

Revealing a population of dual supermassive black holes
at close separation using Subaru's Hyper Suprime-Cam

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Connecting the growth of supermassive black holes (SMBHs) to the galaxy population

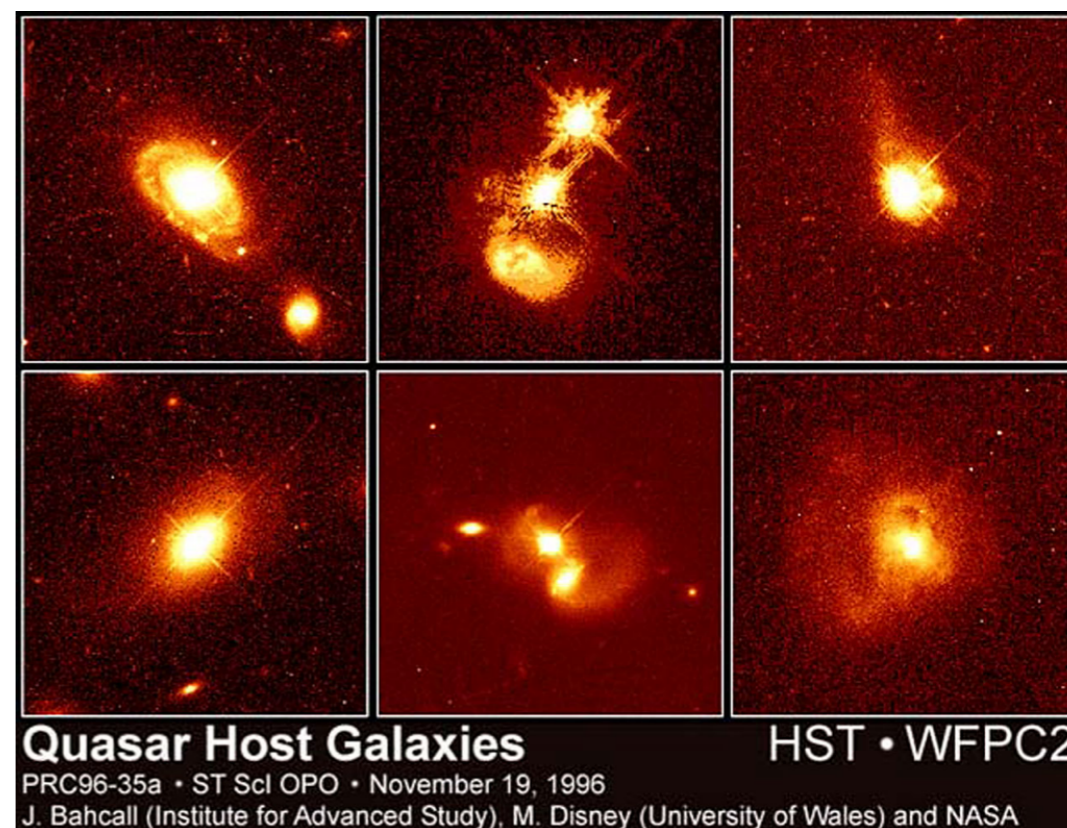
How do SMBHs grow?

What galaxies are most nurturing for fueling black holes?

Role of galaxy mergers



Imaging the host galaxy of
luminous quasars

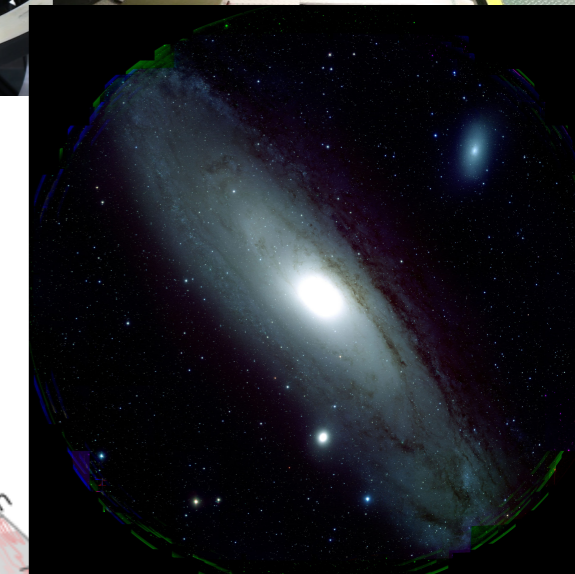
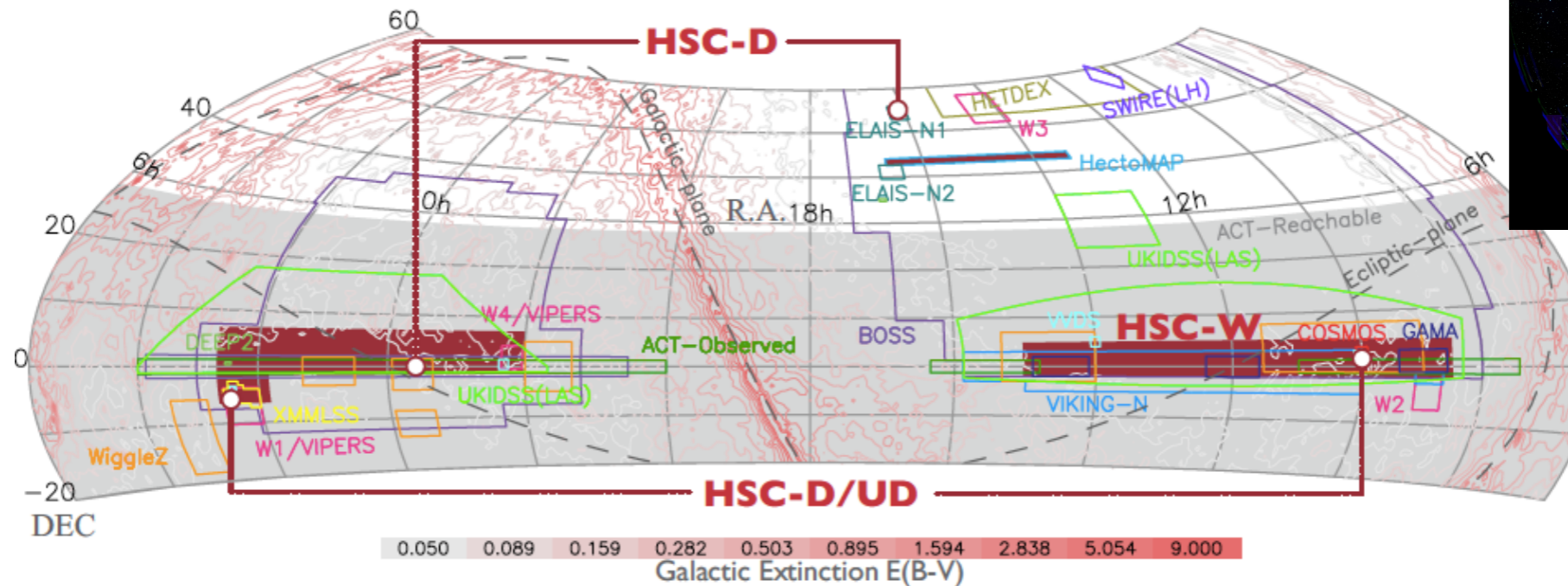
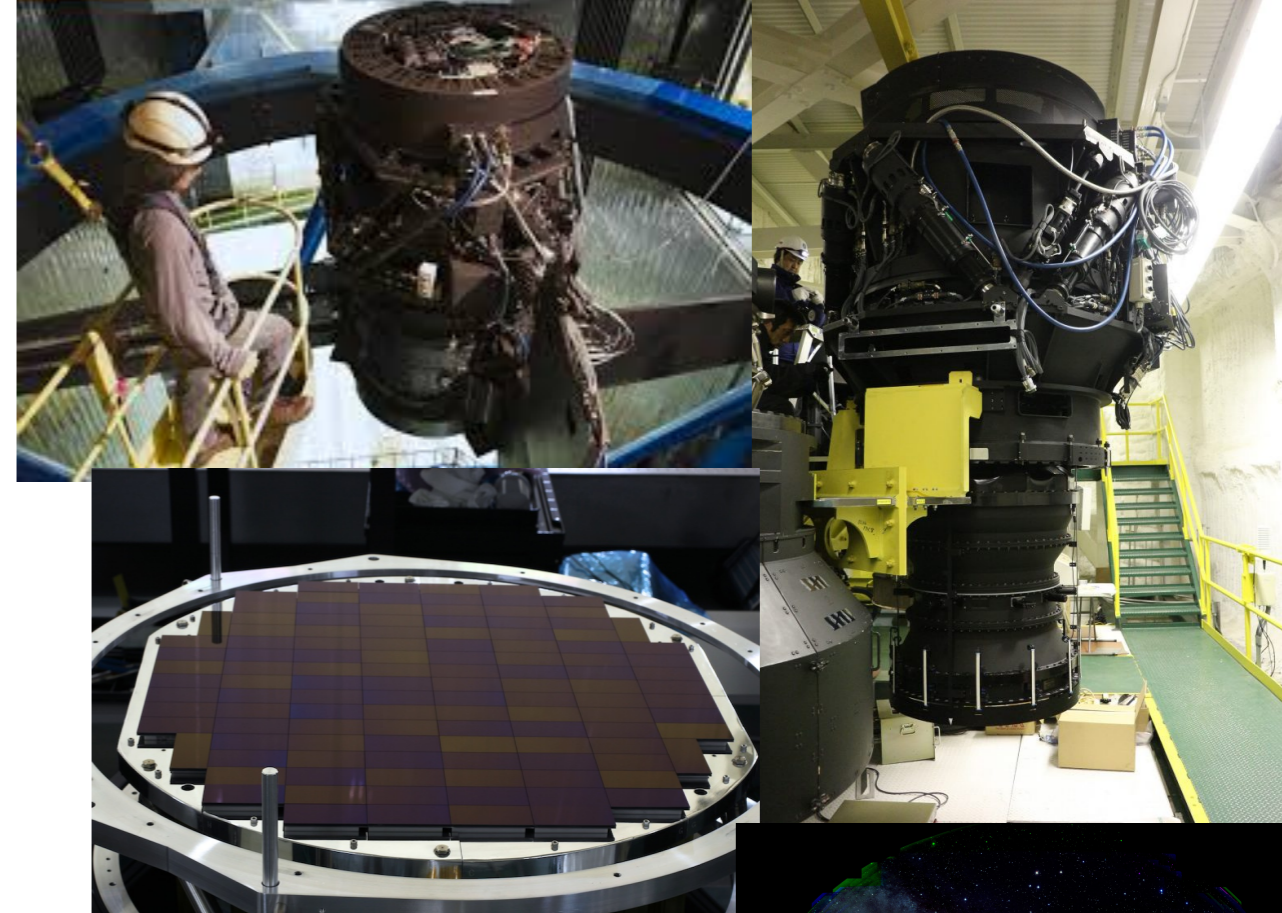


