

# Constraining sub-structures in TeV-emitting gamma-ray blazars with the GMVA

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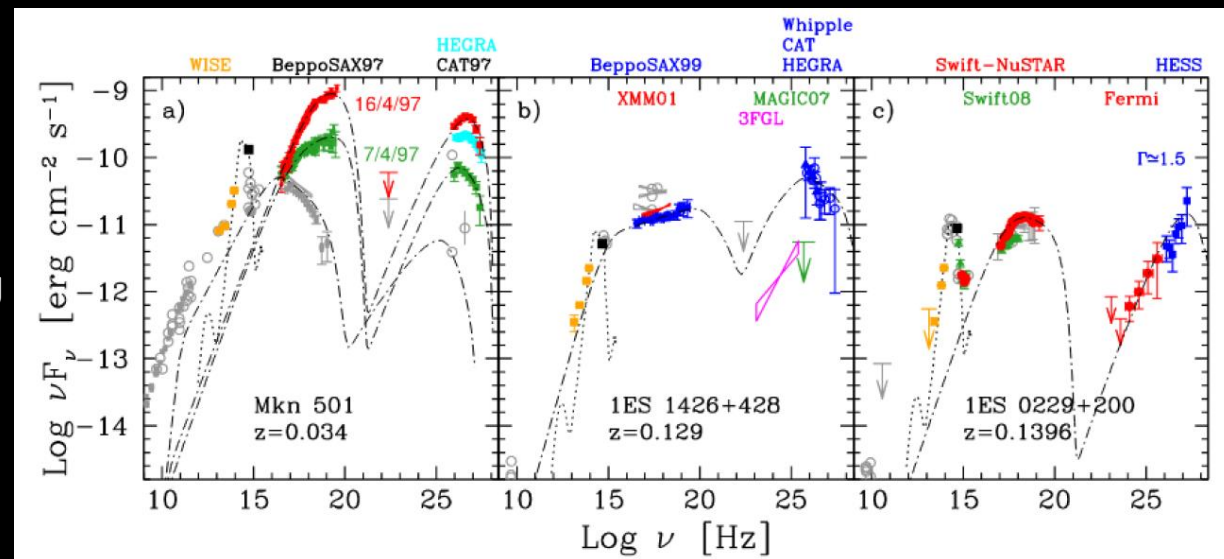
# TeV-emitting gamma-ray blazars

- Mainly HBLs ( $\nu_{peak} > 10^{15}$  Hz) and extreme blazars ( $\nu_{peak} > 10^{17.38}$  Hz  $\triangleq 1$  keV)

-> generally **very faint** radio sources -> mainly observed at low redshifts  
-> high linear resolution achievable

- Three classes of extreme behaviour:  
Extreme during flares;  
Hard synchrotron spectrum w/o persistent TeV-emission,  
Hard gamma-ray spectrum with synchrotron peak in X-ray

- Doppler Crisis -> spine-sheath structures?  
(Ghisellini et al., 2005).



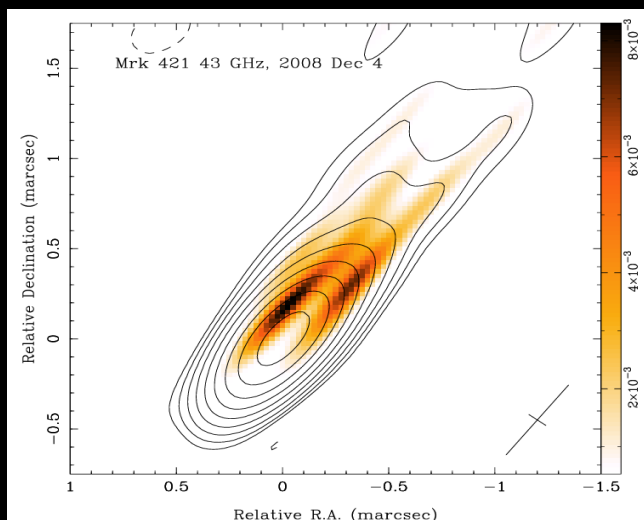
Biteau et al. 2020

- Very relevant in the upcoming CTA era
- Extreme blazars are suggested to be relevant neutrino sources  
(e.g., Tavecchio, Ghisellini & Guetta 2014; Padovani et al. 2015; Giommi et al. 2020)

# Previous studies of extreme blazars

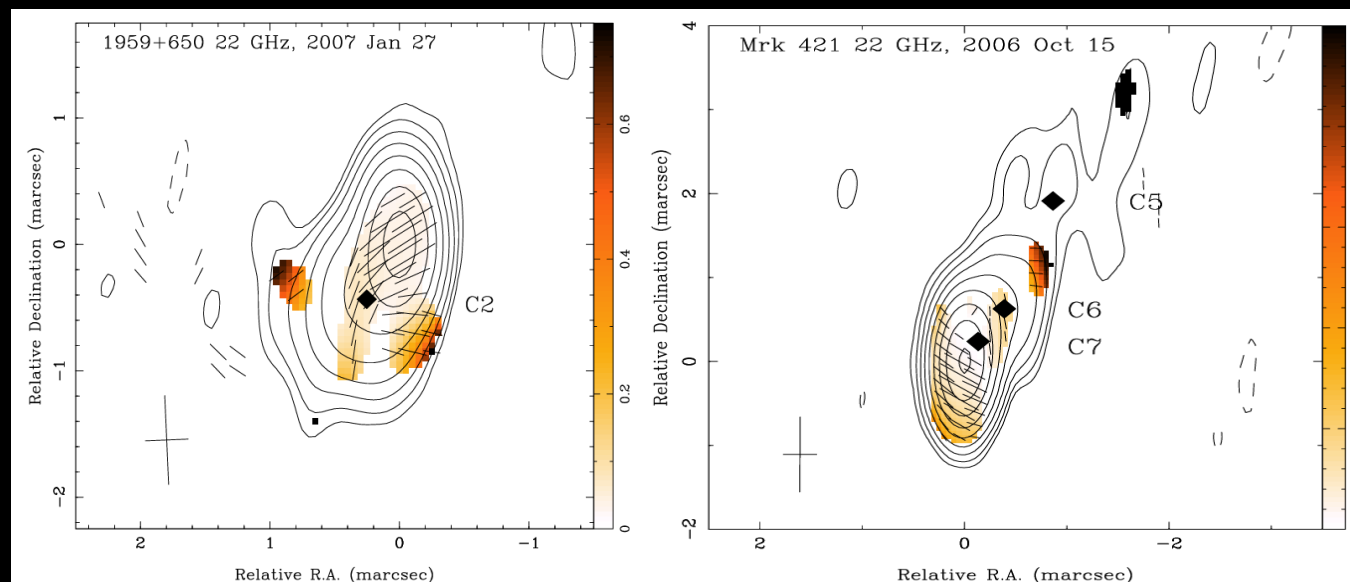
- Mostly at cm-wavelengths (e.g., Piner & Edwards 2004, 2014, 2018; Piner, Pant & Edwards 2008)
- 22GHz and 43GHz VLBA observations by Piner, Pant & Edwards 2010 reveal:

