How the Movie Camera Failed to Become Part of the Standard Astronomical Observational Toolkit (1895–1914)

Vitor Bonifácio

Abstract A series of technological developments driven both by scientific pursuits, particularly Étienne-Jules Marey's motion studies, and commercial reasons led to the birth of Lumières' 1895 'cinematographe'. Its ability to automatically record a sequence of photographic images had previously been attained by Jules Janssen's photographic revolver, an instrument developed to time with high precision the contact instants of the 1874 transit of Venus. While with this pedigree one might expect a rich use of movie cameras in astronomical observations after 1895, current historical accounts of the development of both cinema and astronomy usually cite none. Is this due to historiographical reasons and/or the new technology failed to become part of the astronomers' observational toolkit? Analysing all astronomical movies attempted or shot between 1895 and 1914, we concluded that the low usage of movie cameras in this time period was a consequence of a lack of suitable observable subjects and the small film frames used. While new technological apparatus may open unexpected lines of scientific enquiry, they must also struggle to find a place and function against already established ones. It was precisely this inability to stand out that led to the astronomical moving pictures' fate as a rarely used and indeed seldom useful technique.

Keywords Science movies · Scientific films · Early cinema · Cinema development · Astronomy · Solar eclipses

1 Introduction

Despite its pedigree, earlier astronomical films have been largely ignored by contemporaneous accounts of early-cinema history. Recent research into the role played by scientific pursuits in the development of what would later be called cinema only alludes to Jules Janssen's (1824–1907) photographic revolver and the 1874 transit of Venus observation (Tosi 2007). The DVD, "La vera nascita del cinema. Le origini

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del cinema scientifico" (The true birth of cinema. Origin of scientific cinema) has chapters describing early cinematographical applications in the fields of Botany; Biology and Physiology; Medicine and Surgery; Technical Sciences (ballistic studies); Mathematics and Ethnology but not Astronomy (Tosi 2005). Likewise the "Encyclopedia of Early Cinema" does not cite a single astronomical application despite containing two entries entitled "Scientific films: Europe" and "Scientific films: USA" (Curtis 2010; Lefebvre 2010). Furthermore a recent and otherwise excellent book misunderstands, in our opinion, the reason behind the lack of applicability of astronomical cinematography to high precision time measurements since a time stamp could be simultaneously recorded on film by a convenient choice of apparatus. (André 1912; Carvallo and Vlès 1912; Vlès 1914; Canales 2010, p. 151). On the other hand we found that the few previous works tackling the history of astronomical cinematography although knowledgeably written are incomplete (Vlès 1914; Korff 1933; Bourgeois and Cox 1933; Atkinson 1953; Leclerc 1956; Bianchi 1994).

In this paper we endeavoured to bring to light all astronomical cinematographic attempts made with film cameras for scientific purposes between 1895 and 1914 (Sect. 2). To the extent that astronomers split the continuous flow of time to extract data from different stills, the coincidence of recorded and viewed images per second ratios was usually irrelevant. In fact slow motion and speed up techniques were considered useful research tools earlier on in several scientific areas (Vlès 1914; Chaperon 1995). Any possible pedagogical and commercial value of astronomical moving pictures will not be discussed here.

Possible astronomical applications of movie cameras are analysed in Sect. 3. Finally, in Sect. 4 we present our conclusions.

2 Moving Pictures: 1898–1914

On 10 February 1873 Janssen presented at the Paris *Académie des Sciences* his plan to construct a new instrument "that would enable one to obtain a series of photographs at very short regular intervals" (Janssen 1873). This would, in principle, allow timing with high precision the instants of contact between Venus and the Sun at the 1874 transit. At least nine photographic revolvers of either Janssen or Warren De La Rue (1815–1889) design were used in 1874. A few plates still survive today although not Janssen's expedition original obtained by the Brazilian Francisco António d'Almeida (?–?) at Nagasaki (Japan) (Launay and Hingley 2005; Mourão 2005).

Current film history recognizes Janssen's photographic revolver as the earliest of all cinema precursors (Sicard 1998; Launay and Hingley 2005; Tosi 2005, 2007). In the following years Janssen's 'idea' was developed by, amongst others, Eadweard Muybridge (1830–1904), Etienne-Jules Marey (1830–1904), Georges Demenÿ (1850–1917) and Thomas Edison (1847–1931). A process that led to Auguste (1862–1954) and Louis (1864–1948) Lumière public presentation of the 'cinématographe' on 22 March 1895 in Paris (Tosi 2007)

2.1 William Edward Wilson Sunspot

Less than 2 years later, in early 1897, the Irish amateur astronomer William Edward Wilson (1851–1908) ordered, for his personal observatory, a "special form of Cinematograph […] in order to try whether it would be possible to show visually the changes in the forms of Sun-spots" (Wilson 1898). The instrument was only delivered at the end of the year when the Sun was, according to Wilson, too low in the sky to use it. The first 'film' was shot on August 9th 1898 while 4 days later "400 photographs of a sunspot between 10:45 am and 2:30 pm" were obtained (Wilson 1899; Mc Connell n.d.).

