Spatially Resolved Spectroscopy to Confirm or Disprove Dual Active Galactic Nuclei

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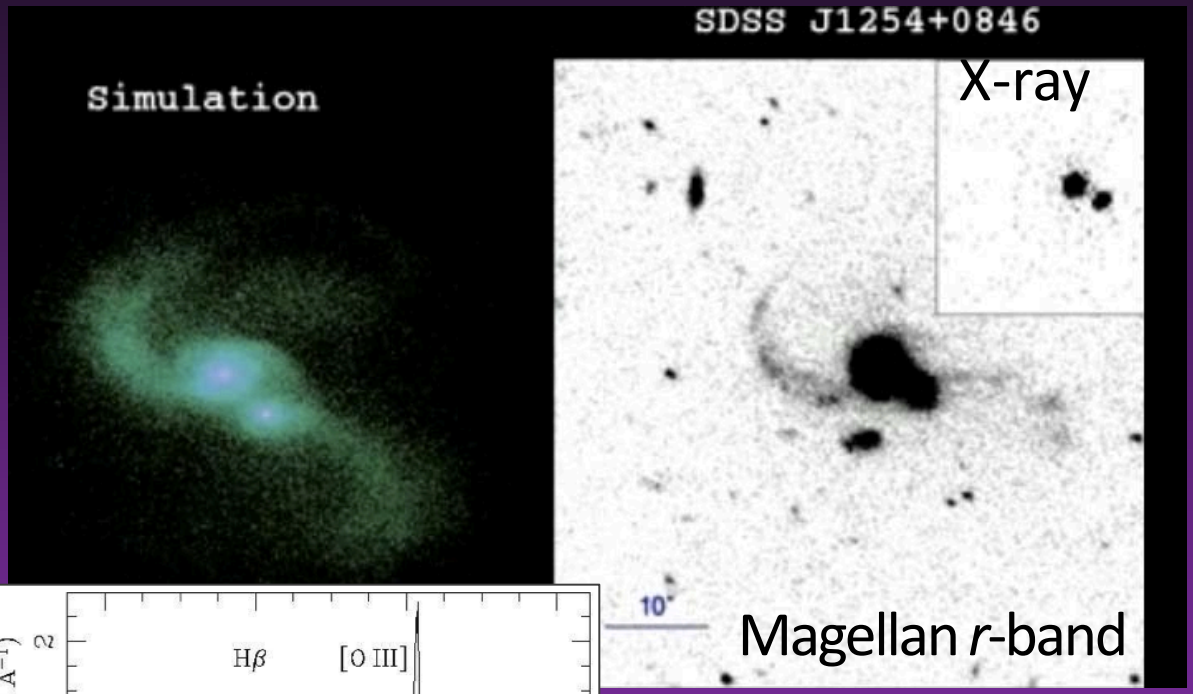
Why are AGNs in mergers important?

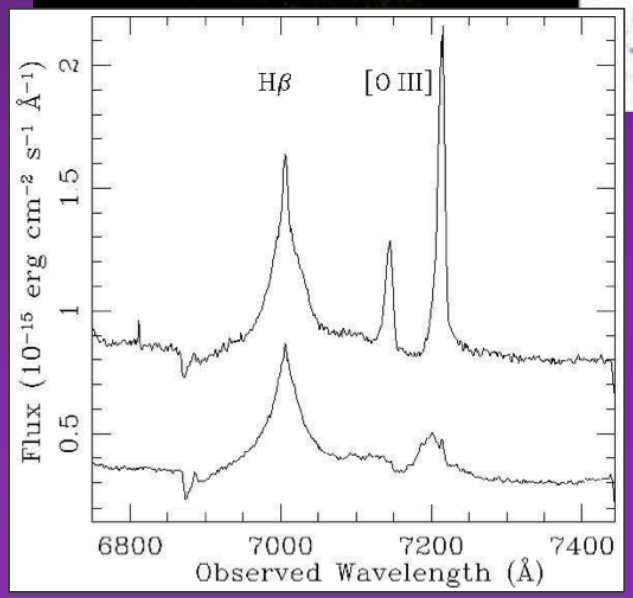
- The existence and statistics of AGNs in mergers provide a probe into:
  - accretion-triggering mechanisms
  - duty cycle - the fraction of time the AGN accretes material and is bright
  - whether mergers trigger AGNs
  - probability of observing black hole coalescence events with ground-based Pulsar Timing Arrays

AGN pairs from galaxy mergers should be observable

- Example of a dual AGN discovered by Green et al. 2010
- Match between simulation and observation



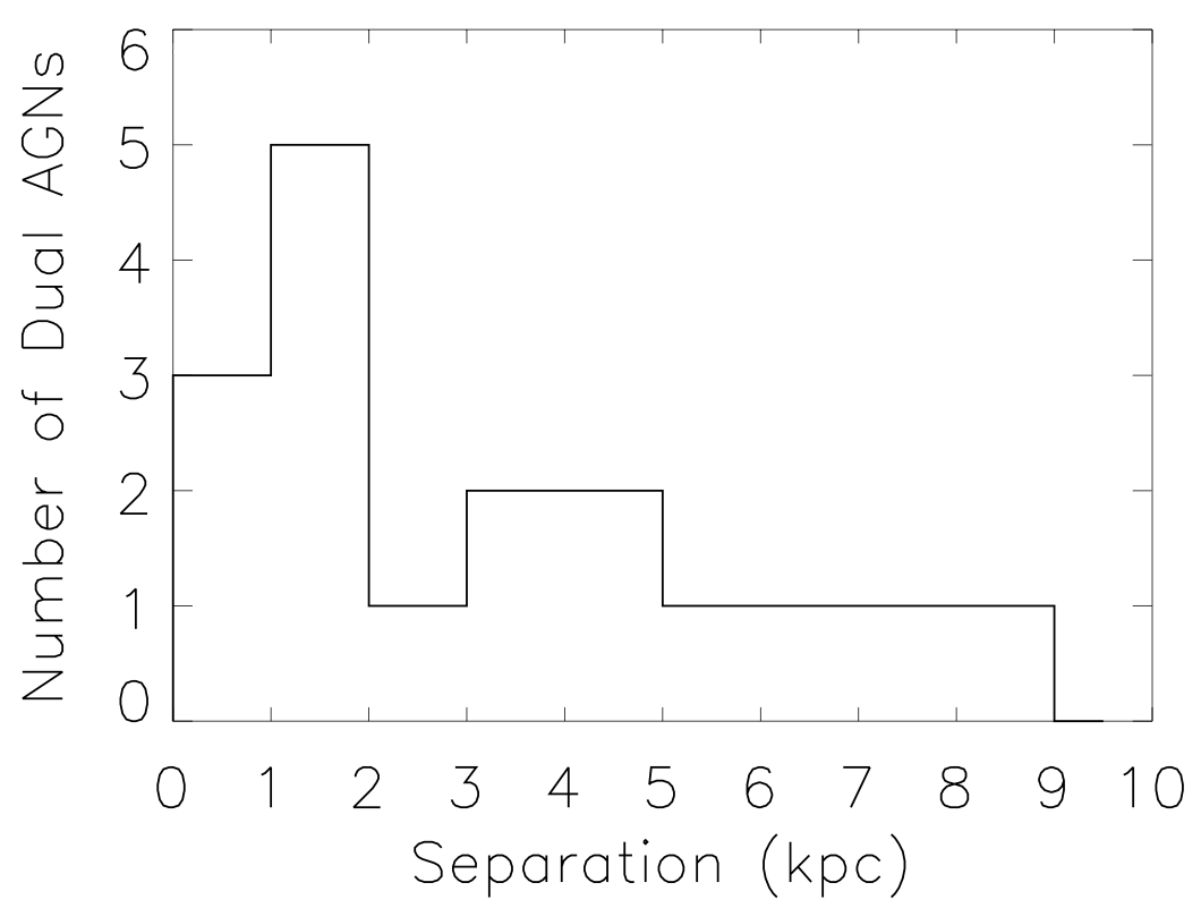
21 kpc separation



Dimmer galaxy

Brighter galaxy

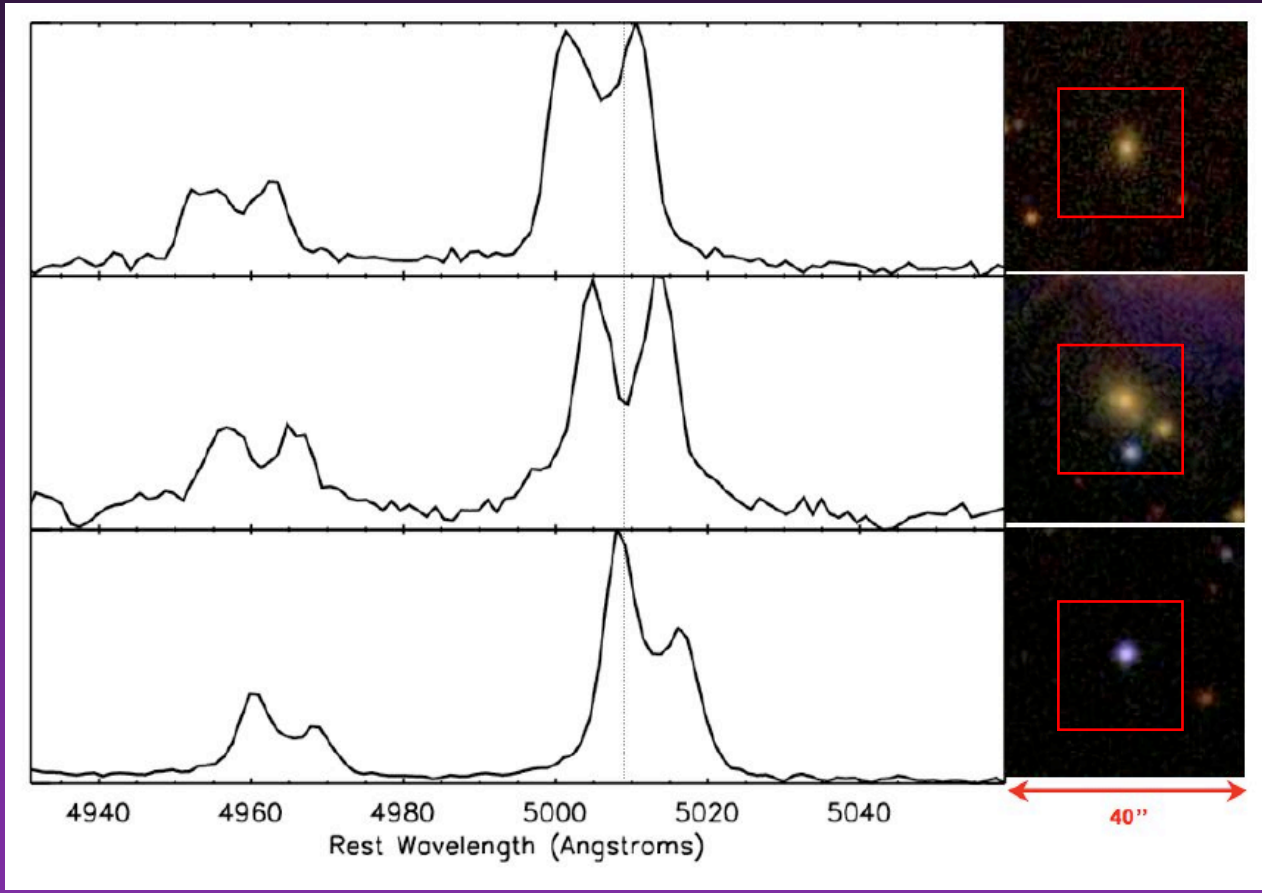
Only 17 confirmed AGN pairs with separations < 10 kpc



Adaptive Optics allows us to resolve these separations and fill in this separation range!

We chose our sample spectroscopically from Smith et al.

