Spatially Resolved Observations of Meteor Radio Afterglows with the OVRO-LWA

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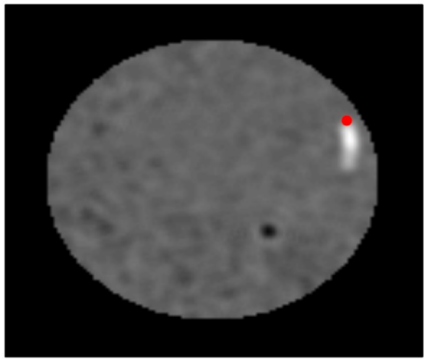
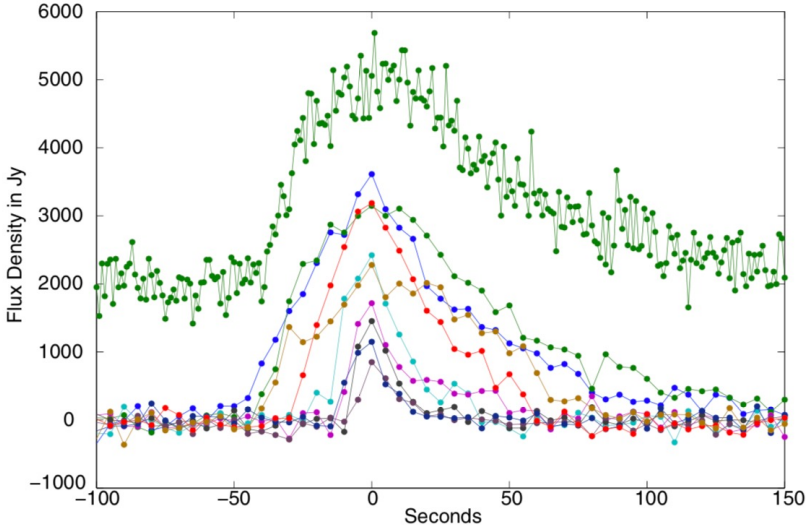
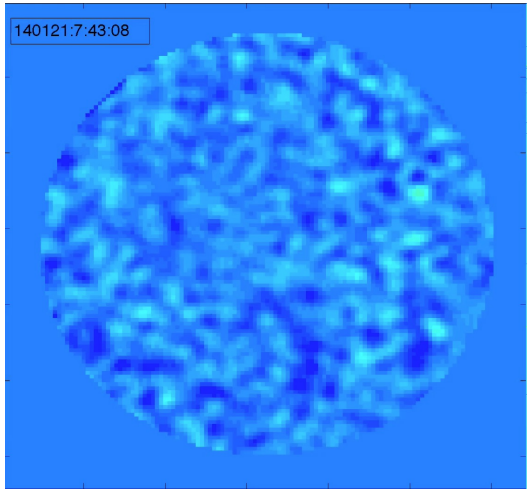
Meteor Radio Afterglows (MRAs)

NASA All-Sky Fireball Network



LWA1



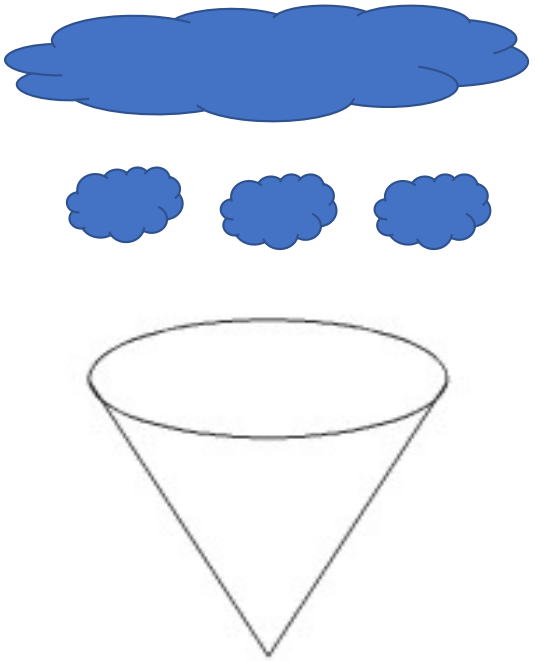


- Non-thermal and unpolarized
- Associated with meteor showers
- Broadband 20-60 MHz
- Altitude cutoff ~ 90 Km
- Origin associated with Persistent trains
- Radiation mechanism ?
  - Plasma wave and Transition radiation hypothesis
- Radiated plasma frequencies proportional to local electron density

Obenberger et al. 2014, ApJL

Probing the MRA emission size scales

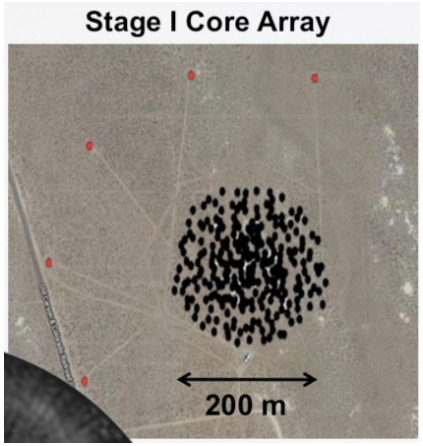
- LWA1 and LWA-SV – 110m diameter
- Limited angular resolution 4 degrees at 40 MHz
- Limits localization and resolving source structure
  - 10 km trails at 100 km distance
  - Point sources
- Probing the plasma structures of MRA requires higher resolution
- A study using LWA1 and LWA-SV → Isotropic nature of MRAs (Varghese et al. 2019)
- Isotropic radiation pattern
  - Incoherent emission on large scale plasma regions
  - Incoherent addition of small coherent regions

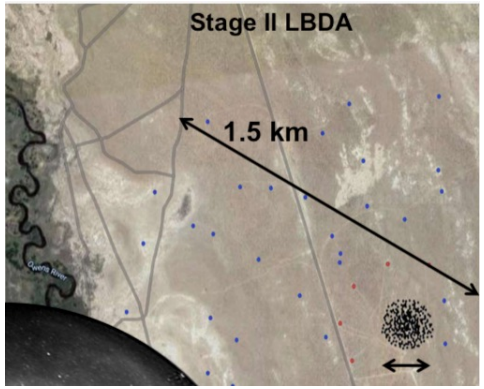


High resolution observations required

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 - 17 arcmin at 40 MHz
- 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
- Raw visibility datasets with 13 s integration