Limb brightening



Mrk421 at 43GHz

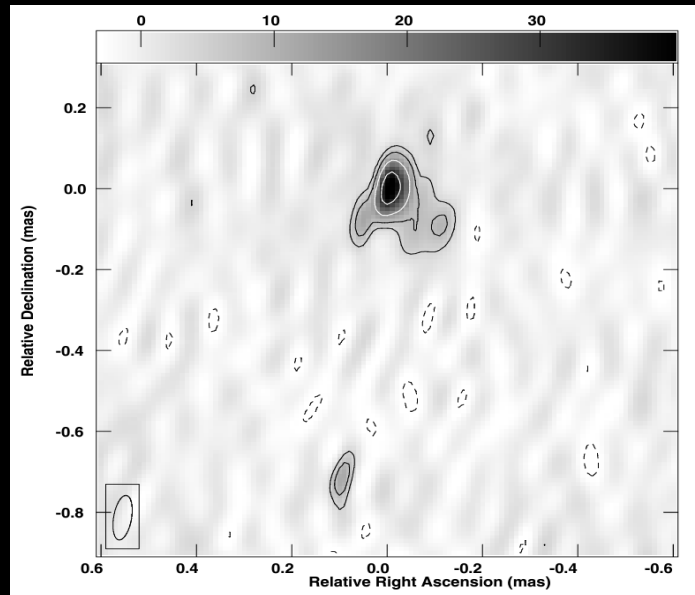
Spine-sheath structures in polarization



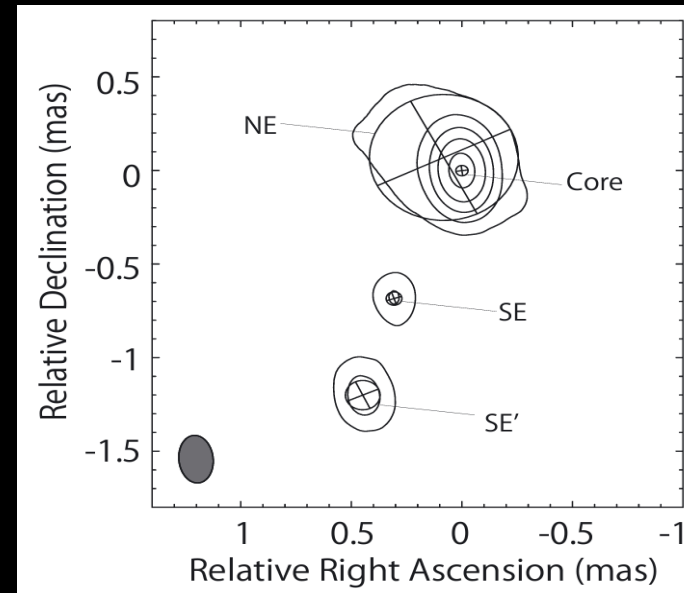
1ES 1959+650 & Mrk421 at 22GHz

# Previous studies of extreme blazars

- Mostly at cm-wavelengths (e.g., Piner & Edwards 2004, 2014, 2018; Piner, Pant & Edwards 2008)
- 22GHz and 43GHz VLBA observations by Piner, Pant & Edwards 2010 reveal limb brightening and spine-sheath structures
- Mrk501 shows signs of limb brightening and extended structure at 86GHz



Giroletti et al. 2008



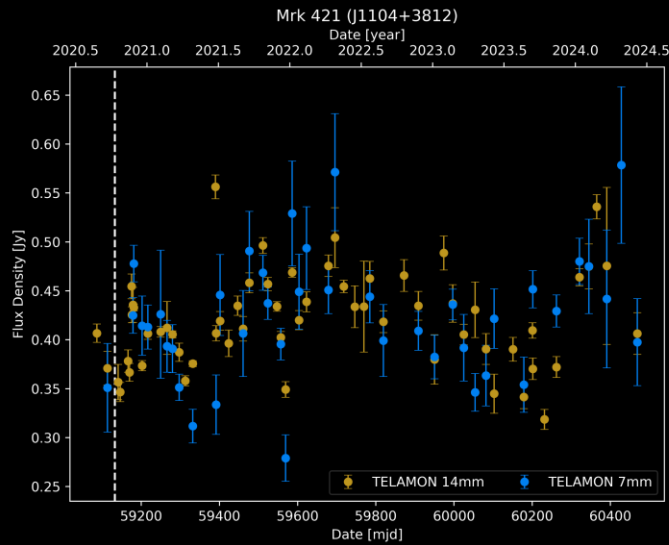
Koyama et al. 2016

# The setup

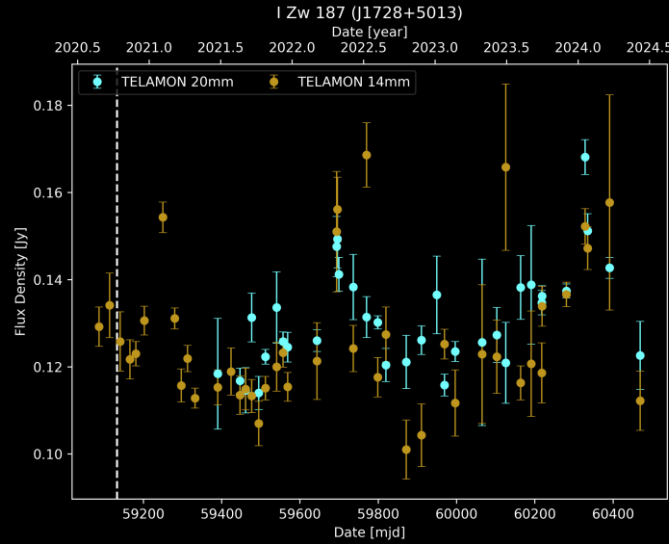
- Idea: observe 5 **sufficiently bright** extreme blazars at mm wavelengths with the GMVA in Oct. 2020 in full polarization mode
- VLBA + EF + PV + YS + ON + MH + KVN 3mm plus interleaved 7mm VLBA-only observations
- Quasi-simultaneous **multi-wavelength coverage**: MAGIC, VERITAS, Fermi, Swift, Effelsberg to construct radio-TeV SEDs to derive values for the Doppler factors of two-zone emission models
- Goals:
  - Image the most-compact jet structure and search for evidence of limb brightening and/or spine-sheath structures
  - Compare results (images, spectral indices, brightness temperatures, etc.) to less extreme blazars

