

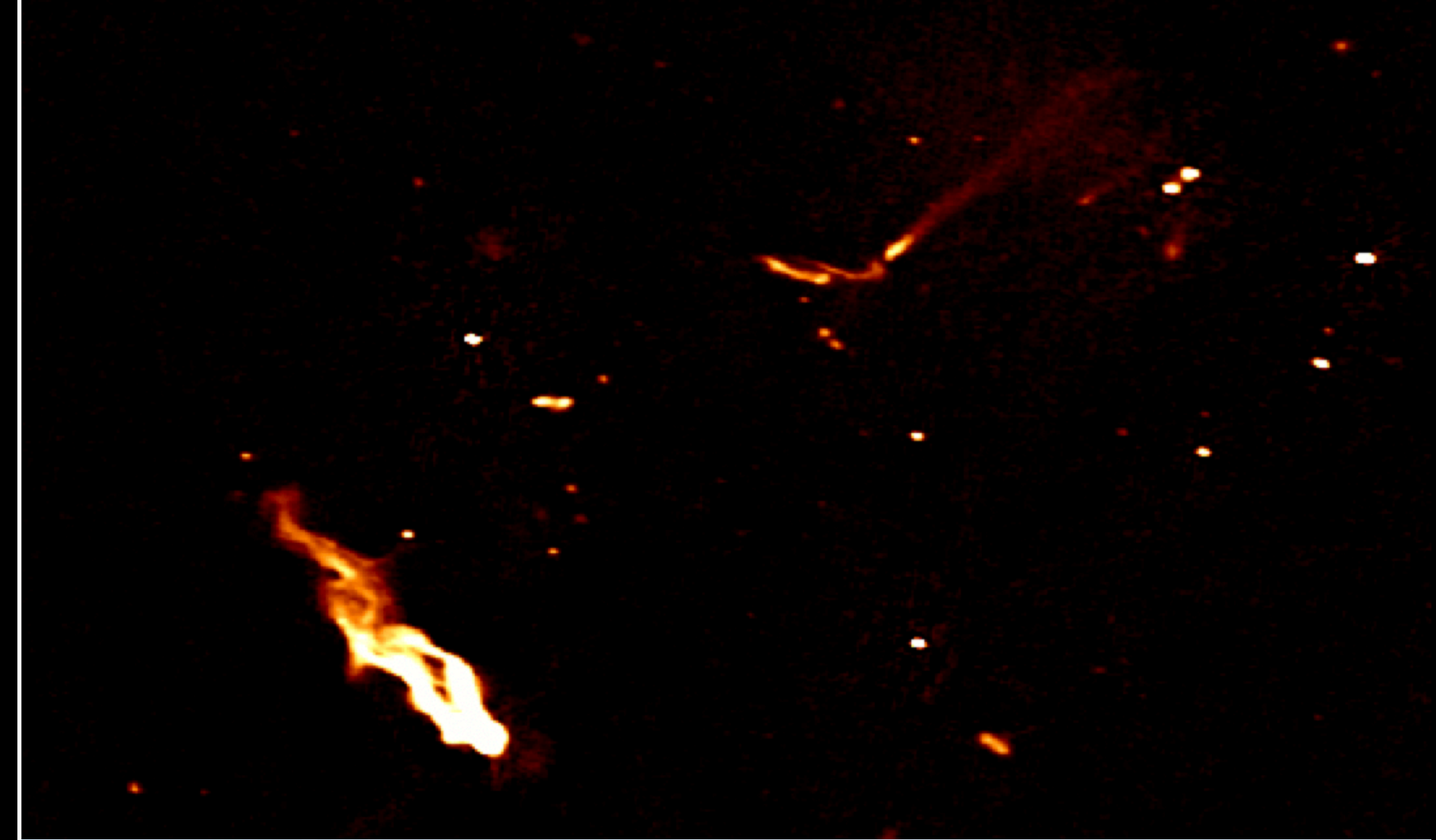


Galaxy Clusters with the LOFAR LBA

Recent results and the path towards
LBA VLBI

Henrik Edler, *Bell Burnell Fellow*, ASTRON

LOFAR Family Meeting, Paris, September 22 2025

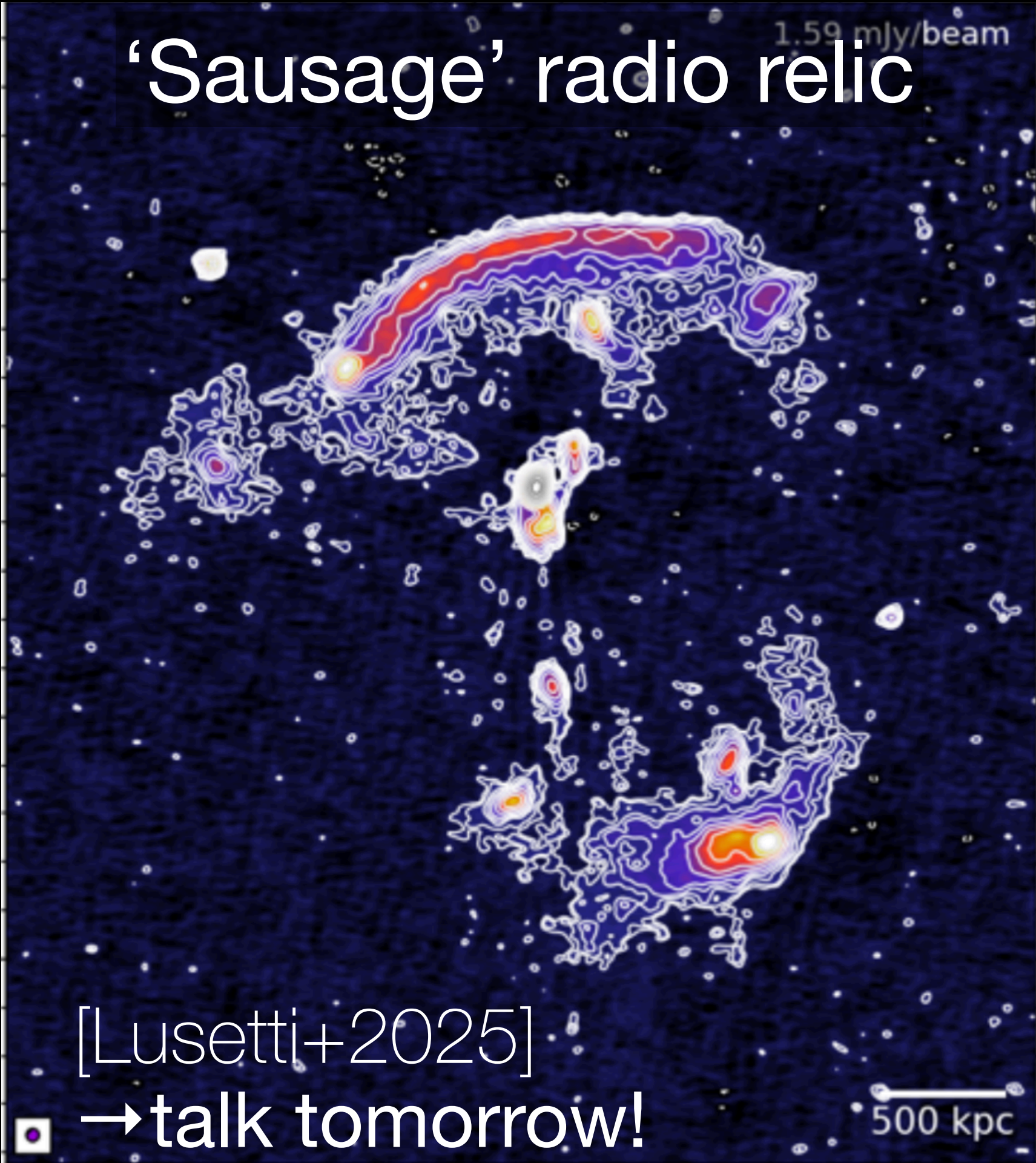
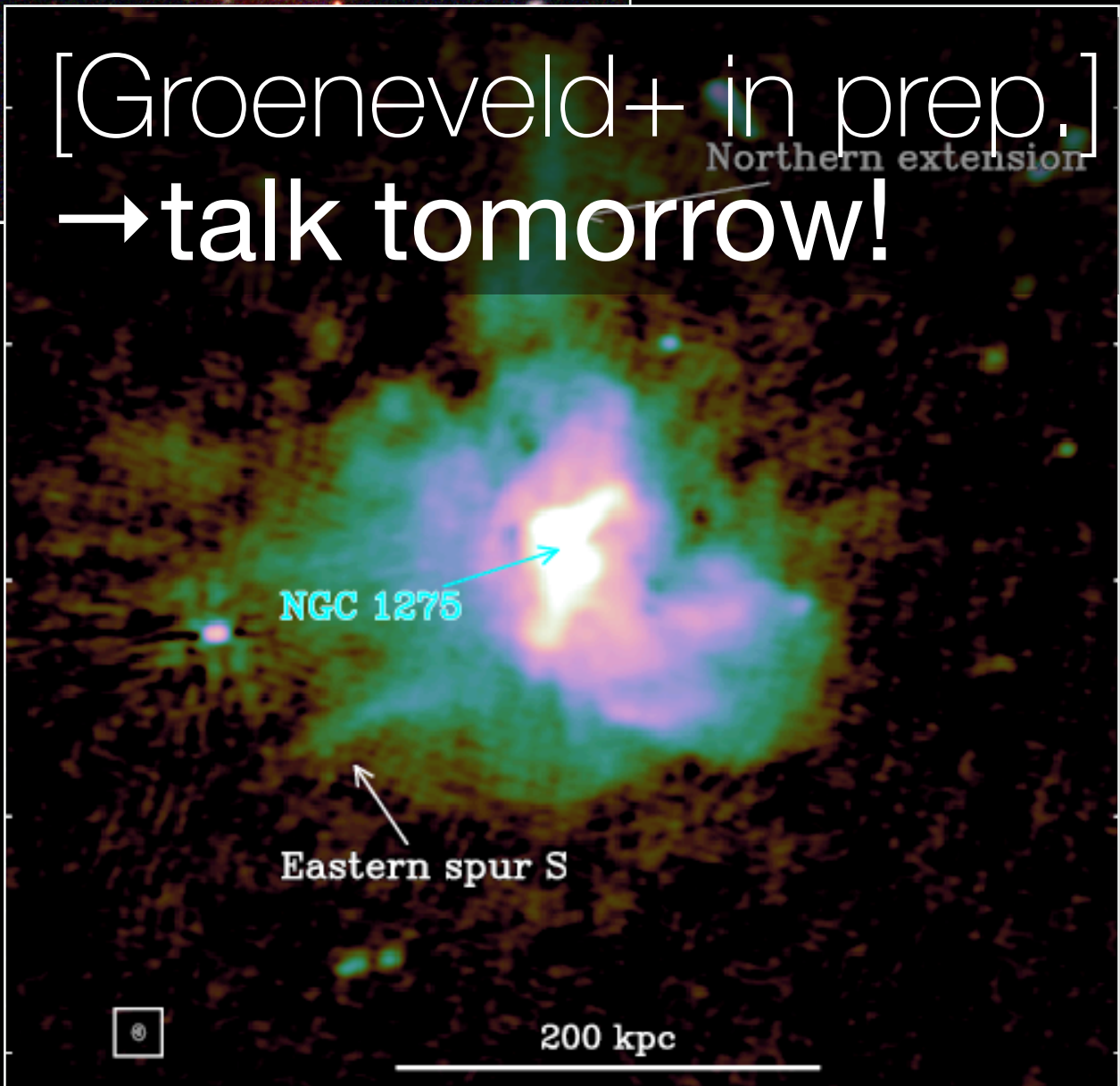
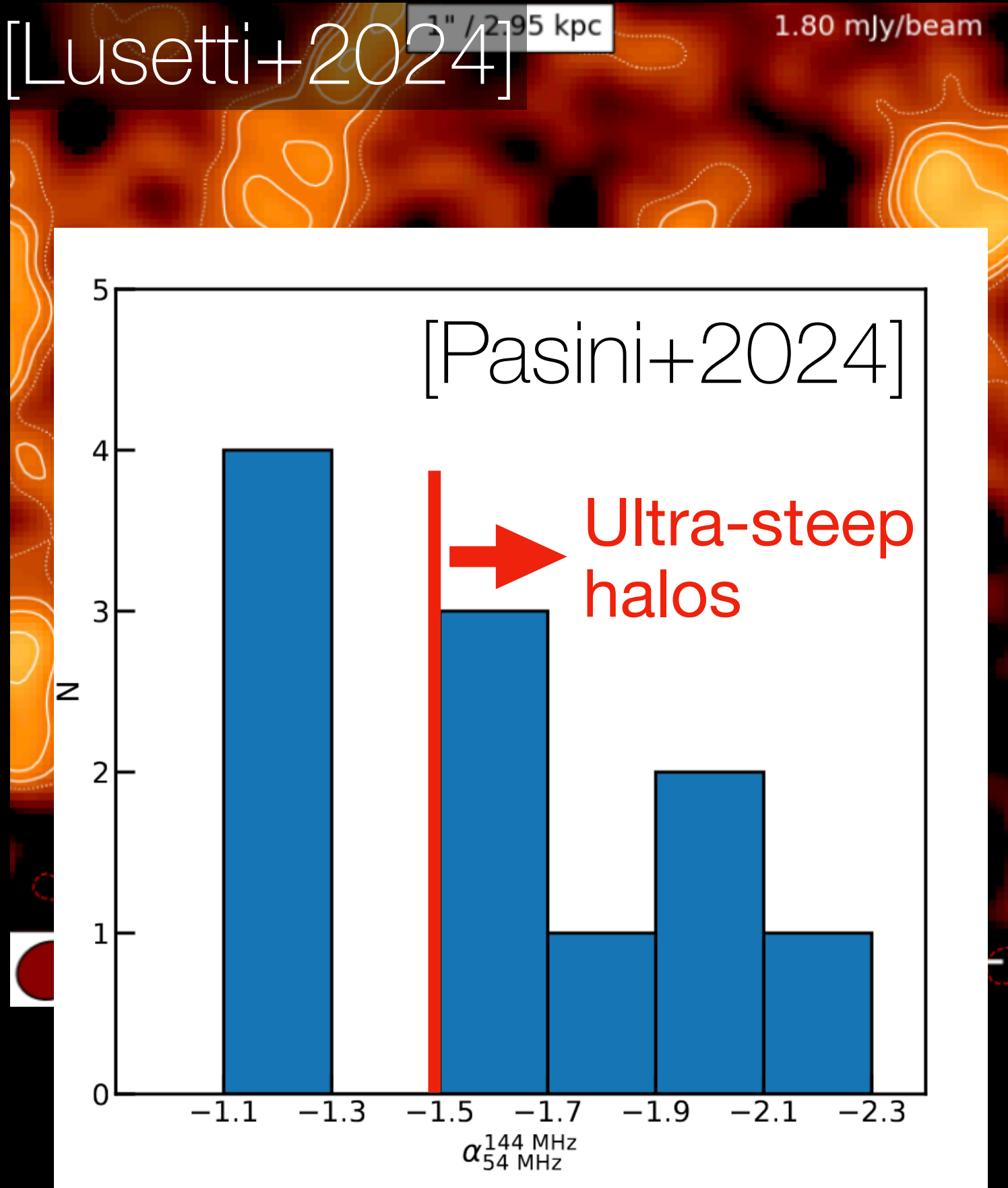


