

# Investigating the AGN-Merger Connection at $z \sim 2$ with CANDELS

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with

Sandra Faber, Harry Ferguson, Paul Nandra,  
Rachel Somerville, Anton Koekemoer, David Alexander

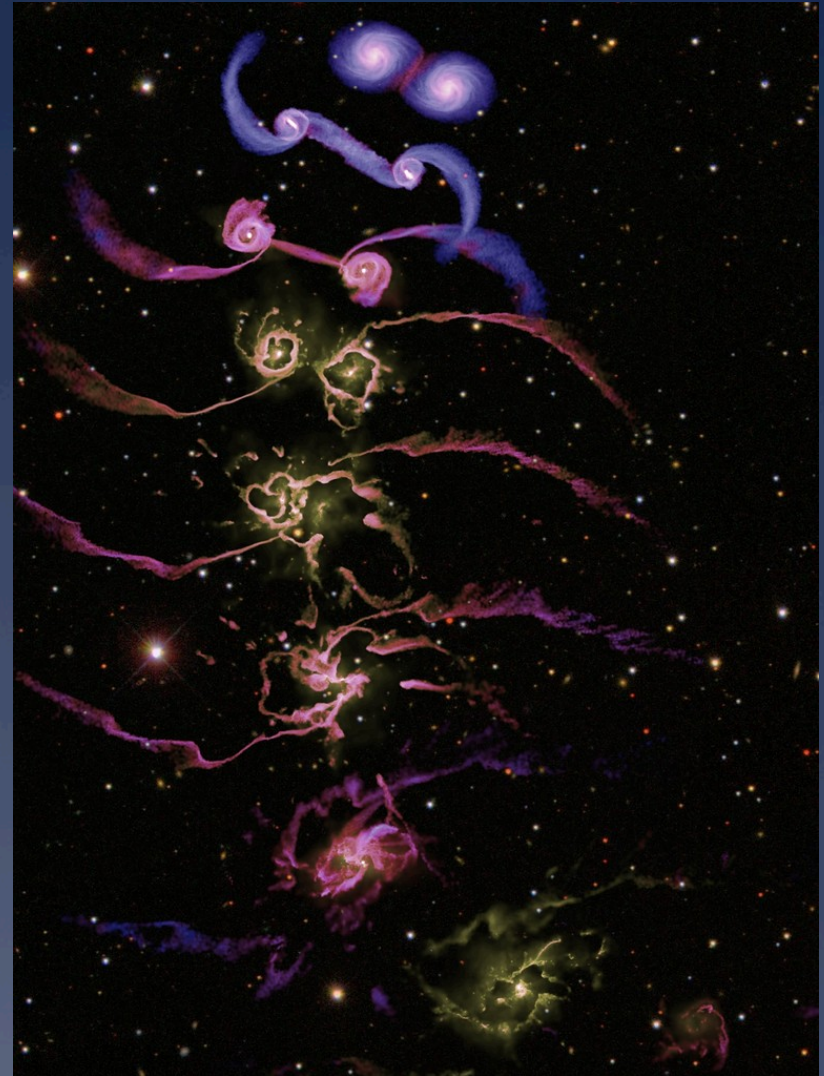
+

The CANDELS Team

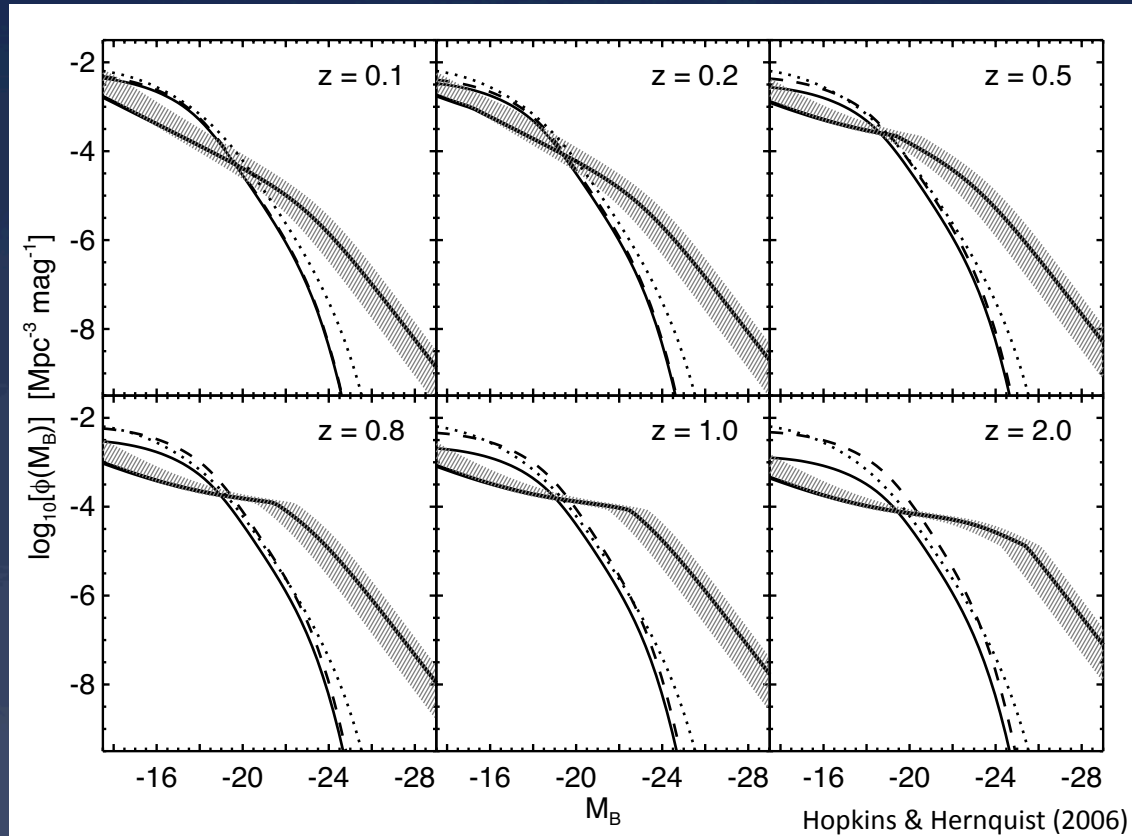
including Jen Lotz, Stijn Wuyts, Elizabeth McGrath,  
Dan McIntosh, Jeyhan Kartaltepe, Arjen van der Wel

## Background

- \* Mergers have long been an attractive AGN fueling mechanism.
- \* Would help explain scaling relations between BH mass and bulge mass and velocity dispersion.
- \* Previous searches failed to find a convincing AGN-merger connection out to  $z \sim 1$ .
- \* Especially true for moderate-luminosity AGN, many of which are found in normal spirals.

