

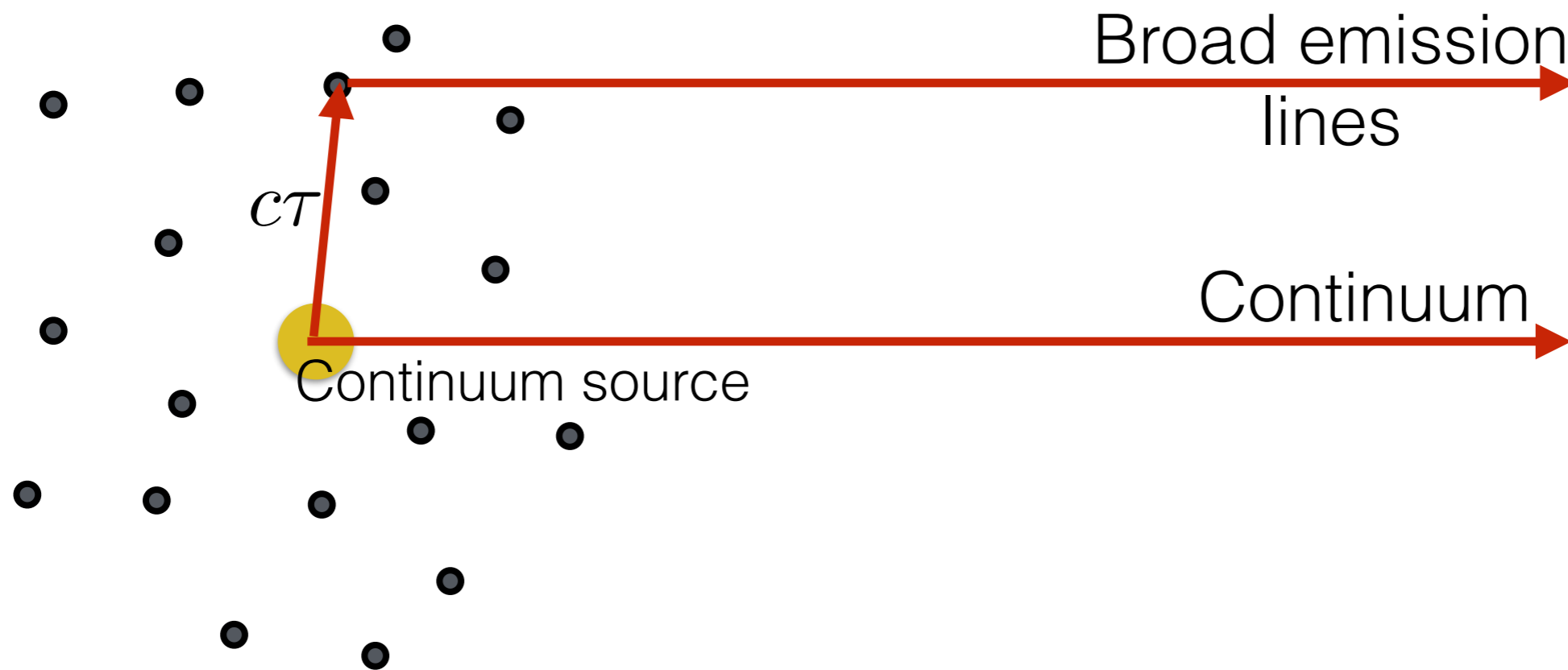
Modeling the Broad Emission Line Region with Reverberation Mapping Data

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AGN Winds, June 28, 2017

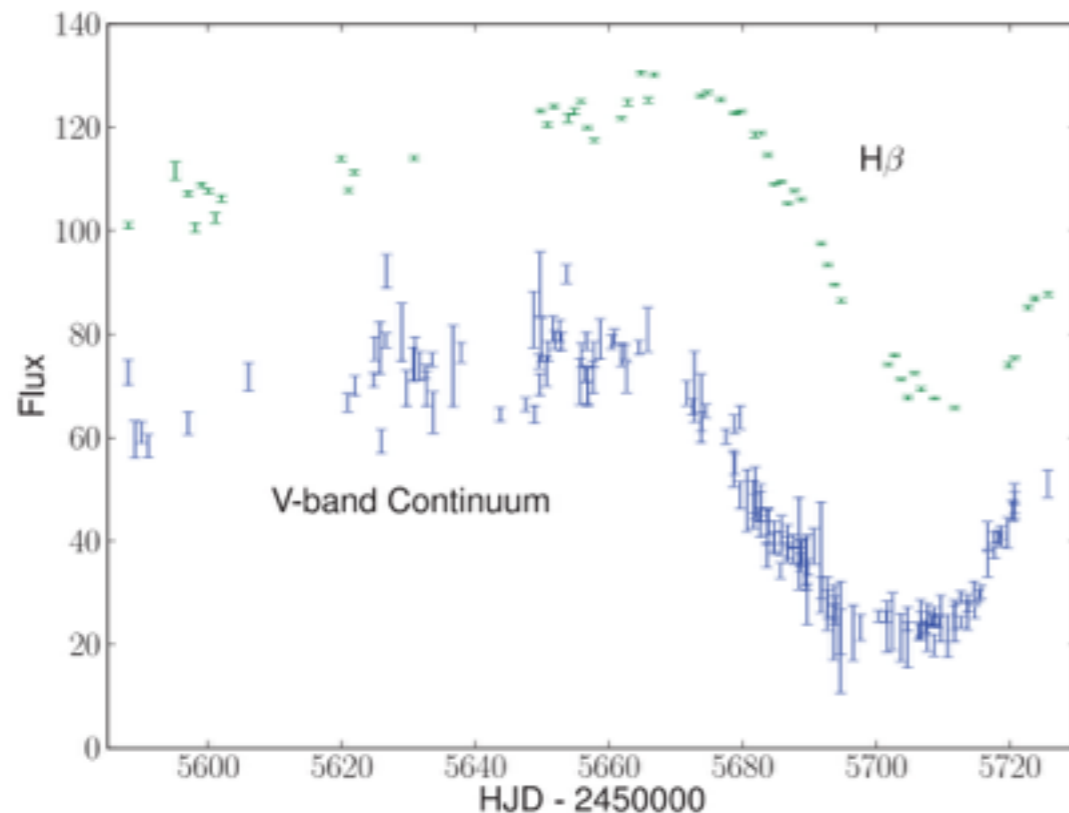
Reverberation Mapping

Goal: Measure time lag between continuum variability and broad emission line variability to obtain a black hole mass



Reverberation Mapping

- Assume BLR clouds are in viral motion $\longrightarrow M_{\text{BH}} = f \frac{rv^2}{G}$
 - v from broad emission line width
 - $r = c\tau$ from time lag



