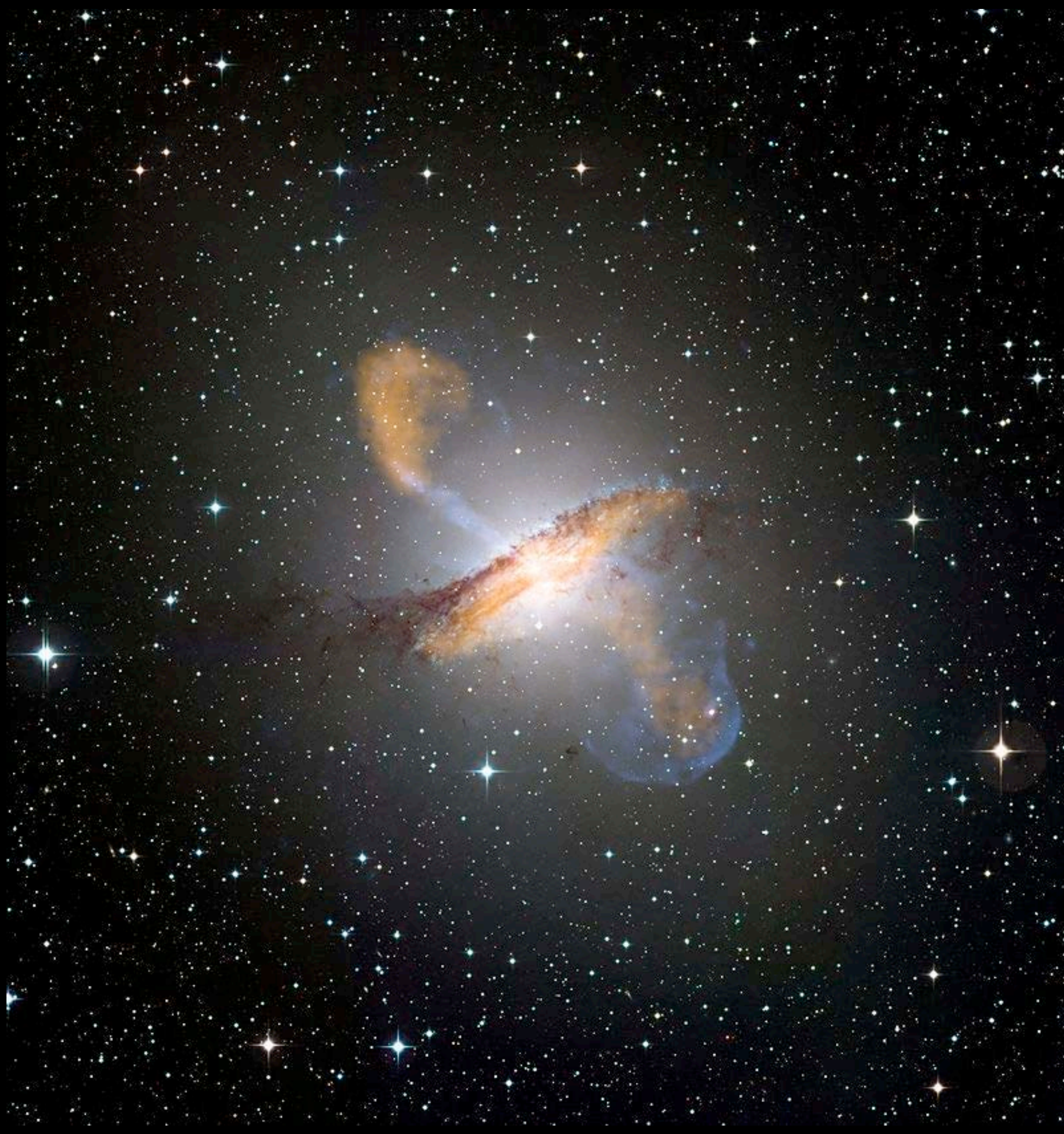


# The Broad Line Region of AGNs

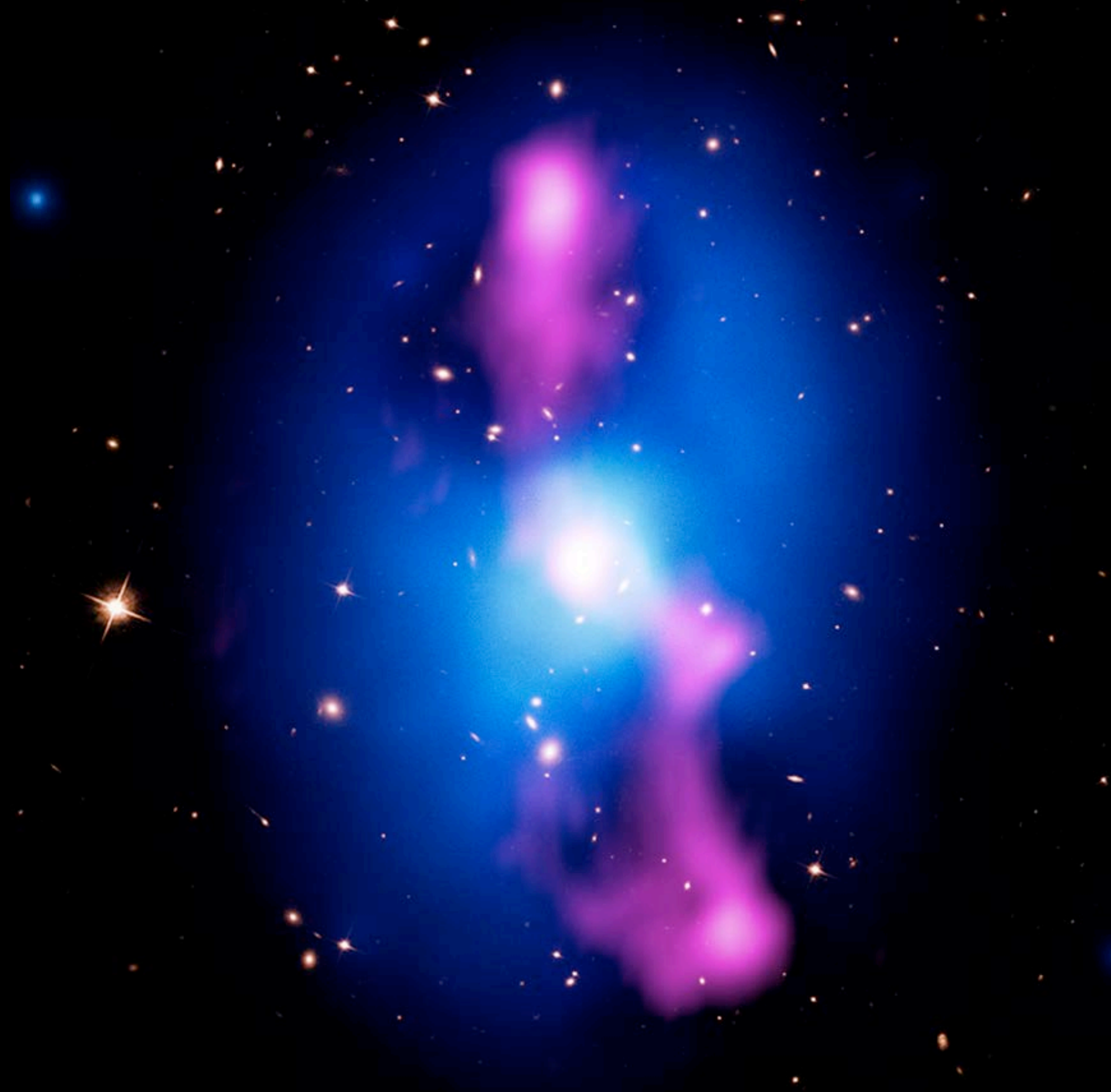


**Misty C. Bentz**  
Georgia State University

# Active Galactic Nuclei Affect Galaxies and Beyond



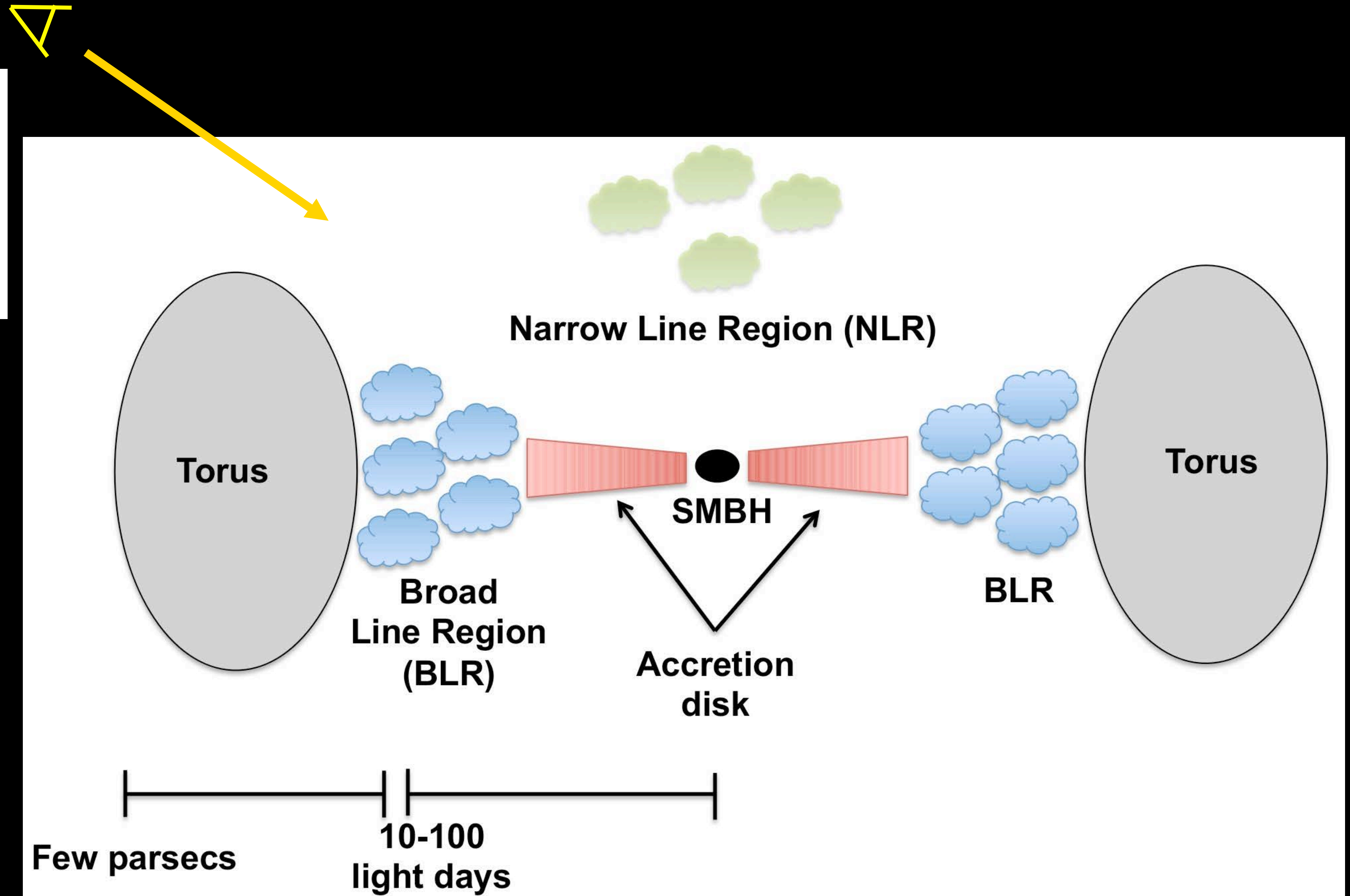
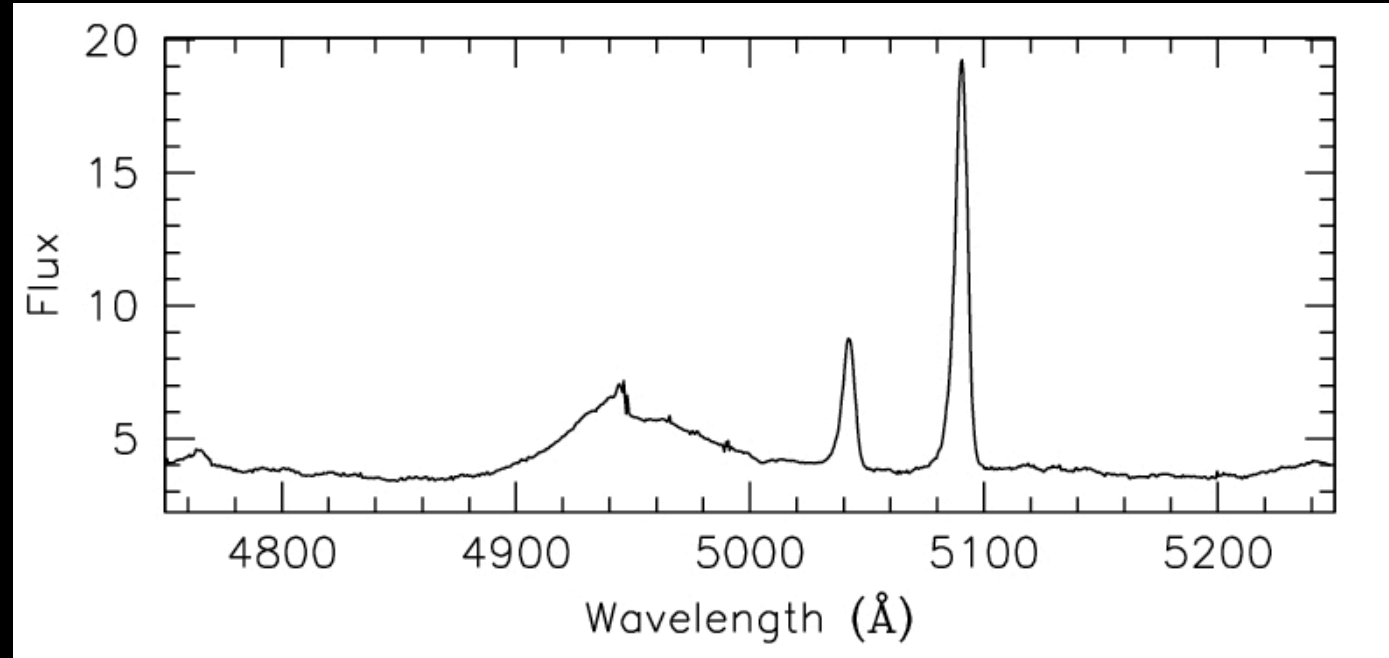
ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre);  
NASA/CXC/CfA/R.Kraft et al. (X-ray)



X-ray: NASA/CXC/Univ. of Waterloo/A.Vantyghem et al;  
Optical: NASA/STScI; Radio: NRAO/VLA

# Broad Line Region in Context

## Broad-lined (Type 1)



BLR gas:

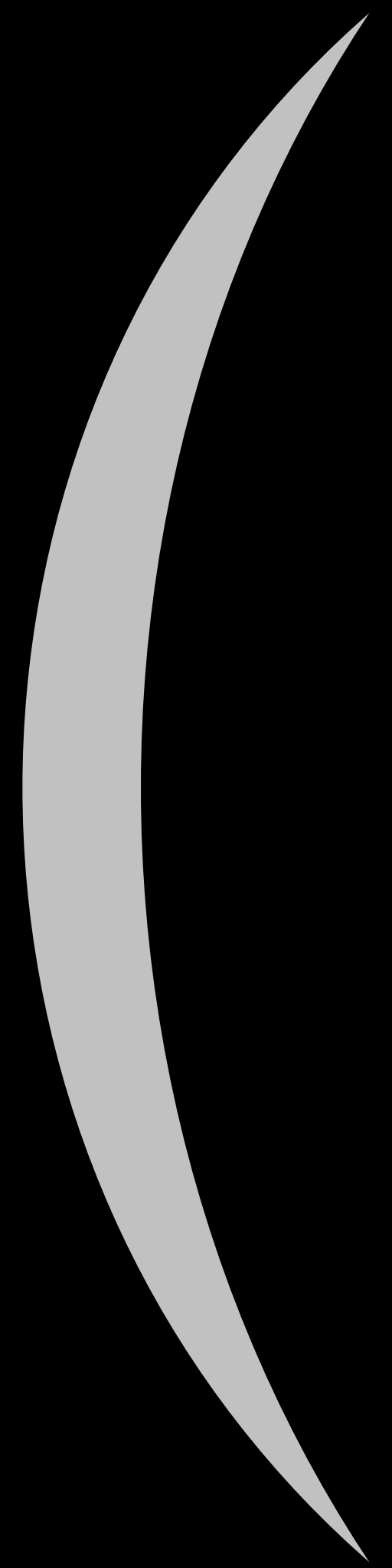
$V \sim$  few 1000 km/s

variable flux

$R \sim$  few–10s of light days

# Measuring Sizes with Time Delays

Telescope



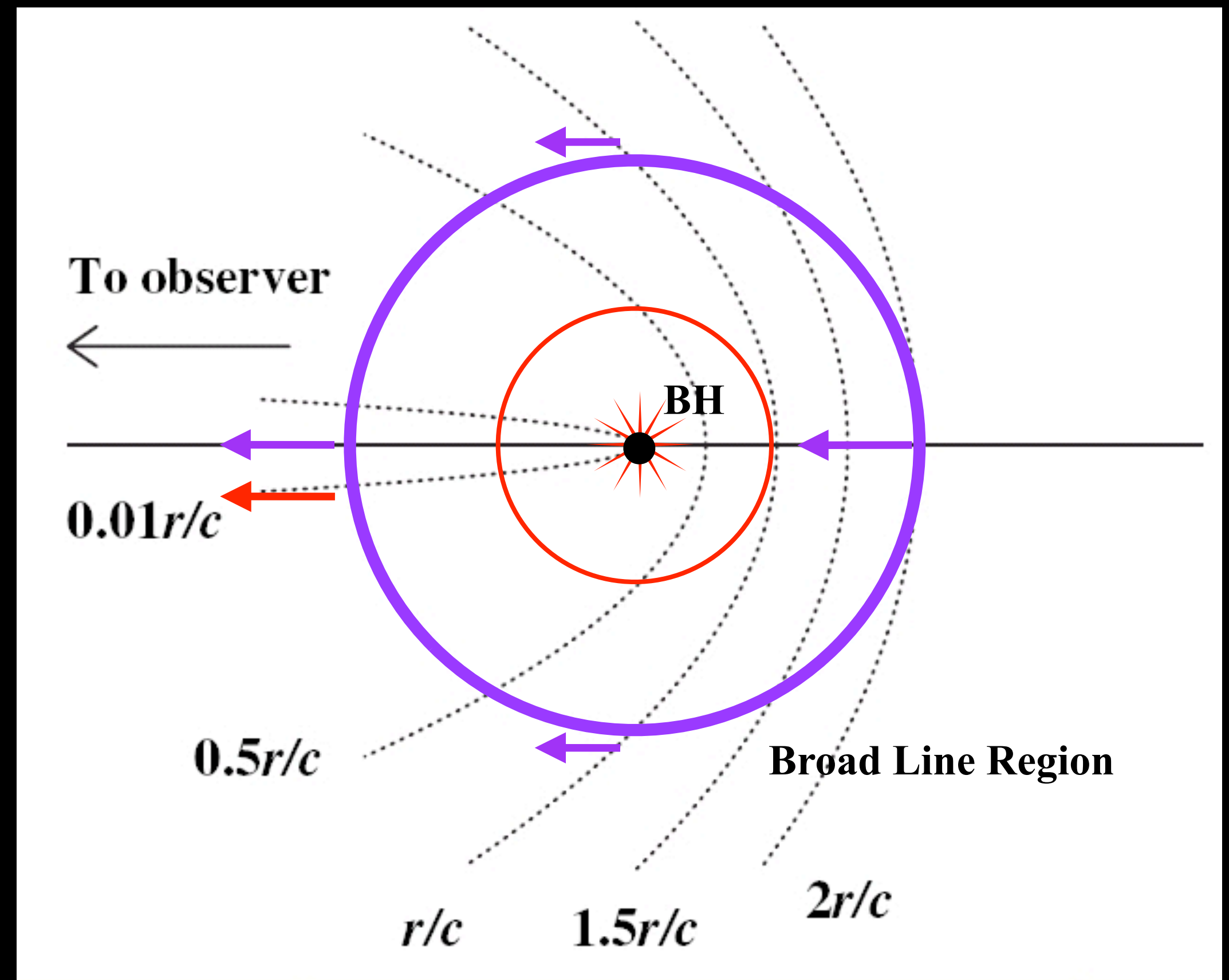
$\tau = 0$

$\tau = 2r/c$

$\tau = r/c$

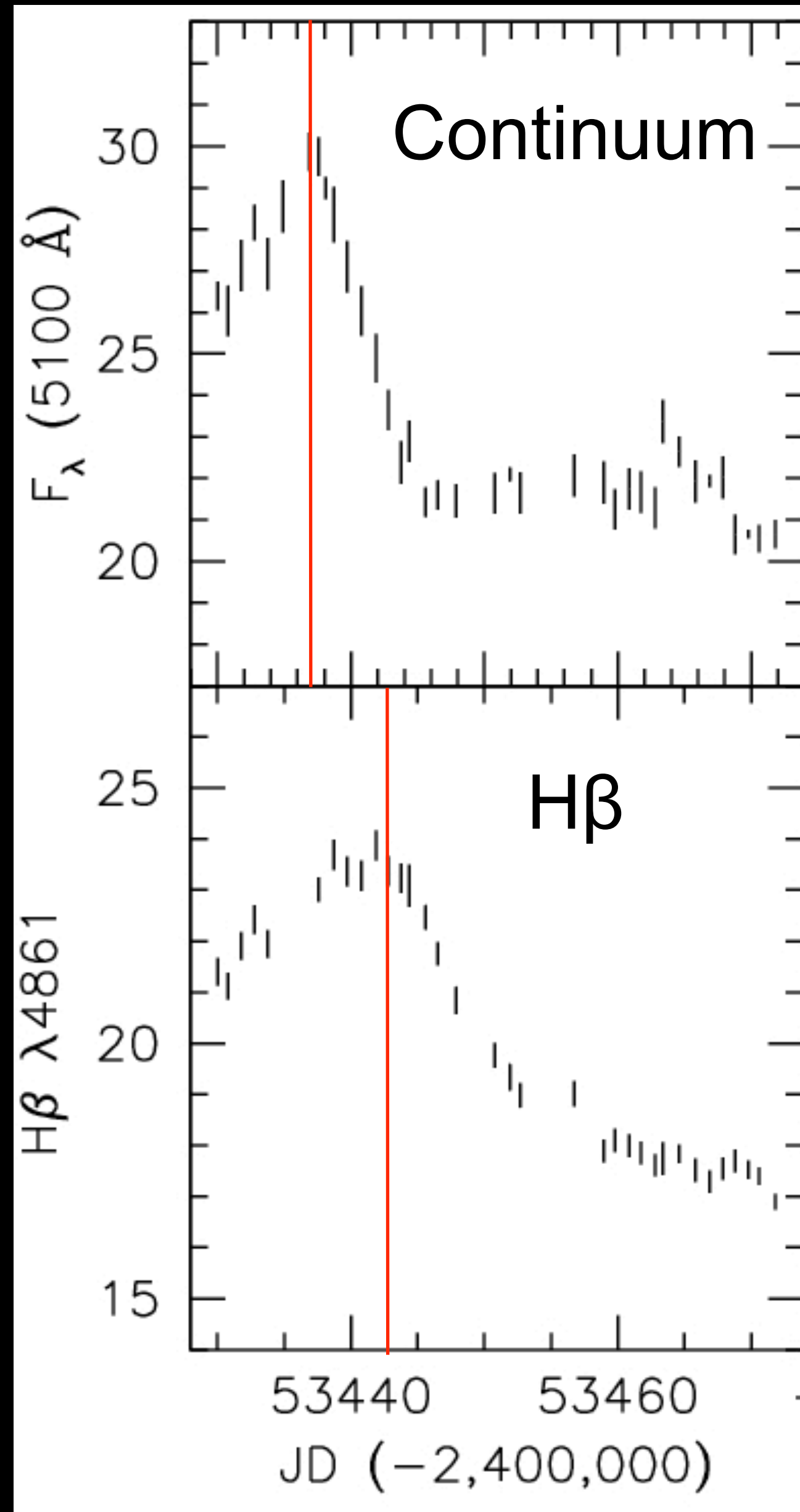
