# A Systematic Approach to Identifying Dual Supermassive Black Holes

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Dual SMBHs Are the Smallest Separation SMBH Pairs That We Know We Can Detect

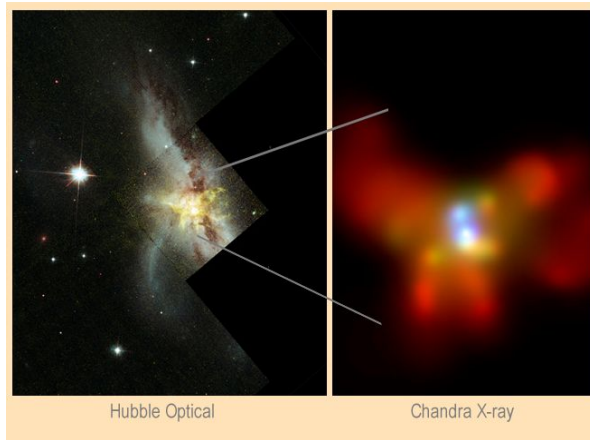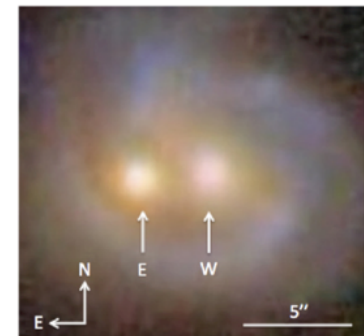Fellows at the Frontiers of Astronomy   Julie Comerford
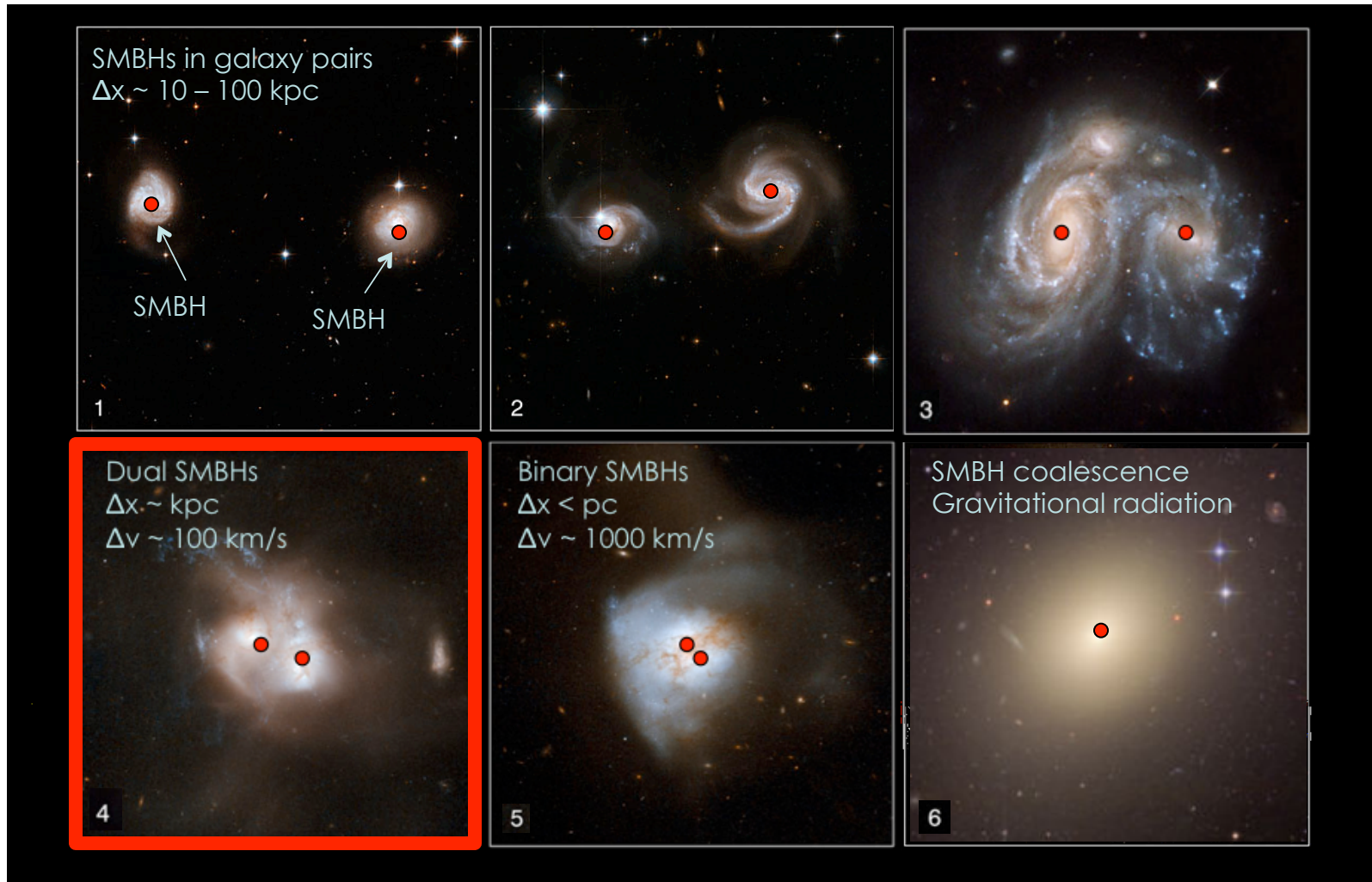
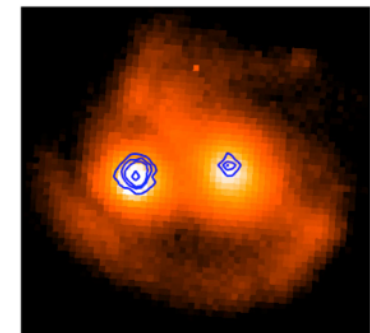# We Expect Dual SMBHs in Merger-remnant Galaxies, Yet Very Few Have Been Found

