



The power of low luminosity AGN: the PARSEC view

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PARSEC project

<http://research.iac.es/proyecto/parsec/main/index.php>

Multiwavelength study of the central parsecs of the nearest galaxies

-> Accretion coverage: $L / L_{edd} \sim 10^{-1} - 10^{-10}$

-> angular scale: $< 0.5 \text{ arcsec}$

(Chandra, HST-JWST, AO-NIR-VLTI-MIR, SMA / ALMA, VLA / ATCA and VLBI)

With J.A. Fernandez Ontiveros, A. Rodriguez-Ardila, S. Markoff, C. Alig, A. Burkert, K. Dolag, G. Bruzual, G. Magris, K. Tristram, D. May, and friends ...



Low activity BH (or Low Luminosity AGN)

- Edd ratios $L / L_{edd} < 10^{-3} \text{ -- } 10^{-10}$
- Lack Big Blue Bump
- Lack IR bump
- Most common state of BHs

Insufficient fuel ?
Radiatively inefficient ?



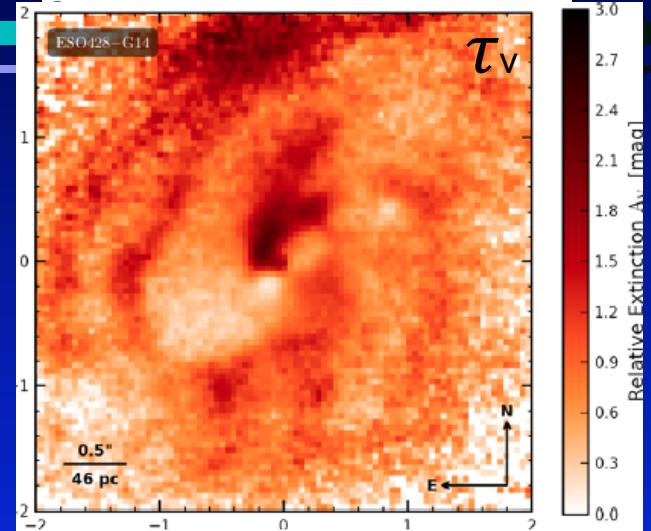
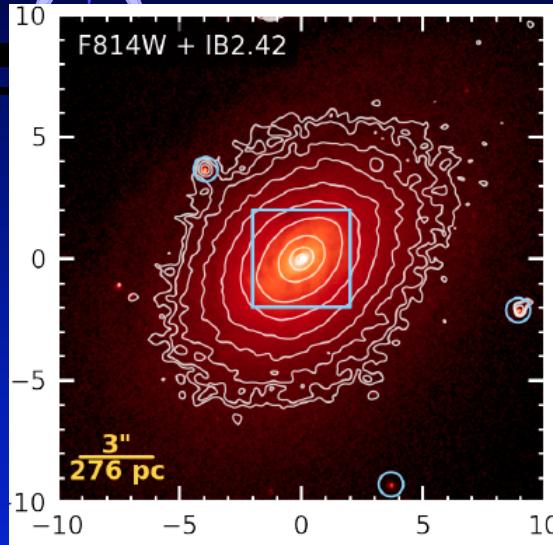
Low Luminosity AGN (LLAGN)

Plenty of fuel at disposal...

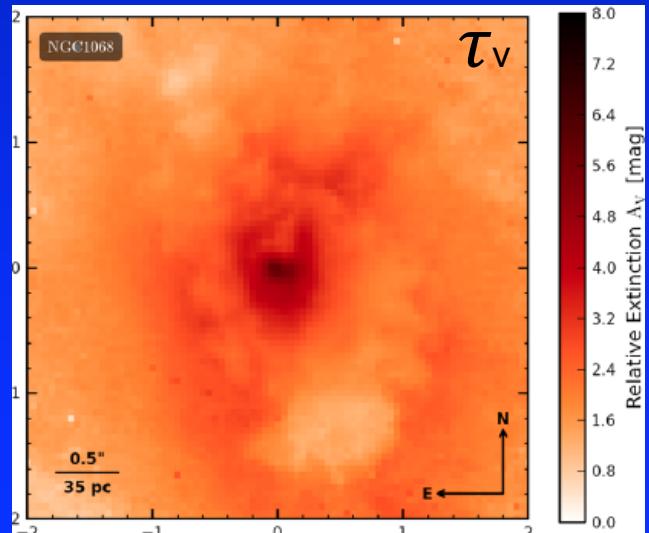
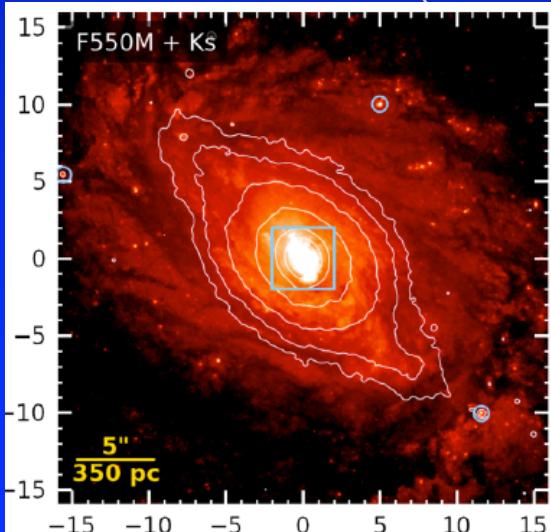


Mass reservoir central parsec type 2 AGN

ESO 428-G14 ($L_{bol} \sim 10^{42}$, $L_{edd} \sim 10^{-4}$)



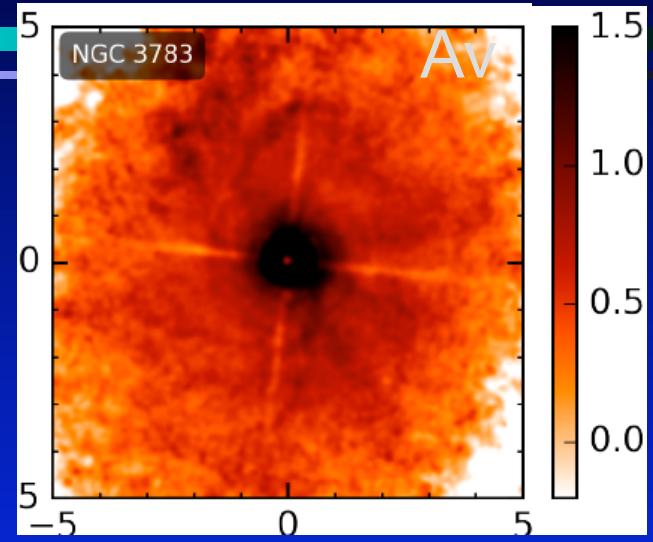
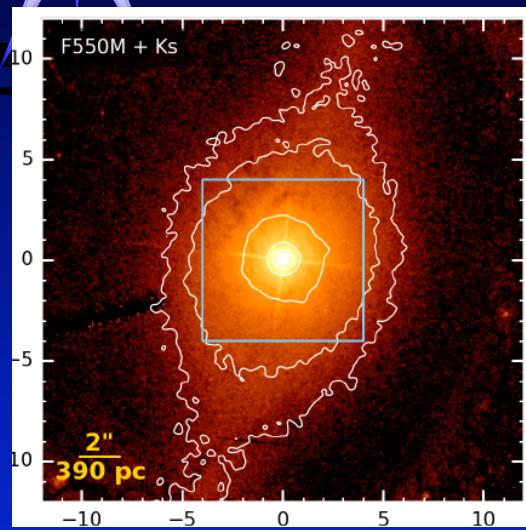
NGC 1068 ($L_{bol} \sim 10^{44}$; $L_{edd} \lesssim 10^{-1}$)