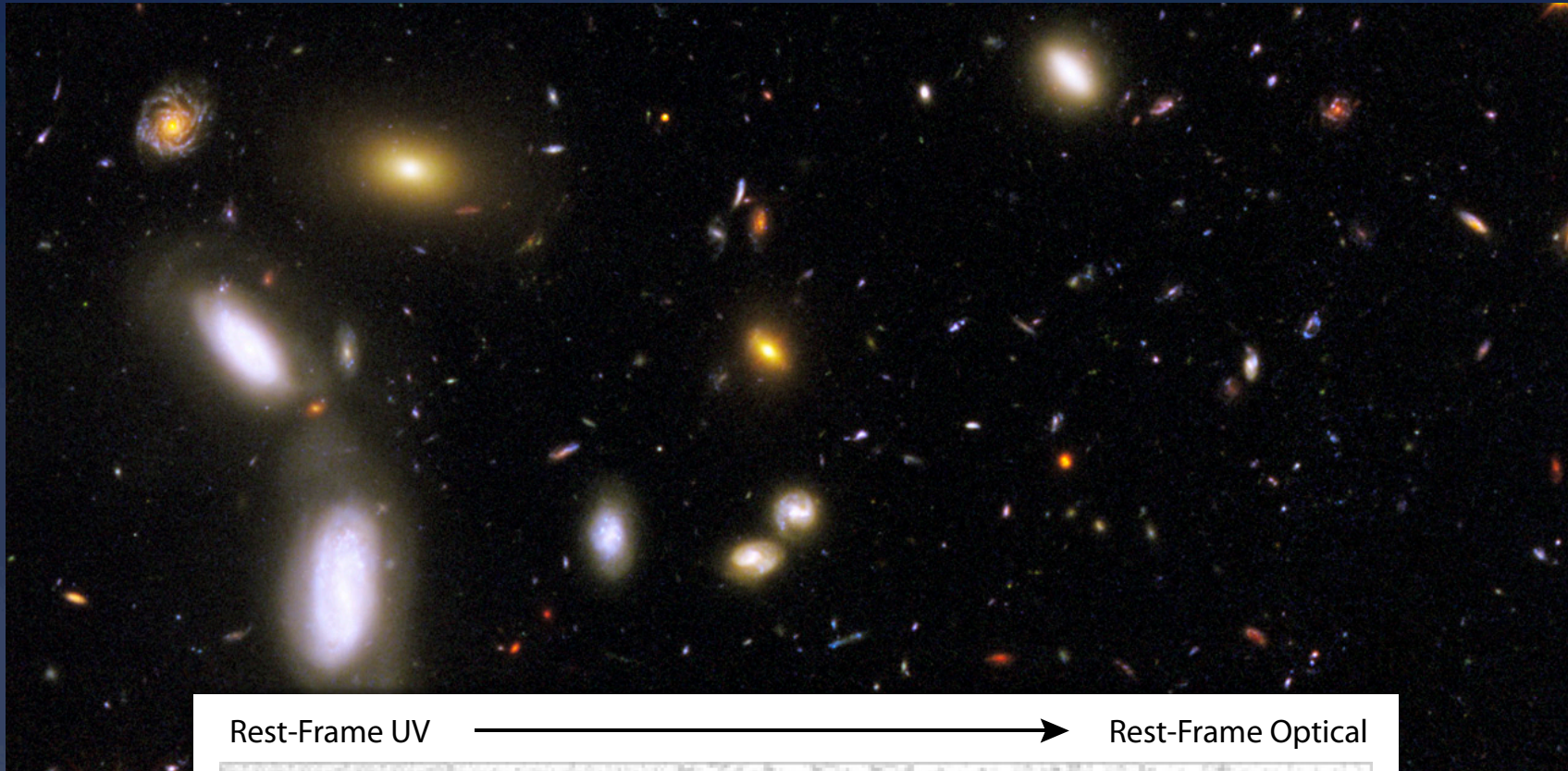


## Evolution of AGN Fueling Modes

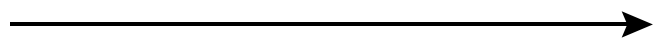


- \* Two fueling modes: merger-driven accretion & stochastic accretion
- \* Frequency of merger-driven accretion evolves rapidly with redshift. At  $z \sim 2$ , mergers expected to be dominant fueling mode.

