The solar corona during the total solar eclipse of October 24, 1995

V. Rušin, L. Klocok, M. Minarovjech and M. Rybanský

Astronomical Institute of the Slovak Academy of Sciences
059 60 Tatranská Lomnica, The Slovak Republic

Received: May 17, 1996

Abstract. A brief description of the scientific goals and preliminary results related to the 24 October 1995 solar eclipse at Neem Ka Thana is given. The white-light corona was of the minimum type with several large helmet streamers seen up to 5 – 6 $R_{\odot}$, and located around the solar equator above the E- and W-limbs. Coronal holes and plumes were located around the solar poles. No CME or comets were observed. The flattening index ϵ turned out to be 0.28. The green corona, observed at the Lomnický Štít coronal station, was relatively low, except above the W-limb, where increased intensities were observed around P. A. 250°. The total brightness of the solar corona could have reached $J_K = 0.63 \times 10^{-6} J_{\odot}$.

Key words: The Sun – corona – eclipses

1. Introduction

A total solar eclipse provides the best opportunity of observing different parts of the solar corona. The solar eclipse of October 24, 1995 has been successfully observed at Neem Ka Thana (Rajastan, India) by the Expedition of the Astronomical Institute (Tatranská Lomnica, Slovakia). The eclipse occurred shortly before the sunspot minimum between cycles 22 - 23 (the minimum is expected to occur by mid-1966). The purpose of our experiments was to study the following problems in the solar corona research:

(1) The large-scale structure of the white-light corona (WLC),

(2) Multicolour photometry (in blue, green and red spectral regions) of the WLC up to 7 $R_{\odot}$,

(3) Fast changes (shorter than 1 s) in the WLC,

(4) Spectroscopy of the WLC (an attempt to find neutral matter in the solar corona).

Indirectly, we are able to study physical properties (temperature, density, and velocities) at different coronal structures, both the global and local magnetic fields of the Sun, heating of the solar corona, etc.. Colour photos are used to derive colour index in the outer corona in order to study the nature of the

Contrib. Astron. Obs. Skalnaté Pleso 26, (1996), 37– 45.

scattered light. The program was a continuation of our former eclipse experiments, e. g., Sýkora (1986), Rušin et *al.* (1992), Klocok and Rušin (1995).

Observations of the emission corona (530.3 nm) and prominences around the eclipse day were made at Lomnický Štít with a Lyot type coronagraph at the standard height above the solar surface (1.04 $R_{\odot}$).

More observations made around the eclipse data are needed to make the connection with disk activity, similarly as between different parts of the solar corona. We will present a preliminary analysis of our observations (mainly for both the WL and emission coronae) made during the eclipse day.

2. Eclipse Equipments

1) **Horizontal Camera, f = 3 m, D = 20 cm.**

The lens was fed by a siderostat mirror (Zeiss 35 cm). Exposures of 8 and 2 s were taken during totality on KODACHROME 100 Plus (plane film 18 x 24 cm).

2) **Equatorially Mounted Camera, f = 0.5 m, D = 6.3 cm.**

9 WLC pictures (from 4 s to 1/60 s) were taken during the eclipse on KODACHROME 100 film.

3) **Static Camera, f = 1.2 m, D = 8 cm.**

A fast KRASNOGORSK-3 movie camera took 36 pictures/s on the ORWO NP-7 film. This system operated about 35 s during the total eclipse.

4) **Coronal spectroscopy.**

A low dispersion spectrograf (0.5 nm/px) was fed by the light from the 4.0/300 mm telelens. There was a CCD ST-7 camera in the focal lenght and the signal was fed to a Texas Instrument TravelMate 3000 computer. One exposure of 2.5 s was made. The spectral range is 480 to 910 nm. The slit was tangentially oriented toward the Sun, above its eastern limb.

Location: Neem Ka Thana (φ = 27°11′14.8″, λ = -75°47′45.4″, H = 400 m, Rajastan.

Time of observations: 08:30:32 - 08:31:19 LT or 03:30:32 - 03:31:19 UT.

Participants: V. Rušin (leader), L. Klocok, M. Minarovjech, P. Zimmermann and D. Očenaš.

