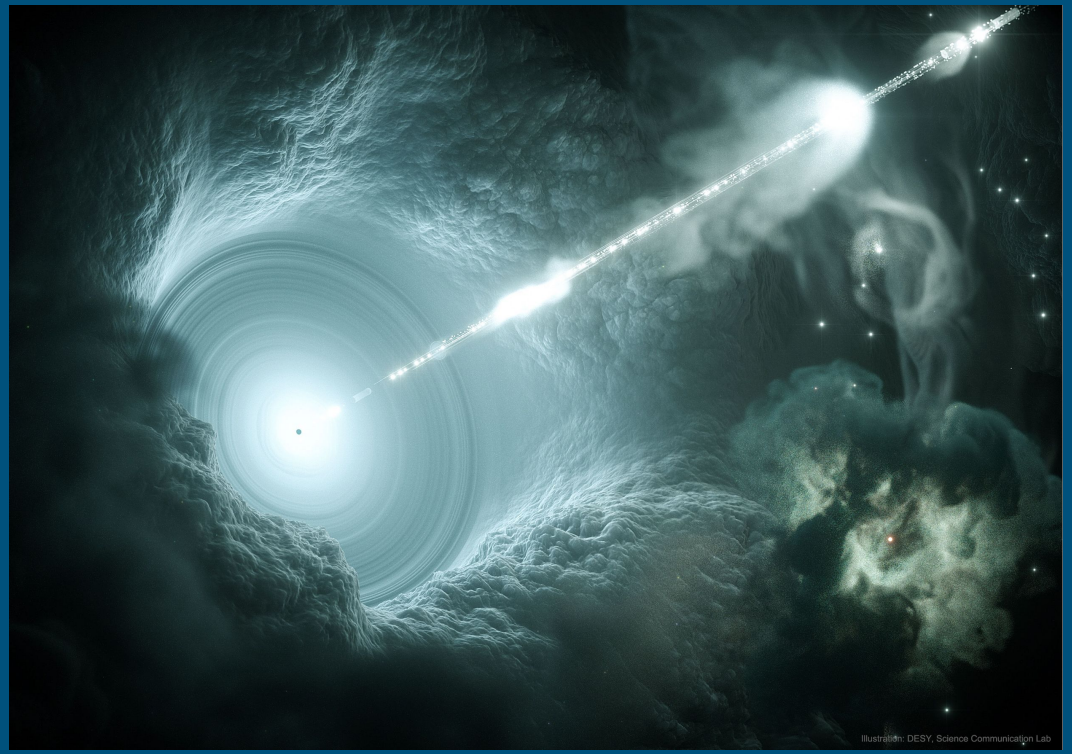
Quasars

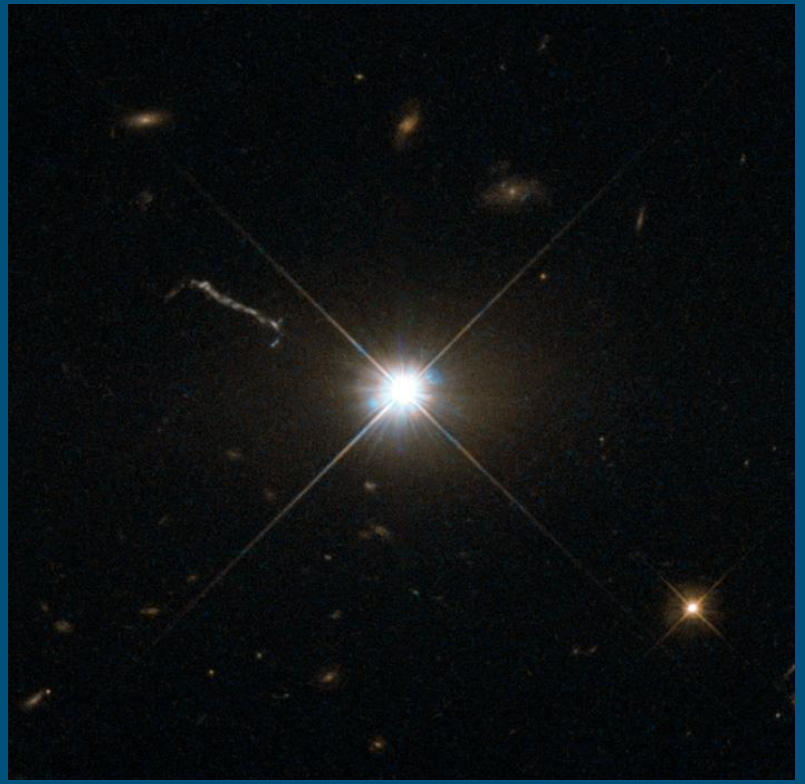
Vanderbilt-QuarkNet Workshop
Collin Dabbieri



First Quasar

-The first discovered quasar (quasi-stellar radio source)

- faint point source that also emits in radio wavelengths

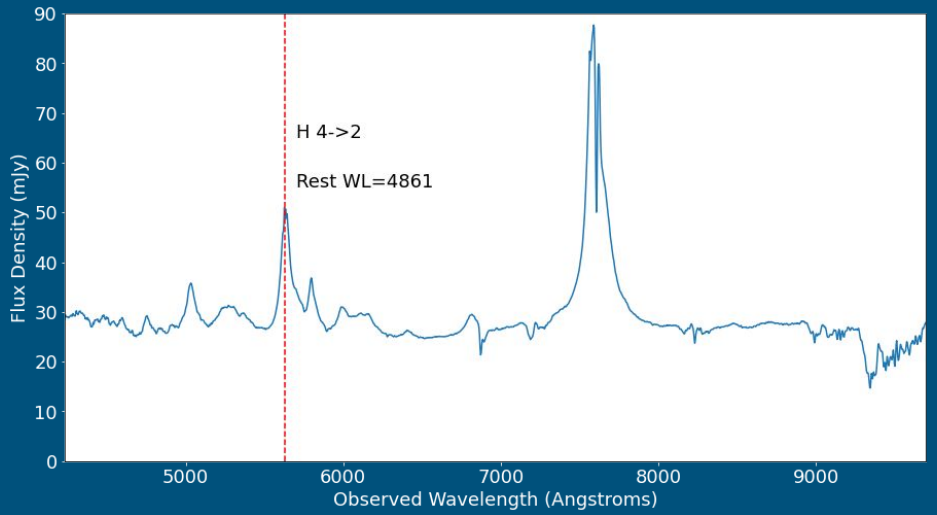


Hubble Space Telescope Image of 3C 273

Optical Spectrum

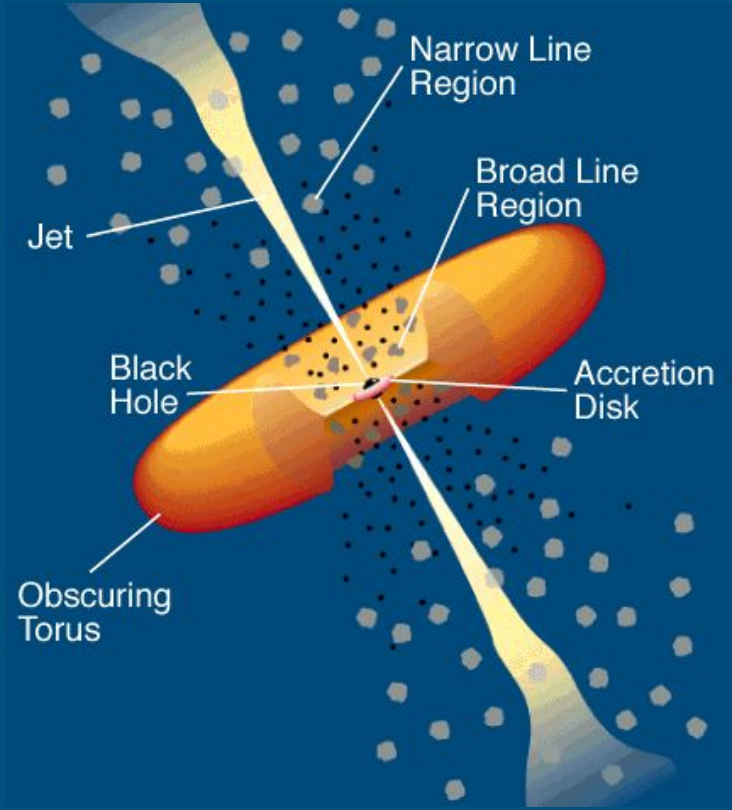
- Does not live in our galaxy!
  Actually 2 billion light years away

- ~200 times brighter than the Milky Way



What is a Quasar?