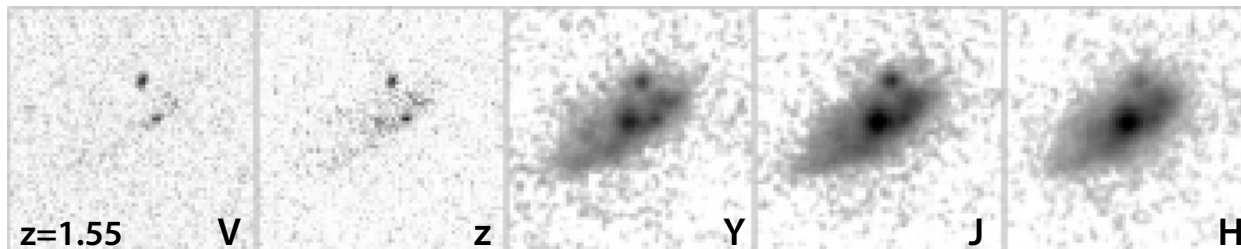
# Wide Field Camera 3



Rest-Frame UV

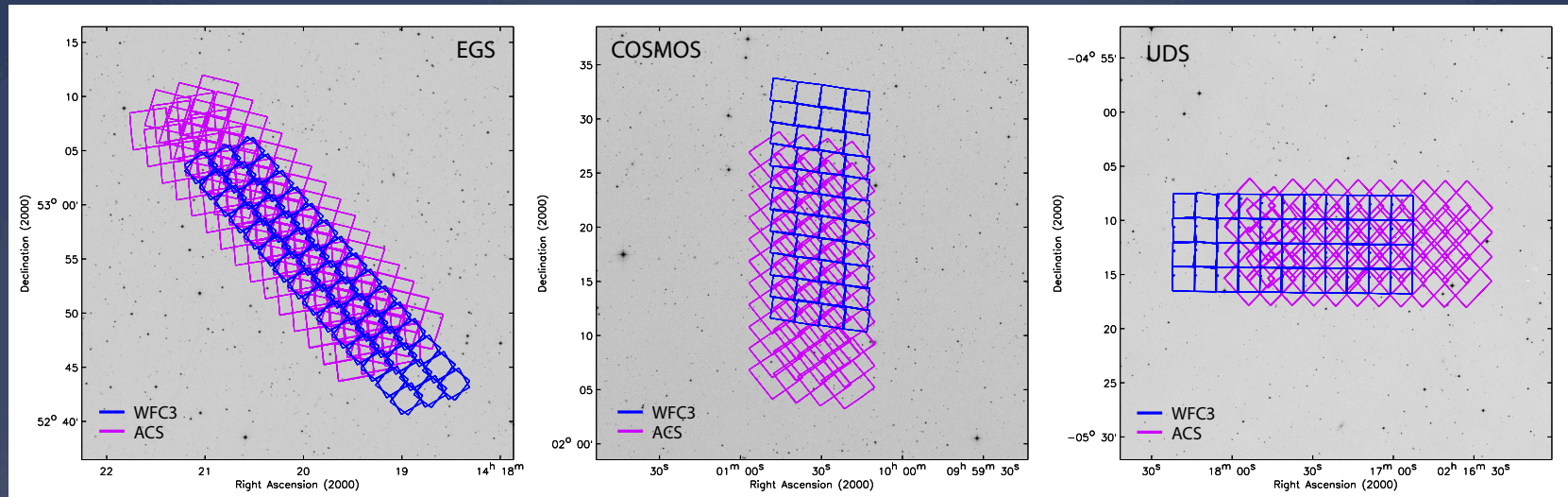


Rest-Frame Optical



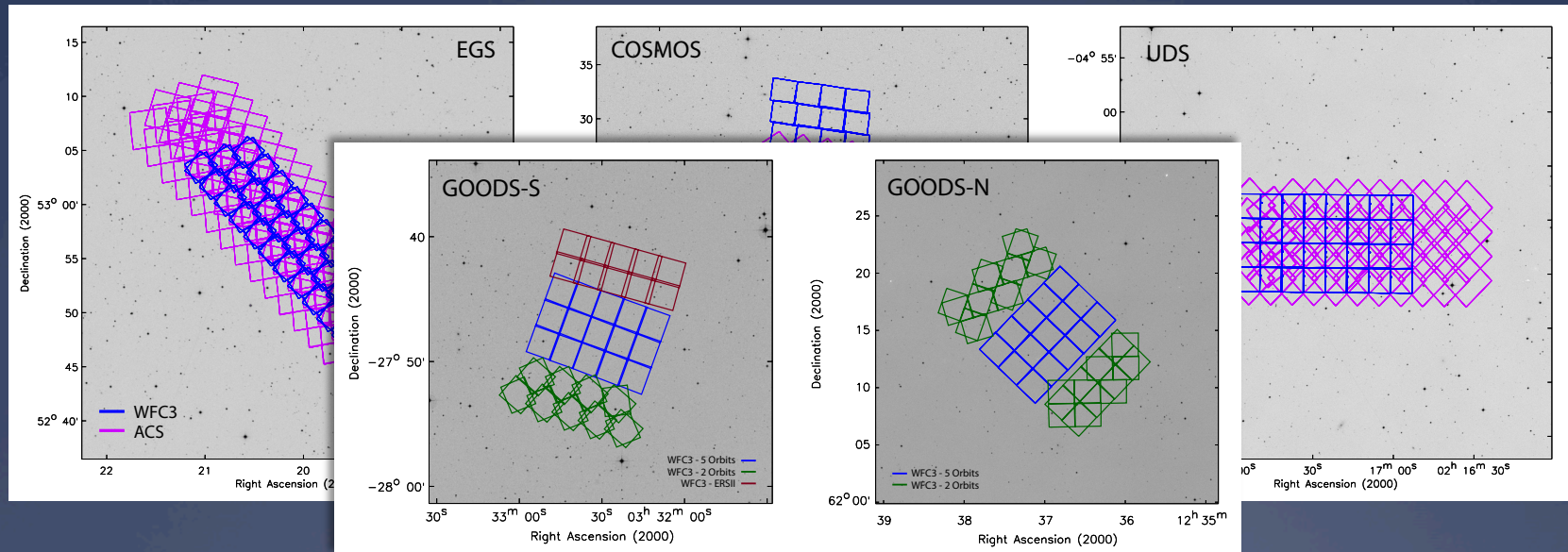
# The CANDELS Project

- \* Pre-Cycle 18 Multi-Cycle Treasury Program (Grogin et al. 2011)
- \* WFC3 Imaging Survey of Five Fields
  - \* Wide: EGS, COSMOS, & UKIDSS/UDS - (1 orbit depth J & H)
  - \* Deep: GOODS-S + GOODS-N - (4 orbit depth Y, J & H)
- \* 902 orbits allocated:
  - \* Largest project carried out with HST to date



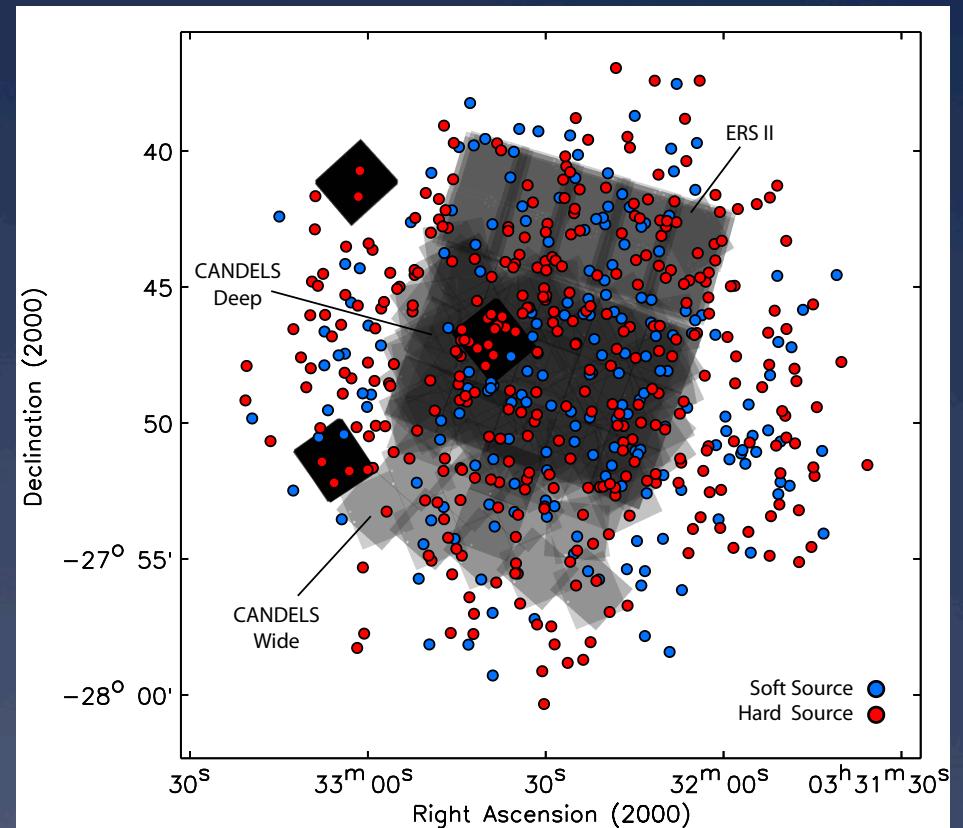
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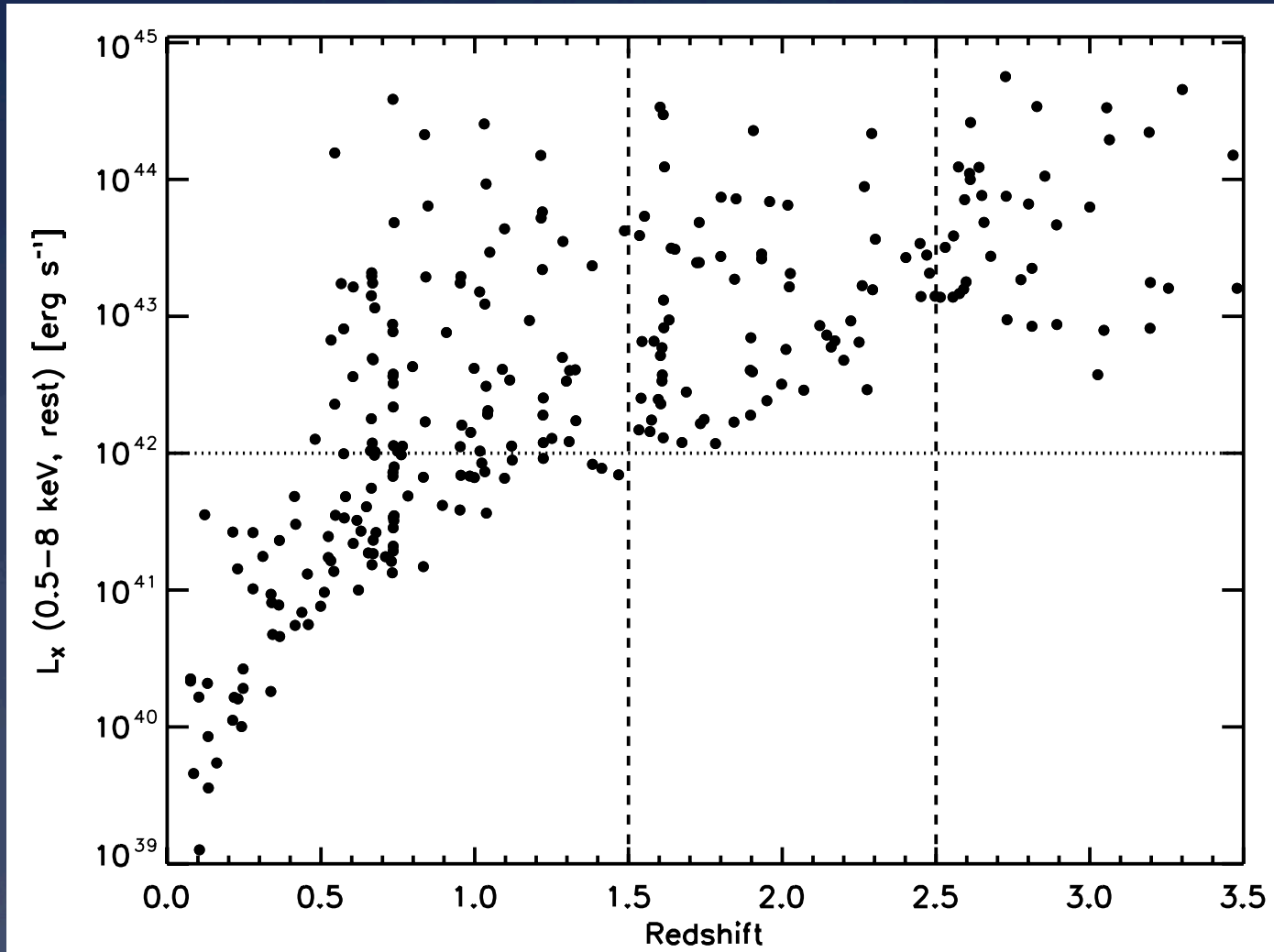


## X-ray AGN in GOODS-S

- \* Selected  $z \sim 2$  AGN using:
  - \* CANDELS WFC3 H-band imaging.
  - \* Chandra 4 Msec dataset in CDFS. Deepest X-ray data available.
- \* Nandra et al. 4Ms source catalog contains 569 sources in CDFS.
- \* Likelihood Matched to WFC3 H-band catalogs.
- \* Redshift Determination:
  - \* Silverman et al. (2010) – Spect-z
  - \* Wuyts et al. (2010) – Photo-z
- \* Results in 72 AGN at  $1.5 > z > 2.5$ .



