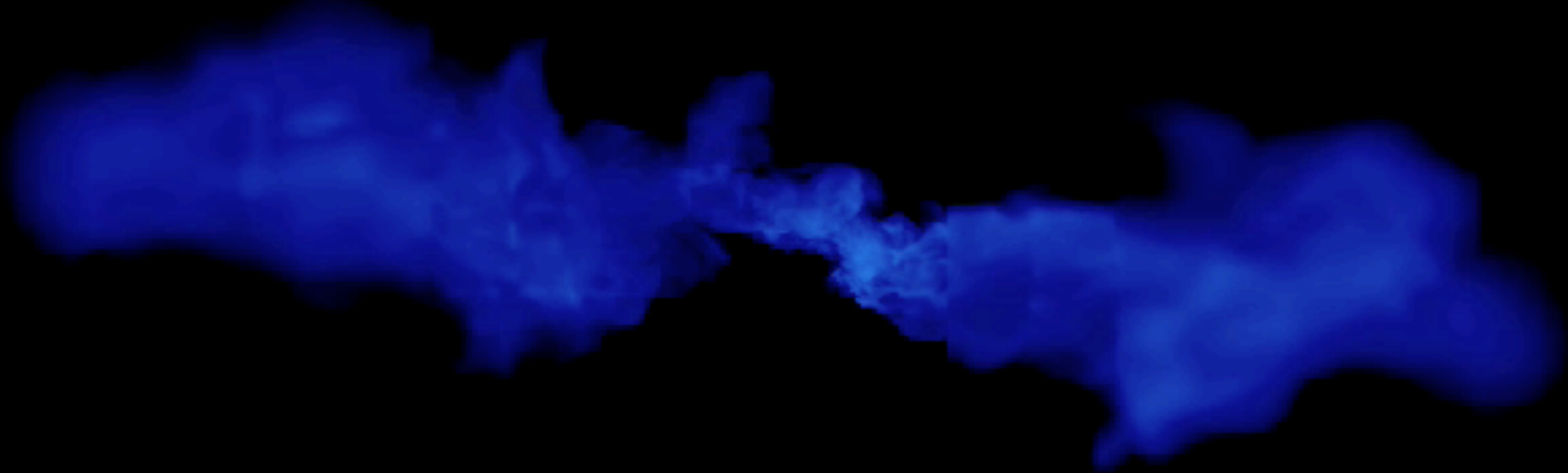


# Search and modelling of remnant radio galaxies at 150 MHz with LOFAR

**Marisa Brienza**

IRA-INAF, Bologna - PRIN SKA/CTA 'FORCAST'



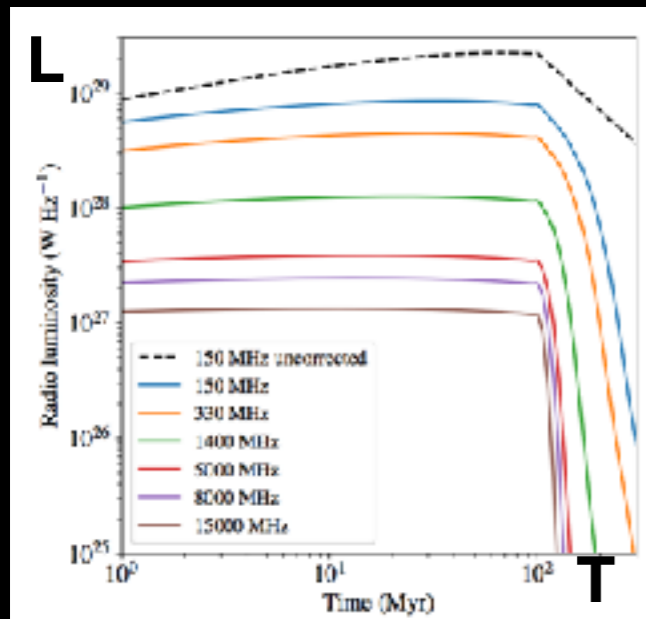
Simulation from Heinz+2016

Collaborators: **I. Prandoni**, R. Morganti, L. Godfrey, N. Jurlin, M. Murgia, B. Mingo, J. Harwood, E. K. Mahony, M. J. Hardcastle, H. J. A. Röttgering, T. W. Shimwell, A. Shulevski et al.

# WHY?

## Radio galaxy evolution models

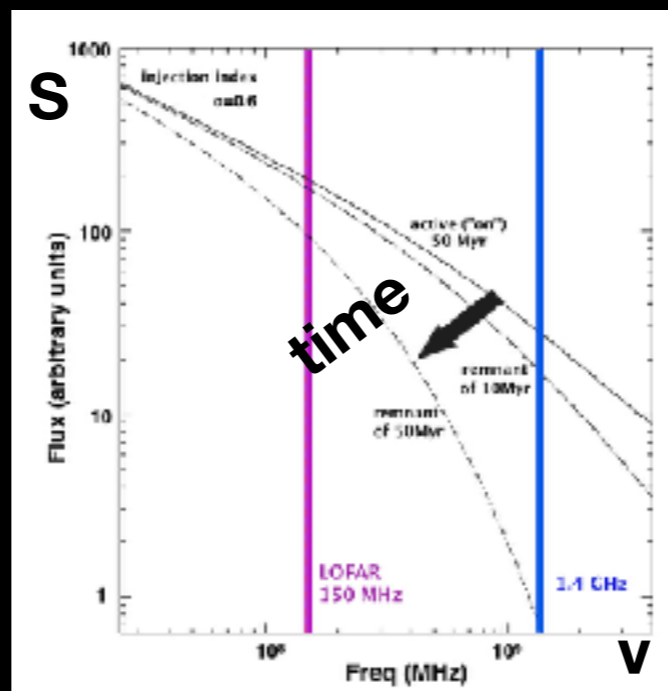
Provide useful constraints to the physical mechanisms acting in radio galaxies



Hardcastle+18

## AGN feedback

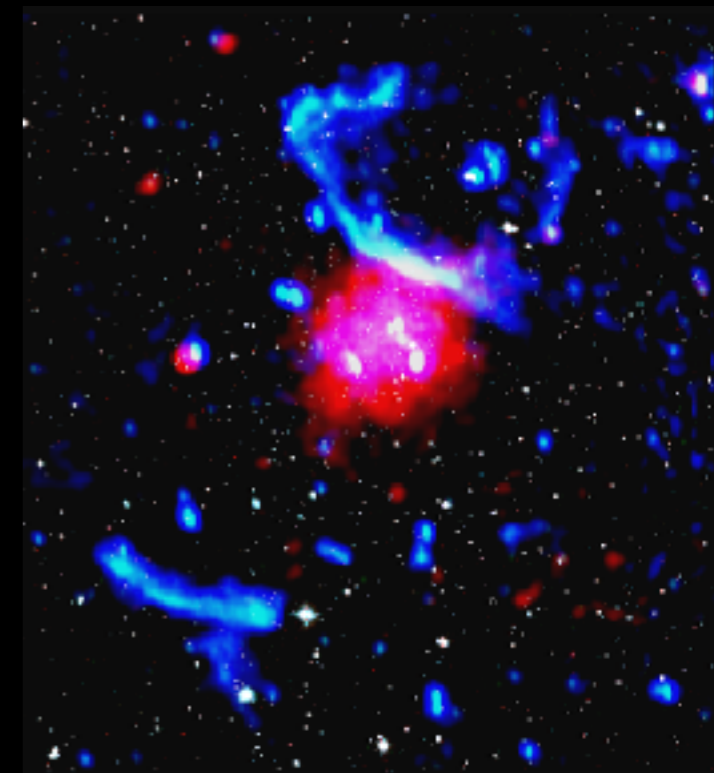
The modelling of their radio spectrum gives indications on the timescales of the jets activity



