# Not All AGNs are Created Equal: How Galaxies Feed and Obscure Their SMBHs

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COSMOS + CANDELS

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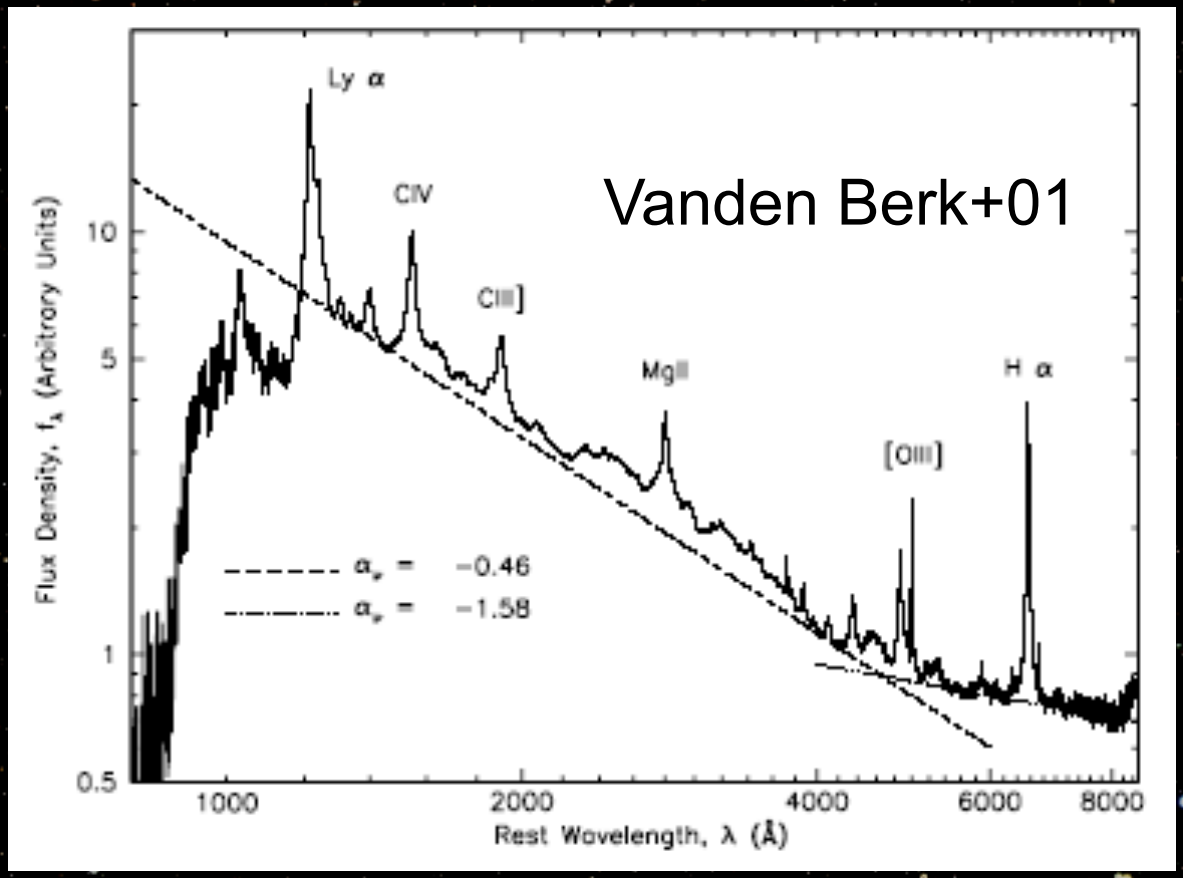
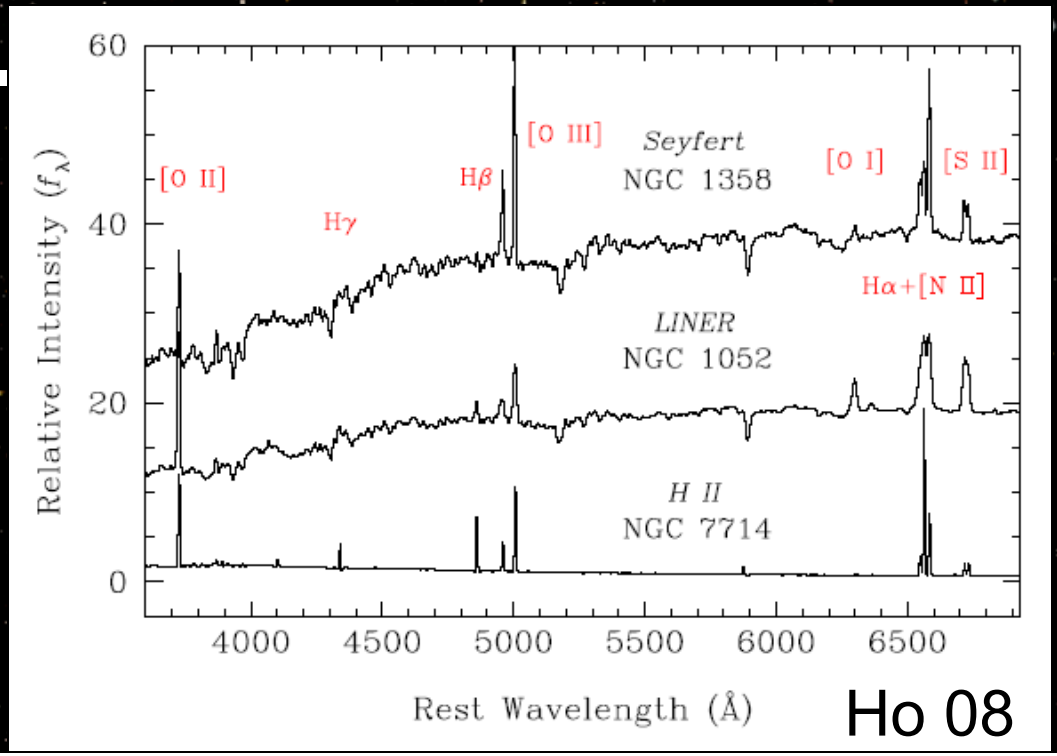
# Broad-line (Type 1) AGN / Quasars

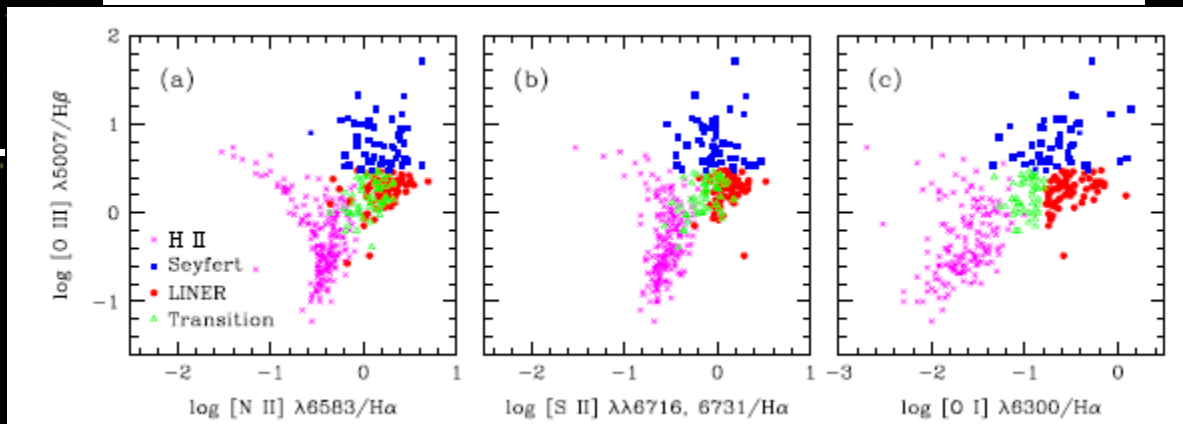
- Luminous
- Unobscured
- Outshine their host galaxies
- Optical/UV: accretion disk (3000 Å peak)
- X-ray power-law
- IR thermal bump



# Narrow-line (Type) 2 AGN

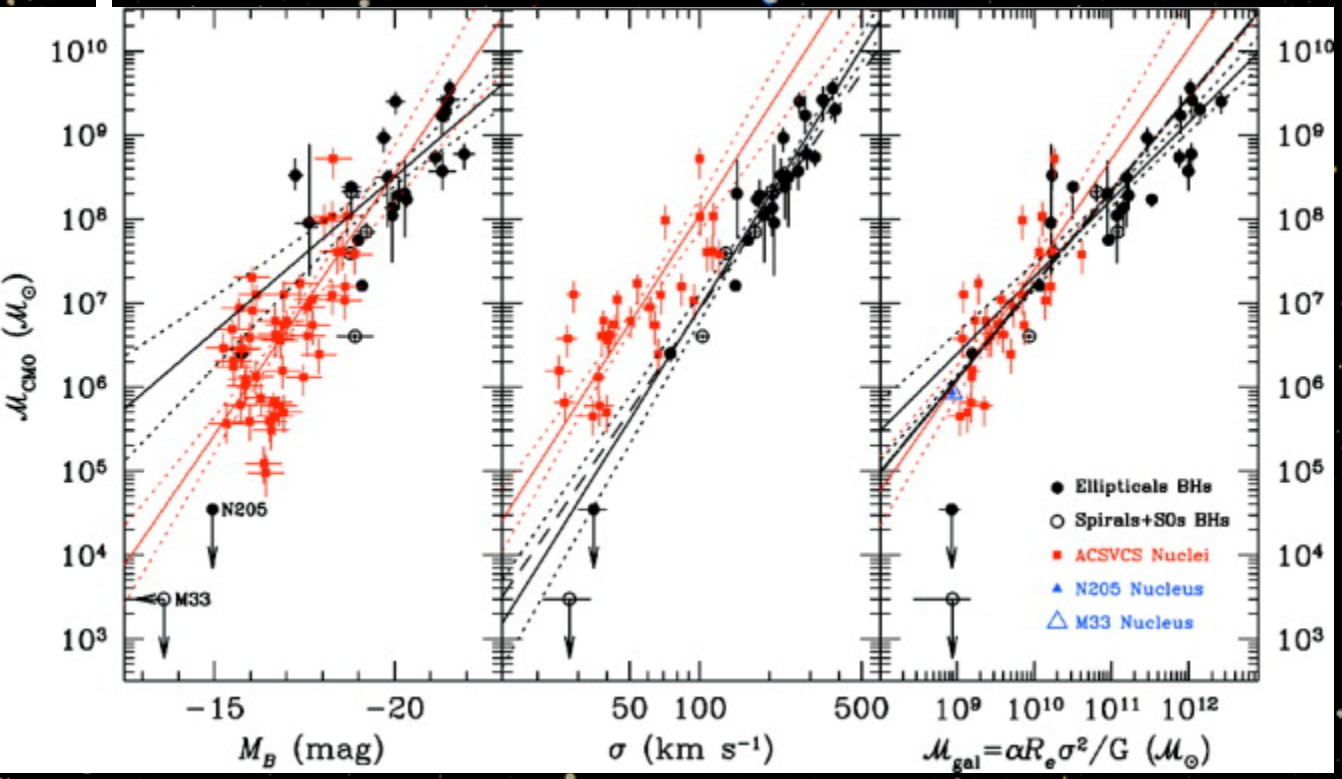
- Fainter
- Often obscured
- Galaxy continuum
- Sometimes host-dominated ("optically dull")
- Distinguished from SF galaxies by line ratios (e.g. BPT81, Kewley +01)



# SMBH – Host Galaxy Connection

- Tight relation between $M_{BH}$ and $M_{bulge}$ / $L_{bulge}$
- Suggests that SMBH & host are connected




*from Ferrarese et al. 2006*

Host regulates SMBH accretion?

AGN phase regulates star formation in host galaxy?

# A Paradigm for SMBH Activity

- What ignites the AGN phase?
  - Galaxy mergers? (Sanders+88, Hopkins+06)
  - Isolated disks? (Hopkins & Hernquist 06, Bournaud+11)

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- Why do AGN look so different?
  - Broad / narrow lines, luminosity, SED vary widely
  - Caused by different obscuration, or accretion physics?
  - Governed by host?