Subaru's Hyper Suprime-Cam & Strategic Survey Program

Aihara et al. 2017, 2019

Exploit the following:

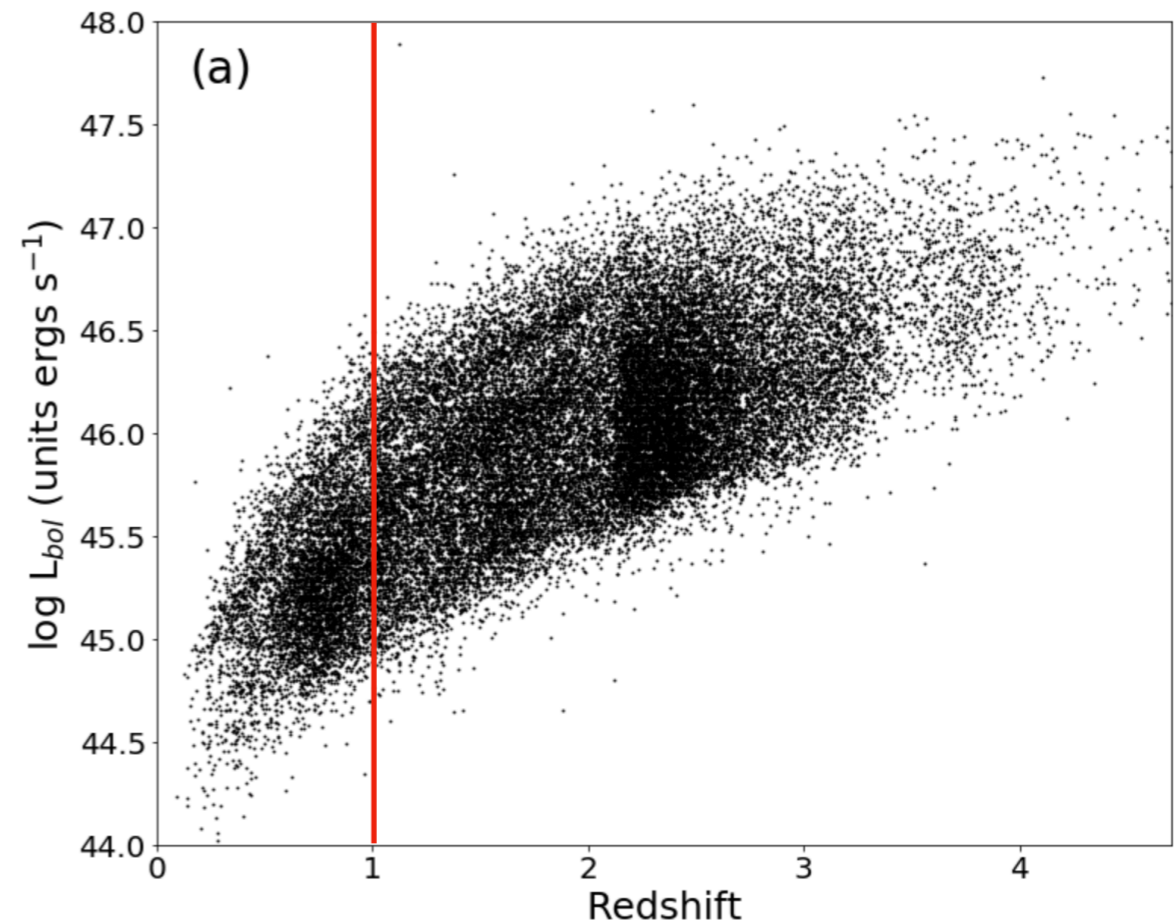
- FOV: 1.5 deg²
- deep (mag~26)
- high resolution (0.6" in i-band)
- wide survey area (~1000 deg²)
- multi-band (grizy)



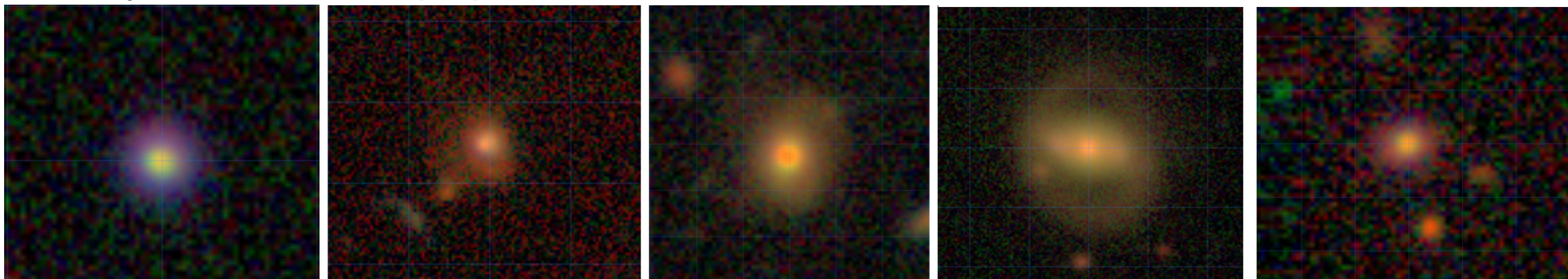
- Three layers: Wide (1400 sq. deg.): Cosmology, Deep (28): Galaxy Evolution, UltraDeep (3.5): Cosmic reioniation

Subaru/HSC imaging of SDSS type 1 quasars

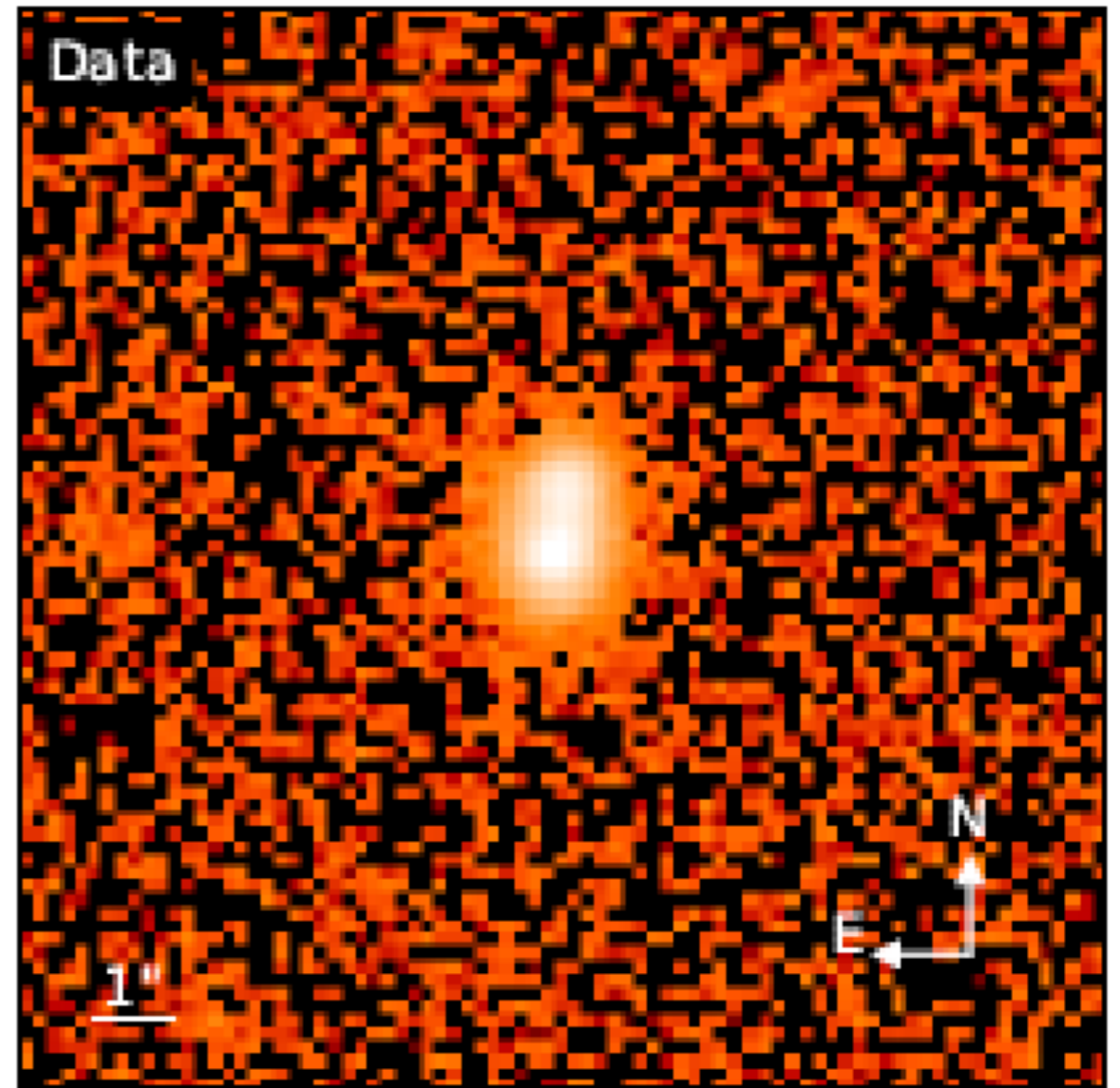
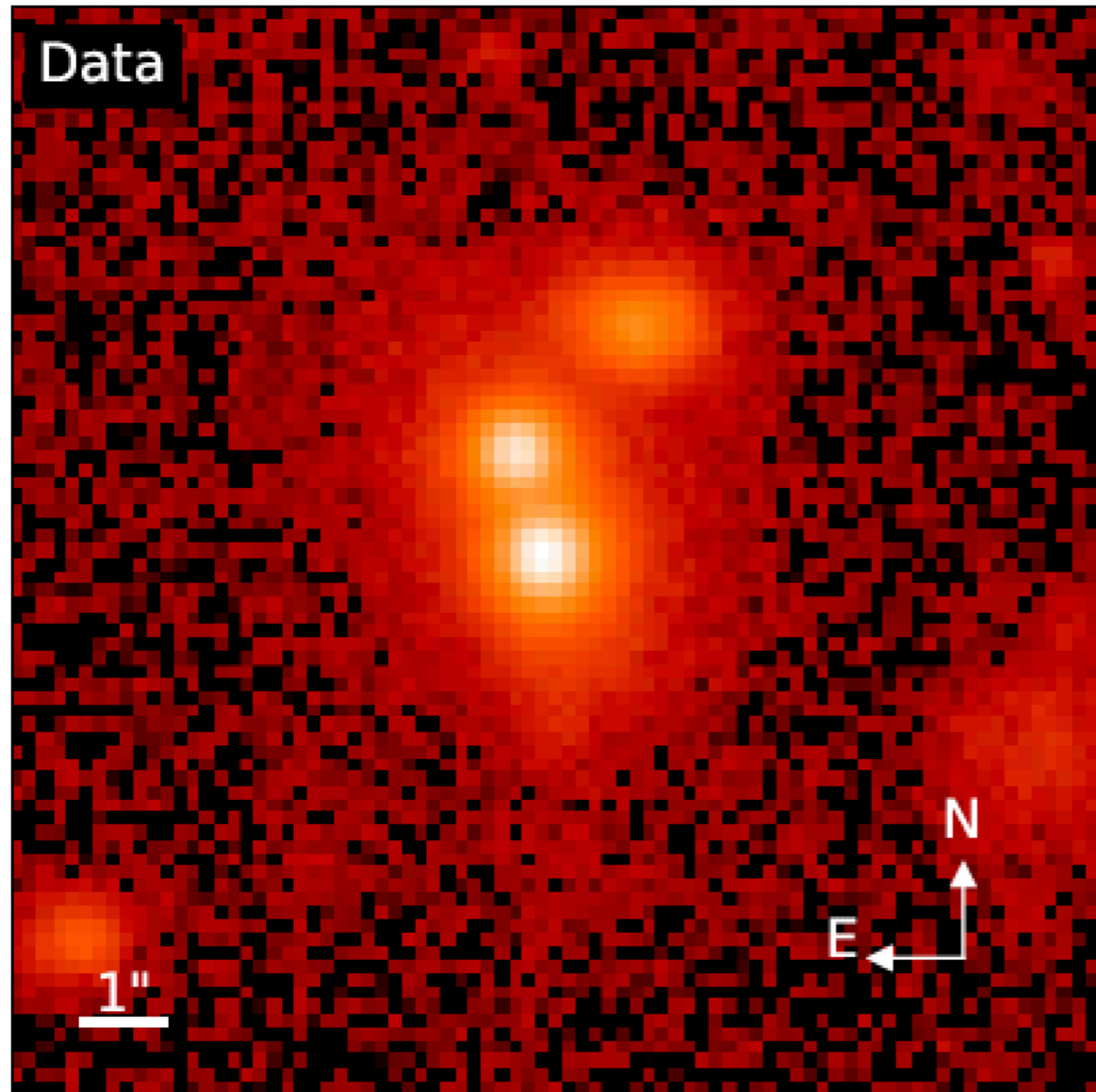
- 34,476 SDSS QSOs from DR14 (Paris et al. 2018) with HSC imaging out to $z \sim 4.5$
- 5,371 at a $z < 1$ with all 5 optical bands
- 2D image decomposition (AGN + host galaxy)
 - forward modeling, empirical psf, MCMC error analysis
 - Galaxies: Sersic profiles