Pancoast et al. 2012

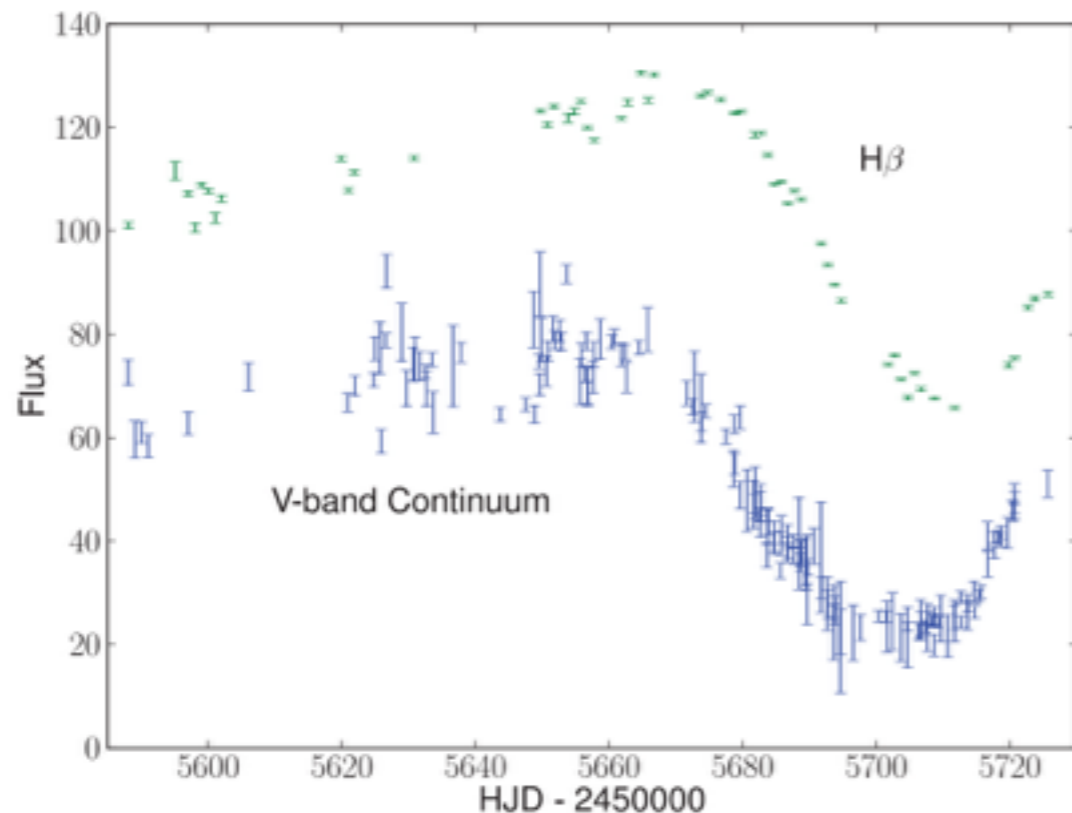
Reverberation Mapping

- Assume BLR clouds are in viral motion
- v from broad emission line width
- $r = c\tau$ from time lag

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

Absorbs details of the BLR structure and kinematics.

~ 0.4 dex uncertainty



Pancoast et al. 2012

Transfer function

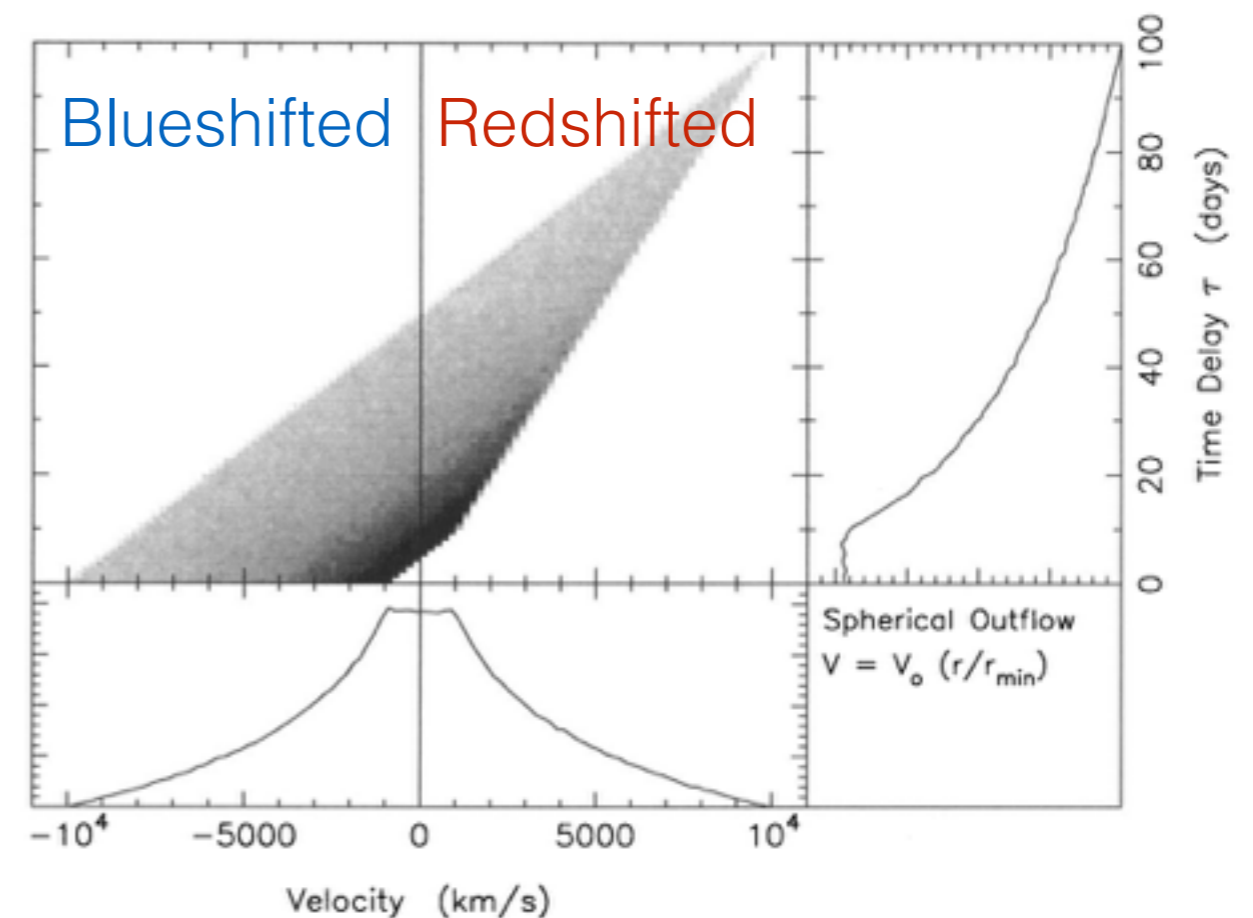
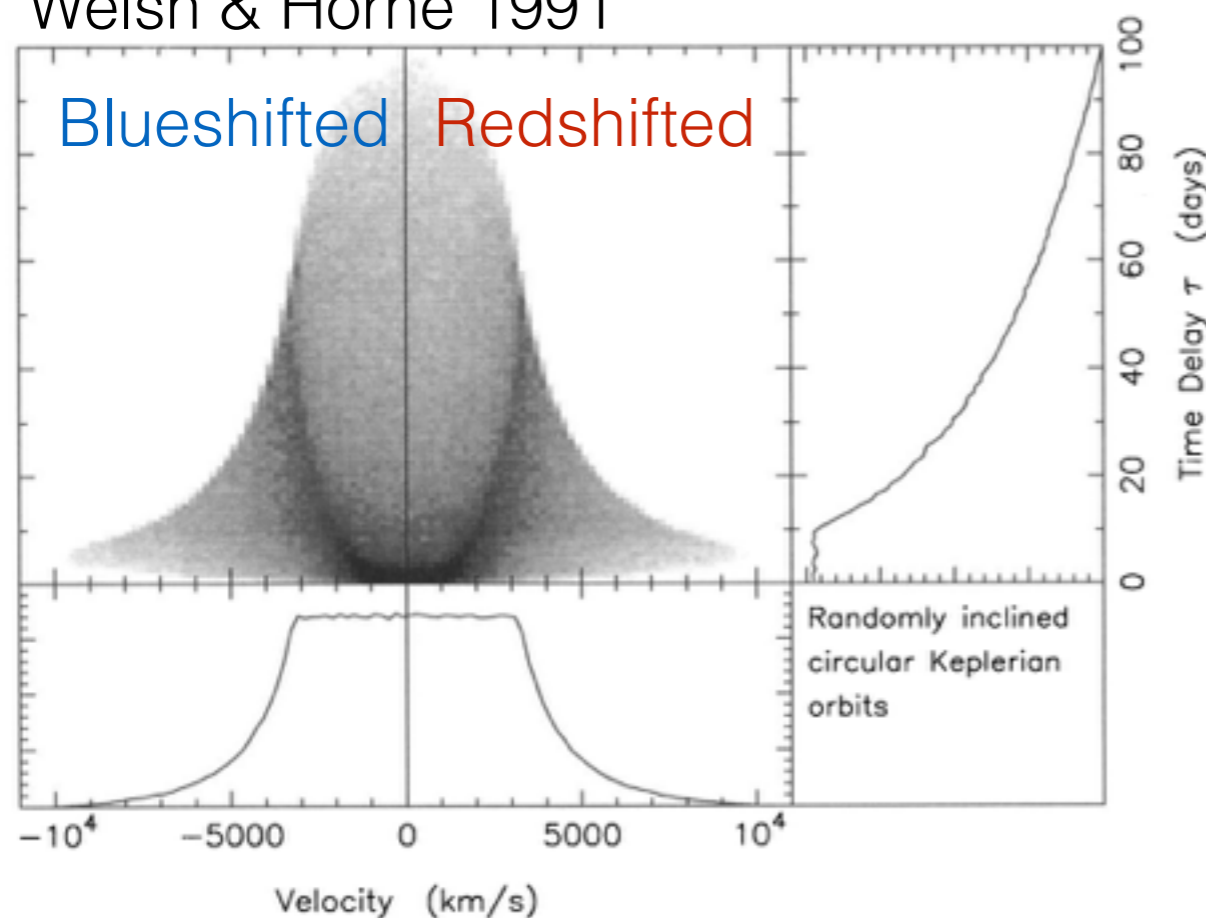
$$\Delta L(t, v) = \int_0^\infty \Psi(\tau, v) \Delta C(t - \tau) d\tau$$