Morganti+17

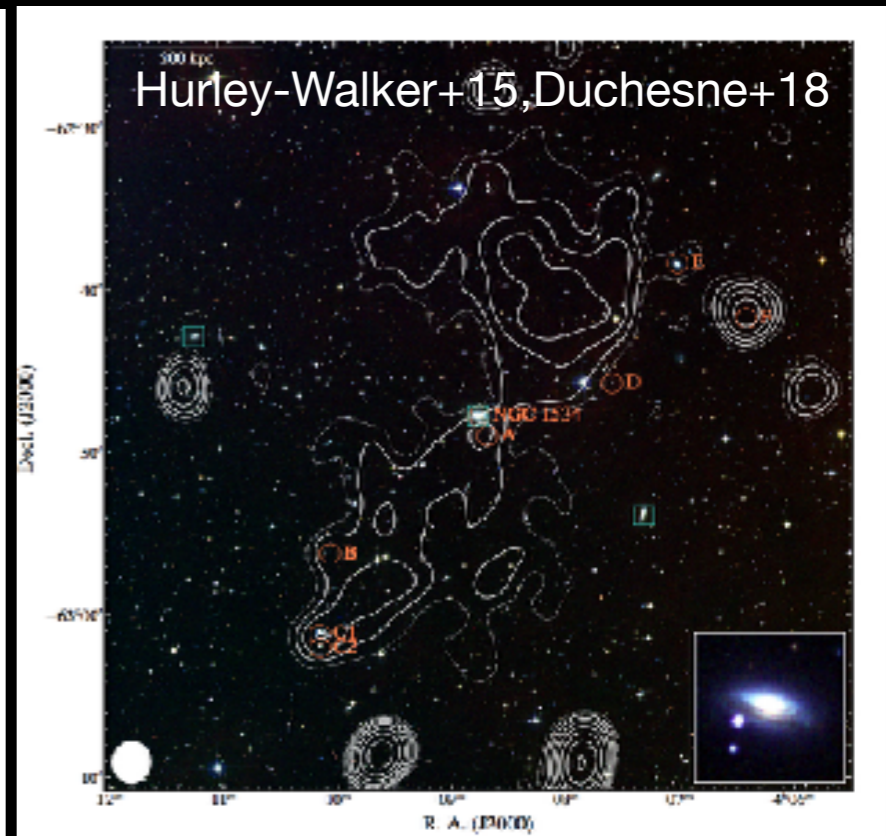
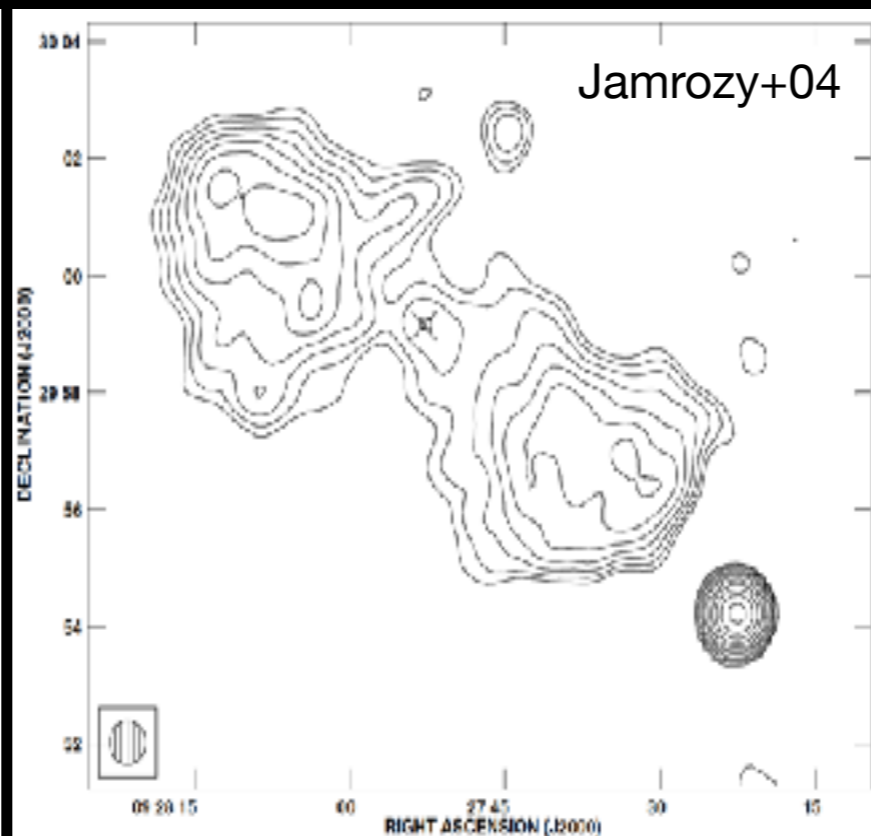
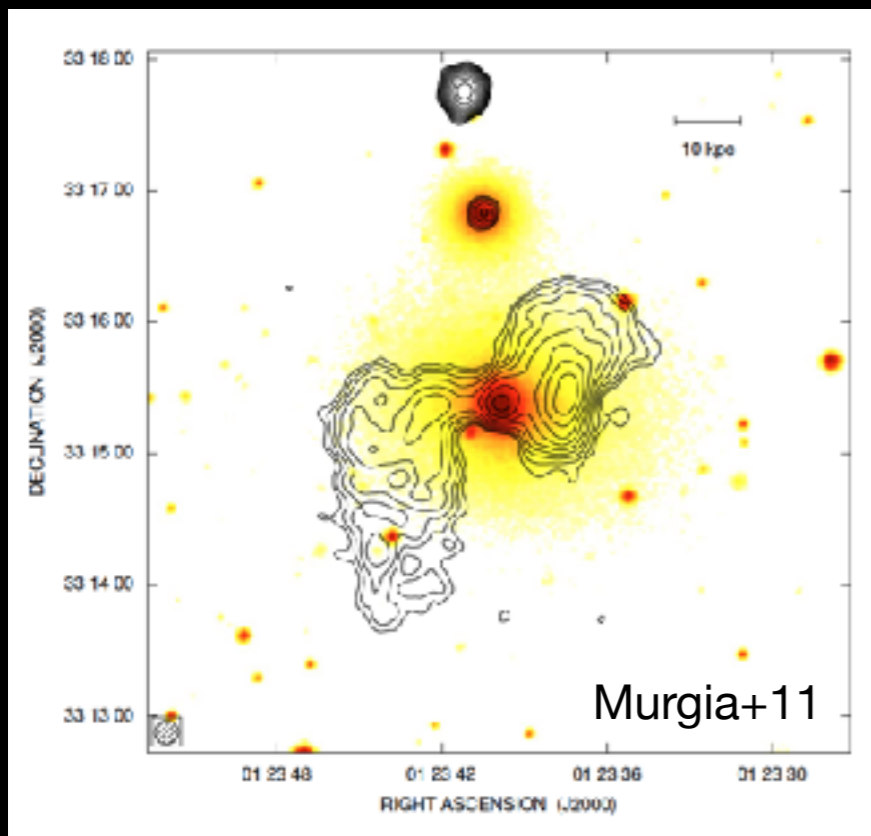
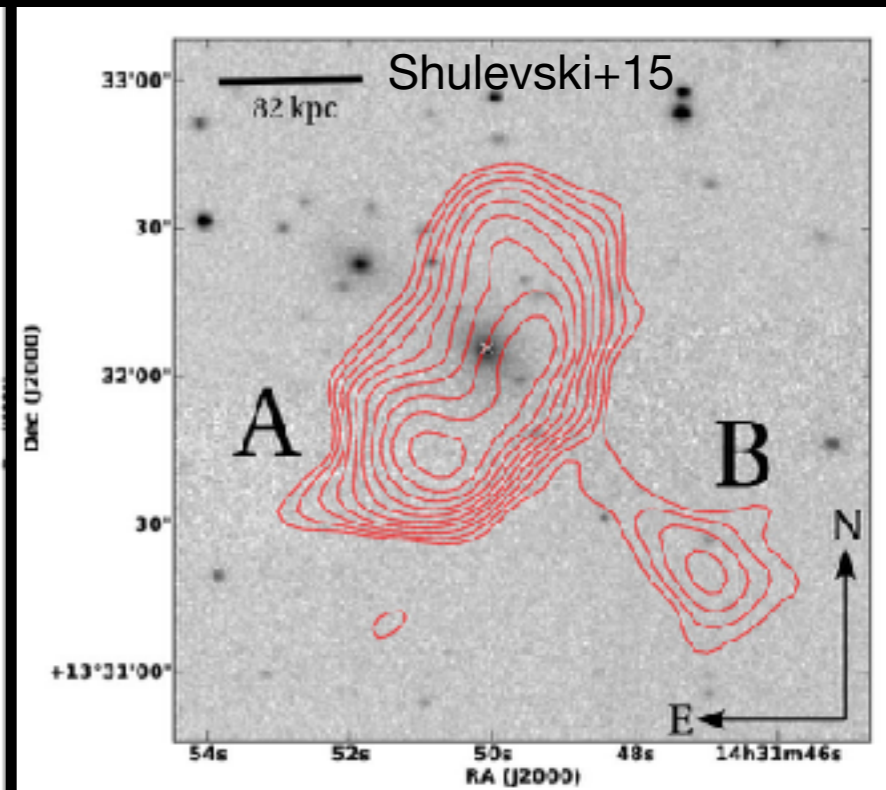
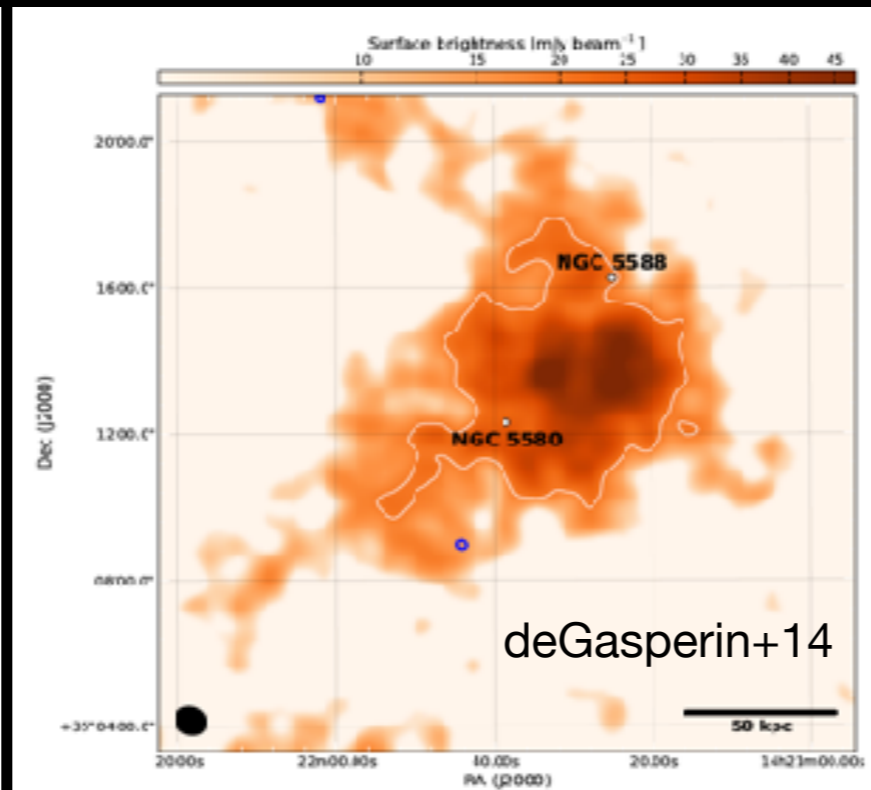
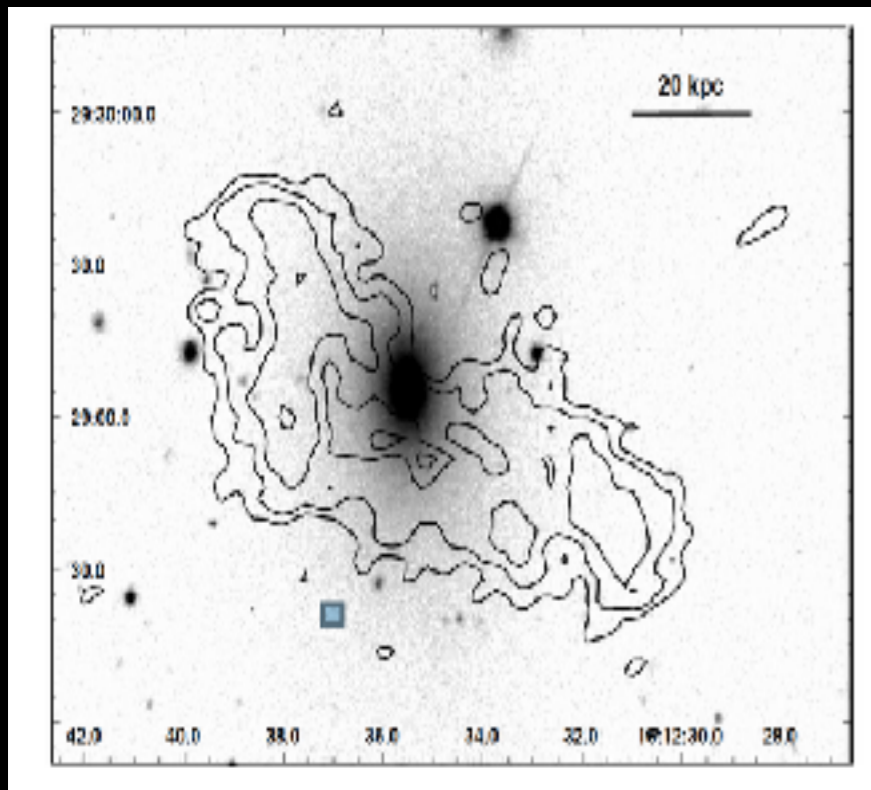
## Galaxy clusters

