Half a Century of Blazars and Beyond, 11-15 June 2018 - Torino

Delving Deeper into Blazar Cores with 3mm GMVA Polarimetric Observations

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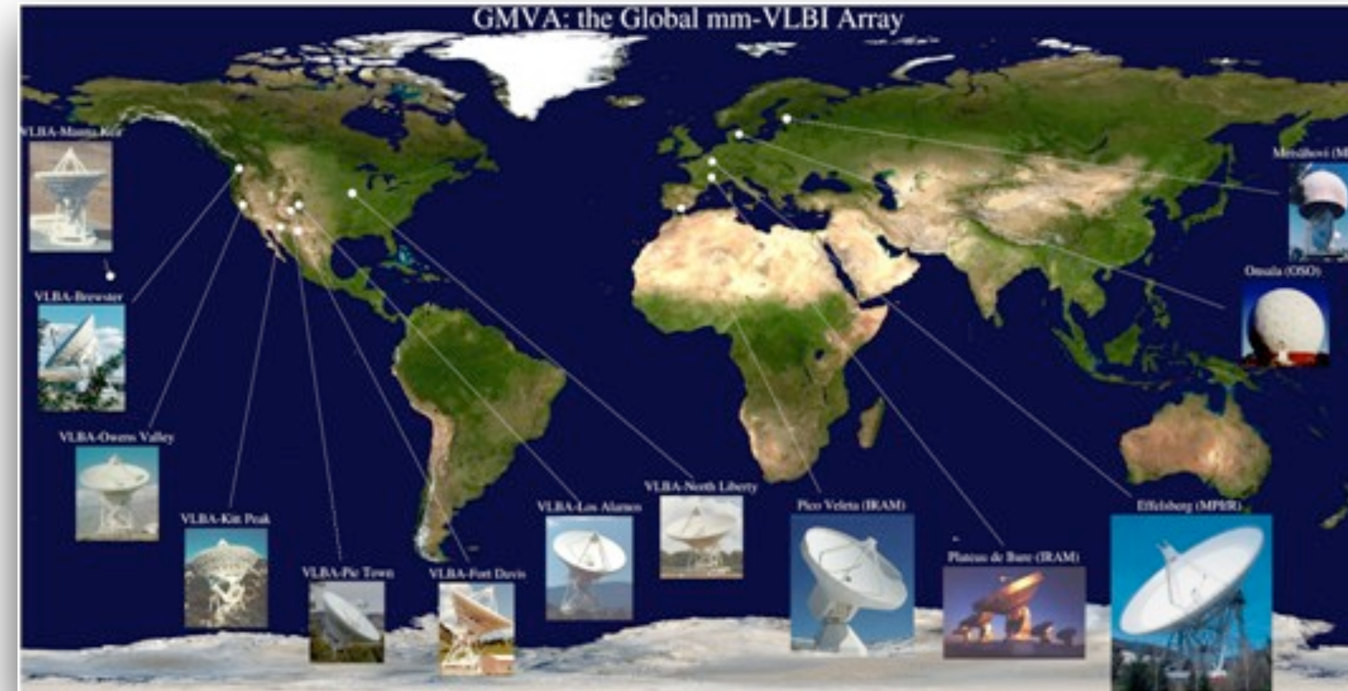
MAX PLANCK INSTITUTE
FOR RADIOASTRONOMY

GMVA observations of gamma-ray bright blazars and radio galaxies

THE SAMPLE

Half of the 37 gamma-ray bright and radio loud AGN from VLBA-BU-BLAZAR Program:

15 FSRQ and BL Lacs
2 radiogalaxies (3C 120, 3C 111)



86 GHz GMVA polarimetric obs. (PI: Prof. Marscher)

http://www.bu.edu/blazars/vlbi3mm/

- VLBA, Green Bank, Effelsberg, Onsala, Yebes, Metsahovi, Pico Veleta, Plateau de Bure, KVN stations
- started in 2008.78, ~ every 6 months
- max angular resolution ~ **0.05 mas** ⟶ 3 times higher resolution !

Goals and Requirements

At 3mm: HIGHER resolution + LOWER opacity

At 7mm: HIGH cadence + more extended structure

GOALS: Magnetic Field structure and morphology in the very inner regions of AGN jets and with unprecedented resolution

BASIC REQUIREMENTS: reliable Total and Linearly Polarized Intensity images

→ Different methods for the calibration of instrumental polarization have been tested

GMVA observations

21 May 2016

Antennas

VLBA + EF + ON + YS + KVN

Sources

3C111
3C120
3C273
3C345
3C454.3
0716+714
0954+658
1510-089
1633+382
BL LAC
CTA102
OJ287

30 Sept 2016

Antennas

VLBA (- MK) + EF + ON + YS + MH + GBT + KVN

Sources

3C345
3C454.3
0716+714
0954+658
1055+018
1510-089
1633+382
1749+096
BL LAC
CTA102
OJ287

31 March 2017

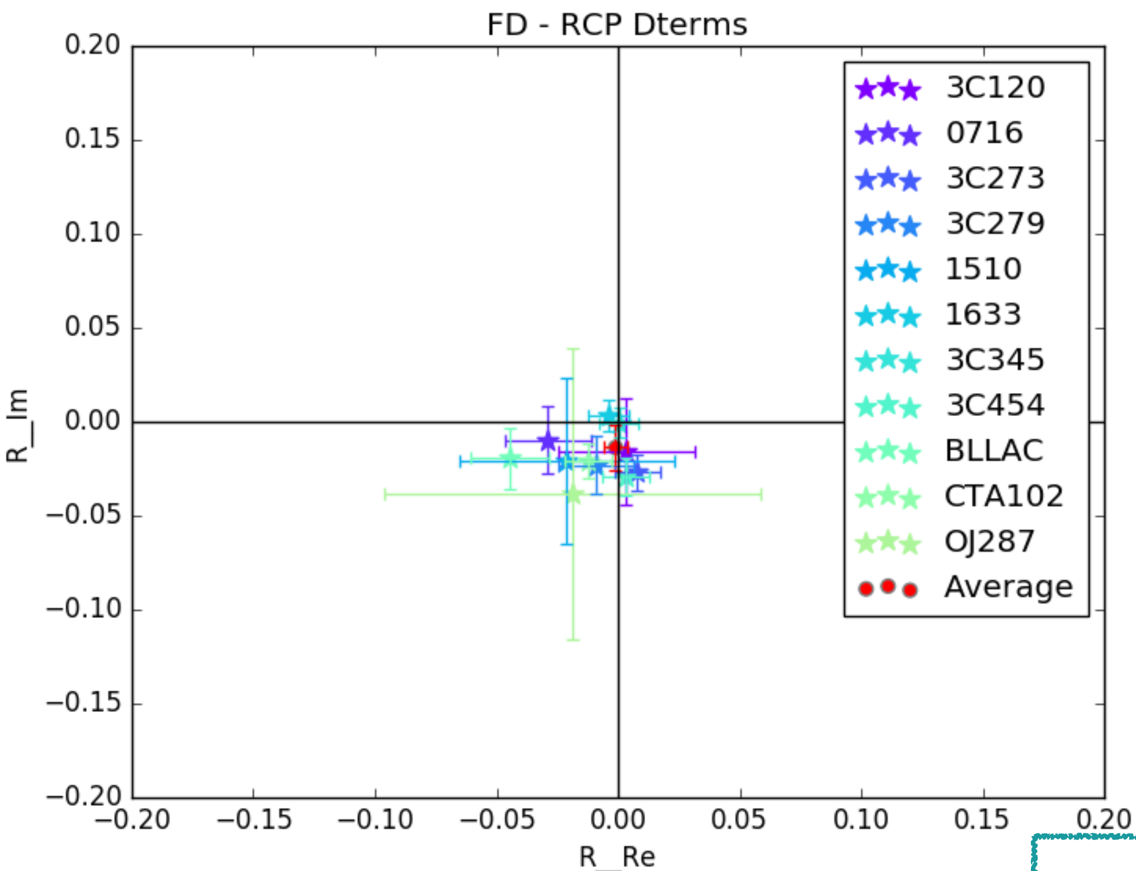
Antennas

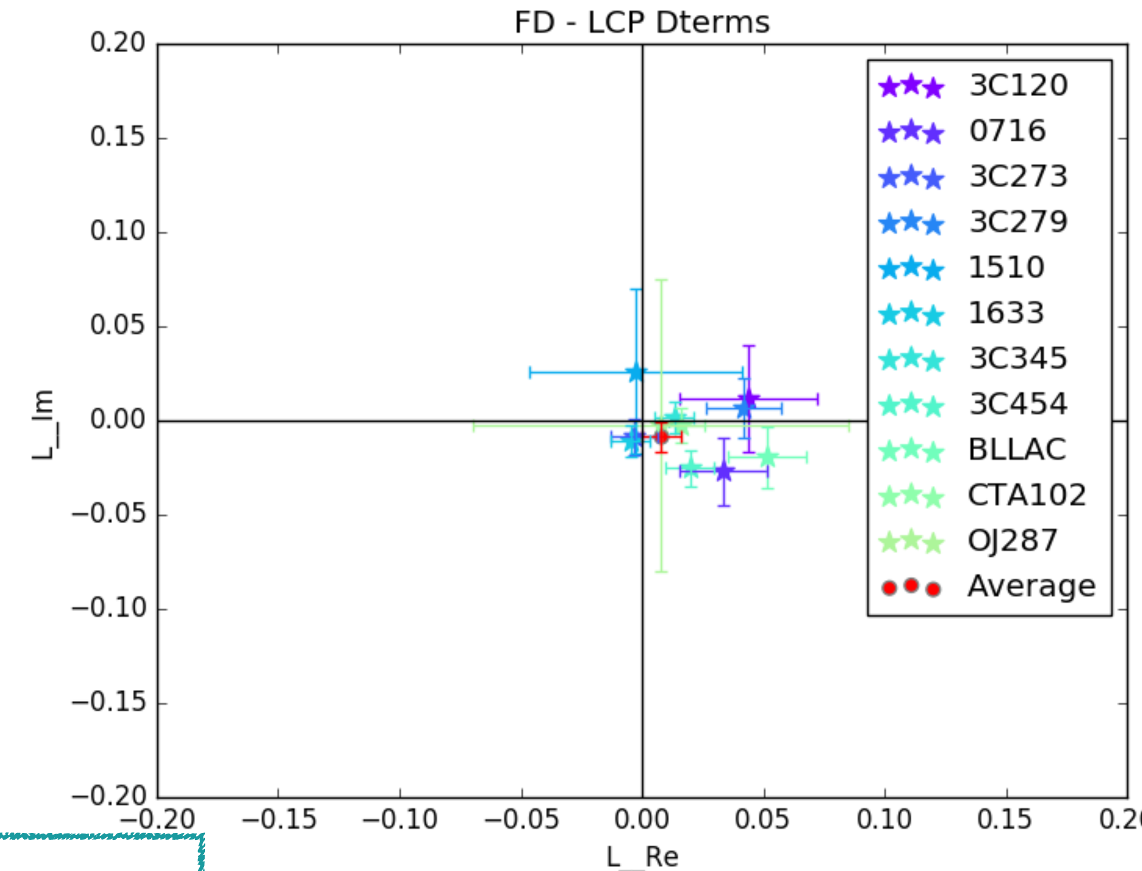
VLBA + EF + ON + YS + MH + PV + GBT +

Sources

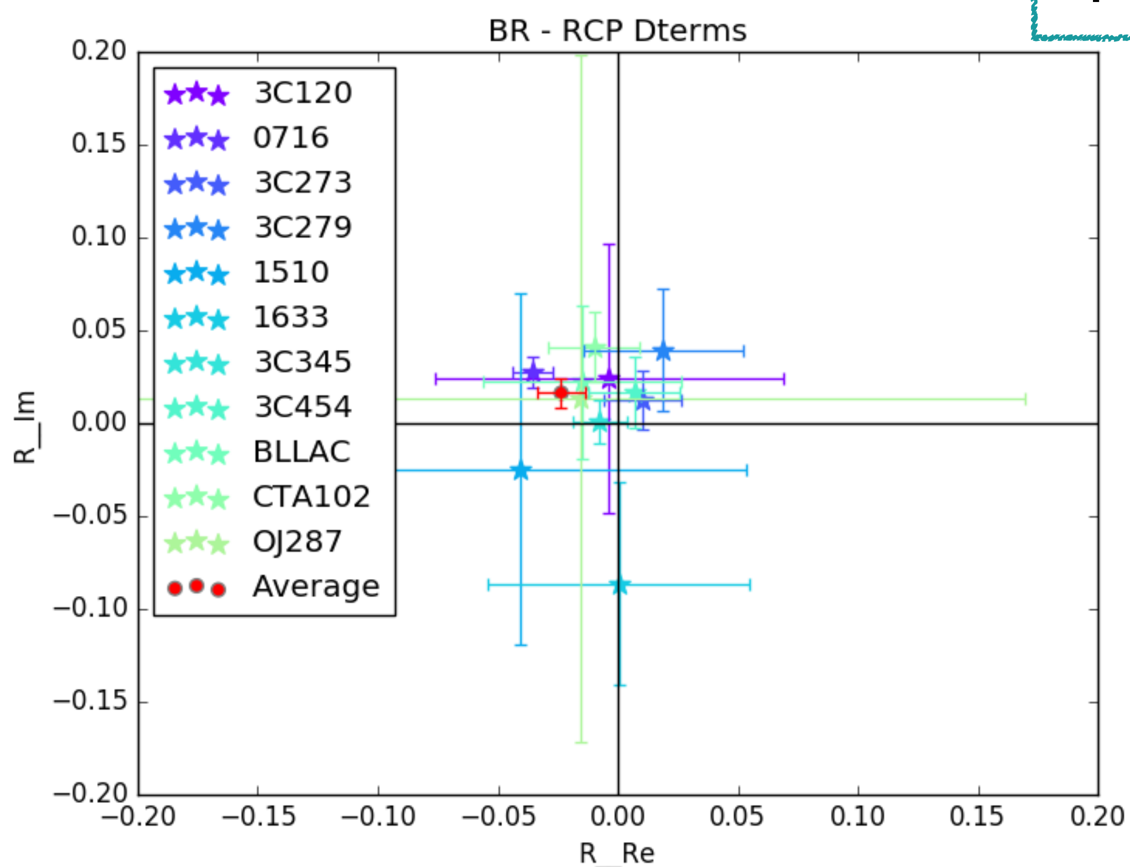
3C120
3C273
3C279
3C345
3C454.3
0716+714
1510-089
1633+382
1749+096
BL LAC
CTA102
OJ287

