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MEMOIRS

# Richard Christopher Carrington: Briefly Among the Great Scientists of His Time

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**Abstract** We recount the life and career of Richard Christopher Carrington (1826 – 1875) and explore his pivotal relationship with Astronomer Royal George Biddell Airy. Carrington was the pre-eminent solar astronomer of the 19th century. During a ten year span, he determined the position of the Sun's rotation axis and made the following discoveries: i) the latitude variation of sunspots over the solar cycle, ii) the Sun's differential rotation, and iii) the first solar flare (with Hodgson). Due to the combined effects of family responsibilities, failure to secure a funded position in astronomy (reflecting Airy's influence), and ill health, Carrington's productive period ended when he was at the peak of his powers.

**Abbreviations**

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|---|---|
| CUA | Cambridge University Archives |
| SJL | St. John's College Library, Papers of John Couch Adams |
| TCL | Trinity College Library |
| RGO | Royal Greenwich Observatory |
| RS | Royal Society |
| RAS | Royal Astronomical Society |
| RCC | Carrington |
| GBA | Airy |

## 1. Introduction

Until recently, the bound volumes of the Monthly Notices of the Royal Astronomical Society in the Air Force Research Laboratory (AFRL) library at Hanscom Air Force Base presented an unusual aspect (Figure 1). Small octavo-size bindings are interrupted in the middle of the

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**Figure 1** The Monthly Notices of the Royal Astronomical Society in the AFRL library as they appeared in 2011. The two large quarto-sized volumes beginning in 1859 that interrupt the series of smaller octavo-sized issues provide a fitting metaphor for the remarkable career of the English astronomer Richard Christopher Carrington (1826 – 1875).

19th century by two large quarto-size volumes. These two books contain reports on all the key solar work of Richard Christopher Carrington – work that remains at the heart of active areas of solar physics. The library has since been broken up and scattered, and it turns out that the arrangement in Figure 1 was an anomaly, most likely unique. But the metaphor for Carrington's brief but brilliant career is irresistible. In this look back, we recount Carrington's life and solar contributions and explore the pivotal relationship of his career, that with George Biddell Airy, Astronomer Royal of England from 1835 – 1881.

## 2. Early Years

Carrington was born to Richard and Esther Clarke Carrington in Chelsea, an area of west London, on 26 May 1826.[1] His father was in the brewing business, and later became joint-owner of the large Royal Brentford Brewery. Following early private schooling and pre-college training, Carrington entered Trinity College at Cambridge in 1844, intended by his father for holy orders. But, as Carrington (1857, p. 3) later wrote, "the tenour of my mathematical studies at the University of Cambridge, acting on mechanical propensities to which I had always been addicted, gradually made it clear to me that I was more naturally adapted for the pursuit of some physical science involving imagination and mechanical ingenuity . . ." Carrington was inspired by James Challis, Plumian Professor of Astronomy and the Director of Cambridge Observatory, to take up astronomical studies. He graduated in 1847 with the rank of 36th "wrangler" in the mathematical Tripos examination.[2] While not a coveted "high wrangler" position, Carrington's result placed him 36th of 277 on the Honor's List. Upon graduating, Carrington sought Challis's help in securing a position in "practi-

[1]For biographical details on Carrington, see Anonymous (1876), Clerke (1917), and Lindop (1993, 1997, 2004). Unfortunately, no picture of Carrington has been found, although there is a record of one being taken (RGO 6/378, 238; January 1857) and several investigators have searched for a photograph (*e.g.*, Eather, 1980, p. 81; Lindop, 1993, p. 95).

[2]Isaac Todhunter was First Wrangler out of 38 (CUA Exam.L.5, p. 23; List of Honors, 29 January 1848). Todhunter was a mathematician who later in life wrote a biography of William Whewell. With Carrington as one of his sponsors, Todhunter became a Fellow of the Royal Society in 1862.

cal astronomy" and eventually received an appointment as Observer at the University of Durham Observatory under the Reverend Temple Chevallier.[3]

Carrington remained at Durham from October 1849 to March 1852. While there, he determined the exact longitude of the Observatory, distinguished himself as an observer of minor planets and comets, and observed the solar eclipse of 28 July 1851 from Lilla Edet in Sweden (Carrington, 1851, 1855b). In early recognition of his skill and industry, he was elected a Fellow of the Royal Astronomical Society (RAS) in 1851. In that same year, Carrington, displeased with the instrumentation at Durham and disenchanted with Chevallier's "nearly nominal" Directorship, proposed to the Syndicate responsible for the Observatory that he be appointed Practical Astronomer accountable only to them and offered a loan of £1000 (∼$110 000 today)[4] to the University for new instrumentation (Hutchins, 2008, pp. 147 – 148, and references therein). Carrington met with the curators in November 1851 and although his proposal was initially favorably received, "in the course of three weeks, some adverse influences prevailed, and when we met next, about December 16, there was so much bitterness and opposition, and such shabby proposals made to me, that I resigned on the 17th."

In 1900, Ralph Sampson, Chevallier's successor at Durham, writing with full hindsight, described Carrington's tour there as the highpoint in the history of the Observatory up to that time (Sampson, 1907; Wolfendale, 1992) and commented, "If [Carrington] had been retained, we should have had, I do not doubt, an Observatory at Durham that would have ranked with the well known observatories of the world."[5]

## 3. Redhill Years

In his correspondence with the Durham Observatory curators, Carrington had written (Lindop, 1993, p. 11), "My private position [of independent wealth] renders me unwilling to fill a subordinate position . . . although I chose so to place myself for a time on coming here" – "with (as he added elsewhere (Carrington, 1857, p. iii)) the object of acquiring experience, and of avoiding wasteful and injudicious expense." Thus, upon leaving Durham, with £5000 (∼$550 000) borrowed from his father (Lindop, 2004), he built and equipped his own observatory, selecting a leasehold plot south of London at Redhill near Reigate in Surrey in June 1852.

### 3.1. Redhill Catalogue of Circumpolar Stars

Carrington (1854a) took as his primary task that of following Bessel and Argelander and completing the catalogue of northern stars from 81° to the pole, down to 10th magnitude. The circumpolar star observing project began in 1854 and the results were published in 1857

[3] RCC to Challis: CUA Obsy G.1 xix, 3 (5 February 1849), 5 (8 February 1849), 6 (1 May 1849), 18 (8 May 1849), and 30 (15 August 1849).

[4] A multiplicative factor of 110 is used throughout this paper to calculate the purchasing power of a given number of British pounds ca. 1860 in current US dollars (http://www.measuringworth.com/). Thus 1£ in 1860 had the same purchasing power as $110 today.

[5] Chevallier, with foresight, wrote to Challis on 17 January 1852 (CUA Obsy. G.1 xxii, 4), "Mr. Carrington, much to our regret, is about to leave Durham. One of our regulations . . . is that the Observer is to be unmarried: and Mr. Carrington is likely soon to marry [this did not happen]. He is also desirous of having a very first rate equatorial; and we have no plans to make such a purchase. He proposes to have some instruments of his own: and if his health is spared, I think he will be a leading astronomer."

by the Admiralty at public expense under the full title "*A Catalogue of 3735 Circumpolar Stars Observed at Redhill in the Years 1854, 1855, and 1856 and Reduced to Mean Positions for 1855.0*."

Carrington was awarded the RAS Gold Medal for the Redhill Catalogue in 1859. In the Medal presentation, Robert Main (1859) said that the judgment of Carrington's work rested on "its utility, and the excellence of its performance." Regarding the first, he noted that Carrington's work addressed the last zone of the northern heavens to be charted, adding "The polar zone is as important as any of the others, but it is by far the most troublesome and difficult, and it requires far more resources, both instrumental and intellectual, than any of the other zones." Carrington tackled these difficulties with "positive zest" and carried out the task with "honesty of purpose, unwearied industry, and consummate skill." The Catalogue included an "instructive dissertation on the whole theory of precession, nutation, and aberration, and especially on the application of it in the case of stars very near the pole."

In the Concluding Remarks of the Catalogue, Carrington (1857, p. 33), confessed to "having intentionally been too detailed in my explanation [of the observing and analysis procedures] rather than too brief. It is to be remembered that the account here given is addressed principally to a future astronomer who may in a far distant year repeat the examination of the star-positions of this region, when the particulars here supplied may be his only source of information on points which may then have an importance not now forseen …" He added, "I have also hoped that at the same time I might thus remedy the want of prestige and authority commonly attached to the results of a private observatory."

## 3.2. Solar Studies

For a "second subject" of study at Redhill, Carrington turned his attention to sunspots. He was motivated by the discovery of the sunspot cycle by Schwabe (1844), which had been brought to the world's attention in 1851 by von Humboldt in his third volume of *Kosmos*. Carrington was also inspired by the discovery, made independently by Sabine (1852) and Wolf (1852), that geomagnetic activity tracked the sunspot variation. Carrington (1863, p. 2) noted "that while the observation of stars for my intended Catalogue required the hours of the night and afforded little matter for speculation, the observation of the Sun … presented more variety and interest."

Despite the award of the Gold Medal for the Redhill Catalogue, it is primarily the solar work carried out at Redhill for which Carrington is remembered. Here, as with the circumpolar stars, his work benefited from clarity of purpose. He narrowly restricted the scope of the study (Clerke, 1894, p. 145). In his own words (Carrington, 1863, p. 2),

> I did not propose to myself "Solar Physics" in their entirety … the subject before my mind reduced pretty much to tracing regularity in the distribution of the maculae [sunspots], detecting the true Period of Rotation of the Body of the Sun, and the determination of the systematic movements or currents of the surface, if such existed in any definable manner. To carry out the plan it was in the first place necessary … to lay altogether new foundations of method in recording, reducing, comparing, and discussing, for I unhesitatingly say that no observer would for any length of time have followed out any of the modes of observation previously practiced.

### *3.2.1. Solar Observing Plan and Technique*

In his monumental "*Observations of the Spots on the Sun from November 9, 1853, to March 24, 1861, Made at Redhill*" [hereafter, "Spots on the Sun"],[6] Carrington (1863, pp. 8 – 9) recalled the requirements that any method to carry out his observing plan must meet:

i) All spots visible with the telescope, big and small, to be drawn and their positions determined.
ii) For speed (in consideration of the local climate), no adjustments of the telescope to be made during determinations of spot positions.
iii) Observations must be made quickly and uniformly, and be intelligible and easily reducible later.
iv) Observations must be highly accurate for the results to justify the great labor involved.
v) Observations should involve an ordinary telescope with no special appliances.

In a passage that captures the essence of any research project, Carrington wrote:

> I may not state the whole, for considerations of this kind are of the nature of prophecy after the event, and do not occur at the time in so orderly a form. One method is thought of and tried, and found to have objections of one sort, and then another, and another, till the observer finds he is satisfied, and cannot further improve on himself. The method I pursued [which first presented itself on 11 October 1853 "whilst out walking at Redhill"; Carrington, 1874a] did not occur at once in its final form, but grew out of a somewhat rude notion of making the disk of the Sun its own circular micrometer, and the process of reduction was successively improved, and more than one volume commenced and put in the fire, as means of shortening and simplifying the process came into view by practice and trial.

Carrington's illustration of his observing technique is given in Figure 2. As Carrington noted, the projection method that he used (shown in (a)) dated to the earliest sunspot observations. It had been employed by Scheiner and was illustrated in *Rosa Ursina*. Carrington's telescope, an equatorial made by Simms, had a 4.5 inch aperture and a 52 inch focal length and a large and flat field since it had been built for comet searching. Carrington wrote, "In the focus of the telescope, however, I placed two bars of flattened gold wire, at right angles to each other (very nearly),[7] and turned *approximately* into the position of being inclined 45 degrees on each side of a meridian, or parallel of declination." The fact that the bars did not have to be exactly placed was key ("the feature of principal importance") because no preliminary adjustment was needed and the telescope could be used at a moment's notice. The telescope declination was held by a rod connecting the eye end and the base of the polar axis while the right ascension was maintained by an ordinary clamp. A large collar was placed around the object glass to keep the projection screen shaded.