May provide seed particles for relics and halos in cluster of galaxies



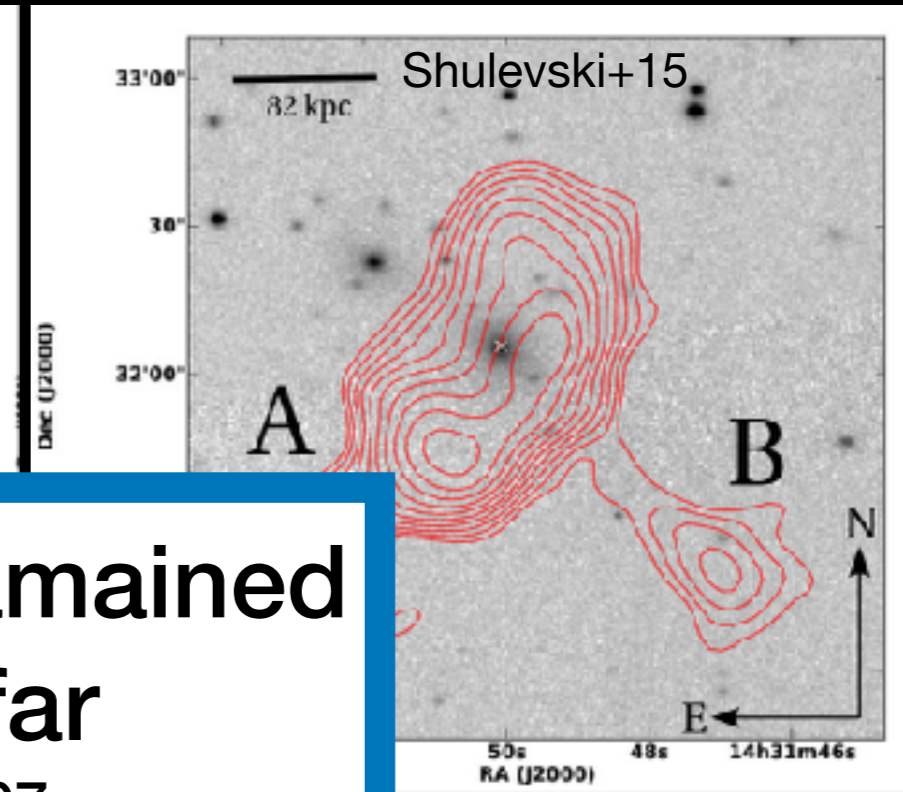
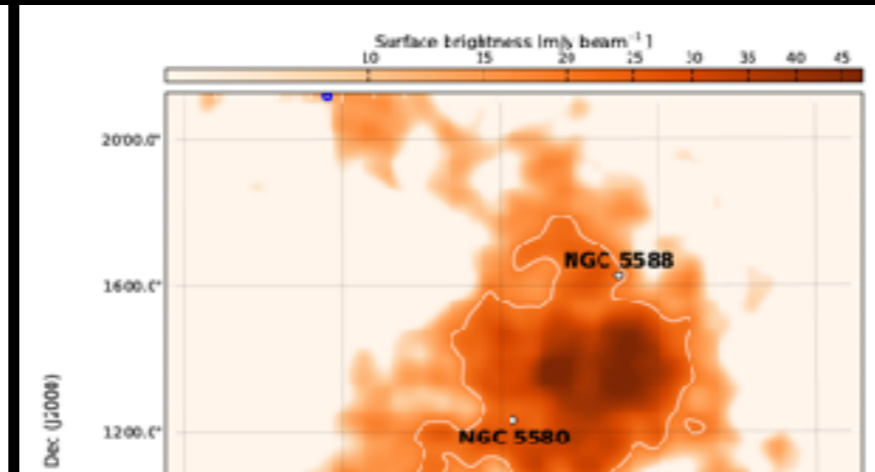
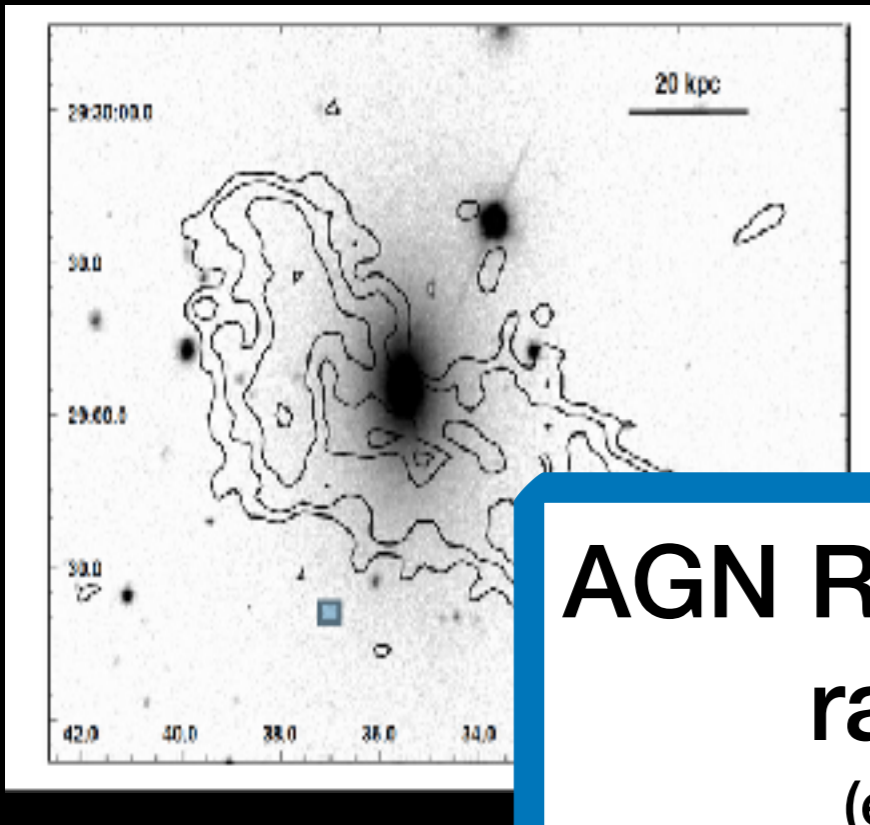
Bonafede+14

