Thin Accretion Disks Around Black Holes:
Modeling the Secondary Outburst

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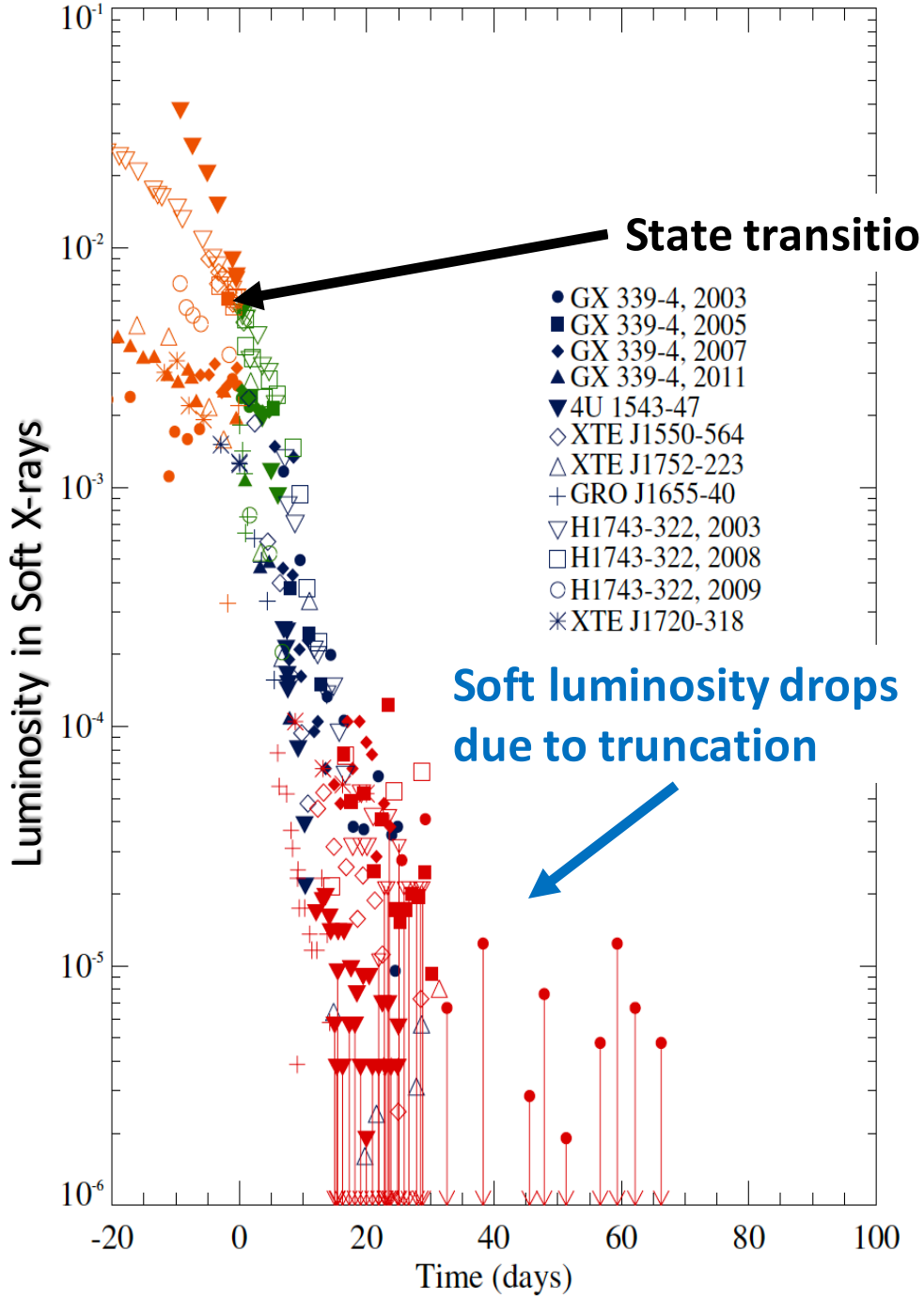
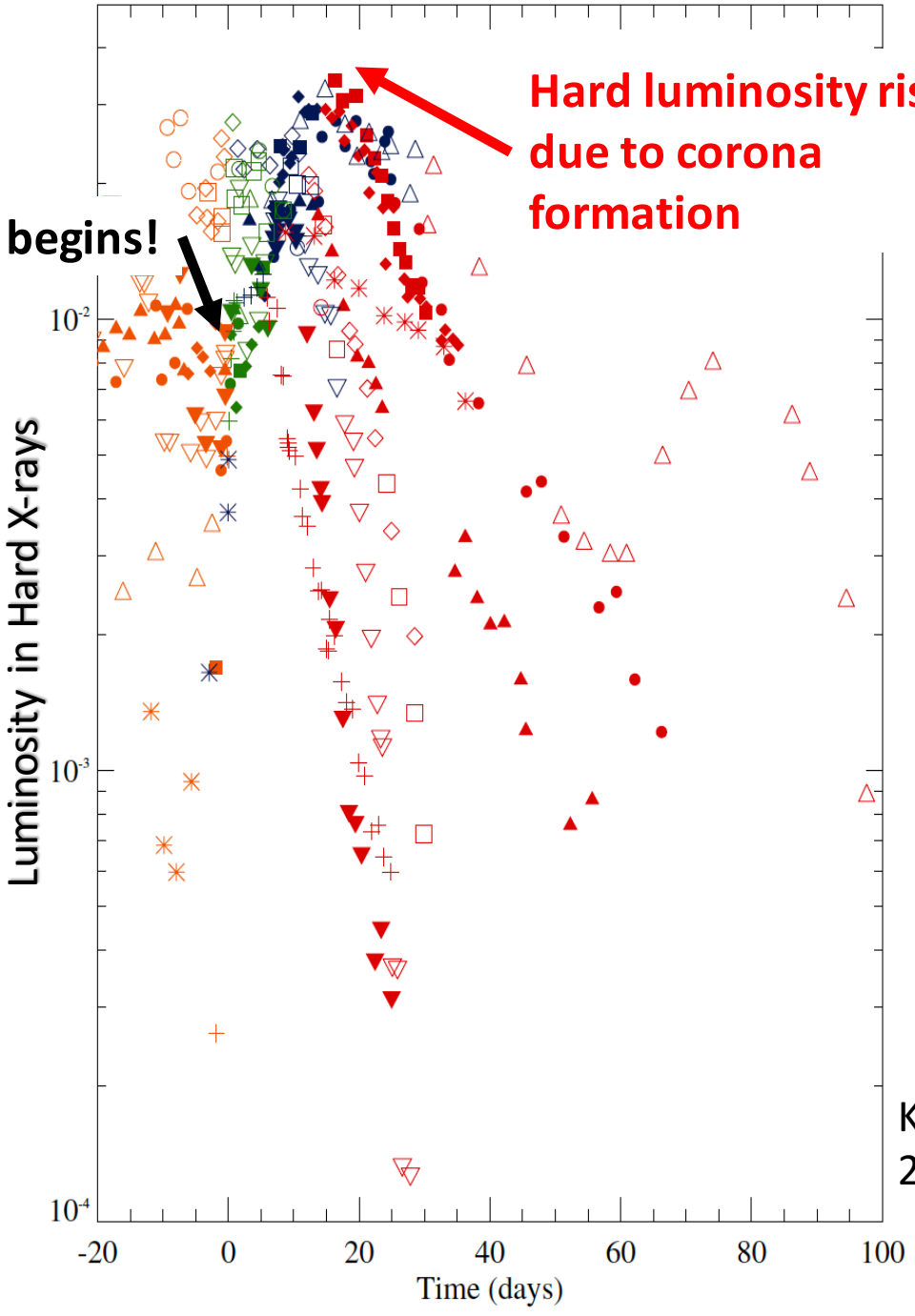
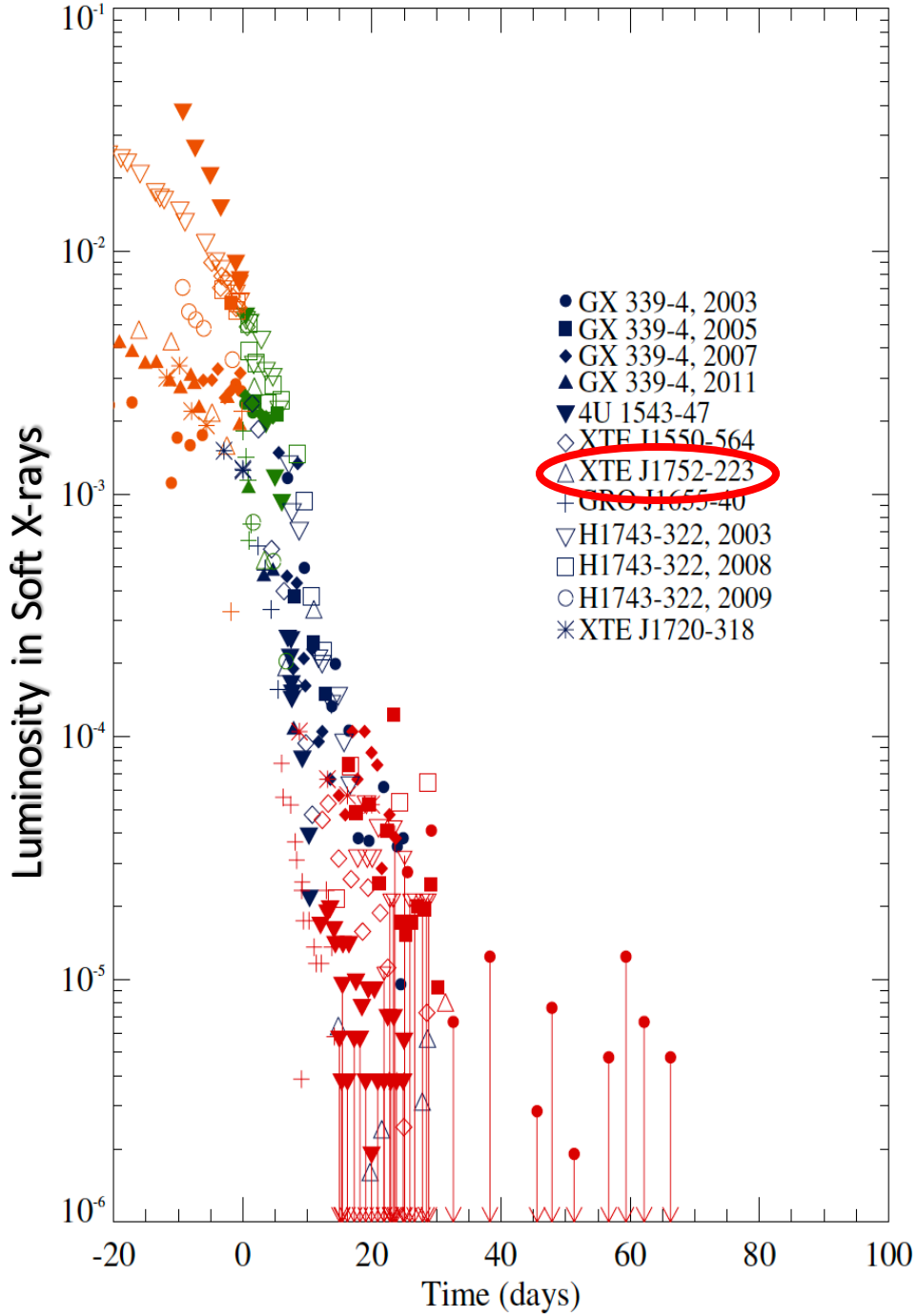
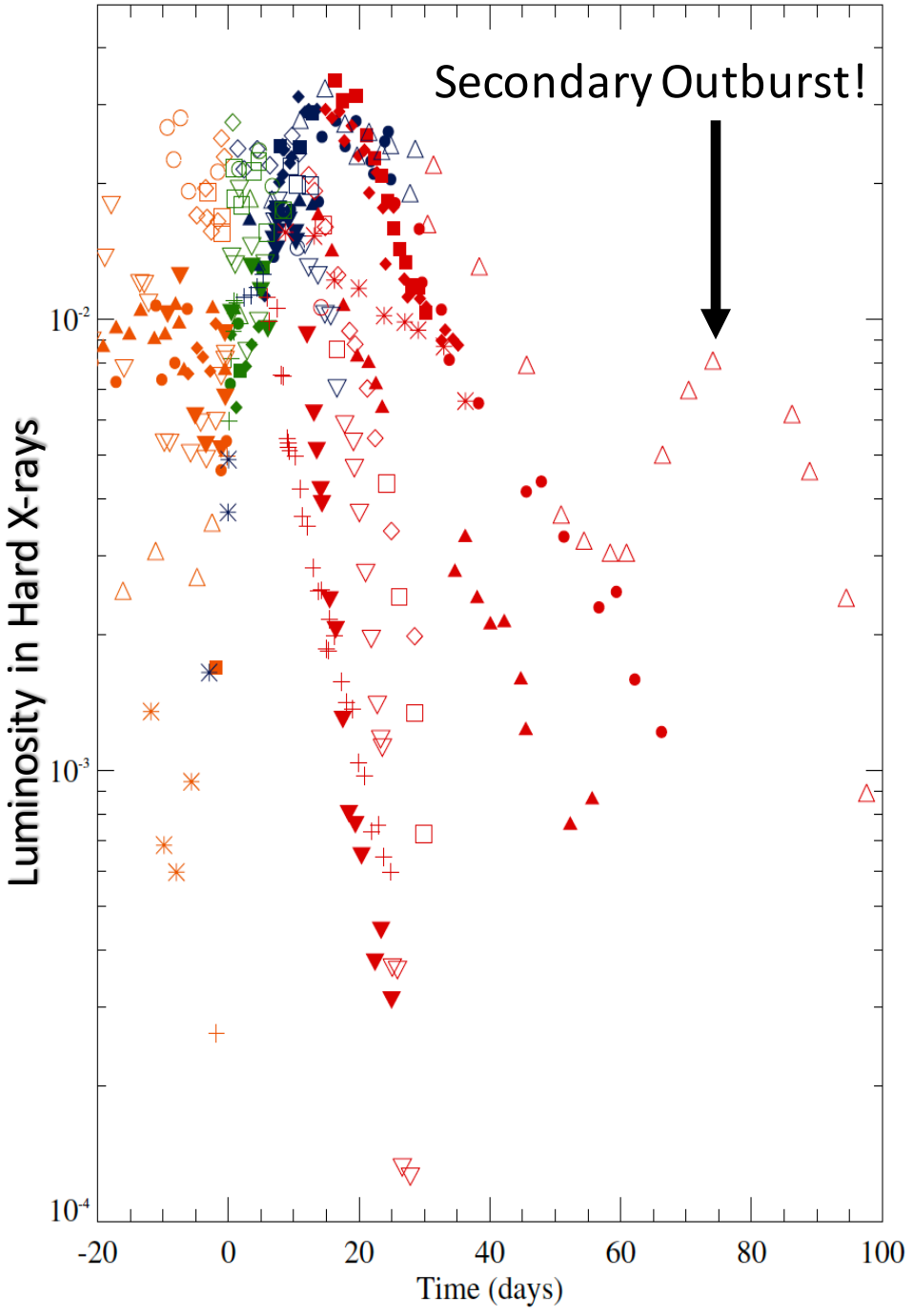