Emission line (points to $\Delta L(t, v)$)

$\Psi(\tau, v)$ (points to the transfer function)

Continuum (points to $\Delta C(t - \tau)$)

Welsh & Horne 1991



Spherically symmetric, random circular orbits

Spherically symmetric, outflow

Broad emission line region model

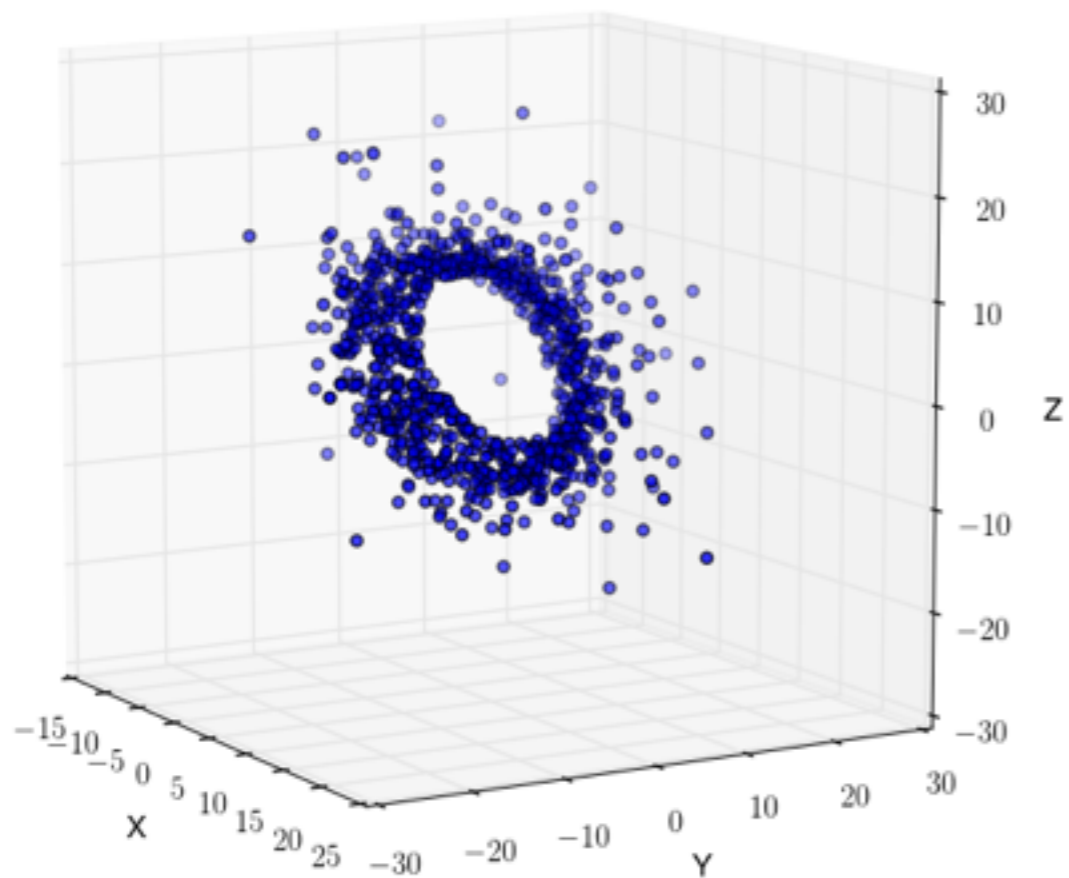
Geometry

Disk with:

- Radial distribution of particles
- Inclination angle
- Opening angle (puff up to 3D)