# Remnant radio galaxies



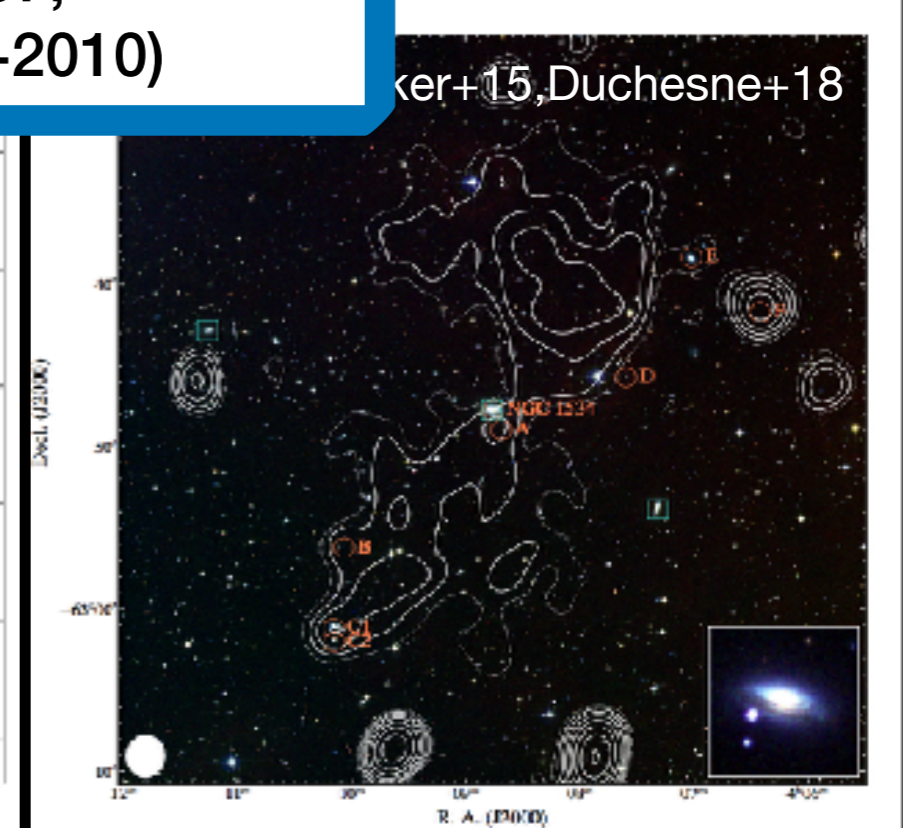
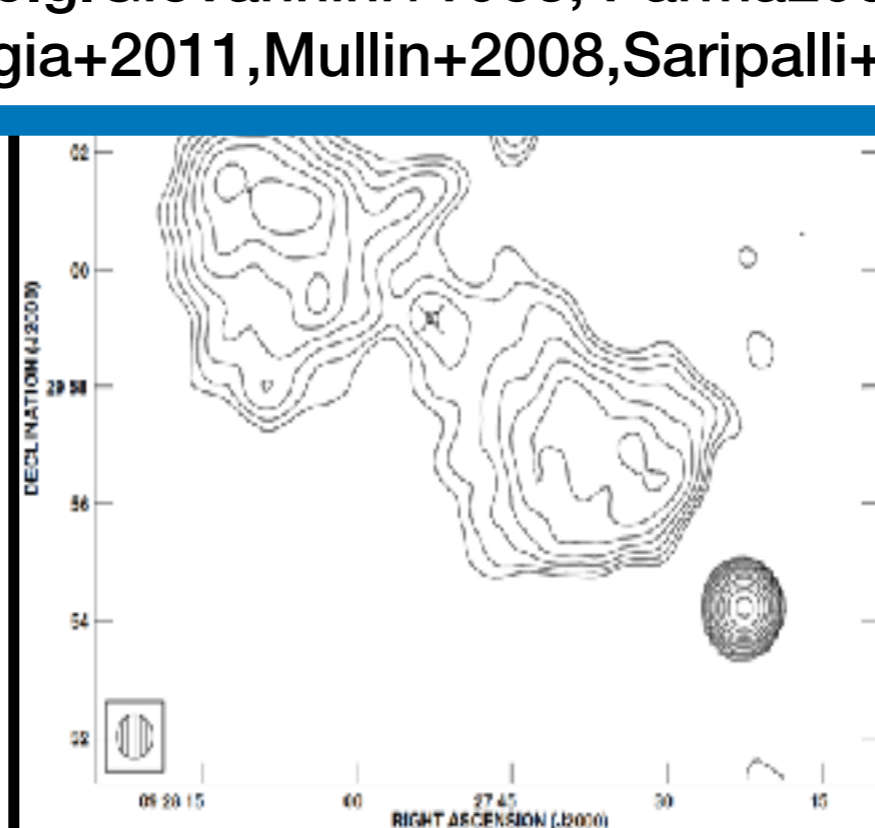
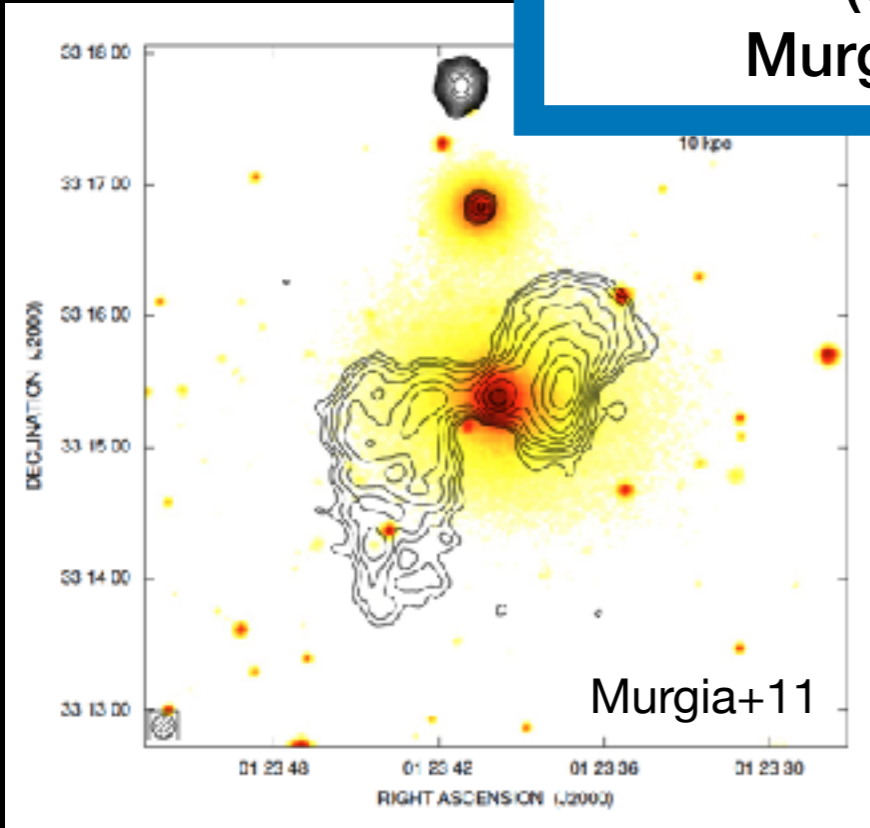


# Remnant radio galaxies



**AGN REMNANTS** have remained rare and elusive so far

(e.g. Giovannini+1988, Parma2007, Murgia+2011, Mullin+2008, Saripalli+2010)



