Light echo studies of the accretion disk and the broad line region in active galactic nuclei

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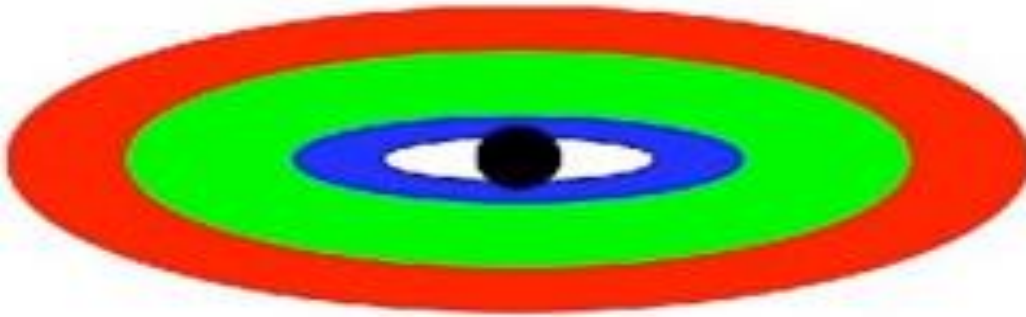
Accretion Disk

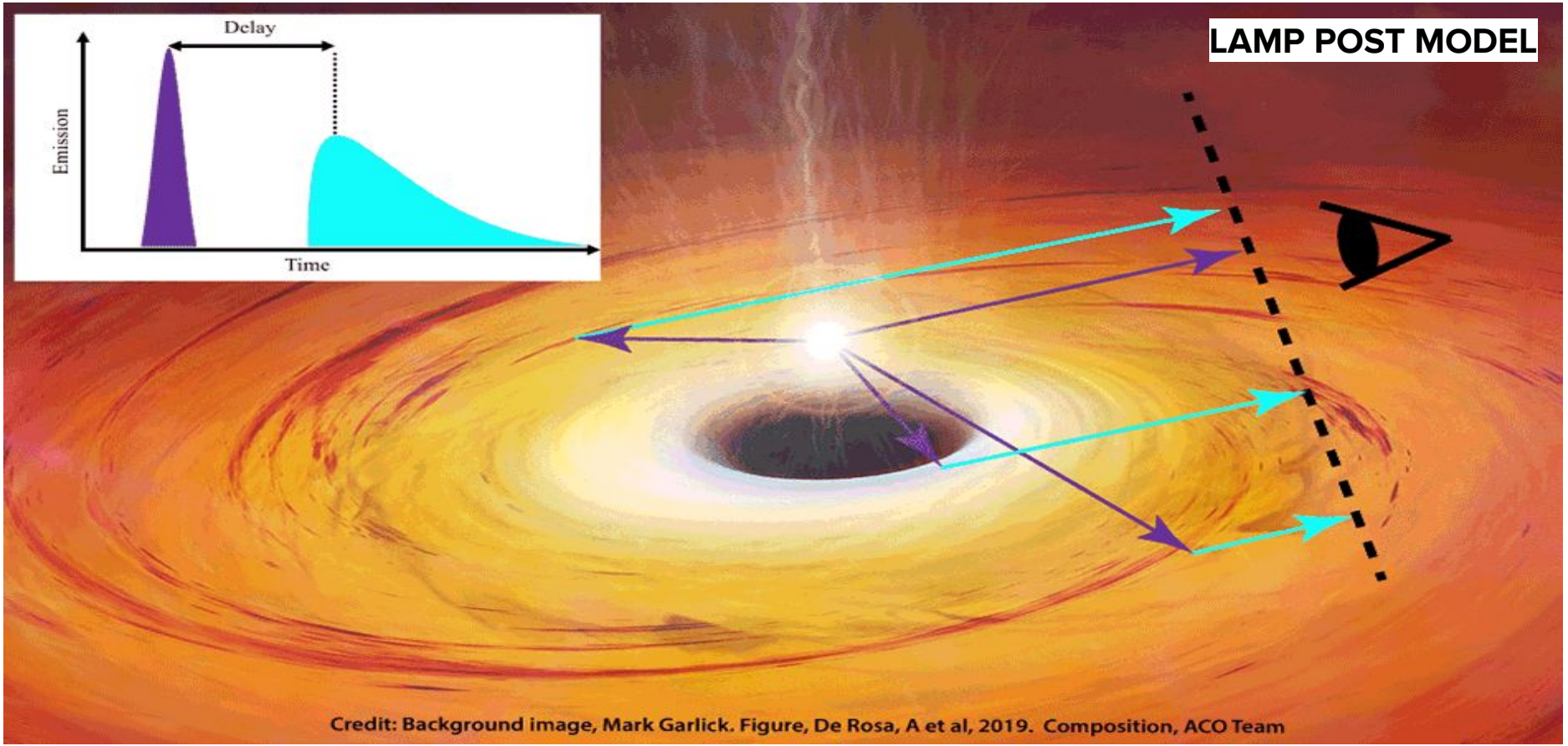
- Flux emitted through disk surface at a given radius(r).

$$F(r) = \frac{3GM_{bh}\dot{M}}{8\pi r^3}\sqrt{1-\frac{6}{r}}$$



- Temperature of disk at given radius.

$$T(r) = \left[\frac{3GM_{bh}\dot{M}}{8\pi r^3\sigma}\sqrt{1-\frac{6}{r}}\right]^{1/4}$$

