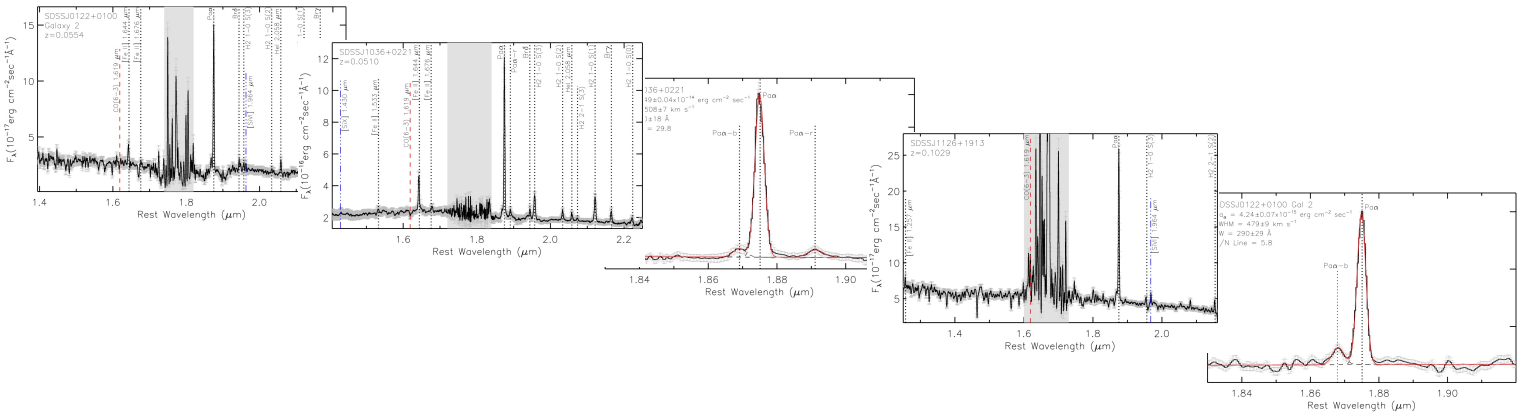
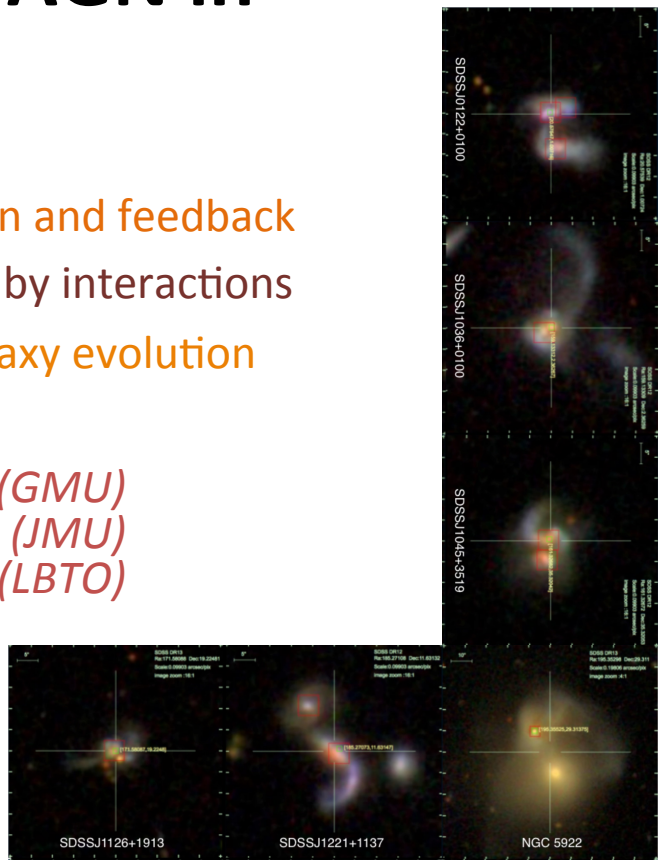


Near-IR Explorations of Buried AGN in Advanced Mergers

- Identify near-IR traits that betray the AGN excitation and feedback
- Quantify the incidence of obscured AGNs triggered by interactions
- Constrain SF properties → study a key phase in galaxy evolution

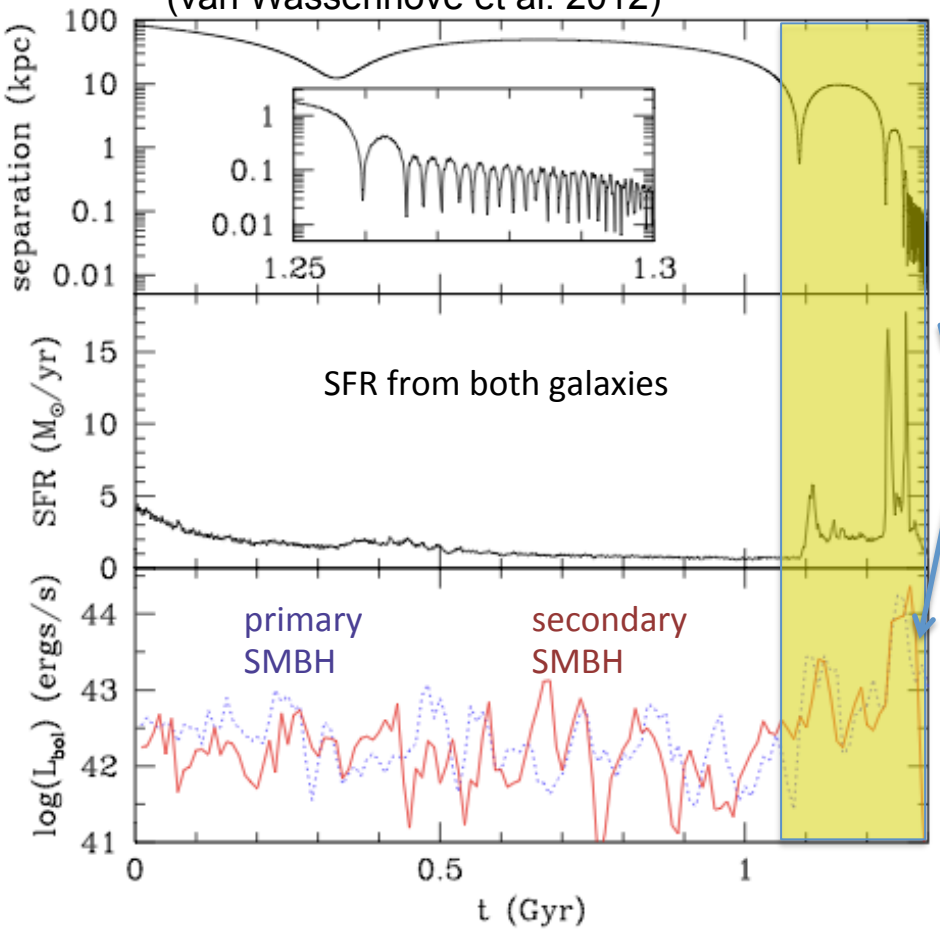
Anca Constantin
James Madison University

with Shobita Satyapal (GMU)
Jason Ferguson (JMU)
Barry Rothberg (LBTO)



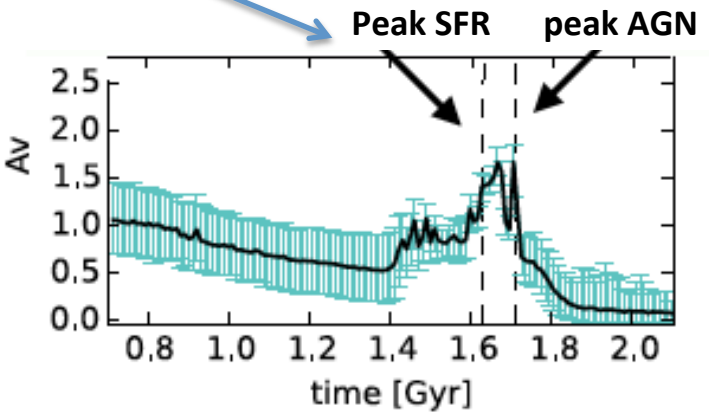
Peak BH growth occurs at small pair separations and is likely obscured

(van Wassenhove et al. 2012)



At D<10kpc

- strong SFR +
- Efficient Dual SMBH accretion
- High extinction values



(Blecha et al. in prep.)

