Active Galactic Nuclei 13

LeMMINGs
the eMERLIN radio legacy survey of nearby galaxies

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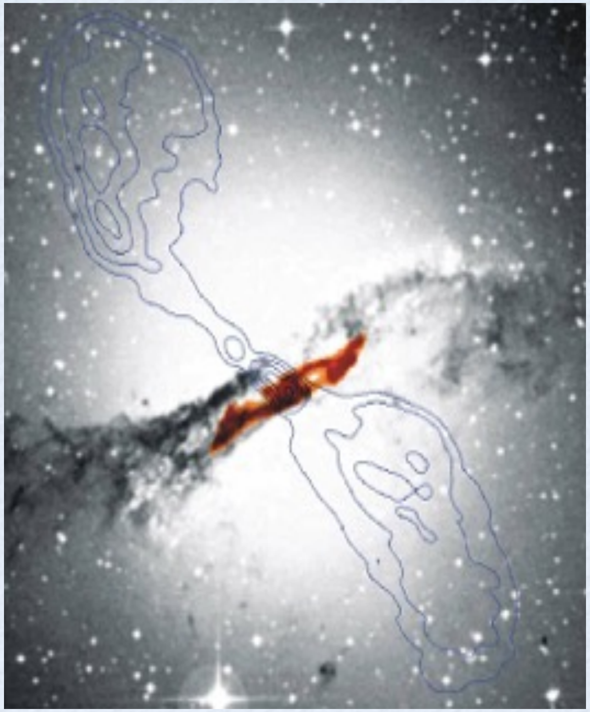
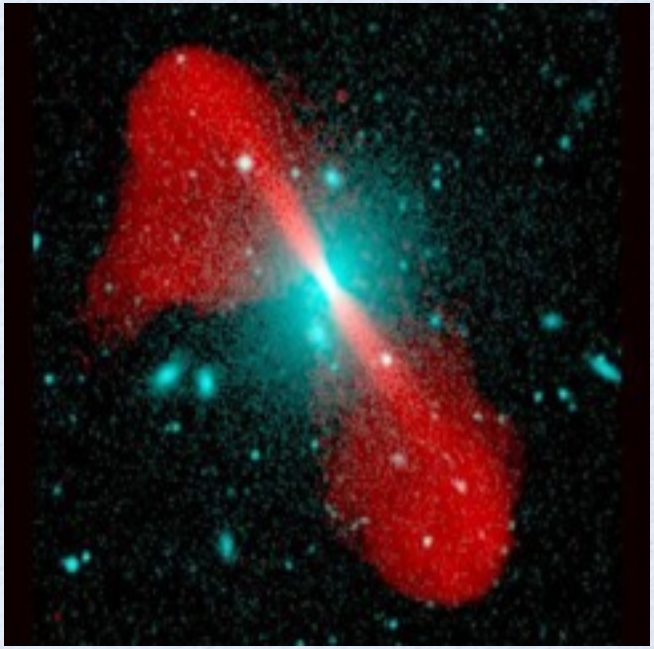
TECHNION Israel Institute of Technology

The radio-loud / radio-quiet dichotomy



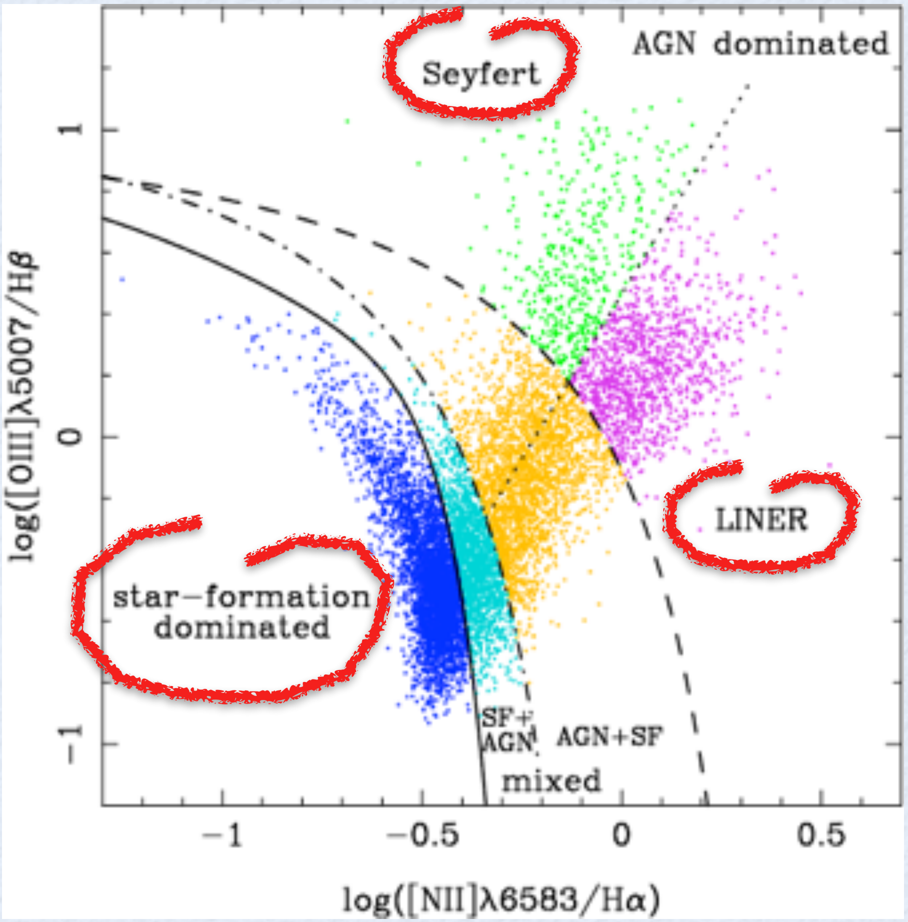
Among the many differences distinguishing AGN, one of the best known and studied effect is the presence of two populations of AGN, which can be separated on the basis of their radio luminosity with respect to the light emitted in the optical band.