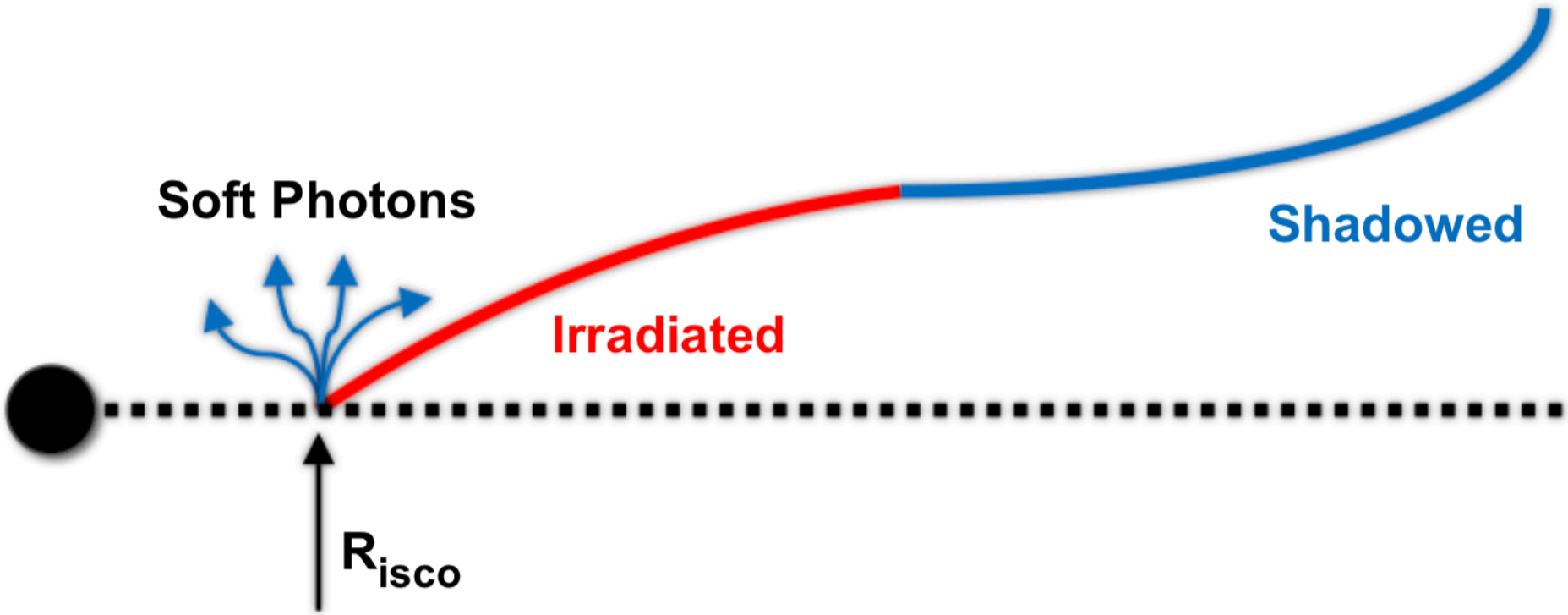


Kalemci et al. 2013

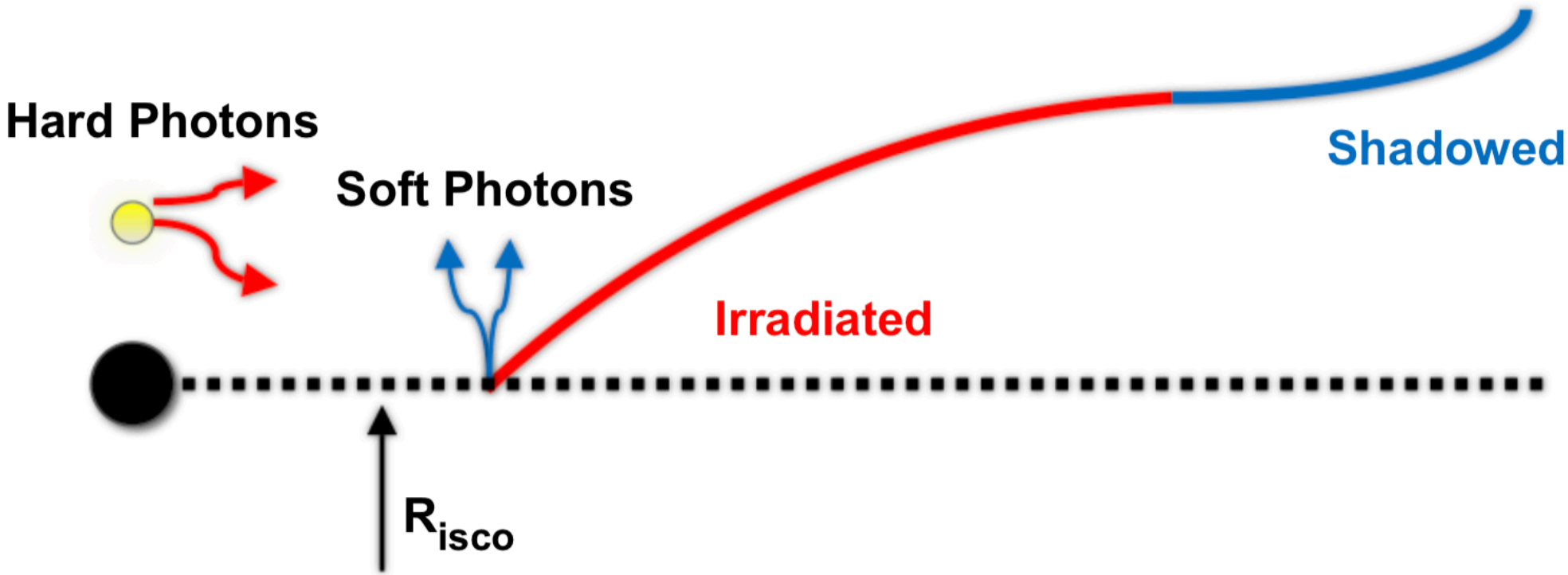

Luminosity in Soft X-rays
Time (days)
GX 339-4, 2003
GX 339-4, 2005
GX 339-4, 2007
GX 339-4, 2011
4U 1543-47
XTE J1550-564
XTE J1752-223
GRO J1655-40
H1743-322, 2003
H1743-322, 2008
H1743-322, 2009
XTE J1720-318

