Searching for pairs of accreting supermassive black holes

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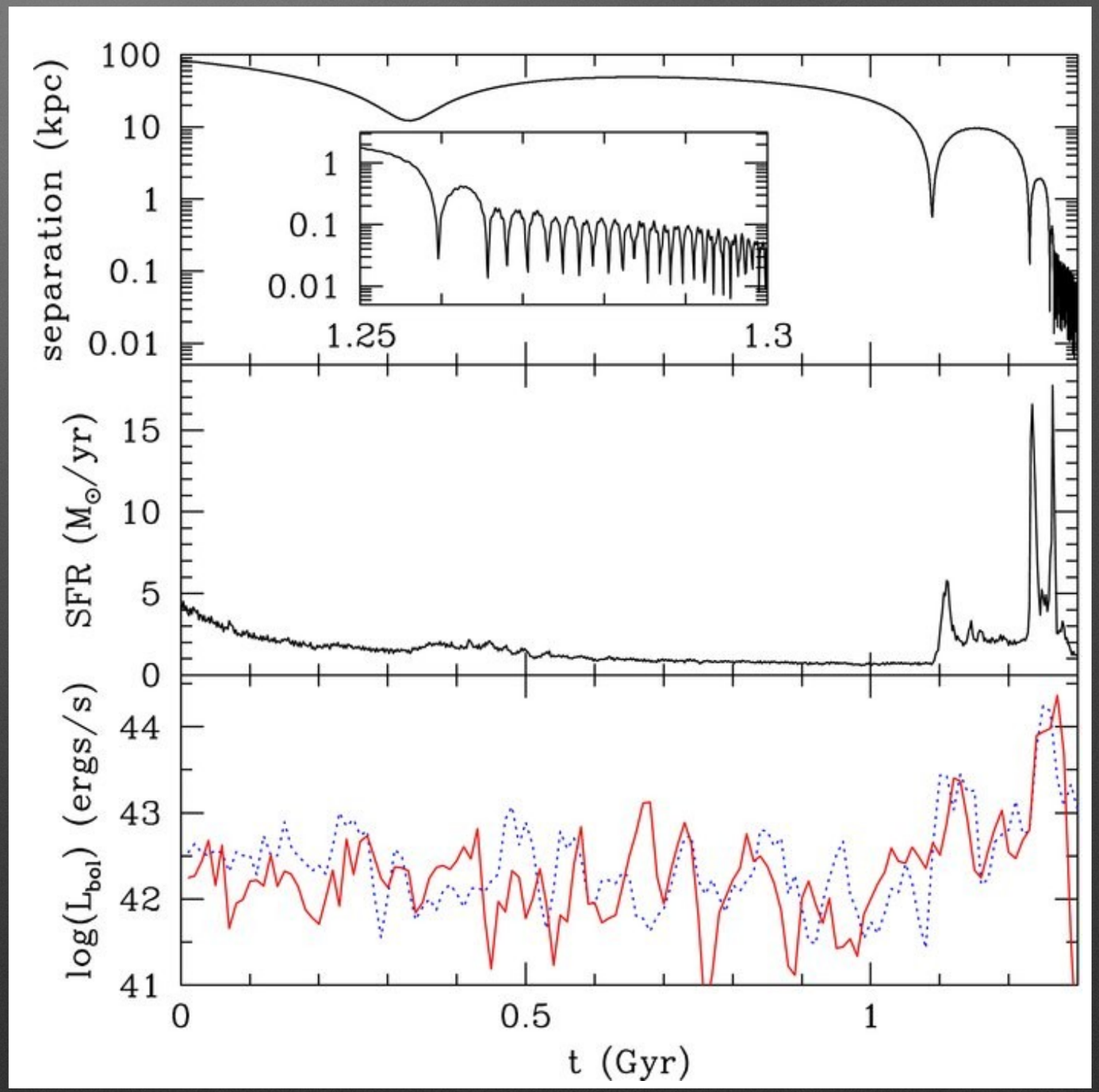
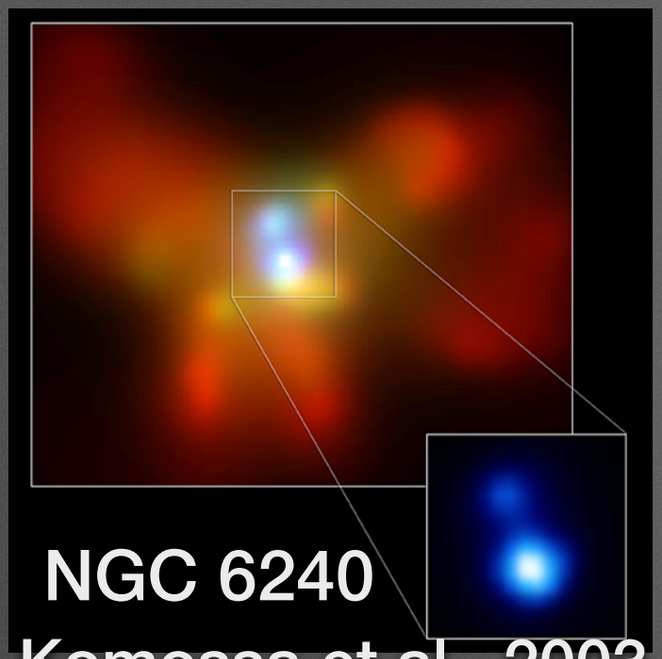
Why?

- Galaxies grew via merging events ⇒ the central BHs merge ⇒ dual/binary BH systems are expected to exist
- AGNs are “easy” to observe compared to non-active SMBHs
- Simultaneous activity is most likely at kpc-scale separation (e.g., van Wassenhove et al., 2012; Fu et al., 2015)



van Wassenhove et al. 2012

Examples



NGC 6240

Komossa et al., 2003

Beswick et al., 2001

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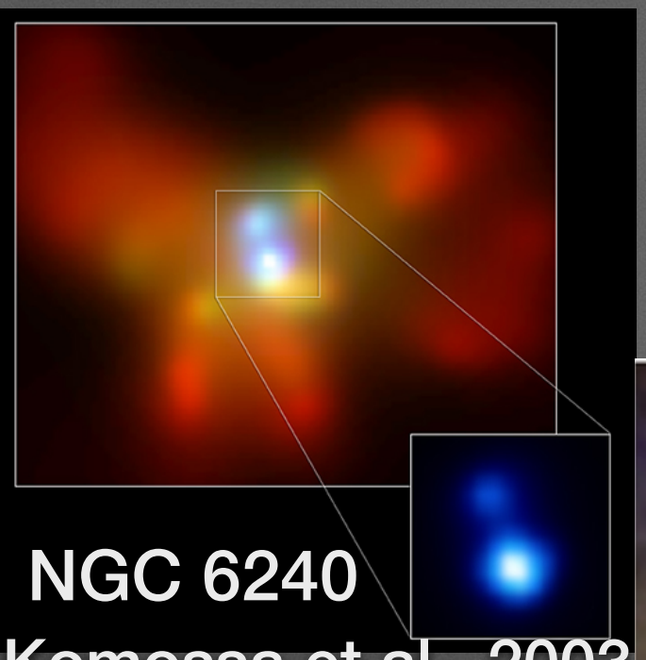

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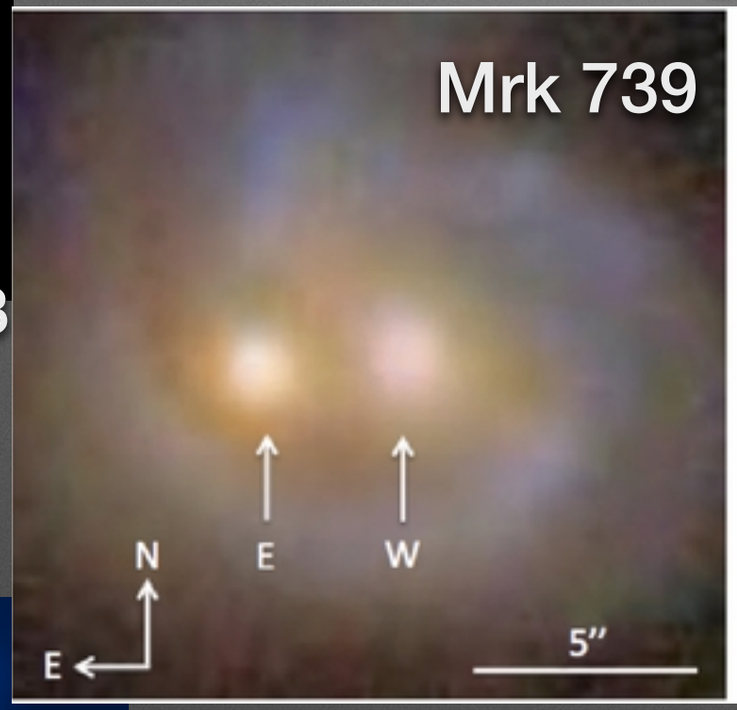
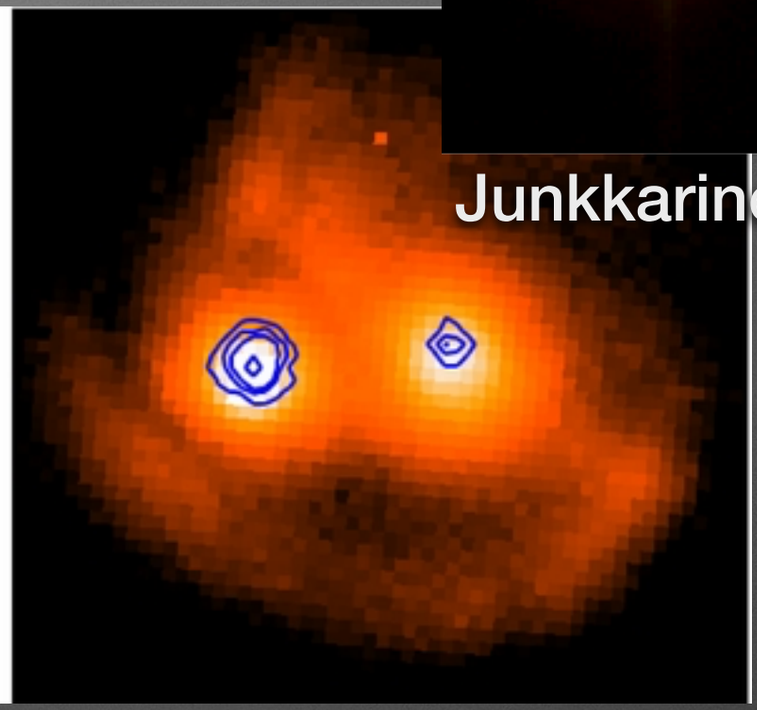
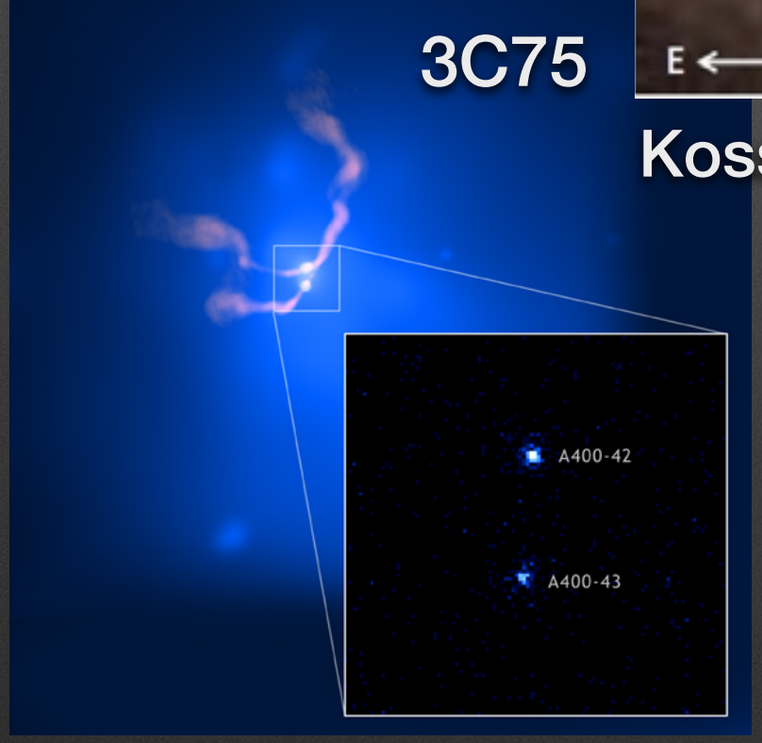


