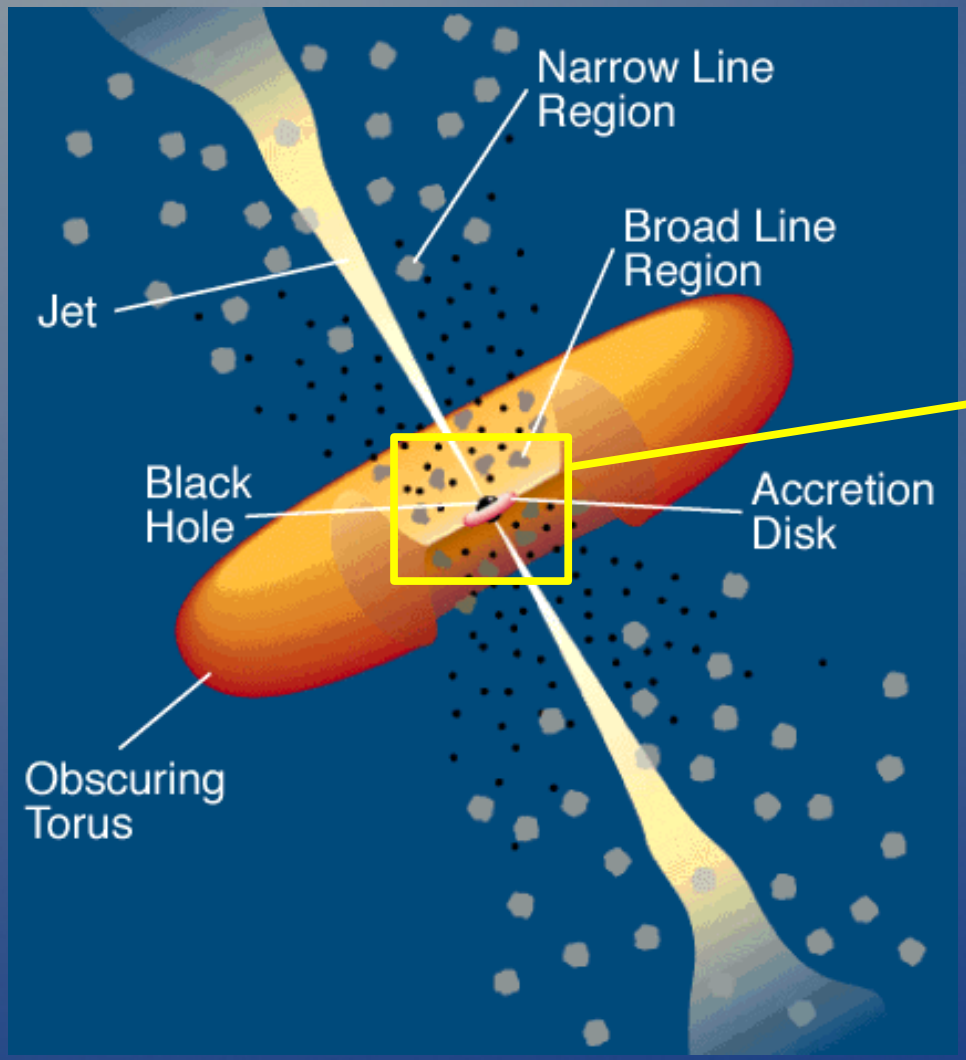
The Lick AGN Monitoring Project 2011: Dynamical Modeling of the Broad Line Region in Mrk 50

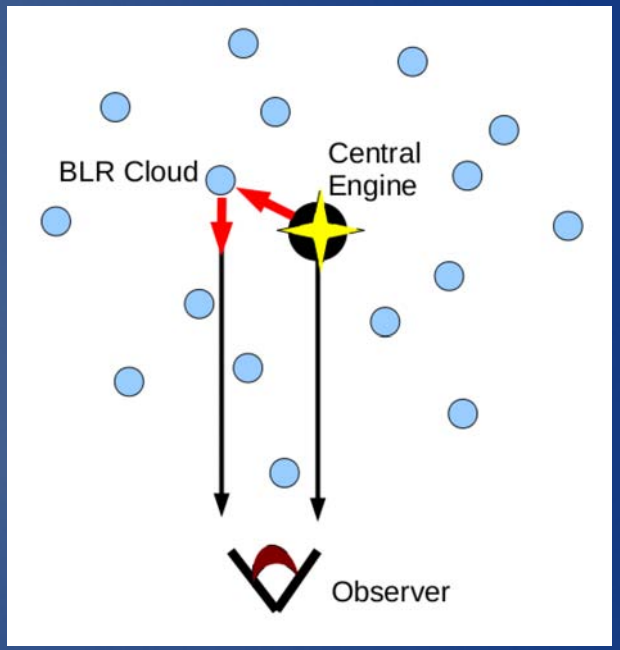
Anna Pancoast (UC Santa Barbara), Brendon J. Brewer, Tommaso Treu + LAMP 2011 Collaboration

AGN Winds in Charleston, October 16th, 2011

Measuring black hole masses in nearby active galactic nuclei (AGNs)



Credit: C.M. Urry and P. Padovani



Reverberation mapping: measure the time lag between the AGN continuum variability and the broad line variability

Measuring black hole masses in nearby active galactic nuclei (AGNs)

- $\mathbf{M = f\, c\tau\, v^2/G}$
- $\mathbf{v}$ = velocity of clouds from broad emission line width
- $\mathbf{c\tau \sim d}$ = average radius of BLR cloud orbits
- **f** depends upon geometry and kinematics (order unity)