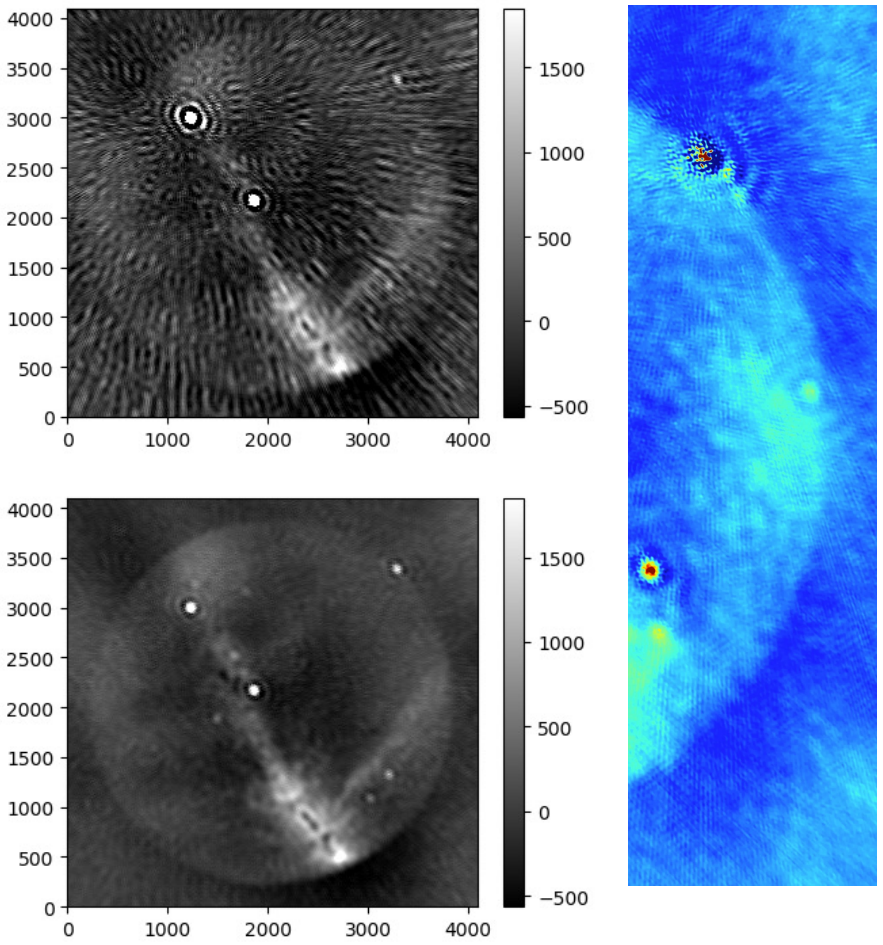




Calibration and Imaging

- Calibration
  - 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.
- Core array at low angular resolution
  - Best for MRAs
  - Avoid any near field complications
  - Faster imaging
- UNM Advanced Research Computing (CARC) for parallelizing calibration and imaging
- One hour HDF5 images

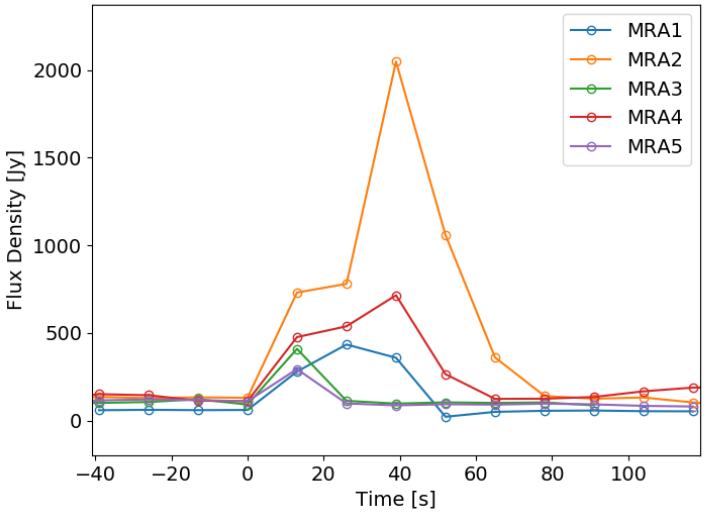
- Existing pipeline for continuous image subtraction (RFI flagging, etc.)
- High resolution imaging after MRA detection
- MS imaging using CASA Clean task with (4096 by 4096 pixels) image size, pixel size of 1.875’
- **Peeling** of A team sources to improve the SNR

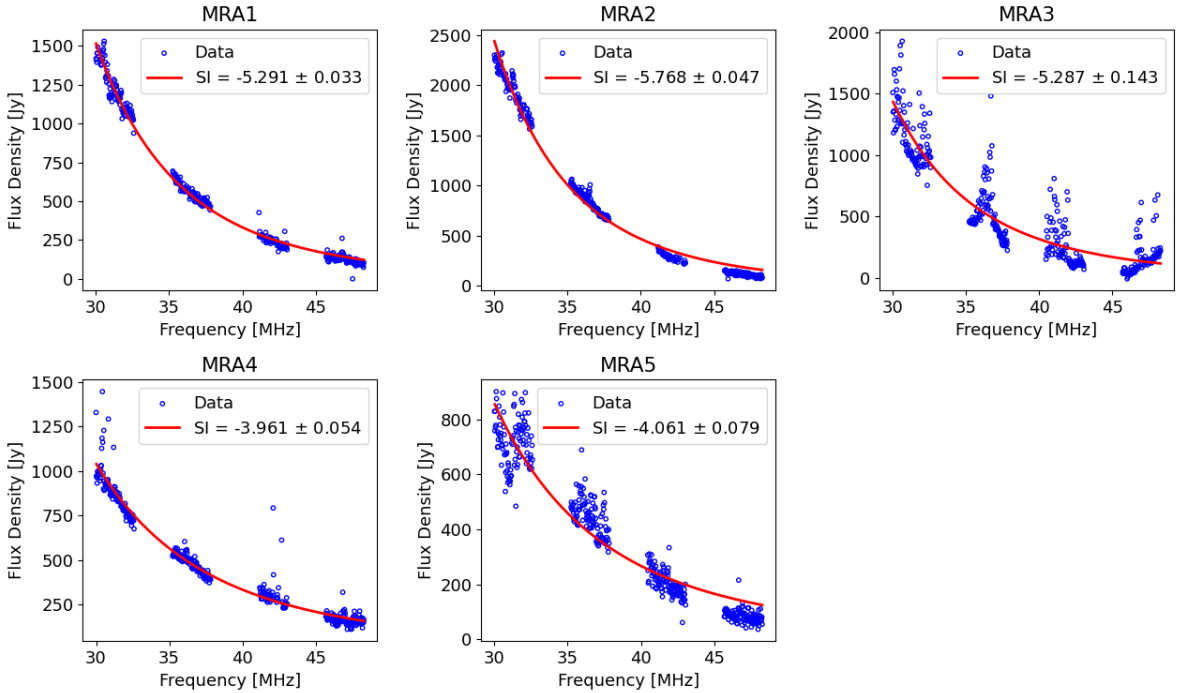


Varghese et al. in prep

Detection of MRAs

Name	RA	Dec	MJD	UTC Time
MRA1	156.050	70.970	58340	20:49:50
MRA2	132.370	42.370	58340	21:06:05
MRA3	238.510	9.140	58341	04:34:09
MRA4	277.800	35.780	58341	06:38:57
MRA5	46.200	-7.320	58346	13:48:06