# The sample

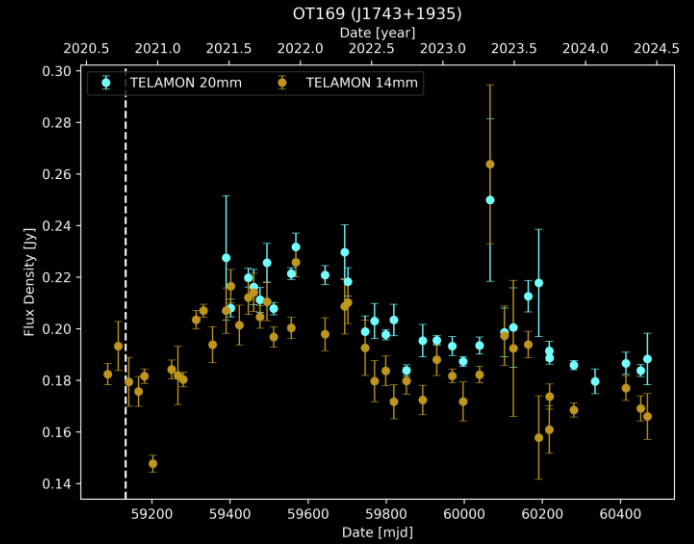
Mrk421 ( $z = 0.0293$ )



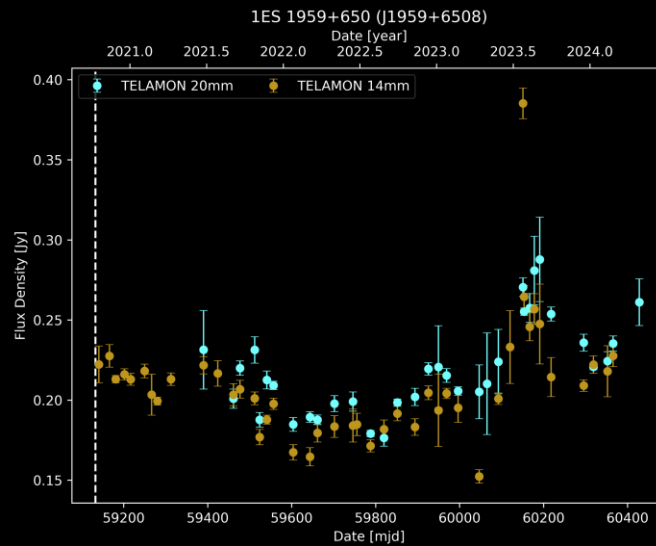
I Zw 187 ( $z = 0.055$ )



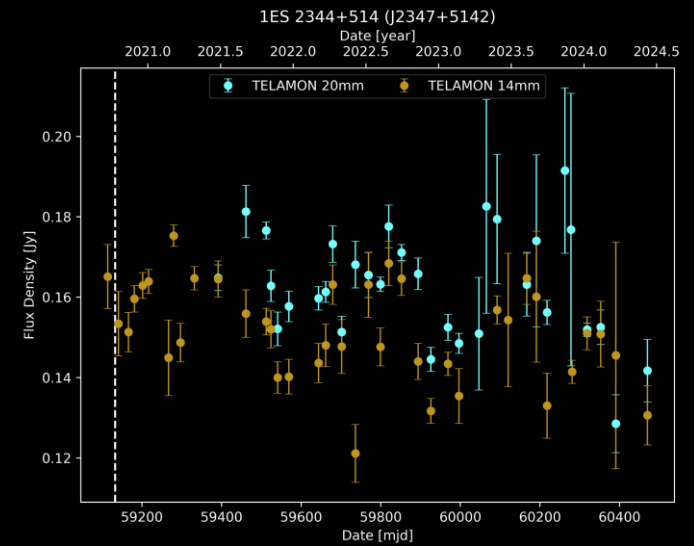
OT169 ( $z = 0.084$ )



1ES 1959+650 ( $z = 0.047$ )



1ES 2344+514 ( $z = 0.044$ )

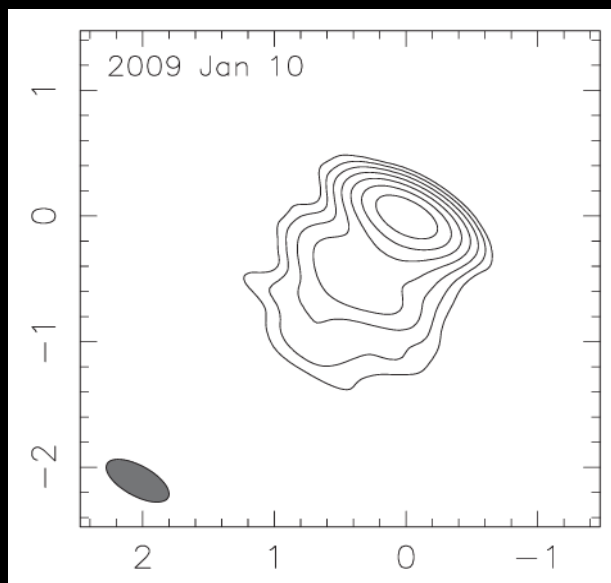
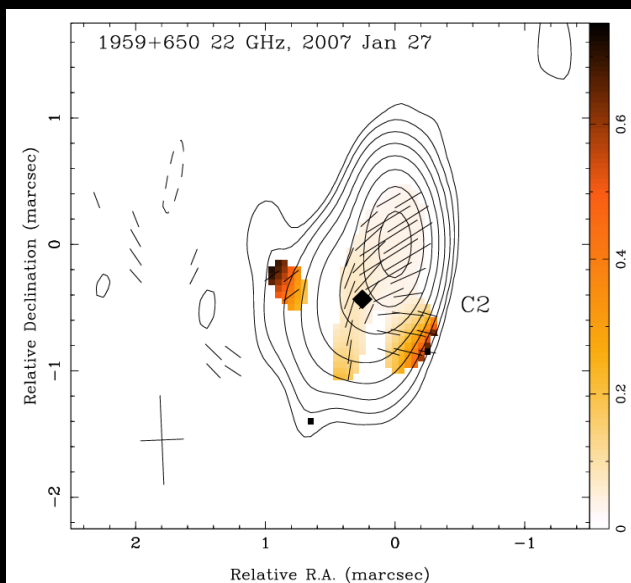


