Exploring radio processes at cosmic noon with WISSH

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ISTITUTO NAZIONALE DI ASTROFISICA

WISSH

SAPIENZA
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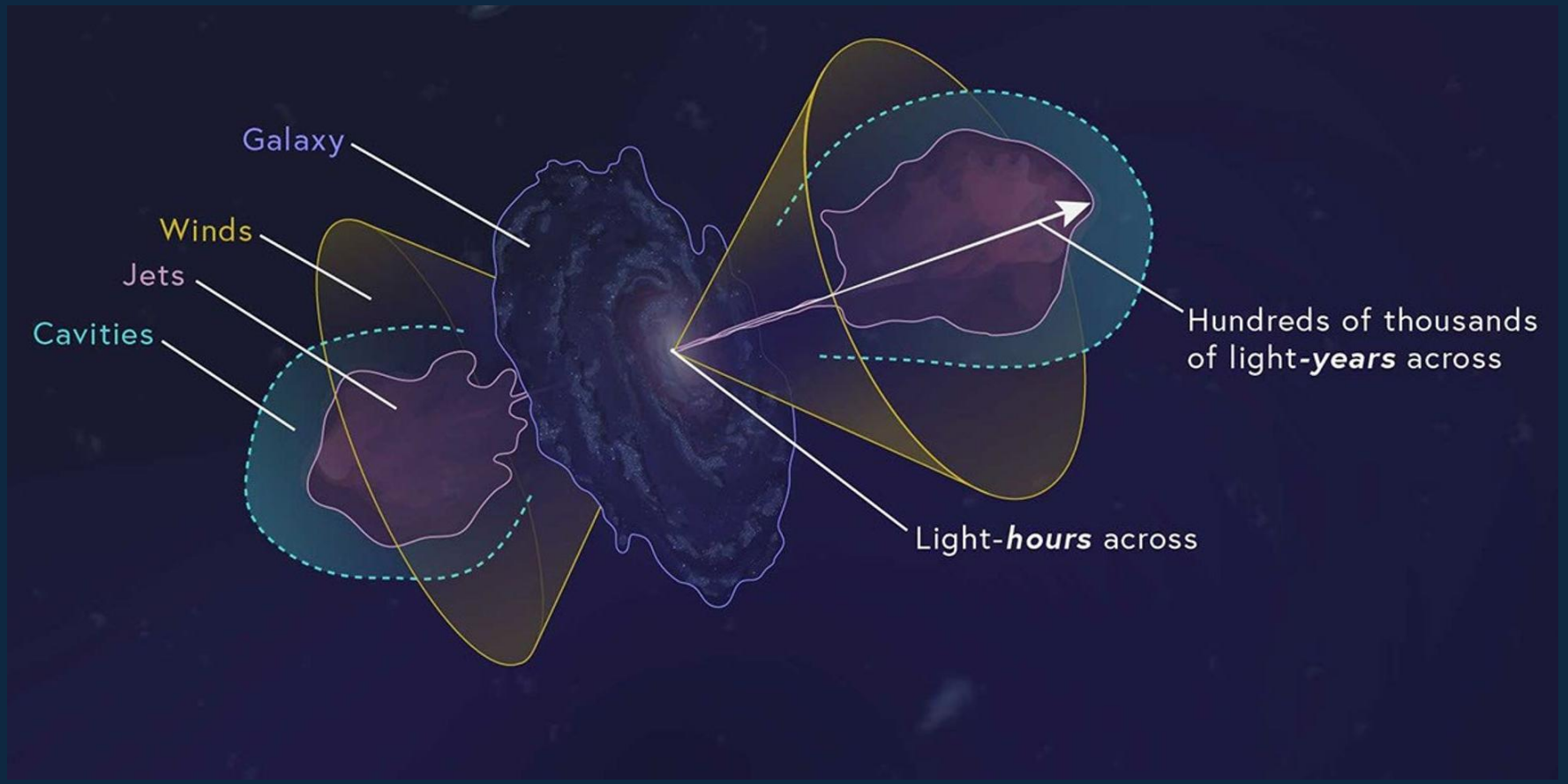
AGN feedback



The WISSH project

WISE- SD**SS H**yper-luminous quasars

85 Hyper-luminous ($L_{Bol} > 2 \times 10^{47}$ erg/s) **radio-quiet** quasars with **z~1.77-4.73** (cosmic noon)-> peak of SMBH accretion

- Very massive black holes accreting at high accretion rates
- Powerful winds, up to ~50,000km/s
- Very high Star formation rates (SFR)

WISSH project: the radio view

Radio characterization: are there jets? or newborn ones? how do they interact with winds?

Our objectives:

- Look for young sources from the SED
- Explore an unknown regime of high redshift and high luminosity radio galaxies
- Test possible star-formation, winds/outflow, corona, and jet models

Observations

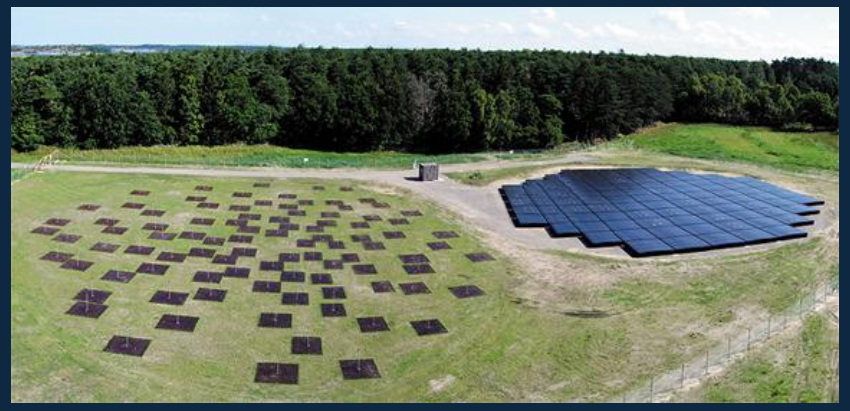
Proprietary data:

- JVLA (PI: Gabriele Bruni):
  - S-band (2-4 GHz, 63/85 detections)
  - C-band (4-8 GHz, 56/85 detections)
  - X-band (8-12 GHz, 38/85 detections)

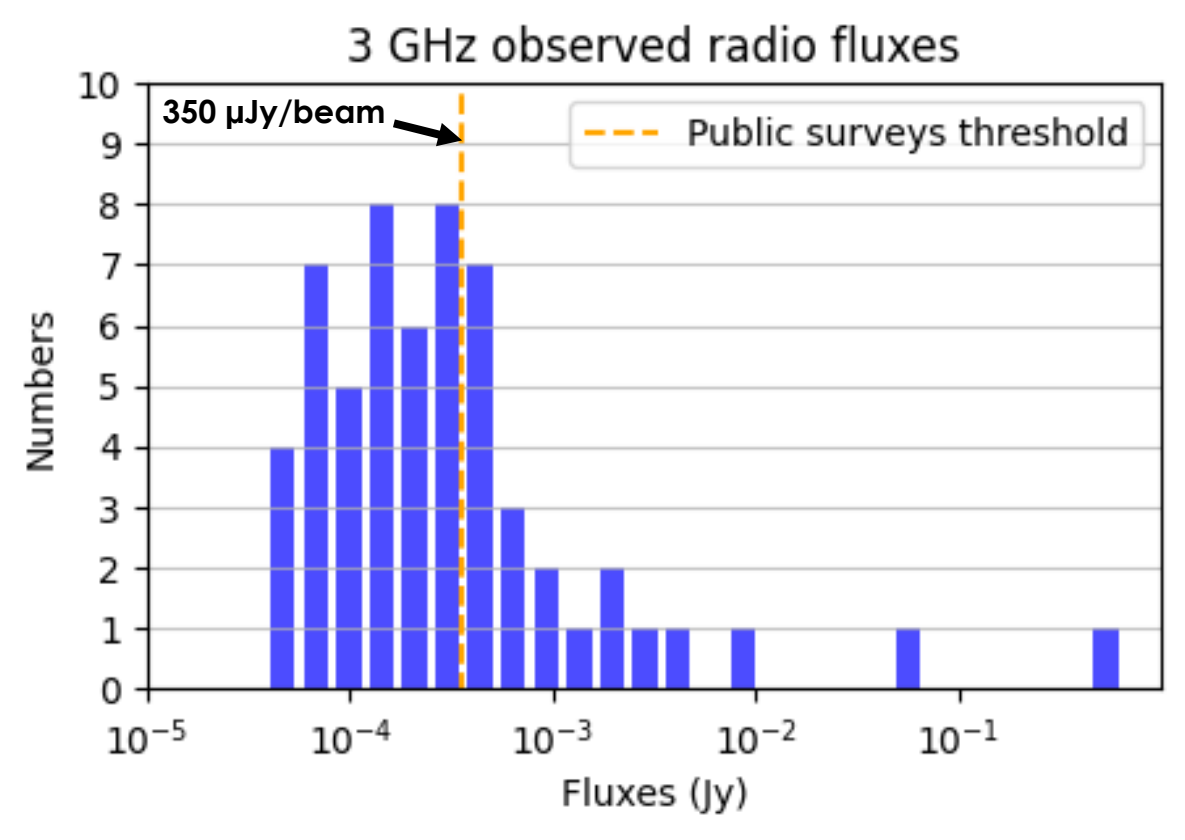
- GMRT (PI: Gabriele Bruni)
  - Band 3 (310 MHz, 39/85 detections)
  - Band 4 (670 MHz, 36/85 detections)

