

# Are AGNs more likely to occur in galaxy mergers?



Claire Max

UC Santa Cruz

Center for Adaptive Optics

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# Some perspectives and a review of the literature

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- Binary black holes and dual AGNs are of strong inherent interest
  - High-energy astrophysics, accretion disk physics, jets, particle acceleration, ...
  - Gravitational physics, gravitational radiation, ...
- Most of the papers at this workshop address these questions
- This talk is my attempt to put dual AGNs into a larger context: how do the AGN and the dual AGN phenomena connect to galaxy evolution?

# How do AGNs and Dual AGNs connect with larger issues of galaxy evolution?

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- Co-evolution of galaxies and supermassive black holes:
  - Almost all galaxies with spheroids have supermassive black holes in their cores
  - Properties of spheroids and black holes are well correlated
  - Why?
- Do both spheroids and black holes grow
  - a) during galaxy merger events, or
  - b) via secular accretion of cold gas? [or both]
- If merger events are important on a large scale, we should see correlation between AGNs and mergers
- Do we see this ??

# Outline

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1. Introduction: framing the question
2. Surveys on the association of AGNs with galaxy mergers
  - Optical, mid-IR, soft and hard x-ray surveys don't agree
  - Selection effects very important
  - Is AGN luminosity the most important parameter?
3. Conclusions

# Key Issues

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## 1. Out of a sample of all AGNs:

- Compared with inactive galaxies, are AGNs more likely to be found in galaxy mergers?
- What fraction of all AGNs are dual AGNs?

## 2. Out of a sample of all galaxy mergers:

- Is the AGN fraction larger than in isolated galaxies?

# Key Issues

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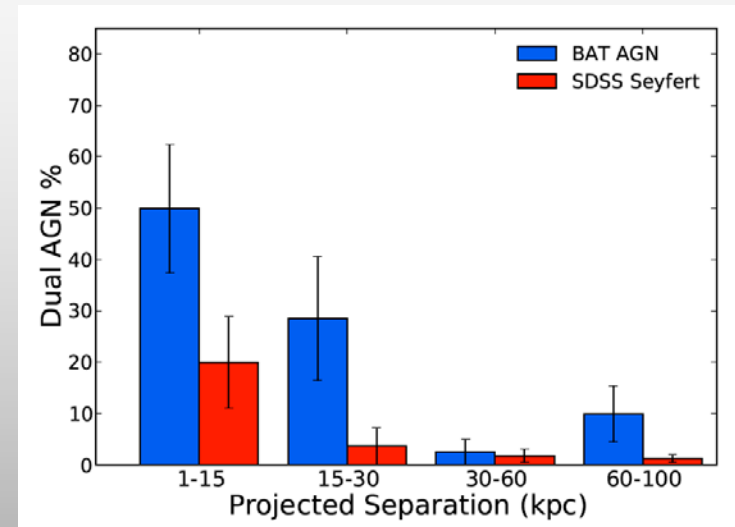
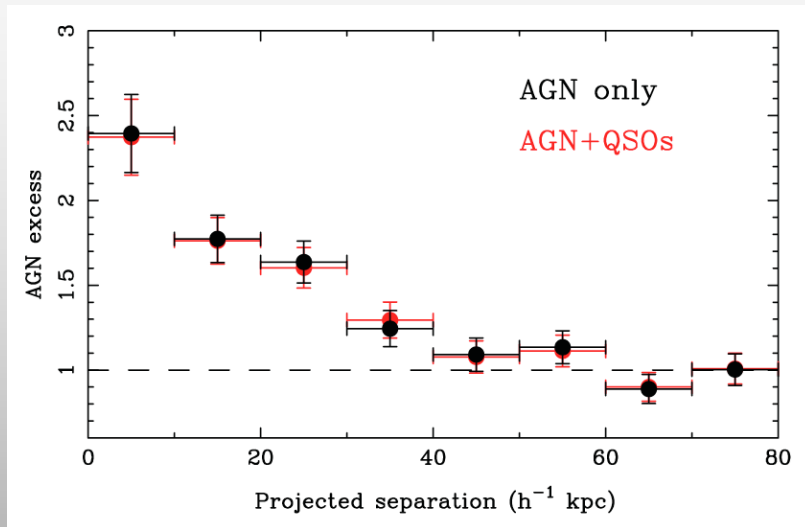
## 1. Out of a sample of all AGNs:

- Compared with inactive galaxies, are AGNs more likely to be found in galaxy mergers?
- What fraction of all AGNs are dual AGNs?
- Answers depend on how sample is selected. Many samples show no correlation of AGNs with mergers.

## 2. Out of a sample of all galaxy mergers:

- Is the AGN fraction larger than in isolated galaxies? **Yes.**

# In samples of galaxy pairs, AGN fraction increases as separation decreases



SDSS mergers  $0.01 < z < 0.2$   
Ellison et al. 2011

BAT and SDSS AGNs,  $z < 0.05$   
Koss et al. 2012

Strongly suggests that merger events play role in triggering AGN / dual AGN activity

# Be careful what question you are asking

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- Let's say that there are 2 potential methods for AGN fueling:
  1. Accretion of cold gas from the cosmic web
  2. Mergers of gas-rich galaxies
- Expected to have different dependence on  $z$ , galaxy mass, and to produce different host-galaxy morphology
- It is easy to imagine that in an epoch where cold-gas accretion dominates, you would find:
  - AGNs and inactive galaxies have almost the same probabilities of being found in galaxy mergers, **BUT**
  - For galaxies the **are** in mergers, the AGN fraction is higher



