

Discovery of a Population of Close Binary AGN: Observing the Hierarchical Assembly of Supermassive Black Holes



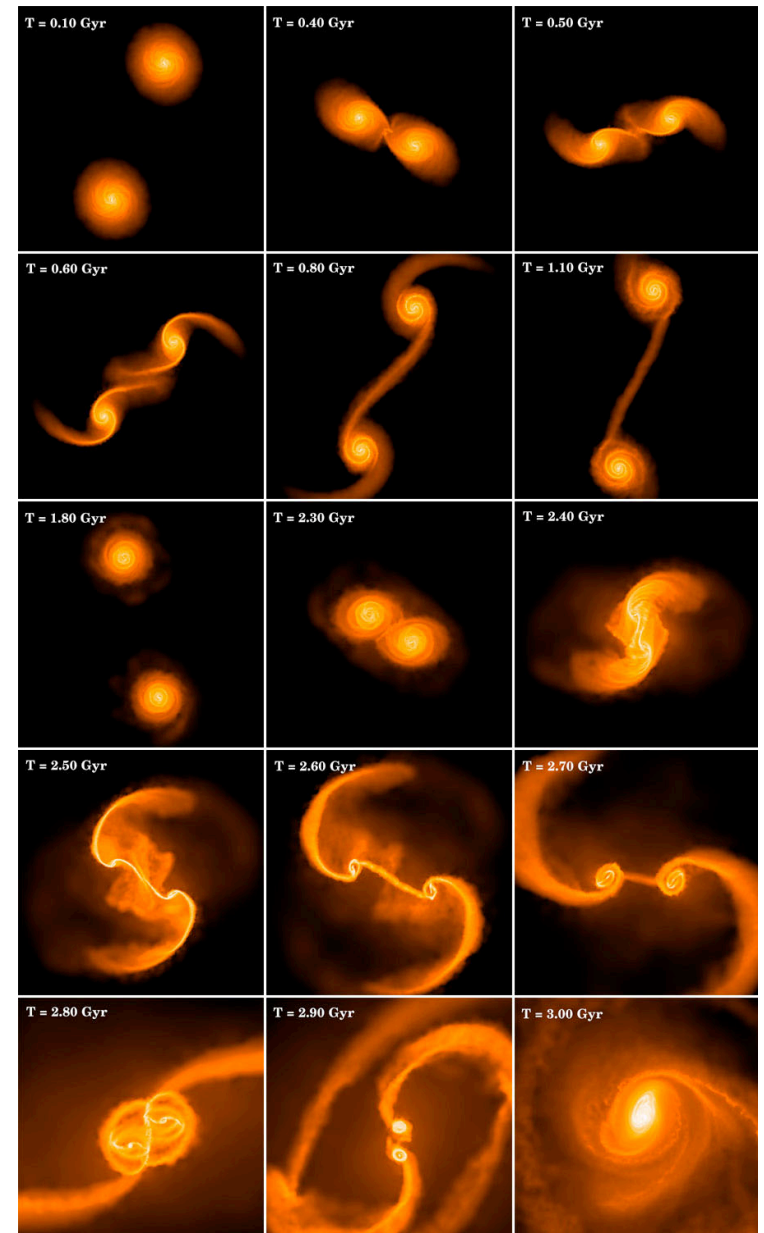
S. G. Djorgovski¹, H. Fu¹, A. Myers², L. Yan³, A. Stockton⁴

