Unveiling AGN Outflows: A High Resolution Morphological Study with LOFAR-VLBI

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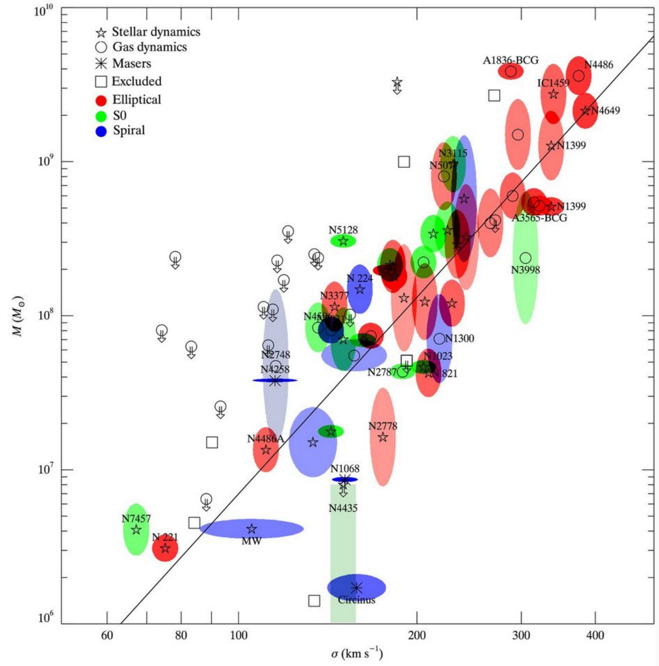
AGN Feedback

- Correlation between the MBH and the velocity dispersion (Gebhardt et al. 2000)
- Remains unclear how this feedback operatures- **What drives it ?**
- **Outflows could be the answer!**
    - Extend into the galaxy on kpc scales and inserts energy to alter galaxies evolution



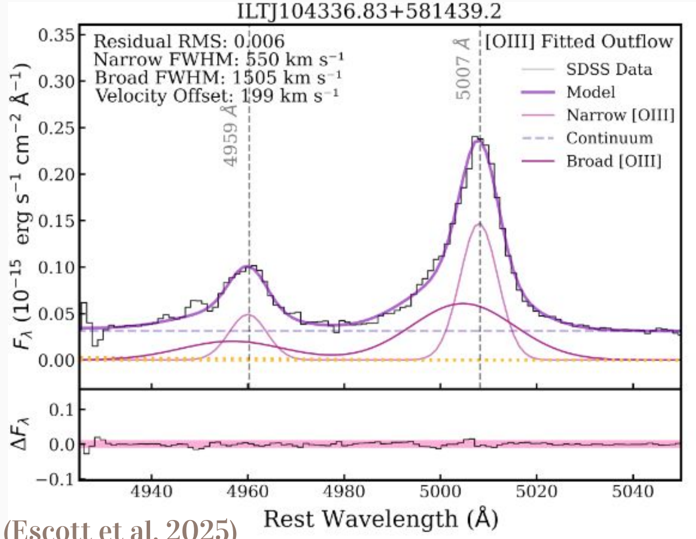
(Gültekin et al. 2009)

[O III] 5007 Å Emission Line

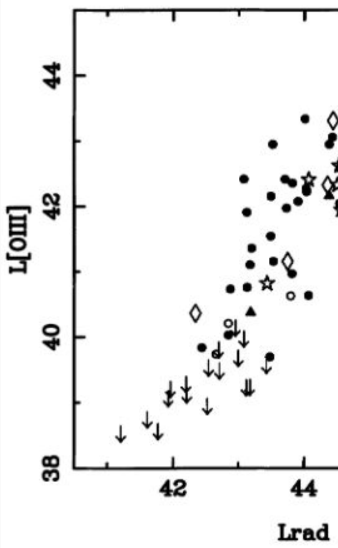
[O III] traces, warm, ionised, gas outflows

If a broad, blueshifted component is fit to [OIII] then this is indicative of an outflow

