



**ASTRON**  
Netherlands Institute for Radio Astronomy

# Sub-arcsecond imaging at 50 MHz of the Abell 2255 cluster

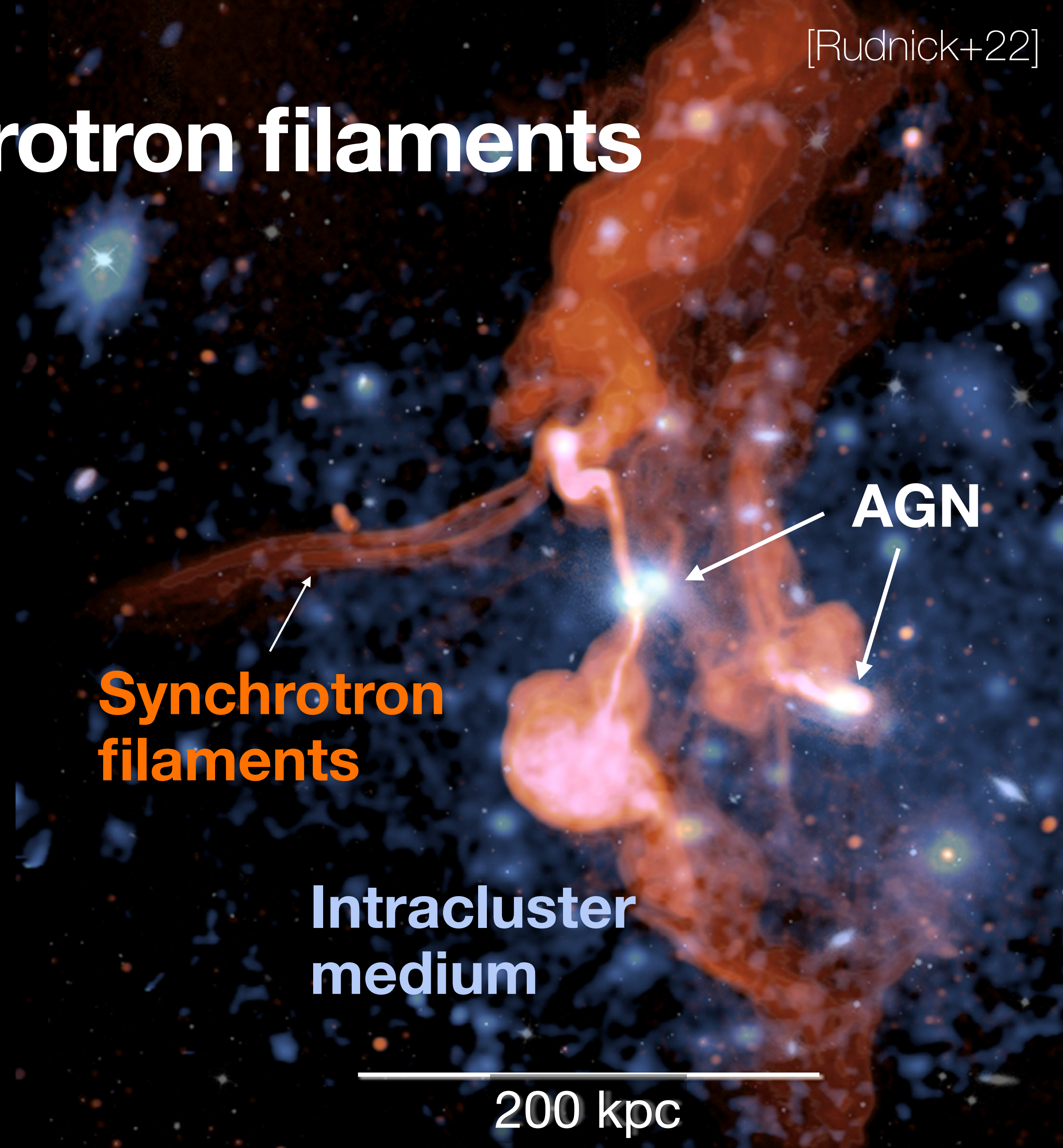
Henrik W. Edler, *Bell Burnell Fellow*, ASTRON

NAC 2026, Egmond aan Zee, May 12 2026



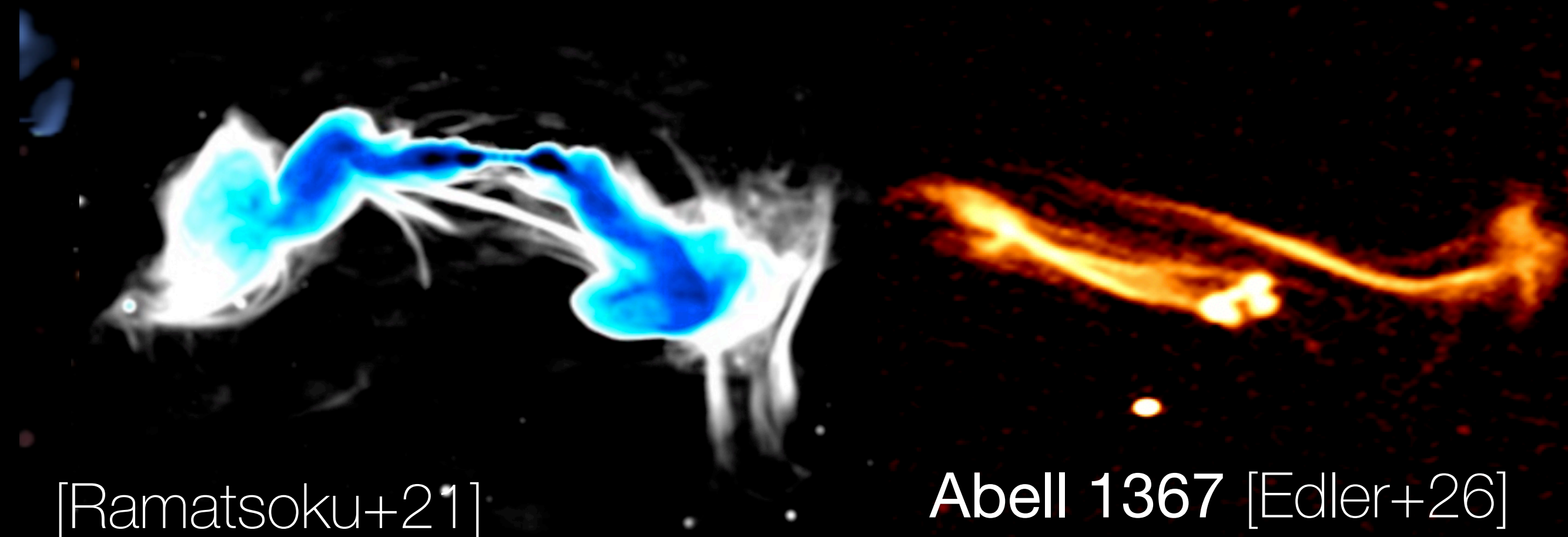
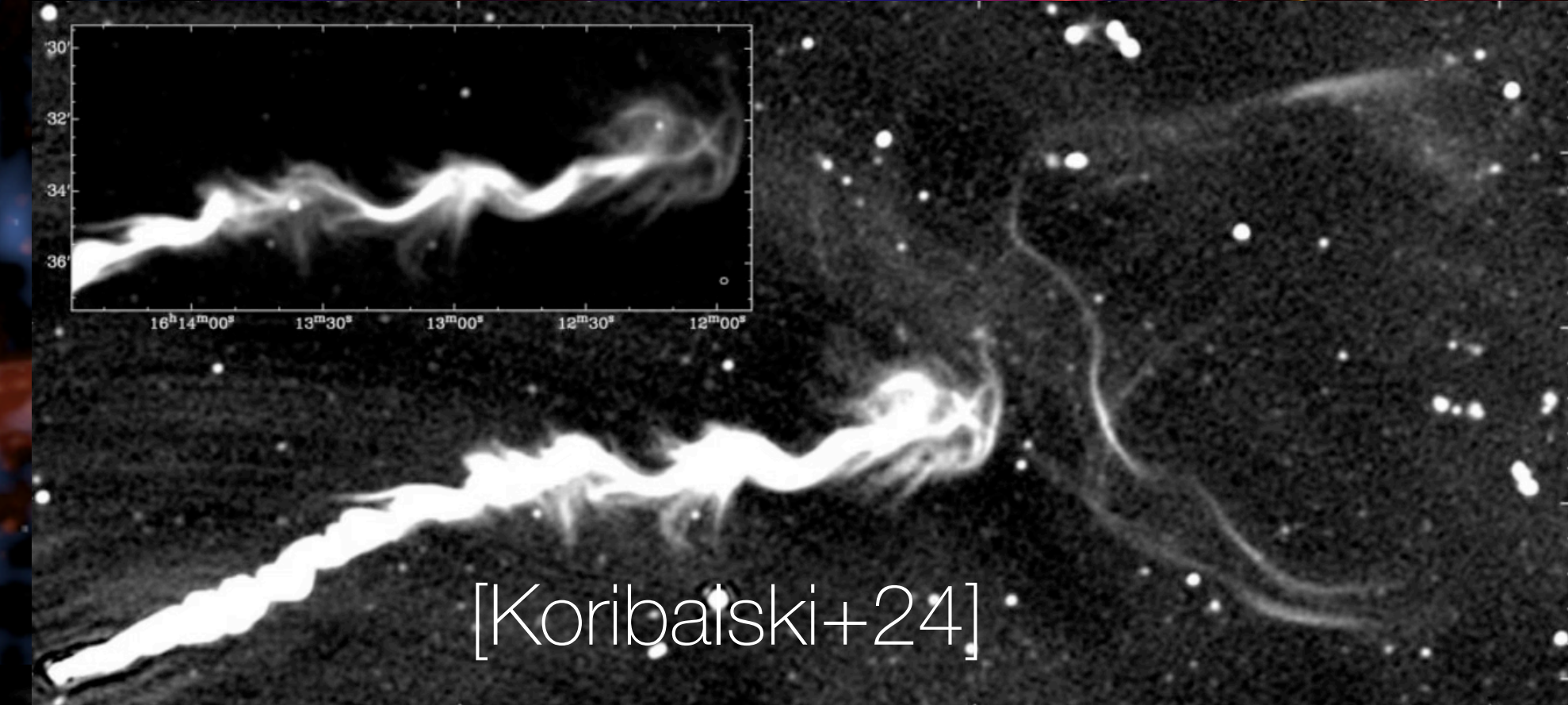
# Galaxy cluster synchrotron filaments

- Long and narrow ( $\sim$ kpc) radio structures
- Connecting to radio galaxy lobes
- Interaction between relativistic plasma and magnetic structures in surrounding medium?



