Identification of Outflows and Candidate Dual Active Galactic Nuclei at $0.8 < z < 1.6$

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Collaborators:
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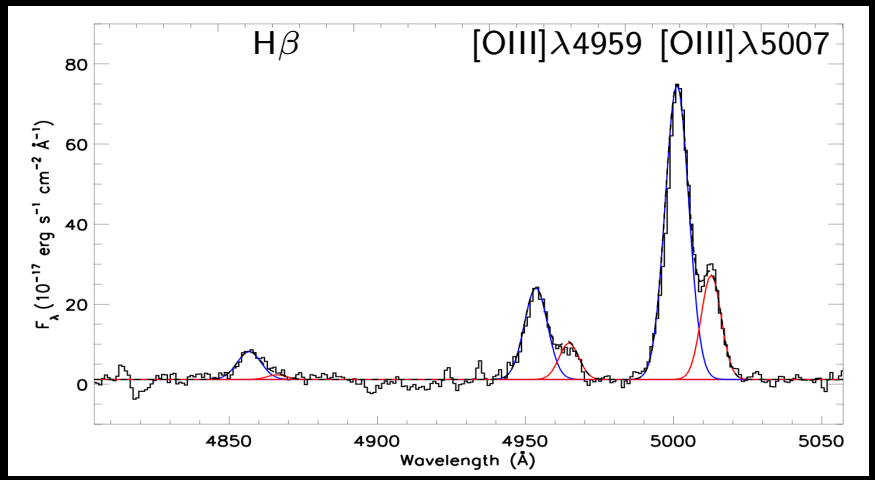
Binary Black Holes and Dual AGN, Nov 30, 2012

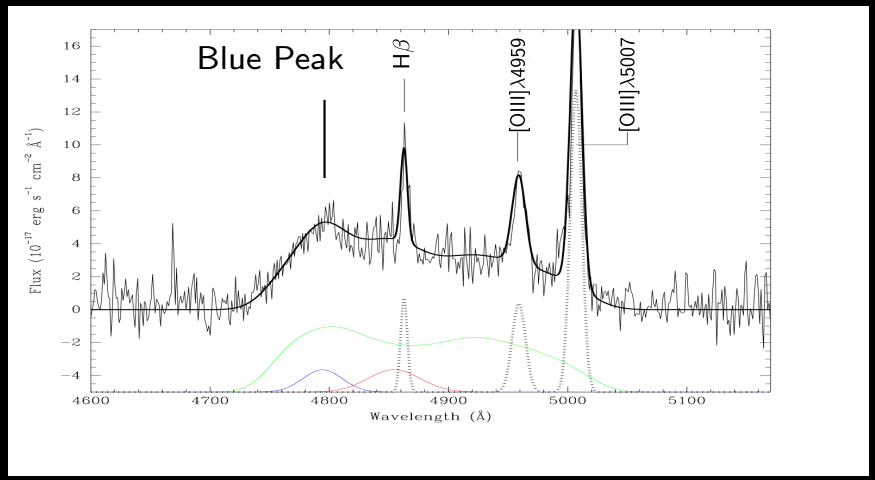
Spectroscopic Selection of Candidates

Dual AGN:
Double-peaked narrow line component



(Barrows et al. 2012)

Binary SMBH:
Double-peaked broad line component



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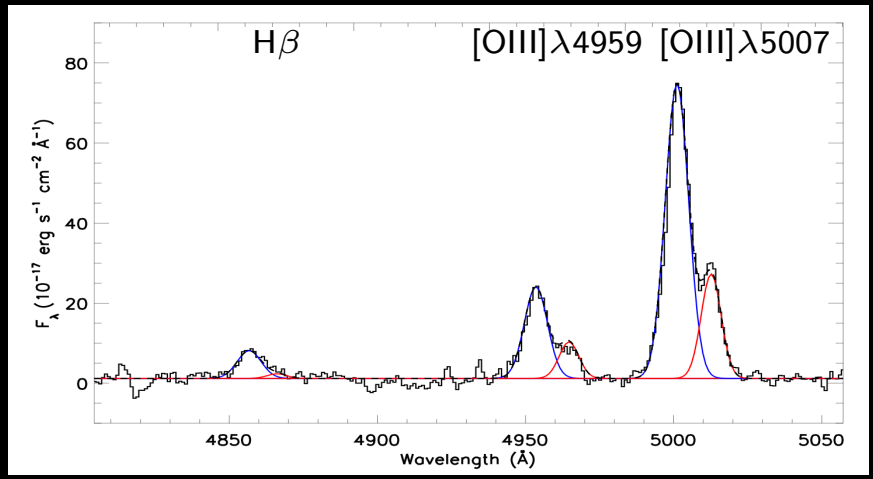

