IRVINE LOS ANGELES RIVERSIDE SAN DIEGO SANTA BARBARA

Southern California CGE Center for Galaxy Evolution

The Relationship Between Black Hole Growth and Star Formation in Seyfert Galaxies

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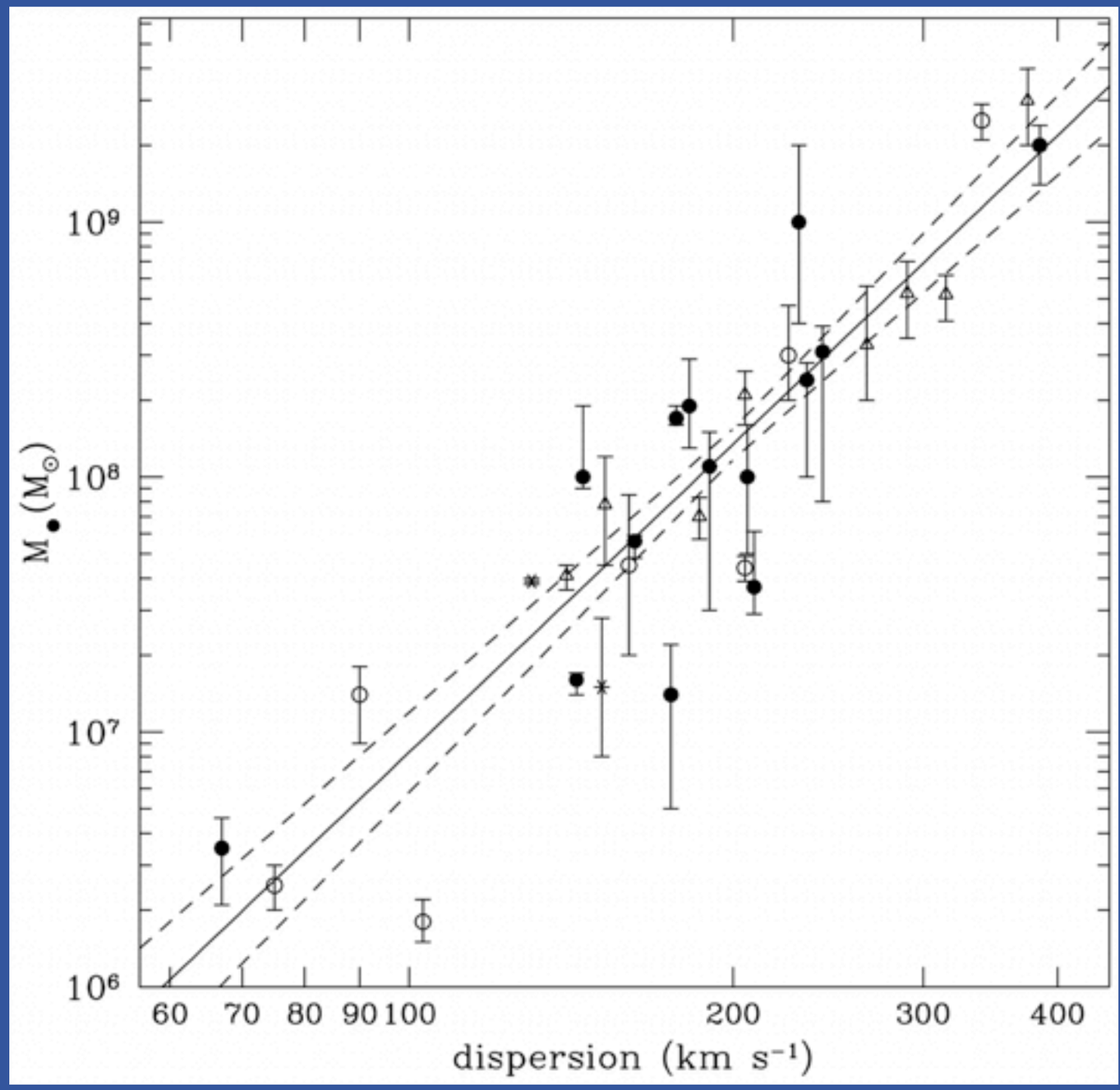
Questions

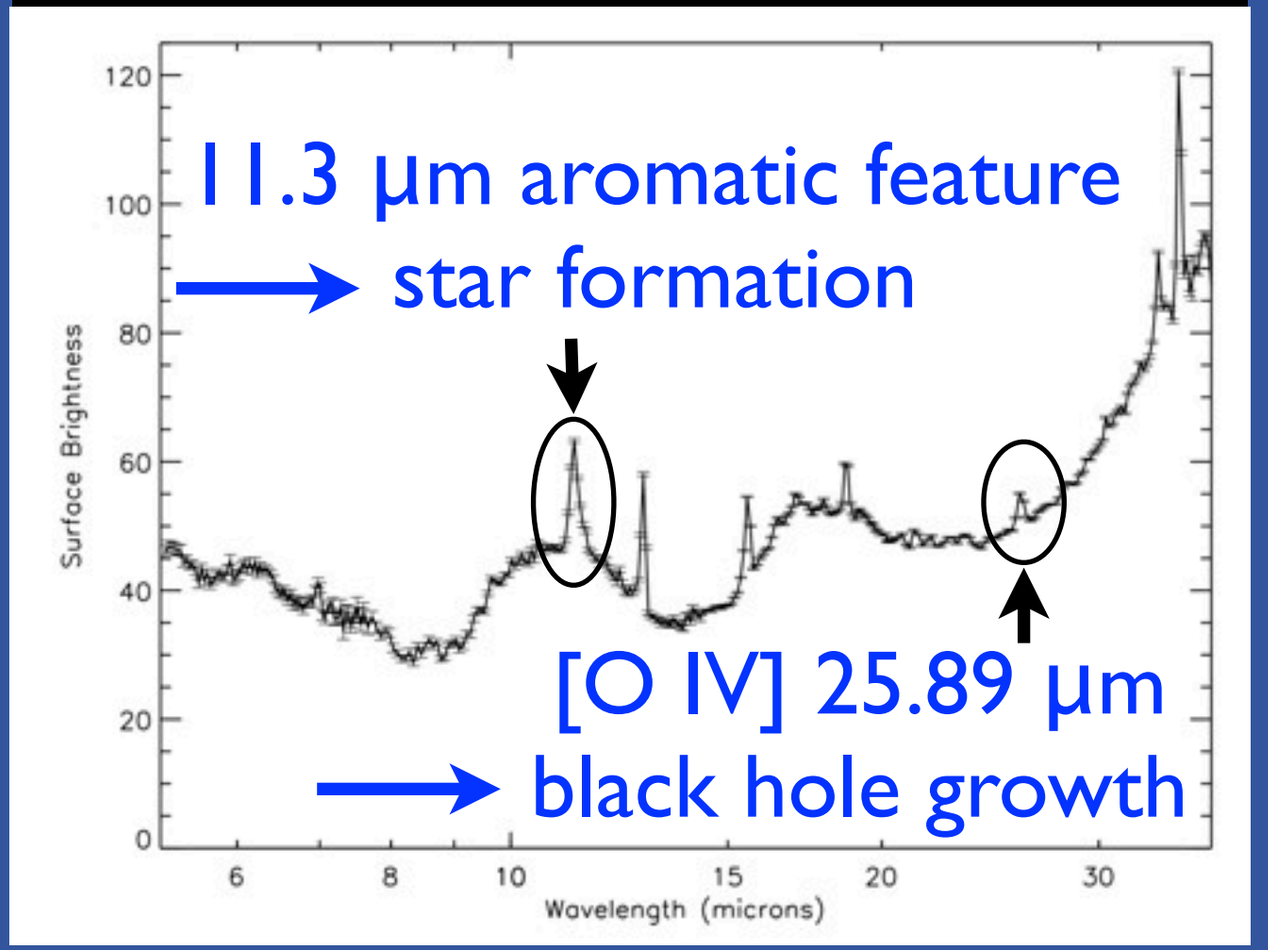
- When / where / how are black holes being fueled?
- How does this relate to the growth of the galaxies they reside in?



Tremaine et al. 2002

Questions

- How well can we measure black hole growth?
- How well can we measure host galaxy star formation?
- What is the relationship between them?



How obscured are typical AGNs?

obscuration towards the narrow-line region?

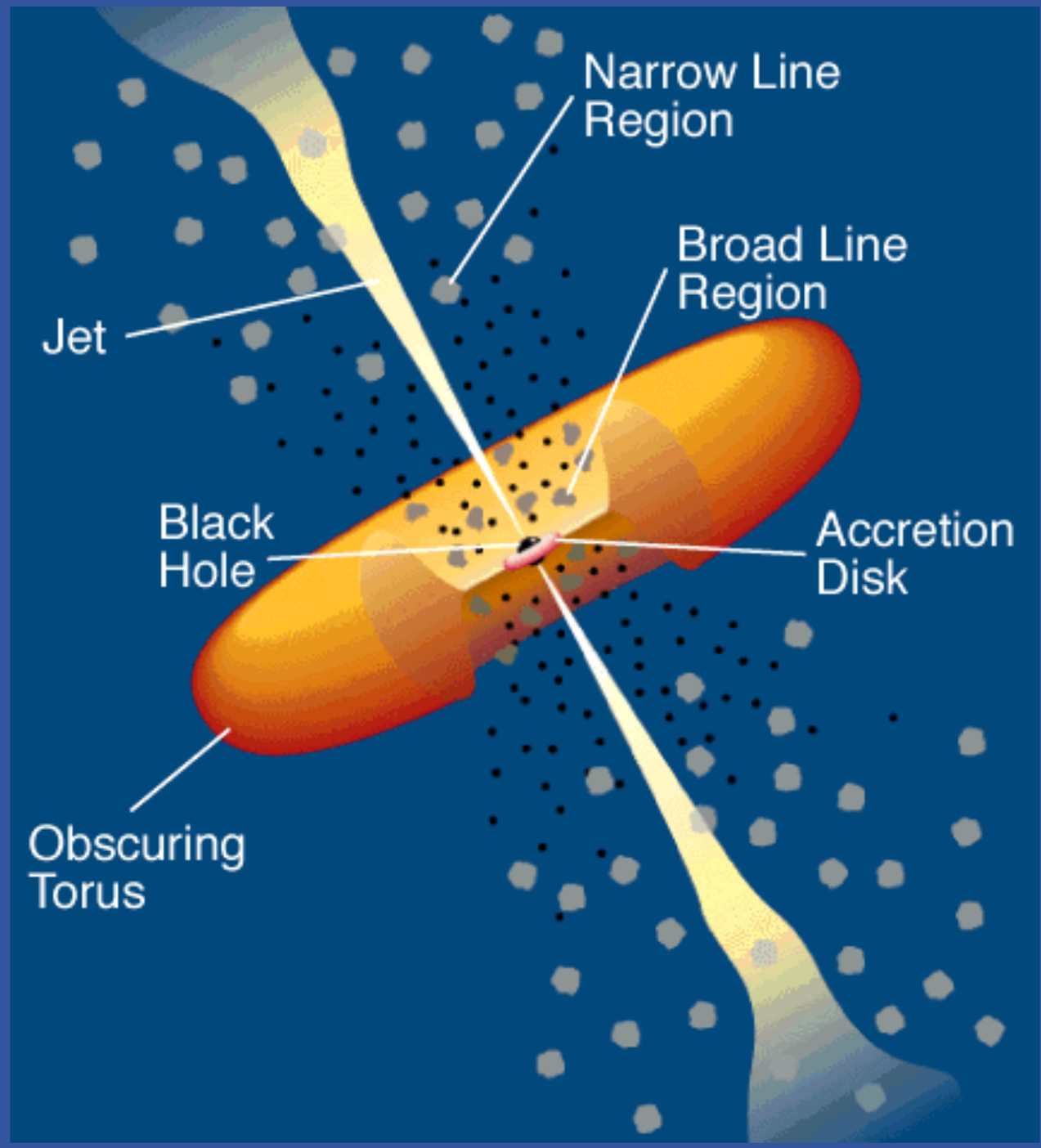
[O IV] 25.89 μm v. [O III] 5007 Å

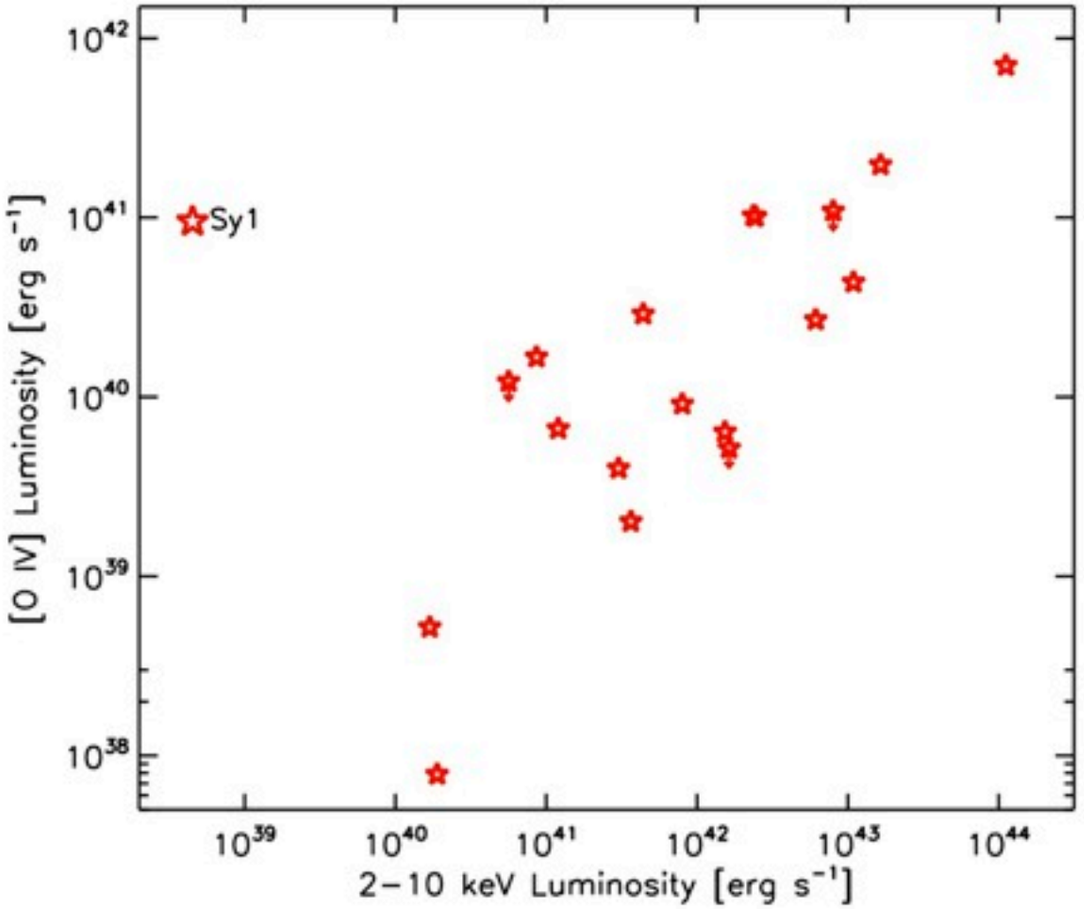
how attenuated are hard X-rays?