- Supermassive Black Hole pulls gas and dust from host galaxy
- Accretion disk emits thermal radiation that can outshine entire host galaxy



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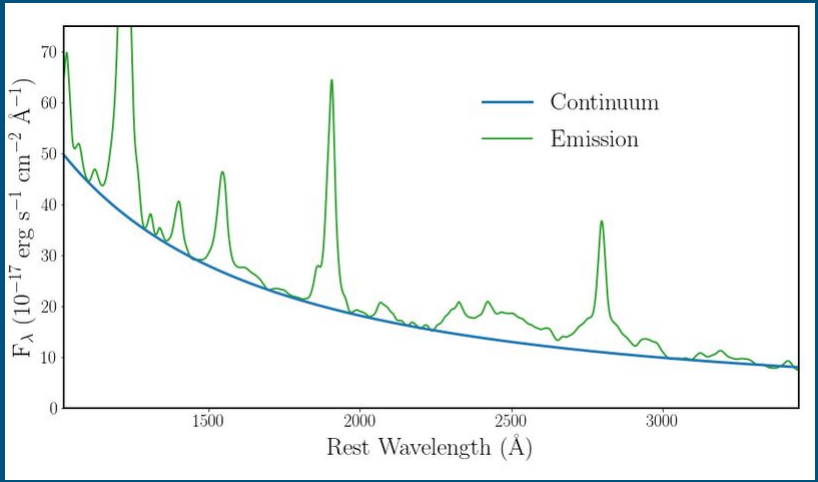
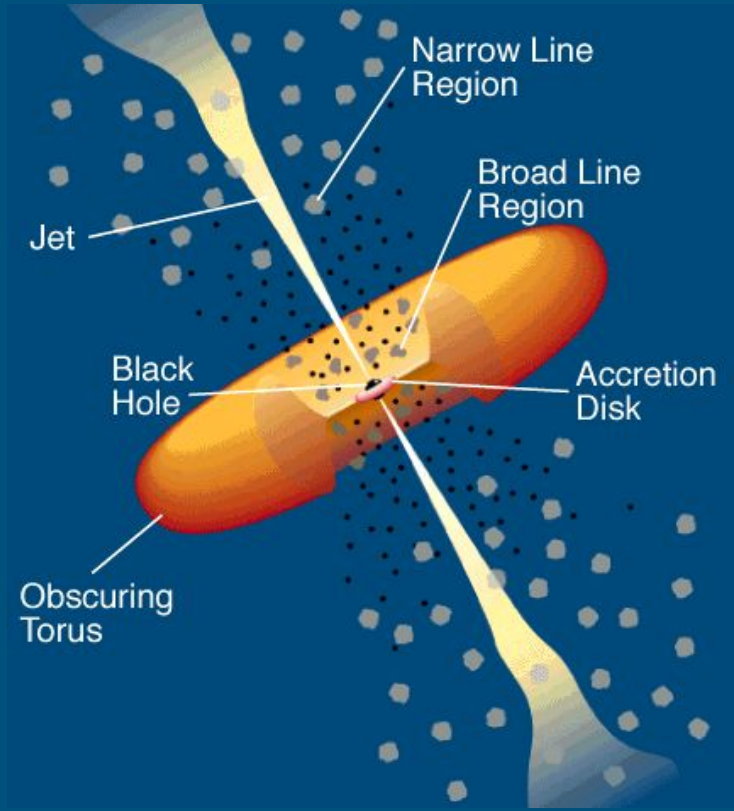
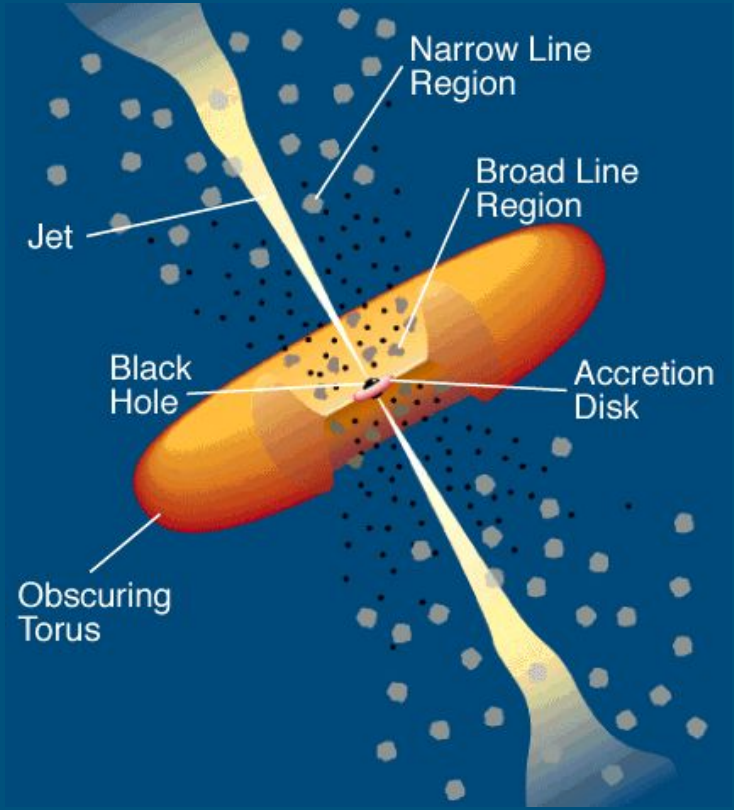




Question

How Far is the Broad Line Region from the Accretion Disk?

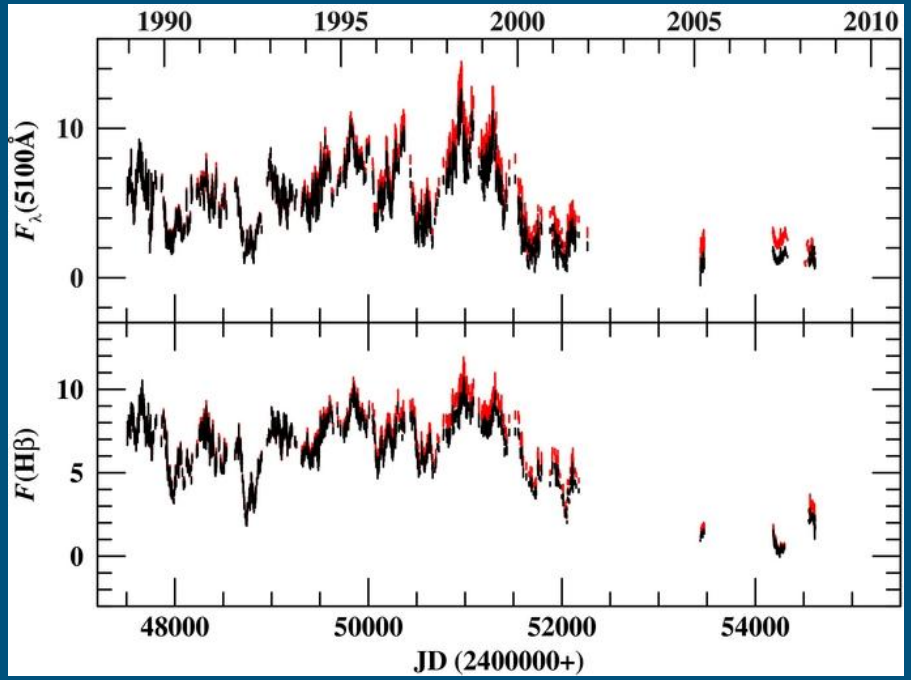


Light Curves

How Far is the Broad Line Region from the Accretion Disk?