¹Caltech, ²UIUC, ³IPAC, ⁴Univ. of Hawaii

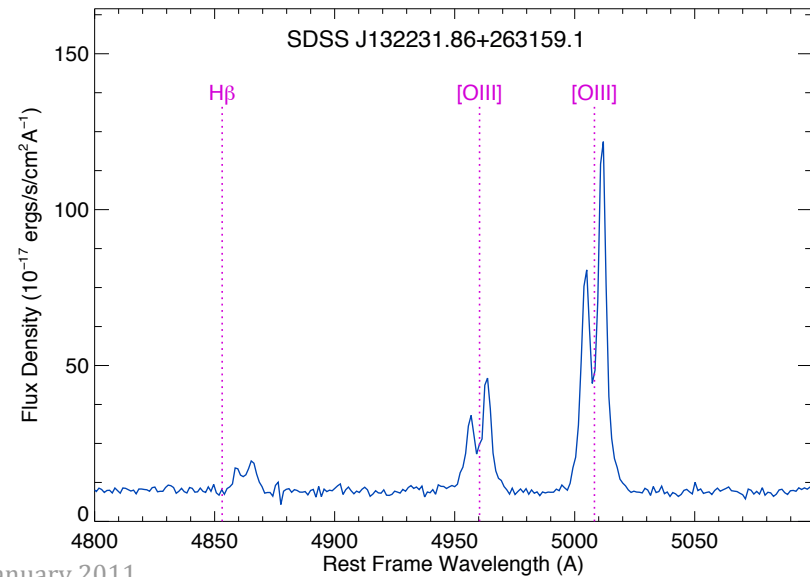
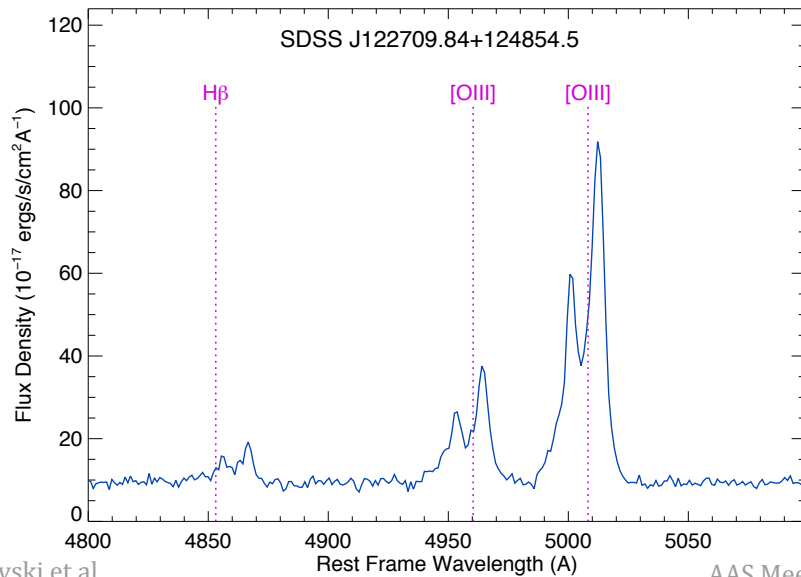
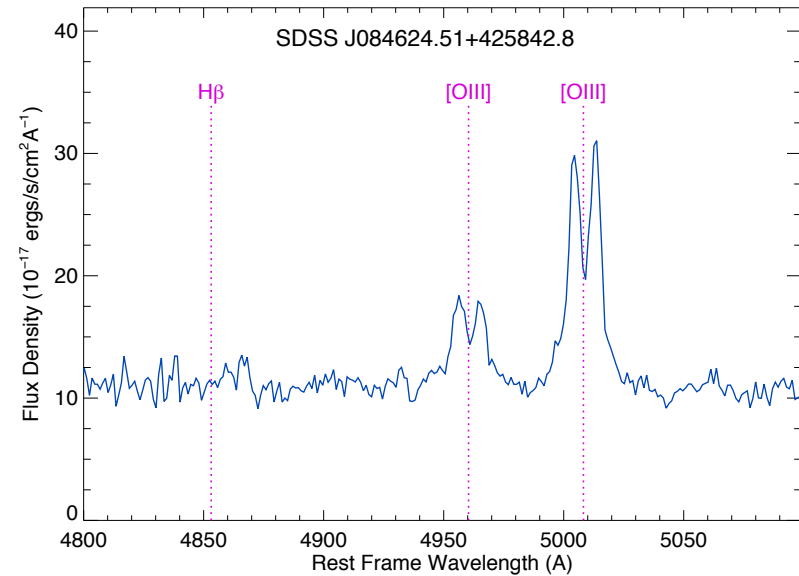
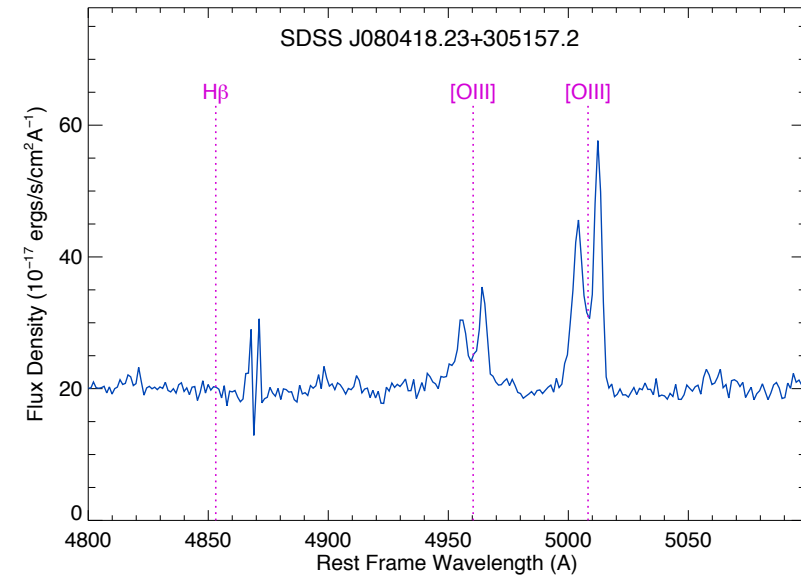
AAS Meeting, January 2011

