

The nature of the IR emission in LLAGN at parsec scales

Does the jet dominate at low luminosities?



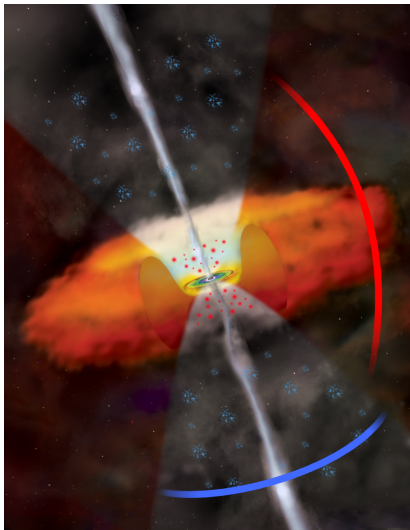
Juan Antonio Fernández-Ontiveros ([MPIfR](#))
M.A. Prieto, J.A. Acosta-Pulido, S. Markoff,
O. González-Martín

The Innermost Regions of Relativistic Jets and Their Magnetic Fields
Granada, June 11th, 2013

Outline

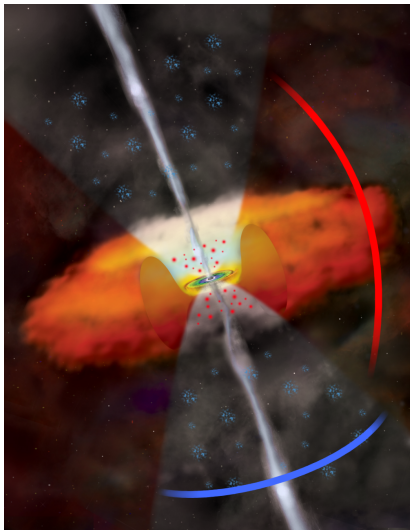
- 1 Introduction
 - The Unified Model
 - LLAGN: Not simply faint AGN
- 2 Observations
 - Multiwavelength dataset
 - Sample
- 3 The nature of the IR emission
 - LLAGN at parsec scales
 - An accretion disk/torus?
- 4 Inflow and Outflow
- 5 Summary

The Unified Model

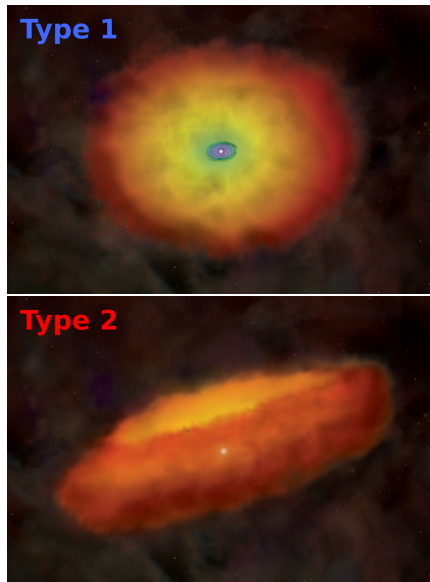


Antonucci (1993), Urry & Padovani (1995)

