

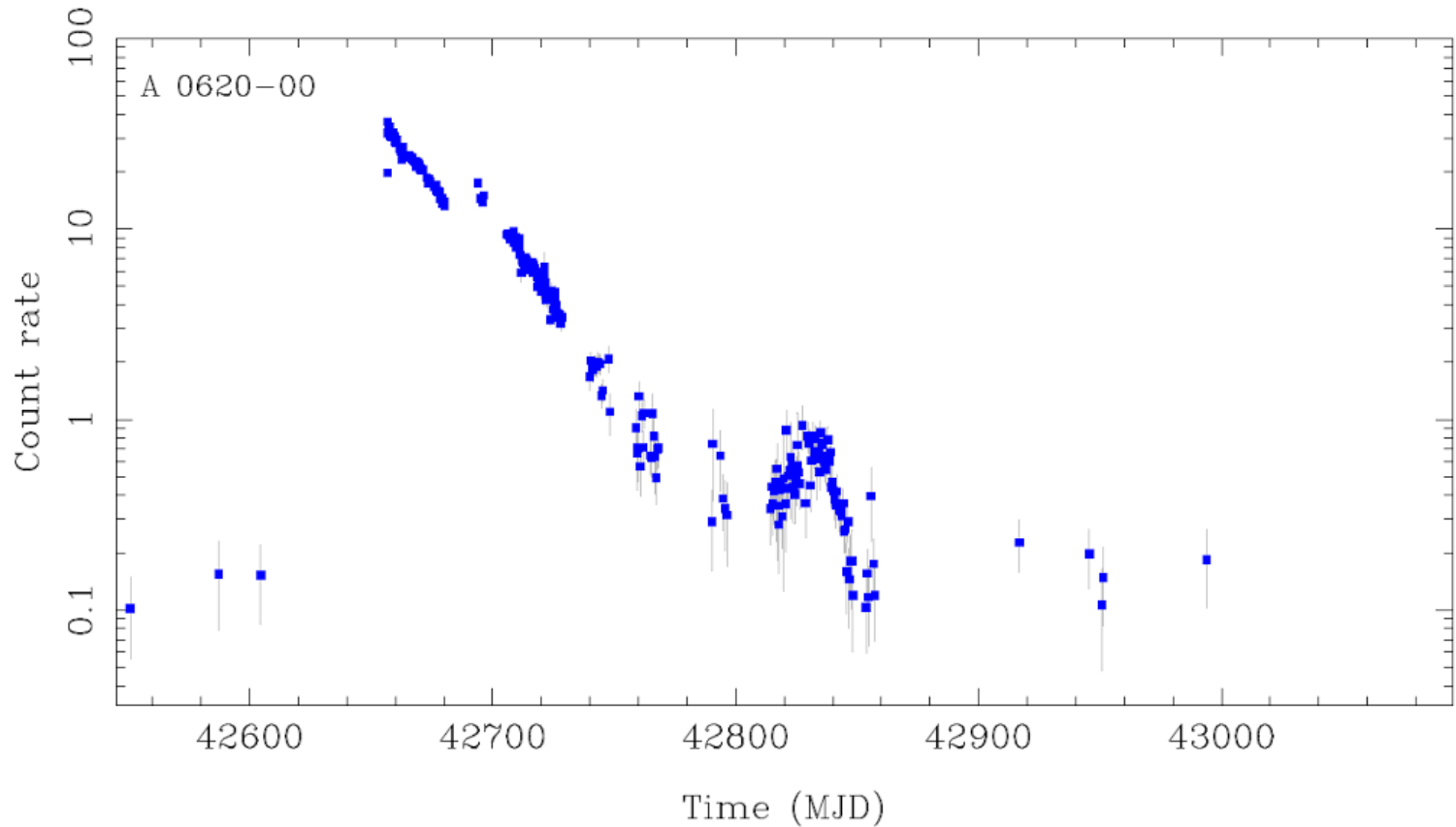
Hybrid accretion flow models and observations of black hole binaries



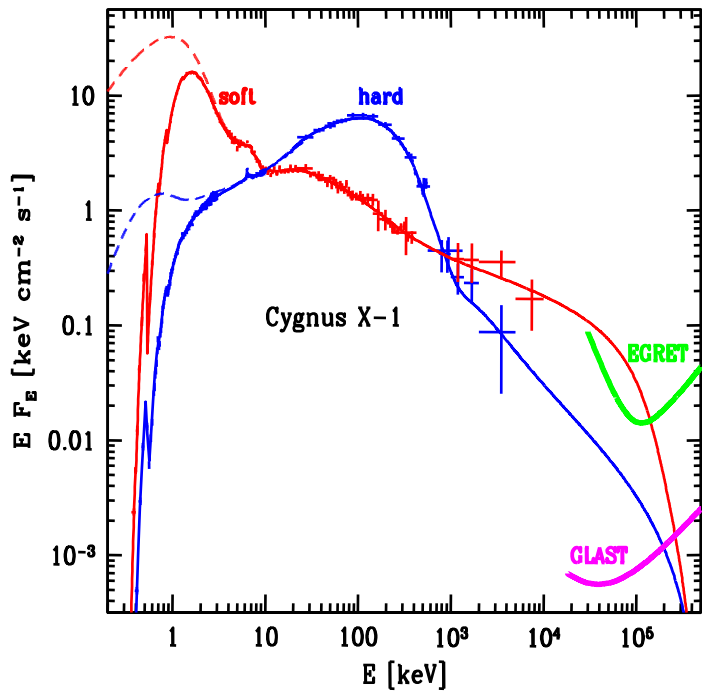
Alexandra Veledina (Nordita)