- SDSS spectra
- Primary criteria:
  - double in both [O III] λ5007 and λ4959

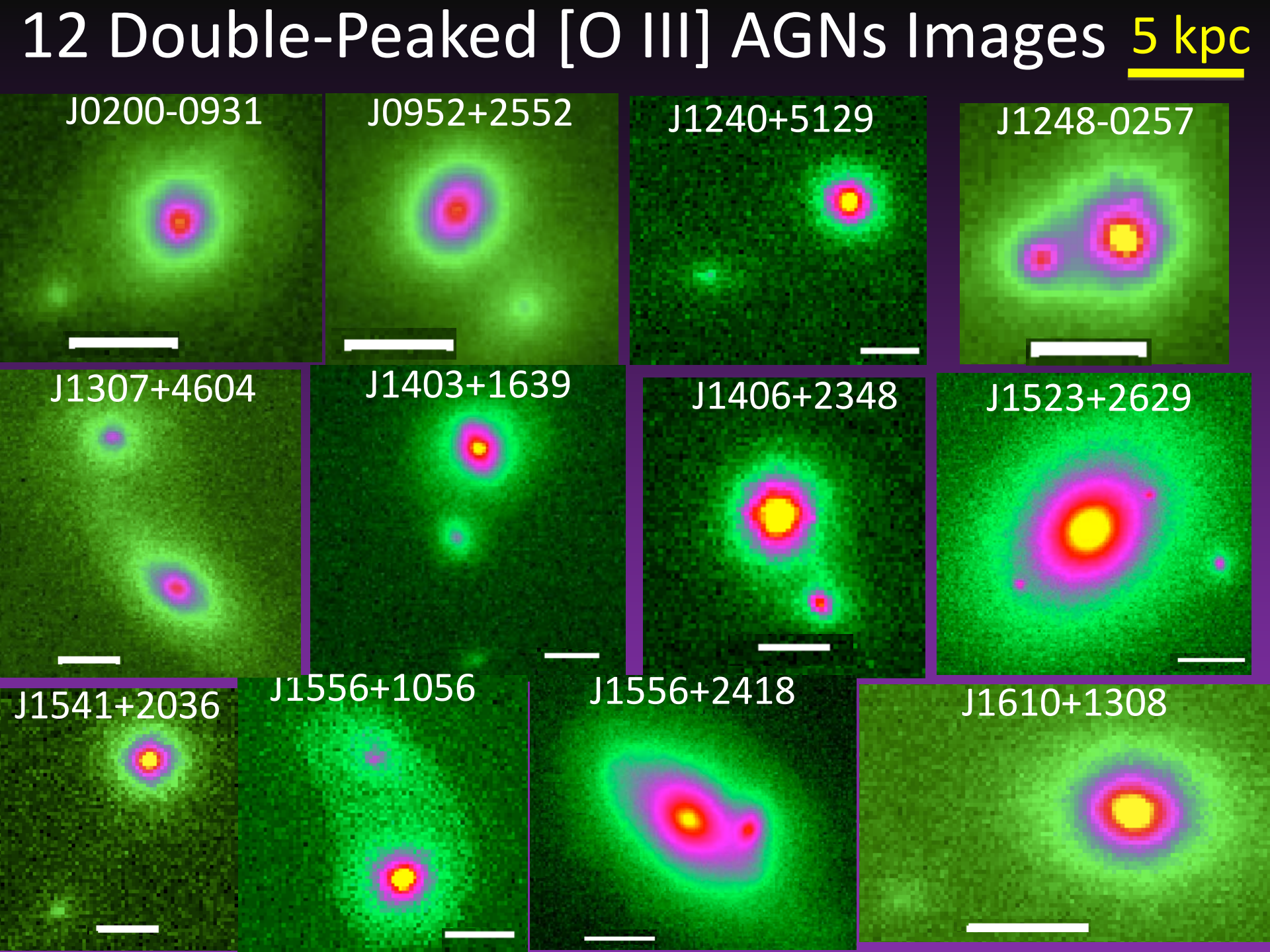


- 148 SDSS double-peaked [O III] AGNs with z<0.7

Smith et al. 2011

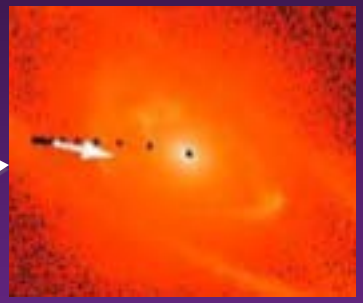
NIRC2 and Laser Guide Star AO on Keck2

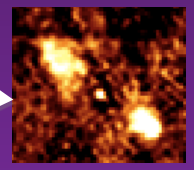
- Of 140 imaged, 40 (29%) show double spatial structure with separations < 3”. (Fu et al. 2012 + us)

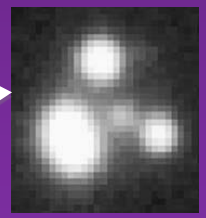

12 Double-Peaked [O III] AGNs Images
5 kpc
J0200-0931
J0952+2552
J1240+5129
J1248-0257
J1307+4604
J1403+1639
J1406+2348
J1523+2629
J1541+2036
J1556+1056
J1556+2418
J1610+1308

What else can candidate dual AGN be?

- Chance superposition of two objects
- Recoiling SMBH
- Jets interacting with the surrounding medium
- Outflows
- Gravitational lenses

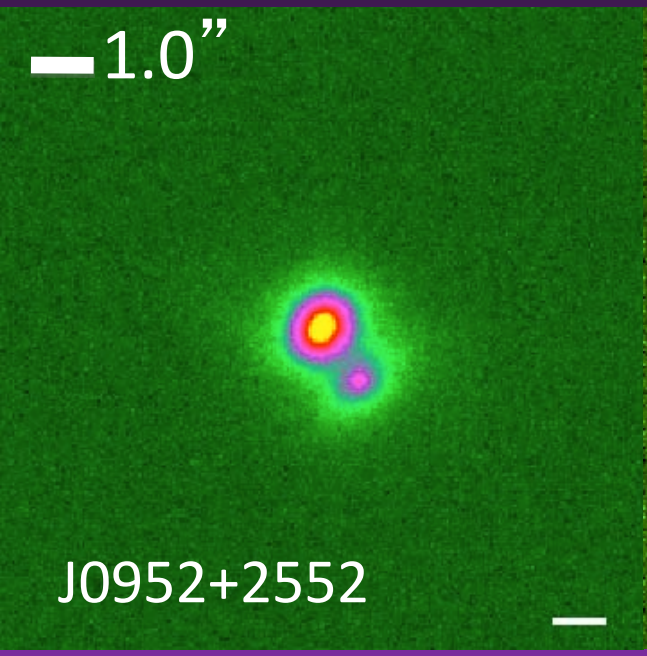


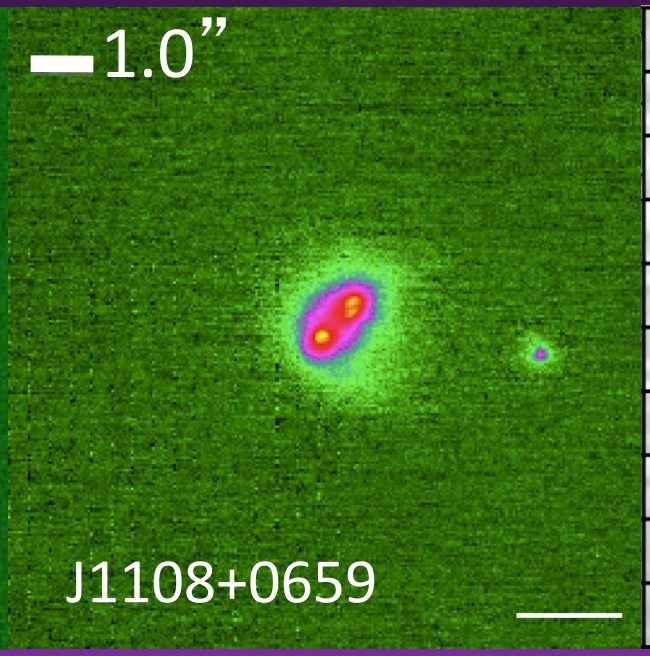


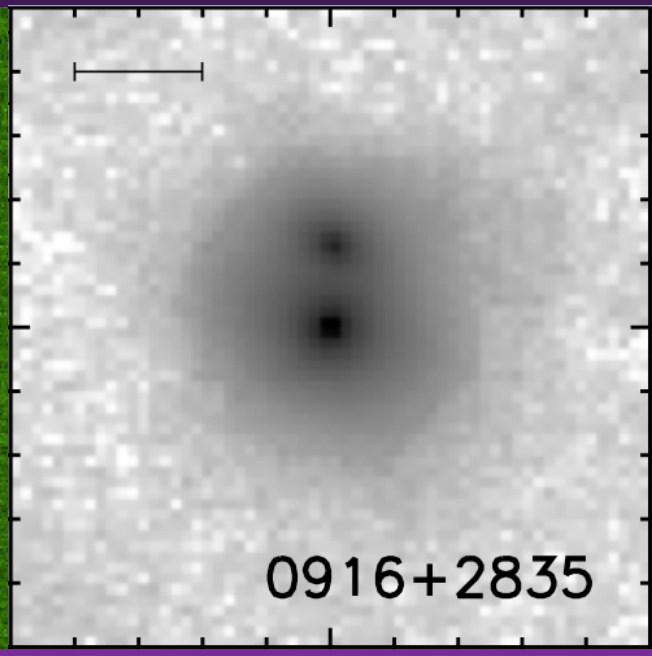


Guedes et al. 2010

Do double-peaked AGNs with companions contain dual AGNs?



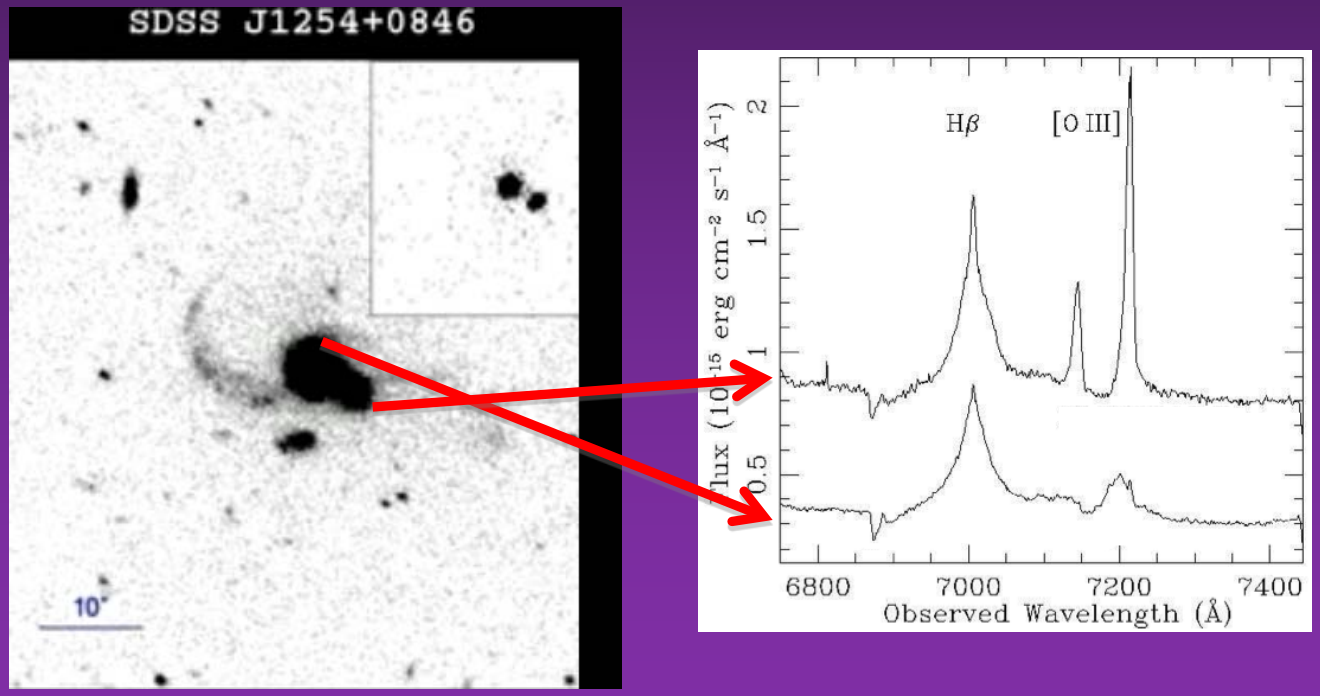




Need to confirm that two AGNs are present in the double spatial structures.