3. Preliminary results and short discussions

All instruments performed well during the eclipse, and the weather conditions were excellent. Quantitative results are mostly not available at present. The WL-C has an asymmetric shape not only between the equatorial and polar regions, but also between the E- and W-limbs.

While only one helmet streamer is located above the eastern limb, the western limb displays many streamers. There are some small-scale structures in the

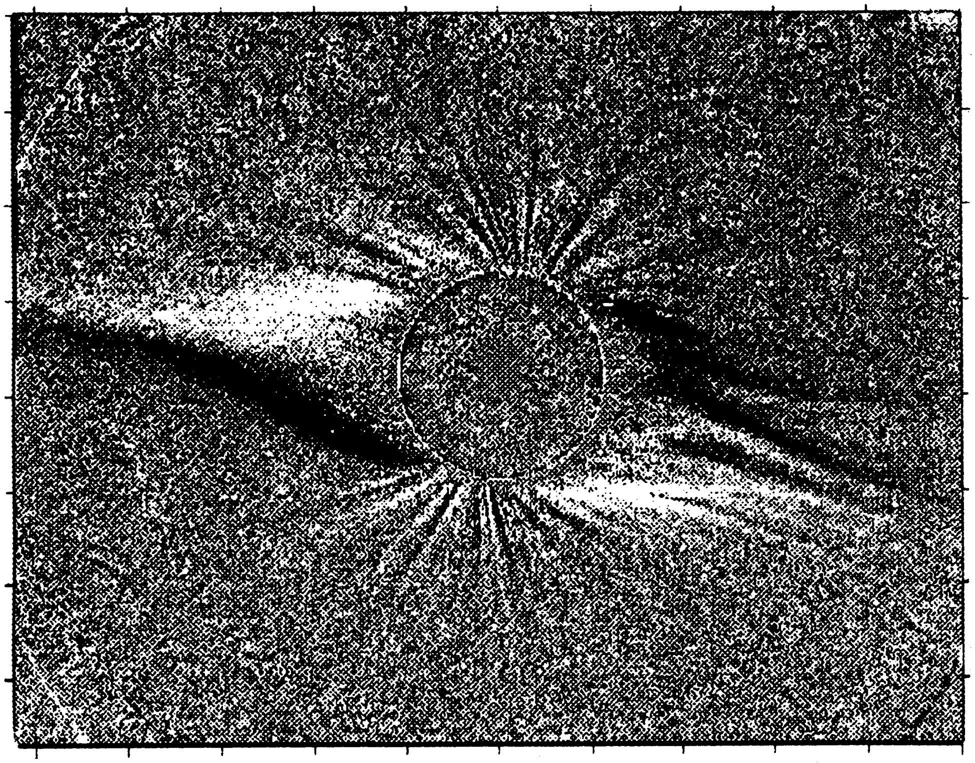

Figure 1. Image-processed WLC of October 24, 1995

helmet streamers (thin loops, arcades). The base of the E-limb streamer is located at P. A. 70° - 157°. The bases of the W-limb streamers are located at P. A. 205° - 324° (see Figure 1). Despite a rather bright sky, long streamers can be seen nearly up to 5-6 $R_{\odot}$, and their orientation towards the solar surface with height is nearly radial. The different distribution of helmet streamers relative to the E- and W-limbs may be used as a proof that surface solar activity is unequally distributed with heliographic longitude.

Many polar rays can be seen in coronal holes above both solar poles. Coronal holes occurred at both poles at P.A. 324° – 70° (the northern) and 157° – 210° (the southern). In a number of cases, the space between the individual polar rays is dark, resembling "coronal voids" (Koutchmy and Laffineur, 1970). These dark features, similarly as thin polar rays, extend up to 3-4 $R_{\odot}$.