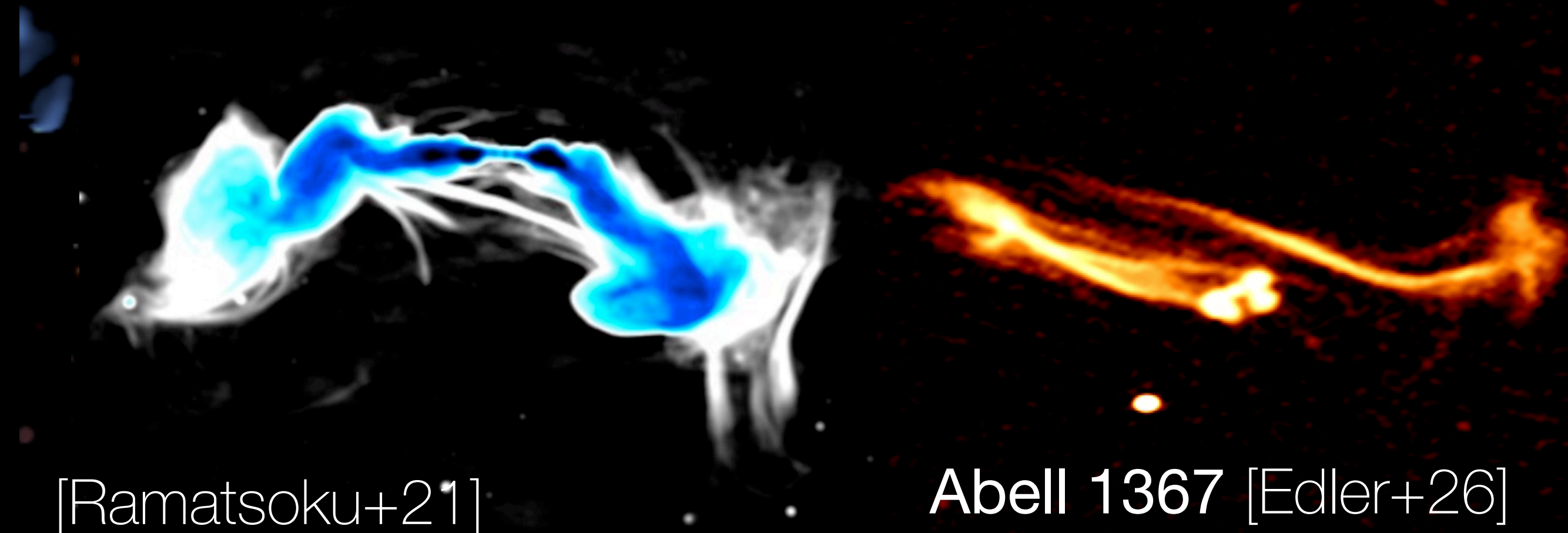
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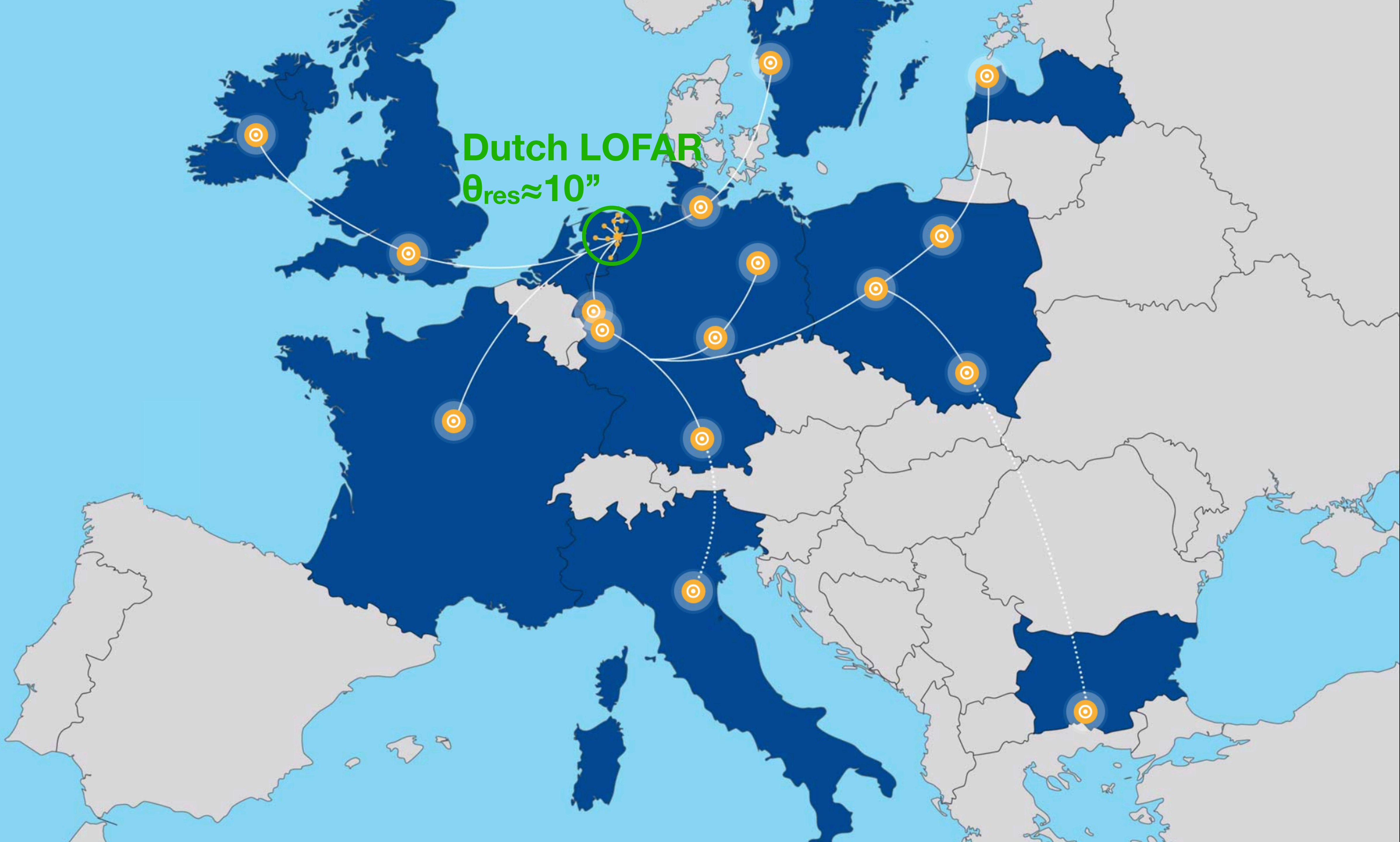


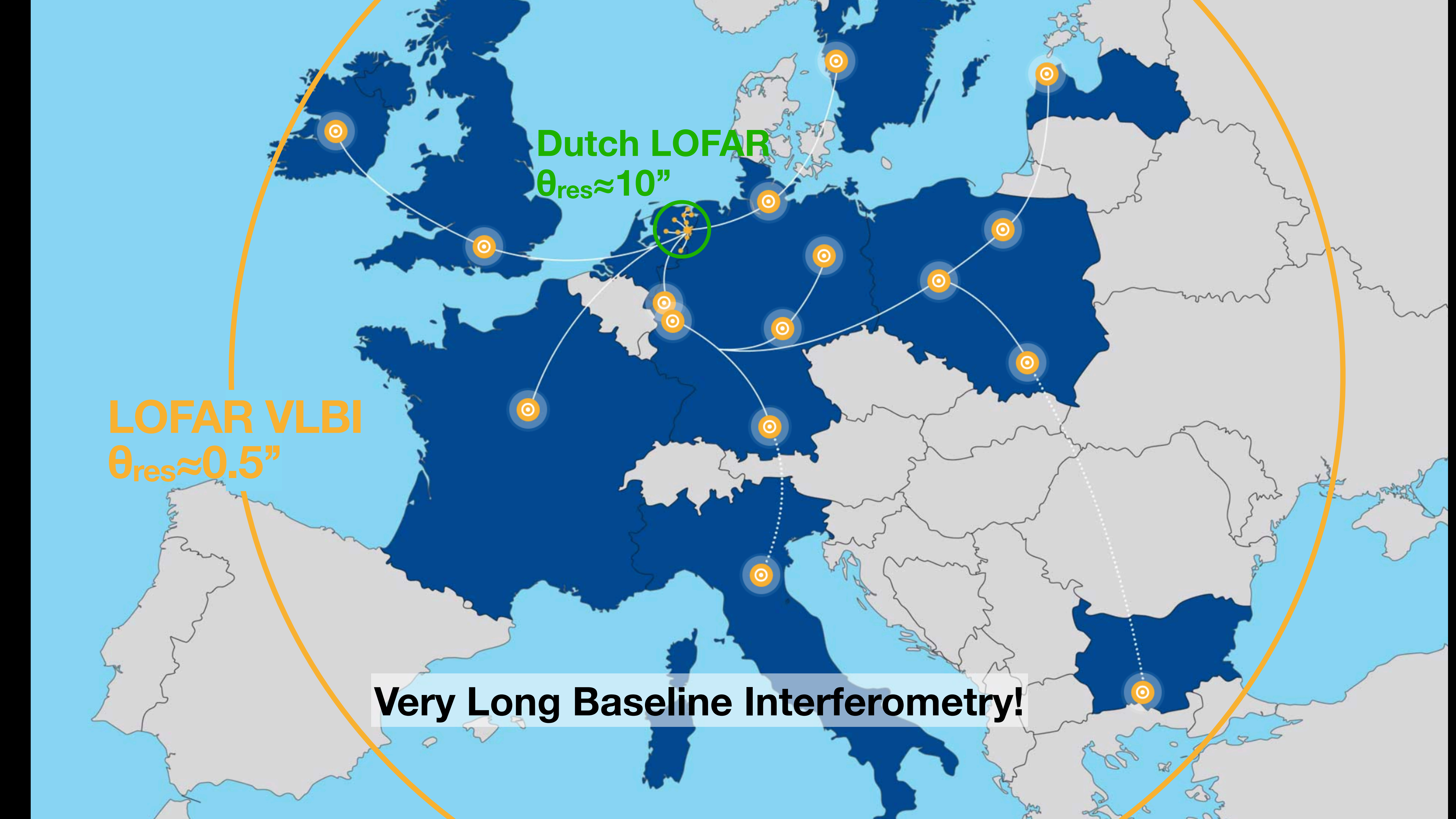
# Galaxy cluster synchrotron filaments

- Narrow ( $\sim$ kpc) radio structures
- Connecting to radio galaxy lobes
- Interaction between relativistic plasma and magnetic structures in surrounding medium?
- Typically have **ultra-steep** radio spectrum