Kathmandu, 18 Oct 2016

X-ray light-curve

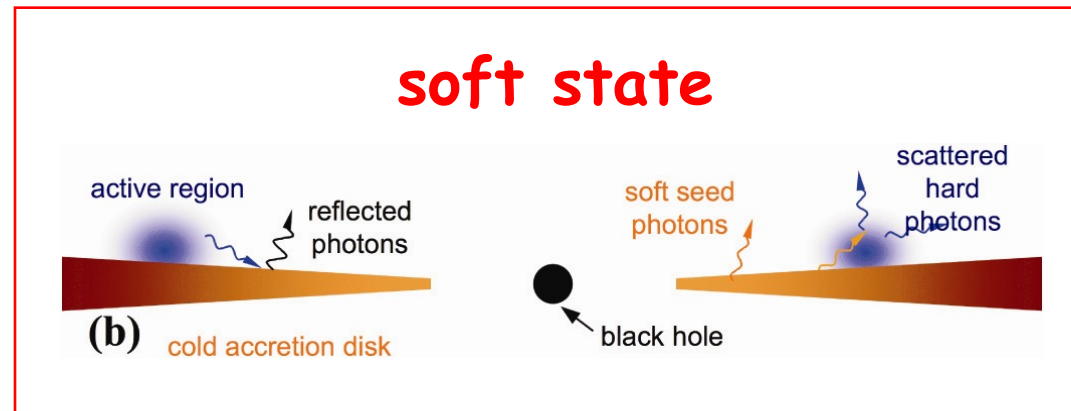
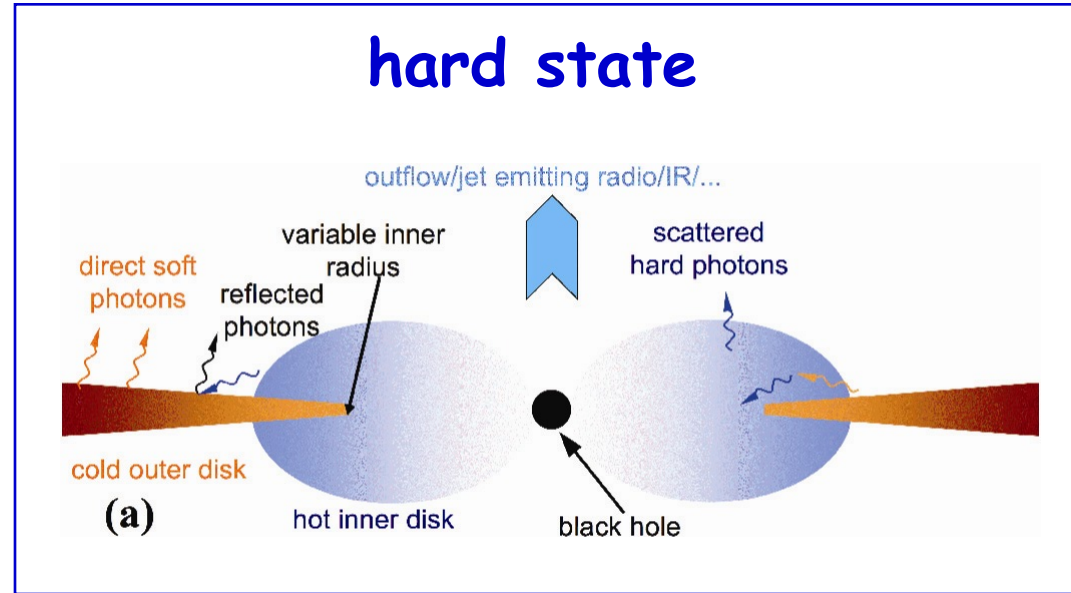


X-ray spectra and geometry



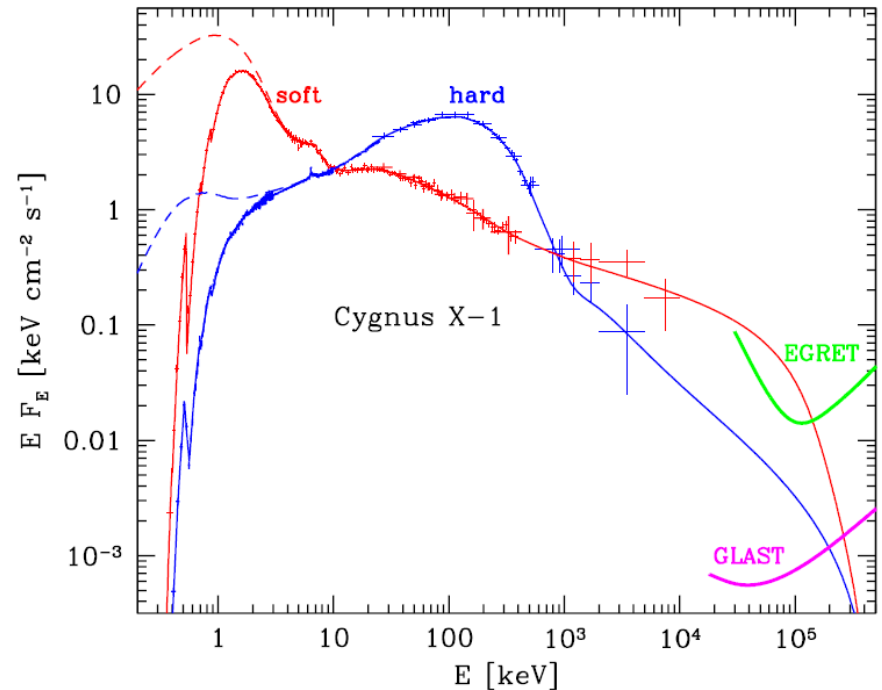
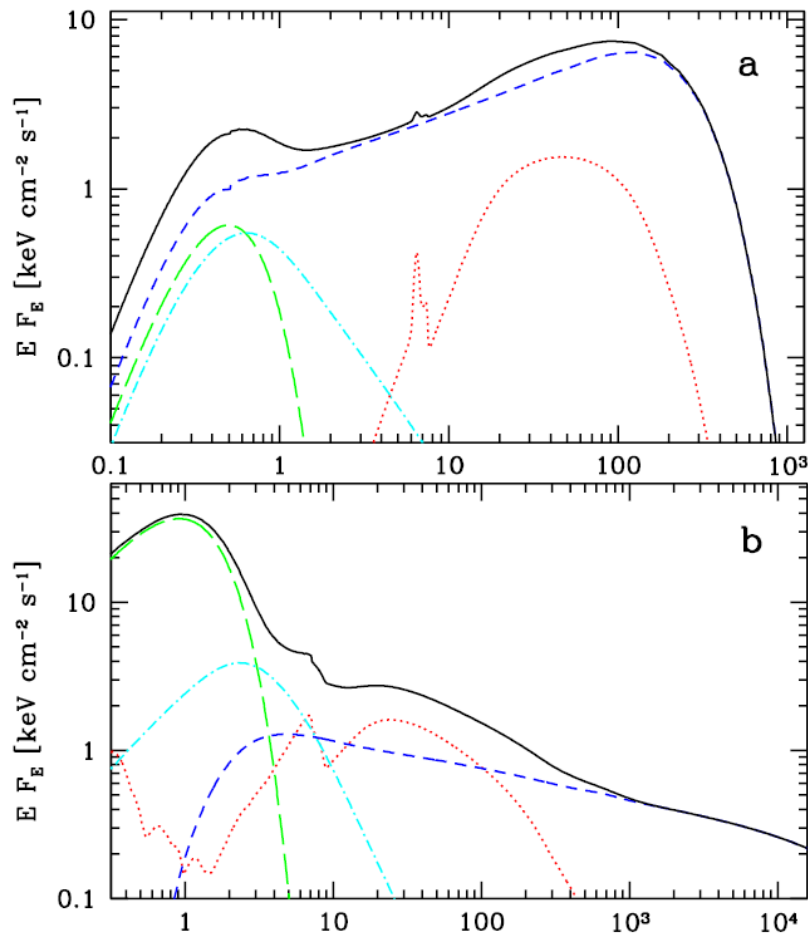
Hard state - standard cold outer disc + hot inner flow
100 keV cut-off