Hierarchical Assembly of SMBHs

- As galaxies merge through the hierarchical structure formation, so should their central SMBHs
 - Major expected source of gravitational wave bursts
 - Part of the co-evolution of galaxies and SMBHs
- Could be observed as binary AGN in merging systems
 - Binary QSOs have separations from tens to hundreds of kpc
- The goal is to find a population of binaries with $\sim$ kpc separations, or closer
 - A few systems have been seen



Targets: selected from the samples of AGN with double [O III] 5007 lines, by Wang et al. (2009), Liu et al. (2010), and Smith et al. (2010), with $0.02 < z < 0.69$, unresolved in SDSS

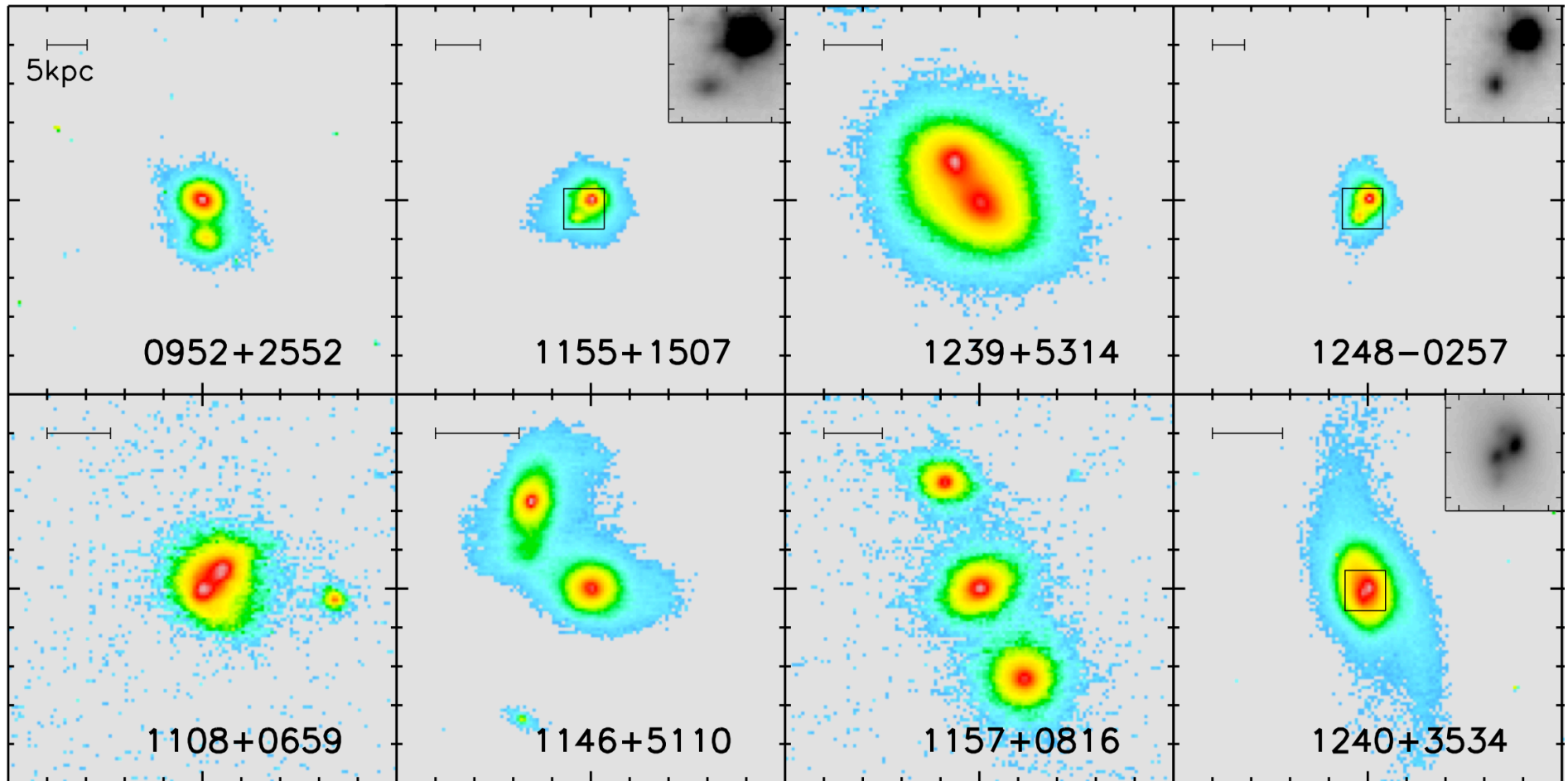


The Observations

- Integral field spectroscopy:
Keck LGS AO + OSIRIS, 6 and 7 March 2010 UT, *H* band
3 sources: 2 type 1 and 1 type 2 AGN
- Imaging:
Keck LGS AO + NIRC2, 3 – 4 June 2010 UT, *K'* band
WF (40 mas/pixel) and NF (10 mas/pixel) modes
47 sources: 15 type 1 and 32 type 2 AGN
- Some long-slit spectroscopy (Keck LRIS and P200 DBSP)

A Population of Close Double AGN

- 16 out of 50 resolved doubles, proj. separations 0.6 – 12 kpc
- Many show merger-type morphology