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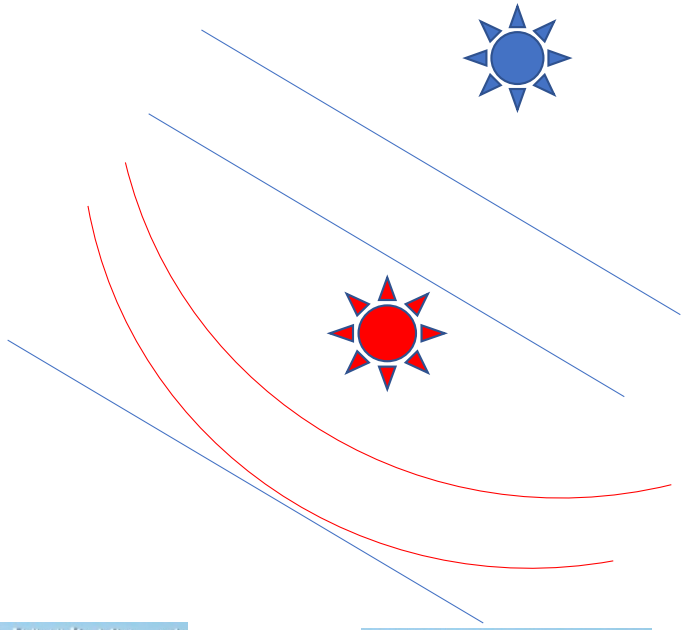
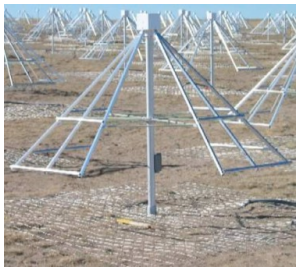
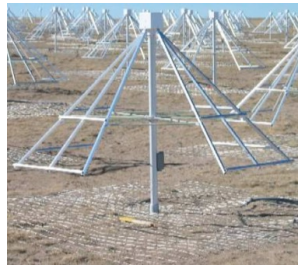
Near Field Corrections

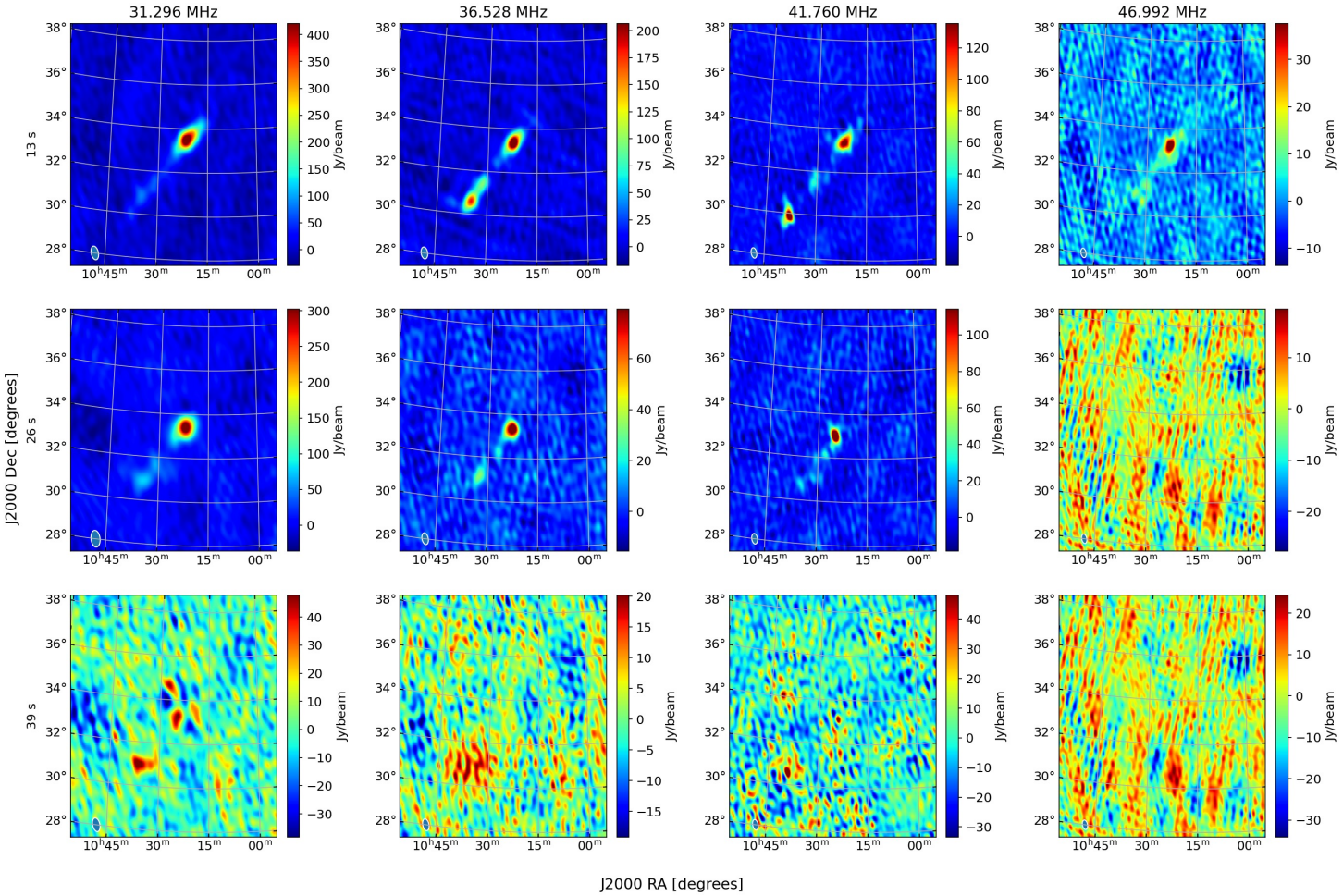
- Correlator assumes plane waves
- Not valid for a 1.5 km baseline when a source at 100 km
- Visibilities phased in the direction of source (assuming 100 km distance)
- Visibility differencing to improve SNR
- Imaging with CASA and interactive deconvolution to map out resolved plasma structures



