

Hagai Netzer – July 2026

The Star

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From *The Nine Billion Names of God: The Best Short Stories of Arthur C. Clarke*

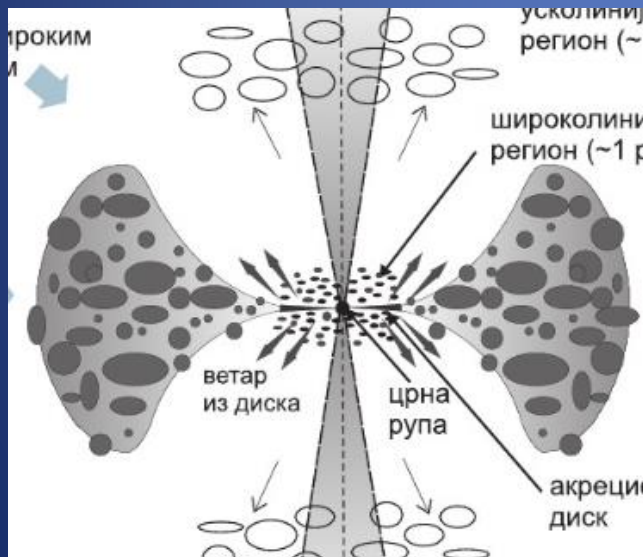
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It is three thousand light-years to the Vatican. Once, I believed that space could have no power over faith, just as I believed the heavens declared the glory of God's handwork. Now I have seen that handiwork, and my faith is sorely troubled. I stare at the crucifix that hangs on the cabin wall above the Mark VI Computer, and for the first time in my life I wonder if it is no more than an empty symbol.

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The Star 1955 - AGN Accretion disks 2026



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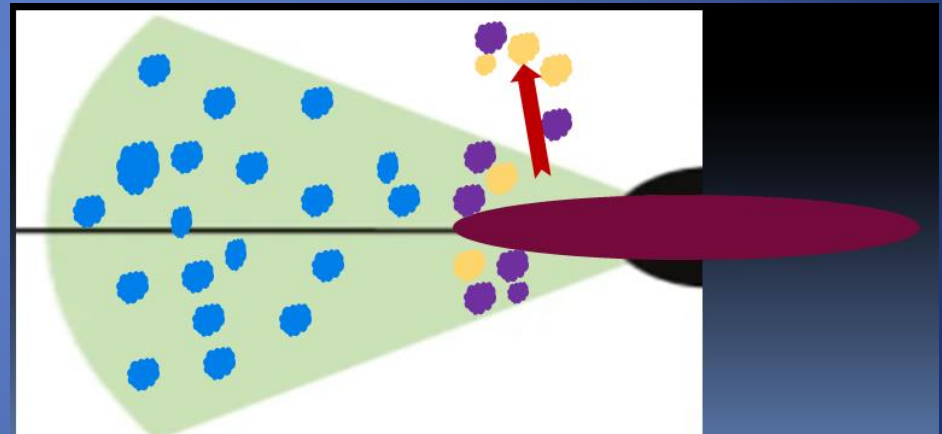
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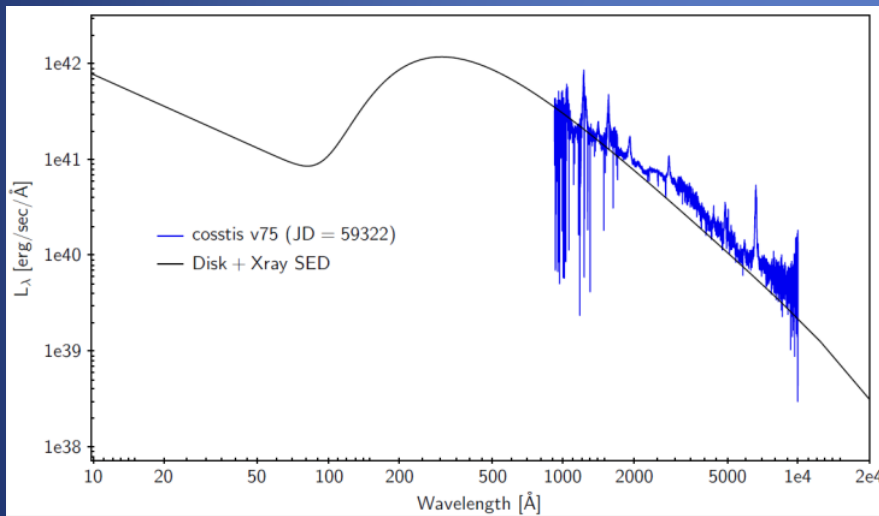
Is the accretion disk the center
of
everything?

Consequences of assuming AGN accretion disks

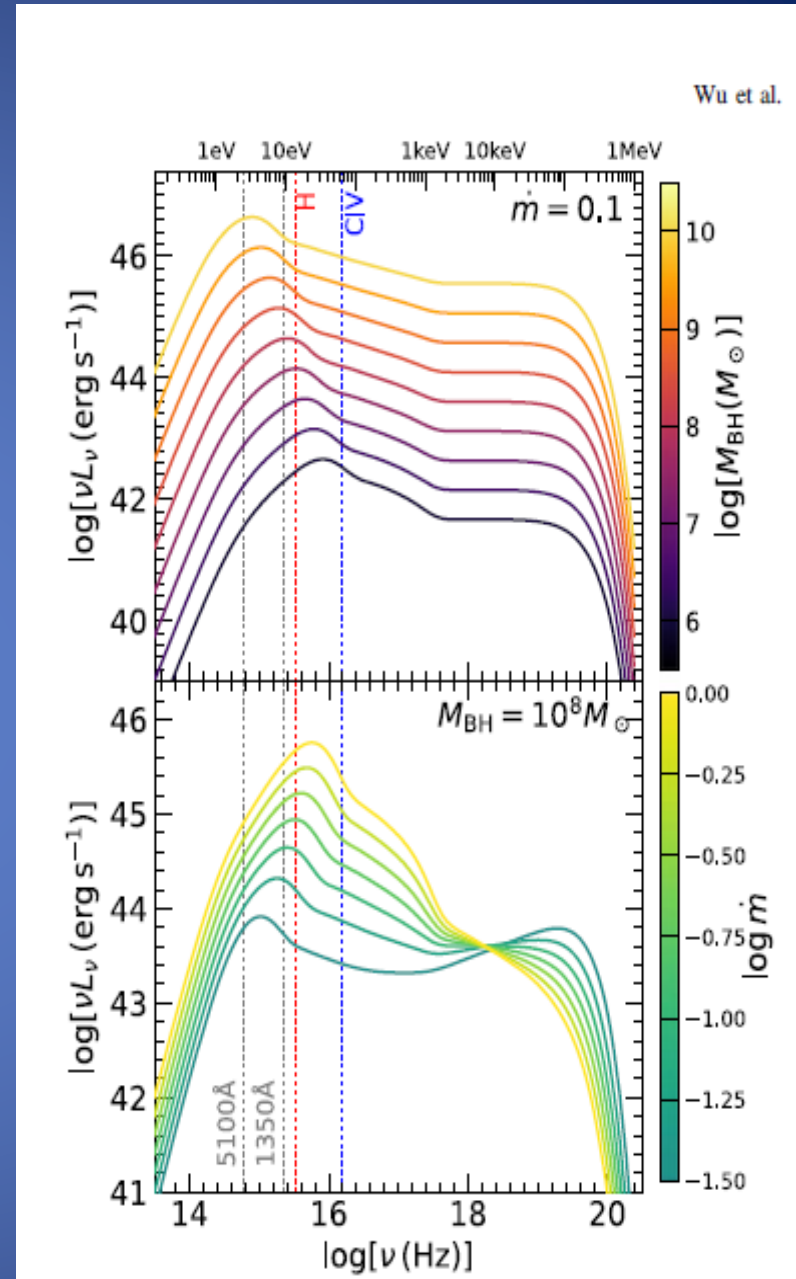
- “Continuum” variations
- Disk winds
- Using disk properties to measure black hole mass