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# Some surveys asking what fraction of all AGNs are in mergers: higher redshifts

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## Optical + x-ray selection: No clear association of AGNs, mergers for $z > 0.2$

- Kocevski et al. 2012  $1.5 < z < 2.5$ 
  - Chandra x-ray selected AGNs,  $L_x = 10^{42} - 10^{44}$  ergs/s
  - AGN host galaxies have same merger rate as controls
- Cisternas et al. 2011  $0.3 < z < 1.0$ 
  - XMM x-ray selected AGNs, median  $L_x = 10^{43.5}$  ergs/s
  - AGN host galaxies have same distortion fraction as controls
- Optically selected quasars  $0.2 < z < 0.7$ 
  - SDSS-selected for double [OIII] lines,  $L = 10^{43} - 10^{45}$  ergs/s
  - $< 0.5\%$  of quasars are in spatially separated galaxy pairs

# Some surveys asking what fraction of all AGNs are in mergers: lower redshifts

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The two lowest-redshift surveys find that AGNs are more likely than controls to be in a merger

- Koss et al. 2010  $z < 0.05$ 
  - Ultra hard x-ray selected (BAT) AGNs,  $L_x \sim 10^{43}$  ergs/s
  - AGN merger rate w/in 30 kpc = 24%, controls = 1%
- Ellison et al. 2011,  $0.01 < z < 0.2$ 
  - Optically selected AGNs and Quasars from SDSS
  - Fraction of AGNs with a close companion within 10 kpc and 200 km/s is 2.5 times higher than control sample

# But beware of selection effects: each sample is seeing different kind of AGN

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- Optical selection (Yan et al. 2011)
  - AGN emission lines often hidden by star formation or dust
  - Requires high SNR optical spectra to subtract host galaxy light
- Mid-IR selection (Assef, Mateos, Stern, ...)
  - Interlopers include other luminous IR galaxies, hi-z galaxies
  - Gas-rich mergers more likely to be strong IR emitters
- X-rays  $< 10$  keV (Yan et al. 2011)
  - Substantial AGN population lost due to heavy absorption by gas
- Ultra-hard x-rays (14-194 keV) (Koss et al.)
  - Unbiased sample of local AGNs, but limited to  $z < 0.1$
  - Still misses the truly Compton-thick AGNs

**One way around this: try to combine samples chosen using multiple methods**

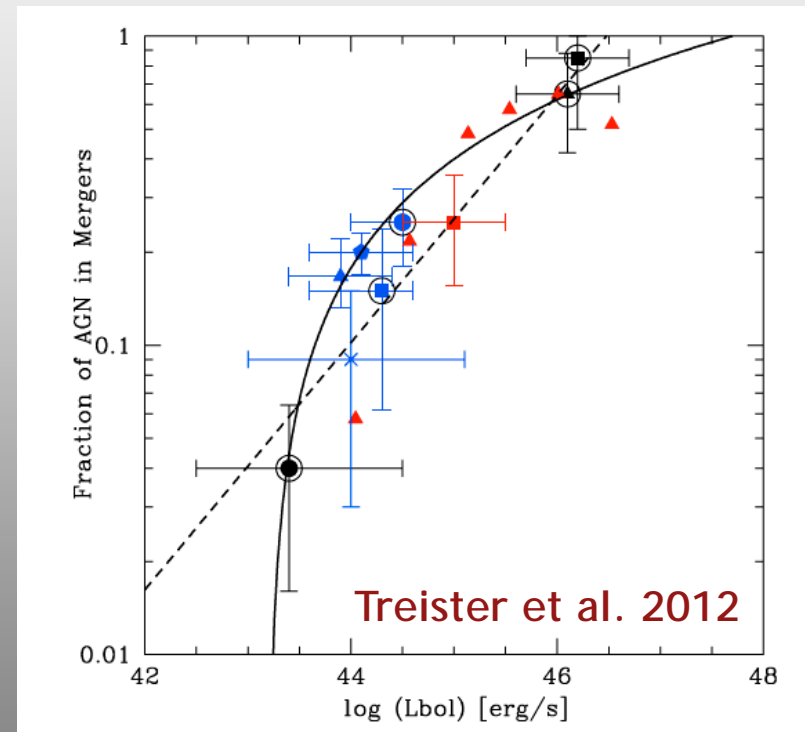
# Treister et al: Fraction of AGNs in mergers is very strong function of luminosity



- Combined samples from SDSS, mid-IR (2MASS & Spitzer), x-ray (Chandra + XMM), ultra-hard x-ray (SWIFT-BAT)

## Conclusions:

- Redshift-independent correlation between AGN luminosity and fraction of AGNs in major mergers
- 50% of black hole growth by mass is associated with major mergers
- Major merger appears to be required for an AGN to reach the highest luminosities



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H
- Difference with surveys showing no AGN-merger correlation: due to mid-IR-selected AGNs?**

# Conclusions

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- Strong hints that mergers play key role in triggering some, but not all, kinds of AGN activity
  - Need more work to quantitatively delineate which kinds
  - Try to compensate for selection effects by including samples chosen at many different wavelengths
  - Treister's paper suggests that mid-IR-selected AGNs have high weight towards merger involvement
  - I suggest re-examining using WISE mid-IR AGN selection criteria
- If mergers trigger AGNs, there should be two black holes involved even when we only see one of them
- See Anne Medling's and Vivian U's talks for how to characterize 2<sup>nd</sup> black hole even when it isn't an AGN