[6]Lindop (1993, p. 68) describes "Spots on the Sun" as "large and heavy – of an inconvenient size and weighing nearly 3-kilograms – ... the bulk of it consists of 166 full-page plates illustrating the spots and their behavior." Publication was aided by a grant of public funds from the Royal Society.

[7]Maunder (1921) writes that the lines should intersect at "exactly" right angles (see also Carrington, 1854b). Maunder also noted that "the optical axis of the telescope should be perpendicular to the plane of the [projection] screen, and should meet it at the point of intersection of the cross-lines."

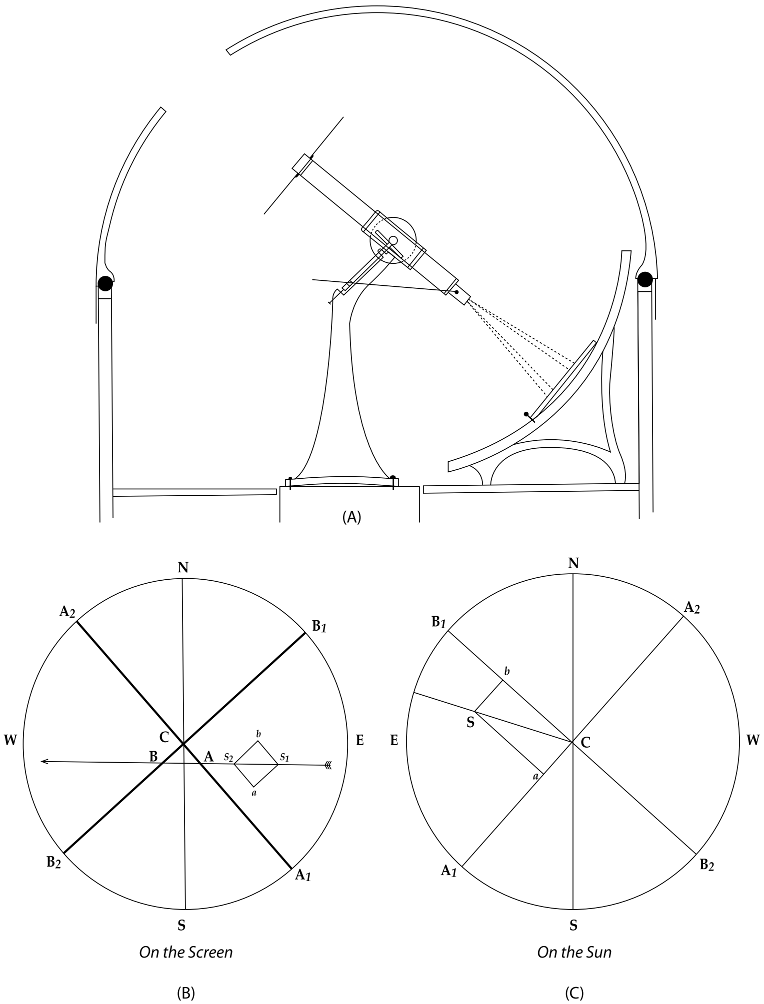


**Figure 2** Drawings taken from "Spots on the Sun" (Carrington, 1863) showing (a) the equatorial telescope with the Sun shade attached near the front of the telescope, the rod from the eye end of the telescope to the base of the polar axis to maintain the declination, the right ascension clamp, and the projection screen. First the sunspots were traced on the projection screen as the telescope (and the screen with it) was driven to track the Sun as it moved across the sky. Then telescope was driven ahead of the Sun and the drive turned off allowing the image of the Sun to drift through the projected field of view (b). As it did so, the times that the Sun's limbs and the position of the spot (S) in (c) crossed lines A1–A2 and B1–B2 were recorded. In this way, the Sun became its own measuring stick and straightforward, if computationally dense, trigonometry specified the position of the spot on the disk. The field of view of the telescope (b) was approximately four times the diameter of the Sun's image (c).

The first step in the observing procedure was to draw each spot or group to scale and mark the "particular nuclei or points of nuclei selected for observation" (Figure 2(c)). Then the Sun was allowed to drift through the telescope field of view – and its projected image across the screen (Figure 2(b)) – and the times, in succession, when the leading limb of the Sun, the spot group (designated nuclei or points of nuclei), and the trailing limb made contact with the two stationary cross wires were recorded to a tenth of a second.[8] Once a set of measurements was taken, the telescope was swung in right ascension ahead of the Sun and clamped and the process was repeated twice more. Measurements of up to five or six spot groups could be taken in a single pass. Since each observing pass took approximately four minutes, the entire process, exclusive of preparation, drawing, and putting away, could be completed in about 12 minutes. As Lindop (1993, p. 62) noted, "Carrington was understandably proud of the simplicity of the method; there was no clockwork movement of the telescope or screen [other than for the sunspot tracing] and the only observations were of the [contact] times ... If the method of observing was simple, the reduction of the measurements was not, and this may be why none of his contemporaries working on sunspots followed his example."

Detailed descriptions of the technique of obtaining the sunspot positions, which involved the "kind of rather arid geometrical exercise in which Carrington seemed to revel" (Lindop, 1993, p. 64) can be found in Carrington (1854b, 1855a, 1863), Maunder (1921), and Teague (1996). Maunder compared positions of sunspots obtained by Carrington's method during the solar eclipse of July 1919 with those obtained photographically and demonstrated that the transit method was capable of yielding comparable results (to within a tenth of a degree in heliolongitude), "provided the instrument is stable, the observer practiced, and a sufficient number of transits secured to eliminate accidental errors in noting the times of contact." Newton (1958, pp. 37 – 38) concurred with this assessment, and Teague noted that modern computing techniques have taken the drudgery out of the method.

### *3.2.2. The Elements of the Sun's Axis of Rotation*

The initial positions of the spots on the disk (sunspot longitude ($\alpha$) and North Polar Distance (NPD)) were based on assumed elements for the position of the Sun's rotation axis: i) the inclination angle ($I$) of the Sun's equator to the ecliptic plane, and ii) the longitude of the ascending node ($N$), which defines the line along which the Sun's equator intersects the ecliptic plane. Incorrect values of these elements would affect the latitude (NPD) determination, in particular, so the true elements of the axis (and the spot positions) needed to be determined by an iterative process. In addition, since Carrington's goal was to determine whether the "spots moved independently of the assumed surface of the Sun and of each other" (Lindop, 1993, p. 73), he needed to assume a mean solar rotation rate or period against which such motion could be detected. For the elements of the Sun's axis, Carrington assumed values ($I' = 7°10'$; $N' = 74°30'$; for 1854) based primarily on elements previously determined by Laugier (1842; 7°9′; 75°8′; for 1840). Similarly, his working value of the Sun's mean rotation period (25.38 days) was close to that of Laugier (1842; 25.34 days). Today, solar rotation periods are numbered from 9 November 1853 when Carrington established a prime meridian (0° longitude) on the Sun.

Carrington (1863, p. 233) precisely defined the problem he faced: "To find the position of the Pole which shall best reduce these motions [of the spots across the disk] to parallelism, and, if any systematic drift towards either pole shall be found, to symmetry with respect to the concluded Equator." To do so, he assumed that the working elements of the pole ($I'$, $N'$) were in error, *i.e.*, differed by "$\Delta I$" and "$\Delta N$" from those of the true pole ($I$, $N$), and calculated $\Delta I$ and $\Delta N$ by setting up equations for the errors in the North Polar Distance in terms of the measured coordinates for a given spot group for each day that it appeared on the

[8]Despite the importance of the clock and its accuracy for his measurements, Carrington does not discuss it in "Spots on the Sun." Because of the 0.1 second precision of the observations, Lindop (1993, pp. 25 – 26) suggests that an automated method, such as reported by Carrington (1861), was employed.

disk. He then subtracted consecutive pairs of equations to eliminate the true NPD and solved the resulting series of simultaneous equations by the method of least squares to obtain $\Delta I$ and $\Delta N$ from the measured coordinates.[9] He thus obtained

$$I = 7°15' \quad \text{and} \quad N = 73°40' \quad \text{(for epoch 1850)} \tag{1}$$

for the true coordinates of the pole. In his final determination, Carrington (1863, p. 226) used only 86 spot groups of the 954 groups he observed by taking the precaution of "rejecting as unsuitable ... spots of abnormal form, changing figure, or the components of groups. ... If single dots ... without penumbra, were frequent and of sufficient duration, they would be still preferable as offering more definitive centers for observation, but these objects rarely remain visible for more than two or three days; and the same consideration induces one to include some normal spots of a larger size than a fastidious choice would approve, because they have the advantage of greater permanence over the very small ones."

In "Spots on the Sun," Carrington (p. 245) proposed the above elements for future adoption "till clearly superseded by the superior means and length of observation of some succeeding Astronomer, who can devote more than eight years of continuous research to the subject, and take advantage of finer skies, and I hope Photography. I believe I shall not be far wrong in saying that a sensible improvement on the above values will not be obtainable at an expenditure of less than five thousand pounds [∼$550 000]." Carrington's elements remained the standard for 50 years. They were not updated until 1913 when Dyson and Maunder (1912, 1913) gave the following corrected elements based on 39 years of photographic observations at Greenwich:

$$I = 7°10.5' \quad \text{and} \quad N = 73°46.8' \quad \text{(for epoch 1850).} \tag{2}$$

The most recent determination of the "Carrington elements" (Beck and Giles, 2005), based on analysis of Dopplergrams taken by the Michelson Doppler Imager (Scherrer *et al.*, 1995) on the Solar and Heliospheric Observatory

$$I = 7.155° \pm 0.002° \quad \text{and} \quad N = 73.5° \pm 0.1° \quad \text{(for epoch 1850)} \tag{3}$$

lie within the minimum estimated errors of Carrington's determination (Figure 3). The errors for Carrington's elements as determined by Stark and Wöhl (1981) ranged from $\pm 0.11°$ up to $\pm 0.44°$ for $I$ ($i$ in Figure 3) and from 0.32° up to 3.41° for $N$ ($\Omega$ in Figure 3). Like that of Beck and Giles, the bulk of other recent (post-1978; H-M) determinations intersect Carrington's error circle, with a preference for the lower end of the range in $i$.

### *3.2.3. Latitude Variation of Sunspot Formation over a Solar Cycle*

Carrington (1859a) referred to his discovery of the latitude variation of sunspots over the solar cycle, as "another and instructive instance of the regular irregularity and irregular regularity which, in the present state of our knowledge, appear to characterize the solar phenomena." He reported that – in apparent contradiction of the dictum *Natura non agit per saltum* (Nature makes no leaps) – sunspot formation jumped discontinuously from low latitudes ($< 20°$ in both hemispheres) before the solar minimum in February 1856 to mainly high latitudes (between 20° and 40°) shortly thereafter. He added that "at the present time" (late 1858), the high-latitude bands of spots tended to be "contracting" toward the equator.

[9] Carrington's (1863, pp. 232 – 244) procedure for calculating $\Delta N$ and $\Delta I$ is outlined in Lindop (1993, pp. 77 – 78).