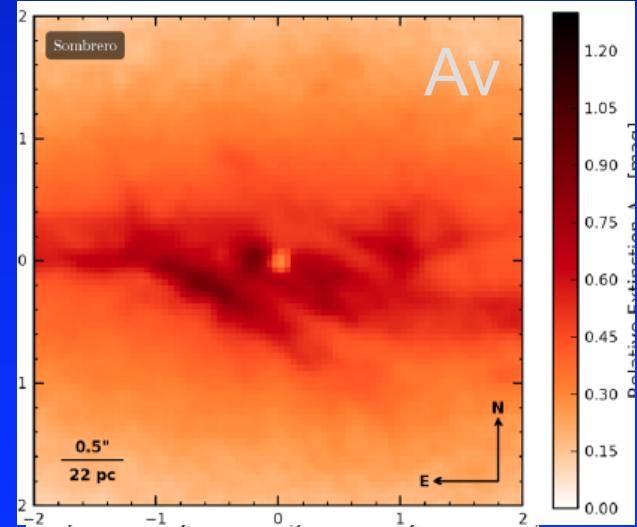
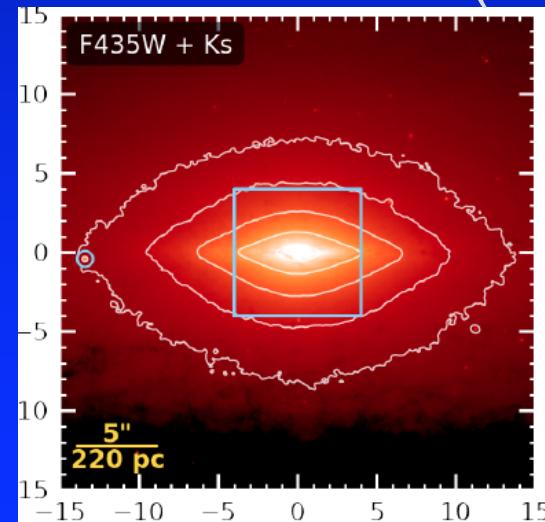


... and in type 1 as well:

NGC 3783 ($L_{bol} \sim 10^{44}$; $L_{edd} \sim 10^{-2}$)



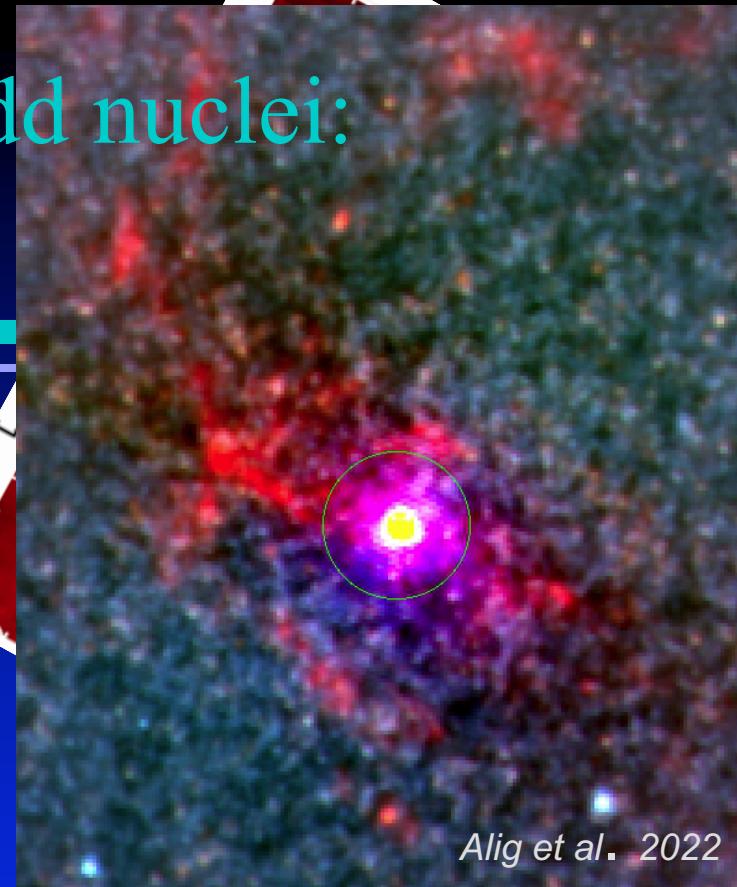
Sombrero ($L_{bol} \sim 10^{42}$; $L_{edd} \sim 10^{-7}$)



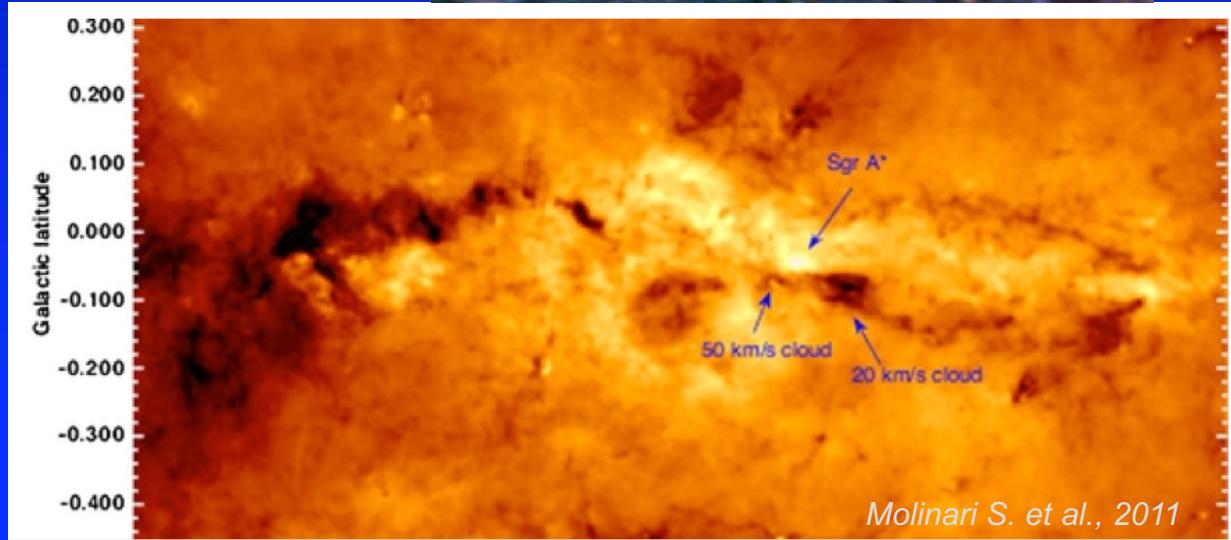


....and in the lowest Ledd nuclei: SgA* and M31

Central 100 pc of M31
BH $\sim 10^8$ Mo
Ledd $\sim 10^{-7}$



Central 100 pc of MW
BH $\sim 10^6$ Mo
Ledd $\sim 10^{-9}$



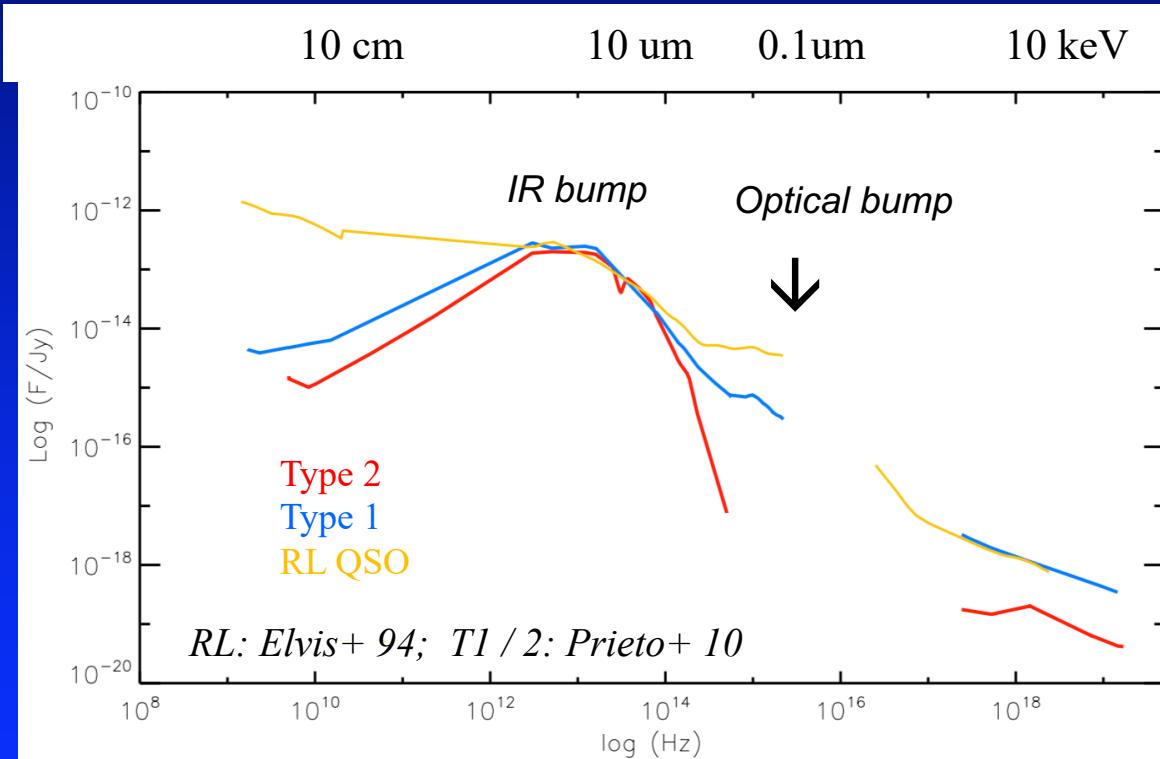


Low Luminosity AGN (LLAGN)