Soft state - standard accretion disc (< 1keV), plus corona



Thermal Comptonization in the hard state: what is the source of seed photons?

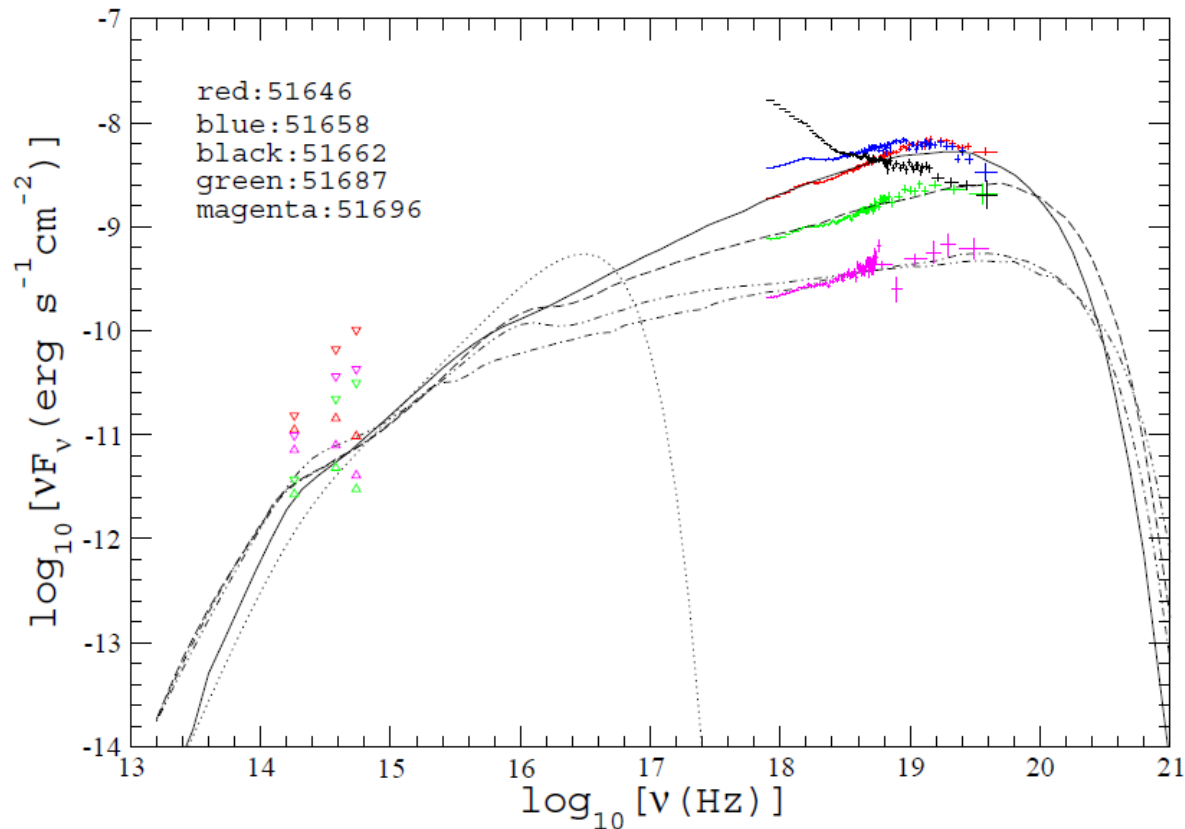
Disc Comptonization



Zdziarski & Gierlinski 2004

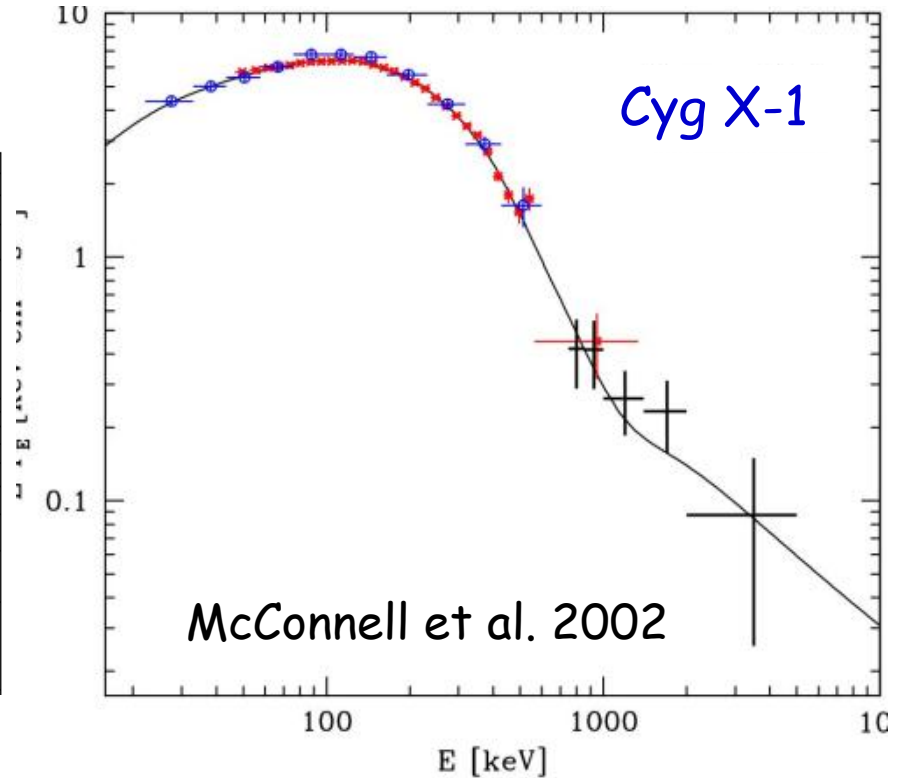
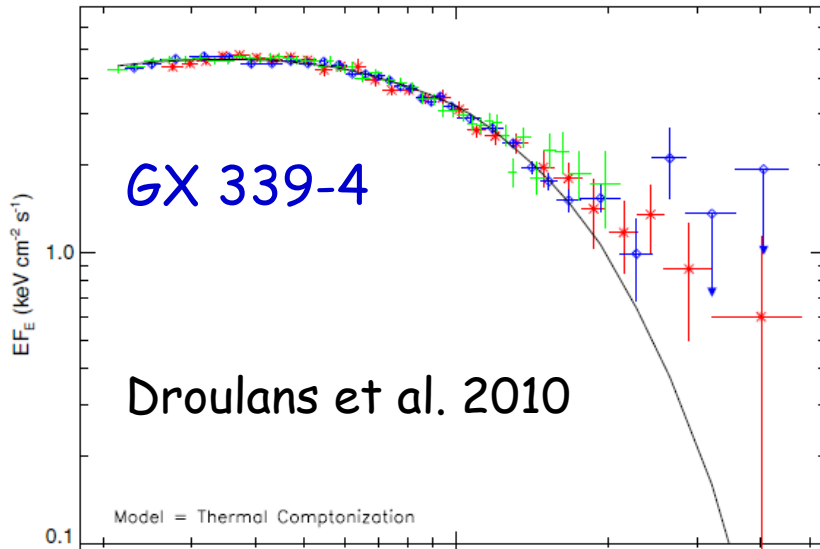
Thermal Comptonization in the hard state: what is the source of seed photons?

Thermal synchrotron Comptonization



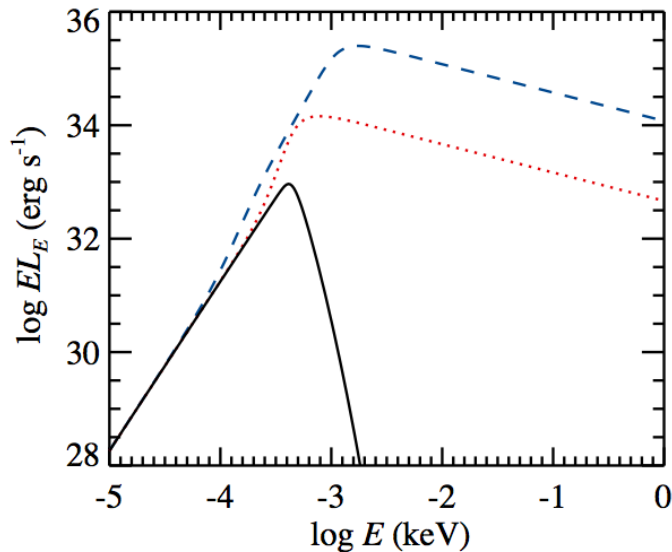
