

Farris et al. (2014)

The ongoing hunt for supermassive black hole binaries



Jessie Runnoe

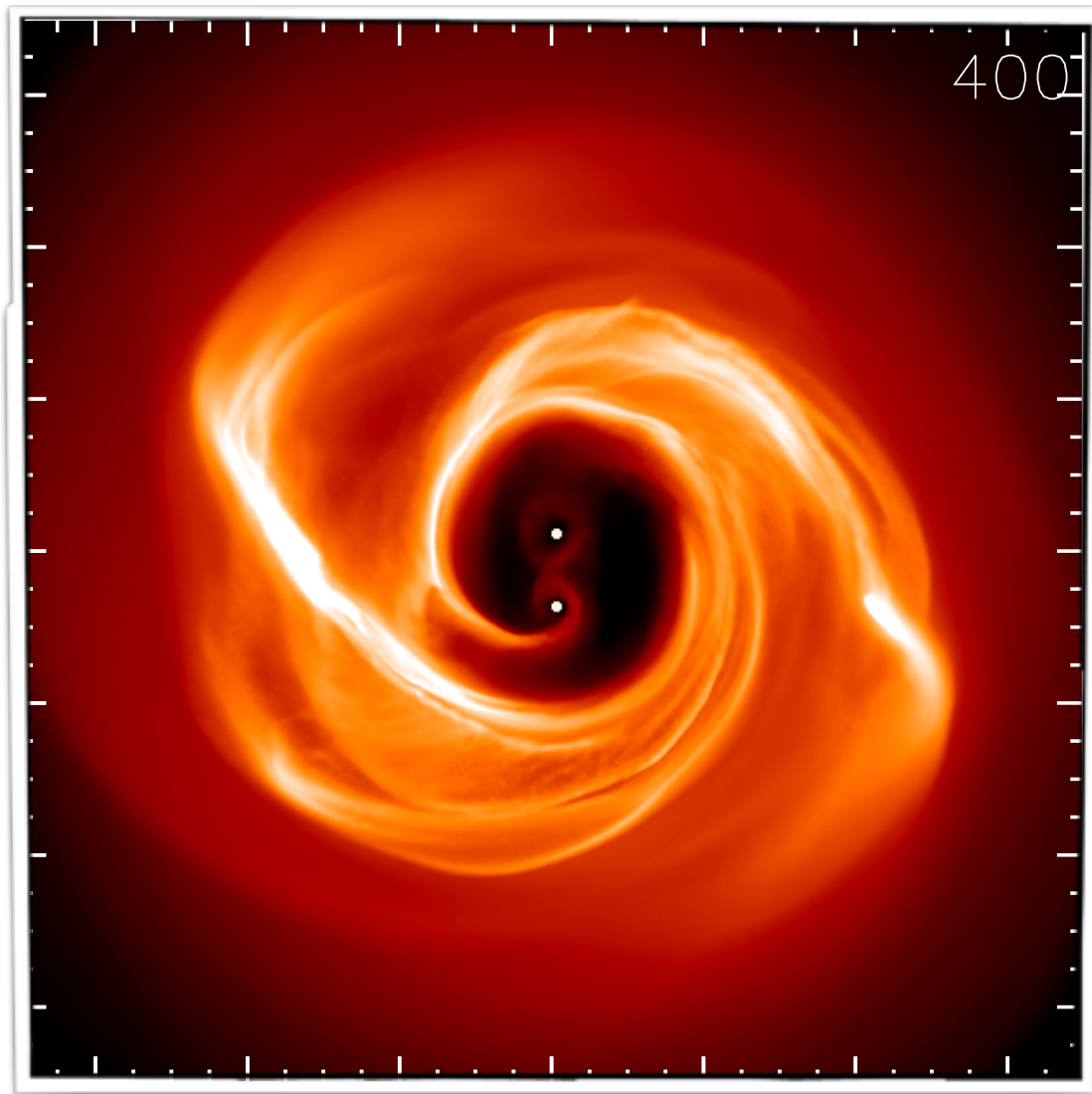
Black Holes in Dense Star Clusters
January 17-22, 2015 - Aspen Center For Physics

Collaborators: **Gavin Mathes**, Michael Eracleous, Todd Boroson,
Jules Halpern, Steinn Sigurðsson, Tamara Bogdanović, **Alison Pennell**