Kinematics

- Radial and tangential velocities for each particle

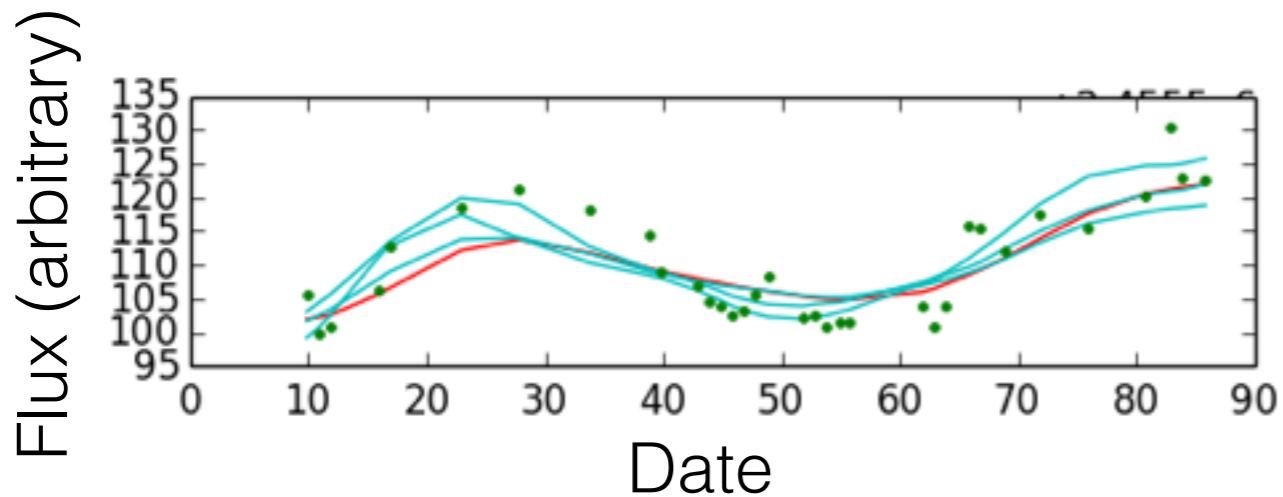
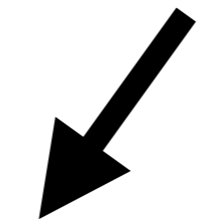
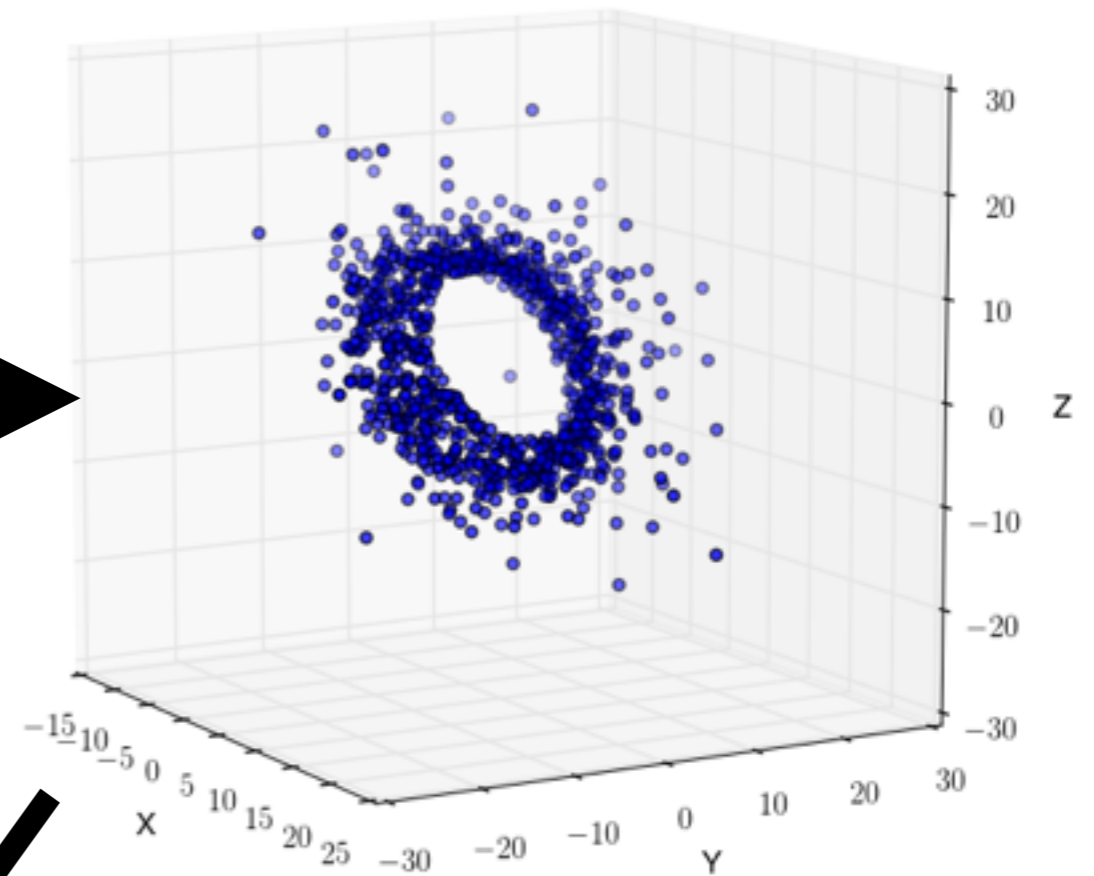
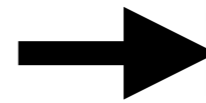
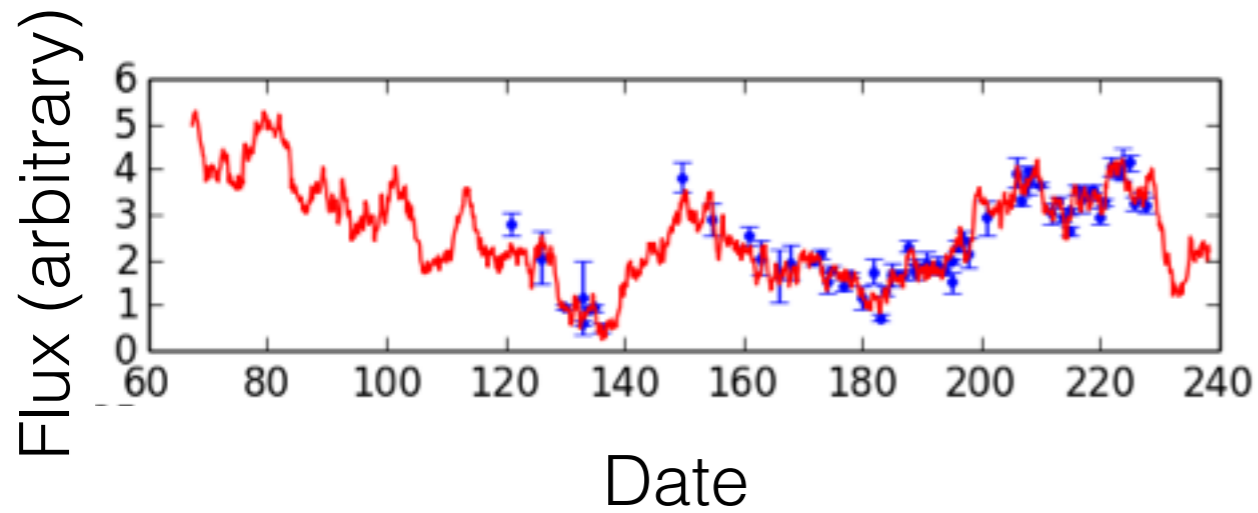


To observer

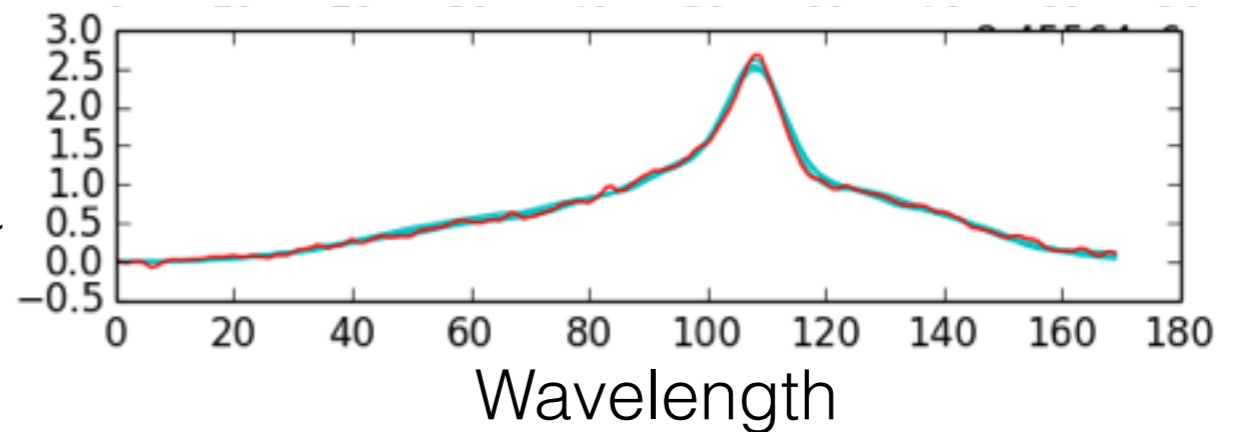


Broad emission line region model

Model the continuum



Flux (arbitrary)