***Is there a Unified Model to describe different active galaxies???***

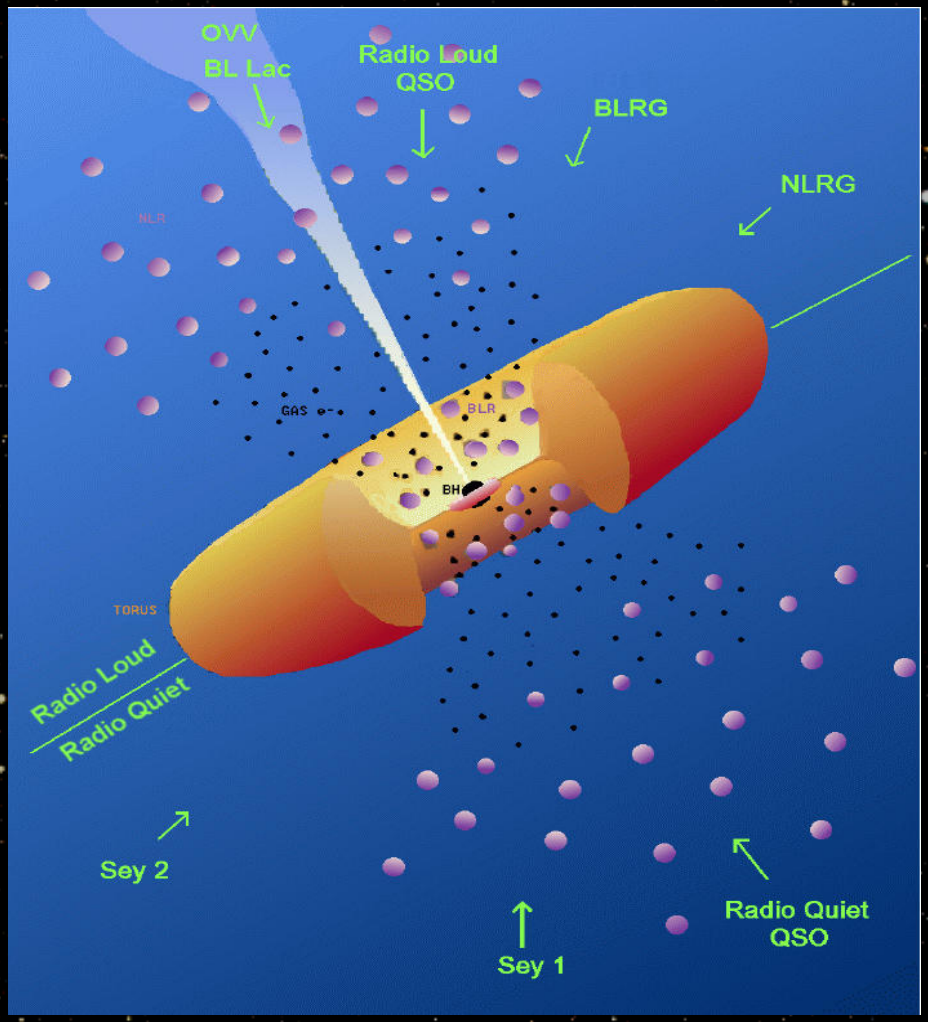
# The Historical AGN "Unified Model" (Antonnucci 93)

Orientation explains:

- Luminous / Faint
- Obscuration
- Type 1 (BL) / 2 (NL)
- Reflected BLR in spectropolarimetry

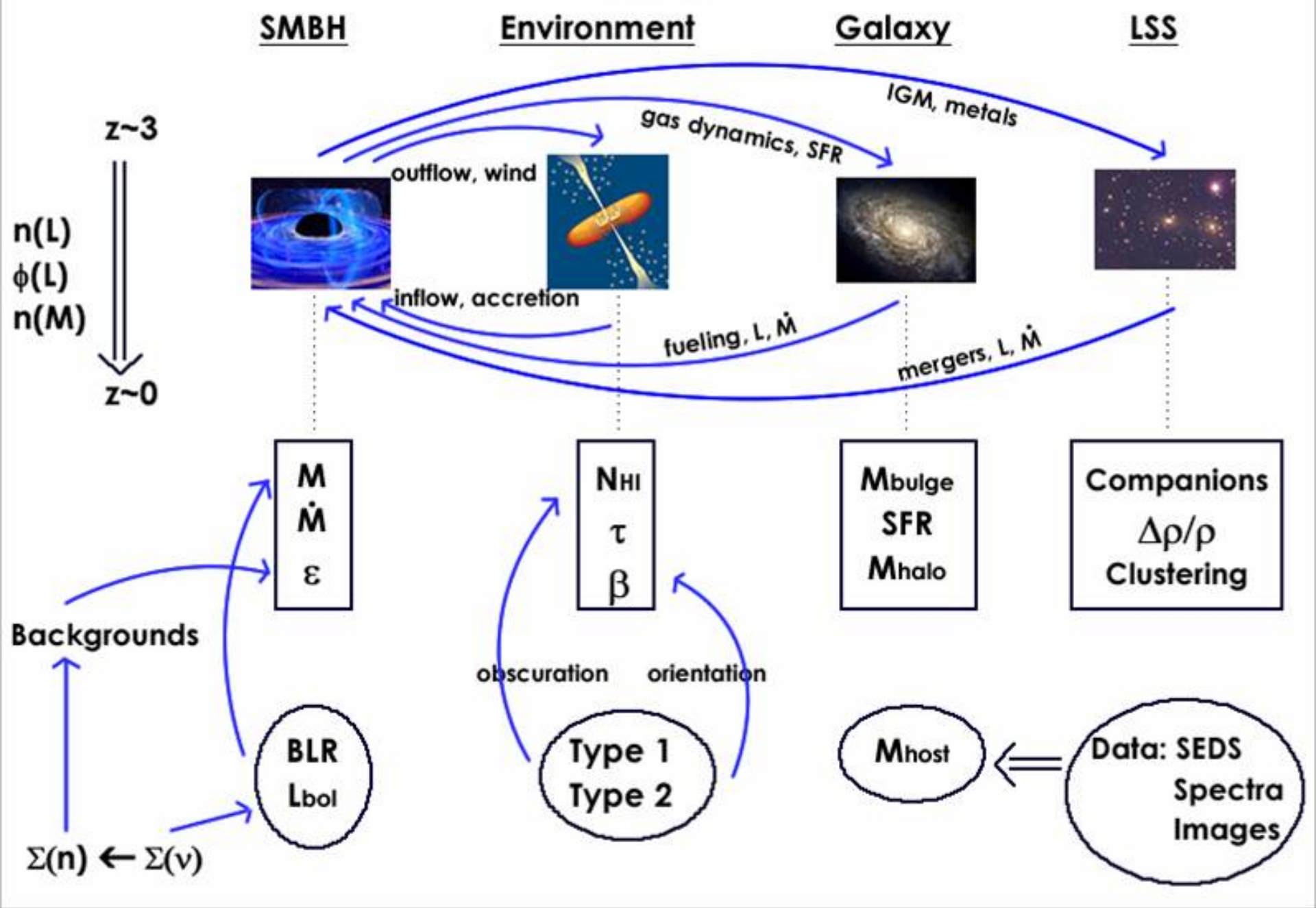
But many objects don't fit!

Many Type 2's have little X-ray absorption (Trouille+09), no IR torus (Trump+09c,11b) & no reflected BLR (Tran 01,03)




*from Urry & Padovani 1995*

# SMBH Demographics & Evolution



# The AGN Unified Model with COSMOS

- Deep + Wide: 2 deg$^2$, 160 ksec of X-ray, spectroscopy to $i_{AB} < 23$
  - 485 AGN with high-confidence redshifts
  - Type 1 AGN masses from virial scaling relations
- HST/ACS data
  - Host morphologies to z~1
  - Type 2 AGN masses from host-SMBH relations
- Complete SEDs
  - Deep radio, IR, optical, UV, X-ray photometry
  - Accurate bolometric luminosities for unobscured AGN
- Bolometric luminosity + Mass = Accretion Rate

# COSMOS Multiwavelength Data

Photometry

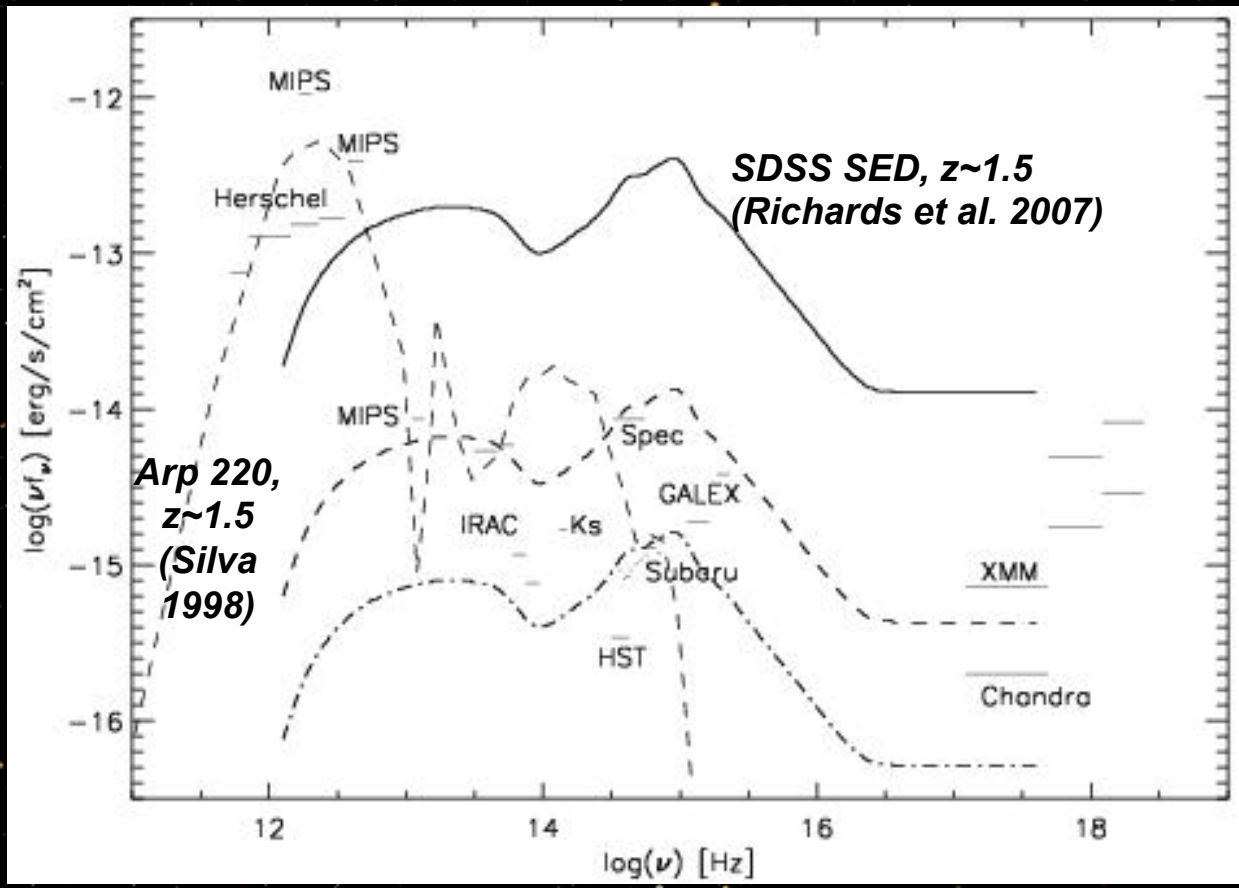
- VLA 1.4 GHz (Schinnerer) – 7 μJy
- Spitzer-IRAC 3-8 μm (Sanders) – 10 μJy
- Spitzer-MIPS 24 μm (Sanders) – 15 mJy
- HST-ACS (Scoville) – $i_{AB}$~27
- Subaru (Taniguchi) – $m_{AB}$~27, 20 narrow bands to $m_{AB}$ ~ 26
- GALEX N/F UV (Schiminovich) – $m_{AB}$~26
- XMM (Hasinger) 0.5-10 keV – $8 \times 10^{16}$ cgs
- Chandra (Elvis) 0.5-8 keV – $2 \times 10^{16}$ cgs

Spectroscopy

- VLT/VIMOS (Lilly) – 10,000+ galaxies to $i_{AB}$<26
- ***Magellan/IMACS (Trump/Impey) – 1000+ AGN to $i_{AB}$<23***

# COSMOS Sensitivity to AGN SEDs

- ~40 times fainter than the typical SDSS quasar
- Sensitive to QSO/Seyfert boundary at z~2
- Multiwavelength, for full SED
- X-ray selection for varied AGN types



