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Observations of the 1983 Total Solar Eclipse in Java, Indonesia

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ABSTRACT

The total solar eclipse of June 11, 1983 was successfully observed by the Shiga University Expedition at a small village, Purworejo, in the suburb of Jogyakarta. By utilizing 4 sets of 8 cm refractors as principal facilities, the following 7 themes of observations were carried out to obtain (1) a multi-exposed color photograph for recording the whole phase of the eclipse, (2) direct color pictures of the corona and prominences, (3) direct images of the sun's disk before and during the partial phase, (4) enlarged pictures of the corona in white light, (5) direct pircutures of the corona in polarized light, (6) flash spectra of the chromosphere, and (7) Hα monochromatic images of the chromosphere and prominences.

In addition to these astrophysical observations, meteorological observations were also performed to record temporal variations of several fundamental quantities, such as the global solar radiation, the atmospheric temperature and pressure, the soil temperature, and the wind direction and velocity. The instrumentations, the methods and the preliminary results of these observations are presented with brief discussion.

1. Introduction

As well known, total solar ecipses provide excellent opportunities for the investigation of upper solar atmospheres such as the chromosphere and the corona. For this reason, a number of eclipse observations have been carried out by a variety of expeditions. The author has also made several times of eclipse observations by taking part in the Kwasan and Hida Observatories expedition sent from Kyoto University: for instance, to the South Pacific in 1965, to Mexico in 1970 and to the West Africa in 1973. The results of these observations have already been published by

*The expedition was composed of 28 persons in total. However, the systematic observations here described were carried out by the following 16 members: Tokio Tsubaki (leader), Hidehito Yamamura (chief), Kouichi Maeda (d°), Hisao Egawa (d°), Masaru Yamashita, Noritaka Tomoda, Yasuo Tsutsumi, Hiroteru Ito, Tohru Tsuda, Shuichi Kinoshita, Akira Kotani, Kunio Taniguchi, Takashi Yasui, Toyoko Yamamura, Masako Maeda, and Takiko Egawa. Among them, 13 members were school teachers mostly graduated from the Department of Earth Science, Shiga University.

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Tsubaki et al. (1971), Kanno et al. (1971), Tsubaki (1971), Kurokawa et al. (1974), Kanno et al. (1974), Trigoso and Tsubaki (1986), and Hanaoka et al. (1986).

The 11 June 1983 Indonesian eclipse was one of the most hopeful total solar eclipses both in astronomical and meteorogical meanings. That is, not only the duration of the totality was considerably long (about 5 min), but we could also expect to have a good sky condition because June is usually the beginning of the dry season in Java island. In order to make a variety of observations at this eclipse, an expedition, consisting of 28 persons in total, was sent to Indonesia from Shiga University. The systematic observations here described however were carried out by 16 members, among whom 13 persons were then school teachers mostly graduated from the Department of Earth Science, Shiga University.

The eclipse day began with hazy sky at the observing site, Purworejo, a small village in the suburb of Jogyakarta. By the time about an hour before the 1st contact, however, the sky had completely been cleared up and it continued until just after the 4th contact. Various kinds of astrophysical observations could therefore be completed under the excellent sky condition. In addition to these projects, meteorogical observations were also performed from early morning to about 1.5 hours after the 4th contact. The primary purpose of the present paper is to describe the instrumentations, the methods and the preliminary results of these observations.

2. Astrophysical Observations

The purpose of the present expedition was not only to make scientific observations but to obtain several kinds of teaching materials useful for each level of school education. A variety of observations have therefore been carried out by dividing 16 members into 5 groups. The instrumentation, the method, and the preliminary result of each observation are described here with brief discussion.

2.1. Multi-exposed Color Picture of the Whole Phase

To record the whole phase of the eclipse on a single frame in color, a multi-exposed photograph was taken with a fixed camera, Mamiya 645-S. A Kodak Ektachrome 64 film, $42 \times 56\,mm^2$ in size, covered the view angle of about 45°, which was somewhat less than the sun's movement between the 1st and the 4th contact. We decided therefore to start at $10^h08^m00^s$ (LT) corresponding to about 15 min after the 1st contact. The exposures were continuously made until $12^h48^m00^s$, about 20 min before the 4th contact, with a constant interval of 5 min. Appropriate combinations of the camera iris, ND-filter and exposure time was selected for keeping each exposure suitable: that is, we employed F16, D4.0 and 1/500–1/125 s for the partial phase, and F4, no filter and 1/125 s for the mid totality, respectively.

Figure 1 shows the multi-exposed color photograph thus obtained. As seen in this figure, all of the exposures have been done quite well, although two of them, the 3rd and the 14th, seem to have been exposed somewhat out of schedule. Anyway, this picture can be a good teaching material for instructing how a total eclipse advances.

2.2 Color Photography of the Corona and Prominences

Using a set of 8 cm refractor (f=1200 mm) and a 35 mm motor drive camera, a series of photographic observations were made to record, on a Kodak Ektachrome 64 film, the entire image of the corona together with prominences. Between $11^h29^m09^s$ and $11^h30^m37^s$ (LT), that is, nearly at the 3rd contact, 12 frames of photographs were obtained by changing the exposure time gradually from 1/125s to 1/4s and *vice versa.* About 10s later from these exposures, when the 3rd contact time was just coming, we started continuous exposures with a shorter exposure time of 1/250s and with 1–2s intervals for making continuous record of the phenomena rapidly changing at the west limb, such as a so called "Diamond Ring".

In Fugure 2, we give, as an example, a picture of the corona taken at $11^h29^m55^s$ with the longest exposure time of 1/4s. As shown in this figure, the global structure of the present corona seems to represent a typical intermediate type between the maximum and the minimum of the sunspot cycle. That is, no elongated equatorial streamers can be seen, while several large scale streamers or arches are seen at relatively high latitudes and polar plumes are also visible around the both poles.

For showing fine structures of the innermost corona along with those of prominences, we give in Figure 3 a pair of less exposed pictures obtained 25 and 17s before the 3rd contact: the upper was taken at $11^h30^m14^s$ with an exposure time of 1/30s and the lower at $11^h30^m21^s$ with 1/60s. As clearly seen in this figure, the corona is much brighter in the western hemisphere than in the eastern side, and many prominences are visible at the west limb, hereby suggesting the existence of active regions there. It is one of advantageous points of color photography that we can easily differentiate by color the structures of prominences from those of the corona.

Figure 4 shows the time sequence of the western limb obtained between about 10s before and after the 3rd contact, that is, from $11^h30^m27^s$ to 30^m48^s. The contact time anticipated at this observing site was $11^h30^m38^s$, but the actual moment seems to have come 1–2s earlier since the photospheric flash light have already appeared on the 2nd frame in Figure 4 which was exposed at $11^h30^m37^s$.

2.3. Solar Disk before and during the Partial Phase

With the same setup as used in the color photography, observations of the solar disk before and during the partial phase was also done. From about 20min before the 1st contact, many exposures were done on a Fuji Minicopy HR-II film (35mm) with exposure times of 1/1000–1/250s. For reducing the light intensity, an ND filter having a density of D=4.0 was used. Figure 5 shows examples of the solar disk image thus obtained. As has already been pointed out in the previous section, it is clearly shown in this figure that an active region, consisting of several sunspots, existed near the west limb, while no sunspot region appeared at the east limb.

