



Black Hole Growth and Quasars

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Overview

- Lifecycle of quasars
- Simulations of galaxy mergers
 - Quasar light curves
 - Resulting models of the quasar and active black hole (BH) populations
- Ways to test these models
 - Measuring the BH mass in quasars
 - Measuring the BH mass in 100,000 quasars
- Results
 - How do the models do?
 - Other results

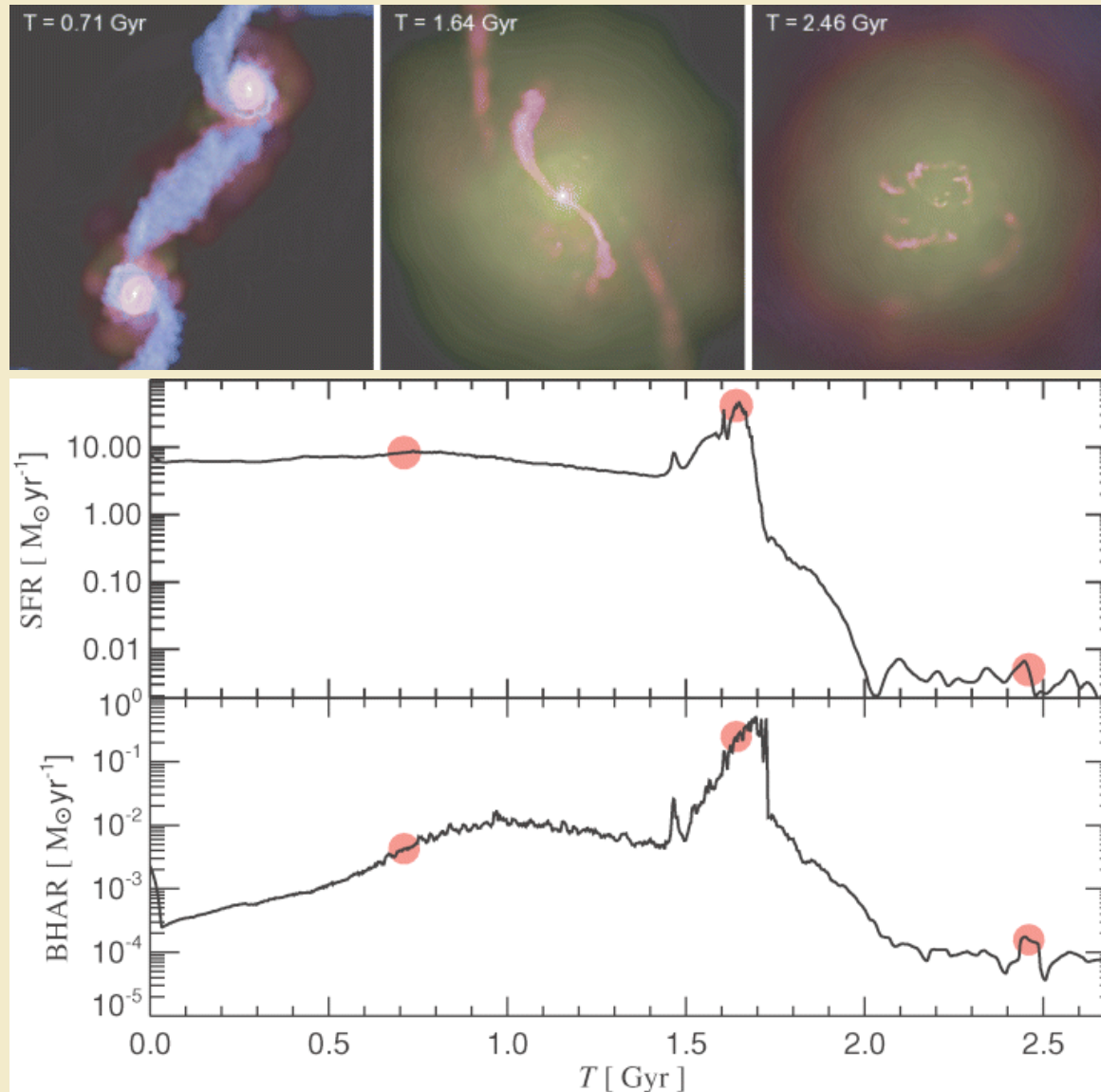


Lifecycle of a quasar





Luminosity history of a quasar



- Simulated quasar light curves give $\partial t/\partial L$ the time spent by a quasar at a given luminosity.

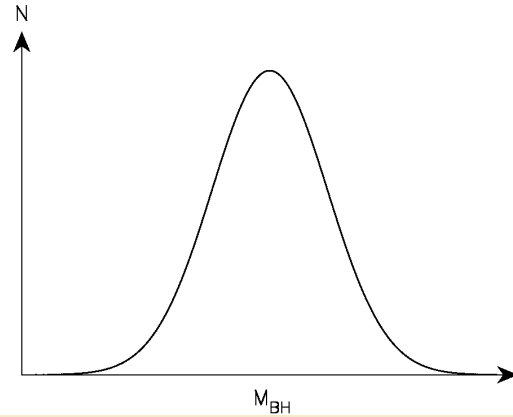
- This is a function not only of L but also the peak luminosity a quasar will attain in its lifetime.

- Convolution of this model for quasar lifetimes with a 'birth' rate function gives the luminosity function.

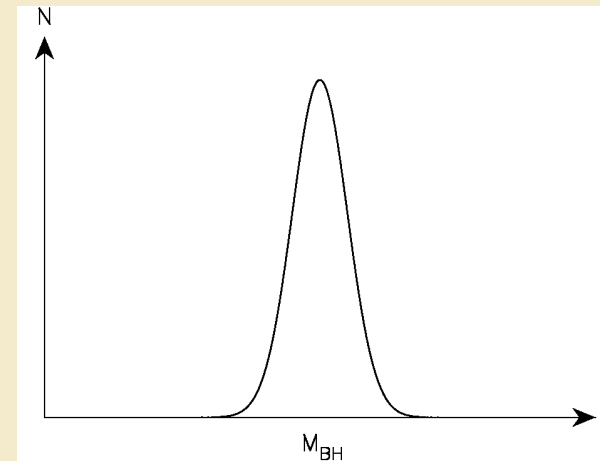
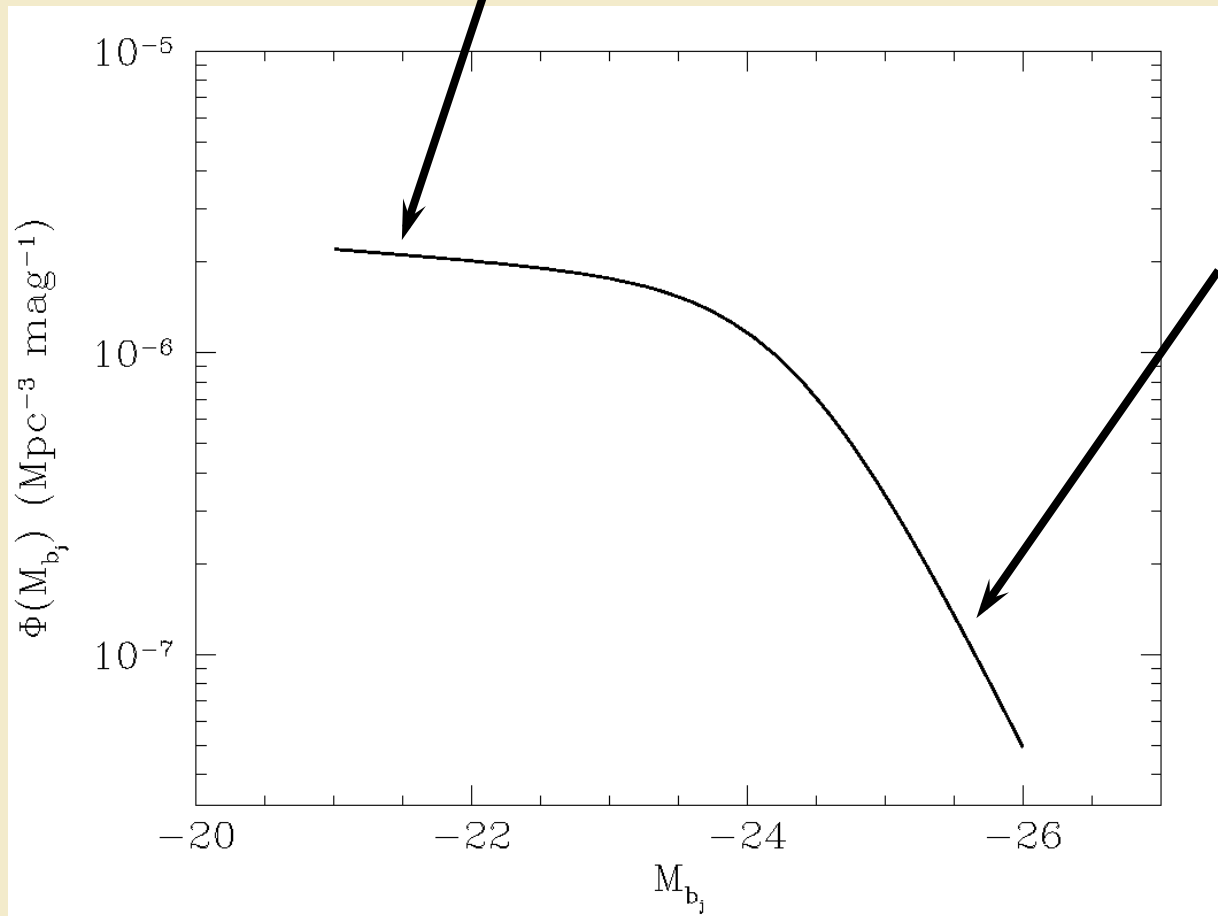
Springel, Di Matteo & Hernquist (2005)



luminosity Function



ing rapidly, and
low accretion rates.

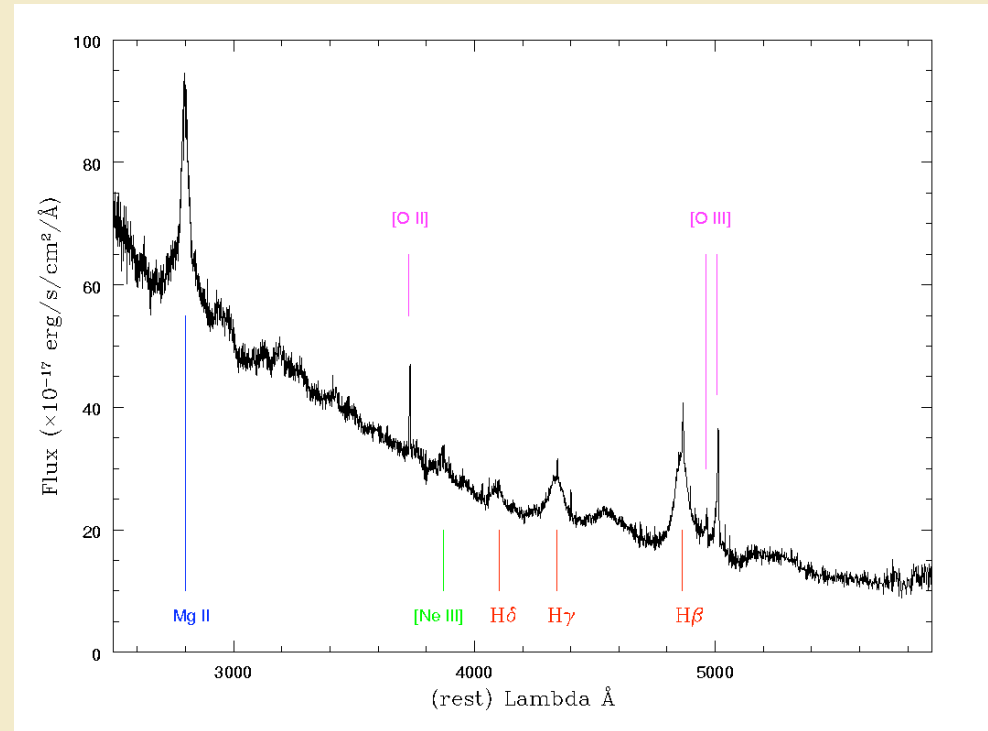
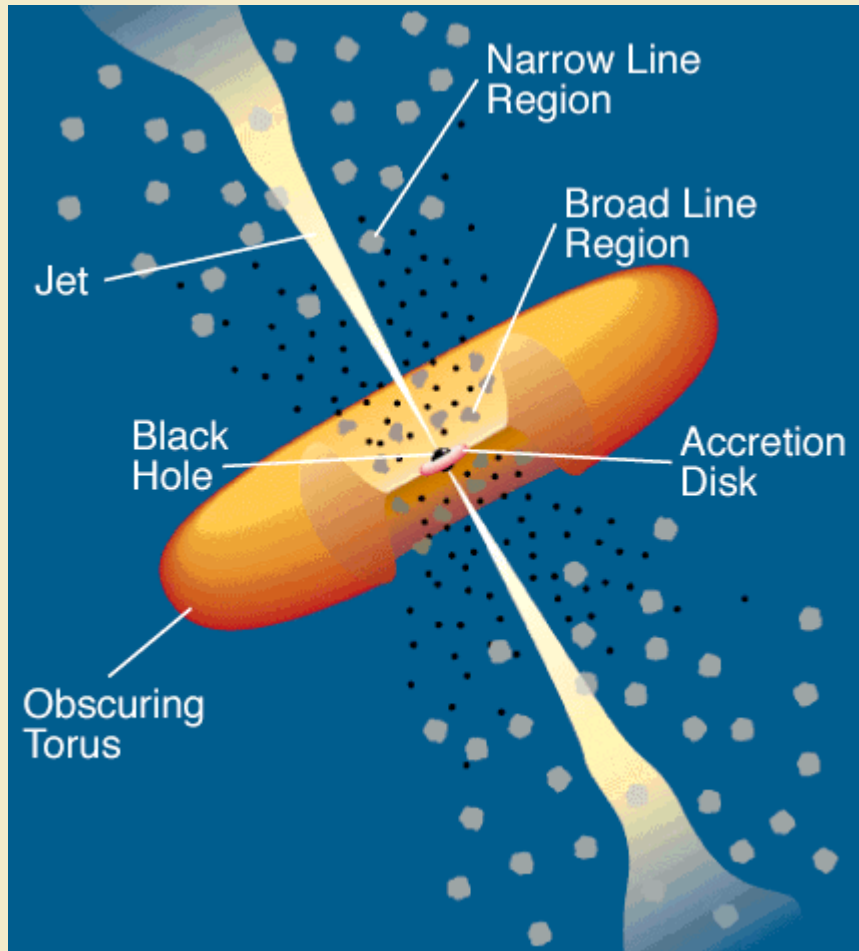


steep BH mass
function.

Accretion rate
constrained by
Eddington limit.



Broad lines and Quasars



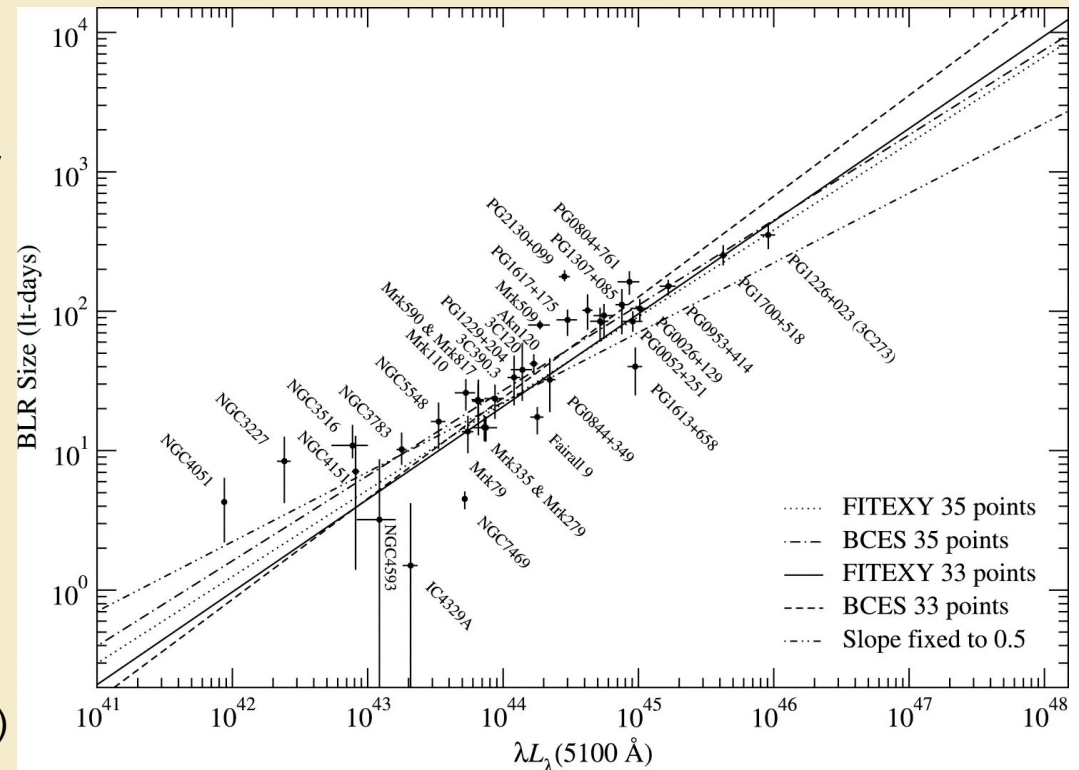


Mass estimation with the virial method

- Broad-line emission region is assumed to be virialised and so the width of a line gives v_{BLR} .

$$M_{BH} \approx \frac{rv^2}{G}$$

- The radius-luminosity relation derived from reverberation mapping campaigns gives r_{BLR} .





Virial problems

- Broad-line region may not be virialised
- Radius-luminosity relation poorly defined (in particular for bright quasars)
- We want the dispersion in BH mass at a given luminosity so:
 - We bin our sample of QSOs by L and z and calculate the dispersion in $\text{Log}(\text{line width})$.
 - Then for a given bin:

$$\text{Dispersion in } \text{Log}(\text{BH mass}) = 2 \times \text{Dispersion in } \log(\text{line widths})$$

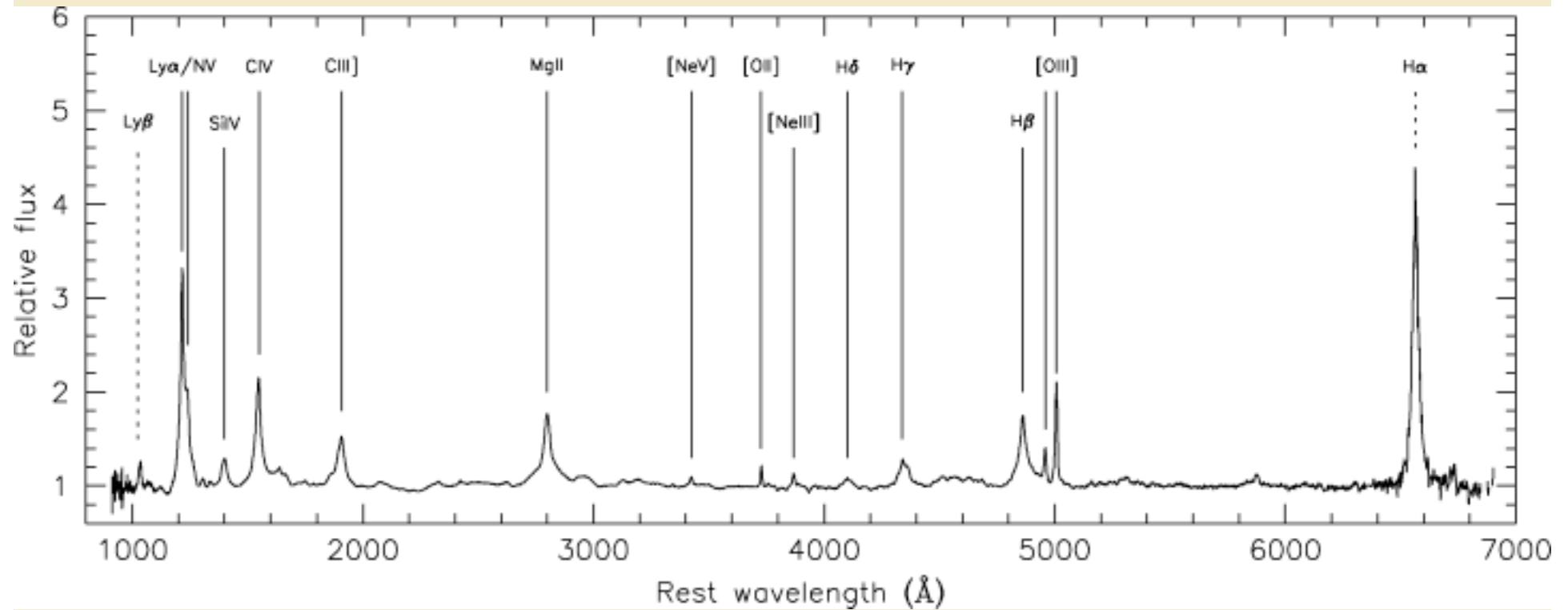


Data

Survey	No. of objects	Mag. range
SDSS	77,000	$\sim 19 > M_i > \sim 15$
2QZ	23,000	$20.85 > M_{bj} > 18.25$
2SLAQ	8,000	$21.85 > M_g > 18.0$



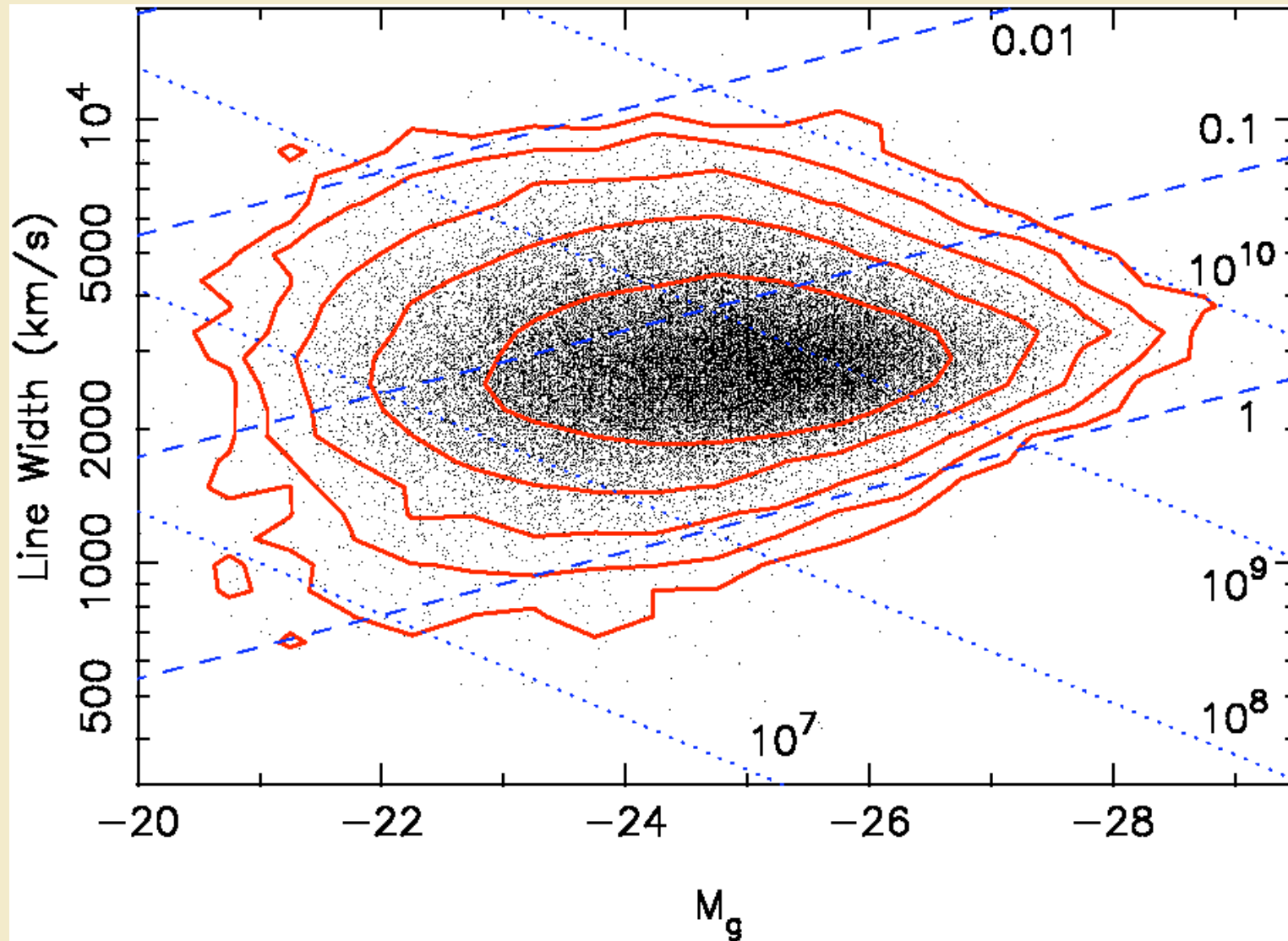
QSO spectrum



Croom et al. (2002)

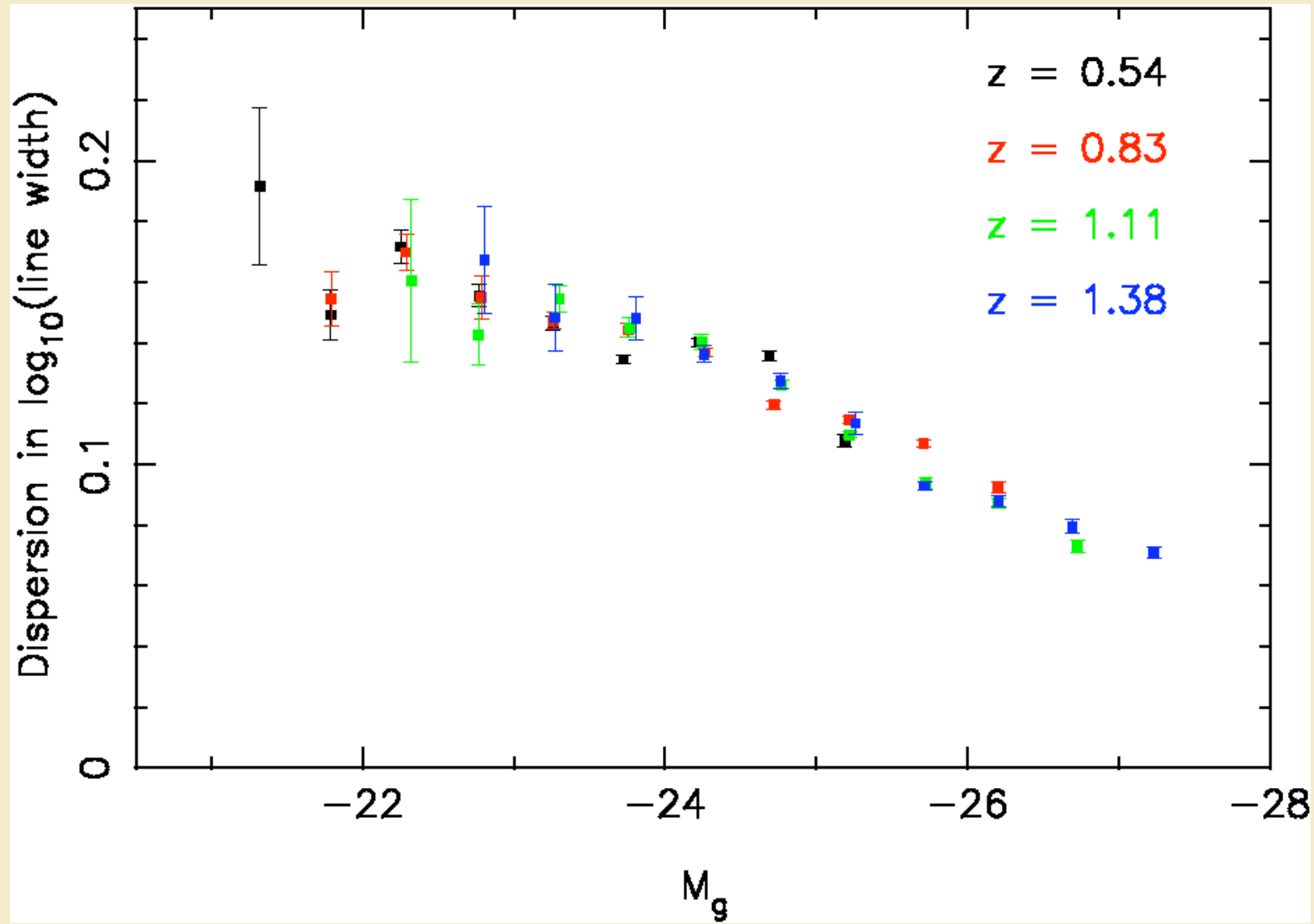


The Results



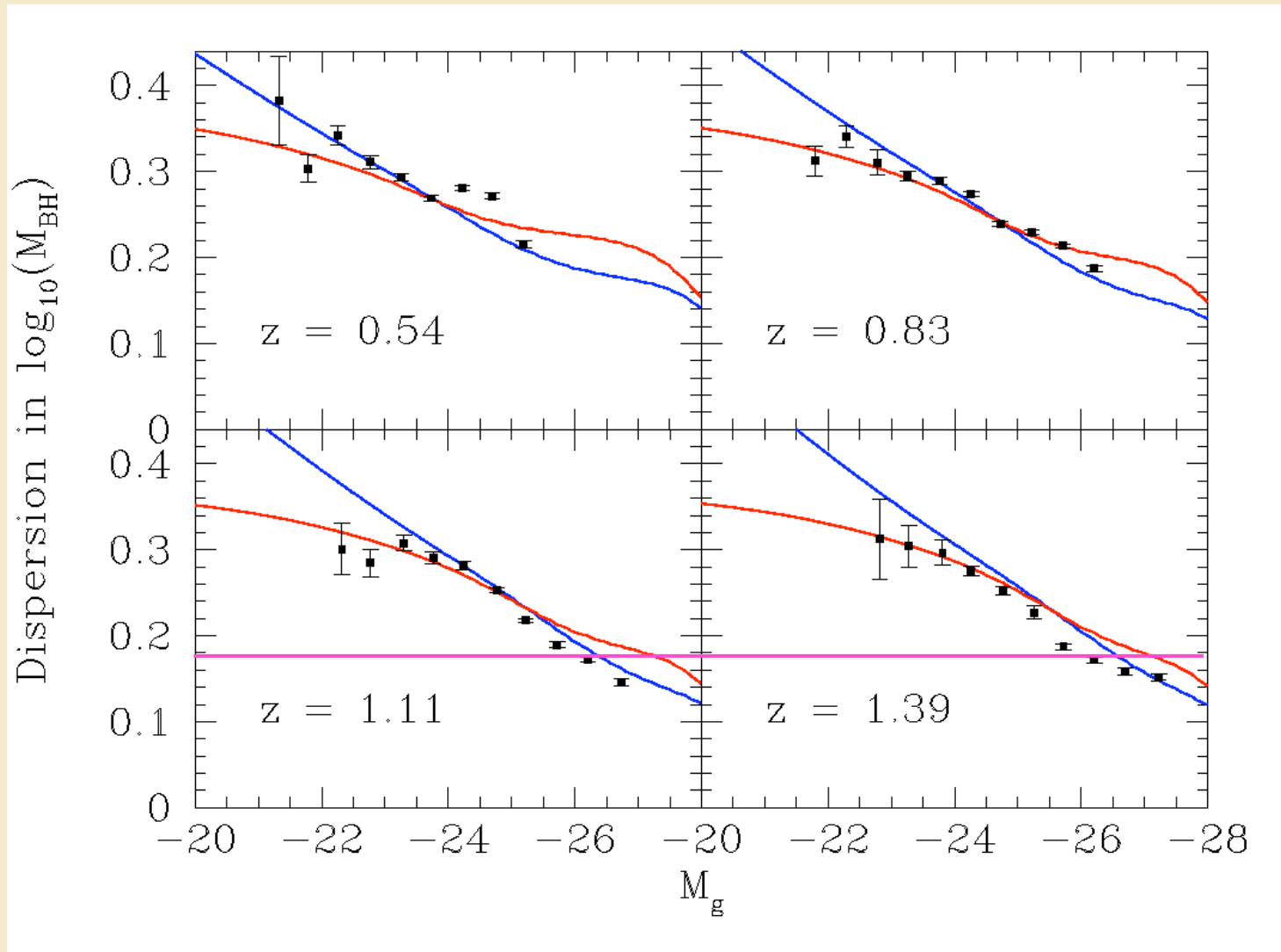


Dispersion Results



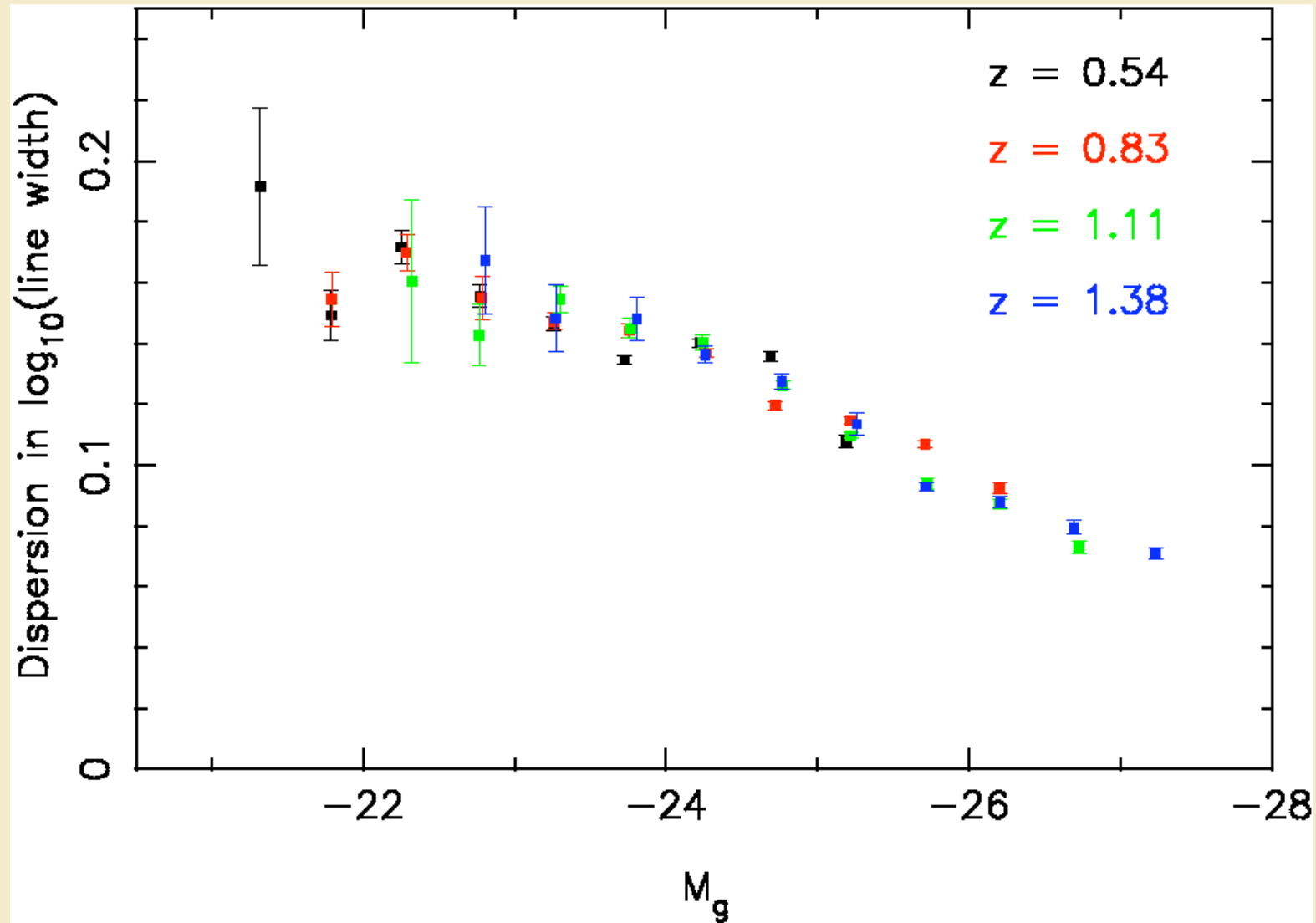


Comparison with Models



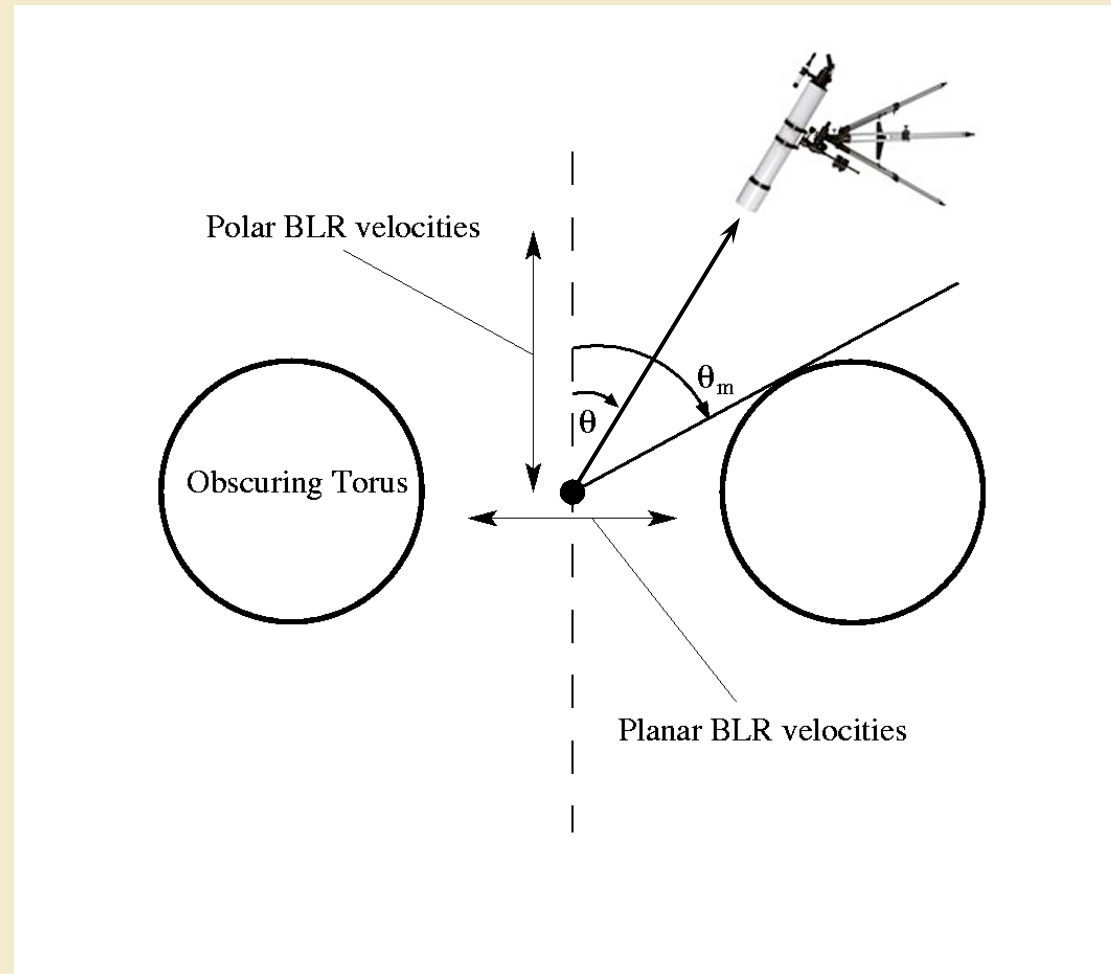


Dispersion Results





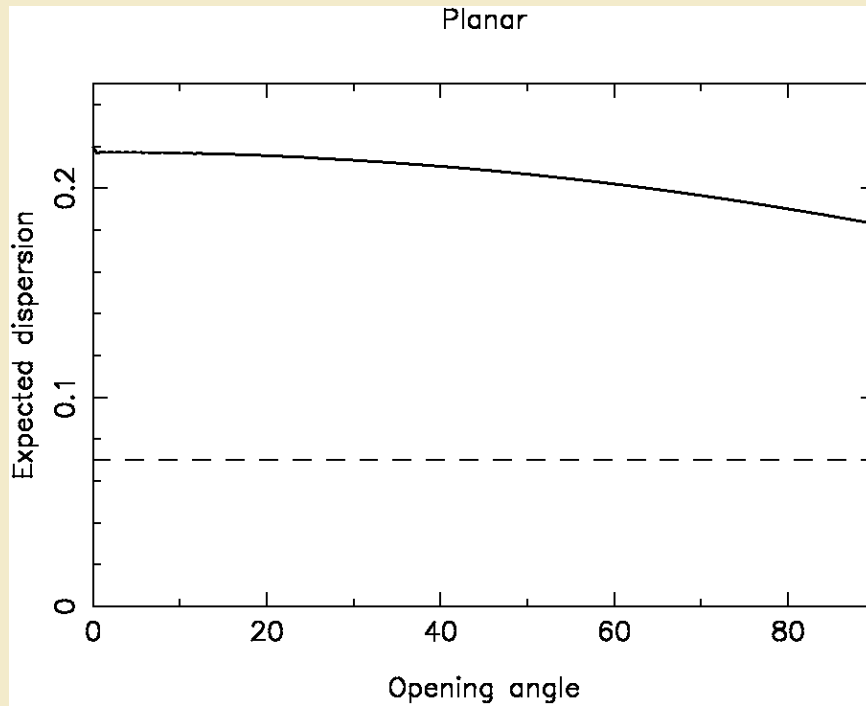
Geometry of the Broad-Line Region





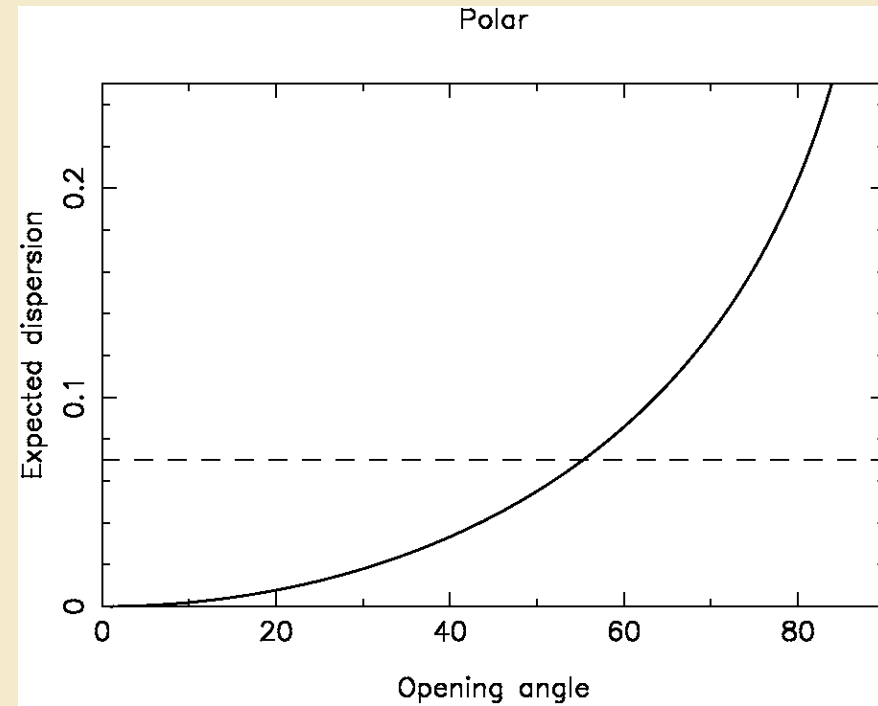
Geometry of the BLR

Disk?



Line width $\propto \sin(\theta)$

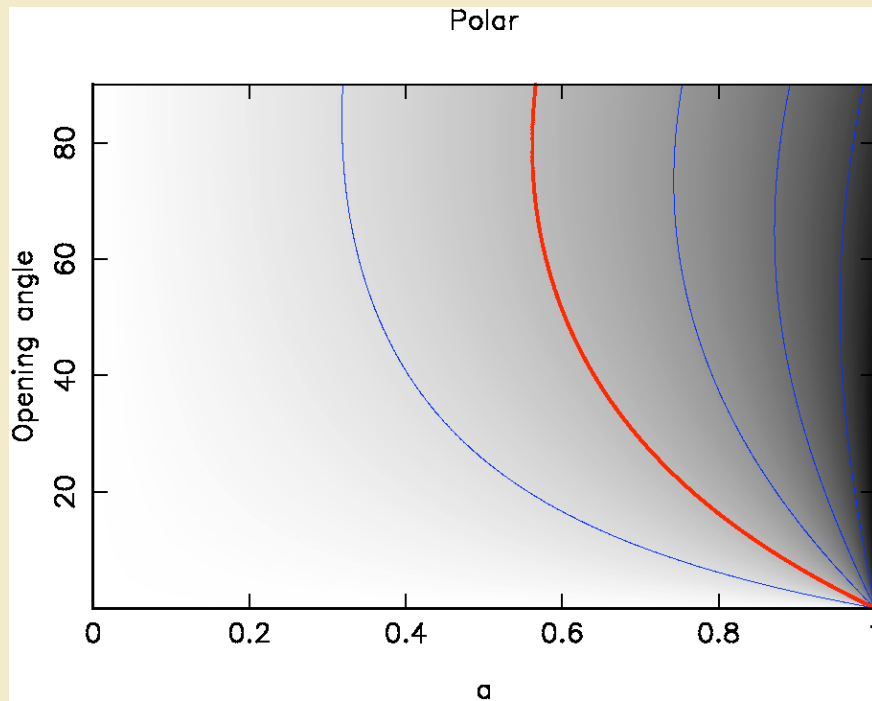
Polar wind?



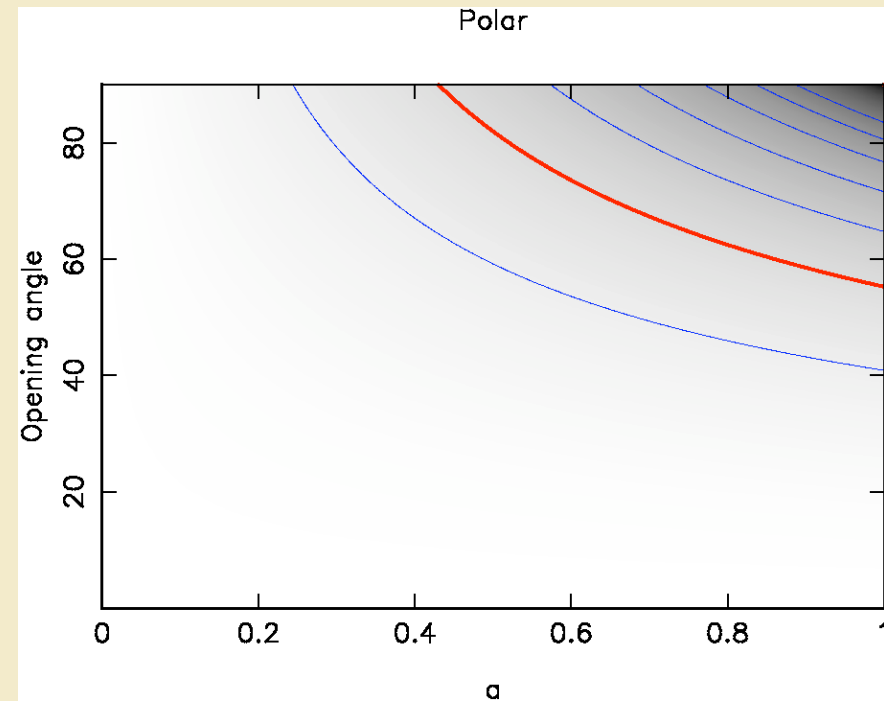
Line width $\propto \cos(\theta)$



Geometry of the BLR



Line width $\propto a \cdot \sin(\theta) + (1-a)$

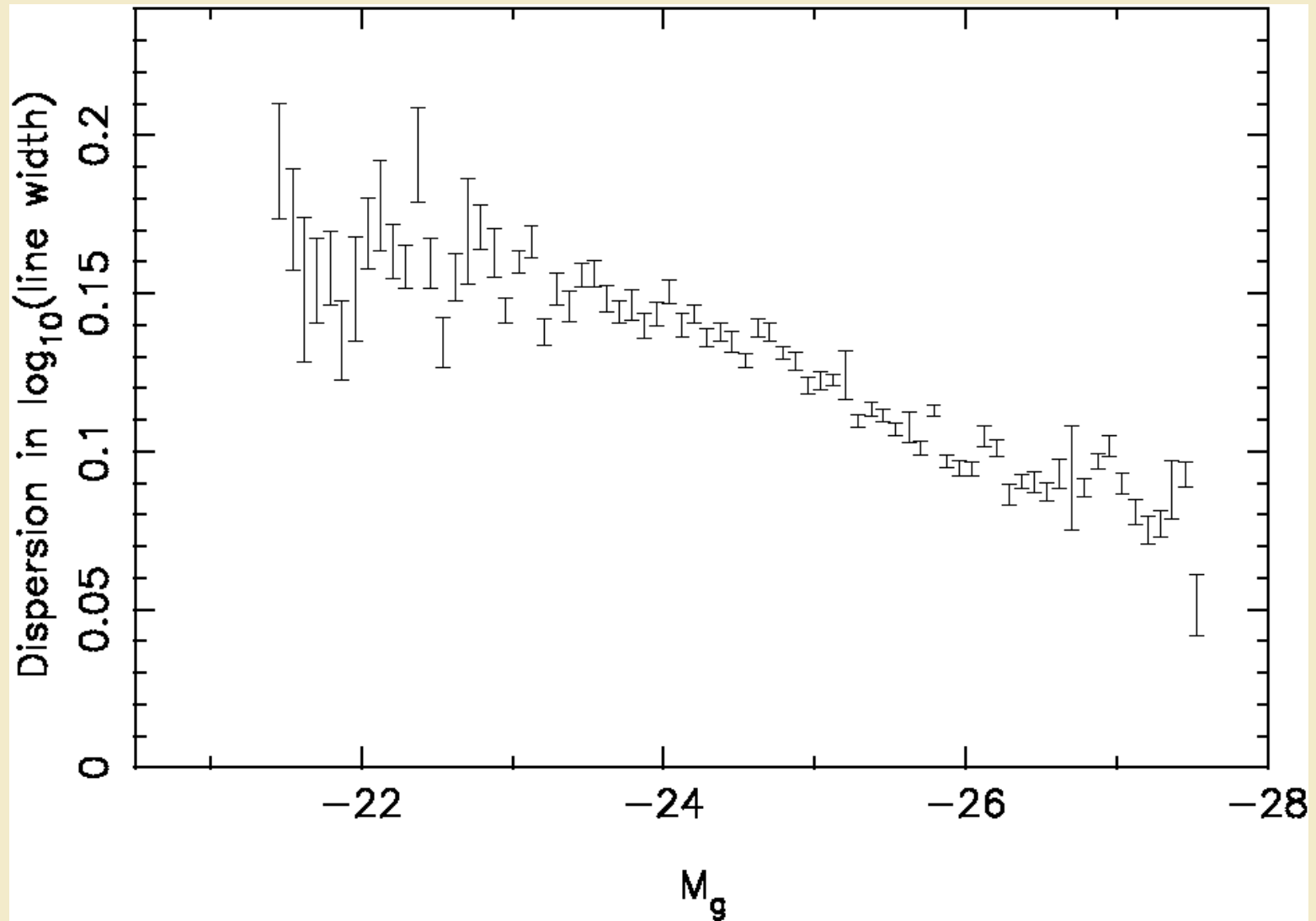


Line width $\propto a \cdot \cos(\theta) + (1-a)$



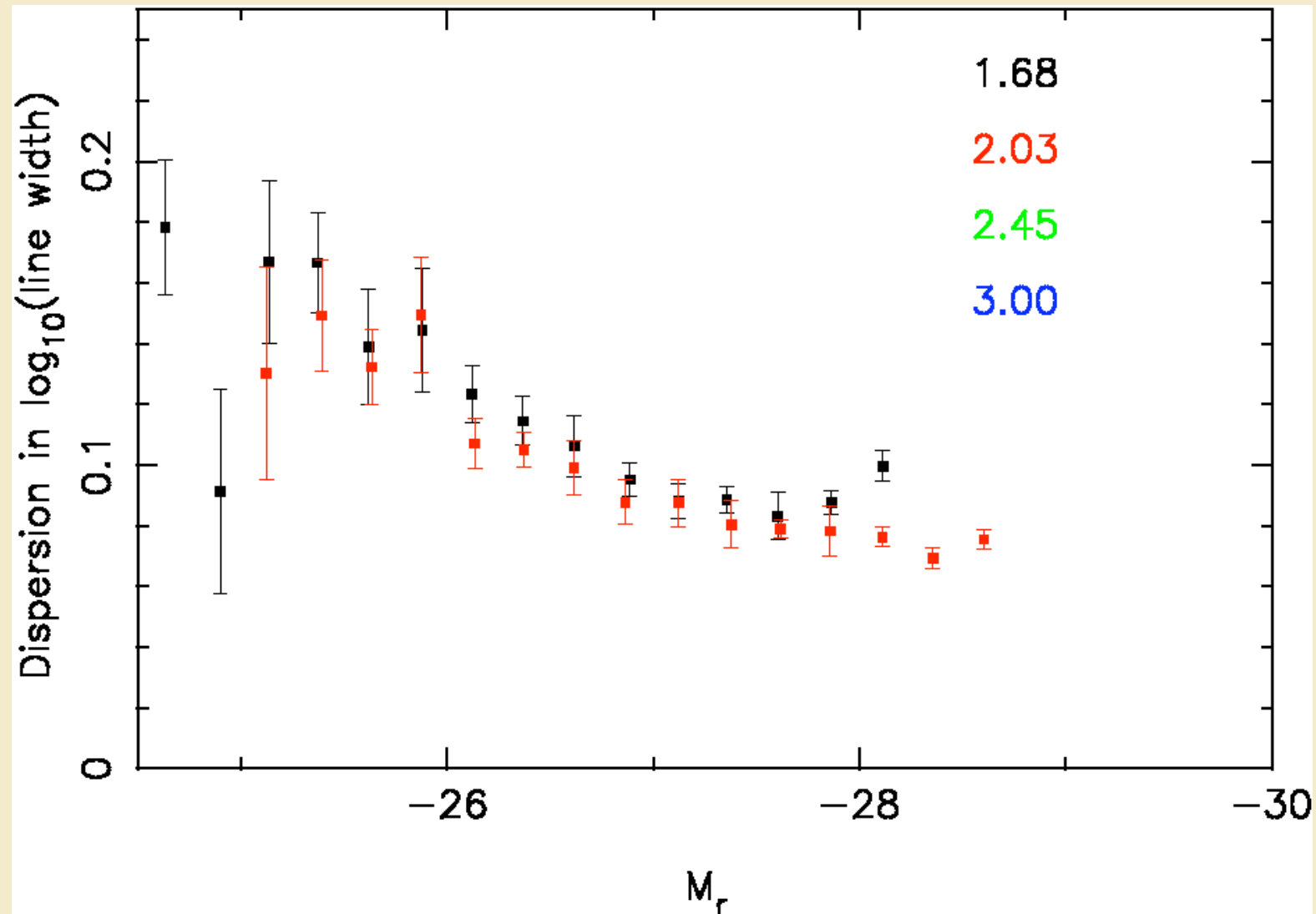
Summary

- There is very little variation in broad-line width between QSOs.
- There is a significant decrease in this variation towards larger luminosities.
- We find an almost identical trend in the dispersion of our line widths as predicted for the dispersion in BH masses.
- The low level of dispersion in line width at high luminosities implies:
 - 1) There is an important aspect of the virial method for BH mass estimation we are yet to understand.
 - 2) The velocity field of the broad-line region in high luminosity quasars is largely spherically symmetric.



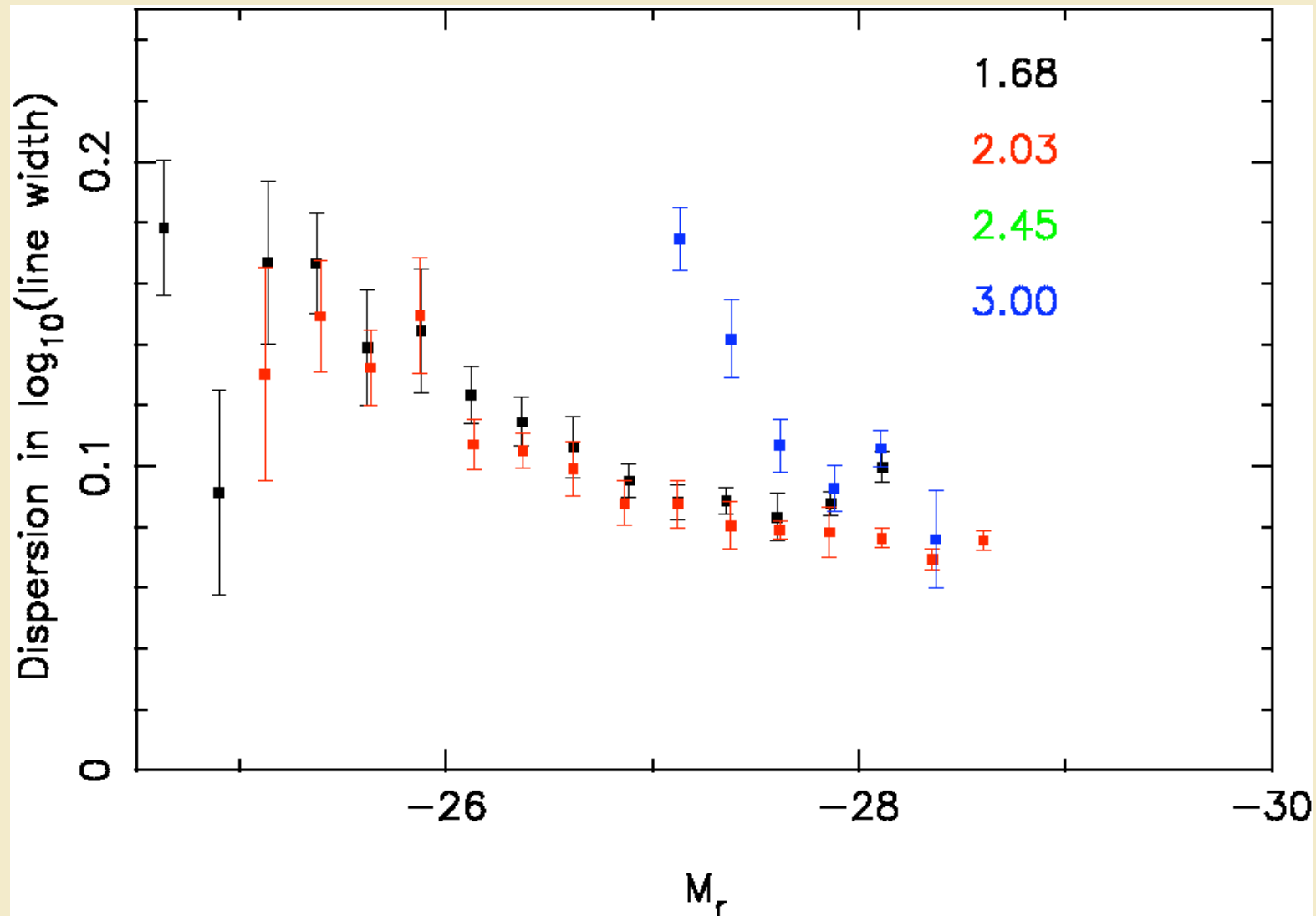


Same with CIV?



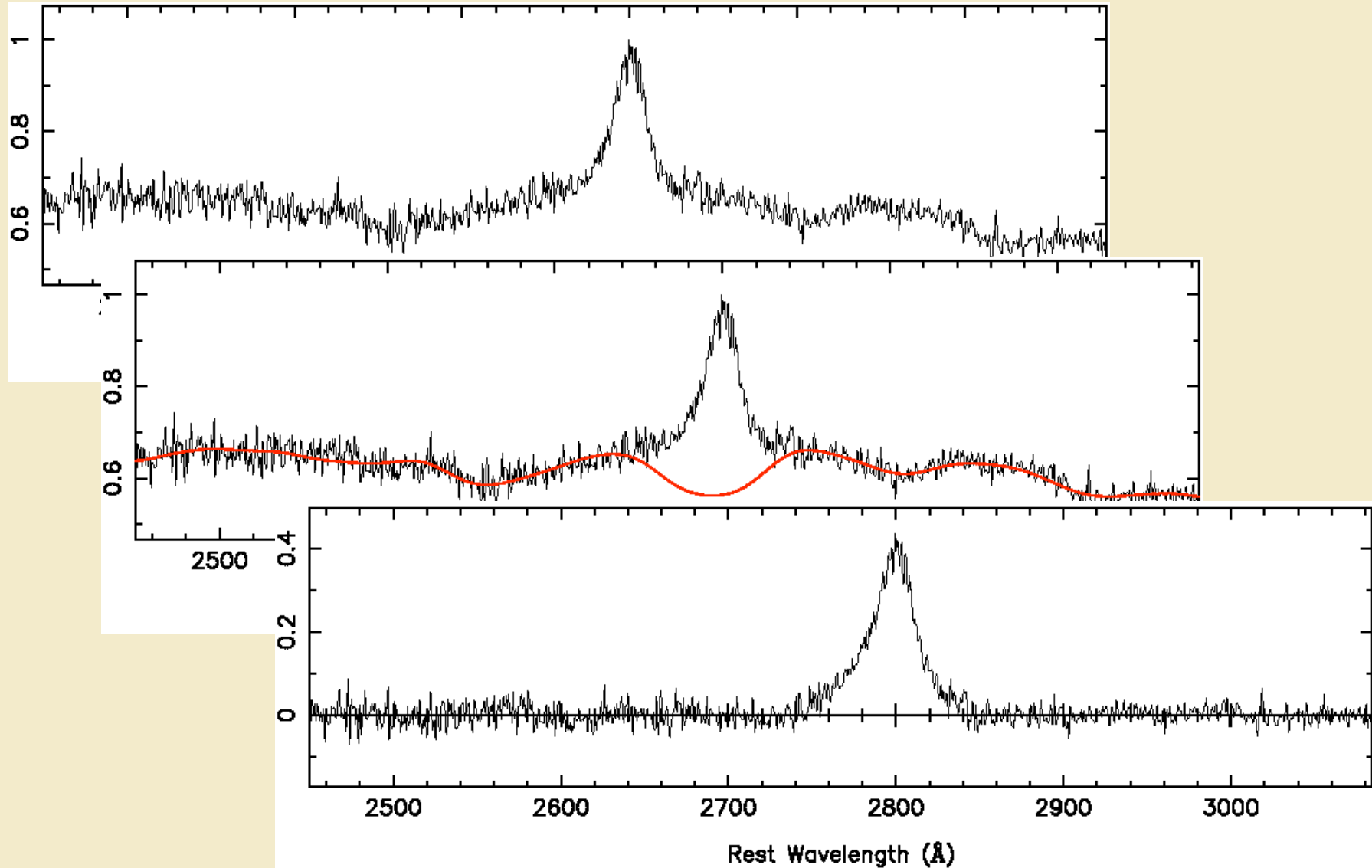


Same with CIV?





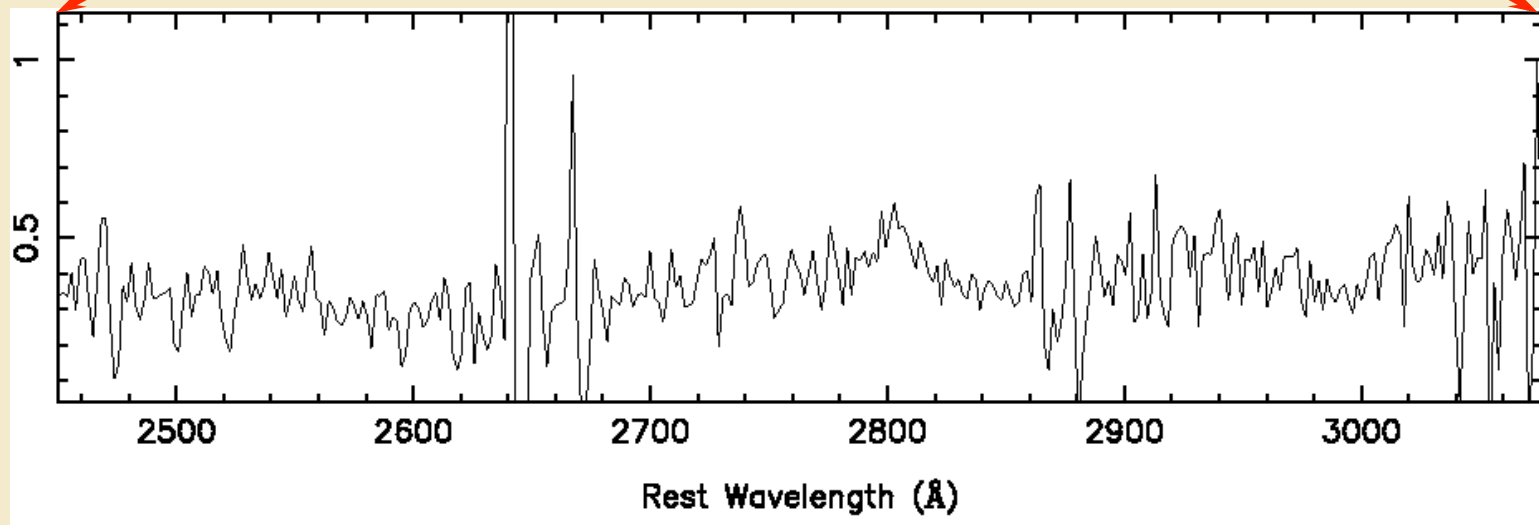
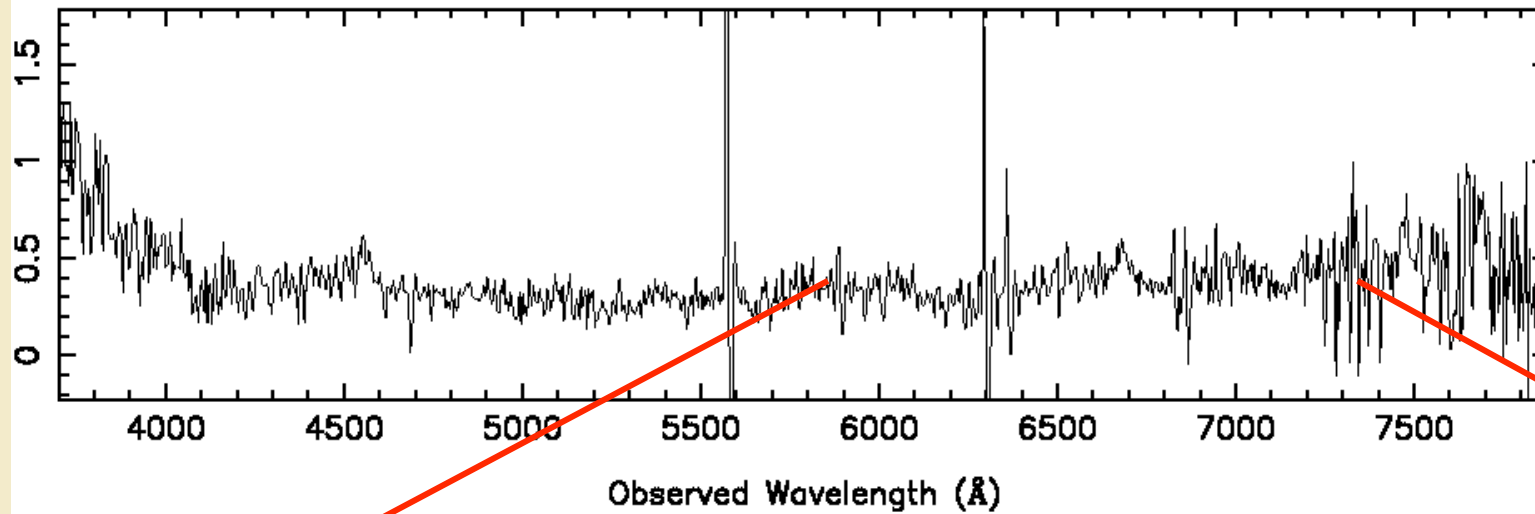
Measuring the MgII line





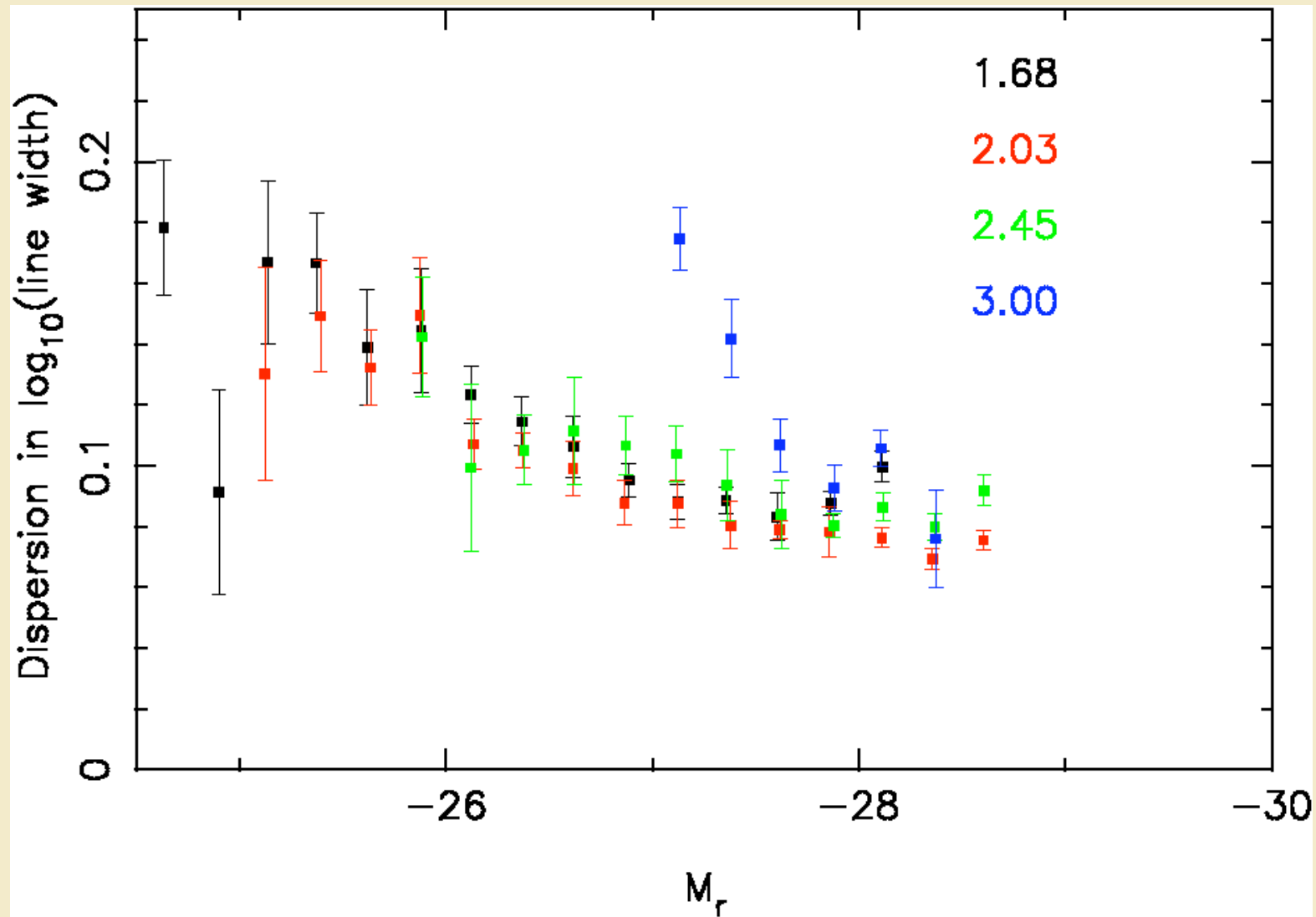
Measuring the MgII line

J081218.86-010223.2



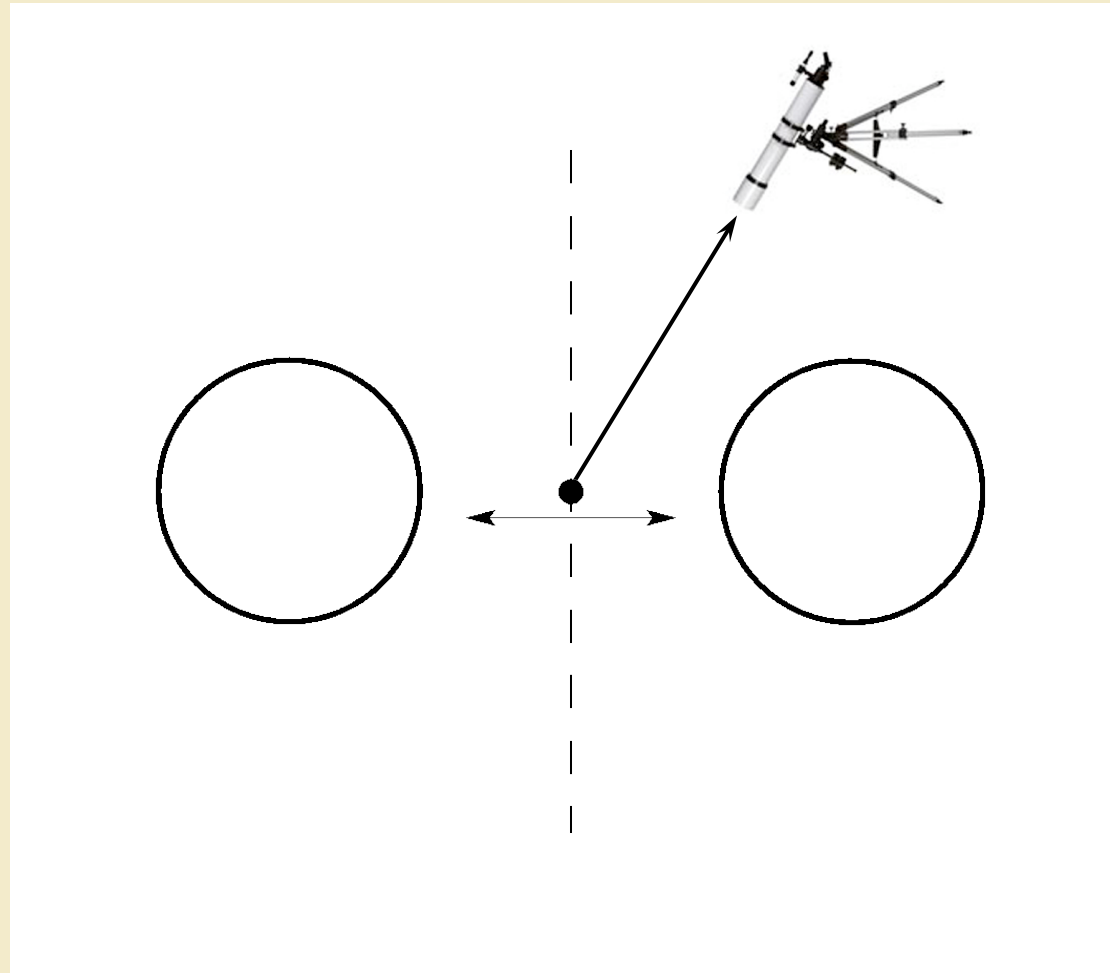


Same with CIV?





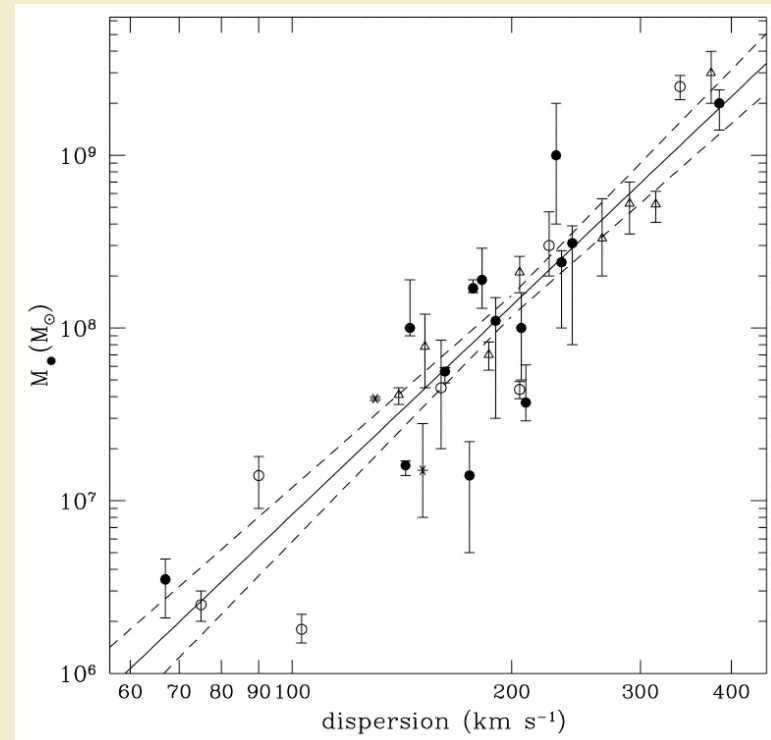
Geometry of the Broad-Line Region





The life and death of a quasar

- Lifecycle of QSOs
 - galaxy mergers → starburst
 - quasar activity → BH growth
 - feedback → spheroid formation
- BH – spheroid correlations (e.g. Tremaine et al. 2002)
- Energetics (e.g. Silk & Rees 1998)
- Simulations of galaxy mergers (e.g. Hopkins et al. 2006)





The radius-luminosity relation