4. Isophotes and the flattening index

Isodensities are the basis of the statistically more significant parameter, the flattening index ε, introduced by Ludendorf (1928). This index is used to describe both the solar-equator asymmetry and solar-cycle related variations of the white-light corona. The radial variation of the flattening index for the individual isodensities, as taken from Fig. 4, is shown in Fig. 5. One may see

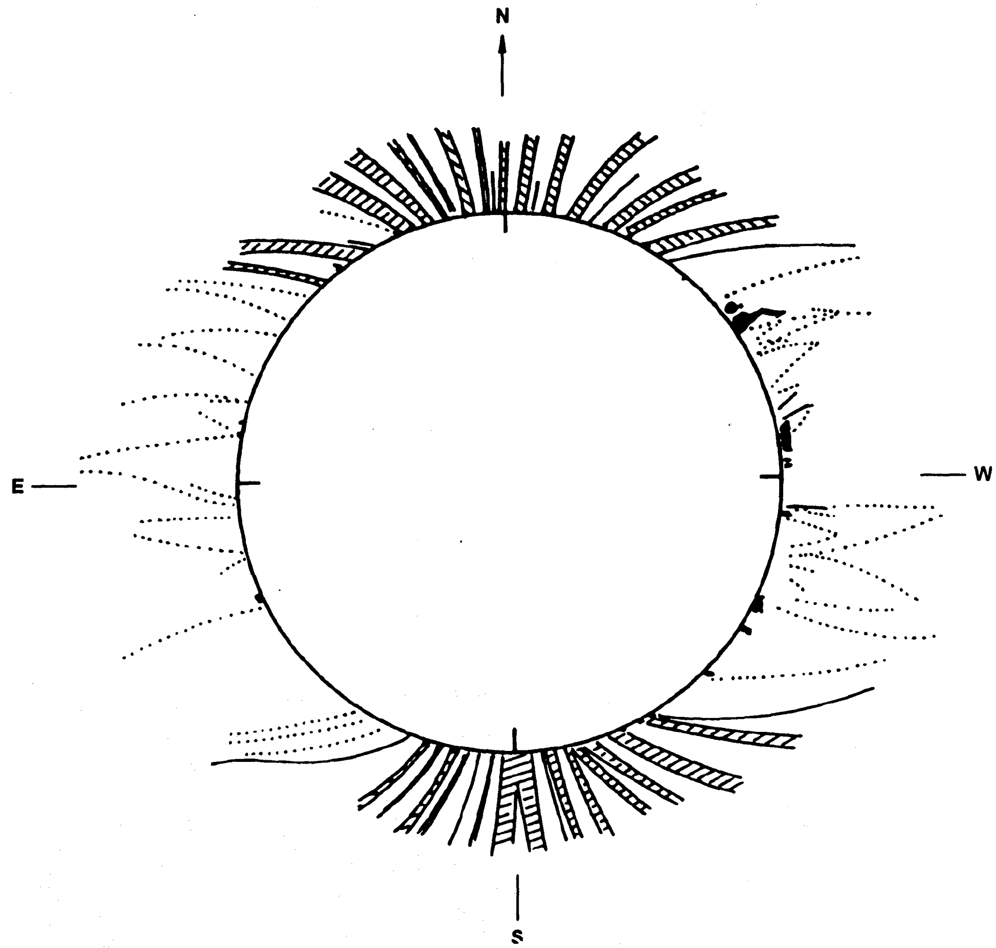

Figure 2. The structure in the inner corona. Prominences are denoted by black areas at the Moon's limb.

that the flattening reached its maximum at heights of 1.7-1.8 $R_\odot$, and then decreased again. Assuming a linear relation to a height of R = 2, the so-called $(a + b)$ parameter was derived from the values in Fig. 3, and its value reached $a + b = 0.28$. This is in good agreement with the observations made during at the same phase of the former solar cycles. Assuming that the next minimum of cycle activity would occur in 1996, we also derived the phase of cycle 22, and according to Waldmeier's definition $\phi = (T - m_1)/(m_2 - m_1)$, where T is the date of observation, m_1, the preceding minimum and m_2 the subsequent minimum, of ϕ would be 0.93.

As was established by Rušin and Rybanský (1985), a good relation exists between the flattening index and the total brightness of the corona. Using this relation, we found that the total brightness of the solar corona should be

