Resolving Meteor Radio Afterglows with the OVRO-LWA

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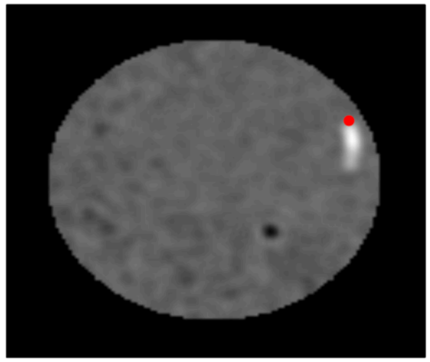
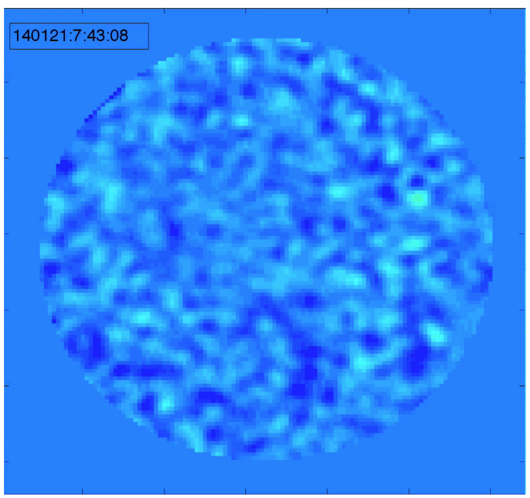
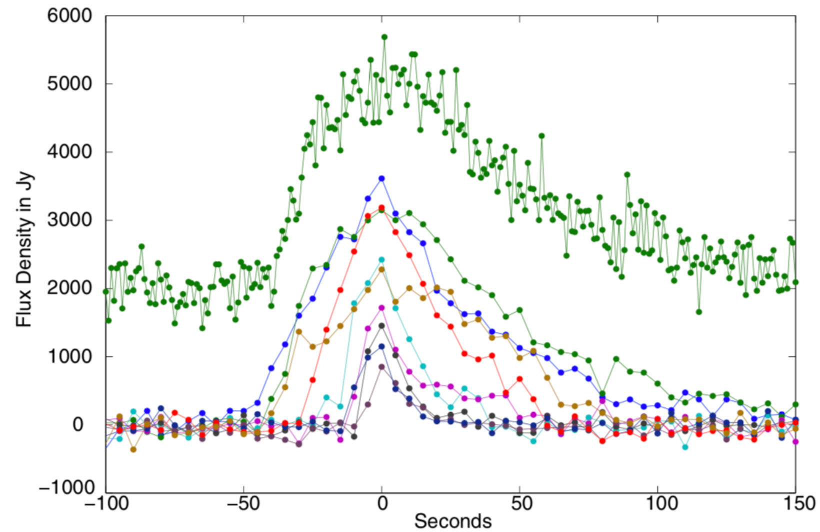
Meteor Radio Afterglows (MRAs)