Galaxy clusters at ultra-low frequencies

Diffuse radio emission

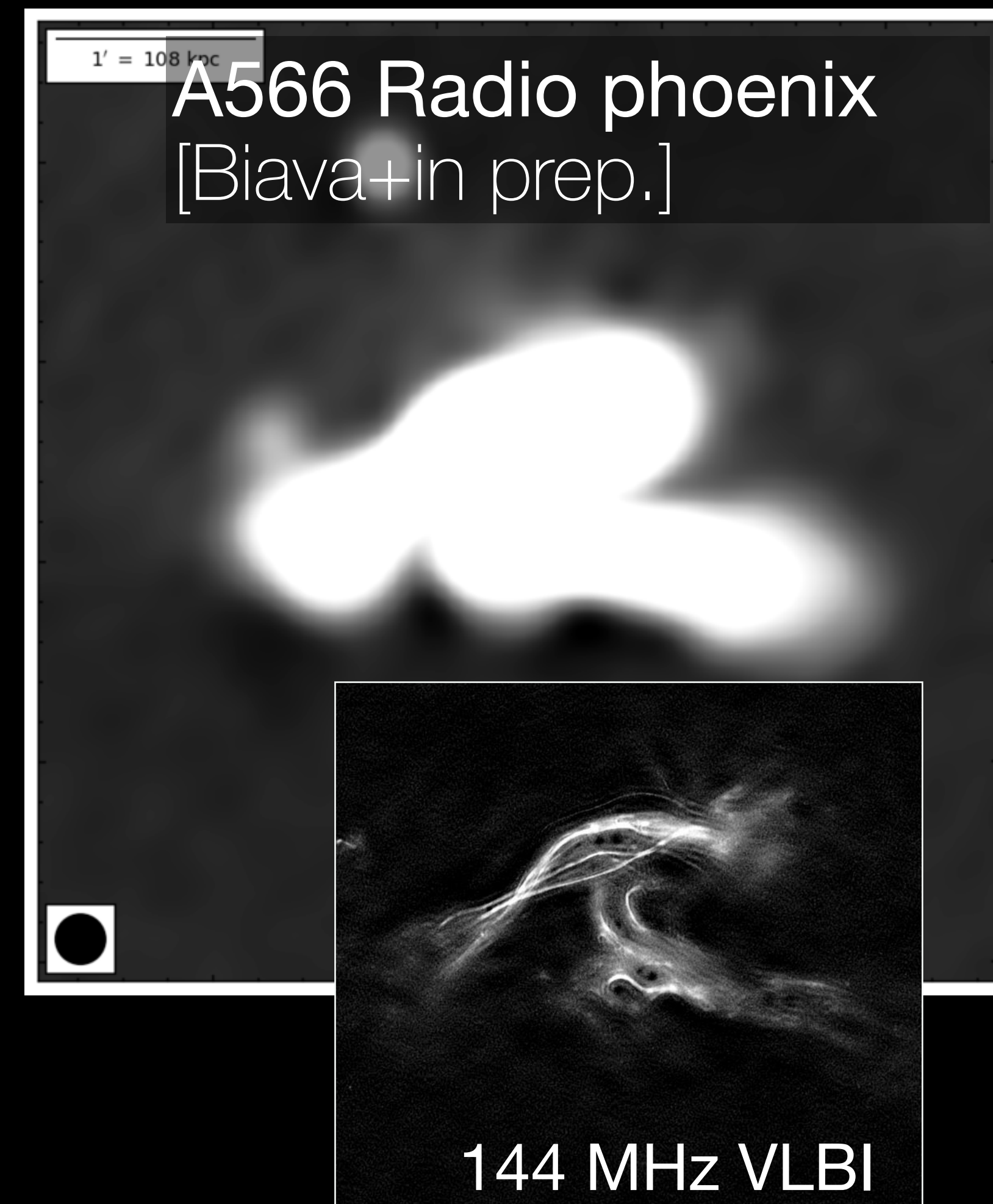
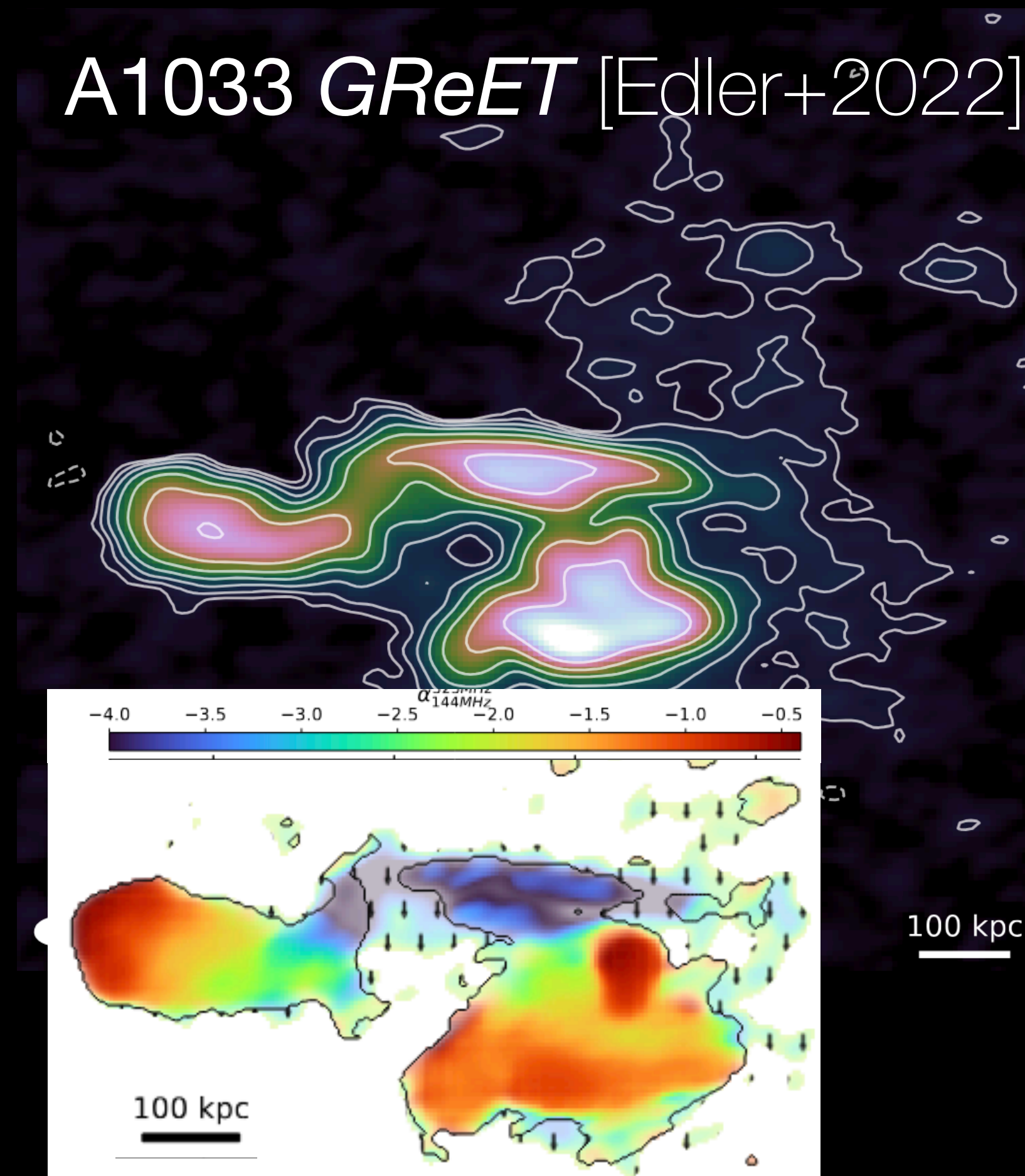
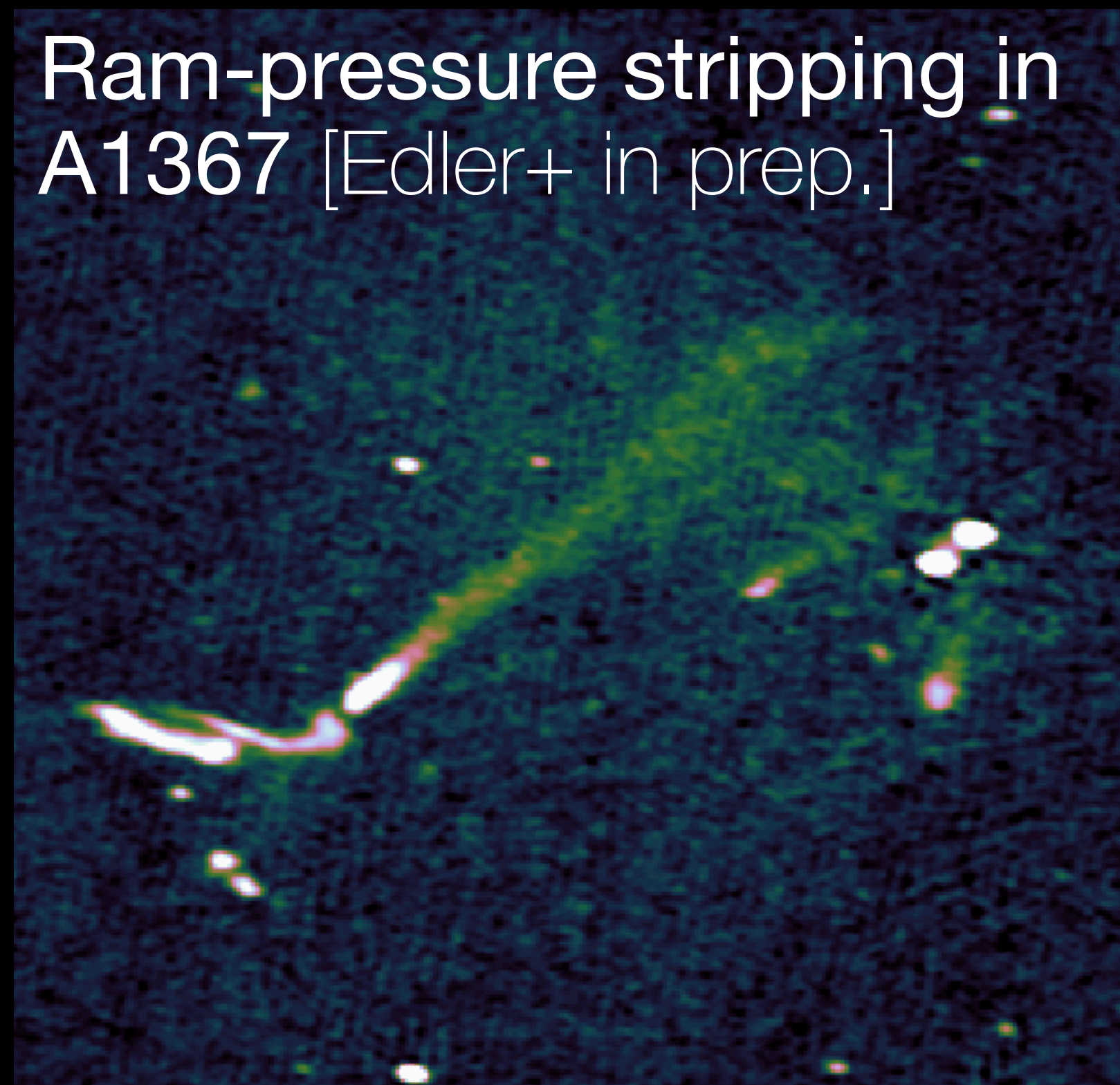
Radio halos