2.4. Enlarged White-light Pictures of the Corona

With the purpose of investigating physical structures of the corona in fine detail, enlarged images of the corona, 30 frames in total, were obtained by using another 8cm refractor. For enlarging the image, a 2x conversion lens, Kenko Teleplus MC7 was attached between the telescope and the camera. On a 35mm Fuji Neopan SS film, a hemispheric corona fitted just in size: that is, the east hemisphere after the 2nd contact and the west before the 3rd contact. For obtaining suitably exposed pictures graded from the innermost to the outer part corona, the exposure time was changed from 1/60s to 1s for each hemisphere.

In Figure 6, we give a sample pair of enlarged pictures thus obtained: the upper is the east side corona exposed at $11^h26^m19^s$ and the lower is the west hemisphere taken at $11^h29^m11^s$, both with the exposure time of 1/2 s. During the partial phase before and after the totality, we made several serieses of exposures for the solar disk using the wedge and various densities of ND filters, by which a precise photometry could be done as has been reported by many authors (see for instance, Tsubaki et al. 1964; Tsubaki 1966, 1967; Dollfus 1968; Dollfus et al. 1974; Dollfus and Martres 1977; Trigoso and Tsubaki 1986).

2.5. Polarigraphic Observations of the Corona

Polarigraphic observations have a great advantage in the fact that we can deduce from the polarization rate the orientation of the coronal structure with respect to the celestial plane. That is, the three dimensional structures can be derived by measuring the polarization rate at each point along the coronal structure. For this reason, a number of such observations have been made up to the present, for instance, by Saito and Hata (1964), McDougal (1971), Dürst (1977), Nikolsky et al. (1977), and Clette et al. (1985).

One of important purposes of the present expedition was to make similar observations by using polaroid filters with the same setup as used for the color photography described above. Two polaroid filters and an ND (T=1/2) filter were attached on a sliding plate so that we can alternately place each filter in a short time between the telescope and the camera. The two polaroid filters were attached in such a manner that the polarization axes subtended mutually a right angle. The ND filter was used for taking direct pictures with the same density as that of the corresponding two polarigrams. From just after the 2nd contact, 6 sets of exposures (each consisting of 2 polarigrams and a direct image) were made with 6 different exposure times, 1/125, 1/60, 1/30, 1/15, 1/8 and 1/4 s.

In Figures 7a and 7b, we give some of the results thus obtained. The lower picture of Figure 7a is the direct image of the corona exposed at $11^h27^m26^s$ with the exposure time of 1/4 s. The upper of the same figure and the two in Figure 7b represent an illustrative set of polarigraphic observations taken, respectively, at $11^h26^m55^s$, 26^m49^s and 27^m01^s with an exposure time of 1/15 s. The polarization axis for the upper picture of Figure 7b is along the right and left direction, and that of the lower perpendicular to it. As clearly demonstrated by these pictures, the coronal structures appear differently in each picture, suggesting that the orientation of each formation is accordingly different.

2.6. Flash Spectra of the Chromosphere

A series of chromospheric flash spectra were taken on a Fuji Neopan SS film by using a pair of objective prisms (a double prism system) and a motor drive camera attached to another set of 8 cm refractor. For enlarging the image size along with the dispersion, a 2x conversion lens, Kenko Teleplus Mc7, was put between the telescope and the camera. The combination of the conversion lens with the two prisms both having a vertical angle of 17° produced a spectrum suitable for the whole range of visible region on a 35 mm film. During the two time durations, from 15 s before to 5 s after the 2nd contact and from 8 s before to 9 s after the 3rd contact, 33 and 36 frames of flash spectra were taken with the fixed exposure time of 1/60 (2nd contact) and 1/30 s (3rd contact), respectively.

Figure 8 shows a smaple spectrogram thus obtained. Strong emission lines visible on this

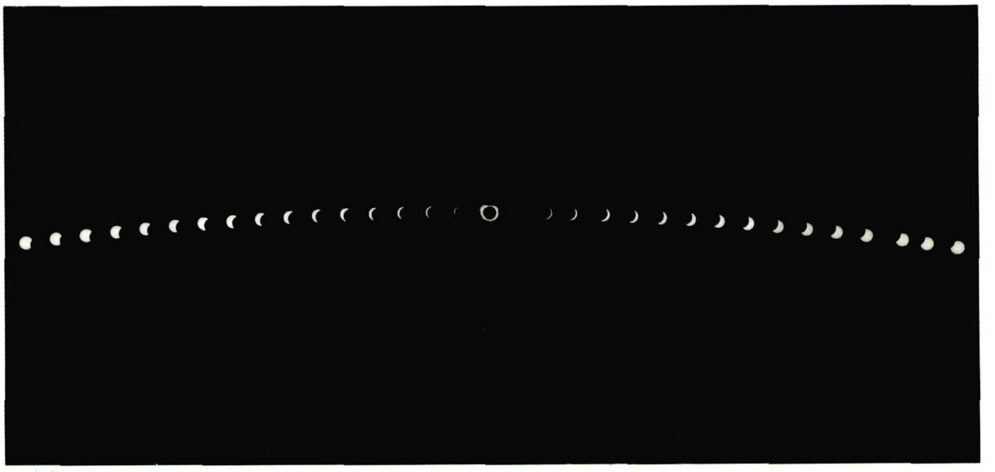


Fig. 1. A multi-exposed picture for recording whole phase of the eclipse. Exposures were made from 15 min after the 1st contact to 20 min before the 4th contact with an interval of 5 min. A kodak Ektachrome 64 film, $42 \times 56\,mm^2$ in size, was used. South is at the top and east to the right.

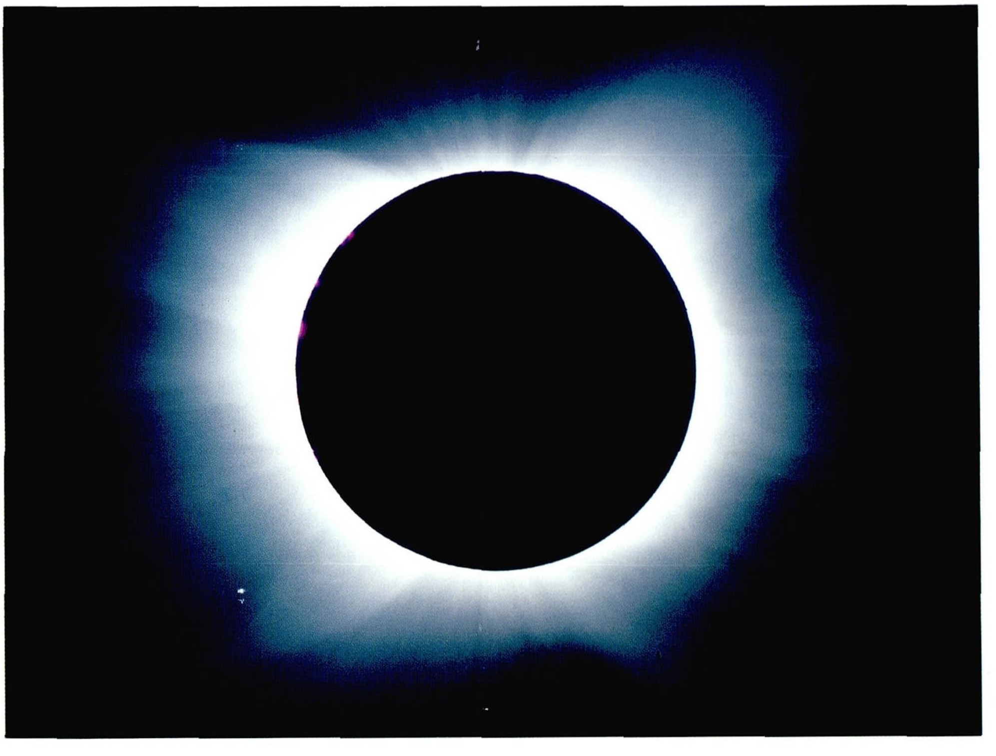


Fig. 2. An example of direct pictures of the corona taken with an 8 cm refractor at $11^h 29^m 55^s$ with the exposure time of 1/4 s. A Kodak Ektachrome 64 film (35 mm) was employed. Global structures show a typical intermediate type: that is, no elongated equatorial streamers are seen, while several large scale streamers or arches can be seen at relatively high latitudes and polar plumes are also visible around the both poles. South is at the top and east to the right.