# Accurate Bolometric Luminosities for Unobscured AGN

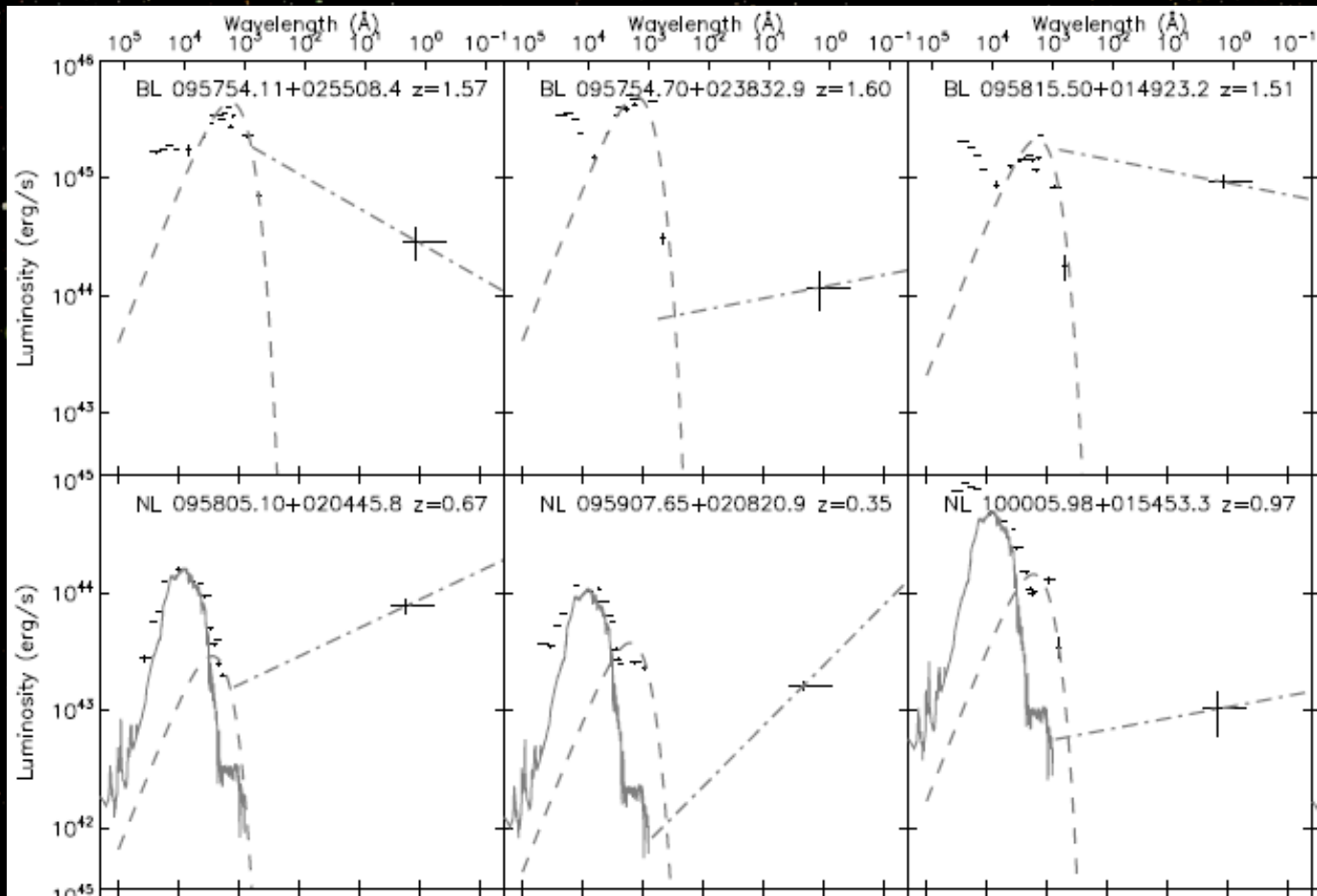
Model SED as accretion disk + X-ray corona

Top: BL

Bottom: NL (with host galaxy)

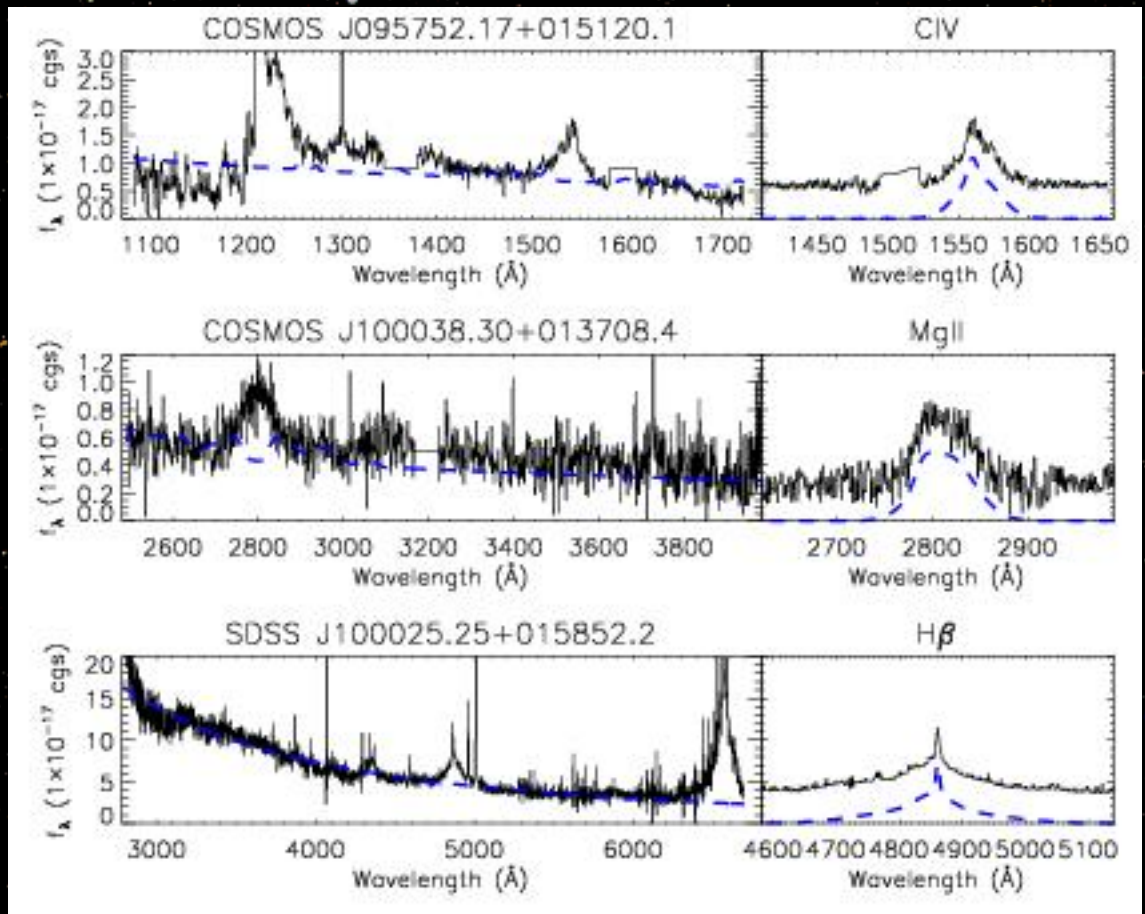
Ignore IR: reprocessed

Accretion disk model from Gierlinski+99 (diskpn in xspec)



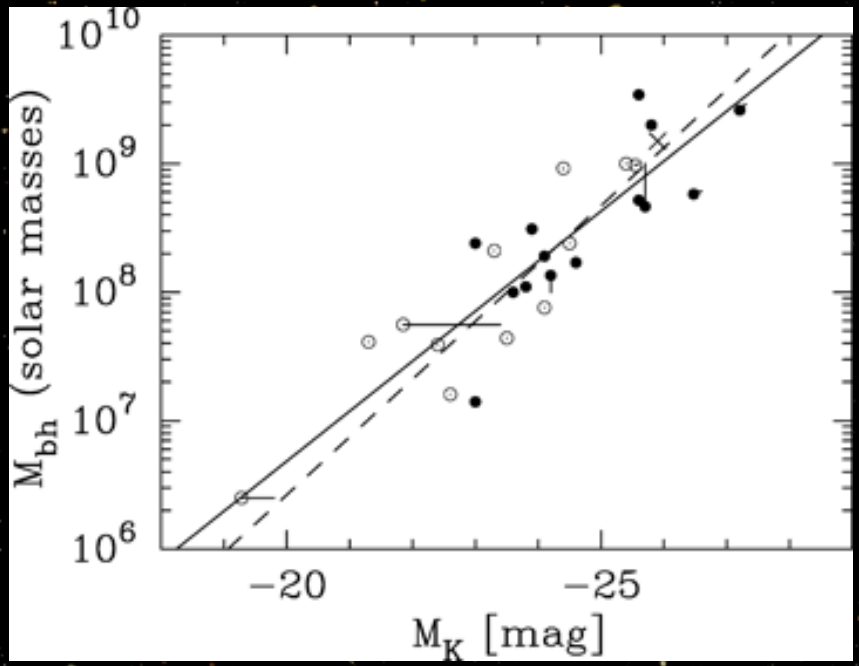
# Broad-Line AGN Masses

- $M_{BH} \sim L^{0.5} \times v_{fwhm}^{2}$, scatter of ~0.4 dex
- Calibrated from reverberation mapping of ~30 local AGN
- Virial theorem: $M_{BH} \sim R_{BLR} v_{BLR}^{2}$
- $R_{BLR} \sim L^{0.5}$ (Kaspi et al. 2000, 07): scaling relations



# Masses for Narrow-Line and Lineless AGN

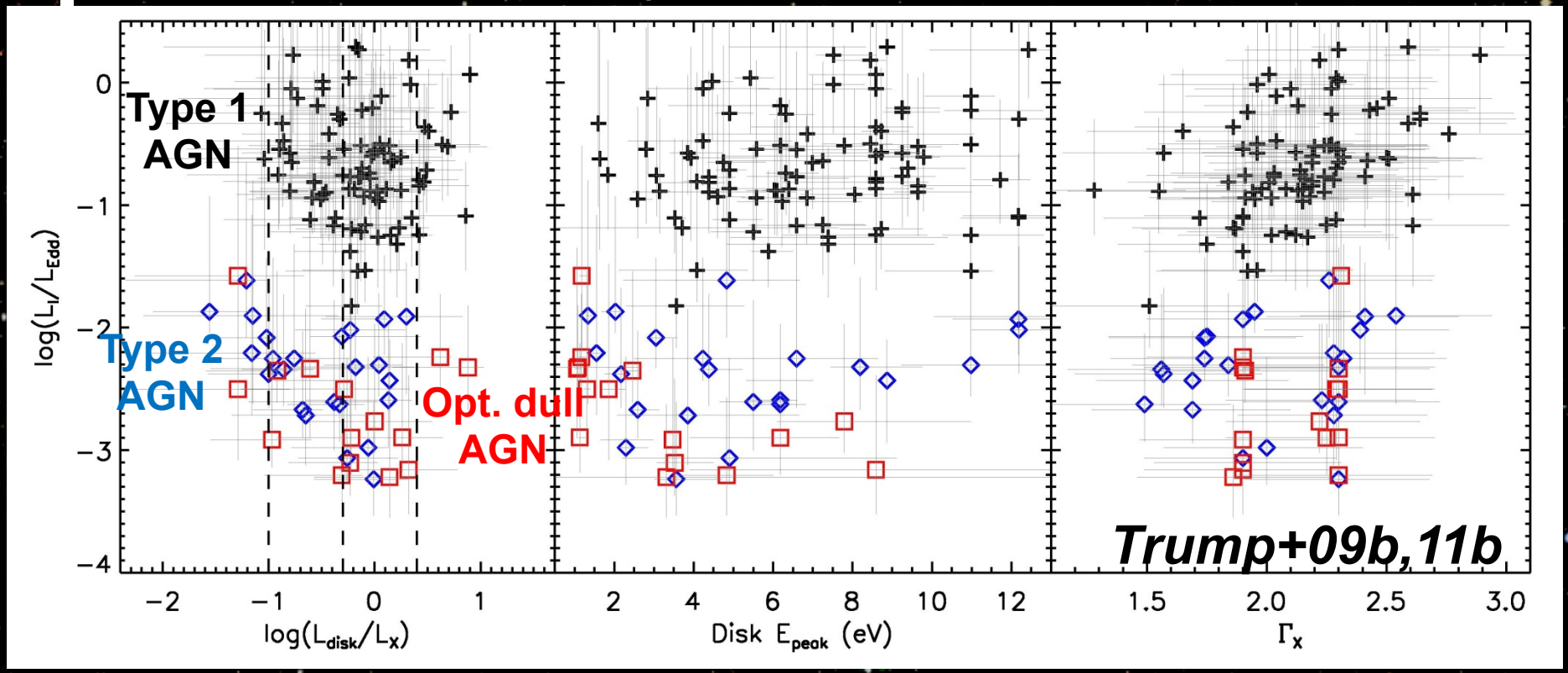
- No broad emission lines... host – $M_{BH}$ relations instead
- $\log(M_{BH}/M_{\odot}) \sim 0.9 \log(L_{K,bulge}) - 31$
- ~0.35 dex scatter
- Bulge luminosities from HST/ACS decompositions (Gabor+09)