PENNSYLVANIA
SPACE GRANT
CONSORTIUM

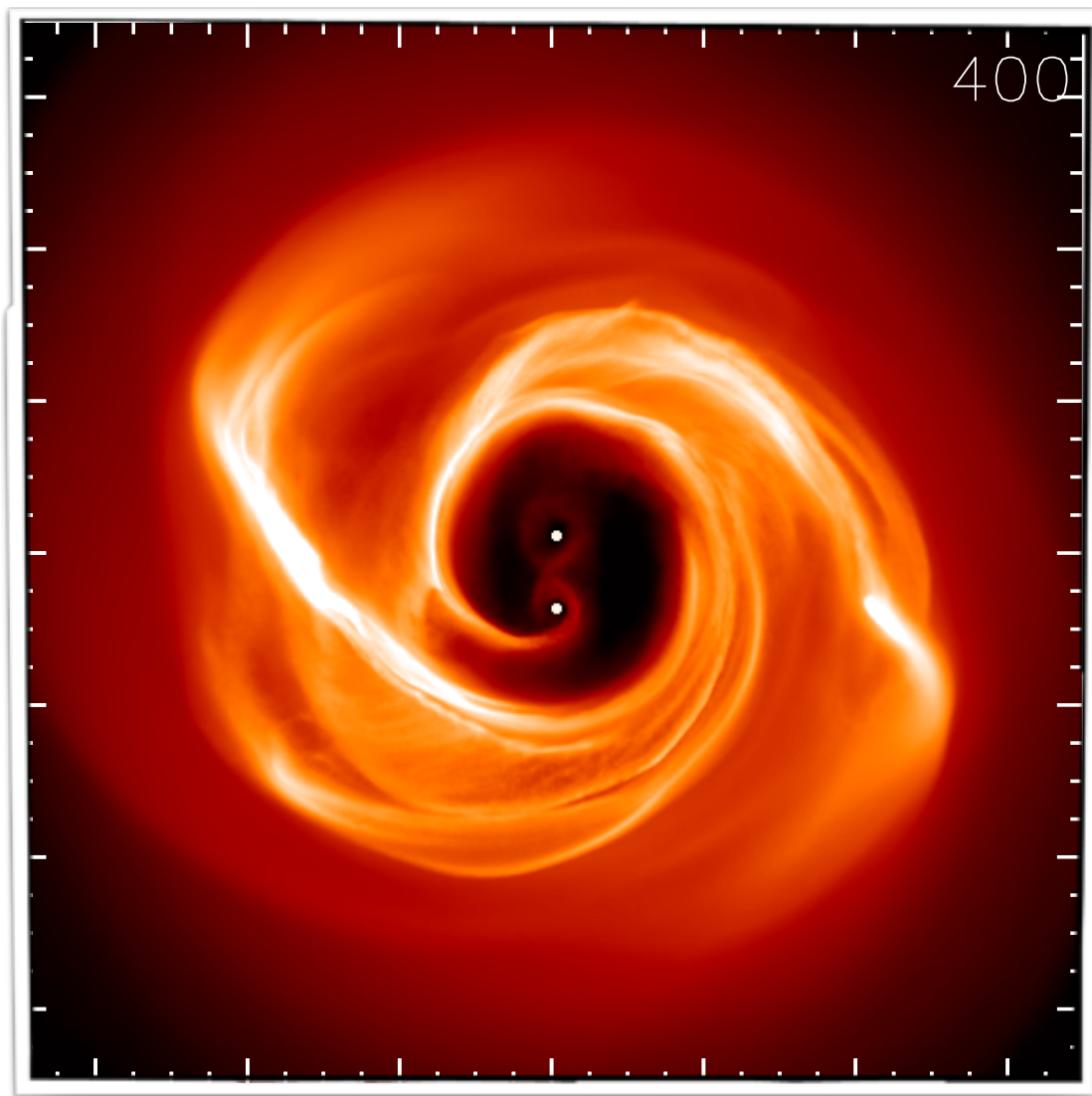


The hypothesis: two black holes in a disk

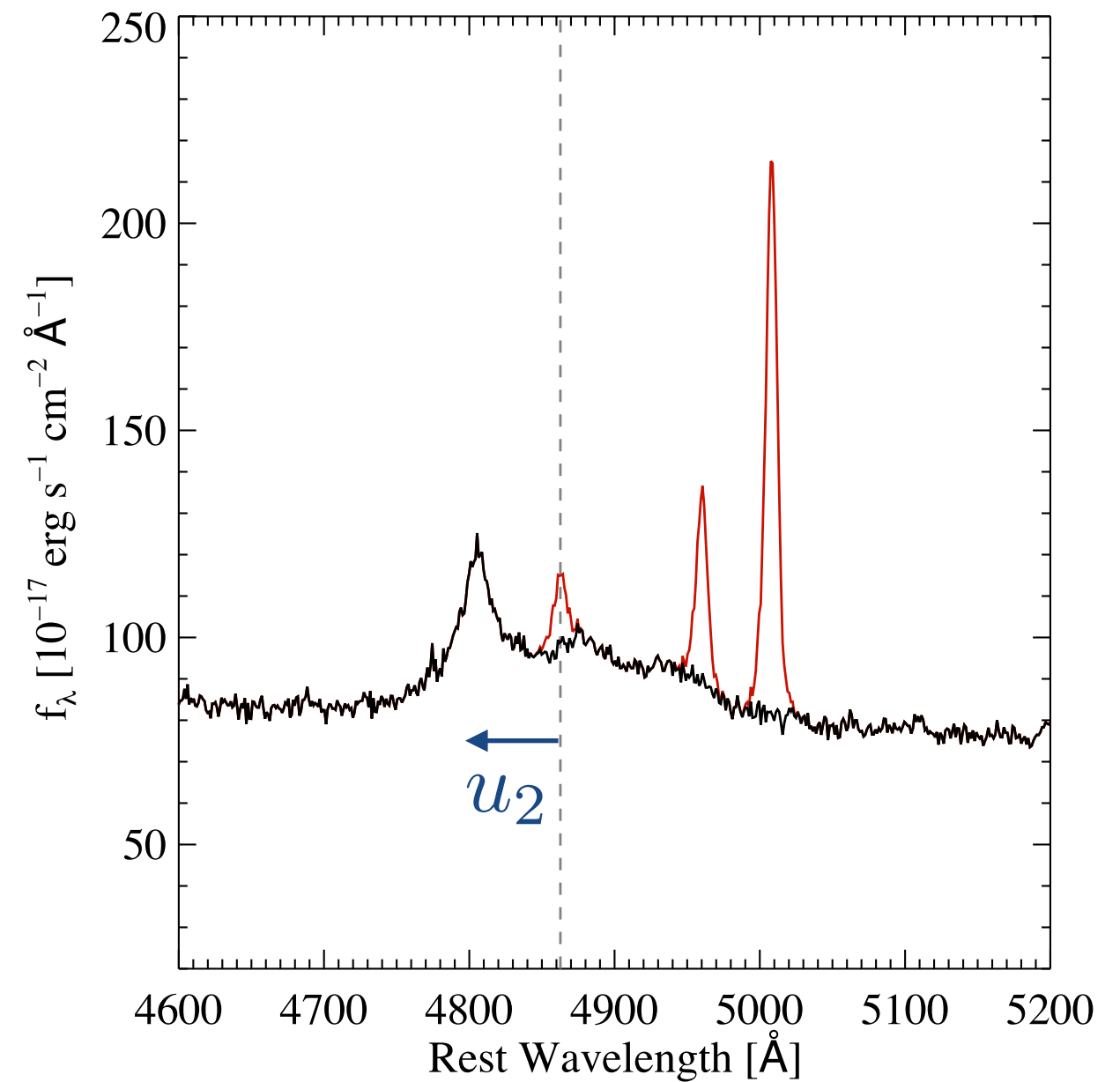


Cuadra et al. (2009)

