THREE LITTLE RADIO GALAXIES IN THE EARLY UNIVERSE

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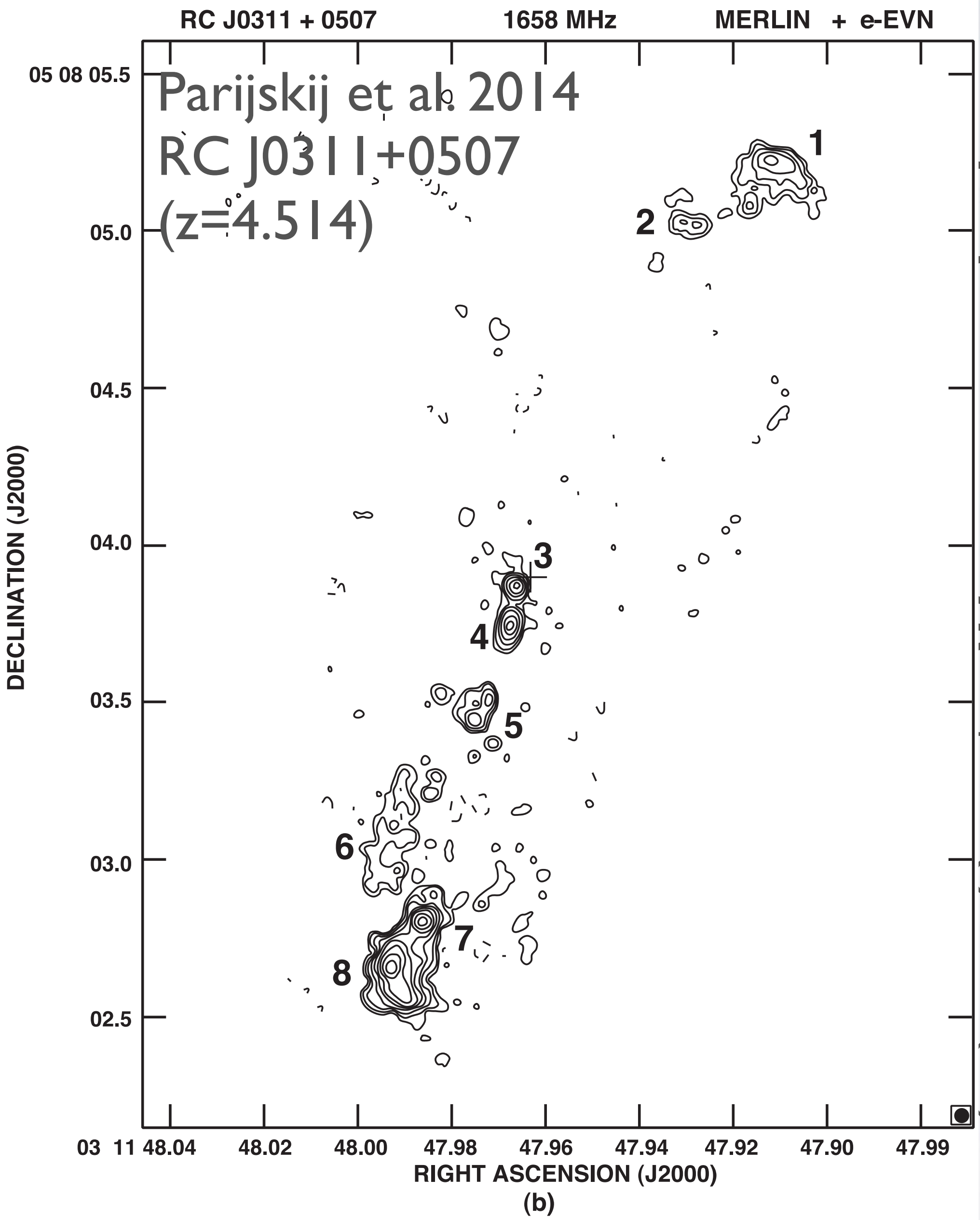
MISSING POPULATION OF HIGH-REDSHIFT NON-BEAMED RADIO-AGN?

- Number of **radio-loud AGN at z≳4** calculated from *Swift*/BAT luminosity function ≪ estimated from the **known z≳4 blazars** - for every blazar there are ~2 Γ^2 non-beamed (Volonteri et al. 2011)
  - **Observational bias**? (SDSS + FIRST sample was considered)
  - Strong **evolution of Lorentz factor** by cosmic age?
  - **Dark bubbles**: off-axis obscuration hinders redshift estimation? (Ghisellini & Sbarrato 2016)
- Few high-redshift radio AGN are known and imaged with interferometry



OPULATION OF HIGH- N-BEAMED RADIO-AGN?

GN **at z≳4** calculated from *Swift*/BAT luminosity

n the **known z≳4 blazars** - for every blazar there

olonteri et al. 2011)

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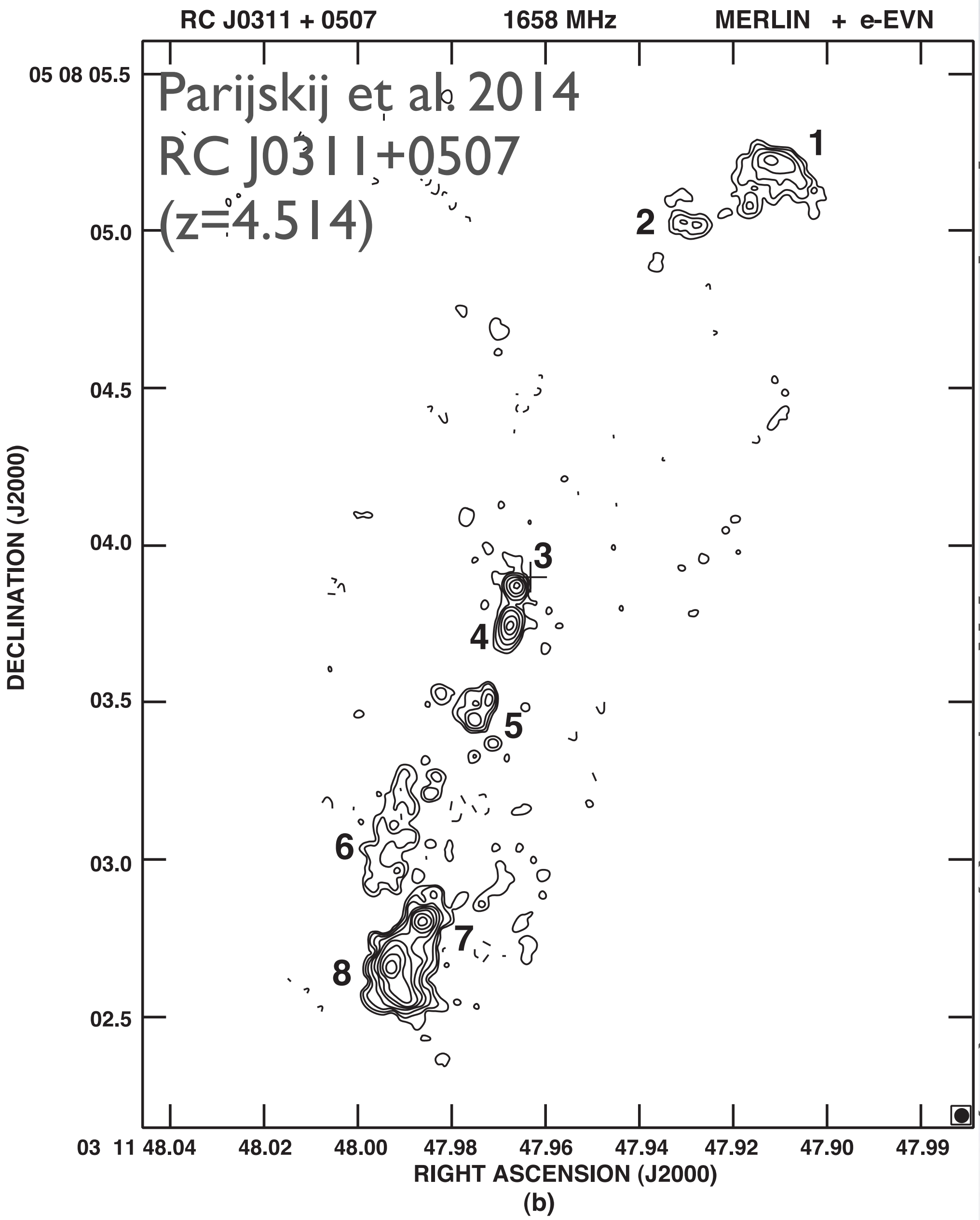

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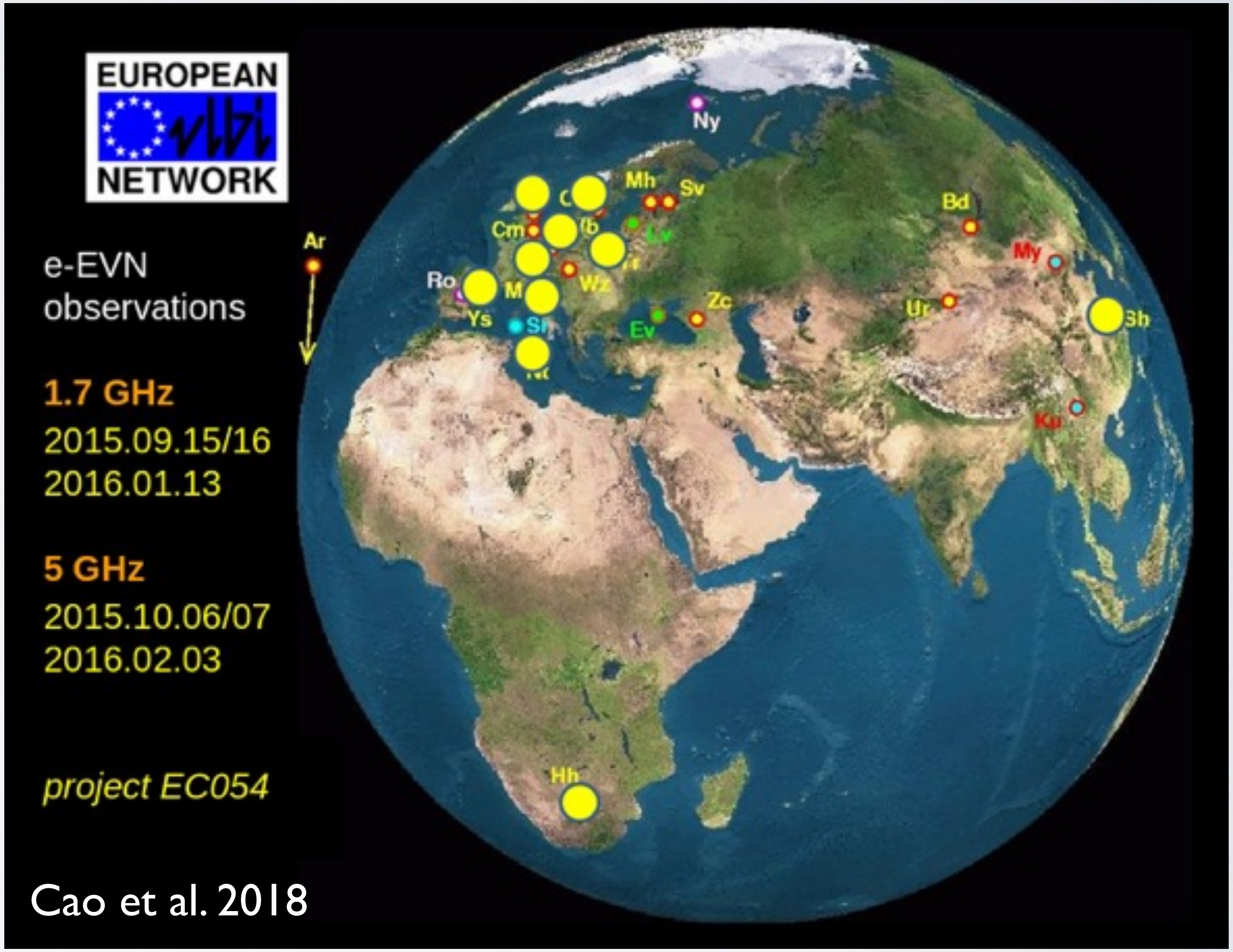
- Few high-redsh

RESOLVING THE POWERFUL RADIO-LOUD QUASAR AT $z \sim 6$

Emmanuel Momjian,[1] Christopher L. Carilli,[1,2] Eduardo Bañados,[3,*] Fabian Walter,[4,1] and Bram P. Venemans[4]

EVN OBSERVATIONS

- **Targets: four** z>4 blazar candidates
- e-VLBI observations at 1.7 GHz and 5 GHz
- 2015 Sept, Oct, 2016 Jan, Feb (EC054)
- Results: **two beamed** sources with high T_B