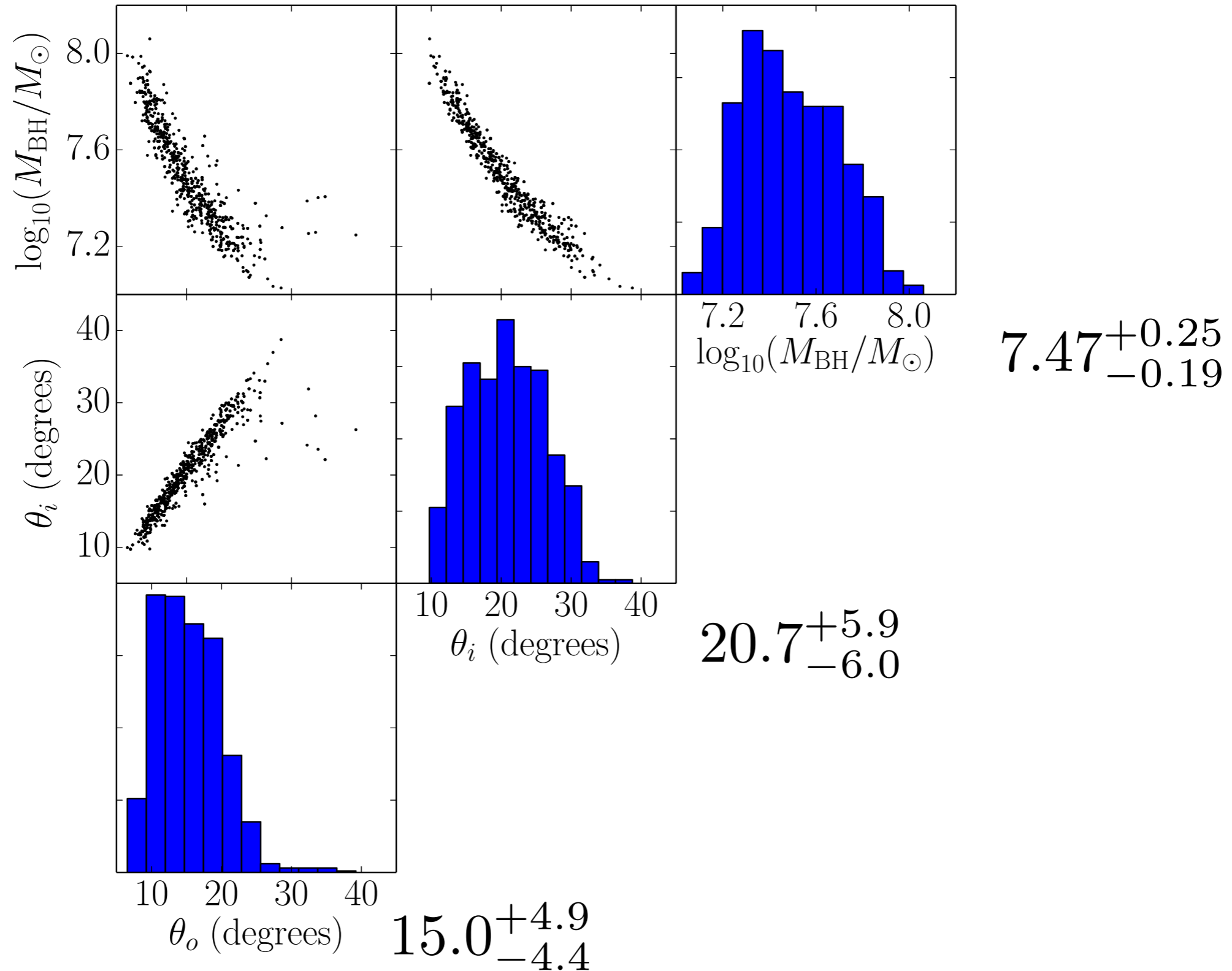


Lick AGN Monitoring Project (LAMP) 2011

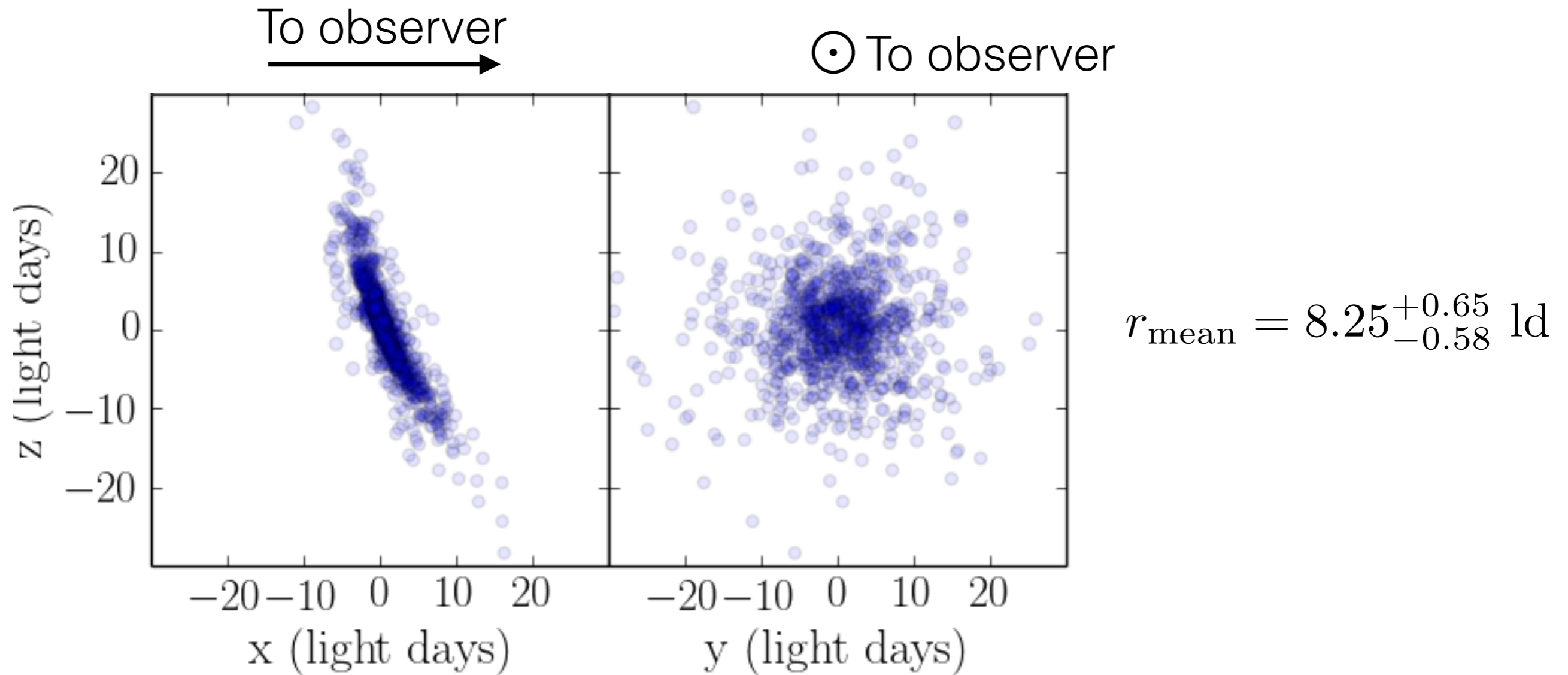
- 69 night spectroscopic monitoring over ~ 2.5 months
- 15 AGN with $\sim 30-45$ usable nights per object
- Photometric monitoring with various queue-schedule and robotic telescopes