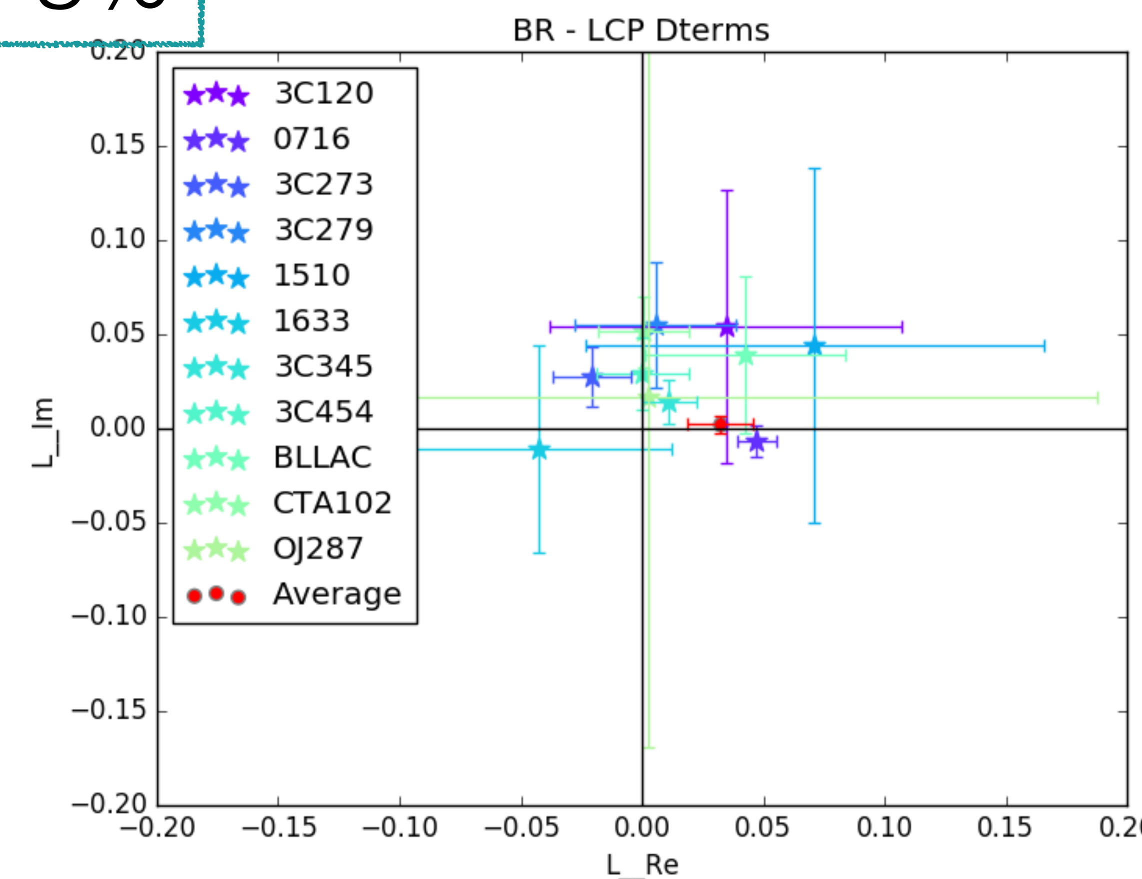
D-terms Comparison





1σ ~3%

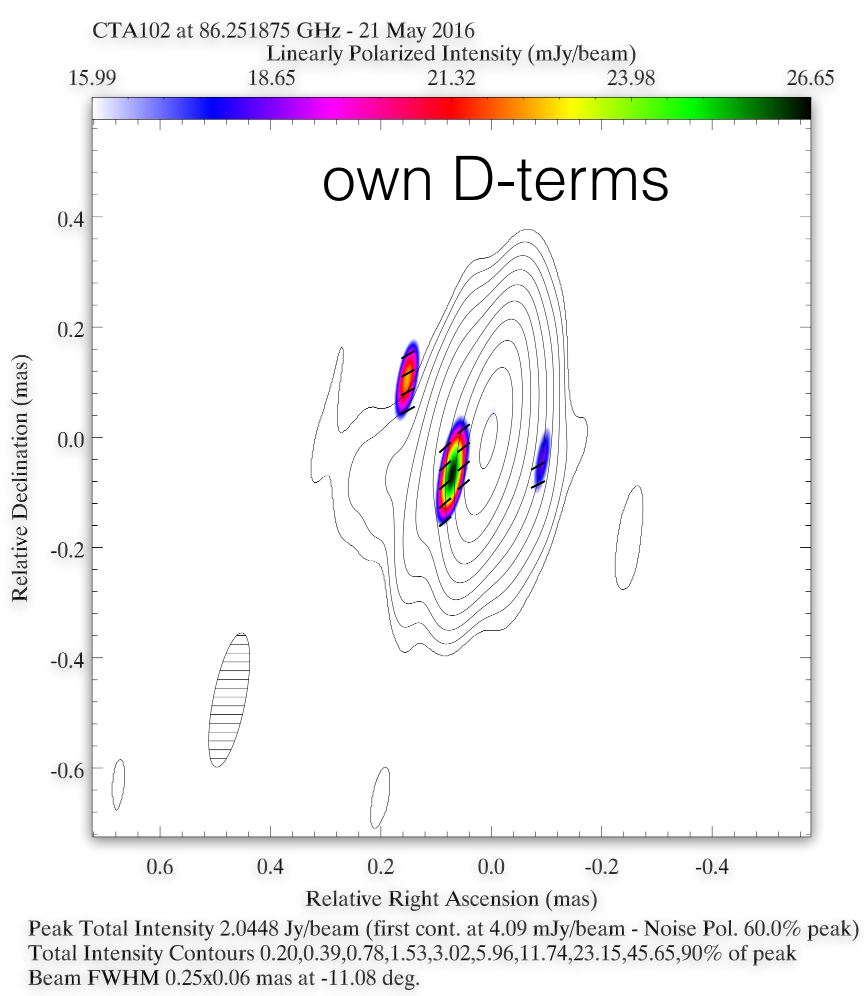


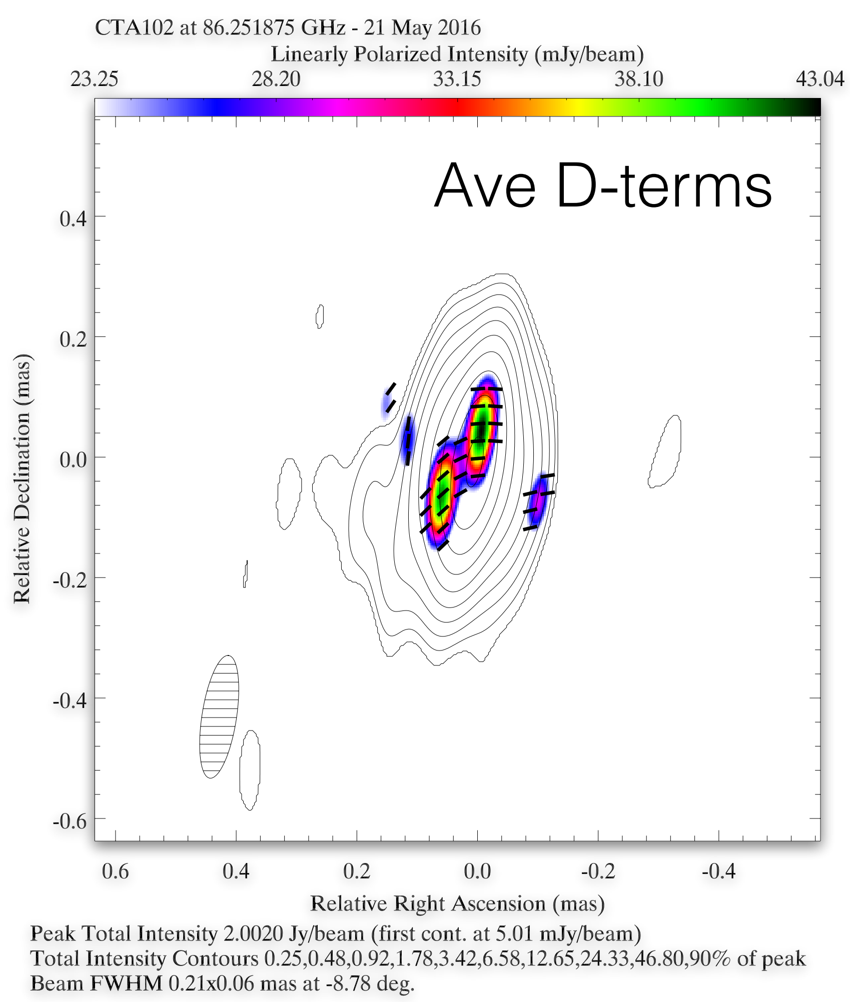


Testing different D-terms

We applied, on a bunch of sources, either their own D-terms and the Average values

Findings: When the source is bright in total intensity but weak in linearly polarized intensity, and the PA coverage is bad, the average d-terms give better results;