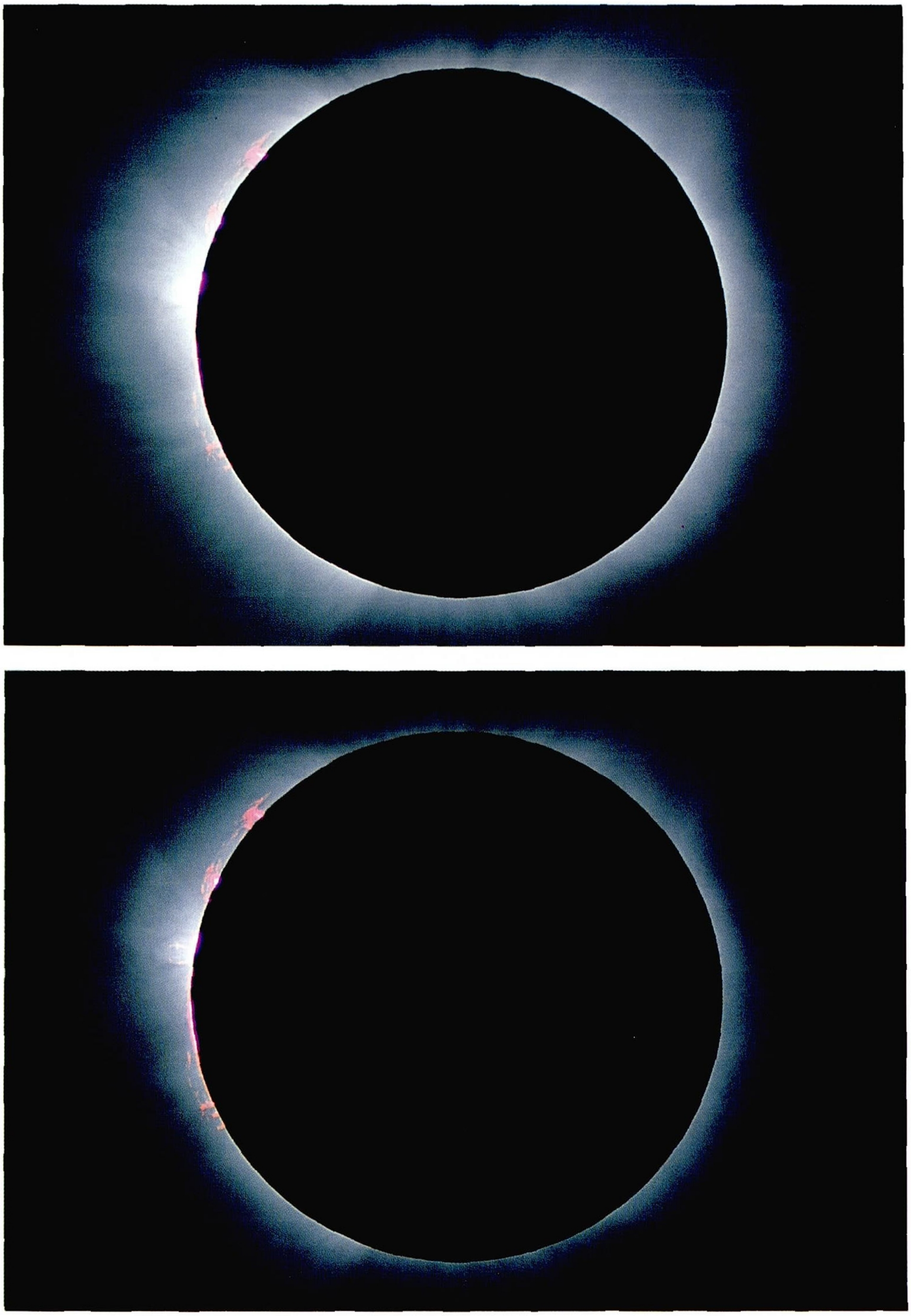


Fig. 3. A pair of direct pictures for showing time structures of the innermost corona along with those of prominences appearing above the west limb: the upper was taken at $11^h30^m14^s$ with the exposure time of 1/30s and the lower at $11^h30^m21^s$ with 1/60s. The orientations are the same as in Figure 2.

