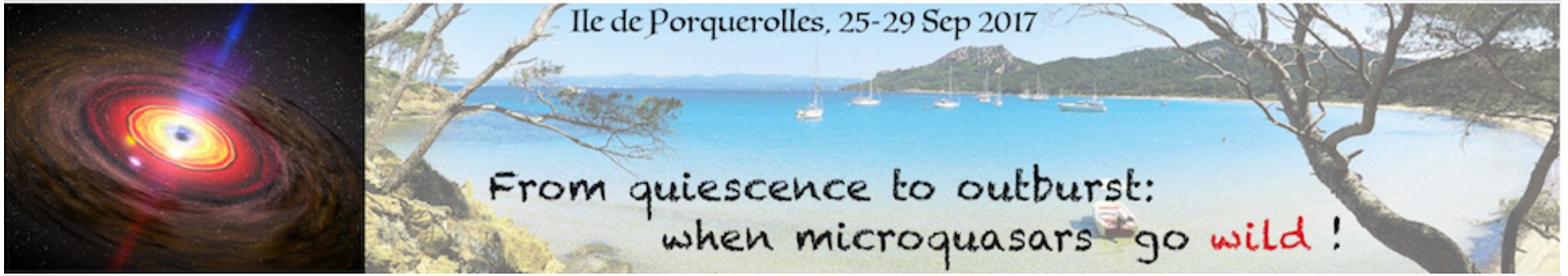
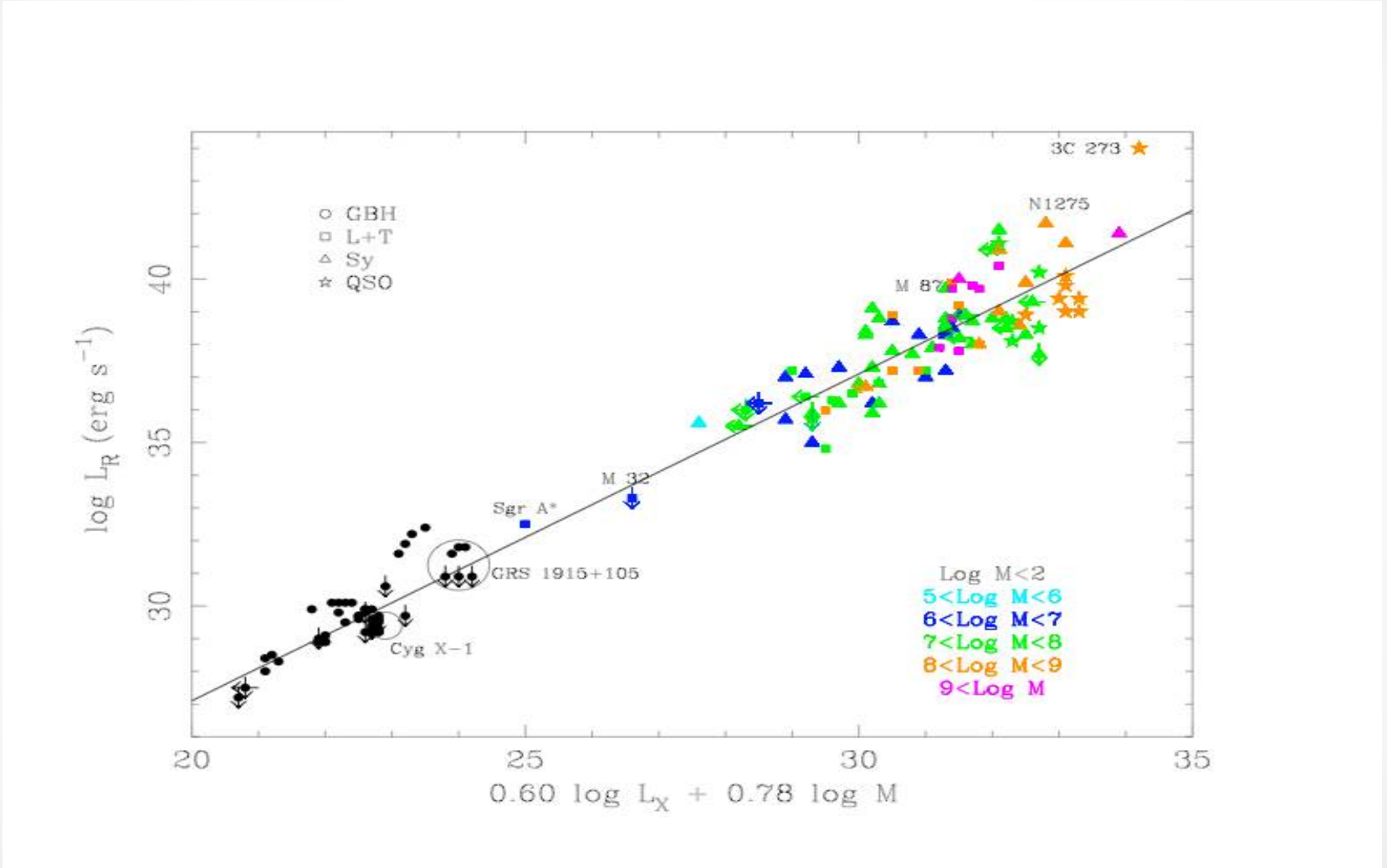



# Disk-jet coupling in *AGN:*
## *caveats on unification with XRBs*

Francesca Panessa

Institute for Space Astrophysics and Planetology
Istituto di Astrofisica e Planetologia Spaziali

# FUNDAMENTAL PLANE FOR BH ACTIVITY



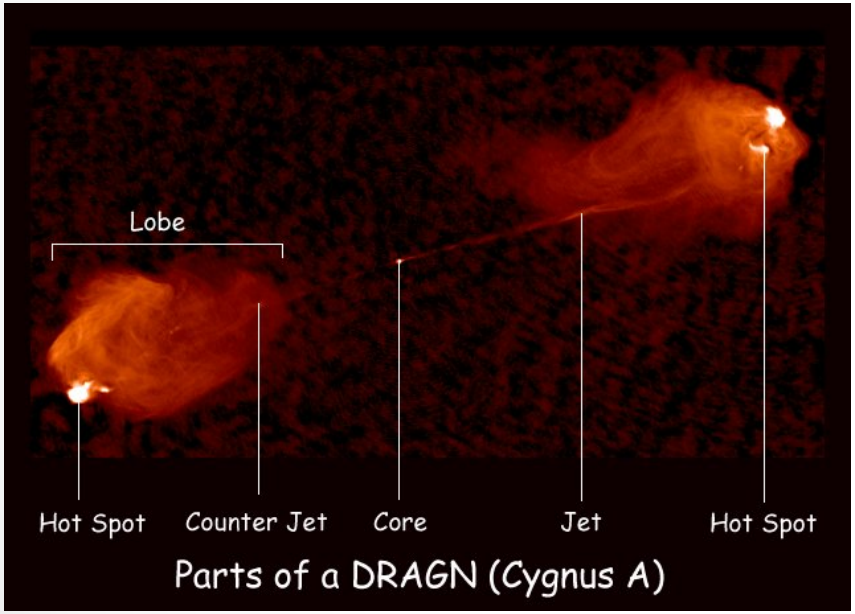

Merloni et al. 2004, Falcke et al. 2004

# AGN: WITH JETS, WITHOUT JETS

With jet:

✓ Large scale radio lobes

✓ Compact luminous cores often with apparent luminal motions



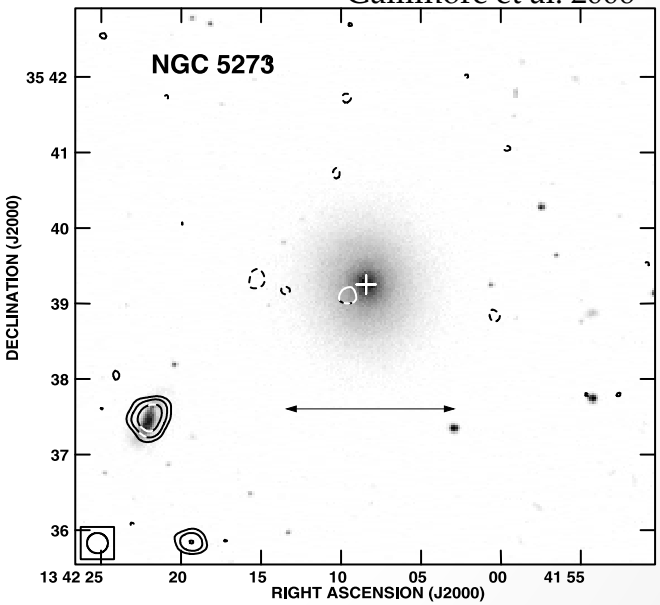

Radio Loud

Without jet:

