Source Dynamics of the Microwave emission during Solar Flares with new EOVSA data

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BACKGROUND

- Source characteristics are valuable in examining the processes involved with particle acceleration and plasma heating in the solar flare site.
- Microwave study is in particularly essential to diagnose magnetic field and particle density due to the fact that the microwave gyrosynchrotron emission is produced from the spiraling of electrons in magnetic field.

How to study sources from observations?

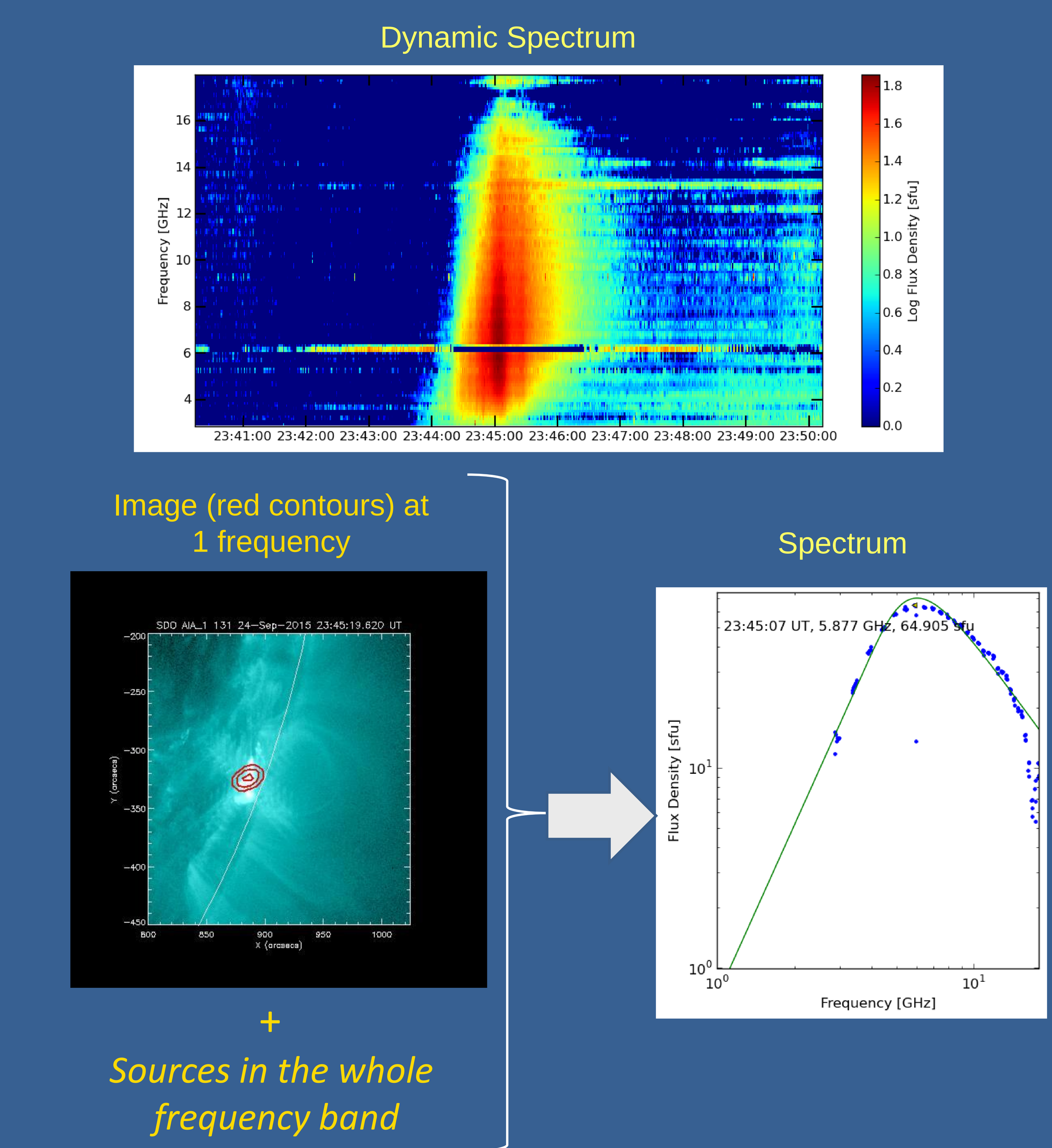

Fig 1: Burst observed by EOVSA on 24 Sep 2015

Shape and slopes of the microwave spectrum are indicators of the source characteristics, analogous to diagnosing images.