ker+15, Duchesne+18

Murgia+11





# LOFAR





# LOFAR



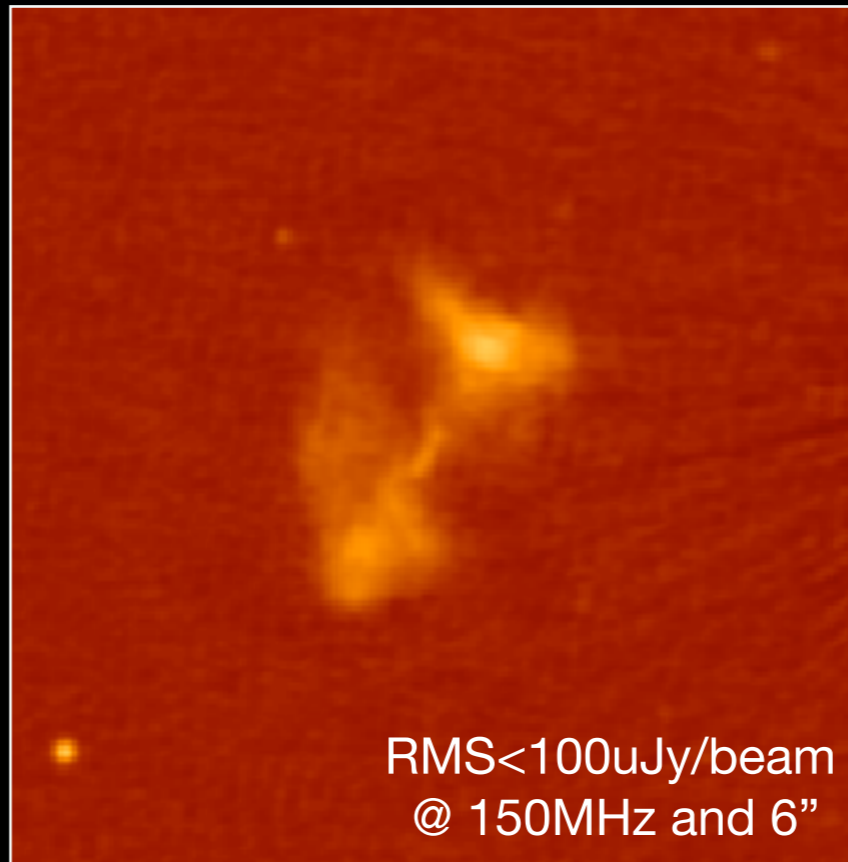
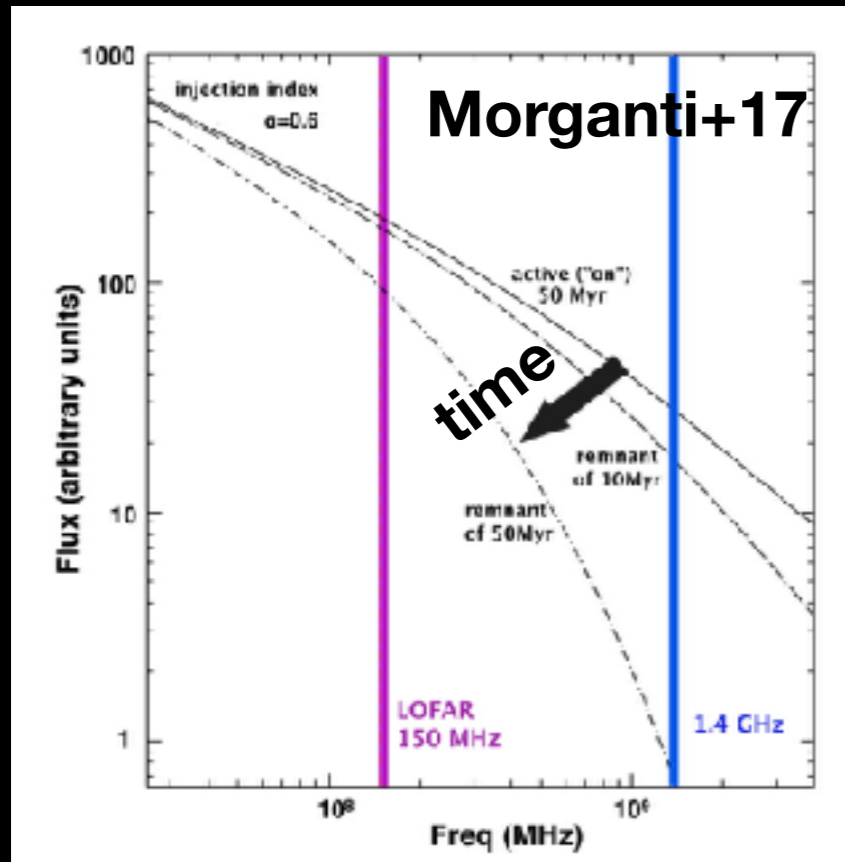
High Band Antennas  
110-250 MHz  
6" with Dutch array  
~100 uJy/beam





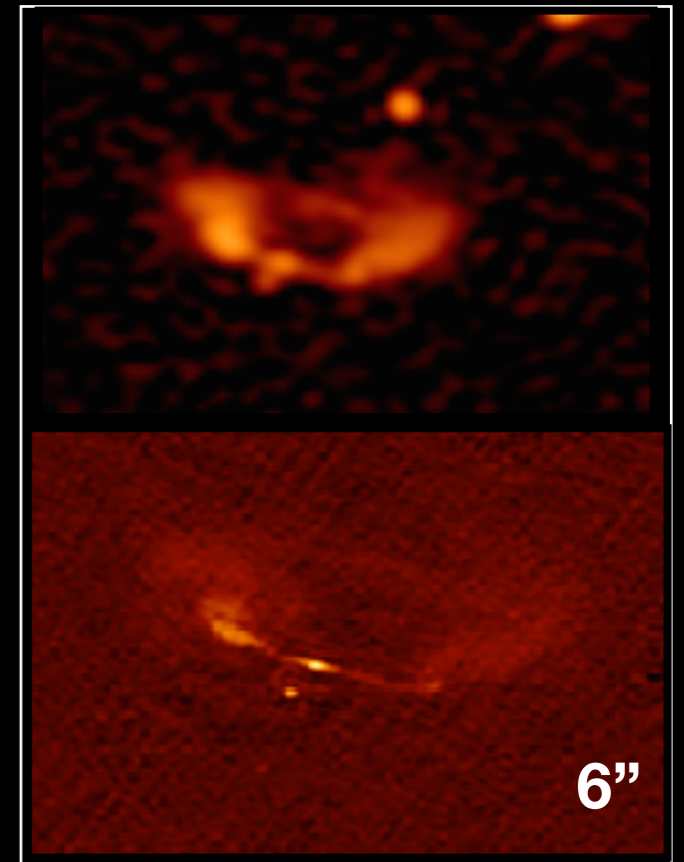
# LOW FREQUENCY

to detect the oldest populations of emitting particles



# UV-COVERAGE

get high resolution and sensitivity to large scales at the same time



# LOFAR discovery of a 700-kpc remnant radio galaxy at low redshift

Brienza+2016,A&A,585, A29

radiative evolution models  
(Komissarov&Gubanov 1994)

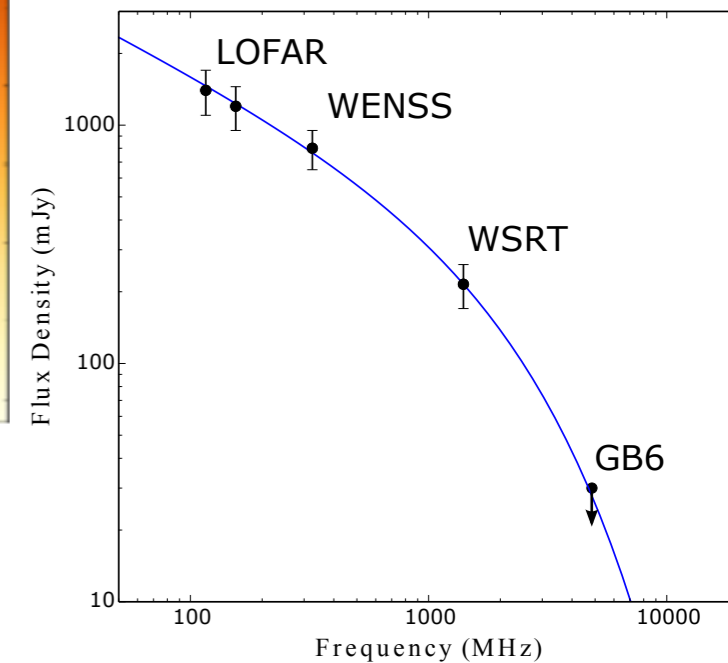
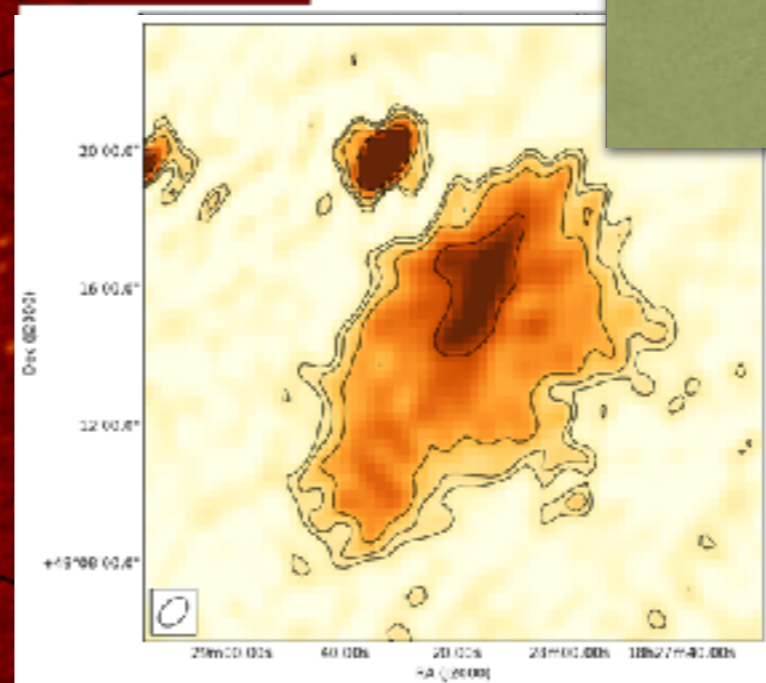
CIOFF