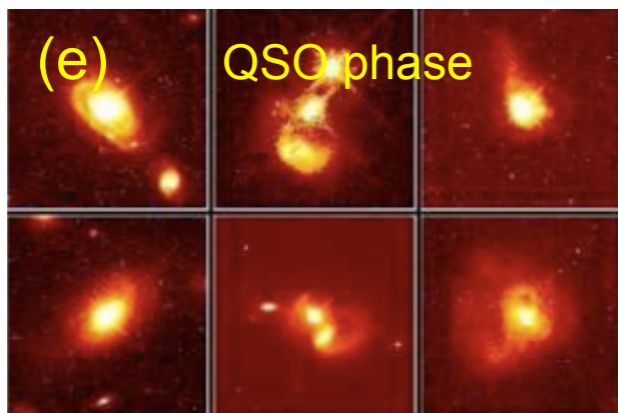
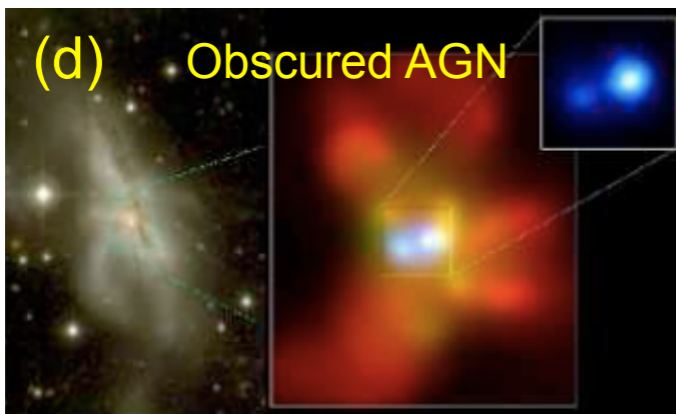
Li, Junyao, JDS et al. in prep



