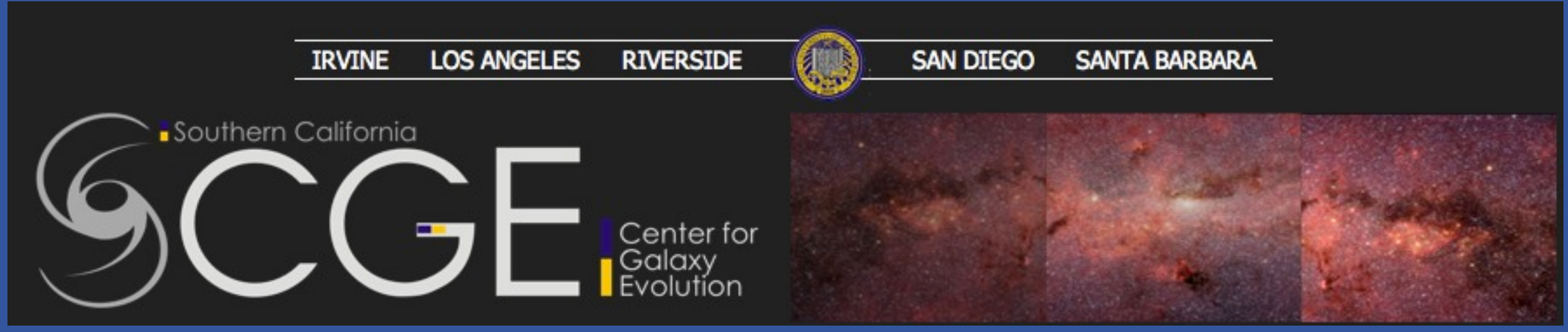

Probing Black Hole Growth and Star Formation in Active Galaxies

Aleks Diamond-Stanic
CGE Fellow, UC San Diego

IRVINE LOS ANGELES RIVERSIDE SAN DIEGO SANTA BARBARA

Southern California CGE Center for Galaxy Evolution

Probing Black Hole Growth and Star Formation in Active Galaxies

Aleks Diamond-Stanic
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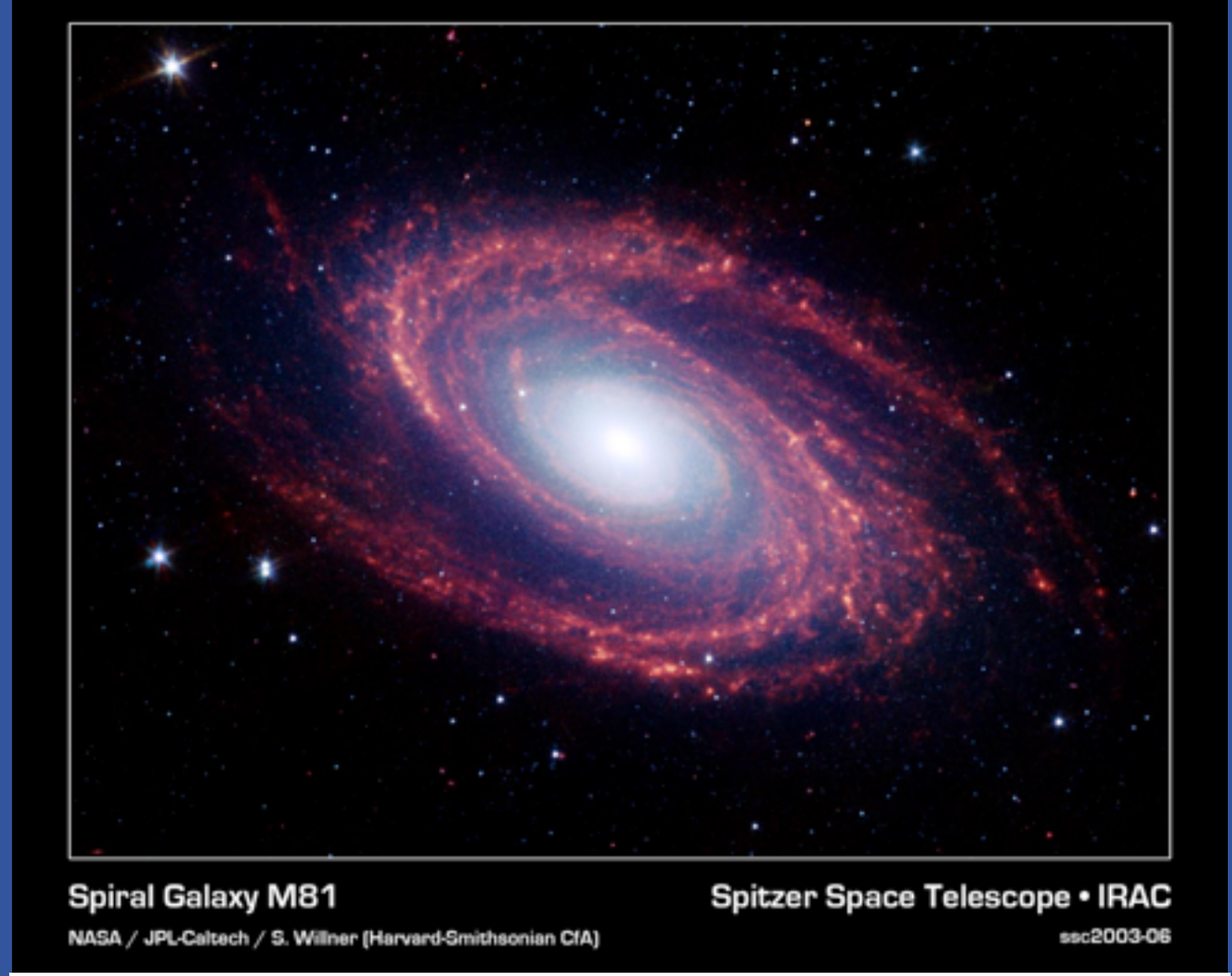
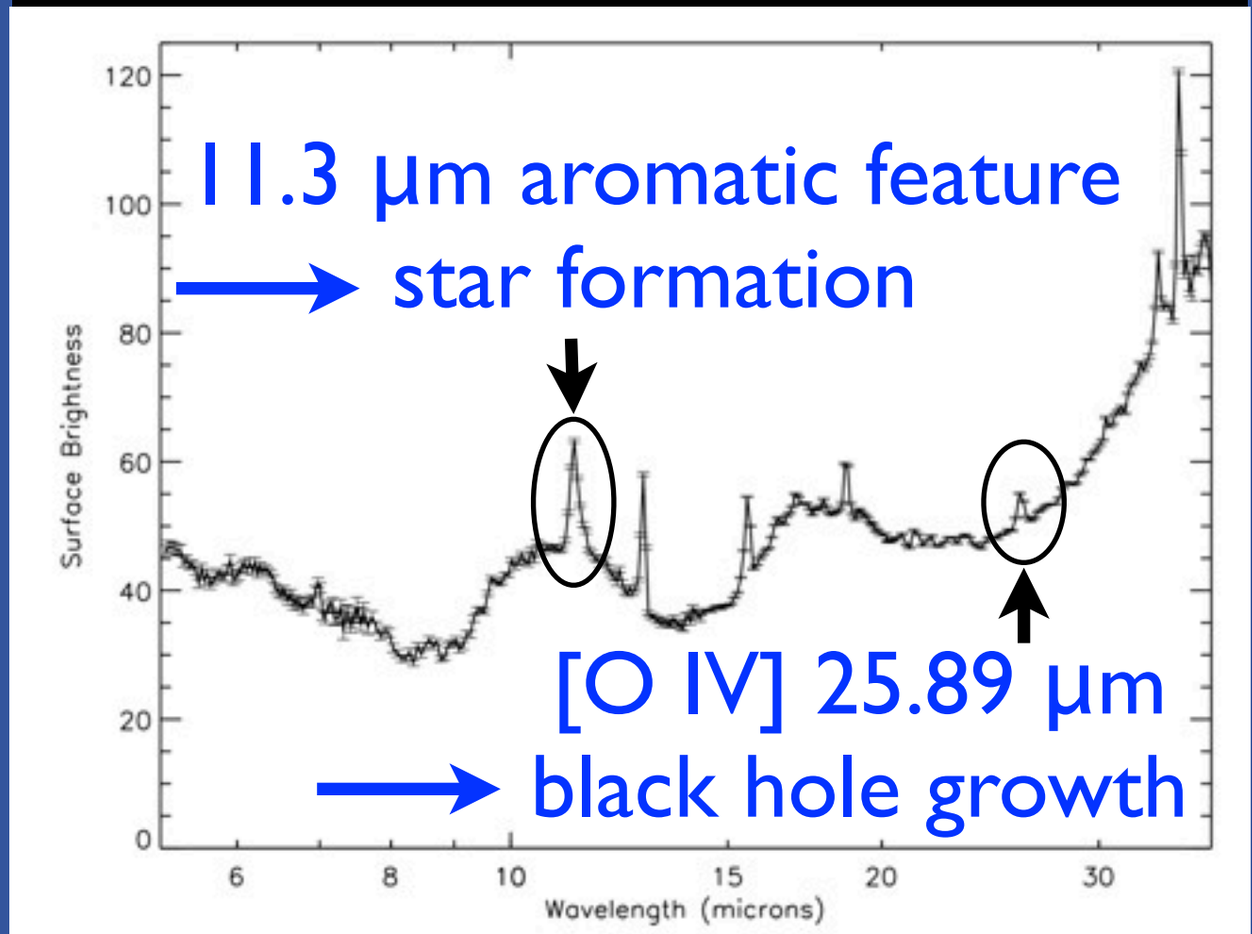
honorary CGE members
from the LA Galaxy

Questions

- When / where / how are black holes being fueled?
- How do galaxies and black holes co-evolve?





How obscured are typical AGNs?

obscuration towards the narrow-line region?

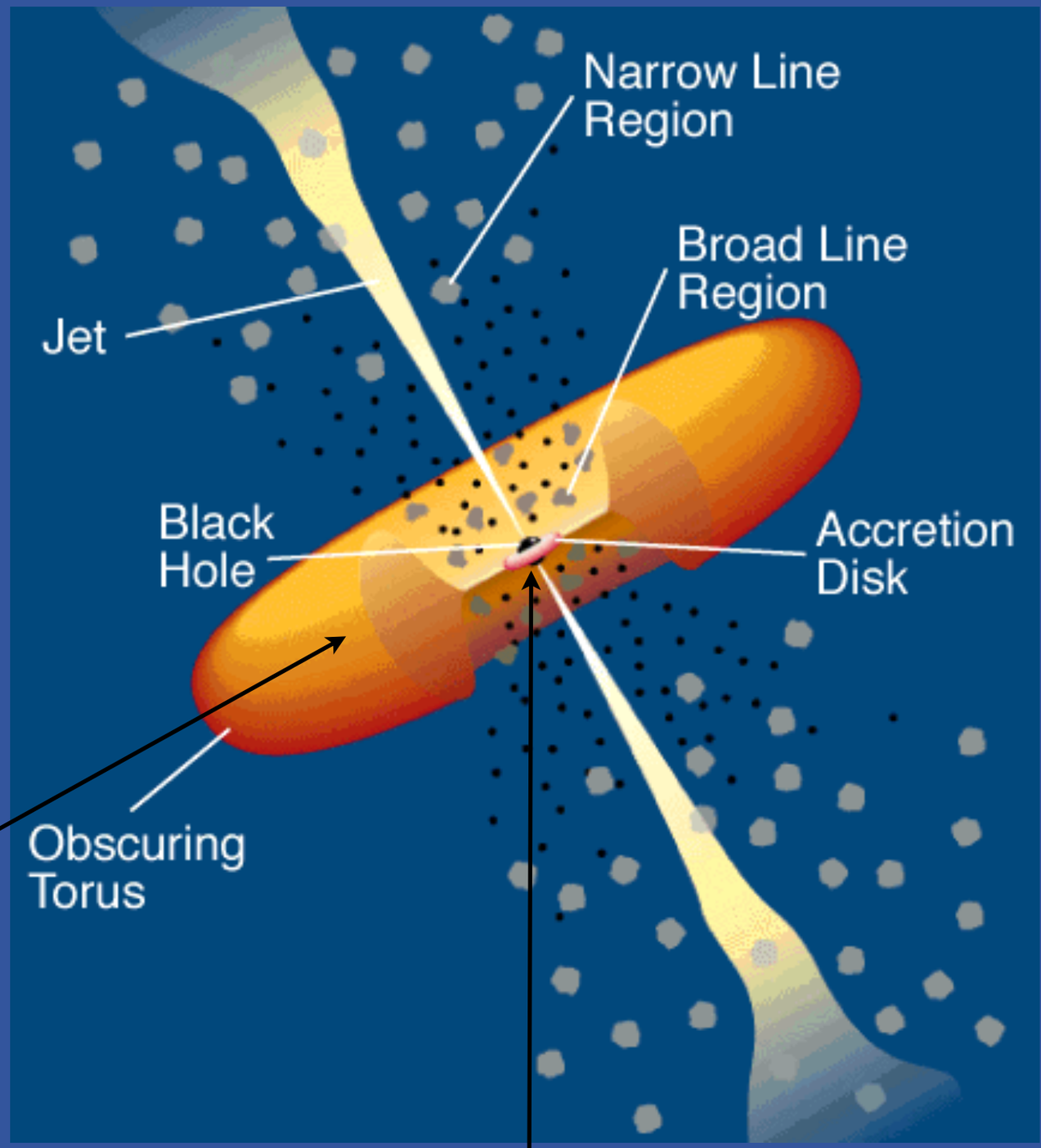
[O IV] 25.89 μm v. [O III] 5007 Å

how attenuated are hard X-rays?