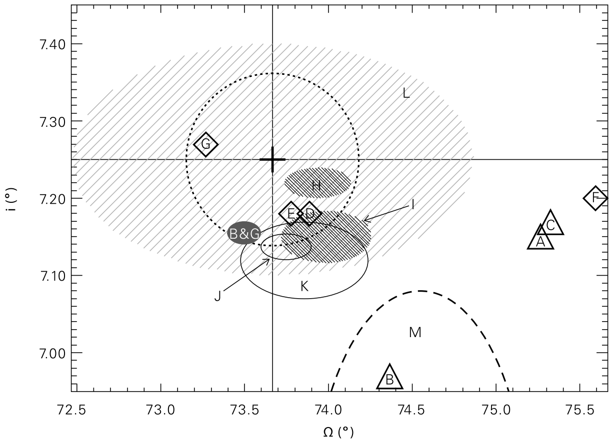


**Figure 3** Various determinations of the elements of the Sun's rotation axis: $i =$ the angle between the Sun's equator and the ecliptic plane and $\Omega =$ the right ascension of the ascending node [from Beck and Giles, 2005; reproduced by permission of the AAS]. The plus sign shows Carrington's determination with the dotted circle giving an estimate (from Stark and Wöhl, 1981) of the minimum uncertainty in his measurement. Other determinations: A = Laugier (1842); B = Spoerer (1866; see Wöhl, 1978); C = Wilsing (1882; see Wöhl, 1978); (D) Dyson and Maunder (1912); E = Dyson and Maunder (1913); F = Epstein (1916); G = Epstein (1917); H = Clark *et al.* (1979; I = Stark and Wöhl (1981); J = Balthasar *et al.* (1986); K = Balthasar, Stark, and Wöhl (1987); L = LaBonte (1981); M = Wöhl (1978); and B&G = Beck and Giles (2005). All determinations are for epoch 1850.0.

Carrington's result was substantiated and codified as Spoerer's "law of zones" (Clerke, 1894, pp. 148 – 149), and the fold-out plot accompanying Carrington's Monthly Notices paper can be considered an early version of Maunder's (1904) butterfly diagram.

### *3.2.4. Solar Differential Rotation*

Carrington's second major discovery followed from his objective of determining whether the sunspots exhibited motion relative to each other or to the solar surface. By the end of 1858, following the procedure outlined above, he had determined that the Sun did not rotate as a solid body. He demonstrated this simply and effectively with an illustration (Figure 4; adapted from Carrington, 1859b) that showed that the low-latitude sunspots before the 1856 minimum had a faster rotation rate than the $14°11'$ day$^{-1}$ corresponding to the assumed sidereal rotation period of 25.38 days, while the high-latitude spots observed after minimum had a rate slower than $14°11'$ day$^{-1}$. By 1862, Carrington had cast this as a "law" of the form:

$$\text{Daily Rotation Rate } (\lambda) = 14°25' - 165' \sin^{7/4} \lambda, \tag{4}$$

where $\lambda =$ heliographic latitude. Thus at the equator, the daily solar rotation rate is $14°25'$ while at $\lambda = \pm 30°$, the rate is $13°36'$. Carrington's assumed approximate (sidereal) solar rotation period of 25.38 days (27.275 days as viewed from Earth), originally selected in part "from its admitting conveniently of much subdivision without remainders" (Carrington, 1863, p. 16), only applies for $\lambda \approx 14°$ (based on (4)). It remains the adopted nominal solar rotation period and applies for $\lambda \approx 17°$ using the modern equivalent of (4) from Cox (2000, p. 362).

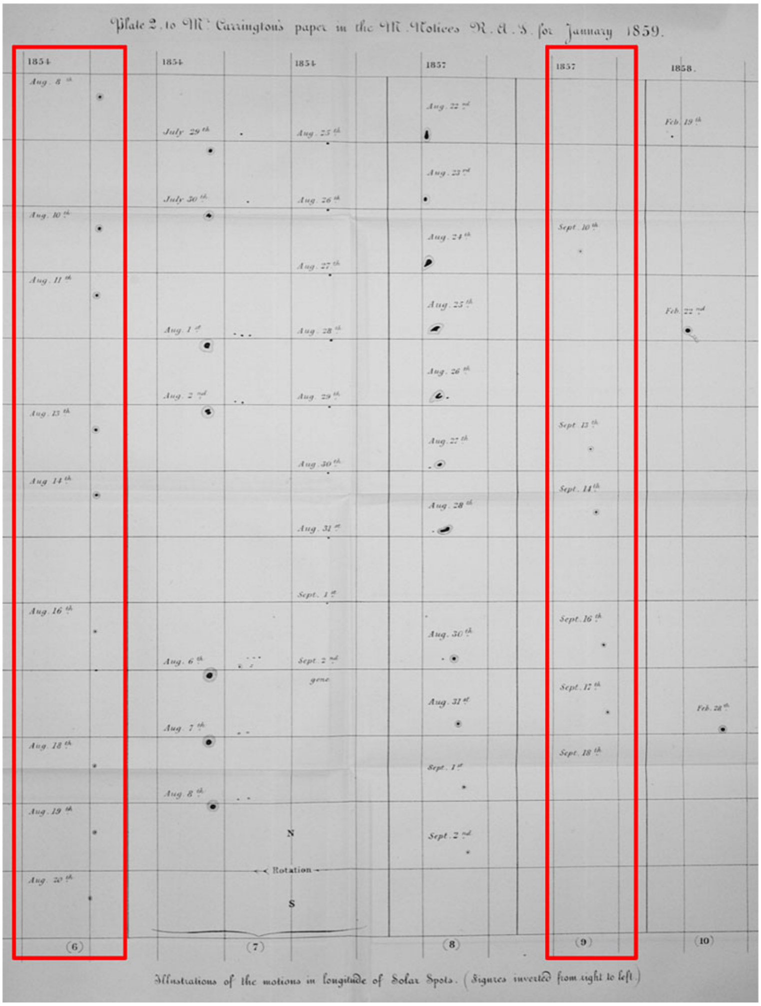


**Figure 4** Carrington's (1859b) figure to demonstrate the Sun's differential rotation. Each column represents a series of daily sunspot observations, with time progressing downward on the figure. The low-latitude sunspot in series (6) in 1854 [in the left red rectangle] drifts to the left over time relative to a fixed meridian (the vertical line to the left of the spots), while the higher latitude spot (series 9, right red rectangle) in 1857, after solar minimum, drifts to the right. The Sun's direction of rotation is to the left in all cases; thus the Sun's rotation rate is higher at lower latitudes. This preliminary result reported near the end of 1858 was presented as a "law" in "Spots on the Sun" in 1863.

In the same year of Carrington's paper on the Sun's differential rotation, as it is now called, Kirchhoff (1859) published his epochal result on solar spectral analysis which marked the birth of astrophysics. Together these two developments would dislodge William Herschel's surprisingly resilient view of the Sun as a cool, dark, solid body with a luminous atmosphere (Clerke, 1894, pp. 54 – 58, 149 – 151). Quoting from Cliver (2005),

> Kirchhoff's interpretation of the dark Fraunhofer lines in the solar spectrum indicated that the internal mass of the Sun must be hotter than the overlying atmosphere in which the absorption lines were formed, while "the extreme internal mobility be-

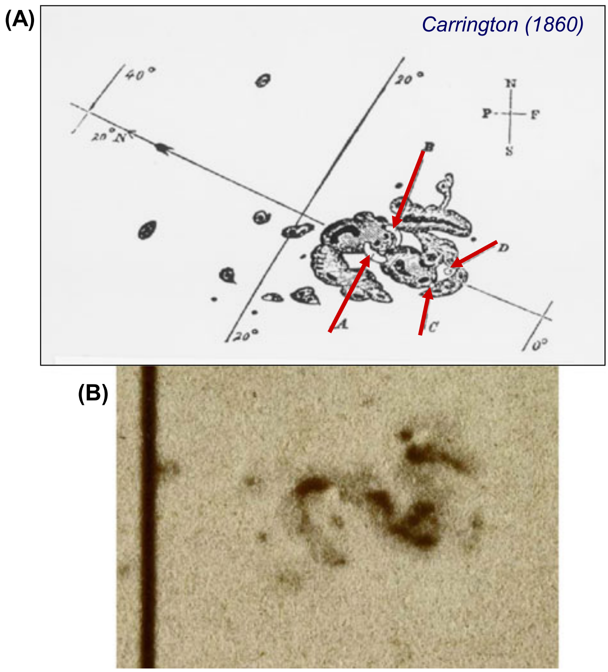


**Figure 5** (A) Carrington's (1860) carefully executed drawing of his sunspot group 520 on 1 September 1859, the first visual record of a solar flare. The initial (A and B) and final (C and D) positions of the white-light emission are indicated. Solar east is to the right. (B) Enlargement of region 520 from an early solar photograph made at Kew Observatory by Warren De Rue on 31 August 1859. [The enlarged portion of RGO 67/266 in (B) is reproduced by kind permission of the Syndics of Cambridge University Library.]

trayed by Carrington's and Spoerer's observations led to the inference that the matter composing the Sun was mainly or wholly gaseous" (Clerke, 1894, p. 151). Agnes Clerke,[10] the authoritative chronicler of nineteenth-century astronomy, reckoned that Carrington's finding that the Sun did not rotate as a solid body may have been more effective than the results of spectrum analysis in serving to "revolutionize ideas on solar physics" (Clerke, 1917).

### *3.2.5. First Observation of a Solar Flare and Its Possible Relationship to Terrestrial Effects*

On 1 September 1859, Carrington (1860) and Hodgson (1860) made the first observation of a solar flare. Carrington's account of the discovery follows:

> While engaged in the forenoon of Thursday, September 1, in taking my customary observation of the form and positions of the solar spots, an appearance was witnessed which I believe to be exceedingly rare. The image of the Sun's disk was, as usual with me, projected on a plate of glass with distemper of a pale straw color, and at a distance and under a power which presented a picture of about 11 inches diameter. I had secured diagrams of all the groups and detached spots ... when within the area of the great north group (the size of which had previously excited general remark), two patches of intensely white and bright light broke out, in the positions indicated in the appended diagram [Figure 5(a)] by the letters A and B, and of the forms of the spaces left white. My first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object-glass, by which the general

[10]For an appreciation of Clerke, see Cliver (2007).

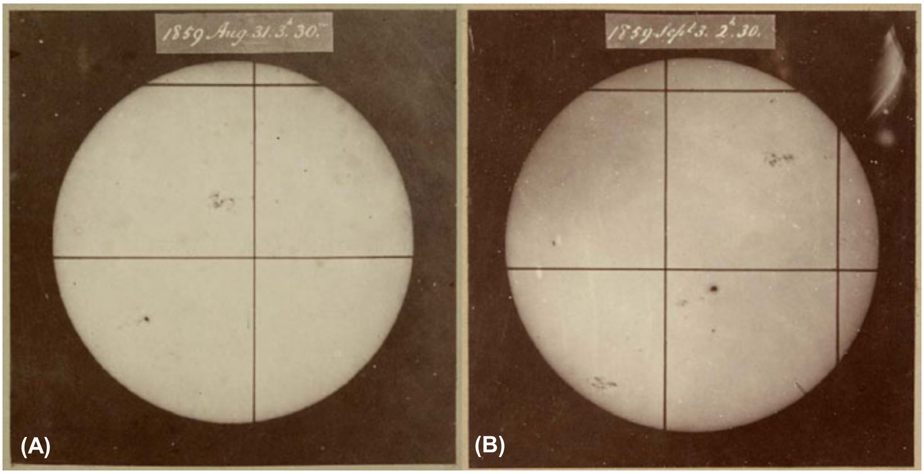


**Figure 6** Images of the Sun on (A) 31 August 1859 and (B) 3 September 1859, showing the great active region (slightly above disk center in (A)) associated with the first recorded solar flare and the first solar-terrestrial event (for which the solar disturbance was observed). Unfortunately, no corresponding photograph was taken on 1 September 1859 (Hodgson, 1860). [RGO 67/266 (A) and RGO 67/267 (B) reproduced by kind permission of the Syndics of Cambridge University Library.]