To Spectroscopically Confirm a Dual AGN…

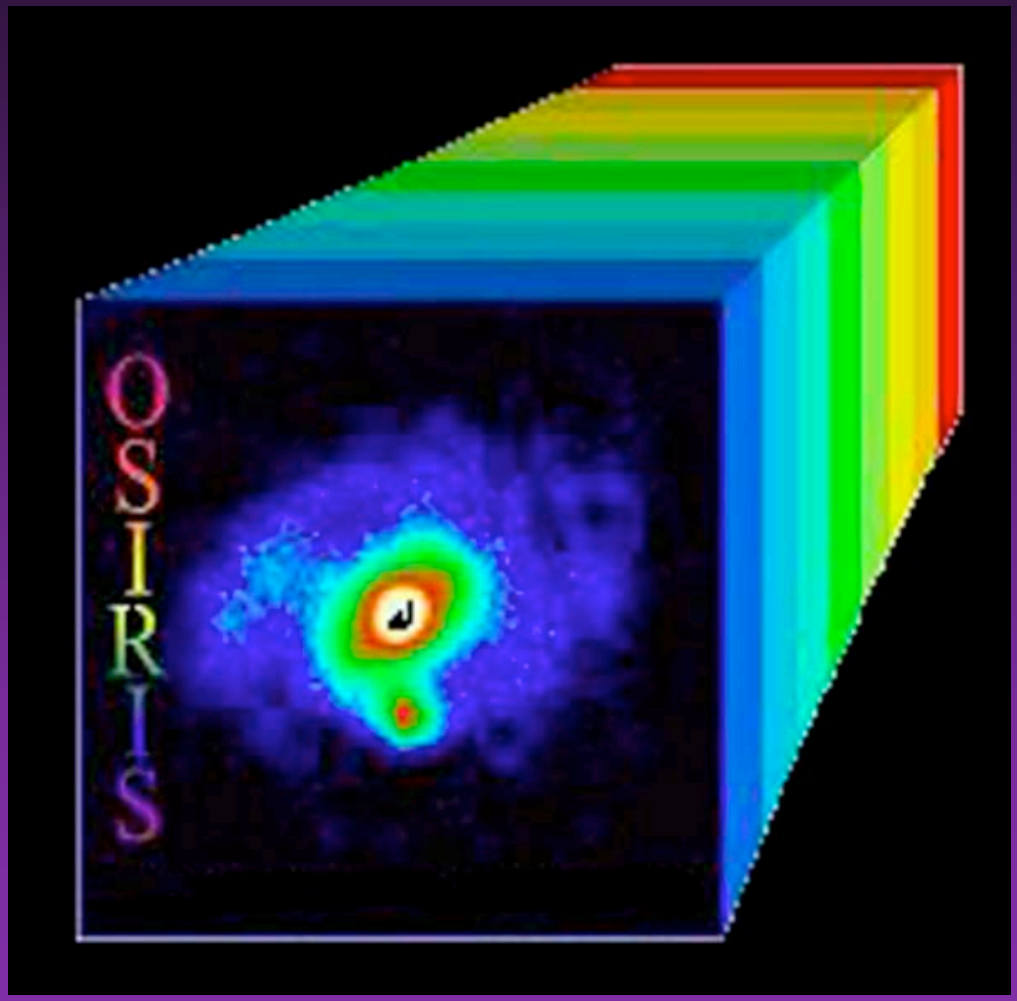
- Each spatially resolved component must have a unique AGN spectrum



Green et al. 2010

Keck OH Suppressing InfraRed Imaging Spectrograph with AO

- An image with a spectrum at every pixel
- 0.1”/pixel to take advantage of AO spatial resolution

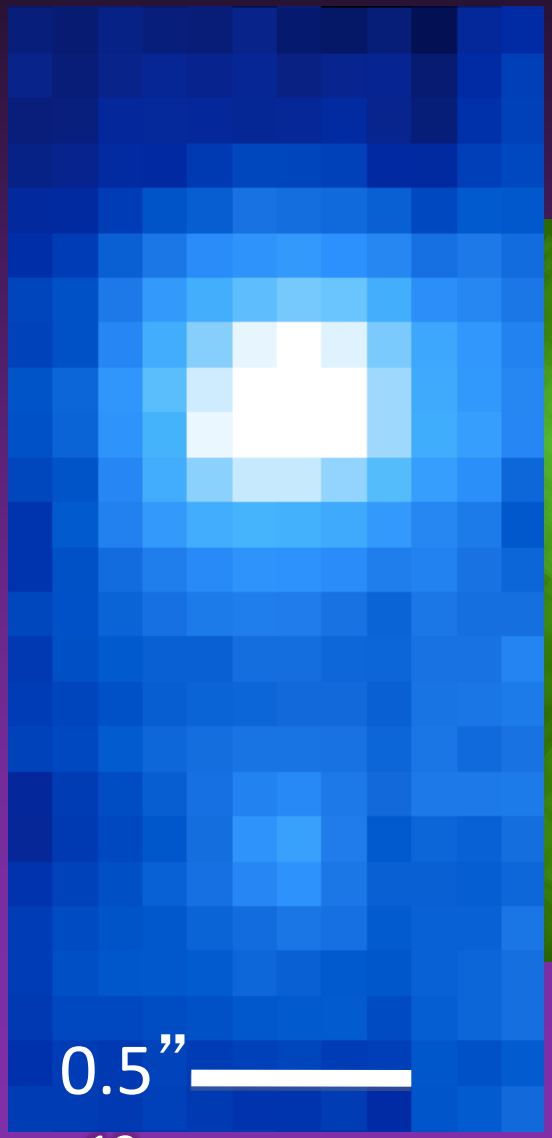


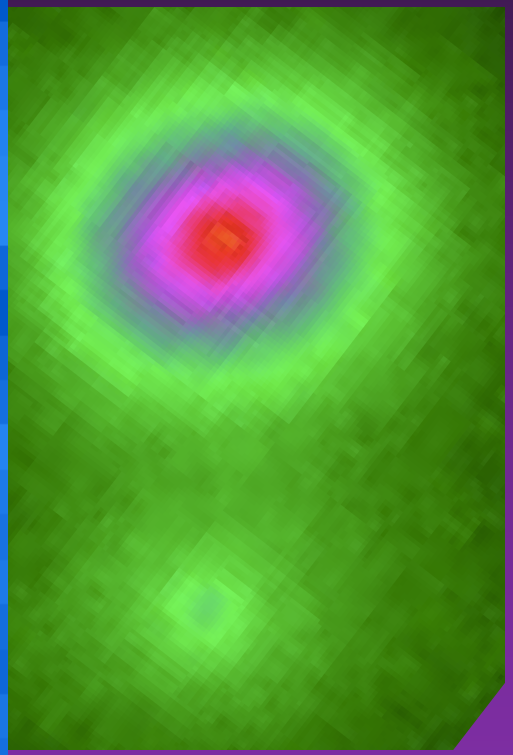
Larkin et al. 2006

OSIRIS spectra will answer two questions:

1. Do the redshifts of the visible spatial structures match the double peaks of the SDSS emission lines?
   - By measuring redshifts of narrow lines
2. What types of objects are the bright galaxy and the companion: Type 1 or 2 AGNs, a starburst, or a quiescent galaxy?
   - Presence of broad lines?
   - Emission line ratios

We observed J0952+2552 with OSIRIS



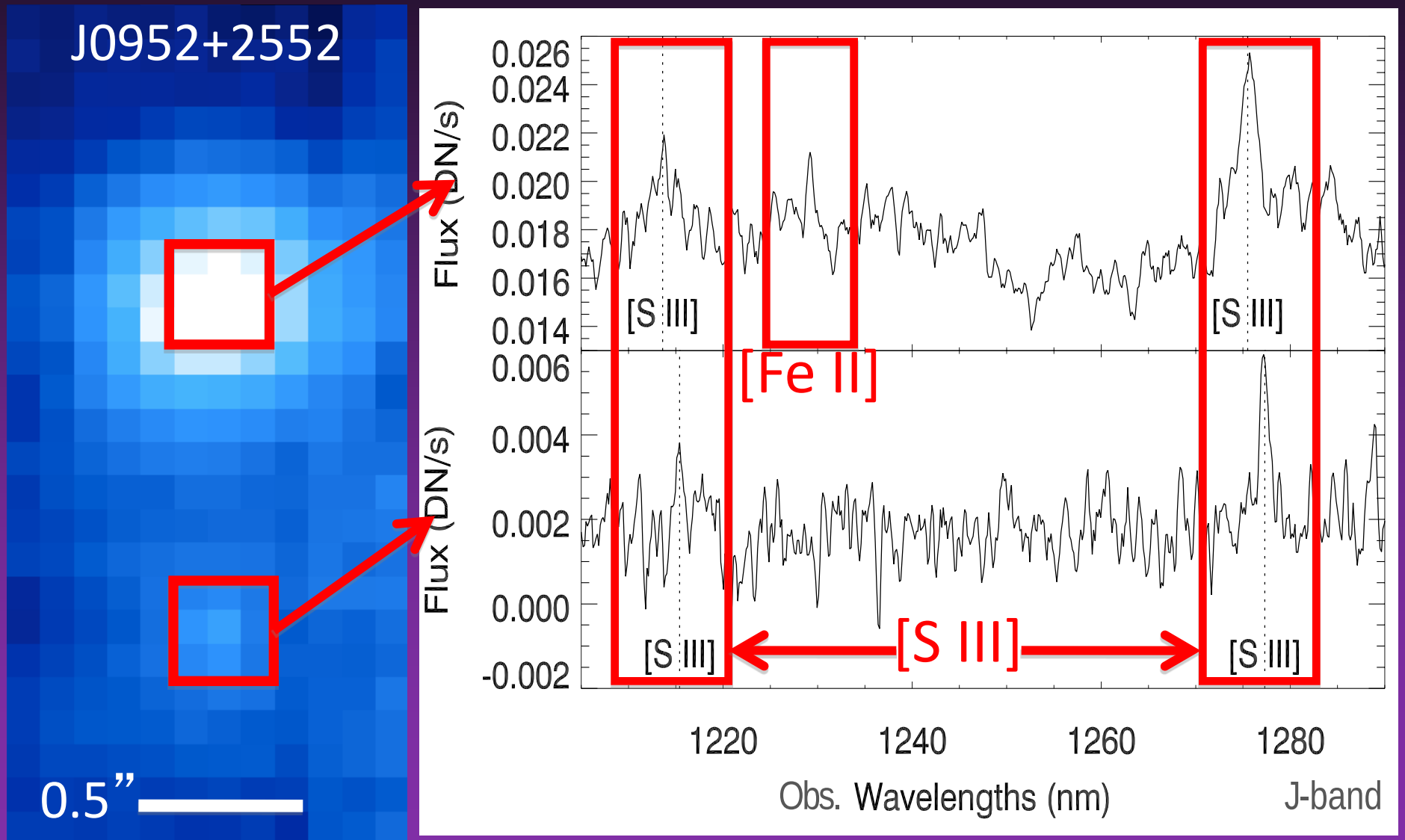


Both images H-band continuum. Left: OSIRIS. Right: NIRC2.

- J, H broadband
- Redshift = 0.339
- Separation = 1.0” = 4.81 kpc

McGurk et al. 2011

Do the redshifts of the spatial components match the double [O III] redshifts?



McGurk et al. 2011

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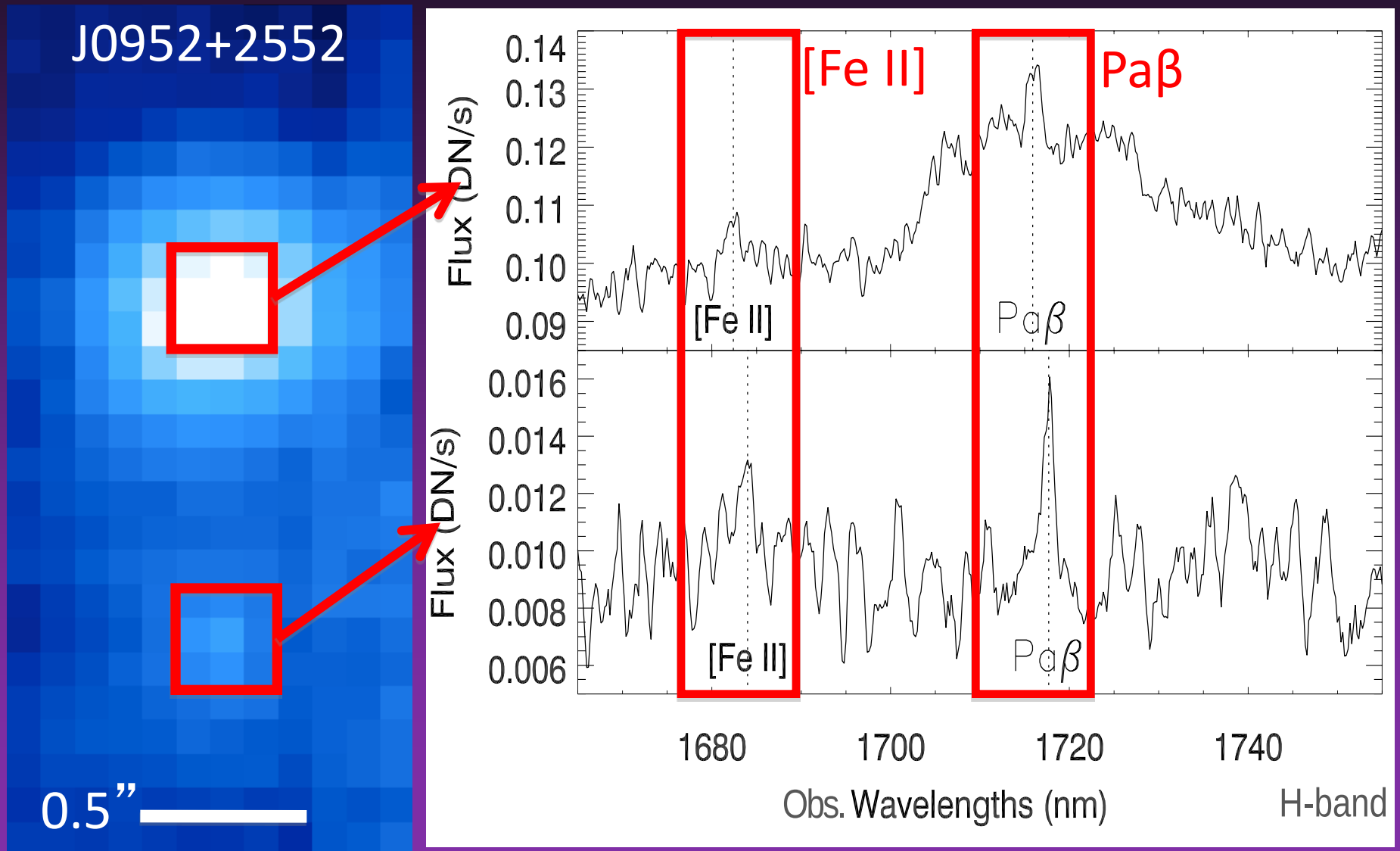