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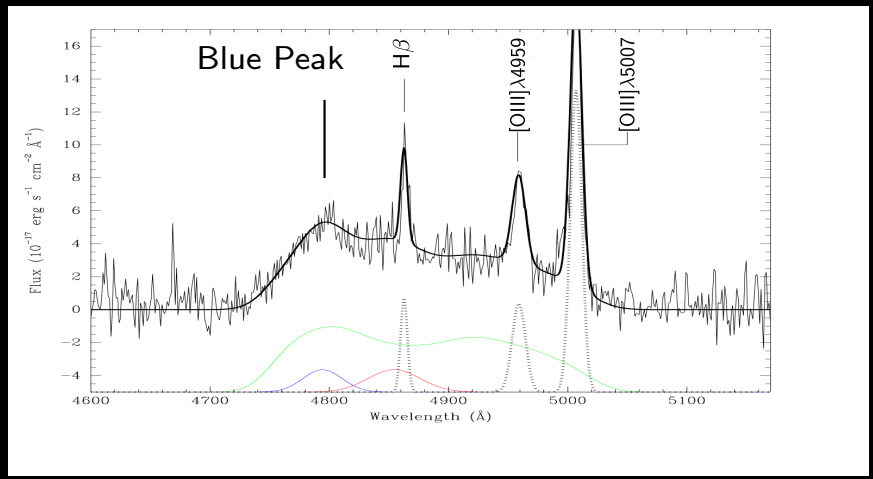
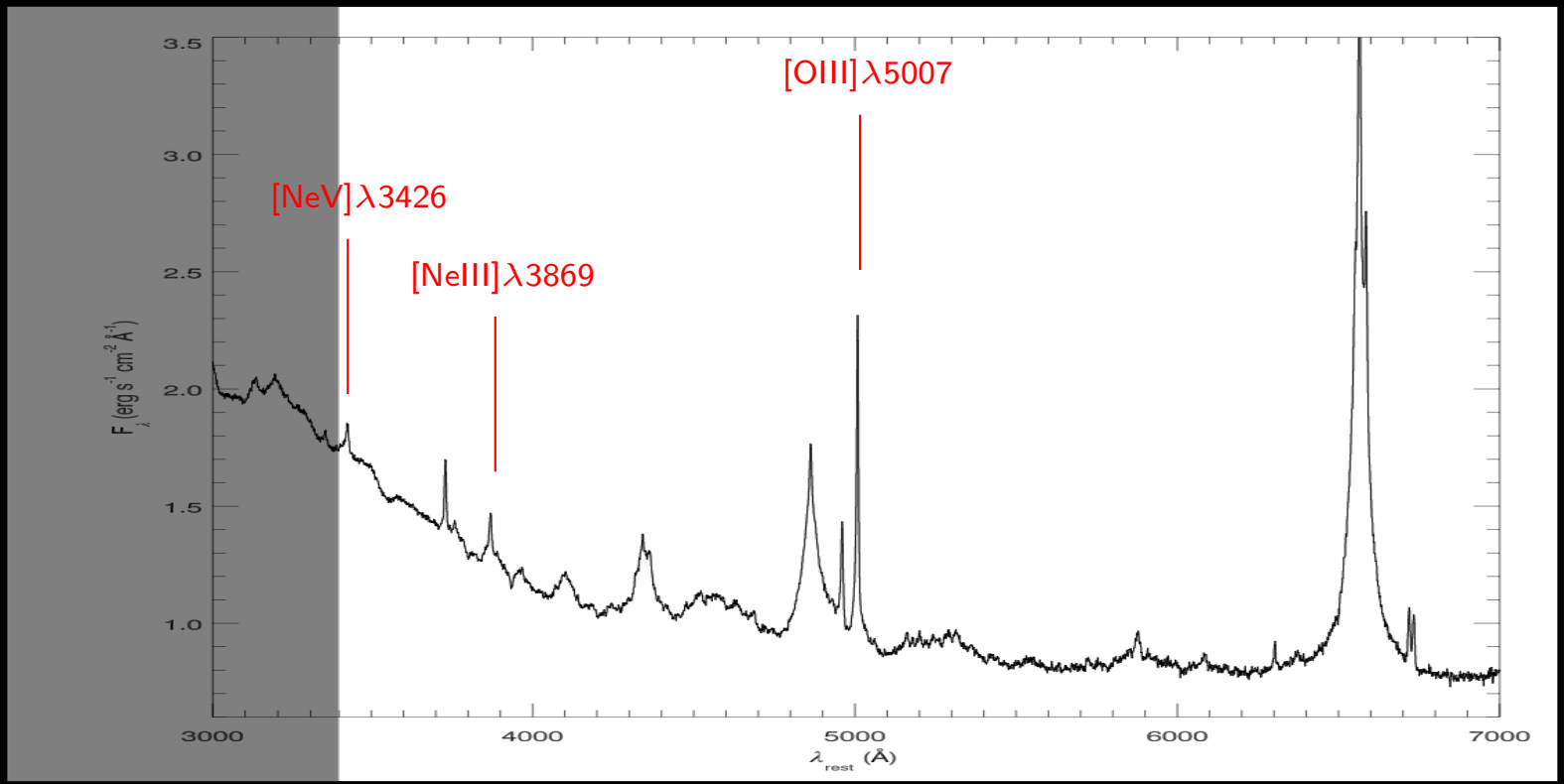


(Barrows et al. 2011)

Utilizing Strong AGN Emission Lines

SDSS filter range: 3800Å–9200Å

Prominent quasar narrow emission lines accessible in SDSS spectra at $z \sim 0.1$

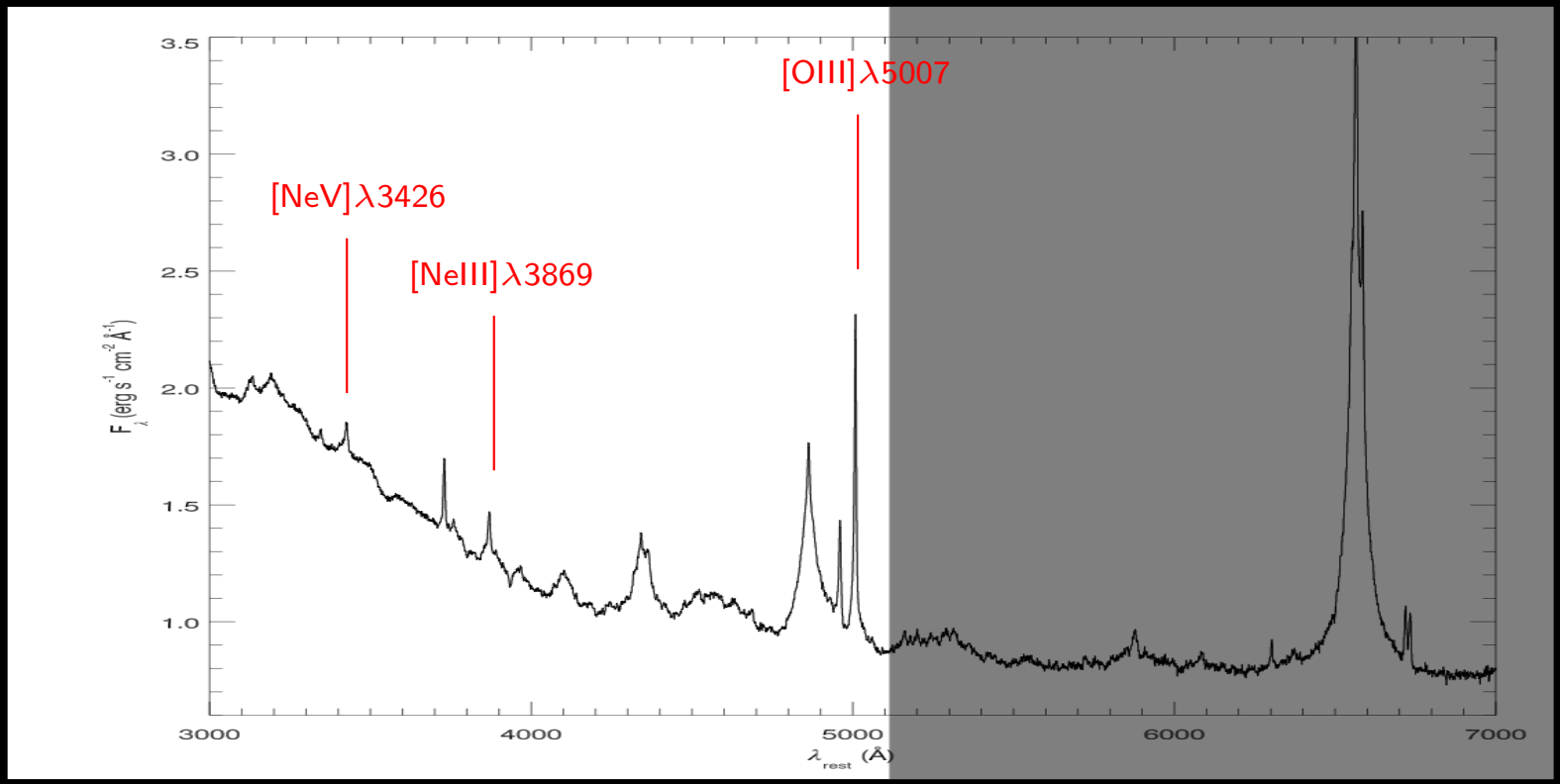


Composite quasar spectrum from Vanden Berk et al., 2001

Utilizing Strong AGN Emission Lines

SDSS filter range: 3800Å–9200Å

Prominent quasar narrow emission lines accessible in SDSS spectra at $z \sim 0.8$