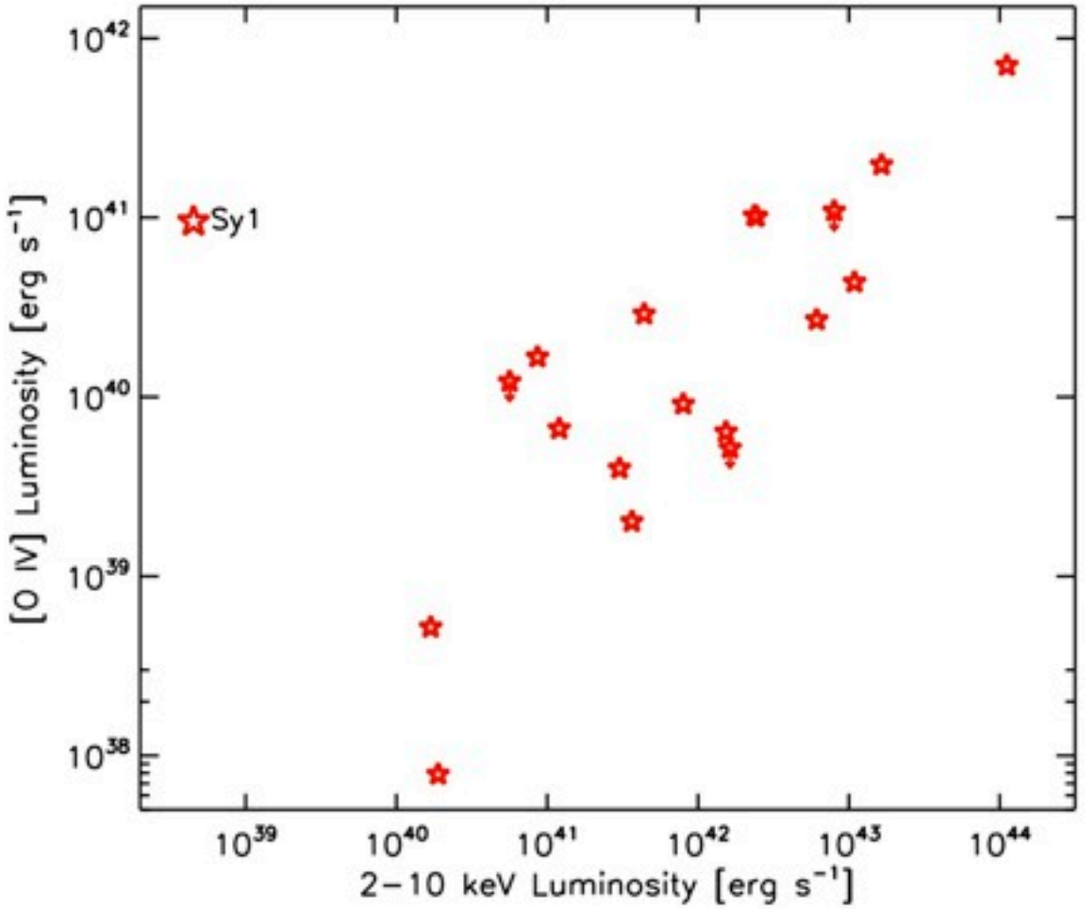
[O IV] 25.89 μm v. hard X-rays

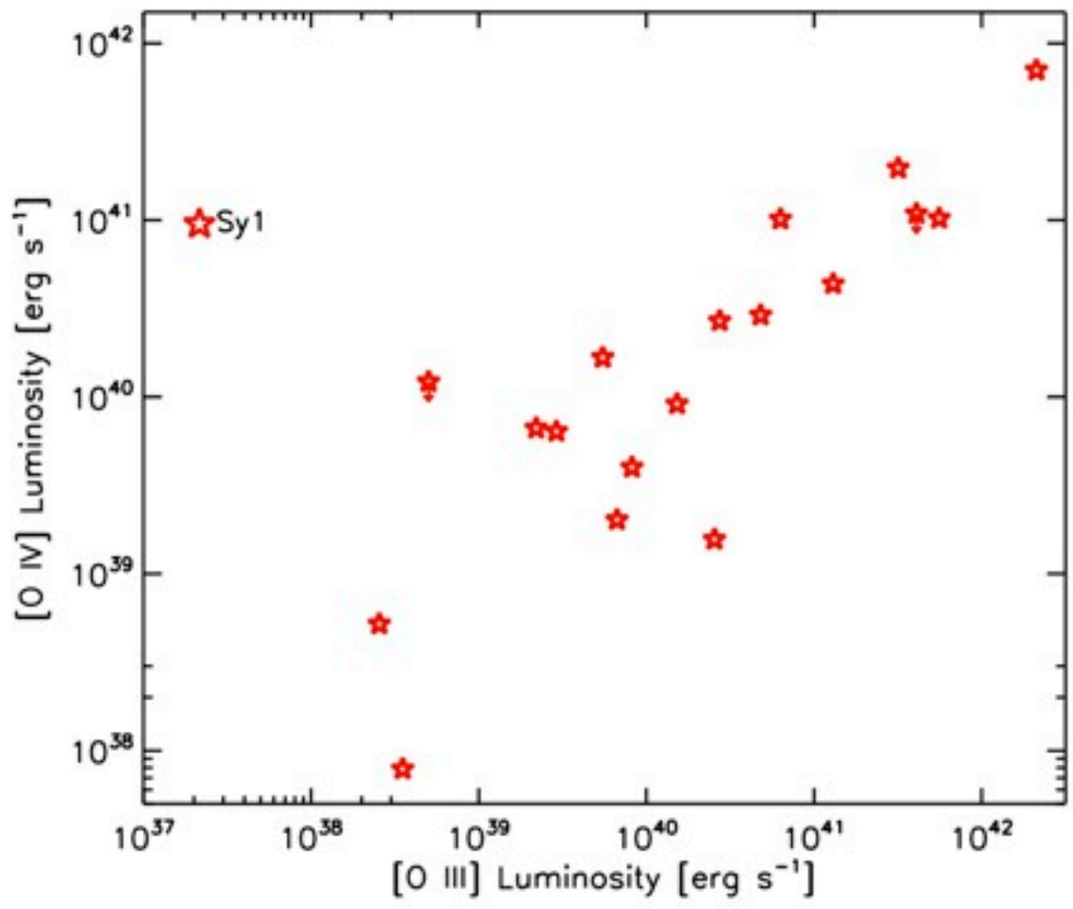
Seyfert 2 = obscured

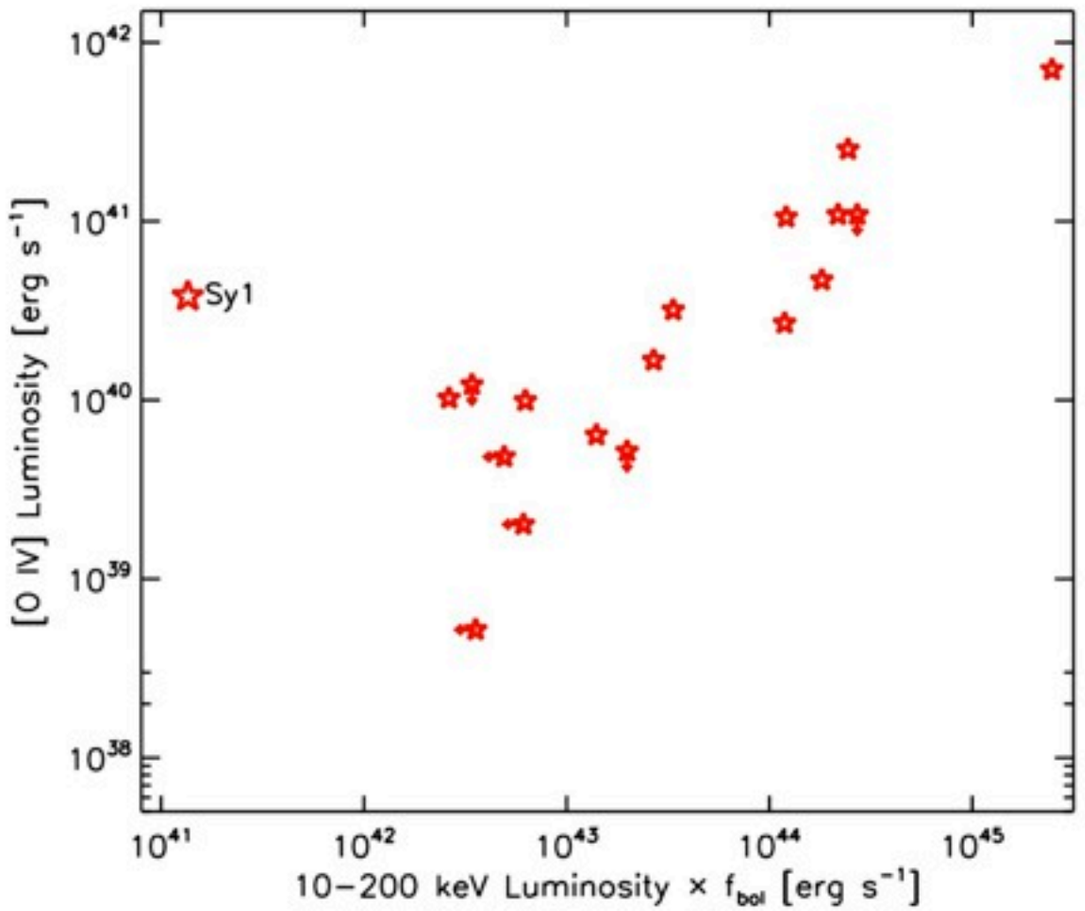
Urry & Padovani 1995



Seyfert 1 = unobscured







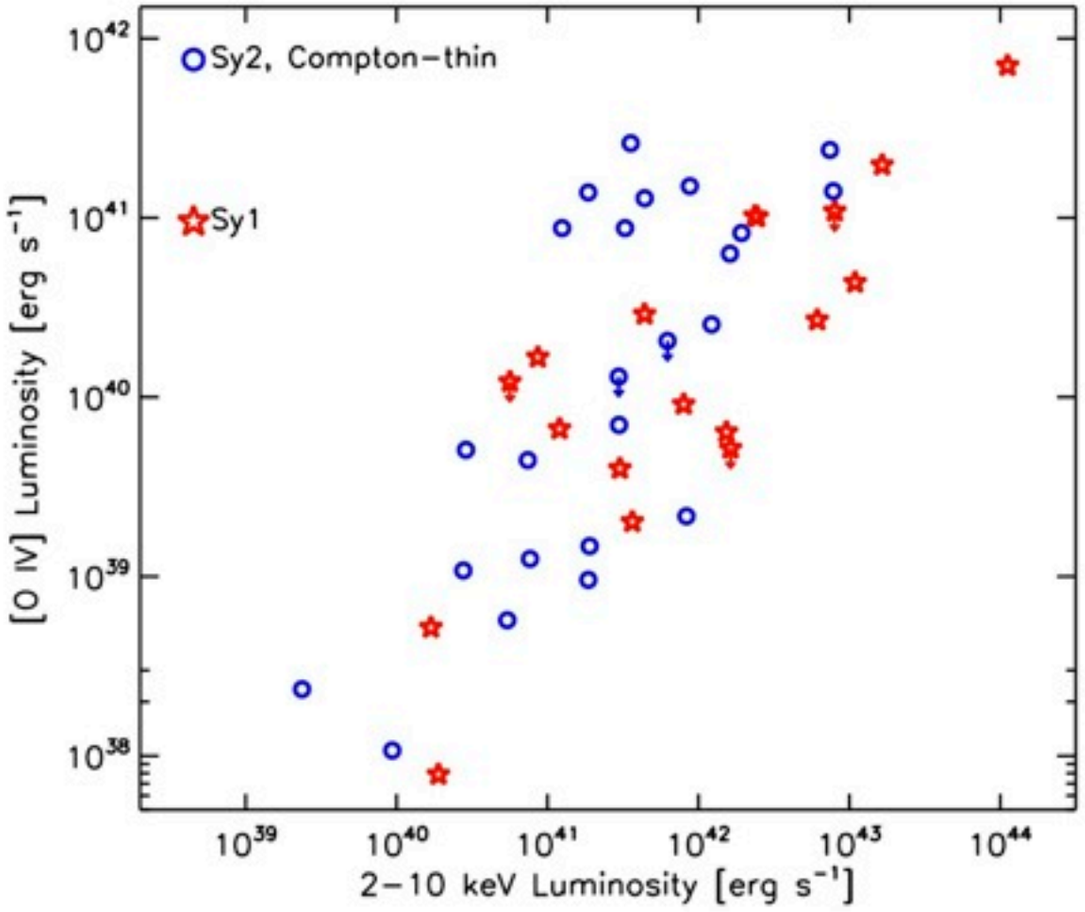
[O IV] v. hard X-rays, [O III]