Results: Mrk 50

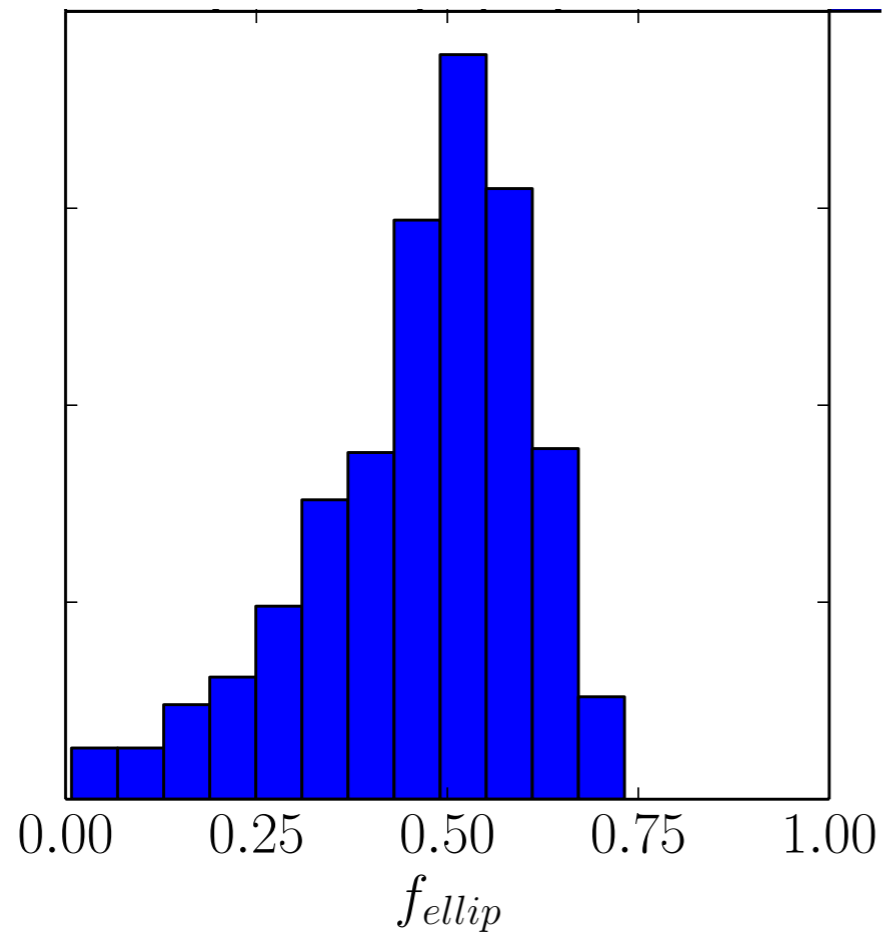


Results: Mrk 50



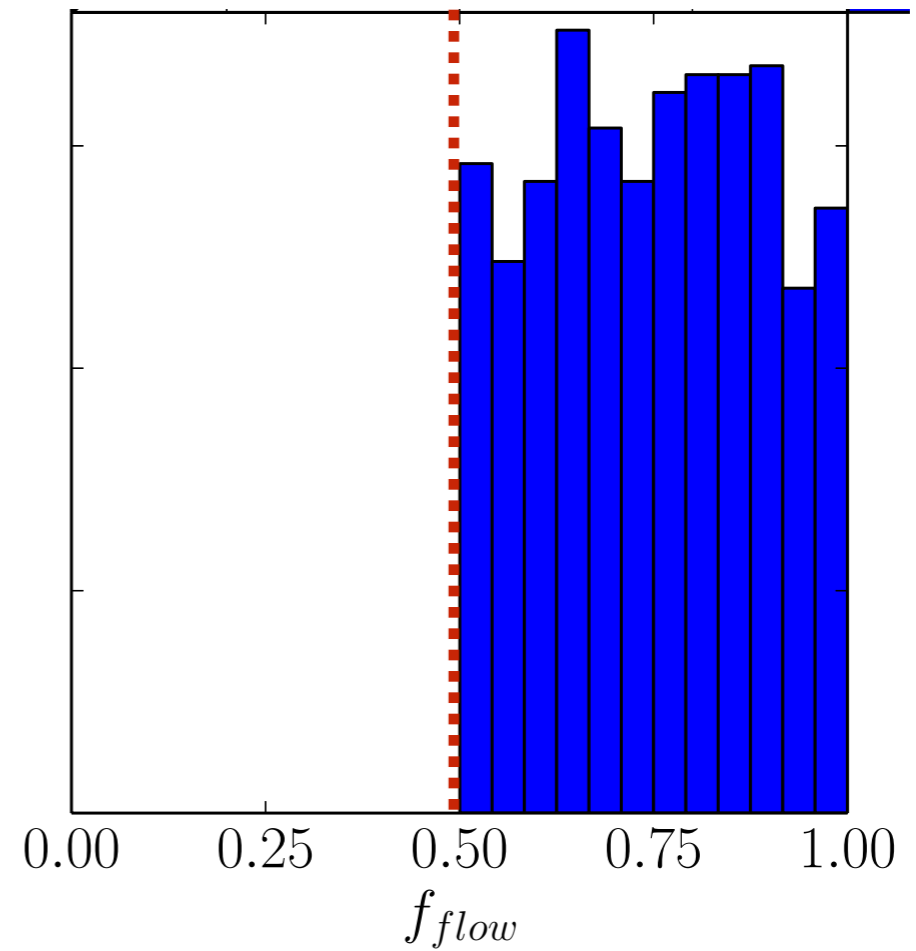
Results: Mrk 50

Fraction of clouds with bound, elliptical orbits

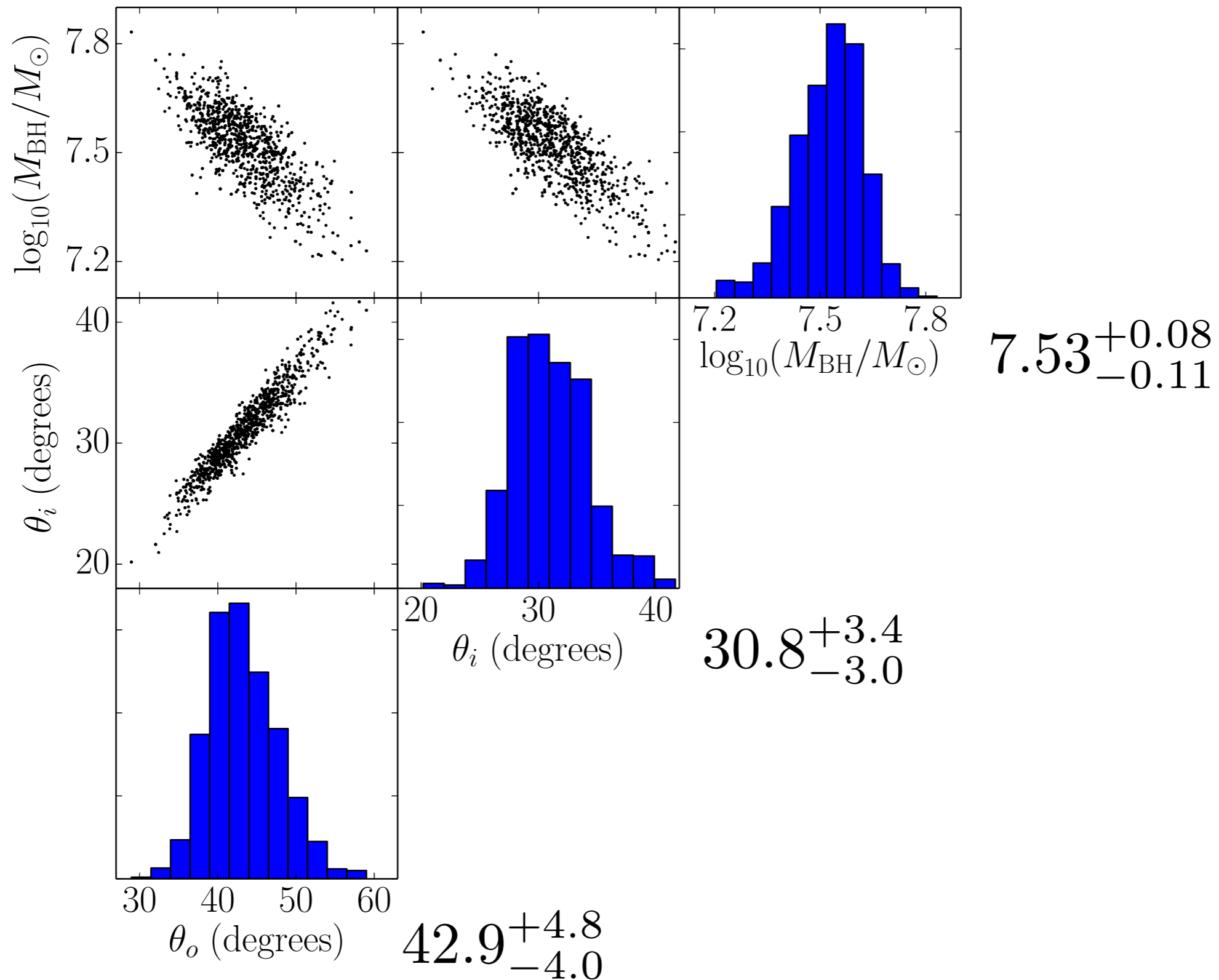


$$f_{ellip} = 0.49^{+0.11}_{-0.17}$$

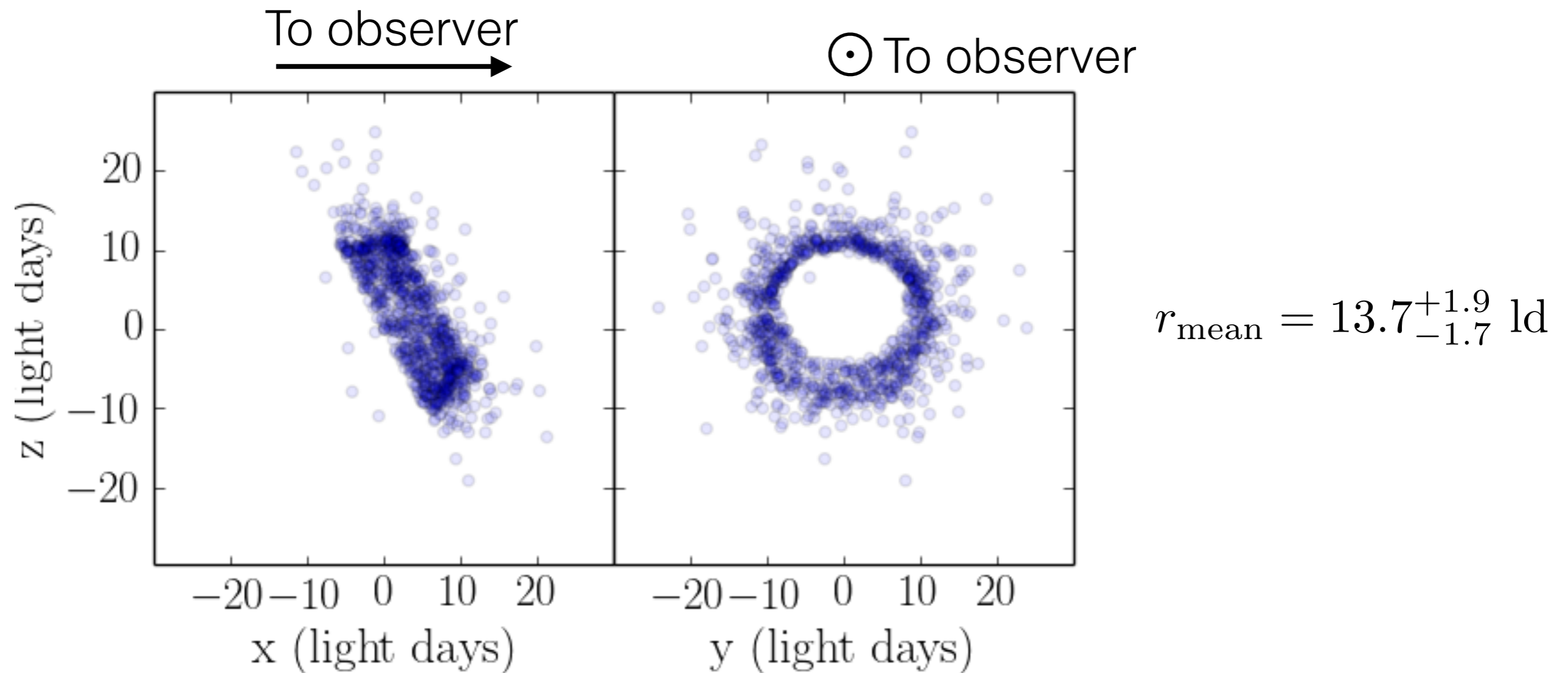
Of unbound orbits:
Inflow Outflow