Wilson's film experiments were probably short lived since they are neither mentioned in later observatory reports presented to the Royal Astronomical Society nor in the 1900 book "Astronomical and physical researches made at Mr. Wilson's observatory, Daramona, Westmeath" (Wilson n.d., 1900, 1901, 1902, 1903, 1904a, 1905a). The local weather apparently played an important role in this outcome. "The intervals of sunshine that we get are too short to make it [the film camera] of any value" wrote Wilson in April 1906 to George Ellery Hale (1868–1938) (Wilson 1906).

We are unsure when Wilson and Hale got in touch. From the extant correspondence it seems likely that the first contact occurred in 1904 as a consequence of Hale's plan to establish what would later become the International Union for Co-operation in Solar Research (Wilson 1904b). Wilson was not present at the St. Louis 1904 meeting but attended, as well as Hale, the 1905 Oxford conference (Anonymous 1905a, 1906). On October 11, less than 2 weeks after the conference ended Wilson sent Hale the "little cinematograph which I hope you will be able to try on a Sun Spot soon" (Wilson 1905b). On 1906 January 12 Hale acknowledged the instrument safe arrival and commented this "is exactly what I wanted, not only for photographing the spots directly but also with the spectroheliograph, to which I think it can be adapted without much trouble" (Hale 1906). Hale's attempts were likely unsuccessful since a few years later he complained to his brother that the "good seeing does not last long enough to get a full set of pictures" (Wright 1994, p. 280). Later, in the 1930s, Hale revisited the idea of using a moving-picture attachment in solar observation but apparently was unable to try it out (Wright 1994, p. 426).

2.2 Total Solar Eclipse 1898 January 22

The first known use of film cameras to record an astronomical phenomenon occurred in 1898 in the course of the January 22 total solar eclipse. Joseph Norman Lockyer (1836–1920) led the South Kensington Observatory expedition to Viziadrug (Vijayadurg, India). The expedition had two film cameras, one to register the eclipse and the other the shadow bands. No results were obtained since the films "were too badly fogged to serve any useful purpose" (Lockyer 1898).

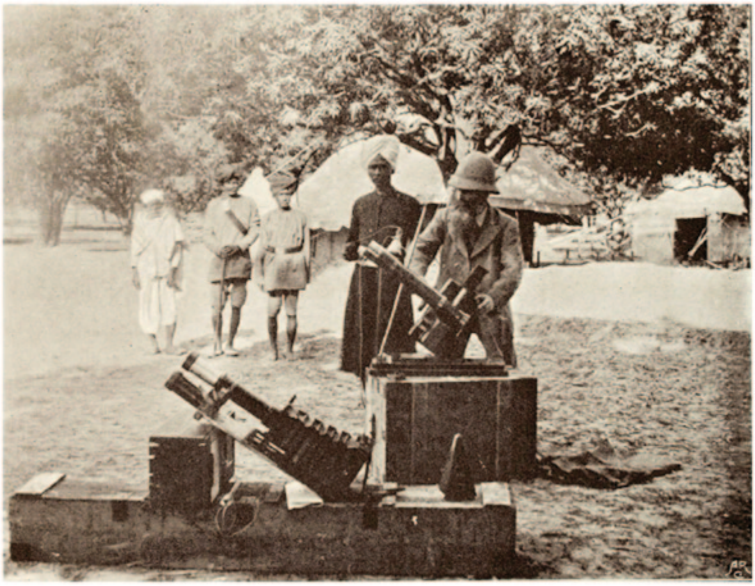

Fig. 1 Bacon at Buxar, India. (Bacon 1907, in front of page 208)

The main eclipse party of the British Astronomical Association (BAA) expedition, led by John Mackenzie Bacon (1846–1904), stood approximately 1500 km away, at Buxar. Bacon planned to study possible coronal variations during the eclipse brief minutes of totality. Following his friend John Nevil Maskelyne's (1863–1924) advice that the "newly invented animatograph might settle the matter" (Bacon 1907, p. 204). Bacon took an "animatograph telescope, specially designed [by Maskelyne] for the expedition" to India (Bacon 1899). During the eclipse Bacon was in charge of the instrument, which worked flawlessly (Fig. 1). That night the 'precious' film was removed from the machine and carefully stowed away to be developed in England (Bacon 1907, p. 210).

