# A BIOGRAPHY OF OUR SUN

## From Ancient Myths and Artifacts to Modern Art and Astrophysics

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# Preface

This book, *Biography of Our Sun*, reflects my own personal vision of the Sun on its historical voyage through time and space, and an exploration of our human perception of the world. This is a journey through art, legends, myths, superstitions, and religion, sometimes mysterious, always fascinating. The main protagonist of the book is our star, the Sun. Nothing has been so important to the development of our existence on Earth. It is a life-giver, like a powerful God, as our ancestors imagined, and indeed they worshiped it.

There are also secondary protagonists in this book: humans. Since prehistoric times they have dreamt up legends, myths, and art in the name of the Sun, and eventually, from the mystery of the unknown, they discovered real science. It has been a long, but marvelous process in human history, so even as secondary protagonists, they are important characters in this book.

I have enjoyed traveling on my imaginary voyage through the history and legends of the Sun's life, from its birth to what is now its mid-life, and finally unveiling the real nature of the Sun through scientific discovery and space exploration.

Writing this book has been fun, interesting, and inspiring experience. I enjoyed looking at actual photos taken by the space telescopes flown by NASA and ESA and translating them into my own personal vision and interpretation of the universe.

For the book's illustrations, I have used the tools of my profession: a furnace for melting glass, "cooked" clay (terracotta), acrylic and oil paints, brushes, canvas, wood, and paper. The illustrations are simple paintings and terracotta figurines, while the Sun, the stars, and the planets are made of fused and blown glass, and I have included some photos taken during my travels. I have tried to represent visually the myths and legends of our ancestors, and hopefully, the way they viewed the Sun.

This book could not have been written without the help, and the great patience of astronomers, astrophysicists, and theoretical physicists. I greatly appreciate their contribution, and also their ability to explain the difficult concepts of astrophysics to the layperson in a clear and comprehensible way. It is thanks to them, the physicists, that I have had the incredible opportunity to learn how the Sun was born, how it lives right now, and how it will probably die. So, I am grateful to all of them.

Professor Luca Baldini, experimental physicist at the University of Pisa, Italy
Professor Hans-Thomas Elze, theoretical physicist at the University of Pisa, Italy
Doctor Hugh Hudson, astronomer at the University of Glasgow, Scotland
Doctor Nicola Omodei, astrophysicist at the University of Stanford, California, USA
Doctor Melissa Pesce-Rollins, astrophysicist at INFN, Pisa, Italy
Professor Horst Stöcker, theoretical physicist at the Goethe University Frankfurt, the Frankfurt Institute for Advanced Studies (FIAS), and the GSI Helmholtz Centre for Heavy Ion Research, Germany

A special thanks to my editor Angela Lahee, who believed in my idea of writing a second book about art and physics, and for guiding me with her valuable suggestions. Thank you, Angela!

Campiglia Marittima, Italy Laura Pesce

# Contents

# 1

# A Brief Introduction to the Sun

This book is about a special star, our star, a luminous disk which has always accompanied us, all living beings on this planet, humans, animals and plants. All phenomena, and processes on Earth are determined by the Sun's energy. The Sun gives us a sense of security through its continuous presence in the sky. Energy is needed for every force that causes things to move. All living organisms take in and release energy, and they do it continually. Energy delivered to us by the Sun, so necessary for life on Earth, is produced by nuclear fusion in its center.

Has the Sun always been in the sky? And will it be there forever to give us life through its energy? Modern astrophysicists say: Certainly not! The Sun too will die in some finite time.

During our own finite time on Earth, we humans have had different ways of thinking about the Sun, from prehistoric people who honored and worshipped it as a god to our technological times, in which it is viewed as one among billions of others in the Universe, but no less important for that.

I remember, as a child, my first serious personal encounter with the Sun, which was inspired by a movie "Miracle in Milan," made in 1951 and directed by Vittorio De Sica. For reasons of age, I did not see it then. I saw it in 1960 on our first black and white TV. The film tells of a group of desperately poor people living on the outskirts of a big city, Milan, a city that is always gray and cold—at least, it was in this story. These people possessed nothing but the pleasure of awaiting the Sun's rays to warm them up in the morning. Indeed, the scene in the movie which impressed me so much at my young age was the vision of a group of people illuminated by a single sunray. They were so happy to receive the precious gift of warmth.



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At the end of the movie, as in the fairy tales so much loved by children, these people are seen flying joyfully toward the Sun to end their miserable lives by reaching a better one somewhere else. There it was—a miracle! At least that was my interpretation as a child. I imagined a generous God giving pleasure to those poor individuals who had nothing else in their lives but the gift of the Sun's warmth. The movie was not only about the Sun's rays on a sad gray day. It was a fairytale set in times of difficult and dramatic social problems: the world post-World War Two! Through my child's eyes, I saw the Sun's rays as a divine intervention sent to help a needy population.

Our ancestors may have had the same feelings about the Sun, and therefore worshipped it as a god for this reason. Now, as an adult, my fascination for our star is still present in my mind. I like the idea of taking a voyage through time, encountering ancient cultures and their myths and legends about our star, and returning to our modern-day astrophysical understanding, which needless to say I find just as fascinating as that ancient folklore.

This book is a biography. Such things are generally written to glorify or denigrate important people, usually long gone, although not necessarily. They could still be alive, but they are always of great importance for their goodness, or their wickedness. Well known poets, writers, artists, scientists, politicians, but all humans. This biography is different. It's a glorification, not of a very important human, but of a very important celestial object: the Sun (Fig. 1.1).

## 1.1 The Sun in Ancient and Recent Human History

Our star has been a central object of religion, legends, and myths from time immemorial, but eventually described by the scientific concepts of astronomy. Solar worship, solar rituals, and solar deities featured in common beliefs across the continents, even when separated by the immensity of the oceans. In ancient times, from Europe to Asia, to the Americas, to China and Australia, humans worshipped our Sun as a life-giver, as a god. The Sun has been a key protagonist since our ancestors appeared on this planet, it's fascination and mystery inspiring myths, legends, superstitions, and beautiful art.

Thanks to early visual art, we know about some of the rituals and beliefs of ancient populations around the world. Artistic representations of the Sun, through paintings, sculptures, architecture, and even music, have given us a wealth of information from before written language was invented. Music in particular has been an innate form of artistic expression since primordial times. It is known to have existed around the world for at least 55000 years,

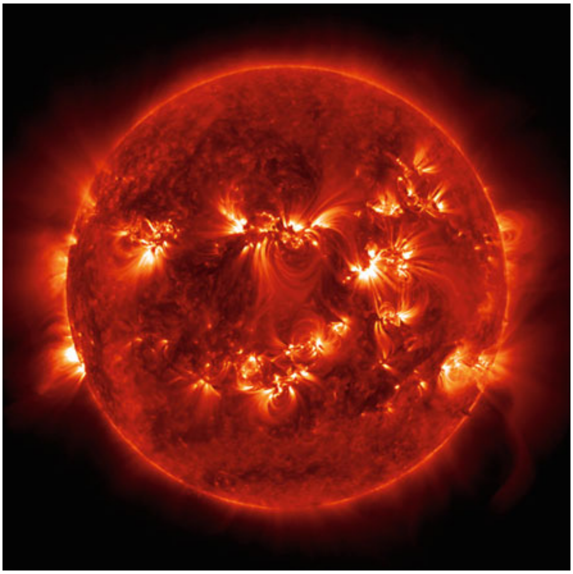

**Fig. 1.1** This is a real image of the Sun taken by the science team at NASA. The Sun has been imagined in different ways across the centuries, as a powerful entity crossing the sky on a golden chariot, sailing on boats, as a beautiful young man or a cruel bloodthirsty being, and many other things besides. But here we see the true face of our Sun, beautiful, powerful, and somehow spooky. Courtesy of NASA/SDO and AIA, EVE, and HMI science team

but, in contrast to visual art, without any written form, it was not possible to record it, so we cannot know what it was really like. Archaeologists have found traces of musical texts on clay tablets, written in a cuneiform alphabet over 3000 years ago. The lyrics of ancient songs were mostly religious, but there is one, entitled “Sumer is icumen in” (Summer is a coming in) written in the thirteenth century by an unknown English musician, in which the summer sun was welcomed. It is the oldest music with lyrics recorded in Medieval England, and as far as we know, anywhere.

Coming back to our own times, on the contrary, songs celebrating the Sun are very present, and can be heard everywhere, on the radio and television, in bars, on city streets, in theaters, yes, just about anywhere. To mention some of the most popular ones, think of “O sole mio” sung by Enrico Caruso, written in the late 1800s, recent ones like the Beatles’ “Here comes the sun”, “Walkin’ on the Sun” by Smash Mouth, “Ain’t no sunshine” by Bill Withers, “Walking on sunshine” by Katrina and the Waves, “Pocketful of sunshine” by Natasha Bedingfield, and “Let the sunshine in” by the Fifth Dimension. All of these belong to the twentieth century, but I am sure there have been many more songs about the Sun in different countries and in different languages.

The Sun has also been a protagonist in poetry, literature, and art, through the centuries right up to our own time. Think of Dante's lyrics in the "Divine Comedy", Charles Baudelaire, Emily Dickinson, Ugo Foscolo, Pablo Neruda, Alessandro Manzoni, Mother Teresa of Calcutta, the list is long. Then there are visual artists like Vincent van Gogh, with his famous sunflowers, painted in the best bright yellow colors ever imagined, and many more artists who have celebrated the Sun throughout history. And of course, there are modern physicists, who celebrate the Sun through science.

Myths, legends, superstitions, and esoteric beliefs about our star have been widespread in all ancient societies, and some of them have survived right up to our own technological times. Astrology, for example, has been practised around the world since the observation of the sky by the Mesopotamian astronomers. Considered as a science for centuries, it is known nowadays to be just a myth or superstition, even though it is still highly appreciated by many contemporary humans. In the astrological chart, the Sun symbolizes our personality, the real aspects of us as a person, so it is the most relevant celestial body for a personal astrological chart.

Tarot card reading is another ancient belief, practised since the fifteenth century. It started in Italy and eventually spread all over Europe, where it is still practised by many even now. It consists of a pack of 78 playing cards used to predict the future. Every card carries an image with a symbol and a story. It is rather like a kind of oracle. In fact, the interpretation of the card depends on the person who reads it. The one picturing the Sun is a particularly important one, with a symbol that predicts happiness, contentment, vitality, self-confidence, and success. The best card of all! At least in my opinion. But to expert tarot card readers, the most important card is the one represented by "the fool", and they may well be right, considering how humanity often behaves. The art of reading tarot cards, like the art of reading horoscopes in astrology, is still appreciated and practised around the world today.

Besides these esoteric beliefs, throughout history there have been remarkable poets who have glorified the Sun through their beautiful poetry. "The Divine Comedy," for example, was written by the well-known Florentine poet Dante Alighieri in the thirteenth century. In the "Paradiso: Canto 33" he alludes to the importance of the Sun in these words "L'Amor che move il sole e l'altre stelle" (love that moves the Sun and other stars). What this means is that spiritual love (God) moves first the Sun and then the other stars in the heavens. The Sun is viewed, through Dante's words, as a glorious and divine central protagonist in the sky. Spiritual love (God) created the Sun and gave it the power to move stars in the heavens. It's a poetic version of the Sun's birth. Considering that "The Divine Comedy" was written in the thirteenth century, and given the state of scientific knowledge at the time, which was based on a geocentric model, the Sun would not have had the power to move all the stars. But this is poetry!

Today, modern astrophysicists tell us a different story about the Sun's birth. We know now that our star was probably born 4.6 billion years ago. It was not spiritual love (God) that gave birth to the Sun. Its birth was triggered by the gravitational collapse of matter from a large dust cloud. At the present time, the Sun is about halfway through its life, and it has not changed much during the last four billion years or so. Astrophysicists think that it could very likely remain stable for another five to seven billion years. By becoming very hot and dense, after a very, very long time from our human point of view, nuclear fusion began to occur in its interior and is still going on today. However, when the fusion in its core has gone to completion, the Sun will change drastically, both internally and externally, and it will eventually die.

Melissa Pesce-Rollins, PhD Staff Research scientist at INFN in Pisa, explains how nuclear fusion works in the Sun:

> The Sun is powered by thermal-nuclear fusion. This is the process where protons (or a single hydrogen atom) are fused together to form helium, and it occurs in the deepest part of the Sun called the core. In order to form a helium atom, four hydrogen atoms must fuse together and the small difference in mass between these two is converted into energy.
>
> This energy release can be explained by Einstein's famous mass–energy equivalence E=mc 2 and it is what keeps the Sun hot and bright. Thermonuclear fusion can only occur in very hostile conditions and is very difficult to mimic on Earth, but in the core of the Sun where the atmospheric pressure is over 200 times that of the Earth, the density is 150 times that of water and the temperature is 150 000 000 degrees Celsius, this process runs as smoothly as a windmill on a windy day.

It's an impressive process, but it is not only relevant to the Sun. All stars are born and live by this process. Perhaps, not a very poetic birth, but nevertheless stunning, impressive, and explosive, the glorious advent of our star in the Universe.

Following this description of the Sun's birth, a common question is, what exactly is our Sun made of? We know that it's a star, and generically speaking, it is a giant ionized globe, made up of atoms which have lost almost all their electrons. The Sun is a big ball of gas and plasma. Of course, the physical model of the Sun is very complex, but experimental physicist Melissa Pesce-Rollins explained things like this to simplify the description.

The Sun has a radius of about 700,000 km and a mass of 333,000 times the mass of the Earth. This is big, but in the Universe, there are many stars that are much larger than our own. As just mentioned, it comprises a combination of gases in the form of a plasma, that is, something similar to a gas, but in which most of the atoms have been ionized. Three quarters of its mass is hydrogen, which fuses together to form helium. This is nuclear fusion, as Melissa Pesce-Rollins described it above. A very small percentage of what remains is made up of other, heavier elements, such as iron, nickel, sulfur, neon, magnesium, calcium, and chromium. The Sun turns on its own axis, and it orbits around the center of the Milky Way, taking something between 225 million years and 250 million years to complete its orbit.

It's difficult to imagine such great distances and the very long time our star takes to orbit around what is actually only a very small part of the Universe. Indeed, our star is only one among millions and millions of others existing in the cosmos!

We see it in the sky as being a bright yellow color, and artists through the centuries have always painted it as a brilliant golden star. However, its real color is white, which contains all the colors of the visible spectrum. This means that the Sun is a combination of all colors mixed together to make it look white. And now, through observations from the International Space Station, it has been confirmed that the real color of the Sun is in effect white. Viewed from space, the Earth's atmosphere is no longer in the way to scatter light from it, and without this interference, we can see the full visible spectrum in its bright white color.

Astronomers call our star a "yellow dwarf" because it produces light in the yellow–green region of the electromagnetic spectrum. The latter consists of waves, most of which are invisible to us. Gamma rays, X rays, and ultraviolet rays (UV) are high frequency waves emitted by the Sun. Most of the UV waves are absorbed by the Earth's atmosphere, while the less harmful UV rays, which manage to get through the atmosphere, are the ones that cause sunburn. The Sun also emits infrared radiation, which is the energy we perceive as heat on Earth. Between the infrared and UV radiation, there is the visible part of the electromagnetic spectrum, the part we can detect with our eyes, which allows us to see all the colors around us.

The effects of the Sun on all living beings, both plants and animals, have been known and understood since prehistoric times. We can find out what our ancestors knew about Nature through primitive archaeological artifacts and cave paintings. Observation of the luminous disk, it's appearance and disappearance, and the fact of its returning again and again on the horizon, may have caused them to regard our Sun as a powerful god. And in a way, it was. We can easily imagine our ancestors, observing the change in light and darkness from day to night, inventing myths to explain the cycle of our star in the sky. Eventually, this primitive belief evolved into more constructive and organized thoughts.

# 2

# Prehistory and the Beginning of History

## 2.1 The Neolithic

The Neolithic period dates back to about 6000 years ago. It began when some groups of people adopted a new lifestyle, switching from their earlier nomadic lives hunting and gathering to land farming and animal farming.

Even before the Neolithic age, humans began to wonder about life on Earth and the stars in the sky, perhaps out of fear, but probably also out of curiosity and purely astronomical interest. The Sun was worshipped as a god from prehistoric times by early humans, but besides religion, there was also a regular observation of the stars. This was the first form of astronomy, which is very likely as old as humankind.

Through archaeological studies, early astronomical observatories have been found, such as the one at Stonehenge, situated in central southern England. It consists of a basic structure of megalithic stones set in a circle that surround more standing stones, amazingly built using only very primitive tools. Stonehenge is the best known astronomical site of Neolithic times, built around 3000 BC, most likely for the observation of the Sun (Fig. 2.1).

The construction of Stonehenge contains a clear alignment of stones, through which, at the summer and winter solstices, one can see the rising Sun at dawn and the setting Sun in the evening. This gives a spectacular view of the Sun, a scene still admired by thousands of tourists who gather at the site during the summer solstice on 21 June. It's a ritual, and for some, a real act of faith, to witness the appearance of the Sun between the geometric figures of the megalith. It's a show which continues even today, perhaps because of the many stories and legends about these mysterious megalithic structures.



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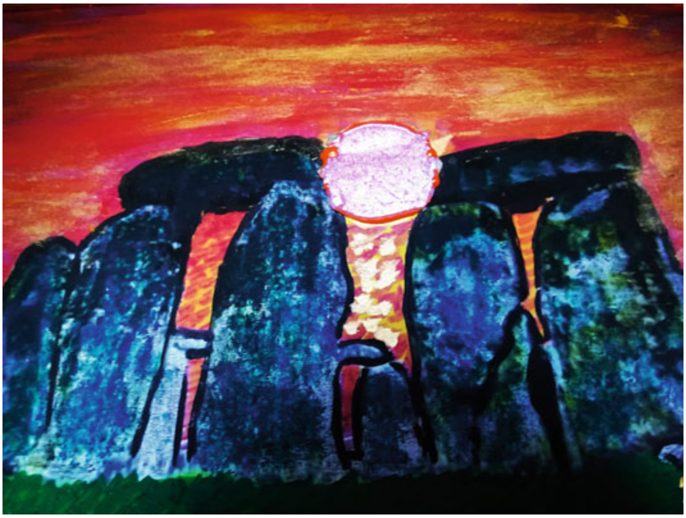

**Fig. 2.1** Stonehenge. This is my representation of Stonehenge on canvas, painted with acrylic colors, to which I have added a bright golden metallic glass Sun. I never been to Stonehenge, but I imagined how the Sun would appear between two megaliths on 21 June

And stories and legends do so fascinate humanity! It has been thought for some time that the Druids (Celtic priests) built Stonehenge. It was John Aubrey in 1640 who first became convinced of this story, but carbon dating has dated Stonehenge to a millennium before, between the Neolithic and the Bronze Age. The Druids were not at Stonehenge when it was built. In a scientific paper published in Nature in 1966, the well-known astrophysicist Fred Hoyle[1] claimed that Stonehenge had an astronomical function (Fig. 2.2).

Stonehenge was not the only Neolithic astronomical observatory of the Sun. A small bronze artifact, the "Nebra sky disk," with a diameter of about 30 cm, has been found in the central part of Europe. It carries a very clear representation of the Sun and the Pleiades star cluster. This artifact probably has a religious meaning, like many such items from ancient cultures, but the

[1] Fred Hoyle was convinced of the extraterrestrial origin of life on our planet. With physicist Chandra Wickramasinghe and many other colleagues, he published a paper in 1978 in which he claimed that life was seeded on Earth by life-bearing comets about 4.1 billion years ago. So, this was a theory of cosmic biology, and not strictly terrestrial biology. Fossils of micro-organisms contained in meteorites of the kind continuously arriving on Earth would be the kind of thing needed to prove Hoyle's idea. In September 2023, NASA's mission Osiris Rex to the asteroid Bennu found traces of carbon, water, and abundant material that would be relevant to a cosmic origin for life on Earth, at least for some of its necessary ingredients, although no living organisms, not even space-resistant bacteria, are likely to be involved. So, of course, Hoyle, was not suggesting that life on Earth began with the arrival of little green men.

**Fig. 2.2** Little green men. Three funny clay aliens representing Martians who have just landed in my town. Acrylic paint on canvas, and terracotta figurines

possibility of serious observation of the Sun in the sky cannot be excluded, perhaps by the priest-astronomers of the time.

Another solar observatory, this time situated in Saxony Anhalt in Germany, is the Goseck circle. It is even older than Stonehenge, and is so far the oldest solar observatory ever found. It was built by an early European culture, even before the civilizations of Mesopotamia, and before the construction of the pyramids in Egypt. Not much is known about this early culture, but we know, thanks to the radio-carbon dating, that this site was built in about 4900 BC. Archaeologists long thought that the circles were an old fortification, but further research in this area of Germany has confirmed that the remains of the structure show a clear astronomical alignment for observing the winter and summer solstices.

In Ireland, there is another Neolithic solar observatory called Newgrange or Sì an Bhrù in Irish, which means "the Sun's cave." It is in fact a tumulus containing a burial site and an astronomical observatory. Newgrange is located about 50 km north of Dublin. On 21 December, the date of the winter solstice, the Sun's rays enter the site to illuminate the interior of the structure. When this happens, light reaches right through to a tomb, giving a "magical" appearance to the site. Newgrange is another megalithic construction, made of huge blocks of stone, not cut, but assembled inside a tumulus of diameter 70 m and containing a corridor 17 m long. During the winter solstice, the Sun's rays enter this passageway and reach all the way to the end, where there is a block of stone decorated with spiral engravings.

Many stones in Newgrange are decorated with these spirals. According to archaeologists, they may represent symbols of divinity. We may suppose that, since they attributed particular importance to the Sun, those who built the site probably honored and worshipped it as a divinity, and they may also have had some knowledge of astronomy. Indeed, Newgrange was built with incredible astronomical competence, considering how old it is, and is one of the most important megalithic sites in Europe.

Nowadays, Newgrange is extremely well known. The site is a popular tourist destination and is open to visitors, especially at the time of the winter solstice. To make it more appealing, the organizers have artificially reproduced the effect of the Sun's rays in the passageway.[2] I have never had an opportunity to visit Newgrange, but I can imagine the reaction tourists must have to this artificial visualisation of the Sun's rays in the passageway. However, the real effect at the solstice must be even more astonishing.

These examples of Neolithic sites, with their solar alignments, are among the best known and most studied by archaeologists. There are many more of them in Europe, less well known than the ones I have described, but no less interesting. The need for astronomical constructions may have been connected with the rise of agriculture. The spring constellations would have been observed as a sign to begin crop planting, and the fall constellations for harvesting before the onset of winter.

Several less well known but no less important astronomical sites are found in Bulgaria. Karanova is the largest and oldest astronomical site in the region. Topchika cave has the oldest rock paintings and Magura cave also has rock paintings representing celestial phenomena, while Tangarduk Kaya is the most important cave with regard to observation of the Sun and its solstices.

During the Neolithic, astronomical observatories may have been built for practical purposes, such as crop planting and harvesting, as previously mentioned, but also for religious and astronomical reasons. Engravings and

[2] Tourism is probably a good thing for economic reasons, but not so good for the preservation of historical sites. Too many people visit these vulnerable archaeological sites, many with little or no respect toward them. Newgrange limits the numbers of tourists, but personally I feel that adding the artificial effects of the Sun's rays was not really necessary.

paintings in caves are clear testimonials to how much our ancestors may have understood astronomy. Martin Sweatman at the Edinburgh School of Engineering has done studies of prehistoric art. In his view, these people had an advanced knowledge of the sky. He declares with some conviction that the people concerned were intellectually hardly any different from us today. Quite a bold affirmation from a scholar in this area! Regarding cave paintings around Europe, there have been interesting studies by archaeologists at the Universities of Kent and Edinburgh. It has been suggested that animal paintings in caves may actually be symbols of constellations, and not simply depictions of people's daily lives.

Well, I asked an astronomer friend for his opinion on these recent studies by the archaeologists. This is his comment:

> I am an astronomer, but I was stupefied on viewing the stars in a truly dark sky on a clear moonless night in the Sierra mountains of California. I can only guess that the early people, who always experienced such dark skies, were just as familiar with the stars as we are today.

His comment makes perfect sense to me, and I find it quite possible that animal paintings in caves may in fact have been representations of constellations, as claimed in the recent studies at the University of Kent and Edinburgh. As I mentioned in my previous book "Close Encounters of Art and Physics" published by Springer 2019, the rock paintings in caves, according to my interpretation, were probably not just artistic expressions by early humans, but a tool for describing their curiosity about and interest in Nature. Animals were very present and important in the lives of prehistoric humans, so it may be that cavemen looking at the stars imagined they saw animals. It is a fact that the meaning and interpretation of the sky can vary from era to era and culture to culture. At the same time, but in a different hemisphere, Native American peoples were also making drawings on cave walls, and on one particular rock, we can clearly see representations of the Sun and stars.

We cannot be sure whether, in the Neolithic and Bronze ages, people had any real knowledge of astronomy, but they were certainly observing the sky, and through their observations, they would have developed myths and legends about the creation of the world. The Sun in particular has been seen as the most important, and indeed life-giving celestial object, and it was therefore often worshipped as a God. In many ancient cultures, myths and legends would have been ways to communicate, and also to explain the very workings of the world. And the most successful tool available would surely have been the visual arts, paintings in particular, and small artifacts.

## 2.2 The Bronze Age

### 2.2.1 Ancient Mesopotamia

Mesopotamia is recognized as the site of some of the world's earliest human settlements and civilizations, dating from the early paleolithic until the era of late antiquity. The region known as Mesopotamia is situated in a valley between two rivers, the Tigris and the Euphrates. It has seen some of the most ancient cultures, and has been labeled by historians "the cradle of humanity." Its inhabitants include the Assyrians and Babylonians, and prior to them, in the late fourth millennium BC, the Sumerians, who were among the first to use cuneiform writing. This attempt at written communication was originally representational. For example, a house would be drawn in order to refer to a house. However, this system was eventually found to be rather inconvenient and evolved to use more abstract symbols and concepts. Cuneiform writing became more phonetic, denoting sounds, and semantic, denoting concepts. It is through the many tablets that have been found that we have learned about their culture and those of their successors.