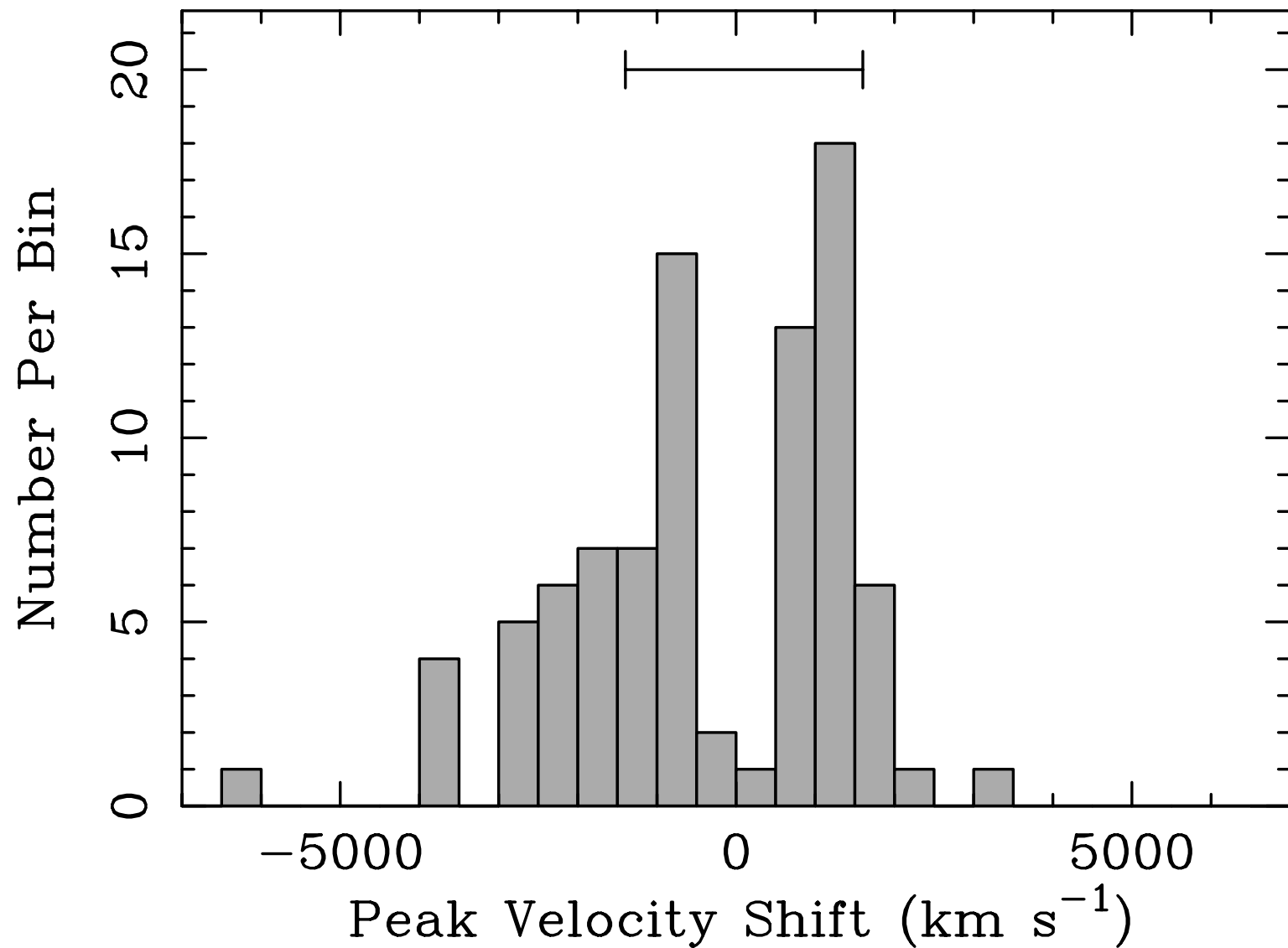
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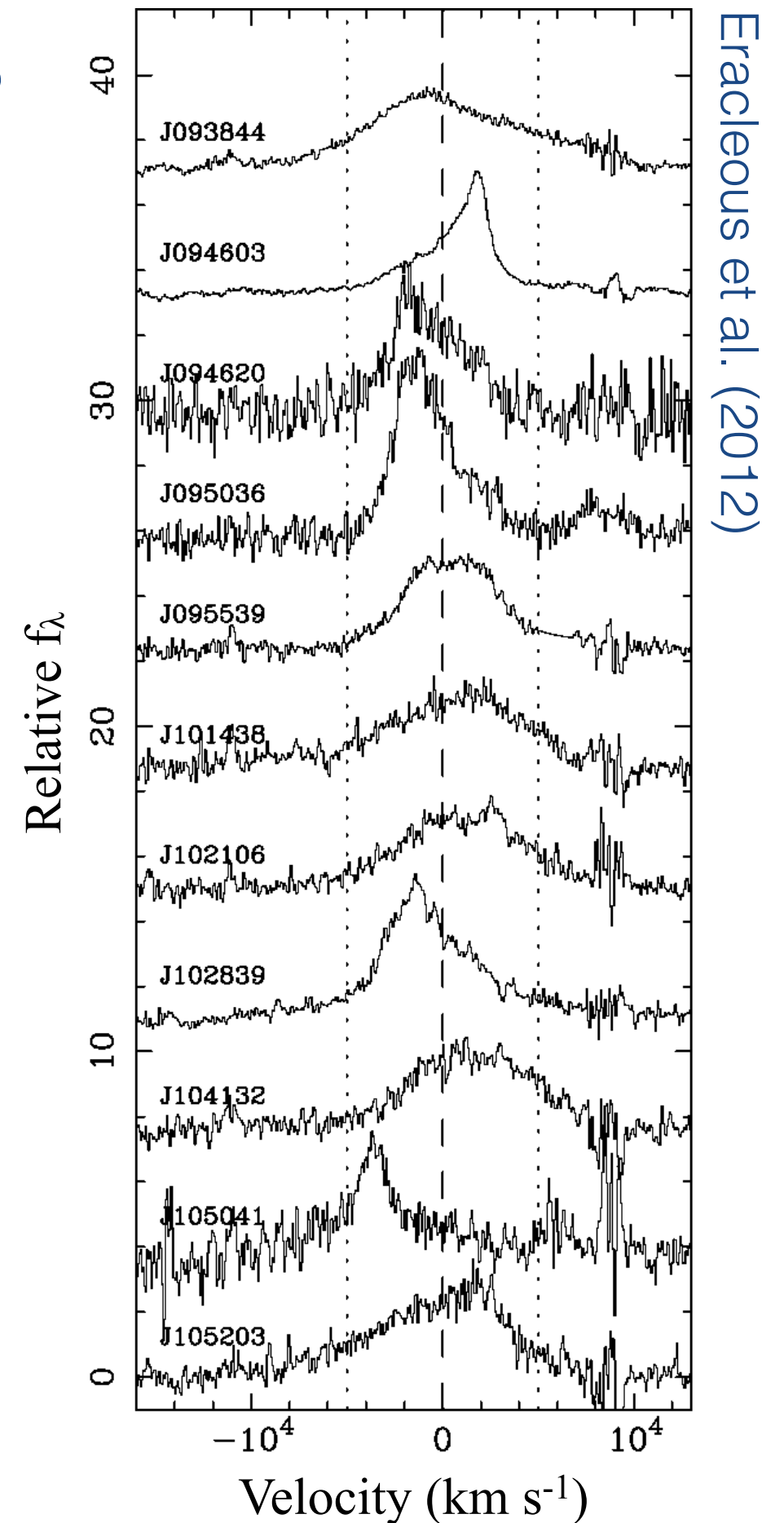
Cuadra et al. (2009)



The binary candidates



- 88 Type I active galactic nuclei
- $0.1 < z < 0.7$



Eracleous et al. (2012)

Project outline

- Continue spectroscopic monitoring observations
 - Measure velocity variations
 - Check for monotonic velocity changes
- Compare spectral variability properties to regular quasars
 - Ensemble flux variability
 - Profile variability
- Optical imaging
 - Look for galaxy interactions.
- Radio imaging
- Simulations of the population of binary properties
- Spectroscopic test for perturbed accretion disks
 - Involves comparison of Balmer and Lyman profiles

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Spectroscopic monitoring campaign

