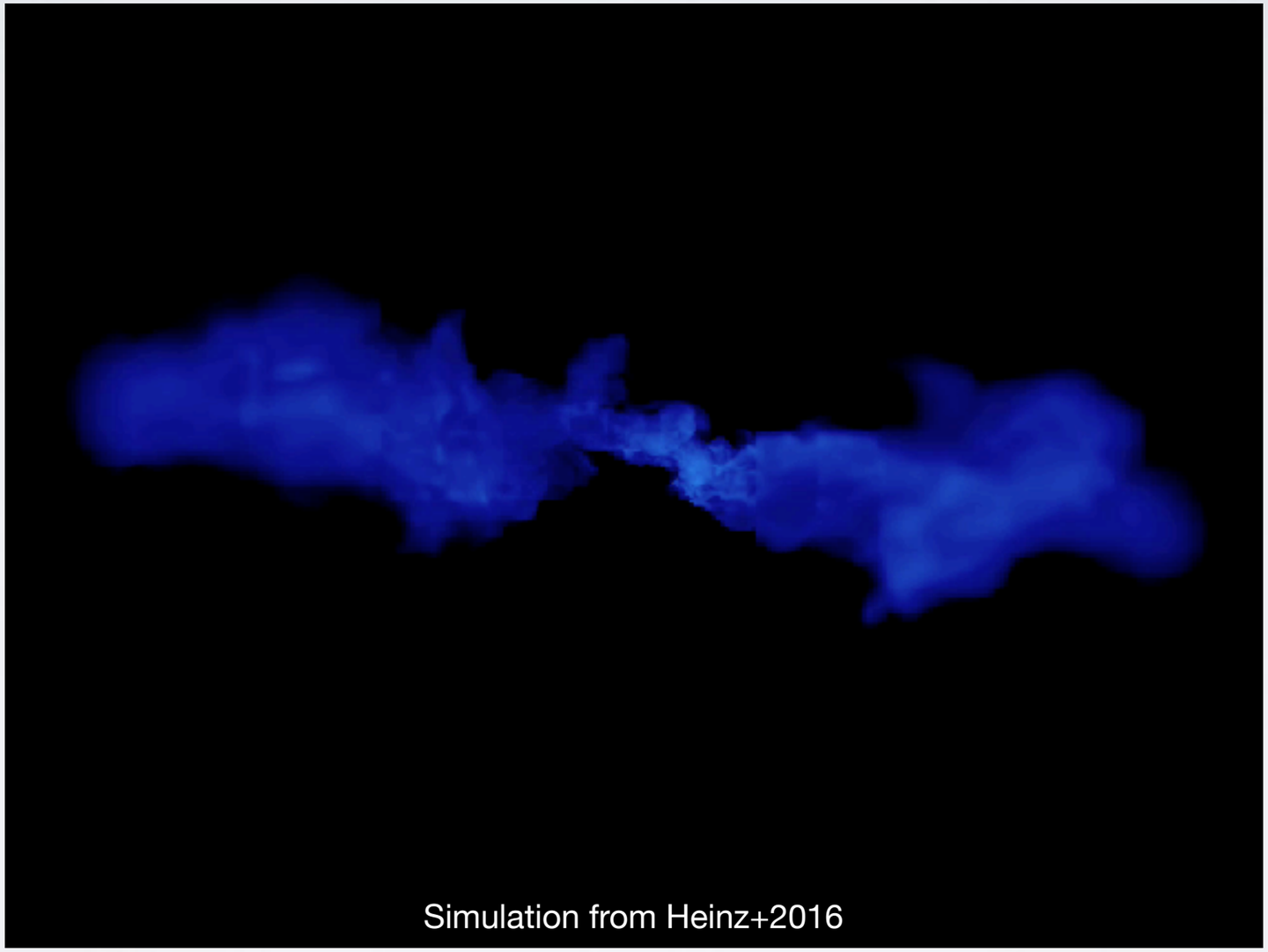
Remnant radio galaxies in the LOFAR Two Meters Sky Survey

Marisa Brienza
IRA-INAF, Bologna



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 and many more..

WHY are remnants important ?

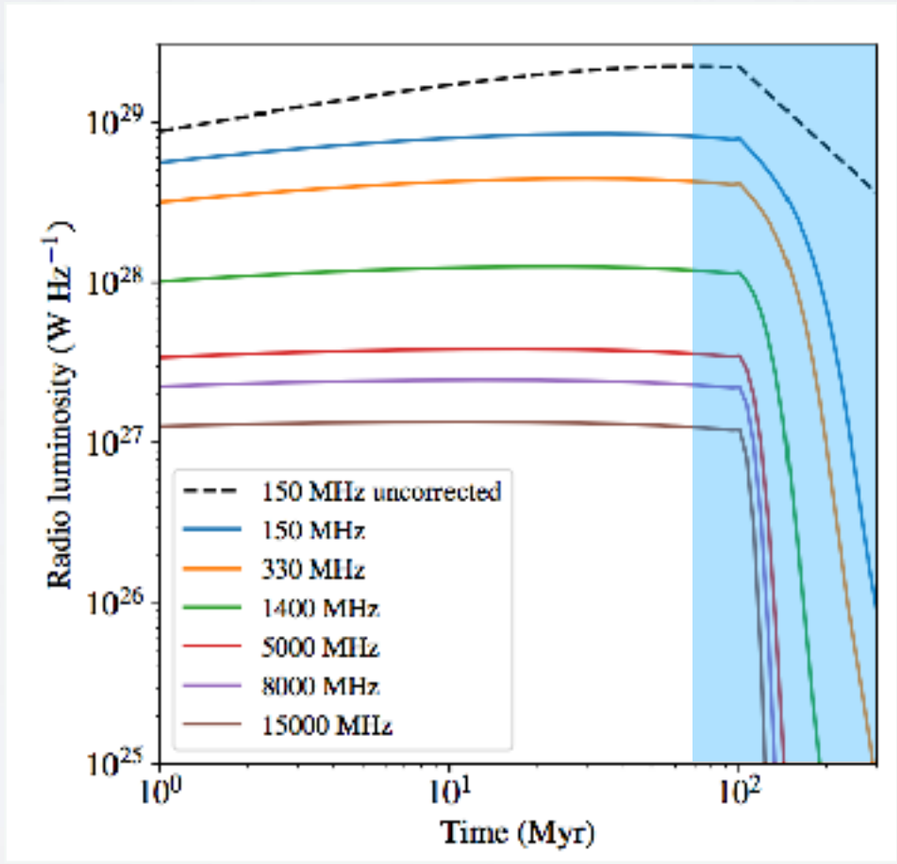
1 **Radio galaxy evolution models (as a function of class and environment) -** provide useful constraints to the physical mechanisms acting in radio galaxies

2 **Jets timescales for AGN feedback and duty cycle -** the modelling of their radio spectrum gives indications on the timescales of the jets activity

3 **Galaxy clusters -** May provide seed particles for relics and halos in cluster of galaxies

WHY are remnants important ?

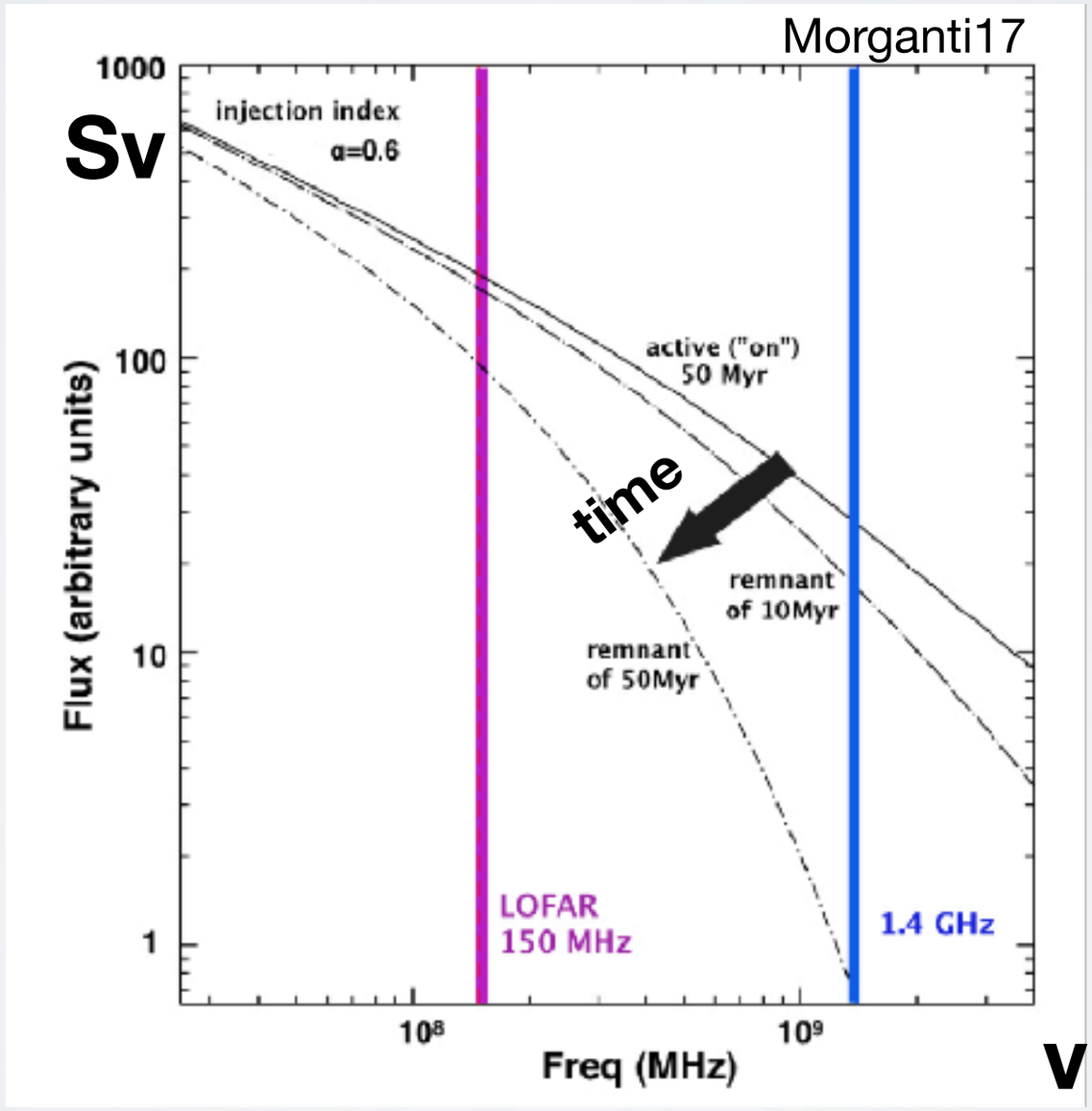
1 **Radio galaxy evolution models (as a function of class and environment) -** provide useful constraints to the physical mechanisms acting in radio galaxies



