

# The Corona Borealis supercluster field as seen by LOFAR



**Alexander Drabent**

LOFAR SKSP Galaxy Cluster WG

22<sup>nd</sup> March, 2019

Thüringer Landessternwarte Tautenburg

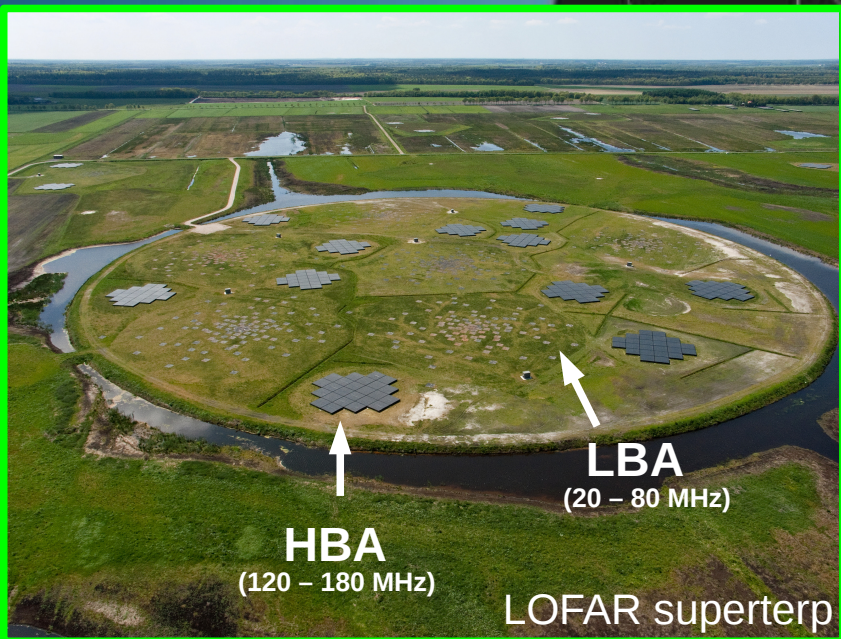
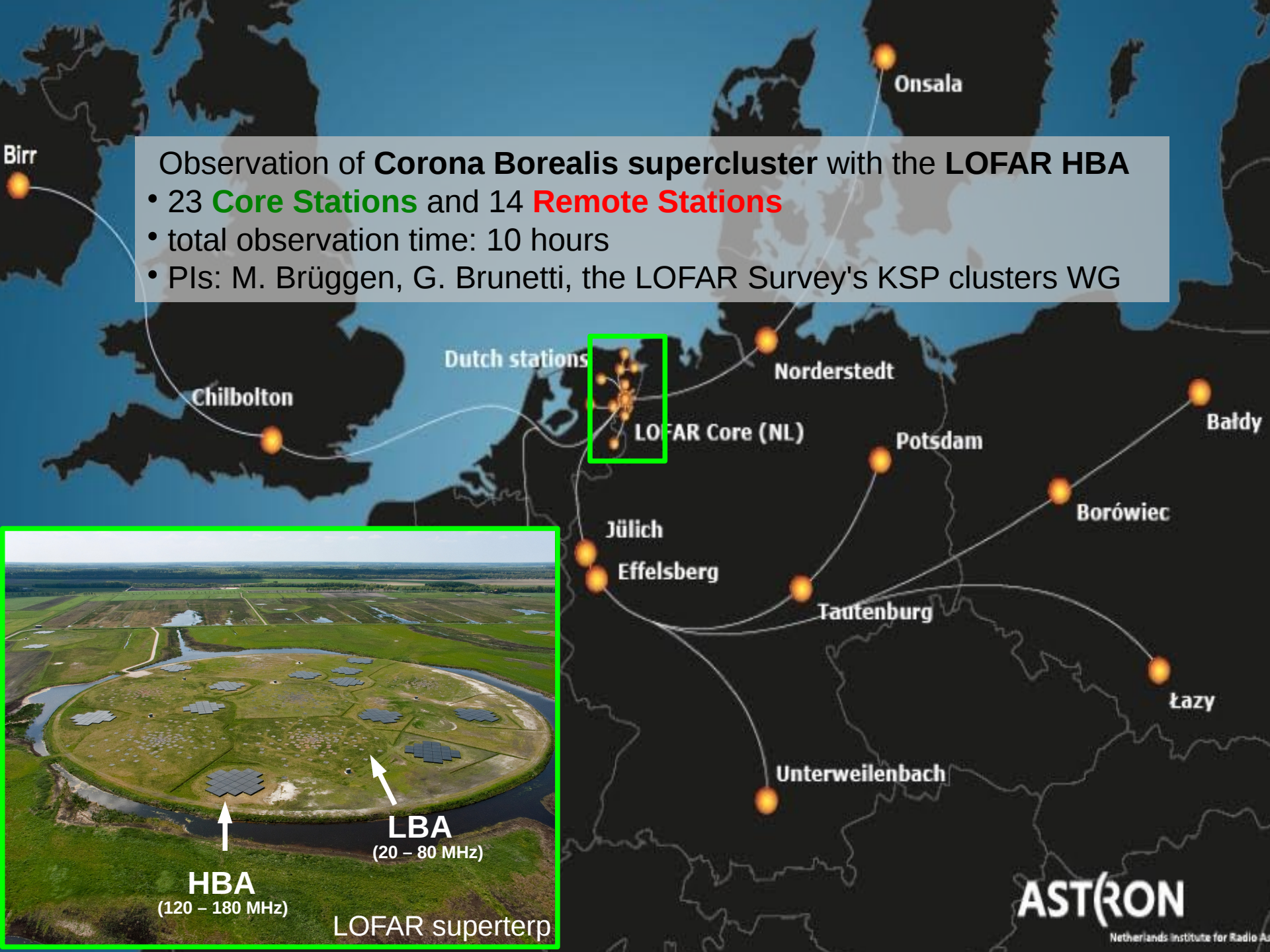
The Metre Wavelength Sky II, Pune, India



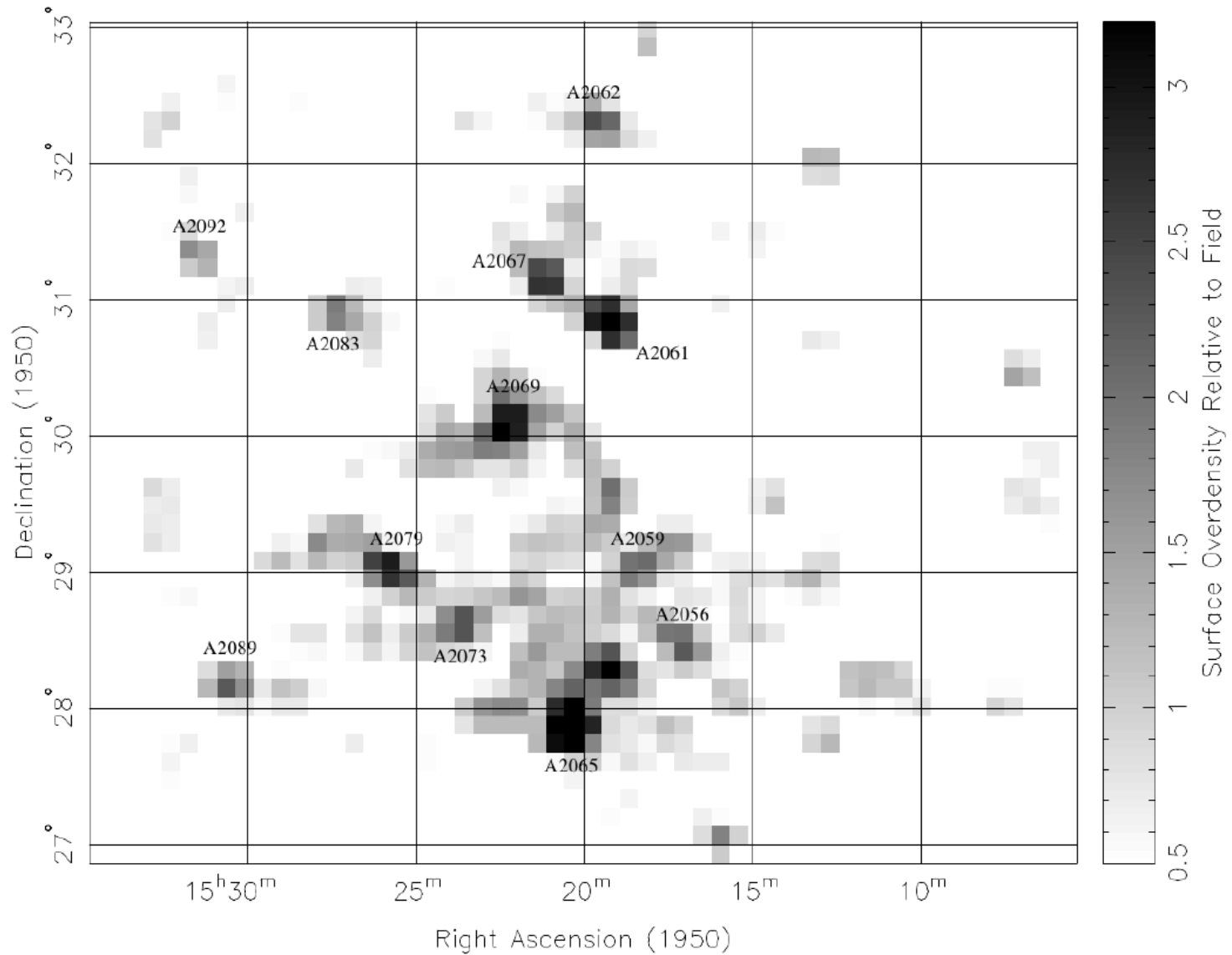
**LOFAR station in Tautenburg, Germany**

## Observation of **Corona Borealis** supercluster with the LOFAR HBA

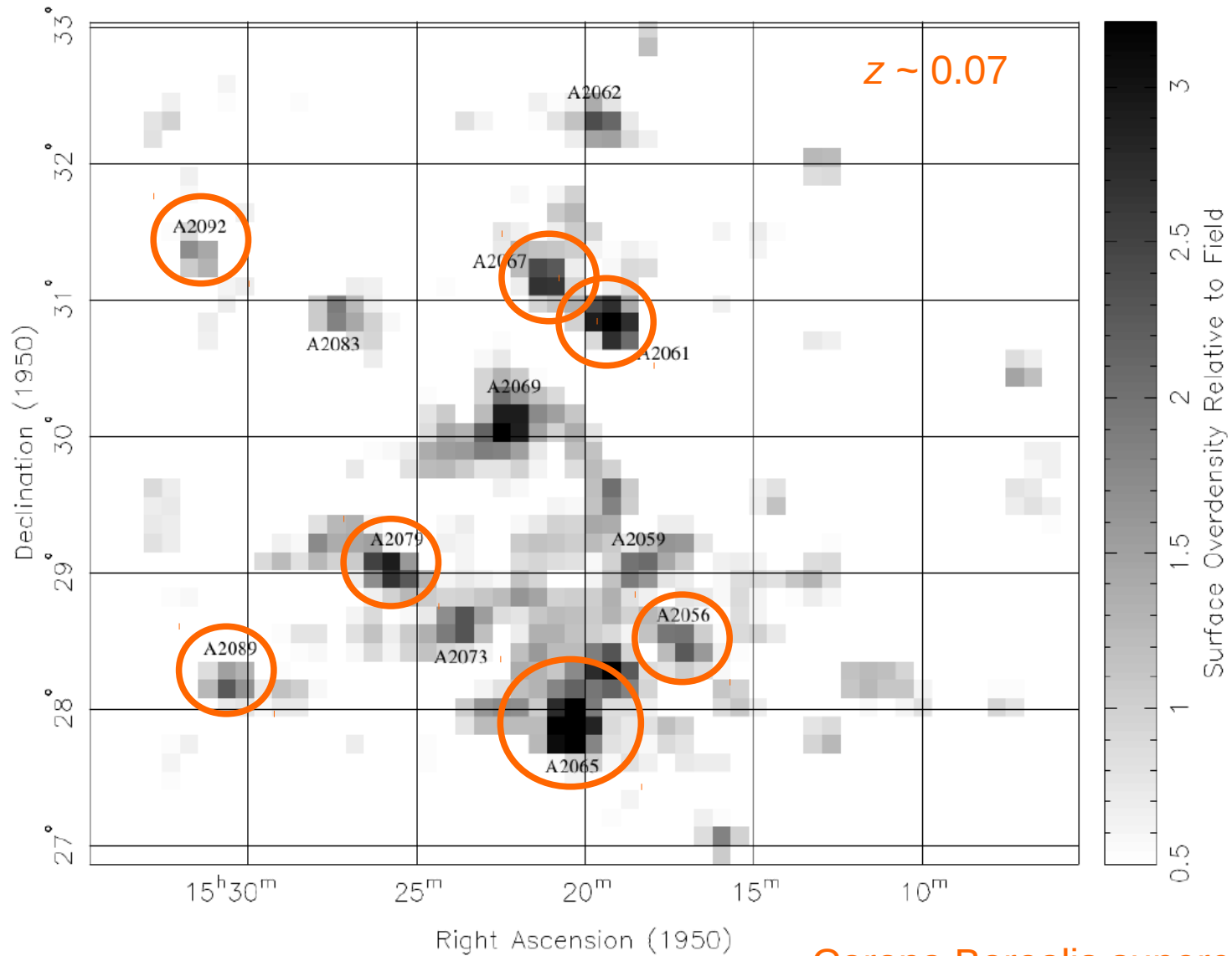
- 23 **Core Stations** and 14 **Remote Stations**
- total observation time: 10 hours
- PIs: M. Brüggen, G. Brunetti, the LOFAR Survey's KSP clusters WG