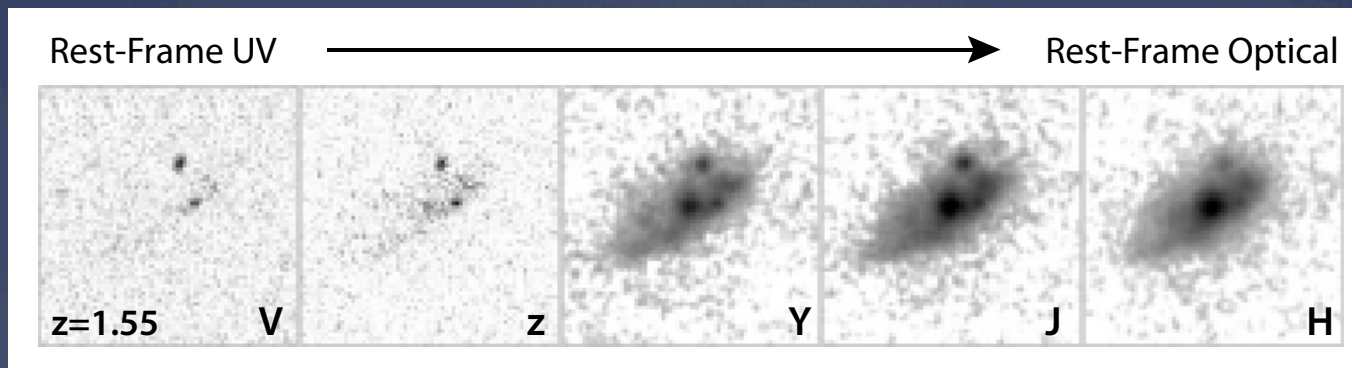
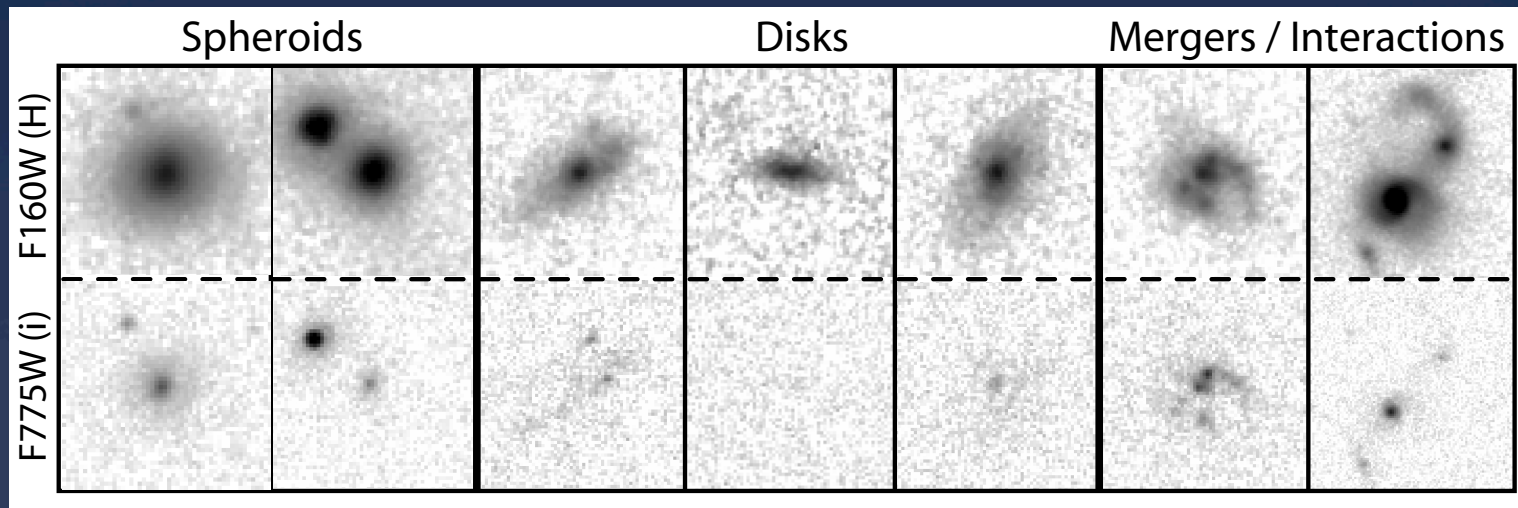
# X-ray Luminosity Distribution