The dichotomy can be parametrized numerically, with a threshold of $L_{radio}/L_o = 10$ (Kellerman + 97) or in X-ray (Terashima & Wilson 03), but in most cases radio-loud AGN can be recognized by the presence of very extended radio-structures clearly associated to large scale jets.

OPTICAL CLASSIFICATION

AGN can be classified on the basis of the emission line ratios.



Active galaxies

Seyfert/HEG ⇨ **standard disc**

LINER/LEG ⇨ **radiatively inefficient disc**

Absorption line galaxies:
no emission lines

BPT: Baldwin+81, Kewley+06, Buttiglione+10

low-luminosity AGN vs QSO

why care about LLAGN and not QSO?

- common, numerous and representative of BH accretion
- similar to quiescent galaxies
- allow to study of galaxy emission
- low accretion regime
- small BH masses
- low end of the luminosity function

The University of Manchester
Jodrell Bank Observatory

UNIVERSITY OF Southampton
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LEMMINGS

Legacy e-MERLIN Multi-band Imaging of Nearby Galaxies

Collaboration between University of Southampton and Manchester

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David Williams (Southampton)
Rob Beswick (JBCA/e-MERLIN)
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e-MERLIN

Southampton

Main goals

L-band high-resolution and high-sensitivity observations of eMERLIN allow to disentangle AGN and SF:

1. low-luminosity AGN (nucleus)
   - radio core, indicative of jet energetics
   - accretion, radio/X-ray connection
   - jets

2. Star formation (host galaxy)

   - individual populations, eg SN, PNe, HII regions
   - unresolved large SF scale emission

eMERLIN beam size is ~10 times smaller than VLA beam size.

Sample

- Sample = **Palomar bright galaxy sample**
  - Best selected sample of nearby galaxies (Ho et al 1995)
  - Optically selected, $B_T < 12.5$ mag, no radio bias
  - All galaxy types: Active (Seyfert, Liner), **Non-active (HII region, Absorption line galaxies)**
  - All 280 galaxies above Dec +20 [median distance 20Mpc]
  - Strong multi-wavelength coverage
    - Complete HST, Spitzer and (mostly) Herschel imaging
    - Almost complete Chandra imaging (Large Program approved)
    - Complete JVLA imaging
- 'Shallow' tier: short observations at L band (1.5 GHz)

Shallow sample: Radio

- Palomar Sample (103 targets, **Baldi et al. 2018**)
  - rms ~70 microJy/beam and angular resolution 150 mas
  - 84/241 (~35%) of the sample detected (F > 0.2 mJy) at 1.5 GHz
  - Detection fraction:

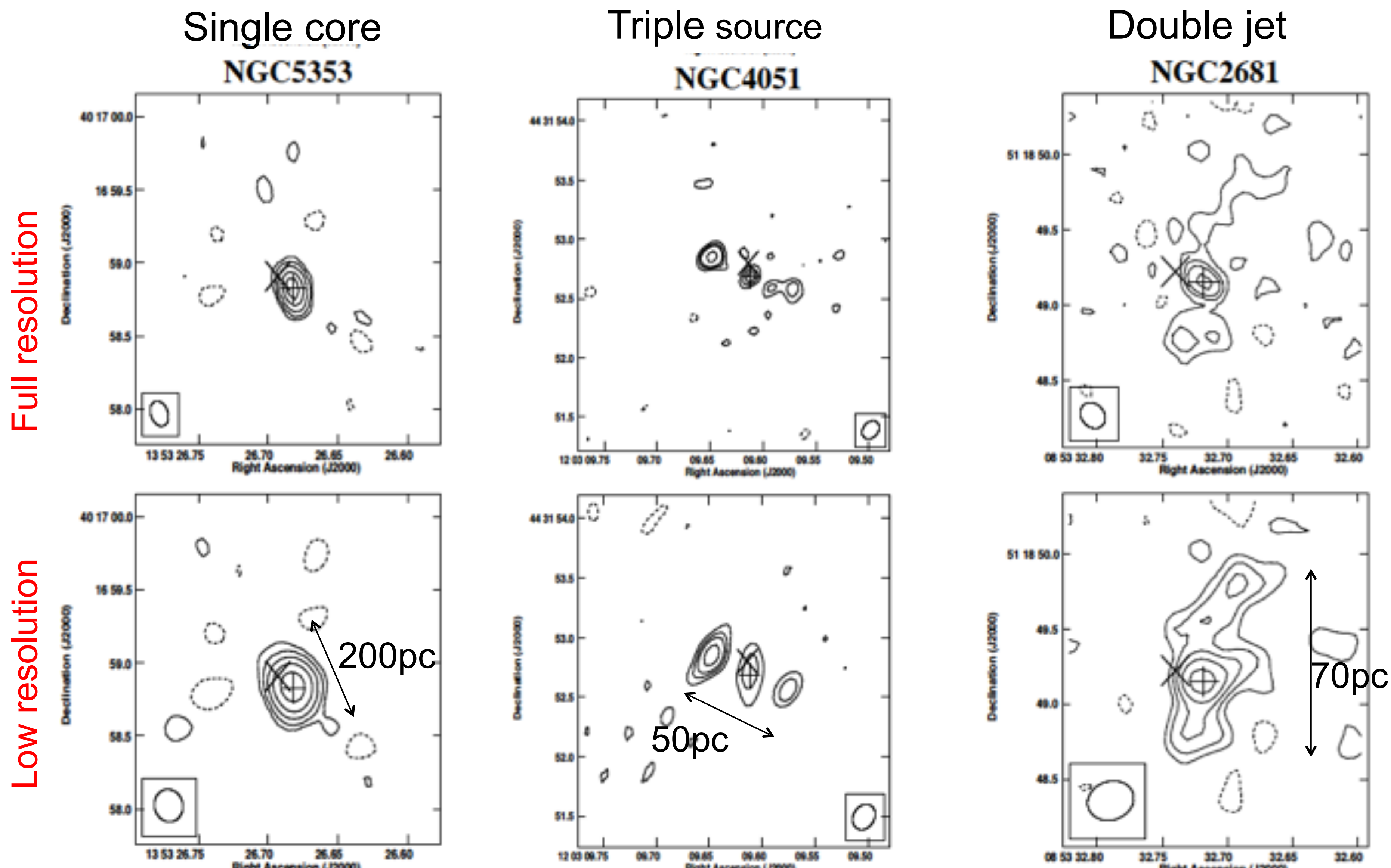
1. LINER: 46 / 77 → 60%
2. Seyfert: 9 / 16 → 56%
3. HII regions: 24 / 119 → 20%
4. Absoprtion line galaxies: 5 / 29 → 17%

} ***Active*** (1–2)

} ***Inactive*** (3–4)

  - Extended radio emission appears with UV-tapering
  - Radio morphologies: core/core-jet, one-sided jet, triple sources, double-lobed, complex

Radio morphologies



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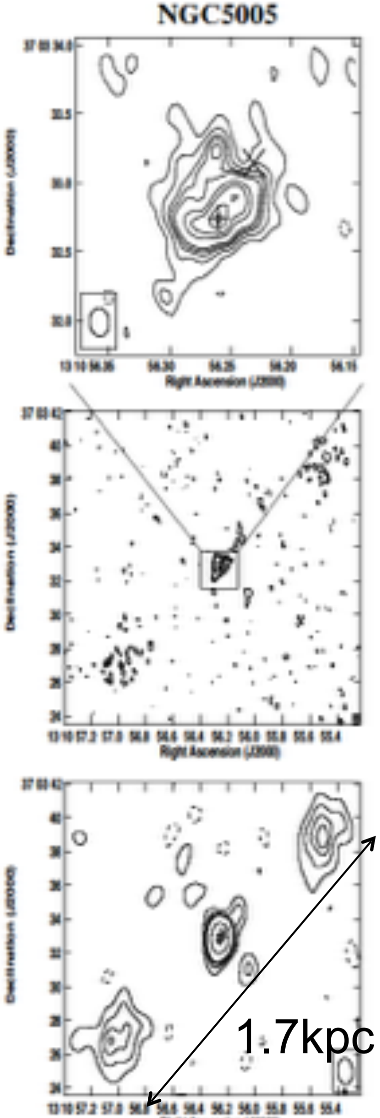
Radio morphologies