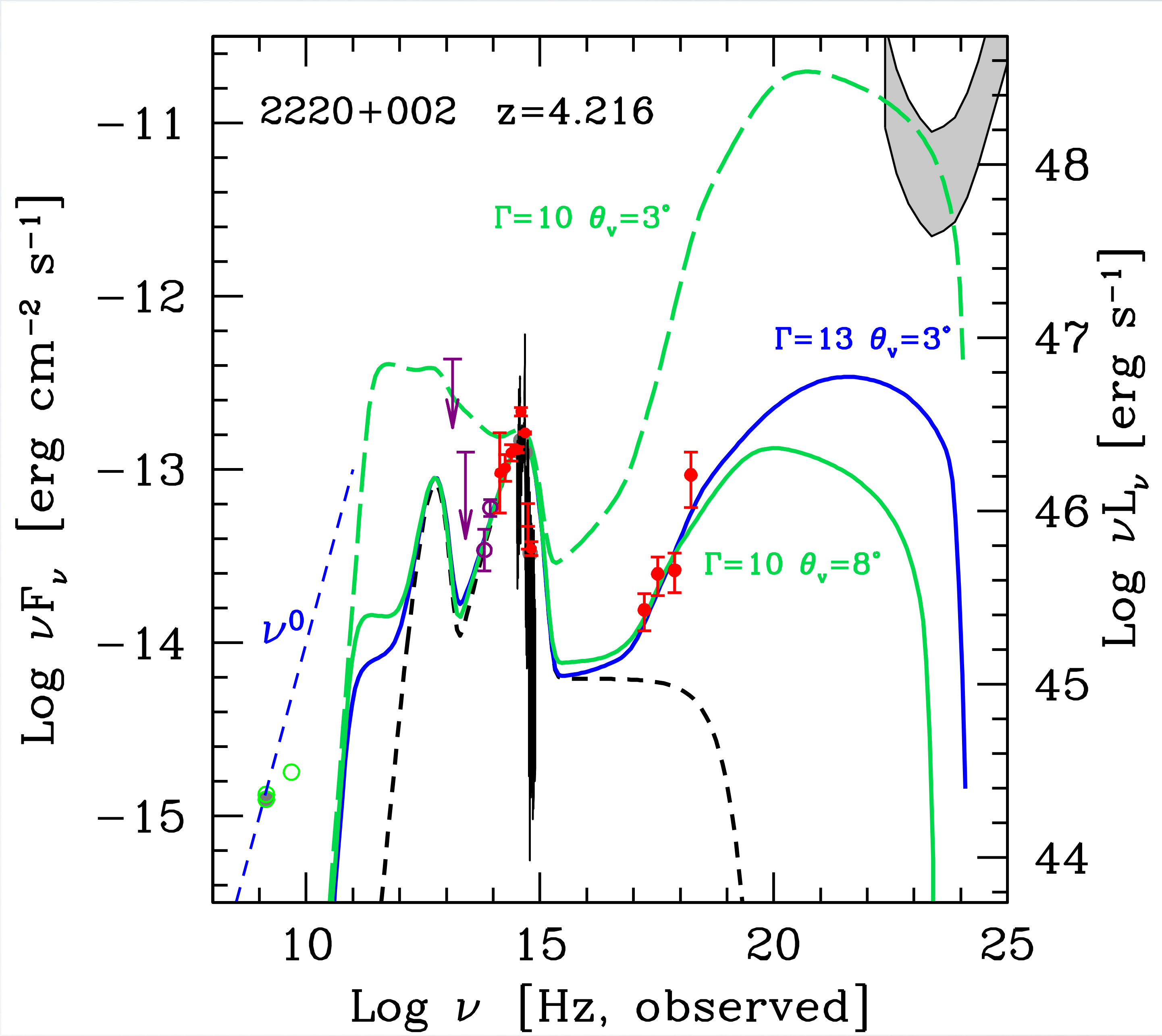
Cao et al. 2018

+ Out of **ten z>4.5 five** showed definite **blazar-like** characteristics. One is a double with 800 mas separation (EC052)

J2220+0025 (z=4.21)

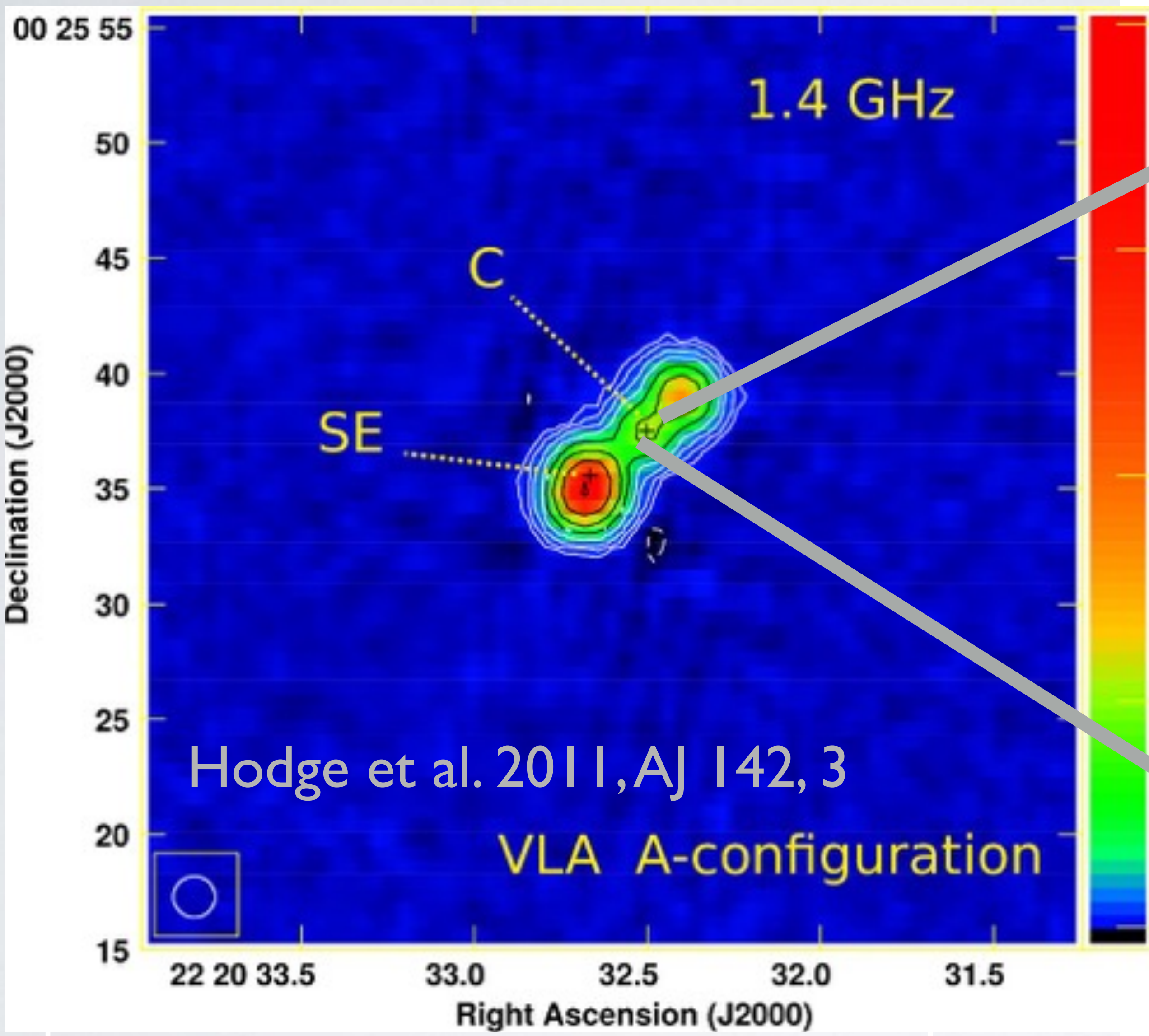
- SWIFT measurements
  - 0.3-10 keV: 10^{-13} erg/cm^2/s
  - v band: 21.16±0.18 mag
- Archival data (e.g. WISE, FIRST)

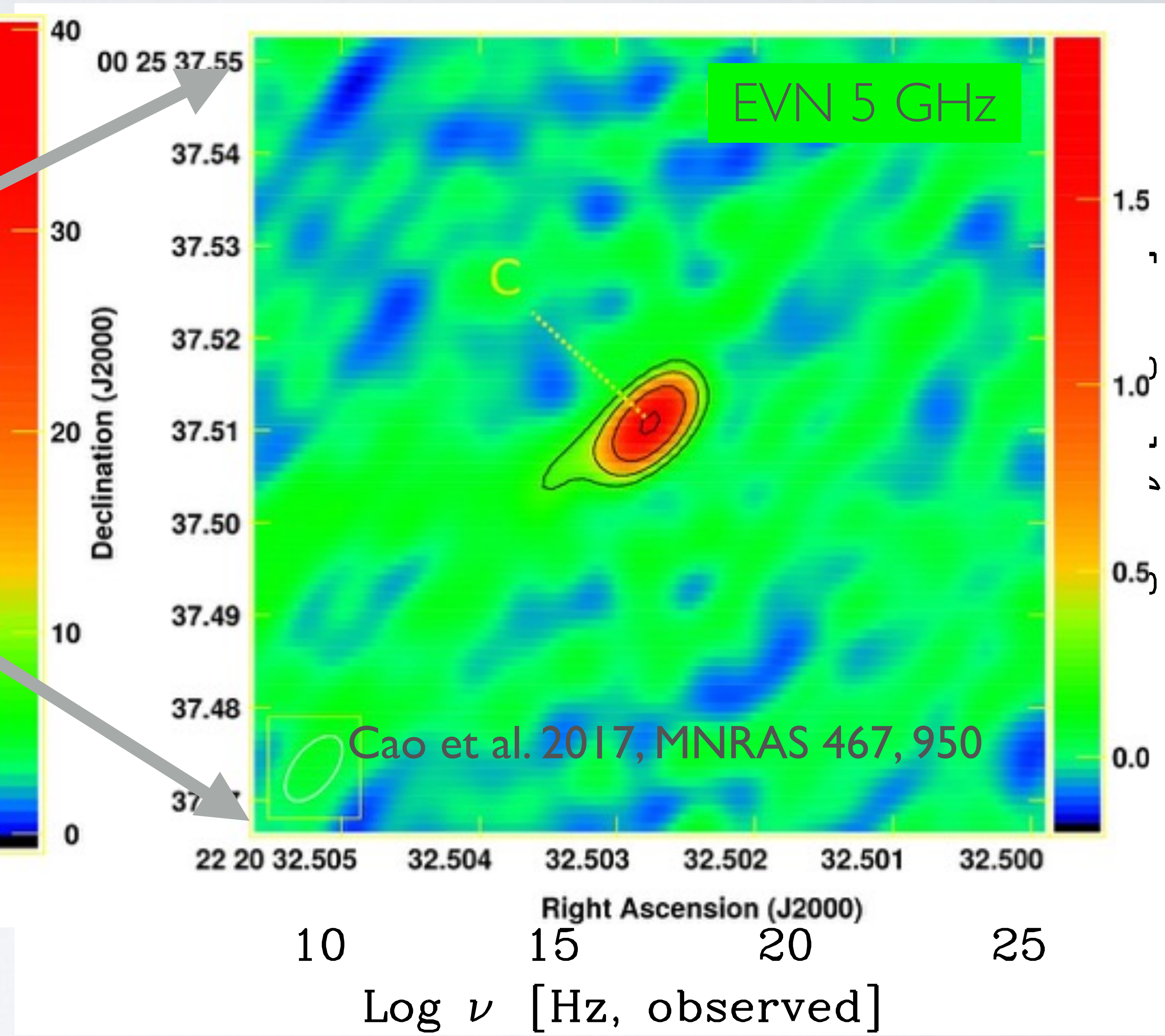
- $M_{BH}=2\times10^9\ M_\odot$
- $R_{BLR}=671\times10^{15}$ cm
- Lorentz factor: 13-10
- Viewing angle: 3°-8°



Sbarrato et al. 2015, MNRAS 446,2483

J2220+0025 (z=4.21)



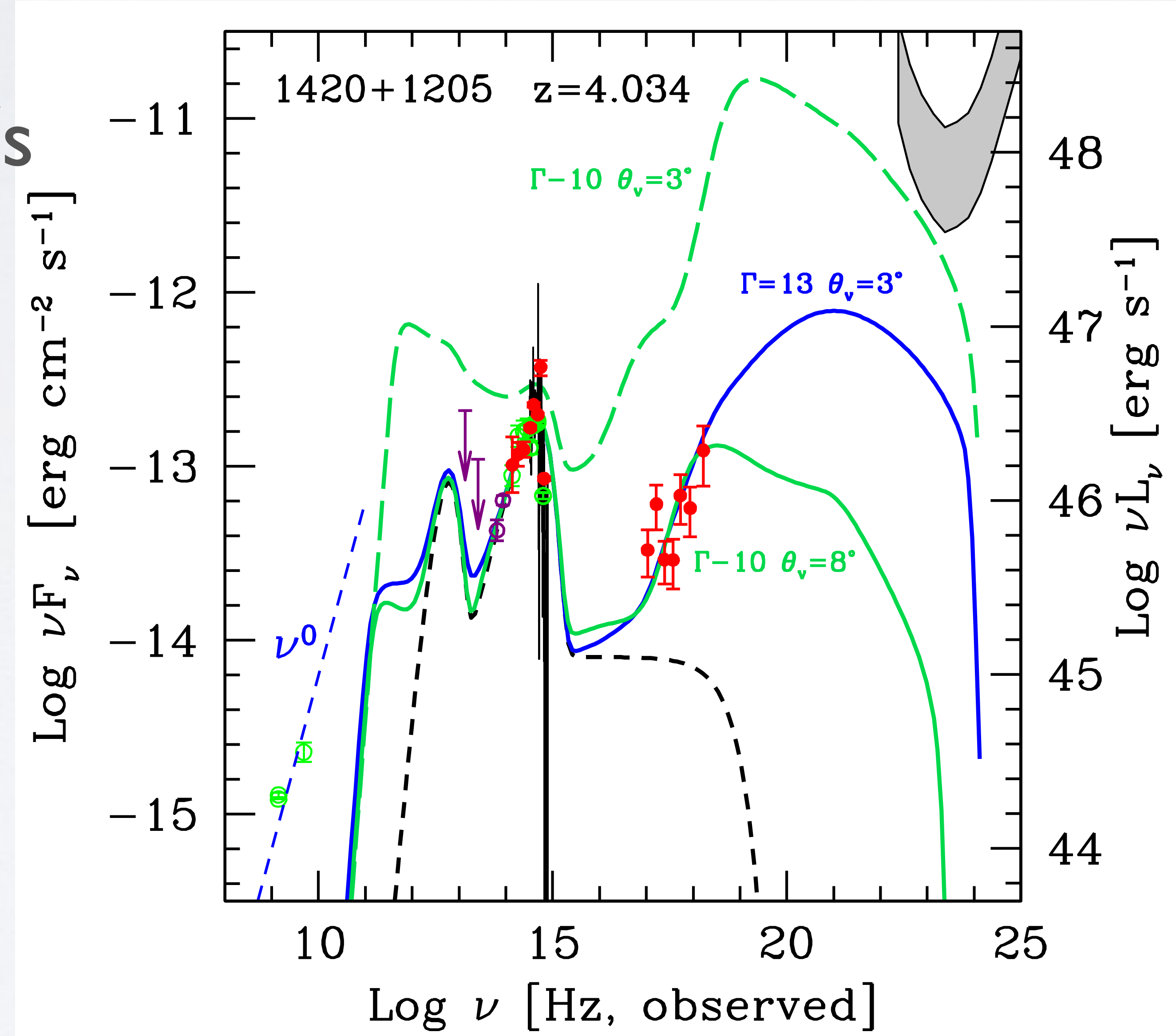


- Lorentz factor: 13-10
- Viewing angle: 3°-8°

Sbarrato et al. 2015, MNRAS 446,2483

J1420+1205 (z=4.03)

- SWIFT measurements
  - 0.3-10 keV: 1.7×10^{-13} erg/cm^2/s
  - v band: 20.43±0.1 mag
- Archival data (e.g. WISE, FIRST)