The Assyrians and Babylonians, for example, are known to have been keen observers of the stars and constellations, and they may well have been the first true astronomers in human history. They lived in the same valley of Mesopotamia, with the Assyrians in the north and the Babylonians in the south, and they shared the same cuneiform writing and the same religious beliefs, inherited from the earlier civilizations of Sumerians and Akkadians. The Babylonian dynasty reigned for about 300 years in the area that is now Iraq.

Hammurabi was the best remembered king of that dynasty, known especially for the oldest known code of law, the Code of Hammurabi. This code is the most complete collection of laws ever written in ancient times. It contains 282 laws, including economic provisions, family law, criminal law, and civil law. And most famously of all, it led to the expression "an eye for an eye, a tooth for a tooth," which meant that forgiveness was not on the agenda! Serious punishment was inflicted on those who did not obey the law. The Assyrians were aggressive warriors. They conquered the lands of Mesopotamia and also the lands we now call Turkey.

During the time they ruled Babylon, the Assyrians created the first library in ancient history, containing thousands of clay tablets, on which they described their science, religion, and Mesopotamian legends in cuneiform writing. But besides writing, we also know how important it was for them to portray visual images relating to religion, war, and legend. Anyone who has had the chance to visit the British Museum in London will never forget the marvelous, and truly enormous, stone figures created at the time of the Assyrians and Babylonians.

Art always had importance as a means of communication in ancient societies, since the majority of the population could not read or write, and indeed, in many early cultures, writing had not yet been invented. Art, in religion as in war, had the role of glorifying gods and kings. It was the most important tool, and maybe the only tool, for communicating with the illiterate population of the time, and this was also true for the Assyrians and Babylonians.

In religion, the cult of the Sun was particularly important for the Babylonians, and one of the priest's roles was to study the Sun and the stars. The Babylonians also believed that the stars could influence their lives, and that by observing and studying the constellations, the future could be read. They created the twelve signs of the zodiac and the first concepts of astrology, imagining the stars as making up mythological figures in the sky. They divided the year into twelve months, assigning each one a figurative zodiac sign. According to the Babylonian priests, the Sun appears in a different constellation each month. By studying the positions of the celestial bodies, they claimed to be able to interpret our lives.

The modern zodiac signs are the same as the ones created by the Babylonians during the late fifth century BC. Many centuries have passed since then, and amazingly enough, astrology is still alive and well. But today, we don't need the ancient Babylonian priests to interpret our future by observing the constellations. Nowadays, we can easily get informed about our astrological horoscope by reading newspapers and magazines, or watching TV. But by looking at the stars, Mesopotamian priest-astrologers did not only read and interpret people's lives here on Earth. They also studied the sky using scientific methods, such as mathematics. In fact, they were probably the ones who invented the concept of zero, or at least, the absence of number.

So, how did these primordial astronomers portray the Sun visually and culturally? And what kind of myths and legends did they create regarding our star? For the Babylonians, the Sun was at the heart of a religious cult, as well as being an astronomical object they could study in the sky. The Sun was a god! Shamash was the Sun god for the Sumerians, and subsequently also for the Assyrians and Babylonians. They imagined Shamash traveling across the sky every morning, opening the gates in the east and entering the gates in the west at the end of the day. In-between, his voyage continued in the underworld, whereupon night appeared on Earth. Sometimes, during Shamash's voyage

**Fig. 2.3** The Mesopotamian Sun god. Shamash was the powerful Sun god of Mesopotamia. I have represented him by a terracotta figure, painted in acrylic gold, with a radiant crown and wings also painted in gold

in the underworld, he could be attacked by demons, causing a temporary obscuration of the Sun which we call a solar eclipse!

The journeys of Shamash explained the cycle of day and night. By an empirical observation, the Assyrians and Babylonians could have better explained the obvious change between day and night, but imagination played a powerful role in this ancient population, and it was important for their beliefs to invent myths and legends. The symbol of the Sun god Shamash was a disk with sunrays, sometimes represented with wings, and later, after the invention of the wheel by the Sumerians in the fourth millennium BC, on a chariot, sitting on a throne and holding the two symbols of his power: a solar disk and a royal scepter. It was believed that Shamash could see everything in the world. As Sun god, he was always present in the sky, whether it was sunny or cloudy, and because he could see everything and all the time, he was worshipped as the divine judge (Fig. 2.3).

## 2.2.2 Bronze Age Egypt

Ancient Egypt was a civilization in the Nile valley in northeast Africa. Upper and lower Egypt were unified into a vast kingdom from around 3100 BC until the conquest by Alexander the Great in 332 BC. The pharaoh was leader of the state and the religion, and considered to be the divine intermediary between the gods and the population.

The Egyptians had a prodigious imagination for myths, legends, demons, and gods. Ra was the Sun god, the most important in Egyptian religion and culture, the creator of everything, from the Universe to humanity itself, the one that gave life on Earth through the warmth of his rays. Ra traveled on a golden boat across the Blue Nile during the day, and lit up the world of the dead at night. Ra could have encounters during his voyage through the underworld, in particular, with a demon, the snake Apep, which could attack the Sun god's boat, temporarily obscuring the Sun. Nowadays, of course, we call this phenomenon a solar eclipse. In all ancient cultures, the fascination with and fear of this celestial phenomenon inspired myths and legends created by the feeling of mystery that surrounds the unknown (Fig. 2.4).

But what is the real nature of a solar eclipse? Hugh Hudson, astrophysicist at the University of Glasgow, Scotland, says: "A solar eclipse is simply the shadow cast by the Moon. It is a rare phenomenon because the motions of the Sun and the Moon have to align exactly with the observer on the Earth; the full shadow (total eclipse) is typically no more than a few hundred kilometers across. This shadow races across the Earth along a different path each time, roughly twice a year, but only those lucky people within the path of totality get to enjoy the spectacular appearance of the solar corona, and only briefly."

So that's it! The mysterious phenomenon of the temporary occultation of the Sun. Not demons or evil serpents from the underworld, but a natural motion of the Moon in front of the Sun.

Doctor Hudson also points out the spectacular beauty of the solar corona during a total eclipse. The Sun's corona is the outermost part of the Sun's

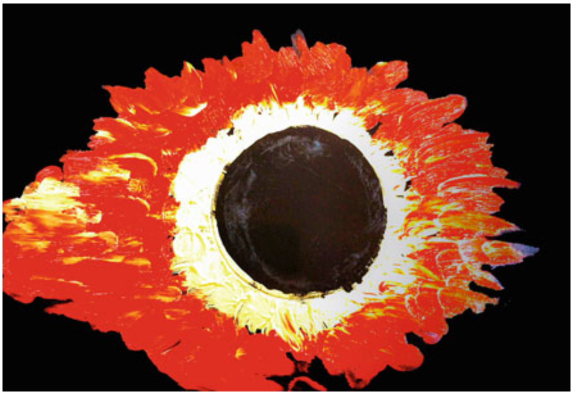

**Fig. 2.4** Solar eclipse. Visual representation of a temporary obscuration of the Sun, depicted with acrylic paint on canvas

atmosphere. We cannot usually see it because we are blinded by the Sun's bright surface. Without a special instrument, the corona can only be viewed during total solar eclipses. At a temperature of about 1 million kelvin, the corona is hotter than the surface of the Sun, but strangely less bright, and despite many years of observation, it is still considered something of a mystery. An enduring problem in astrophysics.

Regarding the solar eclipse, Dr Hudson and colleagues have had a fascinating idea, or as he calls it, "a brilliant idea": eclipse-chasing. For the next very long eclipse in 2024, they would like to record the sound stream from different sites as the shadow reveals the corona to those watching. They are also hoping to put the sound track on the Web. I find this communication idea brilliant indeed. In his words, "One would not believe the gasps and shouts (and profanity) when people see the naked corona suddenly revealed!" Personally, I would love to be one of the people who gasp and shout when the naked corona is revealed!

But, getting back to the religion of Ancient Egypt, Ra was not the only name given to the Sun god, for they worshipped the Sun under several names. These include the falcon-headed Ra-Horakhty, Amun-Ra, and Ra-Aten (Fig. 2.5).

One pharaoh, Akhenaten, is particularly closely associated with Sun worship. He is remembered as the pharaoh who changed religion from polytheism to monotheism. Historians described him as heretic, fanatic, and somehow mad, but also as mysterious, enigmatic, and revolutionary.

He was the first in ancient culture who dared to change a religion. Then, only one God had the power over everything on Earth and over the whole Universe. The change imposed by Akhenaten to a monotheistic worship of the Sun was not widely accepted by the all-powerful priests, nor indeed by the illiterate and superstitious population. Of course, there was a reason for making this choice, and it was not inspired by theological illumination. Through this change, only the pharaoh Akhenaten could communicate with the Sun's disk, without any interference from the many other gods (Fig. 2.6).

The Sun was worshipped as a life-giver, so anything or anybody touched by the Sun's rays was blessed. And there is truth in this ancient belief. In a sense, the vegetation on planet Earth is indeed blessed by the touch of the Sun's rays. We call this phenomenon photosynthesis, a process by which plants use sunlight to store chemical energy in the form of glucose (a sugar), taking in carbon and water from the air and soil and releasing oxygen as a byproduct. Almost all life on Earth depends on this chemical process. By eating plants, herbivores obtain energy, and then carnivores and omnivores like humans obtain energy by eating herbivores. The Egyptians' ancient belief that the

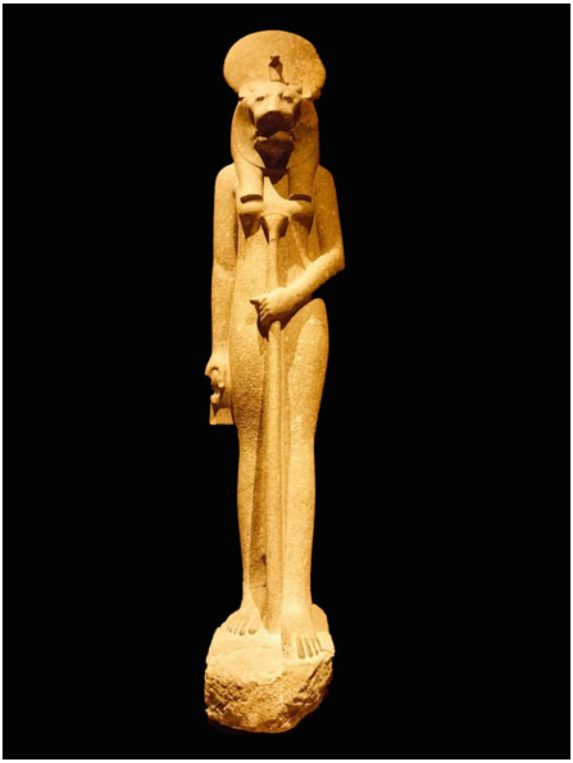

**Fig. 2.5** Sun goddess with lion's head and the symbol of the Sun disk. Egyptian Museum in Turin, Italy. Photo by the author

Sun's rays bless whatever they touch can thus be compared with the process of photosynthesis. It converts the Sun's energy to the chemical energy which has sustained living systems on our planet for billions of years. So, in a way, we can agree with the Egyptians' ancient cult of the Sun. Everything and everyone the Sun's rays touch receives a blessing!

In Ancient Egypt, myths, legends, and religion were always connected to the creation of the world. Ma'at was the goddess of creation and also of truth, justice, cosmic balance, and order. And above all, she was the daughter of the supreme god, the Sun. Justice, order, and laws were given by the gods to humankind at the moment of creation, which means she was a very important deity. In paintings, Ma'at was represented as a woman, seated or standing, with an ostrich feather on her head.

The Sun god himself was worshipped under different names according to the Sun's position on the horizon or in the sky. Khepri was the morning Sun, Ra-Harakhty the Sun at the zenith, the most powerful one, and Atum the evening Sun, the oldest and wisest. The Sun god was represented everywhere,

Fig. 2.6 Pharaoh Akhenaten. Terracotta figurine with golden sunrays

in drawings on papyrus and paintings on grave walls, but also in the architecture of monumental pyramids, sphinxes, and temples, and sculptures from large figures to small clay figurines. He was literally everywhere. During the reign of Akhenaten, the Sun god could only be honored and worshipped indirectly through the pharaoh, who alone had the power to communicate with the supreme God.

The impressive monumental art works of ancient Egypt have been admired throughout antiquity right up to our own time, as has the work of artisans, who played an important role in Ancient Egyptian society. Jewelry-making provides a good example. Body adornment has been a feature of human vanity since the people of prehistoric times. However, the Egyptians, in particular, were masters in the craft of jewelry-making. Artifacts have been found mostly in tombs, some of them going back as far as 4500 BC. It was very common for Egyptians to wear jewelry, from the youngest child to the oldest priest, from the poorest peasants to royalty and the elite. Some types of jewelry were worn during life, others were made for burial. Indeed, it seems that Egyptians were always buried with adornments.

Jewelry was made to be decorative but also to serve a purpose. These crafts have been documented by images in tombs illustrating different techniques. For example, painted scenes have been found of men drilling beads, while others string them together. Notably, glass beads were often used in necklaces.[3]

The artistic style in Ancient Egypt changed very little over time. In fact, the word "art" is absent from their hieroglyphic language, while art itself was very present. Artwork was functional, bound to religion and ideology, and idealized in its form, involving a particularly unrealistic vision of the world. Symbolism played a prevalent role in establishing the sense of order. Animals were represented as symbolic figures, and colors were also used to symbolize different things. For example, blue was a sign of fertility and birth, and also symbolized the water of the Nile. Blue and green were associated with vegetation and were symbols of vitality. Turquoise was used for funerary equipment, black as a symbol of the afterlife, gold as the main symbol of divinity, and perhaps most importantly, red, orange, and yellow as symbols of the Sun.

A change came in the arts during the reign of Pharaoh Akhenaten. It is known as Amarna art, named after the city founded by the pharaoh himself. The monotheistic worship of only one god, the Sun, reflected a major change of culture and style. Figures began to show a kind of movement that was absent before this period, with overlapping images creating an illusion of motion. The culture changed after Akhenaten's death, returning to the polytheistic religion. Akhenaten reigned in Egypt for only seventeen years, and probably died in 1334 BC, whereupon his name and face were completely removed from all paintings and monumental representations. Apparently, it was commonplace in Egypt to denigrate public figures. Akhenaten was not loved by his people. He was completely forgotten for centuries following his death, until the nineteenth century, at which point, through many archaeological excavations, the past existence of Akhenaten was brought back into

[3] Being a glass artist myself, I often make glass beads. I find it interesting that this craft fascinated ancient peoples like the Egyptians, and that it has been around in human history for so many centuries.

**Fig. 2.7** Hieroglyphic text at the Egyptian Museum in Turin. No sign of any written text about Akhenaten. Photo by the author

public view. But note that, despite Akhenaten's "Damnatio memoriae",[4] the Sun god still remained the major divinity in ancient Egypt (Fig. 2.7).

[4] I recently visited the Egyptian Museum in Turin, Italy. I was curious about the Pharaoh Akhenaten and, among the many tombs, sculptures, and hieroglyphic texts, hoped to find something mentioning the importance of Akhenaten's life. Well, it turns out that the "damnatio memoriae" was indeed borne out!

# 3

# Across the Ocean

## 3.1 North America

Humans have been present on the American continent for a very long time, probably around 30,000 years. According to linguistic and genetic data, the indigenous peoples of the north are connected with north east Asia. Native American cultures are not considered a part of the Neolithic era, like the stone age cultures of Europe, Asia, and Africa. Archaeologists simply refer to the North American stone age as the Paleolithic era. Let's imagine that we traveled across the ocean on a time machine, arriving at around 1000 BC. What would we see in North America? In fact, we would see mainly hunters and gatherers, while on the other side of the ocean, there were flourishing civilizations, such as the Akkadians, Hittites, Mesopotamians, and Egyptians.

So, why was there such a difference between the cultures in these two regions? Because it just happened that way? Not a very satisfying explanation, but we must consider that the first humans came from Africa on foot. They could therefore reach Europe, Asia, the near East, and the far East in this way, but they could only reach the Americas when it was possible to walk through lands not yet separated by the ocean. So, timing was the "problem." It's a simple explanation, but it does seem to have happened that way. At any rate, the native peoples who populated the lands of North America had their own culture with their own myths, legends, and art, and all this long before the European colonization.

The native peoples of North America practised different religions. As they did not have a written language, we have learned of their beliefs and culture through the many paintings found in caves, and by orally transmitted


L. Pesce, *A Biography of Our Sun*, https://doi.org/10.1007/978-3-031-54729-4_3

legends. Sun worship was a common practice for most of the indigenous people in that part of the world. From Canada to the Plains, now the United States, the Sun dance was a common ritual for these tribes. Indeed, it was, and in some respects still is, the most important ritual for worshipping the Sun god. The Plains Indians held this ceremony in late spring or early summer, mainly to honor the Great Spirit through worship of the Sun. The Sun dance ritual lasted for days, including a test of endurance for anyone who accepted to endure the test. No food or water was allowed for days until the dancer finally succumbed to the harsh corporal pains or to exhaustion. It was a rather cruel and bloody ritual.

By the 1800s, the American government no longer allowed the Sun dance ceremony. However, it is still an important ritual for many native peoples, but without the endurance test (Fig. 3.1).

The Plains Indians, including the Sioux, Blackfoot, Cheyenne, Comanche, Arapaho, and Kiowa, were mostly nomads, all of them honoring their god

**Fig. 3.1** In this picture I have represented a Sun dance in a simple stylized drawing of Native Americans dancing to honor their Sun god. The Sun dance was in reality a cruel and bloody ritual!

with the ritual of the Sun dance. Among the Plains Indians, the Blackfoot had a particularly interesting perception of the gods, calling them the Sky Beings, "the people of the above" or sacred spirits, created by Apistotoke, the "Creator" or the "Great Spirit" in the Blackfoot language. He had no human form, and lived in a world above the clouds.

The Blackfoot tribe were keen observers of the sky, able to recognize constellations, planets, and the Milky Way. Thanks to their interest in the sky, they personified celestial bodies into deities. This was a key part of their beliefs. Nah-too-si (or Natosi) was the Sun god, considered the most important of all, and the central figure of the Blackfoot religion. Nah-too-si married Komorkis, the Moon goddess, and they were the parents of the morning star Lipiswaahs, the most important of all their star children. The legends about their gods seem endless, from the main divinities of "the above" to the hybrid creatures on Earth and the underground spirits.

The approach to religion between the tribes of North America differs widely from tribe to tribe and from one culture to another. In the southwest, there were the Anasazi, a prehistoric people, probably the oldest community in that part of the continent. They were the ancestors of the present-day tribes of Pueblo peoples, including the Zuni and Hopi, and the Yumans, Pima, Tohono O'odham (Papago), Navajo, and many Apache groups. The Hopi tribe, another people of the south west, believed that in the beginning there were two entities: Tawa, the Sun god, the powerful creator of "the Above" (the sky), and Spider Woman, who controlled "the Below," who was the Earth goddess (Fig. 3.2).

The Navajo people also worshipped the Sun god, but their myths about this god are different from those of the other southwestern cultures. Tsohanoai is the Sun bearer, who carries the Sun on his back across the sky and at night puts the Sun to rest by hanging him on a peg in Tsohanoai's house. I find the image of the Sun being carried on someone's back slightly amusing. The Navajo, like the Hopi, worshipped two entities in particular, the Sun and mother Earth, called Spider Woman. Besides these two major gods, they worshipped many other divinities in the form of animals, rivers, and mountains. Nature has always been considered sacred and respected by all indigenous populations up to today.

The indigenous peoples of North America did not have written languages, so their history was always passed on orally. With European colonization, without regard for their way of living, traditions, and religions, they were classified as "savages." We know now how unfair this was, and understand that what happened to these original populations of North America was a great misfortune. Nowadays, most of these people live segregated by force

**Fig. 3.2** Tawa, the Navajo Sun god. Pencil drawing and acrylic colors on paper

on lands, the so-called Indian Reservations, set aside for them by the United States government (Fig. 3.3).[1]

## 3.2 Mesoamerica

The forerunners of the Aztecs migrated to the land now known as Mexico some time in the twelfth century. Their own name for themselves was the Mexica. The population was devoted to the cult of the Sun, worshipped as the most powerful entity in the Universe. These first Aztecs were semi-nomadic hunters, and it is believed that, to honour the Sun god, the first piece of

[1] The South West Indians never accepted the English name given by the European invaders to their sacred canyon, known to us as the Grand Canyon. But now, a hundred years later, the original name has been restored. The name for the Grand Canyon National Park has been changed back to the Havasupai Gardens.

**Fig. 3.3** The Grand Canyon, now known as the Havasupay Gardens, as the native peoples prefer to call it, represented here in a painted photograph by the author

meat of a hunted animal was given as an offering. This must have been an important offering for a population who lived only by hunting.

Later, when they turned to agriculture, ceremonies were organized to honour the Sun at the equinoxes. These are the two times of the year when the light of day and the darkness of night are equal in length. The vernal equinox marks the beginning of spring and the autumnal equinox marks the beginning of fall, important times for the Aztecs during the agricultural era. And thereafter, the cult of the Sun became more elaborate, maybe due to conquests and expanding territories. For the Aztecs, the Universe was a living entity, with the Sun placed at the center of the cosmos. They believed that the Sun was in continuous motion, and therefore, according to their beliefs, had to be kept constantly alive. To do this, the blood and the hearts of captured enemies had to be made as offerings. But that was not all. Other people, in general their own warriors, had also to be sacrificed. Human sacrifices were made to the Sun god Huitzilopochtli, a powerful god who was also the Aztecs' god of war. For the glory of Huitzilopochtli, monuments were built, great pyramids, dedicated to its cult. These may also have been used as astronomical observatories.

Pyramids were also built by other populations of Mesoamerica, like the Maya, in what is today Guatemala and Belize. Such pyramids were built from about 1000 BC until the Spanish conquistadors invaded the New World in the early sixteenth century. The main purpose of these constructions was religious, and to bury kings, but they were also public sites where they performed execution rituals to honor the Sun god, most of the time through human sacrifices. Many pyramids were built in Mesoamerica, even more than by the Ancient Egyptians.

The best known and best preserved is the Pyramid of the Sun in Teotihuacan, built about 200 AD, and one of the largest structures in the Western Hemisphere. The name comes from the Aztecs who visited the site centuries after it was abandoned. It is believed that the Pyramid of the Sun was plastered and painted in bright colors. There are other pyramids in east-central Mexico, for example, in Chichen Itza in the Yucatan peninsula, but the largest is the Great Pyramid of Cholula, in the state of Puebla.

These monuments were decorated with mythic figures carved in stone. A recurrent symbol is the feathered serpent Quetzalcoatl. It is actually a double symbol of the deity: the feather representing divine nature through its ability to fly, and the serpent representing human nature by the fact that it creeps along on the ground. Such dualism was common in the deities of Mesoamerica. The symbol of a serpent that creeps along on the ground among other animals is also a common religious allegory in Christianity. There, the serpent is a symbol of evil, the one which, according to the Old Testament, caused the original sin in humans, whereupon Adam and Eve were thrown out of the sacred Garden of Eden forever. It is a constant feature of human imagination to portray the duality between good and evil in such a symbolic way!

For the Aztecs, the Sun god's duality corresponded to peace and war: it was a generous life-giver, but also a cruel and bloodthirsty god. Human sacrifice was considered necessary to please the supreme being. Our star too has a duality: it gives the gift of life to all living entities on this planet, but it will eventually become dangerous and destroy all the existing life on Earth. In our case, it's not an immediate worry. It's going to happen a billion years in the future when, very probably, humanity will already be extinct. In any case, it's not because our Sun is a cruel god, but because it simply does not care. Our Sun is a star, just like many others in the Universe, so, regarding its nature, it does what a star does. That's all!

Recent studies in astrophysics, explain that the Sun could pose a certain threat to our fragile technological life here on Earth. This is because of solar storms, which could disrupt telecommunications, interfere with satellites in orbit, and cause blackouts in cities or even entire regions. In 1989, I was personally witness to a power failure due to such a solar storm. I was at the

New York city airport when it happened. I was in line to board my flight to Rome, when all of a sudden, the lights went off and the doors were blocked. Looking through the large airport windows, the lights of New York were gradually disappearing. It was a strange sensation, especially because no one including myself had any idea what could cause such an event. We always take our technology for granted today, but even if it is only gone temporarily, it feels quite scary! Witnessing such an unexplained event can give a feeling of helplessness. But of course, in this case, everything eventually came back to normal and all the passengers were able to go to their respective planes.

Solar storms might sound frightening, but they are a natural occurrence, which have been happening for billions of years, and fortunately affect only some of our technology and not our human bodies.

But coming back to the Mayan and Aztec pyramids, they were built according to a particular process. There was a central core filled with earth and rubble, which was covered with stone to form the walls. Layers of adobe were then applied to smooth the sides. On top of the pyramid a temple was commonly built, probably for human sacrifices. Finally, the whole construction would have been painted in bright colors. One can imagine the beautiful scene with all these colored monuments in the lush tropical forest! (Fig. 3.4).

**Fig. 3.4** Mayan pyramids. Pencil drawing with acrylic colors on paper

Fortunately, the pyramids were not only used for bloody human sacrifices, but also for a better use, as astronomical observatories. The Mesoamerican civilizations were interested in astronomy. The Maya, in particular, had a complex and intricate calendar system. In fact, they actually had two, one consisting of 260 days associated with rituals, and the other with 365 days, which is almost exactly the solar year. They observed the complex motions of the Sun, stars, and planets and recorded this information. In this way, they were able to develop a calendar to keep track of the motions of the celestial objects and the passage of time. Through their observations, Mayan astronomer-priests could even calculate the times of solar eclipses with amazing accuracy.

