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Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

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AGN OR STAR FORMATION?

The role of wide-field VLBI surveys and the path to the SKA

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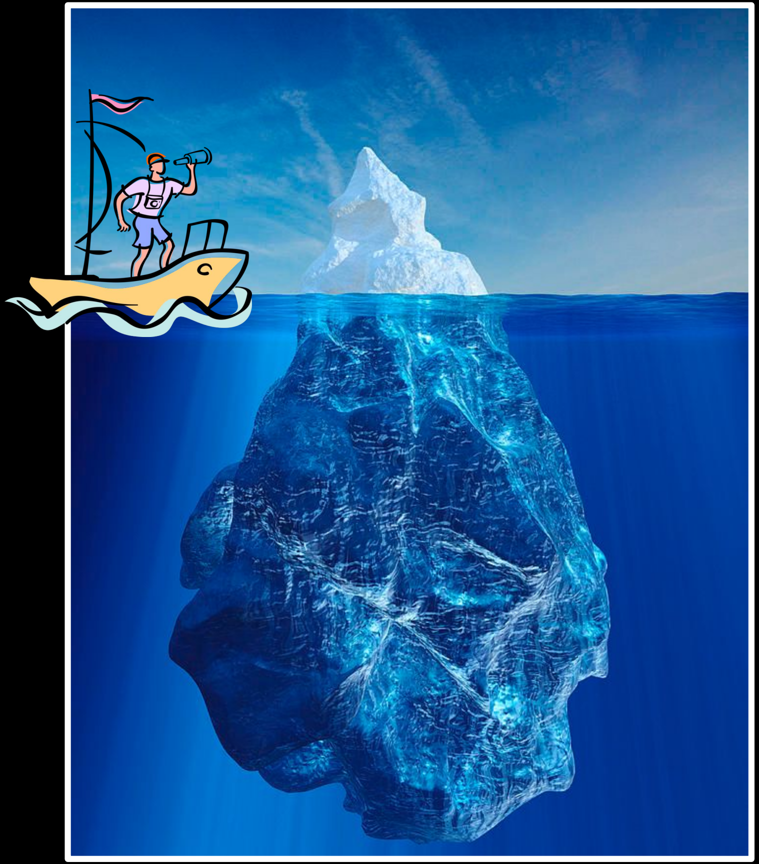
Main collaborators:

J. Radcliffe, C. Spingola, I. Prandoni, G. Peluso, F. Ubertosi, M. Gitti and the COSMOS team

AGN vs SF? A long-standing problem



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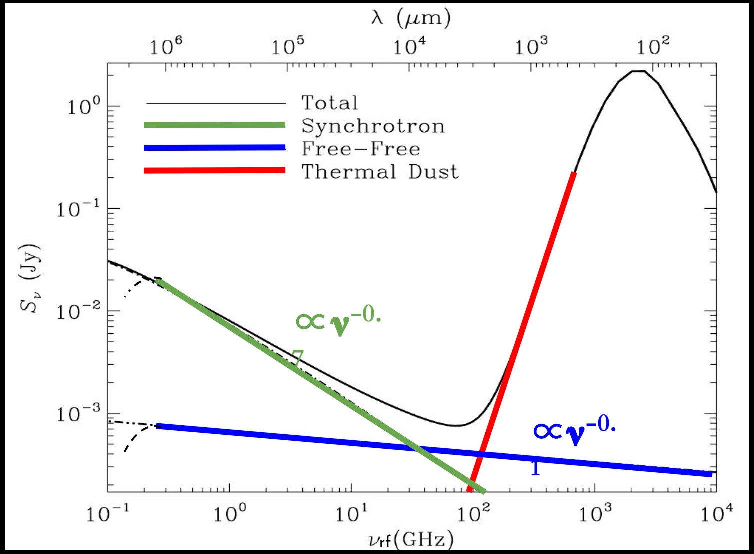

Murphy 2009

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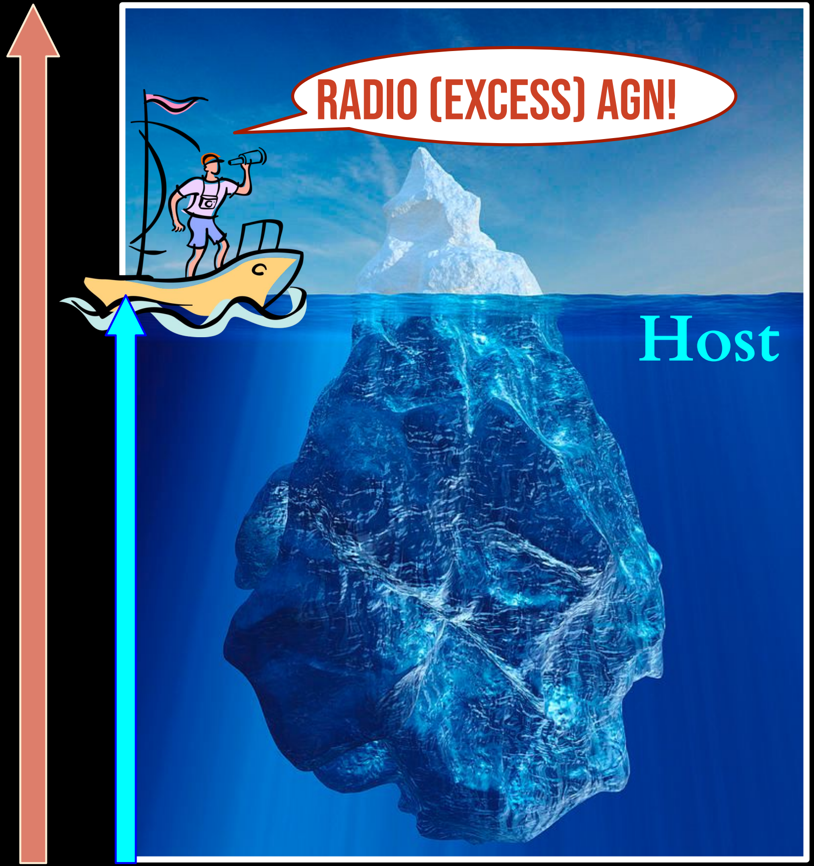
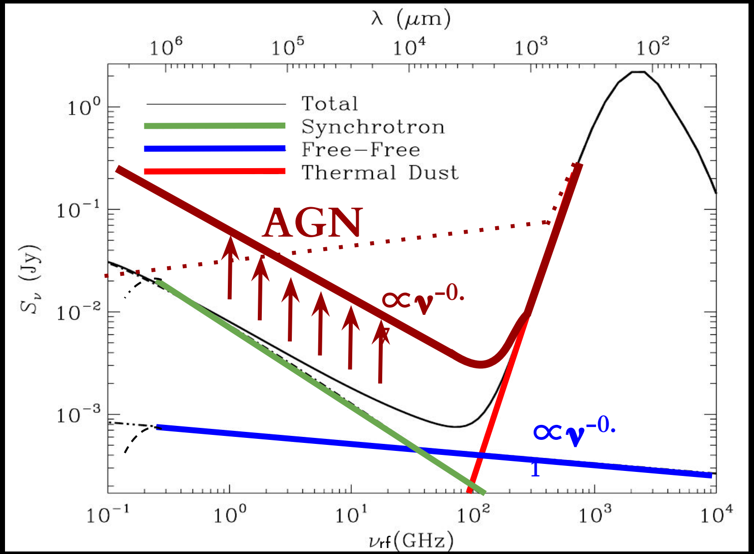


[Radio morphology, spectral index, radio loudness, optical spectra, …]

Brienza+2020; Baldi+2023; Jarvis+2019; 2021; Magliocchetti+2022,2025; Hardcastle+2023, …

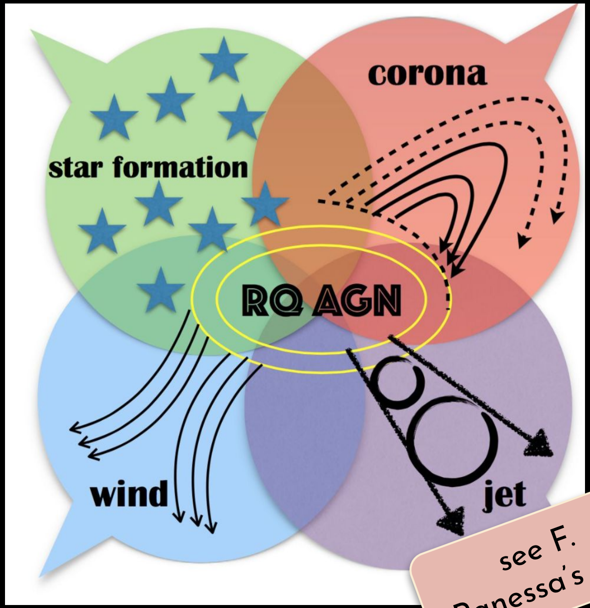


Murphy 2009

AGN vs SF? A long-standing problem

The (composite) nature of RQ-AGN is still debated

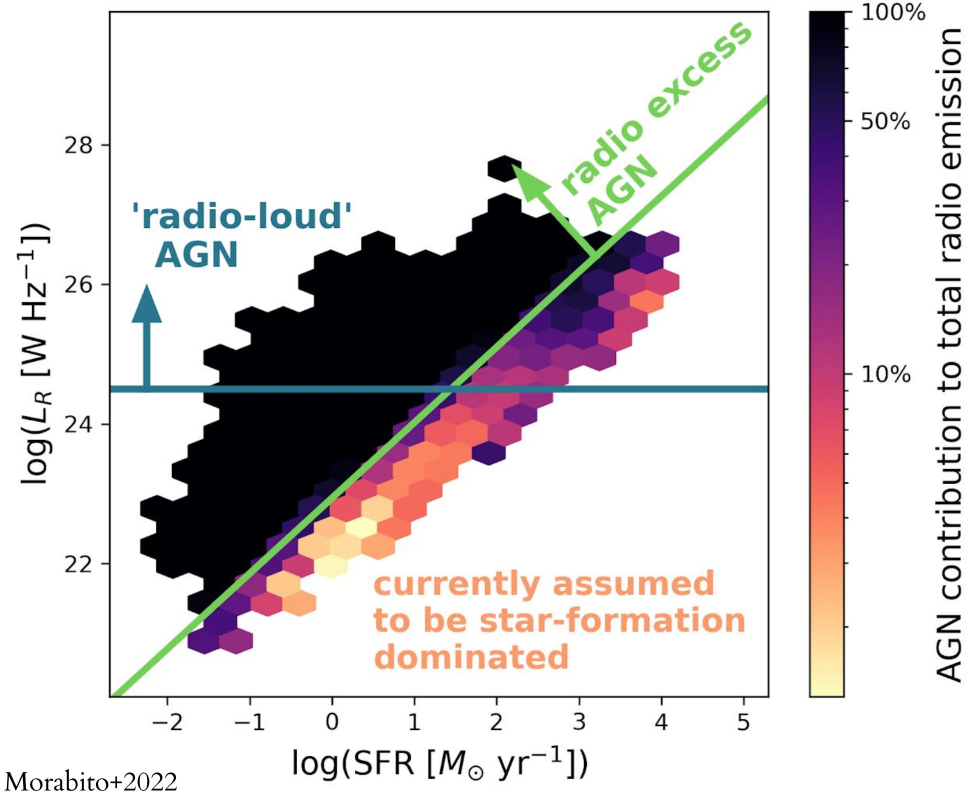
review by Panessa+2019



see F. Panessa's talk

→ There is no "ultimate selection" of RQ-AGN (e.g. Magliocchetti+2022)

