

Occultation of a solar active region at 1.5 GHz during the eclipse of November 3, 1994 (*Research Note*)

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ABSTRACT

We observed the solar eclipse of November 3, 1994 with a 4-m diameter antenna and a radio spectrograph operating at 1.5 ± 0.05 GHz with a time resolution of 100 ms. Here we present the observations of the occultation of the solar active region AR 7798 by the lunar limb. From the derivative of the eclipse curve, we found a source with an angular size of ≈ 12 s of arc associated with this active region.

Key words. Sun: radio radiation – Sun: activity – sunspots – Sun: chromosphere

1. Introduction

Microwave emission from the solar active regions has been studied for many years with high spatial resolution using multi-element interferometers (Kundu et al. 1974; Gary & Hurford 1987; Gopalswamy et al. 1995; Lara et al. 1998). A solar eclipse provides a unique opportunity to get important information about the structure of solar active regions with high spatial resolution even with a moderately sized radio telescope because of the wave diffraction effects on the lunar limb. Valuable data on the radio emitting regions at 1.45 and 4.9 GHz (Gary & Hurford 1987), and sources of supra thermal microwave emission (Correia et al. 1992) at 22 GHz have been obtained in the past during solar eclipses. The solar eclipse of November 3, 1994 enabled us to study the brightness distribution of the solar disk and the structure of an active region. The equatorial asymmetry in the solar brightness distribution and the size of a microwave burst at 1.5 GHz from these eclipse observations were reported earlier by Sawant et al. (1997). In this research note, we present observations of the occultation of a non-flaring source in the active region AR 7798 by the lunar limb, and also estimate the size of this source as ≈ 12 s of arc.

2. Observations and results

The observations reported here were made on November 3, 1994 at Chapeco, Brazil (Longitude: $52^\circ, 38'$ W; Latitude: $27^\circ 5'$ S and Altitude 725 m) with a 4-m diameter parabolic dish antenna in conjunction with a decimeter radio spectrograph operating in the band 1.5 ± 0.05 GHz with 20 channels

separated by 5 MHz, and with each channel having a bandwidth of 3 MHz and time resolution of 100 ms. The one-dimensional spatial resolution given by the first Fresnel zone of diffraction is $2 \times 10^5 (\lambda/D)$ arcsec (Hazard 1976), where λ is the wavelength of observation, and D is the Earth - Moon distance and is ≈ 3.2 arcsec at 1.5 GHz in a direction perpendicular to the lunar limb at the point of occultation. This spatial resolution is comparable to the resolution of the VLA in the B configuration at this frequency. Drift scans of the Sun were taken from 11:30 UT to 14:00 UT on the eclipse day. The data were recorded in digital format with gaps in data of about 3 min for every 15 min of observation for antenna pointing and receiver calibration. The data in 20 channels were integrated in frequency giving an effective bandwidth of 60 MHz, as the structure and radio flux of active regions were assumed to remain constant in our observing range of frequency (100 MHz). These 100 ms set of data were further integrated in time for 1 s, to get a better system sensitivity.

Figure 1 shows the geometry of the eclipse as seen from Chapeco, Brazil on November 3, 1994, with active regions and the lunar limb near the active region AR 7798 at 12:27:50 UT. According to Ramey observatory reports, this active region belonged to the Mount Wilson group 28191, and was located at S13 E14, with B class magnitude, and a corrected area of 140×10^{-6} Hemi, with a spot count of 4 and 2 degrees extension in longitude. This region was chosen for analysis, as there were no other confusing sources along the lunar limb at the time of occultation, and it produced strong diffraction effects. The data for the active region AR 7798 were available only during