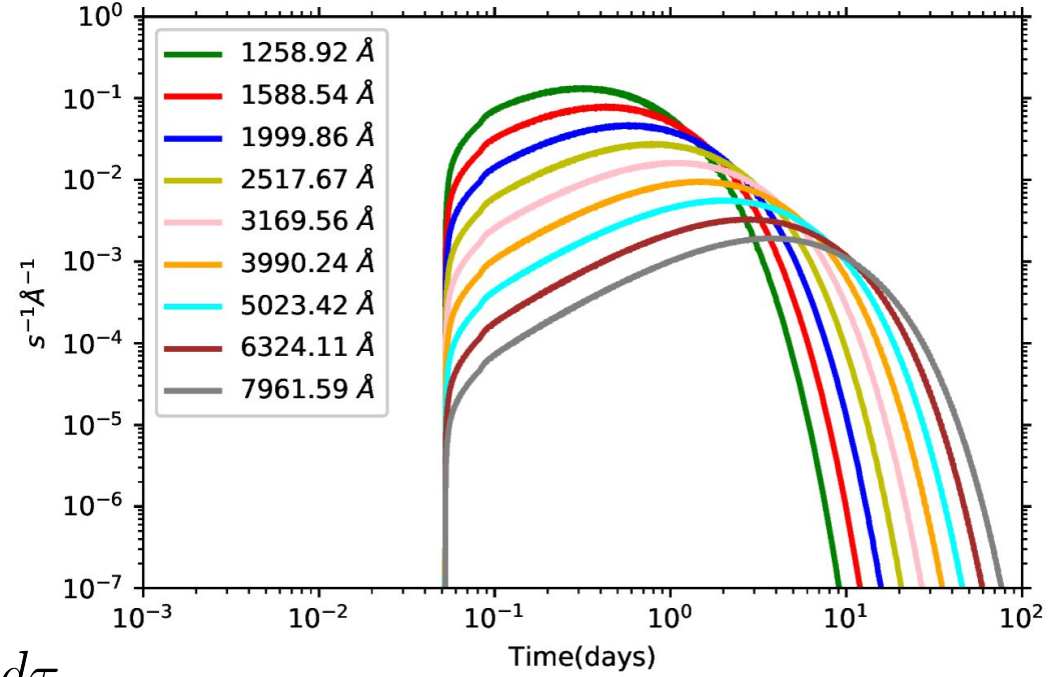


$$F_{new}(r) = \frac{3GM_{bh}\dot{M}}{8\pi r^3}\sqrt{1-\frac{6}{r}} + \frac{L_x h}{4\pi r^3}$$

$$T_{new}(r) = \left[\frac{3GM_{bh}\dot{M}}{8\pi r^3\sigma}\sqrt{1-\frac{6}{r}} + \frac{L_x h}{4\pi\sigma r^3}\right]^{1/4}$$

Response Function

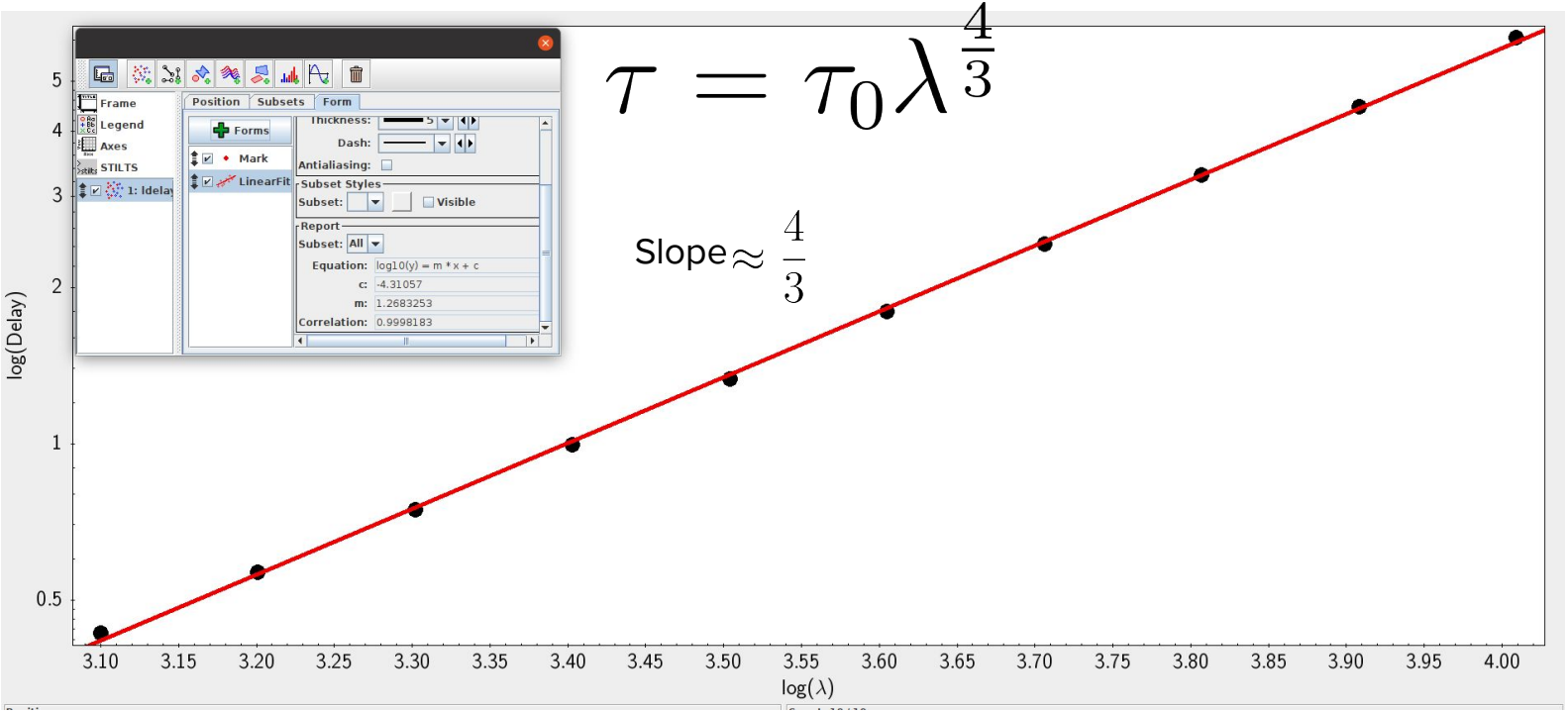
- Black Hole Mass= $10^8 M_\odot$
- Eddington ratio= 1.0
- Corona Height= $5R_g$
- Inner radius= $6R_g$
- Outer radius= $10000R_g$
- Inclination Angle= 30°