Radio-excess criterion: PROs and CONs



Morabito+2022

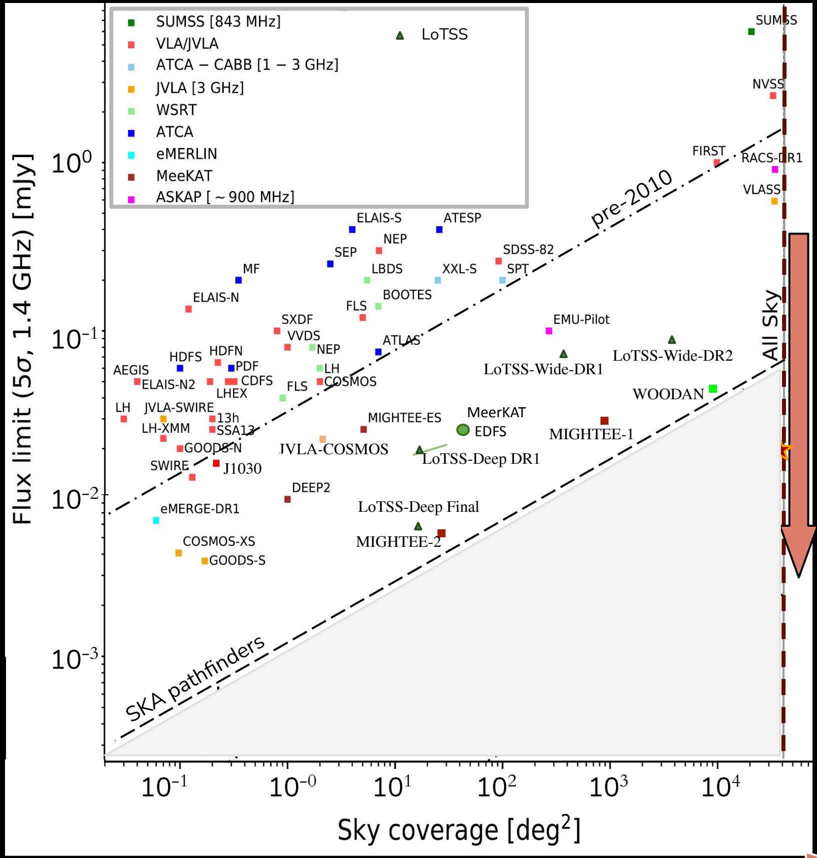
PROs:

- ❑ Reliable AGN tracer
- ❑ Simple recipe

CONs:

- ❑ Incomplete and biased (SFR-dependent)
- ❑ Clear-cut classification based on dominance

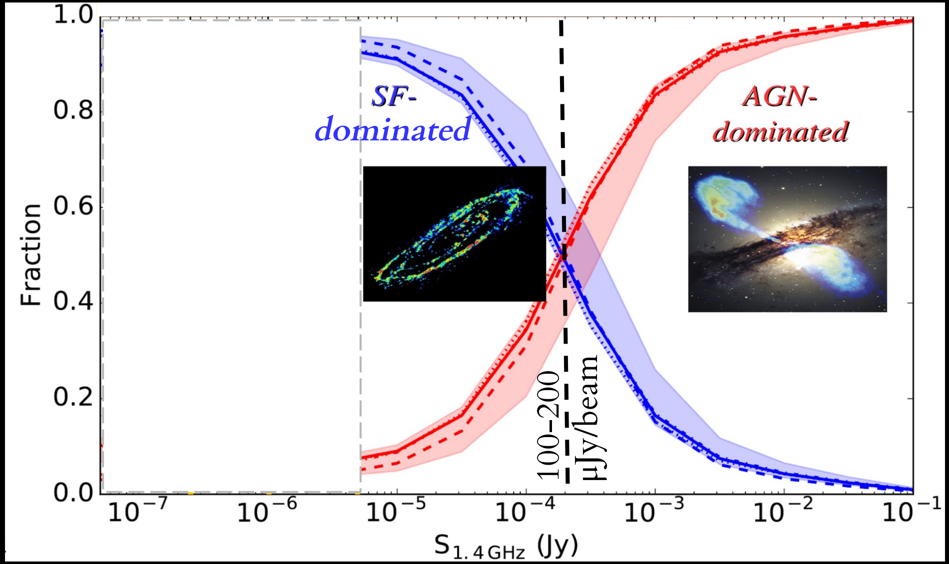
The composite origin of the sub-mJy radio sky



increasing sensitivity

Adapted from Q. D'Amato+2022

increasing area



Adapted from Novak+2018

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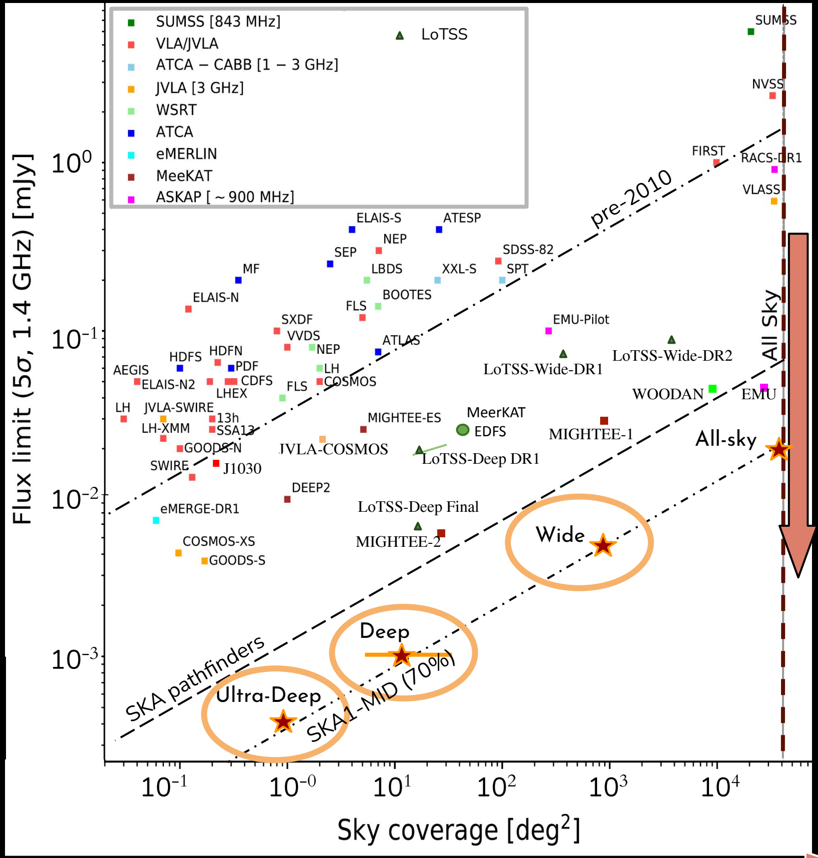

increasing sensitivity

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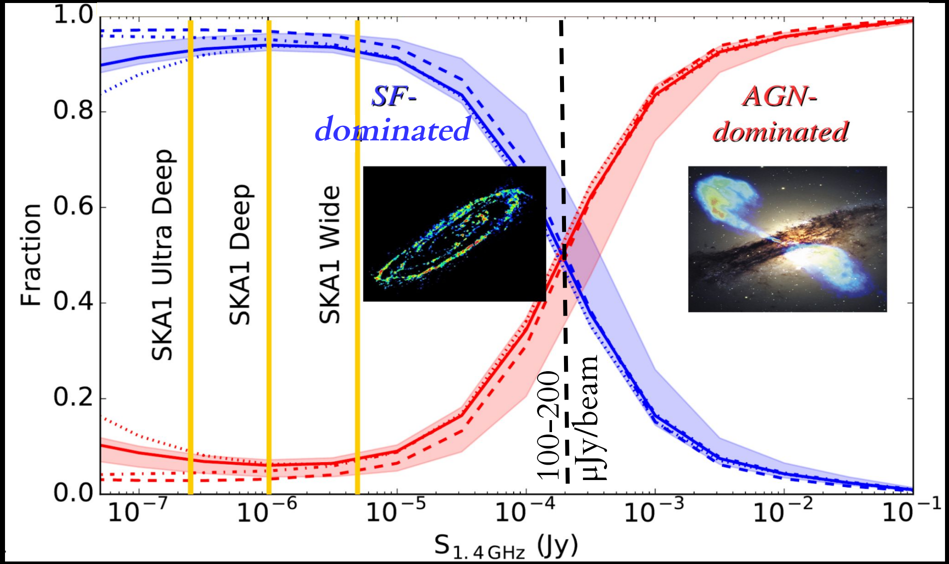

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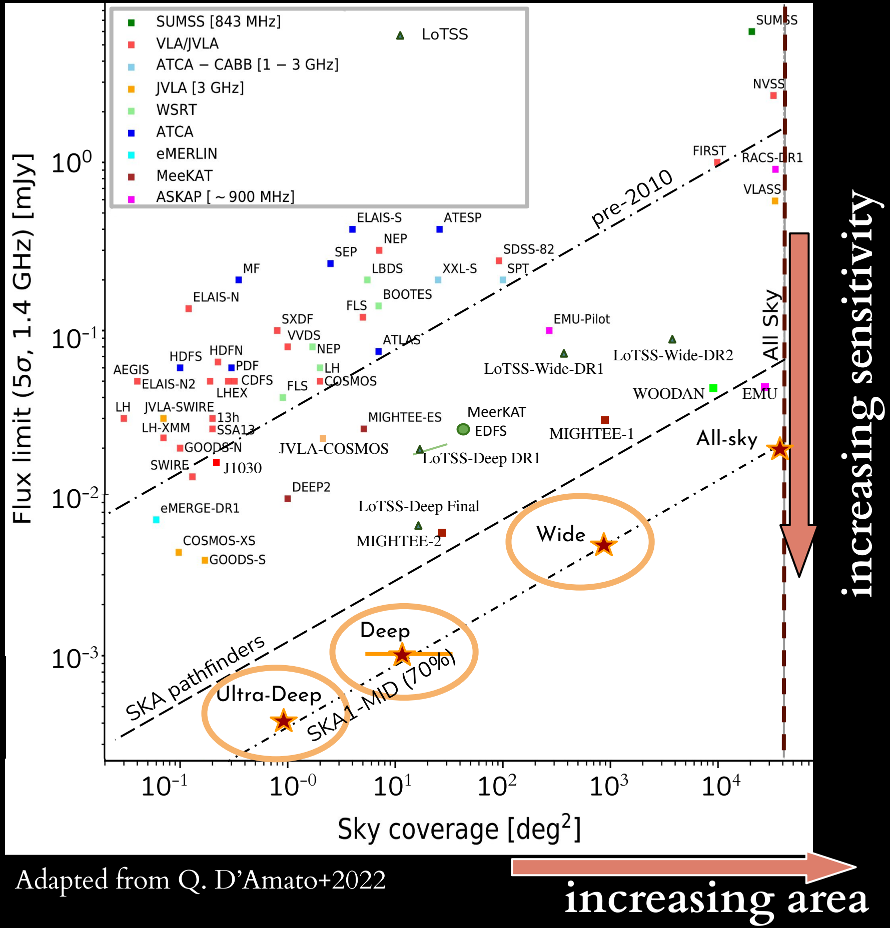