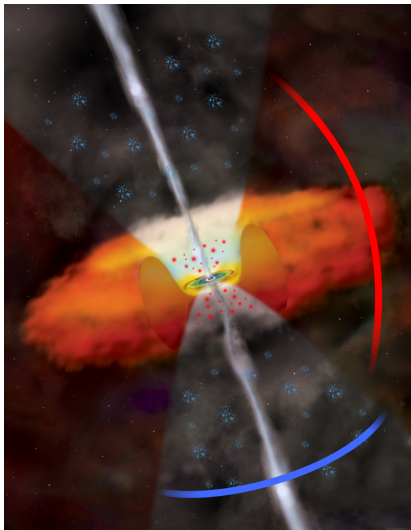
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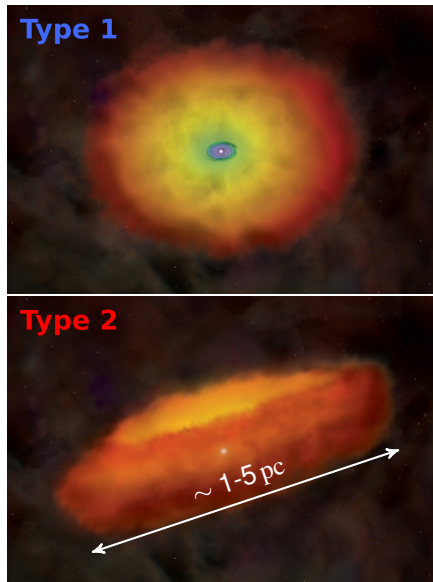
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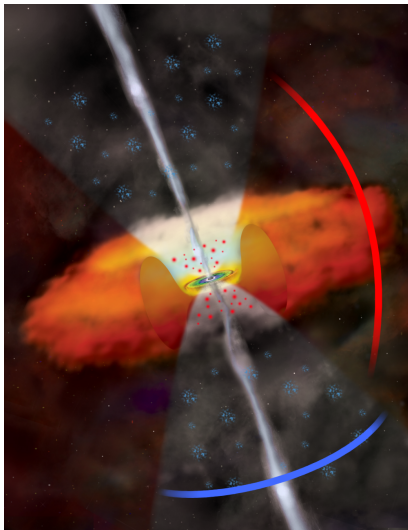
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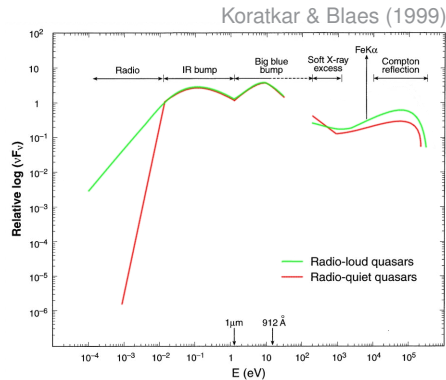
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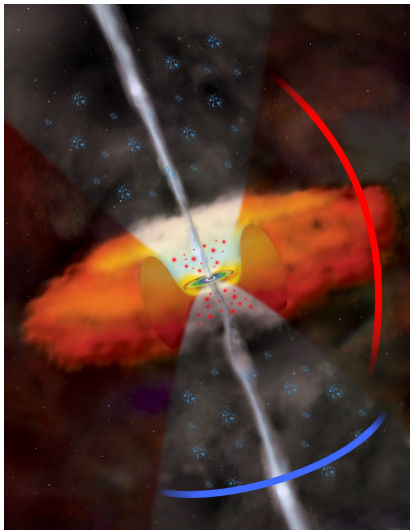
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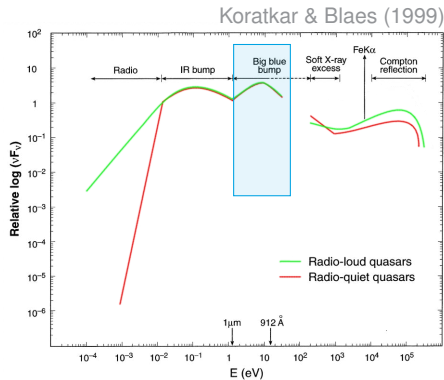
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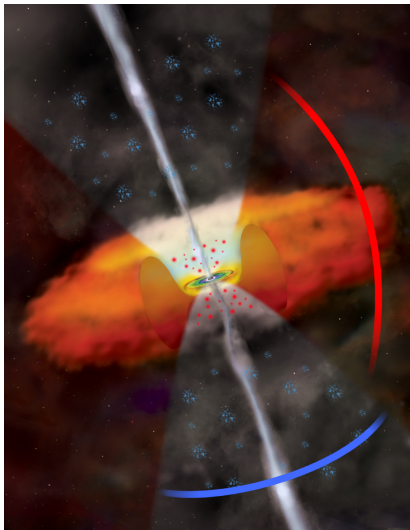


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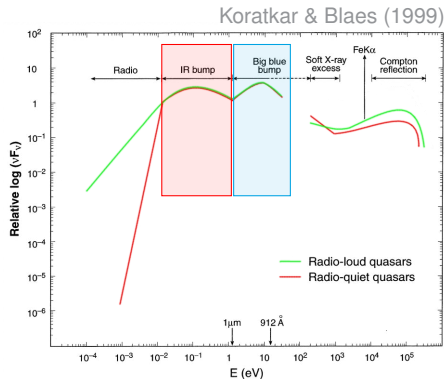