- Multiple follow-up observations
Dec 2009 - Sep 2014

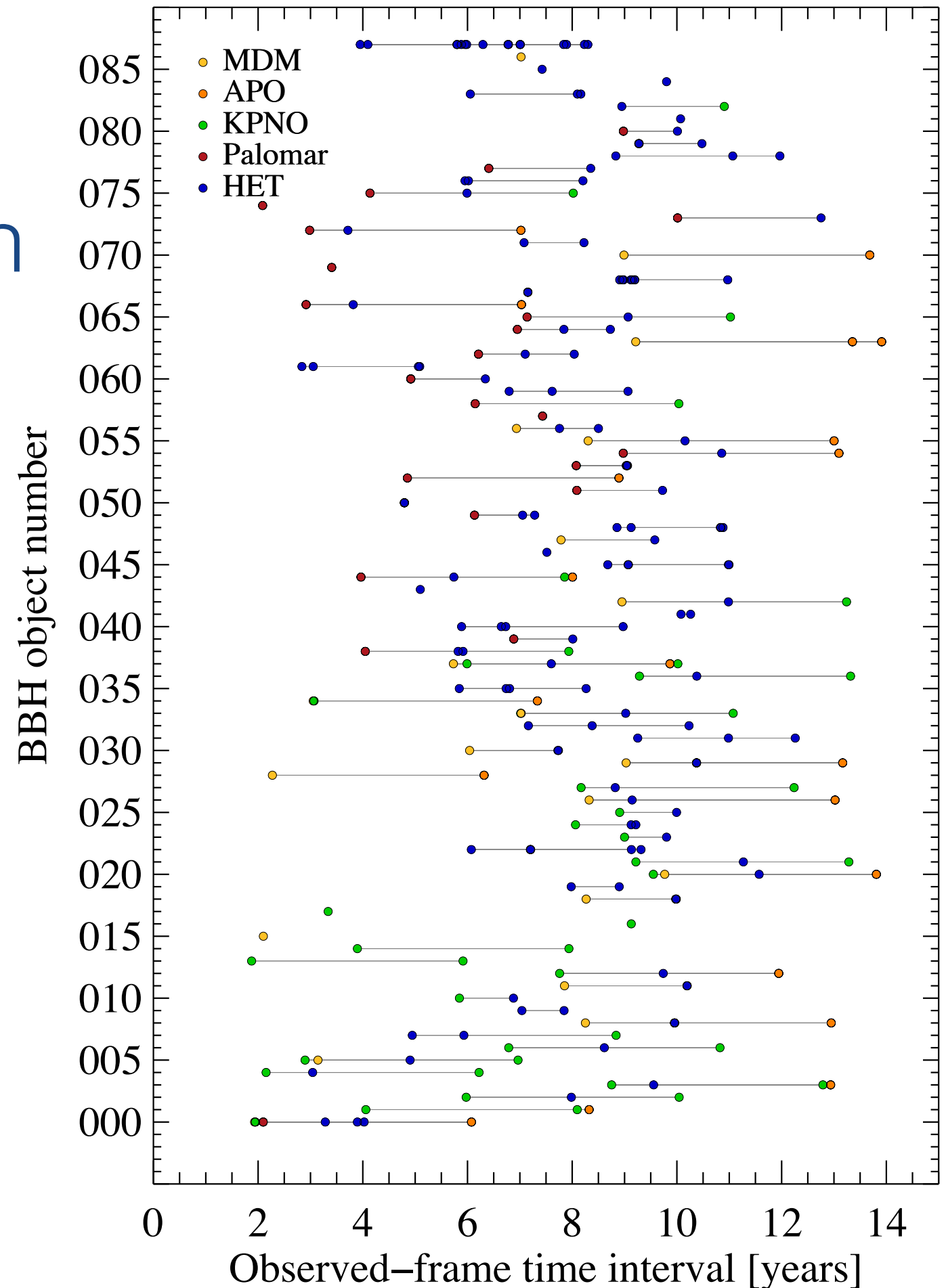
MDM 2.4m Hiltner

APO ARC 3.5m

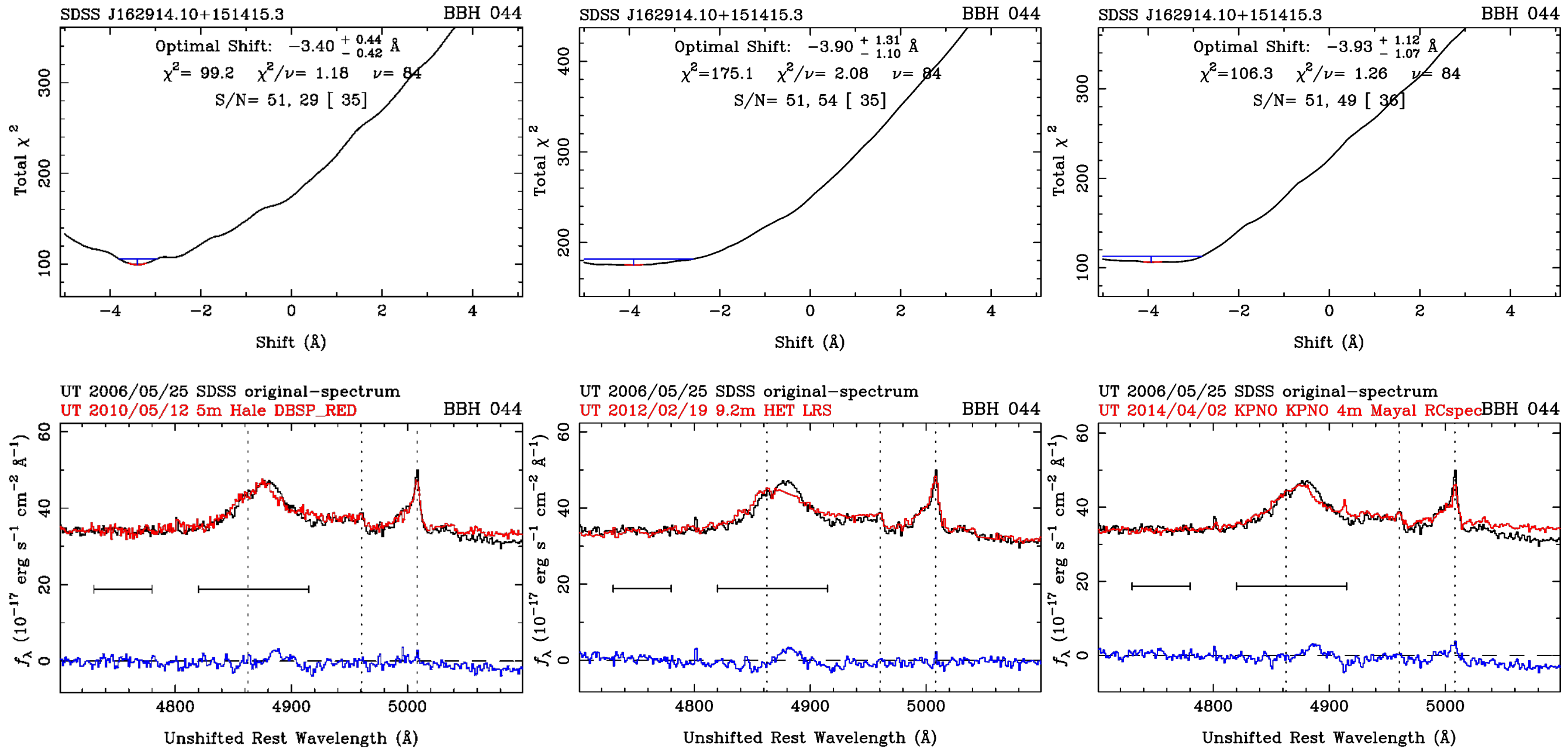
KPNO 4m Mayall