✓ Faint radio sources

✓ Emission confined to sub-kpc scale

Gallimore et al. 2006

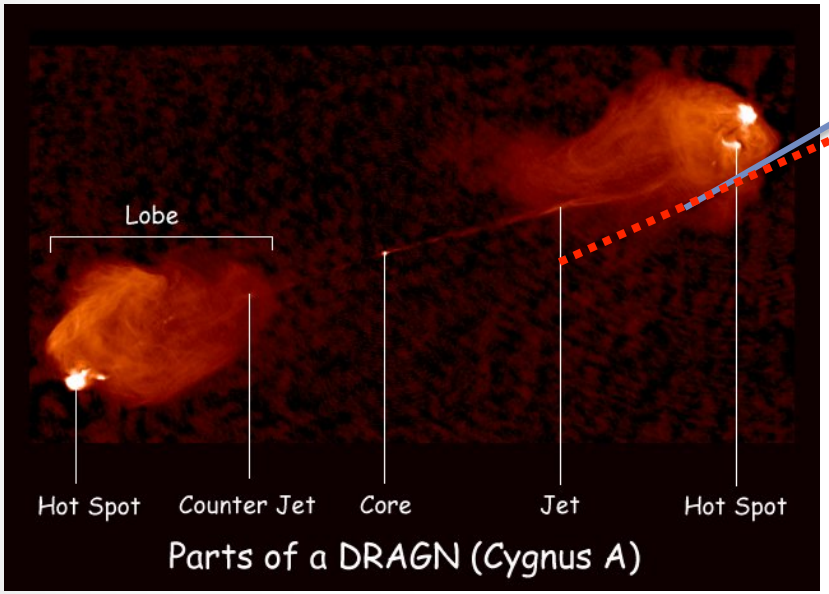


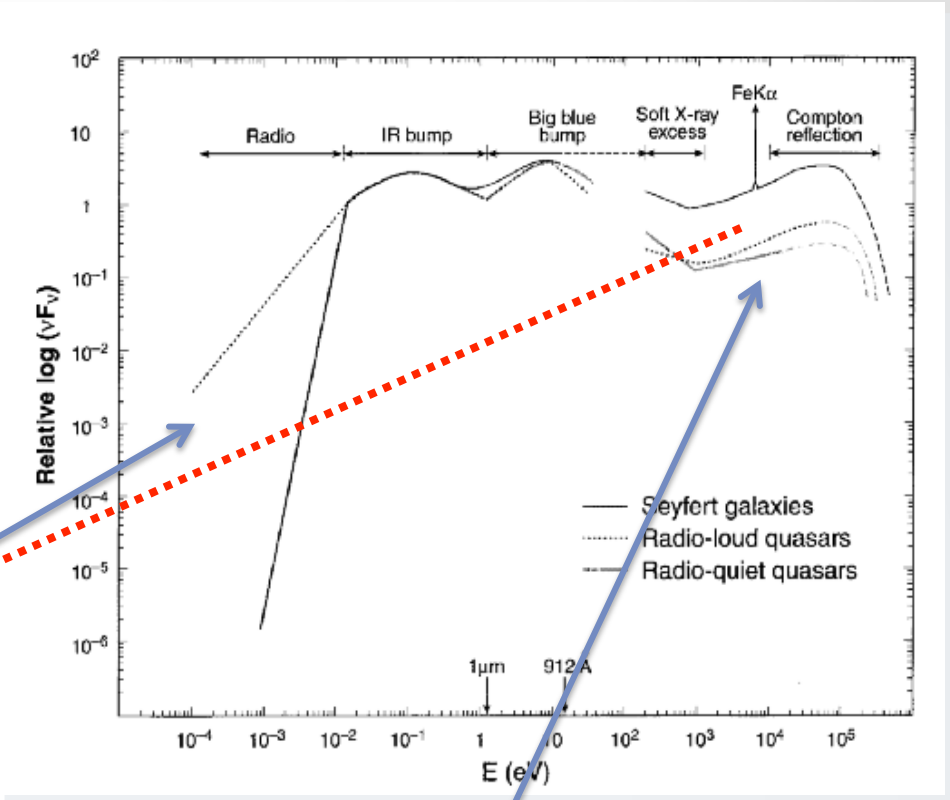

Radio Quiet

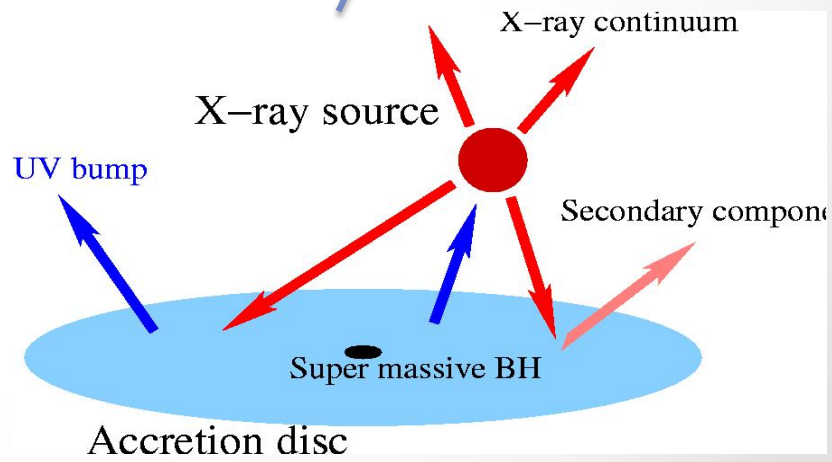
RADIO LOUDNESS  R = L(5 GHz) / L(B)

# AGN with JETS

## Radio Loud



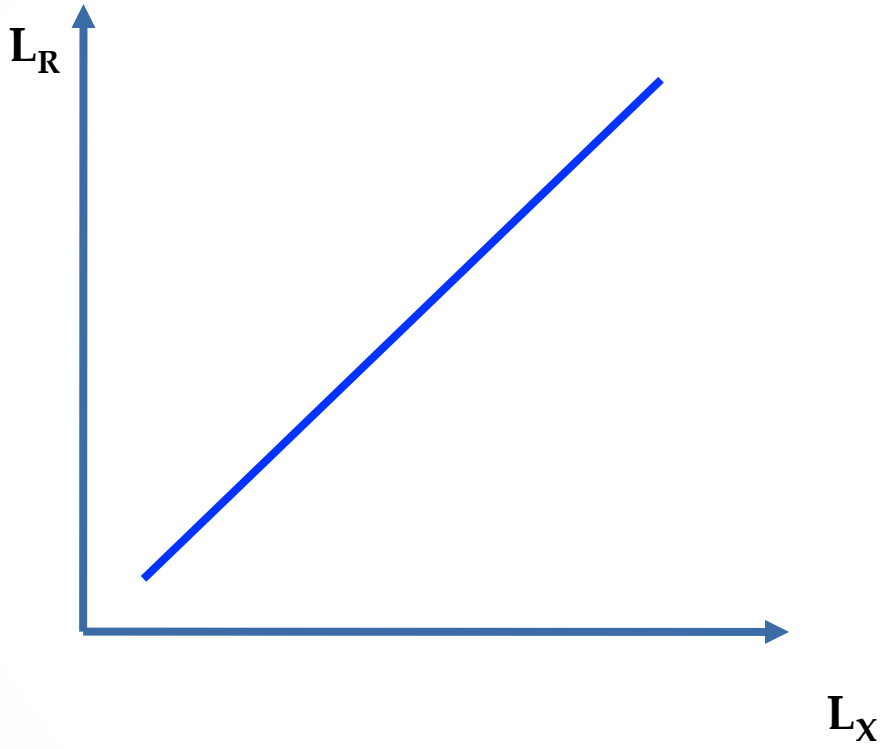




X-RAYS:
Accretion disc + hot corona + jet(?)

# AGN with JETS

## Radio Loud

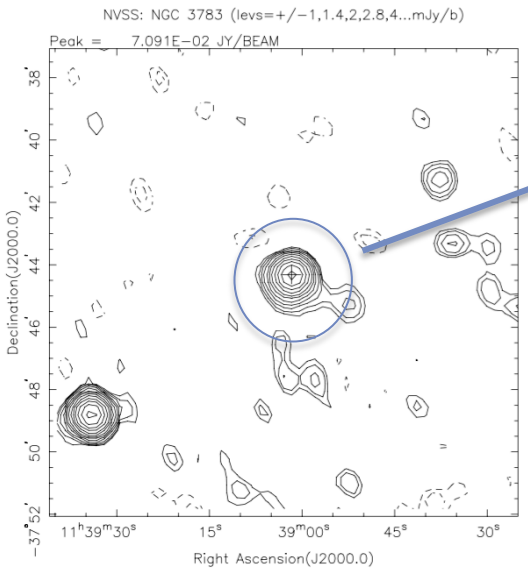
If both X-rays and radio are jet dominated

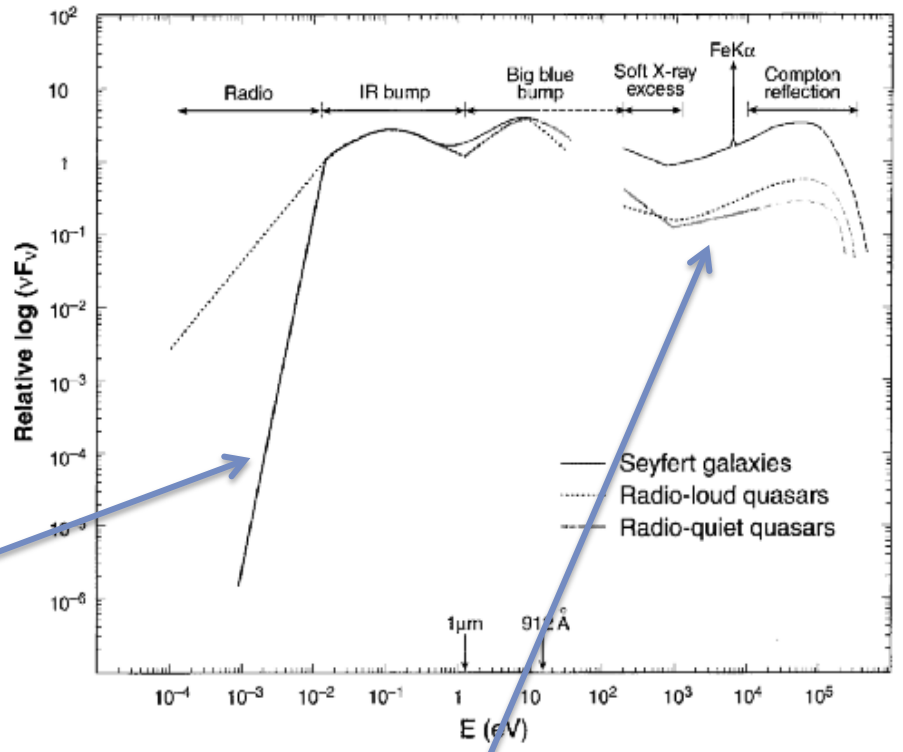


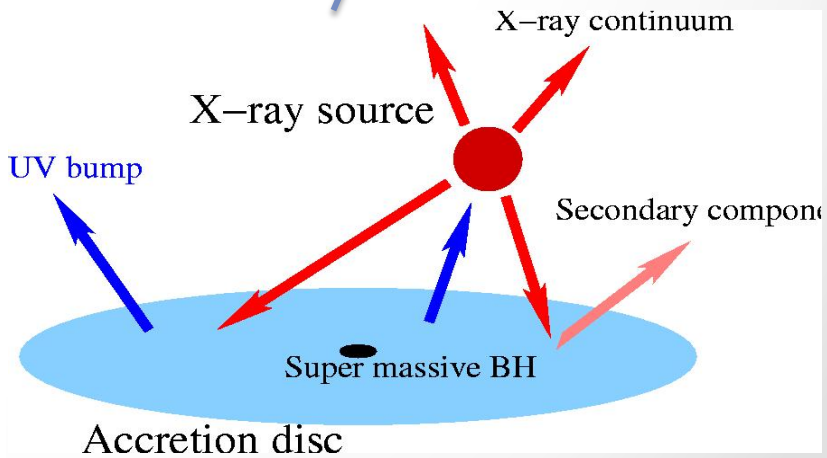
# AGN without JETS

## Radio Quiet

RADIO:



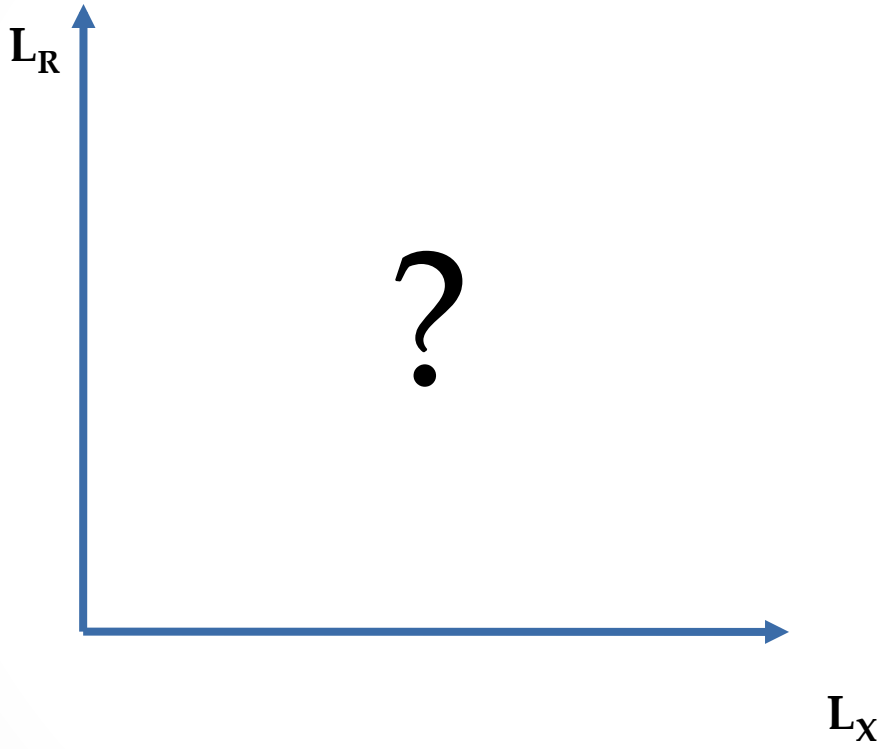




X-RAYS:
Accretion disc + hot corona

# AGN without JETS

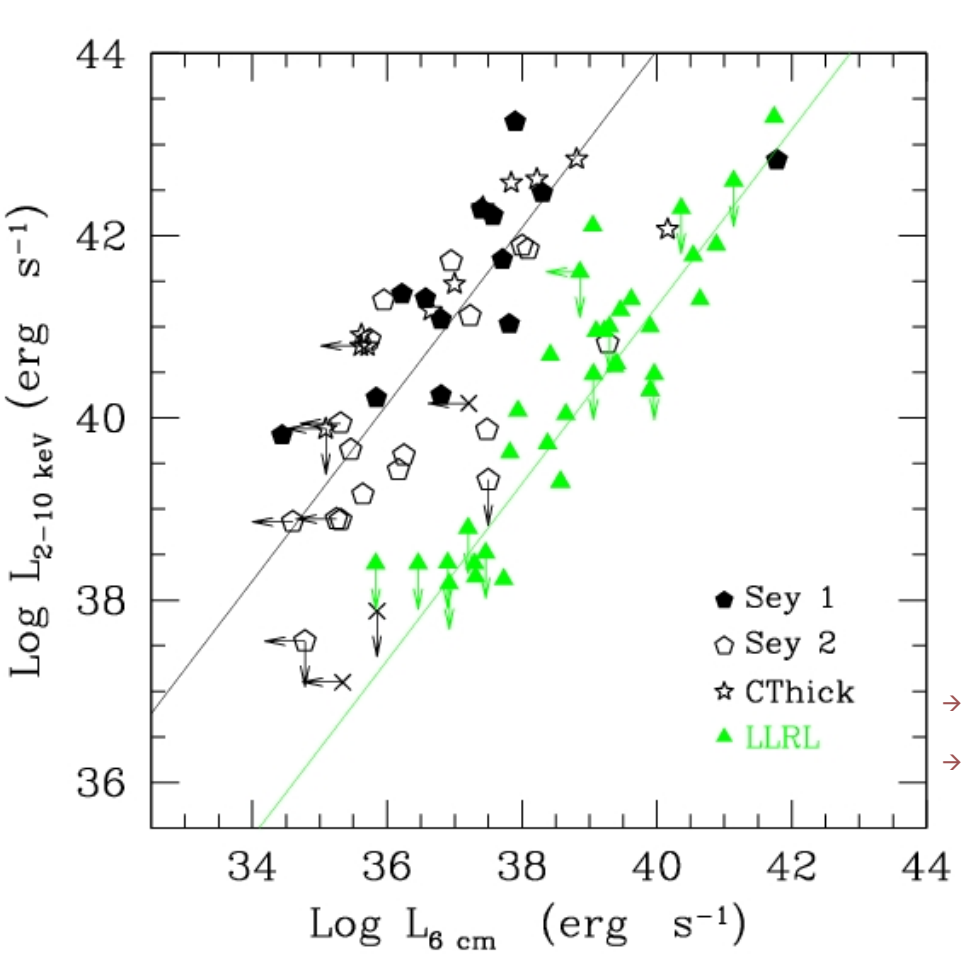
Radio Quiet

If X-rays come from accretion and radio from ?



# AGN without JETS of low luminosity

Radio Quiet




Panessa et al. 2007

Low Luminosity Radio Galaxies

VLA + Chandra

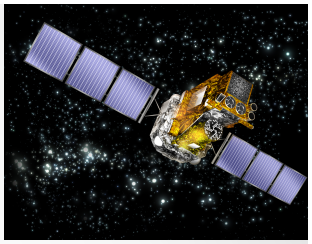
Low Luminosity RQ AGN (Palomar)

VLA + Chandra/XMM

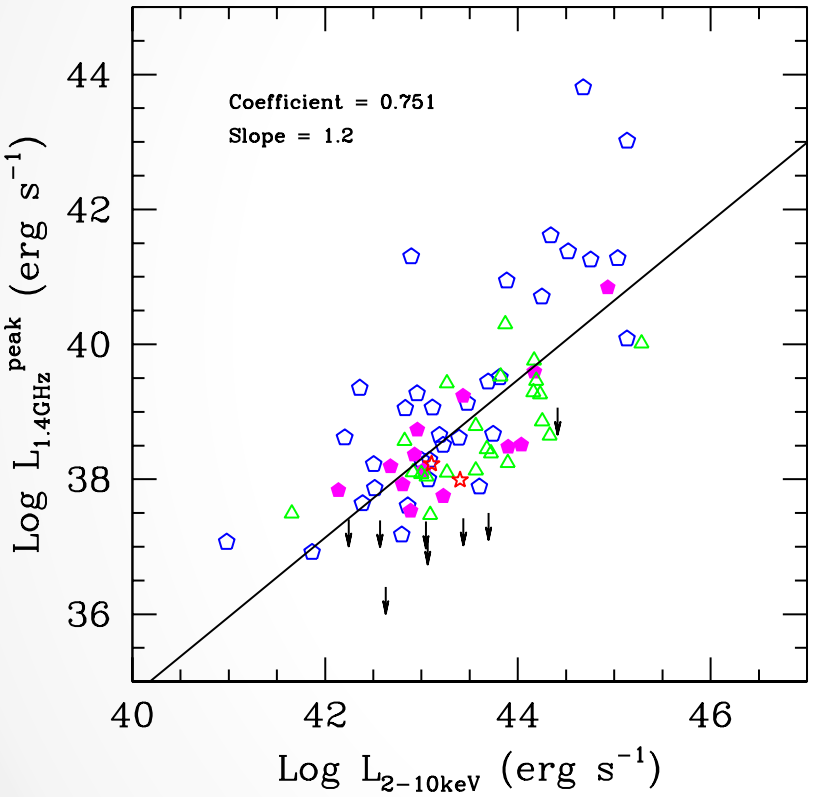
- X-ray and radio from the same component?
- Jet/outflow are disk related (jet, disc-corona)