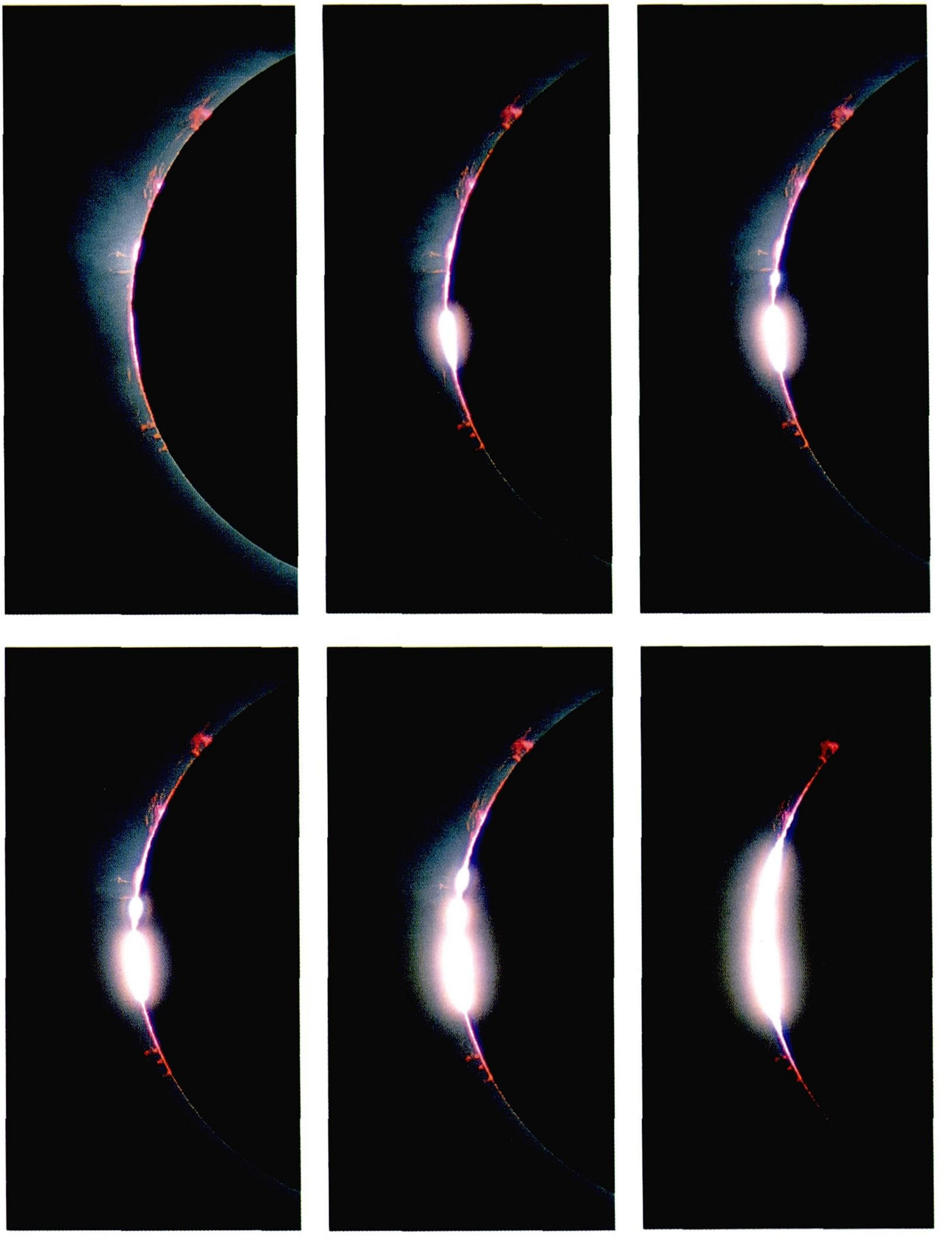


Fig. 4. Time sequence of the western limb obtained between about 10s before and after the 3rd contact: that is, from upper left, at 11^h30^m27, 37, 39, 41, 43, and 48^s, respectively. Exposure times were 1/125s for the first upper-left picture and 1/250s for the rest.

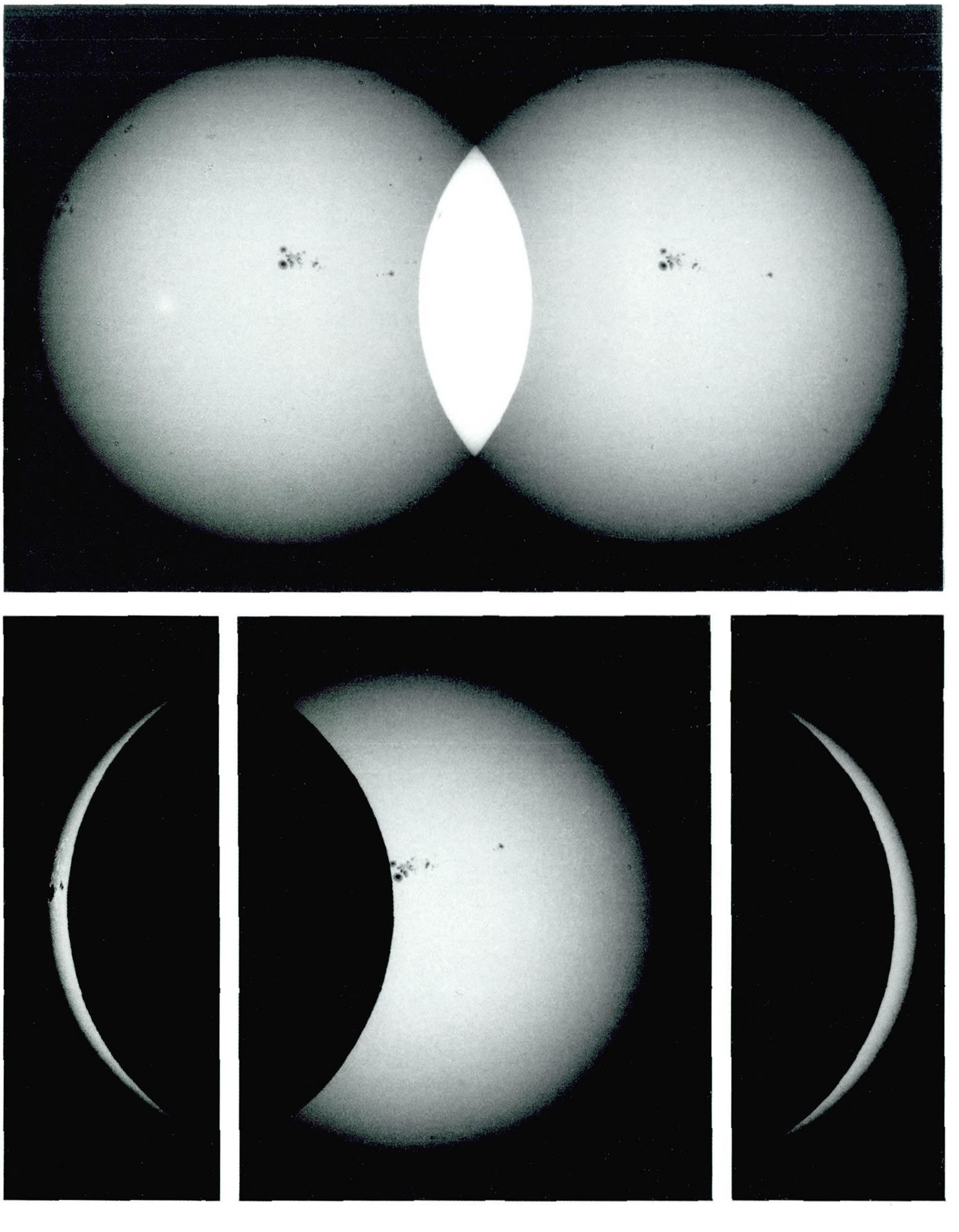


Fig. 5. Direct pictures of the solar disk taken with an 8 cm refractor. Combinations of an ND filter (D=4.0) and exposure times (1/1000–1/250 s) provided suitable exposures on a Fuji *Minocopy HR-II film* processed with Copinal for 6 min at 20°C.