Plus all 54 Northern TeV-emitting blazars

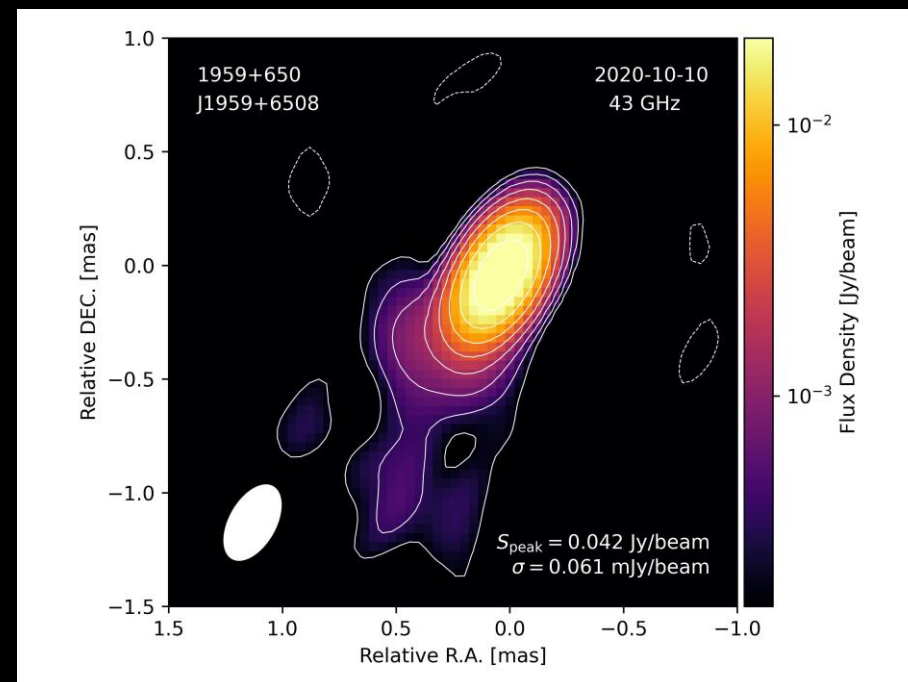


# Example result: 1ES 1959+650

Piner, Pant & Edwards, 2010  
22GHz



Our dataset, 43GHz VLBA  
Calibration with rPicard (CASA),  
Imaging with Difmap



PRELIMINARY

# Comparison with BEAM-ME data

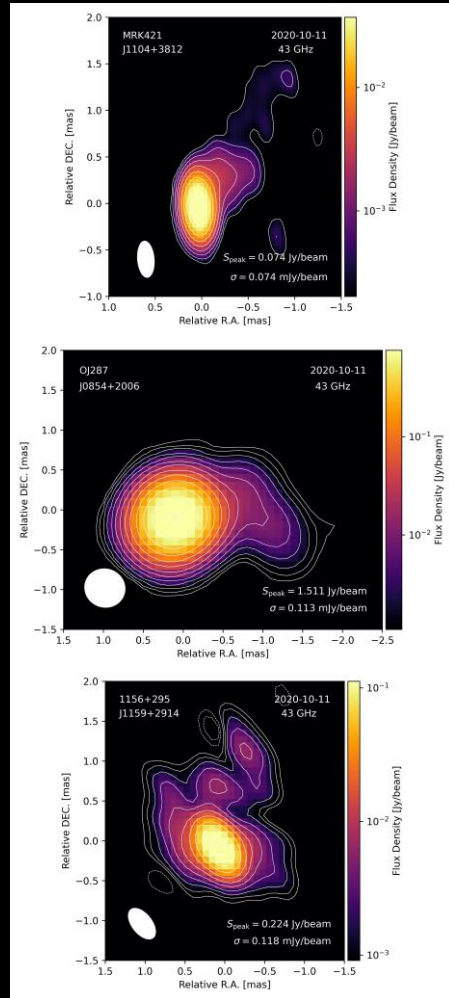
PRELIMINARY

Our dataset  
total fluxes:

0.10 Jy

1.74 Jy

0.31 Jy

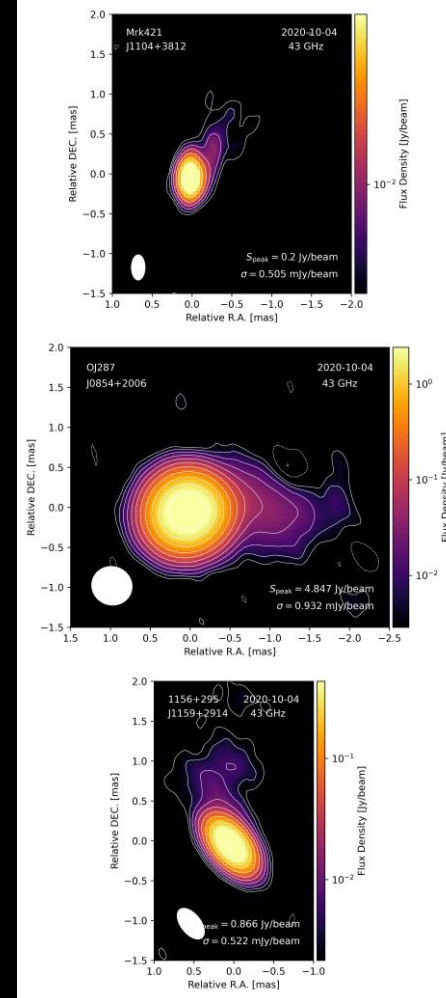


BEAM-ME dataset  
total fluxes:

0.27 Jy

5.50 Jy

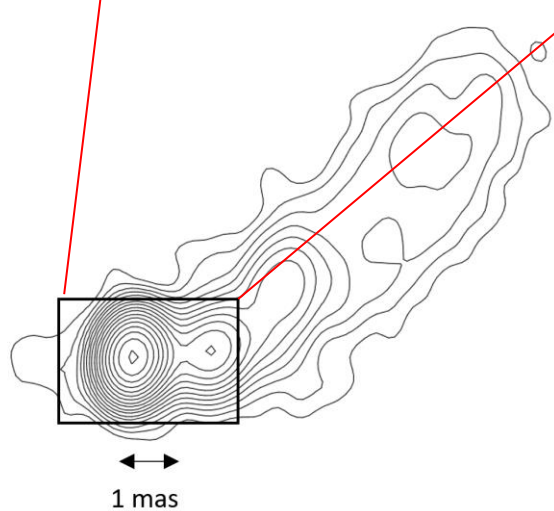
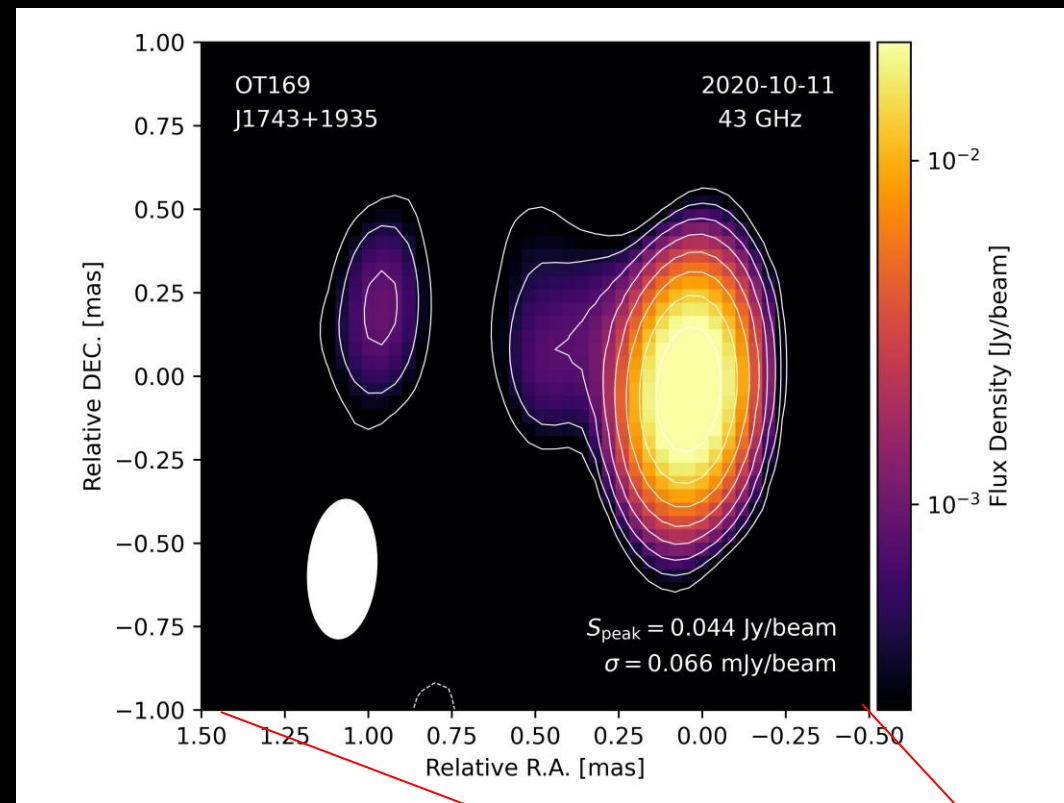
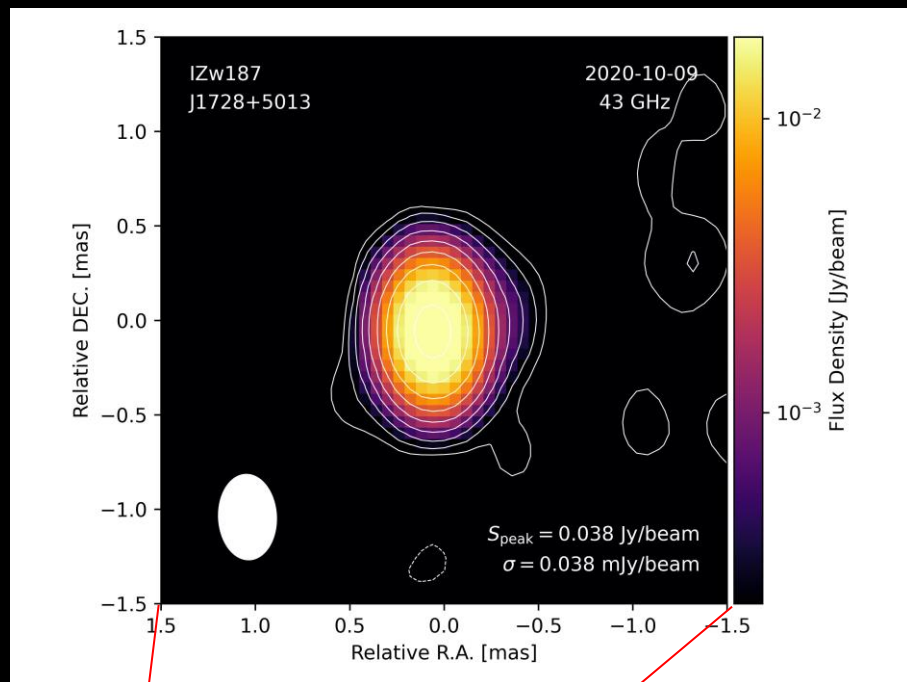
0.91 Jy



BEAM-ME scale with a factor  $\sim 1.6$  to match the single dish fluxes,  
however, we would need to scale with a factor  $\sim 3$  to achieve the same fluxes



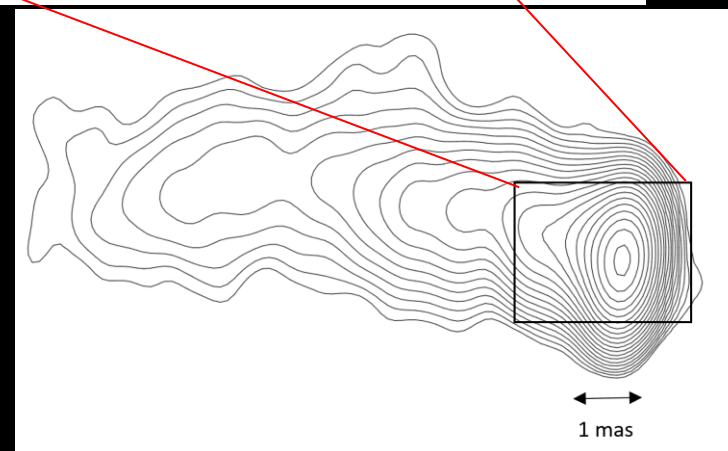
# What's new? First ever 43GHz images of two sources