Results: Mrk 279

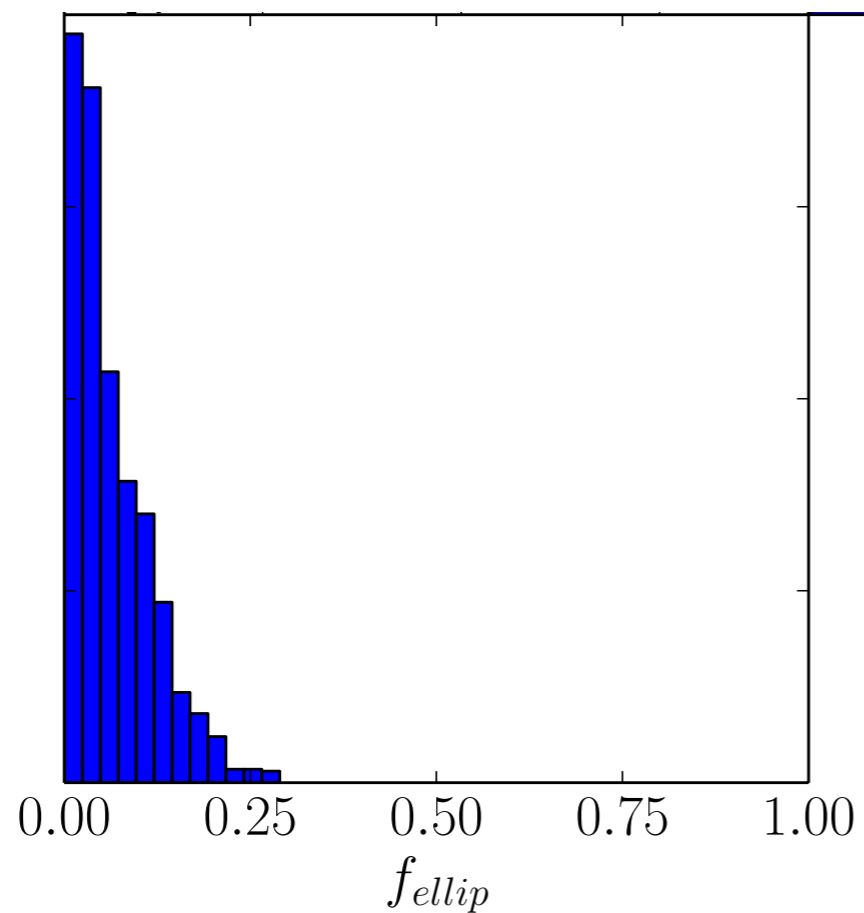


Results: Mrk 279



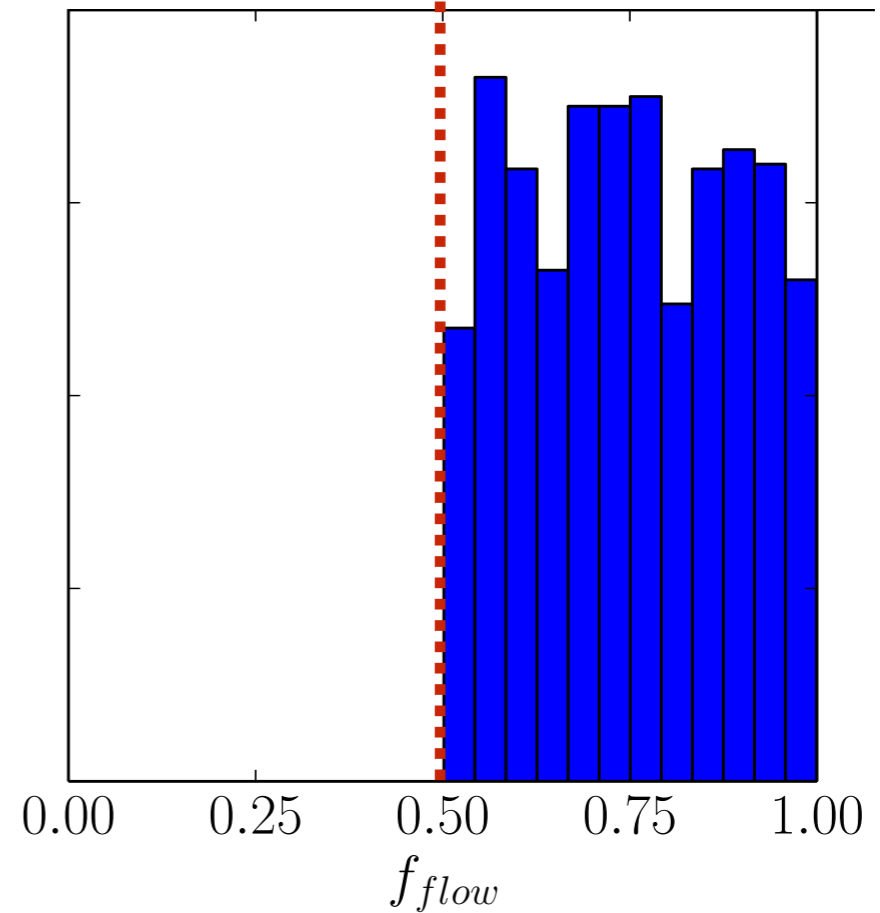
Results: Mrk 279

Fraction of clouds with bound, elliptical orbits

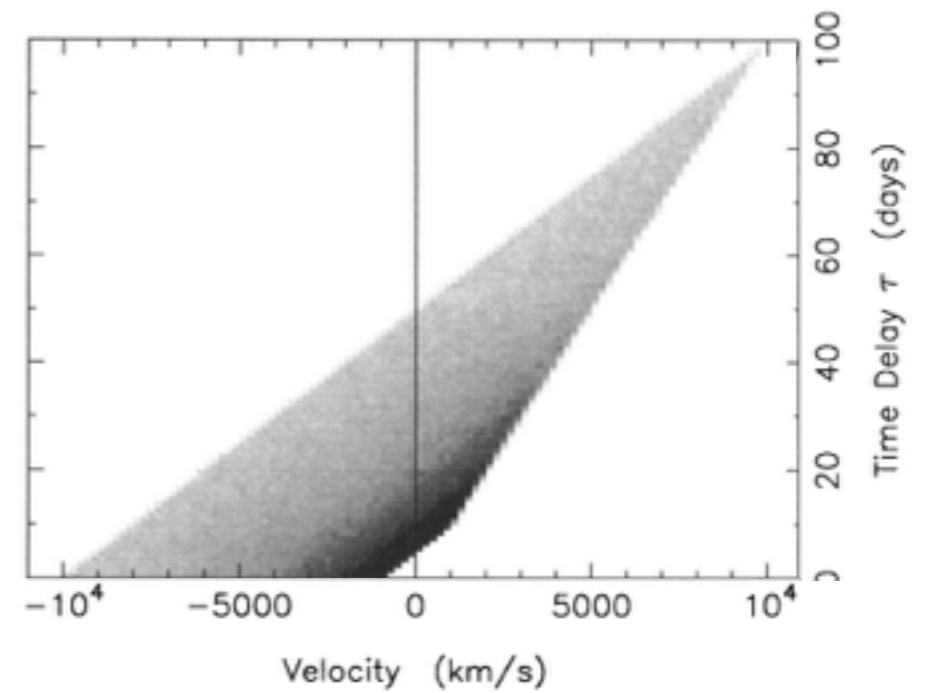
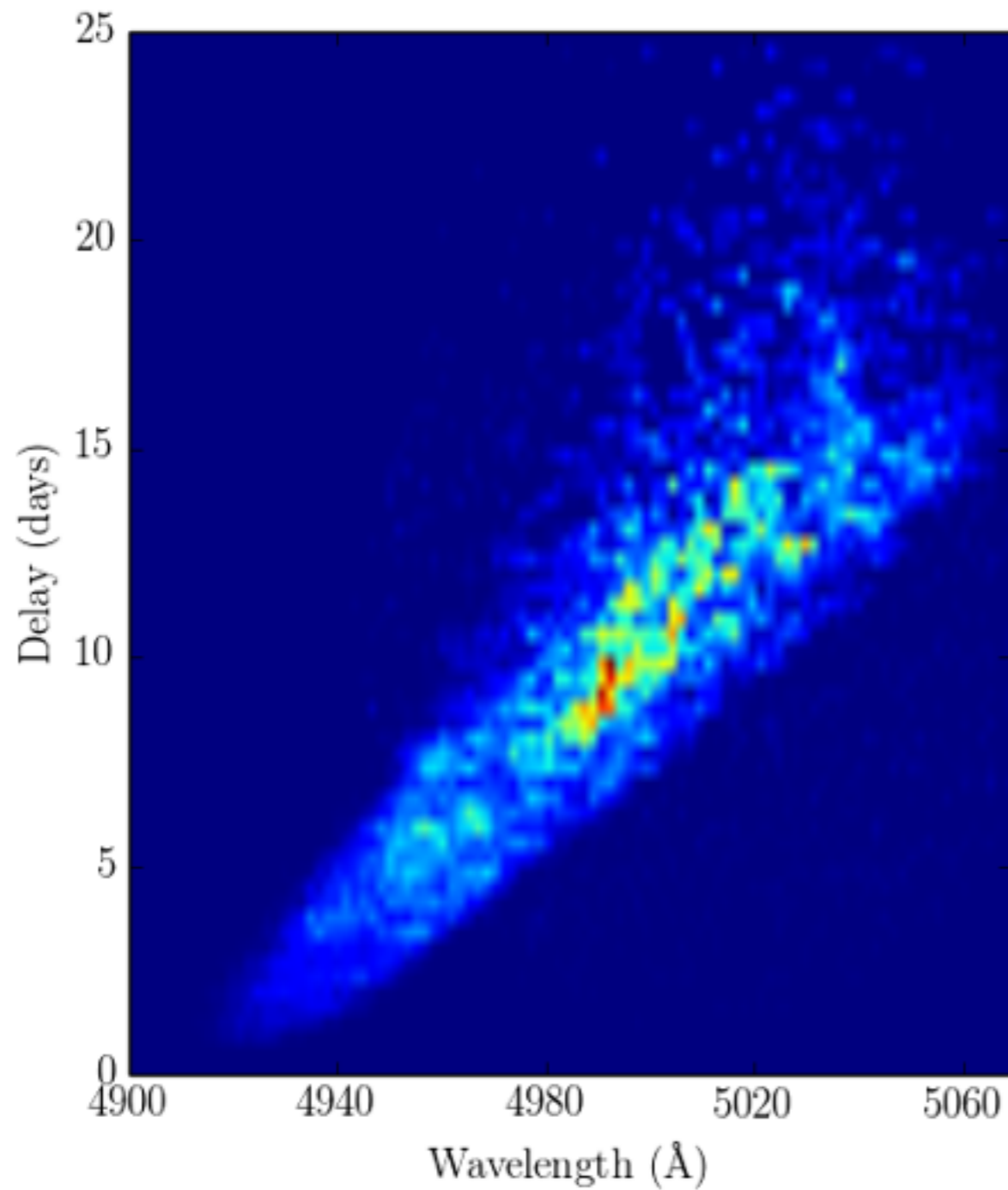


$$f_{ellip} = 0.049^{+0.065}_{-0.036}$$

Of unbound orbits:
Inflow Outflow



Results: Mrk 279



Spherically symmetric, outflow

Looking forward

- Want to improve the broad line region model to include more physics, e.g., photoionization and realistic outflow models
- Limitation: Needs to be computationally feasible
- Come talk to me, thoughts and ideas are welcome!

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Thank you!