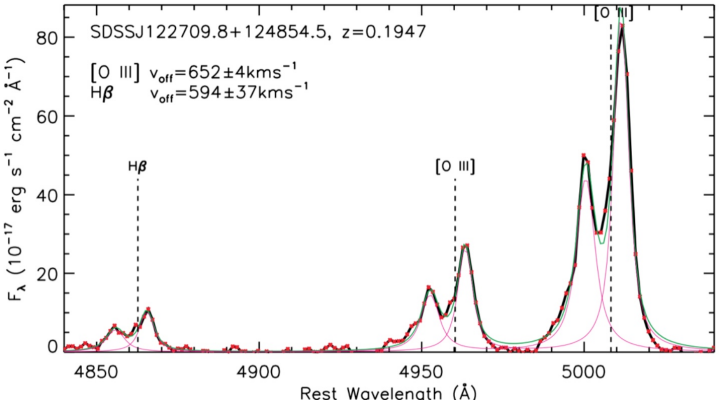
→ complicate detection of the AGN

→ Dual AGNs may be optically obscured the majority of the time when they are active

Optical Searches: Limited!

- < 0.1 % of quasars are binaries (e.g., Hennawi et al. 2010) & peak at ~ 30 kpc separations (Foreman et al. 2008)

- Double-peaked SDSS spectra (~ 1% of all low-z AGN; e.g., Liu et al. 2010, Smith et al. 2010, Wang et al. 2009)



(Liu et al. 2010)

- Double-peaked emission lines can arise (>75%) from rotating disks, bi-conical outflows/jets from single AGN (Müller-Sánchez et al. 2015)

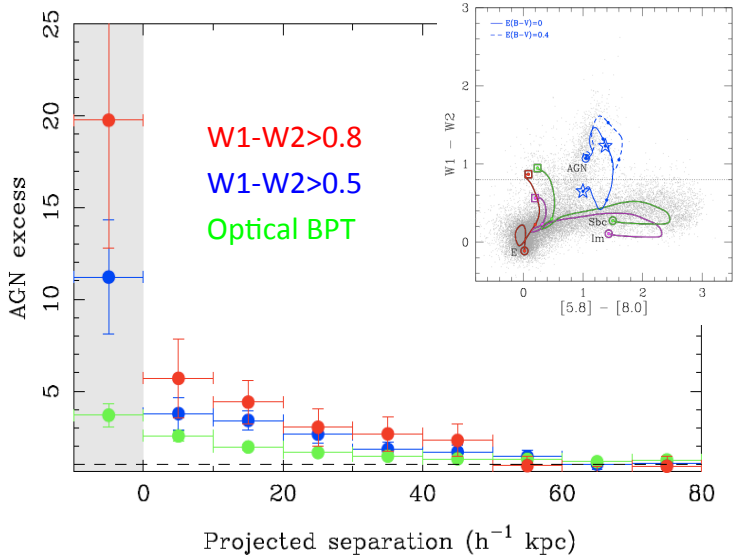
- Only ~2% confirmed dual in follow-up spatially resolved studies (Fu et al. 2011,2012, Shen et al. 2011, Smith et al. 2012, Comerford et al. 2012,2015)

- Theory predicts double-peaks for only small fraction of time (Blecha et al. 2013)

The near-IR sample: the brightest advanced mergers pre-selected by WISE

Sample Selection:

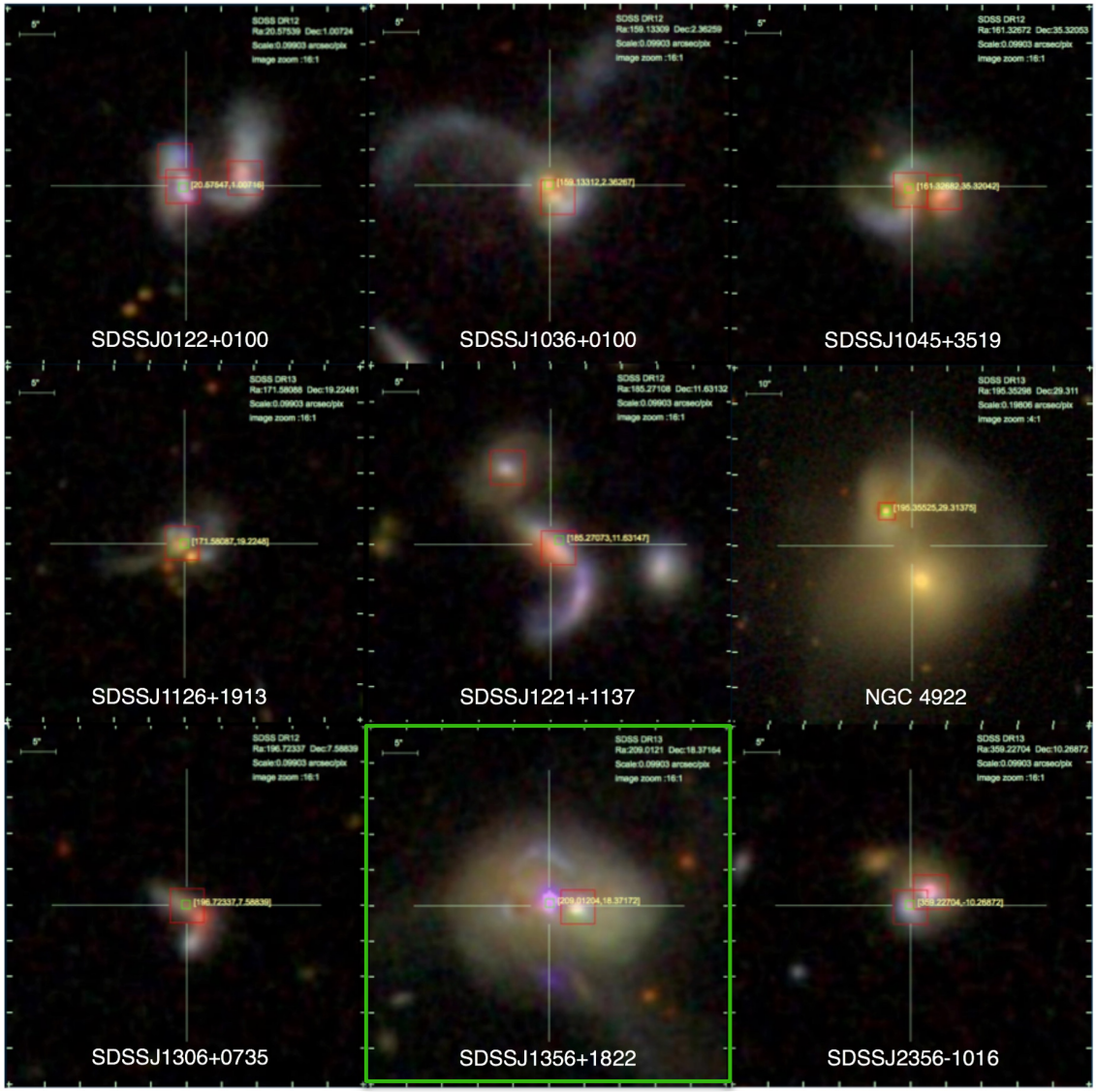
- Drawn from Galaxy Zoo (~667,000 galaxies)
- Required high probability of merger (70%; ~1,500)
- keep only separations < 10kpc
- Required WISE W1-W2>0.5 (86 candidates)
- Obtained follow-up Chandra (cycles 15 and 17) observations of 15 brightest candidates (PI: Satyapal)
  - 5 in X-ray archive. All dual X-ray sources
- Acquired LBT near-IR spectra for 9 systems, more to follow