One example of astronomical observation from a Mayan pyramid is El Castillo in Chinchin Itzà. Each side of this pyramid has 91 steps, and by adding the final step on top, the total becomes 365. It was built to mark the equinoxes. On these days, the Sun cast the image of a serpent descending the main staircase of the pyramid. The appearance of this phenomenon during the equinoxes is so "magical" that it still attracts thousands of people to the pyramid to witness the sight. And it is not only tourists who gather in Chichen Itzà to witness the "magical" scene of the snake's appearance, but also archaeologists, astronomers, and solar scientists. Mayan cosmology underlies this amazing alignment. How they managed to create it we can only guess. Were they magicians or shamans? No, they were definitely among the world's first scientists. And, amazingly enough, the Spaniards wrote them off as mere savages!

## 3.3 South America

It is believed that the first humans who populated South America may have arrived from Asia to North America through the Bering Land Bridge between Siberia and Alaska some 35,000 years ago or more. These first people were hunters and gatherers, and when the ice retreated, they would have gradually followed the progression of game animals southwards, taking thousands of years to reach Central and South America.

The Norte Chico people formed the oldest civilization in Peru, and indeed the oldest we know of throughout the whole of South America. It was a civilization contemporaneous with the Egyptian pyramids. Other cultures were the Atacama, Diaguita, and Araucanians, also descendants of those first migrants who crossed from Siberia to Alaska. We now know that there were many Pre-Columbian civilizations in the Andean mountains prior to the famous Inca Empire (ca. 300–1100 AD). In relatively recent excavations, archaeologists have found artifacts proving the existence of a civilization, the Chavín culture, that was largely unknown up to now. Chavín's populations were the first and most important pre-Inca groups in the northern and central parts of what is now Peru. The first traces of human settlement there date back 20,000 years. These people had developed agriculture by 900 BC, and their civilization lasted until around 200 BC.

The Nazca civilization is famous nowadays for what are referred to as the Nazca Lines, mysterious designs whose meaning remains unknown to this day. And nor do we know who made them. The lines can only be seen by flying over at a certain height, and because of the peculiar aerial views this reveals, modern legends have been created. One such is that extraterrestrial creatures built the lines to be able to land their spaceship. But what purpose did the aliens have? Indeed, what interest would there have been in building a landing strip in the middle of a high arid plane? The legend does not explain. Setting the extraterrestrial myth aside, the Nazca civilization is perhaps better remembered for its remarkable artistic and technological skills.

The Moche civilization flourished on the north coast of Peru between 100 and 700 AD. Their heritage is known through archaeological excavations at sites where the remains of burial ceremonies have been found. A particularly interesting find is an adobe brick temple called "Huaca del Sol". This was a sacred site for worshipping the Sun god. Here they practiced human sacrifice, including the ritual of blood drinking. The Moche were skilled artisans, making pottery decorated with figures representing daily life. As in most ancient populations, visual art was an excellent tool for representing the way our ancestors lived!

The Incas built the biggest empire in South America, but unfortunately for them, it did not last long. It began in 1438 but was wiped out in 1532, when the Spaniards arrived. The Inca Empire spread in a very short time from Ecuador to Chile, imposing its religion, culture, and language, Quechua, to all the territories they conquered. The origin of the Inca people is intimately tied up with the myths and legends which they themselves created. They believed they had been brought into existence by the Sun god Inti, and regarding themselves as "children of the Sun." They were the chosen ones! Consequently, the Inca king was the sole representative of the god Inti on Earth.

The capital of the Inca Empire was Cusco, their religious and administrative center, with splendid temples covered with gold in honor of the Sun. There was a complex of buildings in which the most beautiful of all was the temple of Inti, the supreme god worshipped in the Inca pantheon. Other sacred sites called "huacas" were built on mountaintops, and these actually doubled as astronomical observatories. Their purpose was to practice religious ceremonies by following the astronomical calendar, the motions of the Sun, Moon, and Milky Way (Mayu). These ceremonies were also connected with agricultural practice, especially for planting and harvesting, a common focus of ancient civilizations.

The Incas were masters in the construction of large buildings. Machu Picchu is the best known and most visited architectural site in South America. The Incas built the site around 1450, but it was soon abandoned, in fact only a century later, probably at the time of the Spanish Conquistadors. It is situated in the Peruvian Andes and the Amazon basin, surrounded by a dramatic landscape carved out by the waters of the Urubamba River. Machu Picchu is one of the most intact Inca sites ever found in South America. The Incas did not have a written language, and no European ever visited the site until the nineteenth century, so we don't know the reason why it was built. It may have been for religious purposes, but many archaeologists believe that it was built as an estate for the Inca's first emperor Pachacuti. In any case, it is a beautiful example of Inca architectural and artistic design.

Besides the famous Machu Picchu, there is another marvelous site called Choquequirao, which means "cradle of gold" in Quechua, located between the Andes and the Peruvian Amazon. This site has been hidden in the lush tropical forest for at least four centuries. According to archaeologists, it may have been built by the Inca leaders Tupac Inca Yupanqui or Huayna Capac. The site has been dated to around the fifteenth century and was built mainly for the cult of the Sun god and for astronomical observation. There is evidence to suggest an interest in and knowledge of astronomy, especially regarding the study of solstices and equinoxes (Fig. 3.5).

The arts played an important role in Inca culture. Besides the impressive buildings, there was also metalworking. Gold was the preferred metal, considered to be the sweat of the Sun. All the work made of gold, such as jewelry, figurines, and even everyday objects, was strictly for the Inca nobility. Many gold artifacts were made to honor the Sun god, and also to embellish the many temples of Cusco. It may well have been the abundant display of such goods that brought about the downfall of the Inca Empire.

For, at the sight of so much gold, the Spaniards must have thought that Peru was indeed the El Dorado they had been looking for. In 1533, after only a hundred years of massive expansion of its territories in South America, and a remarkable cultural development in the arts and sciences, the Inca Empire collapsed under the military attack of Francisco Pizarro and a very small group of Spanish soldiers.

**Fig. 3.5** Machu Picchu is one of the most marvelous archaeological sites I have seen during my travels. Here I have represented the site in dark colors to bring out the feeling of mystery. I used acrylic colors only for the surrounding mountains, and the cloudy blue sky

So, who was this Spanish Conquistador? In fact, he was an illiterate man, the illegitimate son of Colonel Gonzalo Pizarro and a poor peasant woman, and he first worked as a pig-keeper. Little is known about his life prior to his arrival in the New World, but at a certain point in his life, his fortune changed for the better. Eventually, he found himself accompanying Vasco Núñez de Balboa on an expedition which reached the Pacific. Once in Peru, Pizarro landed with a relatively small group of soldiers, armed with weapons which had never been seen before by the natives. Using superior military tactics and exploiting an alliance with rebellious local tribes, he swept the Incas away.

Apart from their astonishing greed, the final *coup de grâce* inflicted by the European invaders was above all the dissemination of lethal and hitherto unknown diseases brought by the Spaniards to the New World. It is thought that up to 90% of the native peoples died of these illnesses. It was certainly the greatest human tragedy ever to assail the American continent.

# 4

# The Old World

## 4.1 Greek Myths, Art, and Astronomy

Ancient Greece was a land of innovative art, philosophy, mathematics, and mythology. As in many ancient populations, the Sun was honored as a god. Helios, which in Greek means "Sun," was their Sun god. He drove a chariot across the sky from east to west and sailed on the sea every night. It was a common idea in early human cultures to picture a Sun god crossing the sky in this way and disappearing into the underworld, the land of the dead, or in this case, sailing across the sea. After all, the Sun had to go somewhere at night, so different legends invented a mysterious and dark place for the Sun to rest, before reappearing in the east and continuing his daily routine toward the west. Helios was regarded as the most important god, worshipped especially on the island of Rhodes. Apollo, the deity of purity, was his successor as Sun god, worshipped by the Romans.

Ancient Greek religion was closely connected with astronomy and astrology. Gods and goddesses had superior powers, but at the same time they had human feelings and even a human appearance. The Greeks put their gods in the stars and in the planets, although we use the Roman names for the latter today, i.e., Mercury, Venus, Mars, Jupiter, Saturn, and Neptune. The constellations were named after semi-divine mythological entities, including the gods' favored heroes and the gods' favored animals, such as Andromeda, Aquila, Auriga, Cassiopeia, Cygnus, Orion, Ursa Major, although these are once again the Roman names. And needless to say, the twelve signs of the zodiac were also linked to Greek mythology.


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Western civilization probably could not have existed without Ancient Greek culture, art, philosophy, astronomy, and mathematics, and even their myths and legends influenced subsequent civilizations. In fact, Greece is the reason we have our Western civilization, and it's not an exaggeration! During the Classical period, which lasted about 200 years from the fifth to the fourth centuries BC, art and science flourished thanks to the ingenious minds of men who lived at that time; men such as Empedocles, a philosopher and astronomer, who, in the fifth century BC, was able to demonstrate that the Earth was round. He understood this during a lunar eclipse, when the curved edge of the Earth's shadow passed across the Moon.

Empedocles, who lived from ca. 490 BC to ca. 430 BC, was born to a well educated and wealthy family in Sicily, at that time part of Greece. He studied with the Pythagoreans, but very likely never met Pythagoras himself, as the latter probably died several years before Empedocles was born. He firmly believed that numbers were the most important thing in the Universe. For him, they were the most perfect entities and perhaps the only way to understand the world around us. He believed that there were only four basic elements: air, fire, water, and earth. He also claimed that the speed of light was finite and that mass was conserved in chemical reactions. A proper theory of mass conservation was only formulated much later, in the 1770s, by the well-known French chemist Antoine Lavoisier.[1] The amazing and ingenious mind of Empedocles! He foresaw and formulated this theory many centuries before Lavoisier.

In astronomy, Empedocles, like all scientists at that time, assumed the geocentric model. He conceived of the Sun as a vast ball of fire, and taught that its light must have taken some time to reach Earth, that it could not have reached us instantly, thus inferring that the speed of light was finite. He was perfectly correct. In fact, light from the Sun takes about eight minutes to reach Earth.

Many philosopher-physicists who lived in Ancient Greece made essential contributions to science. Parmenides was another mathematician and astronomer who recognized the roundness of the Earth. He also understood the different phases of the Moon, realizing that the changes were caused by the relative positions of the Sun and the Earth.

Then there was Pythagoras, philosopher, mathematician, and astronomer, who was born in Samos in about 570 BC and died in a region of southern

[1] Antoine Laurent Lavoisier is considered one of the founders of modern chemistry, but he was also an administrator, and an important financier during the French Revolution. Those were bad times to be an aristocrat, and especially a much hated tax collector. It did not help to be the most famous scientist of the day, as he was guillotined anyway during the Terror of the French Revolution, in 1794.

Italy that was at the time colonized by the Greeks. From their astronomical observations, he and his followers, the Pythagoreans, produced a model of the Solar System that was not geocentric. They postulated that, at the center of the Universe, there was a large primordial fire, called Hestia, encircled by an anti-Earth, the Moon, the Sun, Mercury, Venus, Mars, Jupiter, and Saturn. This was a truly innovative concept at a time when the geocentric model was predominant.

But it was the great philosopher Plato who put forward the first model of a heliocentric universe, although later in his life, he went back to the geocentric model. He too, like Parmenides, understood that the Moon received light from the Sun.

Aristotle was a philosopher, mathematician, and astronomer, and generally one of the most brilliant minds in antiquity. He believed that the Earth was composed of the four elements earth, water, air, and fire, together with another, mysterious fifth element or essence, which he called “ether.” This was an invisible, massless, eternal element, pervading an immutable cosmos. Now it so happens that Aristotle’s idea of “quintessence,” has been borrowed by some contemporary cosmologists. It pertains to the problem of the mysterious dark matter and dark energy receiving much attention these days. A few years ago, I had the chance to discuss this with a well-known cosmologist, Christof Wetterich, professor at the University of Heidelberg in Germany. He published a paper entitled “Quintessence.” I was inspired by his scientific paper and by the simple way he explained this difficult physical concept. After our discussion, I painted my version of “quintessence” on canvas.

He explained to me that his quintessence bore no resemblance to Aristotle’s ether as the fifth element. There has already been a modern version of the ether, before Einstein’s theory of relativity made it redundant. It was supposed to be the medium in which electromagnetic waves propagate. The modern version of ether was considered to fill all space between matter. Dark energy, on the other hand, as Professor Wetterich points out, reflects a propriety of the vacuum which is needed to explain the accelerating expansion of the Universe. So, the difference between Aristotle’s quintessence and Professor Wetterich’s is actually quite great. However, in my unscientific mind, I see in the idea of Aristotle’s mysterious fifth element the seed for the modern ether, and dare to compare it with “dark energy.”

Following the Classical period of Ancient Greece, there came the Hellenistic period, which lasted three centuries, from the death of Alexander the Great in 323 BC to the conquest of Greece by Augustus in 31 BC. This era was certainly a golden age for science. Many important contributions were made by philosophers—at that time, there was no clear distinction between physics and philosophy, and philosophers were in effect scientists.

Aristarchus of Samos, who studied the motions of the celestial bodies, proposed a heliocentric model. He also understood that the Earth was spinning on an axis that was tilted with respect to the plane of its orbit around the Sun, since this explained the changing seasons.

The mathematician and astronomer Hipparchus was born in Nicaea in the Kingdom of Bithynia, modern day Iznik in Turkey, in about 190 BC, and died in about 120 BC in Rhodes, by then a Roman Republic, now in modern day Greece. He made fundamental contributions to astronomy. Using old observations from star catalogs, he created a new one containing 850 stars, assigning each its celestial longitude and latitude. He classified the brightness of the stars, now known as stellar magnitudes, on a scale from one to six.

Such catalogs have been compiled over the centuries by many different civilizations, including the Babylonians, Greeks, Chinese, Persians, and Arabs. The earliest known catalogs were compiled by the Babylonians in the second millennium BC and inscribed on clay tablets. One such listed thirty-six stars. In the Hellenistic world, many astronomers and mathematicians compiled star catalogs, but it was Hipparchus who made the most complete catalog. Indeed, he was probably the earliest to map the entire sky, or at least the part that was visible to him. In Roman Egypt, Ptolemy published a star catalog listing 1022 stars, almost entirely based on the one compiled by Hipparchus, as part of his treatise *The Almagest*. It remained the standard star catalog in the Western and Arab worlds for over a thousand years until Tycho Brahe's catalog appeared in 1598.

According to the writings of the Roman naturalist Pliny the Elder, in his star catalog, Hipparchus indicated the names and measured positions of each star. Through his astronomical observations of the orbits of the Sun and Moon, he was able to calculate their sizes and their distances from the Earth, and also predict solar eclipses. He was able to calculate the equinoxes and solstices because he understood about our planet's axial tilt. The Earth is tilted on its axis as it travels around the Sun, so at any given point on the surface, the Earth receives different amounts of sunlight at different times of the year. If the Earth were not slightly tilted on its axis, the Sun would always appear directly overhead at the equator. In this case, there would be no need to look out for solstices and equinoxes to mark the changing of the seasons. The equinoxes fall on about 21 March and 23 September. These are the days when the Sun is exactly overhead at the equator, making the day and night of equal length. The solstices fall on about 21 June, the summer solstice, which marks the longest day of the year, and on about 21 December, the winter solstice, which marks the shortest day of the year.

Philosophy, mathematics, astronomy, and art flourished in Ancient Greece more than in any other culture in Antiquity. Art, in particular, was a discipline based on mathematical principles, and the Greeks took the view that there was a strong similarity between art and science. Mathematics is often considered analytical, while art is considered creative, but they can also be viewed the other way around, with art analytical and mathematics creative. In the end, both are able to inspire the imagination. Good examples of these two disciplines can be seen in Greece during both the Classical and the Hellenistic periods. Astronomers and mathematicians like Plutarch and Hippocrates were effectively using some of the same skills for their scientific work as their contemporaries, people like Phidias and Polykleitos, for their artwork.

In Classical Greek art, the sense of beauty was reached solely through mathematical concepts of symmetry, geometry, and proportions, with the same approach that mathematicians and astronomers used in their work.

But during the Hellenistic period, the arts were considered inferior to those of the Classical period. There was in effect a change by artists in their expression of visual art. From my point of view, and I am not alone, art got even better in the Hellenistic period, as compared with the Classical period. Sculptures became more realistic and more expressive. The anatomical perfection, the mathematical symmetry, and the proportions were kept as they were in Classical art, but artists took a different approach. They were more interested in representing the individual character of the subject. They represented common people, whether young, old, beautiful or otherwise. This was a new understanding of the arts compared to the somewhat over-idealized figures of the Classical era. There was a difference especially in sculpture: artists portrayed not only beautiful people, but also ordinary subjects with wrinkles, flabby faces, or big noses, if that was actually the face of the person they were sculpting. Art follows the changing culture of the time, and the culture was indeed changing.

## 4.2 The Roman Empire

The history of the Roman Empire is a vast subject. Everything began in the sixth century BC with the Republic, but by the third century BC, there was a significant expansion beyond the original territories. The Roman Empire was founded in 27 BC, after Octavian Augustus became the sole ruler in 31 BC, and it lasted until 286 AD, which marked the beginning of the Middle Ages. Famous are the words of the Emperor Augustus about his reign, as quoted by the Roman historian Suetonius: "I found Rome a city of bricks and left it a city of marble."

Under the Emperor Augustus, Rome became the biggest empire in Antiquity, a truly vast empire. It expanded from the region of Etruria in the Italian peninsula to the Mediterranean basin during the Punic wars, and then to continental Europe under Pompey and Julius Caesar, with the conquest of Britannia, Gaul, and Hispania. Then followed the regions of Mauretania, Numidia, and Egypt in North Africa, and Syria, Judea, and Partia in the east and the Middle East, not to mention Asia Minor, Greece, Macedon, and Dacia, and then the islands of Cyprus, Corsica, Sardinia, and Sicily. As the imperial capital, Rome was embellished with magnificent palaces, temples, public baths, theaters, and stadiums (Fig. 4.1).

Following the conquest of Greece, the Romans adopted the Greek culture, including their religion, arts, and science. The Greek language was highly esteemed and was spoken in particular by the elite and intellectuals. Regarding their religion, the Roman Empire was polytheistic. Many gods and goddesses were worshipped, and there were also minor monotheistic religions such as Judaism and the beginnings of Christianity. But the single most influential culture in Rome was the Greek's.

Greeks and Romans worshipped the same gods with different names, for example, Jupiter for Zeus, Juno for Hera, and Minerva for Athena, along with many others. One early Sun god, Sol Indiges, was not represented in Greek religion, but appears in the later Roman Empire as Sol Invictus, which means the "unconquered Sun." So this was a Sun god never worshipped by the Greeks, but very important to the Romans.

When Rome was founded, they introduced the worship of Sol Indiges, a Sun god that was not represented in Greek religion, and this veneration lasted for the first three centuries. According to the Roman historian Tacitus, an old temple had been built in the Circus Maximus during the early agrarian Rome. At the time, Sol Indiges was still of some importance as a Sun god. But following the conquest of Greece, the Romans began to identify the Greek deities with their own, although using different names. For example, Jupiter became Zeus, Juno became Hera, and Minerva became Athena, along with many other such identifications. Apollo became the counterpart of the Greek Sun god Helios, idealized as a beautiful and radiant young man. For the Romans, Apollo was also a god of the arts and science, sometimes portrayed with a musical instrument, the lyre, and also pictured on a golden chariot towed across the sky by four horses (the quadriga). Apollo was identified as a Sun god with human features. It was common in Greek and Roman religion to depict deities with human looks. A beautiful young man, who loved poetry

**Fig. 4.1** Ancient Rome. The Emperor Hadrian's villa, Tivoli, Italy. Photo by the author

and music, and loved many goddesses, and many human women, with whom he had twenty-nine children. And, as was typical in Antiquity, he also loved many beautiful young men.

During Imperial Rome, Apollo was less important as a Sun god. It was not until the Late Roman Empire that the Sun god became the most important and powerful god in the pantheon of Roman religion, going by the name of Sol Invictus, the "unconquered Sun," honored and worshipped by Emperor Aurelian. Sol became a major divinity and a great temple was built in the Campus Agrippae in Rome. Sol Invictus became a symbol of the victory in the campaign of Palmyra,[2] in modern Syria, which took place on 25 December 274 AD (Fig. 4.2).

Ancient Rome celebrated the birth of Sol Invictus on 25 December. It was the Emperor Aurelian who established the Sun cult as the official religion of the empire, later continued by Emperor Constantine I. However, eventually, with the growth of the Christian faith, Constantine abolished the pagan cult of Sol Invictus in favor of the new religion. It was Constantine who wanted to portray the symbol of Sol Invictus on coins, and later declared "Dies Solis"—the day of the Sun, or Sunday—as a day of rest for the Romans. Consequently, according to some historians, it was Constantine who declared 25 December to be the day of Christ's birth. So, this was clearly a major historical and cultural change, replacing the celebration of Sol Invictus by what we now call Christmas!

In a way, we can say that Sun god worship is still happening today, if we replace the Sun god with the Christian god, Jesus Christ. It seems like the sunray symbol for Sol Invictus in the late Roman Empire became a symbol of

**Fig. 4.2** The Emperor Aurelius. Terracotta sculpture painted gold

[2] Unfortunately, the historical city of Palmyra was destroyed in 2013 by the senseless fanatical terrorists of ISIS. The reason, according to them, was that it did not conform to their strict interpretation of Islam, like anything predating the Islamic era.

Christianity in medieval Europe, representing Jesus Christ and the Christian saints with golden halos.

### 4.2.1 Art and Science in Ancient Rome

The golden age of art and science in Greek culture was basically continued into Imperial Rome. In the arts, the Romans applied the geometrical formula used by Greek artists, known as the golden mean or golden section, in their attempts to reach perfection, especially in sculpture. However, there was a difference between the two cultures: the Romans were more concerned with individuality than the Greeks of the Hellenistic period. Roman artists sought to create realistic portraits that would capture the character of the particular subject they were representing.

In science, there was also a continuation from Greek mathematics and astronomy. Roman astronomers studied the motions of the celestial bodies, and like the Greeks before them, they attributed the names of gods and other mythical figures to the planets and constellations. The most famous astronomer of all was without doubt Claudius Ptolemy, who lived from about 100 to 170 AD in Egypt, which was at that time part of the Roman Empire. He wrote scientific treatises of great importance for Western European science, especially during the Middle Ages. The Almagest and the Tetrabiblos were Ptolemy's best known works. He was the last great astronomer of Antiquity, and the most influential astronomer in Europe, the Middle East, and North Africa.

Ptolemy favored a geocentric model of the Universe, as did most of his predecessors. Indeed, Ptolemy's geocentric model was accepted until the simpler heliocentric picture resurfaced in the seventeenth century. Ptolemy's model thus took the Earth as stationary at the center of everything, with the Sun, Moon, and the other planets moving around the Earth. The stars were all fixed to an outermost sphere and carried around the Earth in circular orbits. An inexplicable and mysterious power had to keep the celestial bodies in motion. This apparently simplistic and relatively successful model was in reality far from simple. To make it work, he had to hypothesize the motions of the planets as occurring not only in circles around the Earth, but also in smaller circles superposed on those bigger ones! At any rate, this geocentric model was accepted for centuries, especially while Christianity held sway in the Middle Ages. Man at the center of creation! Just as affirmed by the sacred Judeo-Christian scriptures.

# 5

# Asia

## 5.1 Japan

During ancient times and in every part of the globe, mythology was an important human characteristic, creating beliefs, religions, and ultimately culture. In ancient Japan, the Sun god was female, in contrast to most cultures in which the main god had to be male. The goddess Amaterasu was thus the supreme ruler of the world. In one legend about Amaterasu, the goddess shut herself in a cave, and in doing so, brought darkness upon the world and in the heavens. Her disappearance caused a disaster and distress to all the other gods, who gathered and decided to perform a ritual to convince the goddess to leave the cave. Amaterasu, enticed by the ritual, emerged from the cave to shine light upon the Earth and in the heavens once again. Her light was essential in both realms. As the Sun symbol, she was the most revered and venerated personage in Japanese religion and mythology, and to this day, the symbol of the rising Sun represents Japan on the Japanese flag.

Not only the Sun, but also the stars played an important role in the everyday lives of ancient Japanese people, as indeed they did to scientists involved in astronomical studies. Being one of the most noticeable constellations in the sky, Orion was considered a particularly important group of stars. Astronomy was for the Japanese a symbol of knowledge and culture. They believed that the stars sent messages to humans, but the message was not seen as being for any particular individual. Rather it was viewed as informing the population as a whole, for example, indicating when to plant and when to harvest their crops. Practical information for everyday life!


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As in most ancient civilizations, the constellations were associated with mythology, but also with astronomy which was considered an important science. Archaeological excavations have unearthed an ancient tomb, called the Kitora tomb, near the village of Asukain, in which they found an elaborate astronomical chart. The tomb was built between the seventh and eighth centuries. Through this discovery, we know that the peoples of Japan had an advanced knowledge of astronomy at this time. The tomb comprises a small chamber only a meter high and a little more than two meters long, for the burial of a single person. The four walls of the chamber indicate the cardinal points. The north wall features the Black Divine Tortoise, the east wall the Azure Dragon, the south wall the Red Phoenix, and the west wall the White Tiger. The astronomical chart is on the ceiling of the tomb, which is decorated with a map of the night sky charting 68 constellations. The stars are depicted with gold leaf, while three circles painted in red clearly show the motions of the celestial bodies, and another circle represents the motion of the Sun. This is a great example of astronomy and also the artistic representation of figures. The murals are painted with great descriptive accuracy, so that the viewer can work out the meaning of the story they tell.

An important feature of Japanese art was an understanding of the natural world as a source of human spirituality and emotion. Painting was the preferred artistic expression, practised not only by professionals, but also by amateurs, influenced probably by Chinese culture. In fact, over the centuries, Japan has been subjected to many foreign invasions, and so has absorbed and assimilated elements from other cultures which have contributed to its aesthetic preferences. We can see this very feature of Japanese art in the murals of the Kitora tomb: the understanding of the natural world. The Kitora star chart is considered by archaeologists to be the oldest in the world.