NASA All-Sky Fireball Network



LWA1



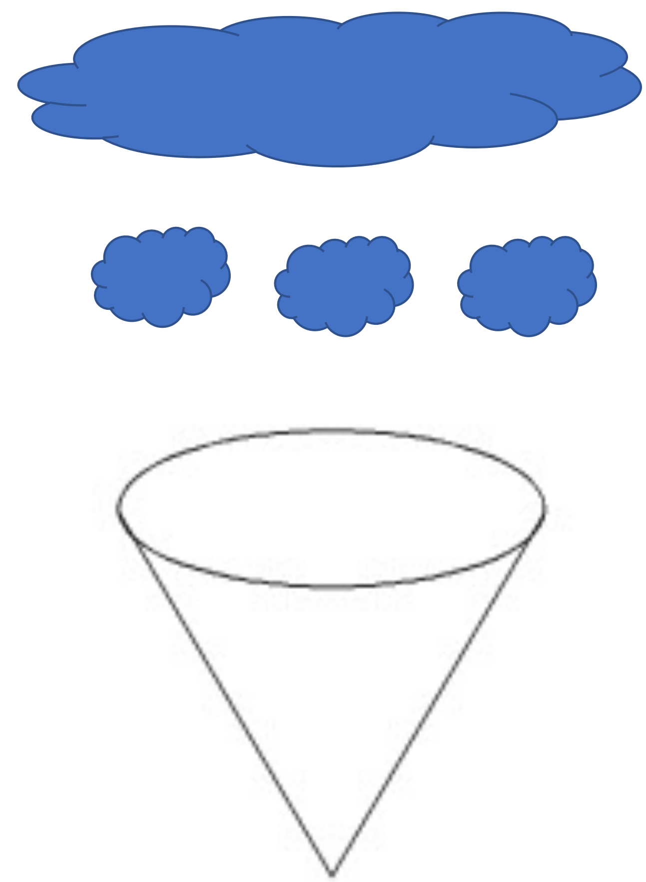


- Non-thermal and unpolarized
- Associated with meteor showers
- Broadband 20-60 MHz
- Altitude cutoff ~ 90 Km
- Origin associated with Persistent trains (Logan's talk)
- Radiation mechanism ?
- Plasma wave and Transition radiation hypothesis

Obenberger et al. 2014, ApJL

Probing the MRA emission size scales

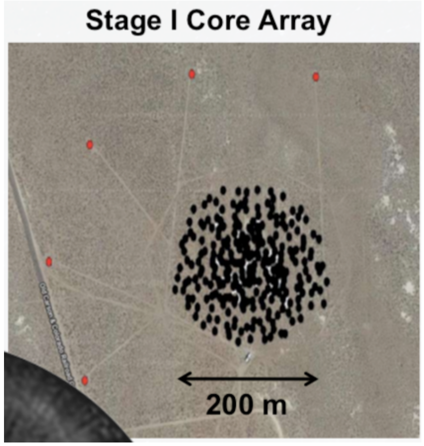
- LWA1 and LWA-SV – 110m diameter
- Limited angular resolution 7 degrees at 30 MHz
- Limits localization and resolving source structure
  - 10 km trails at 100 km distance
  - Point sources
- Probing the plasma structures of MRA requires higher resolution
- A study using LWA1 and LWA-SV → Isotropic nature of MRAs (Varghese et al. 2019)
- Isotropic radiation pattern
  - Incoherent emission on large scale plasma regions
  - Incoherent addition of small coherent regions

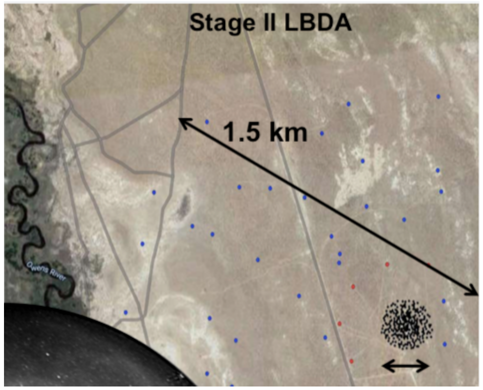


High resolution observations required

High resolution observation of MRAs with OVRO-LWA

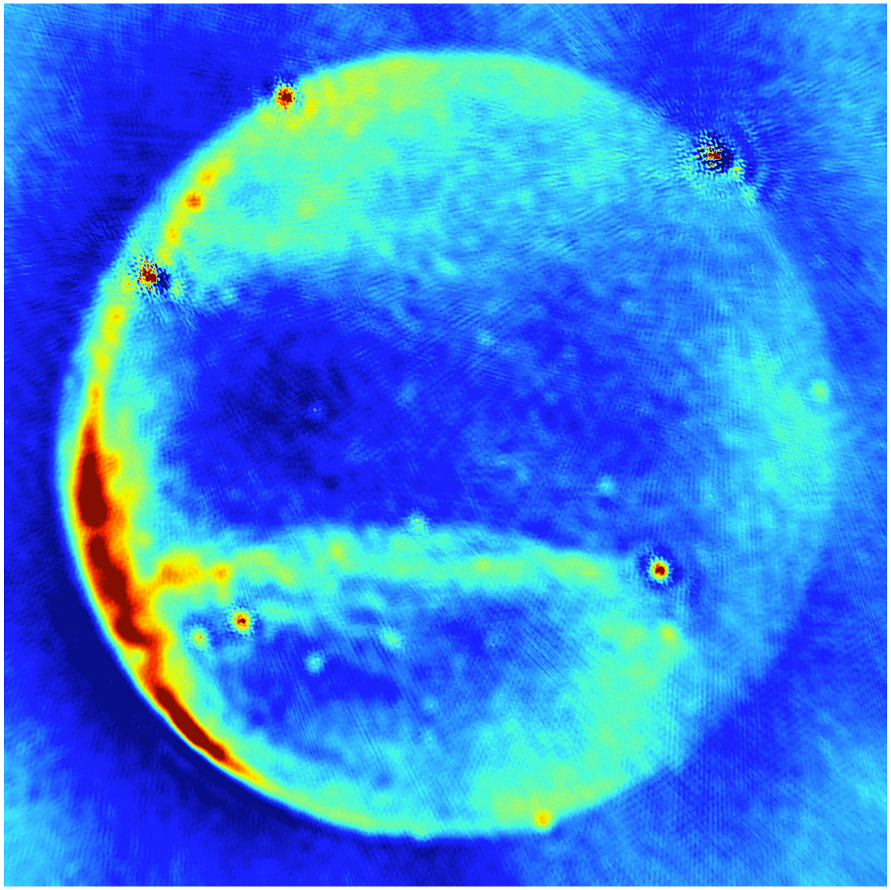
- 27-84 MHz
- 251 element inner core and 32 element extending to 1.5 km
- Angular resolution - 7 arcmin
- Previous searches (Anderson et al. 2019)
- 4 days of data during Perseids meteor shower 2018
- Four sub bands between 30-50 MHz separated by 2.6 MHz