McGurk et al. 2011

Using the narrow lines to measure redshifts…

Redshift error = ±0.00014

Spectral line:	Bright Galaxy	Companion
Pa β	0.3384	0.3397
[S III] 953	0.3379	0.3397
[S III] 907	0.3379	0.3398
[Fe II]	0.3384	
[O I]	0.3380	
SDSS [O III] red		0.3399
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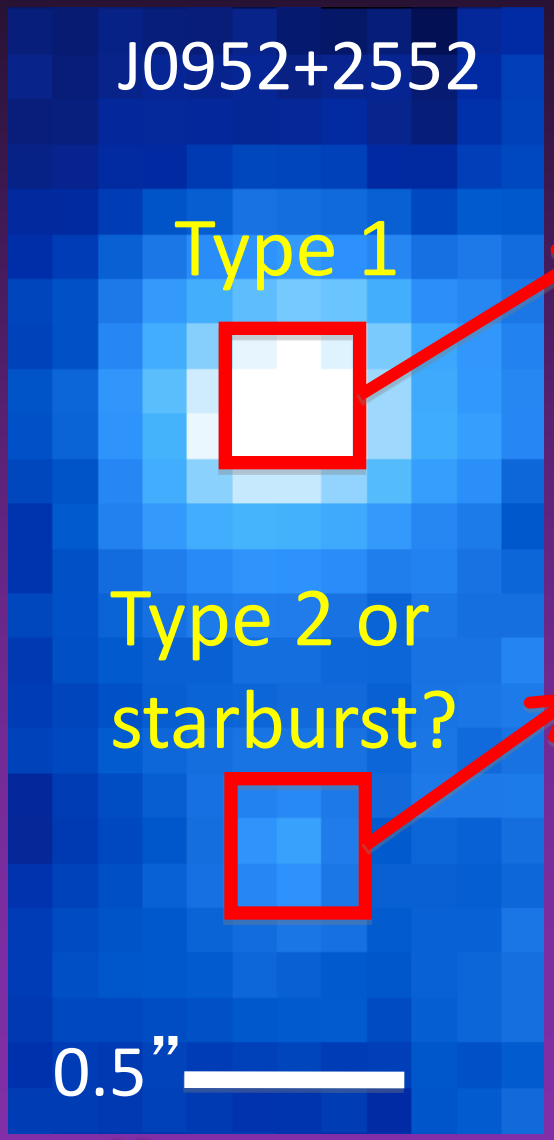
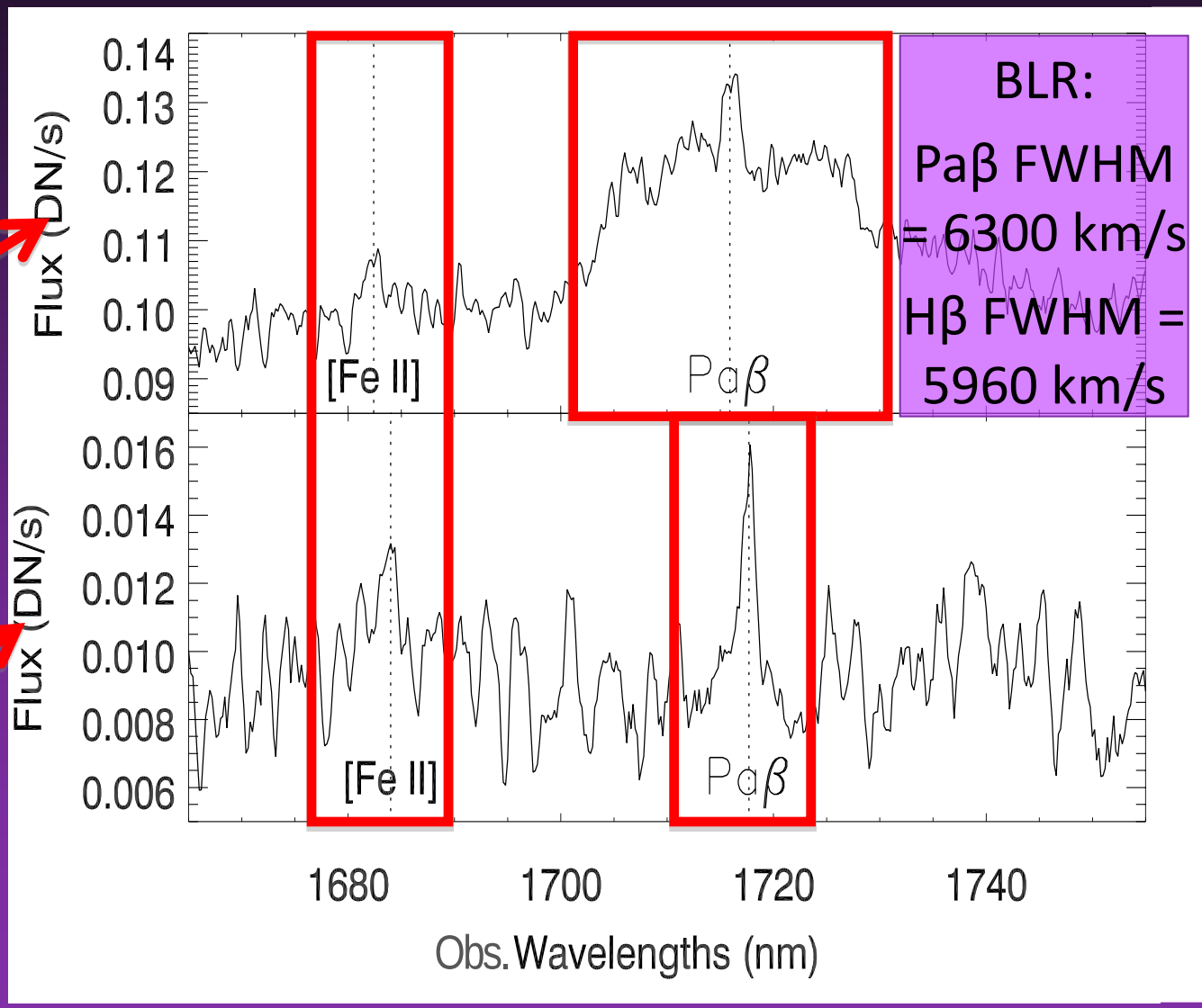
The double spatial structure corresponds to the SDSS double-peaked emission lines!

McGurk et al. 2011

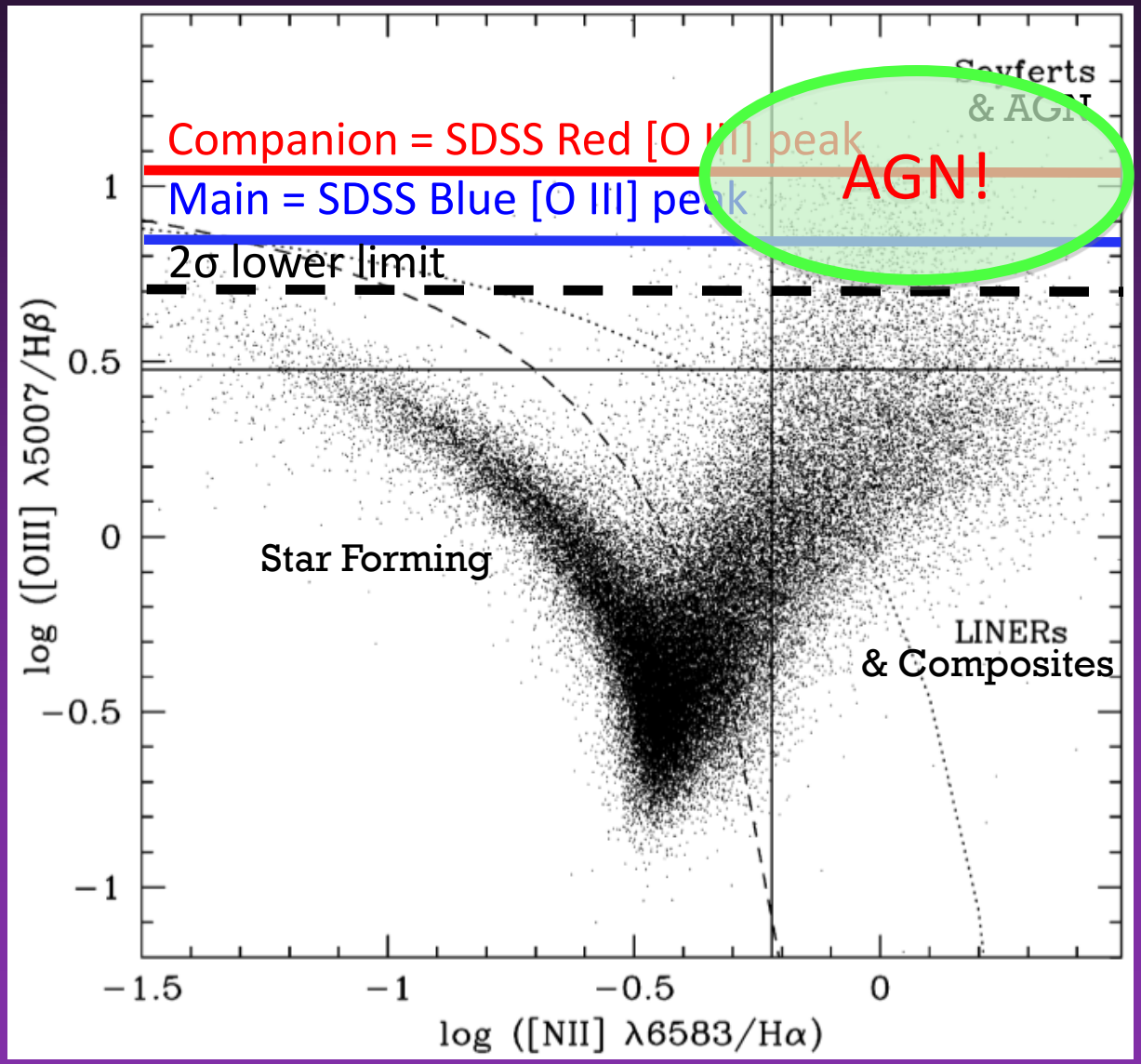
Broad Paβ and AGN type





McGurk et al. 2011

J0952+2552: Is the companion an AGN or a starburst?