I Zw 187  
15GHz MOJAVE

PRELIMINARY

S3 1741+19  
15GHz MOJAVE



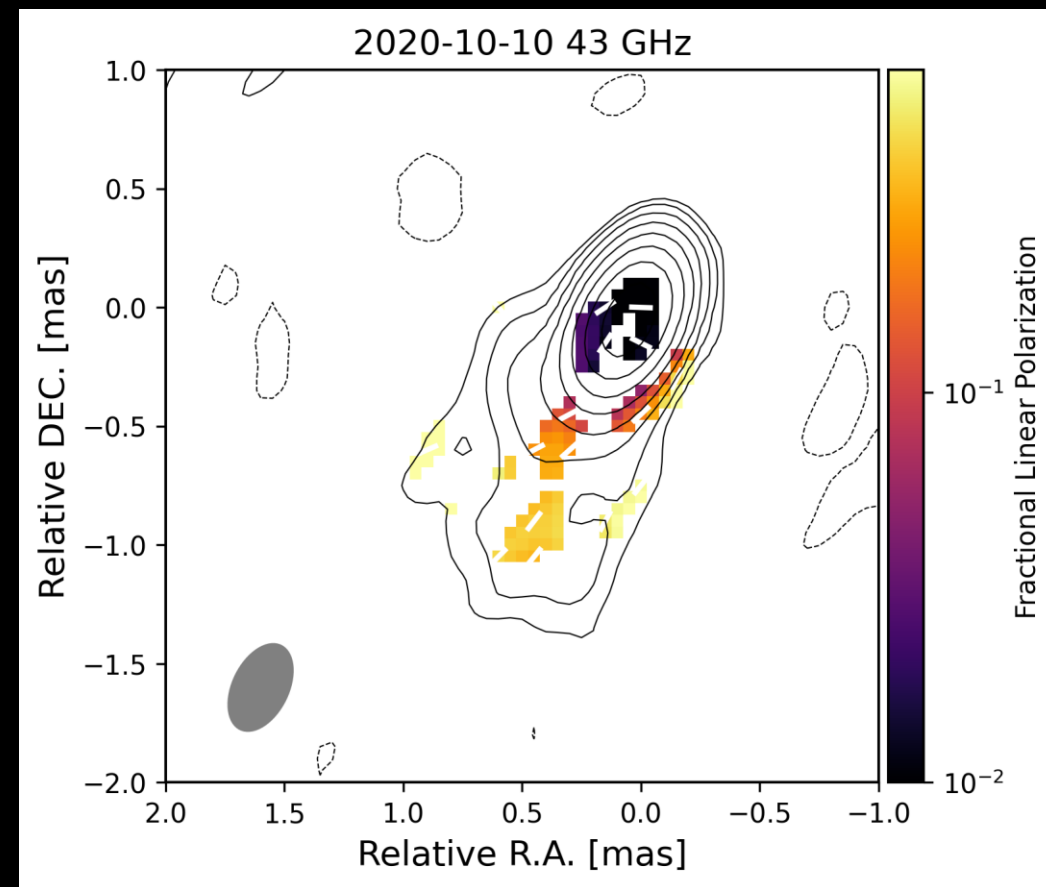
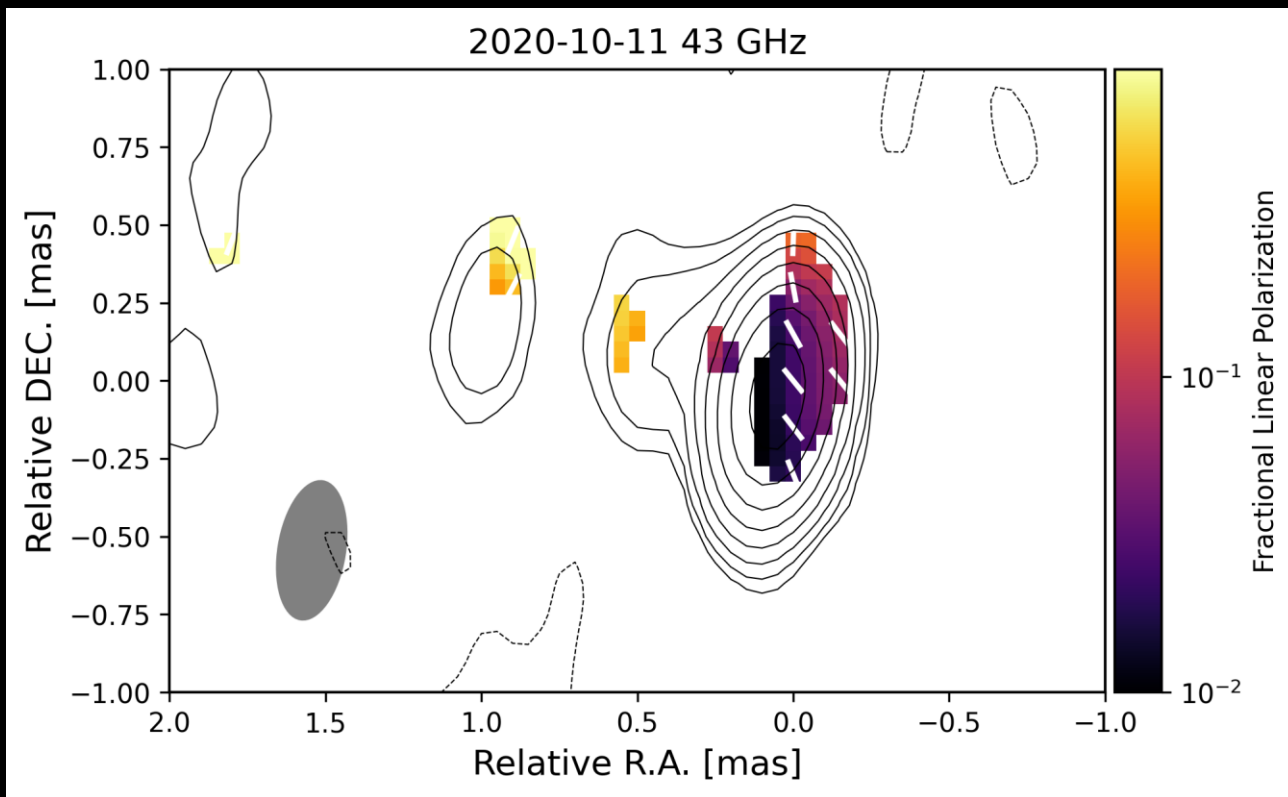
# What's new? Polarization!

Analysis with PolSolve  
(Martí-Vidal et al. 2020)