- Quasars' brightness varies over time

- Variations in the broad line region follow variations in the accretion disk



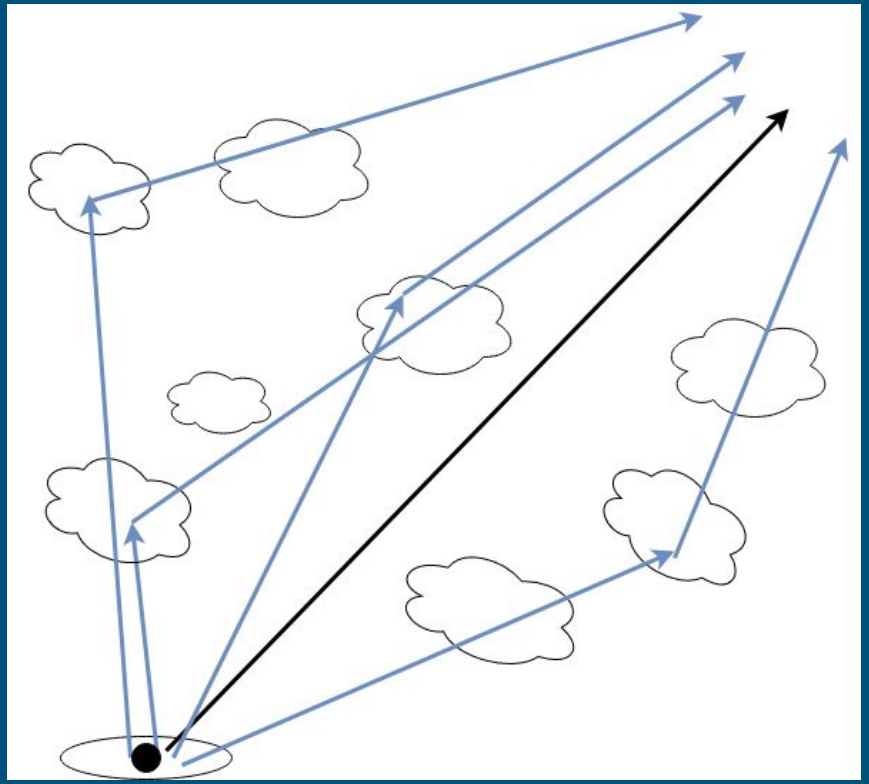
Peterson et al. 2013

Broad Line Region Lag

How Far is the Broad Line Region from the Accretion Disk?

- Variations in accretion disk brightness cause variations in broad line region brightness

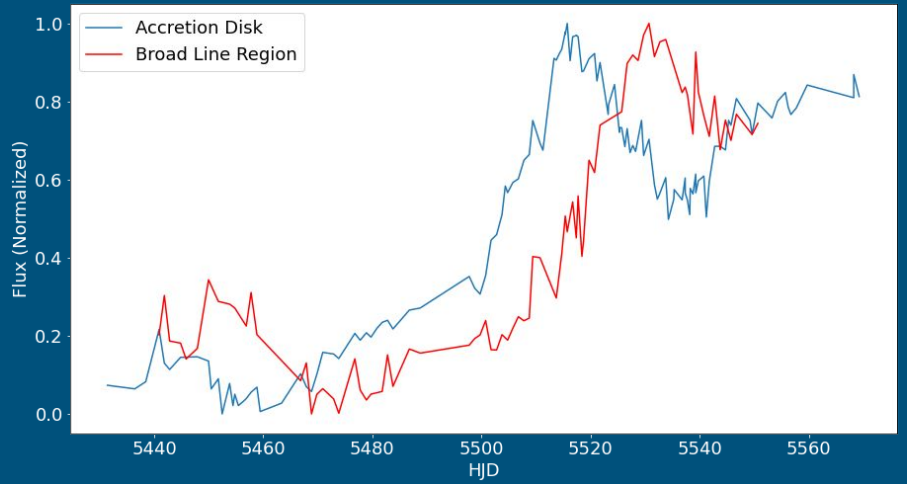
- There is a delay before we observe the Broad Line Region variability



Reverberation Mapping

How Far is the Broad Line Region from the Accretion Disk?

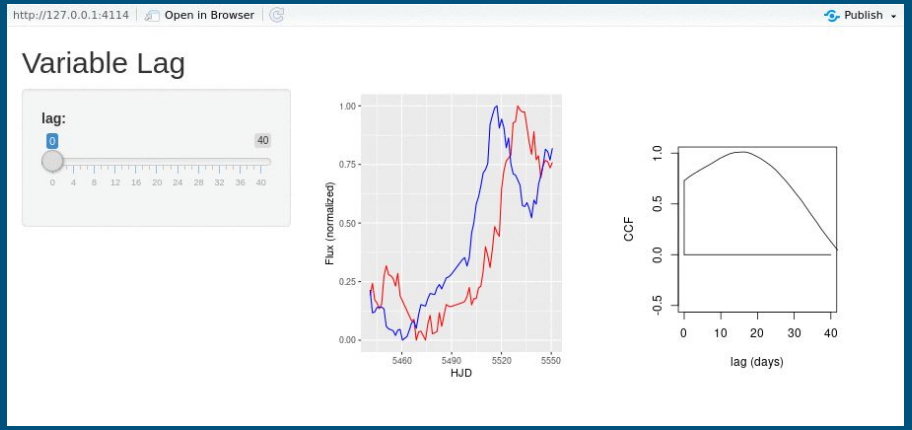
-The lag tells you how long it took for photons to travel from the Accretion Disk to the Broad Line Region



Fitting the Lag

How Far is the Broad Line Region from the Accretion Disk?

- Cross correlation measures the similarity of the two light curves as a function of the displacement lag
- Broad Line Region lags behind the Accretion Disk by about 15 days
- Broad Line Region is about 15 light days or 2,500 AU from the Accretion Disk



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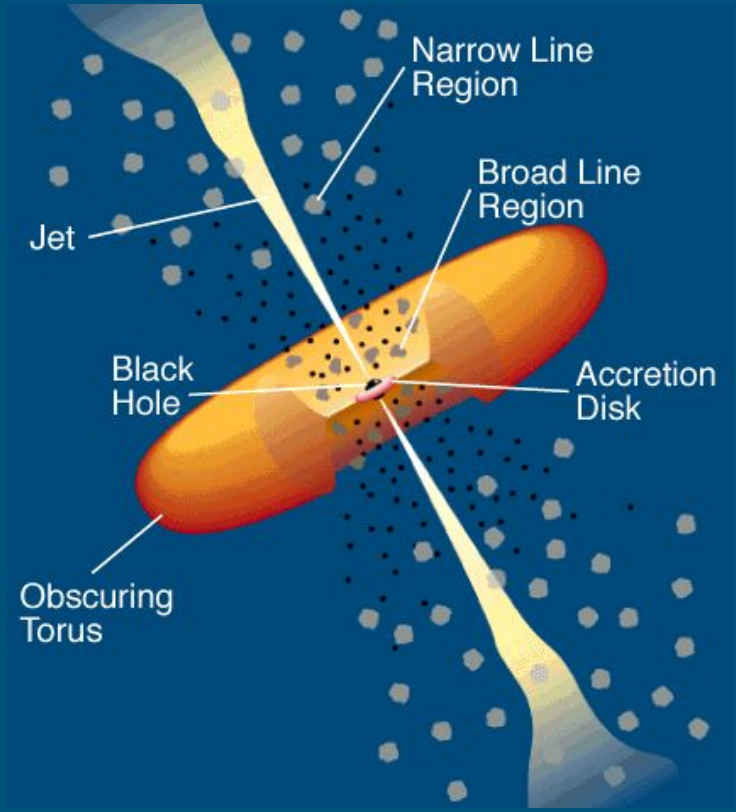
How Massive is the Black Hole?