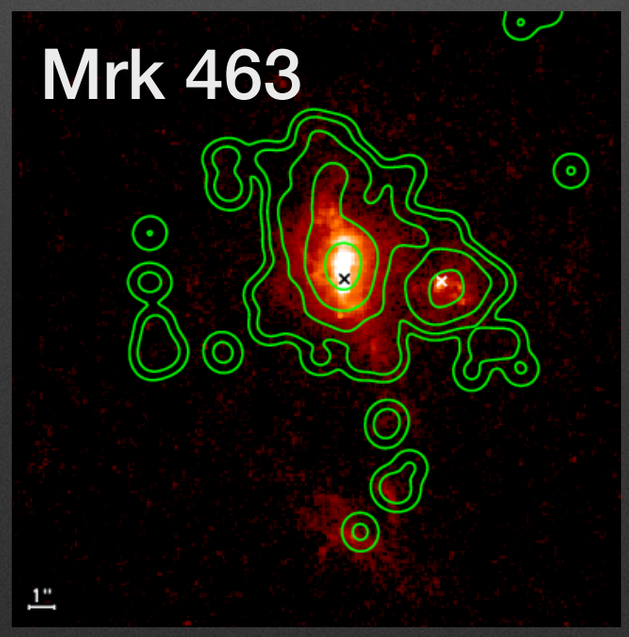
Koss et al., 2011



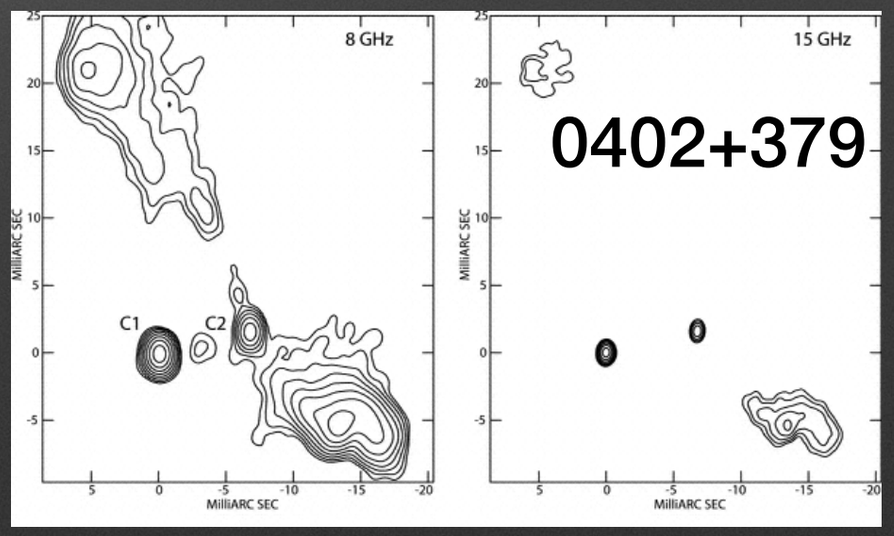
Junkkarinen et al. 2001



Hudson et al., 2006

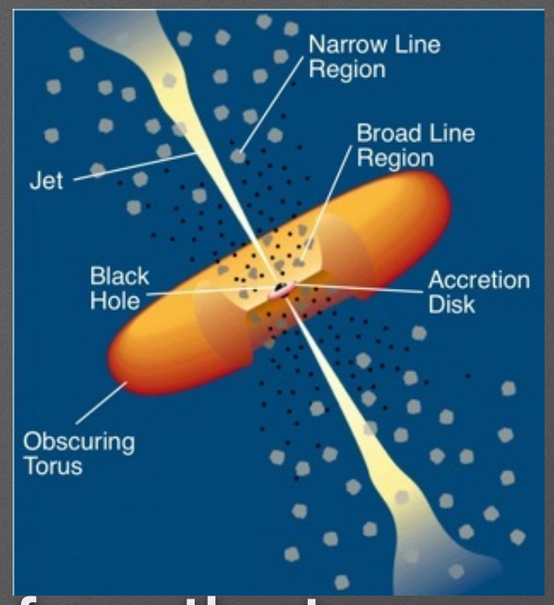


Bianchi et al. 2008



Rodriguez et al. 2006

How to find them?



- Double-peaked narrow optical emission lines - originating from the two distinct NLRs?
  - >70% of the double-peaked AGN are isolated AGN (Fu et al., 2011)
  - Other reasons behind double-peaked: jet-cloud interaction, rotating NLR, outflowing NLR, blobby NLR + extinction, single AGN illuminating the ISM of two merging galaxy,… (Xu & Komossa, 2009; Crenshaw et al., 2010; Heckman et al., 1984)

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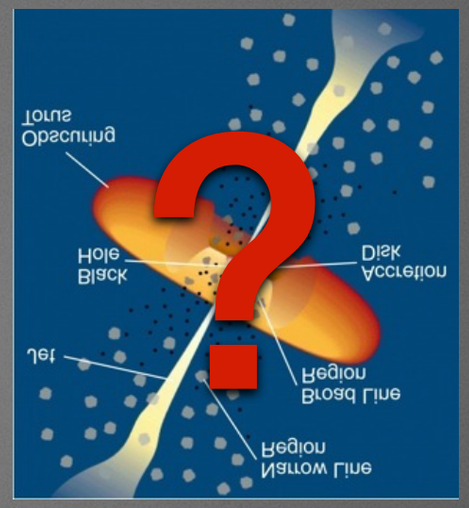

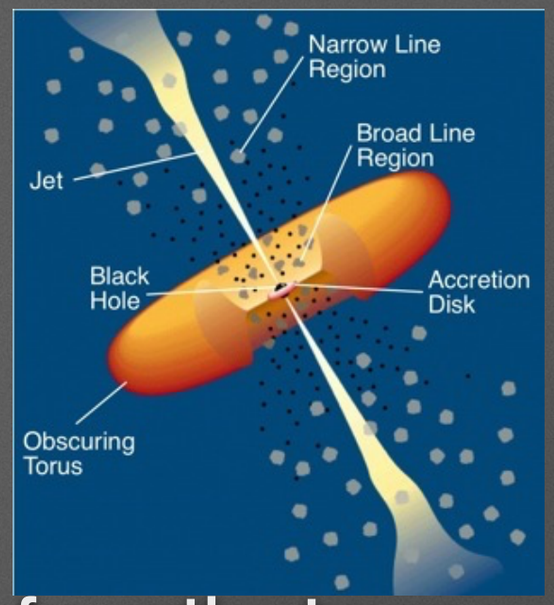

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- Double-peaked + Spatially compact emissions, along the host galaxy axes, an indication for a pair of AGN? (Comerford et al., 2012)

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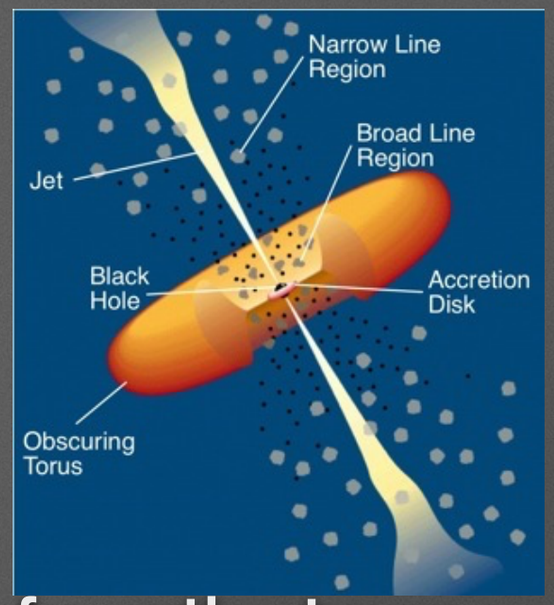

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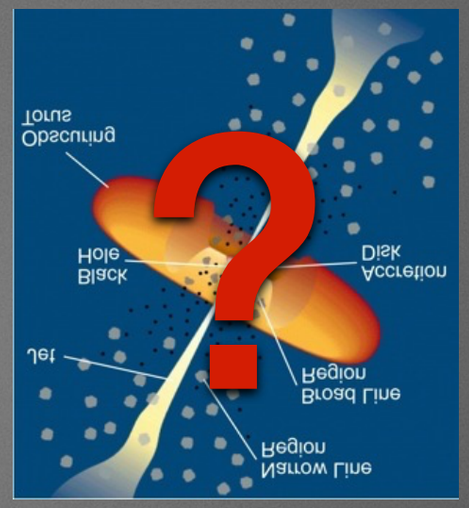

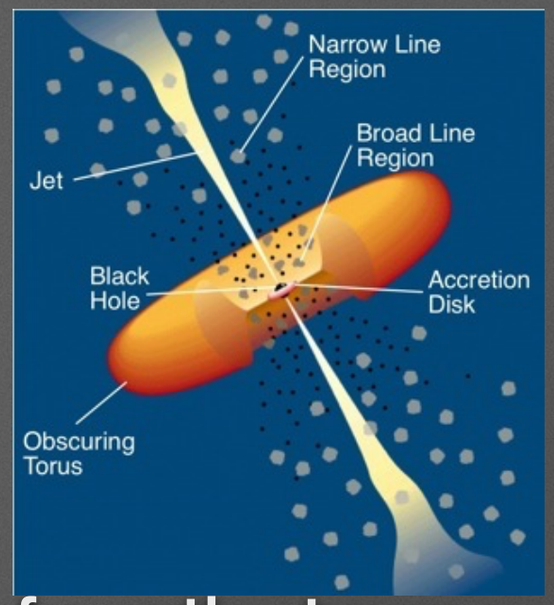

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- Checking VLBI archival observations Burke-Spolaor (2011): 1/3114

Examples of double-peaked sources followed up by radio interferometric observations