# The Corona Borealis Supercluster field

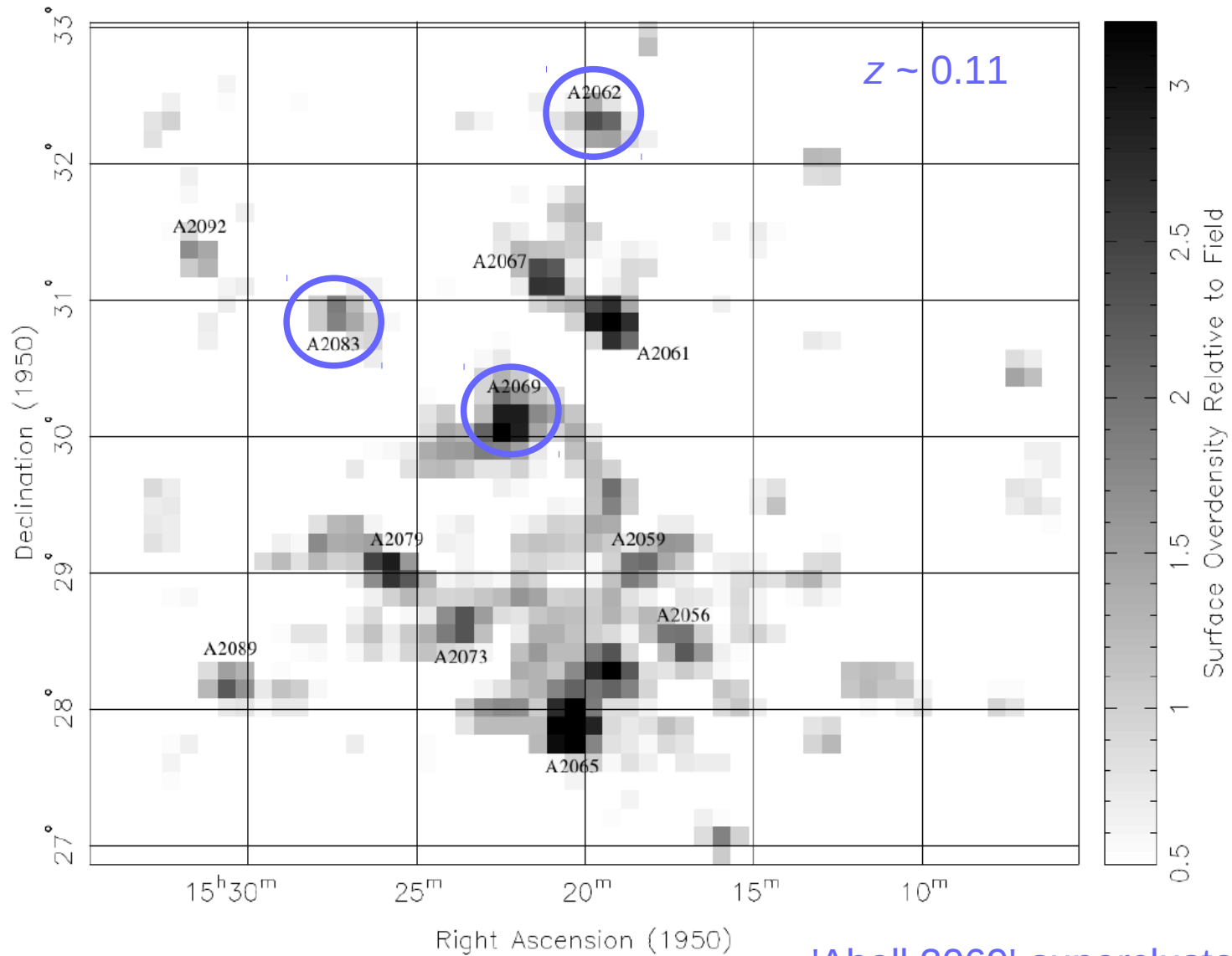


# The Corona Borealis Supercluster field

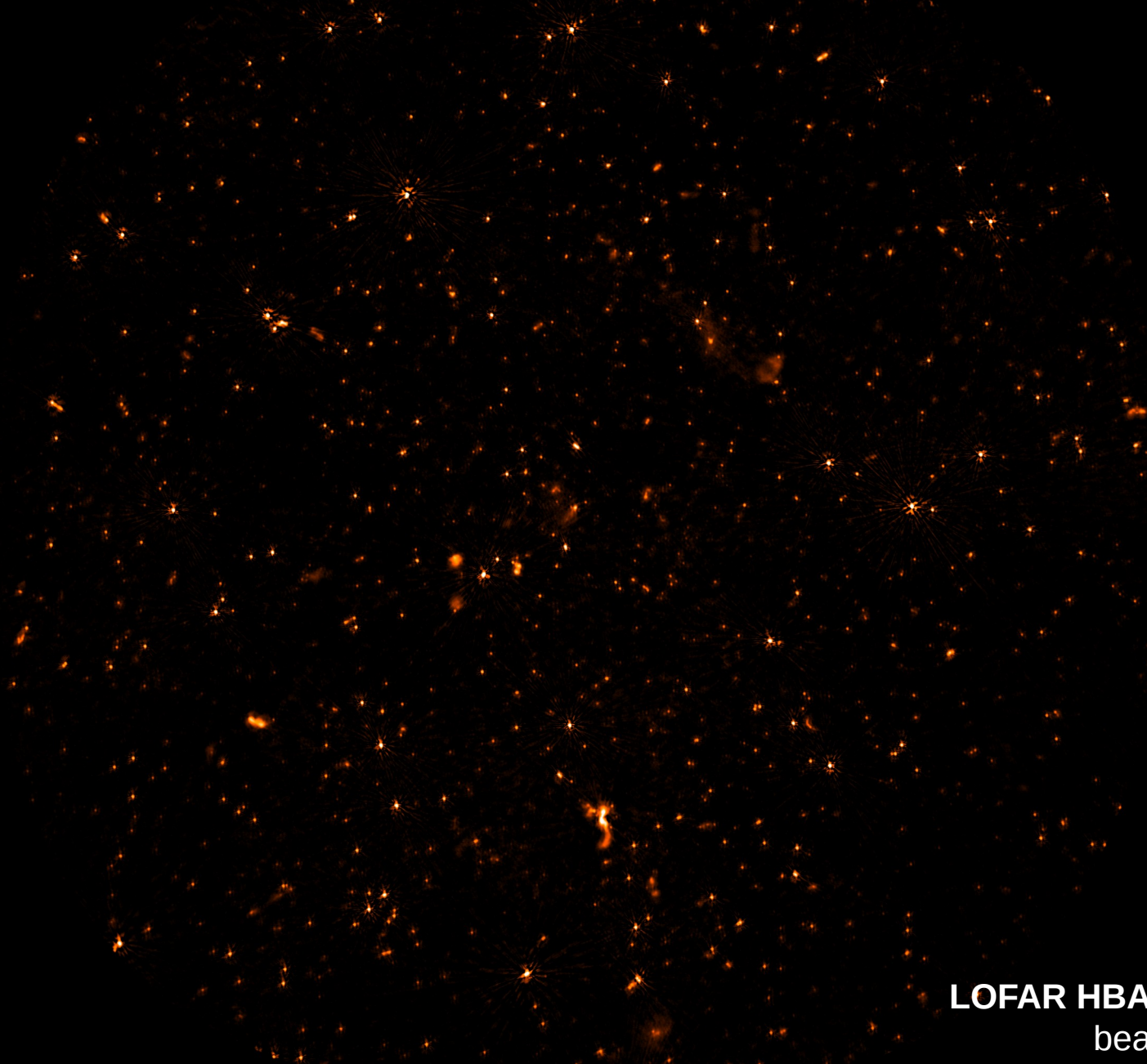


Corona Borealis supercluster

# The Corona Borealis Supercluster field

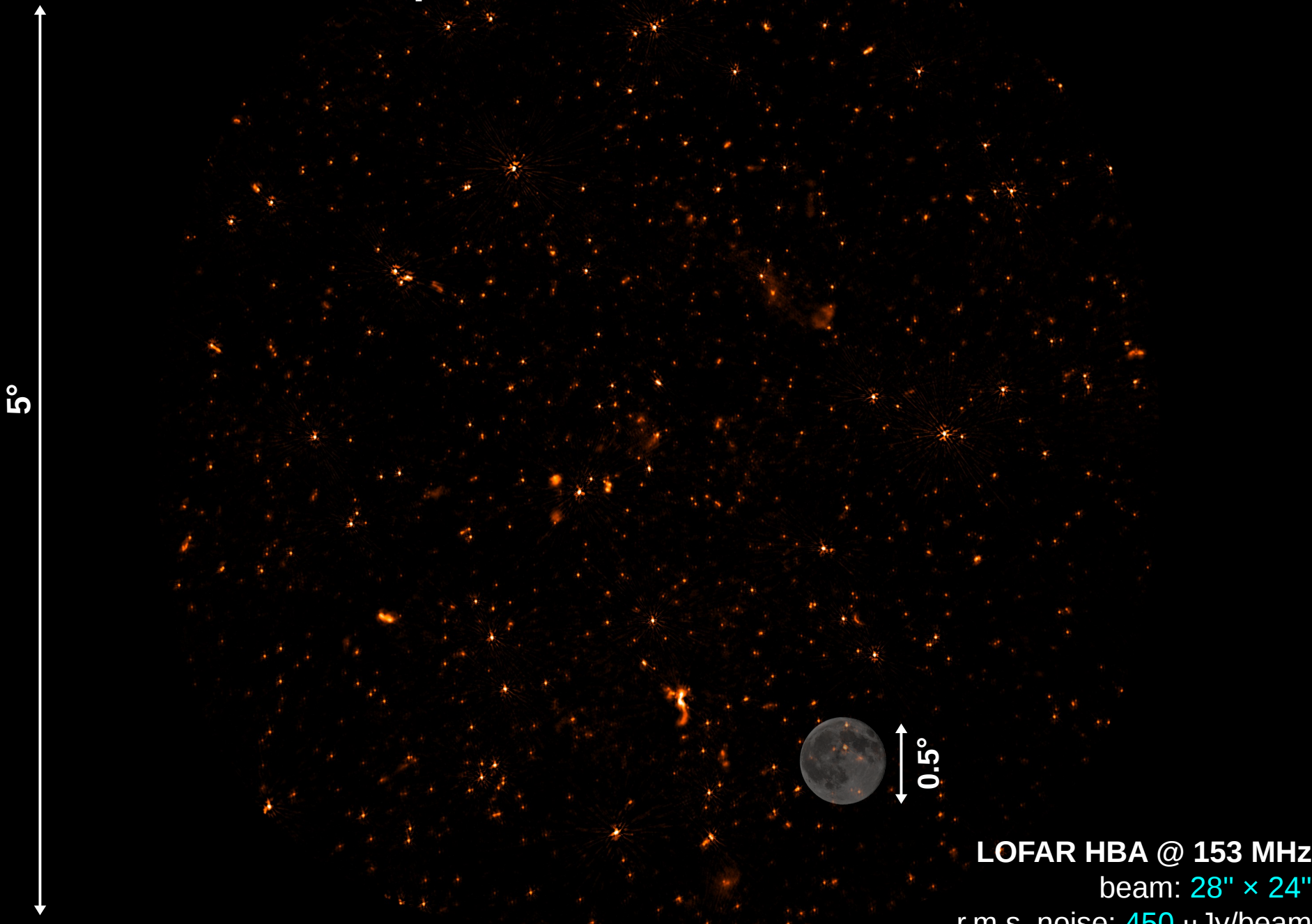


# Corona Borealis supercluster field – there is a lot to discover



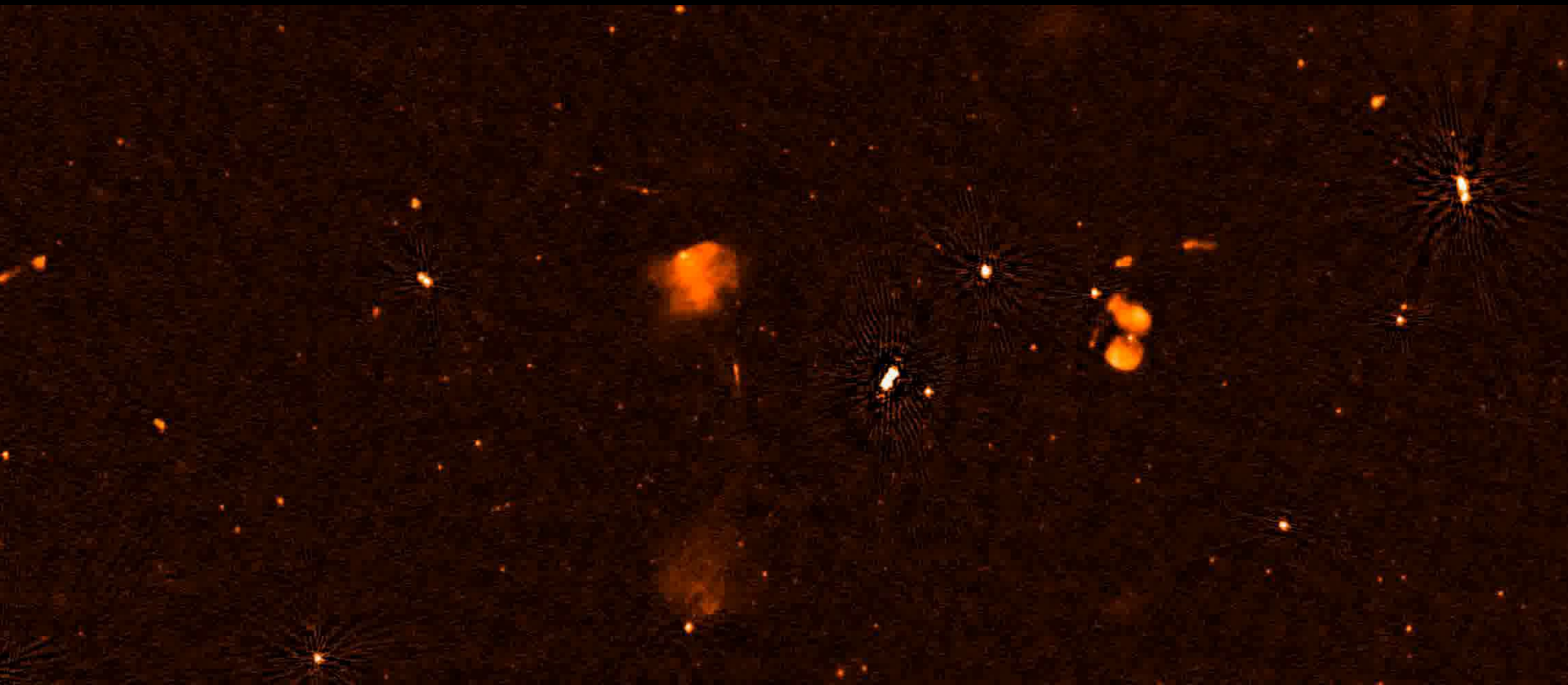
**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Corona Borealis supercluster field – there is a lot to discover