Can identify dual SMBHs observationally if they power dual AGN
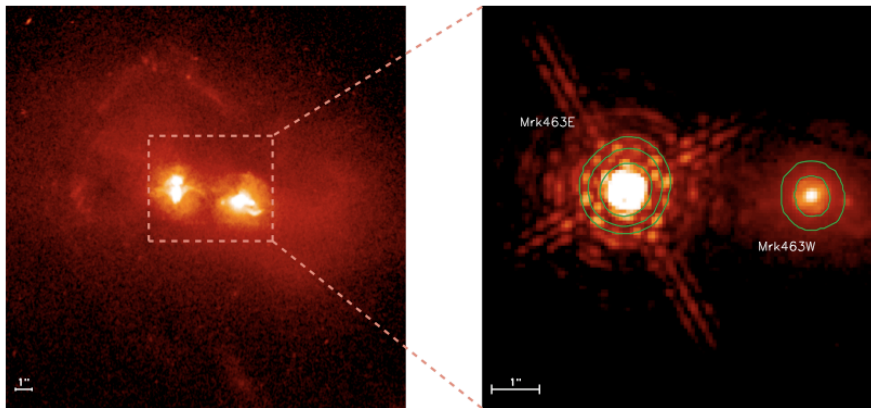
Mrk 463
z = 0.05
Δx = 4 kpc
Bianchi et al. 2008

NGC 6240
z = 0.02
Δx = 0.7 kpc
Komossa et al. 2003

Mrk 739
z = 0.03
Δx = 3.4 kpc
Koss et al. 2011

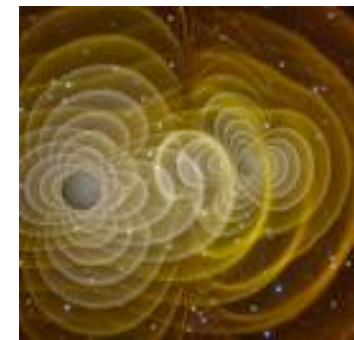# A Large Observational Sample of Dual AGN Would Probe:

1. Independent measure of galaxy merger rate, usually measured by close pairs of galaxies and galaxy morphologies

2. Activation probability of SMBHs in mergers; how much do SMBHs grow by gas accretion during mergers?

3. SMBH mergers, which are expected to produce gravitational waves
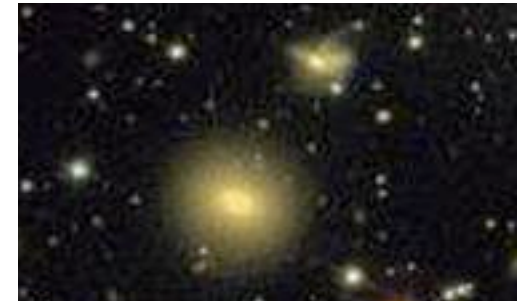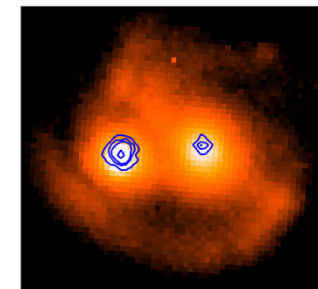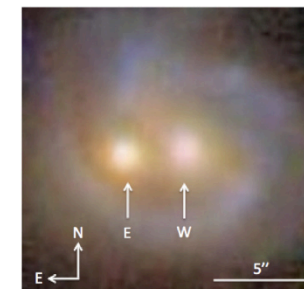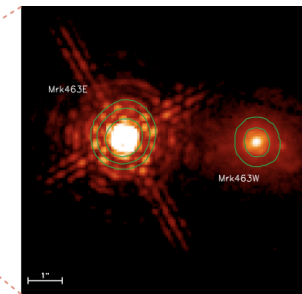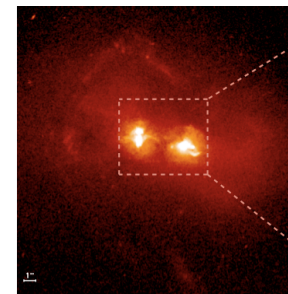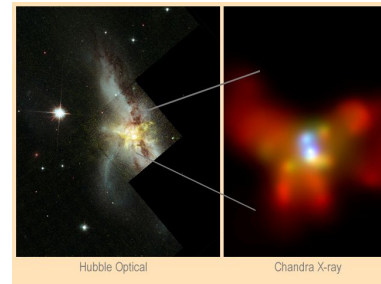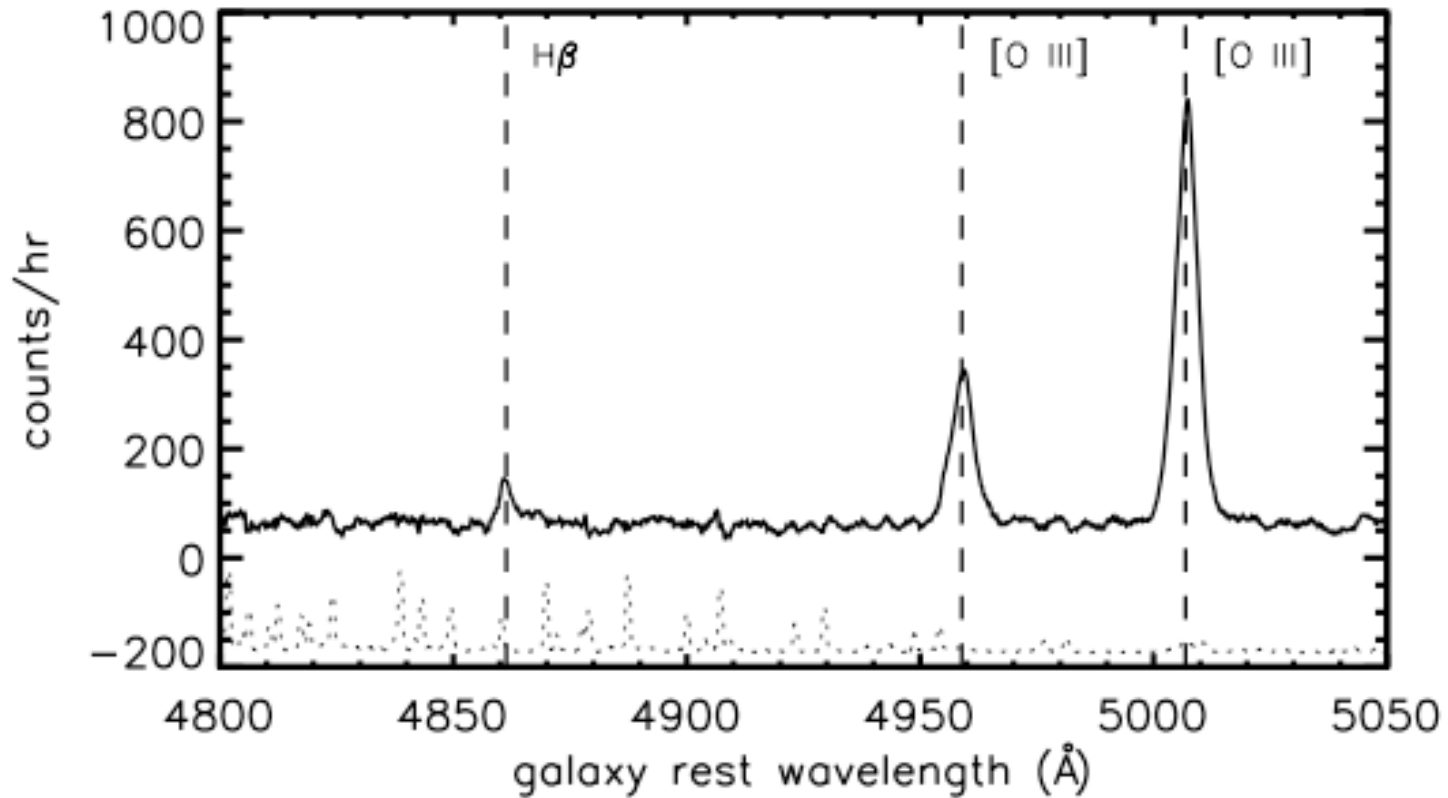
NASA