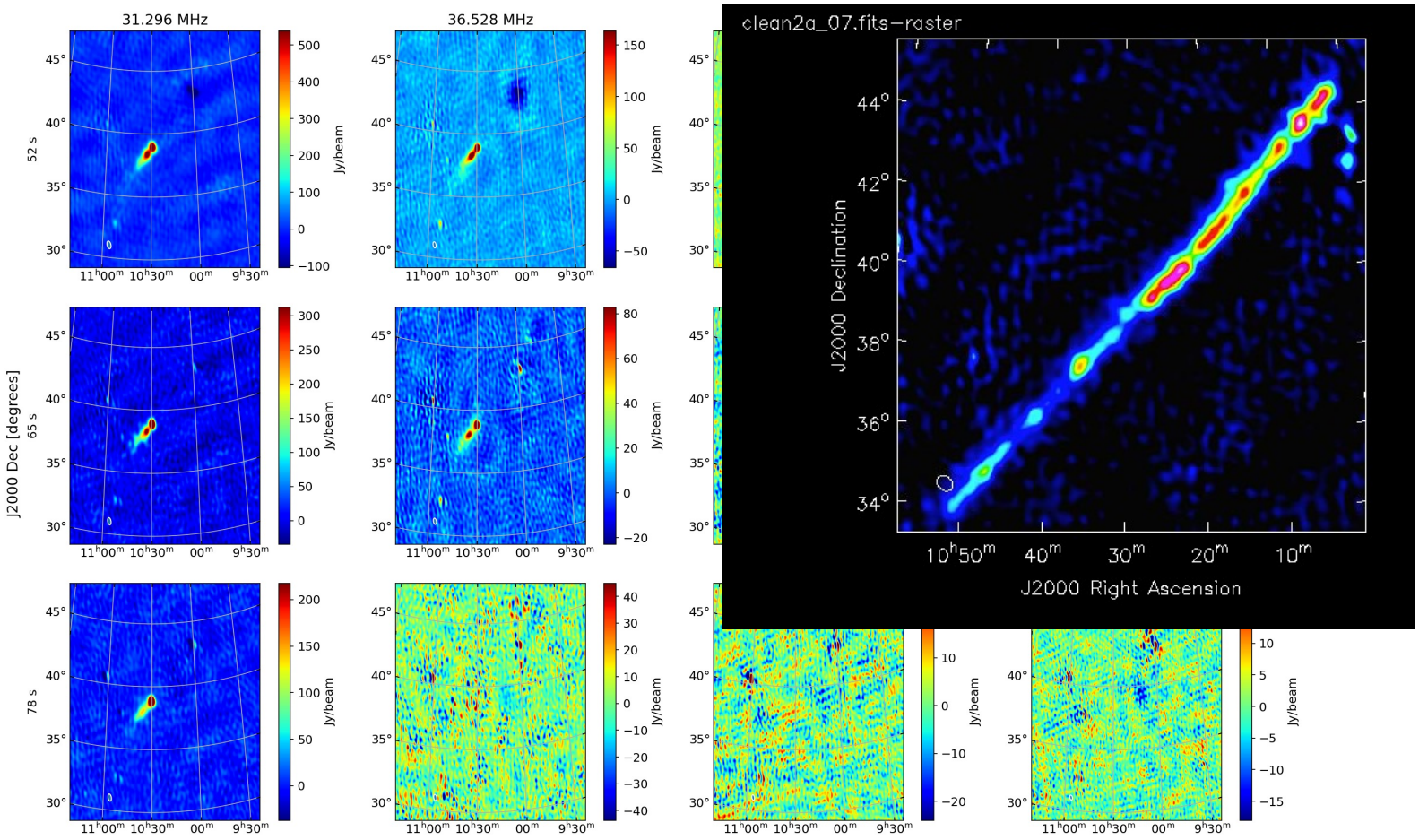




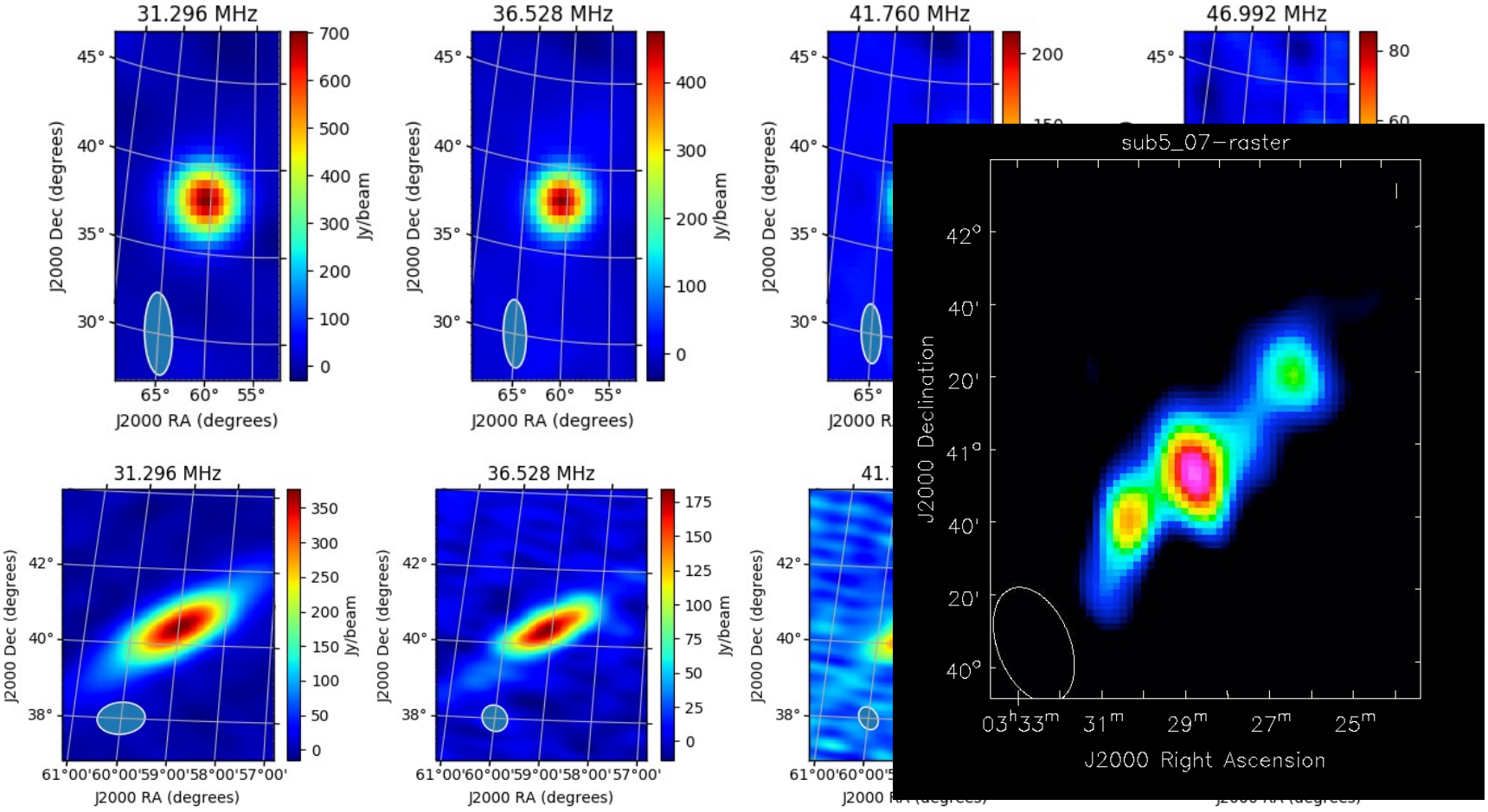
MRA1


31.296 MHz
36.528 MHz
41.760 MHz
46.992 MHz
13 s
26 s
39 s
J2000 Dec [degrees]
J2000 RA [degrees]
Jy/beam

MRA2


31.296 MHz
36.528 MHz
clean2a_07.fits−raster
J2000 Declination
J2000 Right Ascension
J2000 Dec [degrees]
J2000 RA [degrees]
52 s
65 s
78 s
Jy/beam