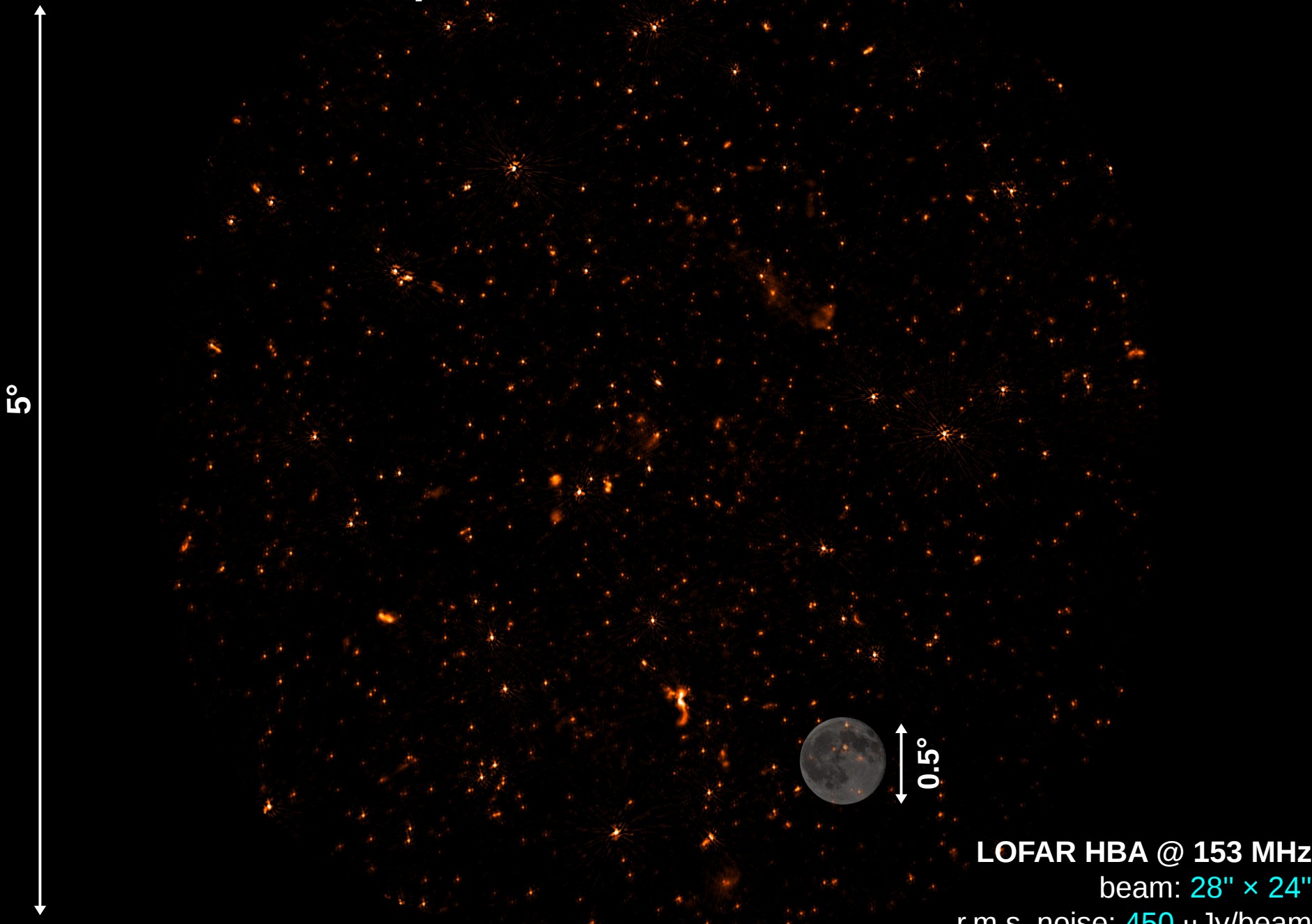


# Corona Borealis supercluster field – there is a lot to discover at high resolution



**LOFAR HBA @ 153 MHz**  
beam: 6" × 6"  
r.m.s. noise: 110  $\mu$ Jy/beam

# Corona Borealis supercluster field – there is a lot to discover

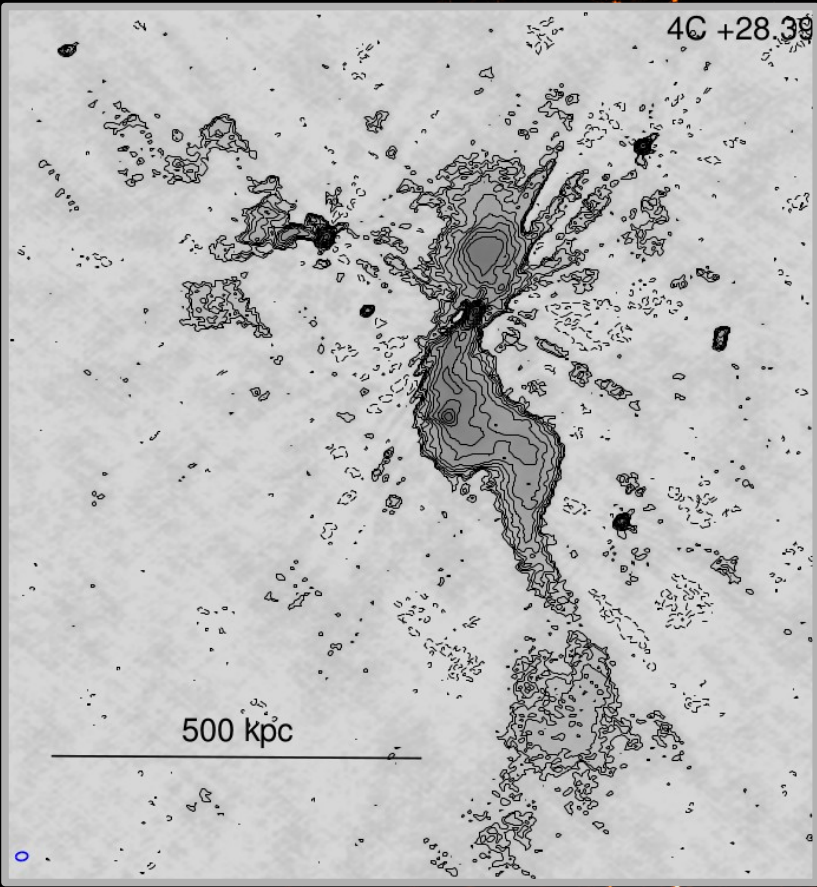


5°

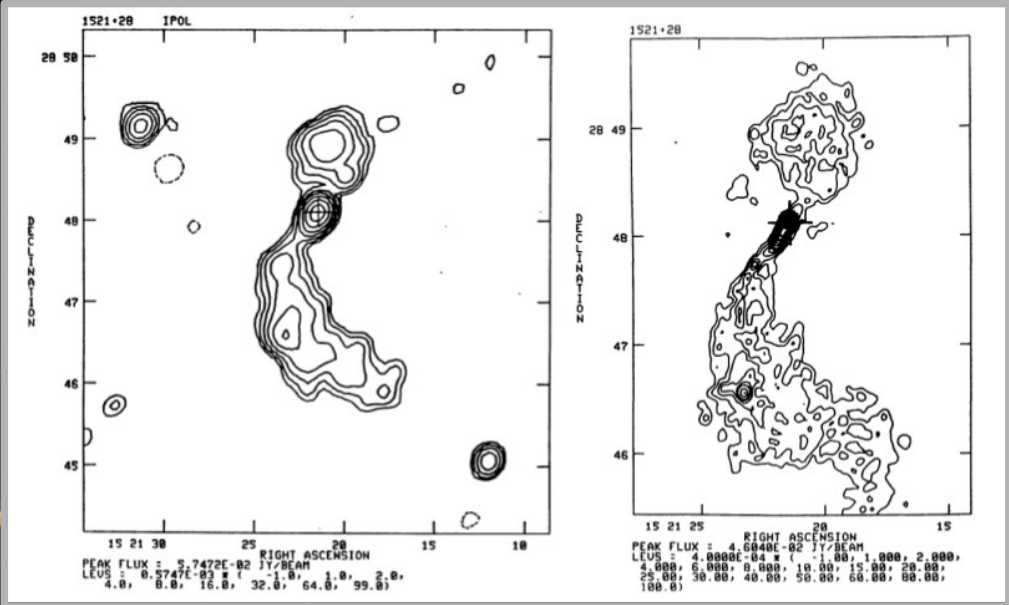
0.5°

**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Corona Borealis supercluster field – there is a lot to discover



LOFAR HBA @ 153 MHz

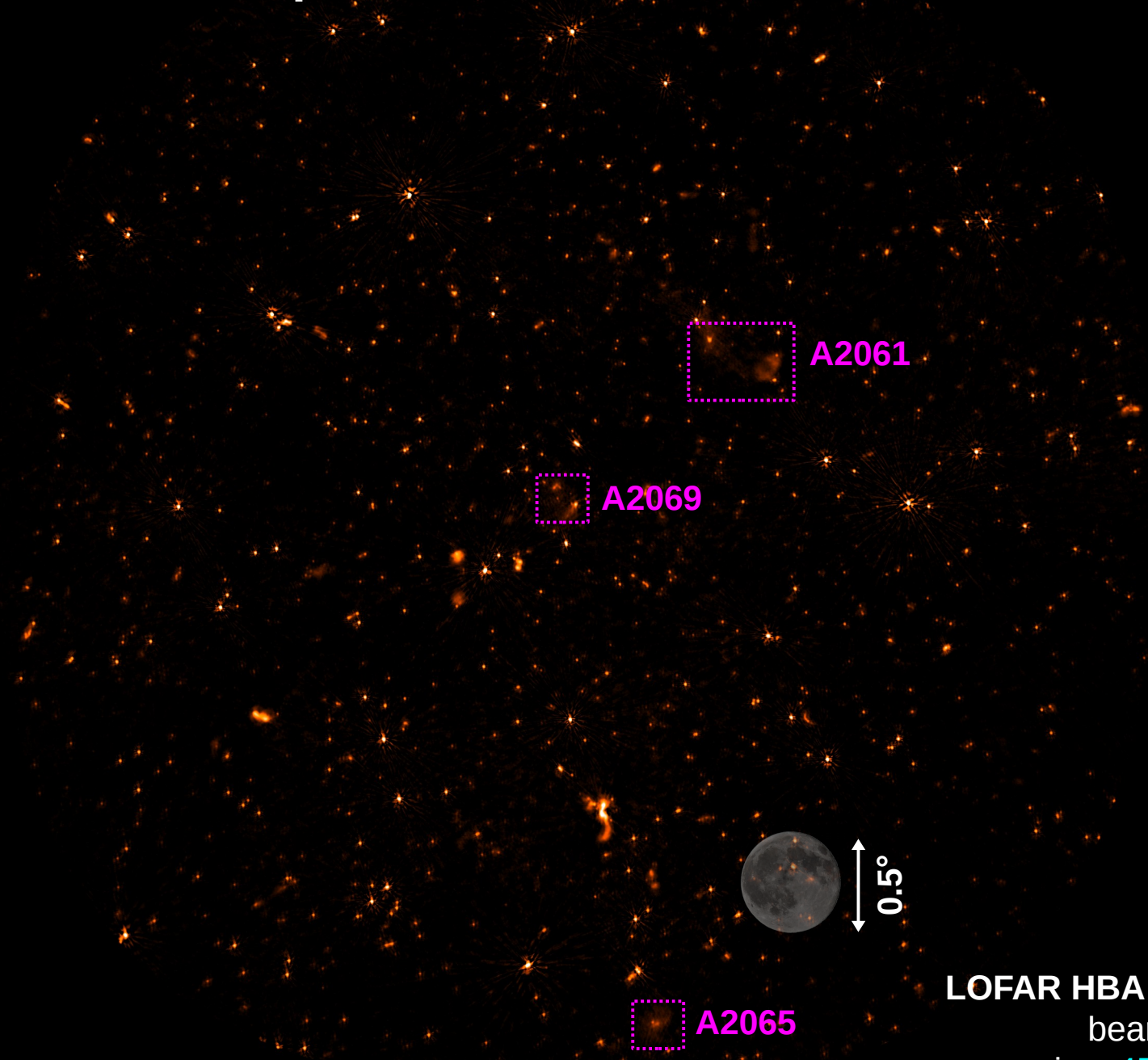


VLA @ 1.4 GHz  
de Ruiter+1986, Fanti+1987



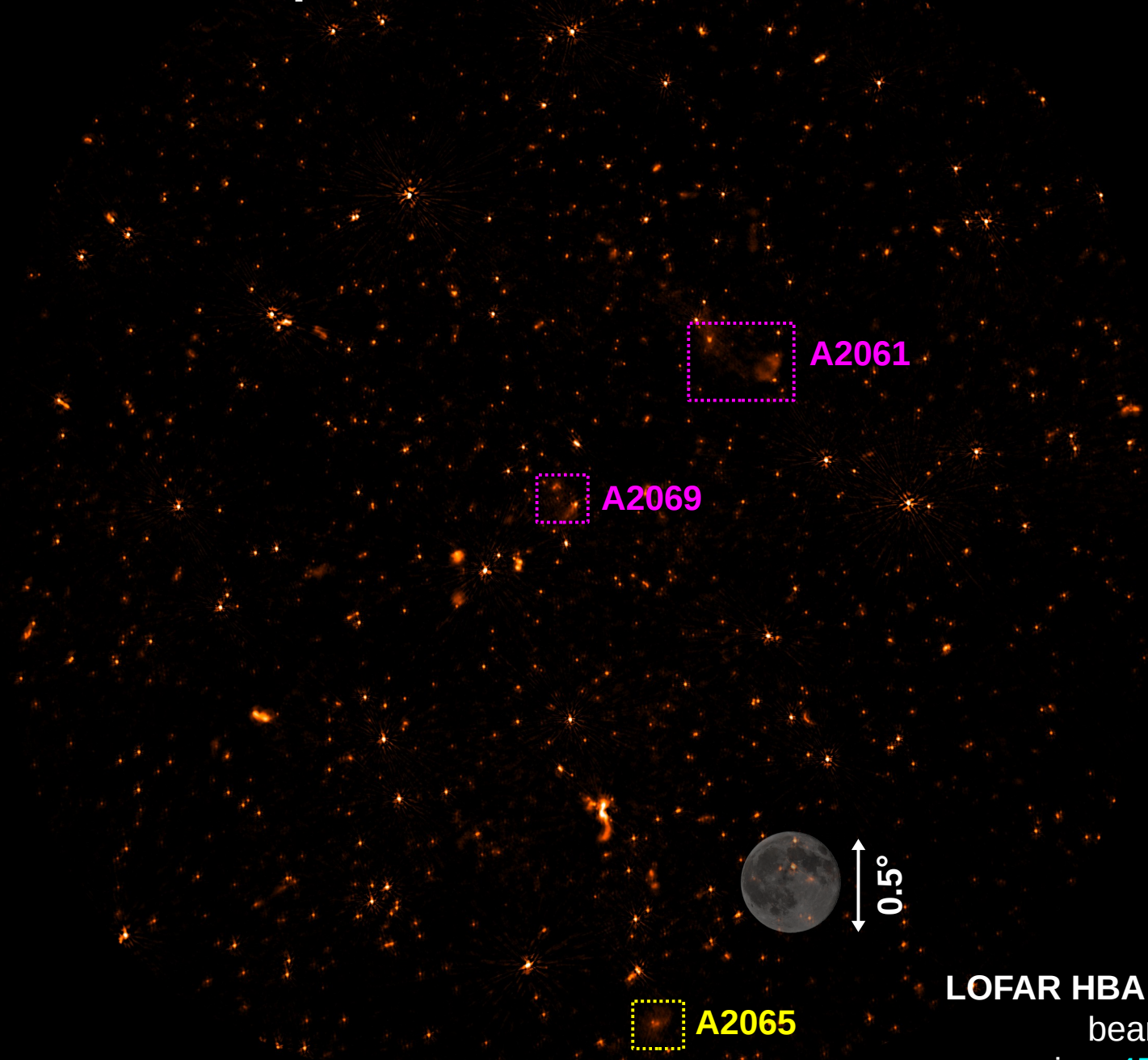
LOFAR HBA @ 153 MHz  
beam: 28" × 24"  
r.m.s. noise: 450 μJy/beam

# Corona Borealis supercluster field – there is a lot to discover



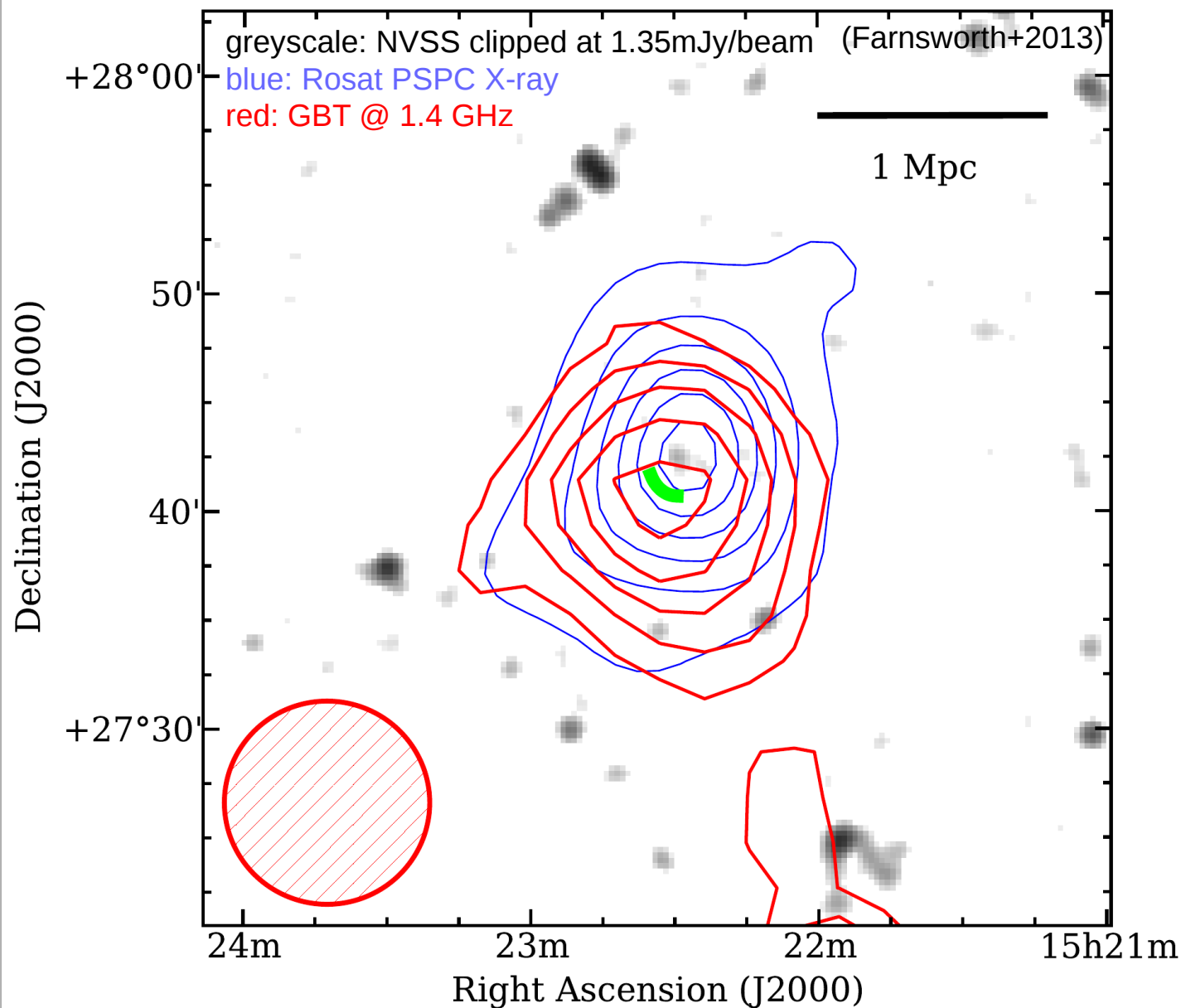
**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Corona Borealis supercluster field – there is a lot to discover