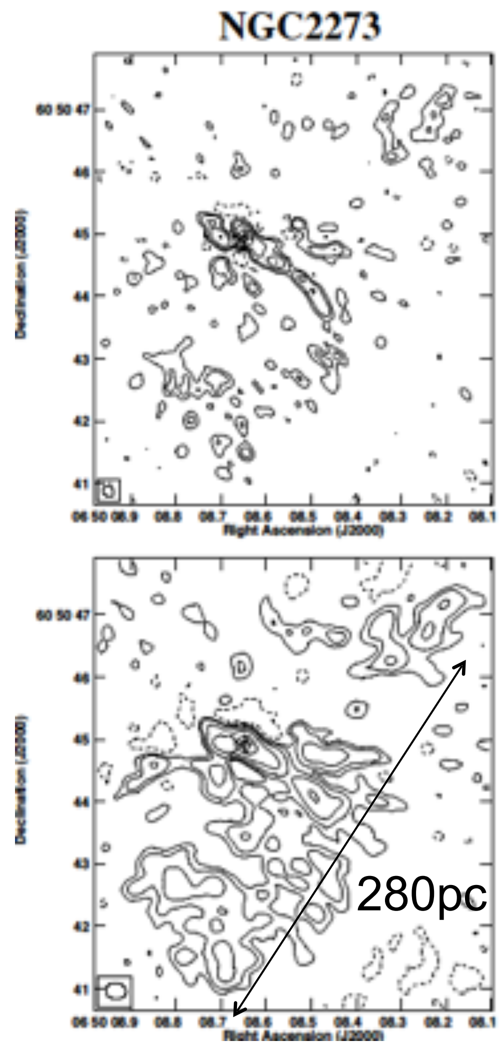
Full resolution

Low resolution

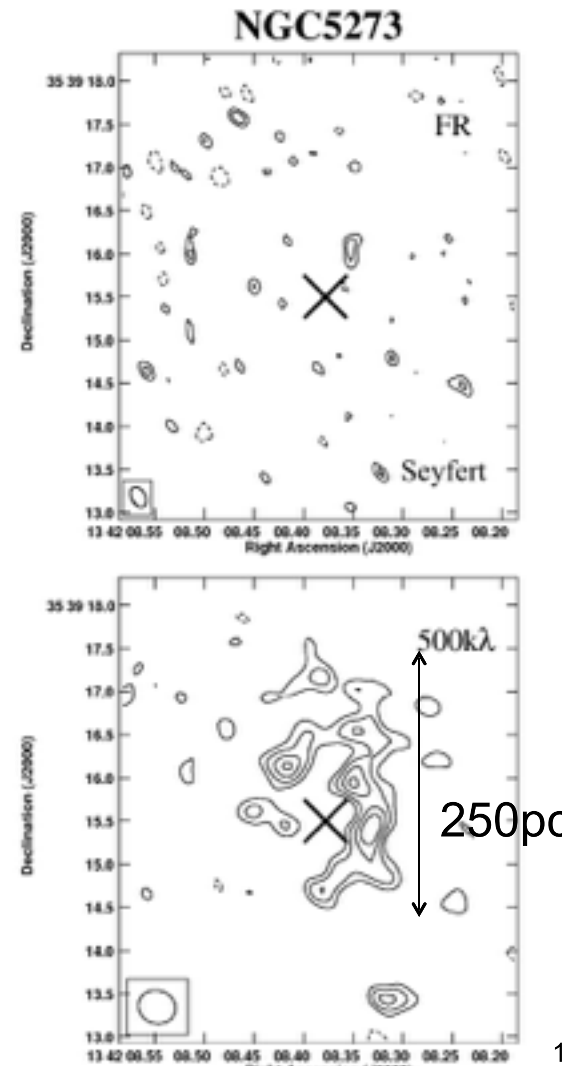
Double-lobed



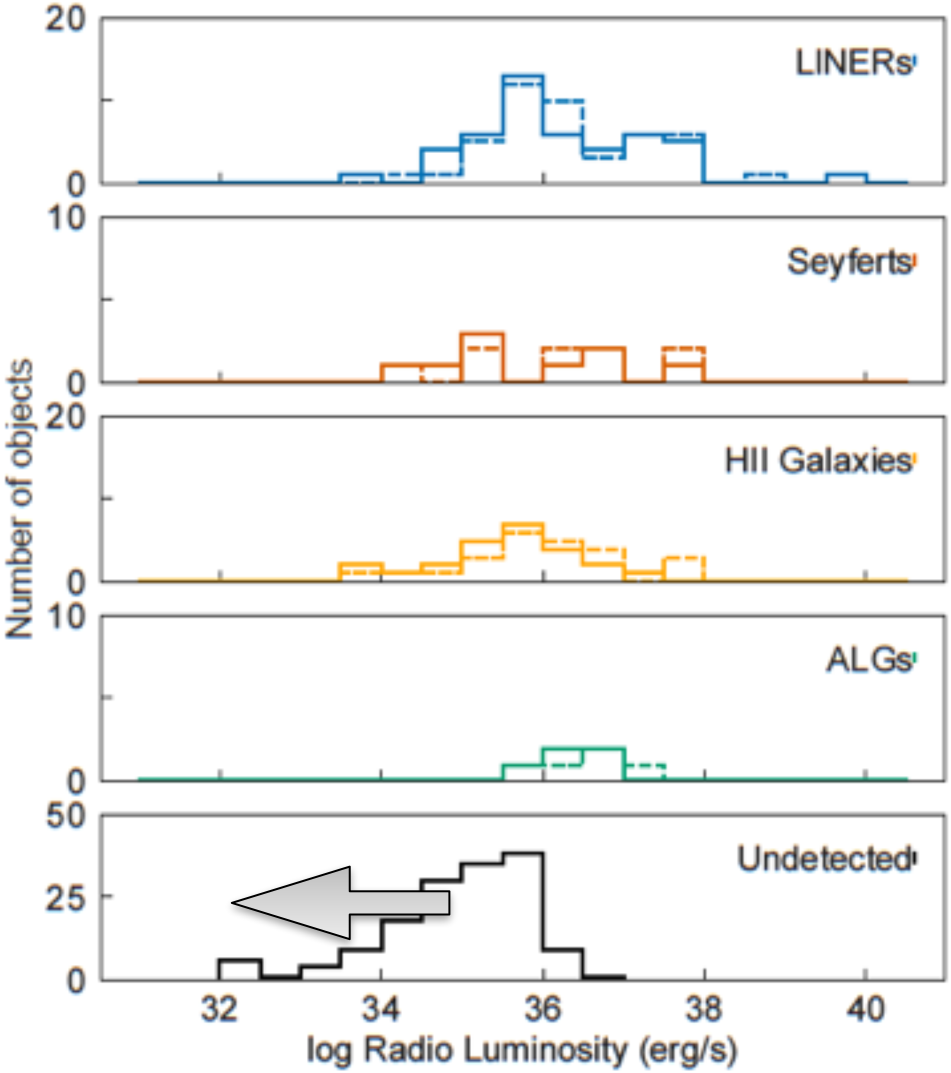
Complex



SF ring



Deeper than any other radio survey of the Palomar sample (Nagar et al. 2002, Filho et al 2006)



- $L_{core} \sim 10^{32} - 10^{40}$ erg s^{-1} ($10^{16} - 10^{22}$ W Hz^{-1})
- Within a factor 100 of Sgr A* (in L band), but aim at reaching radio luminosity function within a factor of 10 in C band.
- LINERs are the brightest and more luminous
- jetted sources in HII galaxies and in BH with $>10^6 M_\odot$

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Shallow sample: X-ray Chandra