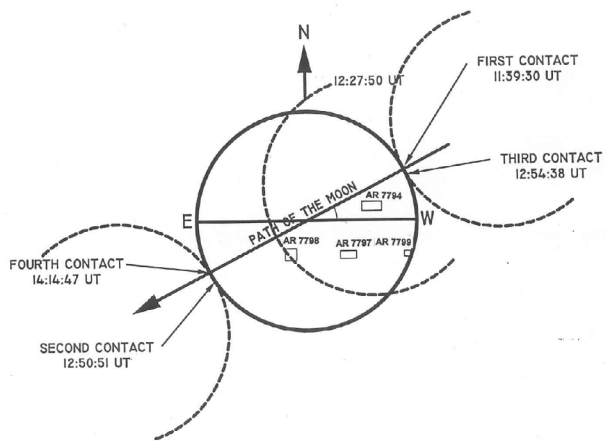


Fig. 1. Geometry of the solar eclipse on November 3, 1994, as seen from Chapeco, Brazil. The solar active regions and the lunar limb near the active region AR 7798 are also shown.

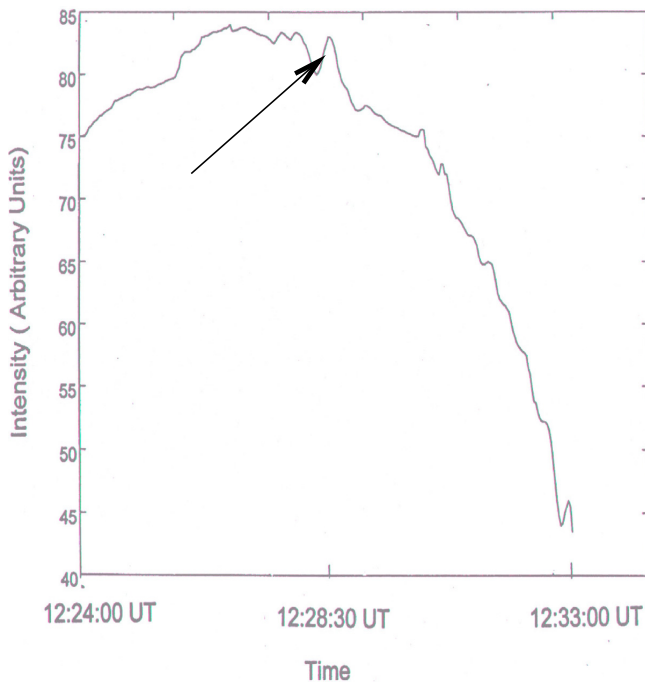


Fig. 2. One-dimensional drift scan of the Sun taken on the day of the eclipse between 12:24:00 UT and 12:33:00 UT. The arrow marks the sudden change in the slope of the eclipse curve.

the ingress, due to the gaps in data mentioned above. Figure 2 presents the drift scan of the Sun taken between 12:24:00 UT and 12:33:00 UT, showing a sudden change in the slope of the scan around 12:28:30 UT. No solar activity like, H_α flares or high frequency solar radio emission were reported during the above period of observations (Solar Geophysical Data 609, part II).

The best way to identify the presence of a source is to use the derivative of the eclipse curve instead of the eclipse curve. Figure 3 shows the derivative of the eclipse curve from 12:27:24.8 UT to 12:29:34.6 UT. On examination of it, we found a strong diffraction effect at 12:28:27.6 UT with a

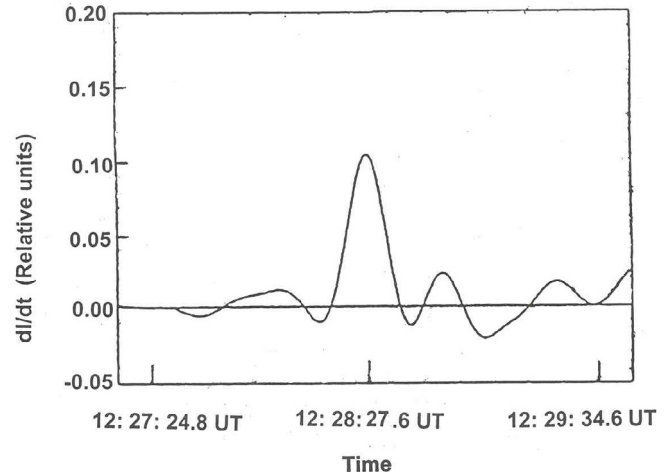


Fig. 3. Derivative of the eclipse curve showing strong diffraction effects at 12:28:27.6 UT.