- **Accretion disk** at optical/UV

The Unified Model

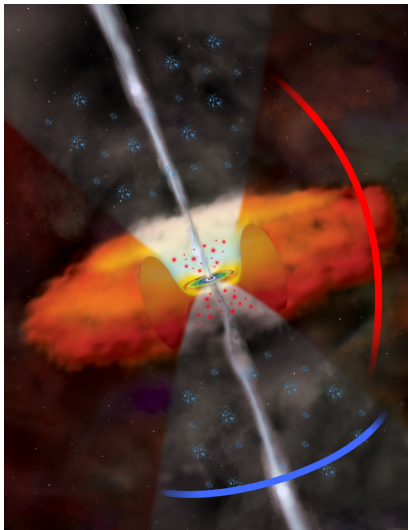


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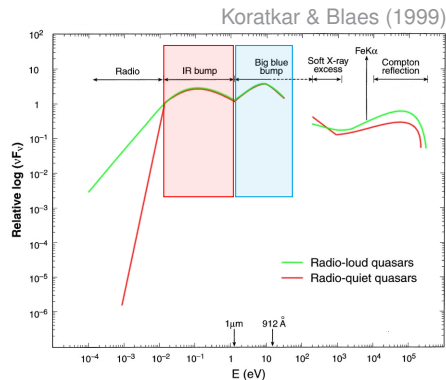


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The Unified Model



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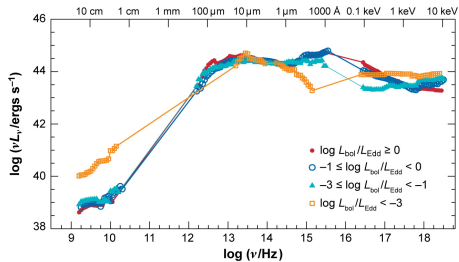
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- **Dust** re-emits in the IR
- $L_{bol} \gtrsim 10^{42}$ erg/s
(Seyferts, Quasars)

Not simply faint AGN

- **Majority** of AGN population
($\sim 1/3$ of nearby galaxies)
- Low luminosity: $\lesssim 10^{42}$ erg/s

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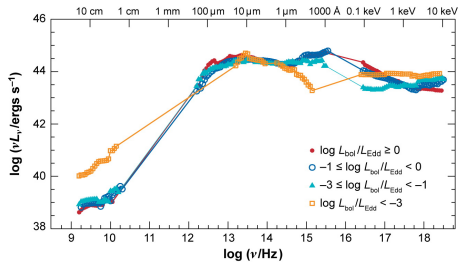
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Annu. Rev. Astron. Astrophys. 46:475–539

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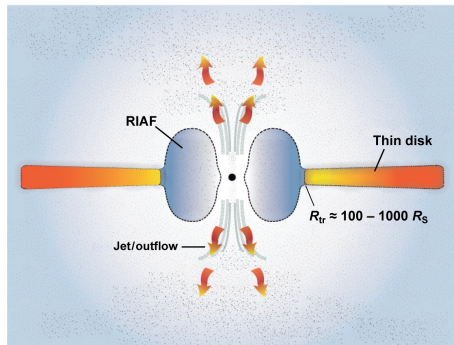
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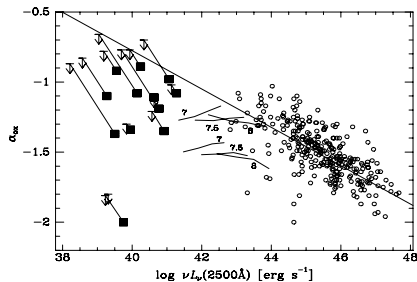
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- **Inflow/outflow** (ADAF/Jet) explain inefficient accretion



Standard accretion?