- Tingay & Wayth (2011): 0/11 (VLBA)
- Müller-Sanchez et al. (2015): 3/18 (VLA)
- Gabányi et al. 2016: 0/4 (VLBA)

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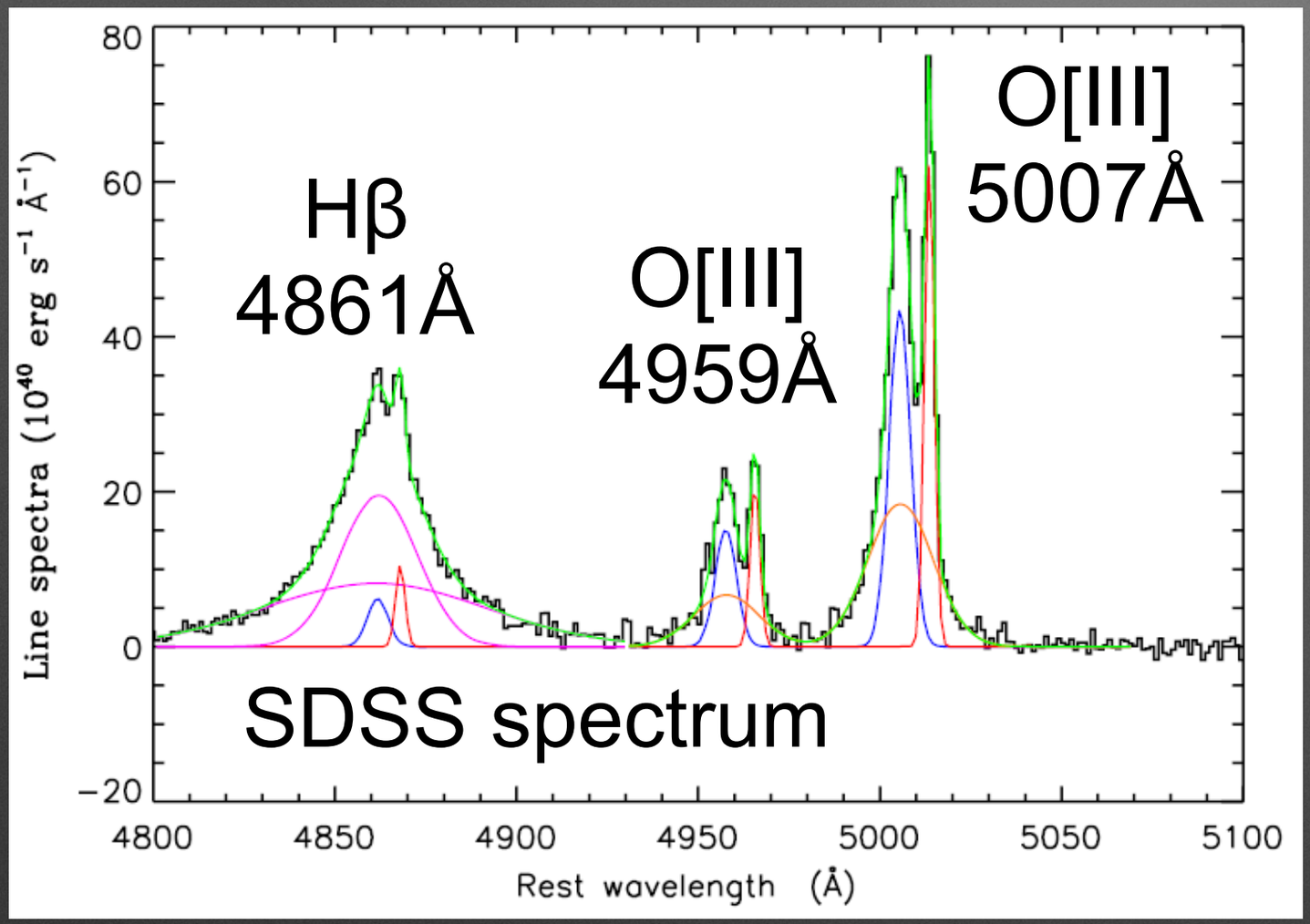
- Bondi & Pérez-Torres (2010): a pair of sub-mJy AGN at 5 kpc separations (EVN)
- Fu et al. (2011): double in near-infrared, dual radio-emitters (sub-mJy, 7.4 kpc) (VLA) → even triple? Deane et al. Nature 2014
- Yang et al. (2016): in NGC 5252 an ULX turned out to be AGN (EVN), see also poster #5 by Minjin Kim

The case of J1425+3231



Peng et al., 2011, RAA, 11, 141

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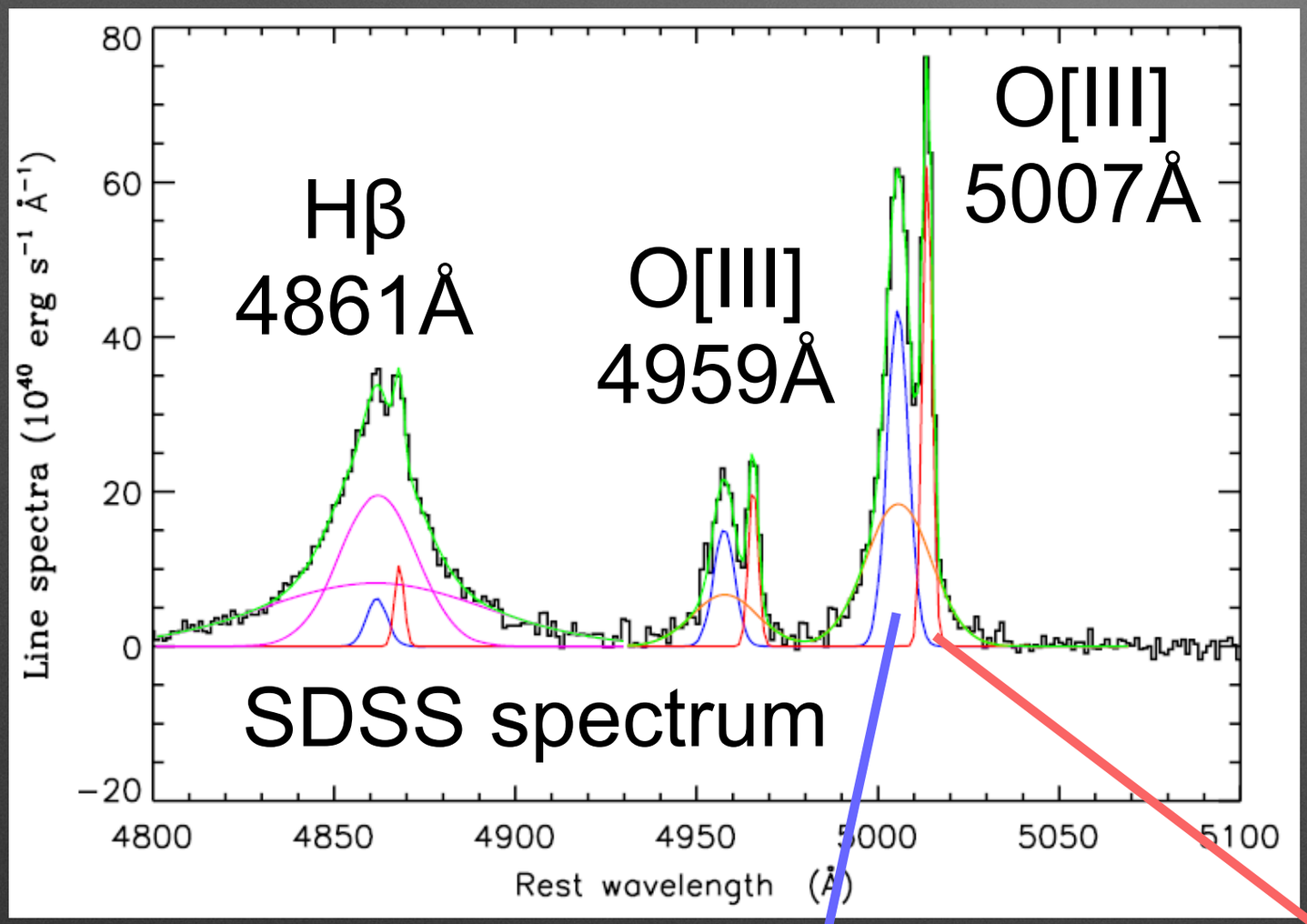

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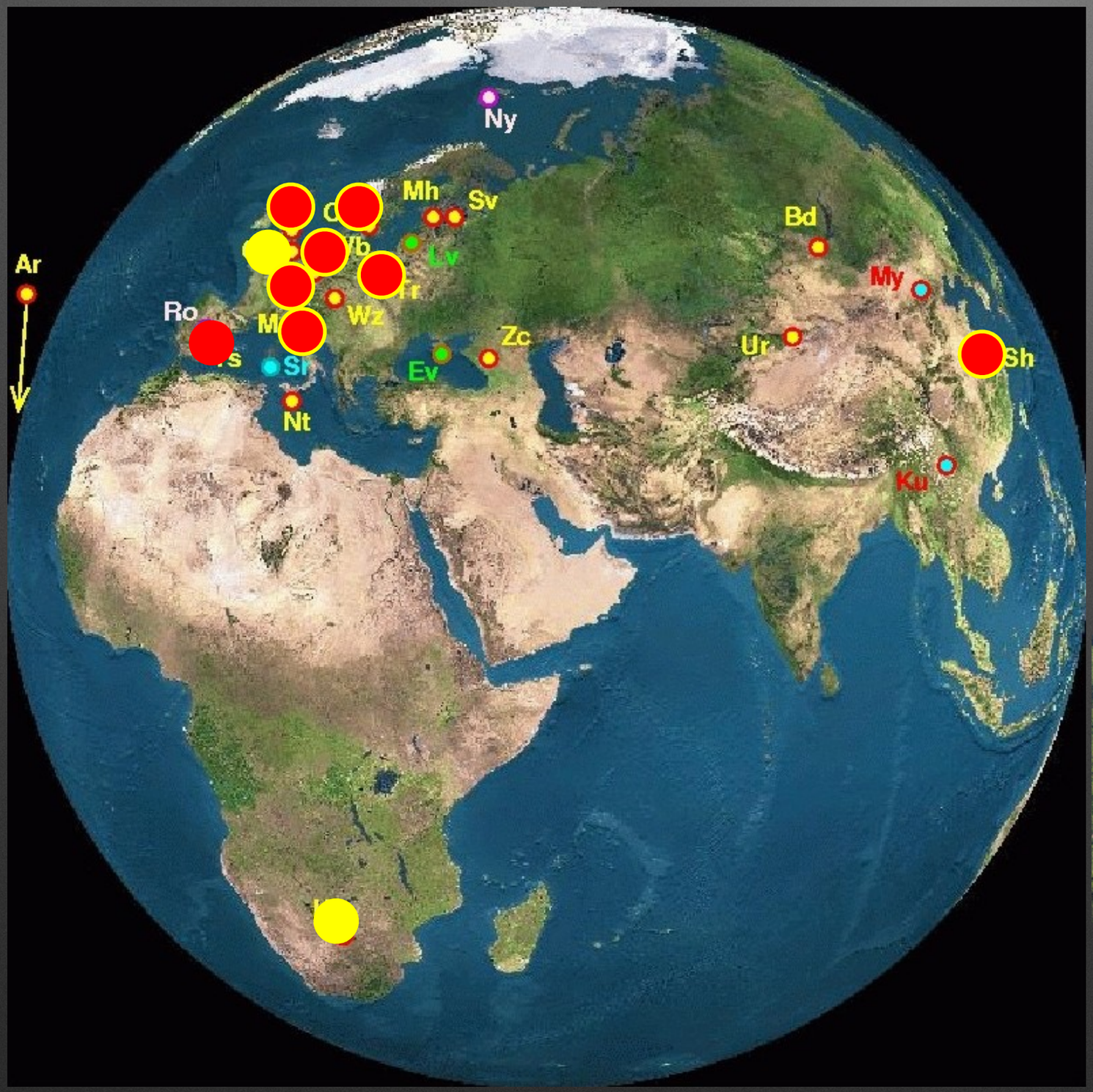
$8.3 \times 10^7\ M_\odot$