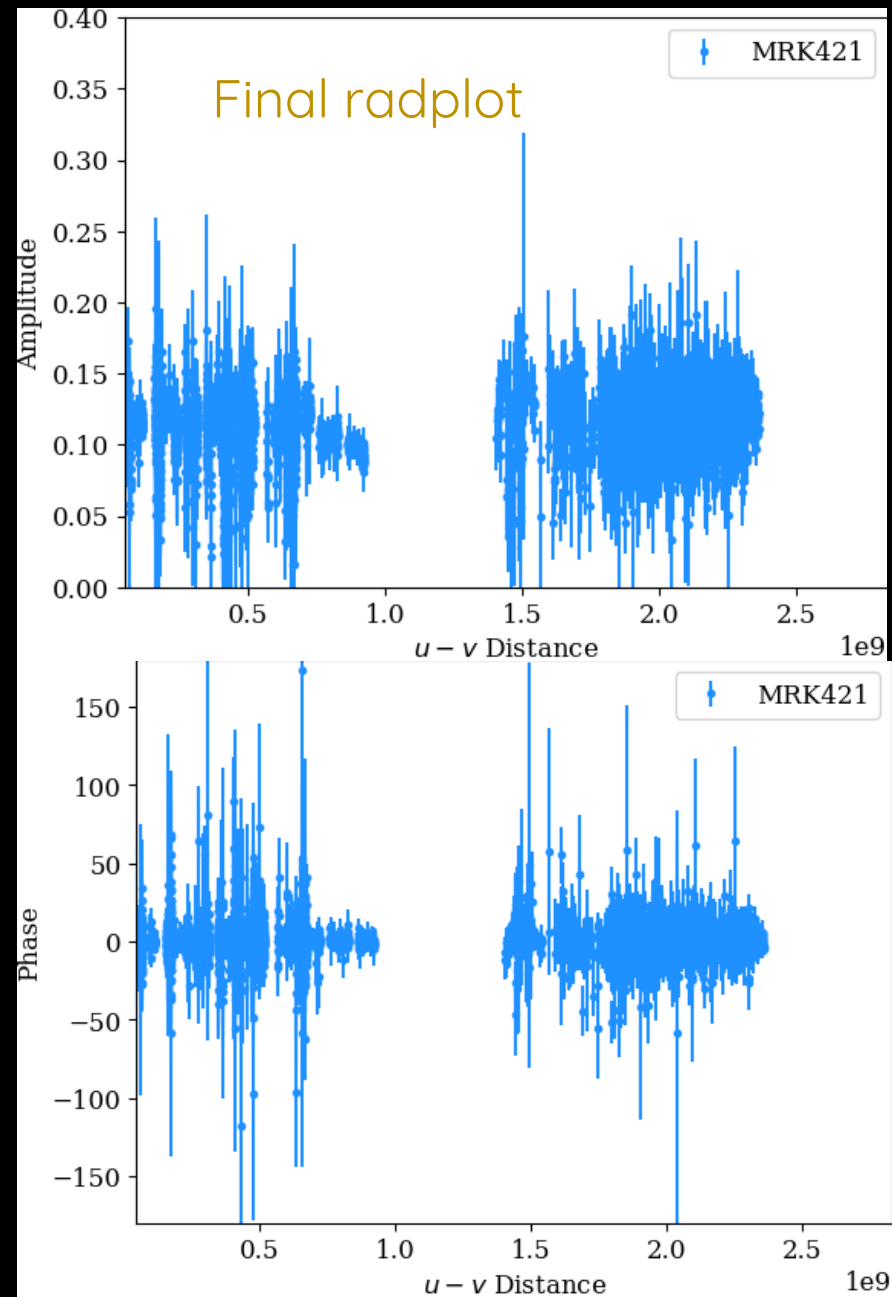
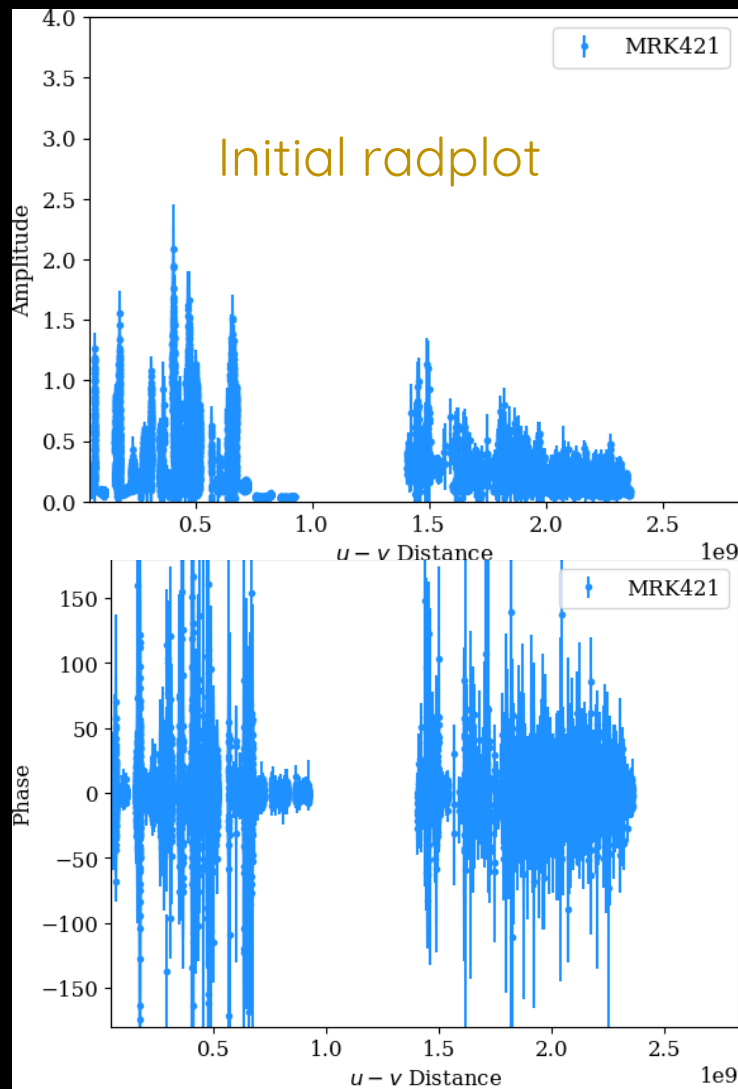
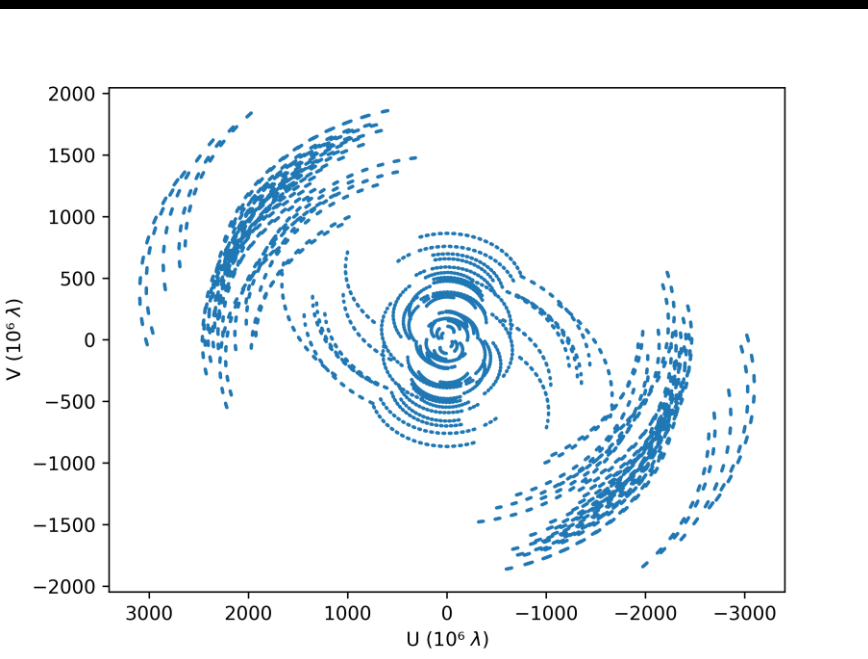
## PRELIMINARY