Archival data:

- LoTSS survey (150 MHz, 59/85 detections)
- FIRST survey (1,4 GHz, 19/85 Detections)

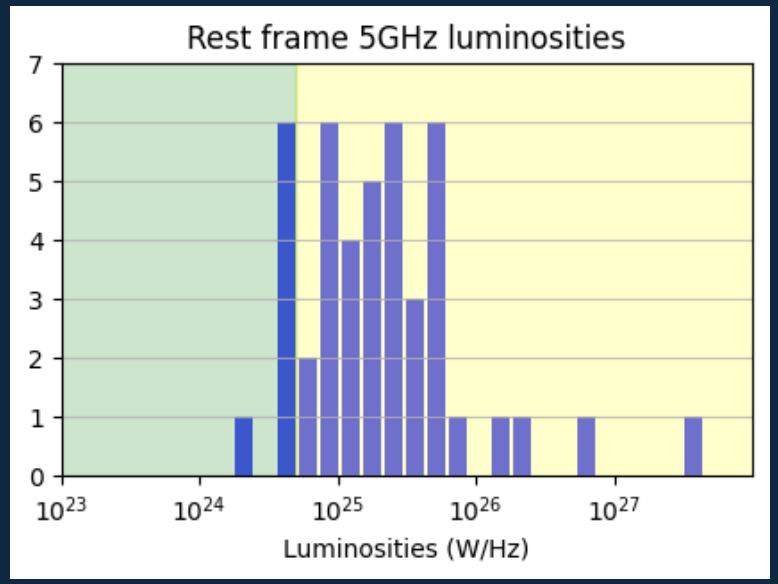


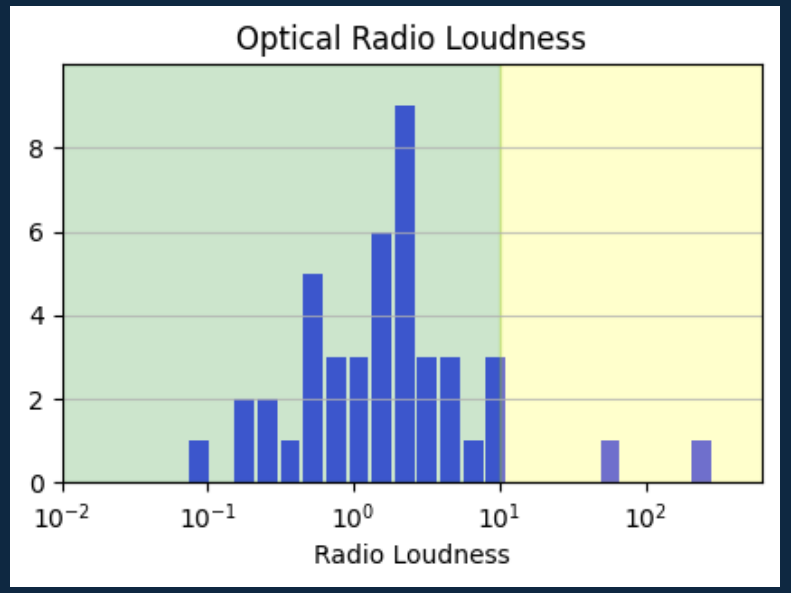
New sensitivity

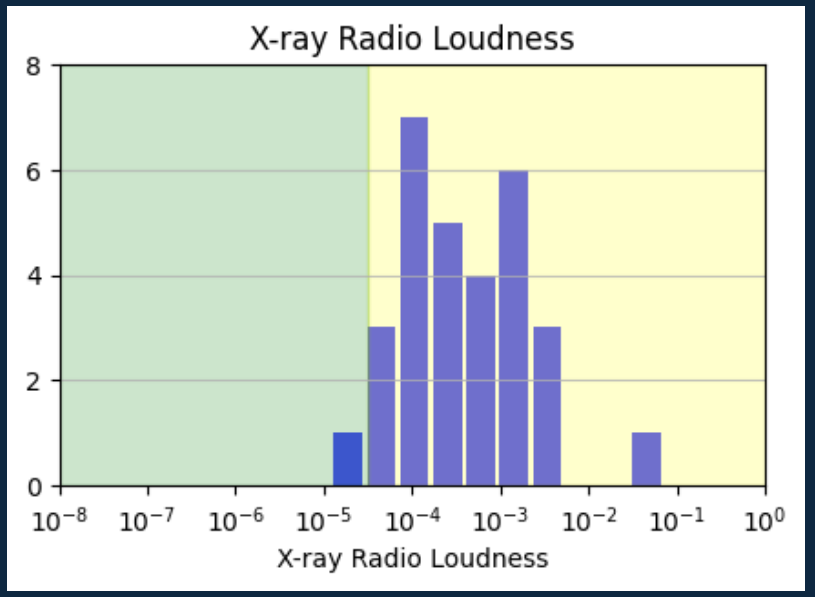


- Bruni et al 2019: only 20 detected sources (~23%) from public surveys (FIRST, VLASS) at ~350 μJy/beam
- New detection rate: ~74% at ~30 μJy/beam
- A new population of sources ''appeared'' with our new observations!

Radio powers/loudness







$$P_{5GHz} > 10^{24.7} W/Hz$$

Padovani 1993

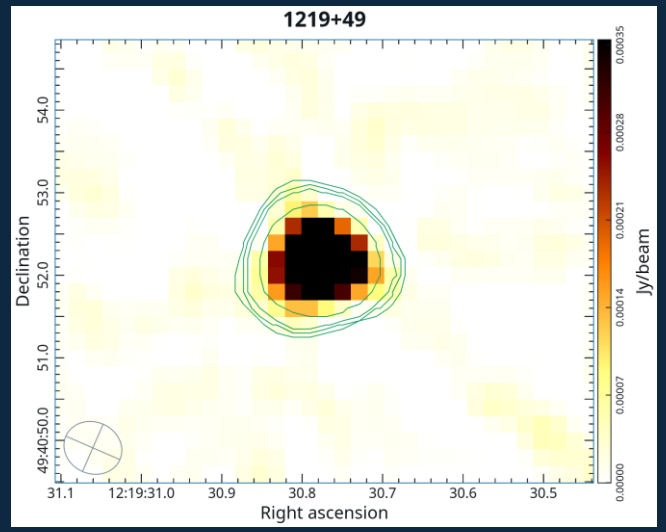
$$R = \frac{L_{6cm}}{L_{4400\text{Å}}} > 10$$