Hardcastle+17

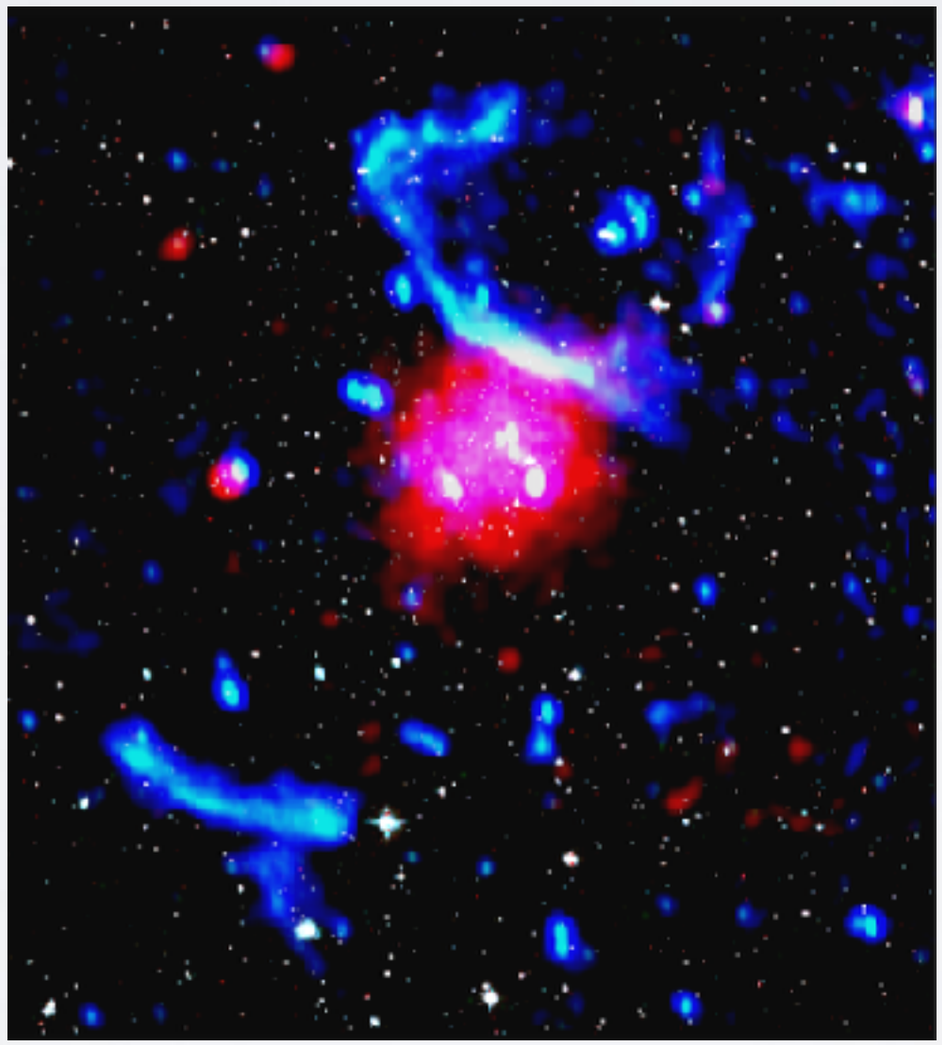
WHY are remnants important ?

2 **Jets timescales for AGN feedback and duty cycle -** the modelling of their radio spectrum gives indications on the timescales of the jets activity



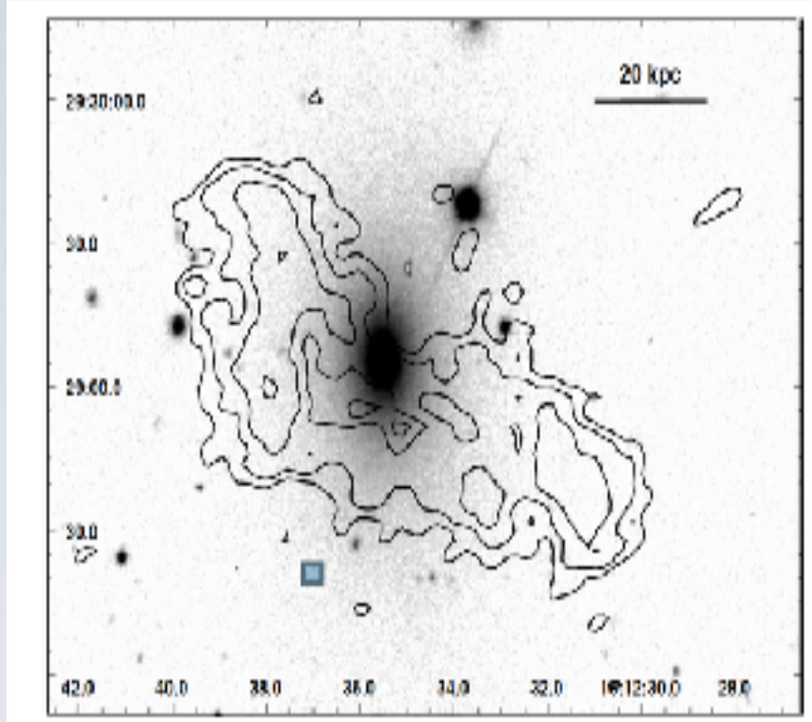
WHY are remnants important ?

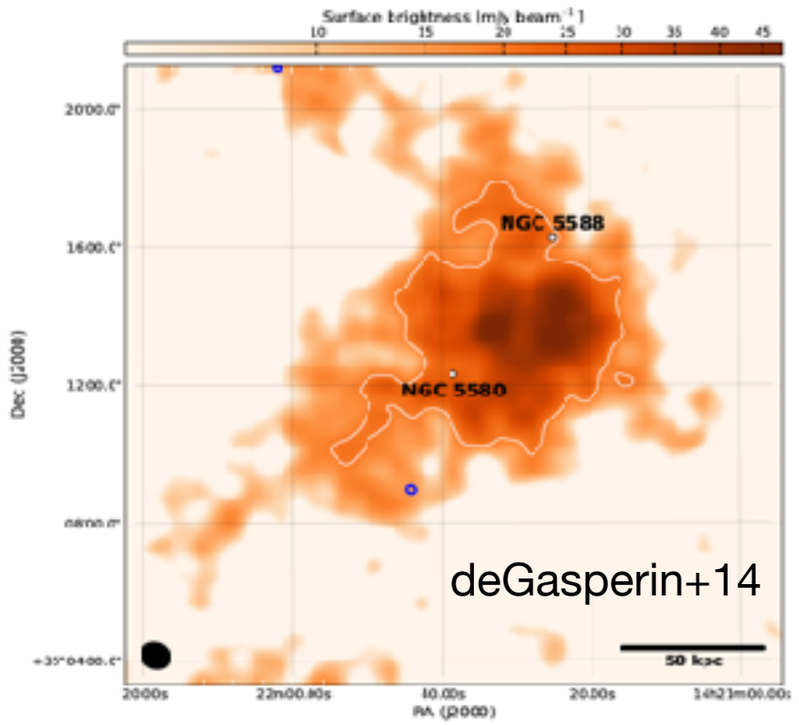
3 **Galaxy clusters -** May provide seed particles for relics and halos in cluster of galaxies