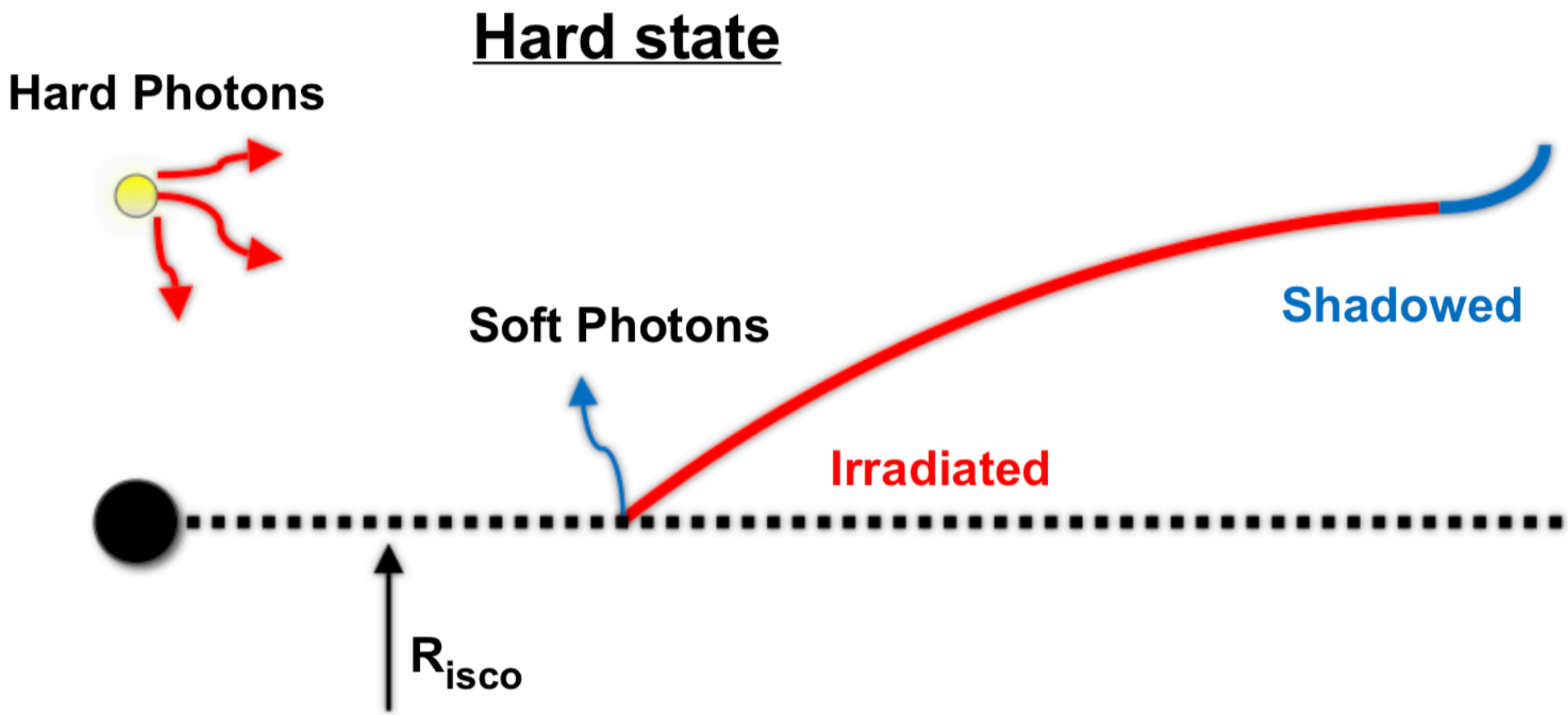

Secondary Outburst!
Luminosity in Hard X-rays
Time (days)