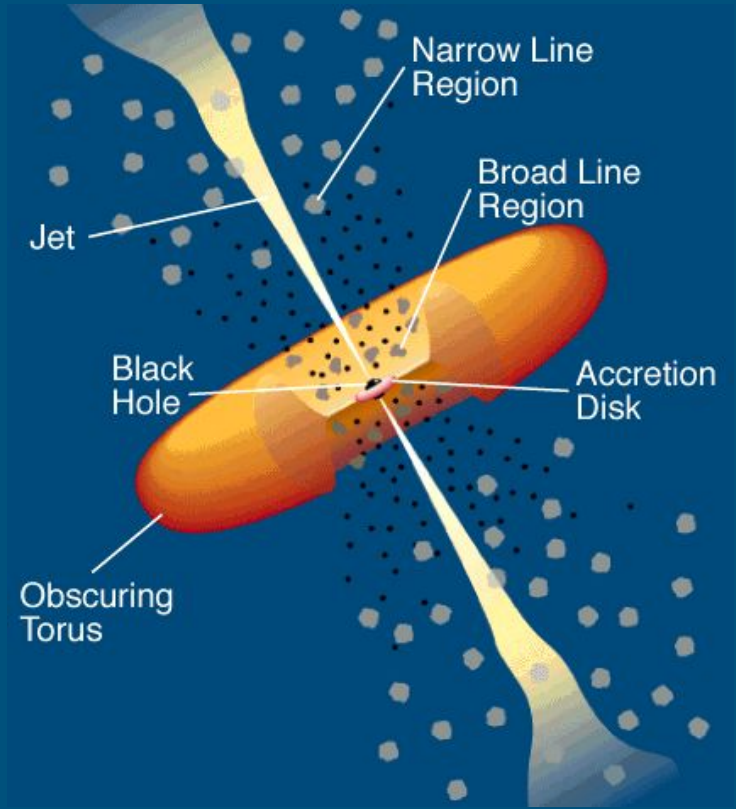


Keplerian Orbit

- Broad Line Region orbits the Black Hole
- We can calculate mass from the radius and velocity of the orbit

$$M_{BH} = f\frac{Rv^2}{G}$$

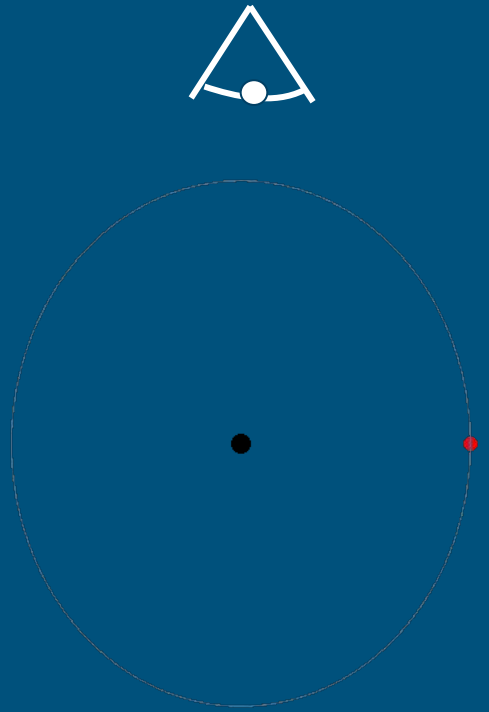
How Massive is the Black Hole?

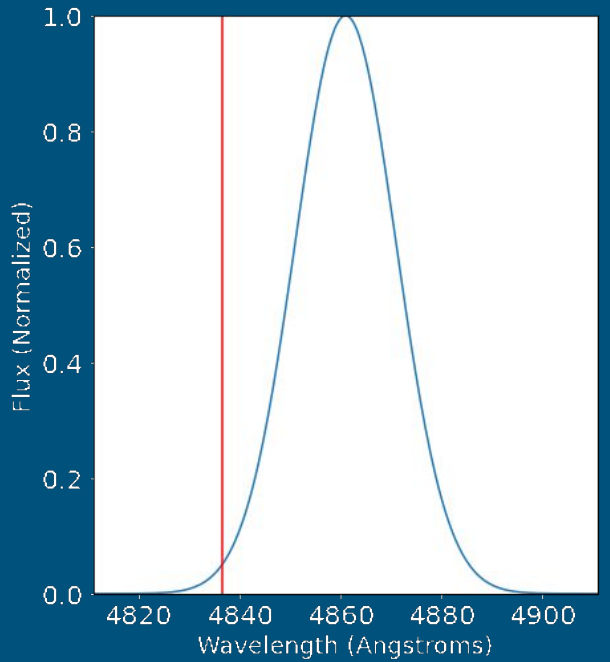


Doppler Broadening

How Massive is the Black Hole?

- When the gas is moving toward the observer, the Doppler effect decreases the wavelength
- The width of the emission line tells us the velocity of the gas





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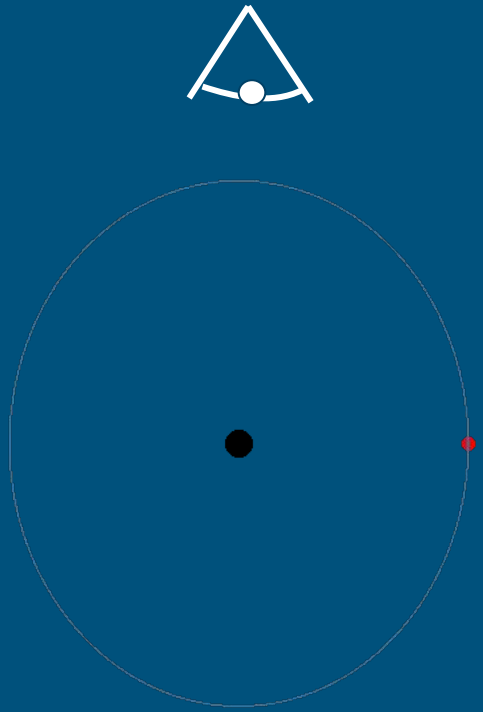
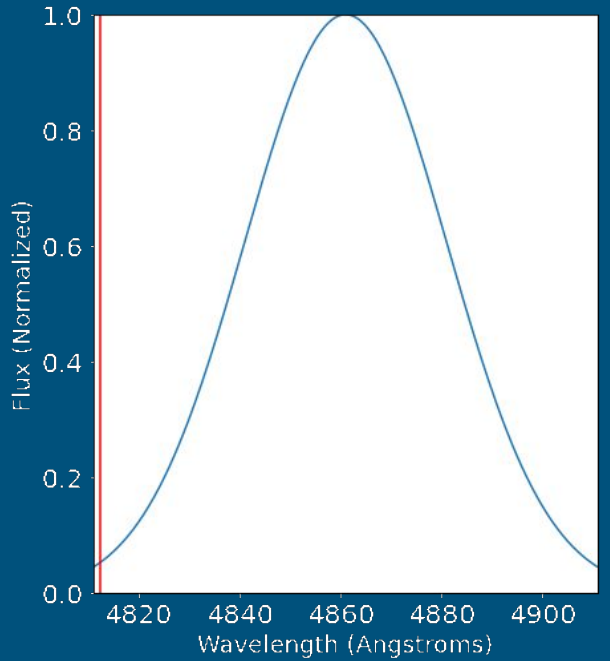




How Massive is the Black Hole?