[Lusetti+2024]



Galaxy clusters at ultra-low frequencies

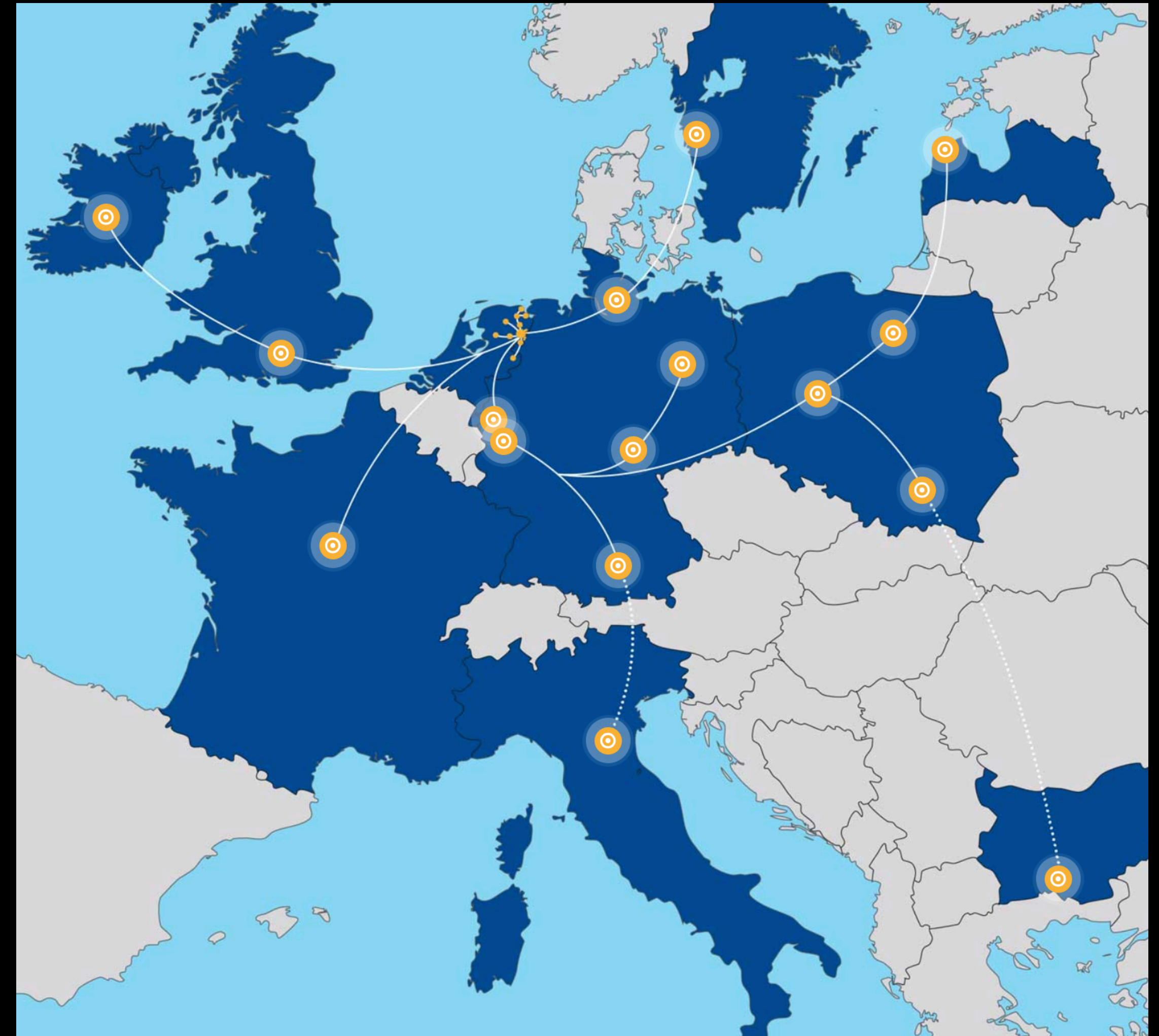
Ram-pressure stripping and re-acceleration



LOFAR VLBI

Where are we now?

- $B=100$ km (Dutch) $\rightarrow B=2000$ km (VLBI)
- Severe ionospheric systematics
- HBA VLBI well developed
- LBA VLBI
 - Stronger systematics, lower S/N
 - Proof-of-concept phase

