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NOTES FOR THE OBSERVER

by T. P. Prabhu

1. Site testing for an astronomical observatory

The astronomial site testing was begun in the nineteenth century by the British astronomers who have always had extremely unfavourable weather for optical observations in the United Kingdom. William Lassell transported his 24-inch equatorially-mounted Newtonian reflector to Malta in 1852 seeking clearer and stiller skies. Piazzi Smyth visited Teneriffe in 1856 with the same objective and found it an extremely good site. Site survey in America began with James Lick's choice of Mount Hamilton for the observatory for which he left behind a generous endowment. In India, N. R. Pogson proposed in 1882 an observatory in the Palni Hills, and tests were conducted at Kodaikanal and Kotagiri by Michie Smith in 1882 and 1892.

The principal requirement of a site for optical astronomy is a good number of clear, dark and still skies over the year. The requirements of an infrared astronomical site are also similar, with an additional constraint of low atmospheric water vapour content. The number of clear days over the year can be assessed from the weather information over several years available from the nearest meteorological observatory, supplemented by the recent data from weather satellites. The major factor influencing the sky brightness in the present century is the contamination by city lights. Thus an astronomer is forced to set up an observatory sufficiently far from the cities and towns that are likely to expand in the near future. This requirement is offset by the problems of logistics and communication which demand that the observatory be not too far from a city. The stillness of air, which gives rise to good seeing, depends on local orography and can be ascertained by detailed astronomical observations over an extended period.

Detailed site surveys made at different parts of the world have indicated that the best sites are on isolated mountain-peaks near coasts with cold off-shore currents. The sites at Mauna Kea, Teneriffe, La Palma and Cerro Tololo are considered some of the best sites in the world. Site surveys conducted in India by J. Evershed (1915), M. K. V. Bappu (1959-1975) and a preliminary study by A. Bhatnagar (1974) show that the general conclusions reached elsewhere in the world may not hold good in the Indian subcontinent. Whereas the maximum cloud-free skies are encountered in Rajasthan desert, the dust blown in from the desert makes the visibility poor. Aurangabad plateau also suffers from ground haze due to high aerosol content. The best astronomical sites in India lie along the lower Himalayas and the eastern slopes of the Western ghats. Isolated peaks in the dusty areas (Mount Abu, Pachmarhi) are also fairly good sites.

After a few possible sites have been selected based on the weather data, it is necessary to carry observations with at least a small telescope over a length of time before the advantages of a site are established. These observations should include—apart from the data on cloud conditions—the determination of seeing, sky transparency and sky brightness at regular intervals over each night of the year. Though a six inch telescope is sufficient for this purpose, if a telescope in the 12-inch to 24-inch range is installed temporarily, and equipped with a photoelectric photometer, useful astronomical information may also be obtained in addition to accurate data on the sky conditions at the site. The seeing can be estimated by ascertaining the observability of double stars separated by 1–5 arcsec. If the eyepiece of the telescope is equipped with calibrated crosswires, one may even use single stars for an estimate of seeing.

In the following are described two simple photometers for evaluating the sky background, one for use in the night and another during the daylight.

R. T. Patel & P. V. Kulkarni from Physical Research Laboratory, Ahmedabad, report :

We have constructed a very convenient portable and compact instrument giving quantitative measurements of the brightness of night sky. The 'sky brightness photometer' (figure 1) is assembled in a cylindrical tube 48 cm long and 7.5 cm in diameter. F is a screw-in interchangeable filter, L_1 an achromatic objective of 190 mm focal length and 65 cm diameter, and A an interchangeable aperture. The aperture needs to be cut on a precision machine and its diameter accurately measured, at it directly enters the calculations. ME is the mirror eyepiece assembly with catch-balls for positioning, allowing the star to be seen through the aperture. When this assembly is pulled out, the starlight falls on the Fabry lens L_2. This is an achromat with focal length 38 mm and diameter 18.5 mm. P is an EMI 7758 photomultiplier tube with S-type cathode and very low dark current. At the base of the photomultiplier on a card C a dc-dc converter circuit supplies 1000V dc to the resistor chain of the photomultiplier. J_1 is the jack giving 3V dc to the dc-dc converter from a battery box BB having two ordinary 1–5V torch cells. Output of the photomultiplier (anode current) comes through J_2, a well insulated, shielded miniature connector, and is directly given to a digital mutimeter having the range of measurement 10nA to 100mA dc. The cylindrical photometer can be conveniently mounted on a sturdy photographic tripod stand, so that pointing to any star becomes very easy.