Upon receiving the packing-case in London Maskelyne realised that the film box "was empty and the film had disappeared!" (Bacon 1907, p. 214). According to Bacon's daughter "Many theories were promulgated in the press and elsewhere, nor were there wanting ill-natured folk who declared the whole thing a hoax—that there was no film, nor ever had been!" (Bacon 1907, p. 214). An advertisement offering a reward in exchange for information appeared in several journals to no avail (Anonymous 1898).

2.3 Total Solar Eclipse 1900 May 28

For his next eclipse expedition, in 1900, Bacon accompanied by Maskelyne travelled to the United States of America.

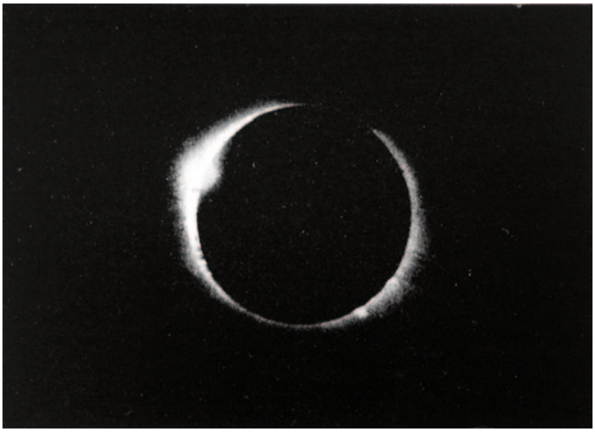

Fig. 2 Photographed at Wadesborough, USA, by Mr. J. N. Maskelyne, with his 3.5 in. kinematograph it shows the 1900 May 18 total solar eclipse second contact. (Maunder and Maunder 1901, in front of page 128)

The expedition started on the wrong foot when it was realised that the "kinematograph telescope" optical part had been left in London (Bacon 1901). Maskelyne being a skilled mechanic managed to improvise a solution and the fine weather on the day of the eclipse at the expedition location, Wadesborough (North Carolina, USA) allowed them to film for

> about 5¾ min, commencing some 25 s before totality, and running for nearly 4 min after totality was ended. In all 1187 exposures were made, 87 before totality, 299 during totality, and 801 after. The corona is seen very definitely on the first exposure, and can be traced right away to number 841, that is to say, to number 455 after the return of sunlight.[1]

A film frame, the earliest from any astronomical film known today, was printed in the BAA 1900 eclipse report (Fig. 2).

Annie (1868–1947) and Edward Maunder (1851–1928) made a positive assessment of the film's "special interest by the way in which it enables us to trace the gradual fading of the corona in the face of the increasing sunlight" (Maunder and Maunder 1901). The film was exhibited both at BAA and Royal Astronomical Society meetings (Anonymous 1900, 1901a). At this last venue Maskelyne pointed out the film's shortcomings due to "unsteadiness of the cinematograph" (Anonymous 1900). Still Edward Ball Knobel (1841–1930), the society president congratulated him

> on the singularity ingenious and interesting exhibition […] It is the first time we have seen anything of the sort, and we are much interested. We shall look forward to the time when Mr. Maskelyne has perfected his instrument, and we may see an eclipse of the Sun without the expense and annoyance of taking such journeys as we have to at present.[2]

The film quality may be better inferred by David Peck Todd's (1855–1939) statement that the first successful eclipse movie was only shot in 1914 despite his awareness of Maskelyne's earlier effort (Todd 1900, 1922).

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[1] Maunder and Maunder 1901, p. 143.

[2] Anonymous 1900, p. 435.

On 28 May 1900 another quite different attempt to record the eclipse was tried by Henry Deslandres (1853–1948).

In the late nineteenth and early twentieth centuries the two 'hottest' solar research topics were the corona and the 'flash spectra' both only observed during a total solar eclipse. The 'flash spectrum' in particular provided information about the vertical structure of the inner solar atmosphere, the chromosphere. Typically the solar spectrum exhibits a series of absorption lines superimposed upon a continuum. Near a total solar eclipse 2nd and 3rd contacts as the Moon covers and uncovers the solar surface, respectively, for a few seconds one may observe the solar atmosphere in the absence of the solar surface and detect the bright chromospheric emission lines. This 'flash spectrum', as it was then known, was first observed by Charles Augustus Young (1834–1908) at the solar eclipse of 22 December 1870 and photographed by William Shackleton (1871–1921) in 1896 (Langley 1871; Anonymous 1911a, 1922; Meadows 1970). Observing from Argamasilla (Spain) the *Bureau des Longitudes* mission led by Deslandres used a mobile chronophotograph lent by Marey to record fast variations in the ultraviolet spectra and in this way complement the longer exposure photographs. The chronophotograph was a late addition to the expedition equipment being brought to Spain by Fallot (?–?), an amateur astronomer, only 4 days prior to the eclipse (Fig. 3).