Similarities with Quasars/Seyferts:

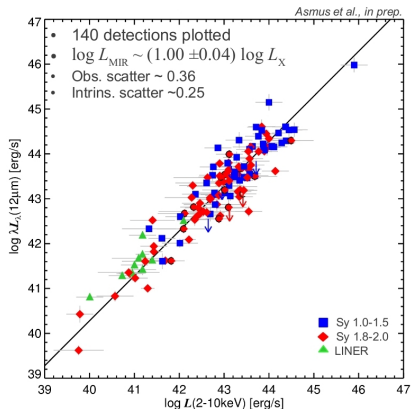
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- **Mid-IR – X-ray** correlation:
 \Rightarrow torus? (Asmus+2011)



Not that easy

Not that easy to study...

- ▶ **Outshined** by galaxy light at arcsec resolution
- ▶ **Sparse data sampling** to constrain models
- ▶ High-spatial resolution to avoid bulge, disk, star-formation, etc.
- ▶ **IR range** \Rightarrow optically faint/obscured nuclei

Multiwavelength dataset

- Follow-up of high-spatial resolution studies of the brightest and nearest Seyfert galaxies (Reunanen+2010, Prieto+2010)

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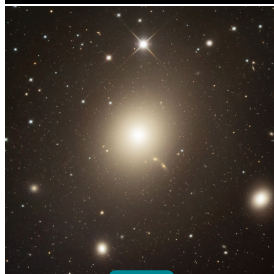
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- Multiwavelength SEDs at **subarcsec** resolution ($\lesssim 10$ pc):
 - ▶ VLT/NaCo adaptive optics (NIR)
 - ▶ VLT/VISIR (MIR)
 - ▶ *HST* (optical/UV)
 - ▶ Radio interferometry (VLA, VLBI, VLBA)
 - ▶ X-rays (*Chandra*, *XMM-Newton*, *Integral*)

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- Characterize the energy output at a **consistent physical scale**

Sample

NGC 4594



M87

NGC 1097



NGC 1052

NGC 1386



NGC 3169

Sample

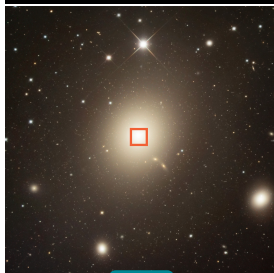
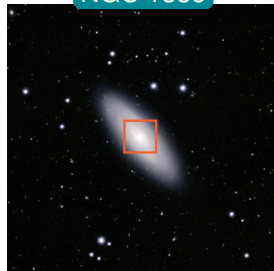
NGC 4594