$$L(\lambda, t) = \int_{-\infty}^{\infty} \psi(\lambda, \tau) C(t - \tau) d\tau$$

NO GR EFFECT
NO REFLECTION

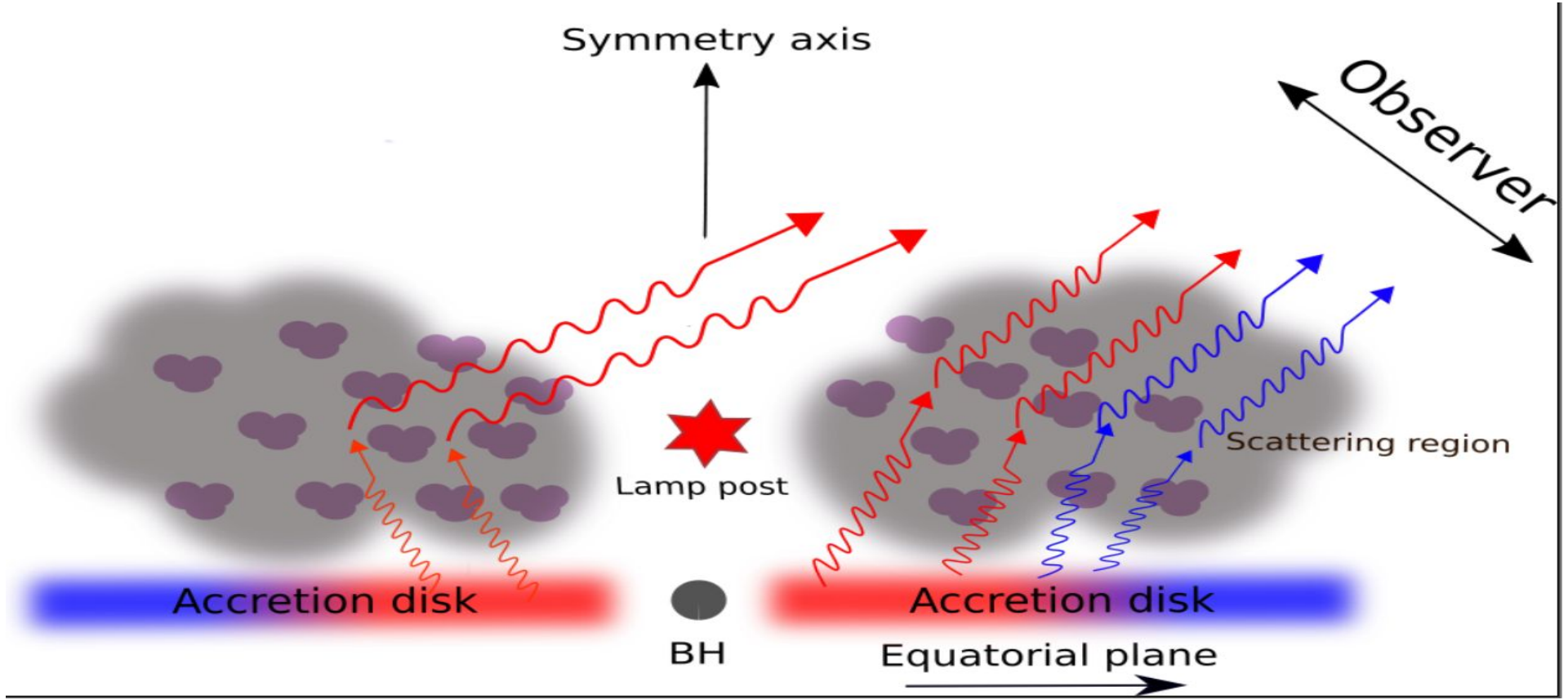
Delay Plot



$$\tau(\lambda) = \frac{\int t\psi(t,\lambda)dt}{\int \psi(t,\lambda)dt}$$

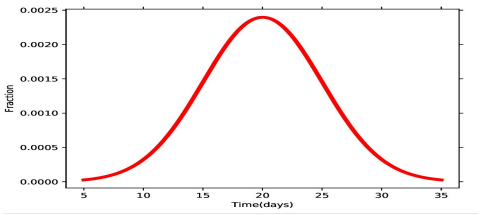
Collier et al. 1999

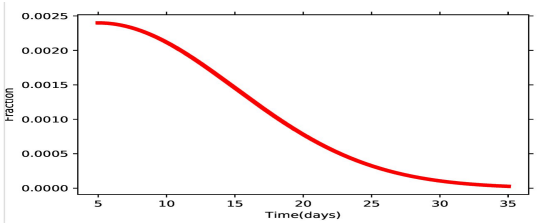
Including BLR Contribution

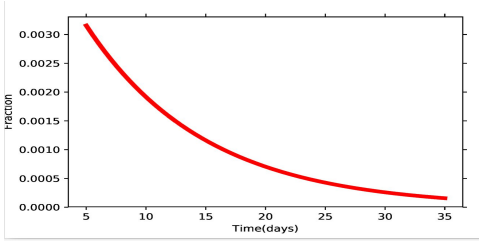


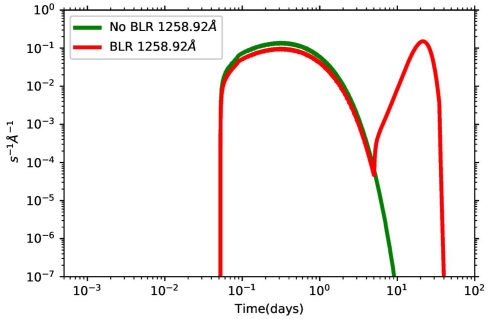
Credit: Dr. Raj Prince

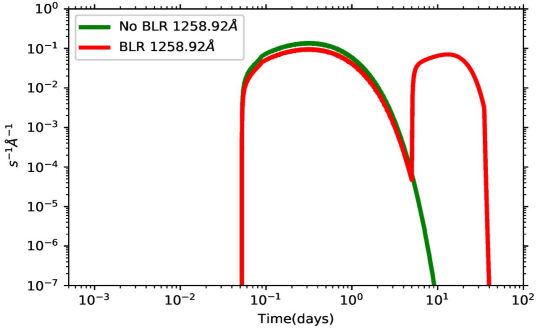
BLR Contribution(30 percent)