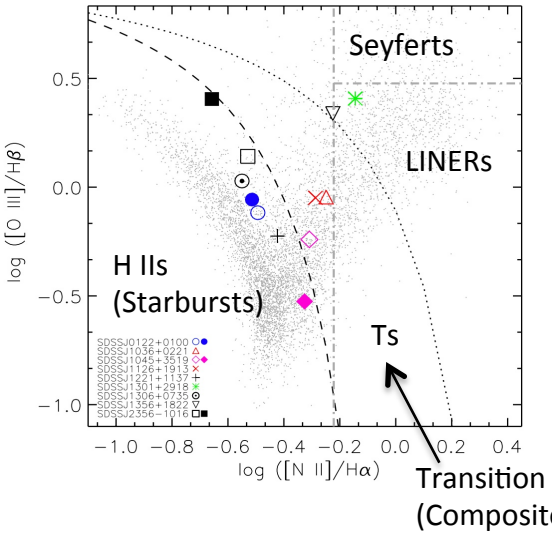
Satyapal et al. (2014)

Merger triggered AGN: detected as red WISE objects, and not seen as AGN in optical.

The near-IR sample: the brightest advanced mergers pre-selected by WISE

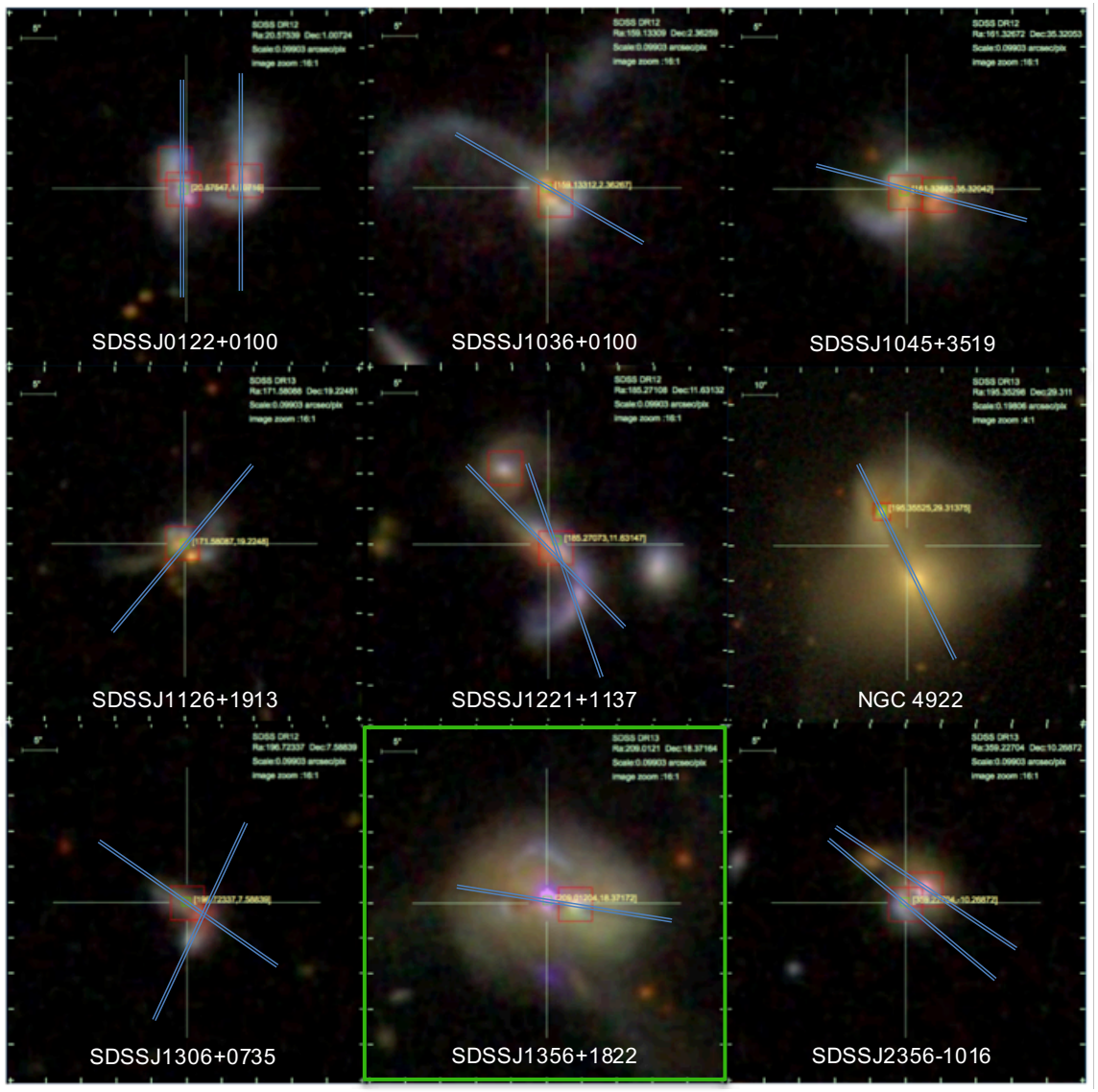


- *gri*-color SDSS images
- All systems exhibit highly disturbed morphologies
- SDSS fibers available for at least one nucleus
- **Optical spectra** consistent with Starbursts **not AGNs**:



- Optical line fluxes from SDSS MPA/ JHU Collaboration

The near-IR sample: the brightest advanced mergers pre-selected by WISE



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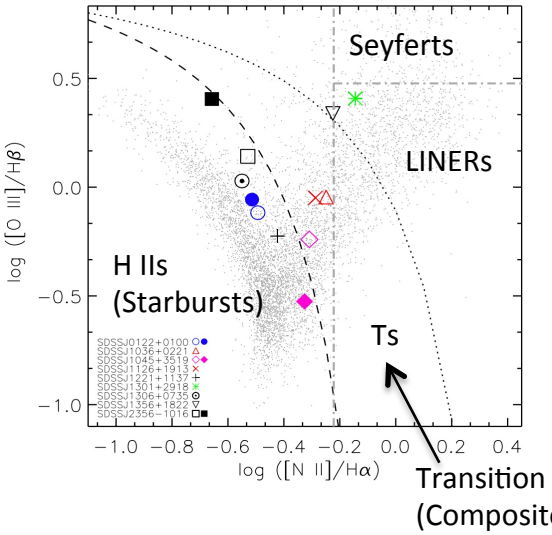
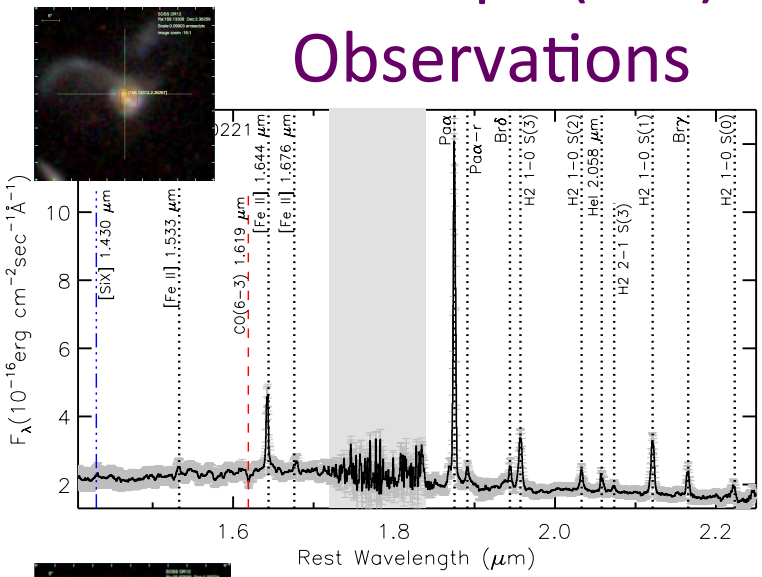
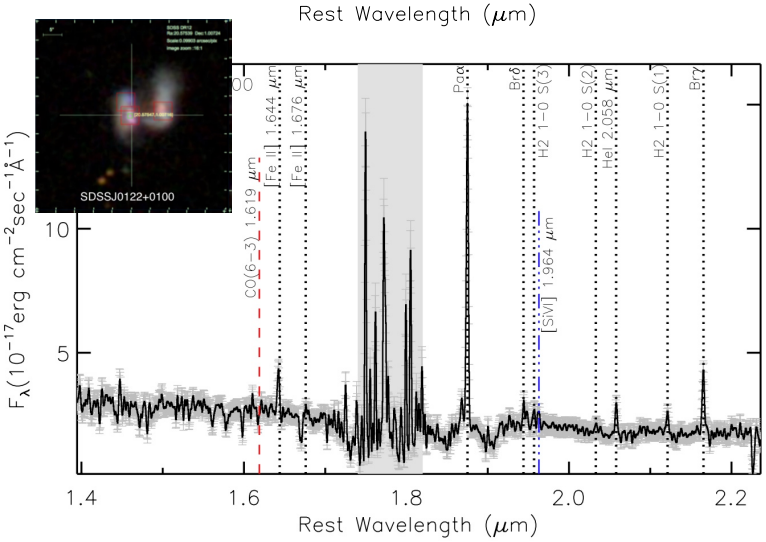
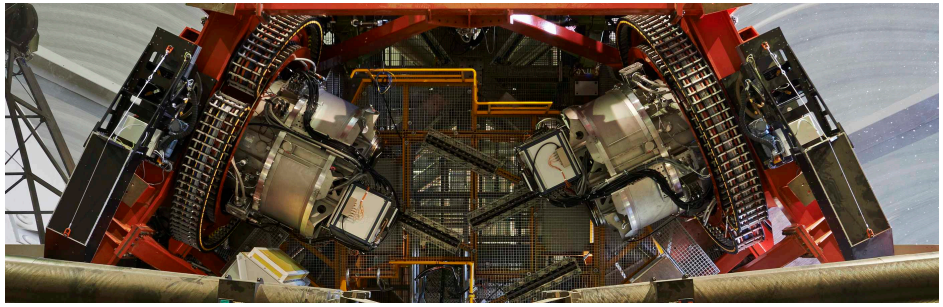


- Optical line fluxes from SDSS MPA/ JHU Collaboration

The Large Binocular Telescope (LBT) Observations





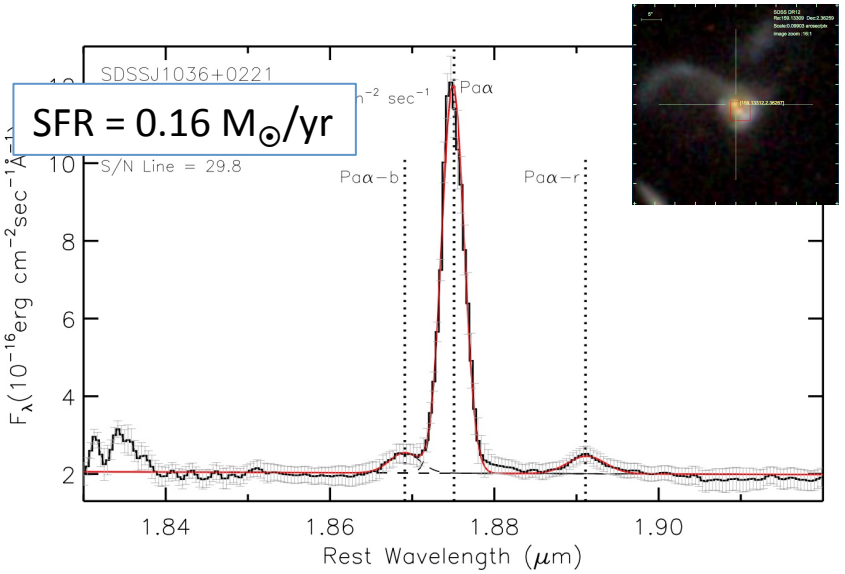


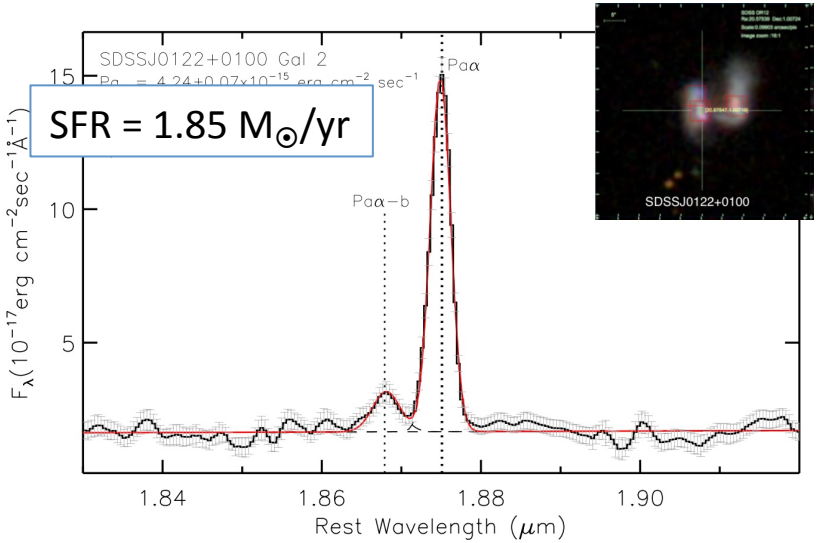
- LUCI 1 & 2 – LBT Near Infrared Spectroscopic Utility with Camera Instruments.
- Total integration time per object 20—30 min.
- 1” & 1.5” width long-slits; 0.25”/pixel
- Spectral resolution R ~ 850 – 1400
- Observed λ range: 0.85 – 2.5 μm (*zJHK* band)
- redshift: 0.02 – 0.1 (1” = 0.7 – 2 kpc)

- Plethora of emission lines: Paα, BrΥ, [Fe II], H_2, coronal lines.
- See Jason Ferguson’s poster