age~75 Myr

$t_{\text{off}}/t_s=0.5-0.7$

LOFAR 150 MHz

$z=0.05$

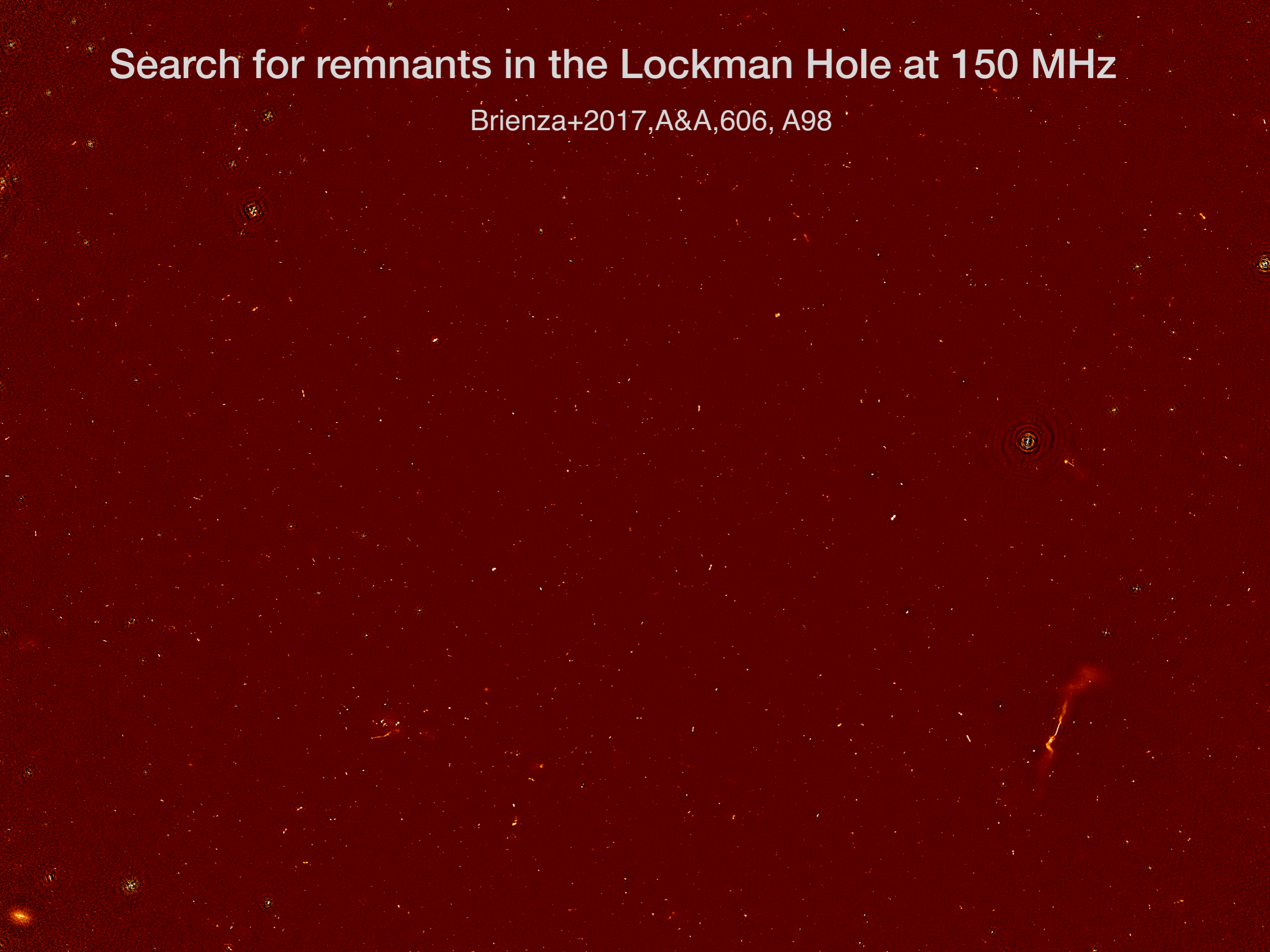


core prominence  
normalised  
 $=0.012$



# Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98





# Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98

110-180 MHz  
~35 deg<sup>2</sup>

10 hrs int. time  
14"x18" resolution  
rms~0.75 mJy  
Mahony+2016  
sources ~6000

40 hrs int. time  
6"x6" resolution  
rms~35 uJy  
sources ~24000  
Mandal+2019



# Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98

110-180 MHz  
~35 deg<sup>2</sup>

10 hrs int. time  
14"x18" resolution  
rms~0.75 mJy  
Mahony+2016  
sources ~6000

40 hrs int. time  
6"x6" resolution  
rms~0.35 mJy  
sources ~24000  
Mandal+2019

## COMPLEMENTARY SELECTION CRITERIA

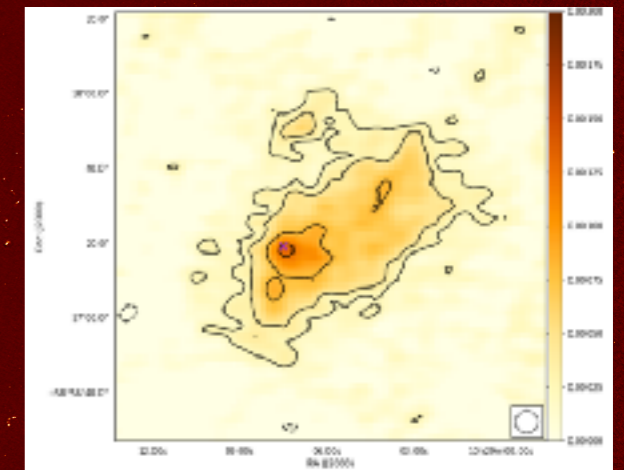
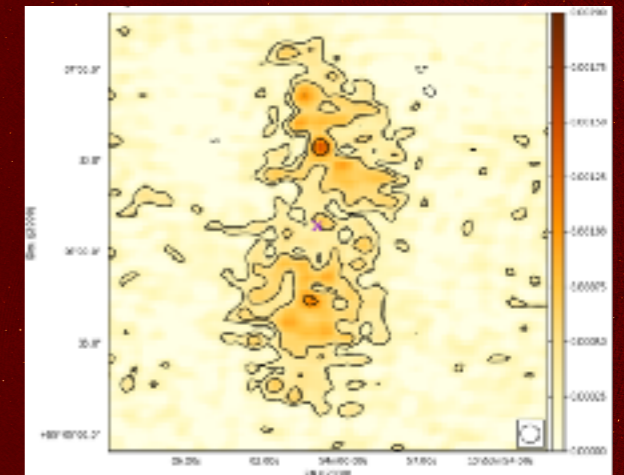
- STEEP SPECTRAL INDEX
- SPECTRAL CURVATURE
- LOW CORE PROMINENCE
- MORPHOLOGY



*23 candidates*



*5 confirmed  
with JVLA follow-ups*





# Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98

110-180 MHz  
~35 deg<sup>2</sup>

10 hrs int. time  
14"x18" resolution  
rms~0.75 mJy  
Mahony+2016  
sources ~6000

40 hrs int. time  
6"x6" resolution  
rms~0.35 mJy  
sources ~24000  
Mandal+2019

## COMPLEMENTARY SELECTION CRITERIA

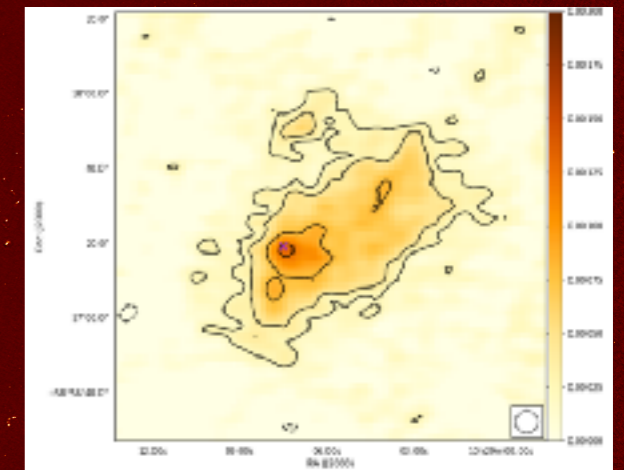
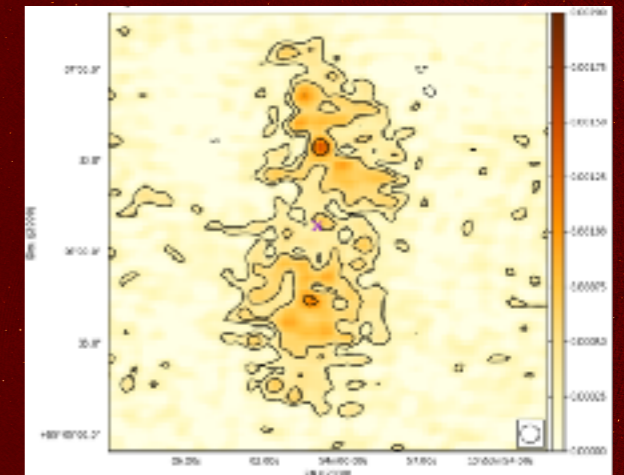
- STEEP SPECTRAL INDEX
- SPECTRAL CURVATURE
- LOW CORE PROMINENCE
- MORPHOLOGY