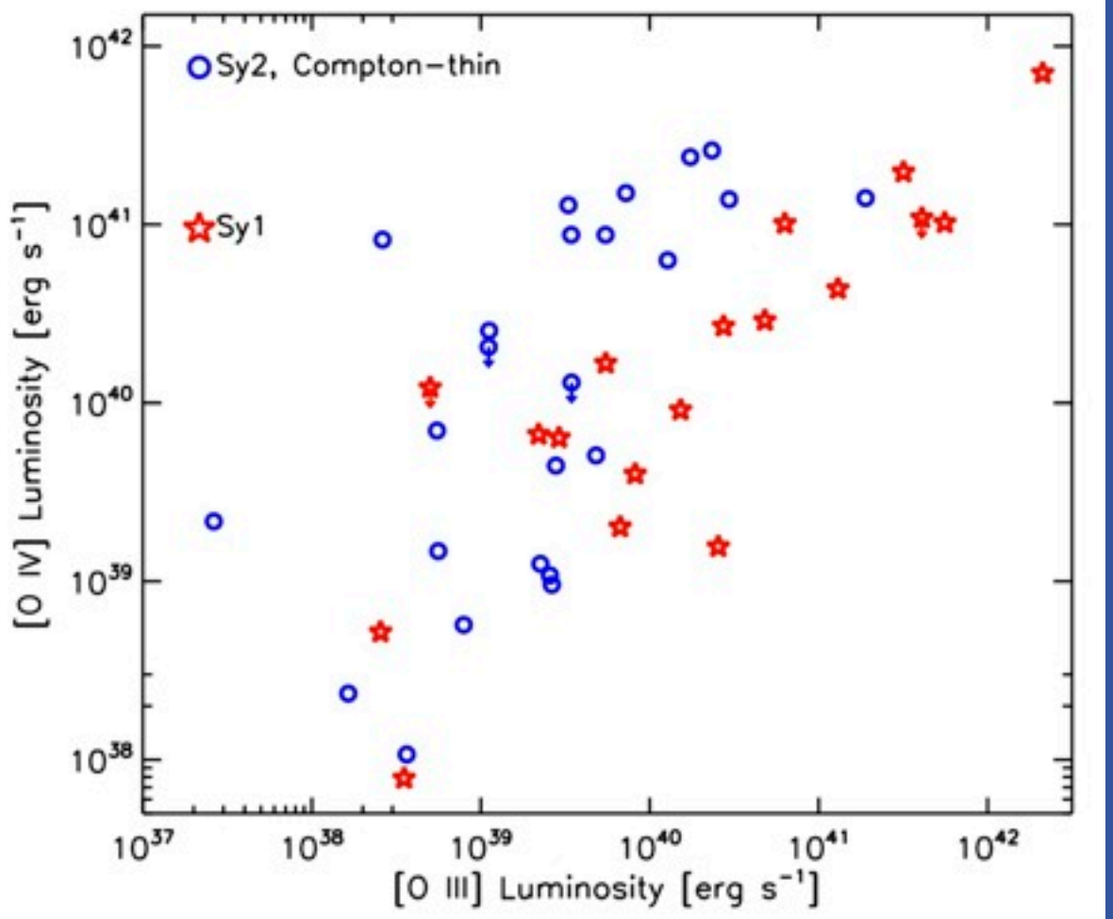
Diamond-Stanic, Rieke, & Rigby 2009

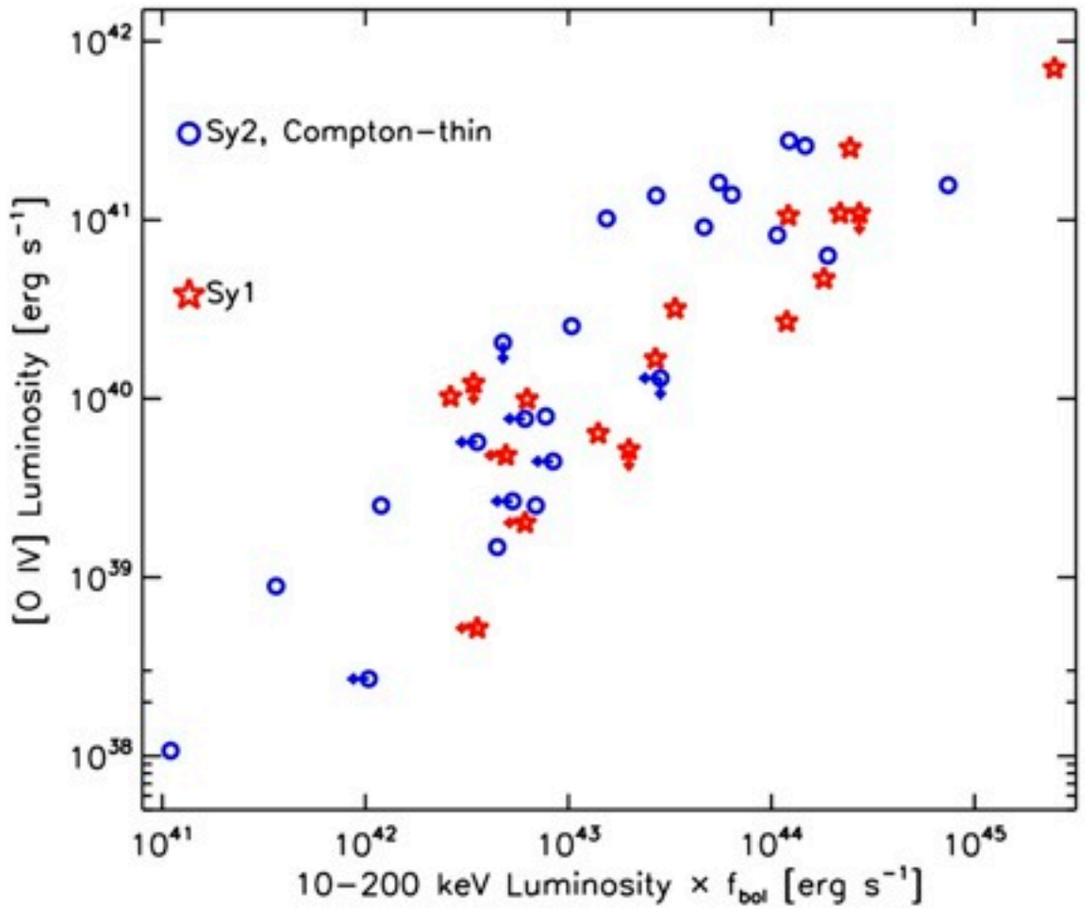
Rigby, Diamond-Stanic, & Aniano 2009

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





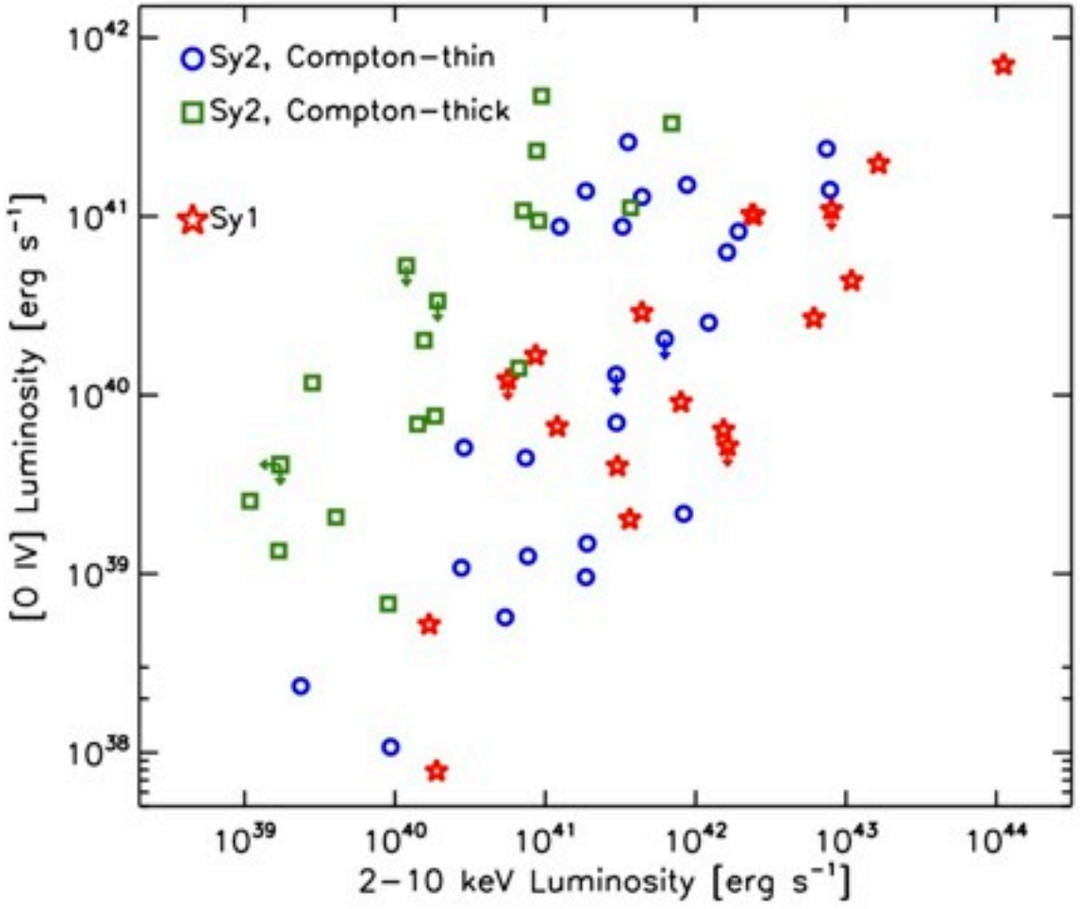


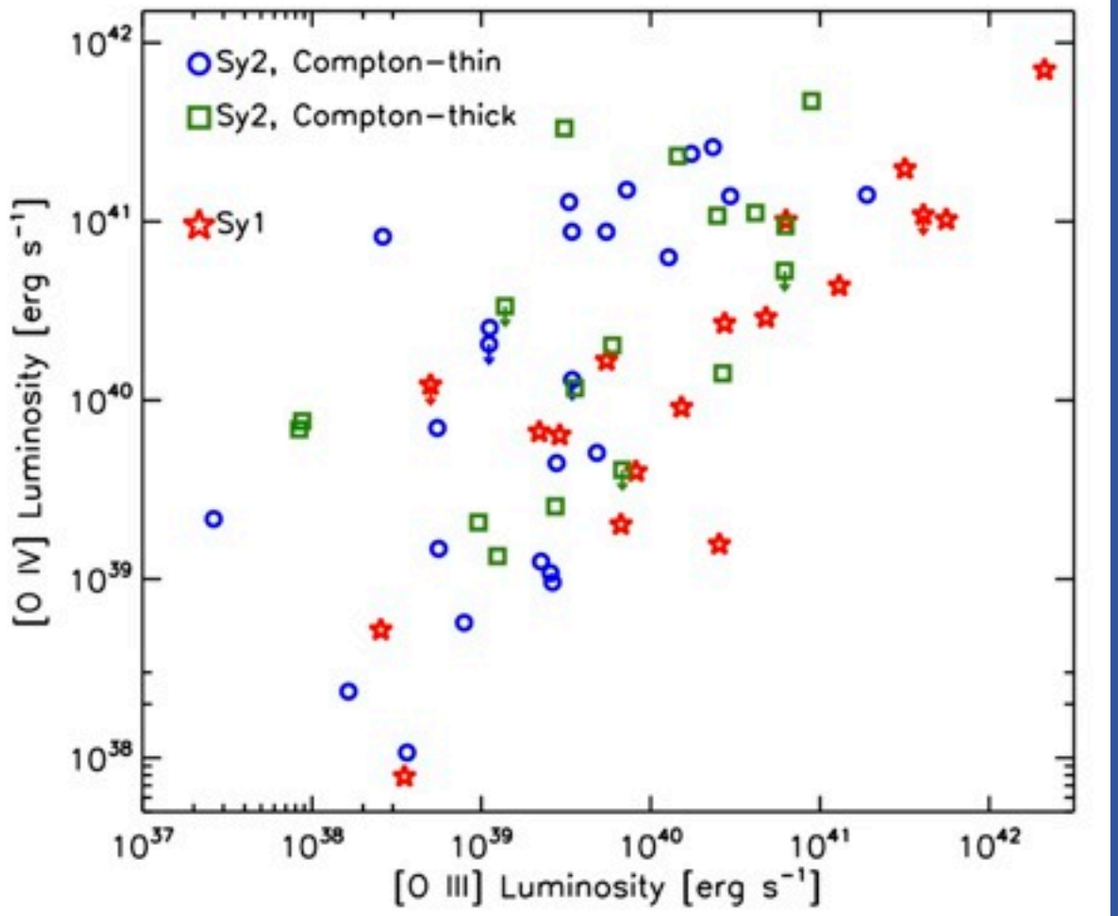
Sy1: unobscured

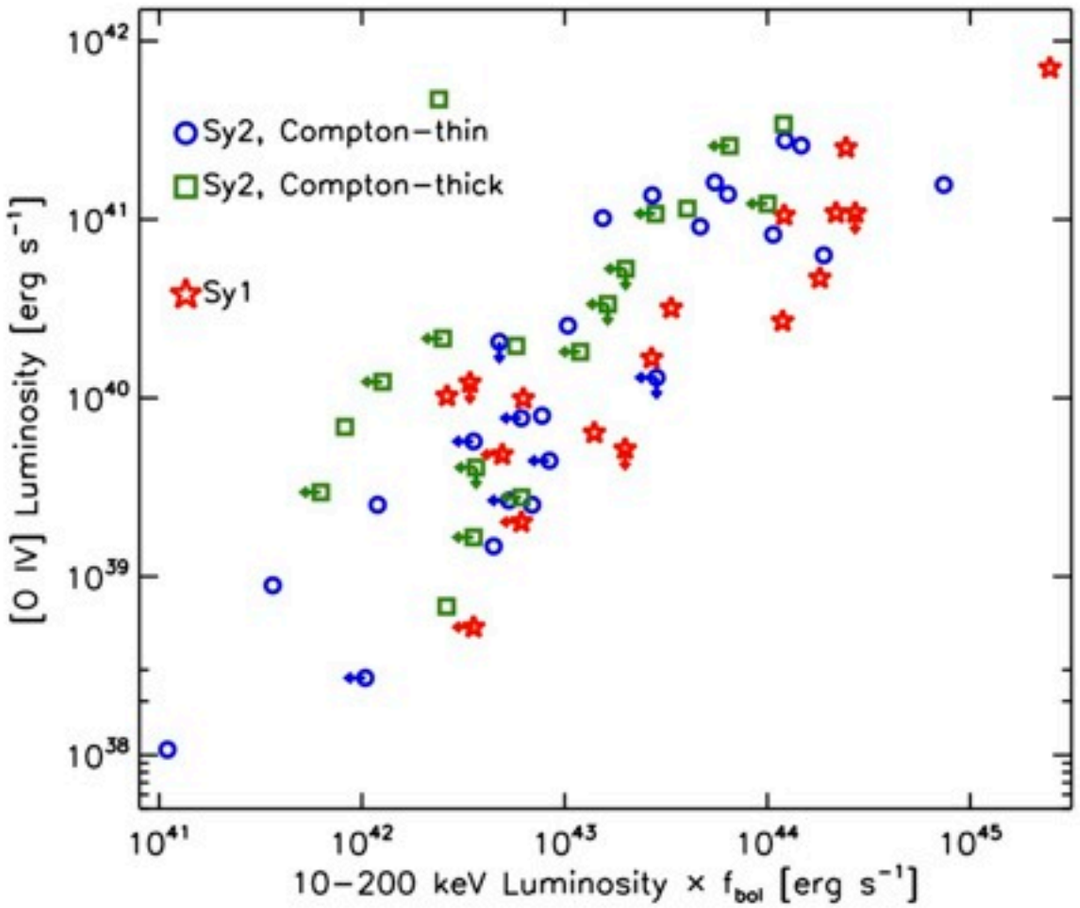
Sy2: obscured