ACS/NASA

C. Henze/NASA

Goal: Build a Large Catalog of Dual AGN to Trace Galaxy Mergers, SMBH Growth, and SMBH Mergers

Need systematic approach to advance from individual systems to assembling a large catalog of dual AGN

Begin by selecting candidate dual AGN in large spectroscopic surveys or imaging surveys of galaxies
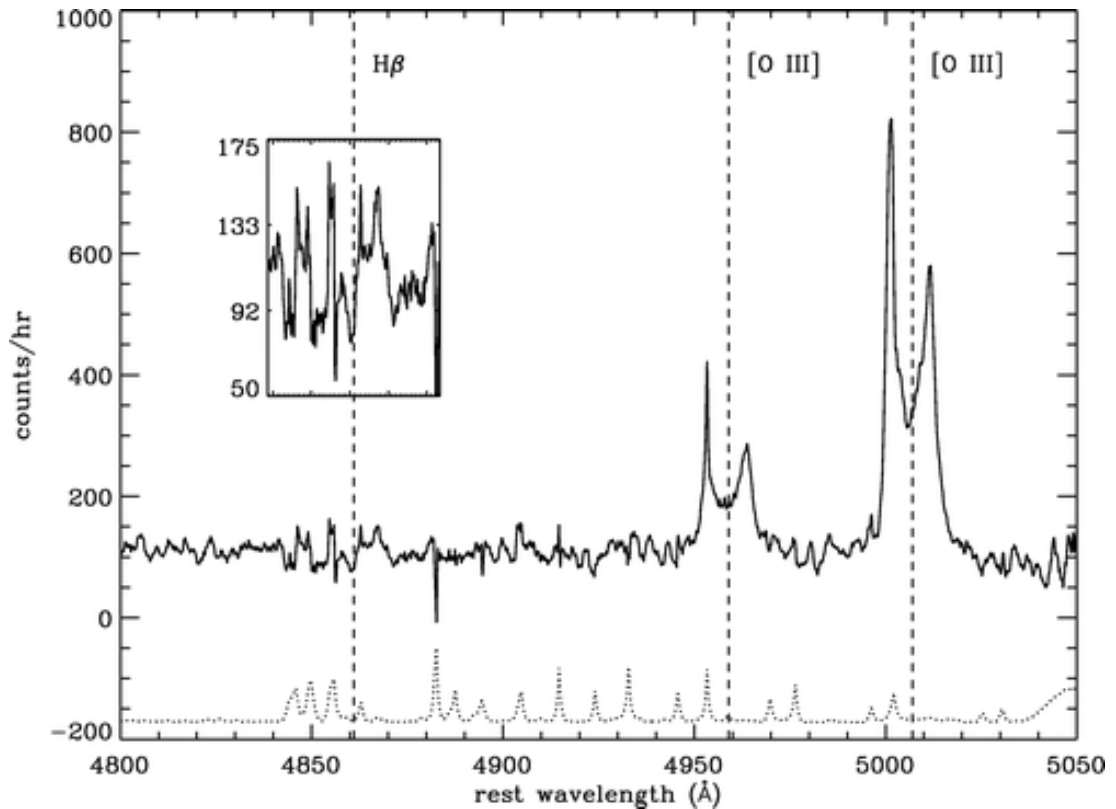
Typical AGN Spectrum

AGN is at rest with respect to the host galaxy

Spectroscopic Signature of Dual AGN: Double-Peaked AGN Emission Lines

Double-peaked [O III] emission lines separated by 630 km/s


Gerke et al. 2007

Julie Comerford

Systematic Search for Dual AGN in the DEEP2 Galaxy Redshift Survey

DEEP2 Galaxy Redshift Survey (PIs Marc Davis and Sandy Faber): 50,000 galaxies observed with DEIMOS spectrograph on Keck II