*Graham 2007*

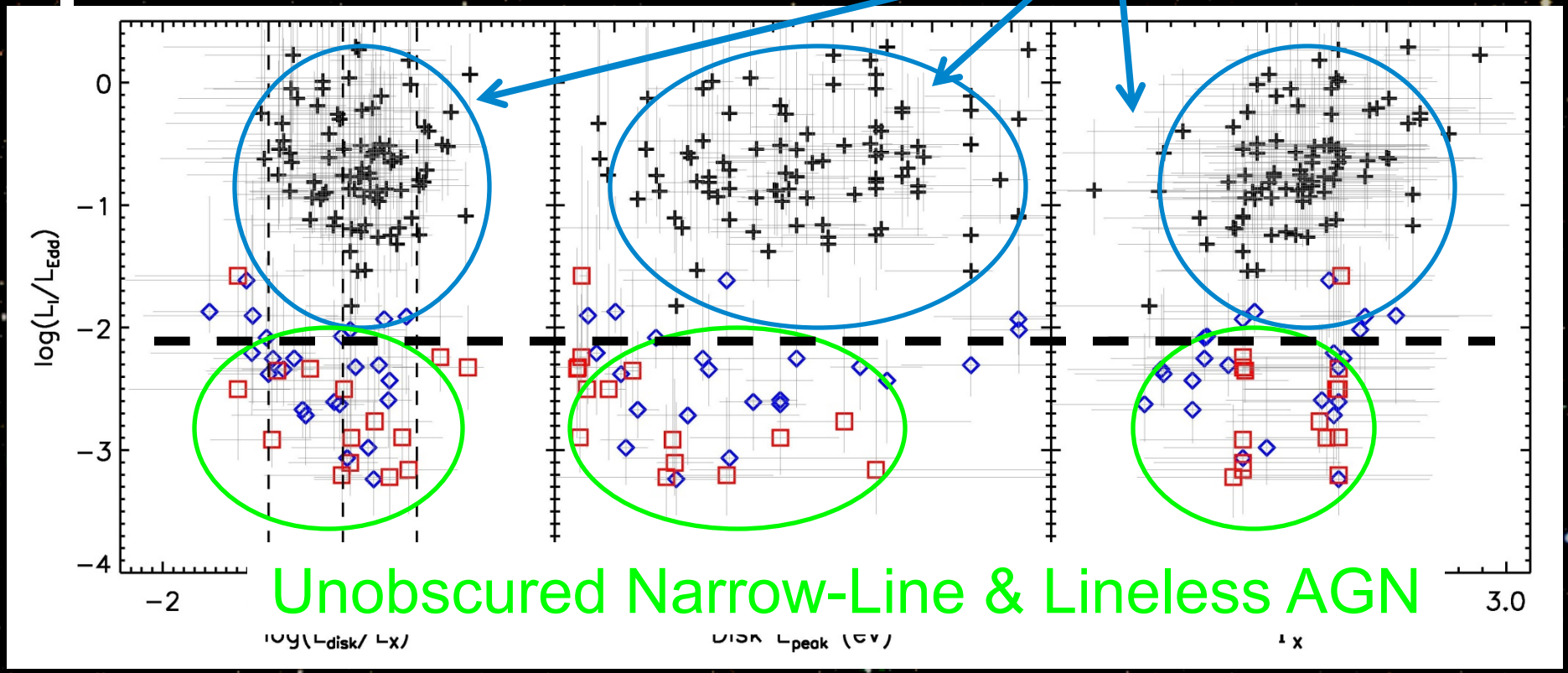
# AGN Fueling (unobscured only: $N_H<10^{22}$ cm$^2$)

- $L_{int}/L_{Edd}$: accretion rate $\dot{m}$
- With $L_{disk}/L_X$, $E_{peak}$ of disk, X-ray slope



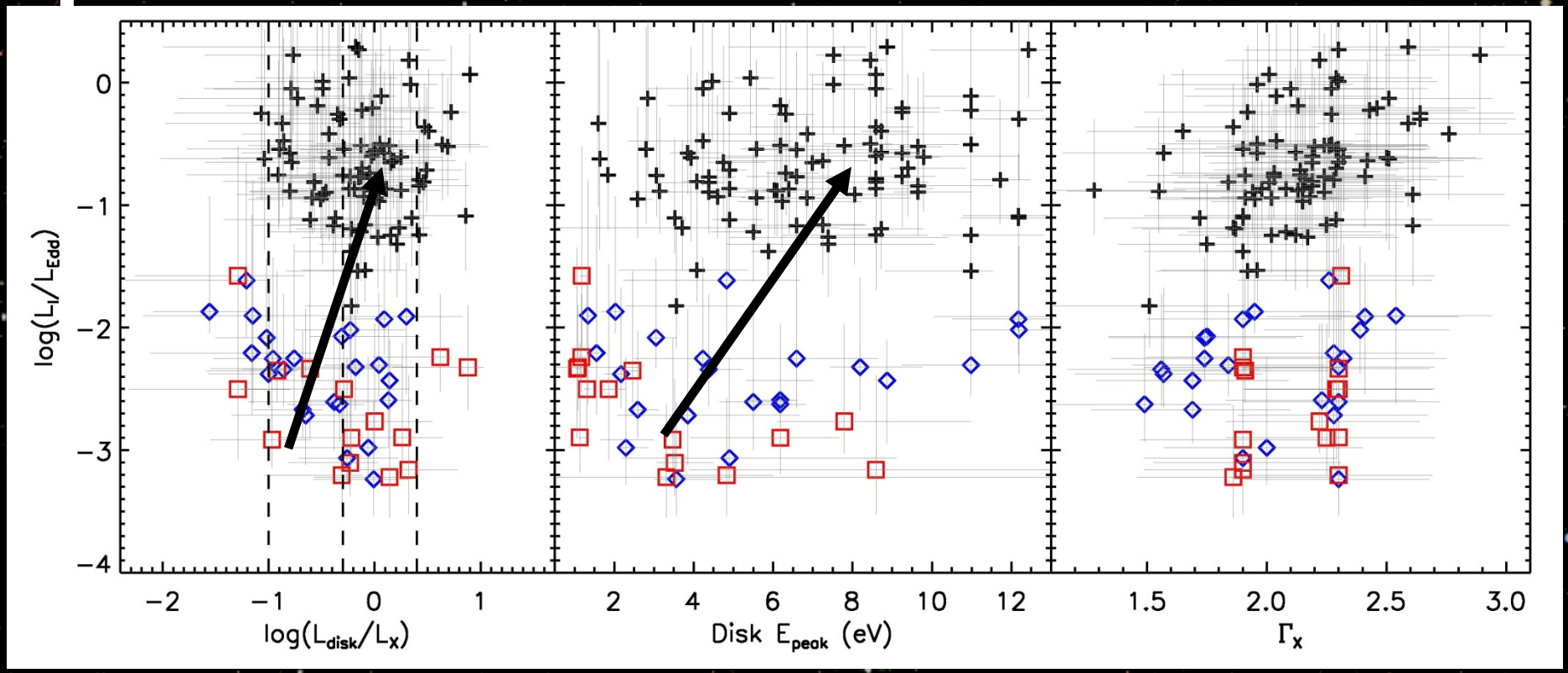
# AGN Fueling

Different $L_{int}/L_{Edd}$ for unobscured Type 1/2



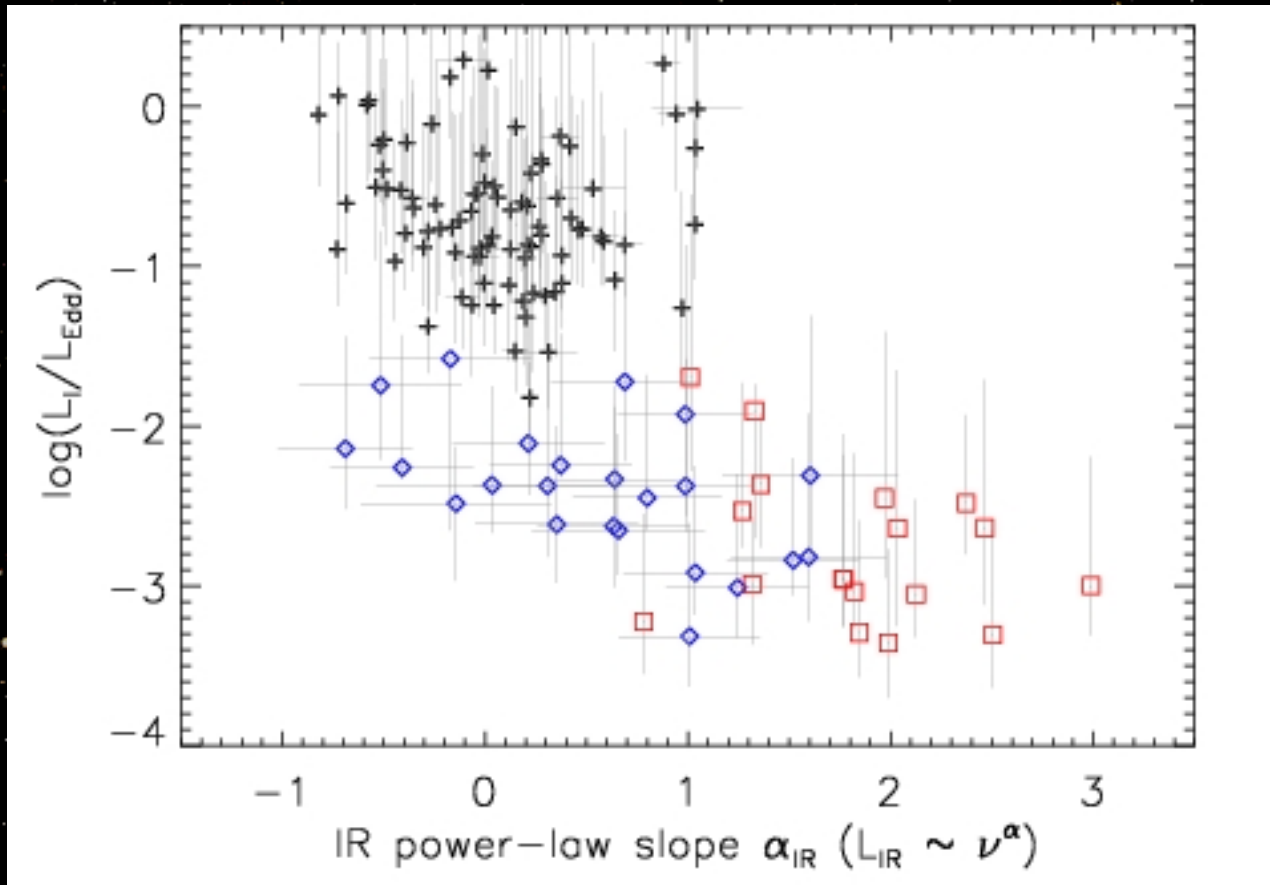
# AGN Fueling

- Disk gets brighter & hotter as accretion rate increases (difference is >3$\sigma$)



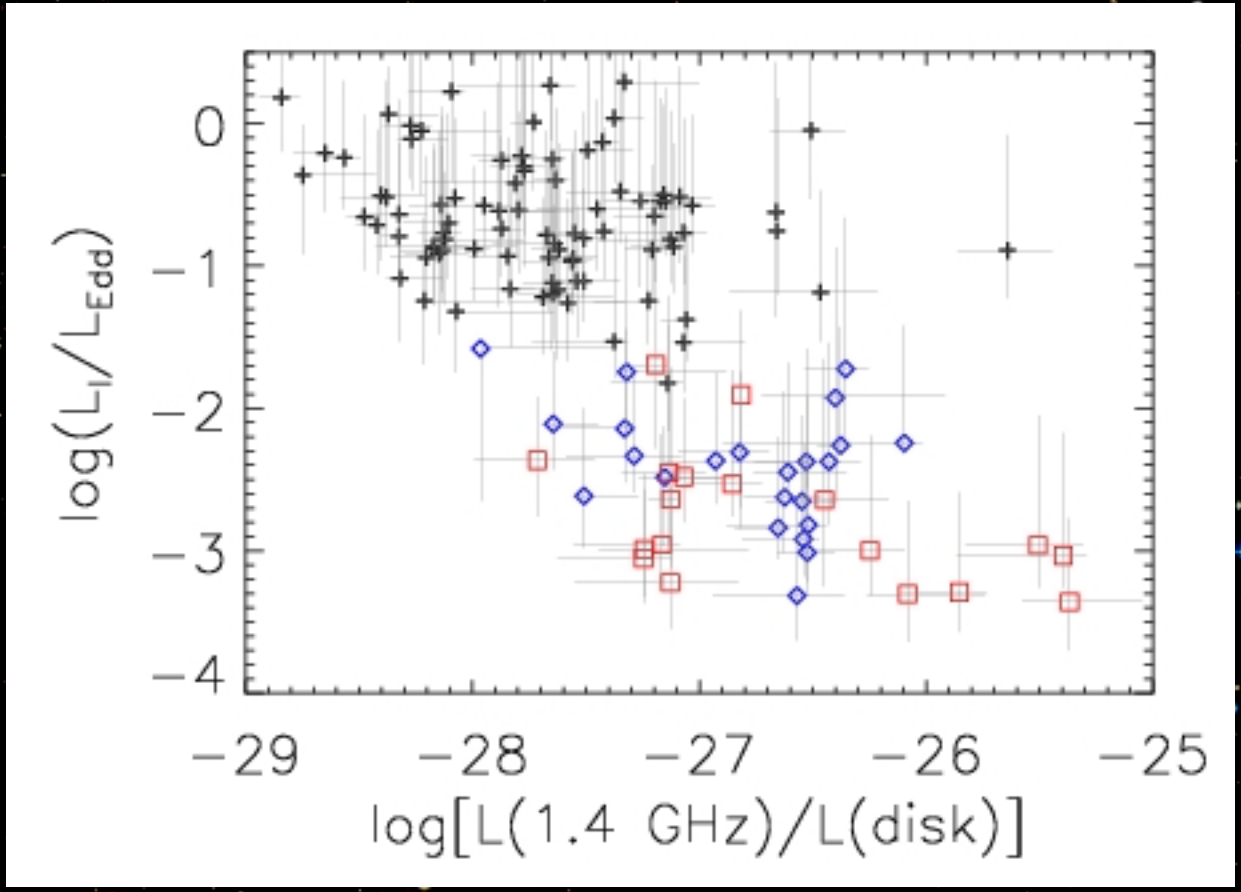
# Accretion Rate and the IR "Torus"