What data is used?

EOVSA **(Expanded** Owens Valley Solar Array) now provides high spectral and temporal resolution of the microwave bursts observation, but with no spatial information (Imaging) currently.

- Utilizing this data in both total power and cross correlated mode, 14 impulsive events are analyzed. Out of them 4 are presented here.

Spectral Analysis:

1. The observed spectra are fitted by the flux density generic function resembling the gyrosynchrotron emission shape as described in Stahli et al. (1989).

$$S(\nu) = A\,\nu^{a}(1-e^{-B\nu^{-b}}), \qquad (1)$$

where ν is the frequency and low-frequency slope (a), high-frequency slope (a-b), peak flux $S(\nu_{pk})$ and peak frequency (ν_{pk}) of the spectrum are the four parameters deduced.

2. Relative visibility is the normalized Fourier transform with the ratio of fringe amplitude to the total power as a function of frequency (Gary and Hurford, 1989). With frequency synthesis it is written as

$$\text{Relative visibility} = \frac{a_{ij}}{\sqrt{a_{ii}a_{jj}}}, \qquad (2)$$

Where a_{ij} and a_{ii}, a_{jj} are the cross- and auto-correlated amplitudes.

Complimentary data from Solar Dynamics Observatory (SDO) ***AIA EUV 131 A*** and Nobeyama Radio Heliograph (NoRH) ***17 GHz*** are correlated with EOVSA spectra.

OBSERVATIONS

How the source regions of these bursts look in terms of magnetic loop structure and in optically thin frequency images?