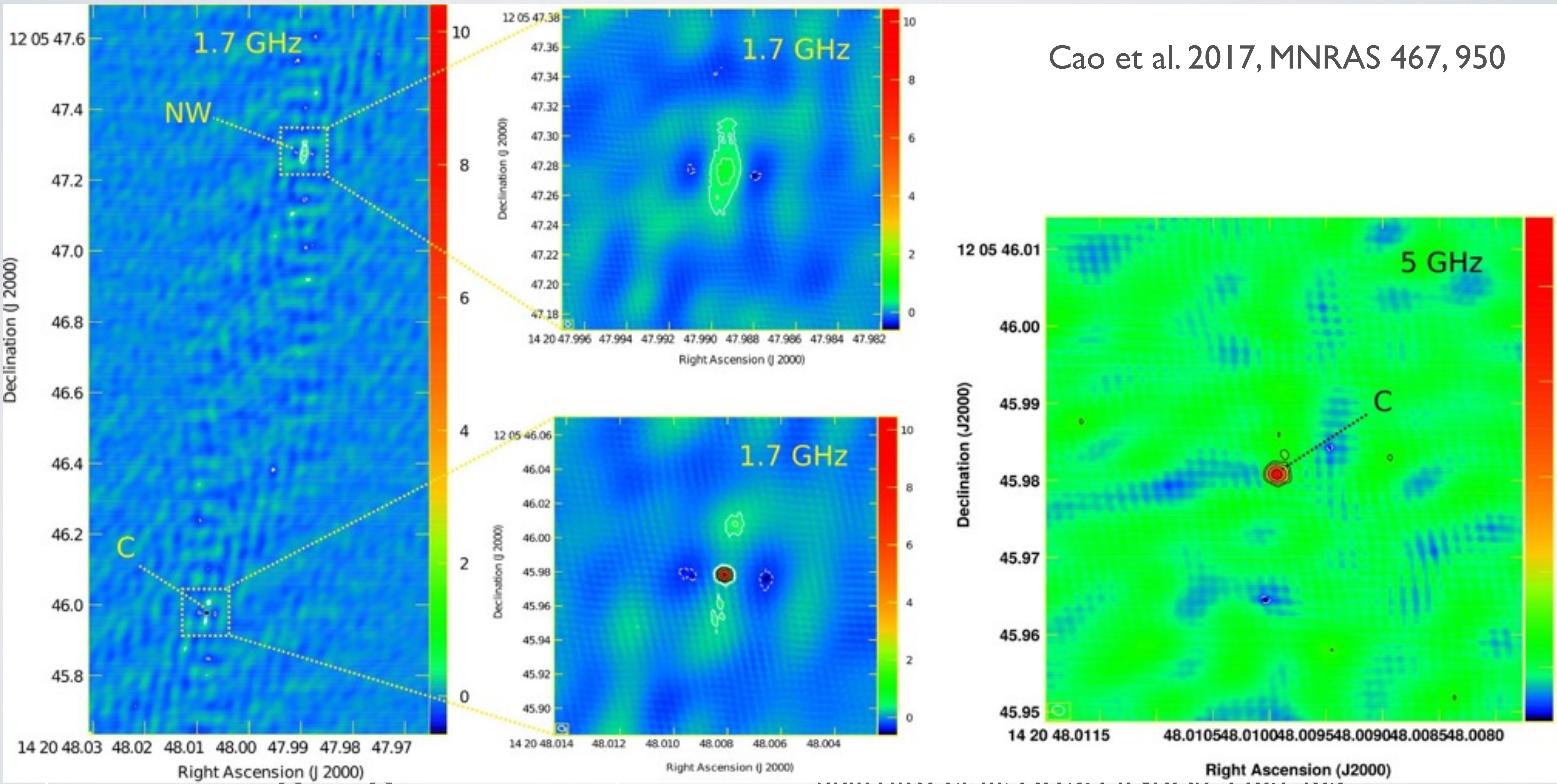


Sbarrato et al. 2015, MNRAS 446,2483

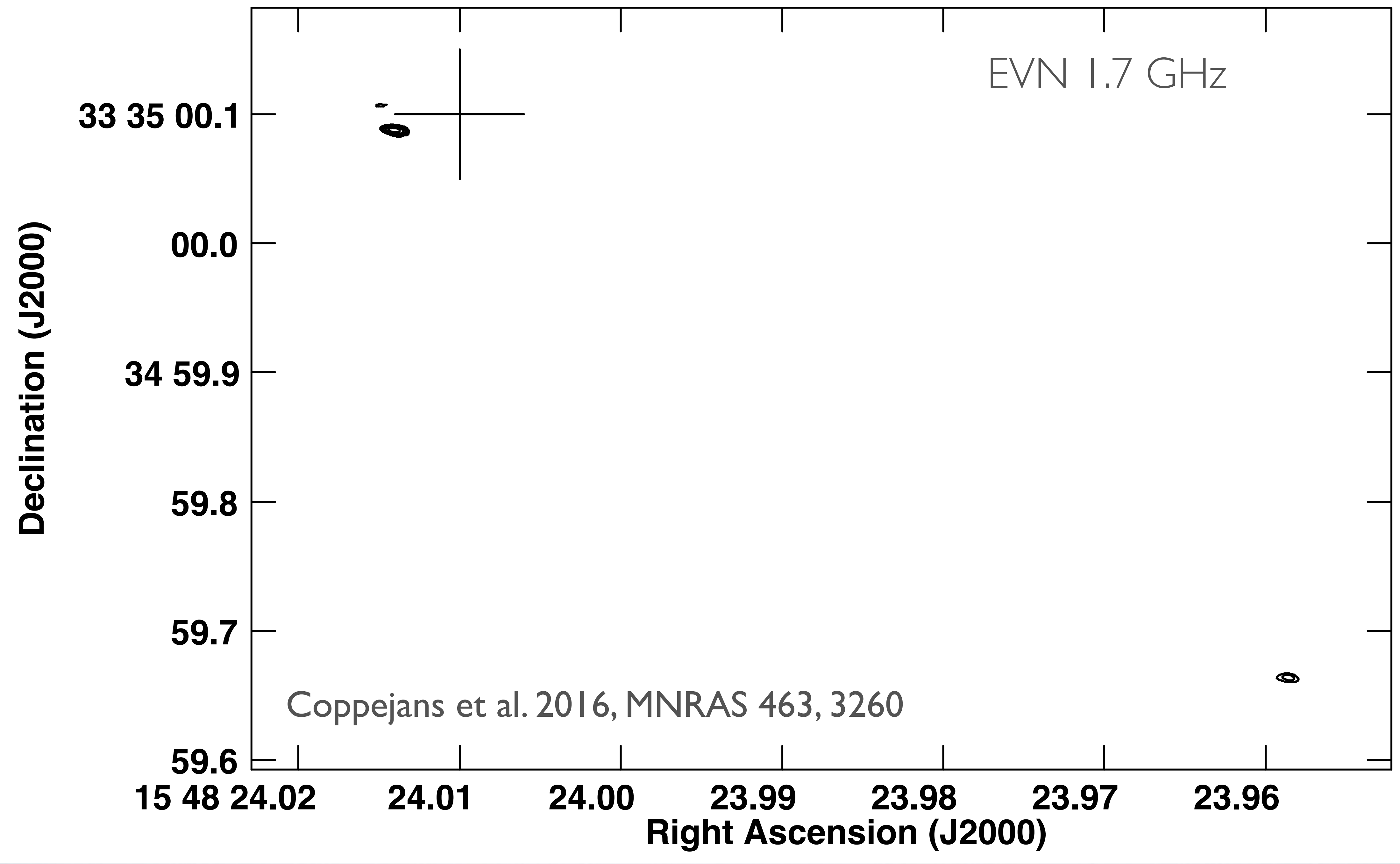
- $M_{BH} = 2 \times 10^9\ M_\odot$
- $R_{BLR} = 725 \times 10^{15}$ cm
- Lorentz factor: 13-10
- Viewing angle: 3°-8°

J1420+1205 (z=4.03)

Cao et al. 2017, MNRAS 467, 950



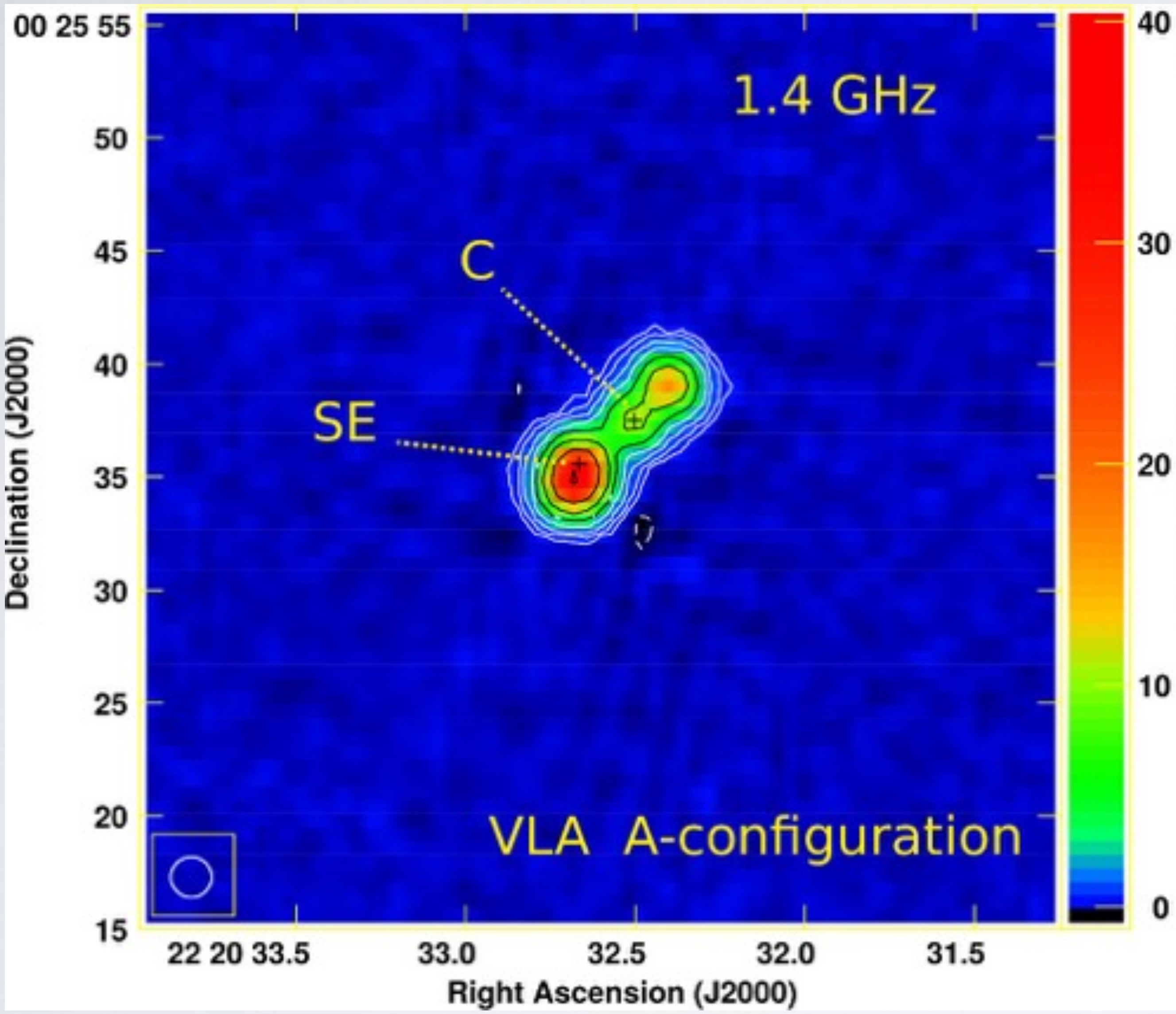
J1548+3335 (z=4.68)

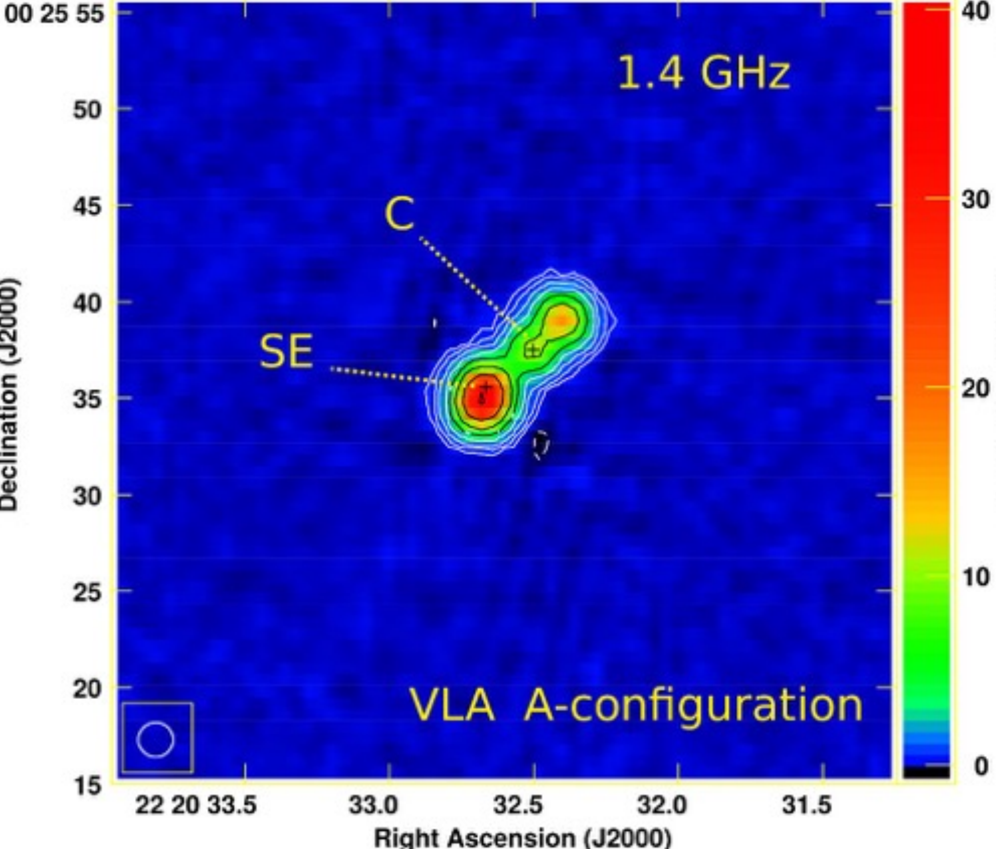


E-MERLIN OBSERVATIONS

- L band: 8 spectral windows, 1.25 - 1.77 GHz
- C band: 4 spectral windows, 4.82- 5.33 GHz
- Antennas: Mk2, Pi, De, Da, Kn, Cm
- 2017.05.13,15
- 2017.06.26, 27, 30