Palomar 5m Hale

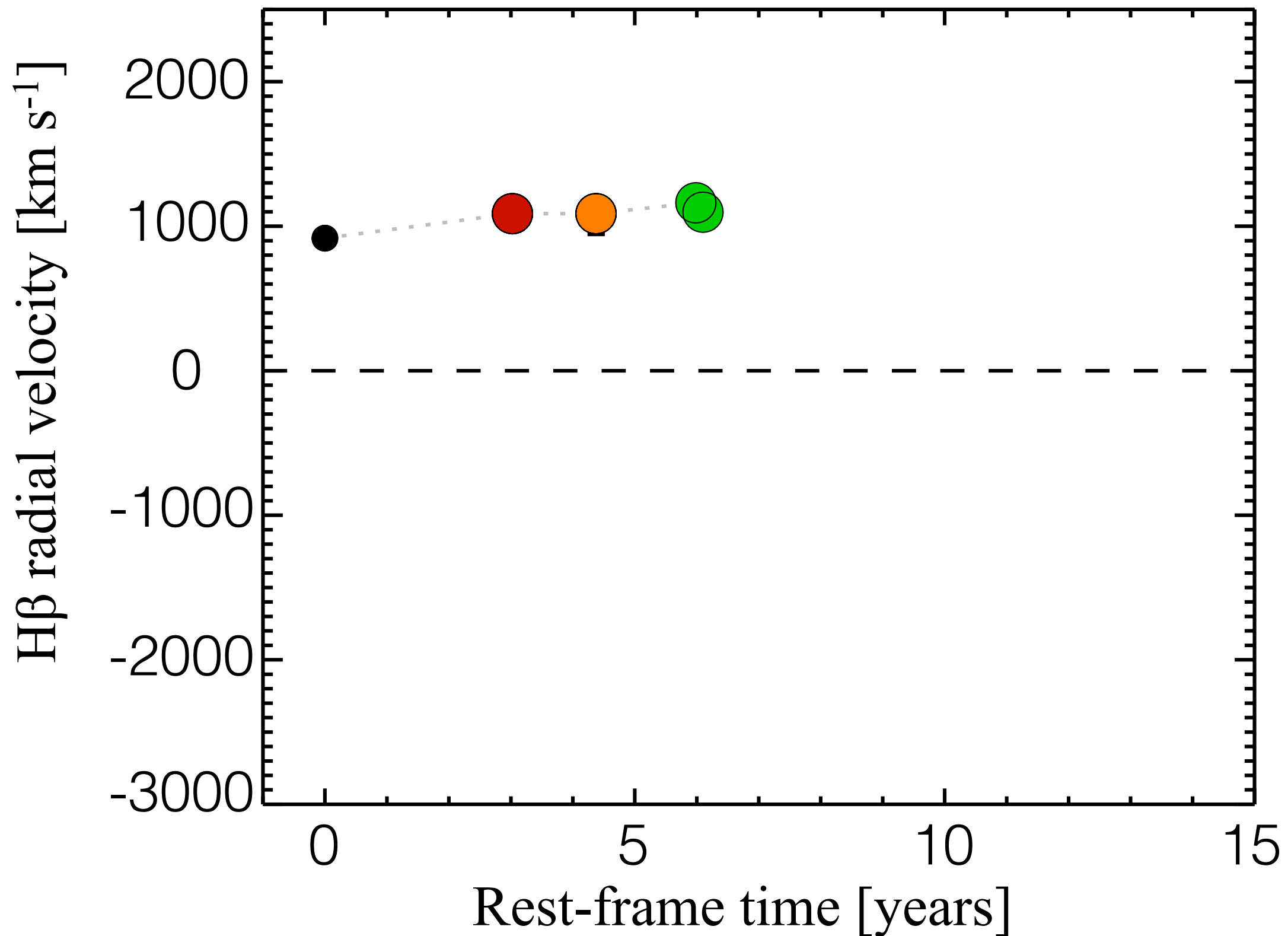
9.2m Hobby-Eberly



Shifts via cross-correlation analysis



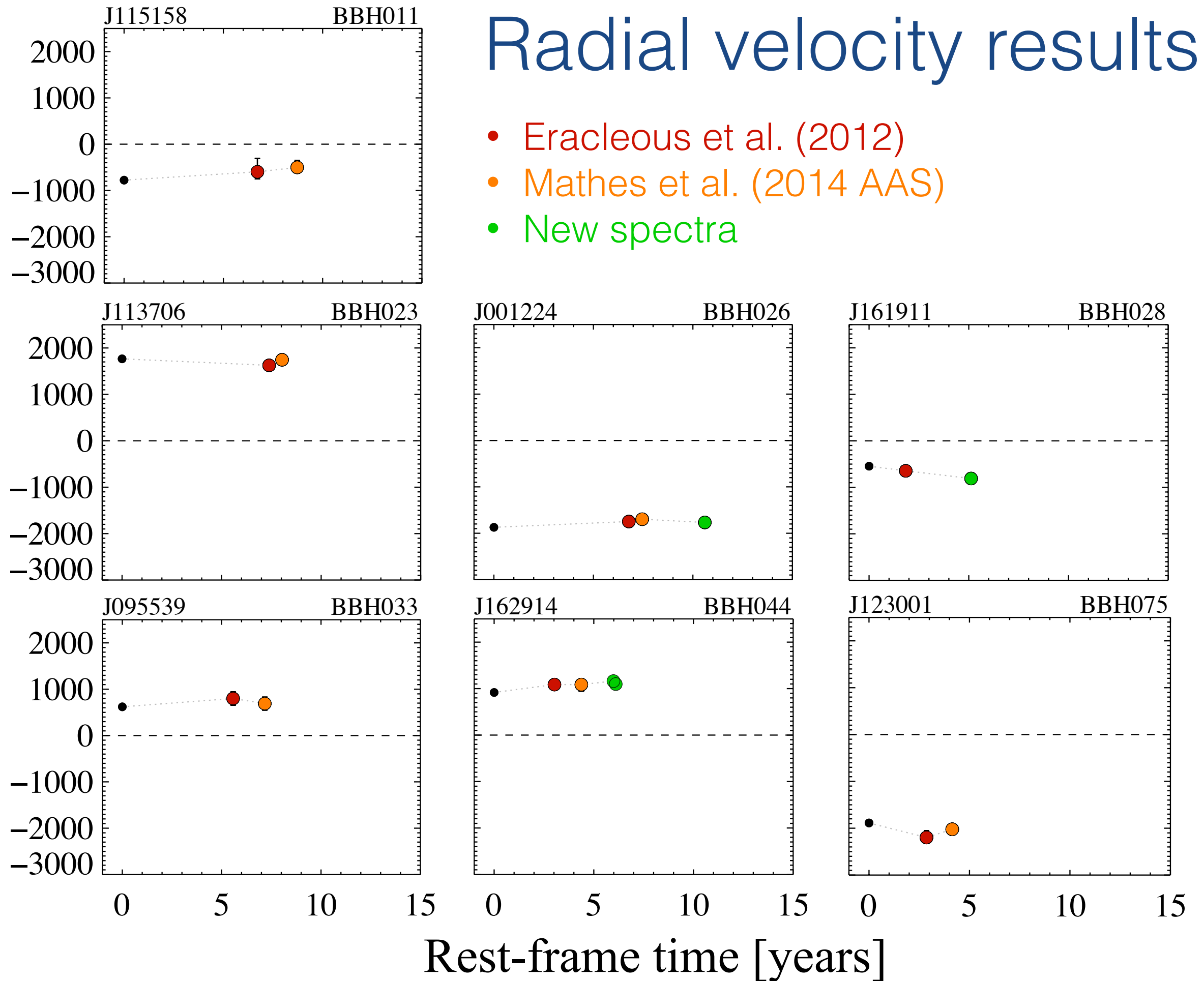