The optical-X-ray spectrum of AGN accretion disks

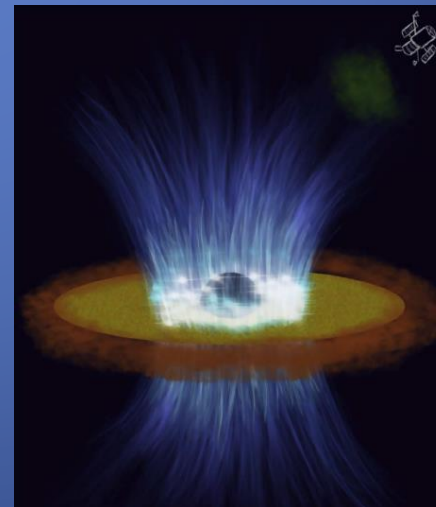
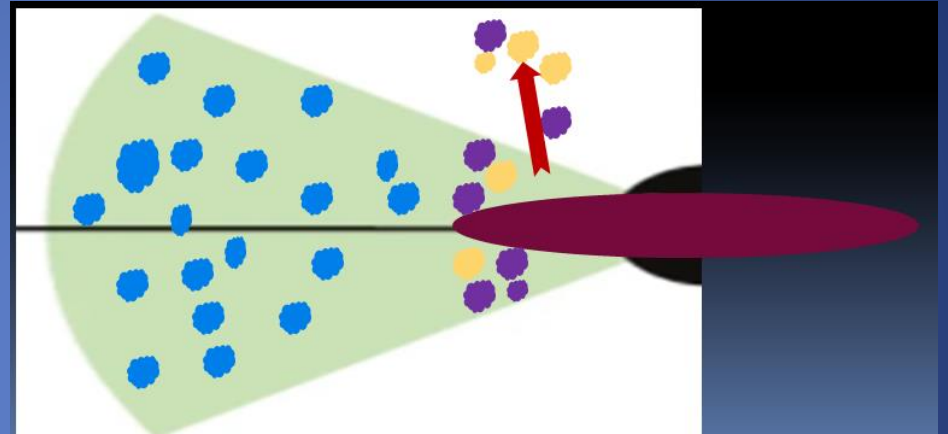
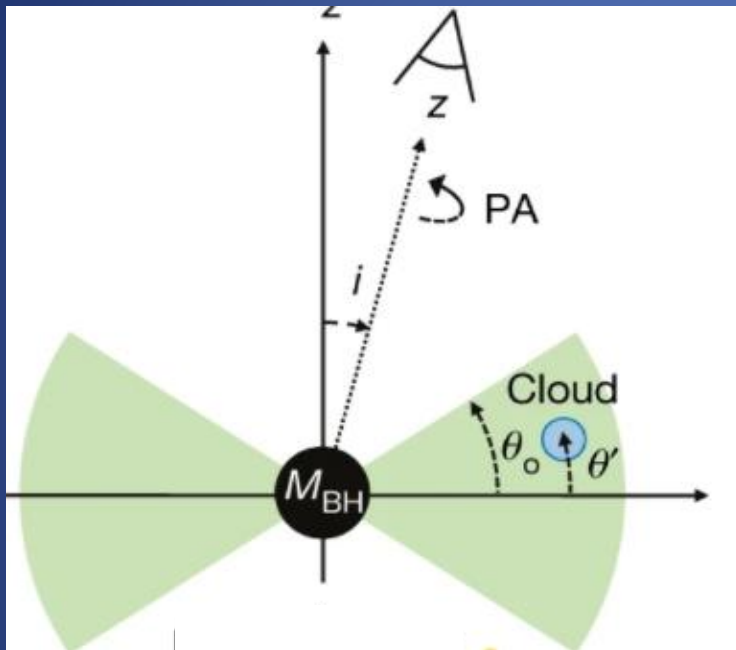


Mrk 817



Wu et al 2025

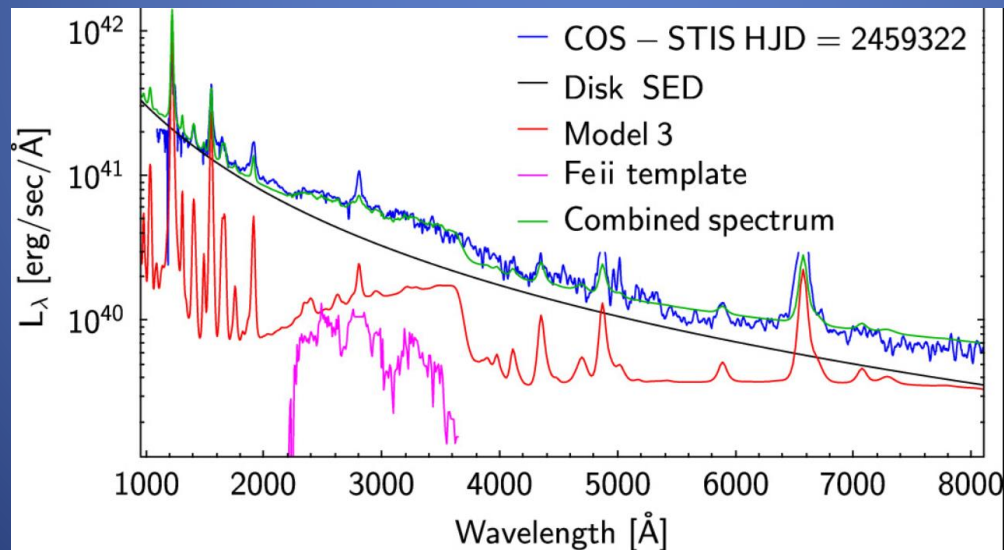
AGN structure and geometry



Dehghanian et al. 2020
Disk wind in NGC 5548

The combined spectrum

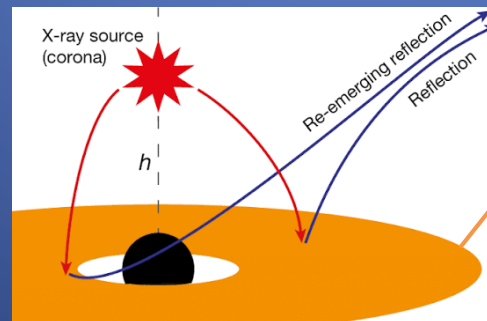
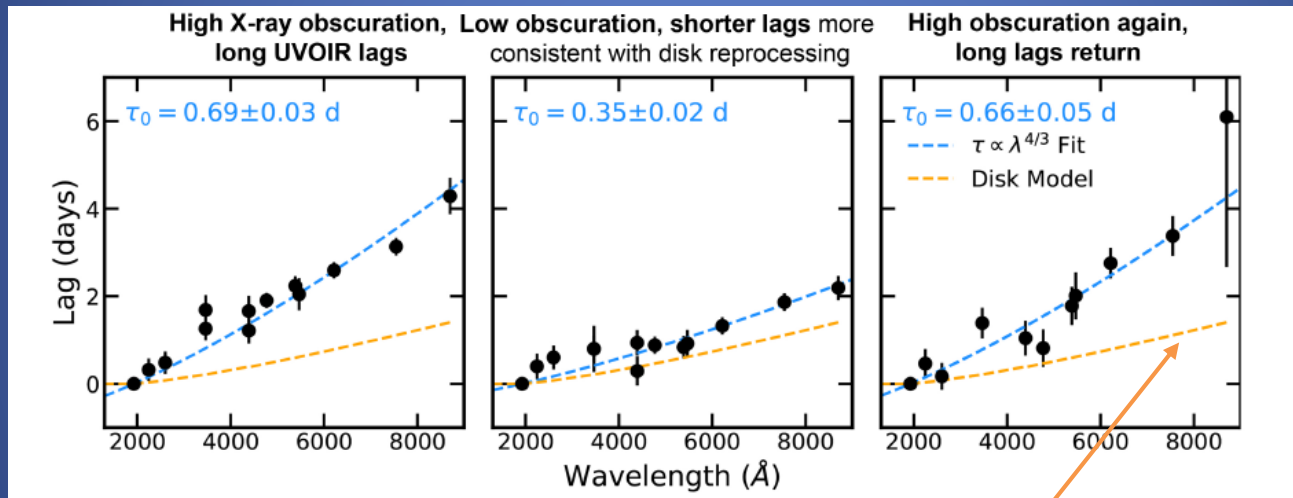
- Optically thick, geometrically thin accretion disks
- RPC (radiation pressure confined) BLR clouds
- Disk wind