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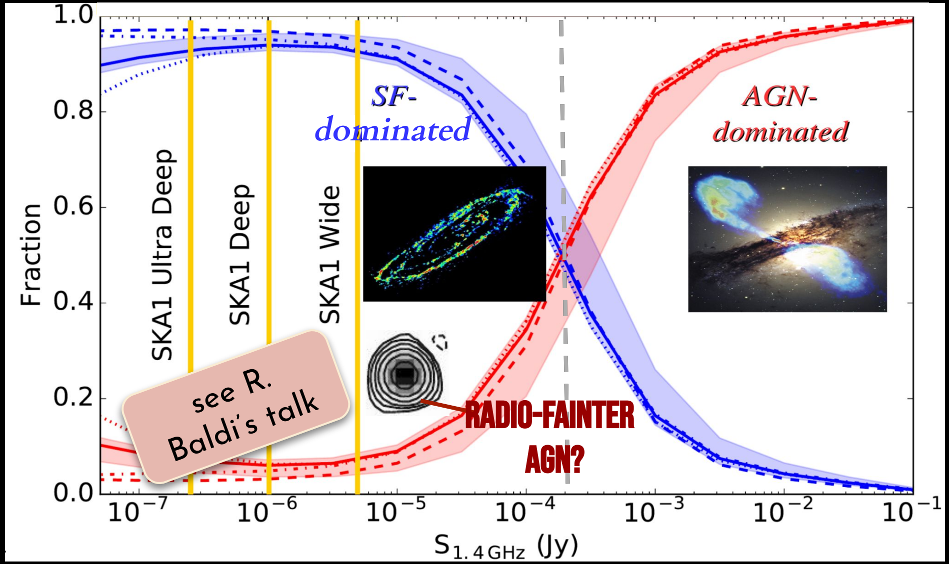


Adapted from Novak+2018

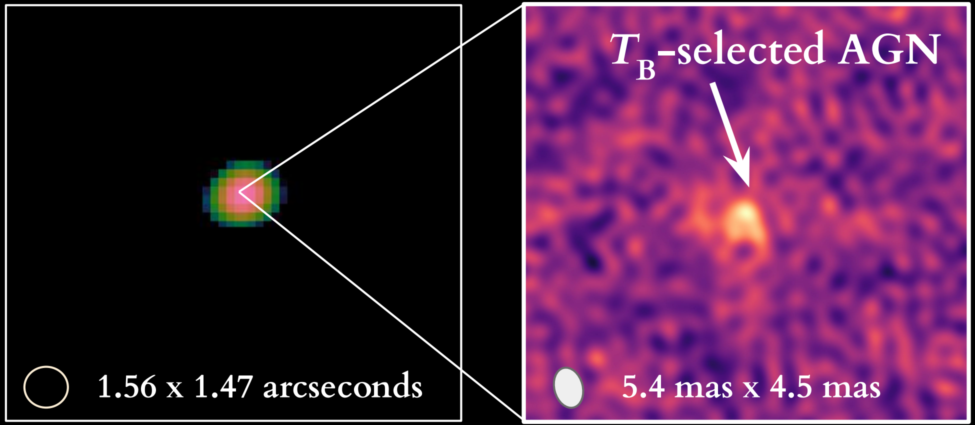
The radio brightness temperature (T_B)

Flux density [μJy/beam]

$$T_\mathrm{B}\ [K] = 1.222 \cdot 10^6 \cdot (1+z) \cdot \left(\frac{S_\nu}{\nu^2 \cdot \theta_\mathrm{maj} \cdot \theta_\mathrm{min}} \right)$$

Frequency [GHz] Angular size [mas]

VLA EVN



Radcliffe+2018

(See Middleberg+2011,2013; Morgan+2013; Rampadarath+2015; Herrera Ruiz+2017,2018; Radcliffe+2018; 2021; Morabito+2022; Njeri+2023, Deane+2024; Morabito+2025 a,b)

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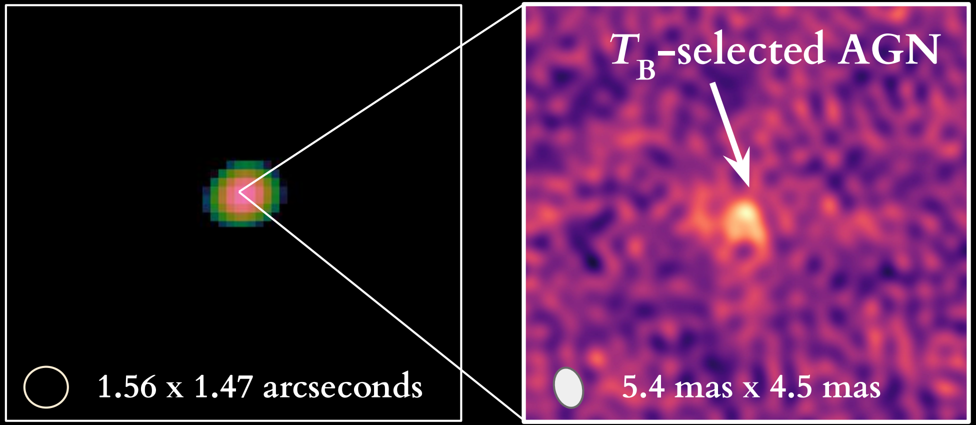

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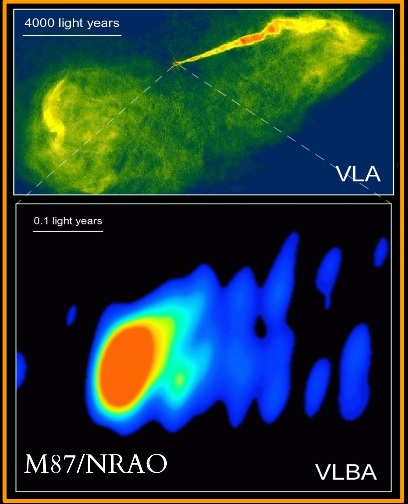
PROs:

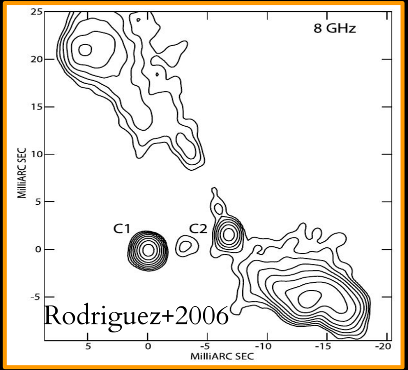
- ❑ Pure AGN tracer if T_B>10^5 (Condon 1992)
- ❑ Independent of the host's SFR

CONs:

- ❑ Small FoV
- ❑ Expensive observations
- ❑ Biased against low SB emission (poor *uv* coverage)

Single follow-up of AGN core/jets



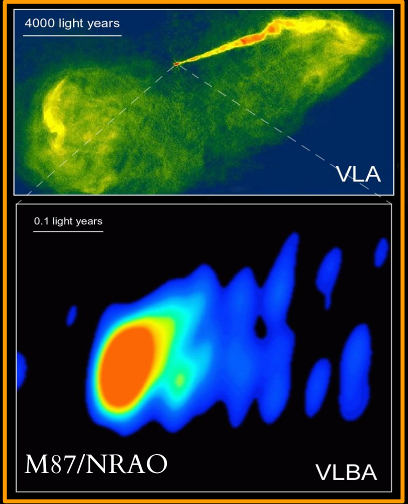


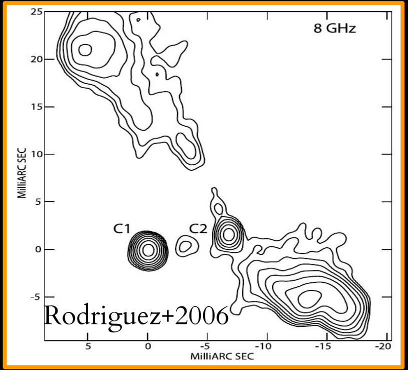
Milli-arcsec resolution

Excellent astrometry

Small fov

Single follow-up of AGN core/jets





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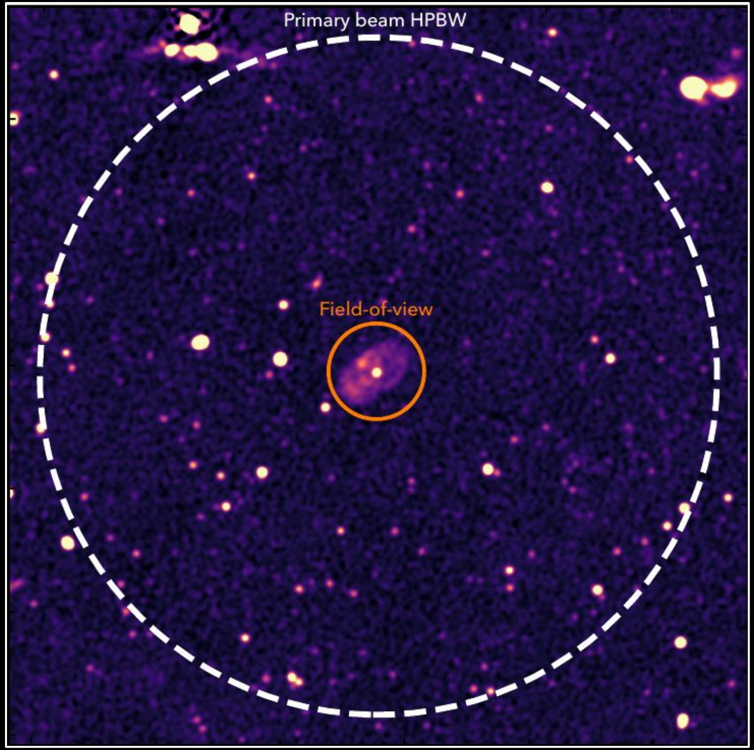
Wide-field surveys of multiple objects



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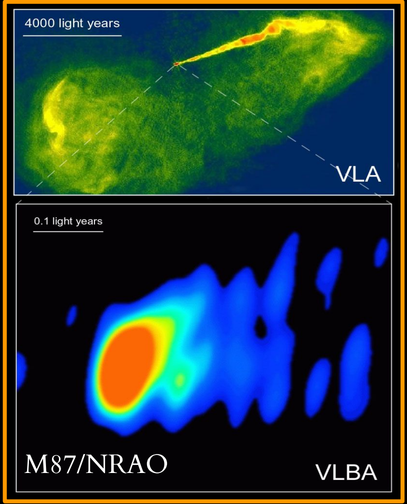

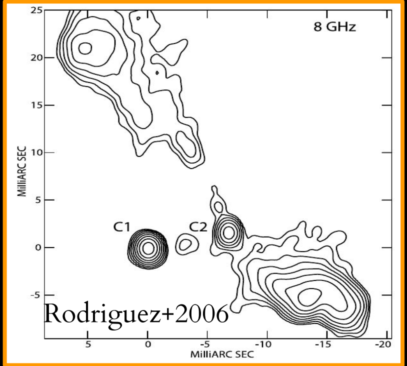

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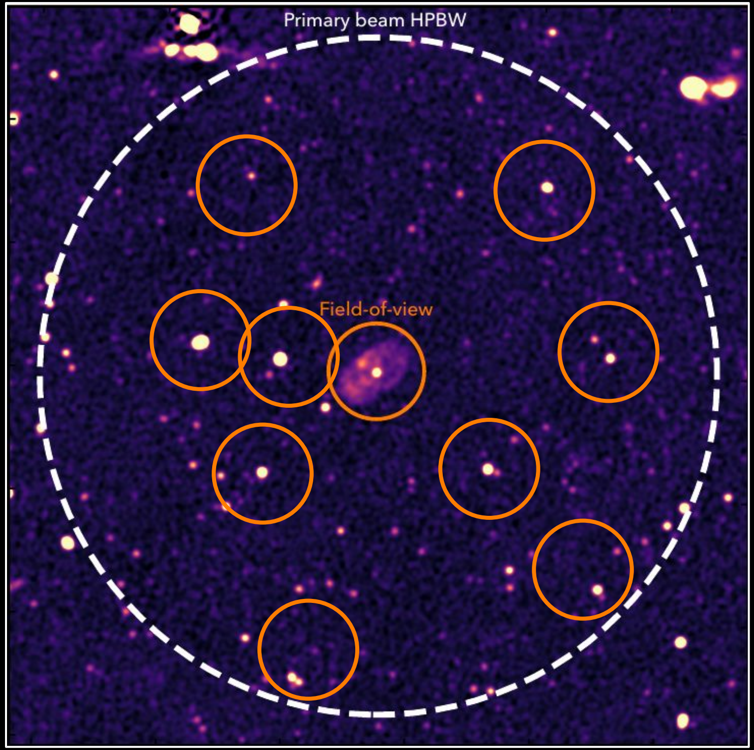

multiphase centre correlation implemented in the DiFX software correlator

(Morgan+2011; Deller+2011)