McGurk et al. 2011

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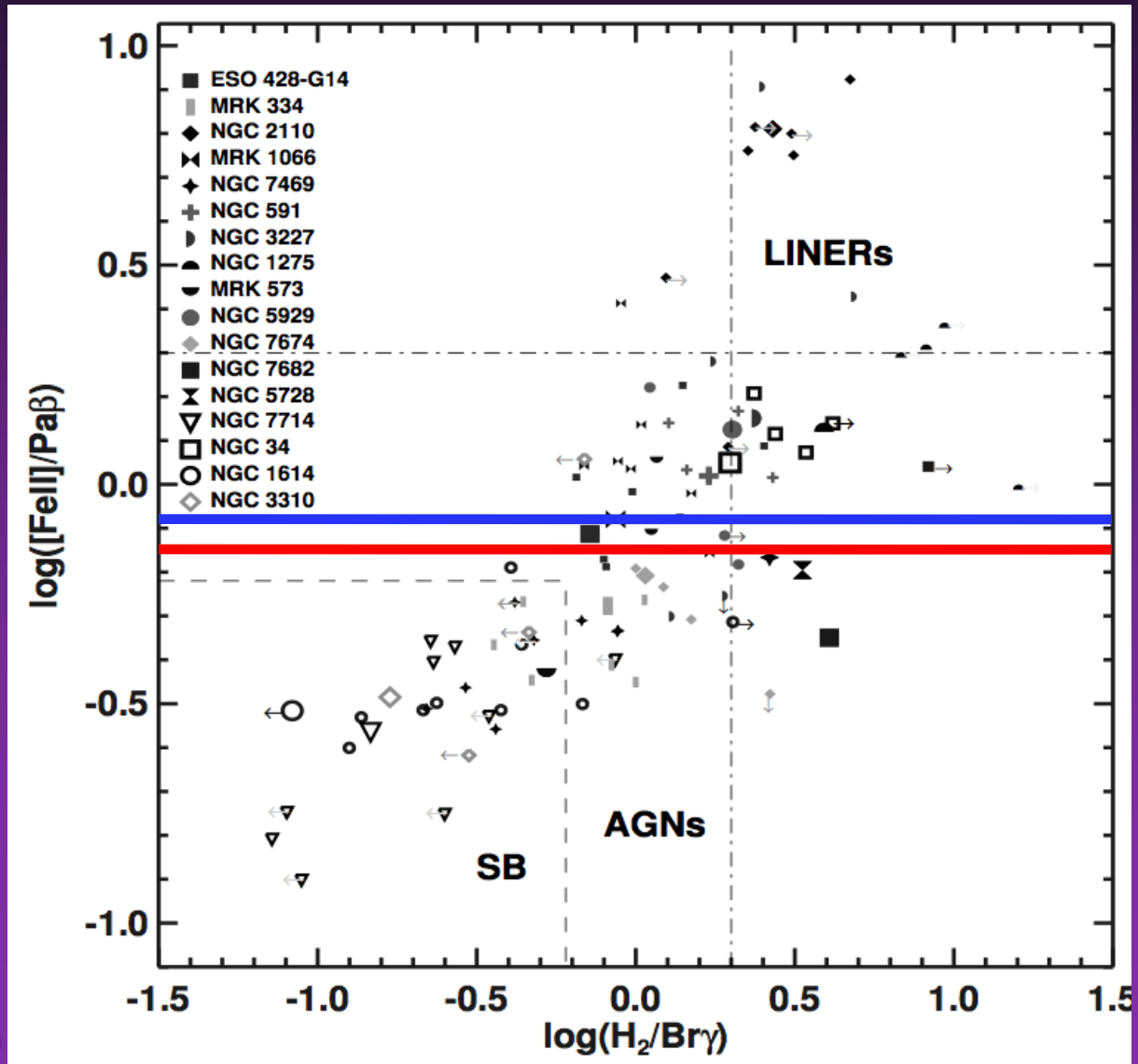