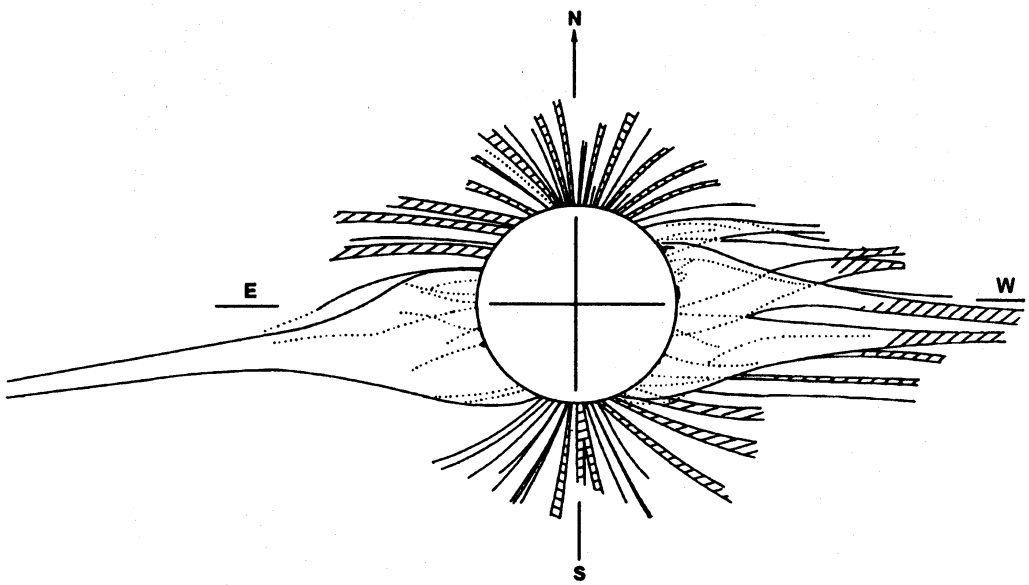

Figure 3. Large-scale structure of the white-light corona. Remarkable helmet streamers up to 5-6 $R_\odot$ are seen in equatorial streamers, polar plumes and coronal holes at the poles.

$J_K = 0.63 \times 10^{-6} J_\odot$.

There are many small prominences around the solar surface visible at the following P. A.: 8.5°, 20.5°, 38°, 78°, 114°, 119°, 206°, 225°, 236°, 242°, 262°, 273°, 278°, 304° and 308° (dark areas in Figure 1). The apparent height of the prominences did not exceed 40 000 km, except for the last one. It seems that the highest prominence (of about 100 000 km) at P. A. 304° was of the dynamic type (by comparison between Lomnický Štít and Neem Ka Thana).

The isodensities of the WLC (arbitrary units) are shown in Figure 4. No comets or CME were seen during the eclipse in our pictures.

The distribution of the green corona brightness is shown in Figure 5. One may see that its values are very low, typically for the minimum. The minimum between cycles 22 and 23 is supposed to have occurred in mid-1996. Increased intensities were observed above the W-limb, between P. A. 240-280°, i.e. at some places where helmet streamers were localized. The faint emission corona above the south pole of the Sun was brighter, than the one above the north pole. Some daily fluctuations were observed above the west limb (an effect of rotation). No important variations occurred above the E-limb, and in general, the emission corona is very low.

The shape of the solar corona, its structures and physical properties are the result of solar activity. Despite all the work that has been done so far in order to understand solar activity phenomenon, it is still not properly understood. Therefore, in our opinion, if any progress is to be made in this field, we should

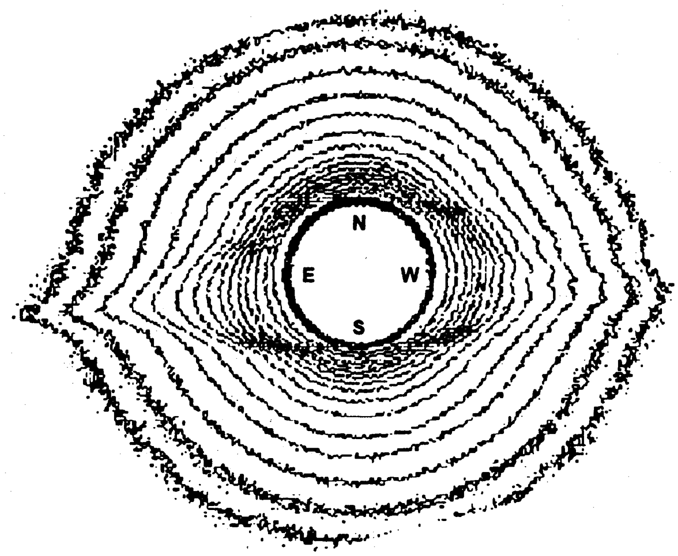

Figure 4. Isophotes of the WLC (arbitrary units).