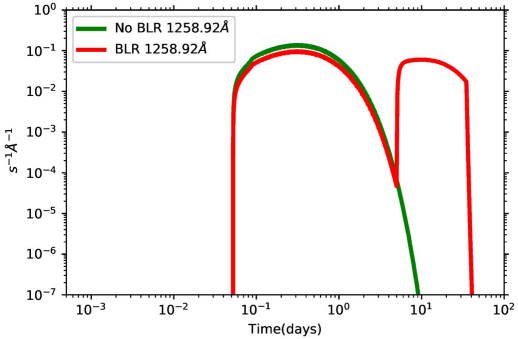






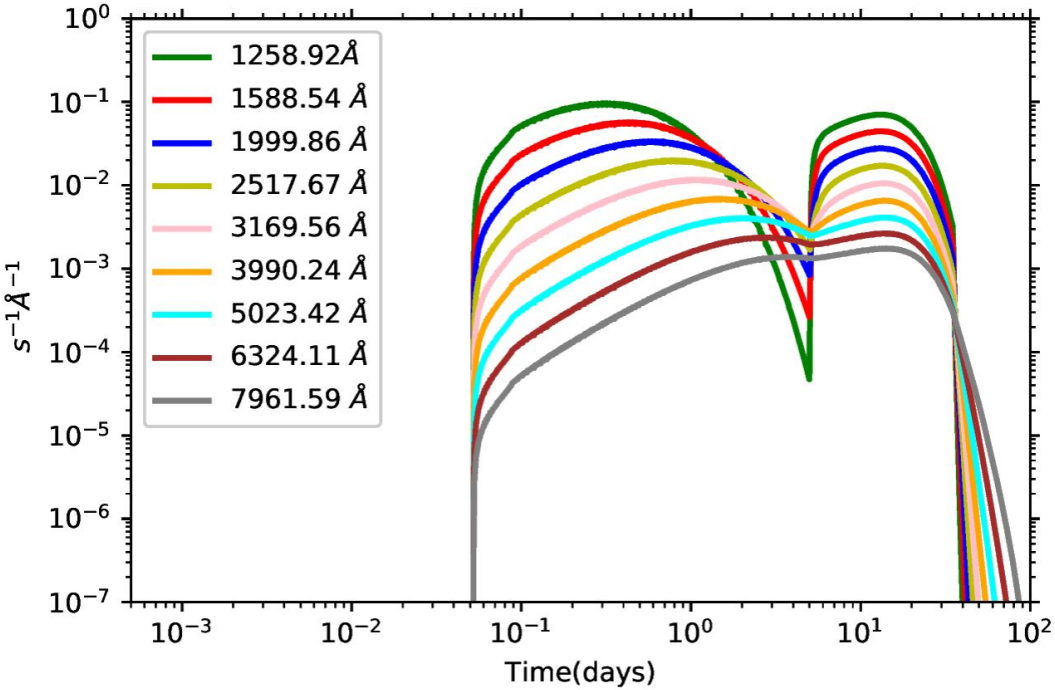




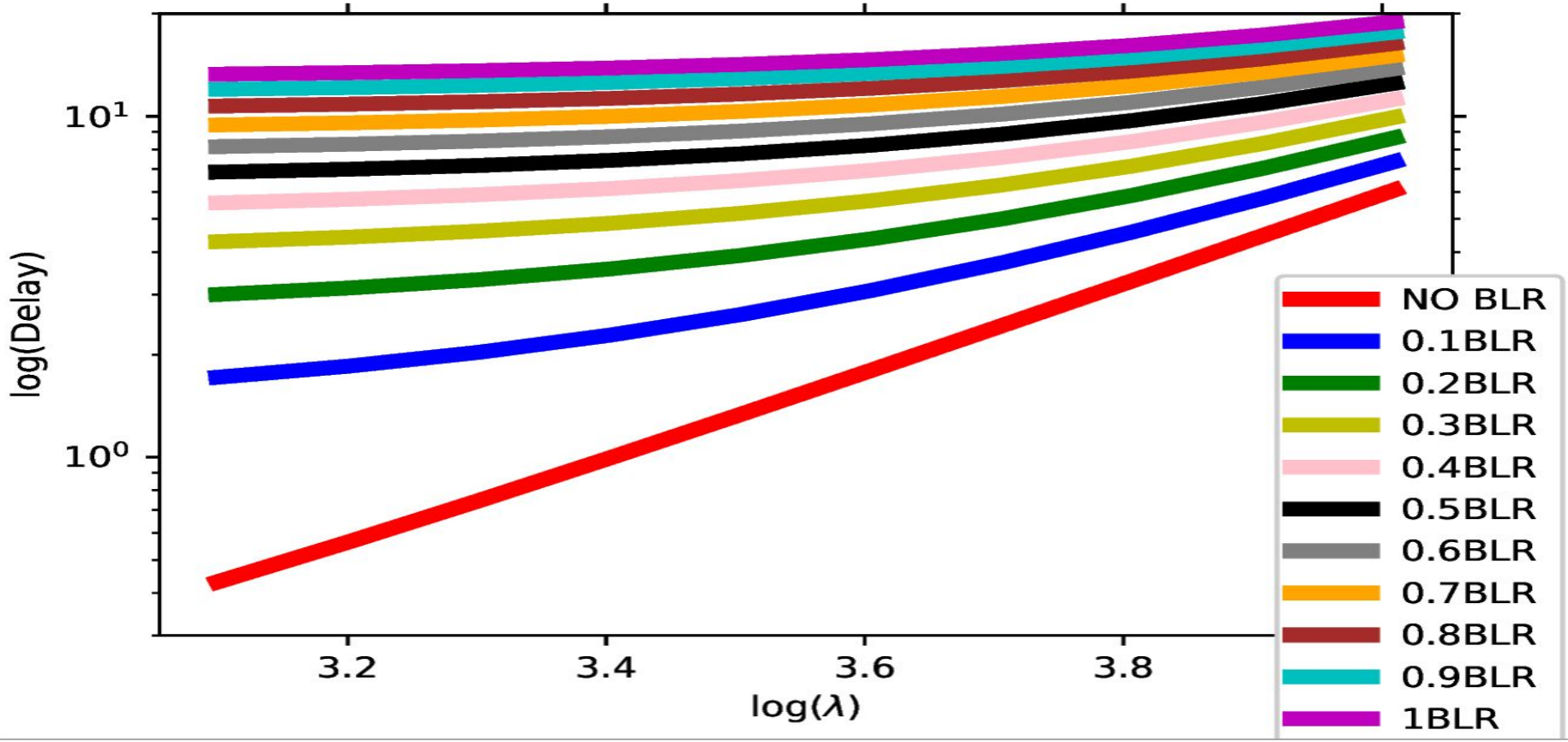


Disk+BLR Response Function for Multiple Wavelengths

- **Black Hole Mass=** $10^8 M_\odot$
- **Eddington ratio=** 1.0
- **Corona Height=** $5R_g$
- **Inner radius=** $6R_g$
- **Outer radius=** $10000R_g$
- **Inclination Angle=** 30°
- **BLR Percentage** = 30%
- **BLR Response**= Half Gaussian