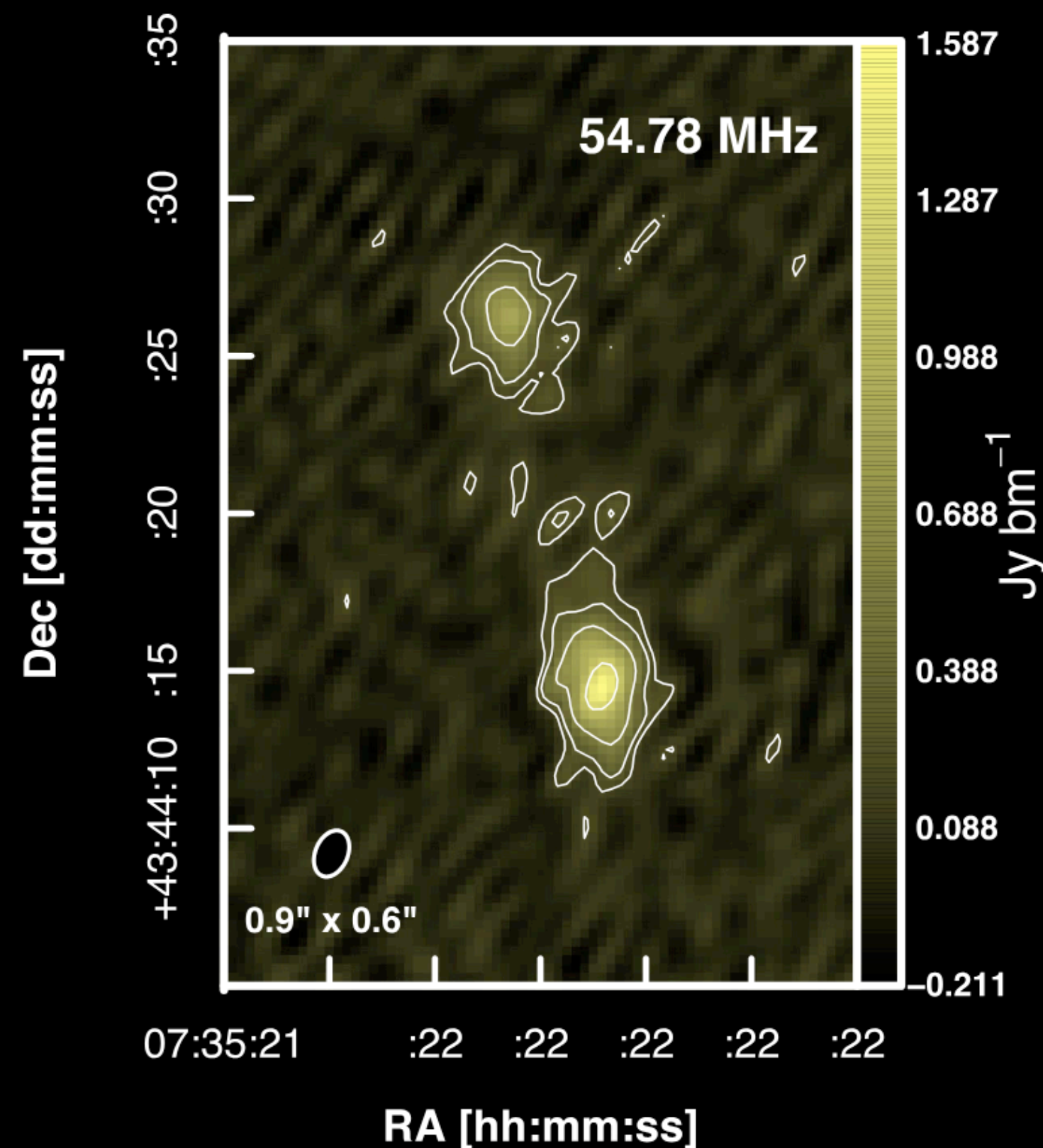


Previous milestones

Pioneering works and calibrator studies with LBA VLBI

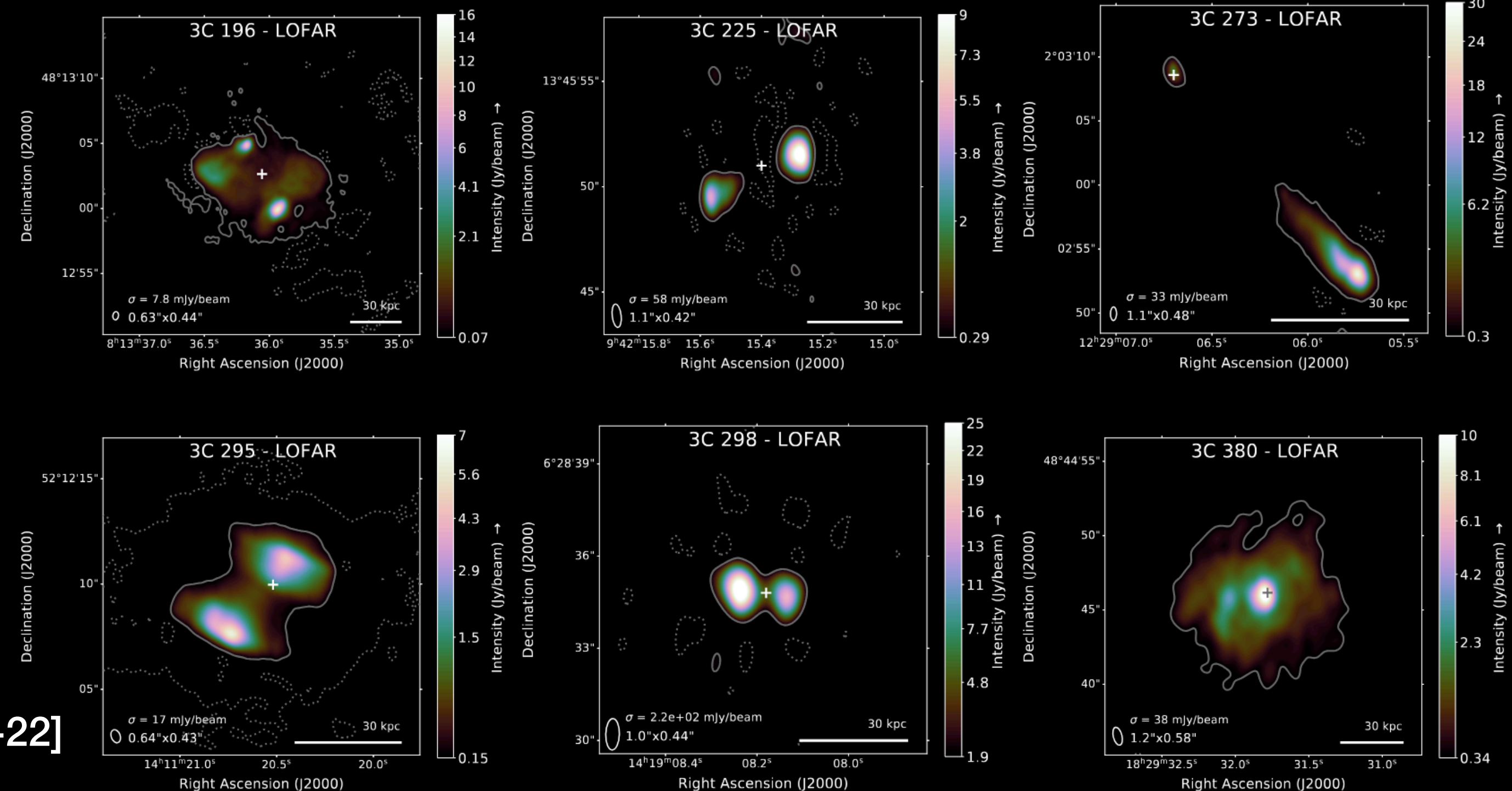
[Morabito+16]

- $0.9'' \times 0.6''$
- $\sigma_{\text{rms}} = 60$ mJy/beam
- 15 Jy at 55 MHz



[Groeneveld+22]

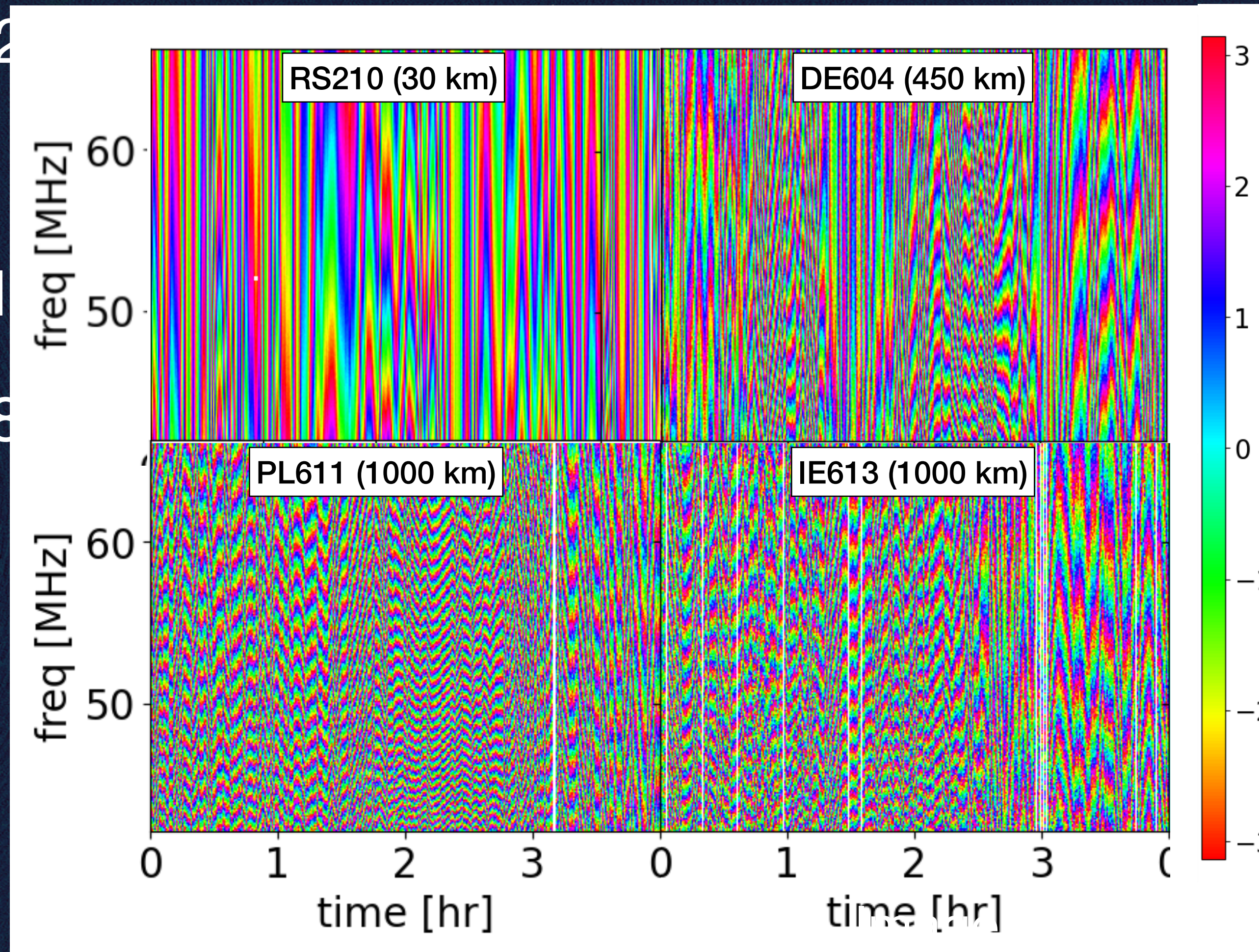
- $1.0'' \times 0.5''$
- $\sigma_{\text{rms}} > 8$ mJy/beam
- > 40 Jy at 55 MHz



- In which conditions can we calibrate fainter (~ 1 Jy) sources?
- Can we do wide-field VLBI at 50 MHz?

LBA VLBI Test-field: Abell 2255

- 2x4h of Abell 2255
- 42-66 MHz
- 12 international
- Calibrator 3c38



A VLBI [de Rubeis+25]

→see talk tomorrow!