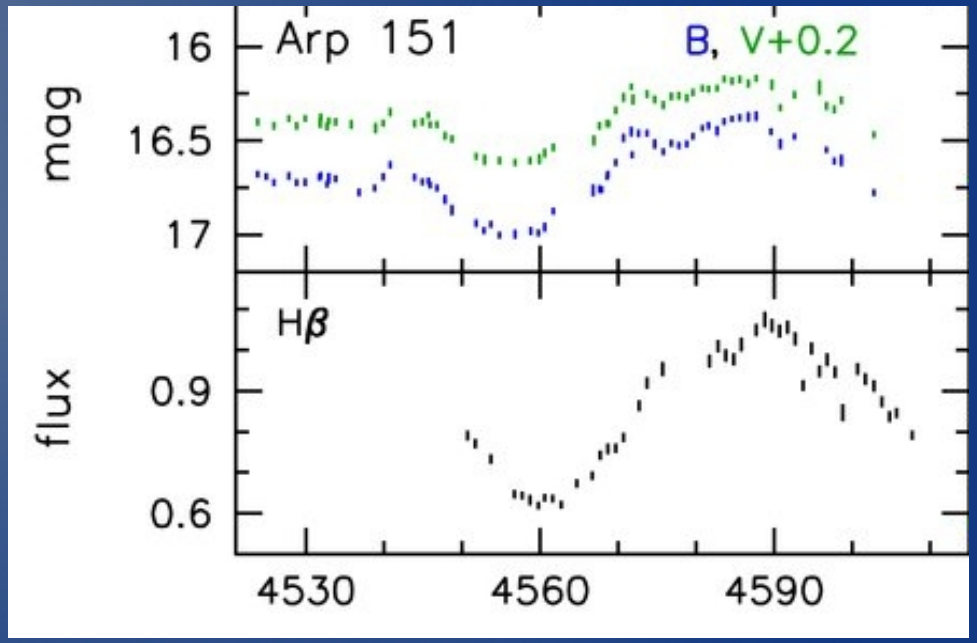


Figure from Bentz et al. 2009 ApJ 705, 199

The Lick AGN Monitoring Project (LAMP) 2011

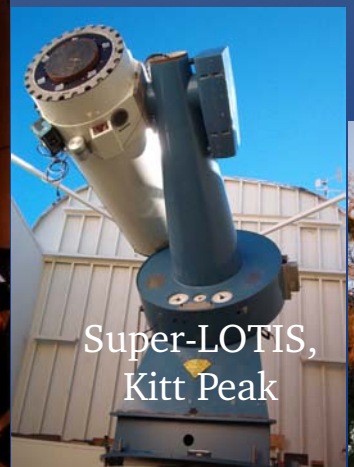
- Number of spectroscopy nights = 69
- Number of nights with data = 48