Average  $\tau = r/c$

AGN

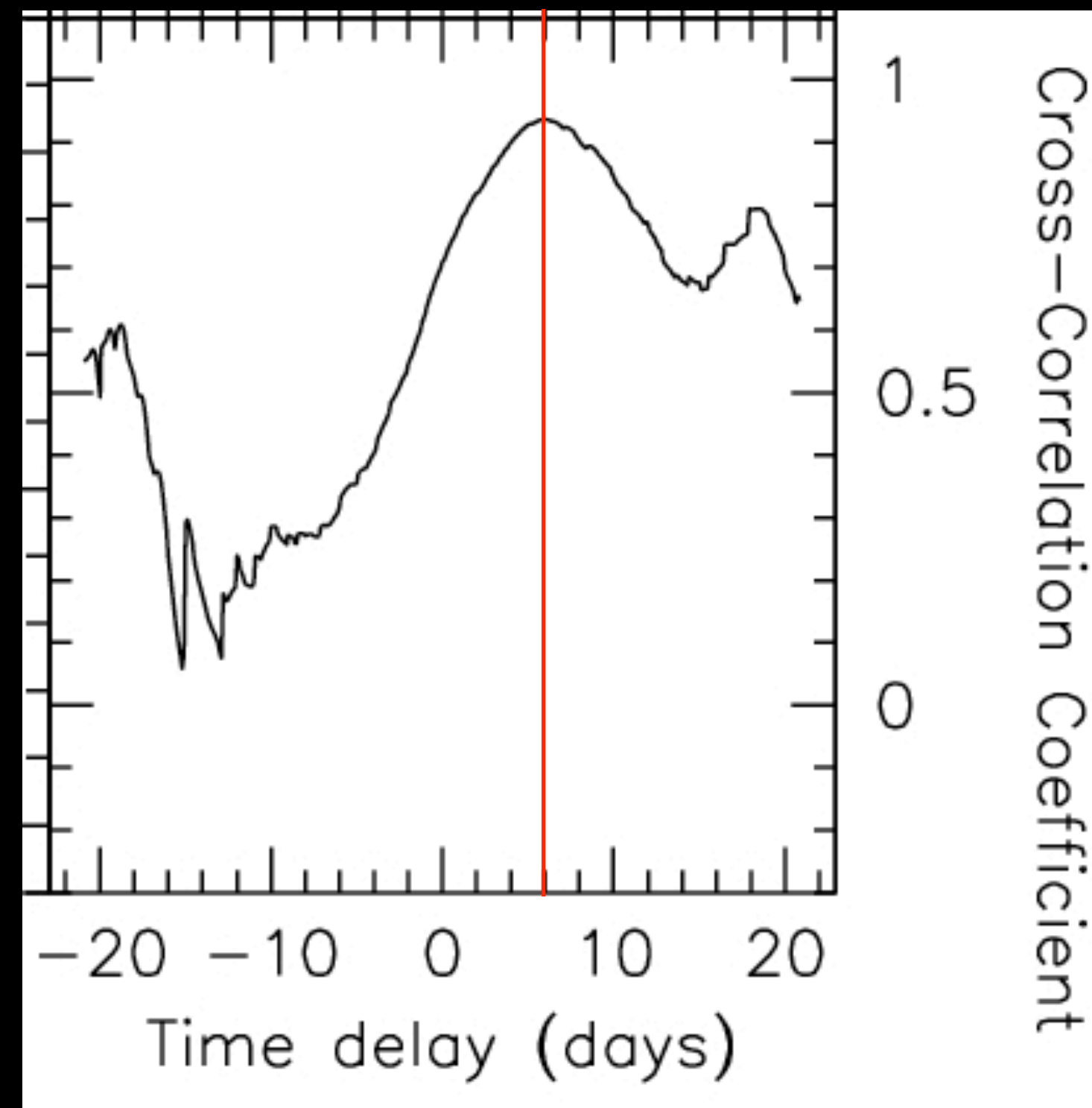


Red = continuum  
Purple = broad line

# Reverberation Mapping with Real Data: NGC4151



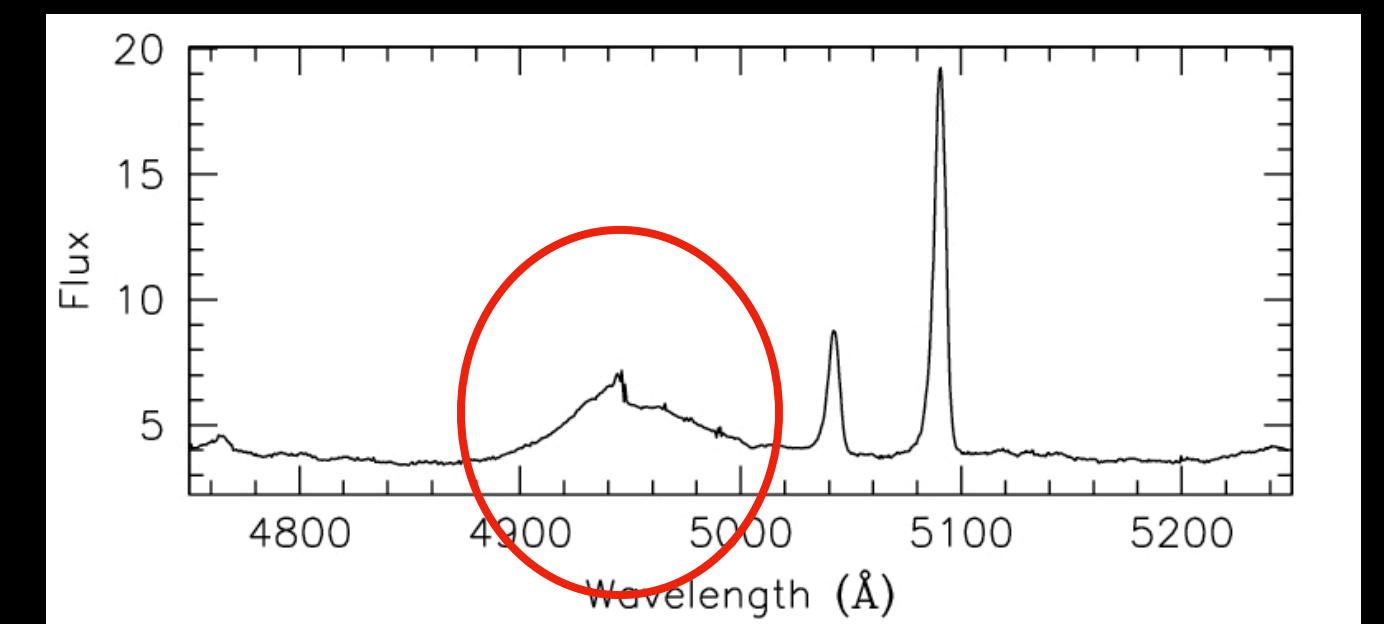
Time delay between the light curves: 6 days