> image is thrown into shade, for the brilliancy was fully equal to that of direct sunlight; but, by … causing the image to move by turning the R.A. handle, I saw I was an unprepared witness of a very different affair. I thereupon noted down the time by the chronometer, and seeing the outburst to be very rapidly on the increase, and being somewhat flurried by the surprise, I hastily ran to call some one to witness the exhibition with me, and on returning within 60 s, was mortified to find that it was already much changed and enfeebled. Very shortly afterwards the last trace was gone, and although I maintained a strict watch for nearly an hour, no recurrence took place. The last traces were at C and D, the patches having traveled considerably from their first position and vanishing as two rapidly fading dots of white light. The instant of the first outburst was not 15 s different from $11^{h}$ $18^{m}$ Greenwich mean time, and $11^{h}$ $23^{m}$ min was taken for the time of disappearance.

Hodgson's (1860) description of the "very brilliant star of light" that he observed on the Sun lacks the specificity of Carrington's account. Hodgson, who was observing from Highgate, north of London, refers to an "eye-sketch" he made of the "curious appearance" but it does not accompany the paper; a footnote refers to this as a "well-executed" diagram that "excited much interest" at the 11 November 1859 meeting of the RAS. Hodgson does mention a photograph of the Sun taken at Kew on 31 August (none was taken on 1 September). Fortunately, prints of this photograph and several others of the Sun's disk made at Kew in late August and early September 1859 (Figure 6) have been preserved in the Royal Greenwich Observatory archives in the Cambridge University Library.[11] Figure 5(b) shows a (left-right reversed) enlargement of the great active region (No. 520 in Carrington's (1863)

[11] RGO 67/262 (28 August), RGO 67/263-265 (29 August), RGO 67/266 (31 August), RGO 67/267-270 (3 September).

list of spot groups) as it appeared on 31 August, for comparison with Carrington's sketch in Figure 5(a) from 1 September.

Carrington's reaction to his observation bears repeating for its prescience. "It was impossible, on first witnessing an appearance so similar to a sudden conflagration, not to expect a considerable ... alteration of the details of the group in which it occurred; and I was certainly surprised, on referring to the sketch which I had carefully ... (and ... fortunately) finished before the occurrence, at finding myself unable to recognize any change whatever as having taken place." Not until the current century was it possible to detect permanent changes in active regions of the type that Carrington expected to accompany the solar disturbance he observed (Wang *et al.*, 2002). While Carrington's impression that the phenomenon he observed "took place at an elevation considerably above the general surface of the Sun" does not apply to the white-light emission of flares that he and Hodgson observed for the 1859 event, his inclination to look above the photosphere for the source of the sudden disturbance is in keeping with current flare models (*e.g.*, Forbes, 2000).

Both Carrington and Hodgson noticed that the Kew magnetometer traces were disturbed at the time of the flare and a parenthetical addendum to Carrington's account also notes the outbreak of a great geomagnetic storm "towards four hours after midnight" on 2 September "which subsequent accounts establish to have been as considerable in the southern as the northern hemisphere." The footnote also states that "While the contemporary occurrence [of solar activity and geomagnetic disturbance] may deserve noting, [Carrington] would not have it supposed that he even leans toward hastily connecting them. 'One swallow does not make a summer.' " Nearly eighty years would pass before Bartels (1937) was able to provide a complete description of the 1859 event. Bartels identified the smaller magnetic disturbance that was simultaneous with the flare as a type of sudden ionospheric disturbance (called a geomagnetic crochet or solar flare effect (SFE)) due to flare ultra-violet ionizing-radiation (Figure 7(a)) and attributed the great geomagnetic storm (Figure 7(b)) and aurora (Figure 8) that followed $\sim$17 hours later to "solar corpuscles", *i.e.*, a coronal mass ejection.

Recently, with increased interest in space weather, the 1859 flare and its associated geomagnetic storm have gained renewed attention (*e.g.*, Tsurutani *et al.*, 2003; Clauer and Siscoe, 2006; Odenwald and Green, 2008). By remarkable coincidence, it appears that the first flare ever reported was associated with arguably the largest solar-terrestrial event yet recorded (Tsurutani *et al.*, 2003; Cliver and Svalgaard, 2004). Since other white-light flares have been observed by methods similar to that used by Carrington (*e.g.*, Angle, 1961), this need not have been the case (Cliver, 2006). A comparison of the SFE for the 1859 flare with those for recent large flares indicates that the 1 September 1859 event "conservatively" had a soft X-ray classification of $>$X10 (intensity $> 10^{-3}\ \mathrm{W\,m^{-2}}$; Cliver and Svalgaard, 2004). Recently, a more detailed analysis by Clarke *et al.* (2010) indicates a classification of $\sim$X40. Such a magnitude would make the Carrington flare comparable in size to the limb event (S19W83) of 4 November 2003, the largest soft X-ray flare observed during the space age [the GOES 1 – 8 Å detector saturated at X18], with estimates ranging from $\sim$X30 to $\sim$X45 (Thomsen, Rodger, and Dowden, 2004; Kiplinger and Garcia, 2004).

### 3.3. Leaving Redhill

Carrington observed the Sun regularly from Redhill until 24 March 1861, ending his patrol well short of the full cycle he had anticipated (Carrington, 1863, p. 2). In taking up his study of sunspots in 1853, he had surmised that the emerging technique of solar photography promoted by John Herschel and others would not soon be brought to application, and that

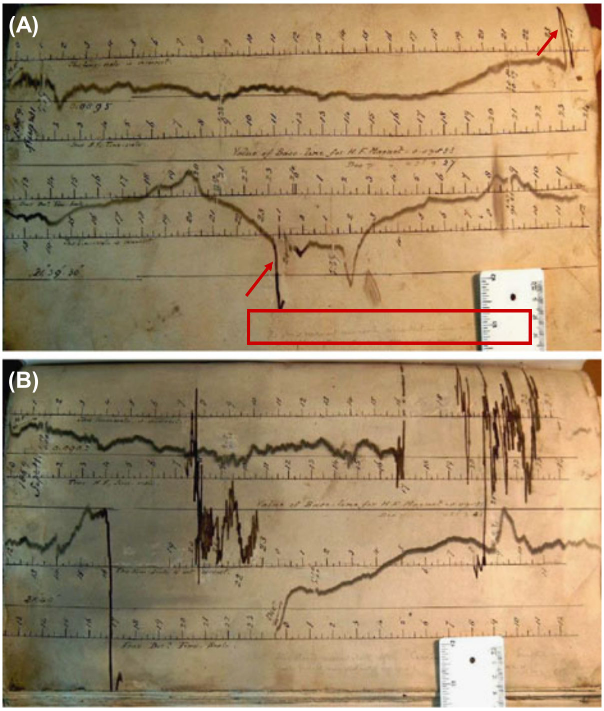


**Figure 7** (A) Greenwich Observatory magnetometer traces (horizontal force on top and declination on the bottom; the two traces are offset by 12 hours) during the time of the first recorded solar flare on 1 September 1859. The red arrows indicate the magnetic crochet or solar flare effect. The writing at the bottom of the photocopy says "The above movement was nearly coincidental in time with Carrington's observation of a bright eruption on the Sun. Disc[overed] over a sunspot. (H.W.N., 2 Dec 1938)." In the late 1930s, sudden ionospheric effects were discovered, enabling Bartels (1937) to explain both the prompt and delayed effects of the Carrington flare. H.W.N. refers to Harold W. Newton, Maunder's successor as the sunspot expert at Greenwich. (B) Greenwich magnetometer traces (driven off scale) showing the storm onset and rapid fluctuations.

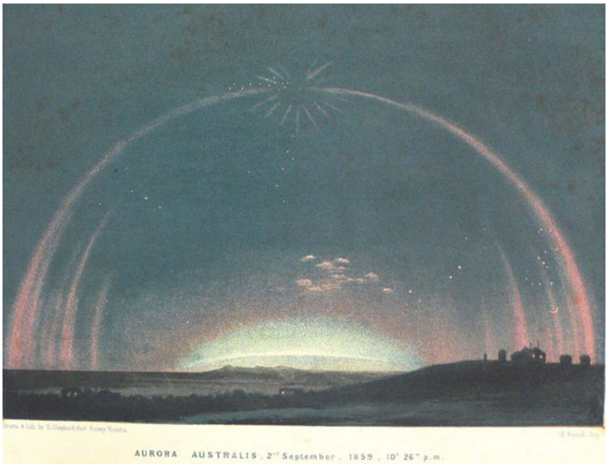


**Figure 8** The September 1859 aurora australis with corona as observed from the Melbourne Flagstaff Observatory (from Neumeyer, 1864).

(p. 3), "... as an unfettered man ... with my free telescope, I should probably have time to store up a respectable harvest before the new reaping machine was brought to perfection." Fortunately, Carrington was able to achieve his goals in the shortened period (Newton, 1958, p. 38). In the closing paragraph of Spots on the Sun, Carrington (1863, p. 248) wrote, "It hardly needs the addition of my opinion that in future observations of the Sun and his Spots, the methods of photographic registration ... brought to a high state of completeness and efficiency by Mr. De la Rue[12] [whose early work includes the photographs in Figure 6] are obviously those to be followed, rather than the method of sketching and time observations which I have employed."

The choking off of Carrington's scientific career began when his father died suddenly in July 1858 and he was forced to take over management of the Brentford Brewery. This unhappy situation was exacerbated by the earlier departure of his valued assistant Simmonds[13] and an inability to retain subsequent help, having no assistant in 1858, and intermittent assistance thereafter. On the departure of Dr. Schroeder in March 1861, Carrington (1863, p. 3) "decided to close up the series and wind up the results I had obtained; the necessity of my being personally engaged in commerce still continuing, and the prospect of my being able to give an observer's attention to the subject having become very remote, in consequence of a decision respecting a certain appointment to which I shall not more particularly allude [see Section 4.3]."

Carrington sold his observatory on 17 July 1861 and moved to Isleworth in west London, near the Brentford Brewery, before settling several years later in the Village of Churt, in western Surrey.[14]

## 4. Carrington and Airy

### 4.1. Airy

George Biddell Airy (1801 – 1892) was formidable (Figure 9).[15] As an undergraduate at Trinity College, he was First Wrangler (with no close competitor) in the Tripos examination and Smith Prizeman (the University's highest distinction for mathematics) in 1823. At age 25 he was selected as Lucasian Professor of Mathematics at Cambridge and shortly thereafter in 1928 became Plumian Professor of Astronomy and Director of Cambridge Observatory. Airy made important contributions to the study and correction of astigmatism (from which he suffered), the theory of planetary motions, and the diffraction of light. During the early 1830s, he received the Copley Medal from the Royal Society, the Gold Medal from the RAS, and the Lalande Prize from the French Academy of Sciences.

In 1835 Airy was offered the post of Astronomer Royal and served in this capacity for 46 years, until 1881. During his long tenure he made substantial improvements to the instrumentation and operation of the Royal Greenwich Observatory, adding magnetic and solar observing programs, while reducing and publishing a huge backlog (1750 – 1830) of planetary and lunar observations.

Airy was a highly dedicated civil servant and fiercely protective of the reputation of the Royal Observatory. Sampson (in Dreyer and Turner, 1923, p. 94) wrote, "... [Airy] was the official guardian of British astronomy, and even of science in general, as no one else has ever been; he deliberately made such a position for himself by cultivating connections at

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[12] Warren De la Rue (1815 – 1889), like Carrington, was one of the Grand Amateur astronomers of the Victorian Age (Chapman, 1998; Anonymous, 1890). He is known today for his pioneering work in astronomical, primarily solar, photography.

[13] In the introduction to the Redhill Catalogue, Carrington (1857, p. 4) acknowledged "the valuable services of my friend and assistant Mr. George Harvey Simmonds, who has shared nearly all my labour in observing, and has borne about three-fifths of the more serious labor of computation."