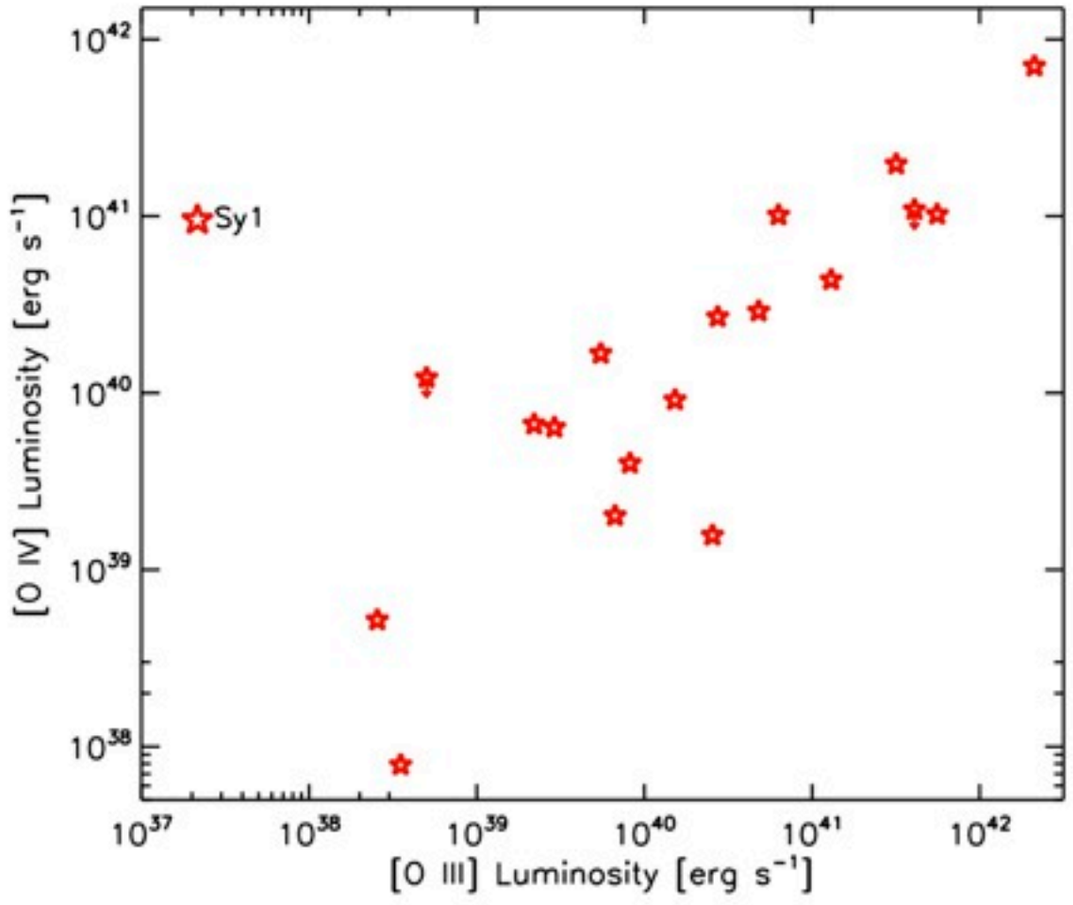
[O IV] 25.89 μm v. hard X-rays

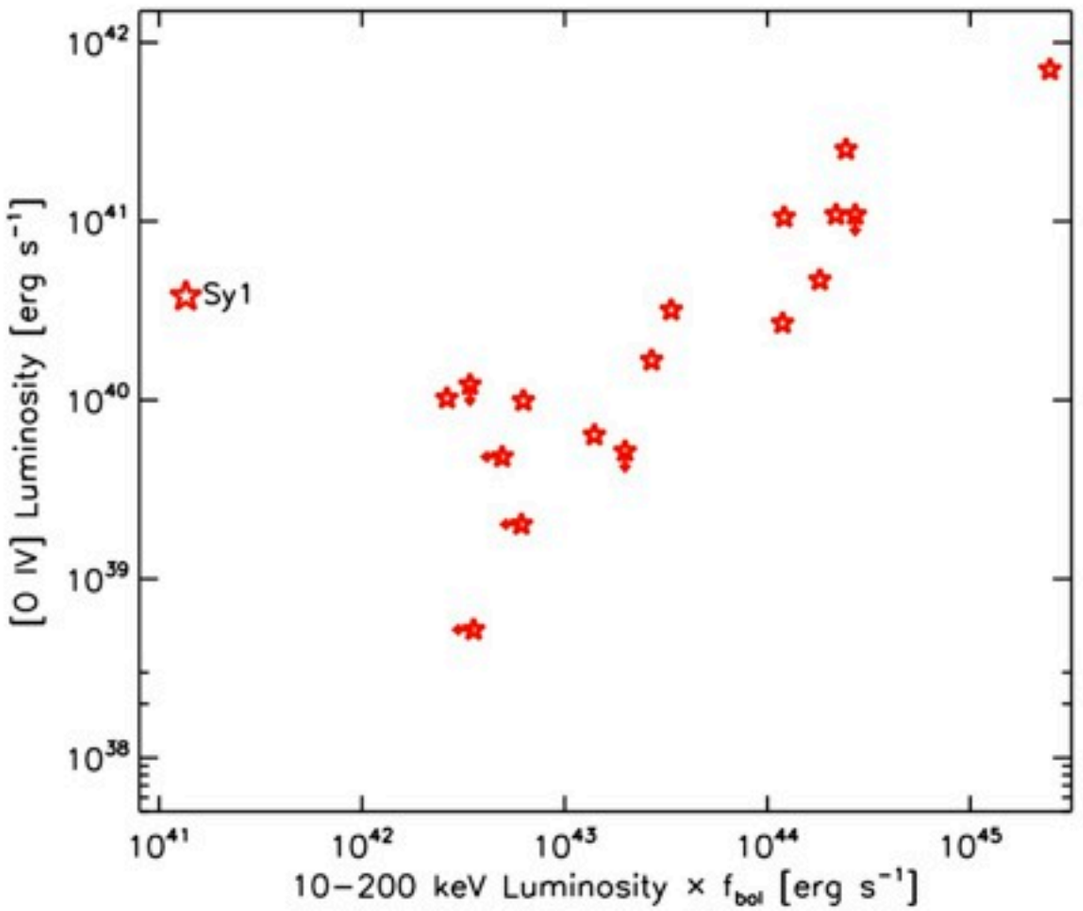
Sample: 90 Seyferts from Revised Shapley-Ames catalog galaxy-magnitude-limited, $B_T<13$ Maiolino & Rieke 1995, Ho et al. 1997

Urry & Padovani 1995









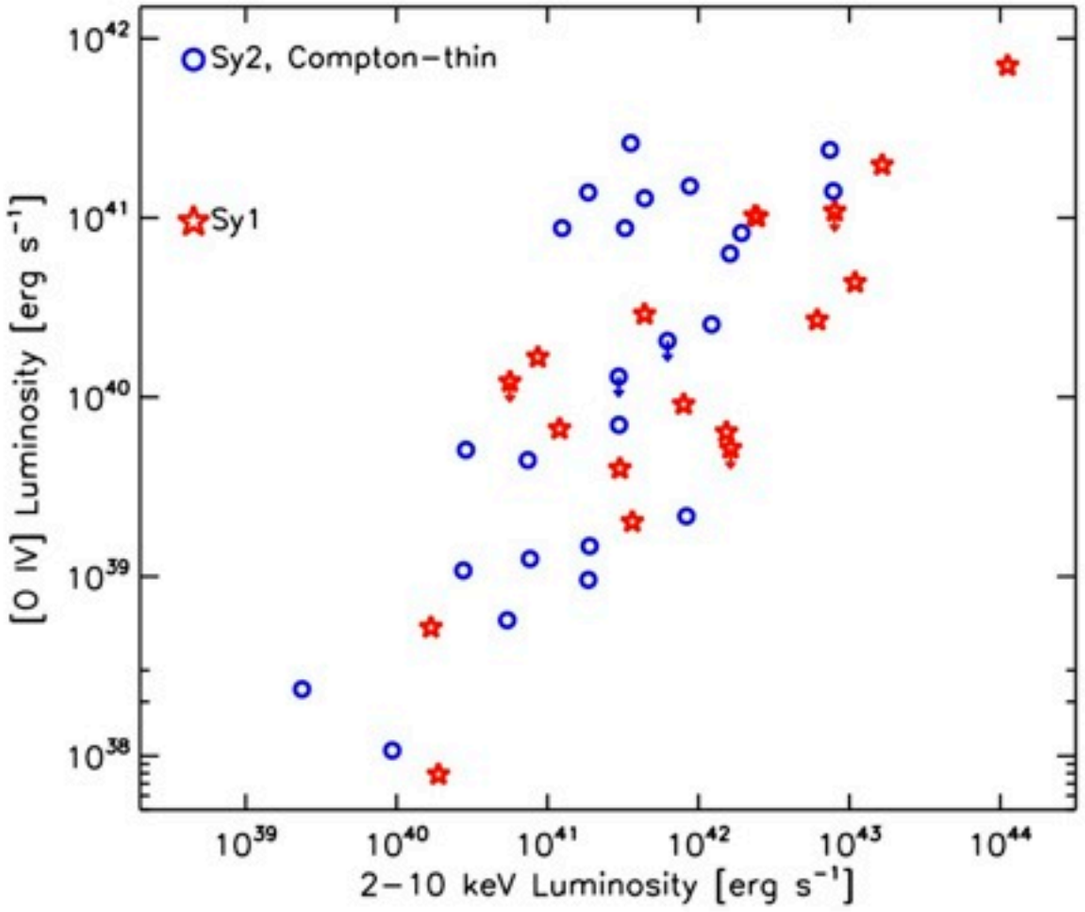
[O IV] v. hard X-rays, [O III]

