Restarting phase of the life - cycle of Radio Galaxies

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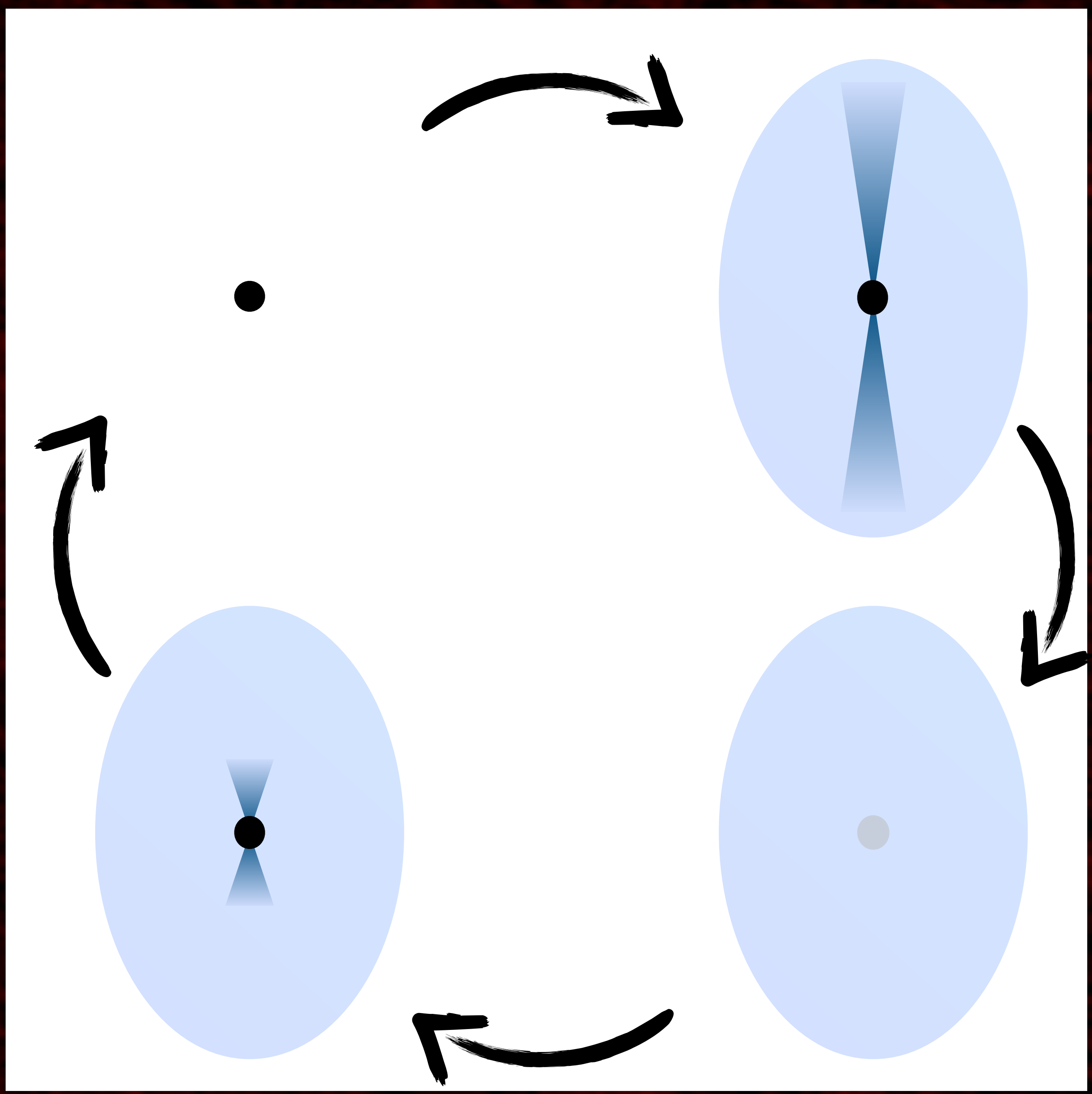
Overview and motivation:

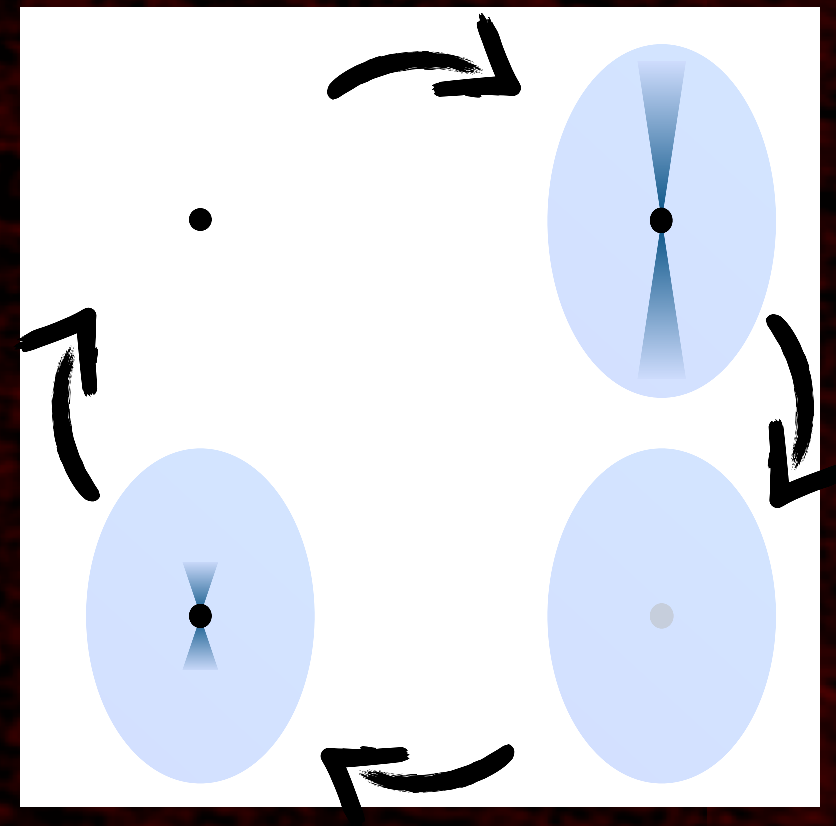
- $L_{1.4\,GHz} > 10^{24}$ W Hz^{-1}
- AGN outbursts → prevention of cooling and infall of the gas



- Influence on the host galaxy
- Constraints on duty cycle

⇢ Larger samples are needed

Our approach:



- **Sample of radio galaxies:**
  - **Remnants (Brienza+17)**
  - **Restarted (this work)**
  - **Active comparison**

  + optical ID

- Restarted phase ⇢ **cycle of activity**

- **First time** to make a **statistical sample** of restarted radio galaxies with wide variety of morphologies

- optical/IR ⇢ redshift ⇢ **radio power, linear size**
  ⇢ **stellar masses, star formation rates**

- **Radio galaxy evolution models**

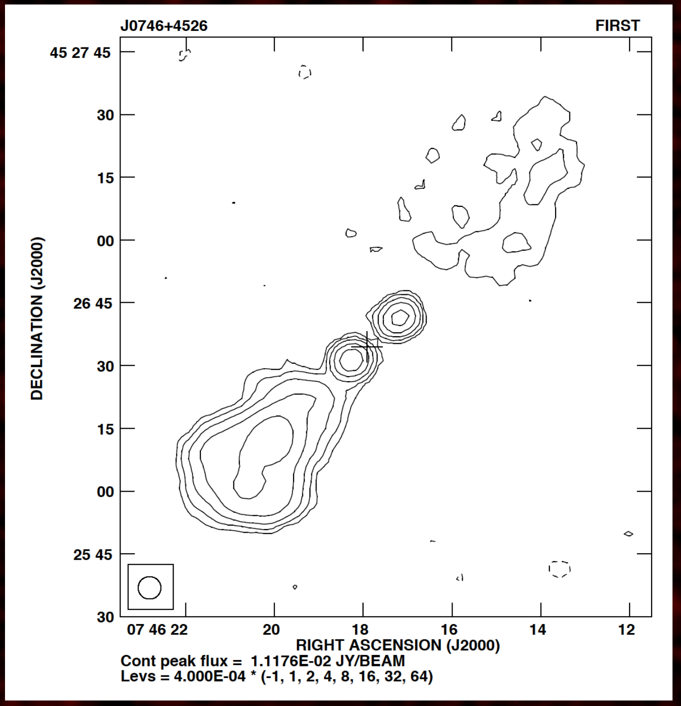
Restarted

- Mostly single objects or small samples; **DDRGs (Schoenmaker+00)**
- Parma et al. 2007
  - 3 ⇢ integrated spectra and morphology
- Nandi & Saikia 2012
  - DDRG ⇢ radio structure and optical ID (10%)
- **Saripalli et al. 2012**
  - Morphological criteria + low surface brightness
  - 24% candidate restarted
- Kuzmicz et al. 2017
  - Radio and optical properties
  - Sources from the literature (8 new)

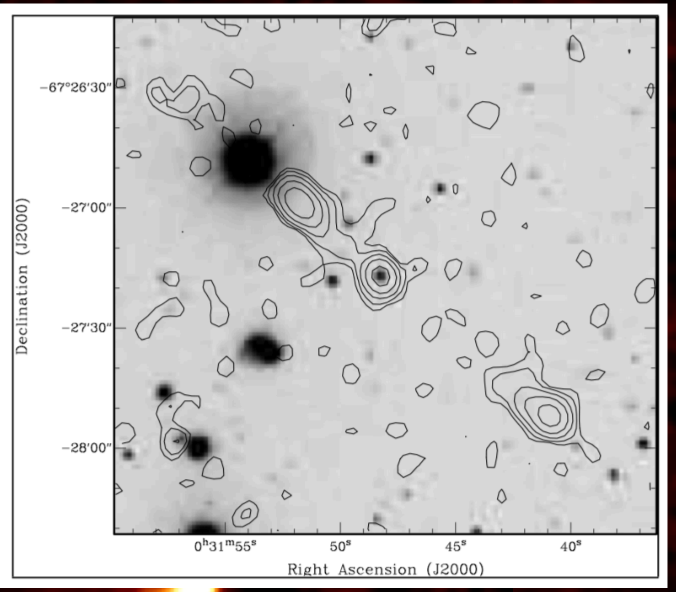
Restarted with LOFAR

- Single object
  - B1834 + 620 (Orrù+15)
  - 4C 35.06 (Shulevski+15)
  - B2 0258 +35 (Brienza+18)
- Mahatma+18:
  - 33 DDRGs