[O III] luminosity correlated with radio emission (Rawlings et al. 1989)



(Escott et al. 2025)



(Tadhunter et al. 1998)

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Optical Sample

SDSS DR16 Quasar catalogue, Lyke et al. (2020)

Broad-line Hα AGN SDSS DR7, Liu et al. (2019)

Radio Data

LoTSS Deep Fields DR1 144MHz

ELAIS-N1, Lockman Hole, Boötes

Restrict optical data to LoTSS Deep Fields

z<0.83 - [O III] visible in optical spectra

SNR<5 sources removed

198 AGN

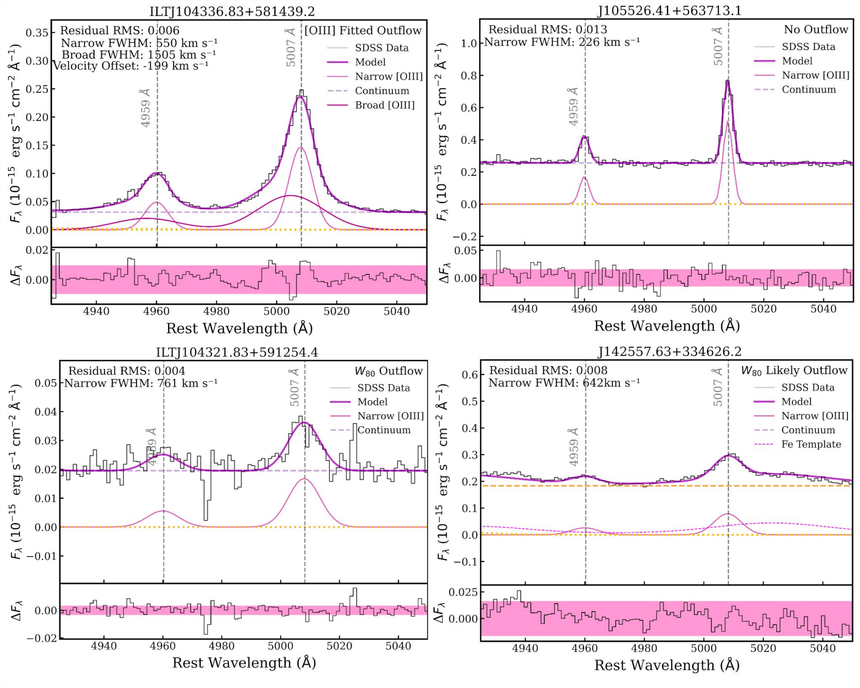
83 Radio non-detected AGN

115 Radio detected AGN

118 AGN matched in **$L_{6\mu m}$ and redshift** - Remove AGN luminosity bias

Identifying [O III] Outflows

- QUEBSPEC MCMC fitting tool (Scholtz et al. 2020)
- Four categories of outflows (Harrison et al. 2014)
  - **Blueshifted, asymmetric shoulder** (Schmit et al. 2017) - [O III] Fitted Outflow
  - Single component and **W_{80} > 800 km/s** - W_{80} Outflow
  - Single component, 600<W_{80}<800km/s - W_{80} Likely Outflow
  - Single component and **W_{80} < 600 km/s** - No Outflow



(Escott et al. 2025)