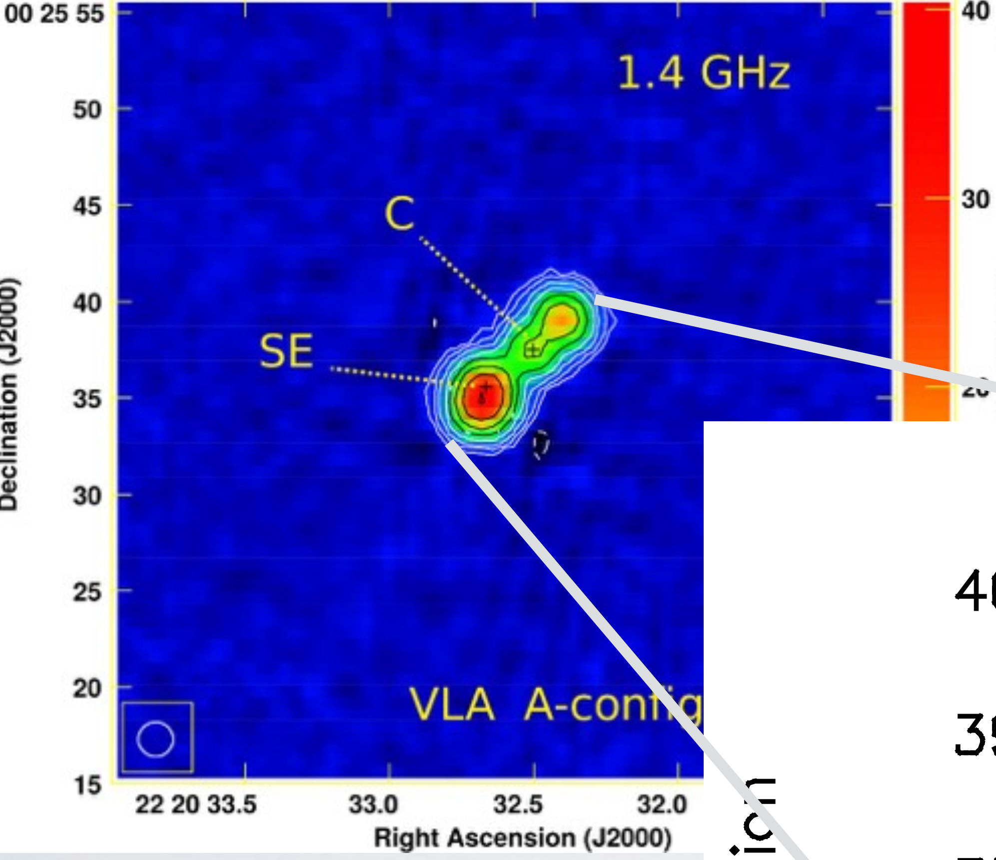
J2220+0025 (z=4.21)

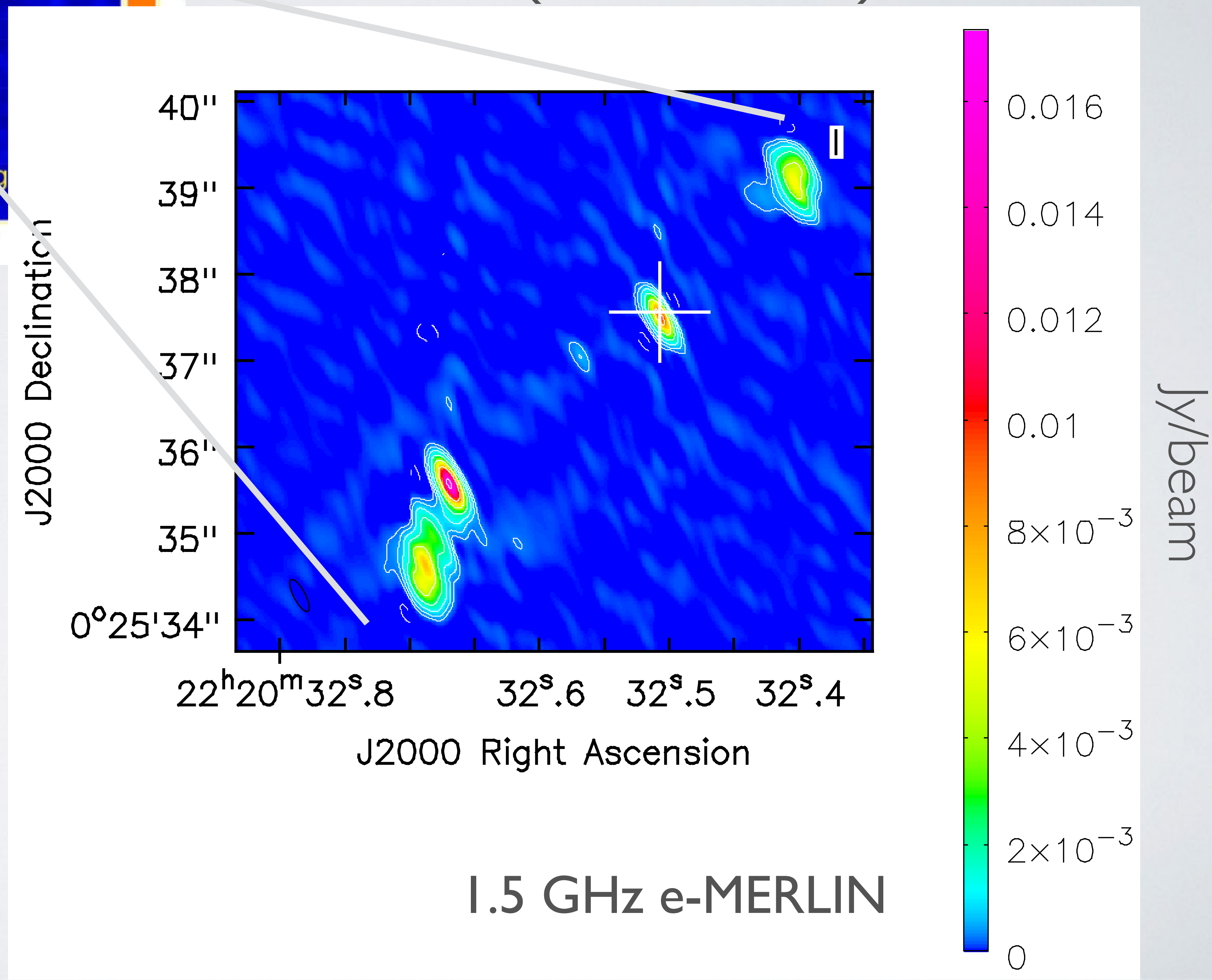


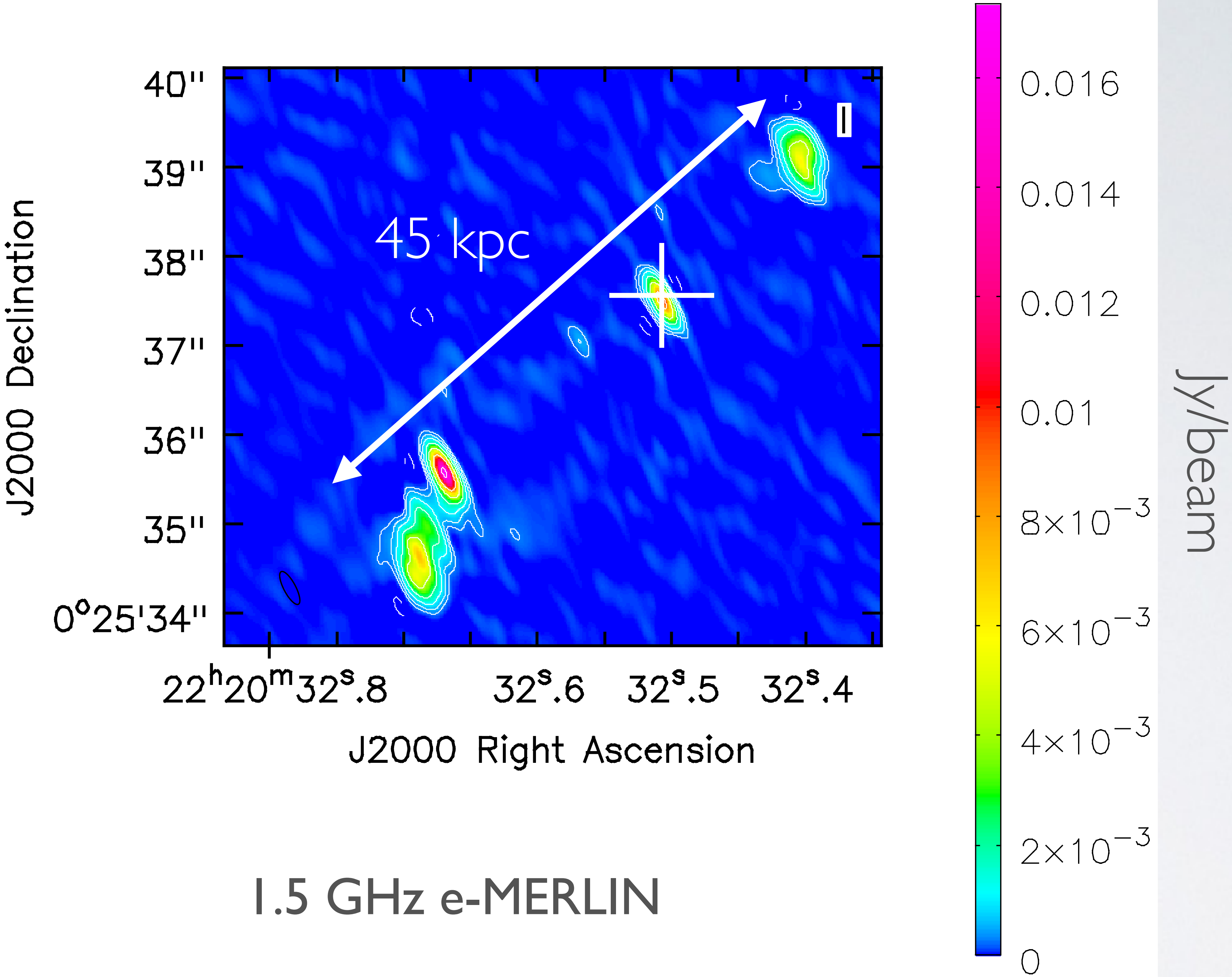

1.4 GHz
C
SE
VLA A-configuration
Declination (J2000)
Right Ascension (J2000)
00 25 55
50
45
40
35
30
25
20
15
22 20 33.5
33.0
32.5
32.0
31.5
40
30
20
10
0

+0025 (z=4.21)

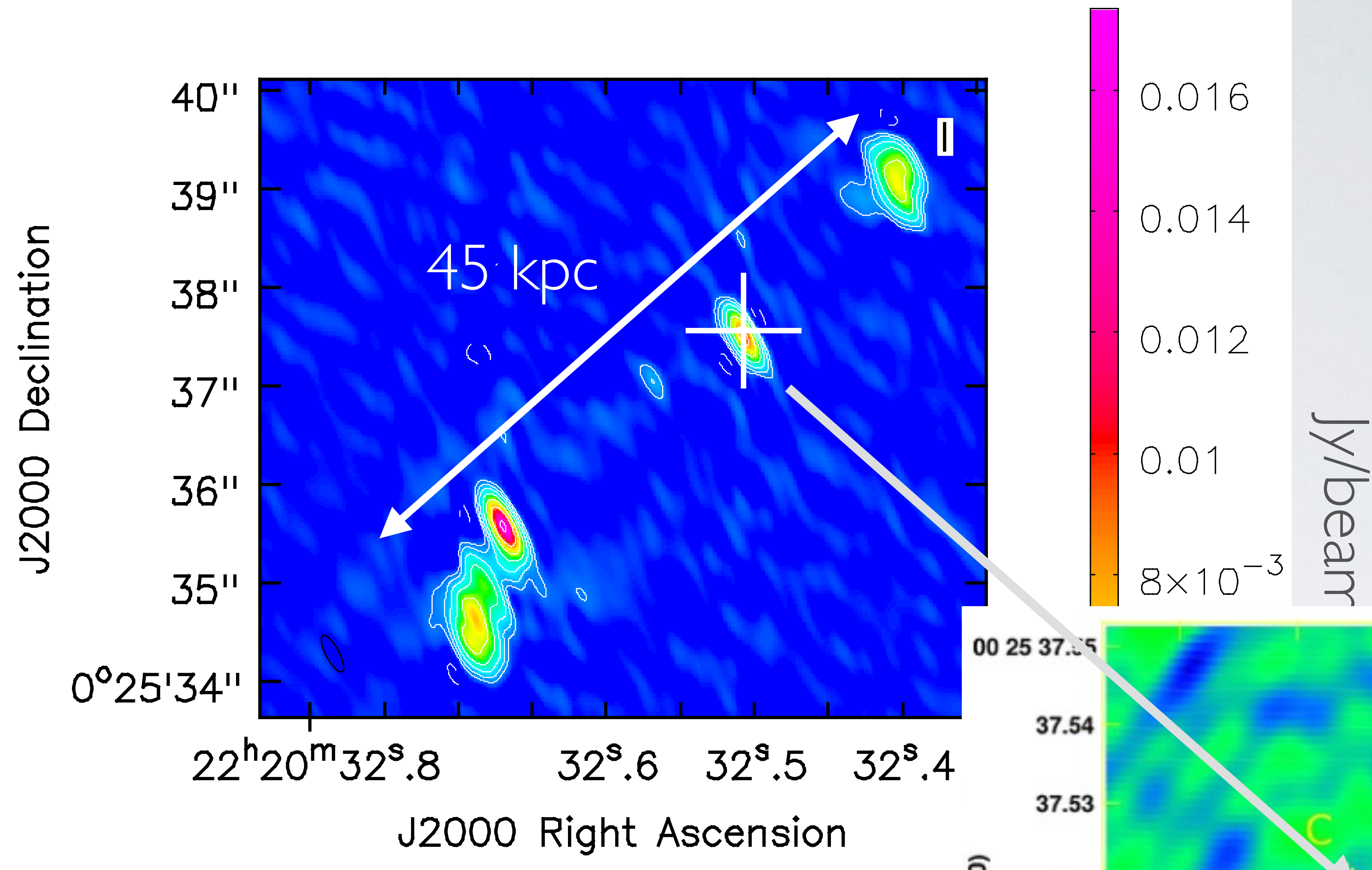
+0025 (z=4.21)


1.4 GHz
C
SE
VLA A-confi
Declination (J2000)
Right Ascension (J2000)
00 25 55
50
45
40
35
30
25
20
15
22 20 33.5
33.0
32.5
32.0
40
30