Luminosity limit at  $z \sim 2$ :  $L_x \sim 10^{42}$  erg/s



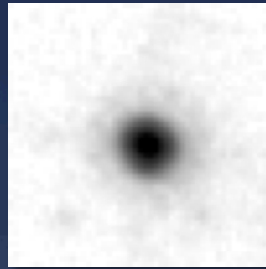
# Host Morphologies



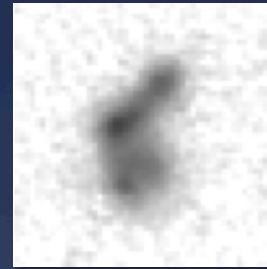
# Visual Classifications



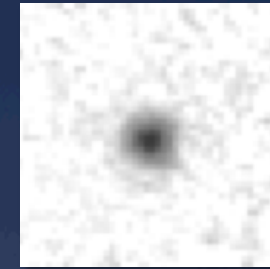
Disk



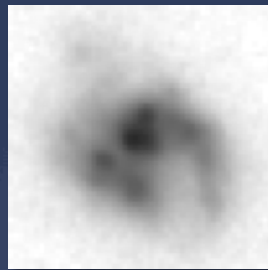
Spheroid



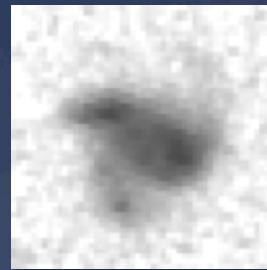
Irr / Pec



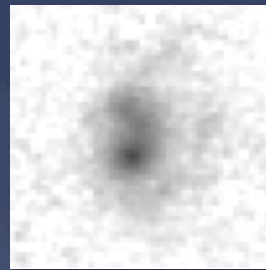
Compact



Merger



Interaction



Disturbed



2x Nuclei

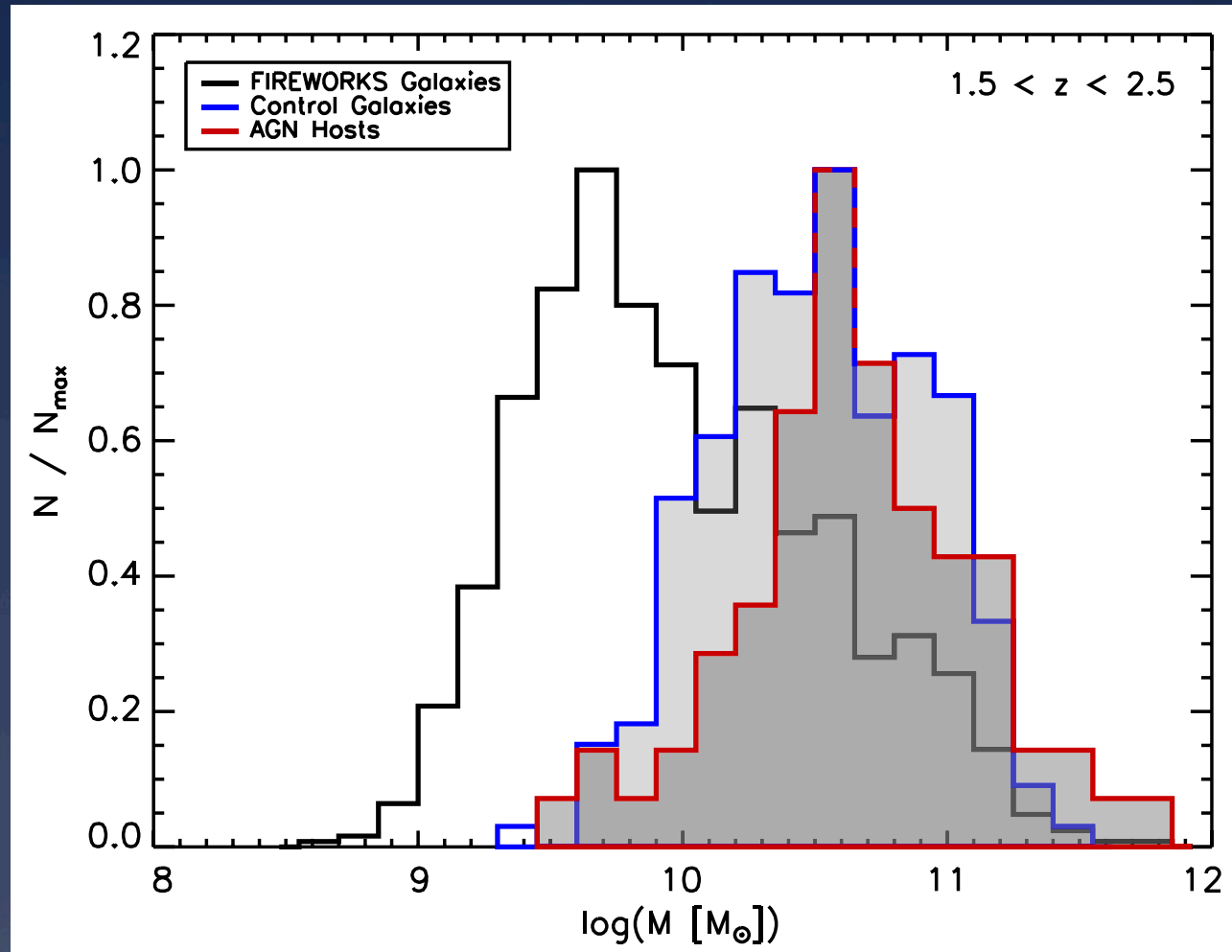


Close Pair

## Classifiers:

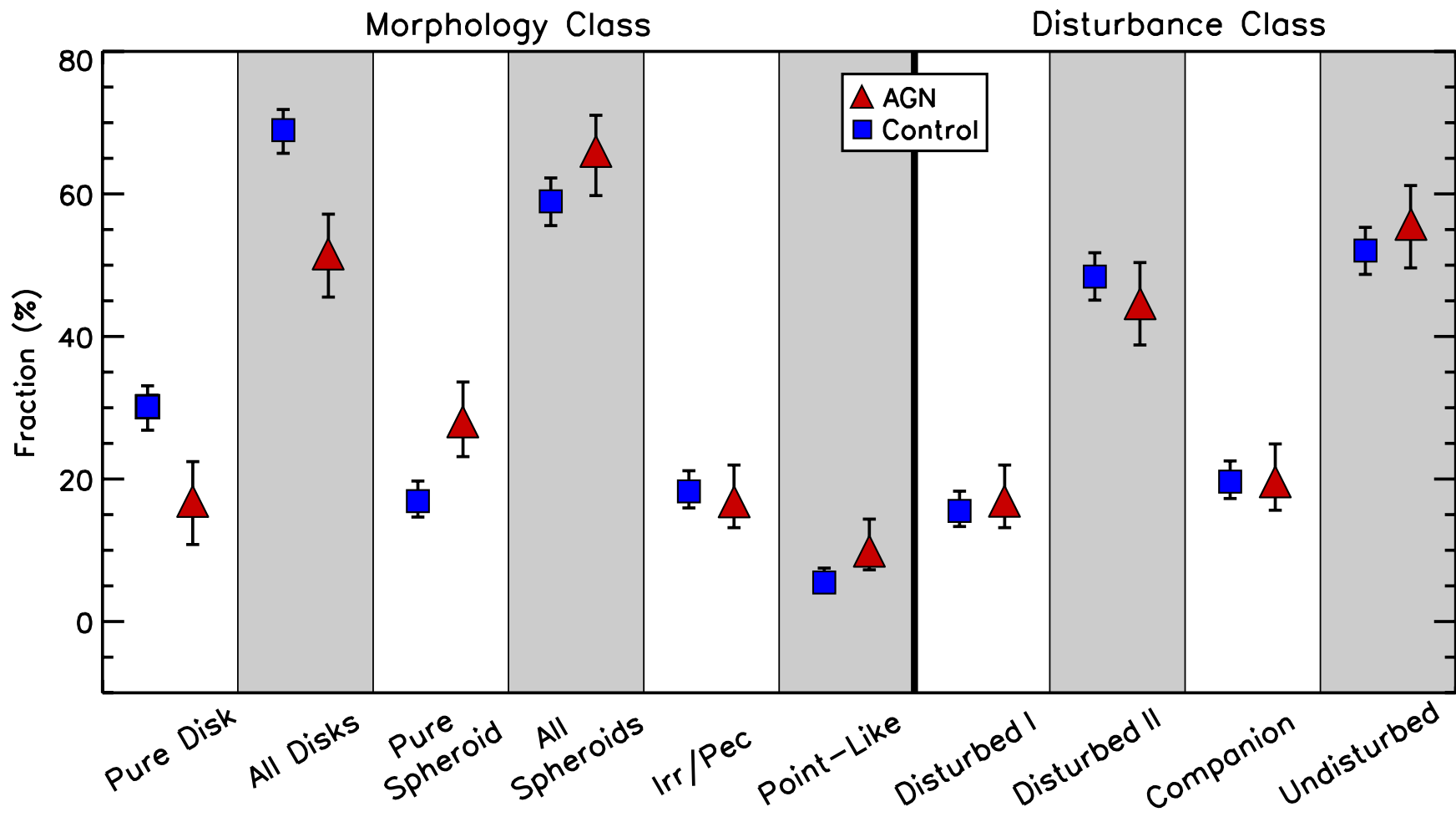
Sandy Faber, Jon Trump, Mark Mozena, Liz McGrath,  
Jeyhan Kartaltepe, Chris Conselice, Jenn Donley,  
Amber Straughn, Ray Lucas, Caroline Villforth,  
Stephanie Juneau, Kamson Lai, Aday Robaina,  
Anton Koekemoer, Norm Grogan.

## Mass-Matched Control Sample



\* Compared against 216 mass-matched control galaxies: ( $M_{\text{Host}}/2 < M_{\text{Gal}} < 2M_{\text{Host}}$ ).

