In Nakamura, T., Orchiston, W., Sôma, M., and Strom, R. (eds.), 2011. *Mapping the Oriental Sky. Proceedings of the Seventh International Conference on Oriental Astronomy*. Tokyo, National Astronomical Observatory of Japan. Pp. 197-206.

THE LICK OBSERVATORY SOLAR ECLIPSE EXPEDITION TO JEUR (INDIA) IN 1898

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Abstract: Between 1889 and 1932 the Lick Observatory maintained a vibrant solar research program and sent a succession of expeditions to the far corners of the glove in order to observe solar eclipses and add to our knowledge of the solar corona and the chromosphere. These expeditions were major logistical exercises that relied mainly on visual, photographic and spectroscopic observations during the brief moments of totality.

In this paper we focus on the Lick Observatory's expedition to Jeur, India, arranged to observe the 22 January 1898 total solar eclipse, and discuss the personnel, their equipment and their observations. We then briefly view this very successful expedition in the context of the overall development of solar astronomy in India, which culminated in the founding of the Kodaikanal Observatory.

1 INTRODUCTION

At the time the Lick Observatory's great 36-inch refractor saw first light in 1888, the facility became a research department of the University of California, USA. The solar eclipse expeditions were an integral part of the Observatory's research strategy from early 1889 until 1932. This forced the Observatory's management to solicit funding, employ staff, and allocate valuable resources to the eclipse program. The solar eclipse expeditions themselves were financed almost entirely by philanthropy (see Pearson and Orchiston 2008).

Altogether, fifteen Lick Observatory solar eclipse expeditions were sent around the globe, and Figure 1 shows the locations of the various eclipse stations and the approximate paths of totality. The large circle indicates the station in India for the 1898 eclipse (ibid.).

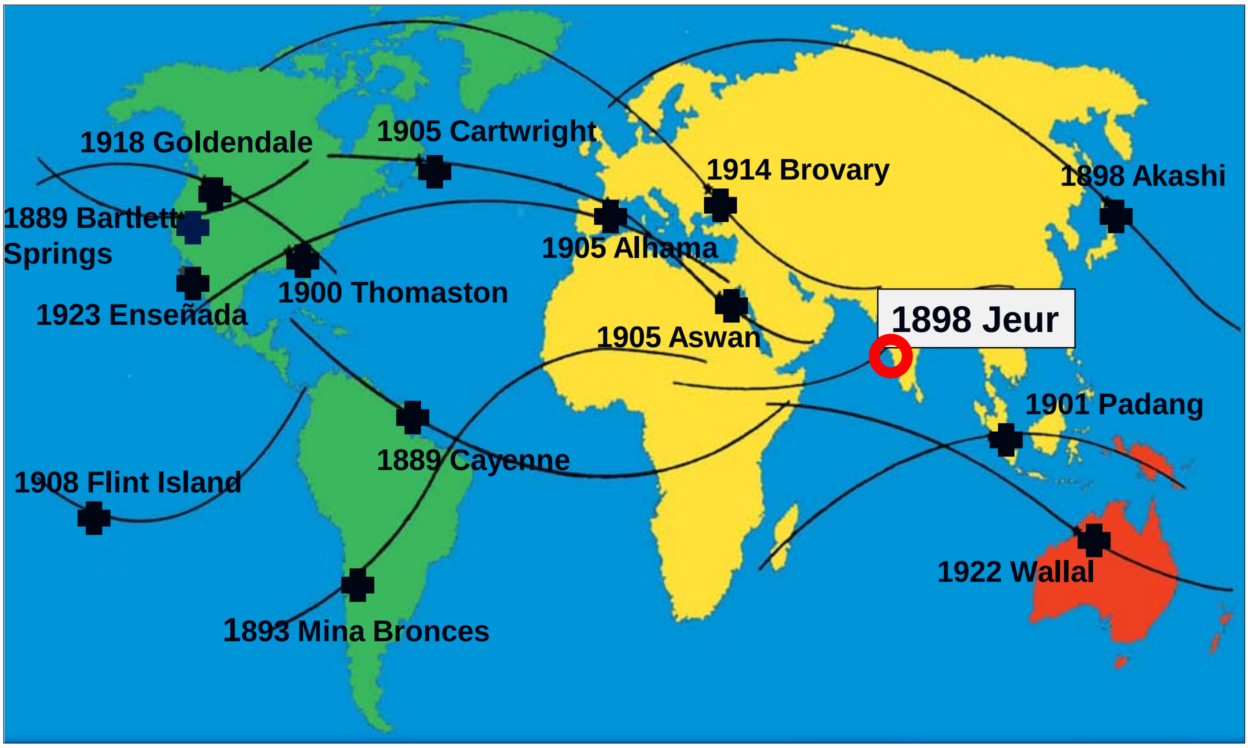


Figure 1: The paths of totality, dates and locations of the various Lick Observatory solar eclipse expedition stations. The Indian station, near Jeur, is indicated by the large circle.