*Bentz et al. 2006*

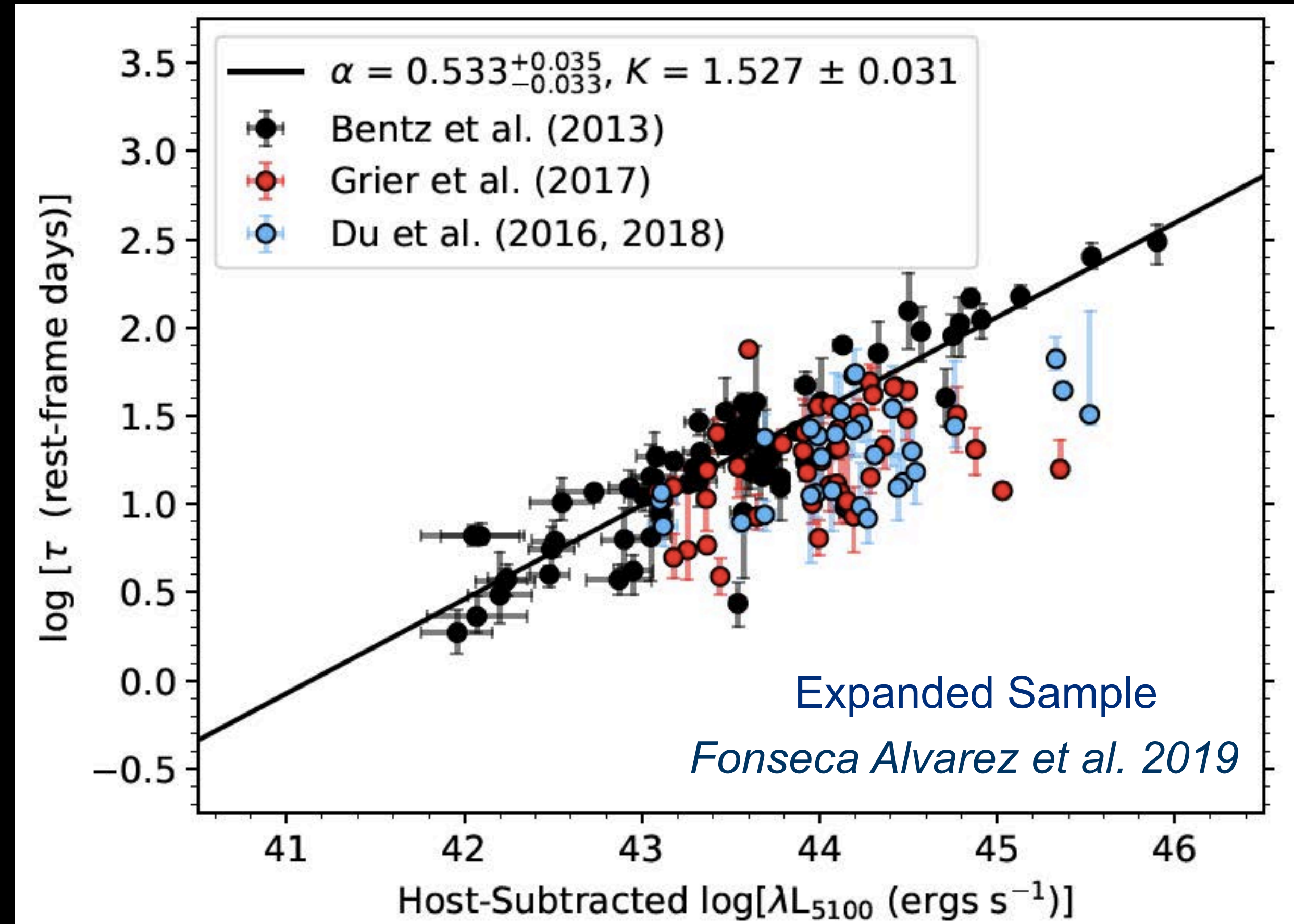
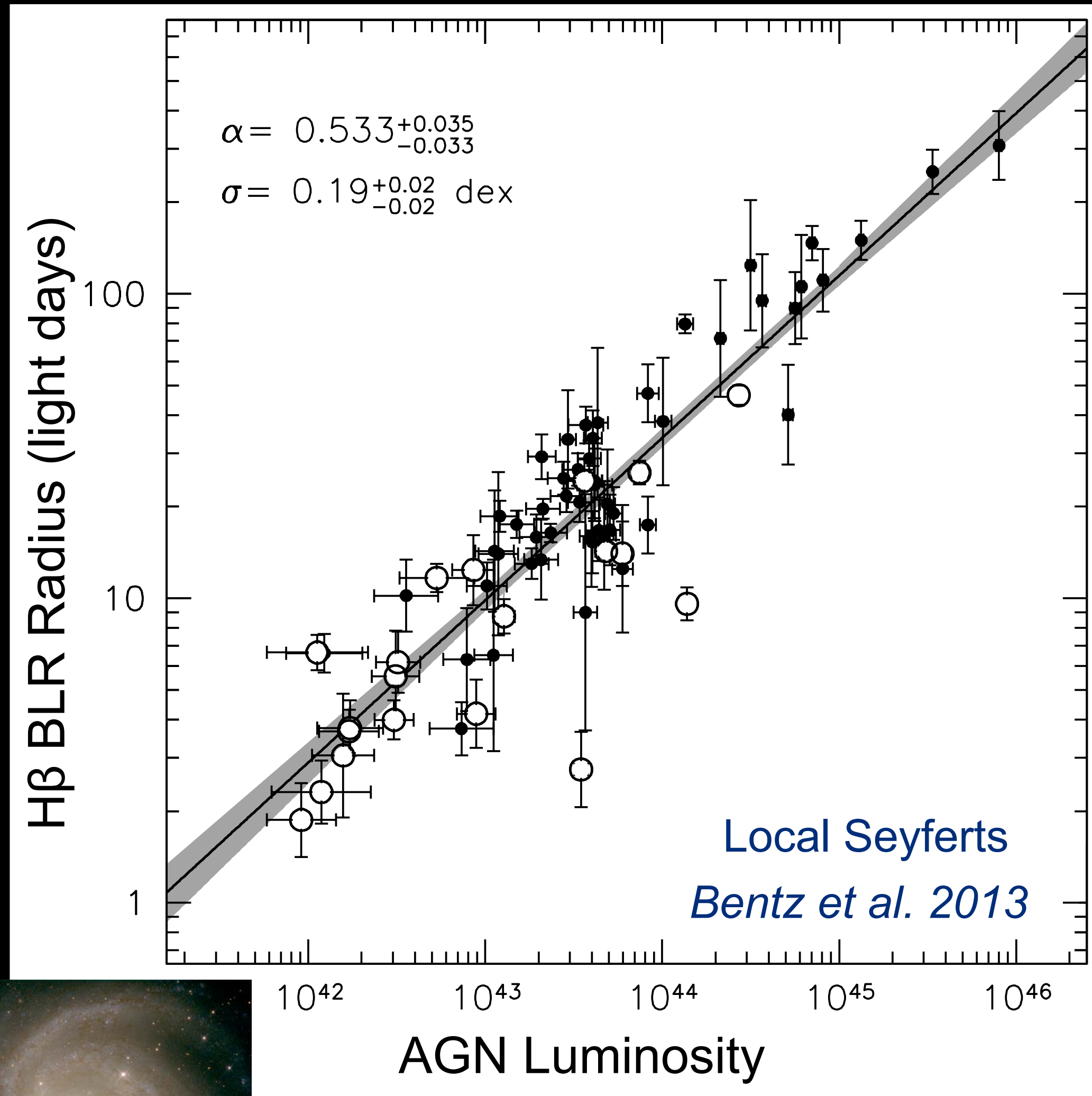
→ typical H $\beta$  reverberating region had  $R=6$  light-days

Combined with broad line velocity width → mass!



# Radius - Luminosity Relationship

Typical size of emission region increases for higher L



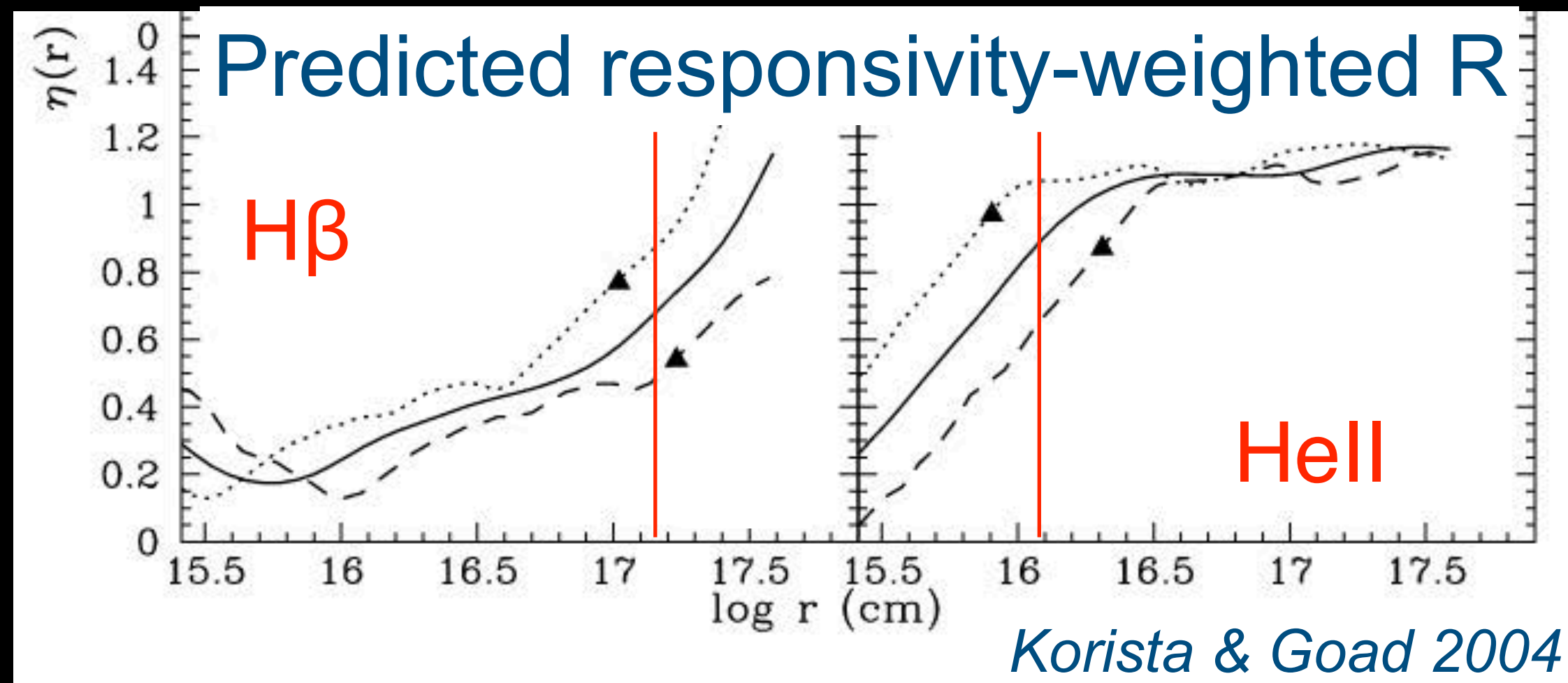
↑ corrected for host-galaxy starlight

Complication: does R have an L or L<sub>edd</sub> dependence?