Shane telescope at Lick Observatory

- Observed 15 AGNs + 8 dropped targets
- First results: Mrk 50


West Mountain Observatory (WMO), BYU


Katzman Automatic Imaging Telescope (KAIT), Lick Observatory


Super-LOTIS, Kitt Peak

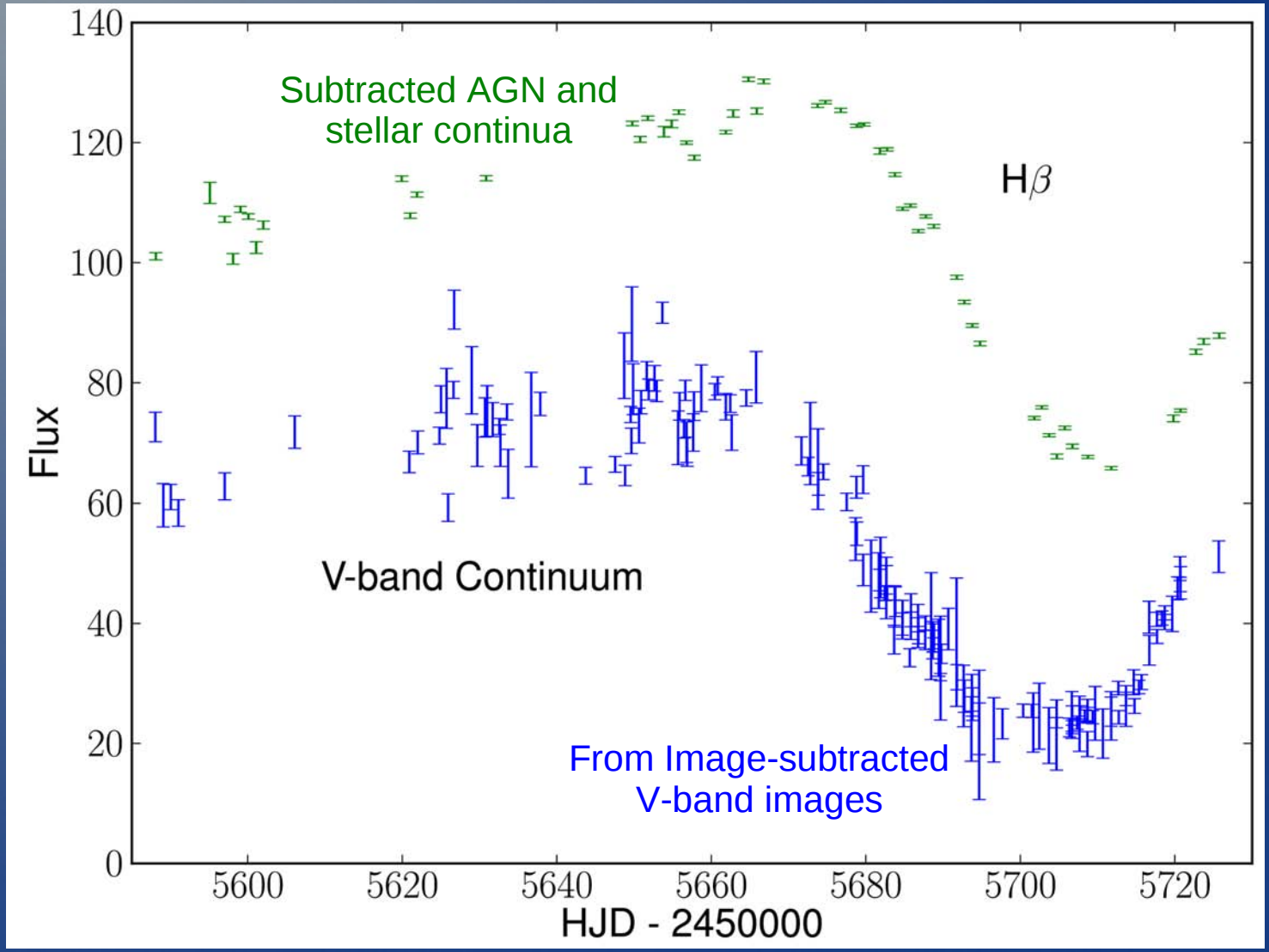

Palomar 60-inch telescope (P60)


Faulkes Telescope South (FTS)

Modeling reverberation mapping data

- Aaron Barth (Barth et al., Submitted) is leading the cross-correlation analysis to obtain traditional reverberation mapping black hole masses and broad line region radii.
- UCSB is leading the BLR modeling analysis to obtain:
  - Black hole masses that do not rely on a virial coefficient or normalizing factor
  - Constraints on the geometry and dynamics of the broad line region
- Dynamical modeling of reverberation mapping for LAMP 2008 data of Arp 151 carried out by Brewer, Treu, Pancoast et al. 2011.

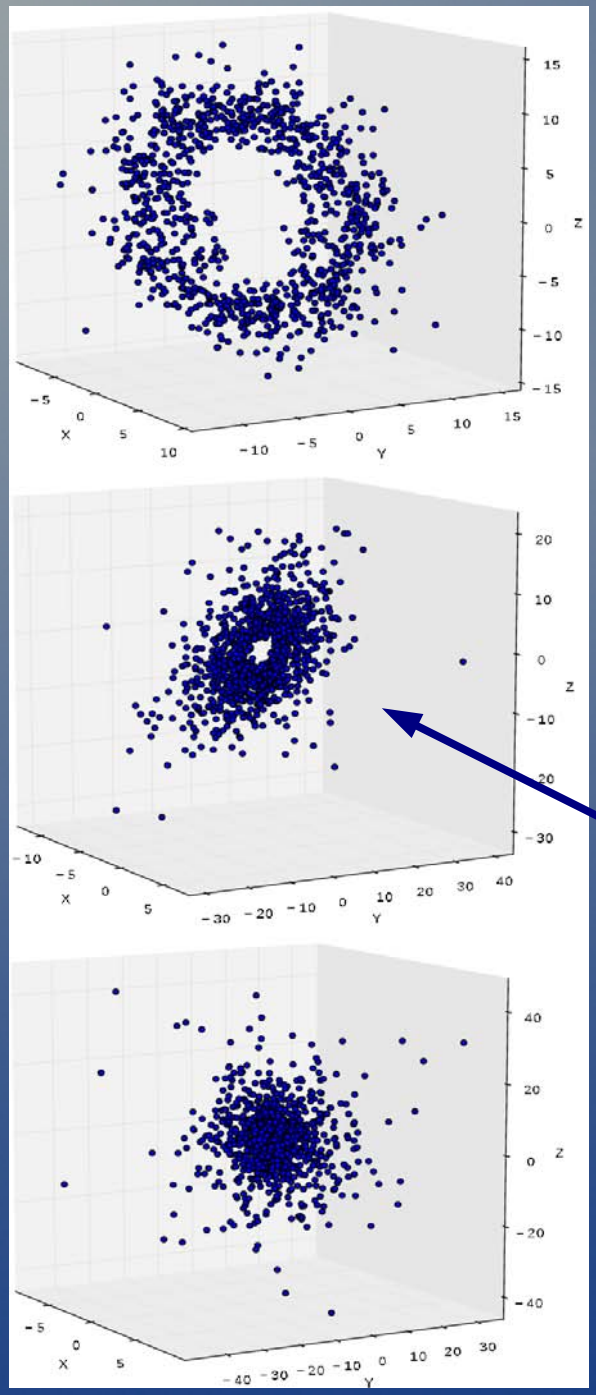
LAMP 2011 Reverberation Mapping Data of Mrk 50