Dutch LOFAR  
 $\theta_{\text{res}} \approx 10''$





Dutch LOFAR  
 $\theta_{\text{res}} \approx 10''$

LOFAR VLBI  
 $\theta_{\text{res}} \approx 0.5''$

**Very Long Baseline Interferometry!**

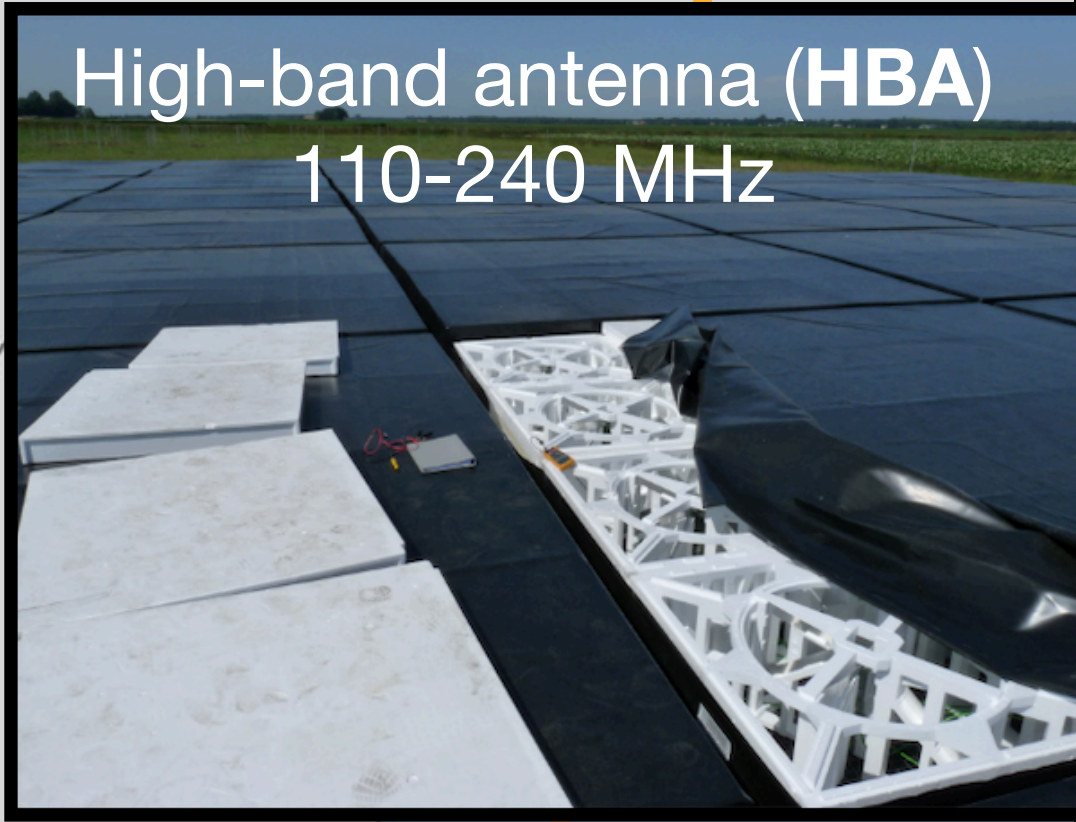
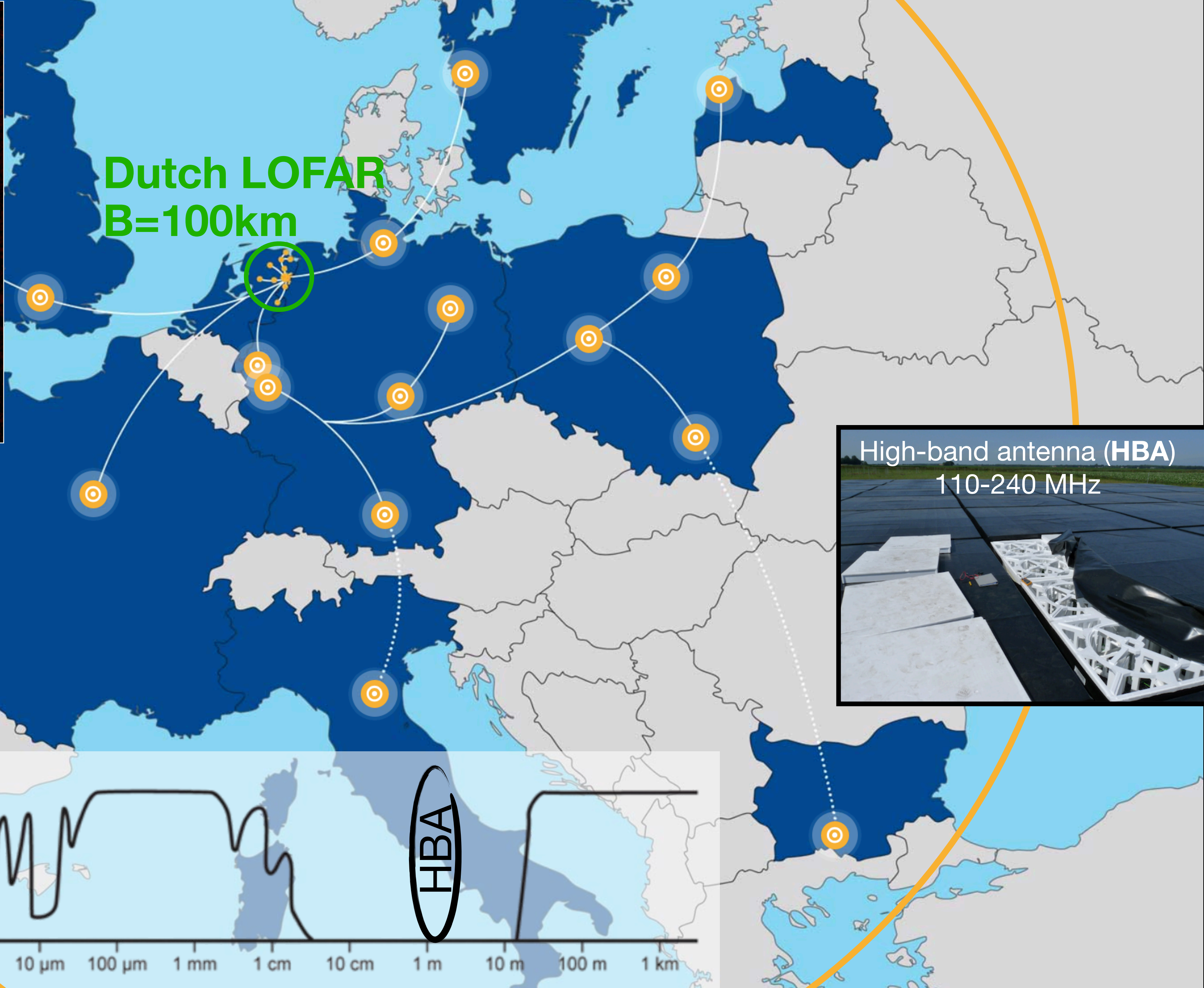
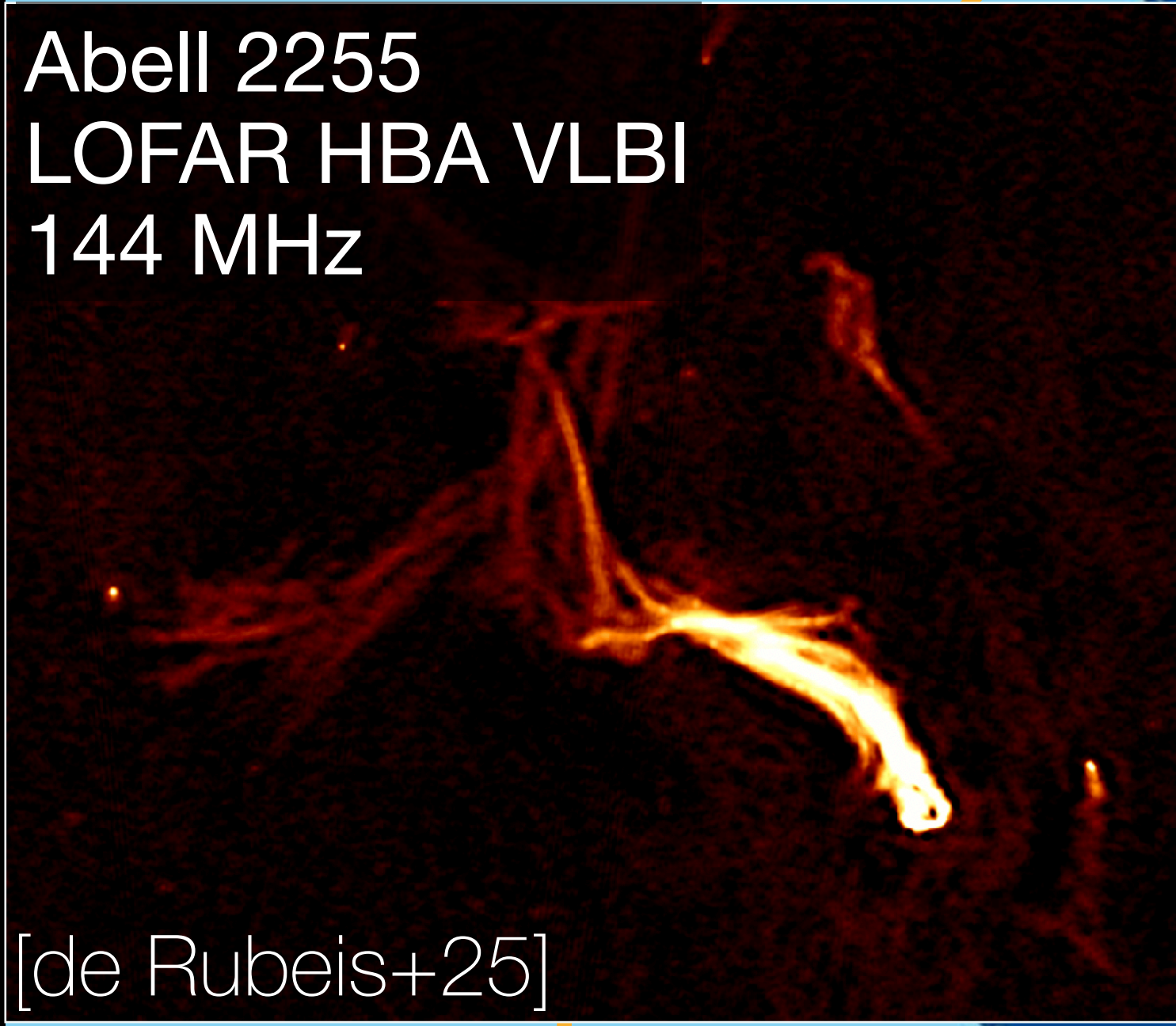
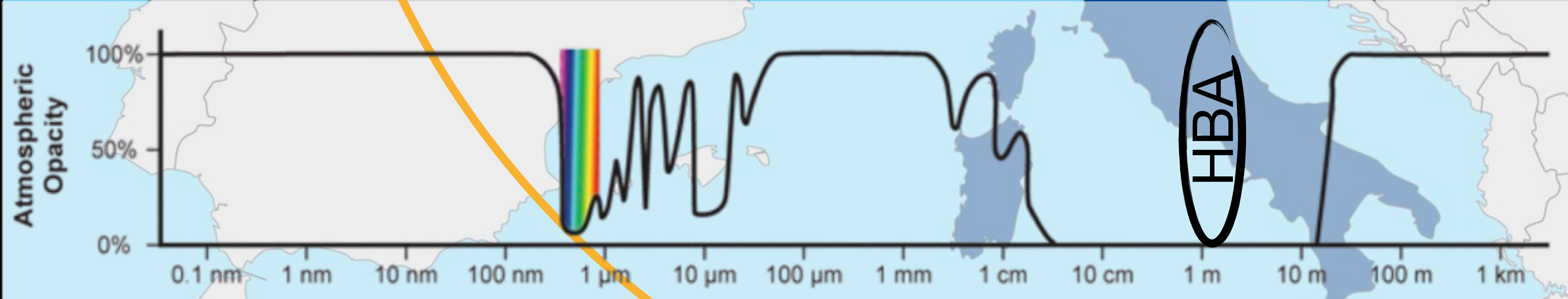
Abell 2255  
LOFAR HBA VLBI  
144 MHz

[de Rubeis+25]

Dutch LOFAR  
B=100km

LOFAR VLBI  
 $\theta_{res} \approx 0.5''$

High-band antenna (HBA)  
110-240 MHz



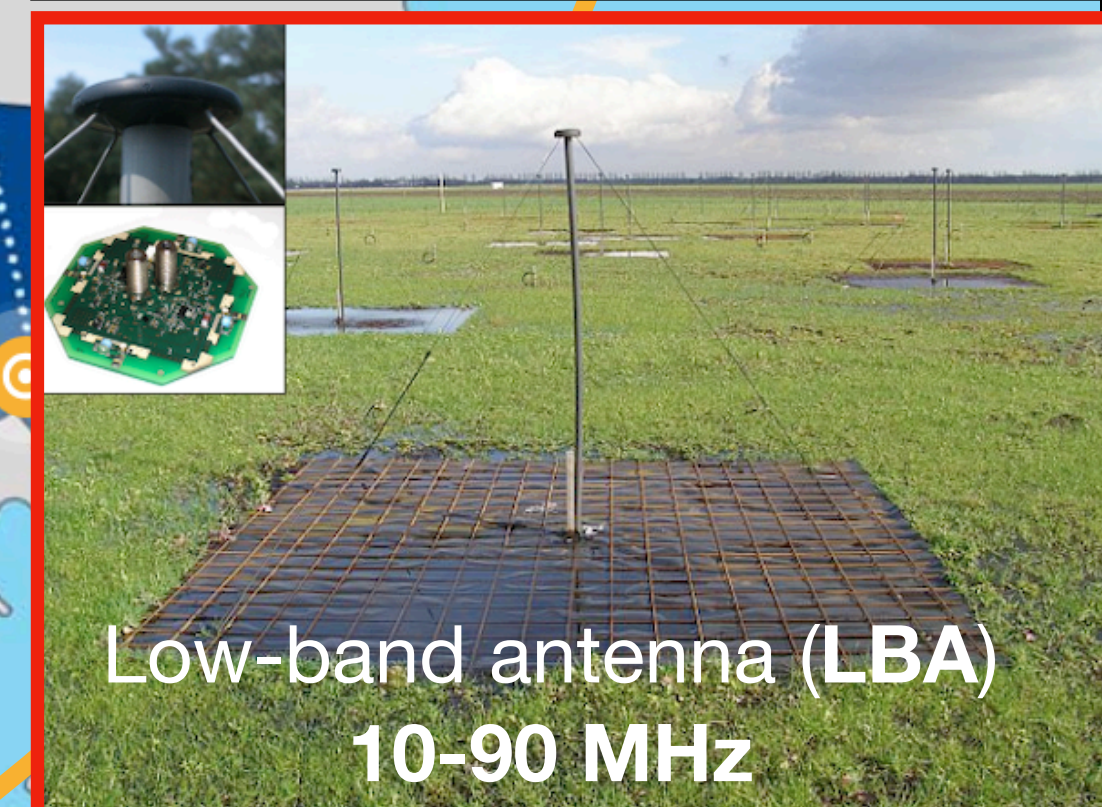
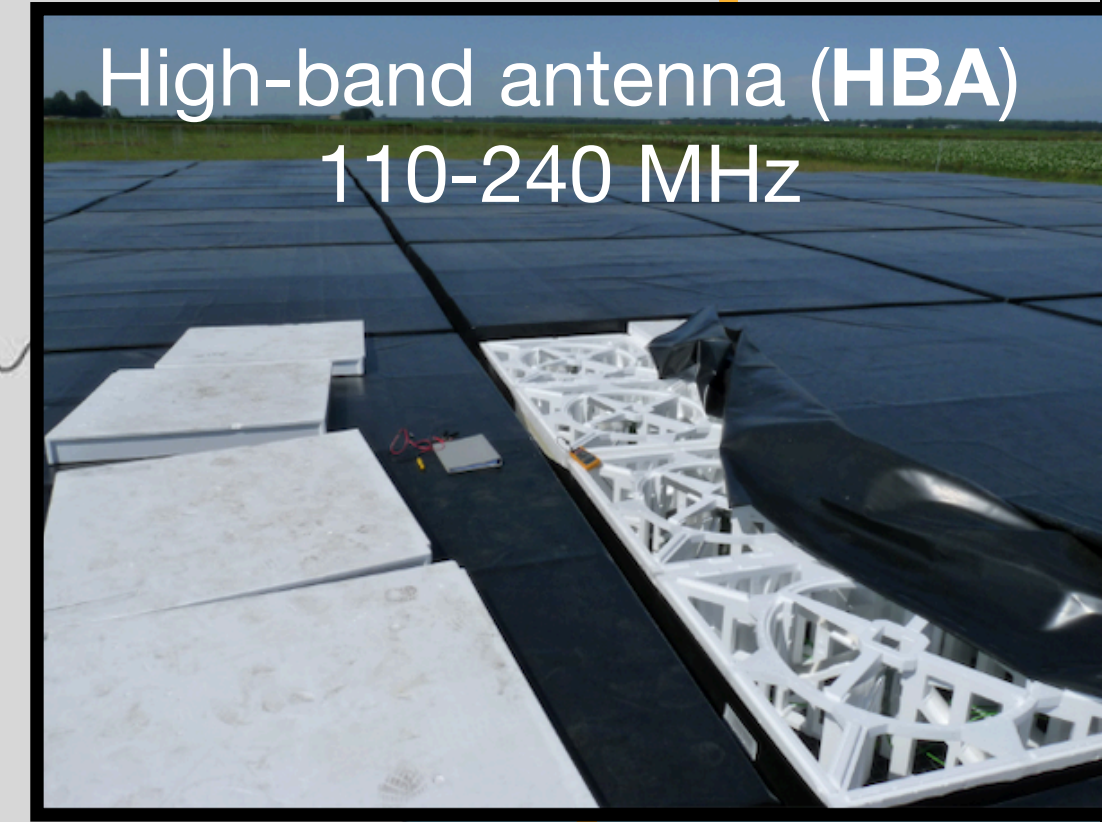
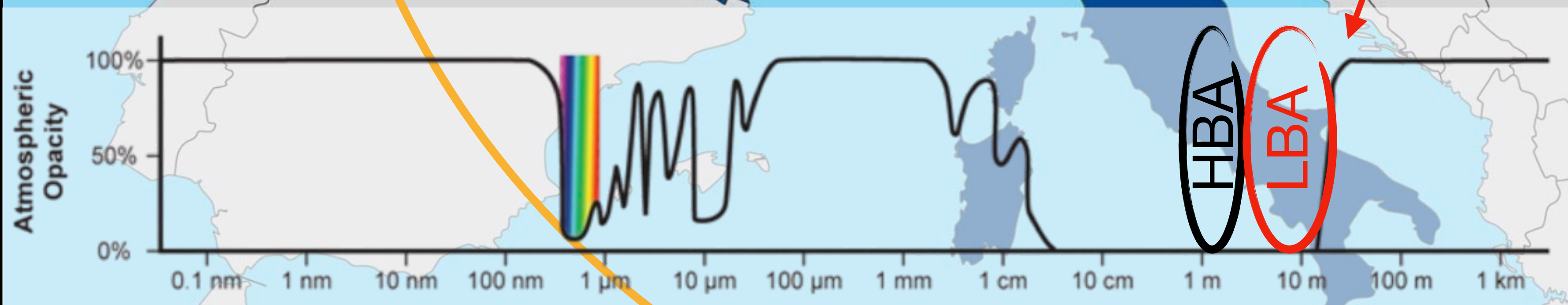
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LOFAR HBA VLBI  
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Ionospheric  
cut-off!