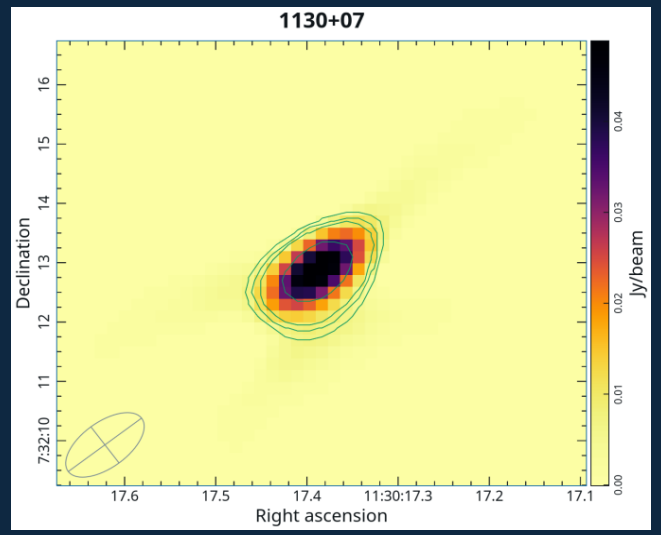
Kellerman et al 1989

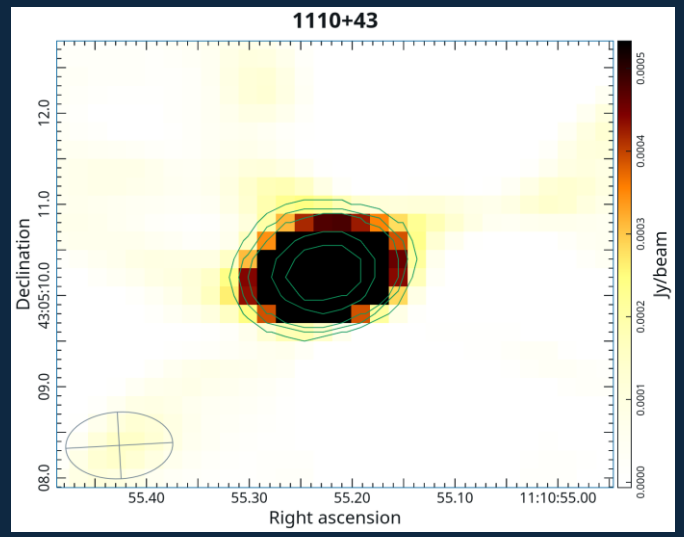
$$R_X = \log_{10}\left(\frac{L_{6cm}}{L_{2-10keV}}\right) > -4.5$$