SDSS type 1 quasars with two or more components

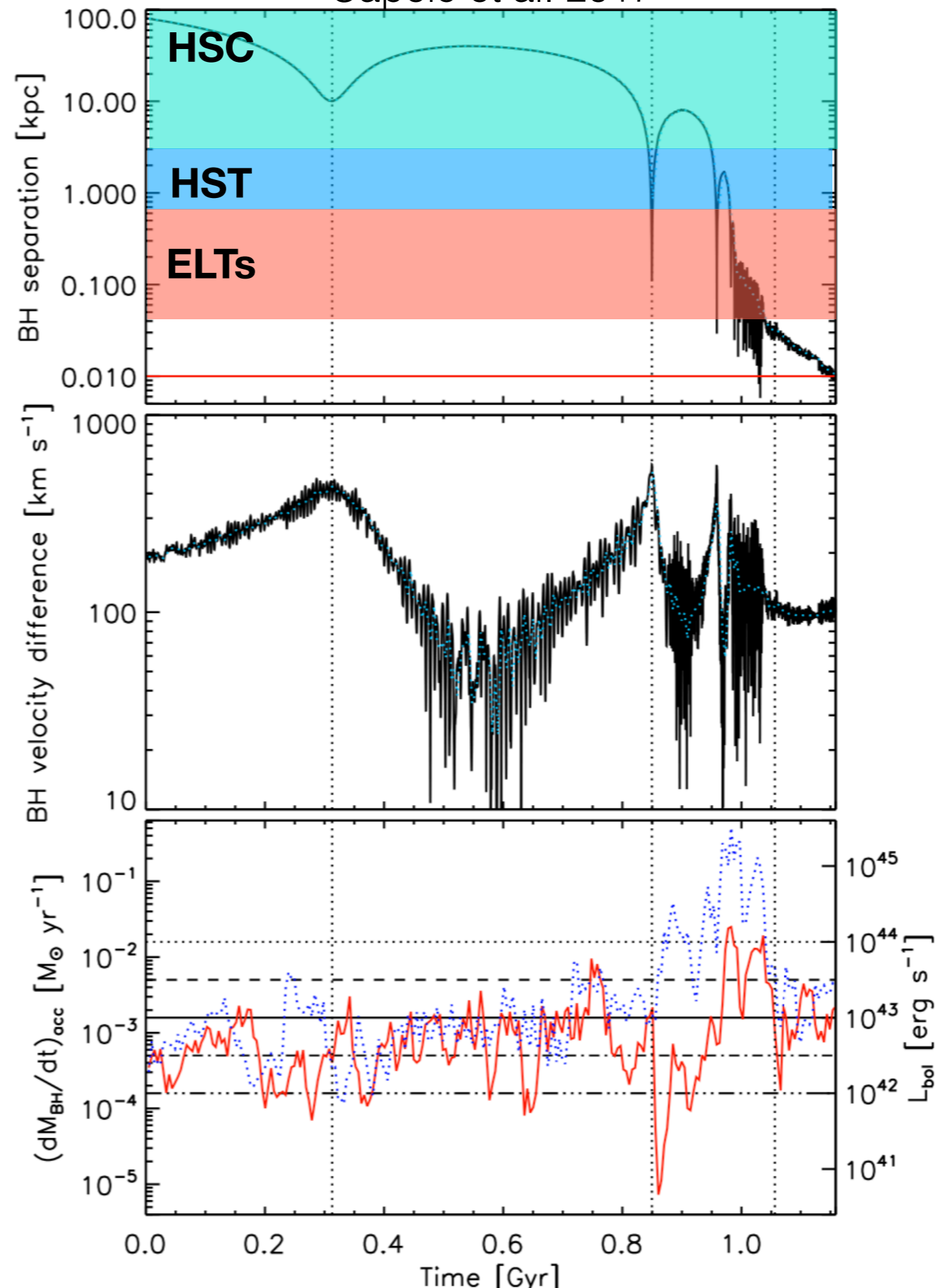


Merger pathway for black hole growth



Hopkins et al. 2006

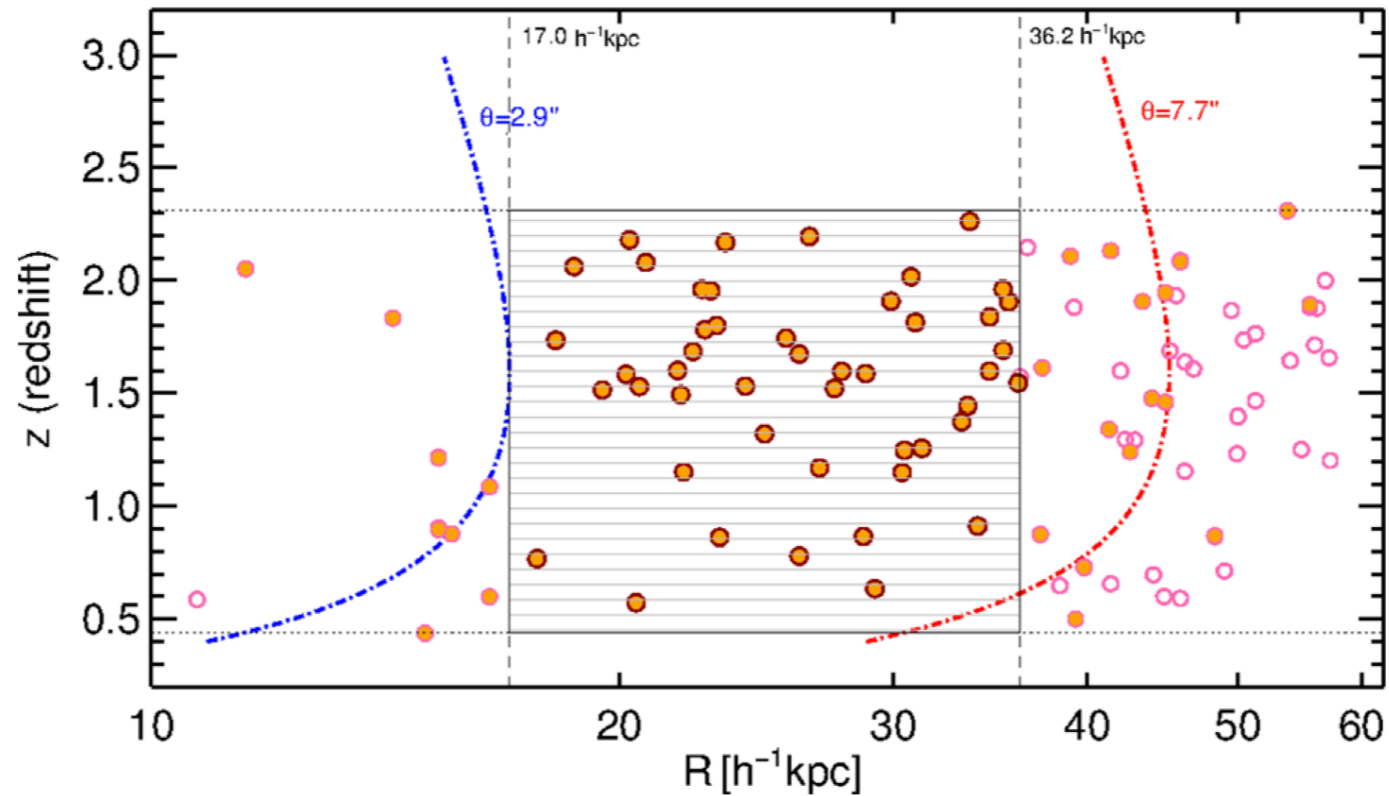
Capelo et al. 2017



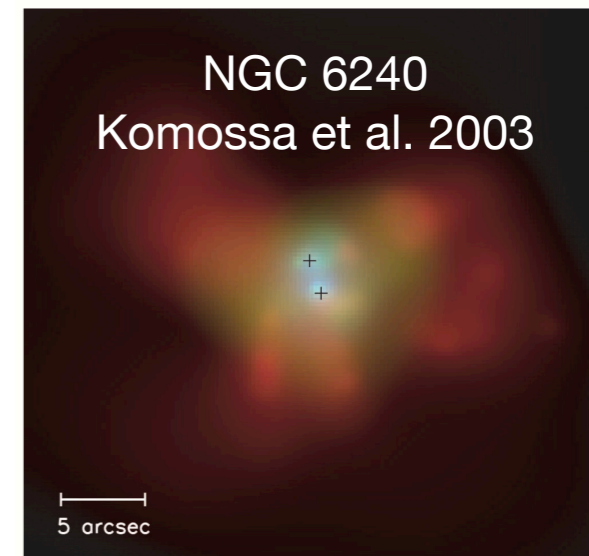
Searches for dual quasars and AGN

Quasar pairs

Hennawi et al. 2006
 Prochaska et al. 2013
 Eftekharzadeh et al. 2017

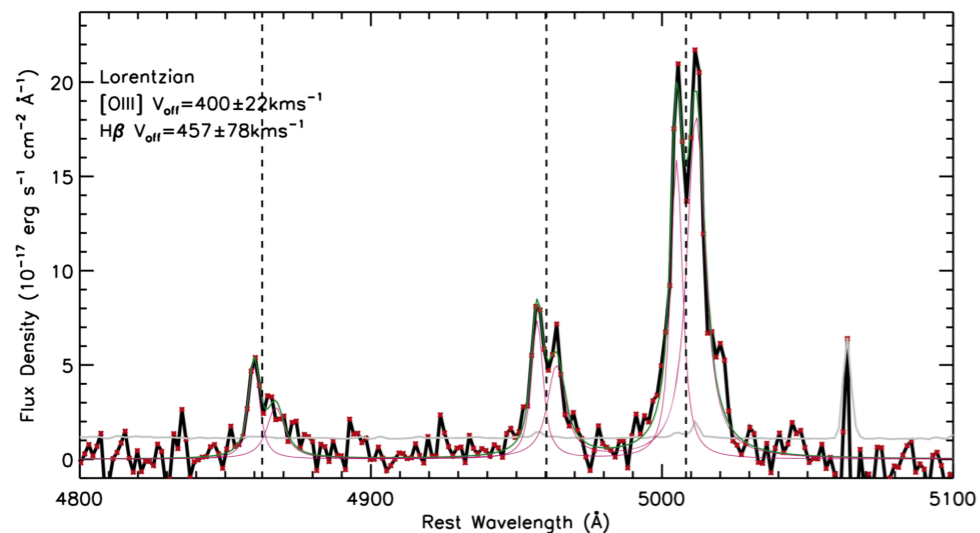


Double X-ray sources



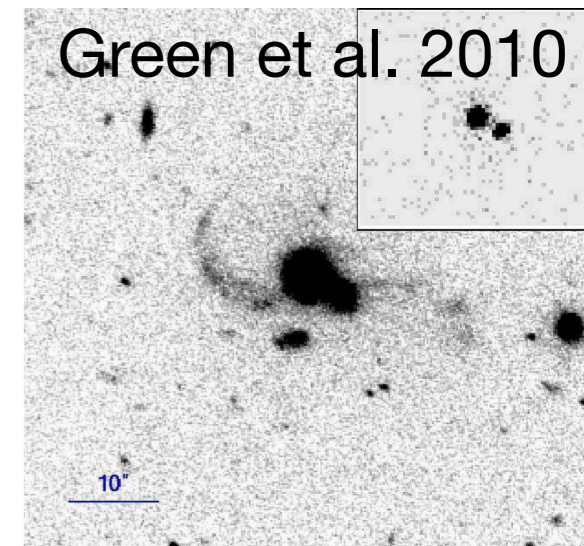
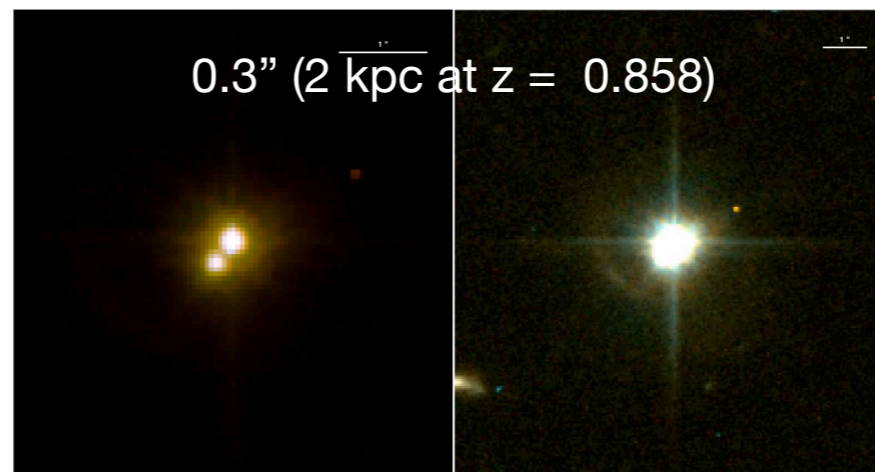
Double and offset [OIII] lines