Dutch array calibration

resolution=15"
 $\sigma_{\text{rms}}=1.4\text{mJy/beam}$

Dutch cal pipeline + survey:
→ Francesco's talk on Wednesday

1 deg



VLBI infield delay calibration

resolution=15"
 $\sigma_{\text{rms}}=1.4\text{mJy/beam}$



1.8 Jy

3.0 Jy

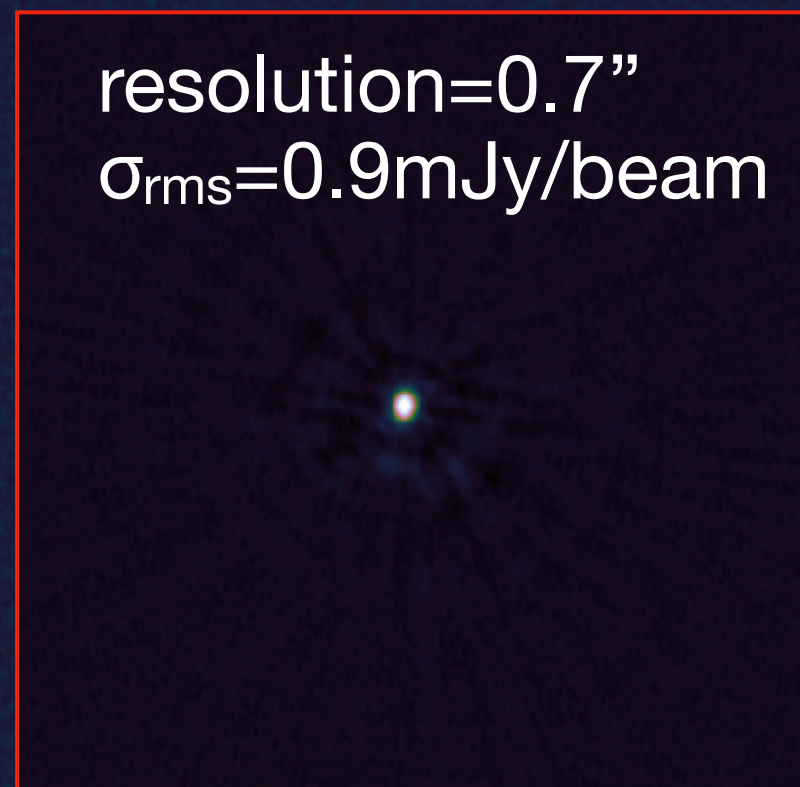
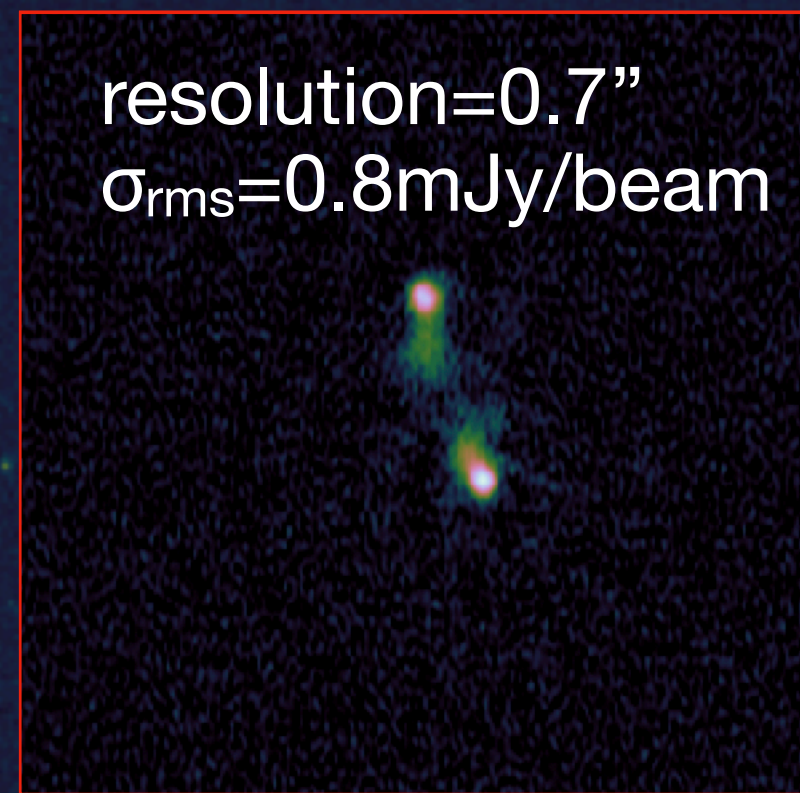


resolution=15"
 $\sigma_{\text{rms}}=1.4\text{mJy/beam}$

1 deg



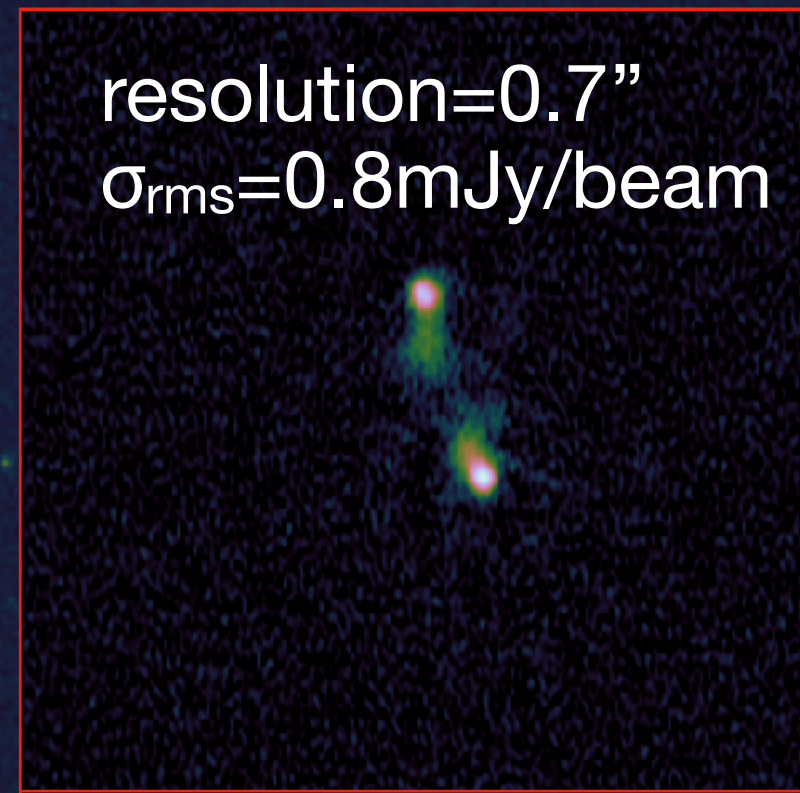
VLBI infield delay calibration



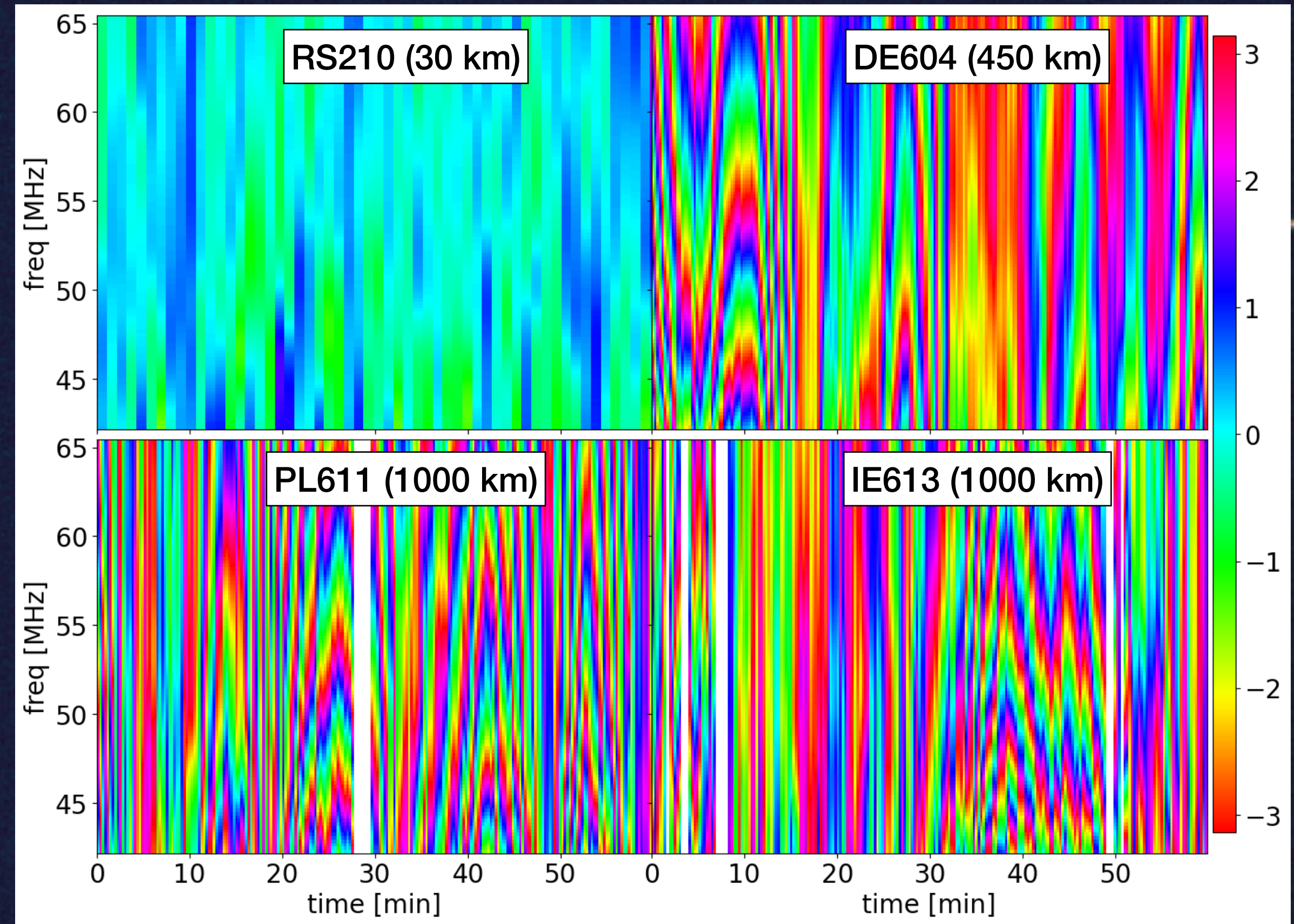
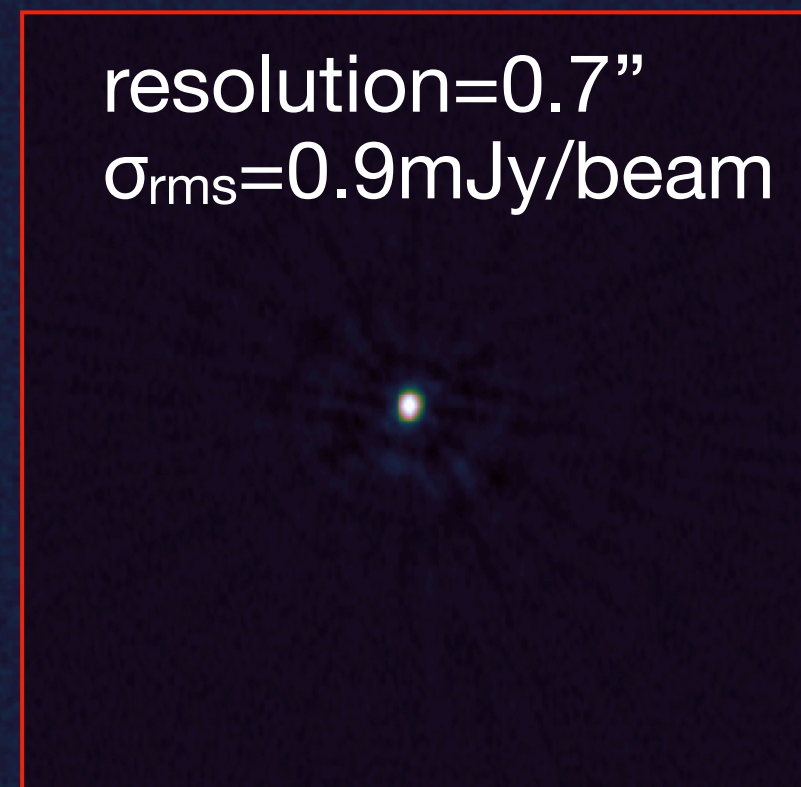
1 deg