1

“Continuum” lags and accretion disk size

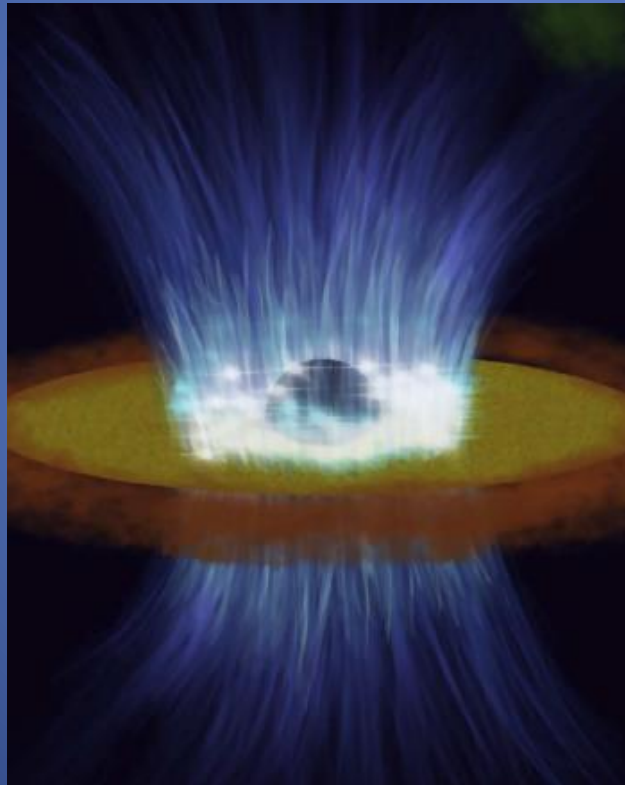
(X-ray illumination of accretion disks)



Disc winds spectral energy distribution and the variability time-scale of active galactic nuclei