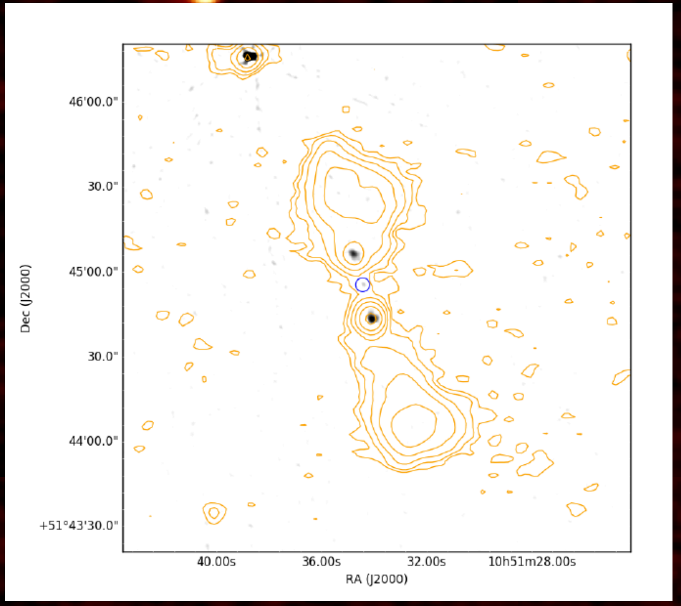
Nandi&Saikia 2012



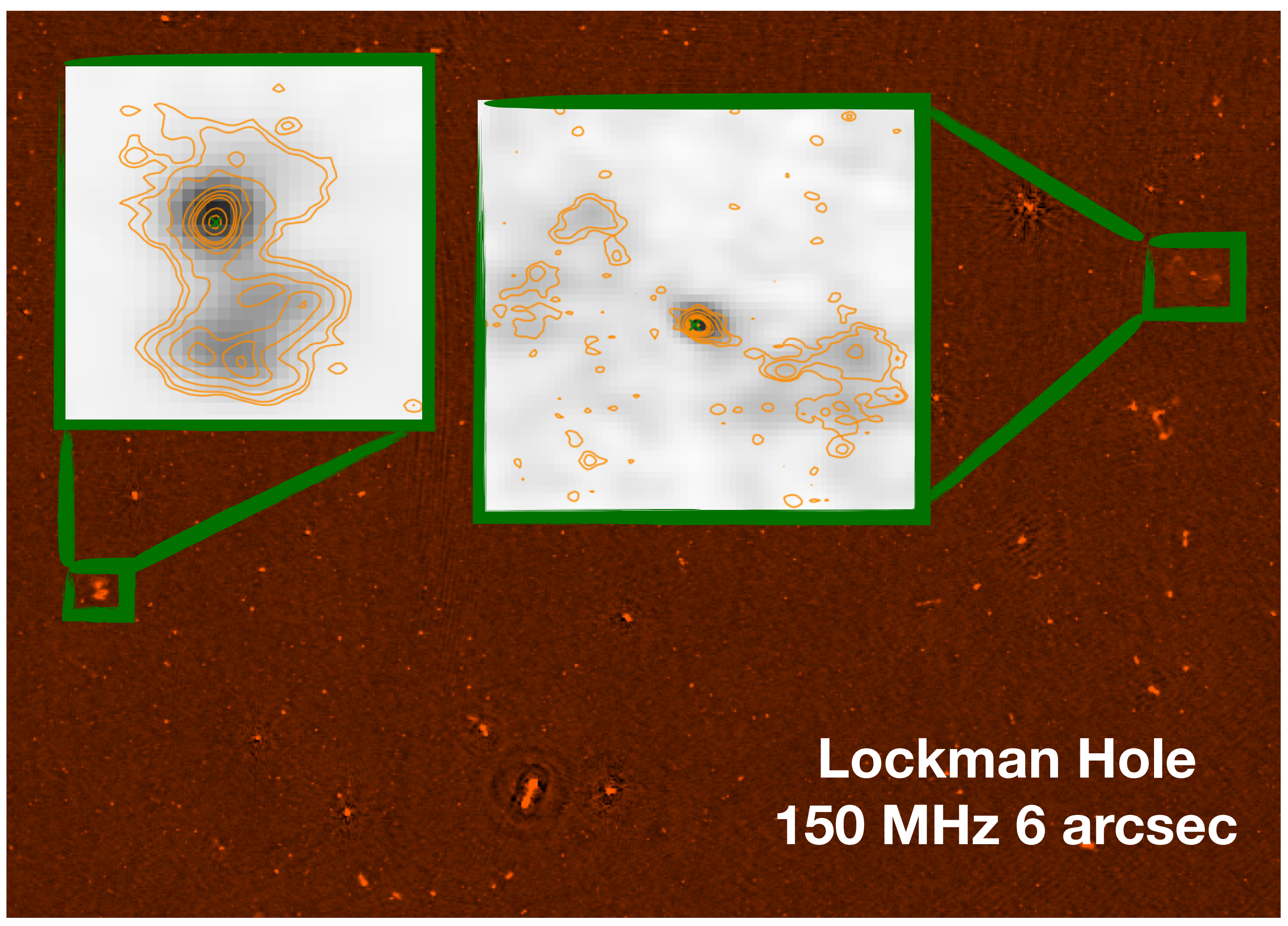
Saripalli+2012



Mahatma+18



Data



Mandal+, in prep

FOV: 25 sqdeg

rms noise: **~45 μJy/beam at 6 arcsec**

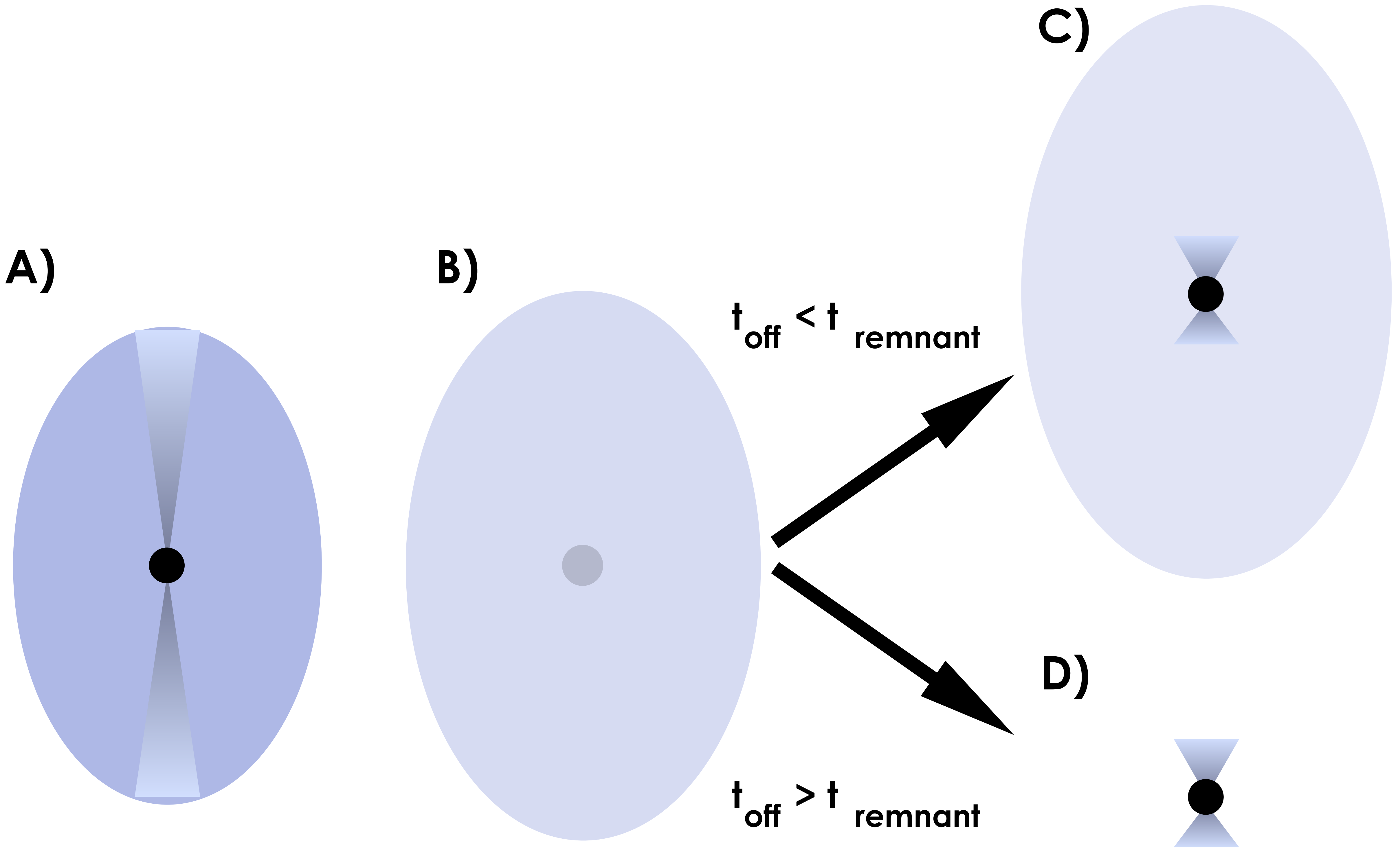
resolution:

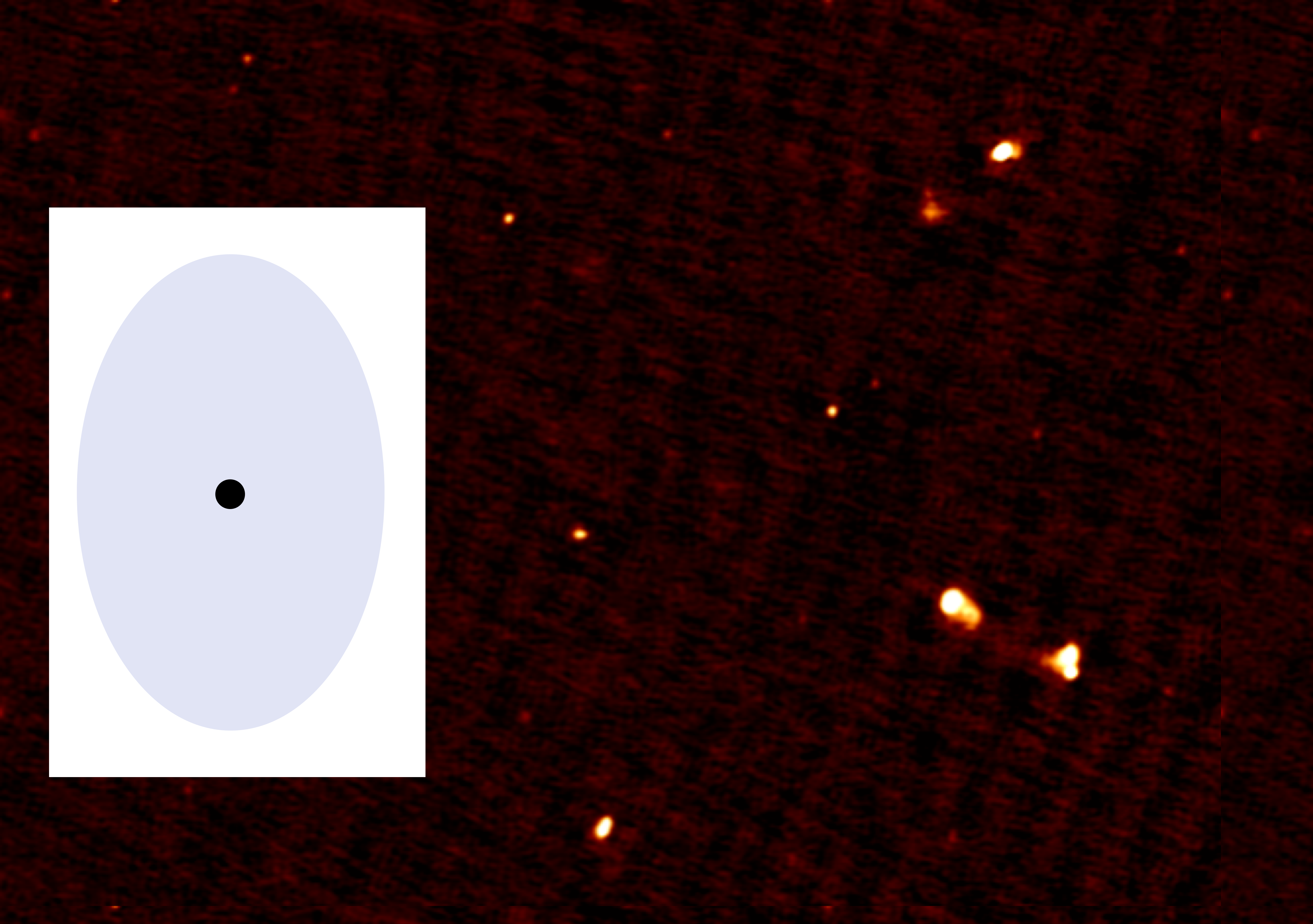
- **18 arcsec** (Mahony et al. 2016)
- **6 arcsec** (Mandal et al. in prep.)