# AGN without JETS of high luminosity

## Radio Quiet



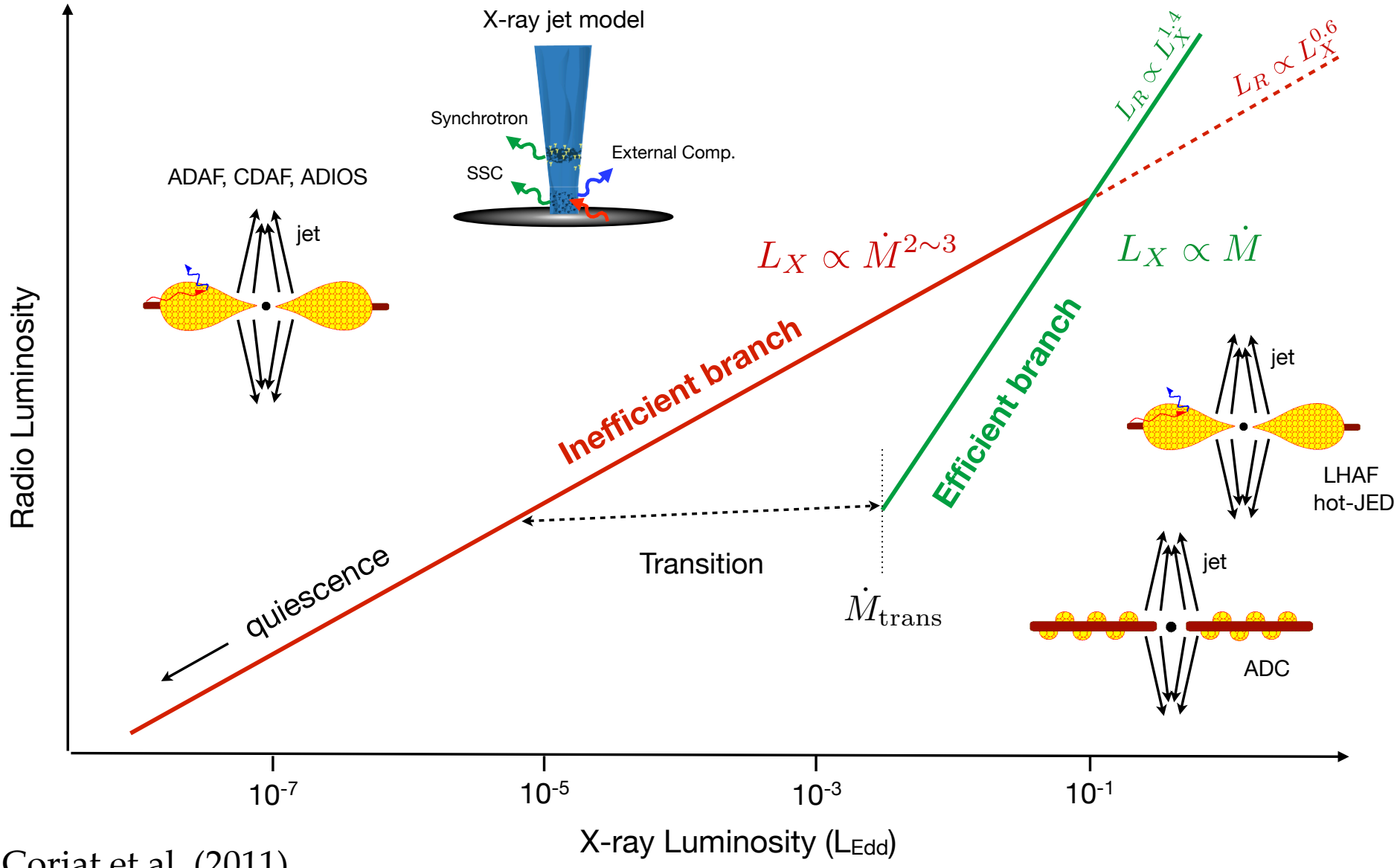
INTEGRAL AGN sample
20-40 keV




Panessa et al. 2015

→ Slope consistent with efficient accretion

# JET-DISK COUPLING

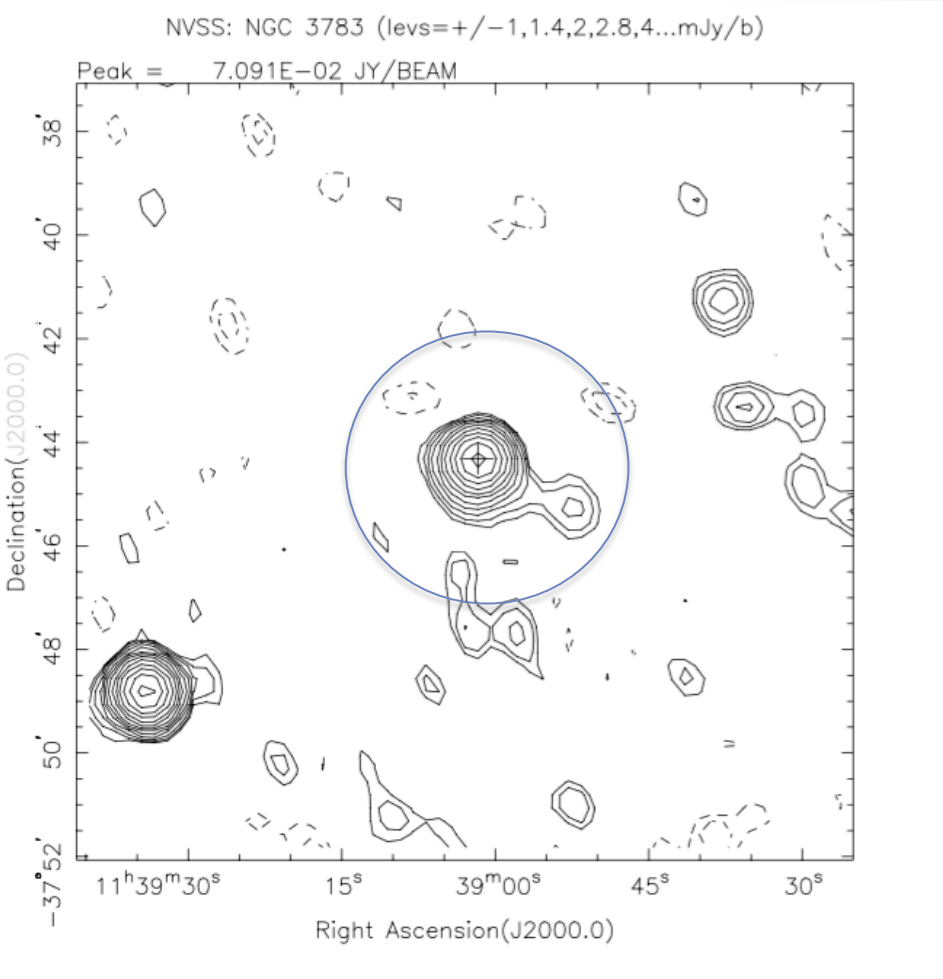



Coriat et al. (2011)

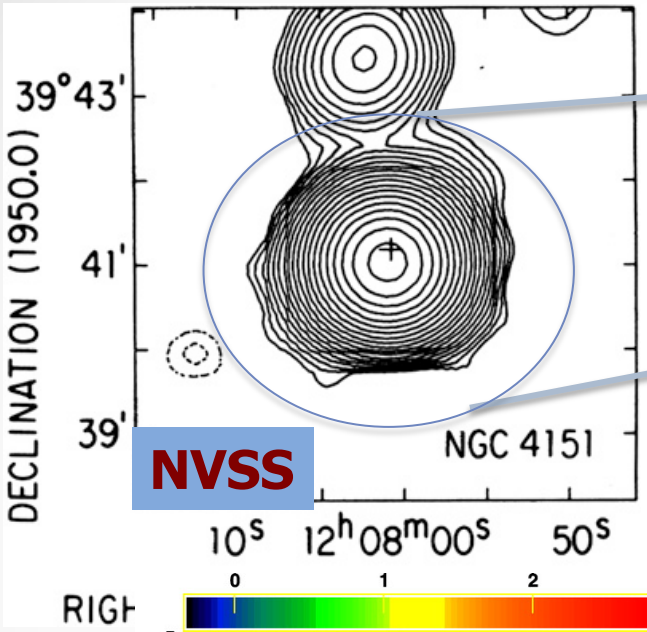
Hannikainen et al. (1998), Corbel et al. (2003), Gallo, Fender & Pooley (2003)

# ORIGIN OF RADIO EMISSION IN RADIO QUIET

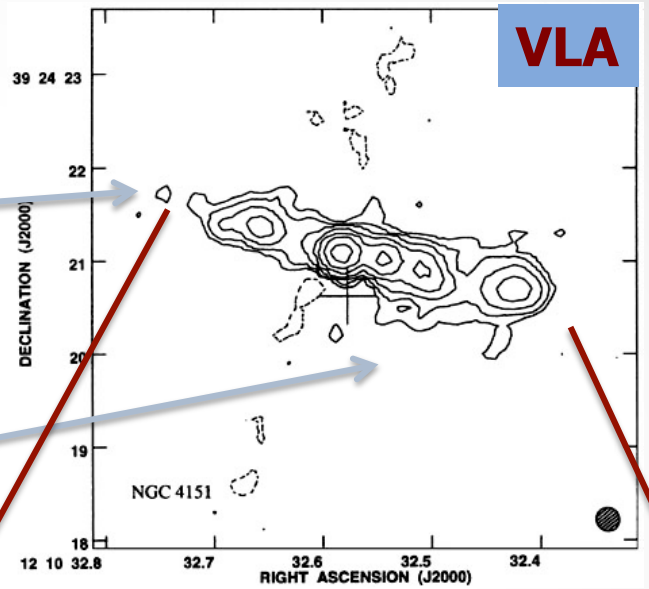
ARE WE SURE THAT THIS IS A JET?