[14] An auctioneer's flyer in the RAS Club Bound Pamphlets (Vol. 42, 17) gives the date of the Redhill sale.

[15] For biographical detail on Airy, see Anonymous (1892), Airy (1896), Clerke (1917), and Chapman (2004).

**Figure 9** George Biddell Airy (1801 – 1892) in about 1870. Astronomer Royal and Director of Greenwich Observatory from 1835 – 1881. "Highly talented with great organizing skills, he was a dominant figure in astronomy from 1835 – 1881." (Hutchins, 2008, p. 61).

home and abroad, both within and without the borders of science ..." In his "Reminiscences of an Astronomer," Simon Newcomb (1903, p. 286), the first President of the American Astronomical Society, wrote, " We may look back on Airy as the most commanding figure in the astronomy of his time. He owes that position not only to his early work in mathematical astronomy, but also to his ability as an organizer ..."

In addition to astronomical/navigational pursuits such as establishing the modern prime meridian through Greenwich in 1851, Airy was the scientific consultant to the government on a wide range of topics including weights and measures, the trans-Atlantic telegraph cable, the gauge of the railway system, and the chimes of Big Ben.

In the 1896 biography of Airy, edited by his son Wilfried and based largely on Airy's extensive journals, it is written that

> The ruling feature of [Airy's] character was undoubtedly Order. From the time that he went up to Cambridge to the end of his life his system of order was strictly maintained. ... In everything he was methodical and orderly, and he had the greatest dread of disorder creeping into the routine work of the Observatory, even in the smallest matters. ...The great secret of his long and successful official career was that he was a good servant and thoroughly understood his position. He never set himself in opposition to his masters, the Admiralty.

It may be added that Airy expected the same kind of obedience from his subordinates.

Maunder, in his *History of the Royal Greenwich Observatory* (published in 1900), is often referred to for his critical comments on Airy's compulsion for order, but it is clear that he had great respect for the Astronomer Royal. Maunder (p. 112) wrote, "...it is to Airy, more than to any of his predecessors, or than to all of them put together, that the high reputation of Greenwich Observatory is due." Maunder's harshest criticism goes to Airy's "despotic" treatment of underlings (p. 117), especially during Airy's earlier years at Greenwich.[16]

### 4.2. He or I Must Go

If Airy represented the stabilizing hand of Victorian Age astronomy (*e.g.*, Hutchins, 2008, pp. 61, 152), Carrington represented the impetus of youth. Constitutionally resistant to authority, aware of his own merits to the point of arrogance, brimming with ideas, and determined in pursuit of them, Carrington was a boat-rocker who presented a persistent challenge to Airy's need for order. In this conflict of strong personalities, something had to give, and it was not going to be Airy. The formal venue for the interaction between Airy and Carrington was the Royal Astronomical Society, the communal hall of British Astronomy, where their tenures on the RAS Council, its ruling body, overlapped from 1854 – 1866. Carrington served as one of the two Honorary Secretaries of the RAS from 1857 – 1861 and was "indefatiguable" in his support of the Society.

Carrington's stature in British astronomy grew both as a result of his service on the Council and the recognition of his scientific achievements. In 1860, with Airy, John Couch Adams, Challis, De la Rue, and Herschel, among others as sponsors, Carrington was elected as a Fellow of the Royal Society.[17] The regard in which Carrington was held by scientists such as these, as well as by non-English scientists such as Le Verrier, gave the motivation for the subtitle of this article which was appropriated from Lindop's (1993) thesis on Carrington and Solar Physics.

The formal relationship between Carrington and Airy, as shown in their correspondence,[18] was generally amicable, if occasionally on the prickly side on Airy's part. More revealing are the letters between Airy and his close confidants, principally Augustus de Morgan (1806 – 1871), Admiral William Henry Smyth (1788 – 1865), Rev. Charles Pritchard (1808 – 1893), and William Whewell (1794 – 1866). This was a distinguished group. Smyth served terms as President of both the RAS and the Royal Geographical Society. De Morgan (fourth), Pritchard (fourth), and Whewell (second) were all high wranglers. De Morgan was a notable mathematician and logician who at age 22 was appointed Professor of Mathematics at London University. Pritchard later became Savilian Professor of Astronomy at Oxford, and Whewell, a polymath who coined the term "scientist" (as well as "astigmatism"), was the Master of Trinity College from 1841 until his death in 1866. The closeness of these men is evident in their letters which are sprinkled with humorous asides. It is in the exchanges with these friends, at a time when letters could be readily sent and received on the same day, that Airy's growing concerns regarding Carrington come to light.

Carrington was a fount of ideas and plans for improving the functioning of the RAS and advancing astronomy. He was not shy about promoting them. He also realized that he was more likely to be successful with Airy on his side. Thus, not long after his first

[16] Maunder (p. 118) decried Airy's "microscopic imperiousness" which "was almost avowedly intended to militate ... against the growth of real zeal and intelligence in the staff."

[17] Warren De la Rue initiated the Royal Society nomination process and Airy agreed to be the first signatory (De la Rue to GBA: 2 December 1859, RGO 6/391, 208).

[18] While Carrington left no archive of his correspondence, Airy's is voluminous and fortunately includes copies of letters he wrote (made with a letter copying press) as well as those he received. Carrington's correspondence with Challis is preserved in the Cambridge Observatory archive (CUA).

appointment to the RAS Council in 1854, he began petitioning for Airy's support on a variety of topics, *e.g.*, proposing Schwabe for the Gold Medal of the RAS (first brought up in 1855; Cliver, 2005);[19] expanding the yearly number of RAS meetings from eight to ten (1855);[20] surveying the programs of British and foreign observatories to avoid duplication of effort and maximize output (1855);[21] and obtaining public funds to publish the Redhill Catalog (1857).[22]

As one of the two Honorary Secretaries of the RAS, Carrington was deeply involved with the publication of the Monthly Notices[23] and played a role in the unusual arrangement of the volumes shown in Figure 1. In late 1858, he was the sole objector to a Council decision to increase the size of the Notices from octavo to quarto so that they could be bound with the quarto-sized RAS Memoirs. In a compromise solution, the Council decided to print the Notices in both formats beginning with volume 19 in 1859.[24] This "curious arrangement" ended with volume 27 in 1867, with only the small-octavo version produced thereafter.[25]

[19]De Morgan announced Schwabe's selection to GBA on 9 November 1856 (RGO 6/235, 665) as follows: "Swabby, or whatever his name is, medalist, unanimous. I think Carrington made out his case." Because the selection of the Medalist was a two-step process, De Morgan wrote to Airy again on 8 January 1857 (RGO 6/235, 671), "As to Medal. I am not strong in inclination toward Mr. Schwabe, but shall by no means oppose it. The thing does possess the character of extraordinary "pertinacity" as our worthy colleague [Carrington] pertinaciously calls it, and great importance has been attached to the results by persons unconnected with us." The reference to Schwabe's "pertinacity" in RAS President Johnson's 1857 medal presentation speech suggests Carrington's authorship of (or contribution to) the address, not unusual, since he had proposed Schwabe for the Medal [RCC to GBA: 18 December 1855, RGO 6/235, 618; see the exchange between Smyth and Airy (12 November 1857, RGO 6/236, 507 and 16 November 1857, RGO/236, 512)].

[20]De Morgan responded to this proposal by reminding Carrington "that we must have officers (Postulate 1) and we would not get them at 10 meetings per annum". De Morgan to GBA (19 May 1855, RGO 6/235, 516).

[21]RCC to GBA: 9 July 1855; RGO 6/235, 530.

[22]RCC to GBA: 12 May 1857, RGO 6/251, 158; In a response to a letter from the Admiralty (13 June 1857, RGO 6/251, 161) requesting his opinion, as Astronomer Royal, on publication of the catalogue, Airy (23 June 1857, RGO 6/251, 162), after weighing the pros and cons of supporting publication, "deem[ed] it my duty to abstain from definitely suggesting to Their Lordships any precise reply to Mr. Carrington." Subsequently, Le Verrier offered to publish the Catalogue in the Annales of the Paris Observatory. It is possible that this offer spurred the Admiralty's eventual decision to cover the cost of publication (Lindop, 1993, p. 18).

[23]For example, when Editor Robert Grant was temporarily away in 1856 – 1857, Carrington volunteered to edit the Monthly Notices "provided he had it all to himself" (De Morgan to GBA: 9 November 1856, RGO 6/235, 665). On 6 April 1857 (CUA G.1 Obsy xxvi, 11), RCC wrote to Challis, "The editing of the Monthly Notices ... in Mr. Grant's absence robs me of a good deal of my time ...."

[24]RAS Special Council Meeting on 20 November 1858, Vol. 6, Minutes of the RAS Council (1856 – 1866), p. 47.

[25]The origin of the format change in 1859 lay in the fact that before then, the Monthly Notices (octavo) and Memoirs (quarto) were billed on their title-pages as "half volumes" which together comprised the "complete" volume of a "session." As reported in Dreyer and Turner (1923, pp. 239 – 240), "this notice disappeared after 1858, the Monthly Notices being recognized as a separate journal." Because of its "rapidity and regularity" of publication, the Notices which contained "abstracts, observations, shorter papers, etc.," had been increasing in popularity *vs.* the Memoirs which was the intended "principal organ" of the RAS and contained full-length papers. "Still the Council wished to make the [Notices] 'become an integral part of the Memoirs'." Thus, from 1859 – 1867 the Monthly Notices (Volumes 19 – 27; the two large books in Figure 1) were printed in both quarto and octavo format, permitting the combined binding of the quarto-size Memoirs and Notices for a given year (see also Anonymous, 1859). After the Special Council Meeting in November 1858, De Morgan wrote to Airy, "We decided to print [the Monthly Notices] in Octavo and Quarto both ... Carrington wanted to make our Mo. No. the chief publication and have the long papers [Memoirs of the RAS] auxiliary. This I call Mo. No. mania." (25 November 1858, RGO 6/377, 163). In regard to the punctuated Monthly Notices series in Figure 1, a few other volumes were missing for early years in the AFRL collection and it appears that the quarto-sized volumes 19 – 27 were obtained to fill such a gap.

Thus, relatively few, if any, other libraries can be expected to exhibit the disrupted sequence seen in Figure 1. If not for Carrington, however, the step in 1859 would be seen in all libraries.

Beyond his stream of requests to Airy for support and advice on various proposals – with the resulting demands on Airy's time – Carrington offended the Astronomer Royal on at least two occasions by seemingly encouraging others who had criticized Airy and/or Greenwich Observatory. Quotes taken from the correspondence between Airy and De Morgan trace the trajectory of Airy's disillusionment with Carrington from good-humoured wariness to real concern over Carrington's perceived potential to bring embarrassment to either the RAS or the Royal Observatory.