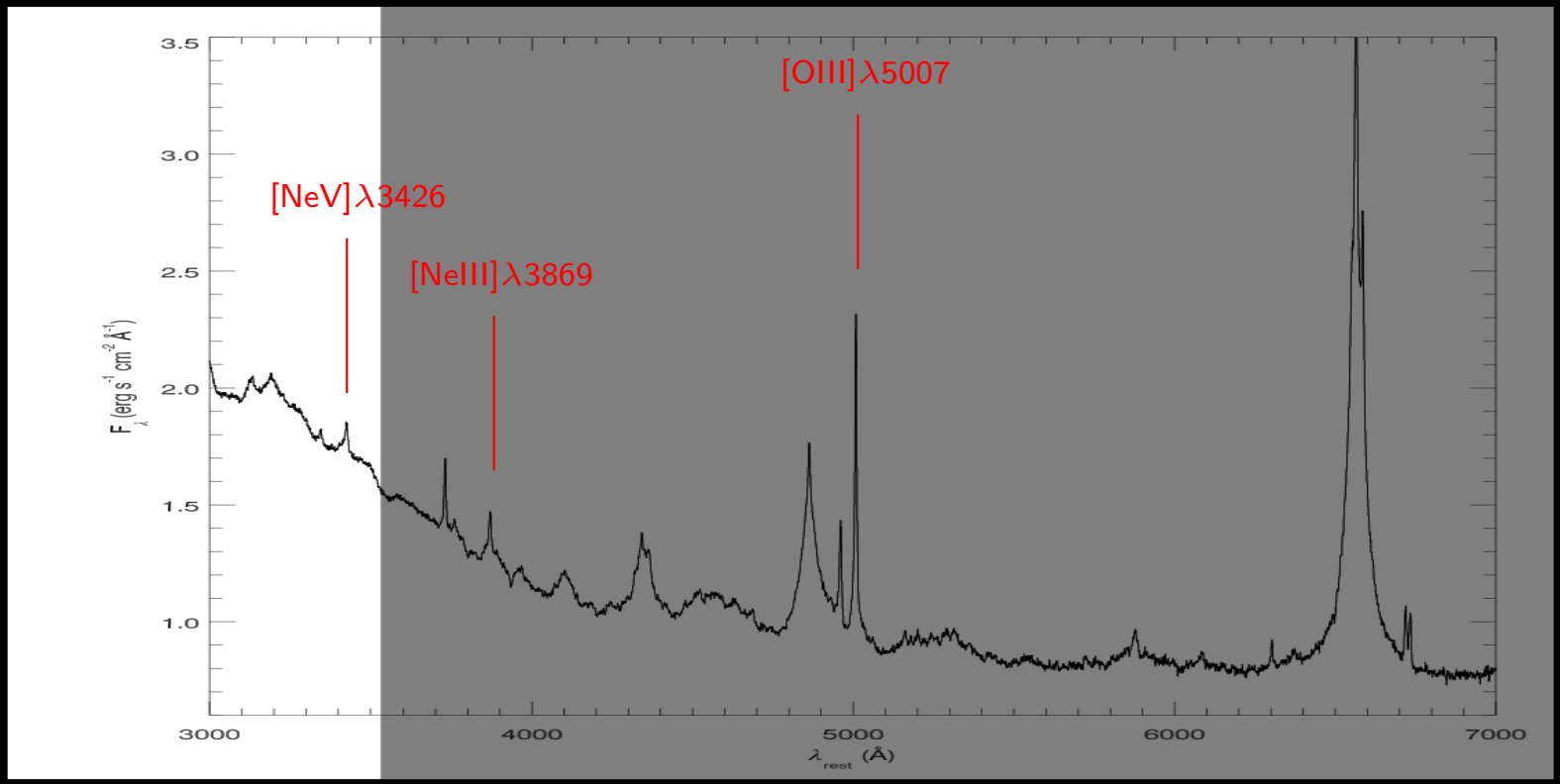


Composite quasar spectrum from Vanden Berk et al., 2001

Utilizing Strong AGN Emission Lines

SDSS filter range: 3800Å–9200Å

Prominent quasar narrow emission lines accessible in SDSS spectra at $z \sim 1.6$



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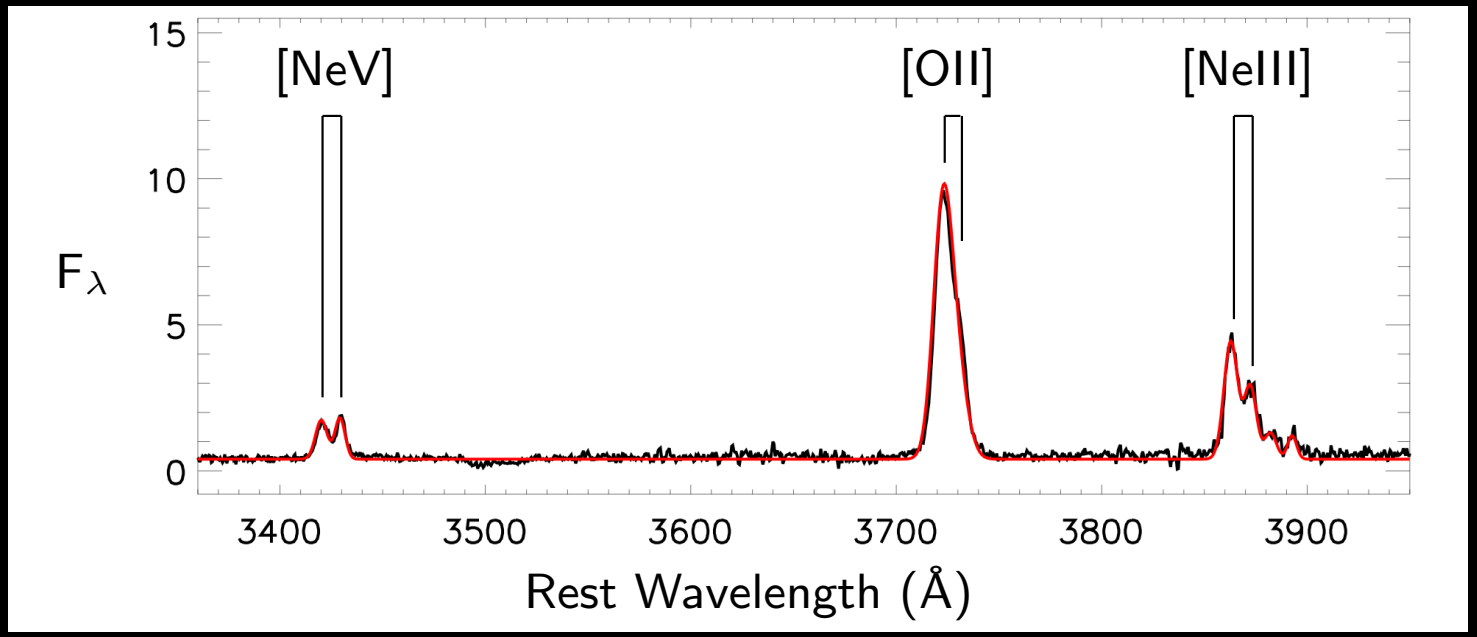
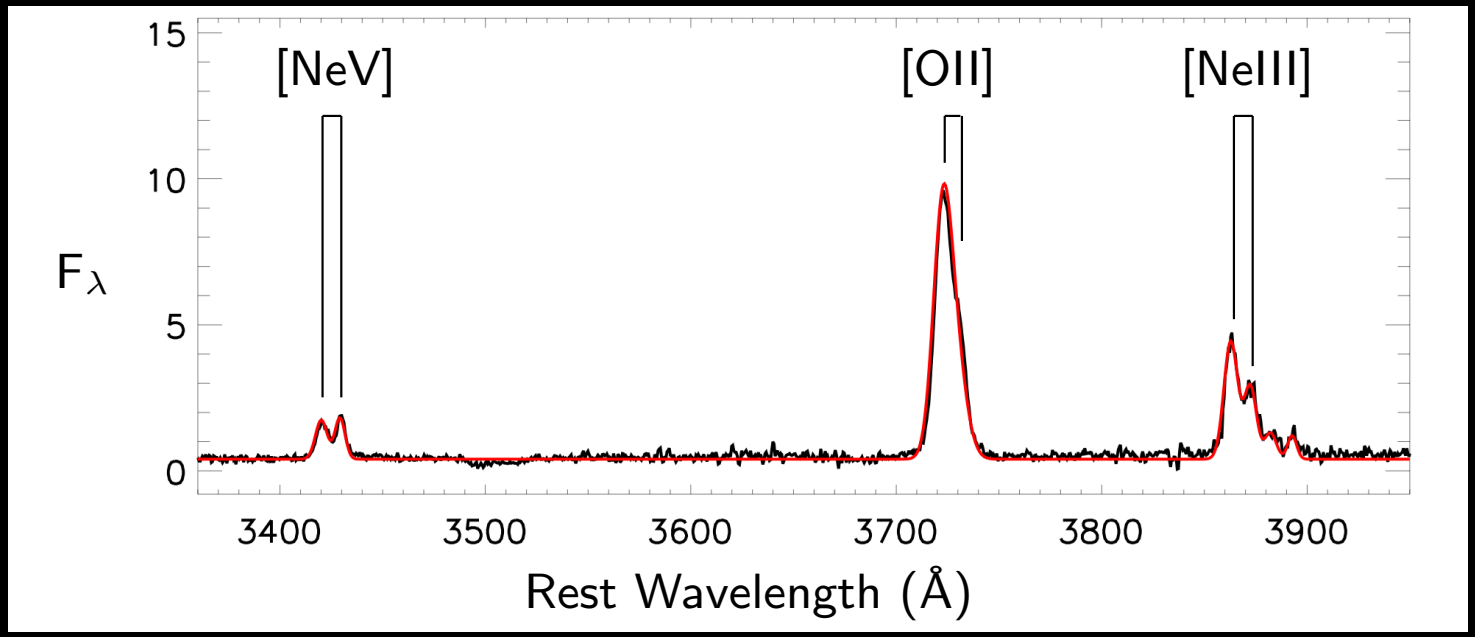
Motivation