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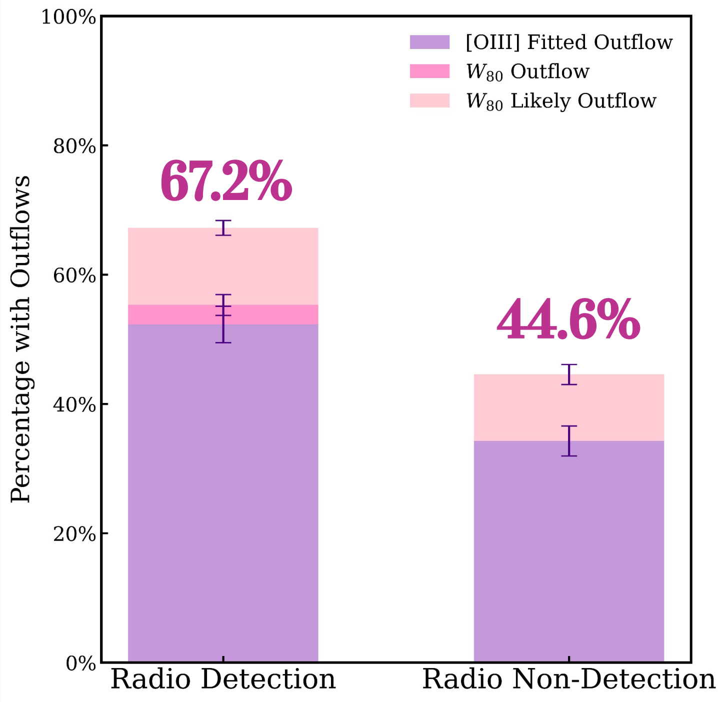
Outflow Detection Rate



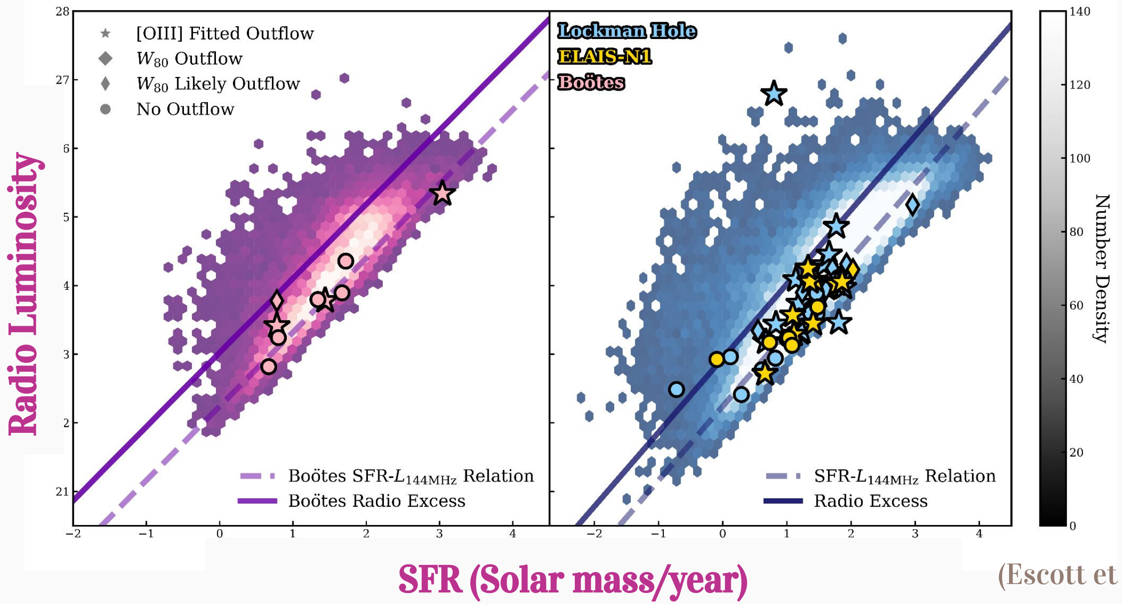
(Escott et al. 2025)

Radio detected AGN are more likely to host an [O III] outflow

- **Radio** detected: **67.2%**
- Radio non-detected: **44.6%**

Evidence that low-frequency radio properties of AGN are linked to [O III] properties