Carrington, who shared Airy's fiscal rigor, at one point wanted the RAS to find out what Adams, who had a government pension, was working on, prompting Airy to write to De Morgan (10 January 1857), "I think that Talleyrand must have had a prophetic vision of Carrington when he gave his maxim 'Above all, not too much zeal'."[26]

In 1858, the RAS rules were changed to make elections more open by a group of Fellows whom Airy and his clique referred to as the "radicals." In a letter to De Morgan, Airy wrote (7 September 1858), "I am in much greater fear of what that crack-brained Carrington may do than of all that the radicals can do. How to smother his desire of interfering with everybody and his general busy-bodi-ness – without giving deadly offence is as difficult as the solution to $\partial^2 u/\partial x^2 + \partial^2 u/\partial y^2 = 0$ without imaginaries."[27]

De Morgan replied on the same day, "Carrington is a queer fellow. But he has mettle for work. I don't think we have let him do any harm; and a few years over his head will set him all right. This is nothing but over-zeal, troublesome, but manageable with trouble."[28]

In 1859, Albert Marth, Bessel's last pupil, attempted for the second time to publish in the Monthly Notices a paper critical of work done with the Greenwich transit circle. When it appeared that Carrington was supporting publication, Airy saw red. In a letter to De Morgan (21 November 1859), Airy wrote:

> The Society is in greater danger than it ever has been in during my connexion with it, and, for various reasons, nobody can do as much as you to save it. The immediate step to be taken is, that Carrington must be removed from office. … The movements which led to this state of things are the following. You know that Carrington has been introducing into the Society the most brutal criticism. He brought to a meeting that blackguard von Gumpach, to insult me from the benches. … he twice brought in Marth's paper which the Council twice put down, and now, as I am informed, he with others … are subscribing to publish Marth's paper. I got a sight of the paper before hearing of this, and I was perfectly astonished at it. It is not, as Carrington represents a comparison of English system with foreign system, it is a continued malevolent criticism on me and on the Greenwich Observatory from beginning to end. If Carrington continues in his design, it is impossible that we meet in [the RAS] Council, he or I must go.[29]

[26] RGO 6/235, 628; Airy gave an abbreviated version of the maxim (Surtout, pas trop de zèle), writing, " 'Point de Zèle, Monsieur.' " (No zeal, Sir.).

[27] RGO 6/236, 532.

[28] RGO 6/236, 534.

[29] RGO 6/236, 724; Baron Johannes von Gumpach ( – 1875), a British subject who later became a Professor of Astronomy at Peking University.

De Morgan's reply was reassuring, "I hope that the matter will lead to nothing – for Main tells me that C & DLR [Carrington and De la Rue] are to read the paper, which they have not done. ... This matter will blow over I think." Though he added, "But the cause and spirit may remain. I have long seen with regret that C has a spirit which may at any time give any trouble. He seems bent on driving [?] the Society with a rod, and one to be used, too."[30]

When considering the RAS Council's nominee for the RAS Presidency in 1861, Airy was worried about Carrington's growing prominence on the Council. Airy wrote De Morgan (2 November 1860) that "... the strength of a President is much wanted now to balance the strength of another officer [clearly Carrington] ... As touching myself [as a candidate for President], there is another personal difficulty, I do not see that I could prefer to act with Carrington. ... Similarly, if Carrington were made President, I should at once relapse into private life."[31] When De Morgan, chided Airy for being too thin-skinned,[32] Airy retorted, "My skin is in fact respectably horny. But I am indignant with Carrington's policy of intermeddling ... I do not see how things are to go on, unless Carrington be shelved."[33]

### 4.3. Blocked Ambition

It was against this background of ill-feeling that Observatory Directorships became open at the two leading English universities: Radcliffe Observatory at Oxford in late February 1859 when its Director, Manuel Johnson, died suddenly, and Cambridge University Observatory in November 1860 when Professor Challis announced his intention to resign from the Directorship. Except for his relationship with Airy, Carrington was well-placed to secure one or the other of these positions. He was highly motivated to do so because it was impossible, even for someone as dedicated and energetic as Carrington, to pursue his astronomical work (with both daytime and nighttime interests) while managing a large brewery and serving as an active officer of the RAS. The Radcliffe trustees held an open competition for the Observatory Directorship – applications could be accepted from outside the University. The position at Cambridge was not publically advertized.

[30] 24 November 1859, RGO 6/236, 731; Marth's paper was rejected for the Monthly Notices but was published the following year in Astronomische Nachrichten (Hutchins, 2008, p. 149).

[31] RGO 6/ 237, 410 Although this type of bluff was common with Airy (see below), the concern was real. If Carrington became RAS President, it would automatically qualify him to be a Visitor of the Royal Observatory, thereby giving him both an official capacity and a forum (the annual visitation) to review and critique the Greenwich program. Lindop (1993, p. 21) noted that Carrington, though not a Member of the Board of Visitors, "eagerly read through each of Airy's Annual Reports and commented on them ... often offering suggestions ..." When Manuel Johnson died, De Morgan wrote Airy (RGO 6/377, 176; 4 March 1859), "I suspect you will be asked who you recommend [to replace him as Radcliffe Observatory Director]. ... Will you have C——n [?] He would keep you well watched and instructed."

In regard to Airy's penchant for threatened resignations: On 2 March 1865, Carrington, as Secretary/Treasurer of the RAS Club, wrote to Airy (RGO 6/238, 828), "Mr. De la Rue has handed to me your letter in which you desire to resign the chair of the Club. I will duly attend ... though I regret your determination." On 13 March 1865, Carrington (RGO 6/238, 831) wrote Airy, "I have to inform you that in your resignation of Membership of the RAS Club you were unanimously elected an Hon[orary] Life Member I believe for the third time." The next day Airy wrote back (RGO 6/238, 832), to "acknowledge the kindness of the Club" in doing so.

[32] 3 November 1860, RGO 6/237, 414; Lindop (2004) refers to Airy's "almost pathological resentment of any questioning of his authority."

[33] 5 November 1860, RGO 6/237, 418 In the end, Airy's name was put forward by the Council for President (along with Carrington's as Secretary) and the radical contingent (which didn't include Carrington) placed Lee's name in nomination for President, with Lee prevailing (Dreyer and Turner, 1923, pp. 140 – 142).

Within nine months after his father's death, and two weeks after Manuel Johnson's, Carrington wrote to the revered John Herschel, "I am about to put myself in communication with the Radcliffe trustee's about the vacant Directorship at Oxford which our friend Johnson's death has so suddenly thrown open, and I should esteem it a favor if you would express your sentiments as to my qualifications to any of the Masters whom you may be best acquainted with . . ."[34] Over a year later, on 2 May 1860, Carrington again wrote to Herschel, "The Radcliffe Trustees met last Friday and considered that from there having been no further applicants beyond myself, Capt [William] Jacob, and Mr. [Robert] Main [a Sixth Wrangler and Airy's First Assistant for 23 years at Greenwich], the circumstances of Johnson's death and the consequent vacancy could not be generally known to astronomers! . . . every observer[?] who can turn a screw knows well of the vacancy . . . My private belief is that any Cambridge candidate has great objections on that sole ground against him. Can you do anything in this matter? The father's of English astronomy have a right in my opinion to be heard in this matter."[35] Norman Pogson had applied for the post as well. Pogson requested a letter of support from Airy, who replied, "Mr. Main's claims on me . . . are like those of a son on the head of a family. . . . This almost prevents me from saying a word in favour of any other person."[36]

In his letter to the Board of Trustees on behalf of Main,[37] Airy stressed Main's sense of propriety (in unstated contrast to Carrington), describing him as, "a person of prudent conduct in business . . . and of gentlemanly manners" who "by . . . correct conduct in all external relations . . . has done very much to establish the [Greenwich] Observatory in [its present position]." Airy added that "The behavior of this Observatory is by no means confined to Technical Astronomy, but implies extensive relations with Men of Science generally, with Officers of the Army and Navy, and with Constructors of Instruments of various kinds. In these transactions, Mr. Main has displayed the same ability and propriety." On 19 June 1860, Robert Main was appointed as the Director of the Radcliffe Observatory (Main, 1862).

Subsequently, Carrington wrote Challis that he found the Oxford selection process to be "very provoking and even injurious." "We . . . had to wait 15 months and no candidate [was] called to a formal interview or had a word to guide him as to when an appointment would even be made."[38]

Carrington's comment to Herschel about prejudice against Cambridge candidates (which Main's selection undercut) suggests that he was unaware of the depth of Airy's personal view of him as a trouble-maker. Thus when the Cambridge post became available, Carrington wrote to Airy (23 January 1861),

> You are doubtless aware that Prof Challis has proposed the early separation of the Plumian Professorship and the Directorship of the Observatory at Cambridge, as he wishes to retire from the latter. On the question of making the Directorship an independent office . . . you will also no doubt be consulted: and it would guide me in proposing myself as a Candidate if you would inform whether you would advise the present separation of the Observatory from the Plumian or other Mathematics Professorships and in the event of the office being so separated whether I may count on your

[34] 13 March 1859; RS: HS.5.206.

[35] RS: HS.5.214. See also RCC to Challis (CUA Obsy G.1 xxx 16; 3 May 1860).

[36] Pogson to GBA (16 May 1859, RGO 6/146, 255); GBA to Pogson RGO 6/146, 256 (23 May 1859, RGO 6/146, 256).

[37] 1 April 1859, RGO 6/146, 253.

[38] 3 July 1860, CUA Obsy G.1 xxx, 26.

> support with W Whewell and other members of the Syndicate. I speak on the supposition that Prof Adams [co-discoverer of Neptune with Leverrier and the Lowndean Professor of Astronomy and Geometry at Cambridge] should not come forward. I am obliged to add that unless this or some similar post falls to me shortly I forsee the probable necessity of relinquishing an occupation to which I am greatly attached and which I can hardly be said now to continue so great are my hindrances.[39]

Airy's reply on the following day was blunt and could have given Carrington no comfort,

> I cannot give the smallest information on the probable course of astronomies at Cambridge . . . I hear that a Syndicate has been appointed as proposed to consider recommendations to the Senate.
> I do not think it at all likely that I shall be in any way consulted; but if I were . . . I can state distinctly what I should recommend. I should certainly detach the Observatory from the Plumian Professorship [Challis] and connect it with the Lowndean [Adams], or, in any case, I should not appoint any other curator of the Observatory on terms which would invite yourself or any other foreign competent person.
> But I do not think this ought to influence you in the most trifling degree, because, as I have said, I think it most extremely improbable that I shall be consulted in any way.[40]

In fact, Airy had made his views on the Directorship known to William Whewell, Airy's close friend[41] and ranking member of the Syndicate,[42] some two years earlier, when he wrote the Trinity Master (10 November 1858) shortly after learning of the death of Lowndean Professor George Peacock,

> I am very sorry indeed to hear of the death of Peacock. He was my earliest and best friend in College.
> Now cannot advantage be taken of this opportunity for altering the absolute and relative positions of the Plumian and Lowndean Professorships. The Lowndean Professorship, it is understood, is well endowed, and has nothing to do. The Plumian Professorship is or was insufficiently endowed and is overloaded with two heavy duties [teaching and the Observatory Directorship]. . . .
> Here is the opportunity for removing a scoundrel [reflecting Airy's poor opinion of Professor Challis],[43] and alleviating a load on the University, such as you may wait

[39] RGO 6/146, 56.

[40] RGO 6/146, 58.

[41] Whewell was the Godfather of Airy's daughter Hilda and officiated at her wedding (GBA to Whewell: 15 June 1864, Add.Ms.a.200.183). When Whewell's wife died, Airy's wife Richarda kept house for him during the mourning period (Airy, 1896, p. 119). Airy and Whewell had worked closely on the Sheepshanks Endowment to Cambridge University for the Promotion of Astronomy (Dreyer and Turner, p. 192) of £10 000 (∼$1 100 000 today) [30 September 1856, TCL Add.Ms.a.200.112; 17 November 1858, TCL Add.Ms.a.200.123; 5 February 1859, TCL Add.Ms.a.200.130] which Miss Sheepshanks supplemented by £2 000 (∼$220 000) in early 1861 [28 August 1860, TCL Add.Ms.a.200.1157; 6 February 1861, TCL Add.Ms.a.200.165]. Both Whewell and Airy were trustees of the fund, along with the Fellows and Scholars of Trinity College.

[42] CUA Minute Book of the Council of the Senate from Nov. 9, 1858 to Dec 7, 1863, vol. II, Min. I.4 (7 Dec 1860).

[43] GBA to Whewell: 2 April 1859, RGO 6/378, 542; Airy wrote [marked "(Private)"], "If you look in the Philosophical Magazine, just published, you will see that Challis is "doing the mystical in Algebra as he has done heretofore in Hydrodynamics and Gravitational Astronomy. He is off his head. I have not the least confidence in him."

for centuries to find again. If the circumstances exist unaltered, and if your opinion agrees with mine, pray mention it to the Vice-Chancellor. He is the only one who can communicate with the Commissioners, and they are the only persons who can do anything.