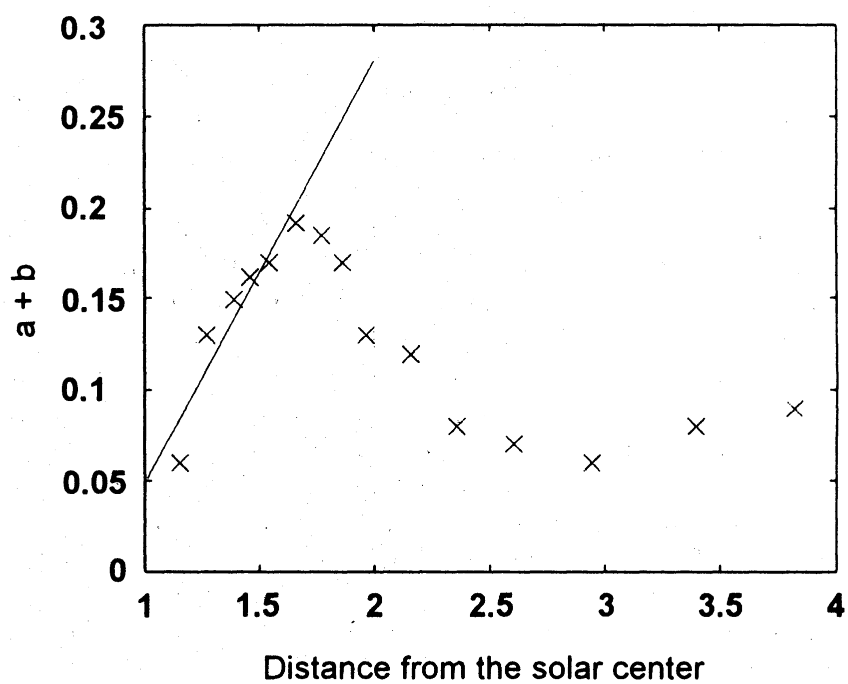

Figure 5. Extrapolation of the radial variation of the flattening index to show the possible value for the WLC alone at R = 2