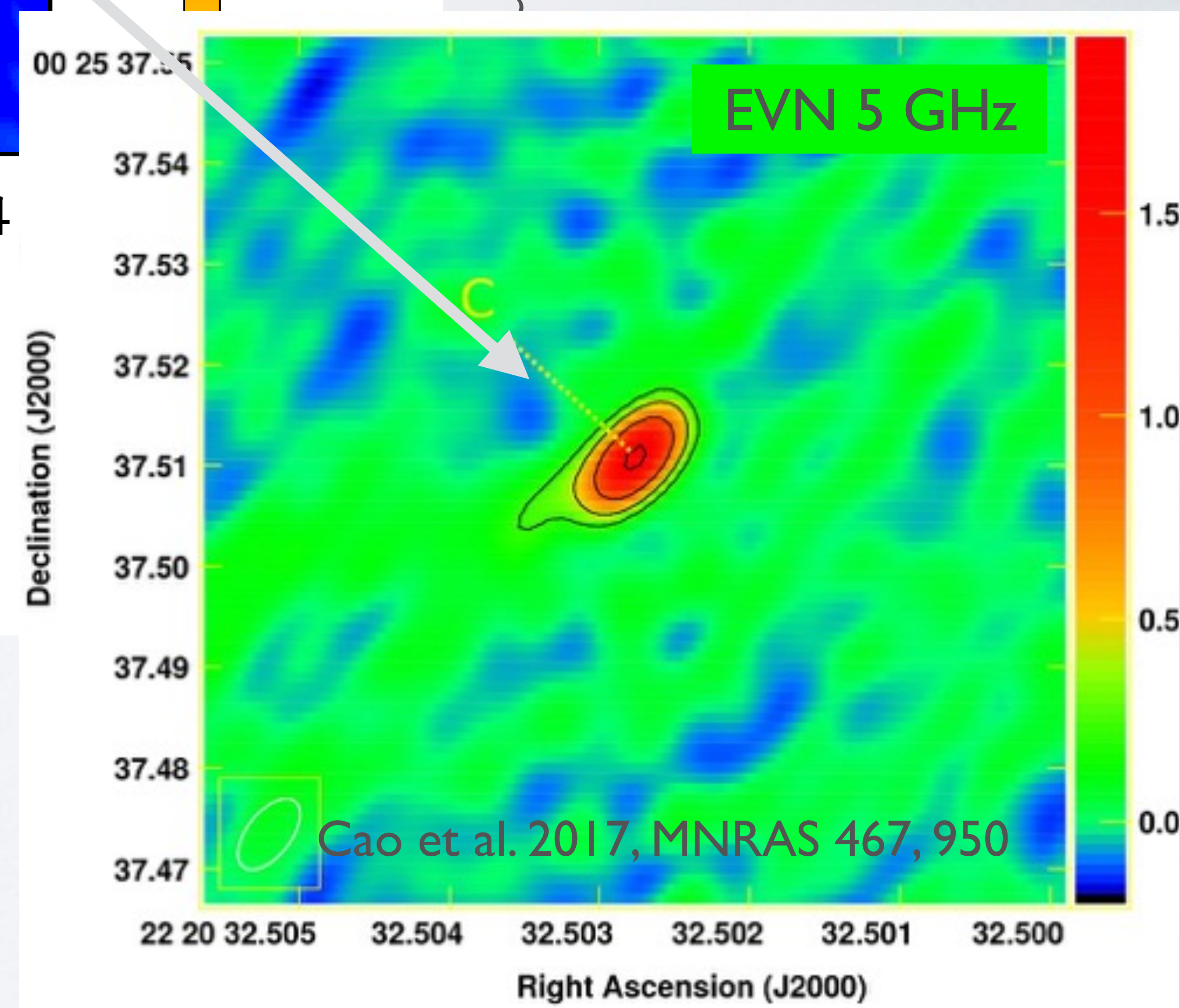

I
40''
39''
38''
37''
36''
35''
0°25'34''
J2000 Declination
22h20m32s.8
32s.6
32s.5
32s.4
J2000 Right Ascension
0.016
0.014
0.012
0.01
8×10−3
6×10−3
4×10−3
2×10−3
0
Jy/beam
1.5 GHz e-MERLIN