total duration of 25 s corresponding to the occultation of a source in AR 7798. From this total duration and the average moon's velocity of 25.5 arcsec/min, we derived the size of the source in the active region AR 7798 as 12 arcsec. The error in the estimated size is ≈ 0.6 s of arc, since the velocity of the moon varied from 27 s of arc/min to 24 s of arc/min from the first to the fourth contact.

3. Discussion

Study of active regions at 20 cm by VLA and large interferometers have revealed radio sources associated with sunspots (Pallavicini 1980) and loop like structures extending across two groups of sunspots with opposite magnetic polarity. Sources with a few arcsec in angular size have been reported by Lang (1974); Felli et al. (1981); and Wilson & Lang (1983). Observations made by Gary & Hurford (1987) during the solar eclipse of May 30, 1984, have shown that the area of the strongest source at 5 GHz is 993 arcsec² in the left-hand circular polarization (LH) and 620 arcsec² in the right-hand circular polarization (RH). Assuming a circular symmetry for the source, the measured source size is ≈ 18 arcsec in the LH polarization and ≈ 14 arcsec in the RH polarization. Sources of angular size less than 1.1 arcsec at 22 GHz have been reported by Correia et al. (1992) from eclipse observations. Lara et al. (1998) also reported measurements of the angular size of solar active regions at 1.5 GHz from VLA observations. The source size estimated by us is near the range of source sizes (17.6 to 48.3 arcsec) of active regions reported by them.

The YOHKOH soft X-ray telescope image of the Sun in the 4 to 60 Å wavelength band (Tsuneta et al. 1991) taken at 02:51:59 UT on the eclipse day is shown in the Fig. 4. The intense X-ray emitting source in the eastern part of the Sun shows loop structures. Since there are no other sources along the eclipse path at the time of occultation we believe that the occulted source lies in the loop structure shown by the arrow in Fig. 4. Gary & Hurford (1987) have suggested that the radio emission below 3 GHz is usually associated with an arcade of loop structures.

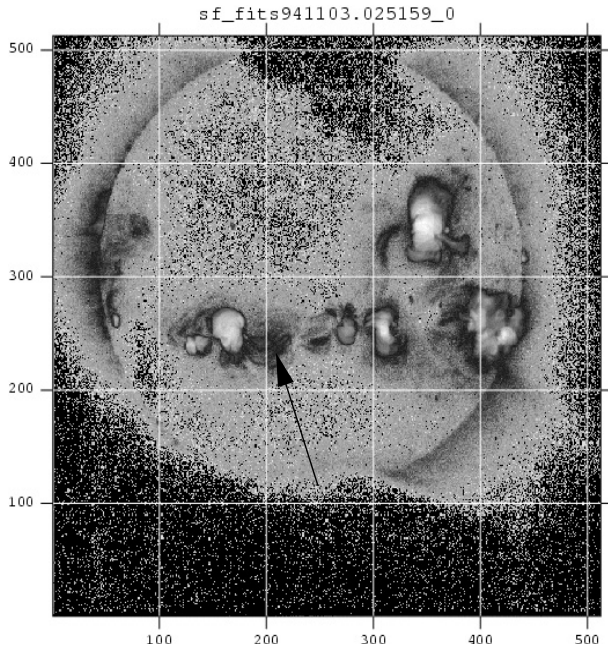


Fig. 4. YOHKOH Soft X-ray image of the Sun taken at 02:51.59:UT. Solar north is at the top and the east is to the left. The occulted source region is shown by the arrow.