Comparison of low resolution and high resolution: MRA5



Core array – 200 m (~2 degrees)

Whole array – 1500 m (~30')

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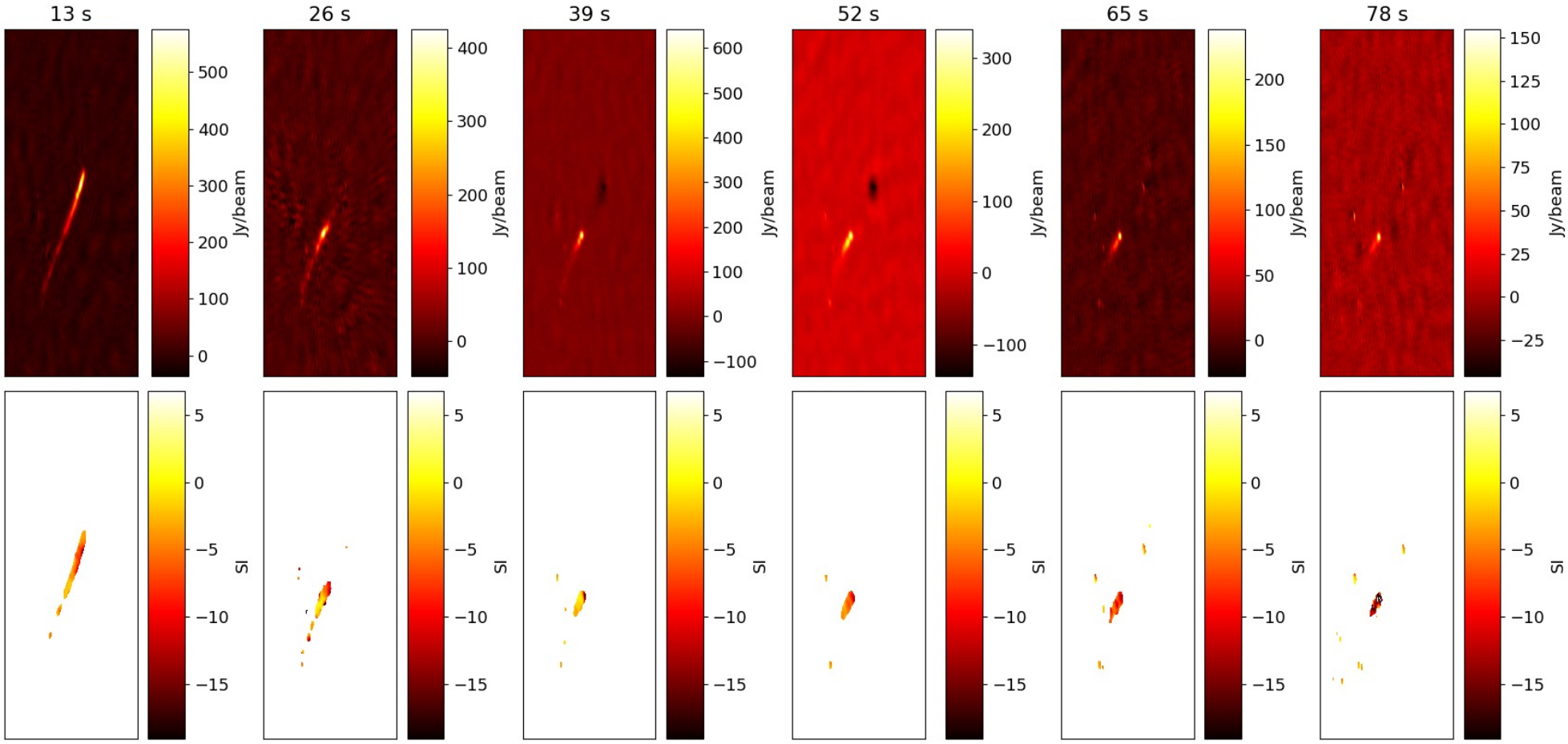
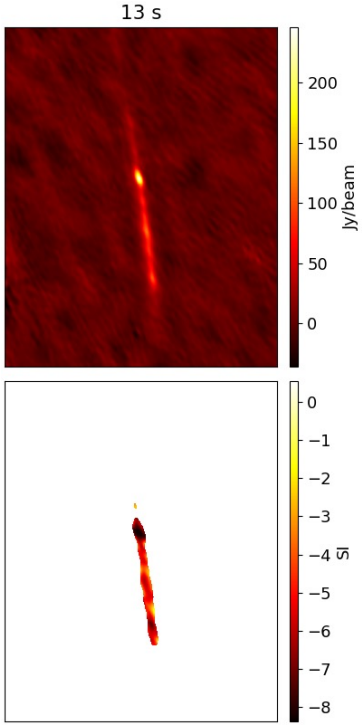
Spectral Index Mapping – MRA2