A Candidate Dual AGN at $z = 1.175$

(Barrows et al. 2012)

Motivation



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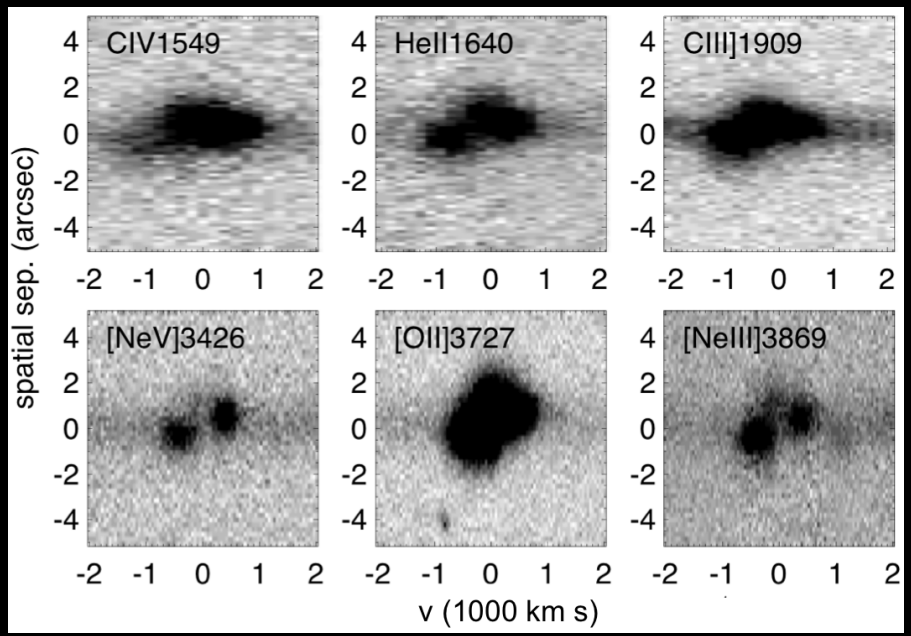


Project Description

Identifying analogs of spectroscopic dual AGN candidates at higher redshifts (Barrows et al., submitted to *ApJ*)

Parent Sample: SDSS DR 7 Quasar Catalog
Redshift cut: $0.8 < z < 1.6$ (35,250)

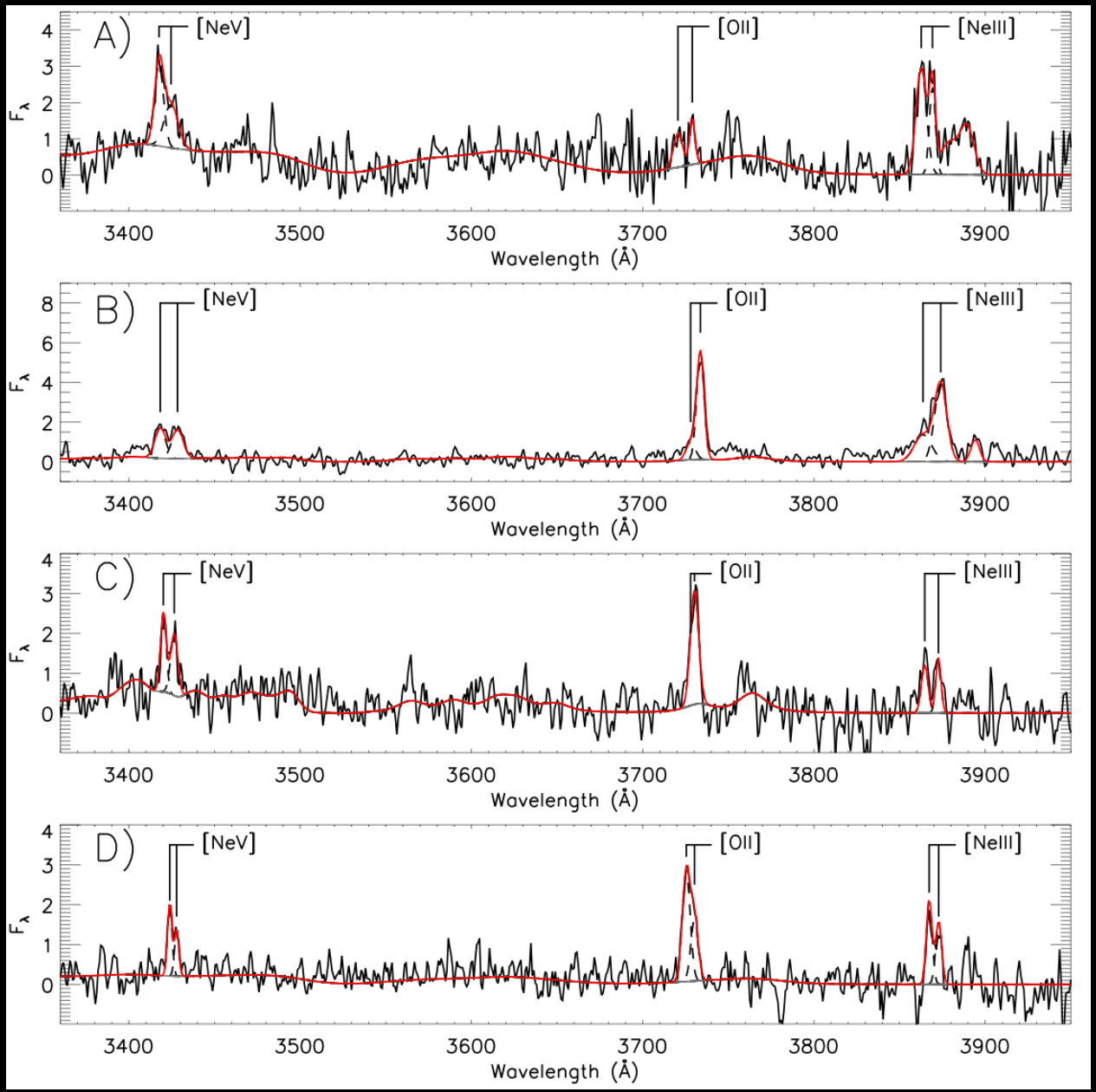
Selection of High-z Sample:

1. Visual identification of sources with double-peaked [NeV] and/or [NeIII]
   $\rightarrow$ 154 sources

2. Spectroscopic modeling of visually-selected sample
   - 2 Gaussians vs 1 Gaussian
   $\rightarrow$ 124 sources

Selection of low-redshift comparison sample
- Type 1 AGN from Smith et al. (2010) with measurable double [NeV]/[NeIII] peaks.
  $\rightarrow$ 42 sources

Examples


A)
[NeV]
[OII]
[NeIII]
B)
[NeV]
[OII]
[NeIII]
C)
[NeV]
[OII]
[NeIII]
D)
[NeV]
[OII]
[NeIII]
F_λ
Wavelength (Å)
3400
3500
3600
3700
3800
3900

Scenarios for a Single AGN

Outflows from AGN

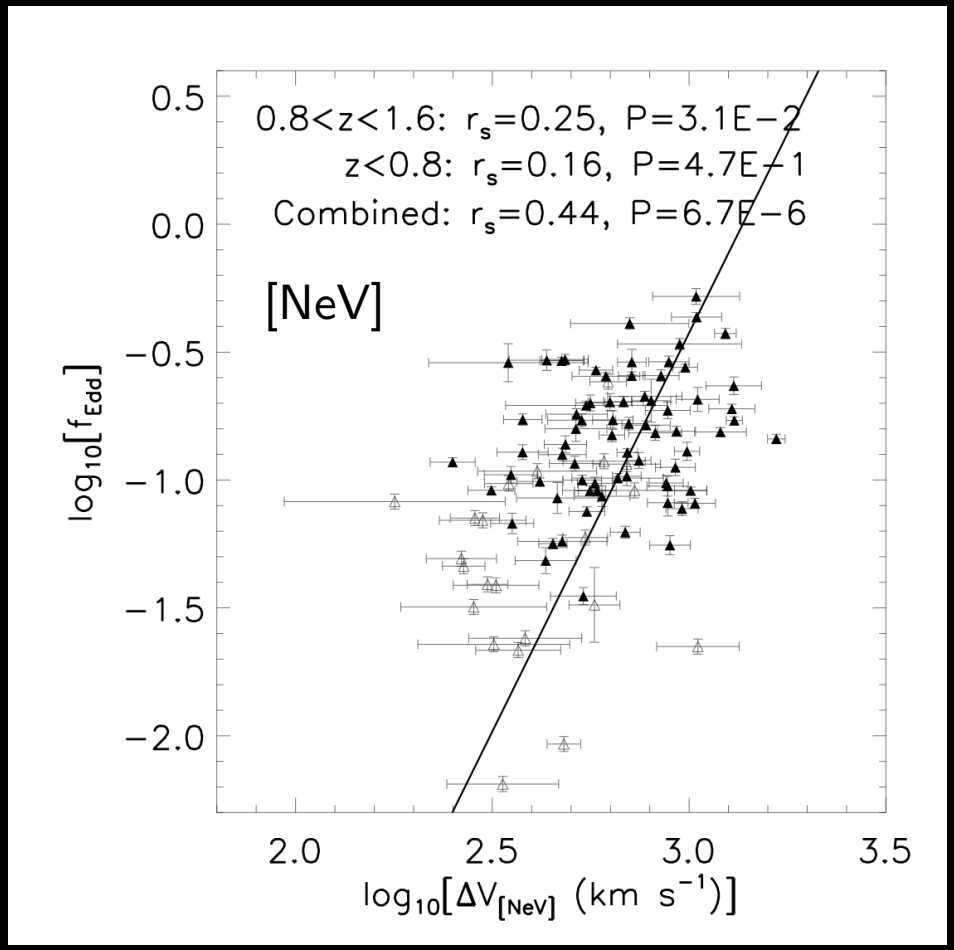
- Driven by the jets of powerful radio quasars
- Driven by radiation pressure in high accretion rate AGN
- Can affect star formation and SMBH growth
- Important in evolutionary models of galaxies (AGN feedback)
- May have been more important at high redshift, when most massive galaxies completed the bulk of their growth

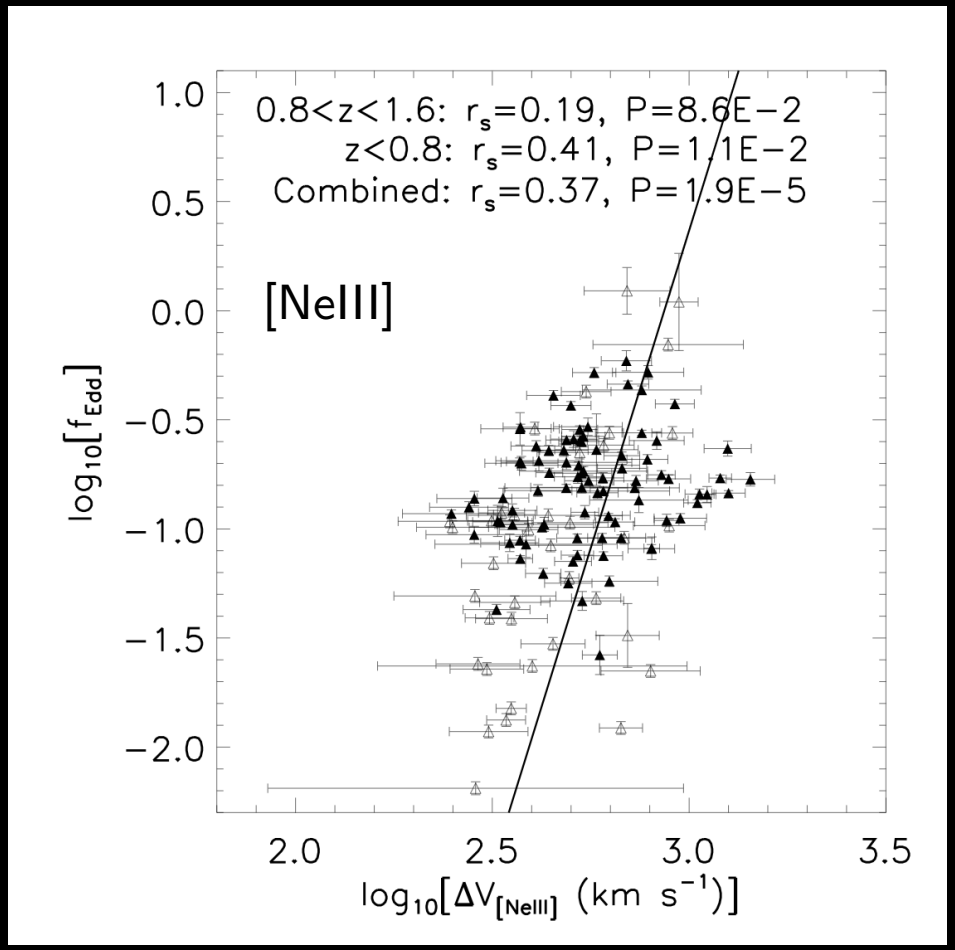
Investigating the Outflow Scenario in our Sample