Soft State

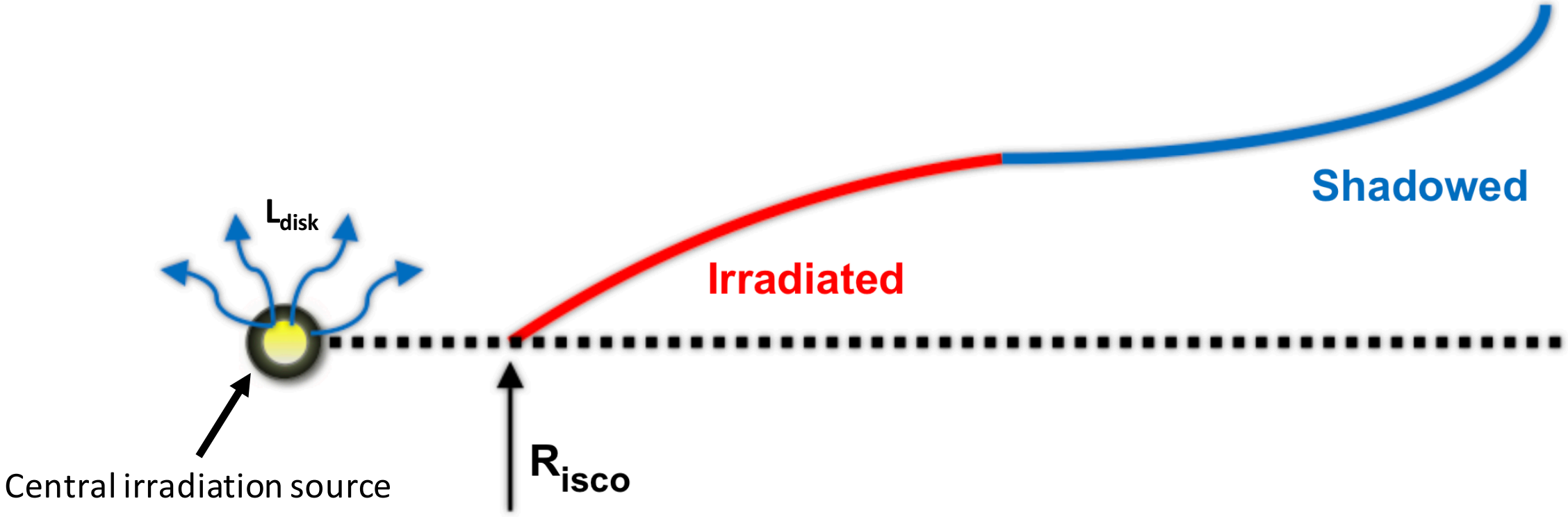


During state transition

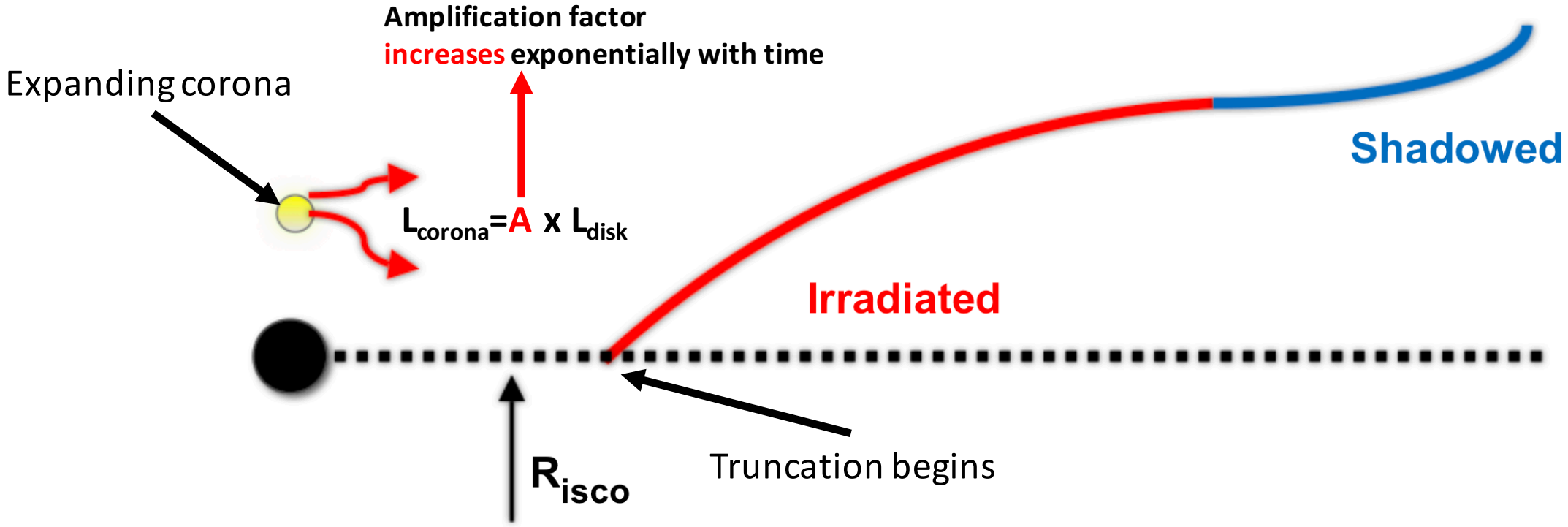



Hard state
Hard Photons
Soft Photons
Shadowed
Irradiated
R_{isco}

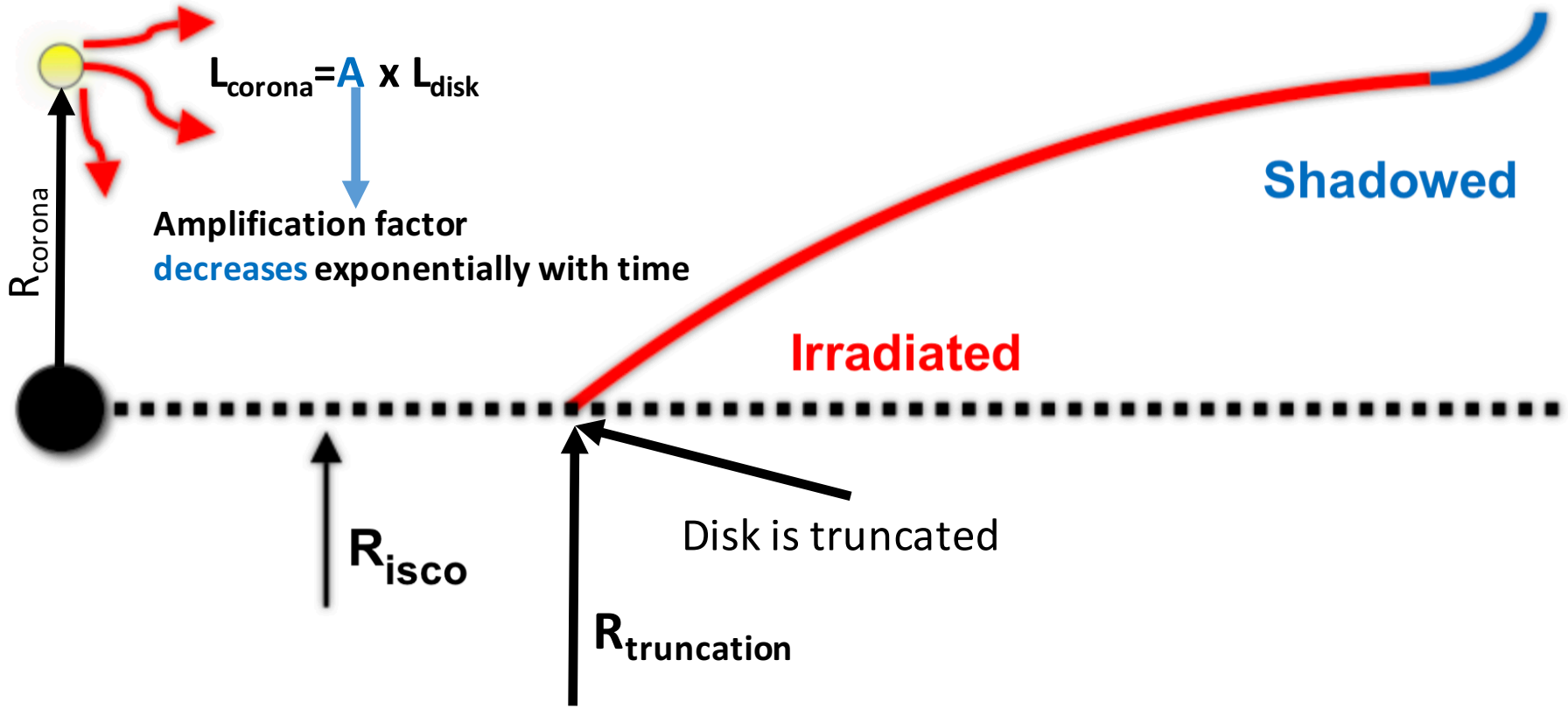
Soft State


L_{disk}
Shadowed
Irradiated
Central irradiation source
R_{isco}

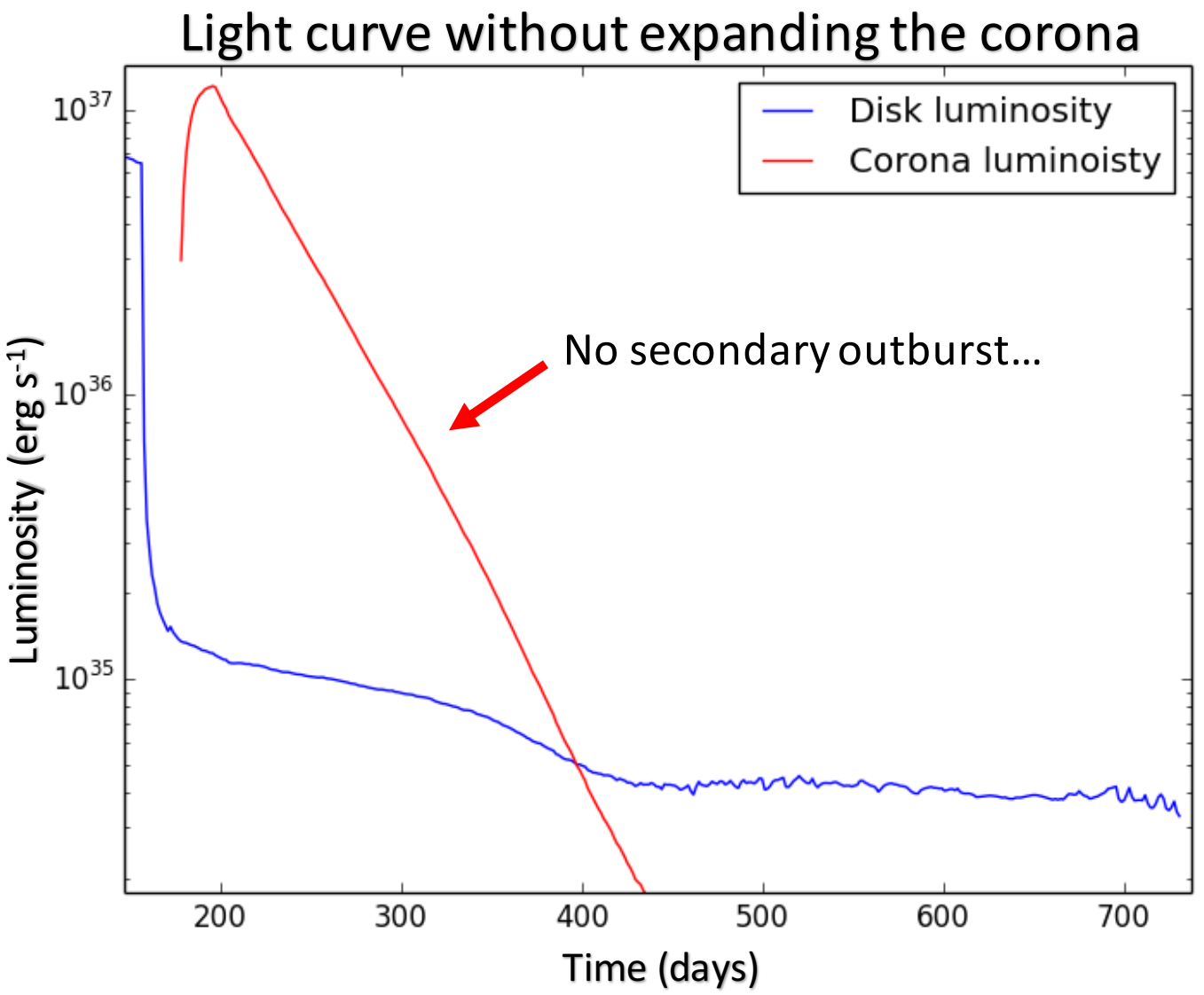
During state transition



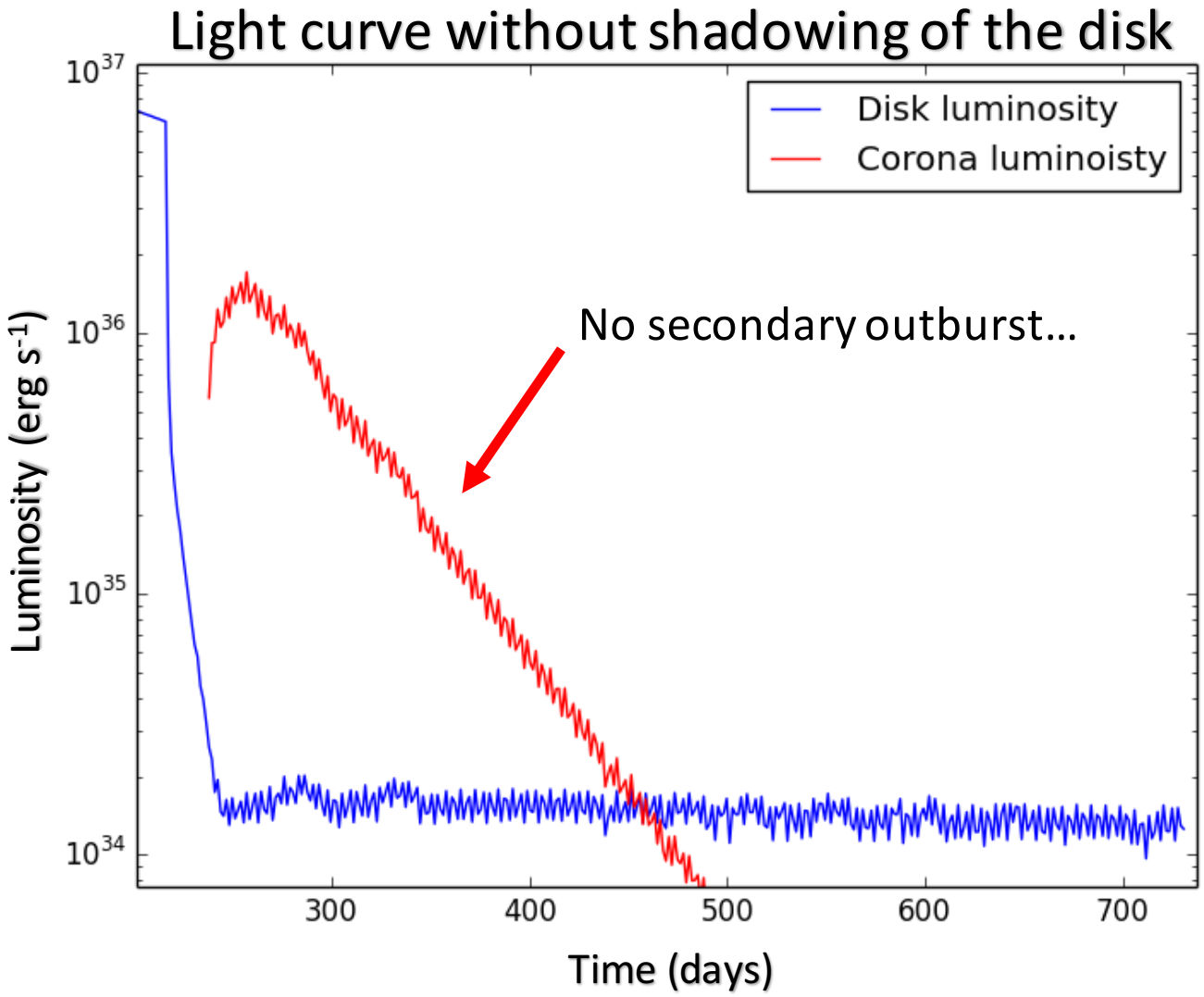
Hard state


L_{corona}=A x L_{disk}
Amplification factor
decreases exponentially with time
R_{corona}
Shadowed
Irradiated
R_{isco}
Disk is truncated
$R_{truncation}$