..... Cold accretion



SED templates central 10 pc nearest AGN

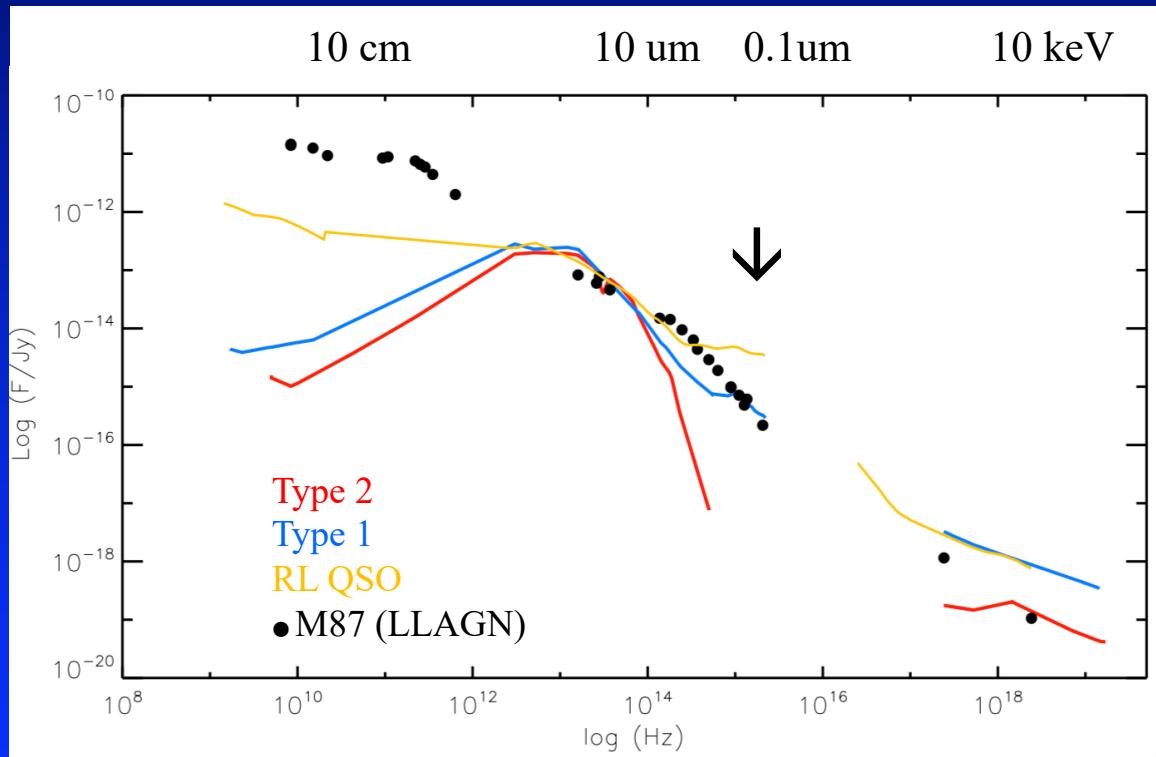
$$L/L_{edd} > 10^{-2}$$


SED shape:

smooth transition from T2 (total obscuration) to T1 (partial) to QSO (low dust attenuation)

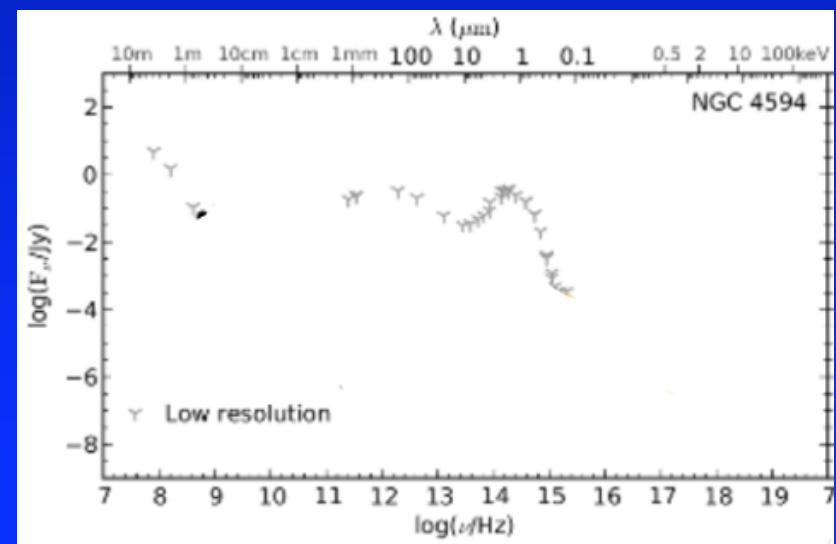
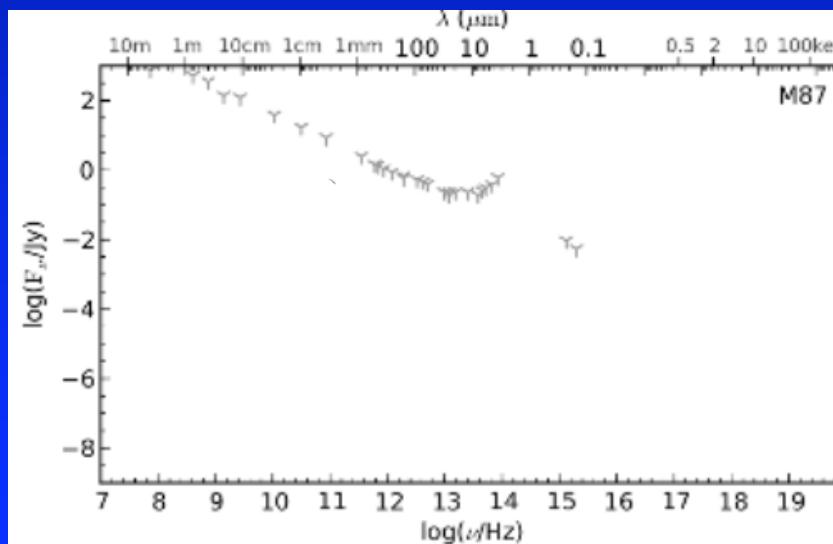
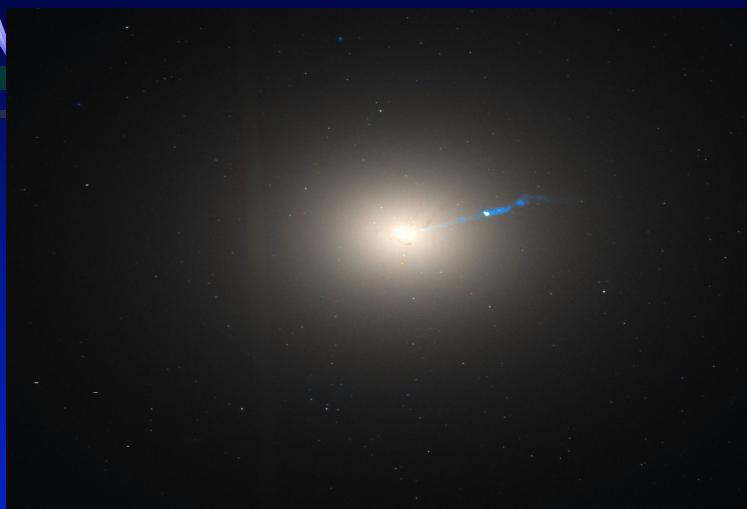