The radial velocity curve



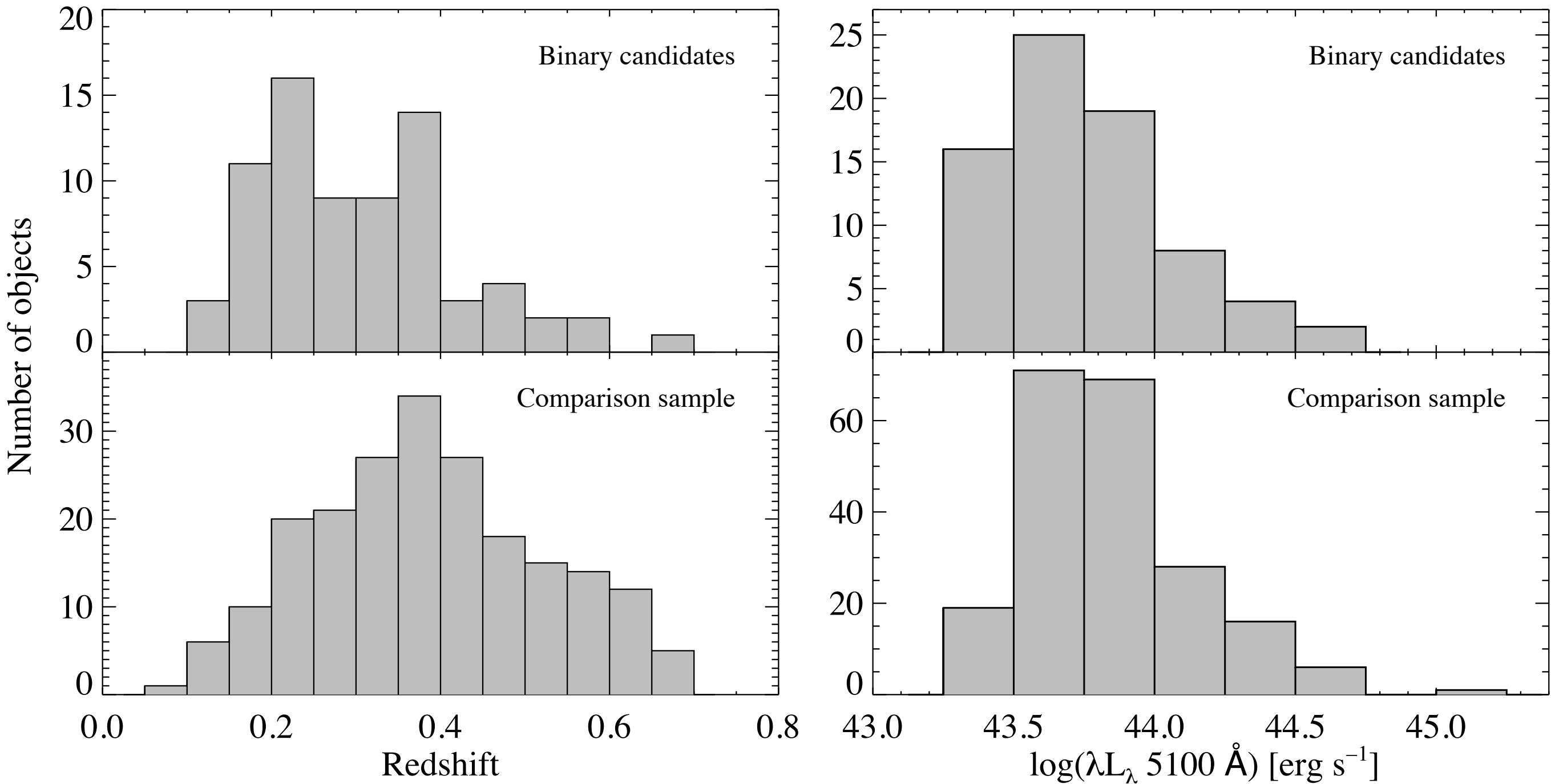
Radial velocity results

- Eracleous et al. (2012)
- Mathes et al. (2014 AAS)
- New spectra

H β radial velocity [km s⁻¹]