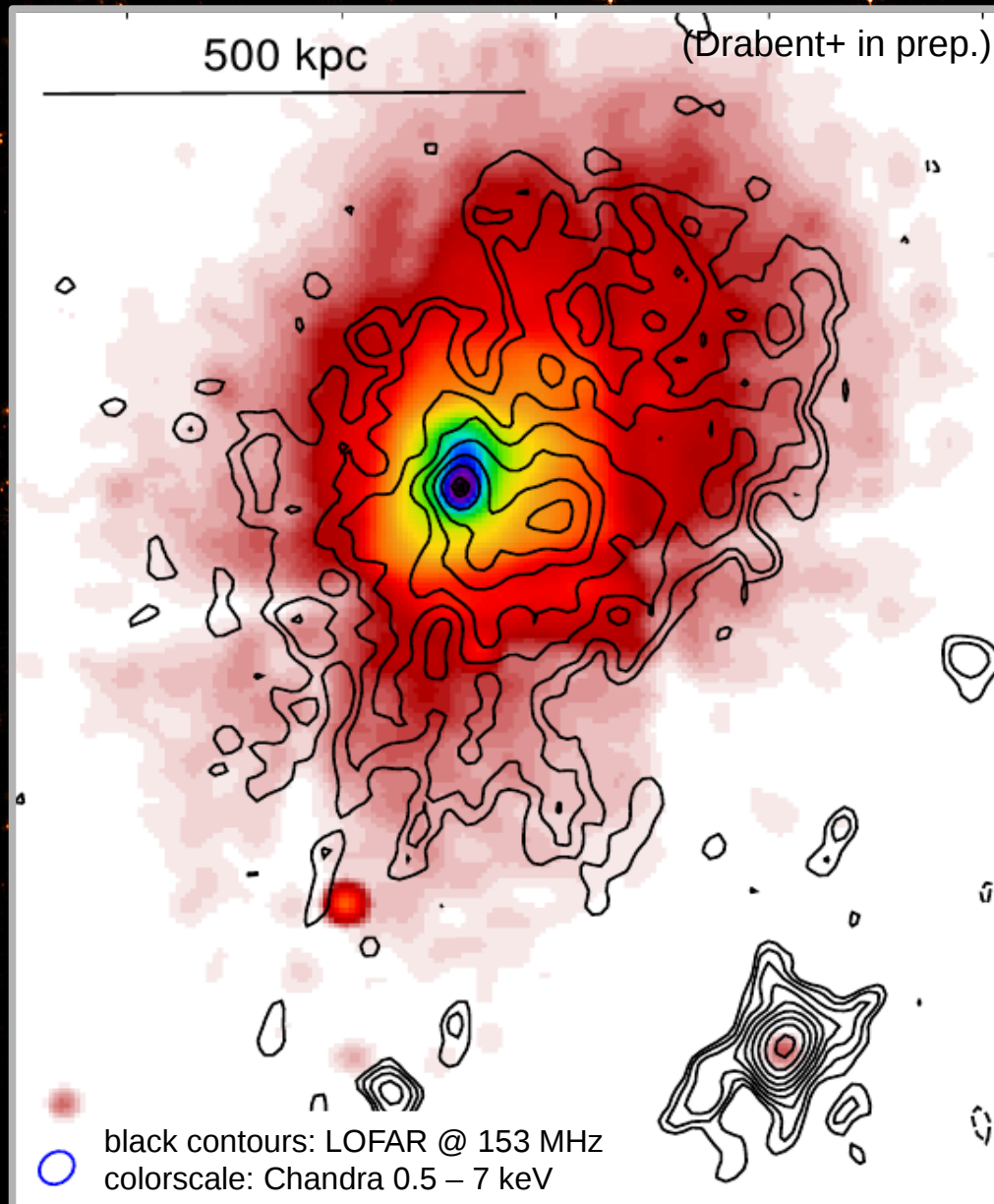
**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Abell 2065



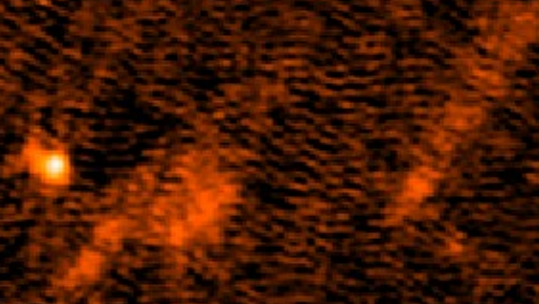
# Abell 2065

## radio halo structure recovered



# Abell 2065

at high resolution

A radio galaxy with a bright central core and a long, diffuse tail extending to the right. The tail is composed of several smaller, bright spots connected by a fainter, more diffuse structure. The background is a noisy, orange-brown field.

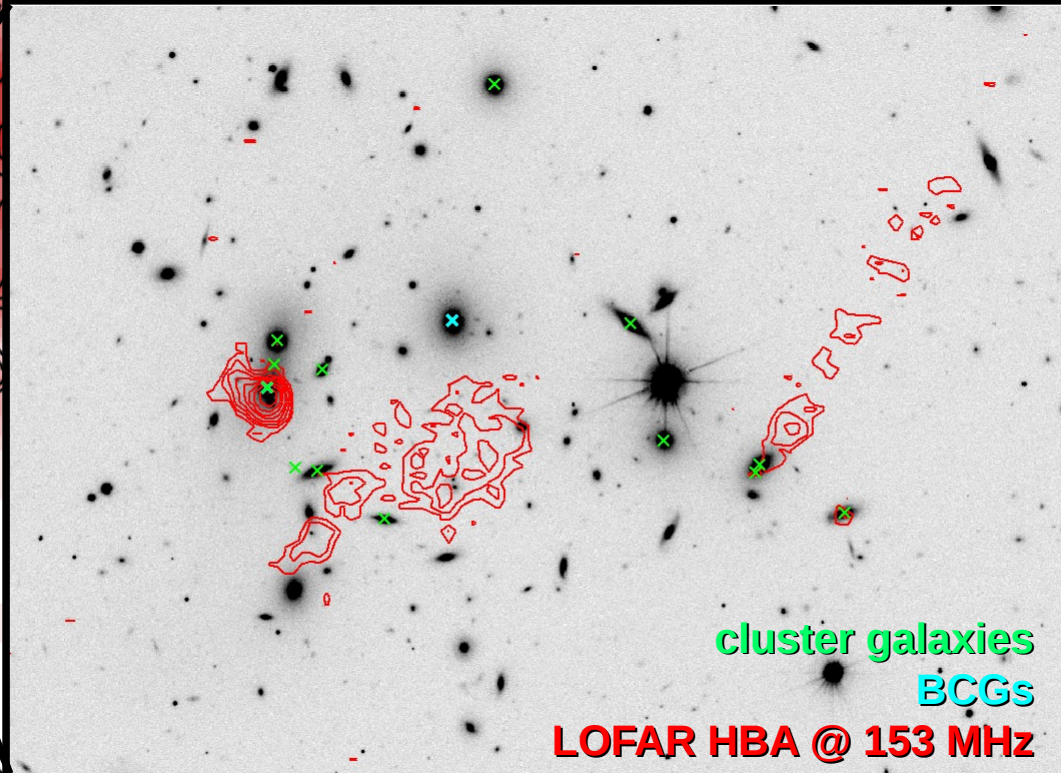
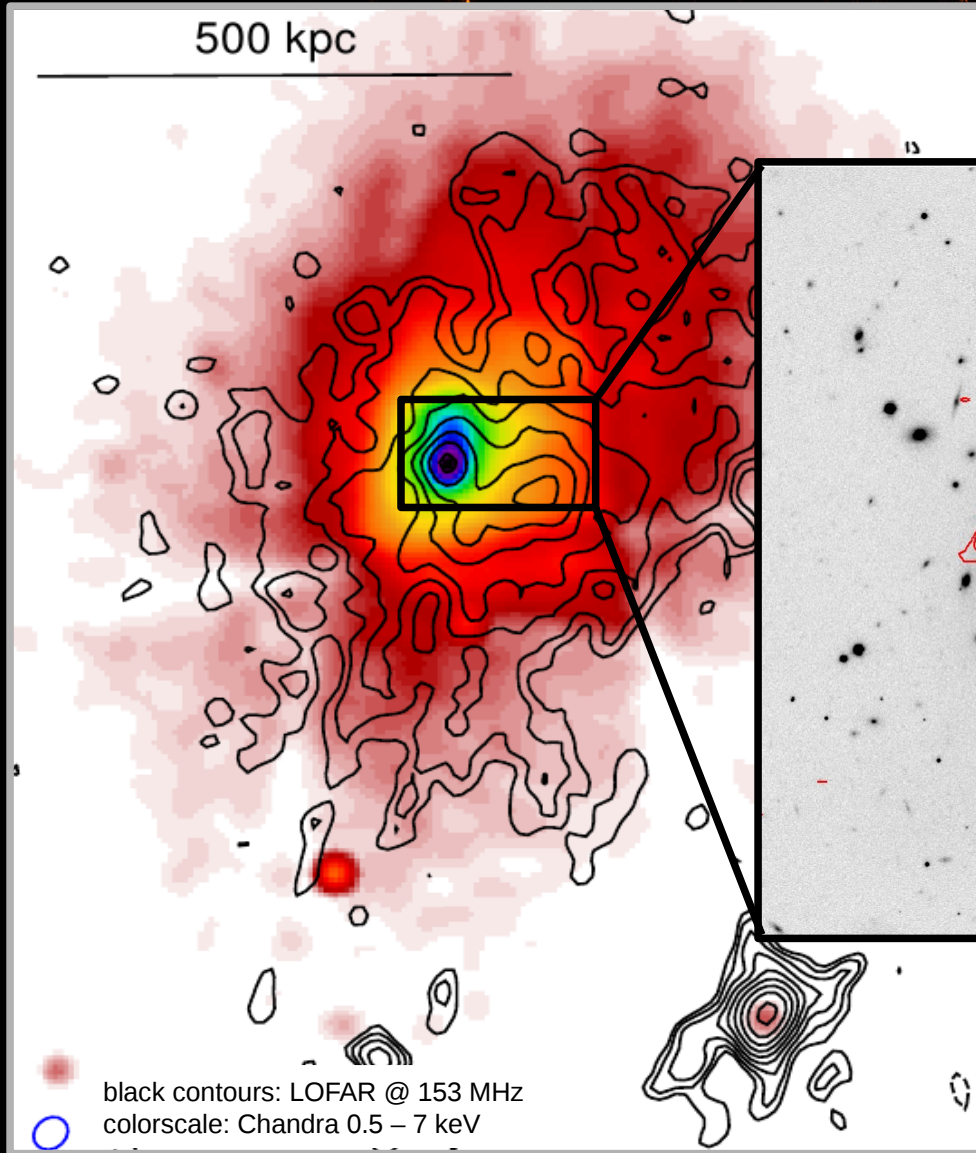
head-tail  
radio galaxy