- Palomar Sample (163 archival data + 48 new ACIS-S 10ks Chandra obs) in 0.3-10 keV band
  - flux limit: 3 x 10^{-15} erg s^{-1} cm^{-2}
  - 149/211 (~71%) of the sample detected in 2-10 keV band

  - Detection fraction:

1. LINER: 64 / 74 ➔ 86%
2. Seyfert: 14 / 15 ➔ 93%

} ***Active***

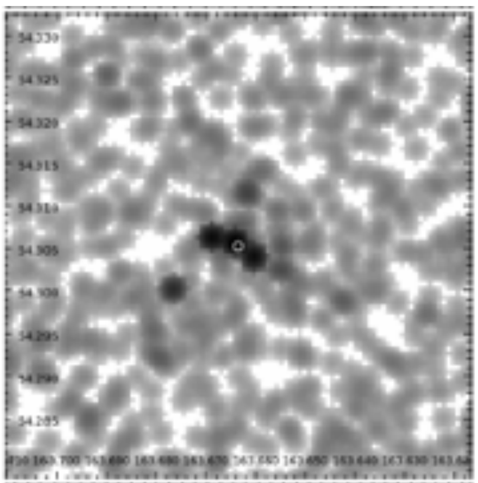
3. HII regions: 50 / 98 ➔ 51%
4. Absoprtion line galaxies: 21 / 24 ➔ 88%

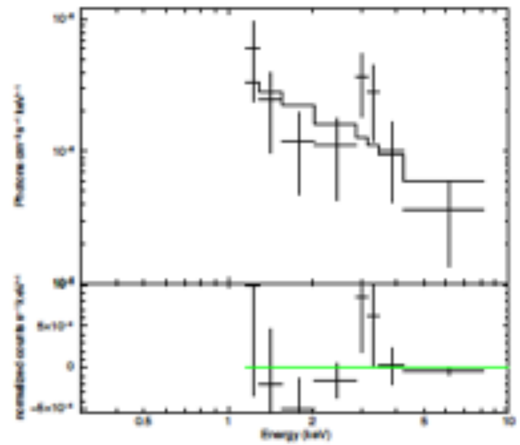
} ***Inactive***

- Photometry and spectroscopy (area of 2'')

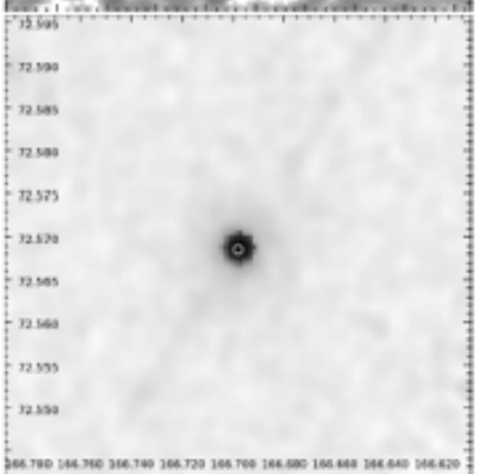
Chandra spectra (0.3-10 keV)

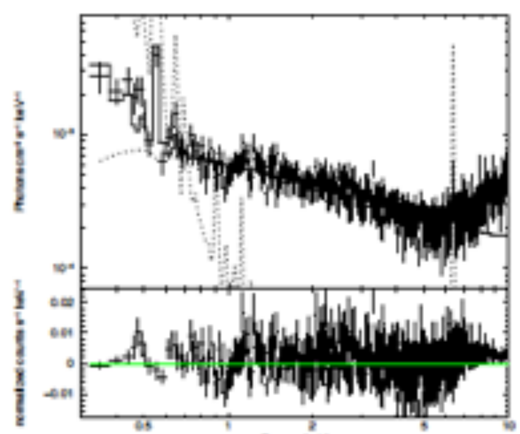
- X-ray Spectral fit for 120/149 sources with more than 200 photons (thermal + absorbed power law)