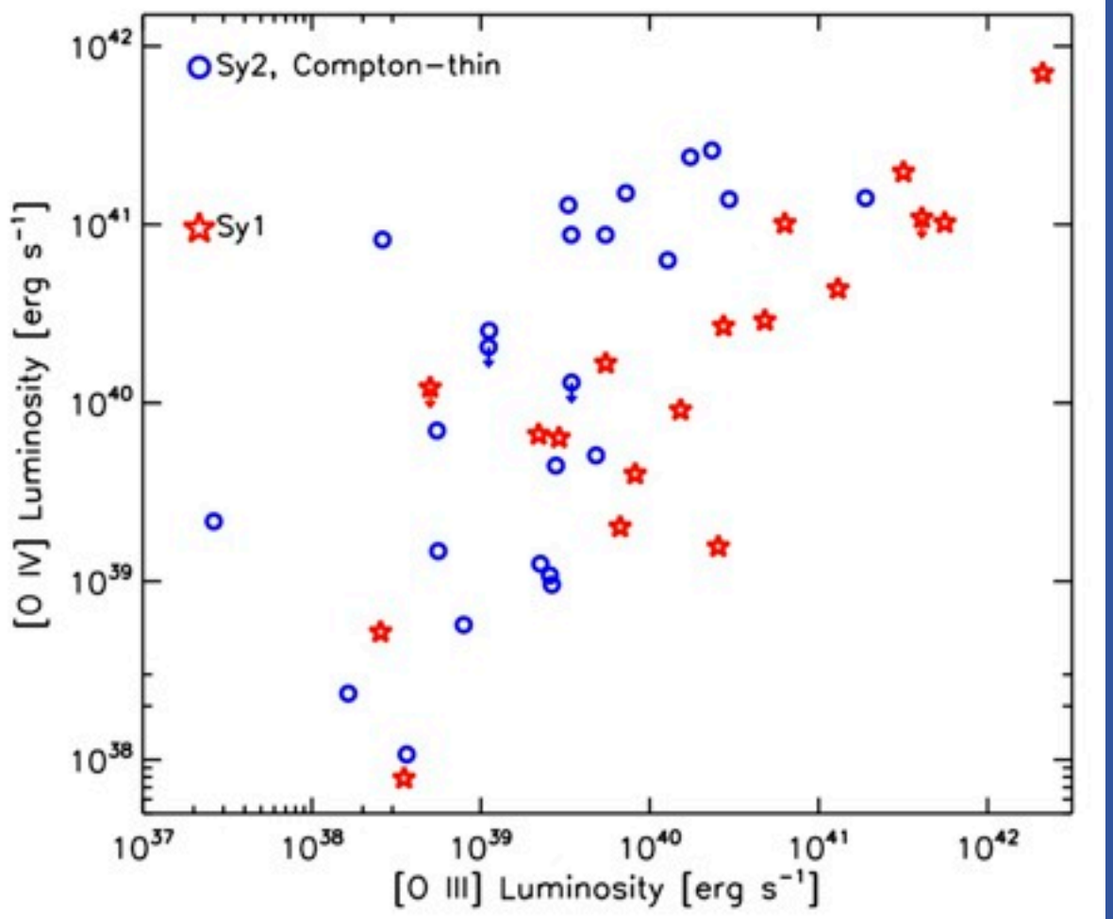
Diamond-Stanic, Rieke, & Rigby 2009

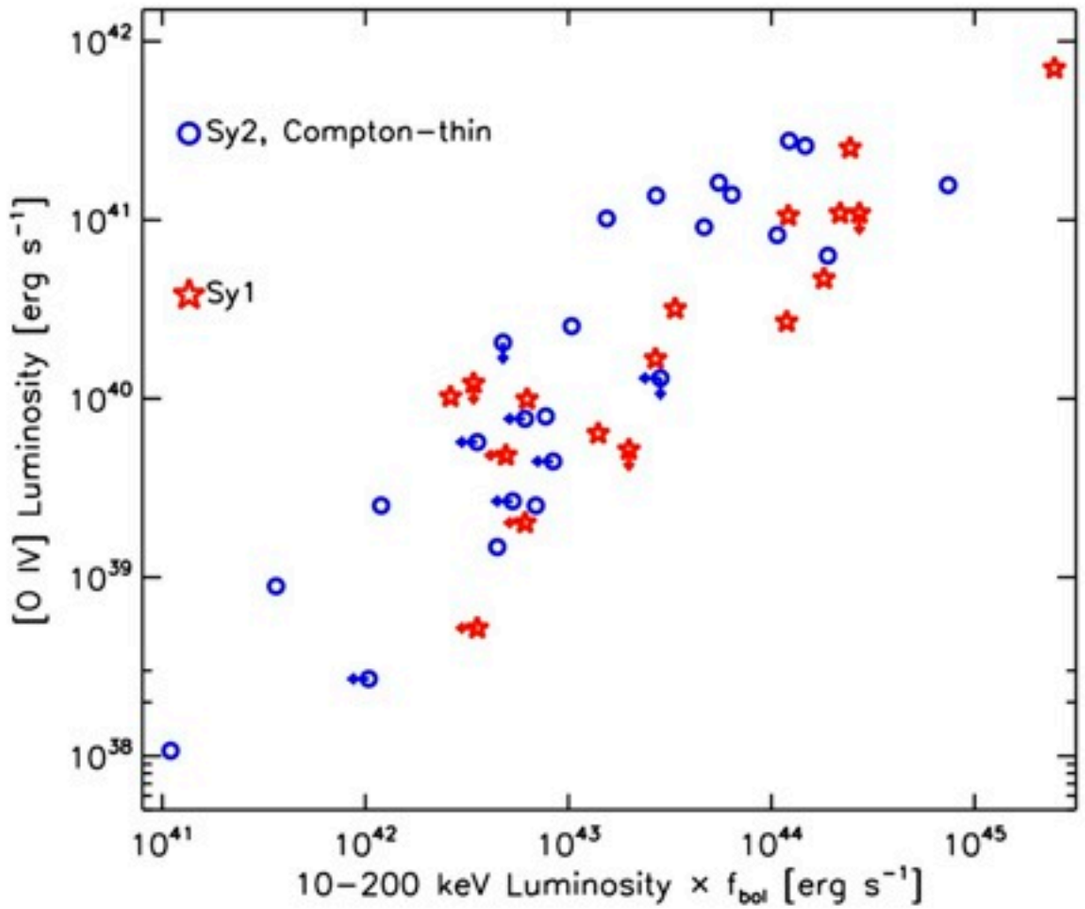
Rigby, Diamond-Stanic, & Aniano 2009

Sy1: unobscured

see also Hass et al. 2005, Melendez et al. 2008, Goulding & Alexander 2009, Baum et al. 2010, Weaver et al. 2010, LaMassa et al. 2010, Kraemer et al. 2011, Goulding et al. 2011







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Compton-thin: $N_H < 10^{24}$ cm^{-2}

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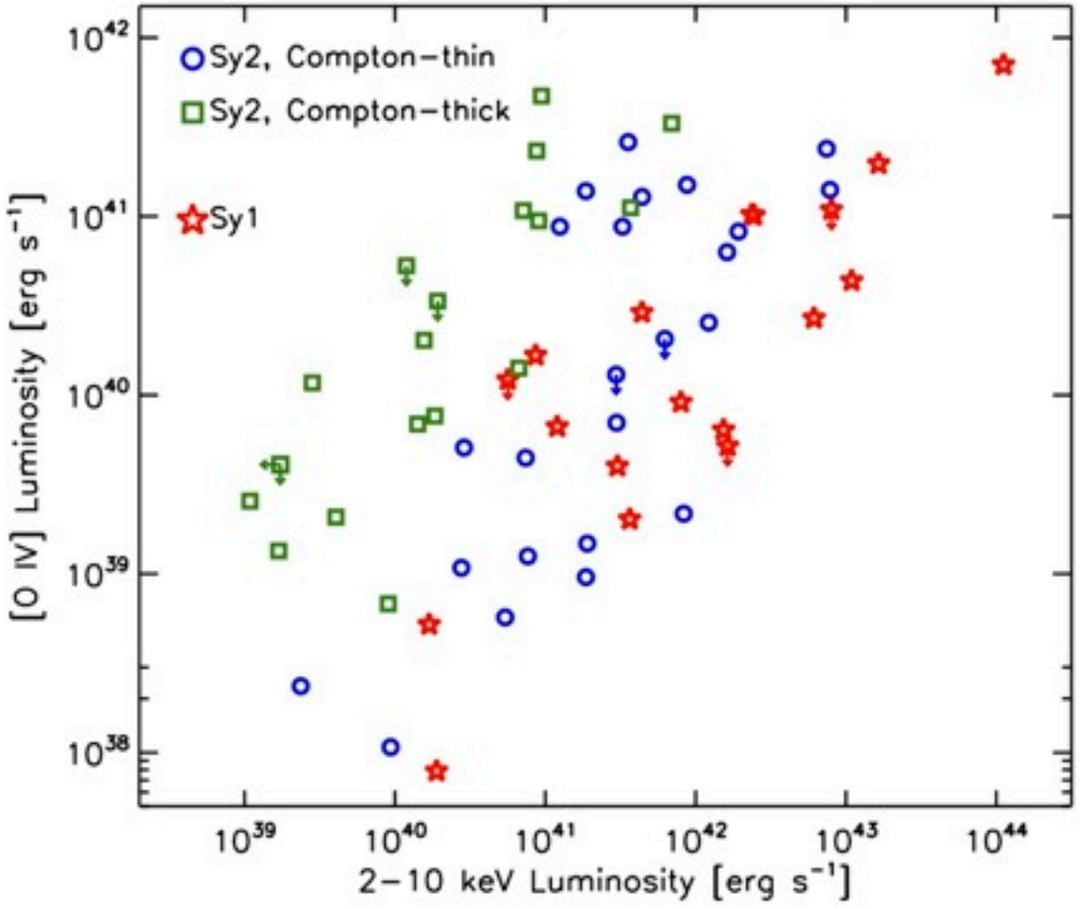