LOFAR HBA @ 153 MHz  
beam: 6" × 6"  
r.m.s. noise: 200  $\mu$ Jy/beam

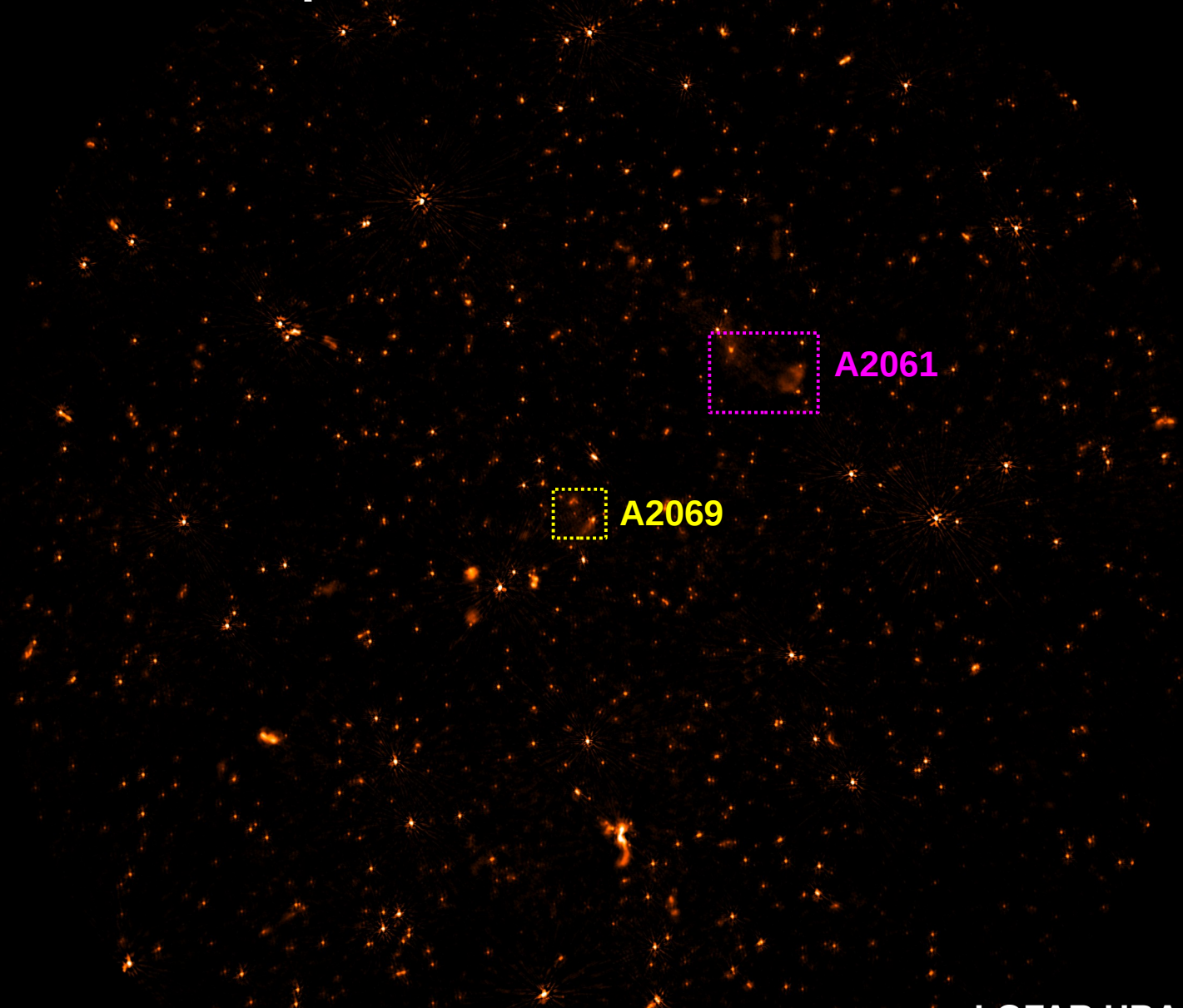


# Abell 2065

## radio halo structure recovered



# Corona Borealis supercluster field – there is a lot to discover



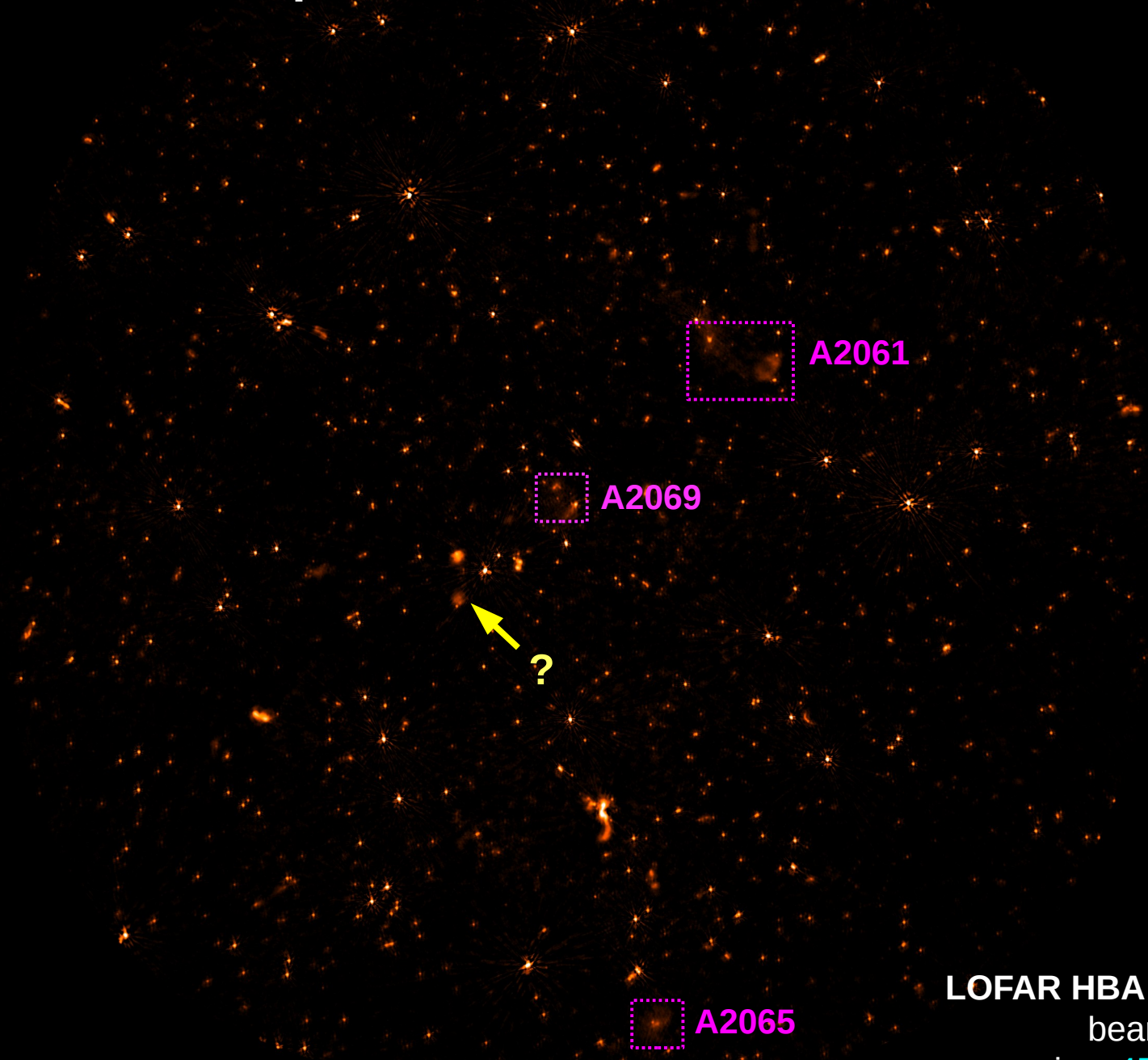
A2061

A2069

A2065

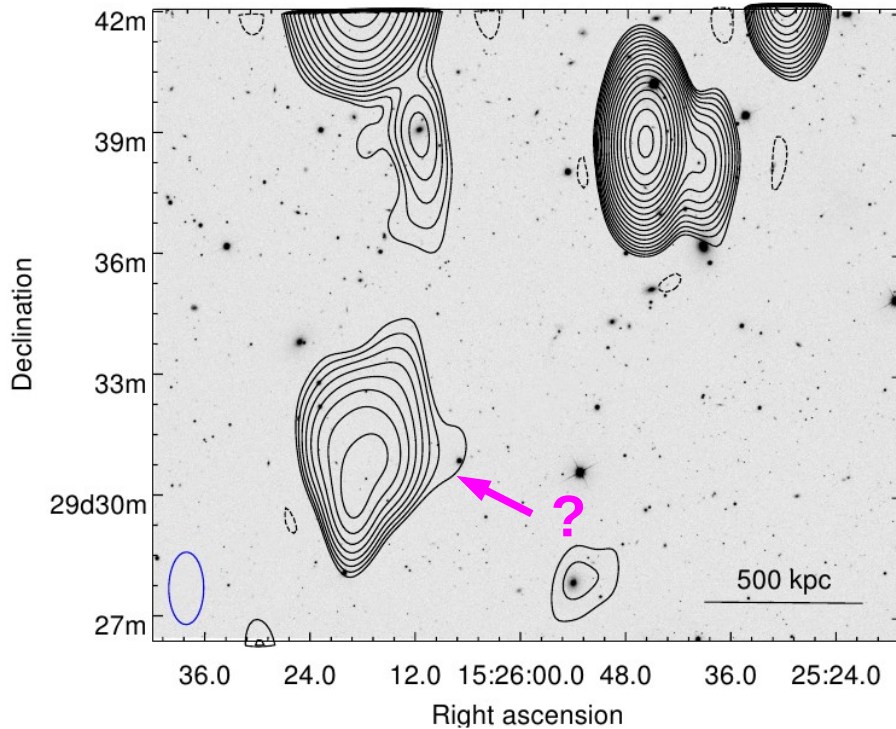
LOFAR HBA @ 153 MHz  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Corona Borealis supercluster field – there is a lot to discover