Origin of Radio Emission



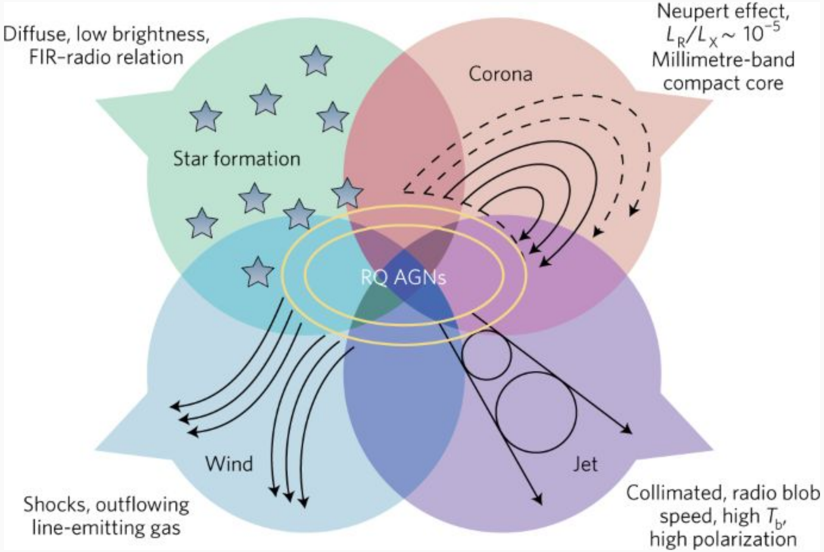
(Escott et al. 2025)

SFR from 4 SED fitting codes (Best et al. 2023)

Radio excess - 0.7dex above expected SFR-Radio relation

Majority of sources are below this divide - not driven by powerful radio jets

Origin of Radio Emission



(Panessa et al. 2019)

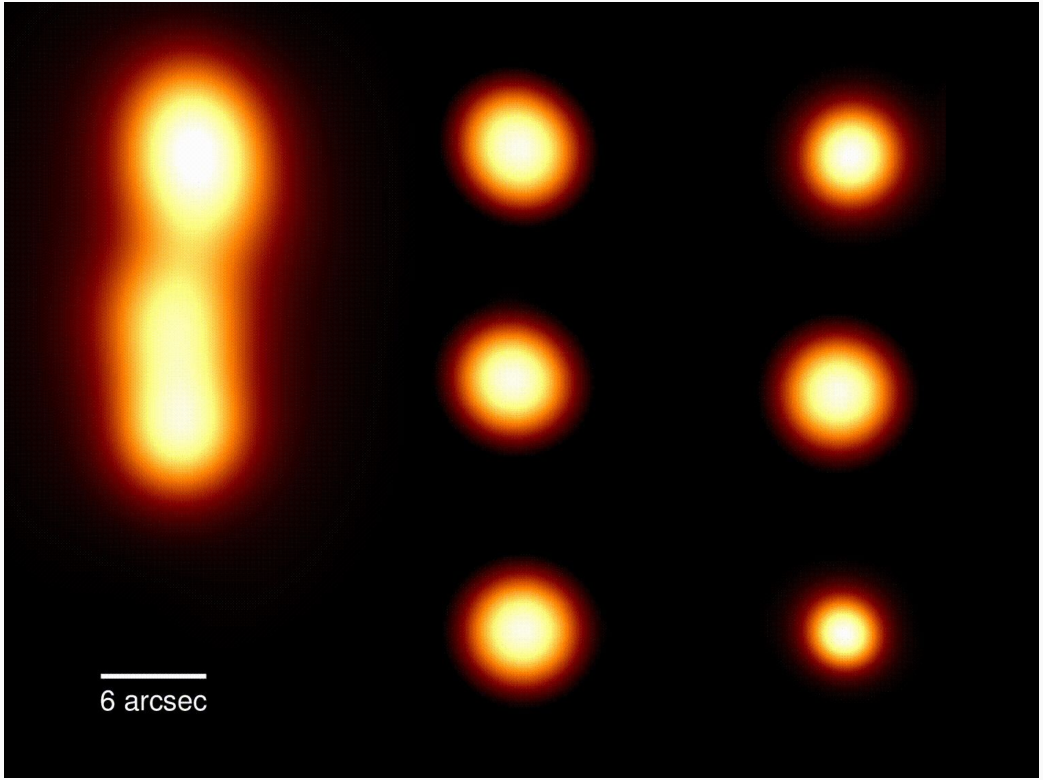
The origin of radio emission from radio quiet AGN is unknown