SED central parsecs of the nearest (efficient) AGN: $L / L_{edd} \gtrsim 10^{-2}$

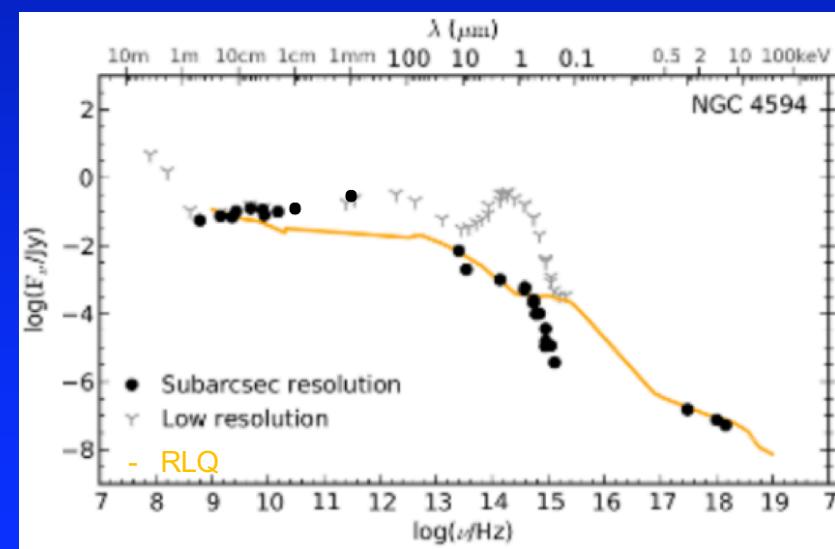
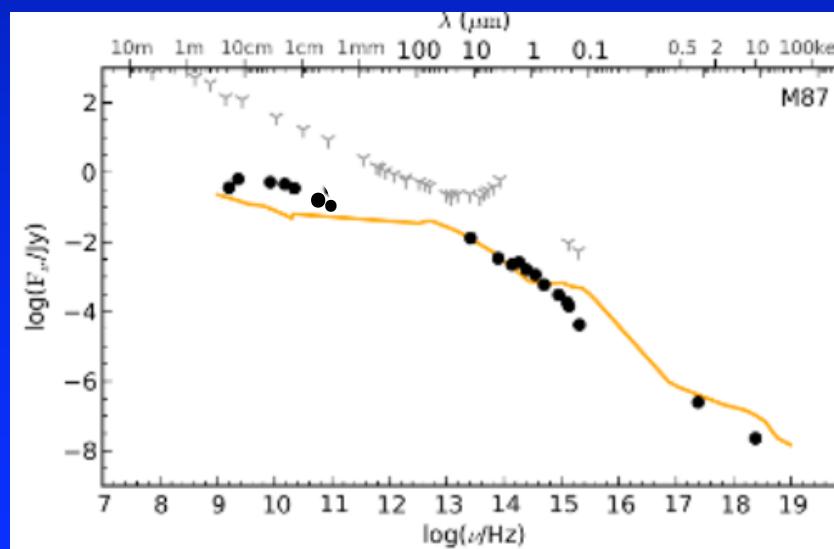
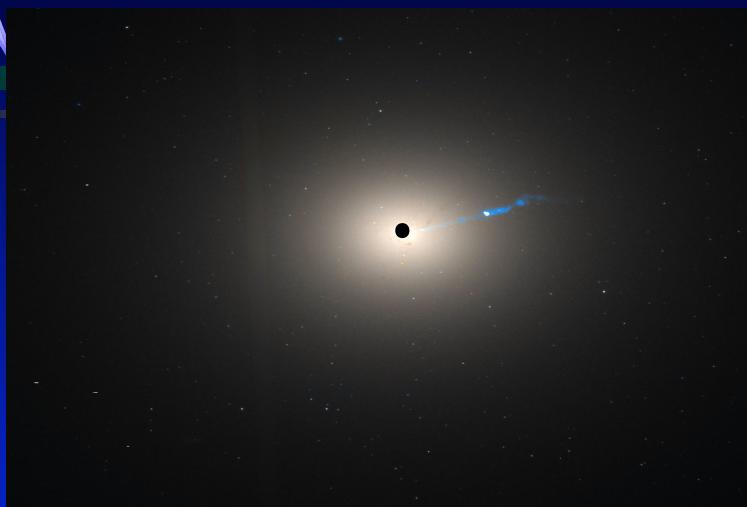


SED shape:
distinct in LLAGN

Where is the accretion disc in LLAGN? It is moving to the red....

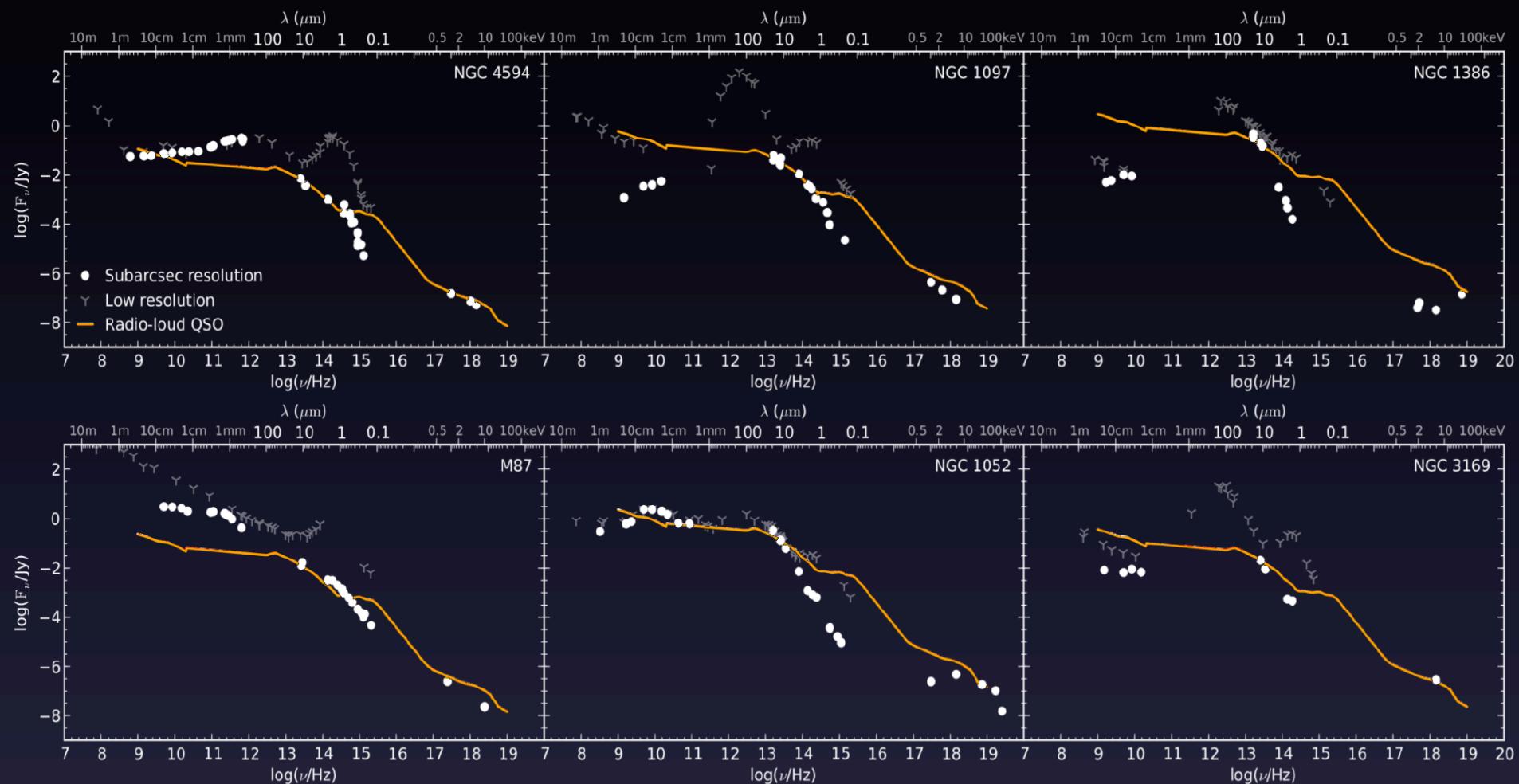


Where is the accretion disc in LLAGN ? It is moving to the red....