LH ⇢ many ancillary data available

- FIRST
- WISE
- SDSS

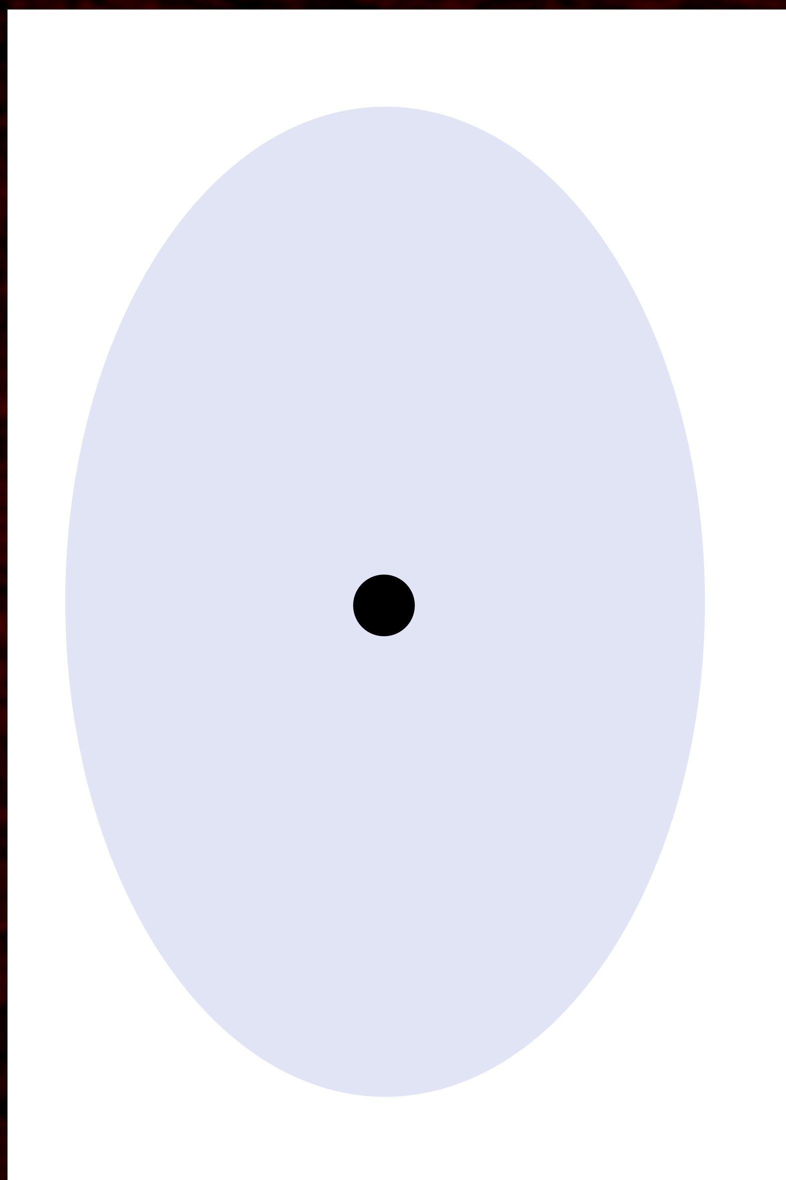
N detections	5323
N ≥ 60 arcsec	159


A)
B)
C)
D)
$t_{off} < t_{remnant}$
$t_{off} > t_{remnant}$

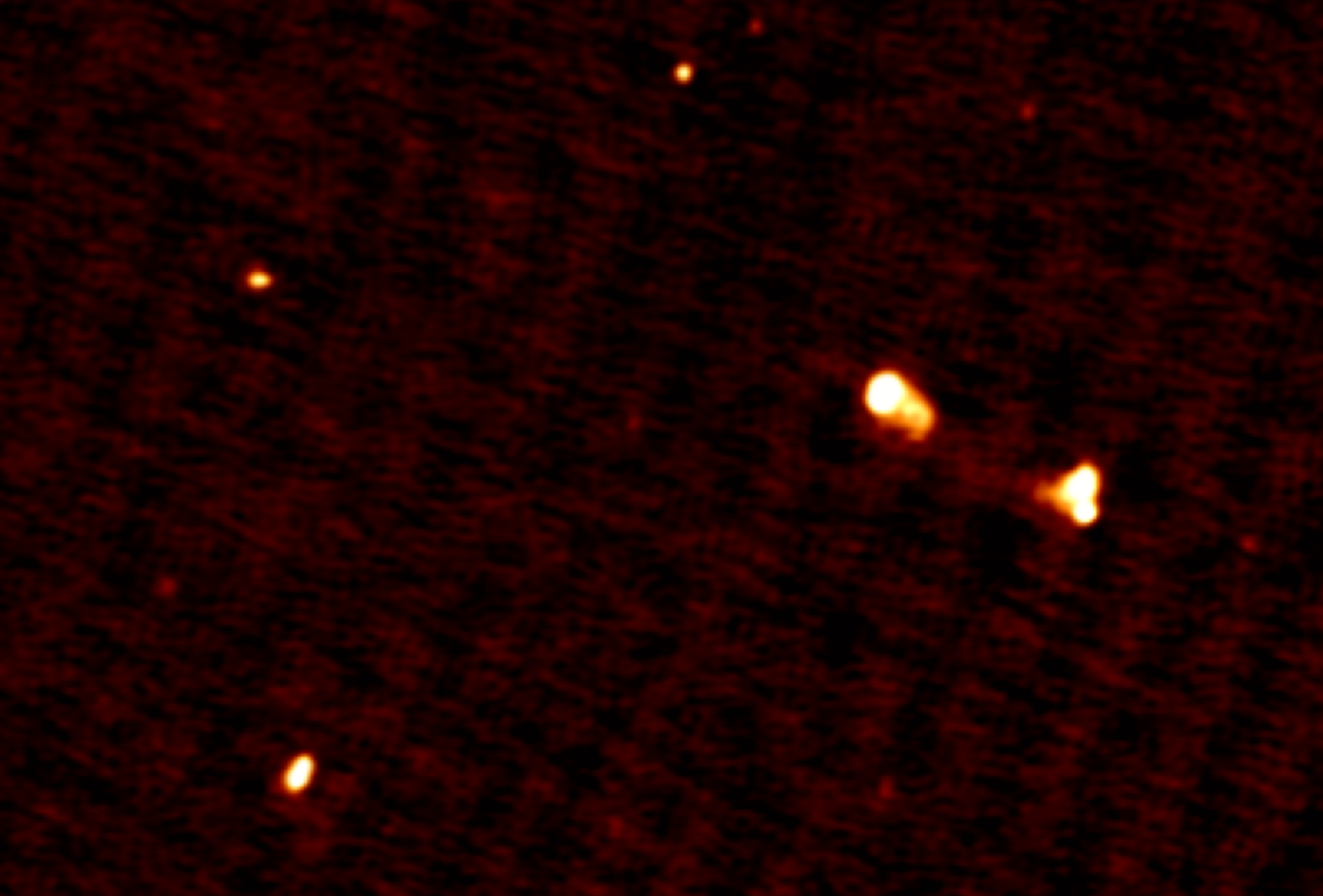


1. Core prominence (= $Score/Stotal$)
+ low surface brightness

- CPrestarted > CPactive
  - ⇢ indication of sub - arcsec jets
- SB comparable to remnant SB



LOFAR 150 MHz 18 arcsec ⇢ 1.4 GHz (SI=0.7)
FIRST 1.4 GHz



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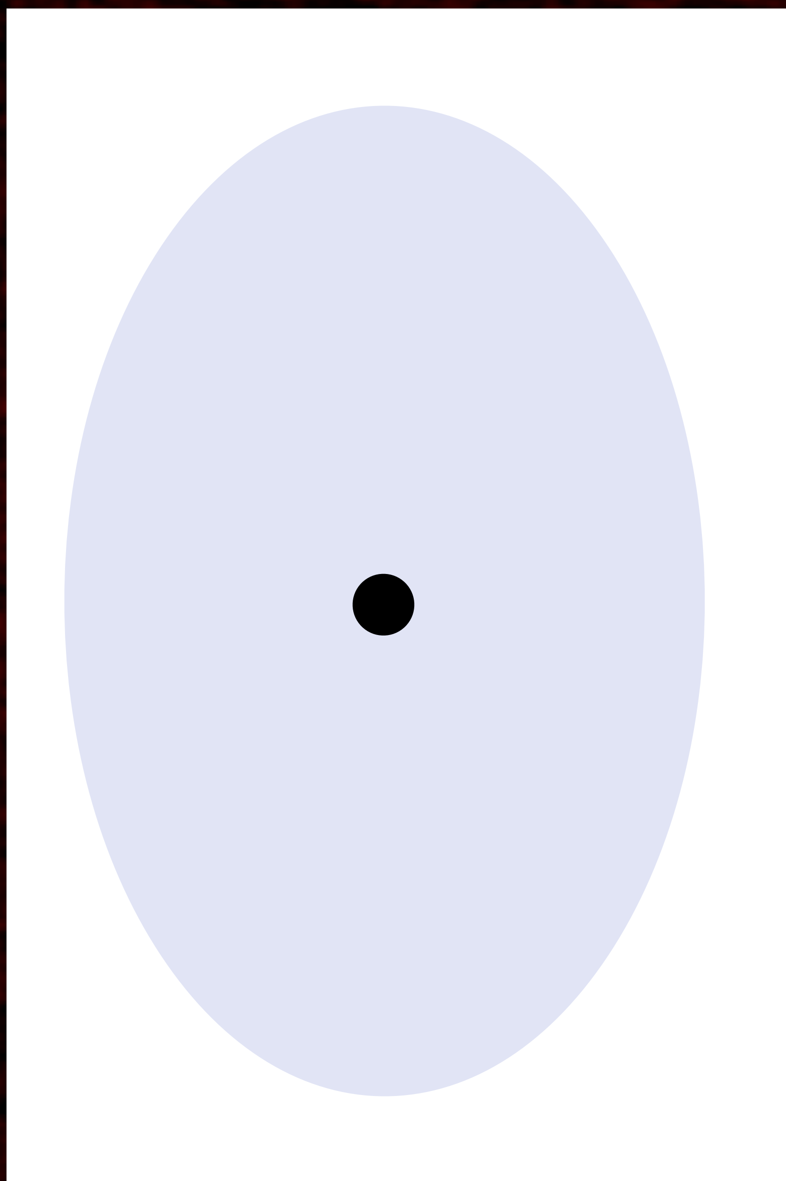

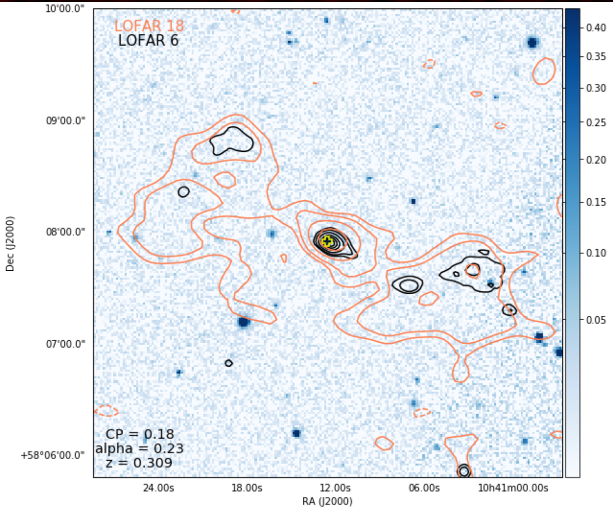

21 (CP≥0.1 + low SB)

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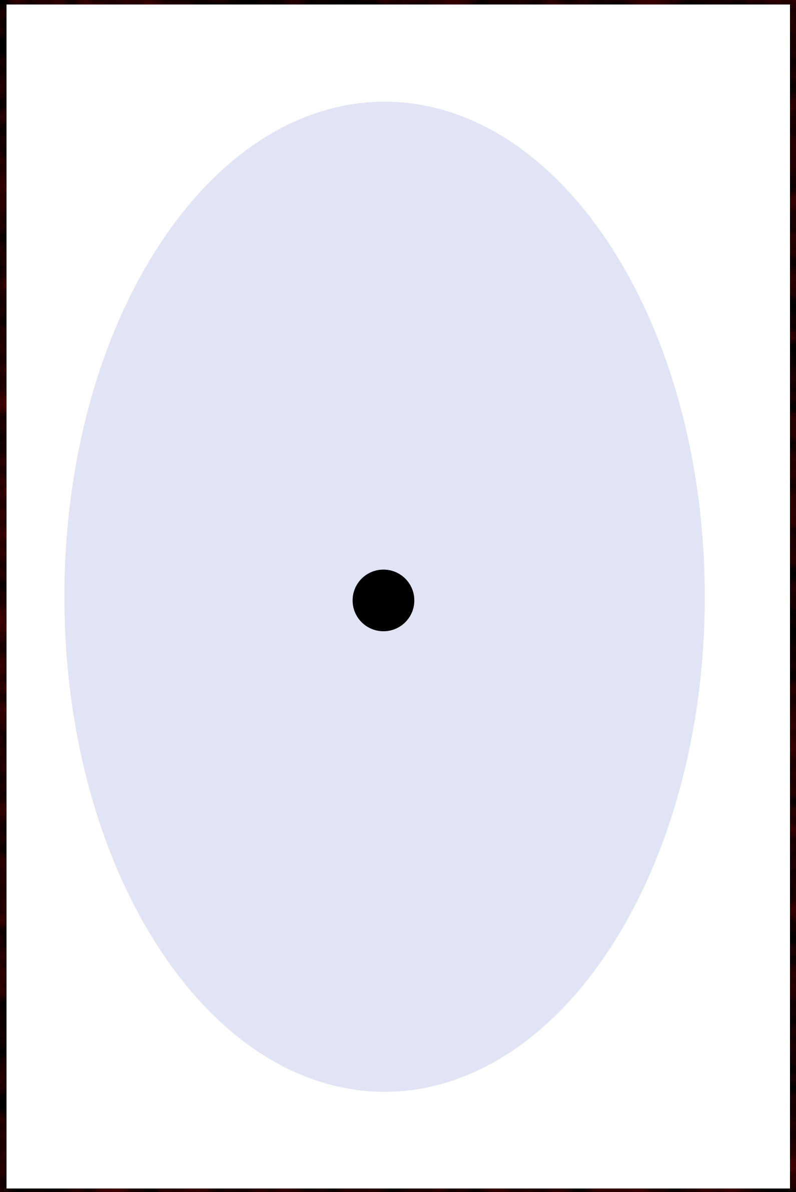

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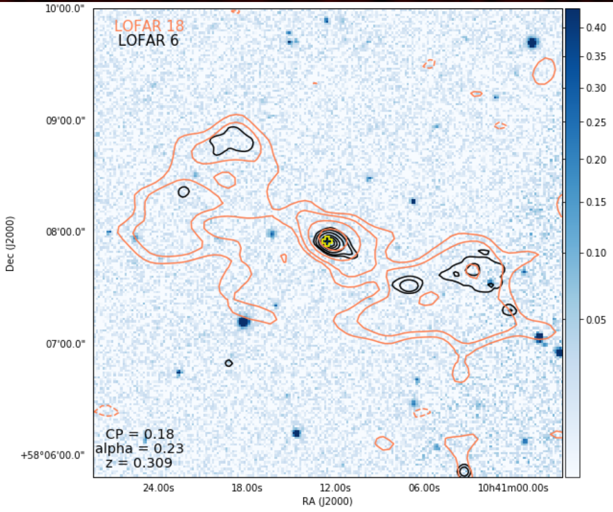

21 (CP≥0.1 + low SB)