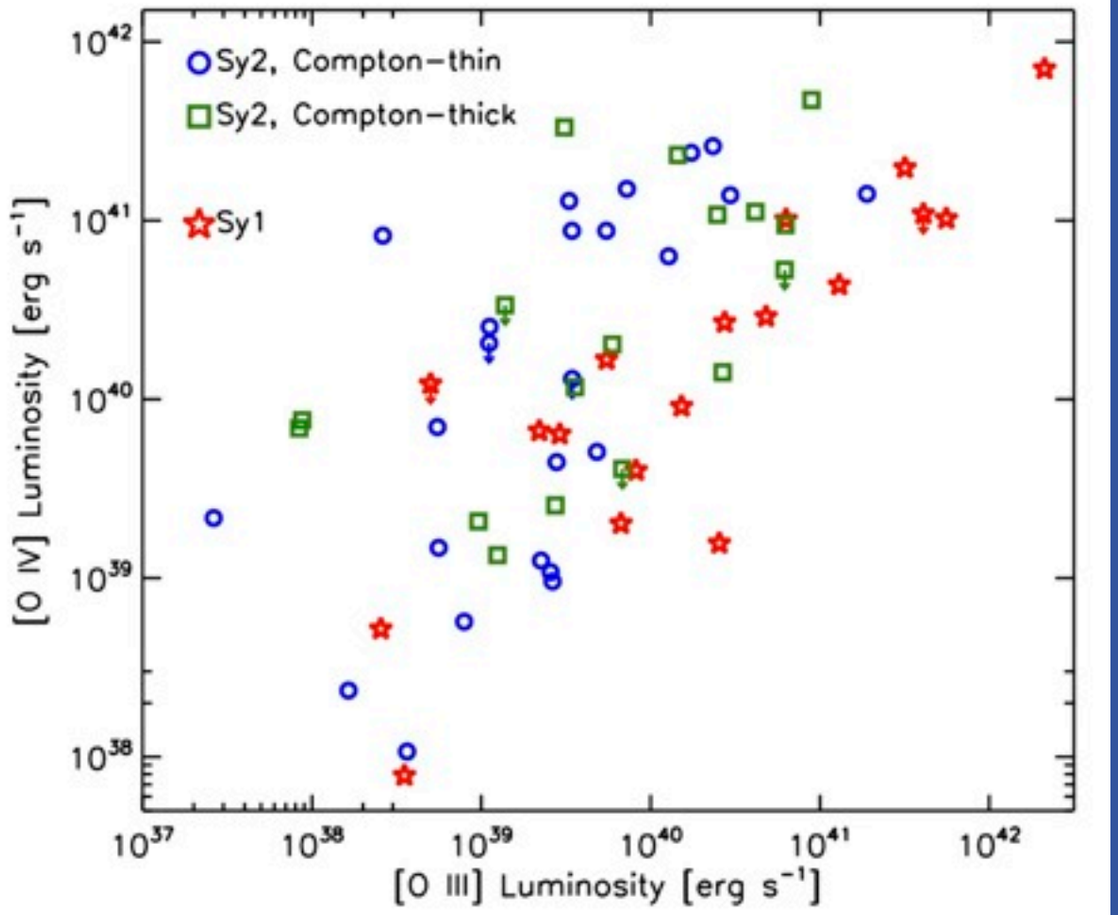

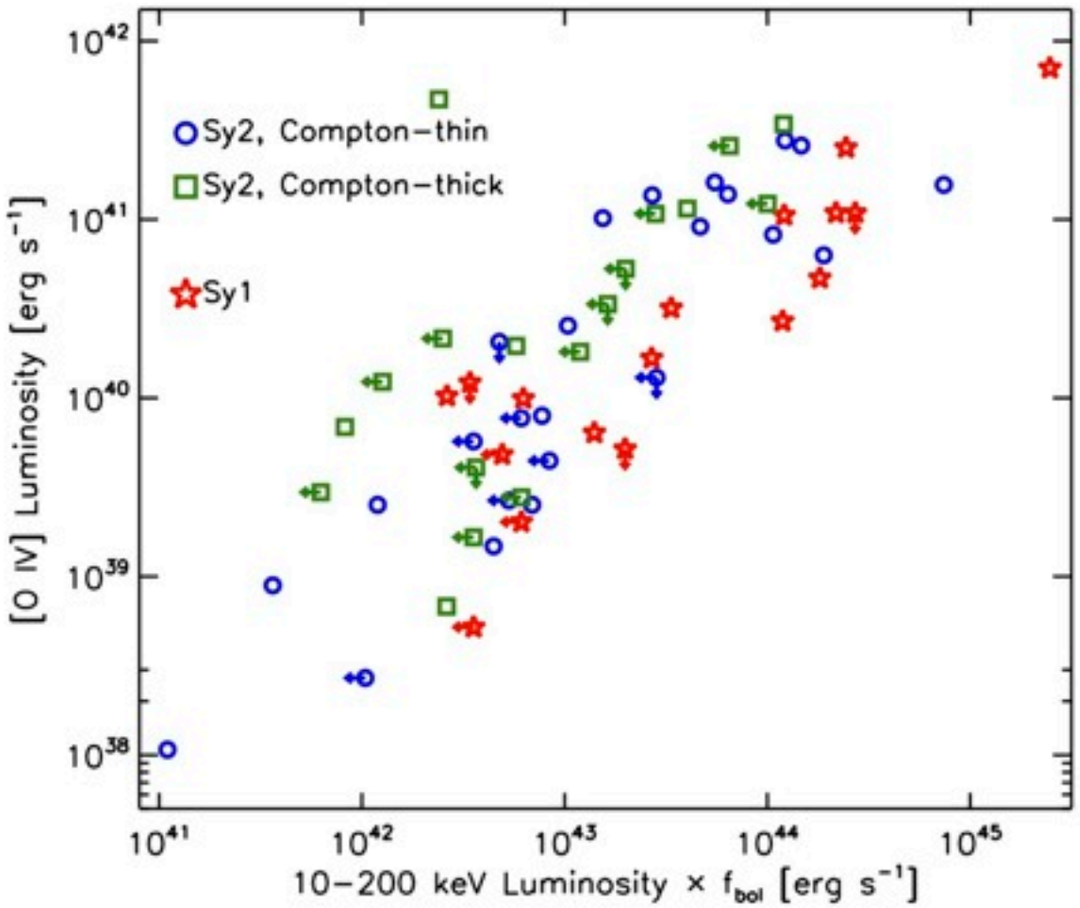

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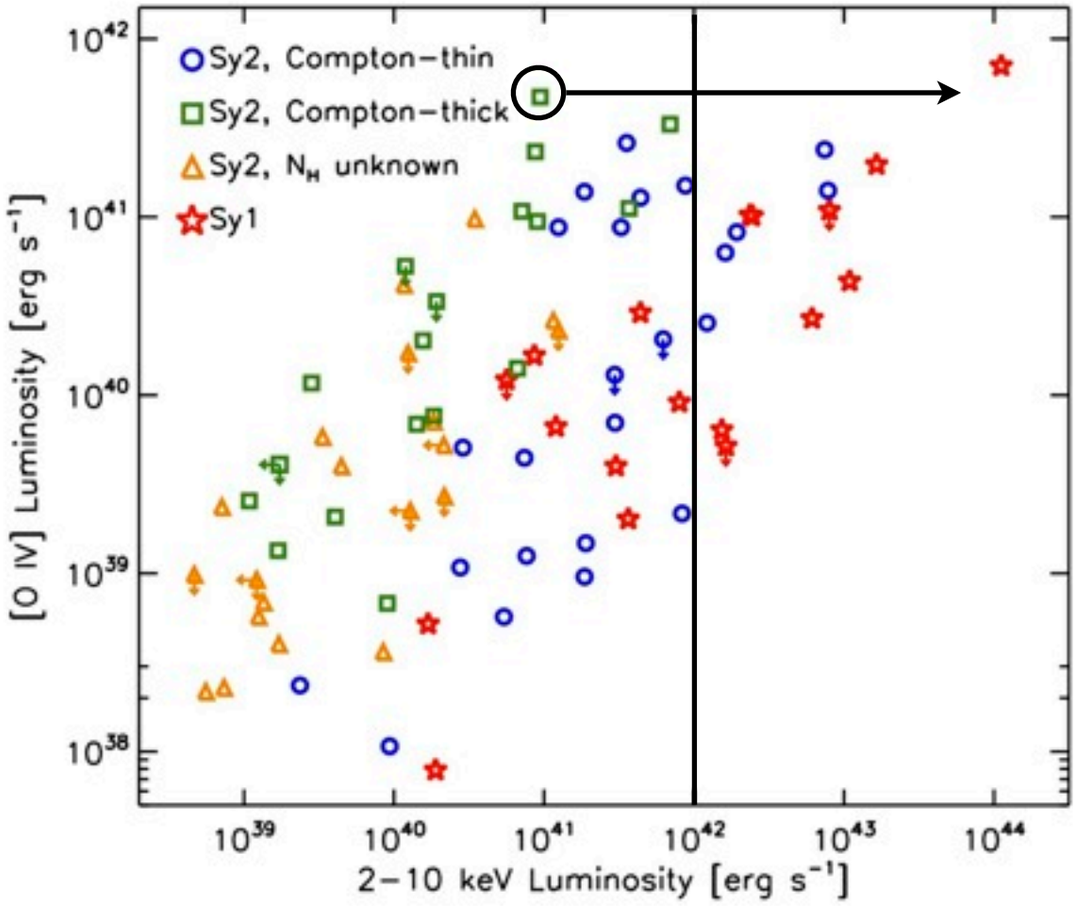
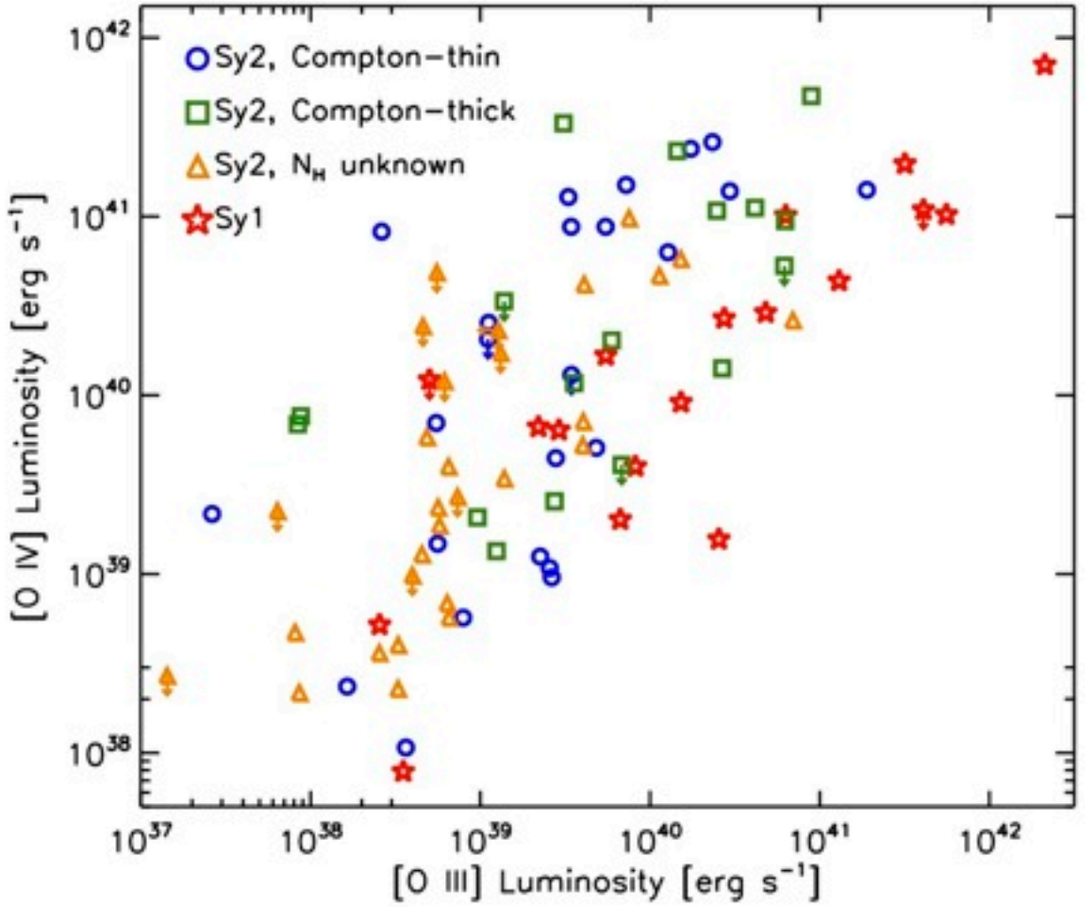
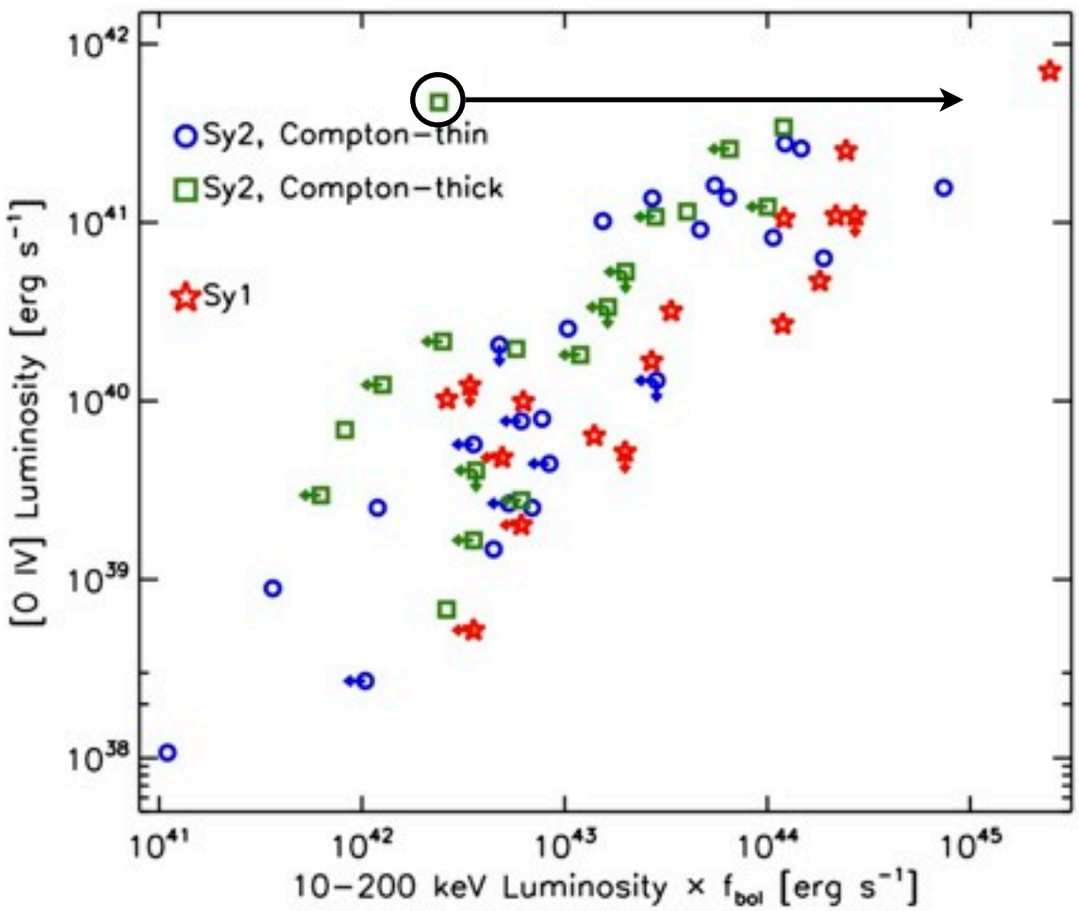
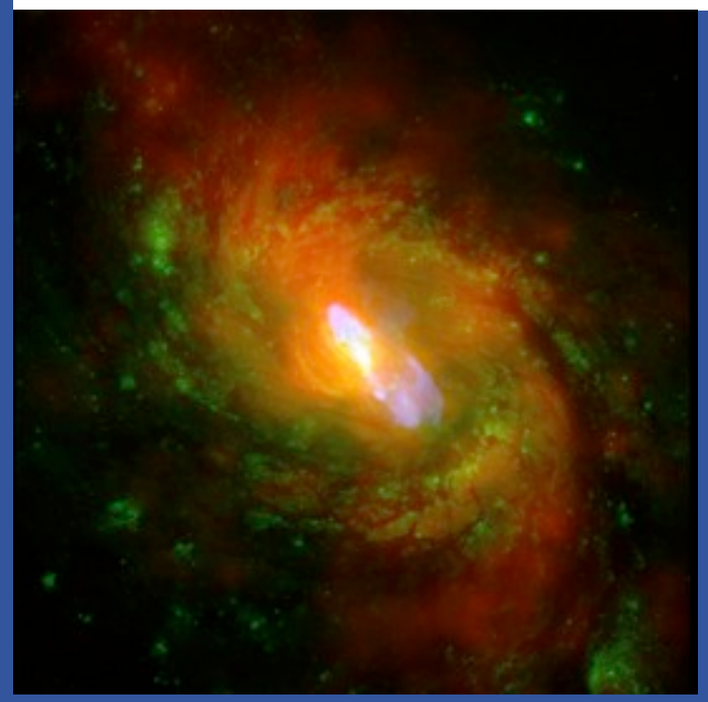






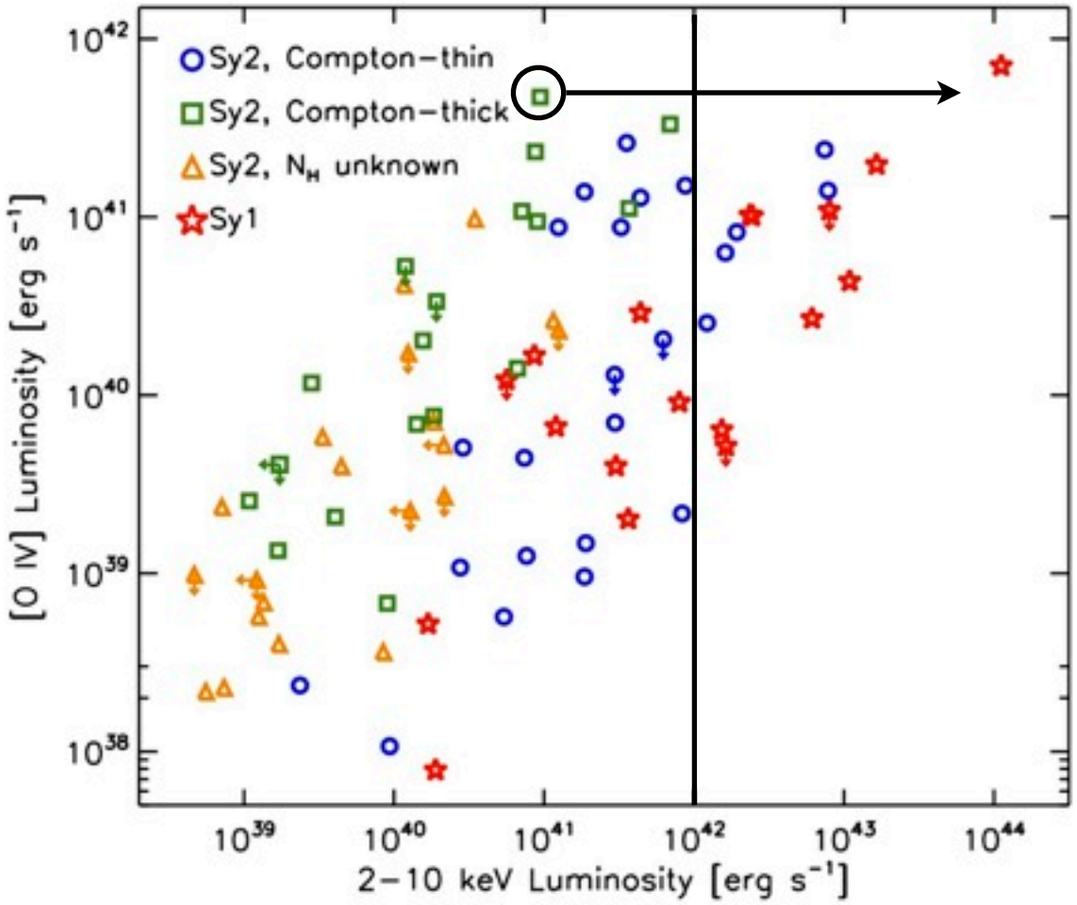


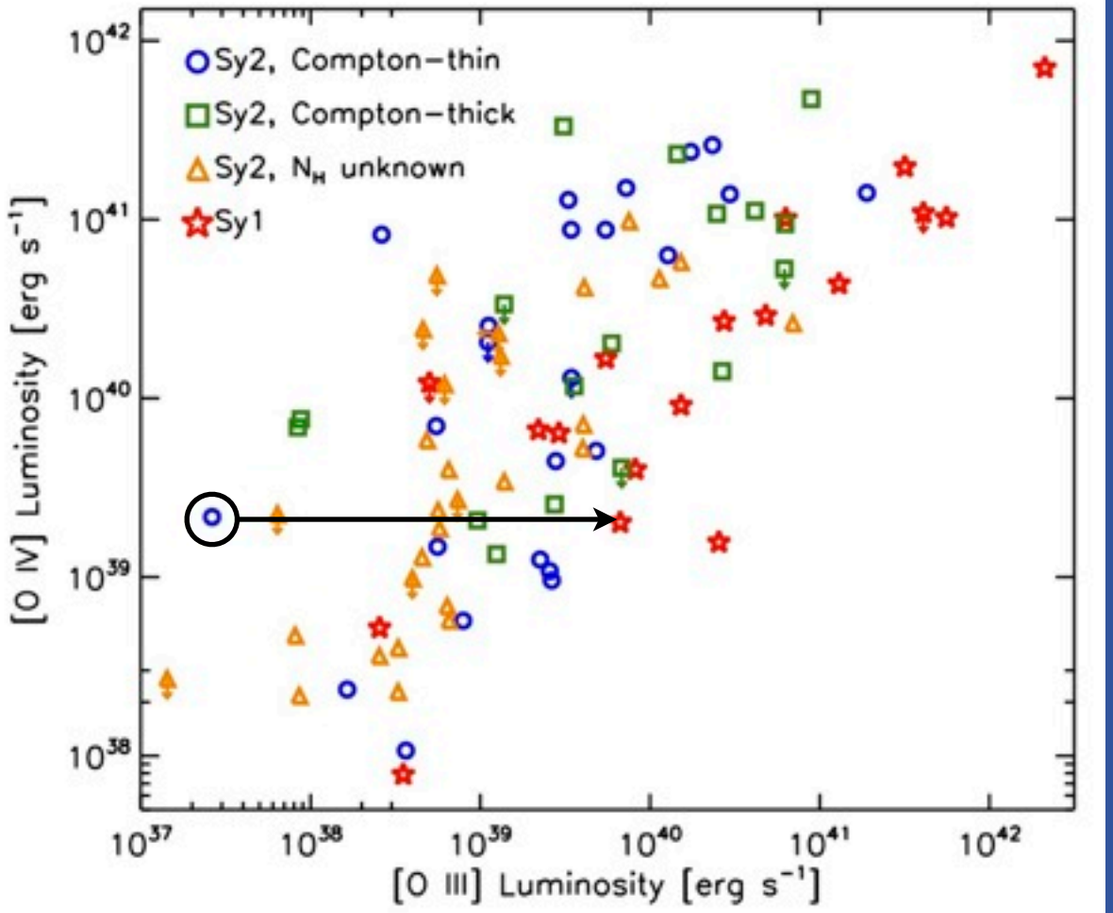
NGC 1068: >99% of hard X-ray photons absorbed