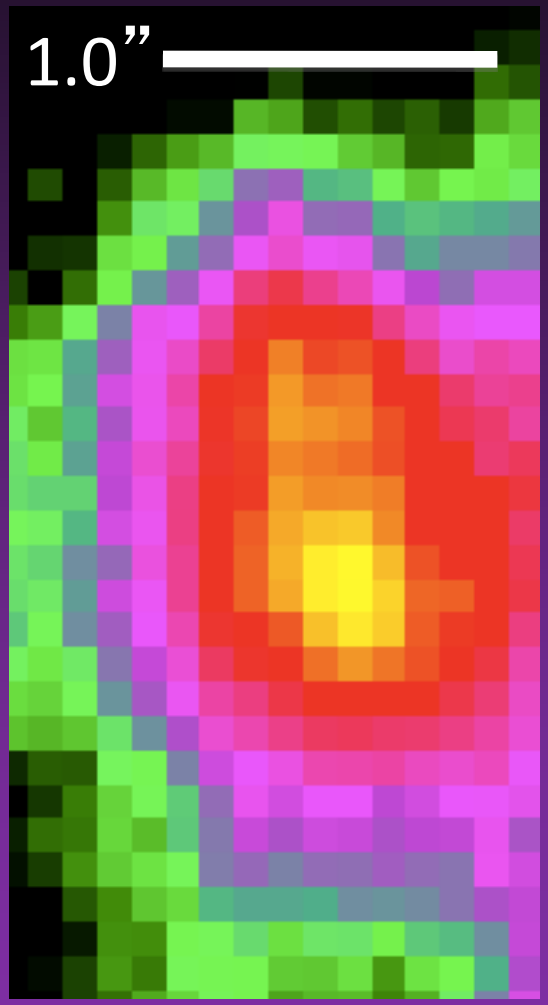
Main galaxy

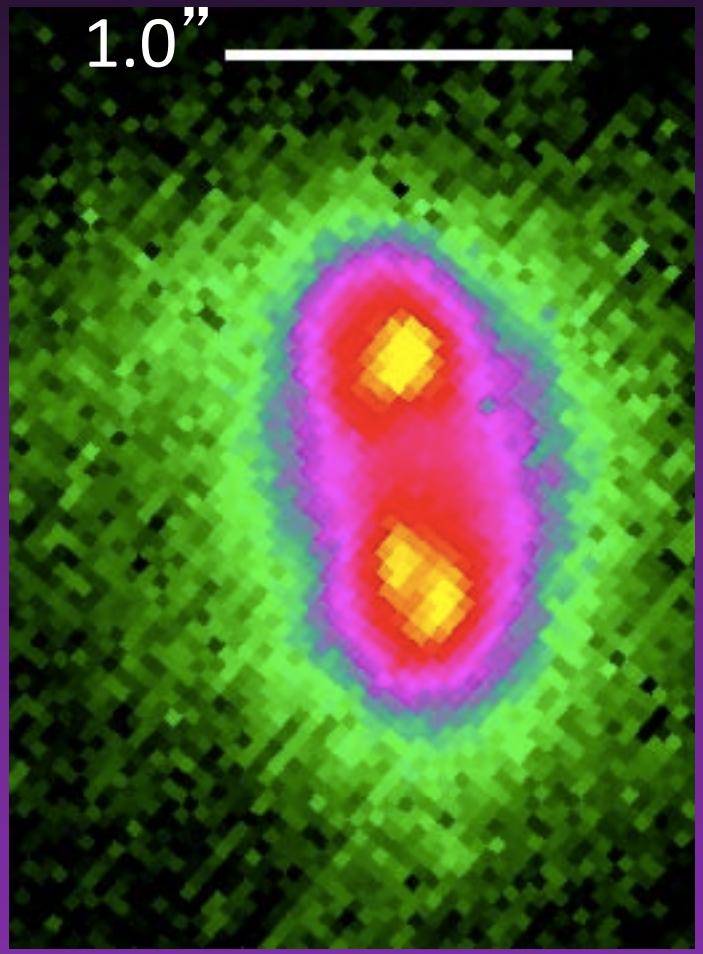
Companion galaxy

McGurk et al. 2011

Rodriquez-Ardila et al. 2008

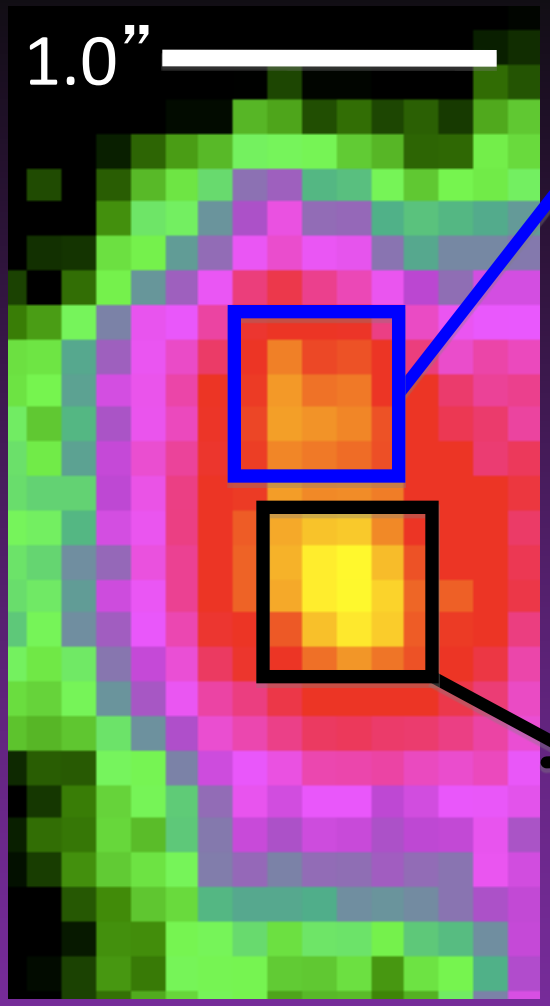
We observed J1108+0659 with OSIRIS

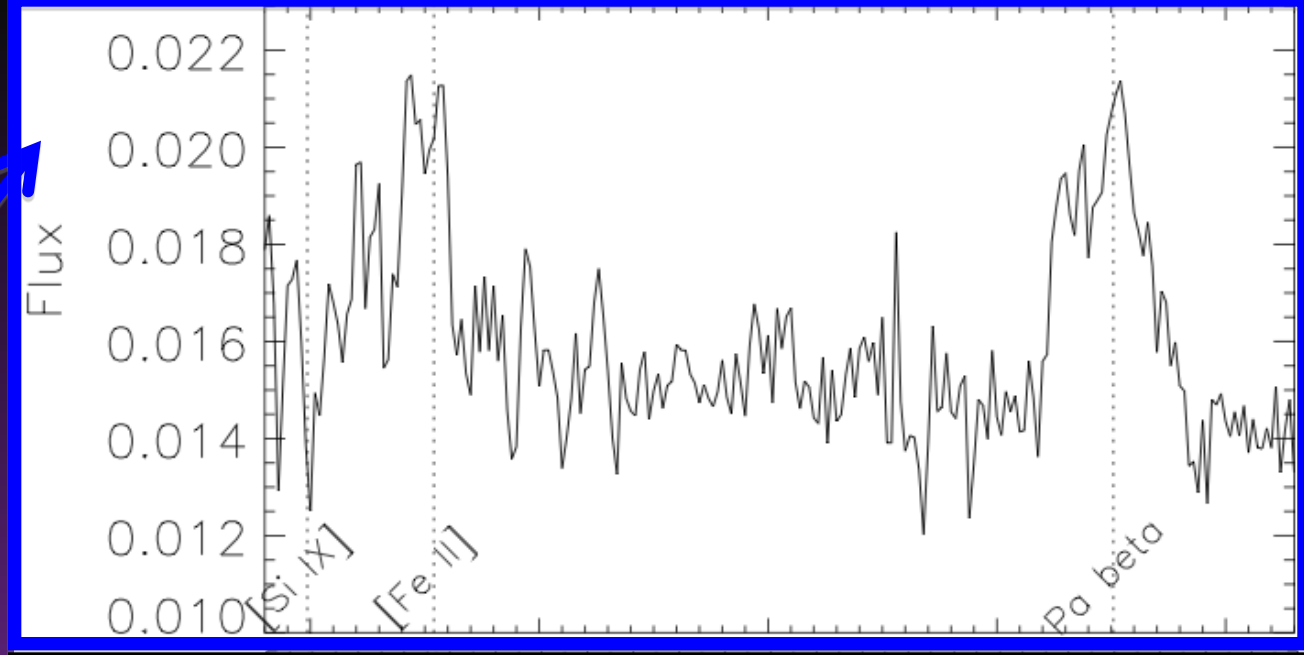


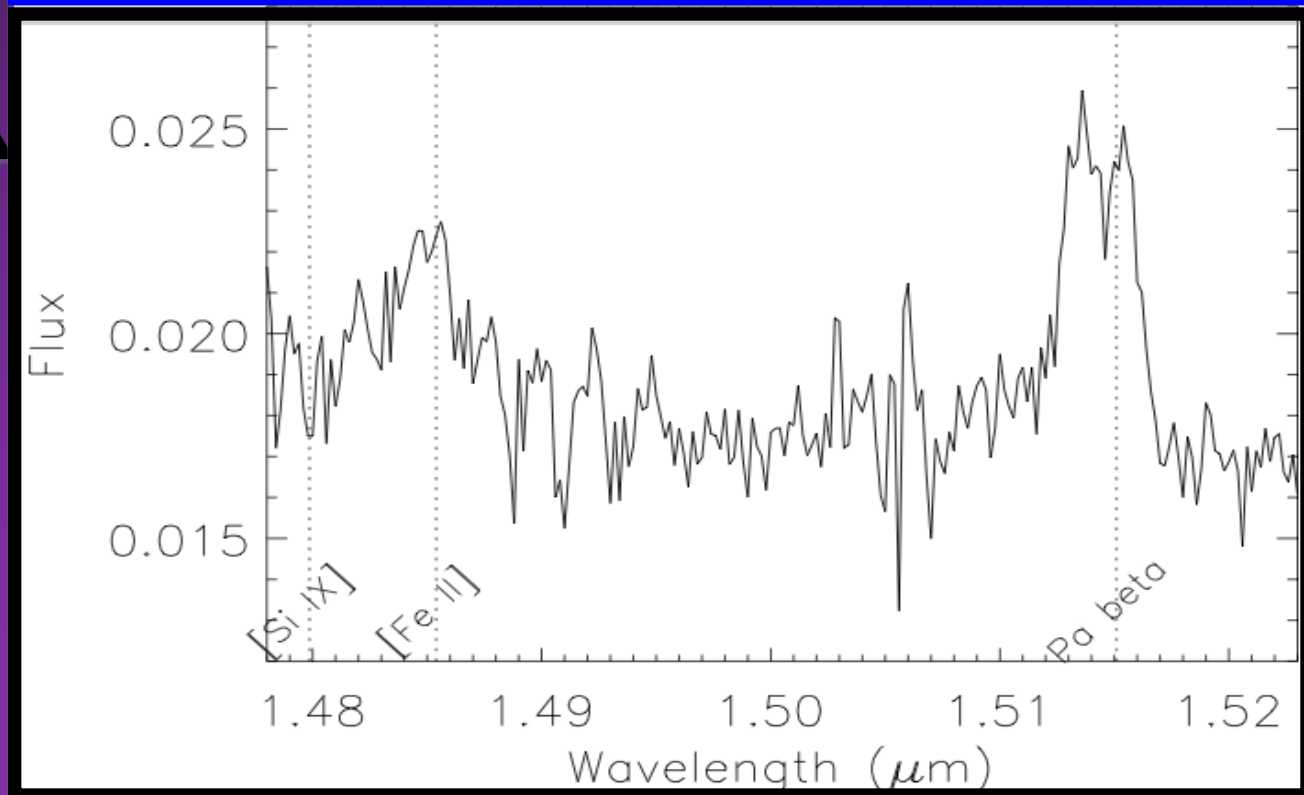


- H broadband
- Redshift = 0.182
- Separation = 0.73” = 2.2 kpc

Left: OSIRIS Hbb continuum. Right: NIRC2 K’ continuum.

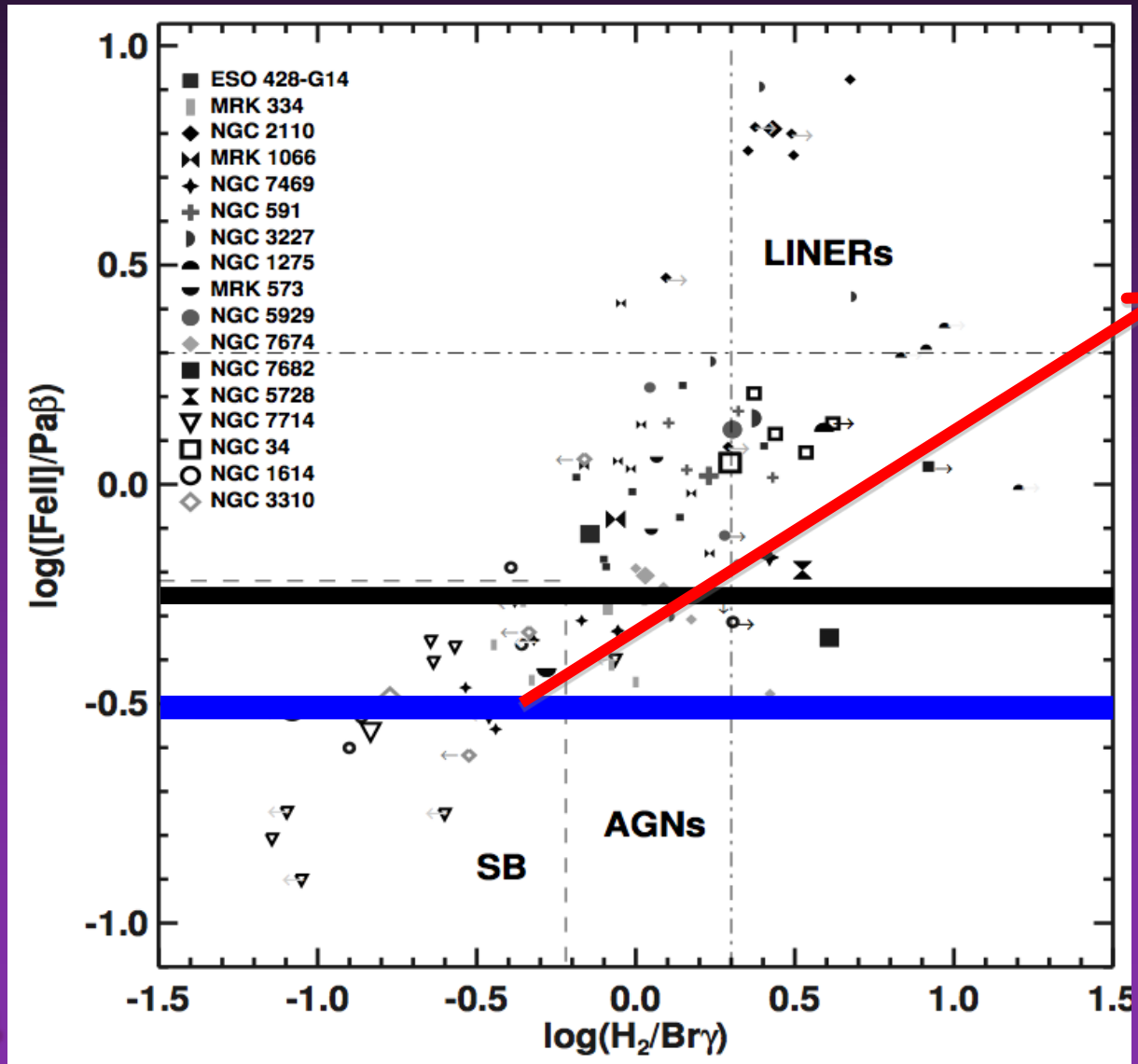






J1108+0659: Both the main and companion have [Fe II] & Paβ

J1108+0659: Is each component an AGN or a starburst?



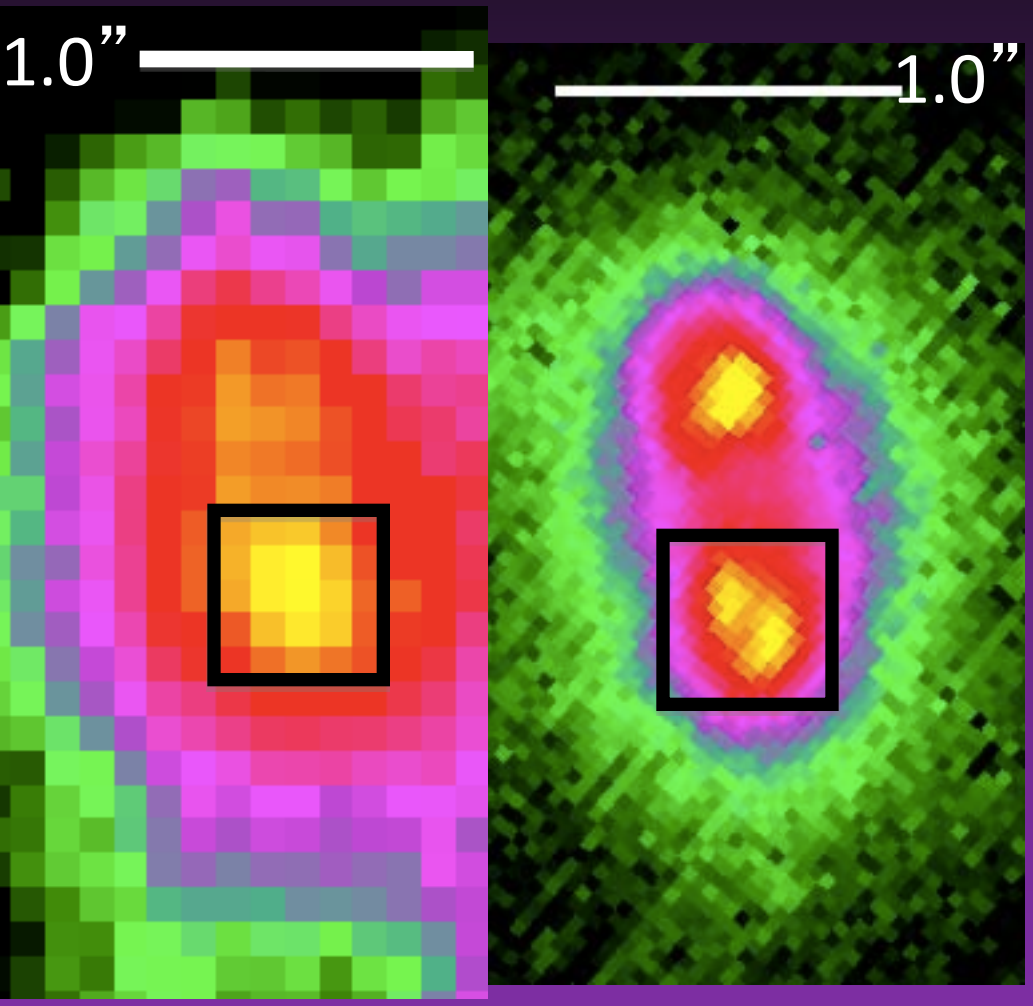
Companion is most likely a star-forming region