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

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







Sy1: unobscured

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

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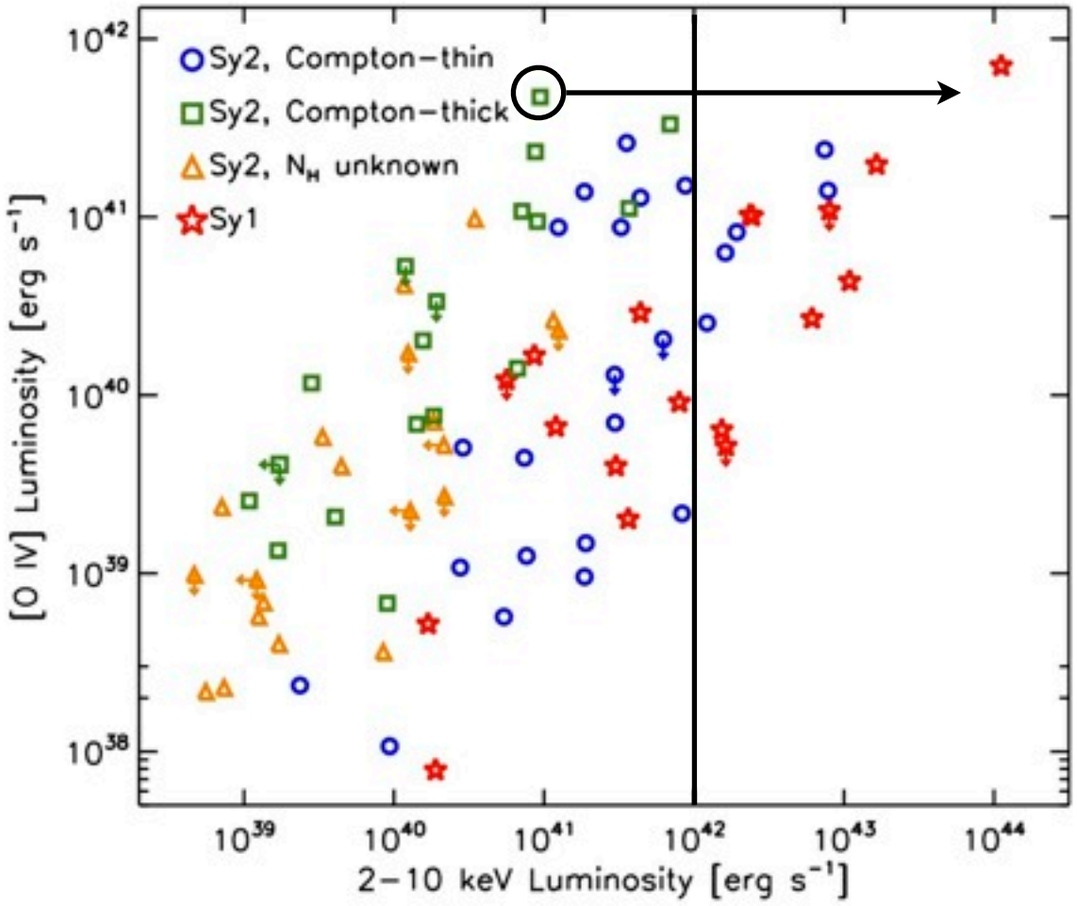
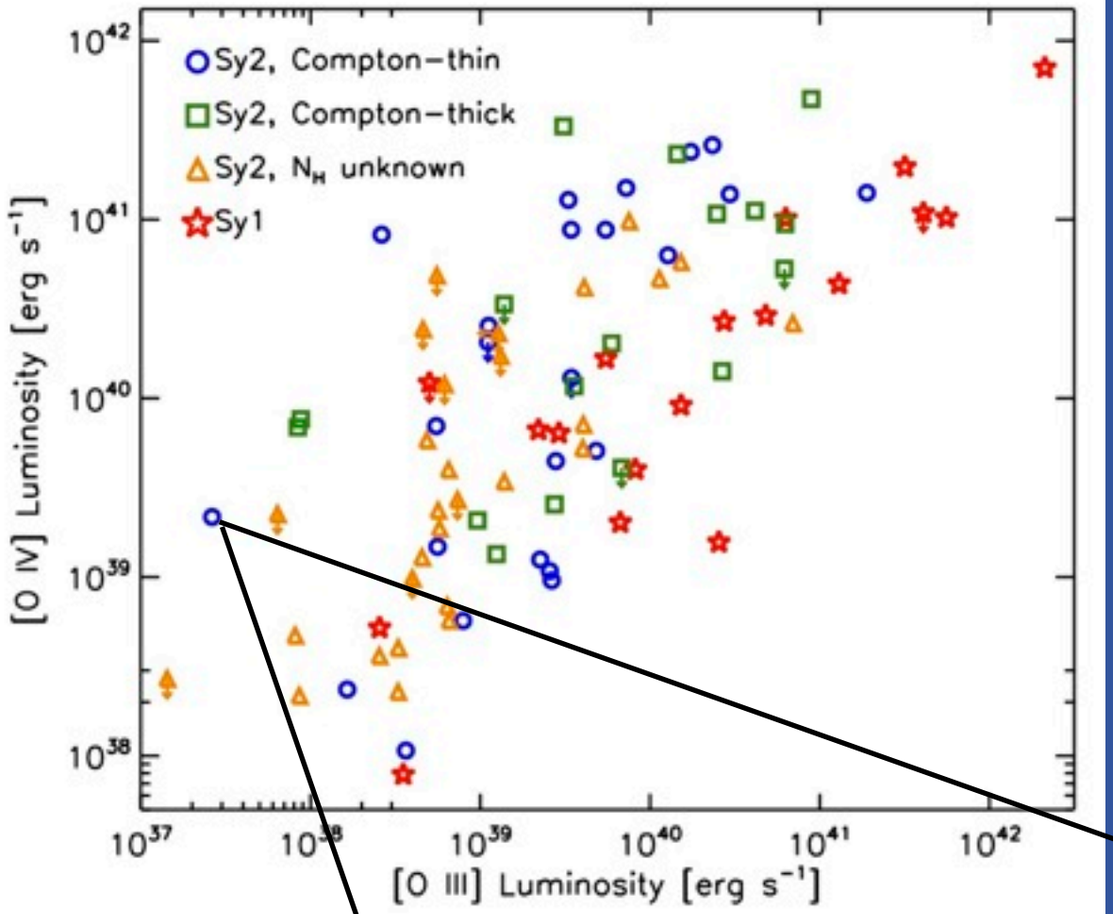
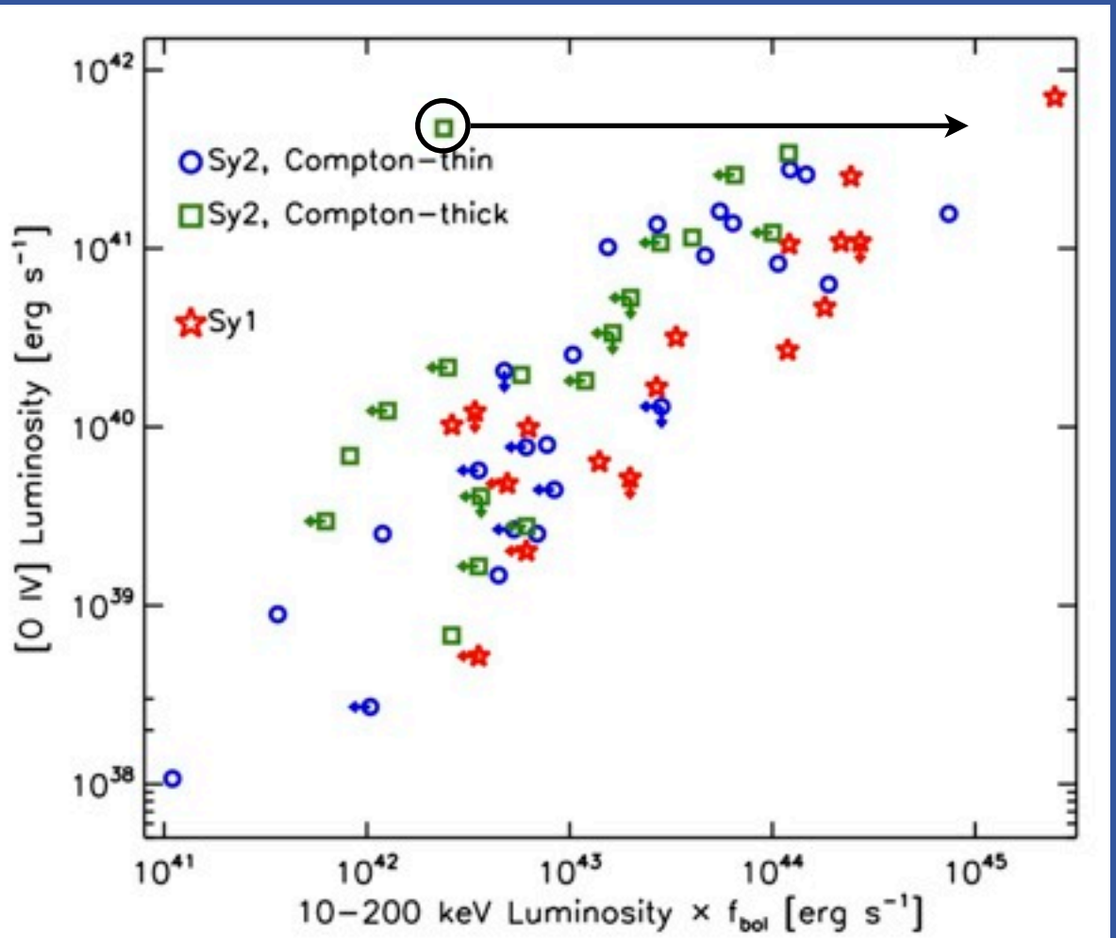






