

Probing the innermost regions of AGN jets with RadioAstron and mm-VLBI at microarcsec resolution

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et al.

A KSP FOR POLARIMETRIC SPACE-VLBI WITH RADIOASTRON

GOAL

RadioAstron provides the first true full-polarization capabilities for Space-VLBI.

Our goal is to develop, commission, and exploit the unprecedented high angular resolution polarization capabilities of RadioAstron to probe the innermost regions of AGN jets and their magnetic fields.

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AO-1 and AO-2 Observations

| Target | Date | Band | Correlation |
|----------|----------------|------|-------------|
| BL Lac | 29 Sep. 2013 | L | Prelim. |
| BL Lac | 11 Nov. 2013 | K | Yes |
| 3C273 | 18 Jan. 2014 | K | Yes |
| 3C279 | 10 March 2014 | K | No |
| OJ287 | 04 April 2014 | K | No |
| 3C273 | 13 June 2014 | L | No |
| 0716+714 | 3 January 2015 | K | No |

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AO-3 TARGETS

- Observations proposed for M87 (L and K-bands), 1633+382/3C345, 3C273/3C279, and 4C39.25/OJ287 (K-band).
- Best uv-coverages for spring 2016, allowing RM and opacity analyses through comparison at 1.3 cm (RadioAstron) and 3mm (GMVA) at similar angular resolutions.

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A LONG-TERM MONITORING OF γ -RAY BLAZARS WITH THE GMVA

PI: A. Marscher

GOAL

Long term monitoring (7 yrs) of 16 γ -ray blazars to identify how the high-energy emission relates to moving and stationary shocks, bends, and other physical structures in the core region.

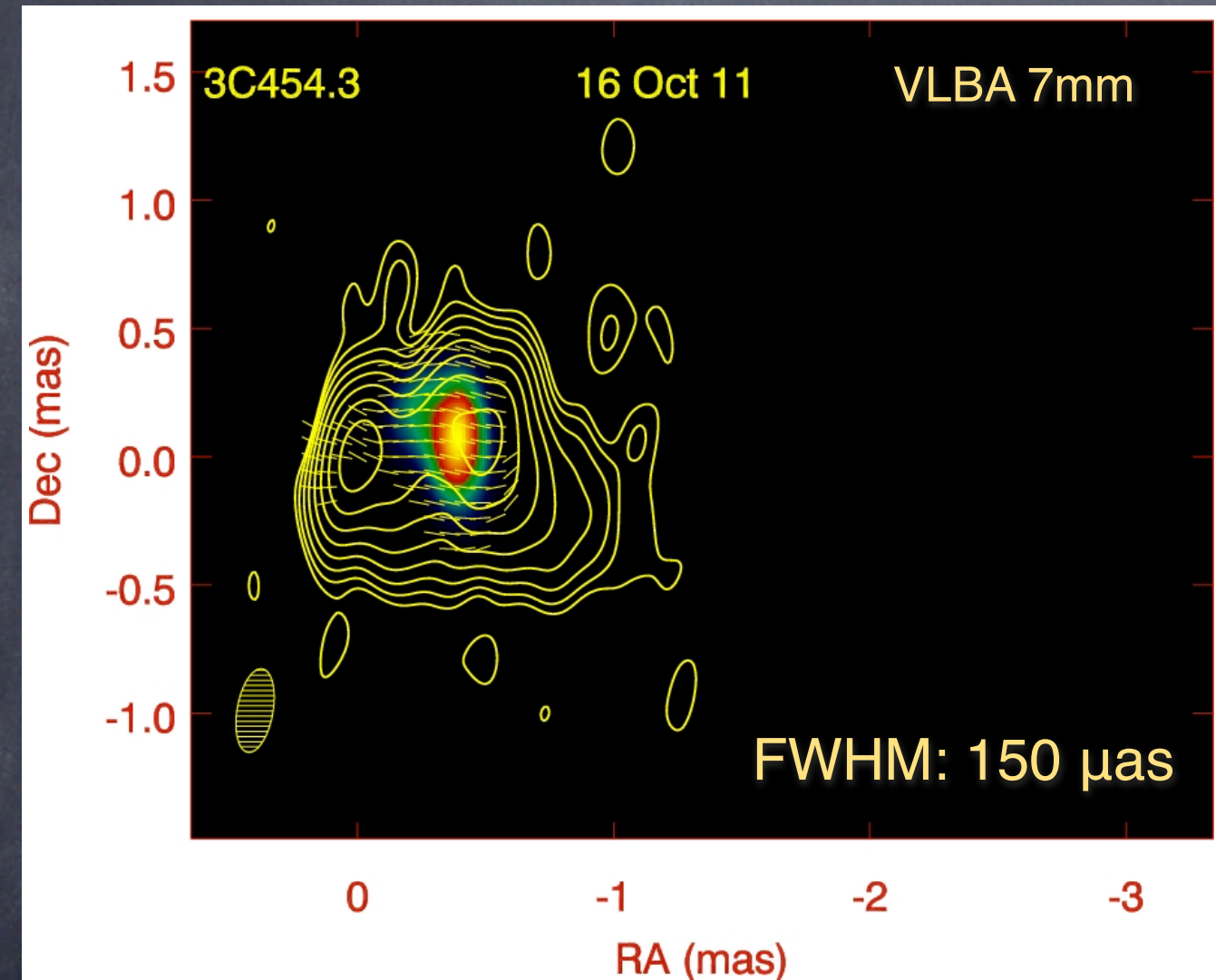
A key aspect is to probe the polarization of the core and inner jet, allowing the study of very high Faraday rotation through polarization comparison at 1.3 cm (RadioAstron), 7 mm (VLBA) and 3 mm (GMVA) observations of the sample of 16 γ -ray blazars.

GMVA targets

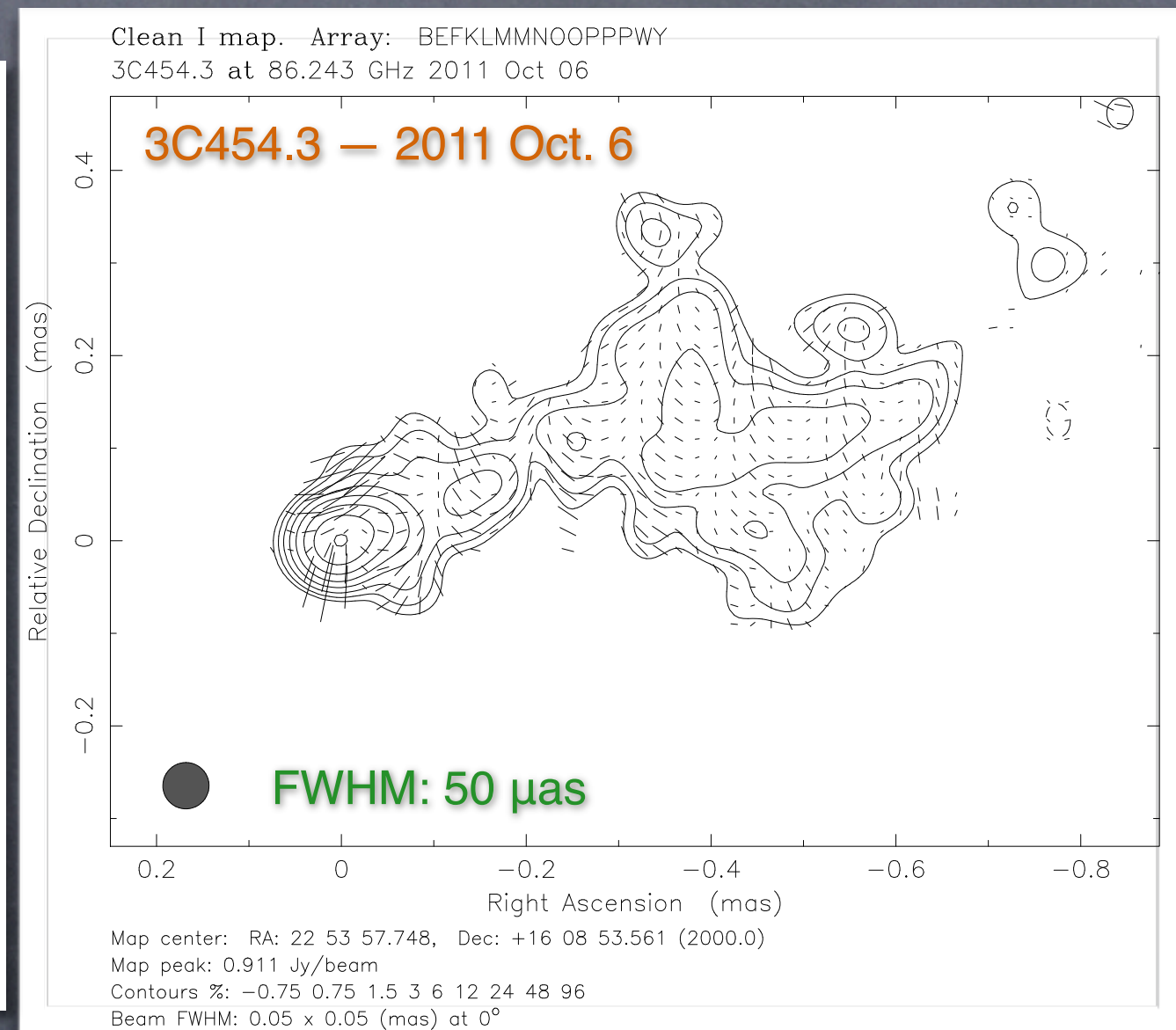
| | | | |
|----------|-------|----------|----------|
| 0235+164 | 3C111 | 0420-014 | 3C120 |
| 0716+714 | OJ248 | 0836+710 | OJ287 |
| 3C273 | 3C279 | 1510-089 | 1633+382 |
| 3C345 | BLLac | CTA102 | 3C454.3 |

A LONG-TERM MONITORING OF γ -RAY BLAZARS WITH THE GMVA

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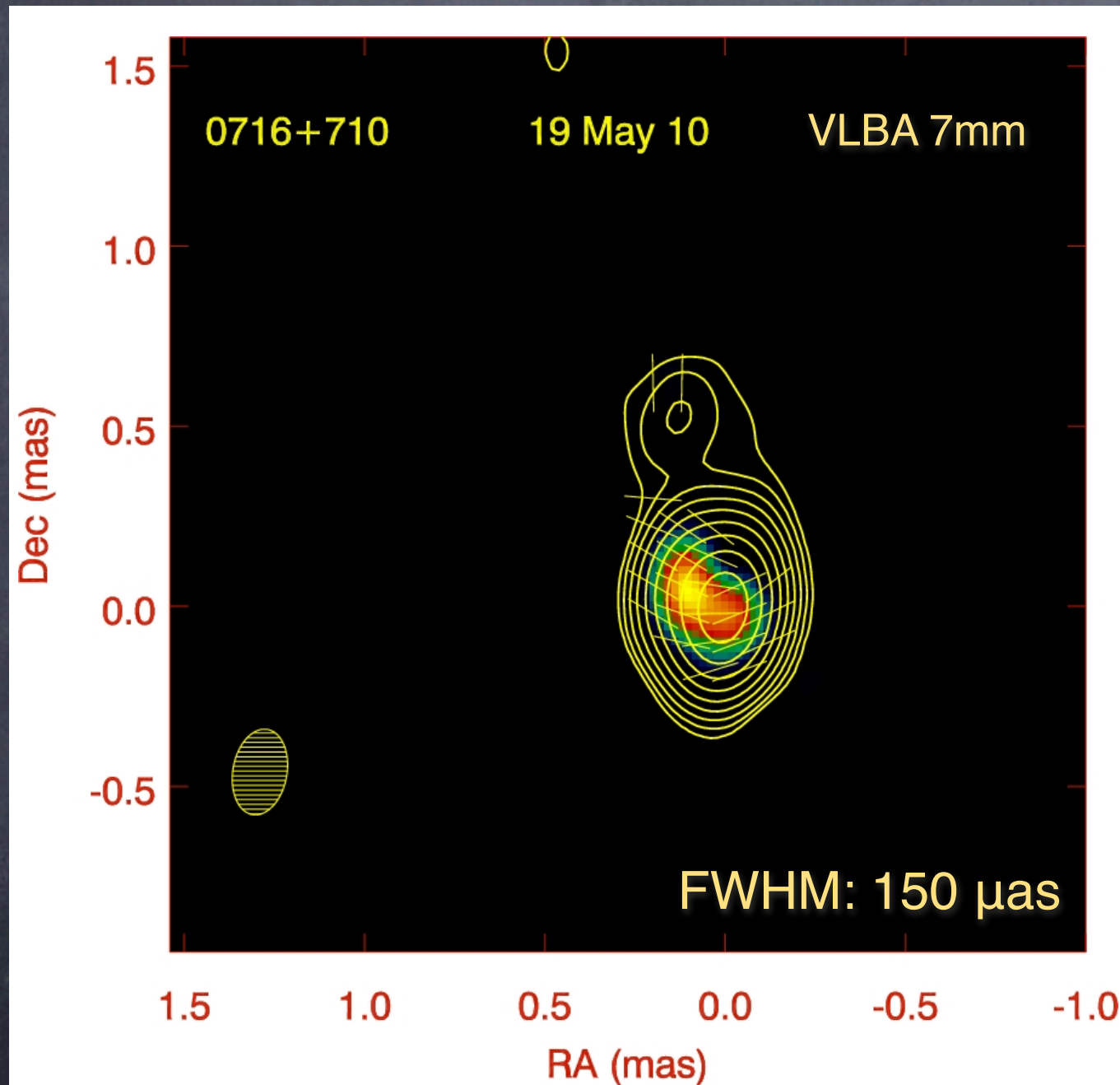
VLBA-BU-BLAZAR 7mm image



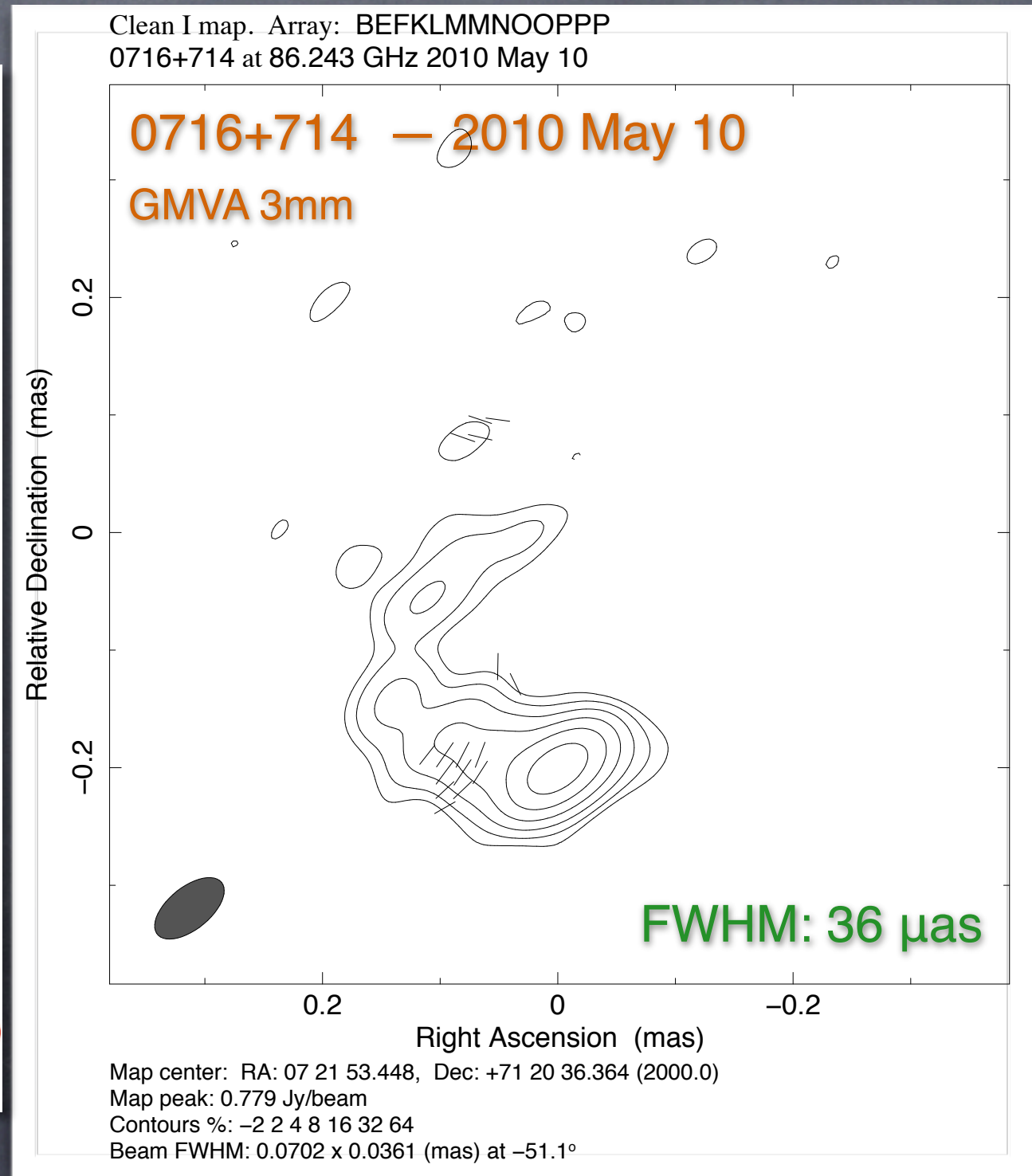
GMVA 3mm image

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VLBA-BU-BLAZAR 7mm image



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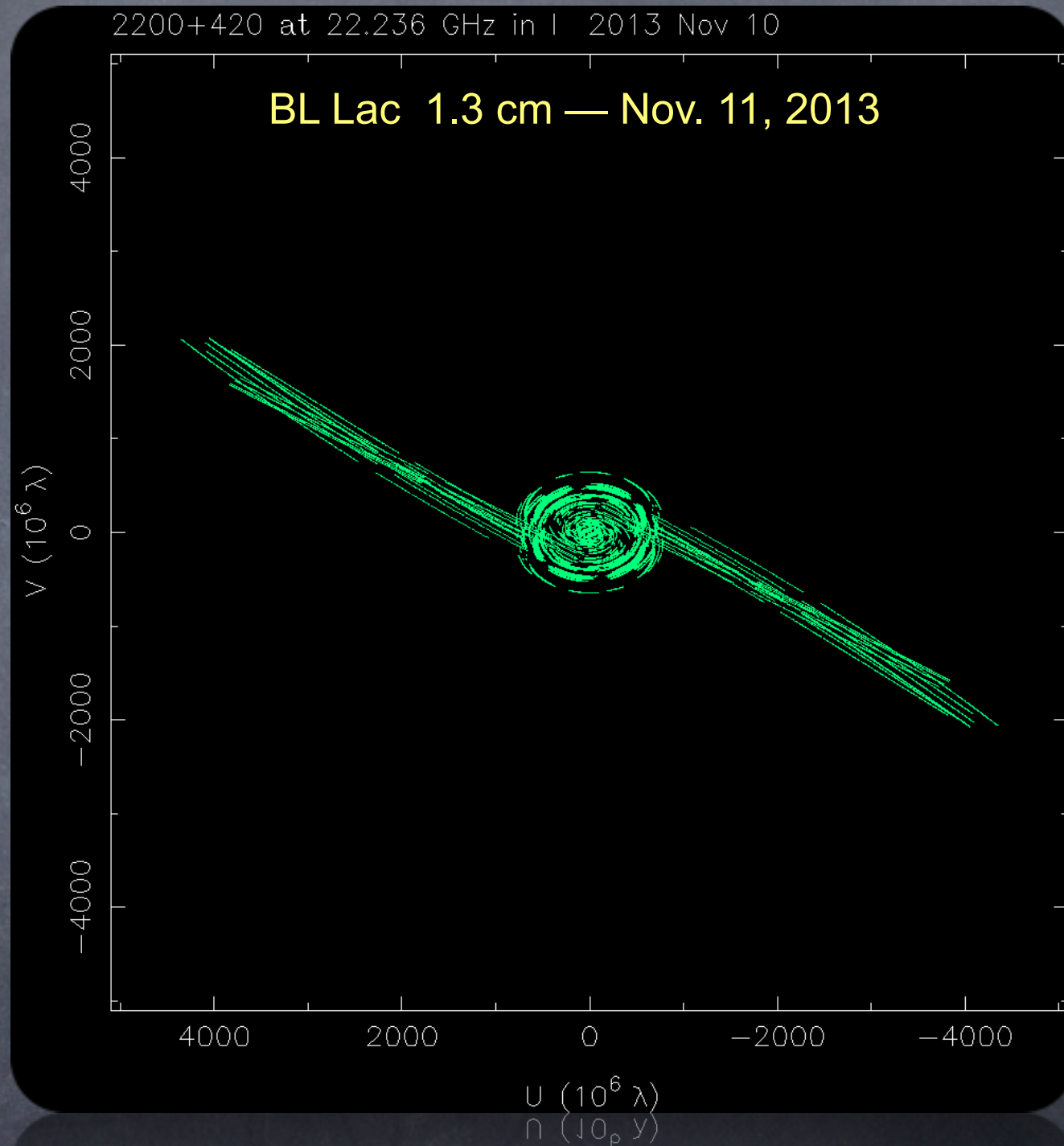
POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

FIRST POLARIMETRIC SPACE-VLBI OBSERVATIONS AT 1.3 CM

First polarimetric space-VLBI observations at 1.3 cm were performed on November 11, 2013.

BL Lac was observed together with 26 antennas on the ground array: EF, YS, JD2, ON, NT, TR, MH, SV, ZC, MC, BD, KVN, SH, UR, and the VLBA.

Due to technical problems data was lost at FD, SC, YS, JB, TR, KVN (3), SH, and UR. A total of 16 antennas correlated, of which MC and BD contained bad data and were edited out.