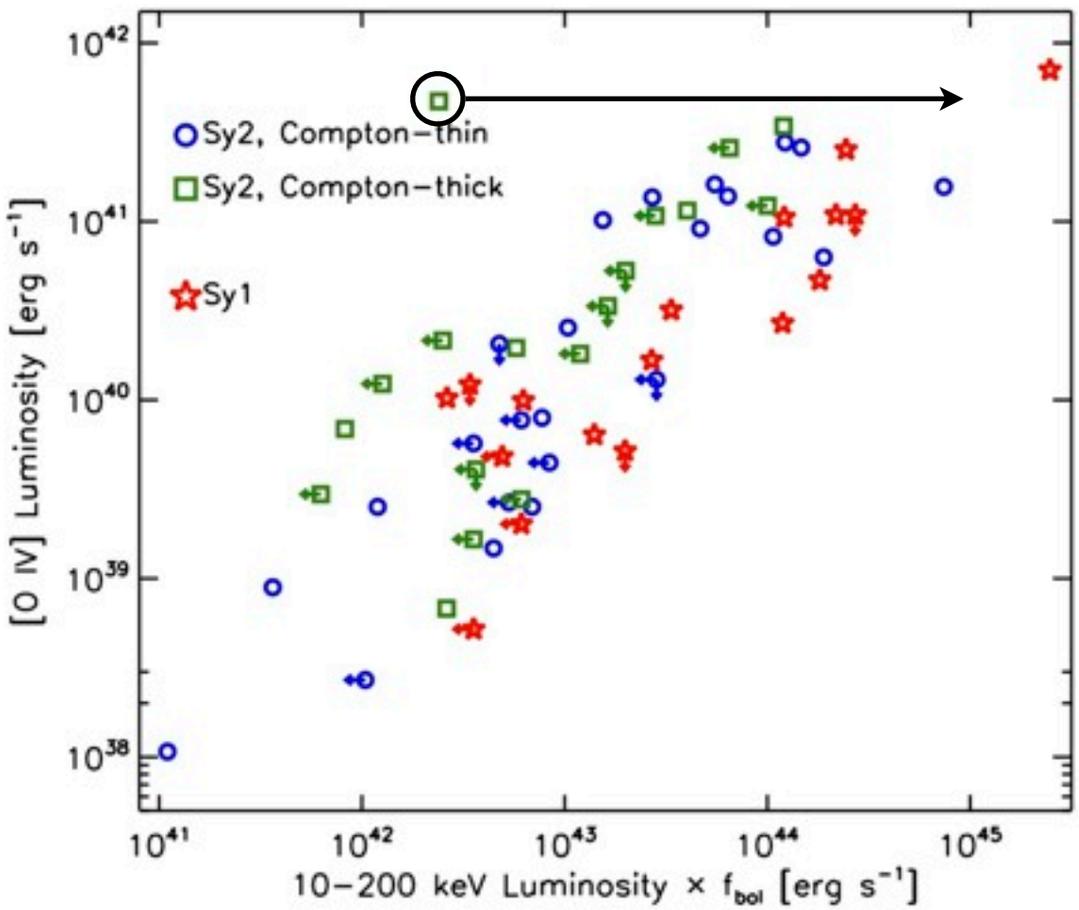
as seen by Chandra / HST / VLA

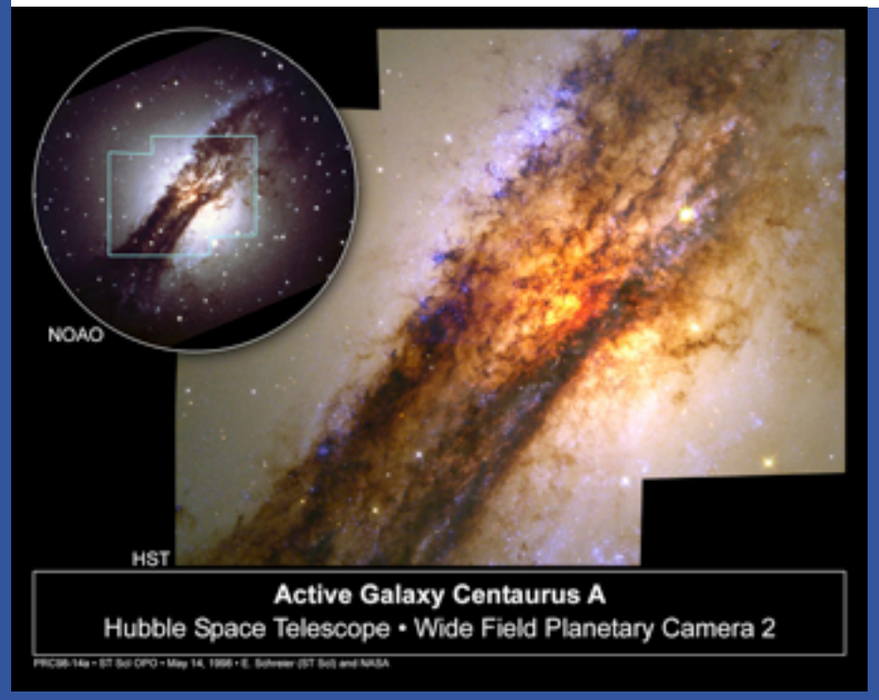
Diamond-Stanic, Rieke, & Rigby 2009

Rigby, Diamond-Stanic, & Aniano 2009









Cen A:
>99% of [O III] photons absorbed

as seen by HST / NOAO

Diamond-Stanic, Rieke, & Rigby 2009

Rigby, Diamond-Stanic, & Aniano 2009

LAGN results

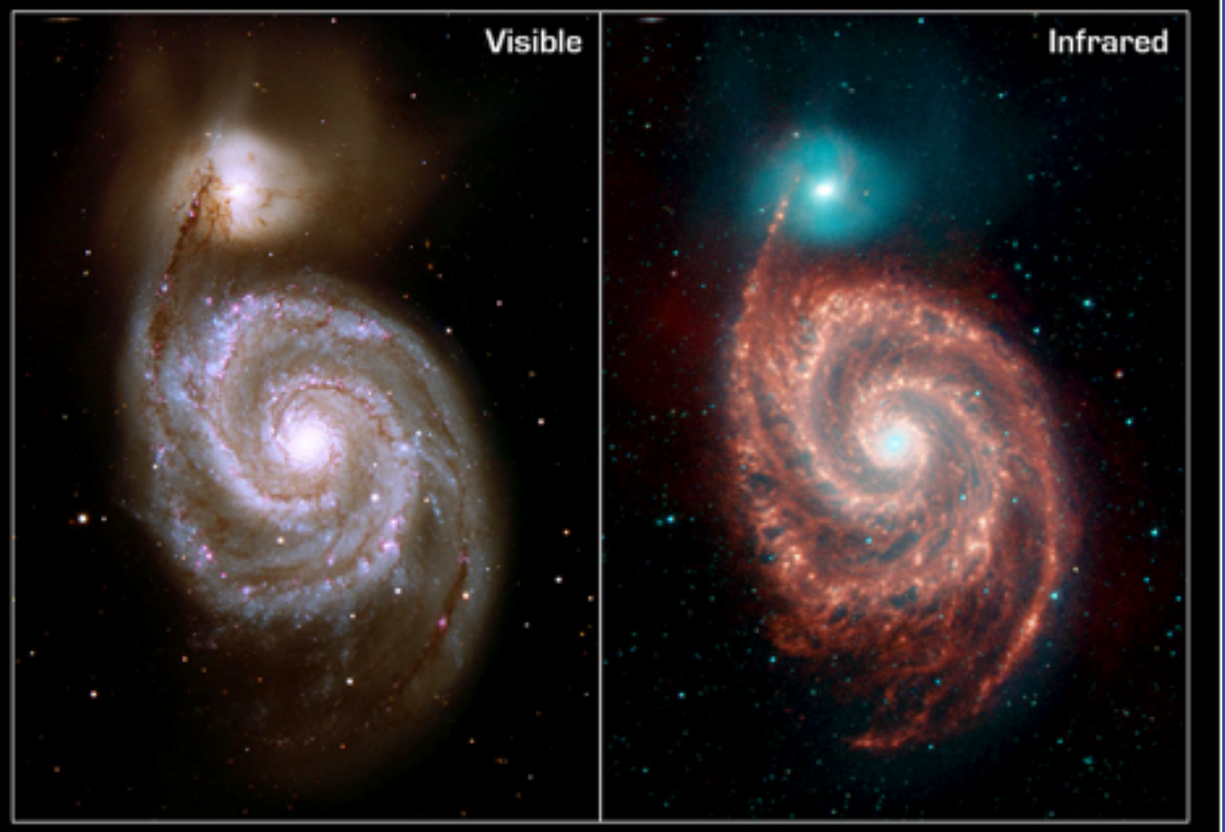
- [O IV] is a useful intrinsic luminosity indicator
  - Sy1, Sy2 luminosity distributions indistinguishable
- 2-10 keV X-rays biased for obscured sources
  - luminosity-dependent obscured fraction?
- [O III] is not isotropic
  - Sy2s systematically fainter, A_V=1-5 host galaxy extinction
- Even 10-200 keV X-rays are absorbed
  - hard X-rays suppressed by x3 for Sy2s

What about star-formation rates?

- Standard SFR tracers contaminated by the AGN
  - e.g., Hα, L_{UV}, L_{IR} (although far-IR probably OK)

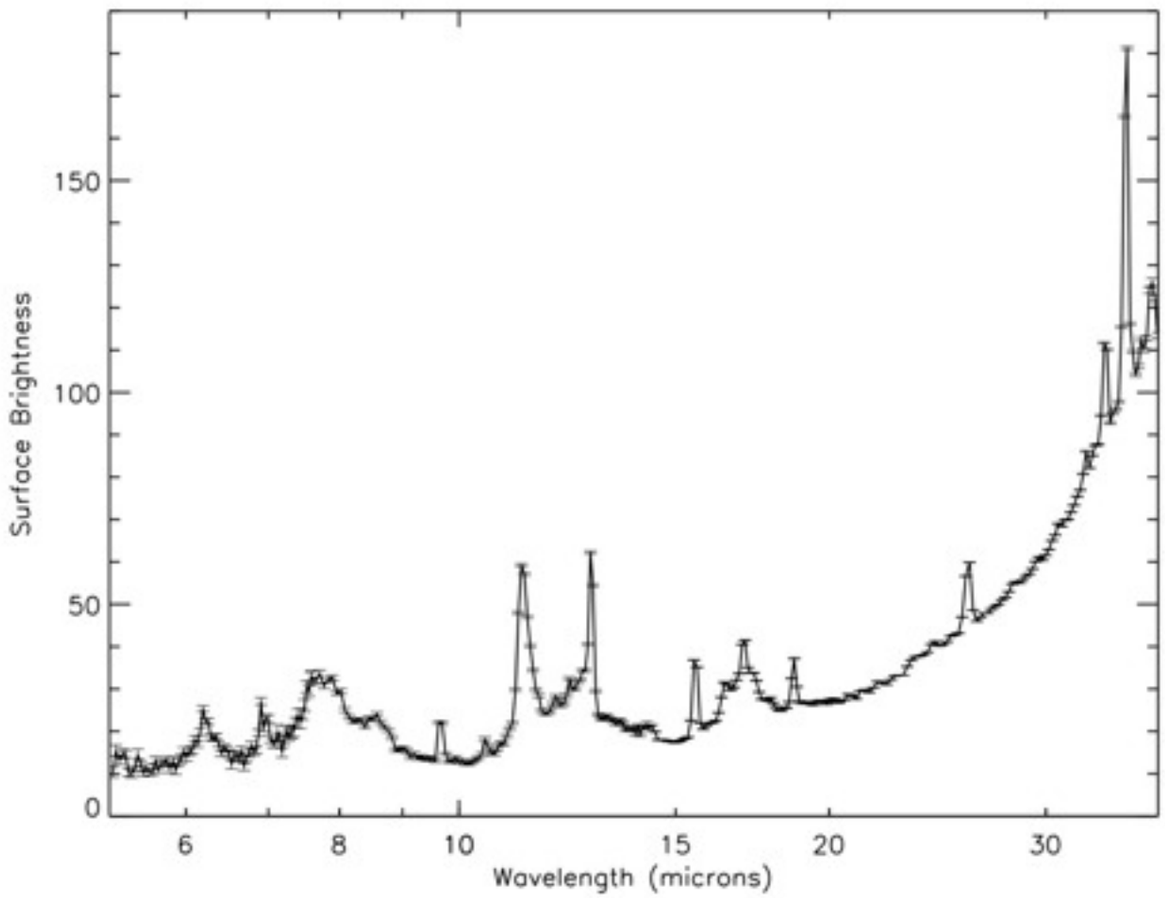
- The mid-infrared PAH features offer a solution
  - trace UV radiation field in photo-dissociation regions

- Black hole accretion rate and star-formation rate
  - Do they trace each other?