Yuan et al. 2007

Thermal Comptonization in the hard state: what is the source of seed photons?



A weak non-thermal tail is present

Synchrotron in hybrid plasma

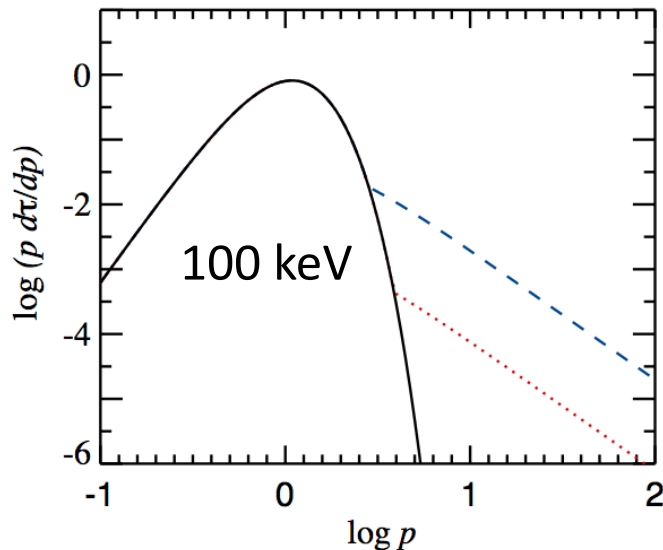


Hybrid electrons, 1% energy
in the non-thermal component

Hybrid electrons, 0.01% energy
in the non-thermal component

Thermal electrons, 100 keV

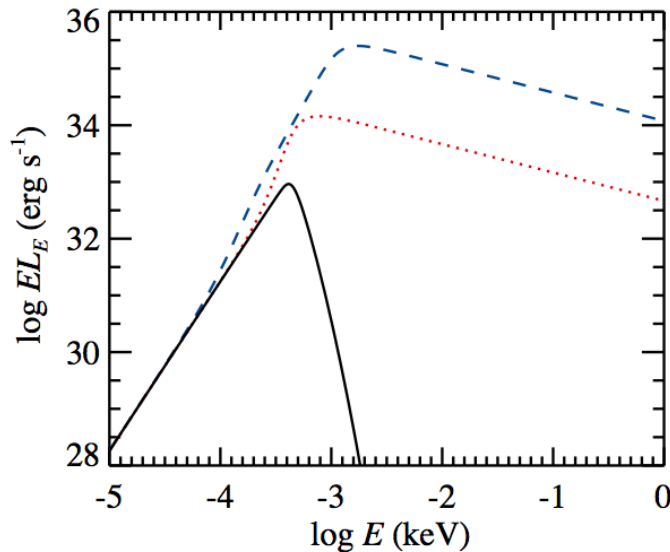
$$R = 9 \times 10^7 \text{ cm} \quad \tau = 1.0 \quad B = 3 \times 10^5 \text{ G}$$