$3.4 \times 10^6\ M_\odot$

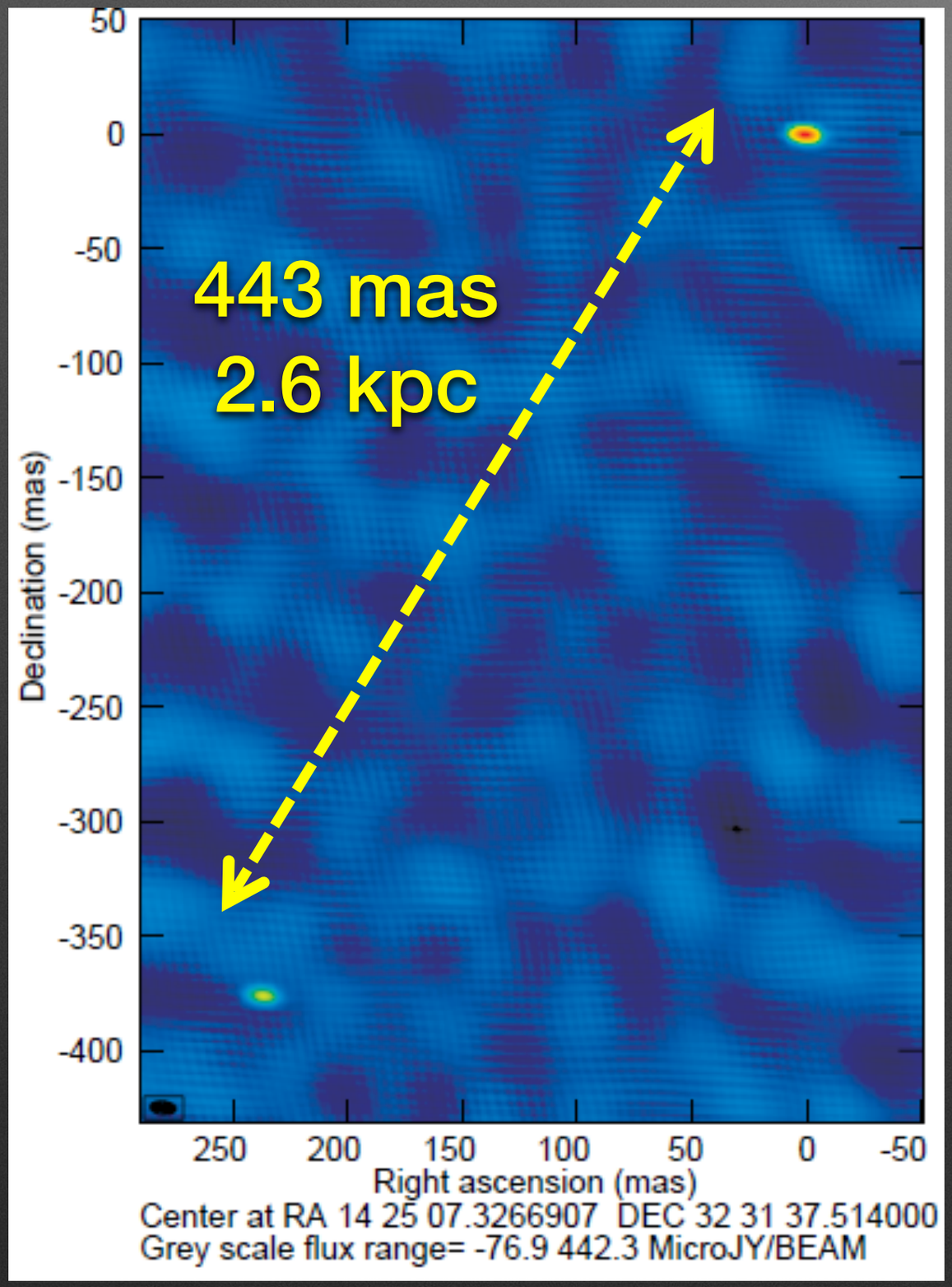
European VLBI Network observations



1.7 GHz - 2011 Jan 26

5 GHz - 2011 Oct 18

EVN results at 1.7 GHz



Frey et al., 2012, MNRAS, **425**, 1185

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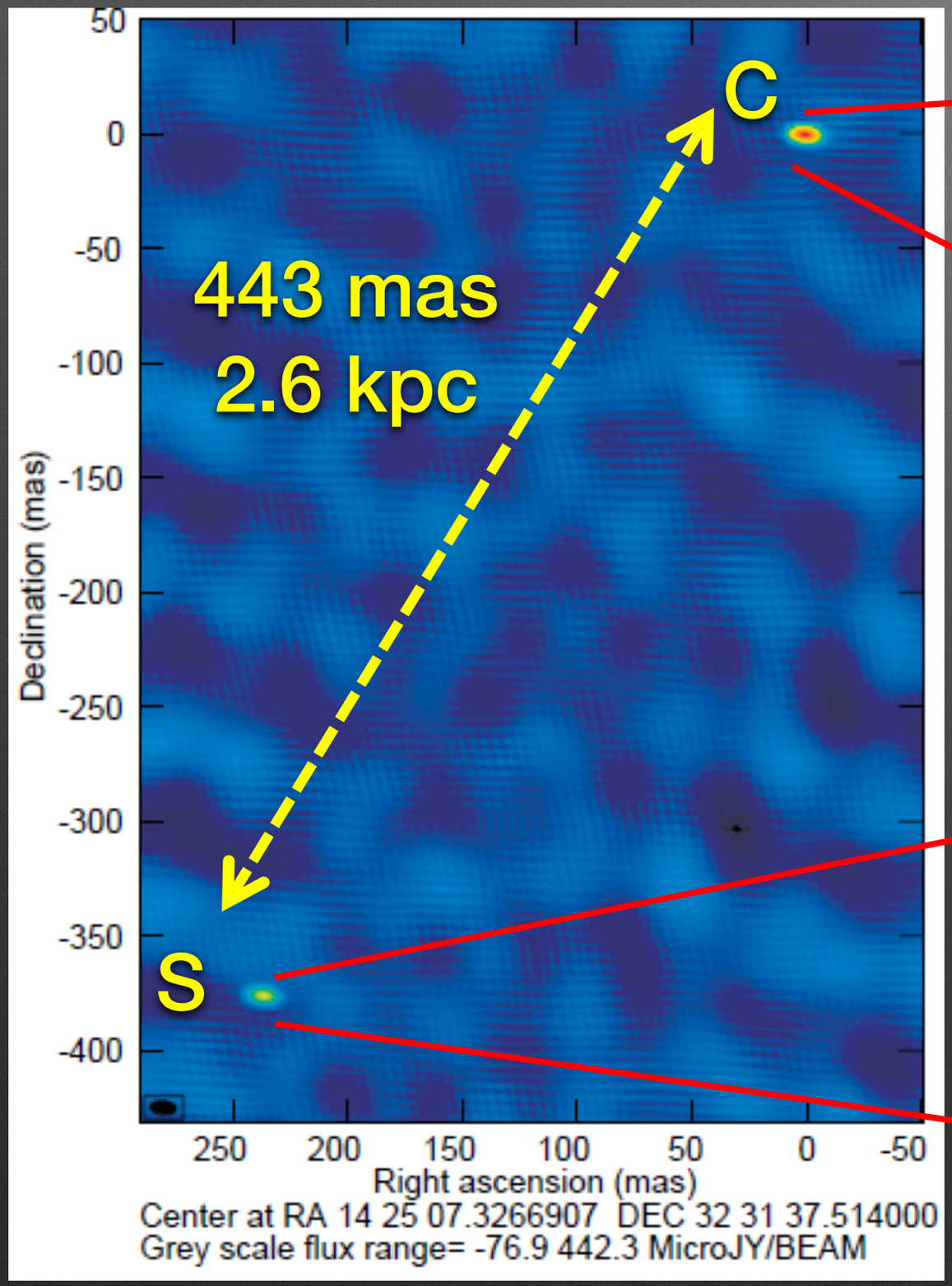