- Correlations between line properties and quasar properties:

1) ΔV vs L_{Edd}
2) Radio Loudness

Statistical Evidence for Radiatively Driven Outflows





- Connection between Eddington ratio and line-splitting
- Stronger for [NeV] than for [NeIII]

  $\rightarrow$ Radiatively driven outflows?

Radio Loud Fraction

Radio loudness: $\mathcal{R} = L_{\nu,5\mathrm{GHz}}/L_{\nu,250\mathrm{nm}}$

Radio powers from FIRST (93% of sample in FIRST footprint)

Criterion:
$\mathcal{R} \geq 10 \rightarrow$ Radio Loud
$\mathcal{R} < 10 \rightarrow$ Radio Quiet

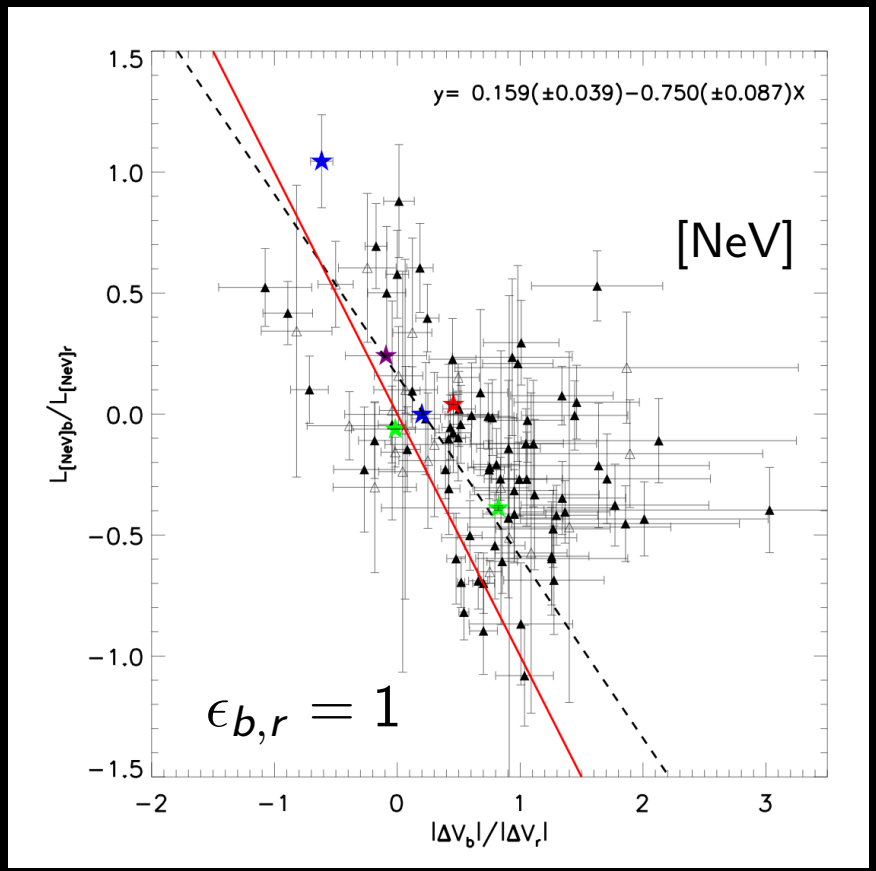
$f_{RL} = 10\%$ in the parent sample (SDSS quasars at $0.8 < z < 1.6$)
$f_{RL} = 22\%$ in our double-peaked [NeV]/[NeIII] sample

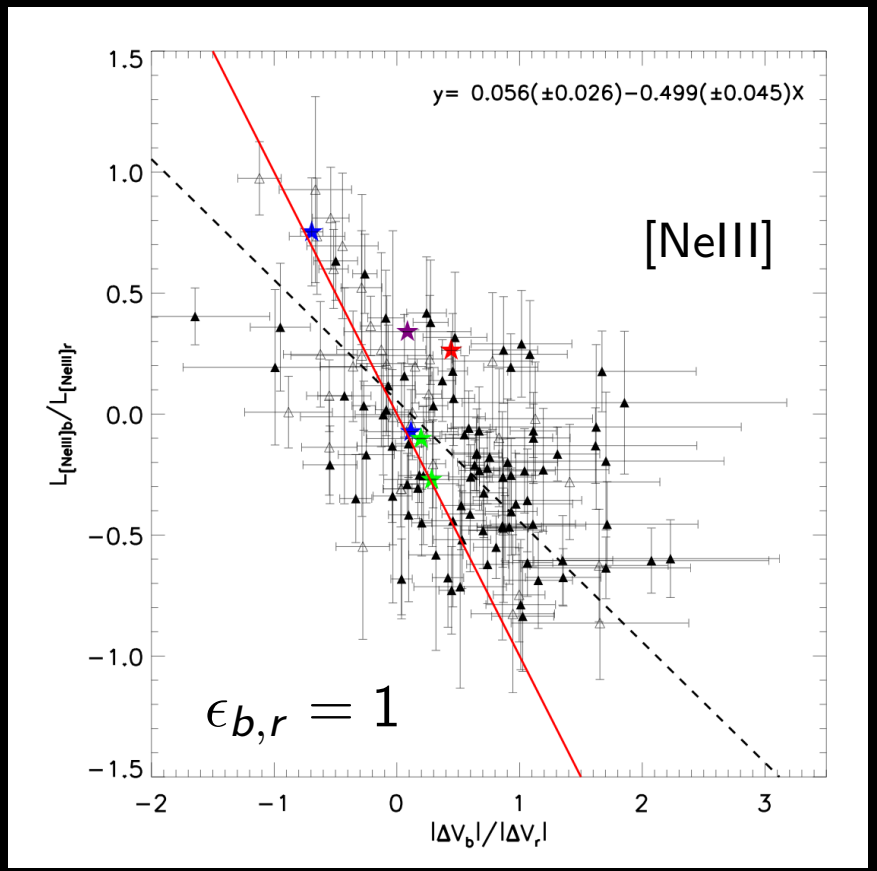
Preferential selection of radio loud sources suggest the origin of the line-splitting may be related to radio jets for some of our sample.