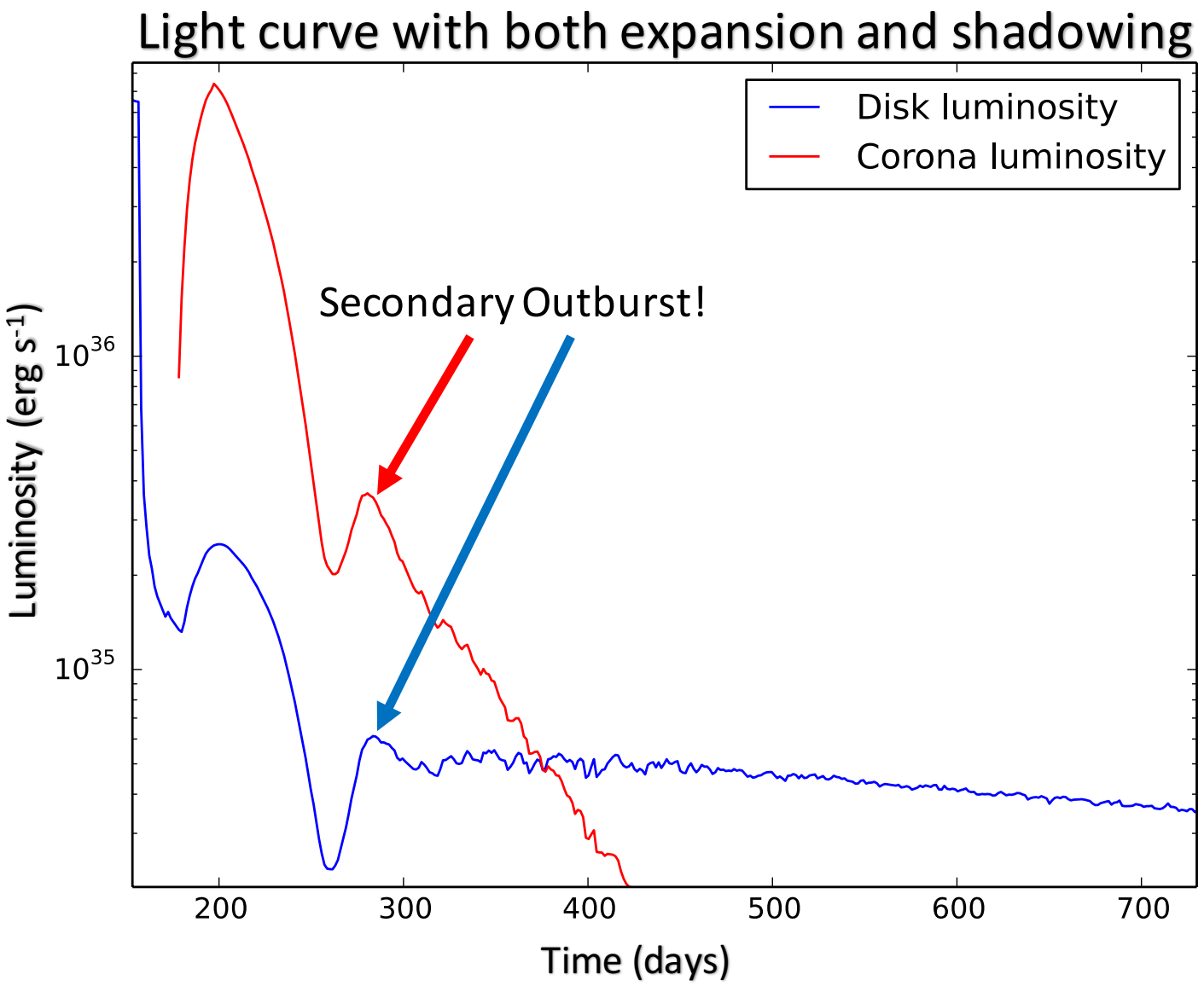
Results:

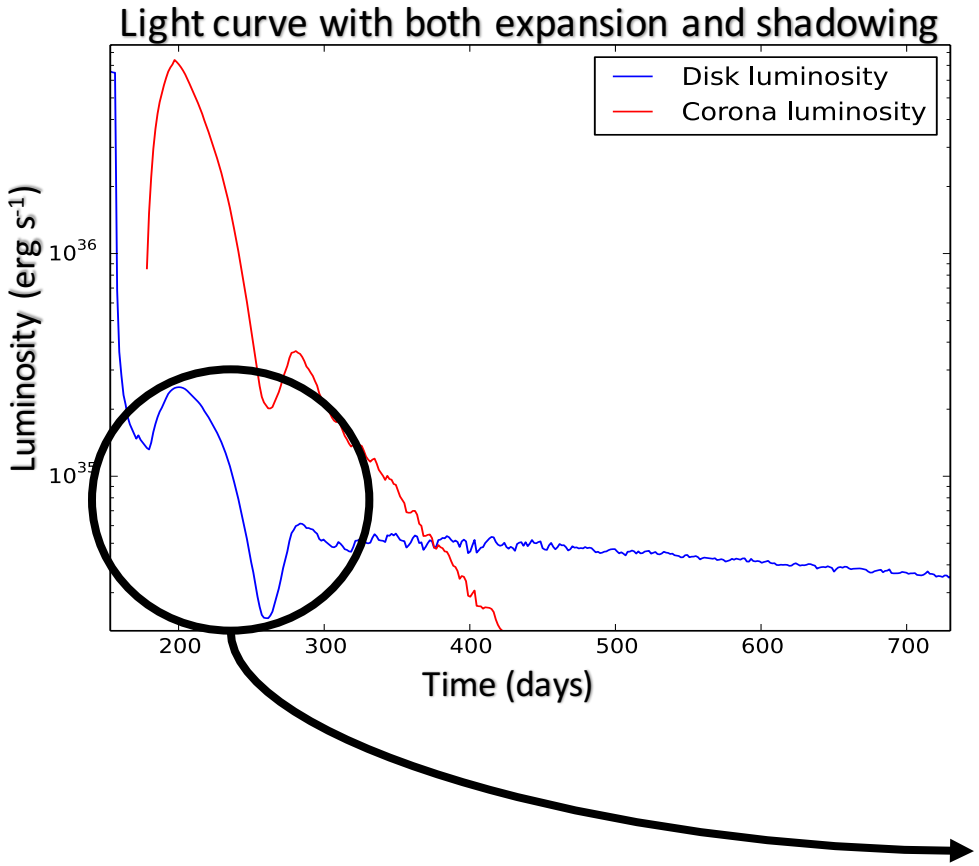

Light curve without expanding the corona
Disk luminosity
Corona luminoisty
No secondary outburst…
10^{37}
10^{36}
10^{35}
Luminosity (erg s^{-1})
200
300
400
500
600
700
Time (days)

Results:

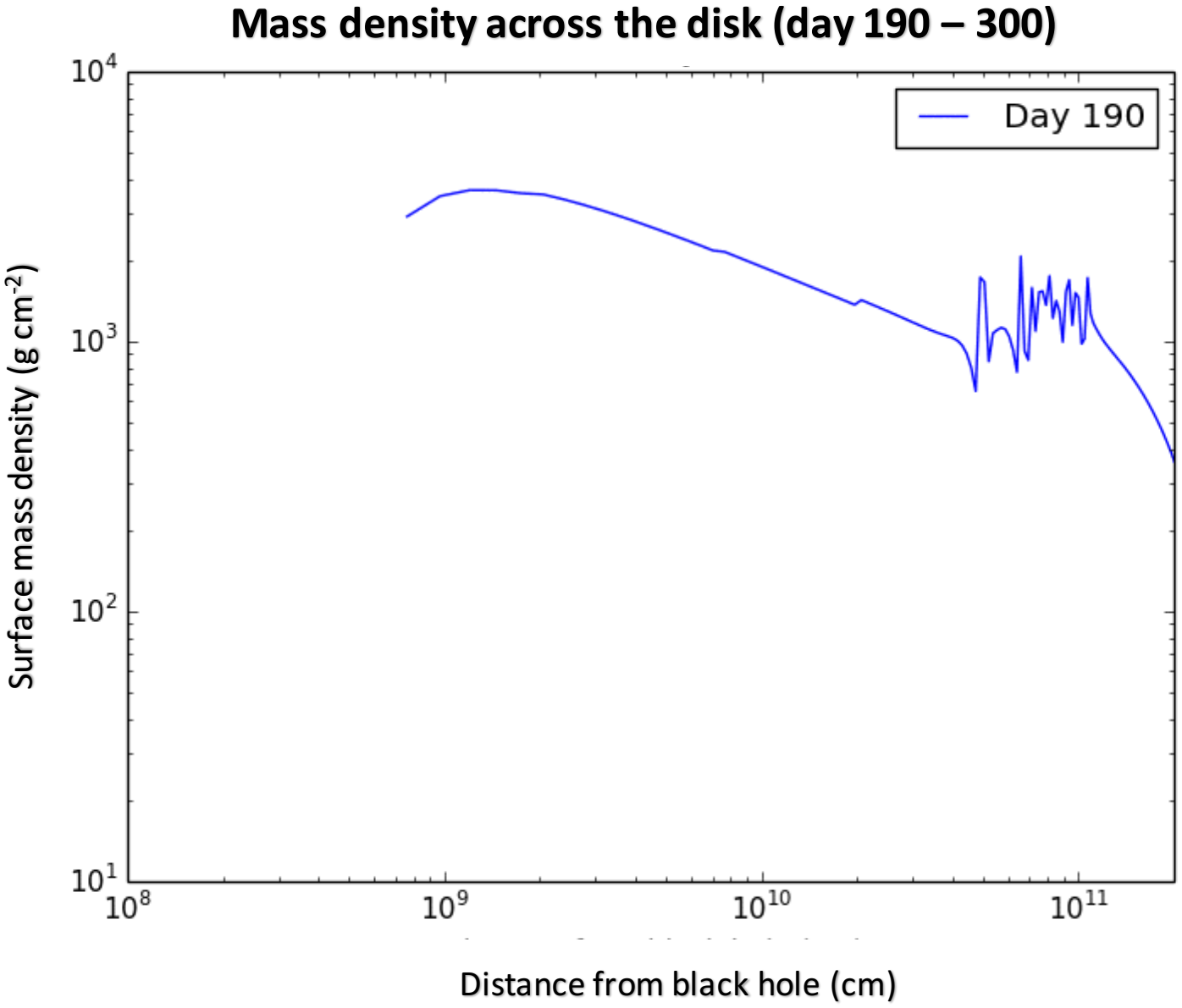

Light curve without shadowing of the disk
Disk luminosity
Corona luminoisty
No secondary outburst…
Luminosity (erg s-1)
10^37
10^36
10^35
10^34
300
400
500
600
700
Time (days)