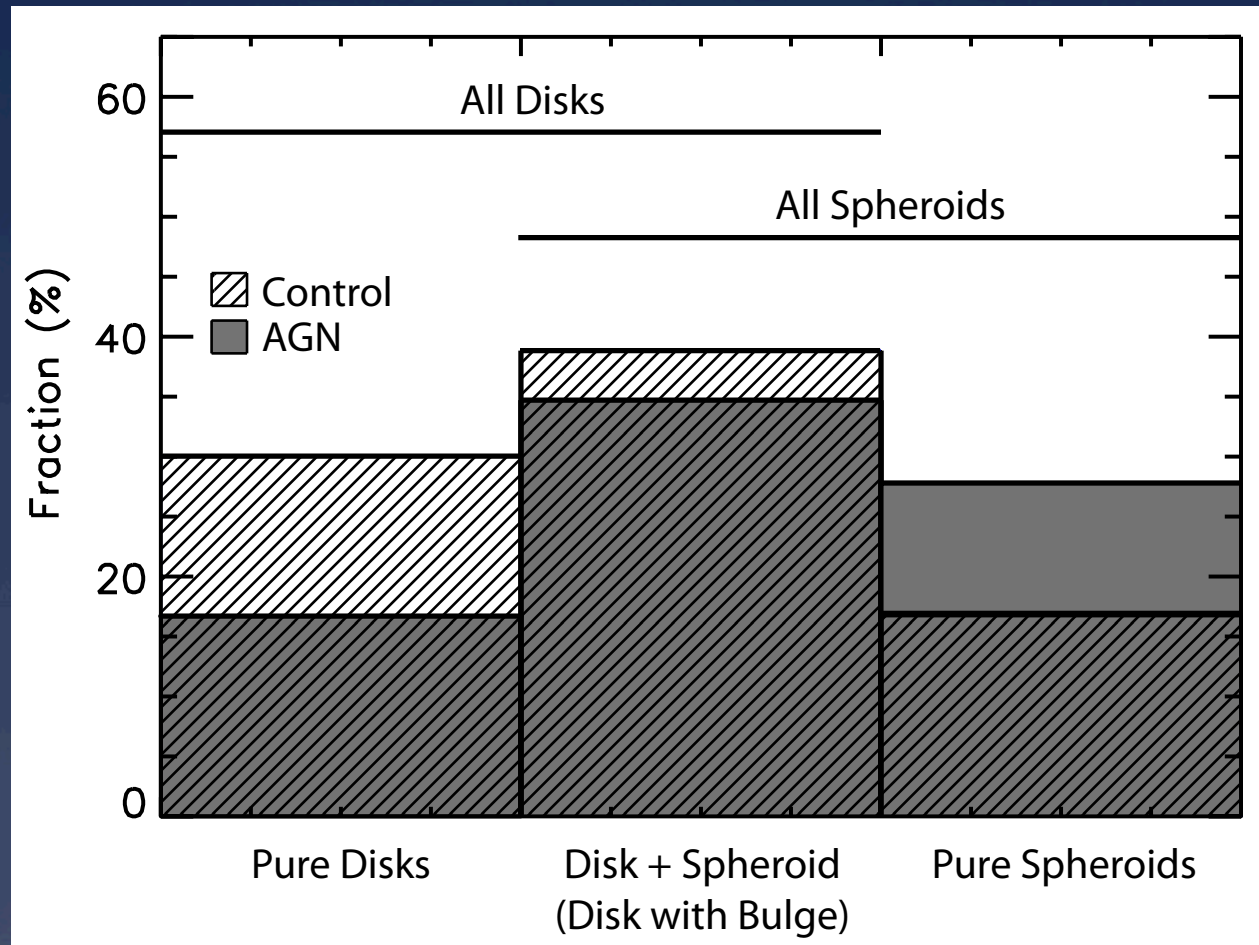
# Classification Results



- \* No excess of disturbed morphs among AGN hosts vs control.
- \* Majority of hosts undisturbed.

- \* Disk most common single morphology for AGN hosts.
- \* AGN associated with spheroids more often control galaxies.

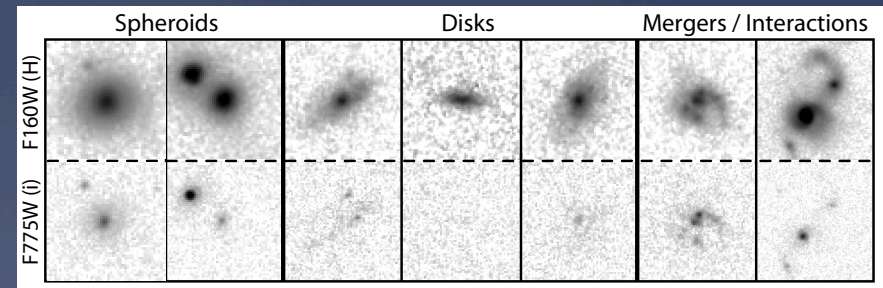
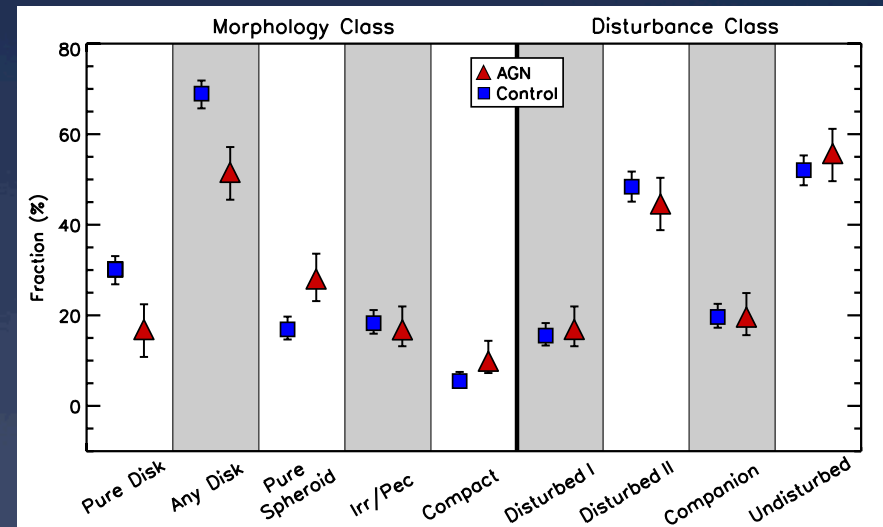
## AGN Still Favor Spheroids



- \* Even in an era where the mass-morphology relationship appears to break down, AGN still preferentially found in spheroidal systems.

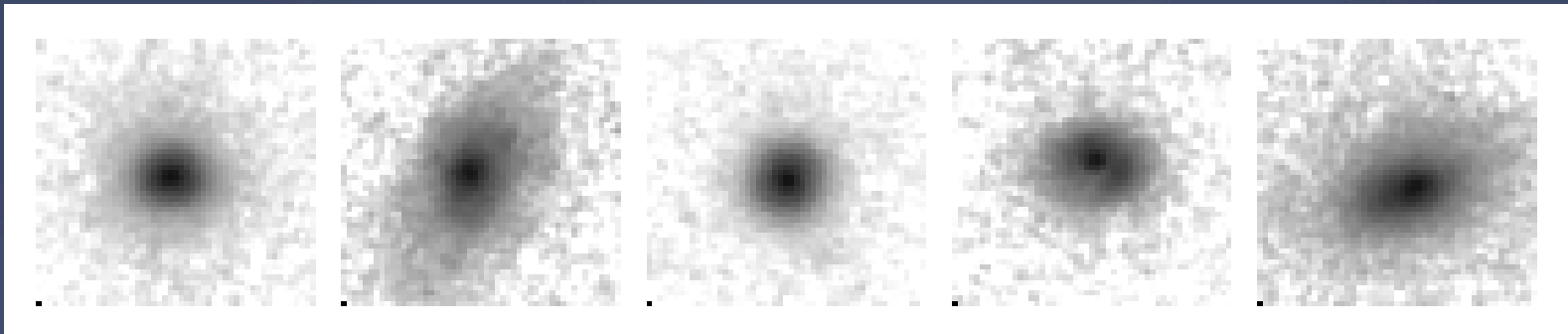
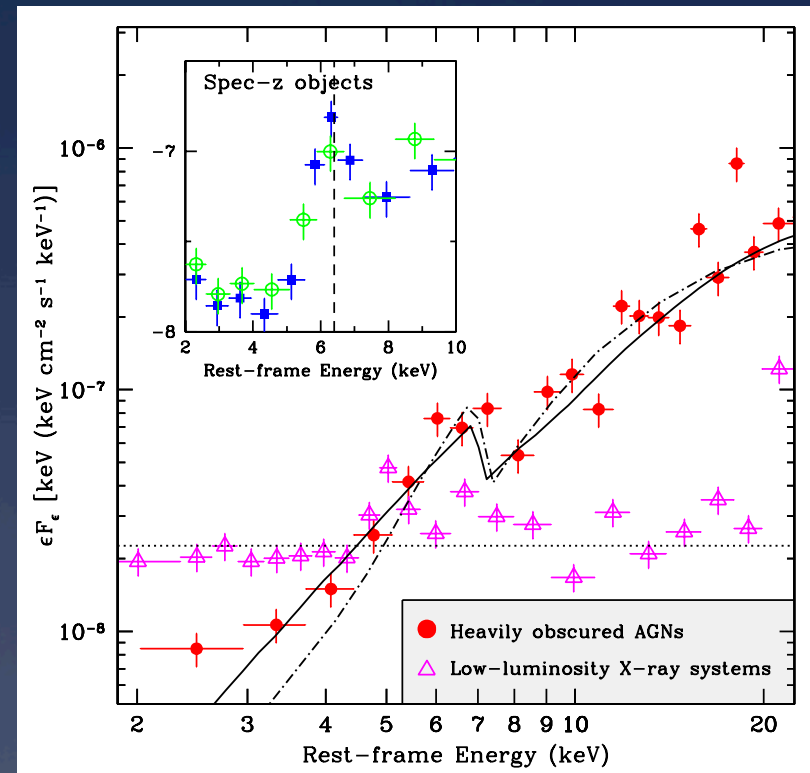
# Standard Caveats

- \* May miss AGN-merger connection because:
  - \* Obscuration
  - \* Time delay between merger and AGN activity
- \* Alternative Triggering Mech:
  - \* Violent disk instabilities (i.e. clumpy disks)
  - \* Secular processes
  - \* Minor Mergers
- \* It appears stochastic accretion plays a larger role in triggering AGN activity at  $z \sim 2$  than previously thought.