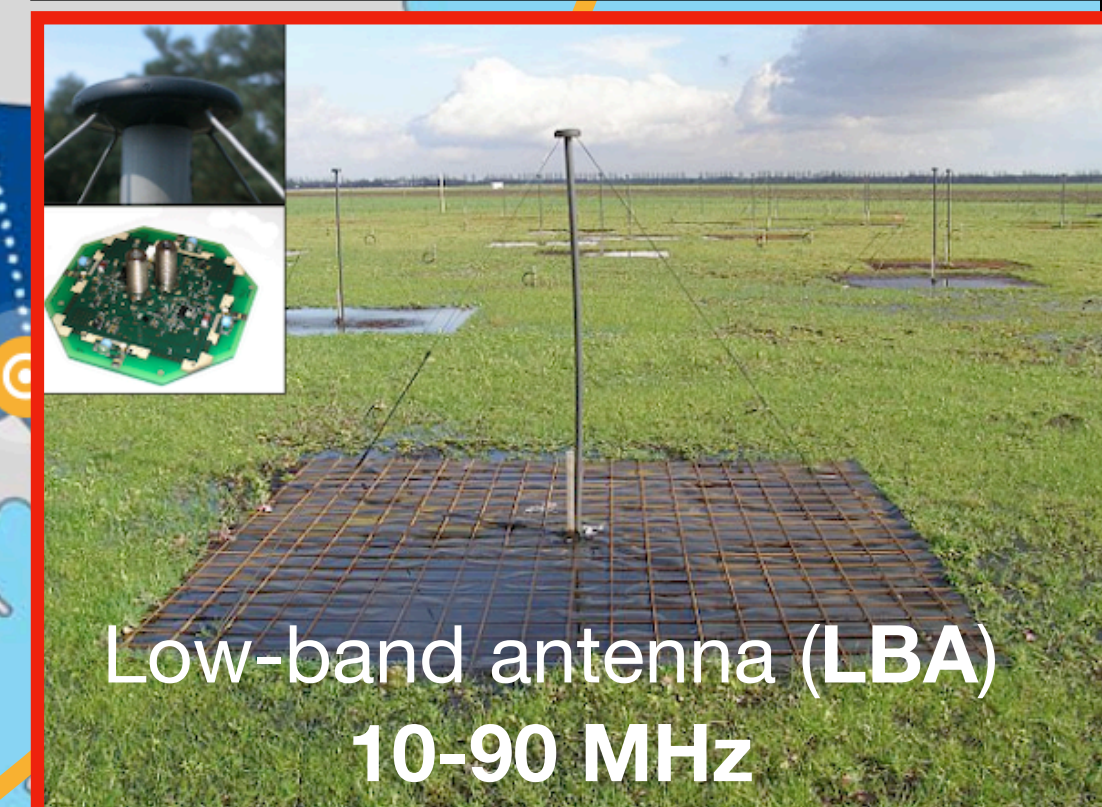
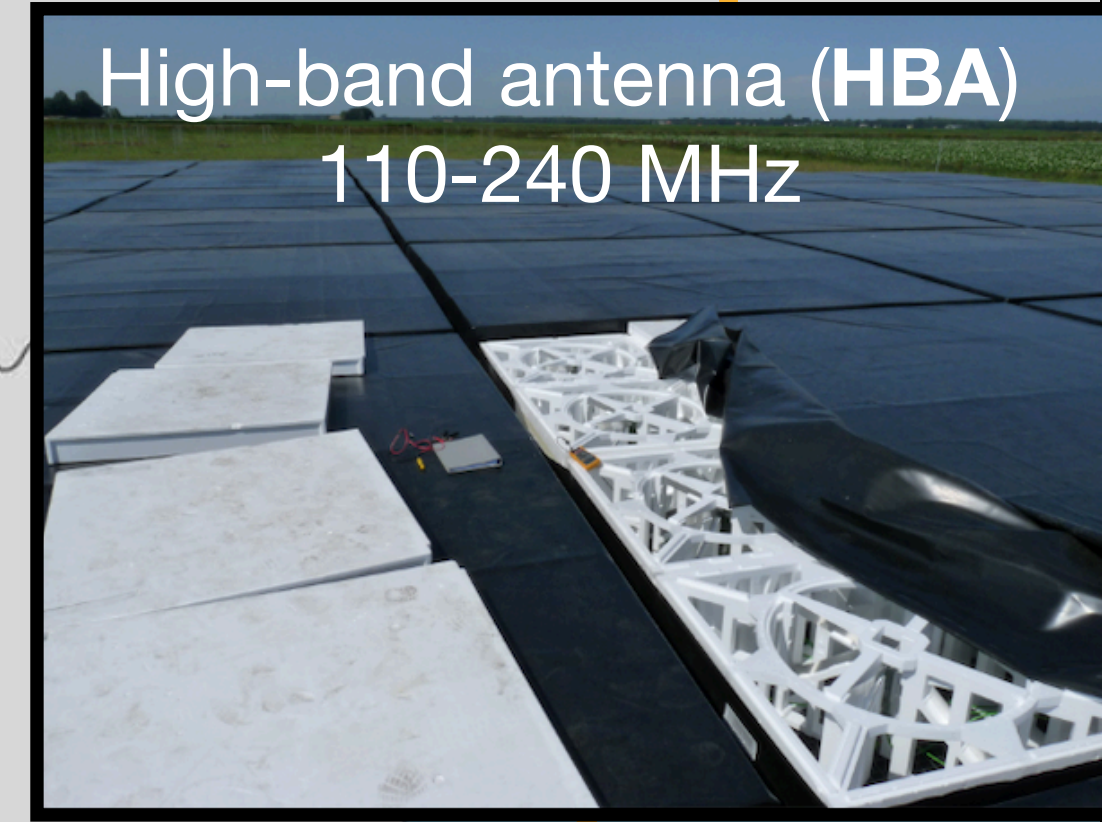
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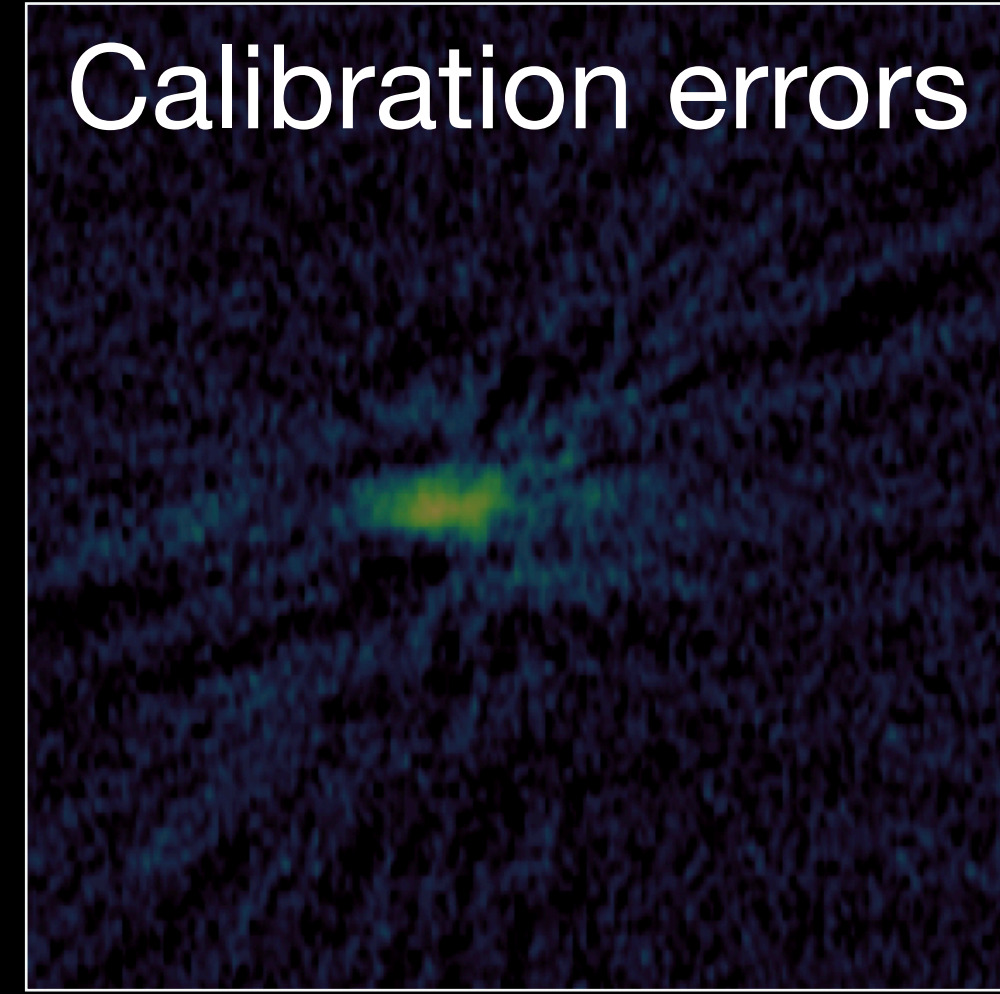
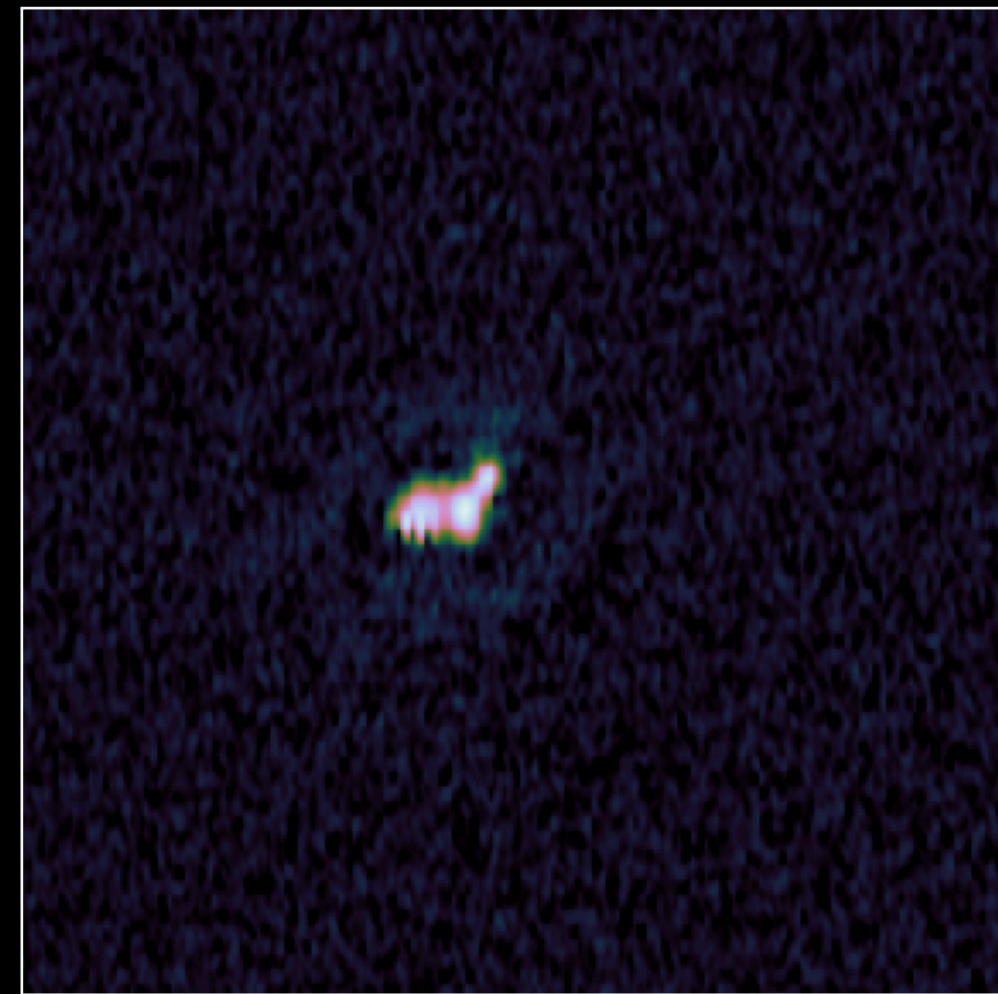
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cut-off!