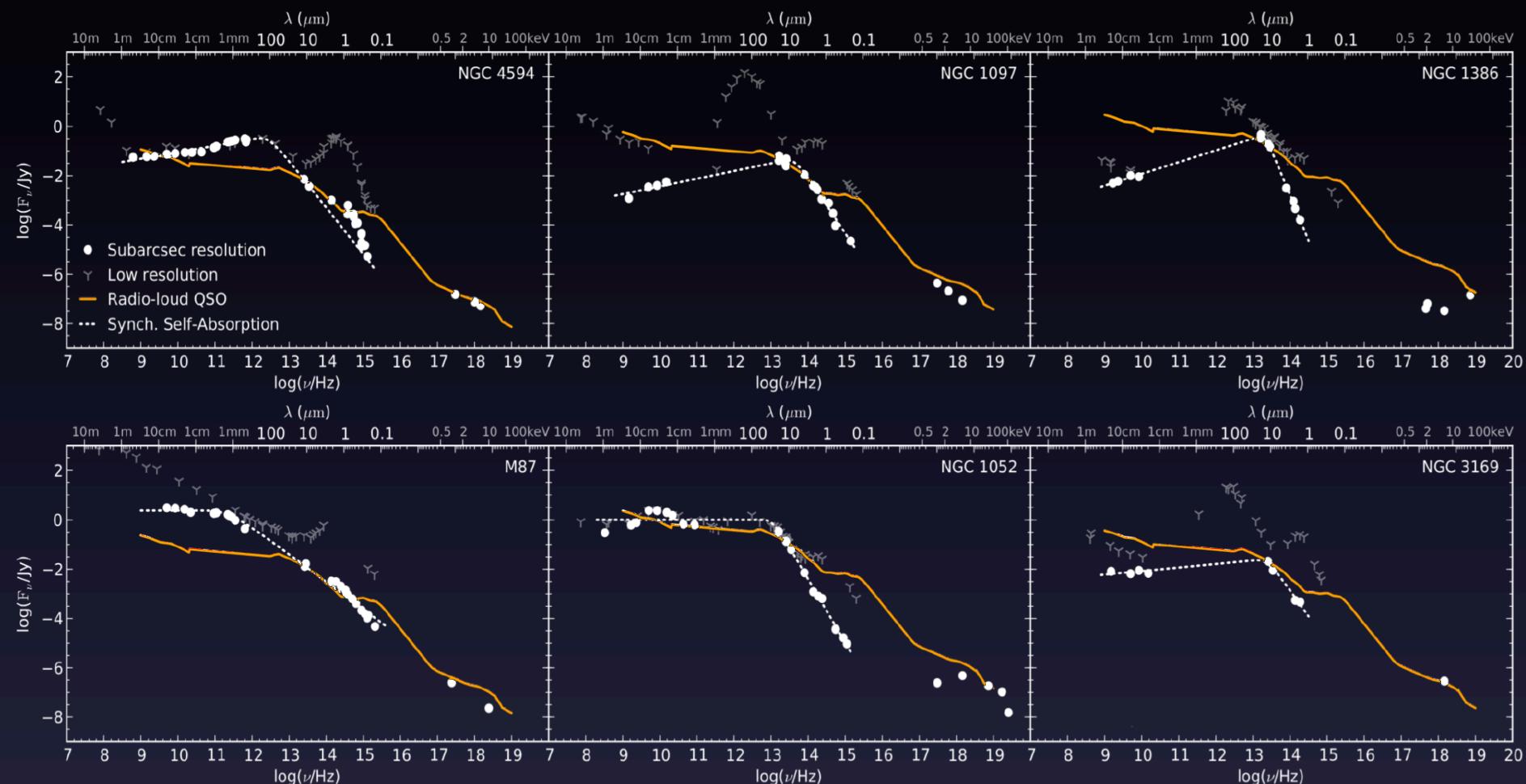
SED central 10 pc for BH with $L/L_{\text{edd}} < 10^{-3}$ no Blue-Bump, no IR-Bump



Subarcsec + Low-spatial resolution + Radio-Loud QSO (Elvis+1994)



Central-10 pc SED for BH with $L/L_{\text{edd}} < 10^{-3}$ no Blue-Bump, no IR-Bump



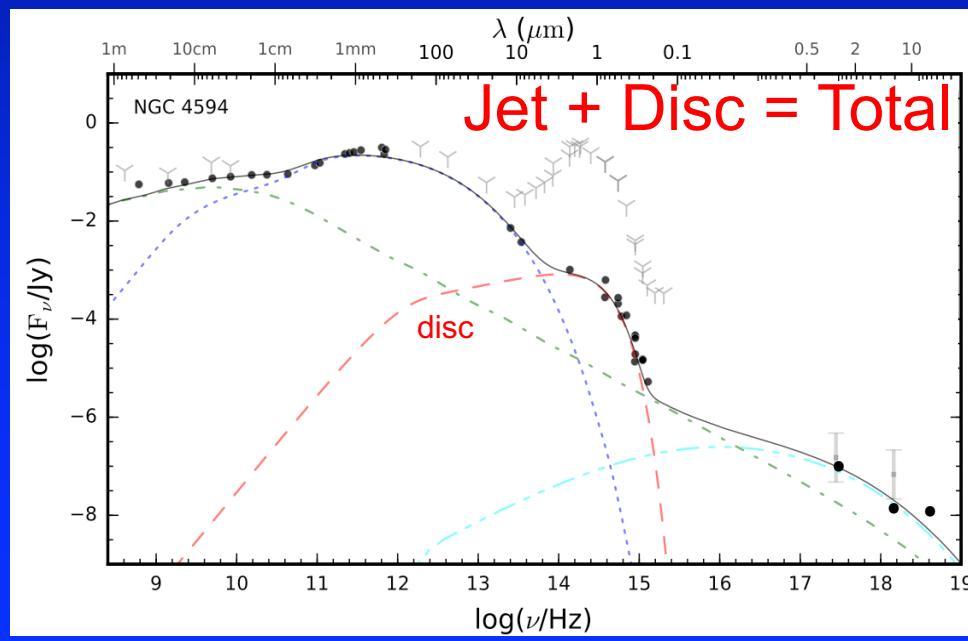
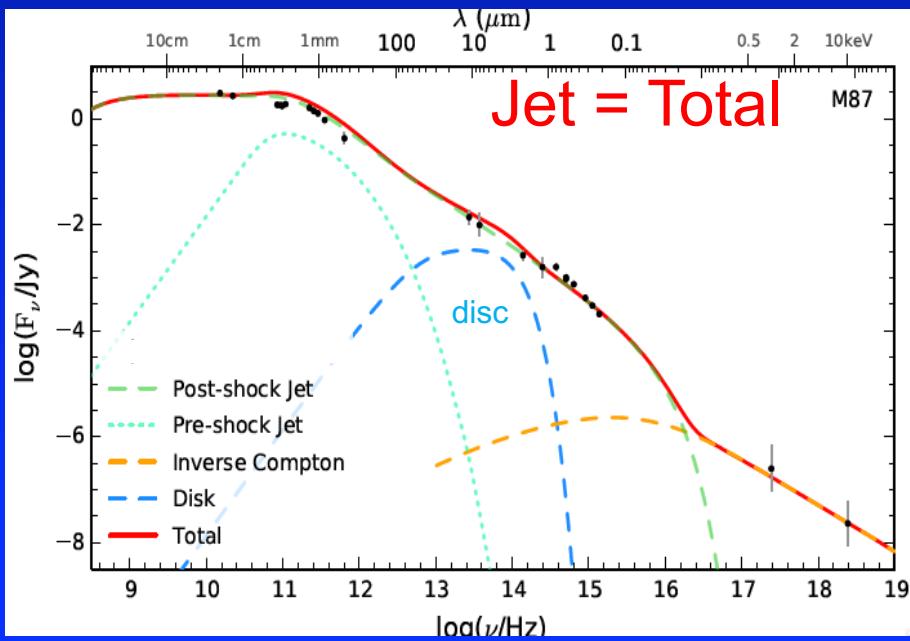
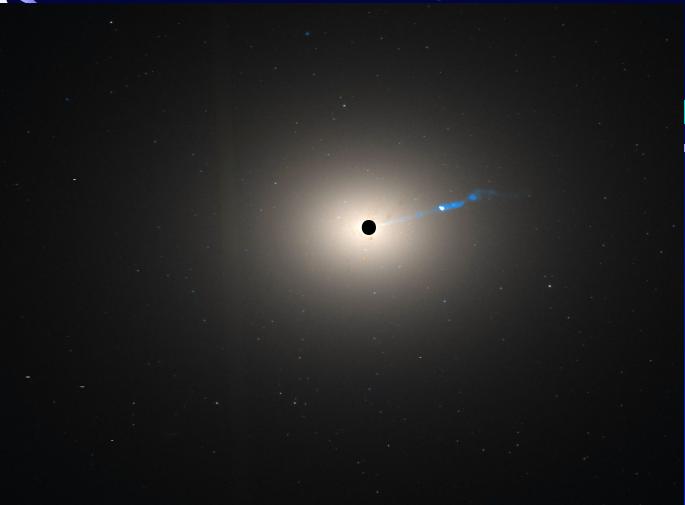
Subarcsec + Low-spatial resolution + Radio-Loud QSO (Elvis+1994)