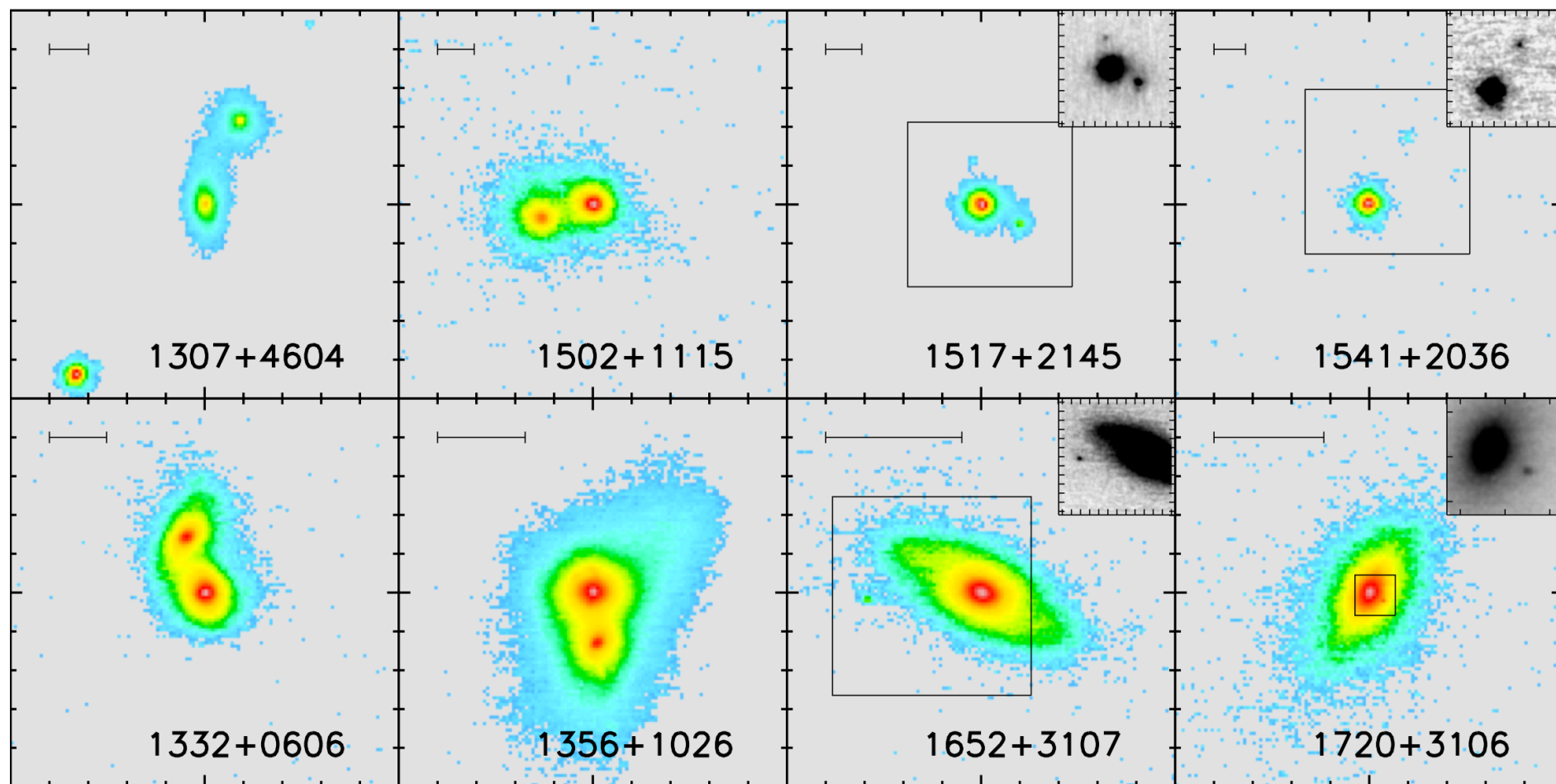


Top row: type 1, bottom row: type 2

FOV = 10 arcsec

A Population of Close Double AGN