The measurements of anode current are made by (i) centering the aperture on a star, and (ii) placing the aperture on adjacent star-free region of the sky. If these two values are denoted by A_1 and A_2 respectively, the total brightness of the star and sky would be proportional to A_1 and the brightness of the sky to A_2. Thus the ratio of brightness of star to that of the sky would be proportional to $(A_1 - A_2)/A_2$. Expressed on a magnitude scale, we have,

$$m_{\text{sky}} - m_* = 2.5 \log (A_1/A_2 - 1).$$

If the diameter of aperture is d and the focal length of the objective f, the diameter of the aperture in arcsec is

$$d'' = 206,265\, d/f.$$

The surface brightness of the sky can then be expressed in mag arcsec^{-2} as

$$\begin{aligned} m_{\text{sky}} &= 2.5 \log (A_1/A_2 - 1) + m_* + 2.5 \log (\pi d''^2/4) \\ &= 2.5 \log (A_1/A_2 - 1) + m_* + 5 \log d'' - 0.26. \end{aligned}$$

We have employed a V filter of peak wavelength 5050 Å, halfwidth 800 Å, maximum transmission 50 per cent and diameter 51 mm, and an aperture of diameter 4 mm. The average sky brightness at Gurushikhar site (near Mount Abu) on the night of 1981 December 25 was measured as $m_v = 20.7$ mag arcsec^{-2}.

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Jagdev Singh from Indian Institute of Astrophysics, Bangalore, writes :

The prime requirement for solar coronagraphic observations is that the atmosphere scatter the light of the sun to a minimal extent. The major difficulty encountered

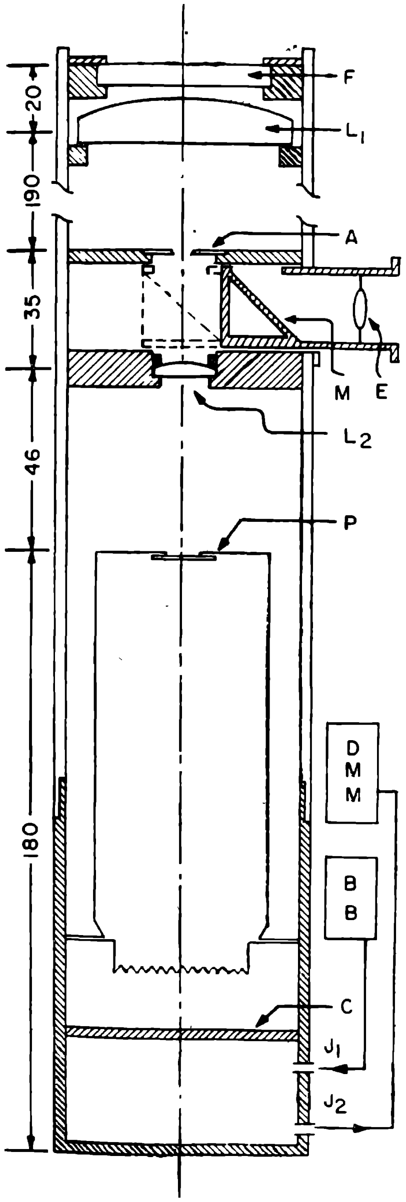

Figure 1. Night-sky brightness photometer constructed at Physical Research Laboratory, Ahmedabad. All dimensions are in millimetres.