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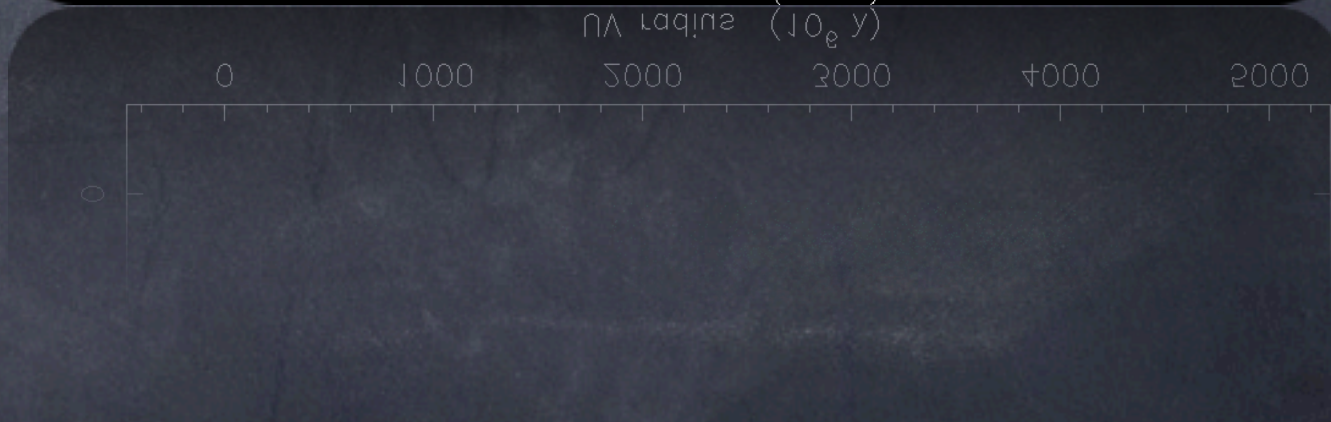
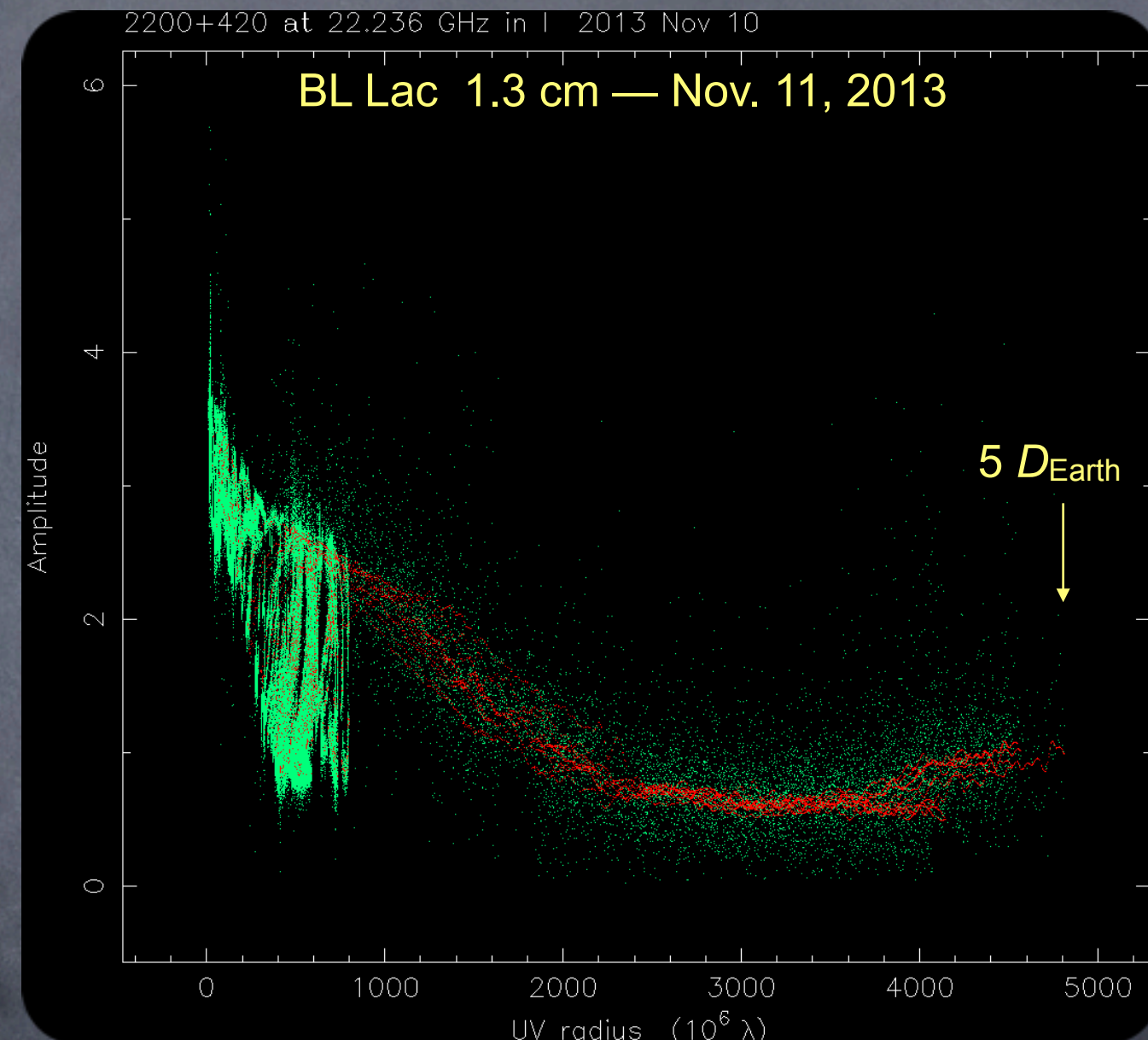
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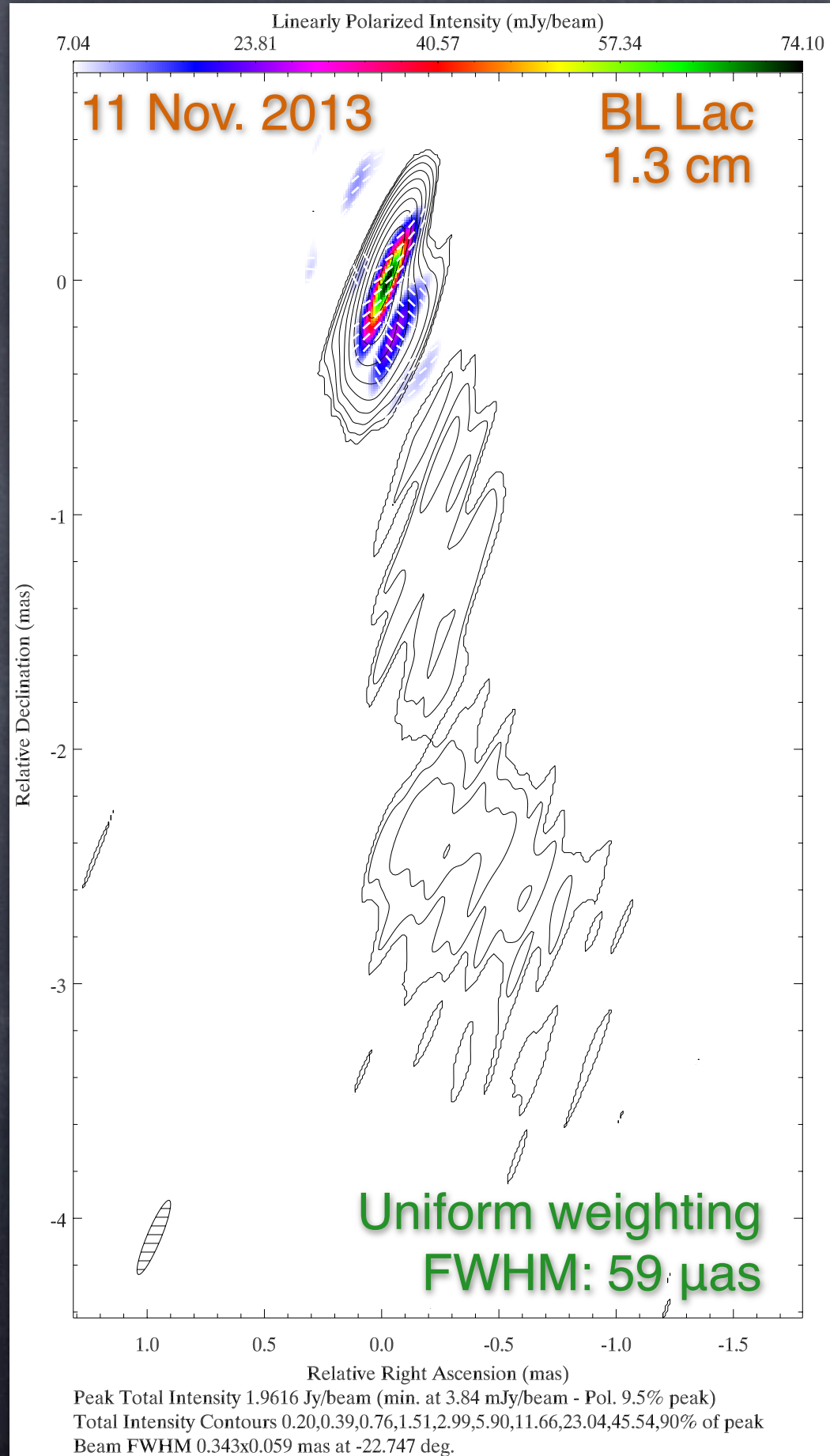
Due to technical problems data was lost at FD, SC, YS, JB, TR, KVN (3), SH, and UR. A total of 16 antennas correlated, of which MC and BD contained bad data and were edited out.

Ground-space baseline detections up to $5 D_{\text{Earth}}$.

Experiment scheduled to extent up to a maximum of $11.5 D_{\text{Earth}}$, but no fringes have been obtained after EF stopped observing.