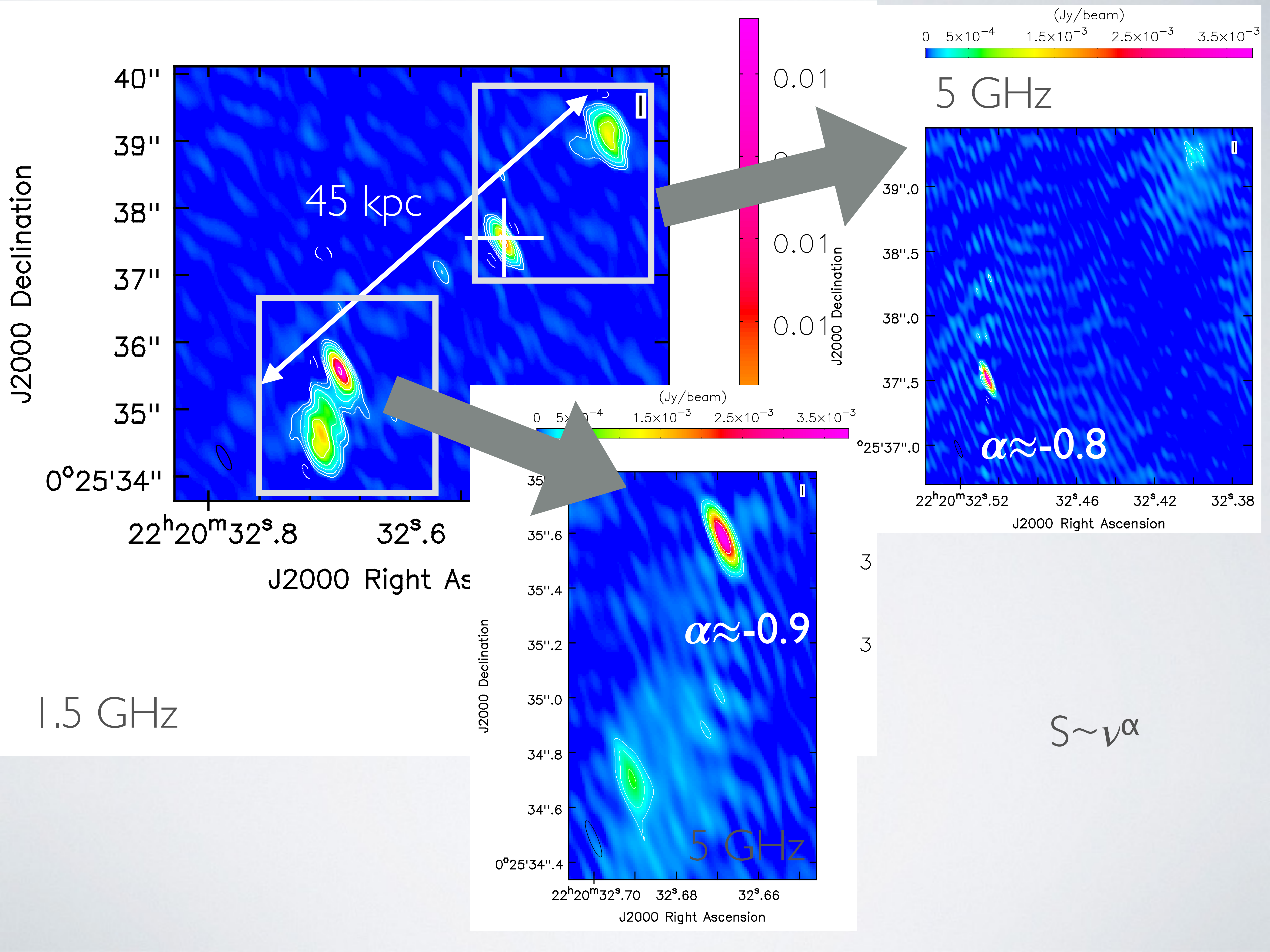


1.5 GHz e-MERLIN



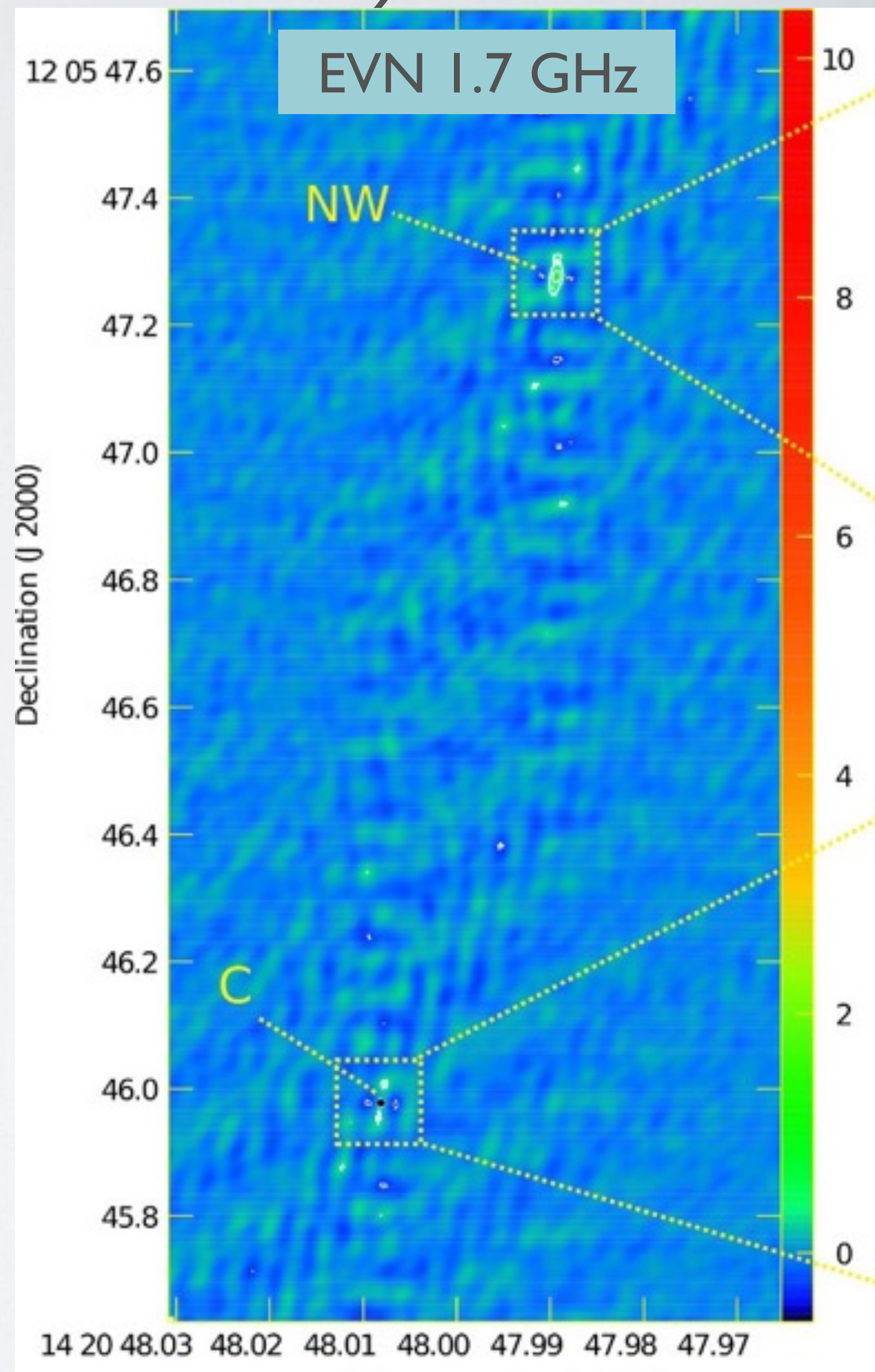
1.5 GHz e-MERLIN



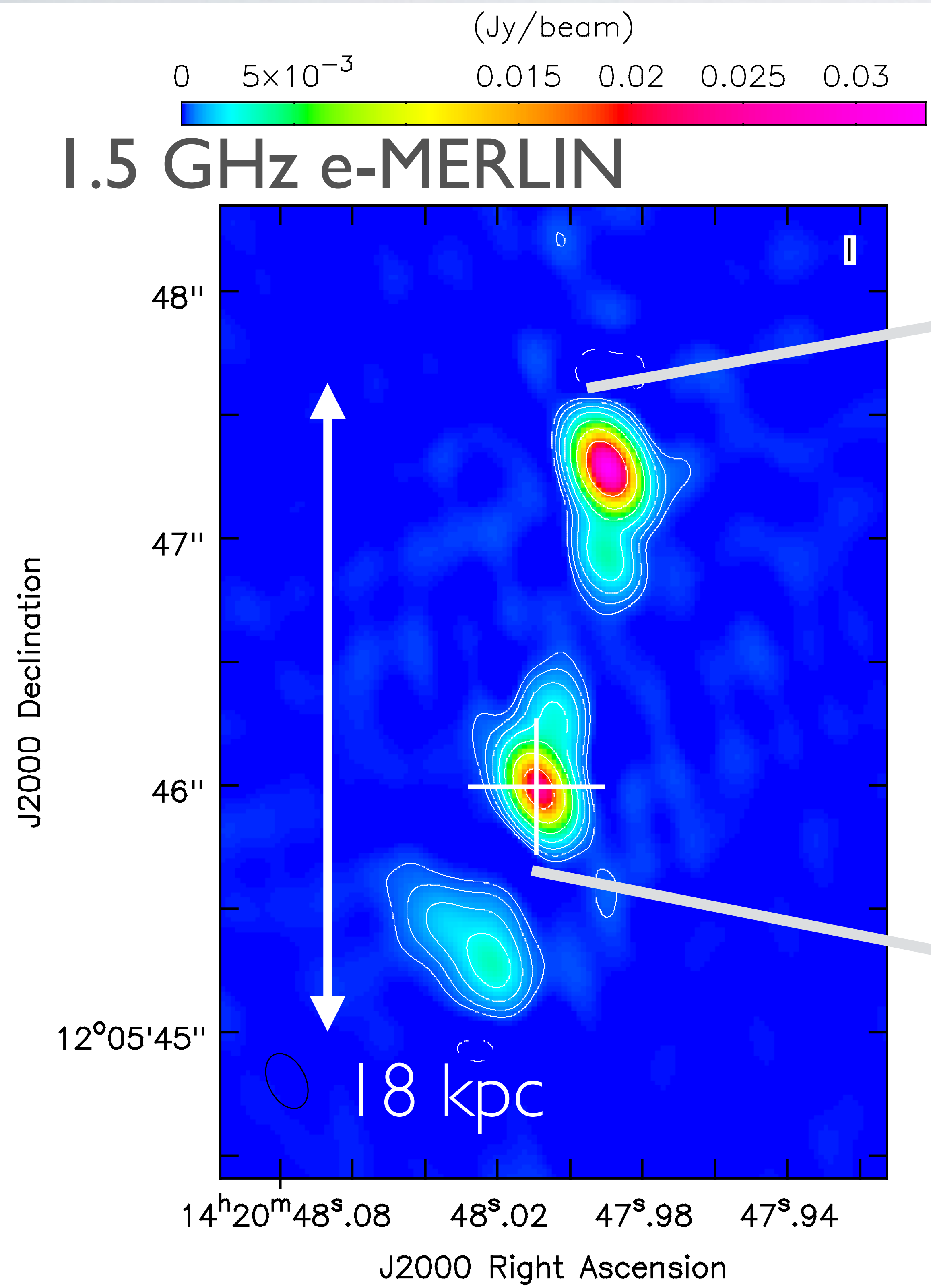


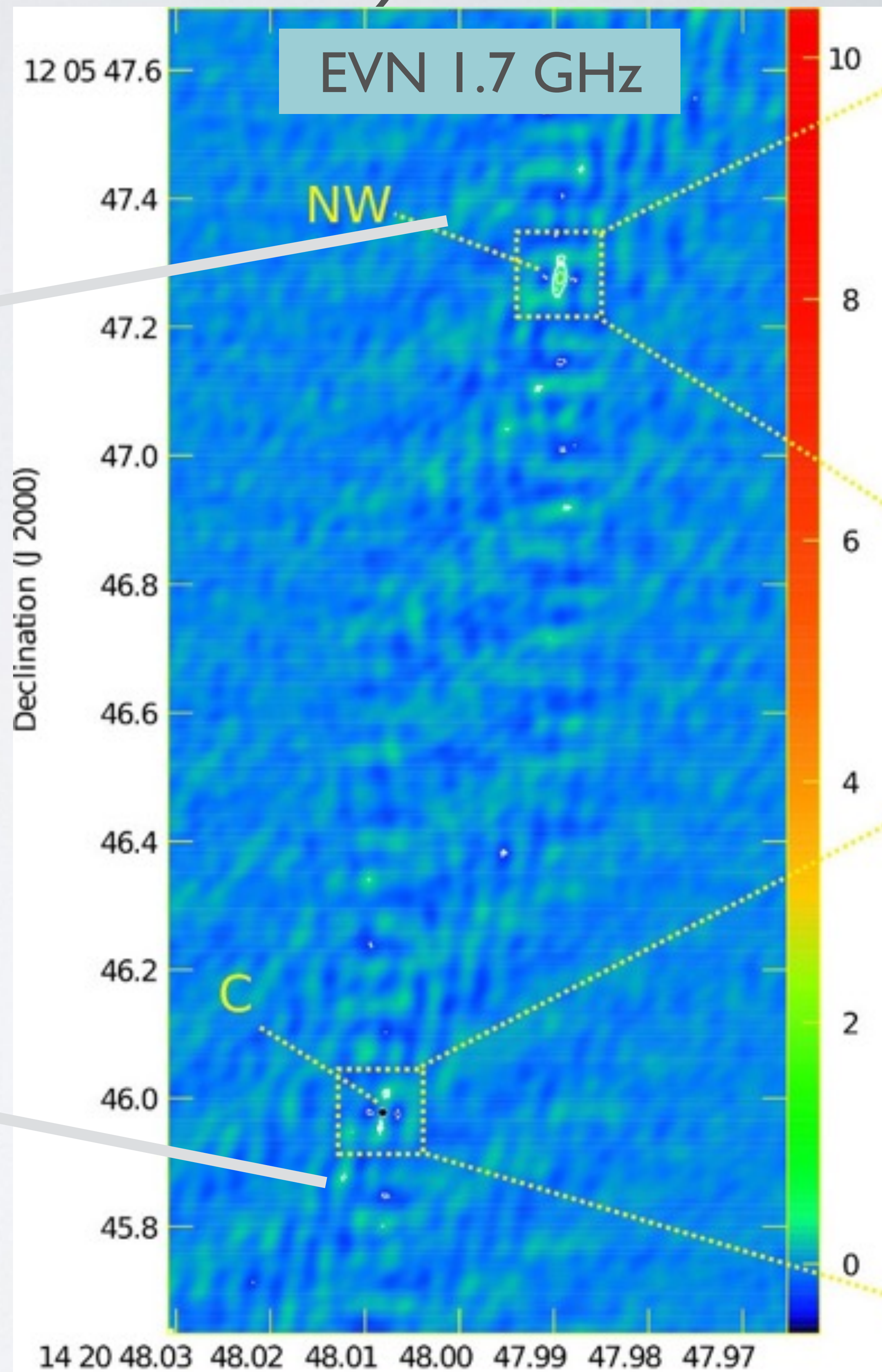
45 kpc
1.5 GHz
5 GHz
α≈-0.8
α≈-0.9
5 GHz
S~ν^α
J2000 Declination
J2000 Right Ascension
(Jy/beam)

J1420+1205 (z=4.03)



J1420+1205 (z=4.03)





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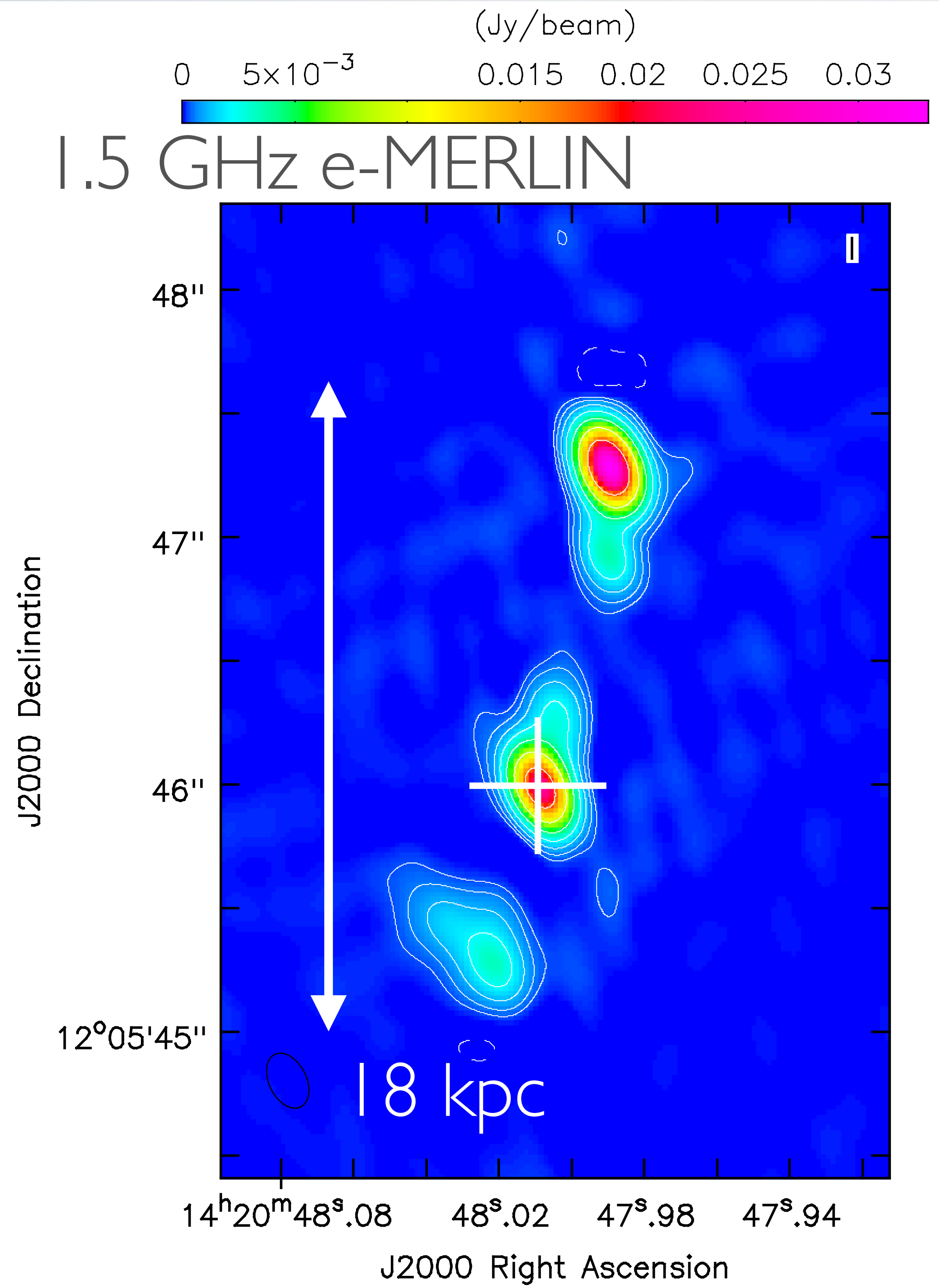

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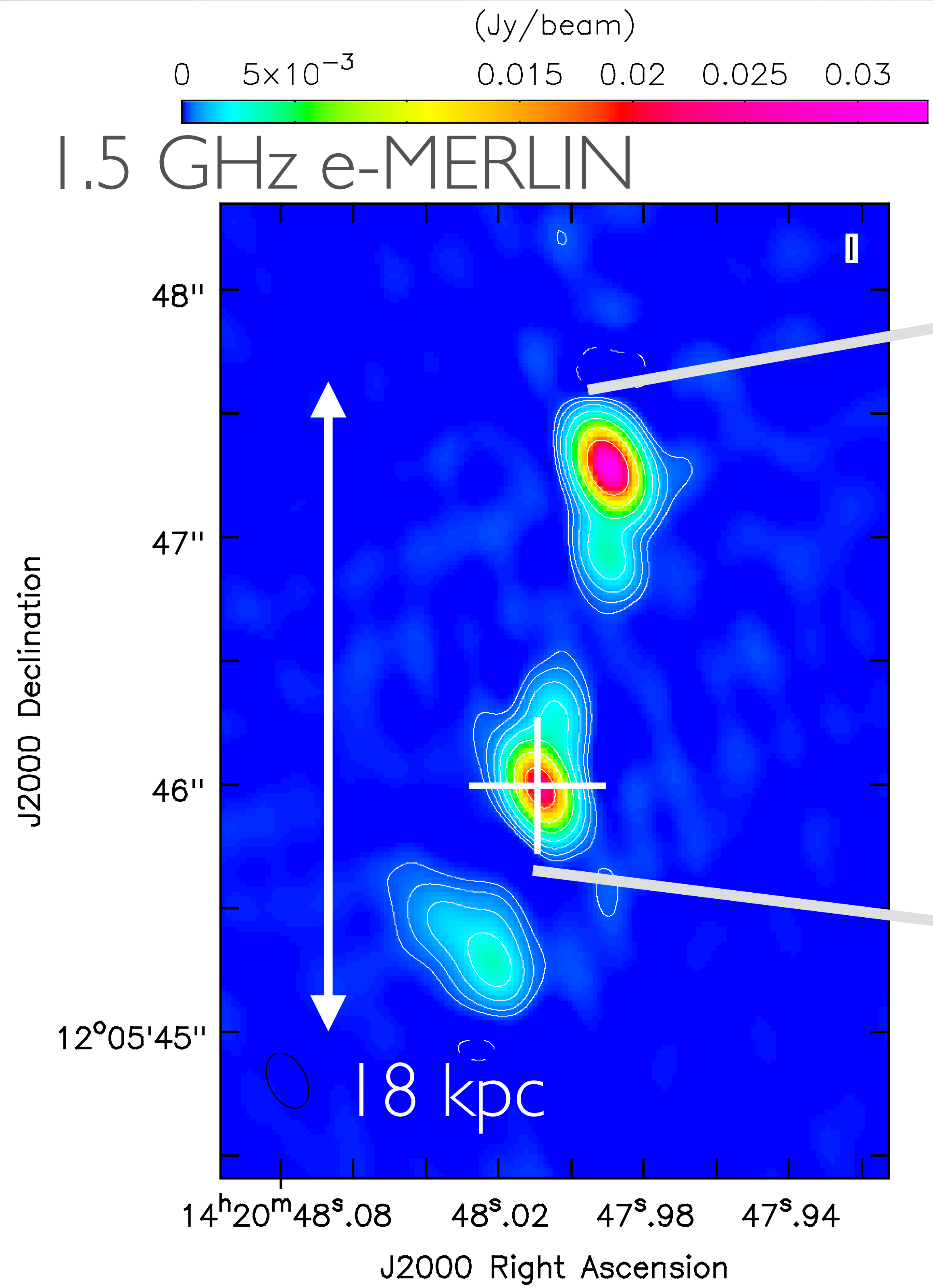