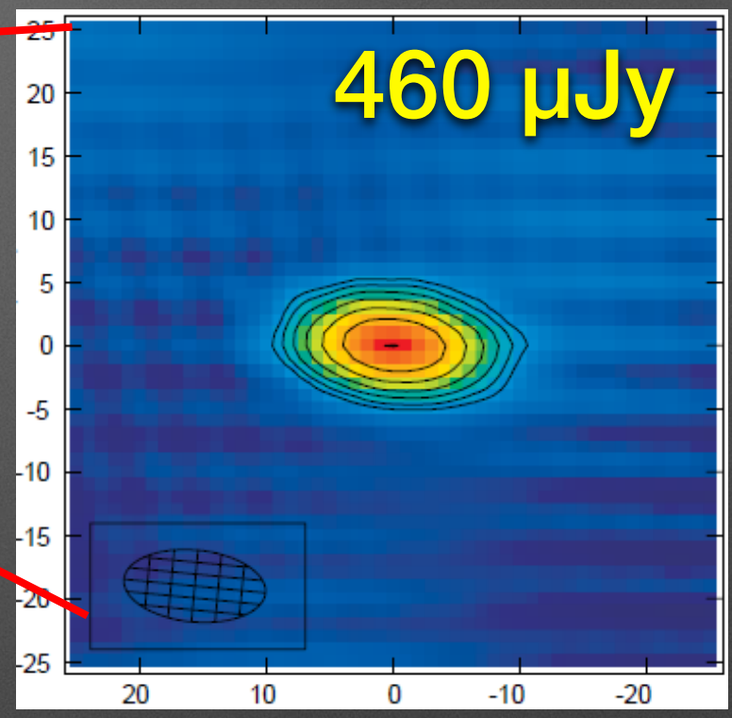

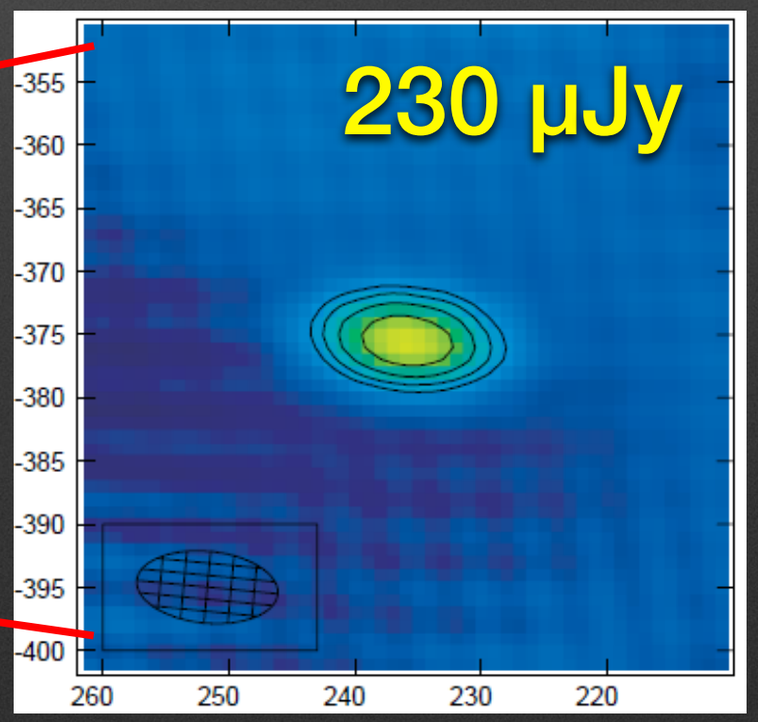

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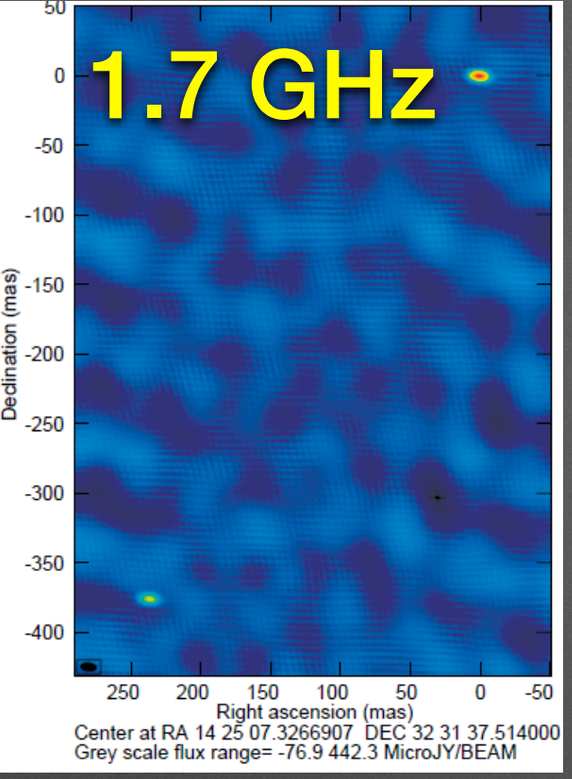

EVN results

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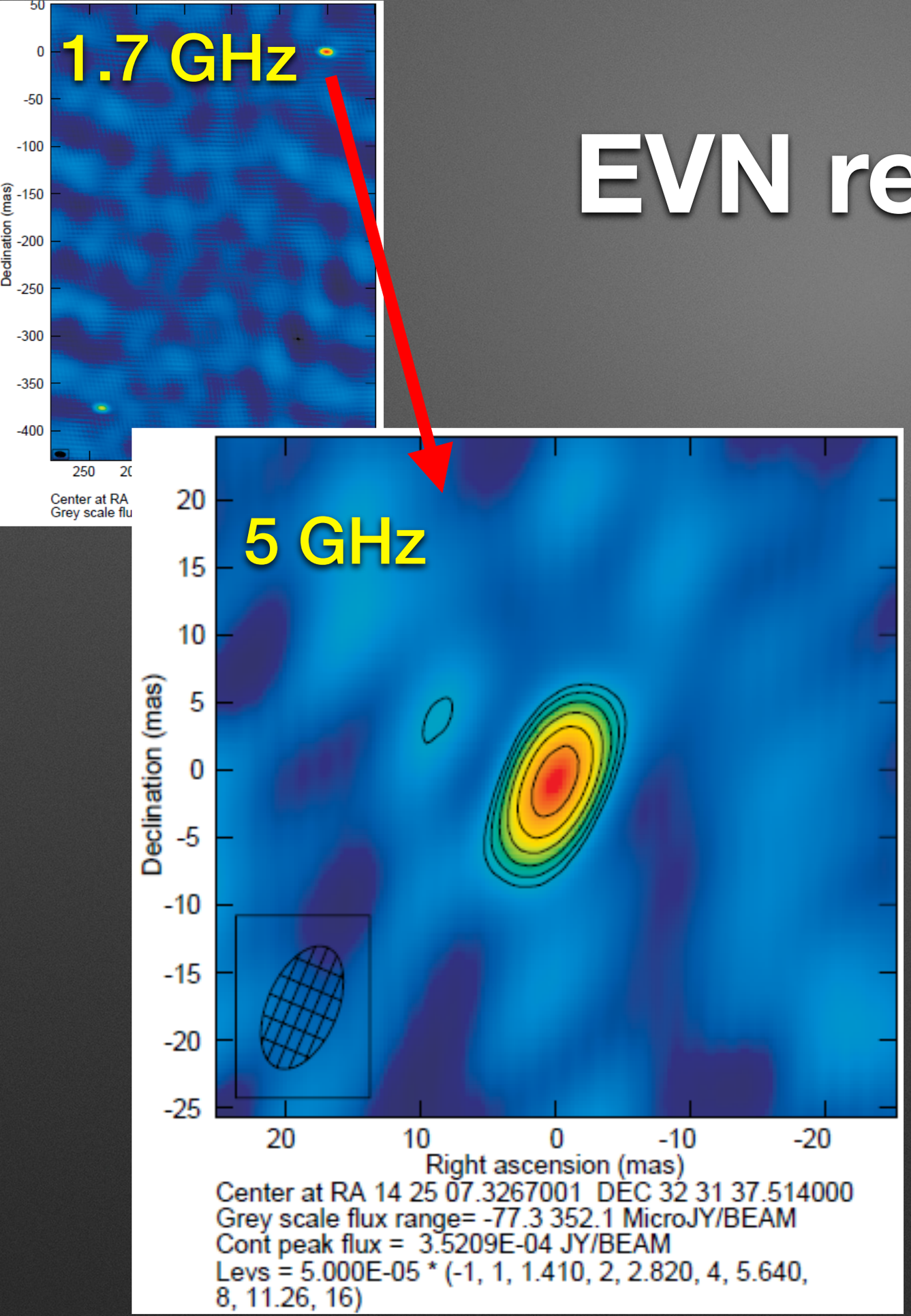


- Only the brighter (C) feature was detected
  - flat spectrum, α=–0.23
  - brightness temperature: 10^8K ⇒ suggests AGN
- S: <0.085 mJy at 5 GHz ⇒
  - steep spectrum, α<–0.9