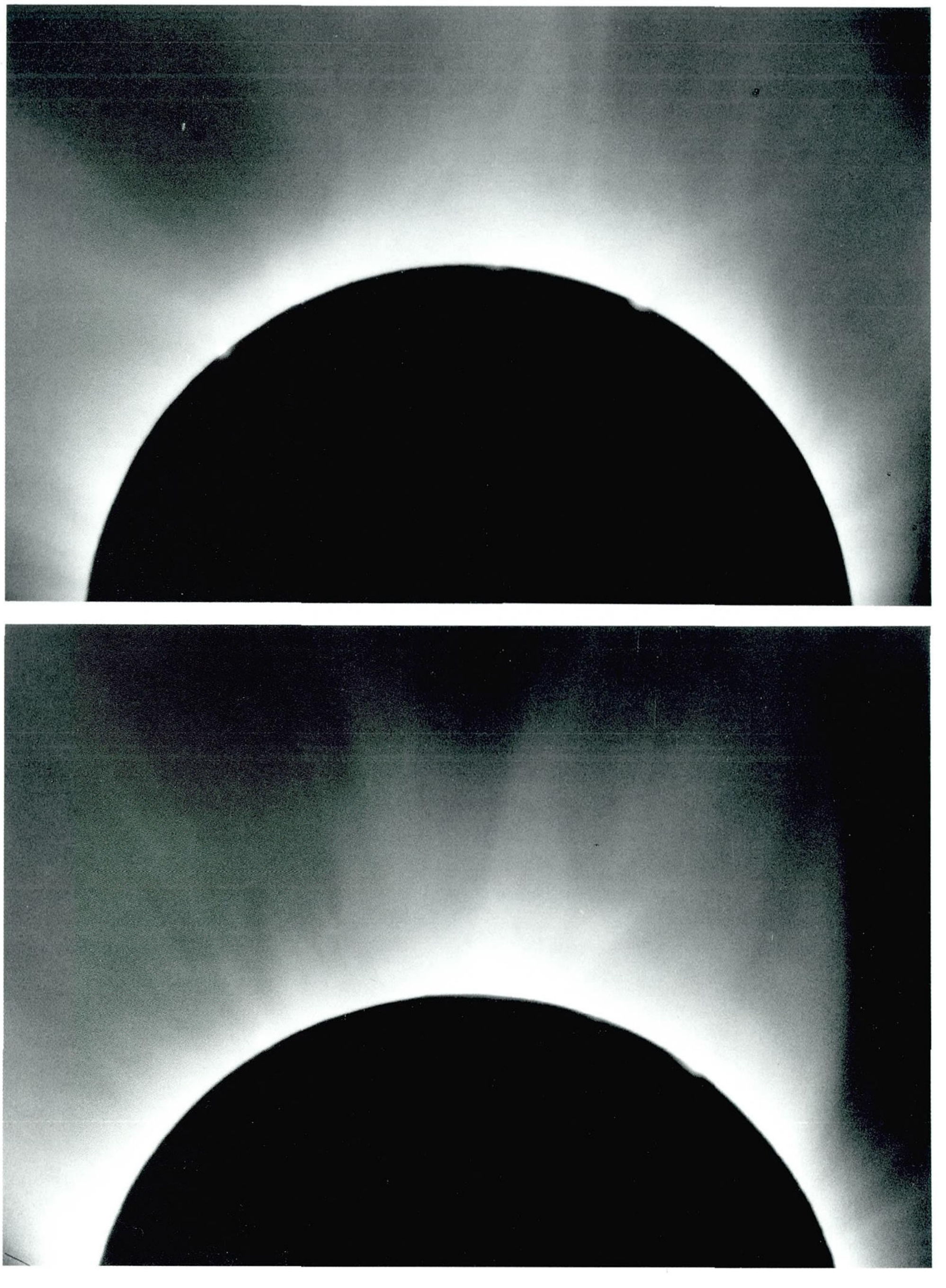


Fig. 6. Examples of enlarged coronal pictures obtained with an 8 cm refractor to which a 2× conversion lens was attached. The upper was taken at $11^h26^m19^s$ for the eastern hemisphere and the lower was exposed at $11^h29^m11^s$ for the western, both with the exposure time of 1/2s. A 35 mm Fuji Neopan SS film was used and developed with Microfine for 8 min at 20°C.

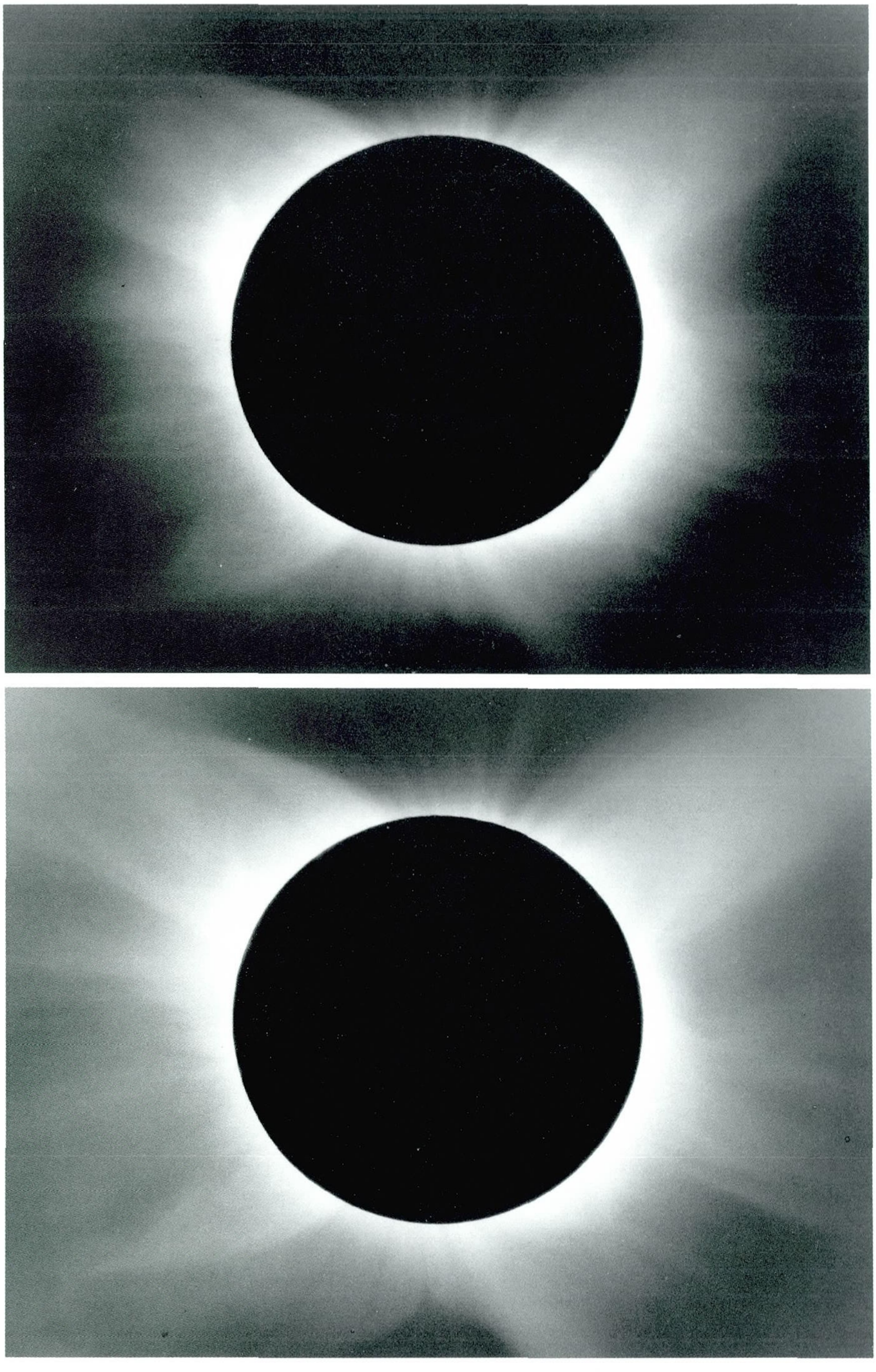
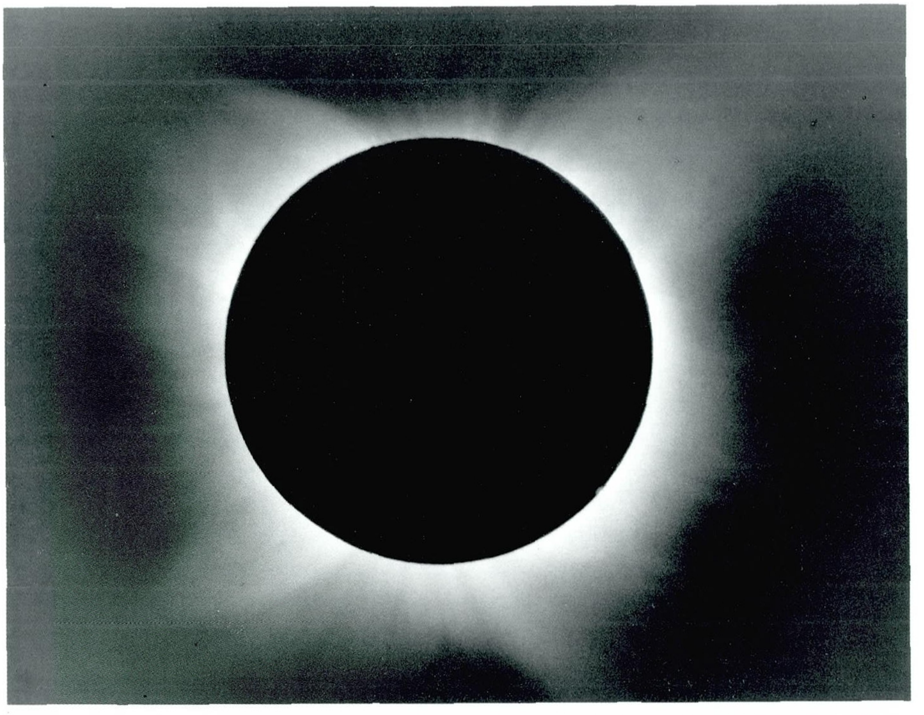


