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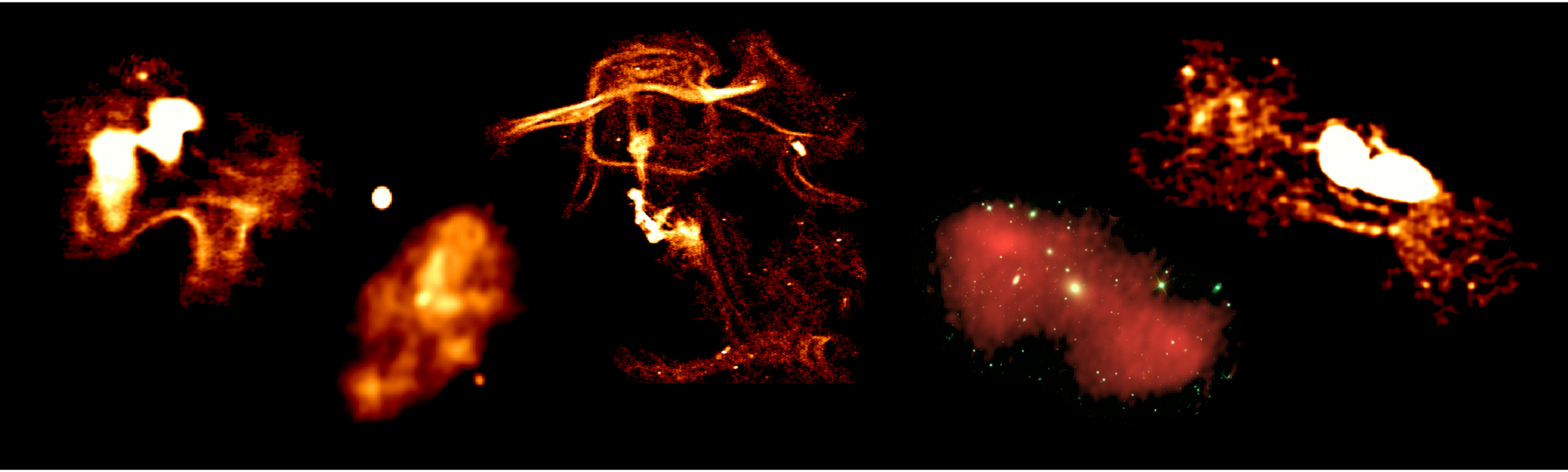
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

STILES – IR0000034 -
CUP C33C22000640006

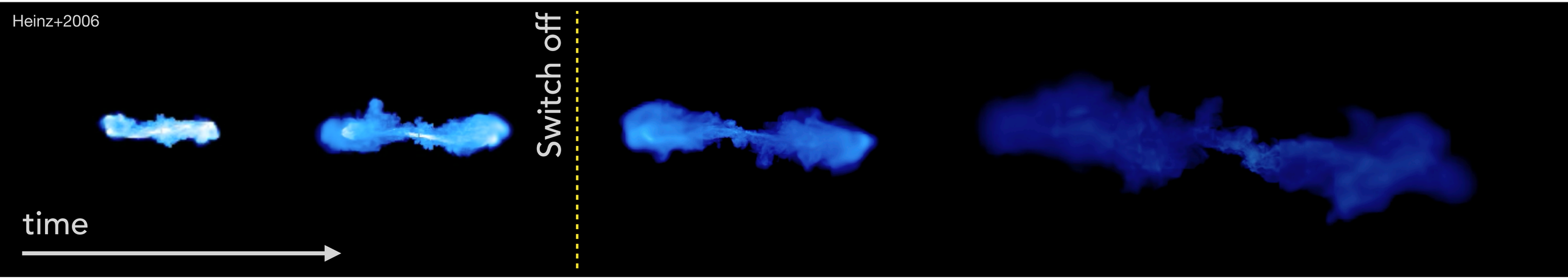
Tracing AGN remnant plasma in the SKA era



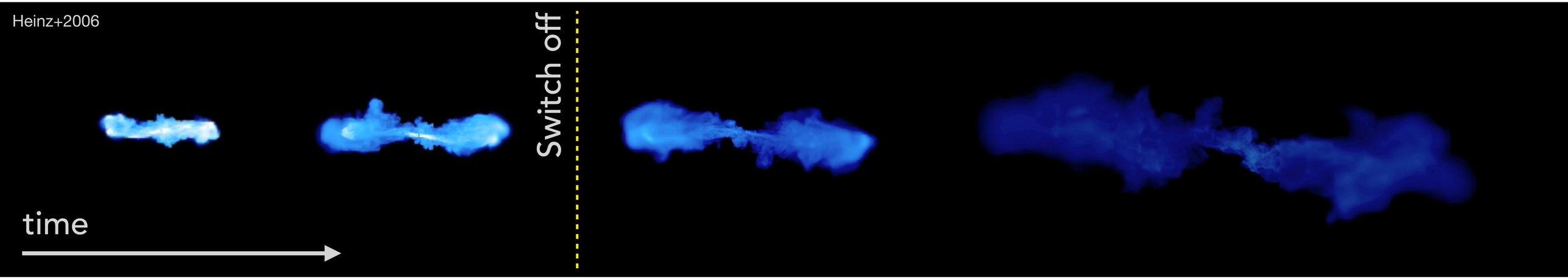
Marisa Brienza

IRA-INAF, Bologna, Italy

At the end of AGN jets..

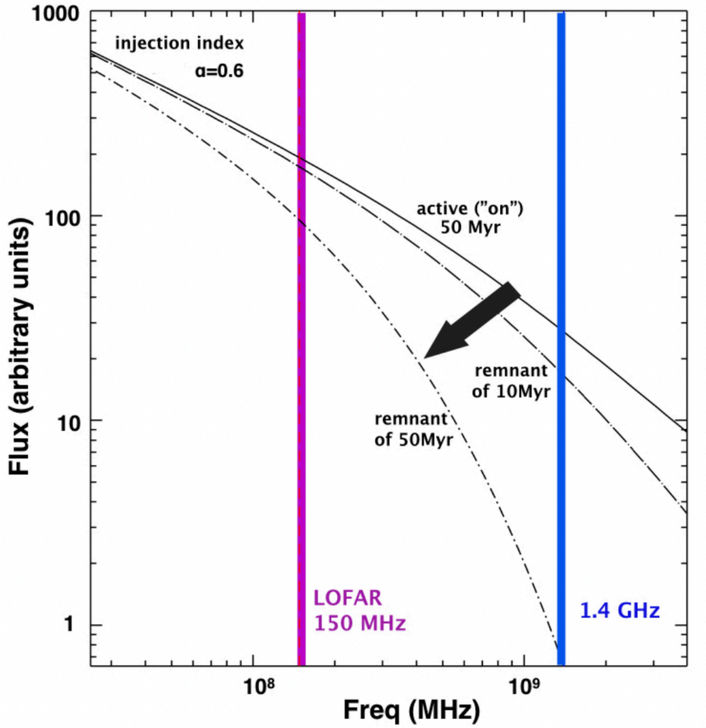


At the end of AGN jets..