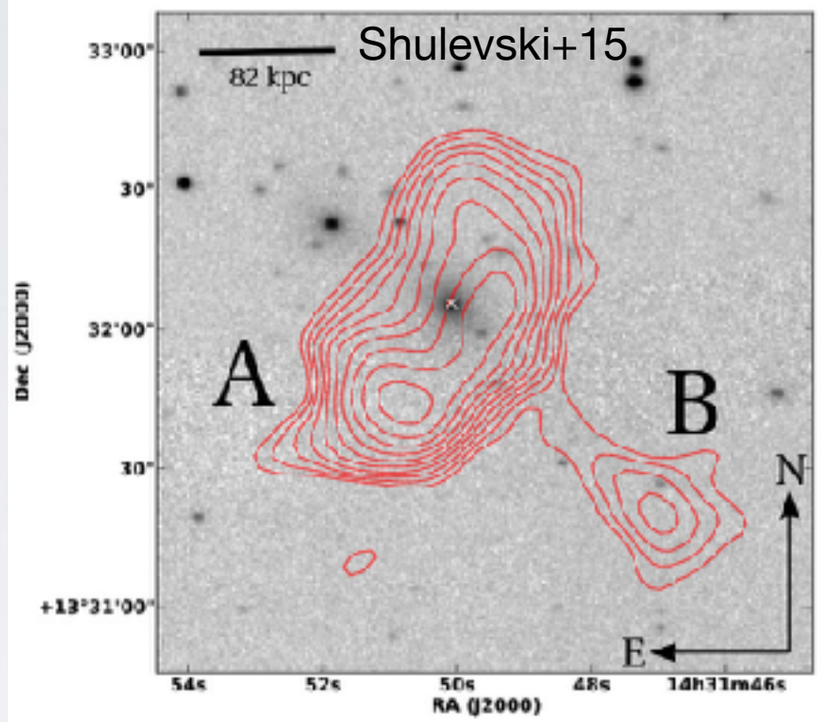


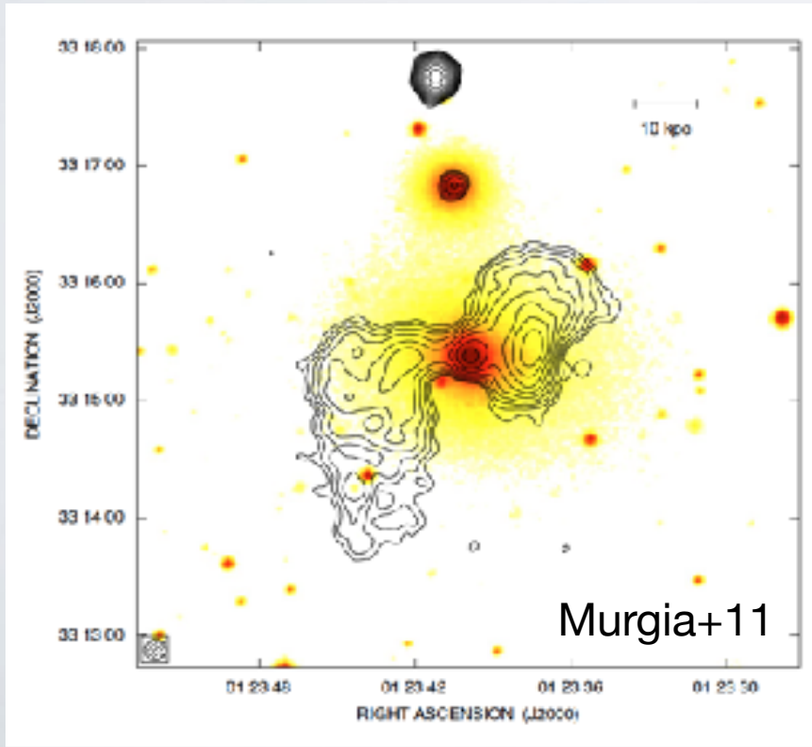
Bonafede+14

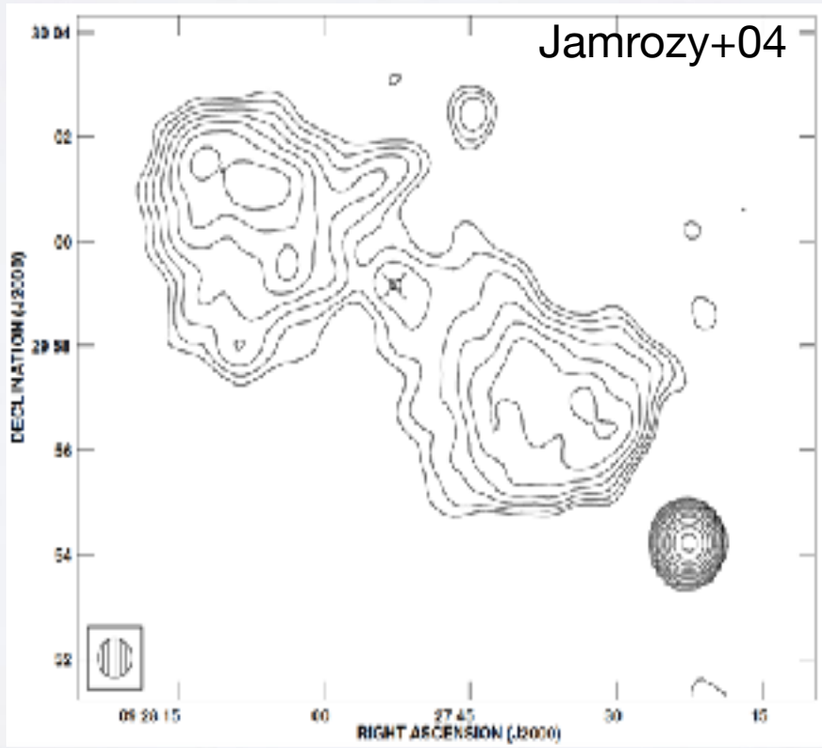
Remnant radio galaxies in the literature