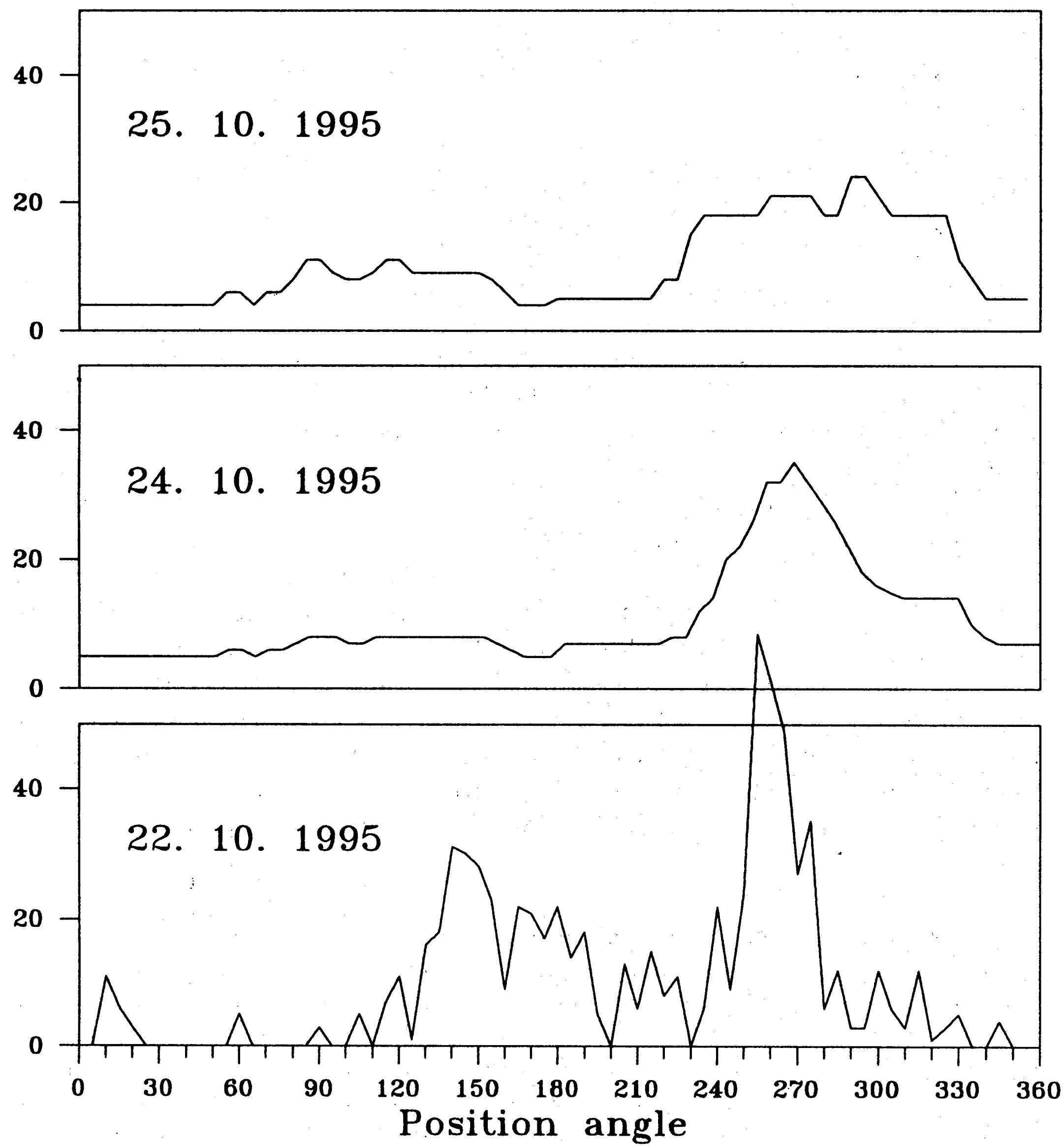

Figure 6. Plot of the azimuthal variations of the Fe XIV emisssion (the green corona) measured around the eclipse days. The date is marked directly in the Figure

abandon the idea of the "exclusive" role of MHD in solar physics and also consider alternative approaches such as that recently proposed by Saniga and Klacka (1993). On the other hand, both the physical properties and structure of the WLC are responsible for the properties of the solar wind in the heliosphere.

5. Conclusion

The white-light and green emission solar corona during the October 24, 1995 was of the minimum type. Two systems of long streamers occurred on the opposite sides of the Sun, seen nearly up to 5 $R_\odot$. The flattening index $a + b$, at the standard height above the solar surface $R_\odot = 2$, reached a value of 0.28 which is in a good agreement with the same former indices observed for the same phase of the solar cycle. No remarkable coronal mass ejections or other structural changes, e.g., Zirker *et al.*, (1992) occurred in the totality path between India and Thailand (Marková and Belik, 1996). Even when the large-scale structure of the solar corona seems to be very simple, except for the W-limb, complicated faint structures (dark and light loops) are seen in the individual coronal structures on a small-scale base. This leads to the conclusion that the solar corona is always a complicated system, reflecting the activity (magnetic fields) of underlying layers. As emphasized by Bagenal and Gibson (1991), there are two systems of magnetic fields in the solar corona that create its structures. The large-scale global coronal structure of the corona is related to the very low order structure in the magnetic field that is poorly determined by photospheric measurements. These low order magnetic fields structures originate deep in the dynamo region while the small-scale structures that dominate the photospheric magnetograms arise from distortions of the dynamo field by small-scale motions in the convection region.

Acknowledgements. The expedition was organized within the framework of co-operation between the Council for Scientific and Industrial Research (India) and the Slovak Academy of Sciences (Grant No. 2004/95). Other sponsors from the Slovak Republic were: Chemosvit, Ltd., Svit; Naftoprojekt, Ltd., Poprad; TESLA, Liptovský Hrádok; Nuclear Power Plants Research Institute, Ltd., Trnava; Air Transport Europe, Ltd., Poprad, Municipal Starý Smokovec, inWare Slovakia, Ltd., Bratislava and the Slovak Astronomical Society. We would like to thank Dr. Jadgev Singh (Eclipse Convenor) of the Indian Institute of Astrophysics, Bangalore, for his help and hospitality, not only before the eclipse, but during our stay in Neem Ka Thana as well. Thanks to all.

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