$\rightarrow$ Jet-driven outflows?

Dynamical Argument for Dual AGN in the Sample

Keplerian Orbit: $\frac{M_1}{M_2} = \frac{V_2}{V_1} \rightarrow \frac{L_b}{L_r} = \epsilon_{b,r} \frac{\Delta\lambda_r}{\Delta\lambda_b}$ (Wang et al., 2009)





Conclusions for Candidate Dual AGN at $0.8 < z < 1.6$

- Line splittings correlated with Eddington ratios
- Stronger correlation for [NeV] than for [NeIII]

  $\rightarrow$ Suggests the presence of radiatively driven outflows

- A significant fraction ($\sim 22\%$) are radio loud

  $\rightarrow$ Radio jets may contribute to line-splitting in some sources

- Bias toward large ΔVs

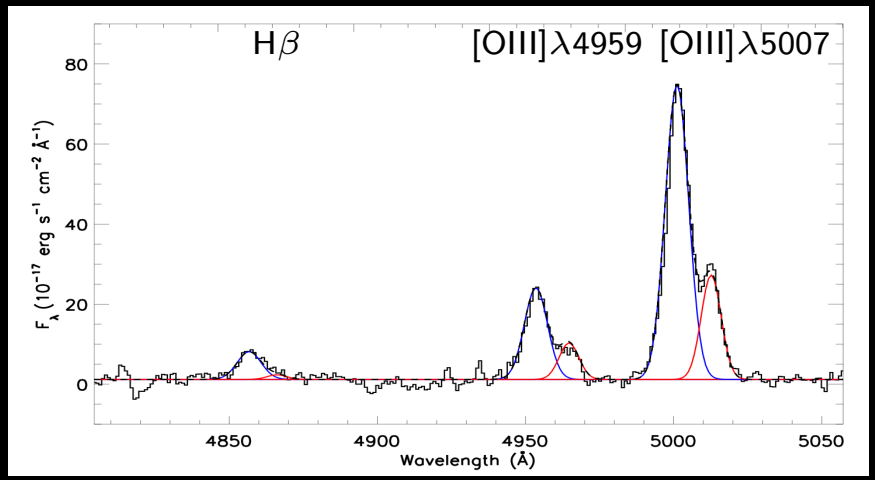
  $\rightarrow$ High velocity outflows, or dual AGN at sub-kpc separations

- Correlation between $\frac{L_b}{L_r}$ and $\epsilon_{b,r} \frac{\Delta\lambda_r}{\Delta\lambda_b}$

  $\rightarrow$ dynamical evidence for dual AGN in the sample

Binary Supermassive Black Hole Candidates

Dual AGN:
Double-peaked narrow line component



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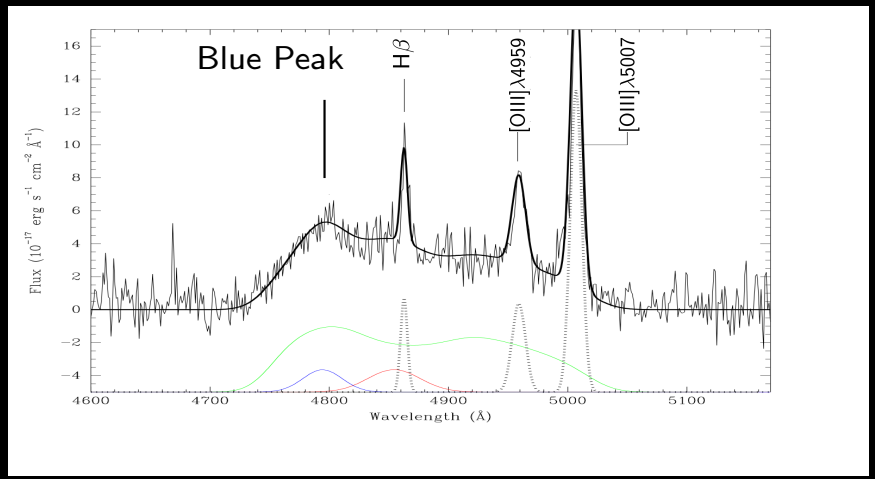
Binary SMBH:
Double-peaked broad line component



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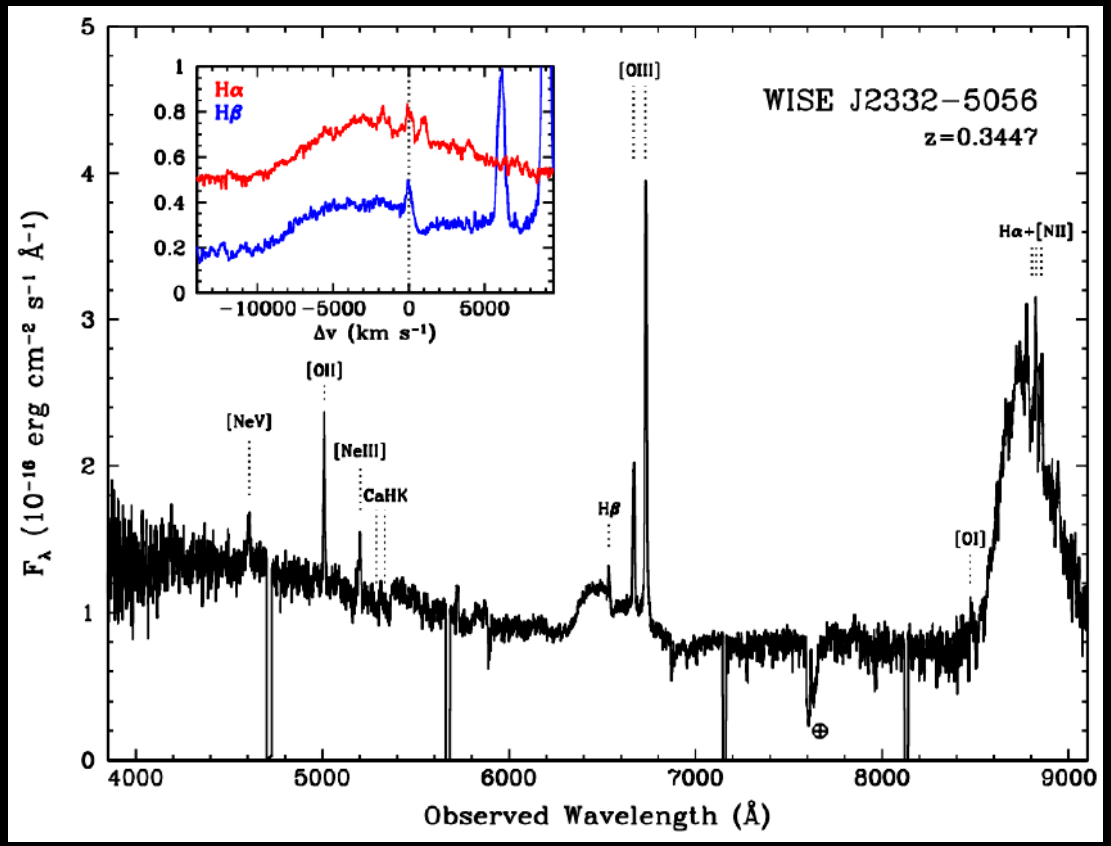
Binary Supermassive Black Hole Candidates