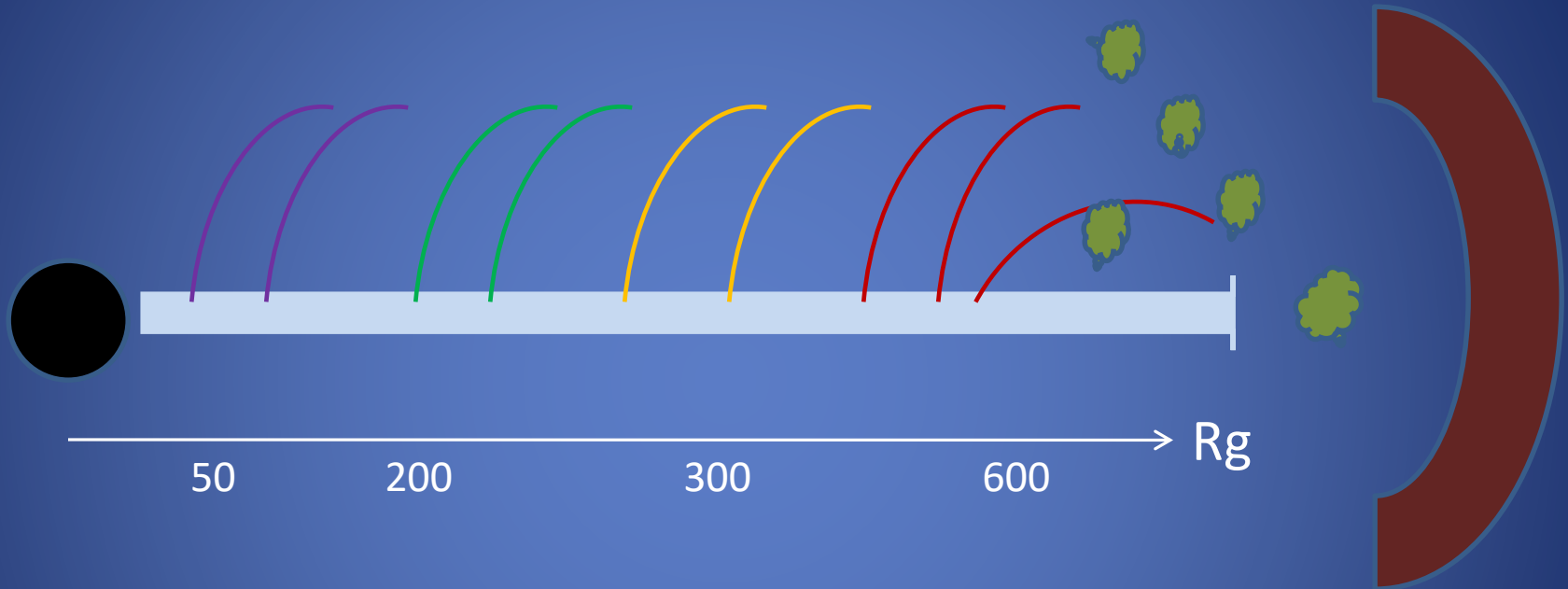
Hagai Netzer  

School of Physics and Astronomy, Tel Aviv University, Tel Aviv 69978, Israel



NGC 5548 Kynoch et al 2022

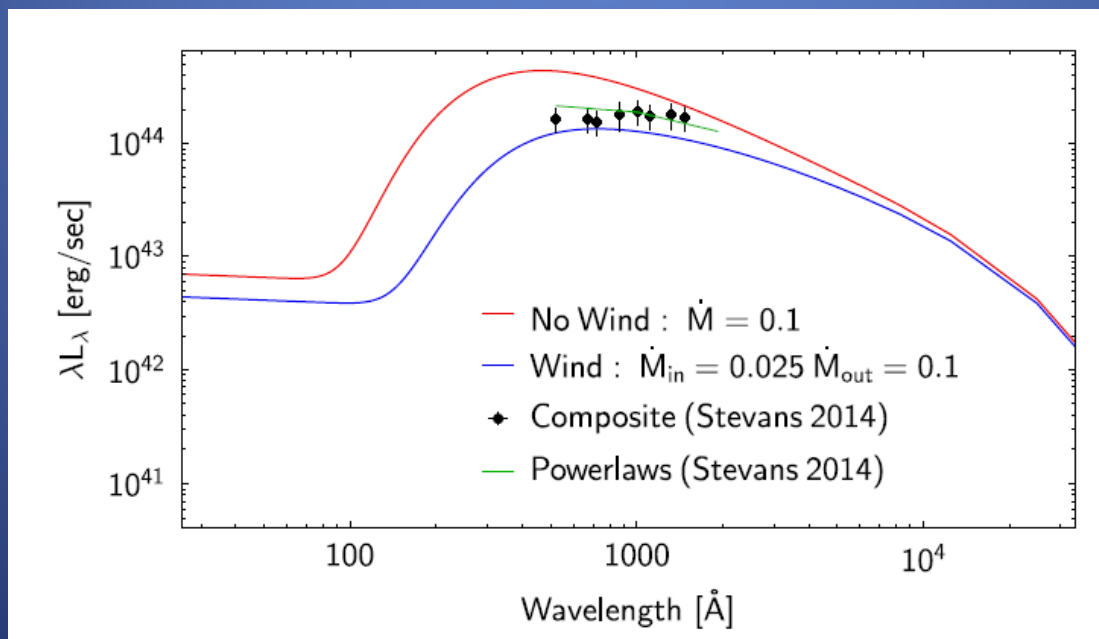
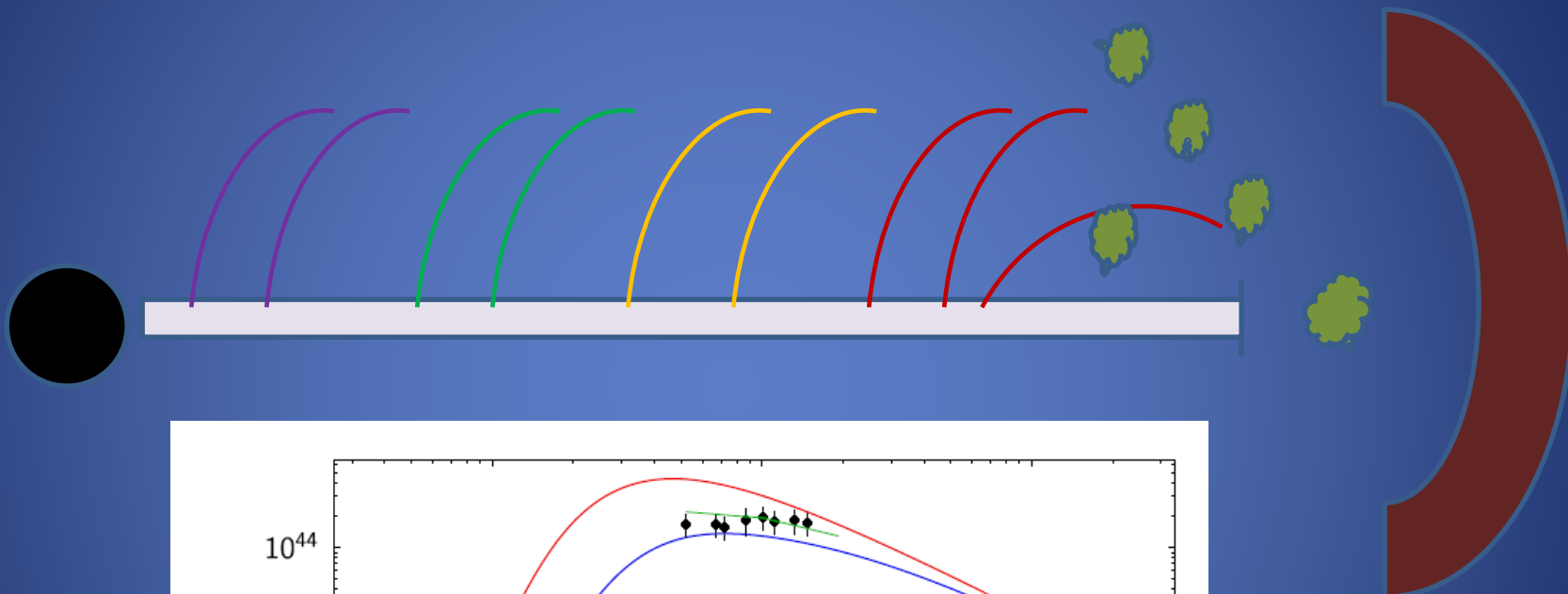
Accretion disk winds in AGN



Time-dependent mass outflows

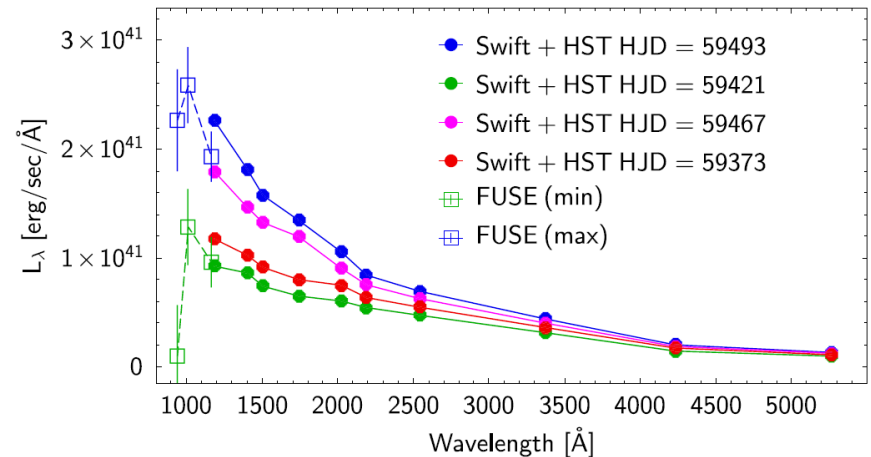
1. Reduce the disk accretion rate and the BH growth rate
2. Change the ionizing SED in a time-dependent way
3. Characterize the observed spectral variations

Disk wind in Mrk 817



Mrk 817

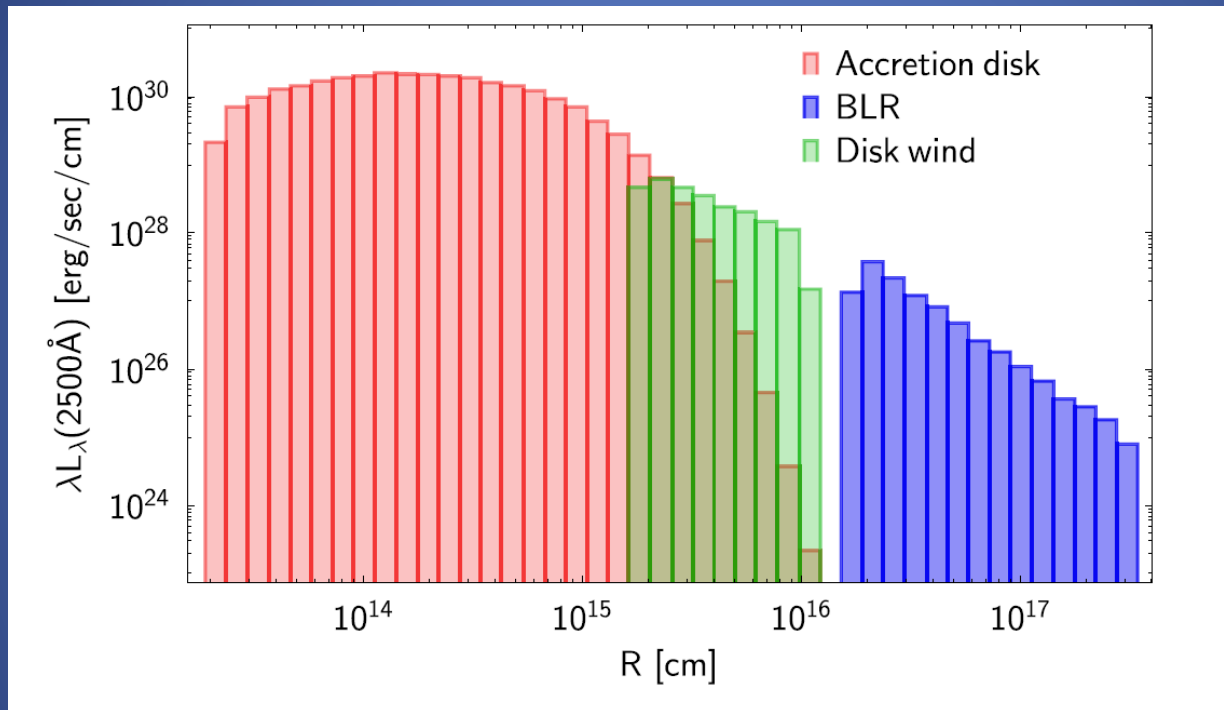
- The SED is bluer when brighter
- Variability time scale ≈ 100 days
- Are these properties correlated?