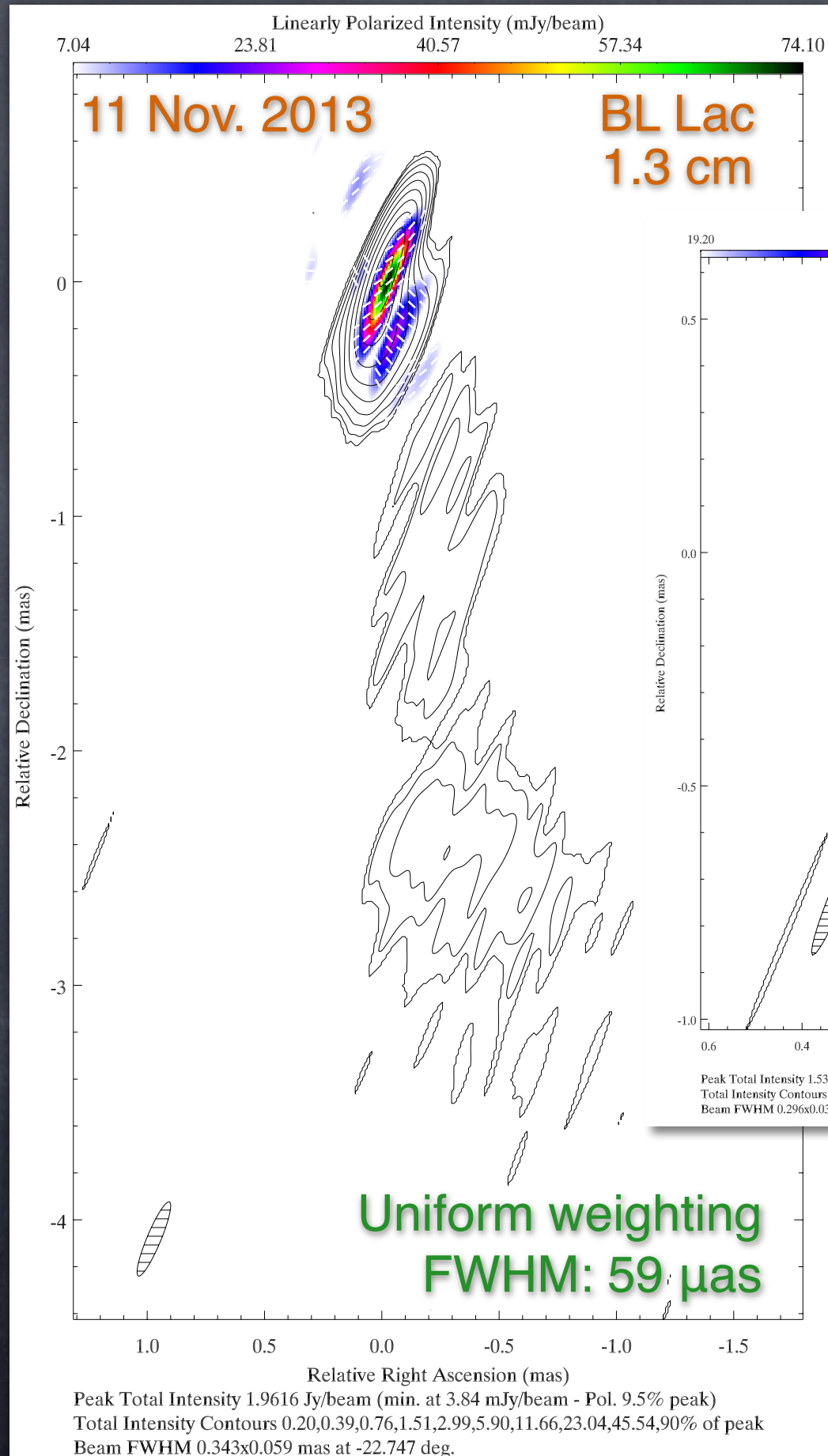


POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

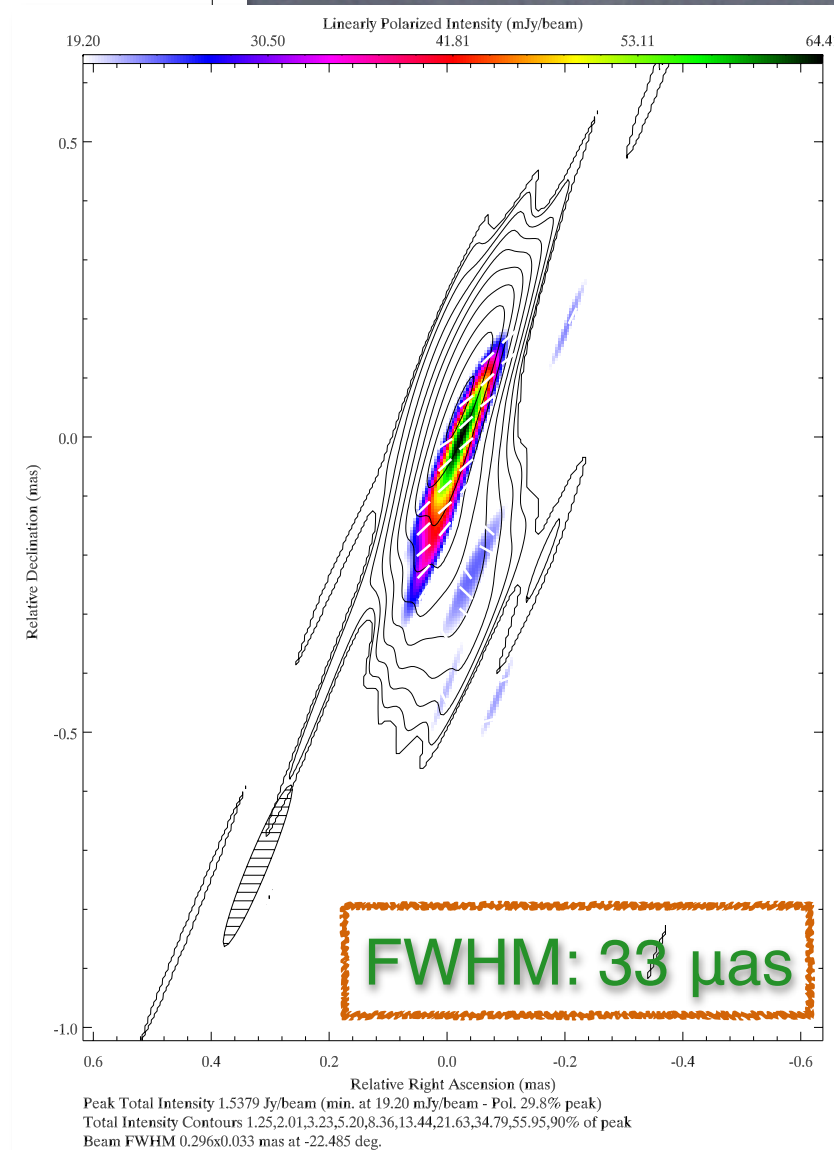


First polarization Space-VLBI image
at 22 GHz

POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



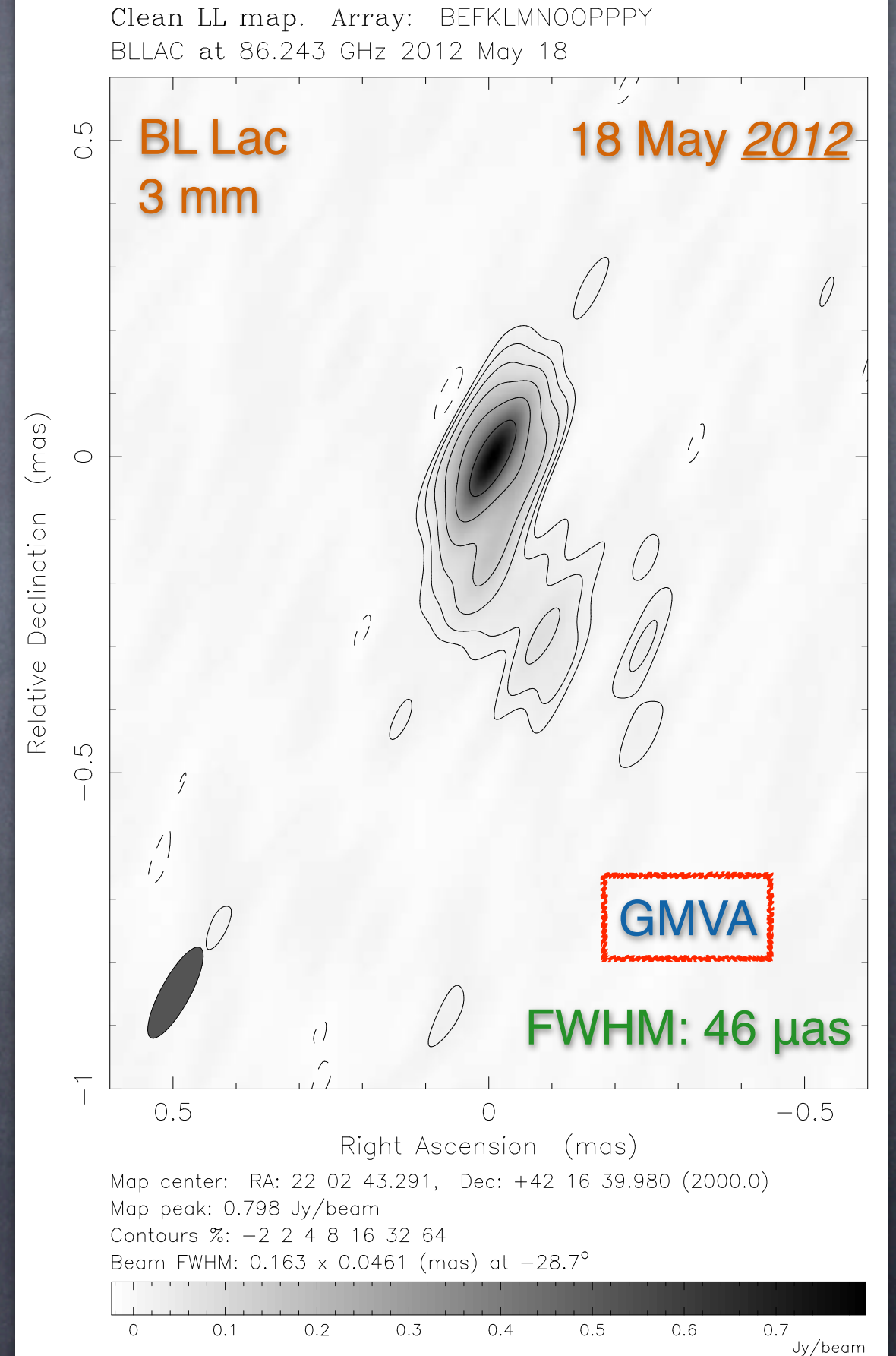
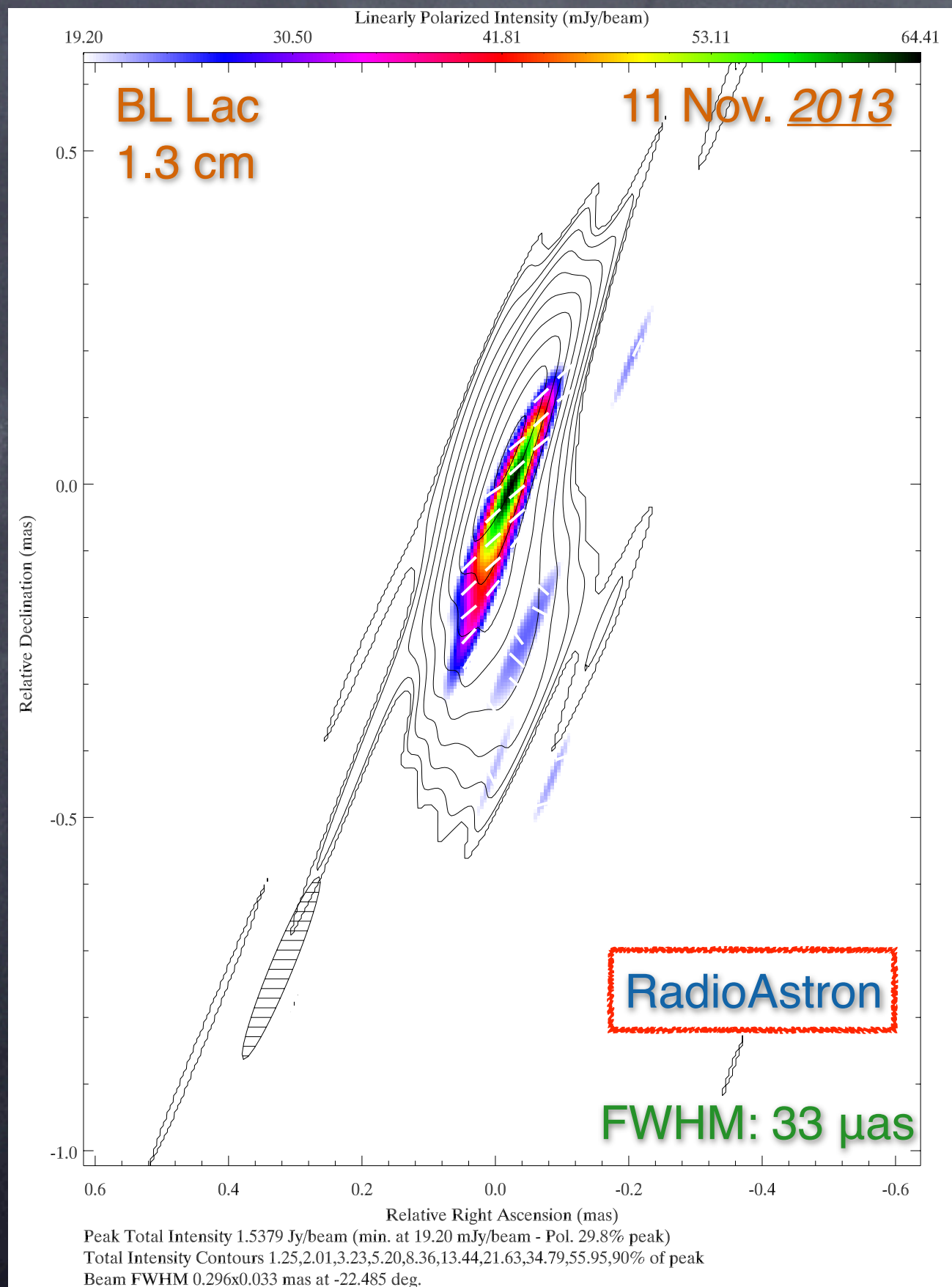
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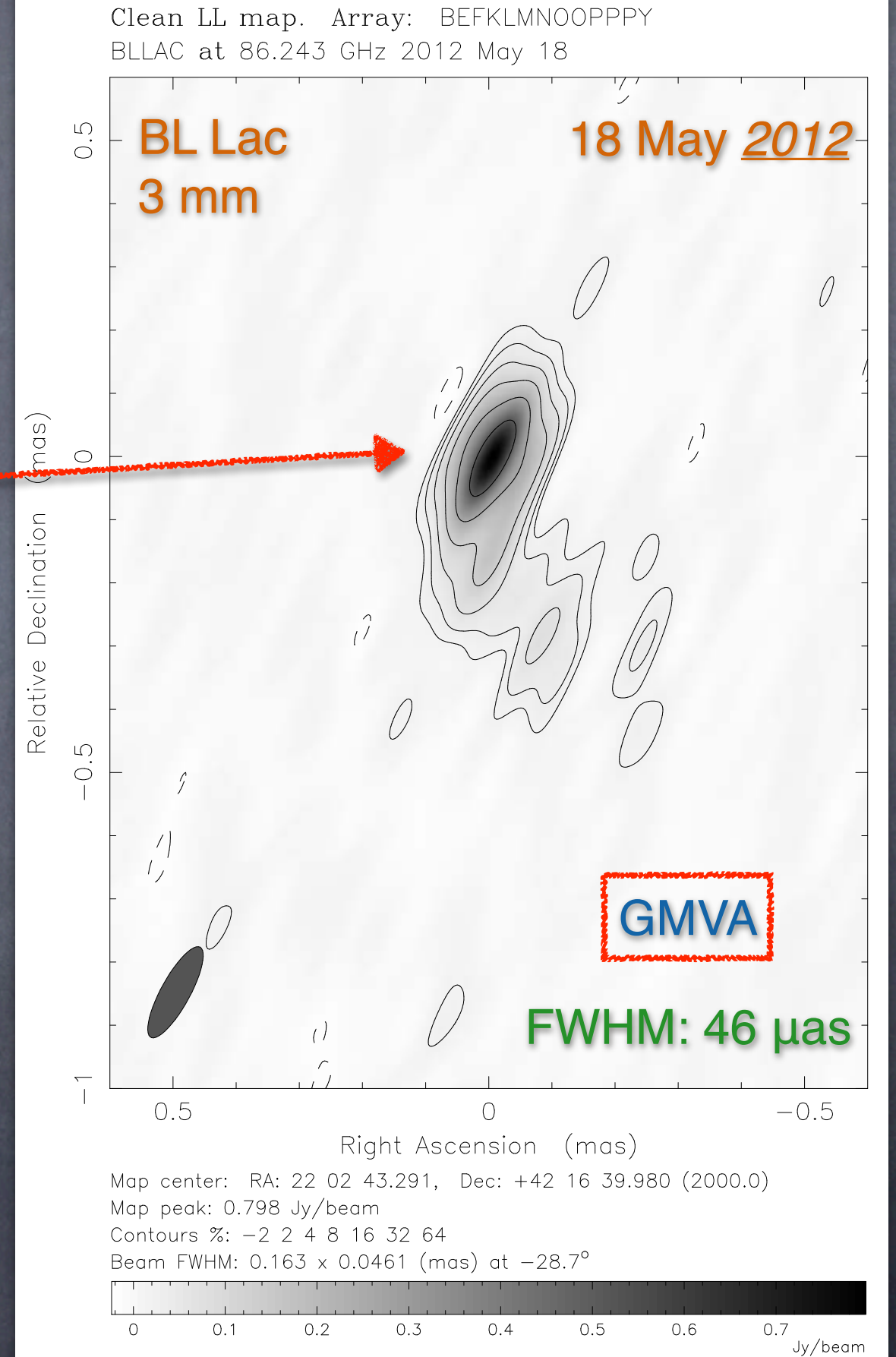
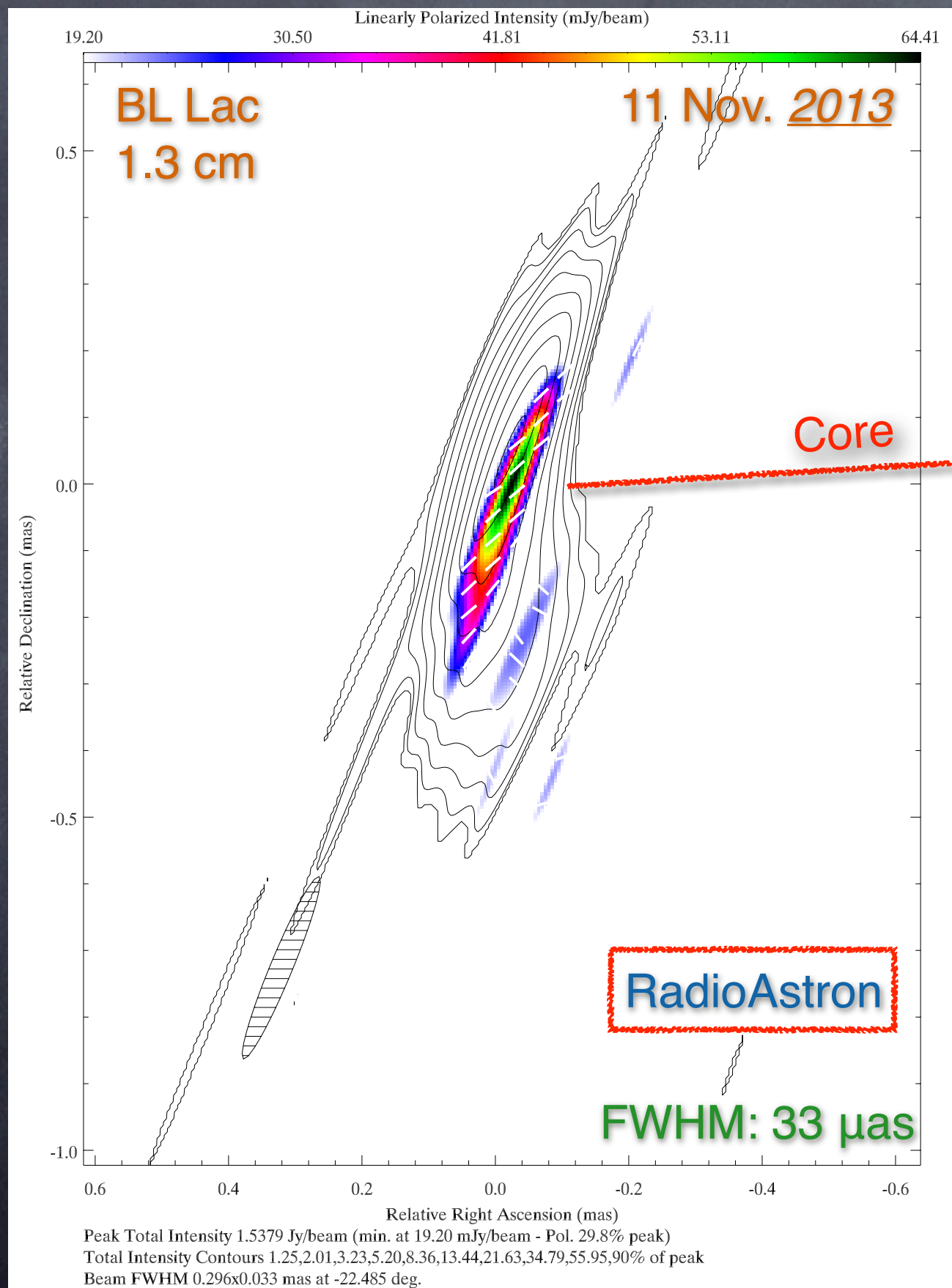
Achieved angular resolution:
FWHM: 0.296x0.033 mas
using “super” uniform
weighting with no amplitude
error weighting. Achieved 5 σ
sensitivity of 20 mJy/beam.

Highest angular resolution
polarization image obtained
to date: 33 μ as

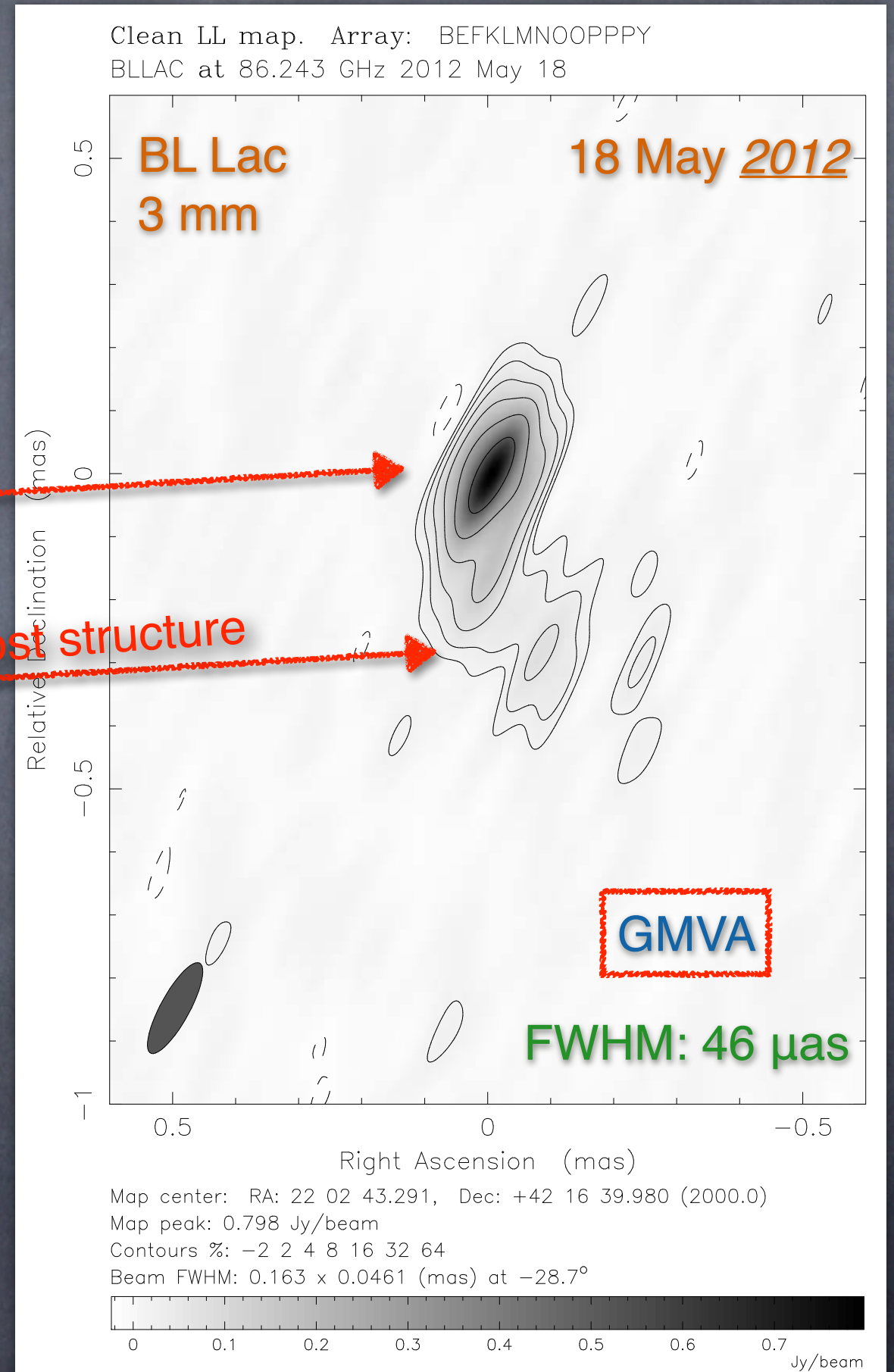
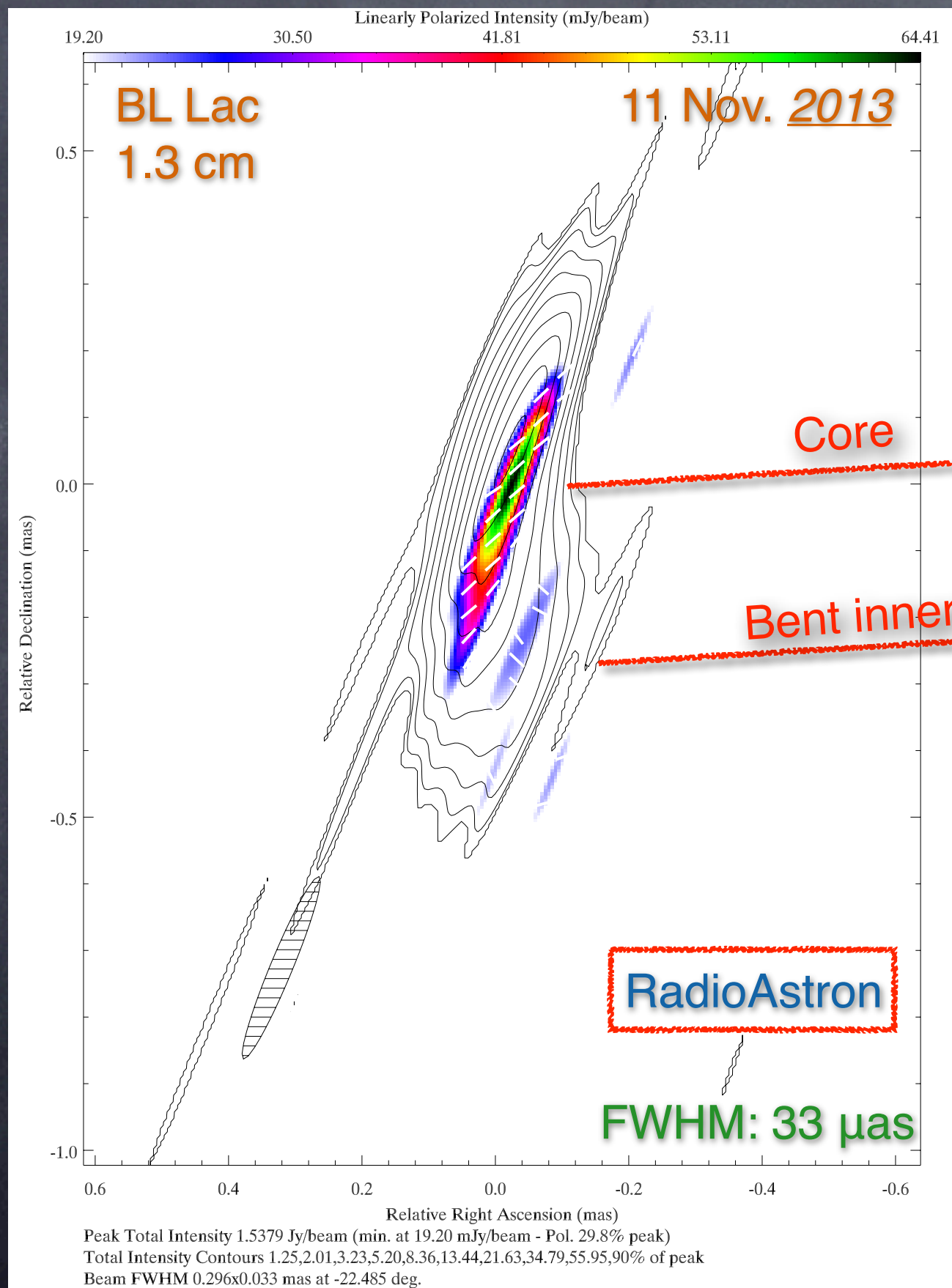
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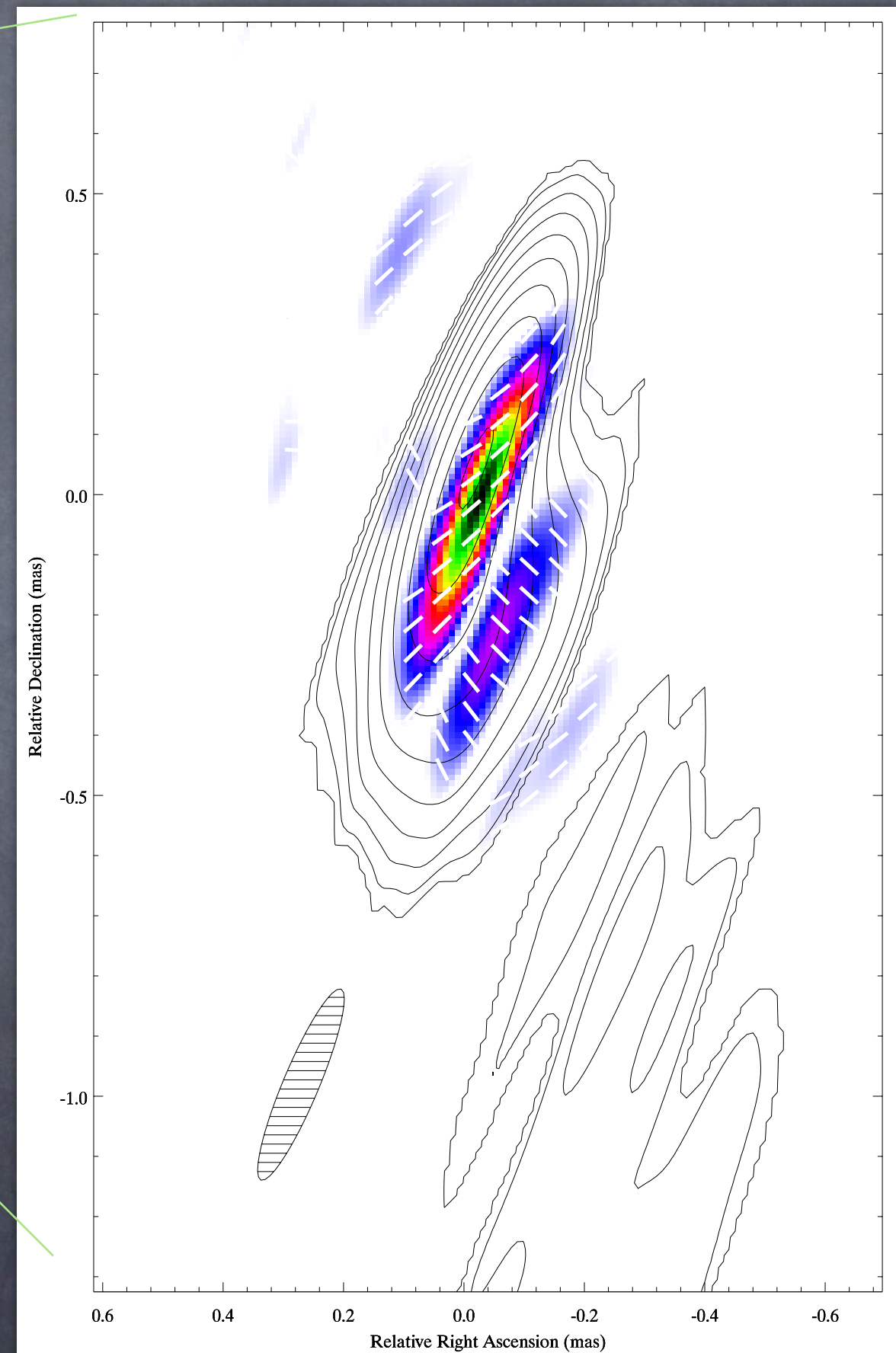
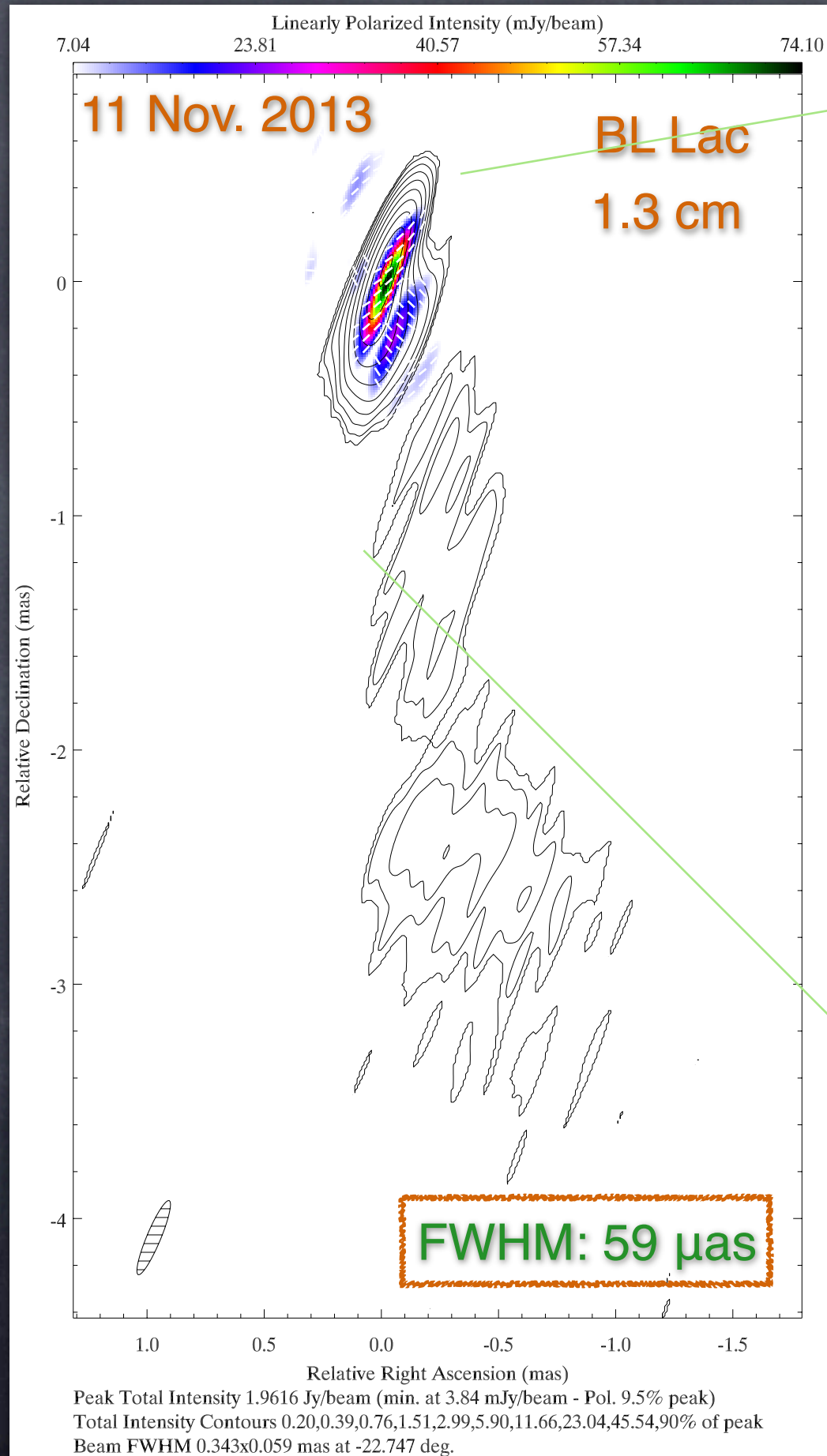
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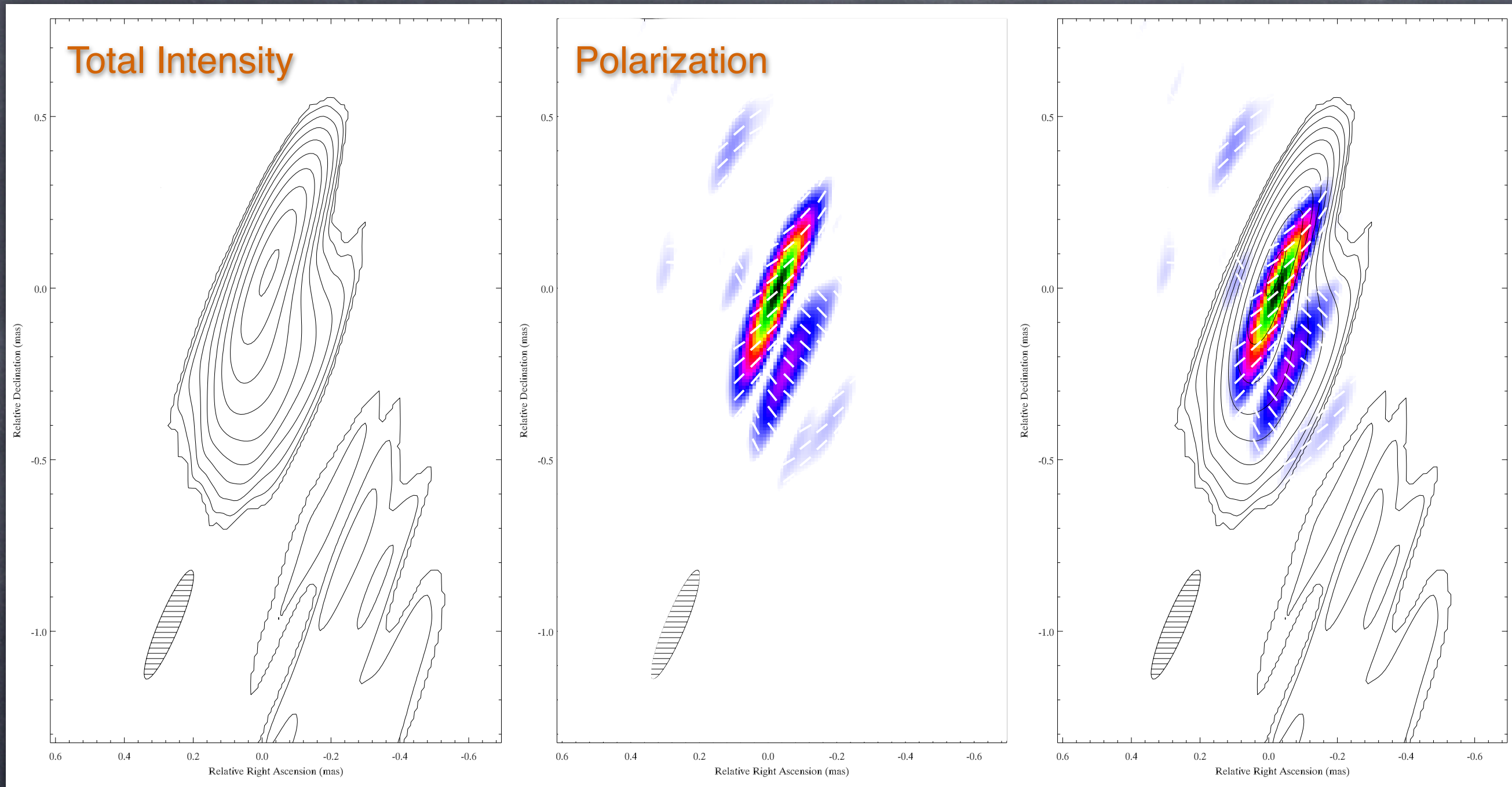
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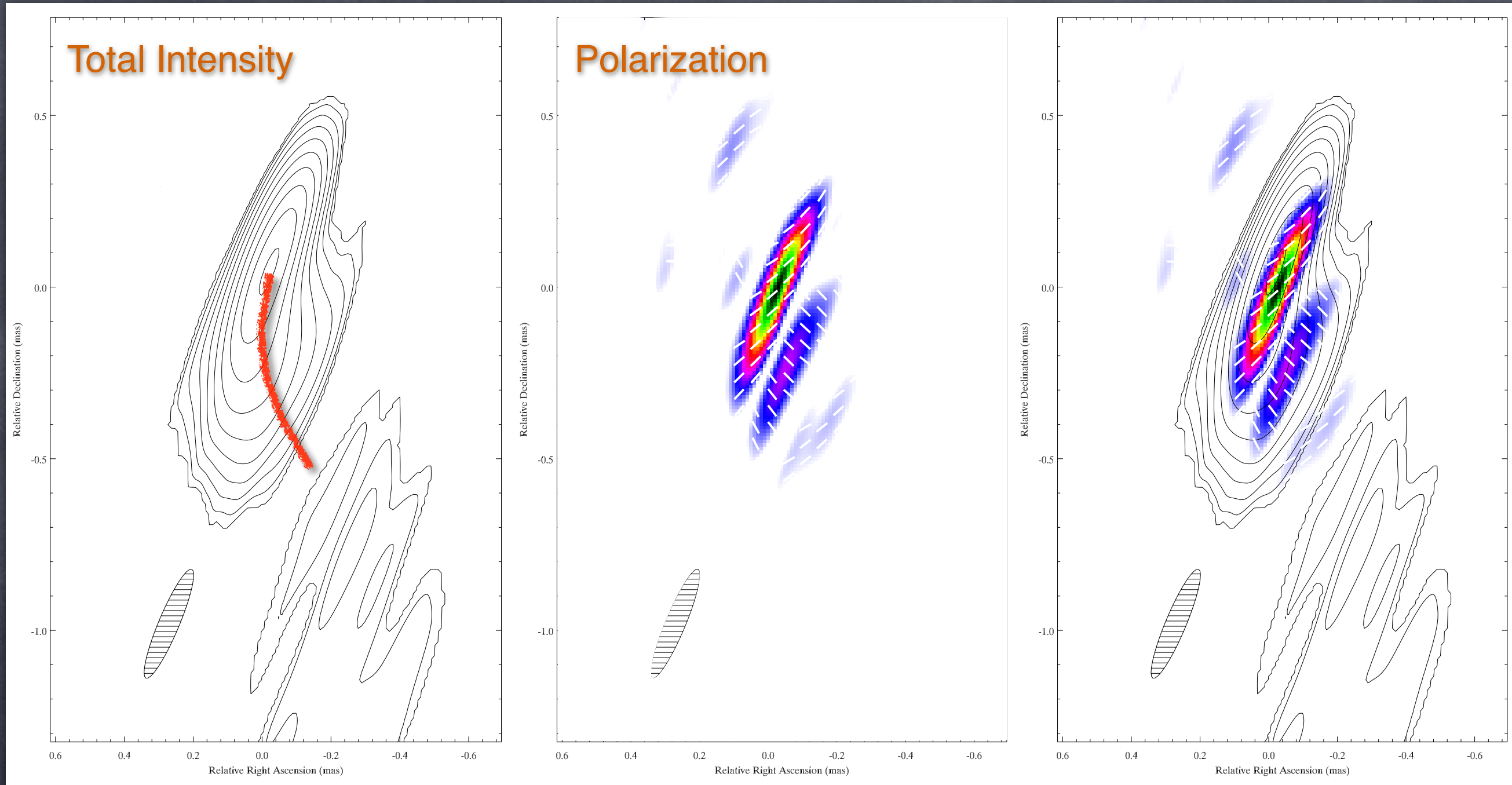
POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