*23 candidates*



*5 confirmed  
with JVLA follow-ups*



**3-10% of extended sources  
(confirmed also by Mahatma+18)**



# Monte Carlo simulations of low power radio galaxies

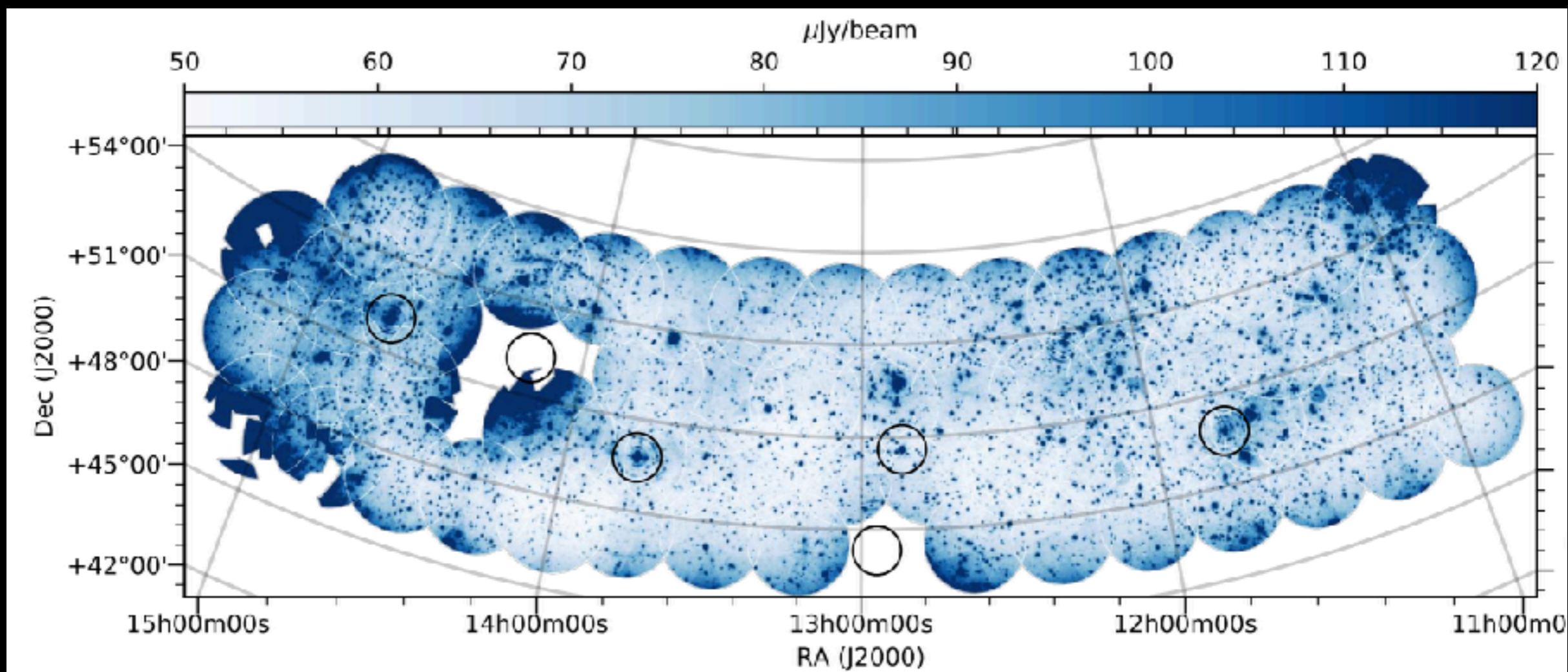
Brienza+2017,A&A,606, A98

- ➔ Simulations based on empirical radio galaxy parameters ( $z$ ,  $Q_{\text{jet}}$ ,  $\alpha$ ,  $t_{\text{on}}$ , age, density profile of external gas, geometry, minimum and maximum energy)
- ➔ **RADIATIVE EVOLUTION**  
Synchrotron + Inverse compton ( Komissarov & Gubanov 1994+ Tribble1994)
- ➔ **DYNAMICAL EVOLUTION**  
Luo&Sadler2011 (pressure limiting case) + adiabatic expansion
- =** **MOCK CATALOGUES** of low power radio galaxies to compare with observed radio catalogues in the Lockman Hole

**<15-10% in mock catalogues are ultra-steep spectrum remnants**



# The LOFAR Two-metre Sky Survey DR1



Shimwell+2019

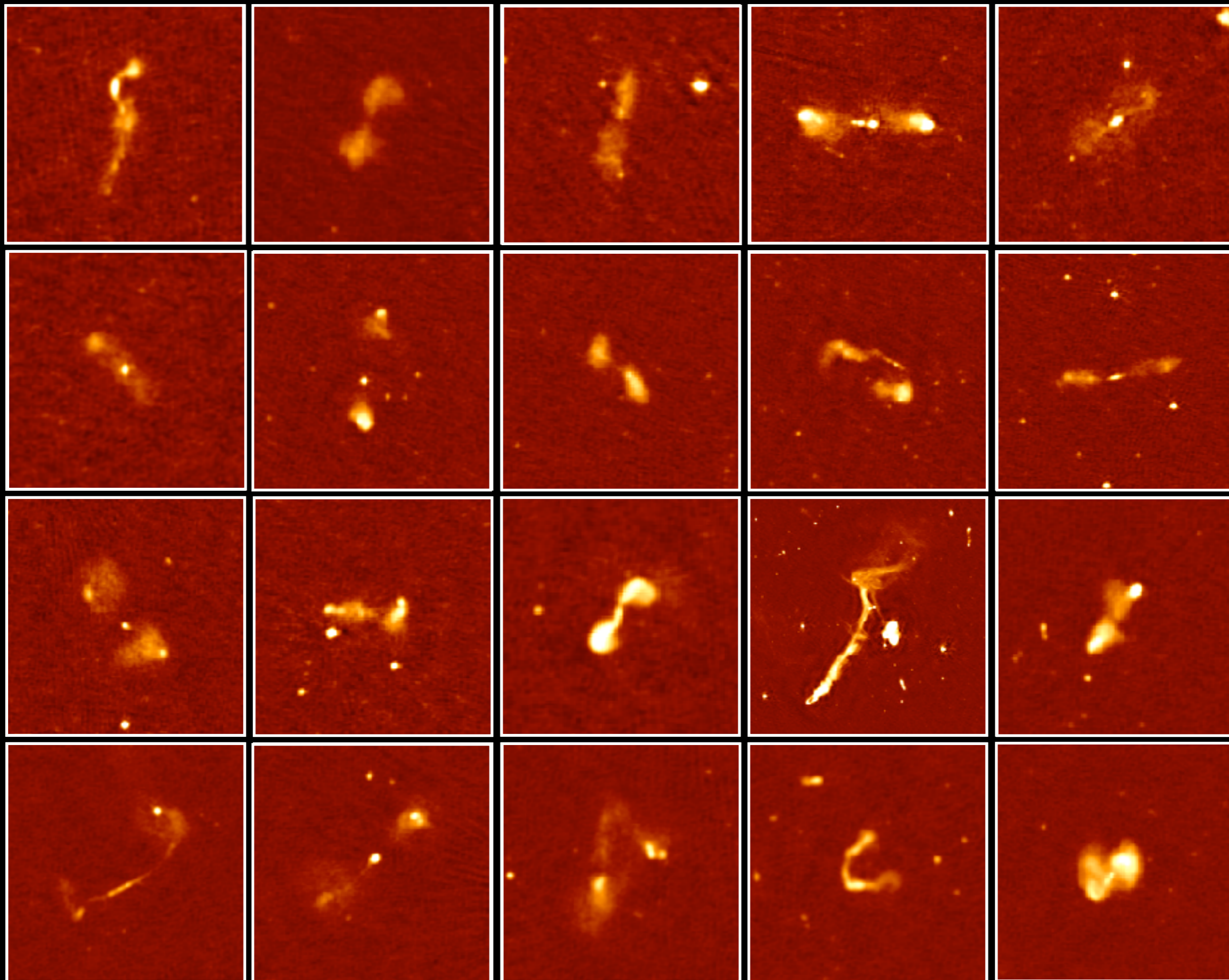
400 squared degrees  
~350,000 sources  
6" , noise 100 $\mu\text{Jy}/\text{beam}$