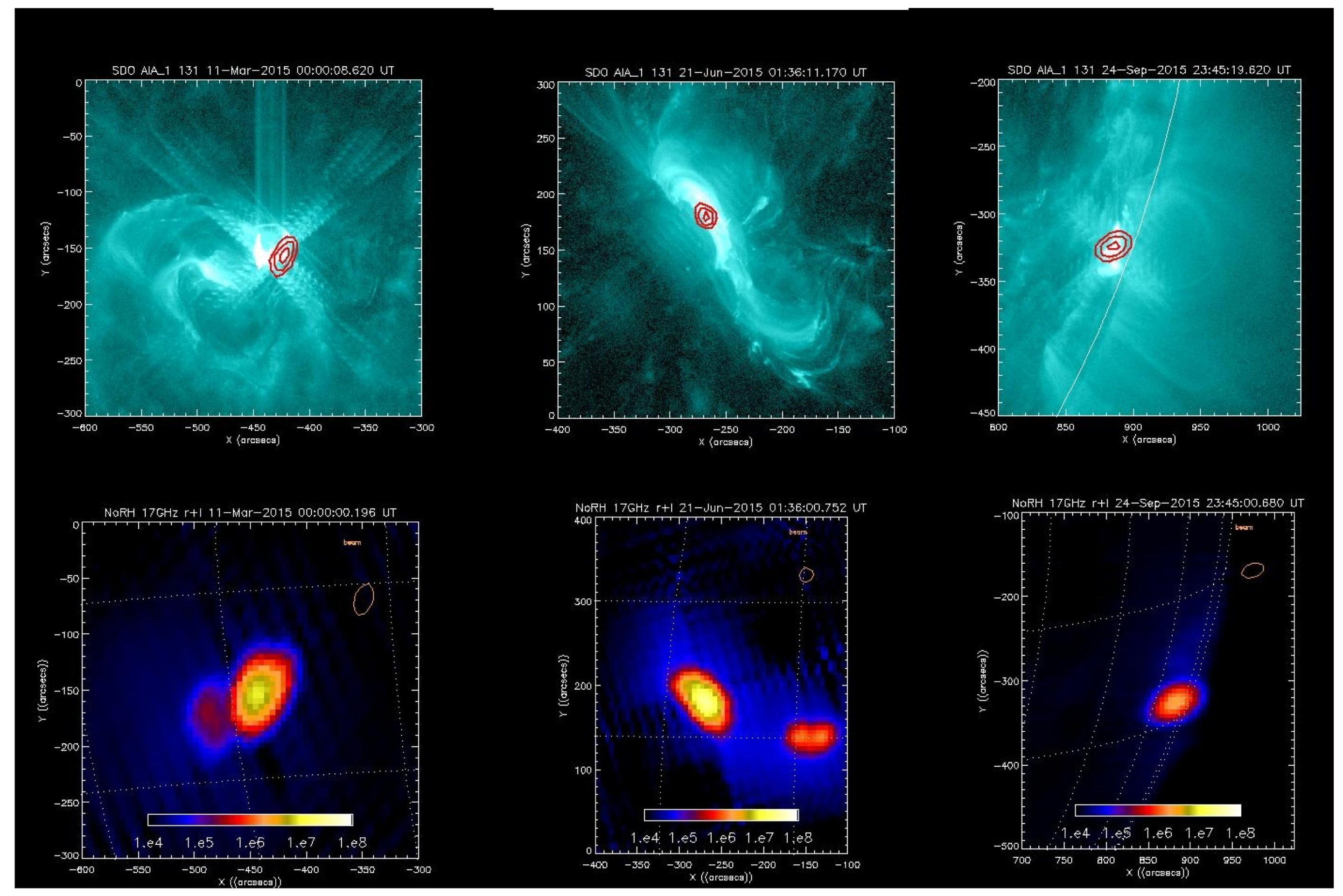

Fig 2: Top panel: Three events (Mar 10, Jun 21 and Sep 24, 2015) SDO EUV 131 A are over-plotted with NoRH 17 GHz (90, 70 and 50% of maximum flux) contours. Bottom panel: NoRH images in brightness temperature.

Results:

- All the three events show single, confined and compact primary sources.
- It is also observed that this nature of sources remained the same throughout the burst duration. No low frequency microwave images are available to determine the source complexity.

SPECTRAL ANALYSIS

What the EOVSA spectrum say about these sources?

