

Occultation of a solar active region at 1.5 GHz during the eclipse of November 3, 1994

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Abstract. We observed the solar eclipse of November 3, 1994 with a 4- meter diameter antenna and a radio spectrograph operating at 1.5 ± 0.05 GHz with a time resolution of 100 msec. 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 sec of arc associated with this active region.

Key words. Sun: Radio radiation - Eclipse - Active regions

1. Introduction

Microwave emission from the solar active regions has been studied for many years with high spatial resolution using multi - element interferometers (Kundu, Becker & Velusamy, 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, Kauffmann & Strauss, 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 sec 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 - meter 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 msec. The one-dimensional spatial resolution given by the first Fresnel zone of diffraction is $2 \times 10^5(\lambda/D)$ arc sec (Hazard, 1976), where λ is the wavelength of observation, and D is the Earth - Moon distance and is ≈ 3.2 arc sec 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 minutes for every 15 minutes 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 msec set of data were further integrated in time for 1 sec, 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 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

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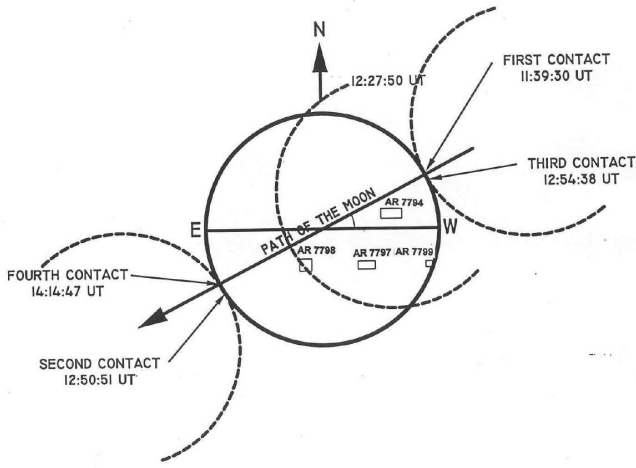


Fig. 1. Geometry of the solar eclipse on November 3, 1994, as seen from Chapeco, Brazil. The solar active regions and the lunar limb near the active region AR 7798 are also shown

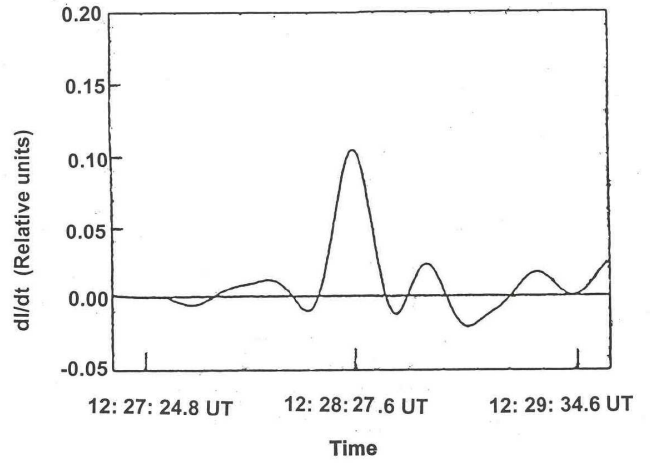


Fig. 3. Derivative of the eclipse curve showing strong diffraction effects at 12:28:27.6 UT

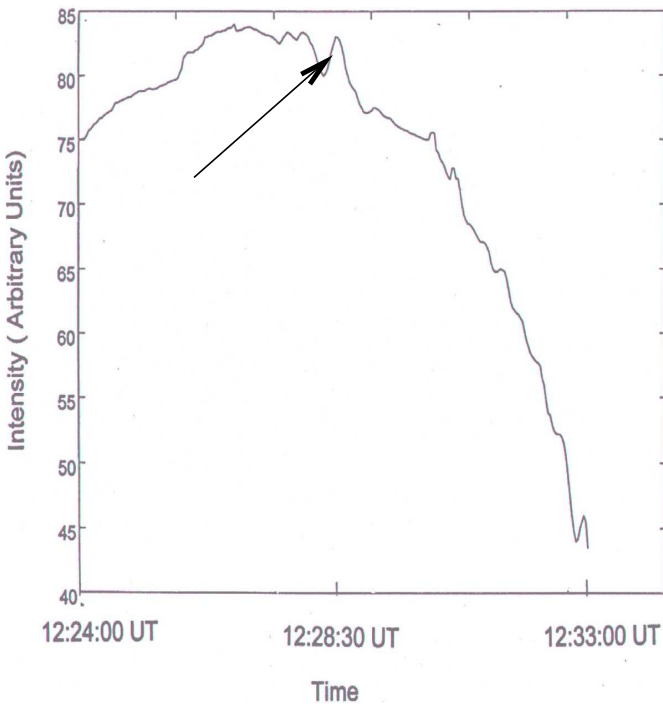


Fig. 2. One - dimensional drift scan of the Sun taken on the day of the eclipse between 12:24:00 UT and 12:33:00 UT. The arrow marks the sudden change in the slope of the eclipse curve

high frequency solar radio emission were reported during the above period of observations (SGD 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 it, we found a strong diffraction effect at 12:28:27.6 UT with a total duration of 25 seconds 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 es-