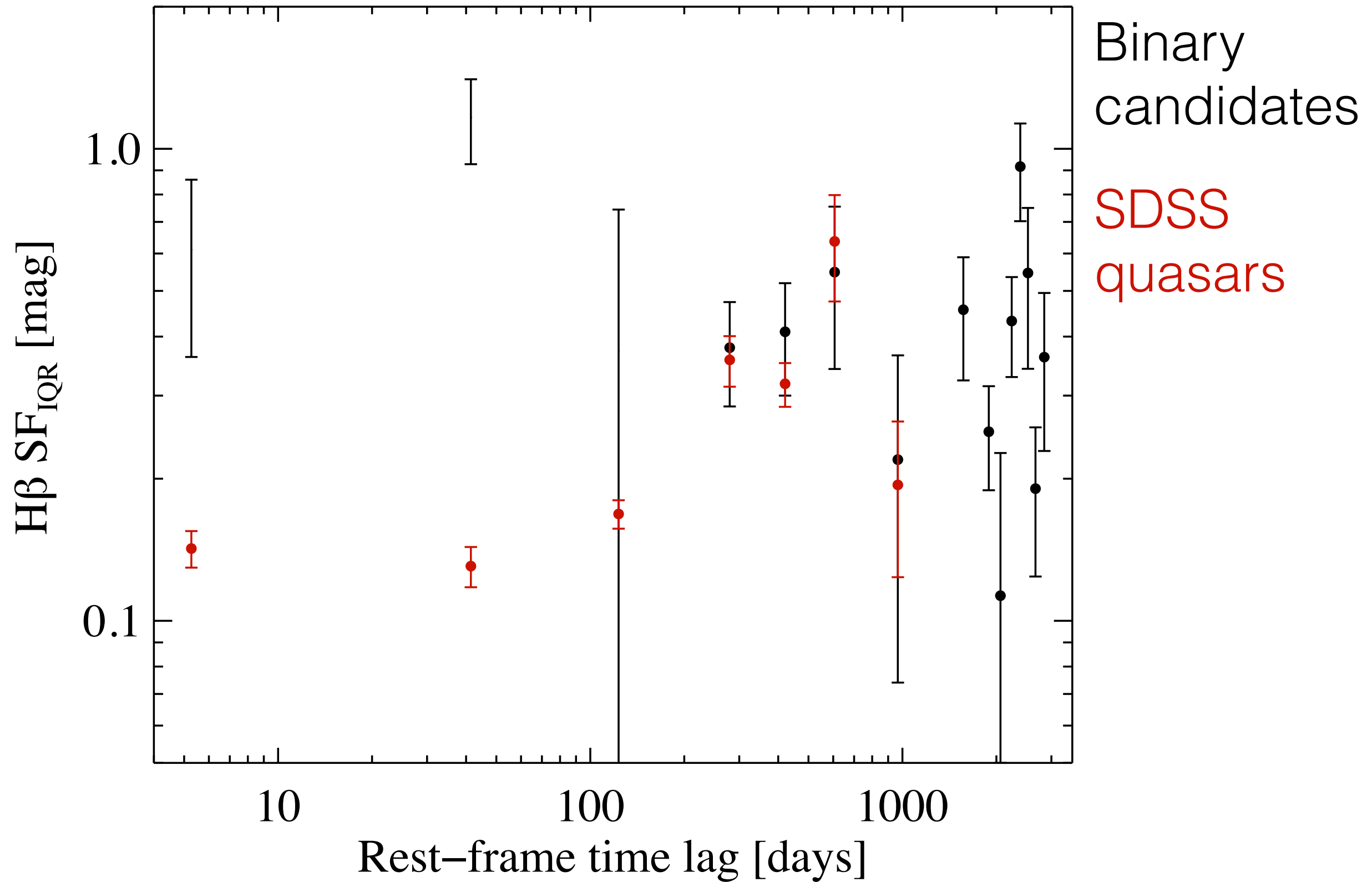


A comparison sample of regular quasars



- 211 Type I active galactic nuclei
- multiple epochs of spectroscopy in SDSS

H β flux variability

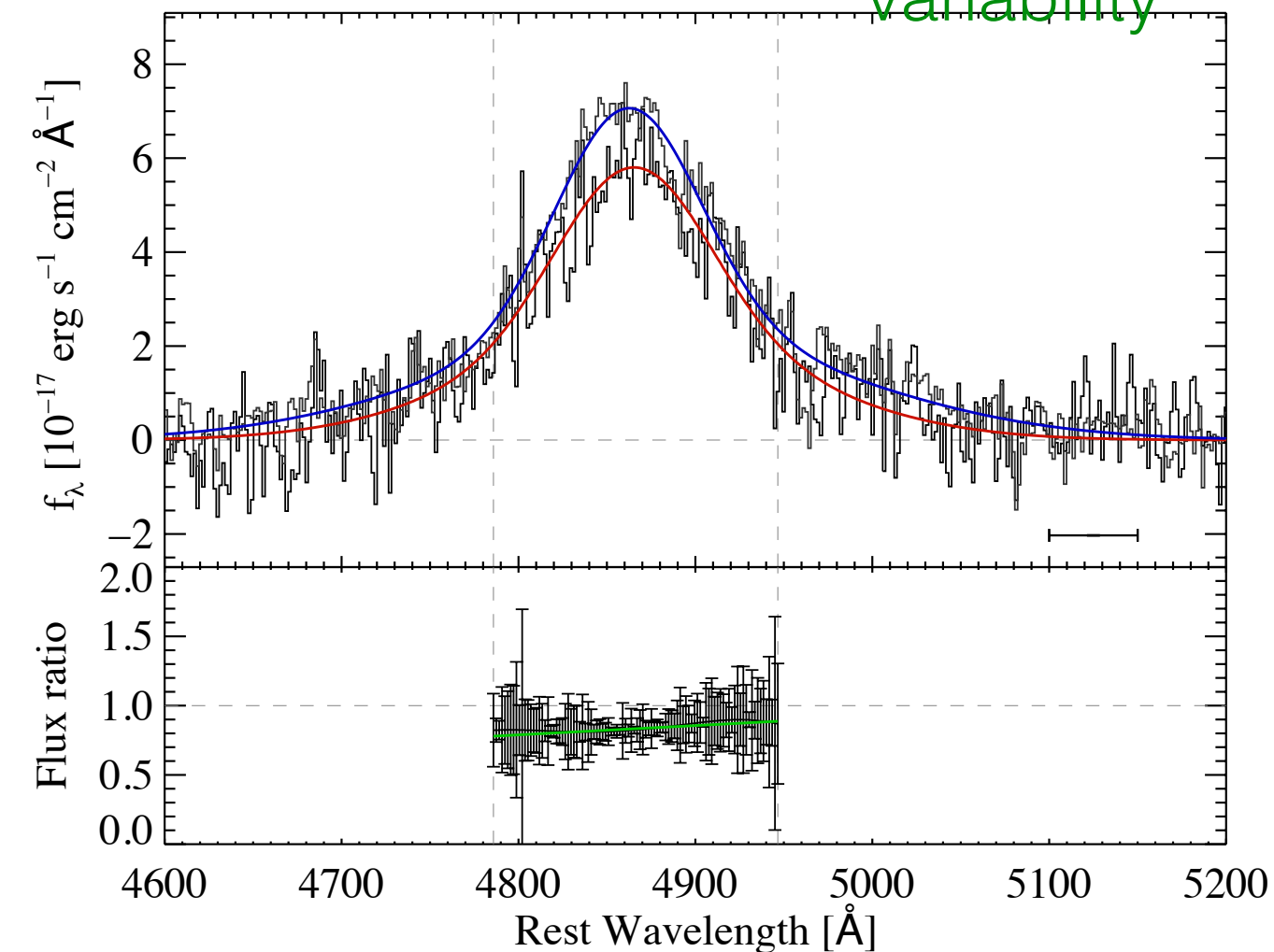


Characterizing profile variability

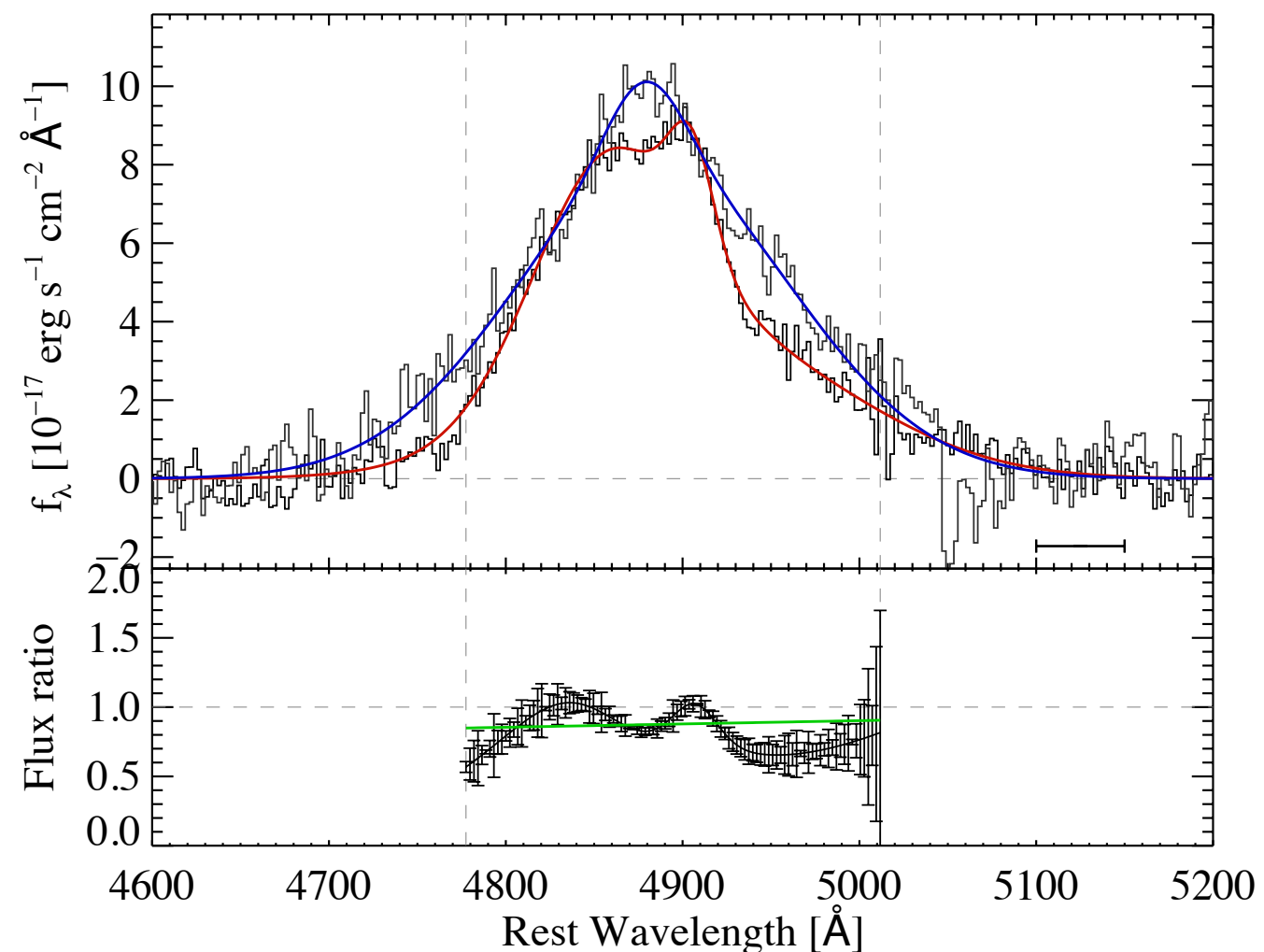
Compare spectra from two epochs.

How well does a line fit the ratio spectrum?