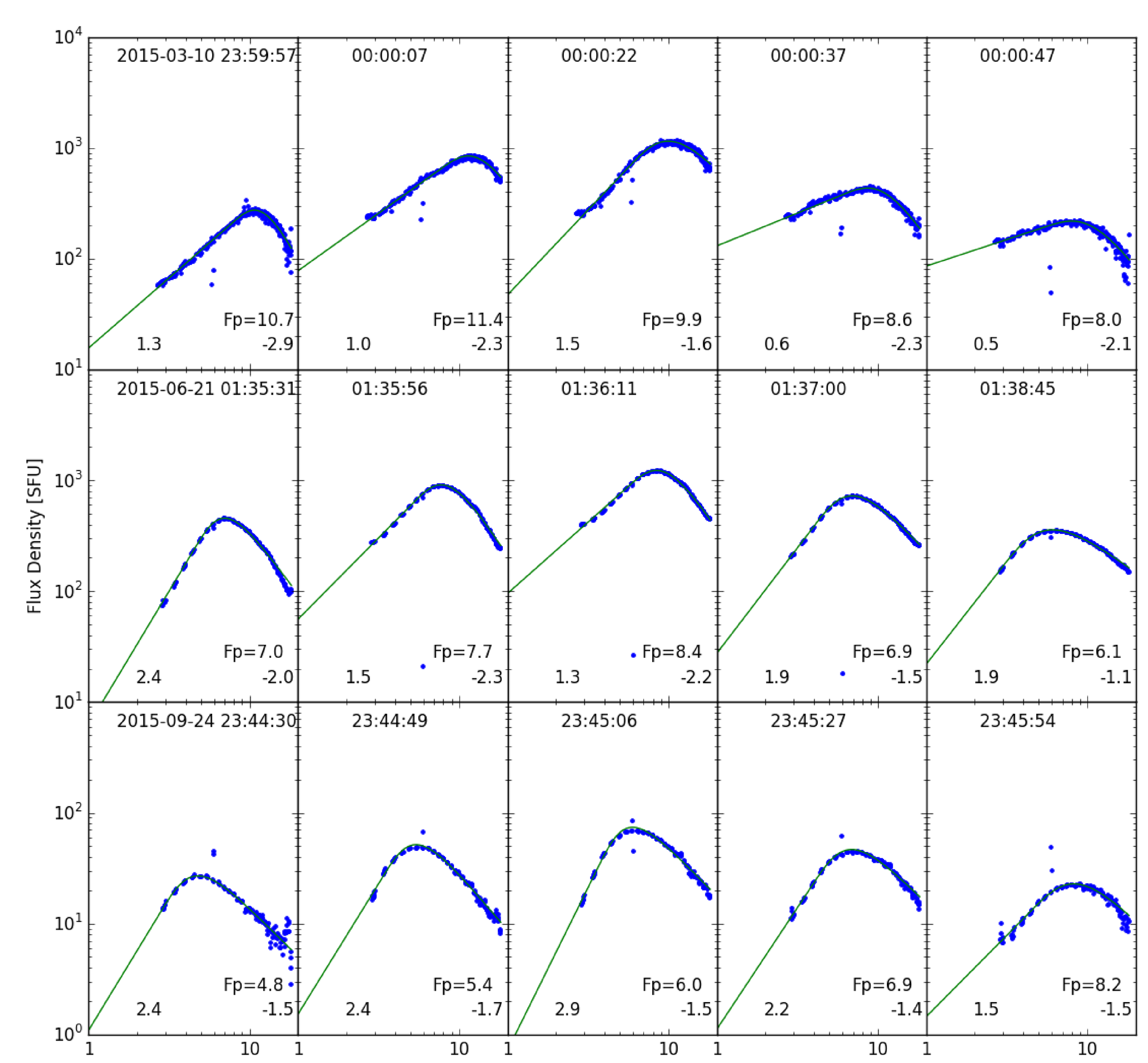

Fig 3: Spectral evolution of the three events (each panel with 5 plots). The green fitting curve is drawn using equation (1). On the bottom corner of each spectrum, low frequency spectral index (left value), high frequency index (right value) and peak frequency (F_p) are marked.

Optically thick spectral indices (low frequency slopes) are indicators of *source characteristics*, which are compared here with homogeneous theoretical model.

Results:

- The *slopes* in the middle and top panel events show that the sources are inhomogeneous in nature. The third event (weak burst) shows the exact slope predicted for a homogeneous source.
- *Peak frequency* is observed to be varying for the first two events and constantly increasing for the third event as a function of time. This can be correlated with its strong dependence on the magnetic field responsible for this emission.

SPECTRAL ANALYSIS

What interferometry – relative visibility data tell us about the source evolution?