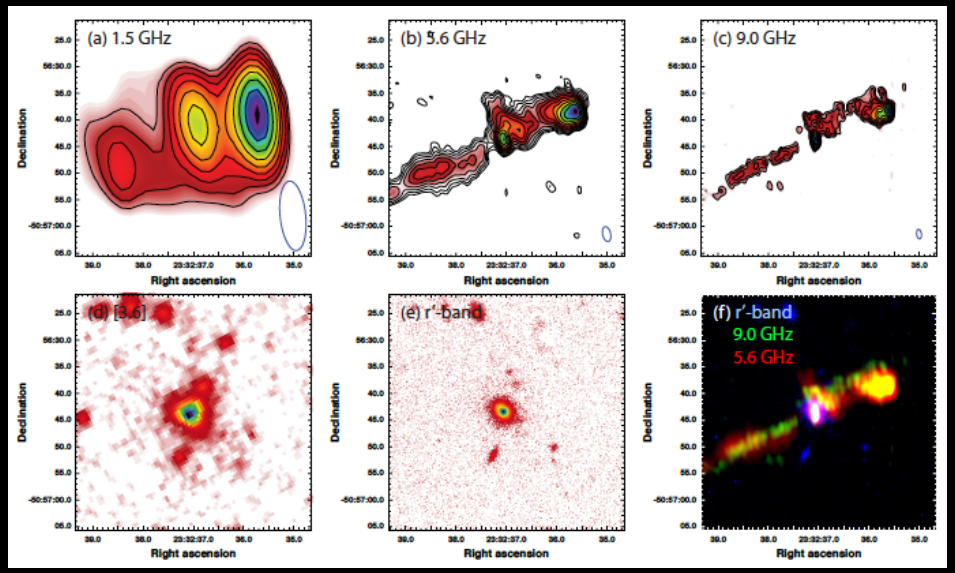
"An Extreme Double-Peaked Broad-Lined AGN with Spiral-Shaped Radio Morphology" (Tsai et al., *in prep*)

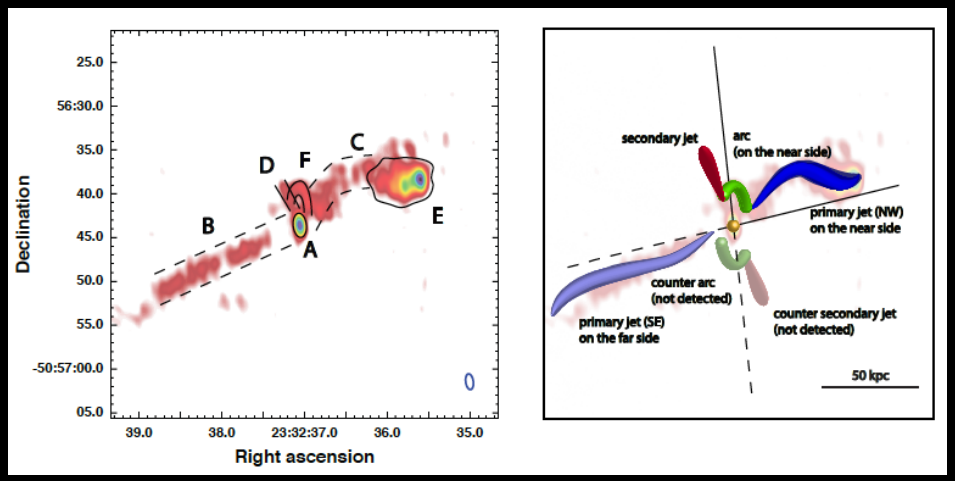


Optical spectrum from GMOS-S revealing a complicated broad line morphology

- Broad line offset of $\sim$ 3800 km s^{-1}
- Broad blue peak
- Possible redshifted absorption feature
- Optical-NIR photometry variability over 3-20 yrs
- Complex radio jet structure

Radio Morphology



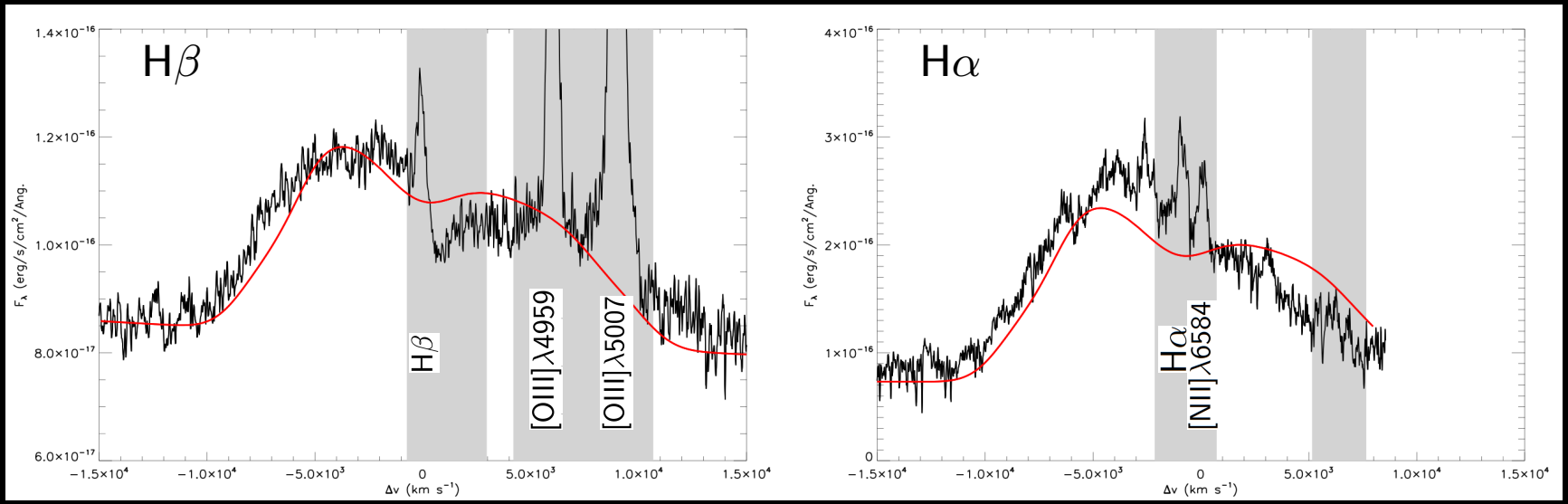


Radio Continuum from ATCA

- Primary jet with FRII hotspot
- 'Zig-zag' pattern in NW primary jet
- Faint, linear structure nearly perpendicular to the primary jet
- Curved, arc-like structure

Suggests two physically perpendicular sets of jets

Broad Emission Line Modelling



Top: Elliptical accretion disk model ($e = 0.6$) from Eracleous et al., (1995)

Bottom: Circular disk model from Chen and Halpern (1989) plus a broad Gaussian

Conclusions for Extreme Double-Peaked Emitter

Scenario for a Single SMBH:

- Single SMBH with a thin, line emitting accretion disk, inclined by 32° from face-on
- Requires external illumination
- Complex asymmetry or non-uniformity in the disk accounting for the excess blue peak emission
- Fails to explain the complicated radio morphology

Scenario for a Binary SMBH

- Secondary, accreting SMBH generates the excess blue peak emission
- Disk profile arises from the primary SMBH's accretion disk
- Both AGN generate radio jets

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