Synchrotron can be the main
source of seed photons for
Comptonization

First noted by Wardzinski & Zdziarski, 2001

Synchrotron in hybrid plasma



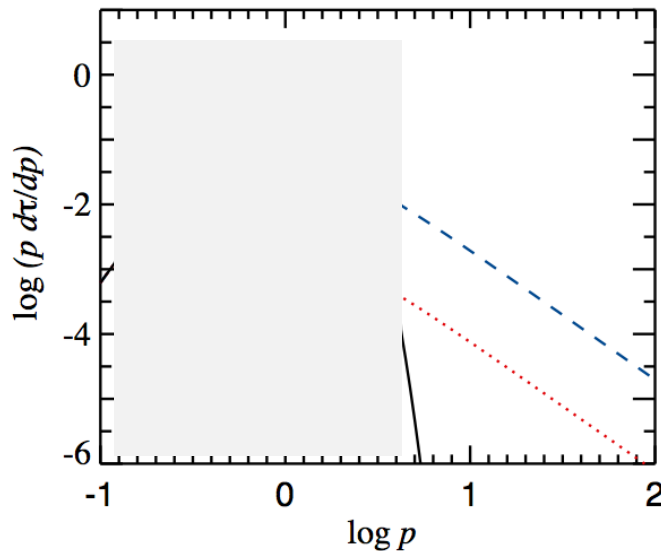
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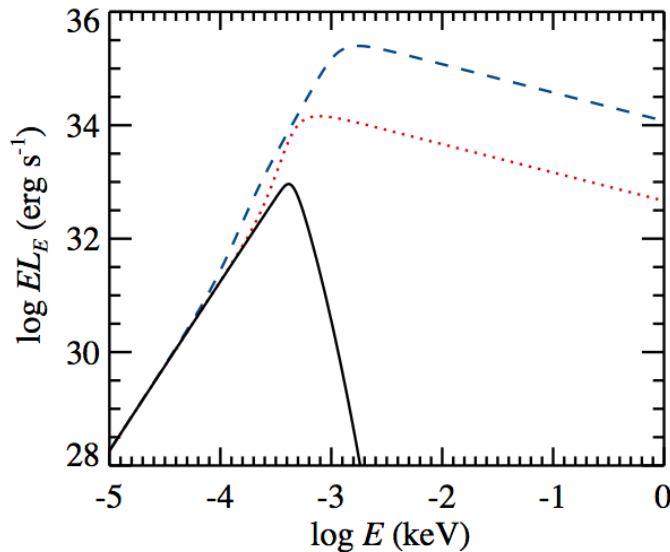
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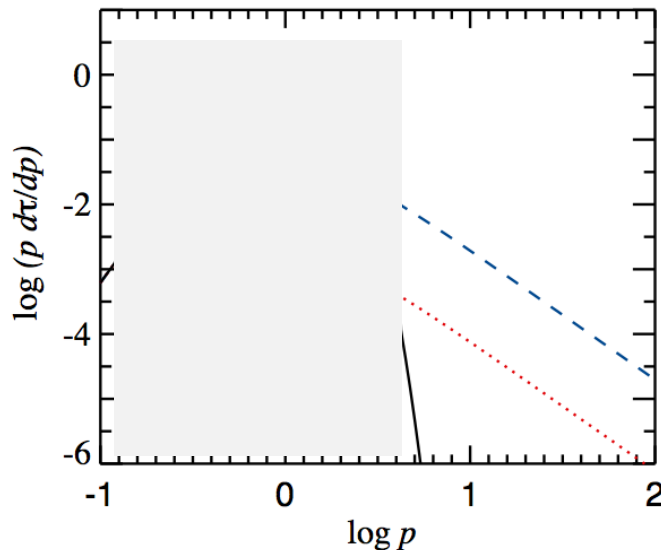
Synchrotron in hybrid plasma



Hybrid electrons, 1% energy
in the non-thermal component

Hybrid electrons in accretion models:

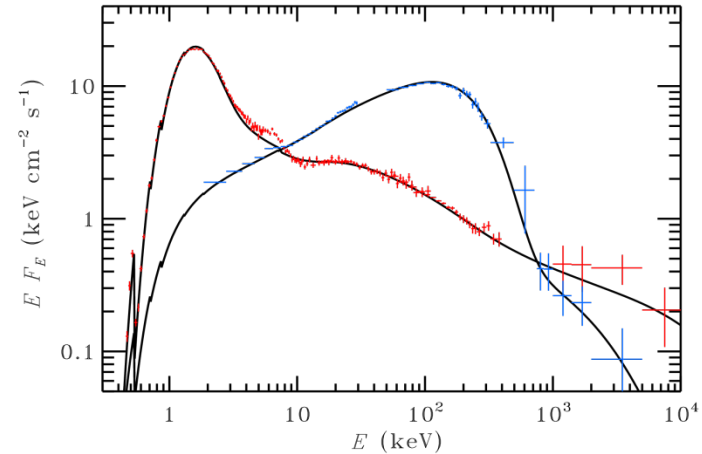
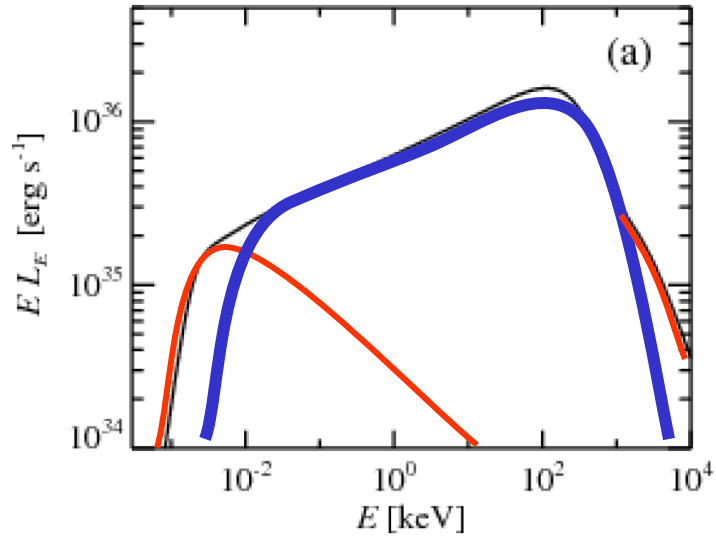
- black hole binaries (Poutanen & Vurm 2009, Malzac & Belmont 2009, Veledina+2013)
- supermassive black holes (Ozel+2001, Yuan+2003, Veledina+2011, Niedzwiecki+2015)