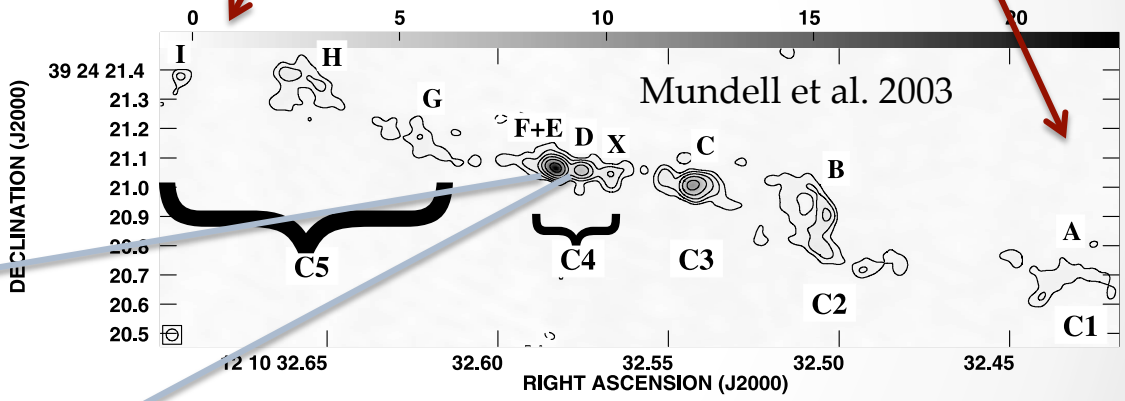
NGC4151 D = 20 Mpc

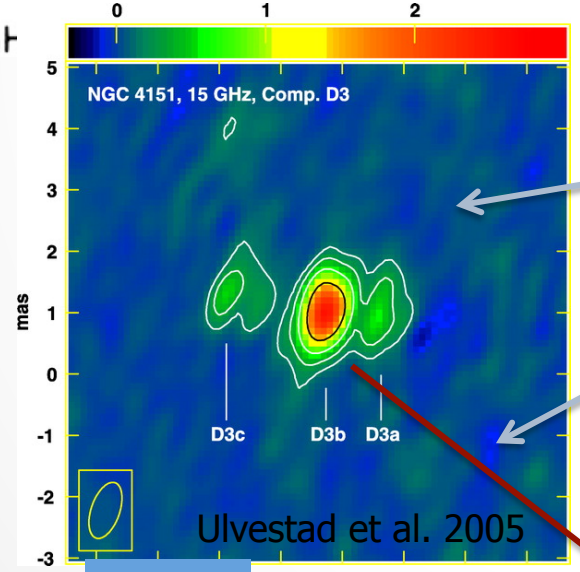



NVSS




VLA



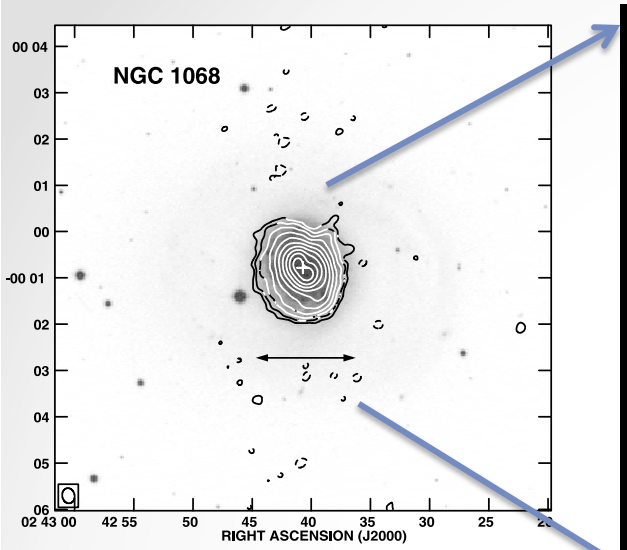

VLBI

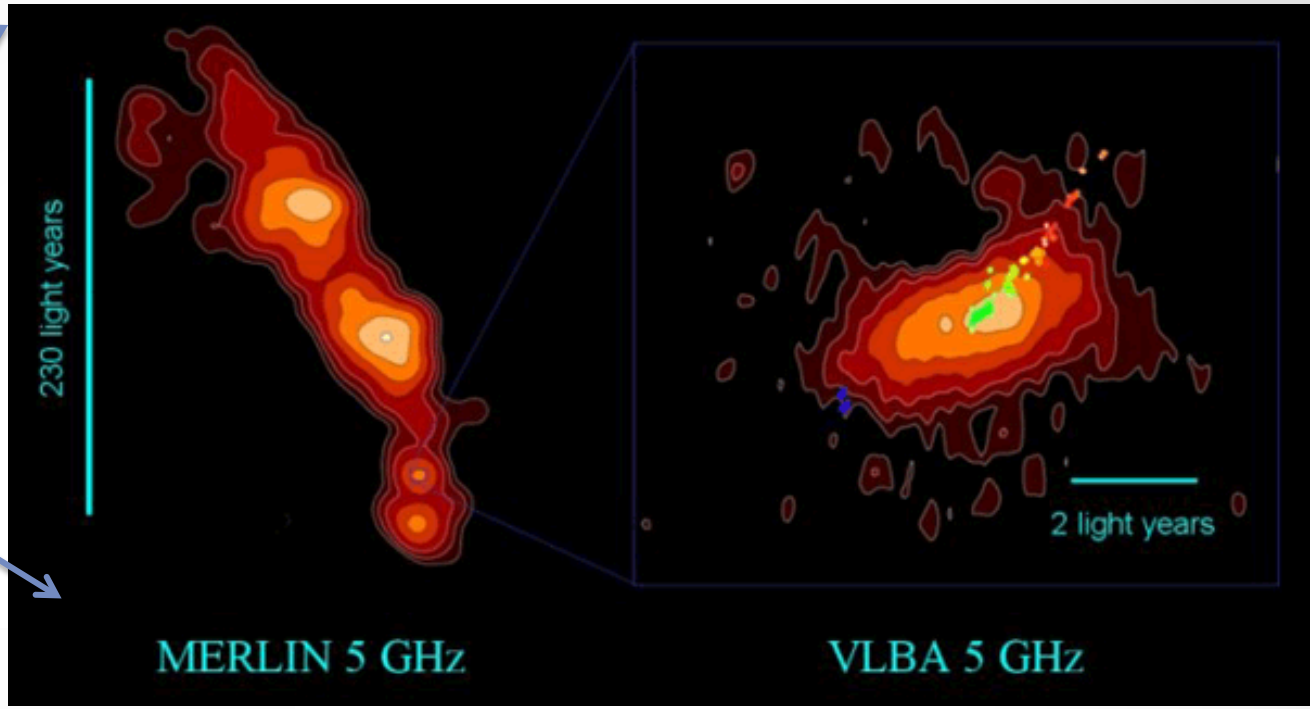
NVSS → up to tens of kpc

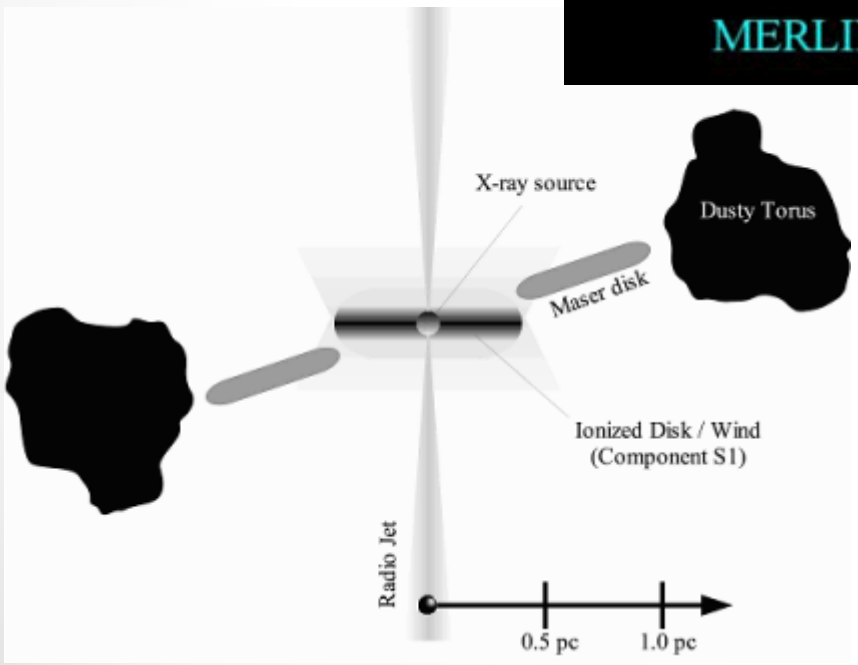
VLA → tens of pc up to kpc scales

VLBI → < 0.1 pc

BLR scale!