---- self absorbed syncrotron

Prieto+2016; Fernandez-Ontiveros+ 22; Reb+18

Pushing for a cold (standard) disk....

(following on Markoff's 05,08 models)

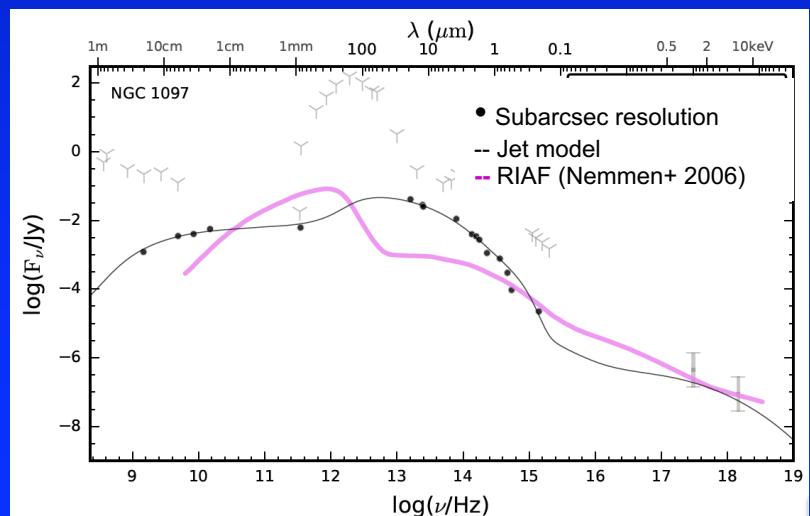
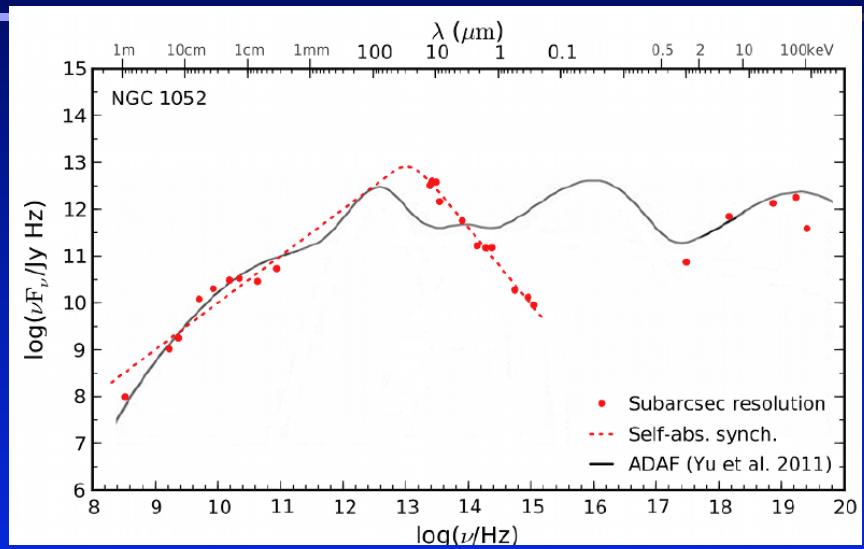
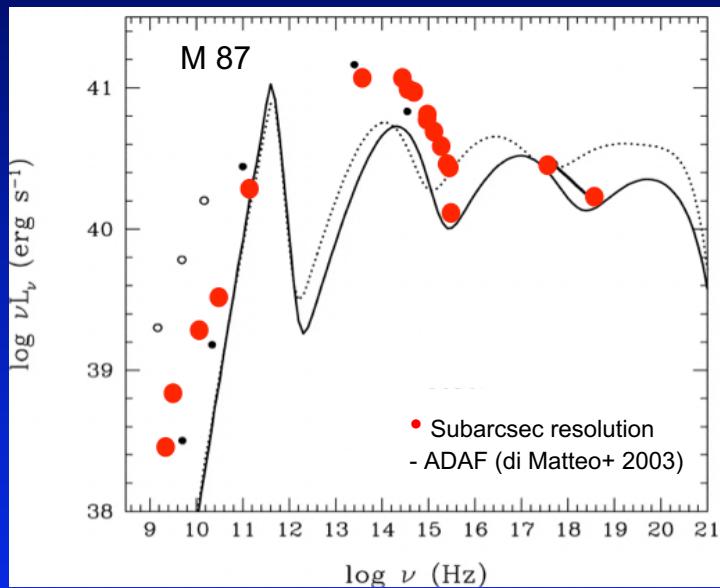




Pushing for a hot accretion flow....

ADAF / RIAF / ADIOS models

(*Narayan & Yi* 94,95; *Abramowicz+* 95; *Blandford & Begelman* 99; *Quataert +* 99,00; *Yu+11*)



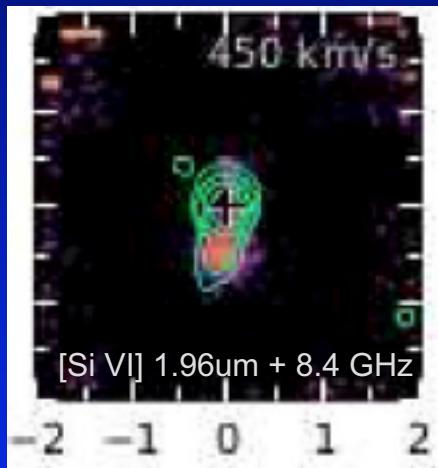


Jet Kinetic POWER of LLAGN



Jet kinetic power at PARSEC scales - from coronal gas

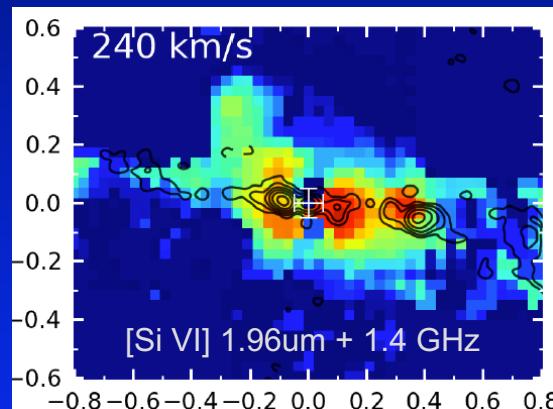
NGC 1386, $L/L_{\text{edd}} \sim 10^{-4}$