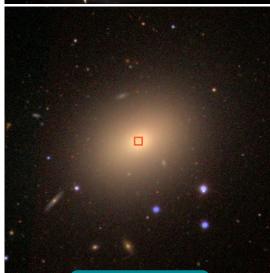
NGC 1097



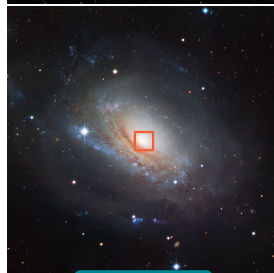
NGC 1386



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NGC 3169

Sample

LINER 1

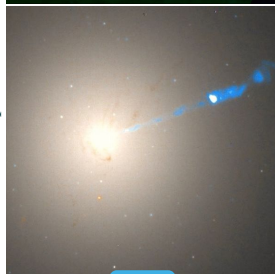
LINER 2

Sy2

NGC 4594



15'' ~ 660 pc



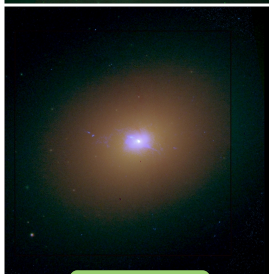
29'' ~ 2.3 kpc

M87

NGC 1097



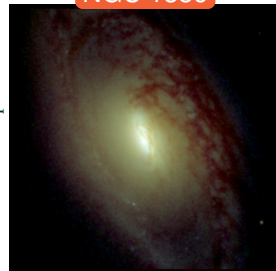
32'' ~ 2.2 kpc



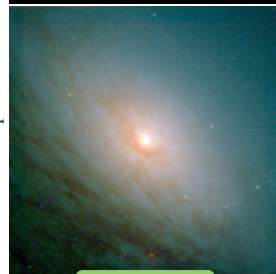
30'' ~ 2.6 kpc

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NGC 1386



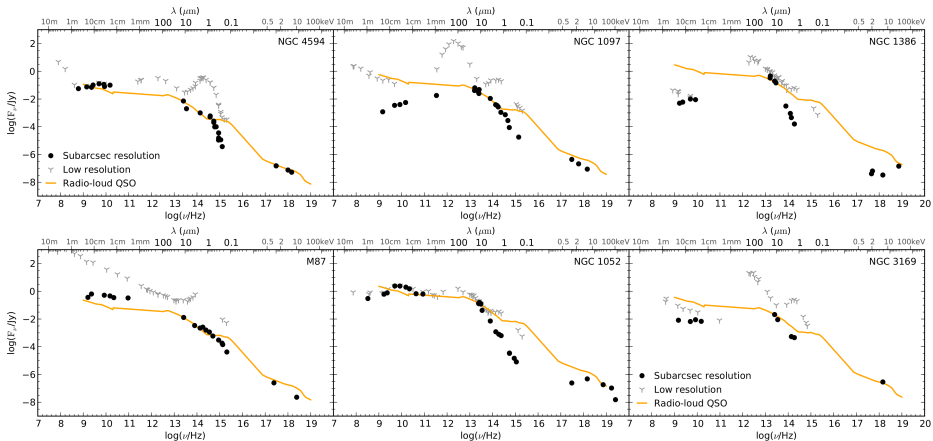
26'' ~ 1.9 kpc



10'' ~ 1.2 kpc

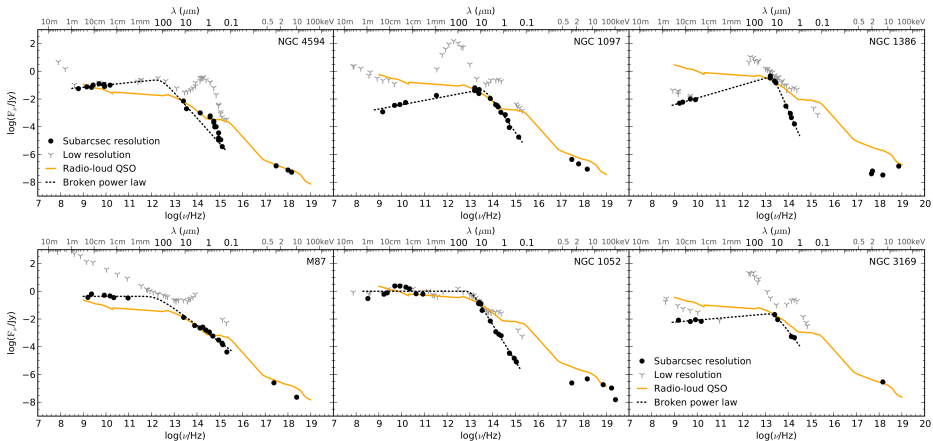
NGC 3169

LLAGN at parsec scales



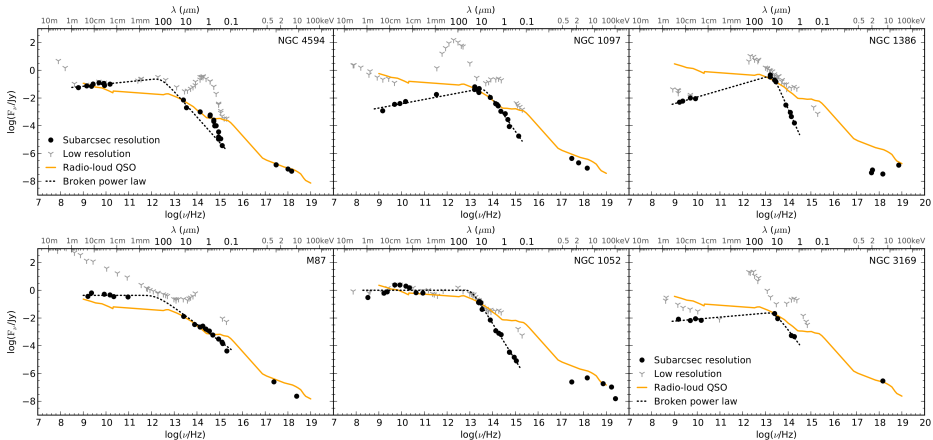
Subarcsec + Low-spatial resolution + Radio-loud QSO (Elvis+1994)