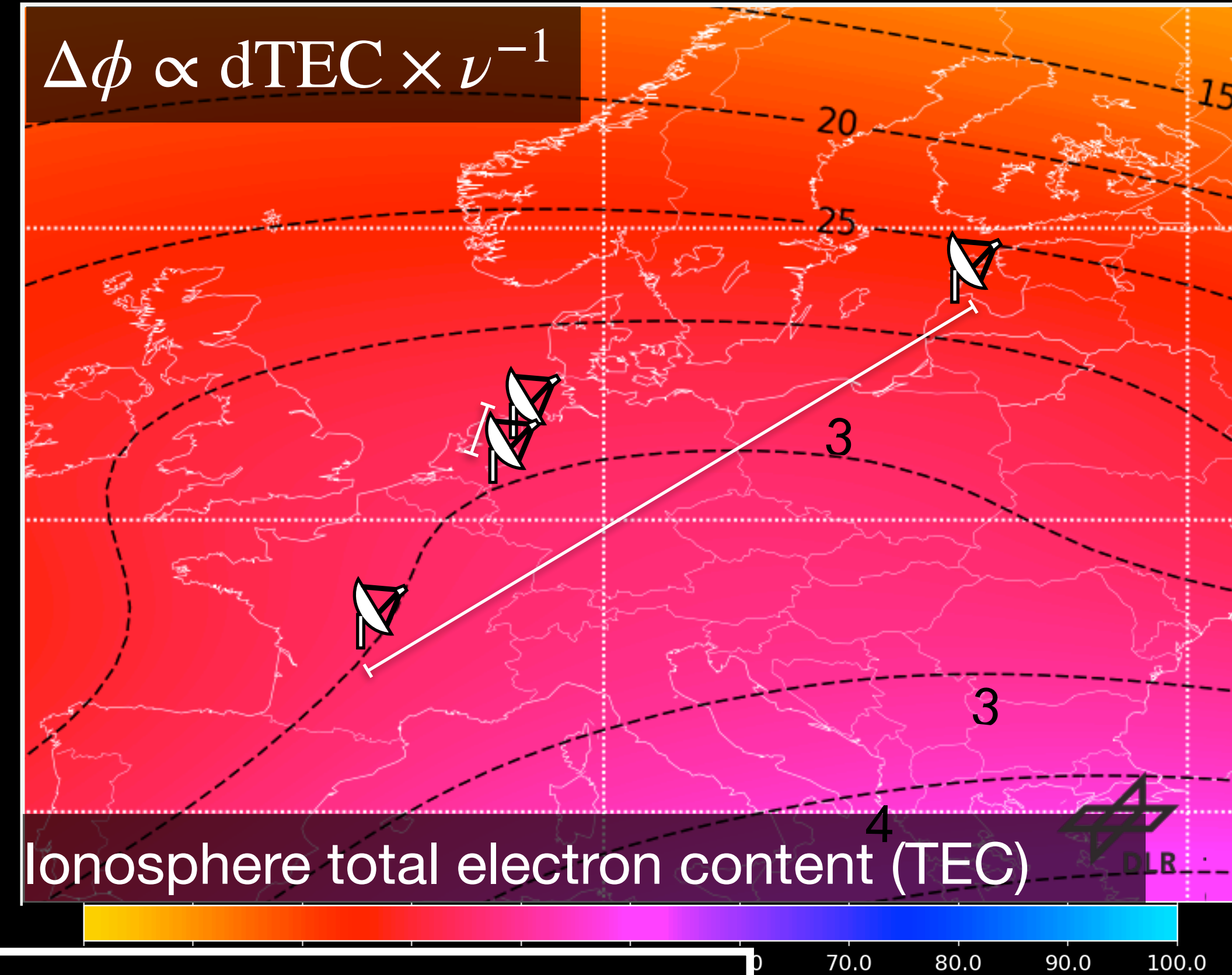


# Without proper calibration, LOFAR LBA VLBI signal **de-correlates**

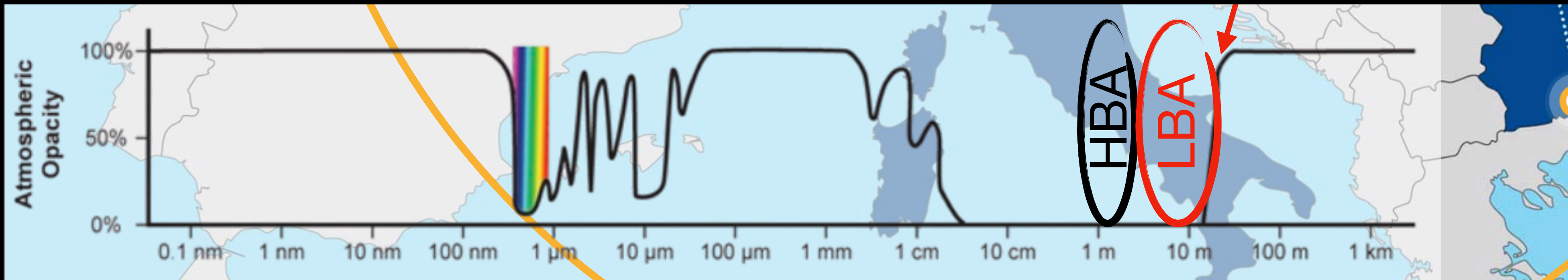
- In seconds
- Over <1 % of bandwidth
- Across tens of arcminutes



Calibration errors



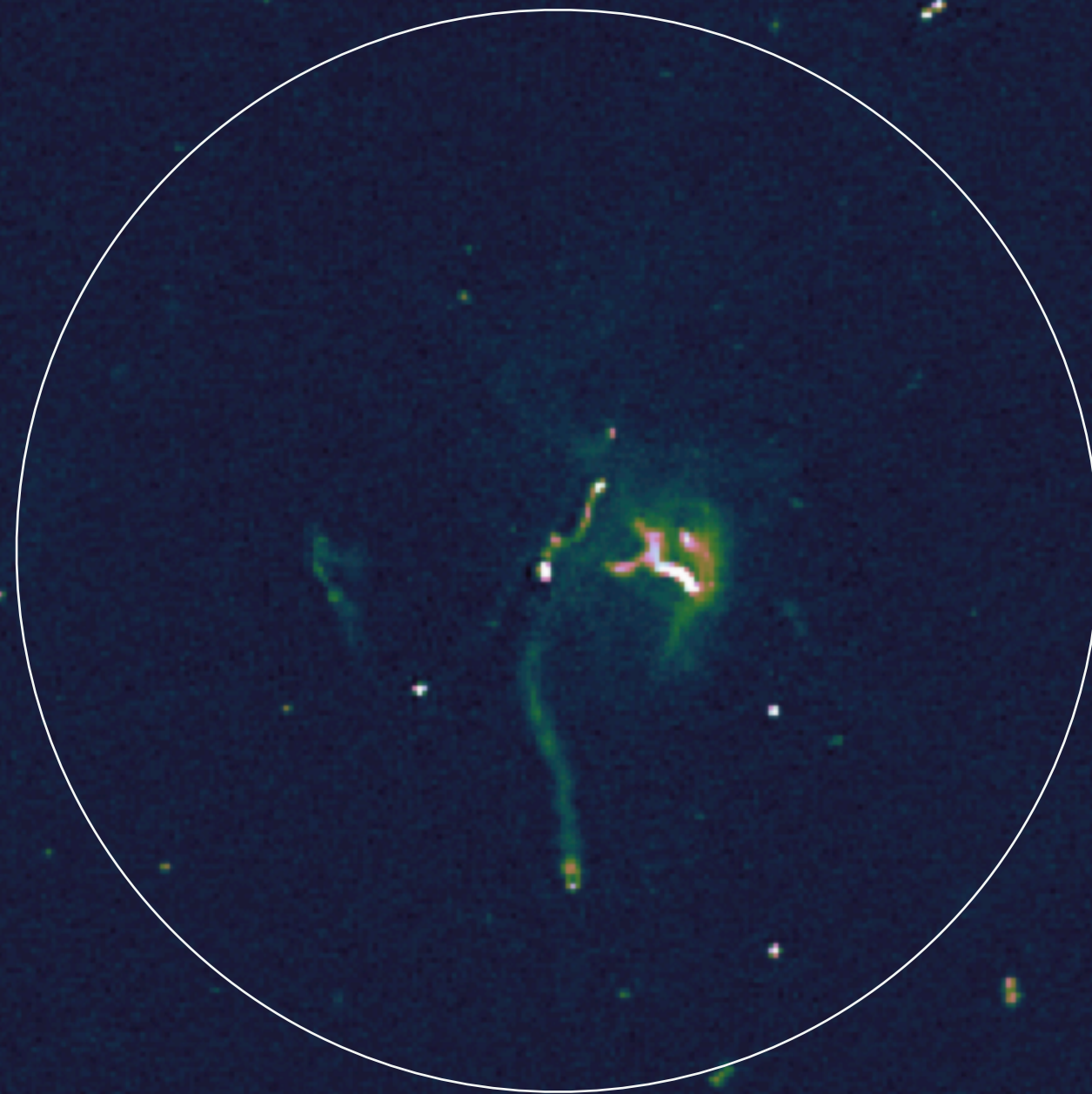
LBA VLBI only proven for individual bright calibrators!  
 [Morabito+16, Groeneveld+22]



Low-band antenna (LBA)  
 10-90 MHz

# LBA VLBI Test Field

- 8h observation
- 42-66 MHz
- 12 international stations



Abell 2255 cluster

Dutch LBA image  
resolution=15''  
 $\sigma_{\text{rms}}=1.4\text{mJy/beam}$

1 deg



# LBA VLBI Test Field

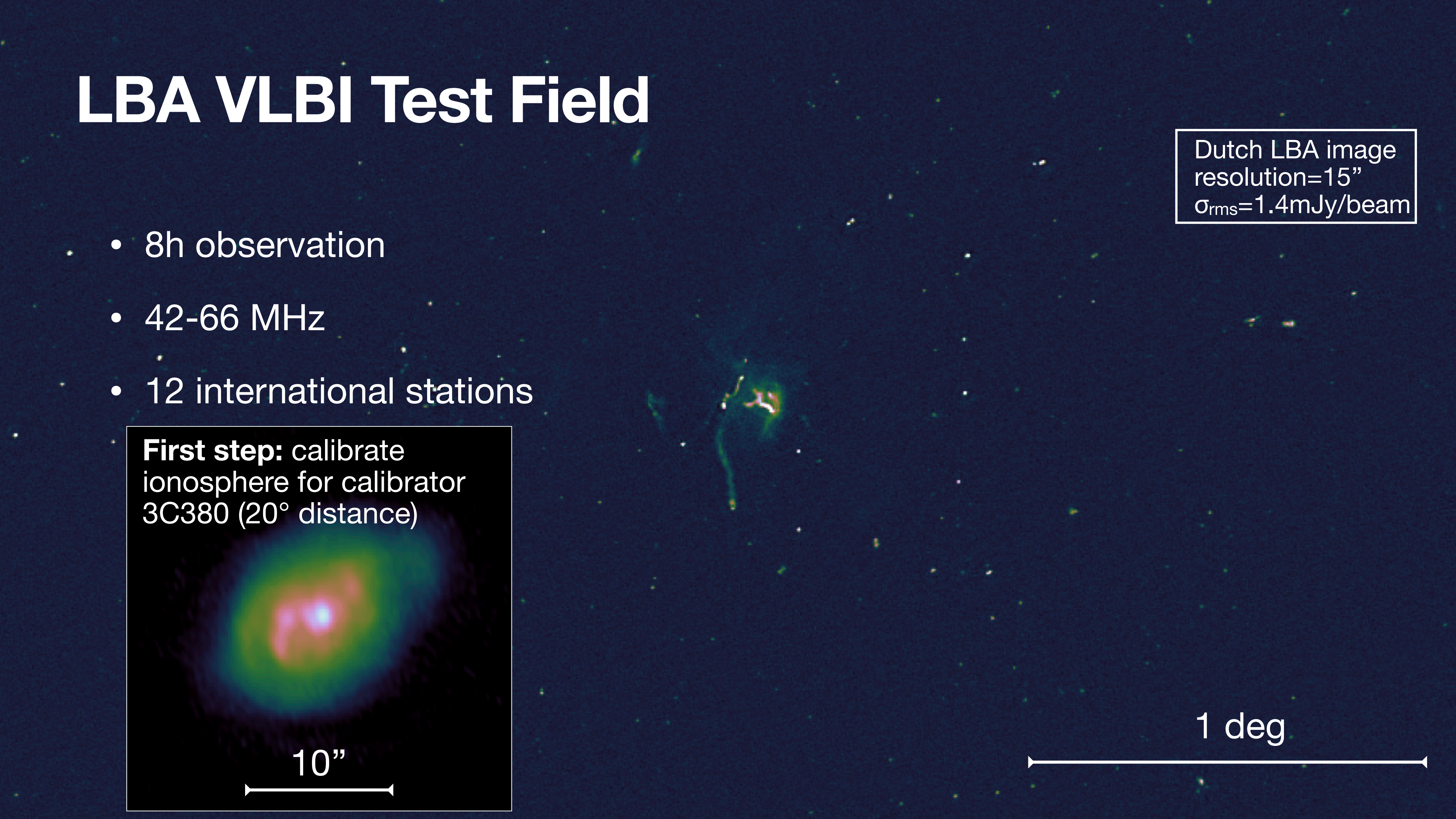
- 8h observation
- 42-66 MHz
- 12 international stations

