Studying Merger Driven BH Growth with Observations of Dual AGN

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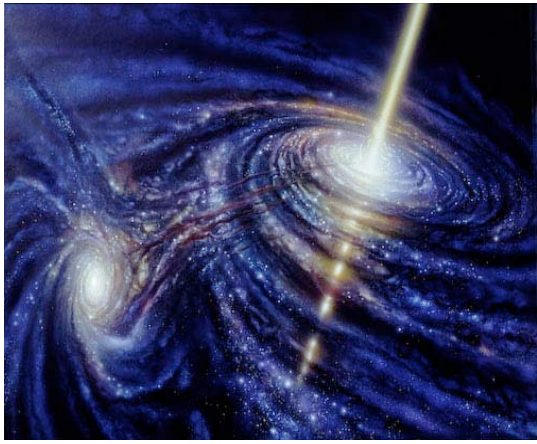
Outline of Talk

1. Dual AGN and Merger Driven BH Growth
2. Results of Recent Surveys
3. Importance of Studying Nearby AGN
4. Implications for Types of Mergers Drive BH Growth
5. Results of Pilot Study: Hidden Mergers and Dual AGN on kpc scales with high resolution imaging.

Importance of Mergers in Black Hole Growth and AGN



AGN Fueling

a) Mergers between gas-rich disk galaxies. **(Mergers)**
b) Gas streaming in galactic bars or steady cold streams **(Non-mergers)**

Vigorous debate dozens observational/theoretical papers for and against mergers.
e.g. Sanders et al. 1988, Mulchaey & Regan 1997, Granato et al. 2004, Di Matteo 2005, Dekel et al. 2009

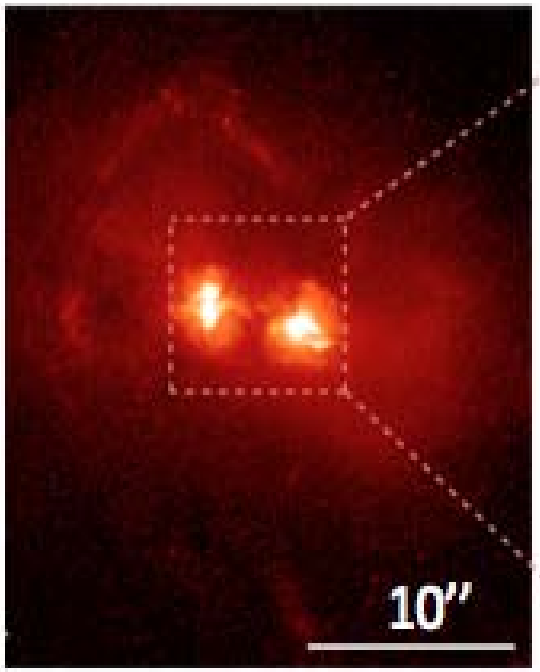
Why is it so hard to figure out?

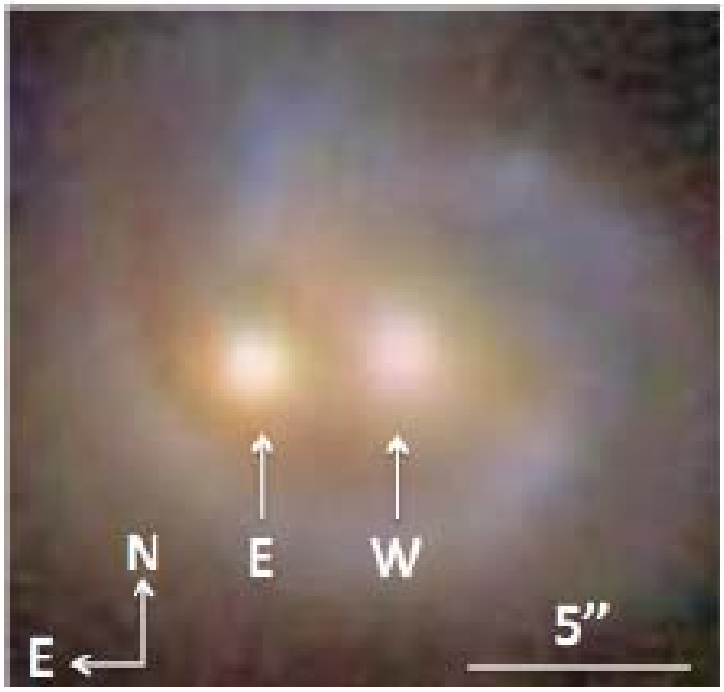
1. Multiple AGN fueling Mechanisms
2. See Galaxies Interacting at Moment in Time
3. AGN Lifetime After Merger
4. Most of the BH growth occurs at higher redshifts (z~1) hard to detect mergers and can only find powerful AGN
5. Merger Driven star formation/obscuration masks AGN signature (Koss 2010).