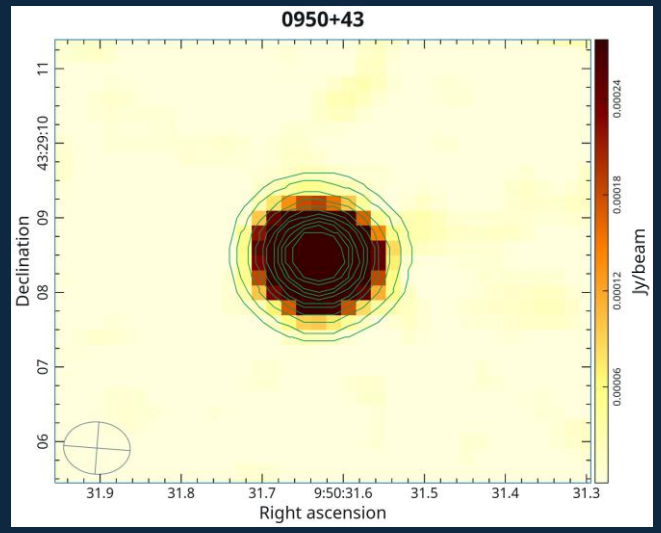
Terashima et al 2003

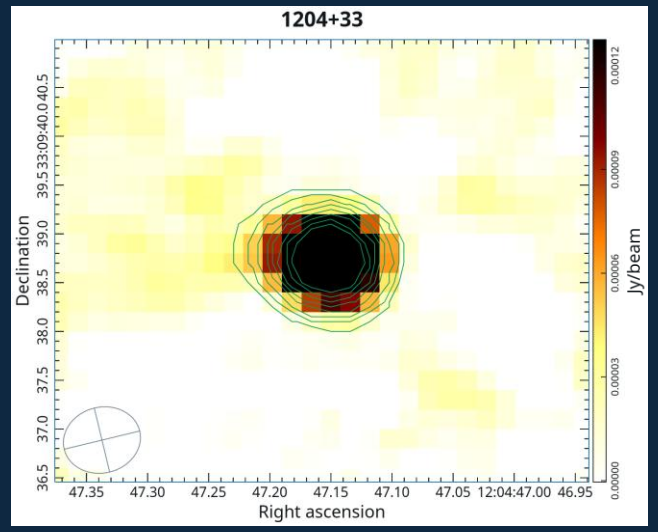
Many unresolved QSOs

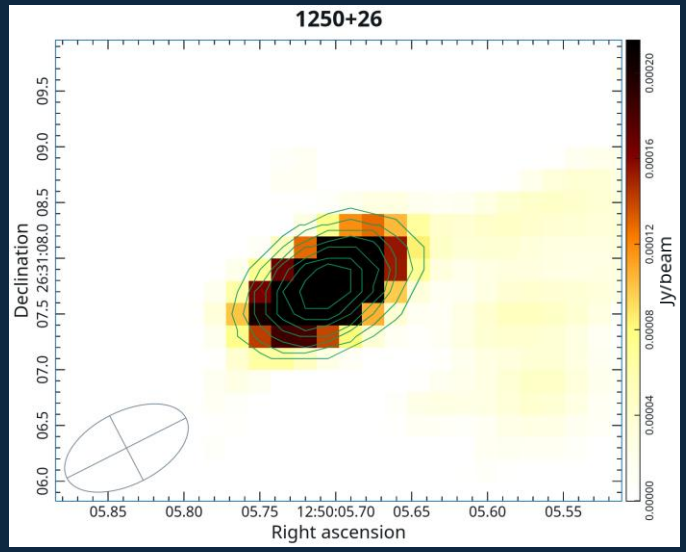




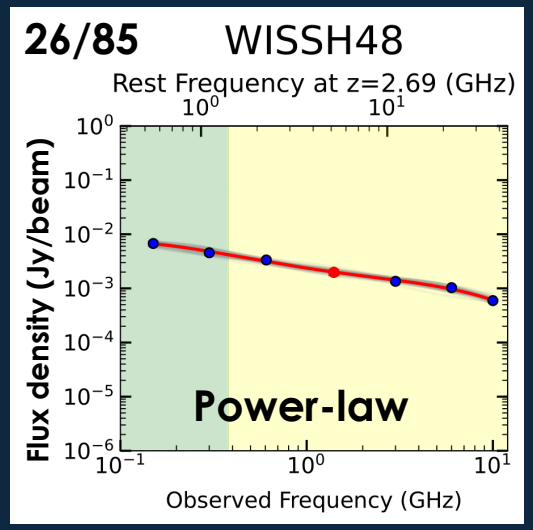


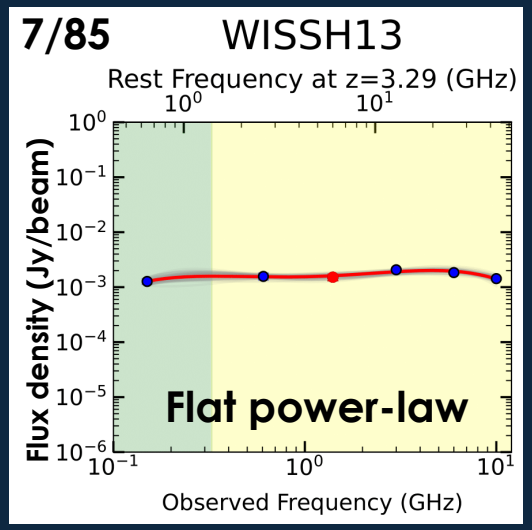


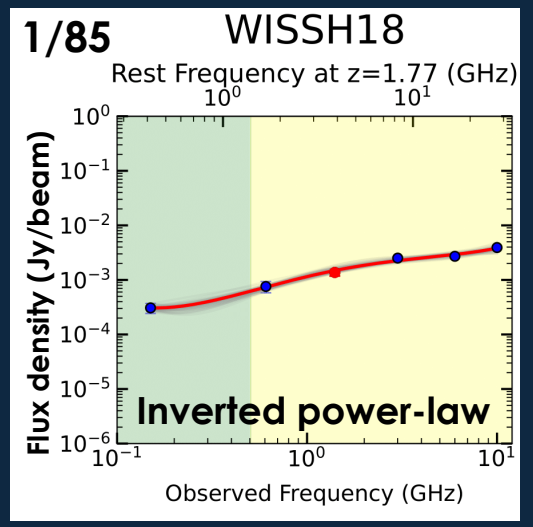


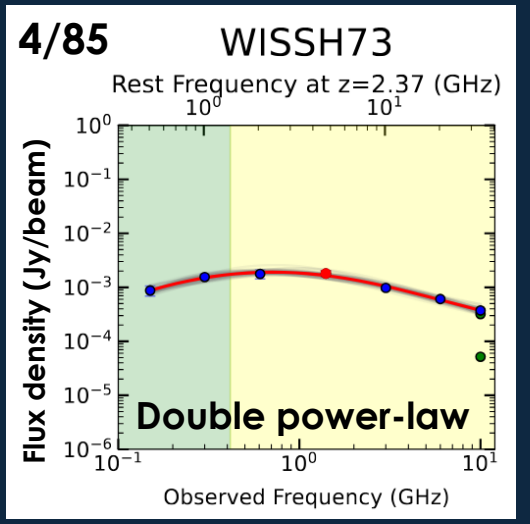


Polynomial SED fitting

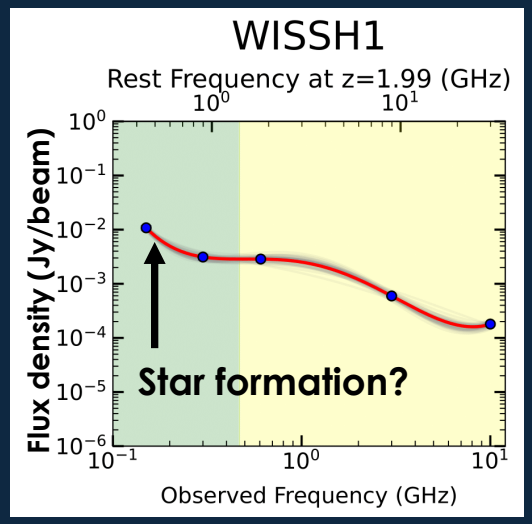


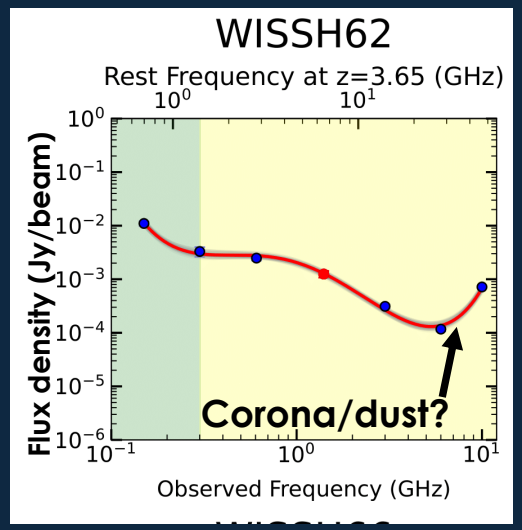


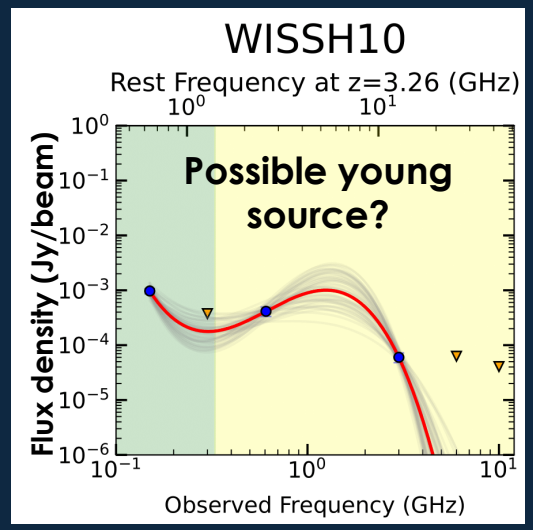




Unclear fits: 19/85
Failed fits: 28/85







Polynomial fit

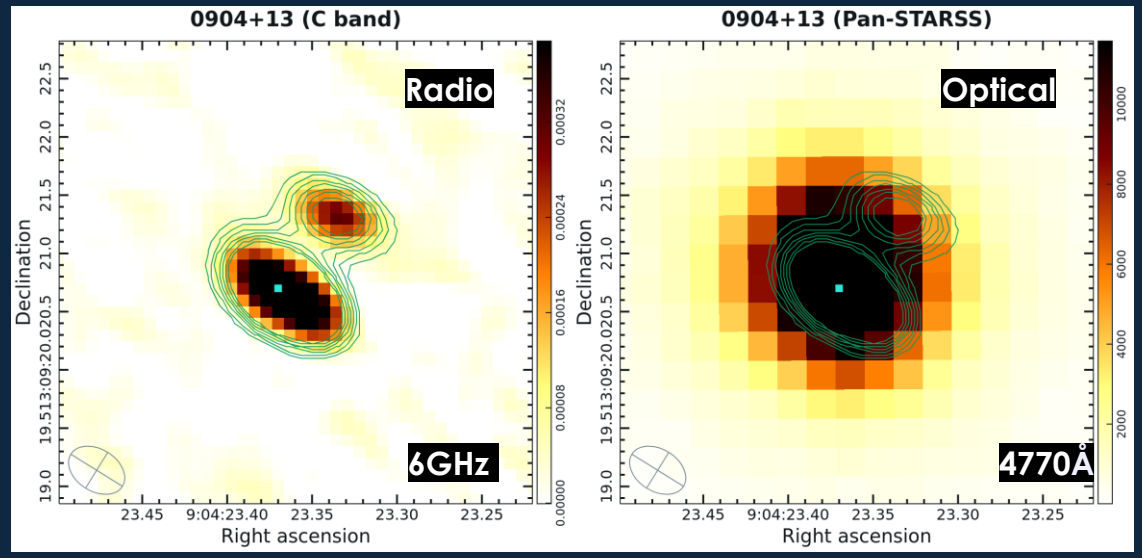
$$y = A_0 + A_1 x + A_2 x^2 + A_3 x^3 + A_4 x^4$$