$$E_{\text{kin}} \sim 10^{42} (\sim 70\% L_{\text{bol}})$$

Rodriguez-Ardila+ 17
May + 18

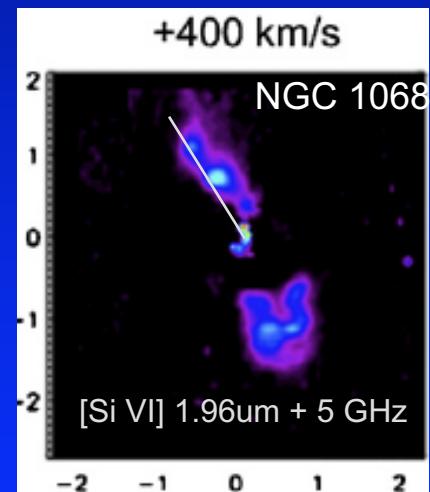
NGC 4151, $L/L_{\text{edd}} \sim 10^{-2}$



$$E_{\text{kin}} \sim 10^{42} (10\% L_{\text{bol}})$$

Prieto+ 22

Sample $L/L_{\text{edd}} \gg 10^{-2}$



$$E_{\text{kin}} \ll 1\% L_{\text{bol}}$$

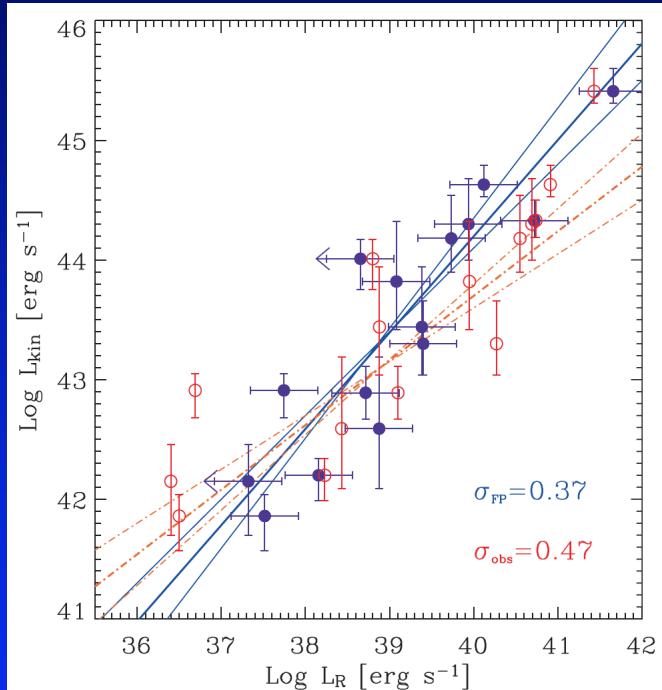
Muller-Sanchez + 11



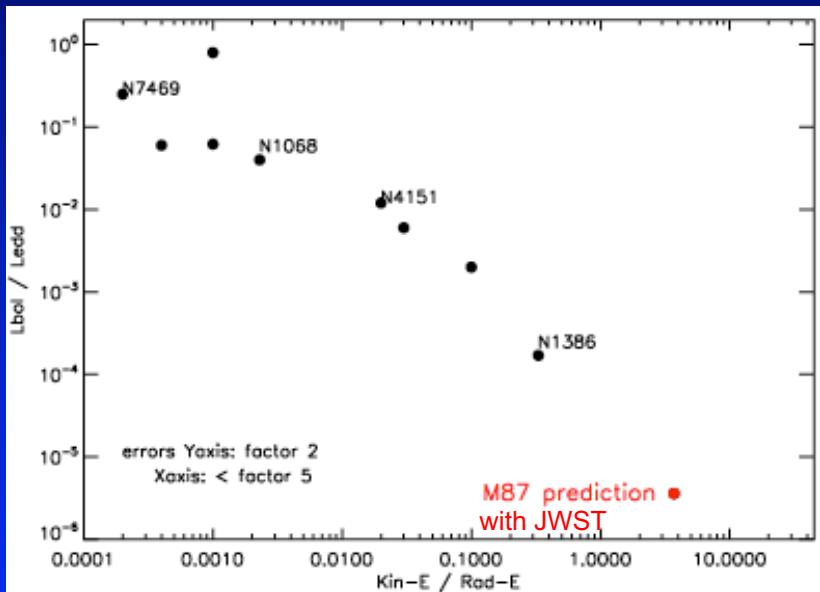
The power

Kinetic: major energy channel in low activity BH

(Ho 02, Nagar +05, Kording+06; Allen+06; Russell+13, Fernandez-Ontiveros+22)



Merloni & Heinz 07:
Ekin from X-ray cavities, shocks,
jet-models



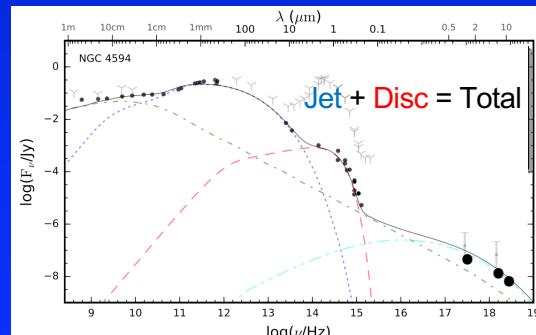
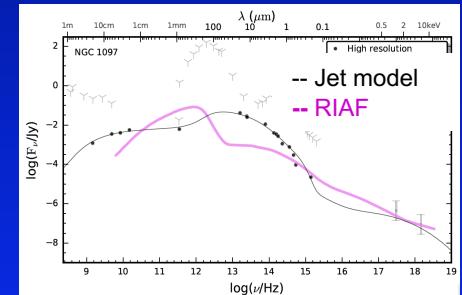
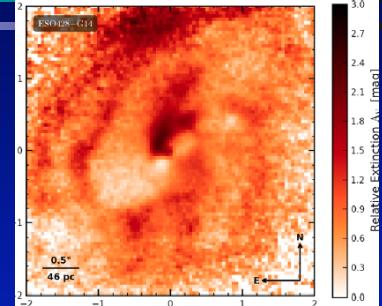
Ekin from coronal gas (Muller-Sanchez+11;
Rodriguez-Ardila+ 17; May+18)

M87 + LLAGN from JWST-Cy 1: ReveaLLAGN project
(Seth+21)



LLAGN Power: Kinetic via the Jet

- ✓ Plenty of fuel at disposal in central parsecs
- ✓ Parsec-scale SED featureless: no BB/IR bumps



- ✓ Jet emission accounts for entire SED
-> Hot accretion incompatible with SED
- ✓ Cold accretion evidence in some cases,
-> limits yield insufficient accretion-power
- ✓ Ledd < 10⁻⁴: >70% energy release is kinetic
- ✓ Ledd > 10⁻²: > 90% energy release is radiative

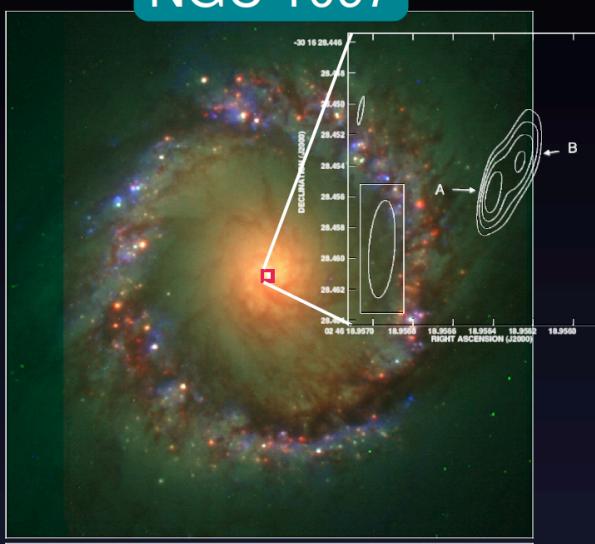
Compact (radio) Jets?