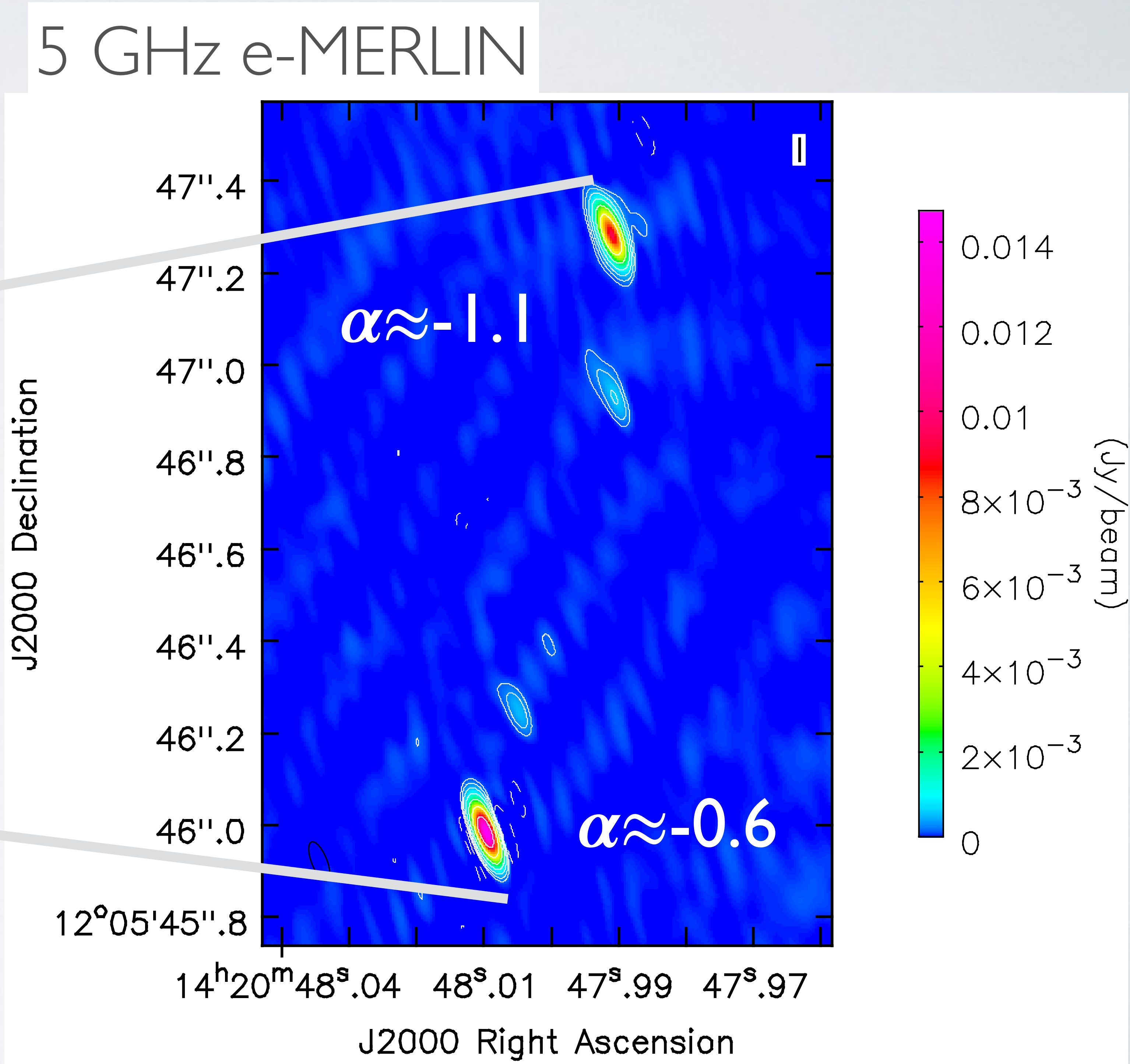

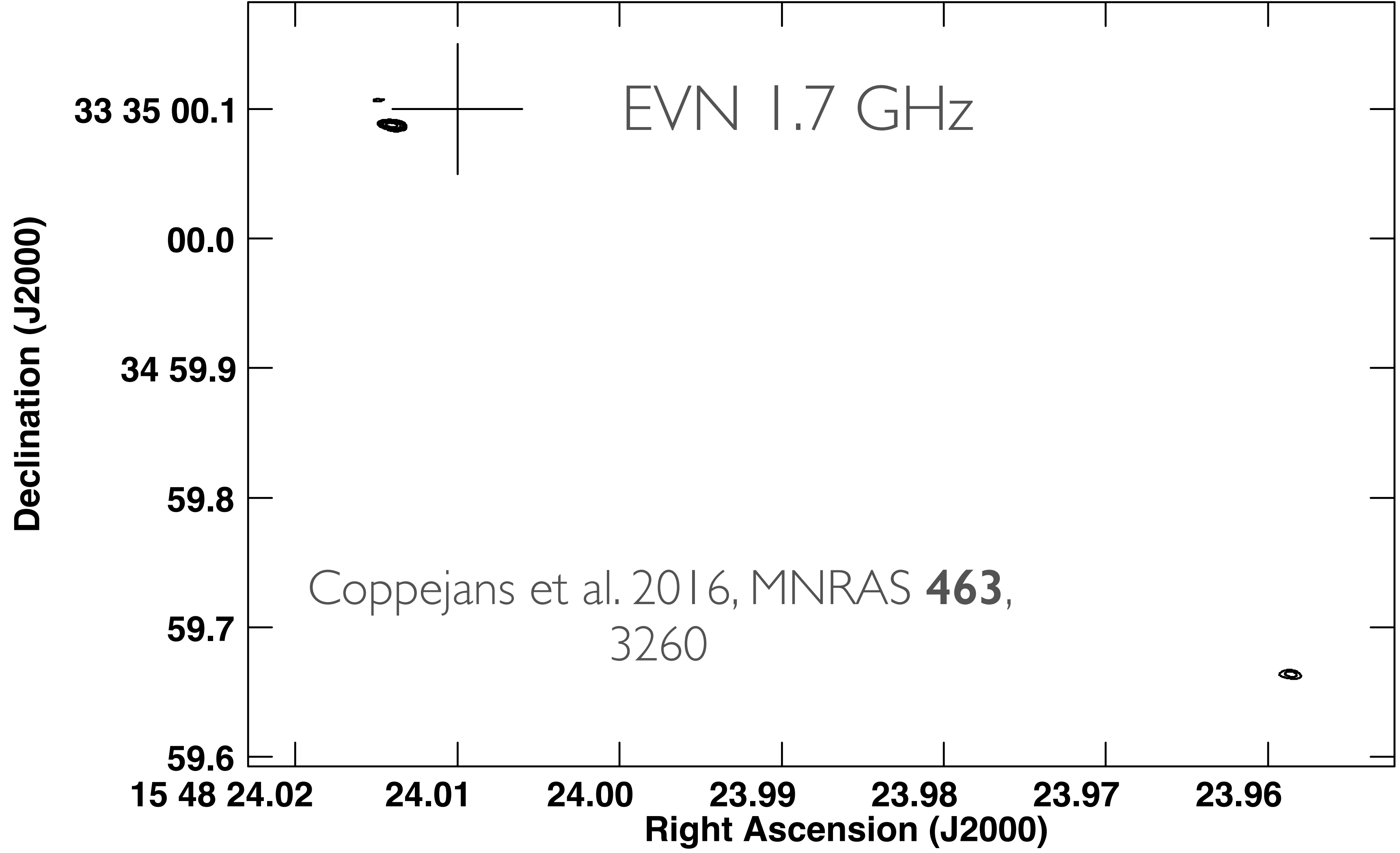

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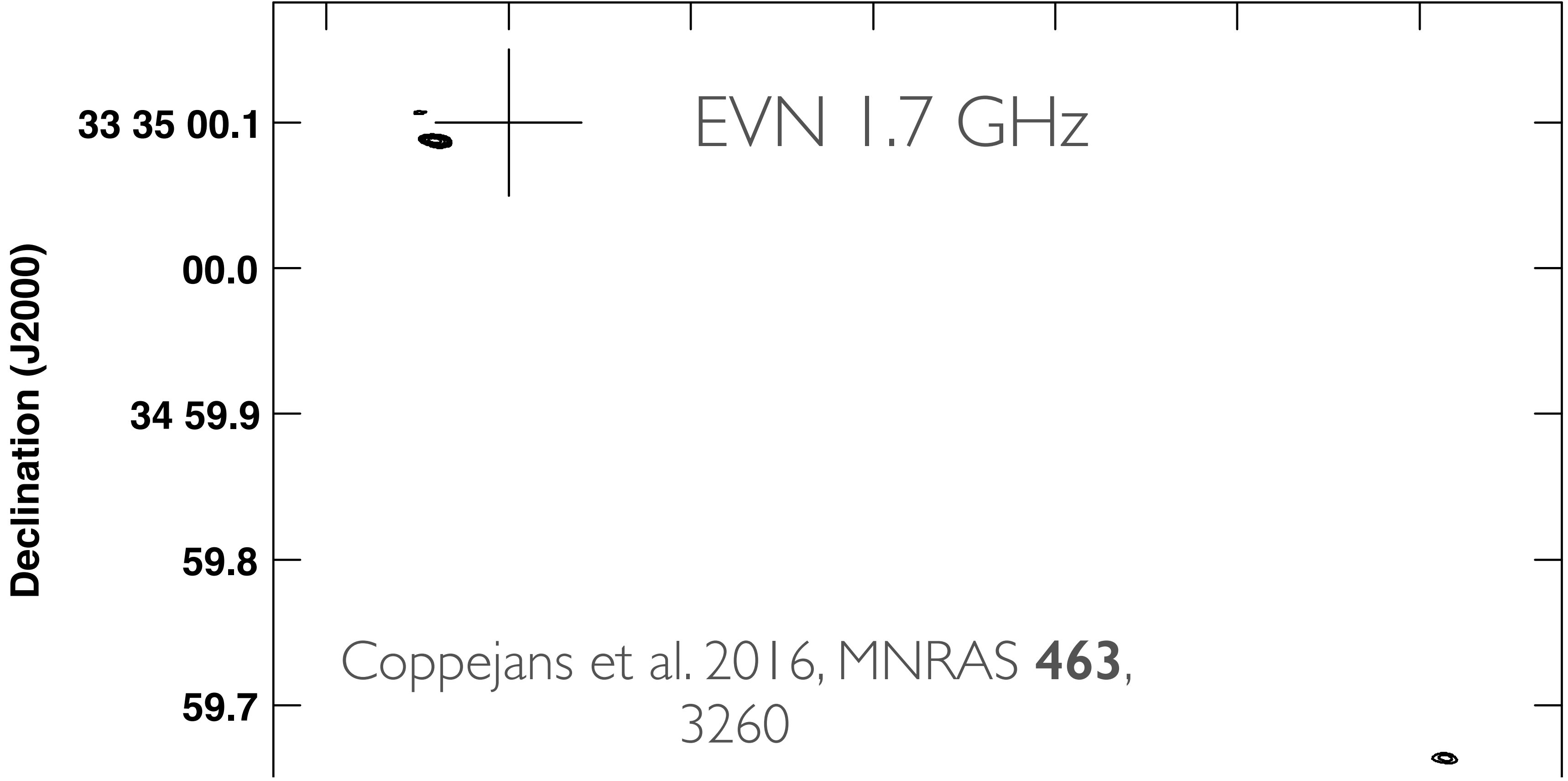
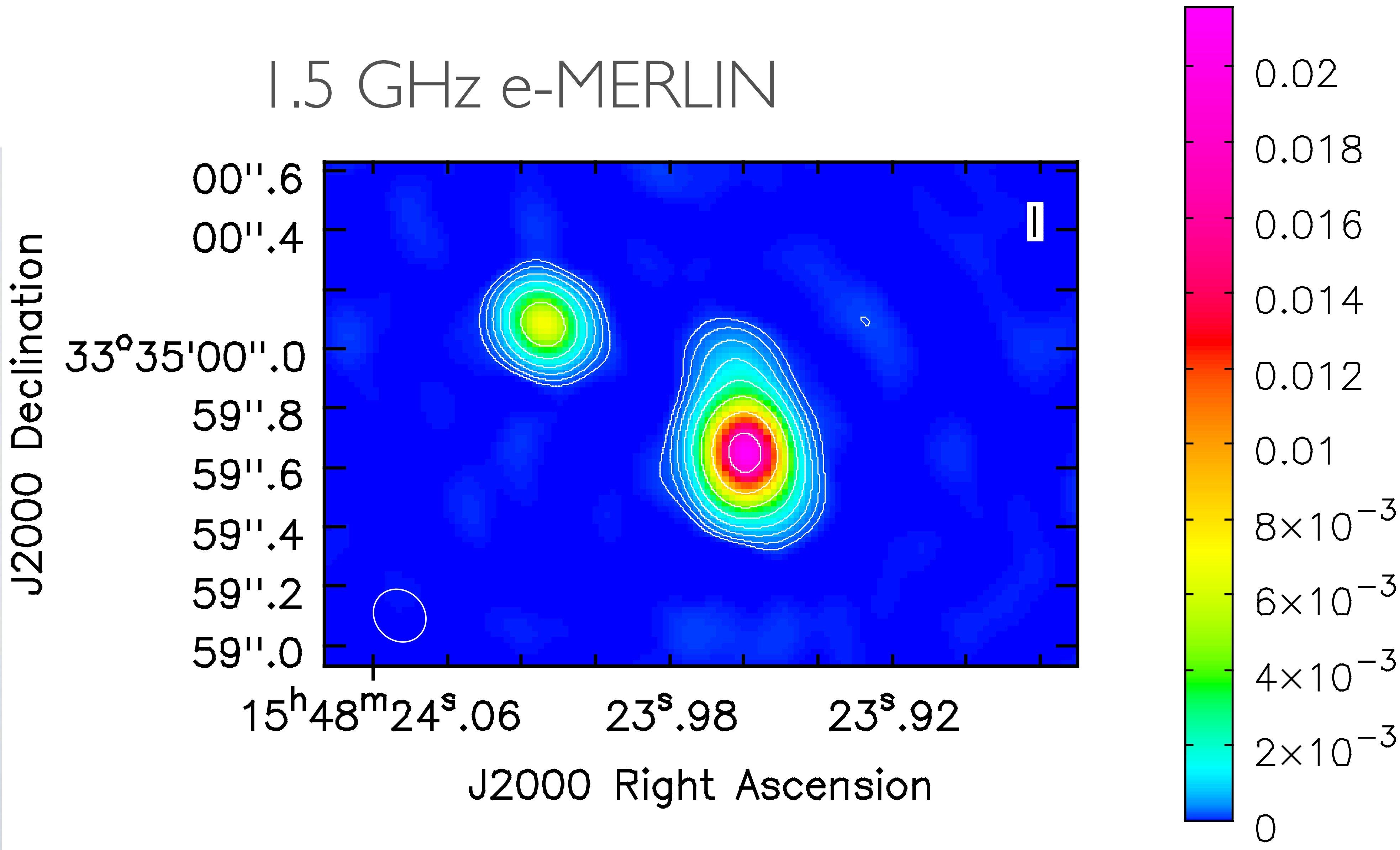