2 CORONAL SCIENCE PRE-1898

From ancient to modern times, mankind has been awed, terrorized, and has paid religious homage to the apparition of a total eclipse of the Sun. The white apparition surrounding the Sun only seen during a total eclipse, known as the solar corona, gave the appearance of large wings and mystic forms. The Lick expeditions focused on the investigation of the corona.

Initially, knowledge of the solar corona, developed at a very slow rate, due to the rarity of solar eclipses. The frequency of solar eclipses was approximately one every eighteen months. Widely scattered about the planet, sometimes inaccessible due to location, and with no guarantee of clear skies, an individual astronomer might accumulate less than seventy-five minutes of useful observing time in the course of an entire lifetime (Campbell 1907: 1). Astronomers needed to generate permanent records in a very short time so that they could carry out a later analysis. The development of photography enabled them to do just that and in a more accurate way, than drawing allowed. Up to the end of the nineteenth century, drawing and photography coexisted together, with photography finally replacing drawing by the start of the twentieth century (ibid.).

It was not until the period of the Lick Observatory eclipse expeditions that a very detailed examination of the solar corona by photography became the norm (see Pearson et al., 2011). A good portion of these detailed studies were made possible by the use of the Schaeberle Camera (Pearson and Orchiston, 2008) and the advancement of photographic techniques developed at the Observatory by E.E. Barnard, S.W. Burnham, and J.M. Schaeberle (Pearson, 2009).

Pre-1898 and again the focus of the India expedition, the coronal science studies emphasis:

1. Schaeberle's Mechanical Theory of the Corona (Schaeberle, 1890a; 1890b; 1890c; 1891a; 1891b; Pearson and Orchiston, 2011).
2. Coronal form/structure.
3. Coronal composition.
4. Coronal brightness (see Figure 2).
5. Coronal motion.
6. The 'flash spectrum'.
7. The identity and precise location of the green coronal line.

Coronal studies of form and structural detail were made of the inner and outer corona. Some of these coronal forms took on the appearance of streamers, rifts, cusps, winged appendages, curves and other interesting shapes classified as 'disturbances'. Some coronal features were found in the vicinity of solar surface disturbances such as sunspots, flares and faculae. Coronal features were found to vary considerably in appearance according to their proximity to the solar equator and polar regions.

Coronal motion studies were made in order to explain the differences of coronal form. Other relationships were found to exist between the coronal streams of ejected matter and the rotation of the Sun. Measurements of the velocity of ejected matter from the photosphere and chromosphere were applied to the study of coronal form.

Coronal constitution studies were concerned with the particle-gas content and distribution within the inner and outer corona. Researchers made polarization studies of the corona in order to determine particle density and distribution by measuring reflected sunlight from particle content within the corona. Photometric studies of the corona were also carried out in a bid to measure the variability of brightness within the inner and outer corona.

3 THE 1898 LICK EXPEDITION TO JEUR, INDIA

3.1 Expedition Planning

Of the numerous United States Government, State and private observatories, the Lick Observatory under the directorship of Edward S. Holden, located in the state of California, was one of only two stations to mount an expedition to India. The second party, the small-scale Chabot University Observatory under Professor Burckhalter, came from Oakland in the near proximity of the Lick Observatory (Burckhalter 1898: 4). The Lick and Chabot staff had a very close working relationship with each other with Chabot often loaning their instruments to Lick's expeditions in time of need (Holden 1897a).

By 21 June 1897, Campbell still did not have a field expedition approved (Holden 1897b). Four days later the expedition was approved by the University of California Board of Regents. Holden asked R.S. Ball, President of the Royal Astronomical Society, to help obtain the necessary permissions and site arrangements in India (Holden 1897c). The English Government in India sent detailed meteorological reports. Banker magnate Charles F. Crocker, as for previously expeditions, funded the expedition at a cost of $1250.00 (Schaeberle 1897). This would be the first eclipse expedition that Mrs. Campbell accompanied her husband. She would maintain a lengthy diary of the trip, *In the Shadow of the Moon* which remains unpublished.