Quick luminosity decrease

Frequencies below ~1 GHz are key

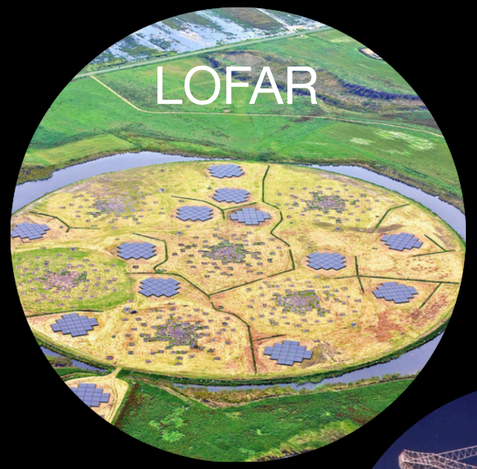


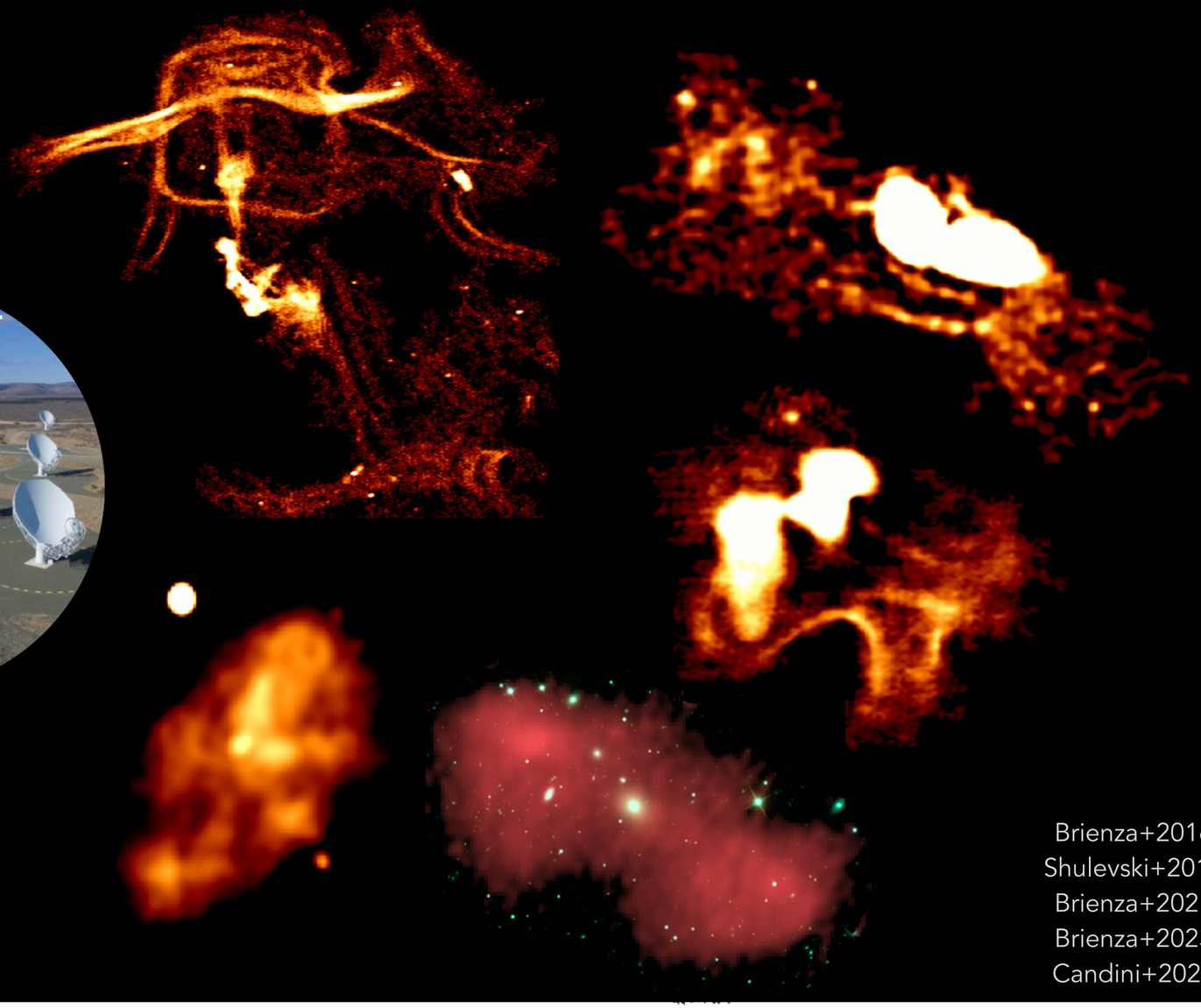
➡ Expansion losses (depends on jet power, external gas)

➡ Radiative losses (depends on magnetic field, redshift)

SKA precursors and pathfinders

Frequencies below ~1 GHz are key

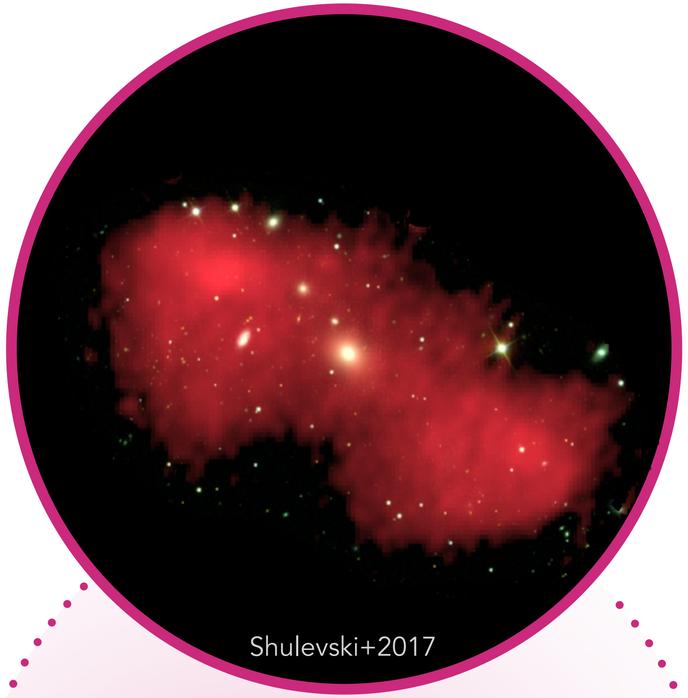




Brienza+2016
Shulevski+2017
Brienza+2021
Brienza+2023
Candini+2024

● Sensitivity ● Angular resolution ● LAS

Why tracking AGN remnant plasma?



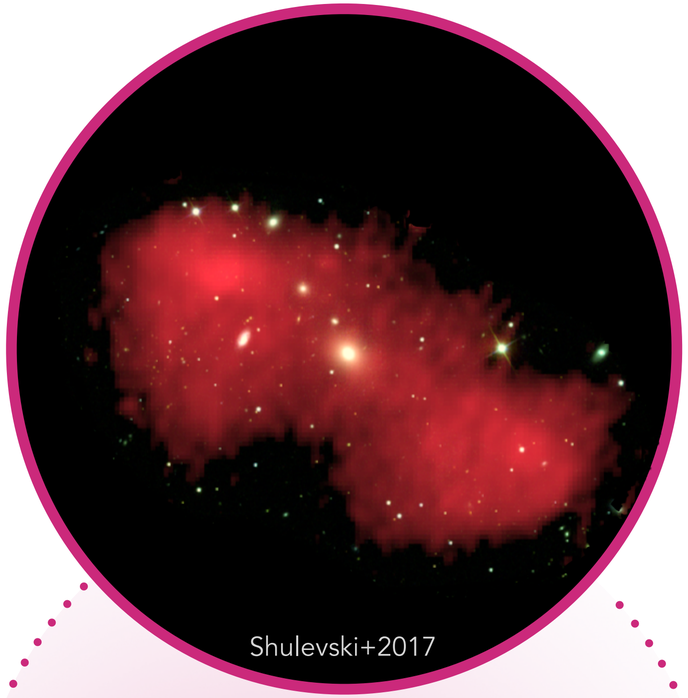
Shulevski+2017

Jet evolution & feedback

- Timescales of jet activity
- Long-term thermalisation of energy

Why tracking AGN remnant plasma?