Four crown prisms placed in front of the chronophotograph allowed the study of the 3500–3800 Å spectral range. The second and third contacts were recorded at six to ten images per second.

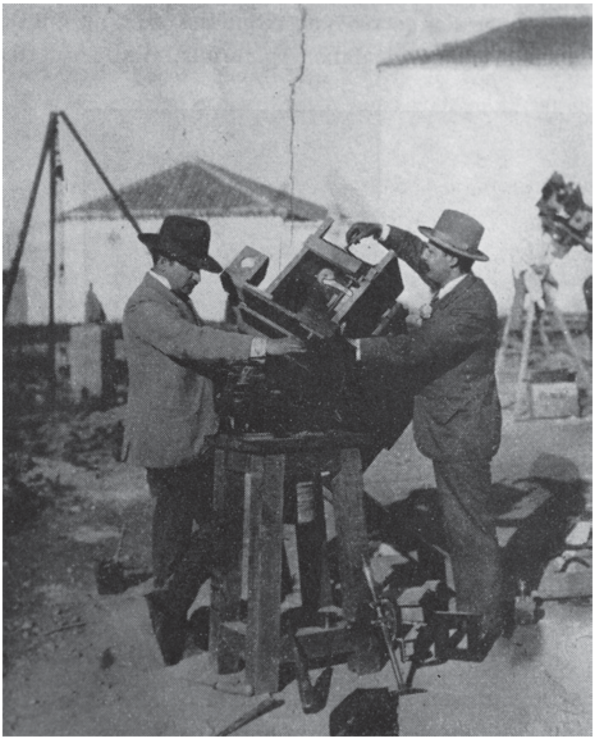

Fig. 3 Marey's chronophotographe used by Deslandres mission. (Leclerc 1956)

The images obtained were in general jumbled or made out of double spectra due to vibrations provoked by the rotation of the motion handle and gears. The experience proved nevertheless, according to Deslandres, the possibility of obtaining a flash spectrum with short exposures and the practicability of recording the spectral changes in a way more complete than had been previously done (Deslandres 1900a, b, 1905).

2.4 Total Solar Eclipses of 1901 May 18 and 1905 August 30

The total eclipse on 18 May 1901 was particularly compelling due to its long duration of approximately six and a half minutes. Maskelyne lent his film camera to Edward Maunder to be used in the BAA's eclipse expedition to Mauritius but unfortunately the "kinematograph gave no result, the film tearing across before totality was reached" (Anonymous 1901b; Maunder 1902).

The next successful film observation was accomplished by the Spanish astronomer, director of the Fabra observatory, Josep Comas Solà (1868–1937) at the 1905 August 30 solar eclipse (Ruiz-Castell 2008, p. 201). At the May 1900 eclipse Comas Solà had obtained two chromospheric spectra photographs (Solà 1900). In 1905, planning to further his studies, he placed a Mailhat prism in front of a Gaumont film camera. In an October communication to the Paris *Académie des Sciences* Comas Solà made a brief reference to the film results—they confirmed the photographic and visual observations. Nevertheless in the same article Comas Solà pointed out that "the spectro-cinematograph process" was a powerful ally of other spectroscopic observations (Solà 1905). One should point out that this article was partially reprinted in the influential journal of the *Société Astronomique de France*, *L'Astronomie*, with all references to the movie observation edited out (Anonymous 1905b).

2.5 Movie Cameras Galore—The Hybrid Solar Eclipse of 1912

A series of eclipses observable either from the ocean or locations of difficult access may explain why the next astronomical motion pictures were only shot during the hybrid solar eclipse of 1912 April 17. The eclipse started as annular in Venezuela crossed Portugal and Spain as total before becoming annular again over the golf of Biscay. It ended in Russia, after crossing France, Belgium, Germany, Latvia and Estonia. According to recent predictions the eclipse totality lasted at best only 2 s (Espenak n.d. a) and consequently against contemporaneous practice the main scientific interest of its observation was astrometrical rather than astrophysical (Lobo 1912a). In 1912 the slightly different eclipse elements used by different calculators led to conflicting predictions. The eclipse could, within the uncertainties, either be annular or hybrid. Mutually exclusive shadow paths upon the Earth's surface were also predicted (Bonifácio et al. 2010 and references therein).

In the day of the eclipse at least ten movie cameras were placed in observing stations from Portugal to Germany. This bounty was a probable consequence of the eclipse characteristics, a favourable shadow path and the films commercial potential.