LLAGN at parsec scales



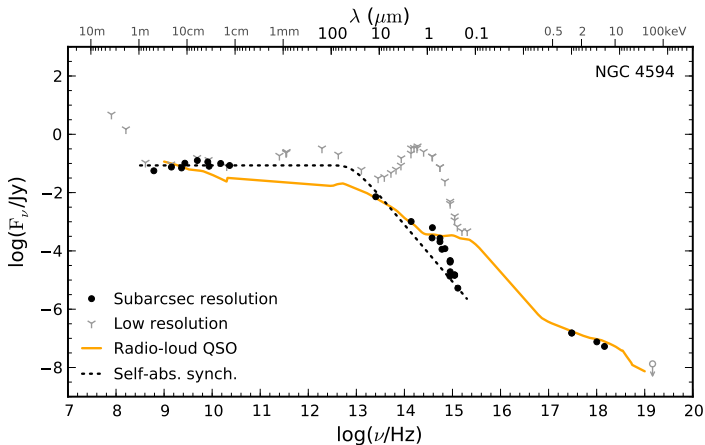
Subarcsec + Low-spatial resolution + Radio-loud QSO (Elvis+1994)
 Self-absorbed synchrotron emission (see also Mason+2012)

LLAGN at parsec scales



Subarcsec + Low-spatial resolution + Radio-loud QSO (Elvis+1994)
 Self-absorbed synchrotron emission (see also Mason+2012)
 Soft thermal bump $\sim 1 \mu\text{m}$

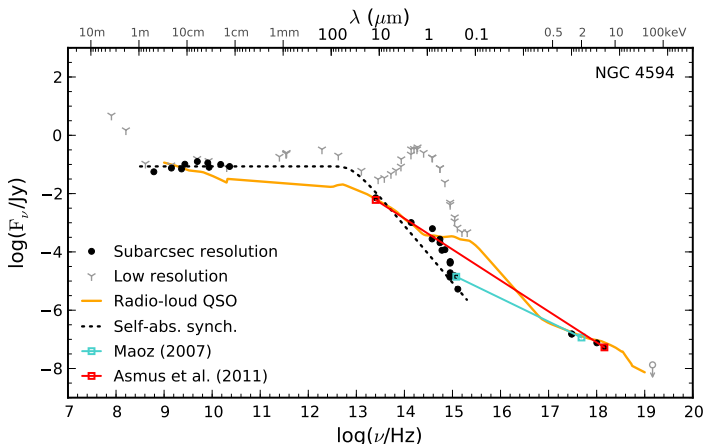
An accretion disk/torus?



$$\alpha_{thick} = -0.2, \alpha_{thin} = 1.8$$

$$S_{\nu} \propto \nu^{-\alpha}$$

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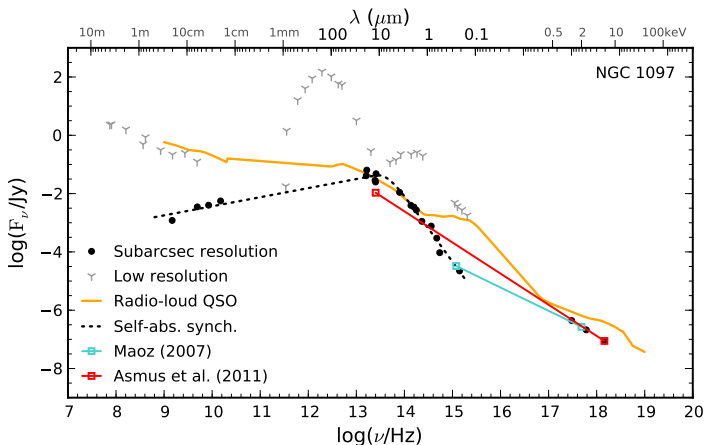
$$\alpha_{thick} = -0.2, \alpha_{thin} = 1.8$$

$$\alpha_{ox} = -0.8, 2500\text{\AA} \text{ to } 2\text{ keV}$$

$$\log(F_{MIR}/mJy) = 14.35 + 1.12 \log(F_{2-10\text{ keV}}/\text{erg cm}^{-2} \text{ s}^{-1})$$