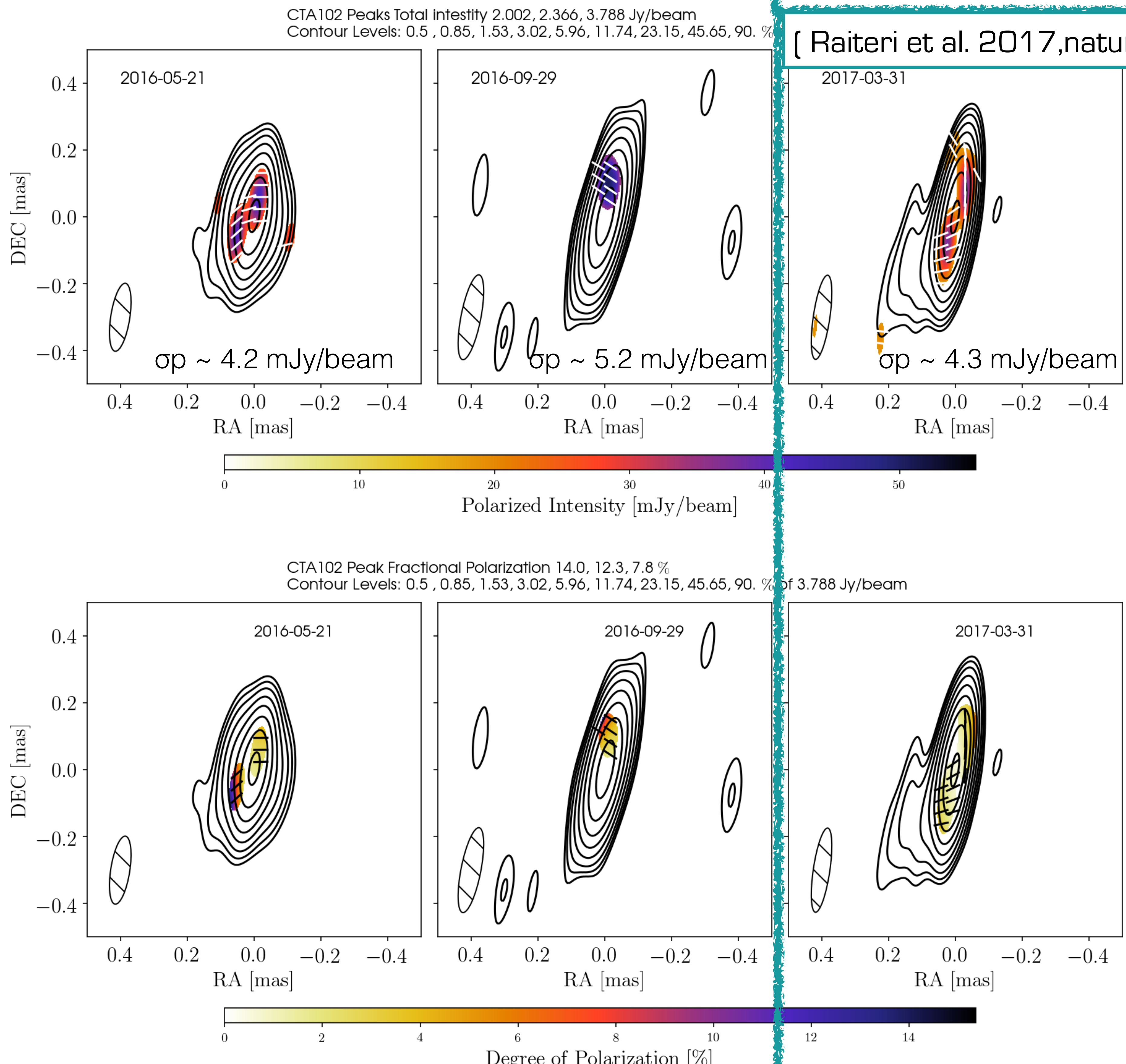


→ We applied the set of Average D-terms to all sources

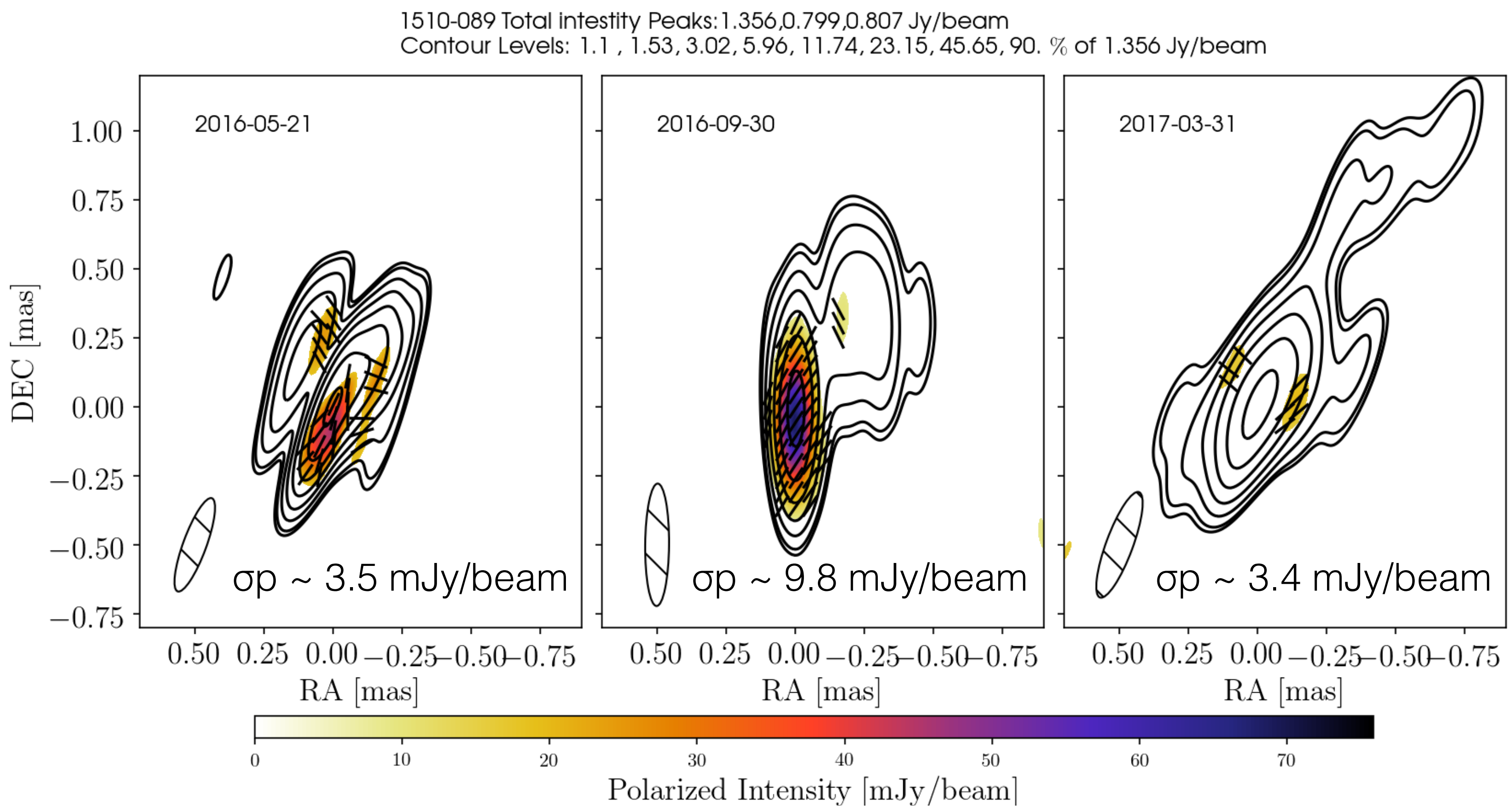
CTA102

gamma-ray, optical and X-ray flare

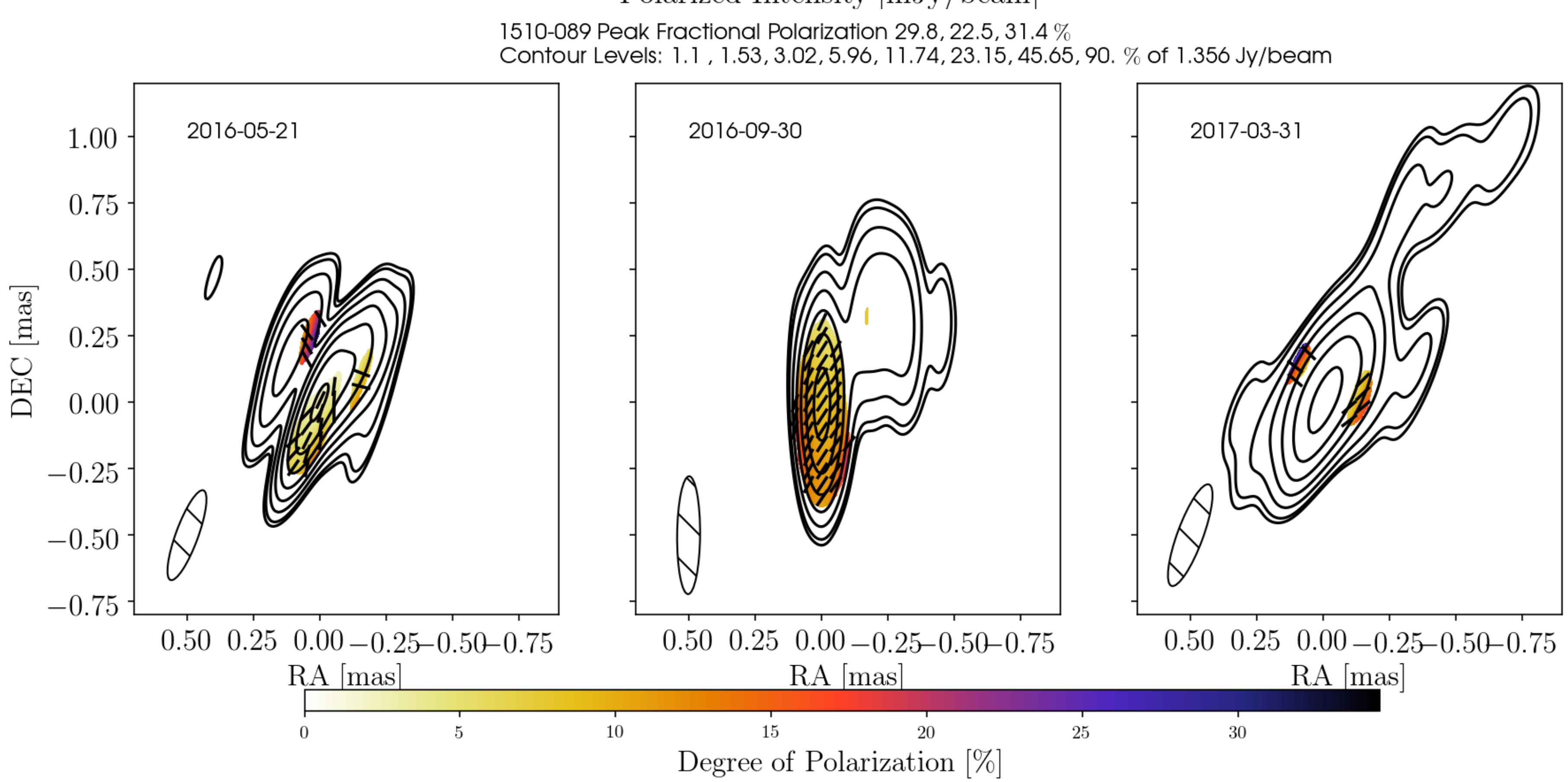
(Raiteri et al. 2017,nature24623)



1510-089

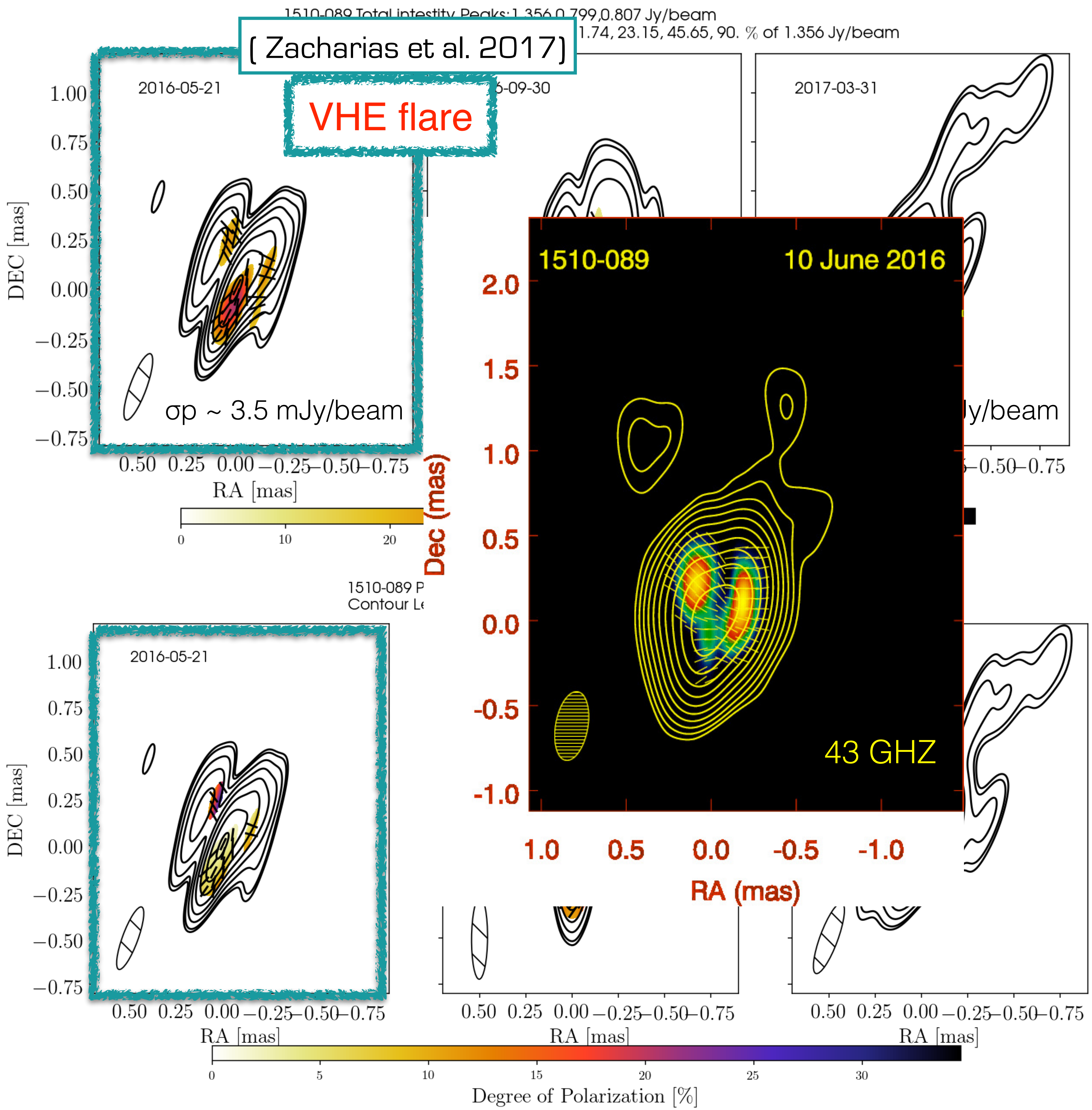


1510-089 Total intestity Peaks:1.356,0.799,0.807 Jy/beam
Contour Levels: 1.1 , 1.53, 3.02, 5.96, 11.74, 23.15, 45.65, 90. % of 1.356 Jy/beam
2016-05-21
2016-09-30
2017-03-31
σp ~ 3.5 mJy/beam
σp ~ 9.8 mJy/beam
σp ~ 3.4 mJy/beam
DEC [mas]
RA [mas]
Polarized Intensity [mJy/beam]