Spiral Galaxy M51 ("Whirlpool Galaxy") — **Spitzer Space Telescope • IRAC**

NASA / JPL-Caltech / R. Kennicutt (Univ. of Arizona) — ssc2004-19a



NGC5194

Surface Brightness [MJy sr^{-1}]

6 8 10 12 14

Observed Wavelength (μm)

PAH 6.2
PAH 7.7
PAH 8.6
H_2 9.7
PAH 11.3
PAH+[Ne II] 12.8

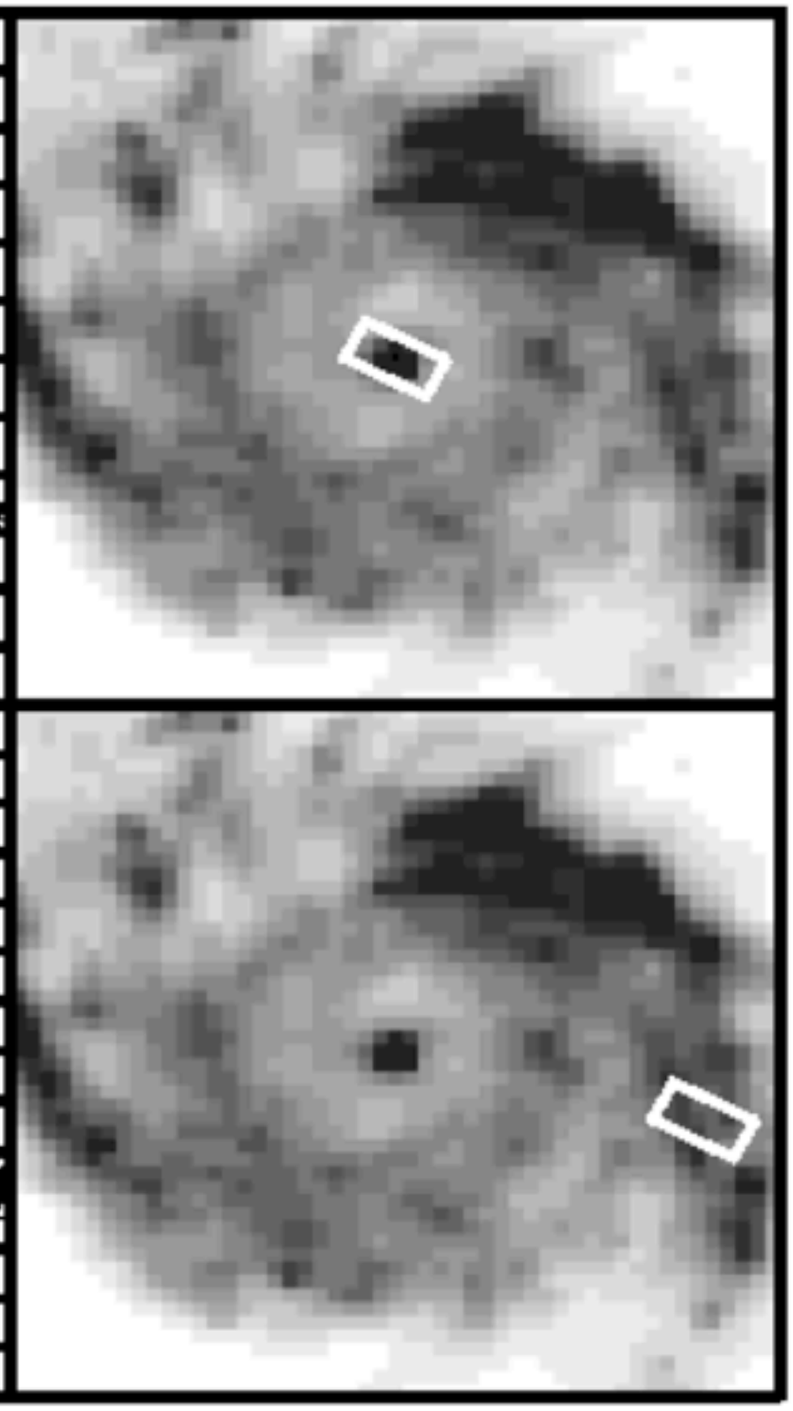
NGC5194

Surface Brightness [MJy sr^{-1}]

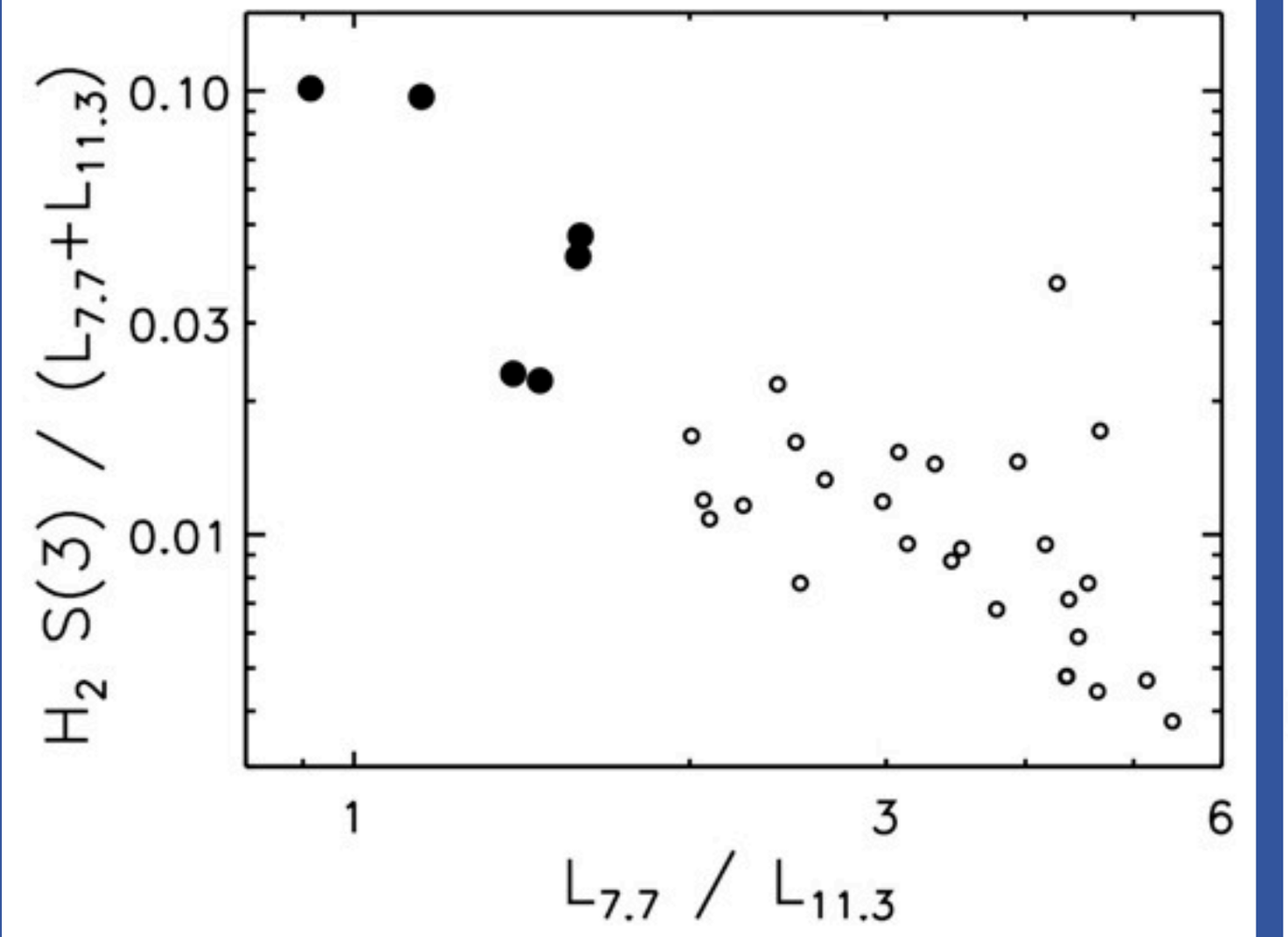
100
50
0
60
40
20
0

6
8
10
12
14

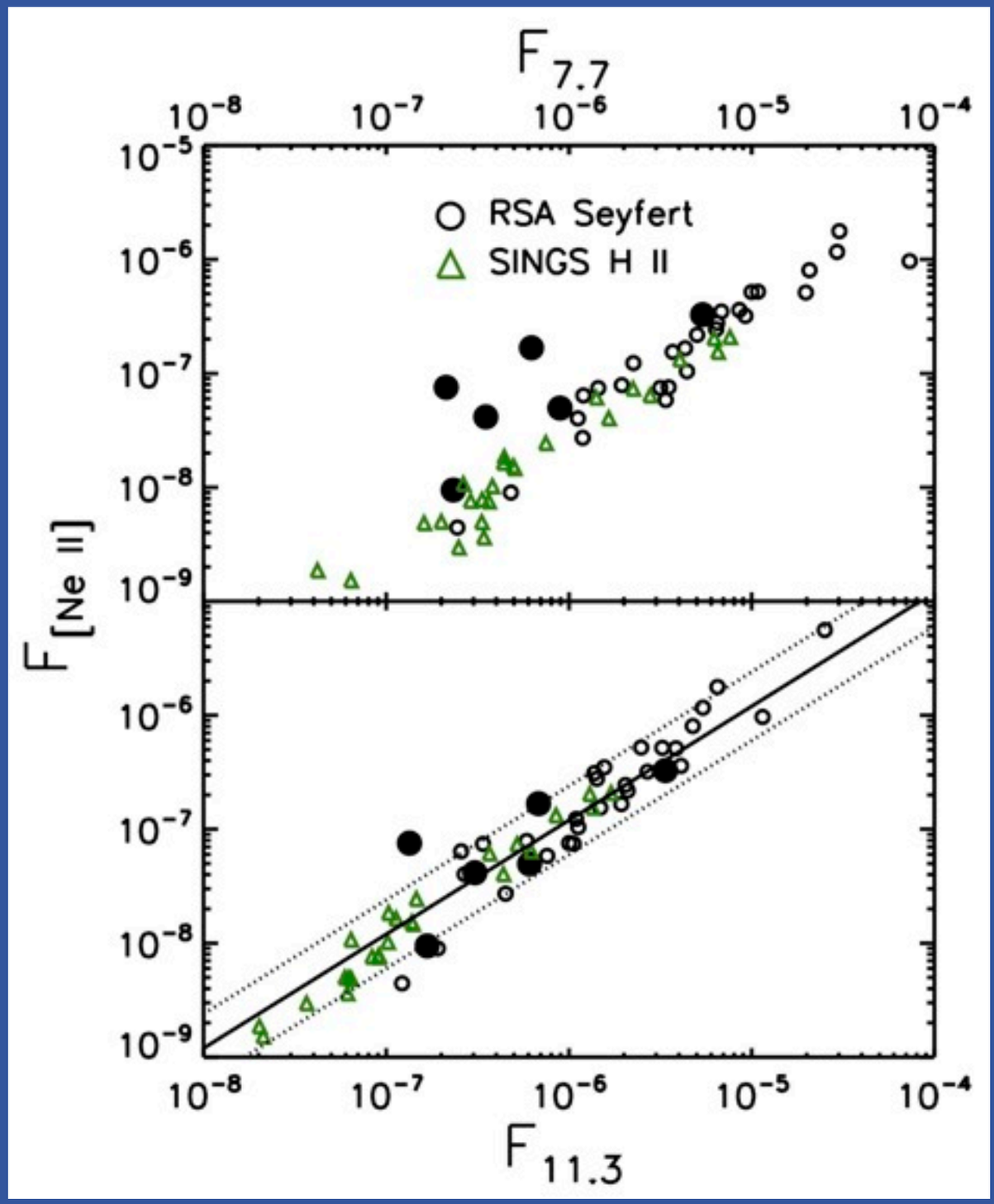
Observed Wavelength (μm)



evidence for shock processing



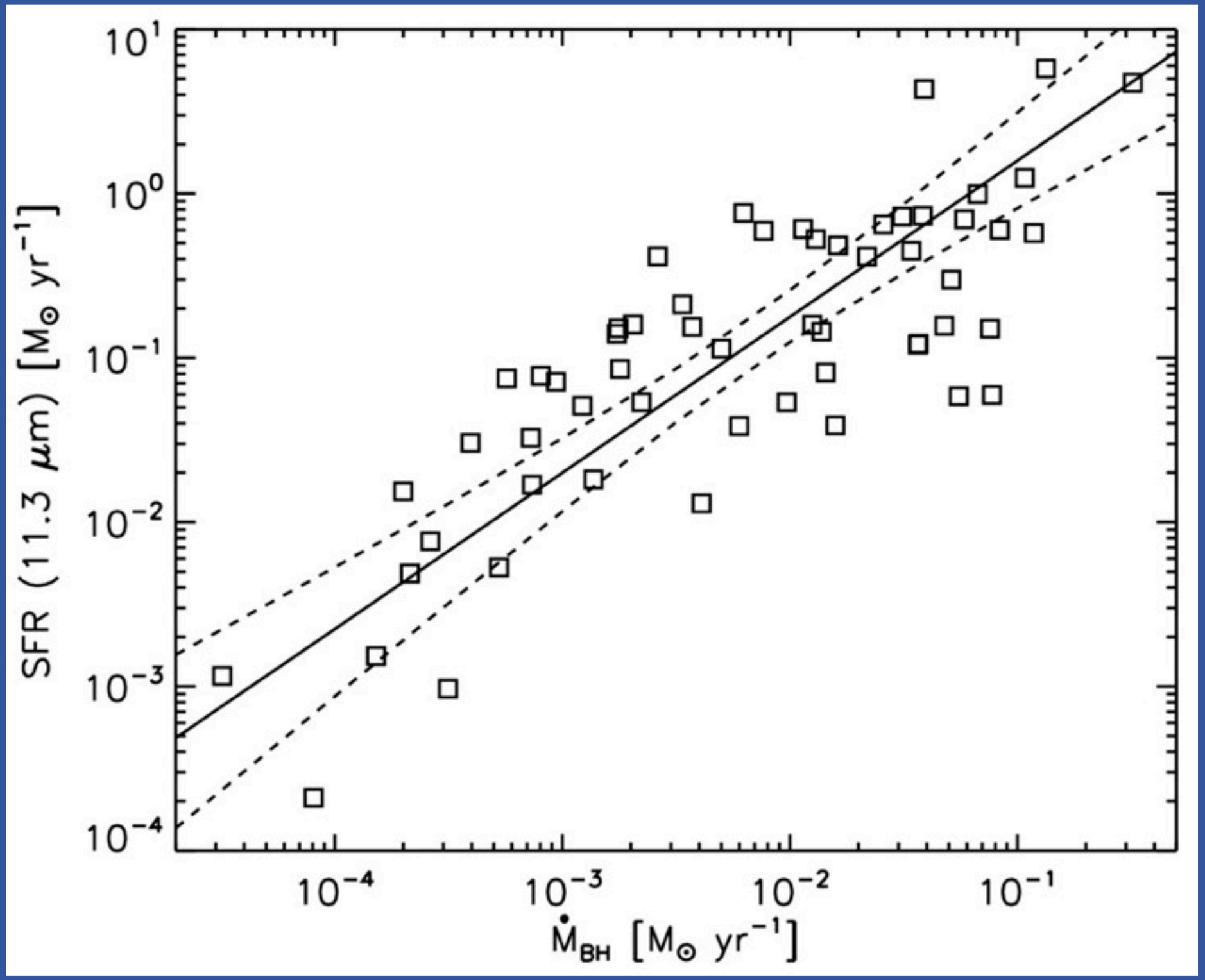
11.3 μm PAH feature remains a robust tracer of the SFR