Found 2 double-peaked AGN and 30 offset AGN in 2000 DEEP2 red galaxies at 0.3 < z < 0.8

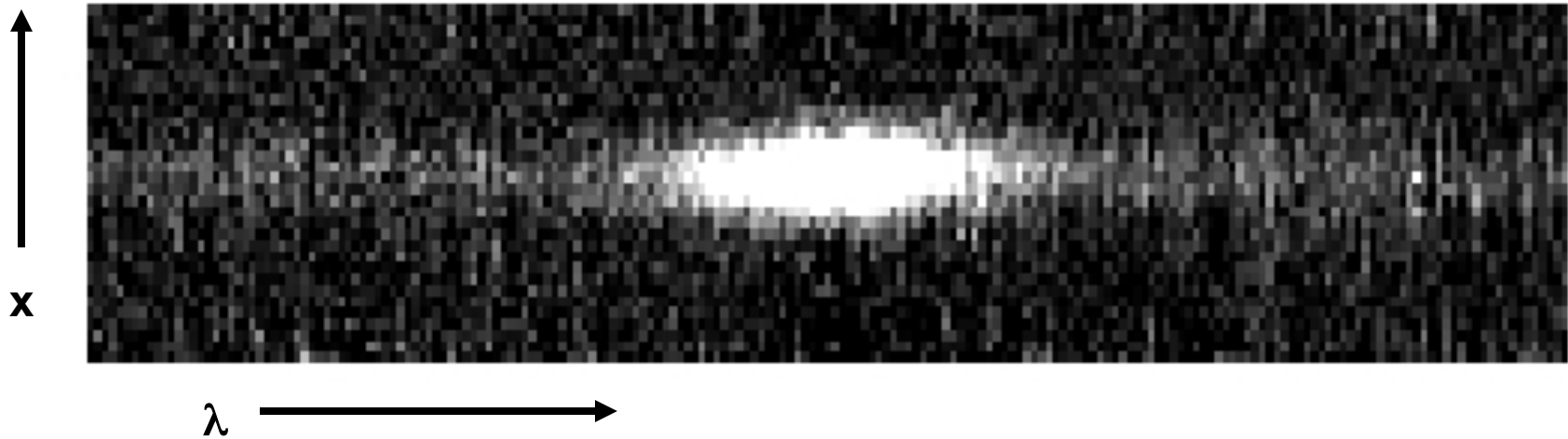Implies galaxy merger fraction of ~30% for red galaxies at 0.3 < z < 0.8

Comerford et al. 2009a
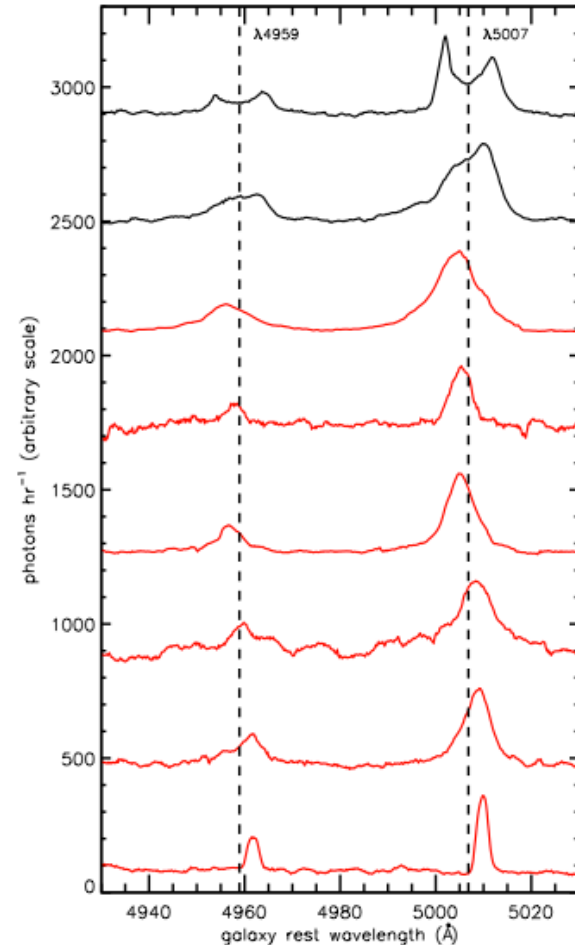
[O III] λ5007 Emission from One AGN