Pancoast, Brewer, Treu et al., In preparation

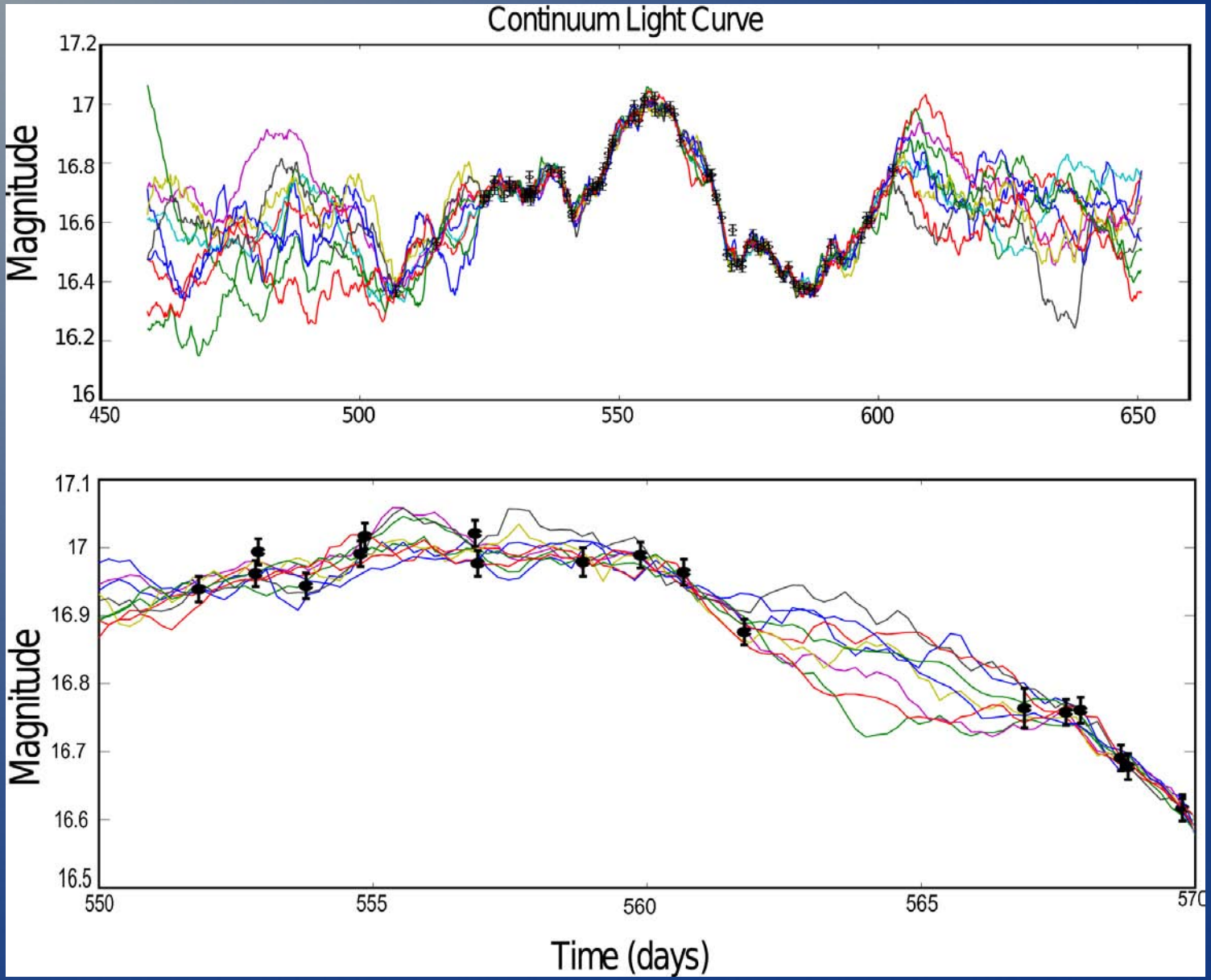
Our model for the broad line region (BLR)

- Model the V-band AGN continuum using Gaussian Processes



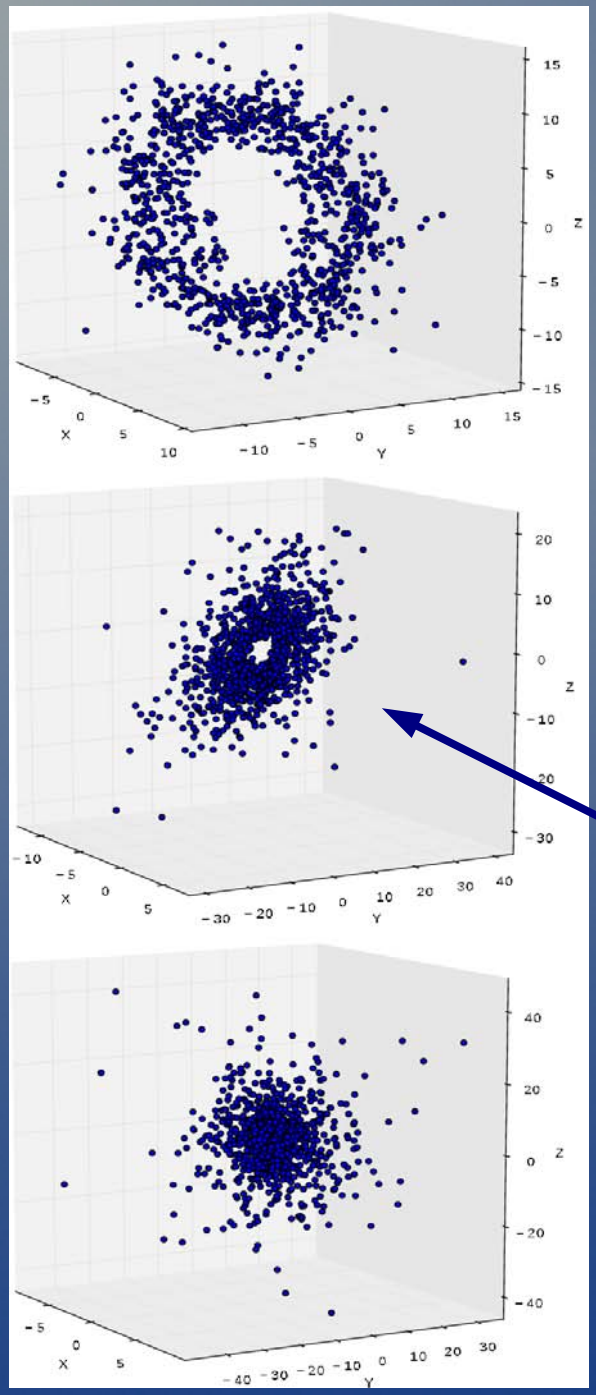
Pancoast, Brewer, Treu et al., In preparation