AGN Variability

“break” time, dynamical time, and thermal time
of
AGN accretion disk

A 2500 Å portrait of Mrk 817



$$L_{\text{disk}} : L_{\text{wind}} : L_{\text{BLR}} = 1 : 0.21 : 0.12$$

Consequences to microlensing observations

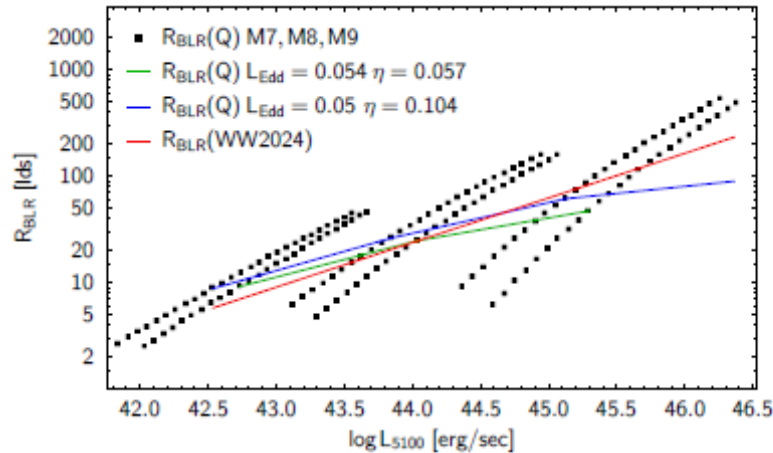
3

Measuring BH mass
using
Reverberation Mapping

Are we using the correct equations?

RM estimates of BH mass

Assume ionization by an accretion disk continuum



A single-term approximation:

$$R_{\text{BLR}} = a_1 L_{5100}^{\beta} \quad (\beta \approx 0.5)$$

Two-term approximation of BH mass

$$R_{\text{BLR}} = a_1 L_{5100}^{\beta} + a_2 (L_{5100}/M_{\text{BH}})^{\delta}$$

a_1 and a_2 are unknown constants.

$$M_{\text{BH}} = R_{\text{BLR}} \times f \text{FWHM}^2 / G$$

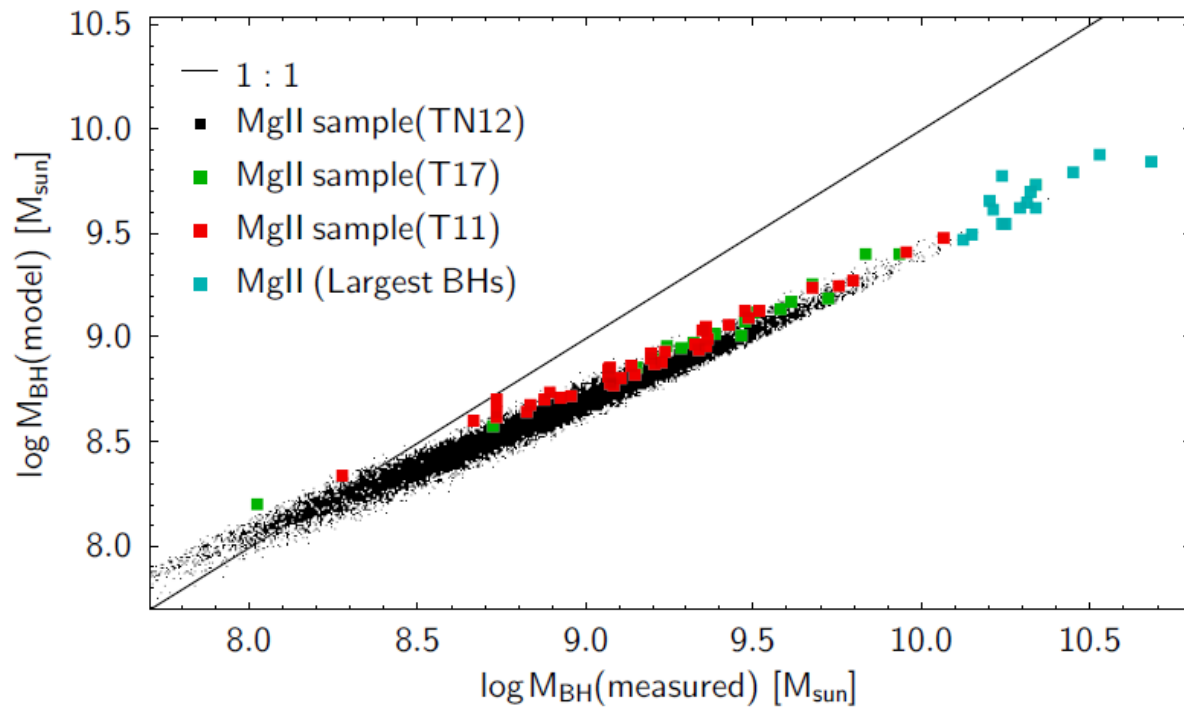
$$M_{\text{BH}} = \frac{1}{2} a_1 L_{5100}^{\beta} \text{FWHM}^2 \left[1 + \sqrt{1 + \frac{4a_2 L_{5100}^{1-2\beta}}{a_1^2 \text{FWHM}^2}} \right]$$

M_{BH} is known from the assumed disk model

FWHM is observed

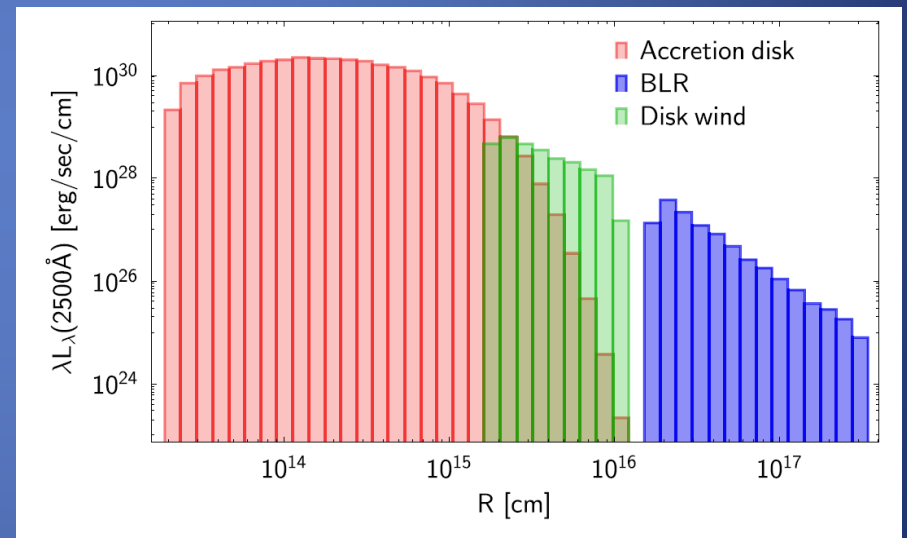
a_1 and a_2 are obtained from fitting large AGN samples

The most massive BHs: Single-term vs. two-term approximations



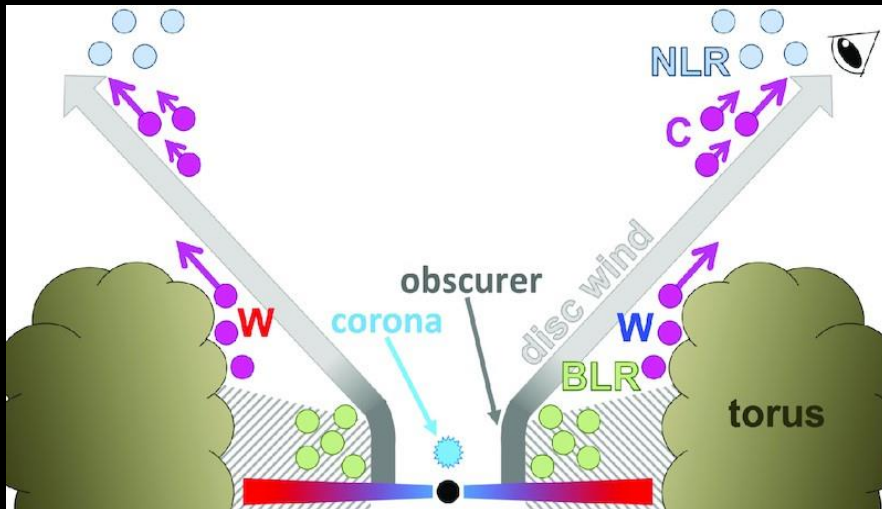
Observational consequences of AGN accretion disks

- “Continuum” variations
- Disk winds
- Using disk properties to measure black hole mass



But what about LRDs?