- Broad Line Region radius comes from reverberation mapping

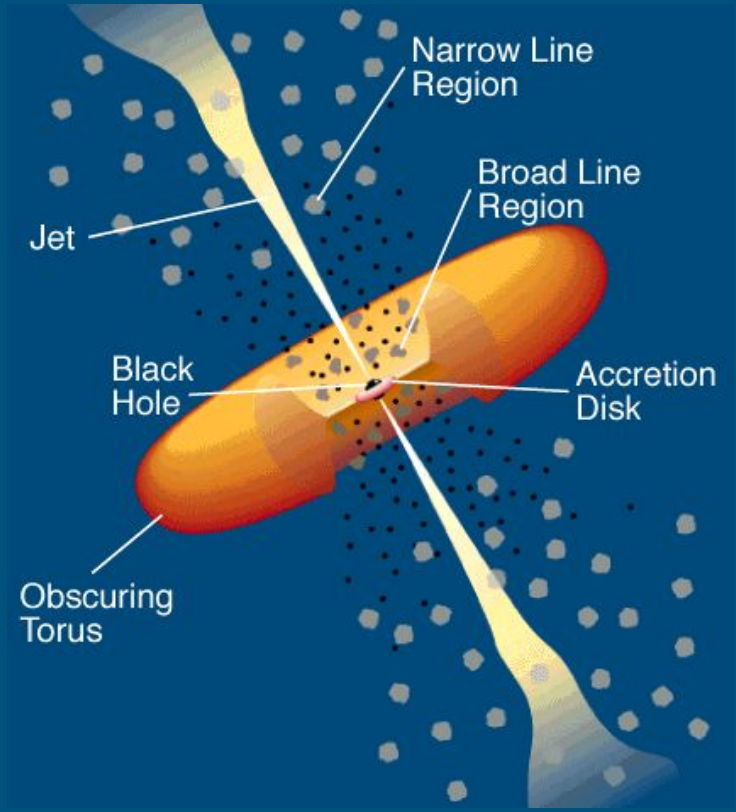
- Broad Line Region velocity comes from width of emission line

$$M_{BH} = f\frac{Rv^2}{G}$$

Name	Log Black Hole Mass (Solar Masses)
Mrk 335	7.23
Mrk 1501	8.07
PG0026+129	8.49
PG0052+251	8.46
Fairall9	8.30
Mrk 590	7.57

Question

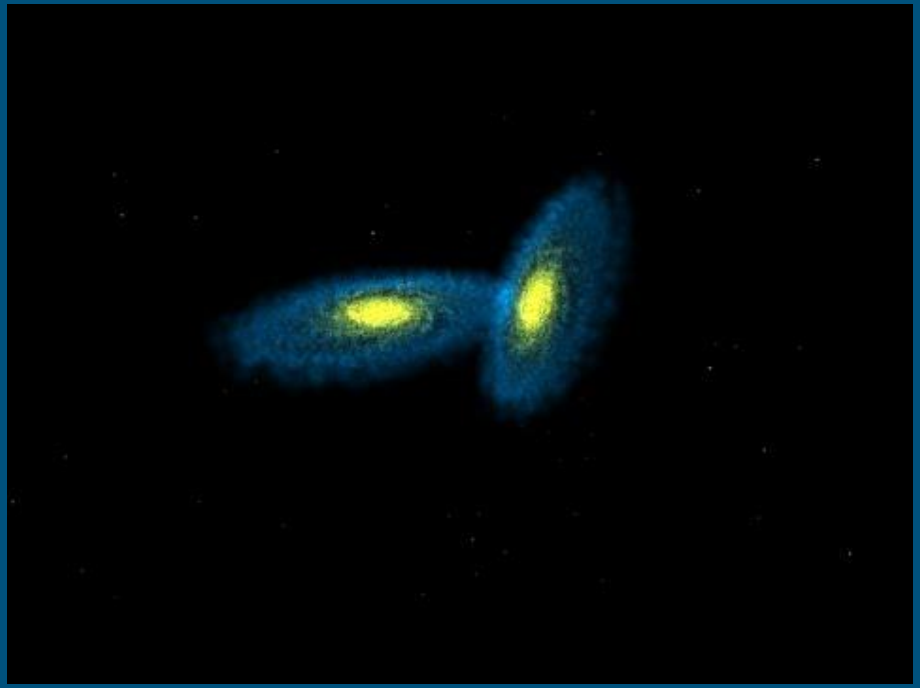
What about Quasars with SMBH binaries?



Galaxy Mergers

- Every massive galaxy has a SMBH at its center
- Galaxies mergers are common. When they merge, their SMBHs merge too
- Galaxy mergers might ignite quasar activity by feeding the black holes

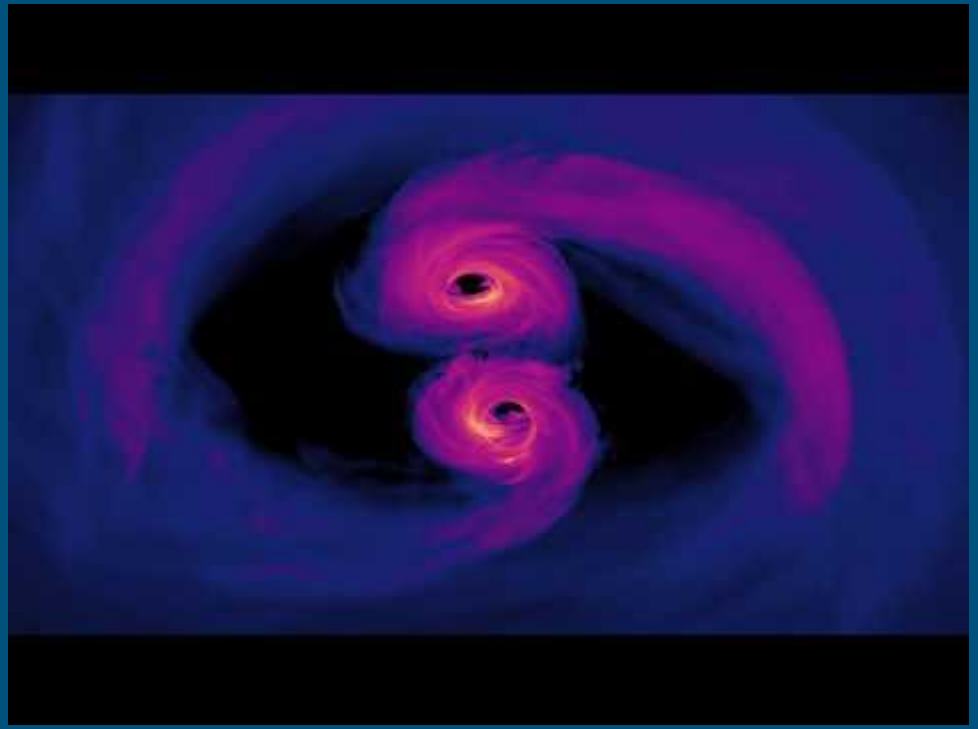
What about Quasars with SMBH binaries?



Black Hole Binaries

- Simulation of two supermassive black holes with accretion disks
- Relativistic boosting causes periodic changes in brightness

What about Quasars with SMBH binaries?

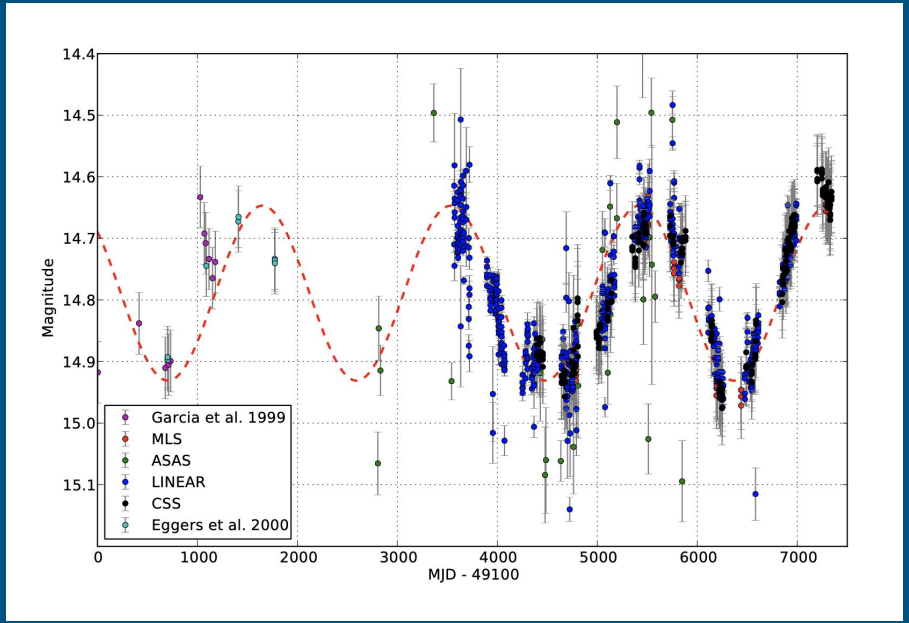


NASA’s Goddard Space Flight Center

Binary Candidate

- PG 1302 recognized as a binary candidate because of its periodic light curve

What about Quasars with SMBH binaries?