Formation of
diffuse radio sources
in merging
galaxy clusters



Jet evolution & feedback

- Timescales of jet activity
- Long-term
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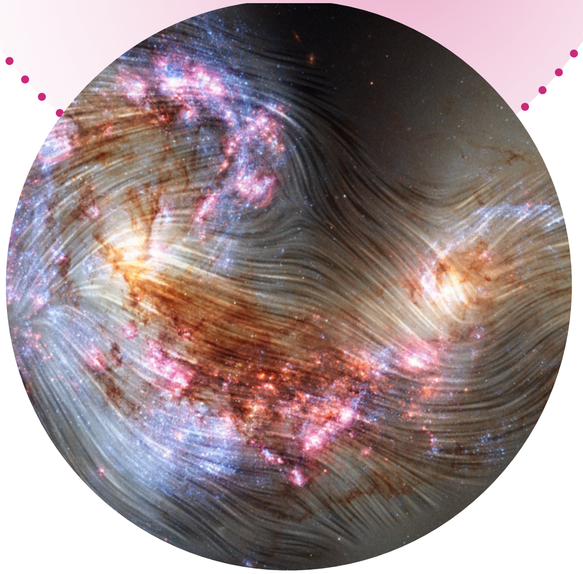
Magnetization
of
intergalactic medium



The challenge of selecting AGN remnants

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Selection criteria:

- **Ultra steep spectrum (alpha>1.2)**
- Spectral curvature > 0.5
- Morphology
- Core prominence

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1

Complementary wide-area survey
at low and high frequency
with consistent uv-coverage

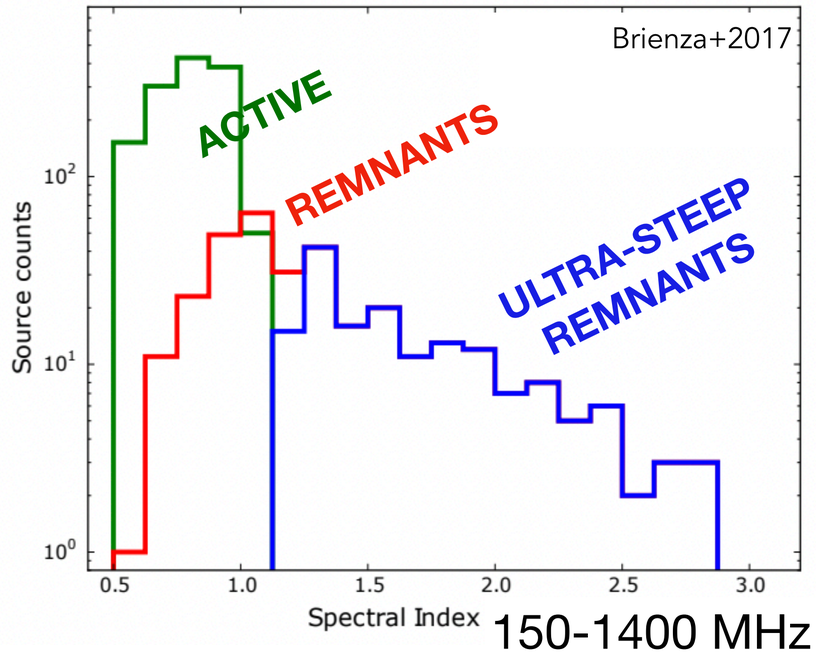
LOFAR LoTSS 150 MHz noise ~100 μJy/b @ 6″

↓ alpha>1.2

1.4 GHz noise <20 μJy/b

2

SIMULATIONS (radiative+expansion losses)



150-1400 MHz

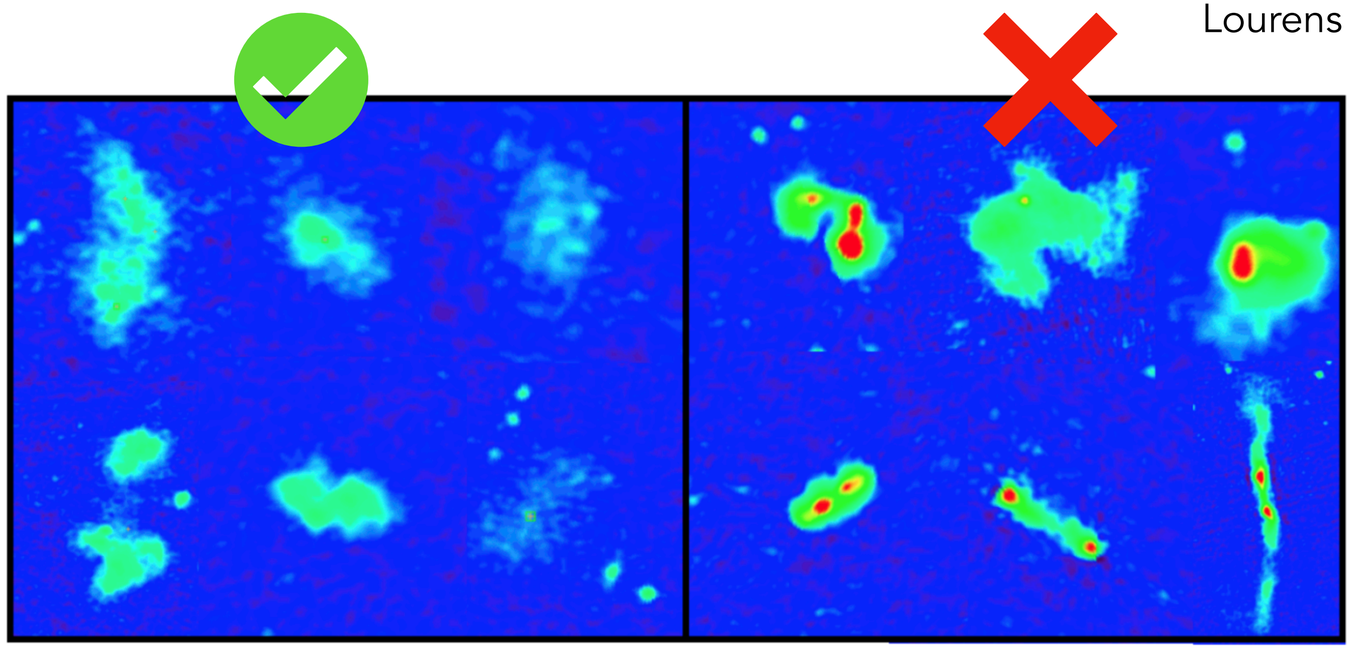
~50% recovered with USS between 150-1400 MHz
~98% recovered with USS between 150-5000 MHz

The challenge of selecting AGN remnants

Brienza, Morganti
Lourens in prep.