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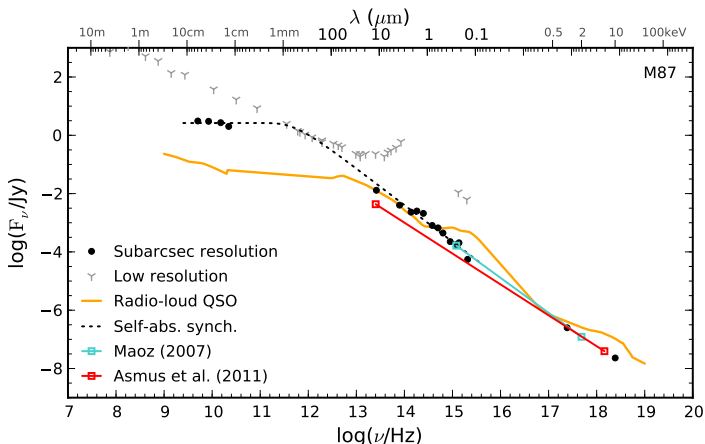
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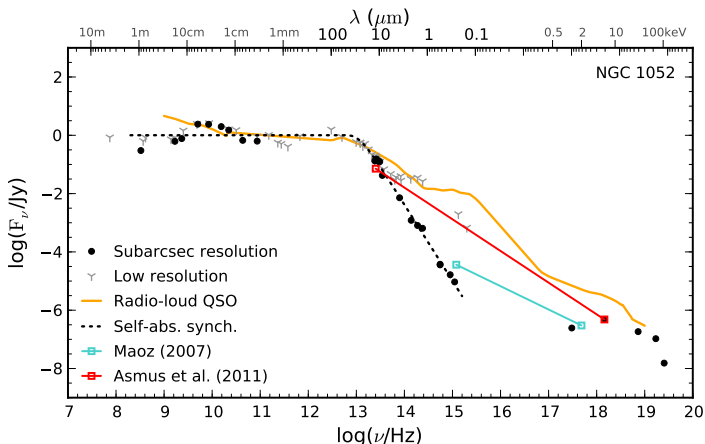
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α_{OX} similar to disk-dominated AGN
 \Rightarrow **accretion disk**

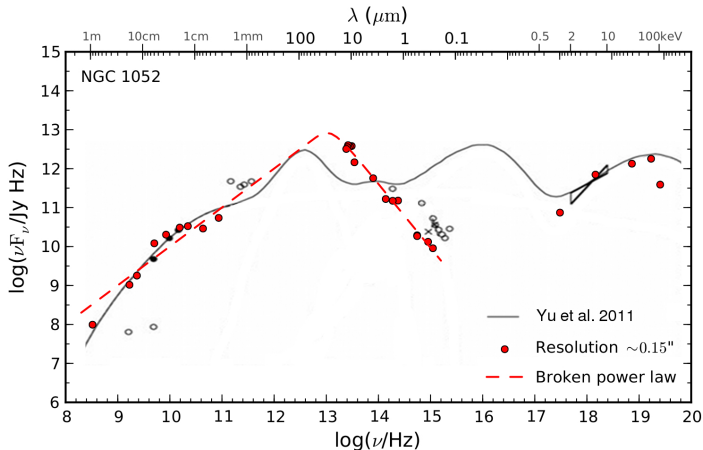
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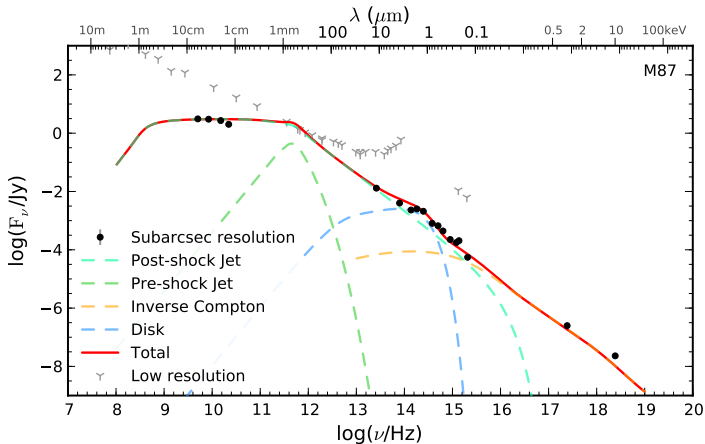
Mid-IR vs. X-ray similar to bright AGN
 \Rightarrow **torus**