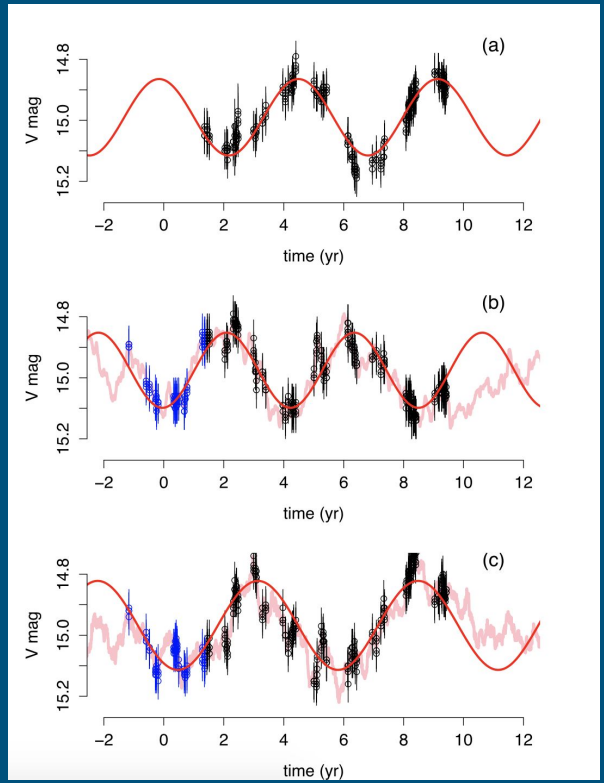


Graham et al. 2015

False Periodicities

- SMBH binaries should be rare, so you must search over a large sample to find them (~100,000s)
- Normal quasar variability has some probability of appearing sinusoidal over a few periods
- Needle in a haystack, but every piece of hay has some probability of looking like a needle

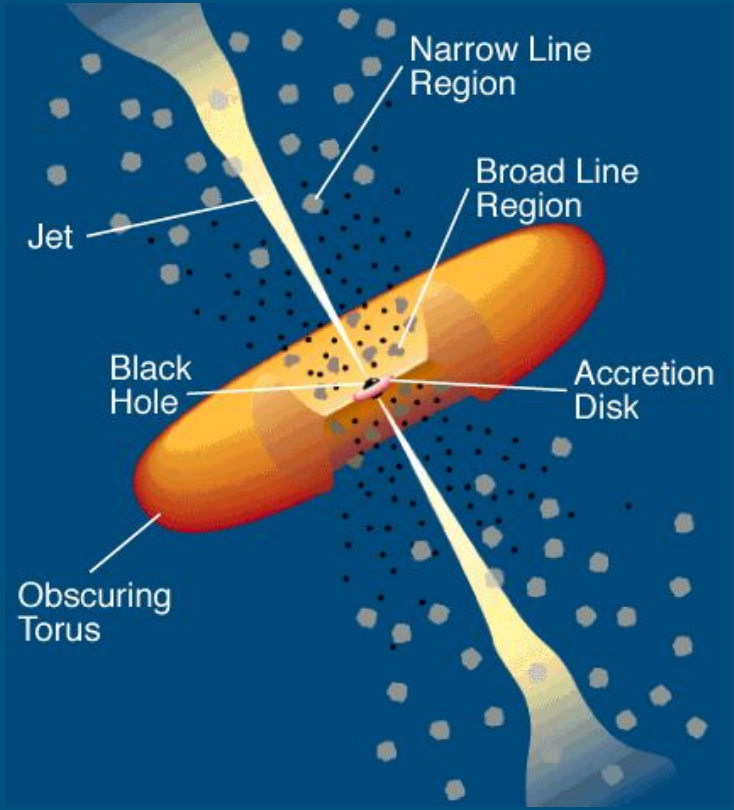
What about Quasars with SMBH binaries?



Vaughan et al. 2016

Question

What are you working on?



Sloan Digital Sky Survey

- Most recent Data Release 16 has spectra for 750,414 quasars
- 129,841 quasars have more than one spectral observation

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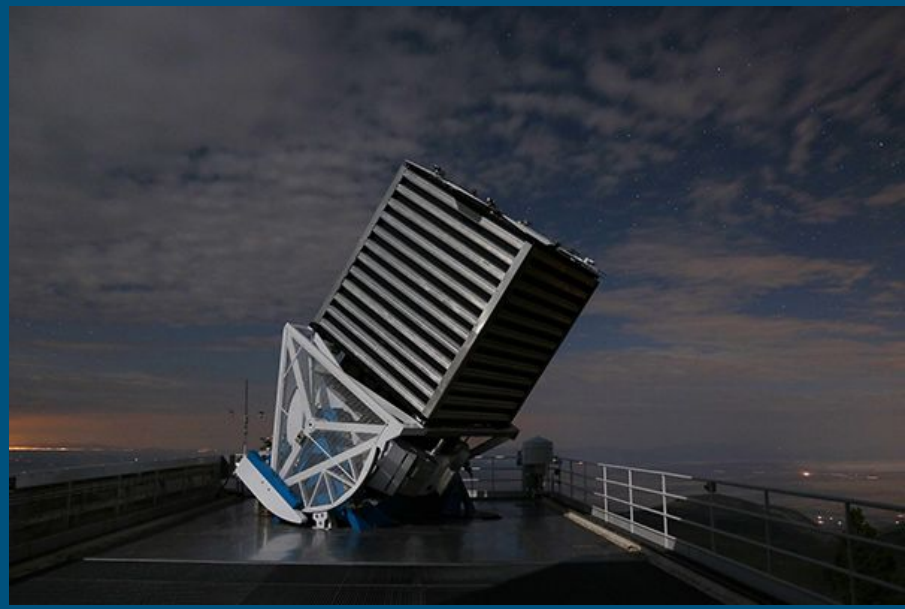
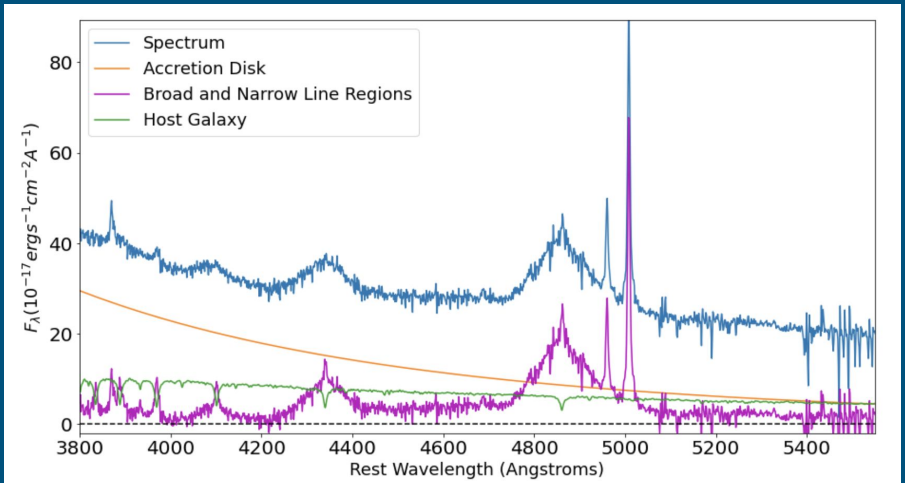


Spectral Decomposition

- Break each spectrum down into its components
- Too many spectra to check on results by eye, so you must have a rigorous fitting method