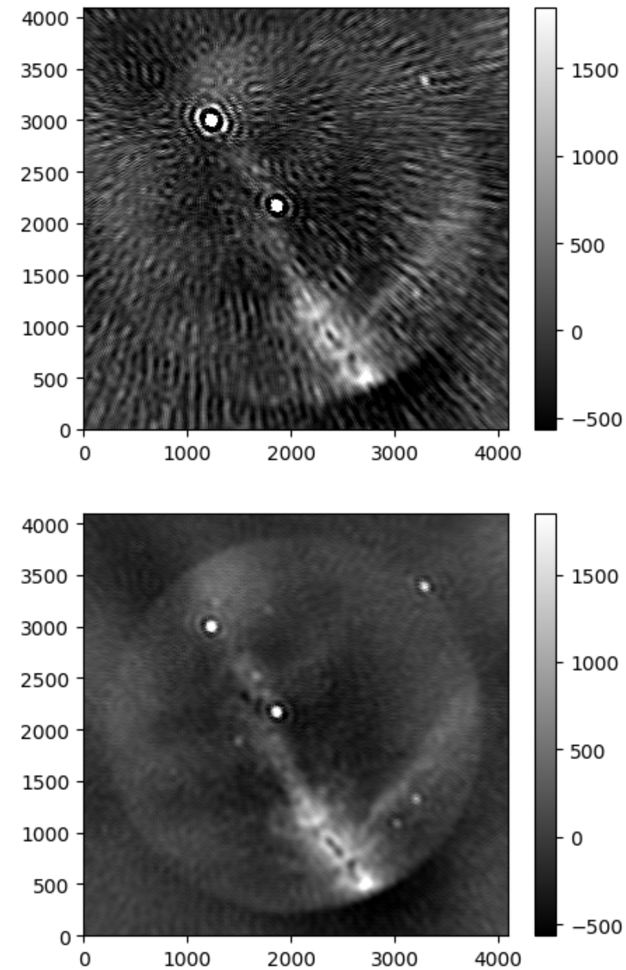
Calibration and Imaging

- Removed 20% antennas, 1 % baselines
- Two-point source sky model with Cyg A and Cas A
- CASA bandpass task -> derive antenna gains per channel
- Solutions derived per integration basis (13 s) when Cyg A at higher elevations.
- MS imaging using CASA Clean task with (4096 by 4096 pixels), pixel size of 1.875’