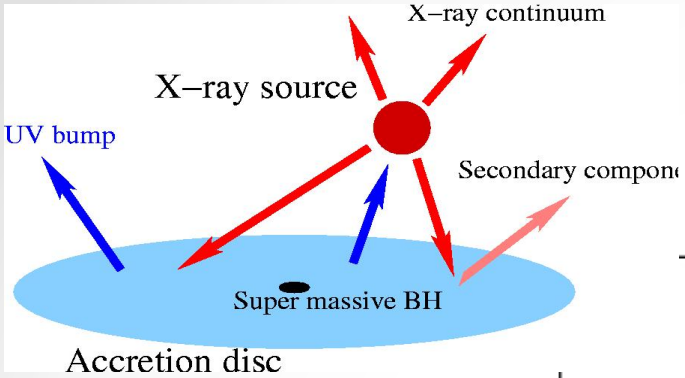



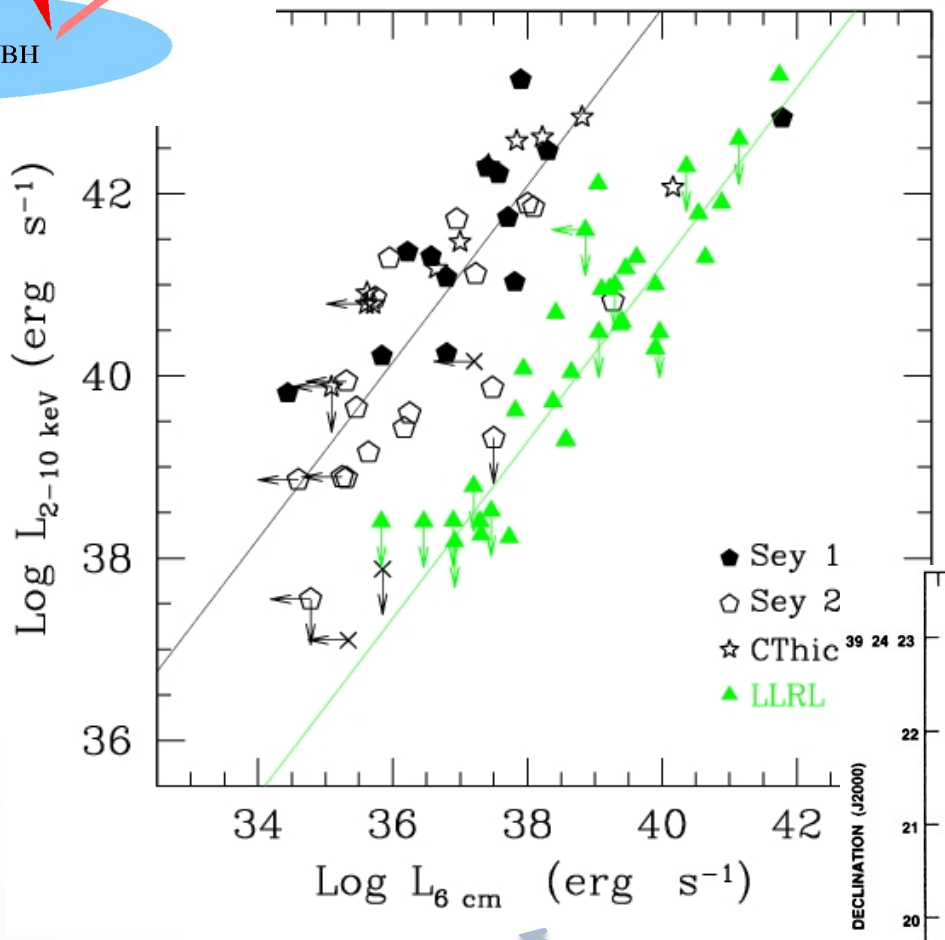

NGC 1068
Gallimore et al. 2004

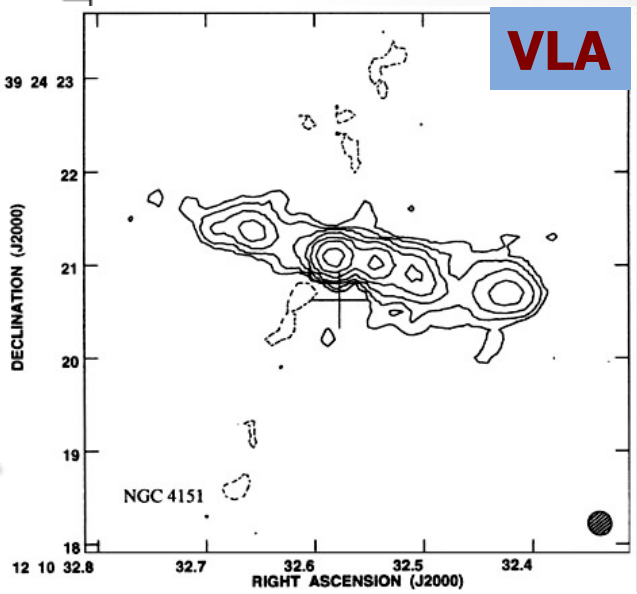
MERLIN emission: low power jet

VLBA emission: free-free emission from the hot X-ray corona



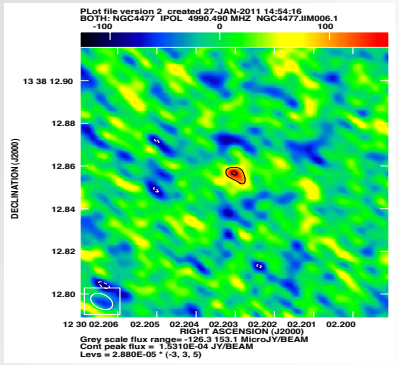

X-rays → a few $R_S$

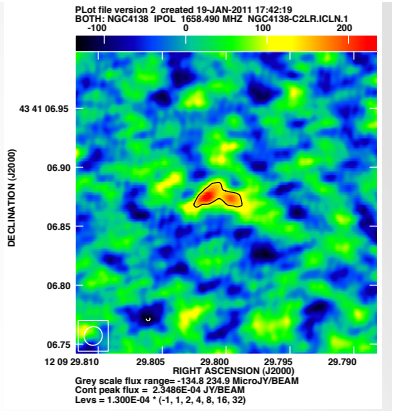


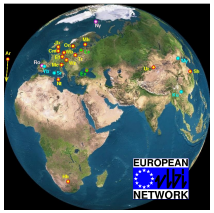



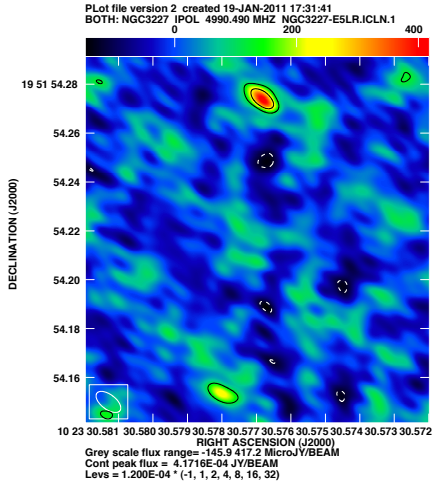

VLA → tens of pc up to kpc scales

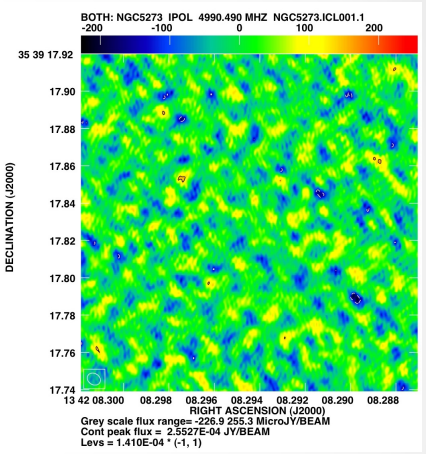
# The European VLBI Network (EVN) survey of local nuclei < 22 Mpc



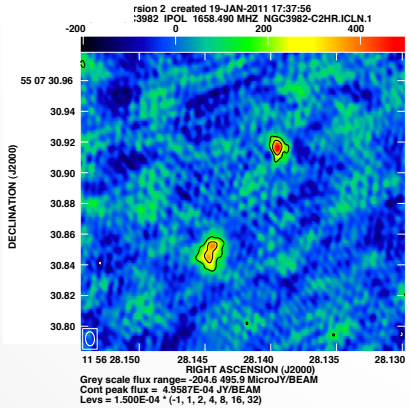



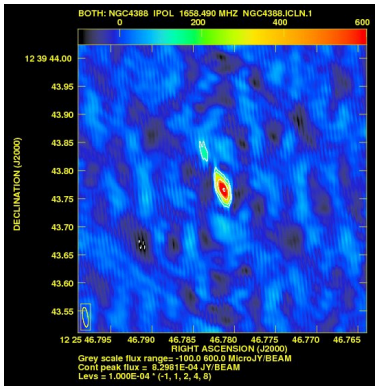



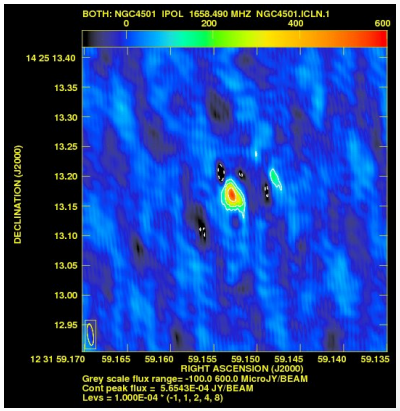




- 6 and 20 cm survey
- 90 microJy/beam
- Linear scales 0.05 pc @10 Mpc




Giroletti & Panessa 2009, Bontempi et al. 2012, **Panessa & Giroletti 2013**

- ✓ Single compact
- ✓ Double at one freq.
- ✓ Double at both freq.
- ✓ Jet like structure
- ✓ Non detection (8/23)

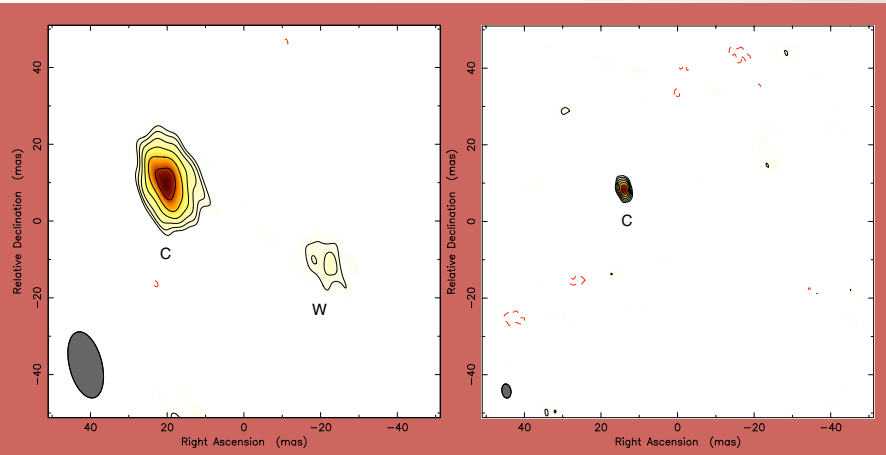



**Figure 3.** NGC 4138 at 1.7 GHz (left) and 5 GHz (right). Contours are traced at $(-1, 1, 2, 4, \ldots)\times$ the $\sim 3\sigma$ noise level, which is 0.14 and 0.09 mJy beam$^{-1}$ at 1.7 and 5 GHz, respectively. HPBW are shown in the lower left corner, and their size is 8.5 mas × 17.7 mas in P.A. 14° and 2.4 mas × 3.7 mas in P.A. 8° at 1.7 and 5 GHz, respectively.

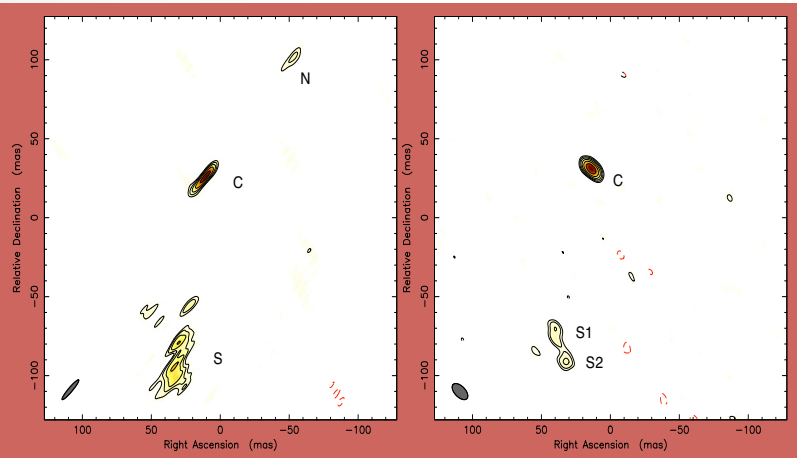



**Figure 1.** Images of NGC 3227 at 1.7 GHz (left) and 5 GHz (right). Contours are traced at $(-1, 1, 2, 4, \ldots)\times$ the $\sim 3\sigma$ noise level, which is 0.13 and 0.08 mJy beam$^{-1}$ at 1.7 and 5 GHz, respectively. HPBWs are shown in the lower left corner, and their size is 2.9 mas × 17.3 mas in P.A. −44° and 7.2 mas × 13.5 mas in P.A. 50° at 1.7 and 5 GHz, respectively.

- ✓ Flat/inverted spectrum
- ✓ Steep spectrum

- ✓ Thermal (torus/corona)
- ✓ Non thermal (jet base)

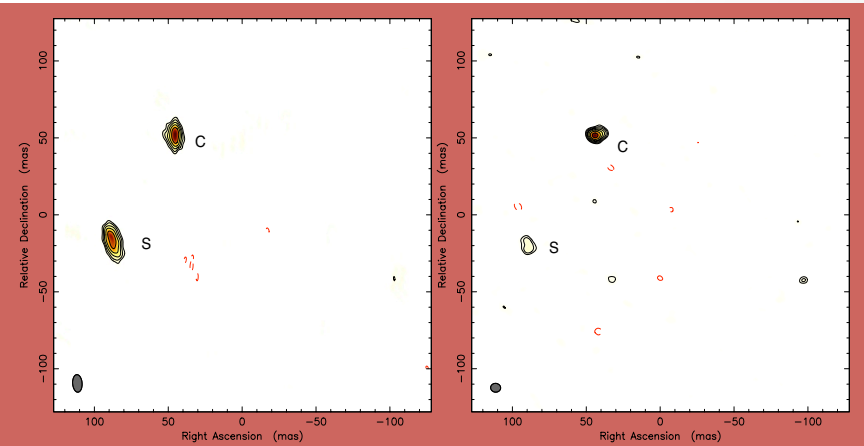



**Figure 2.** NGC 3982 at 1.7 GHz (left) and 5 GHz (right). Contours are traced at $(-1, 1, 2, 4, \ldots)\times$ the $\sim 3\sigma$ noise level, which is 0.20 and 0.09 mJy beam$^{-1}$ at 1.7 and 5 GHz, respectively. HPBW are shown in the lower left corner, and their size is 6.4 mas × 11.4 mas in P.A. 4° and 5.7 mas × 6.8 mas in P.A. 85° at 1.7 and 5 GHz, respectively.