Single follow-up of AGN core/jets

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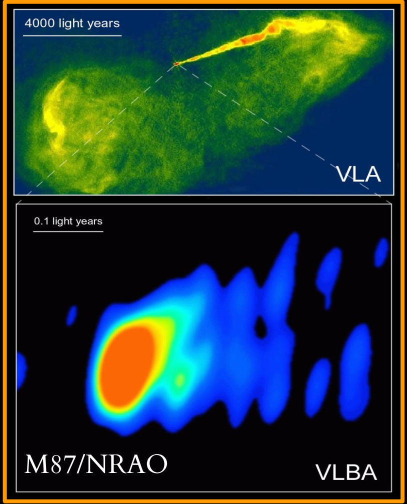

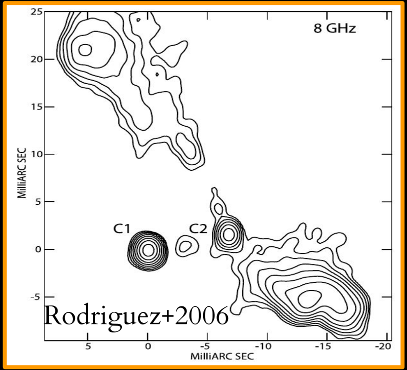

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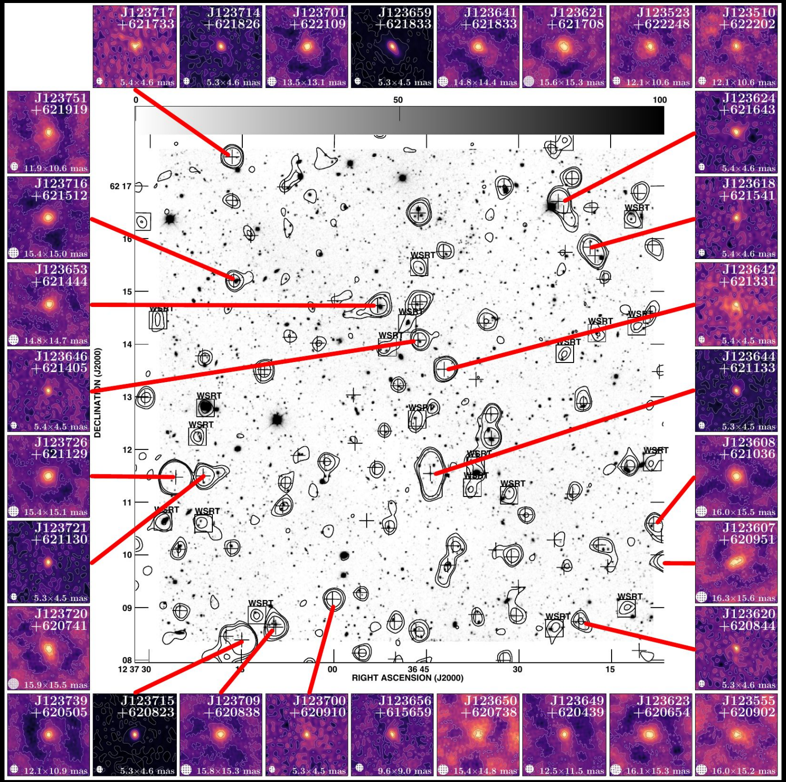
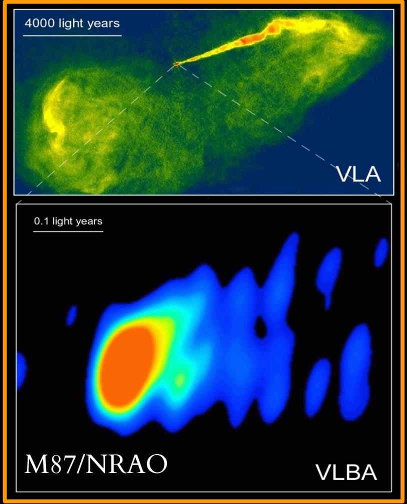


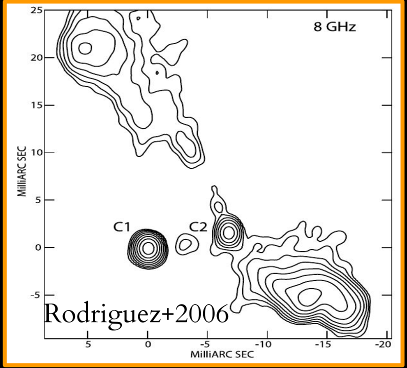
Radcliffe+2018 (GOODS-N: EVN+eMERLIN)

(See Middleberg+2011,2013; Morgan+2013; Rampadarath+2015; Herrera Ruiz+2017,2018; Radcliffe+2018; 2021; Morabito+2022; Njeri+2023, 2024; Deane+2024; Morabito+2025 a,b; Saikia+2025)

Single follow-up of AGN core/jets

Wide-field surveys of multiple objects





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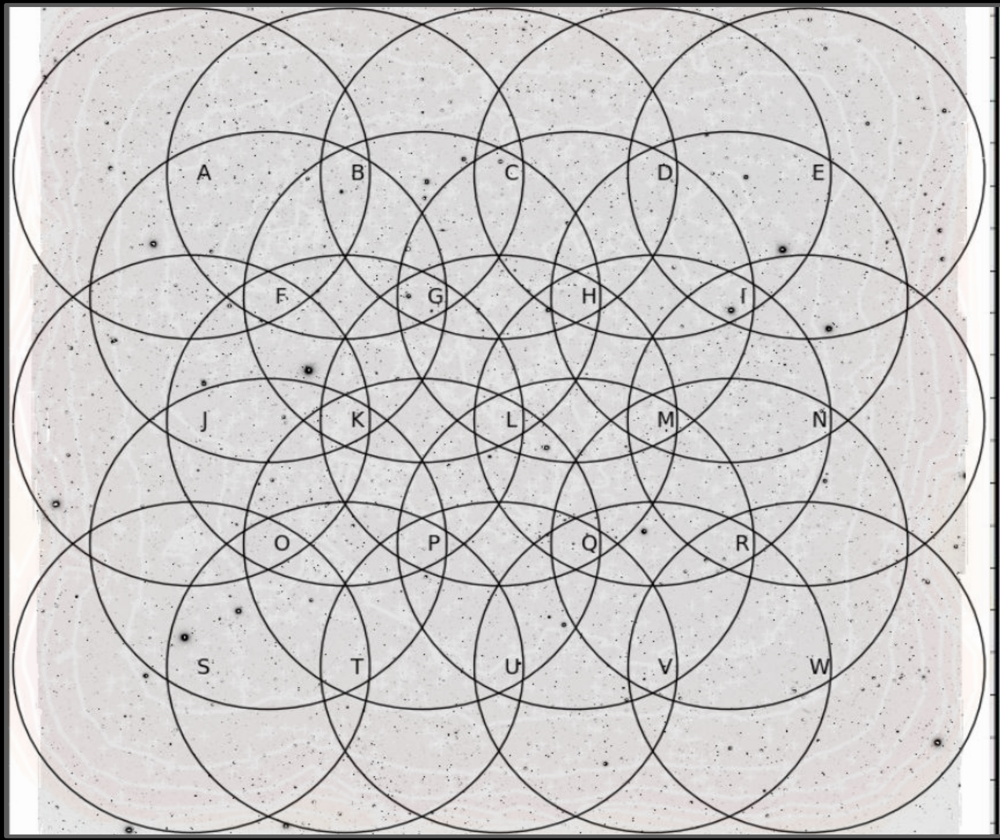
Excellent astrometry

Small fov



Herrera Ruiz+2017

Single follow-up of AGN core/jets

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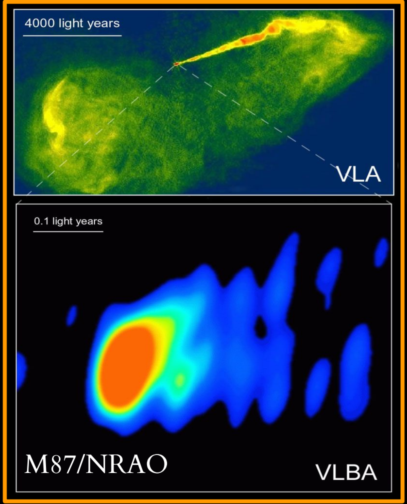
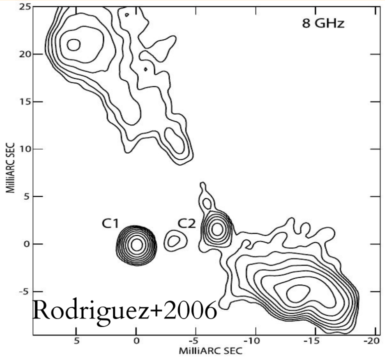