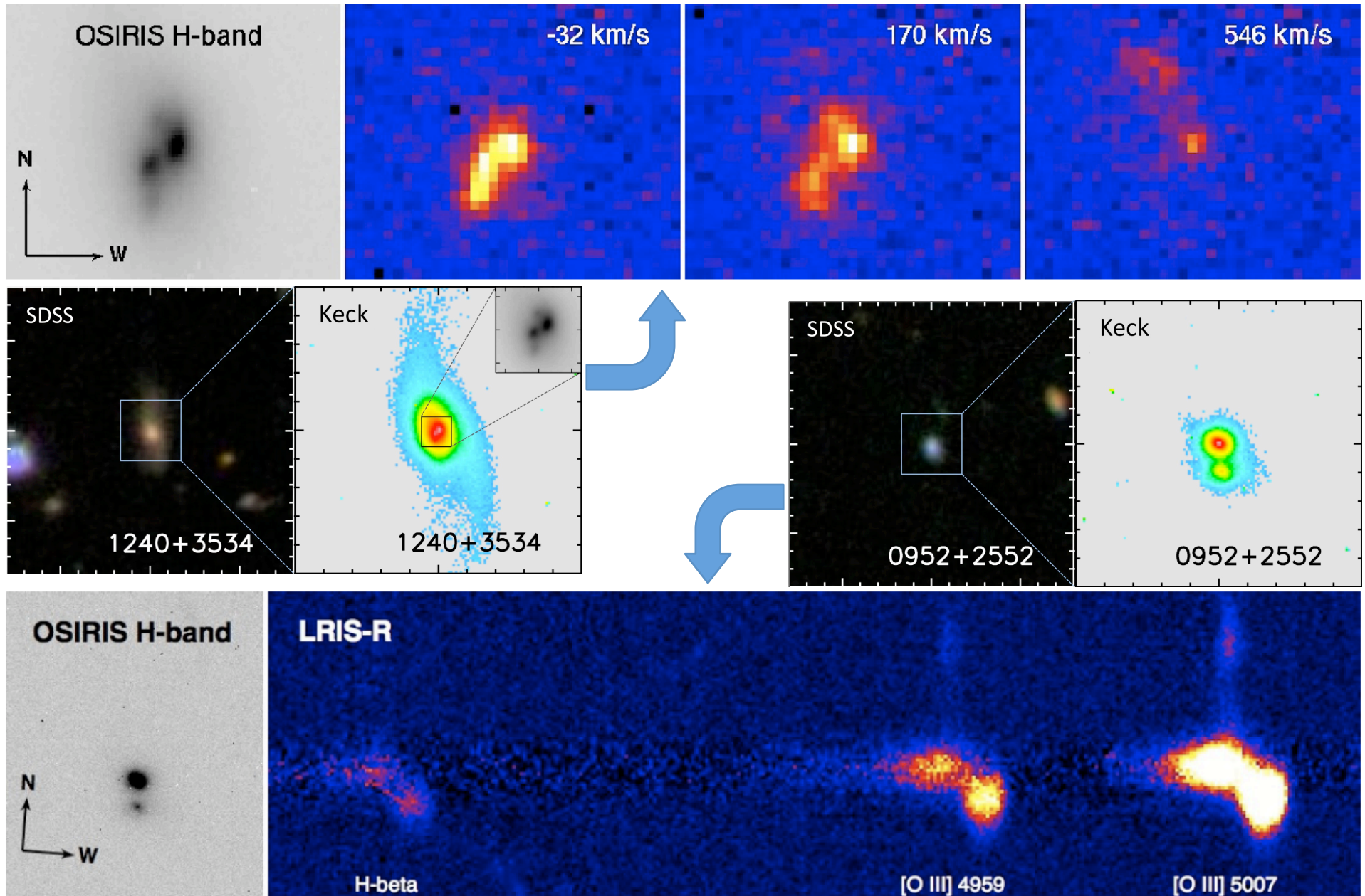
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