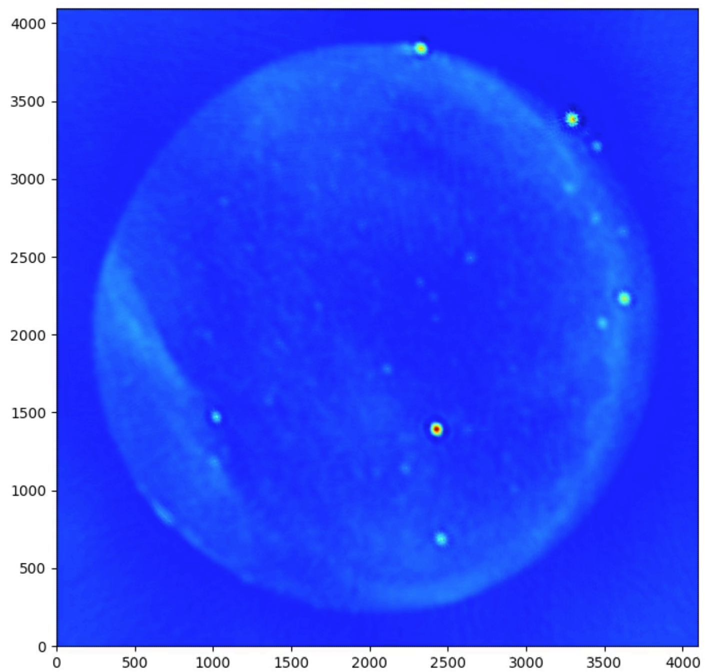
- **Peeling** of sources to improve the SNR
- UNM Advanced Research Computing (CARC) for parallelizing calibration and imaging
- One hour HDF5 images
- Existing pipeline for continuous image subtraction (RFI flagging, etc.)
- Core array at low angular resolution
    - Best for MRAs
    - Avoid any near field complications
    - Faster imaging
- High resolution imaging after MRA detection

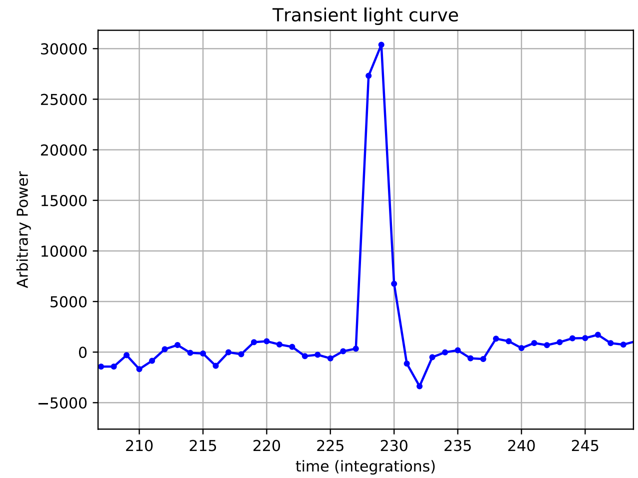
Varghese et al. in prep

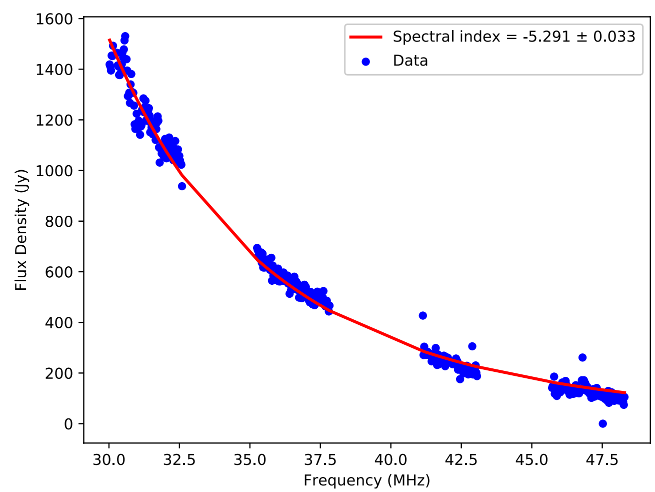


Results:

5 MRAs detected







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Near field corrections

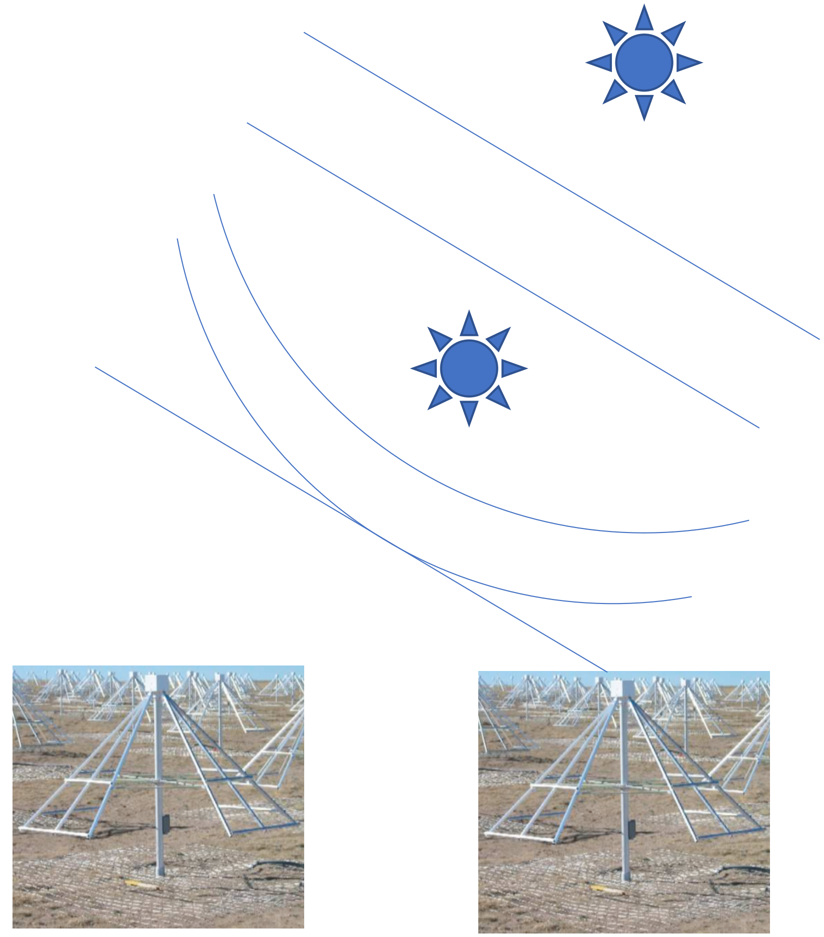
- Correlator assumes plane waves
- Not valid for a 1.5 km baseline when a source at 100 km
- Visibilities phased in the direction of source
- Correction phase factor (Synthesis Imaging in Radio Astronomy : Solar System Objects) applied to all baselines