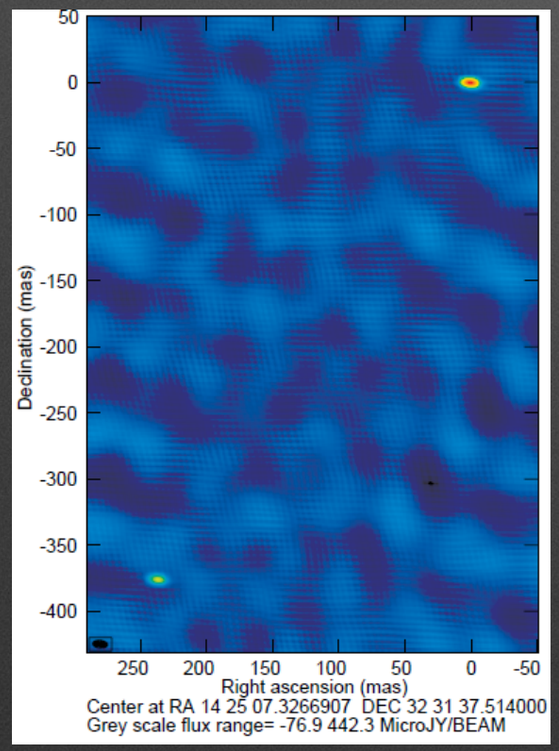
Frey et al., 2012, MNRAS, 425, 1185

e-MERLIN observations

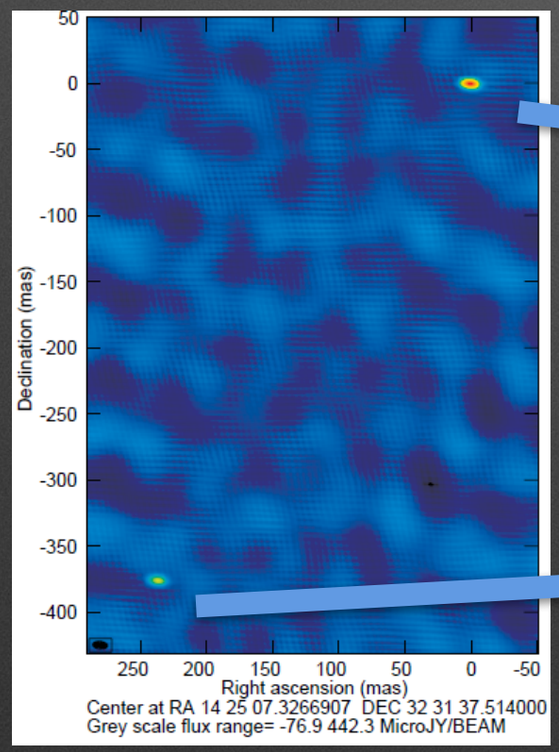
1.6 GHz - 2015 Oct

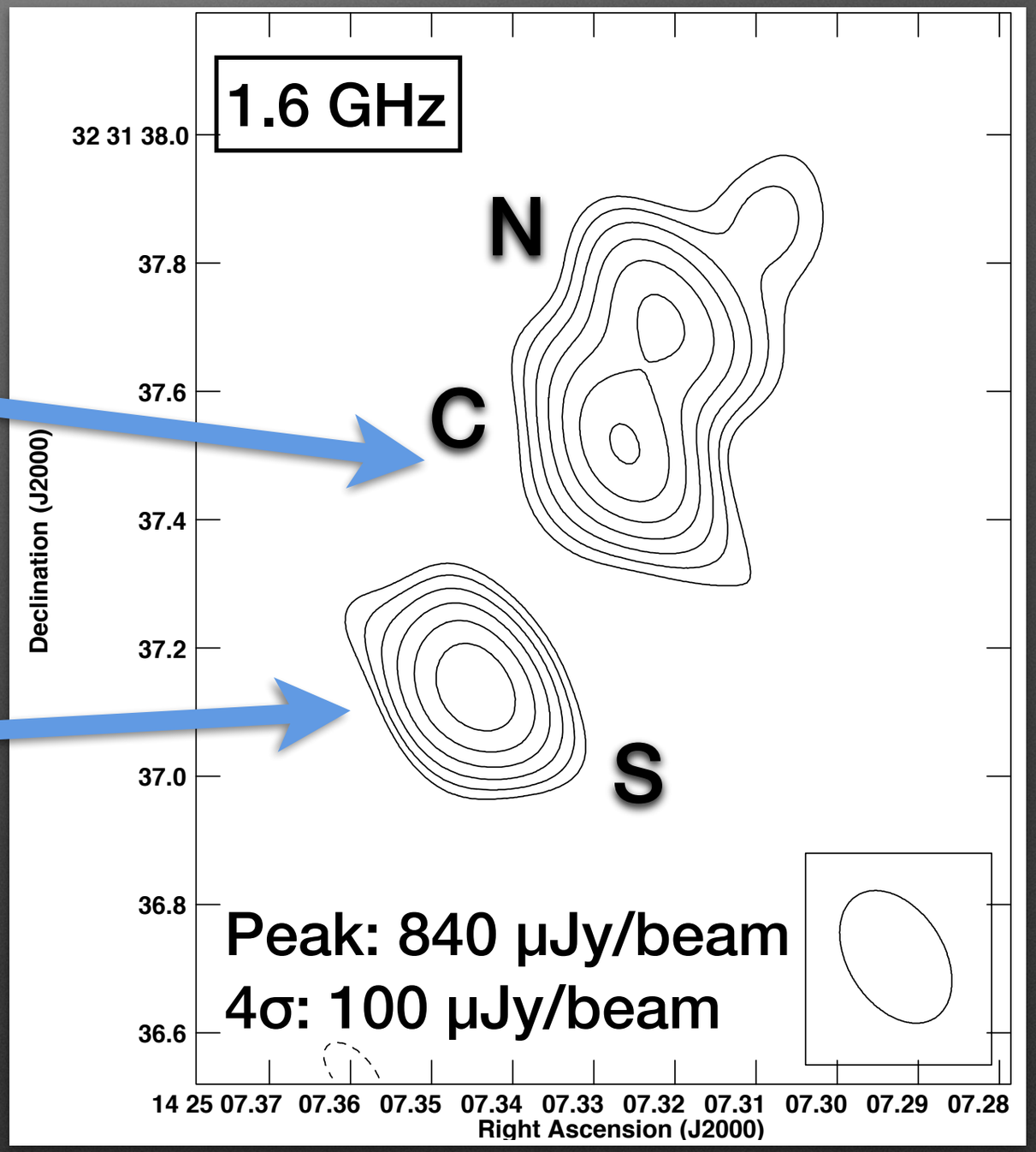
5 GHz - 2014 Nov

e-MERLIN results at 1.6 GHz



e-MERLIN results at 1.6 GHz





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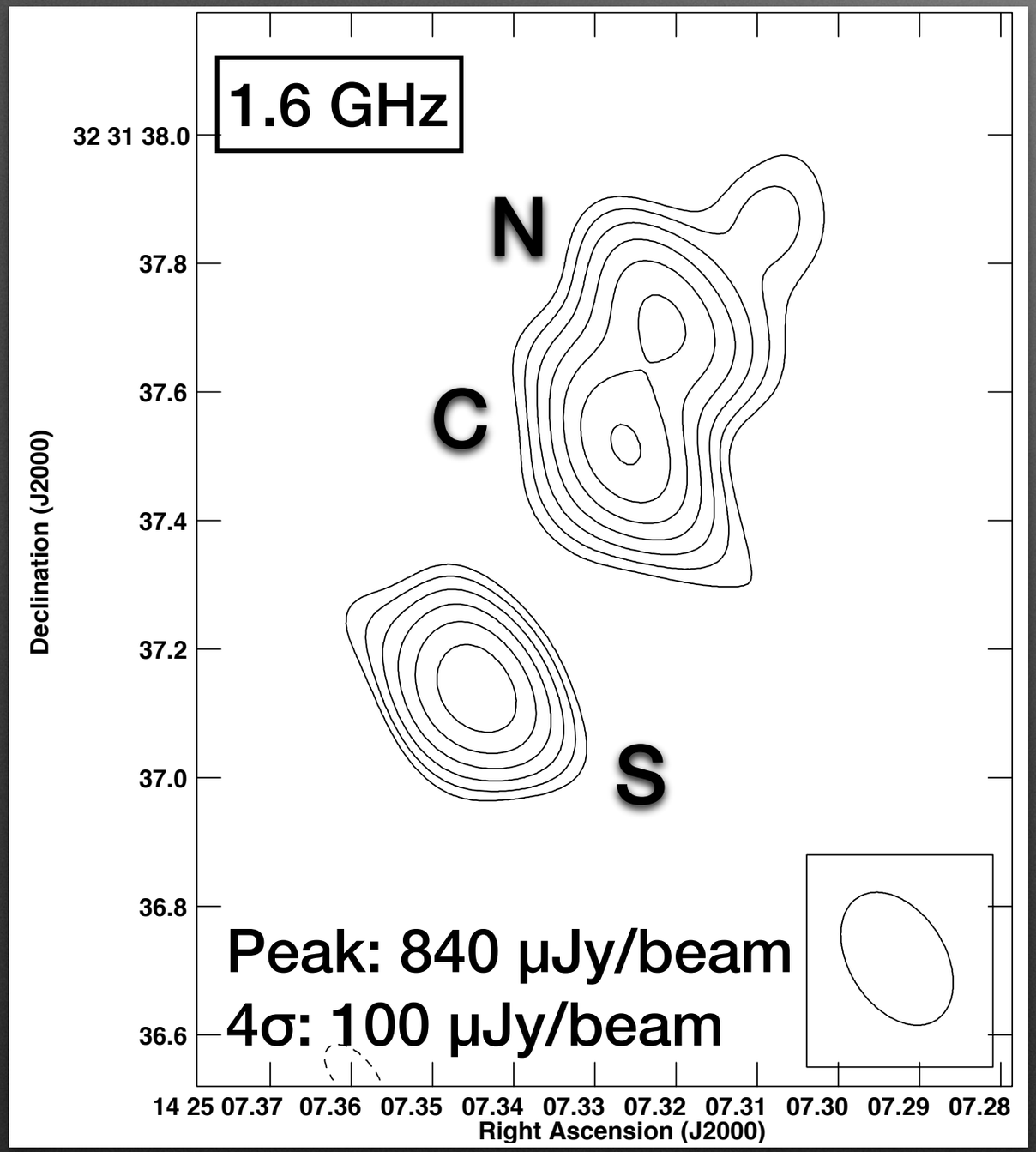

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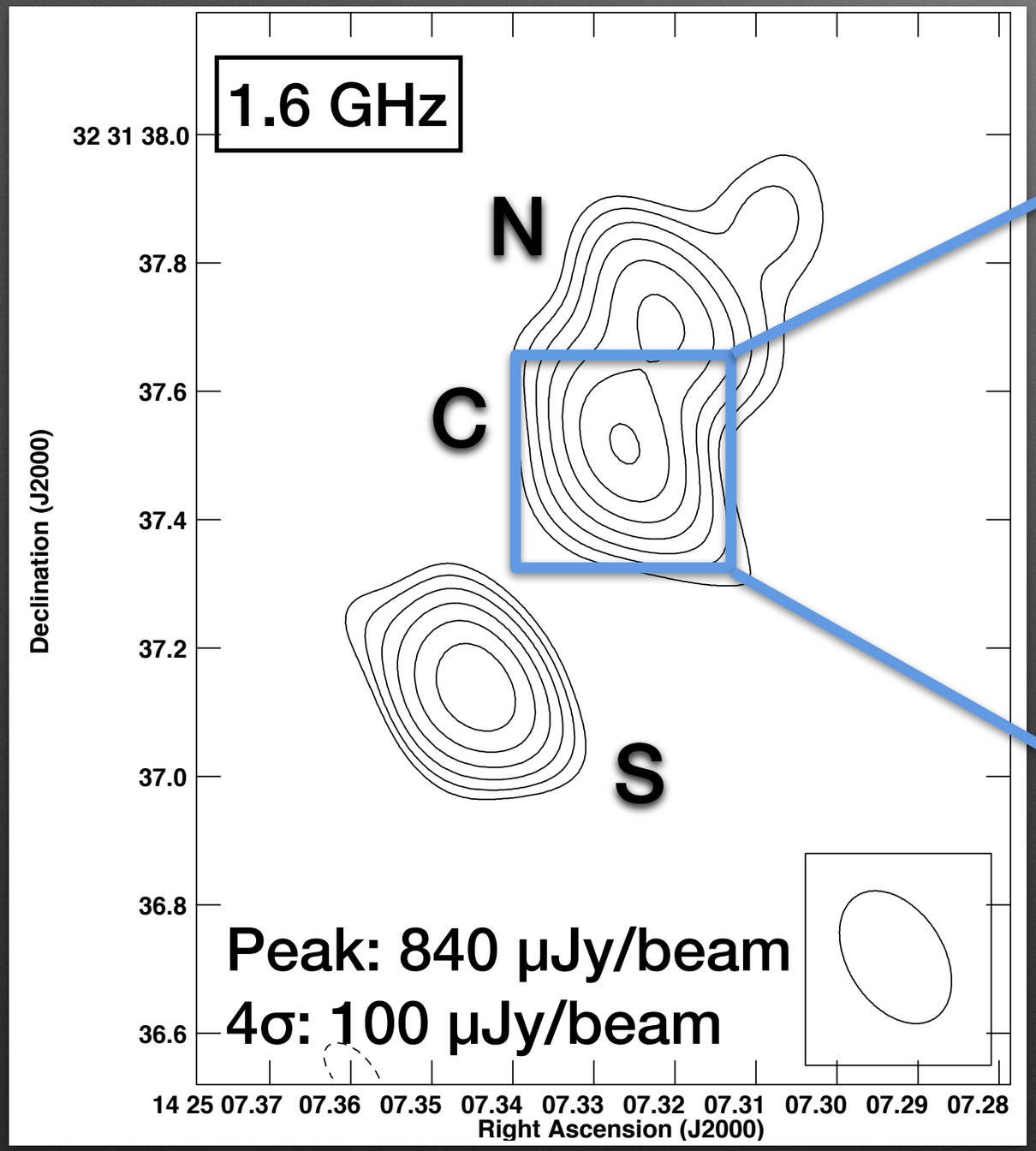