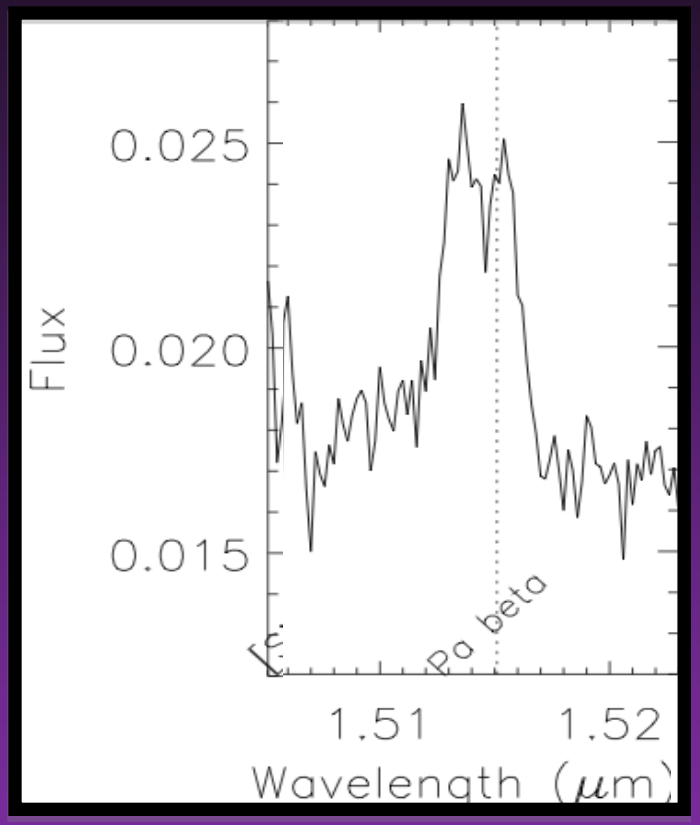
Main galaxy

Companion galaxy

Rodriquez-Ardila et al. 2008

We observed J1108+0659 with OSIRIS

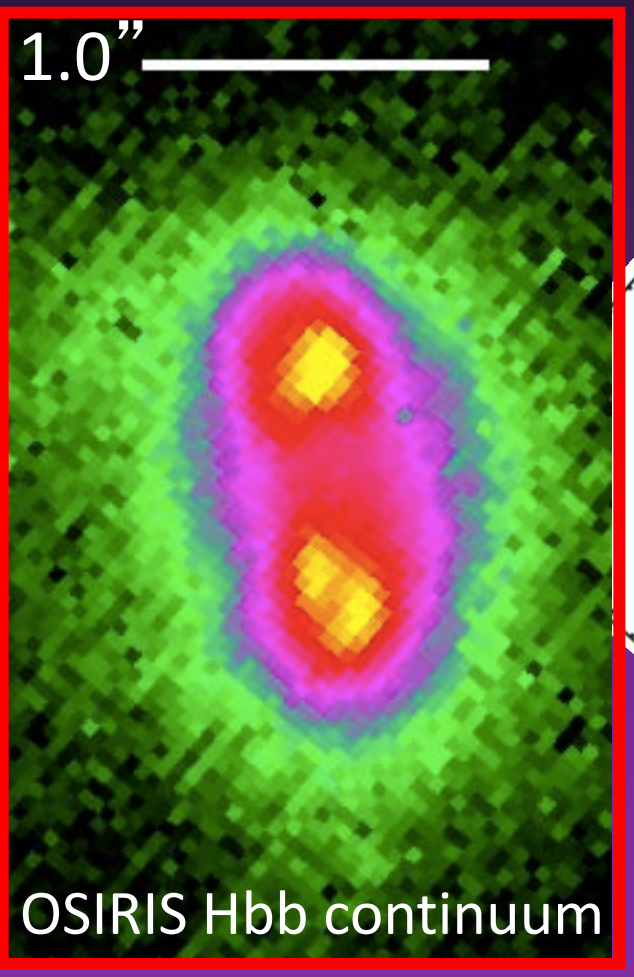


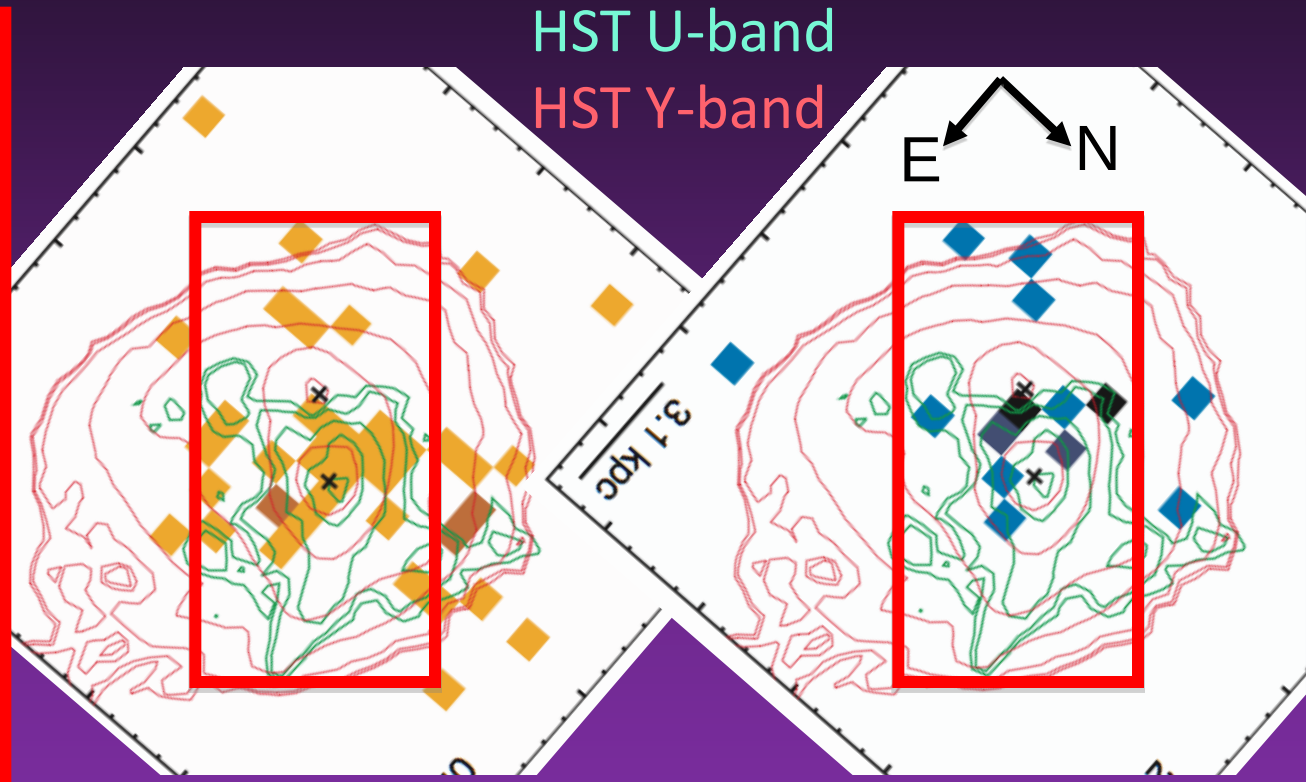


- Our Paβ Δv = 450 km/s
- SDSS double [O III] Δv = 209 km/s

Left: OSIRIS Hbb continuum.
Right: NIRC2 K’ continuum.

Chandra says: Both Nuclei are on the Borderline Between AGN and SF





Comp $L_{X,0.5\text{-}10keV} = 1.1 \times 10^{42}$ erg/s

Main $L_{X,0.5\text{-}10keV} = 0.9 \times 10^{42}$ erg/s

Szokoly et al. 2004

Liu et al. 2012

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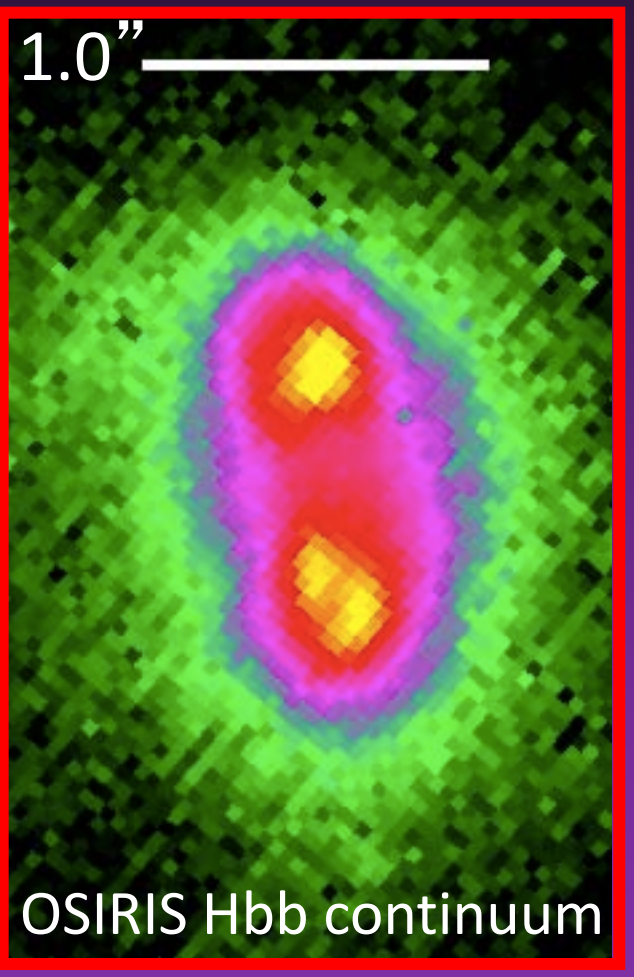