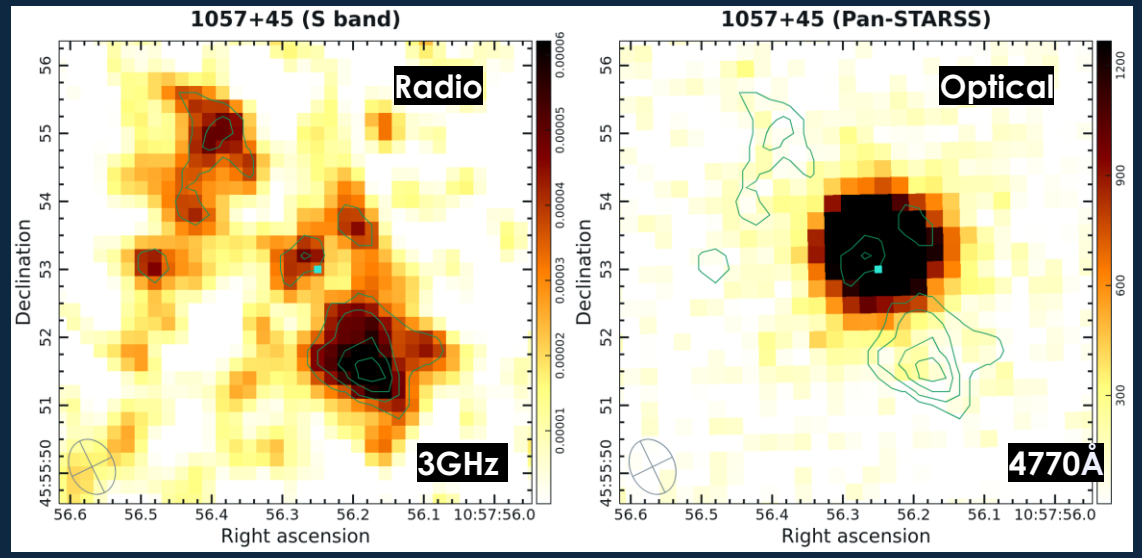
$$y = A_0 + A_1 x + A_2 x^2 + A_3 x^3$$

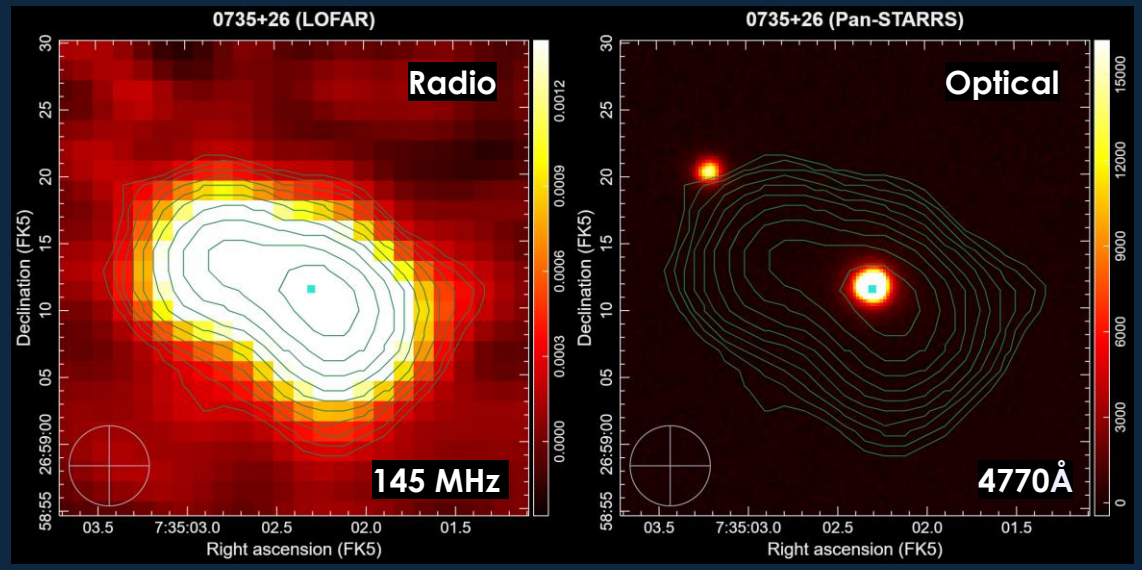
Inspired by Boxelaar+2025

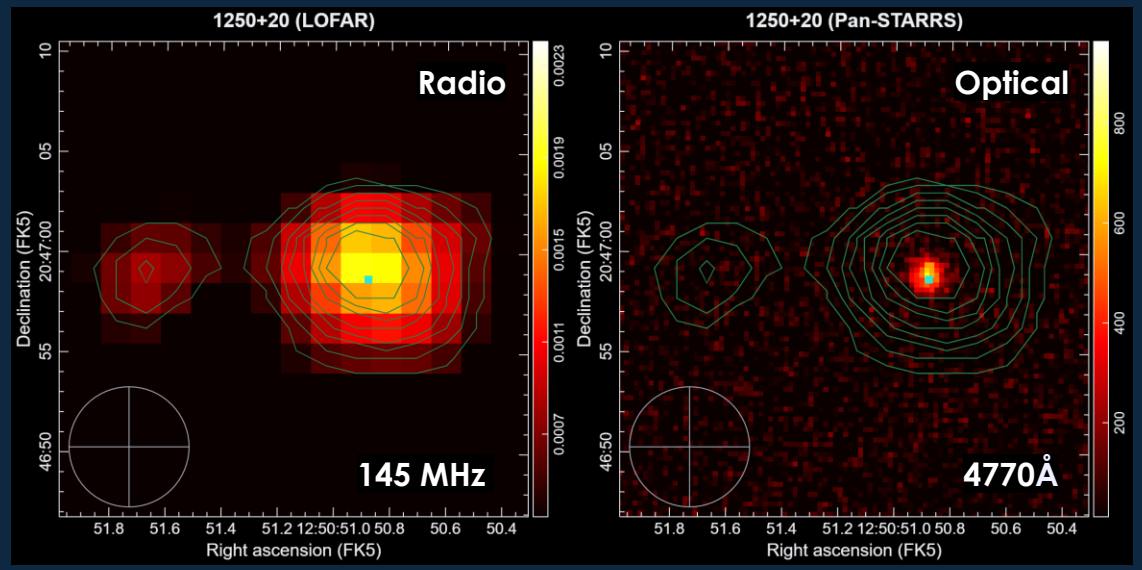
Resolved sources

VLBI images coming soon!

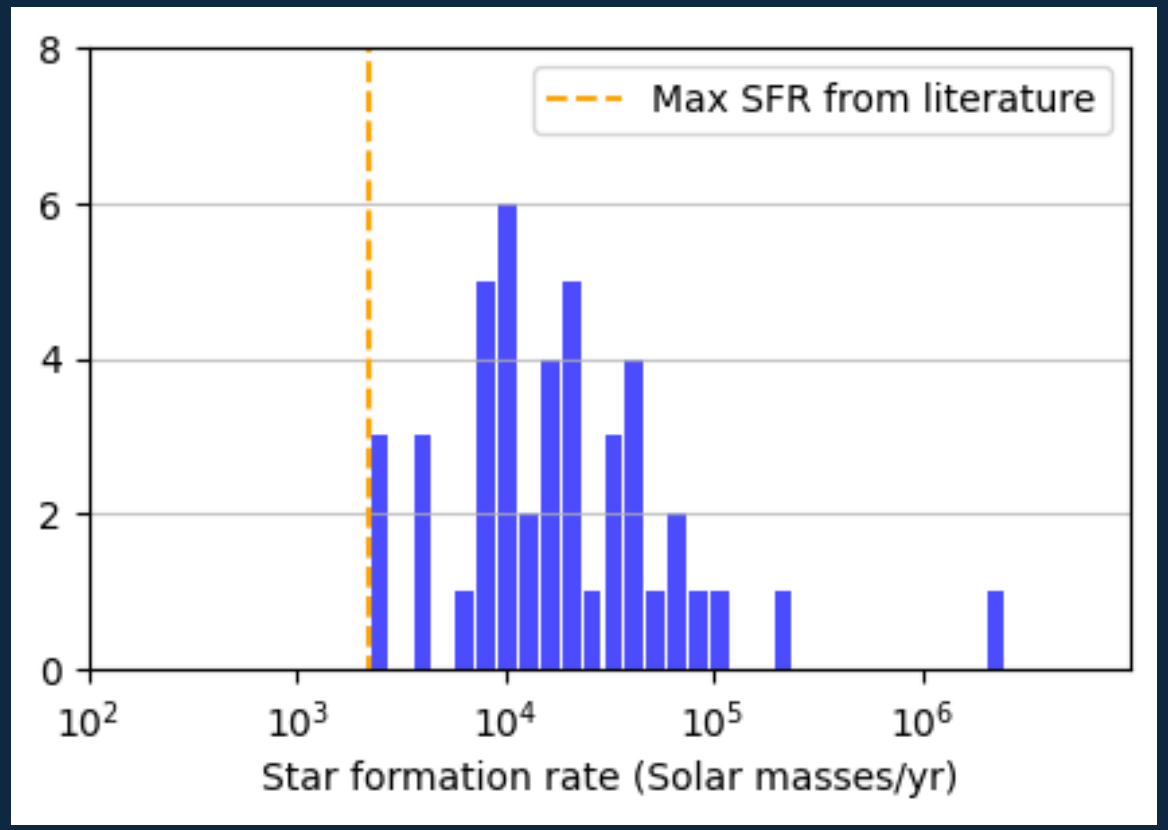








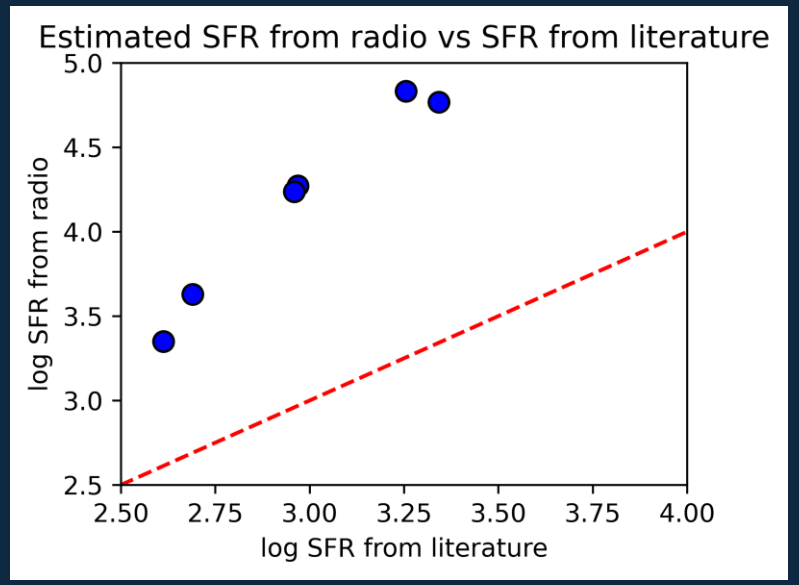
Is this star formation?