In 1912 two types of movie observations were performed—visual and spectroscopic. Comas Solà took a "spectro-cinematograph" to Barco de Valdeorras, Galicia (Spain) whereas all the other films were visual. Francisco Miranda da Costa Lobo (1864–1945) placed one movie camera at his main observing station in Ovar (Portugal; Lobo 1912b). Fred Vlès (1885–1944) and Jacques Carvallo (?–?) took two cameras to Cacabelos (Spain) (Carvallo and Vlès 1912). In France an unknown number of movie cameras from Gaumont's film company were located between Trappes and Neauphle in the Paris Polytechnic School observing line set-up by Emmanuel Carvallo (1856–1945) while Aymar de La Baume-Pluvinel (1860–1938) shot the eclipse from Saint-Germain-en-Laye (France) (Carvallo 1912; Baume-Pluvinel 1912b). Father Fernand Willaert (1877–1953) at Namur (Belgium) and the Hamburg observatory expedition positioned at Hagenow (Germany) recorded an annular eclipse (Schorr 1912; Lucas and Willaert 1912). Finally at Lyon Observatory the partially eclipsed Sun was projected onto a screen beside which a chronometer was placed. A film camera recorded them simultaneously at approximately ten images per second (Andrè 1912). Good weather and almost faultless instruments allowed for the successful recording of several films.

As usual in the following months several eclipse observation reports were published. Fred Vlès, Jacques Carvallo and Richard Schorr (1867–1951) used their films to estimate the camera location relatively to the eclipse central line. De la Baume-Pluvinel determined the time of the middle eclipse with a 0.2 s precision from the Baily's Beads assuming equal lunar valley depths on both the East and West sides of the Moon (Baume-Pluvinel 1912b; Carvallo and Vlès 1912; Schorr 1912). Using Lyon's film, Charles Andrè (1842–1912), timed the eclipse first and second contacts with an uncertainty of approximately one second, an improvement upon equivalent visual observations where uncertainties of a few seconds were common (Márquez 1861; Andrè 1912). In his May 30 paper, written in Spanish but published in the *Astronomische Nachrichten* journal, Comas Solà described the spectra in 16 instants in the vicinity of the local eclipse maximum, T. He concluded that the spectral evolution was asymmetrical around T and that the complete spectral inversion—from absorption to emission—of the Calcium H and K lines occurred at $T+2$ s. This indicated, in his opinion, a non-uniform gaseous distribution of the lower solar chromosphere (Solà 1912). One should nevertheless point out that due to the special characteristics of the 1912 April 17 eclipse any observations are highly dependent on the observer's line of sight and Comas Solà was, by his own reckoning, a few kilometres outside the eclipse's narrow shadow path.

From the above summary one quickly realises that, with the possible exception of Comas Solà, no new information was extracted from the eclipse movies. By contrast in a paper read at the Paris *Académie des Sciences* in May 20th Costa Lobo proposed an unforeseen result based solely upon a film analysis. Having realised that the Baily's Beads were not uniformly distributed around the lunar limb (Fig. 4)

Fig. 4 Consecutive frames from Costa Lobo's Ovar film. (Lobo 1912b)

and assuming the observed asymmetry arose from a lunar polar flatness Costa Lobo, proceeded to estimate it in two limiting situations. Initially he proposed a polar flatness in the range [1/1800; 1/600], a value he later revised to [1/1136; 1/380] (Lobo 1912b, c; Bonifácio et al. 2010). This was unexpected since, at the time, the scientific community believed that the Moon was either a sphere or a prolate spheroid with major axis in the Earth-Moon direction. A small article "The Moon is not round: Moving Pictures of the Eclipse Accepted as Proof of This" even appeared on the New York Times newspaper (Anonymous 1912b). In the following weeks several authors supported Costa Lobo's conclusion. Camille Flammarion (1842–1925), for instance, thought that Léon Gaumont's (1864–1946) film, shot in Grand-Croix (France) equally showed "a bigger Moon in the orientation of its movement than in the perpendicular direction" (Flammarion 1912a).

Father Fernand Willaert reported that his annular eclipse film displayed a solar ring thicker at the poles than at the equator. Assuming a circular Sun this implied, in his opinion, a lunar disc slightly flattened at the poles albeit by a lower value than Costa Lobo's, 1/2050 (Lucas and Willaert 1912).

Possibly induced by Costa Lobo's paper Fred Vlès studied the effect produced by different conveniently scaled geometric figures moving in front of each other (two circles and a circle and an ellipse). In mid-September he communicated to the Paris *Académie des Sciences* that the Moon and Sun could not both have circular projections on the sky and that an elliptical Sun provided a better fit to his results. More damaging, we believe, was Flammarion's change of mind. Following his analysis of the eclipse reports sent to him and received by the *Société Astronomique de France,* Flammarion proclaimed that the observed Baily's Beads asymmetry was due to the irregularities of the lunar profile (Flammarion 1912b).

In fact both effects were of the same order of magnitude and no final decision could be made in the absence of new observations (Bonifácio et al. 2010). Costa Lobo himself carefully remarked, "It is evident that other observations are necessary in order to establish definitive values". Unfortunately he also knew that one would be unable to repeat a similar observation before 1927 due to the 1912 eclipse's particular characteristics (Lobo 1912b).