## 5.2 Chinese Mythology, Astronomy, and Art

Chinese culture is one of the world's oldest, and considered by historians to be the dominant culture of East Asia. The Neolithic began in China in 7000 BC, with the appearance of the first agriculture, the construction of buildings, the manufacture of pottery, and ritual burial of the dead. Based on ancient texts and archaeological sites, the oldest dynasties, the Shang (ca. 1600–1046 BC) and Zhou (1600–221 BC), were located in the central, lower, and middle plains of the Yellow River. It was during these times that the ancient Chinese culture began to take shape, adopted later by the dynasties that followed.

Some historians affirm that the traditional traits of their ancient culture are still visible to this day.

During the Shang and Zhou dynasties the population was literate. In fact, we know their culture through their writings. They engaged in large scale building projects and kept records of these projects through a form of writing using pictograms. Culturally, they developed their religion, political philosophy, and artistic style.

Art in China differed from art in other ancient cultures in that artists were not professionals, but amateurs, usually nobles, members of the elite, and sometimes women, which was very unusual in those days. These artists were nevertheless scholars, intellectuals, and literate people, mainly men but including also a few women. They were probably students of Confucianism, which was one of the three major religions along with Taoism and Buddhism. Confucianism in particular was perhaps more of a philosophy than a religion. The role of these doctrines, besides being spiritual, was to influence government, science, and art through a philosophical approach to life. Apart from being scholars and intellectuals, Chinese artists were also keen observers of nature. Their style was minimalist, and somehow austere. Artistic skills were secondary; expressing the good character of the artist was more important.

Of course, there were also professional artists, employed by the imperial court and by rich patrons to decorate buildings and tombs. For the Chinese, the main art forms were calligraphy and paintings. They developed a notion of connoisseur of the arts, somehow a form of artistic snobbishness, which was not widespread at that time in history. But I dare say art snobs are actually a typical feature of our own times! In his "Record of the Classification of Old Painters" (unfortunately lost) Xie He, an art critic and historian of the sixth century AD, published six important points that should be observed in order to obtain a perfect work of art. These rules concerned: (1) vitality, (2) use of the brush, (3) depiction of form, (4) color, (5) spatial composition, and (6) copying of models. These were considered essential rules for becoming a good artist, and they were in fact quite rigid rules compared with our concept of art today. Even so, according to the ancient Chinese view of the arts, the most important thing for an artist was to transmit his or her feelings. This was more important than the craftsmanship of the work. And that idea very much reflects our own view of art today, but maybe without Xie He's rigid rules.

The arts occupied a very important place in Chinese culture. Besides calligraphy and painting, there was also sculpture. Monumental examples have been found in many places across the vast territories of China, but without doubt the best known are the life-size sculptures of the "Terracotta Army" of Qin Shi Huang. This "army," included 7000 warriors, 600 horses, and a great many chariots, guards the emperor's tomb. Simply astonishing! There were also sculptures on a smaller scale, cast in bronze, representing animals and mythological creatures in three-dimensional form.

Chinese mythology is also a vast collection of religious traditions, legends, and folktales, transmitted either orally or in written form. As in many ancient cultures, the myths represent and express the people's image of themselves in their everyday lives, and also their beliefs. The myth of creation, for example, refers to a female cosmic deity called Doumu, which means "Mother of the Big Dipper," born when the Universe was created by Pangu. Doumu was the mother of the "Nine God-Kings" of the heavens, and it was believed that these were represented in the night sky by the seven stars in the constellation of the Big Dipper and two others not visible to the naked eye. This constellation was viewed as a chariot, and the goddess was also called "Lady Mother of the Chariot," and sometimes "Queen of Heaven," or "Mother of Heaven." In ancient China, mythology and cosmology were tightly intertwined, as the myth of Doumu demonstrates. Doumu was part of the mythology, she was the goddess, but the stars which form the Big Dipper and represented her sons were a clear reference to observation of the night sky.

Another myth about the Sun involves the archer Hou Yi. According to this legend, there were originally ten suns in the sky, which normally crossed the sky one by one. But one day, they all came out at once, causing people on Earth great suffering due to the terrible heat. Then Hou Yi appeared in the guise of hero and shot nine of the suns down, leaving only one in the sky, whereupon normal life was restored.

China was principally an agricultural country, but through archaeological studies, we know that there was a continuous development of astronomy. For purely practical reasons, being an agricultural society, the observation of celestial phenomena was essential in order to determine when to plant and harvest crops, as it was in most ancient cultures. But as time went by, the interest in astronomy became more scientifically oriented, and at the same time, it was understood that humans and their environment were closely connected with each other. In a philosophical sense, this connection between the environment and people was a response to their actions, thoughts, and emotions, similar to the philosophical position the ancient Chinese adopted toward the arts.

Astronomical study of the Sun was very important in China. The Chinese were among the first to record solar eclipses, having started in around 2000 BC. It was the astronomer Shi Shen in the fourth century BC who first understood what actually caused solar and lunar eclipses. In the first case, the

Moon passes between the Earth and the Sun and blocks out the Sun's light, and in the second case, the Moon passes through the shadow of the Earth and turns red or darkens. Astronomers had already recorded 1600 observations of solar and lunar eclipses by 750 BC. Shi Shen understood that moonlight was just light reflected to us from the Sun, just as the Ancient Greeks Parmenides and Aristotle had already realized. During the Song Dynasty (1031–1095 AD), the scientist Shen Kuo used the model for solar and lunar eclipses to prove that the celestial bodies were round and not flat, something that had also been understood in Ancient Greece by similar reasoning.

And it was during the Song Dynasty (960–1279) that many observatories were built. A number of star maps have been found carved on wood, painted on ceramics, and painted on the walls and ceilings of tombs. On one star map carved on wood during the Han dynasty and dated to 2000 years ago, we can see the Sun, the Moon, several comets, and the Milky Way. Another sky map painted on the ceiling of a tomb in Luoyang in the province of Henan shows over 300 stars, the planets, and the Milky Way. The unknown artist painted the stars in red, using different shapes to indicate the brightness and correctly indicating the relative positions of the stars in the sky. This mural, dated to the sixth century AD, shows that the artist had a good knowledge of science and art.

Archaeological excavations have discovered an ancient observatory in the province of Shaanxi, a structure about 2200 years old, dating to the Qin Dynasty. The site covers an area of 2 $km^2$, with 1424 round and square platforms corresponding to 332 stars and galaxies in the sky. An attempt to create heaven on Earth. Indeed, in ancient China, there was a social and traditional aspiration to connect the heavens with Earth.

Astronomers observed the sky simply with the naked eye, and yet still made important discoveries. Gan De discovered Ganymede, one of the natural satellites or moons of Jupiter, without a telescope. It would be more than 2000 years before Galileo succeeded in discovering Jupiter's satellite Ganymede. As attentive observers of the sky, the ancient Chinese astronomers recorded the appearance of Comet Halley more than 2600 years ago.

Interest in astronomy was always important in ancient China, and it is still alive and well today, although now with knowledge of modern astrophysics. China currently has one of the most active space programs in the world, although unfortunately there are few serious links with its Western counterpart, the USA. The space program of the People's Republic of China plans to launch satellites to explore the Moon, Mars, the Solar System, and deep space. On 29 November 2022, Shenzhou 15 was launched with three astronauts aboard, taking them to China's first space station Tiangong, which means Heavenly Palace. It has been a successful mission, and China is now the third nation to have a permanent space station after the USA and Russia. Many scientific experiments are planned in the space station Tiangong, such as the launch of a new space telescope Xuntian which will map and catalog stars, an ancient Chinese tradition. But not only! It will also be looking out for supermassive black holes.

Recently, I had an interesting conversation about star catalogs with Luca Baldini, professor of experimental physics at the University of Pisa, Italy.

He pointed out that ESA's Gaia mission can be considered as a contemporary star catalog. Its mission is to map the distance, luminosity, temperature, and composition of the stars. Professor Baldini explains that Gaia will effectively create an extremely precise three-dimensional map of more than a thousand million stars in our galaxy and beyond. Just imagining millions of stars is an extraordinary idea, so it will be quite an impressive catalog! This mission will answer important questions about the origin and structure of the stars, including of course our own star, the Sun, and their evolution in our galaxy.

Professor Baldini also told me about an Earth-based mission that is mapping distant stars. The LSST telescope, managed by the SLAC National Accelerator Laboratory, is now called the Vera Rubin Observatory, in memory of the well-known American astronomer. This is an optical telescope. From its position on a mountaintop, it is observing the entire visible sky, capturing its changes over periods of time from seconds to years. With its sensitive camera, the Rubin Observatory will eventually produce images of a billion galaxies with greater accuracy than all previous instruments could ever have obtained.

Coming back to the Tiangong space station, there is also a plan to launch a mission to Mars and to build a Moon base with Russia. At the present time, with the war in Ukraine, the project could at best be indefinitely postponed.[1]

[1] The International Space Station was a peaceful collaboration between different nations with different ideologies, and thanks to science, it did work well for several decades. However, the war in Ukraine has changed everything, and up to now (2024), it does not look like the change is for the better. But that's just my personal opinion! On the other hand, three astronauts, one American woman and two Russian men, arrived aboard the International Space Station on a Soyuz spacecraft in September 2023. So, there is still a peaceful collaboration here despite the profound tensions between the two nations down here on Earth. They announced: "Here we get along just fine in contrast to the conflict on Earth. Symbol of peace and collaboration.".

## 5.3 India

I visited India when I was still an undergraduate student in art history. I traveled by land, when it was still possible to do so. From Italy, I went through Greece, Turkey, then Iran, where revolution was in the air! In the capital city of Tehran, young women could still wear miniskirts, but not for long. This was at the end of 1977. The Shah Pahlavi would soon be deposed and forced into exile in Europe. Immediately afterwards, he was replaced by the Ayatollah Khomeini, who came back from his own exile in Europe. What happened to Iran following the revolution is well known: a not very democratic government took control of the country, the regime of the ayatollahs, replacing the previous and also not so democratic government of the Shah. The effects of the Islamic revolution are still being felt today.

I then went through Afghanistan. In the capital city of Kabul, a few young women could be seen dressed in Western fashion at that time. In the rest of the country, women wore the veil known as the burka, which covered them entirely from head to toe. How could these poor women possibly see the outside world? In fact, they were not even part of the outside world; segregation was their destiny. As a traditional patriarchal and tribal society, Afghanistan has not been a good place for women for many centuries. To make the misery of the Afghan people even worse, a Russian invasion would soon be knocking at their door.

Next on my route was Pakistan. Misogyny there was, and probably still is, a painful reality. Muslim culture has existed for more than a millennium, and it is rich in beautiful art, poetry, and science, but that beauty has frequently been inaccessible to women. The same attitude has of course prevailed throughout Antiquity in many countries, but misogyny is still predominant in some, if not all, Muslim countries. Although I wouldn't wish to be overly controversial, this is without doubt an historical fact.

And finally, I arrived in India! My first impression was a rainbow of colors illuminating the countryside, the villages, and the cities. Of course, there was also unbelievable poverty, with many, many people simply living on the streets. There were thousands of people crowding the cities, along with a chaotic flow of cars, bicycles, and horse-drawn carriages, holy men wearing huge live snakes around their necks, and other men, holy or otherwise, semi-naked, covered in ash. A truly unreal scene! But compared with the restrictions I had witnessed in the countries I had just visited, it was a joy to see India. A few months later, it was not possible to go back home the same way I came. The whole area was on fire, and it still is. But not India.

Indian culture, including its religion, art, and science, is vast, and has been since the earliest times. Human activity goes back at least as far as the beginning of the Holocene period over 10 000 years ago. Civilization in the Indus valley dates back to 7000 BC. Archaeological excavations in the village of Balhathal in the province of Rajasthan have unearthed sites which clearly prove the antiquity of this civilization, but it could be even older. India is perhaps the nation with the most different religions and the greatest ethnic diversity, compared with other countries around the world, and it has always been this way since the beginning of its history. The main religions were Hinduism and Buddhism, but today there is also Islam, Sikhism, Christianity, Jainism, Zoroastrianism, Judaism, and several more. As in ancient times, religion occupies a central role in the lives of India's population (Fig. 5.1).

Astronomy has also been influenced by the religious and spiritual outlook of the world. The book "The Tao of Physics," written by physicist Fritjof Capra, perfectly translates the spiritual and religious connection to science of

**Fig. 5.1** The Indian Sun god Surya. Pencil drawing on paper colored with gold acrylic paint

the ancient populations of India, which continues even today. According to Capra: "Physicists do not need mysticism, and mystics do not need physics, but humanity needs both." For him, there is a connection between quantum theory and the ideas of Hinduism, Buddhism, and Taoism, a connection between subatomic physics and the mystics.

Ancient Indian astronomy can be dated to the second millennium BC. References to astronomy can be found in the Vedas, extremely important sacred texts for Indian culture, which primarily include religion, but also art, science, and astronomy. This so-called Vedic astronomy focused mainly on studies of the Sun and Moon, and in particular their motions in relation to days, months, seasons, years, equinoxes, and solstices. To make astronomy comprehensible to the people, mythological gods were created, corresponding to the Sun, the Moon, Mercury, Venus, Mars, Jupiter, and Saturn, the seven "planets" that appear to move around the Earth. Besides these seven celestial bodies, there were another two, in fact two invisible demons, Rahu and Ketu, who sometimes made the Sun disappear. Once again, mythology was being used to explain the Solar System and eclipses to a largely illiterate population.

One of the best known astronomers of ancient India was Aryabhata. He was a mathematician and astronomer who made many discoveries relating to the motions of the Solar System. Very little is known about Aryabhata's personal life, but he was probably born in 476 AD in Ashmaka or Kusumapura, India. We know his inventions and discoveries mainly through his magnum opus "Aryabhatiya," which was probably already highly valued during his own lifetime. Unfortunately, the majority of his written works have been lost. He calculated the circumference of the Earth to a very good approximation, close to the measured value today, and predicted solar and lunar eclipses. Aryabhata realized that the stars appear to move because of the Earth's rotation about its own axis, and he may even have understood that the planets revolve on elliptical orbits around the Sun. So, he was in effect proposing a heliocentric model, ten centuries before Copernicus came to the same conclusion in fifteenth century Europe.

As I mentioned earlier, astronomy was explained through mythological stories and figurative art. In the Rigvedic period, Mercury was identified with the god Vishnu, who was a brother of Indra, sometimes identified as the Sun god. In later traditions, Vishnu became the solar deity, an important god among the crowded pantheon of Hindu divinities. One of the essential features characterizing Vishnu were the three strides he took to measure out the world: the first was to measure the Universe, the second was to measure what could be seen by humans, and the third was to measure what lay beyond mortals. Another interpretation of the three strides refers to the course of the Sun in the Universe, in relation to the Heavens, the Earth, and the Netherworld.

In ancient India, there is no mythology or astronomy without the contribution of art. These things were indeed closely entangled. Subhash Kak, professor at the university of Oklahoma in the United States and scholar of Vedic culture, says that the best way to understand India is through art and cosmology, and he adds that art is not only an aesthetic expression of our sense of beauty, but reflects the cosmos and the divine.

Early artistic expression in India can be found in prehistoric cave paintings. The Bhimbetka rock paintings data back to the Paleolithic and Mesolithic and continue right up to the historic period. There are mostly painted scenes of animals and humans hunting them. This site is situated in the state of Madhya Pradesh in central India, and since 2003 it has been a UNESCO World Heritage Site. There are shelters in caves extending over 10 km, and archaeologists say that some of these shelters were probably inhabited for as long as 100 000 years, thus dating them back to the early Stone Age. The oldest cave paintings at Bhimbetka have been dated to 8000 BC.

During the Vedic period, the stars in the sky were represented as cosmic beings. This connection between stars and living beings, between the biological and the astronomical, and between microcosm and macrocosm constituted a prime belief in India, and to some extent it is still present today. Now, India is at the forefront of contemporary astrophysics and cosmology, and it has an advanced space program. The Indian Space Research Organization (ISRO) has launched its first astronomical mission, Aditya-L1, to study the Sun. The latter is no longer viewed as the god Vishnu! Modern Indian astrophysicists can now explain the real nature of our star.

The Aditya-L1 mission was launched on 2 September 2023 to observe the solar corona and the chromosphere, which is a thin layer between the photosphere and the corona, and to study the physics of the partially ionized plasma of coronal mass ejections, the coronal magnetic field, and flare exchanges. The mission will last for five years. But first the Indian mission must travel 1.5 million kilometers across space, a journey that will take some four months, stopping a long way from the Sun and in fact at a distance of 150 million km from the Earth at one of the so-called Lagrange points of the Sun–Earth system. These are a kind of "parking" position in space where objects have a tendency to remain where they are thanks to the equilibrium of gravitational forces. This is a way of reducing fuel consumption, but it also provides a good position from which to observe the exterior layers of the Sun with its specially designed scientific instruments (Fig. 5.2).

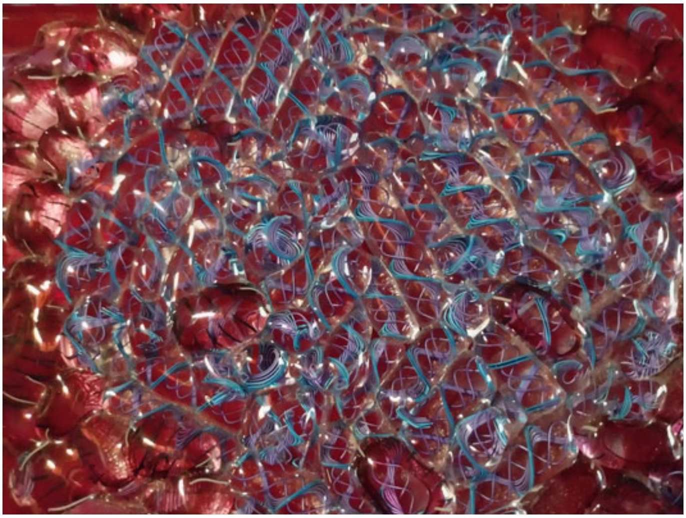

**Fig. 5.2** The chromosphere, represented in blown glass. This is my interpretation of the thin layer called the chromosphere above the Sun's photosphere

As pointed out by Hugh Hudson, astrophysicist at Glasgow University, the corona can be seen only briefly during a total eclipse of the Sun. This mission will supply much more detailed information and hopefully clear up some of the mysteries surrounding the Sun's brilliant corona. Aditya-L1 will also study solar magnetic storms, the solar wind, and solar energetic particles. This is the first Indian mission dedicated to the study of the Sun.[2]

[2] Aditya comes from Sanskrit and is a synonym of the Hindu solar deity Surya.

# 6

# The Middle Ages

## 6.1 Europe

Traditionally, the Middle Ages began in 476 AD, after the fall of the Roman Empire, and ended around 1400 AD. It represents almost a thousand years of continuous political, social, and religious change, including a schism in the Christian faith between Catholic and Orthodox, the crusades with the development of organized military orders, feudalism and the medieval model of government in which people had access to land and worked in return for that access, and the construction of castles used by rulers to demonstrate their wealth and power with the help of knights, soldiers raised to a new high-ranking military status (Fig. 6.1).

The Middle Ages are often described as an era of ignorance, superstition, and intellectual obscurantism. However, recent studies of the thousand years following the fall of the Roman Empire suggest that there was not in fact an intellectual decline in medieval Europe. On the contrary, there was attentive observation of nature in science and in the arts. Moreover, the first universities were founded during the medieval era in Bologna, Italy, and then in Paris, France, followed shortly afterwards by many more universities in cities all over Europe. And, of course, the scientists of the day were well aware that the Earth was not flat.

During the later Middle Ages, magnificent cathedrals were built in Western Europe, embellished with splendid stained-glass windows. The cathedral of Chartres in France, built around 1200, is a good example of the impressive buildings erected during the so-called "Dark Ages." It is 130 m long and was originally 105 m high (there is now a taller tower), and it was filled



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**Fig. 6.1** Medieval Sun. Photo of sunrise with terracotta Sun. In the Middle Ages, the Sun was often depicted with a face

with sculptures representing figures from the Old and New Testaments. The purpose, as usual in those times, was to preach to and instruct the illiterate population about religion. The main feature of Chartres cathedral is without doubt its stained-glass windows, all 176 of them. The purpose of these beautiful windows was once again educational, to preach religion by illustrating the Old and New Testaments. Art was the most effective tool for communication, and I believe, and hope, that it can still be an important tool for communication even in these technological times.

Unfortunately, Notre Dame cathedral in Paris, built in 1163 and completed in1344, was very seriously damaged by a fire in April 2019. This sad event damaged part of the roof and many works of art in the interior. Now the discussion between the many experts centers on how to reconstruct the missing part: reproducing it the way it was originally, or giving the cathedral a touch of modernity.

During the Middle Ages, particularly in Italy, there were many innovative artists. Nicola Pisano, Cimabue, Duccio di Buonisegna, Arnolfo di Cambio, and, especially, Giotto di Bondone, often considered the most important of all. Giotto was born near Florence in 1266 and died in Florence in 1337.

He was a painter and architect and lived at the end of the period sometimes referred to as the "Dark Ages," just prior to the Renaissance. But, in his work, he certainly sowed the seeds of the innovations to come in the Renaissance style of art, which developed a century or so later. His best known works are the frescos painted in 1301 in the Scrovegni Chapel in Padua, Italy. The chapel is almost 30 m long and 13 m high, and the vault of the chapel is painted in an intense blue color to depict the sky with gold stars. There are scenes from the New Testament, and the birth of Christ is depicted in one part of the chapel, with Halley's comet brightly painted over the stable. Very likely, Giotto observed it himself during its passage in 1301. On the large west wall of the chapel, there is a representation of the "Last Judgment," which probably inspired Michelangelo to paint his more famous "Last Judgment" in the Sistine Chapel in Rome. Giotto's Scrovegni chapel frescos are considered one of the finest works of art in the whole of Western culture, and the chapel has been a UNESCO World Heritage site since 2021.[1]

During medieval times, the model of the Universe was Ptolemaic, and indeed, Ptolemy's model was widely used to calculate the positions of the planets relative to the fixed stars. Dante's "Divine Comedy," and in particular "Purgatorio," includes many lessons of astronomy, alluding to the positions of the Sun, Moon, and planets to indicate the time of day. According to Dante, astronomy was the noblest science. In his other work, the "Convivio," as in the "Divine Comedy," there are many astronomical allusions. His understanding and knowledge of astronomy were derived from a commentary on Aristotle written by Albertus Magnus ("On the Heavens"). This commentary was widely known during the Middle Ages, and Dante's "Paradiso" and "Inferno" can therefore be described as Aristotelian in nature.

There were many Italians among the intellectual scholars of medieval times. One of these was Leonardo Pisano, known as Fibonacci, who was born in Pisa in 1170 and died there in 1240. He is remembered as a mathematician, but he was also a rich merchant who was fond of traveling, something that was not so common at the time. In fact, he undertook his journeys a generation before the more famous travels of Marco Polo. Fibonacci traveled for his business, but also through curiosity with regard to other cultures. He went to Algeria in North Africa, where he had contacts with Islamic intellectuals and mathematicians. He was the one who introduced the Hindu-Arabic decimal number system into Europe, where it replaced the Roman numeral

[1] Enrico Scrovegni was a rich man who practised usury in Padua. In fact, he was more of a usurer than an art lover. He commissioned the painting of the chapel in order to be absolved from his sins, a common practice at the time. Wealthy sinners could buy their place in heaven with the complicity of wealthy and just as sinful clergy. Therefore, in his "Divine Comedy: Inferno," Dante placed him in hell.

system. He is famous for the Fibonacci sequence, in which each number is the sum of the two preceding numbers. This is a sequence which often crops up in different areas of mathematics and science today. Fibonacci sequences can be found in natural systems like cells, the petals of flowers, honeycombs, seashells, and many more, including the never-ending patterns of certain fractals.

I have mentioned some of the best known minds of the medieval period, but there were many less well known and just as brilliant. Personally, I think it's unfair to label this period the "Dark Ages." Europe was not really in decline and deprived of intellectual freedom. It is true that the great majority of the population were ignorant and superstitious, but that was the way things were from Antiquity and right through the following centuries.

Castles, knights, dragons, and beautiful princesses like Rapunzel, the best known fairytale princess with her long blond hair, are all part of the idealized image of the Middle Ages. It was indeed a time rich in myths and legends, but there were also substantial changes in society and politics. In Western Europe, the glory and the myths of Ancient Rome were somehow still present, so it was not a total break with the classical period. In the ninth century, the Carolingian Empire of the Franks was based on the ideals of the Roman Empire. The main political change in medieval times was perhaps the construction of castles, the introduction of the feudal system, and the foundation of monastic orders (Fig. 6.2).

There was a proliferation of castles in Europe in the ninth and tenth centuries. These fortified structures were built by the nobility and royalty, or by the military orders. They were offensive and defensive at first, built for military use with the purpose of controlling the territory, and as symbols of power, but they were later inhabited and embellished. Castles were built everywhere in Europe, and many of them can still be seen and admired in our modern countries. In Germany, there are 25,000, maybe more than in any other European country, while in Italy some 45,000 buildings are classified as being from this period, but that includes many watchtowers, which cannot be counted as real castles.

I live in a small medieval village in Tuscany, Italy, surrounded by many castles, but there is one with a particular gruesome story. This is a true story which took place near Bolgheri, a small town near Pisa. The count of Donoratico, Ugolino della Gherardesca, was imprisoned in the tower of Muda with his two sons and two grandsons. Dante rated Ugolino as a traitor, sent to hell, the "Inferno," where he would have to eat the brains of his offspring for all eternity, and indeed, the five unfortunate people never left that tower alive. Nowadays, Bolgheri is still owned by the Della Gheradesca family, and the

**Fig. 6.2** Medieval castles and knights. Acrylic paint on canvas with two knights made of iron and holding illuminated glass shields

sad story of count Ugolino has been forgotten. Bolgheri is instead famous for its excellent red wine.