Comerford et al.; Liu et al. 2018



Serendipity

Shields et al. 2012



Dual quasar detection

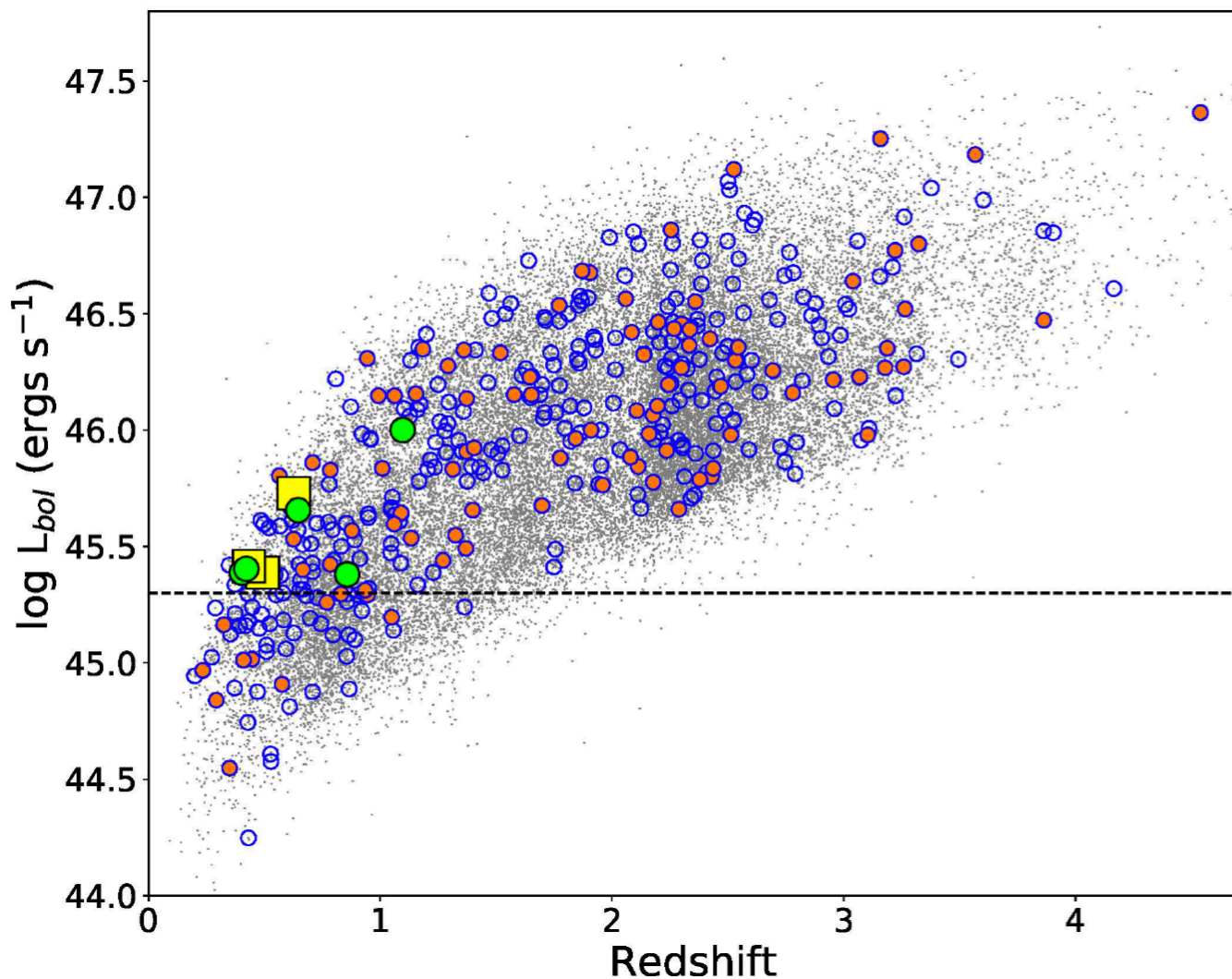
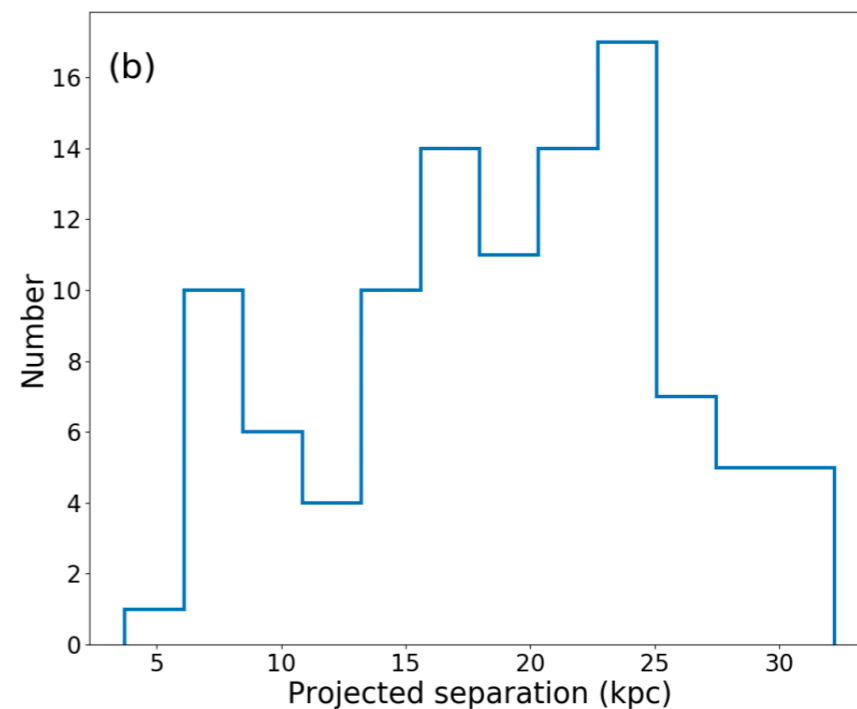
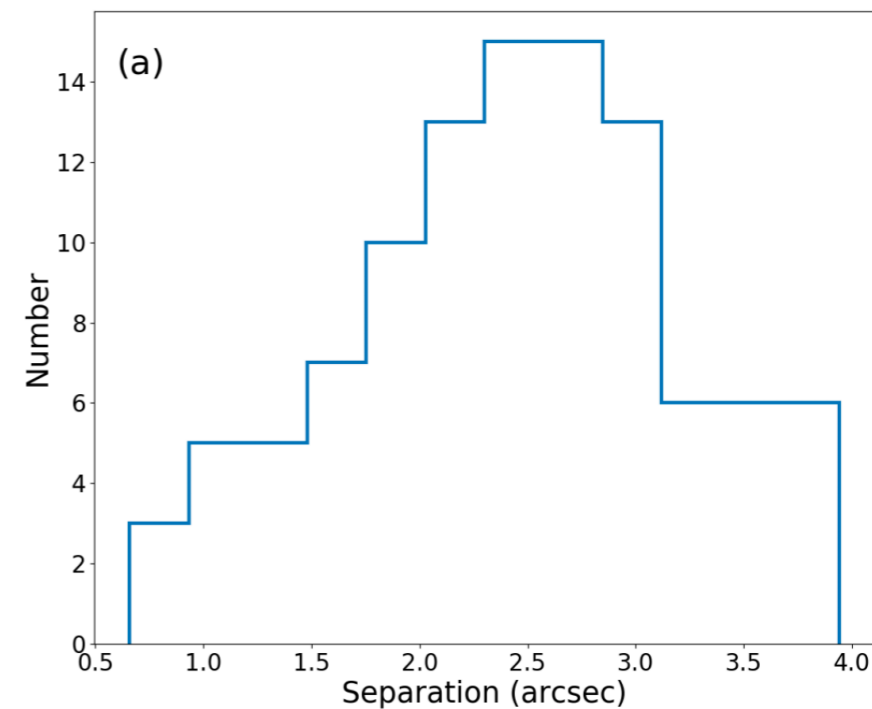
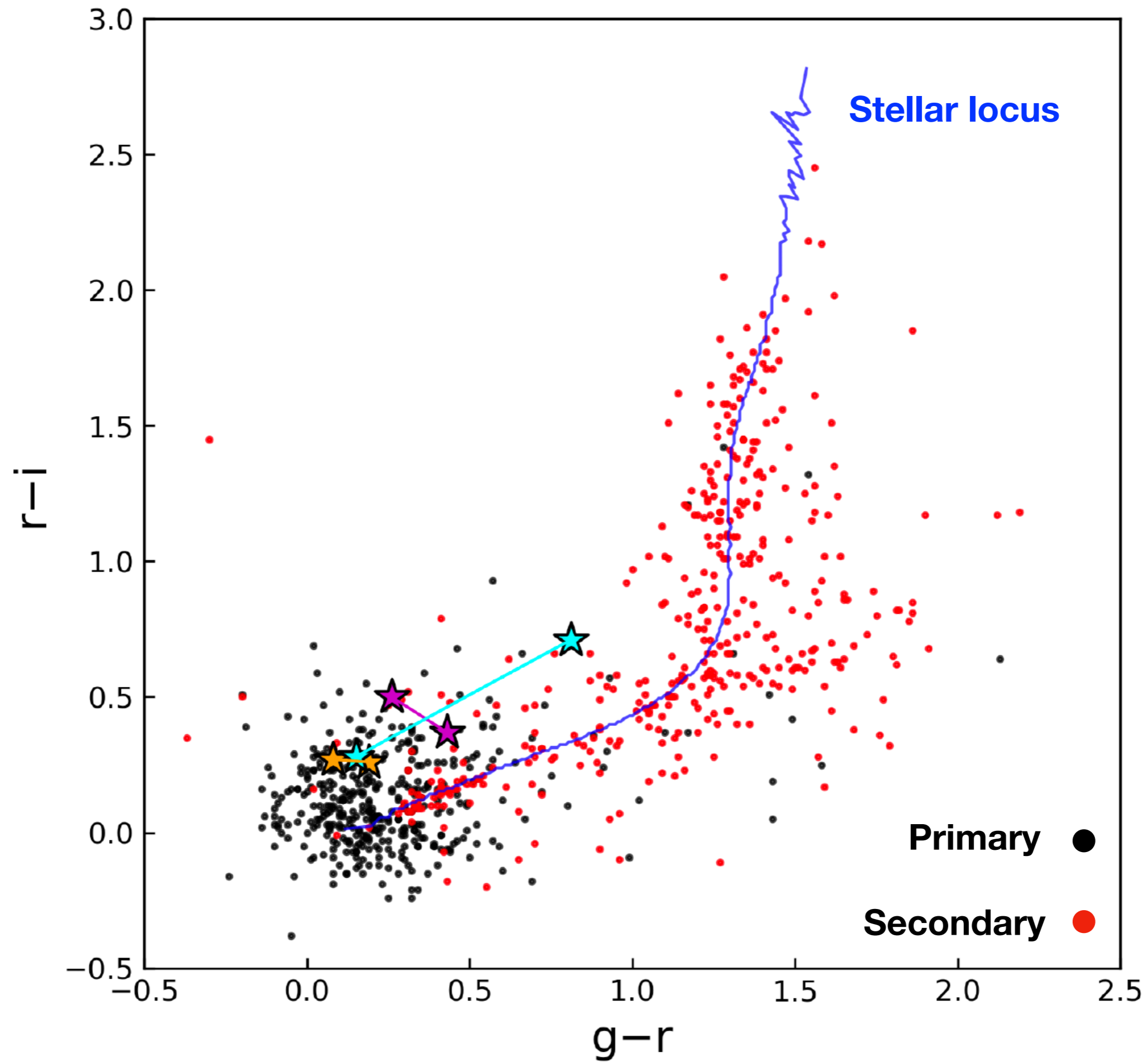