2. Steep spectral index of the inner region

- Indication of sub - arcsec jets

LOFAR 150 MHz 6 arcsec
FIRST 1.4 GHz 6 arcsec

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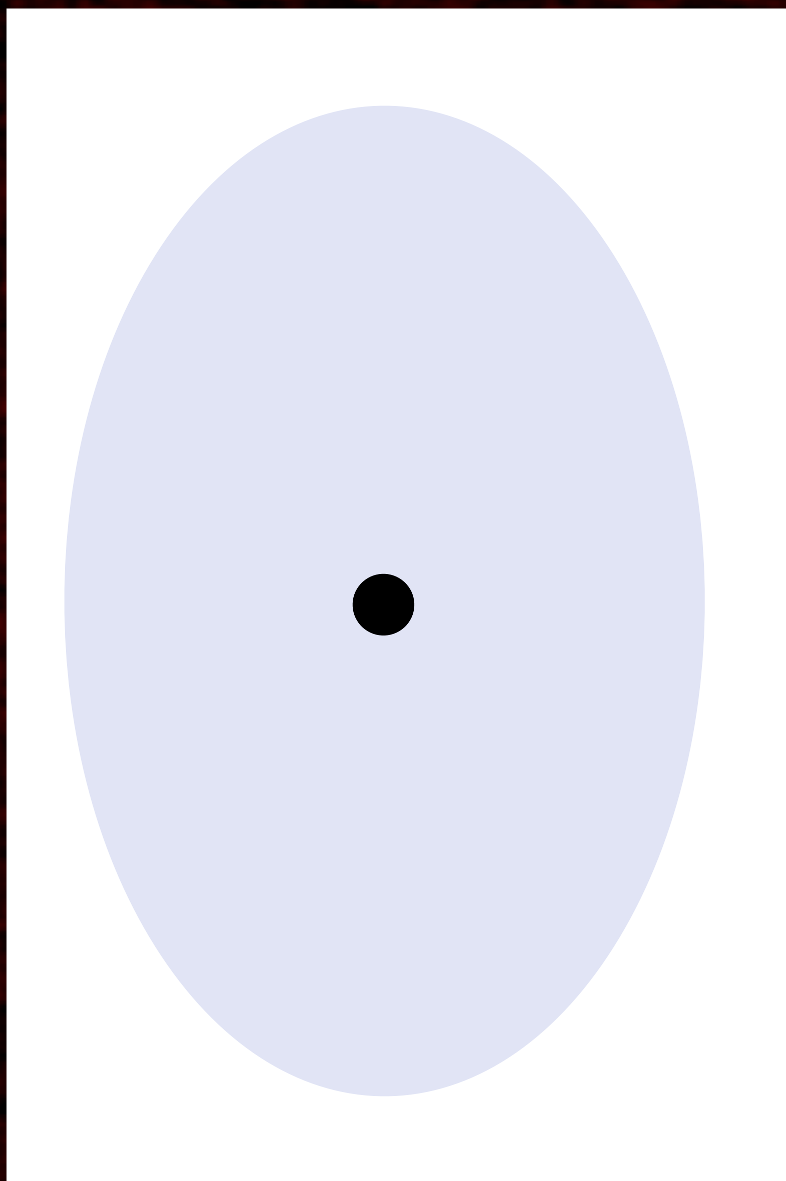

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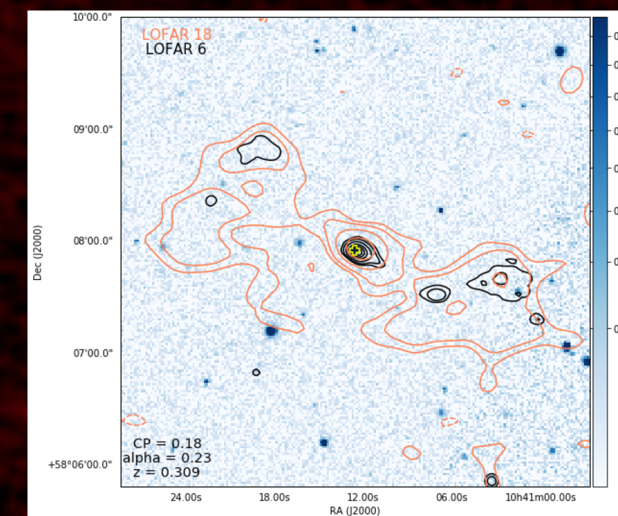
FIRST 1.4 GHz



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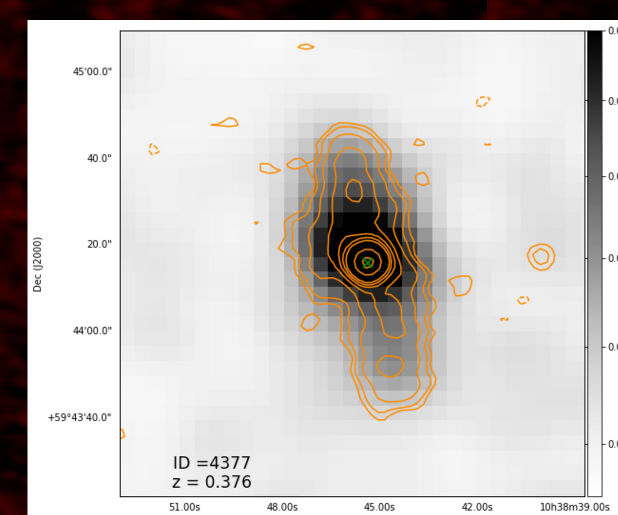

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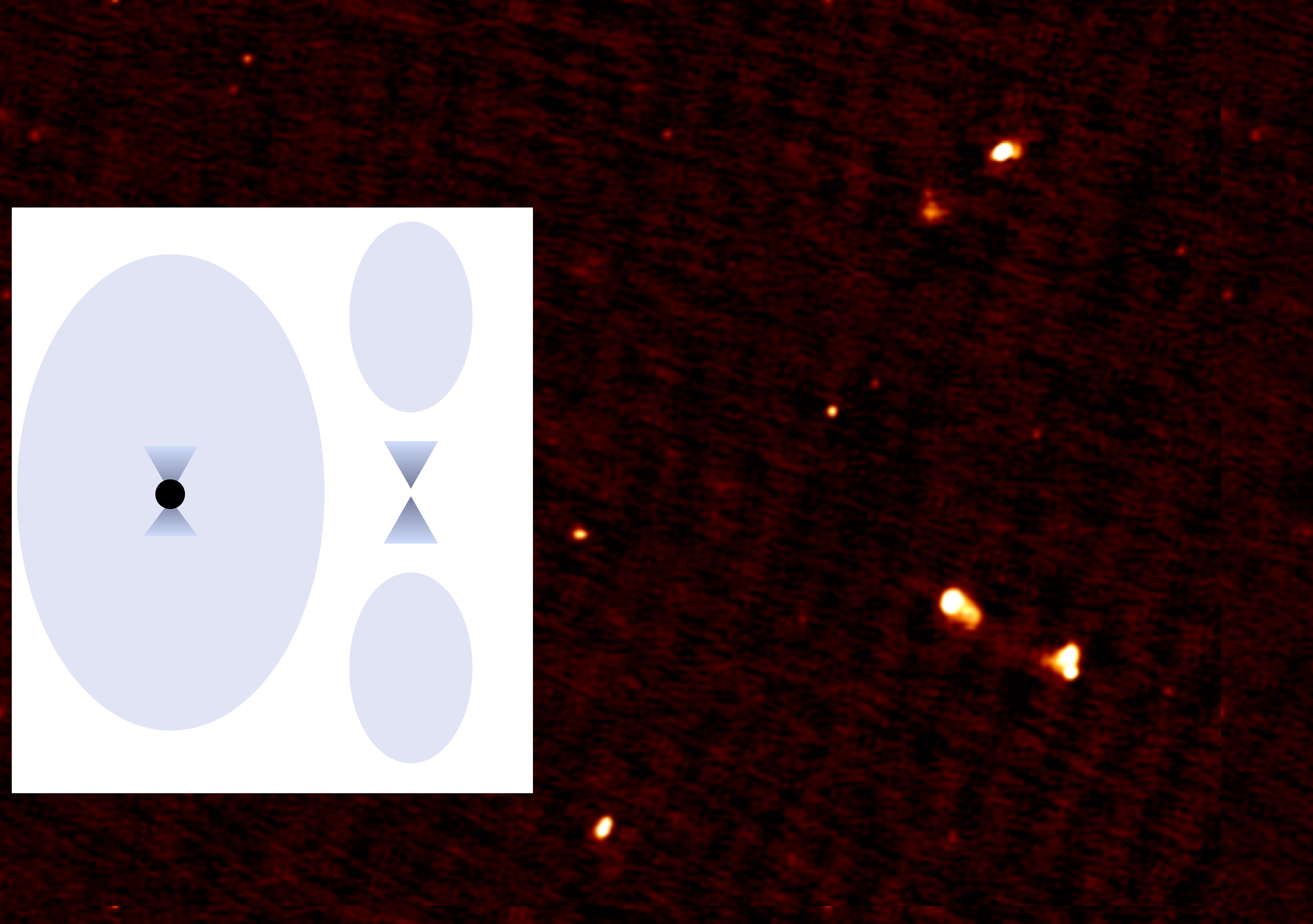
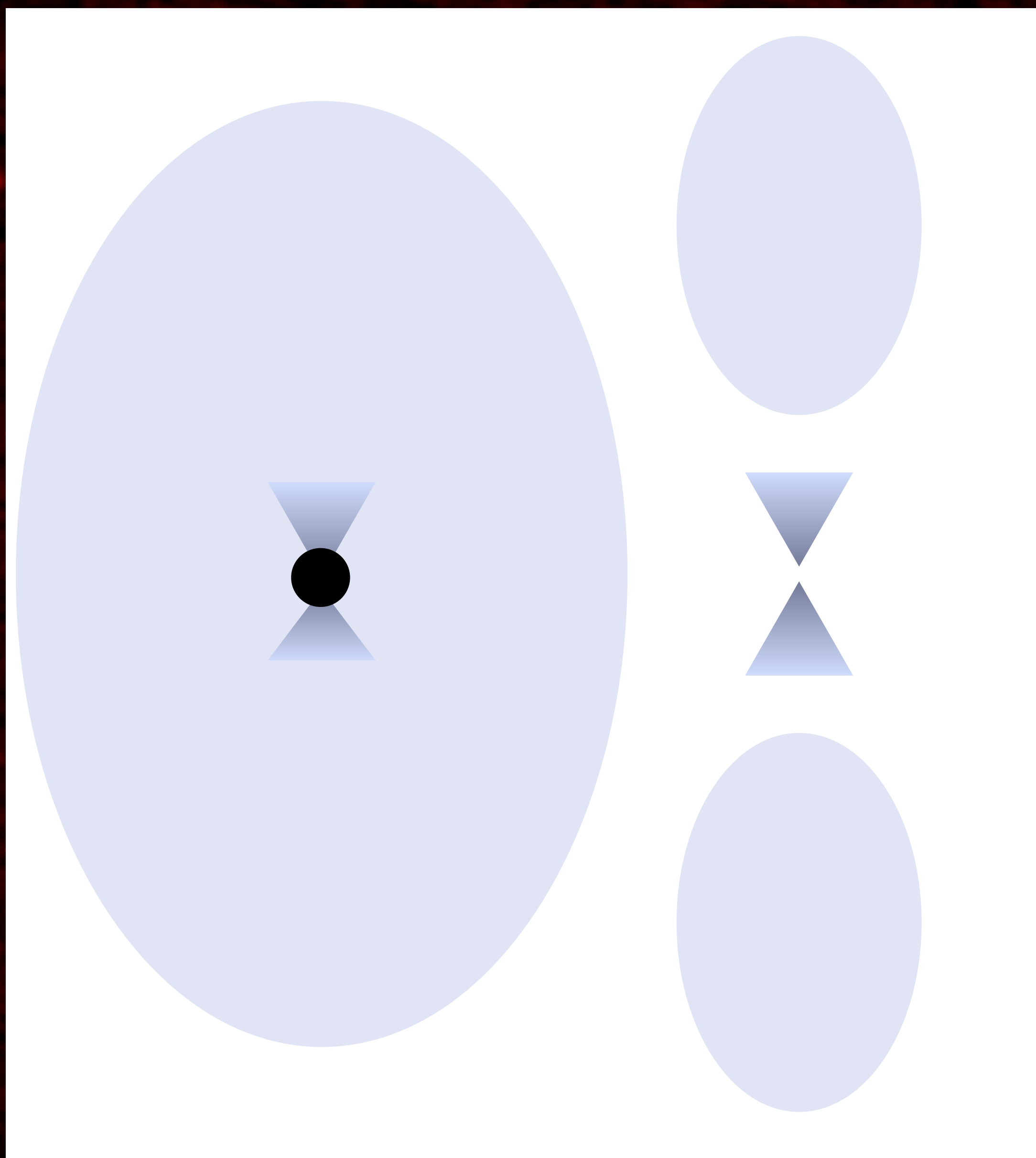
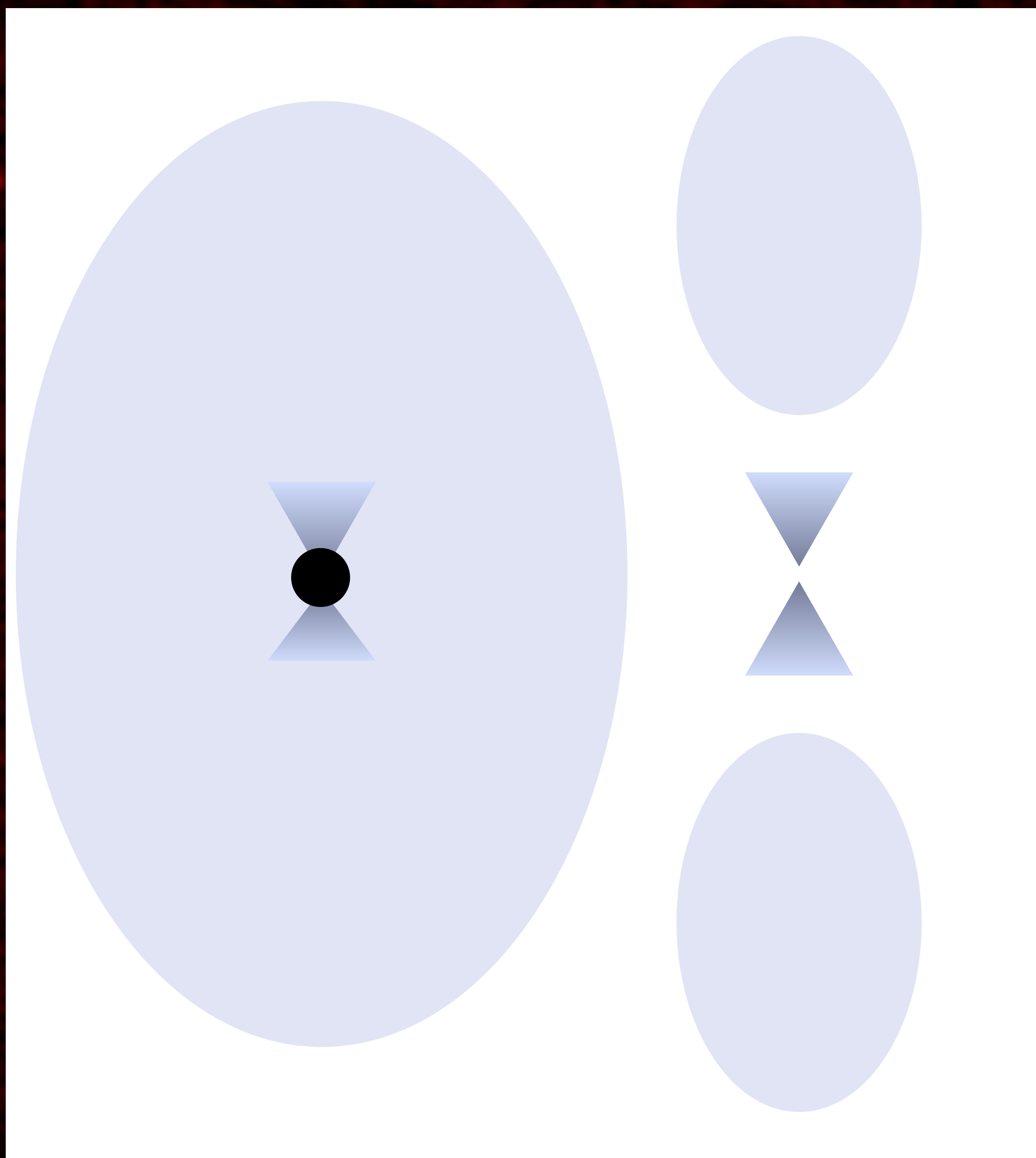