3.2 The Trip to India

On 21 October 1897 the expedition departed San Francisco onboard the steamer *China* for the trans-Pacific segment of the voyage to Hong Kong. After stopping in Honolulu, Hawaii, they arrived in Hong Kong after twenty-eight days at sea. *En route*, the Campbells spent many hours in their stateroom seasick, with their luggage sliding back and forth across the floor. In Honolulu the ship picked up 300 scantily-dressed Chinese passengers who gambled incessantly. The ship left in a festive mood for Yoko-

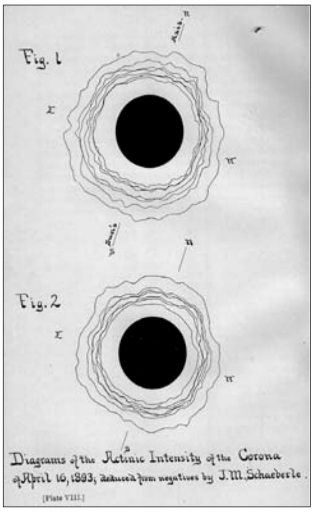


Figure 2: C.D. Perrine's 1,000-point contour mapping of coronal brightness from the 1893 coronal photometry (after Schaeberle, 1895).

hama, Japan, with seasickness returning for the duration of the voyage. After a train trip to Tokyo, Osaka and Mogi, the Campbells departed for Kobe, with Mt Fuji as a scenic back drop. Next visited were Nagasaki, Shanghai, and finally Hong Kong. They the boarded the P & O ship *Ancona* for the 17 day trip to Bombay,[1] India, stopping en route in Singapore and Colombo (Ceylon) before finally reaching Bombay, in India, on 10 December. By this time W.W. Campbell was feeling very ill from the 'rotten chow' (Campbell 1898a: 131-132, E.B. Campbell n.d., 1898: 1-64).

3.3 Establishing the Eclipse Station

In Bombay Campbell rounded up a small army of military and scientific volunteers, and soon became mired in logistical red tape. They learned that their intended destination of Karad, was closed due to the bubonic plague. Other parties sent by the British and Japanese were faced with the same issues as the Lick party (Maunder 1899). Campbell picked another site four miles from the railroad station at Jeur, where they were greeted by the local natives (Figure 3). He had a very difficult time rounding up more volunteer workers as the non-commissioned officers could not eat or sleep with the commissioned officers. The promised time signals for the establishment of the exact positional coordinates of the site did not materialize. When Campbell asked the station official for an accurate time reading to one second, the operator replied: "Why should he be so impatient over one second? There are plenty of seconds." (Campbell 1898).

Days were hot, typically in the mid-90s, with the nights in the low to mid-40s, giving a diurnal range of around 50º F.

Figure 3: The local inhabitants in Jeur meet the expedition party (courtesy: Mary Lea Shane Archives).

3.4 The Eclipse Instruments

Campbell roped off an area for the instruments (Figure 4) and set to work erecting the impressive-looking 40-foot Schaeberle Camera. From the Lick Observatory's 1893 eclipse expedition this camera had produced exquisite large-scale images on 18-inch by 20-inch glass plates of the eclipsed Sun, and its ability to reveal the complex form of the coronal matter was fundamental to the solar researcher's early understanding of the physics of the corona.

Figure 4: A scene showing the Lick Observatory party ready for the eclipse. All of the instruments are in place and the volunteers are at their practice stations. The 40-foot Schaeberle Camera with its twin wooden towers dominates the scene.

Campbell had selected the originally eclipse station site using contour maps to locate a suitable hill for the camera, but the terrain was flat at the new site so Campbell (1898a: 133) came up with the original idea of supporting the Camera's primary lens and tube cover with two isolated wooden towers.

The local natives were amazed at Campbell's ability to work hard. Mrs Campbell noted in her diary: "He is working from before dawn till after the sun has left the sky. Stones that four men cannot move, he lifts with ease. And he is never tired!" On flat ground, Campbell set forth to build the two towers needed to raise the objective lens and tube of the Camera to an altitude of nearly 51°. He initially lacked materials and skilled labor to construct them and figured that he would have to do everything himself that needed accuracy. Teak lumber and nails, for the towers, were obtained from the Indian city of Poona which was 100 miles away. Campbell (1898a: 134-135) did the work, himself, erecting the towers after he fired the local lead worker. The diagonal-braced wood tower frame measured 12 feet square at the bottom and tapered to 14 inches square and inclined at the top. The tube end was held in place by iron pins driven into the ground. The tube was further anchored with a system of duplicate wire cables. A 9-foot rock wall surrounded and anchored the bottom of the tower. The 5-inch aperture Clark primary lens was fastened to a plank at the top of its separate wooden tower. The south, north and east faces of the outer tower were completely covered by a large canvas sheet from above the lens to the bottom of the rock wall. Despite strong winds the optical system remained vibration free. The day before the eclipse, Campbell discovered that an animal had bumped into or someone had tampered with the plate guiding tracks and clock mechanism, so he had to spend valuable rehearsal time re-adjusting the affected parts. To prevent any further disruption, that night the eclipse camp was placed under guard (Campbell 1898a: 136-137).