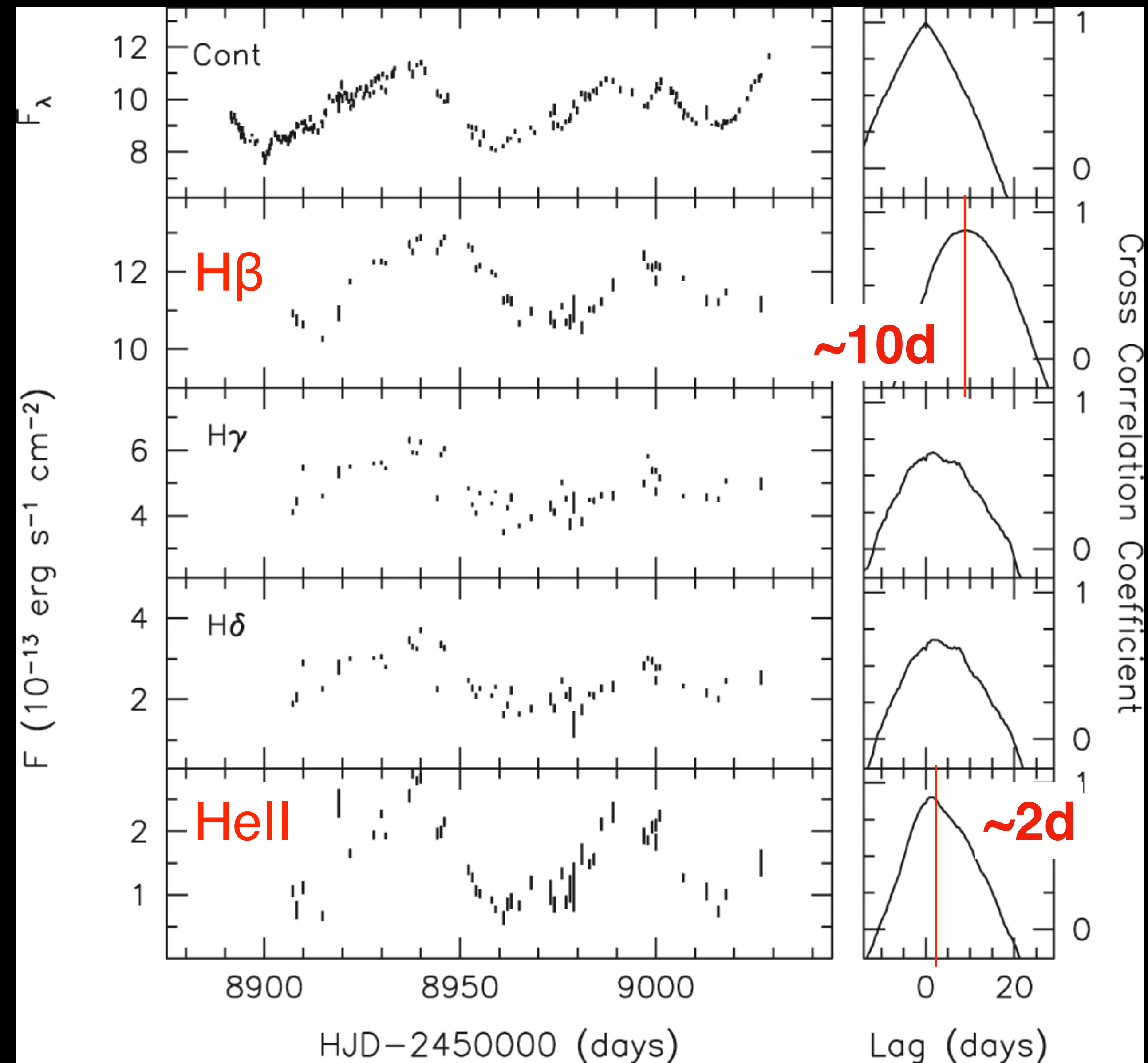
# Ionization Stratification

Gas at different distances/  
ionization parameter  
will “echo” with different lags

Lower ionization parameter  
*farther* from the black hole



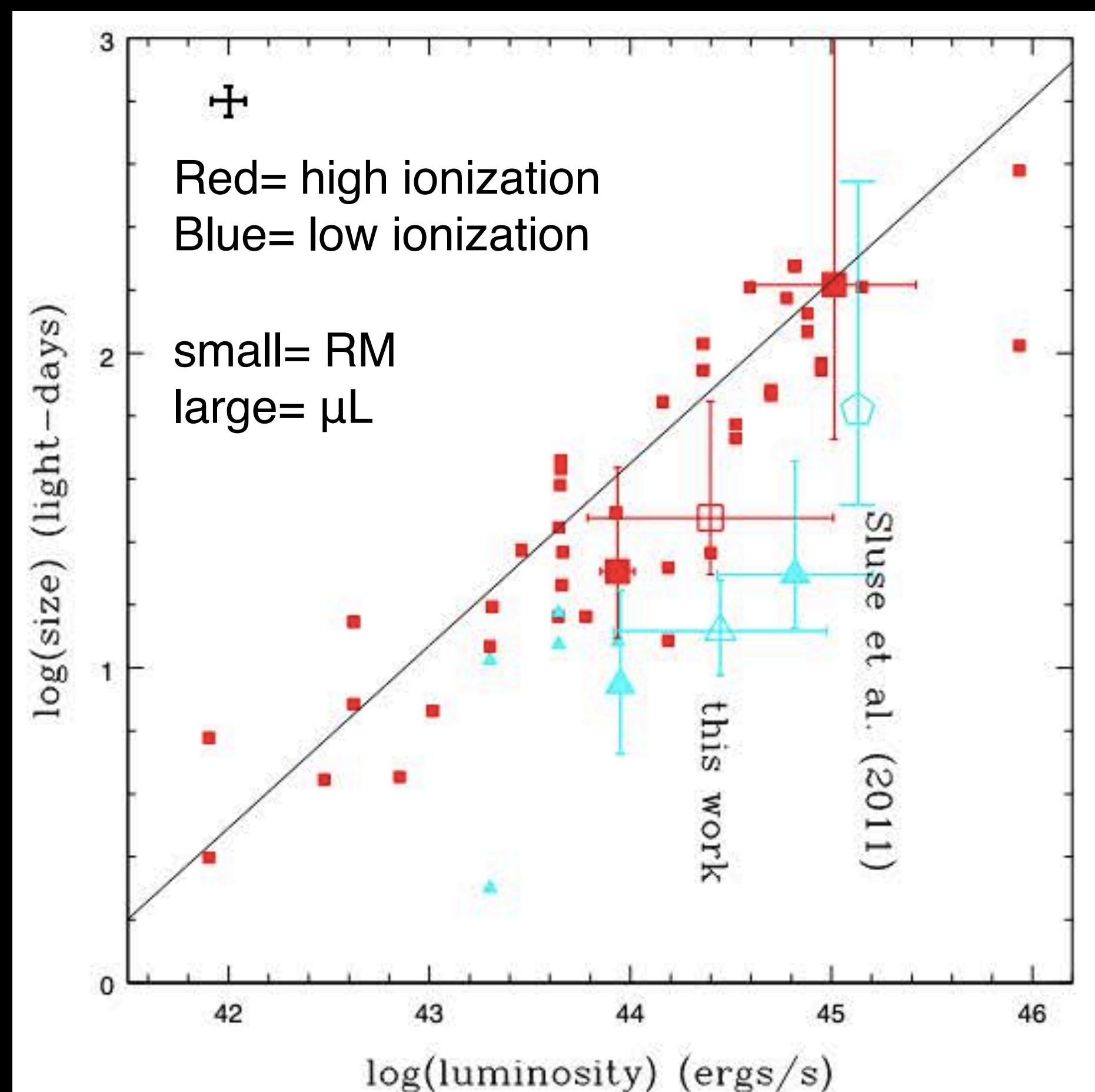
Higher ionization parameter  
*closer* to the black hole



