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Appearance of the Atmospheric Scatter Field during a Solar Eclipse

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Abstract. The polarization of the circumsolar scatter field was surveyed during the total solar eclipse of 7 March 1970. Its instantaneous distribution over an area of $50 \times 60 r_{\odot}^2$ was photographically recorded in green light, using a modified Savart filter. This arrangement resolved the unit areal of the polarized component to about $5 r_{\odot}$ and indicated its intensity as being 2.5% of the backscattered light. A distribution asymmetry of about 0.5% was detected.

Key words: Atmospheric scatter field – Solar radiaton – Solar eclipse.

Scattered radiation, its content of polarized light, and its angular distribution offers clues to the nature and density of light scattering particles. In the terrestrial atmosphere, investigations of light in the circumsolar near field are much influenced and often impaired by the brightness of the solar aureole. The scattered light is only slightly polarized (Foitzik and Lenz, 1960; Coulson, 1975) and the mapping of the quasi-neutral zone between Babinet and Brewster points becomes difficult to interpret. Its causative variables are: the direct incidence bright solar component, the random density distribution of atmospheric scatterers, and the changes of the terrestrial albedo. Accurate measurements in the zone of the neutral points are usually carried out at low solar altitudes, and by spotwise photoelectric surveys. Ideally, the remnant field of polarization and scatter intensity should be symmetrical around the solar aureole, and the eclipsed sun should render itself most suitable for verifying such symmetry.

Previous polarization surveys were mostly conducted by solar physicists, whose interest remains limited to a region of about 10 solar radii. At this distance, solar atmospheric scattering dominates the field of view (if excellent seeing prevails), and data on the extent, emission and polarization of the corona may be obtained (Newall, 1906; Beckers and Wagner, 1970). Few if any discussions are found in literature on the brightness symmetry and the distribution of polarized light in the solar far field (Dandekar and Turtle, 1971; Shaw,

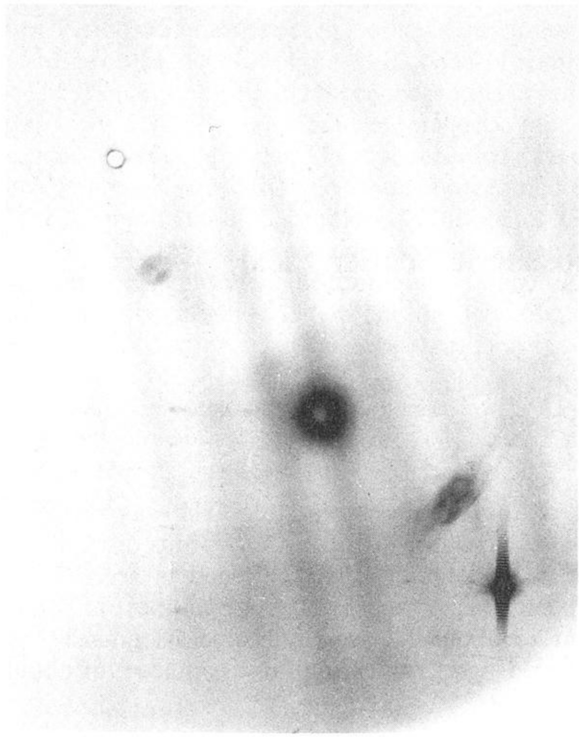

Fig. 1. Positive of the solar far field to $r_{\odot} \approx 50 \times 70$ during the solar eclipse of 7 March 1970. The negative was exposed by filtered light of $\lambda - 540$ µm through a Savart plate showing extent and orientation of polarized scattering. Measured photographic densities for range 0 to max. 5.27: solar center (overexposed), 1.36; background, 0.12; fringes at $r_{\odot} = 8$; 0.15 to 0.16; derived percentage polarization: 2.5 %

1975) which can only be observed with specialized optics (Newall, 1906; Laffineur, 1969; Serkowski, 1973).

The present attempt employed a 30 cm focal length camera with external objective filters that consisted of a modified Savart polariscope and an interference filter for passing monochromatic light at about $\lambda = 535 \pm 5$µm. The photographic plate was exposed through the filter pack and covered an angular area of about 50×60 solar radii at the sky, or about 12×15 degrees. One of the exposed plates is reproduced as a positive in Figure 1. The image features of the eclipsed sun match those that were photographed by other observers (e.g. Newkirk and Lacey, 1970; or Menzel and Pasachoff, 1970). The original negative shows the same dark bands of interference of low overall contrast, which extend through almost the entire field of view. These fringes originate from the scattered polarized sky radiation that had been intercepted by the filters before entering the camera. The contrast of the interference bands is a measure of the degree of polarization of the light scattered from the sky. Fringes of very high contrast commensurate with 100% polarization, if we discount the small and unavoidable losses by the sensing inefficiency of the Savart plate. Details of the fringe forming mechanism of the Savart filter and of the fringe contrast evaluation are sufficiently described elsewhere (Serkowski, 1973; v. Heel and Strong, 1957; Gerharz, 1975).