Figure 5: Campbell's moving plate spectrographs as they appeared in 1905, showing one of the gas-driven pistons that moved the plate-holder in order to obtain a continuous recording of the coronal spectrum throughout totality (courtesy: Mary Lea Shane Archives).

Other cameras represented a range of focal-lengths, and provided very wide to moderately long field of views. There were two notable cameras among the array of instruments used: (1) the 5-inch aperture, 33-inch focal length Pierson Dallmeyer Camera, which was basically a high quality portrait lens camera; and (2) the Floyd photographic telescope of 6-inches aperture and 67-inches focal length (Schaeberle 1893). The first camera provided plates from which sky brightness measurements could be made, while the plates from the Floyd camera were ideal for the study of overall coronal form.

In addition to the photographic program, the 1898 eclipse was also to be the subject of spectroscopic analysis. Altogether there were four spectrographs, and Campbell designed three of them, which for the first time used moving plate-holders (see Figure 5). Three spectrographs were for recording the spectrum of the solar limb continuously. One of the spectrographs featured a Rowland grating. C.A. Young of Princeton University loaned a train of four compound prisms for the spectrographs which were used to assemble a one prism spectrograph and a six prism spectrograph. The six prism spectrograph would record the bright coronal green line at 1474 K in an attempt to measure the displacement of the bright line due to motion in the line of sight, and to determine the rate of rotation of the corona for the first time. The Bruce spectrograph from the Observatory's Crossley Telescope rounded out the spectrographic array. A clock driven equatorial mounting made of shipping crates that rotated on steel pivots carried five of the instruments (Campbell, 1898a: 127-131). Driving clocks for the instruments were loaned by W.J. Hussey and L.C. Masten (Campbell 1898b).

3.5 The Scientific Staff and Volunteers

As with previous Lick Observatory eclipse expeditions, the successful observation of the Indian eclipse depended to a large extent on the input of volunteers. W.W. Campbell led the expedition with Mrs Campbell and Miss R. Beans as official American volunteers, but between 17 and 21 January highly-qualified locally-sourced volunteers arrived at the eclipse station and began practising their assigned duties. The list of personnel included: Captain H.L. Fleet, R.N. who was in charge of Her Majesty's marine forces in Bombay Harbor; Royal Navy Lieutenants Kinehan, Mansergh and Corbett; Major Boileau and Mr Garwood from the Royal Engineers; the Reverend Dr J.E. Abbott, who was one of Professor Young's former Dartmouth College student; Major S. Comfort, the U.S. consul at Bombay, and Mrs. Comfort (see Figure 6).

Figure 6: The Campbells and the volunteer instrument operators (courtesy: Mary Lea Shane Archives).

3.6 Schedule of Solar Science Observations

The expedition focused on obtaining spectrograms of chromospheric, reversing layer and coronal spectra. Campbell (1897) wanted to test whether H, K or hydrogen lines were truly coronal, or whether they diffused from the chromospere and prominences. He also wanted to find if the lines were due to diffusion, as this would apply to Deslandre’s rotation of the corona theory. This was an important development as the Observatory had not attempted eclipse spectroscopy since the January 1889 eclipse.

In contrast, the direct coronal photographic program would continue as at previous eclipses. Brightness studies of the corona would be conducted with photometry of selected standardized plates.

3.7 Eclipse Day

Eclipse day arrived with perfectly calm and clear weather conditions. All natives and non-participants were kept away from the stations by the Government of India (Campbell 1898a: 137-140). The eclipse had began at sunrise in central Africa with the path heading northeast across India to end at sunset in Mongolia. The eclipsed Sun at an altitude of 51° saw 2nd contact at 00 h 59 m 14.8 s and 3rd contact at 01h 01 m 15.0 s, Local Mean Time. 1st and 4th contacts were not recorded (Campbell 1900a). Totality lasted for a rather short 01 m 59.5 s.

Captain Fleet at the Schaeberle Camera called out the traditional ‘Go’ signal at 2nd contact. Volunteers, Captain Fleet and Engineer Garwood, operated the camera having practiced the plate loading, timing of the plate exposures, and plate removal many times. Captain Fleet began the 1st exposure at exactly the moment of 2nd contact. There was a small area arranged for the two operators to escape and view the eclipse directly during the longer exposure, but they did not leave their stations at the plate holder. The rest of the eclipse party carried out their observations in a calm professional manner. According to Campbell (1898a: 139), “It is plain that no astronomer was ever more ably assisted by volunteer observers.”