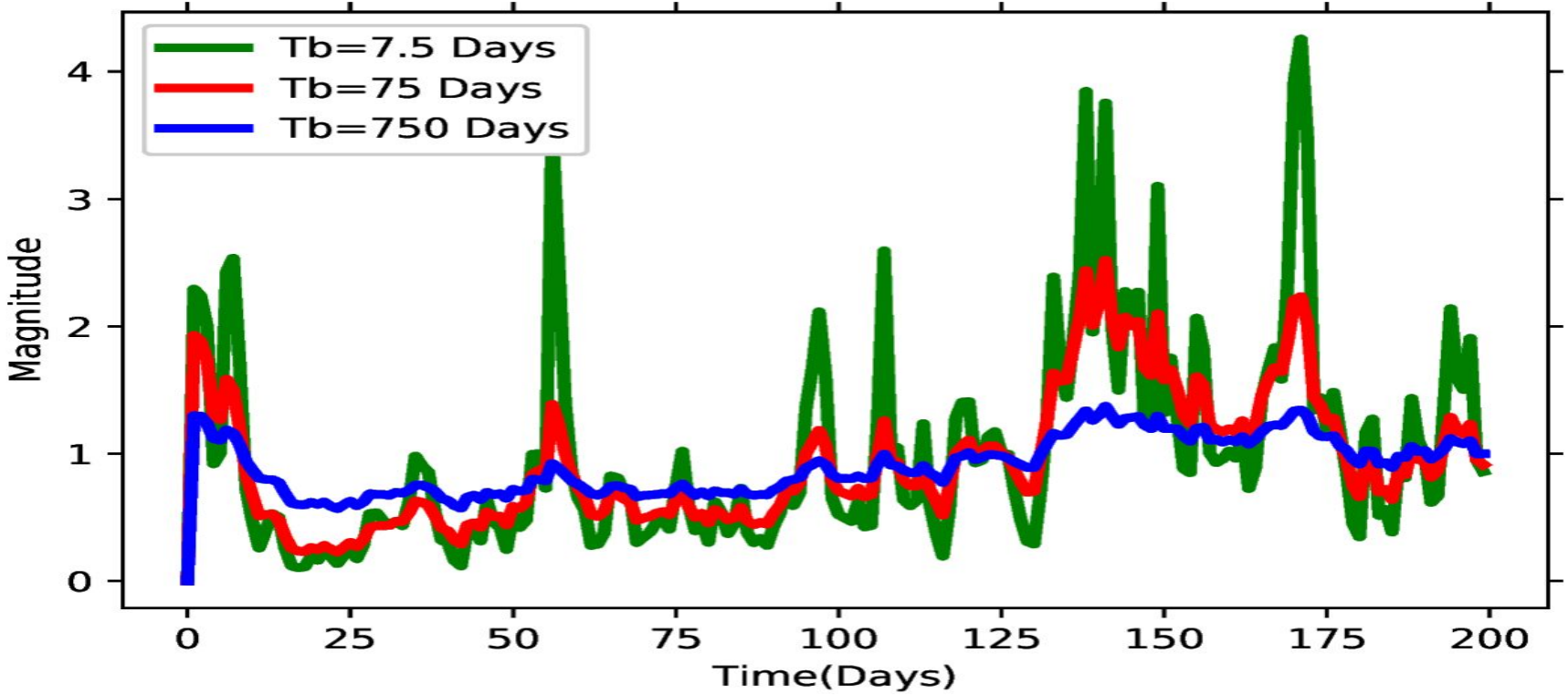


Delay Vs Wavelength

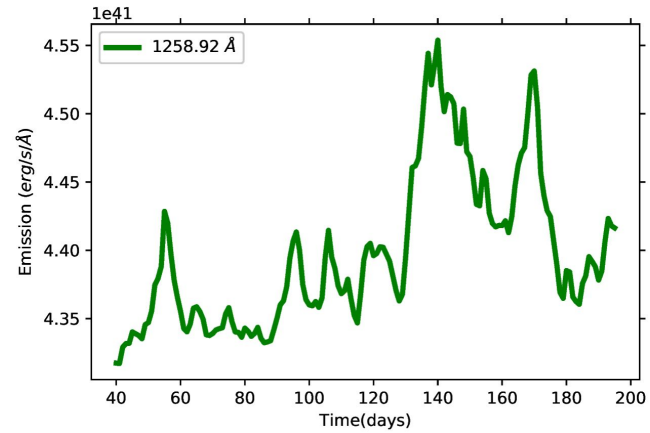


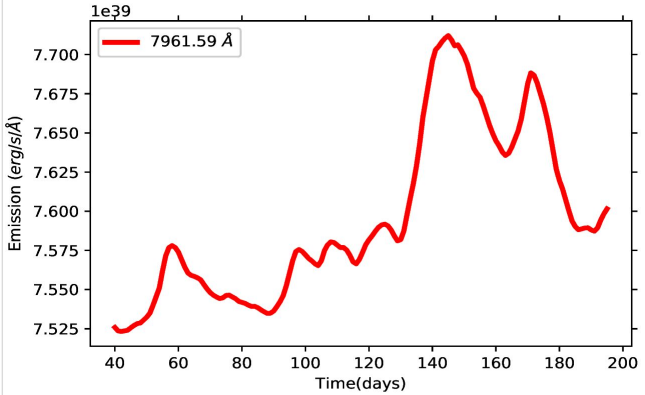
X-Ray Light Curves from Corona

$$L(\lambda, t) = \int_{-\infty}^{\infty} \psi(\lambda, \tau) C(t - \tau) d\tau$$