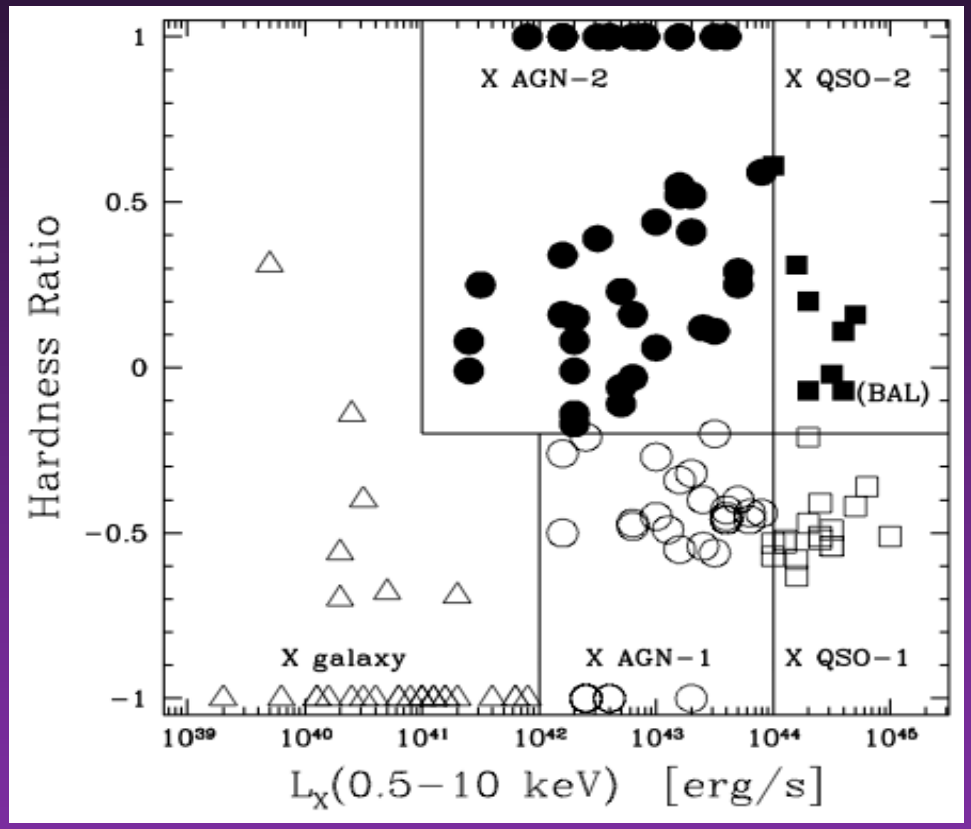

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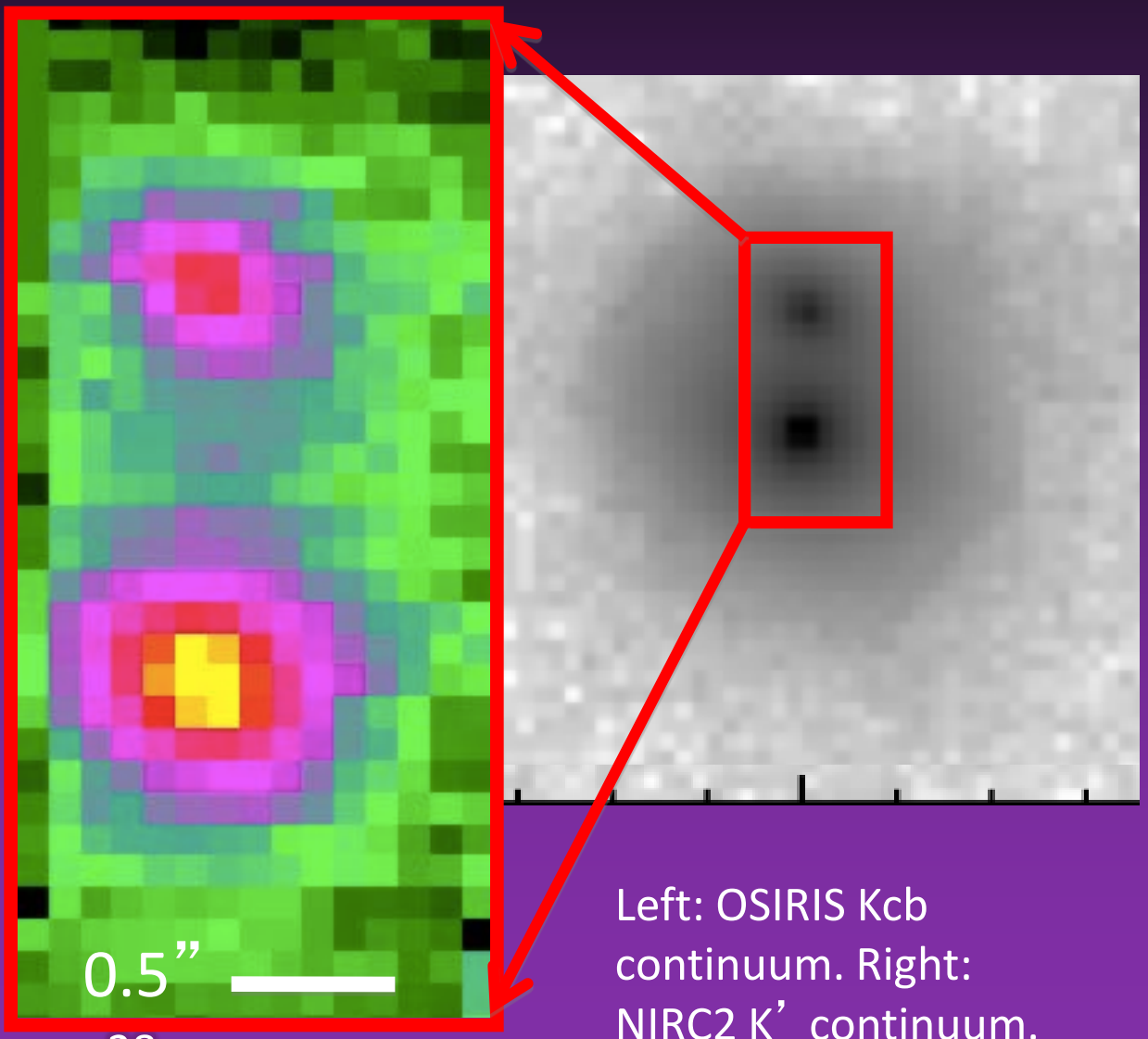
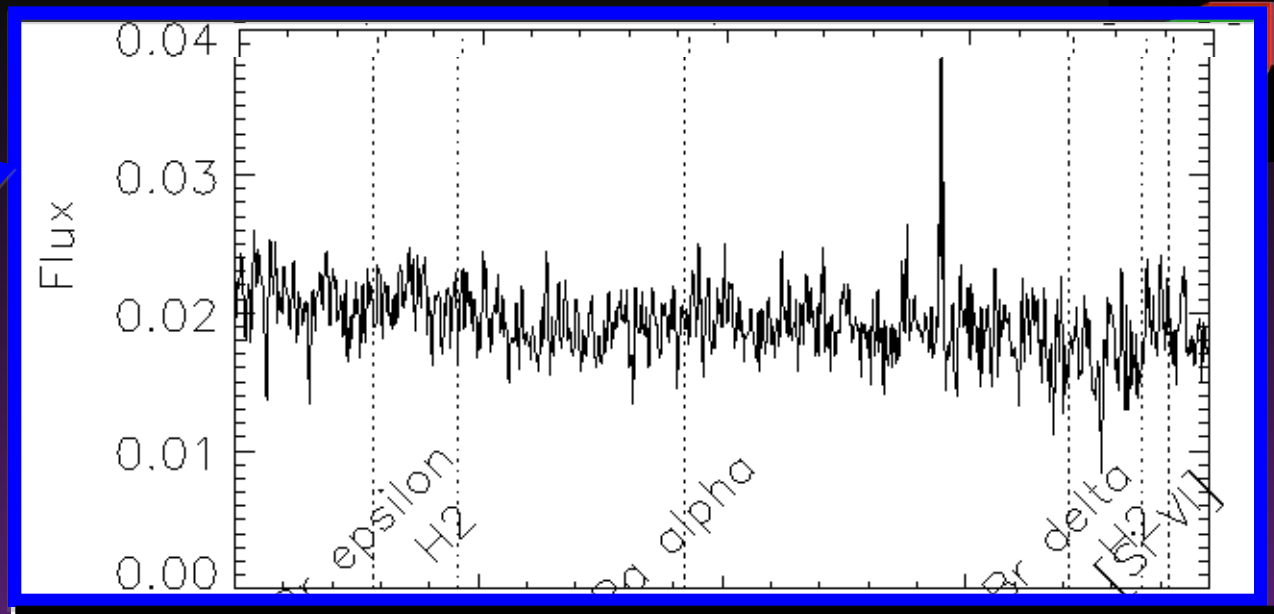
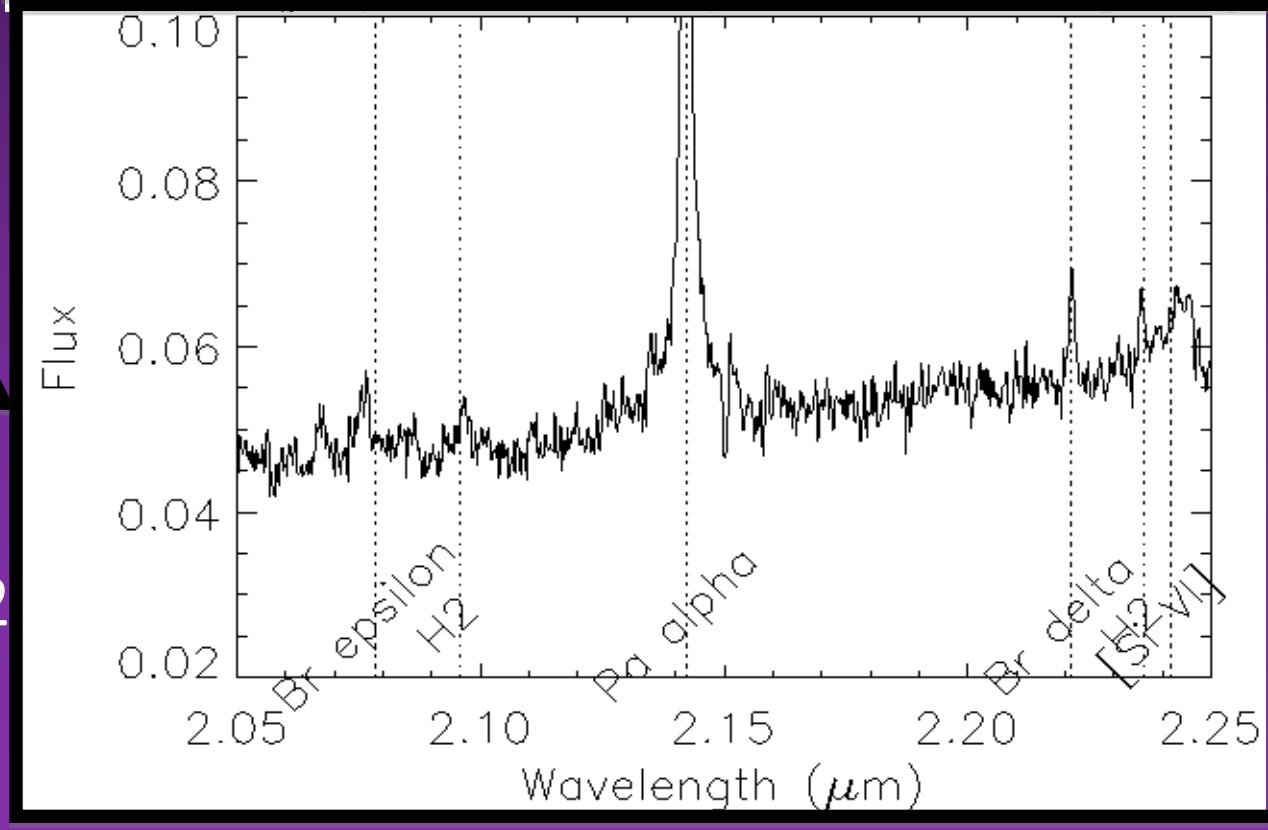
We observed J0916+2835 with OSIRIS



- K broadband
- Redshift = 0.142
- Separation = 1.2” = 3.1 kpc

Left: OSIRIS Kcb continuum. Right: NIRC2 K’ continuum.





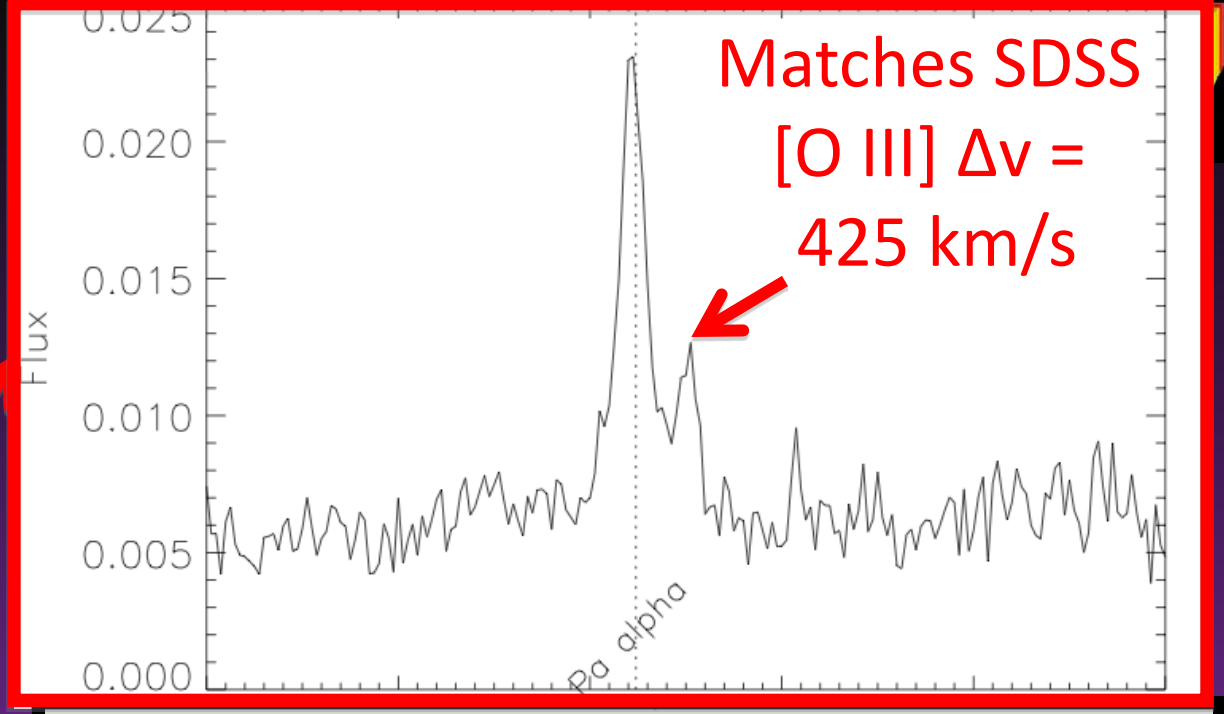
Bottom Nucleus:

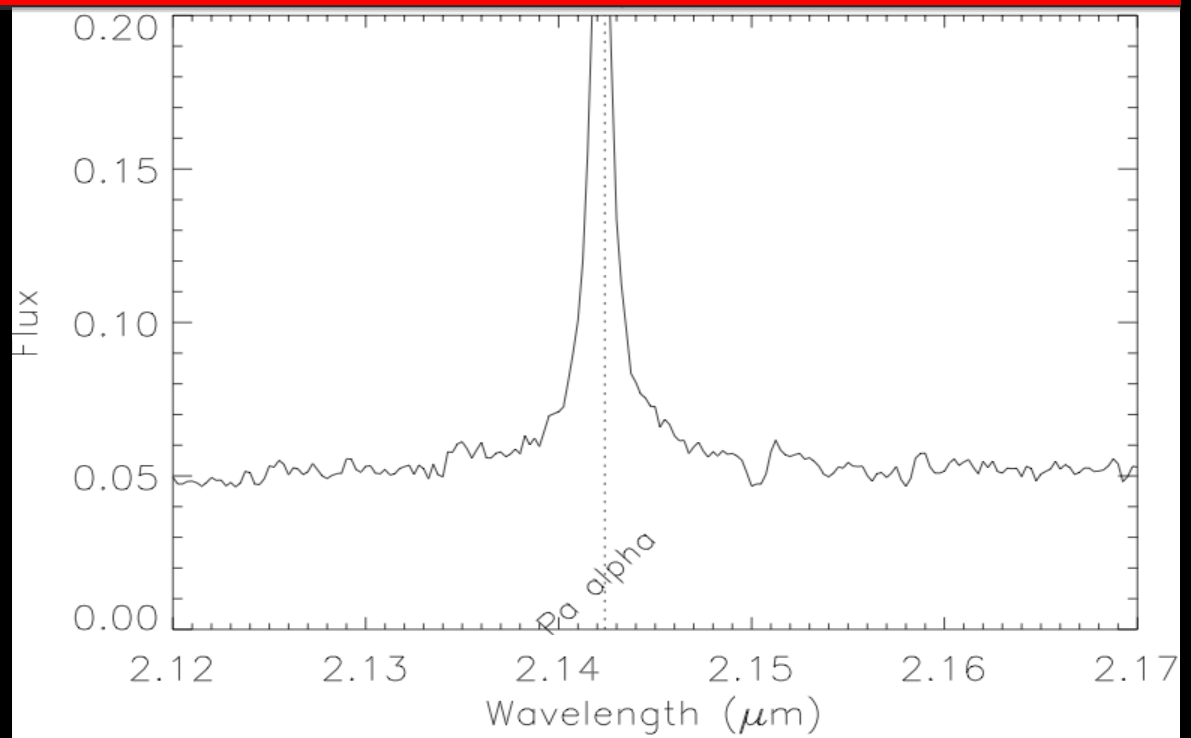
Type 1 AGN at z=0.142

Top Nucleus:

unknown

Matches SDSS [O III] Δv = 425 km/s





Bottom Nucleus: Type 1 AGN at z=0.142

Right Feature: Red peak at +450km/s

Finishing thoughts

- 30% of double-peaked [O III] AGNs have a companion within 3”
- OSIRIS shows some candidates are dual AGNs and some are caused by other phenomena

Future work to confirm candidate dual AGNs:

- Companion orientation known from our NIRC2 images, opening the door to Shane KAST, NIRSPEC, and NIRSPAO longslit observations