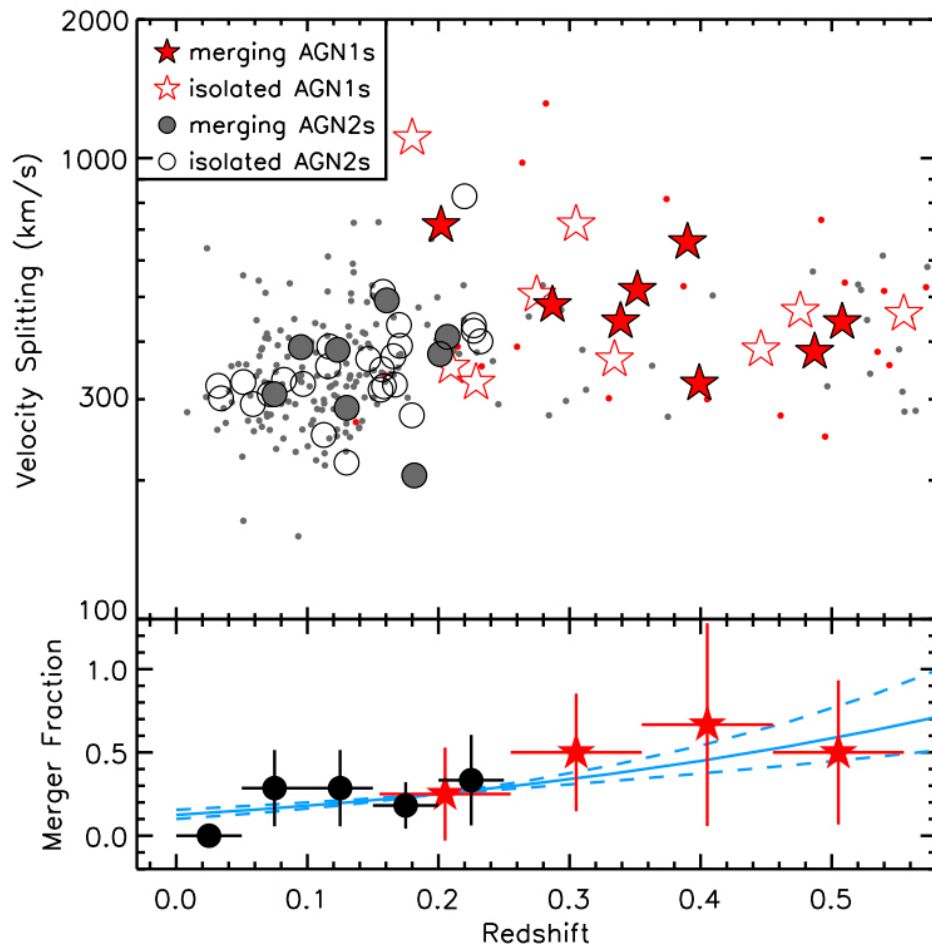
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Resolved Spectroscopy