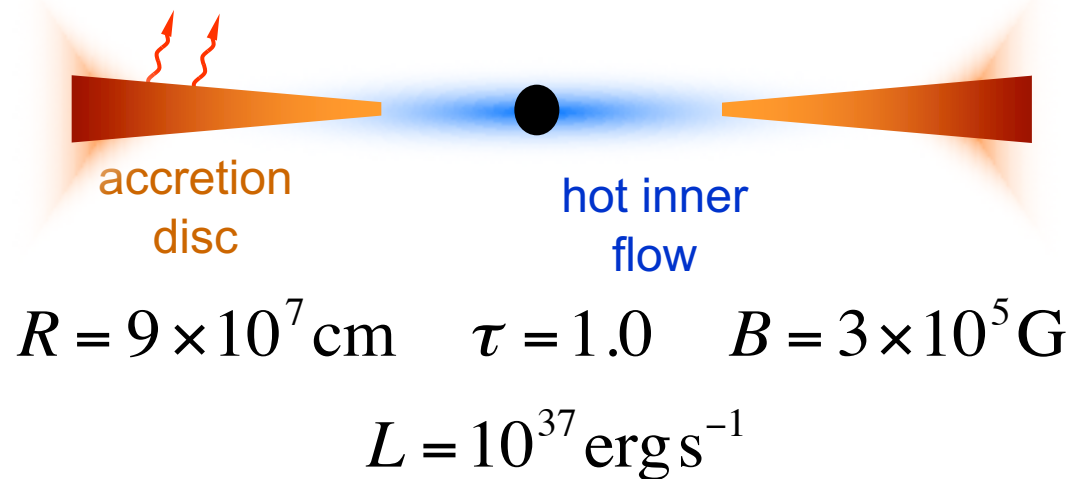
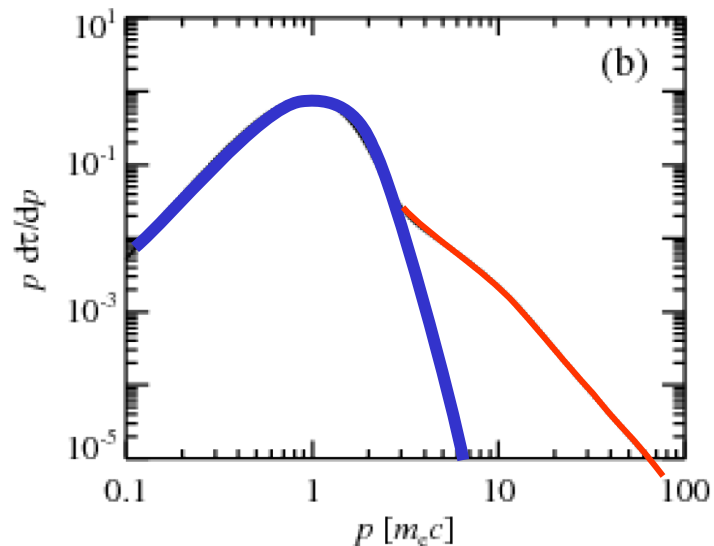
Comptonization

First noted by Wardzinski & Zdziarski, 2001

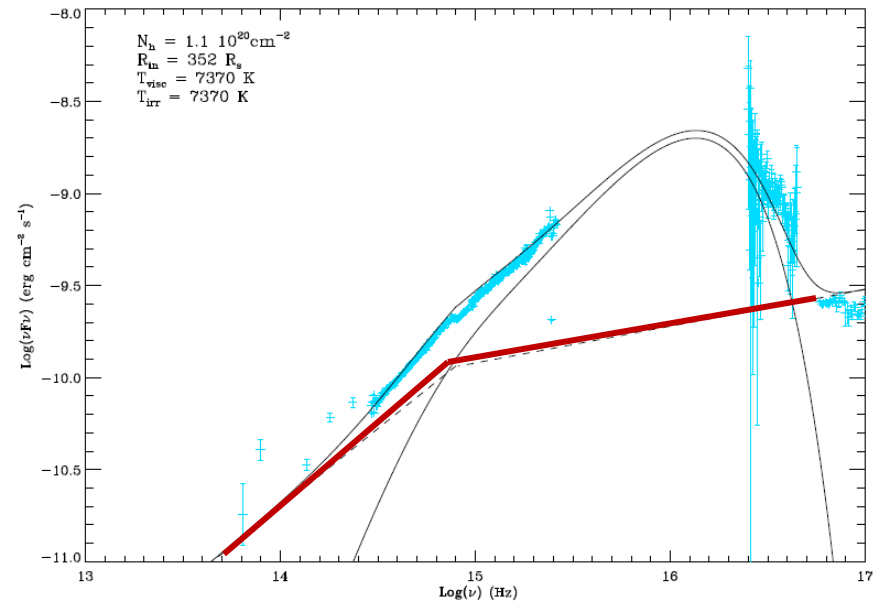
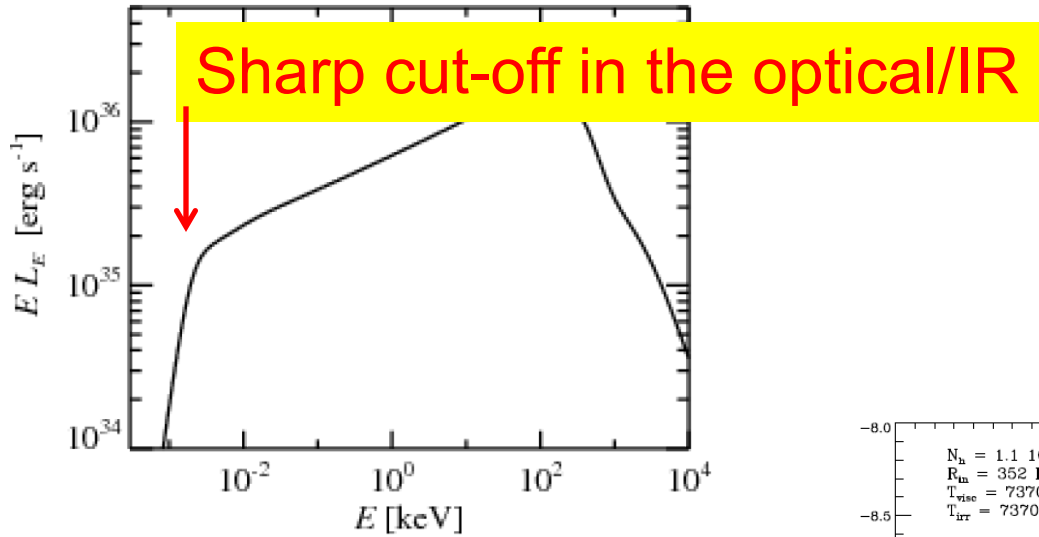
Synchrotron Self-Compton (SSC) mechanism in hybrid plasma