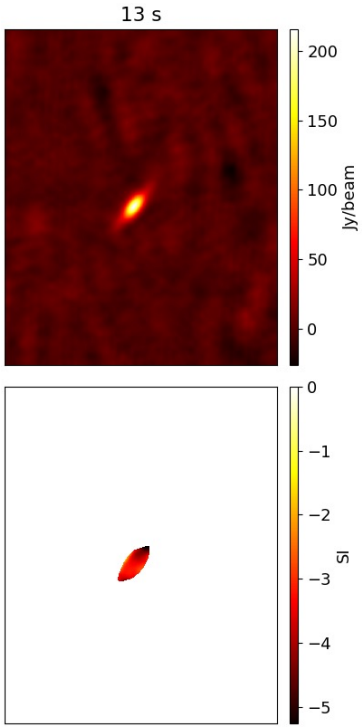


Spectral Index Mapping – MRA3, MRA5 and MRA4

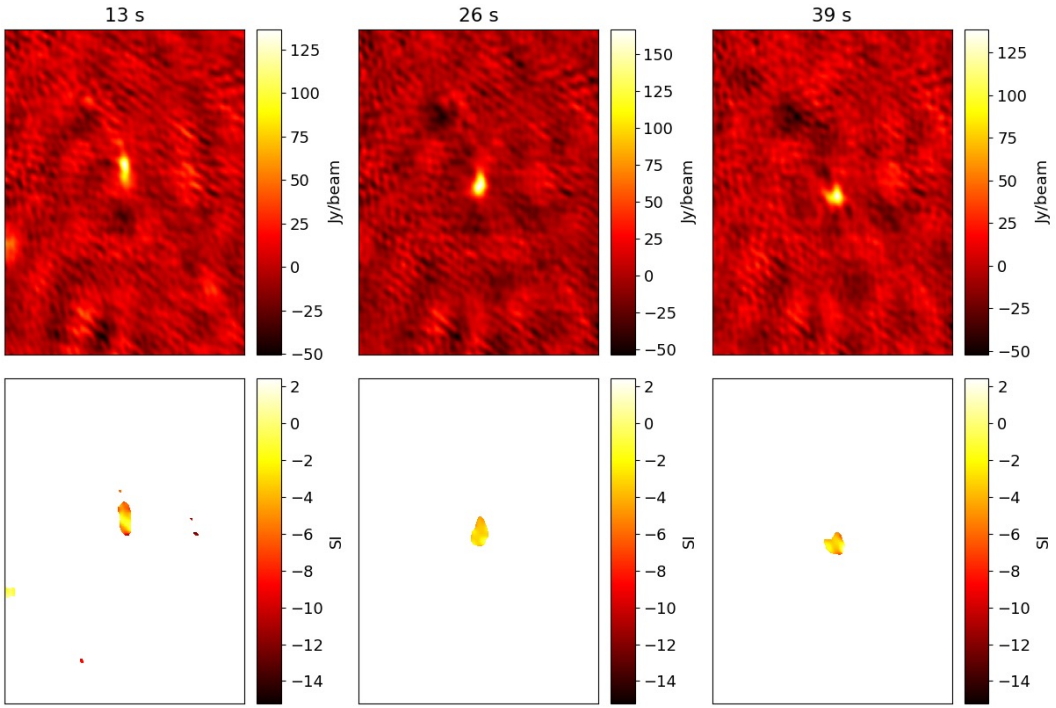
MRA3



MRA5



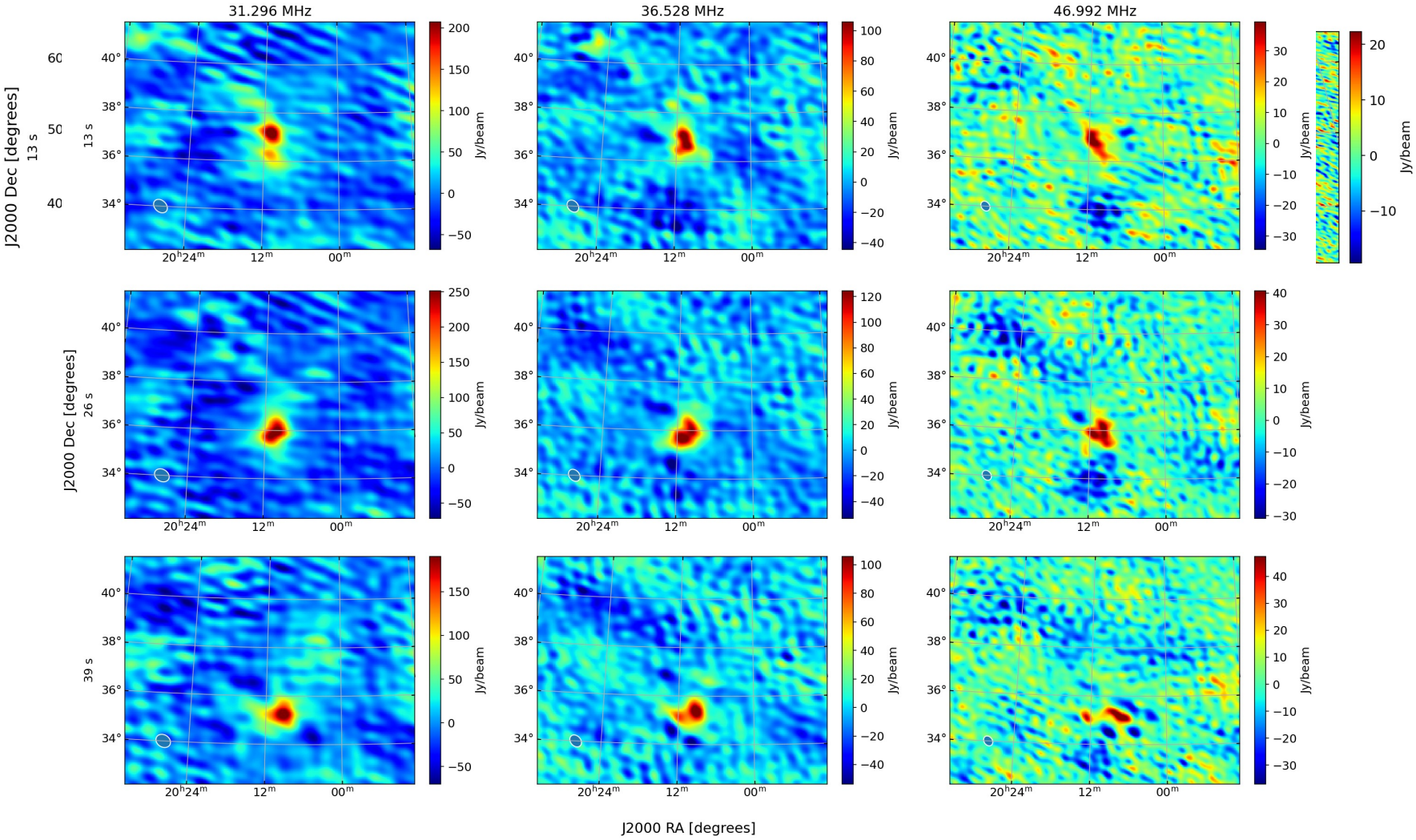
MRA4



Summary

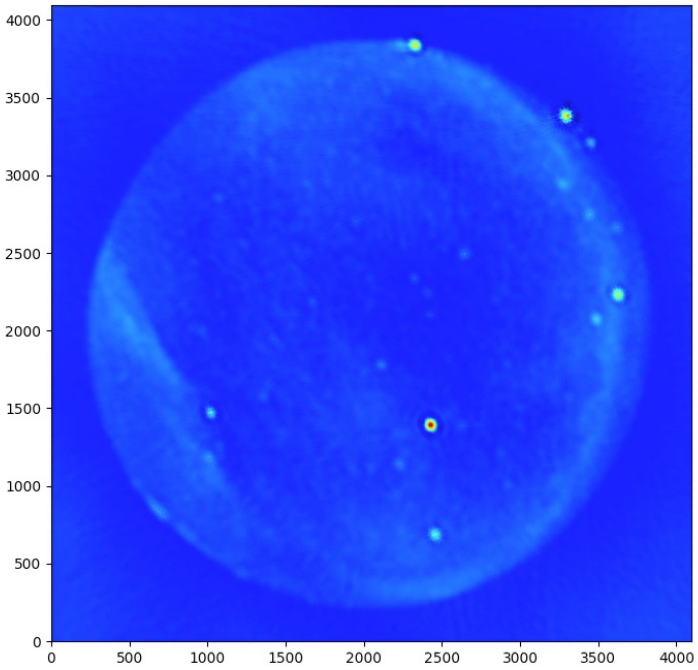
- Detection of MRAs at higher angular resolution
- Resolved MRAs down to less than 30’ or 1.36 km
- MRA plasma made of small-scale structures
- Long duration event showing the diffusion of MRA emission in SI maps
- Effects of neutral winds can be studied – might need higher time resolution

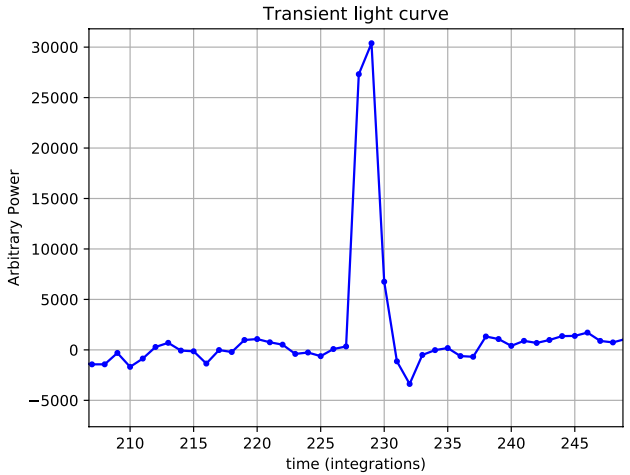
MRA3 and MRA4

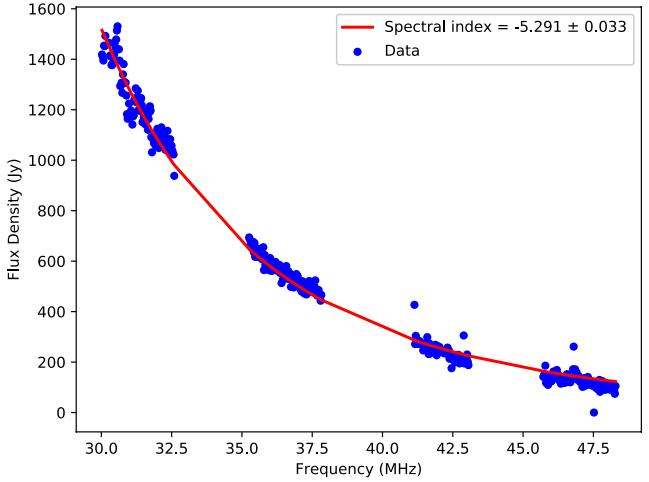


Detection of MRAs

5 MRAs detected







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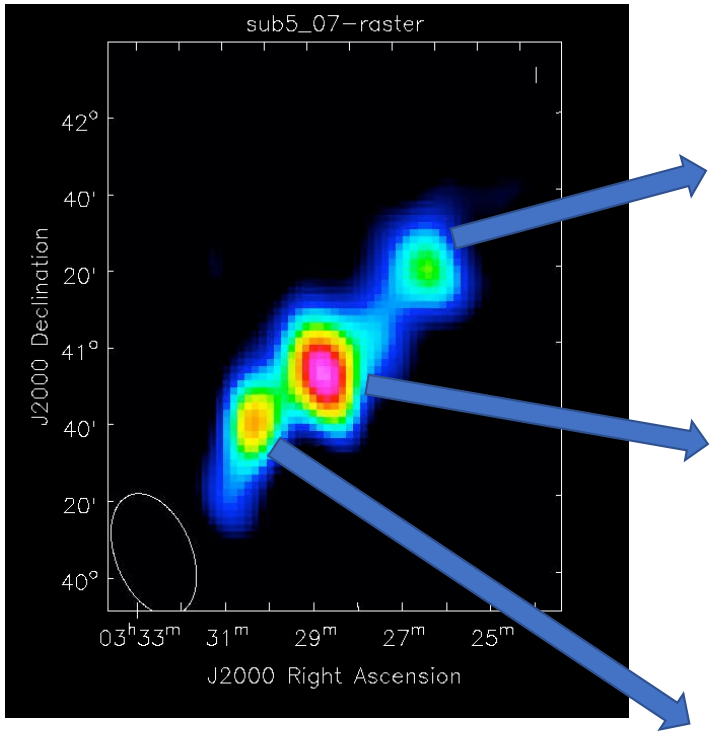
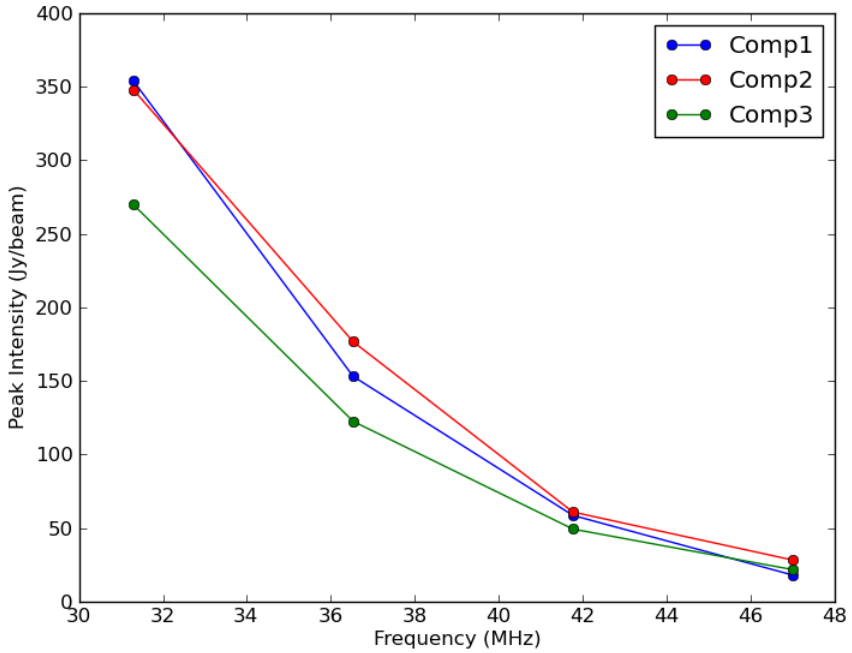
High resolution components





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

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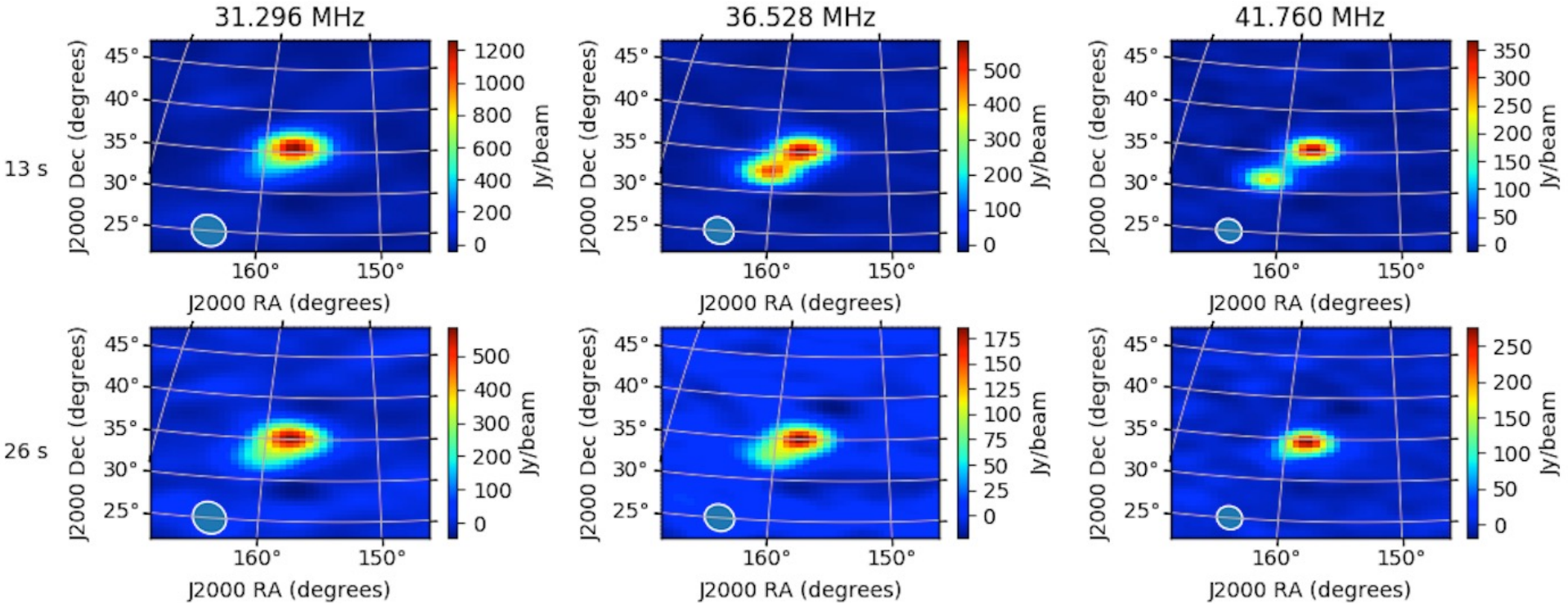
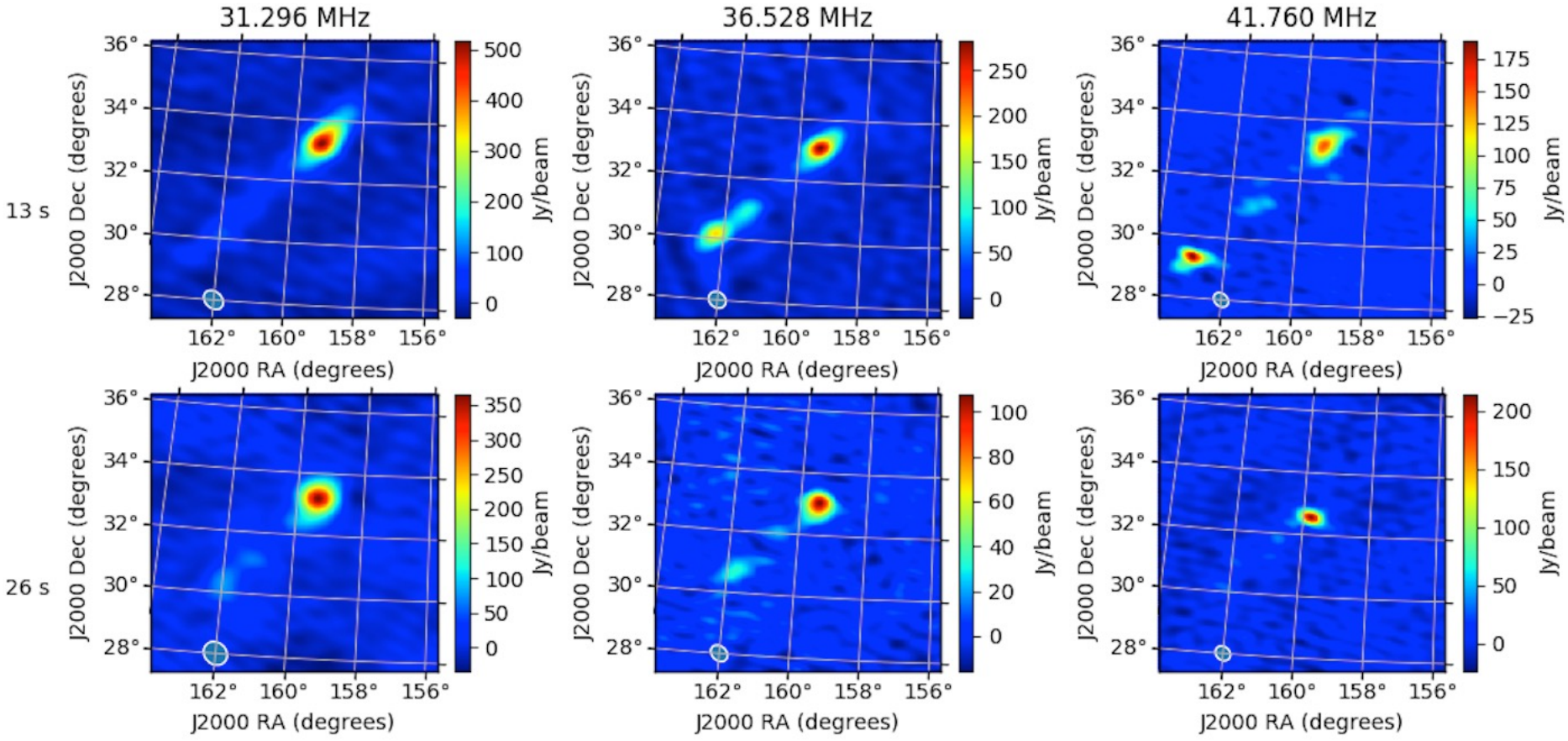
Comparison of low resolution and high resolution: MRA2 (26 S event)



Core array – 200 m

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



Whole array – 1500 m