Expected radio power from only star formation contribution

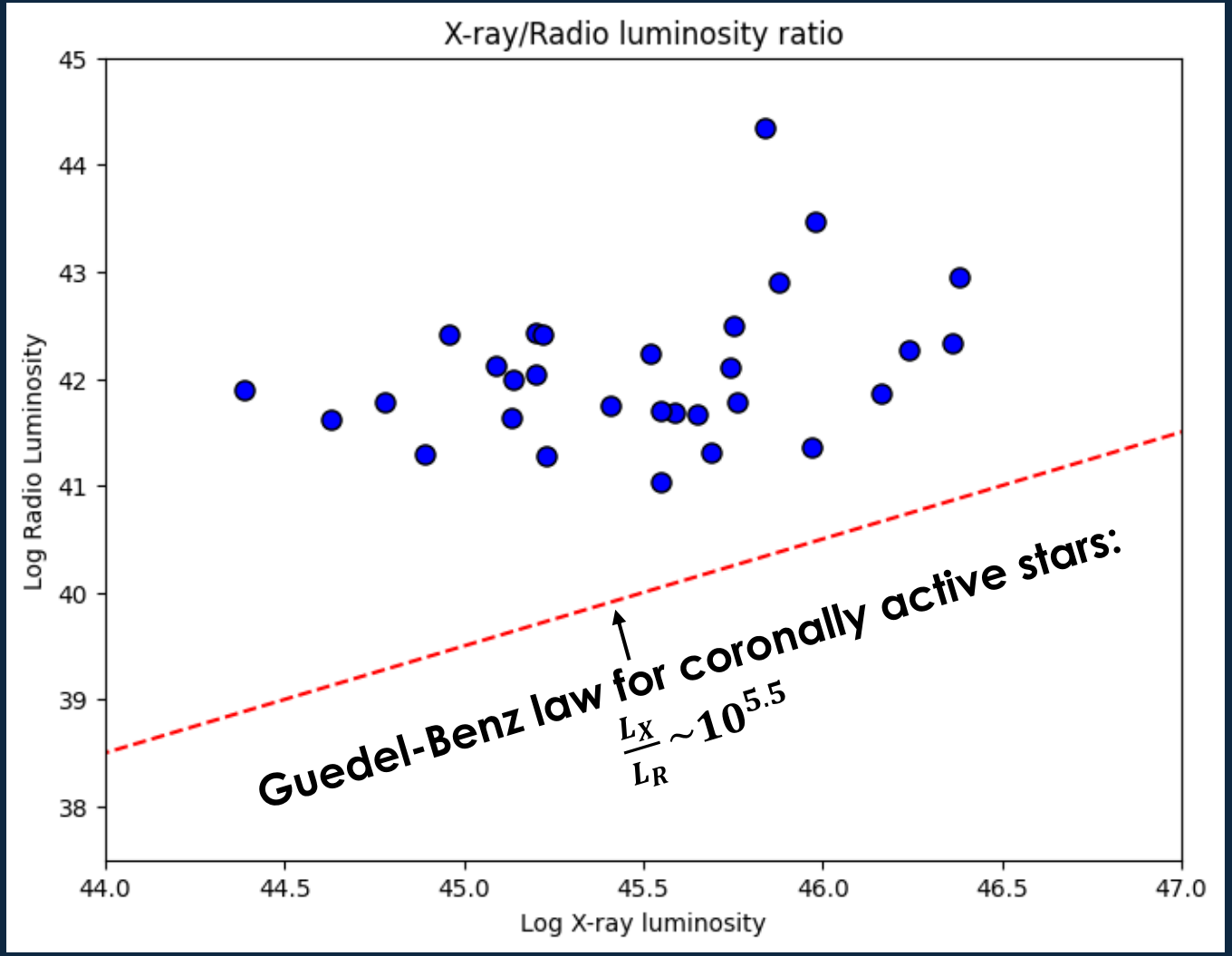
$$SFR_R \approx 4.6 \times 10^{-22} \left(\frac{L_{1.4GHz}}{W/Hz} \right) M_\odot/yr.$$

Condon 1992



…not likely.

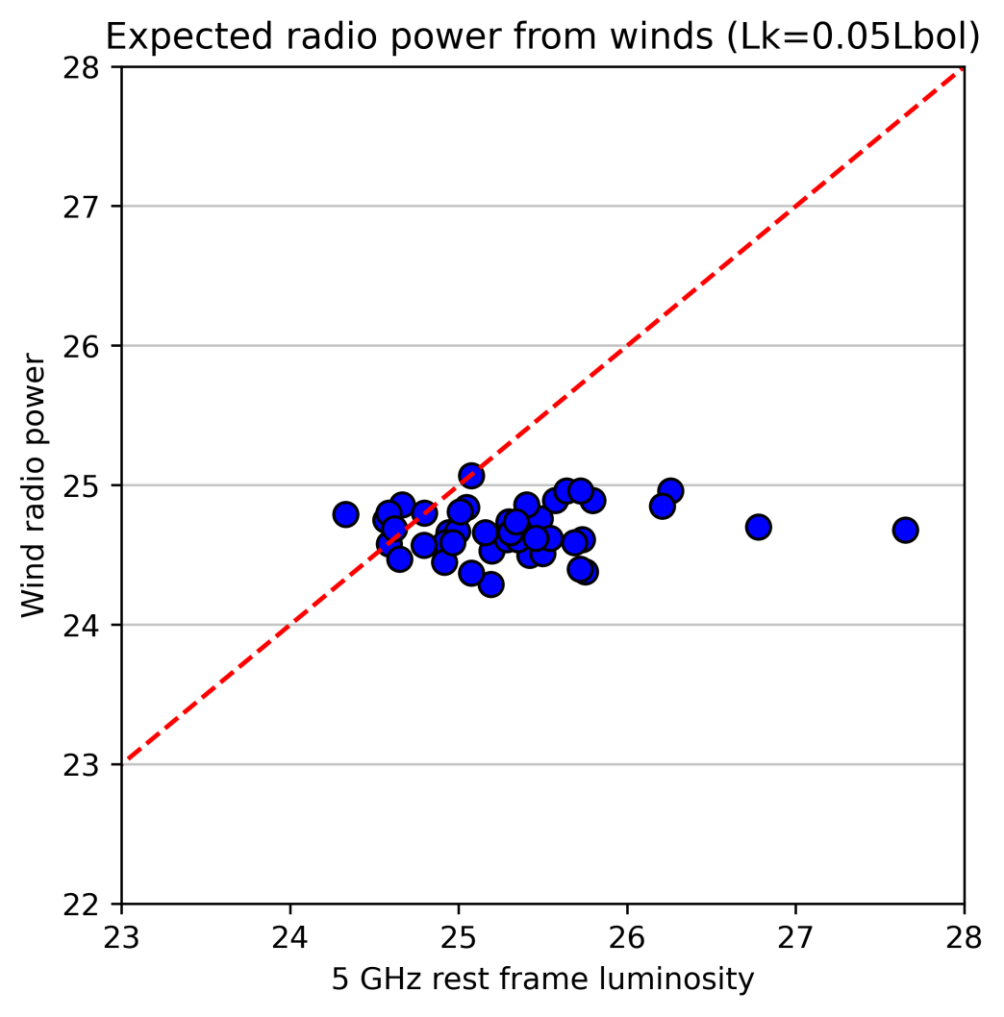
Is this coronal emission?



Guedel Benz 1993

...not likely.