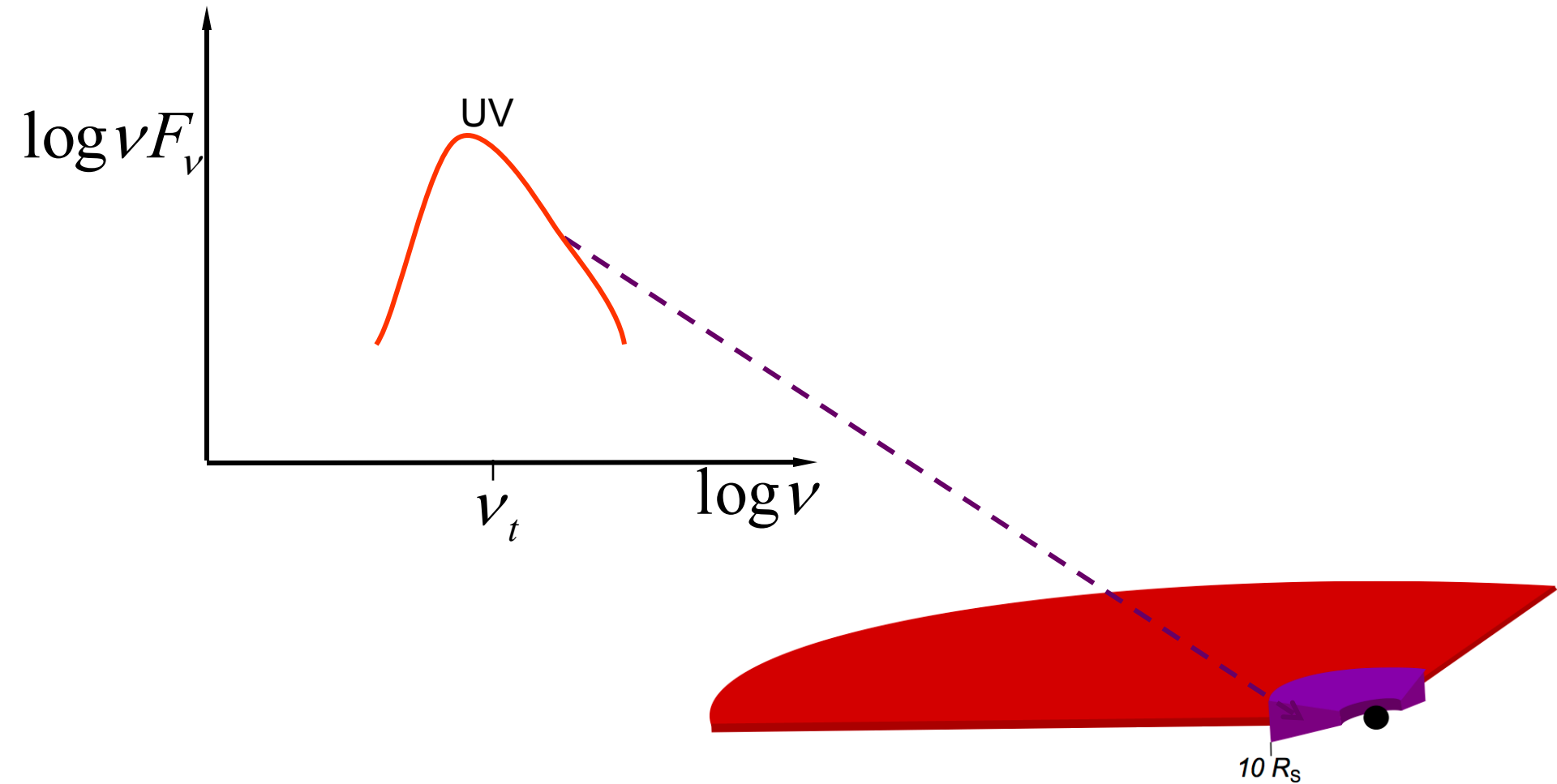
Poutanen & Vurm 2009, Malzac & Belmont 2009