# NGC 4051

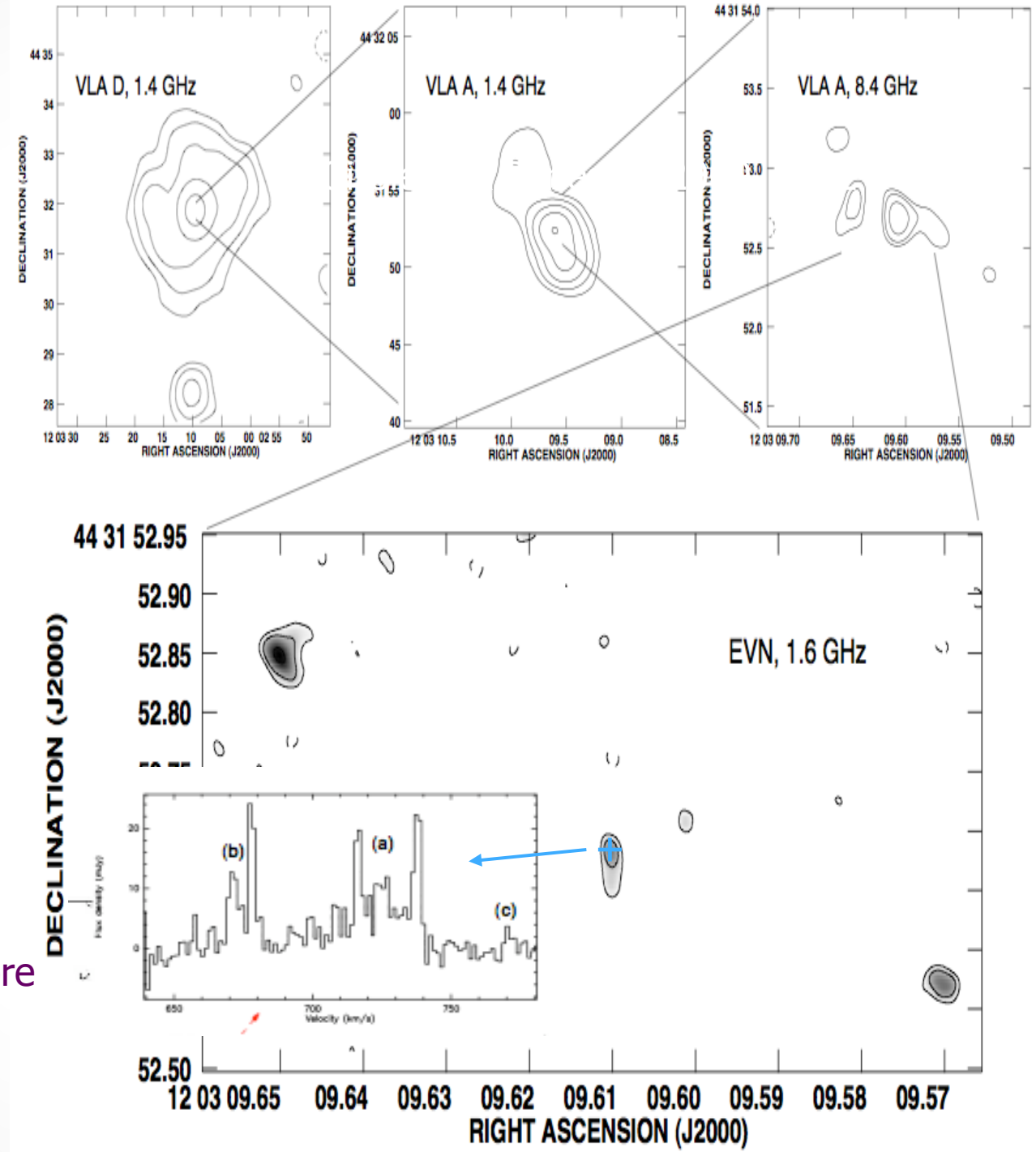
Giroletti & Panessa 2009, ApJL

Linear size < 0.31 pc
(BLR size 0.006 pc)

✓ Log $L_{5\ GHz}/L_{2\text{-}10\ keV} < -5.8$

$H_2O$ Maser coincident with core

See also Tarchi et al. 2011, A&A

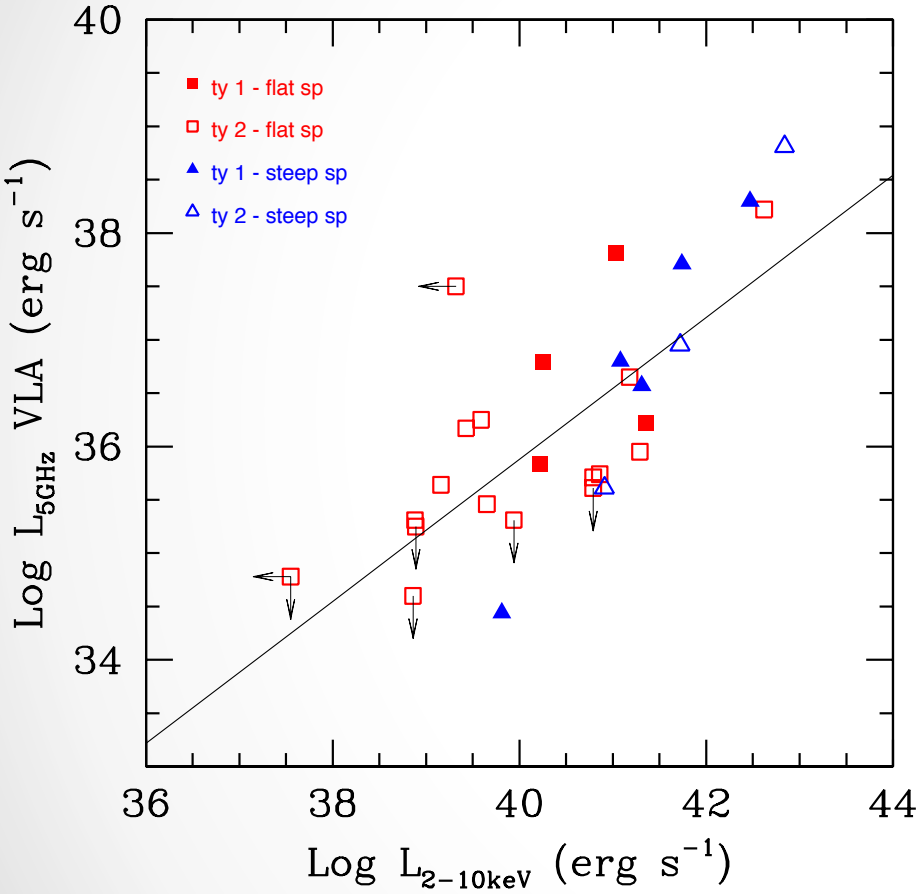


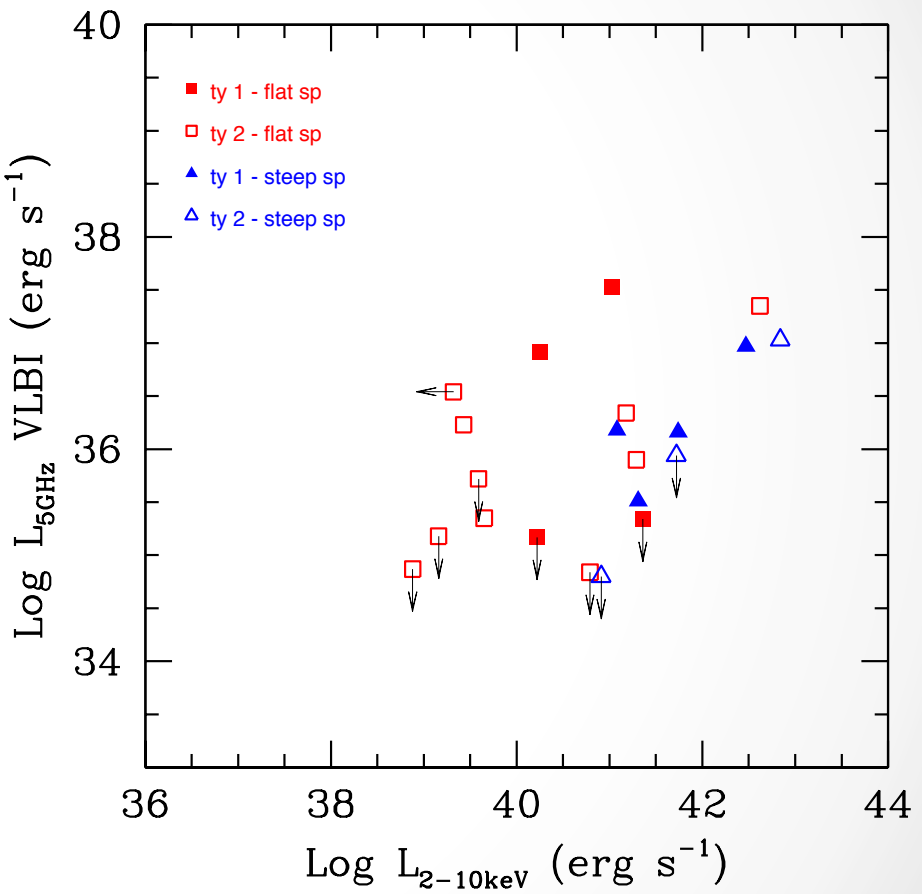
# ORIGIN OF RADIO EMISSION IN RADIO QUIET

Possible physical mechanisms in Radio-Quiet:

- ✓ Synchrotron emission from a jet:
  - ✓ Mostly sub-relativistic and weak jets
  - ✓ Possible outflows
- ✓ Free-free emission from a molecular torus or corona
- ✓ Maybe ADAF