VLBI infield delay calibration

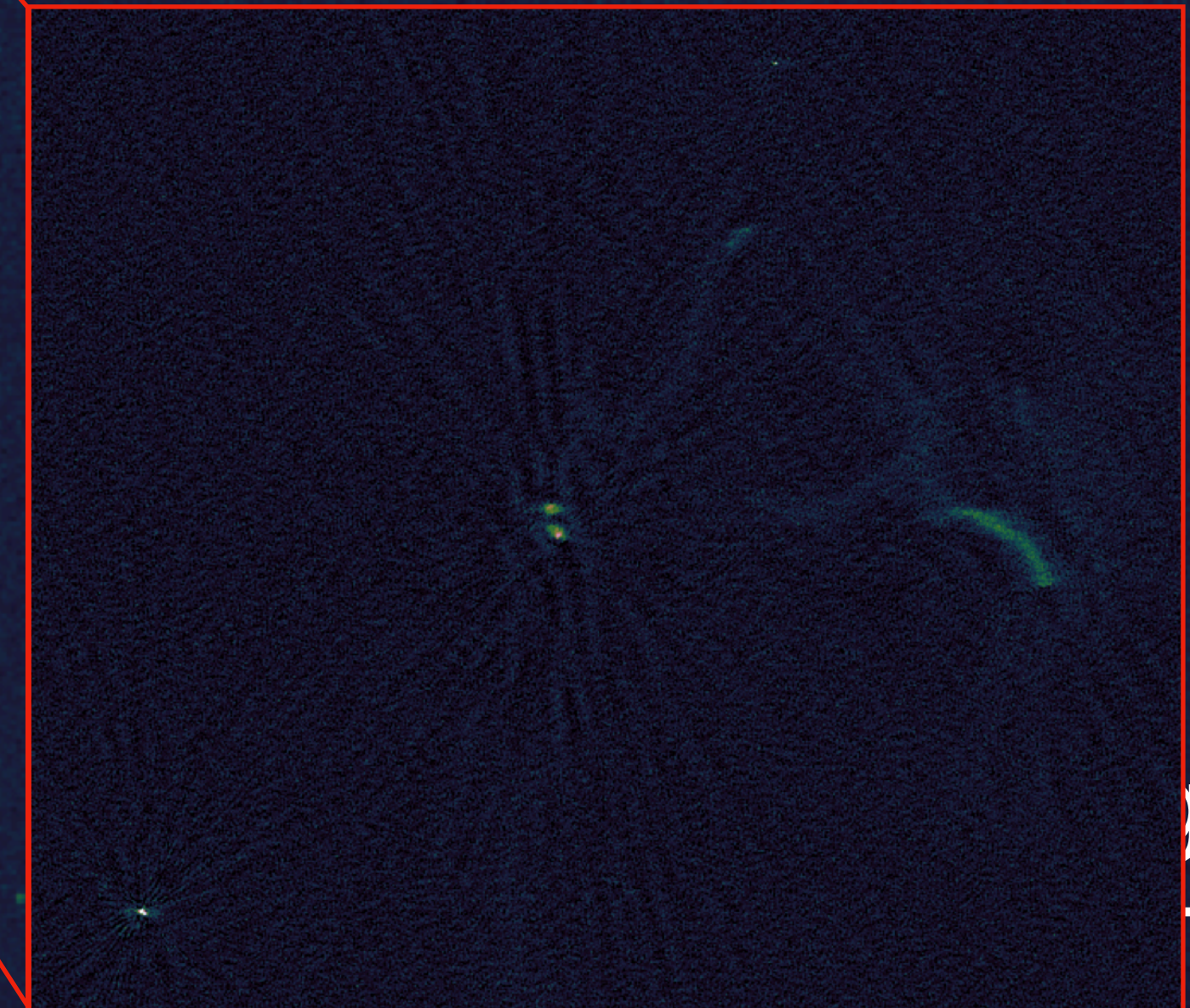
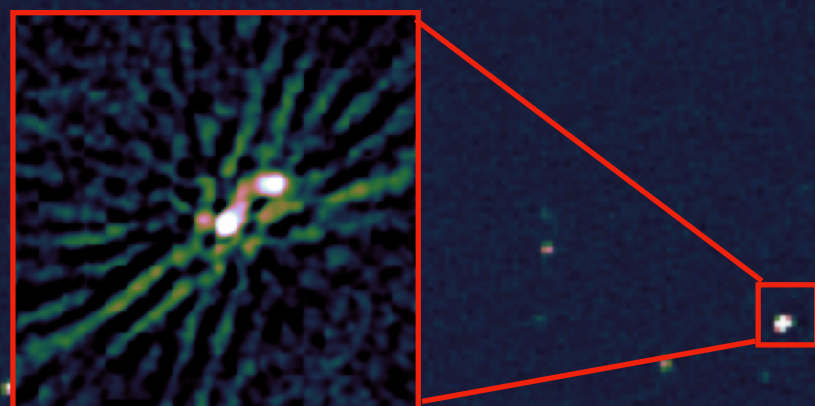
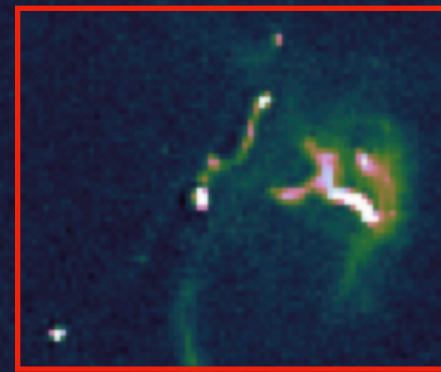
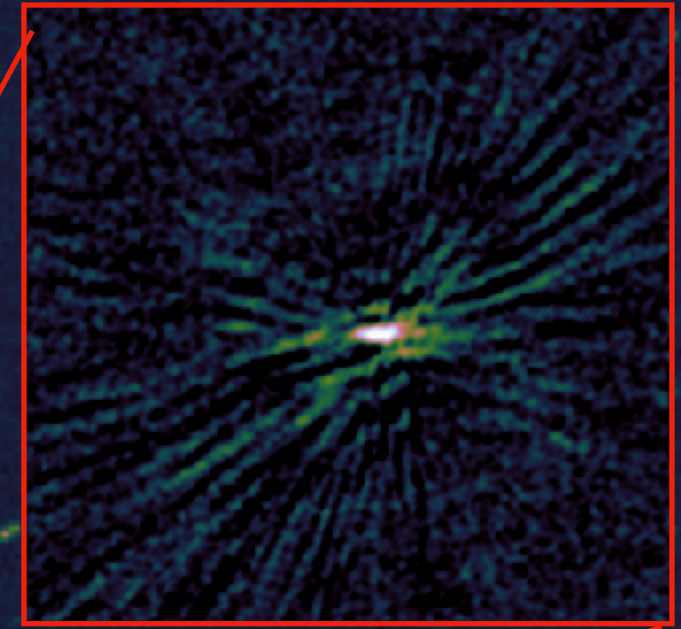
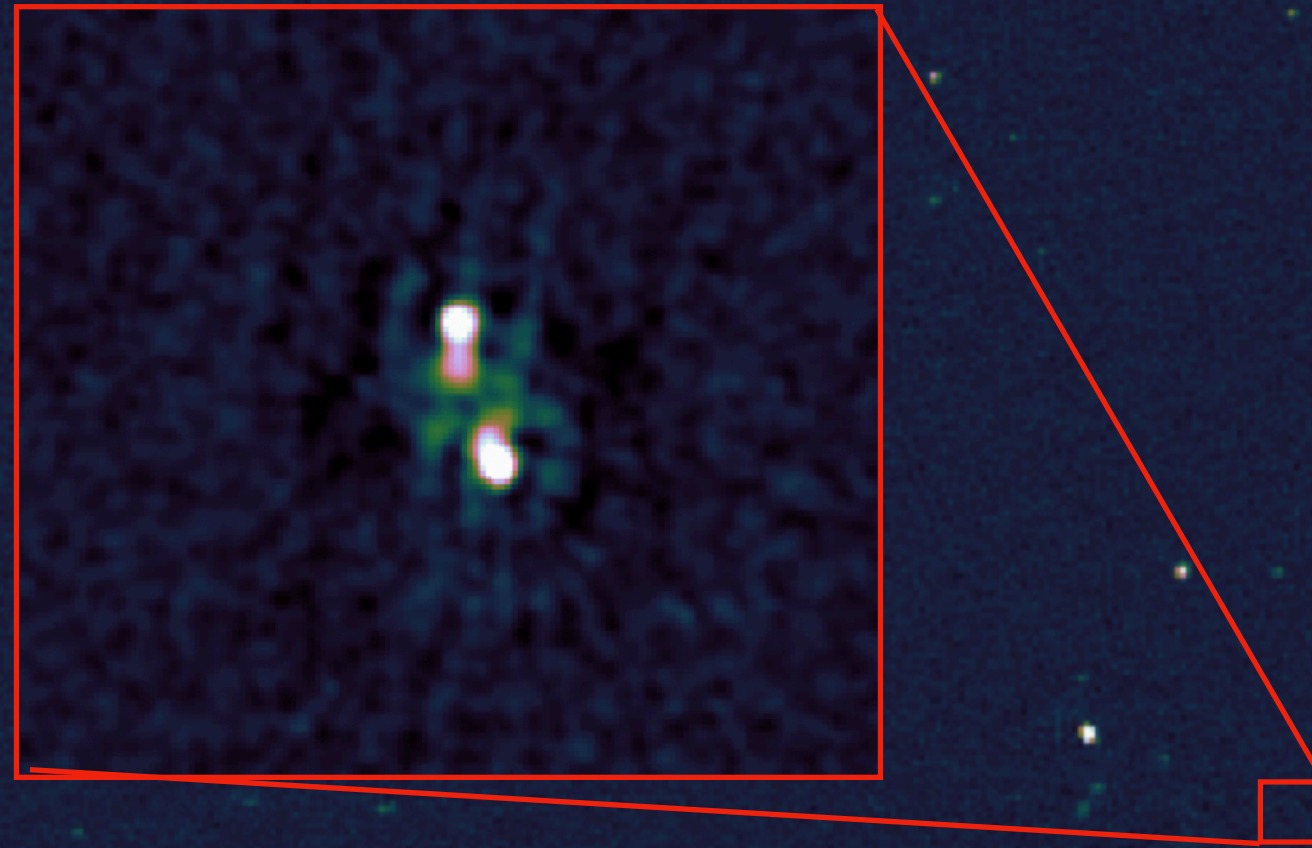