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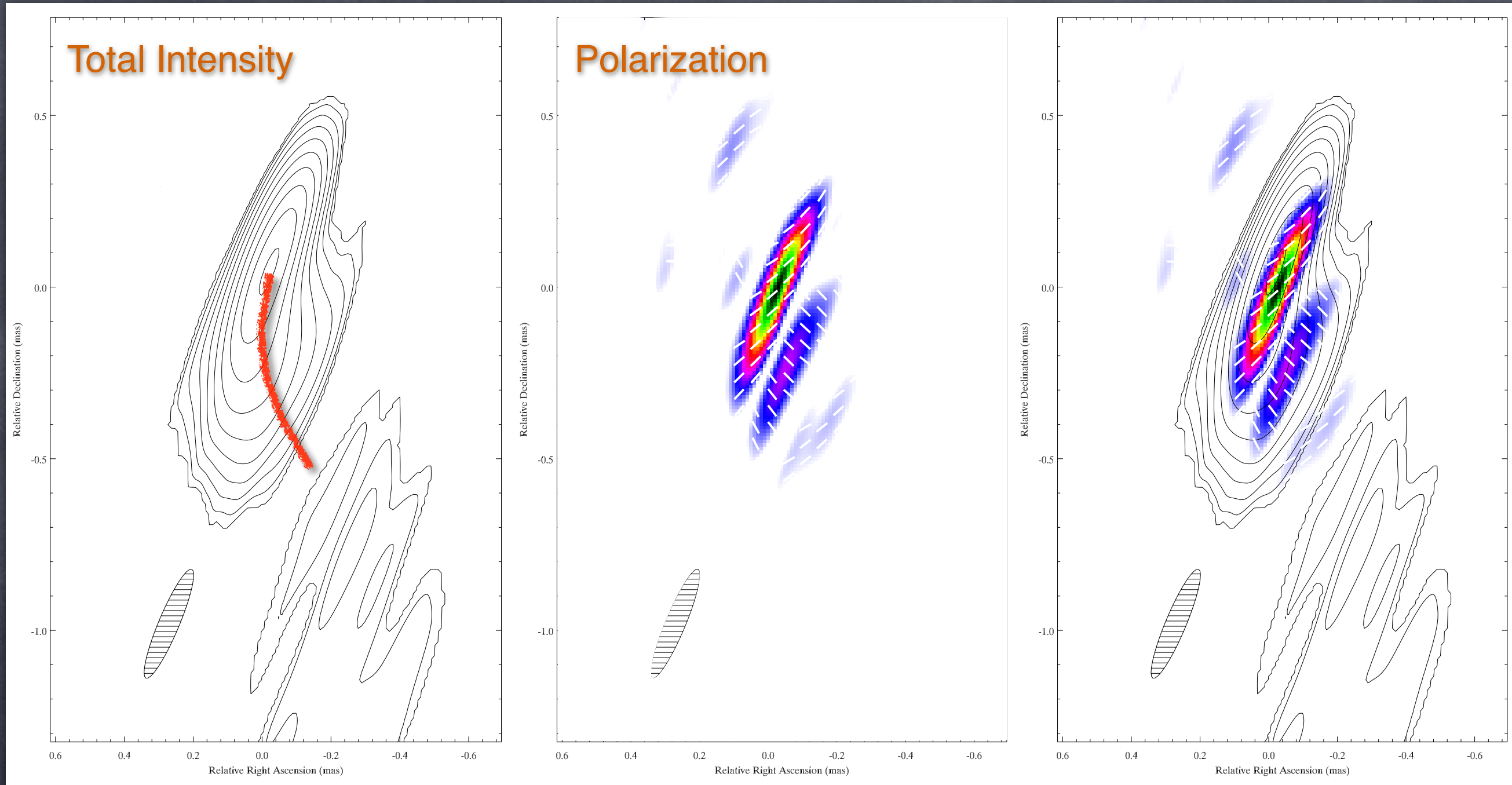


POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



- Total intensity shows a highly bent structure in the innermost 0.5 mas.
- Highest resolution in the direction of the jet.

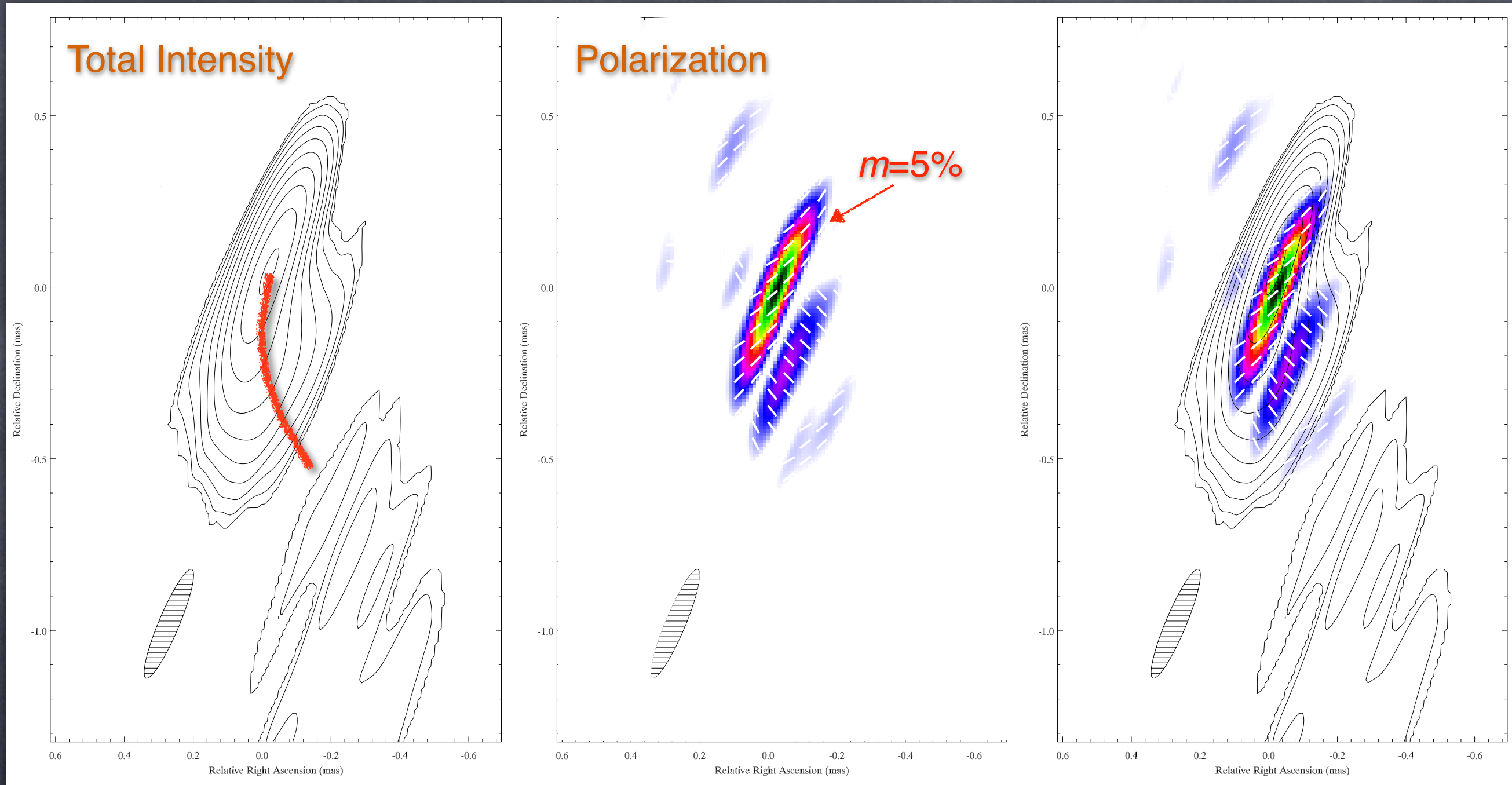
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- Two components.