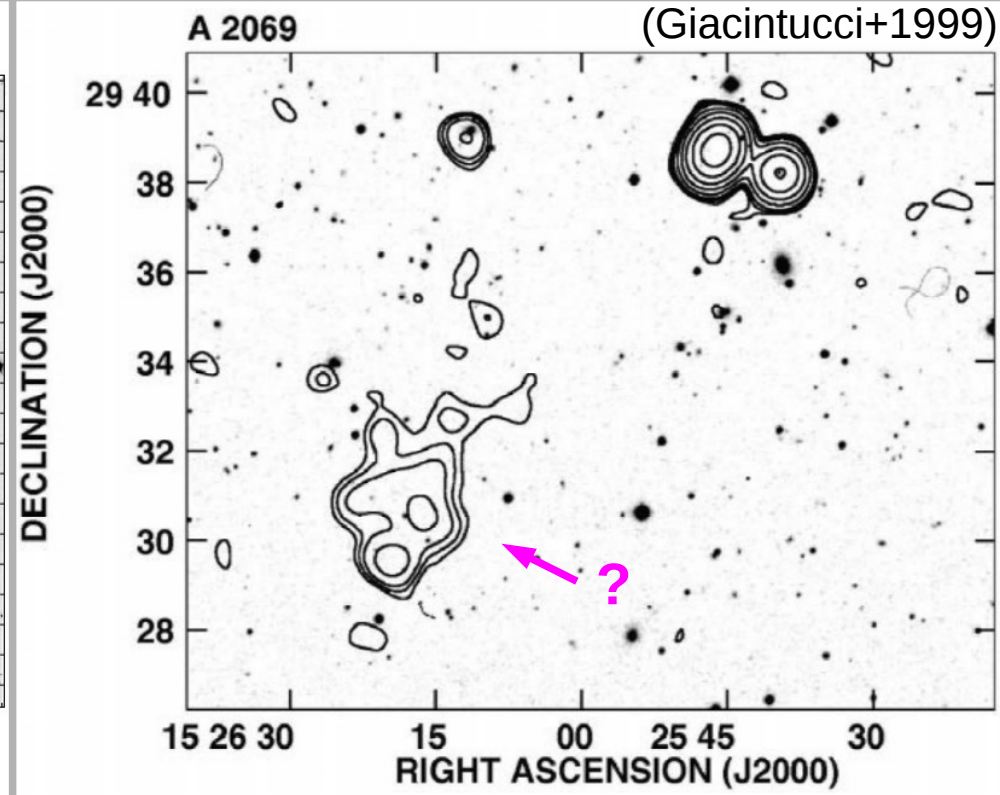


**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Abell 2069 radio relic candidate: nature uncertain



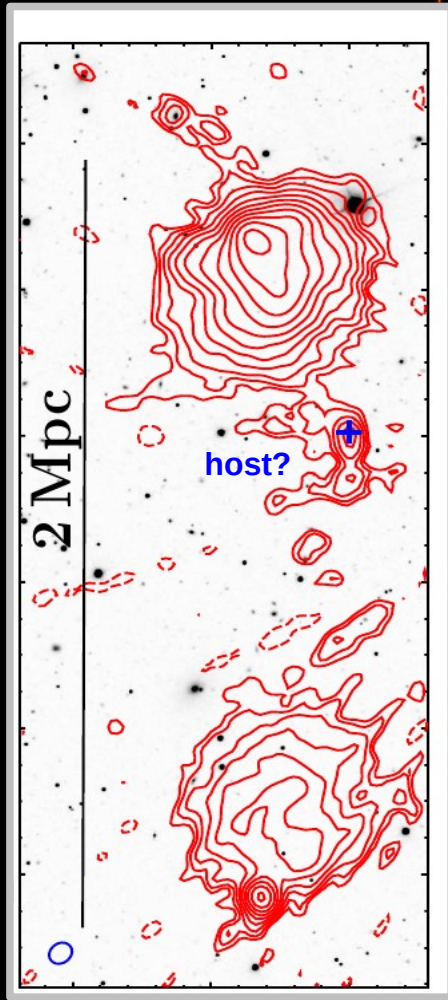
contours: WSRT @ 346 MHz



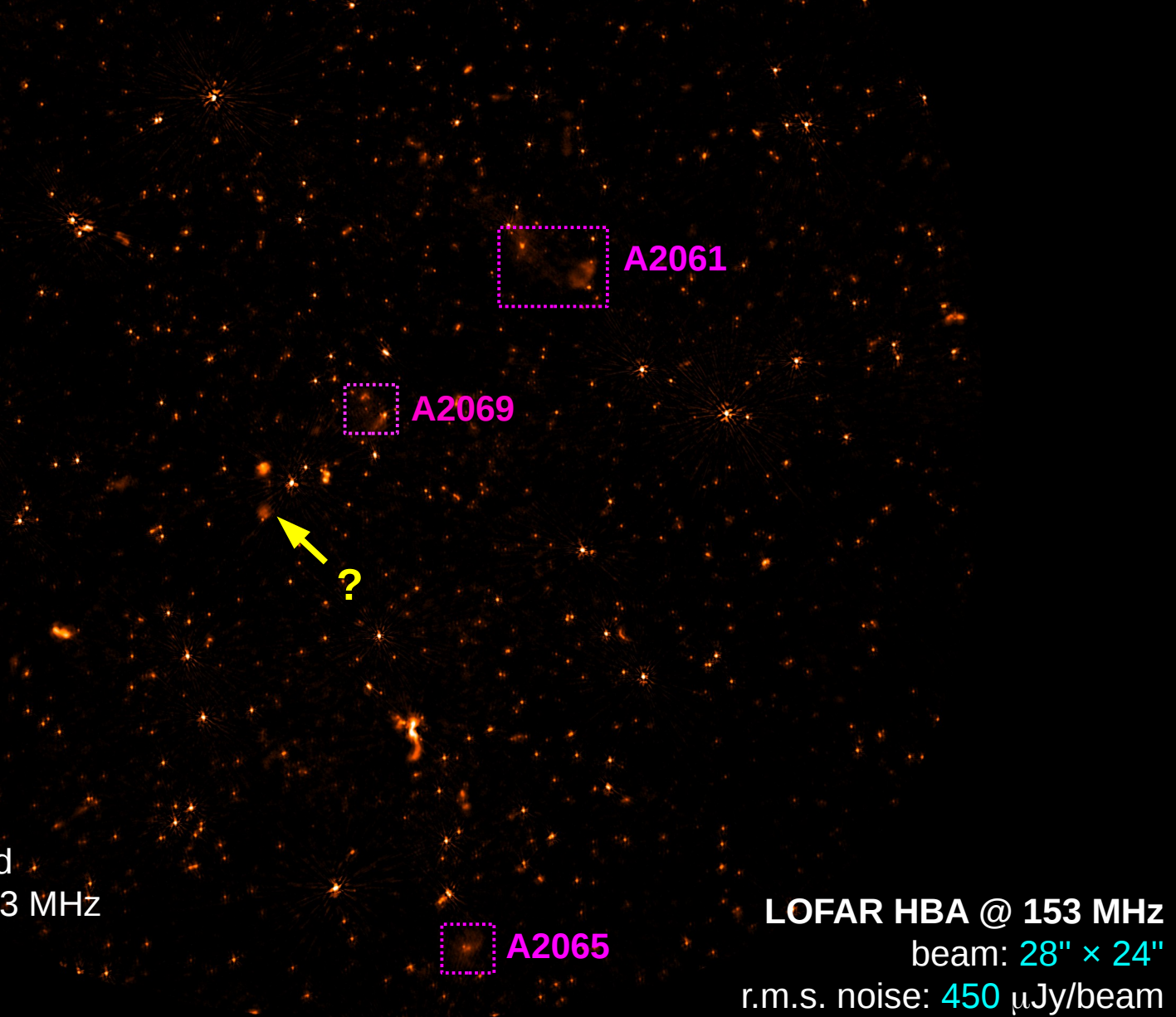
contours: NVSS @ 1.4 GHz

distance of the source to galaxy cluster center: 4.6 Mpc

# Abell 2069 radio relic candidate: southern lobe of a giant radio galaxy?

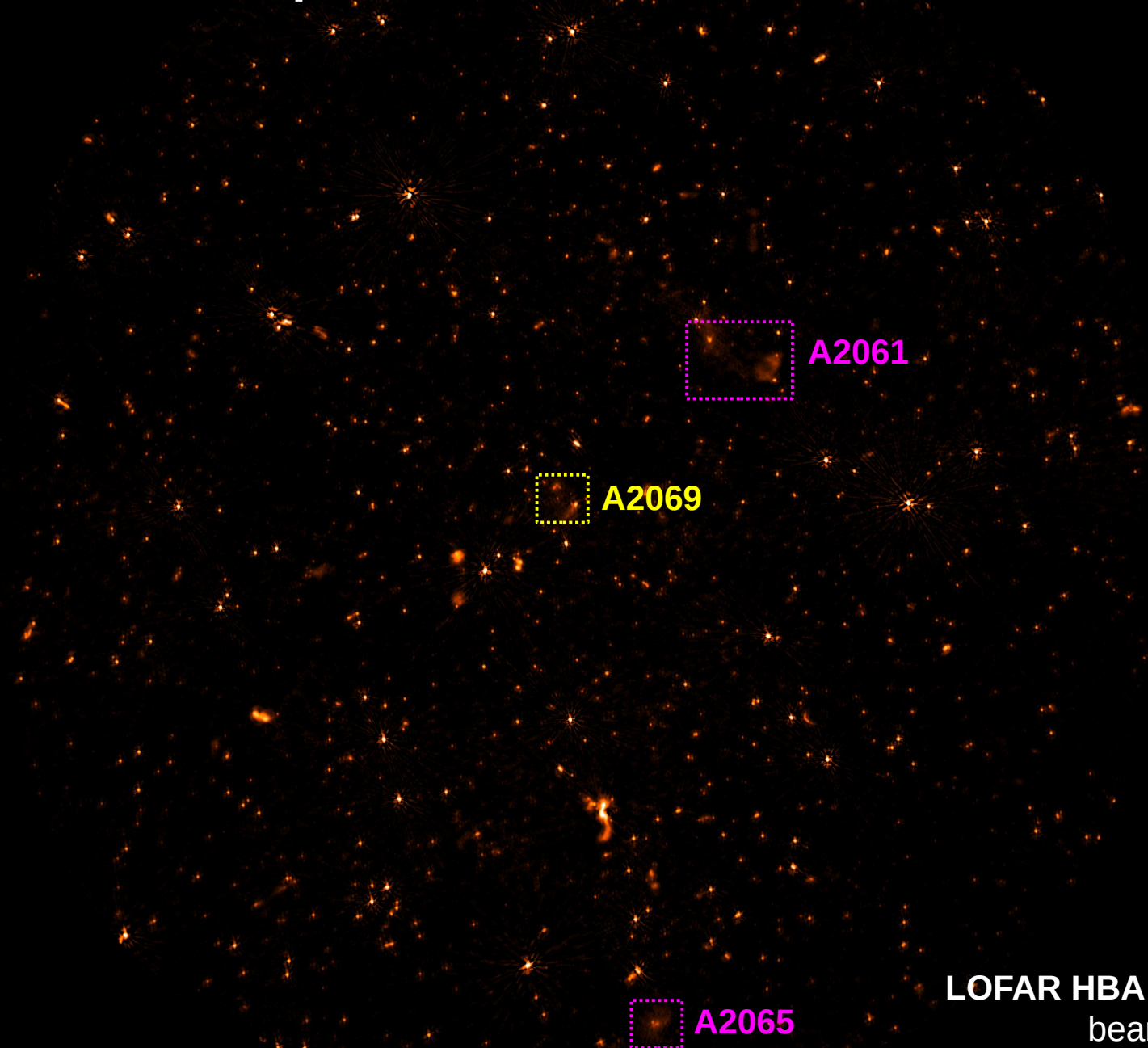


greyscale: SDSS r-band  
contours: LOFAR @ 153 MHz



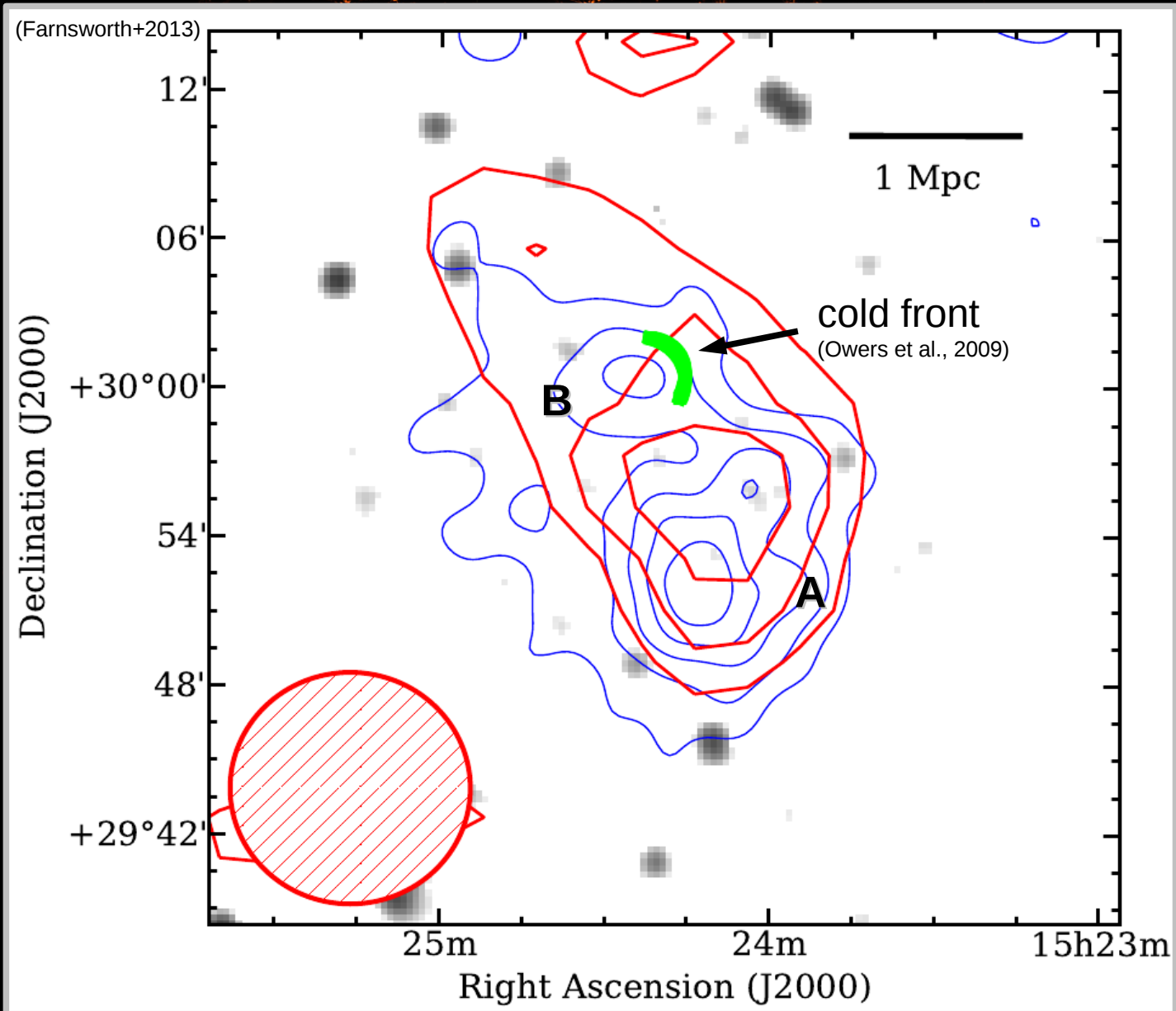
**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Corona Borealis supercluster field – there is a lot to discover



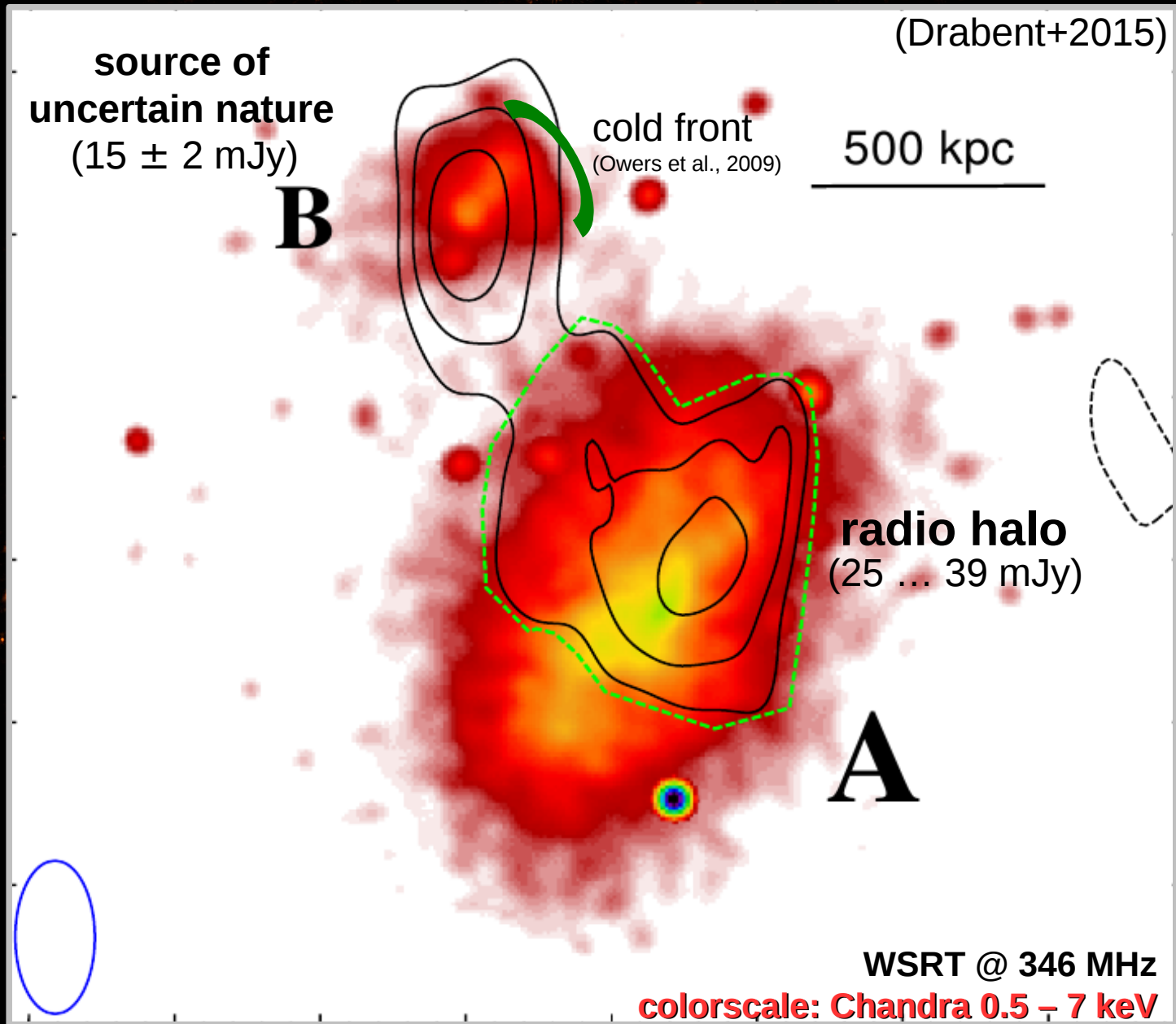
**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

# Abell 2069: diffuse emission in both components



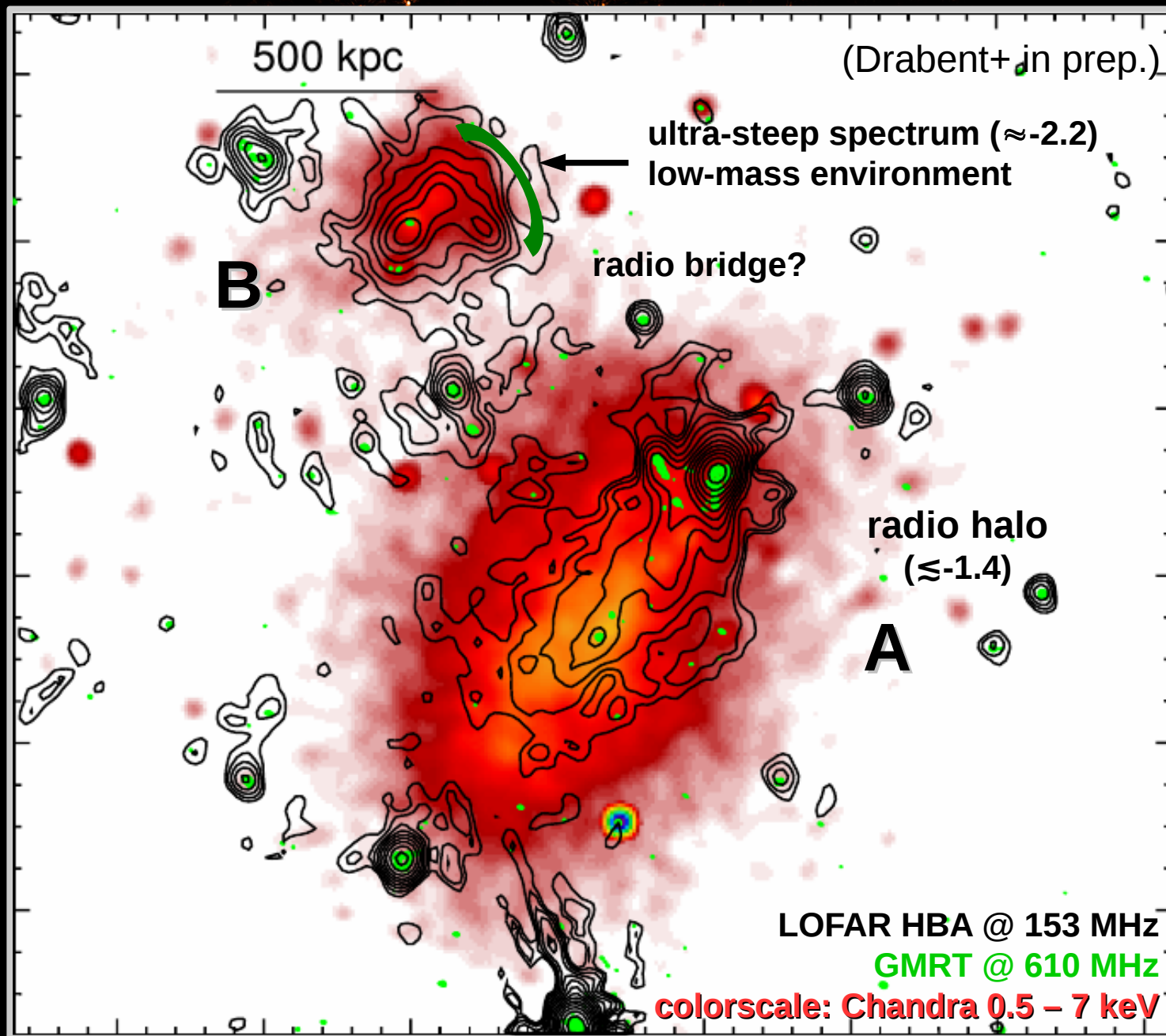
greyscale: NVSS clipped at 1.35mJy/beam  
red: GBT blue: Rosat PSPC X-ray

# Abell 2069: diffuse emission in both components





# Abell 2069: diffuse emission is ultra-steep



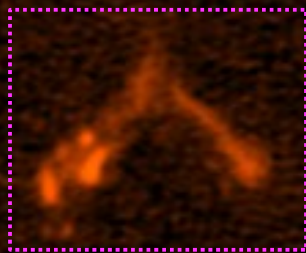
**Abell 2069: diffuse emission in both components**  
at high resolution

**B**

**A**

LOFAR HBA @ 153 MHz  
beam: 6" × 6"  
r.m.s. noise: 110  $\mu$ Jy/beam

# Abell 2069: diffuse emission in both components at high resolution



**B**

**A**

LOFAR HBA @ 153 MHz  
beam: 6" × 6"  
r.m.s. noise: 110  $\mu$ Jy/beam

# Abell 2069B: no powerful AGN present

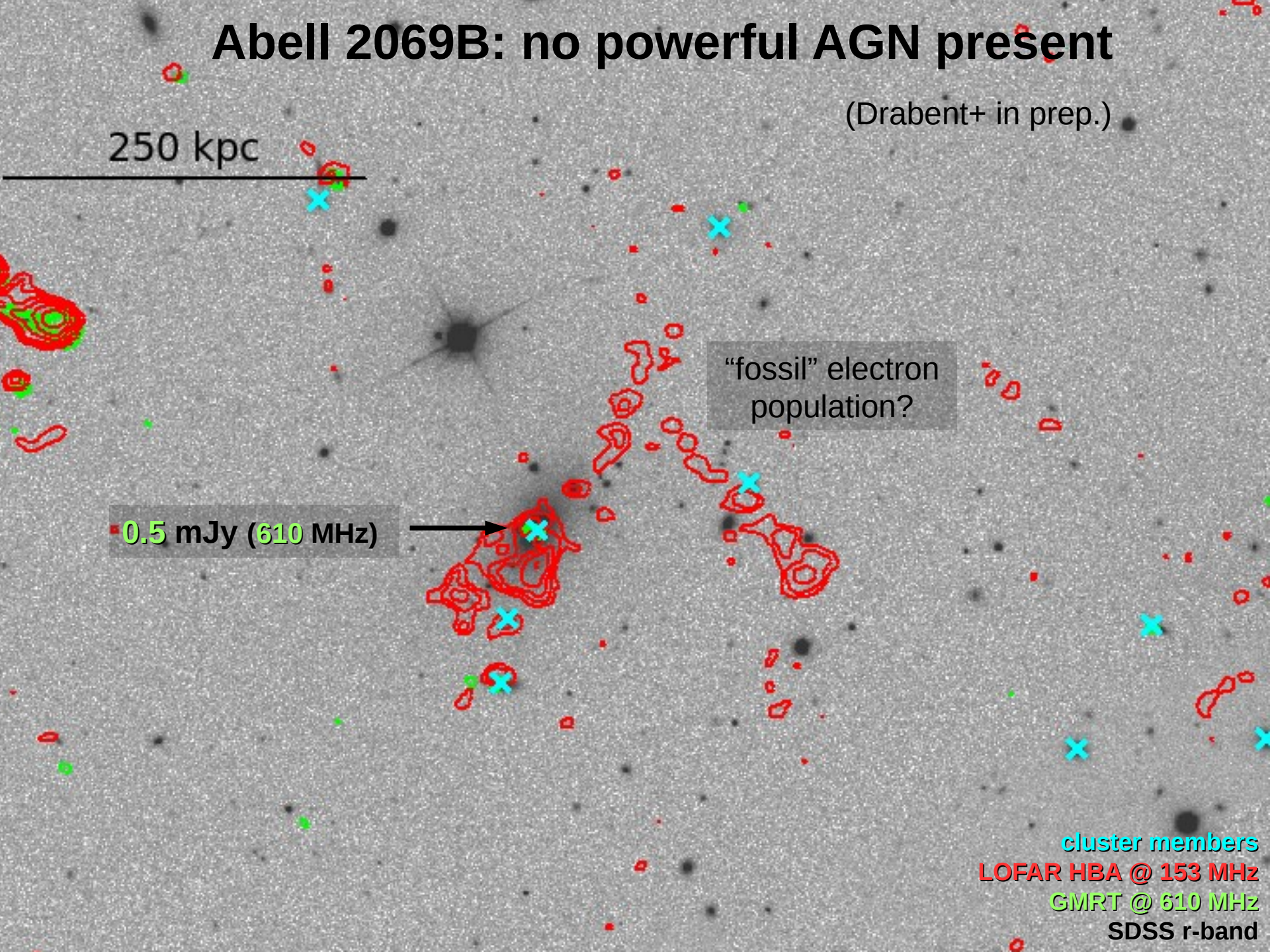
(Drabent+ in prep.)