in the measurement of sky brightness around the sun is due to the scattering of light within the instrument at the edges of the diaphragm, or by the dust on the lens and so on. This problem becomes particularly acute on mountain sites where the brightness of the sun is about 10^5 times the brightness of the surrounding sky. Hence such a photometer needs to be constructed with the same care as one takes in the construction of Lyot's coronagraph. One such photometer has been described by D. S. Evans (1948, *J. Opt. Soc. Am.* **38**, 1083). The principle of this photometer is shown in figure 2. An aperture A_1 is placed in the shadow of a disk O_1 which occults the sun. The lens L_1 forms an image of the sky around the sun at the position O_2 around another disk ; the light rays are folded by a glass plate M which is darkened to reduce the intensity of the image. The lens L_2 forms an image of the sun on the disk O_2 which is painted white for diffuse reflection. The two images formed at O_2 are viewed through the aperture A_2 behind the eyepiece L_3. A continuously varying density wedge D placed in front of L_2 is adjusted until the two images appear equally bright. If the transmission t_D of the density wedge is known, the brightness of the sky around the sun B can be calculated in terms of the brightness of the sun B_0 by the formula

$$B = \alpha B_0 \, t_D,$$

where α is an instrumental constant given by

$$\alpha = \frac{\phi^2 r_2 \cos \beta \, t_2}{t_1 r_m}.$$

Here ϕ is the angular radius of the sun in radians, β the angle of incidence of sunlight at O_2, t_1 and t_2 the transmission of the lenses L_1 and L_2, γ_2 the diffuse reflecting power of O_2 and r_m the reflecting power of M. In practice, α is determined in the laboratory by looking at a uniform source of light, which implies $B = B_0$ and $\alpha = t_D^{-1}$.

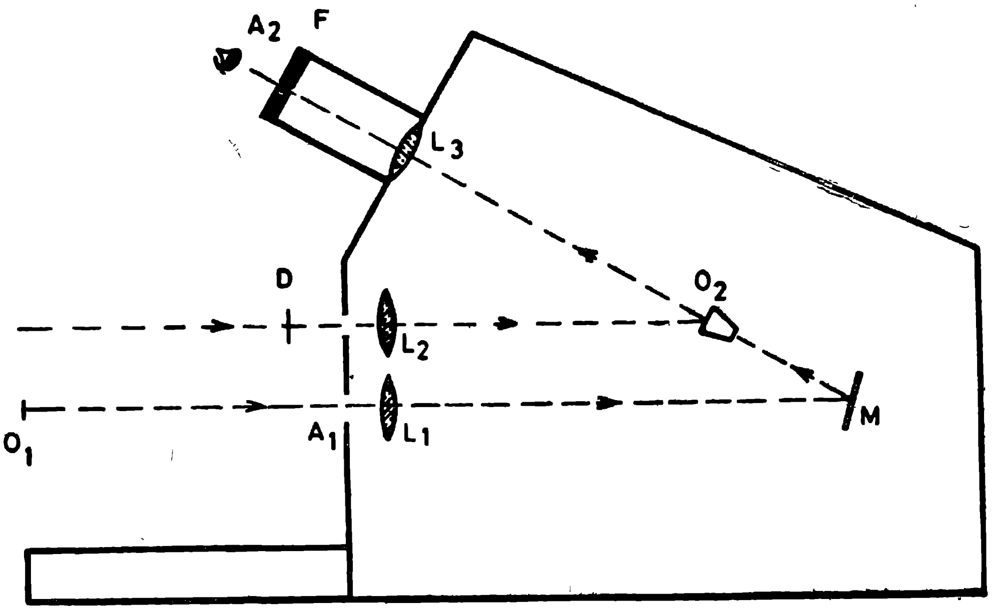

Figure 2. Evans' sky photometer.