To make matters worse, cinematographic observations although not new had not been discussed in this manner before and the scientific community apparently did not attribute great weight to them. Their perceived value may be judged by how quickly the movie results were forgotten (Bonifácio et al. 2010). The 1913 Royal Astronomical Society report on "Solar Research in 1912" simply mentions that

"Kinematograph records were obtained by some of the French observers" (Anonymous 1913). While at the 1913 Fifth International Union for Co-operation in Solar Research conference the committee for the organization of eclipse observations completely ignored the 1912 films (Anonymous 1914). An unexpected oversight since De la Baume-Pluvinel, the committee secretary, shot one of them and prior to the event believed that "to follow all the eclipse details and the rapid appearance and disappearance of the Baily's Beads we cannot do better than cinematograph the Sun during its maximum phase" (Baume-Pluvinel 1912a).

2.6 After 1912

The fact that several early practitioners, Deslandres, De la Baume-Pluvinel, Lockyer and Maunder did not persevere in their cinema pursuits may hint to the medium inadequacy for astronomical research. Still at least four 1912 April 17 eclipse observers undertook astronomical movies in the following years.

As early as 1911, Nicolae Donici (1874–1956) (also known as Nicolae Donitch) planned to "undertake kinematographic observations of the flocculi and prominences" at his Dubasarii Vechi (Moldova) private observatory (Anonymous 1911b). Curiously Donici's 1912 eclipse station was located at Ovar (Portugal) in the vicinity of Costa Lobo's one. At the 1922 International Astronomical Union (IAU) first general assembly held in Rome, Donici stated that he "was recording changes in the forms, of granules, faculae, and prominences by means of a cinematograph" (Fowler 1922, p. 161).

Fred Vlès had been involved with scientific cinema prior to the 1912 eclipse. In 1909 he co-authored a paper about the kinematics of the segmentation and growth of an urchin's egg observed by micro-cinematography (Chevroton and Vlès 1909). Following his 1912 observation Vlès made various unsuccessful astronomical movies and published the first thematic book on the topic (Vlès 1914). In particular, his plan to cinematograph the 1914 March 12 partial lunar eclipse failed due to cloudy skies. Vlès also tried to use a film camera as a transit instrument attachment, hoping to increase the timing precision of solar meridian passages by simultaneously recording a time stamp on the film via a two-hand chronometer. One chronometer hand ticked each 0.2 s while the other had a continuous motion. In this manner one could measure time fractions of 0.2 s without interpolations. According to Vlès this would "probably greatly improve the precision attained by visual observations, at least those done with a fixed reticule" (Vlès 1914). Despite this positive assessment from 1914 onwards Vlès seems to have abandoned all astronomical pursuits and focused instead on his life sciences research interests.

To observe the next total solar eclipse visible from Europe on 1914 August 21 Costa Lobo devised a new camera with an equatorial mount (Fig. 5). Fully aware that he could not repeat the 1912 observation, Costa Lobo planned to use the movie camera to study any Baily's Beads brightness variability due to the presence of a tenuous lunar atmosphere in the deepest lunar valleys, the likelihood of which, he thought, was shown in his 1912 eclipse film.

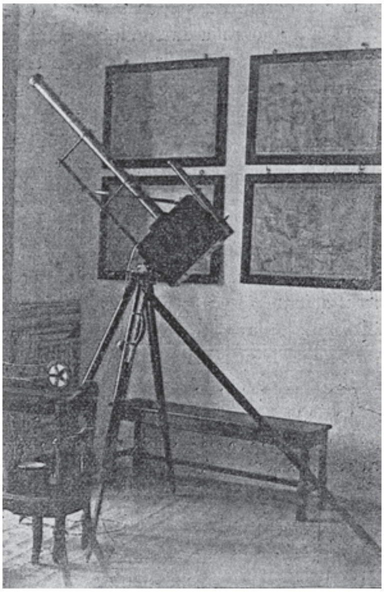

Fig. 5 Costa Lobo's 1914 film camera. (Lobo 1914)

Travelling inland to Feodosia, Crimea (Ukraine, then part of Russia) the Portuguese expedition members were in Berlin in August 1, 1914, the day the German Ambassador to St. Petersburg presented Germany's Declaration of War to Russia. The expedition was cancelled and its members returned home via Switzerland. Costa Lobo observed a partial eclipse at Coimbra University Astronomical Observatory (Lobo 1914). A few years later, in 1927, he had yet another chance to film a solar eclipse. Unfortunately adverse weather conditions at Stonyhurst (Great Britain) impeded the observation of the June 29 total solar eclipse (Anonymous 1927).