3. Morphology - visual inspection

- Diffuse outer lobes with faint radio emission
- Bright core (+ bright inner lobes)
- DDRGs

LOFAR 150 MHz, 18 arcsec and 6 arcsec



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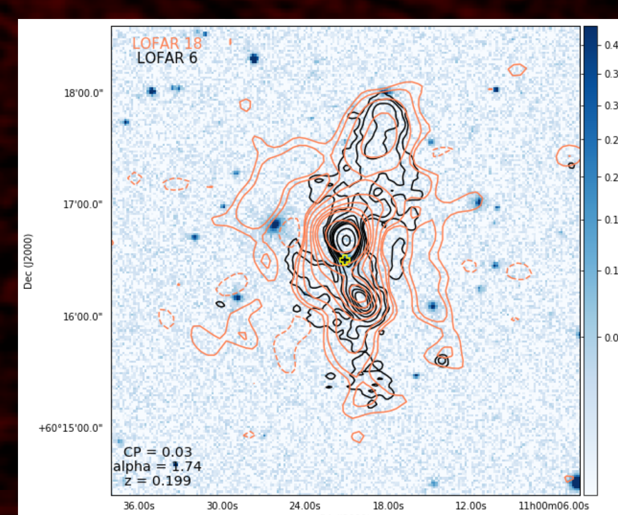
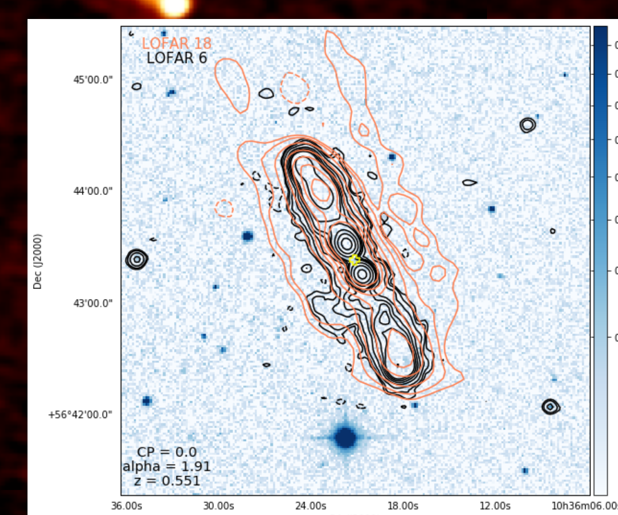
6





Candidate restarted radio galaxies:

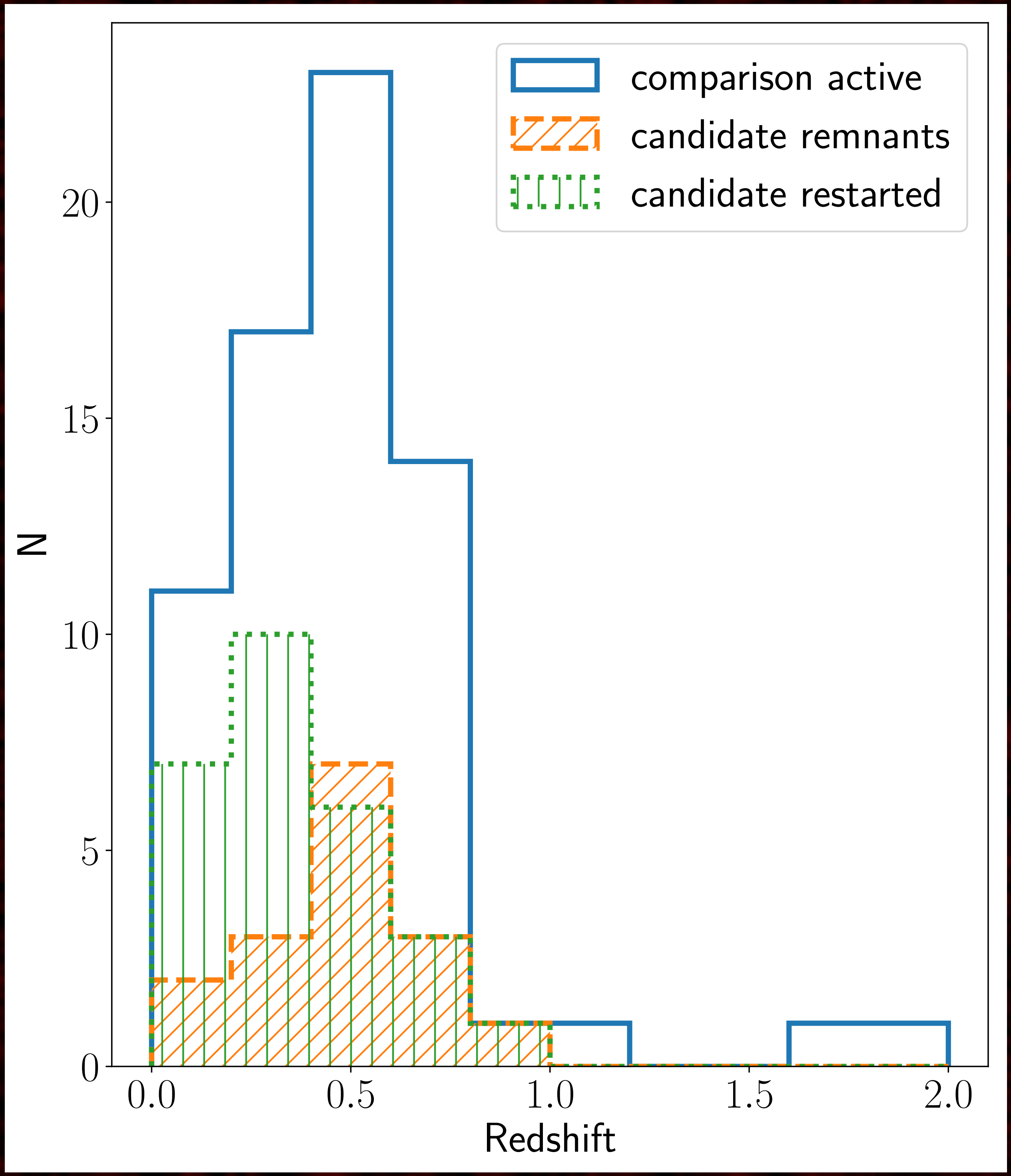
23% candidate restarted radio galaxies
~79% optical identification
z [0.028, 0.886]

Candidate remnant radio galaxies:

12% candidate remnant radio glaxies
~84% optical identification
z [0.034, 0.831]

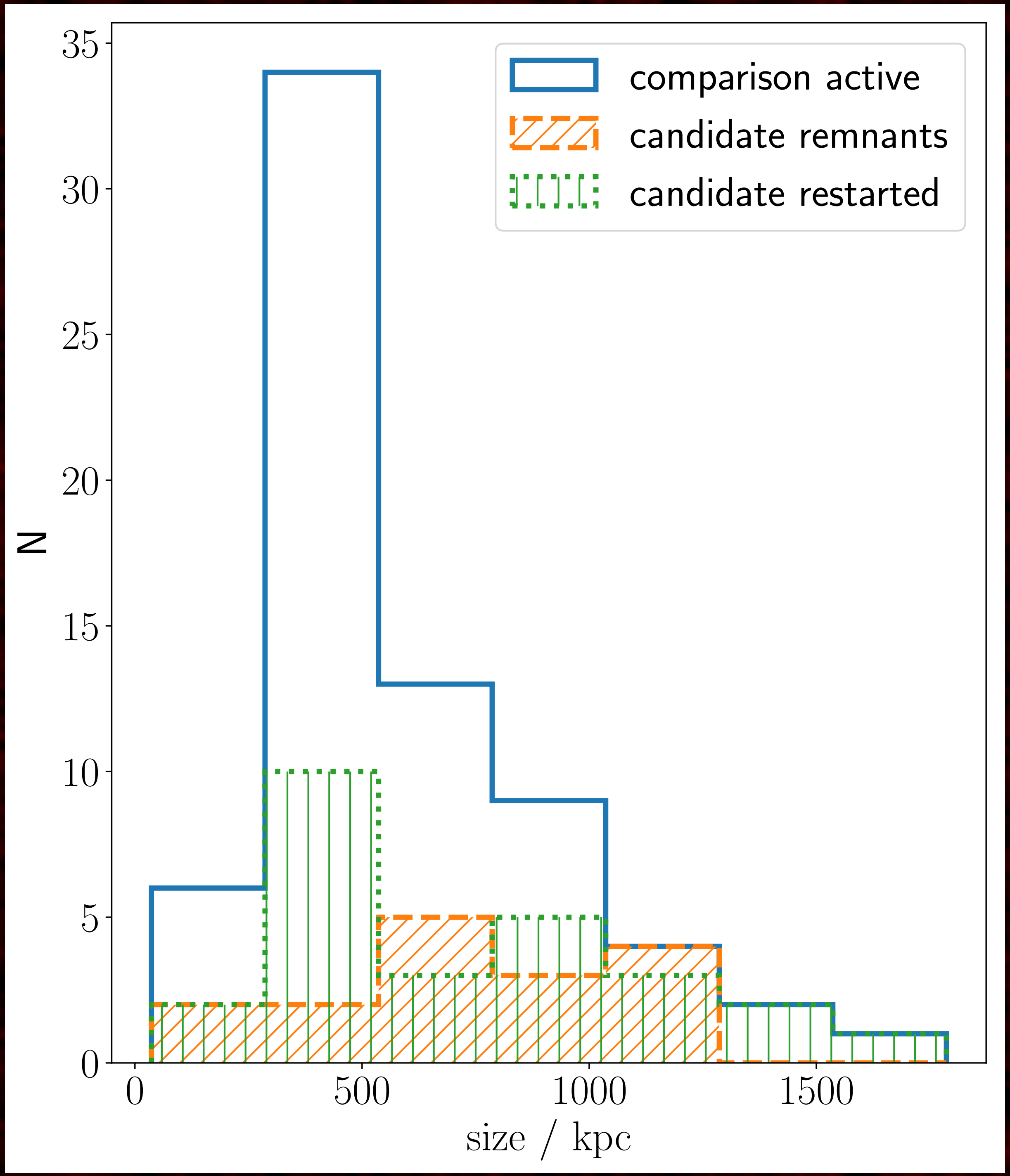
Active comparison radio galaxies:

65% candidate radio glaxies
~65% optical identification
z [0.027, 1.933]



1. Remnants fade quickly (Brienza+17) and a **large number of them manages to restart before remnants manage to fade away**

Radio properties



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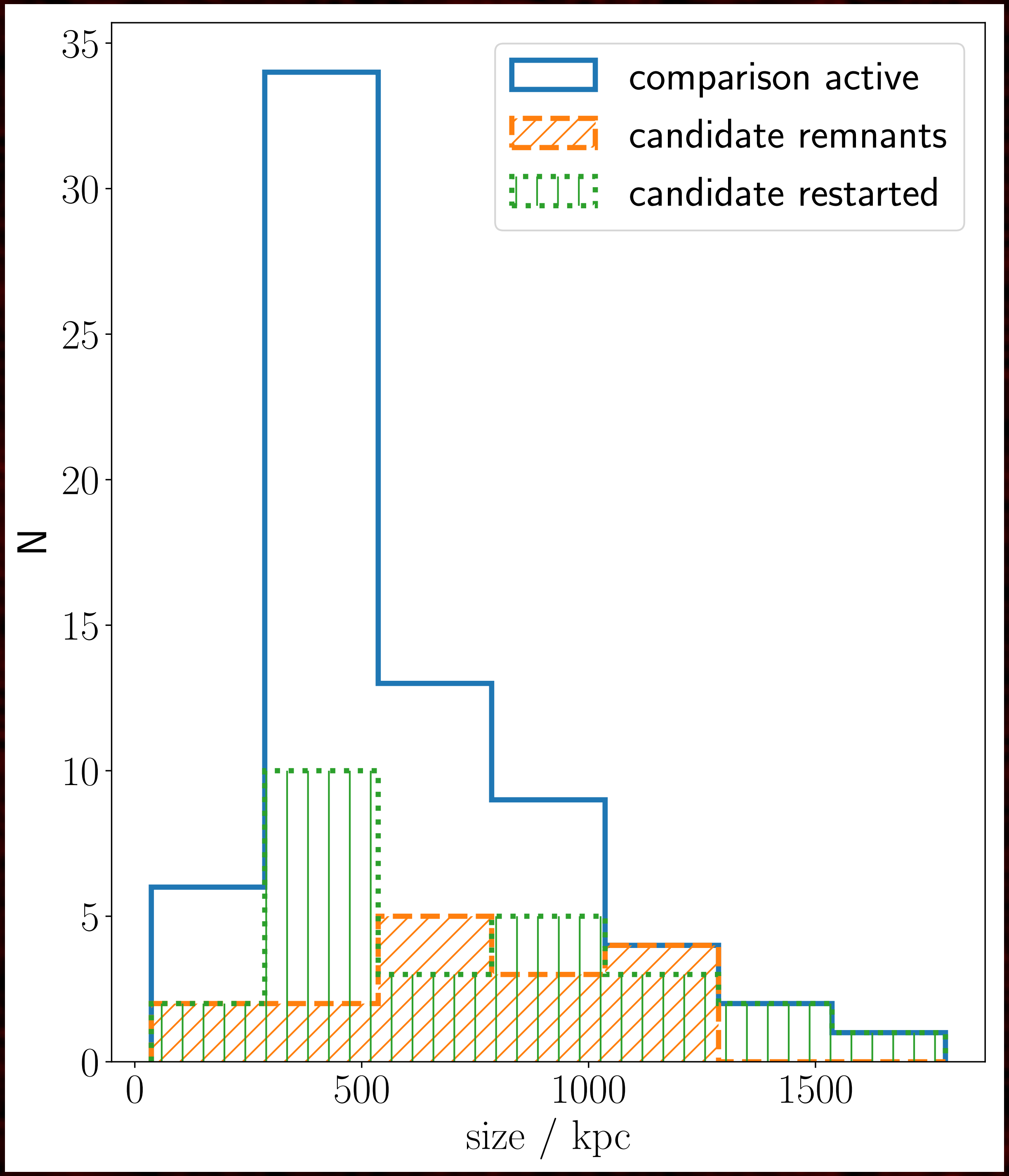
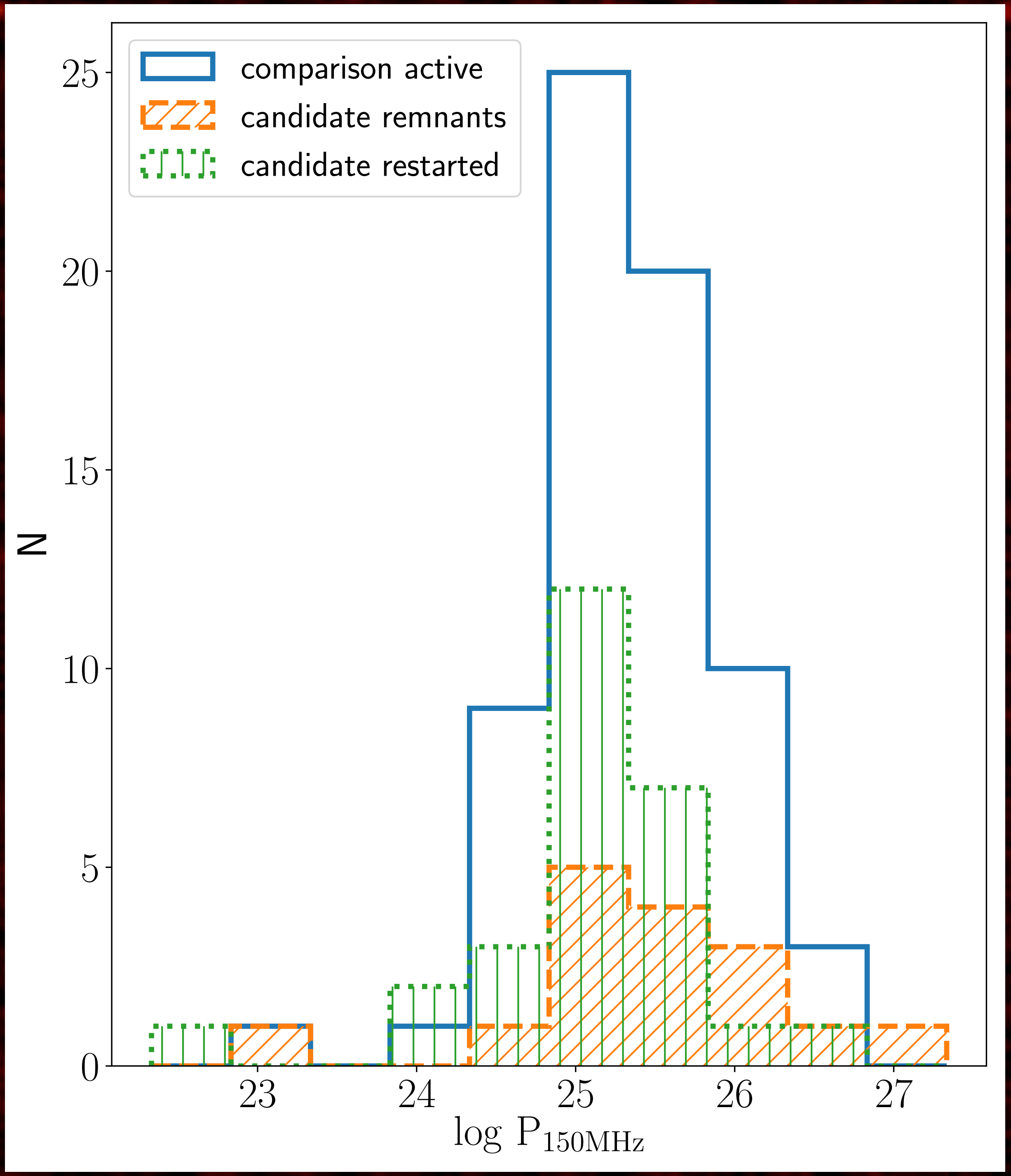
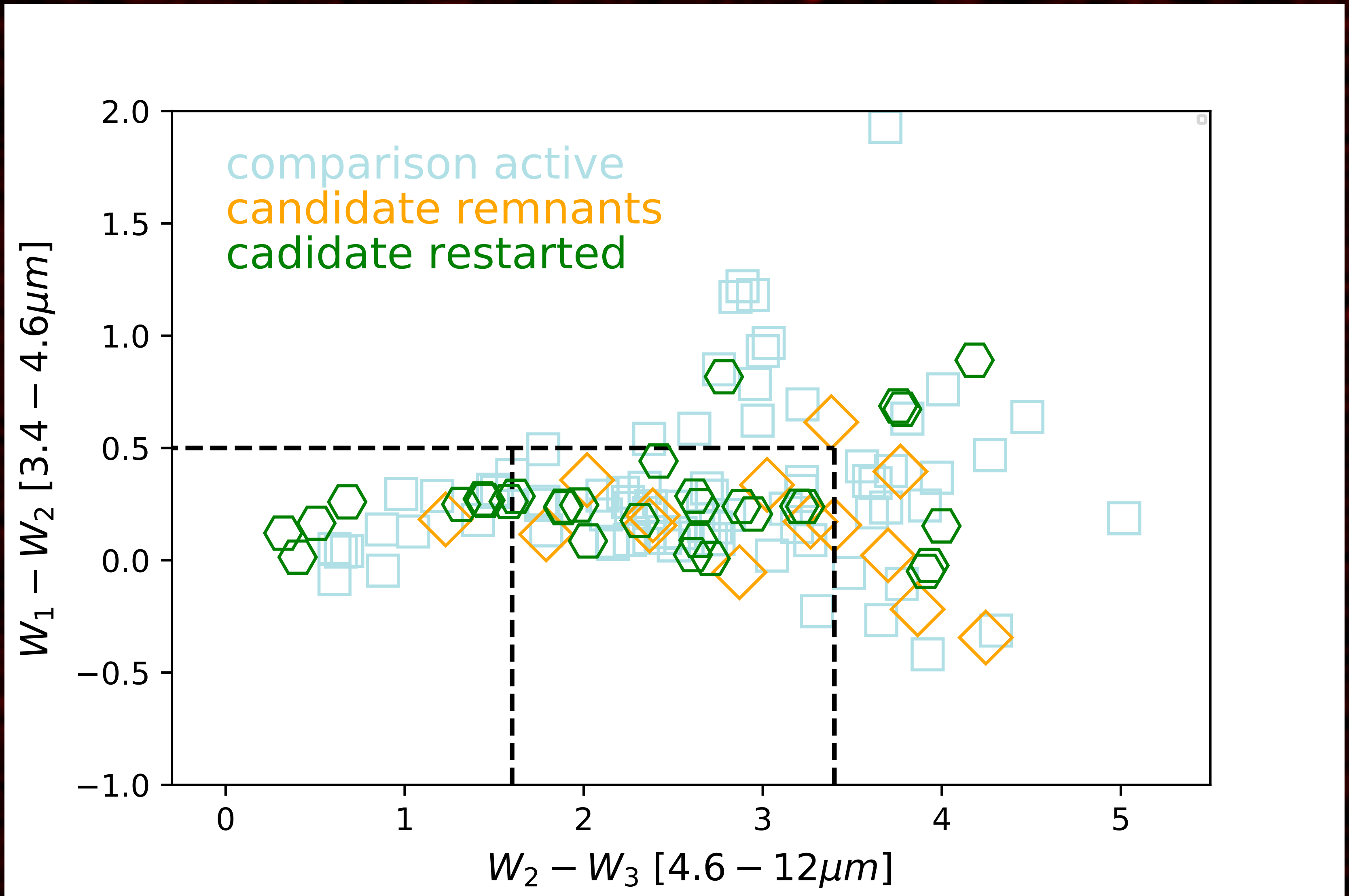