Diamond-Stanic & Rieke 2010

see also Smith et al. 2007, Roussel et al. 2007, Ogle et al. 2007, O'Dowd et al. 2009, Guillard et al. 2010

Star Formation v. Black Hole Accretion

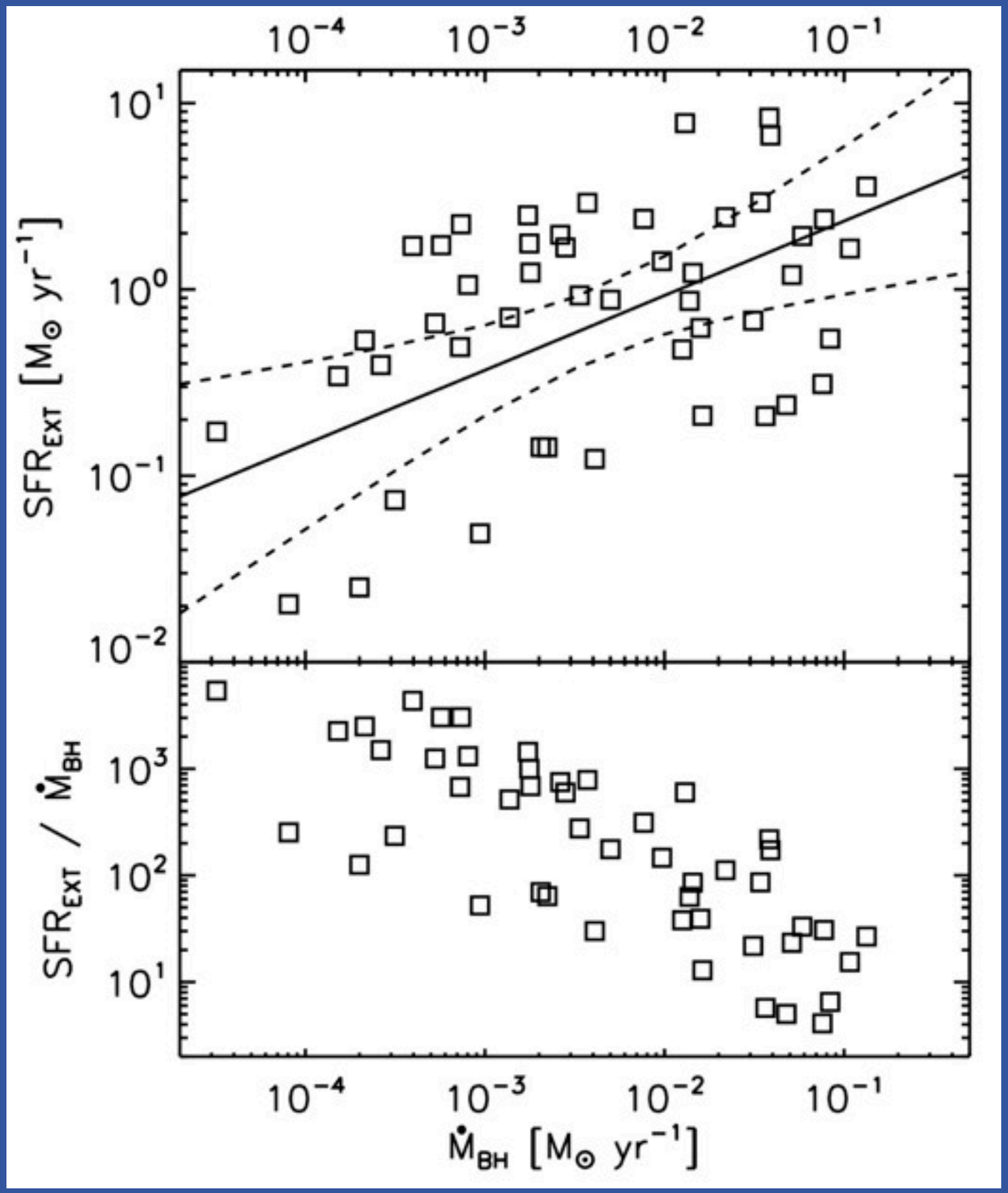


Black hole accretion strongly correlated with nuclear star formation

see also Lutz et al. 2008, Netzer et al. 2009, Shi et al. 2009 for PAH-based SFRs

Diamond-Stanic & Rieke 2011, arXiv:1106.3565

Star Formation v. Black Hole Accretion



Black hole accretion and extended star formation are poorly correlated

see also Satyapal et al. 2005,
Hao et al. 2005,
Sliverman et al. 2009,
Lutz et al. 2010,
Bonfield et al. 2011,
Mullaney et al. 2011

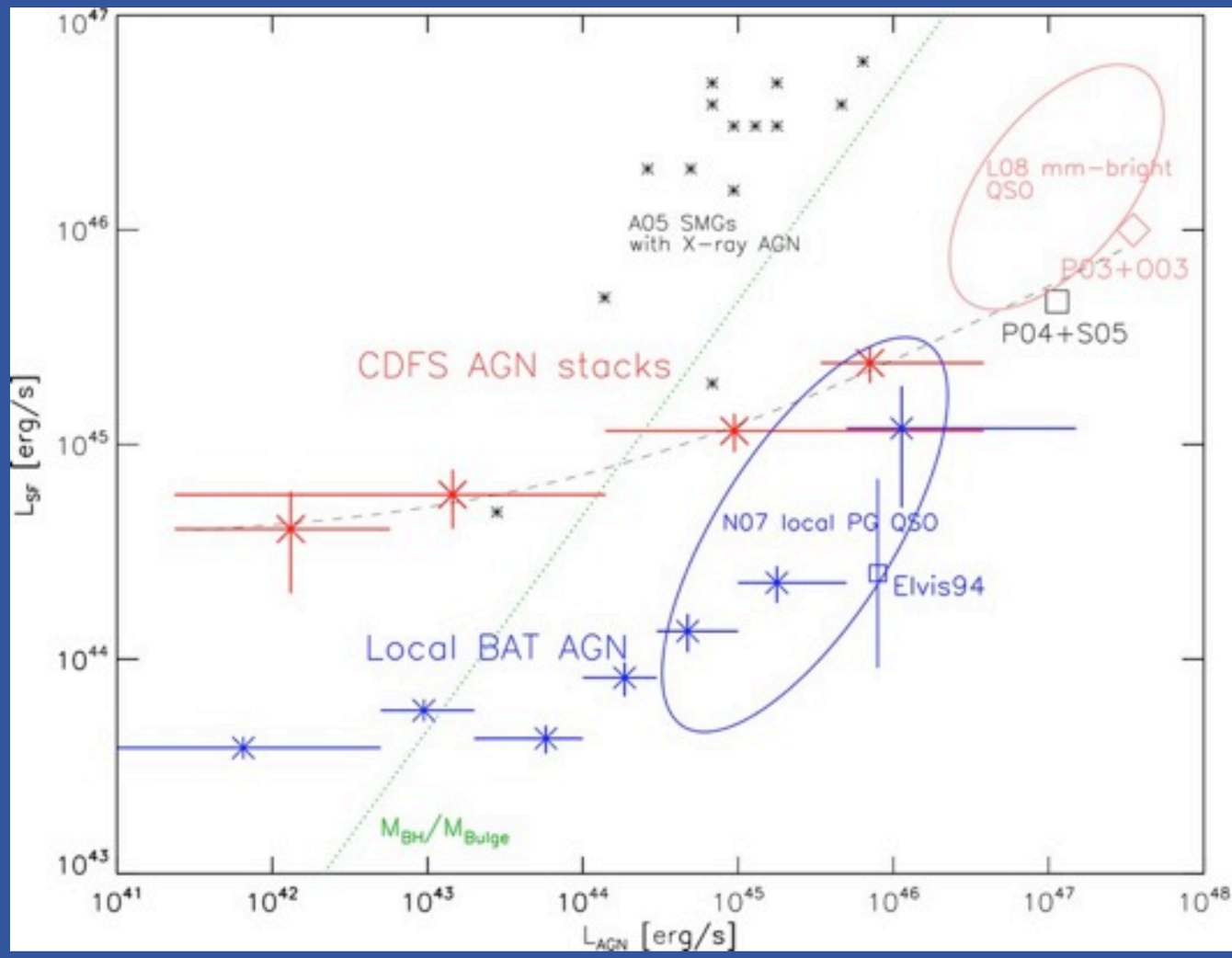
Diamond-Stanic & Rieke 2011, arXiv:1106.3565

Implications for SF-AGN connection

- black hole accretion related to nuclear, but not extended, star formation

- fueling dominated by secular processes (i.e., not mergers)

- 5%-10% AGN duty cycle can maintain black hole--bulge correlations



Lutz et al. 2010

Questions

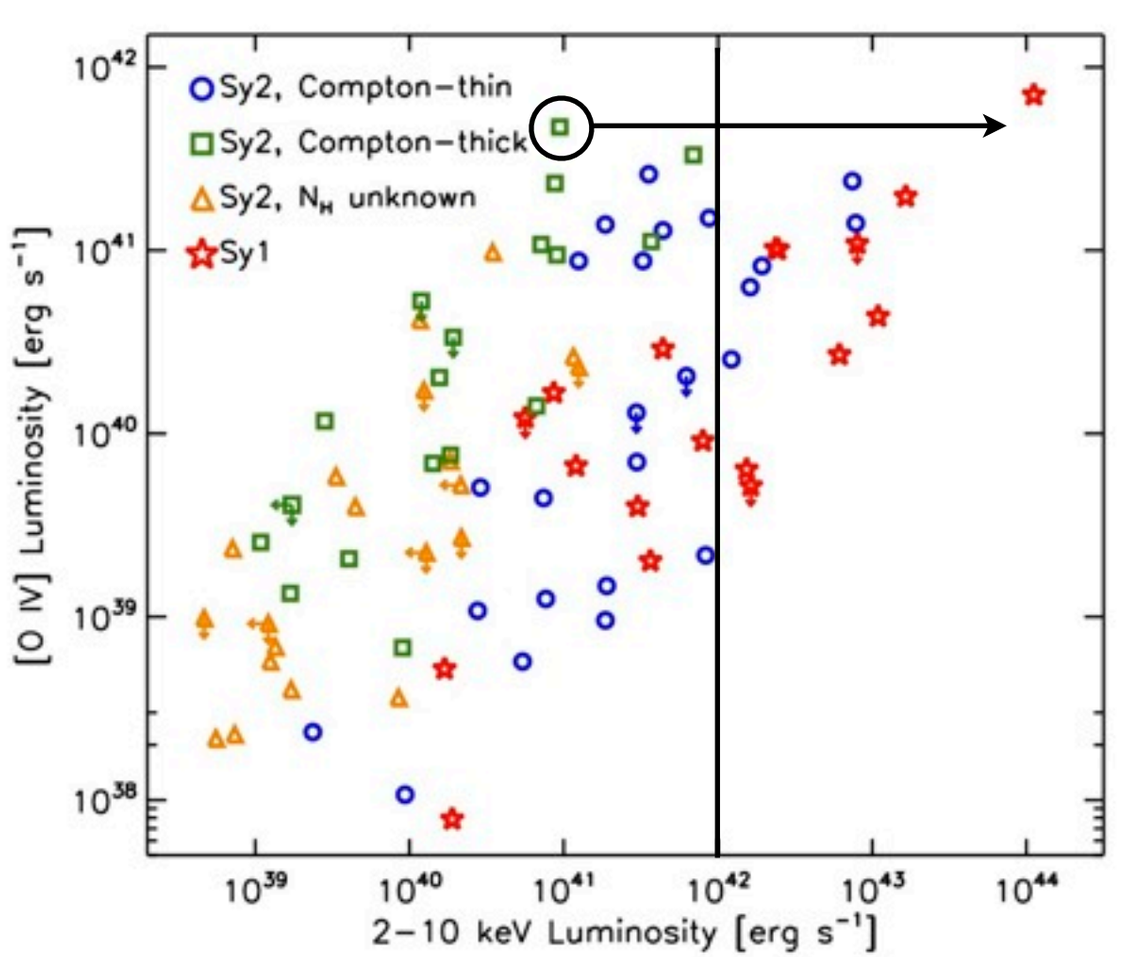
- When / where / how are black holes being fueled?