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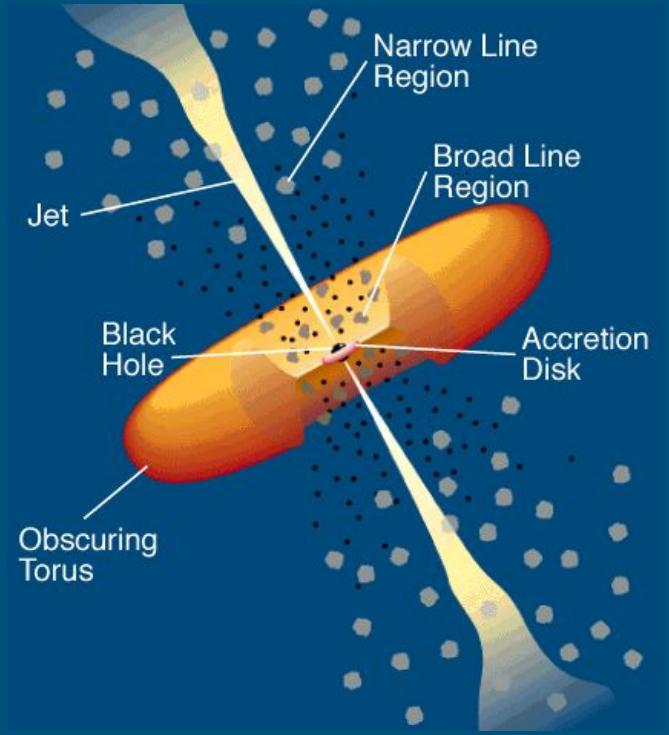
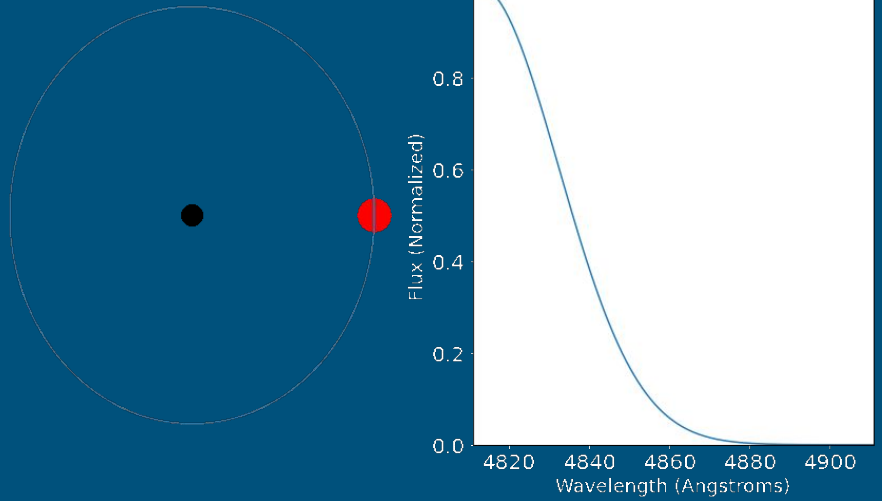


Radial Velocity ‘Jitter’

- Bulk motion of gas can cause the whole emission line to move!

- By collecting measurements of the change in velocity of an emission line for a given quasar, we gain info about how the Broad Line Region changes over time

What are you working on?



Introducing Jitterfitter

- Python package for fitting changes in radial velocity of quasar emission lines
- Pre-alpha

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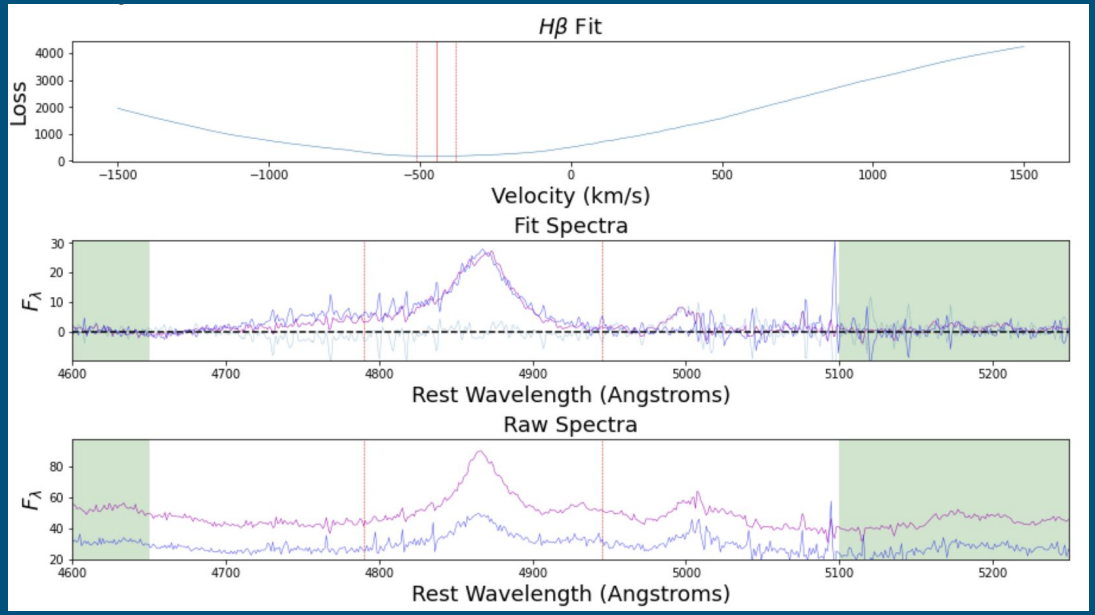
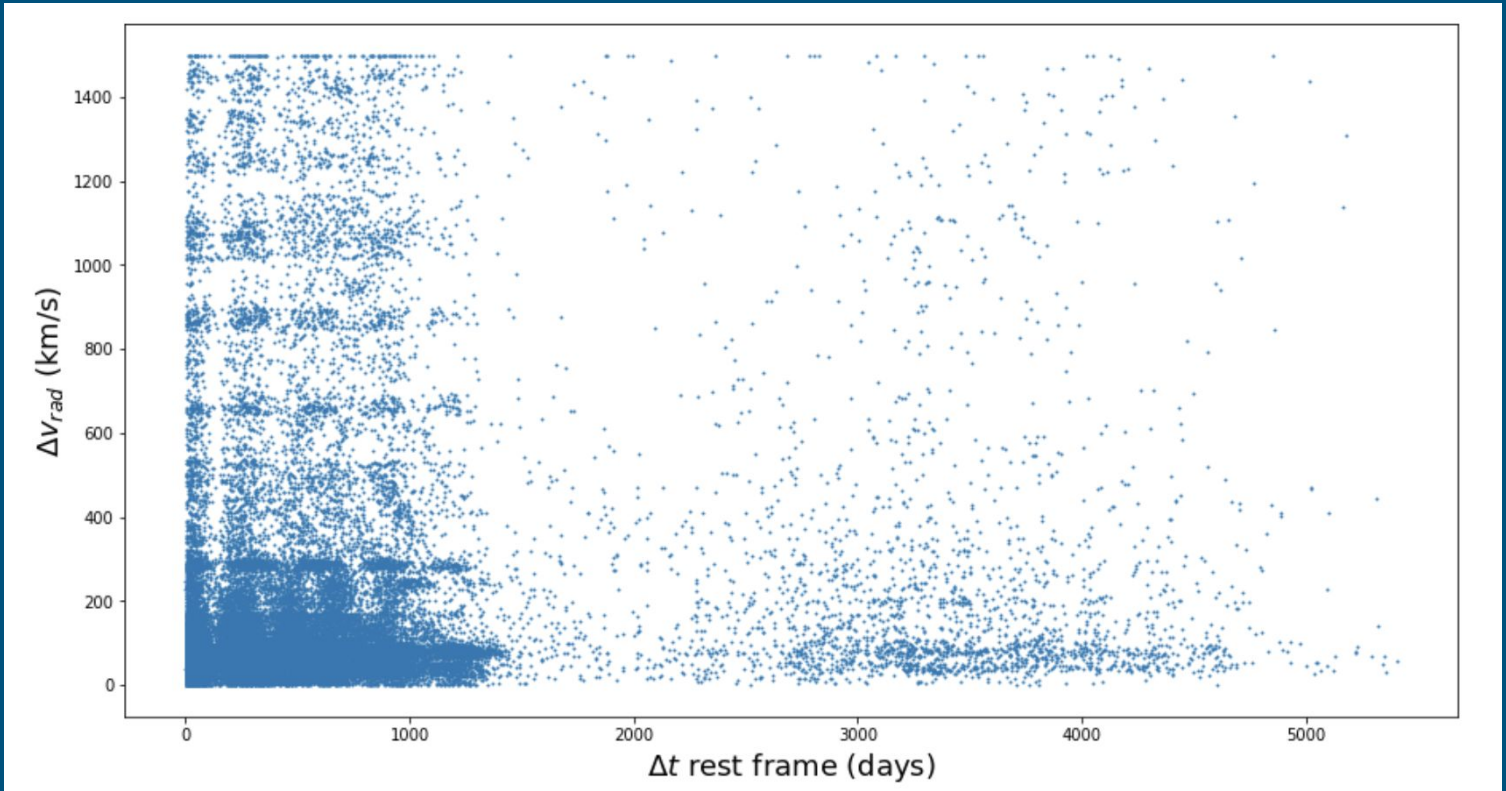