Fig. 7a. White light direct pictures of the corona obtained with an 8 cm refractor. The upper was taken at $11^h26^m55^s$ with the exposure time of 1/15 s, and the lower was exposed at $11^h27^m26^s$ with the exposure time of 1/4 s. A 35 mm Fuji Neopan SS film was used and developed with Microfine for 8 min at 20°C. South is at the top and east to the right.



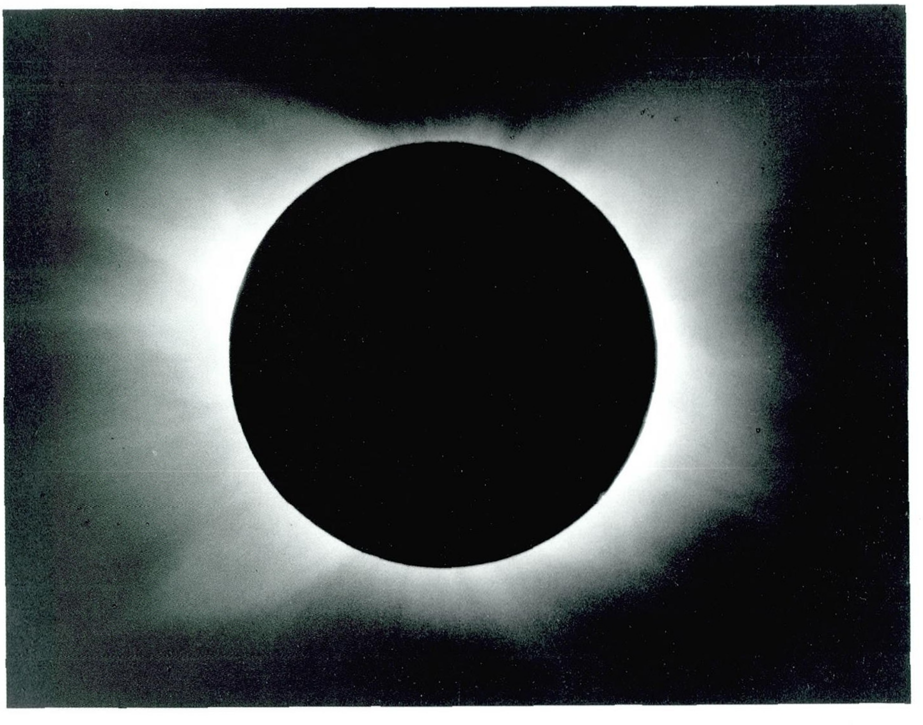


Fig. 7b. The same as the upper picture in Figure 7a but taken in polarized light by using polaroid filters. The upper was taken at $11^h26^m49^s$ with the polarization axis along the right and left direction, and the lower at $11^h27^m01^s$ by setting the polarization axis perpendicular to that of the upper picture.

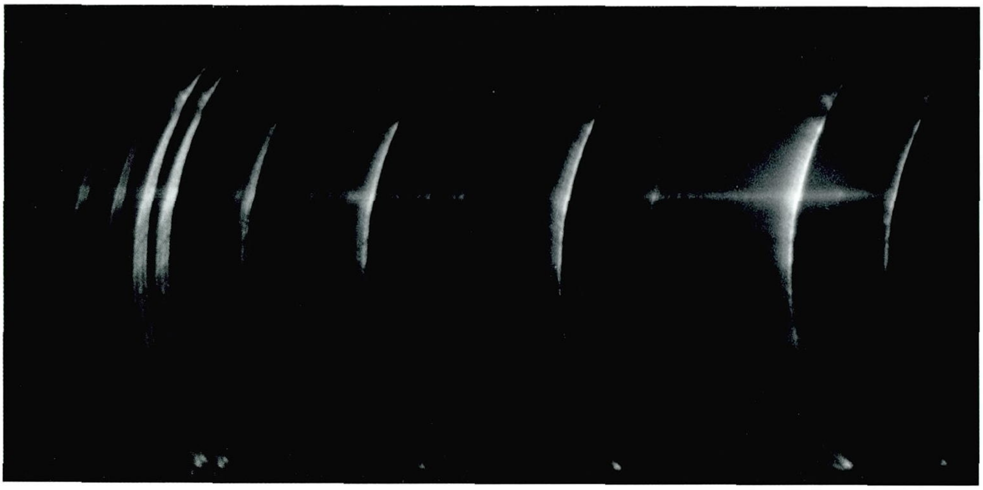


Fig. 8. Flash spectrum of the chromosphere obtained with a pair of objective prisms and a 2x conversion lens attached to an 8 cm refractor. Strong emission lines visible on the spectrogram are, from right to left, Hα λ6563, HeI D_3 λ5876, Hβ λ4861, Hγ λ4341, CaII H λ3968 and CaII K λ3934, respectively. The splitting of the line is due to miss-alignment of the two prisms.