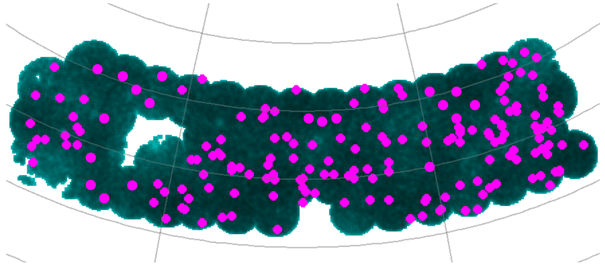
Selection criteria:

- Ultra steep spectrum (alpha>1.2).
- Spectral curvature > 0.5
- **Morphology**
- Core prominence



Automatic algorithm to identify sources with **uniform surface brightness distribution - size > 60”**

170 good candidates in HETDEX LoTSS 150 MHz (~400deg2) (noise ~100 μJy/b @ 6”)



~1 source / 2deg^2

(after removal of false positives)

The challenge of selecting AGN remnants

Brienza, Morganti
Lourens in prep.

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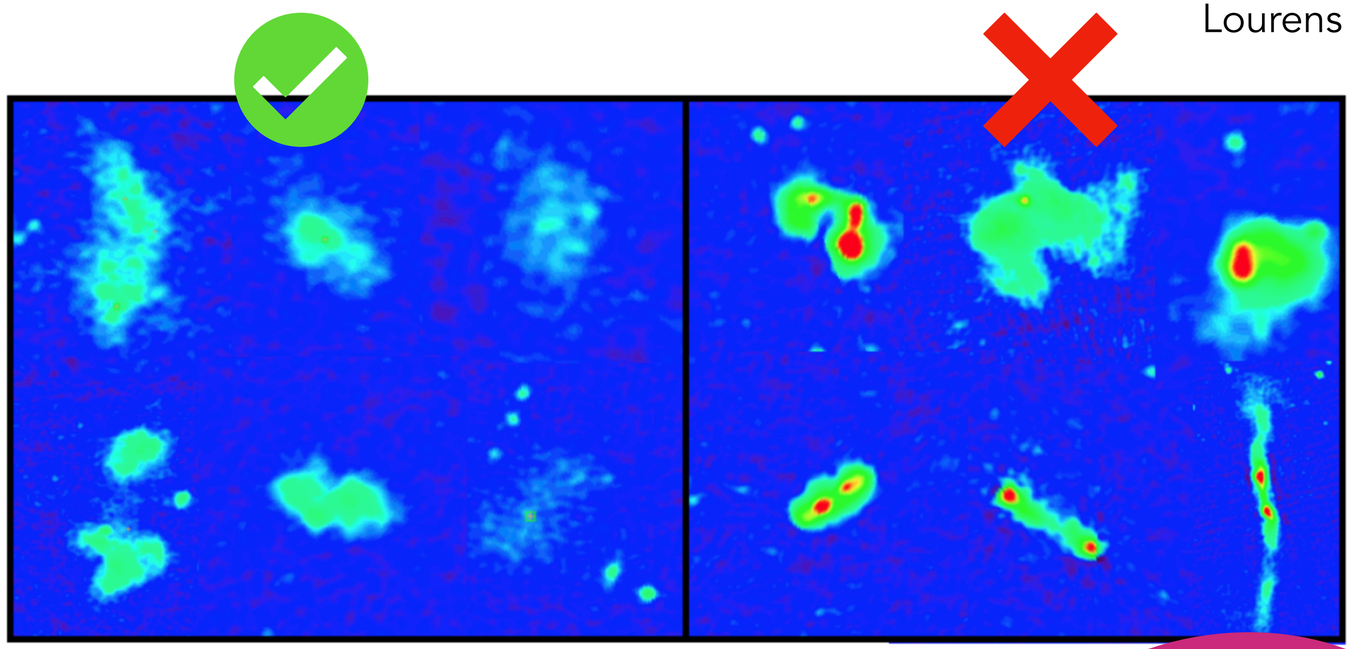

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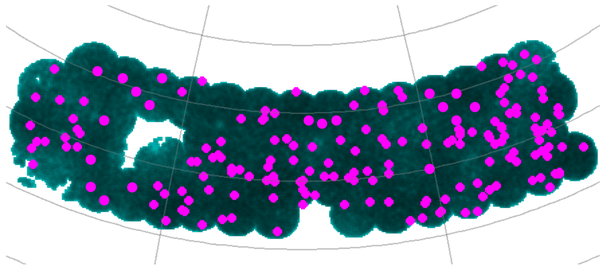


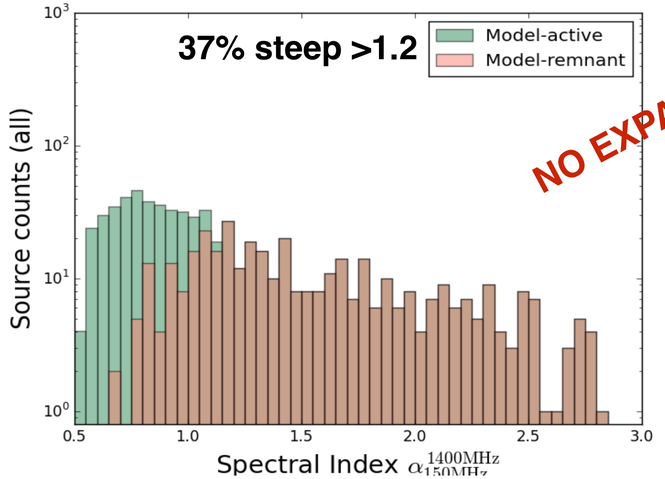
~1 source / 2deg²

(after removal of false positives)

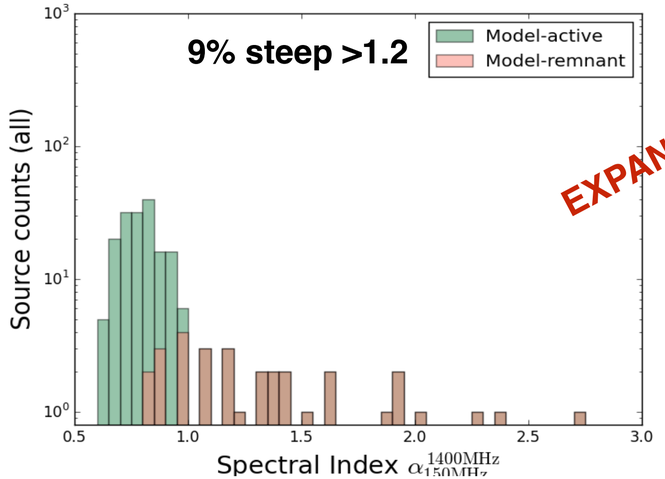
Properties as a function of environment/galaxy