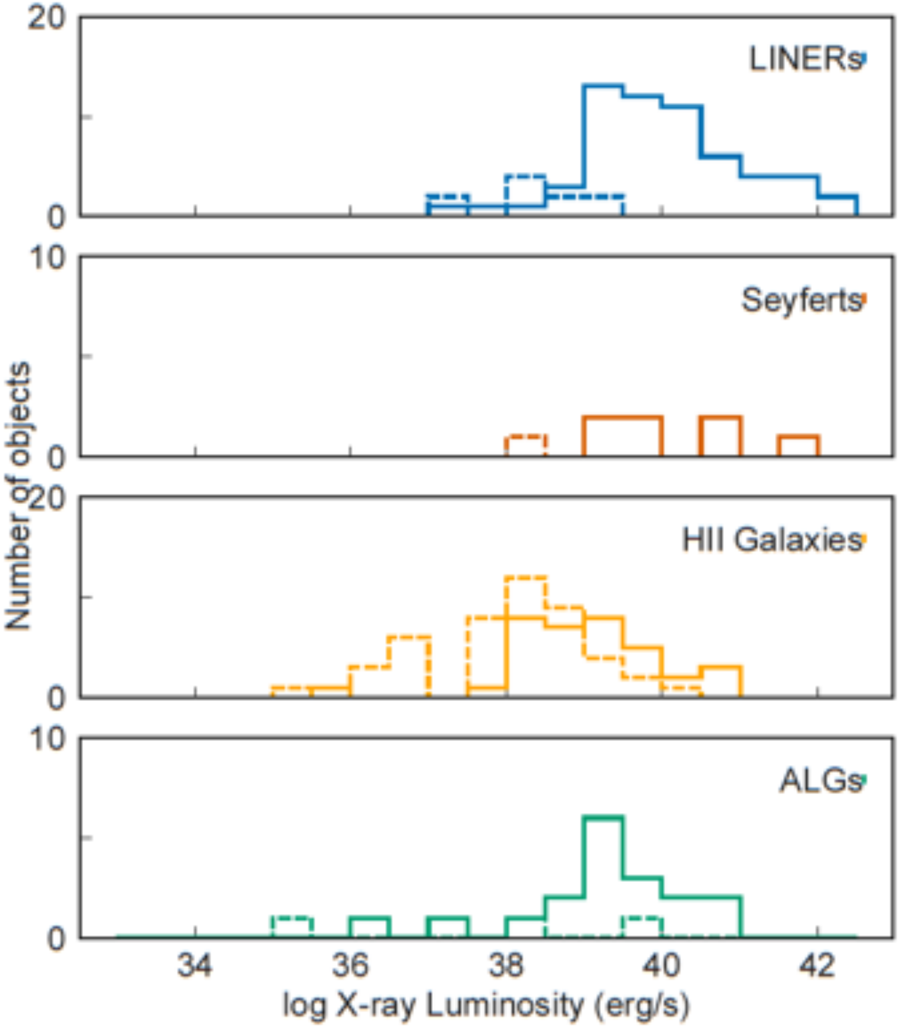
NGC3448

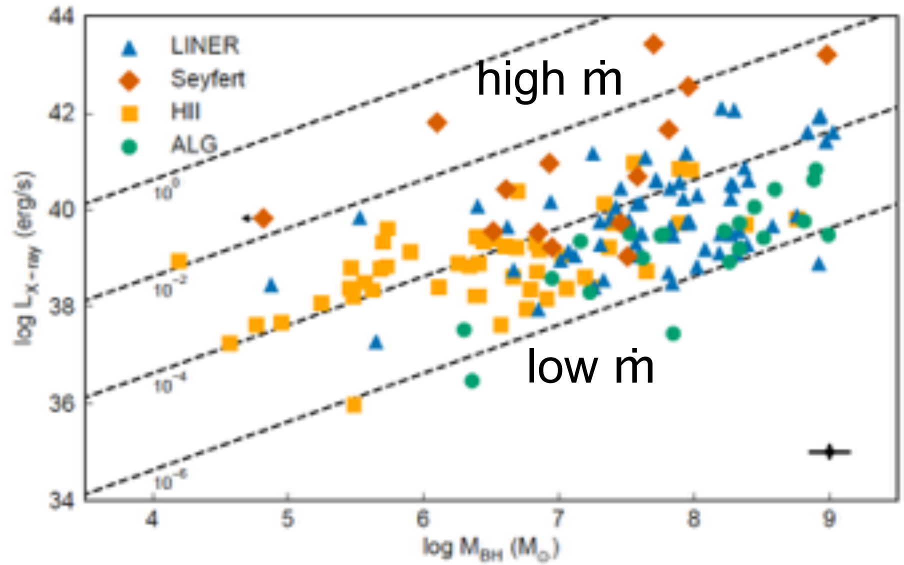




NGC3516

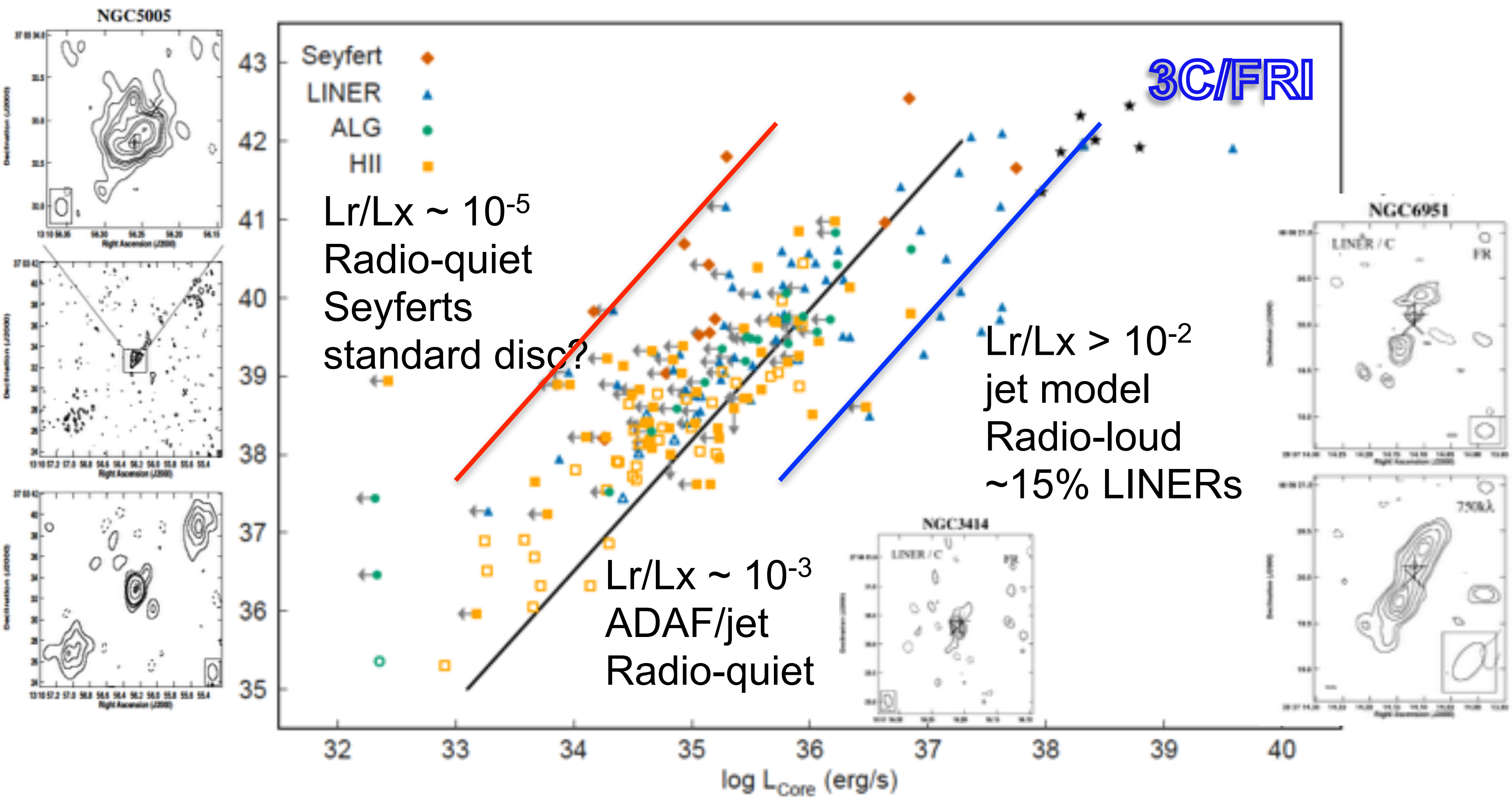
X-ray luminosities





- LINERs and Seyferts are among the brightest and more luminous
- LINERs and ALGs: low Eddington ratios
- Seyferts: high Eddington ratios