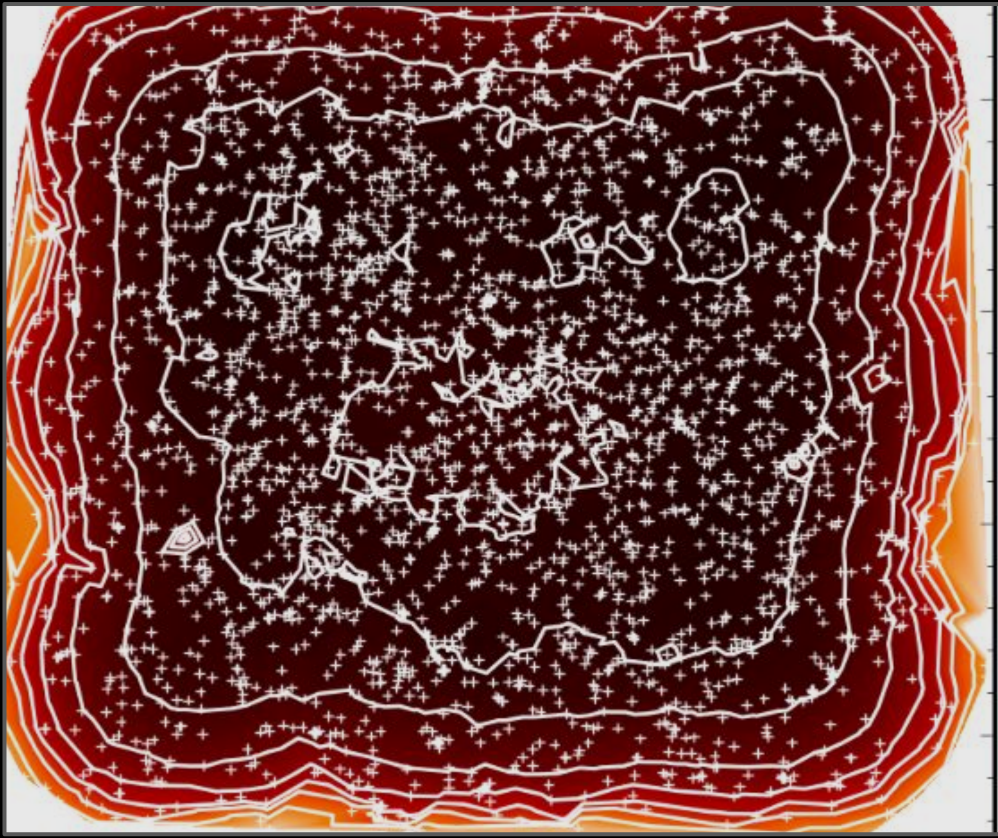


Rodriguez+2006

Milli-arcsec resolution

Excellent astrometry

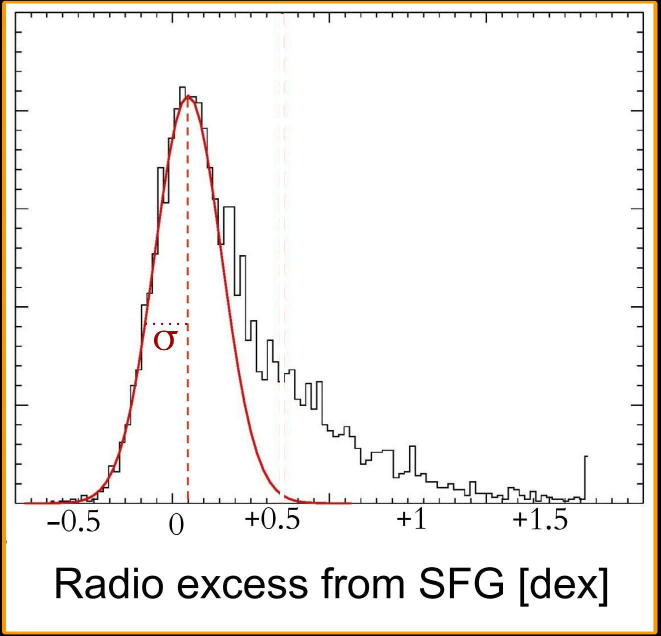
Small fov

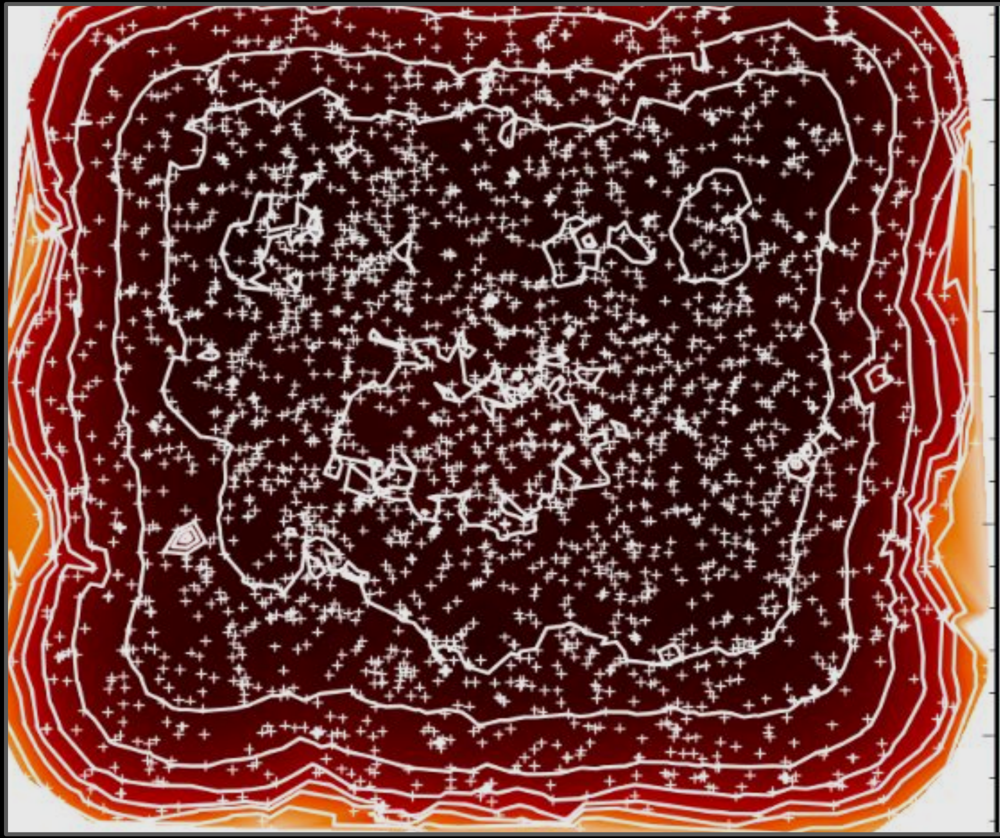


Herrera Ruiz+2017

The VLBA-COSMOS survey

1σ = **12 μJy/beam** @ 1.4 GHz
>2800 VLA targets over 2 deg^2

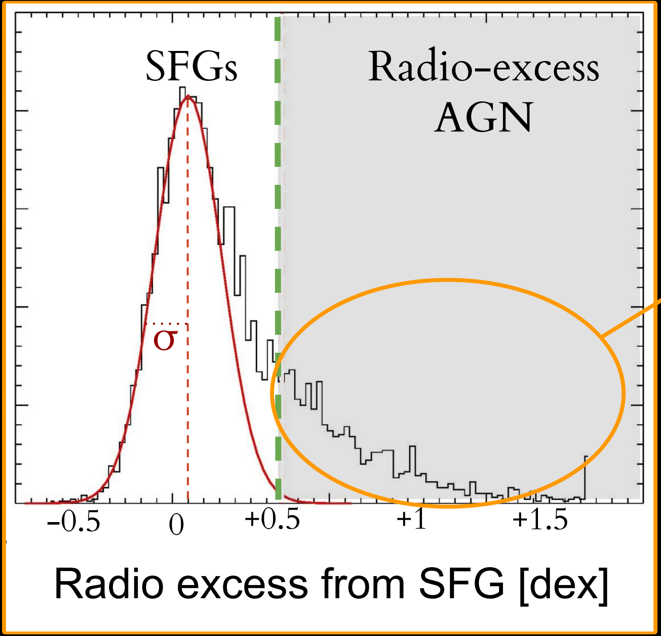


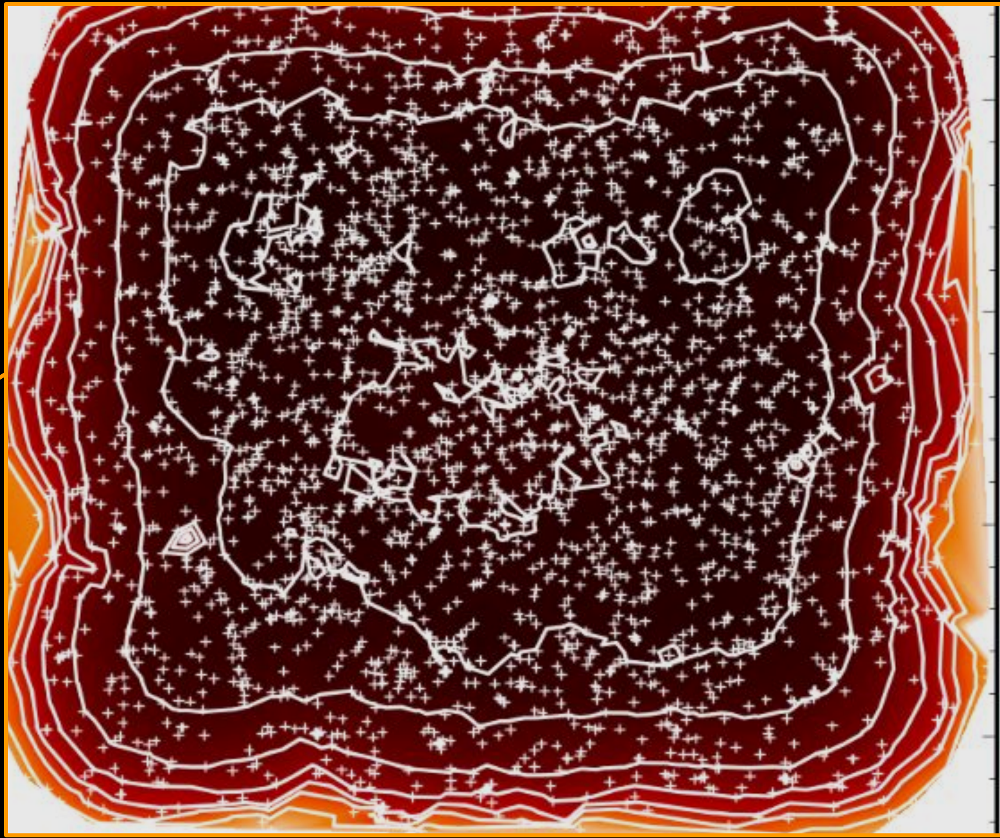


Herrera Ruiz+2017

The VLBA-COSMOS survey

1σ = **12 μJy/beam** @ 1.4 GHz
>2800 VLA targets over 2 deg^2
~500 detections at S/N>5.5

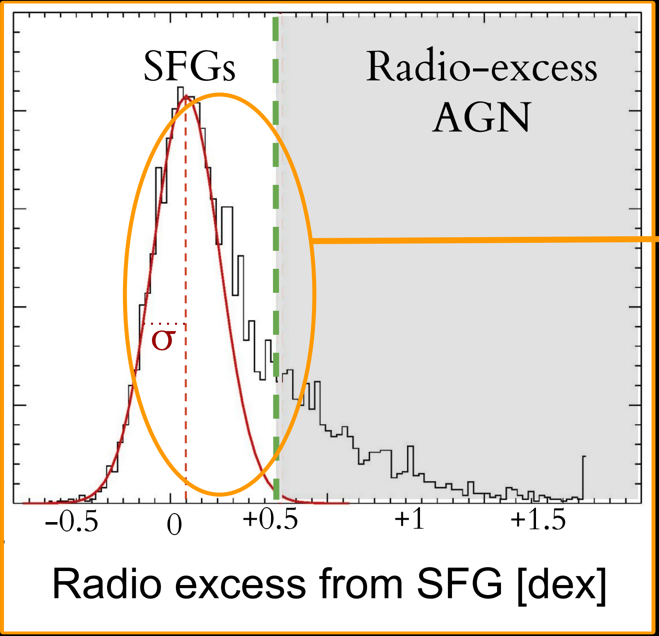




Herrera Ruiz+2017

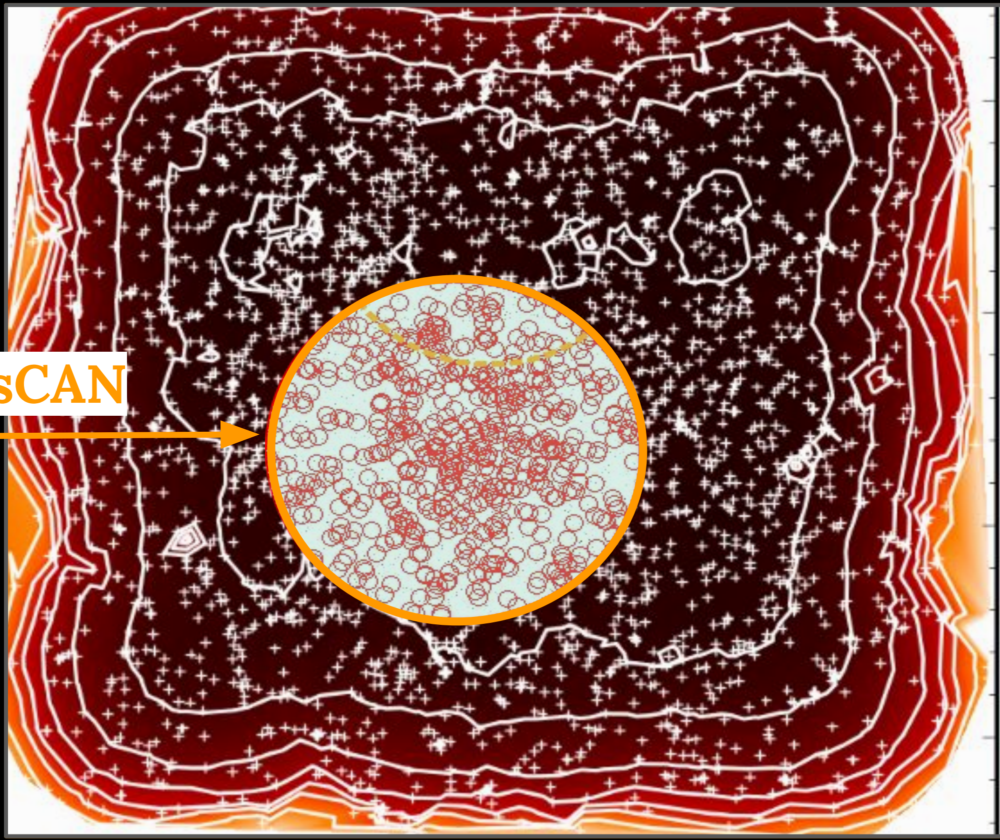
AGN-sCAN: radio-faint AGN in normal SFGs?