It could be produced from **jets, star formation, corona, or winds** (Panessa et al. 2019)

92% of the radio detected sample are **unresolved** in LoTSS

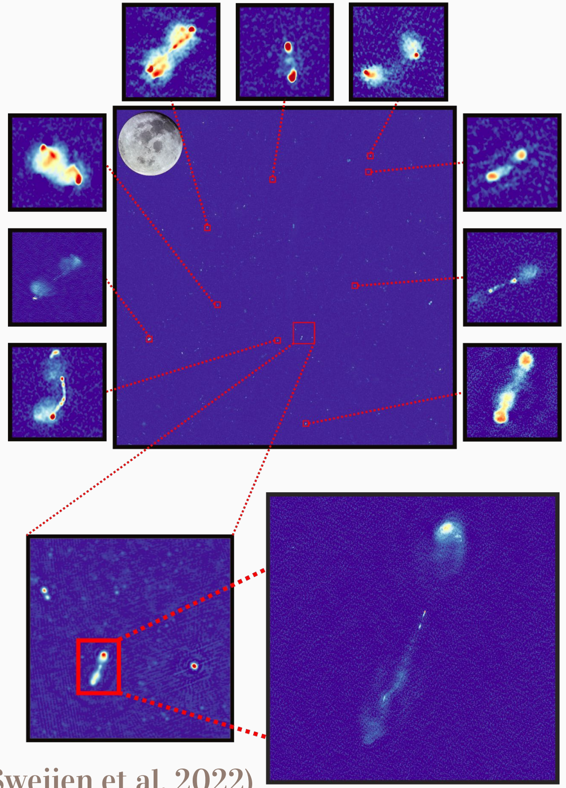
Requires high resolution imaging to determine the radio morphology which can tell us the origin of this emission

LOFAR VLBI



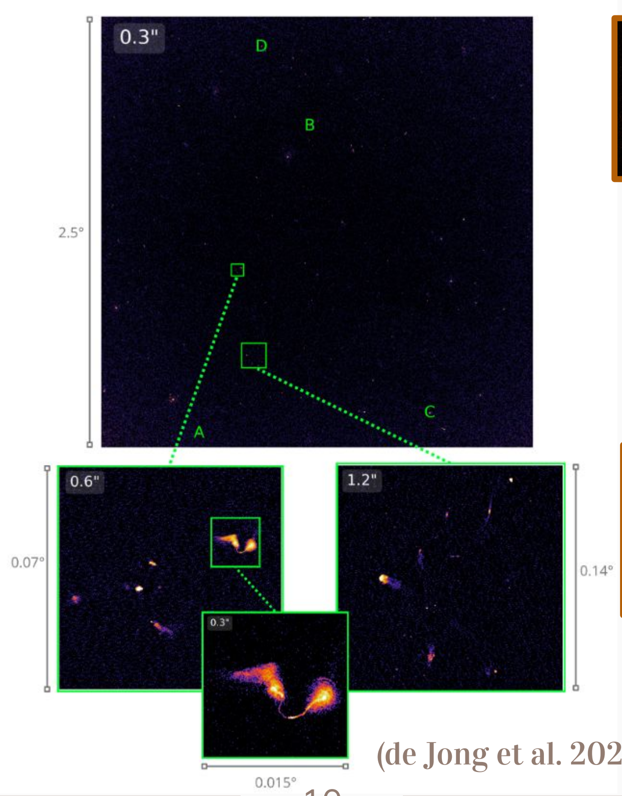
(L. Morabito)