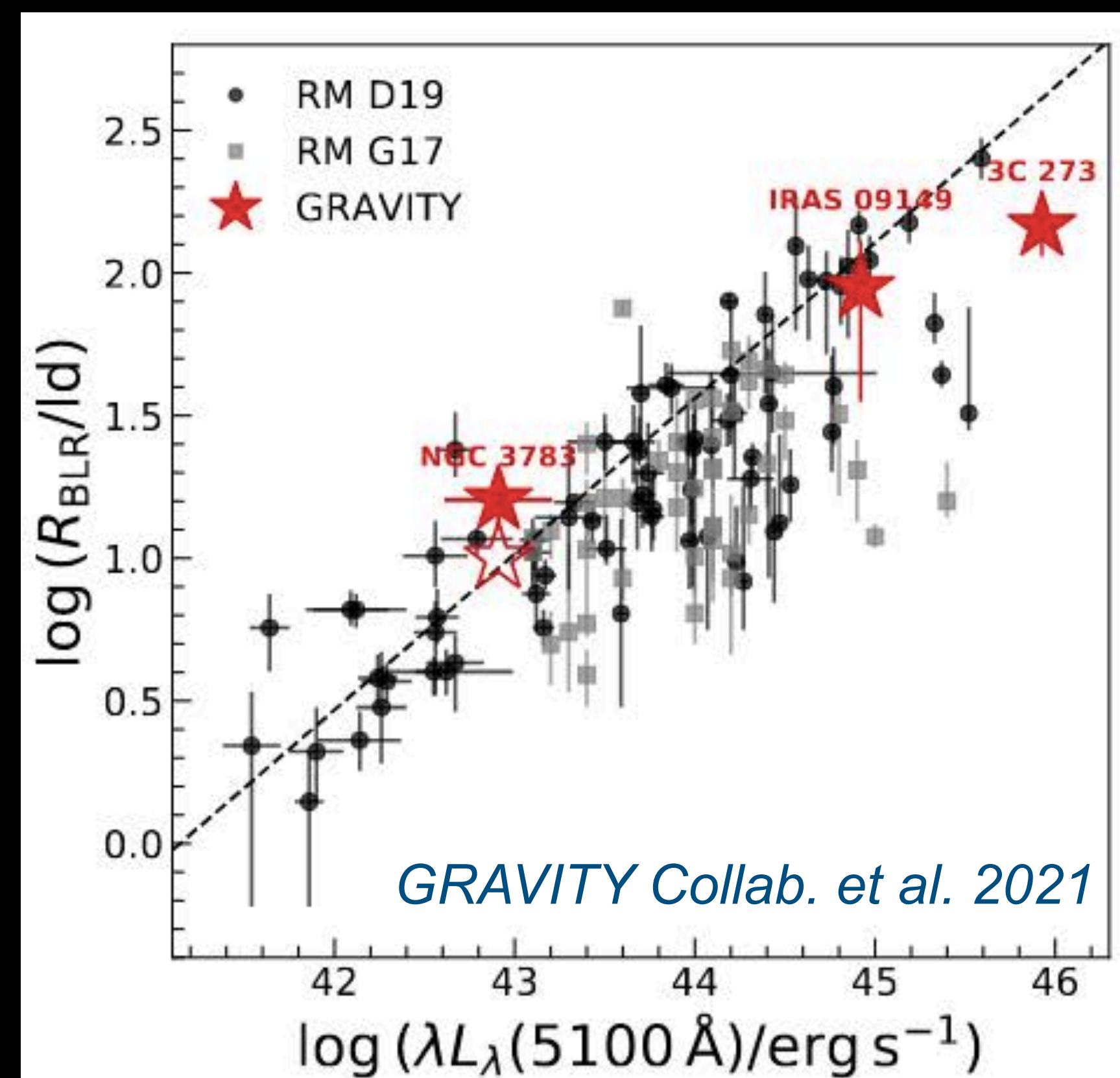
*Bentz et al. 2021*

# Comparing BLR Size Measurements

Microlensing and interferometry show good agreement with BLR sizes from RM



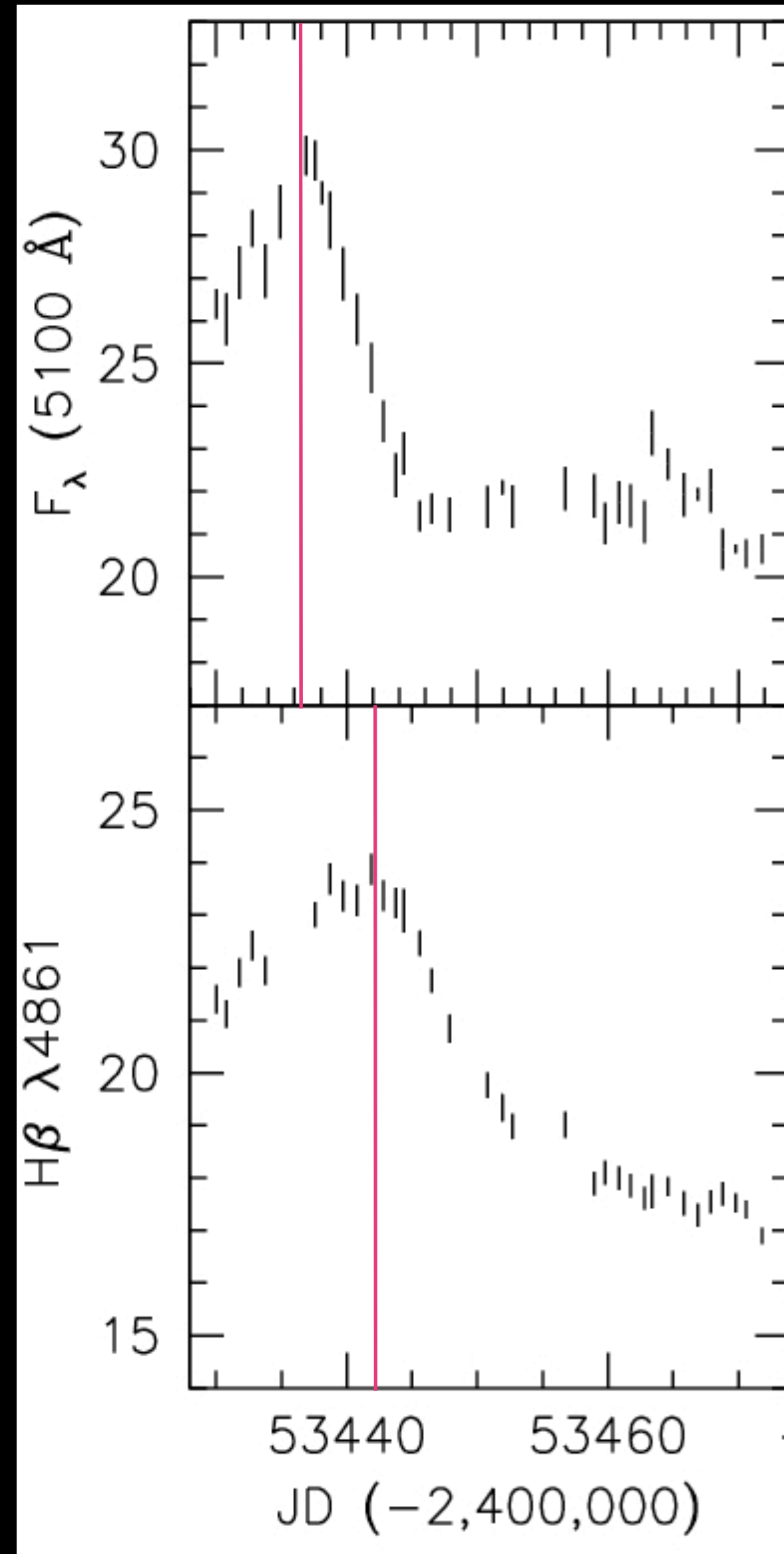
*Guerras et al. 2013*



Complications:

- flux-weighted vs. responsivity-weighted measurements
- photoionization differences between emission lines

# Mapping the BLR: Inverse Approach



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

Emission Line

Response

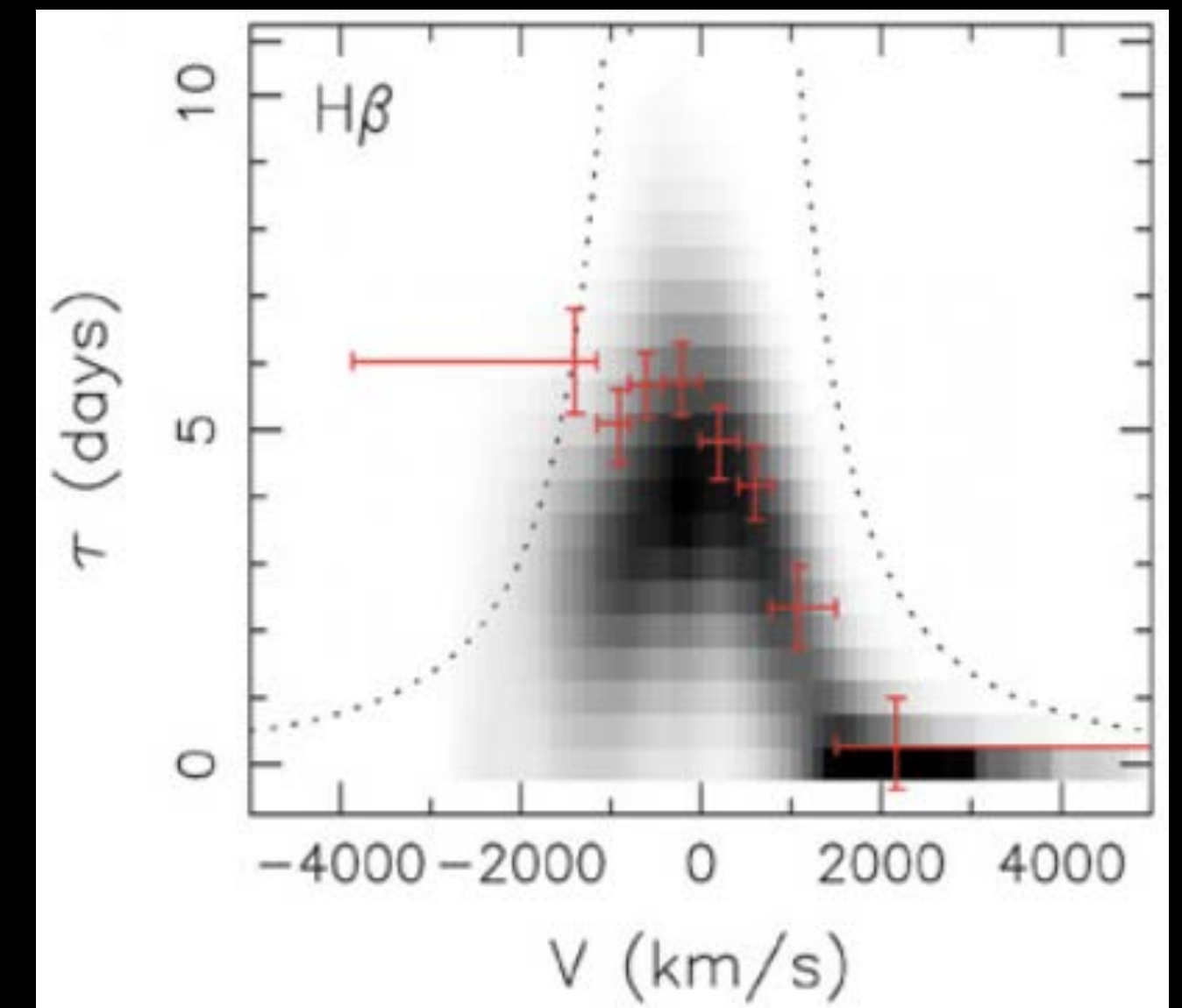
Continuum

Deconvolution:

Obstacles to overcome:

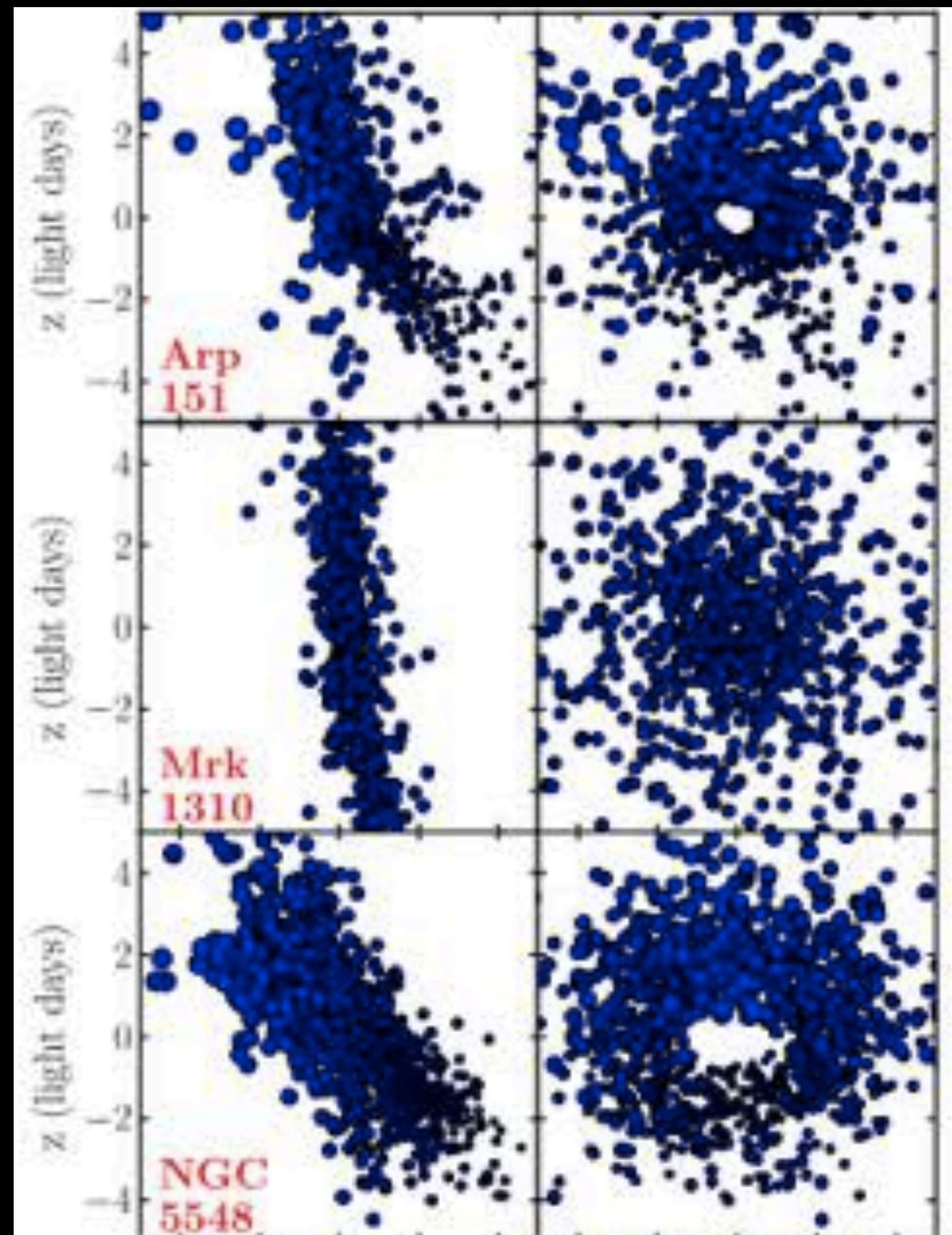
- Finite data length
- Irregular sampling
- Noisy data
- Sparse coverage