1σ = **5 μJy/beam** @ 1.4 GHz
500 targets (30 arcmin FWHM)
without strong radio excess



AGN-sCAN

$T_B > 10^5$ K



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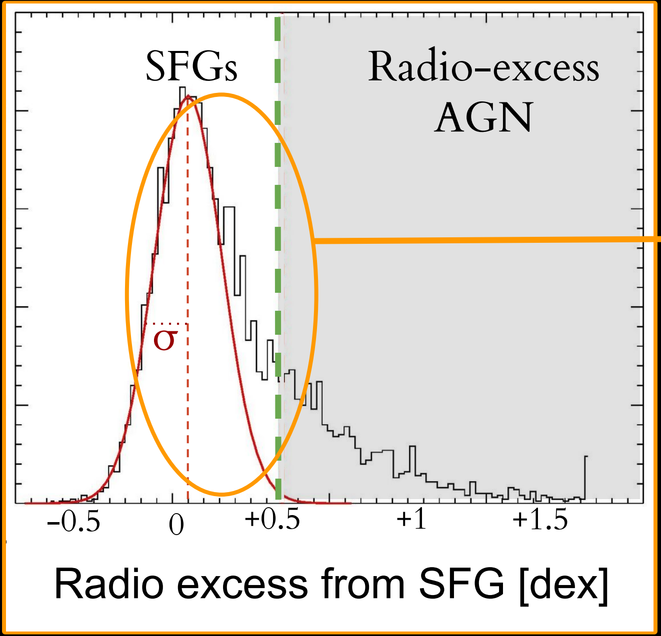

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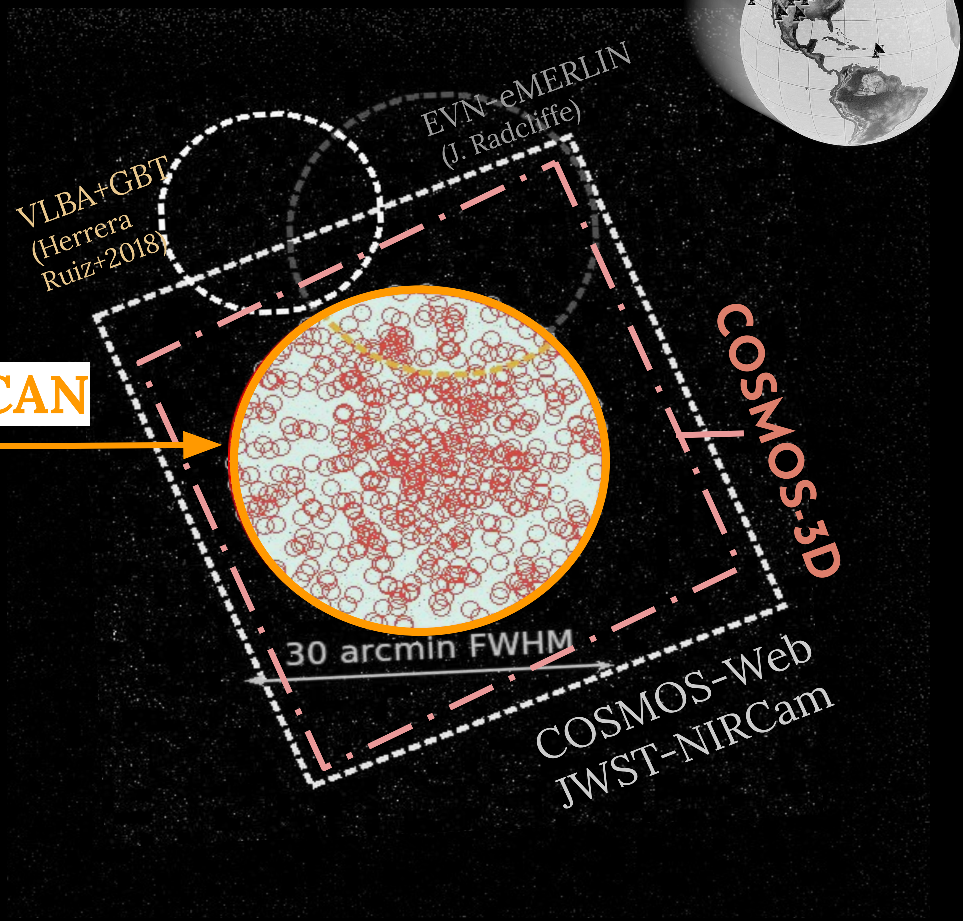
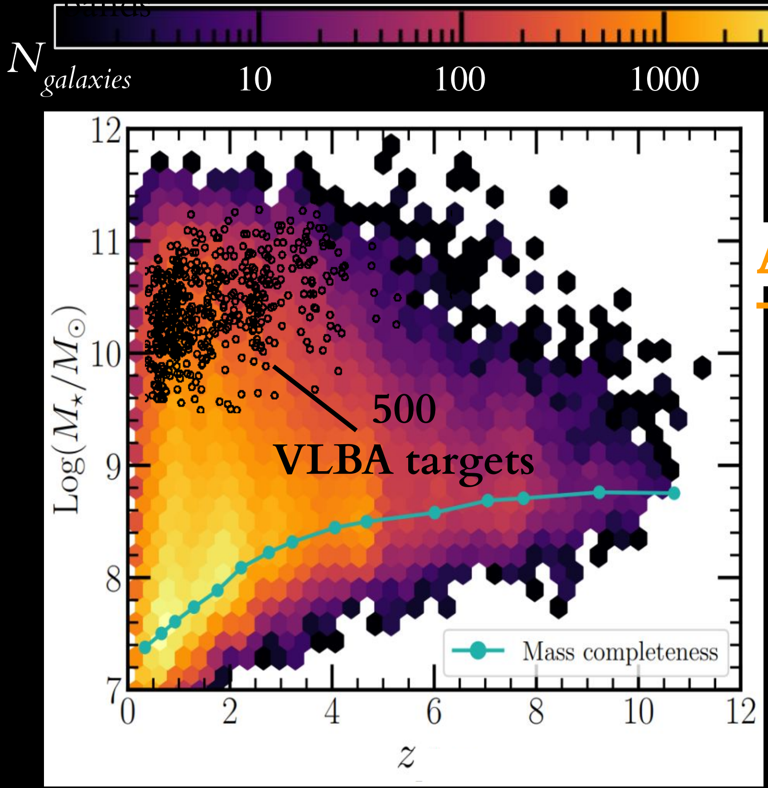


AGN-sCAN: radio-faint AGN in normal SFGs?

500 massive SFGs at 0.5<z<5 detected at IR (Herschel / ALMA) and radio (VLA / MeerKAT) bands



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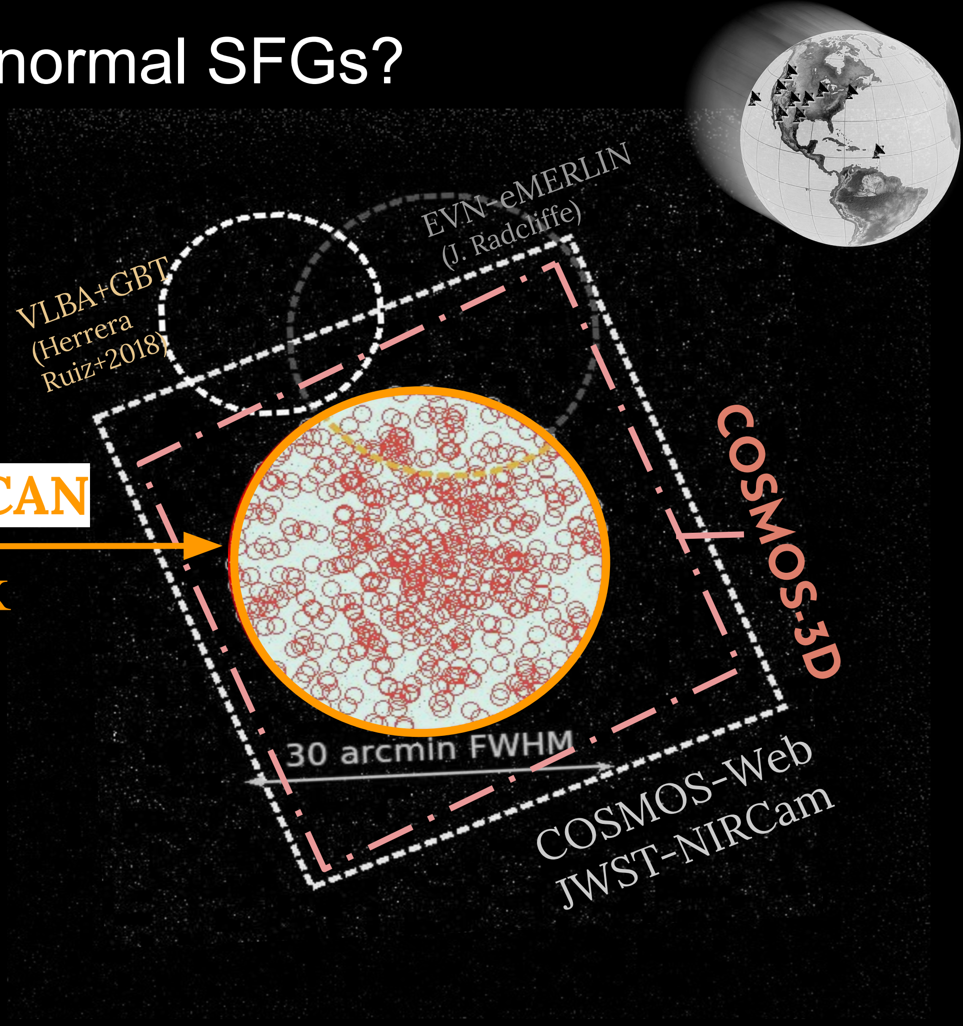

VLBA detections

https://github.com/jradcliffe5/VLBI_pipeline

- Peak S/N > 5.5 (as in Herrera Ruiz+2017)
- d < 0.2” (VLA-VLBA)