AGN diagnostics in near-IR (I):

Broad emission lines (FWHM > 1000 km/s)





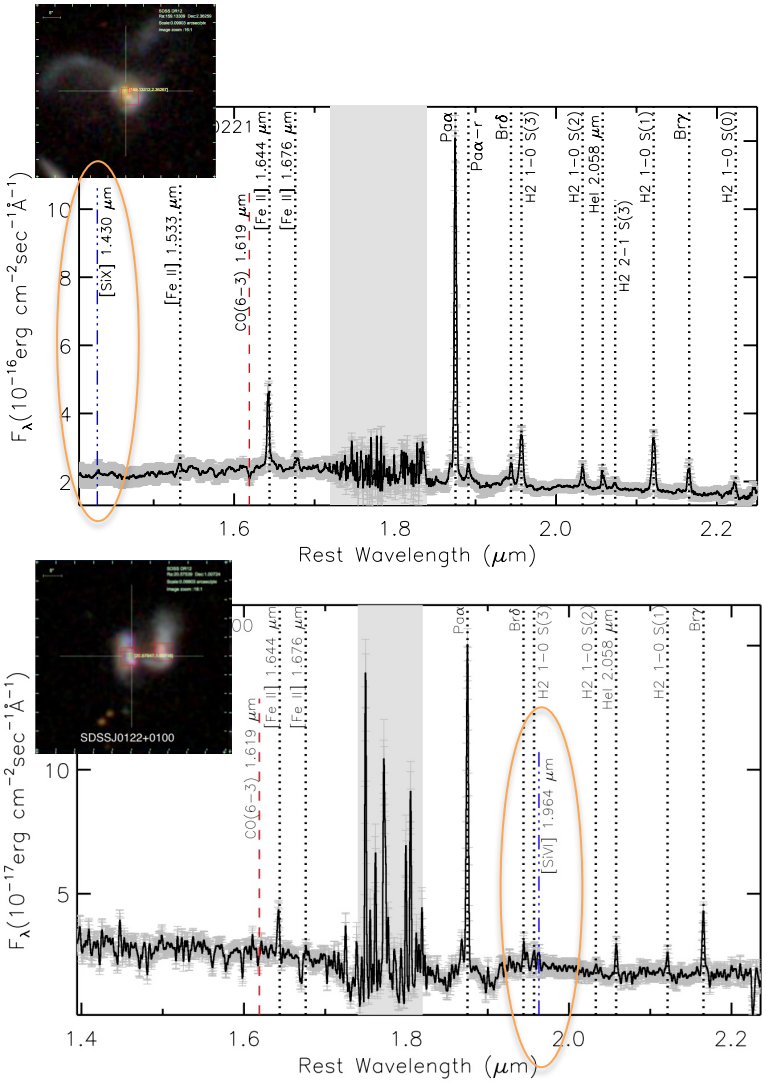
- None detected, unfortunately ☹
  - ⇒ expected to be missing for very high extinction, anticipated in late stage mergers.
    Our near-IR estimates: A_V = 4 - 15
  - ⇒ found only in 10% of Sy2s (e.g., Lamperti et al. 2017)

- However, red/blue -shifted wings in Paα are ubiquitous (at least one Galaxy in all pairs)
  - ⇒ indicative of outflowing gas or hidden BLR ($\Delta v \approx \pm 1500$ km/s)

  Weak SF => AGN for origin of outflows

AGN diagnostics in near-IR (II):

High ionization coronal lines



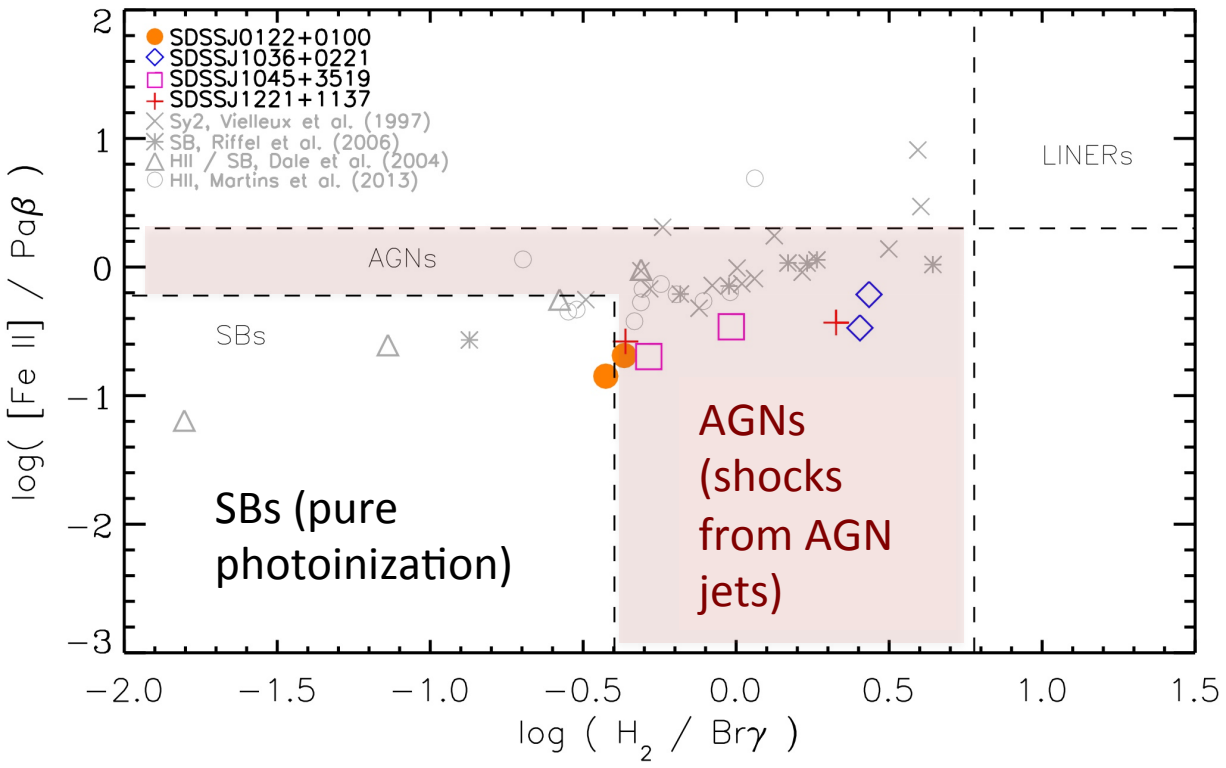
- indicative of hard-ionizing photons from AGN accretion disks (harder than H II regions)

- We detected: [Si X] 1.43 µm, [Si VI] 1.963 µm in 30% of the sample.
  => AGN activity!

- generally, only detected in < 40% of bona-fide type 2 AGNs (e.g., Rodriguez-Ardilla et al. 2008; Lamperti et al. 2017)

- Non-detection:
  => dilution by continuum stellar light
  => very hard AGN ionizing continuum
  => high obscuration

AGN diagnostics in near-IR (III): Line flux ratio diagram



[Fe II]/Paβ:

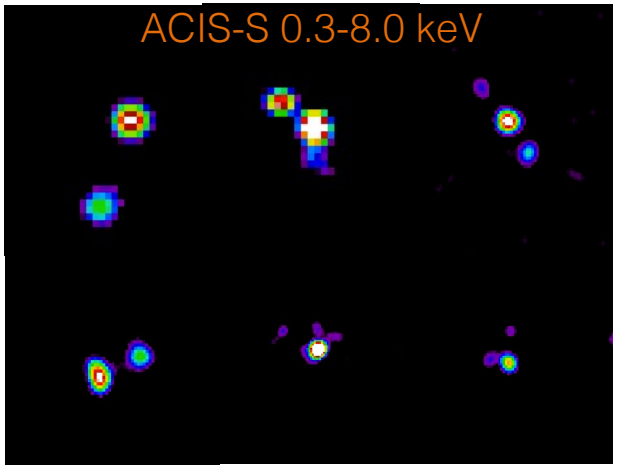
- constrains amount of [Fe II] produced by HII vs. AGN jets.