Lockman Hole



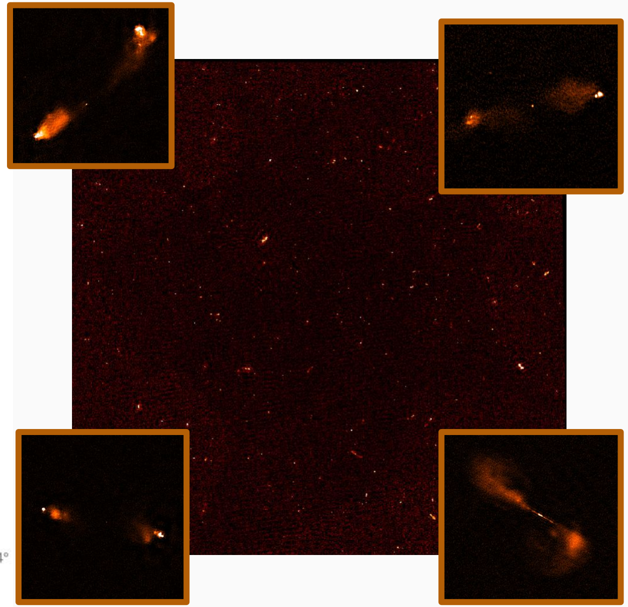
(Sweijen et al. 2022)

ELAIS-N1



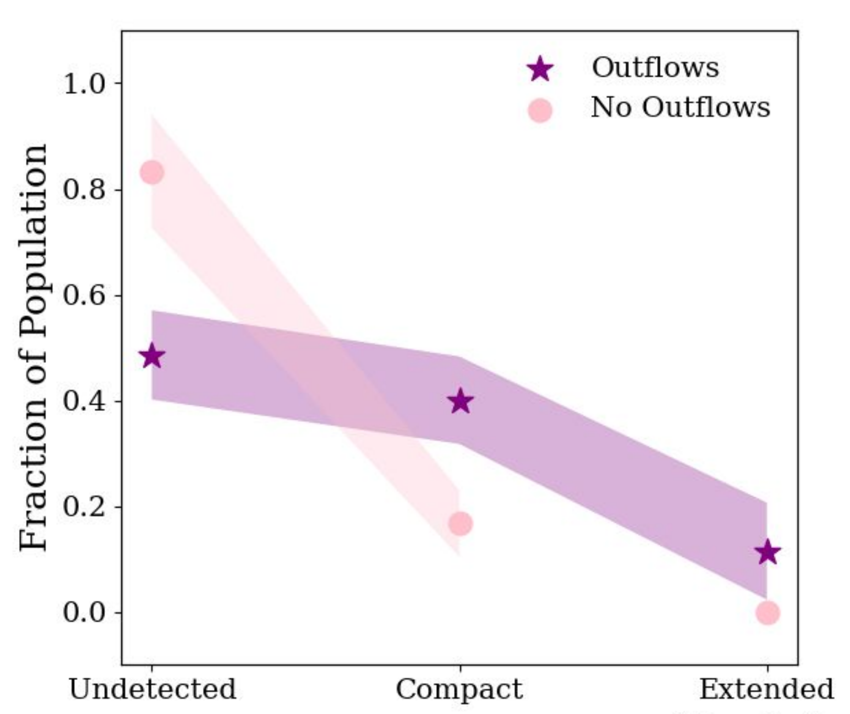
(de Jong et al. 2024)

Boötes



(Escott et al. in prep)