$$V'(u,v) = e^{i\Phi}\, V(u,v)$$

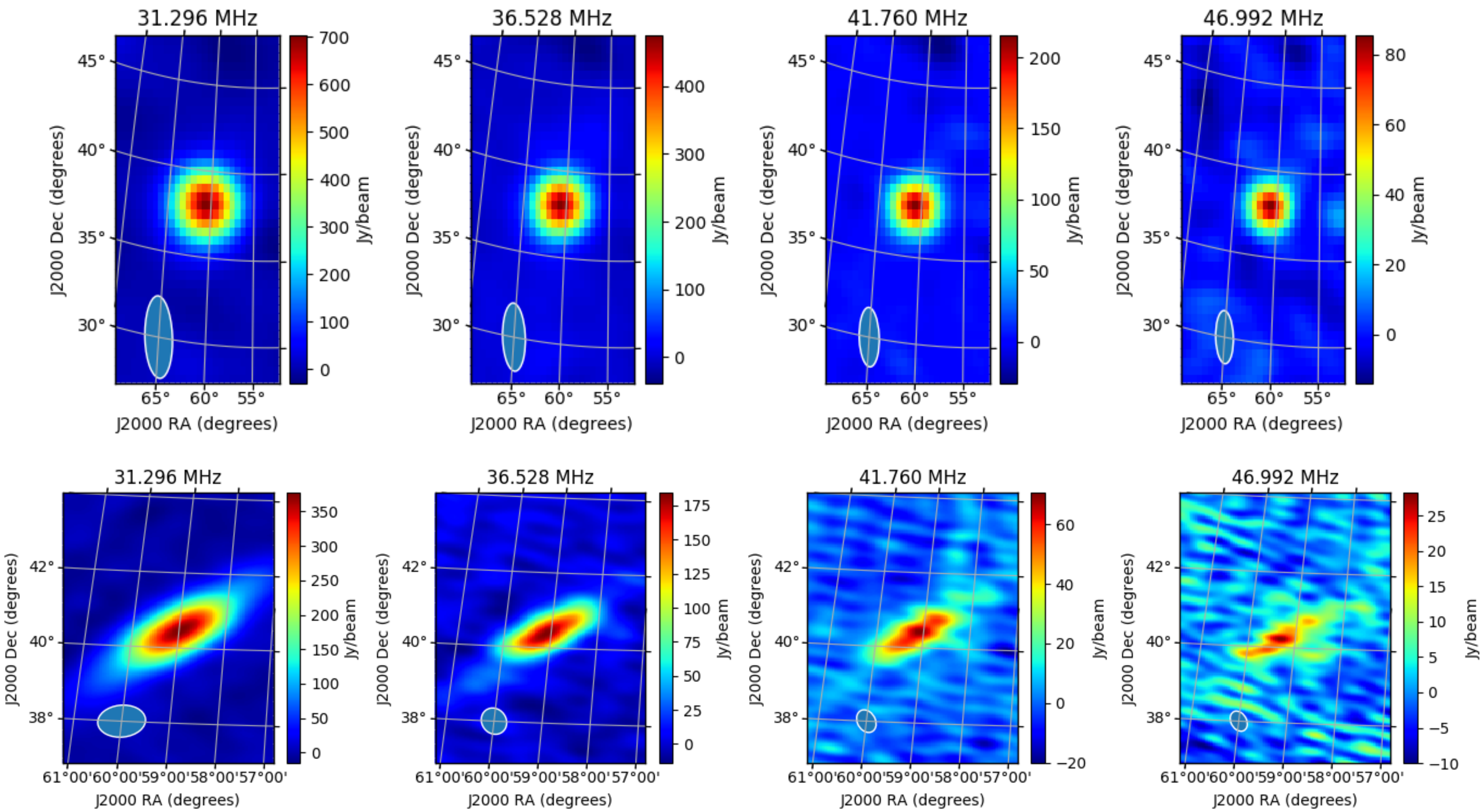
$$e^{2\pi\delta/\lambda}$$

$$\delta = \frac{x_1^2 + y_1^2 - (x_2^2 + y_2^2)}{2\,D}$$

- Visibility differencing to improve SNR
- Imaging with CASA and interactive deconvolution to map out resolved plasma structures



Comparison of low resolution and high resolution: MRA1 (13 S event)