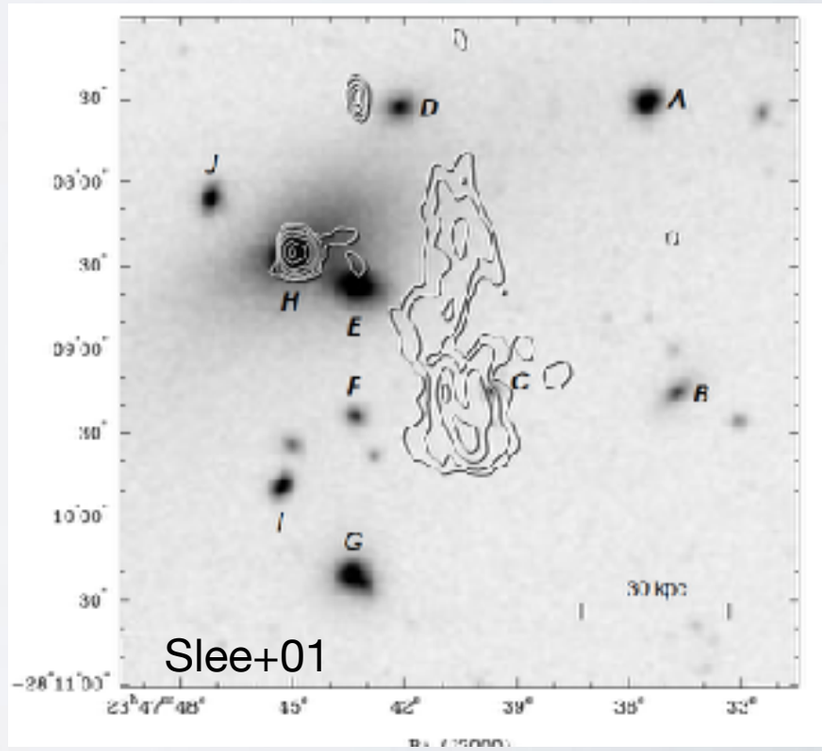




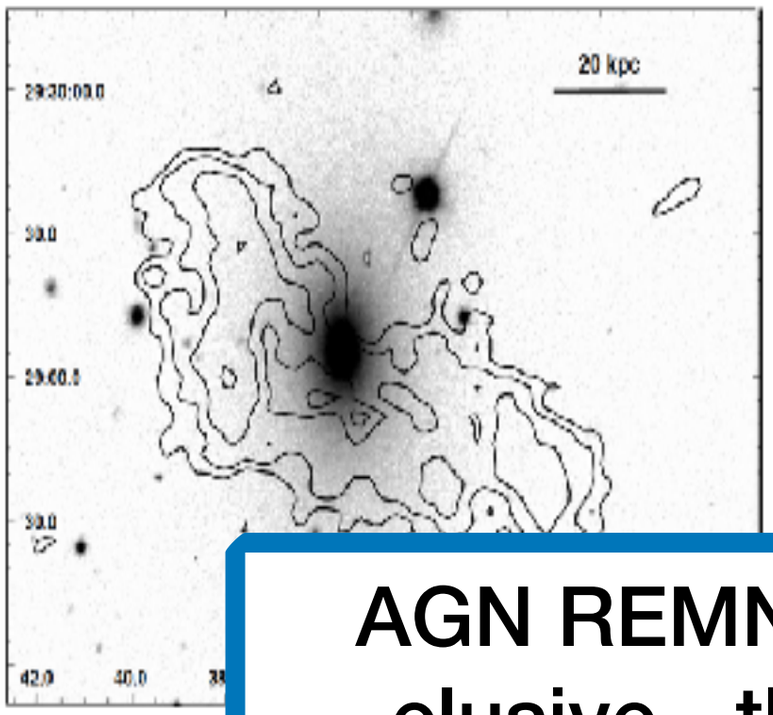


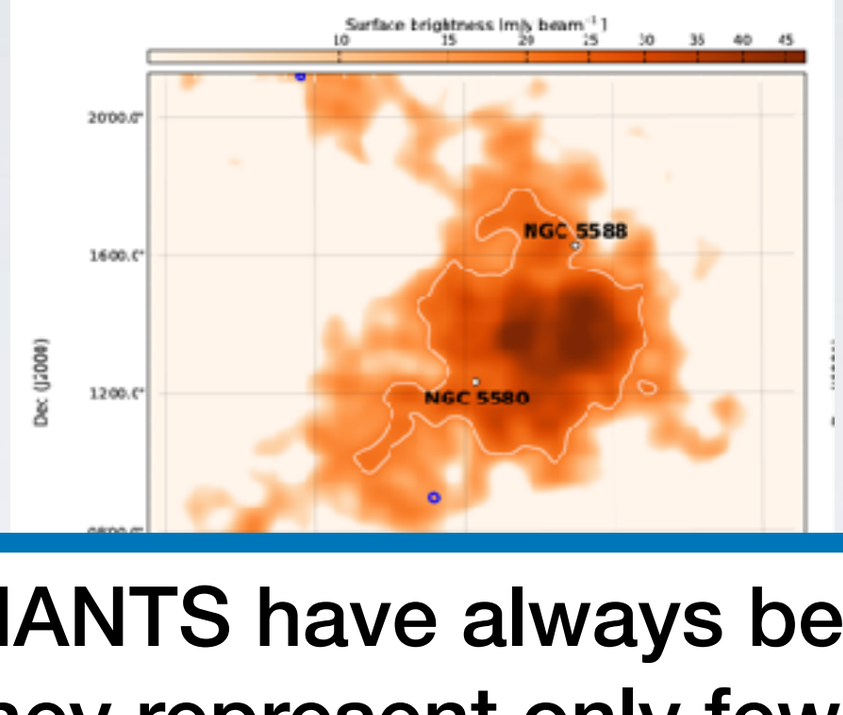


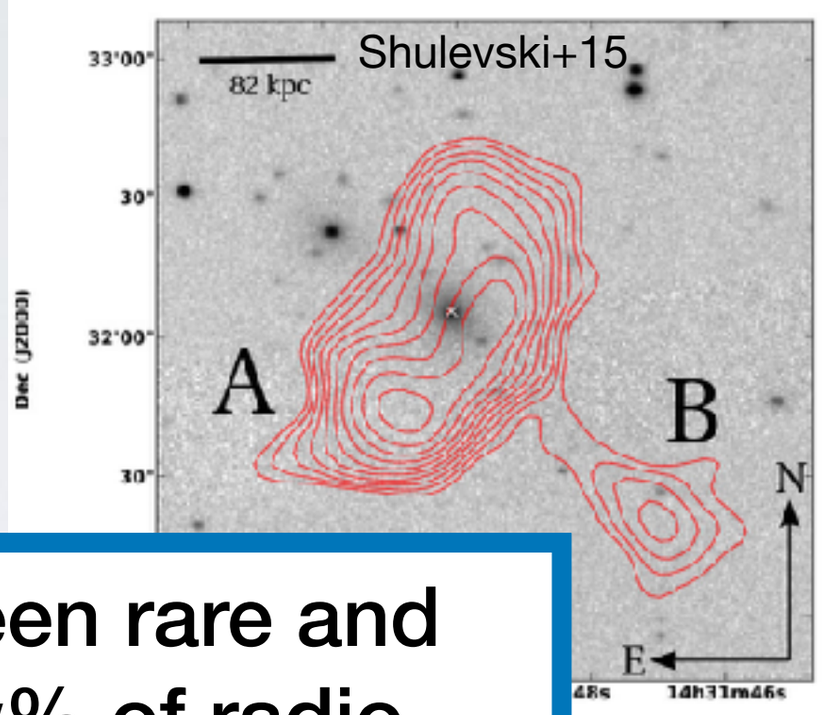




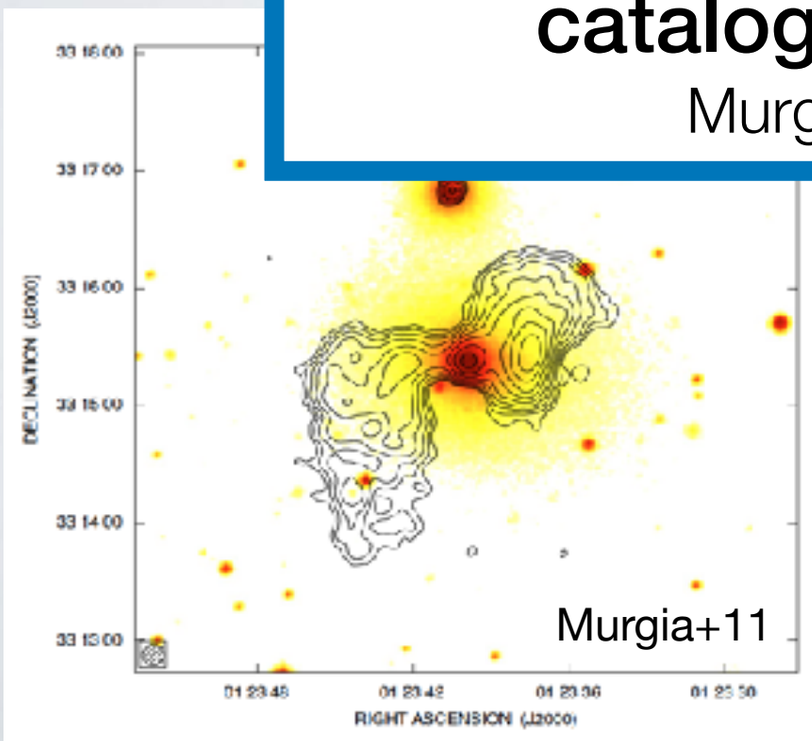
Remnant radio galaxies in the literature

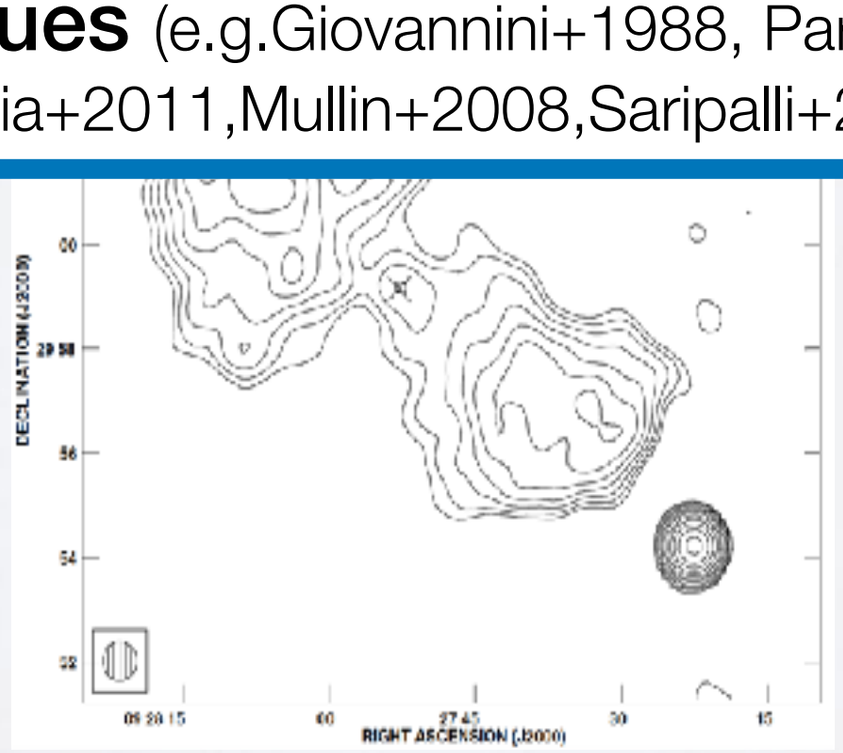


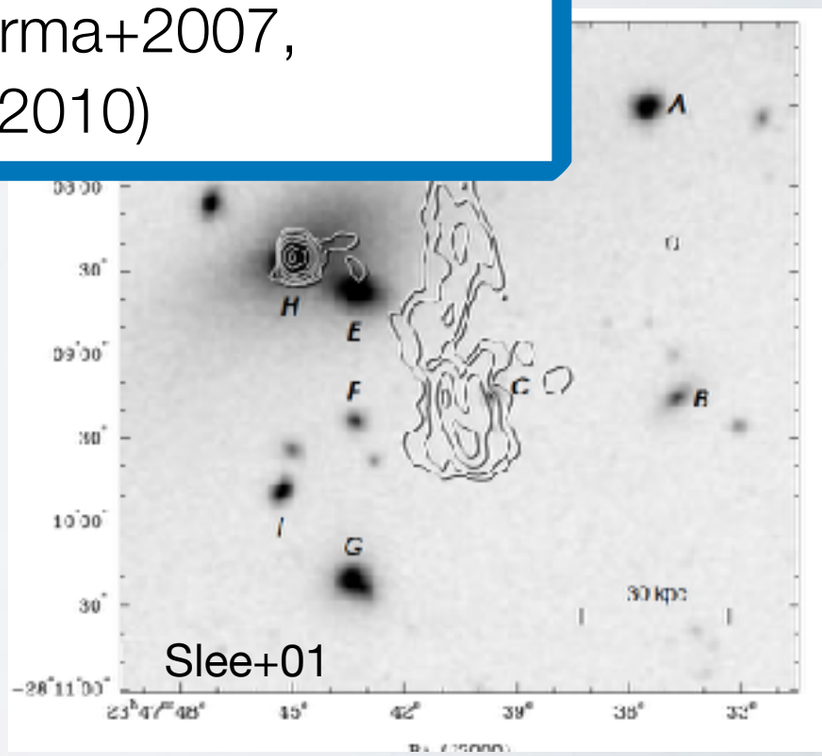


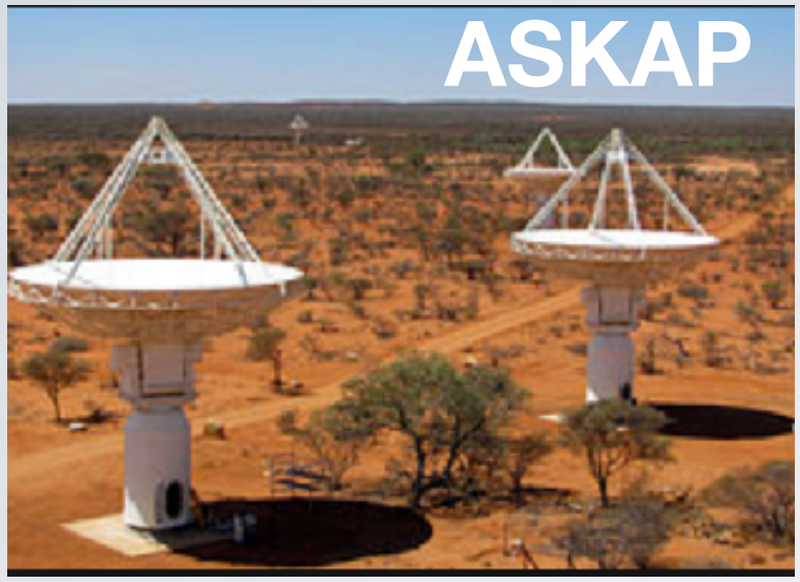


AGN REMNANTS have always been rare and elusive - they represent only few% of radio catalogues (e.g.Giovannini+1988, Parma+2007, Murgia+2011,Mullin+2008,Saripalli+2010)