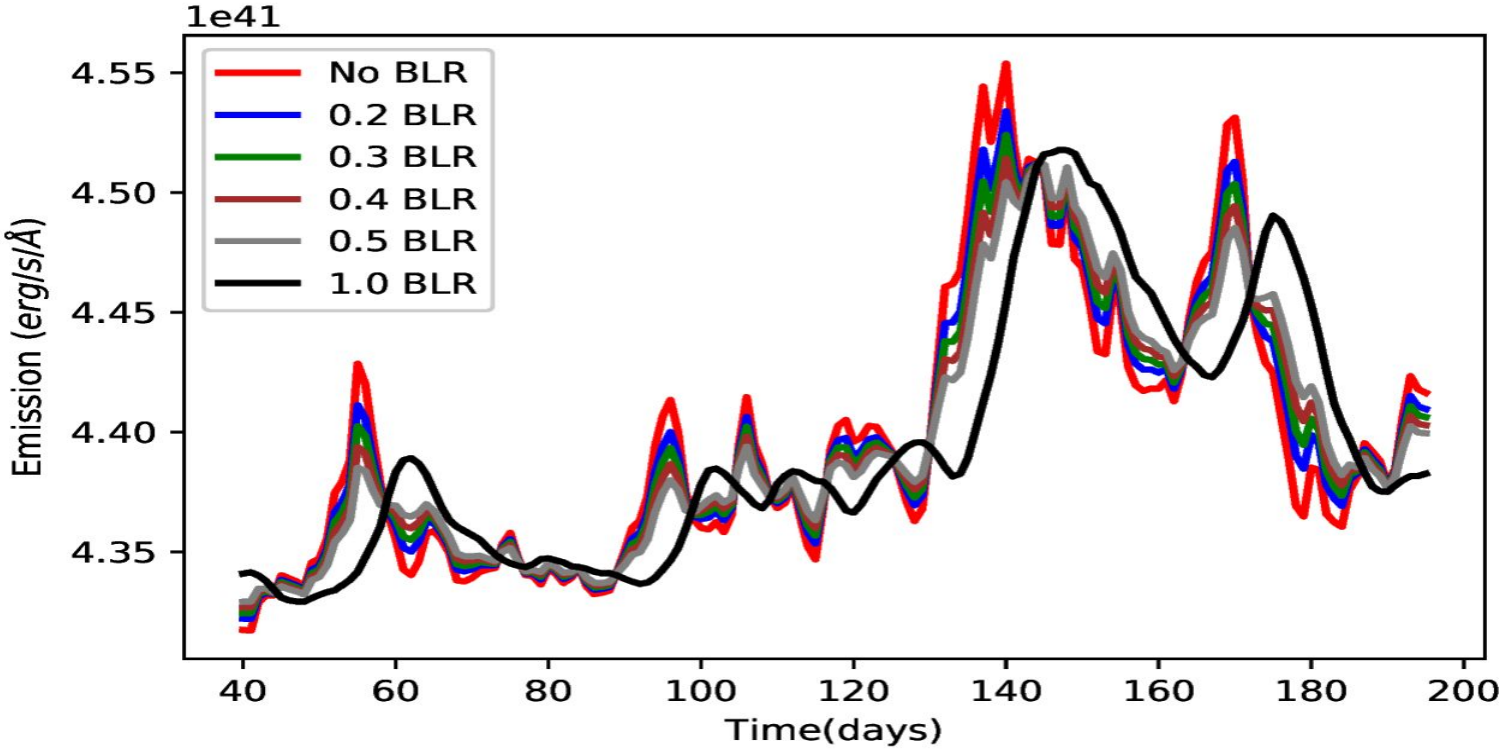
Accretion Disk Light Curve(No BLR Contribution)



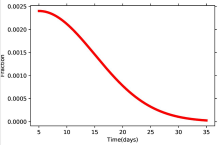


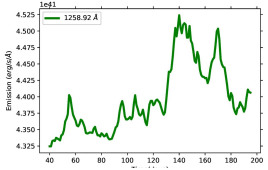
ICCF Delay=5.93241 days
Chi Square Delay=5.61723 days
Javelin Delay=6.1467206 days

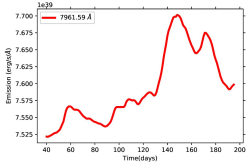
Disk + BLR Light Curve (With Different BLR Contribution)

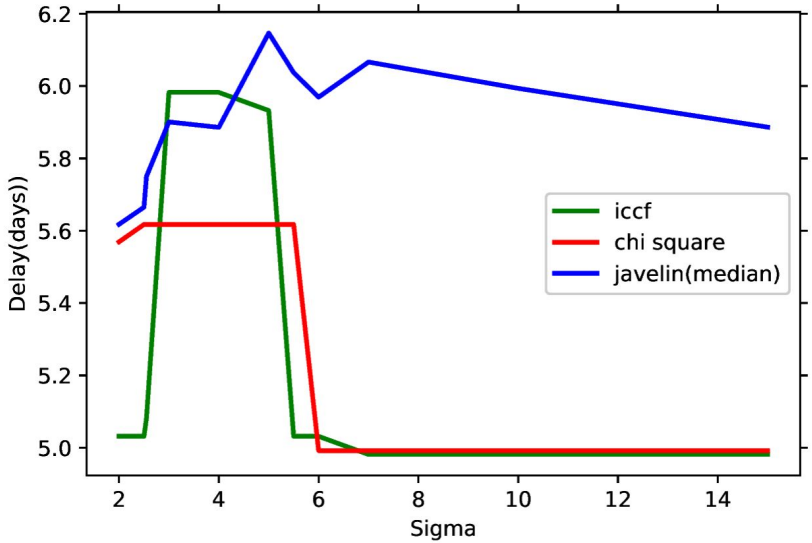


Disk + BLR(Tb=75 Days)