Figure 7 (left): A coronal image made with the 40-foot Camera in 1898 (courtesy: Mary Lea Shane Archives).

Post eclipse, the plates were processed. The chemical plate developer formula had to be altered to accommodate the extreme range of temperatures from 93° F in the daytime to a cold 42° F at night and to allow for the humid climate (Campbell 1898a: 139). The plates were processed at night in moments of cool weather, and Campbell (ibid.) judged all of the negatives to be successful for their intended area of study. A print of one of the exposed plates is reproduced here in Figure 7.

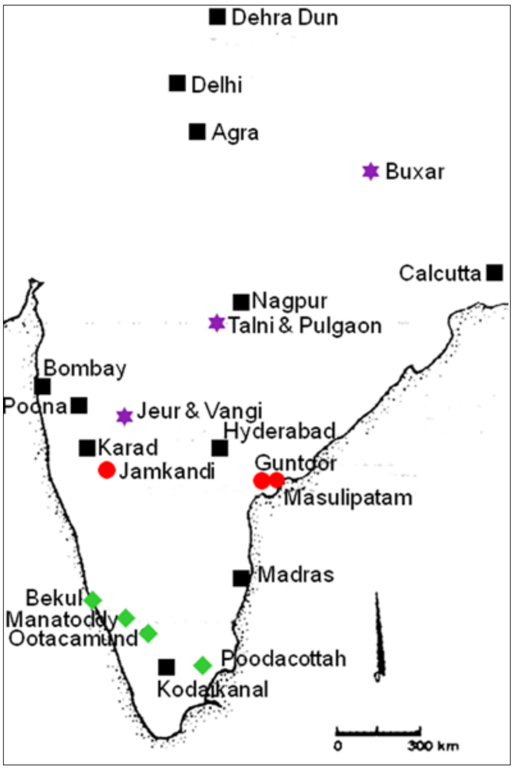


Figure 8 (left): Map of India showing localities mentioned in the text. Eclipse key: dots = 1868 eclipse; diamonds = 1871 eclipse; stars = 1898 eclipse.

3.8 The Observations and Scientific Results

Campbell (ibid.) described totality: "… it is impossible to describe the beauty of the Sun's surroundings. The corona was exquisite more beautiful by far than anything else we saw in a journey around the world." (cf. Figure 7).

From selected plates, he found a unique feature of streamers beautifully displayed with streamer hoods inclosing the prominences. There are no published reports that coronal structure analysis was conducted, even though a full range of cameras was employed. Addressing the issue of coronal motion, Campbell (1898c) found:

> All the evidence given by the prominences leads to the conclusion that this matter is in rapid motion and that instead of rising from the sun's surface in irregular masses, the structure is must as definite as is found to be the case in the coronal streamers. In other words, very prominence and protuberance visible during this eclipse was made of individual streams of matter apparently moving in elliptical orbits with the prominence at one of their foci.

In the spectrographic report there is mention of enclosed 'hoods' around the principal prominences. A strange series of 5303 λ line masses existed and were uniformly distributed in the equatorial region on either side of the Sun, but the 40-foot Camera plates did not reveal a correlation between these masses and prominences or curved streamers. Campbell wondered (1900b: 229-232) what forces might be at work and brought to the table the idea that radiant pressure may have been present.

Campbell's measurement of the wavelength of the coronal green line agreed closely with the value published by Norman Lockyer (Campbell 1899), but the spectrographic plates failed to provide him with information about the rotation of the solar corona (ibid.).

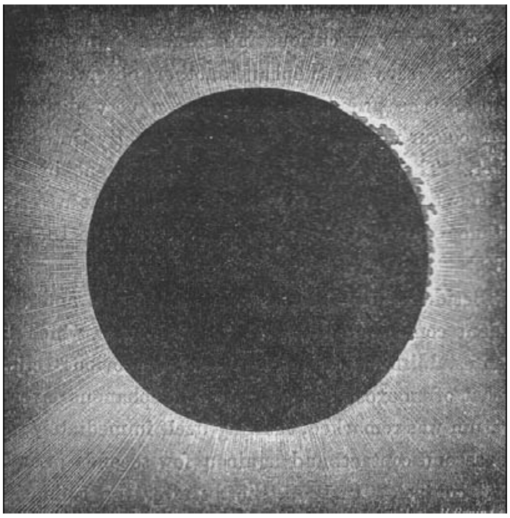


Figure 9 (left): Tennant's sketch of the Sun and the corona during the 1868 eclipse (after Guillemin, 1870: 251).