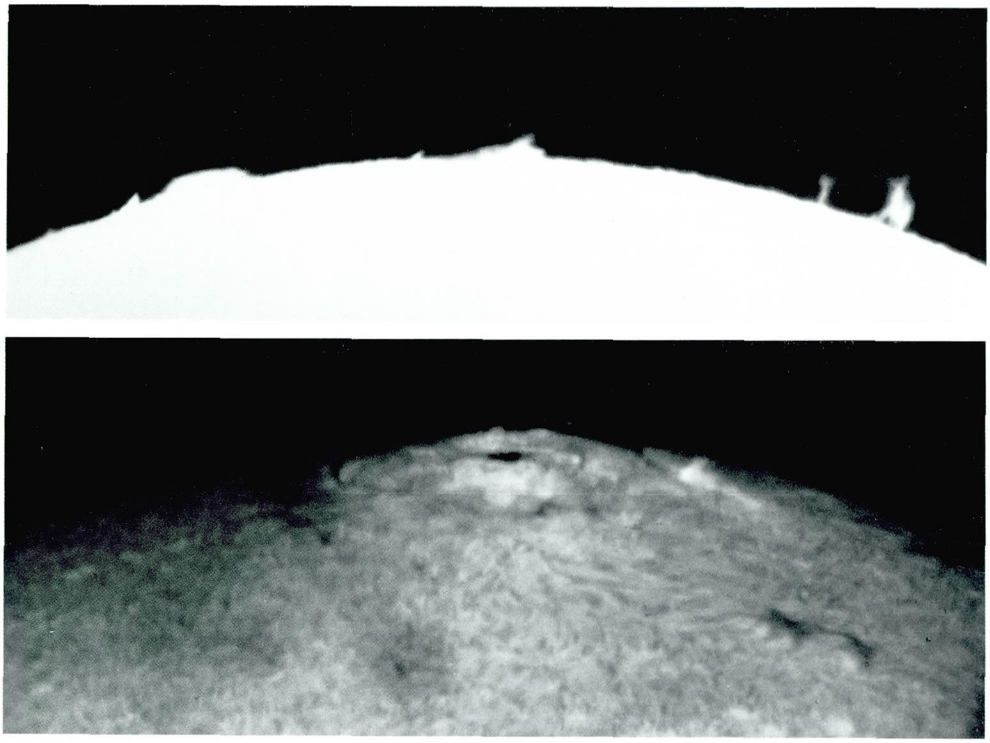


Fig. 9. Hα monochromatic images of the west limb obtained on the eclipse day by using a 10 cm refractor with the Daystar filter at the Department of Earth Science, Shiga University. Exposures were made on a Kodak 2415 film with the exposure times of 1/4 and 1/30 s for the upper and the lower, respectively.

picture are, from right to left, Hα λ6563, HeI D_3 λ5876, Hβ λ4861, Hγ λ4341, CaII H λ3968, and CaII K λ3934, respectively. It is to be noted here that the alignment of the optical axes of the two prisms seems to have been somewhat out of order. This caused an emission line to split into three parts at the lower half of the spectrogram.

2.7. Monochromatic Observations in Hα

Using another 8 cm refractor with an Hα monochromatic filter, we tried to record, on a Kodak 2415 film, temporal variations of the chromosphere both around the 2nd and the 3rd contact. Unfortunately, however, this project was almost unsuccessful because the interval between successive exposures was so short that the telescope might be vibrating while each exposure was in progress (due to the manual winding of the film). Most of the pictures thus obtained, therefore, are blurred out and are not good enough for analysis.

Very fortuately, however, Hα monochromatic observations were simultaneously carried out by several students at the Department of Earth Science, Shiga University. With the use of a 10 cm refractor and a Daystar filter, many enlarged Hα pictures were obtained with a variety of exposure times. Two of them taken at the west limb are given in Figure 9 for an illustration: the upper was exposed for prominences above the limb with a longer exposure time of 1/4 s, and the lower was for the chromosphere on the disk with a shorter exposure time of 1/30. These pictures can sufficiently make up for the fail of the monochromatic observations described above.

3. Meteorogical Observations

With the purpose of clarifying how and by what extent the meteorogical elements change as the eclipse progresses, temporal variations of the following fundamental quantities have been recorded: that is, the global solar radiation, the atmospheric temperature and pressure, the soil temperature, and the wind direction and velocity. The instrumentations, the methods and the results are given in this section with brief discussion.

3.1. Solar Radiation and Temperatures

A babble cassette data recorder spcially designed was used for digitizing and recording the following three kinds of data nearly simultaneously. For the measurement of the global solar radiation, a thermopile pyranometer was installed on the top of a pole having a height of about 2 m. To measure the atmospheric temperature, a platinum resistance thermometer was hanged from the pole at a height of 1.5 m with a shade. Another platinum resistance thermometer was buried in the soil with a depth of 2–3 cm for measuring the soil temperature. All of these three quantities were automatically and continuously recorded with an interval of 1 min from early in the morning to 1.5 hours after 4th contact.

Figure 10 shows the results for the three quantities thus obtained: from top to bottom, the global solar radiation, the atmospheric temperature, and the soil temperature, respectively. The preliminary conclusions derived from this figure can be summarised as follows.

(1) The effect of cloud passing is clearly shown by the short period flux fluctuations of global solar radiation except for the time duration from 1 hour before the 1st contact to just after the 4th contact, hereby confirming the fact that the whole phase of the present eclipse was observed without any disturbance due to the cloud. The rapid increase of the flux seen around

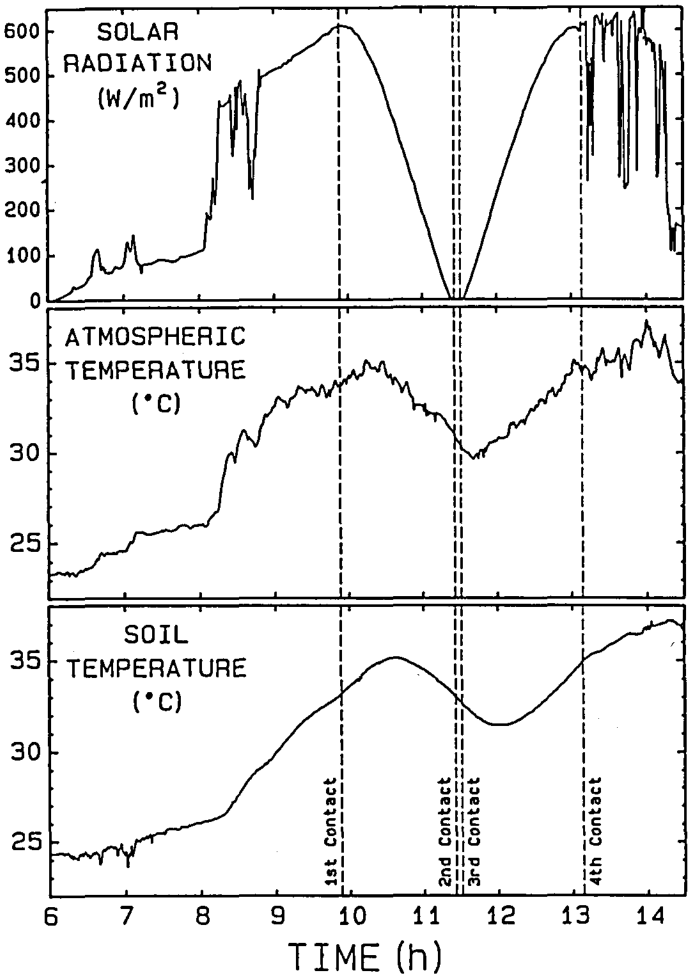


Fig. 10. Temporal variations of the three meteorogical quantities, from top to bottom, the global solar radiation, the atmospheric temperature, and the soil temperature, respectively. Short period fluctuations of the global solar radiation, visible between 8^h and 9^h and also after the 4th contact, are due to cloud passings: no such fluctuations during the eclipse confirm that the present observations have been done without any disturbance from the cloud.

$8^h 10^m$ suggests that the haze, with which the sky had totally been covered, was going to be removed since that time.

(2) As soon as the eclipse started, the flux of global solar radiation began to decrease and reached a value less than the detectability limit of the pyranometer ($1\,w/m^2$) 1–2 min before the 2nd contact, and recovered symmetrically from 1–2 min after the 3rd contact. The symmetry of this change is just what we expected.

(3) A similar but somewhat delayed variation can also be seen in the atmospheric temperature. It is an interesting fact that the time delay was not constant resulting in the asymmetrical variation. That is, the decrease began about 35 min after the 1st contact while the temperature reached the minimum 12–13 min after the mid totality, and the maximum temperature was

observed around at 14^h00^m, about 50min after the 4th contact. This can be taken as the evidence that the atmospheric temperature is determined not only by the solar radiation but also by the effect of convection: that is, the horizontal turbulence or the wind plays an important role.