(Simpson+1996, Larkin+ 1998, Rodriguez-Ardila+ 2005, Riffel+ 2013)

- Good: Our galaxies fall into AGN locus

- Not so great: many (~60%) Starburst galaxies also fall into that parameter space!

AGN diagnostics in near-IR (IV): Comparison with L_X



4×10^{40} erg s^{-1} < $L_{2\text{-}10\ keV}$ < 2×10^{41} erg s^{-1}

≈ comparable to upper limit of $L_{2\text{-}10\ keV}$ in most luminous SF galaxies (Lehmer et al. 2010)

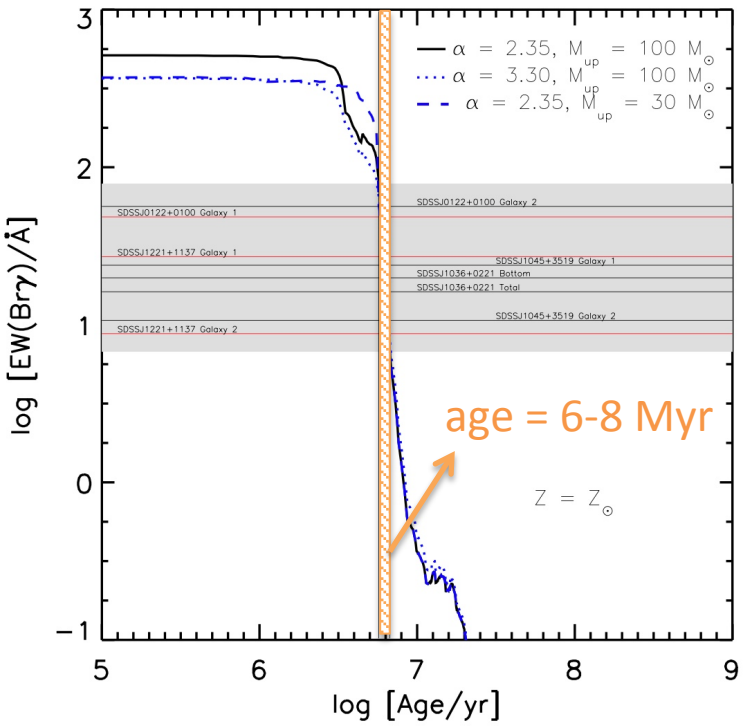
=> X-ray emission from XRBs?

- Near-IR spectra => extinction-insensitive SFRs —(+ M* (SDSS MPA/JHU); Lehmer et al. 2010)→ L_X produced by XRBs
- Assuming Paα flux solely from gas ionized by hot young stars => near-IR-derived SFR = only an upper limit → upper limits of L_X (XRBs)
- Comparison: L_X (XRBs) < $L_{2\text{-}10\ keV}$ → XRBs not sufficient to account for observed L_X

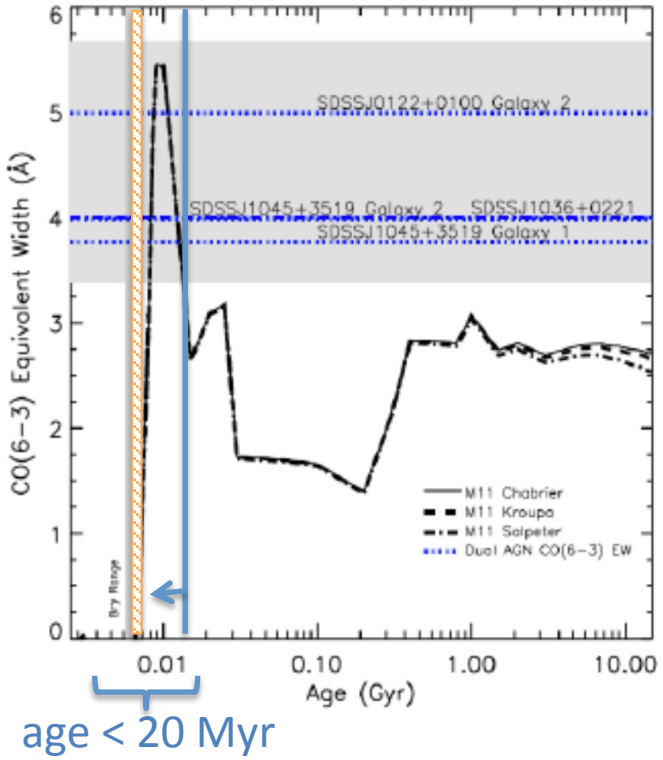
=> Highly suggestive of presence of at least one AGN

Near-IR spectra consistent with not too young starbursts

Starburst99 models (Leitherer et al. 2014)



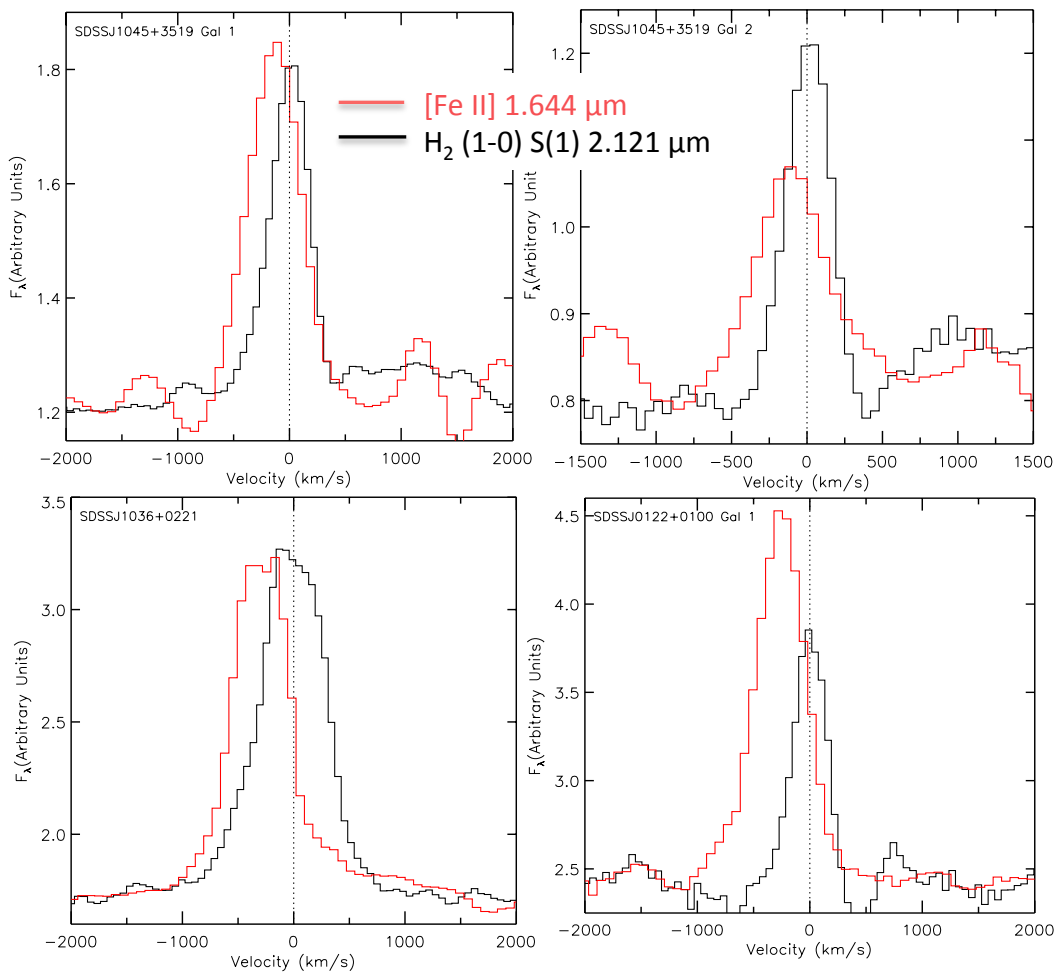
Maraston & Strömbäck (2011)