Results:

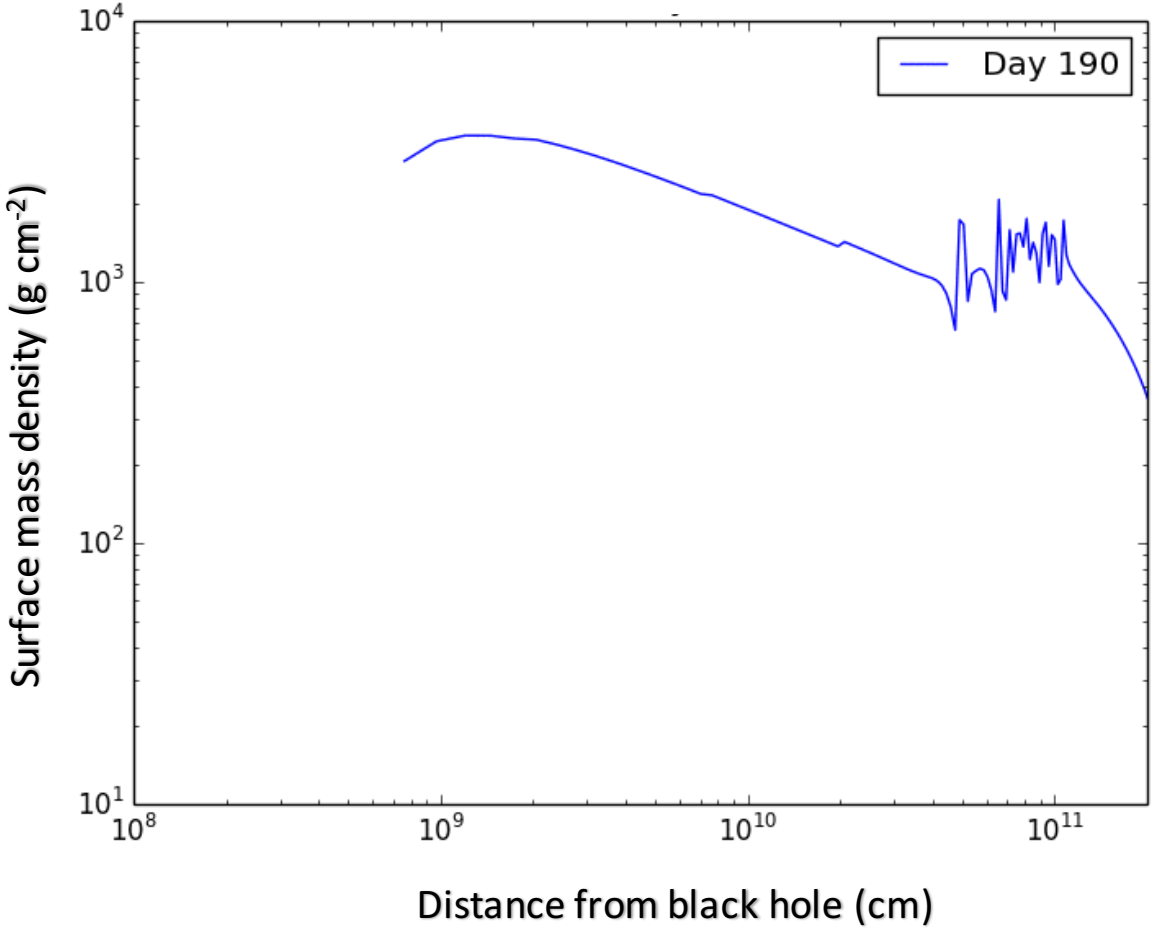

Light curve with both expansion and shadowing
Disk luminosity
Corona luminosity
Secondary Outburst!
Luminosity (erg s^{-1})
10^{36}
10^{35}
200
300
400
500
600
700
Time (days)



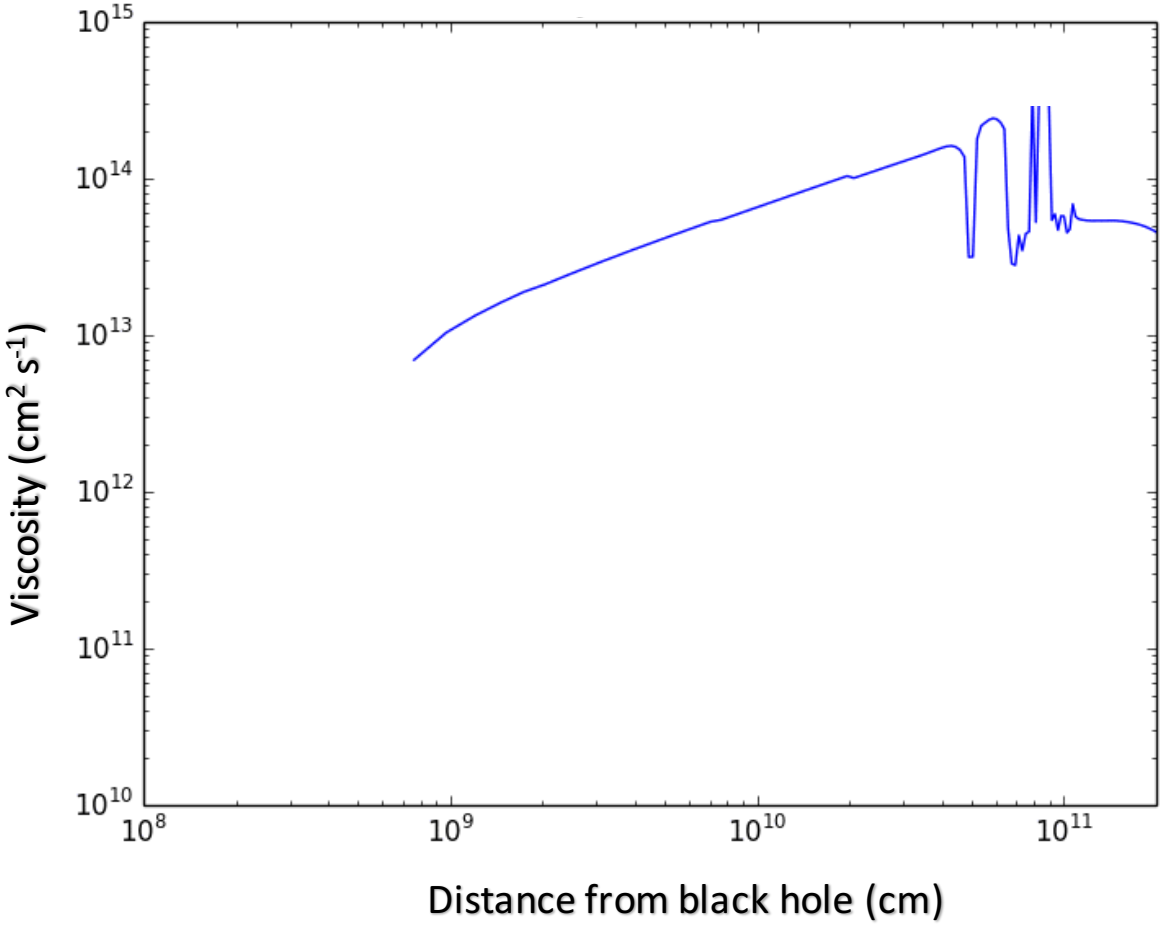
What happens to the disk? (day 190 – 300)



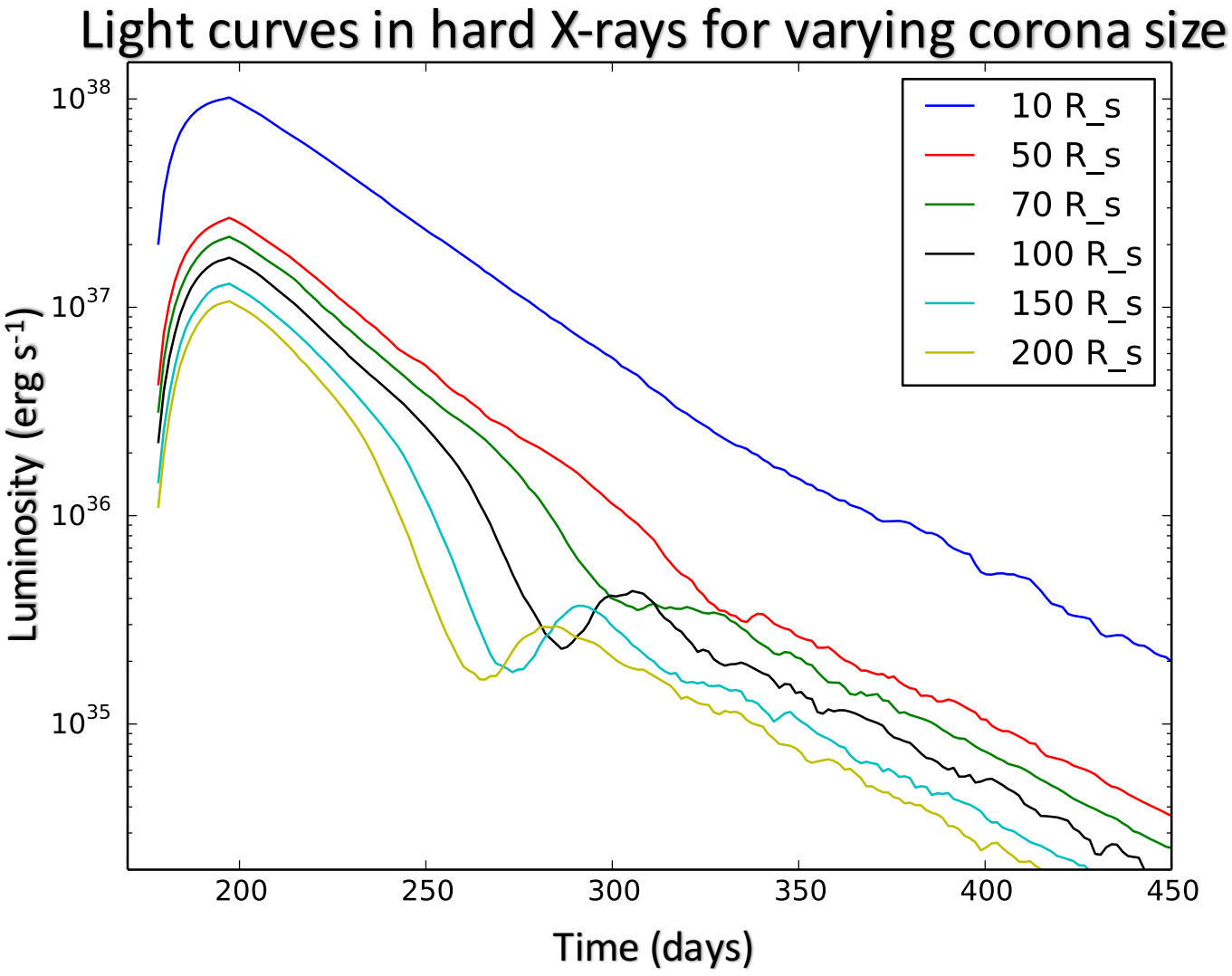
Mass density across the disk (day 190 – 300)