- Hot "torus" dust will have IR signature from 1-10μm with $\alpha_{IR}$<0.5 (Donley+07)
- Weak AGN lack this IR signature
- Can be explained by disk wind of both BLR & clumpy dust



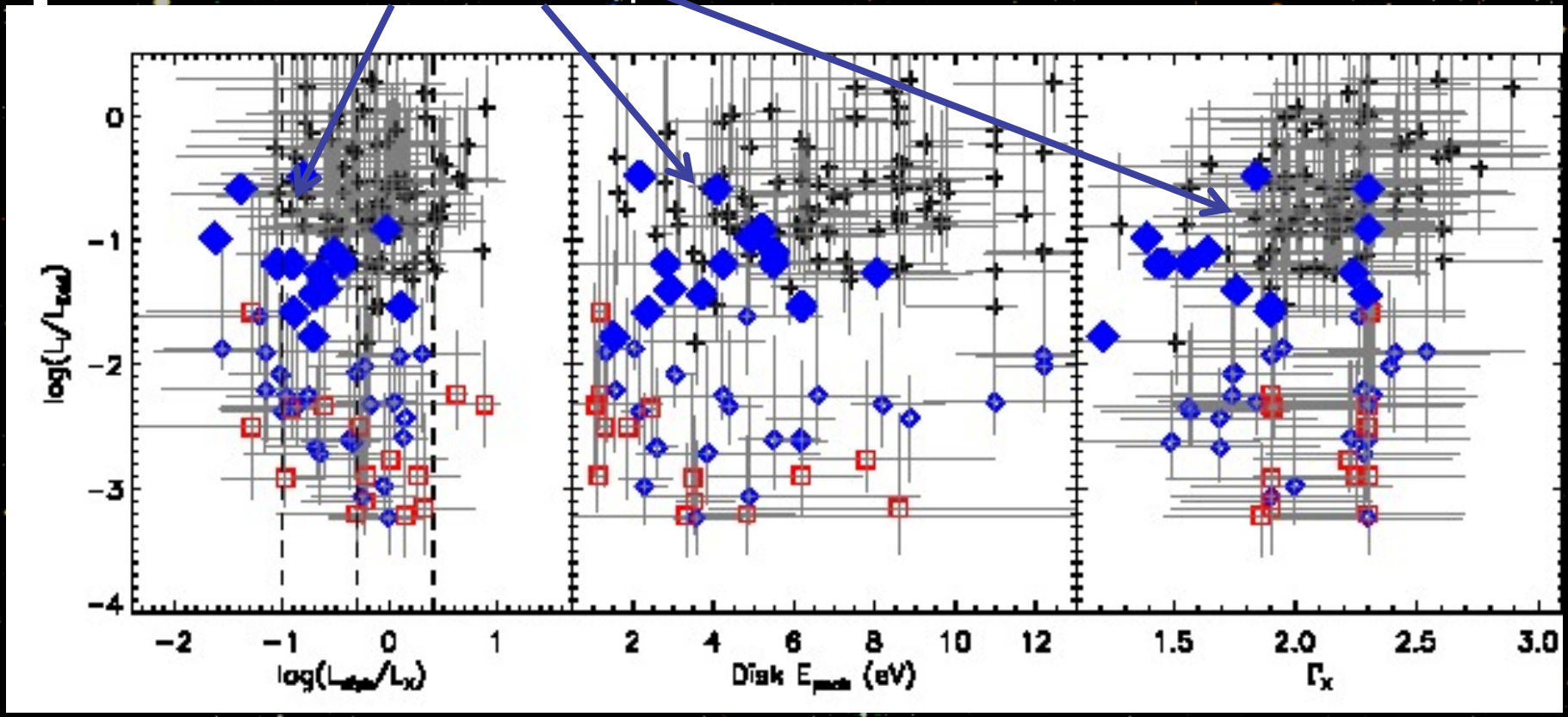
# Accretion Rate and Radio Jets

- Weakly accreting AGN are more radio-loud!
- Weak AGN may be more important for radio-mode feedback (e.g. heating cluster cores, IGM enrichment)



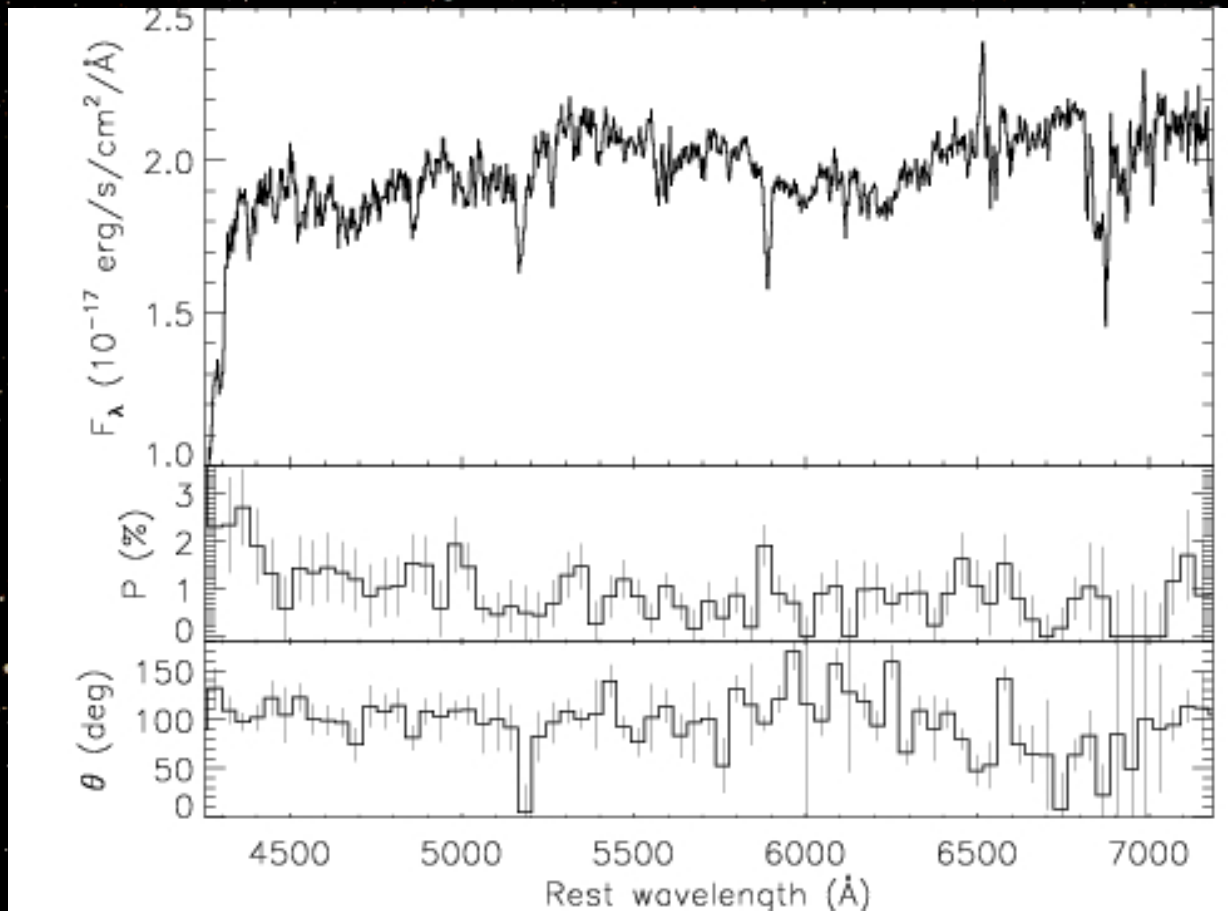
# What about Obscured AGN?

High $L_{int}/L_{Edd}$ like unobscured Type 1s
(using $L_{int} = 8L_{6\mu m}$, Richards+06)



# Radio Jets and Polarization

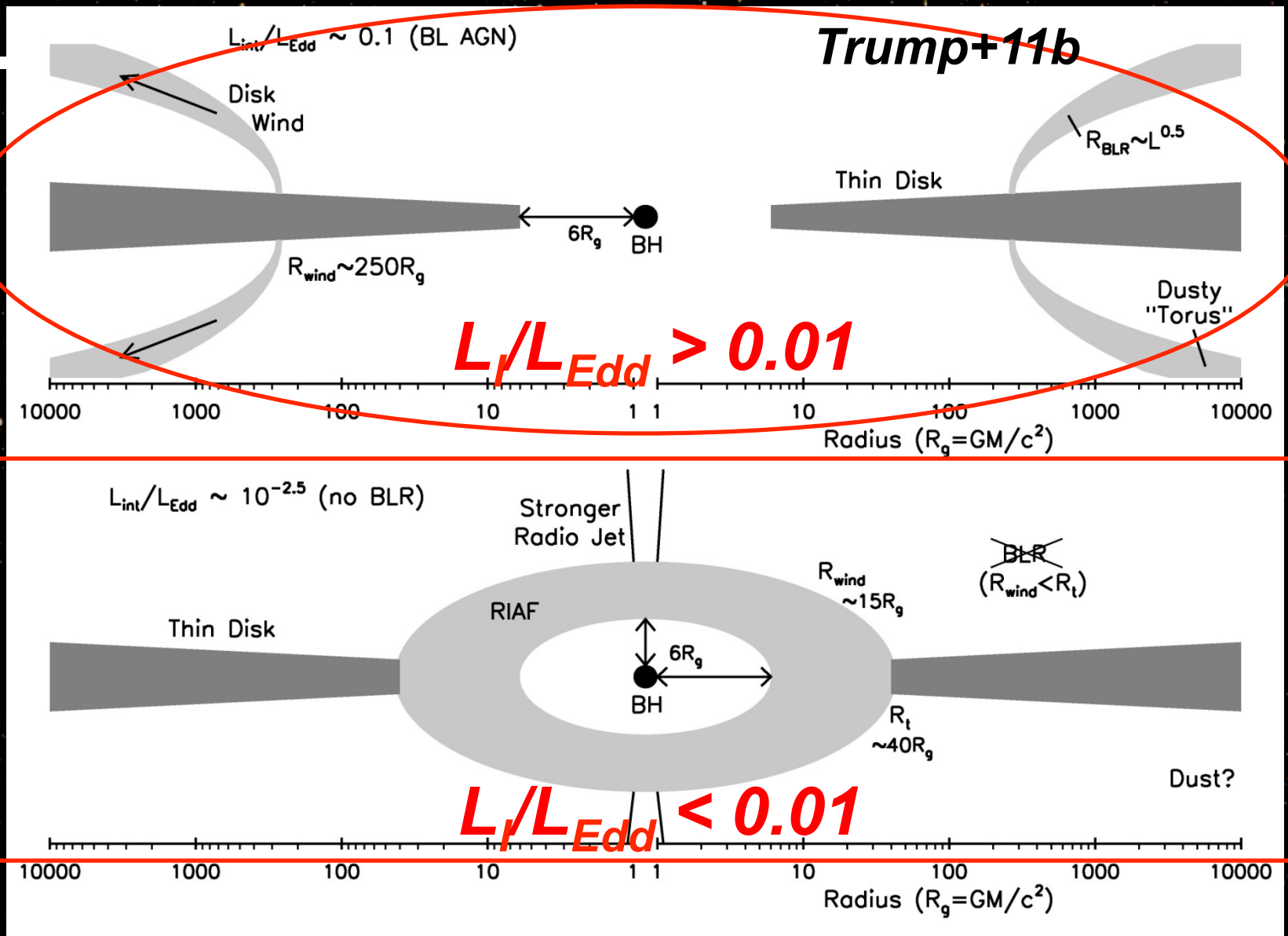
- Sychrotron emission from a radio jet results in polarized continuum emission
- Subaru / FOCAS (***Trump+11a***)
- One ADAF candidate AGN has P=1.4±0.2%
- Matches well with BL Lac