Large samples to constrain radio galaxy evolution models

Expansion losses



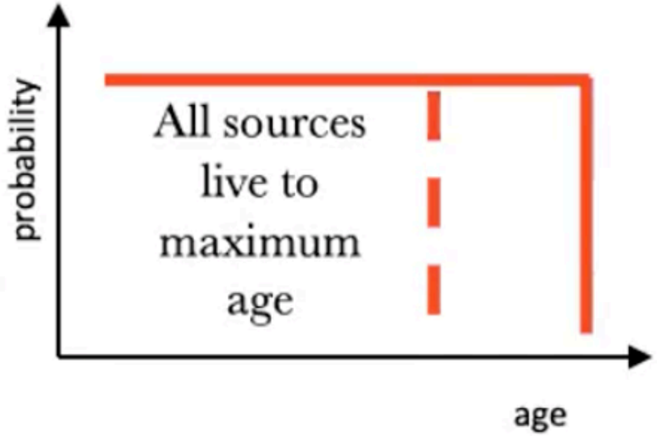
NO EXPANSION



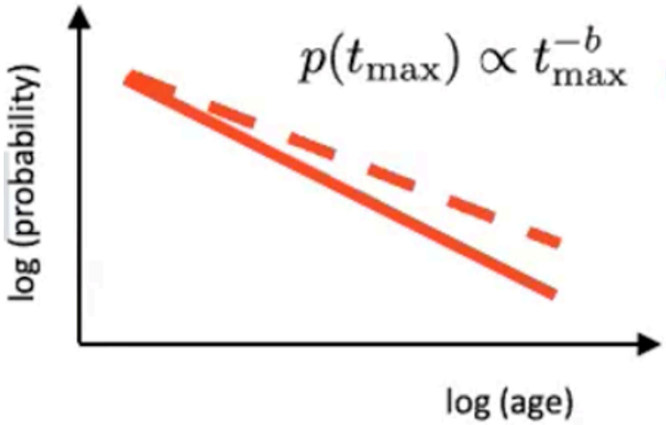
EXPANSION

Brienza+2017

Jet activity duration



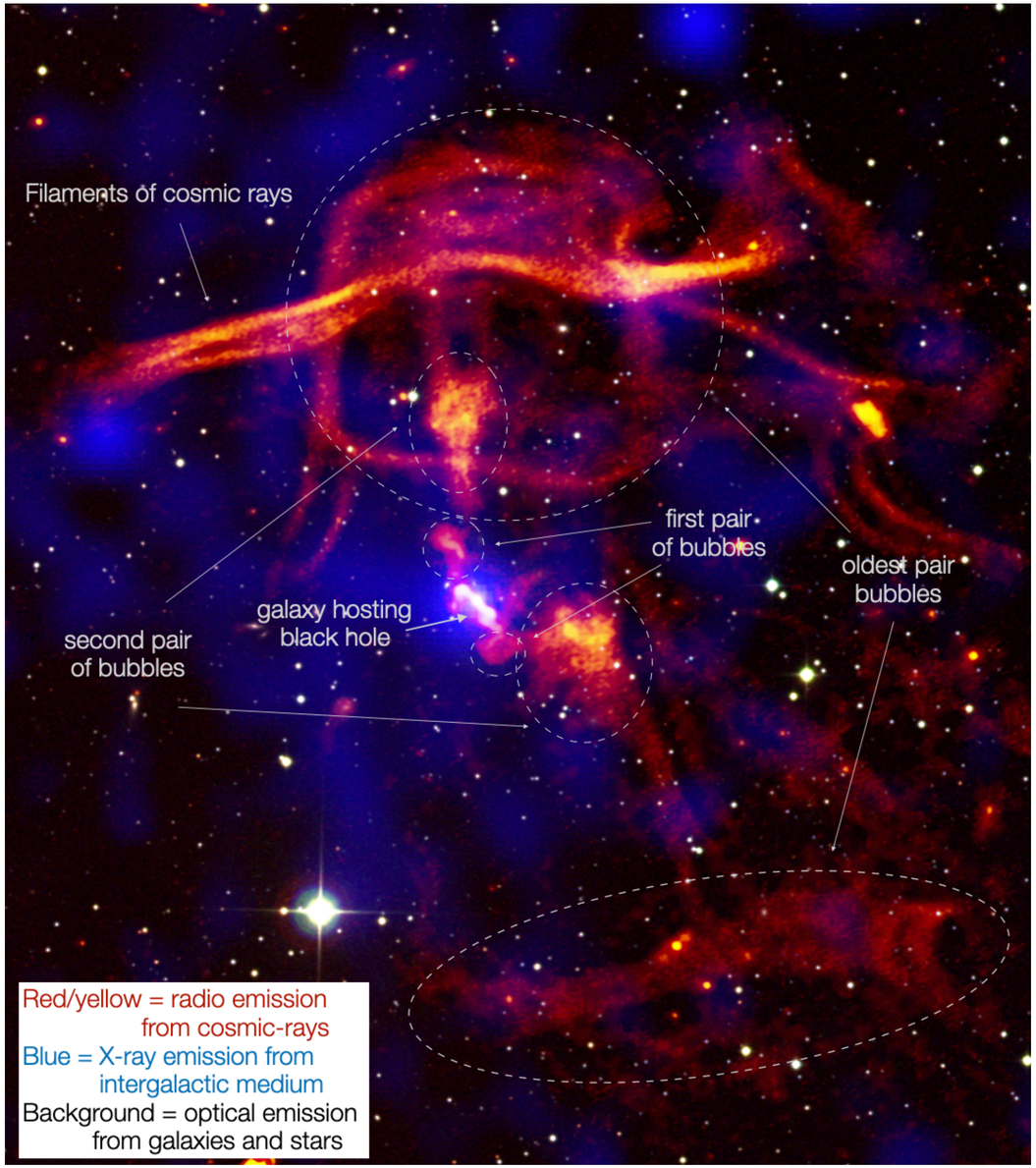
<5% remnants



>10% remnants

Shabala+2020

Physics & evolution of remnant plasma and duty cycle

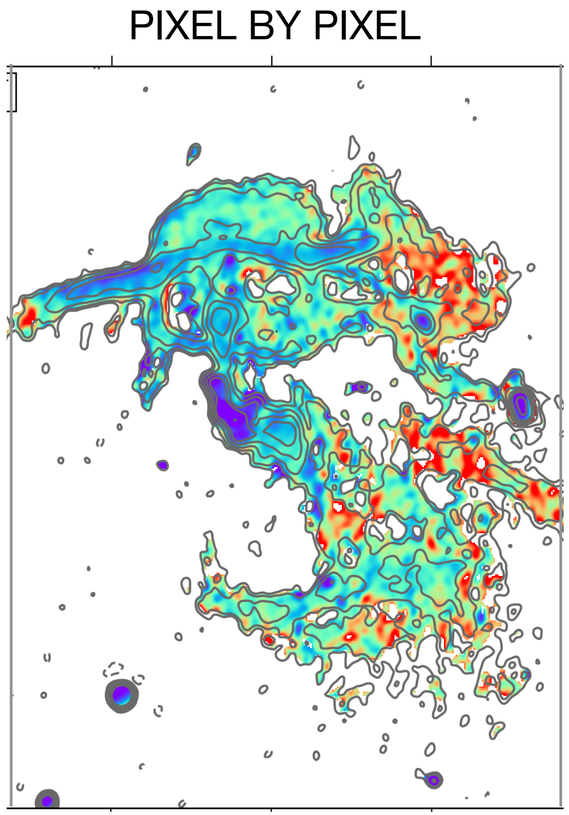


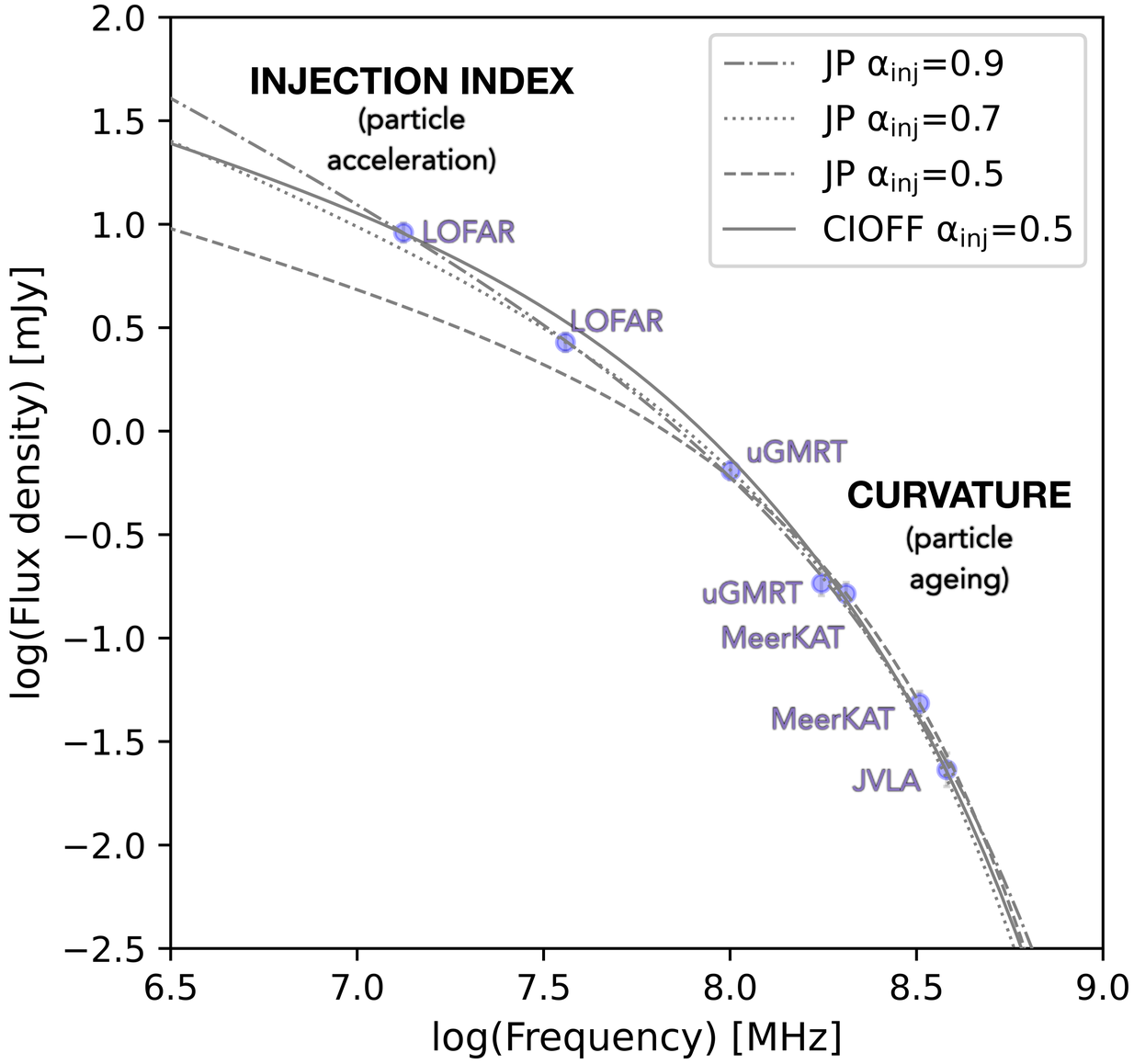
Nest200047

- Galaxy group ~6e13 Msun, z=0.018
- Multiple generations of AGN bubbles
- Old plasma clearly **spread** over large portion of the **group volume**