Diamond-Stanic, Rieke, & Rigby 2009

Rigby, Diamond-Stanic, & Aniano 2009

LAGN results

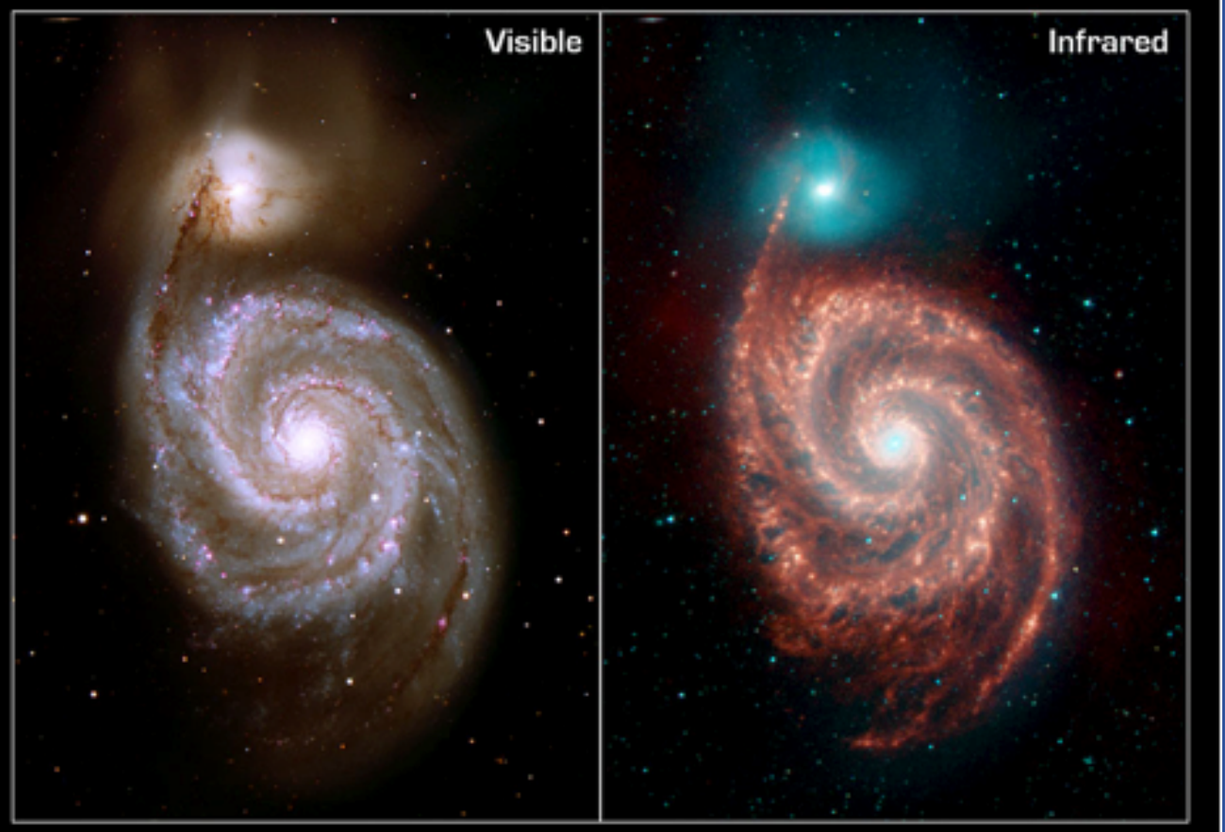
- [O IV] is a useful intrinsic luminosity indicator
  - Sy1, Sy2 luminosity distributions indistinguishable
- 2-10 keV X-rays biased for obscured sources
  - luminosity-dependent obscured fraction?
- [O III] is not isotropic
  - Sy2s systematically fainter, A_V=1-5 host galaxy extinction
- Even 10-200 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_{IR}, L_{UV}

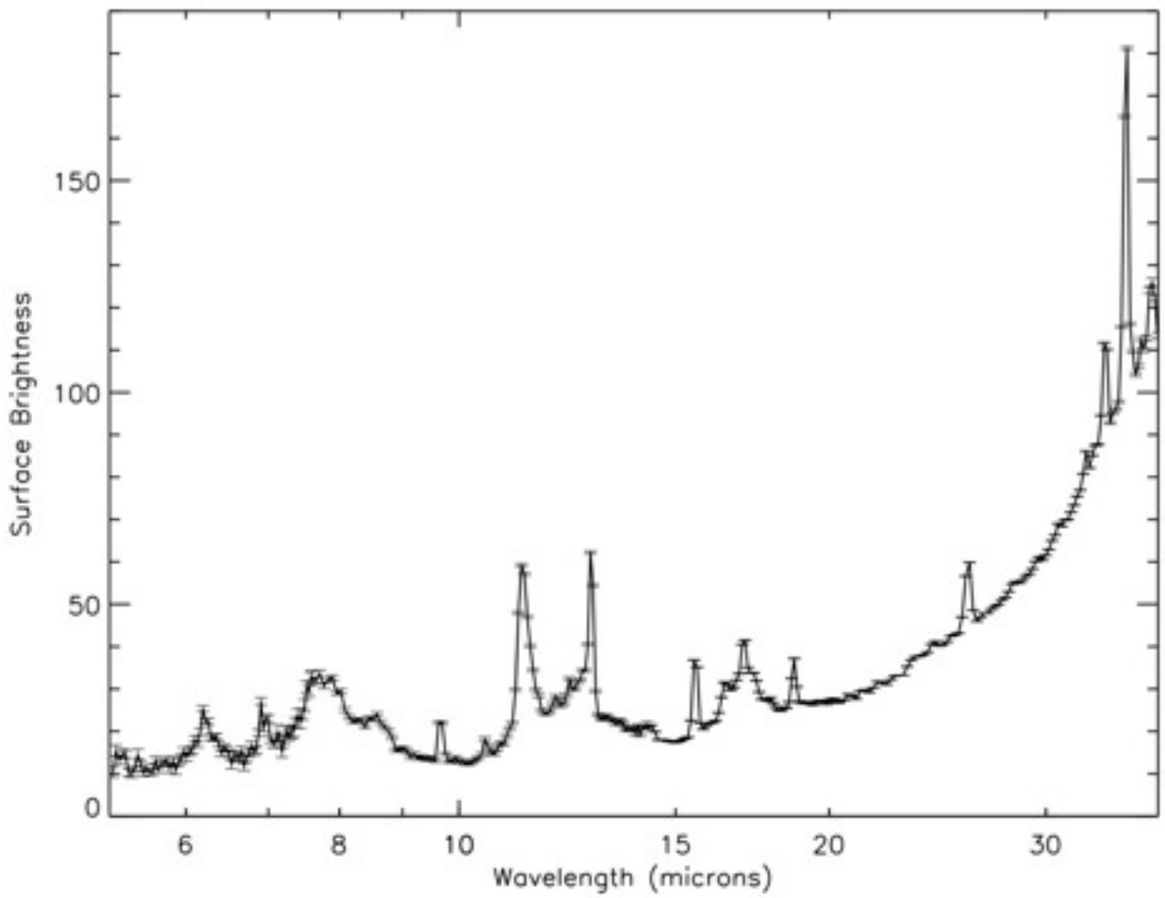
- The mid-infrared PAH features offer a solution
  - trace UV radiation field in photo-dissociation regions

- 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

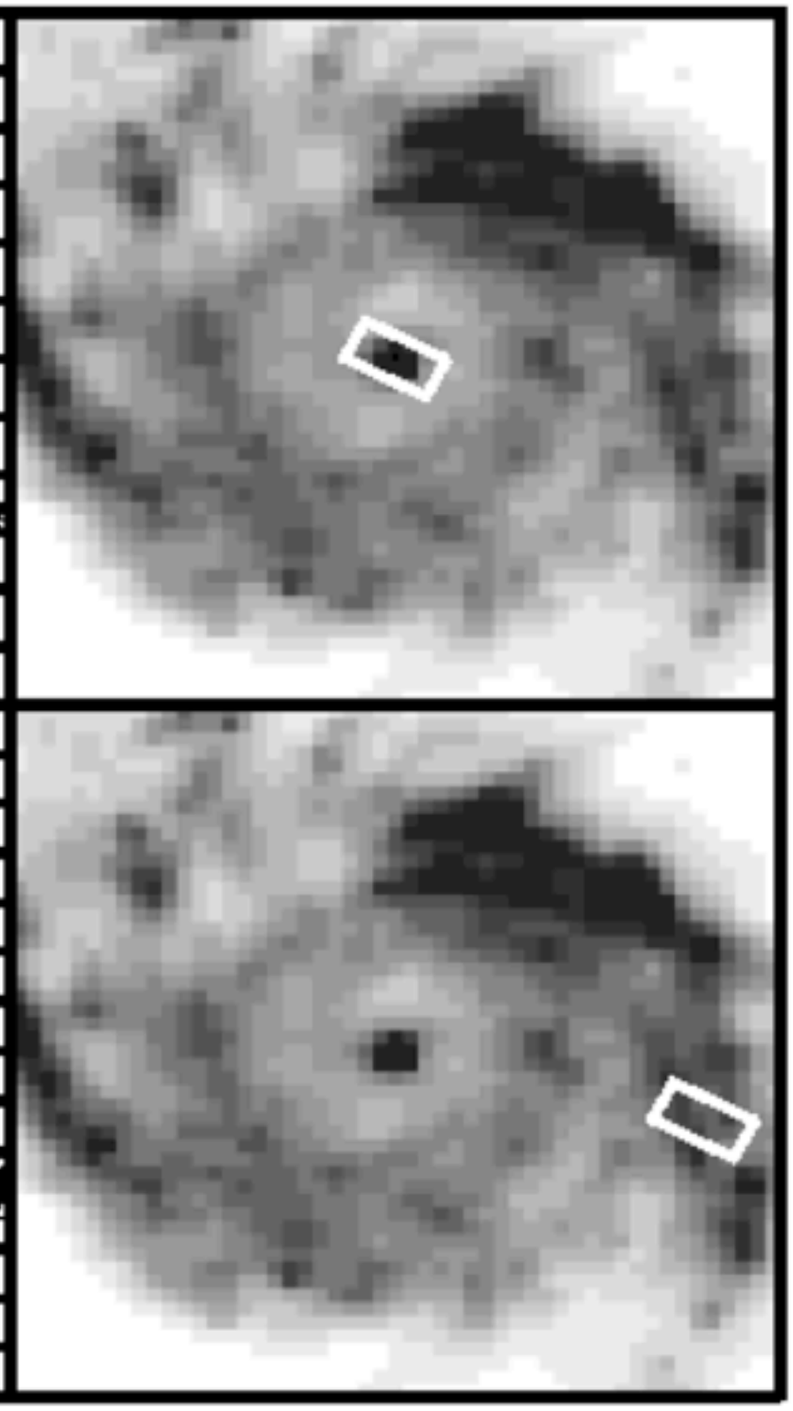
NGC5194

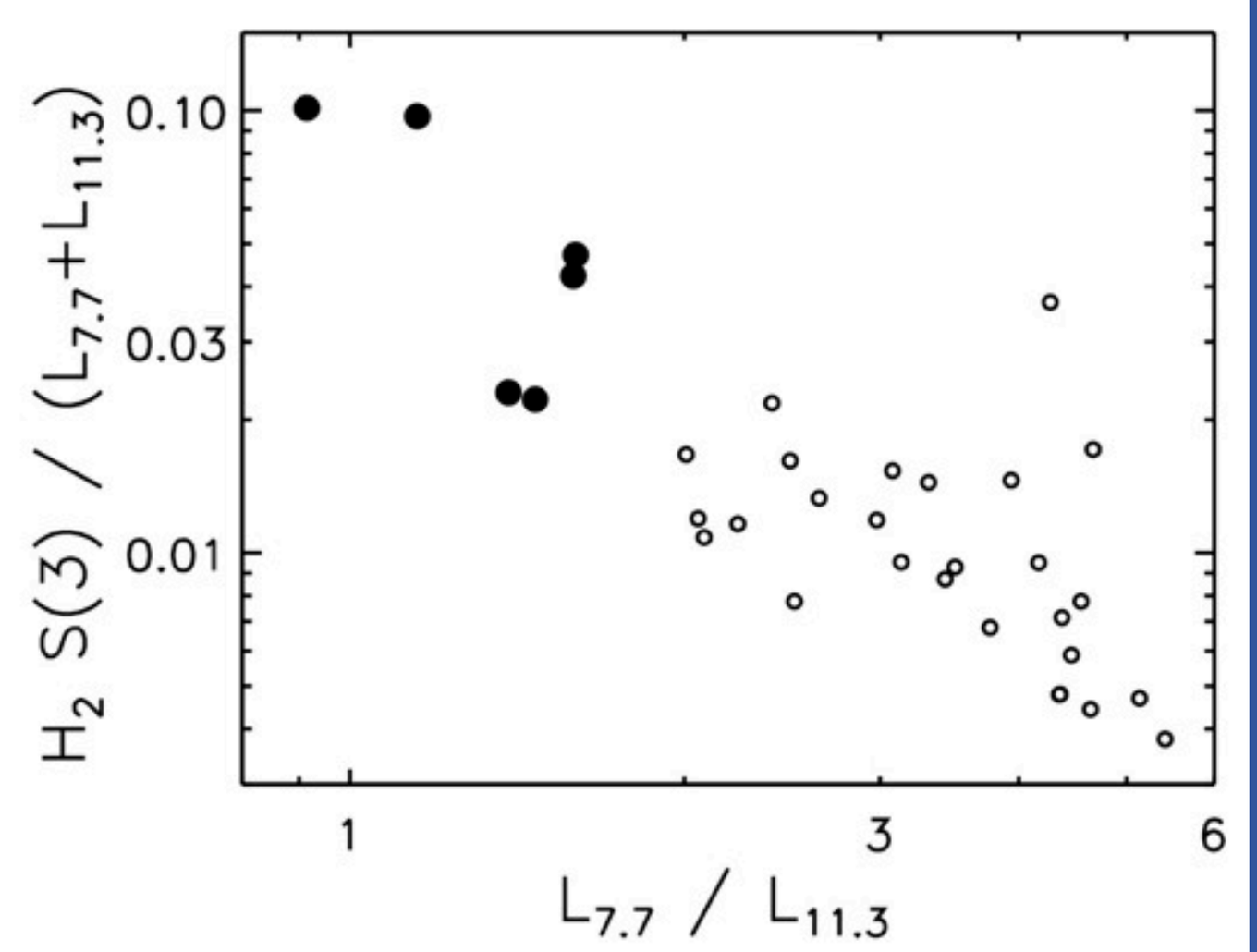
Surface Brightness [MJy sr^{-1}]