2. Hypersensitization of astronomical emulsions

The low-intensity reciprocity failure of photographic emulsions has been a severe handicap in astronomical applications. When the photons arrive at a slow rate, the rate of production of electron-hole pairs would be low and consequently, a developable silver speck does not form efficiently. Several methods have been developed to increase the sensivity of astronomical emulsions. These methods are collectively known as the methods of hypersensitization. Since the gain resulting from hypersensitization reduces during storage and the storage increases the background chemical fog, it has not been possible for the manufacturers to supply hypersensitized plates to the users. Consequently, it is imperative for the astronomers to hypersensitize their plates themselves prior to exposure in order to use the emulsions most efficiently.

Some standardization of hypersensitizing procedures is necessary in order to derive maximum benefit from the technique and also to intercompare the performances of different observatories. A few standard terms used are the following.

Speed of an emulsion is defined as the exposure ($E = I \times t$) in photons per 1000 μm^2 at a given wavelength and specified exposure time required to reach a specified density above chemical fog. The standard density is 0.6 on the diffuse scale. *Gain factor* is the ratio of the speeds of hypersensitized and unhypersensitized emulsions. *Input signal-to-noise* is the signal-to-noise ratio for the light incident on the photographic emulsion. Since the photon noise is $\sigma_E \propto \sqrt{E}$, $(S/N)_{in} = E/\sqrt{E} = \sqrt{E}$. *Output signal-to-noise ratio* is the S/N derived from a photographic exposure. $(S/N)_{out} = E/\sigma_E = E/(\sigma_D.\ dE/dD)$. The value of dE/dD can be obtained from the characteristic (H — D) curve. The slope of the curve (γ) is defined by

$$\gamma \equiv \frac{dD}{d(\log E)} = \frac{dD}{0.4343\, d(\ln E)} = \frac{E}{0.4343}\ \frac{dD}{dE}\,.$$

Hence $(S/N)_{out} = \frac{E}{\sigma_D} \cdot \frac{0.4343\,\gamma}{E} = \frac{0.4343\,\gamma}{\sigma_D}$. *Detective quantum efficiency*, which describes the efficiency of a detector is defined by

$$\mathrm{DQE} = \left\{\frac{(S/N)_{out}}{(S/N)_{in}}\right\}^2 .$$

Pre-flashing

Exposing the emulsion to a uniform low-intensity light prior to the actual exposure is an easy way of increasing its sensitivity. The idea here is to supply the threshold energy needed for the photographic action, so that the final exposure is easily registered. The preflash density is generally limited to 0.2 D. This technique increases the background and reduces the contrast. The increase in the background has the effect of reducing the signal-to-noise ratio. The total exposure E_T is the sum of object exposure E_S and the background E_B. Hence the object S/N is given by

$$(S/N)_{obj} = \frac{E_T - E_B}{\sigma_{E_T}} = \left(1 - \frac{E_B}{E_T}\right)\frac{E_T}{\sigma_{E_T}} = \left(1 - \frac{E_B}{E_T}\right)\frac{S}{N}.$$

Thus, if the background exposure is a substantial fraction of the total expoure, there is a high degree of reduction in $(S/N)_{obj}$. Hence pre-flashing is used only when the other methods of hypersensitization are not possibe, and further, only when input (S/N) is large.

Evacuation and baking

Efficient hypersensitizing techniques involve removal of oxygen and water vapour from the emulsion. A variant of the method is exposing the plate at a temperature below 0 C which freezes the moisture in the emulsion, reduces ion mobility and results in a stable latent image. However, the condensation of water vapour from the atmosphere makes the design of a cooled plate-holder complicated. Hence outgassing by evacuation and/or baking in an inert atmosphere prior to exposure has become a more popular technique of hypersensitization.

Evacuation at $4-5 \times 10^{-4}$ torr for a few hours removes oxygen and water vapour efficiently. Higher vacuum may have a bad effect on the gelatine. If the exposure is made in vacuum or dry atmosphere, better results can be achieved. Evacuation is normally done in combination with the baking technique.