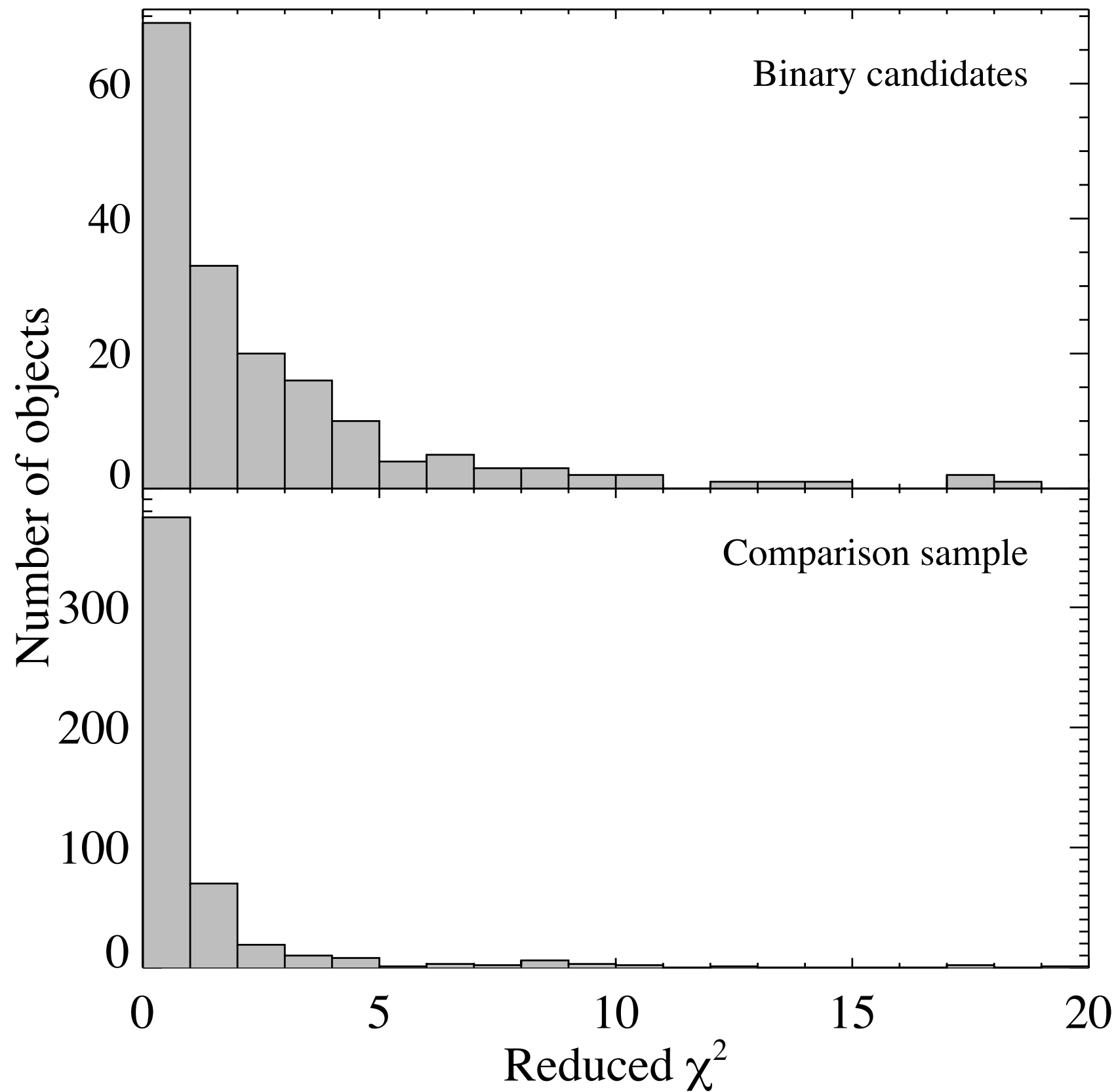
$\chi/\nu^2=0.03$, no profile variability



$\chi^2=13.7$, profile varied



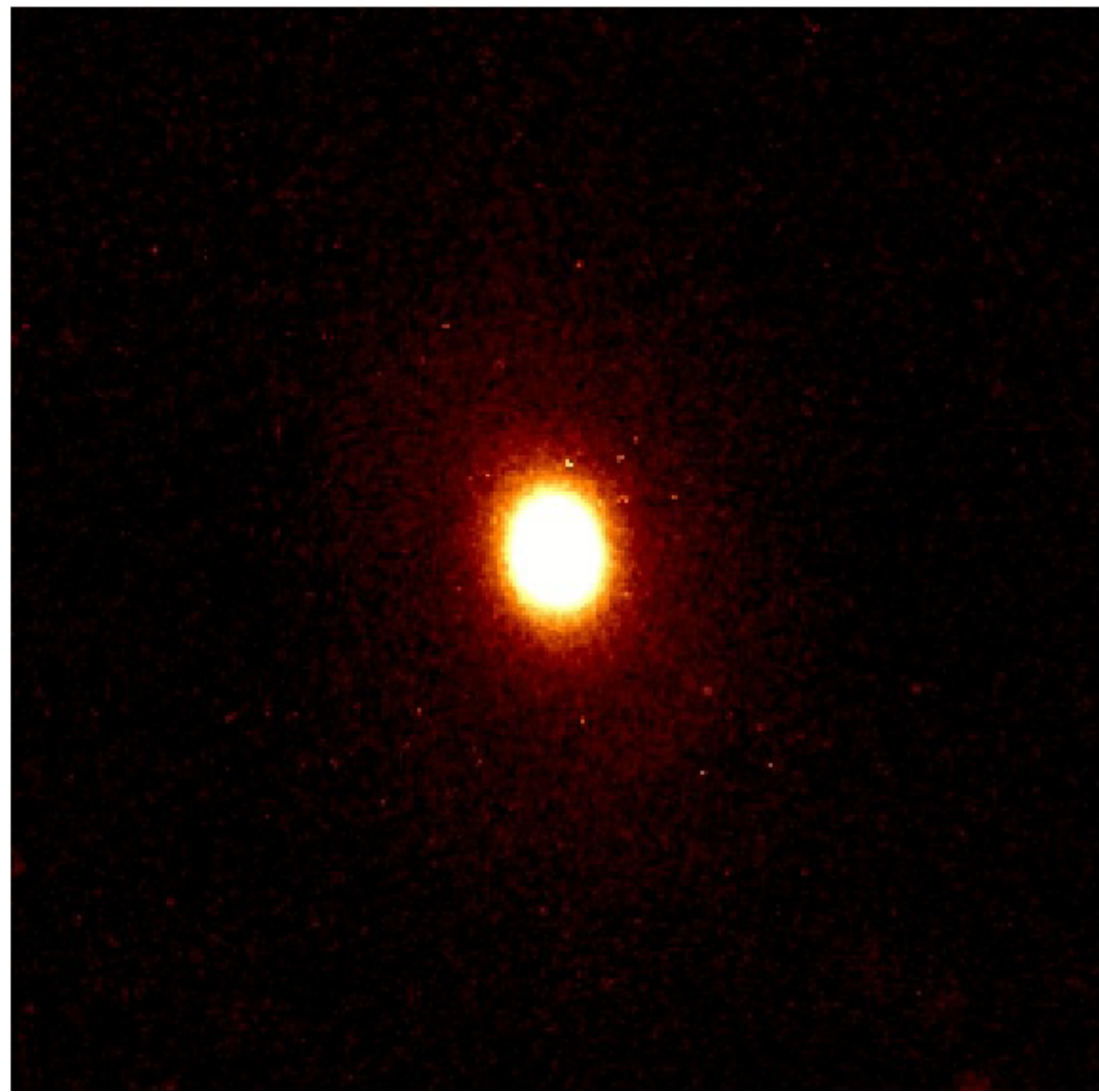
Profile variability results



Up next: a look at the host galaxies



J113651.66+445016.4



J143123.52+392501.4



The End.