Is this wind emission?



Expected radio power from only-wind contribution

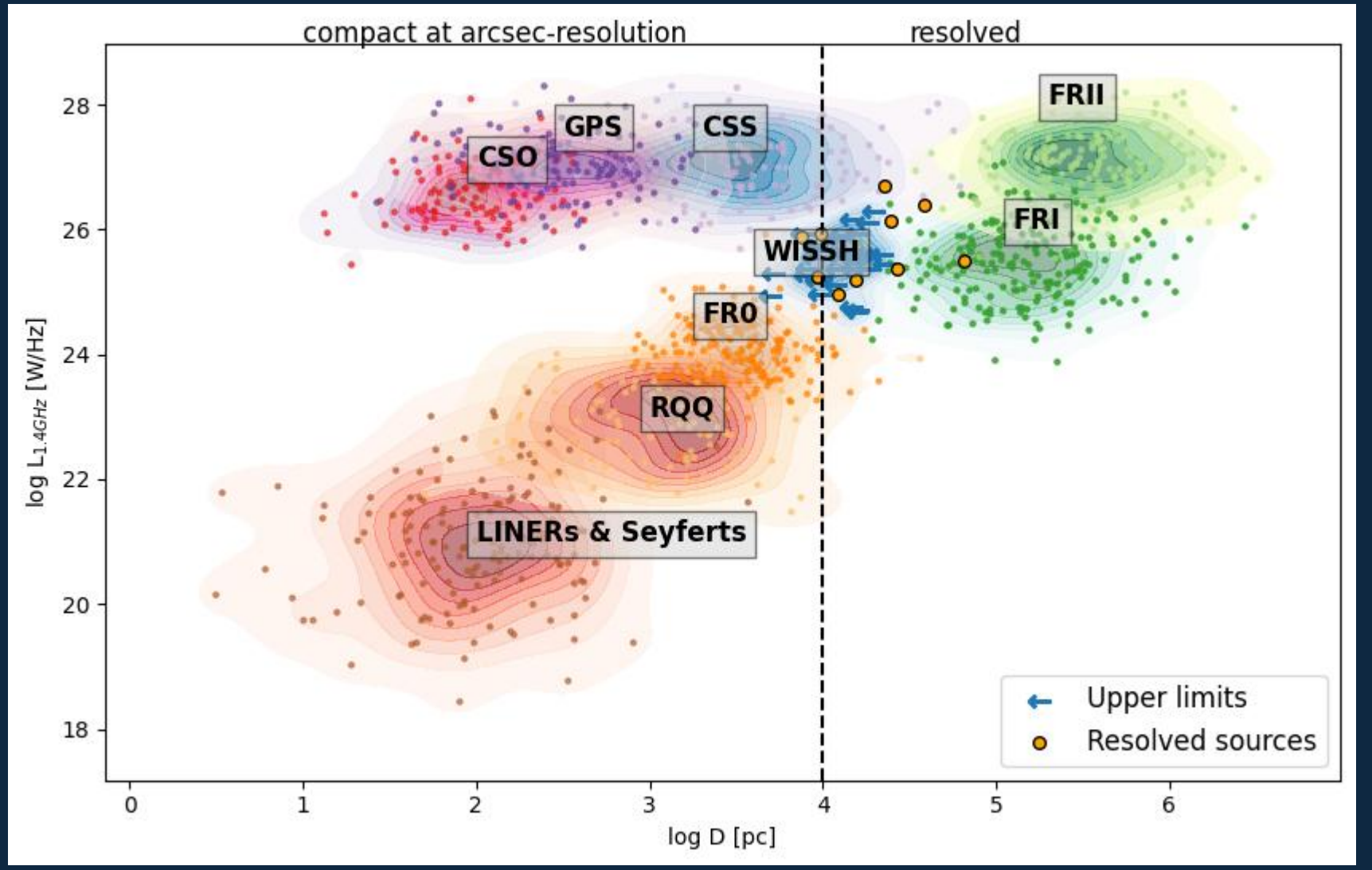
$$\nu L_\nu \approx 10^{-5} \xi_{-2} L_{bol} \left(\frac{L_k}{0.05 L_{bol}} \right) erg/s$$

Nims+2015

Assuming $L_k = 0.05 L_{bol}$ estimated from the literature

…maybe.

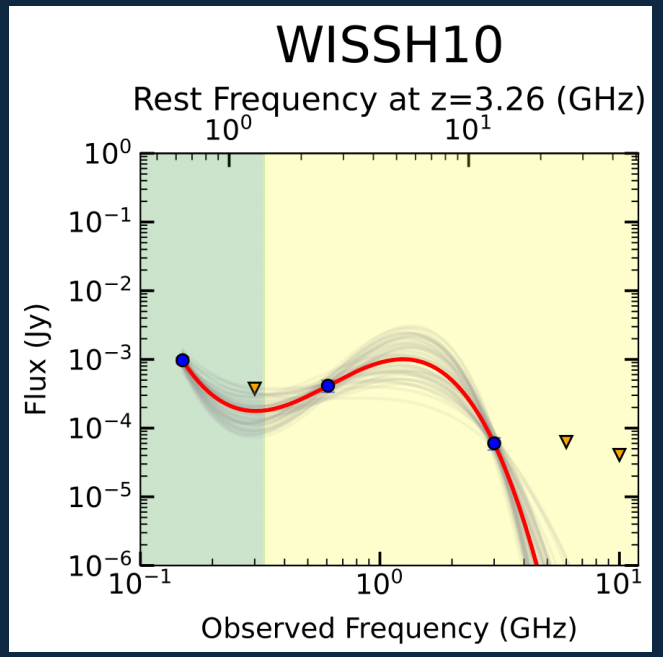
Linear sizes vs luminosity



Inspired by Baldi+23 and Amenta+ in prep

How will SKA help us?

- SKA alone would be able to reproduce this whole study for the southern sky, maybe even at higher redshifts
- More sensitivity:
  - Even higher detection rates
  - New constraints on the spectral shapes
  - New complex structures
- SKA VLBI will help us resolve in great detail the radio structures