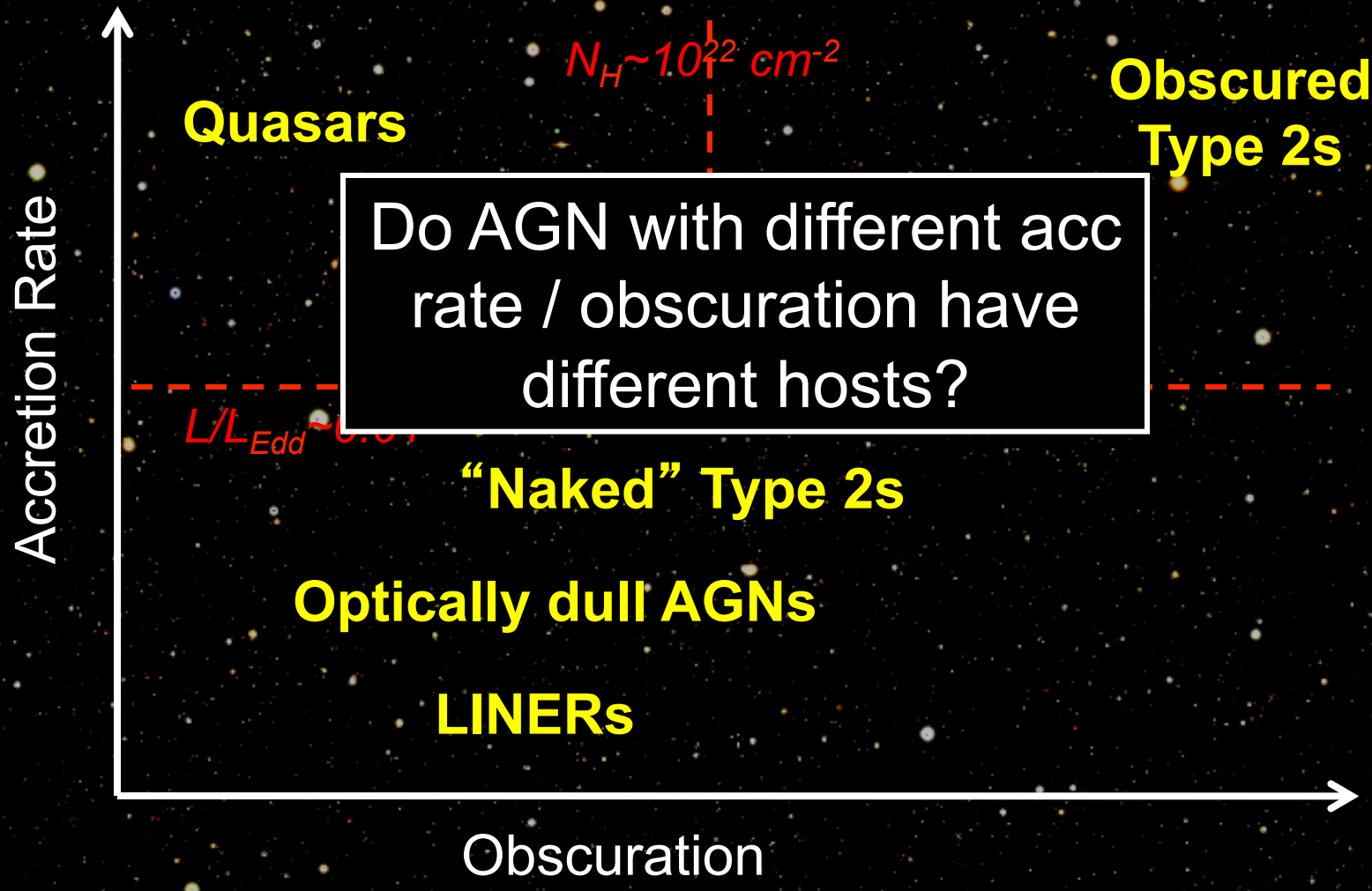
# AGN Fueling

- With decreasing accretion rate ($L_{int}/L_{Edd}$)…
  - Disk luminosity decreases compared to X-rays
  - Disk becomes cooler
  - Stronger radio outflows
  - No IR “torus” signature
  - Broad emission lines & obscured Type 2 AGNs disappear (at $L_{int}/L_{Edd} < 0.013\ (R_t/80R_g)\ M_8^{-1/8}$)
- Accretion rate is an axis of AGN unification!
  - At low accretion rates, theory predicts an advection dominated accretion flow (ADAF) which can produce these effects (Narayan & McClintock 2008)

# Accretion in AGN Unification

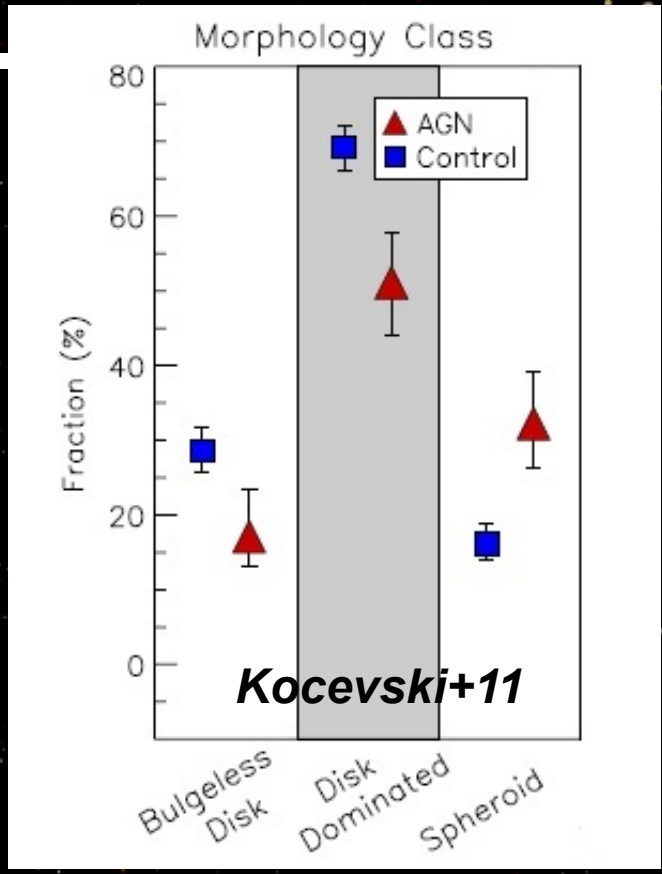


# Two Axes in AGN Unification



# Are Active Galaxies Disks or Spheroids?

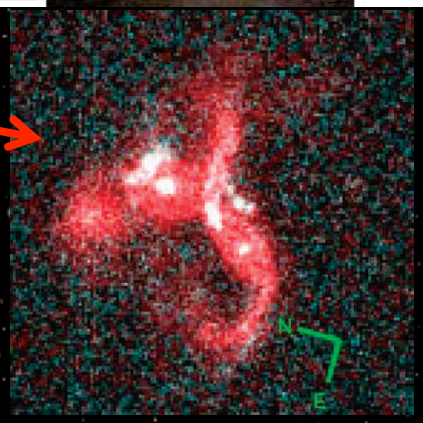
- AGNs are frequently in disks! (e.g. ***Gabor+09***)
- But, AGNs are more typically in spheroids… and spheroid fraction increases with $L_{AGN}$
- Disks are unlikely to have recent merger (but see Robertson+06)




***Weak X-ray AGNs in disks, Luminous X-ray AGNs in spheroids***

# Do Mergers feed Quasars?

- ULIRG AGNs (Sanders+88, ***Kartaltepe+10***)
- Hard X-ray (Swift) AGN (Koss+10)
- BALQSOs (Urrutia +08)

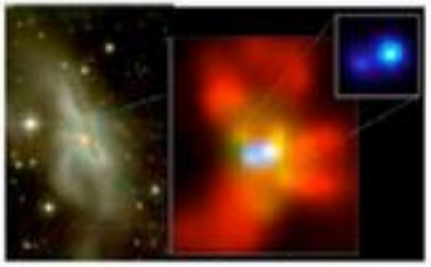



***All these are obscured, rapidly accreting, and local (z~0)***

(c) Interaction/"Merger"

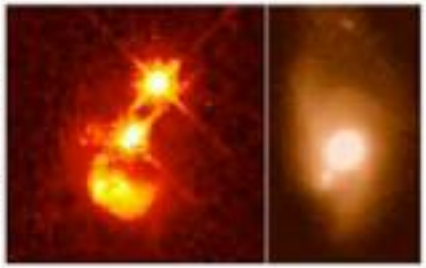

- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG



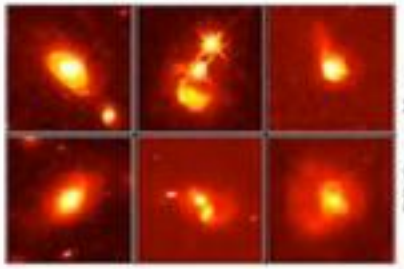

- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"




- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

(f) Quasar

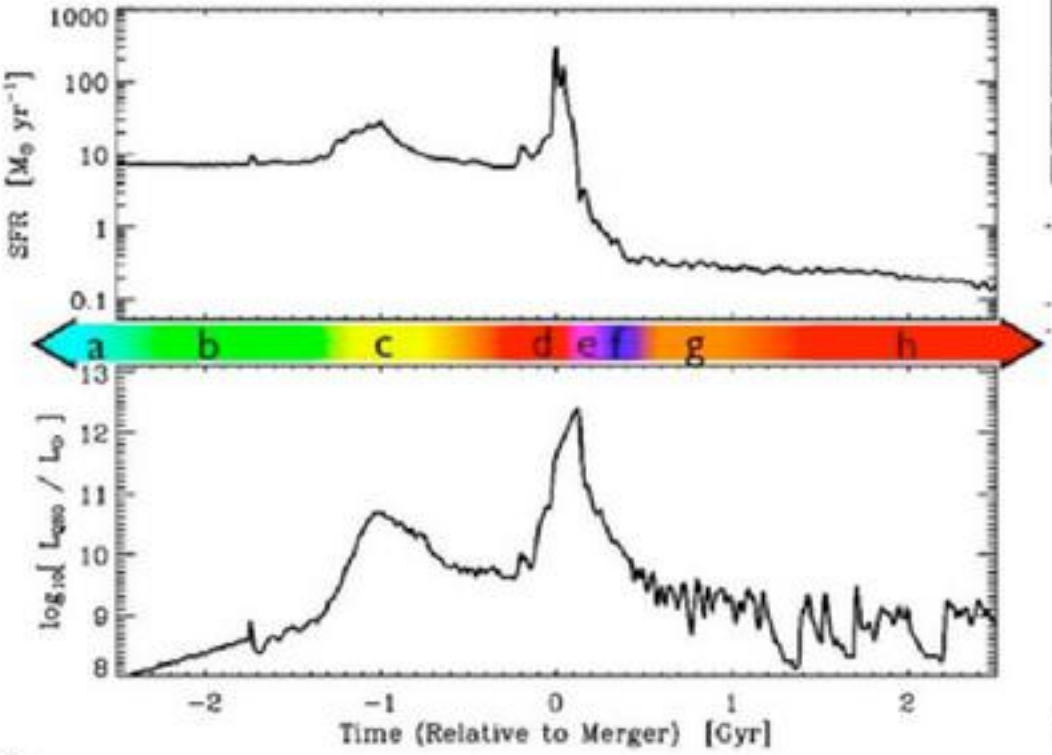



- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) "Small Group"


- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- $M_{halo}$ still similar to before: dynamical friction merges the subhalos efficiently

from Hopkins+06




(g) Decay/K+A


- QSO luminosity fades rapidly
  - tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
  - sets up quasi-static cooling