Extremely Preliminary Results



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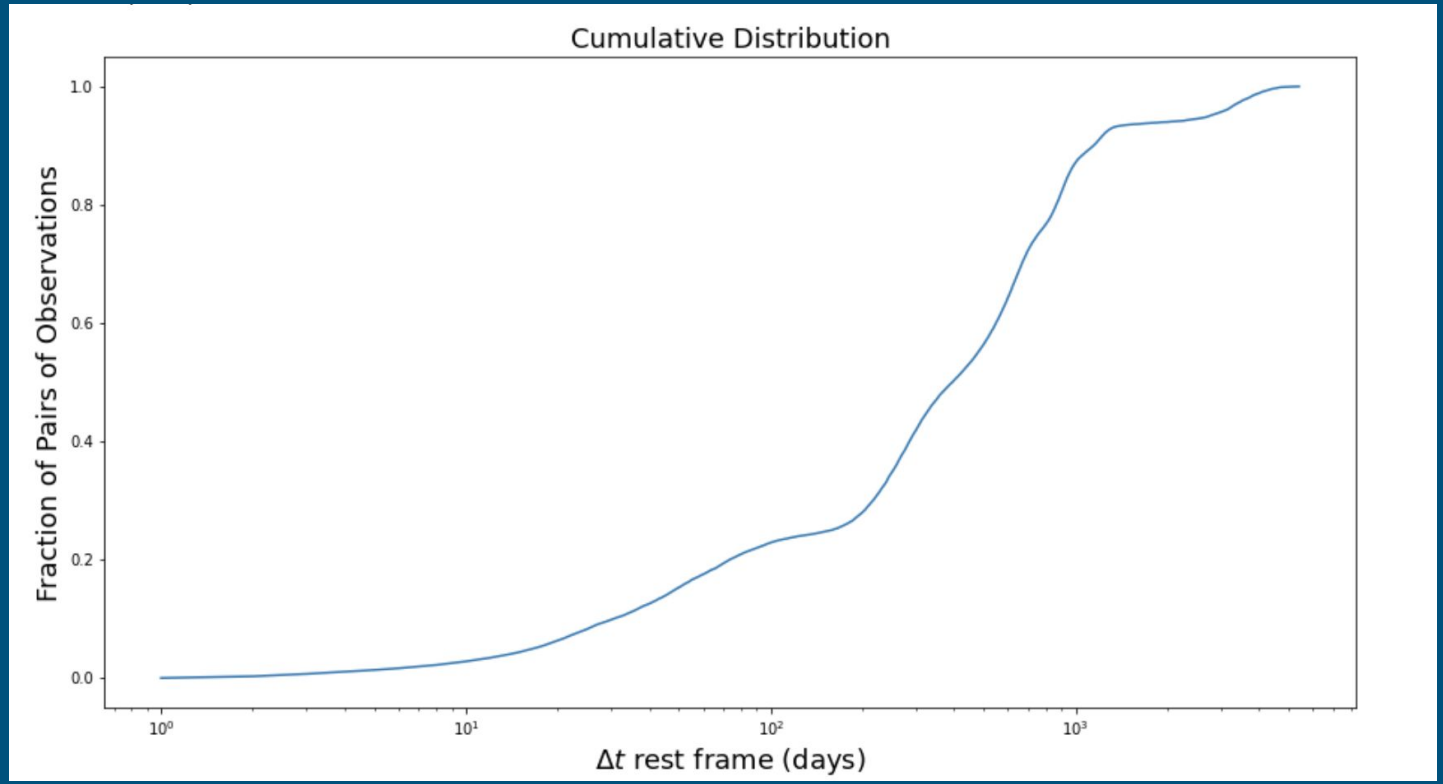

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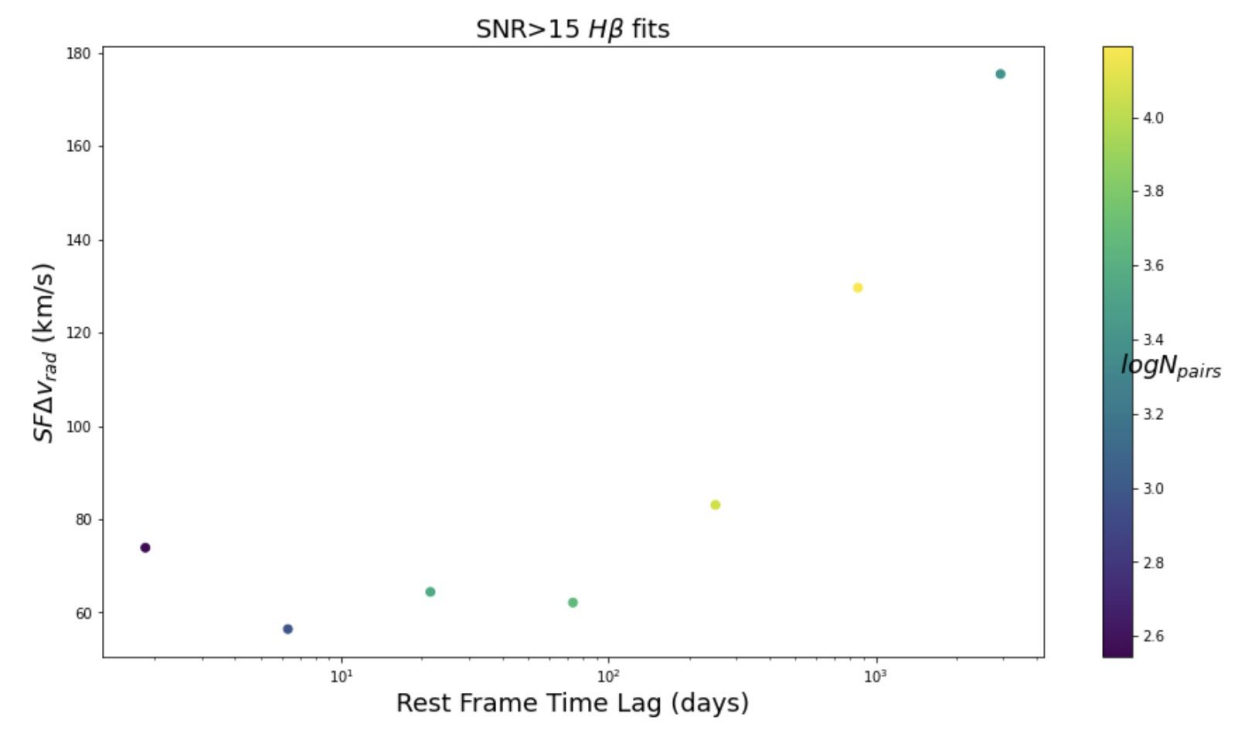

Sources

Peterson et al. 2013 - The Astrophysical Journal, Volume 779, Issue 2, article id. 109, 8 pp. (2013).

Graham et al. 2015 - Nature, Volume 518, Issue 7537, pp. 74-76 (2015).

Vaughan et al. 2016 - Monthly Notices of the Royal Astronomical Society, Volume 461, Issue 3, p.3145-3152