**First step:** calibrate ionosphere for calibrator 3C380 (20° distance)

10''

Dutch LBA image  
resolution=15''  
 $\sigma_{\text{rms}}=1.4\text{mJy/beam}$

1 deg



# VLBI infield calibrator



1.8 Jy

3.0 Jy

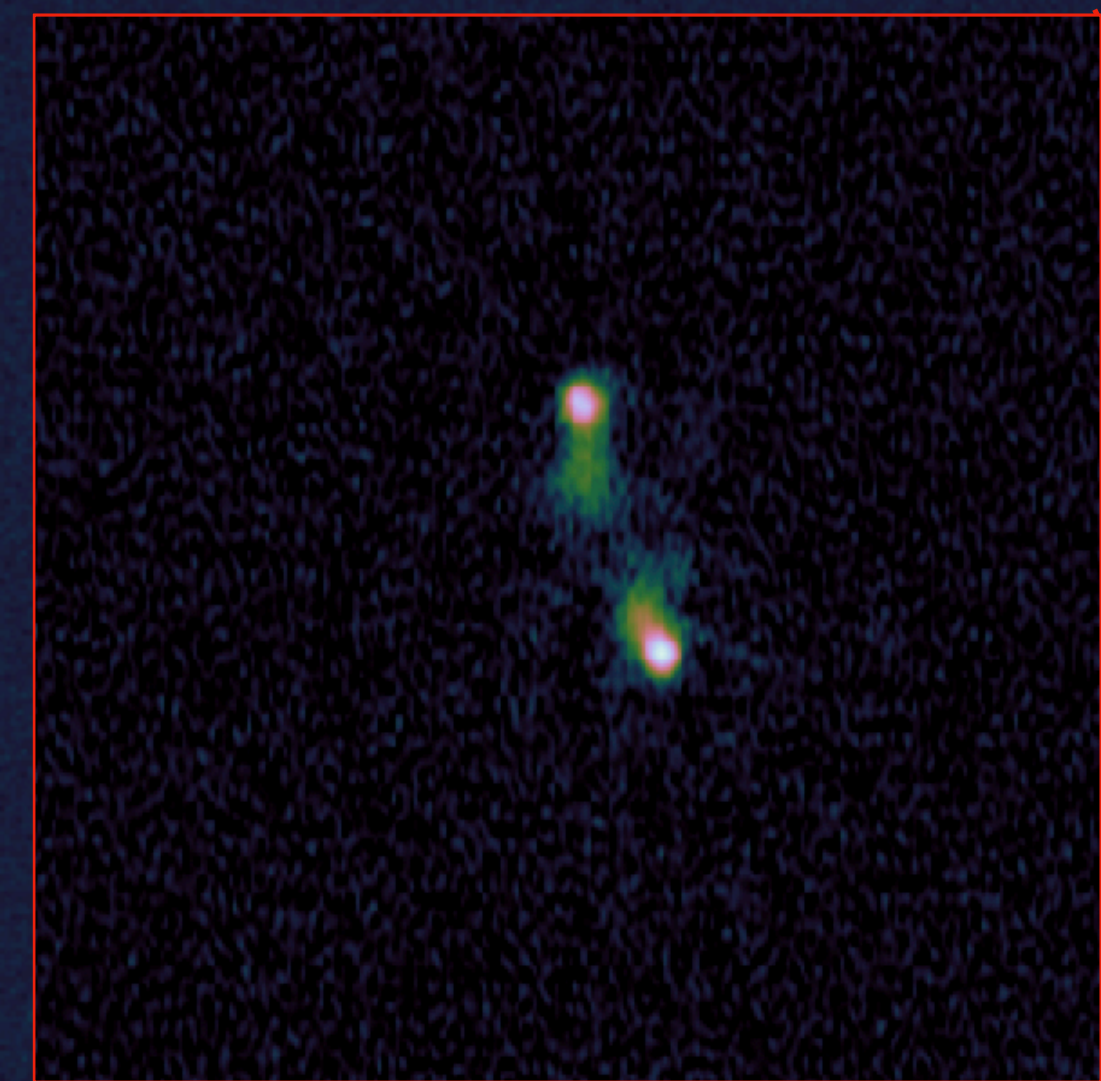
resolution=15"  
 $\sigma_{\text{rms}}=1.4$  mJy/beam



1 deg



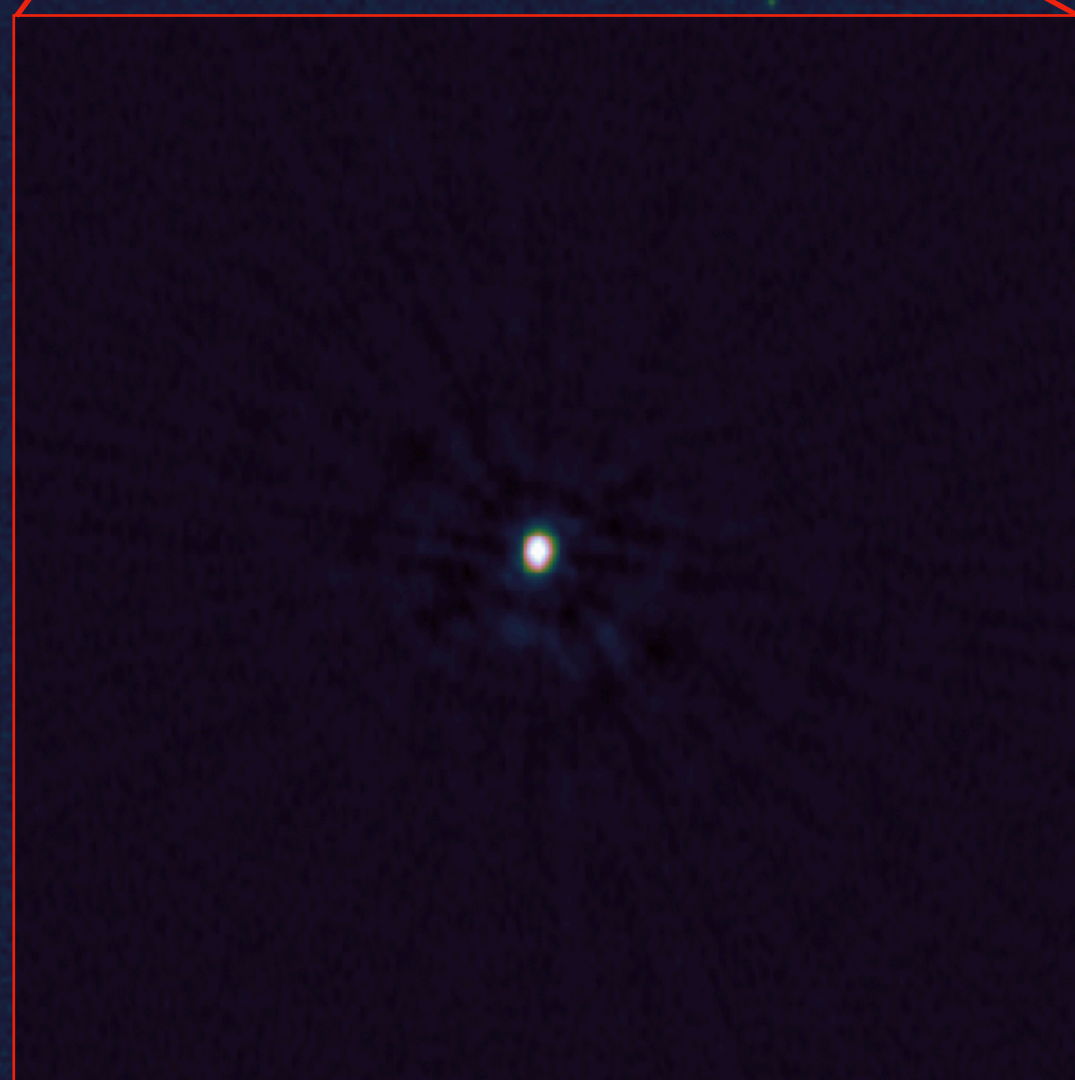
# VLBI infield calibrator



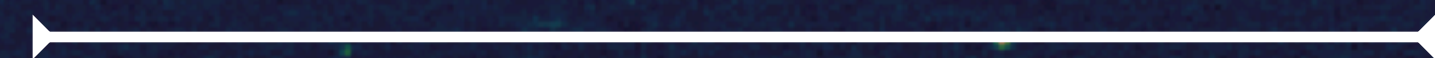
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3.0 Jy