(Mezcua & Prieto 2014; Hummel+1987; Claussen+1998; Hada+2013)
Gallimore +2006

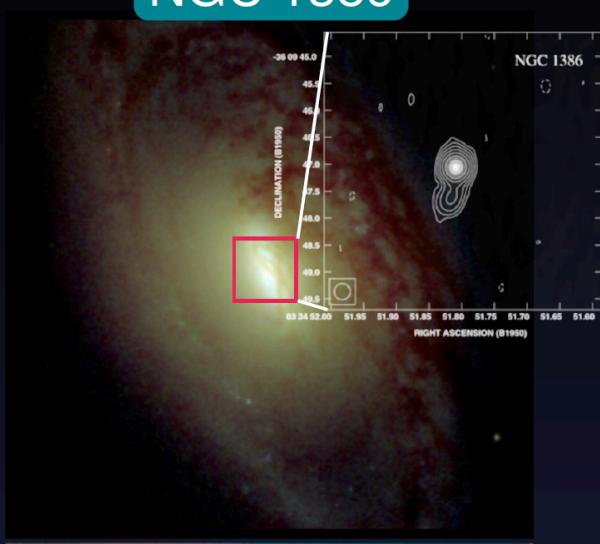
NGC 4594



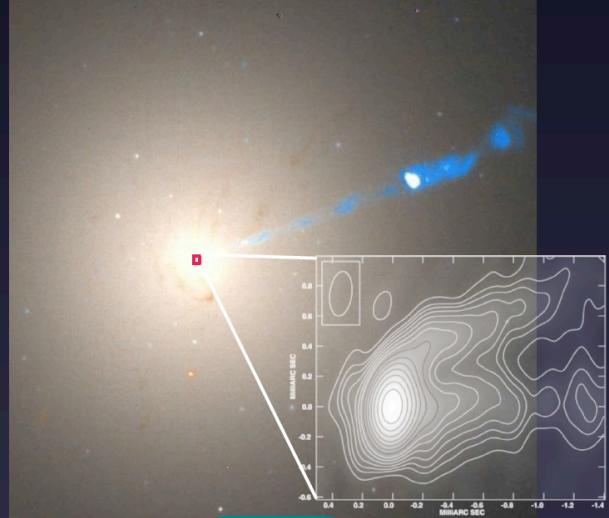
NGC 1097



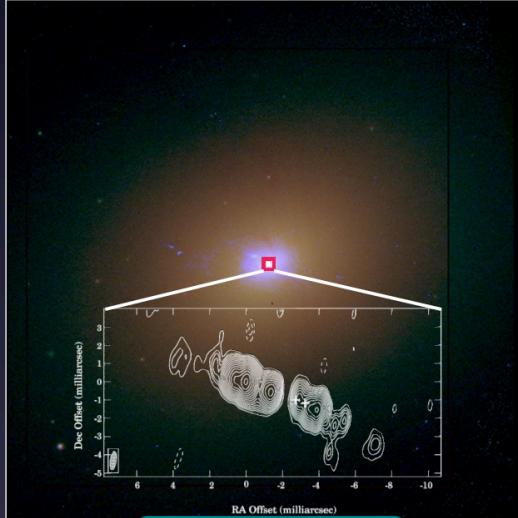
NGC 1386



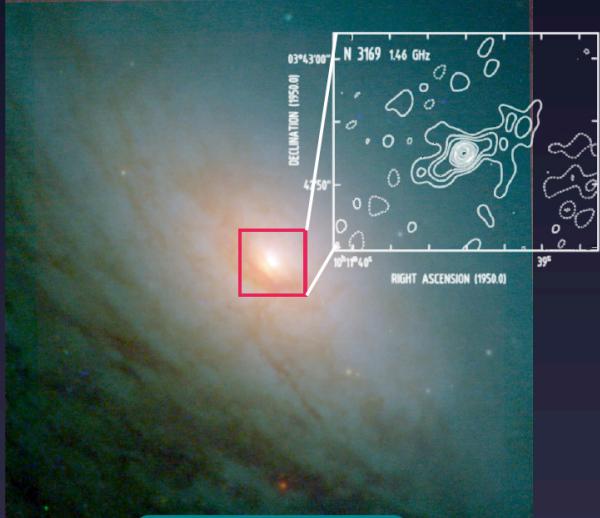
M87



NGC 1052



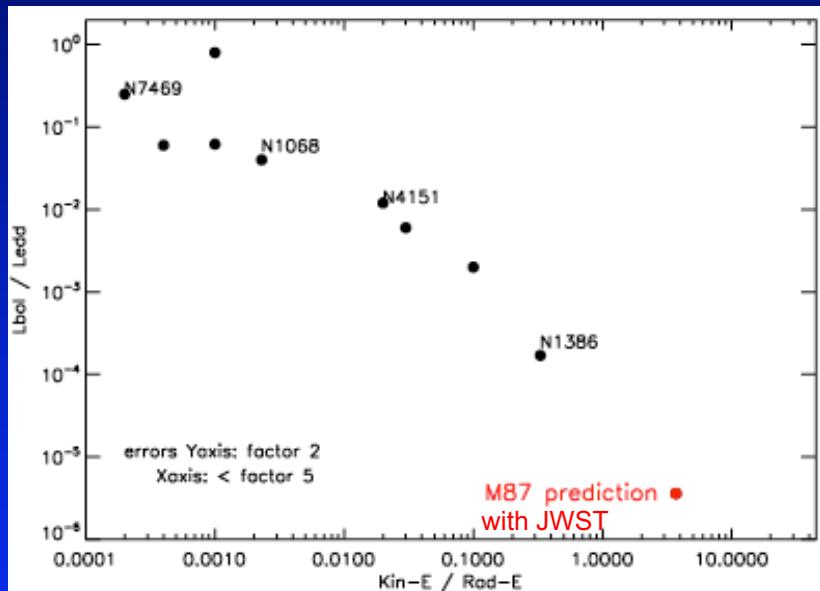
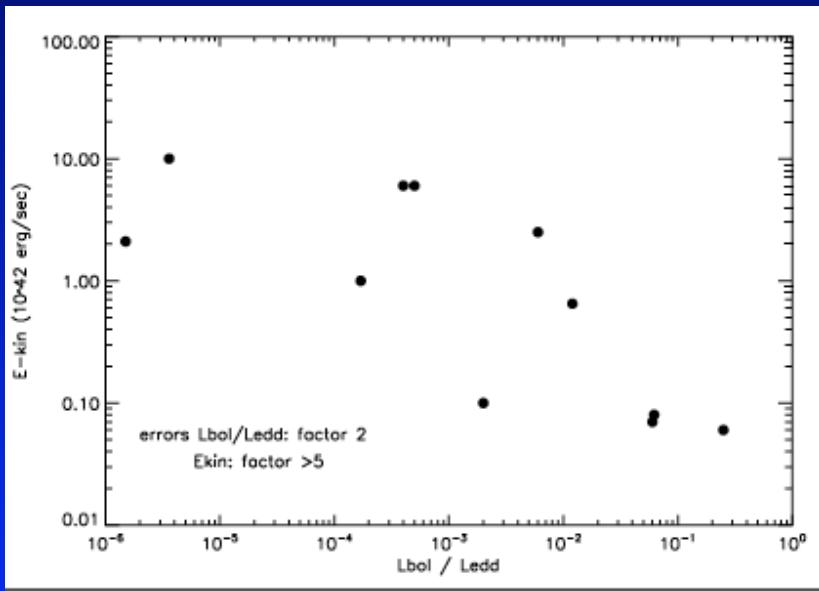
NGC 3169



The power

Kinetic: major energy channel in low activity BH

(Ho 02, Nagar +05, Kording+06; Allen+06; Russell+13, Fernandez-Ontiveros+22)



Ekin from coronal gas (Muller-Sanchez+11;
Rodriguez-Ardila+ 17; May+18)

M87 + LLAGN from JWST-Cy 1: ReveaLLAGN project
(Seth+21)

The power

Accretion power estimate from the SED:

=> $P_{\text{accretion}} \ll 3 \times 10^{42} \text{ erg/s}$

$L_{\text{rad, de-boost}} \Rightarrow 6 \times 10^{41} \text{ erg/s} / \text{OK}$

$E_{\text{kin}} \gtrsim 10^{43} \text{ erg/s} / \text{no OK}$
 (Churazov+02; Forman+05; Allen+06...)

=> $P_{\text{accretion}} \sim < 2 \times 10^{41} \text{ erg/s}$

$L_{\text{rad, de-boost}} \Rightarrow 8 \times 10^{40} \text{ erg/s} / \text{OK}$

$E_{\text{kin}} \sim 2 \times 10^{42} \text{ erg/s} / \text{no OK}$
 (Mezcua+14)