- Oldest bubbles ~400 Myr broken into **FILAMENTS** probably promoted by **turbulence** and **supported by magnetic fields** -> still not mixed with external gas

Brienza+, NatureAst, 2021
Brienza+, A&A, 20025

Multi-frequency spectro-polarimetric radio analysis 53-1500 MHz

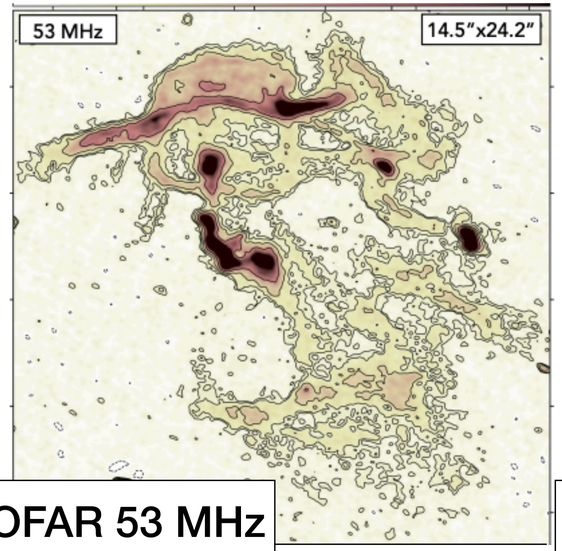




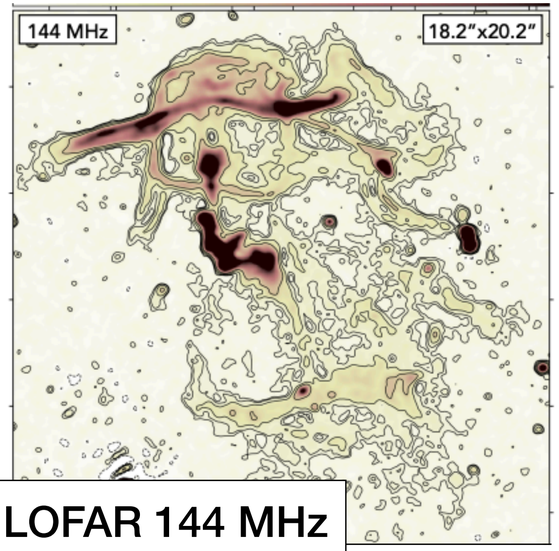
Ageing models
Injection index
Curvature

DUTY CYCLE
~90 Myr ON
~few Myr OFF
~70 Myr ON
~few Myr OFF
~50 Myr ON
~few Myr OFF
Restarted (compact jets)

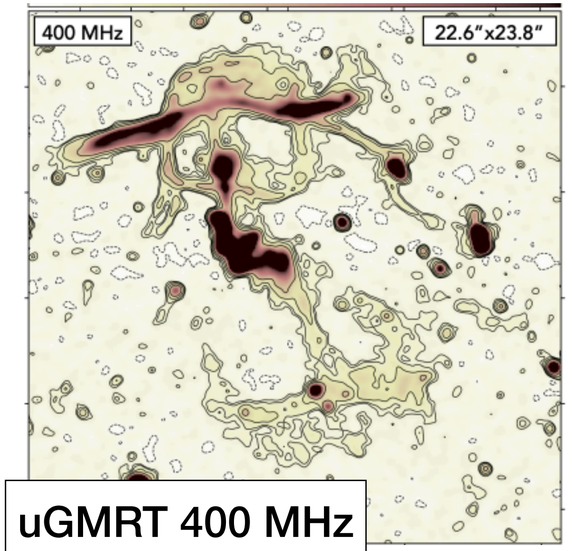
Multi-frequency spectro-polarimetric radio analysis 53-1500 MHz