250 kpc

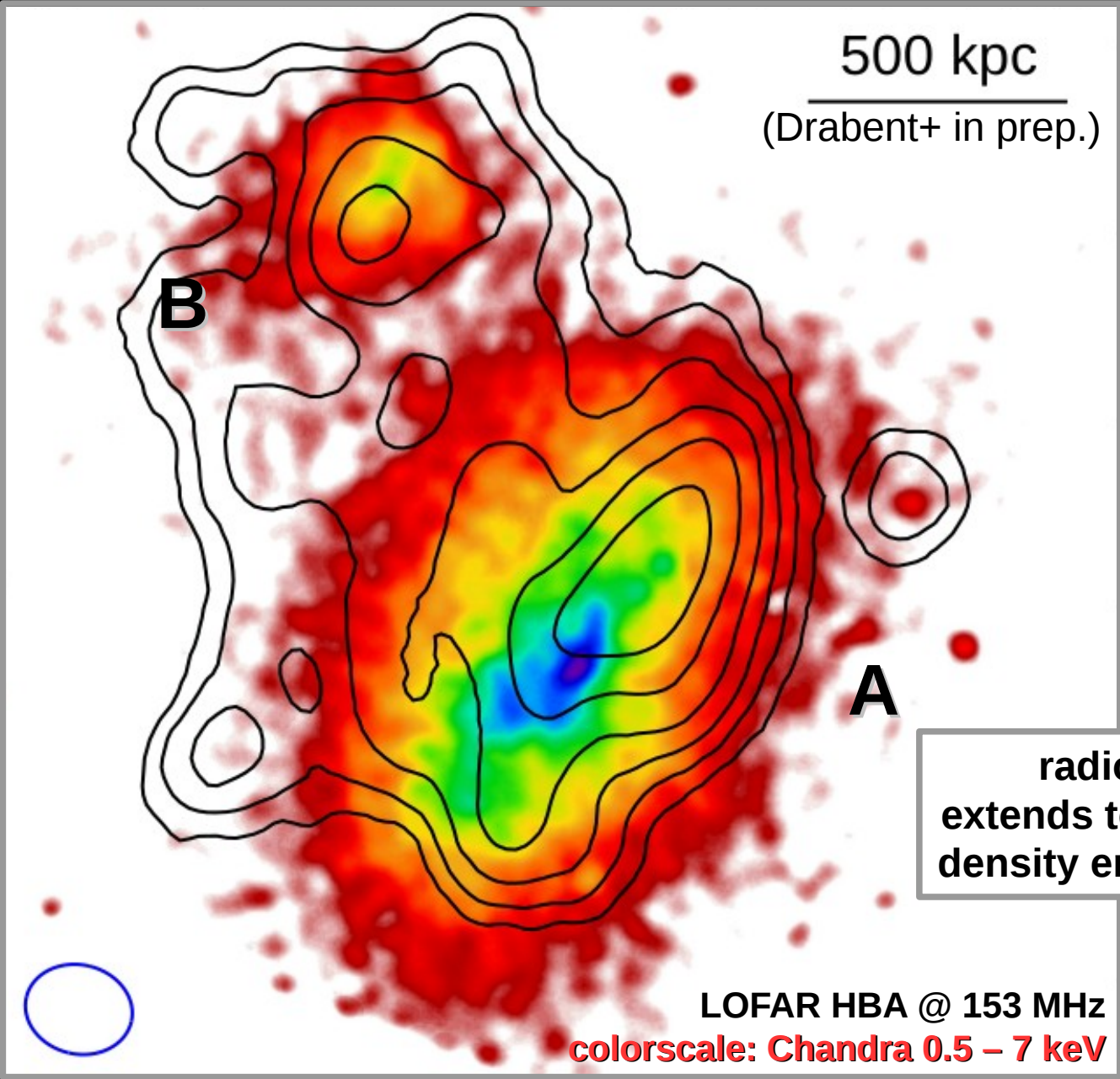
“fossil” electron population?

0.5 mJy (610 MHz)

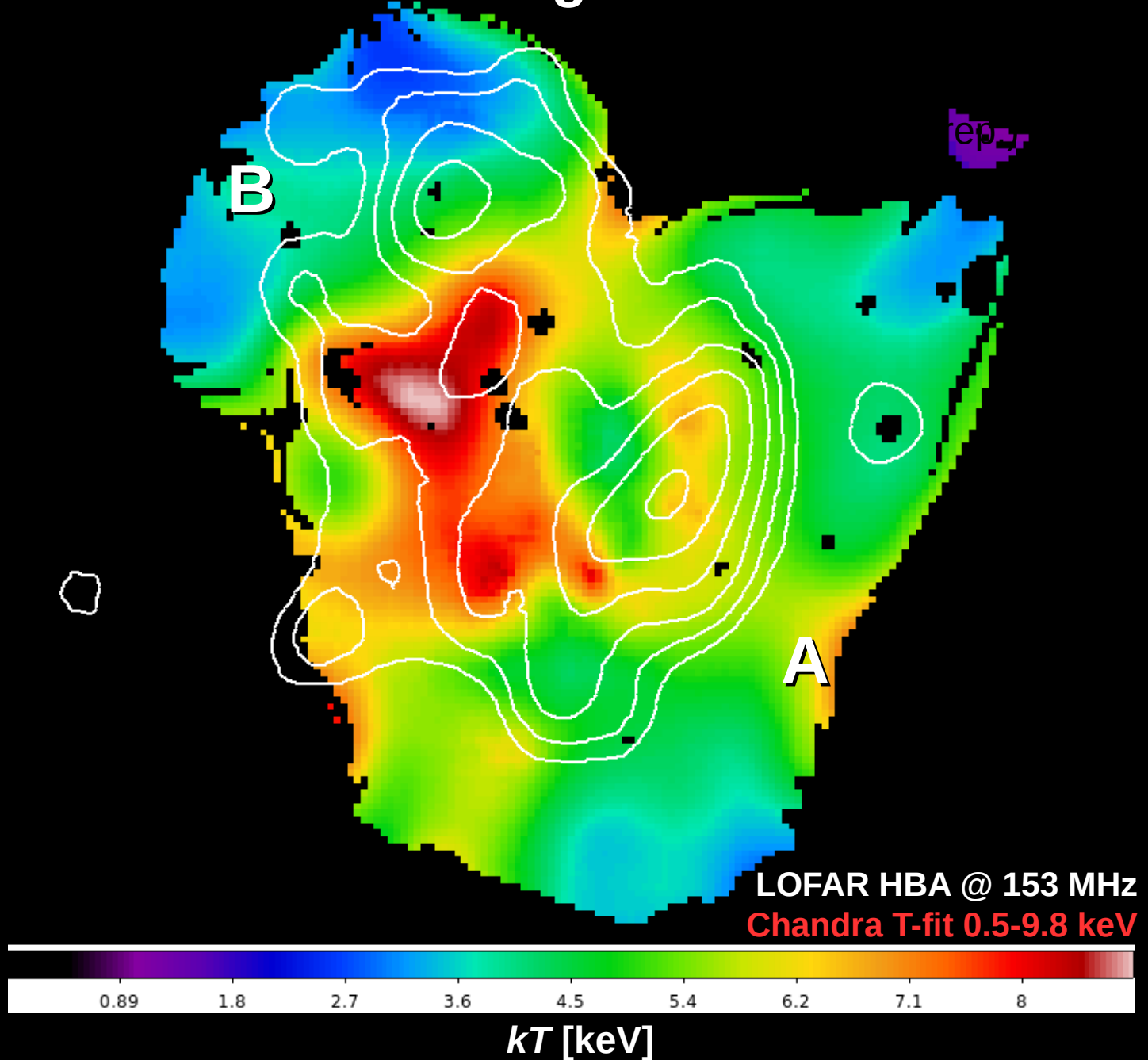
cluster members  
LOFAR HBA @ 153 MHz  
GMRT @ 610 MHz  
SDSS r-band



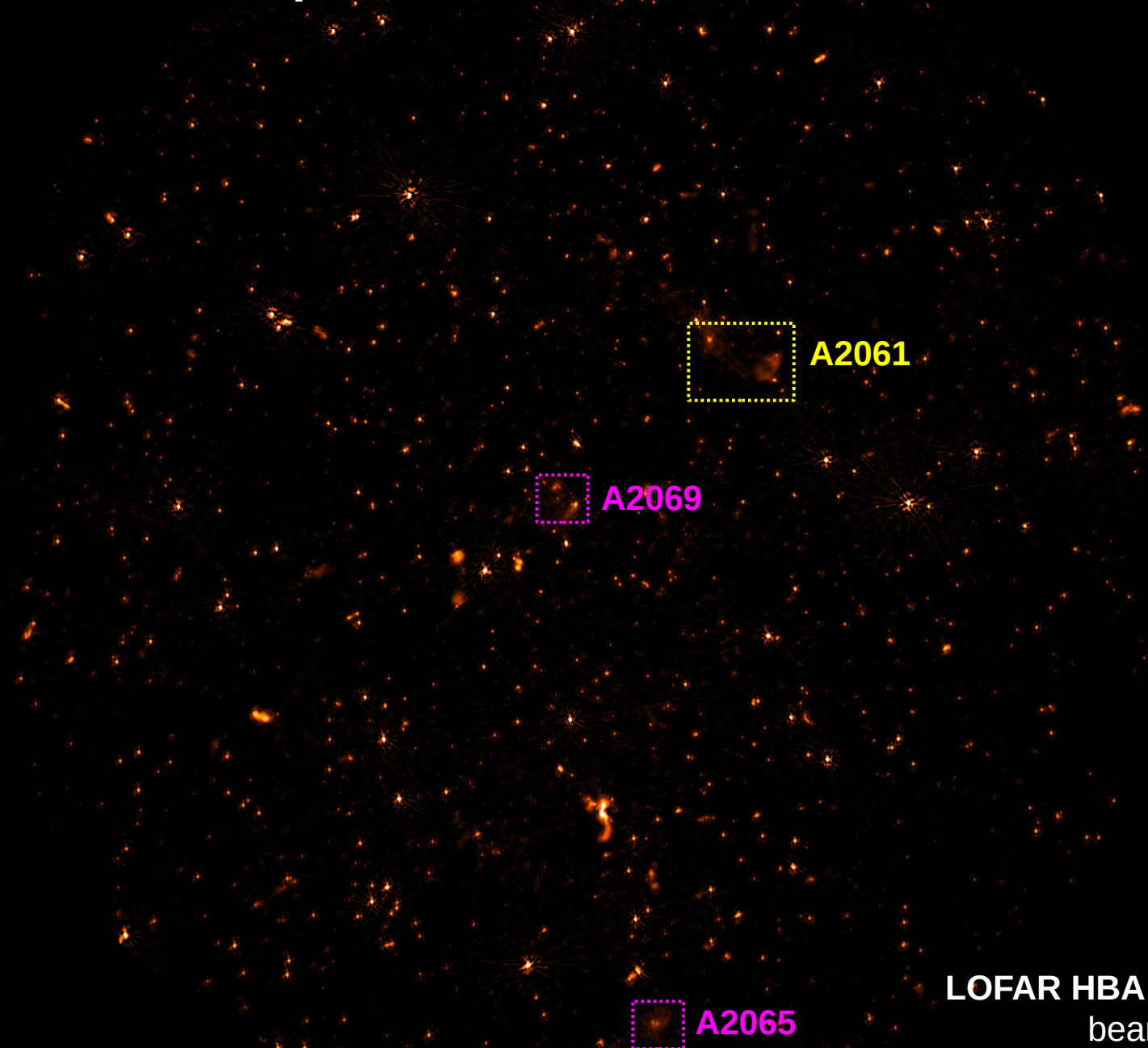
# Abell 2069: low-surface brightness emission present



# Abell 2069: hot gas is traced



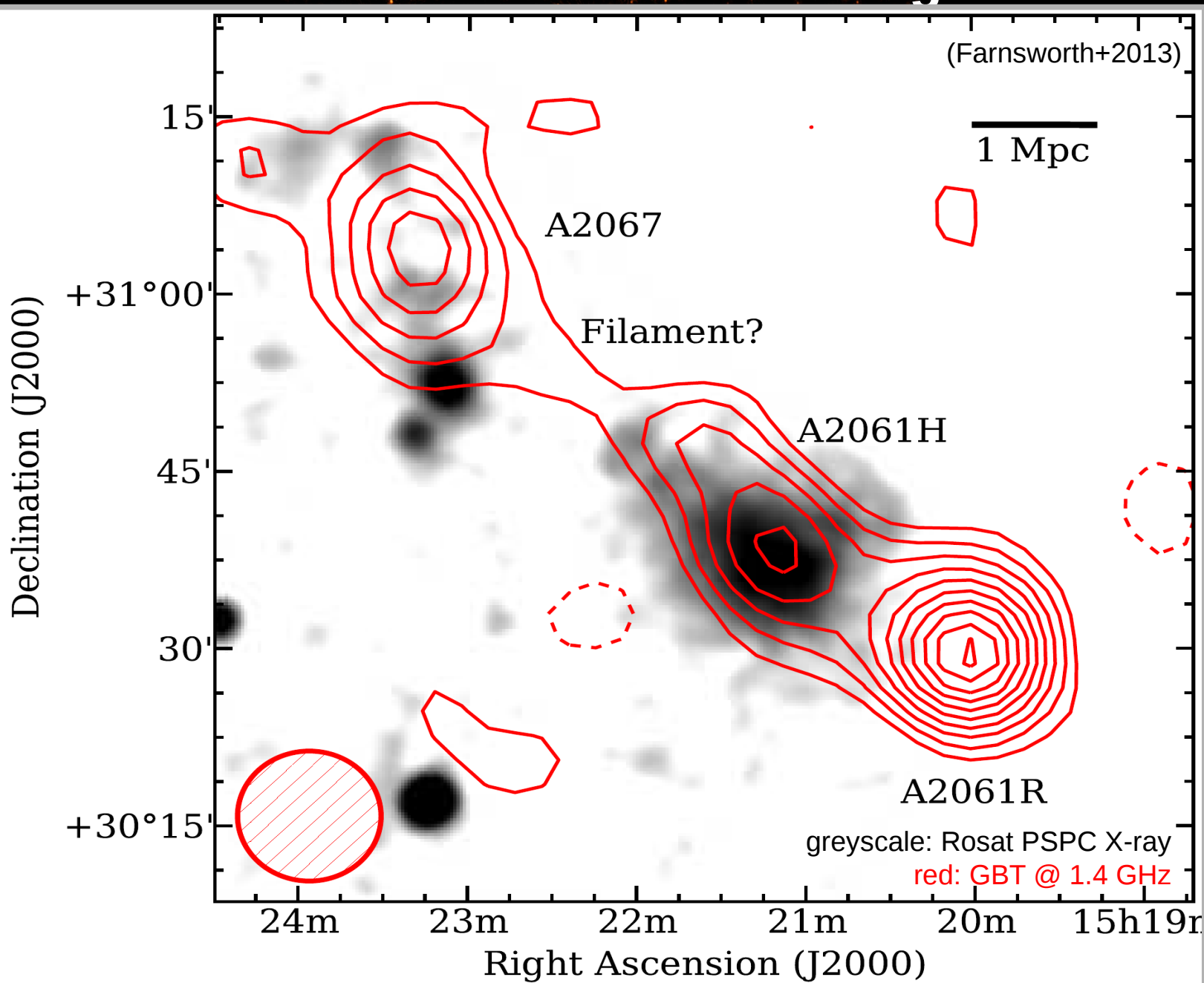
# Corona Borealis supercluster field – there is a lot to discover



**LOFAR HBA @ 153 MHz**  
beam: 28" × 24"  
r.m.s. noise: 450  $\mu$ Jy/beam

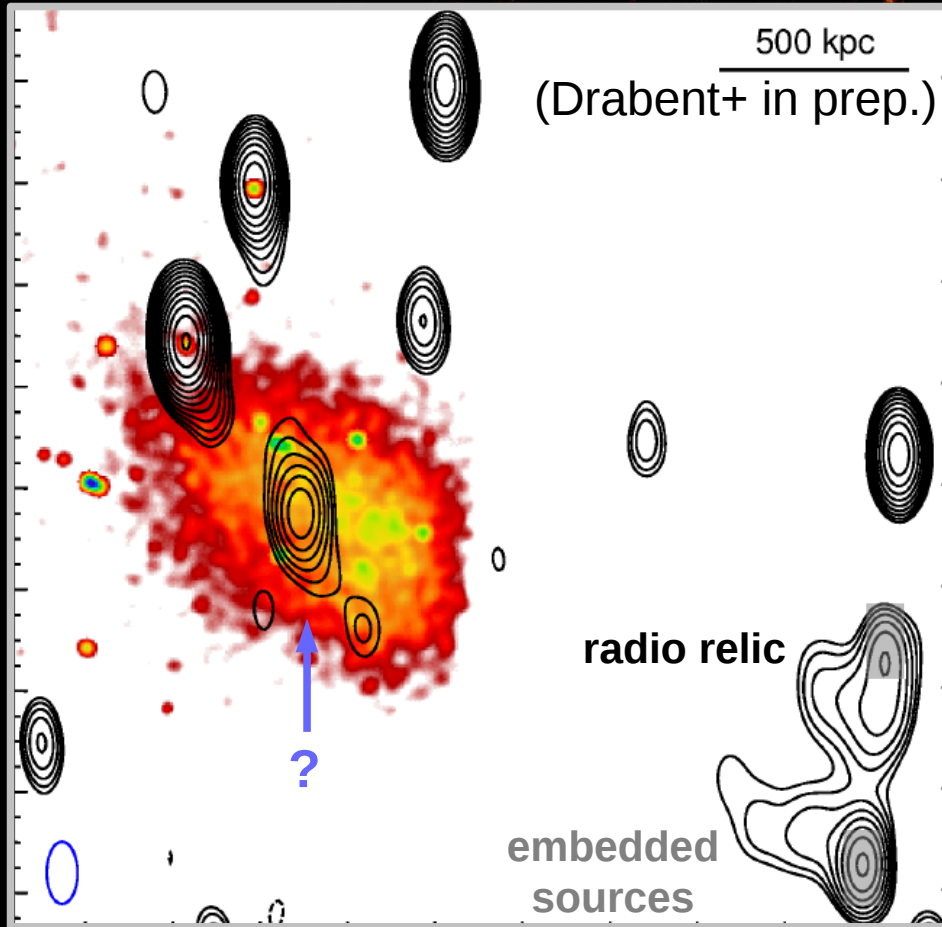
# Abell 2061 – Abell 2067 bridge?