In any case, I hope that Adams will be attached to Astronomy in the University somehow.[44]

Although the separation of the Observatory Directorship from the Plumian Professorship to which Airy alludes was not accomplished at that time, Adams was brought back to Cambridge (from St. Andrews in Scotland) to succeed Peacock as Lowndean Professor of Astronomy and Geometry in March of 1859.[45] The second half of Airy's plan was achieved when the Syndicate – after George Stokes, the Lucasian Professor of Mathematics, declined to consider the Observatory Directorship[46] – offered the position to Adams, who hesitantly accepted, provided that he be considered at liberty to resign the same at any time, should the work interfere with his theoretical research in astronomy".[47]

Carrington was incensed. Even though the Directorship had not been advertized outside of the university, and though he had high regard for Adams, he felt a moral claim to the position as the best qualified candidate and was offended, as an astronomer, at the seeming lack of respect given to the post. In the first of two letters addressed to Latimer Neville, the Vice-Chancellor of the University, Carrington (13 April 1861) wrote,

I am aware that it has been more than once proposed, though not finally contemplated, to create the Directorship a separate office in the place of a mere addition to the duties of one of the existing chairs of Theoretical Astronomy[48] ...The Directorship of a

[44]TCL, Add.Ms.a.200.122.

[45]The task of choosing Peacock's successor as Lowndean Professor took place during the time that the selection procedure for this position was being changed. Under the old procedure, selection and appointment was made by high government officials, *e.g.*, the Lord High Chancellor, the Lord President of the Privy Council, the Lord High Treasurer, the Lord Steward of the King's Household, etc. Under the proposed new system, the electors would be the Vice-Chancellor of the University, the President of the Royal Society of London, the Astronomer Royal, The Lucasian Professor of Mathematics, the Plumian Professor of Astronomy, the Sadlerian Professor of Pure Mathematics (once established), and the President of the Royal Astronomical Society. This proposal was confirmed by a Grace of the University Senate on 26 November 1857 (CUA CUR 39.12 / 22(2)) and was sanctioned by an Order of Her Majesty in Council on 7 March 1860 (CUA CUR 39.18 / 37(1)). Adam's formal notification of his selection on 23 March 1859 was made in the traditional manner, by the Lord Steward of the Queen's Household (SJL Adams 20/10/1,2; Adams to Walpole: 11 November 1858, SJL Adams 16/65,1), but it seems certain that the government officials would have consulted with, or taken advice from, the astronomical/scientific establishment and the University (*i.e.*, the new slate of electors). There appears to have been some confusion about who would make the selection early on because John Wrottesley (JW), President of the Royal Society, wrote Adams (JCA) on 12 November 1858 that if JW was required to act in capacity of Elector, JCA could depend on his support (SJL Adams 15/37/1). On 15 November 1858, one week after Peacock's death, Prime Minister Stanley unofficially informed Adams (SJL Adams 14/18/1) that he had been unanimously chosen by the Electors, adding, "It has been represented to us that of late years the Lowndean Professsorship has been practically a sinecure..." On 13 December 1858, Airy wrote to congratulate Adams and urged him to keep the Sheepshanks fund (Hutchins, 2008, pp. 127 – 128; footnote 41) in mind "when you have any great thundering calculations to be made." (13 December 1858, RGO 6/377, 10).

[46]Stokes to Vice-Chancellor, Special Observatory Syndicate: 15 February 1861, CUA CUR.29, 48.3.

[47]Adams to Vice-Chancellor, Special Observatory Syndicate: 15 February 1861, CUA CUR.29, 48.4; In the Adams archive, in a draft letter to the Vice-Chancellor (never sent) dated 27 April 1861, Adams offered to withdraw his name from consideration because the position was being contested [by Carrington]. (SJL Adams 16/48/1; Franzl, 1999).

[48]When leaving Cambridge Observatory for Greenwich, Airy, himself, had written (Observatory Minutes, 1st Minute Book, 1817 – 1845; Report on the proceedings in the Observatory since May 30 1835, 9 December

> Public Observatory ... demand[s] qualifications of a special kind which all theoretical men, even of the highest class, are not found to possess ...
> I have devoted nearly the whole of the thirteen years since I left the University to establishing, with such means and such abilities as I have possessed, a reputation for success in the labours of Practical Astronomy, specially with the object of obtaining such a position as is about to become vacant at Cambridge; and although I shall always be among the first to recognize the eminent abilities of Professor Adams in his own department of Astronomy, I shall, without hesitation, claim the right on both public and private grounds to contest with him the relative fitness for such an office as the Directorship of the Cambridge Observatory; for it is as much an injustice ... to pass over that person in the country who may have established the foremost claim to the vacant Directorship (and I claim to be that person) as it would be to some one else to appoint me Downing Professor of Laws or First Surgeon to Guy's Hospital. ...

Carrington then reviewed his qualifications for the vacant directorship (including visitations of all the leading observatories of England, Scotland, and Ireland as well as many of those on the Continent, and widespread acquaintance with opticians and observers), concluding:

> I will lastly point out that in nothing that I have done have I shown any tendency to make an observatory under my charge a weak imitation of any other ...
> It may be asked of me how, having with success maintained an independent position, I wish to enter the service of a University, and place myself in a position where I shall be responsible to others. I reply, for two reasons: firstly, for the sake of the public position; and, secondly, because I shall have the advantage of instruments and a staff of computers, such as my private means will not support.[49]

Carrington's efforts to have the Syndicate reconsider their decision were unsuccessful. On 29 April 1861, at a meeting of the Council of Senate, "The Vice-Chancellor [Latimer Neville] read a letter from Mr. Carrington ... and was requested to communicate to [him] that the Council saw no reason for interfering with the arrangement proposed by the Syndicate."[50]

In all Carrington sent four letters to Cambridge. The last of these was sent to the resident members of the Cambridge University Senate on 4 May 1861, after that body had approved the Syndicate's recommendation of Adams. Carrington wrote to take

> the opportunity of repeating his dissatisfaction, not necessarily at the result, but the mode at which the result has been arrived at, as characterized by an avoidance of due publicity ... He continued, "the principal object ... appears to have been to get the office in question privately taken at less than half the remuneration adequate to the services to be rendered ..." and lamented that the salary of £250 ($27 500) would not "ultimately contribute to the prosperity of Astronomy or Astronomers ..."[51]

1835), "Whether the Director of the Observatory might not be more advantageously attached to an office not encumbered with lectures, is a question that I scarcely venture to raise." Adams (CUA CUR.29, 48.4) in his letter to the Vice-Chancellor on 15 February 1861 also advocated separating the Directorship from any Professorship.

[49] Syndicate papers in Cambridge University Senate Archives, CUA CUR.29, 48.7.

[50] CUA Minute Book of the Council of the Senate from Nov. 9, 1858 to Dec 7, 1863, vol. II, Min. I.4 (29 April 1861).

[51] Syndicate papers in Cambridge University Senate Archives, CUA CUR.29, 48.9, 3; Carrington, himself, appears to have paid his assistants well. Chapman (1998, pp. 40, 149) calculates that Simmonds was paid

In a post-selection exchange of letters, Whewell wrote to Airy (2 May 1861), "You will have heard that Adams is to work the Observatory. Carrington sent two scolding letters to us and came here himself: but independent of financial difficulties [at Cambridge University (Hutchins, 2008, pp. 128 – 129)], he writes and talks like a man who would be a troublesome official."[52] Airy replied, "Carrington sent me his letters. I cannot conceive how a man could be so stupendously foolish. The notion of taking a position by storm in that manner! But in every way you are well to be rid of him. With good intentions probably, which I suppose go to their well known place, he is a quarreler, and a promoter of other quarrelers, – conceited and insolent, – in a short time you would have been compelled to turn him out by force, and to stand a lawsuit and criminal prosecution.[53]

As evidence of the importance of Airy's patronage (Hutchins, 2008, pp. 60, 72 – 73), we note that, from 1859 – 1861, four British, or British Government, Observatory Directorships became open: Glasgow, Oxford (Radcliffe), Cambridge, and Madras (India), and all four selectees (Grant, Main, Adams, and Pogson, respectively) benefitted from Airy's endorsement.[54] All four selectees were beholden to Airy and none were boat-rockers, thus meeting Airy's primary need for order. There is an additional aspect to consider. Carrington's claim that no observatory under his charge had been "a weak imitation of any other" was not an idle boast. Sampson reckoned that, under Carrington, the Durham Observatory, with far less in resources than Cambridge, could have become a world-class institution. Hufbauer (1991, p. 66) noted that, years later, when Lockyer "persuaded Thomson, De la Rue, Stewart and others to endorse the idea of a national physical observatory," Airy "refused to countenance such a rival to the Greenwich Observatory," and used his influence with the RAS Council to oppose such a development.[55]

## 5. After Redhill

Despite this crushing disappointment of being denied the Cambridge post, Carrington did not lose his enthusiasm for astronomy. From 1861 – 1863, he completed "Spots on the Sun" for which he was awarded the Lalande Prize by the French Academy of Sciences in 1864 (Anonymous, 1865).[56]

Moreover, he remained active in the affairs of the RAS. Even at the height of the dispute over the Cambridge Observatory Directorship, Carrington was communicating cordially with Airy about a proposal to the government for the hill station at Pune in India. For example, on 28 April 1861, Carrington wrote to the Astronomer Royal, "The principal reason why I am additionally ardent about the scheme <u>now</u> is that I am impressed with the

£126 per year, with apartment, making him "one of the best-paid [privately employed] assistant astronomers of the day."

[52] RGO 6/147, 35.

[53] 3 May 1861, RGO 6/147, 36.

[54] Grant (GBA to Prof. J.D. Forbes, 15 November 1859, 6/146, 88); Main (GBA to Radcliffe Trustees, 1 April 1859, RGO 6/146, 253); Adams (GBA to Whewell, 10 November 1858, TCL, ADD.Ms.a.200 (122)); Pogson (GBA to Prin. Sec. of State for India, 25 Sep 1860, RGO 6/146, 200).

[55] See also Smith (1991) & Hutchins (2008, p. 153).

[56] RAS Minutes of (RAS) Council, Vol. 6 (10 November 1865, p. 214; 8 December 1865, p. 216); also Dreyer and Turner (1923, p. 147); At the November meeting Carrington was nominated by Hodgson and Airy to receive the Gold Medal for 1866 for his work on the solar spots but at the December meeting Carrington requested (via a letter) that his name be removed from consideration.

great additional advantage" of the availability of Capt. Jacob, a seasoned and capable practical astronomer, for the observer's position.[57] The proposal, which included observations of planets, nebulae, variable stars, double stars, and the zodiacal light, was approved, and on 8 August 1861 the Treasury granted £1000 pounds ($110 000) for the three year effort (Dreyer and Turner, 1923, pp. 138 – 140). During 1862, Carrington initiated an effort in the RAS to complete the southern star catalogs. Although the proposal initially met with Airy's resistance,[58] Carrington eventually secured the Astronomer Royal's support, and a plan was drawn up.

Unfortunately, both of these attempts by Carrington to conduct astronomy by proxy failed. Neither the Hill Observatory nor the Southern Survey fulfilled their early promise. Captain Jacob, who had been invalided out of his previous post in Madras, died of "a violent liver attack" in Pune eight days after arriving in India in August of 1862 (Anonymous, 1863). The effort was abandoned, with the remaining £500 returned to the Treasury.[59] The Southern Survey languished and was not completed until Gill and Kapteyn conducted a photographic survey between 1893 – 1901 (Dreyer and Turner, 1923, p. 146].