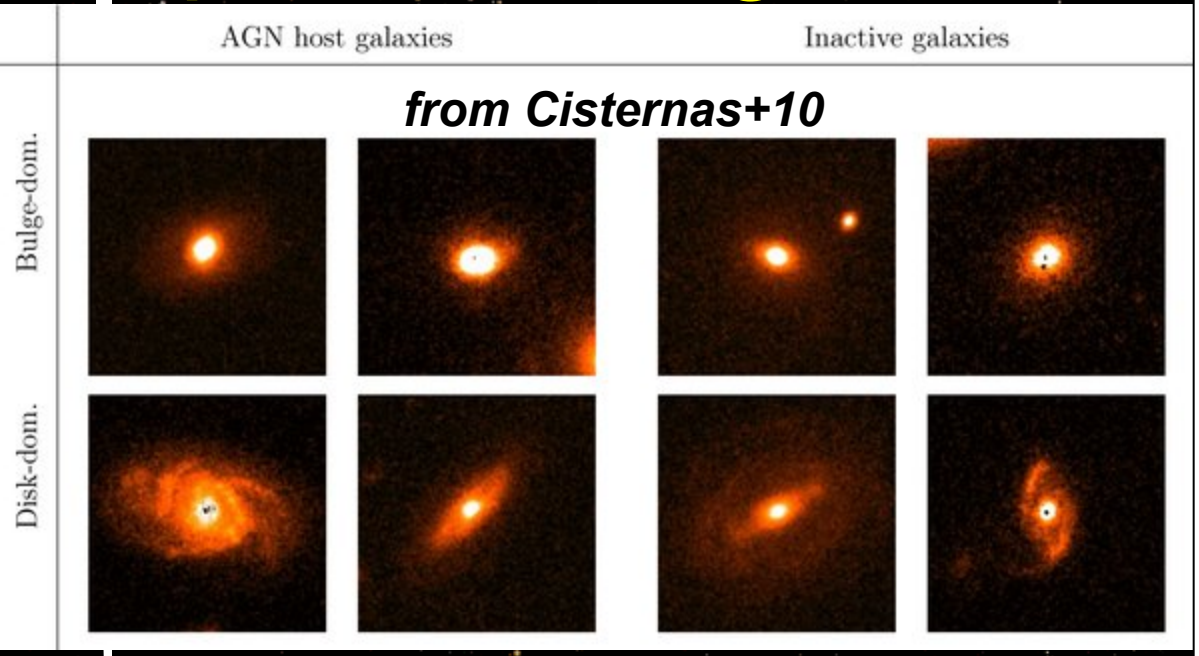
(a) Isolated Disk

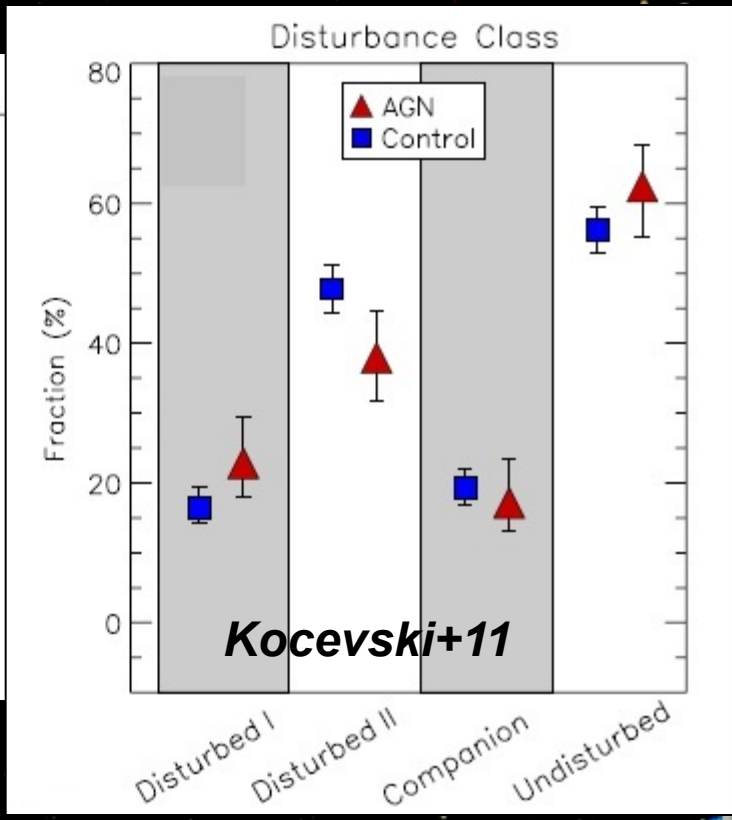

- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with $M_B$>-23)
- cannot redden to the red sequence

(h) "Dead" Elliptical


- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers

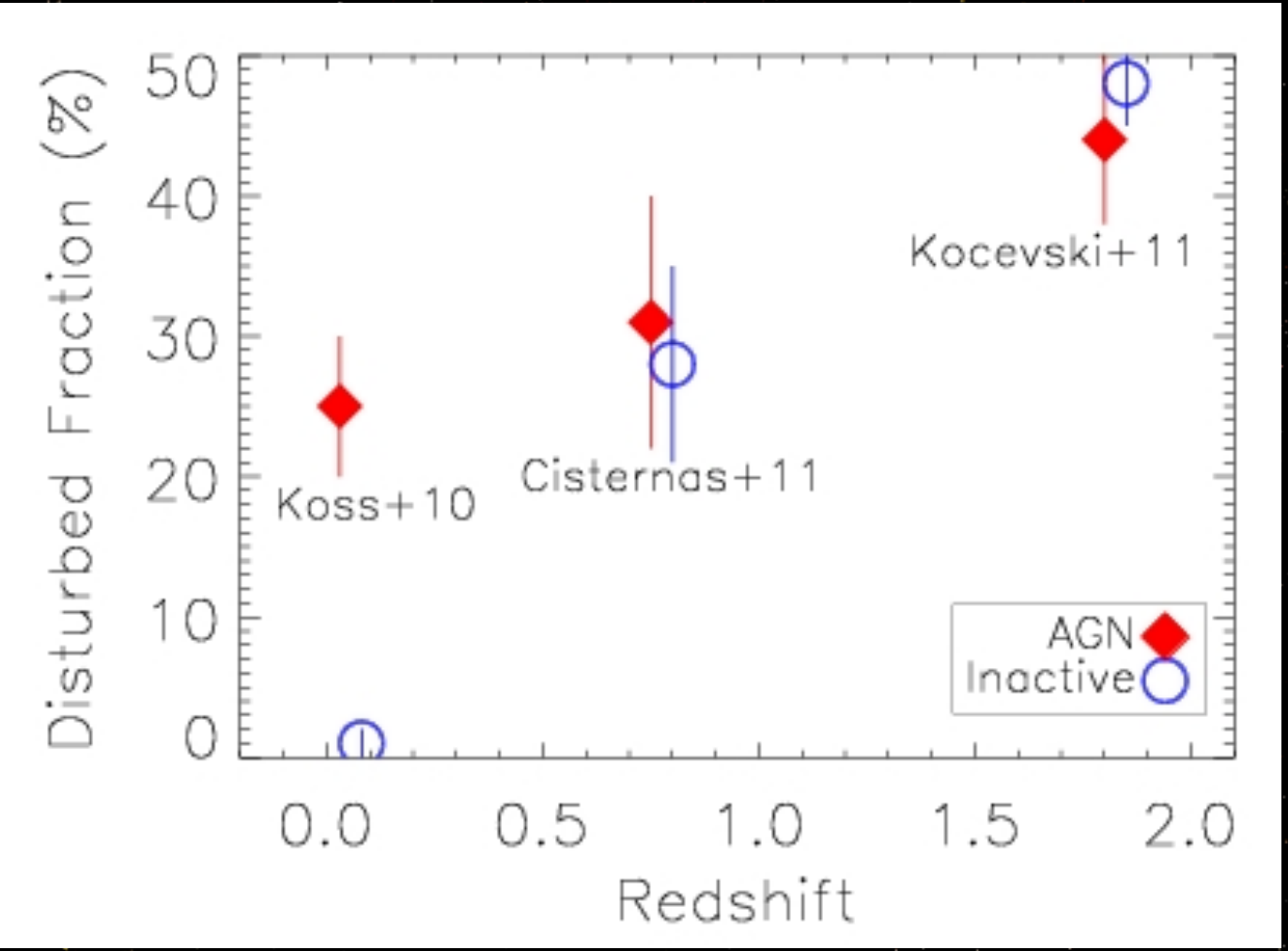
# X-ray AGNs at z>0 do not prefer mergers



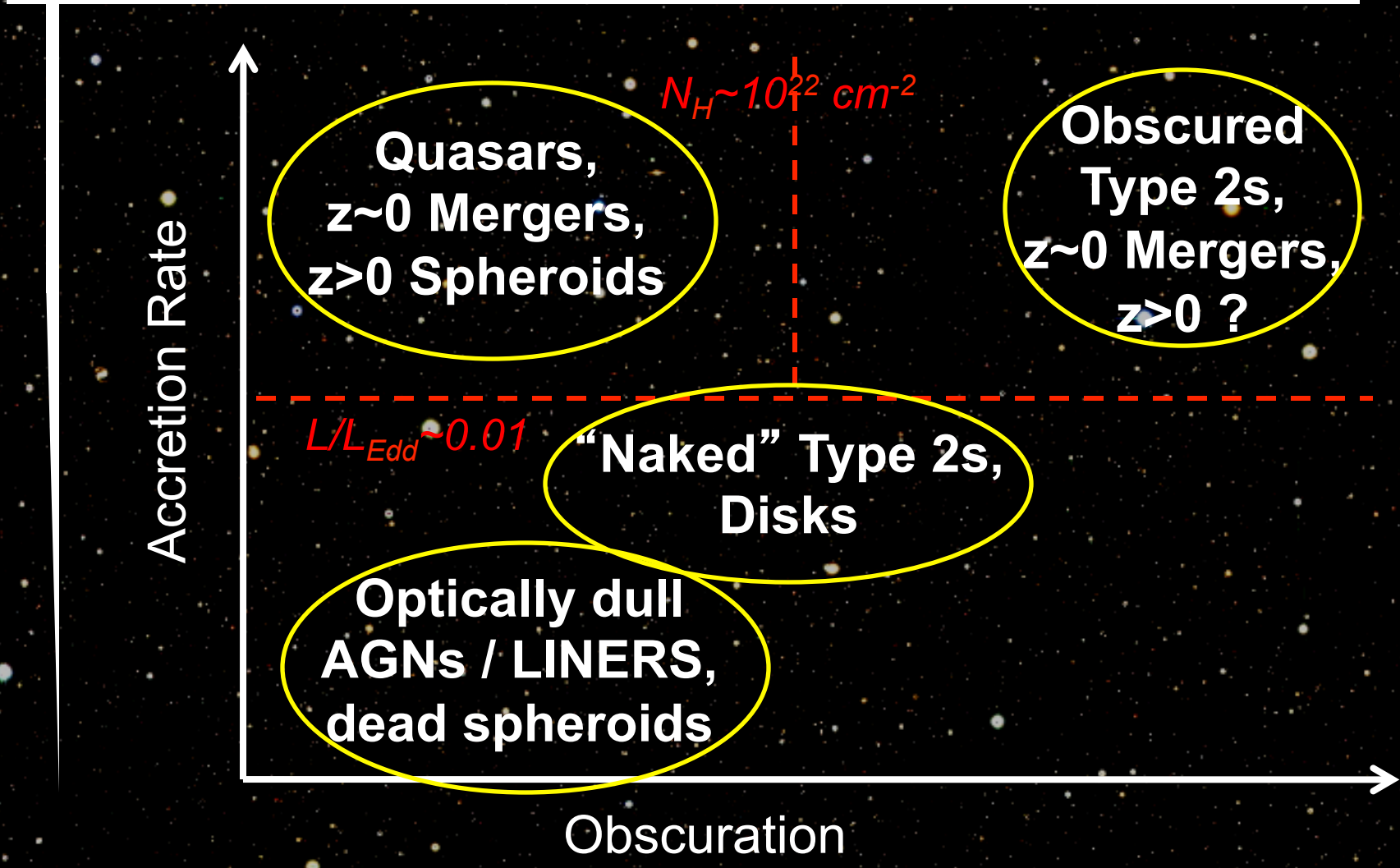




- Not in mergers!
- (Grogin+05, Pierce+07, ***Gabor+09***, ***Cisternas+11***)
- Is this because the AGN only appears after the merger is relaxed?

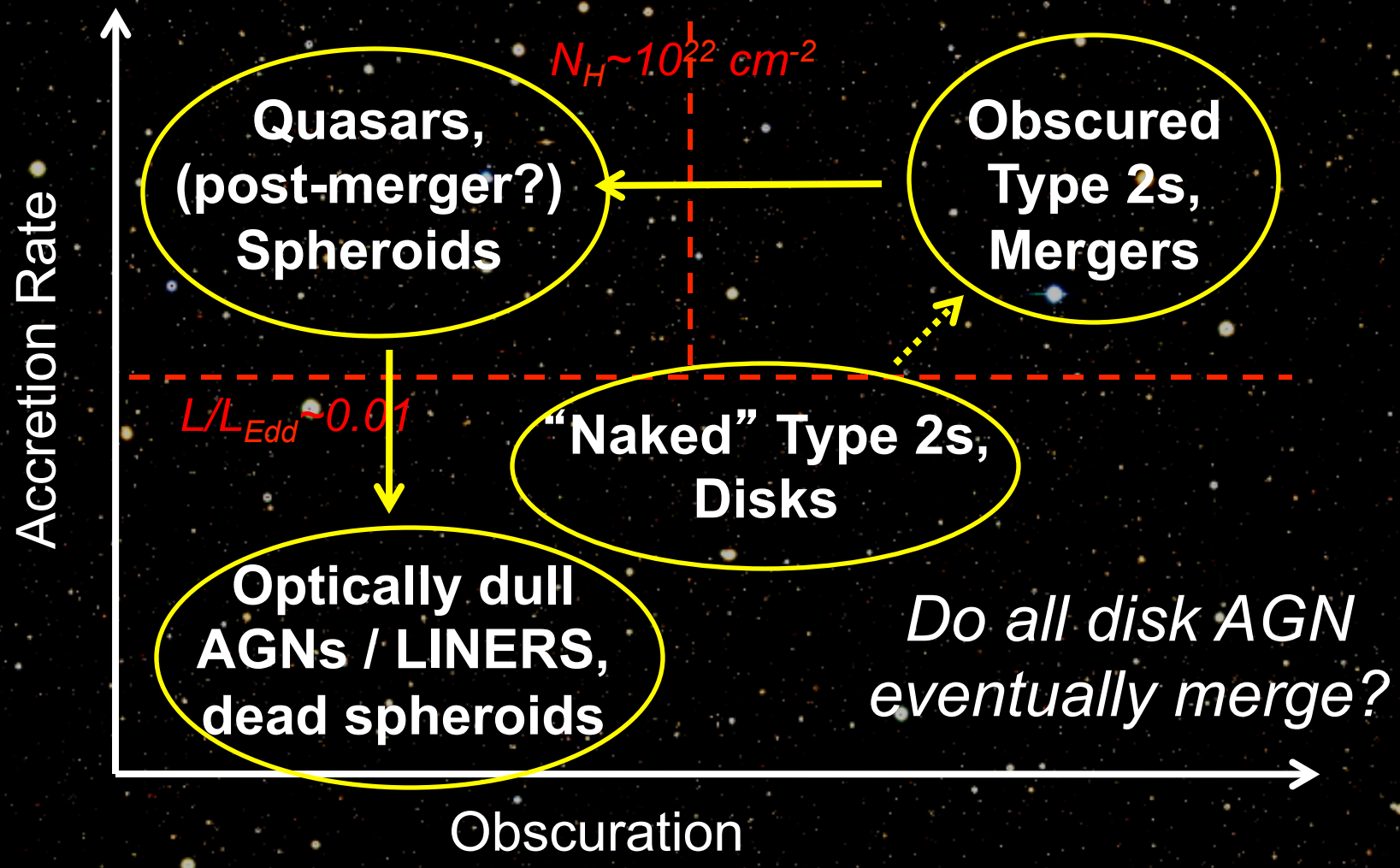
# Evolution in the Merger-AGN Connection?