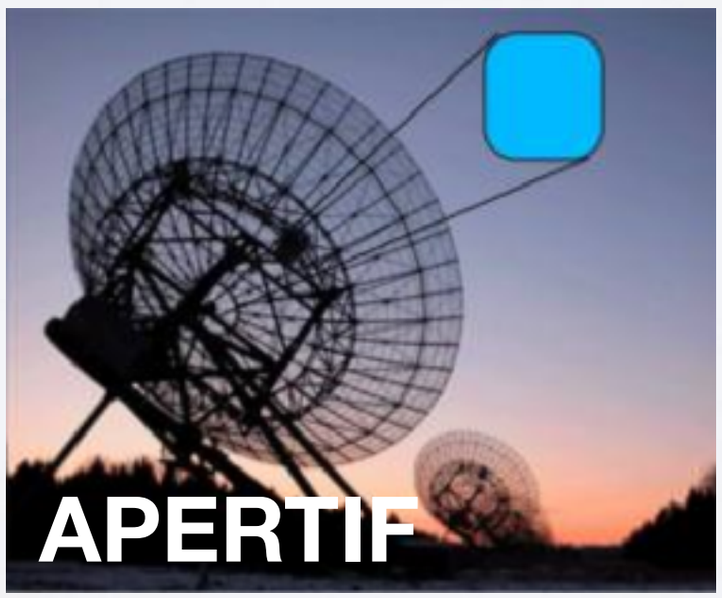




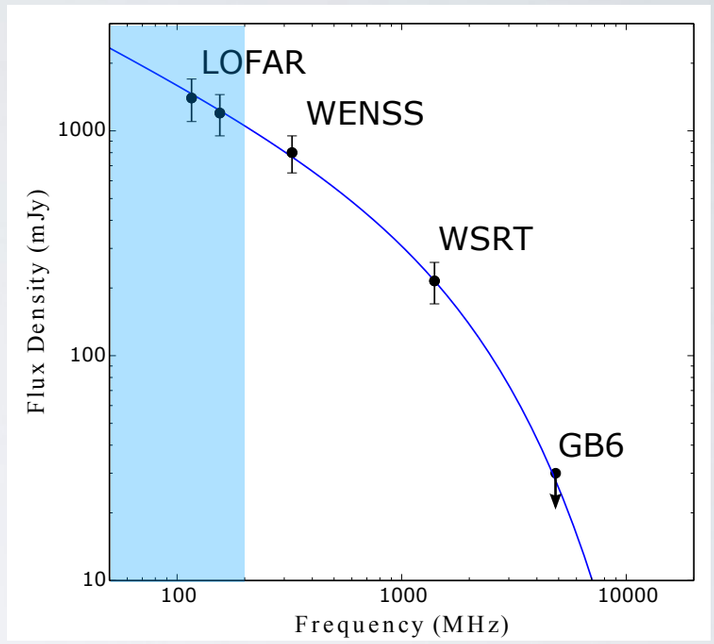


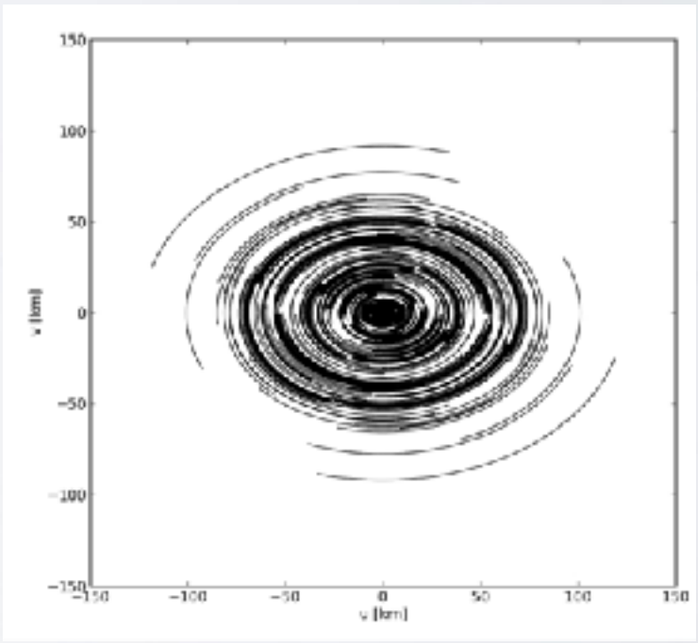


Observations with
NEW GENERATION
INSTRUMENTS



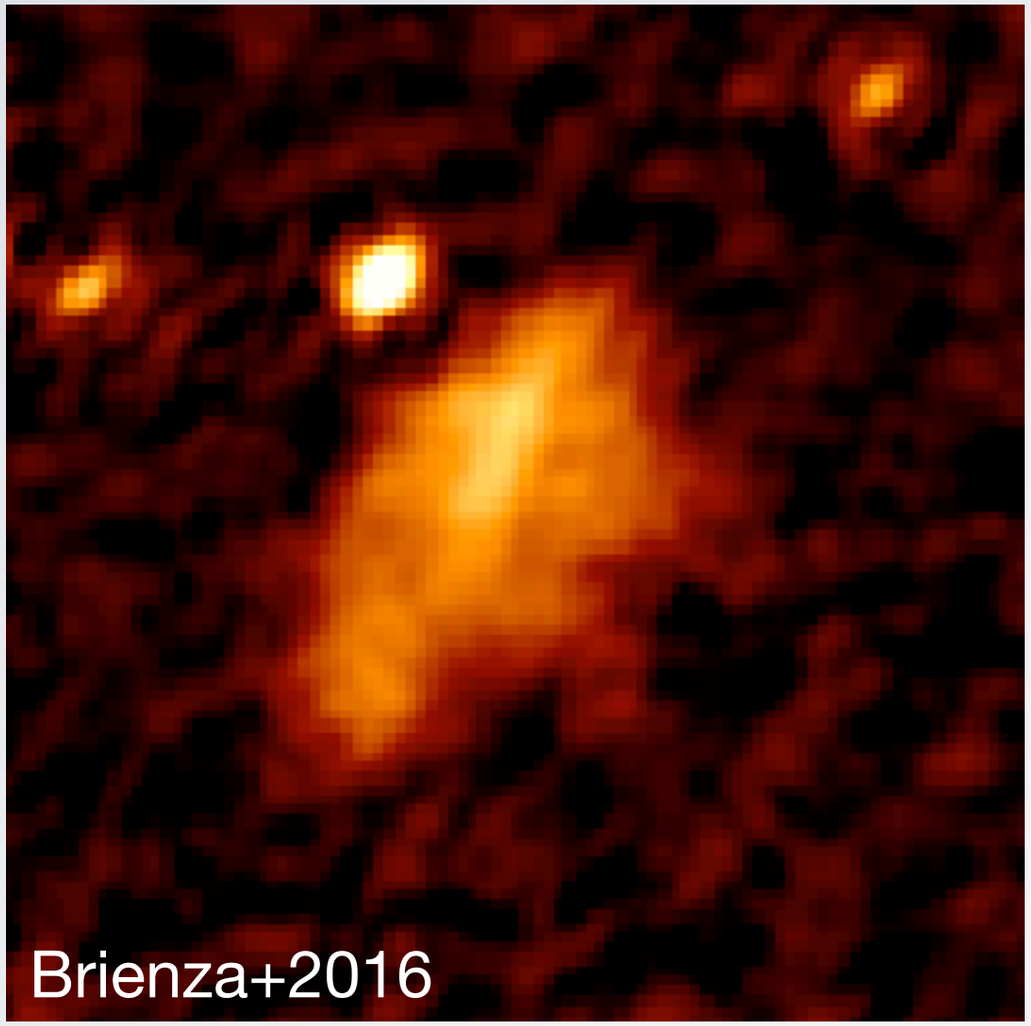
LOFAR

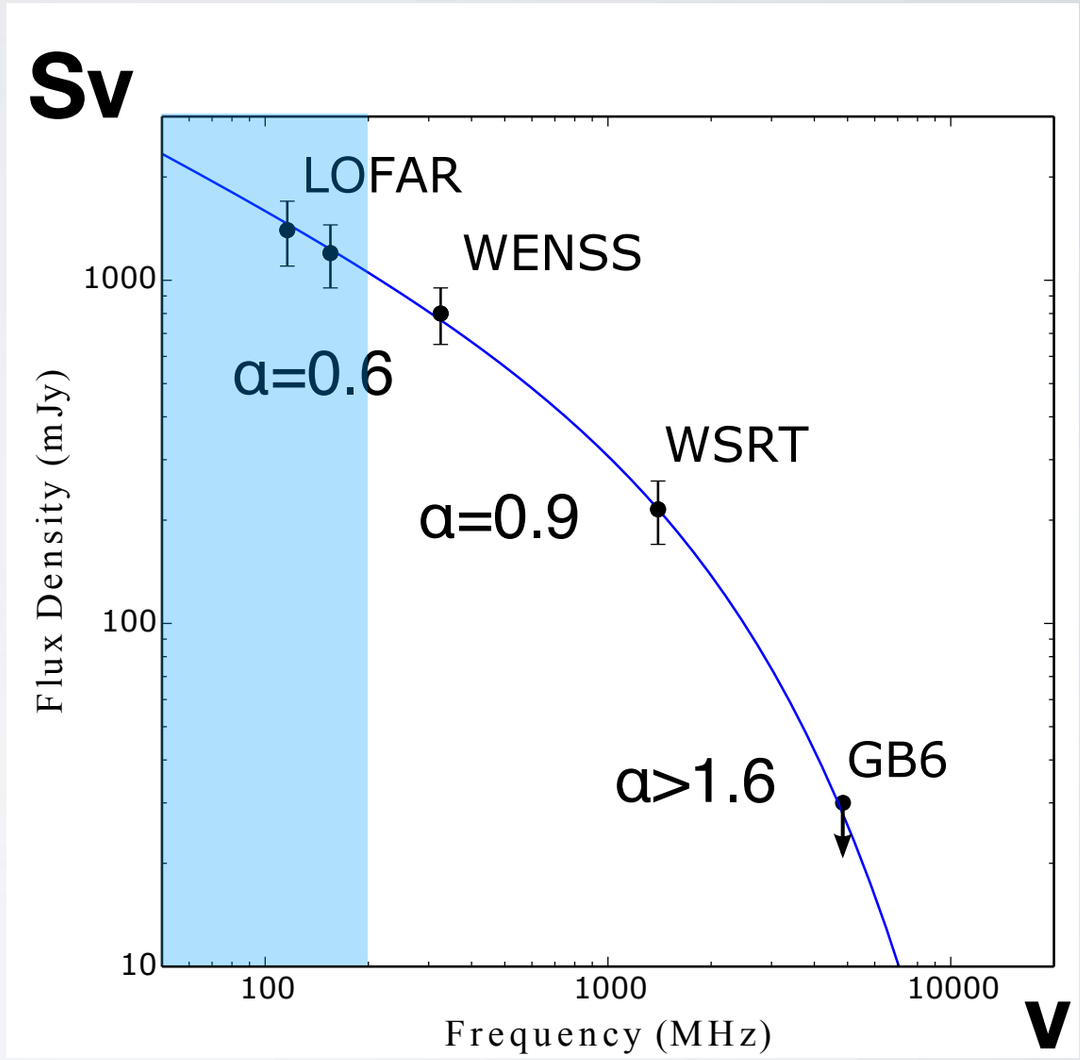




High Band Antennas
110-250 MHz
6” with Dutch array
~0.1 mJy/beam in 8h

Remnant radio galaxies : characteristics