The Nobeyama radio image of the Sun at 17 GHz (Nakajima 1994) taken at 02:45:00 UT is shown in Fig. 5. The radio emitting spot on the eastern part of the Sun is visible on this total intensity image. This source is elongated along the south east–north west direction. It has to be noted that due to the one-dimensional nature of the scan by the lunar limb during the eclipse, locating the radio emitting region exactly on the Sun is not possible from a single station alone, as one requires multi-station observations for triangulation analysis.

4. Conclusion

We have derived the angular size of a source in the active region AR 7798 at 1.5 GHz from the measurements made with a 4 m diameter dish and a radio spectrograph during the solar eclipse of November 3, 1994. Our results show the presence of a source of ≈ 12 arcsec in the active region AR 7798.

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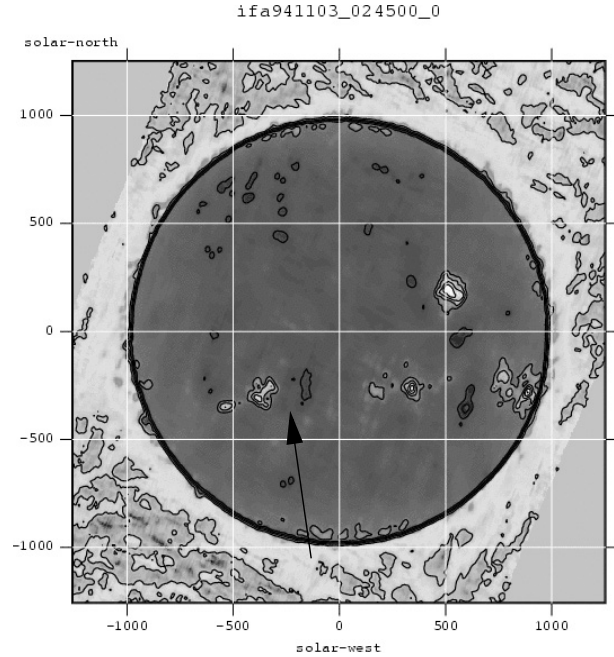


Fig. 5. The Nobeyama radio image of the Sun at 17 GHz taken at 02:45:00 UT. Solar north is at the top and the east is to the left. The occulted source region is shown by the arrow.

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References

- Correia, E., Kauffmann, P., & Strauss, F. M. 1992, *Sol. Phys.*, 138, 223
- Dulk, G. A. 1985, *ARA&A*, 23, 169
- Felli, M., Lang, K. R., & Wilson, R. F. 1981, *ApJ*, 247, 325
- Gary, D. E., & Hurford, G. J. 1987, *ApJ*, 317, 522
- Gopalswamy, N., Raulin, J. P., Kundu, M. R., et al. 1995, *ApJ*, 455, 715
- Hazard, C. 1976, in *Methods of Experimental Physics, Astrophysics, Part C*, ed. M. L. Meeks (New York: Academic Press), 92
- Kundu, M. R., Becker, R. H., & Velusamy, T. 1974, *Sol. Phys.*, 34, 185
- Lang, K. R. 1974, *Sol. Phys.*, 36, 351
- Lara, A., Gopalswamy, N., Kundu, M. R., Perez-Enriquez, Koshiishi, H., & Enome, S. 1998, *Sol. Phys.*, 178, 353
- Nakajima, H., et al. 1994, *Proc. IEEE*, 82, 705
- Pallavicini, R. 1980, in *Radio Physics of the Sun*, ed. M. R. Kundu, & T. E. Gergely (Dordrecht: Reidel), IAU Symp., 86, 109
- Sawant, H. S., Srivastava, N., Trigos, H. E., et al. 1997, *Adv. Space. Res.*, 20, 2359
- Solar Geophysical Data 609, May 1995, Part II
- Tsuneta, S., Acton, L., Bruner, M., et al. 1991, *Sol. Phys.*, 136, 37
- Wilson, R. F., & Lang, K. R. 1983, *ApJ*, 124, 12