2 Double-peaked AGN in DEEP2

[O III] λ5007

z = 0.71
Δv = 630 km/s
Δx = 1.2 kpc

[O III] λ5007
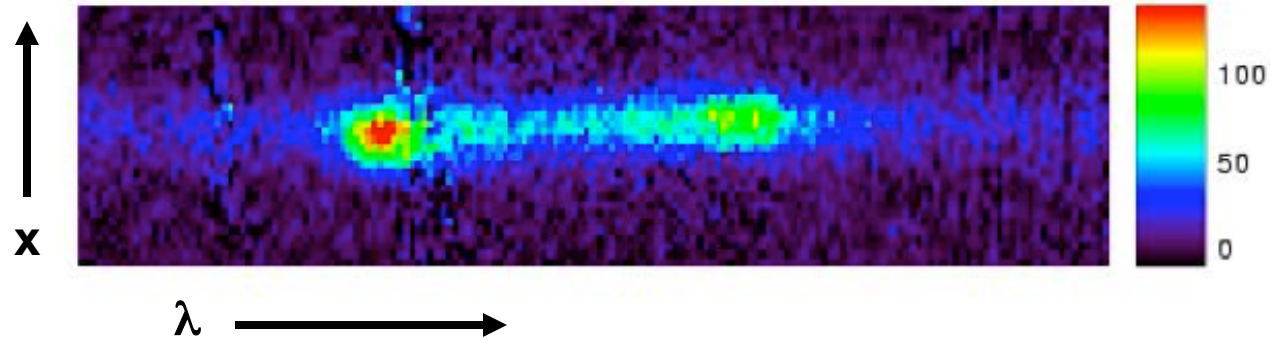

z = 0.62
Δv = 440 km/s
Δx = 2.3 kpc
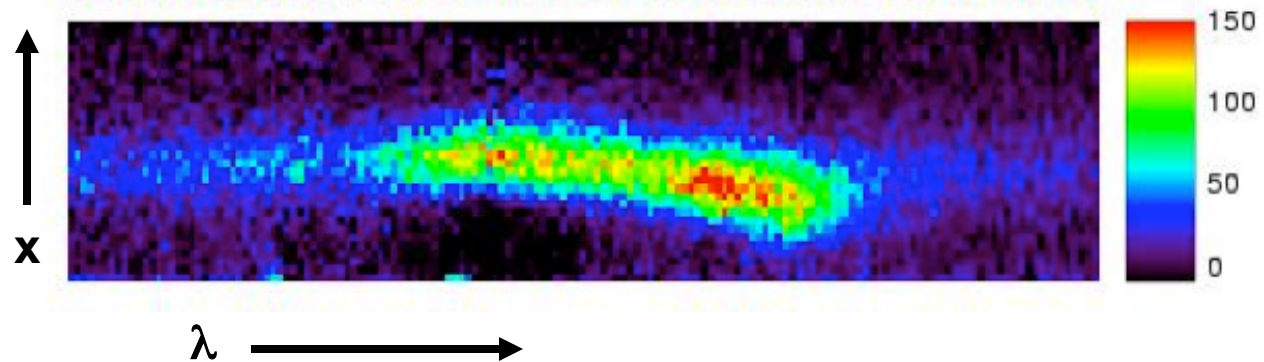
Comerford et al. 2009a

These Two Objects Are Most Likely Dual AGN, Not AGN Outflows

> We find consistent [O II], Hβ, and [O III] velocities, as expected for dual AGN (whereas outflows would have higher velocity [O III] relative to [O II] and Hβ)

> We compare to nearby outflowing AGN (e.g., NGC 1068, NGC 4151) --- if they were observed with DEIMOS at z~0.7, the DEIMOS spectrum would not show velocity offsets
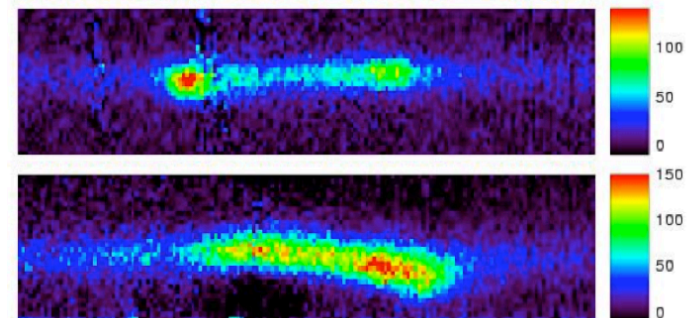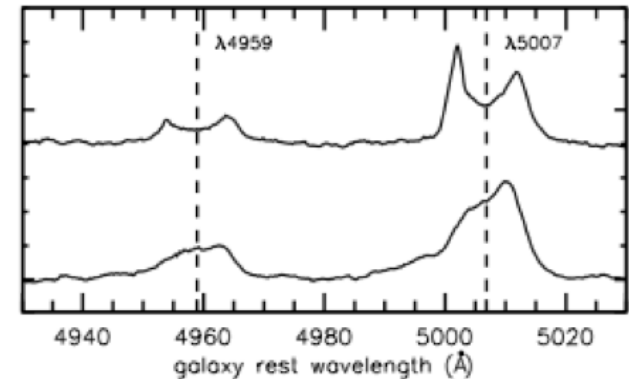
# Finding Dual AGN in Imaging Surveys

Another Way to Find Dual AGN: HST/ACS Imaging Surveys

Catalog of HST/ACS imaging of ~500,000 AEGIS, COSMOS, and GOODS galaxies (Griffith et al.)

Use existing X-ray, infrared, and radio detections to identify ~4000 galaxies that host AGN