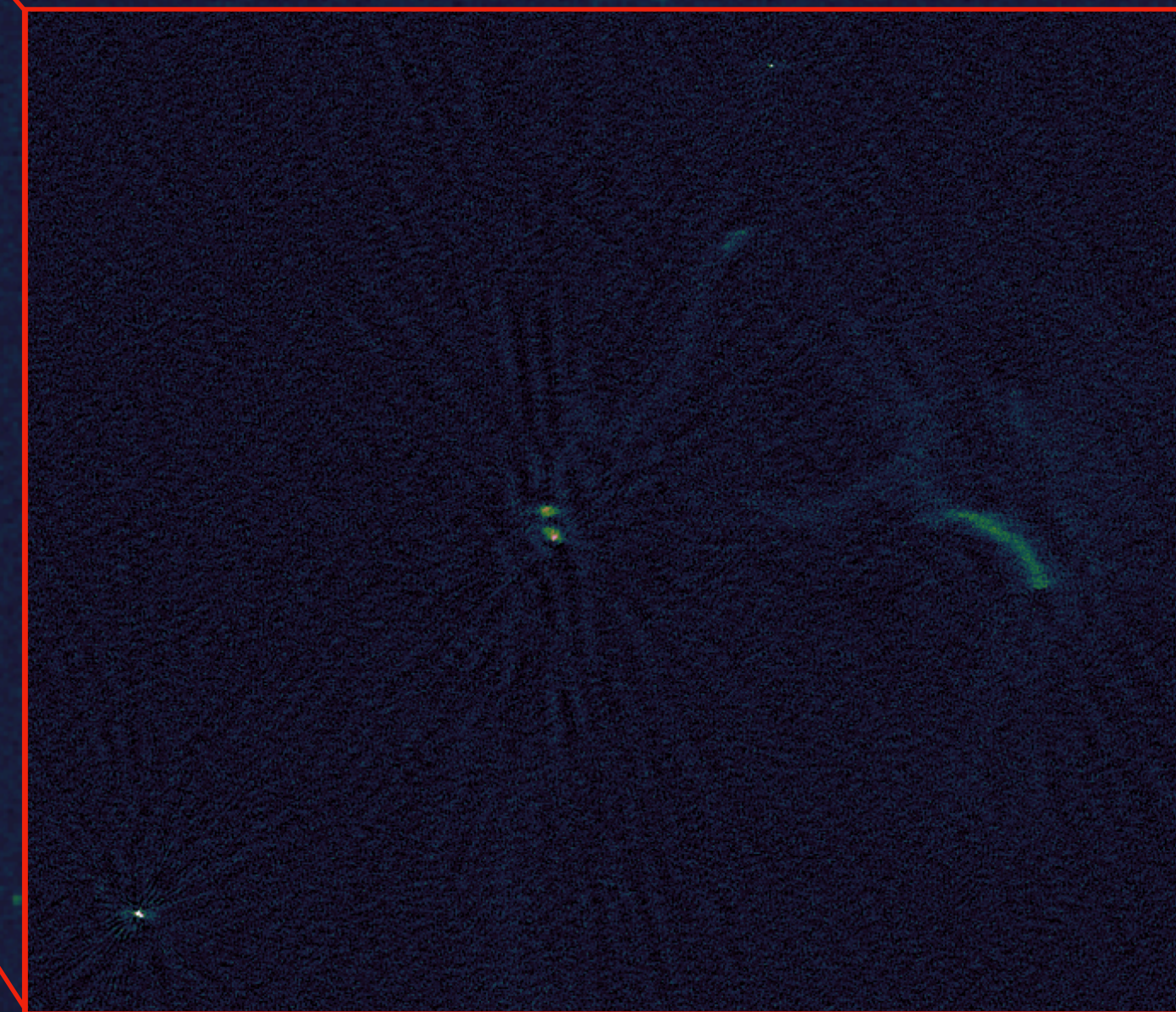
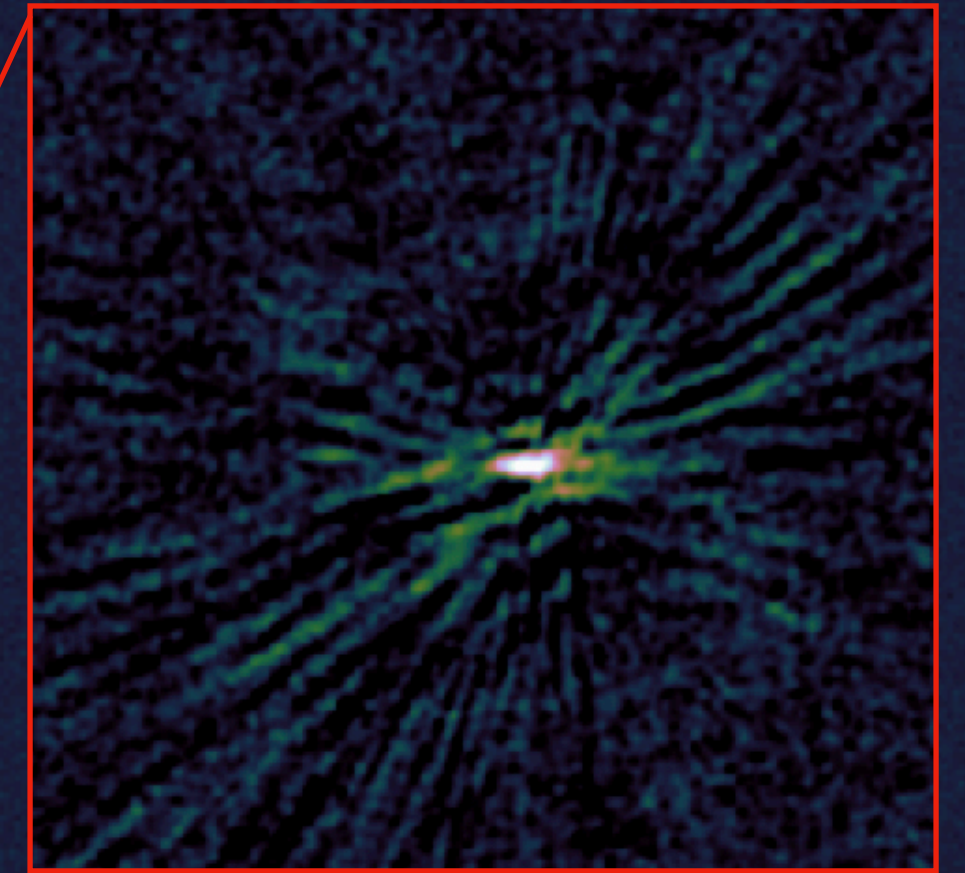
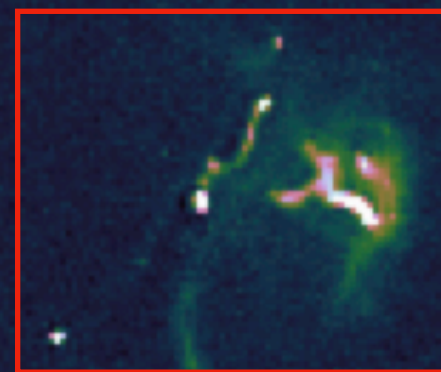
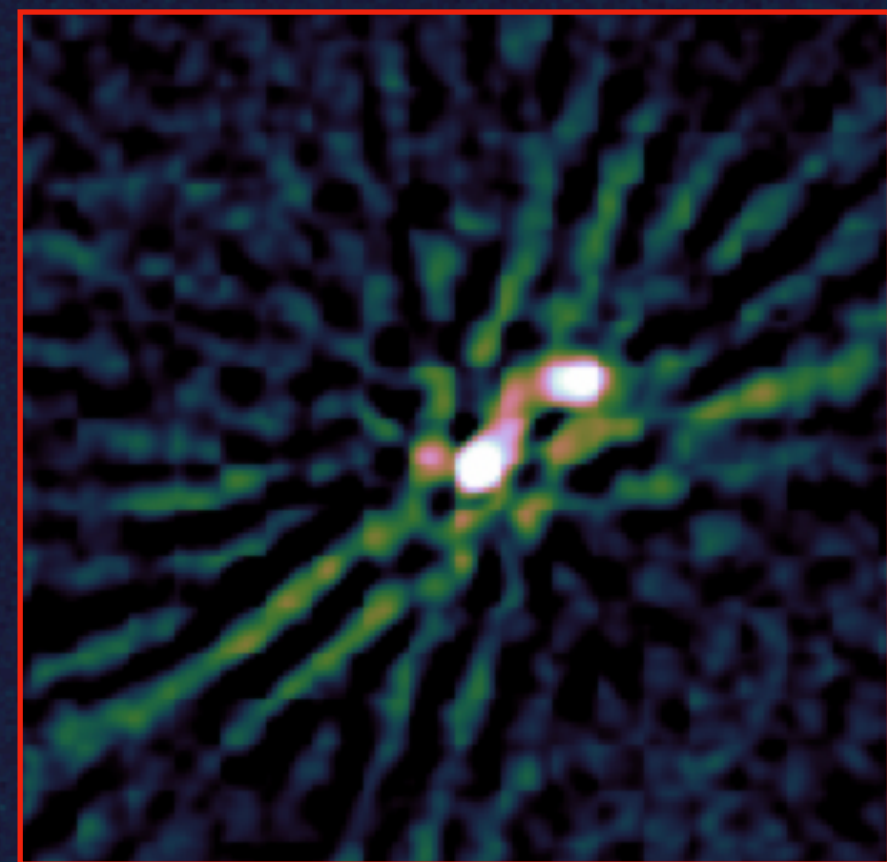
resolution=0.7"  
 $\sigma_{\text{rms}}=0.8$  mJy/beam