Thanks to the thousands of handwritten books kept in monasteries during medieval times, we now have valuable records of medieval culture. Monks were the guardians of history, science, religion, and art, and the books were embellished with very carefully drawn illustrations. Monastic orders were founded mainly in Italy, but also in the south of France. The Dominicans, Franciscans, Benedictines, Cistercians, Carmelites, and Clarisses were called the mendicant orders because of their vows of poverty. The majority of monastic orders arose in the twelfth and thirteenth centuries, but one of the best known was the order founded by Saint Benedict, in the sixth century.

The Benedictine order had strict vows of poverty, chastity, and obedience. They were allowed no personal property and carried out their daily tasks in silence. The lives of the medieval monks revolved around prayers and work, both manual and intellectual. From the fifth to the thirteenth century, the monasteries were the sole producers of books in Europe, and the monks were involved in every aspect of their production, from writing, to illustrating and anything needed to obtain the finished product. A library was a must in these abbeys. According to the rules of Saint Benedict, monks had to work in silence in a room in which the only light came from a small window. Every day, no matter what the weather or their state of health, the work of the monks had to be done.

To get a feel for the atmosphere in a medieval monastery, the book and the movie "The Name of the Rose" give a perfect example. The story takes place in the year 1327, when a Franciscan monk, William of Baskerville, and his novice, Adso, travel to a north Italian monastery. As soon as they reach the abbey, one cold and snowy day, the story becomes intriguing. The book was written by Umberto Eco and the movie was directed by Jean-Jacques Annaud in 1986. The reader of the book, like the viewer of the movie, immediately gets a feel for what life must have been like in the Middle Ages, witnessing the wealth of the monks, the extreme poverty of the peasants, the heresy, the witchcraft, and the cruelty of the inquisition imposed by an all-powerful church. Then there is the library, a labyrinth containing thousands of manuscripts, carefully copied by the monks, who illustrated them with amazingly detailed drawings and paintings, working every day in their lonely and dark environment. And so goes this accurately constructed scenario describing medieval life in a monastery.

The libraries in the monasteries of Europe tell us how studies of philosophy, theology, art, and especially astronomy were of great importance. Throughout the Middle Ages, astronomy, in particular, was a required discipline for every student. People at that time believed that the radiant Sun, the Moon, the stars, and the planets held a power over their lives. There was no distinction between astrology and astronomy. By carefully observing the twelve astrological signs of the zodiac, astronomy provided a foundation for astrology. Medieval people organized their daily lives from sunrise to sunset around the positions and motions of the Sun and Moon. A manuscript called a miscellany illustrated the cosmic forces by personifying and attributing colors to the celestial bodies: the Sun as an emperor, the Moon as a woman, Mars as a knight, Mercury as a doctor, Jupiter as a bishop, Venus as love, and Saturn as an old man. Each figure is associated with its own particular color: the Sun traditionally with gold, the Moon with green, Mars with red, Mercury with silver, Jupiter with blue, Venus with white, and Saturn with black.

Science in medieval Europe was closely connected with faith. Ptolemy's geocentric theory was the one accepted by the church. The religious idea of man as the most important of God's creations, with the Earth at the center of the Universe, provided the perfect connection between science and faith, and until the heliocentric revolution of the seventeenth century, medieval astronomers remained faithful to the Aristotelian and Ptolemaic systems.

## 6.2 Other Parts of the World

Art and astronomy in medieval times were not limited to Europe. Indeed, the monks in monasteries across Europe were not the only ones to produce manuscripts. The Islamic world also contributed significantly to the study of astronomy, astrology, and the arts from a cosmological standpoint. The philosopher Al-Farabi, who lived from 870 to 950 AD, described astronomy through mathematics, music, and optics. He used Ptolemy's studies of astronomy to calculate the Sun's position when viewed from any fixed place.

Astronomy was always a very important discipline in the Muslim world, for practical purposes such as navigation and determination of an accurate calendar, and also for religious purposes, because observations of the Sun and Moon were used to determine prayer times. During the Middle Ages, large observatories were built to observe the sky. The Maragheh astronomical observatory was founded in 1259 under the reign of Ilkhanid Hulagu, and directed by the Persian astronomer Nasir al-Din al Tusi. It included many constructions related to observation of the Sun, as well as a library of some 400,000 manuscripts. Solar observations in Maragheh came under the supervision of the astronomer al Tusi, who worked with twenty astronomers from different countries and more than hundred students. All in all, it was a highly innovative international collaboration between scientists and students.

In the year 1424 an observatory was built in Samarkand, the work of the astronomer Ulugh Beg. It was a monumental building with a very long meridian arc, which was part of the Fakhri sextant, used for observation of the Sun. It had a radius of 40.4 m and was the largest, and indeed the finest instrument of the time. The observatory in Samarkand remained active until 1500 AD, whereupon it disappeared for unknown reasons and was only rediscovered in 1908 following archaeological excavations.

Many other astronomical observatories were built by the Muslims during the medieval period, but many of them were destroyed by natural causes such as earthquakes, and also by invasions. The Isfahan Observatory was another large one, now in ruins, and in the eighth century, the Muslims built observatories in India. In this period, Muslim astronomers also invented new instruments, and developed others like the astrolabe, an instrument that had been known since Antiquity. The astrolabe was used to calculate the position of the Sun when it rises and when it sets, and also to locate other celestial bodies and to tell the time. It was a key instrument for astronomy, astrology, and navigation. Arabs introduced a better designed astrolabe to Europe in the eleventh century.

Alchemy was widely practised in medieval Europe, but also in the Muslim world, although with a difference. In Muslim culture, alchemy was considered a science of the cosmos and the soul, and as a path toward spirituality in which nature was regarded as sacred. It was related to the practice of astrology, but also to what we now call chemistry. Here, for example, different metals were associated with the different planets.

This was the way Islamic culture moved toward science during the period 900–1400. In Europe, on the other hand, alchemy was viewed almost like magic! It was firmly believed that metals could be changed into gold if only they could find the right recipe.

The approaches of the two cultures were also different in the arts. Calligraphy was the dominant form of artistic expression for Muslims, often used to add verses of poetry on ceramics and the walls of their homes, along with geometric and flower motifs. Early examples of religious art did not contain figurative images, as this was not allowed by Islam, but private residences were filled with figurative paintings, sculptures, and mosaics. Examples of these works can be found in bathing scenes at Qasr Amra in Jordan, built in about 730 AD, and at Khirbat al-Mafjar in Jericho, which are both private residences. Major art forms besides calligraphy were ceramics, books, carpets, metalwork, glass, and decorated scientific instruments, all of them considered by Western cultures as strictly decorative art. Architecture was another important form of artistic expression in many different Muslim countries. Mosques were built in North Africa, Iran, India, and even as far afield as China. Muslim art cannot be considered as confined to a single country, and neither can it be classified as religious art, even though, in those different countries, people professed the same religion. In the Islamic world, the various dynasties in different countries each developed their distinctive style of art.

# 7

# Rebirth

## 7.1 The Renaissance

The Renaissance was the period in European history from the fifteenth through to the seventeenth century, viewed as a rebirth after the supposedly "dark" medieval times, and as a revival of Classical Greek and Roman art and philosophy. The Greek philosopher Protagoras made the famous claim that "man is the measure of all things," thus affirming the central importance of man, and his statement was widely appreciated in the Renaissance, pointing out as it did a radical change from medieval thinking, in which God was always placed at the center of everything.

A new approach to art, architecture, and science, and in particular to astronomy, came along with a humanist philosophy that drastically changed the European vision of the world. New techniques were invented, not least the printing press, by Johannes Gutenberg in 1440, which revolutionized the spread of books across the whole of Europe. (But note that the printing press had appeared centuries before in China.) Mathematical developments changed the world of the arts, when the Florentine architect Brunelleschi invented perspective. The heliocentric model was introduced by Copernicus and advocated by Galileo and others. There were major explorations and discoveries of new worlds which had remained quite unknown to Europeans up until then. And on the downside, there was also the unfortunate spread of the Black Death, the plague which killed millions of Europeans.

The changes that took place during the Renaissance did not happen at the same time across Europe. Historians place the first ideas of this period in



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Italy, as early as the thirteenth century, with the writing of Dante, the paintings of Giotto, and the science of Fibonacci. Florence was the city where the Renaissance began, the initial epicenter. It then spread to Rome, Venice, Milan, Naples, and the other major cities in Italy, before eventually extending to all European cities. Society changed from medieval feudalism to a capitalist market economy. In science, there were great advances in astronomy, mathematics, anatomy, and medicine. The Renaissance was a transition from an ancient world to a modern one, providing the foundation for the Age of the Reason and the Enlightenment of the 1700s.

In the arts, the change from previous times was manifested in paintings through the new technique of linear perspective. It was the architect Filippo Brunelleschi who introduced this mathematically and geometrically based technique, which changed painting dramatically. He showed how to portray a building from a given point of view by constructing its vanishing point. Leonardo da Vinci extended the theory of linear perspective to a curvilinear one, taking into account the curvature of the retina in the eye. Leonardo had a good knowledge of human anatomy. And, with his "sfumato" technique, playing with shades of light and dark, he gave the effect of depth and distance to the figures he represented in his paintings. Leonardo was a painter, scientist, and inventor, the perfect example of a Renaissance man and without doubt a genius. He was a humanist artist, and, like other humanist artists of the time, promoted studies of anatomy with mathematical perspective to depict physical space in a realistic way.

However, Renaissance art focused on religious matters, mainly because the majority of its patrons belonged to the rich and powerful Catholic church. But not all of them. In Florence there were rich and powerful families like the Medici, for example, who were patrons of the most important artists of the time, including Michelangelo, Botticelli, and Leonardo, and this work was not always religious. Religion nevertheless remained an important part of people's lives, as it had been in the previous medieval times. But in the Renaissance, art involved a unique fusion of natural beauty and artistic imagination not seen in the previous era. Michelangelo, Raphael, and Botticelli were all symbols of the innovative paintings and sculptures, while Leonardo da Vinci and Piero della Francesca were not just great artists but also scientists. In his painting "The school of Athens," Raphael represented perfectly the three main symbols characterizing the Renaissance: science, philosophy, and beauty.

In literature, the classical philosophy of Plato and Protagoras was revived, promoting through writing the importance of knowledge and the centrality of humankind. Humanistic literature was a cultural and intellectual movement relying on science and reason to understand the world from a non-theistic point of view. Francesco Petrarca, or Petrarch, is considered the father of this movement. He was born in Arezzo, Tuscany, in 1304, and died in Arquà in 1374. Poet, writer, and philosopher, he was an intellectual with a sense of a mission through literature.

Niccolò Macchiavelli was a writer, philosopher, politician, and diplomat who worked for the Florentine Republic during the years from 1498 to 1512. He was a controversial figure at the time when the Medici family was governing Florence. Today, he is considered the founder of modern political science. In his most famous book, "The Prince," he says that a good politician should be free from ideology, morals, and theology. Indeed, the prince should be unscrupulous, but vigorous in justifying his methods, even cruel ones, if that was what was needed to achieve the desired ends. No wonder he chose Cesare Borgia to be the epitome of a good prince. Borgia was an illegitimate son of Pope Alexander VI and a very controversial political figure at the time.

Another important figure was Giovanni Boccaccio, who was born in Florence in about 1313 and died there in about 1375. He was a poet and writer. His best known book is "The Decameron." Historians consider Boccaccio to be one of the most important writers of the Renaissance. He inspired writers across Europe, including Geoffrey Chaucer in England and Miguel de Cervantes in Spain. Italian humanist literature soon spread to other European countries. In England, in the late sixteenth century, the great writer and poet William Shakespeare is said to have been influenced by Boccaccio. With the invention of the printing press, it became easier to spread new ideas in the arts, literature, science, and especially astronomy (Fig. 7.1).

## 7.2 Here Comes the Sun

At this time the Sun was becoming a key protagonist in scientific and mathematical studies by Renaissance astronomers. Not just legends and religion now, but real science. Nicolaus Copernicus, Tycho Brahe, Johannes Kepler, and Galileo Galilei are the names that spring to mind as the ones who revolutionized astronomy.

In 1543, following many centuries in the sway of geocentric theories, the Polish mathematician, philosopher, and astronomer Nicolaus Copernicus published his heliocentric theory of the Solar System. He actually wrote it much earlier, around 1515, and worked on it all his life. He feared he would

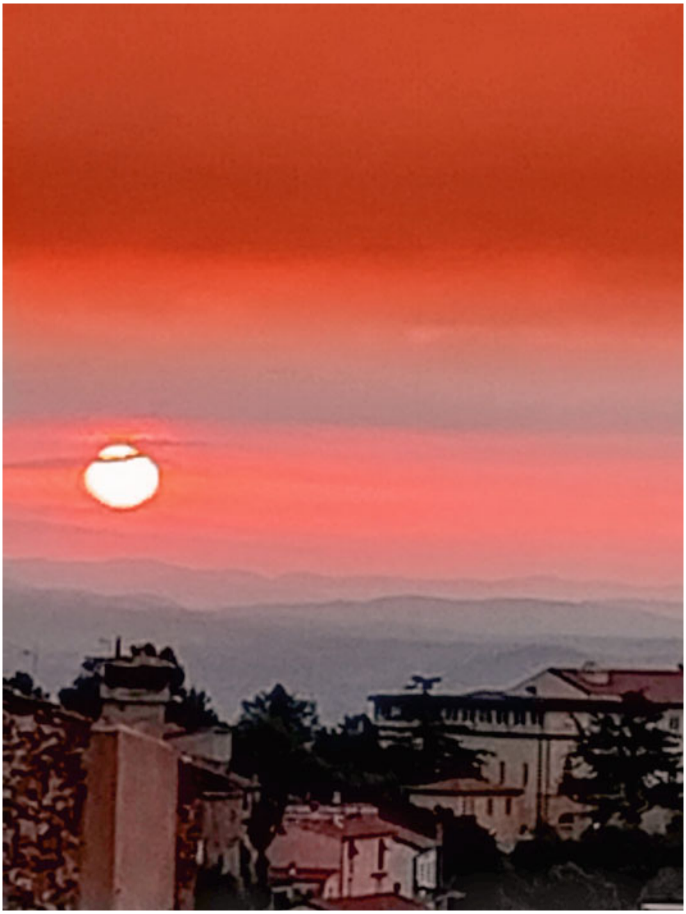

**Fig. 7.1** "Here comes the sun." Photo of dawn by the author, recalling the Beatles song of 1968

be condemned as a heretic by the Catholic Church, so he never dared to publish his book "On the Revolutions of the Heavenly Spheres." It was thanks to his friend and pupil Joachim Rheticus, a young mathematician, that "De revolutionibus orbium coelestium" was finally published and its author became known. There were actually six volumes, in which he explained, using complex mathematics, the heliocentric theory, placing the Sun at the center of the Solar System, and the Earth as just another of the other planets orbiting around it, rather than the Sun orbiting around the Earth.

Today, we take the heliocentric theory for granted, but at that time, it was hard for many to accept such a new and revolutionary concept, after millennia believing the opposite. Copernicus had to reorder the orbits of the planets around the Sun, from the fastest, Mercury, to the slowest, Saturn, in order to explain their retrograde motion against the starry background and thereby assert his heliocentric model, even though he could have no real proof of the Earth's motion without a telescope.

Tycho Brahe was a Danish astronomer who was born into a noble and very wealthy family in 1546 and died in 1601. The King of Denmark, Frederick II, gave him the island of Hven, on which he built the Uraniborg observatory. This became the first dedicated institute of scientific research in Europe. Tycho Brahe made extensive and accurate measurements of the positions of celestial bodies, and he was considered the last, and maybe the best astronomer before the invention of the telescope. He developed the Tychonic system, a hybrid theory based conceptually on the geocentric model, but containing some of the mathematical features of the heliocentric model.

One year before his death, Tycho hired Johannes Kepler as his assistant. Kepler was a German astronomer and mathematician. His role was to use mathematical calculations to prove the correctness of Tycho Brahe's geocentric model. As it happened, Kepler had a preference for Copernicus' heliocentric view. He eventually discovered three laws of planetary motion, and, despite his strong belief that Copernicus had been right, he did differ with regard to some points, placing the Sun at the center of a dynamic universe in which the planets followed elliptic orbits.

Galileo Galilei was an astronomer, mathematician, and philosopher. He was born in Pisa, Italy, in 1564, and died in Arcetri, Florence, in 1642. Like Copernicus and Kepler, he much favored the heliocentric model over the geocentric model which had been accepted for centuries, especially by the all-powerful Catholic Church. He made fundamental contributions to astronomy and to the development of the scientific method, insisting that the language of science had to be mathematics. Galileo's experimental approach was eventually recognized as the best method to discover and understand Nature.

With the invention of the telescope, to which he greatly contributed, he could prove that Copernicus' heliocentric theory was right. When he pointed his new telescope toward Jupiter, he discovered four "stars" very close to it, which he realized later were in fact moons. His curiosity led him to point the telescope at Venus, and then the Sun! He did not know how dangerous it was to look at the Sun without protecting his eyes, and this was the reason why, later in life, he lost his vision completely. Galileo discovered some dark regions on the surface of the Sun. These were what we now call sunspots.

Galileo was not the first astronomer to see and record sunspots. The earliest record comes from China and dates to before 800 BC. In fact, by 28 BC, Chinese astronomers were regularly and accurately recording sunspots. In the western hemisphere, the Greek astronomer Theophrastus, a student of Plato and Aristotle, mentioned sunspots around 300 BC. Galileo himself began observing sunspots by telescope from 1612.

Modern astrophysicists know what causes these dark regions on the surface of the Sun, in fact, on the photosphere. They can last anything from a few days to a few months, and eventually disappear. The larger ones are so immense that they can be seen from Earth without a telescope. Sunspots indicate intense magnetic activity which accompanies other phenomena like solar flares and coronal mass ejections in other regions of the Sun. Sunspots appear as dark regions because they are cooler than the other parts of the surface. The joint ESA/NASA mission SOHO was launched to observe the Sun in 1996 and is still operating (Fig. 7.2).

By affirming the heliocentric theory against the Church's belief in the geocentric model, Galileo was accused of heresy by the Inquisition, and

**Fig. 7.2** Sunspots. Dark spots on a real sun with clay rays

sentenced to house arrest for the rest of his life. He lived in his home in Arcetri, near Florence, where he died in 1642. In 1989, his life was commemorated with the launch of the Galileo space probe to Jupiter and its moons. It was a fourteen-year journey, during which the spacecraft flew by Venus, Earth, and the asteroid Gaspra, and subsequently observed the impact of Comet Shoemaker–Levy 9 on Jupiter, before flying on to Jupiter's moons Europa, Callisto, Io, and Amalthea. Galileo's observation of the sky laid the foundations for modern day space probes and telescopes.

# 8

# The Age of Enlightenment

## 8.1 The Triumph of Reason

Hard on the heels of the Renaissance came the Enlightenment, a triumph of reason and empirical methods. There were three characteristic philosophies: deism, which accepts the existence of a creator, but one that no longer interferes with the Universe; liberalism, which believes in human rights and freedom; and republicanism, which holds that a nation should be governed as a republic with an emphasis on liberty. These were the ideals of the time, and they show through every aspect of eighteenth-century culture.

Isaac Newton could be thought of as the greatest scientist that had ever lived until then. He was born in England in 1642 and died there in 1726. Newton was a mathematician, physicist, astronomer, and theologian, and he was considered by his contemporaries as a natural philosopher. He formulated the laws of motion and the universal law of gravitation, which remained the most important scientific theories for more than two centuries, until Einstein formulated his special and general theories of relativity. Newton's publication "Philosophiae Naturalis Principia Mathematica," known as "Principia" for short, was a turning point in the scientific revolution. The story of the apple falling from the tree may actually be true or just a famous anecdote, but the idea suggested to him how he could formulate the effects of gravity. The realization was that the same force that pulled the apple to the ground also held the Moon on its orbit around the Earth, and the planets in their orbits around the Sun.

It was the greatest theory ever formulated, but Newton needed astronomical telescopes and precise measurements of the planetary motions to prove


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the correctness of his theory. The necessary observations were provided by a German musician and astronomer William Herschel who had emigrated to England and was soon considered the best astronomer and telescope builder of his time. He constructed a larger and more powerful telescope than any other ever built in the eighteenth century. Thanks to Herschel's expertise, Newton could successfully put his theory of gravity to the test. Using his telescopes, Herschel himself discovered many new nebulae, clusters of stars, and a new planet, the first discovered since the Ancient Greeks hundreds of years before. The planet he discovered was Uranus. Herschel, who soon became Sir William Herschel, realized that there were plenty of new discoveries to be made in the Solar System and beyond. And he was absolutely right!

Edmond Halley was an English astronomer, who was born in 1650 and died in 1742. He discovered the proper motion of closer stars relative to more distant ones. He also used Newton's theory to deduce the periodicity of certain comets, and in particular the one which bears his name. Indeed, Halley's Comet had been seen and catalogued by Chinese astronomers many centuries before. It was also seen by the painter Giotto in the thirteenth century. Giotto must have witnessed it crossing the sky in 1301, because he painted it in his representation of the nativity in the Scrovegni chapel in Padua, Italy. I myself had the good fortune to see Halley's Comet in the night sky of the Sonoran Desert in Arizona. It was beautiful, exciting, and so bright in the sky. Thank you, Sir Edmond! It turns out that the comet has been witnessed many times through centuries. Edmond Halley was quite right about the periodicity of comets. During his many observations of the sky, he catalogued 350 southern hemisphere stars, and by observing the transit of Mercury, he realized that he could use a future transit of Venus to determine the distances between the Earth, Venus, and the Sun.

Giovanni Cassini was an Italian mathematician, astronomer, and engineer, who was born in Italy in 1625 and died in France in 1712. At only 25 years old, he became professor of astronomy at the University of Bologna, the oldest university in the world, and later became the director of the prestigious Paris Observatory. He discovered four natural satellites of Saturn: Iapetus, Rhea, Tethys, and Dione. He also noted the division of Saturn's rings and he was the first to observe the differential rotation of Jupiter's atmosphere.

In 1997, the Cassini Space Probe was launched to study the planet Saturn and its system. It was the fourth probe to visit Saturn and the first to orbit around the planet. The Cassini Space Probe no longer exists, having crashed into the planet's atmosphere after twenty years of honorable service.

## 8.2 Science from the Nineteenth Century to Contemporary Astrophysics

By the nineteenth century, astronomers were going beyond merely cataloguing stars and planets. New and more efficient telescopes were built, opening up the possibility of discovering new planets and other celestial bodies. There was more and more research in other fields of science relevant to the development of astronomy, such as mathematics, physics, chemistry, and geology. The increasing interest in studying the formation of stars, planets, and comets rather than just cataloguing them led to a general improvement in scientific methods.

The field of spectroscopy was developed in physics and chemistry, and became a crucial tool to identify the chemical components of the stars and to understand the formation of the Solar System. The discovery of spectroscopy by the chemist Robert Wilhelm Bunsen and the physicist Gustav Robert Kirchhoff was used to compare the spectrum produced by passing sunlight through a prism with spectra produced chemically in the laboratory. This idea could be applied to demonstrate which chemicals were present in the Sun, and indeed, spectroscopy was soon being used to study the solar corona during total eclipses, which are the only times when the corona is visible.

During the nineteenth century, expeditions to observe solar eclipses became very popular, and for the first time, it was not only professionals that showed an interest, but also amateur astronomers. It was around this time that international collaborations sprang up between different observatories, and it was in 1865 that the term "astrophysics" was coined by Johann Karl Friedrich Zolner to describe the relevant mix of physics, chemistry, and astronomy. Astrophysics is thus the study of astronomical objects and phenomena, such as the Sun, the stars, galaxies, extrasolar planets, and the famous cosmic microwave background. Astrophysicists use methods from many and varied disciplines of physics, including classical mechanics, electromagnetism, statistical mechanics, thermodynamics, quantum mechanics, and nuclear and molecular physics. In short, it is a branch of theoretical and observational physics.

The Sun is treated by astrophysicists as a special celestial body, not because it is a powerful god, as it was considered in Antiquity, but because it is the nearest star to Earth. All the other stars are tremendously far away, so cannot be observed in anything like the same detail as the Sun. But by studying the Sun and comparing it with the others, astrophysicists have been able to understand a great deal about the other stars. On 14 December 2021, NASA's

Parker Solar Probe was launched to observe the Sun at close range. It is the first time in human history that a spacecraft has been able to get so close to the Sun, in fact, coming close enough to reach the Sun's upper atmosphere, the corona, and observe the magnetic fields there.

Since prehistoric times, man has looked up at the skies and invented gods, visualizing the Sun god as crossing the sky on a golden chariot, or, as in ancient Egypt, sailing over the Blue Nile on a boat. A beautiful humanized divine Sun was created in Ancient Greece and Rome, a generous life-giver for humanity, but at the same time the ancient peoples of Mesoamerica portrayed their most important divinity as cruel and bloodthirsty. Think, for example, of the religious cult of the Aztec kings, who believed in the importance of honoring the Sun by drinking the blood of sacrificed victims. Throughout human history, the Sun was represented as a god through myths, legends, and cults, and depicted by the visual arts to help people get a better understanding. There were myths like the flight of Icarus whose wax wings melted when he dared to get too close to the Sun, whereupon he fell into the sea and died. And there were many more myths, legends, and superstitions in the different cultures of the ancient civilizations.

But right from the beginning, there were some insightful minds who, observing the sky, imagined that the world might actually be more complicated than it was made out to be in the myths and legends. In Ancient China, Ancient Greece, and even during the European "Dark Ages," hesitant and timid ideas appeared in the minds of some humans who dared to imagine the possibility of a different Universe (Fig. 8.1).