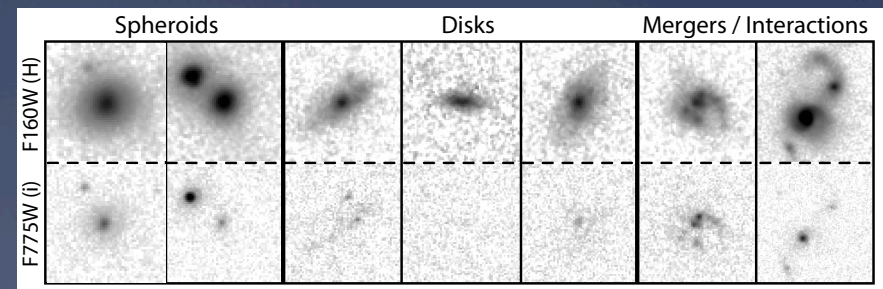
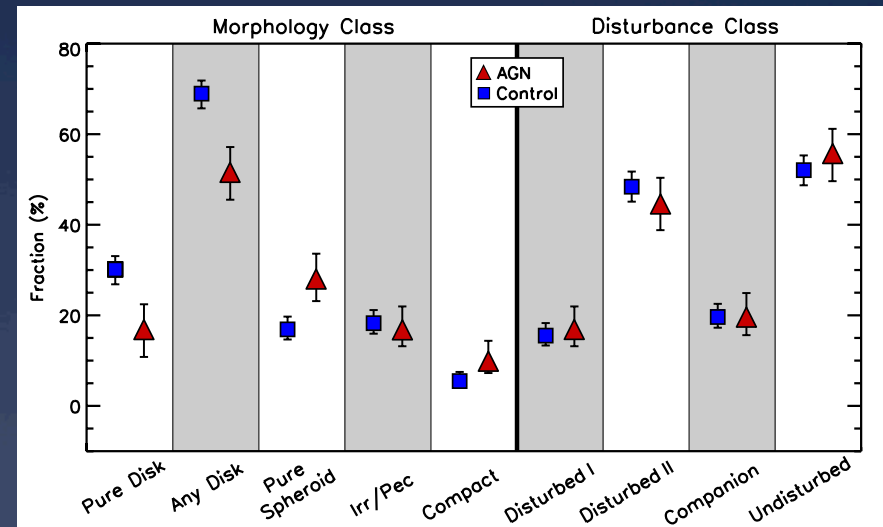
# Morphologies of Compton Thick AGN

- \* Can test obscuration bias by examining morphs of Compton thick sources.
- \* Alexander et al. (2011) find 11 sources in CDFS at  $z \sim 2$  with reflection dominated X-ray spectra, suggesting extreme column densities ( $N_H > 10^{24} \text{ cm}^{-2}$ ).
- \* Morphology of these sources do not appear considerably different than entire sample.



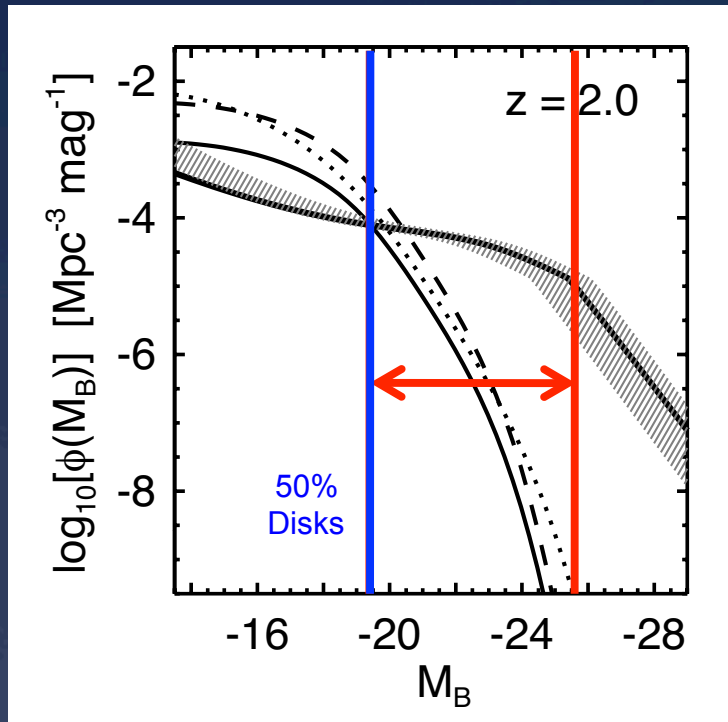
# Constraints on Time Delay Caveat

- \* May miss AGN-merger connection because:
  - \* Time delay between merger and AGN activity
- \* Morphologies:
  - \* 51% found in Disks (17% bulgeless)
  - \* 28% found in Spheroids
  - \* 17% have irregular morphs
  - \* More bulge-dominated than non-active, massive galaxies.
- \* Disks may survive major mergers, when gas rich, but unlikely (Bournaud et al. 2011).
- \* If spheroids = triggered by past major mergers, disks = fed by secular processes, then we find far too little merger activity.

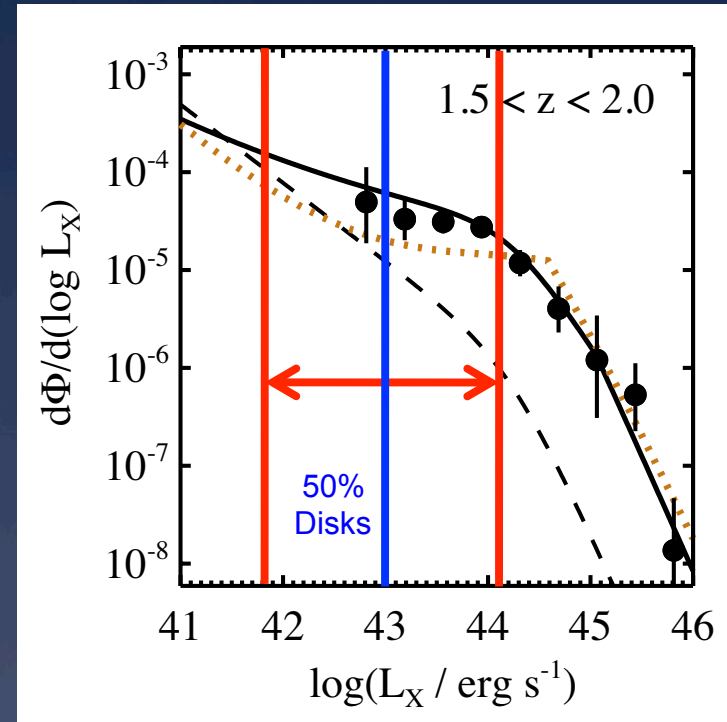




## Implications for AGN Fueling Models



Hopkins & Hernquist (2006)