model-independent result,  
but requires interpretation

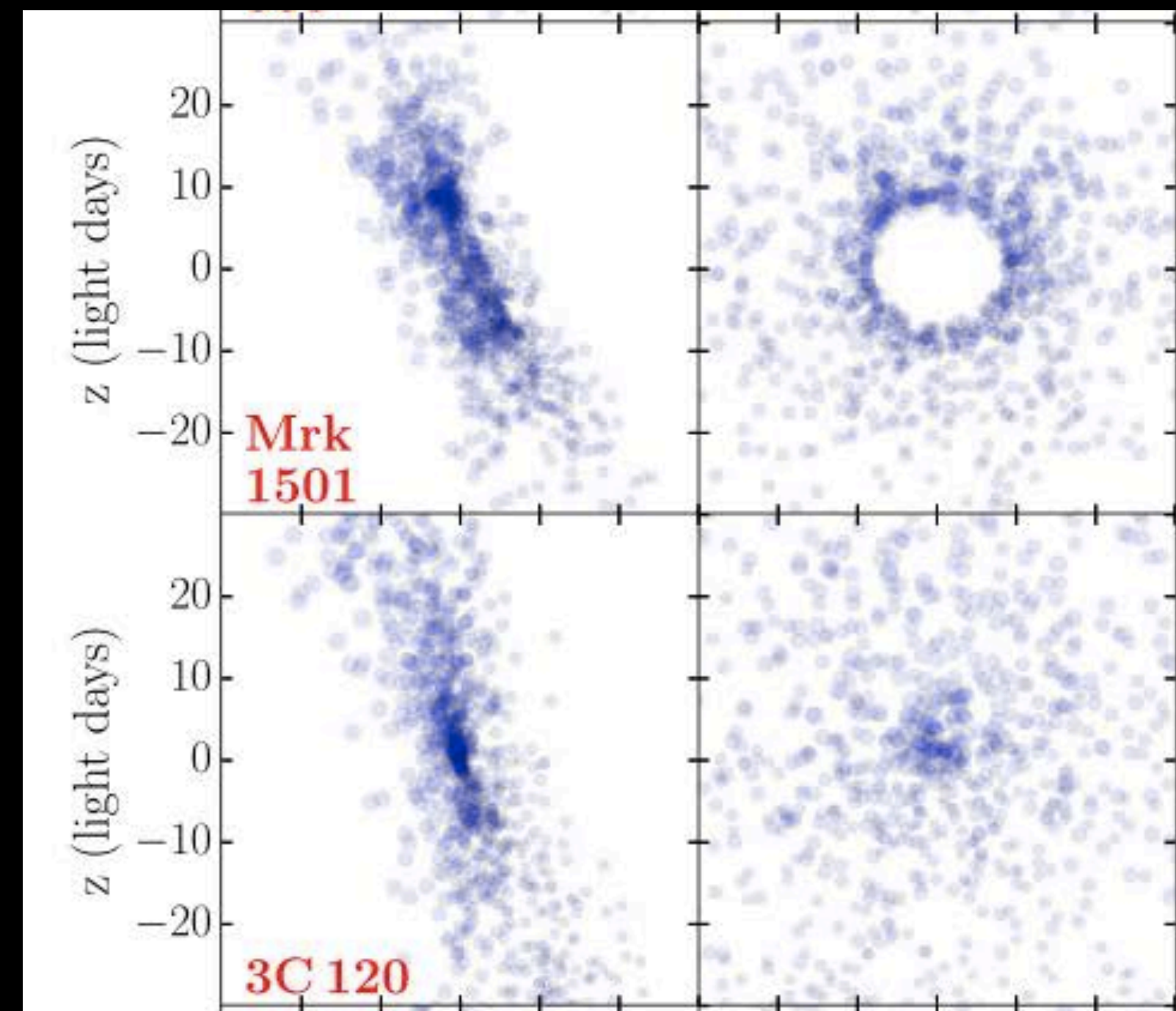


# Forward Approach: Direct Modeling of RM Data

fits geometric & kinematic models directly to the lightcurves and spectra



*Pancoast et al. 2014*



*Grier et al. 2017*

*Also: Williams et al. 2018, 2020*

*Villafaña et al. 2022*

*Bentz et al. 2021, 2022*

model dependent  
(big caveat: no photoionization  
physics included yet)  
but results are  
straightforward to interpret

~25 AGN modeled so far have:

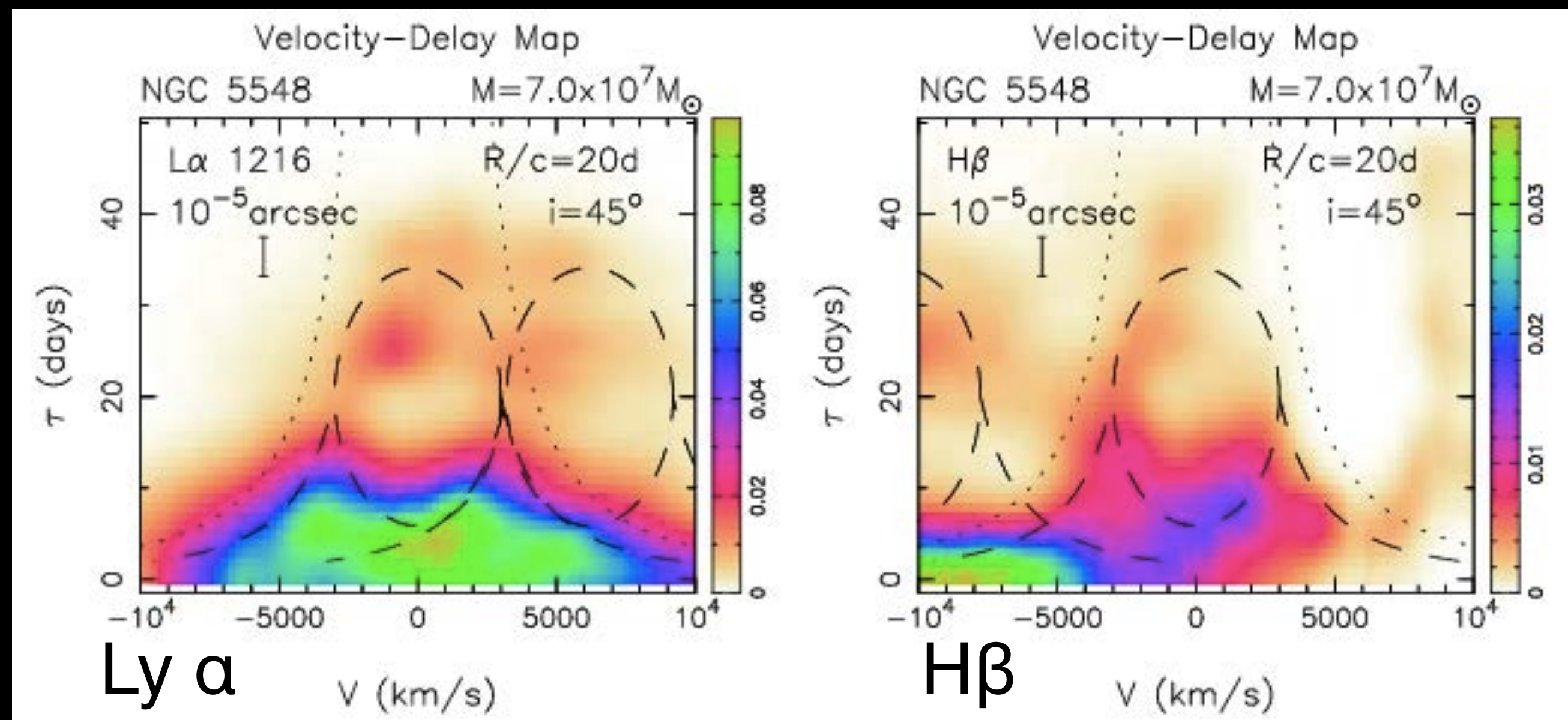
- inclined, flattened geometry
- significant scale height
- mostly rotation and/or infall