The outbreak of the First World War (WWI) thwarted several 1914 eclipse expeditions and disrupted scientific research and international co-operation in the years to come (Todd 1915; Anonymous 1918). In particular the failed Hamburg's (Bergedorf) observatory 1914 expedition to Feodosia is worth mention since movie observations were planned (Anonymous 1916). A cinematographic record was, however, obtained by the Swedish amateur astronomer Nils Viktor Nordenmark (1867–1962) with the aim of determine the eclipse contact times (Rodès 1914). The film shot at Solleftea captured a few hundred "quite perfect pictures of the corona, the coronal ring being clearly caught for several seconds of the partial phase" (Todd 1915).

3 A Limited Choice of Movie Subjects

At this point the reader surely has already realised that the majority of astronomical moving pictures attempts were directed at the Sun (Table 1).

Table 1 Scientific moving picture made between 1898 and 1914

Date	Event	Responsible	Nr	Obs. type	S	Images/s
1898 Jan 22	Total solar eclipse	J. M. Bacon	1	V	?	5–6
		J. N. Lockyer	2	V	Films fogged	
1898 Aug	Sunspot	W. E. Wilson	1	V	×	
1900 May 28	Total solar eclipse	J. N. Maskelyne	1	V	×	~3.4
		H. Deslandres	1	S	*p*	6–10
1901 May 18	Total solar eclipse	E. Maunder	1	V	Film tore up	
1905 Aug 30	Total solar eclipse	J. Comas Solà	1	S	*p*	
1912 Apr 17	Hybrid solar eclipse	J. Comas Solà	1	S	×	
		F. Costa Lobo	1	V	×	560 frames per minute
		F. Vlès and J. Carvallo	1	V	×	15–20
			1	V	p	15
		Léon Gaumont	?	V	×	
			1	V colour	×	
		A. Baume-Pluvinel	1	V	×	13–14
		C. André	1	V	×	
		F. Willaert	1	V	×	14
		R. Schorr	1	V	×	9 frames in 1.2 s
1914?	Solar transit	Fred Vlès	1	V	×	
1914 Mar 12	Lunar total eclipse	Fred Vlès	1	V	Cloudy	
1914 Aug 21	Total solar eclipse	F. da Costa Lobo	1	V	WWI	
		R. Schorr	1	?	WWI	
		N. V. Nordenmark	1	V	×	~6

Meaning of abbreviations: *Nr* number of movie cameras; observation type is either visual, *V*, or spectroscopic, *S*; *S* successful observations are indicated by × while partial ones by *p*, in case of failure reason is presented if known.

The reason behind this 'bias' stems from the lack of suitable objects, as we will show below.

In 1914 a few days prior to the March 12 lunar eclipse, Vlès used a 0.72 m focal length and ten F-number apparatus to register, in an Eastman film, the Moon in less than 0.1 s (Vlès 1914).

Table 2 Exposure times using Vlès 1914 apparatus calculated for two limiting situations: the observation day occurred at first quarter, t_L and full Moon, t_U

Celestial object	t_L (s)	t_U (s)
Sun	4.0×10^{-14}	2.5×10^{-13}
Proeminences and inner corona	0.067	0.37
Moon (quarter)	0.10	0.56
Full Moon	0.018	0.10
Light total lunar eclipse	64	360
Mercury	0.046	0.26
Venus	0.0032	0.018
Mars	0.032	0.18
Jupiter	0.11	0.60
Saturn	0.40	2.25
Brightest star (other than the Sun)	0.00042	0.0023

In Table 2 we used the brightness values provided by Convigton (1999, Appendix A) to estimate the exposure times required to film various celestial objects with Vlès apparatus. Two different situations were considered since the Moon's brightness varies considerably throughout the lunar cycle (Espenak n.d. b). As it is unlikely that Vlès would made a test as early in the lunar cycle as the first quarter, one may regard the exposure times, t_L and t_U, presented in Table 2 as lower and upper limits, respectively (IMCCE n.d.). The brightness of planets is highly dependent on their relative position to both the Sun and the Earth. Values were computed around maximum planetary brightness. One should nevertheless point out that these results do not take into account, for example, atmospheric absorption, film wavelength response and reciprocity failure. As such they may be considered only as a crude estimation.

Not surprisingly one concludes that the Sun, Moon, Baily's Beads, chromosphere, proeminences and, at least, inner corona, are all phenomena bright enough to be captured by Vlès's apparatus. It is clear from Table 2 that early movie cameras could record other solar system planets and the brightest stars at a few frames per second, although no attempt to do so was found in the time period under consideration.