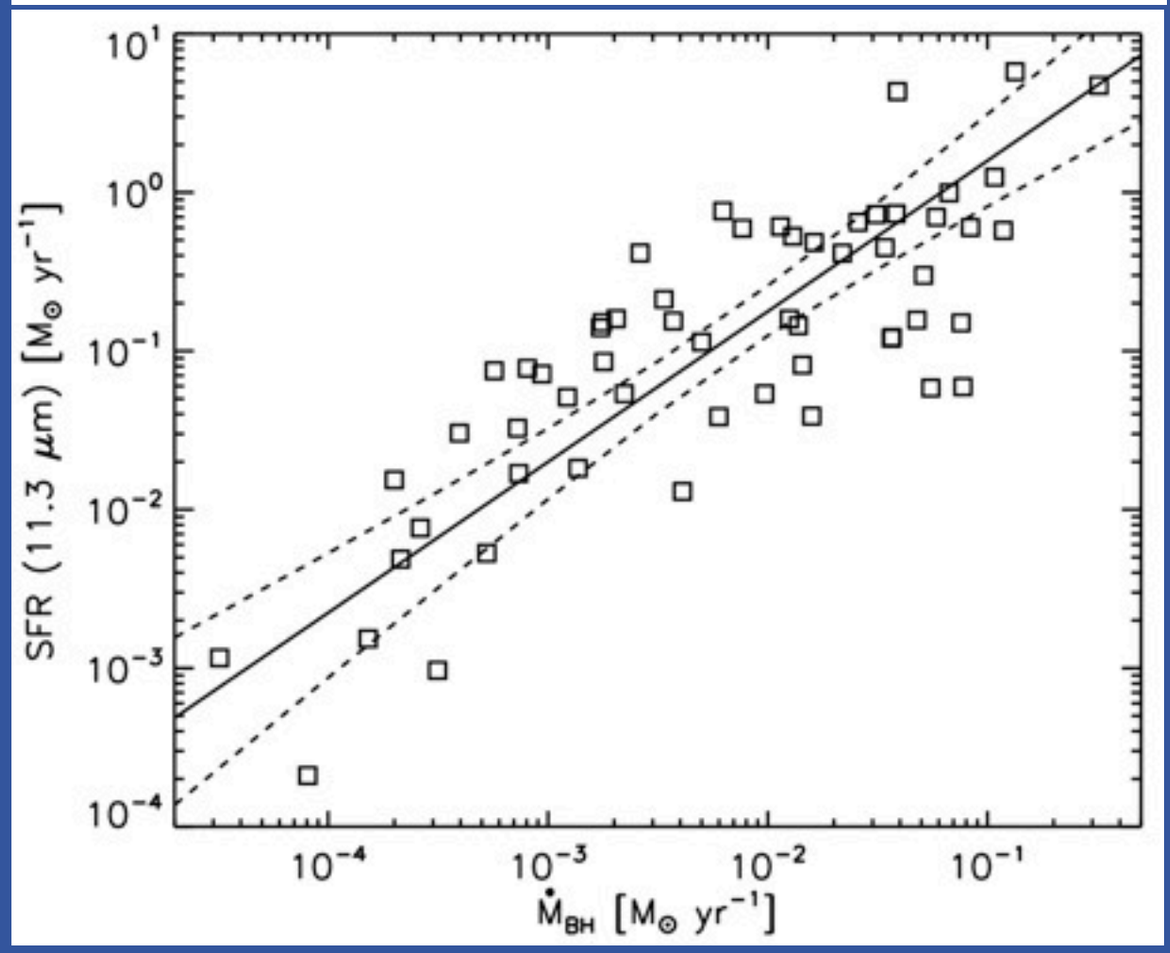
- How do galaxies and black holes co-evolve?

most AGNs are obscured

black hole growth related to nuclear star formation

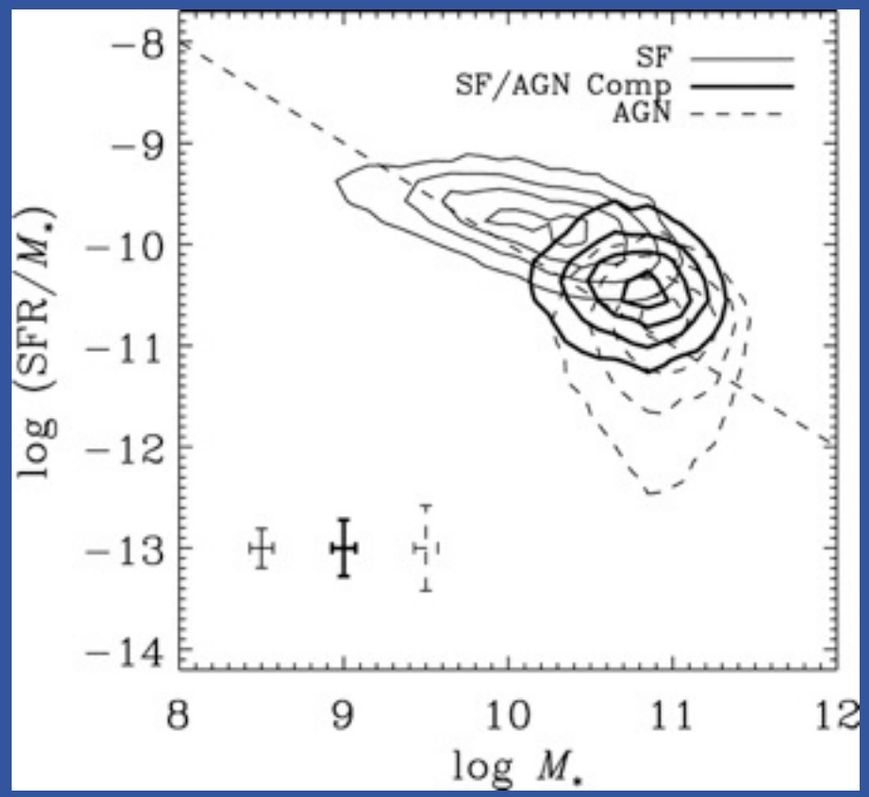
⟶ apparently unrelated to external processes on >kpc scales



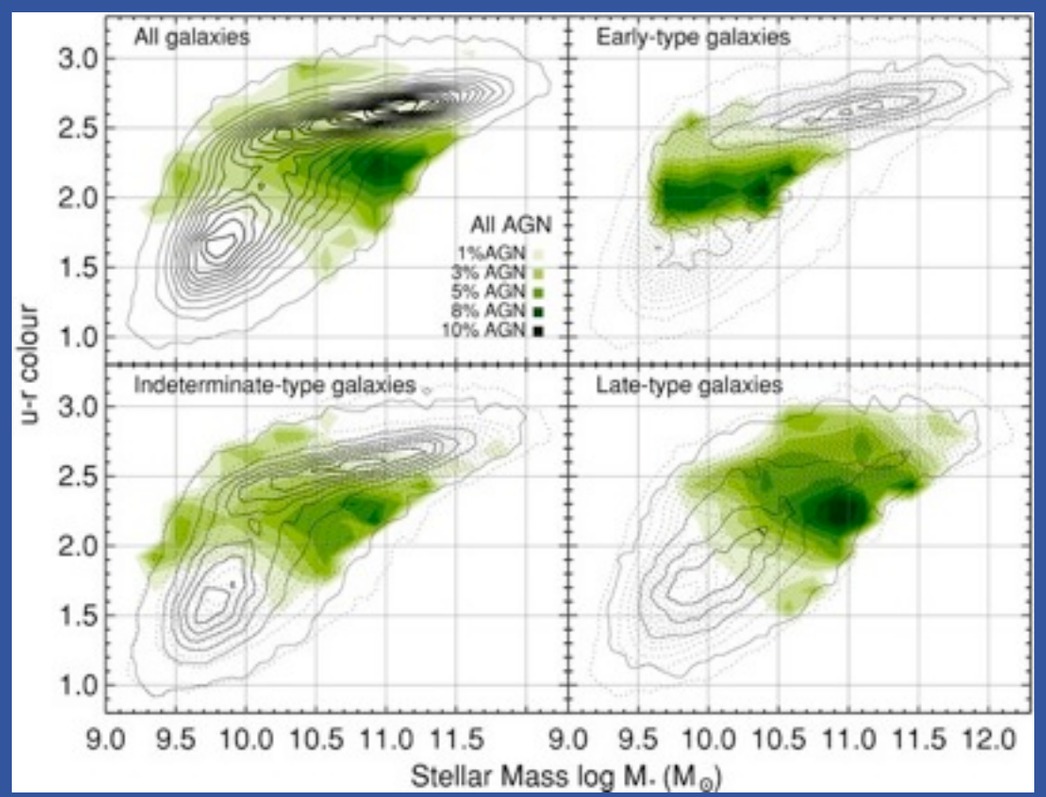


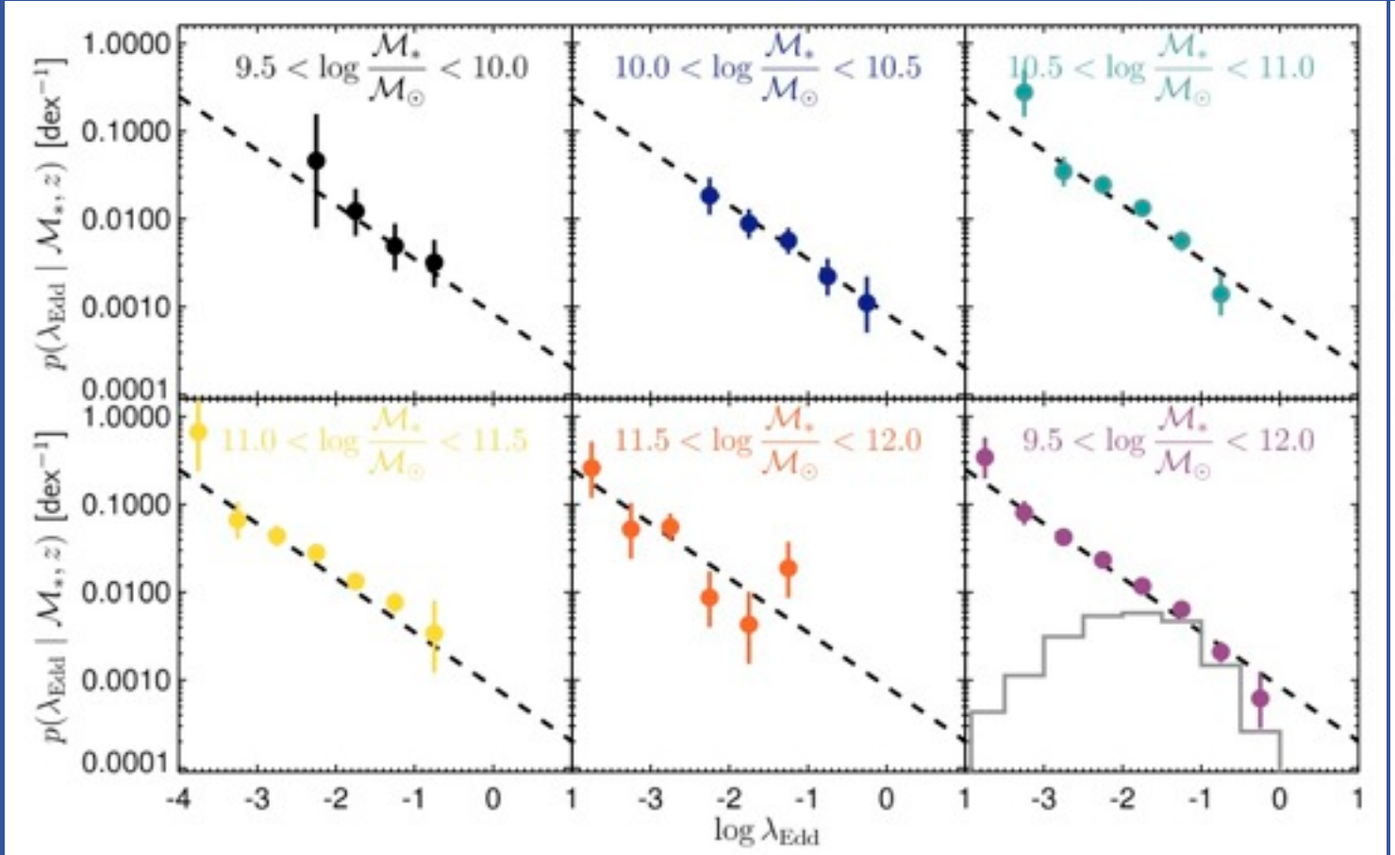
Is there a preferred scale for AGN activity?

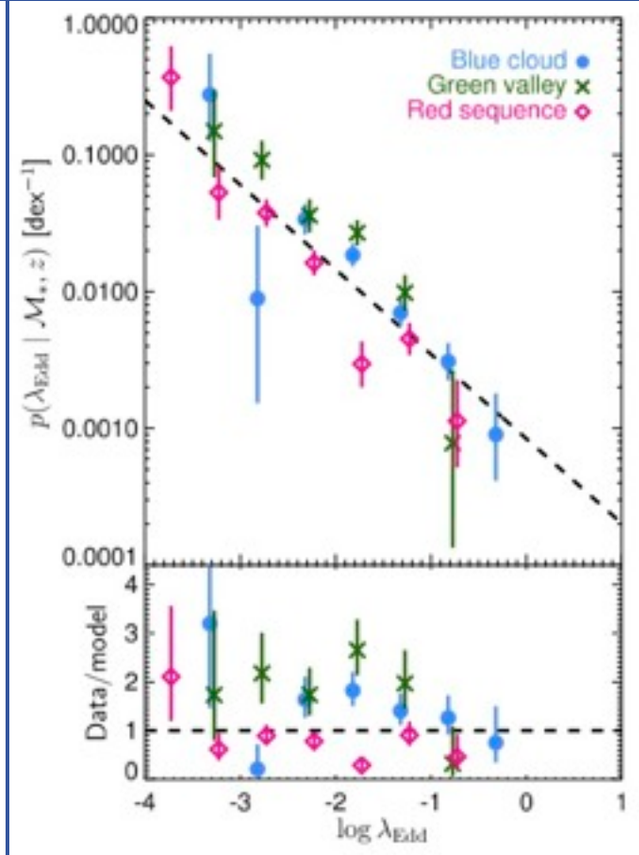
Salim et al. 2007



Schawinski et al. 2010







Aird et al. 2011, arXiv:1107.4368

AGN are everywhere but occur more often in gas-rich galaxies