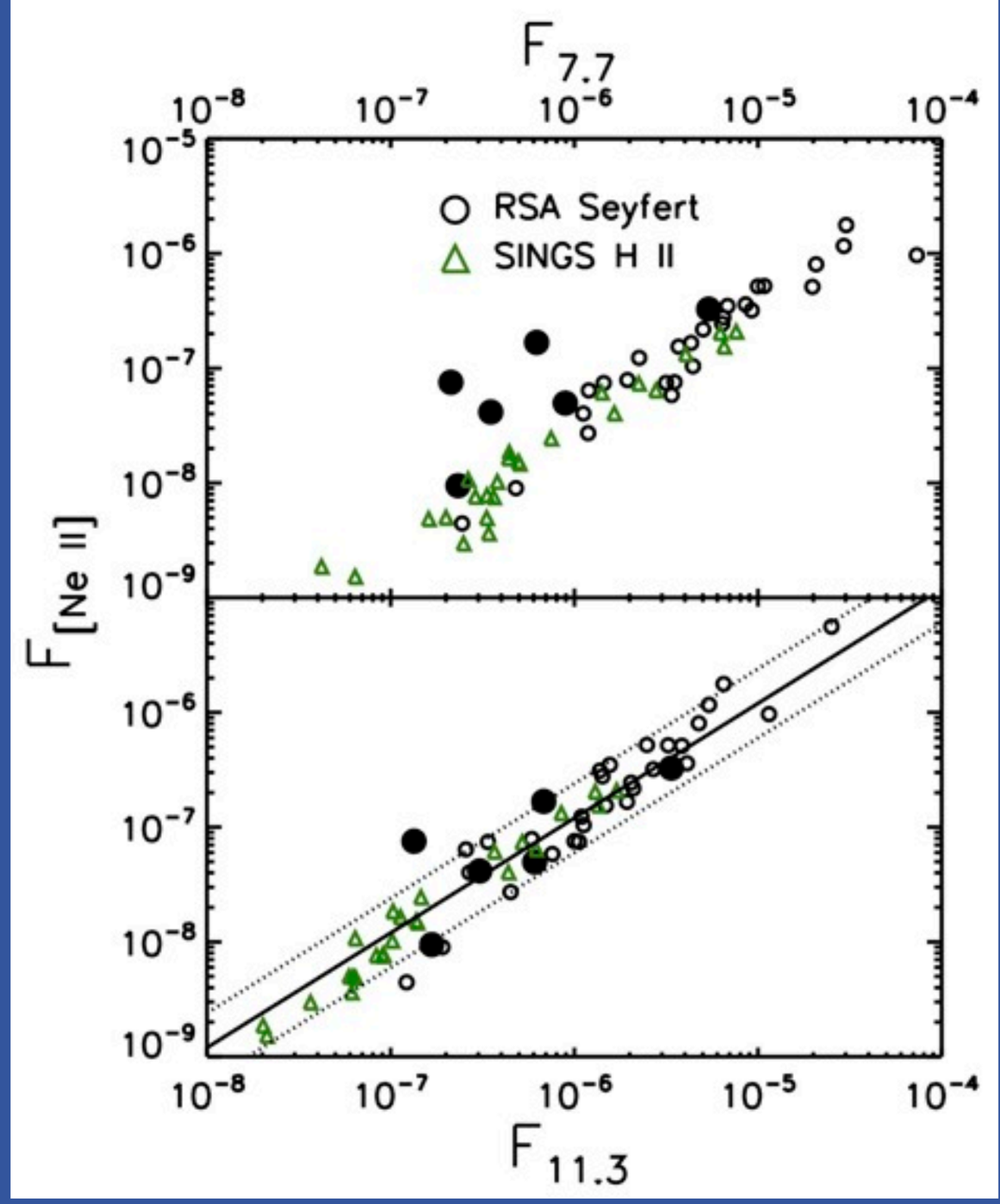
100
50
0
60
40
20
0

6
8
10
12
14

Observed Wavelength (μm)