Gaussian Processes



Pancoast, Brewer, & Treu, 2011, ApJ 730

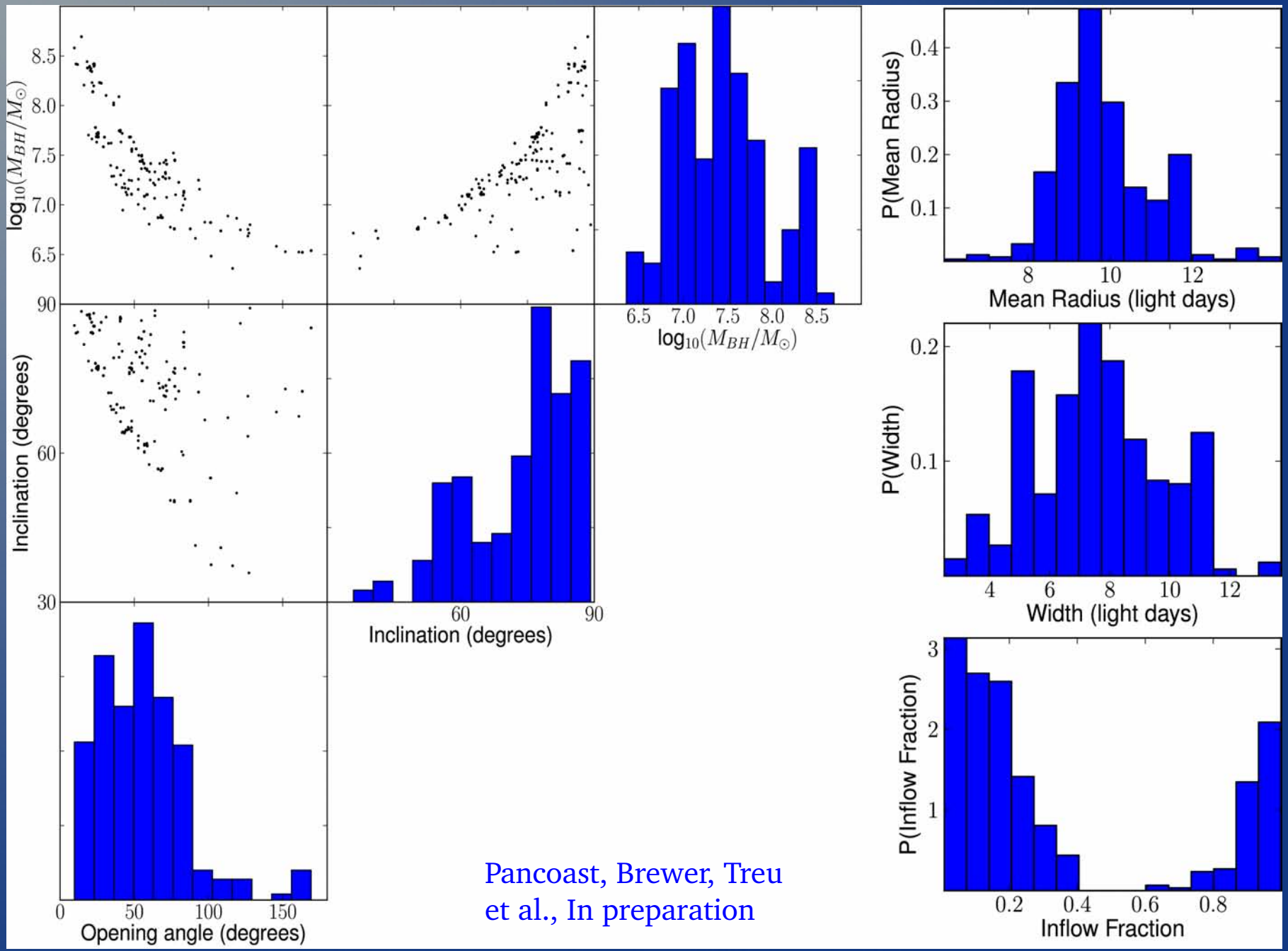
Our model for the broad line region (BLR)



- Model the V-band AGN continuum using Gaussian Processes
- Model the Hβ light curve using either a:
  - geometry-only model (gives the mean radius of the BLR)
  - geometry + dynamics model (gives the mean radius + black hole mass)