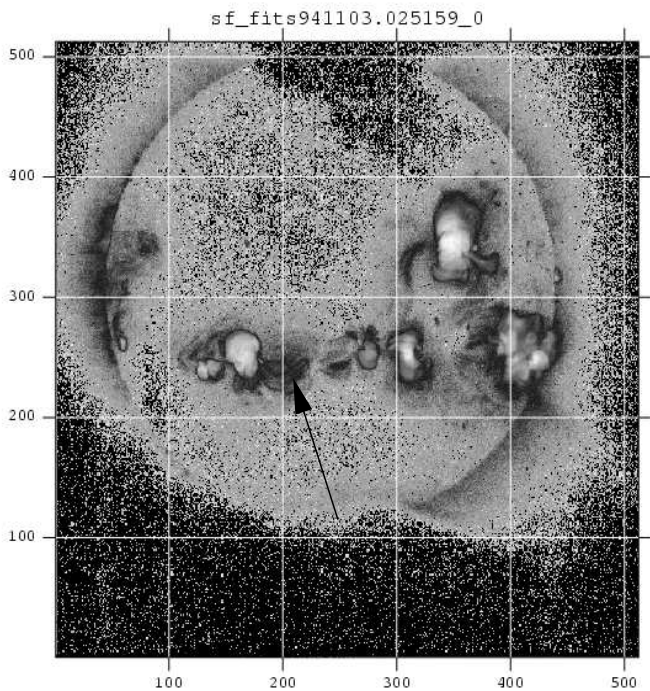


Fig. 4. YOHKOH Soft X-ray image of the Sun taken at 02:51.59:UT. Solar north is at the top and the east is to the left. The occulted source region is shown by the arrow

timated size is ≈ 0.6 sec of arc, since the velocity of the moon varied from 27 sec of arc/min to 24 sec 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, Lang & Wilson (1981); and Wilson & Lang

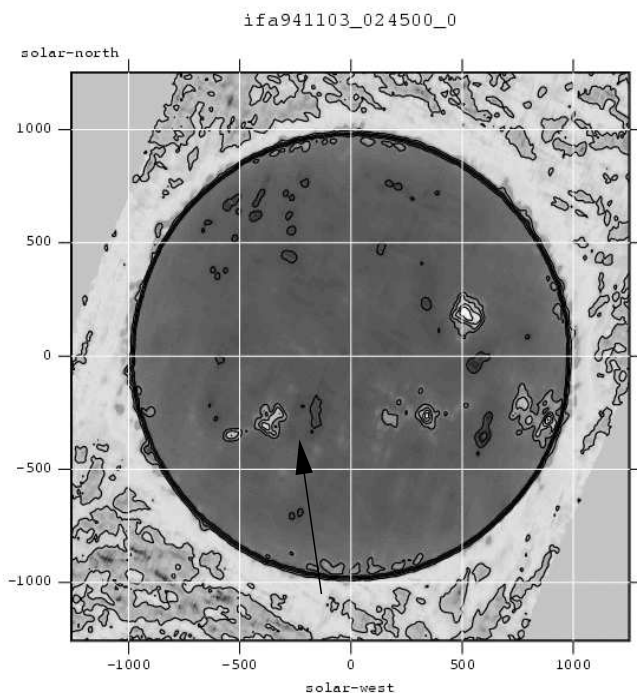


Fig. 5. The Nobeyama radio image of the Sun at 17 GHz taken at 02:45:00 UT. Solar north is at the top and the east is to the left. The occulted source region is shown by the arrow

(1983). Observations made by Gary and Hurford (1987) during the solar eclipse of May 30, 1984, have shown that the area of the strongest source at 5 GHz is 993 arcsec^2 in the left-hand circular polarization (LH) and 620 arcsec^2 in the right-hand circular polarization (RH). Assuming a circular symmetry for the source, the measured source size is $\approx 18 \text{ arcsec}$ in the LH polarization and $14 \approx \text{arcsec}$ 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 \AA 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 and Hurford (1987) have suggested that the radio emission below 3 GHz is usually associated with an arcade of loop structures.

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 $\approx 12 \text{ arcsec}$ in the active region AR 7798.

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