# DISK-JET COUPLING

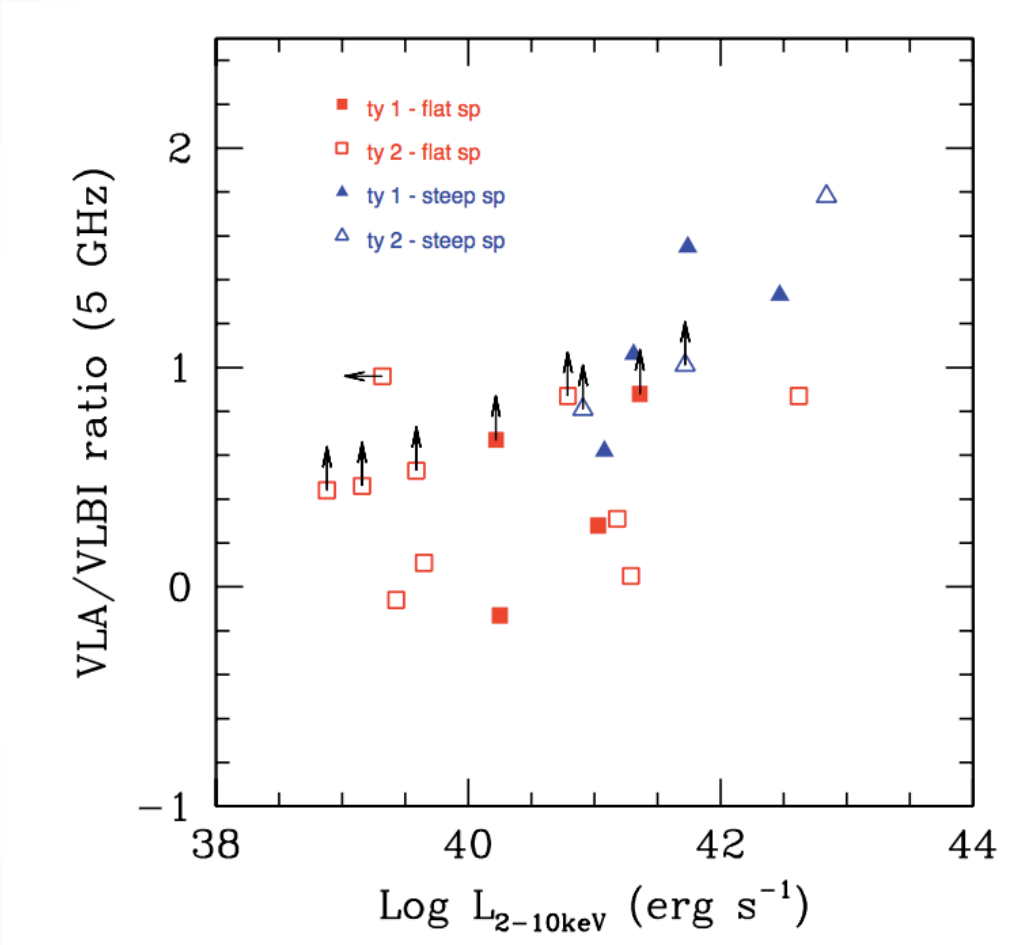



No significant correlation at VLBI sub-pc scales

Panessa & Giroletti 2013 MNRAS

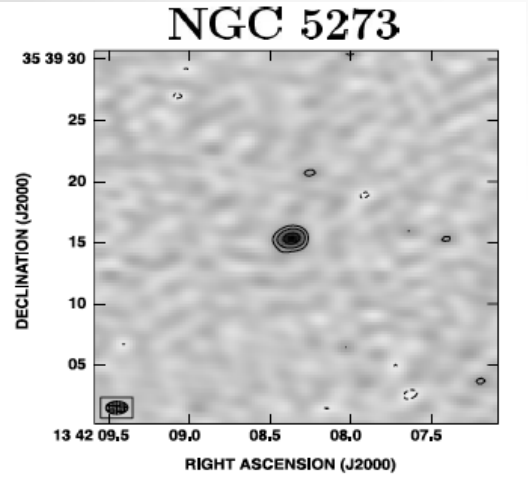
# DISK-JET COUPLING



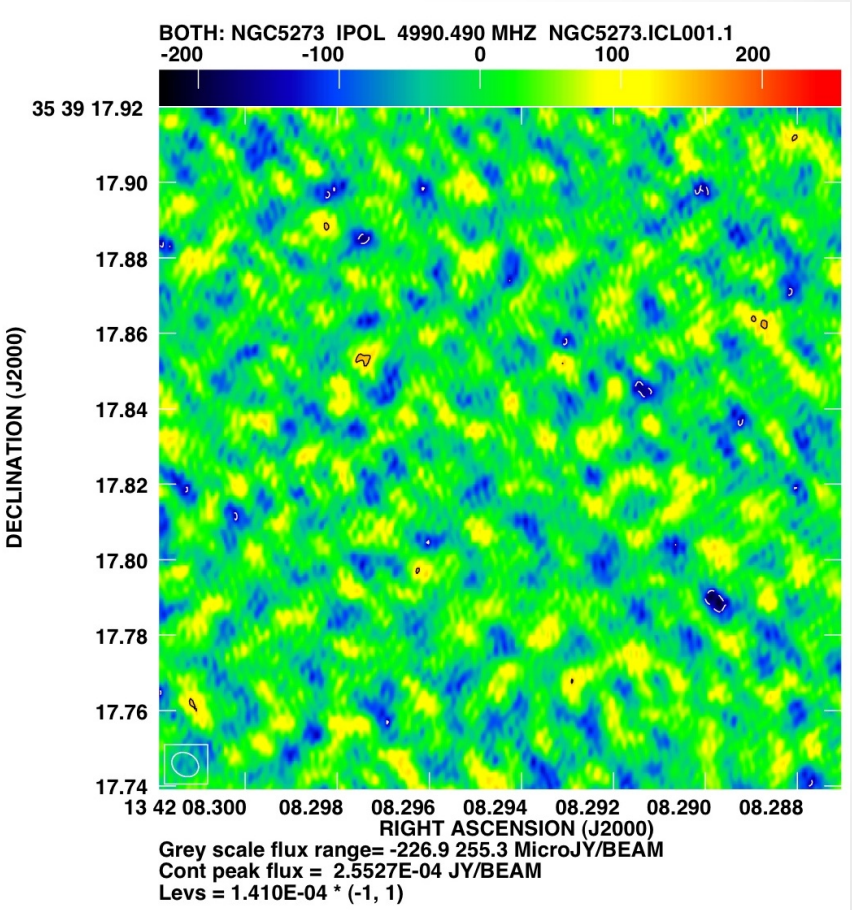

Most of the VLA emission is resolved out!!!

Panessa & Giroletti 2013 MNRAS

# NGC 5273: a LLAGN with no jet



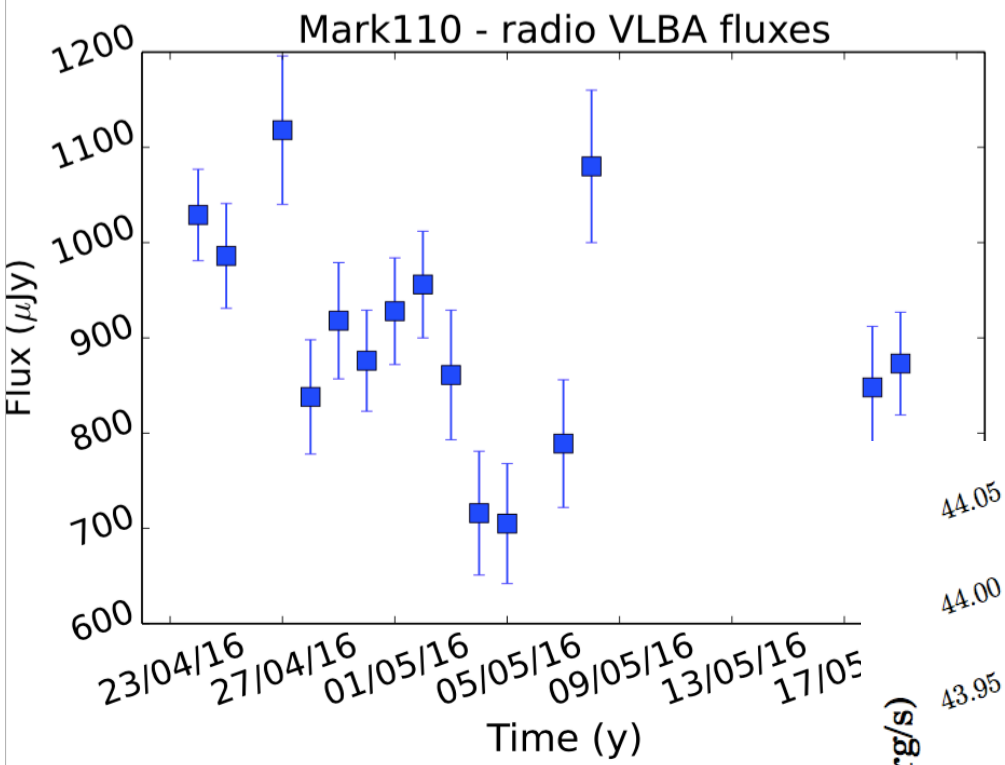

- ✓ VLA flux of 0.6 mJy
- ✓ VLBI non detection!!!
  (3 σ peak < 90 microJy at 1.6 GHz)
  - 95 % of the VLA flux resolved at 20-300 mas scale
  - significant variability
- ✓ Log $L_{5\ GHz}/L_{2\text{-}10\ keV} < -6$
- ✓ Log $L_X/L_{EDD} = -3.2$




Resolved radio emission or variable radio source?

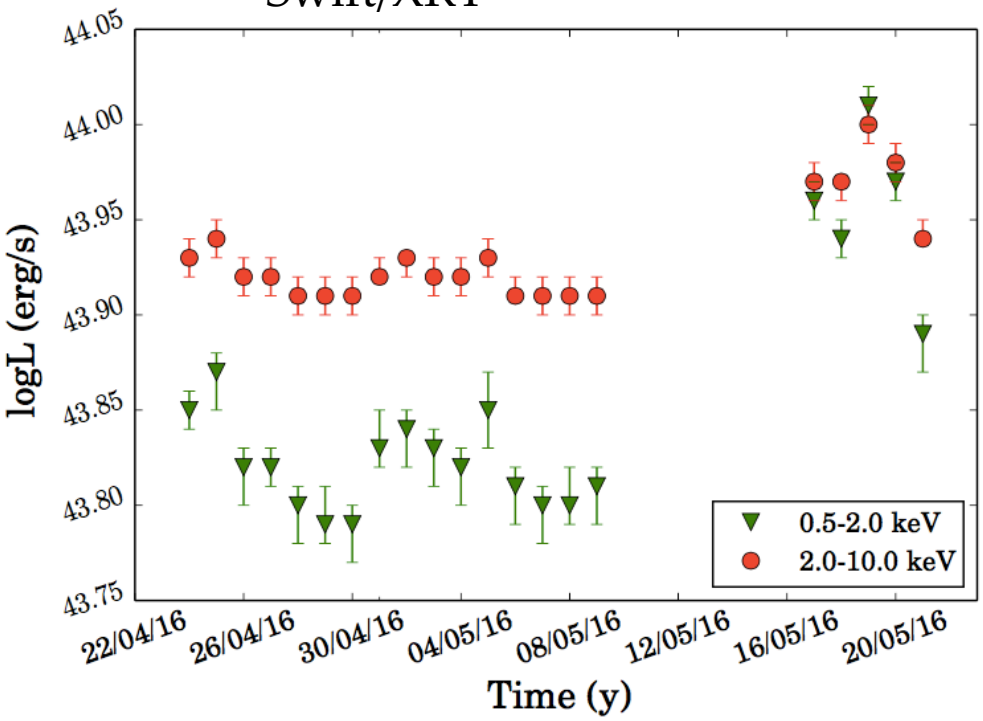
Giroletti & Panessa 2009, ApJL

# SIMULTANEITY - VLBI monitoring of a RQ AGN!




Evidence of variability at VLBI scales!

Swift/XRT




No conclusive on time lags

Panessa et al. in preparation

# BE CAREFULL WHEN USING RADIO DATA for correlations in AGN and XRB unification:

- ✓ CHECK SPATIAL RESOLUTION! PHYSICAL SCALE…
- ✓ CHECK THERMAL VS NON-THERMAL ORIGIN!
- ✓ CHECK THE EFFICIENCY STATE OF THE AGN!

# Open position in Rome coming soon:

- ✓ Two years post-doc
- ✓ X-ray/radio + theory of TDE and FRB

→ Jet formation and propagation in different systems

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