WISE colour-colour plot



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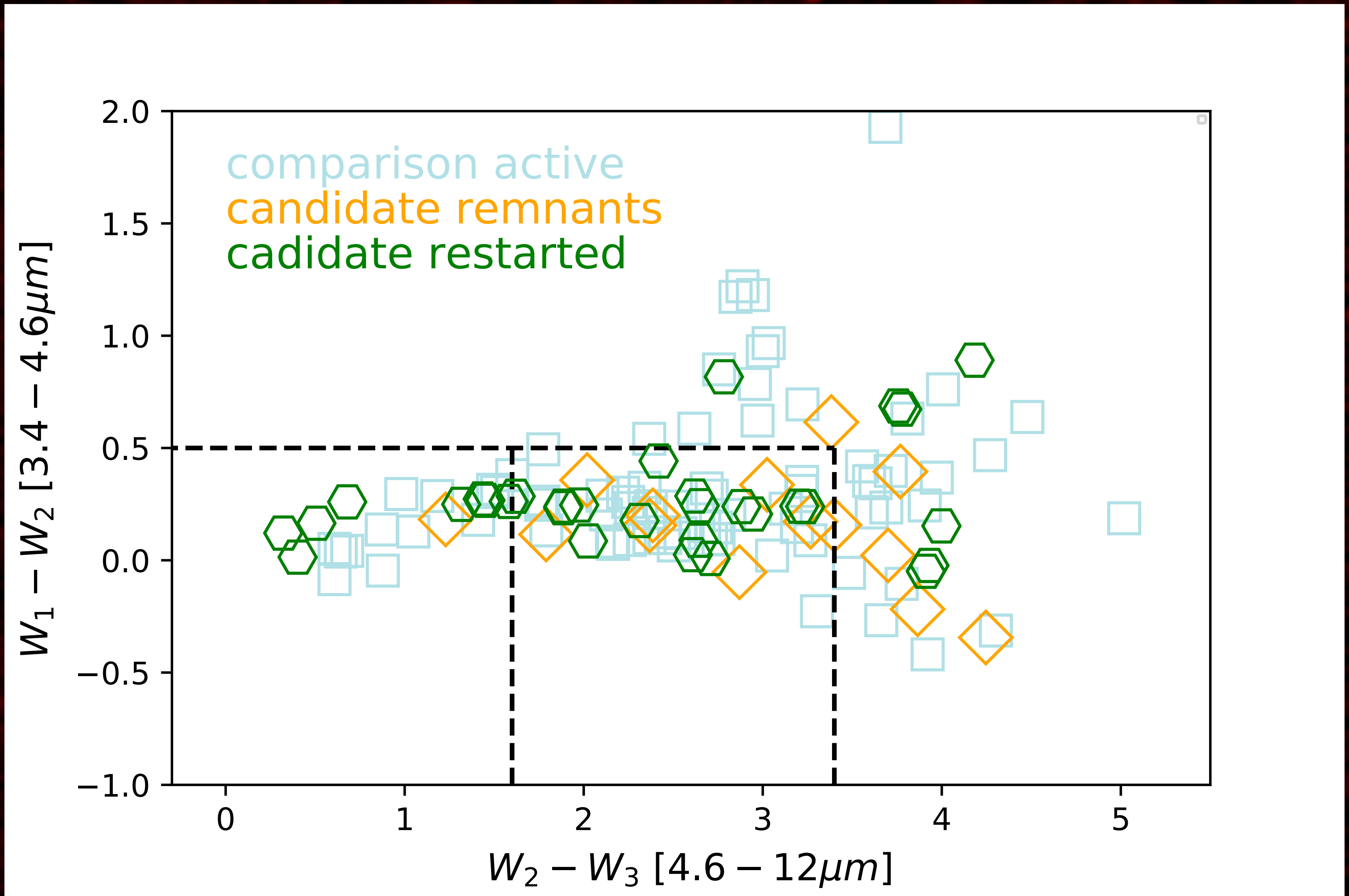
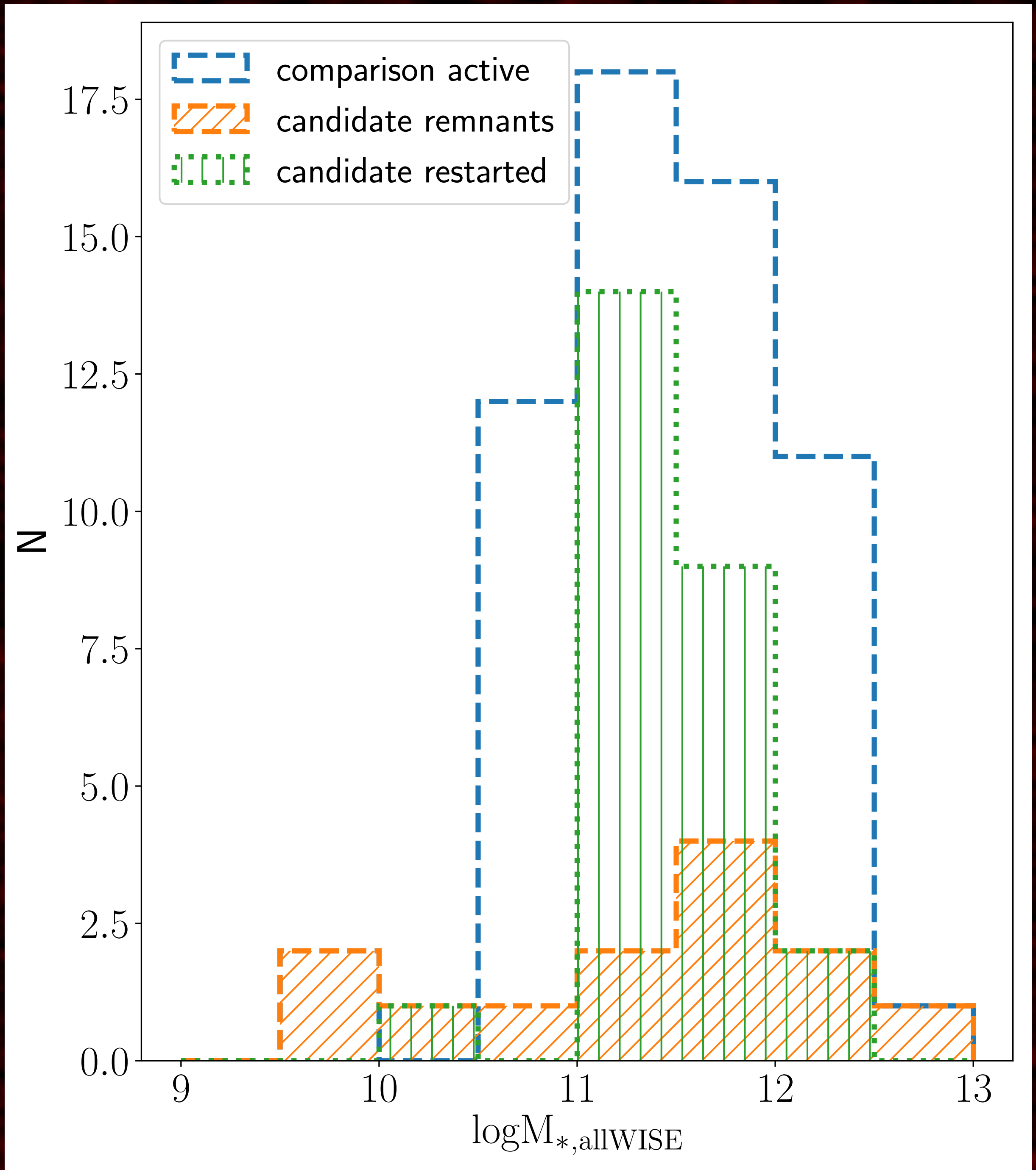
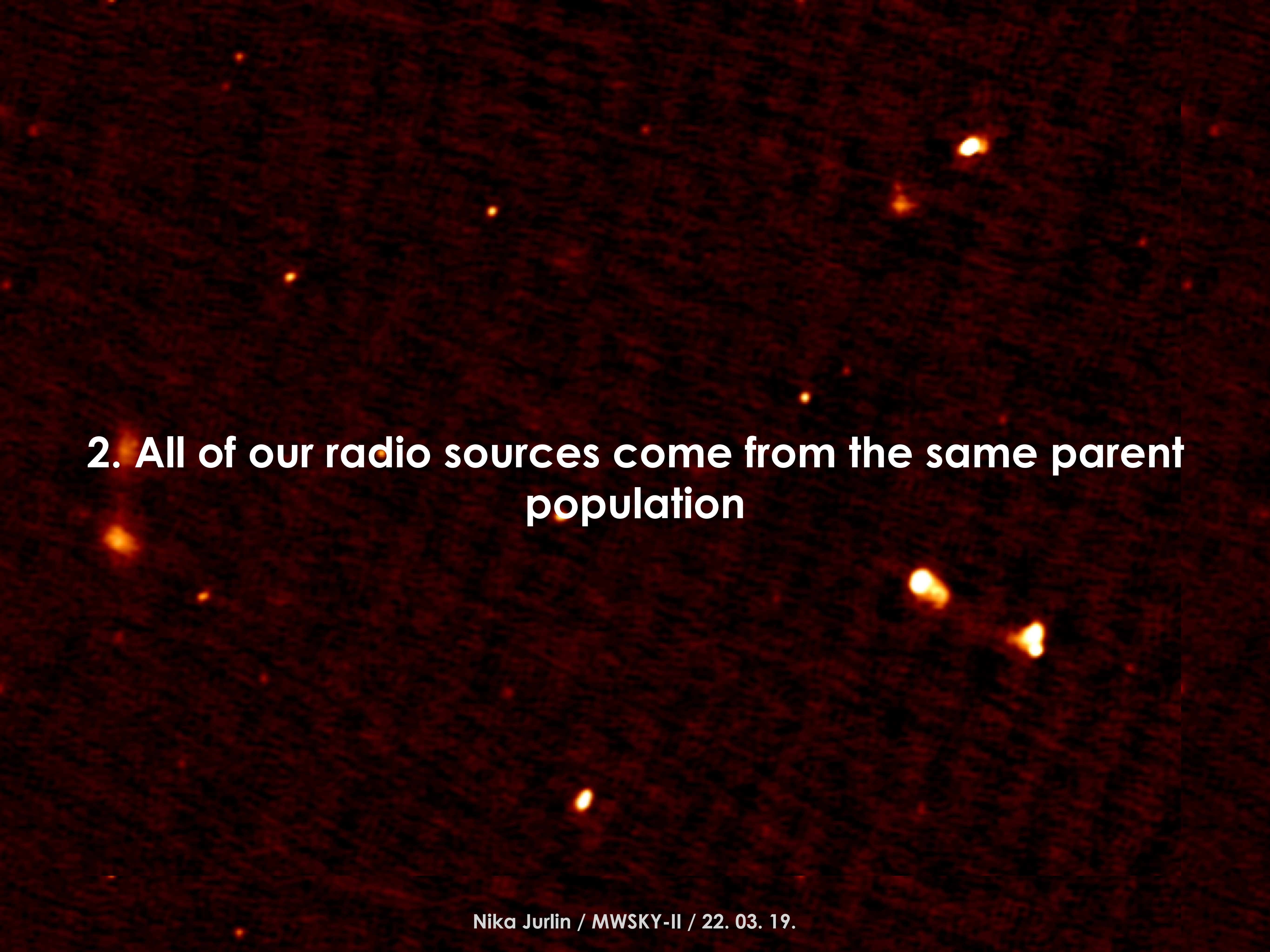


ENVIRONMENT:

- 30 sources in a cluster (NED)
  - 3 remnants
  - 6 restarted
  - 21 comparison

Properties of the host galaxy




2. All of our radio sources come from the same parent population
Nika Jurlin / MWSKY-II / 22. 03. 19.

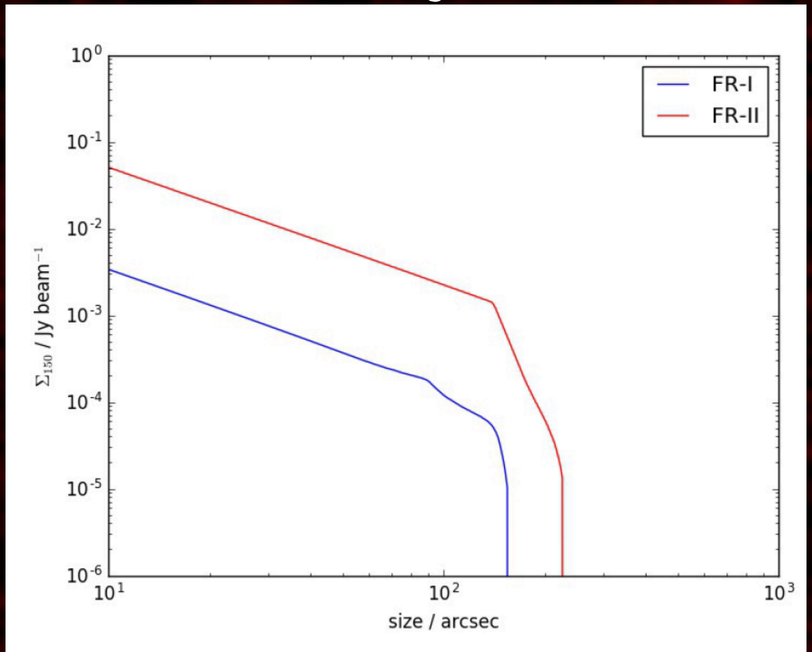
In progress!