Select dual AGN candidates as the active galaxies with two bright nuclei

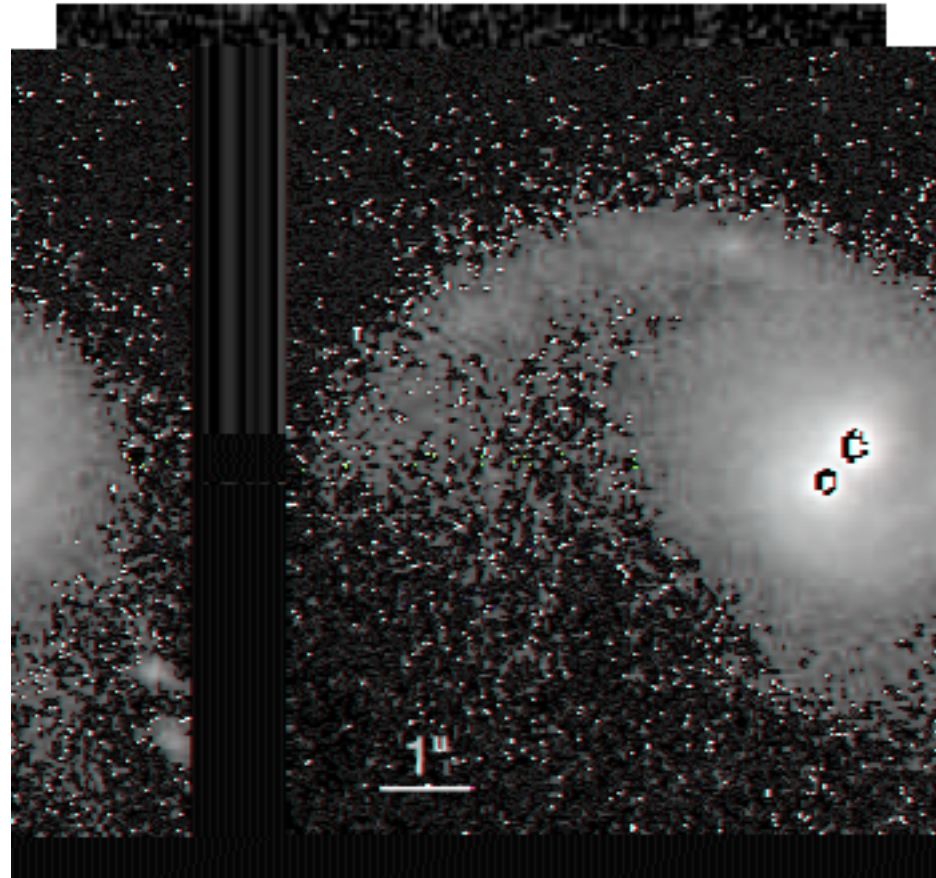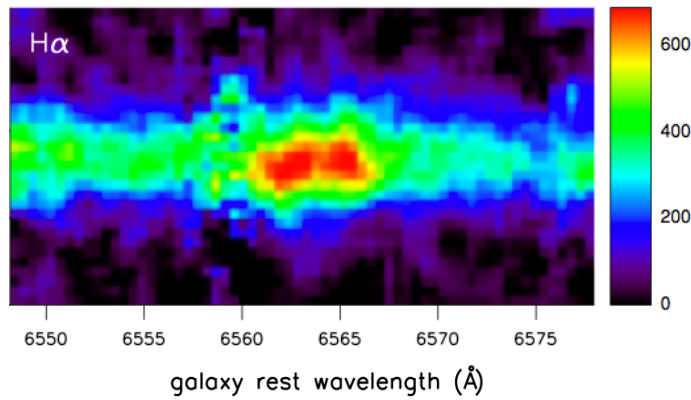Obtain follow-up observations to confirm dual AGN
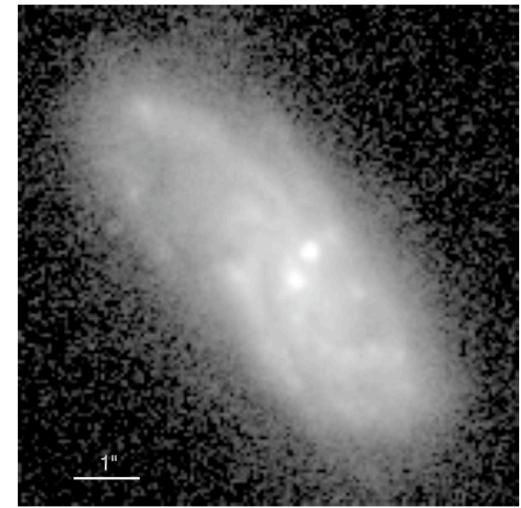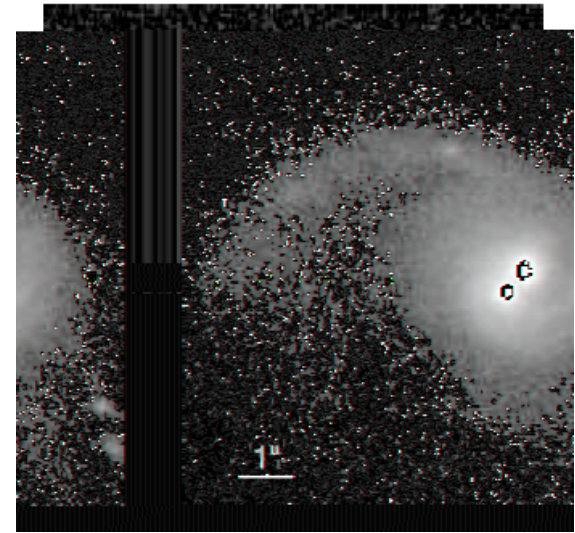
Dual AGN Candidate in COSMOS

COSMOS J100043+020637

z=0.36, two bright nuclei separated by 2.5 kpc

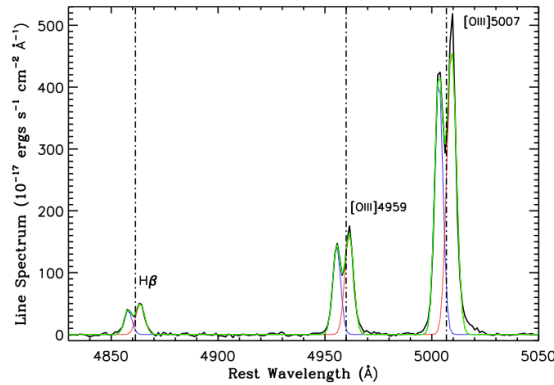Our follow-up DEIMOS spectrum shows both nuclei are associated with AGN emission