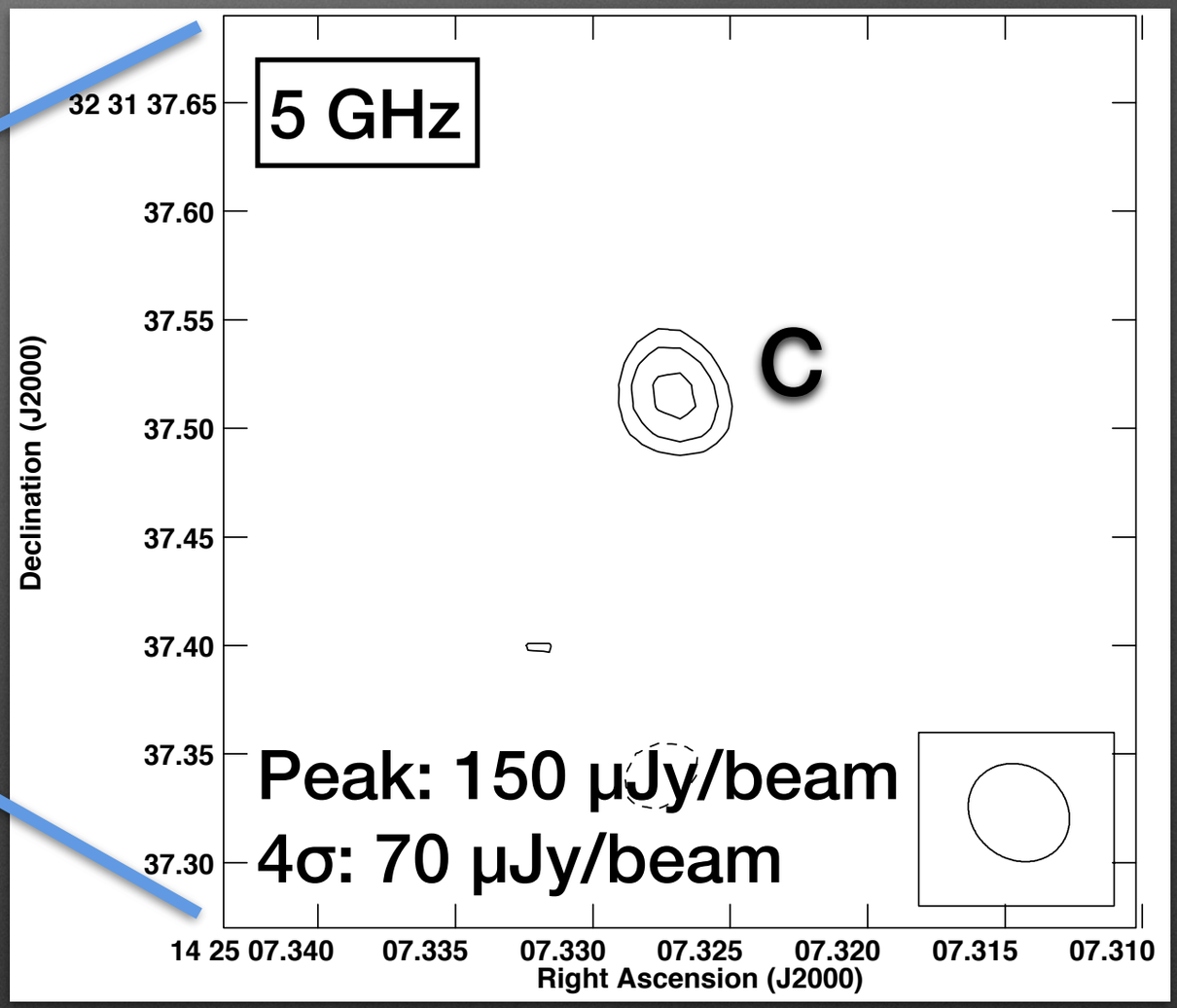

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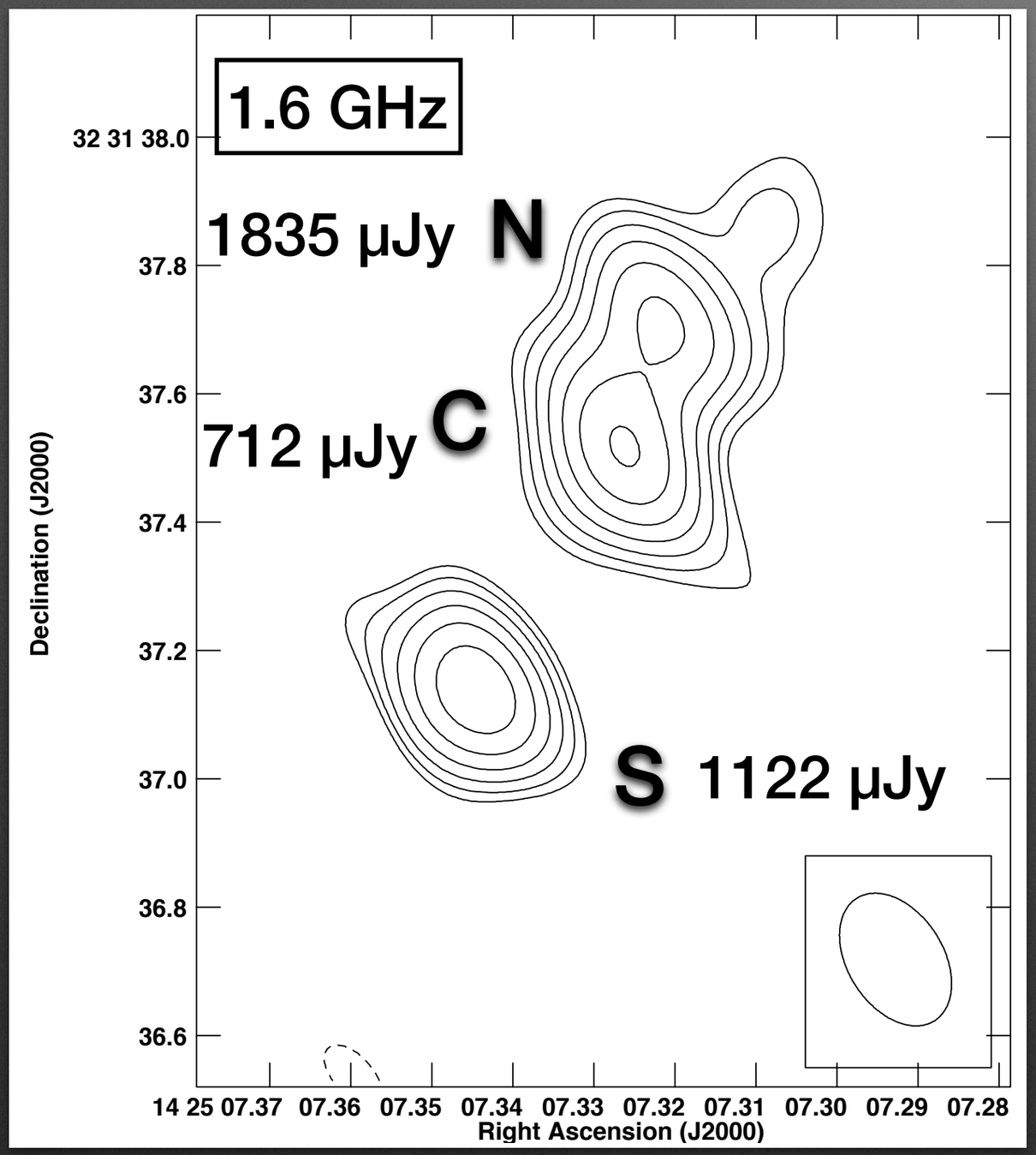
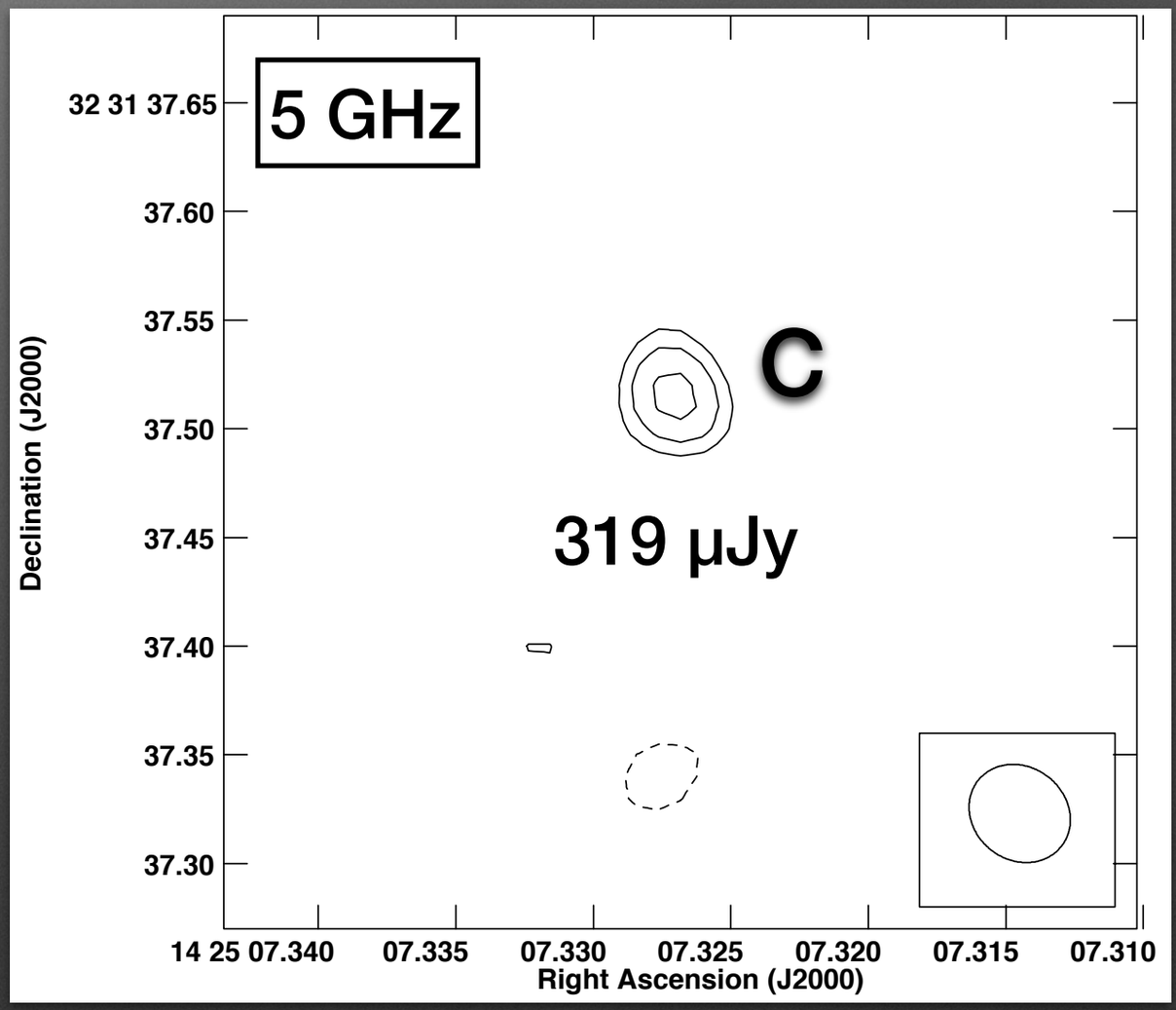
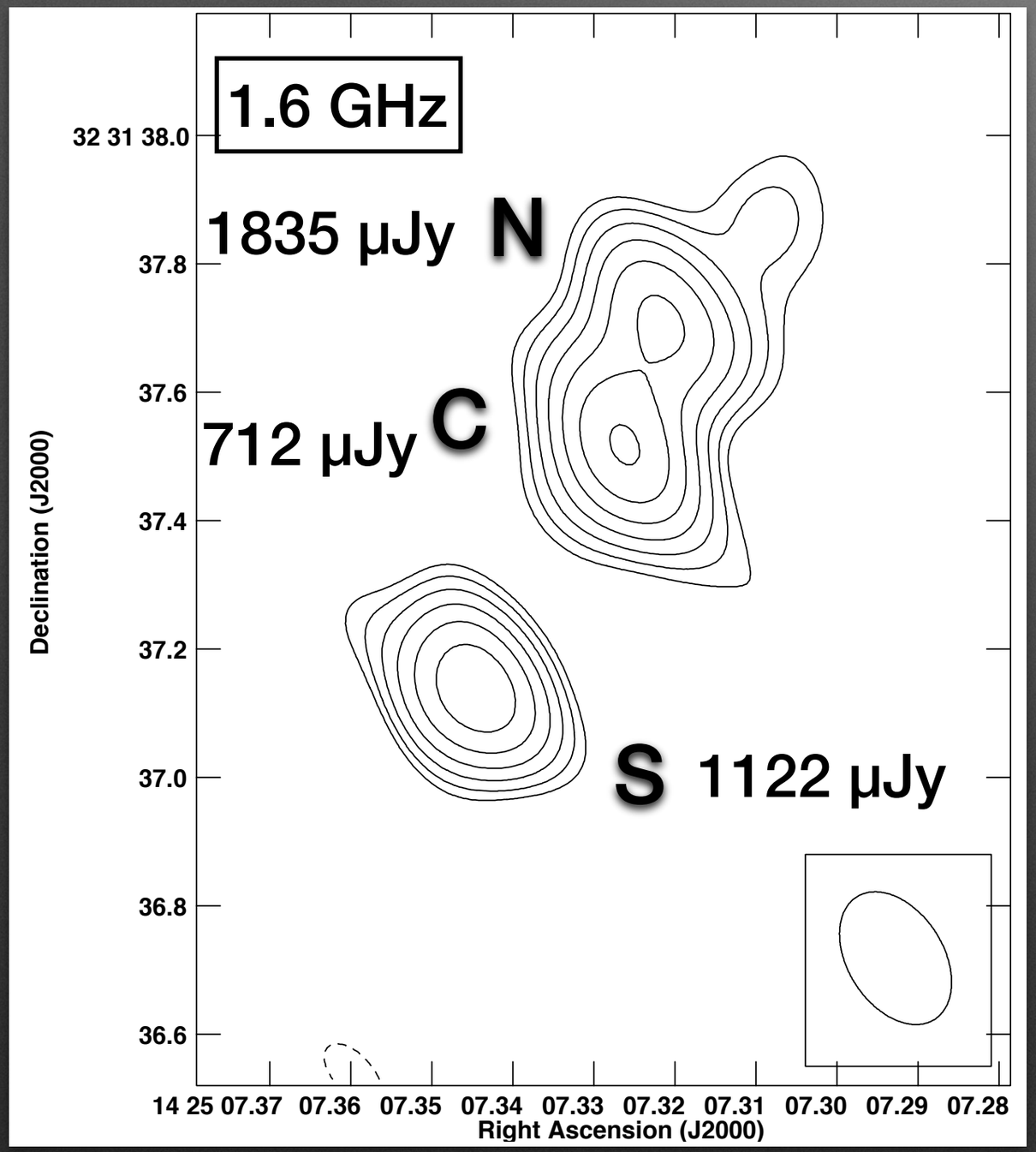