The Star 1955 - AGN Accretion disks 2026



?

???

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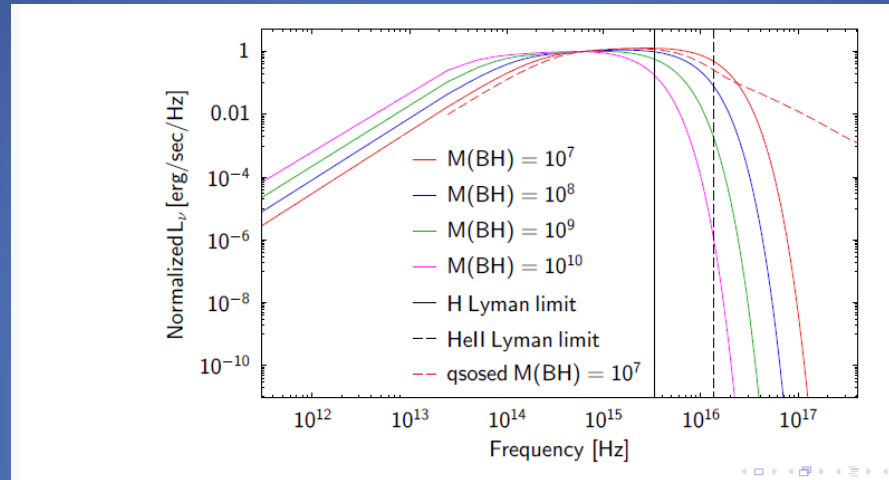
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Ionization parameter and R_{BLR}



$$U = \frac{L(ion)}{R_{BLR}^2 n c} = \text{const.} \quad R_{BLR} = a L(ion)^{0.5}$$

$L(ion)$ is not observed

Let us assume

$$L(ion) \propto L(5100\text{\AA})?$$

Variability

“break” time, dynamical time, and thermal time
of
AGN accretion disk

$$t_{\text{break}} \propto M_8^{0.55-0.65} (L/L_{\text{Edd}})^{0.3-0.35} \text{ days}$$

Arévalo et al. 2024

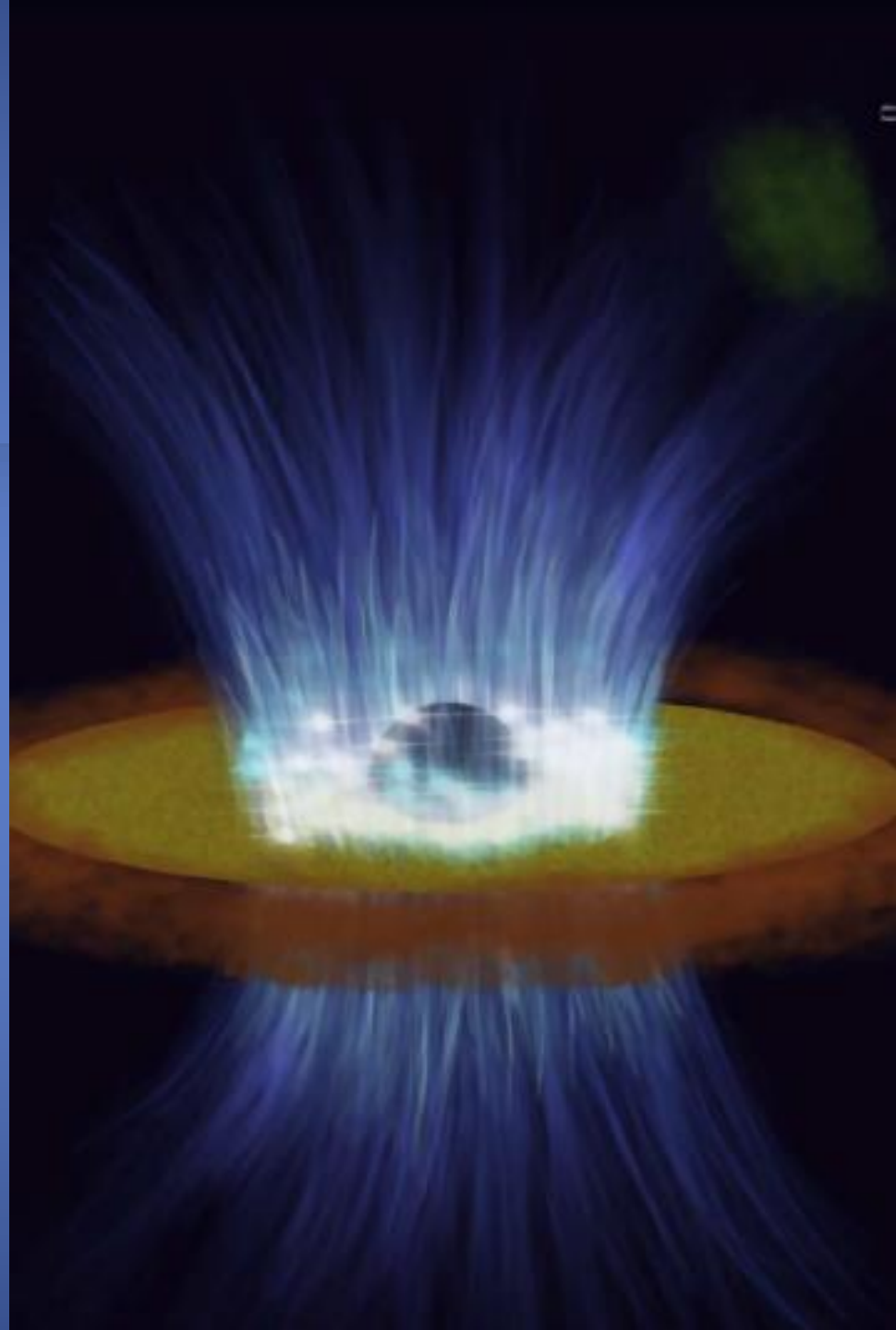
$$t_{\text{dyn}} = 0.005 M_8 \left[\frac{R}{R_g} \right]^{3/2} \text{ days}$$