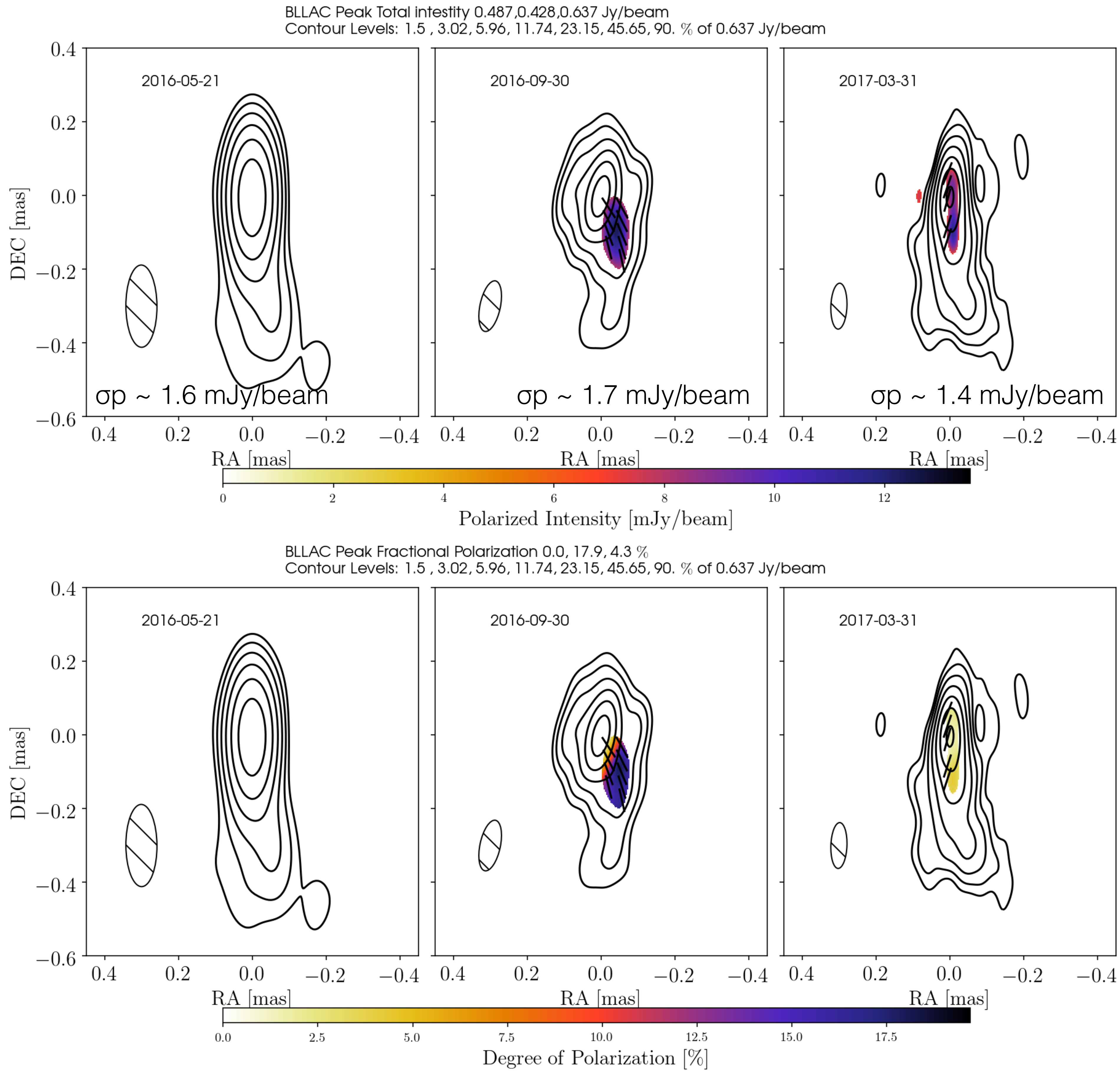
1510-089 Peak Fractional Polarization 29.8, 22.5, 31.4 %
Contour Levels: 1.1 , 1.53, 3.02, 5.96, 11.74, 23.15, 45.65, 90. % of 1.356 Jy/beam
2016-05-21
2016-09-30
2017-03-31
DEC [mas]
RA [mas]
Degree of Polarization [%]

1510-089



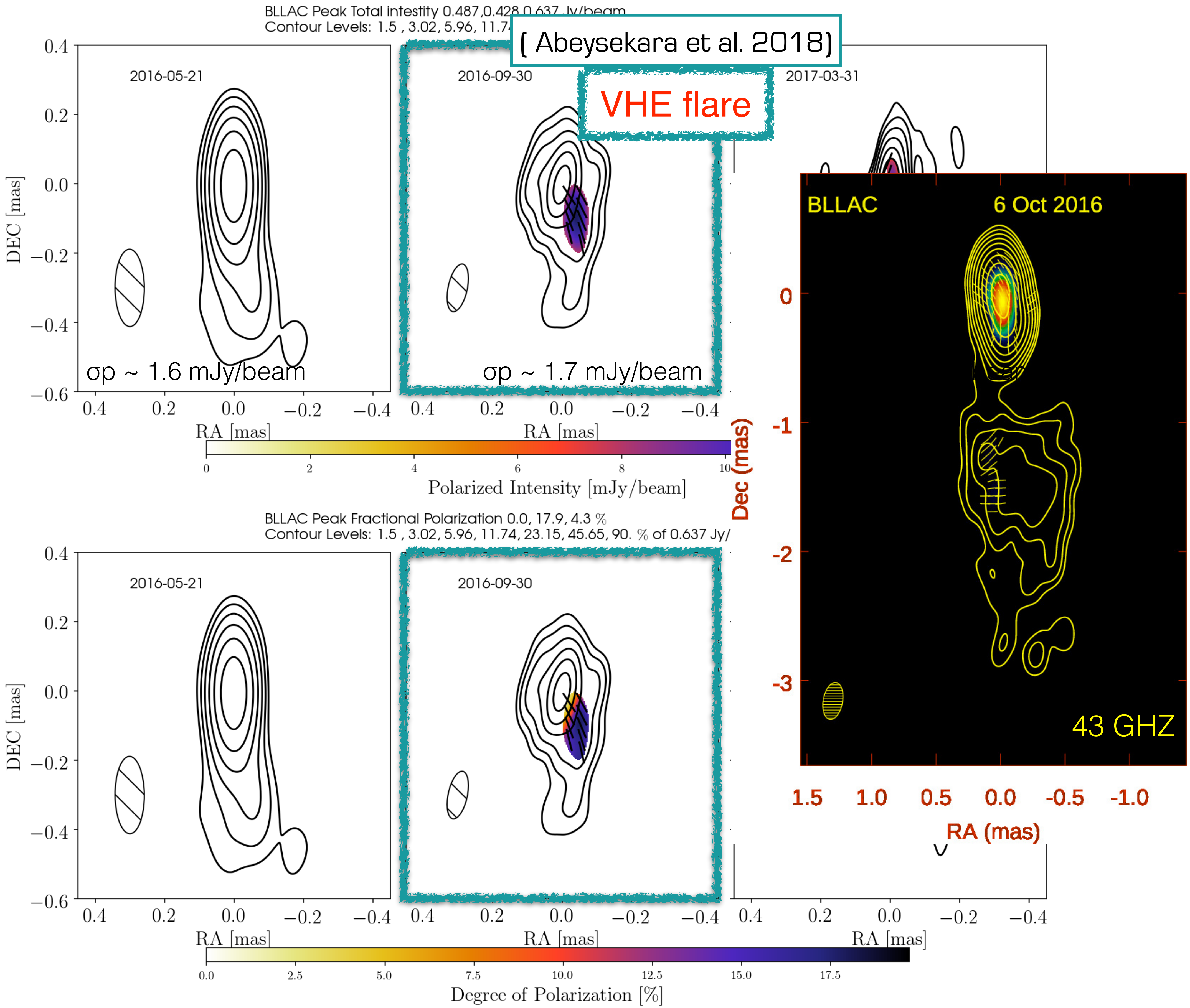
1510-089 Total intestity Peaks:1.356,0.799,0.807 Jy/beam
1.74, 23.15, 45.65, 90. % of 1.356 Jy/beam
(Zacharias et al. 2017)
VHE flare
2016-05-21
2017-03-31
σp ~ 3.5 mJy/beam
Jy/beam
DEC [mas]
RA [mas]
1510-089 P
Contour Le
1510-089
10 June 2016
43 GHZ
Dec (mas)
RA (mas)
Degree of Polarization [%]

BL LAC



BLLAC Peak Total intestity 0.487,0.428,0.637 Jy/beam
Contour Levels: 1.5 , 3.02, 5.96, 11.74, 23.15, 45.65, 90. % of 0.637 Jy/beam
2016-05-21
2016-09-30
2017-03-31
σp ~ 1.6 mJy/beam
σp ~ 1.7 mJy/beam
σp ~ 1.4 mJy/beam
DEC [mas]
RA [mas]
Polarized Intensity [mJy/beam]
BLLAC Peak Fractional Polarization 0.0, 17.9, 4.3 %
Contour Levels: 1.5 , 3.02, 5.96, 11.74, 23.15, 45.65, 90. % of 0.637 Jy/beam
Degree of Polarization [%]