After the eclipse, the expedition members packed up all of their equipment and the collection of plates. The plates were then sent home via Hong Kong on the stream ship *Socotra*, while the Campbells separated from the rest of the eclipse party and before setting off on a world tour visited Delhi, Agra and the Himalayas. They then stopped off at the observa-tories in Cairo, Rome, Florence, Milan, Nice, Paris, Green-wich, Tulse Hill, Kensington, Cambridge, Oxford and Williams Bay before finally returning to the Lick Observatory (ibid.).

4 DISCUSSION AND CONCLUDING REMARKS

While scientific astronomy has a long history in India (see Kochhar, 1991; Kochhar and Narlikar, 1994), solar astronomy was a phenomenon of the second half of the nineteenth century, when total solar eclipses in 1868, 1871 and 1898 attracted the attention of overseas and Indian-based astronomers. All three eclipses occurred at a time when the introduction of the spectroscope led to important advances in coronal science and India would play a pivotal role in these developments.

The 1868 eclipse has a special place in astronomical history, as explained by Agnes Clerke (1893: 209; our italics):

> In the year 1868 *the history of eclipse spectroscopy virtually began* … On the 18th of August 1868, the Indian and Malayan peninsulas were traversed by a lunar shadow producing total obscuration during five minutes and thirty-eight seconds. Two English and two French expeditions were dispatched to the distant regions favoured by an event so propitious to the advance of knowledge, chiefly to obtain the verdict of the prism as to the composition of prominences.

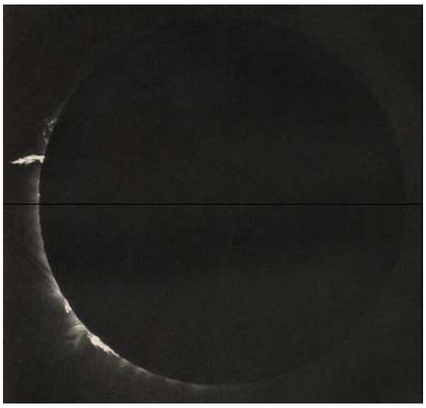
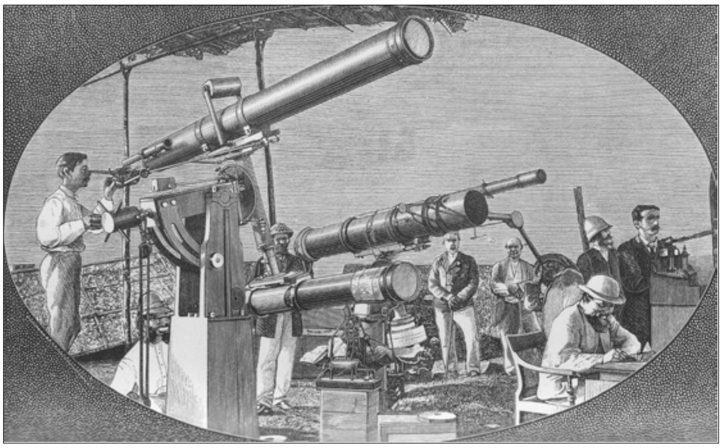


Figure 10 (right): One of Tennant's photographs of the 1868 eclipse showing prominences and the 'Great Horn' (after Tennant, 1869: Plate 5B).

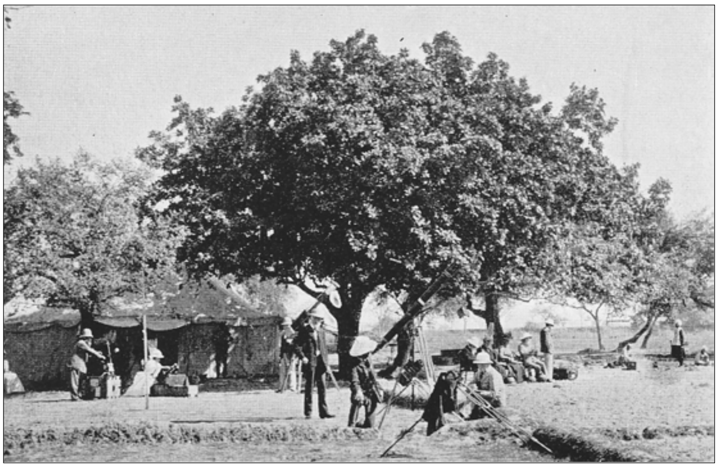
One of the British expeditions to India was mounted by the Royal Astronomical Society and led by Major J.F. Tennant (1869). They were based at Guntoor (see Figure 8 for Indian localities mentioned in the text) and successfully carried out photographic, polarisation and spectroscopic observations (see Orchiston et al., 2006.). The second British expedition to India, based at Jamkandi, was led by Lieutenant John Herschel from the Indian Trigonometrical Survey. They used equipment supplied by the Royal Society and also succeeded in observing the eclipse (see Herschel, 1869). There was also a local professional observing party which successfully observed the eclipse. This was led by Madras Observatory Director, Norman Pogson, and was based at Masulipatam, on the east coast, near Guntoor (Ranyard, 1879). The sole French eclipse expedition to India was led by the celebrated Jules Janssen (1824–1907; see Launay, 2008), and also was based at Guntoor, less than a kilometre to the west of Tenant's compound. Janssen (1868) and his team also succeeded in observing the eclipse.

