Solar Eclipse observation in Radio Frequencies:
A review

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Introduction

• Observations of the Sun in radio frequencies during an eclipse
• Tracking/monitoring a region of interest on the Sun's surface, when the Moon covers (uncovers) the field of view
• Similar to Lunar occultation
Motivation

- Higher angular resolution and improved sensitivity with added use of interferometric technique
- Study the structures of limb, quiet-Sun, sunspots observed during the eclipse
- Determine the coronal brightness temperature, magnetic field strength
- Interpretations of the radio emission mechanisms related to the solar atmosphere
1. Radio emission

- Radio brightness temperature
  ➔ True temperature of the Sun's atmosphere

- Large radial distances from the solar surface

- Radio disk vs Optical disk
  ➔ Time of obscure
  ➔ Velocity of the Moon and the Sun
Radio emission above the Sunspots

- Moment of time of optical contacts
- Moment of time of radio contacts
  \[ R_{\text{radio}} > R_{\text{moon}} > R_{\text{sun}} \]
- Residual fluxes of the concealed Sun's emission
  1.4 and 1 % at 3.2 and 4 cm respectively
- Characteristics of radio emission sources

Abbasov et al., 1965
Radio emission above the Sunspots

21 July 1963

\[ \lambda = 10 \text{ cm} \]

\[ \lambda = 3.2 \text{ cm} \]

Abbasov et al., 1965
2. Quiet Sun Observations

- Observation of stationary structures – coronal holes, Prominences, Sun's surface
- Phenomena related to convection and its energy

**In radio,**

- Height scan with changing observing frequency
- Heating events in the quiet upper chromosphere, the transition region and the corona
- Correlation with the chromospheric network
Spatial structure in the quiet Sun at 6 cm

Amplitude and phase variations

Spatial structure in the quiet Sun at 6 cm

Radio map

Halphpa map

Spatial structure in the quiet Sun

- No clear correlation with the chromospheric network
- 3 out of 6 source positions consistent with small bipolar regions
- Raises the possibility of association of radio sources with X-ray bright points
3. Solar Limb during the Eclipse

- Moon as an occulting disk provides great angular resolution for limb brightening measurements (Shimabukuro et al., 1975)

- Measurements of limb brightening at mm wavelength are important in the study of the chromospheric models?
Solar limb at 4.9 and 10.7 GHz during the Solar Eclipse

Solar limb at 4.9 and 10.7 GHz during the Solar Eclipse

- Limb brightening at 4.9 GHz with $T_b = 40,000$ K
- Little or no measurable limb brightening at 10.7 GHz
4. Magnetic Field of the Solar active regions

- The electron gyrofrequency for magnetic field strengths of \(~100-2000\ G\)

- Gyrofrequency

\[ \nu_B = 2.8 \times 10^6 B. \]

is strong wherever \( B > 300 \ G \)
Multifrequency Observations of a Solar Active Region

Multifrequency Observations of a Solar Active Region

Multifrequency Observations of a Solar Active Region

- Direct observation of the change in the emission mechanism
  - Free-free $\rightarrow$ Gyroresonance
  - 3 GHz
Gyroresonance emission

- High frequencies – emission above the sunspots

- Low frequencies – emission near magnetic neutral lines of the loops joining underlying sunspots
Very Large Array-RATAN 600 observations of a solar active region

VLA maps show shift in the emission away from the leading spot with increasing wavelength

Bogod et al, SolPhy, 1992
Very Large Array-RATAN 600 observations of a solar active region

RATAN (1.7 -4.0 cm) - Stronger sunspot source shifts inward toward the center of the AR with increasing wavelength

Bogod et al, SolPhy, 1992
Very Large Array-RATAN 600 observations of a solar active region

- Compact sources of size 10-40" with $T_b = 0.2 - 2.2 \times 10^6$ K above penumbra (2, 3.5, and 6.2 cm)

- Extended looplike structure of size 4.5' with $T_b \sim 10^6$ K between dominant spots (20 cm)

- Comparisons with the predicted gyroresonance radiation indicate source heights of 2500-17500 km
Summary

During Eclipse, in Radio wavelengths

- 1965, Emission above the sunspots by Abbasov et al.,
- 1980, 2.5" x 12.7", Correlation of the chromospheric network, Quite Sun by Marsh, Hurford & Zirin
- 1981, 13.8" and 7.4", Limb brightening, Solar limb by Marsh, Hurford & Zirin
- 1987, 2.6", Structure and characteristics of solar active region with emission mechanism during eclipse by Gary & Hurford
- 1992, Structure and emission mechanism in solar active region around the time of eclipse by Bogod et al.,
- 2012, 1.2", Observations with JVLA for active regions
Current Study

• JVLA 2 to 4 GHz observation of the annular eclipse
• The peak and the height of the differenced emission light curves show the core of the radio sources over the active region
• Active region picture with differencing technique
• Correlation with the other wavelength data
Challenges in the current study

- Delay clunking – solved- reduced frequency resolution
- Calibration – Attempt with self-calibration

Ongoing work
- Calibration – CASA and AIPS
References


2. Solar and Space weather radiophysics, Gary, Dale E., Keller, Christoph U.,

3. Physics of the solar corona, Aschwanden Markus
Thank you