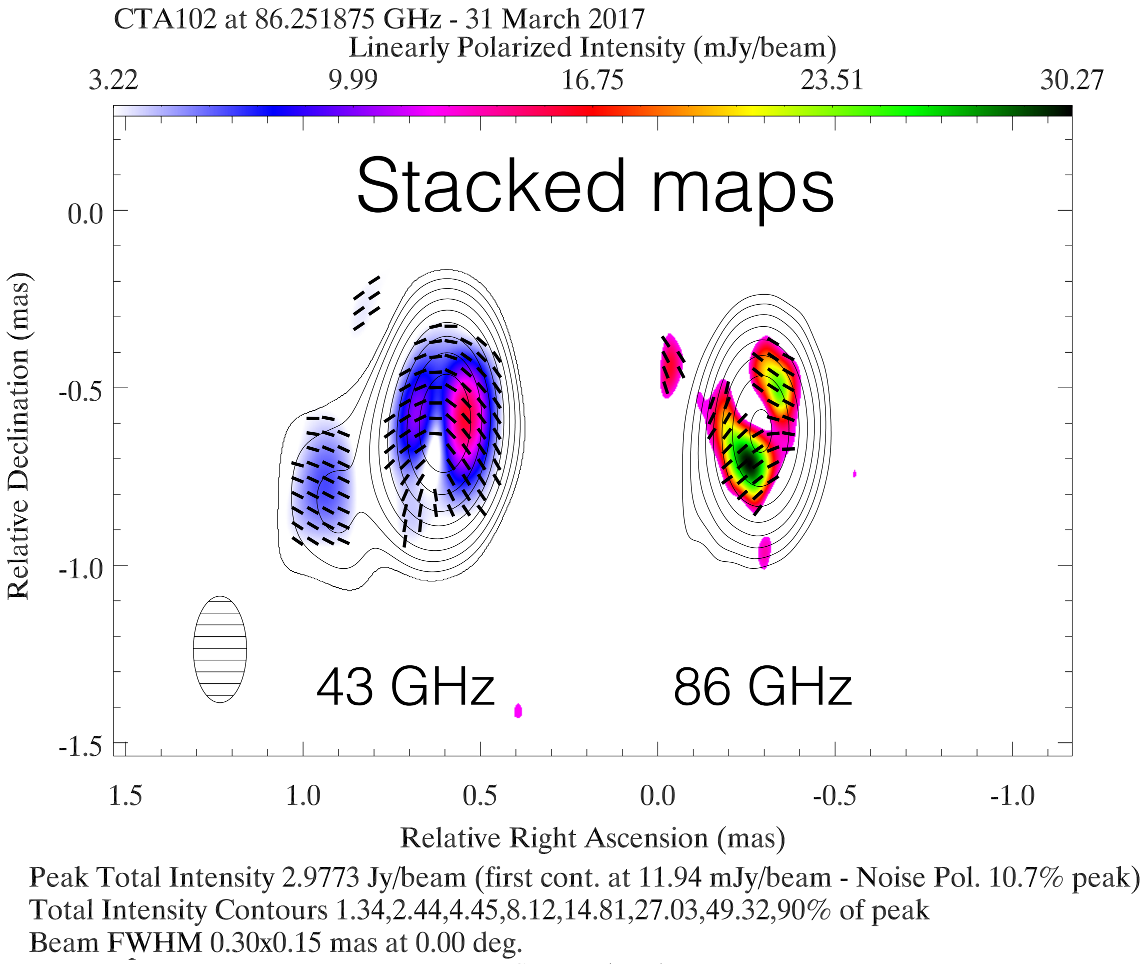
BL LAC

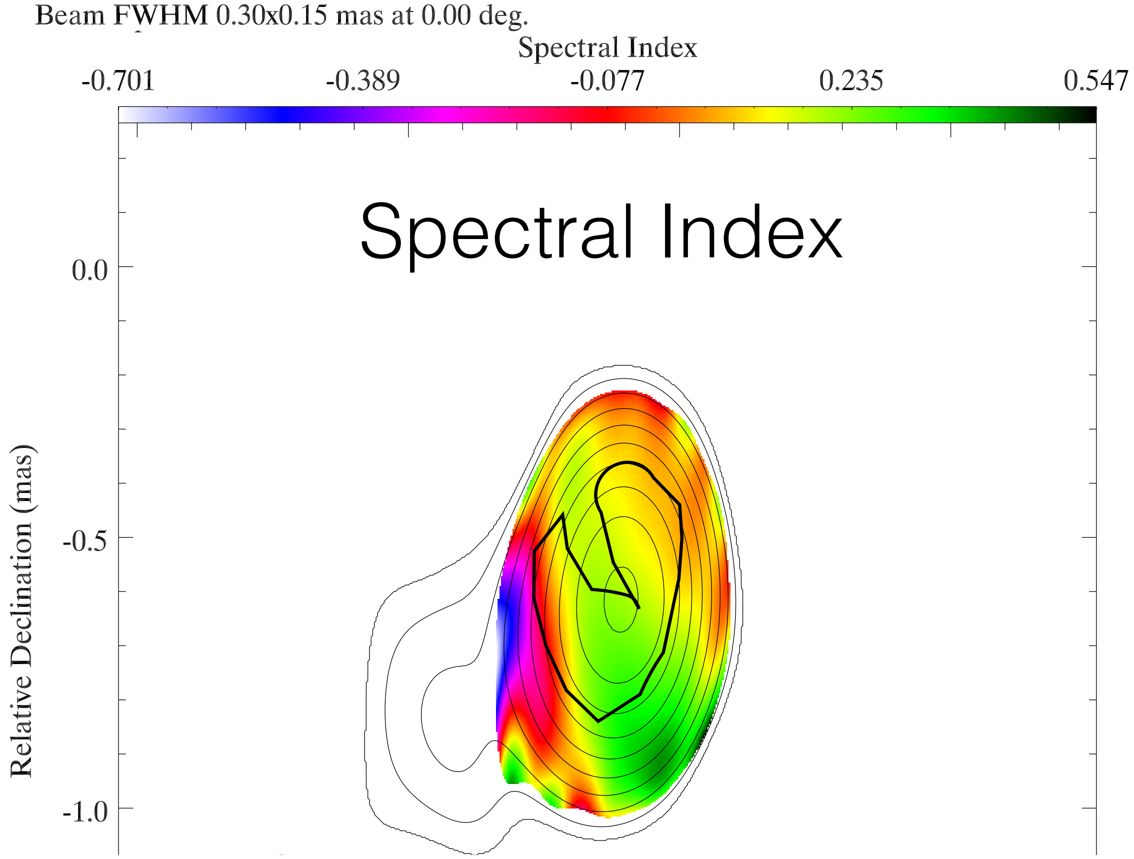


BLLAC Peak Total intestity 0.487,0.428,0.637 Jy/beam
Contour Levels: 1.5 , 3.02, 5.96, 11.7
(Abeysekara et al. 2018)
VHE flare
2016-05-21
2016-09-30
2017-03-31
σp ~ 1.6 mJy/beam
σp ~ 1.7 mJy/beam
DEC [mas]
RA [mas]
Polarized Intensity [mJy/beam]
BLLAC Peak Fractional Polarization 0.0, 17.9, 4.3 %
Contour Levels: 1.5 , 3.02, 5.96, 11.74, 23.15, 45.65, 90. % of 0.637 Jy/
Degree of Polarization [%]
BLLAC
6 Oct 2016
43 GHZ
Dec (mas)
RA (mas)

CTA102 Rotation Measure analysis

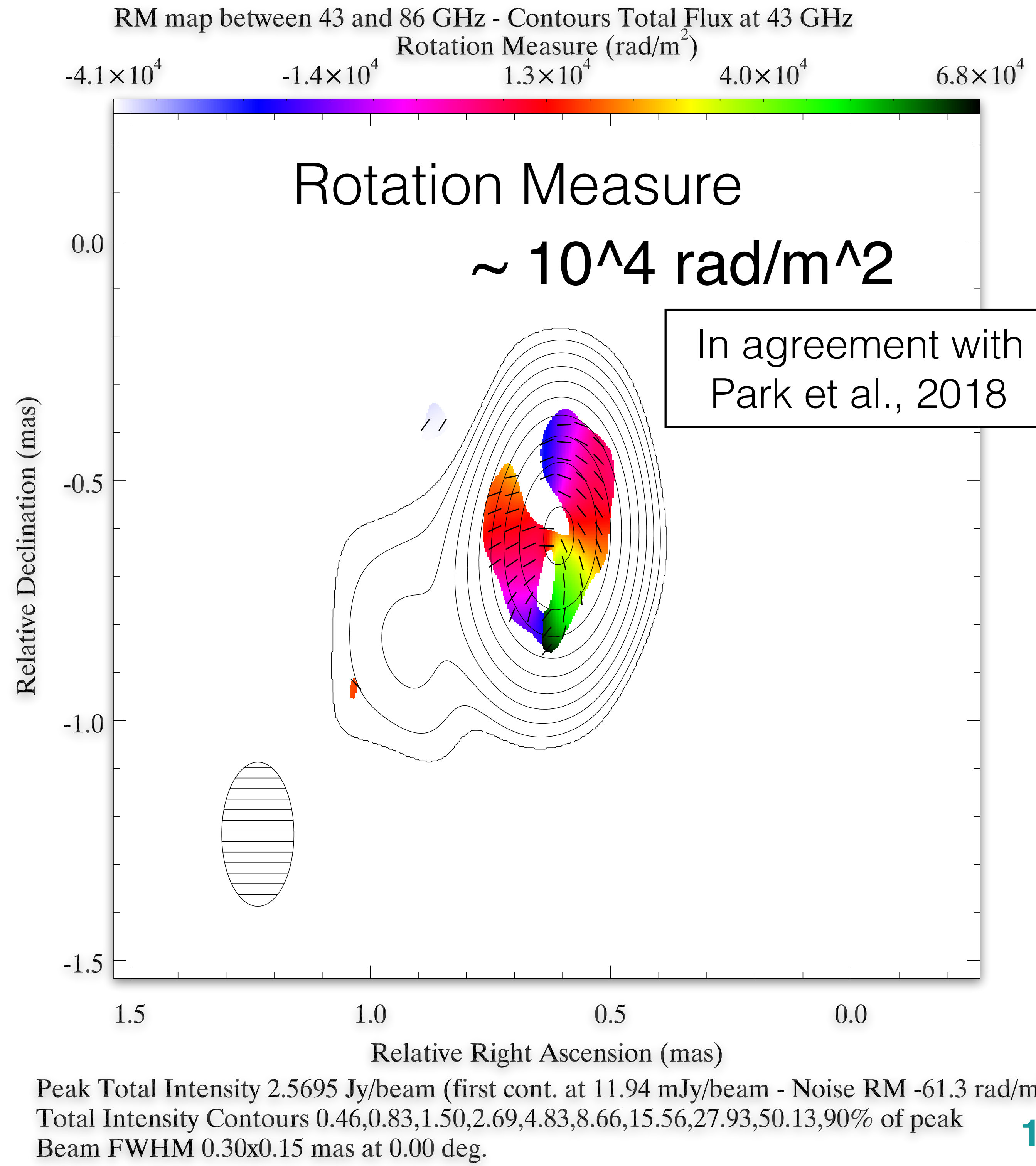
Casadio et al., in prep.





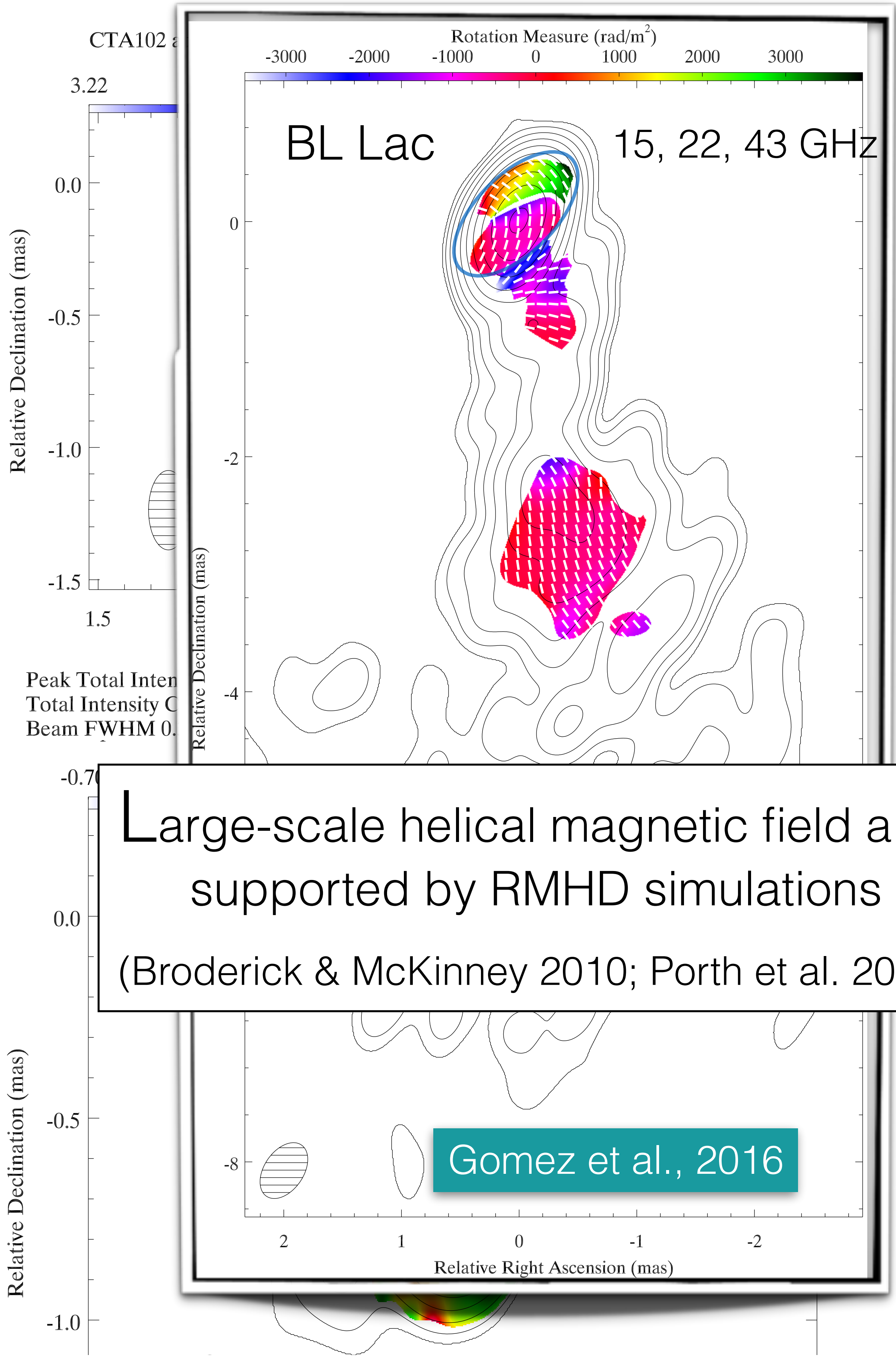
Stacked map at 43 GHz : June 2016 - April 2017

Stacked at 86 GHz : May, Sept 2016 and March 2017



CTA102 Rotation Measure analysis

Casadio et al., in prep.

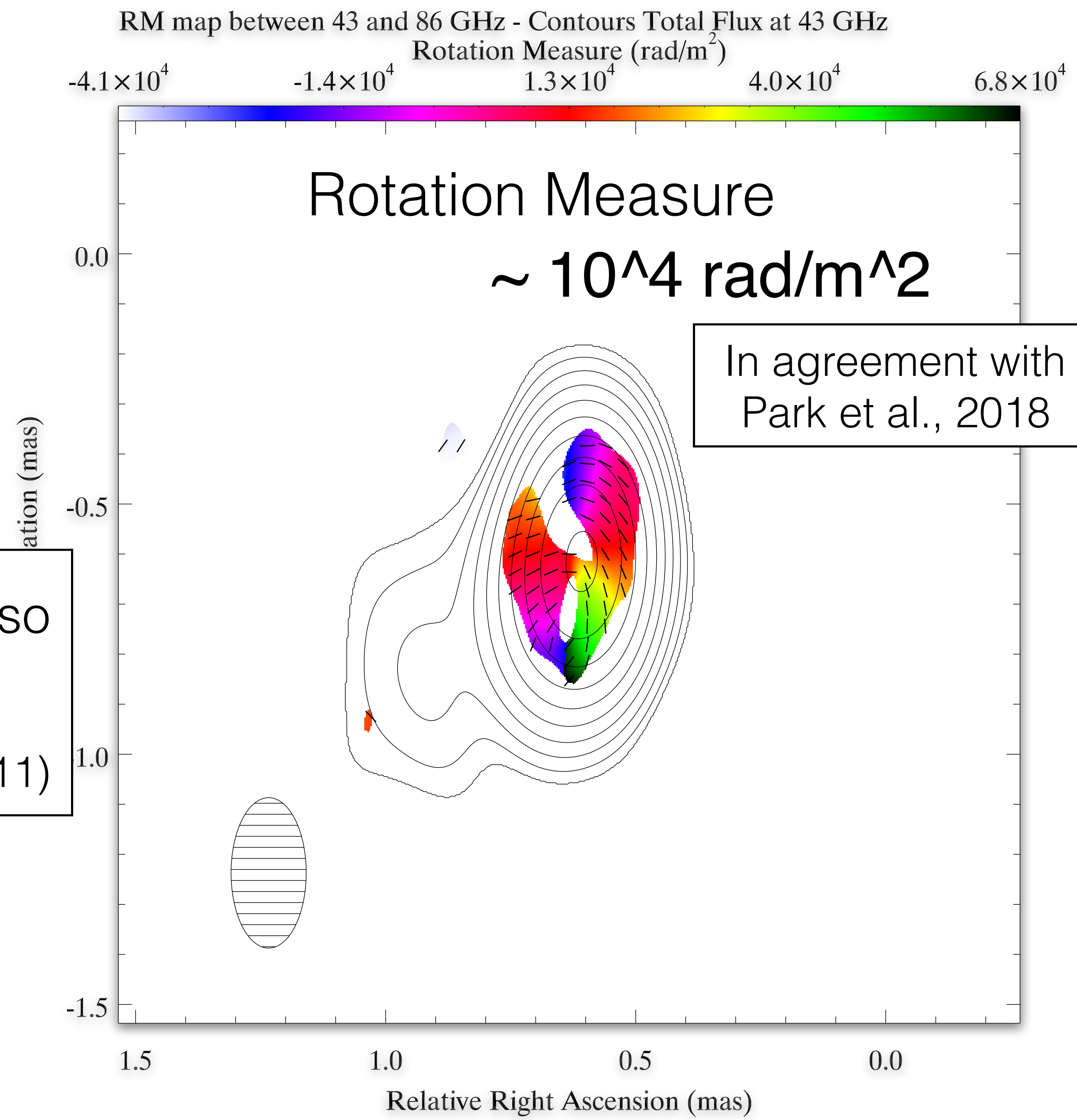


Large-scale helical magnetic field also supported by RMHD simulations

(Broderick & McKinney 2010; Porth et al. 2011)