Pancoast, Brewer, Treu et al., In preparation

Inferred Model Parameters for Mrk 50



Pancoast, Brewer, Treu et al., In preparation

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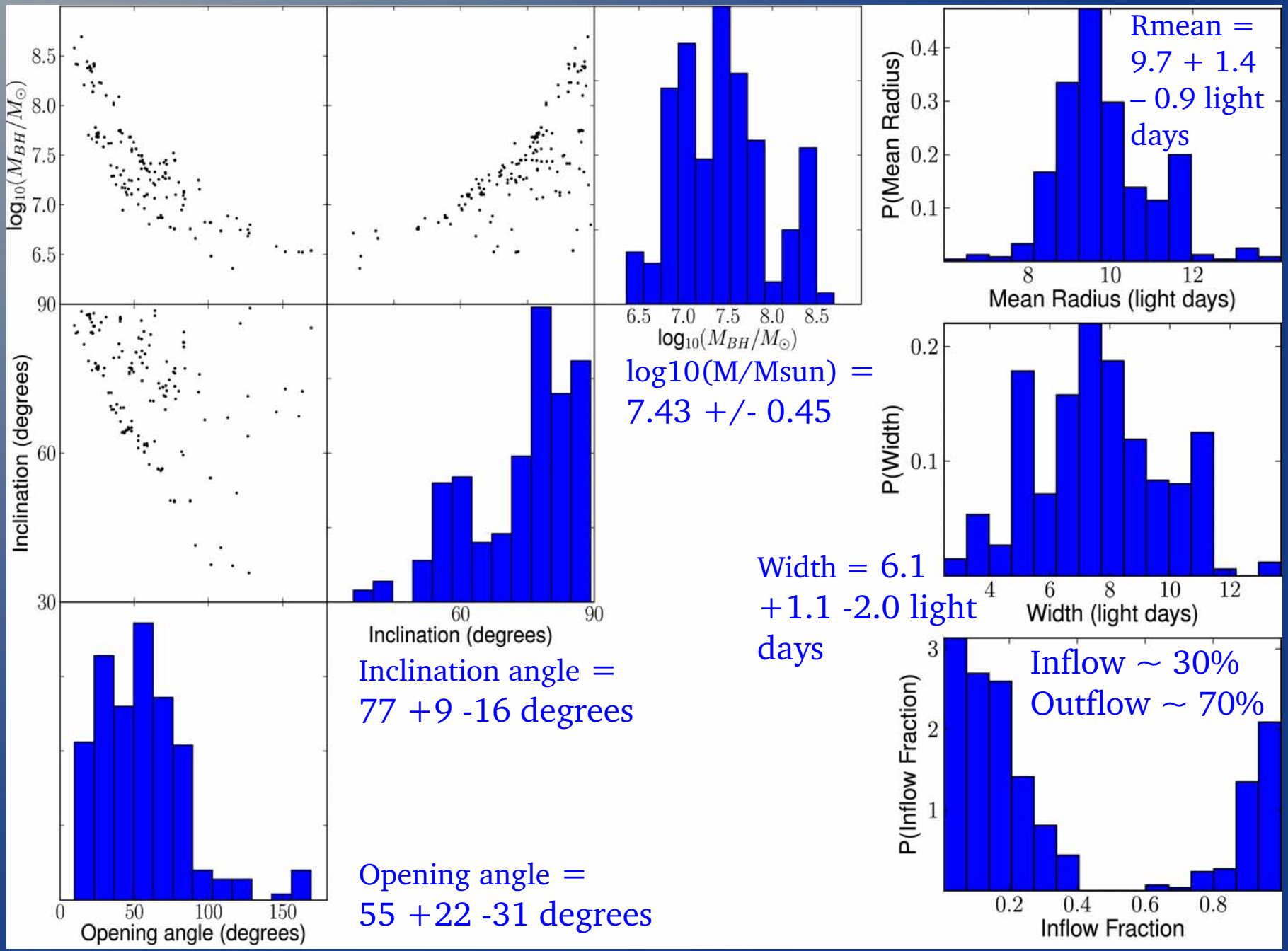


Black Hole Mass and the Normalization Constant

- $\log_{10}(M/M_{sun}) = 7.43 \pm 0.45$

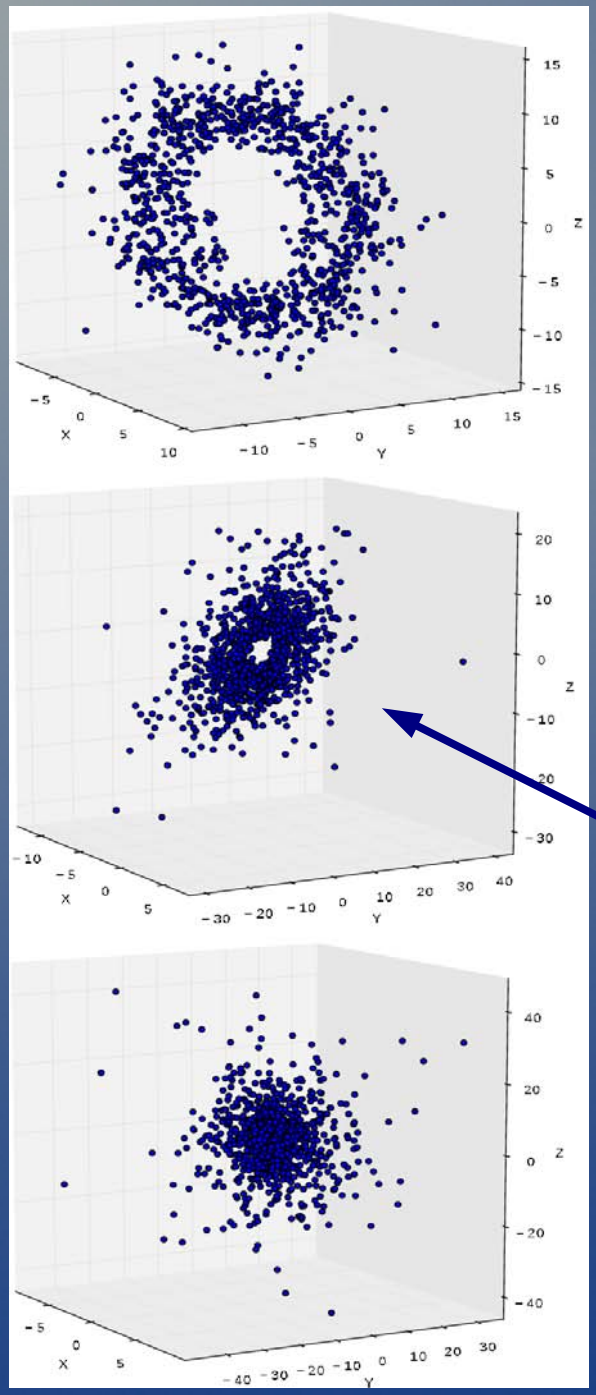
  or $M/M_{sun} = 2.69\ ^{+4.90}_{-1.74} \times 10^7$ → factor of 3 uncertainty