# Where Can Arcus Help?

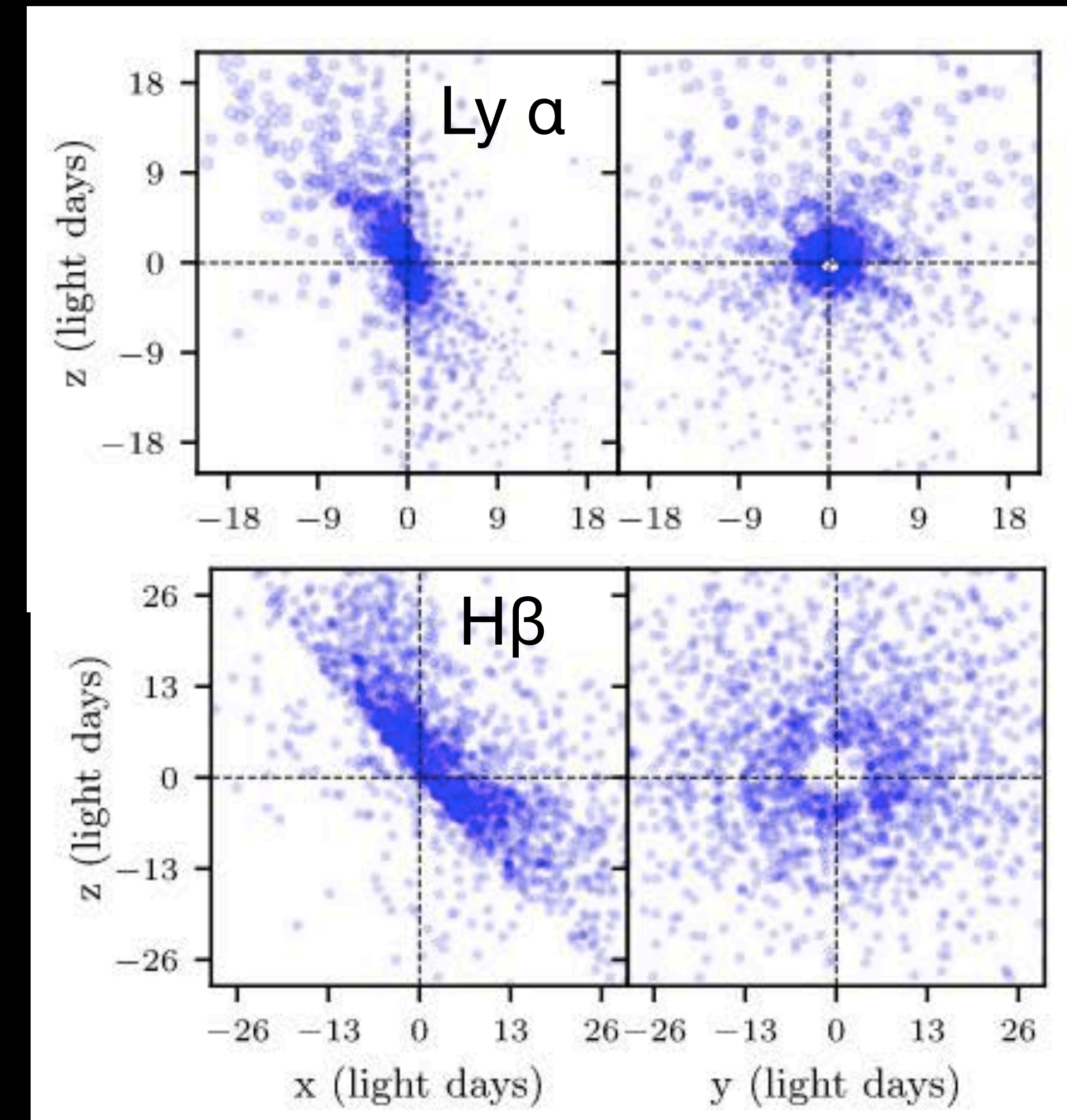
## 1. Reverberation mapping of UV broad emission lines

NGC 5548: only high-fidelity RM results in UV (so far)

UV BLR appears to be disk-like and have similar properties as optical BLR



*Horne et al, 2021*



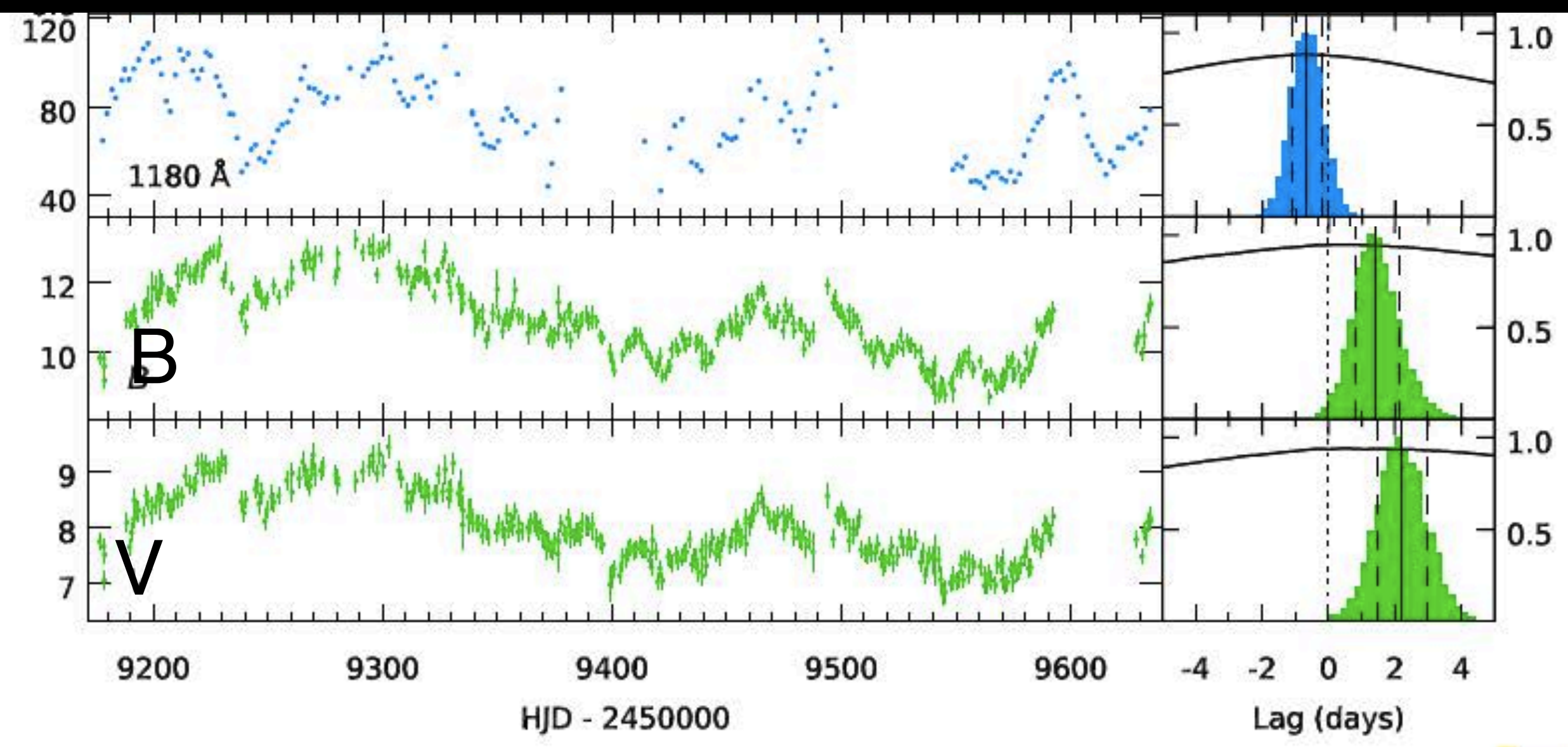
*Williams et al, 2020*

# Where Can Arcus Help?

## 2. Explore continuum time delays between UV and optical

By necessity, most RM experiments use the optical continuum

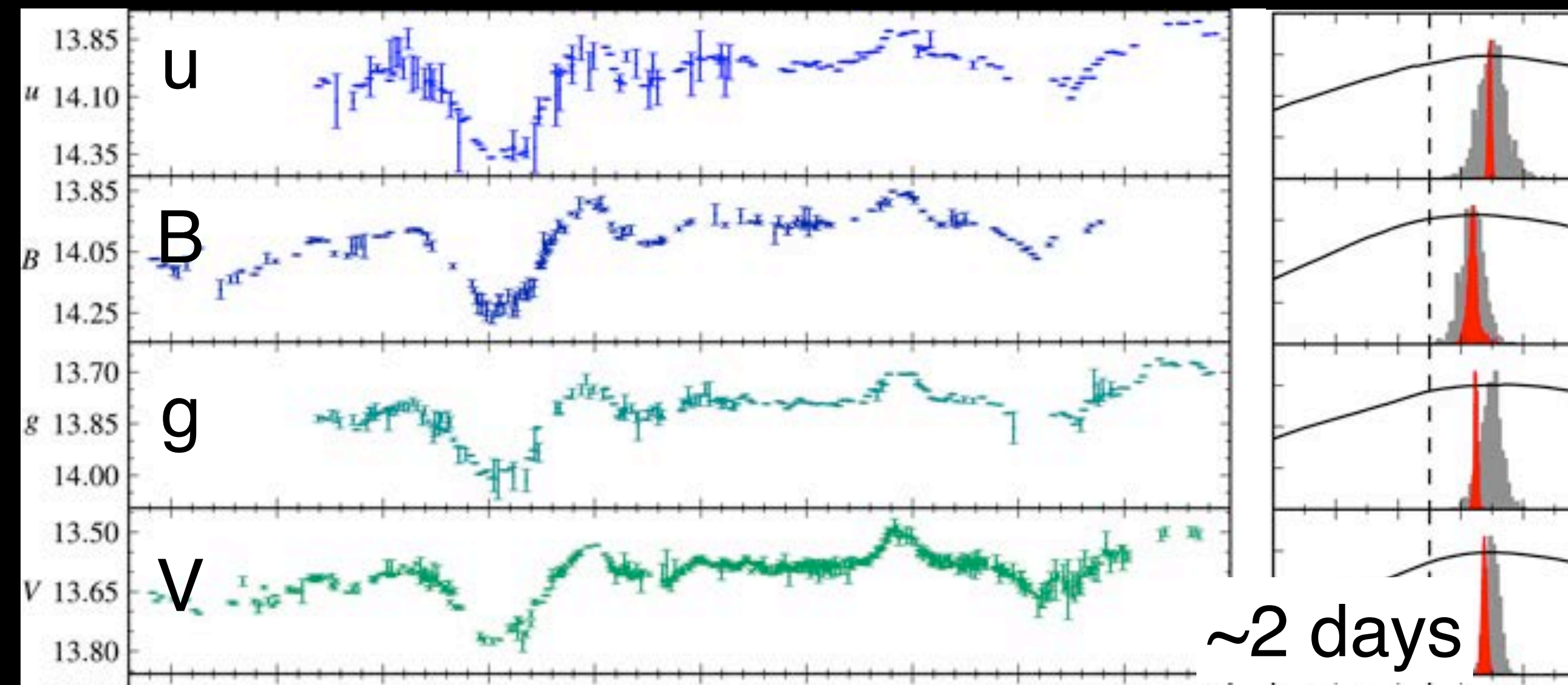
Mrk 817,  $\log L \sim 43.7$



*Cackett et al., in prep*

V lags 1180Å by ~2.5 days

NGC 5548:  $\log L \sim 43.0$



*Fausnaugh et al. 2016*

V lags 1367Å by ~2 days

# Summary

UV spectroscopy is an important component for understanding AGN broad line regions

UV spectroscopic monitoring with Arcus has the potential to affect:

- black hole mass measurements (local universe & high- $z$ )
- details of feeding and feedback
- black hole and galaxy (co-)evolution