1.8 Jy
3.0 Jy

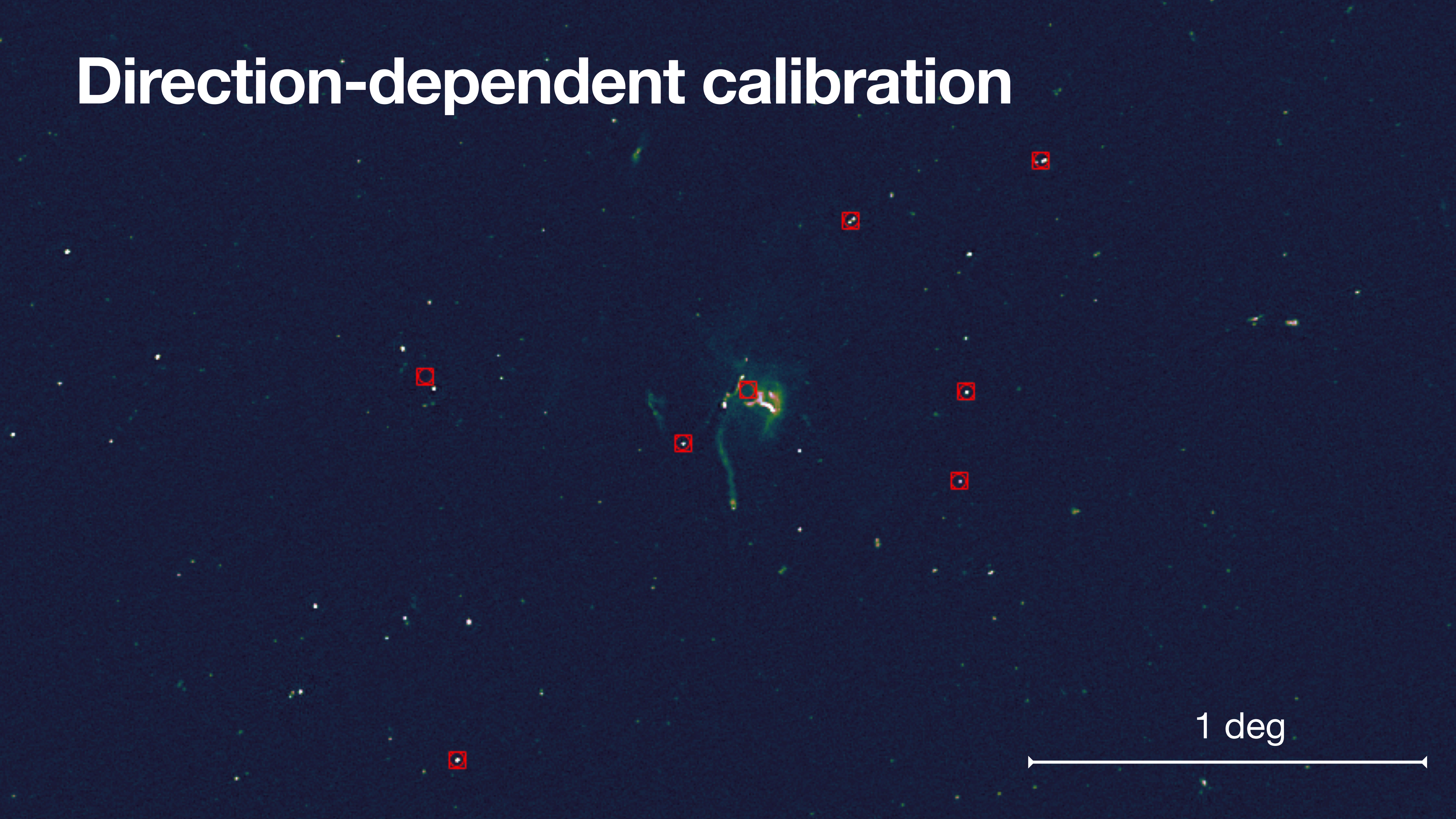


1 deg

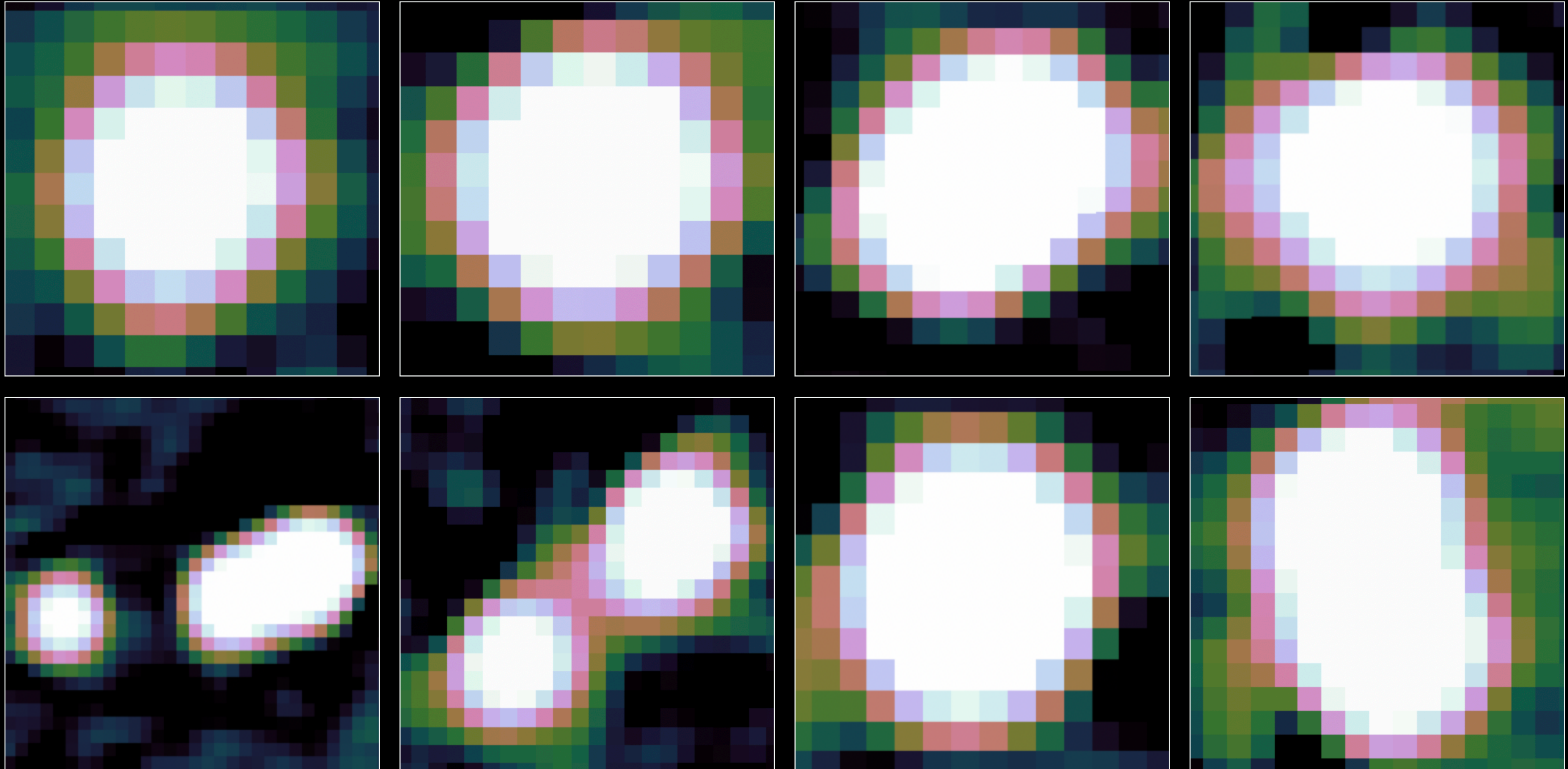
Sources after DI-VLBI calibration



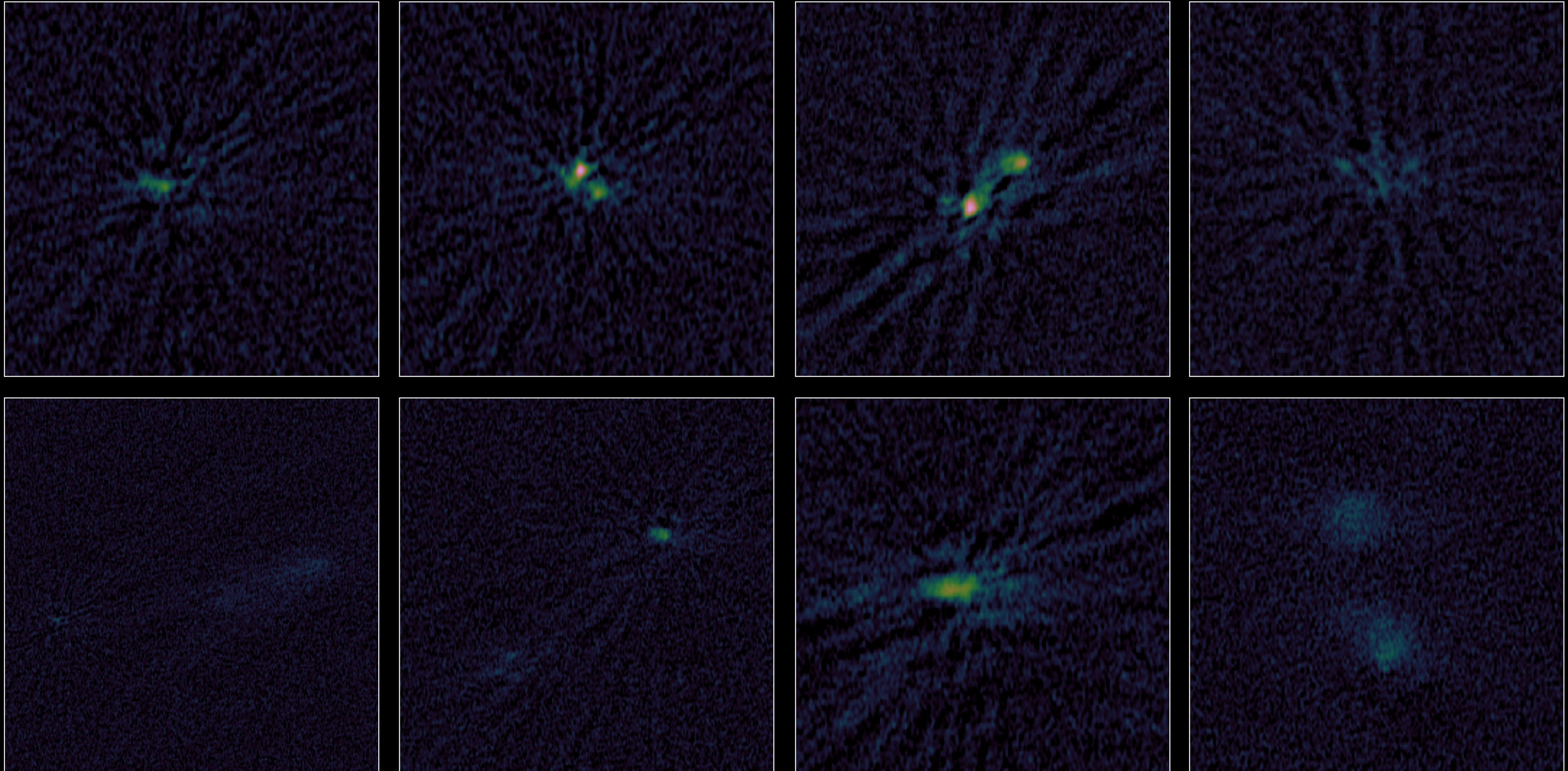
Direction-dependent calibration



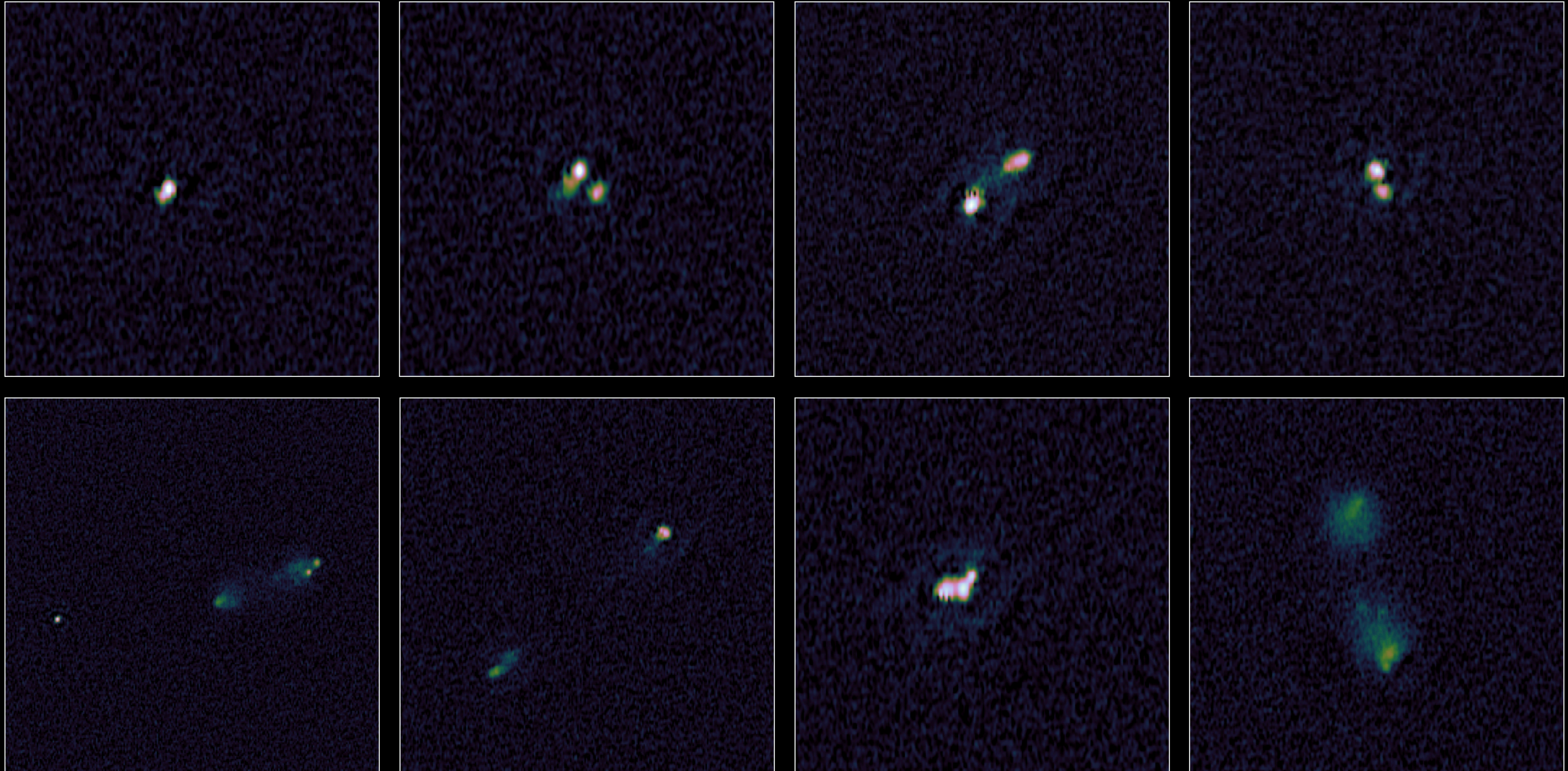
DD-calibrators (Dutch array)



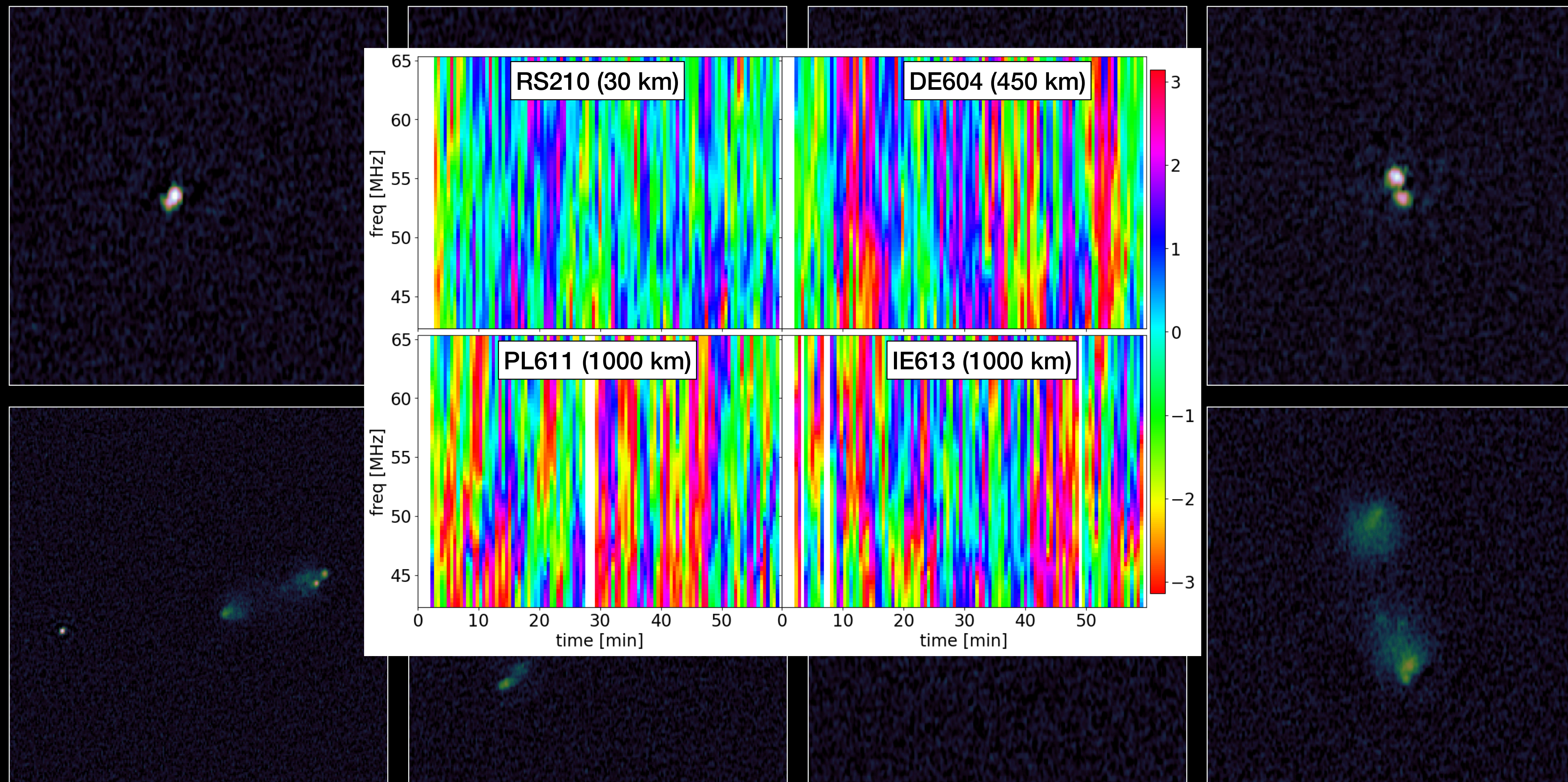
DD-calibrators (DI VLBI)



DD-calibrators (DD VLBI)



DD-calibrators (DD VLBI)



First LBA VLBI
wide-field image!

- 9 directions
- 0.9"x0.5"
- 650 μ Jy/beam
- ~400 sources

Dir08