Jack Radcliffe

VLBA detections

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Jack Radcliffe

- Peak S/N > 5.5 (as in Herrera Ruiz+2017)
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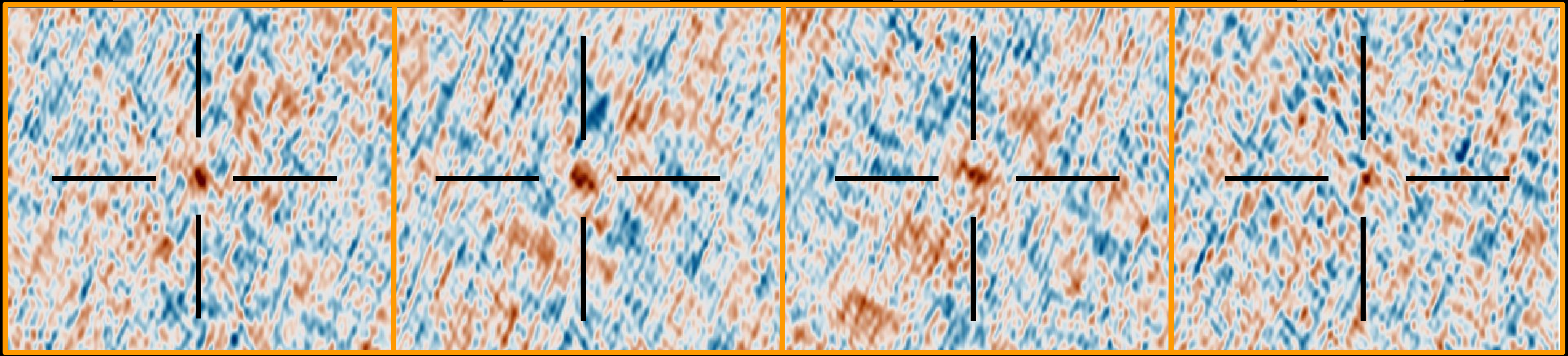
4 VLBA detections

Detection rate (rms-matched) ~ 9%

see G. Peluso's talk

VLBA 351 VLBA 408 VLBA 338 VLBA 498

0.2"



ID+2025 in prep

S/N=6.2 (z=2.92) S/N=6.0 (z=1.30) S/N=5.8 (z=1.475) S/N=5.6 (z=0.68)

VLBA detections

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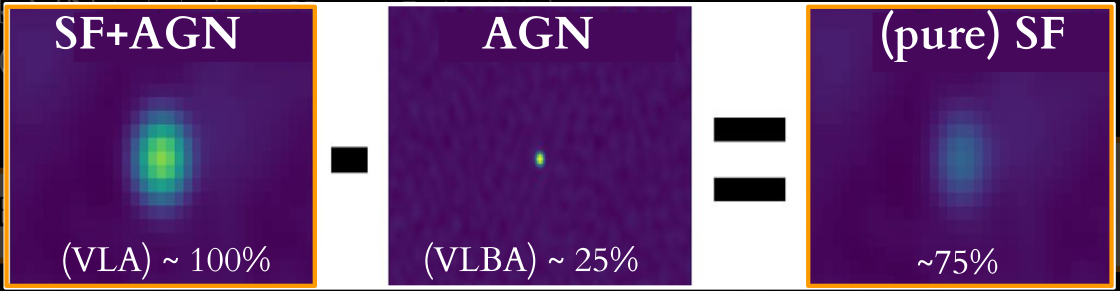
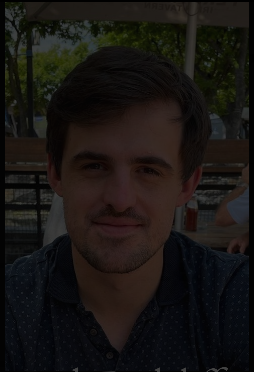
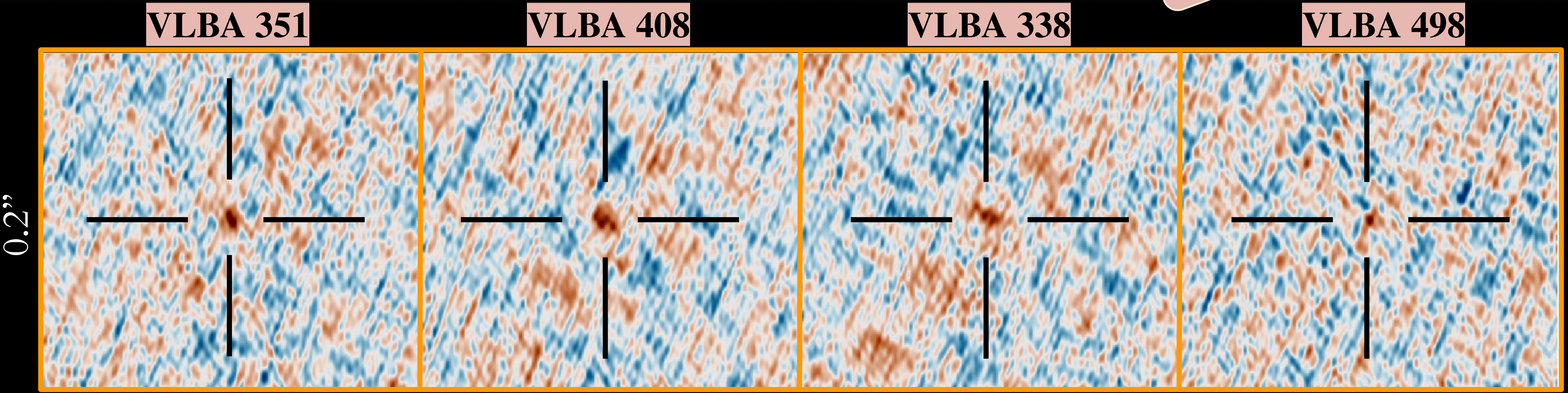


see G. Peluso's talk



Jack Radcliffe



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ID+2025 in prep

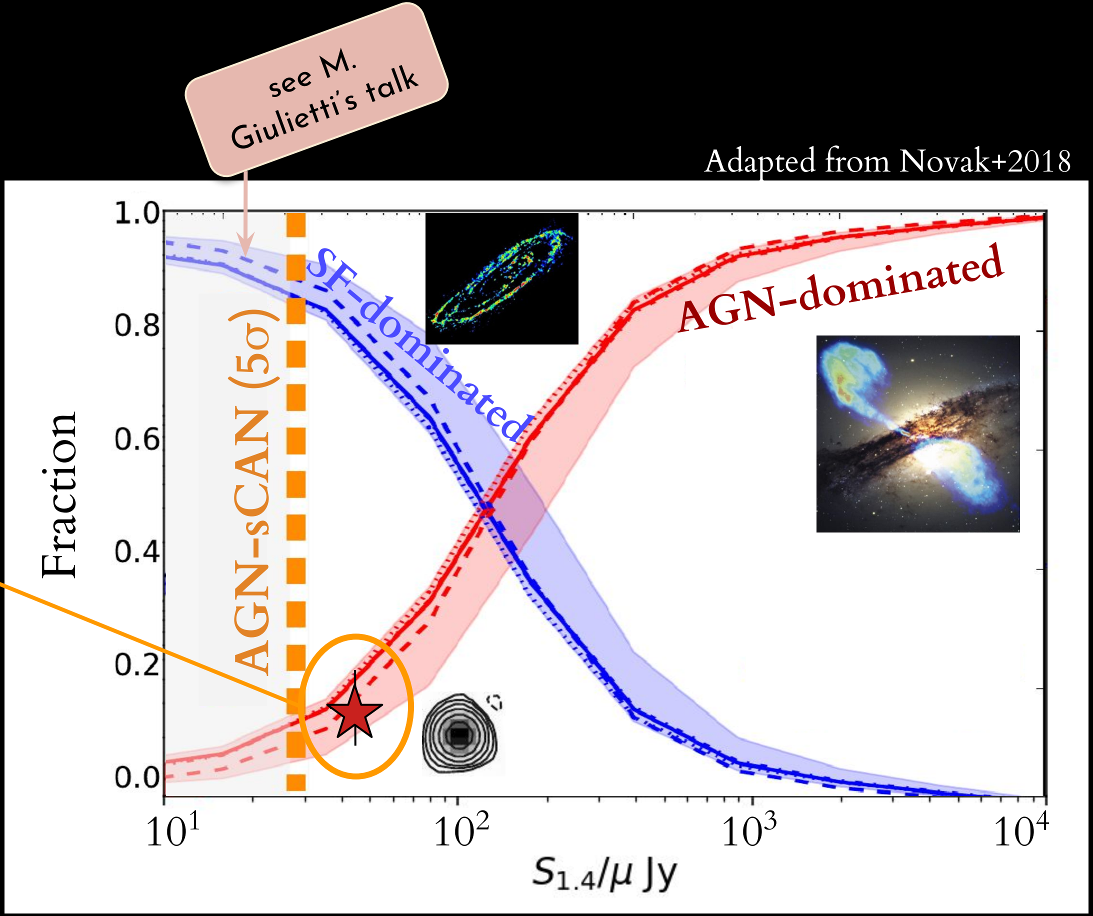
VLBA AGN fraction

- Peak S/N > 5.5 (as in Herrera Ruiz+2017)
- d < 0.2" (VLA-VLBA)

4 VLBA detections

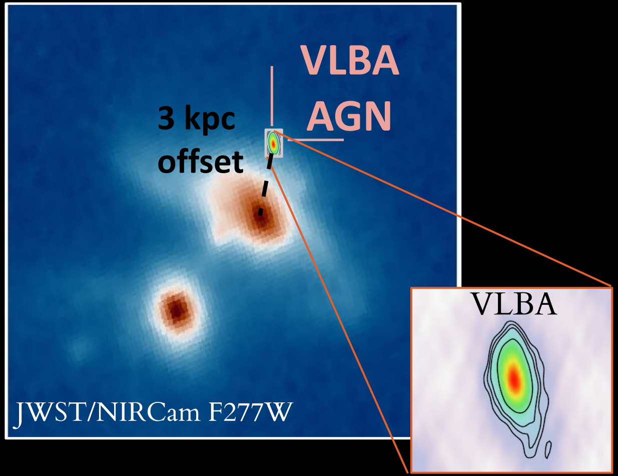
Consistent with expectations from deep radio surveys: ~10% (compact) AGN at $S_{1.4}$ ~ 30-50 μJy

Adapted from Novak+2018



Rare & peculiar objects

Wandering AGN candidate



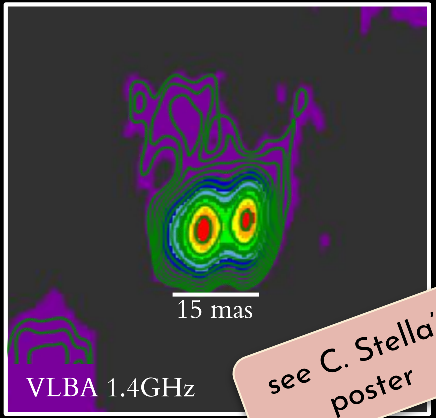
9h JWST NIRSpec/IFU
Cycle4 GO program
(#8325: PIs: ID & G. Peluso)

15h HSA (VLBA + phased VLA)
PI: ID

"Little Red Dots"

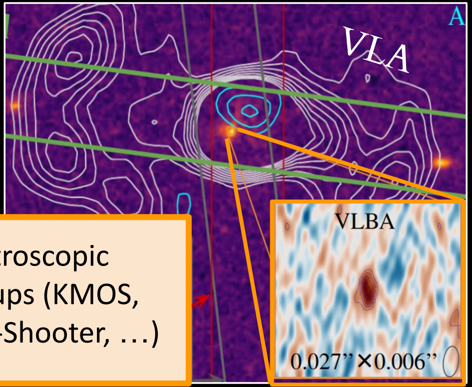
20h full HSA
(VLBA + GBT+ phased VLA)
PI: ID