Table 1
Sample selection

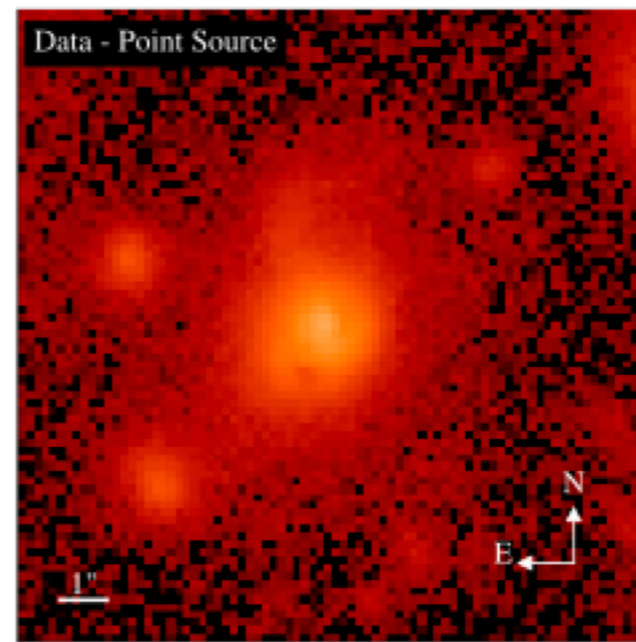
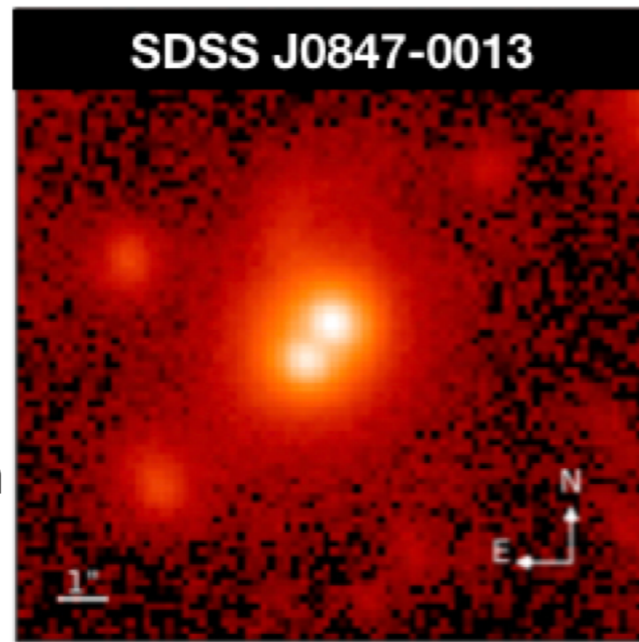
Category	Number of objects
SDSS DR14 quasar catalog	526357
Imaged by the HSC wide-area survey	34476
Dual quasar candidates with 0.6–4'' separation	452
'' after visual inspection	425
'' minus known lenses	421
'' with 5-band photometry available	401
'' having flux ratio within 10:1	385
'' with the companion having $g - r < 1.0$	116



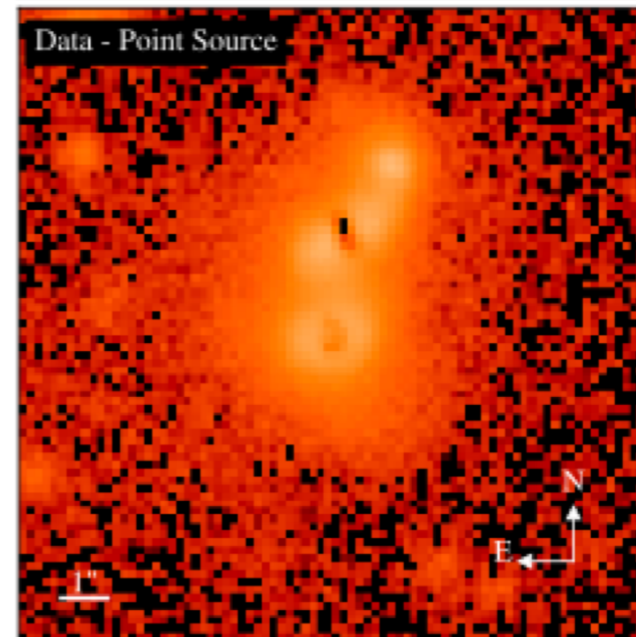
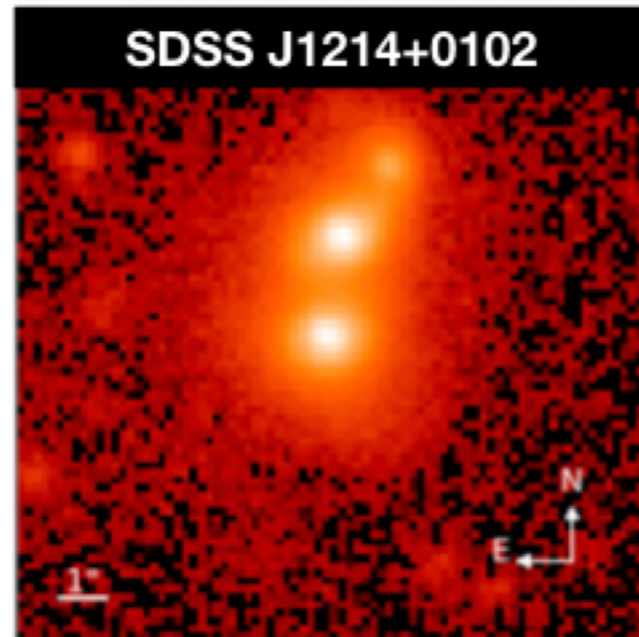


Confirmed dual quasars

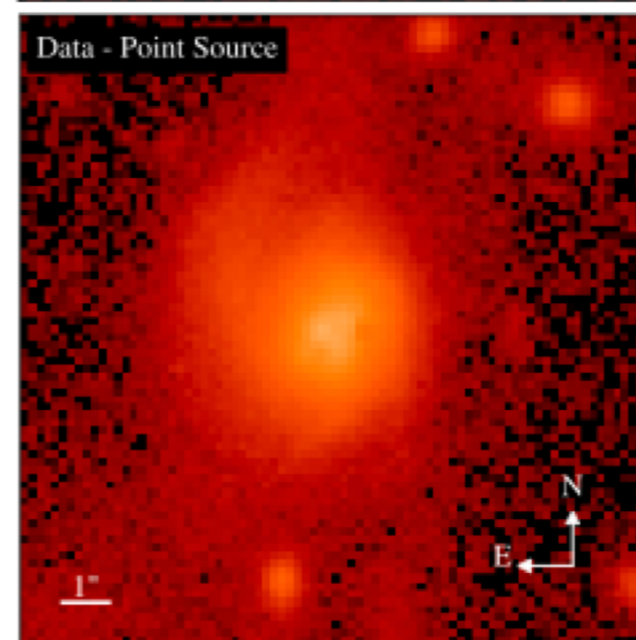
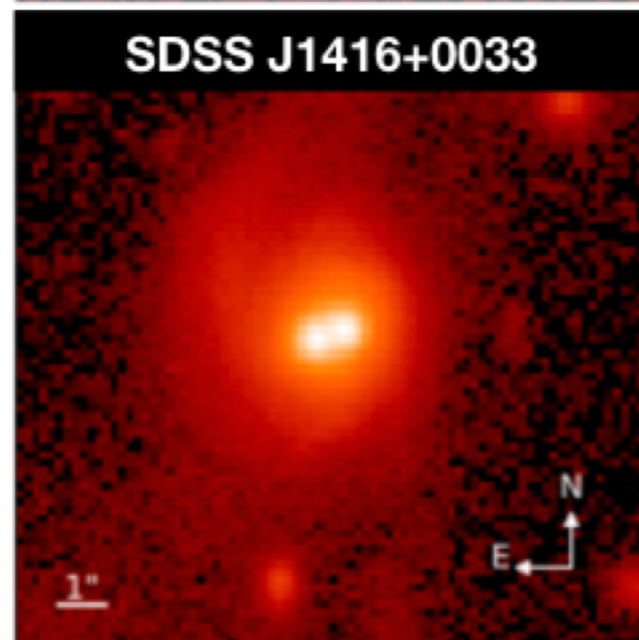
$z=0.630$
1" separation
6.8 kpc