The exposed plates were analyzed by a microdensitometer and indicated a maximum component of about 2.5% polarized light in the immediate solar

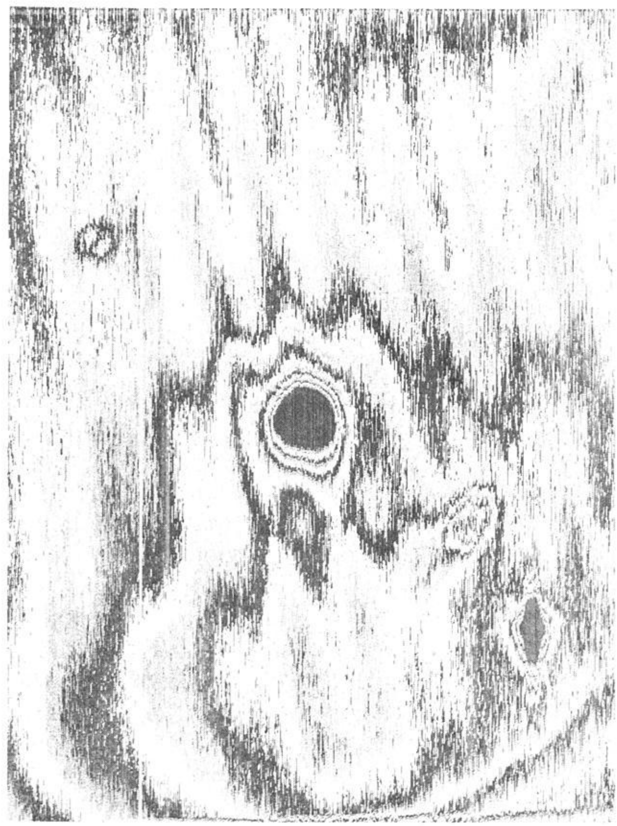

Fig. 2. Isophotes of the field of Figure 1, showing fringe density asymmetry of 0.5 %. The three disturbances in the solar far field were caused by two secondary images and a density calibration mark at the lower right corner

vicinity, starting at $r_{\odot}=6$. The recorded solar image itself suffers from inferior contrast and resolution because of secondary images from reflections and filter defects. These do not severely restrain the formation and contrast of the fringes and their distribution in the observed area.

Figure 1 was obtained from an exposure in mid-totality of the eclipse of 7 March 1970 in the central path of the umbra at N35° 51.7′, W72° 2′ near Williamston, S. Car., USA, when the local solar altitude was 45° at 13.34 UT. Figure 2 reproduces a display of isophotes of the same exposure, ignoring the solar near-field to about 7 solar radii. In this graph, it is very noticeable that a brightness asymmetry of the fringes had developed which follows the direction of the original bands, and which indicates, that contrast and percentage of polarization of the scattering field had slightly increased. This local difference of the fringe contrast amounts to not more than about 0.5% at equal distance from the sun. Such polarization asymmetry should also occur at clear sky without an eclipsed sun (Foitzik and Lenz, 1960), but its cause has not been specifically pointed out in previous reports (see e.g. Shaw, 1975; Fig. 10, p. 392).

During a solar eclipse, polarization asymmetry should be found enhanced, if good seeing prevails, and if the observer positions himself further away from the center of the path of the umbra. A further increase of the polarized component may be expected when the scattered light intersects large pockets of cool, moist air that may have formed in the wake of the moving lunar shadow. Moreover, the predominant direction of the plance of polarization is expected to change during totality for any location of the observer, while the eclipse proceeds from 2nd to 3rd contact.

The geometry of these changes is determined by the observer's view through a varying slant range of air in the umbra, before the directly scattered sunlight is encountered. Depending on the observer's site in relation to the center of the umbra, the sources of scattered light may be located at a considerable atmospheric altitude (i.e. the umbral screening height), from where components of scattered sunlight are re-emitted into the umbra at near grazing incidence.

However, the present observer failed to detect such changes of polarization and intensity on account of his limited recording instrumentation. A much more pronounced asymmetry of the polarization field with a value up to 20% was reported by Shaw (1975), who observed when isolated clouds flanked one side of his location. It is not known, if the presence of these clouds might have influenced the polarization field by their tertiary scattering effects.

The large interval between about 10% and 25% of polarized light at $r_{\odot}=50$, reported by Shaw (1975), contrasts the rather minute and faint signatures of about 0.5% shown in Figure 1, which was obtained in exceptionally clear weather, with no clouds visible at the entire sky, long before and after the center of totality had arrived. It appears questionable that the albedo of the earth may be cited as the principal contributor for this large component of polarization, because Figure 1 was also (like the data by Shaw (1975)) taken in the vicinity of a large body of water (the Atlantic) at one side of the solar azimuth.

Asymmetries of the intensity and the polarization of light curves that were taken through various propagation paths of the terrestrial atmosphere at numerous astronomical events in the past have often been presented implicitly (e.g. by Briggs 1938, de Bary et al., 1961; Gerharz, 1969), but these are still devoid of systematic observations, discussions and analysis from the viewpoint of global physical parameters.

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