We need systems with unique observational flag of merger driven BH growth

→ Dual AGN

Nearby Dual AGN





Dual AGN, Komassa 03, Bianci 08, Koss 11

Interesting but… need systematic study to understand the effect of galaxy interactions on nuclear activities/BH growth!

Diffences in Studying Dual AGN Frequency

***<0.1%** Quasars are binary*

- Active 50 to 100 kpc, stable at <30 kpc (Mortlock 99)
- Peaks at ~30 kpc, tail at 100 − 200 kpc (Foreman 08)

*Double Peaked Spectra **(0.3-0.5%, <15 kpc,** Rosario 11**)***

- Higher redshift require high S/N and resolution to resolve gas kinematics etc.
- 98% of double peaked sources involve a single AGN (Fu 11).
- Not all dual AGN are double peaked (i.e. NGC 6240).

*Nearby SDSS AGN **(1.5%, <30 kpc, Liu 2011)***

- Optical Spectroscopy, Issues with fiber collision limits, no X-ray/Radio coverage

*Nearby Hard X-ray Selected AGN **(8%, <30 kpc, Koss 2012)***

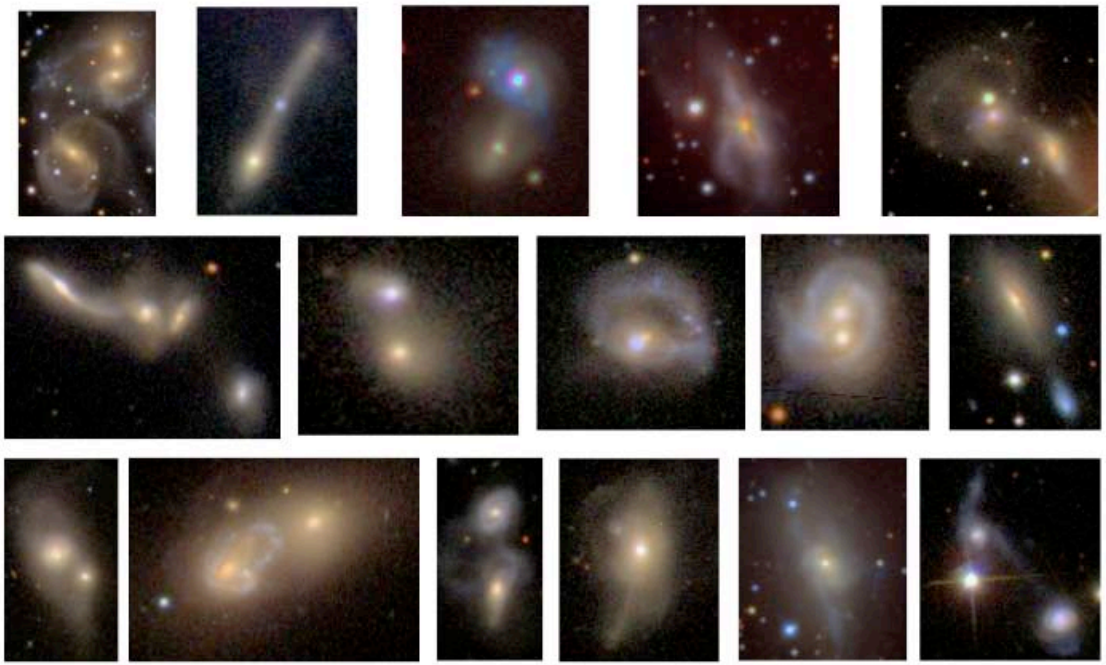
- Incomplete X-ray coverage below 10 kpc, No Radio, Bias against <3 kpc

Spread of at least 5-10 times

Differences tell us important things about merger driven BH growth

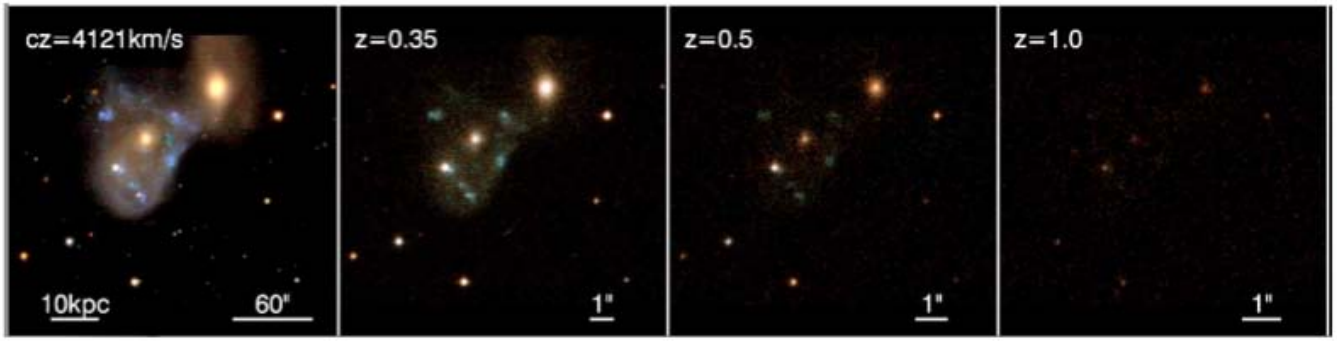
Sample and selection biases really do matter…

Advantage of Studying Nearby Galaxies (z<0.05)



X-ray Selected AGN in mergers (z<0.05)

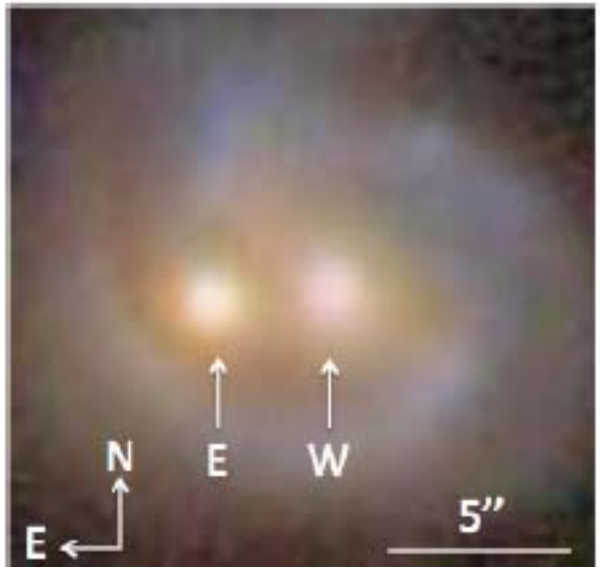
Surface Brightness Dimming …



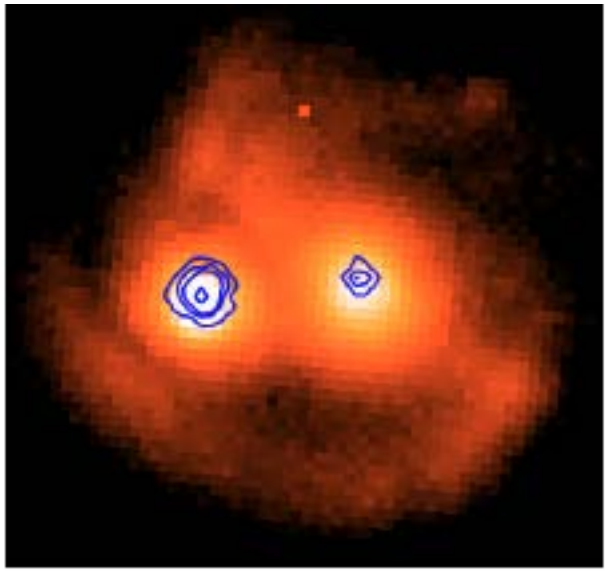
z=0.013 modeled using FERENGI (Barden 08)

Can Study Close Mergers and Morphology Much More Easily at Low Redshift

Advantage of Studying Nearby Galaxies
High S/N Resolved X-ray Spectra and Optical Spectra



SDSS gri Mrk 739



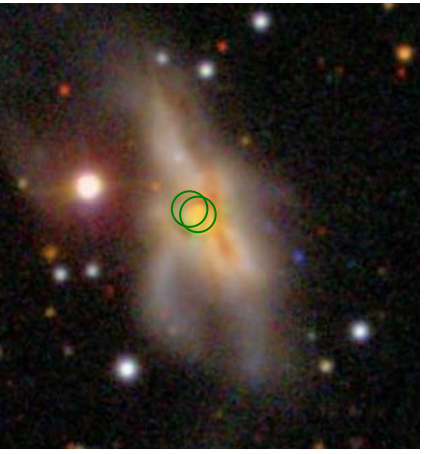
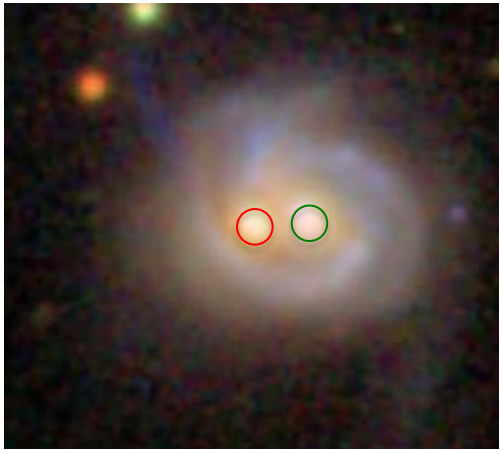
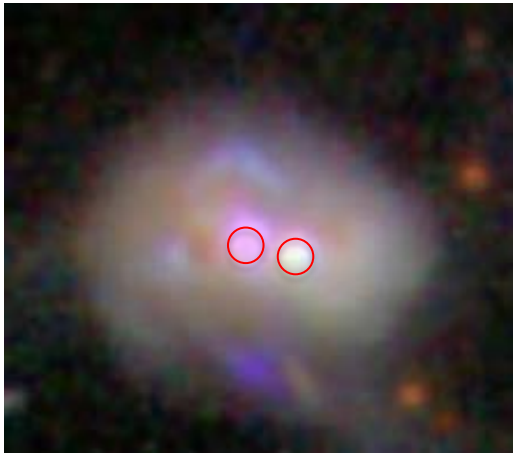
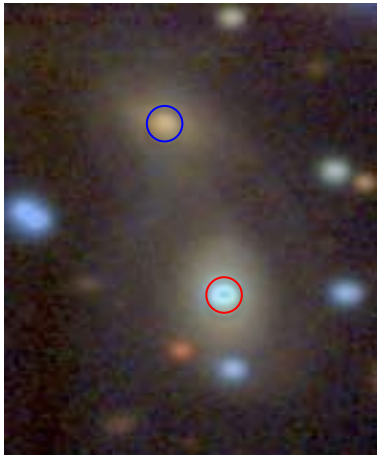
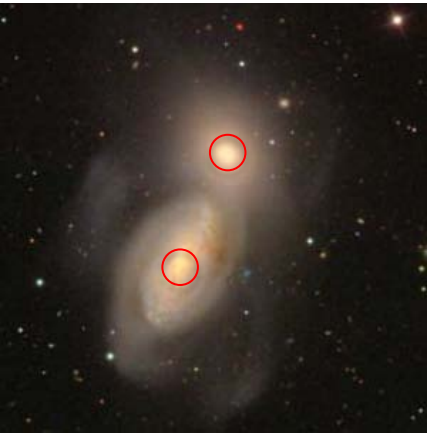
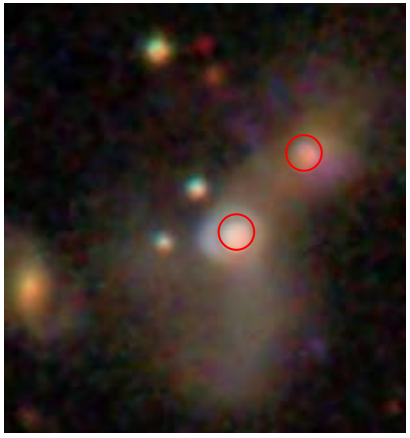
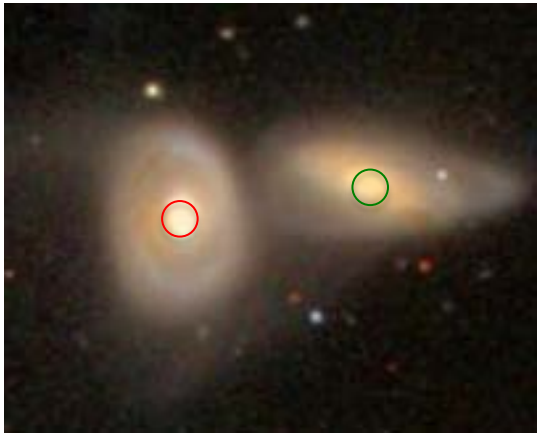
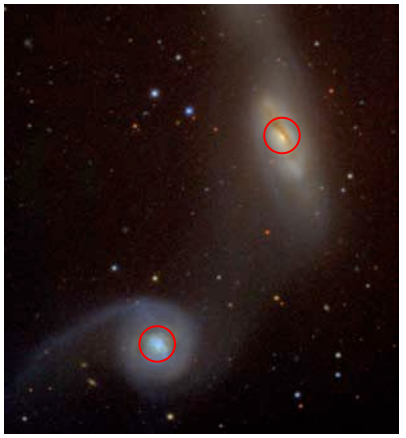
2-10 keV contours
3.4 kpc Separation

Secondary AGN not detected in emission line diagnostics (GMOS) or in radio (VLA)
Luminous ($L_{2-10\ keV}$=10^{43} and 10^{42} erg/s) X-ray Point Sources
X-rays PS consistent with center of optical nuclei
Other than NGC 6240, stands as nearest confirmed dual AGN (<5 kpc)

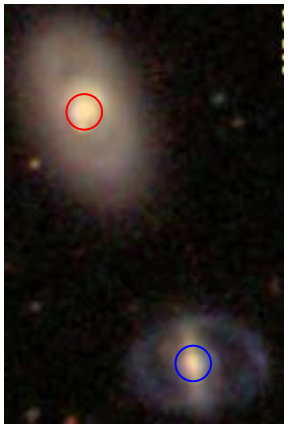
At higher redshifts (z>0.1) not detected in X-rays (faint) or as double peak source (faint+close lines)

Koss et al. ApJL 2011, 735, 42

Dual AGN Study X-rays+Optical (16/167)

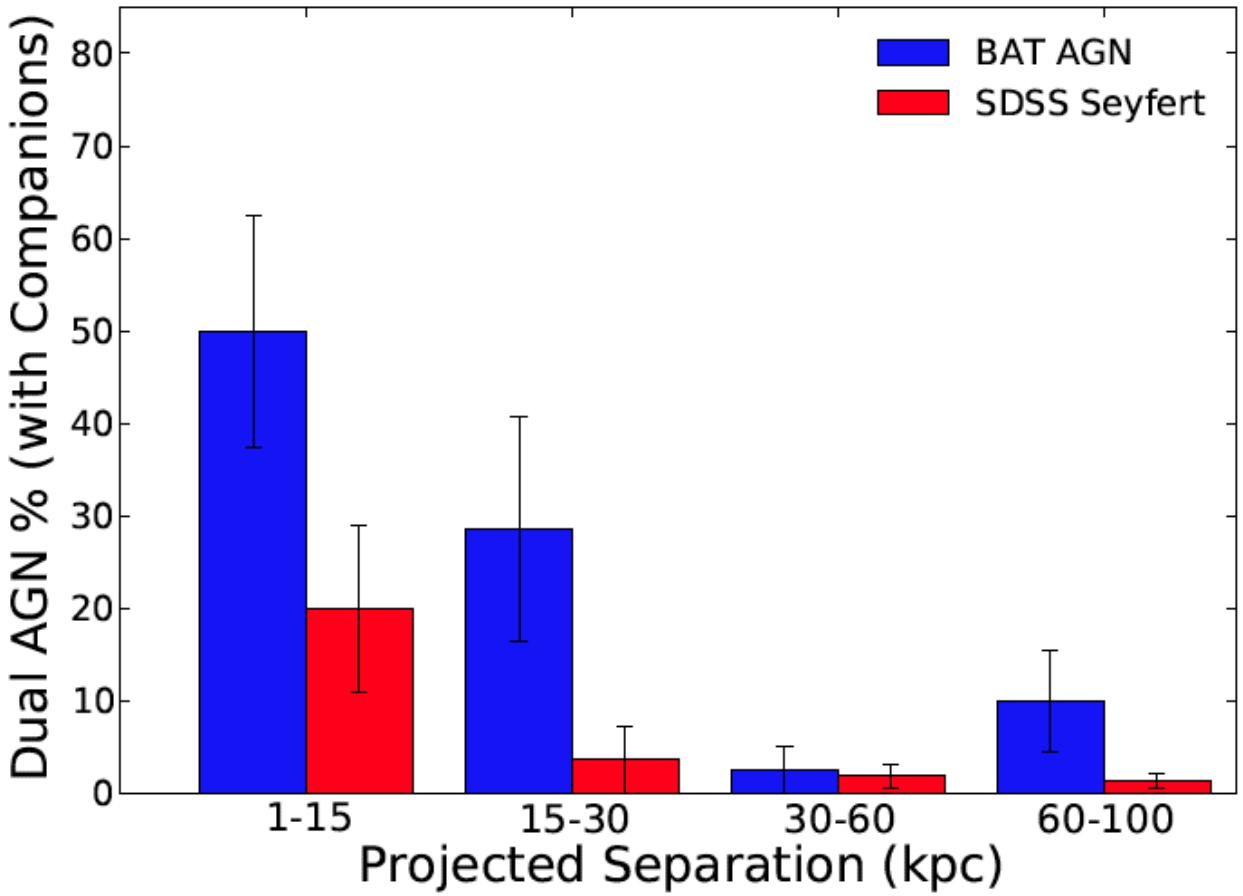




Sample of *Non-Detections* <30 kpc

Minor Mergers (<3 mass ratio) and absorption line galaxies (elliptical)

Dual AGN Fraction with Separation



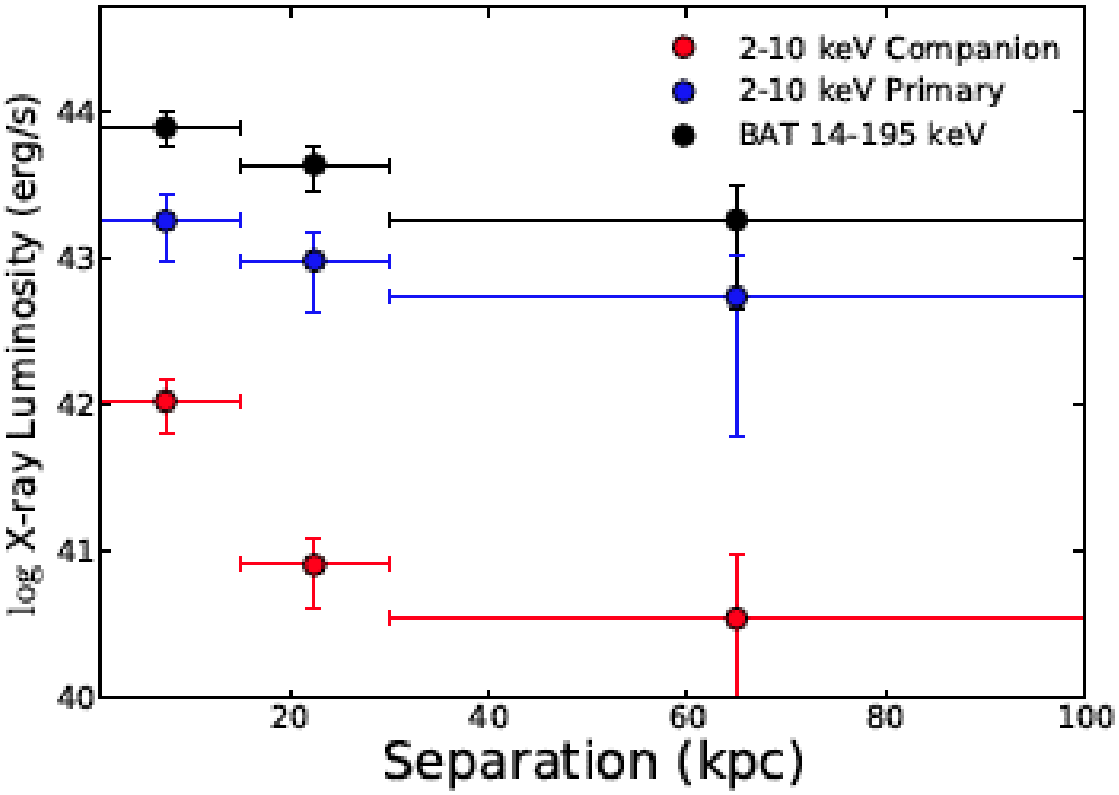
Dual AGN Activity Increases at Closer Separations

More SMBH growth happens in the later stages of a merger process

All close (<30 kpc), major merger, non elliptical systems are duals!!!

Koss et al. 2012, ApJL 746,22

X-ray Luminosity with Separation



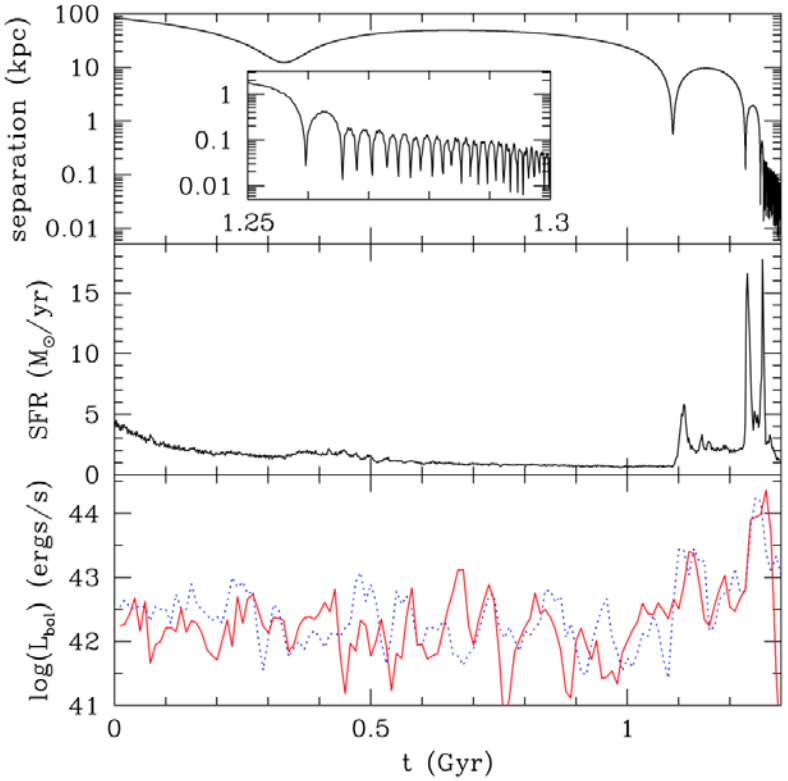
X-ray luminosity increases dramatically at small separations (< 15 kpc)
Consistent with merger-driven model

Suggests targeting luminous systems is critical to finding close dual AGN <5 kpc
Higher Dual AGN fraction (<30 kpc) for luminous systems

- Lbol>10^45 is 17%
- Lbol<10^45 is 4%

Koss et al. 2012, ApJL 746,22

Results from Simulations



Van Wassenhove et al. 2011.

AGN activity is brightest at small scales (<5 kpc)

Broad Agreement with X-ray observations

Designing a Well Selected Sample For Adaptive Optics High Resolution Studies (<5 kpc)

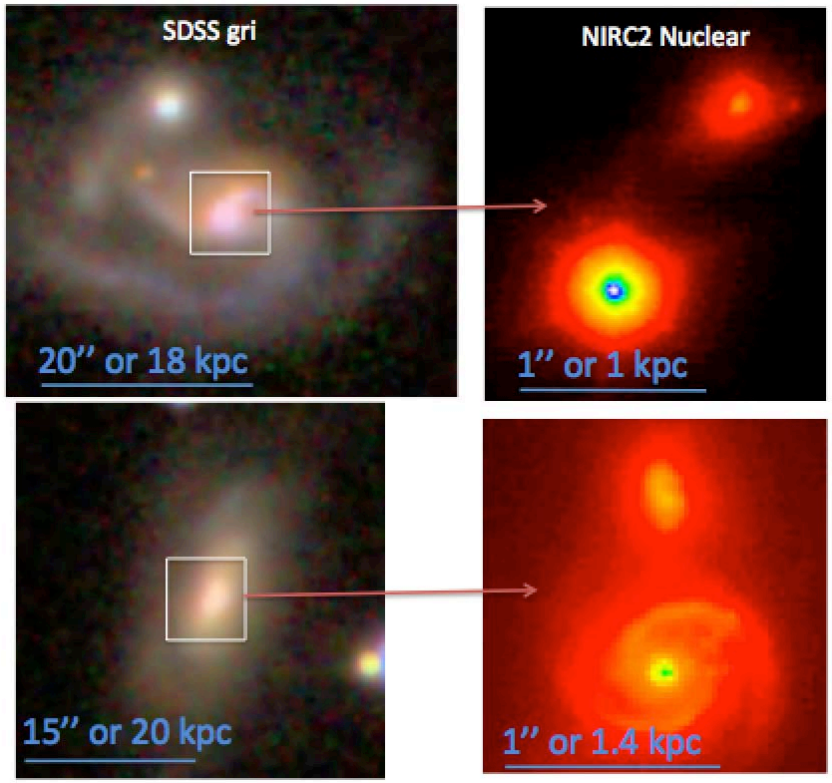
1. Nearby Systems (z<0.1)
2. High Luminosity AGN
   - Low Luminosity AGN well studied in HST
   - Obs+Sim suggest mergers/dual AGN
3. Careful of AGN Survey Bias
   - Difficulty detecting AGN in mergers with high SFR (e.g. optical spectroscopy, Koss et al. 2010)

Problems with AO

1. Bias to bright Sey 1 for good corrections
2. Observationally Expensive

Keck Pilot Study of 15 AGN

(L_X-ray Bolometric>10^45 erg/s, z<0.1)



2/15 (13%) are in Hidden Mergers

Much Higher Fraction of Hidden Mergers than Past HST NICMOS Studies (i.e. 0.5%, Malkan 2004)

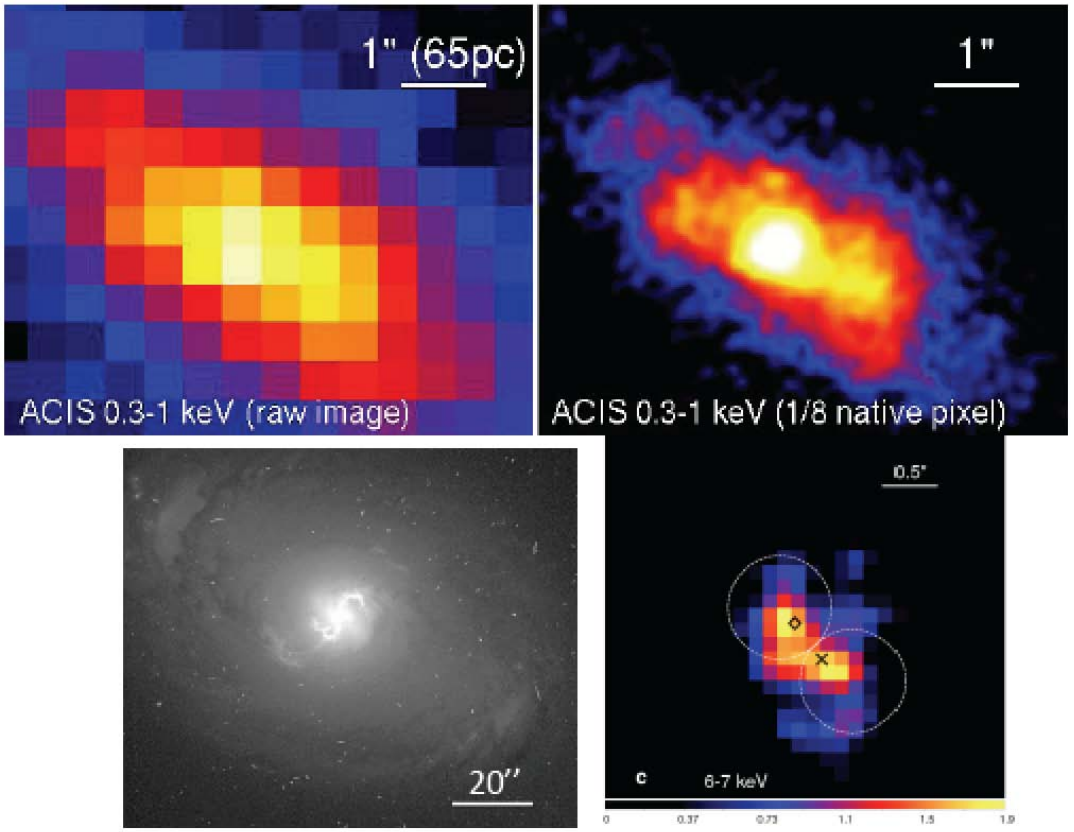
IFU Optical Spectroscopy (0.6'' seeing, UH 2.2m)

- Same redshift as primary galaxy
- 1/2 are dual AGN (preliminary)
- Higher Quality X-ray/IFU Follow-up Needed

Both Mergers are at Smaller Angular Separations than NGC 6240 (1.9'')

4 nights approved in 2013

New X-ray Imaging Techniques



Wang et al. 2011, Fabbiano et al. 2011

Constraints on Dual AGN using nearby AGN and X-ray Stacking

Funded Chandra Archival Proposal (Koss 2013)

Summary

Sample Selection Matters
Advantages of Studying Nearby AGN

Dual AGN Activity

1. Peaks at Small Separations
2. Gas-rich, major mergers
3. Avoids elliptical galaxies
4. High Luminosity AGN

Preliminary Results for Hidden Mergers at kpc scales

1. Population of hidden mergers in luminous AGN
2. Excellent kpc dual AGN candidates
3. Much Higher than low luminosity AGN