$$t_{\text{th}} = t_{\text{dyn}} / \alpha$$

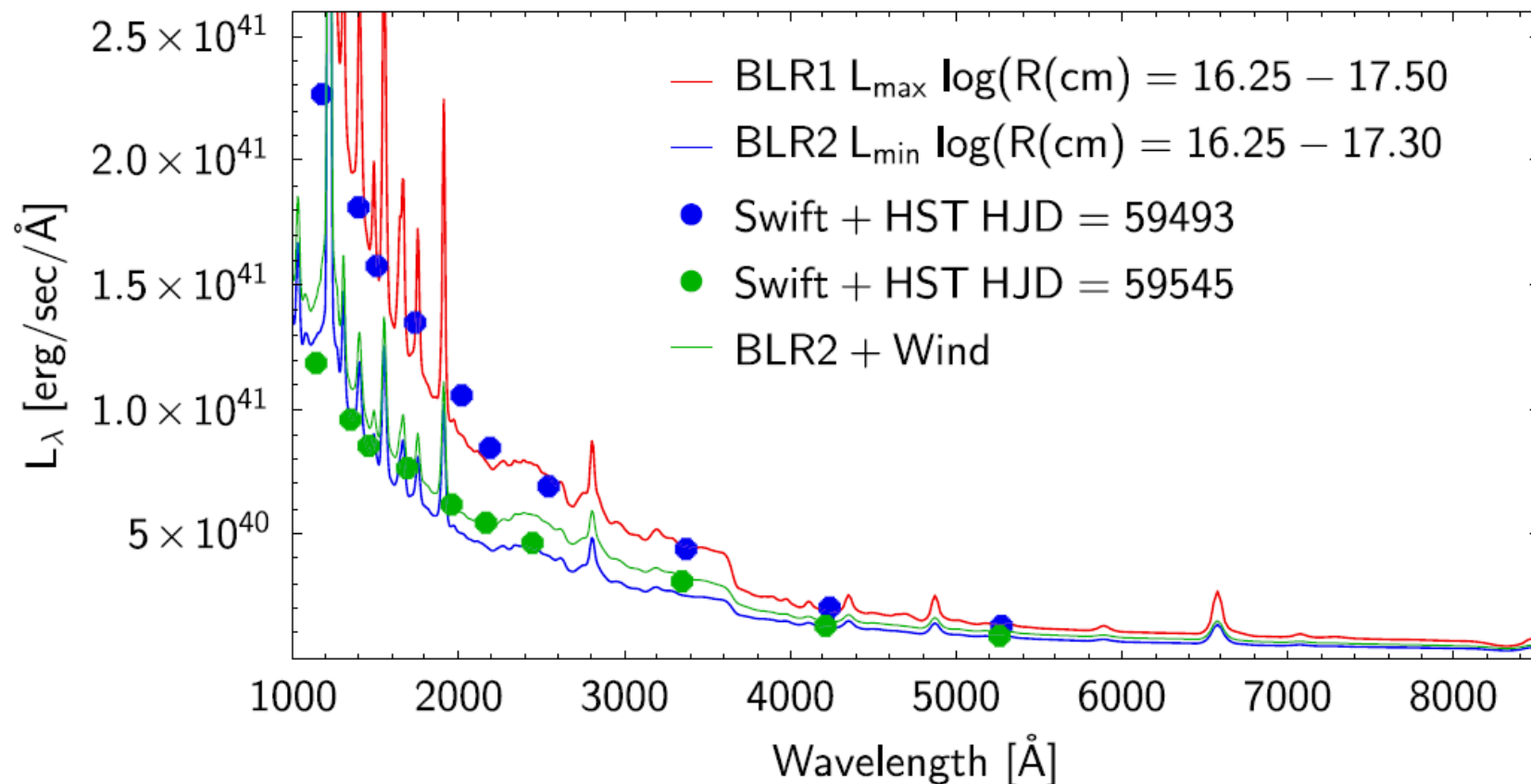
For Mrk 817, $t_{\text{th}} \approx 100$ days
(similar to the location of the blue continuum)

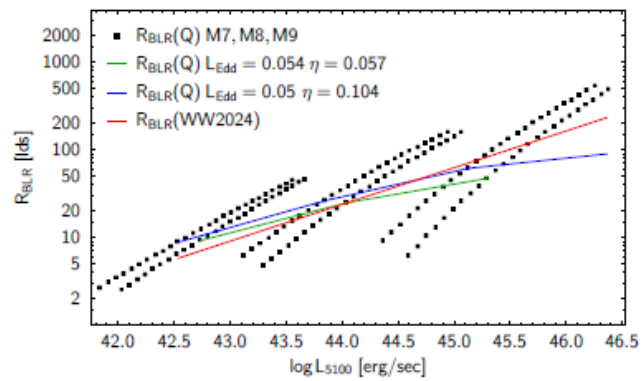
A short summary (so far ...)

- Unstable accretion disks
- X-ray illuminations: The origin of some of the continuum variations
- BLR variations: The largest contribution to “continuum” variations.”
- An additional ingredient - Disk wind

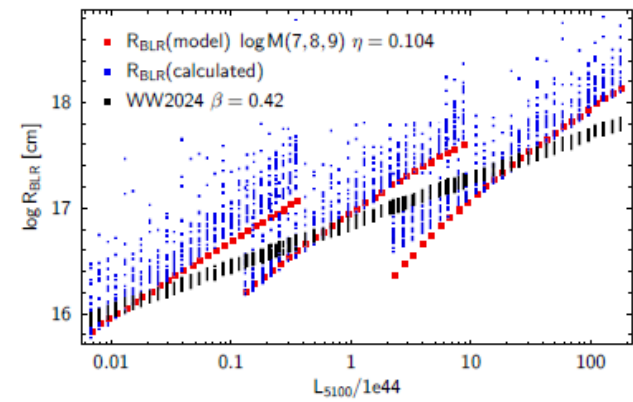


Photoionization models with and without wind





Single-term approximation



Two-term approximation

The most massive BHs

A single-term approximation

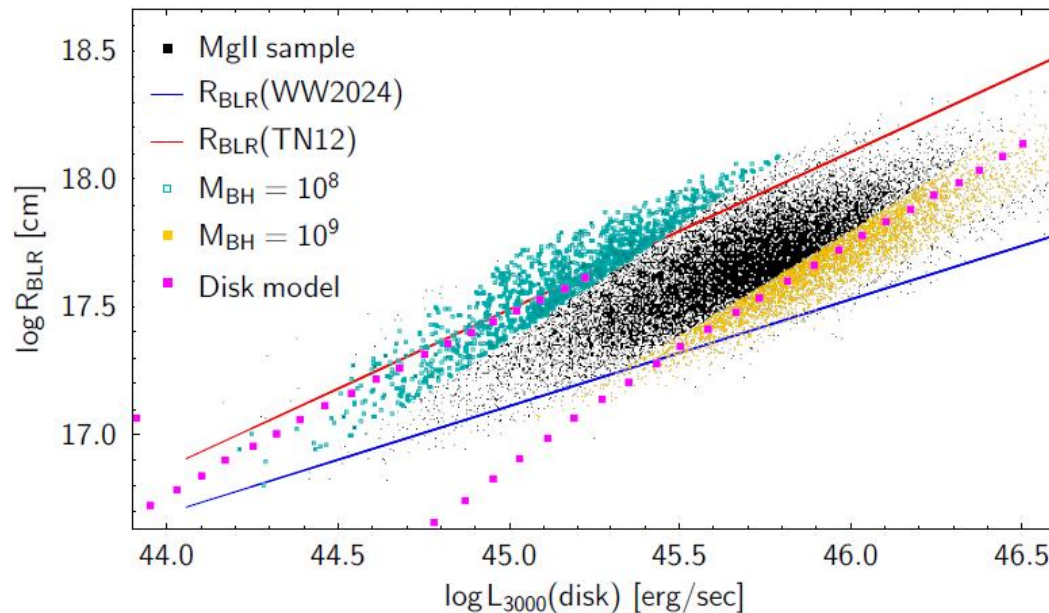
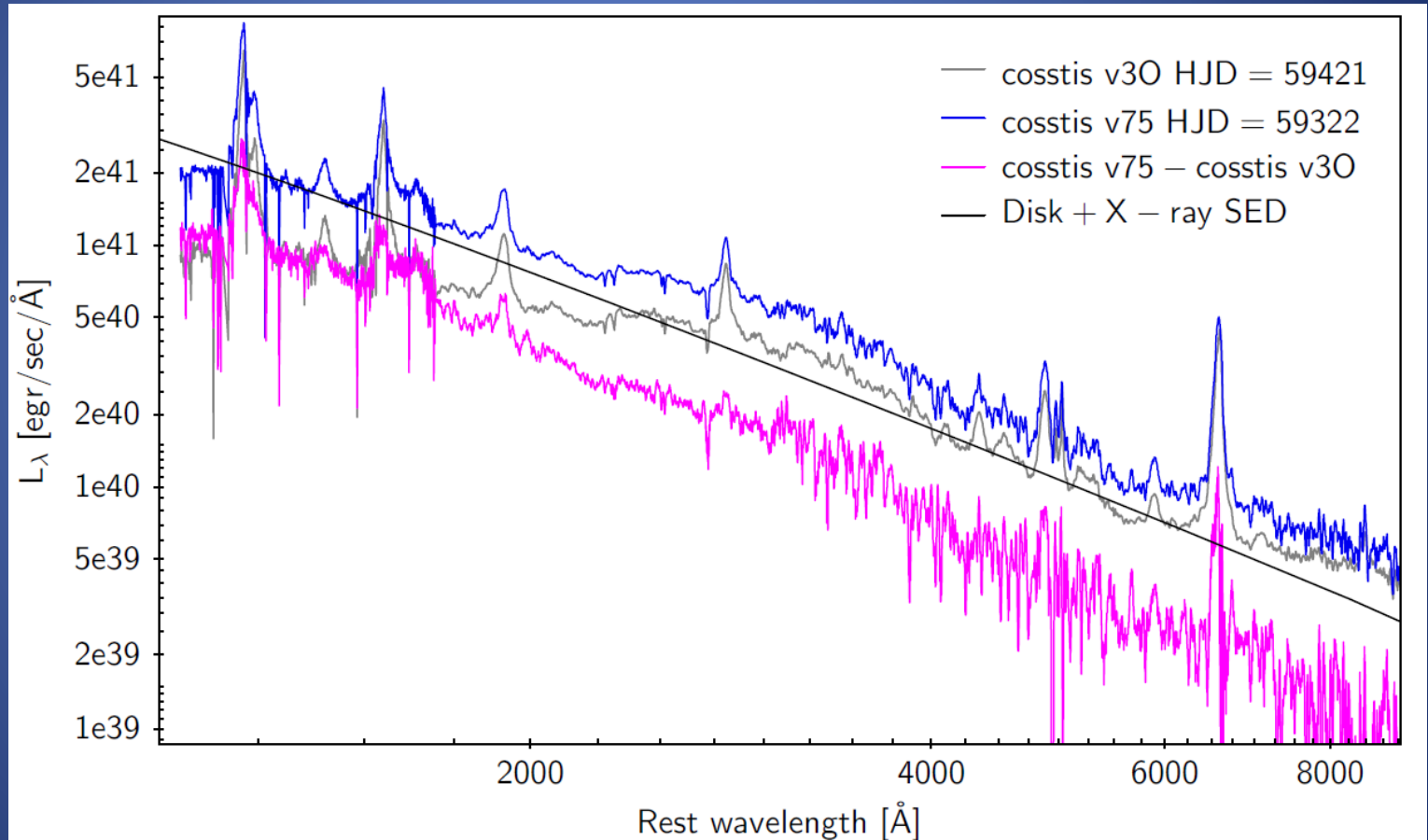