The years immediately following his departure from Redhill were a difficult period for Carrington; he did not take fettering well. On 2 March 1865, Pritchard wrote to Airy, "I am glad you were not at the [RAS] Annual Dinner because R.C.C. made a pointed speech on the subject of his losing both the Cambridge and Oxford Observatories."[60] Shortly thereafter, RAS President Warren De la Rue, who had worked closely with Carrington during the years 1857 – 1861 when both were Honorary Secretaries, wrote to Airy, in reference to insubordination on Carrington's part over publication of the annual RAS Treasurer's report, "No one can esteem Mr. Carrington more highly than I do for his intrinsic worth and no one can regret more than I do his little regard for the feelings of others. He in my opinion is a man most desirous of promoting the interests of the Society but at the same time shows too little regard for the worthy attributes of those not possessing the peculiar aptitudes he prizes most."[61]

[57] RCC to Airy (RGO 6/237, 382) Capt. William Stephen Jacob (1813 – 1862) first made observations at Pune when engaged in the Survey of North-Western India during the 1830s. From 1848 – 1859 he was appointed Astronomer at Madras Observatory "without application on his part, but from his several papers transmitted to [the RAS]". (Anonymous, 1863; Ananthasubramaniam, 1991).

[58] The letter Carrington wrote to Airy on 13 October 1862 on this topic was vintage Carrington, "If you should take a favourable view of my proposal, you will greatly promote a general desire that I have long entertained to see our Council proceed from merely conducting publication and evening meetings to action in real astronomical business where their influence may be usefully exerted to lead undertakings of more importance." (RGO 6/238, 220). And the response on 16 October 1862 was vintage Airy, "I cannot take any part in the proposal. The idea of sending to the Cape Observatory a Chief scarcely inferior to the established Cape Observer, with a large and expensive staff, to carry out a plan of observations which has not originated with the Cape Observer and on which (I believe) he has not been consulted, will not, I conceive, be accepted by any official person." (RGO 6/238, 222).

[59] Hamilton to GBA (7 November 1862; RGO6/238, 184); Whitbread to GBA (15 November 1862; RGO 6/238, 187).

[60] RGO 6/239, 689.

[61] 6 March 1865, RGO 6/239, 695; As a result of Carrington's insubordination, De la Rue threatened to resign his Presidency (De la Rue to GBA, 4 March 1865; RGO 6/239, 693). Carrington's provocation of the even-tempered De la Rue is noteworthy. RAS finances were a concern (some might say obsession) for Carrington from 1862 – 1865. He desired to make the accounting system he promoted "a model for other societies." Pritchard to GBA (2 March 1865; RGO 6/239, 689). During this period, Airy wrote to De la Rue that he believed Carrington to be "truly insane", continuing, "after [Carrington's] breaking of all rules of order and subordination ... we should be put down as simpletons if we put him in nomination [for the RAS Council] again." (13 November 1865, RGO 6/240, 468).

Late in 1865, Carrington suffered a serious unspecified illness. The only hint as to its nature suggests a stroke.[62] Carrington, who was a regular at the RAS Club, having attended all meetings in 1865 and having missed only sporadically before then, was absent from January 1866 – July 1867. He retired as the Secretary/Treasurer of the Club in February 1866.[63] This illness caused Carrington to sell the Brentford Brewery and marks the end of his active involvement in the RAS and the RAS Club although he continued to attend Club meetings regularly and did not resign until April 1872.[64]

In 1870, in his first Monthly Notices paper since late 1865, Carrington reported that he had "bought the freehold of almost nineteen acres of land situated . . . south of Farnham . . . in the village of Churt. It contains a conical hill, sixty feet high, which is entirely detached . . . It goes by the name of the Middle Devils Jump . . ." On this hill, Carrington built a new observatory "below ground" since he did not need elevation, with the instruments "just peeping over the hill" (Figure 10). In the observatory he sank a dry well, 6 feet in diameter and 40 feet deep to keep the clock "at a position of invariable temperature." He hoped that he should shortly have "the most perfect clock in England, perhaps the world."[65] From observations made at his new observatory, Carrington (1874b) published a single inconsequential paper.

In one of his last papers, Carrington (1873b) proposed an exotic "double altazimuth" as the next advance in meridional instrumentation. The projected cost was enormous. Carrington estimated that the price of just the required pair of prisms would be £41 160 ($\sim$ $4 500 000). To the begged question of "What is the use of proposing schemes which can never be accomplished?" he answered "What is the use of sitting still and never imagining anything beyond what is put before you?"

## 6. Last Years

The narrative of Carrington's final years is dominated by his ill-fated marriage to Rosa Helen Jeffries (1845 – 1875), a beautiful young woman that he met in the summer of 1868. At the time she met Carrington, Rosa was living with William Rodway, a former soldier and circus worker, whom she passed off as her brother. Her secret relationship with Rodway continued after her marriage to Carrington in August 1869. In August 1871, Rodway, in a fit of passion,

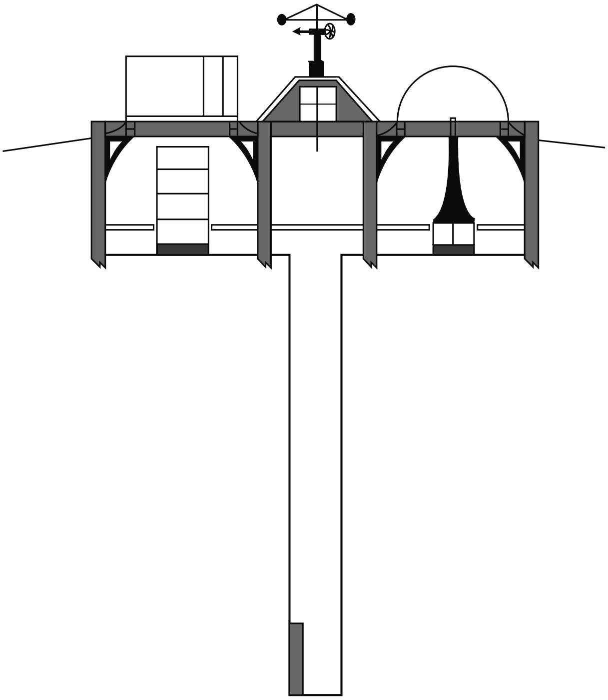
62 Carrington died at age 49 of a cerebral hemorrhage and at the inquest, his physician, Mr. R. Oke Clark, surgeon, "said he had attended deceased, who told him he had had an attack of paralysis." [See footnote 66 for reference.] No time is given for the attack but it is possible that it was not a current ailment but rather one he gave as part of a medical history in which case it might have referred to the debilitating event in late 1865. The timing of the 1865 illness is based on RAS Bound Pamphlets, 42(2S), Carrington's tract entitled "Appeal on the Accounts at the Special General Meeting, 1866" (9 February 1866), in which he wrote, "illness . . . has kept me at home for the last six weeks, and is likely to keep me at home as long again."

63 Records of the RAS Club 1820 – 1923, ed. H.H. Turner (1904).

64 At the March 1872 meeting of the RAS Club, Carrington moved that Mr. Fletcher be removed from the list of members for "non-attendance" in accordance with Rule 10. "A show of hands was taken, and only one hand was held up in favor of enforcing the rule. Mr. Carrington objected to this decision and left the room." At the April 1872 meeting, the Secretary read a letter from Carrington requesting that his named be withdrawn from the list of members. (Turner, 1904).

65 Carrington's misadventures with this clock provide a sad coda to his career (Lindop, 1993, pp. 34 – 35). In his quest for a high vacuum, Carrington (1873a) reported breaking "eight pieces of glass, half an inch thick each, at an expense of £3 each" (for a total cost of $\sim$$2500)", prompting Robinson (1873) to point out that the problem could be avoided by not using large flat surfaces of glass in the clock case but instead using convex surfaces "on the principle of the arch."

**Figure 10** Cross-section drawing of the observatory Carrington established at Churt (Carrington, 1870), with instruments just "peeping" over the rim of the hill. The clock is shown at the bottom of the 40-foot deep dry well which could be reached by a horizontal shaft, 166 feet in length, from the base of the hill.




went to Churt and attacked Rosa with a knife, seriously injuring her. He was found guilty of attempted murder and sentenced to 20 years of hard labor. The scandal was thoroughly reported by the local newspapers.[66]

Despite the turmoil, Carrington and Rosa remained intact as a couple. On the morning of 17 November 1875, however, Rosa was found dead in bed. An inquest was held and the cause of death was ruled to be "suffocation, but how such suffocation came about there was not sufficient evidence to show." Chloral hydrate, which Rosa, was taking as a sleep aid, may have played a role.[67] Because Rosa suffered from epilepsy, Carrington was held to be "open to very great censure, considering his wife's state of health, that he had not provided her with proper nursing attendance." Only ten days after Rosa's death, on 27 November, Carrington himself died of a cerebral hemorrhage.

In Carrington's will, he requested that he be buried in the grounds surrounding his house at Churt and that no memorial be erected.[68] This wish was not granted and Carrington was

[66]Unless otherwise noted, all information in this section is from the Surrey Advertiser and County Times: 26 August 1871, 9 September 1871, 30 March 1872, 20 November 1875, 29 November 1875, and 11 December 1875.

[67]Clark testified that "the quantity of chloral taken by deceased could not by any possibility have caused death," although he allowed that chloral may have contributed indirectly to Rosa's death by hindering her mobility. Subsequently, others have suggested that chloral hydrate was the main cause of death: Clerke (1917), Forbes (1969, p. 92), Chapman (1998, p. 41), and Clark (2007, p. 126). Chloral was also implicated in Carrington's death, but autopsy results seem definitive that it was not a factor in his case.

[68]Carrington set up an annuity of £200 ($22 000) per year for his mother, forgave his brother David's debt, and bequeathed to the Royal Society and the Royal Astronomical Society £2000 ($220 000) each.

interred, in the family crypt in the South Metropolitan (now West Norwood) Cemetery in the London Borough of Lambeth (Keer, 2000). His grave marker bears the inscription "*Sic Itur Ad Astras*" (thus you shall go to the stars).

## 7. Retrospective

Today, Carrington is memorialized by the terms "Carrington Longitude" and "Carrington Rotation." Carrington Rotation 1 began on 9 November 1853 when Carrington established the prime meridian on the Sun. This coordinate system would pay an important dividend ~50 years later when Maunder (1905) used a stacked plot of Carrington rotations of geomagnetic storms to identify the 27-day solar rotation period in magnetic activity and convincingly argue that Earth's magnetic disturbances have their origin in the Sun.[69] The questions raised by Carrington's discoveries – latitude variation of sunspots over the solar cycle, differential rotation, and solar flares – are at the focus of key areas (*e.g.*, dynamo studies, space weather) of current research. Newton (1958, pp. 37–38), Maunder's successor at Greenwich and a pioneer in solar-terrestrial studies (Cliver, 1995), described "Spots on the Sun" as "a classic studied with feelings of admiration by all sunspot observers," and, in the clear eye of Agnes Clerke (1894, p. 144), Carrington was "a self-constituted astronomer, gifted with the courage and the instinct of thoughtful labour."

We can only speculate on what Carrington might have done had he received either the Oxford or Cambridge Observatory postings (*e.g.*, Franzl, 1999).[70] What we know for certain is that both of the tasks he undertook at Redhill were recognized by his peers for their excellence and that his solar work has stood the test of time.

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[69] Maunder's finding countered Lord Kelvin's 1892 Presidential Address to the Royal Society in which Kelvin, on the basis of a calculation of the amount of work the Sun would need to do to produce a moderate magnetic storm, famously ruled out a solar cause for geomagnetic storms (Cliver, 1994).

[70] Franzl (1999; p. 543) asks if Carrington might have anticipated some of Hale's discoveries.

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