Inflow and Outflow

Subarcsec resolution SED + ADAF model Yu+(2011)
 IR to optical/UV largely departs from ADAF prediction

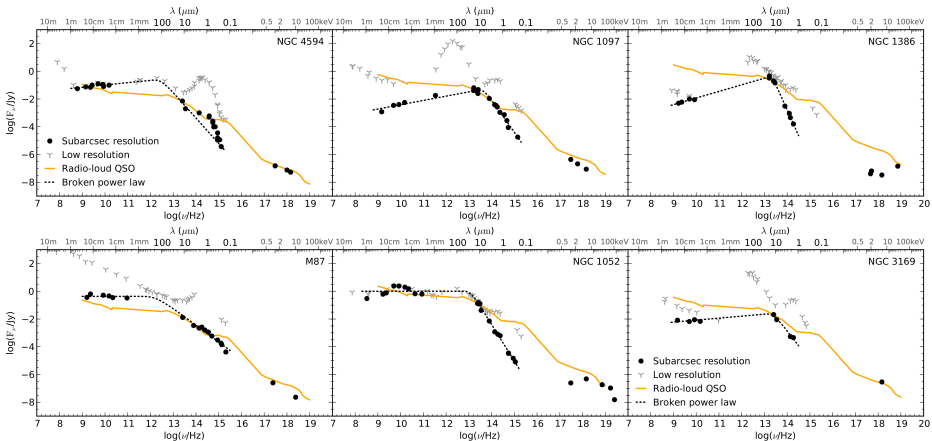


Inflow and Outflow



Example of Jet+truncated disk model (Markoff+2005,2008)
on a contemporaneous M87 core SED

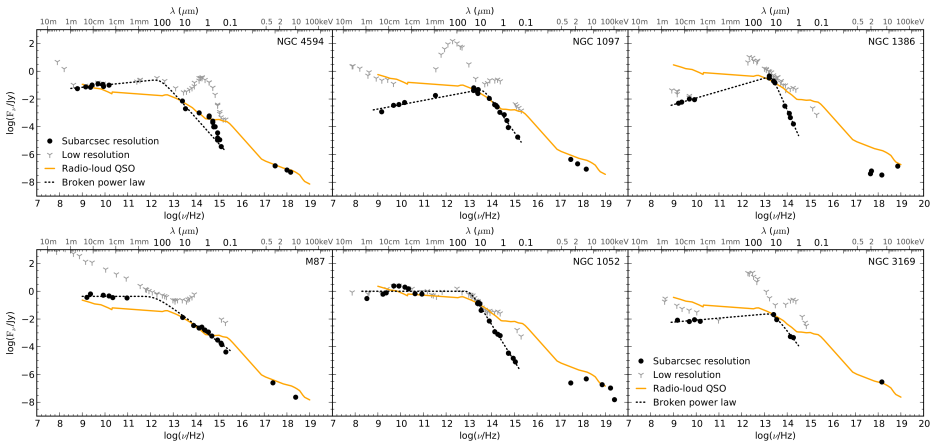
Inflow and Outflow



Optically thin component much steeper ($1 \lesssim \alpha_{\text{thin}} \lesssim 3$) than canonical synchrotron cooling slope of ≈ 0.7 in the $\sim 2000 \text{ \AA} - 20 \mu\text{m}$ range

(Fernández-Ontiveros et al. in prep.)

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Variability? $\simeq 11\%$ in optical/UV (Maoz 2005)

Summary

- ▶ High-spatial resolution needed to isolate LLAGN from their hosts
- ▶ No signature of **accretion disk** or **torus** in the SED
- ▶ **Outflow scenario**: continuum dominated by the jet
- ▶ **Steep power law** ($1 \lesssim \alpha \lesssim 3$) in the mid-IR to optical/UV range