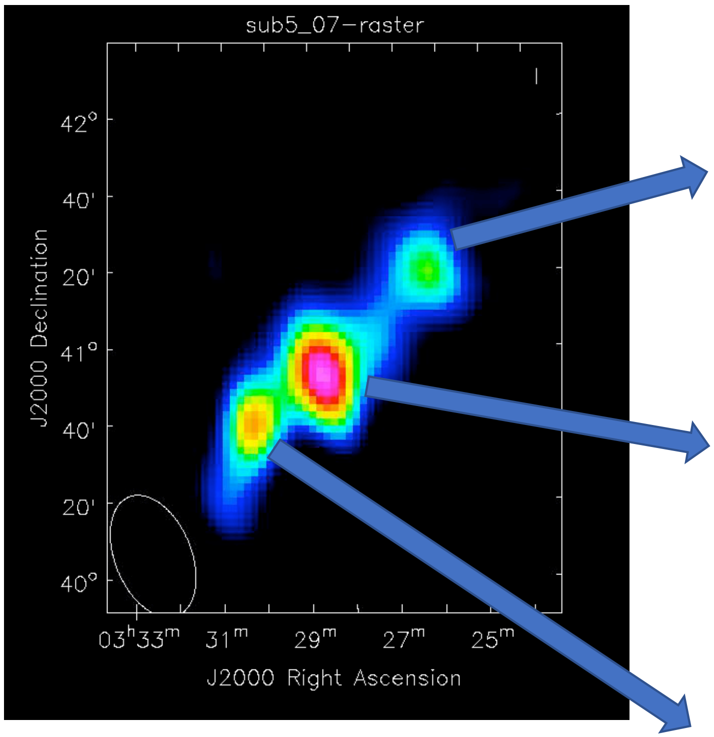


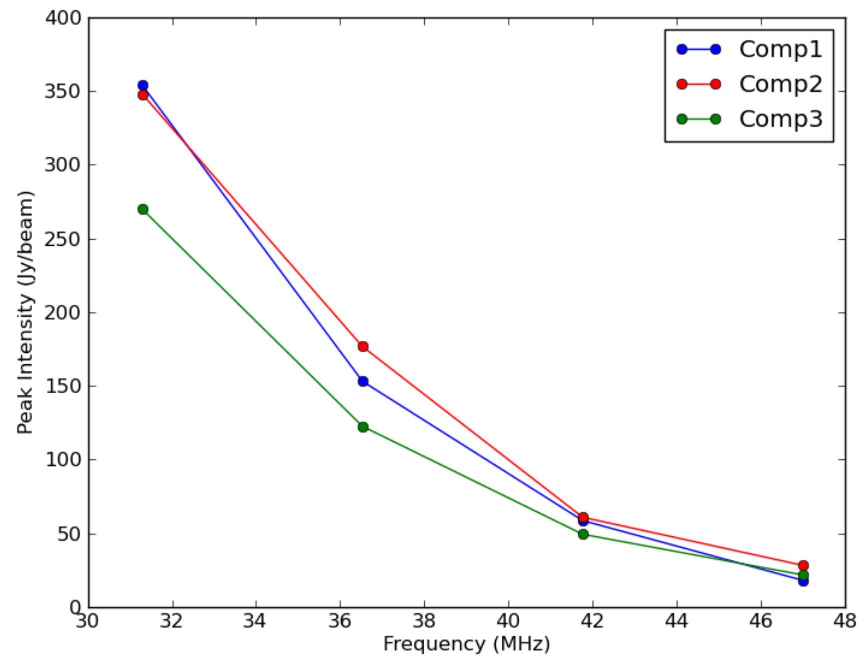
Core array – 200 m (~2 degrees)

Whole array – 1500 m (~30’)