$z=0.493$
2.2" separation
13.2 kpc



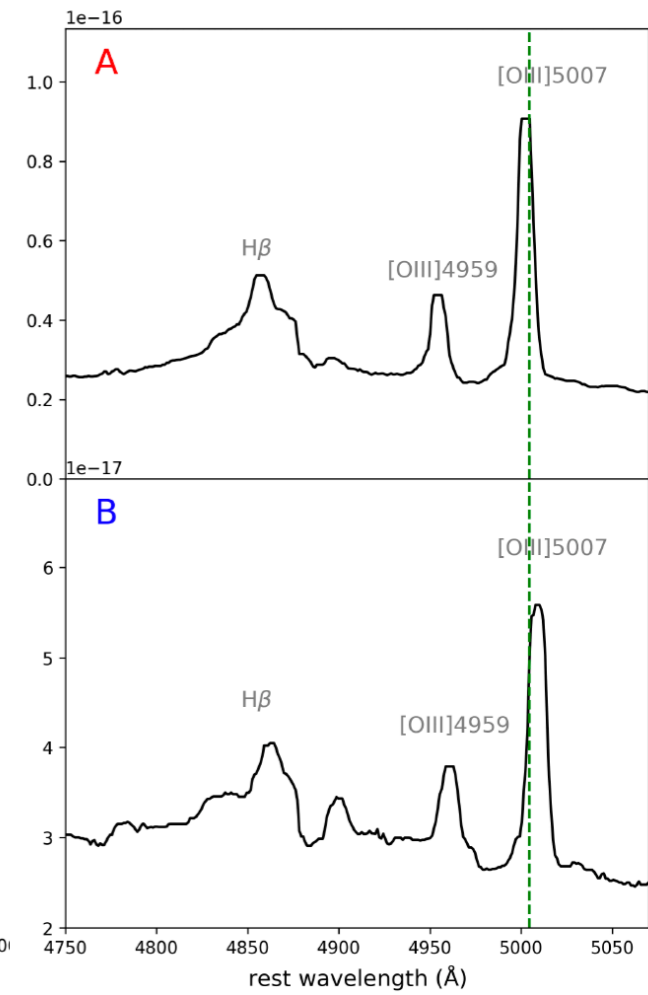
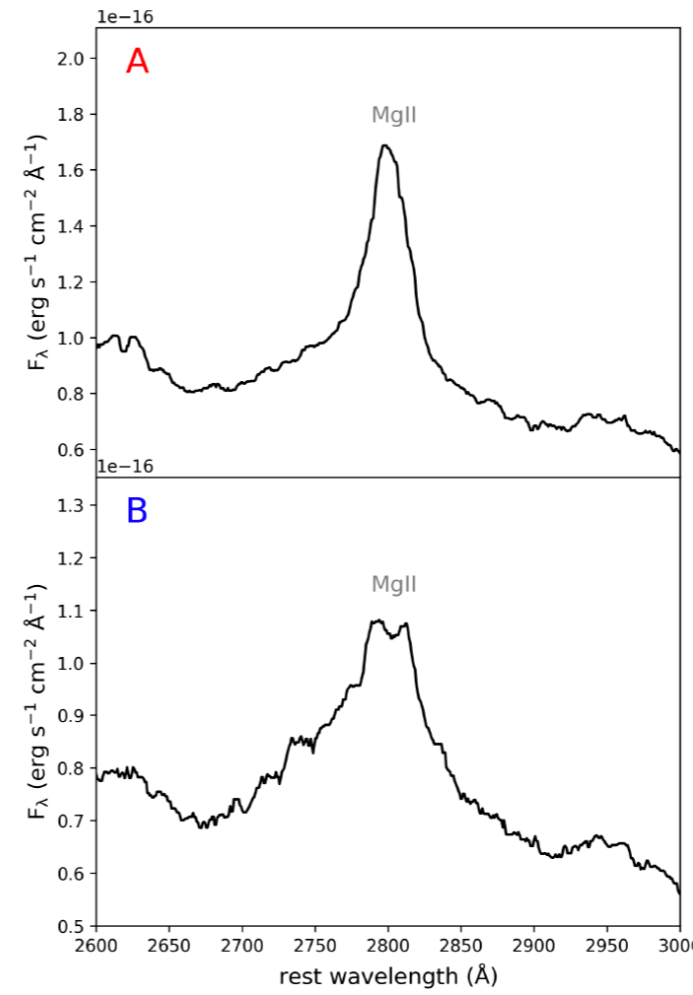
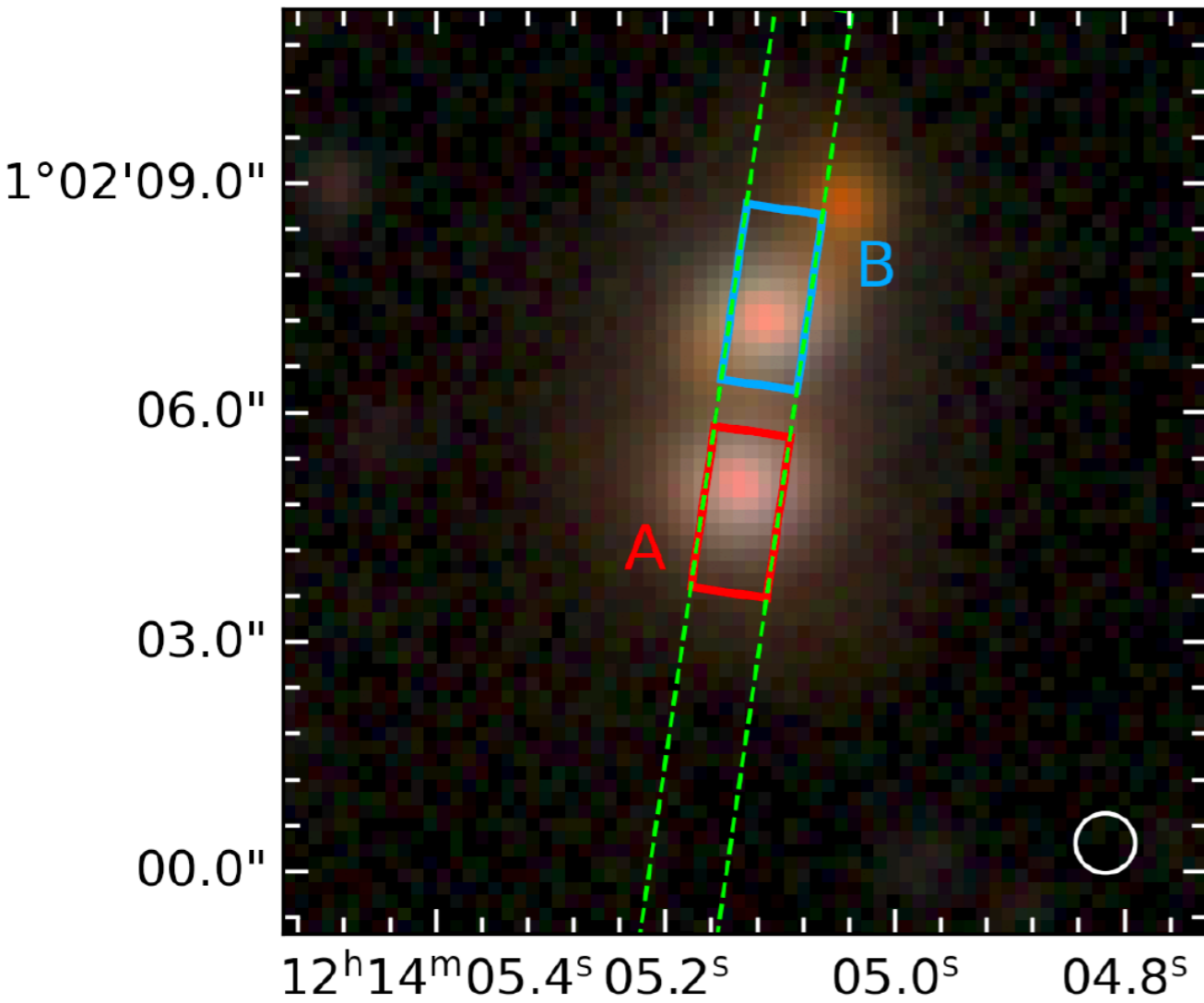
$z=0.434$
0.66" separation
3.9 kpc



Inada et al. 2008

Optical spectroscopic confirmation with Keck-I/LRIS (courtesy K.G. Lee - Kavli IPMU)

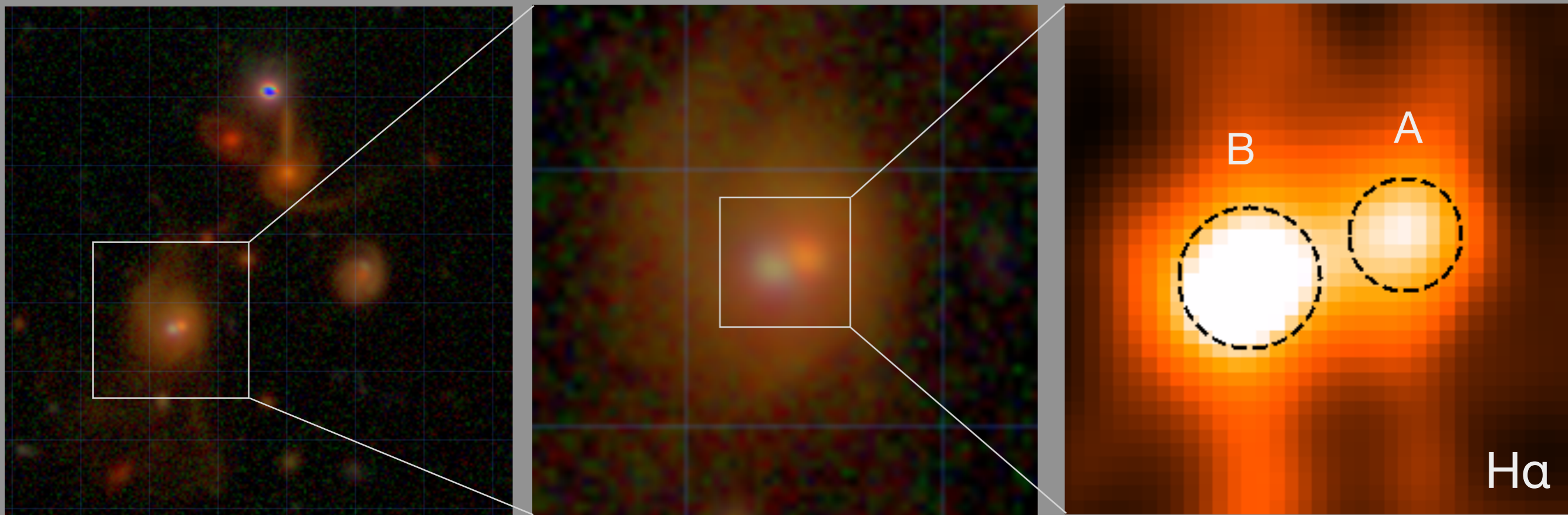
SDSS J1214+0102



SDSS J141637.44+003352.2

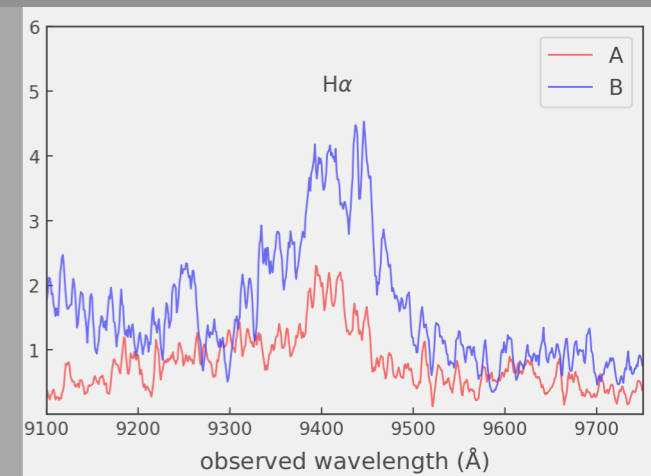
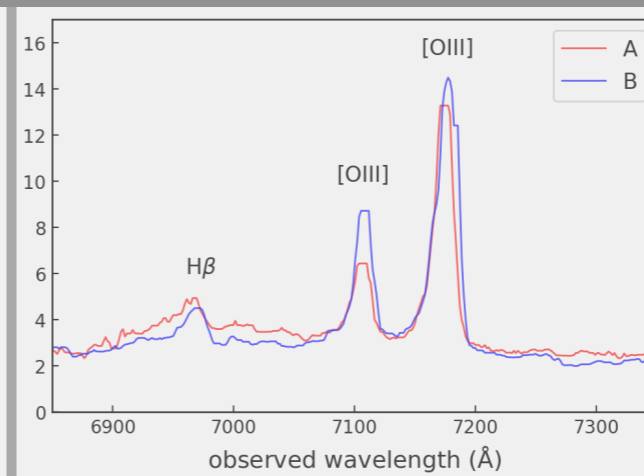
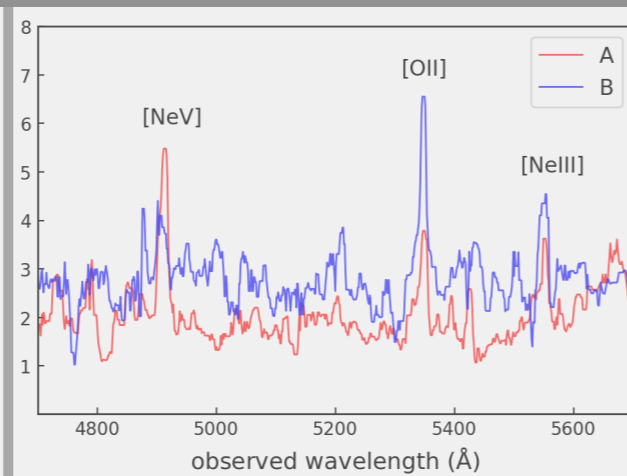
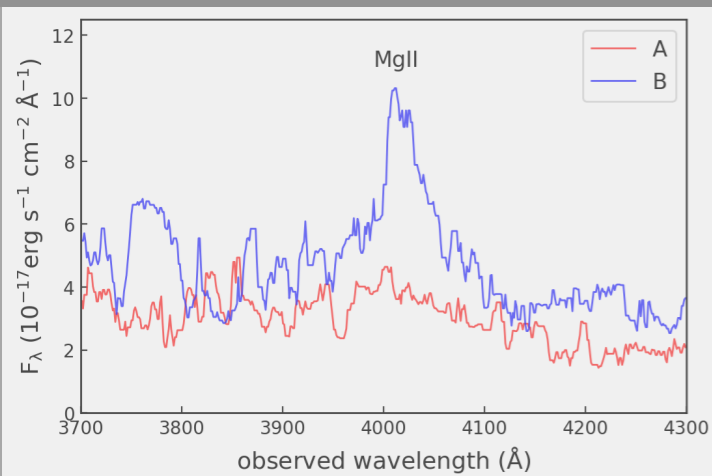
$z = 0.4336$