Stacked map at 43 GHz : June 2016 - April 2017

Stacked at 86 GHz : May, Sept 2016 and March 2017

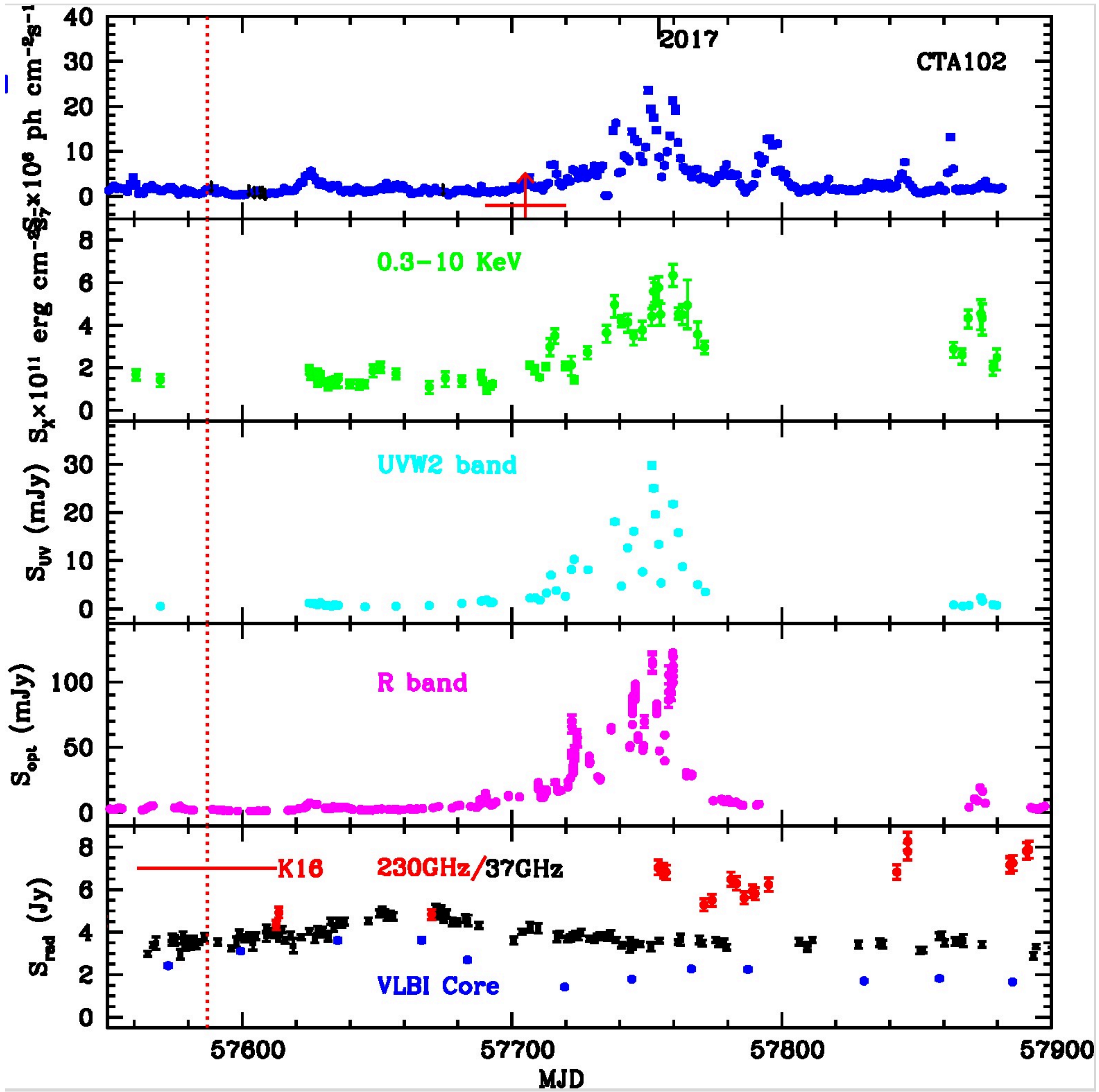


In agreement with Park et al., 2018

Peak Total Intensity 2.5695 Jy/beam (first cont. at 11.94 mJy/beam - Noise RM -61.3 rad/m^2
Total Intensity Contours 0.46,0.83,1.50,2.69,4.83,8.66,15.56,27.93,50.13,90% of peak
Beam FWHM 0.30x0.15 mas at 0.00 deg.

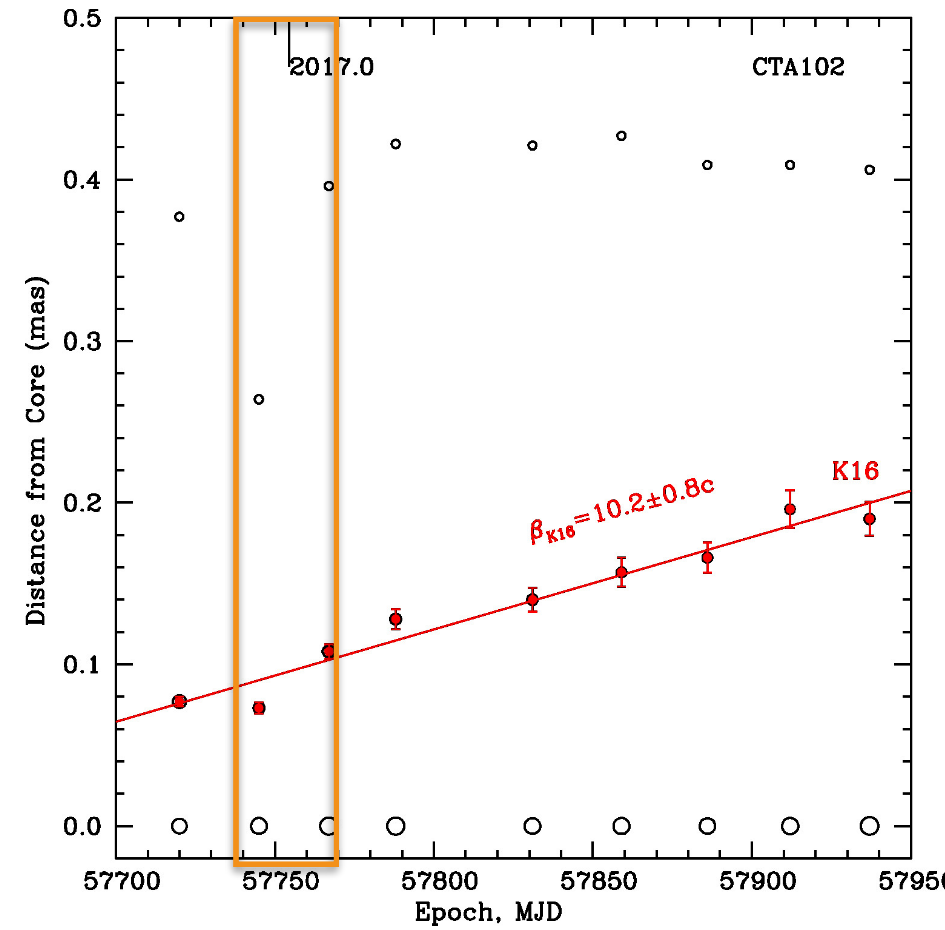
The multi-wavelength bright flare in December 2016 - January 2017

Multi-wavelength flare in
December 2016 - January 2017

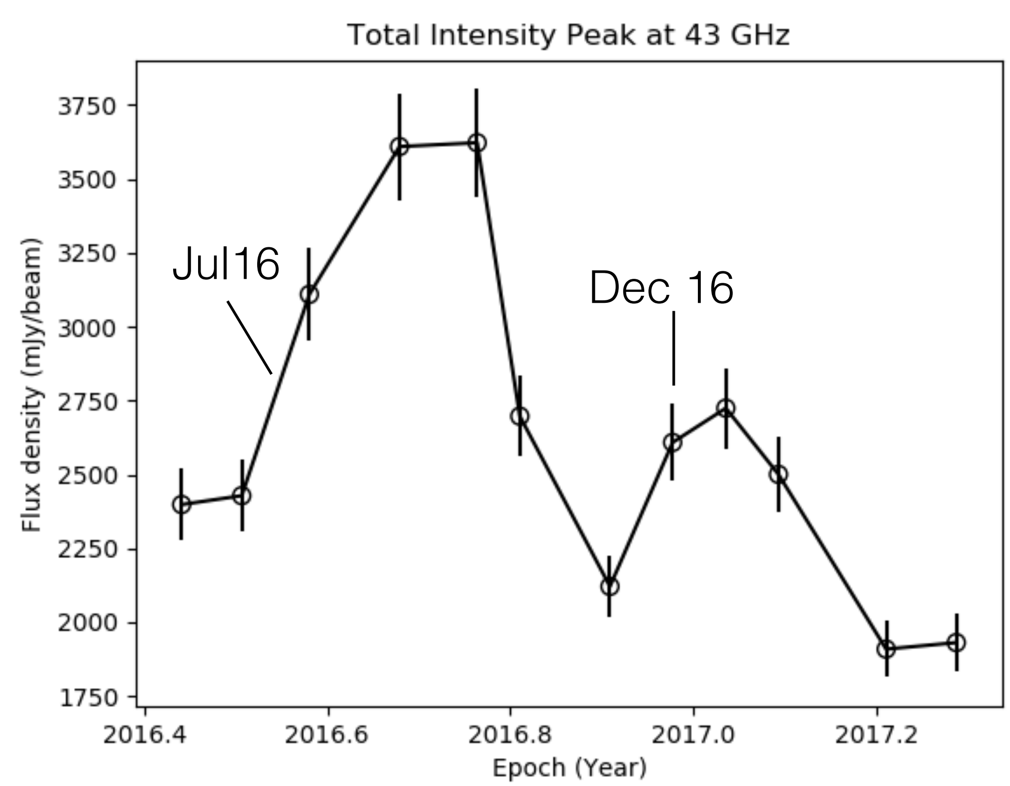


credit: S. Jorstad

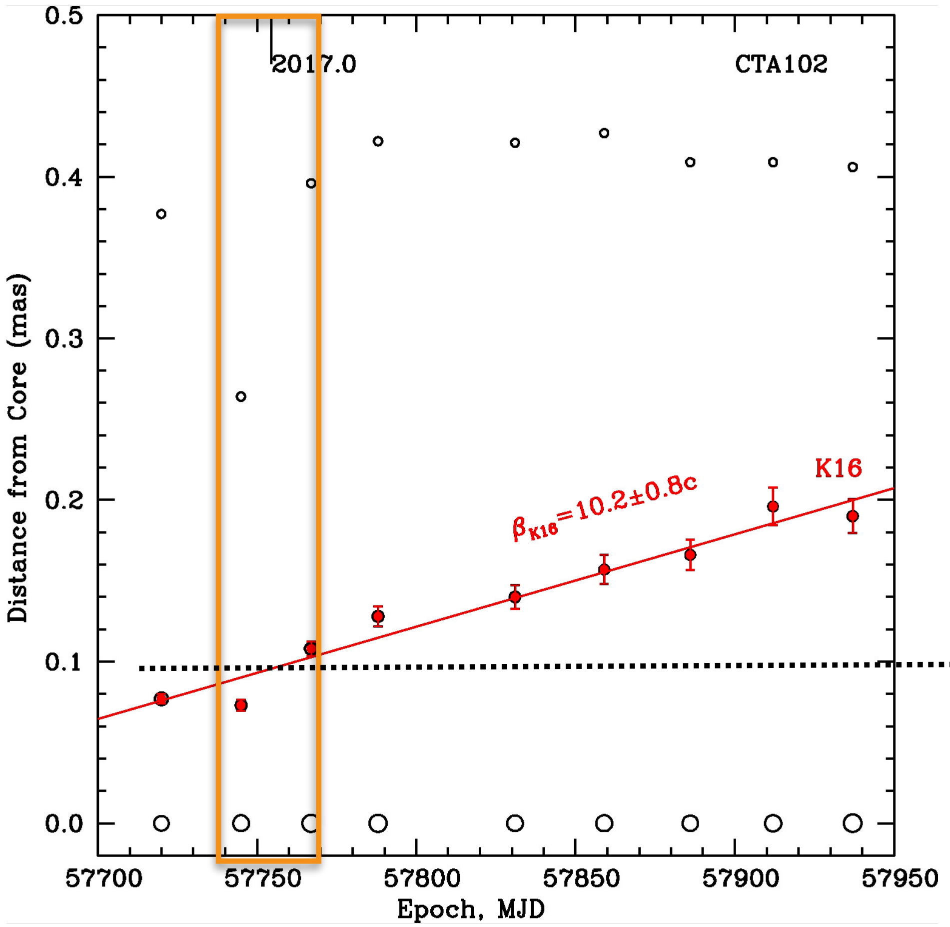
A new component (K16) has been ejected in July 2016
and it takes till November 2016 to exit from the core