Viscosity across the disk (day 190 – 300)



Results:

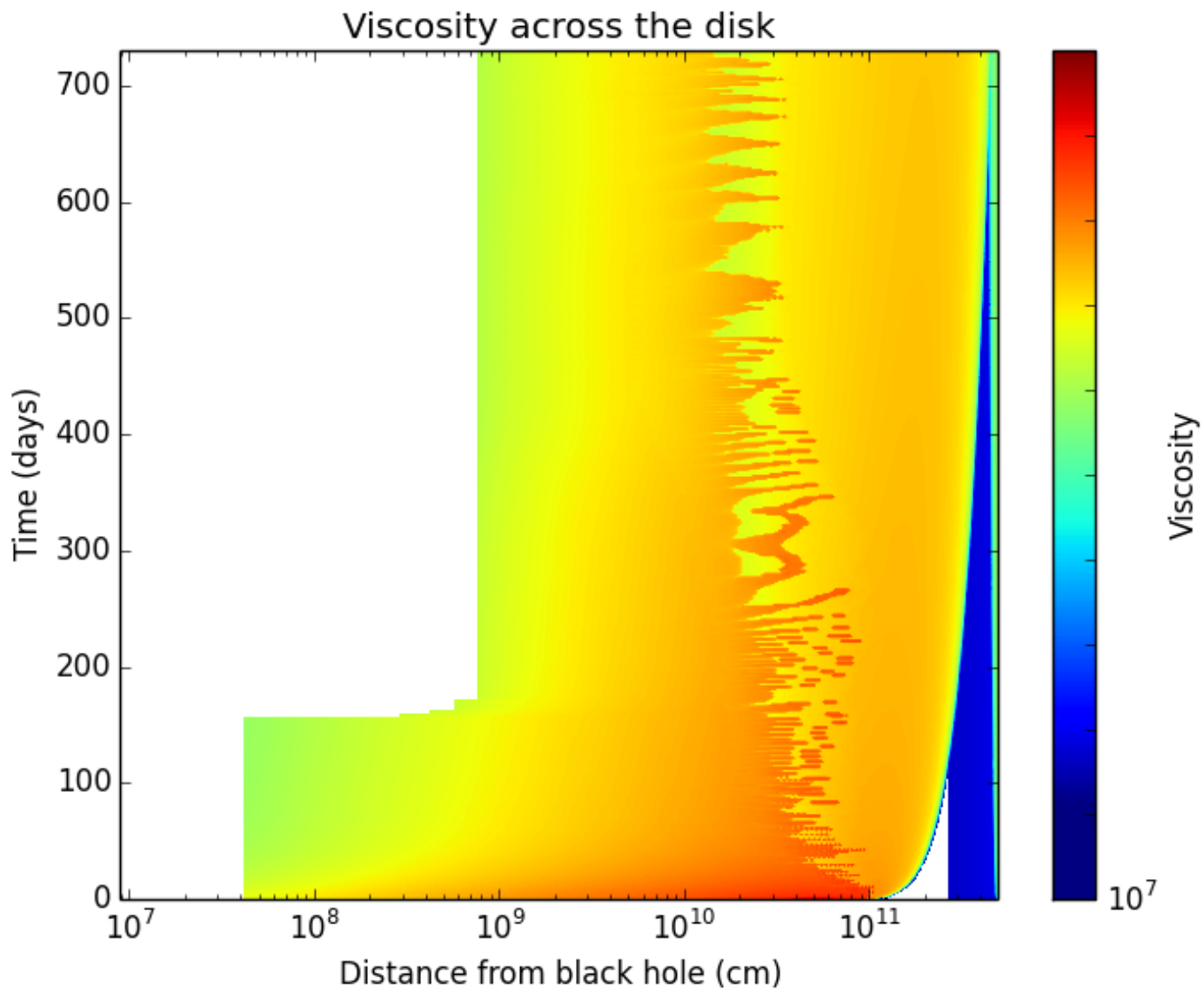

Light curves in hard X-rays for varying corona size
10 R_s
50 R_s
70 R_s
100 R_s
150 R_s
200 R_s
Luminosity (erg s-1)
10^38
10^37
10^36
10^35
200
250
300
350
400
450
Time (days)

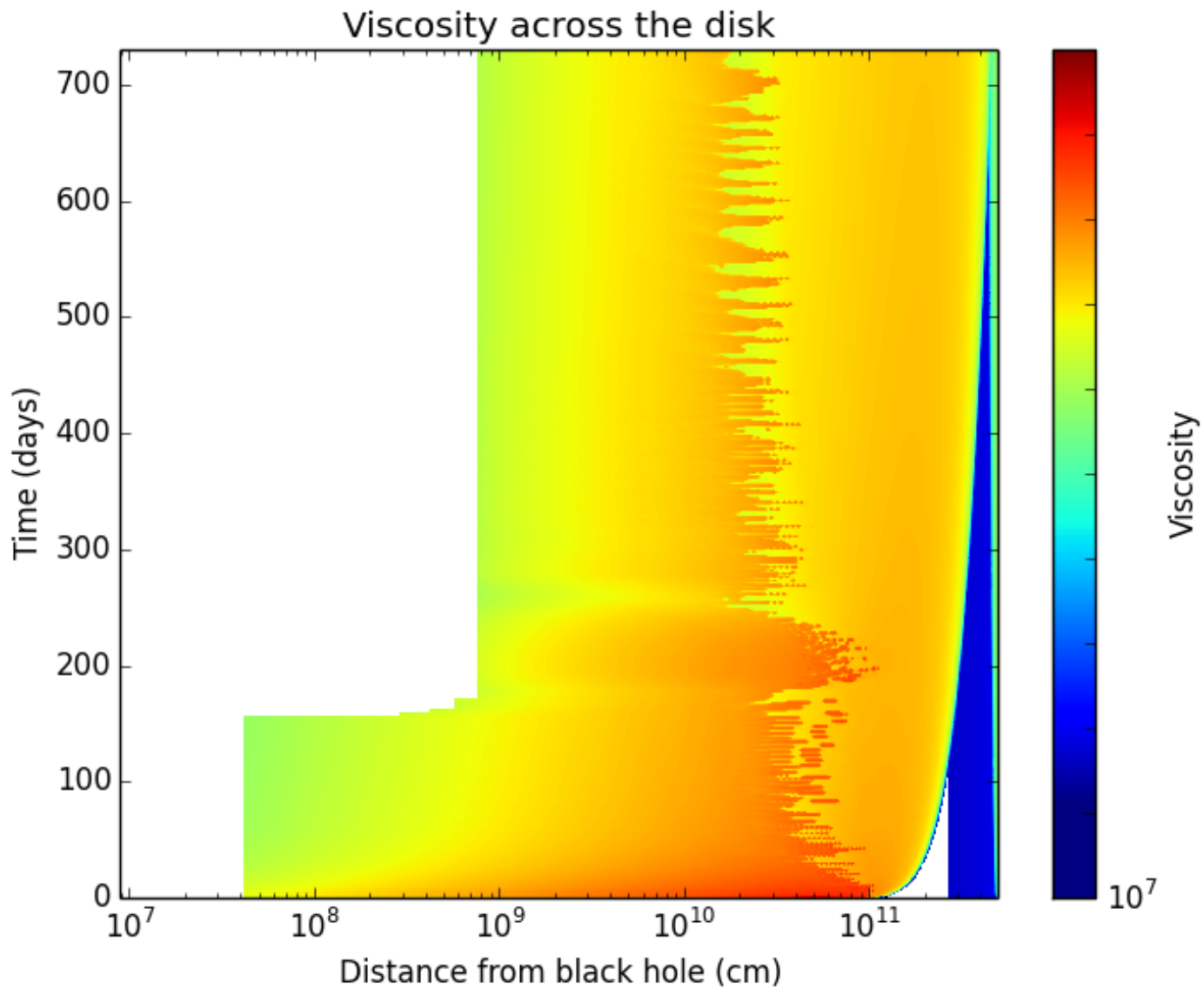
Conclusion

- Successfully simulated an accretion disk around a black hole.
- Irradiation and shadowing of the disk influences the evolution of the accretion disk.
- It is possible to retrieve information about the corona geometry by modeling the secondary outburst.

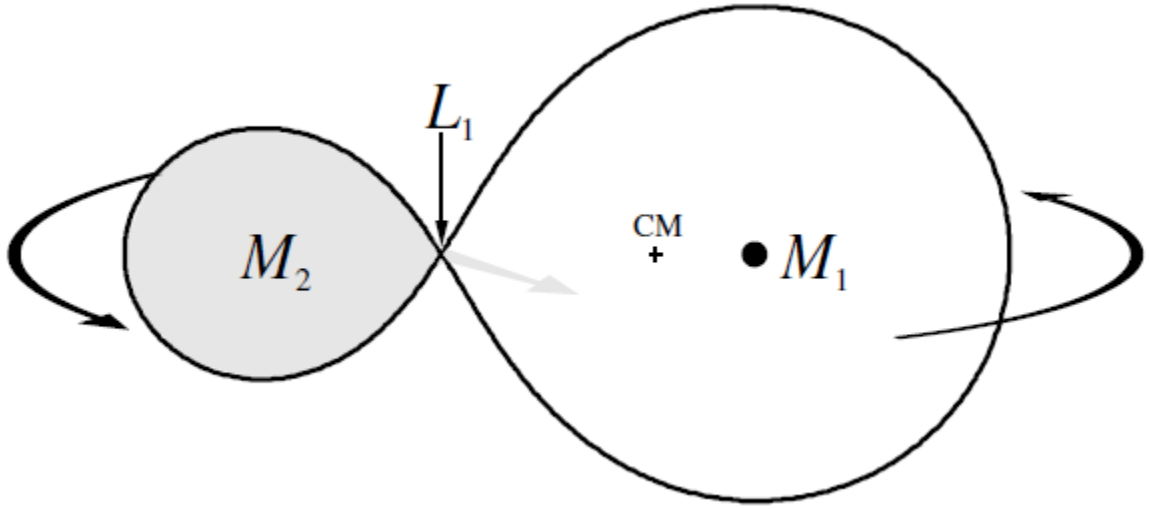
Thank you!