Dual AGN candidates



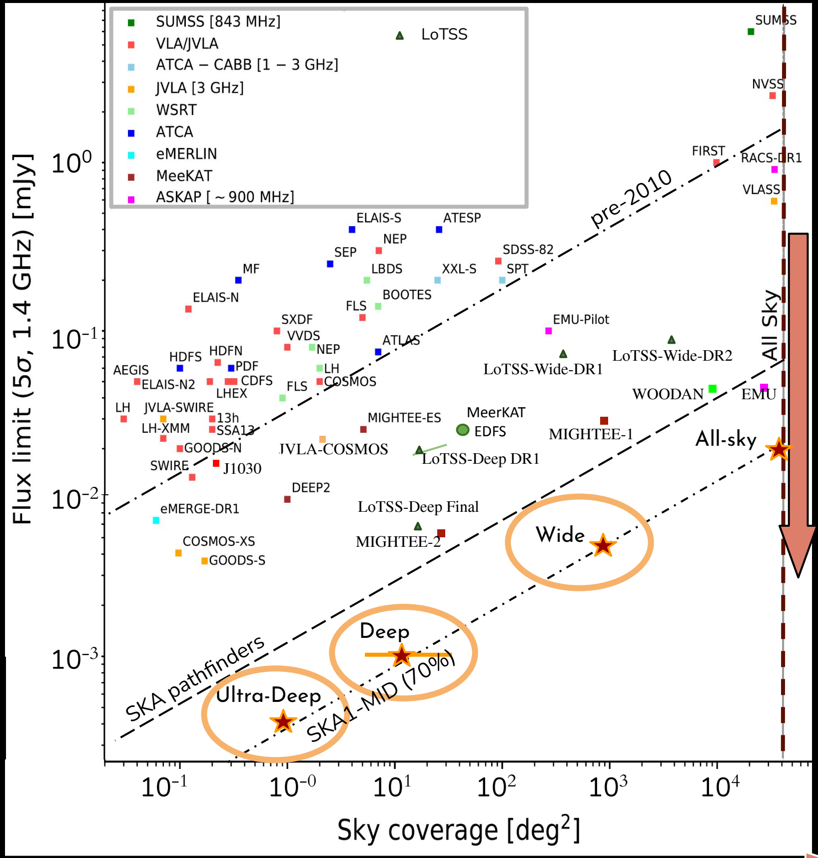
see C. Stella's poster

Recurrent AGN?



Spectroscopic
follow-ups (KMOS,
FORS2, X-Shooter, …)

Pushing radio decomposition at low stellar mass and high-z

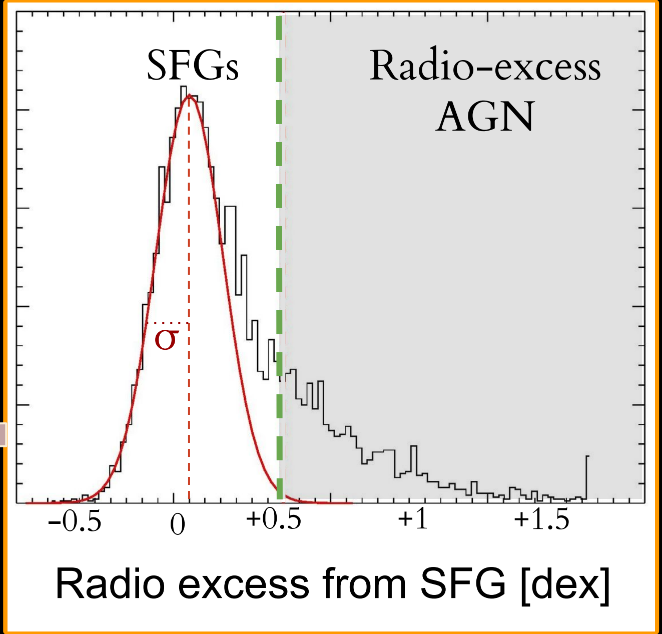


increasing sensitivity

Adapted from Q. D'Amato+2022

increasing area

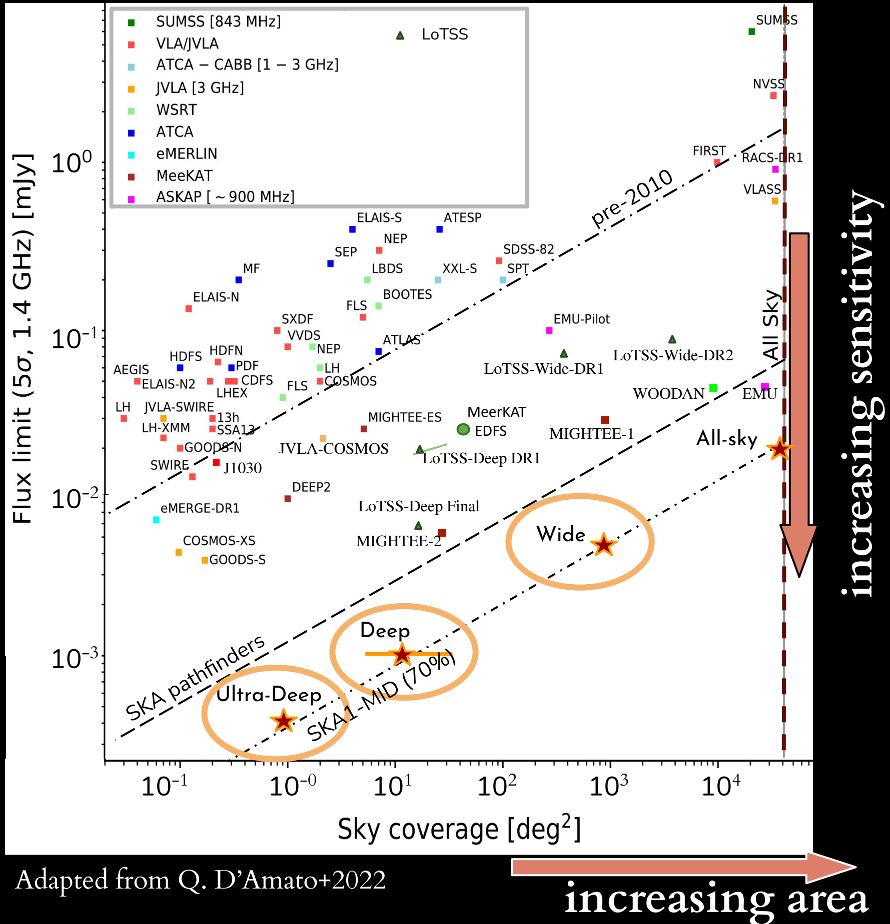
Calibrated on massive ($M_\star > 10^{10}\ M_o$)



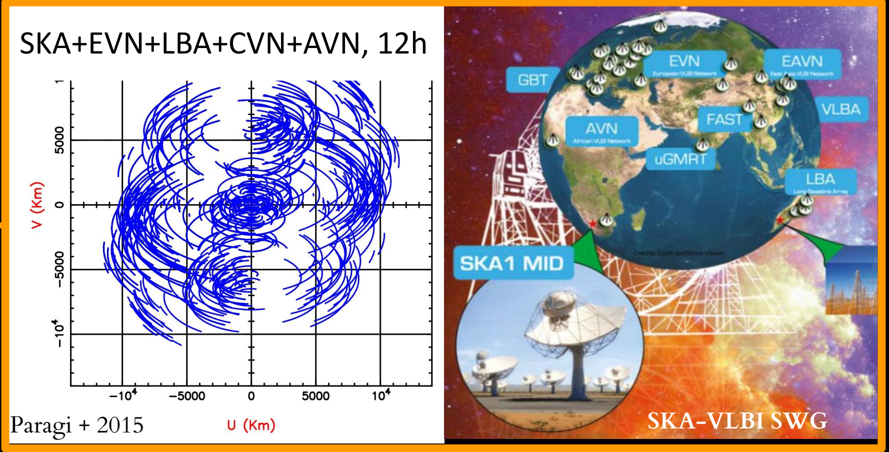
SKA1-Mid (UD, band2): SFR<10 M_o/yr up to z~4 down to dwarf galaxies!

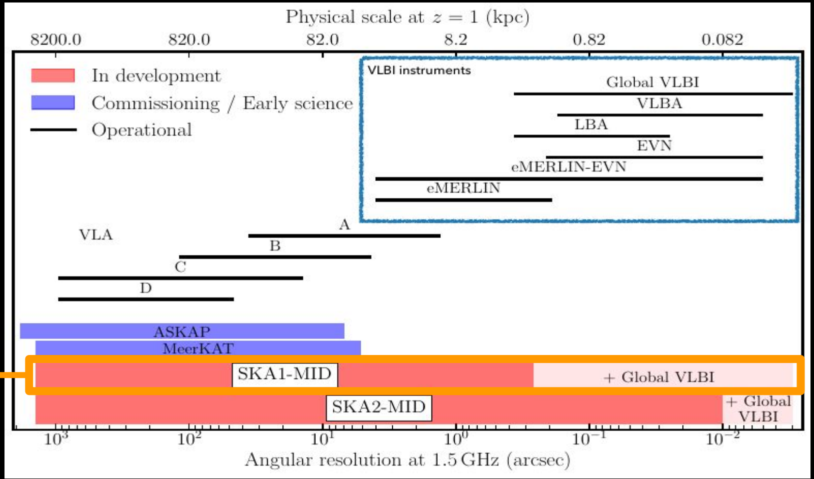
Prandoni & Seymour 2015; Coogan+2023

SKA-VLBI: AGN-vs-SF decomposition in single sources



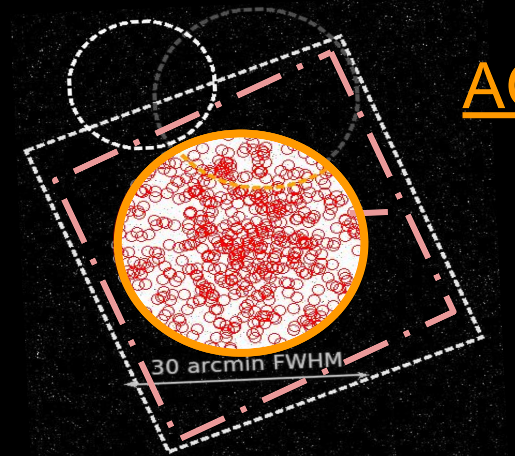
Adapted from Q. D'Amato+2022





Courtesy of J. Radcliffe

AGN-sCAN: take-home points



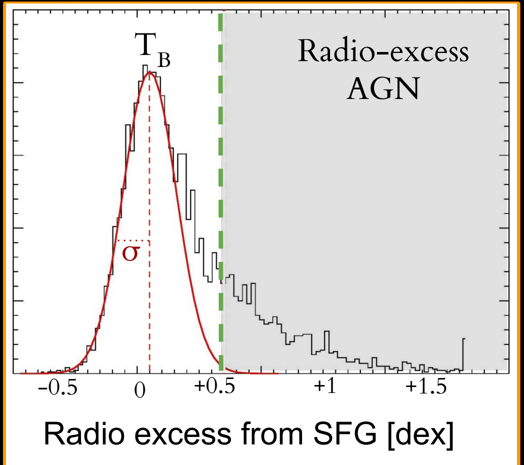
Milli-arcsec resolution

Excellent astrometry

pure AGN

SKA-VLBI

- ❑ Radio-faint AGN in massive SFGs **with no radio excess**
- ❑ G. Peluso (Next talk): Impact the radio-SFR relation?
- ❑ SKA1-MID: radio AGN and SF in high-z / low-M_* galaxies



SKA-VLBI

from clear-cut to morphological classification