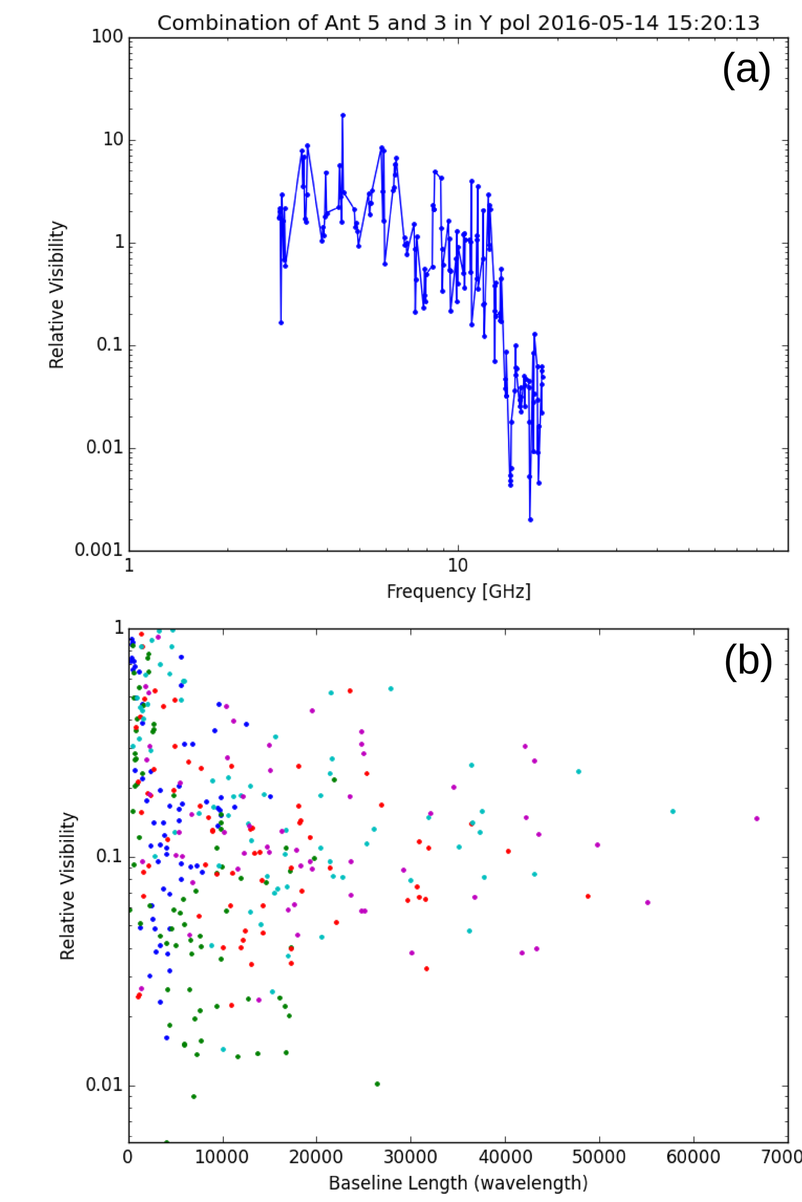

Fig 4: Relative visibility plots as a function of (a) frequency and (b) baseline length for the burst observed on 14 May, 2016. The colored dots in (b) are visibilities of five discrete frequencies.

- At the low frequencies, for a single Gaussian source observed the relative visibility (RV) value is near to unity.
  RV ≈ 1 for a point source
- At high frequencies, frequency synthesis technique makes the fringe spacing smaller resulting in the over-resolution of the source decreasing the RV value.
  RV < 1 for an extended source

Thus, RV spectral shape depends only on the source size, which decreases with an increasing source size.

Results:

- RV at peak time of the burst in the first plot shows decreasing curve with respect to frequency as expected.
- RV distribution in baseline length plots shows decrease in RV as a function of baseline length which in turn says that the source size is increased.

SUMMARY

- EOVSA provides promising data to conduct this study of source characteristics and dynamics for the first time after the array's Expansion phase. The study shows that the microwave sources are *majorly observed as inhomogeneous in nature* with the observed flux density and relative visibility spectrum. The homogeneous source values observed in the fitted spectra can be diagnosed further for the effects of ambient medium.
- The inhomogeneity that we see here is not enough for confirming the source characteristics. A spatially resolved spectrum on the source to probe each pixel on the source image will tell more about the source, in turn about the particle acceleration and its consequent radiation at the flare site.
- EOVSA will be soon generating such powerful spectrum with images, which will be the first of its kind for its high resolution to potentially determine the source dynamics.

REFERENCES

1. M. Stahli, D. E. Gary, and G. J. Hurford. Sol.Phys., 120:351-368, September 1989. doi:10.1007/BF00159884.
2. D. E. Gary and G. J. Hurford. ApJ, 339:1115-1122, April 1989. doi: 10.1086/167366.

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