Varghese et al. in prep

High resolution components

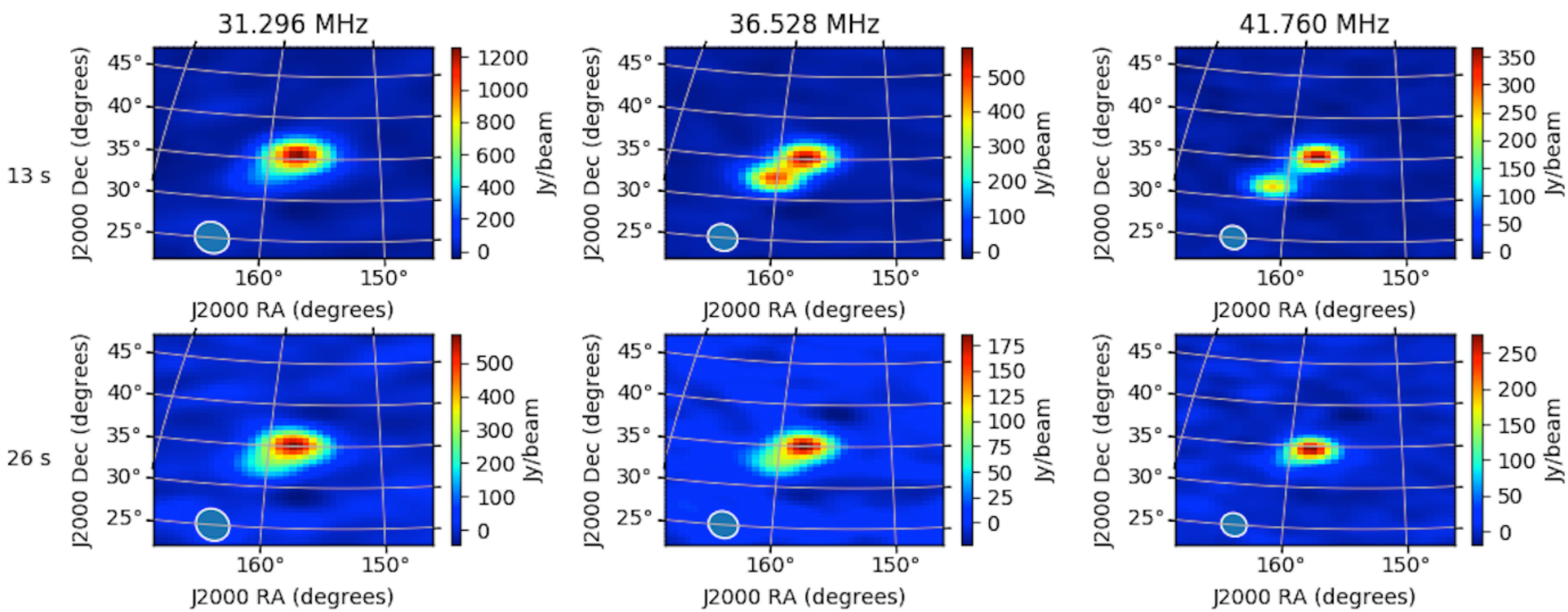




Varghese et al. in prep

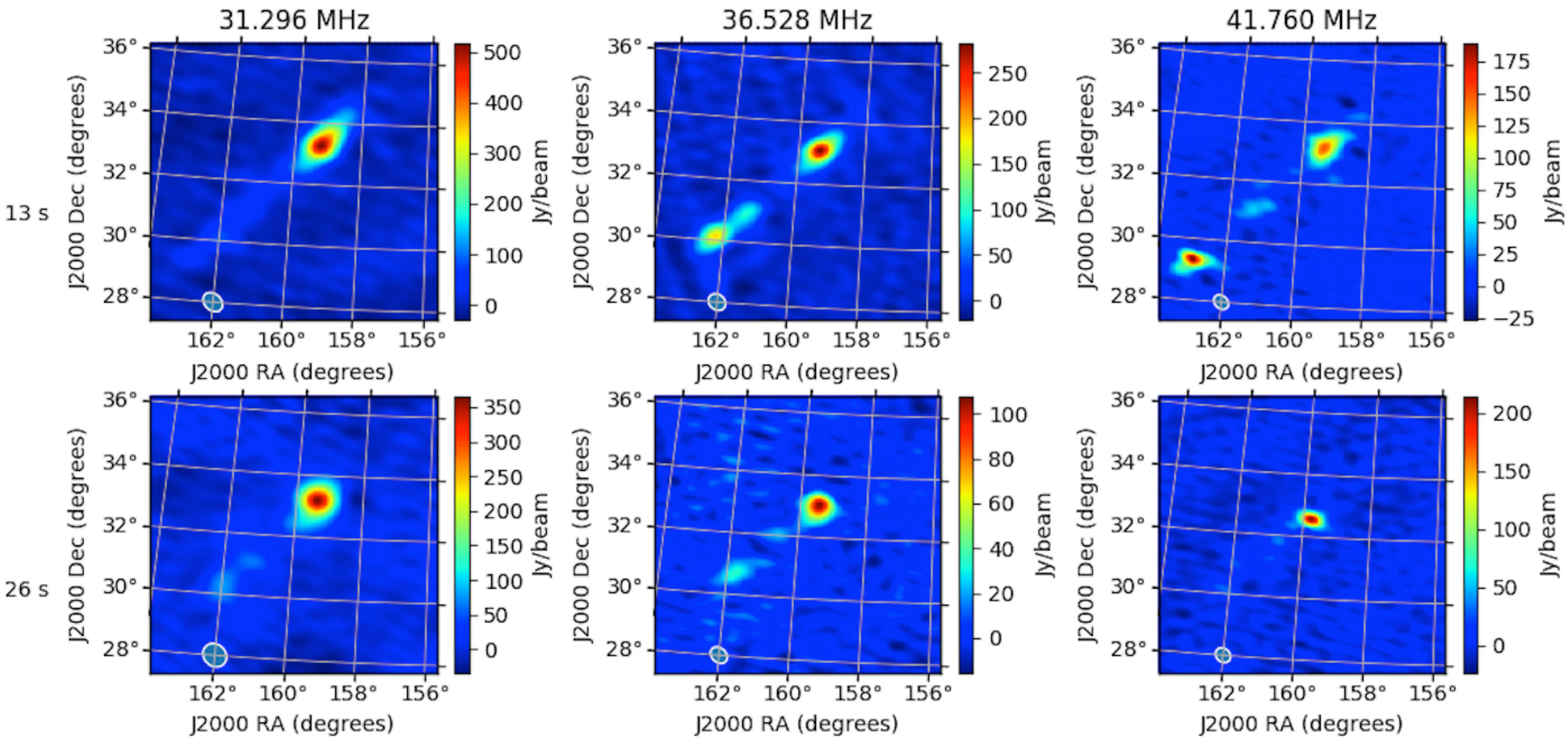
- Resolved down to less than 30’ or 1.36 km at 100 km distance
- What determines the spectral shape of MRAs/plasma structures?

Comparison of low resolution and high resolution: MRA2 (26 S event)



Core array – 200 m

Comparison of low resolution and high resolution: MRA2 (26 S event)



Whole array – 1500 m

Summary

- Detection of MRAs outside NM and at higher angular resolution
- Resolved MRAs down to less than 30’ or 1.36 km
- MRA plasma made of small-scale structures
- Understand the evolution of plasma structures
- Effects of neutral winds and magnetic field can be studied
- Work in progress