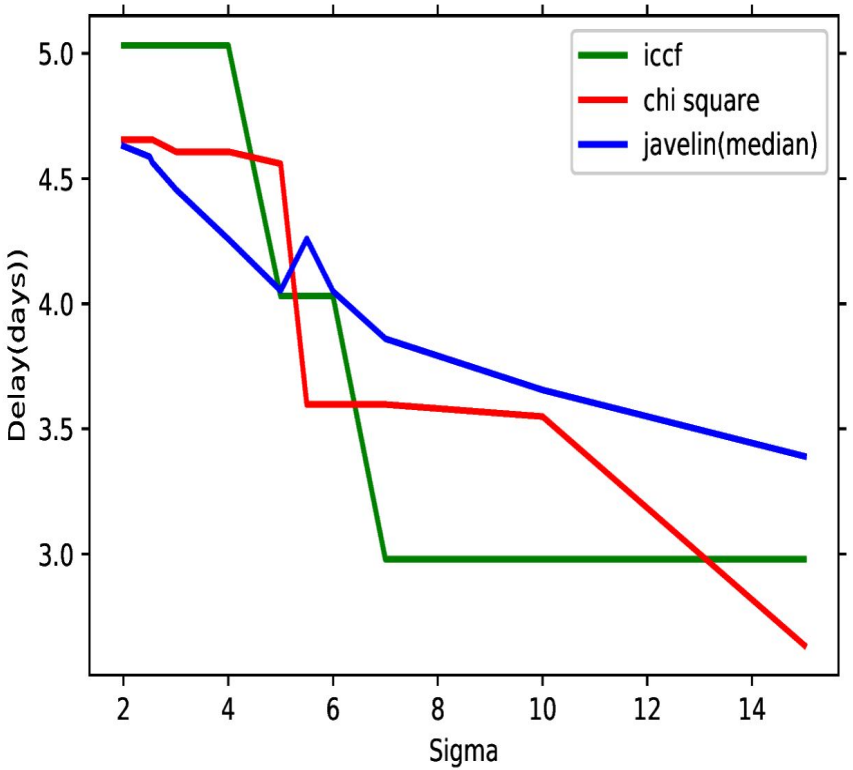




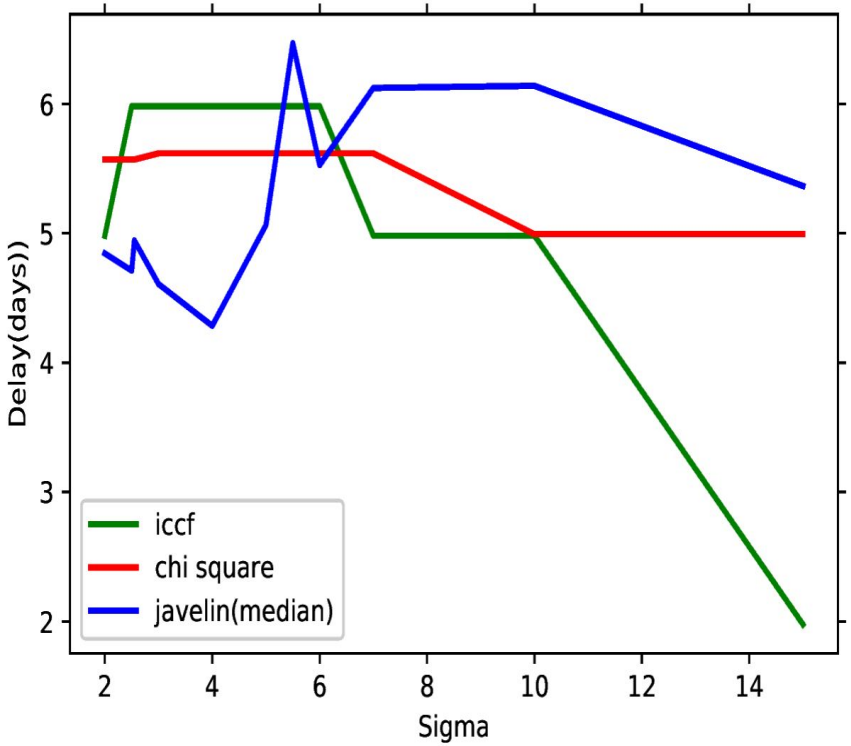
Width	End points	ICCF	Chi sq	Javelin
5	5-35	5.93241	5.61723	6.14672
10	5-35	4.98122	4.9919	5.99363
3	5-35	5.98247	5.61723	5.90079
7	5-35	4.98122	4.99198	6.066417
15	5-35	4.981225	4.99198	5.886415
2	5-35	5.031288	5.56913	5.617664
4	5-35	5.982477	5.61723	5.885771
6	5-35	5.031288	4.99198	5.96935
2.5	5-35	5.031288	5.61723	5.665034
2.55	5-35	5.081352	5.61723	5.75010
5.5	5-35	5.031288	5.61723	6.03699

Disk + BLR Continue....

Tb=7.5 Days



Tb=750 Days



COSMOLOGY

$$D = 3.3 Mpc \left(\frac{\tau}{days}\right)\left(\frac{\lambda}{10^4 \mathring{A}}\right)^{-3/4}\left(\frac{f_\nu / cosi}{J_y}\right)^{-1/2}\left(\frac{X}{4}\right)^{-4/3}$$

$$H_0 = 89.6 \frac{kms^{-1}}{Mpc}\left(\frac{\lambda}{10^4 \mathring{A}}\right)^{3/2}\left(\frac{z}{0.001}\right)\left(\frac{\tau}{days}\right)^{-1}\left(\frac{f_\nu / cosi}{J_y}\right)^{1/2}\left(\frac{X}{4}\right)^{4/3}$$

Collier et al. 1999

Questions and Comments

Thank you