- Compare to M_{vir}, calculated using traditional reverberation mapping analysis by Barth et al. (Submitted), to estimate the normalization constant:

  - $M/M_{vir} = f \qquad \log_{10}(f) = 0.64 \pm 0.45$

- Given the uncertainty on f, our estimate for Mrk 50 is consistent with values by Onken et al. 2004, Woo et al. 2011, and Graham et al. 2011.

What does Mrk 50 look like?



Observer's
LOS
(x-axis)

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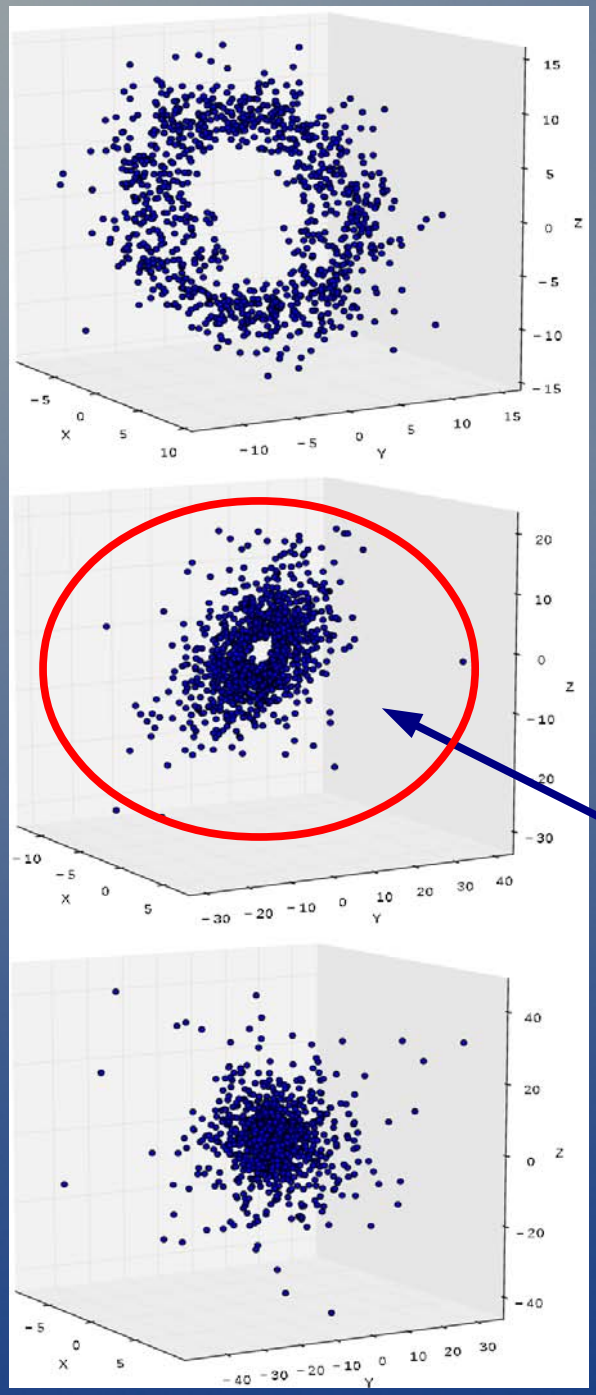