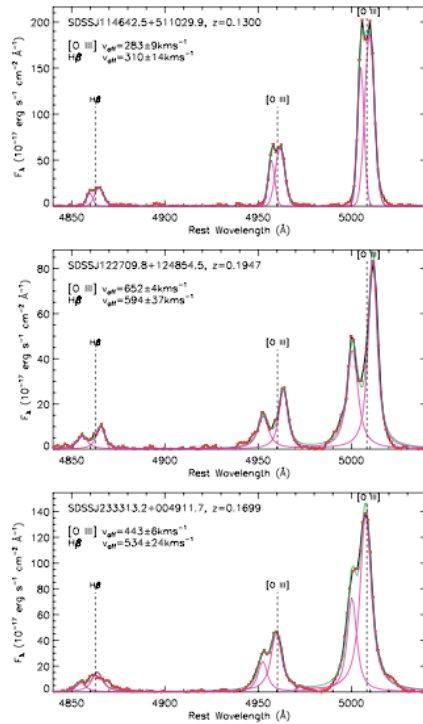
Comerford et al. 2009b

see also Civano et al. 2010

Back to Finding Dual AGN in Spectroscopic Surveys

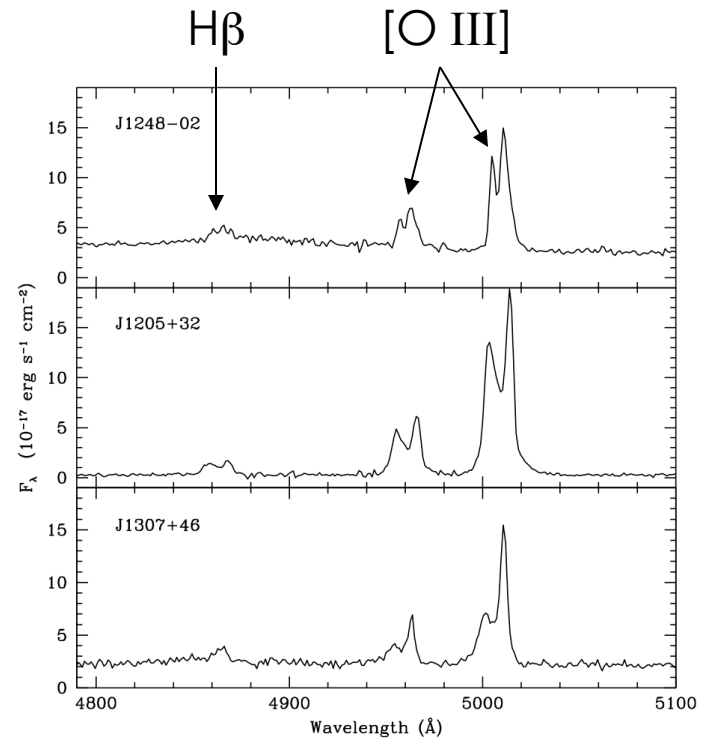# Another Way to Find Dual AGN:
340 Double-Peaked AGN in SDSS

1. Select dual AGN candidates as galaxies with double-peaked AGN emission lines
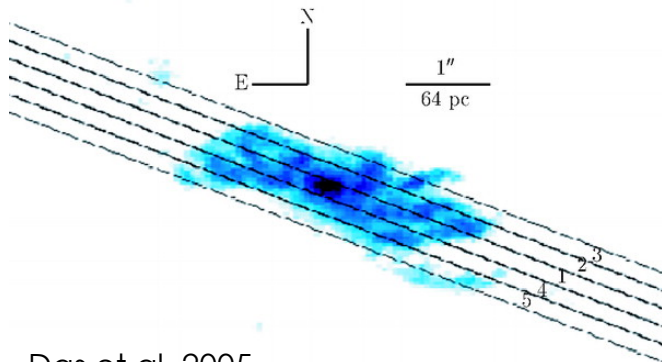

Wang et al. 2009

Liu et al. 2010

Smith et al. 2010

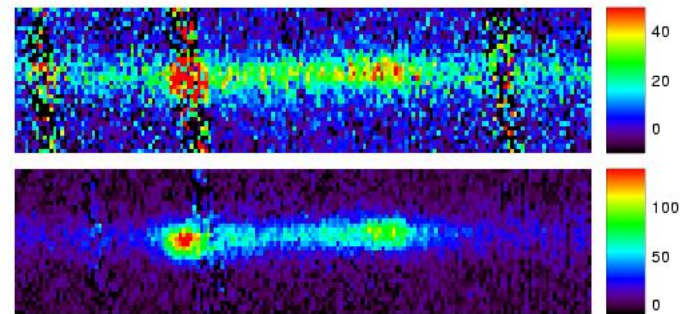# Determining the Nature of Double-Peaked AGN Emission Lines

2. Obtain follow-up longslit spectroscopy to determine the spatial extent of the AGN emission and help distinguish between outflows and dual AGN
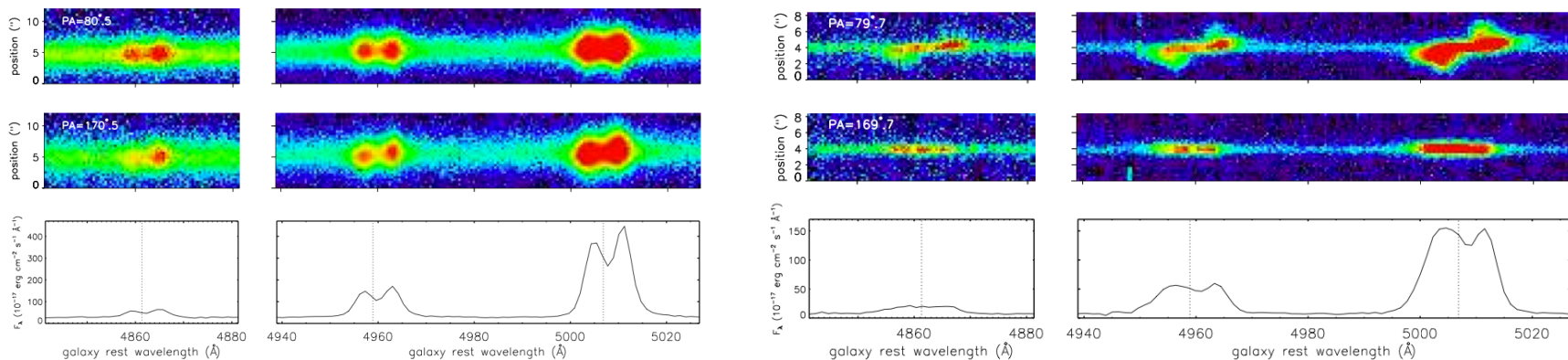
[O III] in AGN outflow:

[O III] in dual AGN:

Das et al. 2005

Use Longslit Spectroscopy to Identify the Most Promising Dual AGN Candidates

Obtained Lick/Palomar/MMT longslit spectroscopy for 81 of the SDSS double-peaked AGN