Absent in Table 1 are Venus and Mercury transits movies. This cannot be attributed to any exposure difficulty since in a transit the planet is seen, in silhouette, against the Sun. Following the disappointing 1874 transit of Venus photographic results, visual observations were in 1882 once more preferred by many, namely the British and the French expeditions, i.e., those who had previously used the 'photographic revolver'. In 1882, Janssen himself opted to perform astrophysical rather than astrometric observations (Launay 2008, p. 118). The next transit of Venus occurred only in 2004 well outside the time period under study.

Mercury, on the other hand, transits the Sun more often. Transits occurred in 1878, 1881, 1891, 1894, 1907 and 1914 (Espenak n.d. c). The lack of observations is, in our opinion, related with their perceived unimportance since Mercury transits were unsuitable for astronomical unit determinations.

4 Conclusion

The low film speed was a handicap clearly perceived at the time. For instance, Frederico Oom (1864–1930) sub-director of the Lisbon Astronomical Observatory wrote, in 1900, that

> A great future is undoubtedly foreseen for this new species of solar eclipse photographs as soon as one manages to solve the film sensitivity difficulties.[3]

While 11 years later Colin Bennett wrote in "The Handbook of Kinematography" that

> There would seem to be a considerable field for the application of the motion picture camera to the telescope, especially to the astronomical telescope. […] For this purpose undoubtedly, some system of gearing down the rate of taking to compensate for want of light in the bodies themselves, as also for reasons of economy of film length exposed, would, however, be necessary.[4]

Notwithstanding the small number and limited focus of moving picture attempts cannot be, as shown, simply explained by the low brightness of celestial objects. These are, we believe, a consequence of two other impediments: film frame size and the timescales of many celestial phenomena.

The small solar diameter on film, approximately 6.7 mm with Vlès apparatus, limited the amount of detail that could be extracted from individual frames. Especially taking into account that by the end of the nineteenth century daily solar photographical images were already at least ten times larger (Bonifácio et al. 2007). In another example of the problems created by the small film frames, when Paul Bourgeois (1898–1974) and Jacques Cox (1898–1972) tried to record Mercury's 1927 November 10 transit they realised that the planet's image was too small for its position to be obtained (Stroobant 1927). Mercury's apparent angular diameter at inferior conjunction varies between 10″ and 12″. That is, the Sun to Mercury angular diameter ratio falls in the range 158–196 (Bigourdan 1907). At the 1927 transit Mercury's angular diameter was near its lower value (IMCEE n.d.) and consequently if the Sun's image in the movie had a diameter of 10 mm, then Mercury would appear as a 0.051 mm circle.

On the other hand the long time scales of several celestial phenomena implied that if time-lapse images were required it would be preferable to use an already standard piece of equipment, the photographic camera, with its larger plates despite the difficulties experienced by contemporary astronomical sequential photographers and the slim results obtained (Bonifácio 2011)

It seems that the lack of convenient subjects explains the small number of attempts made and the almost non-existent in-depth analysis of the few movies obtained. An exception occurred in 1912 when at least ten film cameras recorded the April 17 solar eclipse and the first astronomical hypothesis solely based on an astronomical movie was put forward. A scientific discussion of the different film

[3] Oom 1900, p. 71.

[4] Bennett 1911, p. 243.

results ensued in several international journals but despite this visibility they were quickly ignored by the astronomical community. As Table 1 shows, April 1912 also marks the usage peak of movie cameras in a single astronomical observation in the time period studied. The eclipse characteristics and favourable shadow path played a part in the high number of movie cameras used, likely helped by the interest in exploiting the eclipse film's commercial potential. The 1912 interaction between film companies and astronomers still needs to be analysed. In the Portuguese case the company *União Cinematographica Limitada* provided, at least, the manpower and equipment necessary to shoot the Ovar film. In May the eclipse film was exhibited in cinemas in Porto and Lisbon (Anonymous 1912a; Ribeiro 1978). A 1912 eclipse film also became part of Gaumont's educational series known as *L'encyclopédie Gaumont* (Delmeulle 2001).

The fact that astronomical cinema results were forgotten almost as soon as they were obtained clearly reflects their lack of relevance to the scientific community. The 'gap' between early practitioners' claims concerning the possibilities of astronomical cinema and their failure to pursue them also leads us to infer that the technology was not yet ripe for use in an astronomical context.

In a nutshell, in our opinion the lack of suitable movie subjects constituted the Achilles' heel of astronomical cinematography. With the notable exception of solar eclipses there simply weren't many bright fast celestial events of interest.

Technological developments may improve experimental data and/or determine new ideas and open-up new lines of research. Still, as it is known, every new medium 'struggles' to find its place and function against already established ones. While the details of the implementation process are defined by a broad set of conditions, a new scientific tool needs to be more efficient than its predecessors in, at least, a particular useful situation (Pingree and Gitelman 2003). It was precisely this inability to stand out that led to the astronomical moving pictures ultimate fate as a rarely used and indeed seldom useful technique.

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