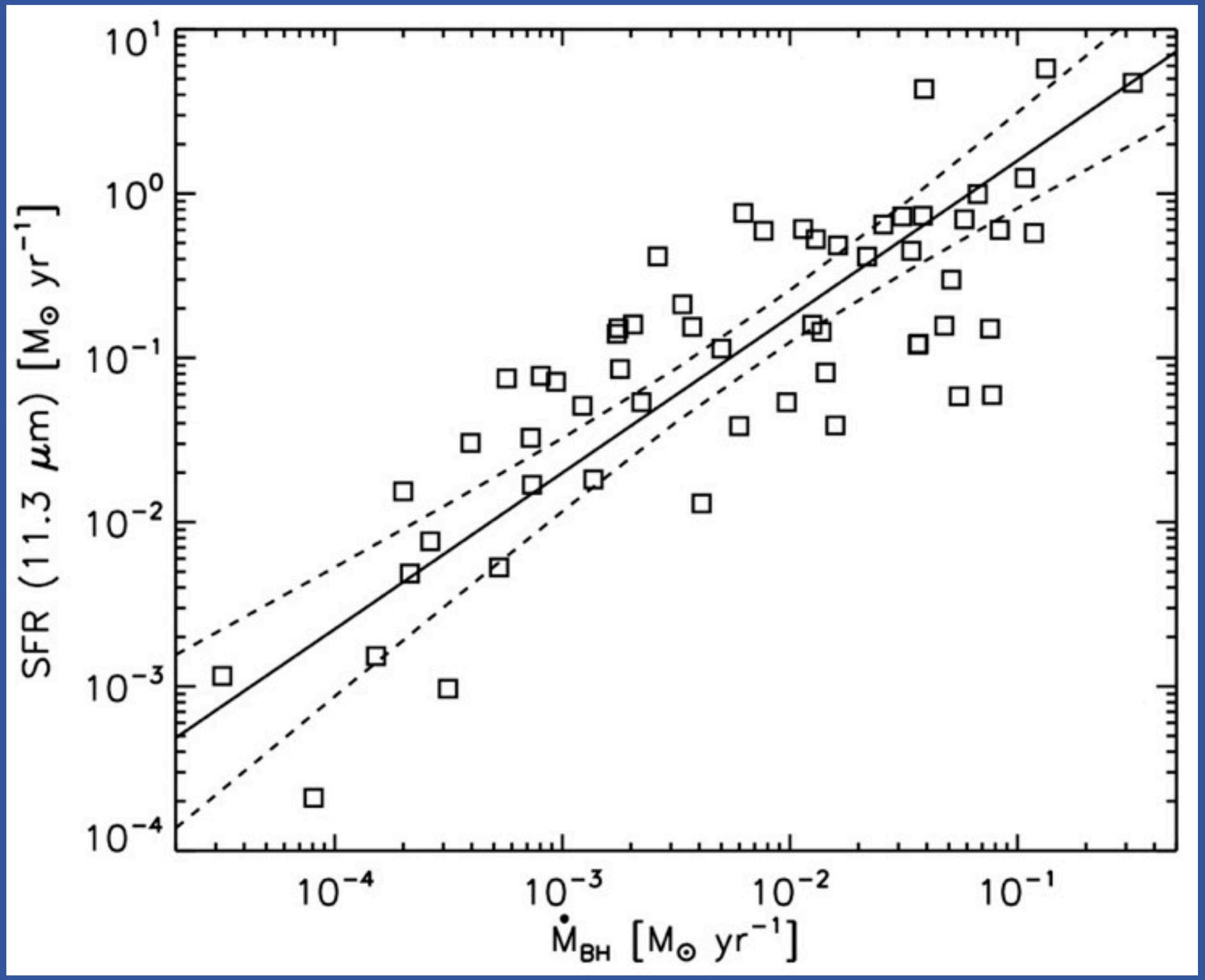


Diamond-Stanic & Rieke 2010

evidence for shock processing

11.3 μm PAH feature remains a robust tracer of the star-formation rate

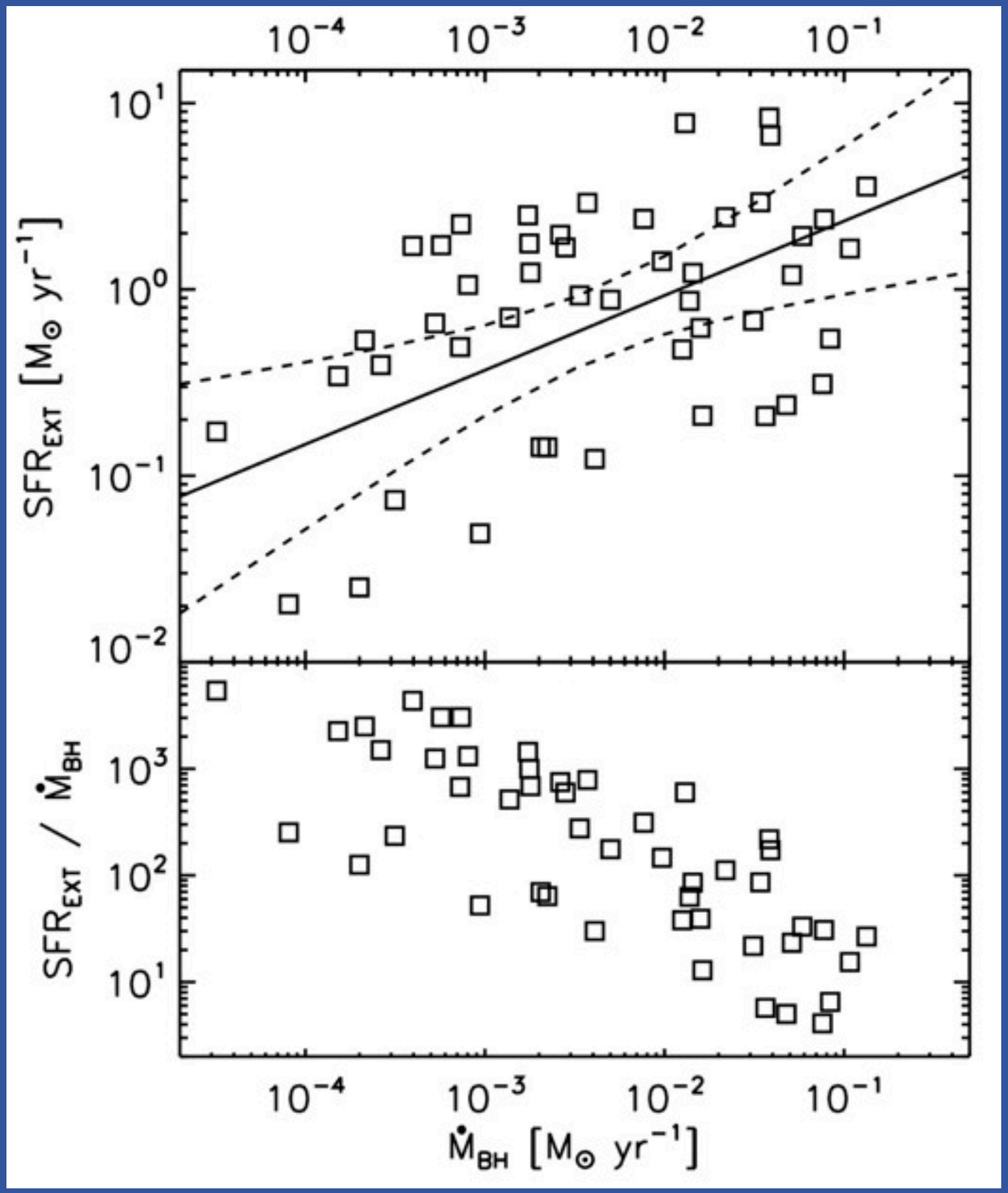
Star Formation v. Black Hole Accretion



Black hole accretion strongly correlated with nuclear star formation

Diamond-Stanic & Rieke 2011, arXiv:1106.3565

Star Formation v. Black Hole Accretion



Black hole accretion and extended star formation are poorly correlated

Diamond-Stanic & Rieke 2011, arXiv:1106.3565

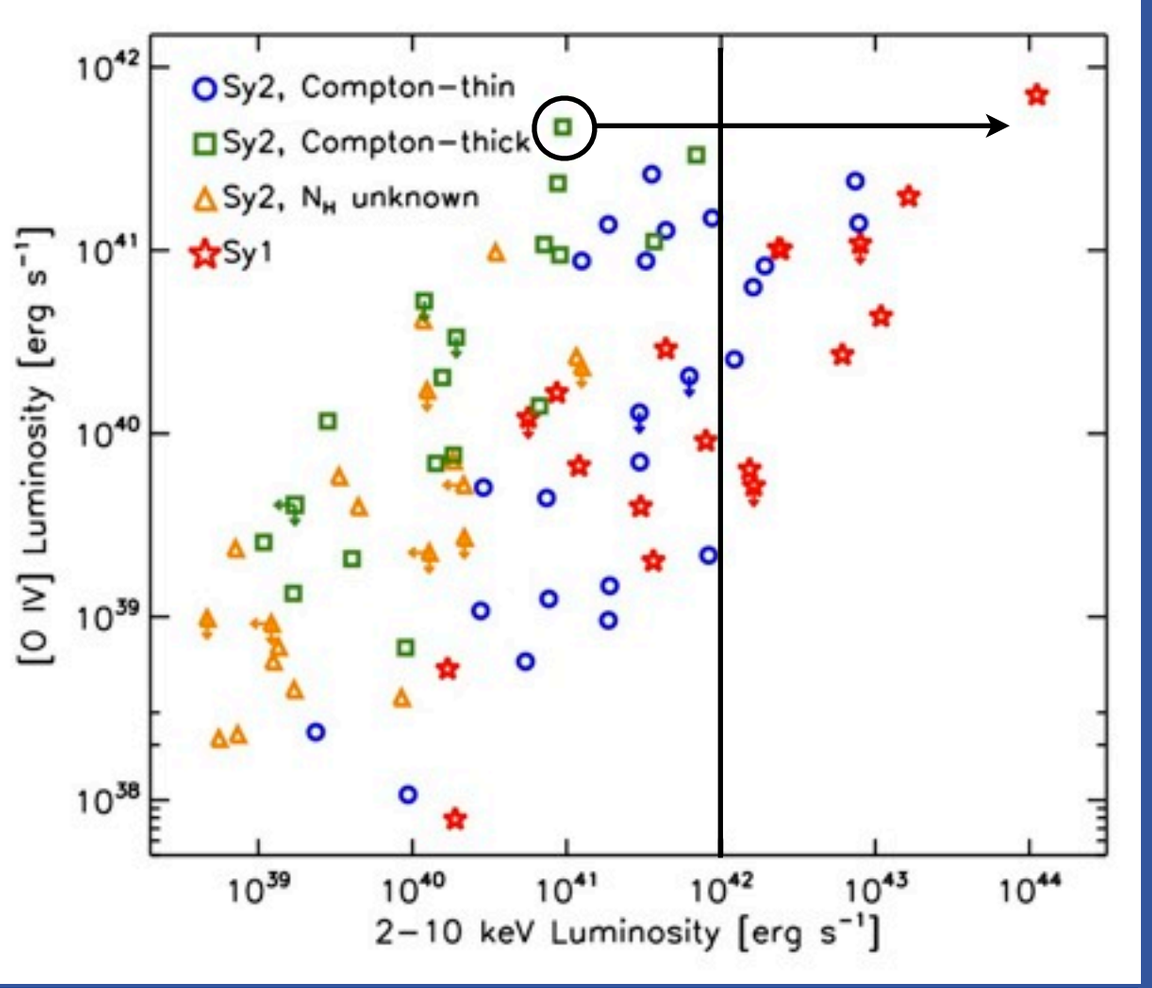
SFR results

- 6--9 μm aromatic features suppressed in Seyferts
  - H_2 emission suggests processing by AGN-driven shocks
- Star-formation rates for AGN host galaxies
  - 11.3 μm feature appears to be robust
- Relationship between black hole accretion and star formation
  - strong correlation with nuclear star formation
  - weak correlation with extended star formation

Questions

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

- How do galaxies and black holes co-evolve?