<https://lofar-surveys.org>

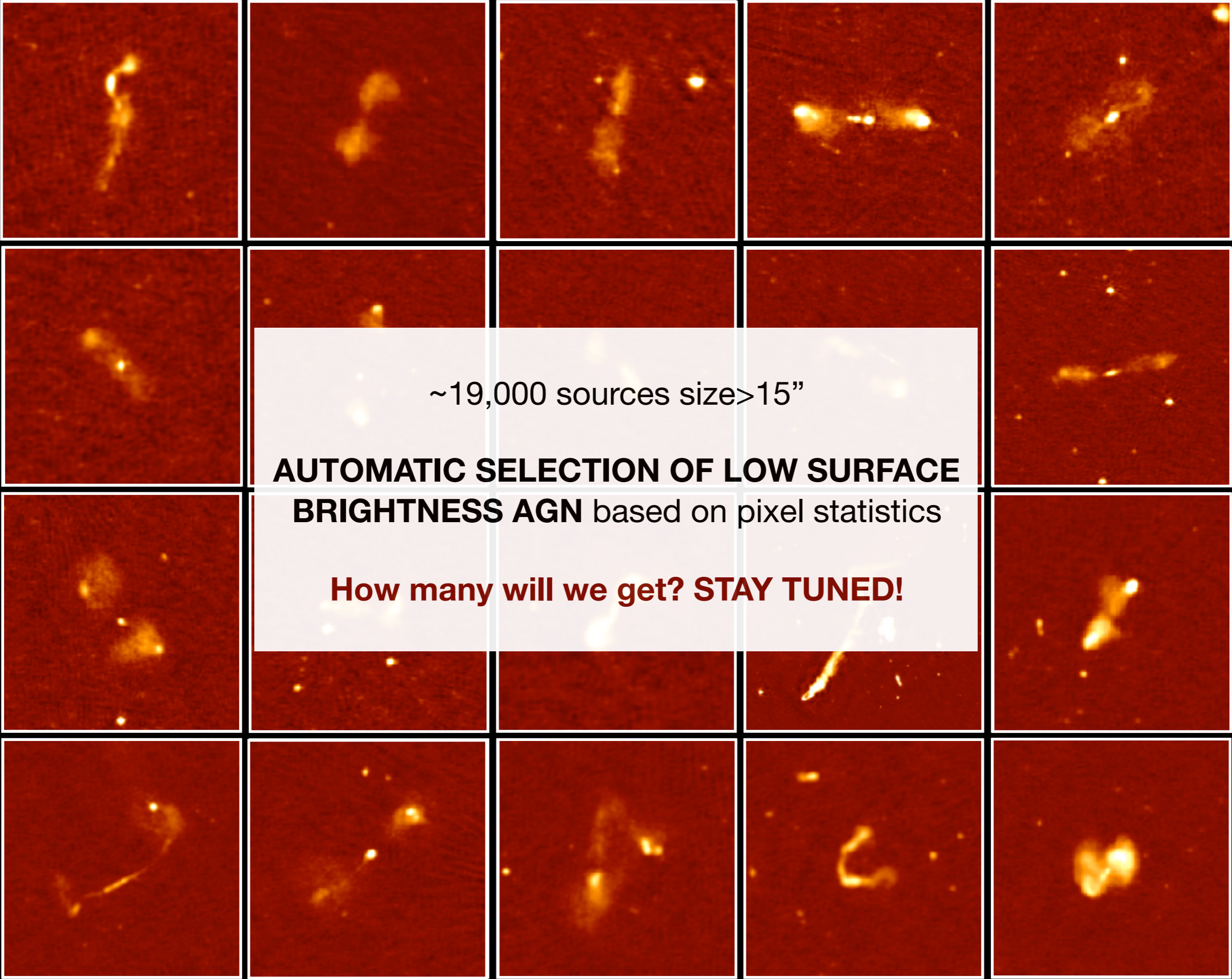












~19,000 sources size > 15"

**AUTOMATIC SELECTION OF LOW SURFACE  
BRIGHTNESS AGN** based on pixel statistics

**How many will we get? STAY TUNED!**



# CONCLUSIONS

Remnant radio galaxies seem to represent a small fraction of the radio-loud population even at low frequency and high sensitivity

➔ This implies a rapid luminosity evolution of the plasma

Searches on larger areas of sky are required to confirm this result and to build up larger samples of remnants that allow for a statistical study of their properties

➔ **LOFAR** is the perfect instrument to start this search and study in view of **SKA-LOW** and can become even more powerful when combined with data from other new generation instruments such as **APERTIF** or **uGMRT**

➔ **MIGHTEE** 6" @ 1.4 GHz with few  $\mu\text{Jy}/\text{beam}$  RMS can complement what is done with LOFAR in the Southern sky



# CONCLUSIONS

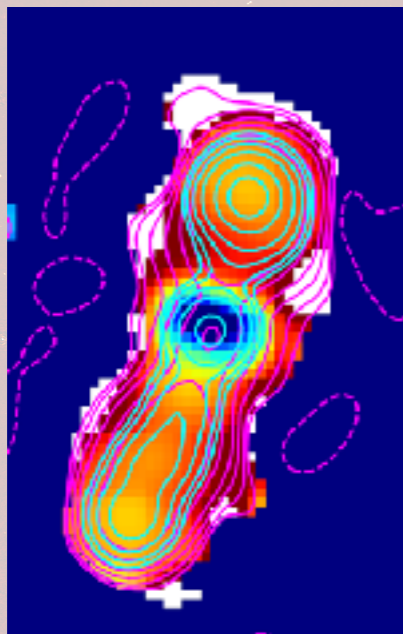
Remnant radio galaxies seem to represent a small fraction of the radio-loud population even at low frequency and high sensitivity

➔ This implies a rapid luminosity evolution of the plasma

Searches on larger areas of sky are required to confirm this result and to build up larger samples of remnants that allow for a statistical study of their properties

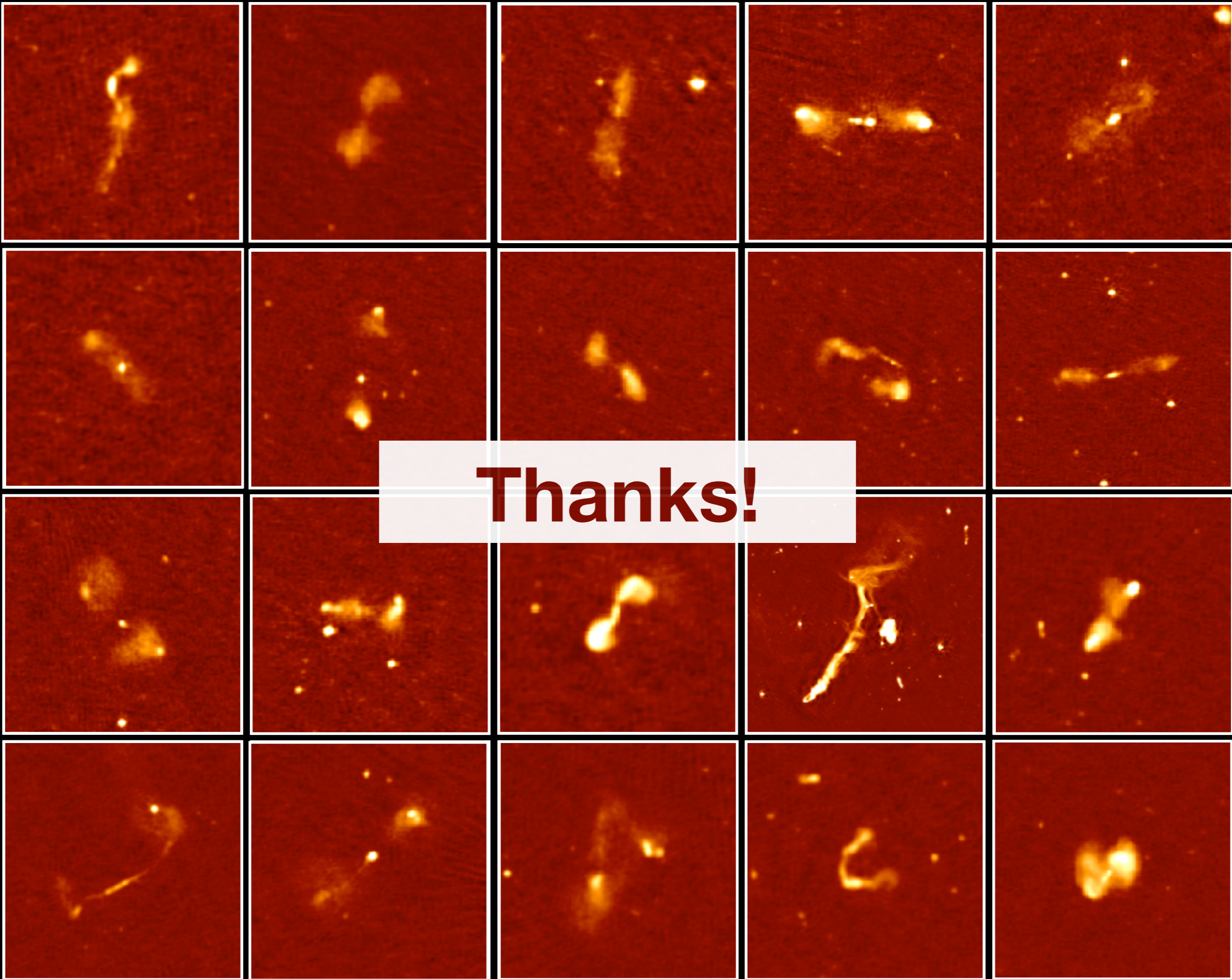
➔ **LOFAR** is the perfect instrument to start this search and study in view of **SKA-LOW** and can become even more powerful when combined with data from other new generation instruments such as **APERTIF** or **uGMRT**

spectral index map  
150-1400 MHz



➔ **MIGHTEE** 6" @ 1.4 GHz with few  $\mu\text{Jy}/\text{beam}$  RMS can complement what is done with LOFAR in the Southern sky





**Thanks!**