S3 1741+19  
~6% frac. polarization

1ES 1959+650  
~4% frac. polarization

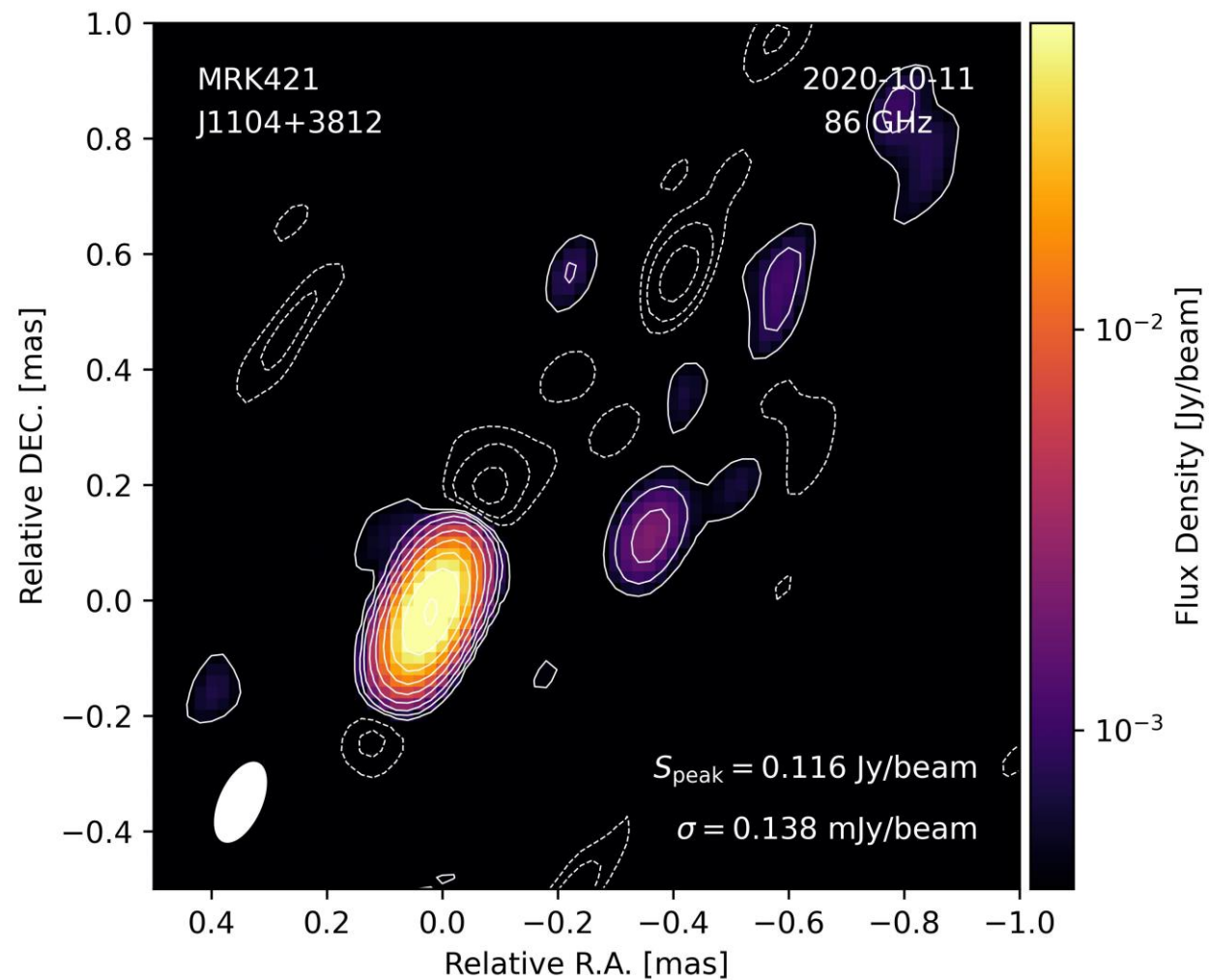


# What's new? 3mm detection of MRK421



# What's new? 3mm detection of MRK421

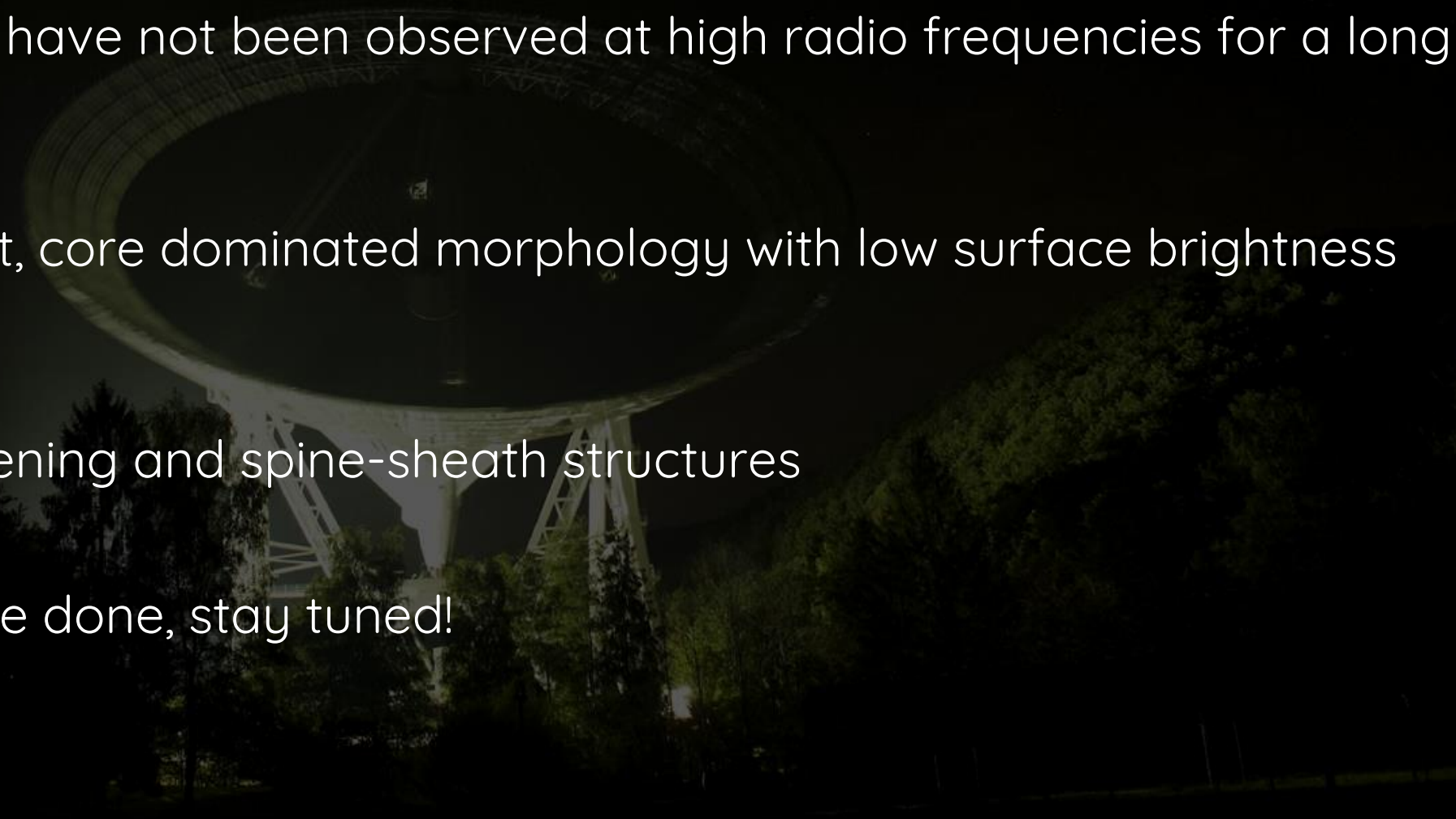
## PRELIMINARY



# What's to come?

- Analysis of the **first ever** interferometric 86GHz observations of 4 of the 5 target sources
- Refine calibration strategies with rPicard and dedicated AIPS calibration
- Understand and fix missing flux problems, especially at 7mm
- Calculate spectral indices (is the core flat as in Mrk501? Koyama et al. 2016) and brightness temperatures (relatively low?)
- Refine polarization analysis

# Conclusion

- TeV blazars are close-by, but generally relatively faint radio sources
  - Most of our targets have not been observed at high radio frequencies for a long time **or ever**
  - At 7mm mainly faint, core dominated morphology with low surface brightness jets
  - Hints of limb brightening and spine-sheath structures
  - Still much work to be done, stay tuned!
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# THANK YOU!