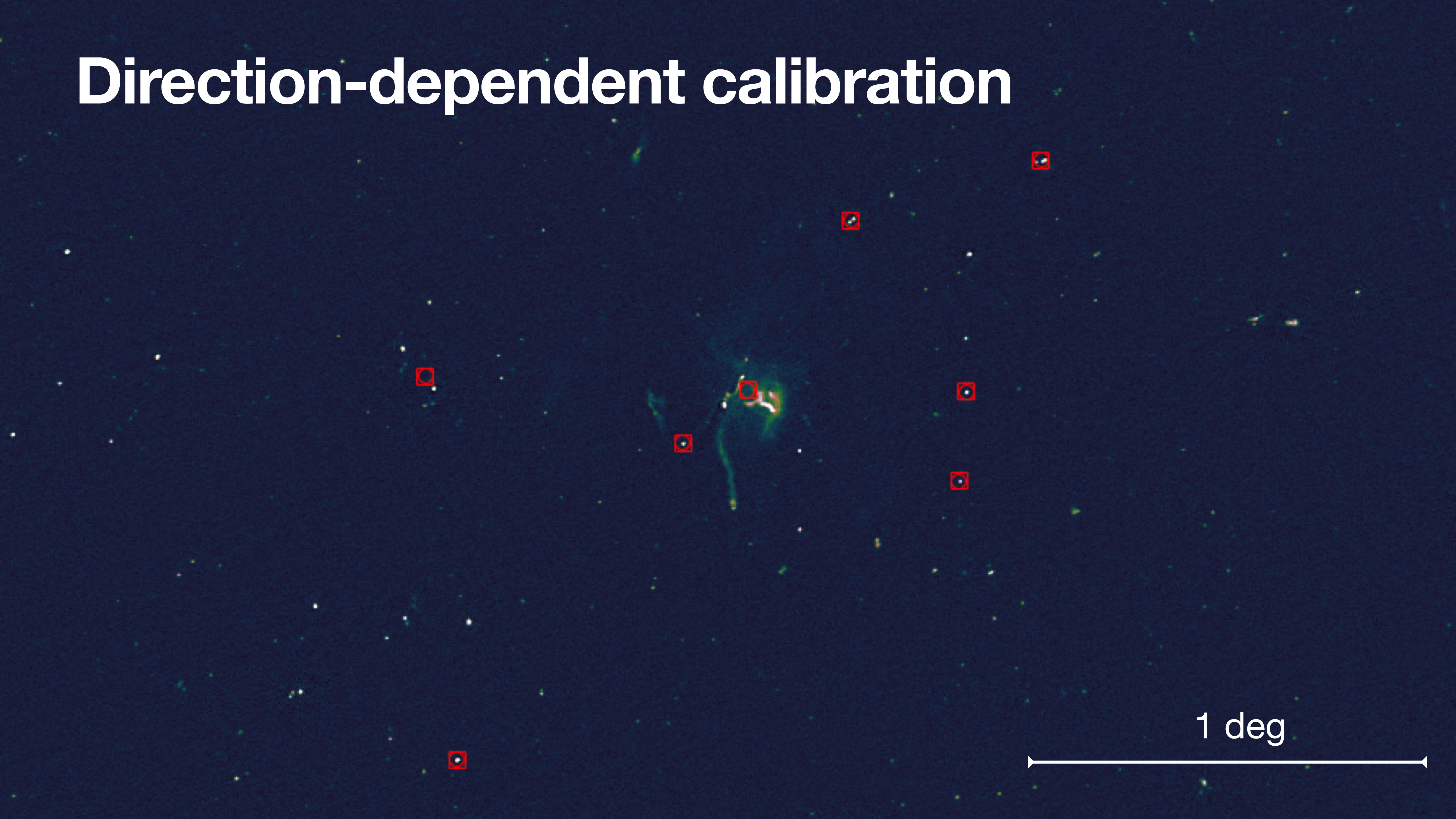
1 deg



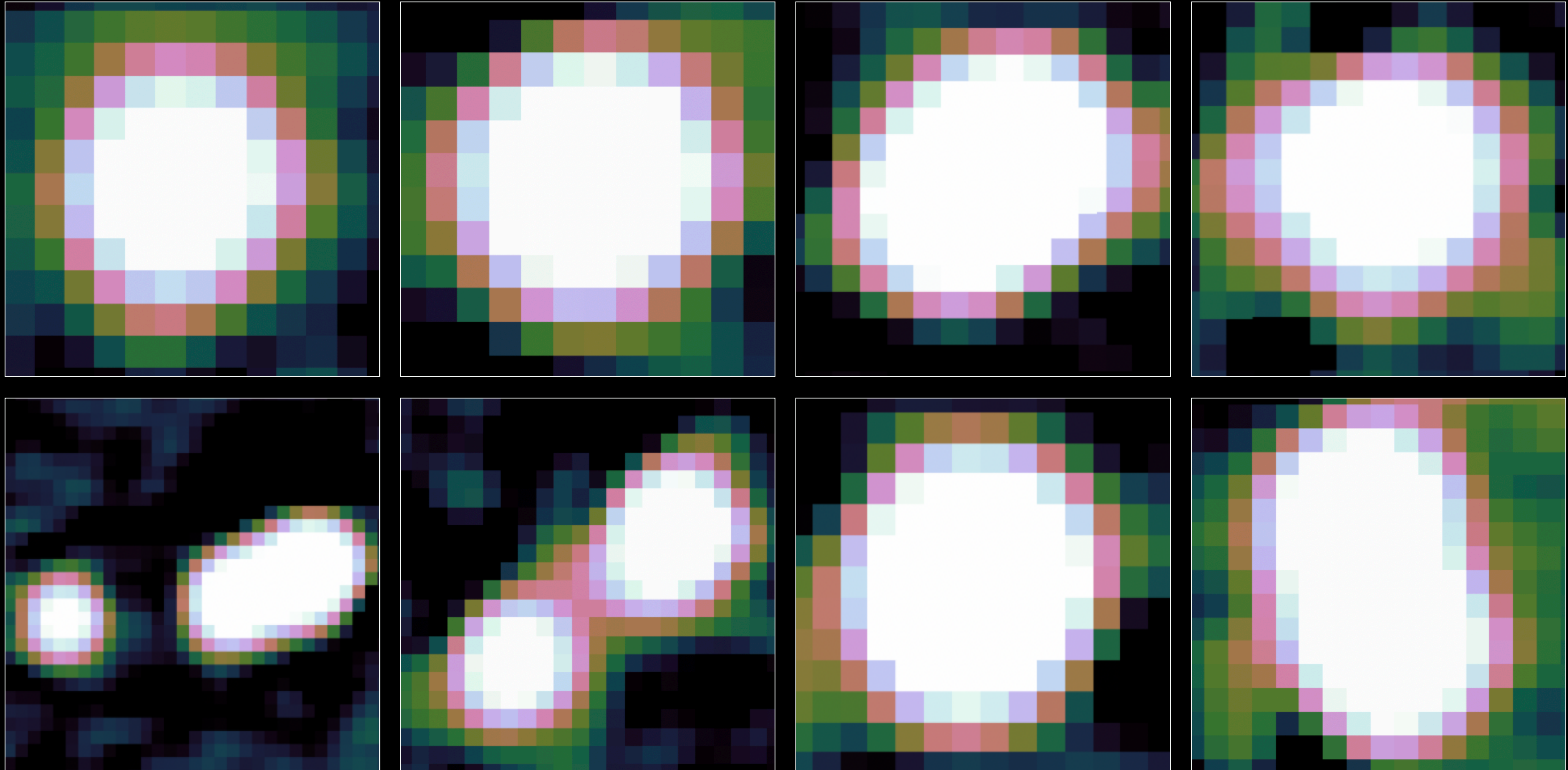
# Direction-dependent systematics



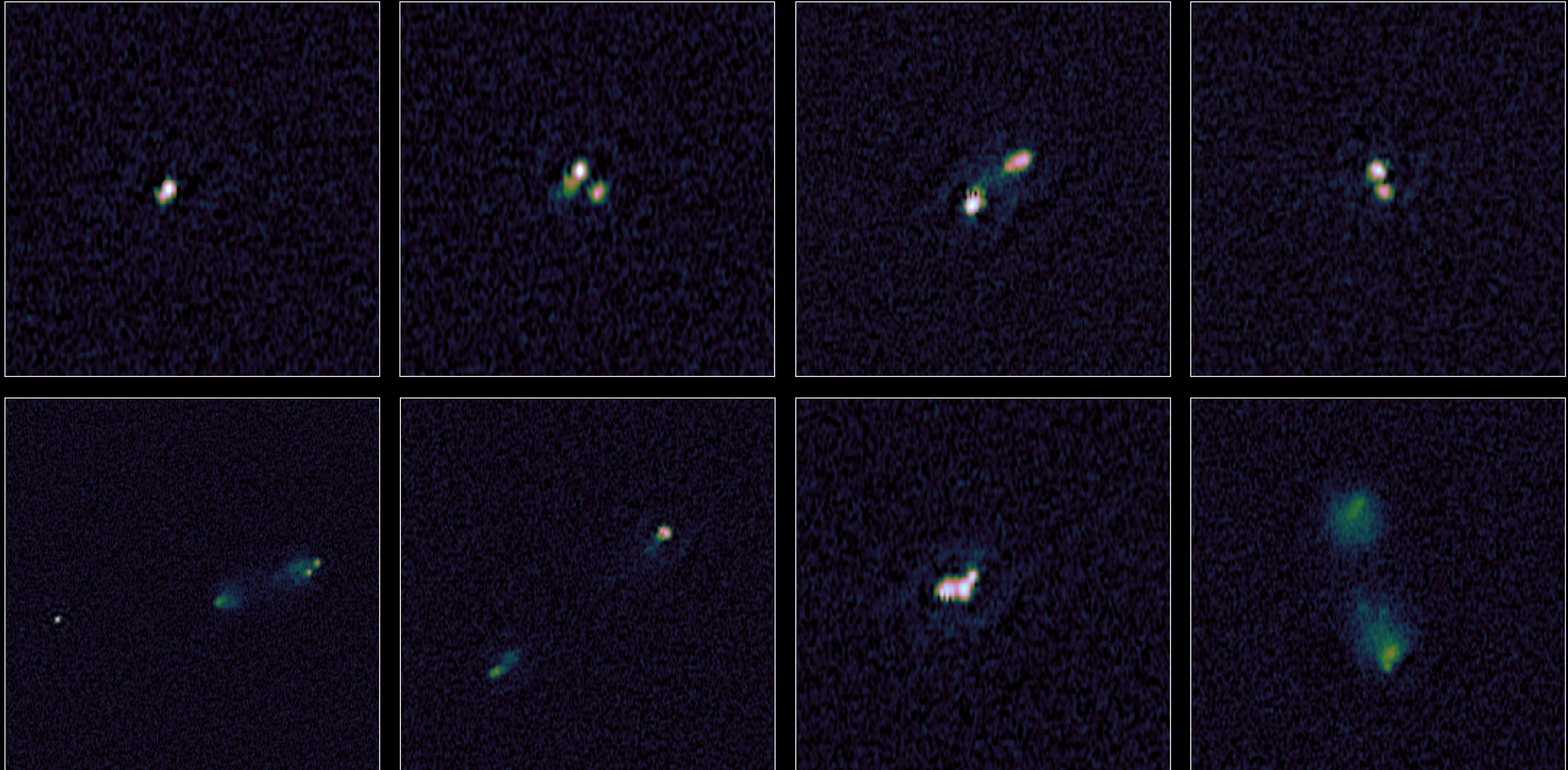
# Direction-dependent calibration



# Direction-dependent calibrators (Dutch array)



# Direction-dependent calibrators (VLBI)



First LBA VLBI  
wide-field image!

Dir08  
□

Dir04  
□

Dir01  
□

Dir05  
□

Dir02  
□

Dir06  
□

Dir03  
□

• 9 directions

• 0.9" x 0.5"

• 650  $\mu$ Jy/beam

• ~400 sources

Dir07  
□

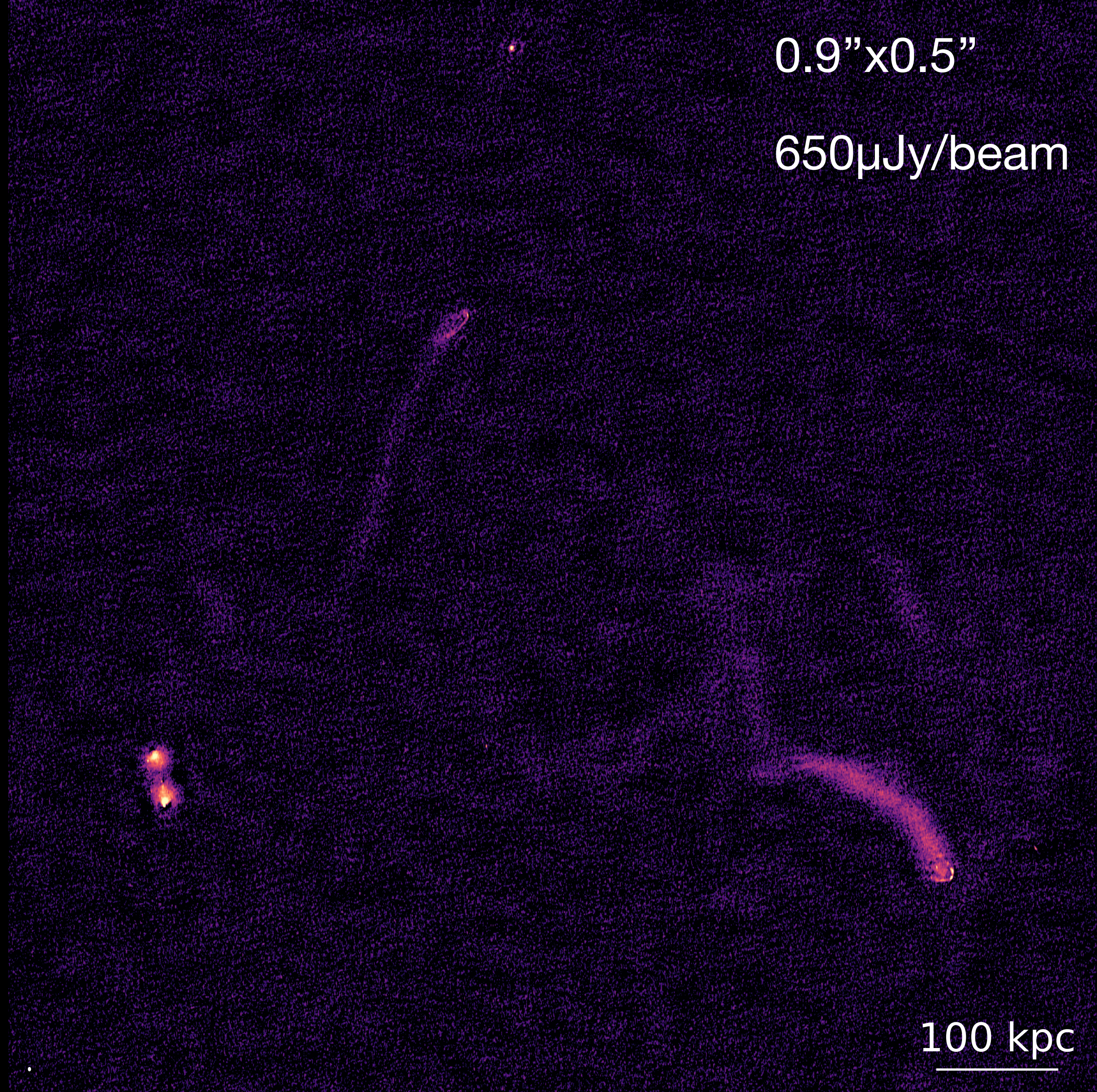
1 deg



# Abell 2255

0.9" x 0.5"

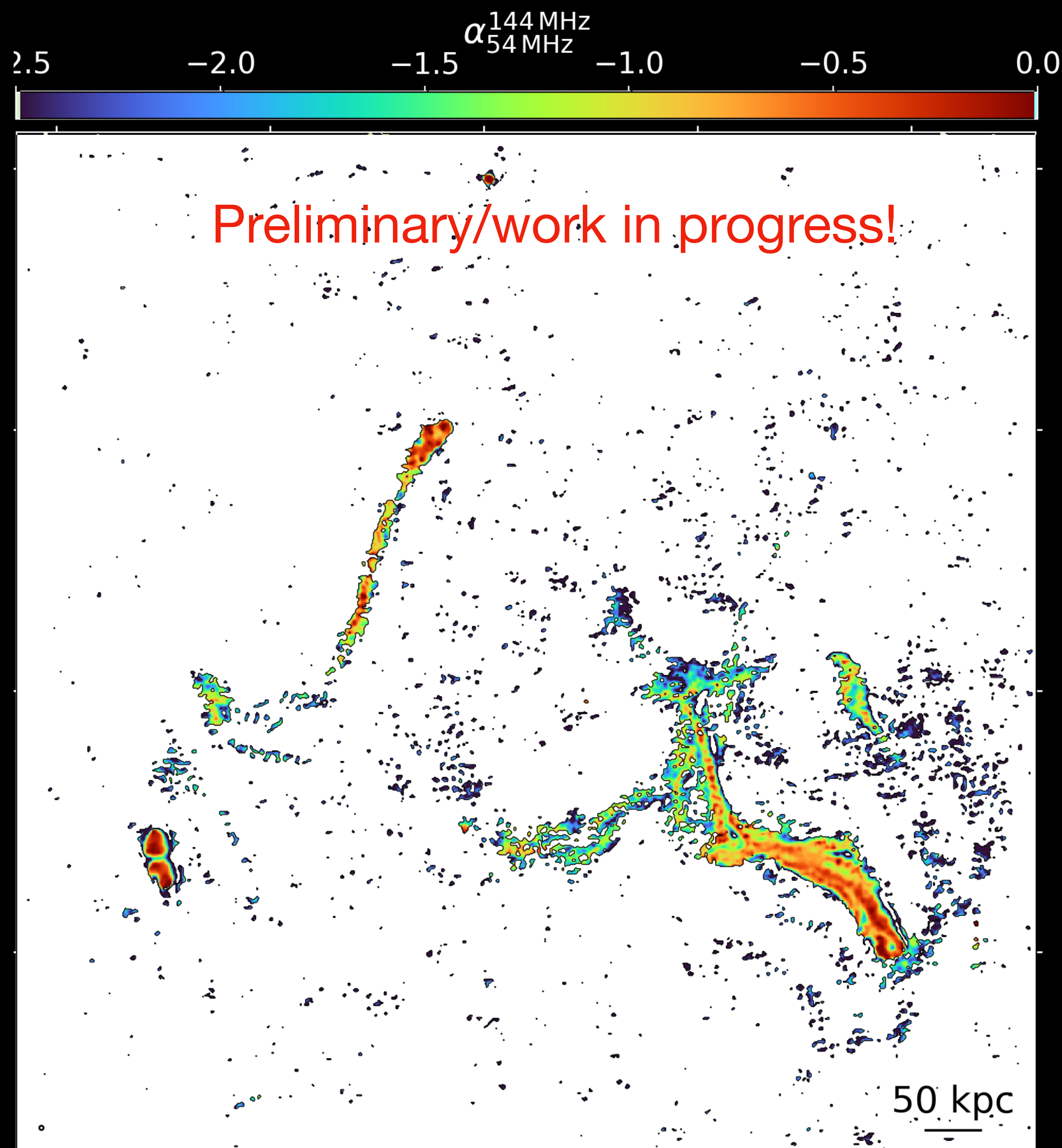
650  $\mu$ Jy/beam



100 kpc

# Abell 2255

- LOFAR Low + High-band VLBI spectral index
- Resolution: 2''



# Conclusions

- Study cluster filaments using LOFAR LBA VLBI
- First wide-field sub-arcsecond resolution image  $< 100$  MHz
  - LOFAR 1: require few-Jy in-field calibrator & calm ionosphere
- Ongoing **LOFAR 2.0** upgrade will be a game changer!
  - Increased sensitivity
  - Simultaneous low+high-band