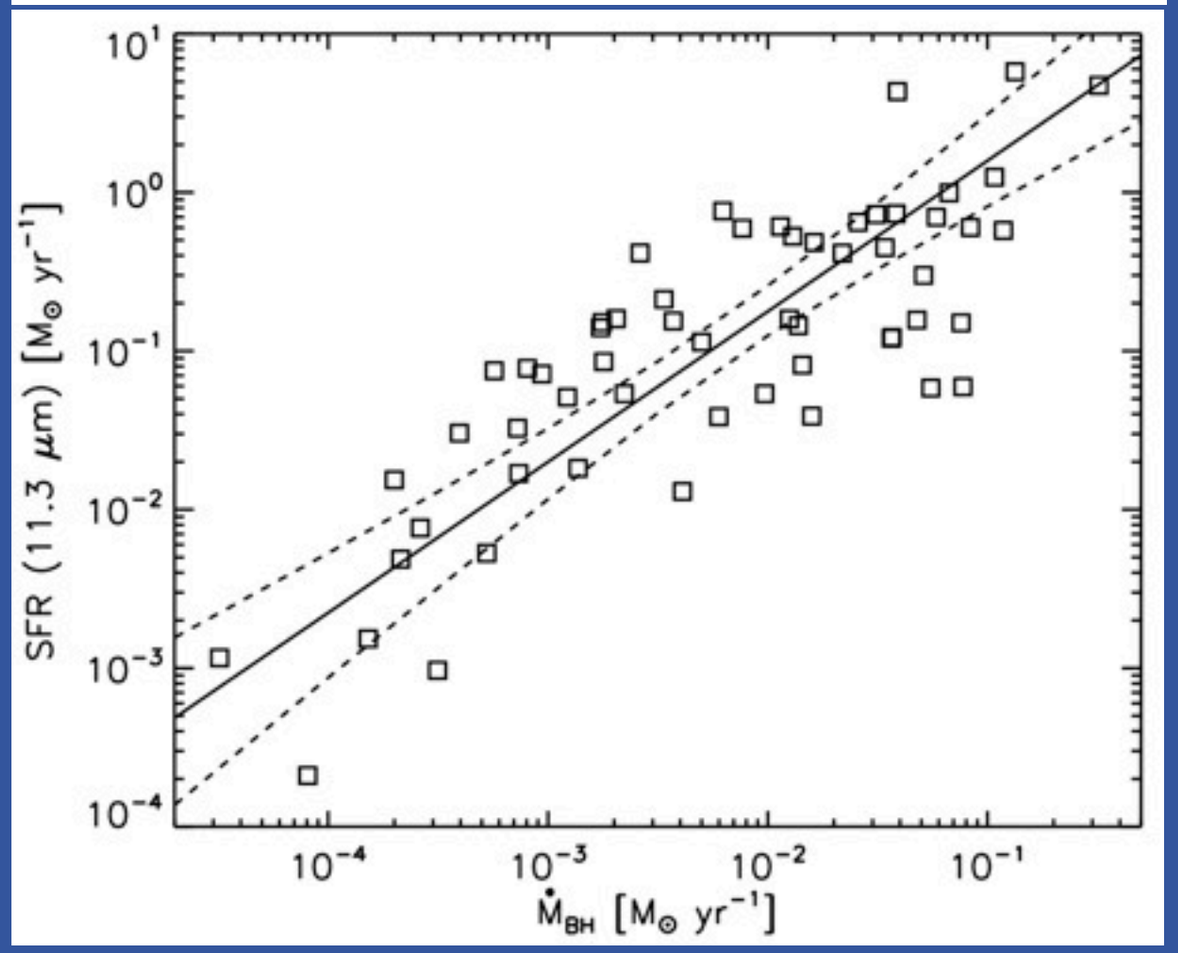


most AGNs are obscured

most AGNs are not mergers

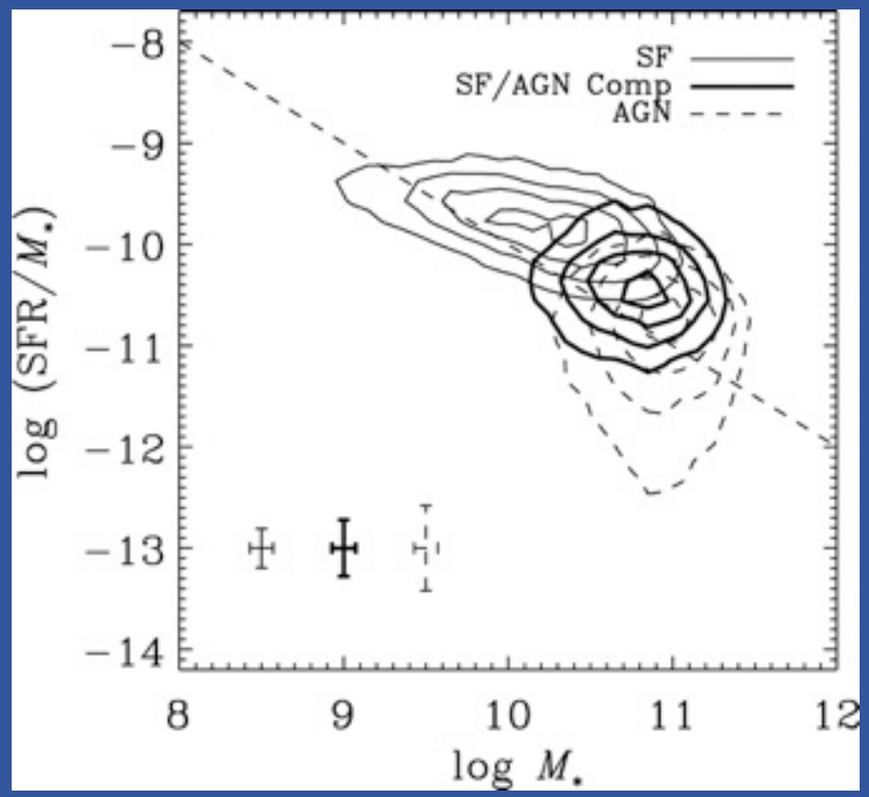
→ fueling by secular processes

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

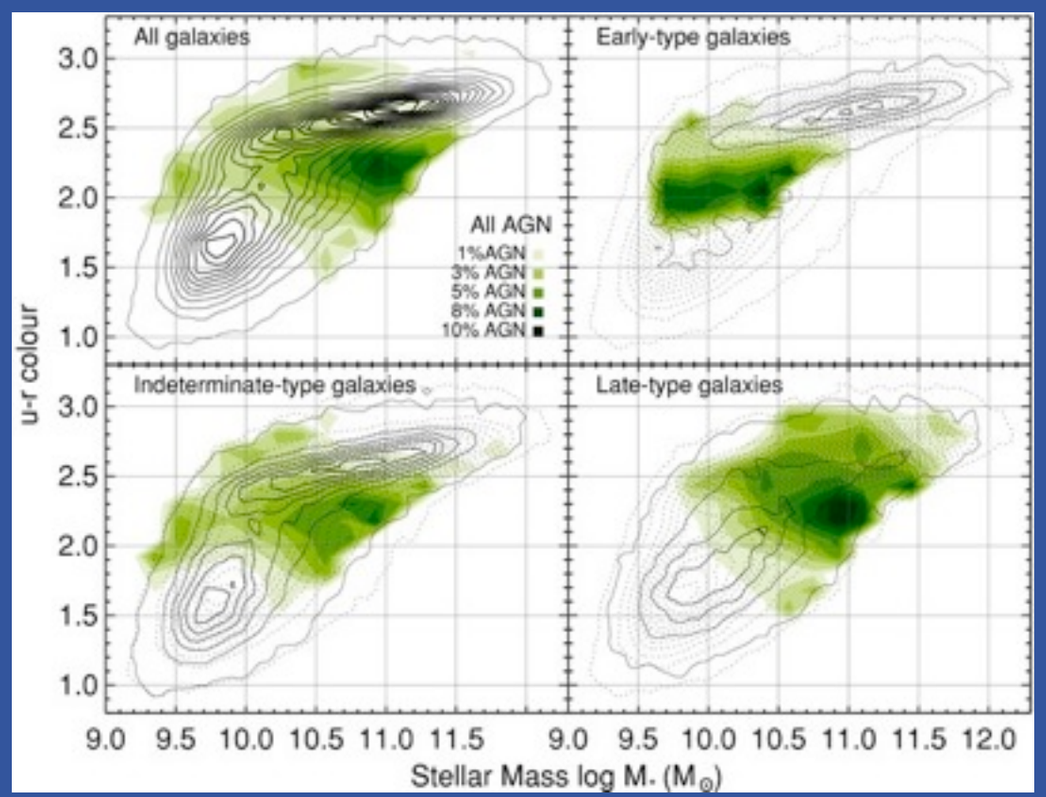


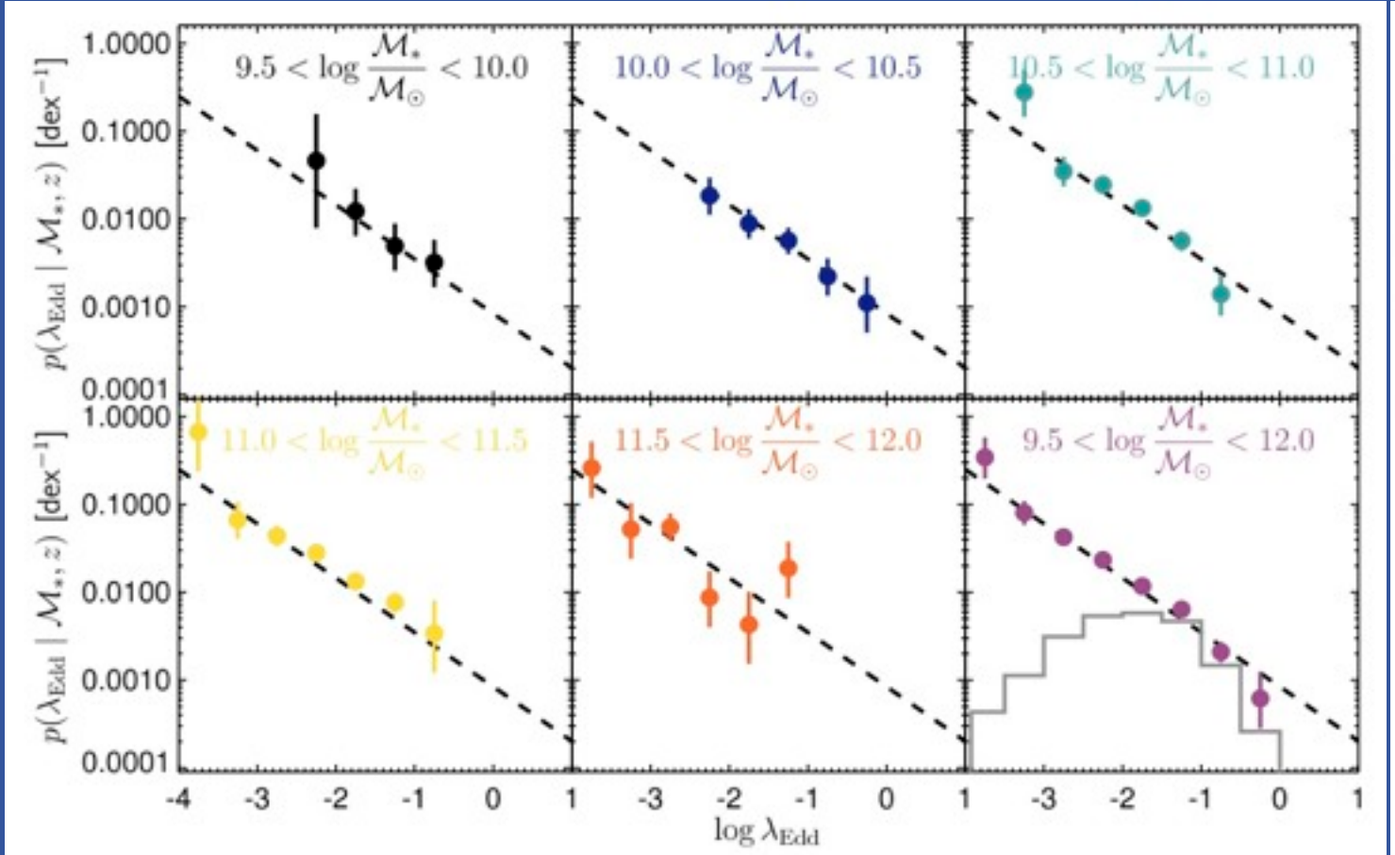
Is there a preferred scale for AGN activity?

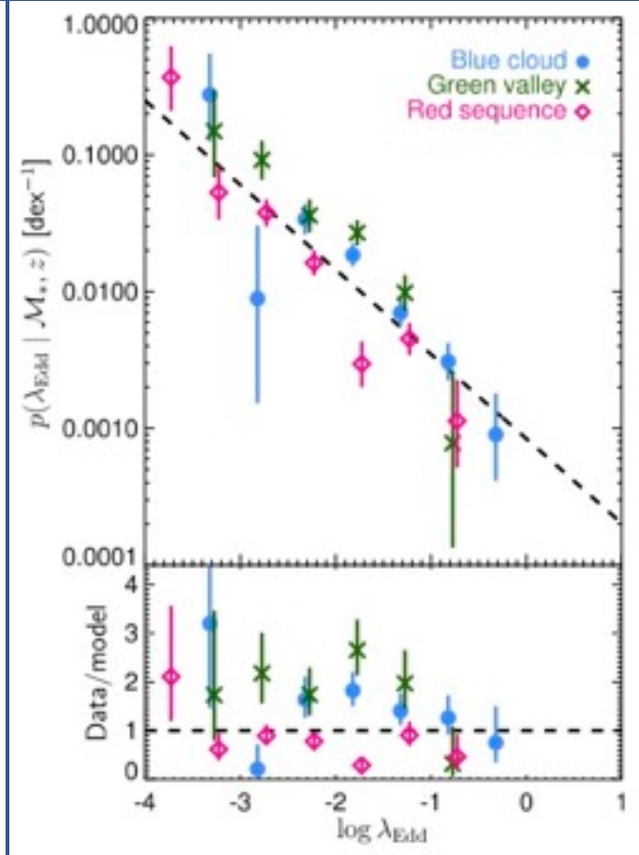
Salim et al. 2007



Schawinski et al. 2010





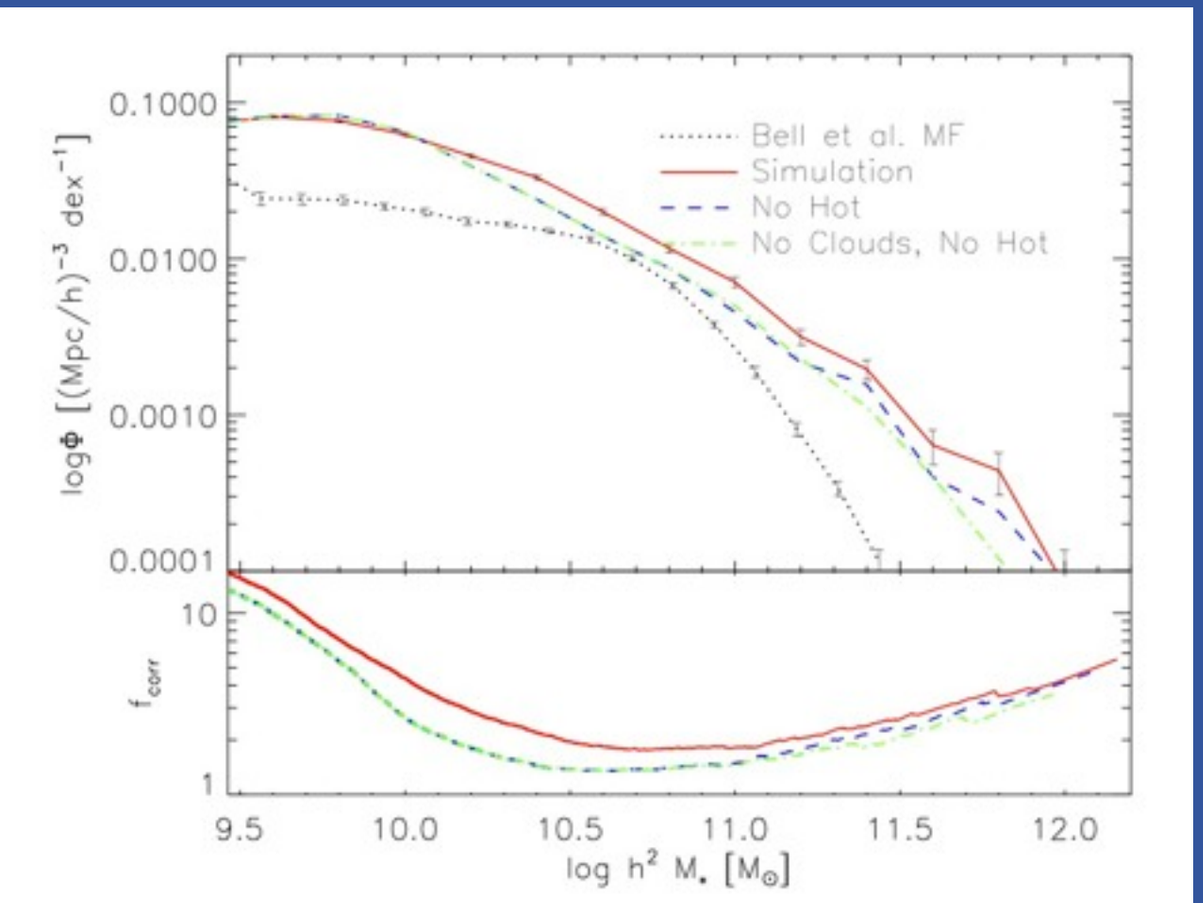


Aird et al. 2011, arXiv:1107.4368

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

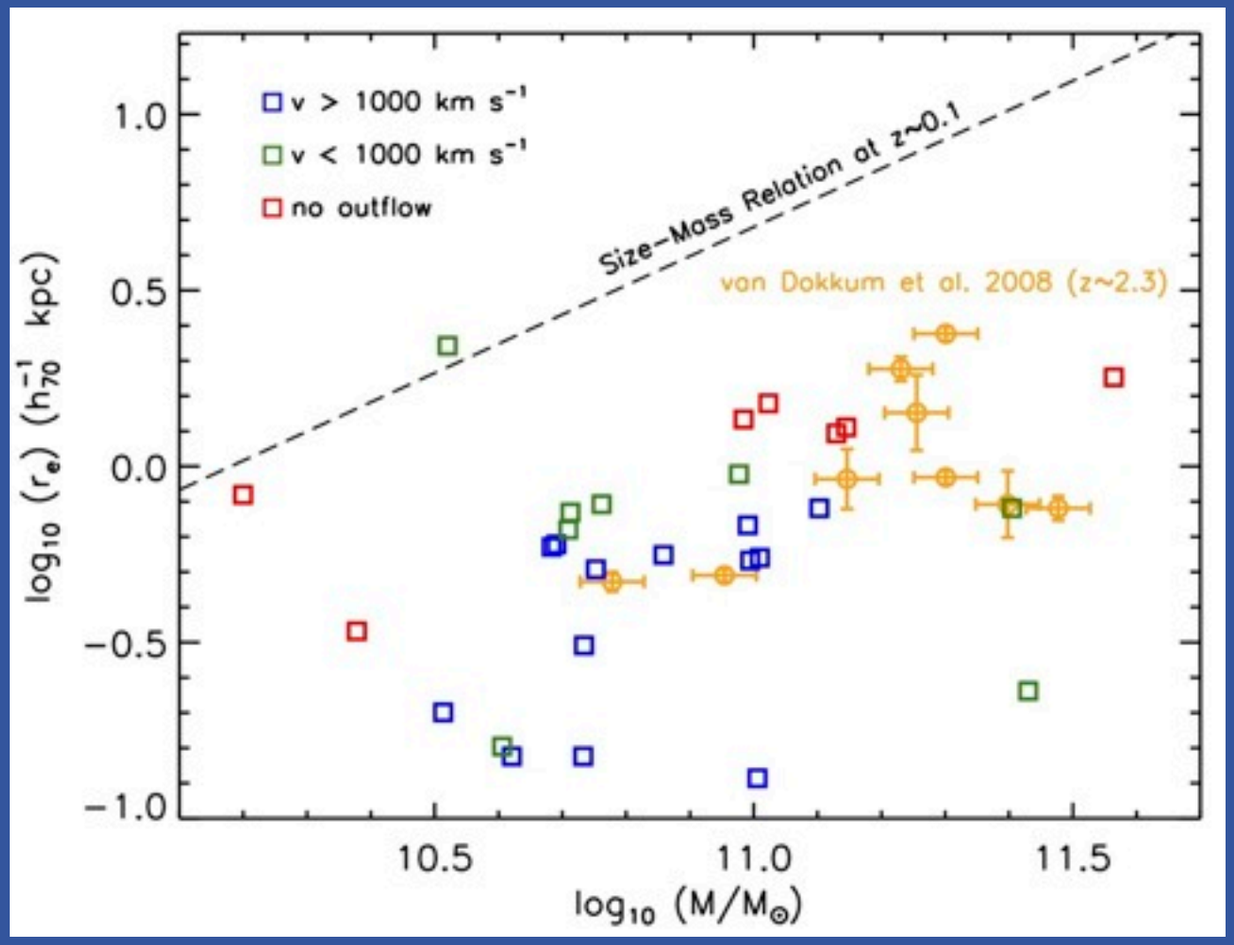
What about AGN Feeback?

theory problem:
simulations w/o feedback
produce too many stars



Keres et al. 2009

observational evidence: not
clear that AGN feedback
quenches star formation



z~0.6 post-starburst galaxies with extreme outflows

Tremonti, Moustakas, Diamond-Stanic 2007

new result: compact sizes suggest extreme
star-formation feedback

Future Discovery Space w/ ALMA

How is gas transported to the accretion disk?

→ study morphology, kinematics of molecular gas

→ inward gas flows, radial distribution of star formation