□

Dir05
□

Dir06
□

Dir04
□

Dir02
□

Dir03
□

Dir01
□

Dir07
□

1 deg



First LBA VLBI
wide-field image!

Dutch

VLBI DI

VLBI DD

Dir08

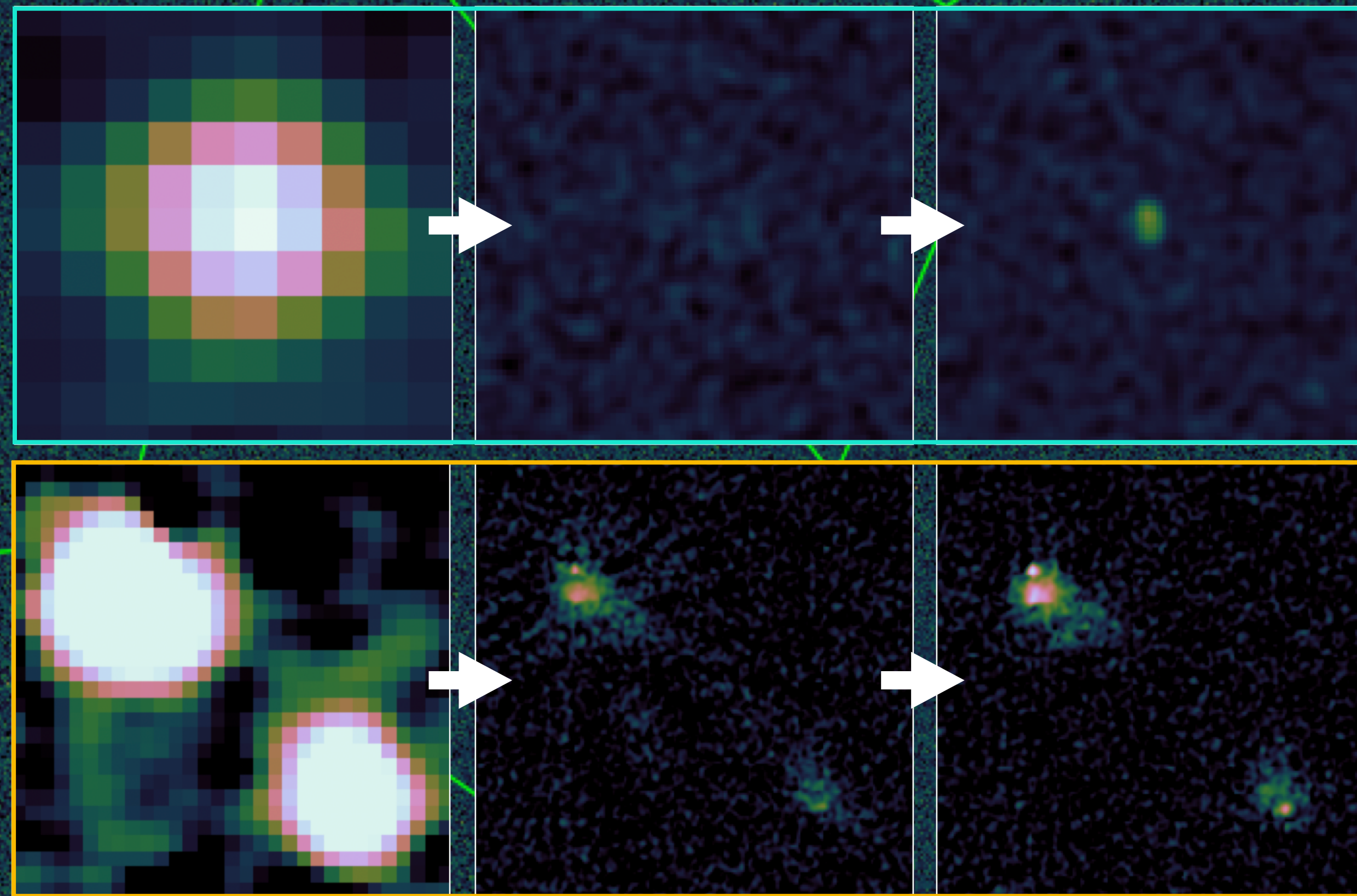
Dir04

Dir01

- 9 directions
- 0.9"x0.5"
- 650 μ Jy/beam
- ~400 sources

Dir07

1 deg



Can we do this for large sky areas?

Critical for success:

- Calm ionosphere
- Compact, few Jy infield-delay calibrator

LOFAR 2.0 considerations

- Greater sensitivity
- New stations
- Simultaneous observations LBA+HBA
- NenuFAR Super-Station