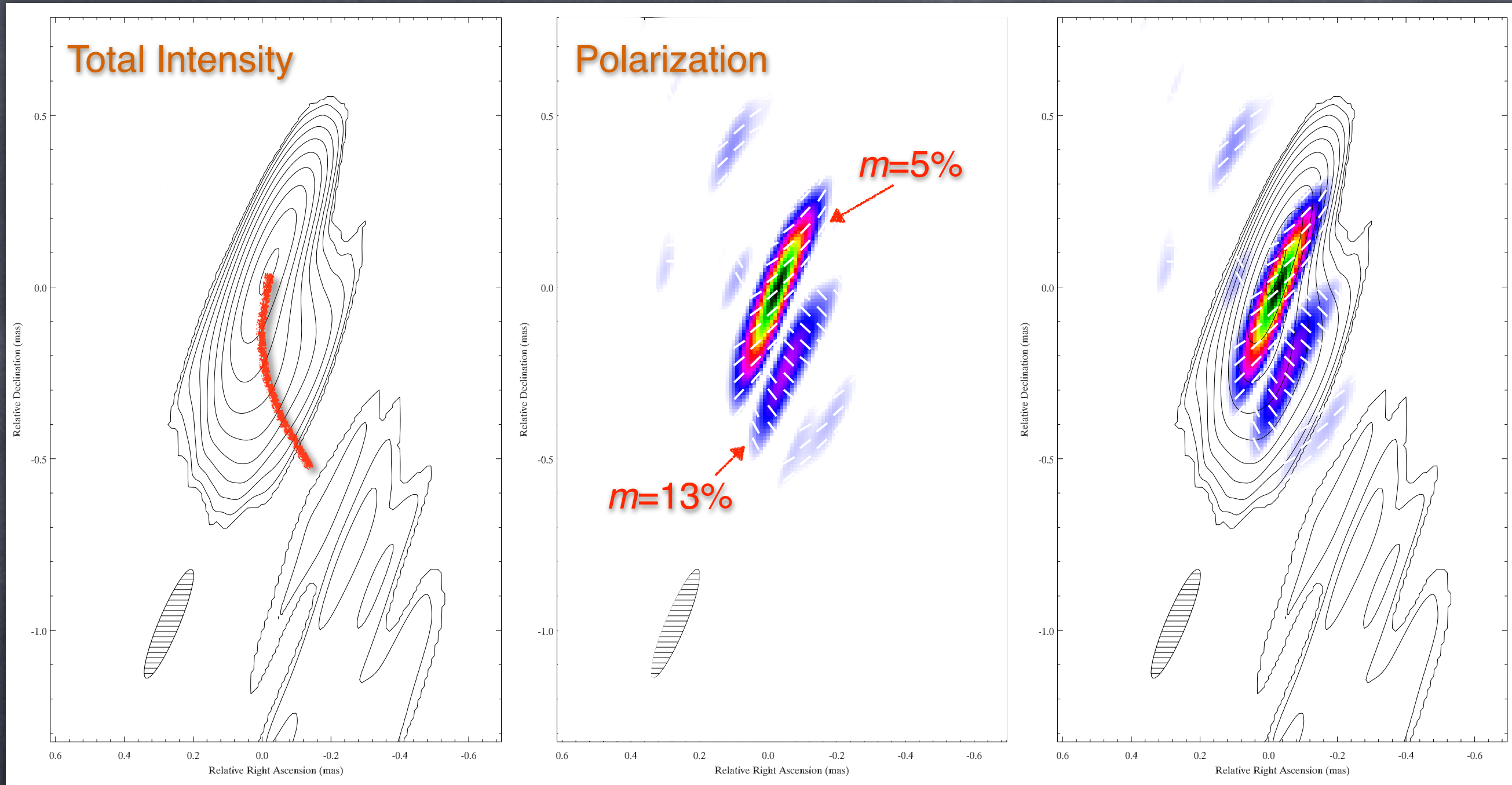
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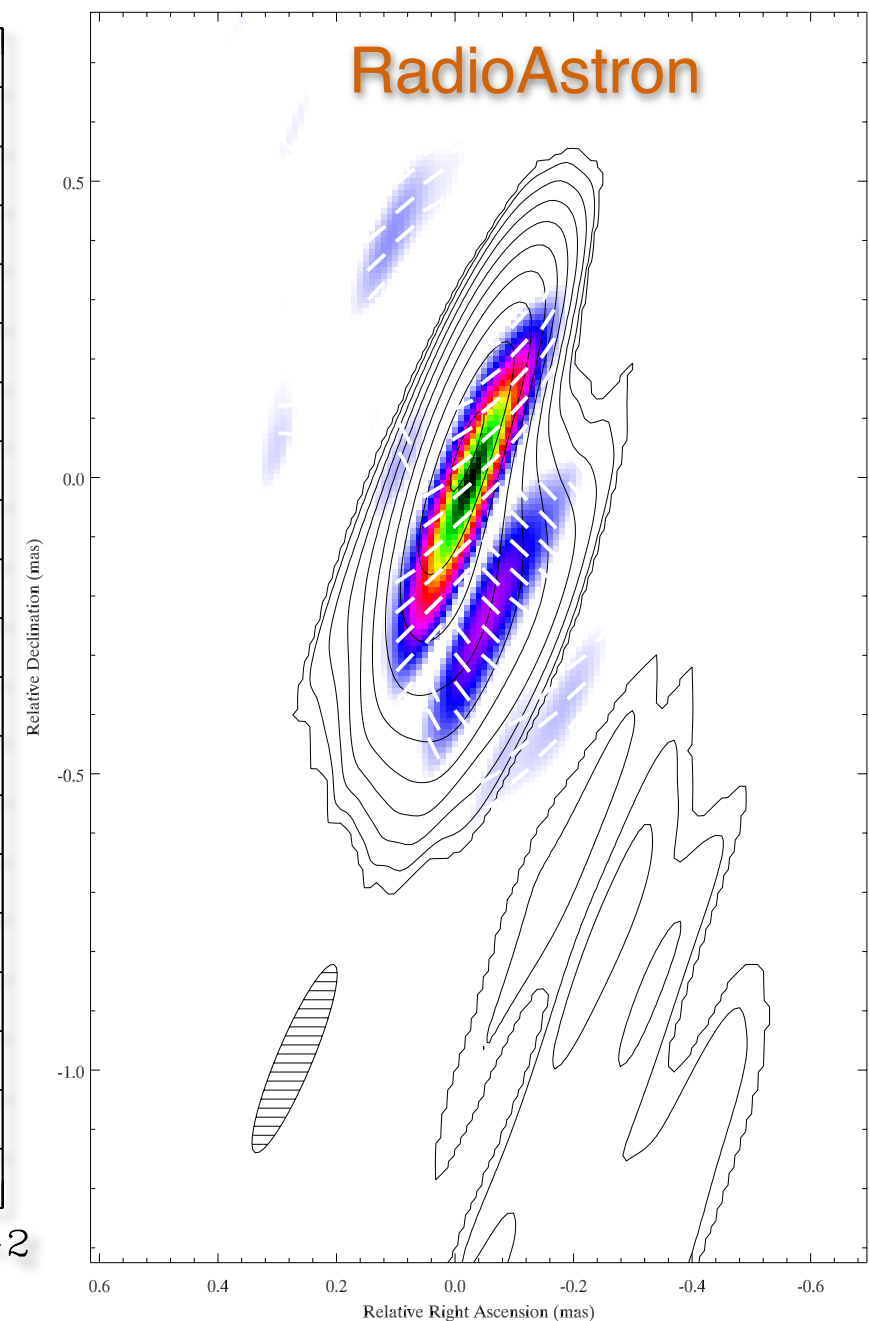
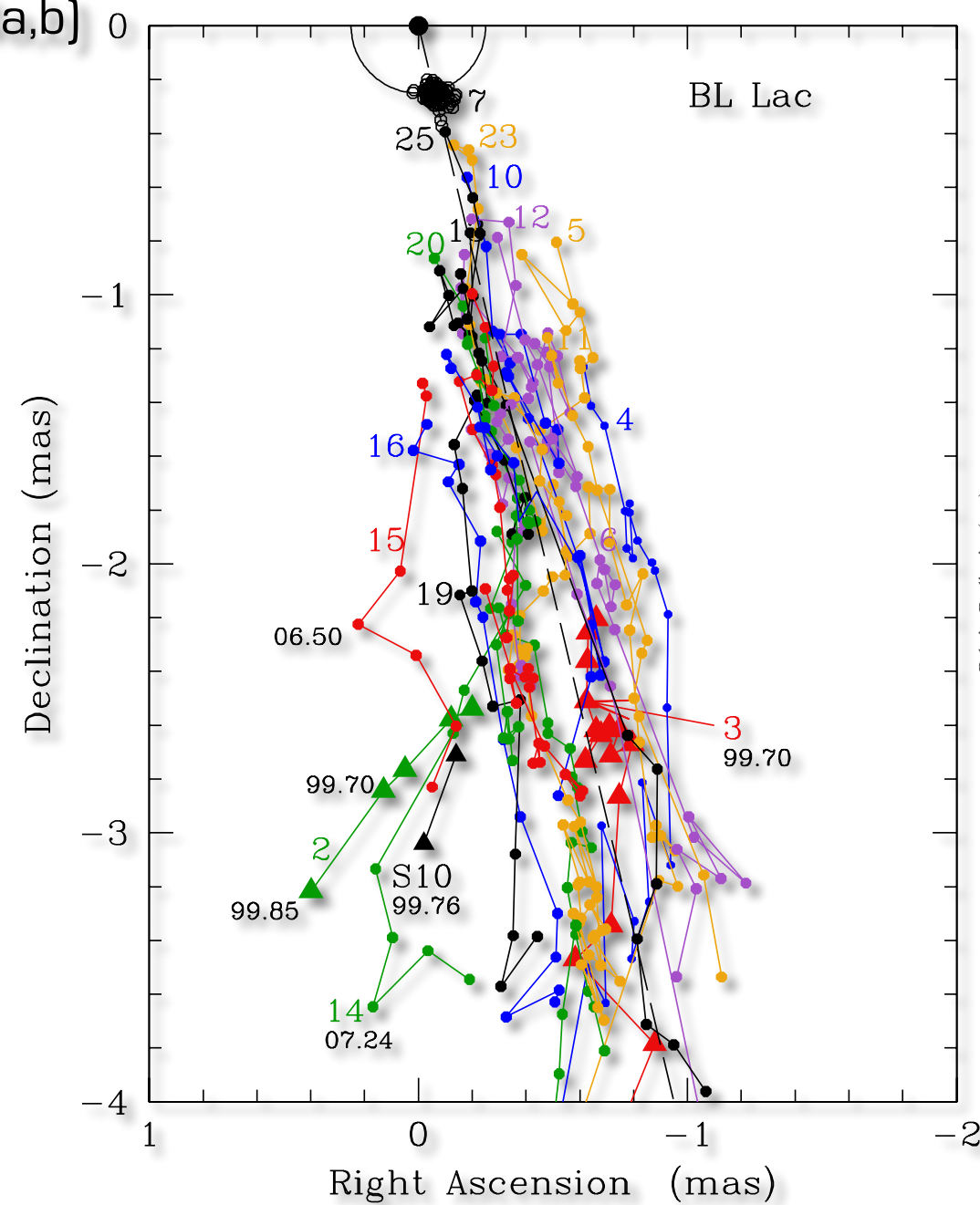


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- Core EVPAs perpendicular to the jet direction.
- Component with aligned EVPAs

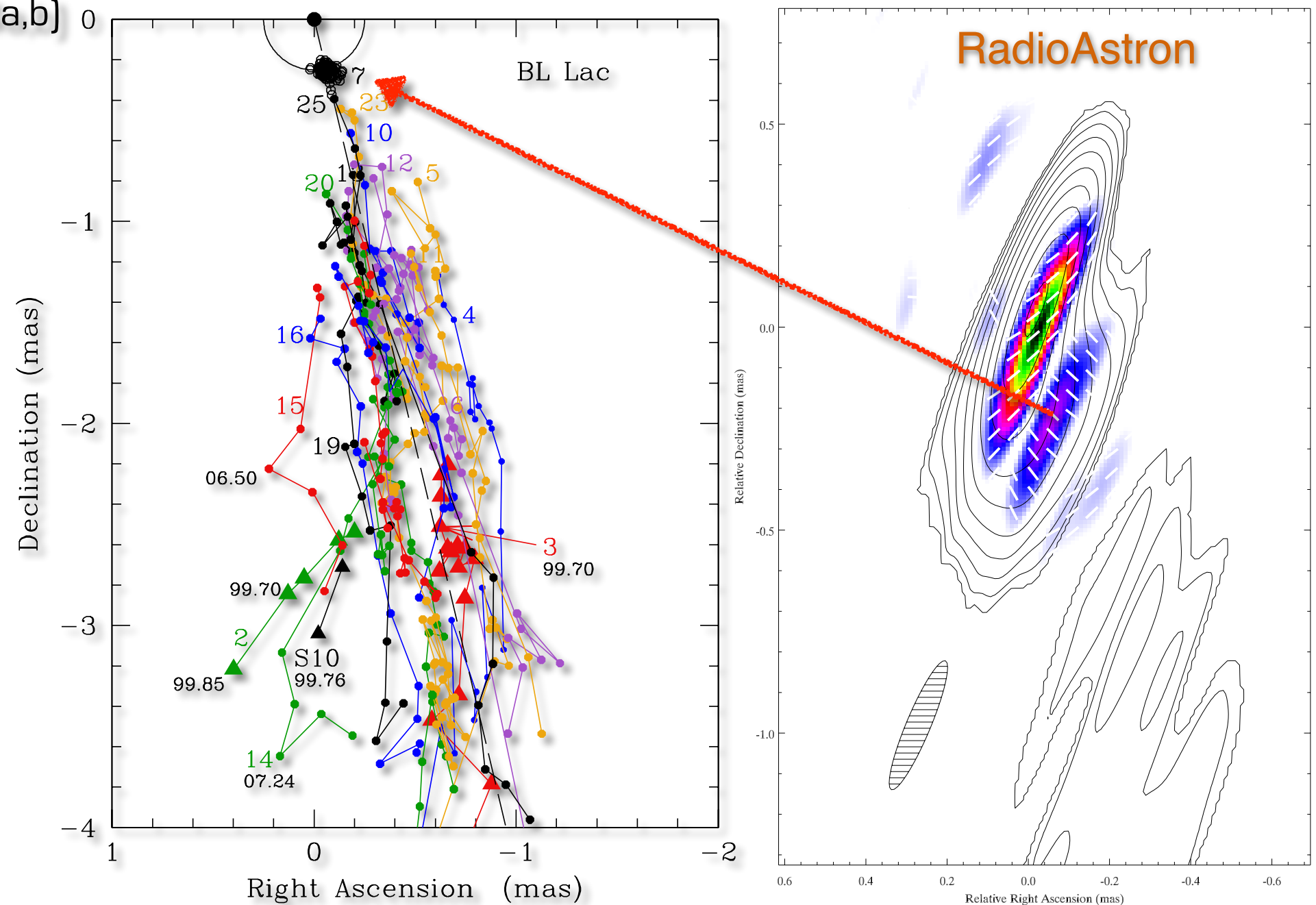
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Cohen et al. (2014a,b)



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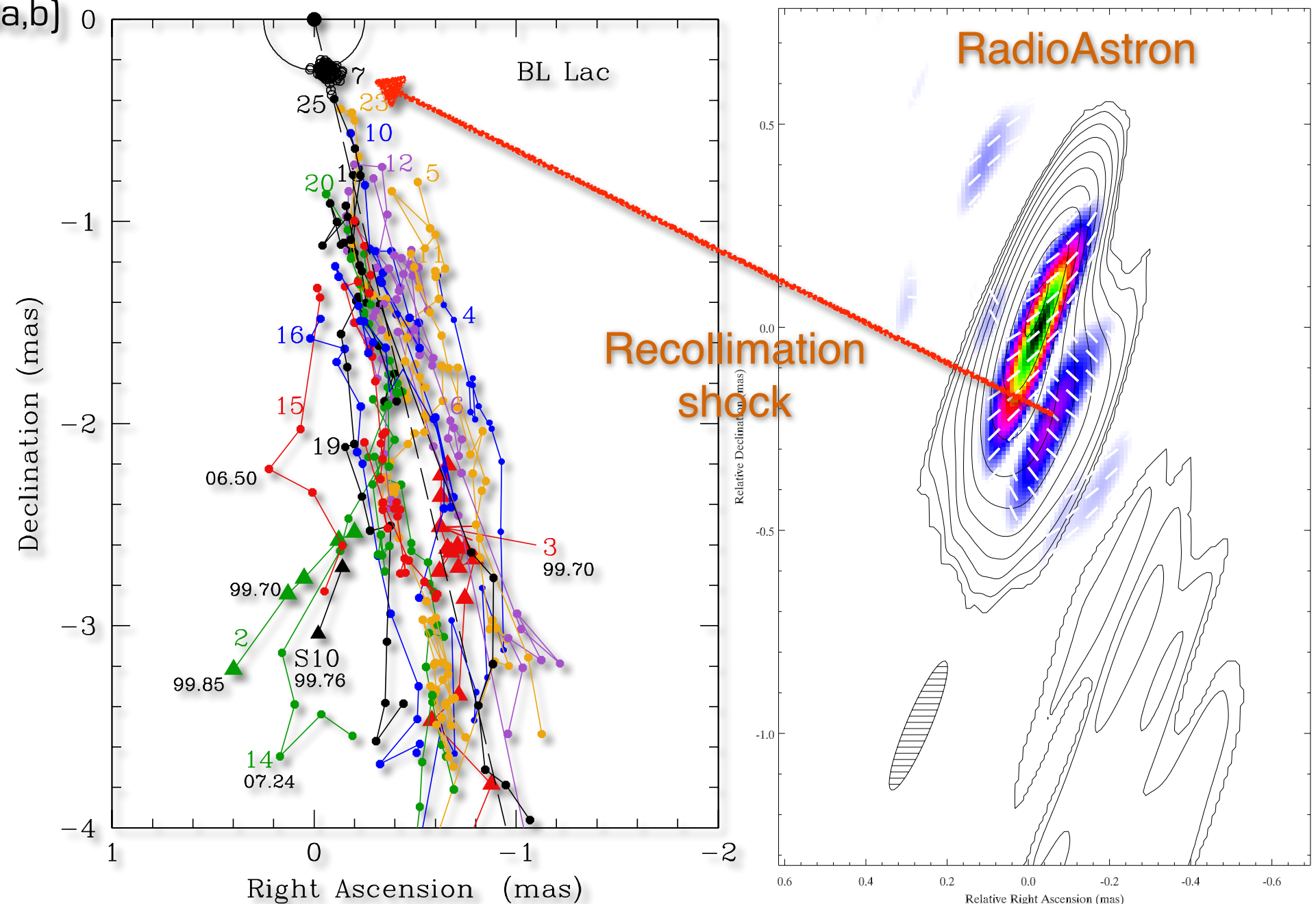
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- Comparison with Cohen et al. (2014a,b) observations reveals that our component at 0.3 mas corresponds to their C7.

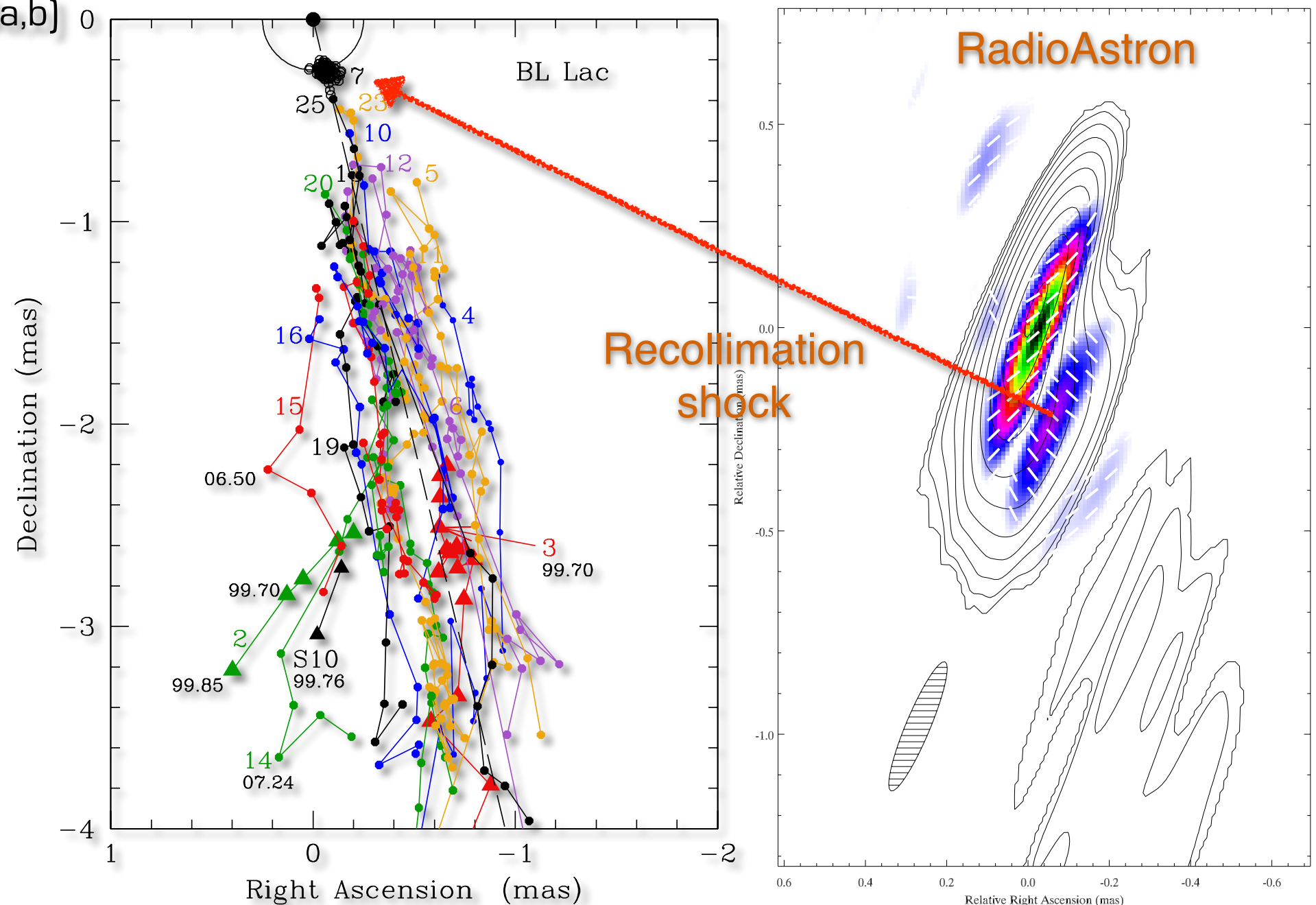
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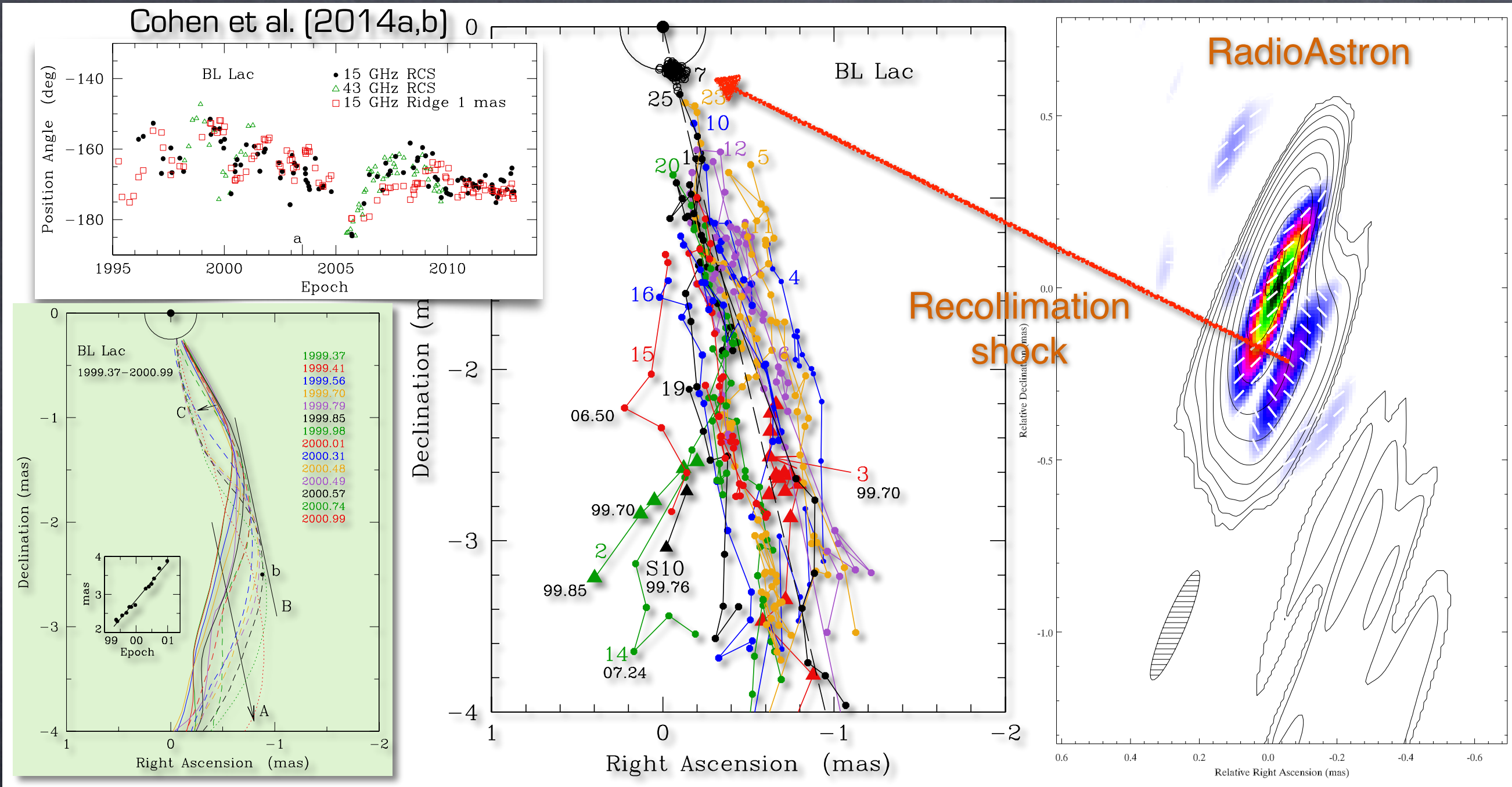
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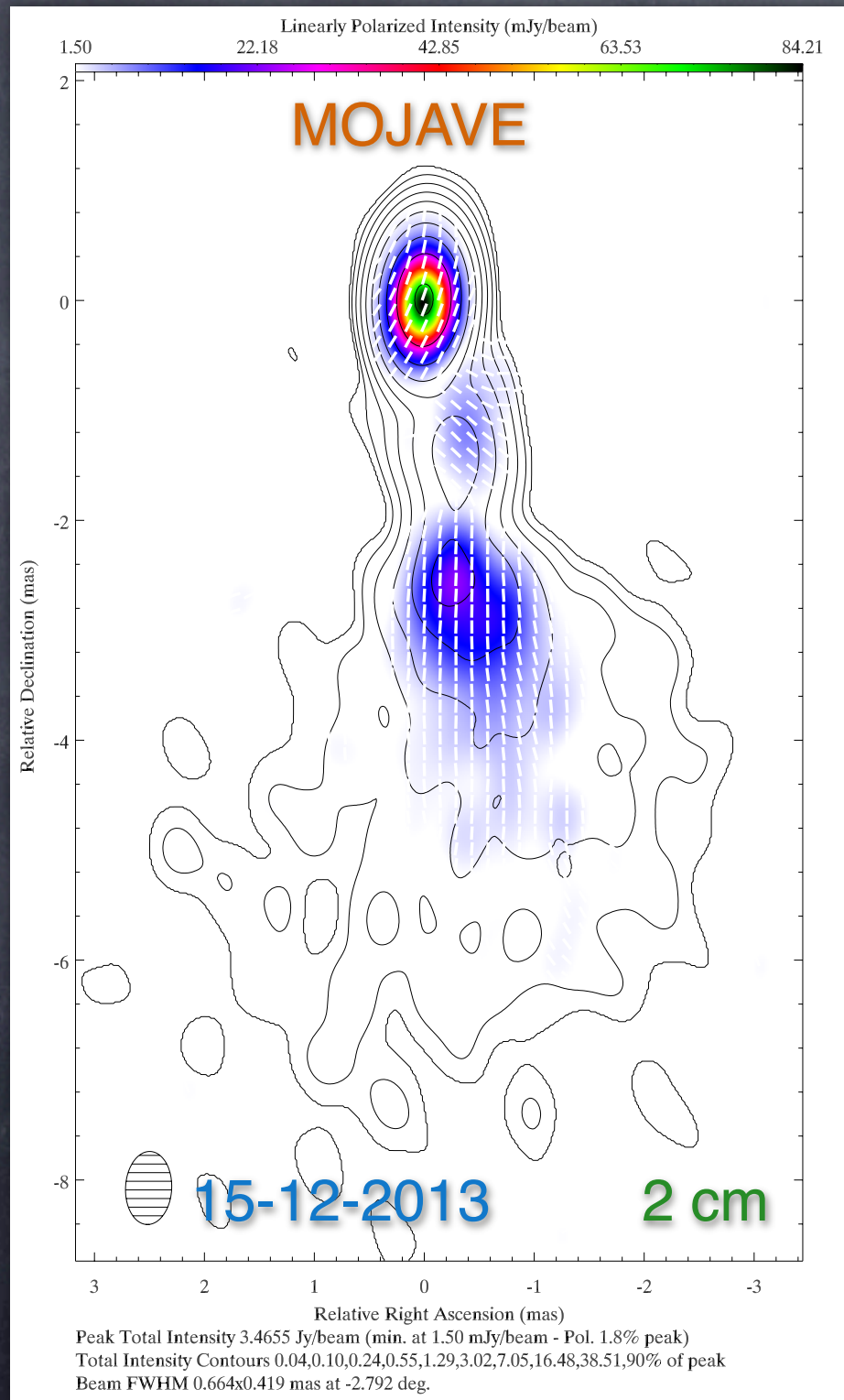


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- Our RadioAstron observations reveal that C7 has a polarization orthogonal to the core, and aligned with the jet direction.
- C7 swings in position angle, triggering Alfvén waves in the jet ridge line, like waves on a whip.

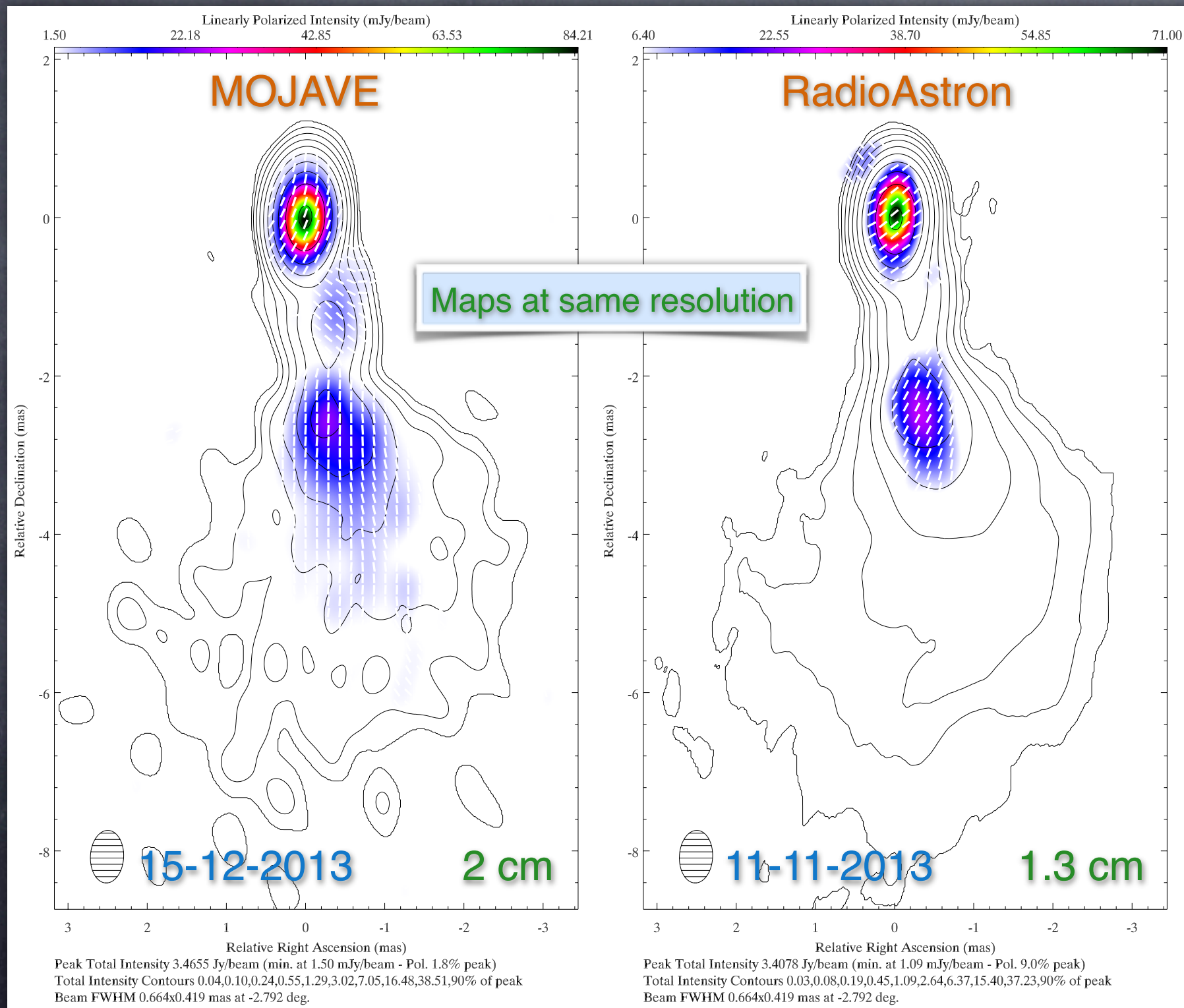
POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

MAP COMPARISON ACROSS 15, 22, AND 43 GHz FOR RM ANALYSIS



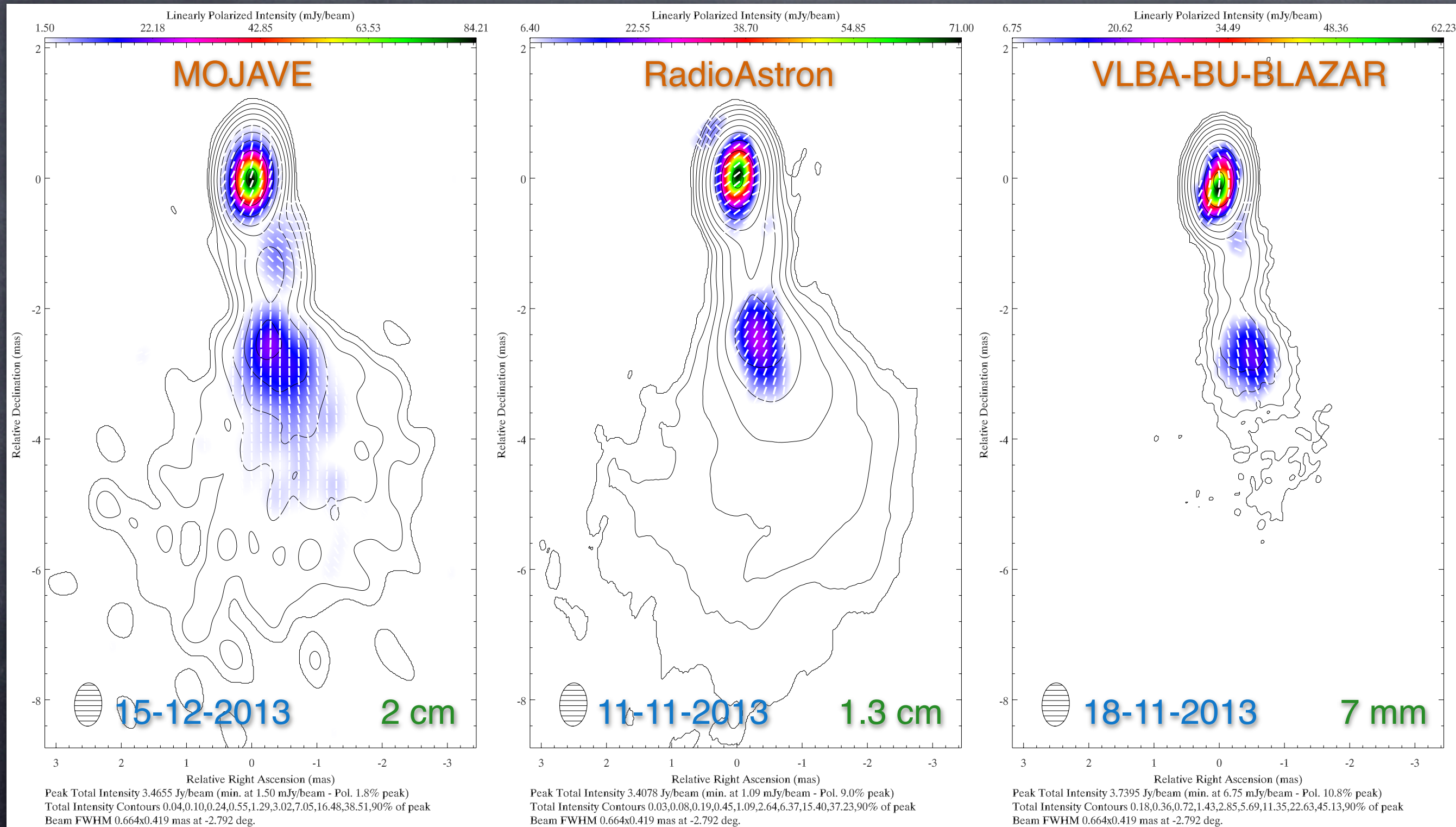
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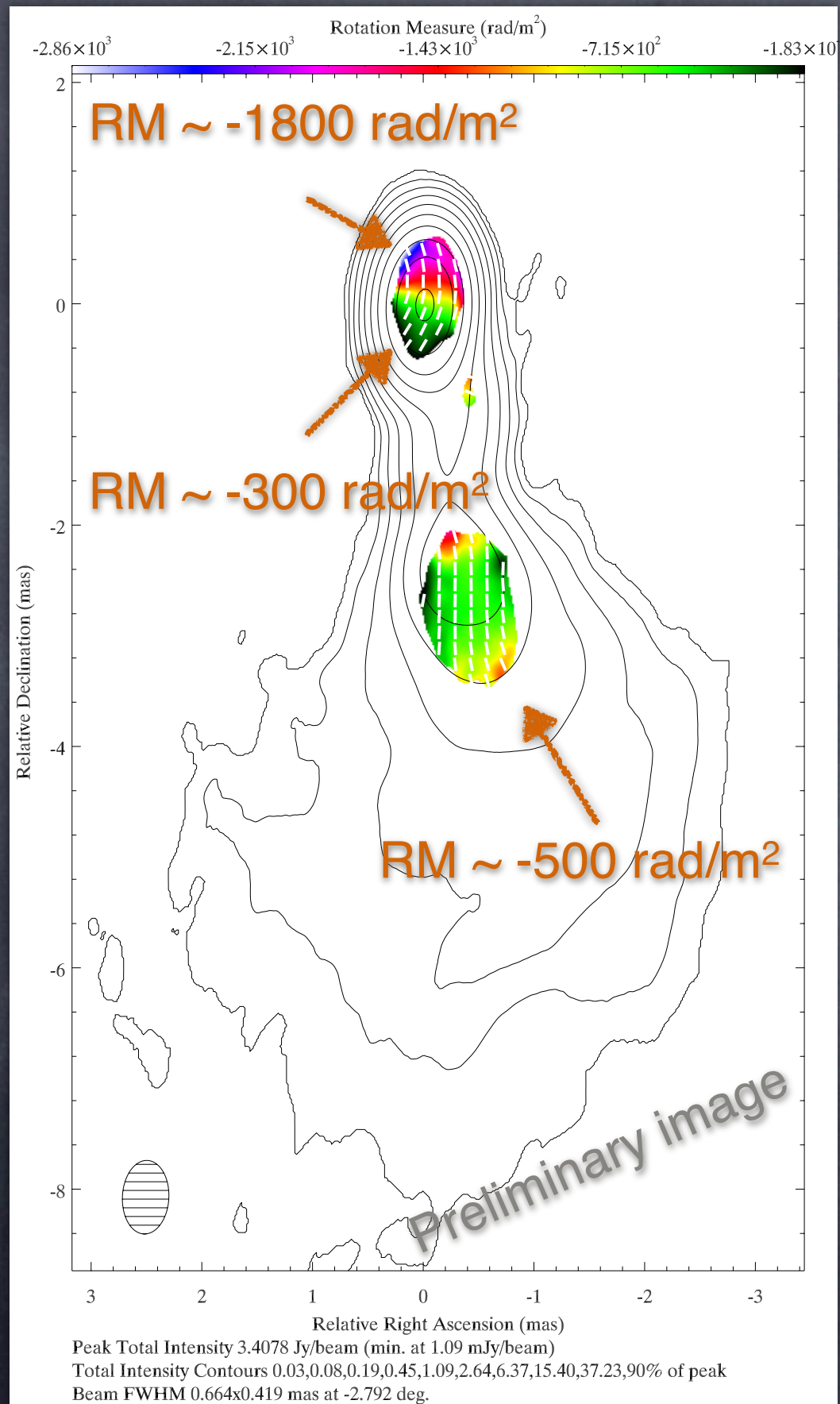


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POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



Preliminar Faraday rotation analysis

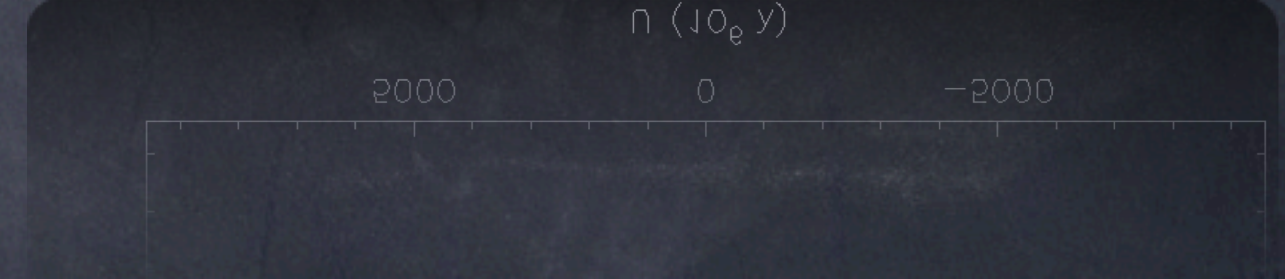
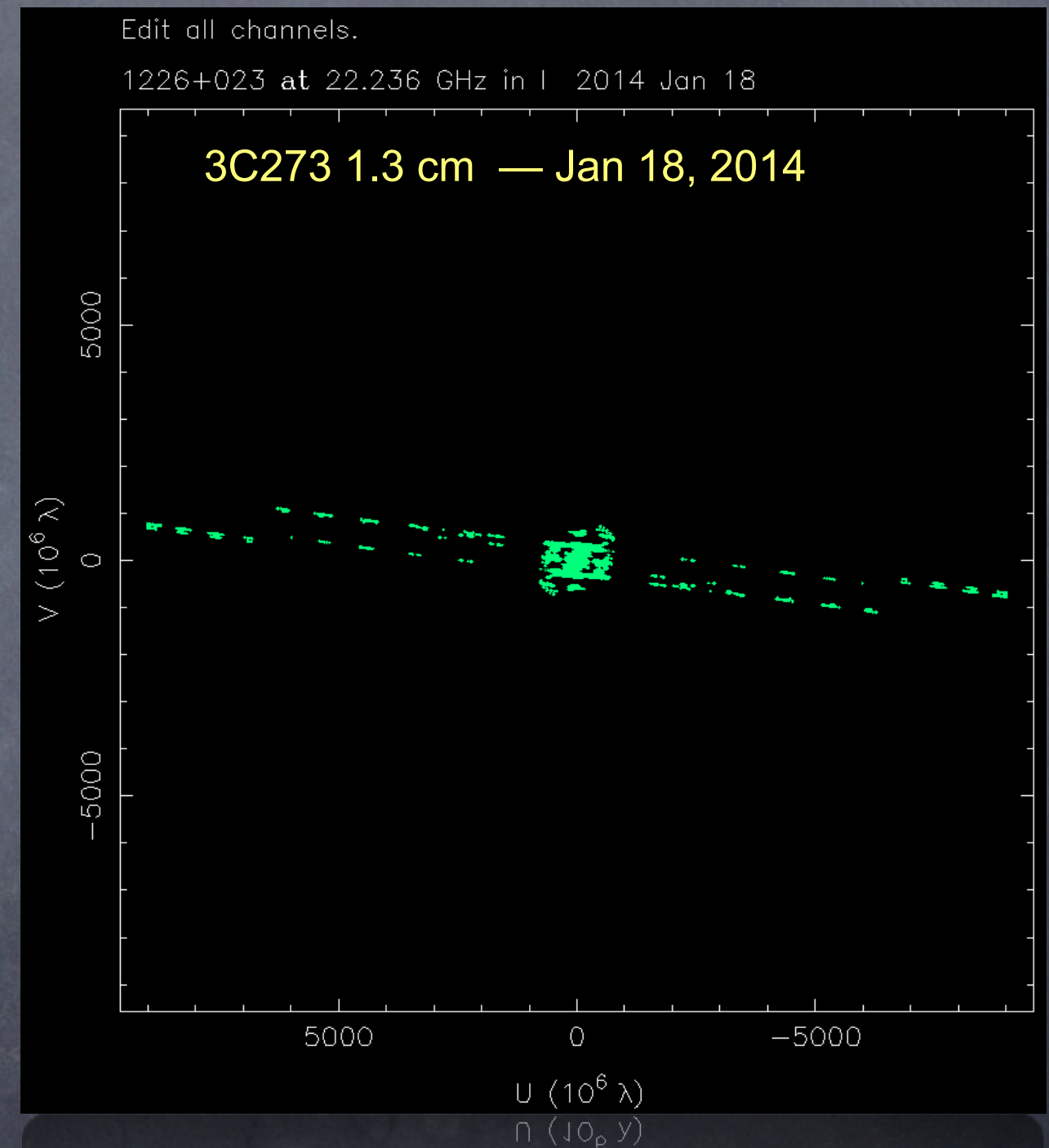
- Core region shows a **gradient in RM**, decreasing in the jet direction. Values change from $\sim -1800 \text{ rad/m}^2$ to -300 rad/m^2
- Jet shows $\text{RM} \sim -500 \text{ rad/m}^2$
- RM to be extended up to 3mm through comparison with GMVA observations.

POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

RADIOASTRON OBSERVATIONS OF 3C273 AT 1.3 CM

RadioAstron observations of 3C273 at 1.3 cm were performed on January 18, 2014.

3C273 was observed together with 22 antennas on the ground array: AT, CD, HO, MP, KL, HH, EF, MC, TR, SV, ZC, GB, and the VLBA.