(see also Liu et al. 2010, Shen et al. 2010, Greene et al. 2011, McGurk et al. 2011, Fu et al. 2011)
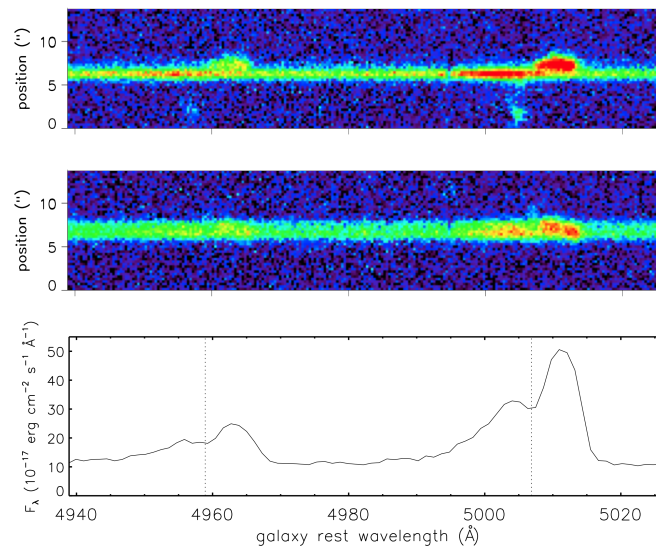

Comerford et al.

# Examples of the Most Compelling Dual AGN Candidates

We find several double-peaked AGN that have double emission components in the longslit spectra that are coincident with double stellar nuclei visible in AO
(see also Liu et al. 2010, Shen et al. 2010, Greene et al. 2011, McGurk et al. 2011, Fu et al. 2011)

SDSS J095207+255257
z=0.34
Δv=475 km/s
Δx=4.8 kpc (1")

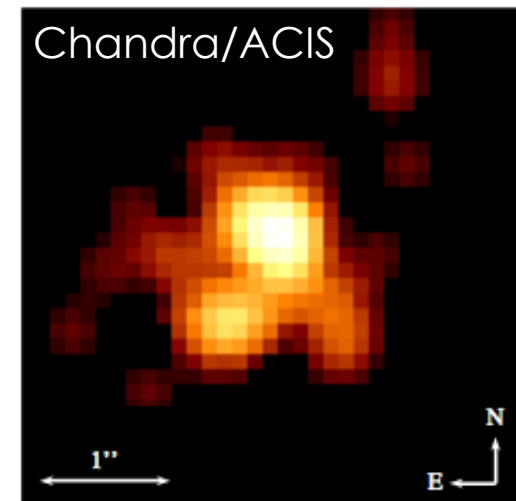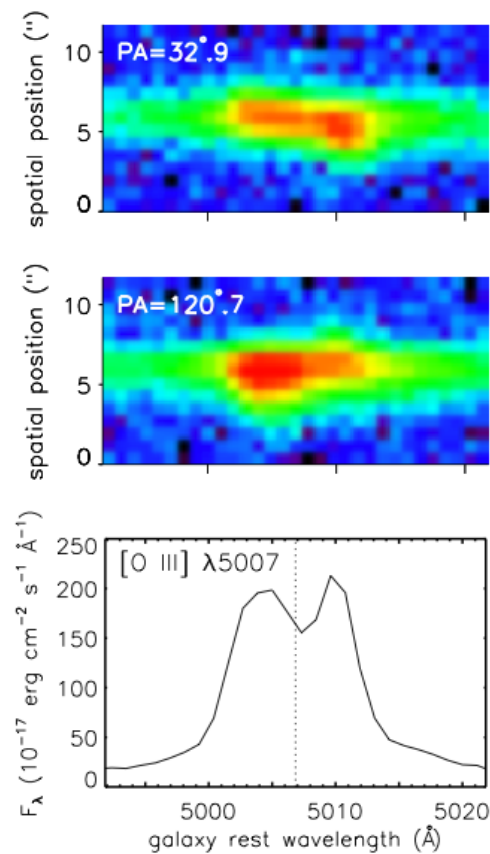Upcoming Chandra observations will confirm whether these are dual AGN

Comerford et al.
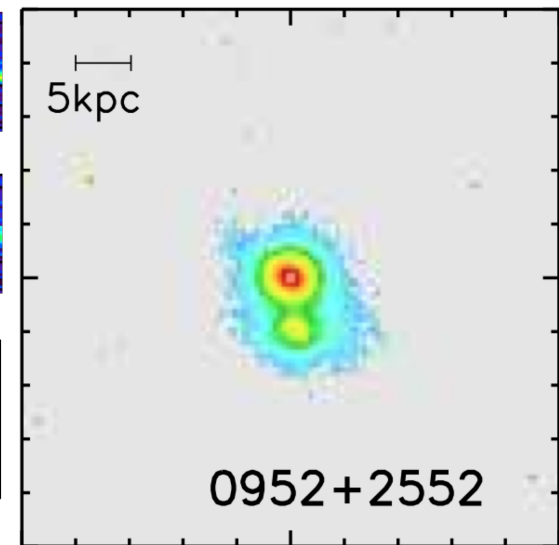
Fu et al. 2011

For Definitive Proof of Dual AGN, Need X-ray or Radio Detections

SDSS J171544+600835   z=0.16
Δv=350 km/s, Δx=1.9 kpc (0.68''), PA=147° E of N

Double emission components in longslit observations coincide with double X-ray sources in Chandra observations

➜ Compton-thick dual AGN

Comerford et al. 2011

Systematic Search for Dual AGN

1. Identify dual AGN candidates as
   a) Double-peaked AGN in
   spectroscopic surveys (e.g., SDSS, DEEP2)
   -- or --
   b) Active galaxies with two nuclei in
   imaging surveys (e.g., HST/ACS)

2. Obtain follow-up observations (e.g., longslit, AO) to identify most promising dual AGN candidates

3. Obtain follow-up X-ray/radio observations to confirm or refute dual AGN nature

Use large catalog of dual AGN to probe galaxy merger fraction (~30% for red galaxies at 0.3 < z < 0.8), SMBH growth, and SMBH mergers