credit: S. Jorstad



Kinematics at 43 GHz

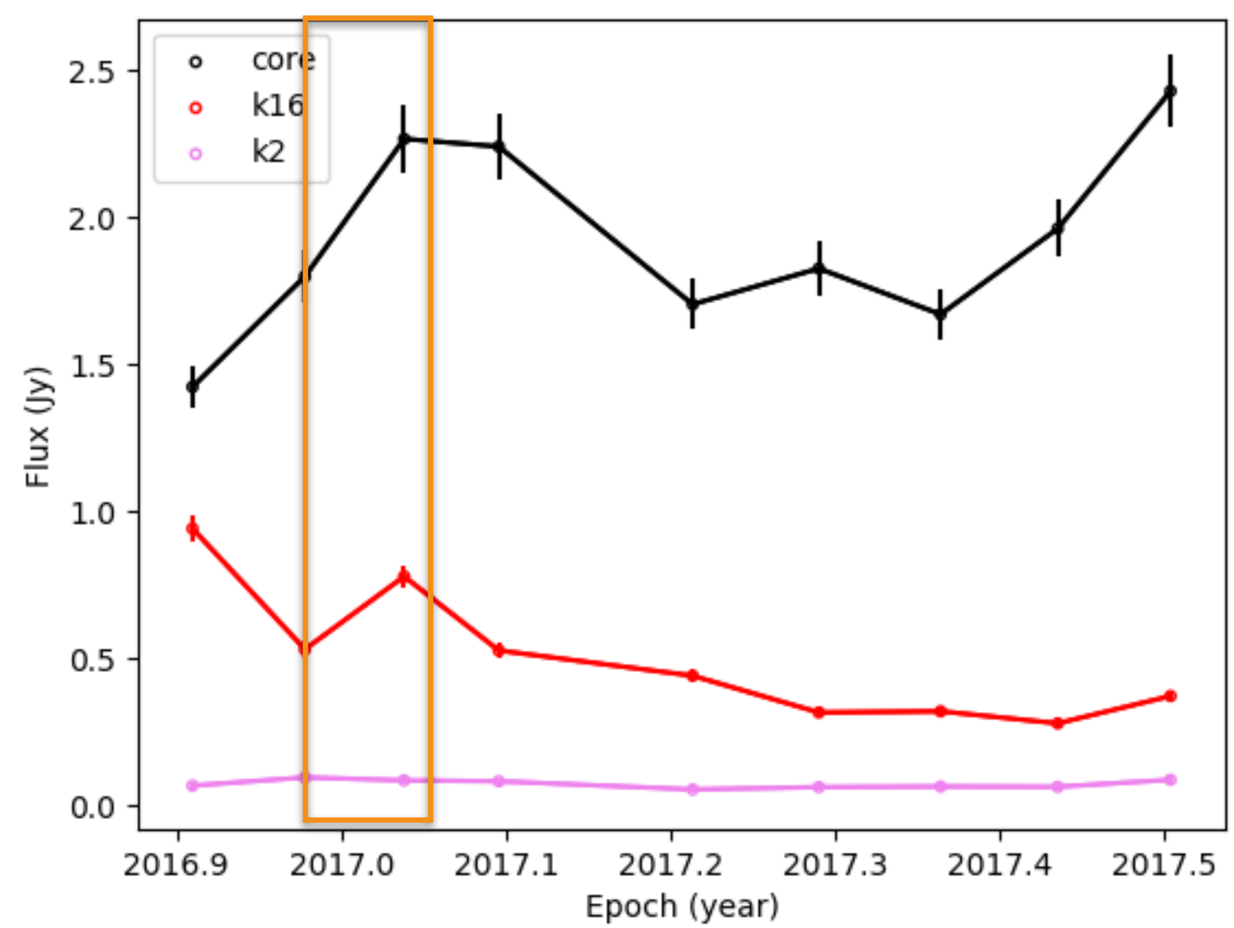


credit: S. Jorstad

A new component (K16) has been ejected in July 2016 and it takes till November 2016 to exit from the core

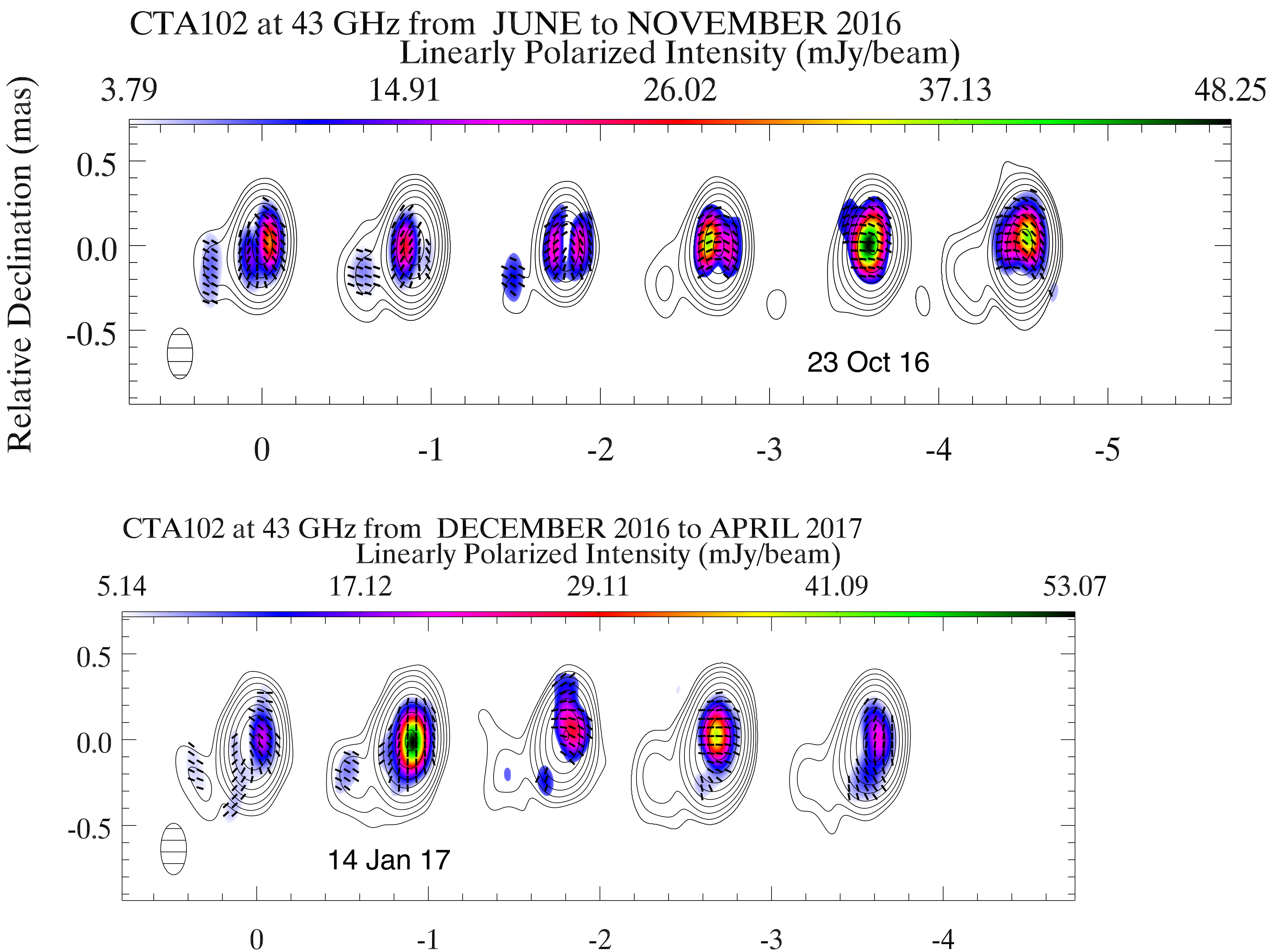
A stationary component at ~ 0.1 mas reported in previous studies (Jorstad et al., 2001,2005) and interpreted as a recollimation shock (From et al., 2013; Casadio et al., 2015)

Small increase in flux when K16 crosses the component at 0.1 was



Evolution of Polarized emission at 43 GHz data

Casadio et al., in prep.



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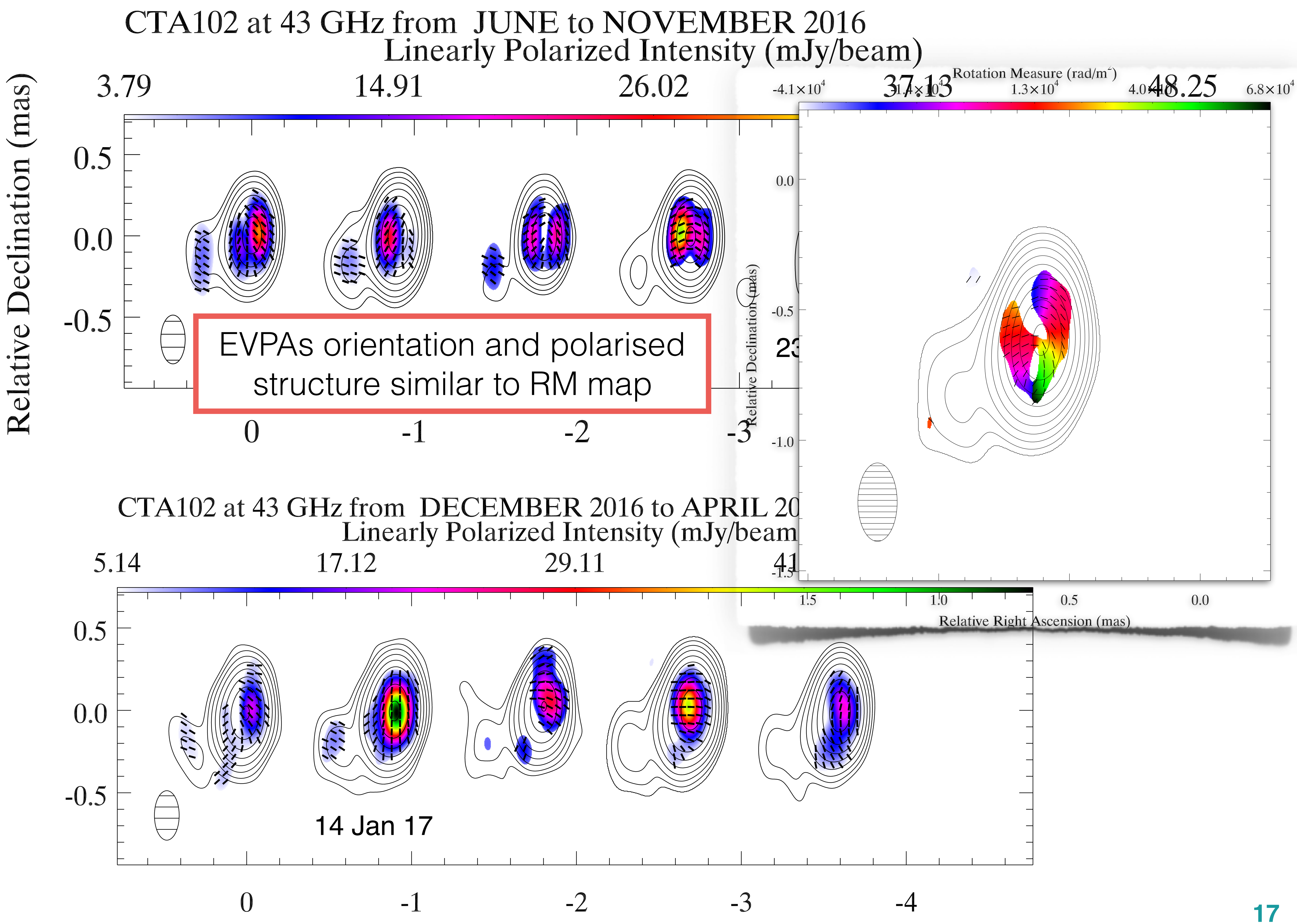