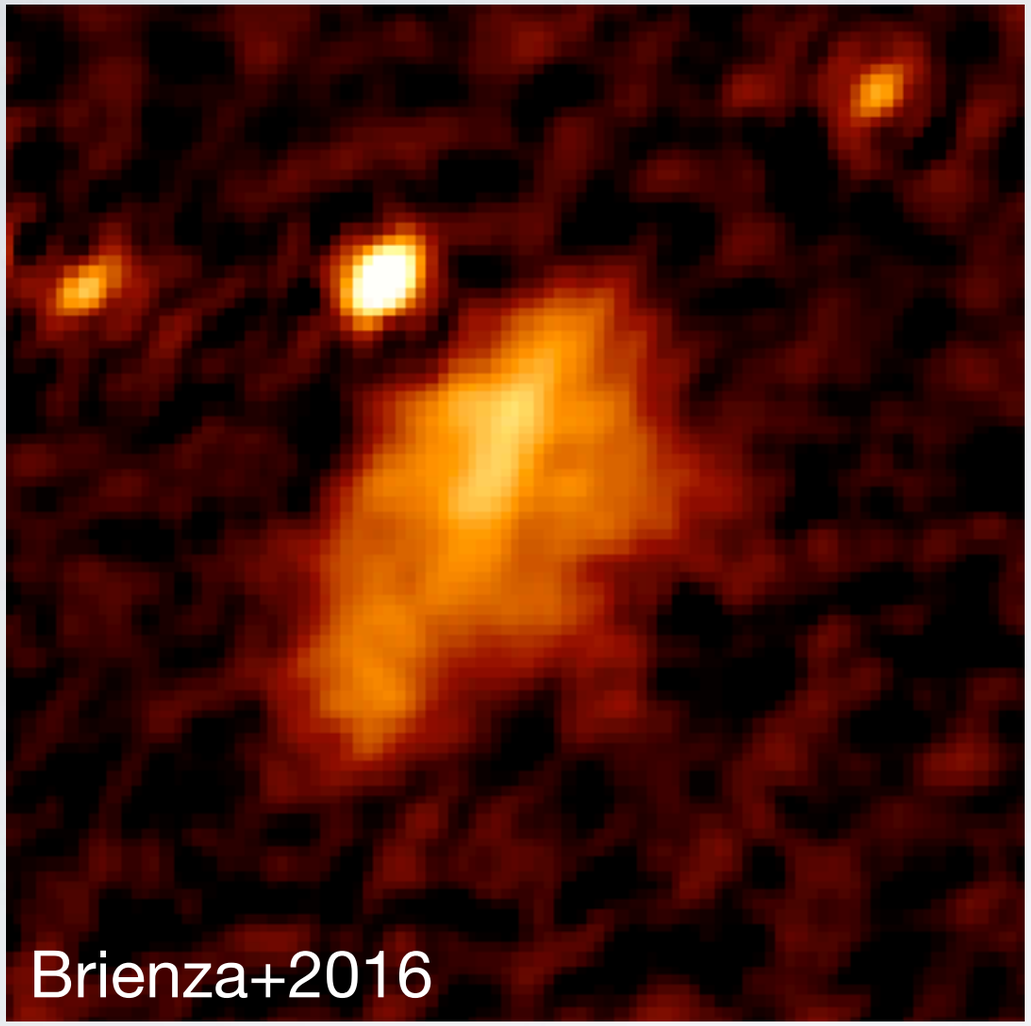


Very low surface brightness on large scales

(few mJy/arcmin^2 @ 1400 MHz
few tens of mJy/arcmin^2 @ 150 MHz)

absent or very weak compact components

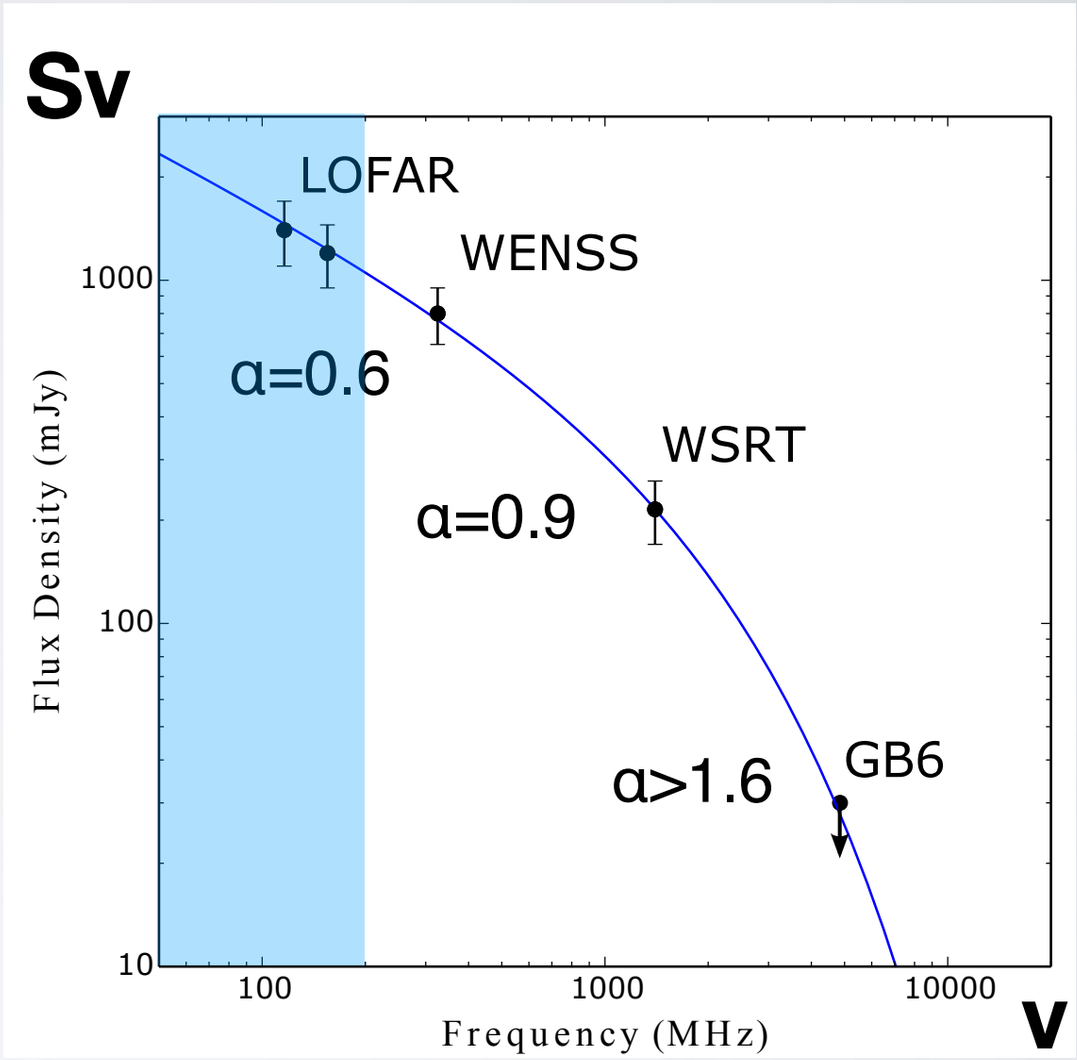
Remnant radio galaxies : characteristics



Very low surface brightness on large scales

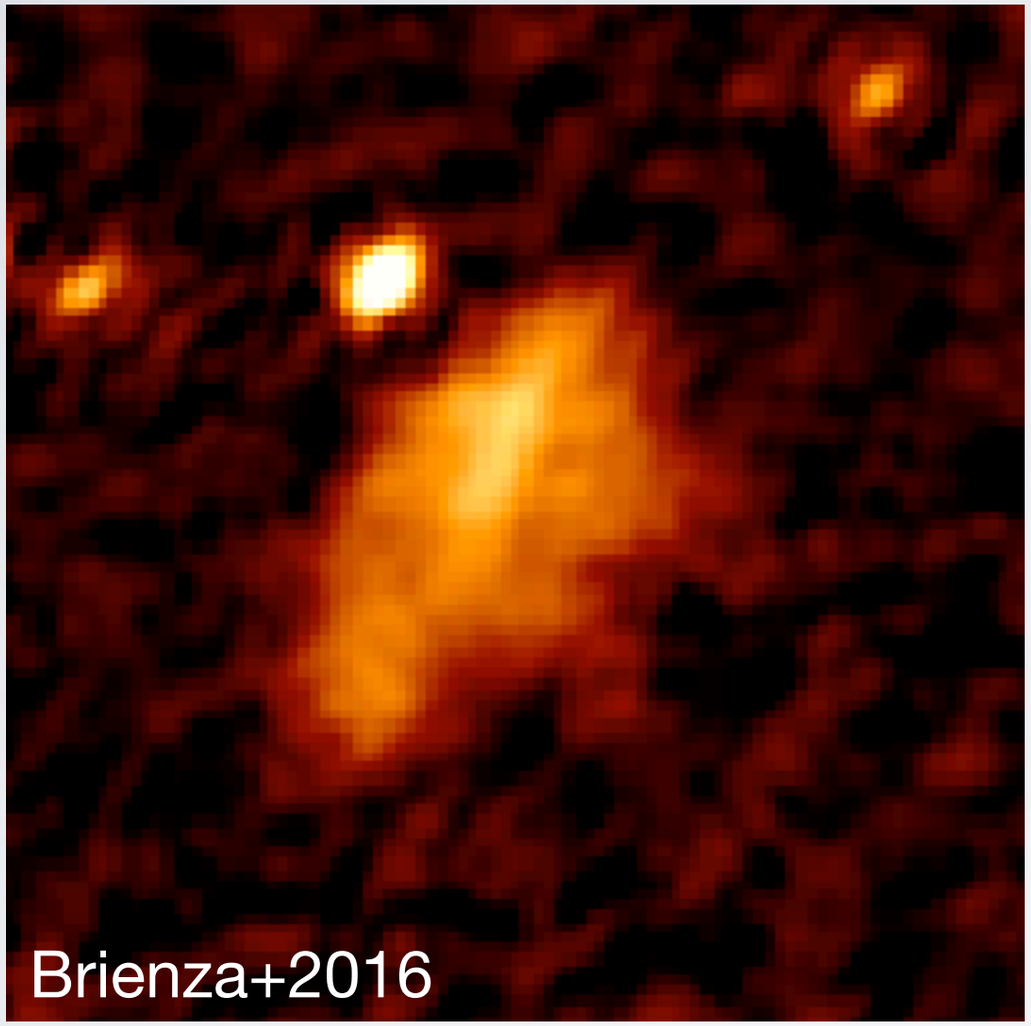
(few mJy/arcmin^2 @ 1400 MHz
few tens of mJy/arcmin^2 @ 150 MHz)