LOFAR 53 MHz



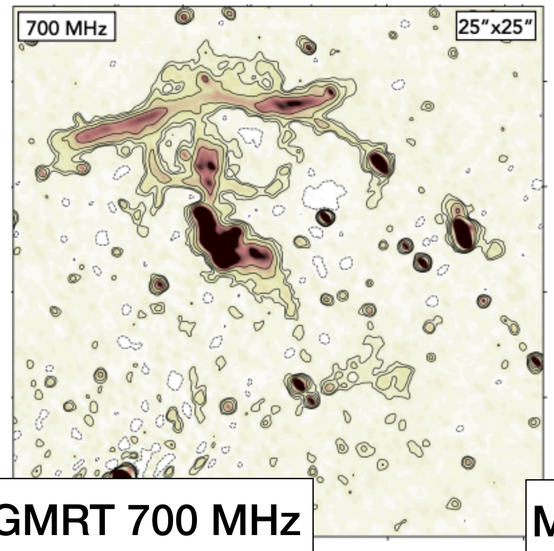
LOFAR 144 MHz



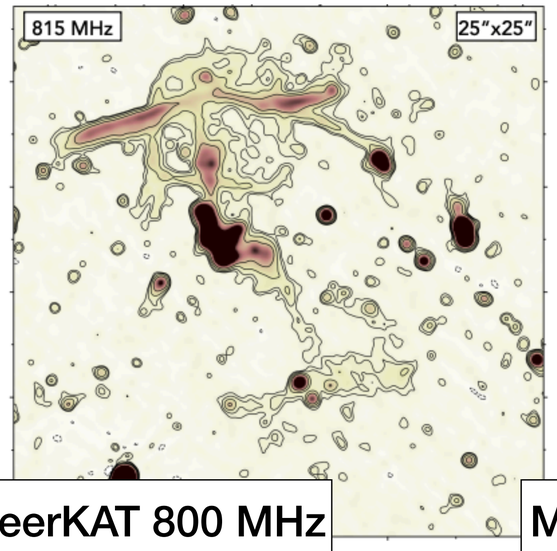
uGMRT 400 MHz

4 TELESCOPES
>50 h TIME

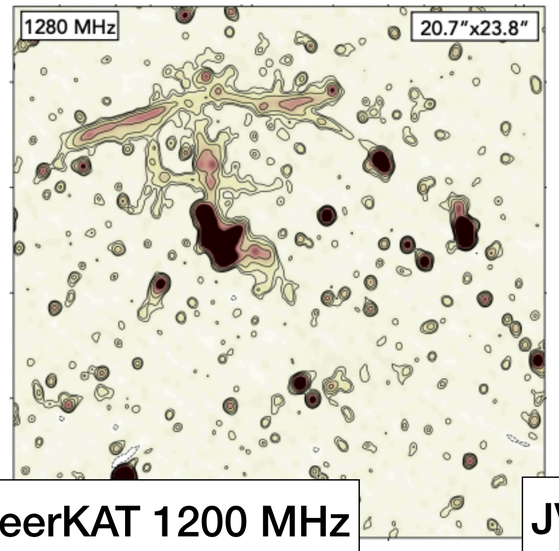
Brienza+, NatureAst, 2021
Brienza+, A&A, 20025



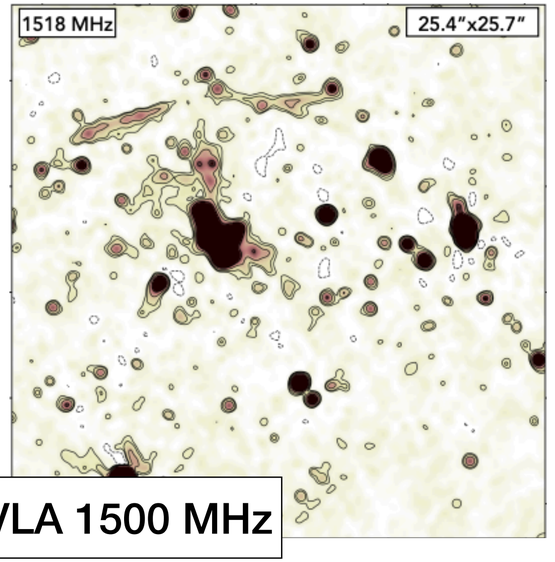
uGMRT 700 MHz



MeerKAT 800 MHz



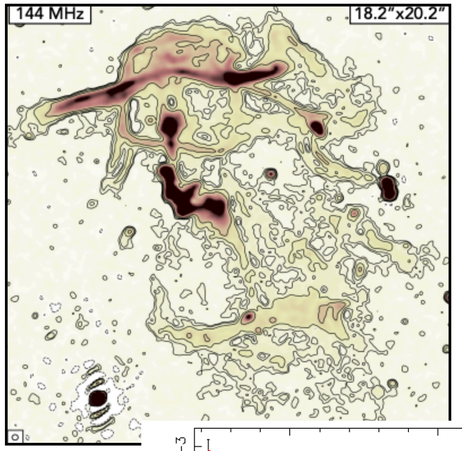
MeerKAT 1200 MHz

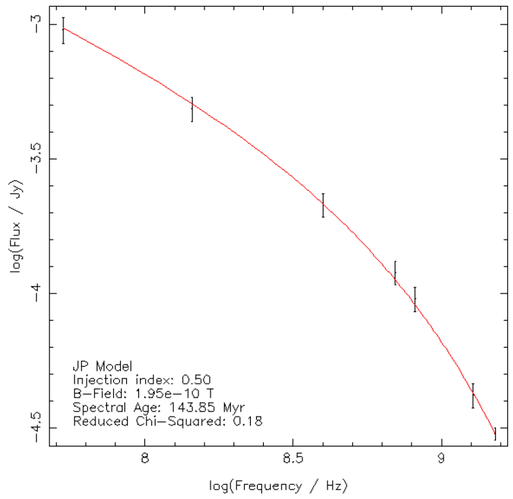


JVLA 1500 MHz

SKA AA* prospects and synergies

Detailed multi-frequency analysis of single targets (0.2-8GHz)





SKA-LOW

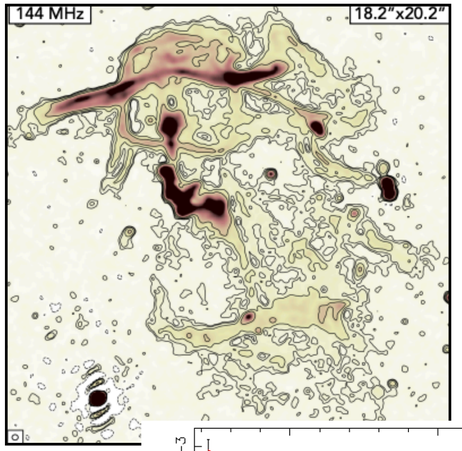
200 MHz ~1h with Briggs0
noise ~13 μJy/b with
beam~8"

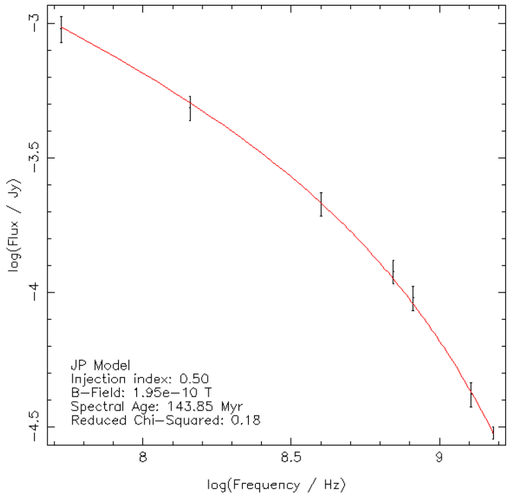
-> **FACTOR ~6-10**
deeper than LoTSS

LOW DENSITY
ENVIRONMENTS!