Evolution of Polarized emission at 43 GHz data

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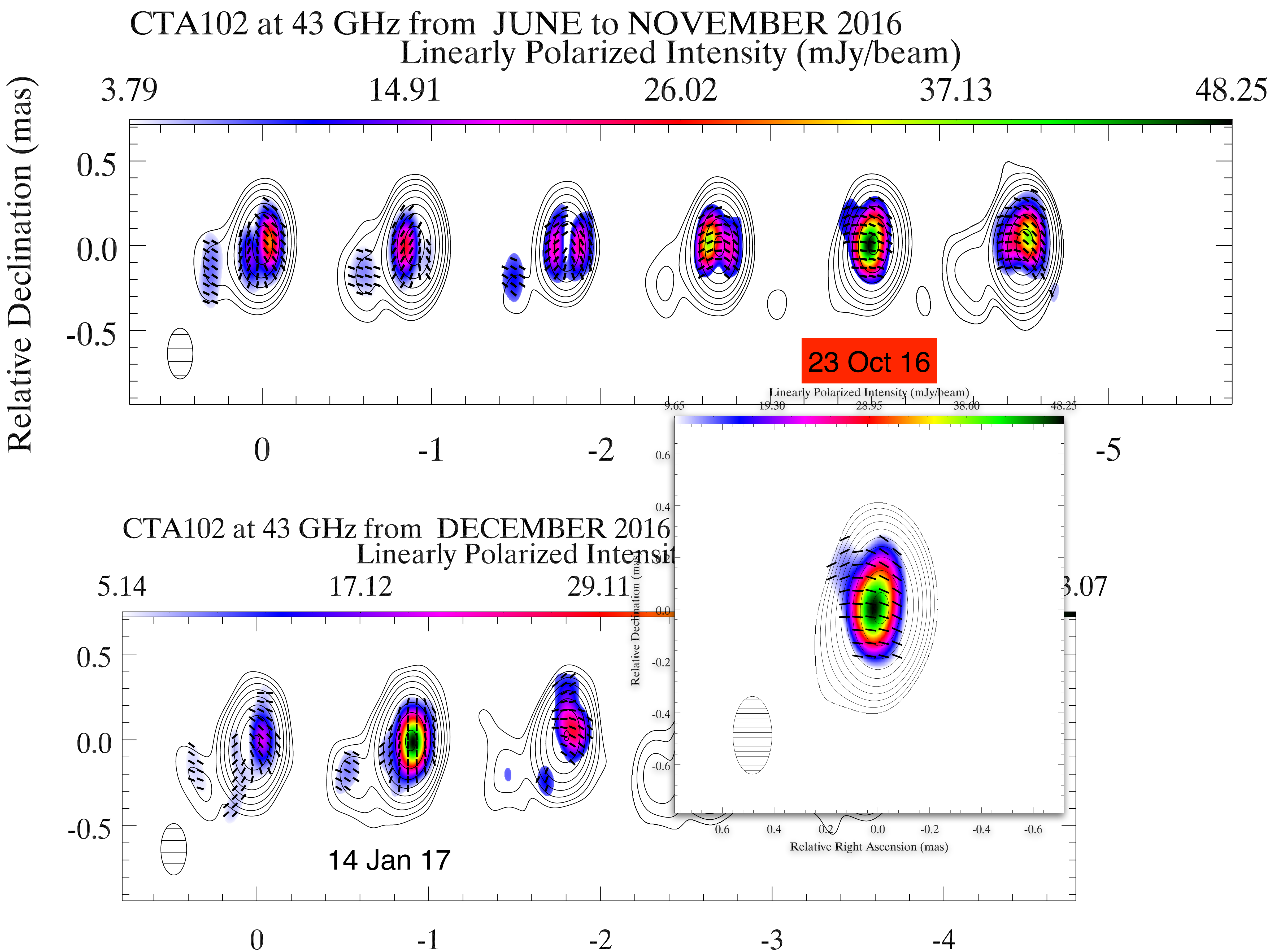

Evolution of Polarized emission at 43 GHz data

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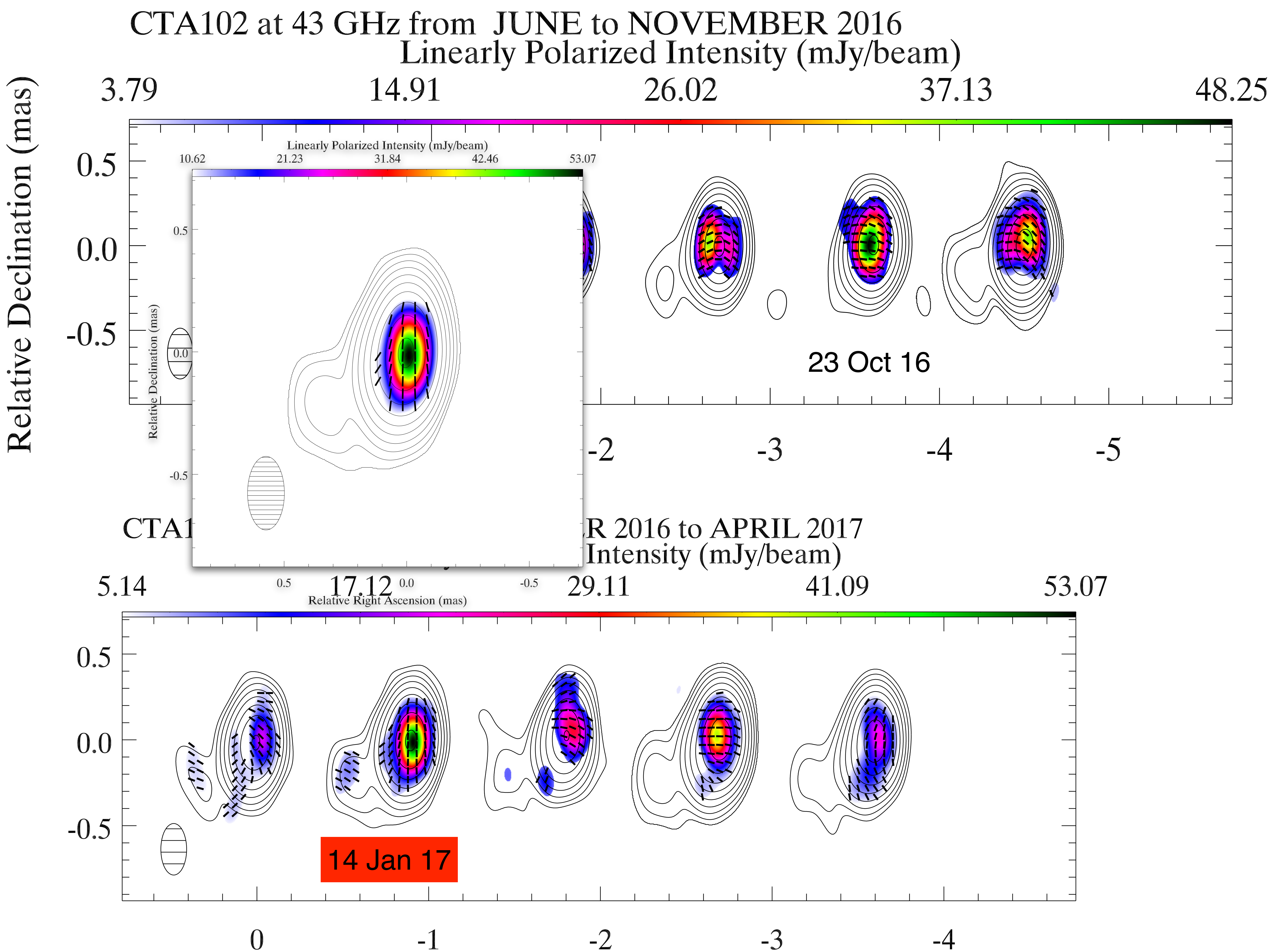


CONCLUSIONS

Casadio et al., in prep.

We have analysed polarimetric 86 GHz GMVA data of a sample of ~ 12 bright gamma-ray blazars and radio galaxies in 3 observing epochs (May 2016, September 2016 and March 2017)

→ We have been testing two different methods for the calibration of instrumental polarization and we finally decide to apply the set of Average D-terms to all the sources ⟶ More stable polarimetric images to study the evolution of polarised emission

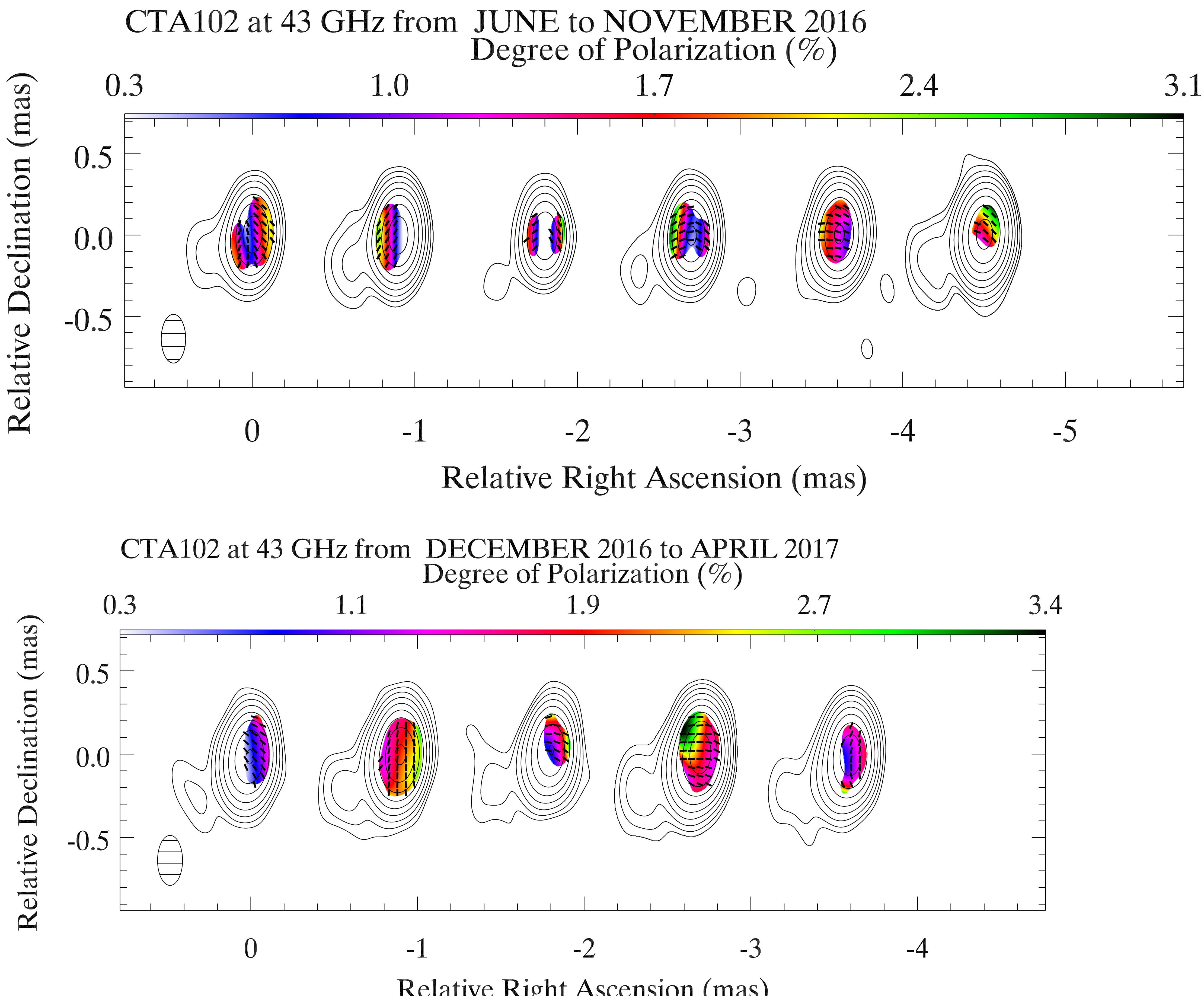
→ We produced polarimetric images (θ ~ 0.05 mas) that allow us to distinguish more substructures than in 43 GHz images, also in coincidence with High Energy Flares, and in general we found higher degree of polarization than at 43 GHz

→ We have obtained the *Spectral Index* and *Rotation Measure maps* between 43 and 86 GHz for CTA102 ⟶ The core at 43 GHz is optically thick

⟶ The RM at 86 GHz is few 10^4 rad/m^2 and it shows a gradient in the core region as well as a change of sign

⟶ The EVPAs corrected for Faraday rotation displays a peculiar rotation in the core region (similar orientation in 43 GHz maps when a new knot is crossing the core)

→ CTA102: we think that the passage of a new component through the core and another recollimation shock at 0.1 mas highlights the local magnetic field there, (visible at 43 GHz in different epochs) and that the bright multi-wavelength flare in Dec 2016 - Jan 2017 is triggered by the passage of the component through the recollimation shock at 0.1 mas


CTA102 at 43 GHz from JUNE to NOVEMBER 2016
Degree of Polarization (%)
0.3
1.0
1.7
2.4
3.1
Relative Declination (mas)
0.5
0.0
-0.5
0
-1
-2
-3
-4
-5
Relative Right Ascension (mas)
CTA102 at 43 GHz from DECEMBER 2016 to APRIL 2017
Degree of Polarization (%)
0.3
1.1
1.9
2.7
3.4
Relative Declination (mas)
0.5
0.0
-0.5
0
-1
-2
-3
-4
Relative Right Ascension (mas)