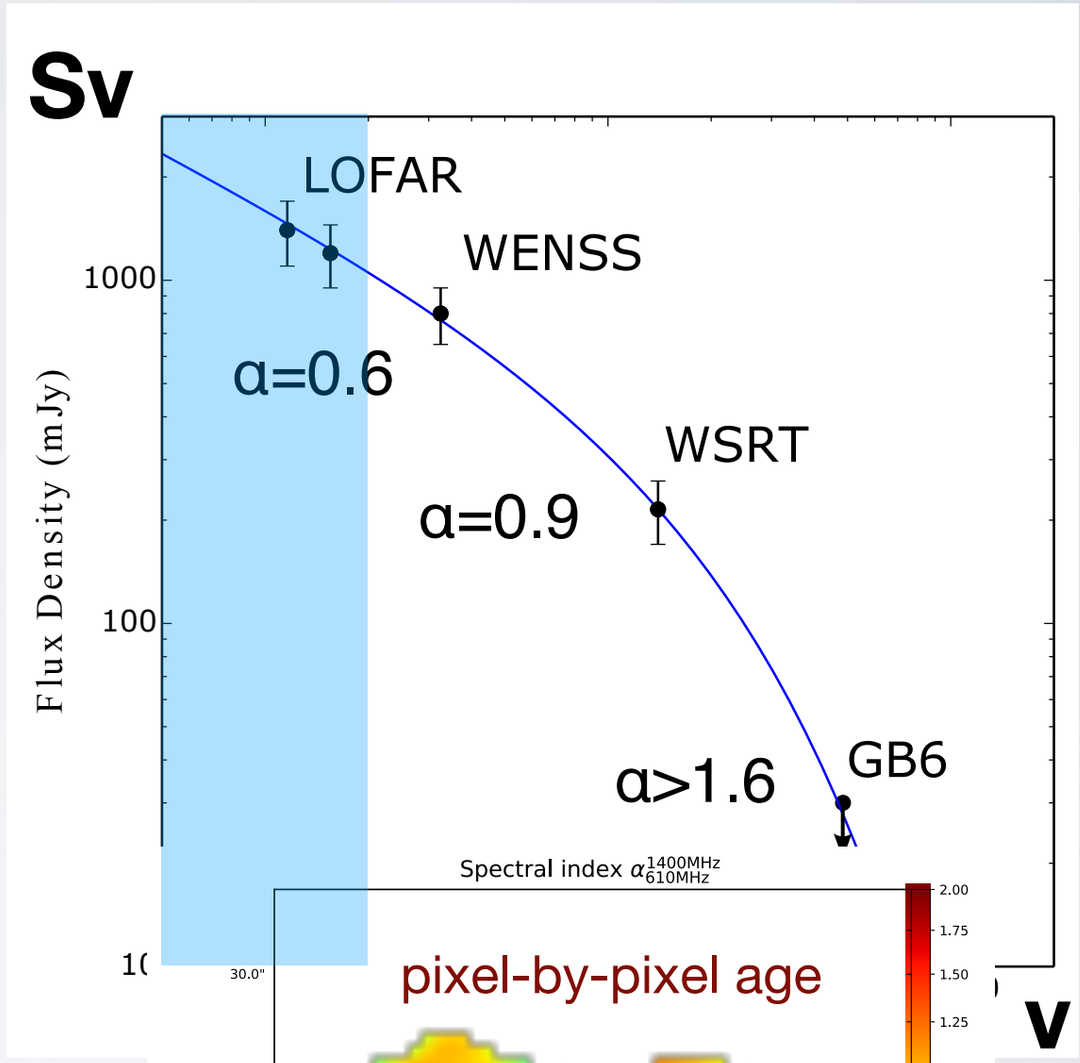
absent or very weak compact components



Radiative evolution models
(Komissarov&Gubanov1994)
CIOFF
ACTIVE TIME = 15 Myr
INACTIVE TIME = 60 Myr

Remnant radio galaxies : characteristics





Very low surface brightness on large scales

(few mJy/arcmin^2 @ 1400 MHz
few tens of mJy/arcmin^2 @ 150 MHz)

absent or very weak compact components

Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98 and Jurlin et al. in prep

Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98 and Jurlin et al. in prep

110-180 MHz
~35 deg^2

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

LoTSS DEEP
40 hrs int. time
6”x6” resolution
rms~0.045 mJy/b
sources ~24000
Mandal+2019

Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98 and Jurlin et al. in prep

110-180 MHz
~35 deg^2

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

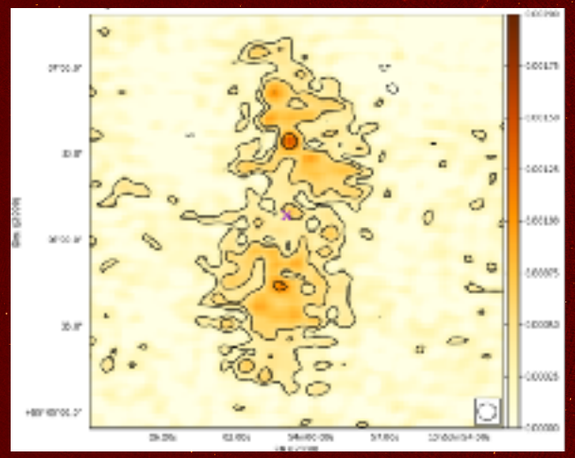
LoTSS DEEP
40 hrs int. time
6”x6” resolution
rms~0.045 mJy/b
sources ~24000
Mandal+2019

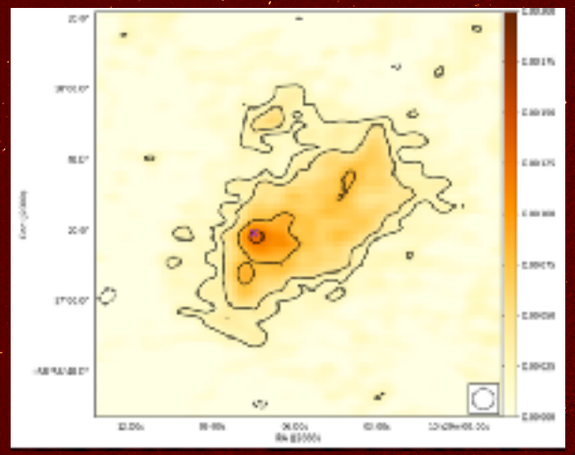
COMPLEMETARY SELECTION CRITERIA

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

↓

23 candidates





Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98 and Jurlin et al. in prep

110-180 MHz
~35 deg^2

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

LoTSS DEEP
40 hrs int. time
6”x6” resolution
rms~0.035 mJy/b
sources ~24000
Mandal+2019

COMPLEMETARY SELECTION CRITERIA

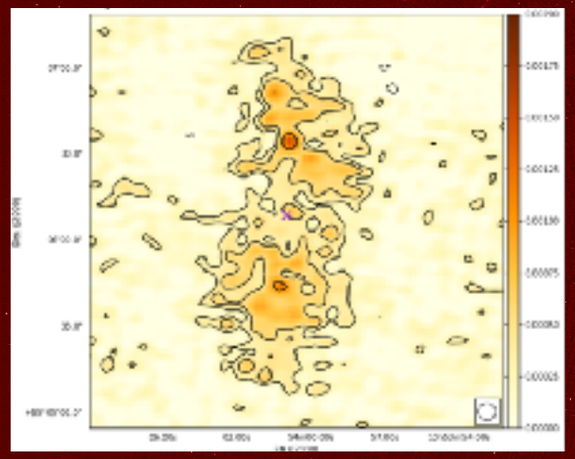
- ULTRA-STEEP SPECTRAL INDEX
- SPECTRAL CURVATURE
- LOW CORE PROMINENCE
- MORPHOLOGY

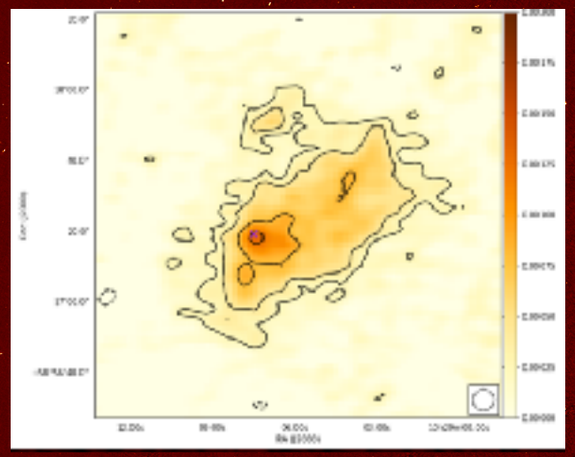
↓

23 candidates

↓

Follow-up:
*- **JVLA** 5 GHz Aarray **CORES***
*- **JVLA** 5 GHz Darray **SPC***
*- **WHT** SPECTROSCOPY **ID***





Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98 and Jurlin et al. in prep

FIRST RESULTS

1) Remnant plasma fades away quickly even at low freq <12% of sources with size>60”

2) As suggested by the study of blob1 not all remnant AGN have ultra-steep spectral index at low freq but they may become **ultra-steep above 1.4 GHz**

3) When observed with high resolution & sensitivity most of these sources show **weak radio cores** -> change in the accretion regime?