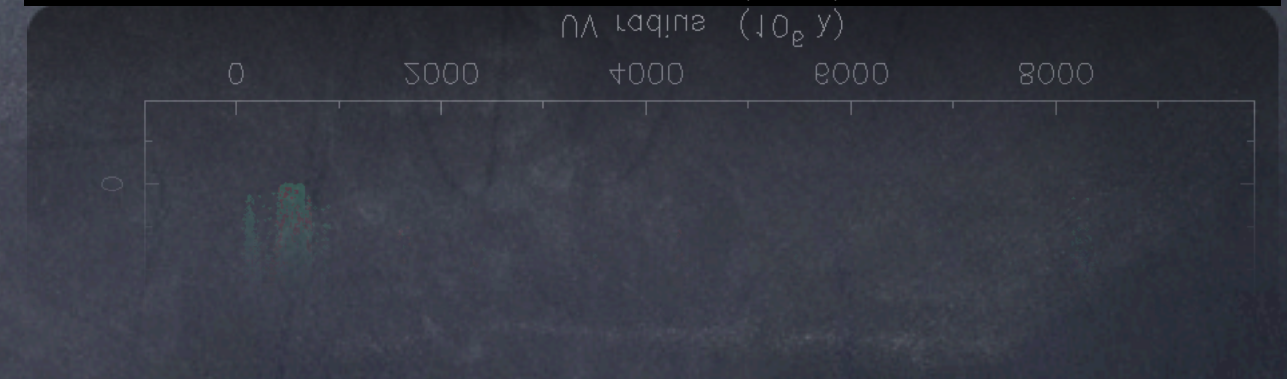
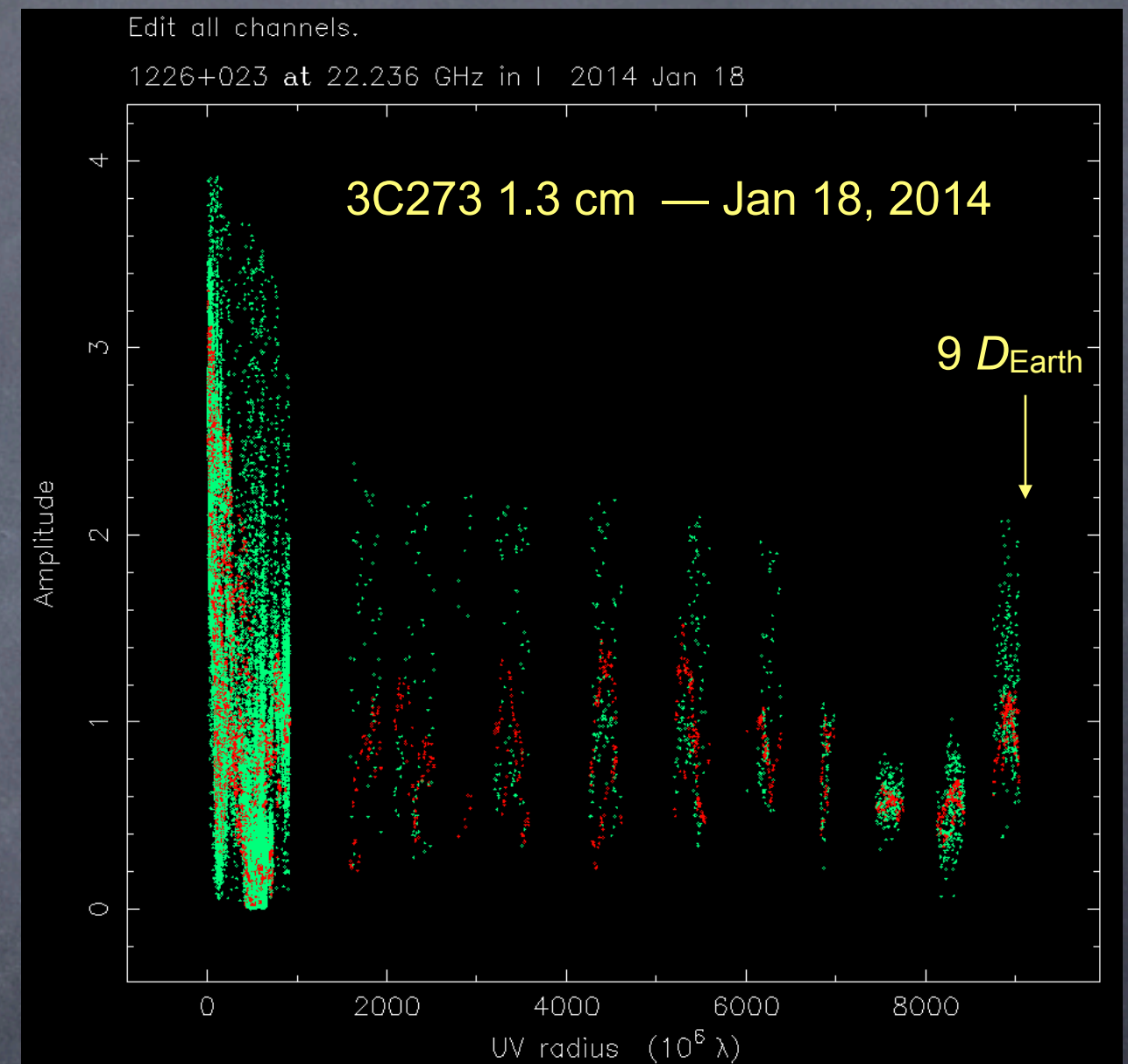
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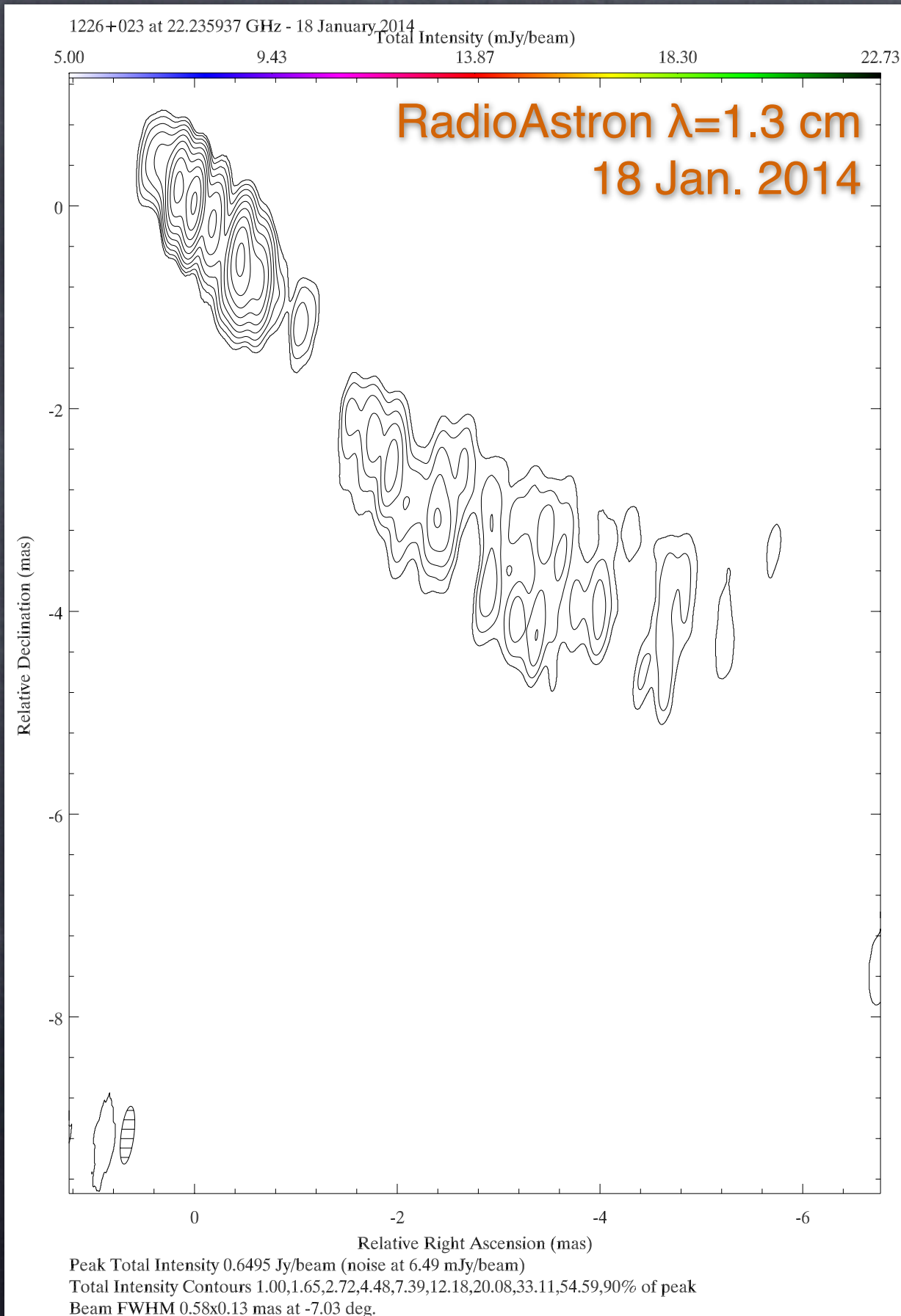
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*Preliminary analysis shows space-ground **detections up to 9 E_{Earth}** . Polarization is detected on the ground array, but *no cross-hand fringes have been detected in space-ground baselines yet.**



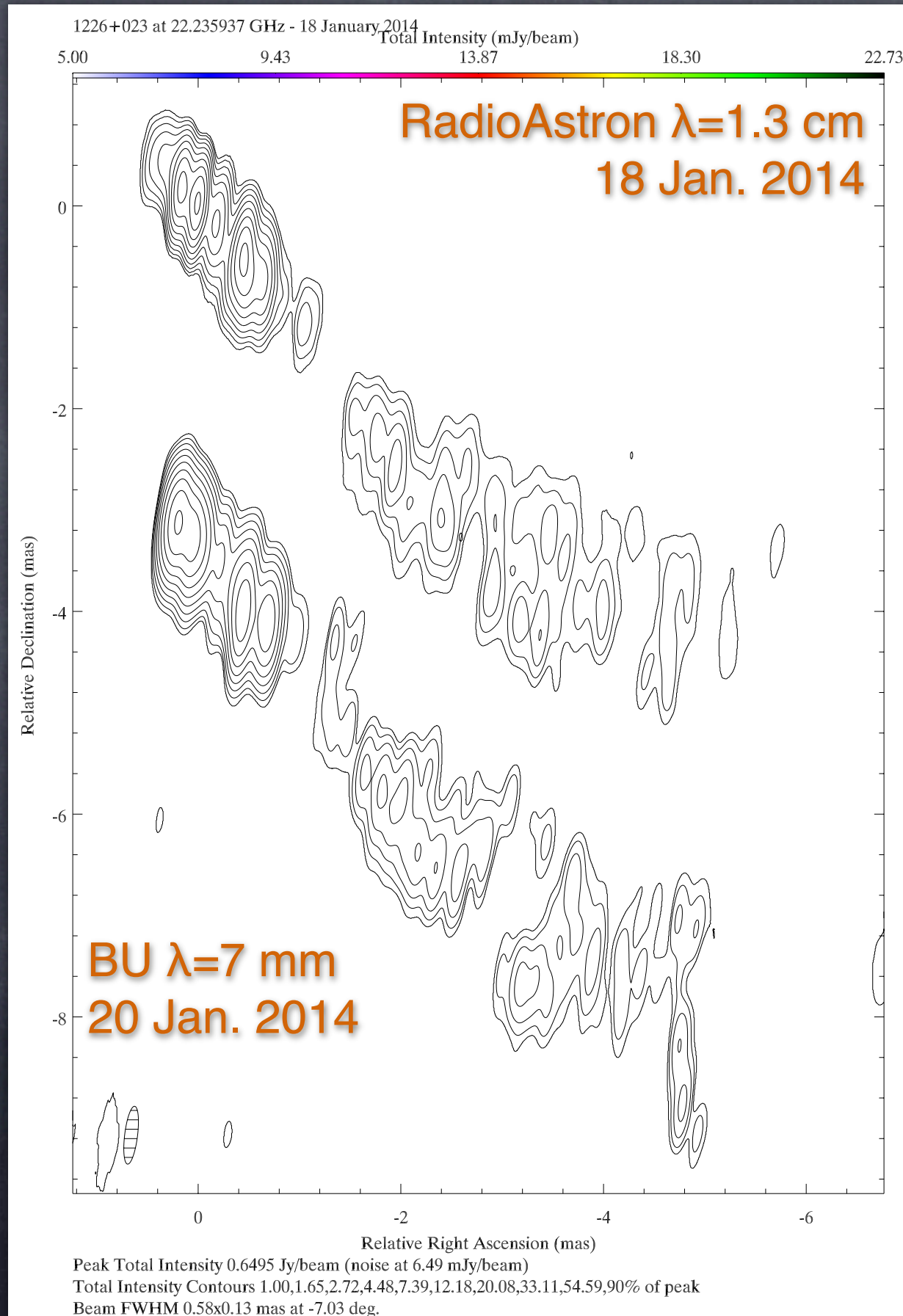
POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



RADIOASTRON IMAGE OF 3C273

Natural weight total intensity image at 1.3 cm achieving an angular resolution of 130 μ as.

POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



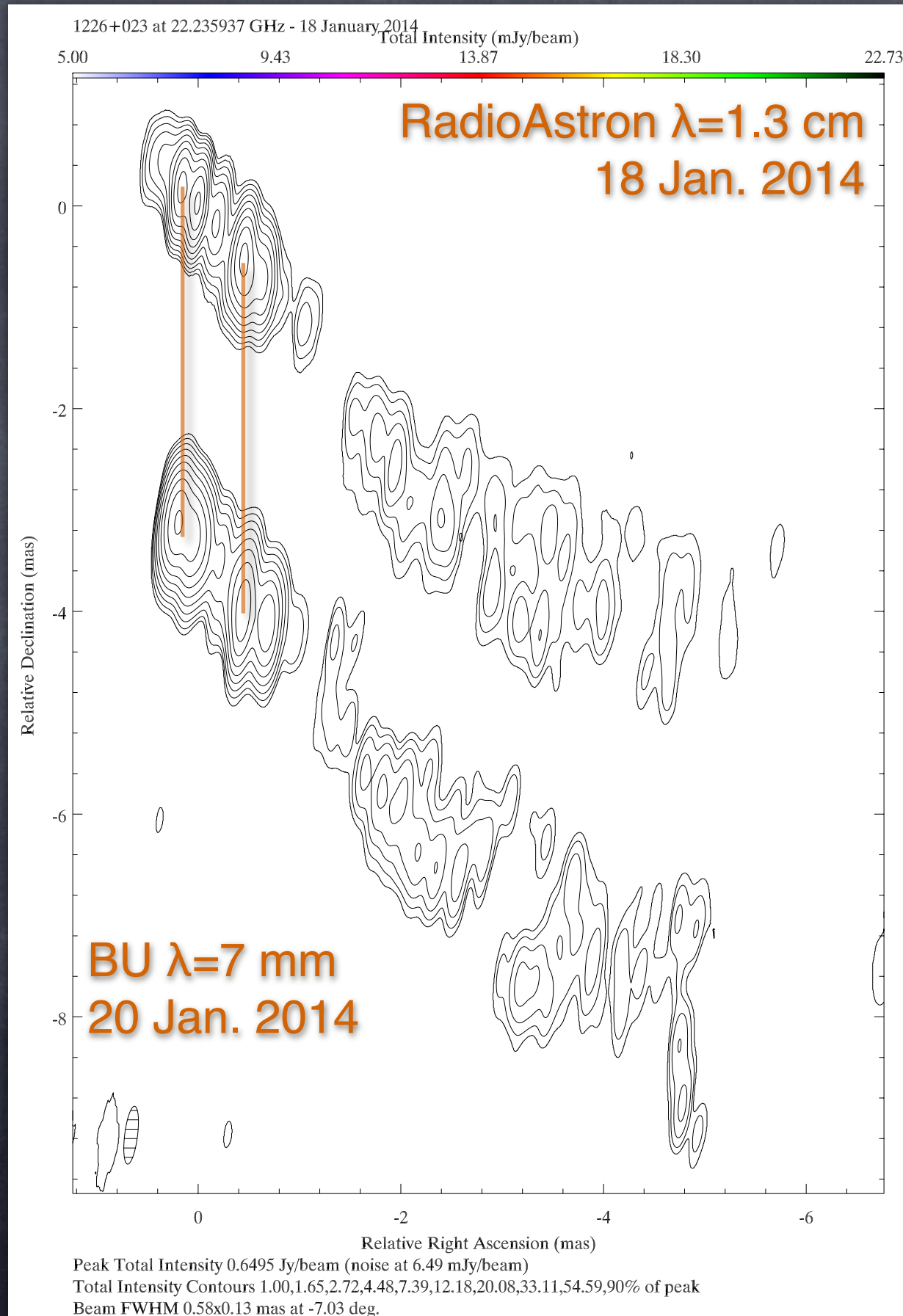
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COMPARISON BETWEEN RA AND BU

Excellent comparison between RadioAstron 1.3 cm and VLBA-BU-BLAZAR at 7 mm for images taken just 2 days apart.

POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



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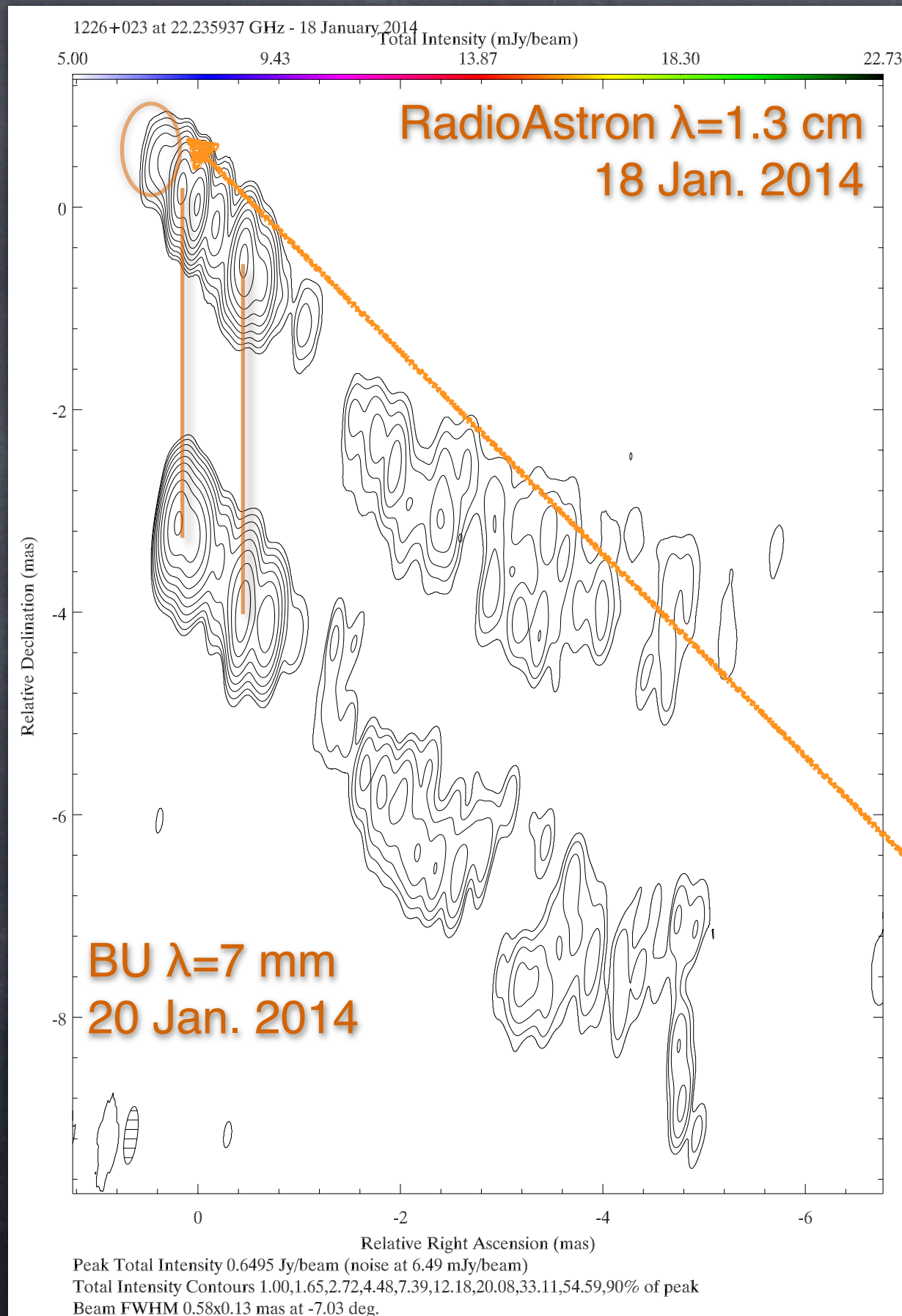
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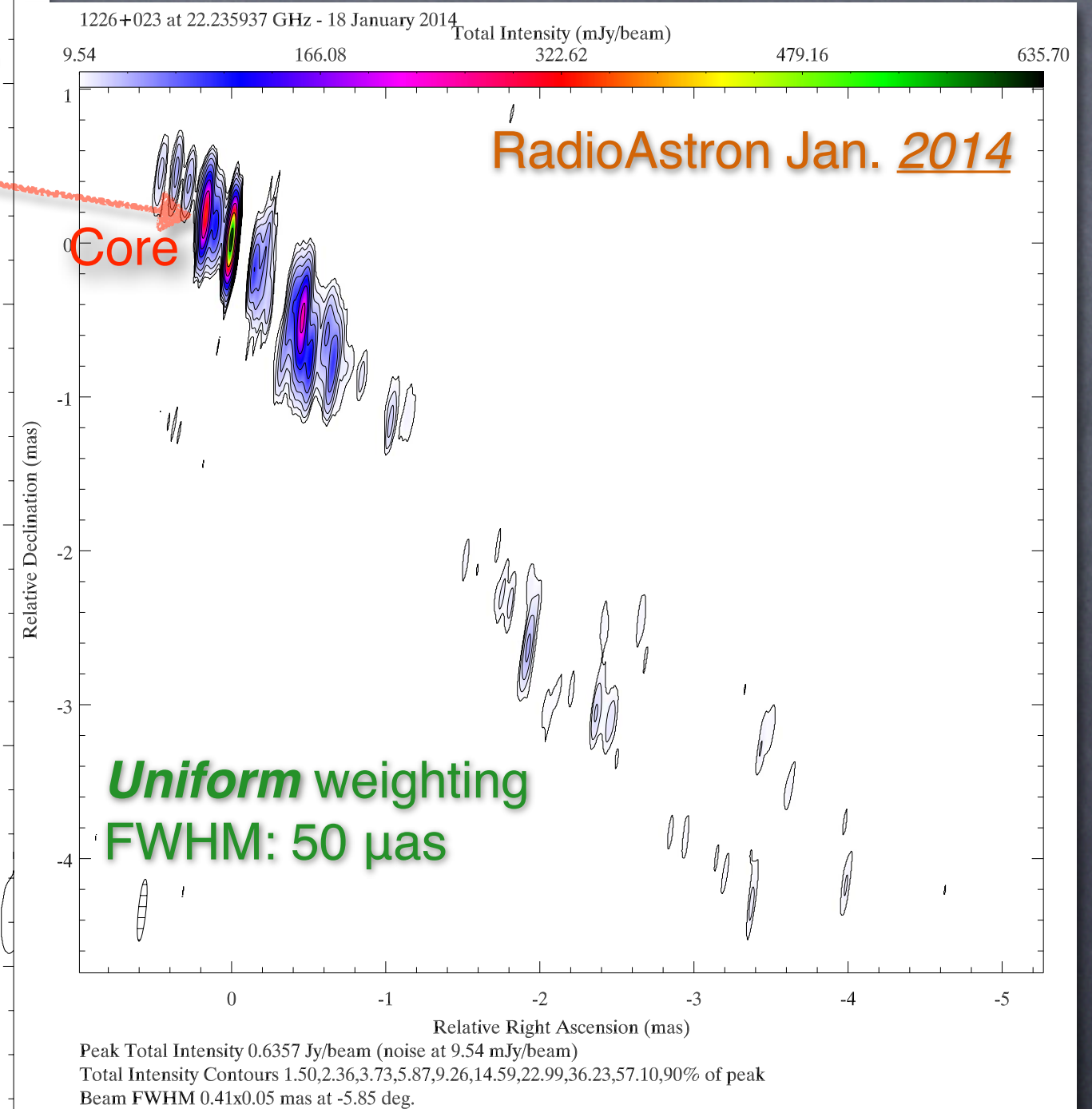
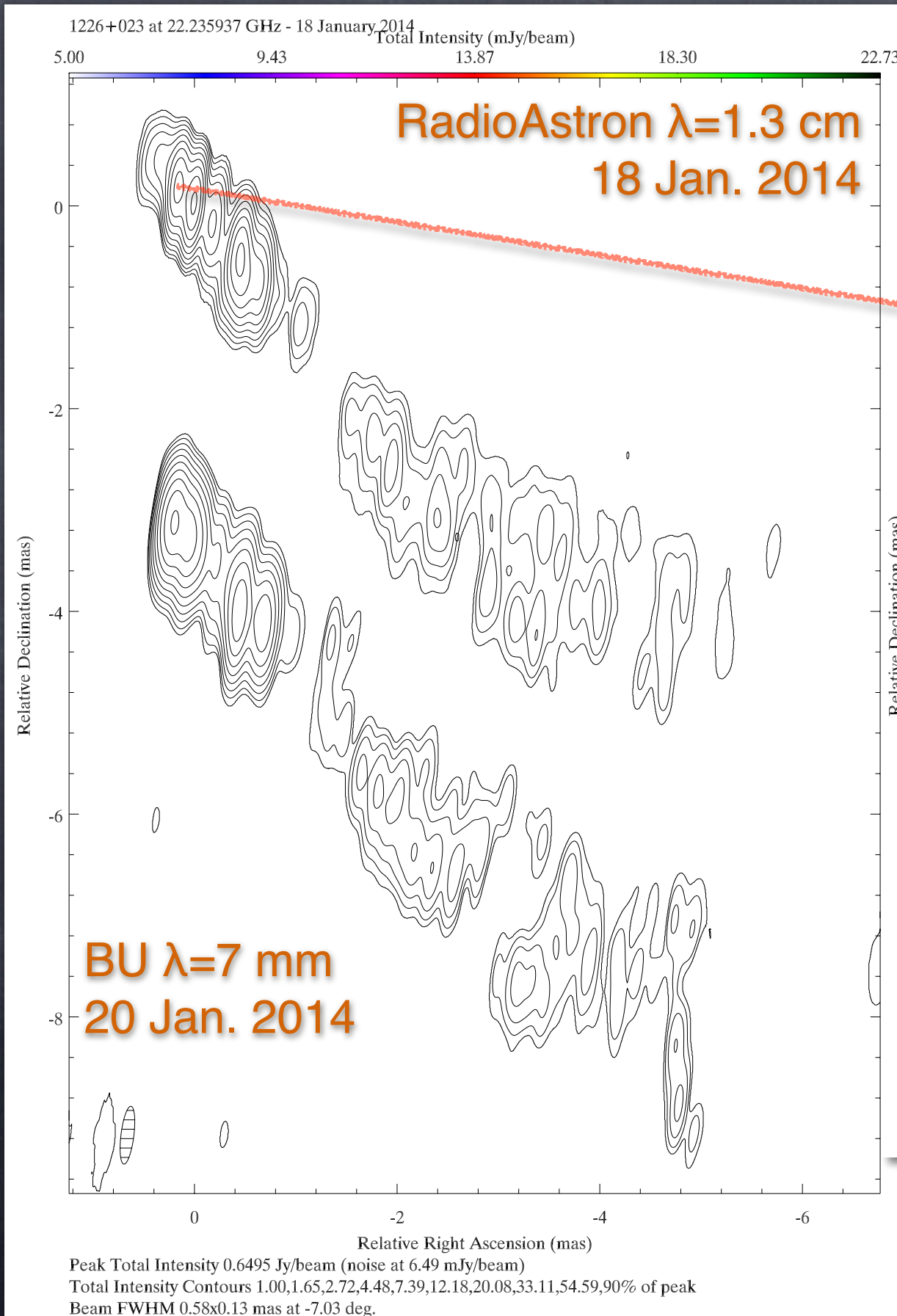
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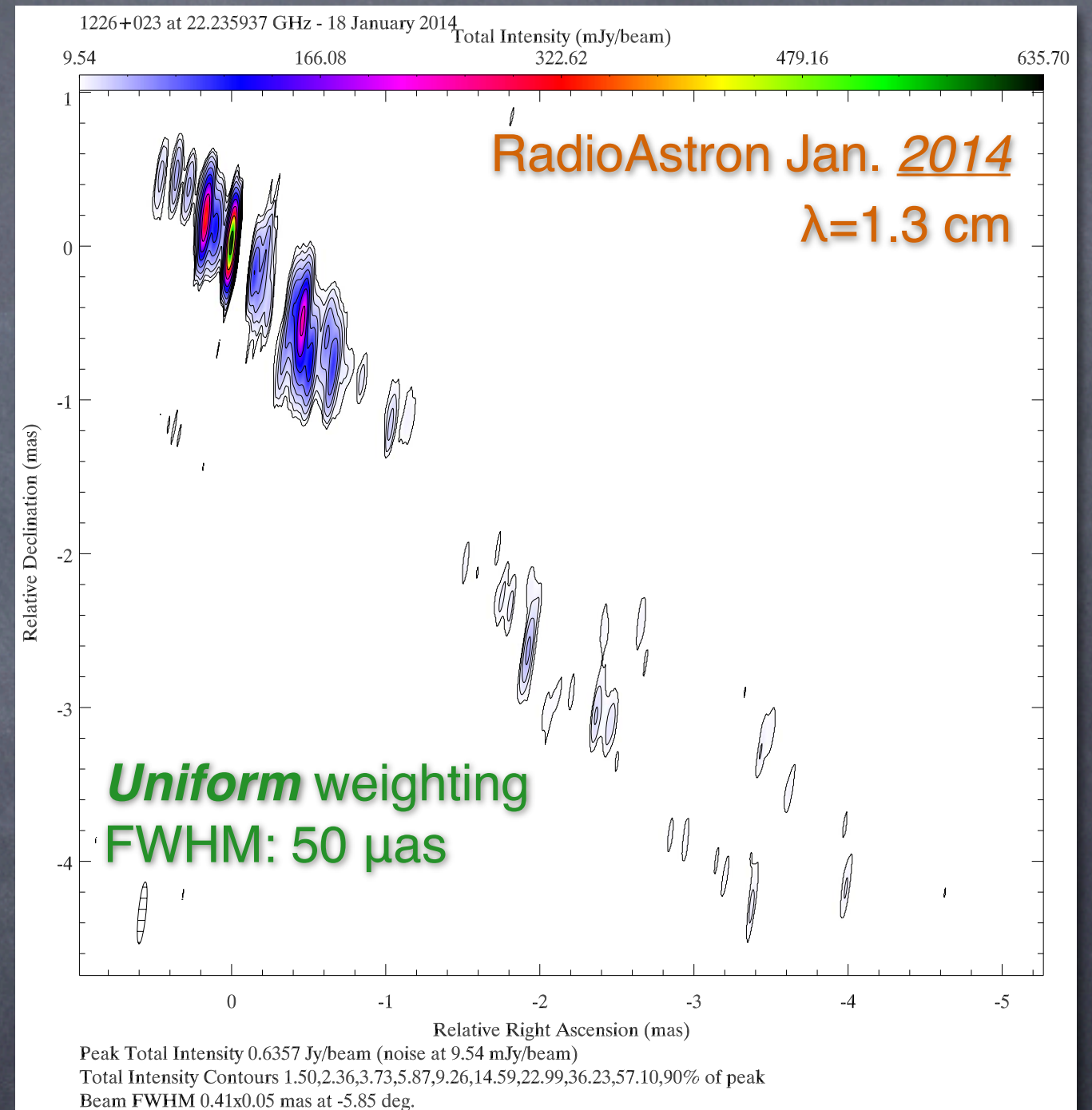
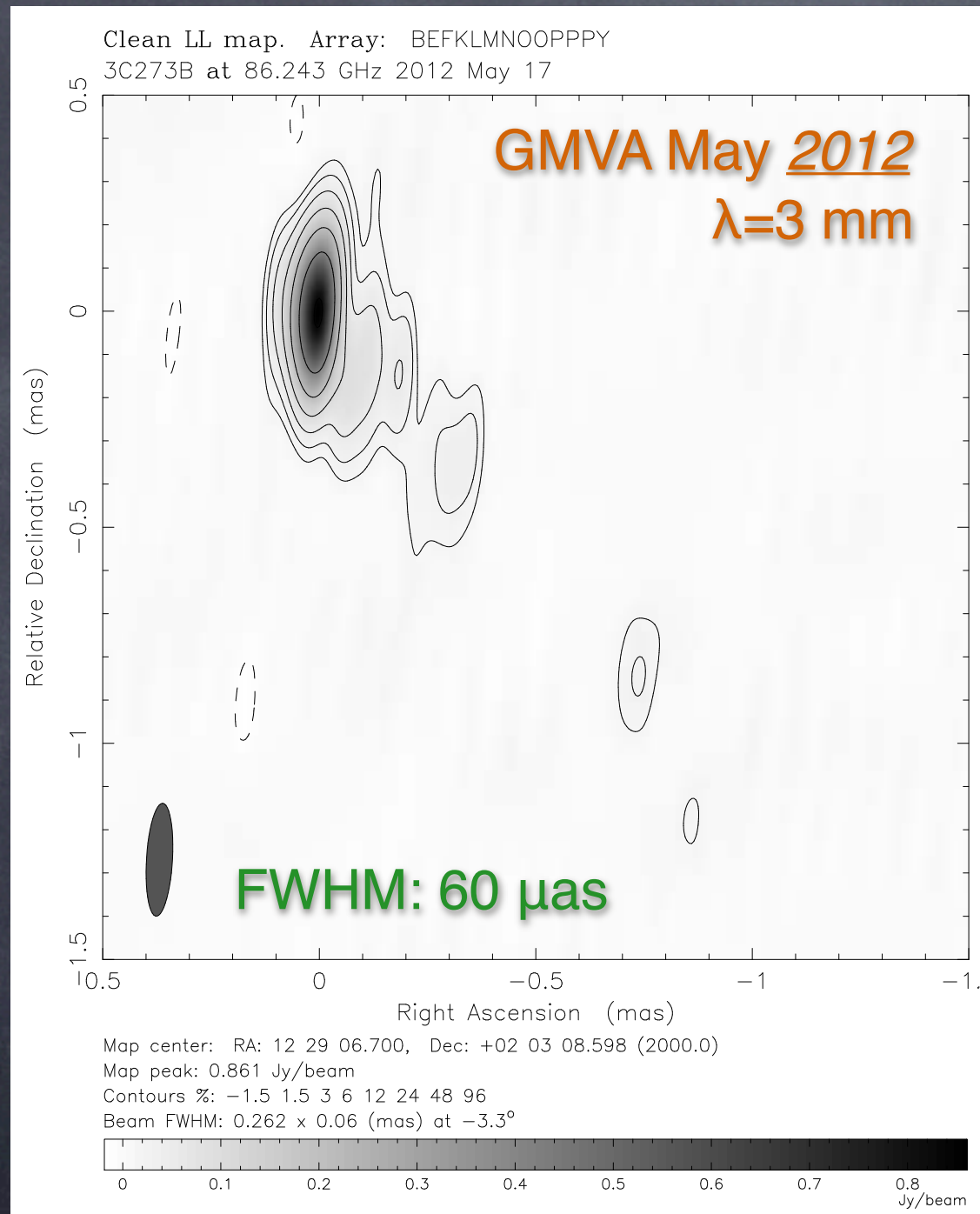
Weak emission is observed upstream of the core. Further analysis to check whether it is an artifact or actual emission from the counter-jet.

POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI



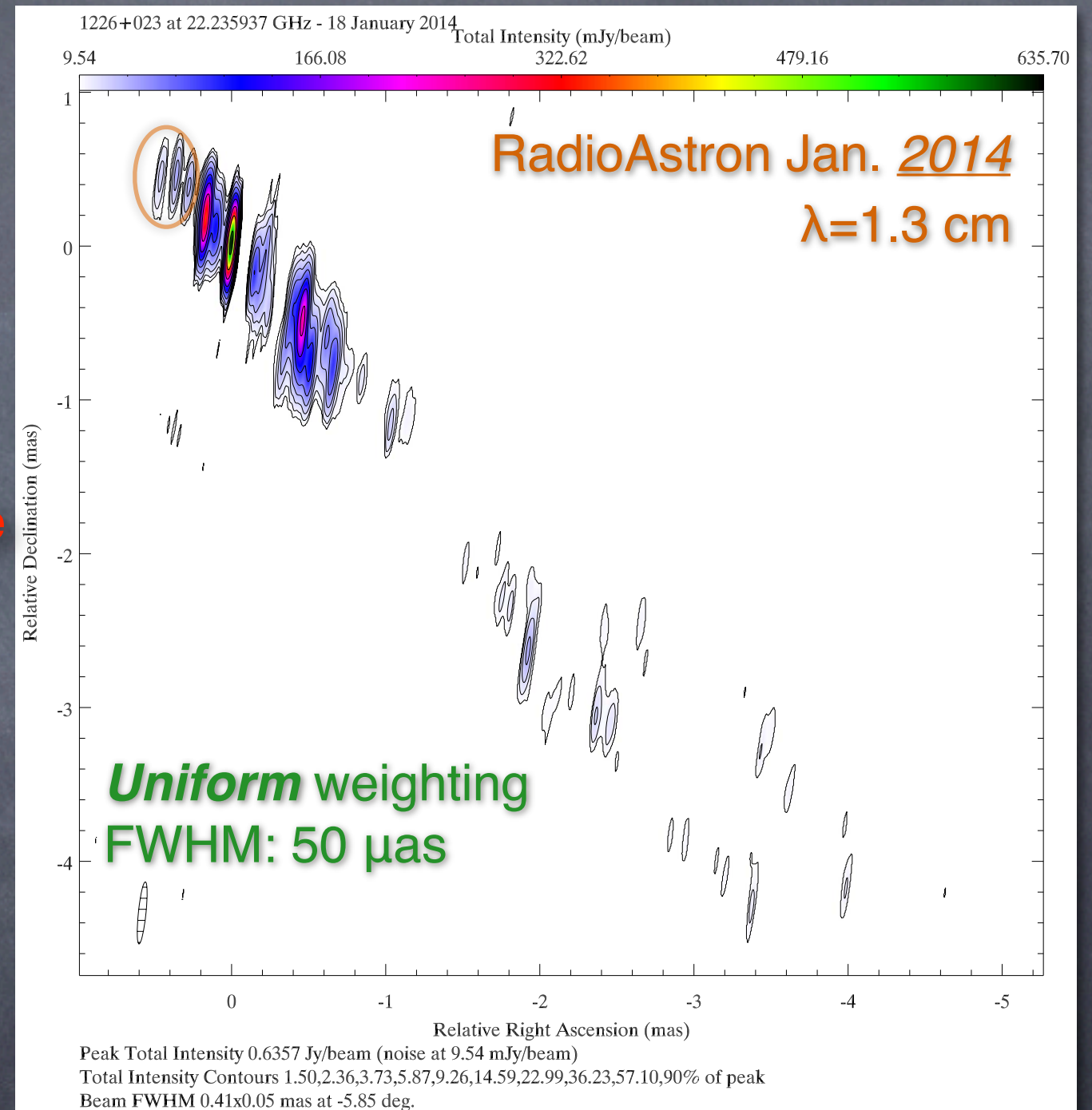
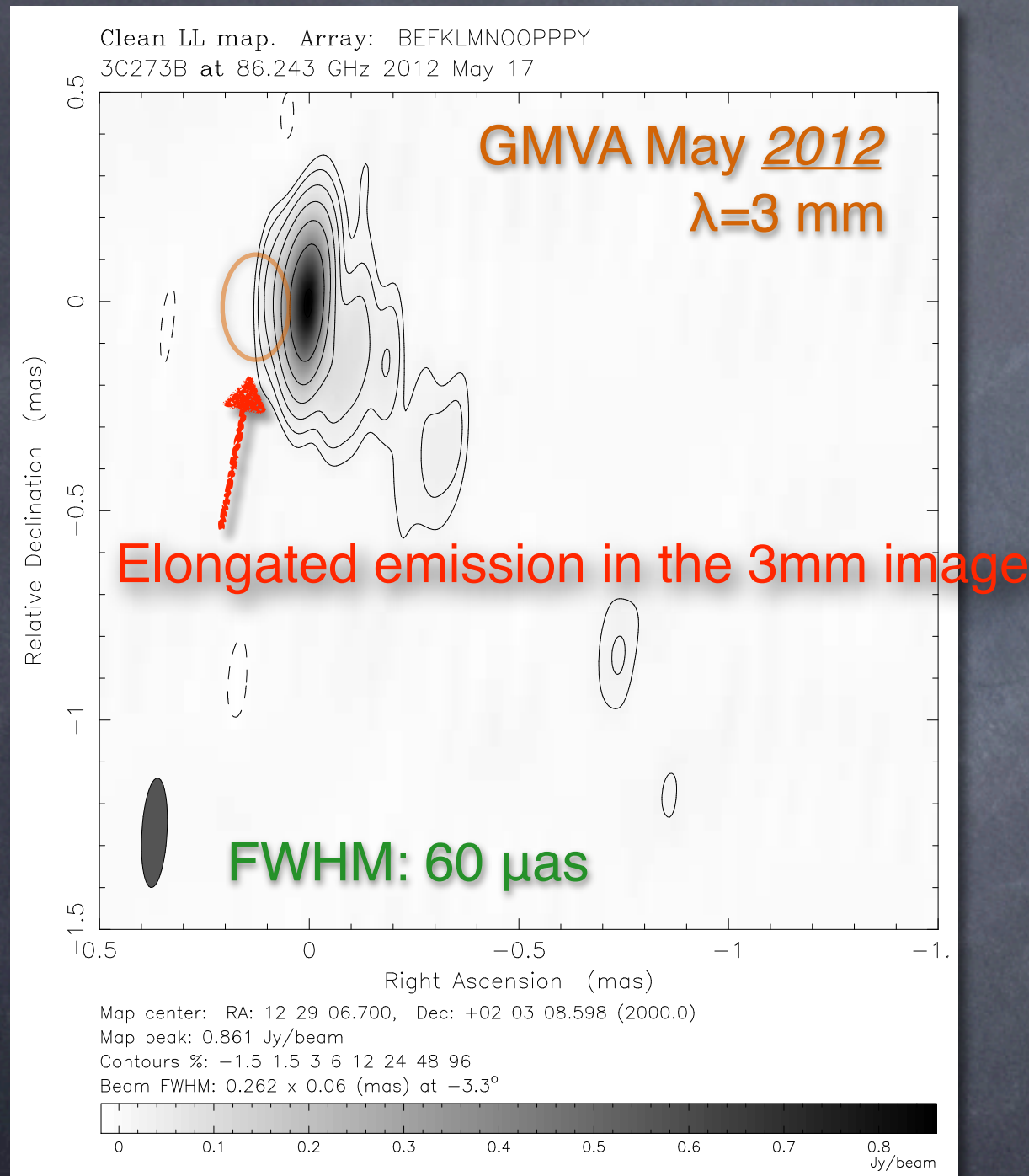
POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

COMPARISON BETWEEN RADIOASTRON AND GMVA



POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

COMPARISON BETWEEN RADIOASTRON AND GMVA



POLARIMETRIC SPACE-VLBI WITH RADIOASTRON AND MM-VLBI

SUMMARY

- We are carrying out a RadioAstron KSP in polarization, as well as a long term GMVA monitoring program (PI Marscher) of 16 γ -ray blazars.
- Our project is aimed to probe the innermost regions of AGN jets and their magnetic fields, to understand the formation mechanisms and establish the location and origin of the high-energy emission.
- First successful space-VLBI polarimetric observations at 1.3 cm, revealing the innermost magnetic field structure in BL Lac with an angular resolution of $33 \mu\text{as}$, best to date.

RadioAstron allows polarization imaging with angular resolutions of $\lesssim 30 \mu\text{as}$

- Total intensity RadioAstron imaging of 3C273 achieved at $50 \mu\text{as}$, showing indications for a counter-jet.
- Interpretation of the data through GRMHD simulations (Martí et al. 2015, Mizuno et al. 2014) to determine the physical parameters of the fluid (velocity field, energy density), non-thermal population, and magnetic field.