$\theta = 0.67'' = 3.9 \text{ kpc}$

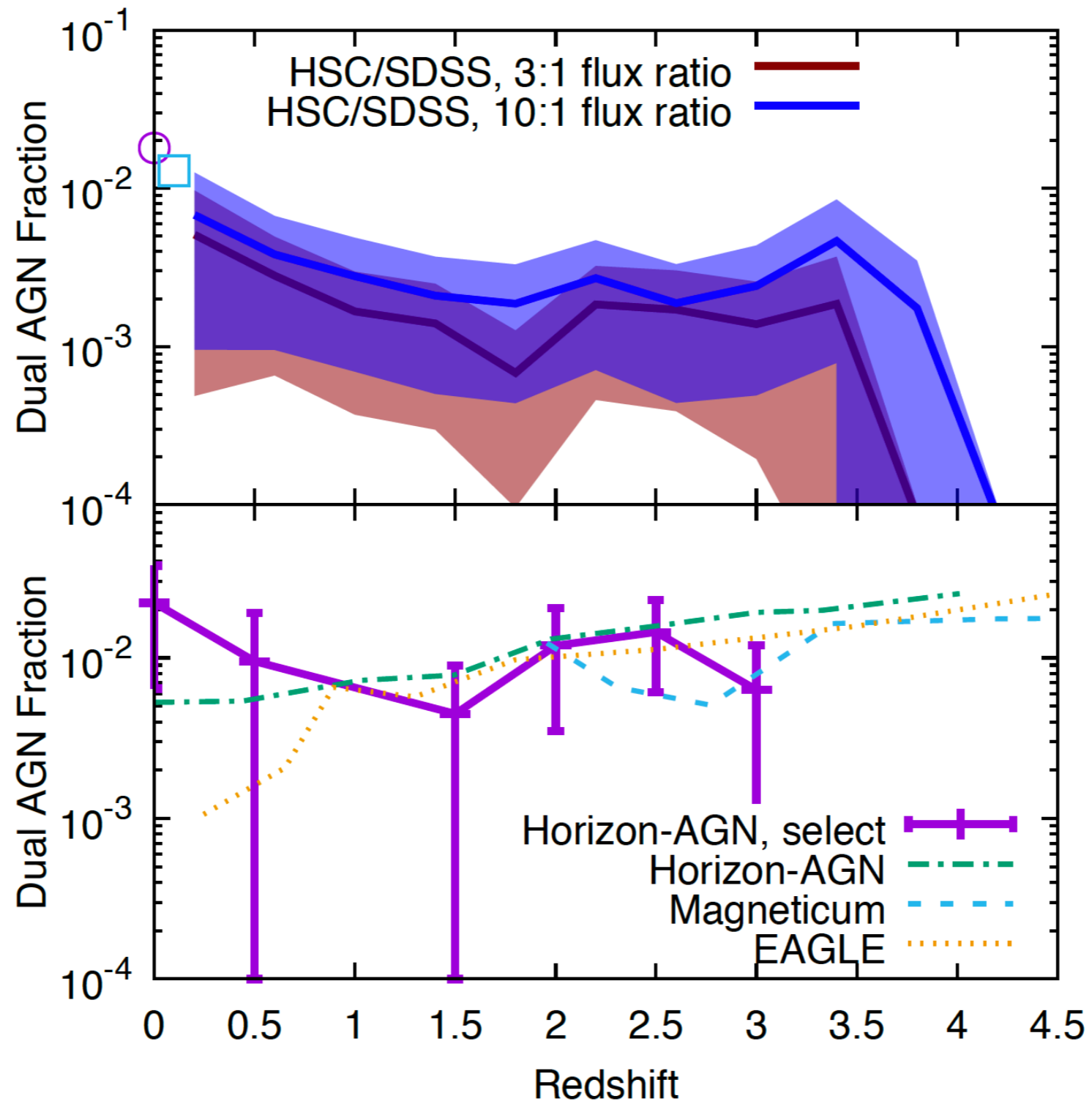


Keck

Gemini-N



Dual quasar fraction (5 - 30 kpc)



Thank M. Volonteri for Horizon-AGN results

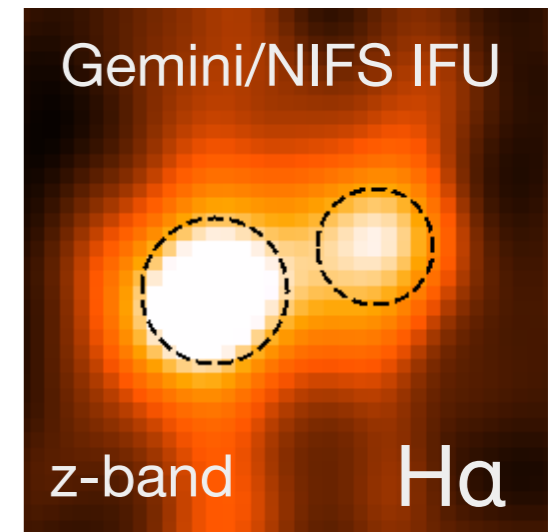
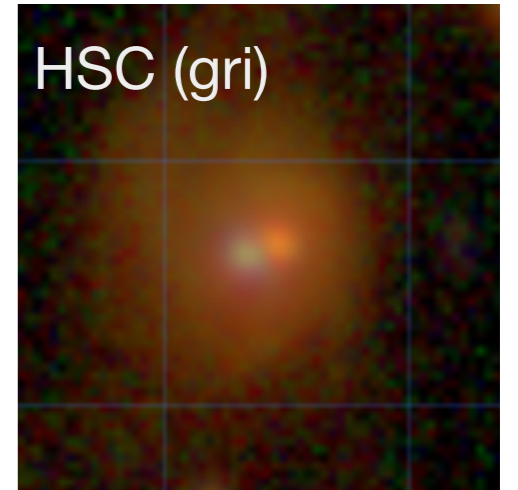
Use of SWIMS

Need larger sample with spectroscopic confirmation and detailed studies of confirmed cases

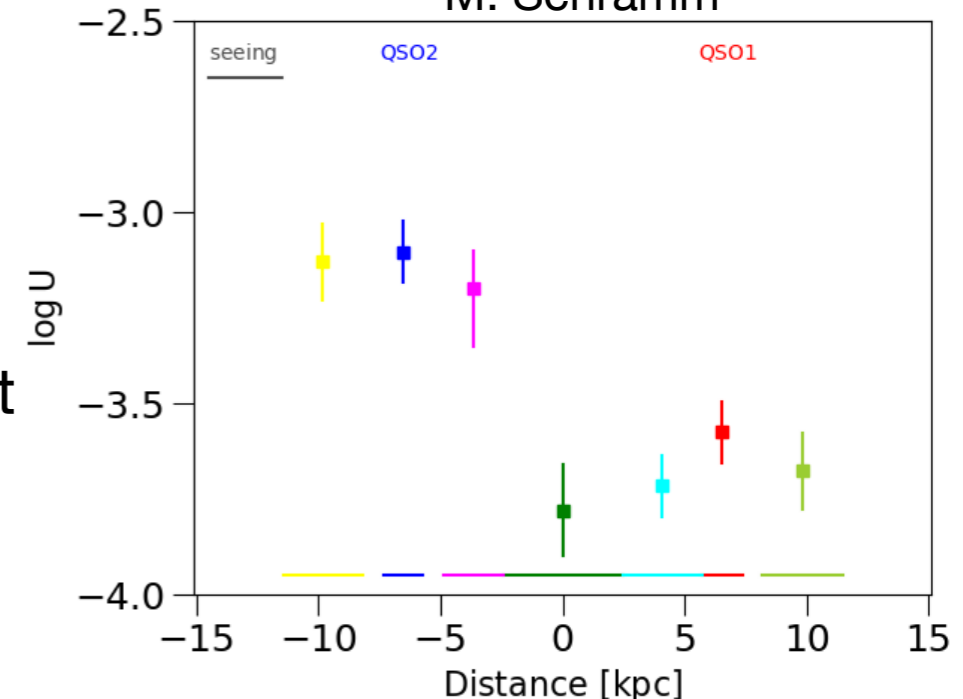
IFU spectroscopy:

Purpose: kinematics of both the broad- and narrow-line regions

- Viral black hole mass estimates
- Feedback effects on gas kinematics
- $H\alpha + [NII]$: $0.4 < z < 2.8$
- $H\beta + [OIII]\lambda 5007$: $1.0 < z < 3.9$



Ionization parameter
M. Schramm



Long-slit spectroscopy: confirm the dual quasar nature

- presence of broad emission lines in each component
- narrow lines characteristic of AGN photoionization

Summary

Wide and deep field imaging with HSC is making great strides in detecting rare objects (e.g., dual quasars).

Optical spectroscopy is underway to confirm a statistical sample of HSC dual quasar candidates

SWIMS followup with the IFU will probe the spatially-resolved ionized gas kinematics (and possibly the stellar populations) in dual quasars