Figure 11 (right): Some of the instruments at Bekul ready for the 1871 eclipse(after Lockyer, 1874: f343).



During the 1868 eclipse, apart from an obvious corona (Figure 9), a remarkable feature of the eclipsed Sun was the 'Great Horn', a massive prominence that extended ~142,000 km beyond the solar limb (see Figure 10). Collectively, the Indian observations of this eclipse confirmed the solar nature of the corona and showed that it shone by reflected sunlight. They also established the gaseous composition of the prominences and revealed emission lines associated with hydrogen, magnesium and helium (although this last-mentioned identification only came later, through Janssen's efforts). Meanwhile, while at Guntoor, Janssen demonstrated that spectroscopic investigation of prominences was possible outside of eclipse, thereby initiating an important new methodology in solar observational astronomy. By a strange coincidence, quite independently the very same idea occurred to both Norman Lockyer and William Huggins in England (see Meadows, 1970).

Figure 12 (right): Part of the BAA eclipse camp at Buxar with various instruments being readied for the 1898 eclipse (after Maunder, 1899: 42).



Having another total solar eclipse that was also visible from India so soon after the success of the 1868 event meant that overseas expeditions again flocked to India in 1871. With the aid of British Government funding, Lockyer (1874) led a team of nine astronomers, who carried out successful observations from Bekul, Poodocottah and Manatoddy in India and two sites on the neighbouring island of Ceylon (now Sri Lanka). This ambitious expedition (e.g. see Figure 11) attracted general attention back in England, where it featured in the pages of *The Illustrated London News* (see The eclipse expedition …, 1872). The well-known Italian astrono-

Figure 13 (left): The BAA eclipse camp at Talni in 1898 (after Maunder, 1899: 15).

mer, Lorenzo Respighi was also based at Poodocottah (Janssen, 1873). As might be anticipated, this eclipse also attracted Herschel and Tennant (1875), who joined forces and carried out successful observations from Dodabetta Peak near Ootacamund (see Figure 8). Nor could the Madras Observatory miss this fine opportunity, and it mounted a successful eclipse expedition, using an observing site at Avenashi, which was also near Ootacamund. Meanwhile, Jules Janssen (1873; cf. Launay 1997) also returned to India, and recorded the eclipse from the village of Sholur in the Nilgiri Hills near Ootacamund (Mahias, 2010). Results from all of these Indian observations of the 12 December 1871 total solar eclipse consolidated those obtained in 1868, although one new area of special interest was the investigation of the coronal green line at 1471 K, which Young had discovered during the 7 August 1869 eclipse and assigned to 'coronium' (Maunder, 1899). The 1871 total solar eclipse therefore built on India's reputation as a place that could contribute in a meaningful way to solar science.

The 1898 solar eclipse offered India one final opportunity to build on the legacy established in 1868 and 1871 and contribute to the rapidly-accumulating international knowledge of the solar corona. Apart from the Lick Observatory's venture, various overseas expeditions headed for India. The British Astronomical Association (BAA) mounted an ambitious expedition, using two observing sites, and in a copiously-illustrated 184-page book, Edward Maunder (1899) provides a detailed account of this venture by some of Britain's leading amateur astronomers (e.g. see Figures 12 and 13). One of the BAA camps was at Talni (see Figure 8) where Maunder and John Evershed carried out spectroscopic observations (Maunder, 1899: 4-28), while the other was at Buxar (Figure 8) where successful photographic observations were made (Maunder, 1899: 31-46). Just 9.5 km from Talni, at the site of Pulgaon, the British Government party led by Captain Hills and Mr Newall carried out successful spectroscopic observations (Hills and Newall, 1898), while the Astronomer Royal of Scotland, Dr Ralph Copeland, made his observations from the site of Ghoghlee, 16 km north-west of Nagpur (Copeland, 1898). At Jeur three other parties were sited near to the Lick Observatory eclipse camp. Immediately adjacent to the Lick astronomers was a group from the College of Science in Poona (Figure 14) under Professor Naegamvala (1902), and just 90 metres from them was the Japanese team from Tokio University led by Professor Terao (see Terao and Hiryama, 1910). A little further away, adjacent to the village of Vangi, was a U.S. party from Chabot Observatory which was led by Professor Burckhalter (1898). All carried out successful observations, and one of the notable successes during this eclipse was the photographs taken of the flash spectrum (e.g. see Figure 15). Although this unusual spectrum was first observed during the 22 December 1870 eclipse by Professor Young, the first successful attempt to photograph it only occurred in 1896 (Maunder, 1898), and the images of it obtained during the 1898 Indian eclipse marked a major advance.