Any questions?

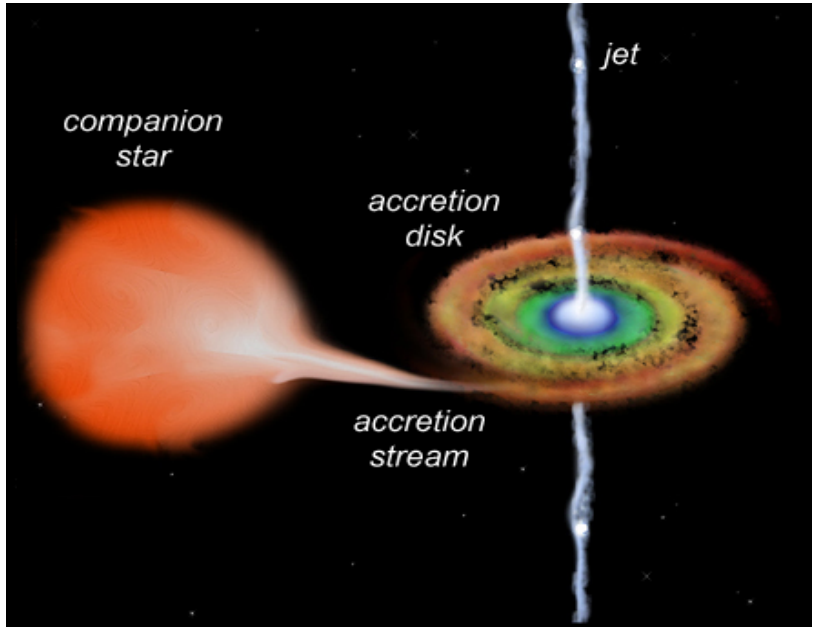

Viscosity across the disk
Time (days)
0
100
200
300
400
500
600
700
10^7
10^8
10^9
10^{10}
10^{11}
Distance from black hole (cm)
Viscosity
10^7


Viscosity across the disk
Time (days)
0
100
200
300
400
500
600
700
10^7
10^8
10^9
10^{10}
10^{11}
Distance from black hole (cm)
Viscosity
10^7

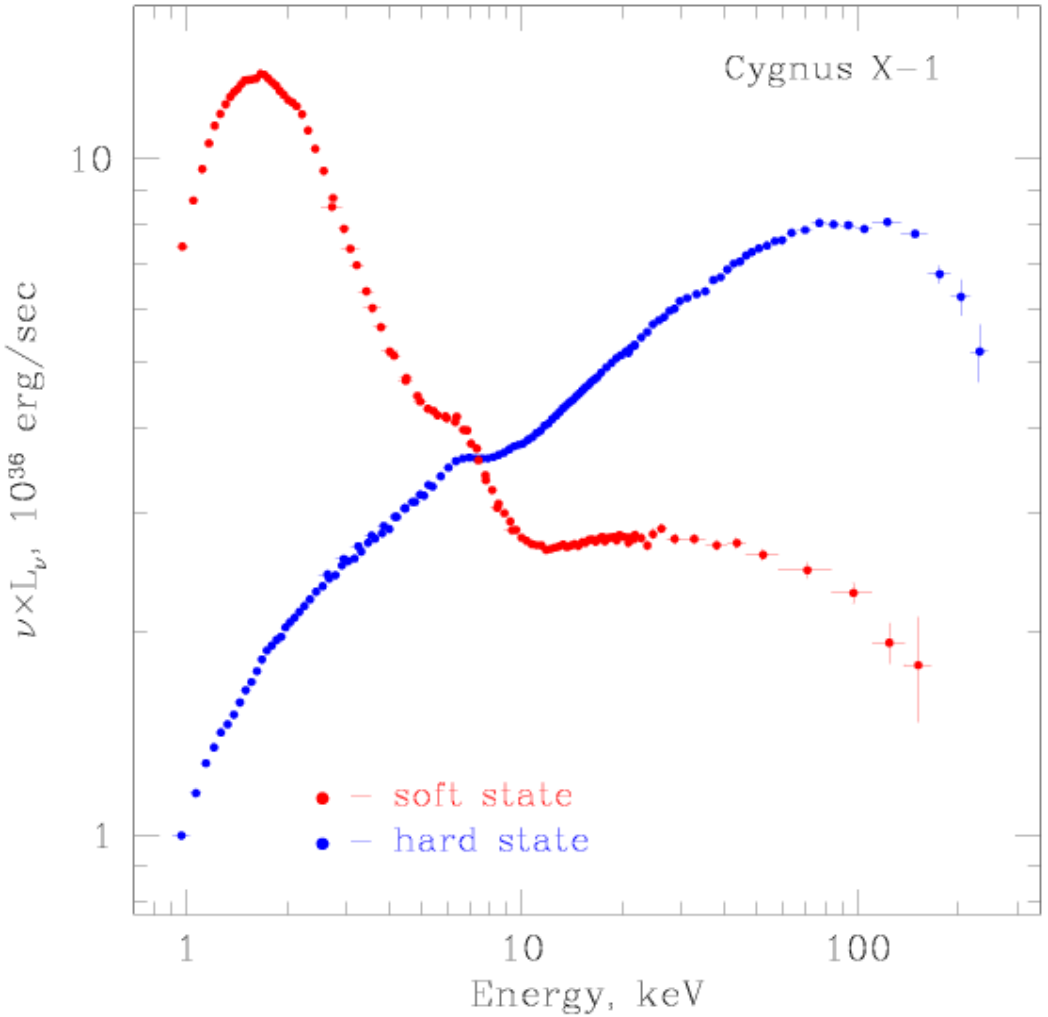
Disk formation in black hole binaries:

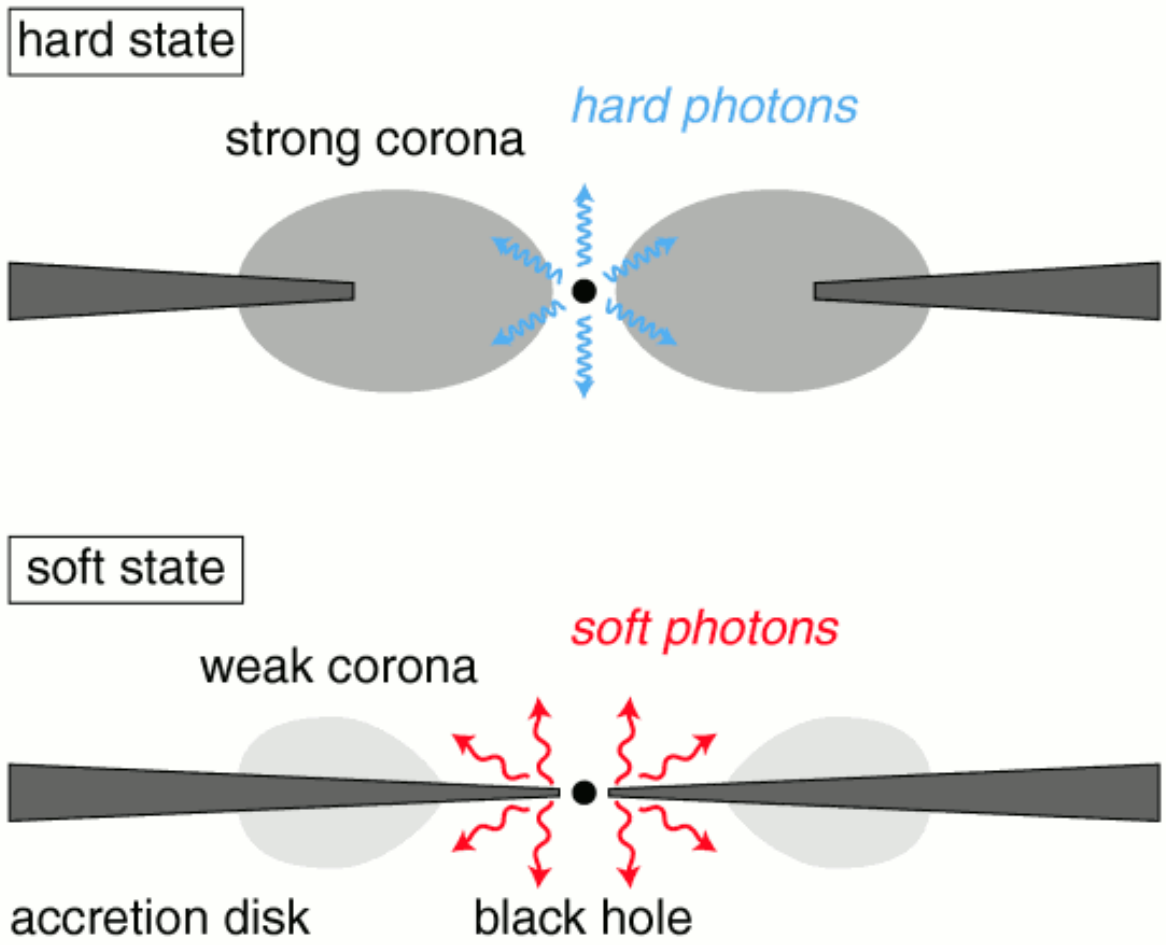


- Accretion via Roche-lobe overflow.
- Magneto-hydrodynamic instabilities lead to transport of matter inwards and transport of angular momentum outwards.
- Disk will heat up due to viscous dissipation.



Spectral states of an X-ray binary:





Typical light curve of an X-ray binary:

- Starts in hard state.
- Enters low state at the maximum of the outburst luminosity.
- Enters hard state again during the outburst decay.