During the later years of the cultural rebirth in the Renaissance, the vision of the world began to change. The Sun was no longer seen as a god, while its important role in human life was maintained. Heliocentrism began to take over, with our star placed at the center of the Solar System and all the other planets, including the Earth, orbiting around it. So, we might say that the status of the Sun as a sacred divinity was kept, but in a different way. It maintained its great importance in the known Universe, and especially its role as life-giver to all living beings on Earth. On the other hand, our planet lost its central position and therefore its importance in the cosmos. And as we now know, even this grand view of the Sun would not last long, in the sense that there have been more and more discoveries which prove our Sun to be just another star, no different from many, many millions of others in the Universe. At any rate, for us, inhabitants of planet Earth, the Sun is still our life-giver, as powerful and important as only a god could be.

**Fig. 8.1** The universe. This is my vision of how our universe might be, with strange objects immersed in a dark blue space. Blown glass

## 8.3 Discoveries in the Nineteenth and Twentieth Centuries

Since the Enlightenment in the eighteenth century and during the nineteenth century, science steadily took on a more modern approach. One truly revolutionary discovery which was absolutely fundamental for science was the theory of electromagnetism. The first to understand how the phenomena of electricity and magnetism could be unified into a theory of electromagnetism was the mathematician and physicist James Clerk Maxwell, who was born in 1831 in Edinburgh, Scotland, and died in 1879 in Cambridge, England. This discovery is widely considered one of the greatest scientific achievements of the nineteenth century. Maxwell discovered that electric and magnetic fields could propagate together as waves at the speed of light, and concluded that light is actually an electromagnetic phenomenon. Needless to say, this discovery is essential to many modern technological applications. Indeed, any system exploiting electricity or magnetism owes much to Maxwell's ingenious set of equations.

When it reached the twentieth century, astrophysics would go through a number of scientific revolutions. Right through the nineteenth century, the composition of the Sun had remained completely unknown, and even in the 1920s, the brilliant astronomer Sir Arthur Eddington thought that the Sun had much the same composition as the Earth. It was eventually thanks to the work of the astrophysicist Cecilia Payne that this situation was rectified. She discovered that the composition of the Sun is very different from that of our planet. In fact, it is made up of 74% hydrogen, 24% helium, and 2% metals. This discovery was another great breakthrough in the history of science.

To give another example, in the early twentieth century, it was thought that there was only one planetary system, our own, and that the Milky Way was all there was in the Universe. Later in the century, the astronomer Peter van de Kamp suggested that there should be other planetary systems besides our own, and by the end of the twentieth century, many such exoplanets had been discovered. So, our Solar System is not the only one in our galaxy, as had been thought for thousands of years. We may say that the twentieth century has been the era of astronomical ages, for we have been able to determine, at least approximately, the ages of planets, stars, galaxies, and even the Universe itself, although we still don't know the origin of everything on Earth and in the Universe.

Here is a comment on twentieth century physics by theoretical physicist Hans-Thomas Elze:

> The twentieth century, and in particular its first half, was a period with such a large number of discoveries in science that it cannot be compared with any earlier epoch that we know of. This holds especially in physics, with revolutionary new concepts entering the way we describe and try to understand the physical world around us. Especially, the developments of special and general relativity and of quantum mechanics have changed forever our understanding of matter, space, time, and the cosmos as a whole. Earlier ideas were mostly derived from experiences gained via our senses, more or less in our daily human lives, and considering phenomena that we are able to perceive first-hand "with our own eyes". The change came when technical instruments became more and more sophisticated and allowed us to study (and manipulate) reality beyond the range of our senses: the very small, the very large, the very fast, and so on and so forth, with no natural or intrinsic end to further exploration in sight.
>
> Let me mention some of the outstanding physicists who played a decisive role in interpreting the new experimental findings in the early 1900s and reformulating this new knowledge into powerful theories that allow us to predict new and even stranger phenomena. We must keep in mind that

this has not just been the academic playground of a few "mad scientists", but that their studies and "practical" applications of their results have transformed all our lives ever more rapidly and profoundly, for better or for worse – think of nuclear forces and the resulting bombs, of radio, television, digital computers, the internet, and smartphones. Think also of the upcoming possibilities of quantum computers and, perhaps most questionably these days, artificial intelligence.

One of the first steps was taken by Max Planck, a German theoretical physicist (1858–1947), who studied problems raised earlier in the description of radiation emitted by hot bodies. In a bold intellectual step he took in 1900, this allowed him to introduce a "quantum of action", implying that no physical action (which has a precise meaning in terms of measurable quantities) can take place in smaller bits and pieces than this quantum! This was then interpreted in due time as a first indication from experimental science that the physical world may have fundamentally discrete aspects – but recall Plato's outrageous idea of atoms composing matter, more than two thousand years earlier.

Then, in 1905, Albert Einstein, who was born in Germany in 1879 and died in the USA in 1955, interpreted the so-called photoelectric effect in terms of photons, massless particles that can be thought of as composing electromagnetic radiation. Up to this point, this radiation was generally regarded as being made up of waves, following Maxwell's theory, not as pointlike clumps of energy – but recall the debate between Goethe and Newton about the nature of light. These photons have a quasi-mechanical effect when they impinge on a metal surface, where they kick out small, massive, and electrically charged particles called electrons. Einstein understood this and gained a Nobel Prize for his work – all in that same year when he also formulated the special theory of relativity, considering bodies moving at very high velocities with respect to each other and deducing the relationship between mass and energy, encoded in the famous equation $E = mc^2$ – which manifests itself, for example, in nuclear energy and, thus, the energy-producing processes that make the Sun shine – besides formulating a statistical theory of Brownian motion.

Einstein arguably became the most famous scientist in history, especially when a prediction that followed from his general theory of relativity of 1915 was glamorously confirmed in 1919. It implied that the path of light from a distant star that passed very close to the Sun before reaching us on Earth would be slightly bent due to the gravitational attraction of the large mass of the Sun, which acts on the starlight photons! In order to observe the predicted small effect, the overwhelmingly intense light of the Sun had to be blocked for a short while. But how could this possibly be done? Two expeditions instigated by the renowned astrophysicist Arthur Eddington to Brazil and to Sao Tome e Principe in the Gulf of Guinea were sent to observe the total solar eclipse that took place in 1919, which blackened out the Sun in the sky and allowed us to see starlight that literally came from behind it. A glamorous conjunction of ideas indeed!

General relativity has changed our views of space and time and the role of the gravitational force in all of this.

Following these first revolutionary steps, there was a rapid succession in the progress that brought relativity and quantum mechanics into full bloom. Most notably, the dynamics of the motion and interaction of the quanta and their waves attracted theoretical and experimental physicists, since it could be studied in ever more detail in the laboratories of the time.

Max Born, a German physicist (1882–1970), naturalized British, is known for his research on the further development and foundations of quantum mechanics, solid state physics, and optics. He received the Nobel Prize in Physics for his fundamental work in quantum theory, especially for suggesting a statistical interpretation of the so-called wave functions associated with all quanta.

During the founding years of the new theory of quanta and related seemingly strange phenomena, Niels Bohr, a Danish physicist born in Copenhagen (1885–1962) played an important role in guiding the discussions among the leading physicists through his firm stand on philosophical principles, which eventually led to the "Copenhagen interpretation" of quantum mechanics. He remained in continuing controversy with Einstein, and related debates remain active up to the present day. Bohr made fundamental contributions to our understanding of the structure of atoms and undertook important steps towards a precise mathematical formulation of quantum theory, receiving the Nobel Prize in Physics in 1922.

Werner Heisenberg was a German theoretical physicist (1901–1976) and one of the pioneers of the theory of quantum mechanics. He is widely known for his principle of uncertainty. He received the Nobel Prize for his work in formulating quantum theory in unconventional, but very powerful mathematical terms that have stood the test of time. He wrote his far-reaching paper when he was only 23 years old.

Erwin Schrödinger, an Austrian theoretical physicist (1887–1961), along with Heisenberg, has been considered one of the founding fathers of quantum theory. In fact, he proved later that his own and Heisenberg's formulations, though employing very different methods, were equivalent, describing the same physics. He received the Nobel Prize in 1933, together with another outstanding physicist, Paul Dirac. In popular culture Schrödinger is known because of "Schrödinger's cat," a thought experiment invented to illustrate some particularly strange and mind-boggling consequences of quantum theory, which have since been observed!

I have made this excursion into some aspects of the history of physics in the early twentieth century to point out the intimate connectivity among all scientific knowledge, and physics in particular. There are not only bare facts out there to be measured, but scientists have been able to identify patterns within these facts, "laws of nature" that appear miraculously comprehensible to

> humans! From the early twentieth century onwards, the range of understandable phenomena has been increasing in manifold ways and at breathtaking speed.
>
> Quantum theory and the theories of special and general relativity are indispensable in order to understand what we can observe in increasing detail about the Sun. Without them, the nuclear fusion reactions that power its energy production would remain mysterious. Nor could the chaotic behavior of the Sun's outer layers and their hot radiation be unraveled as plasma physics par excellence, a study which may eventually help us to build fusion energy machines on Earth. And we could have no picture of what will happen to the Sun in the far future. Back down on Earth, without these theories, we could not even dream of building the ever more precise instruments we need to learn about the world around us, the Universe. All is one.
>
> (Professor of Theoretical Physics, Hans-Thomas Elze)

Professor Elze's comments bring out perfectly the importance of the twentieth century as a revolutionary moment in science, reminding us of all those brilliant minds who changed our vision of the world and, through their discoveries, made possible the technology we now take for granted. Specifically, he pointed out that, without the scientific discoveries of the great physicists of the past century, it would have been impossible to know how the Sun and the other stars in the Universe work. Many books have been written and many documentaries and movies have been made about Einstein, both as a physicist and regarding his private life. In popular culture he has been pictured as the typical eccentric scientist, but nothing was typical about Einstein. He was simply a genius!

# 9

# Space, the Last Frontier

## 9.1 Science Fiction Books and Movies

The exploration of the cosmos is the last frontier for humans to discover. Science fiction books and movies have imagined many unknown worlds, inhabited by all kinds of strange creatures, aliens from space looking like giant insects, fish, dragons, and more recently blue avatars, not to mention the Martians, the classic little green men. Science fiction allows us to fantasize on journeys to distant, somewhat improbable worlds populated by sometimes scary, sometimes friendly aliens, depending on the creative impulse of story-writers and film-makers, all of them enriched by views of futuristic landscapes and cities on planets lost in the immensity of the Universe. Star Trek, created by Gene Rodenberry, is a classic among science fiction TV series and movies, and even if it is now considered outdated, it still remains a classic of its kind, with the refrain:

> To boldly go where no man has gone before.

This is the famous phrase pronounced by Captain Jim Kirk, and Captain Jean Luc Picard at the beginning of each episode of Star Trek. I never missed a single one! It's still my favorite among the many science fiction stories. Star Wars is another classic of its kind, like Alien, Avatar, and numerous others, some interesting and based on real science, many totally absurd but often amusing for their originality in imagining strange and distant worlds.

Some scientists have become science fiction writers, like Isaac Asimov, a chemist by profession, who authored many fantastic stories in which he


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described different life forms on a futuristic planet Earth, or strange intelligent beings from faraway planets in our vast Universe. The physicist Arthur C. Clark was also a science fiction writer. Of the many books he wrote, the most famous is "2001: A Space Odyssey," which became a successful movie directed by Stanley Kubrick. A classic of its kind. The "Dragon's Egg" is a book written by the physicist Robert Forward. It tells the fascinating story of life evolving on a neutron star. The astronomer Carl Sagan wrote "Contact" a best-selling book that was made into a successful movie. The story is about the unusual encounter between a young woman physicist and an alien entity. It happens on a voyage through a worm hole. I really enjoyed reading the book and watching the movie. Only a talented and romantic astronomer like Carl Sagan could have created such a beautiful story. He was the perfect scientist to describe this exciting possibility of contacting a distant, alien world.

## 9.2 Exploration

Now that there are so many NASA and ESA space programs, it seems that the possibility of knowing and maybe even visiting faraway worlds is no longer so remote. We have already walked on the Moon, and it seems like Mars could be the next planet on the list. And then there are many others we can only dream about. So, let's keep watching Star Trek and remember what Mr Spock used to say: Fascinating!

And indeed, the stars have been fascinating generations of humans throughout history. Naturally, the Sun, being the largest and the closest star to Earth, has been the most admired and feared. But the Sun is only one of the hundred billion stars in the Milky Way, which is our galaxy, and there are billions of galaxies in the known universe, each with countless suns of their own, stretching across the vast space of the cosmos.

One way to study the formation of the stars is by analyzing our own star, taking advantage of its being the closest to us. However, this is not the only way to investigate distant objects. The discovery of spectroscopy means we can now analyse the composition of the planets in the Solar System and also of the stars, using our knowledge of electromagnetic radiation. We now have reliable information to replace what over the past centuries was mere speculation. Radioastronomy, infrared astronomy, ultraviolet, X-ray, and gamma-ray astronomy have all greatly increased our understanding of the Universe.

The dream of traveling across space, away from our planet, to explore the unknown began in the mid-1950s. Space exploration began by sending unmanned spacecraft into space. The first was Sputnik 1, launched by the Soviets in October 1957, followed by the American Explorer 6, launched in 1959.

In a way, the Cold War between these two empires gave a great boost to space exploration. The motivation was primarily to achieve military supremacy of one nation over the other. Fortunately, with the end of the Soviet Union, a peaceful collaboration was established between the two superpowers. Science helped to end a long and dangerous conflict, but it now seems that this was just a reprieve. At the time of writing (2024), it looks as though, with the Ukraine–Russia war, the conflict between the two is back, and as serious and dangerous as ever.

But let us get back to peaceful space explorations. NASA launched eight "Orbiting Observatories" between 1962 and 1971. It was the first attempt in human history to get a closer view of the Sun. Most of them were successful. They analyzed the Sun at ultraviolet and at X-ray wavelengths, and they also succeeded in photographing the Sun's corona.

Then, in 1990, NASA and ESA, European Space Agency, launched the "Ulysses probe" to observe the Sun's polar regions, both the south pole and the north pole. It was named Ulysses in honor of Homer's mythological hero, and also Dante's Ulysses, who, in the "Divine Comedy," was sent to hell (Inferno) because he dared to go beyond the allowed world. Ulysses was therefore the perfect character to associate with a probe that would observe the Sun. It was definitely a difficult and daring task. The Sun was long considered out of bounds for such exploration.

Ulysses was launched on the Space Shuttle Discovery on 6 October. The idea was to get it into a polar orbit around the Sun, in other words, overflying the Sun's poles. To achieve this, it had to fly by Jupiter, using the gravitational strength of the giant planet to change the inclination of its orbit relative to the plane of the Earth's orbit around the Sun. Well, that's a simplified explanation of the very complex interplanetary trajectory that finally got the probe in the right place. A voyage in space is not as glamorous as one might think from TV programs or movies. A lot of scientific and engineering expertise is needed, and then a lot of work, accompanied inevitably by mistakes and disappointments, on the way to success. Some astrophysicists think that Ulysses, like Homer's character, will probably continue to orbit around the Sun indefinitely.

The Solar and Heliospheric Observatory (SOHO) is a collaboration between NASA and ESA launched in May 1996 and extended to December 2025. This probe has successfully investigated the Sun's core, the corona, and the solar wind. However, before achieving all this, soon after its launch, SOHO had a series of structural problems. It took the collective efforts of NASA, ESA, and the large Arecibo radiotelescope in Puerto Rico to solve all the technical problems, but it is now considered one of the most successful missions ever launched. The instruments on the probe make continuous observations of the Sun, including taking photographs of the photosphere (Fig. 9.1).

One particular instrument carried aboard SOHO screens the Sun itself in order to get a better view of the corona, rather like what happens naturally during a total eclipse. In this way, astrophysicists can observe the expulsion of billions of tons of solar plasma, some of which may eventually reach the Earth and interfere with the terrestrial environment, whence the importance of observing and understanding these potentially dangerous solar events. It is crucial to study the relationship between solar activity and the Earth environment, for many reasons. The most common interference with space weather is the disruption of radio transmissions, but worse can happen: a blackout the world over. According to astrophysicists, extreme solar activity could modify the composition of ions in the near-Earth space, affecting the orbits of satellites, such as those providing the GPS system. Considering how dependent on this technology we humans have become, it is indeed important to know when and how solar phenomena come about, and how they might interfere with the Earth. SOHO's instruments were also able to detect a new

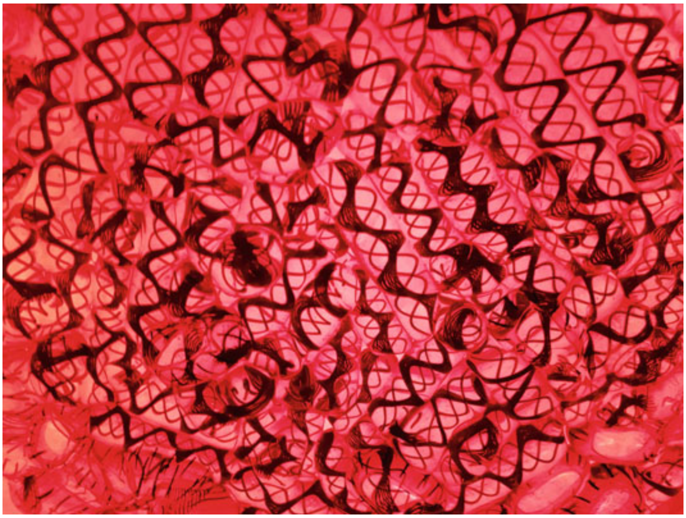

**Fig. 9.1** The photosphere, the outermost layer of the sun. I have represented it here using an intricate griddle-blown glass

phenomenon through observation of the corona: the fall of many comets into the Sun.

The Parker Solar Probe, launched by NASA in 2018 and due to continue until December 2025, is named in honor of Professor Emeritus Eugene Newman Parker, astrophysicist and pioneer in the modern study of the Sun. The mission involves getting within close range of the solar corona. It is already the spacecraft which has come closest to the Sun, closer than any other before it. In fact, physicists announced with great excitement that the Parker Solar Probe had actually touched the Sun! Of course, a real landing on the Sun would not be possible, but by getting within 6.5 million kilometers of the surface, the probe can perhaps be considered to have touched the Sun. During its mission, it should provide the answers to several unsolved questions. For example, why is the corona hotter than the Sun's surface? How is the solar wind accelerated? And what are the sources of the various high energy particles?

Doctor Nicola Omodei, heliophysicist at the University of Stanford, California, explains the significance of these questions:

> Named after the solar astrophysicist Eugene Parker, who predicted the existence of the solar wind in 1958, the Parker Solar Probe is a heliophysics NASA mission aimed at exploring the Sun's atmosphere and answering some of the most fundamental questions about our star.
>
> Launched on August 12, 2018, this spacecraft is the first ever to venture into the Sun's corona, the outermost layer of the Sun's atmosphere, and study its behavior and characteristics up close.
>
> The Parker Solar Probe is using the gravitational pull of the planet Venus during seven flybys to gradually orbit closer to the Sun, and eventually the spacecraft will fly through the Sun's atmosphere as close as 3.8 million miles from our star's surface, well within the orbit of Mercury and more than seven times closer than any spacecraft has come before. (Earth's average distance to the Sun is 93 million miles.) This allows the Parker Solar Probe to perform a series of in situ measurements which, combined with remote-sensing observations of the magnetic field, plasma, and energetic particles, are revolutionizing our understanding of the corona and expanding our knowledge of the origin and evolution of the solar wind. Ultimately, this will also make critical contributions to our ability to forecast changes in Earth's space environment that affect life and technology on Earth.
>
> In general, the Parker Solar Probe targets processes and dynamics that characterize the Sun's expanding corona and solar wind. The solar magnetic field plays a defining role in forming and structuring the solar corona and the heliosphere. In the corona, closed magnetic field lines confine the hot plasma in loops, while open magnetic field lines guide the solar wind expansion. The

energy that heats the corona and drives the wind derives from photospheric motions, and is channeled, stored, and dissipated by the magnetic fields that emerge from the convection zone and expand in the corona, where they dominate almost all physical processes therein. In fact, the magnetic field of the Sun, plays a critical role in coronal heating and, in general, in particle acceleration in the solar wind. The corona is a complex system, characterized by different forms of magnetic activity and highly dynamic phenomena, such as coronal mass ejections (CMEs), flares, and small-scale features such as spicules and jets (Fox et al. 2016).

One of the key questions that the Parker Solar Probe aims to answer is why the Sun's corona, with temperatures that reach millions of degrees, is so much hotter than its surface, which has a temperature of around 5500 degrees Celsius. Solar wind proton heating refers to the process by which protons in the solar wind, which is a stream of charged particles that flows continuously from the Sun's corona, are heated to very high temperatures as they travel through space. The heating occurs as a result of the interaction between the protons and the magnetic field of the Sun, which causes the protons to gain kinetic energy and move faster.

The Sun's magnetic fields are very complex, with loops and knots that extend from the surface into the corona. When these magnetic fields become twisted and tangled, they can release huge amounts of energy in the form of solar flares and CMEs. This energy can heat the corona to millions of degrees Celsius. Additionally, protons collide with other particles in the solar wind (electrons or other protons), and the resulting transfer of energy can lead to an increase in temperature. For example, Mozer et al. (2023) recently determined the perpendicular and parallel (relative to the local magnetic field) proton heating rate in the solar wind, using measurements by the SWEAP Solar Probe ANalyzer (SPAN) electrostatic analyzers, one of the instruments on board the Parker Solar Probe. Their main result is that, for the first time, it was shown that perpendicular proton heating increases with solar radius between 20 and 160 solar radii, while there is basically no heating nor cooling of the parallel protons below 70 solar radii. Overall, the heating of solar wind protons is an important process that helps to drive the dynamics of the solar wind and its interaction with the Earth's magnetic field. It also has important implications for space weather, as high-energy particles in the solar wind can pose a risk to satellites and other spacecraft in orbit around the Earth.

One of the topics close to my heart is the study of the acceleration and transport of solar energetic particles (SEPs). It is challenging to differentiate models of particle acceleration at and near the Sun using data collected at 1 AU (either by Earth or Earth-orbiting satellites). The reason for this difficulty is that particle propagation through the solar wind on its way to 1 AU distorts the time-ordered structures and energy-spectral features created by the particle acceleration processes. It also mixes particles from different acceleration sites. The Parker Solar Probe addresses this problem by measuring intensities, energy spectra, and pitch-angle distributions of energetic electrons, protons, and heavy ions in the innermost region of the heliosphere. The particle distributions measured by the Parker Solar Probe are therefore less distorted by propagation effects than those measured further from the Sun. This will provide valuable information in identifying the mechanisms of acceleration.

For example, Dresing et al. (2023) studied the widespread SEP event associated with the flare–CME on 17 April 2021. This event was observed by five well-separated spacecraft in the inner heliosphere, including the Parker Solar Probe, with additional constraints provided by observations at Mars. Observing this event from multiple points of view produced a complex picture. Electron and proton observation by the Parker Solar Probe, and, in particular, the long-lasting anisotropy of the proton event, which is not observed in the case of the electrons, suggests a long-lasting proton injection, most likely related to the CME-driven shock. Some of the CME-shock accelerated protons can also travel back to the Sun, colliding with the Sun's surface and producing energetic gamma-rays. These are in fact the result of pion decay, and are related to the intense emission in high-energy gamma-rays we are observing with the Fermi Large Area Telescope (LAT) (Omodei et al. 2018, Ajello et al. 2021). Proton acceleration at the CME driven shock also offers a natural explanation of flares observed by Fermi LAT from behind the visible limb (Pesce-Rollins et al. 2015), since accelerated protons can travel along magnetic field lines that connect the CME shock front with the visible side of the Sun, even if the originating flare was occulted.

Alternatively, the coupling of coronal waves in the visible disk and the acceleration of protons as traced by the observed > 100 meV gamma-ray emission, as reported by Pesce-Rollins et al. (2022), suggests that the protons driving the gamma-ray emission from solar flares and coronal waves behind the limb share a common origin. Combined observation with Fermi, Parker Solar Probe, Solar Orbiter, and other observatories during the upcoming solar maximum, when the flaring activity will be high, will help us to better understand these mechanisms and to shed light on particle acceleration and propagation in the solar corona.

Overall, the Parker Solar Probe is a groundbreaking mission that has already yielded valuable scientific data and is poised to make many more discoveries in the years to come.

(Nicola Omodei, astrophysicist).

ESA's probe Solar Orbiter, launched in 2020, is now carrying out its mission to study solar and heliospheric physics. This is said to be the most complex scientific laboratory ever sent into space to study the Sun. Some of the questions which scientists hope to answer are: What causes the Sun's eleven-year cycle. What generates the solar wind? What makes the upper layer of its atmosphere, the corona, so hot? And how do all these phenomena influence our planet's space weather? Solar Orbiter obtained the first image of the Sun which shows solar flares near the surface. These are spectacular images for any viewer, scientist or commoner.

On the subject of solar flares, Melissa Pesce-Rollins, astrophysicist at the INFN in Pisa, explains as follows:

> Solar flares are explosive phenomena that emit electromagnetic radiation over an extremely wide range from radio to gamma rays. It is generally accepted that the magnetic energy stored in the solar corona and released through reconnection during a flare is capable of accelerating electrons and ions to relativistic energies. Flares are often also accompanied by ejections of plasma mass from the Sun's corona, known as coronal mass ejection (CME) that can reach velocities greater than 3000 km/s. The radiation that is emitted from these and other solar phenomena is absorbed by the Earth's atmosphere, in some rare cases causing interference with short-wave radio communications on Earth.
>
> Other more captivating consequences of the Sun's activity are the aurorae.

Physicist Pesce-Rollins explained to me what an aurora is. The aurorae, also called the northern or southern lights, appear around the north and south poles, respectively, moving at high velocity across the clear night skies. These phenomena are caused by an interaction of the solar wind with the Earth's magnetic field, which produces a swirl of greenish-blue light. A spectacular sight! The solar wind consists of particles charged up by processes in the Sun and streaming outwards in all directions until some are captured by the magnetic field of the Earth and drawn toward the poles at high speed. The aurorae occur when particles collide with atoms and molecules in the ionosphere. At this point, some of their kinetic energy is transformed into visible light, and the aurora borealis and australis appear in the sky.