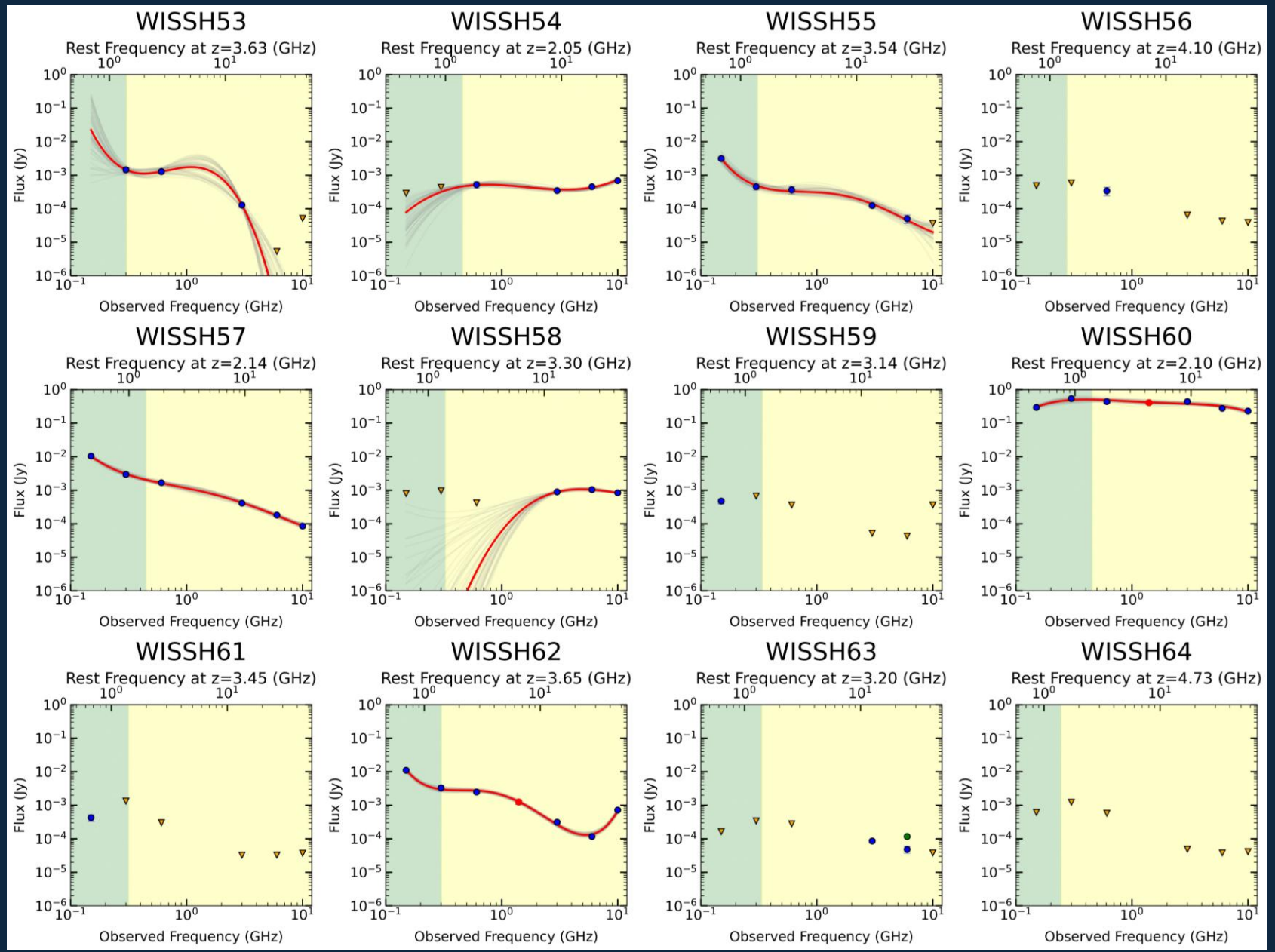
Conclusions and next steps

- Very high detection rates
- Peculiar spectral features (strong radio, very strong optical, weak X-rays)
- Strong clues of outflows activity, such as 29 resolved sources

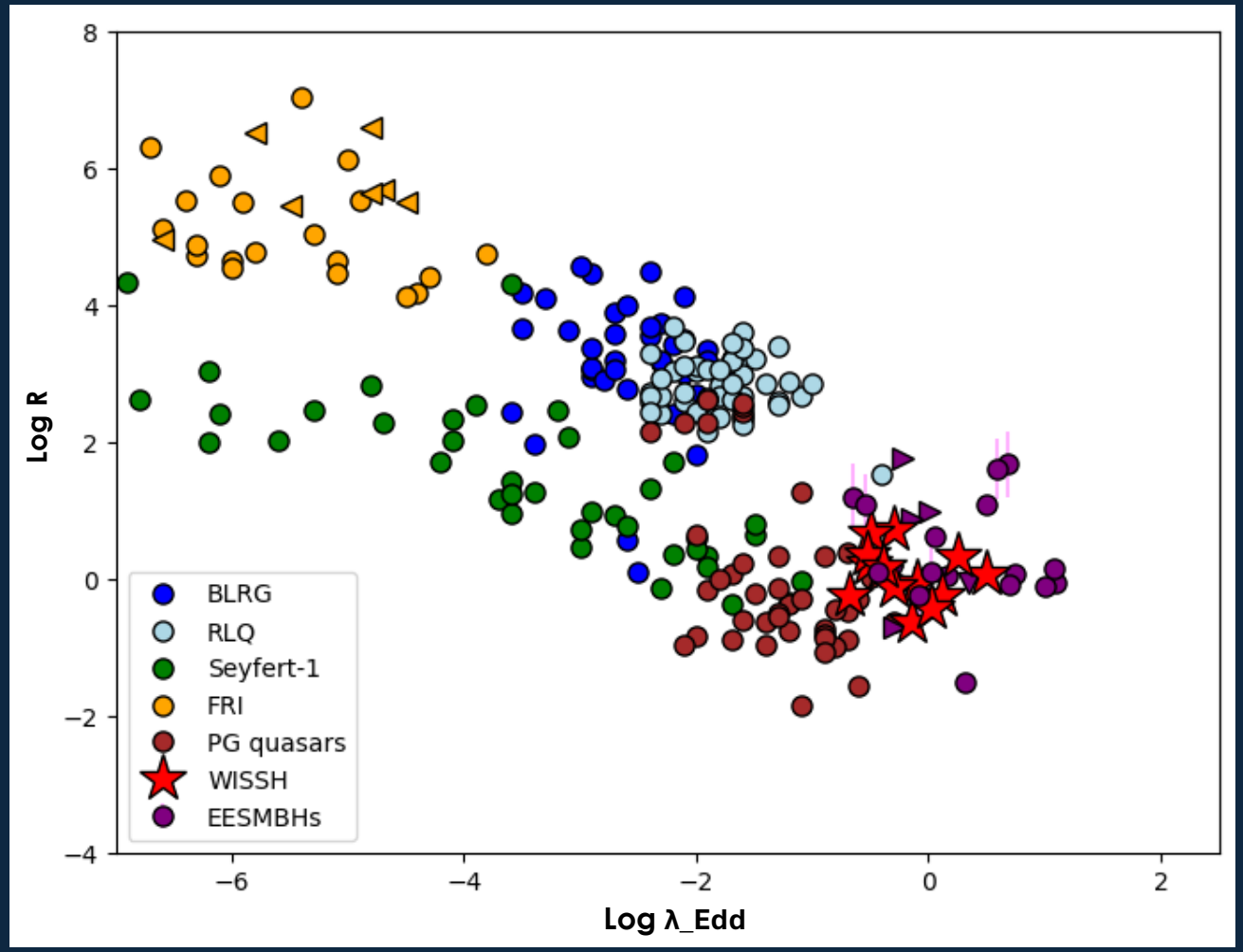
Next steps:

- Submitted EVN proposal to look for compact jets signatures
- Search for coronal activity with JVLA

Backup slides


WISSH53
Rest Frequency at z=3.63 (GHz)
WISSH54
Rest Frequency at z=2.05 (GHz)
WISSH55
Rest Frequency at z=3.54 (GHz)
WISSH56
Rest Frequency at z=4.10 (GHz)
WISSH57
Rest Frequency at z=2.14 (GHz)
WISSH58
Rest Frequency at z=3.30 (GHz)
WISSH59
Rest Frequency at z=3.14 (GHz)
WISSH60
Rest Frequency at z=2.10 (GHz)
WISSH61
Rest Frequency at z=3.45 (GHz)
WISSH62
Rest Frequency at z=3.65 (GHz)
WISSH63
Rest Frequency at z=3.20 (GHz)
WISSH64
Rest Frequency at z=4.73 (GHz)
Flux (Jy)
Observed Frequency (GHz)

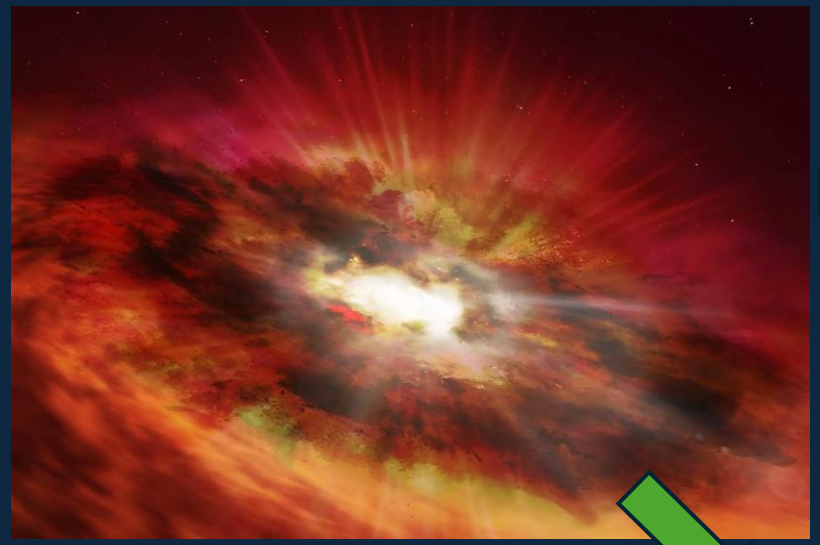
Black hole properties



Inspired by Yang+2020

Evolutive scenario

Obscured



WISSH

Jetted/outflow
(blow-out)

Evolutive scenario