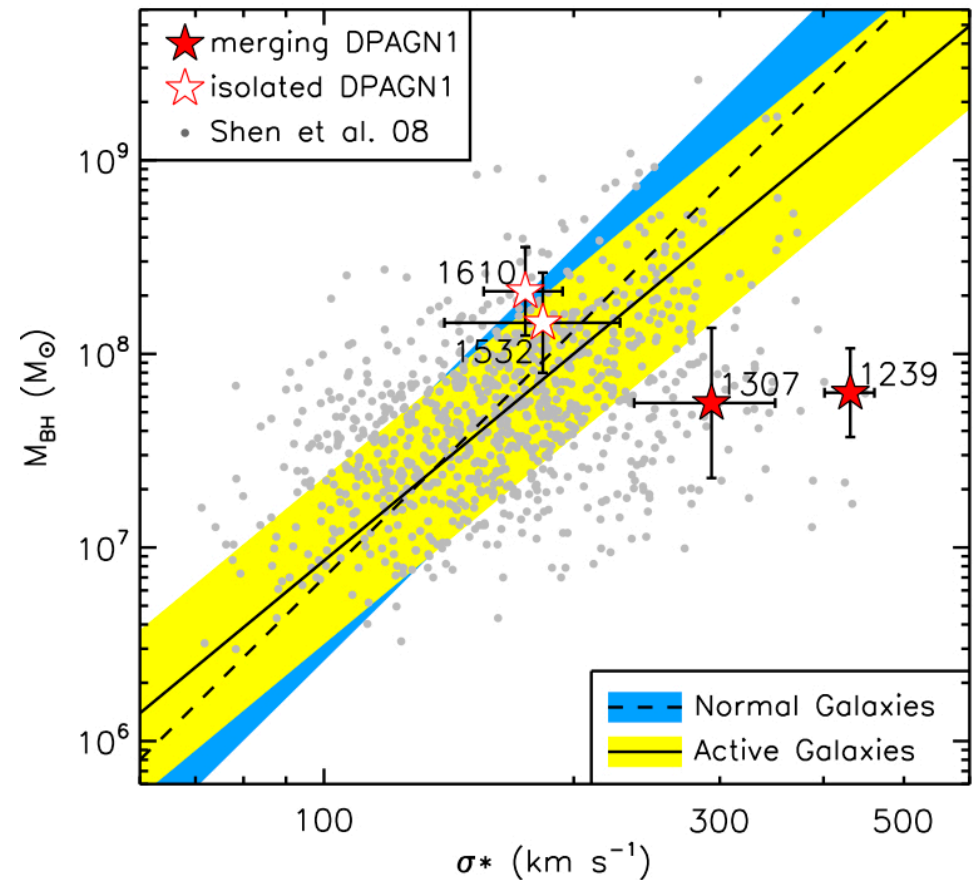
Some Interesting Trends

Velocity splitting does not depend on the morphology or the AGN type



$$\text{Merger rate} \sim (1+z)^{3.8 \pm 1.2}$$

Resolved binary AGN are outliers in the $M_{\text{bh}} - \sigma_*$ relation; unresolved binaries probably contribute to its scatter



Conclusions and Future Work

- At least $\sim 1/3$ of all double-line AGN are resolved doubles with $\sim$ kpc separations; the rest may be:
 - Unresolved, with sub-kpc separations
 - Due to other mechanisms: jets, truncated/asymmetric NLRs...
- This is most likely the expected population of SMBH binaries on their way to merging
 - Supported by the merger-type morphologies of the hosts
 - Merger fraction increases with redshift as expected from the structure formation models
- Close binaries increase the scatter of the $M_{\text{bh}} - \sigma_{\star}$ relation
- Future work: increasing the sample, kinematical measurements and modeling