The CuSP mission was launched by NASA in November 2022, but contact was lost after an hour or so. The aim was to study solar winds, particles, and magnetic fields, and it was designed to explore interplanetary space. The CuSP team had problems of communication sooner after the launch, and it seemed they could not restore radio transmissions. Despite our technological expertise, problems are commonplace during interplanetary voyages. It is easy to imagine how tense physicists and engineers must be at the time of the launch. Fortunately, most of the time, these probes function as expected.

Aditya-L1 was launched by the Indian Space Research Organization (ISRO) in September 2023 specifically to observe the solar corona, solar atmosphere, and solar magnetic storms, and their impact on the space environment around the Earth.

The Solar Orbiter and Parker Solar Probe are two of the most recent and perhaps most spectacular missions sent from the Earth to explore our star. Other missions to study the Sun are Earth-based, using very large telescopes. So, there is constant observation of the Sun from the Earth and from space.

NASA set up a multidisciplinary program called Living With a Star, or LWS. This program involves the missions Solar Orbiter and Solar Probe, which are already in space, and the Solar Dynamics Observatory (SDO), and Space Environment Testbeds (SET), which are studying the global interaction of the Sun with the planets and interplanetary space. Another interesting program called the Geospace Dynamics Constellation (GDC) is planned for the near future as part of LWS. For the first time, this mission will be studying the upper atmosphere, the ionosphere, and the troposphere, and their interaction with the solar wind. It is very important to know how to connect space meteorology with atmospheric meteorology, and to study the possible connection between solar storms and the dynamic atmosphere of the Earth.

Another future mission to study the Sun is an interesting and innovative joint mission between ESA and China called SMILE, scheduled for launch in 2025. Besides measuring the electromagnetic plasma and fields, SMILE will produce detailed ultraviolet and X-ray images of the interaction between the solar wind and the magnetosphere. Finally, China has recently communicated the possible launch of two probes to the limit of the heliosphere. The Chinese probes will reach the giant gas planet Jupiter by the end of the next ten years, then continue to the end of the Solar System and beyond by 2049.

We are living in an era of space exploration, with missions traveling through deep space which, not too long ago, were the stuff of science fiction. Astrophysicists say that, with today's technology, we have probably reached our limits, at least for now, but they also add that we are at the beginning of an important scientific revolution which will allow us, as Captain Jean-Luc Picard says, to "boldly go where no man has gone before," and hopefully gain a better understanding of the Universe beyond our Solar System.

# 10

# Contemporary Myths and Art Inspired by the Sun

There has been a wealth of myths, legends, and beautiful representations of the Sun in the arts over thousands of years of human history. But now, in these technological times, do we still have such myths and beautiful art to honor our life-giving star? I would definitely say that we do. We do still honor our Sun through the myths and legends inherited from our past. Humans still enjoy populating beaches for the simple pleasure of feeling the warmth of the Sun's rays on their bodies (sometimes foolishly getting sunburnt), and ritualistically, almost religiously watching the setting of the Sun from beaches and mountains around the world. This daily ritual of witnessing the sun rise and set is an act which some people, either for personal belief or religion, consider a duty to honor and thank the Sun. Humans today do still love ritual and legends, perhaps due to some subconscious primordial belief in the sacred, which ensures that the fascination remains.

## 10.1 Solstice Celebrations

The summer solstice falls on 21 June, and in Stonehenge, England, many people gather around the site to observe the Sun's rays appearing between the megaliths. The same has happened for thousands of years, and today, at the summer solstice, a ritual procession of "Druid priests" continues,[1] followed by common people, to honor the Sun. This is a legend that some of the more

[1] The Druids were not around at the time when Stonehenge was built, but this is a legend, so time is not important!


L. Pesce, *A Biography of Our Sun*, https://doi.org/10.1007/978-3-031-54729-4_10

nostalgic humans like to remember. Stonehenge is not the only place where an ancient legend, myth, or even a religious ritual continues up to our own time. People also gather in Newgrange, the prehistoric solar observatory in Ireland, to witness the Sun entering the passageway at the summer solstice.

Myths and legends about the Sun are alive and well in many other countries, surviving well into our modern times. In North America, Native Americans practise the Sun dance, a ritual of great importance in their culture. Over the centuries, there have been some changes in this practice, but the myth of the Sun and the ritual of the Sun dance remains.

In Mesoamerican cultures, the symbol of fire was linked to the Sun, as a symbol of order and balance, and even now, the link between the heat and power of the Sun remains. Today, in Guatemala, on 7 December, the eve of the feast of the Immaculate Conception, people burn effigies of the devil on piles of garbage in front of their houses. In ancient times, the ritual of fire was more drastic. People even burned their entire house as a rite of renewal!

In ancient Mexico, the fire ceremony was also linked to the Sun, and the precious offerings made to the gods were human hearts and blood. Today the offerings are less bloody, the fire ritual has been changed, burning copal or more often just candles. Throughout Mesoamerica, the main ritual practices to honor the Sun related to flame and smoke.

In India, the Sun god, Lord Surya, is worshipped by devotees through pilgrimages and festivals, where the chanting of mantras is a necessary ritual every morning at dawn to welcome the Sun. These festivals are celebrated throughout India by worshipping Surya according to ancient Vedic rituals, and through this worship, devotees receive many benefits, such as energy, power, wisdom, health, intellect, and protection from harmful forces. The festivals mark the beginning of the harvest season, and for this reason they are particularly important for farmers, but not only. Indeed, festivals are celebrated across the nation by every citizen in honor of the god Surya, and the rituals practised today are the same as those that have been practised for centuries. India is a country of truly ancient traditions, myths, and legends, which they have kept alive right up to our own time.

In Europe, the midsummer festivals are linked to ancient legends and rituals rooted in pagan and Christian traditions which have been celebrated for thousands of years. Today, especially in Europe, but also elsewhere around the world, these festivals are related to the solstices, so the Sun is still honored in many countries even in our own time. In Fairbanks, Alaska, very close to the Arctic Circle, the summer solstice celebration is associated with the midnight Sun in a festival faithfully attended every year by both adults and children. In Ottawa, Canada, the summer solstice festival focuses on the indigenous tradition to honor the Sun in the longest day of the year. In Reykjavik, Iceland, there is a Secret Solstice festival, although no one knows why it's called that way since the whole population knows about it. Once again, the summer solstice is celebrated together with the midnight Sun. And in Helsinki, Finland, the Juhannus Festival is a celebration of the summer solstice and is also a traditional time for celebrating weddings, fertility, and love on the longest day of the year.

In St. Petersburg, Russia, the summer solstice is celebrated for many days with festivals, theater, ballet performances, and music. In the Tyrol in Austria the solstice is celebrated with bonfires. This is inspired by ancient tribal rituals, worshipping the Sun through mysticism and paganism. Today, bonfires are still the main form of celebration for the summer solstice in the mountains of Austria.

At the ancient site of Chichén Itzá in Mexico, celebration of the summer solstice is truly spectacular! People from around the world gather to witness the effect of the Sunrise over the pyramids. El Castillo, the central pyramid, is illuminated on one side, while the other remains in full shadow, a sight which occurs only twice a year, giving El Castillo an ethereal appearance as though it were cut in two.

In Peru in South America, the Inti festival is organized to celebrate the summer solstice. In the ancient Inca culture, Inti was a Sun god imagined as a man, while the Moon was his wife. Being in the southern hemisphere, the summer solstice is celebrated on 21 December and is called Qhapaq Raymi. As in ancient times, but even now, the celebration in honor of Inti, involves offering flowers, plants, animals, and dancing. The festival is always accompanied by drinking large quantities of "Chicha de Jora," a fermented type of beer, and continuously chewing coca leaves.

So festivities dedicated to the summer solstice are found all over the world. Rituals from the past are still popular and widely practised, and the Sun, creator of life on Earth, is still worshipped! But let me conclude my short stories about the summer solstice and festivals around the world, with the Italian version of old and new celebrations: the Vestalia.

The Vestalia is an ancient Roman ritual carried out at the summer solstice in honor of the goddess Vesta, and it was celebrated between 7 and 15 June. With Christianity, the summer solstice was superseded by a celebration in honor of John the Baptist, on 24 June. It seems that the pagan summer solstice was Christianized and replaced by the (probable) birth of Saint John the Baptist. Since I was a child, 24 June has meant a lot to me, being the beginning of summer, therefore the end of school, therefore the beginning of vacations on the beach, and hence a very important festival to look forward to.

## 10.2 Modern Myths and Art

Other modern myths in the Western world are different from those in the past. There are no more mythological creatures, half human and half beast, no dragons or unicorns or winged horses or Minotaurs. Actually, some of these mythological figures, the unicorn in particular, are still present in the form of children's toys, highly appreciated by the little ones and by the factories that produce them. In our technological society, such mythological creatures have been replaced by fantastic, invented characters, such as super heroes with super powers, robots looking and acting like humans, and artificial intelligences which can create anything, including art. Times change, and so do the myths.

My own feelings about the changes from the old myths are to some extent negative. The modern-day heroes typical of our times are different from those of the past. Now the heroes are movie stars, musicians, astronauts, athletes, and lately, a new species called influencers. These are people of our technological times who communicate through social media and sometimes became instantly famous for their knowledge or expertise on certain topics. It could be anybody. Some are celebrities and some will become celebrities, depending on their ability to influence a large number of followers. Those we call mega influencers could have more than a million followers, and a good chance to use their popularity in marketing. So, an influencer is someone who has the power to influence a purchase decision, or perhaps even a political decision. It all depends on their ability to affect others through their authority or knowledge. This might involve marketing tools or simply social connections, but whichever, it is a new way to communicate on a large scale which has never existed in past cultures.

In the field of the arts, I am to some extent positive about the change. Technology is a new tool which gives artists an opportunity to create incredible visual effects that could not otherwise be obtained. For example, the representation of our star in video art could be spectacular, depending of course on the ability of the artist. Imagine a beautiful view in which the spectators feel as though they are present in space, looking at the Sun, admiring its sunspots and its amazing solar flares, and even witnessing a total solar eclipse as it reveals the "naked" corona, as Hugh Hudson put it.

In 1962, the physicist James Webb suggested starting an art program at NASA, called the NASA Artists' Cooperation Program, as a collaboration between artists and scientists. Well-known artists like Robert McCall, Fred Freeman, and Robert Rauschenberg were invited to take part in this innovative idea. Unfortunately, by 1975, this program had considerably slowed down, but the paintings it had produced were appreciated for their artistic quality, and indeed for their communication of the early space program. They are now in the National Air and Space Museum in Washington, DC.

Fifty years have gone by since the first attempts to paint the Universe by the above-mentioned artists. But even earlier, one pioneer of "space art" was definitely Chesley Bonestell, born in San Francisco in 1888. An architect and painter, he was the first artist to represent the cosmos before any space program even existed. His interpretations of stars and planets were proved true in many cases.

The development of new technologies has changed the pictorial representation of the Sun and Universe by visual artists. Artists working for NASA today represent the Sun, the planets, the nebulae, and the many other celestial objects in the cosmos to provide a visual explanation of space exploration missions. Through the age of the Gemini and Apollo missions, artists also painted portraits of astronauts. An example is Mitchell Jamieson, who painted Gordon Cooper's portrait with the title "First step," in which the astronaut is represented figuratively on an abstract background. NASA's art program continued after the early stages by attracting famous artists like Norman Rockwell, Andy Warhol, and Annie Leibowitz.

Besides painters, there were, and still are, poster artists with great talent who, with imagination and technical expertise, take the viewer on a voyage to distant worlds in the cosmos. At the Jet Propulsion Laboratory (JPL), there is something called "The Studio," a group of contemporary artists, illustrators, and designers who have created poster series entitled "Visions of the Future." So far there have been fourteen series, each representing a NASA space program in a style reminiscent of the old way of making poster illustrations. As commented by illustrator Joby Harris: "A combination of nostalgia and vision of the future, and a perfect way to help people imagine these strange new worlds." The other illustrators at "The Studio" are Liz Barrios De La Torre, Stefan Bucher, Jessie Kawata, Lois Kim, and Ron Miller. They have been, and they still are, artists who worship the Sun through their artistic interpretations.

Of course, there have also been artists in the past who "worshipped" the Sun. In one of his works, "The Agony in the Garden," the fifteenth century Renaissance painter Giovanni Bellini succeeded in capturing the Sun's light at dawn as no other artist of any era has ever done. Art historians think Bellini must have waited for the Sun's appearance at dawn to paint this celestial event so accurately. The French impressionist painter Claude Monet depicted his sunrises and sunsets by observing the reflection of the Sun's light on water or fields as his main subject, and always giving the Sun a mysterious appearance. Caspar David Friedrich's "Woman before the Rising Sun," painted in 1818 in a romantic style, shows a woman with her back to us who appears to be worshipping the Sun god.

Vincent van Gogh, is particularly well known for his series of sunflower paintings. I personally see them as representations of the Sun itself, depicted in the bright yellow colors of our star. Sunflowers are a symbol of the search for happiness. They always try to face the Sun. For me, though, van Gogh's sunflowers are not flowers, but suns!

And in more recent times, in one of his beautiful photographs entitled "Lux," the photographer Wolfgang Tillmans captured and perfectly portrayed the luminosity of the Sun. In his own words, "Light is all." Another a contemporary artist is Olafur Eliasson. His recent work, "The Weather Project 2003," is a large installation in the Turbine Hall at the Tate Modern museum of contemporary art in London, England. The installation is a truly sublime cosmic view of the Sun. This exhibition is a must if you have a chance to visit London.

There are also other artists who depict the beauty of the Universe according to their own personal view and interpretation. Artistic representations of the Sun and other celestial bodies can be seen in science fiction movies. In some of these films, besides their subjects, the scenes shown could be classified as fine art. "2001: A Space Odyssey" was written by physicist and writer Arthur C. Clark and later became a movie directed by Stanley Kubrick. The story is about scientist-astronauts sent into space to study the appearance of a black monolith, accompanied by the supercomputer Hal. The role of Hal is particularly interesting, since it explores the relationship between humans and the evolution of artificial intelligence, a theme much discussed these days. The visual effects of the film are like a painting in motion. It was made in 1968, times in which our contemporary technology had not yet been invented. The film is not only a classic in the science fiction genre, but it is regarded as one of the most influential films ever made.

Avatar is a more recent movie and another example of visual art in motion. I very much enjoyed the ever-present blue tones of the characters in the picture. If the scenes of the film could be frozen for a moment, the effect would be a large blue painting.

Colors are of great importance in life: in movies, paintings, flowers, the ocean, and the sky. Indeed, our whole environment is a palette of color, a great gift that Nature has given to humans, and not only to humans. Through our eyes, we see all kinds of colors. The sky and the sea are blue with different hues, depending on the weather, the seasons, and the position of the Sun, and during a sunset or after rain, the blue can change to purple, orange, or gold. Flowers have infinitely many different tints of color, while clouds can be white, but they can also be gray, pink, red, or violet, and trees and grass have different shades of green. Everything around us comes in practically all the colors of the rainbow. But this idyllic perception of what we see in our environment depends on the Sun's light and the way our eyes perceive it.

The colors with all their tints form a spectrum which astronomers call visible light. This is actually part of a bigger spectrum, the part that human eyes are able to detect. The spectrum as a whole is made up of all the possible wavelengths of electromagnetic radiation, but we humans can see only a small portion of it. When white light like the light from the Sun is passed through a prism, it separates into all the colors of the rainbow. Each color, or rather, each tint of color corresponds to a different wavelength. The human eye can detect wavelengths in the range from 400 nm, which we perceive as violet, to 700 nm, which we perceive as red. The result is a full palette of colors, a pure pleasure for all, and we have this thanks to our star because it radiates in all those colors, so we humans should not take it for granted.

Our colored surroundings are available in different ways to other living beings on this planet. Indeed, animals have different kinds of color vision, depending which part of the electromagnetic radiation spectrum their eyes can detect. For some, their visible range extends into the infrared, that is, wavelengths longer than 700 nm, and for others, the ultraviolet, that is, wavelengths shorter than 380 nm. Like many other insects, bees can see in ultraviolet, picking up patterns on flowers which are invisible to us and which serve to attract pollinators. Birds can also see in ultraviolet, but not in infrared. In fact, most animals that can see color can see ultraviolet. It is because of the Sun that we perceive visible light, because we have evolved to make use of the light available to us.

Changing something's temperature can also change its color. Hot objects radiate energy in the form of visible and infrared light. When something burns, that also leads to radiation of visible and infrared light. I have a personal example. When I work with hot glass using a blowtorch, the flame changes from reddish to bluish as oxygen is added to the propane gas to make the flame hotter. I am familiar with this change of appearance just by doing simple glass work, in the same way as an astrophysicist can recognize the temperatures of the stars by their color. Viewed from space, the Sun appears in a white light because its surface temperature is 5500 degrees Celsius. If it were cooler, it would look reddish like the star Betelgeuse, and if it were hotter, it would look blue like the star Rigel (Figs. 10.1 and 10.2).

There is a sense in which the visible part of the electromagnetic spectrum does not contain all colors. Some of the colors we perceive, such as pink or magenta, are absent from the spectrum because they do not correspond to a single wavelength, but occur when several different wavelengths are detected at the same time. I am a visual artist by profession and I have been confronted with the problem of the "absent" colors, like pink, magenta, and purple and their combinations. The unavoidable question is: why do we see these colors which do not correspond to their own wavelength? According to biologist Timothy H. Goldsmith, color is only in our heads, a perception created in our brains. More recent research suggests that people can be made to see the "forbidden colors." We see them because our brain creates them, according to Goldsmith. Valid scientific research or eccentric speculation? Maybe both.

The human brain, being a powerful, imaginative, mysterious, and poorly understood "object," can somehow mix colors with different wavelengths

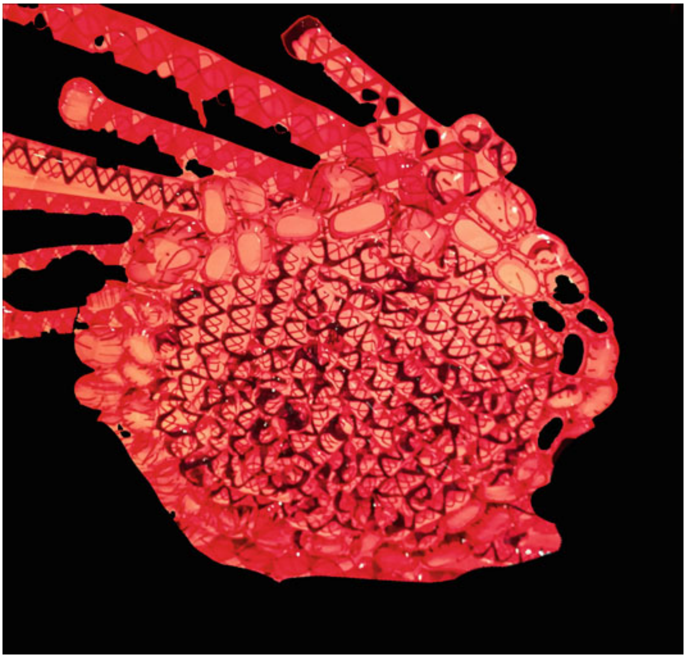

**Fig. 10.1** A cool star. Betelgeuse is an example of a cool star, with a reddish color. Blown glass sphere

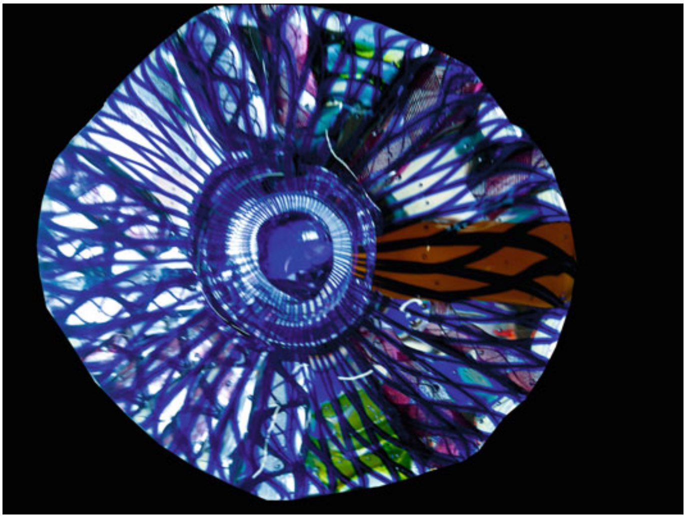

**Fig. 10.2** A hot star. Rigel is an example of a hot star, with a bluish color. Blown glass sphere

to obtain these so-called “forbidden colors.” Historically, there have been observations of this phenomenon. In the seventeenth century, Isaac Newton discovered that a prism could disassemble and reassemble white light. He described this phenomenon in his book “Opticks,” in which he claims that light is made of corpuscles, that is to say, particles, of different colors. In the eighteenth century, Johann Wolfgang von Goethe wrote about optical spectra in his book “Theory of Colors,” in which he hypothesized that a beam of light with a wider aperture produces reddish-yellow and blue-cyan edges with white between them, and he claimed that the spectrum appears only when the edges are close enough to overlap.

In the nineteenth century, part of the electromagnetic spectrum outside the human visible range was discovered by William Herschel. In fact, he discovered the infrared. Johann Willem Ritter discovered the ultraviolet, while Thomas Young was the first to measure the wavelengths of the different colors in the year 1802. Young and Hermann von Helmholtz put forward a theory of color vision according to which the human eye uses only three receptors to detect colors. Some species on Earth can detect light at wavelengths outside the human visible spectrum, while other species detect no colors at all. As mentioned earlier, insects can detect ultraviolet light, so bees can see patterns in flowers containing nectar where we would see no pattern. Plants need insects for pollination, and these patterns in ultraviolet light serve to attract them. We humans see flowers and plants only in the colors corresponding to the visible spectrum, so the patterns they present to us may look different. Some birds perceive ultraviolet light, while others also perceive some reddish wavelengths.

As far as other animals are concerned, there are many different possibilities: most mammals are dichromatic; dogs and horses may be color blind; reptiles can detect some infrared wavelengths; and apes and monkeys can see the same as humans. One issue studied by physicists and biologists concerns the way light is perceived and asks whether there is a limit to the visible spectrum. It seems that this depends on the amount of radiant power which reaches the retina, and the response of the individual observer. In general, the lower limit for visibility lies between 360 and 400 nm, and the upper limit between 760 and 830 nm. Everything else depends on personal differences.

But let us return to the subject of science fiction movies. "Contact," as I mentioned earlier, is a book written by Carl Sagan, which also became a very successful movie. Being an astronomer and writer of popular science books, Sagan imagined a voyage to a distant place on the other side of our galaxy, traveling through a wormhole. "Close Encounters of the Third Kind" is another classic science fiction movie, created and directed by Steven Spielberg. It describes a first encounter between humans and aliens, a peaceful encounter, in which the communication between these two alien worlds occurs through music, and not through mathematics as happened in Sagan's book "Contact." Many more science fiction books and movies have been made, many of them successfully depicting our innate human curiosity to explore the unknown.

# 11

# Solar Energy

The most important feature of the Sun is its enormous energy, which is vital for all living beings on this planet. And now, more than ever, for its human population, which needs energy so badly. The climate is changing because of our disrespect toward the Earth. We humans and our ancestors have inhabited this planet for millions of years, but we should realize and accept that we do not own it. We are only temporary guests, and it is our duty to repair the damage we have caused. Up to now, there has been only talk and more talk, and empty promises by all the shortsighted politicians in all the governments on Earth.

The use of fossil fuels like coal and gas has not been good for our suffering planet, and nuclear power carries its own risks. Naturally, and at last, we are looking to the Sun for a solution. It has been faithfully present in the sky for millions of years and is a valid source of energy to give us what we desperately need: a clean and ever available supply of energy. Solar energy should be a major part of the solution! Using photovoltaic systems, it can provide electricity for heating water and housing. It is a clean and efficient source to replace the unclean and dangerous fossil fuels. In short, it is an essential, natural, and renewable source of energy.

But even in this apparently ideal solution, some problems remain to be solved. Solar energy from photovoltaic panels depends on having a suitable location for them and a clear sky, with not too many cloudy days. It also helps to be not too far from the equator. Moreover, a lot of space is required for the necessary equipment. Another problem is to find a way to store energy during the night. And there is the question of recycling the large amount of materials these systems use.



L. Pesce, *A Biography of Our Sun*, https://doi.org/10.1007/978-3-031-54729-4_11

Lately, a new and clean form of nuclear energy has been considered, which would imitate the nuclear fusion occurring inside the Sun. This has been much written about in the newspapers, and often mentioned on radio and TV news, accompanied by a general enthusiasm around the world. This could be a real solution that could eventually produce an endless supply of clean energy, something particularly good for us and the health of our planet. Have humans at last found the holy grail of a never-ending clean energy source? This miracle from our Sun god may eventually be achieved, but it is not happening yet, and there is only a hint that it could do so in a not too distant future.

Professor Hans-Thomas Elze, theoretical physicist at the University of Pisa, explains the recent studies regarding the possibility of a nuclear fusion reactor that could satisfy our energy requirements:

> In order to understand why it is difficult to harness on Earth the fusion processes that power the Sun's energy output, we need to recall how the Sun does this.
>
> The Sun weighs about 333,000 times as much as Earth, and the resulting gravitational attraction it exerts on its outer parts is roughly 10 times stronger than on the surface of our planet. It is this force which keeps the flaming gaseous body from flying apart and dispersing freely into space. At the same time, it compresses the interior to densities and temperatures which suffice to ignite the fusion of the atomic nuclei of hydrogen into those of helium, the energy-producing process that has been going on for more than 4.6 billion years (and will continue for another 5 billion years).
>
> It is then easy to understand that the problem of laboratory fusion consists in creating a sufficiently dense and sufficiently hot hydrogen "plasma," i.e., a gas of protons and electrons, the components of hydrogen atoms, to start the reaction. While this can be achieved in various ways, such as in thermonuclear bombs, a more civilized civilian use of the fusion process and energy production will require us to maintain a stable plasma state for a sufficiently long time. (The product of its density, temperature, and lifetime has to give a sufficiently large figure of merit. This is known as Lawson's criterion.) Otherwise, not enough fusion reactions will take place and the energy cost in such a laboratory, and eventually in an industrial size power plant, will outweigh the energy gain.
>
> At present, two approaches to reach the goal of controlled thermonuclear fusion are being widely studied, and corresponding experimental and large-scale engineering projects are underway internationally. The laser ignited inertial fusion facility at Lawrence Livermore Laboratory in California attempts to create the plasma state by shining numerous extremely intense X-ray lasers, perhaps the most powerful ones on Earth, from all sides on a small pea size pellet which essentially contains frozen hydrogen – by heating and evaporating

its outer shell, the laser light at the same time leads to an enormous compression of the hydrogen and so may lead to fusion, as desired. In December 2022, it was demonstrated that one arrives at a more or less spherical plasma, fulfilling Lawson's criterion, and leading to fusion reactions that produce energy. However, it should be said that this demonstration of the working principle is still years away from the construction of an operating power plant.