Sub-arcsecond Resolution



47 matched AGN of the 115 radio detected AGN lie within the ILT's field of view

Outflows

4/35 extended - 11%

14/35 compact - 40%

17/35 undetected - 49%

No Outflows

0/12 extended - 0%

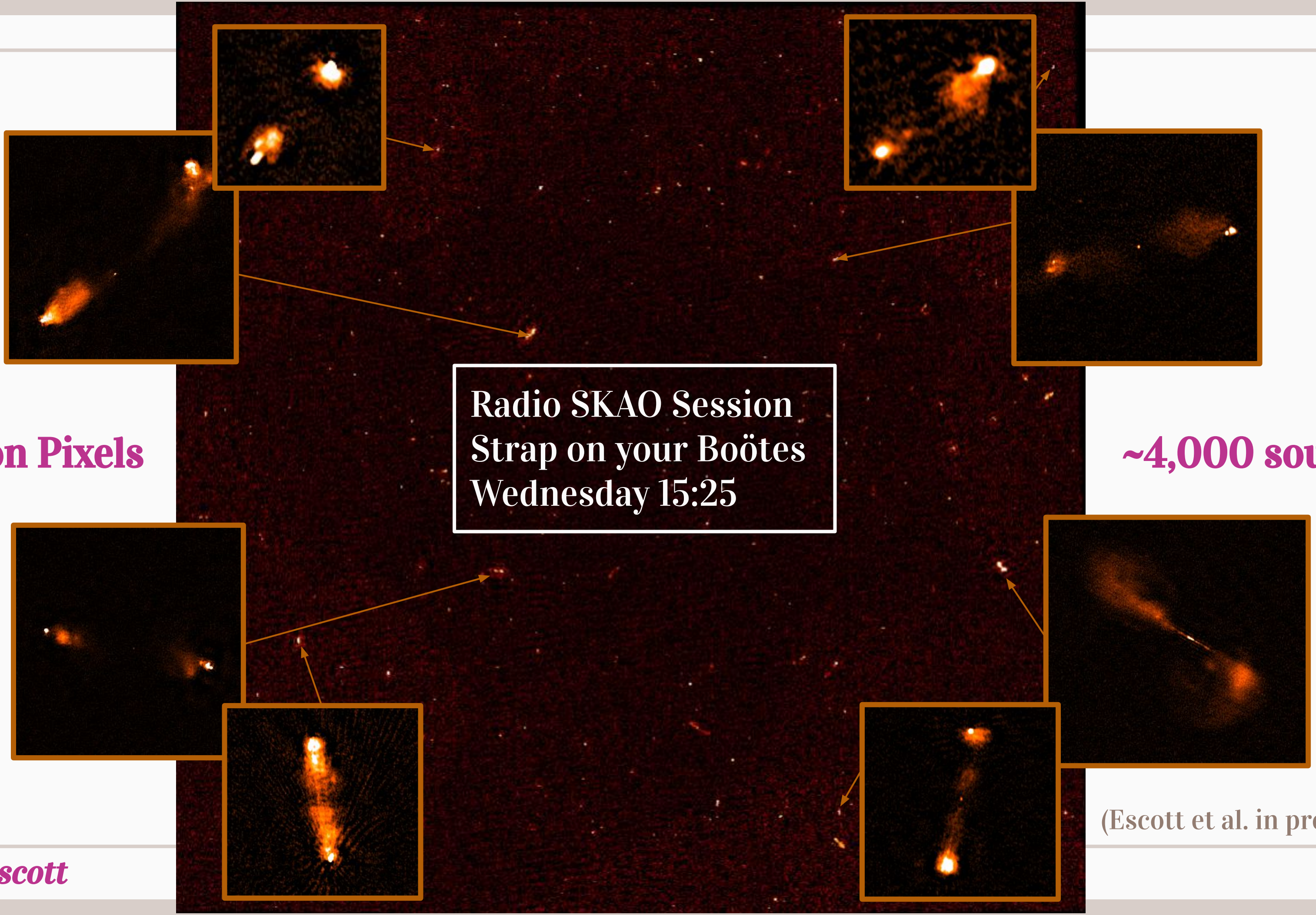
2/12 compact - 17%

10/12 undetected - 83%

Summary

- We study [O III] kinematic of 198 optically selected AGN with spectra from SDSS
- We find AGN outflows are more likely to occur if the AGN has a detection at 144 MHz
- At 6” resolution rule out powerful jets as origin of radio emission
- Introduced LOFAR-VLBI Widefield mode
- Final sub-arcsecond resolution image of Boötes
- Resolved sub-arcsecond morphologies are more likely to most an outflow than not
- Radio emission from outflows appears to be from small scale emission e.g AGN

~9 Billion Pixels



~4,000 sources

(Escott et al. in prep)

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