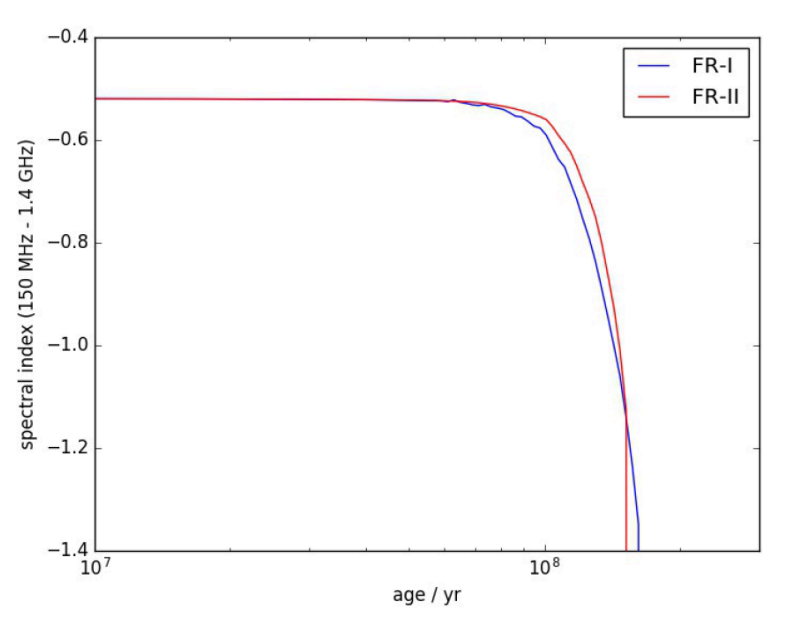
Modelling (**RAiSE** model; Turner&Shabala 2015)

Dr **Stas Shabala**, University of Tasmania

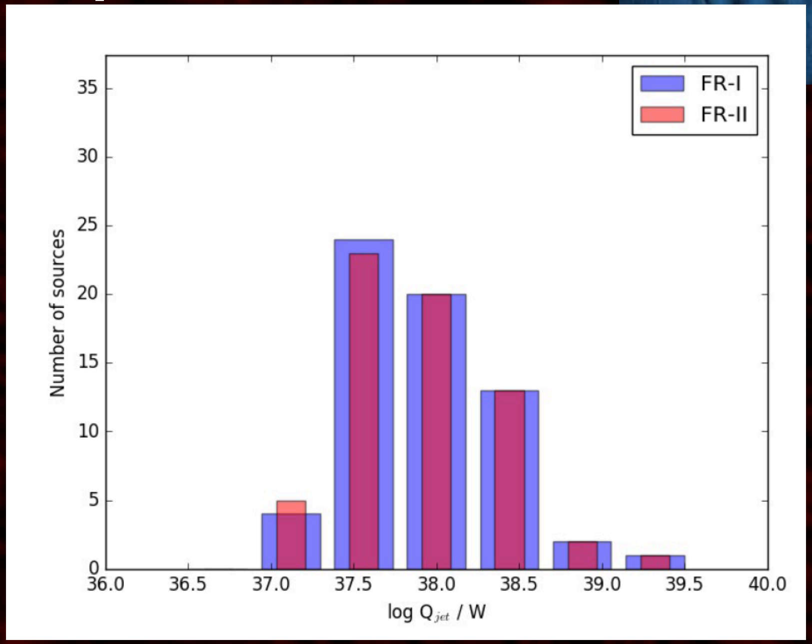
- Jet power
- Environment
- Redshift

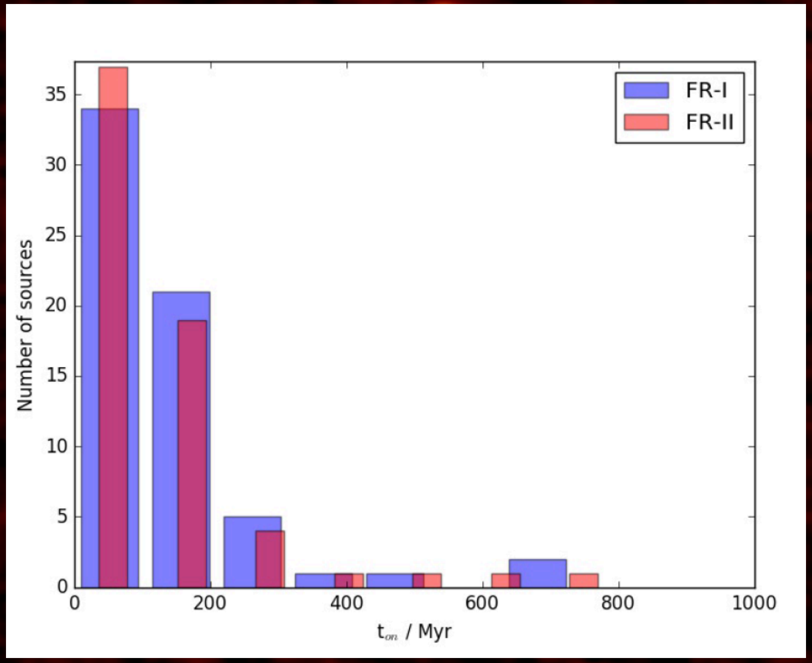
Individual objects





Population distribution





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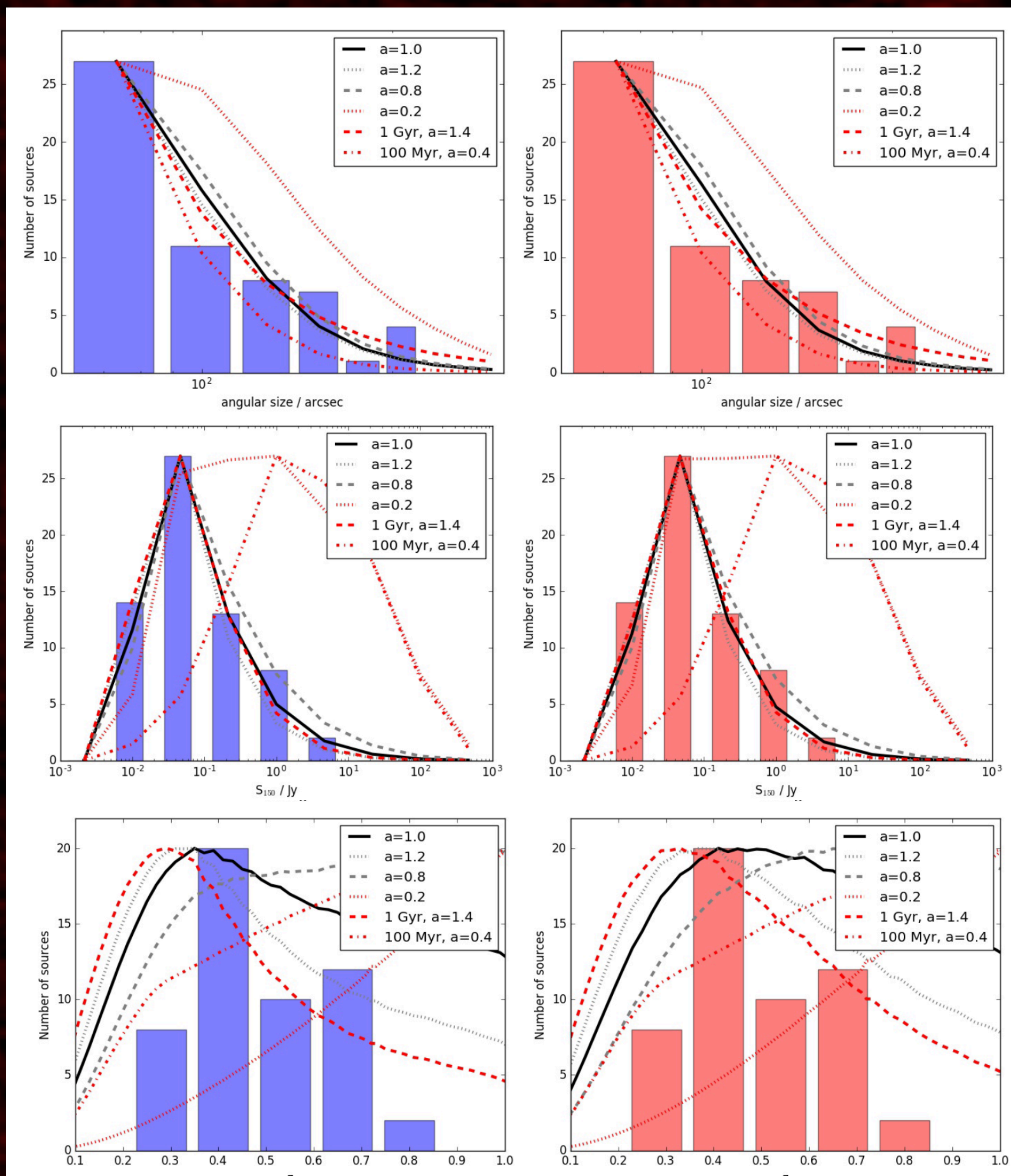
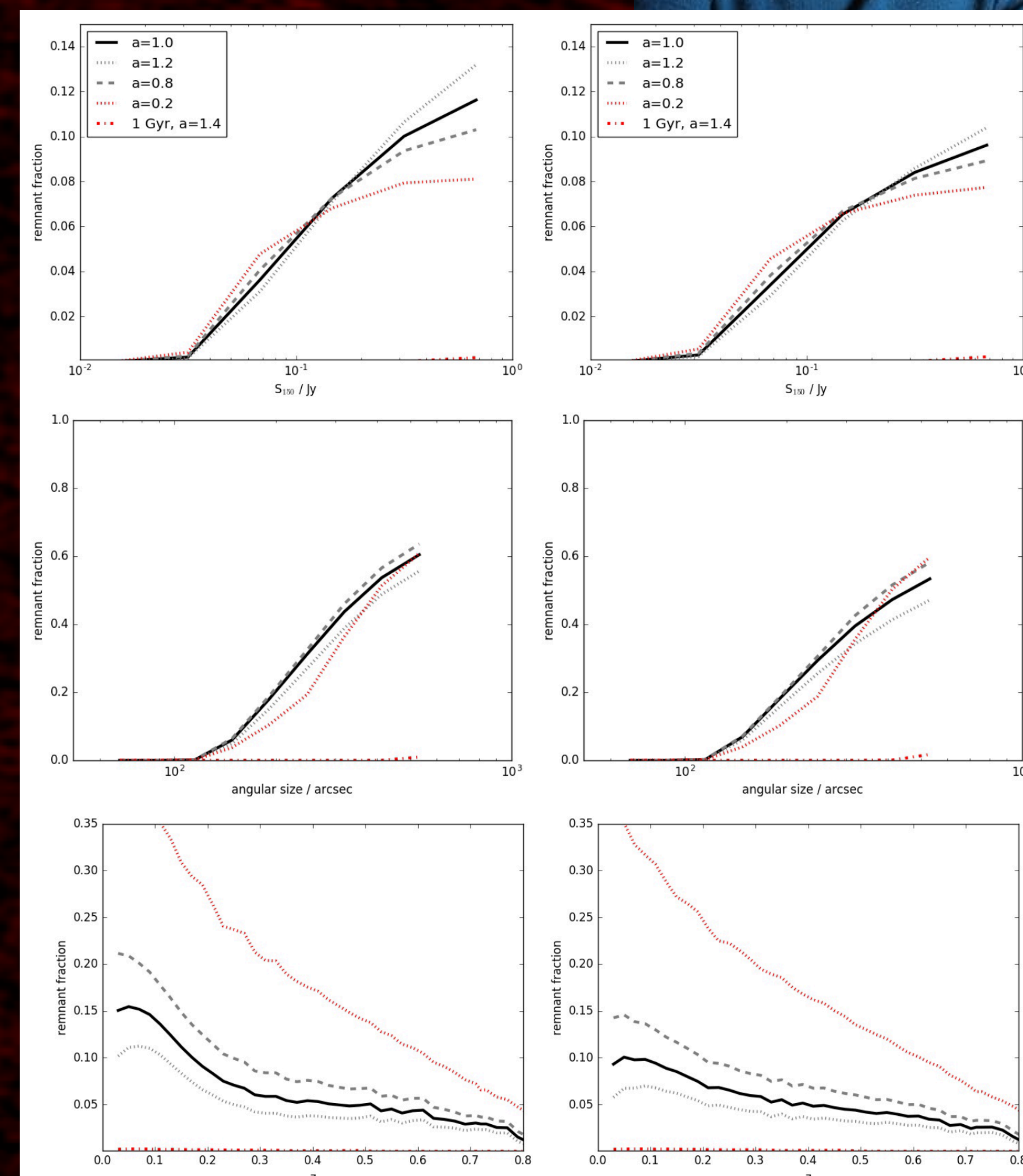
Active RGs



Remnant fraction
= N(rem)/N(act+rem)



Summary and future

- Restarted radio sources exhibit various radio properties and morphologies
  ⇢ need for statistical sample

- Remnants fade quickly (Brienza+17) and a large number of them manages to restart before remnants manage to fade away

- All of our radio sources come from the same parent population

- Modelling

- High reslution VLBI

- Look for HI (Apertif)

- Apply criteria to HETDEX