Coppejans et al. 2016, MNRAS **463**, 3260

1.5 GHz e-MERLIN



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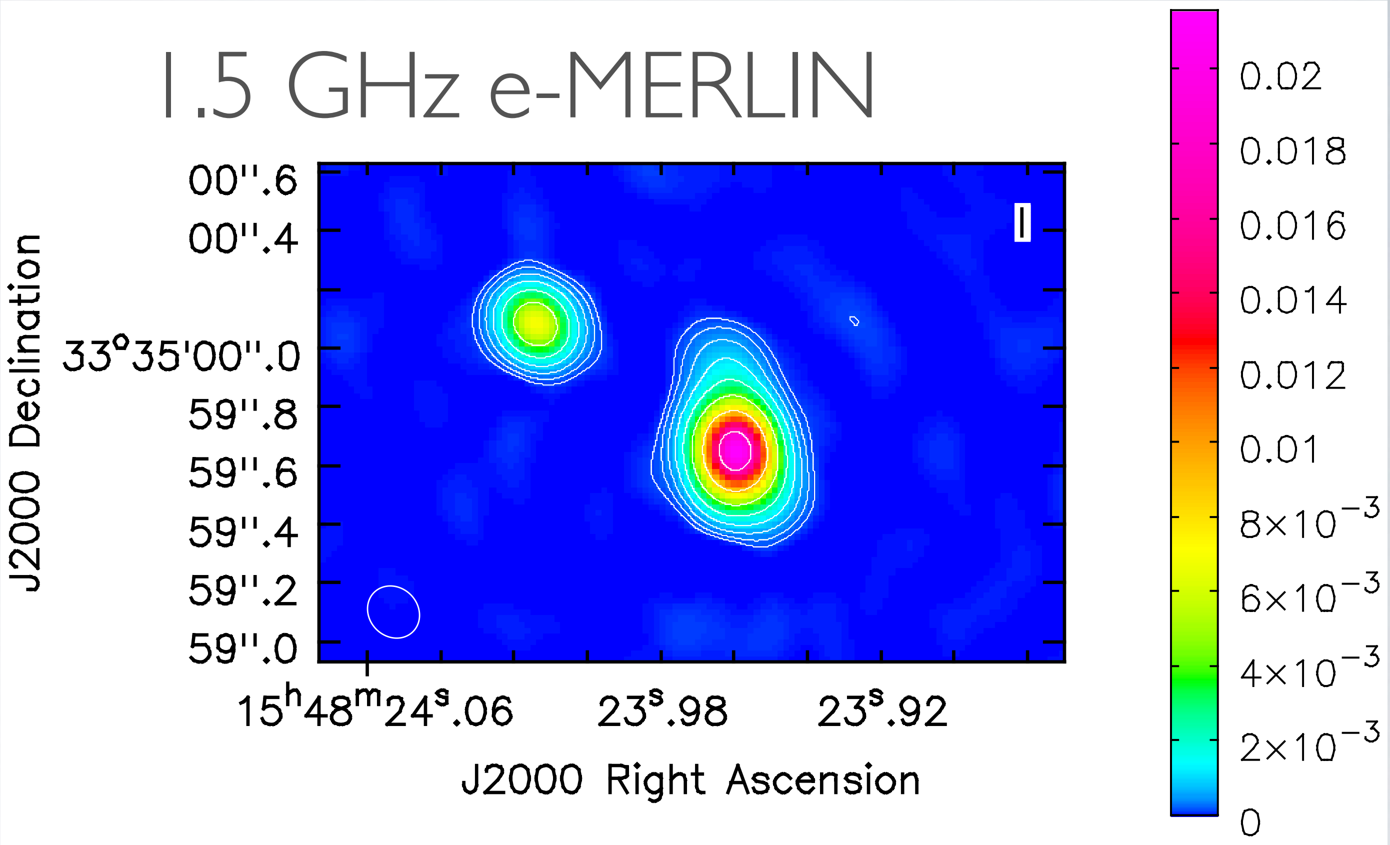
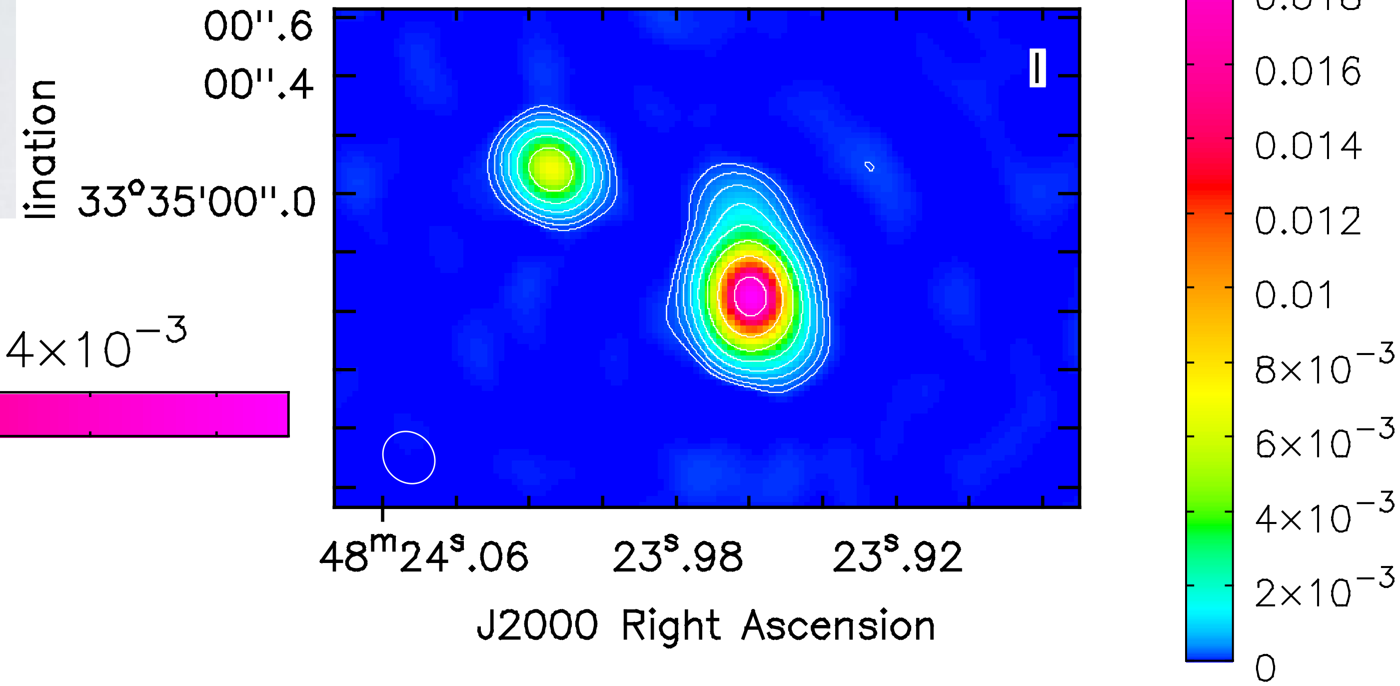
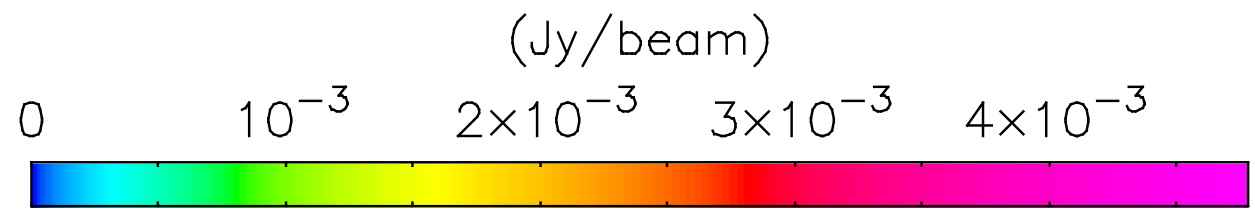


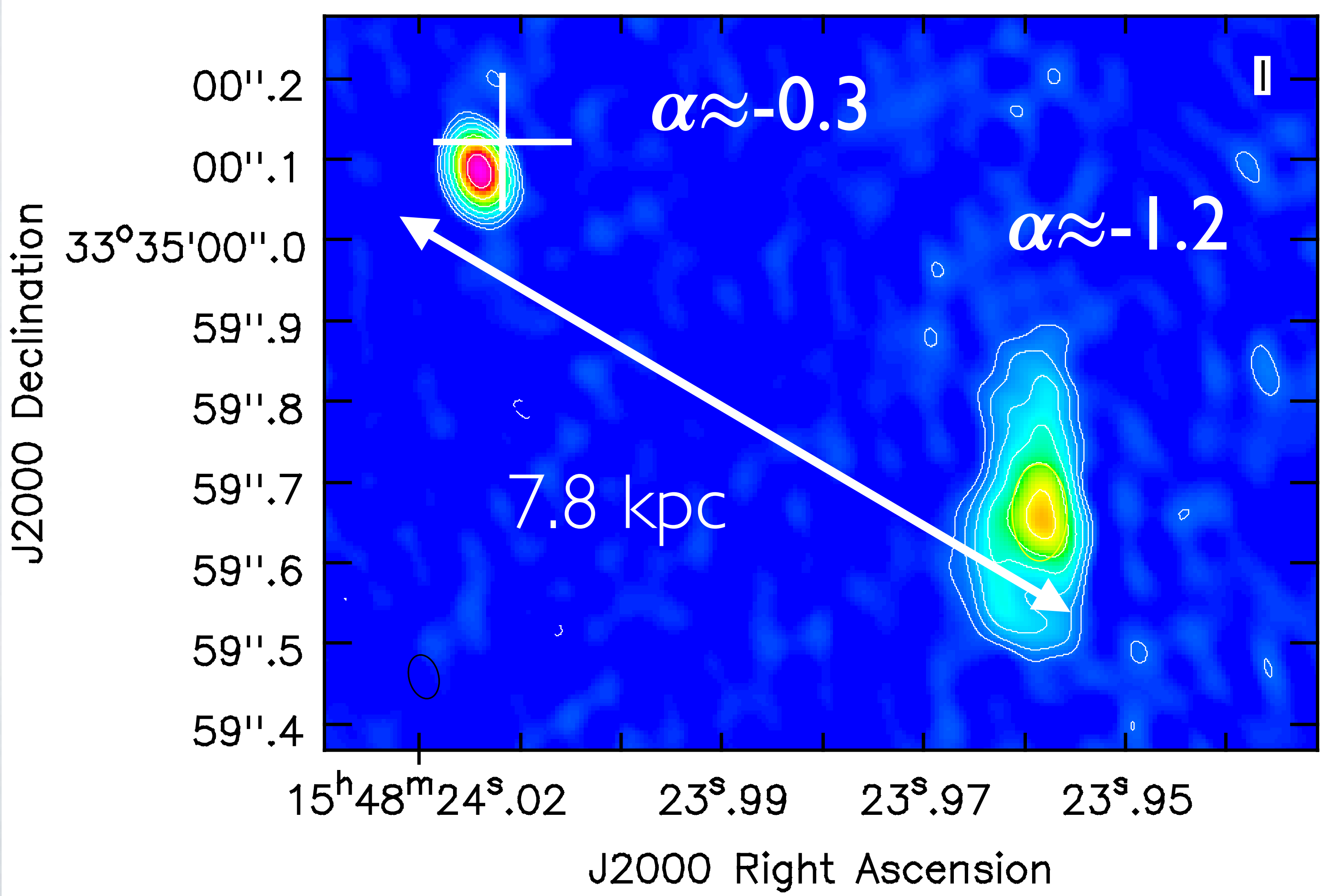
J1548+3335

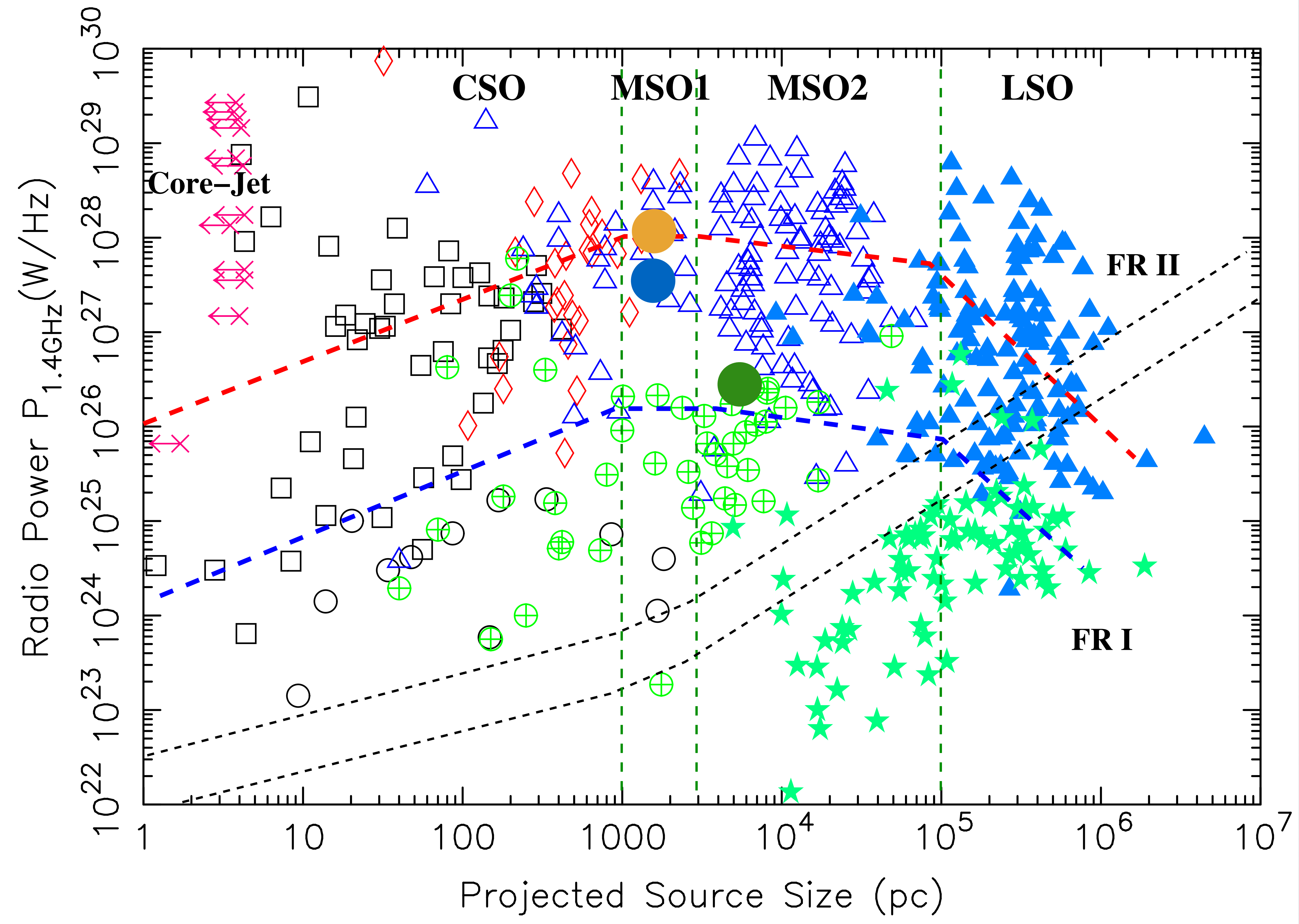
1.5 GHz e-MERLIN





5 GHz e-MERLIN





An & Baan, 2012 ApJ **760**, 77

SUMMARY AND FUTURE WORK

- VLBI can confirm or falsify the blazar nature of candidates
- e-MERLIN to map hot spots, lobes and jets
- Can the X-ray emission originate from the hot spots?

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