4) Not all remnants seem to live in cluster environment

Search for remnants in the Lockman Hole at 150 MHz

Brienza+2017,A&A,606, A98 and Jurlin et al. in prep

FIRST RESULTS

1) Remnant plasma fades away quickly even at low freq <12% of sources with size>60”

2) As suggested by the study of blob1 not all remnant AGN have ultra-steep spectral index at low freq but they may become **ultra-steep above 1.4 GHz**

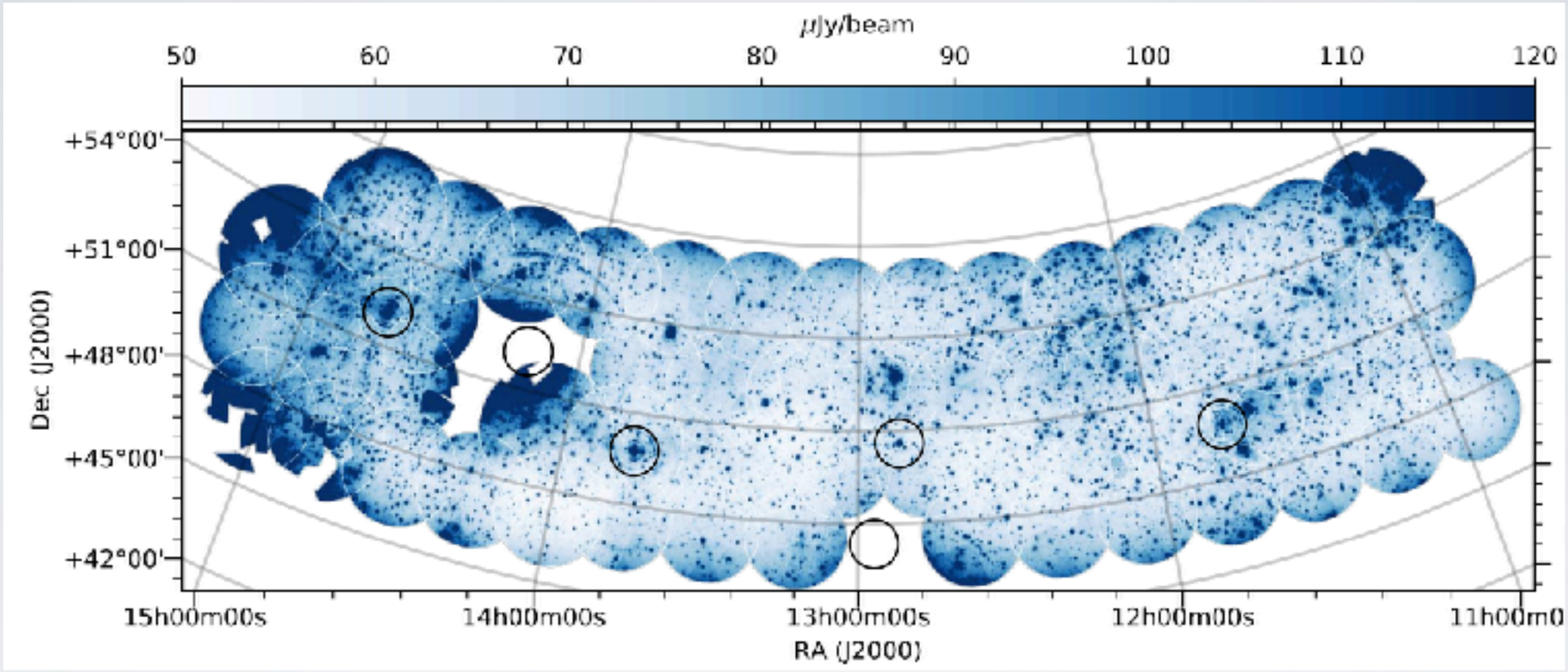
3) When observed with high resolution & sensitivity most of these sources show **weak radio cores** -> change in the accretion regime?

4) Not all remnants seem to live in cluster environment

(consistent also with Mahatma+18 in H-ATLAS)

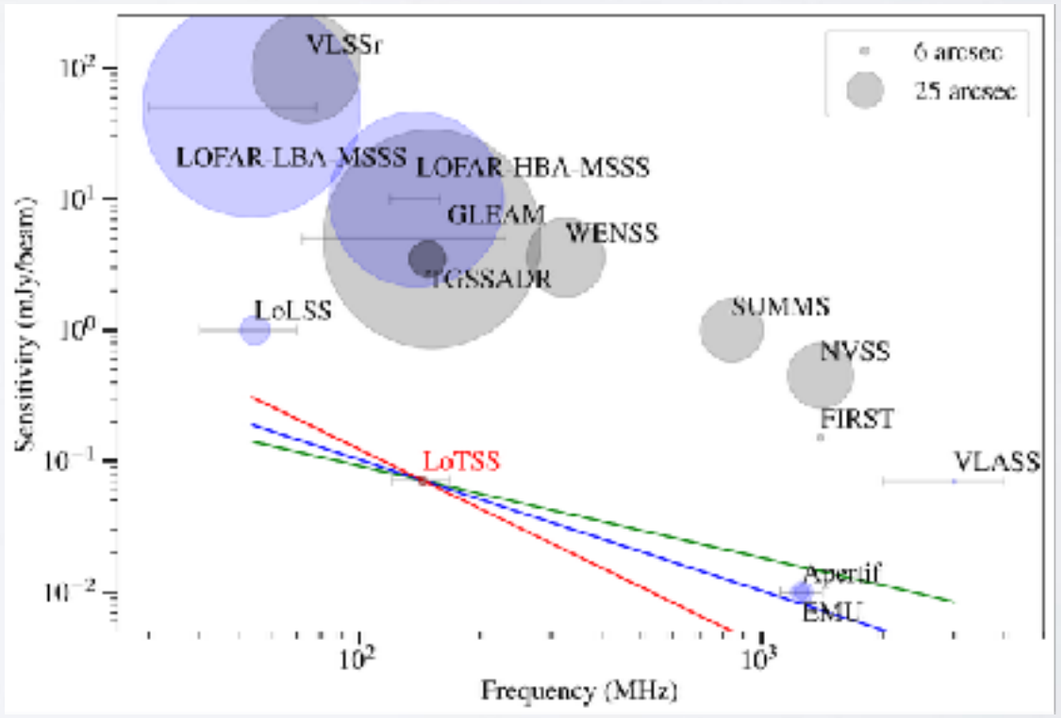
Remnants in the LOFAR Two-metre Sky Survey DR1

THE ABSENCE OF AN
WHICH CONSTRAINS
SEARCH TO ONLY MO



Shimwell+2019

400 squared degrees
6” , noise 0.1mJy/beam
~320,000 sources



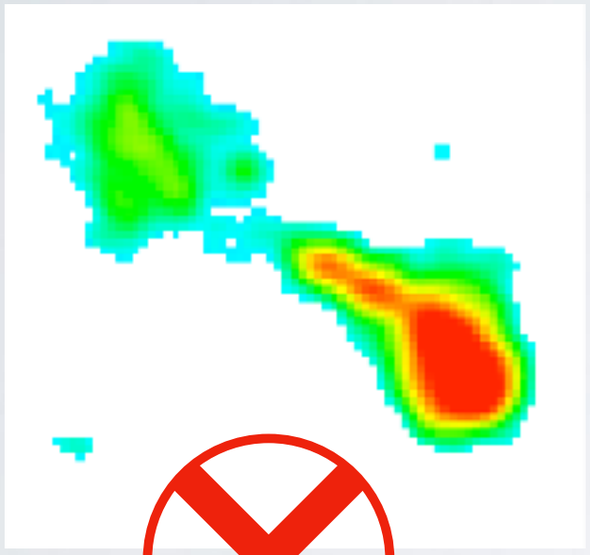
320,000 sources -> 10,129 sources size>30”

AUTOMATIC SELECTION OF LOW SURFACE BRIGHTNESS AGN

Remnants in LoTSS : first results

sources with size>30”

selection based on source pixel statistics (mean, max, surface brightness)



exploring the parameters space

~20% selected
57% with candidate ID from catalogue
0% with FIRST counterpart
!contamination by other classes of sources eg spirals

Monte Carlo simulations of radio galaxies

Brienza+2017,A&A,606, A98
Godfrey+2017, MNRAS 471, 891
Hardcastle+2018, MNRAS 475 2768
Shabala+2019, in prep

→ Simulations based on empirical radio galaxy parameters (z, Qjet, alpha, t_{on}, age, density profile of external gas, geometry, minimum and maximum energy)

→ **RADIATIVE EVOLUTION** Synchrotron + Inverse compton

→ **DYNAMICAL EVOLUTION**

= **MOCK CATALOGUES** of radio galaxies to compare with observed radio catalogues in the Lockman Hole

<1-15% in mock radio catalogues are expected to be remnants

CONCLUSIONS

New generation radio instruments have opened a new era in the search and study of remnant radio galaxies

- They represent a small fraction of the radio-loud population even at low frequency or/and high sensitivity
  - This implies a rapid luminosity evolution of the plasma
- First studies with LOFAR suggest that they may have a variety of characteristics, which we will confirm using **a larger sample selected in LoTSS** and complementary data at higher frequencies