⇒ Stellar population age not consistent with peak in HMXBs
(# drops below 1HMXBs at 7Myr; e.g., Linden et al. 2010)

⇒ AGN activity more likely!

AGN behavior in near-IR (V): Kinematics of [Fe II] and H_2



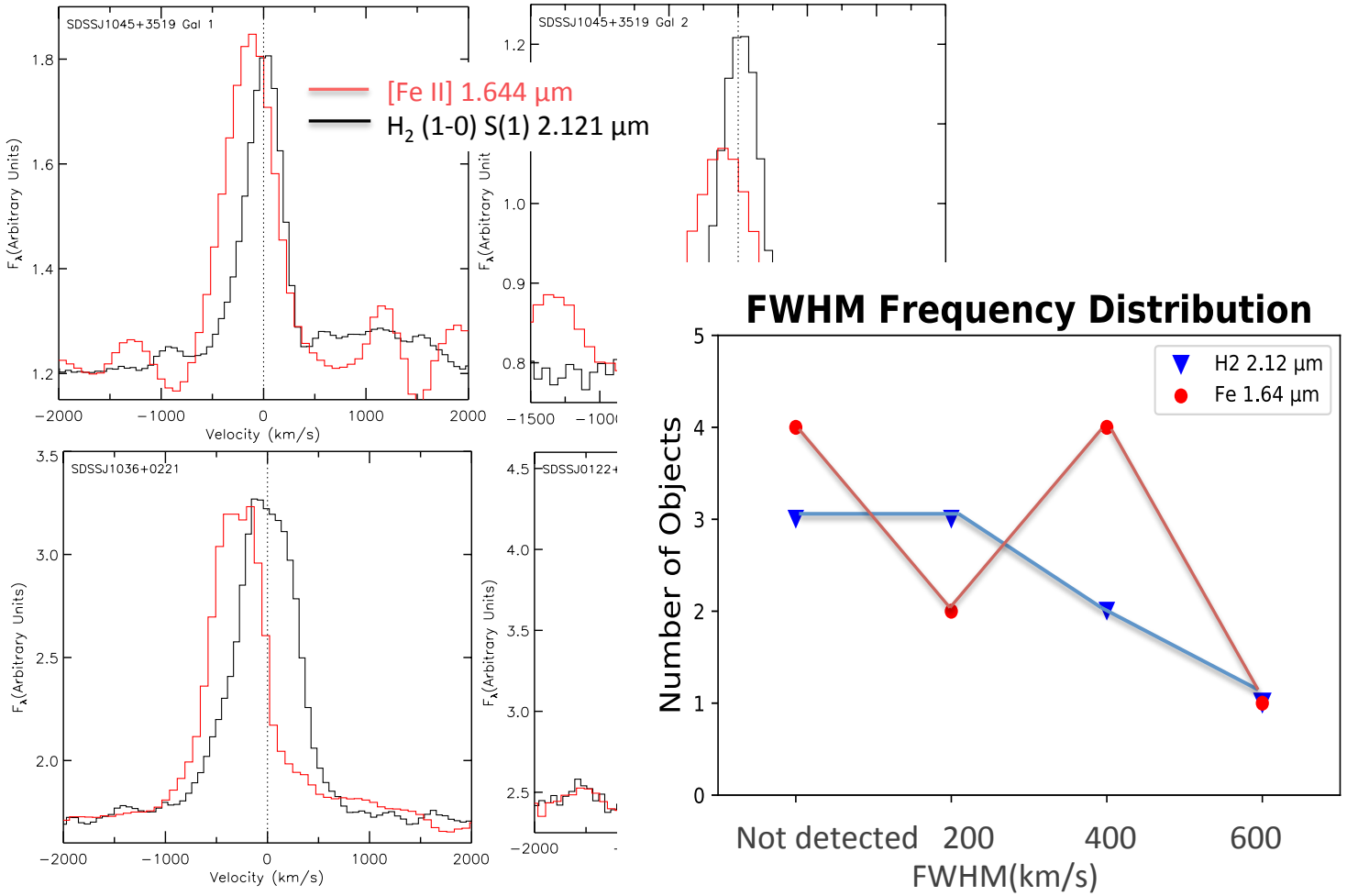
In single AGNs:

- Differences in FWHM distributions (e.g., Rodriguez-Ardila et al. 2004/5)
- Suggestive of different location and morphology of H_2 and NLR

In our dual AGNs candidates:

- Line widths are smaller in H_2
  - ⇒ Similar to single AGN behavior
  - ⇒ a disc of H_2 surrounds the nuclear region
- [Fe II] blueshifted relative to systemic velocity ($\Delta v \approx 500$ km/s)
- No shift in H2
  - ⇒ Evidence for outflows?