SKA AA* prospects and synergies

Detailed multi-frequency analysis of single targets (0.2-8GHz)





SKA-LOW

SKA-MID

200 MHz ~1h with Briggs0
noise ~13 μJy/b with
beam~8"

-> **FACTOR ~6-10**
deeper than LoTSS

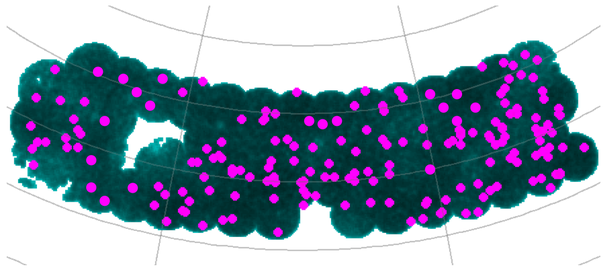
LOW DENSITY
ENVIRONMENTS!

~300μJy/b with 8" @ 200 MHz
detected with matched beam

B1 1h 800 MHz (8μJy/b)-> alpha ~1.8
B2 1h 1.3 GHz (3μJy/b)-> alpha ~1.9
B5a 1h 6.5 GHz (1μJy/b)-> alpha ~1.3

SKA AA* prospects and synergies

Search and large samples



1000deg2

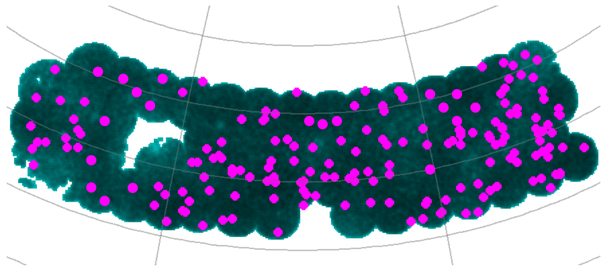
Hundreds remnants selected with both spectral and morpho criteria

SKA-LOW 200 MHz 160h
SKA-MID 800 MHz ~700h

alpha ~1.8

SKA AA* prospects and synergies

Search and large samples



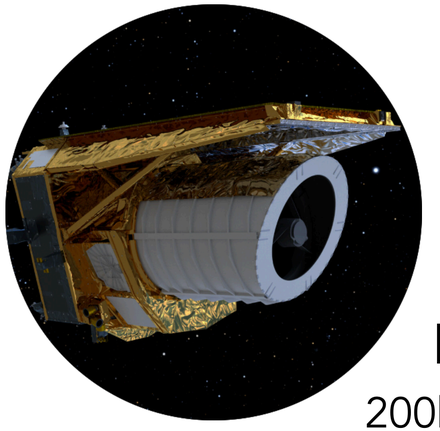
1000deg2

Hundreds remnants selected with both spectral and morpho criteria

SKA-LOW 200 MHz 160h
SKA-MID 800 MHz ~700h

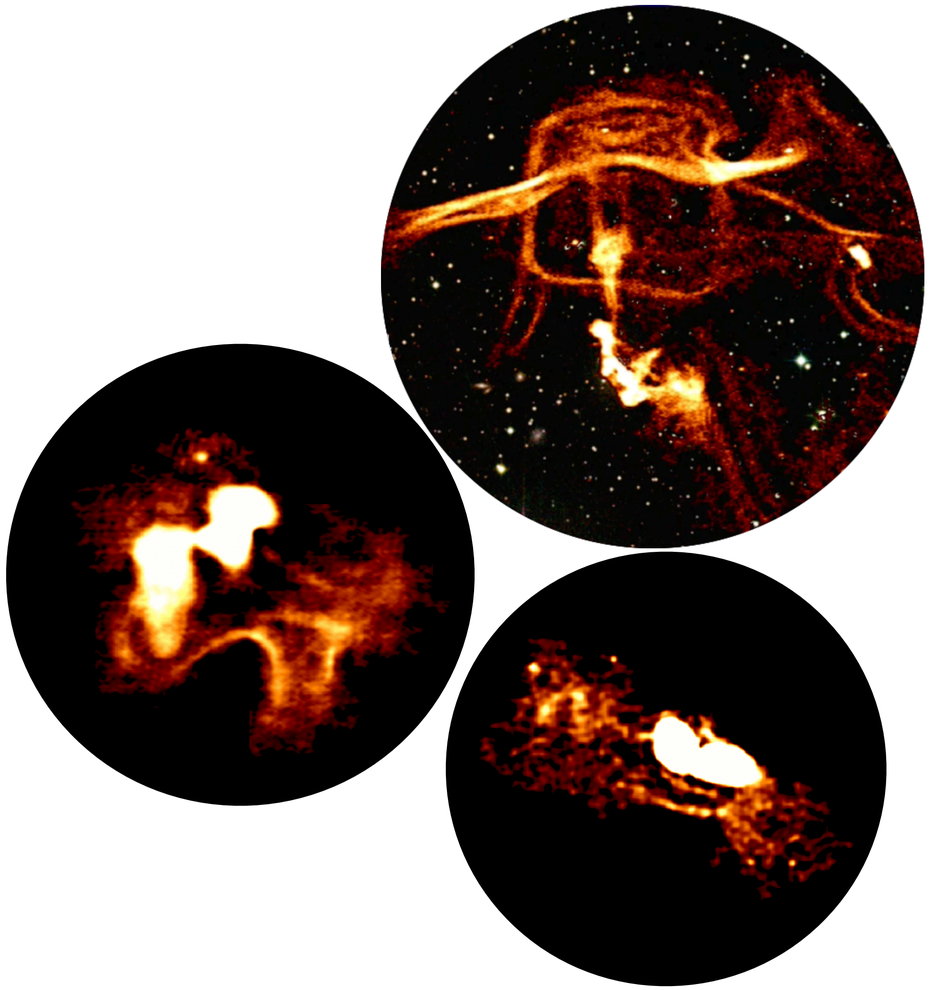
alpha ~1.8

eROSITA
12k groups and clusters z<1 (Balbul+24)
-> 4x deeper upcoming



Euclid
200k clusters +
300k groups expected at z<1

Summary



SKAO (Low+Mid) will be key to study the remnant AGN plasma with implications on:

- Jet evolution & duty cycle
- Feedback
- Enrichment of IGM with cosmic rays and magnetic fields

Synergies with multi-wavelength facilities
(e.g. eROSITA, Euclid) for environment

Synergies with Magnetism & VLBI & HI WGs

SKA WHITE BOOK CHAPTERS

1) Radio Galaxies and Jet Duty Cycles (**Hardastle+..MB**)
2) Galactic hubs: new insights and SKA view of AGN feedback in galaxy groups (**Pasini, MB, Riseley**)
3) AGN jets from formation to dissipation (**Baczko+..MB**)