(Farnsworth+2013)

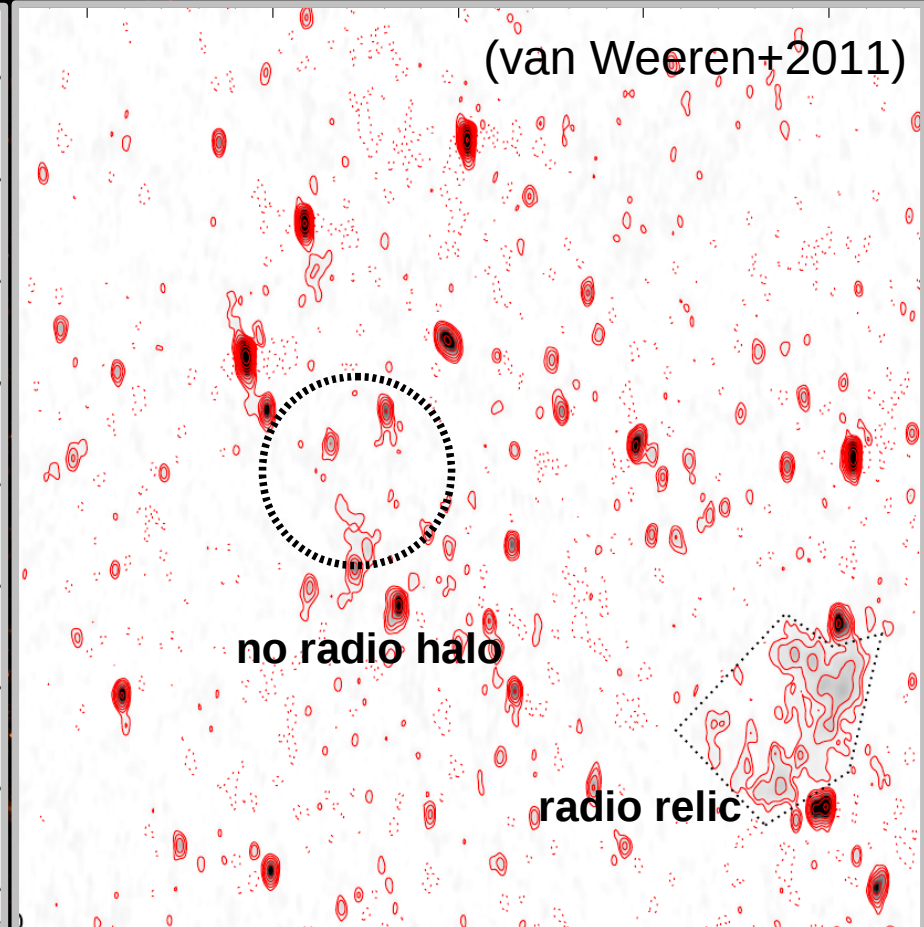




# Abell 2061: very steep radio source in cluster center



colorscale: Chandra 0.5 – 7 keV  
contours: WSRT @ 346 MHz



contours: WSRT @ 1.4 GHz

# Abell 2061:

radio halo + embedded ultra-steep spectrum source  
at high resolution

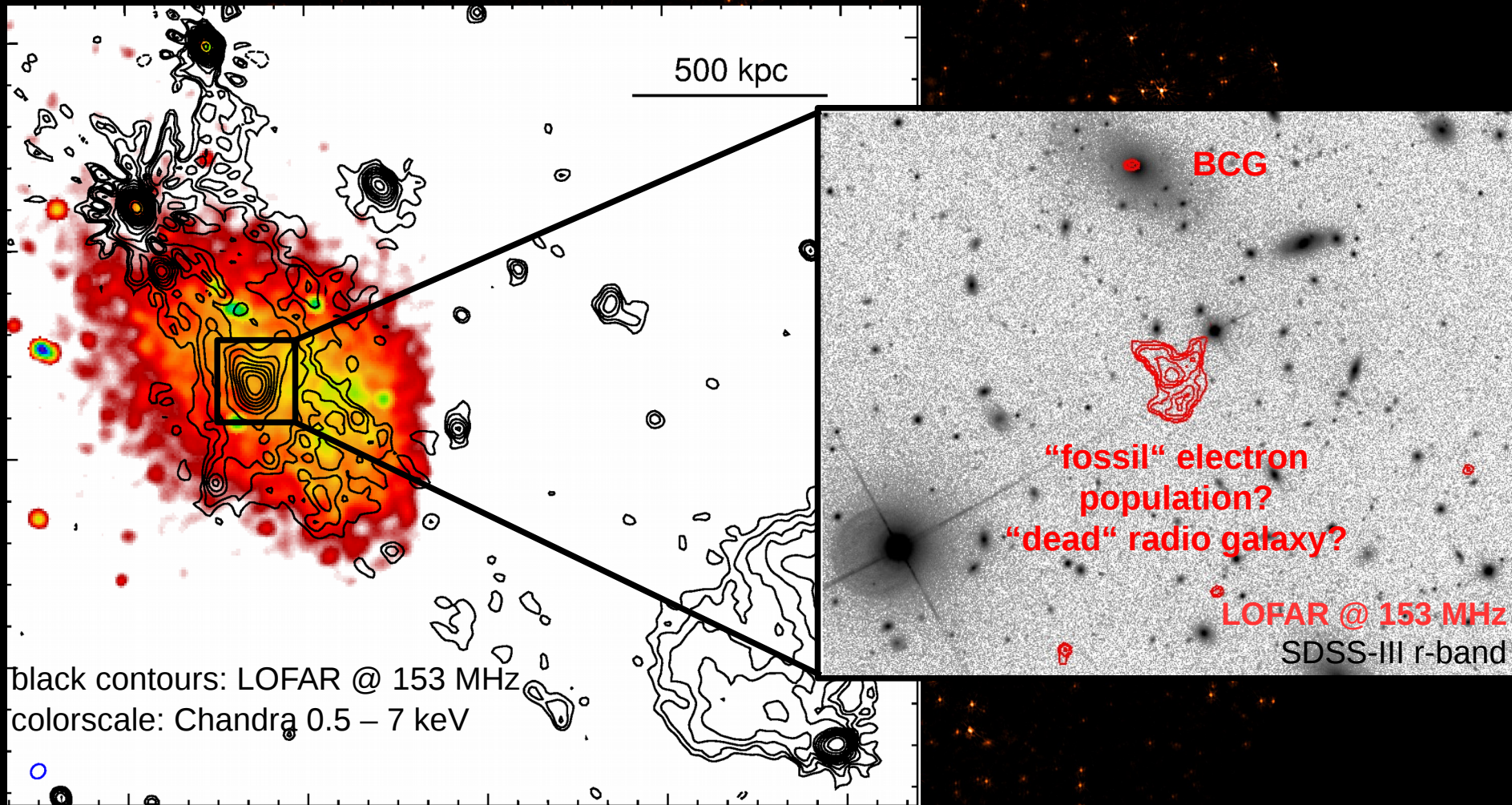
ultra-steep-spectrum  
source

radio relic

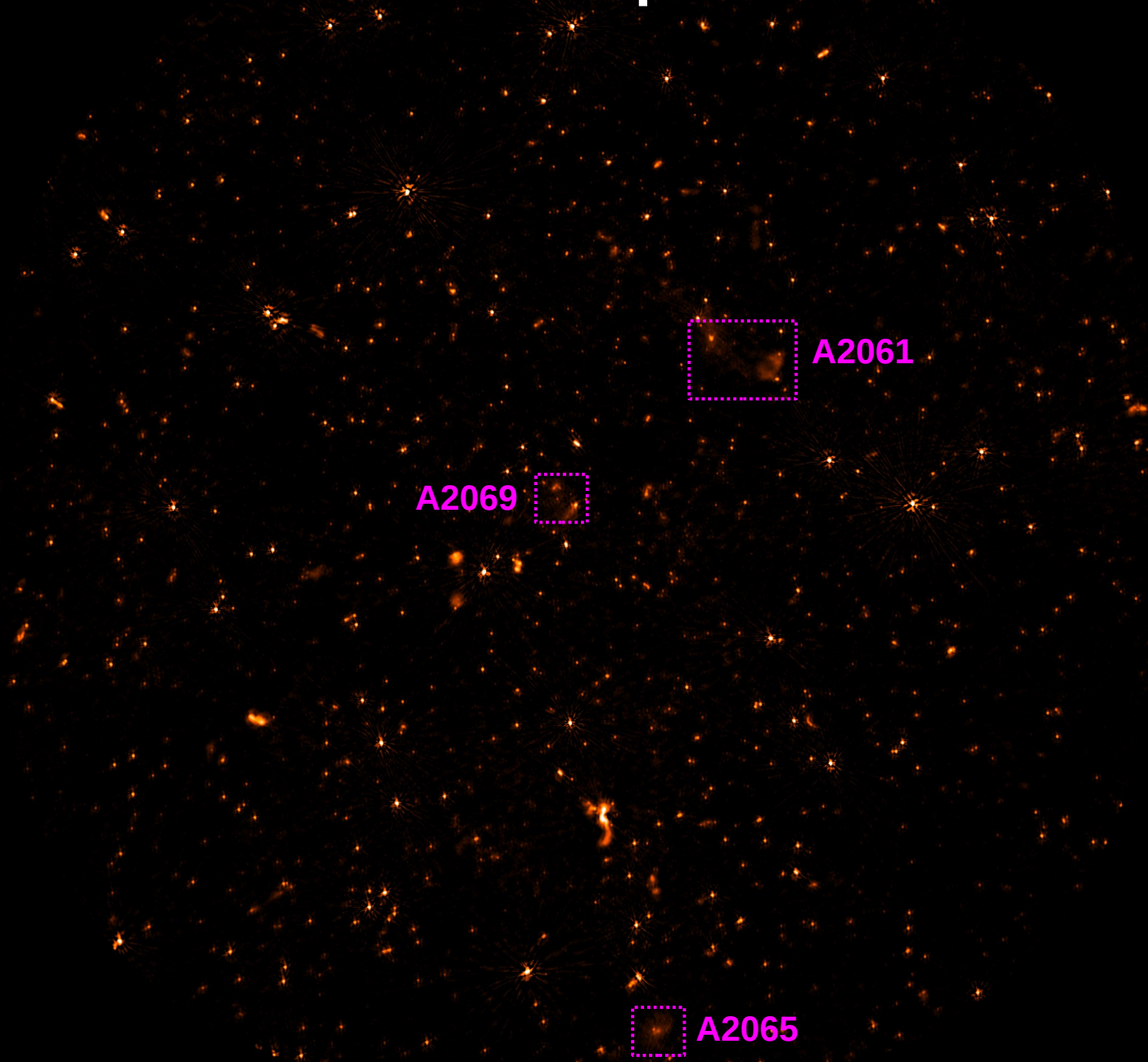
LOFAR HBA @ 153 MHz  
beam: 6" × 6"  
r.m.s. noise: 130  $\mu$ Jy/beam

# Abell 2061:

## radio halo + embedded ultra-steep spectrum source



# Corona Borealis supercluster field



A2061

A2069

A2065

# Corona Borealis supercluster field

- radio relic more extended at low frequencies
- peculiar radio halo with embedded **ultra-steep spectrum** source
- no signs of a filament

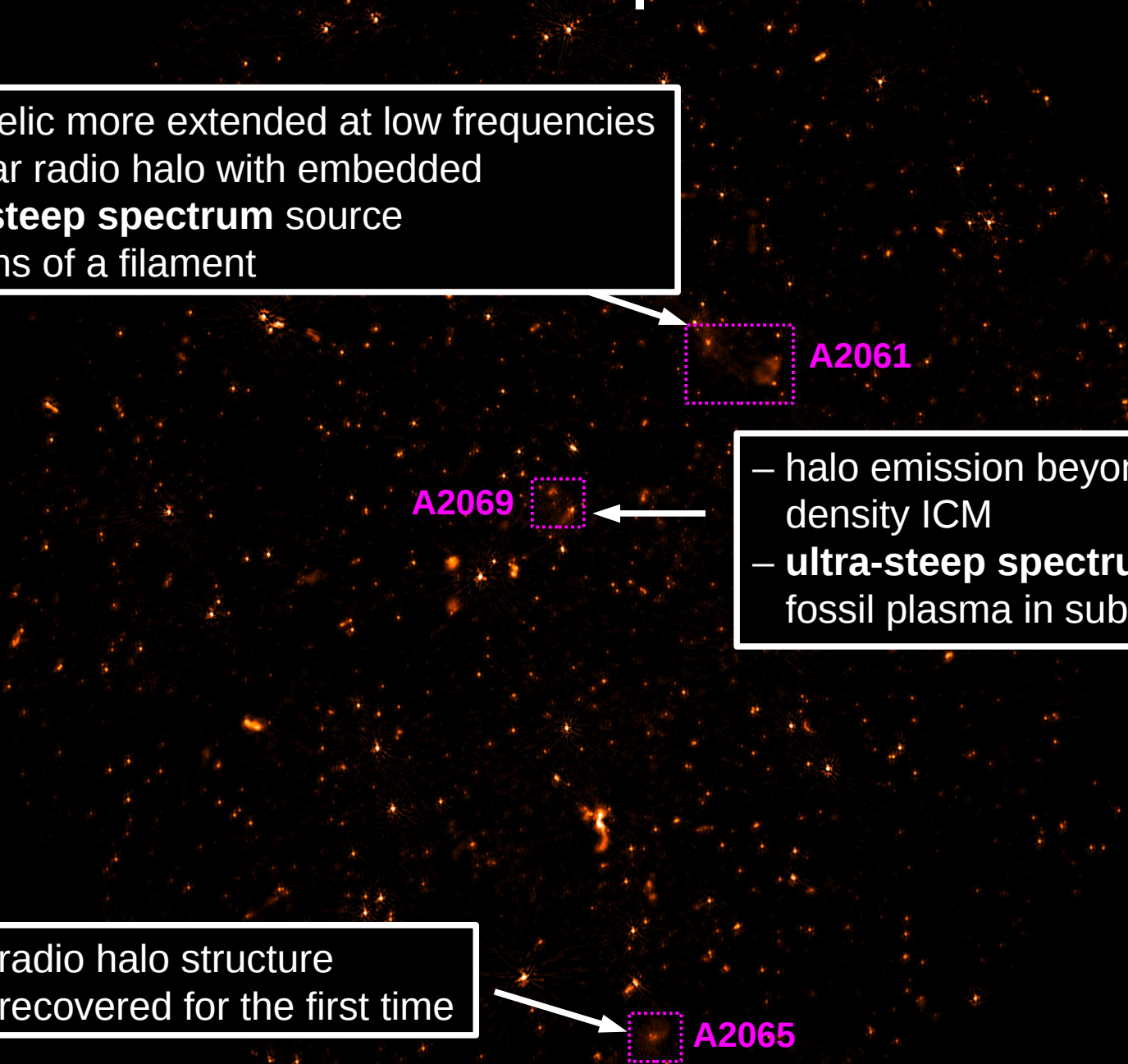
A2061

- halo emission beyond high-density ICM
- **ultra-steep spectrum** fossil plasma in subcluster

A2069

- radio halo structure recovered for the first time

A2065



# Corona Borealis supercluster field

- unveil presence of **ultra-steep spectrum** radio sources in galaxy clusters
- indicates the existence of “fossil” electron population
  - potential source of seeds for relativistic re-acceleration of electrons



How can turbulence be induced in low-mass environments?



**Thank you for  
your attention!**

500 kpc

Radio  
X-ray  
Optical (SDSS)

Abell 2069