AGN diagnostics in near-IR (V): Kinematics of [Fe II] and H_2

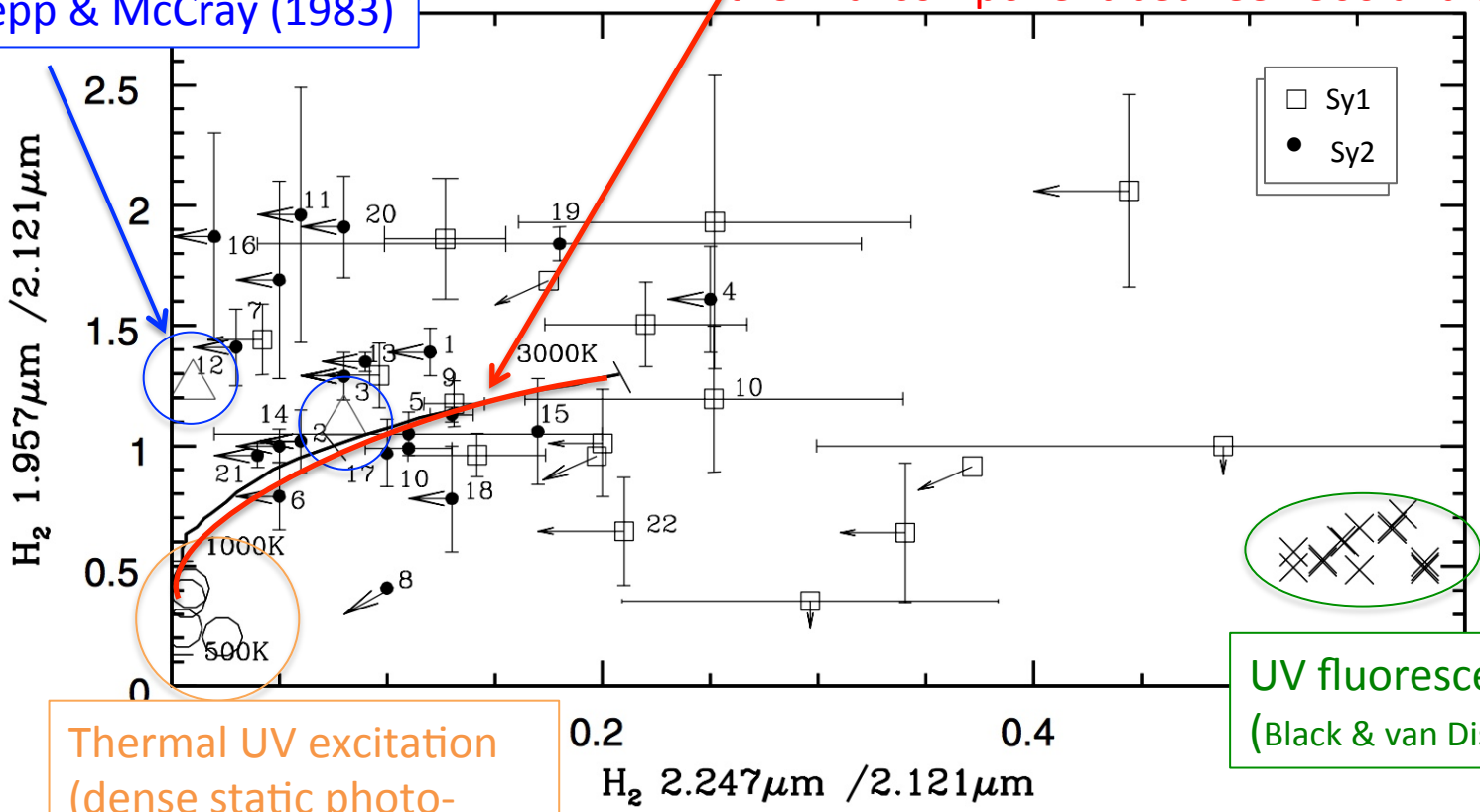


AGN diagnostics in near-IR (VI):

Excitation mechanism of the H_2 lines

X-ray heating
Lepp & McCray (1983)

thermal component between 500 and 3000 K



Thermal UV excitation (dense static photo-disociation; Sternberg & Dalgarno 1989)

UV fluorescence
(Black & van Dishoeck 1987)

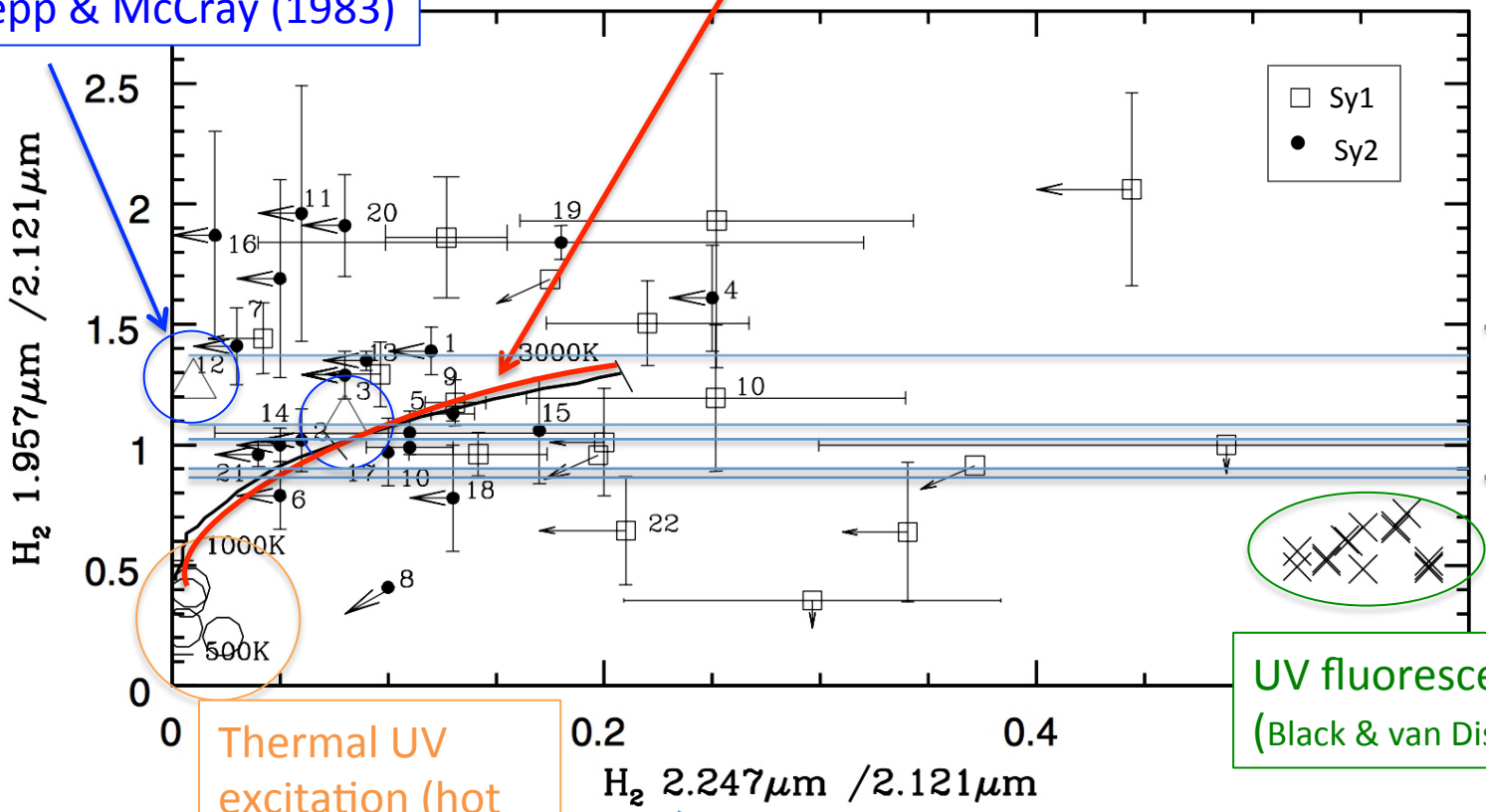
(adapted from Rodríguez-Ardila, Riffel & Patoriza 2005)

AGN diagnostics in near-IR (VI):

Excitation mechanism of the H_2 lines

X-ray heating
Lepp & McCray (1983)

thermal component between 1000 and 3000 K



Our sample

UV fluorescence
(Black & van Dishoeck 1987)

Thermal UV excitation (hot young stars; Sternberg & Dalgarno 1989)

No data; no constraints on x-axis values

(adapted from Rodríguez-Ardila, Riffel & Patoriza 2005)

Summary and new directions

- SF and AGN activity peak during the advanced merging phase but highly obscured
- Near-IR Sample not complete but the largest so far of dual AGN (candidates)
- No reveal for hidden BLR but possible detection of outflows
- 30% with coronal lines: at least one secure AGN/pair
- Diagnostic diagrams consistent with AGN ionization in all cases*; H_2 excitation most likely produced by AGN*
- SP ages not young enough to account for the observed X-ray emission via XRBs or HMXBs.
- final near-IR census and characterization dual AGNs to be announced soon! (Satyapal et al. 2017, submitted; Constantin et al. in prep.)