When combined with the excellent daytime seeing condition that typified parts of the Indian Subcontinent, the cumulative effect of the 1868 and 1871 solar eclipse expeditions on Indian astronomy was profound, and led to the establishment (with aid from the Solar Physics Committee in England) of a solar observatory at Dehra Dun, in northern India, in 1878 (Kochhar, 1991). It was hoped that regular solar photography would aid our understanding of the Sun and its role in the monsoonal weather patterns, which was vital for the survival of rural and urban communities in India. Solar photography continued at Dehra Dun until 1925 (Kochhar, 2002).

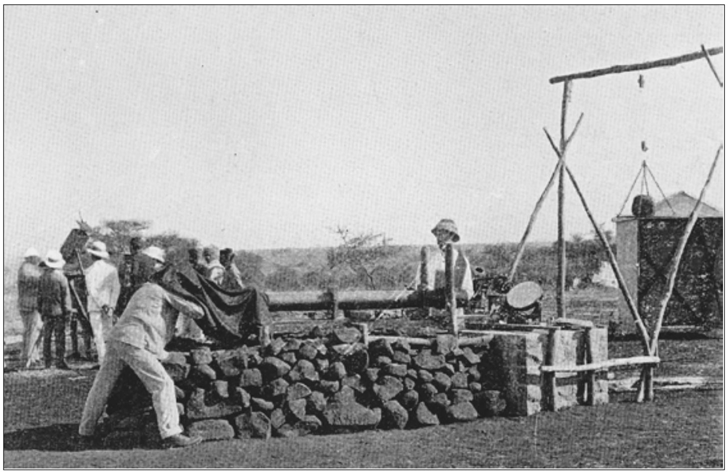


Figure 14 (left): Professor Naegamvala's horizontal photographic telescope at Jeur in 1898 (after Maunder 1899: 81).

However the foundations of a more permanent solar facility rested on the initiative of those at the Madras Observatory, and

> At the Indian Observatories Committee meeting of July 20, 1893 with Lord Kelvin in the Chair, the decision was taken to establish a Solar Physics Observatory at Kodaikanal with Michie Smith as Superintendent … The observatory was to be under the control of the Government of India … (Bappu, 2000: 105).

This was the genesis of the Kodaikanal

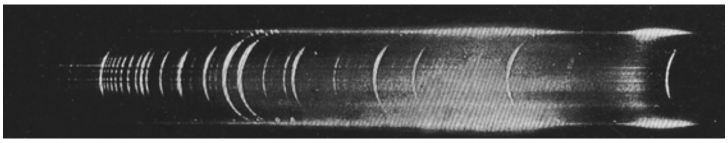


Figure 15: Example of one of the photographs of the flash spectrum obtained by BAA observers in 1898 (after Maunder, 1899: 73).

Observatory (Figure 16), which formally came into existence on 1 April 1899 and since 1901 has continued to make a valuable and ongoing contribution to solar physics (see Bappu, 2000; Kochhar, 2002). The Kodaikanal Solar Observatory is now owned and operated by the Indian Institute of Astrophysics.

Figure 16: The original building at the Kodaikanal Observatory.

5 NOTES

1. In this paper we have adopted the original spelling of Indian place names as used in the nineteenth century. Some of the places shown in Figure 8 now have new spellings (e.g. Bombay is now Mumbai).

5 ACKNOWLEDGEMENTS

We are grateful to Dorothy Shaumberg from the Mary Lea Shane Archives at the University of California for access to archival records relating to the Lick Observatory solar eclipse expeditions and for making available photographs reproduced in this paper. We also wish to thank Dr Francoise Launay (L'Observatoire de Paris) and Peter Hingley (RAS Library) for kindly supplying references relating to Jules Janssen and Ralph Copeland, respectively, and Dr Mitsuru Sôma for funding assistance that made it possible for one of the authors (W.O.) to attend ICOA-7.

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