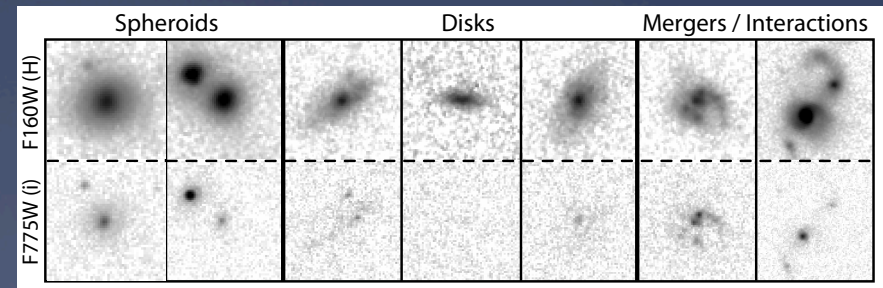
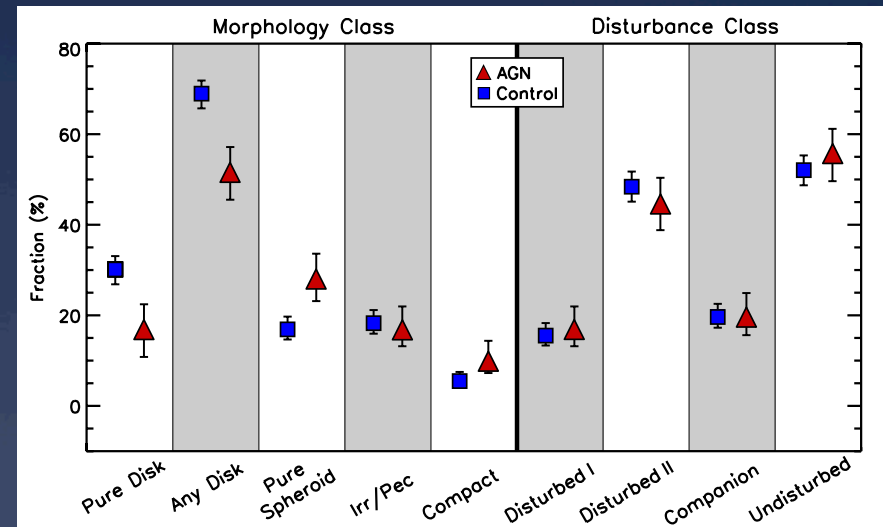


Aird et al (2010)

- \* Number density of stochastically fed AGN rival merger-triggered AGN roughly 2 orders of mag below knee.
- \* Knee in XLF:  $L_X \sim 10^{44} \text{ erg/s}$  (2-10 keV)
- \* We find 50% disk-like fraction at  $L_X \sim 10^{43} \text{ erg/s}$
- \* Implies stochastic accretion plays a larger role in triggering AGN activity at  $z \sim 2$  than prev thought.

# Alternatives to Mergers

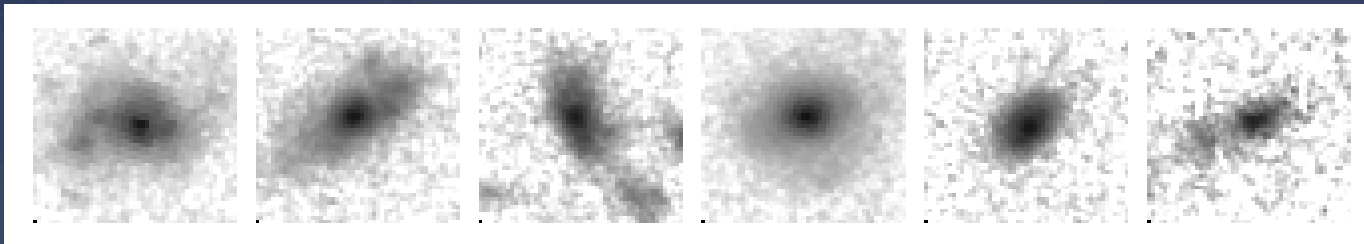
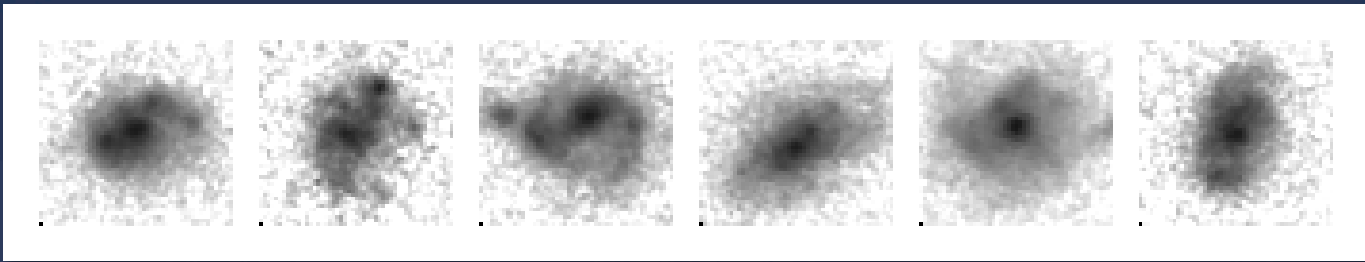
- \* May miss AGN-merger connection because:
  - \* Obscuration
  - \* Time delay between merger and AGN activity
- \* Alternative Triggering Mech:
  - \* Secular processes
  - \* Minor Mergers
  - \* Violent disk instabilities (i.e. clumpy disks)
- \* It appears stochastic accretion plays a larger role in triggering AGN activity at  $z \sim 2$  than previously thought.



# Clumpy Disks Among AGN Hosts

- \* Violent disk instabilities should be visible as clumpy disk morphs.

Control Galaxies



AGN Hosts

- \* Some evidence clumpy disks more prevalent among non-active galaxies.

## CANDELS: THE AGN-MERGER CONNECTION AT $Z \sim 2$

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### ABSTRACT

Using HST/WFC3 imaging taken as part of the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS), we examine the role that major galaxy mergers play in triggering active galactic nuclei (AGN) activity at  $z \sim 2$ ; the first such analysis at this redshift. Employing visual classifications, we have analyzed the rest-frame optical morphologies of 72 galaxies at  $1.5 < z < 2.5$  which host moderate-luminosity ( $L_X \sim 10^{42-44} \text{ erg s}^{-1}$ ), X-ray selected AGN in the Chandra Deep Field South. To determine if the AGN host galaxies show merger signatures more often than similar non-active galaxies, we compare their morphologies to a sample of 216 mass-matched control galaxies at the same redshift. We find that a majority of the AGN reside in late-type galaxies (51.4%), while a smaller percentage are found in early-type hosts (27.8%) and systems with irregular morphologies (16.7%). Despite the high disk fraction, the AGN hosts are more often associated with spheroids than non-active galaxies of similar mass. Roughly 16.7% of the AGN hosts have highly disturbed morphologies and appear to be involved in a major merger or interaction, while the majority of hosts (55.6%) instead appear relatively relaxed and undisturbed. These fractions are statistically consistent with the fraction of control galaxies that show similar morphological disturbances. Our results suggest that the hosts of moderate-luminosity AGN are no more likely to be involved in an ongoing merger or interaction relative to non-active galaxies of similar mass at  $z \sim 2$ . Furthermore, the high disk fraction observed among the AGN hosts appears to be at odds with predictions that merger-driven accretion should be the dominant AGN fueling mode at  $z \sim 2$ , even at moderate X-ray luminosities. The presence of a large population of relatively undisturbed late-type hosts suggests that secular evolution and the stochastic accretion of gas plays a greater role in triggering AGN activity at these redshifts than previously thought.

*Subject headings:* galaxies: active — galaxies: evolution — X-rays: galaxies

**Kocevski et al. (2011)**

Submitted – on astro-ph soon

# Conclusions

- \* AGN hosts at  $z \sim 2$  do not show irregular morphs more often than mass-matched non-active control galaxies.
- \* Undisturbed disks most common morphology
- \* If disks have not experienced major merger in recent past: **stochastic accretion must play a greater role in fueling AGN activity at  $z \sim 2$  than expected.**
- \* Cannot rule out minor mergers.
- \* Kocevski et al. (2011) – Submitted