(4) The soil temperature showed a pattern similar to the atmospheric temperature with the delay of about 15min. It is natural that the fluctuation of the soil temperature is much smoother than that of the atmospheric temperature. The maximum temperatures after the 1st contact were the same (35.1°C) both for the atmosphere and for the soil while the minimum values were 29.6°C (atmosphere) and 31.5°C (soil). The amount of temperature drop, corresponding to the decrease of the radiation flux, was therefore 5.7°C for the atmosphere and 3.6°C for the soil.

3.2 Atmospheric Pressure

For obtaining continuous record of the atmospheric pressure, a self recording aneroid barometer was installed in a room of the Mutiara Hotel located about 70km east from the observing site, since we could not find a suitable housing around the observing site. The recording was made for about 49hours, that is, from June 9, 20^h50^m to June 11, 21^h40^m. Figure 11 shows temporal variations of the atmospheric pressure thus obtained.

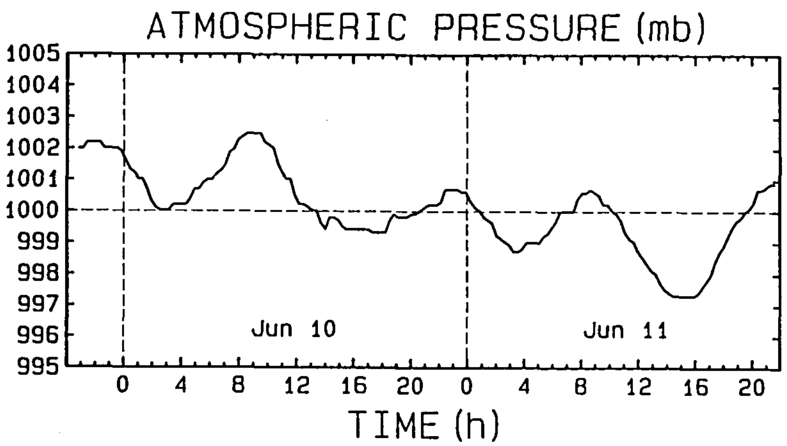


Fig. 11. Temporal variations of the atmospheric pressure observed for two days. A 12-hours period of daily change is visible with drifting decrease until the evening of the eclipse day. It is impossible, however, to derive a peculiarity caused by the eclipse because of the similarity of the pattern for both days.

As seen in Figure 11, the pressure showed periodic daily change for these two days. The period (12hours) and the amplitude (2mb) were almost identical for both days, but the pressure value itself was relatively lower on the eclipse day except for the part late in the evening. Since the patterns for both days are almost the same between 0^h and 14^h, it is impossible to derive, from this observation, a peculiarity caused by the eclipse.

3.3. Wind Direction and Velocity

From about 7^h30^m to 13^h30^m, the wind direction and velocity were observed with a constant interval of 15min. By using a hand compass, the trail of a thin string, the one end of which

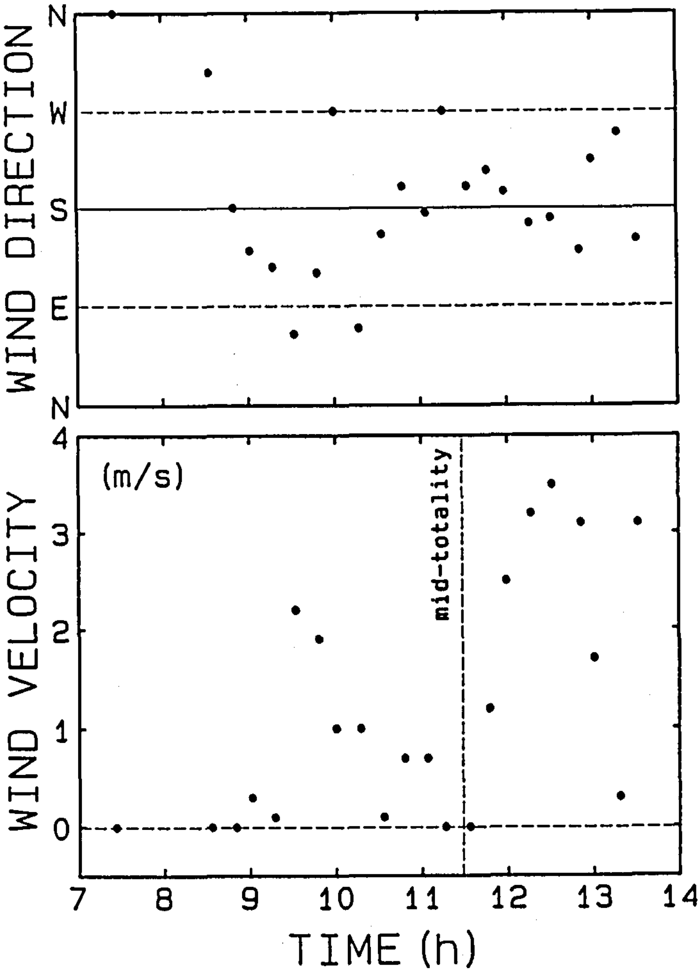


Fig. 12. Wind direction and velocity observed from about 7^h30^m to 13^h30^m on the eclipse day. The calm visible around the totality seems to be a common phenomenon caused by the total eclipse.

was fixed on a pole having a height of 2.5 m, was read off to measure the wind direction. Using a portable anemometer, we measured the wind velocity for each 30s, and the mean value was adopted. Fiture 12 shows the results thus obtained.

As seen in this figure, 1–2 m/s of light air began to blow from the east at around 9^h30^m, weakened as the totality approached, and stopped nearly completely for about 30min before and after the totality. From about 11^h45^m, it restarted to blow with somewhat larger velocities of 2–4 m/s. Meanwhile, the wind direction changed from the east to the south or to the southwest. Since the observation was done only for the eclipse day, it is difficult to derive characteristic features due to the eclipse phenomenon. The calm we had for 30min around the totality, however, seems to be a common phenomenon caused by the eclipse because the author has several times of similar experiences, for instance, at the 1970 Mexican eclipse and the 1973 African eclipse.

4. Concluding Remarks

As we have described in the preceding sections, a variety of astrophysical and meteorogical observations were performed at the 1983 total solar eclipse in Java, Indonesia. Although few of them were incomplete, most observations were sucessfully carried out and a number of photographs and numerical data, useful both for scientific analyses and for teaching materials, have been obtained. It is the largest characteristic of the present expedition that a variety of observations have been systematically done by the cooperative work of a large number of members, that is, 16 persons in total. This has been possible only because the most of the expedition members are graduates of Shiga University, the Department of Earth Science.

The present paper is nothing but a preliminary report describing the purposes, the instrumentations, the methods, and the results of the observations. We strongly believe however that the materials presented here should be of great interest and include many invaluable informations for further scientific analyses as well as for preparing teaching materials at each level of shcool education.

Acknowledgements

I would like to express my deepest thanks to all members of the eclipse expedition for their intimate cooperations. I am especially indebted to Yamamura, Maeda, and Egawa, who played great roles acting as the chiefs of the expedition. I must express my hearty thanks also to Dr. Saito of Kwasan Observatory, University of Kyoto, who kindly computed the eclipse elements for our observing site, and to the National Committee, Indonesian Institute of Science (LIPI), for providing useful informations and for making various kinds of arrangements at the observing site.

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