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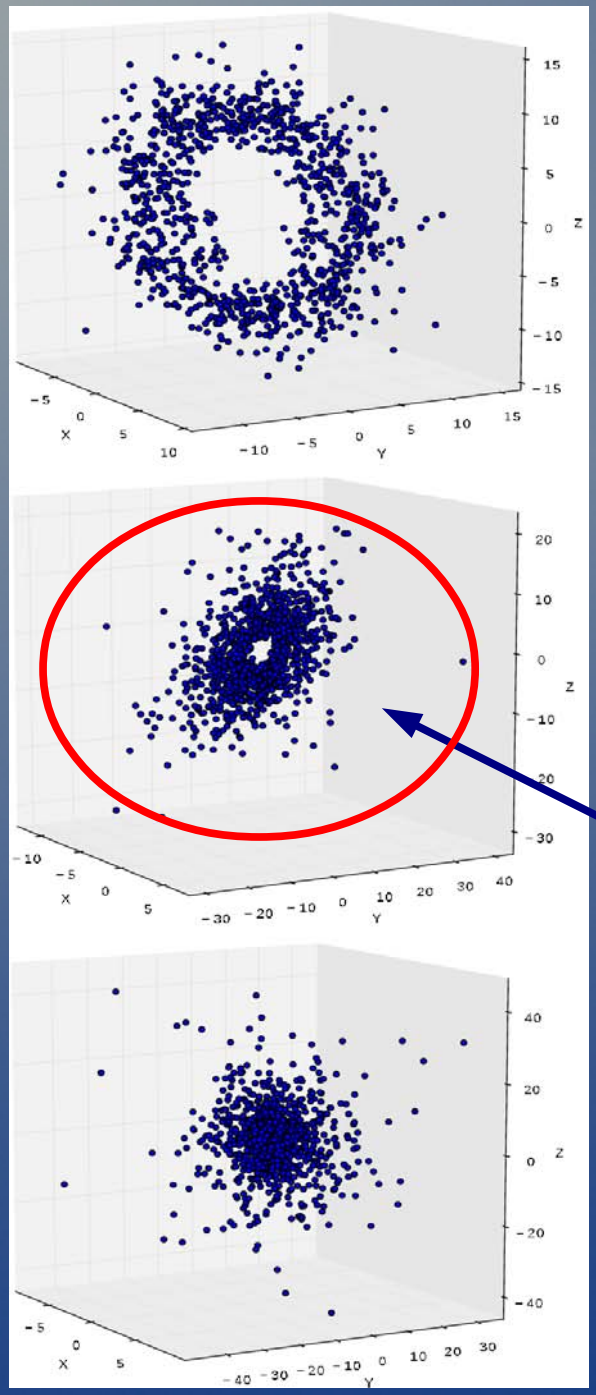
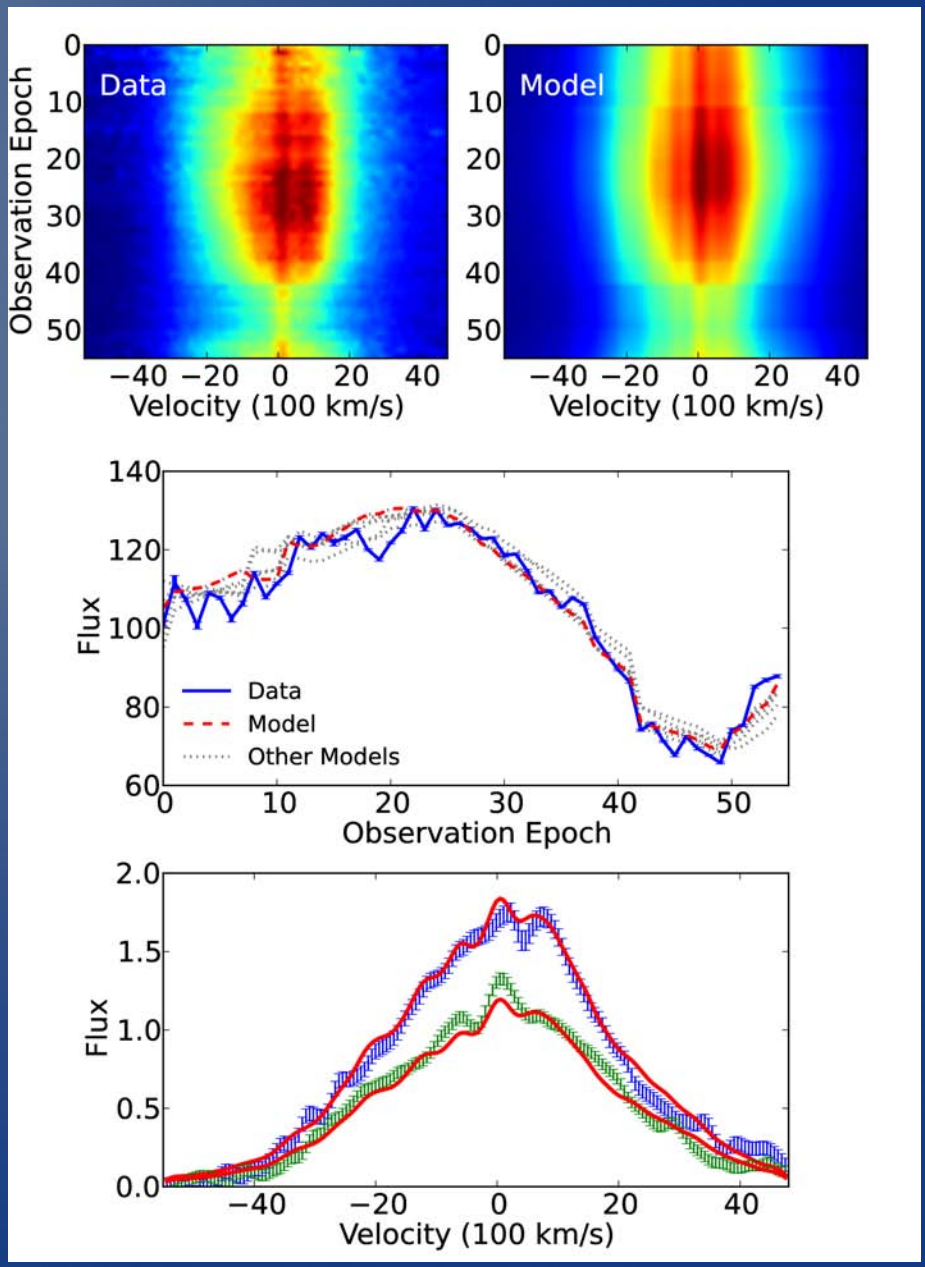
And how good is the model fit?



Observer's LOS (x-axis)



Pancoast, Brewer, Treu et al., In preparation

Conclusions

- We recently completed a reverberation mapping campaign: Lick AGN Monitoring Project 2011 with 15 bright AGNs
- Dynamical modeling of Mrk 50 allows us to constrain black hole mass and the geometry/dynamics of the BLR:
  - Black hole mass and normalization constant constrained to within 0.45 dex
  - Geometry constrained to be a nearly face-on wide, thick disk
- Future goal: Within this direct modeling framework implement and test more physically motivated models.
  Suggestions welcome!