In contrast, the international ITER facility at Cadarache in southern France aims to arrive at a prototype magnetic confinement reactor. Here use is made of the fact that the hydrogen plasma consists of electrically charged particles, and so can be manipulated by electromagnetic and, in particular, magnetic fields. The underlying physical problems of stability (Lawson's criterion again) have been studied in many places for decades, and the proponents of the scheme are confident that not only an "in principle" but also a technologically if not economically interesting reactor will eventually be built. The actual construction at Cadarache is underway.

(Professor of Theoretical Physics, Hans-Thomas Elze).

An interesting solar energy technology was invented by Carlo Rubbia, theoretical physicist and inventor, who received a Nobel Prize in Physics in 1984. He began working at CERN in 1961, and became CERN's Director-General from 1989 until 1993. For the last 15 years, he has dedicated his research to the question of energy, focusing on new technology for renewable solar energy. In his Archimede project, he developed a technology based on solar power at high temperature. His idea came from an ancient invention by Archimedes, the Greek mathematician who lived in Sicily when it was a Greek colony. In 212 BC, Archimedes succeeded in defending the port of Syracuse against the Roman invasion, and he is said to have done this by using mirrors pointed toward the setting Sun to set fire to all the Roman ships. A simple, but ingenious idea, which won the battle against the strongest military power of Antiquity.

But in this case, it was the ingenious mind of Carlo Rubbia that built this solar thermal technology to improve the efficiency of the existing solar power plant. The Archimede project, as Rubbia named it, uses a more efficient solar thermal technology than conventional photovoltaic panels. Professor Rubbia replaced the panels with mirrors, inspired perhaps by Archimedes' idea. With an aperture of 5.76 m, each mirror focuses the Sun's heat on a tube of diameter 11 cm containing molten salt and potassium nitrate at a temperature of 550 °C. This is then used to produce steam which provides the power for an electrical generator. Through this innovative technology, the energy produced by the Sun can be stored in molten salt tanks. This is a simple, but incredible discovery. The energy can be accessed any time it's needed, even on cloudy days and at night, whenever the Sun is not shining. As usual, though, there are some drawbacks, as with every seemingly perfect solution: firstly, this kind of project takes up a certain amount of space, and secondly, it will be most efficient only in desert and semi-desert areas. The Archimede technology has been adopted in Spain, Morocco, the USA, South Africa, Australia, Mexico, Egypt, and Dubai. But of course, it is less efficient in Europe.

## 11.1 Solar Architecture and Urban Planning

Sunlight has influenced human beings since they began planning the construction of their homes. So, this can already be called solar architecture. Since they left their cave dwellings and began to build their own houses, humans must always have taken orientation into account, having them face south to receive light and warmth from the Sun. Native American tribes, for example, made sure the entrance to their homes faced the sunrise. In the southwestern region of North America, the indigenous people fixed an overhang on their home to shade it from the hot summer Sun, and took it off during the winter to let in as much solar warmth as possible. Mesa Verde in Colorado is the best known site for cliff dwellings in this region. There were many such dwellings, although unfortunately not all are well preserved. The native peoples carved out small caves to erect their homes on the canyon walls. The largest and best preserved of these sites in Mesa Verde is called Cliff Palace.

Ancient Greek architects, following the shortage of their main source of fuel, charcoal, obtained by burning trees, had to think of an alternative. They had the idea of using materials that could absorb solar energy, such as stones, which were more readily available than coal, and built their homes facing toward the south. Here too, overhangs were fixed onto the buildings to shade them from the hot summer Sun, and removed in the winter to let the sunlight in. This was a simple and efficient structure to provide cooling or heating when they were needed. The Romans improved the Greek idea by covering the southern face of their constructions with transparent fabrics like a canopy. Even the Colosseum had awnings made of such fabrics to protect people from the hot summer Sun while attending the "Ludi," the popular entertainment in Ancient Rome.

Throughout history, there have been attempts to use the power of the Sun to produce energy, to keep living environments cool in the summer and warm in the winter, but it was only after many centuries experimenting with rudimentary ways of exploiting the Sun's energy that more efficient technologies were finally devised.

In 1866, Augustin Mouchot used a parabolic reflector to produce steam for the first solar steam engine, while in the same year, the first patent for a solar collector was obtained by Alessandro Battaglia from Genoa, Italy, and the inventors John Ericsson and Frank Shuman worked to find more efficient designs to obtain solar energy. During the twentieth century, research continued, and in 1968, Giovanni Francia built the first solar plant near Genoa, Italy. The plant produced 1 ~ MW, which was a great success at the time. In 1981, a more powerful plant was built in southern California, called Solar One. This was then converted into Solar Two in 1995.

Architects in Europe and the USA, like George F. Keck and Frank Lloyd Wright, the great innovators of the day, kept alive the growing interest in reducing power production from fossil fuels, and so looked to solar power as a solution. George Keck was a pioneer in designing passive solar houses in the 1930s and 40s. For an exhibition in Chicago, he designed “The House of Tomorrow,” made almost entirely from glass according to the passive solar power model. Frank Lloyd Wright also designed passive solar homes. In 1944, in his “Solar Hemicycle” home, he incorporated south-facing windows.

There are basically two ways to profit from solar energy: passive systems and active systems. The first is obtained when the design incorporates materials which optimize the direct heat and light of the Sun. The second uses mechanical or electrical devices like photovoltaic panels, for example, to convert the Sun’s energy to a usable form, and thereby obtain electricity, hot water, heating, cooling, and so on.

Solar architecture refers to the approach in which architects take into account the Sun to supply clean and renewable passive and active solar power. Now, in contemporary solar architecture, the main objective is to have a clean and renewable source of energy, but hopefully, not forgetting the importance of aesthetics. Photovoltaic panels are a common choice for homes and commercial buildings. They can be seen on the rooftops of many houses, and they are indeed efficient systems these days, now that they have gone through the necessary experimental stages. The photovoltaic cell was in fact invented in 1954 by the Bell Telephone Laboratories, but they were not efficient enough for marketing. However, by 1973, the University of Delaware had built Solar One, the first system designed for home use, although there was still some inefficiency in the design. In 1988, a company called Oxford Photovoltaics developed and produced a better panel for home use. Now solar panels are widely used in many homes around the world to supply electricity for water heating and ventilation.

But what about aesthetics? Architects are involved in innovative building design in many major cities around the world, trying to combine technical efficiency with aesthetics. Homes and commercial edifices are springing up which look more like large contemporary sculptures than typical everyday buildings.

In Silicon Valley, California, the ultimate realm of new technology, there is one building in particular in the Google Bay View Campus that I think deserves a special mention. Architects BIG and Heatherwick Studio designed the roof of this building in the form of a dragon. The structure has an undulating form covered by 50 000 solar panels, which can generate seven megawatts of energy. The result is a beautiful abstract sculpture of a giant dragon.

During Dubai's Expo 2020, the Dutch Biotope pavilion, designed by V8 Architects, used translucent pink and blue photovoltaic panels to make a skylight giving the effect of stained-glass windows, beautifully designed by artist Marjan van Aubel. The purpose was to create an art form providing renewable energy, and Van Aubel definitely achieved her goal. The result is a beautiful solar panel skylight belonging to a contemporary art gallery, but which will instead be installed on the rooftops of homes. One can imagine the beautiful transformation of city neighborhoods if these new ideas for combining technology with art could be more widely introduced in the future. At the moment, though, these beautiful installations are too expensive and remain out of reach for the common citizen.

Another interesting example is Melbourne's Sol Invictus Tower. Recall that that Sol Invictus (meaning "unconquered Sun") was the Sun god of the Late Roman Empire. But this one is a sixty-storey apartment building in Melbourne, Australia. It was designed and built by Peddle Thorp Architects. The facade of this skyscraper is wrapped around with solar cells, and wind turbines have been mounted on the roof. A distinguishing feature of the design is that the exterior of the building will catch as much sunlight as possible as the Sun moves from east to west. Indeed, from sunrise to sunset. Sol Invictus is the perfect name for a very tall tower which can catch the power of the Sun the whole day long by means of rotating panels.

Another interesting work of architecture is the main building of Apple Campus 2 in Cupertino, California, nicknamed "the spaceship." The project contains the largest amount of glass ever used for one building, and thousands of gigantic solar panels are mounted on the rooftop, generating up to 16 megawatts of power. On the campus, 2500 indigenous trees have been planted in addition to existing ones, making a total of 7000 trees, and there are miles of biking and jogging routes. Altogether, the Apple headquarters has 80% of green space, making a good combination between state-of-the-art technology and environmental protection. It looks for all the world like a spaceship that has just landed among thousands of trees, a giant work of art.

The Copenhagen International School is another innovative architectural construction which aims to integrate sustainability with aesthetics. The building features the largest solar facade ever built, with 12,000 irregularly-shaped solar panels colored in bluish-green tones. The overall impression we get from this building is of a giant contemporary sculpture, in cubist style. Very interesting! The school curriculum offers "Solar Studies" with classes on physics and mathematics. Brit van Ooijen, chairman of the board of the Copenhagen International School, says: "The goal of the school is to enhance students' competence in an international environment so that they become responsible citizens of the world with a focus on sustainability." I totally agree with the comment of Doctor Ooijen that schools should enhance their students' competence in this way.

"La Seine Musicale" is a building shaped rather like a ship, near Paris. It was designed by the Japanese architect Shingeru Ban. It is mounted on rails so that it can be moved in such a way as to shade the building from direct sunlight when necessary, or turned toward the Sun if so desired. The wall is covered with solar panels which follow the path of the Sun. This architectural structure, like the others mentioned above, is not just a building, but a livable sculpture. The beauty of "La Seine Musicale" continues within, because the interior has been designed to provide spectators with a relaxed and warm atmosphere.

MVRDV's Sun Rock is a solar architectural building in Taiwan. It is without doubt among the most beautiful structures in the world, with a unique shape accompanied by advanced technological solar power. The facade is covered with solar panels that generate electricity, in fact, one million kilowatt hours of clean energy every year. The rocky shape of the structure is designed to fit in with the local landscape. Besides the energy efficiency of the building, which contributes to a sustainable green architecture in Taiwan, the "Rock" is a beautiful contemporary urban sculpture.

As a visual artist, and because I work predominantly with glass, I find this new kind of innovative urban planning particularly interesting. The widespread use of glass in these structures enhances the overall effect of reflected sunlight. The sustainable green technology of solar power and the incorporated aesthetics gives the viewer a feeling of well-being which is so important for us humans. Naturally, these beautiful building-sized sculptures are very expensive to realize, at least for the moment, but this kind of architecture will be necessary to respond to the threat of climate change. And by incorporating artistic design, it will also help to introduce art into our urbanized and otherwise homogenized modern world.

The beautiful cathedrals and monuments built by our ancestors can now be admired in every city around the world. Their construction required considerable economic resources and many years and even centuries, in the case of the medieval cathedrals. In general, the patrons who contributed to these amazing constructions were important and wealthy politicians or clergy. Without their wealth, and maybe also their love for art, we would not have the beautiful historical sites to admire today. My conclusion is that we should welcome solar architecture into our cities, not only to provide a healthy and beautiful environment, but also to add a touch of aesthetics, hopefully with the help of individual contributions to support the development of green homes.

I have mentioned all the beautiful buildings around the world, built by qualified architects who have successfully combined technology and aesthetics, but what about the majority of people, who cannot afford the high cost of famous architects and designers? Well, the creativity of some artisans and some factories has solved the problem of high costs without sacrificing the beauty of artistic solar panels. Of course, they cannot compete with the perfection and the high quality of the best designers who created those grand buildings, but they can add a joy of colors and beautiful patterns to our regular homes.

## 11.2 The Solar Revolution

With our increased need for energy, solar power is not limited to homes or commercial buildings. There are solar greenhouses, cars, laptops, phones, and even clothes, and all kinds of gadgets.

An active solar greenhouse uses solar panels which collect sunlight to transform it into heat. This is a very efficient way to obtain the correct environment to grow plants, no matter what the outside weather conditions may be. All greenhouses use solar energy either actively or passively because they depend on sunlight for the plants to grow. An active solar greenhouse needs propane gas or electricity to heat the place at night or in cold winters, while the passive method instead uses only the heat of the Sun, and its efficiency depends upon the natural elements used as a thermal mass. Solar energy greenhouses use solar panels oriented toward the Sun to generate electricity for heating or cooling the environment when needed. There are many advantages in using solar panels for a greenhouse. In particular, this limits the toxic gas emissions produced by the traditional greenhouse and is therefore good for the environment. It is also efficient for controlling the temperature and protects against plant diseases. Finally, once the panels have been installed, there are no further energy costs.

The solar revolution is becoming more popular in all kinds of fields, some of which are genuinely interesting, while others are merely amusing, with a kind of illogical creativity, but no real solar technology. One interesting example is the Solar Protocol network, which involves solar-powered internet servers. These can only work when there is sufficient sunlight. Websites may load more slowly at times, so they will work optimally only in certain circumstances and locations. This a good green technology, but not efficient for everyone.

Another use of the Sun's energy is in solar sails, an idea put forward by NASA to propel spacecraft. The idea is similar to the way the wind pushes sailing boats on the sea, except that solar sails use the pressure of light from the Sun to push the spacecraft, without using any fuel. The sails would be made of thin films with a reflective coating by the company NeXolve. This technology has a lot of potential because of its capacity to reach very high velocities, given the abundance of solar radiation in space. A spacecraft could reach deep space destinations faster than with fuel propulsion, and NASA is considering it as a valuable aid for future missions to Mars. Some day!

Back to our everyday lives on Earth, solar energy could eventually be used to power electric cars. Lightyear is a Dutch startup working on solar electric cars. Emanuele Cornagliotti, the lead solar engineer of Lightyear, said that, in twenty years, when solar cars are being mass produced and prices have been brought down, they will become the new normal. These cars of the future will have five square meters of solar panels on the roof and on the tailgate. In a sunny country like Spain, for example, the car could be used for seven months without the need to plug it in. Eventually, solar cars will cost less and require fewer charges, and, if one does not need to drive all the time, it will be possible to drive them practically for free. So, at last, something good to tackle climate change on the planet.

Big names like Hyundai, Mercedes-Benz, and Tesla are looking with interest at these new energy-saving cars. The hope is that this technology will help to end the problem of fuel dependency, and also the problems that still exist in cars running on electricity. Cornagliotti and his team at Lightyear are designing a way of replacing the panels on the top with a regular body part, thereby preserving the original design of the car. Again, technology, innovation, and aesthetics.

Photovoltaic panels have traditionally been rather large in size for incorporation into buildings, but they are now becoming smaller and lighter, and this change in technology will facilitate their use in different projects. Adidas, for example, is a well-known brand of sportswear that recently created wireless headphones that can be charged by solar energy, or by artificial light. The headphones consist of a headband made with solar cell fabric, able to convert sunlight and artificial light into electricity.

Another example are solar blankets. Solar power is produced in a conductive yarn made from a polyester composite, to generate the heat needed to warm the whole blanket. Personally, I still prefer the old-fashioned woolen blankets!

Solar-powered textiles created by designers and physicists at the university of Aalto in Finland have been used to develop clothing with solar panels. A solar cell system is incorporated inside a light textile, so that the sunlight can get through. They hope to be able to apply this technique to all sportswear. A few fashion designers are involved in creating more and more wearable items powered by solar cells, such as windbreaker jackets, backpacks, watches, and so on. The Dutch designer Pauline van Dongen has invented a durable and waterproof textile which she calls SUNTEX. This is a solar polar generating textile which can even be used to make fashionable clothes. During the Solar Biennial in Rotterdam, Holland, van Dongen also said that SUNTEX could be used to cover an entire building and create a completely new aesthetic. As a designer, aesthetics are of major importance for her in the finished product, so colors and patterns are essential, as essential indeed as using recycled polymer yarns. She believes that SUNTEX could also be produced for tents, curtains, parasols, and swimming pool covers, and she emphasizes that the textile is durable and recyclable. A combination of sustainability, clean energy, and aesthetics. Solar energy seems to be extending to as many fields as possible, the visual arts included.

Another example is a solar-harvesting prototype called Ecacia created by the London-based designer Samuel Wilkinson. This mimics trees in the African savannah and can be placed in a public area to shelter people from the summer heat. Or again, a solar energy kiosk developed by the design studio "Cream on Chrome" in Rotterdam, which serves fresh orange juice. I can see both of these solar ideas being much appreciated by beachgoers around the world, including the beach near where I live.

The Sun comes into so many different areas of our lives, and sometimes in ways which completely lack any scientific foundation, as I mentioned earlier. Astrology is a perfect example, using the exact position of the Sun on someone's birthday to personalize their astrological chart. And what about a cosmetic for makeup, skin care, and body care, advertised as "Sun Revolution Beauty." This is perhaps the most absurd and original "revolution" ever advertised.

# 12

# This is the End!

## 12.1 The Death of the Sun

Our star has been considered as a god throughout the many centuries of human existence. It was Ra for the Egyptians, Helios for the Greeks, Sol Indiges and Sol Invictus for the Romans, Inti for South America's Incas, and something else in each of the ancient cultures. Now, in this last chapter, a name will be needed for the necrology of the Sun. Perhaps, Sol would be appropriate, like the ancient Roman Sun god Sol Invictus. An important name for an important star. As previously mentioned, our star was born in an interstellar cloud of dust and gas. Such is the nursery of all stars, including "Sol." Stellar nurseries are abundant in the many galaxies of the Universe. All stars are born in the same way (Fig. 12.1).

Sol is now in the middle stage of its life, and like everything in the Universe, it is finite and will eventually die, a natural ending for all evolving beings. Nothing lasts forever, and that includes the Sun. It will die when all its helium has been used up, at which point it will shrink and become a white dwarf, blasting its outer layers into space and leaving what is misleadingly known as a "planetary nebula." This is a much-abridged description of the death of such an important star as Sol, life-giver to all the inhabitants of planet Earth. But humans will not be present to witness its death because most astronomers estimate that our Sun has probably five to six billion years left to live, while others estimate even longer before it dies. At any rate, we are talking about a very, very long time, so humanity is not going to witness this disaster. Although we cannot predict that for sure, it seems likely that by then humanity will be long gone.


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**Fig. 12.1** Stellar nursery. Acrylic paint on canvas and stars in fused glass. In this painting, I imagined a goddess taking care of new born stars

Astrophysicists can say fairly precisely how the death of our star will come about. It will eject a large mass of gas, called the envelope, into space, revealing only the core of the star. At this point, the nuclear fuel which kept the Sun alive will run out, and our star will die. But before this, it will go through different stages and transformations. In five billion years from now, it will become a red giant, and this is when the core of the Sun will shrink and the outer layers will expand, engulfing the nearby planets. Mercury and Venus will thus be destroyed. The Earth should survive the destructive force of the Sun, but it will no longer be inhabitable.

Indeed, the online publication ScienceAlert suggests that humans have only one billion years left to live comfortably on Earth, since the Sun gets brighter and hotter by about 10% every billion years. This means that, even a billion years from now, there is a real possibility that life on Earth will have come to an end. With such enormous heat, everything will burn, the oceans will evaporate, and the surface will become too hot for any possibility of supporting life. But the Sun will continue the transformations leading up to its death.

From a red giant it will become a white dwarf, and after exhausting all its fuel, it will expel its outer material, and create a so-called "planetary nebula." Only the hot core of the star will remain. At this point it will become a very hot white dwarf, at a temperature of 100 000 K. From there, it will very gradually cool down over the following billion years. Its mass will shrink to half of the previous mass of the Sun, but it will be 200 times as dense. A white dwarf is among the densest objects in space, surpassed only by neutron stars and black holes. According to NASA, the gravity on the surface of a white dwarf would be some 350 000 times as strong as we feel here on Earth. So, a person weighing 68 kg on Earth would weigh over 22 million kg on the surface of a white dwarf.[1]

At this final point, our dear Sol would in no way resemble the Sun god adored by so many different human cultures. Eventually, after its death, Sol will turn into a "planetary nebula," a kind of solar corpse. So, now, it looks like the biography of the Sun is definitely finished, and, as in the old movies, all that remains to say is "THE END"! (Fig. 12.2).

## 12.2 Not Quite!

Actually, it's not quite the end yet, because, as scientists always point out, energy does not just disappear: it transforms. So, there are more questions to be asked. What happens to the stellar remnants, and to the transformation of the Sun? The answers to those questions belong to cosmology and theoretical physics.

Horst Stöcker, Professor Laureatus for theoretical physics at the Goethe University Frankfurt, the Frankfurt Institute for Advanced Studies (FIAS), and the GSI Helmholtz Centre for Heavy Ion Research, explains how our Sun

[1] Scientists think there might be a crust 50 km thick below the atmosphere of a white dwarf, and it may be that, at the bottom, we would find a crystal lattice of carbon and oxygen atoms. Scientists even compare such a carbon–oxygen white dwarf with a very large diamond! But at that point, who could possible care how many diamonds could be found at the center of a white dwarf.

**Fig. 12.2** White dwarf. In this painting, I imagined how the Sun could shrink into compact object called a white dwarf. Oil paint on canvas with bright metallic fused glass

and the other stars finally die. Once the nuclear fuel in a star is exhausted, it will become either a white dwarf, a neutron star, or a black hole. This represents the final stage in the evolution of any star. Our own star, being a low to intermediate mass star, will return most of its mass to interstellar space and become a white dwarf. Ninety-five percent of the stars in the Milky Way will become white dwarfs. In the case of a massive star, the stellar remnant is initially a proto-neutron star. During its evolution—stellar evolution is the process by which a star changes over the course of time—neutrinos are produced abundantly in the nuclear reaction. In these stages, they can easily escape from the star, but when the core collapses, the neutrinos trapped inside can cause a violent explosion and the star becomes a supernova. In some cases, when the explosion fails, or does not manage to expel enough mass, the process continues, until the gravitational collapse results in a black hole.

The mass lost by stars plays an important role for stellar evolution, and also in the chemical evolution of our galaxy. According to Professor Stöcker, the mechanism of mass loss of evolved stars is not yet fully understood.

So, the Sun will disappear from the sky in that way, but astrophysicists mention the encouraging fact that it will continue to exist in some sense through its interaction with matter in the Universe. Energy does not just disappear. It gets transformed. In that case, it will still be there as a kind of invisible ghost, as the white dwarf slowly fades away.

It turns out that the smallest stars take longer to fade away, because they burn slowly, and can live up to 100 billion years. This is somewhat paradoxical, because it is much longer than the current age of the Universe. The lifetime of a star depends on its mass, and can range from a few billion years for the massive ones, to trillions of years for the least massive, which may still be around at the very end of the Universe.

It's not easy to grasp the concept of the unlimited conservation of energy. Is energy really immortal? Some physicists hypothesize that the energy can gradually decrease until it becomes very faint, thereby decreasing in quality the dynamic of the cosmos, gradually spreading out, but never lost. Others imagine the end of the Universe to be an ocean of photons. The ultimate fate of the cosmos is unknown, of course, but there is plenty of speculation. Maybe, there will not be much left besides cold, dark space stretching into the void, and certainly no trace of our dearest Sol.

But there is an interesting cosmological model called conformal cyclic cosmology (CCC), proposed by theoretical physicist and mathematician, Roger Penrose, a recent Nobel laureate, and his colleague Vahe Gurzadyan. In 2001, Penrose suggested that the end of the Universe might be the beginning of a new one. The model accepts the expansion of the Universe until the complete dissolution of all matter and the absorption of all light by black holes. At that point, what remains will be similar to the initial condition of the gravitational singularity. According to the CCC model, the Universe would go through infinitely many cycles, called aeons. Every infinite future of spacetime represents a repetition of the previous one, identified with the singularity of the Big Bang. The CCC model, as Penrose affirms, is based on studies of the cosmic background radiation and on waves which have been discovered in the residual material of previous universes. So, the final state of the Universe could be the beginning of another.

Sir Roger Penrose's theory is somehow comforting! An infinite cycle of repeating universes could mean that the end of time is not an end but a beginning of aeons of galaxies, stars like our own, and life.

A cyclic cosmology was also proposed by physicist Paul Steinhardt of Princeton University in 2001. He described a Universe exploding into existence, not once, but repeatedly over time. Penrose's theory is different, because the final state of his Universe tends to a cold and disordered emptiness, where the notion of time starts to lose meaning. There is the same entropy (disorder) that there was before the Big Bang, the cause being the evaporation of black holes.

The Hindu religion has believed in such a cyclic universe for at least five thousand years. For Hindus, humans are also recycled, through reincarnation of the soul. But perhaps this is just wishful thinking, a search for eternal life. Professor Penrose is a physicist and mathematician, and explains the cyclic cosmology through science, not as a consequence of blind faith.

I conclude this biography of the Sun with my own personal kind of wishful thinking. I hope that this is not the end, and that the stars, the galaxies, even our own Sun will come back through eternal cycles of death and rebirth, again and again. So, to conclude this book, the final words "The End" will not be necessary (Fig. 12.3).

**Fig. 12.3** It's not the end. Painted glass

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