Radio – X-ray relation



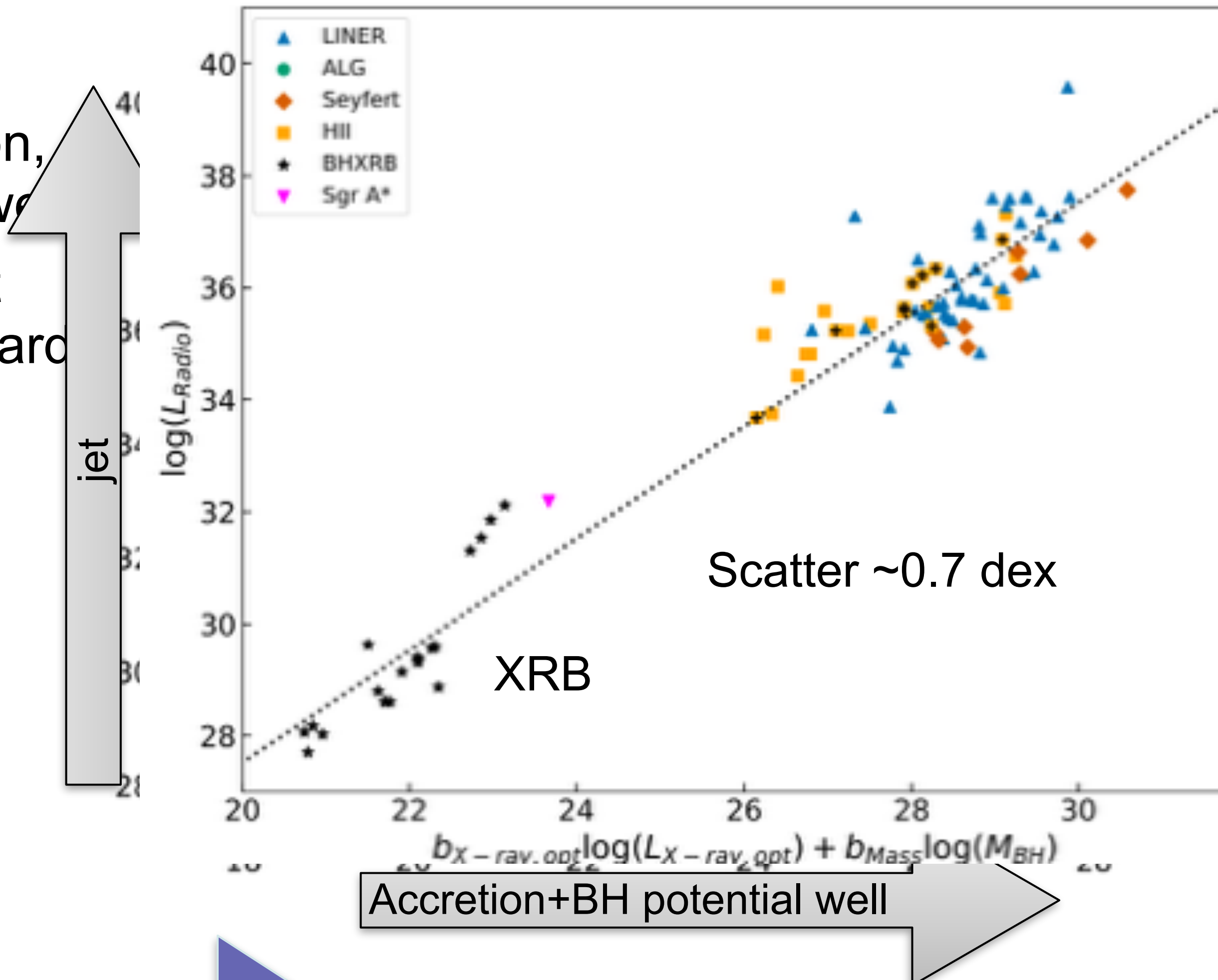
LINERs: radio-quiet - loud LINERs. Radio-loud LINERs are scaled-down FRI

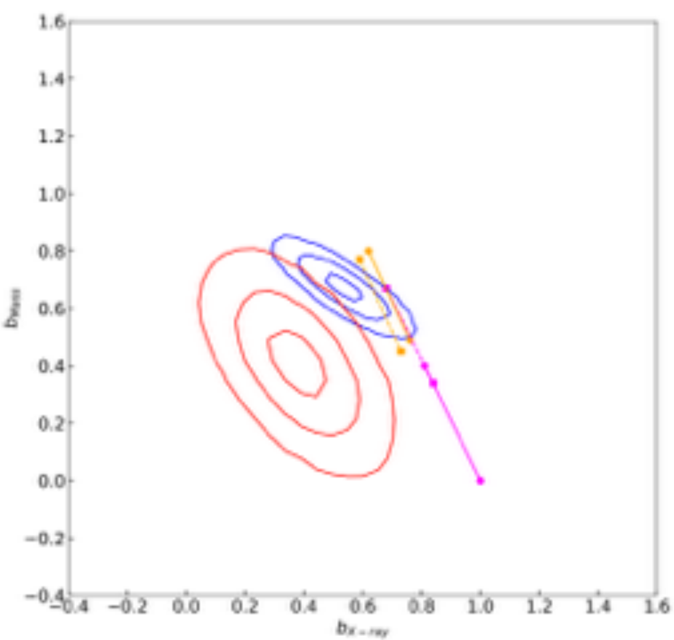
Seyferts are above the correlation: standard accretion?

HII regions : SF and AGN dominated?

Fundamental plane of BH activity

- radio - M_{BH} - X-ray
- relation between accretion, jet and BH gravitational well
- Bayesian fit with different models (ADAF, jet, standard disk)





a radiatively inefficient disc is needed to fit the fundamental plane

CONCLUSIONS

- Nearby galaxy surveys with eMERLIN have great potential for study of LLAGN, jets and star formation on crucial small scales.
  1. LeMMINGs: Palomar sample (241 so far, Baldi et al 2018): deepest Palomar radio survey, ~10^{32} erg s^{-1}
  2. pc-scale radio jets from BH down to ~10^{6} $M_{\odot}$

- Radio-loud LINERs are the scaled-down version of FRI radio galaxies

- Low-luminosity Seyferts are powered by higher accretion rate and higher radiative disc efficiency than the ADAF disc seen in LINERs (but less than in QSO?).

- HII galaxies have optically SF dominated but can hide a LLAGN

- Fundamental plane of BH activity for the Palomar sample requires an ADAF/jet coupling


THANK YOU