Explaining the radio data of J1425+3231



(I) single AGN:

- core - C
- N - jet
- S - lobe with a compact hotspot

(II) pair of AGN:

- C and S are cores
- N: one-sided jet of C

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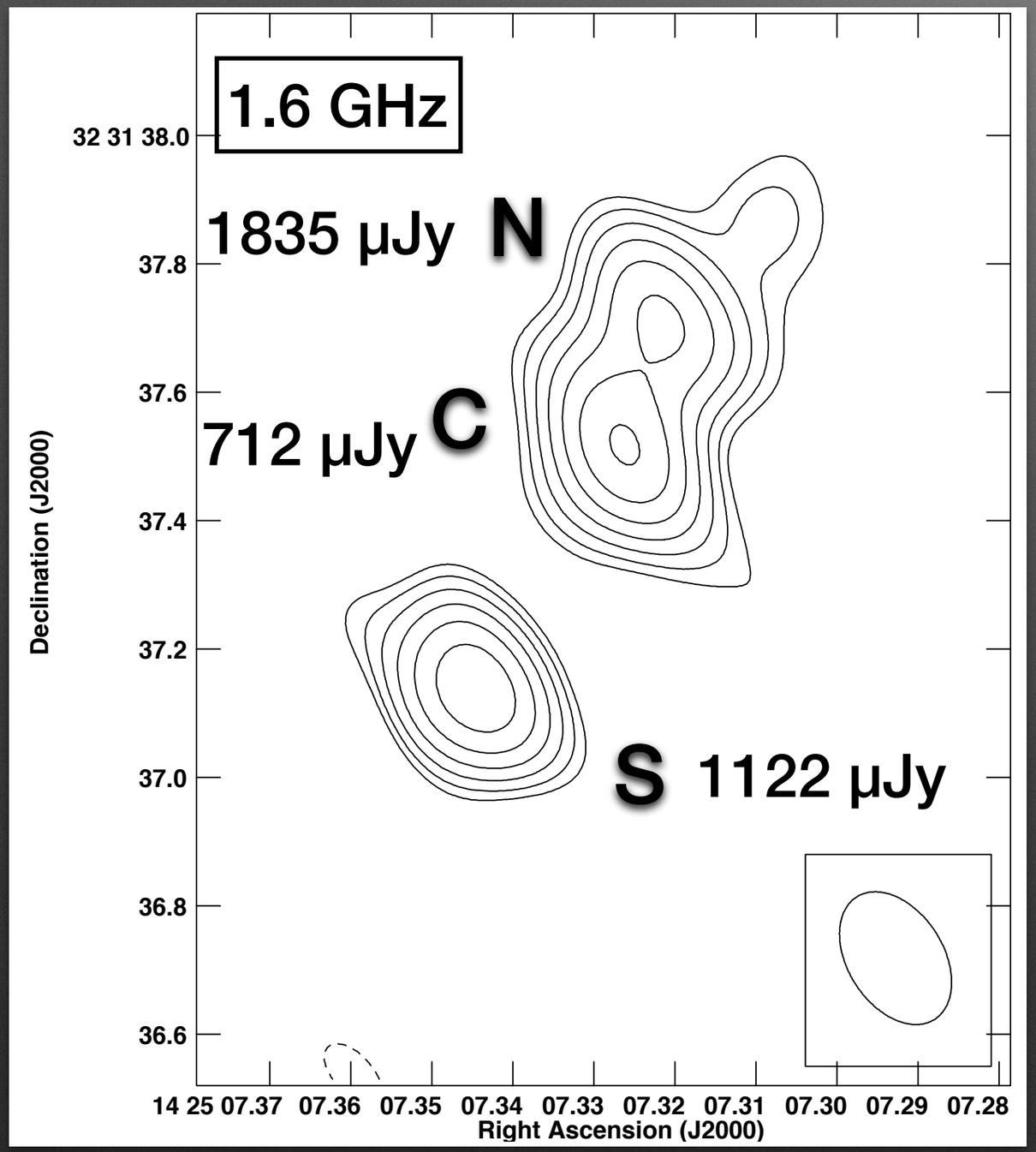

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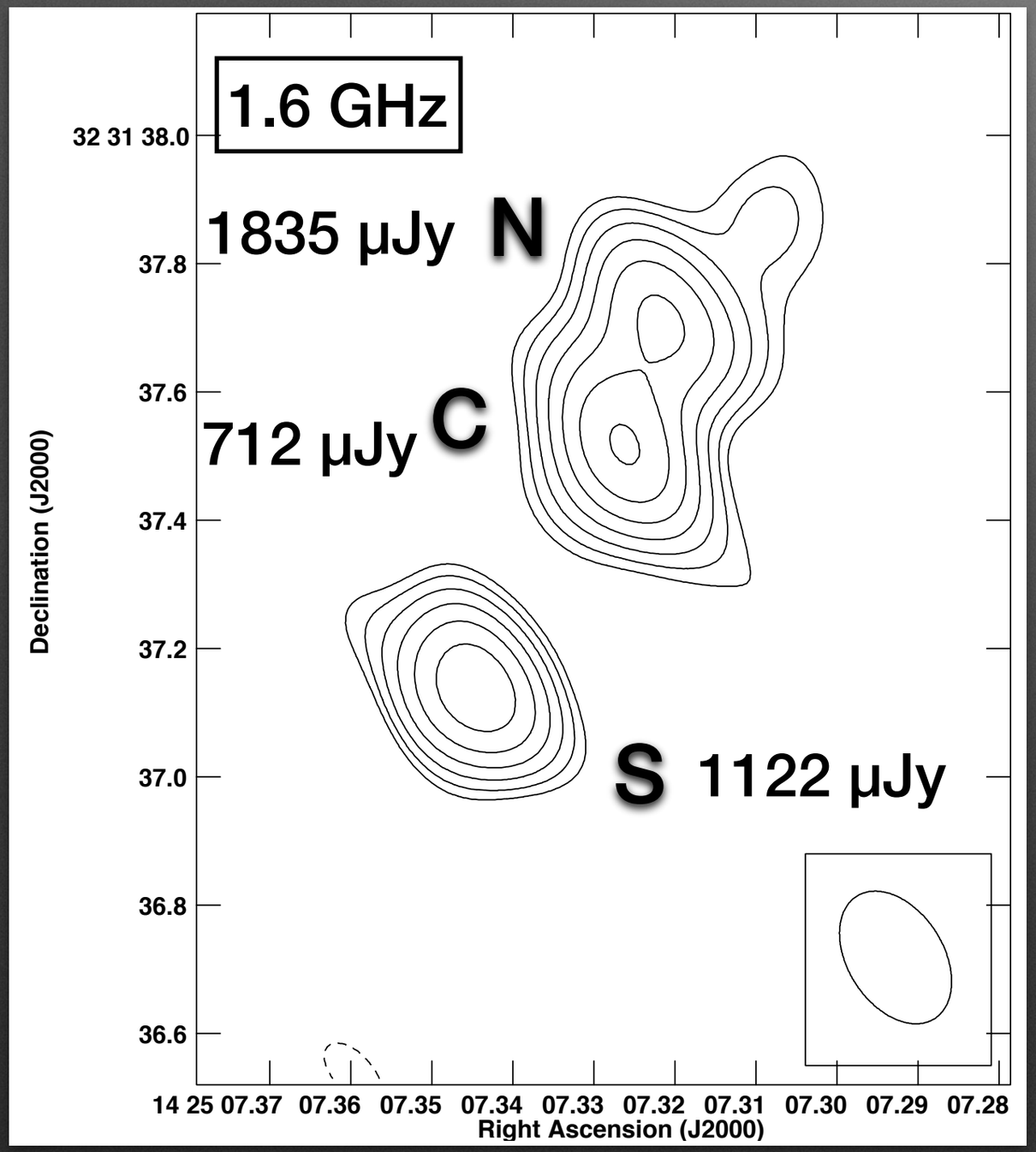

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→ double-peaked lines are likely related to outflows

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↔ S is undetected at 5 GHz

Conclusion

- Not everything is dual AGN which looks like a dual AGN
- We still need reliable indicators to assemble large sample of dual AGN candidates

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If you see too many doubles: