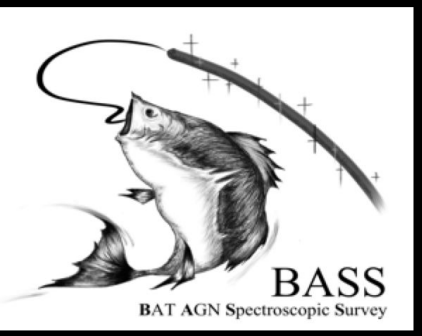
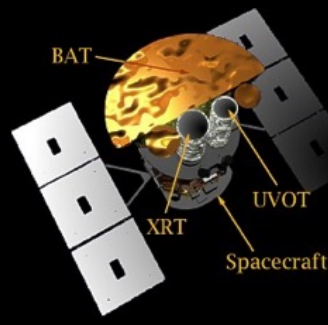


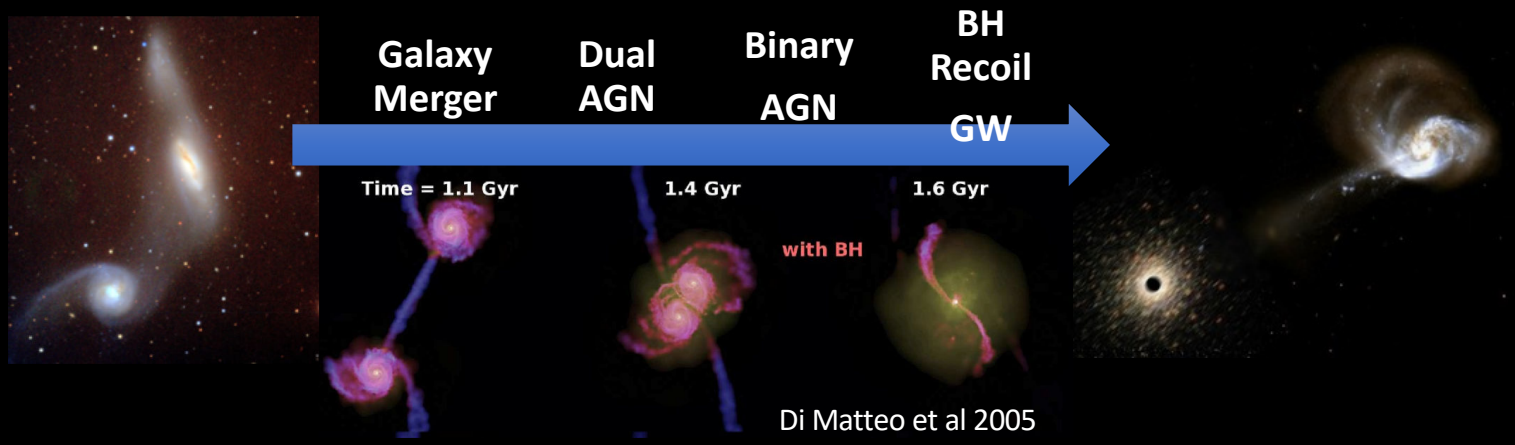


Growing Black Holes in Galaxy Mergers

Mike Koss Eureka Scientific

Claudio Ricci (UDP, Chile), **Benny Trakhtenbrot** (ETH Zürich/Tel Aviv), **Kevin Schawinski, Laura Blecha (UF),** Richard Mushotzky, Daniel Stern, Meg Urry, Ezequiel Treister, Fiona Harrison, Sylvain Veilleux, and the Swift BAT Team

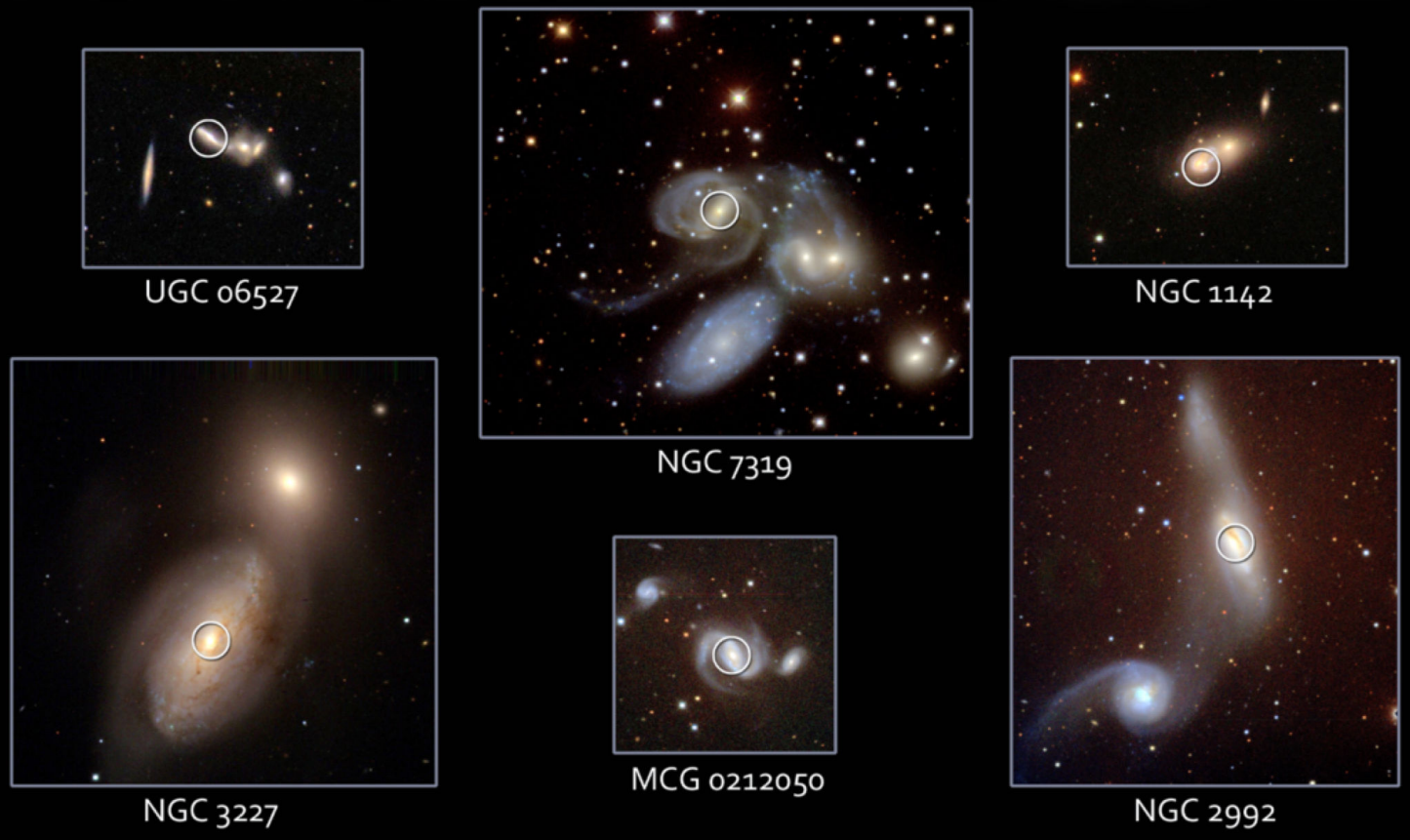
Galaxy Mergers
A Timeline



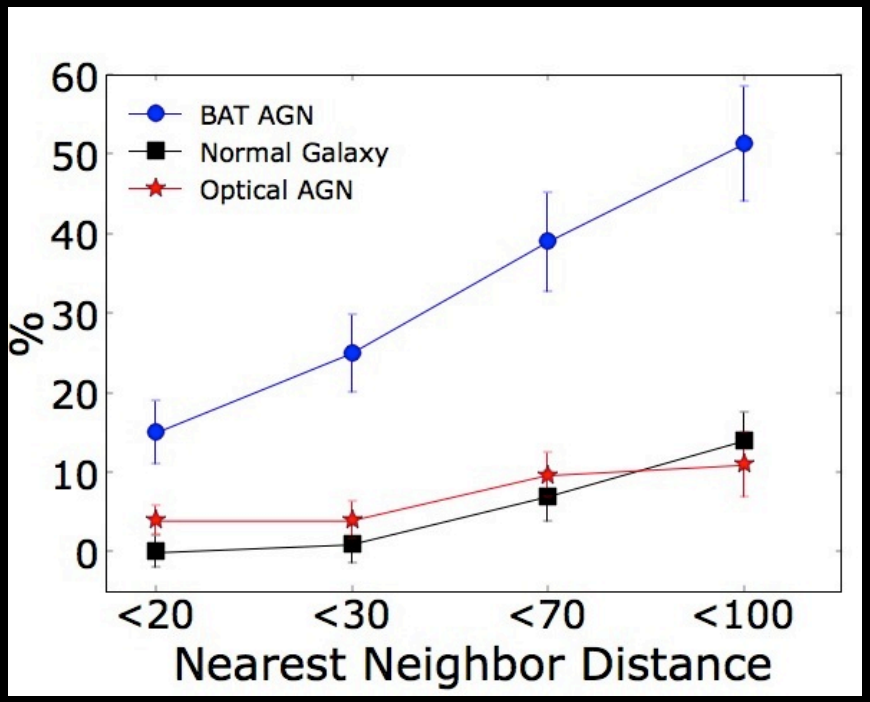
Di Matteo et al 2005

1. Are galaxy mergers linked to BH growth?
2. Dual Black Holes- Simulations and Observations
3. Sub-kpc mergers

Nearby galaxy mergers are very clear in imaging.

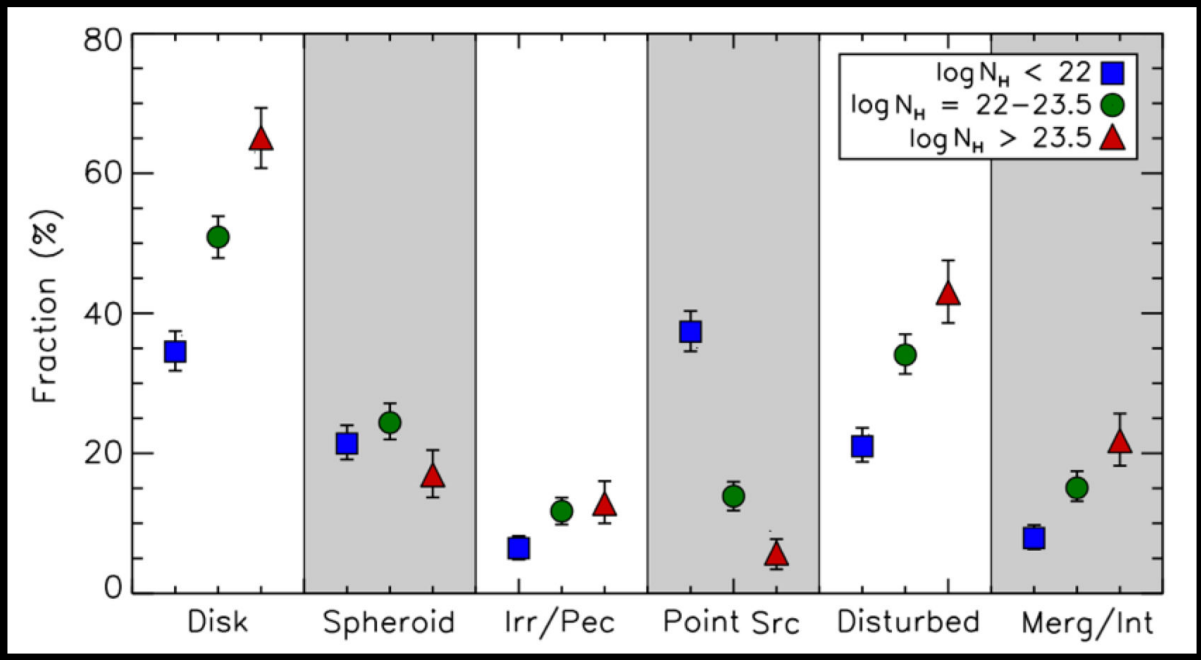


Nearby X-ray Selected AGN show a clear excess of mergers over matched inactive galaxies.



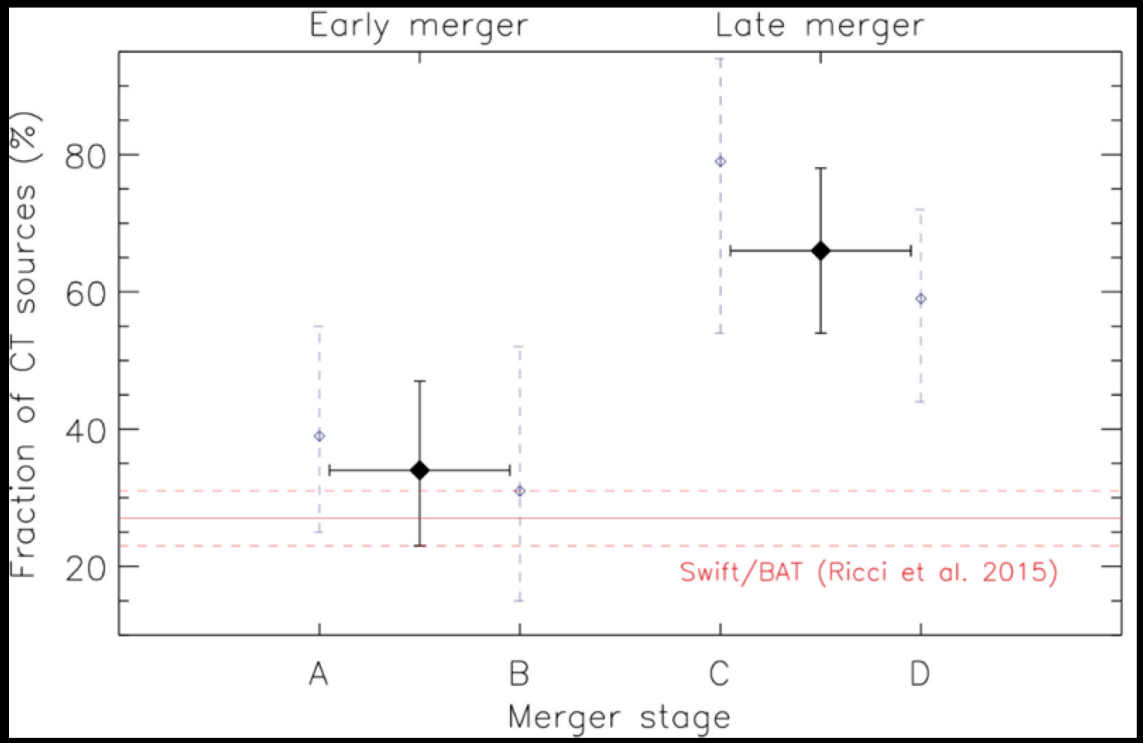
Koss et al. 2010

Highly obscured AGN tend to be preferentially in mergers.



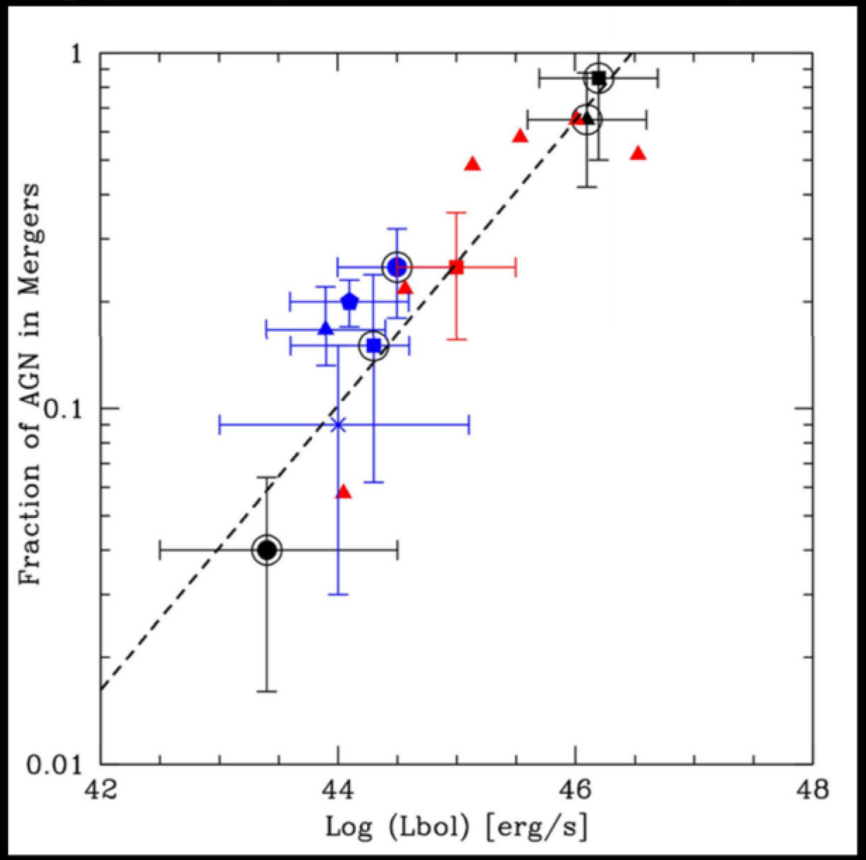
Kocevski et al. 2015

Obscuration peaks at later stages (<10 kpc).



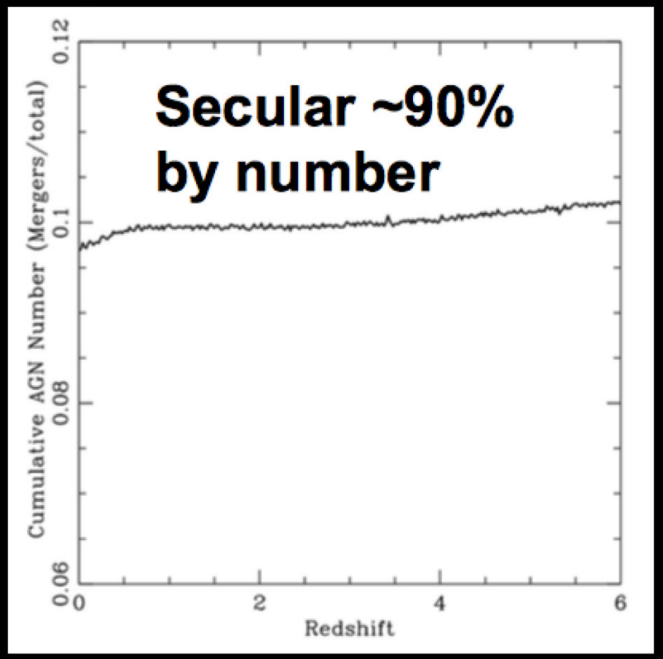
Ricci et al. 2017, see also Koss et al. 2016b.

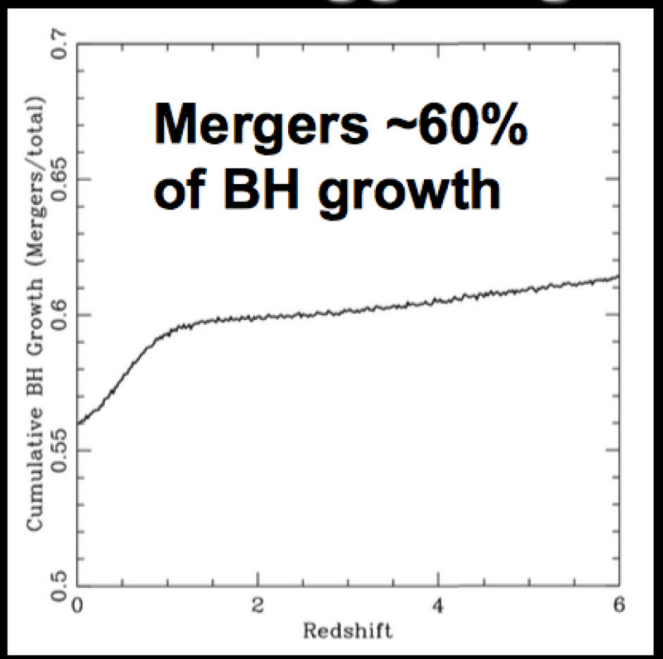
Luminous AGN show excess of mergers.



Treister et al. 2012

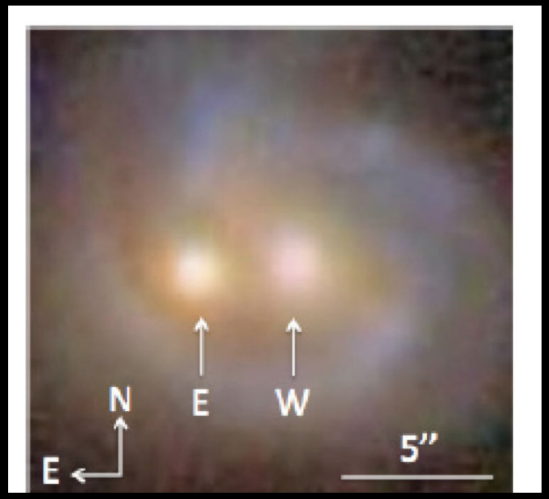
Mergers are less numerous, but larger percentage of total black hole growth.



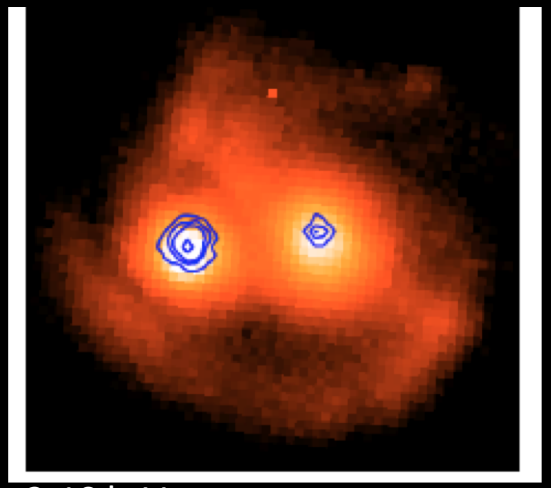


Treister et al. 2012

High resolution X-ray imaging is critical for dual AGN.



SDSS gri 3.4 kpc Sep



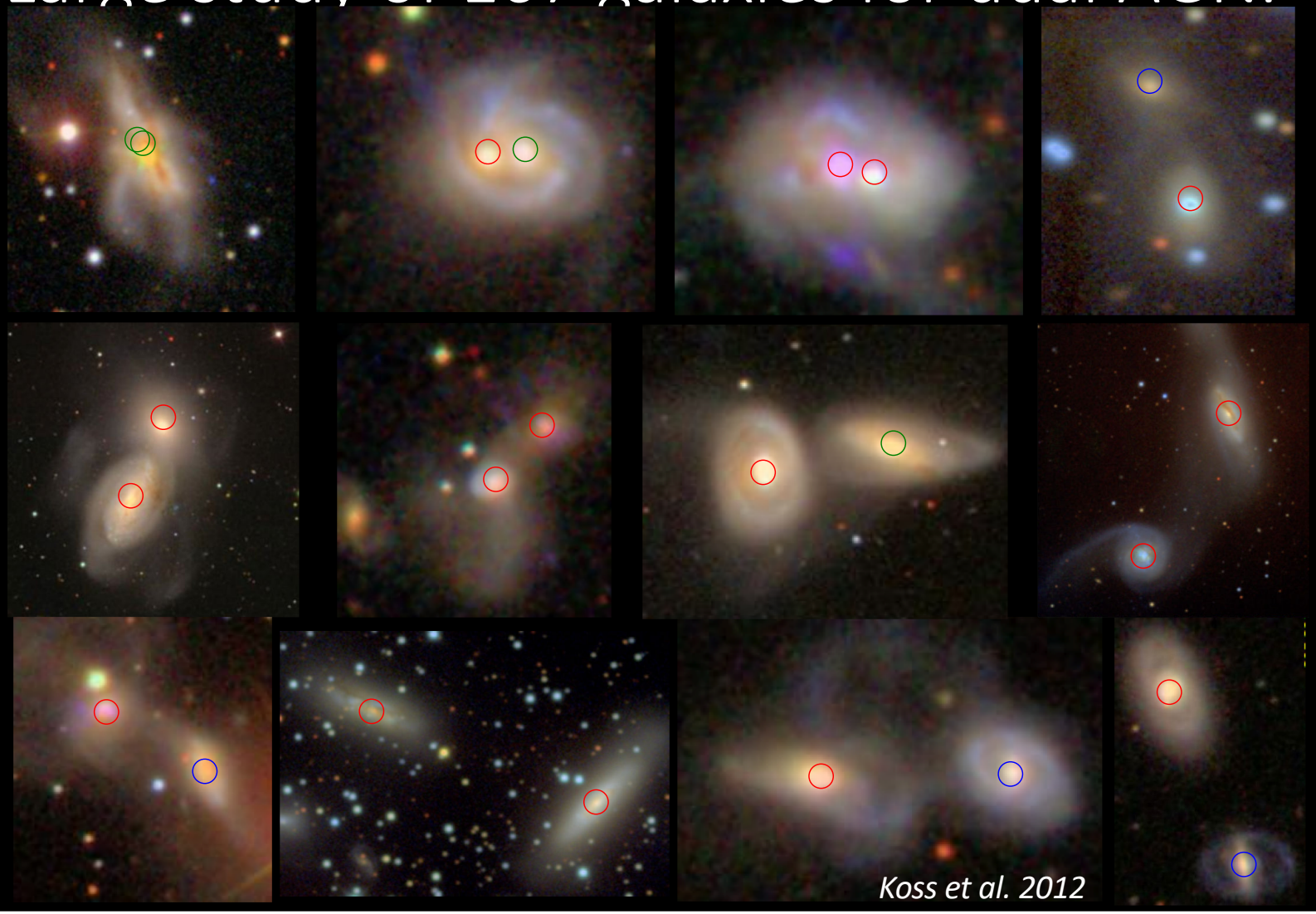
2-10 keV

Koss et al. ApJL 2011

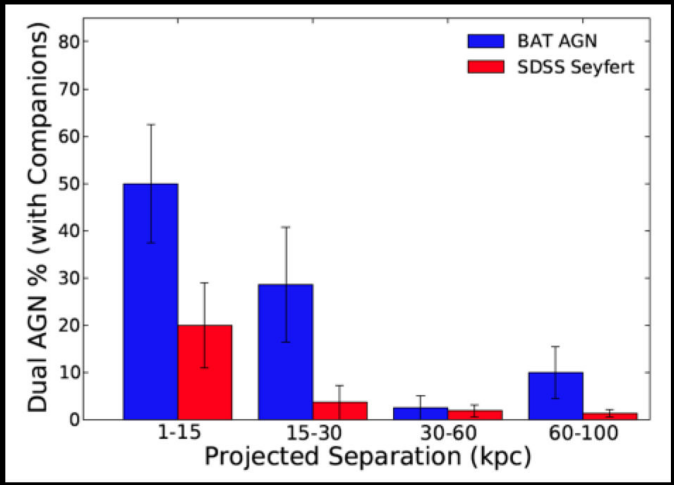
Secondary AGN not detected in emission line diagnostics or in radio (VLA)
Luminous ($L_{2-10\ keV}=10^{43}$ and 10^{42} erg/s) X-ray Point Sources
Likely SF and obscuration hides AGN

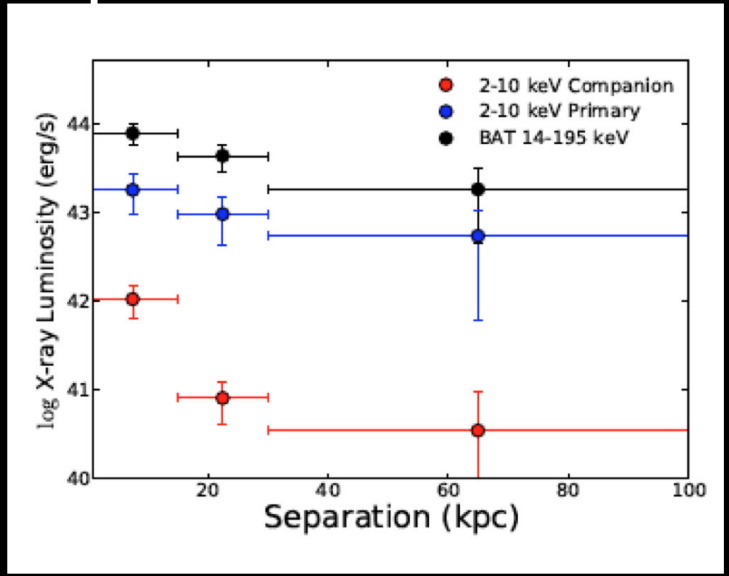
NGC 6240 is a very similar case (Komossa et al. 2002)

Large study of 167 galaxies for dual AGN.



Dual AGN fraction and luminosity increase with separation.





Dual AGN Activity Increases at Closer Separations

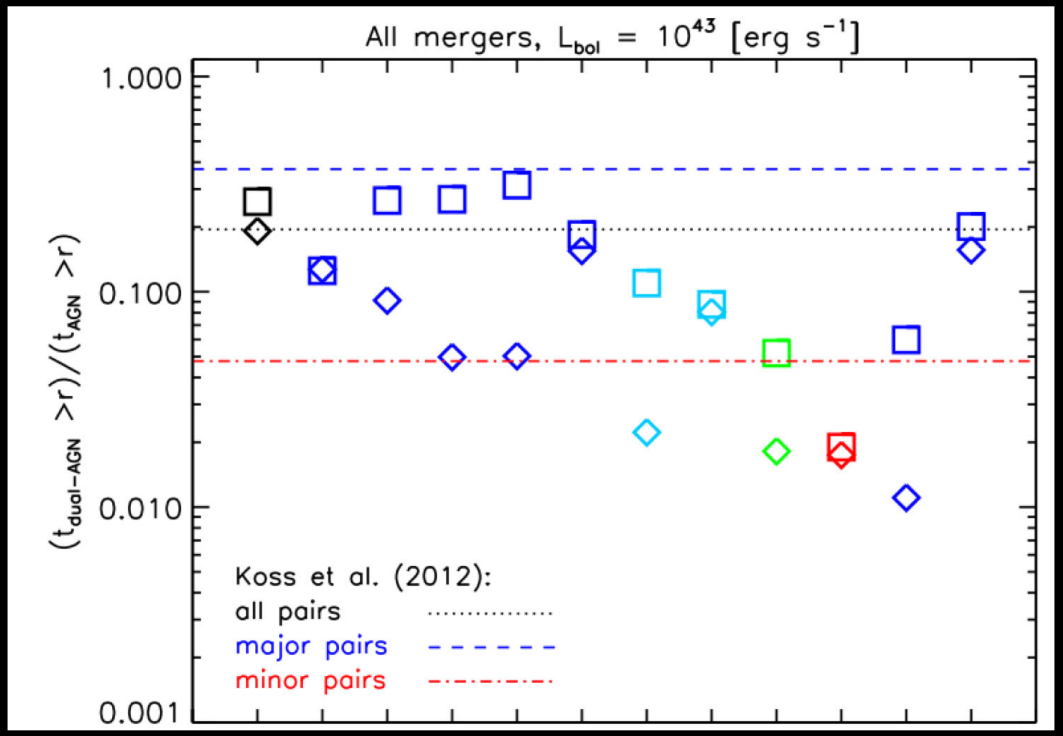
X-ray luminosity increases dramatically at small separations (< 5 kpc)

Dual AGN fraction was 10/100x larger than from SDSS

Typical luminosity ratio of ~10

Koss et al. 2012b, ApJL 746,22

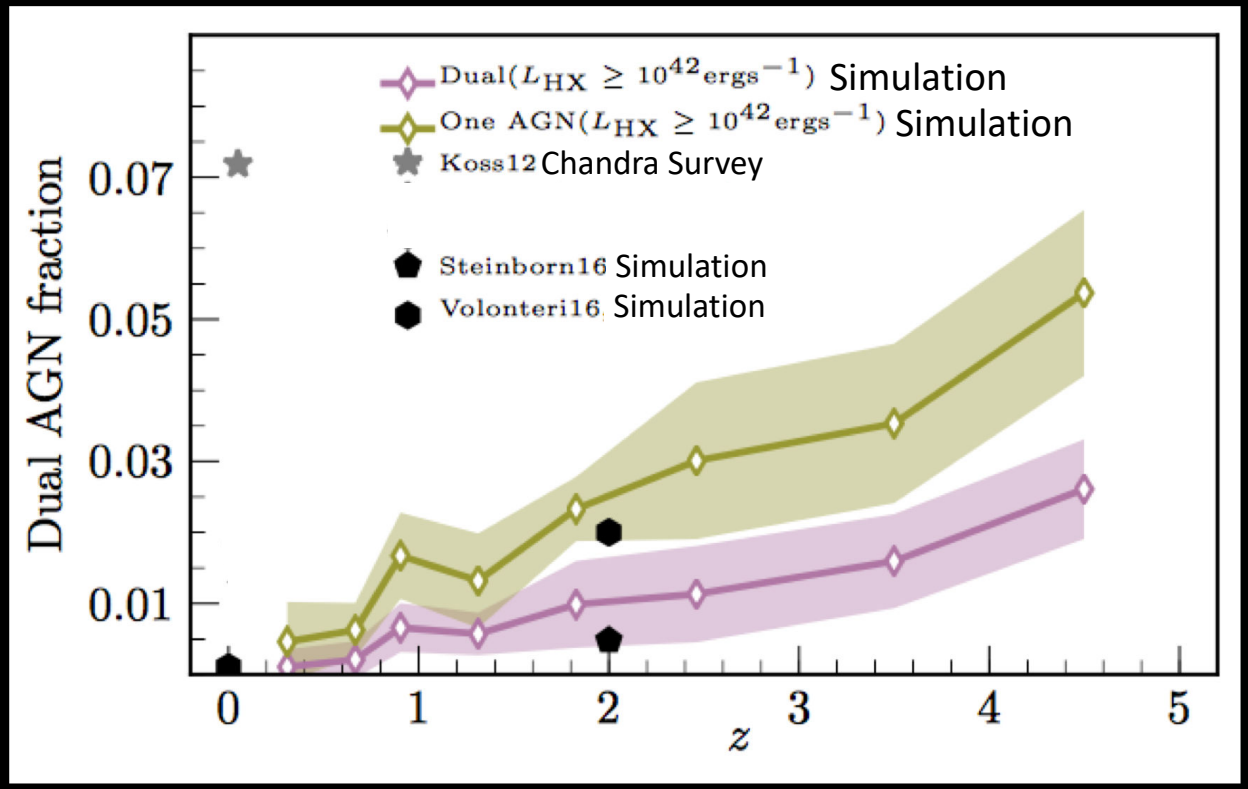
Simulations broadly agree with observations.



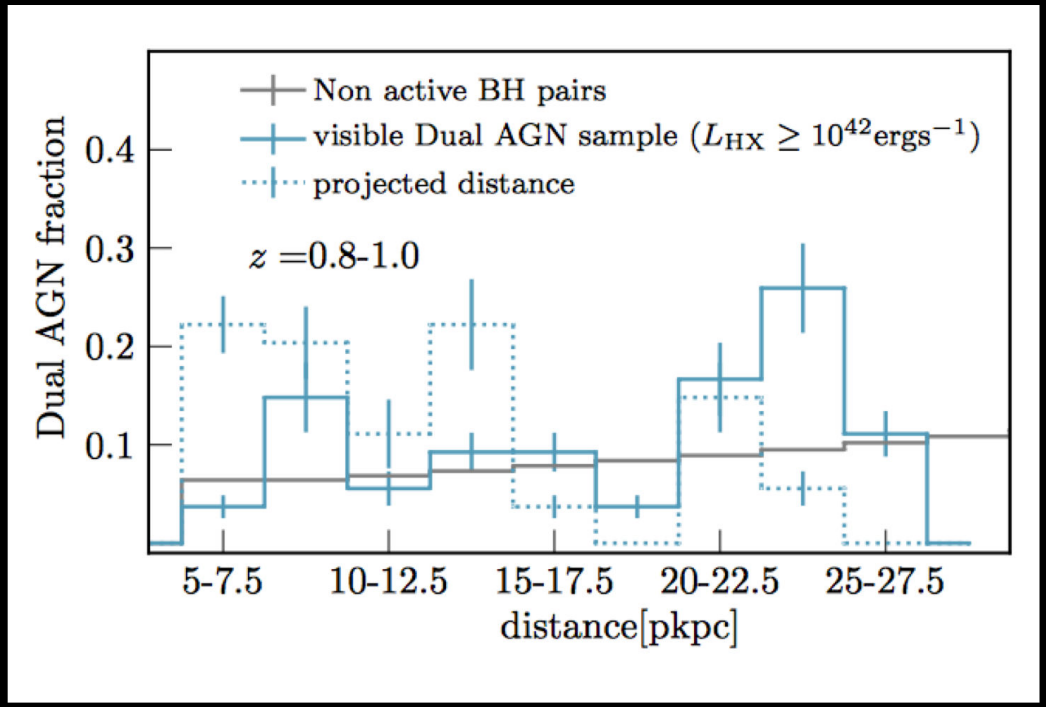
Capelo et al. 2017

Smoothed particle hydrodynamics simulations-Gasoline

Eagle Simulations, increasing dual AGN fractions with redshift, offset from observations.



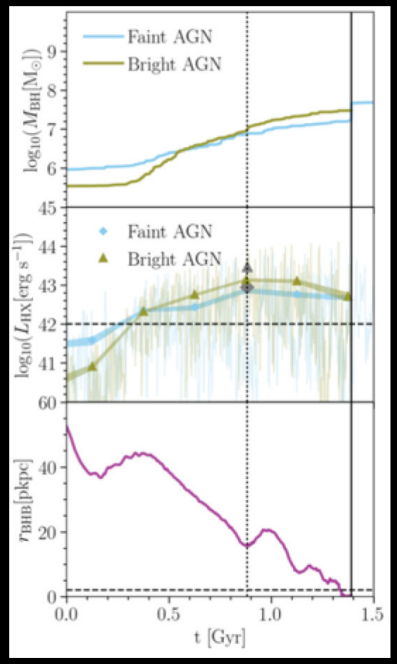
Eagle simulations suggest higher fractions at larger separations because of projections.



Much higher fractions at larger separations than observed.
Differing gas fractions?

Rosas-Guevara et al.2018

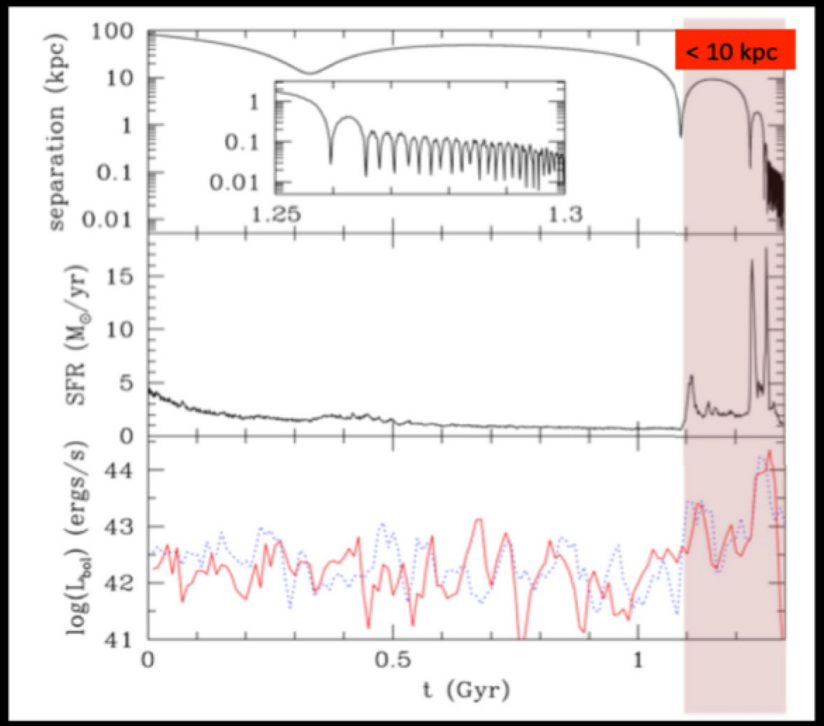
Eagle simulations show dual AGN with similar brightness.



Typical luminosity ratio for dual AGN in our sample was 11.

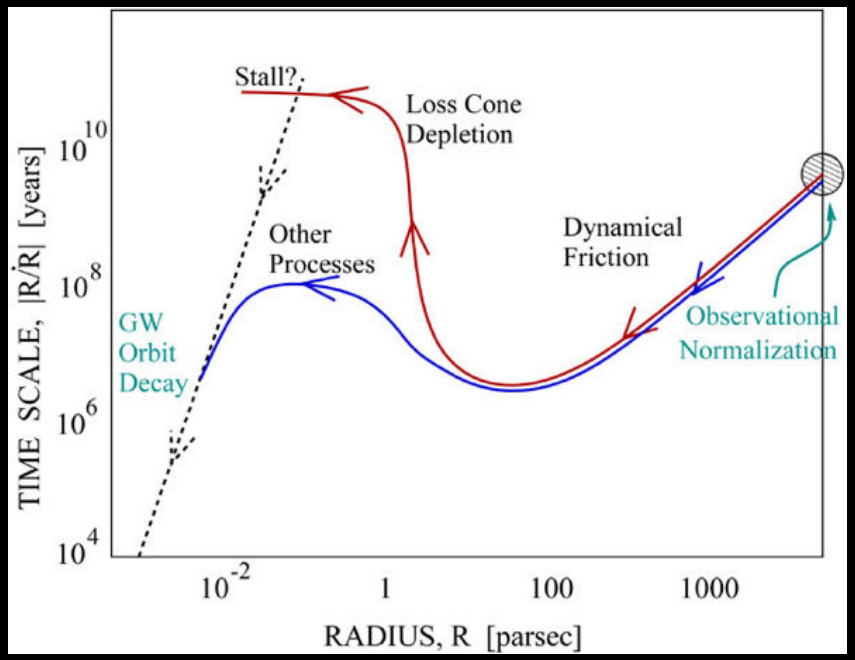
Rosas-Guevara et al. 201

Most observational studies are limited to scales of several kpc, but greatest activity is in final phase.



Van Wassenhove et al. (2012)

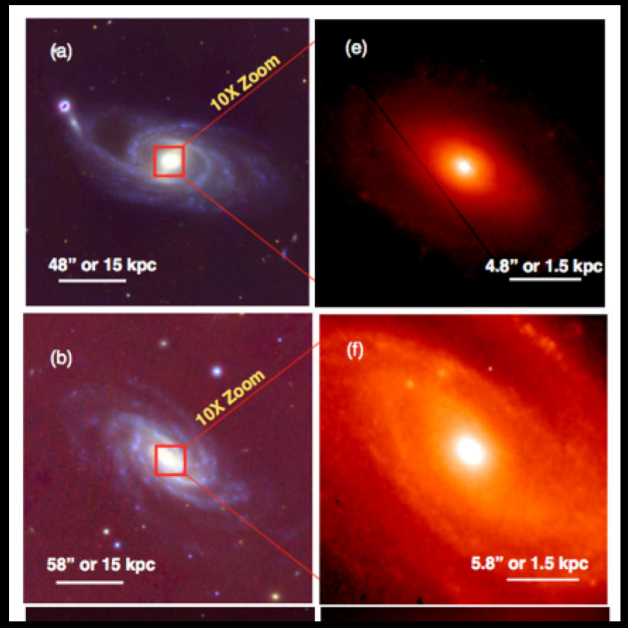
Studying AGN mergers at kpc separations is important to constrain final dynamical friction phase

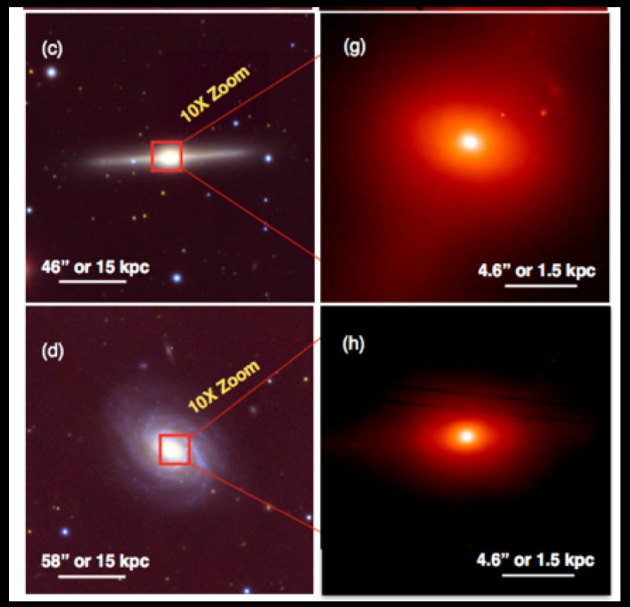


Gives a prediction about locations of typical black hole binaries/rates mergers

Backer et al. 2003

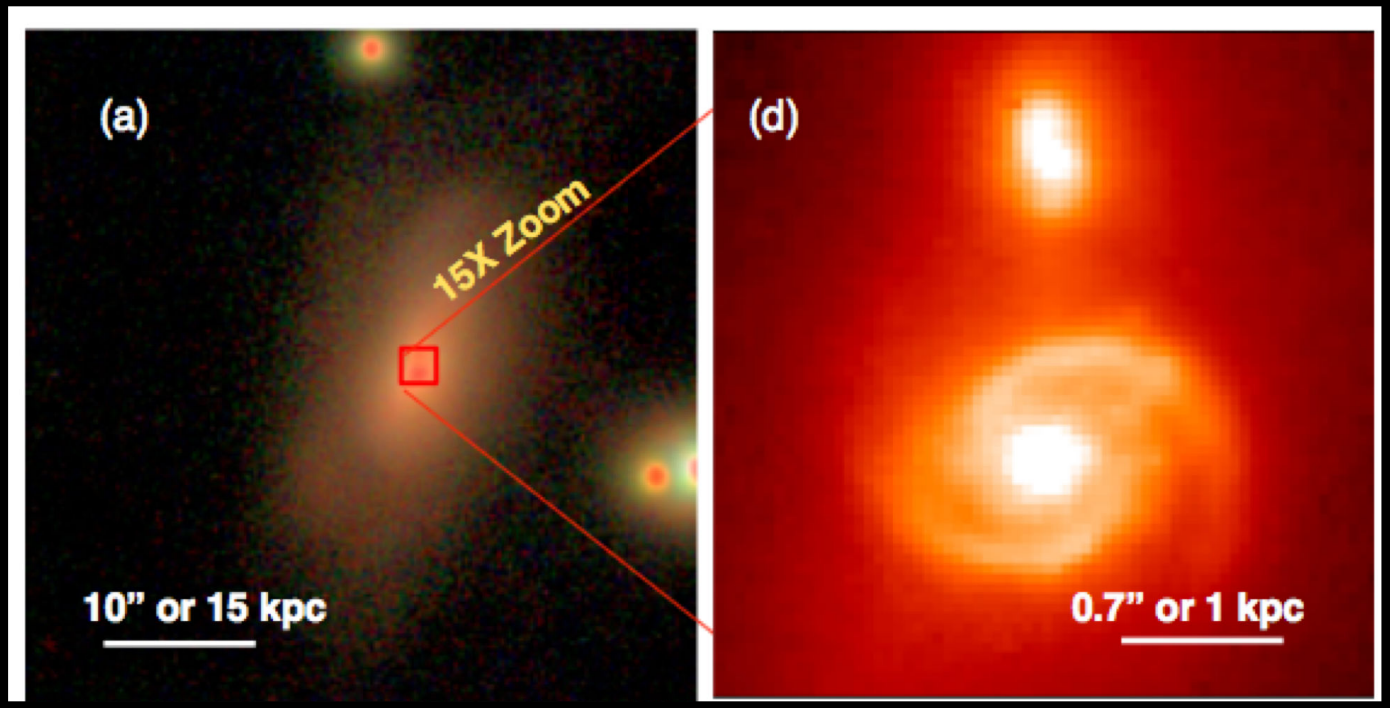
Large samples of high resolution images of nearby galaxies in the NIR now exist within HST archive





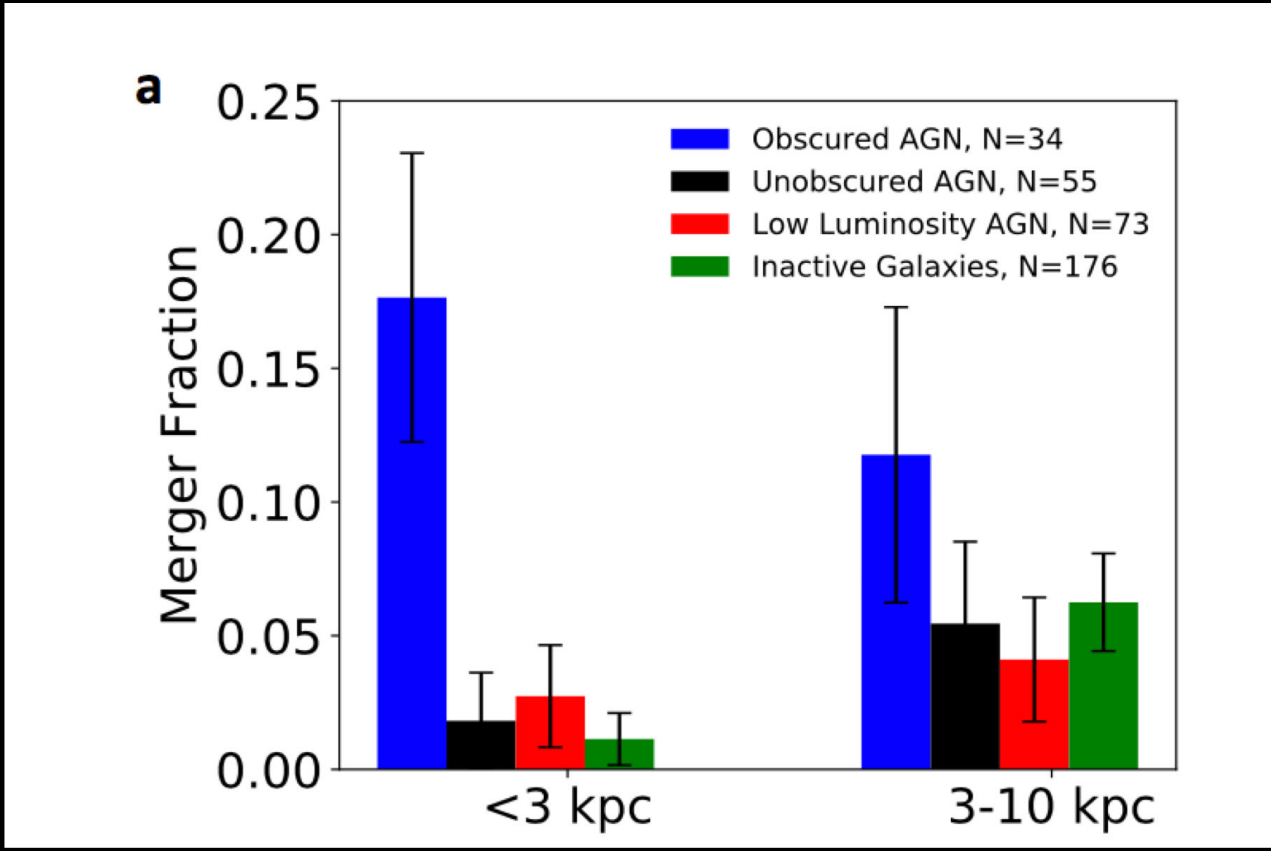
Most galaxies show boring bulges.

Hidden mergers (< 3 kpc) in luminous obscured AGN

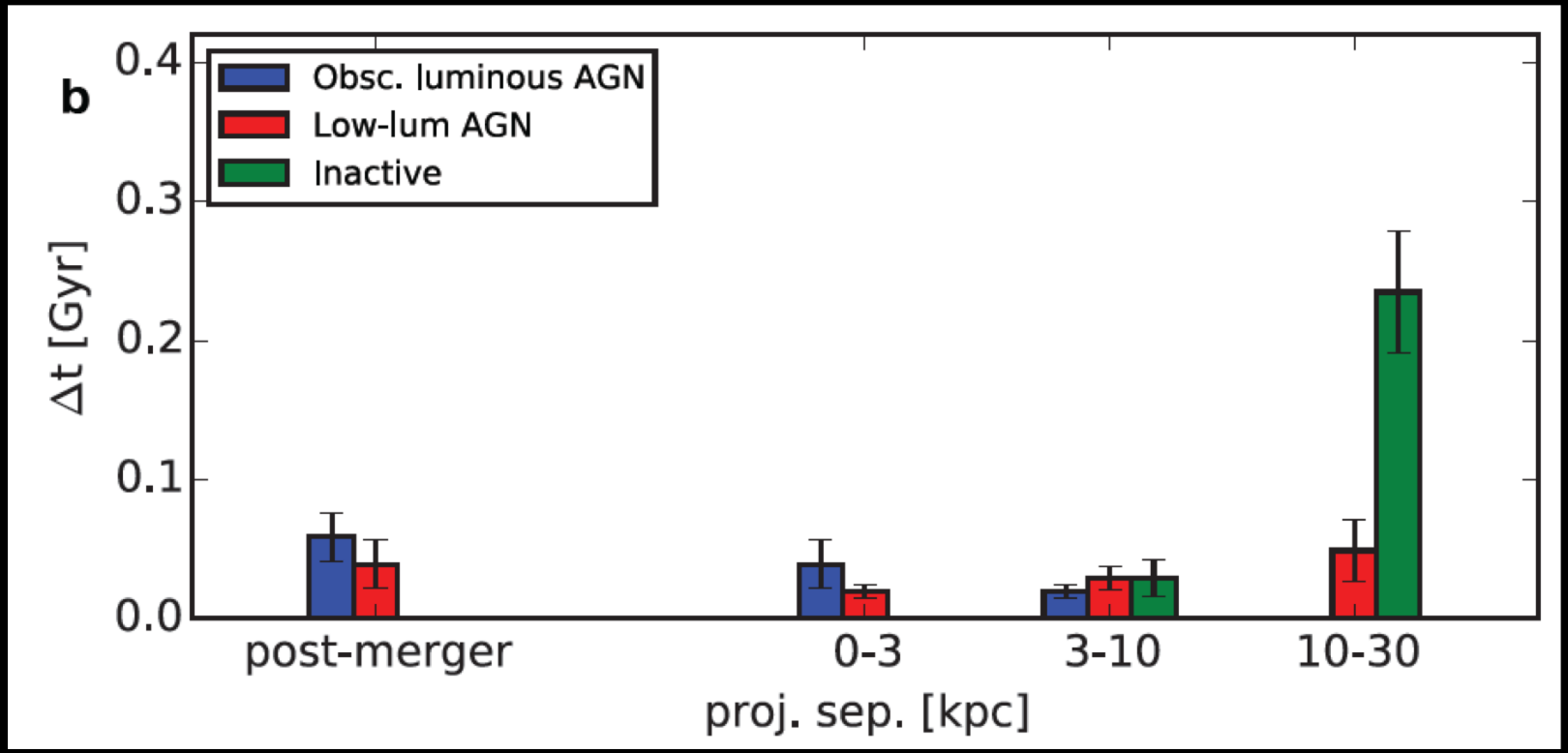


~17% of obscured luminous AGN show hidden mergers
Are these obscured AGN with nuclear mergers the prototypes for GW sources?

Significant excess in luminous obscured AGN



Observations roughly agree with simulations matched in stellar mass, gas fraction, Eddington ratio.



Future approaches to surveying dual AGN, mergers, and black hole growth.

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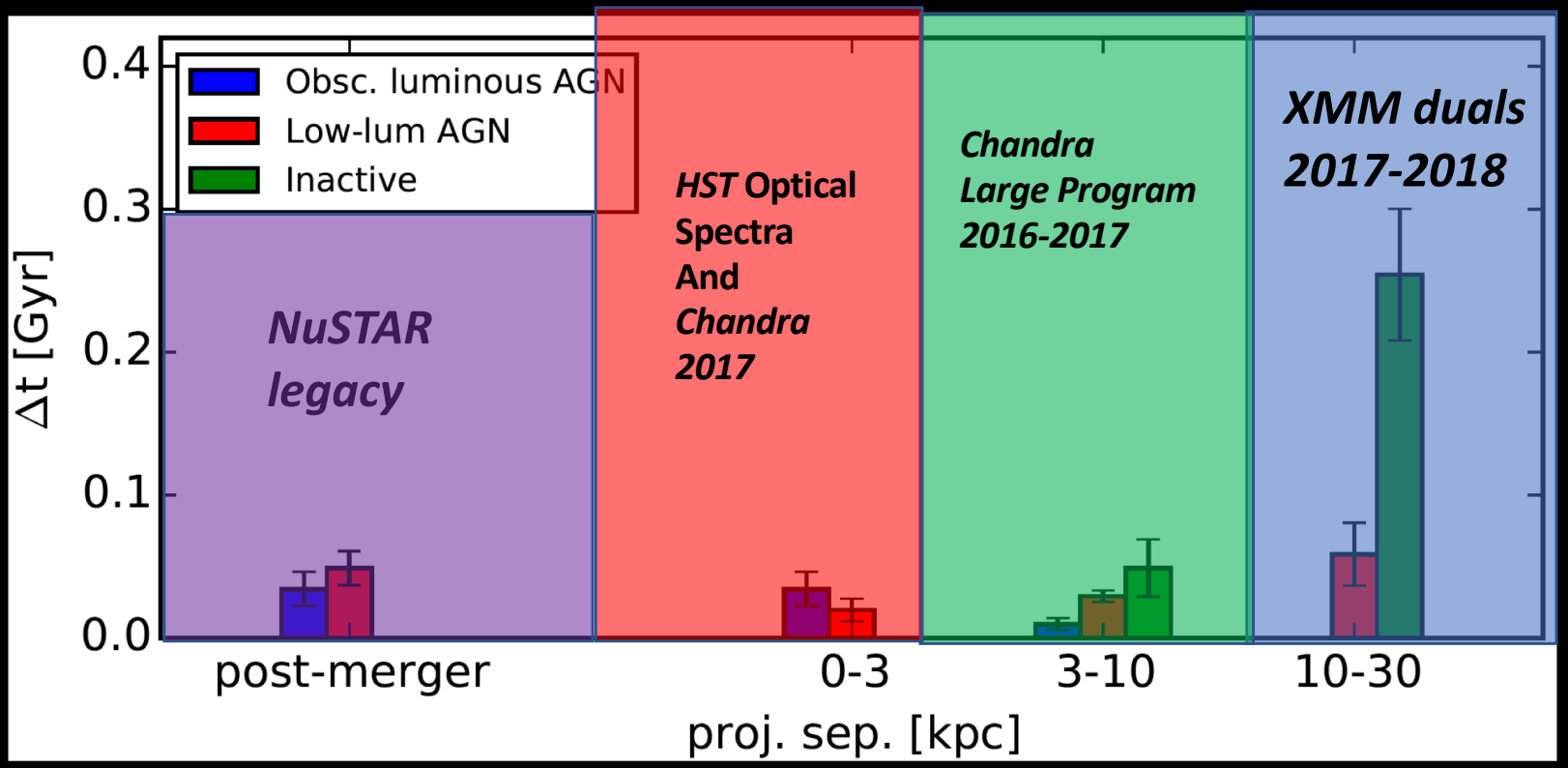

Key Questions:

How does the AGN accretion rate, black hole mass ratios, and and obscuration change with merger stage?

How are environments of dual AGN different?

Uses large survey of molecular gases and black hole masses (Palomar/xshooter).

Summary: Galaxy Mergers and Dual AGN

- Mergers linked to black growth across redshifts in luminous AGN
- Black hole growth, obscuration, dual AGN, and mergers consistent with simulations
- Large X-ray and optical surveys necessary to interpret results
- Hidden population kpc scale mergers in obscured AGN in NIR
- Precursor population of SMBH mergers