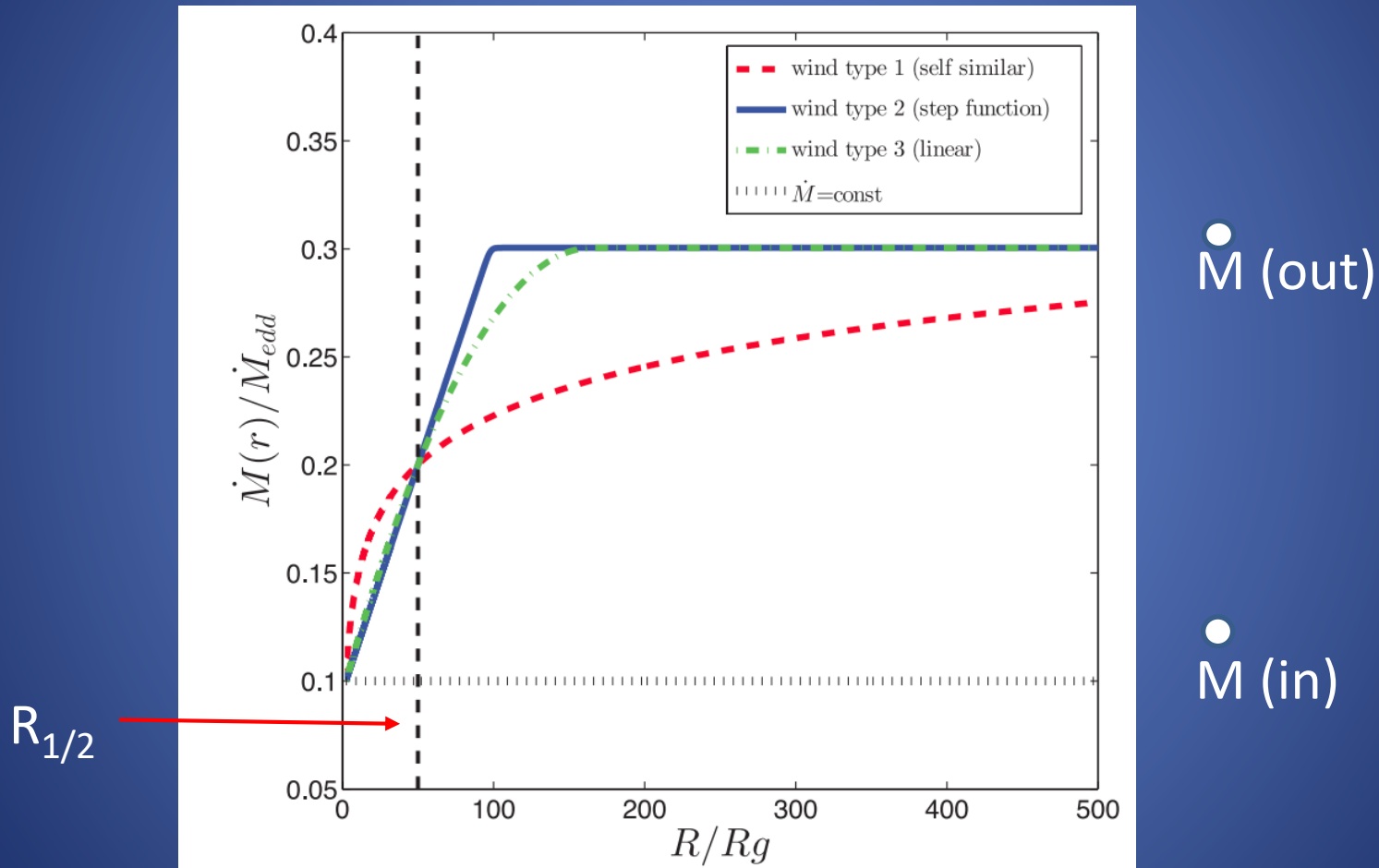
Figure: The TN12 sample, BH spin=0.7, $a_1=1.9$, $a_2=3.8 \times 10^8$

Brighter is bluer



Various types of disk winds

Slone and Netzer (2012)



Wind profile depends on ejection mechanism – e.g., thermal instability

Mrk 817: More observations

L_{bol} changed by a factor of 3 during the campaign, and $L_{\text{ionization}}$ by a factor of 4

$t_{\text{break}} = t_{\text{thermal}} = 100$ days, in agreement with the launch location of the wind.

The variability amplitude, the variability time scale, the location of the wind, and the observed changing SED, all indicate a mass outflow rate of $\approx 0.1 \text{ Msun/yr}$ and $R_{1/2} = 50 \text{ Rg}$

General consequences

- Time-variable mass outflows from AGN disks may be related to the thermal timescale of these sources. The wind may be driven by thermal fluctuations in the disk atmosphere.
- Consequences to high accretion rate AGN
 - NLS1s
 - The most luminous high- z AGN
- Consequences to scaling relationships
 - Black hole mass measurements
 - L/L_{edd} measurements
- Consequence to the duty-cycle of Supermassive BHs
- Consequences to AGN feedback
- Consequences to CL AGN??