# AGN Host Types

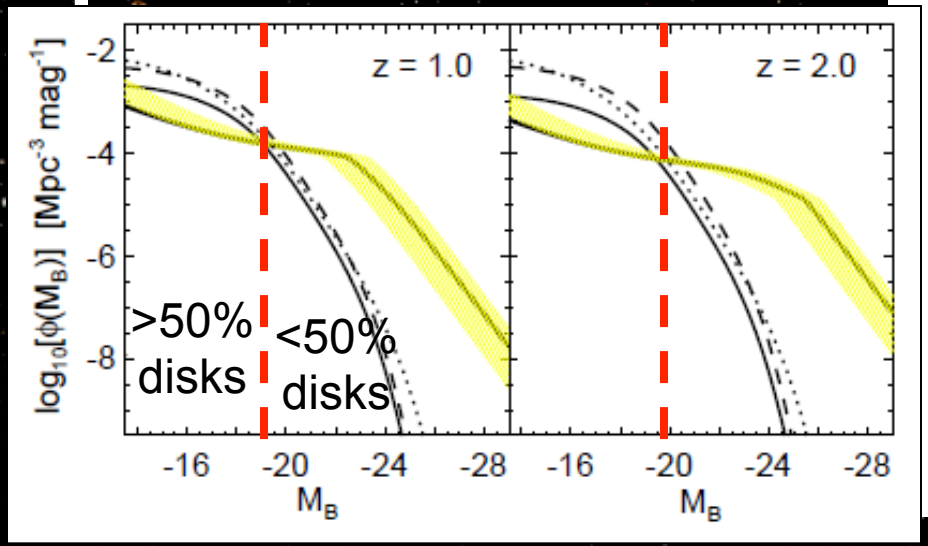


# AGN / Host Evolution

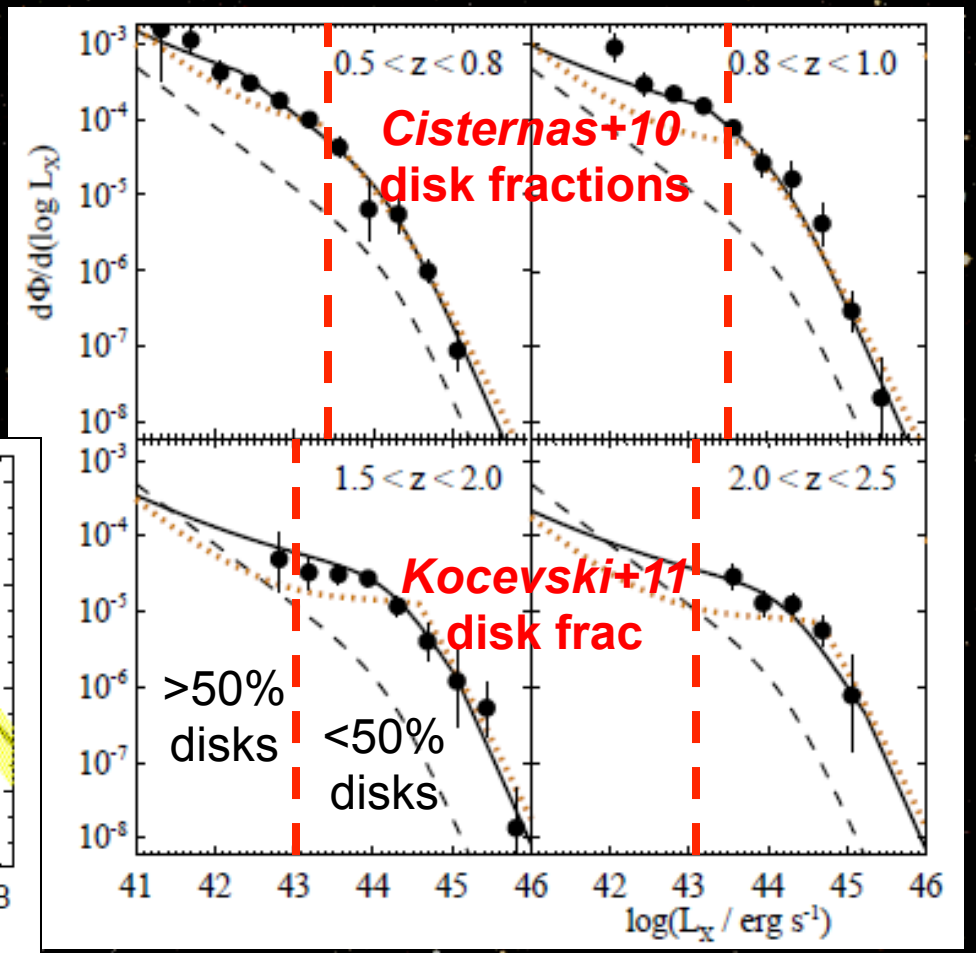


# How important is disk fueling?

- More disks than predicted (~40×)
- QSOs (& mergers?) still dominate XLF



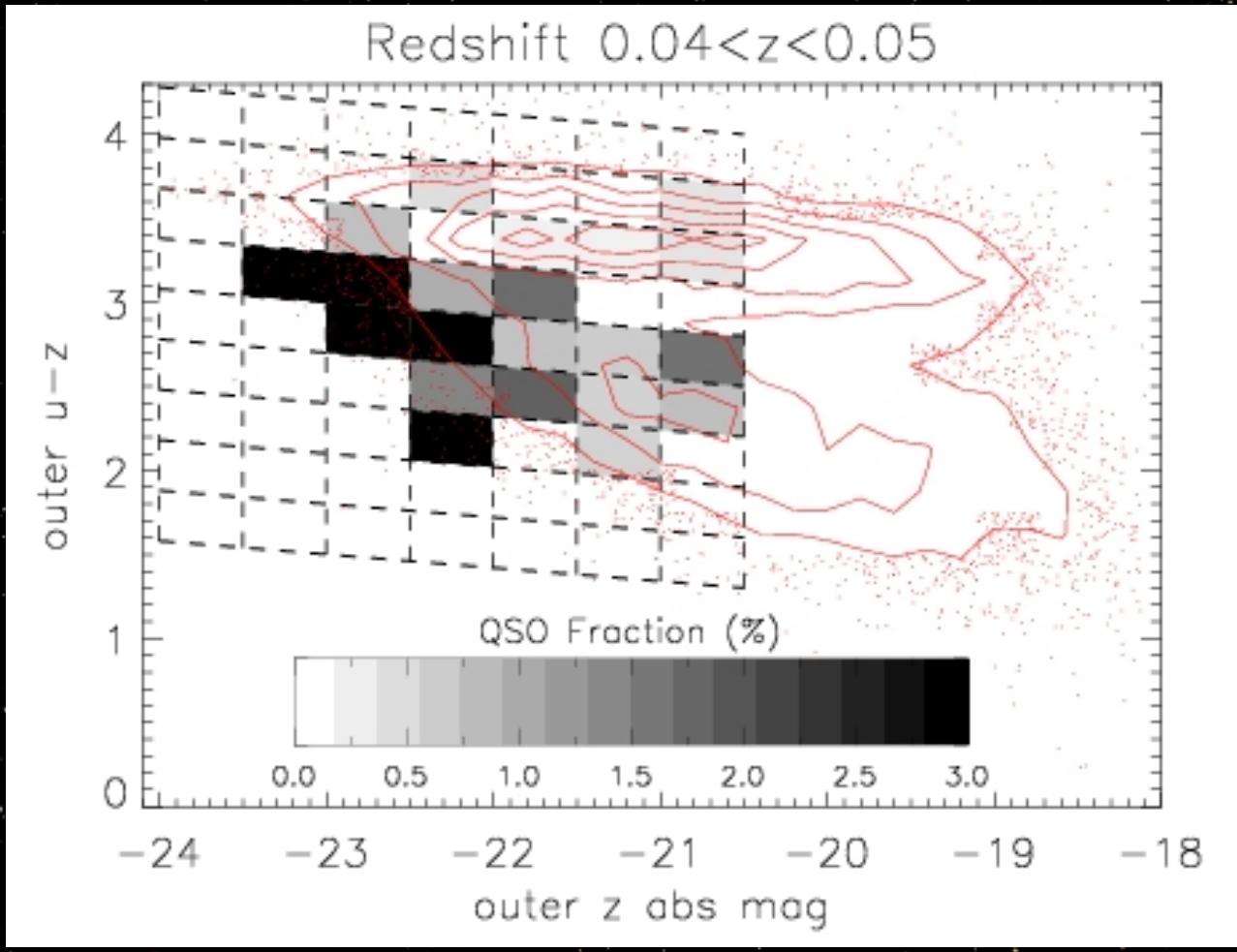

Hopkins & Hernquist 06 model




XLF from Aird+10

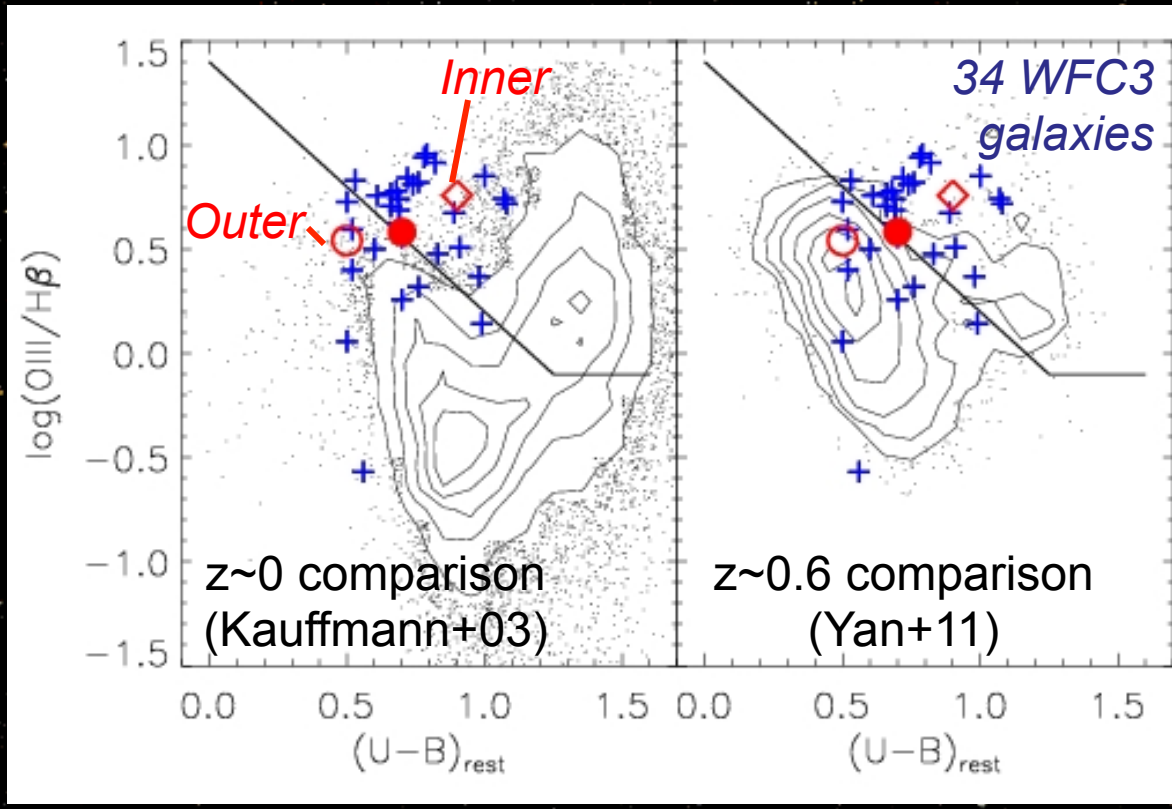
# QSO hosts are massive S0 / green valley, not red & dead

- QSO host galaxies from SDSS, with QSO point source removed
- *Trump & Hsu in prep.*



# AGN present in low-mass galaxies at z~2

- WFC3 slitless grism
- z~2 galaxies typically have AGN ratios in stacked core!
- Similar result from Wright+10 (1 galaxy)
- Also see recent Aird+11 paper




***Trump+11c***

# Summary

Accretion Rate: new axis in AGN Unification

- Low accretion rate: ADAF at inner radii
- ADAF: radio-loud, cooler + weaker disk, different IR, BLR disappears
- Rapid accretion / obscured -> merger
- Rapid accretion / unobscured -> spheroid
- Weak accretion (“naked” Type 2) -> disk