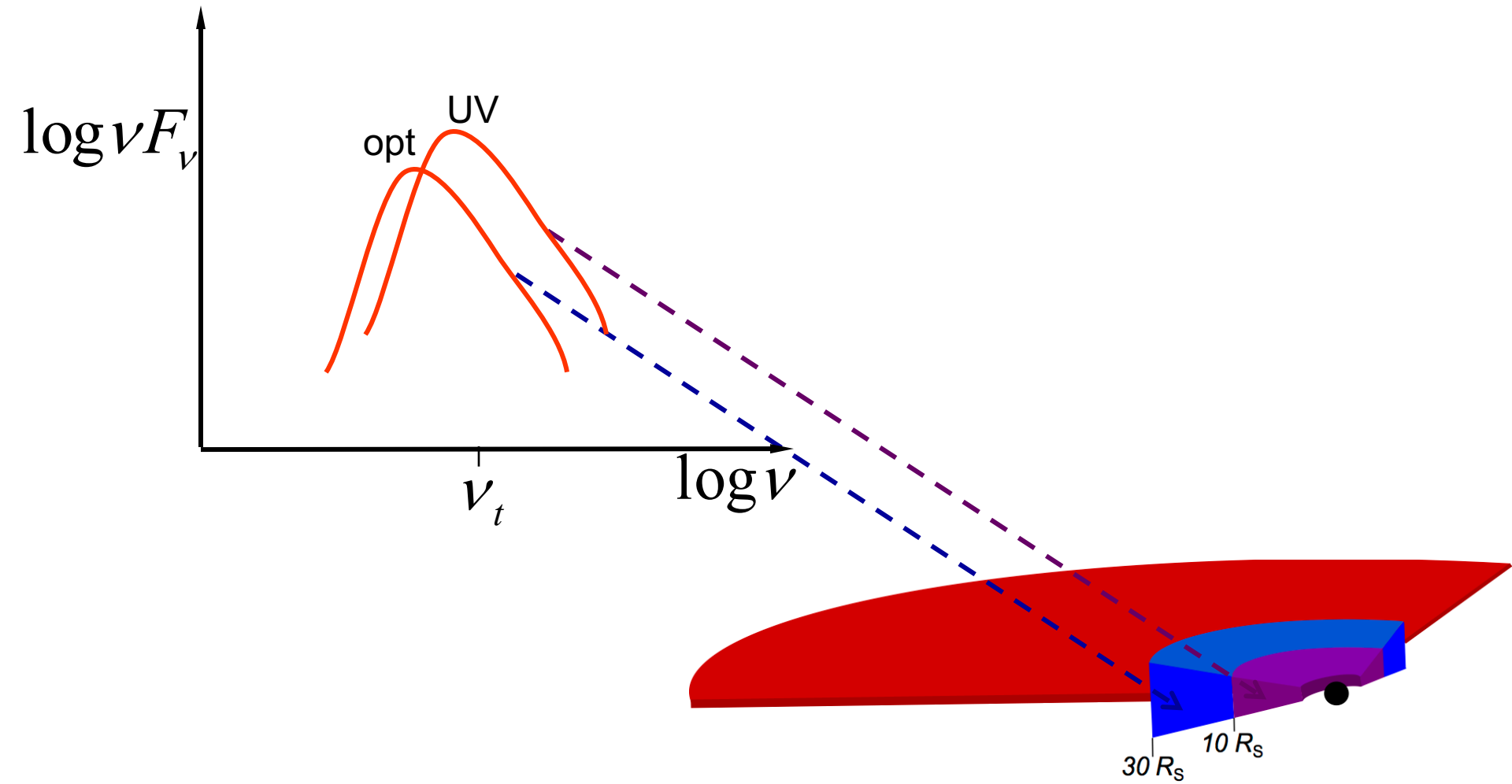
Homogeneous accretion flow



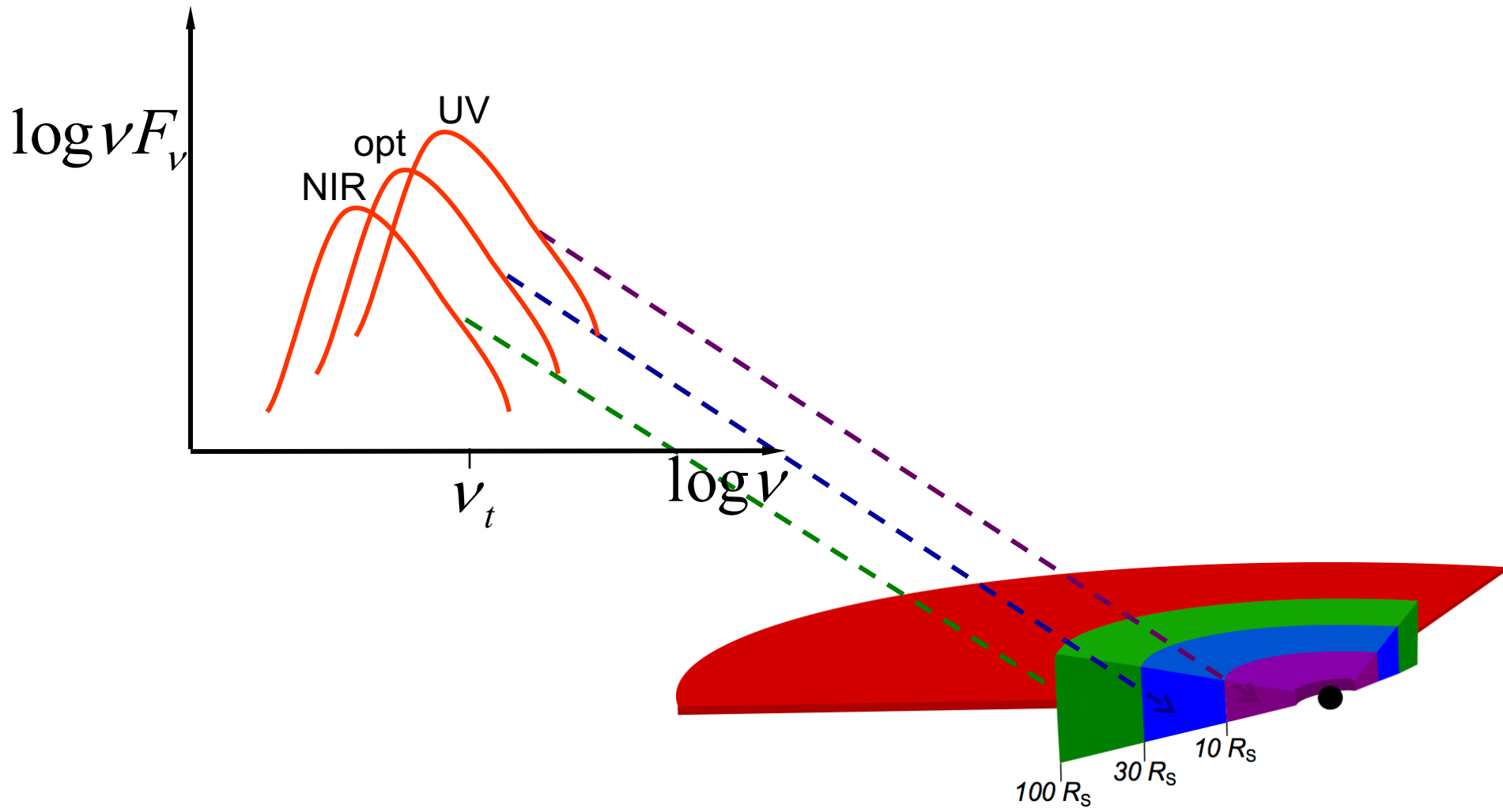
Inhomogeneous accretion flow



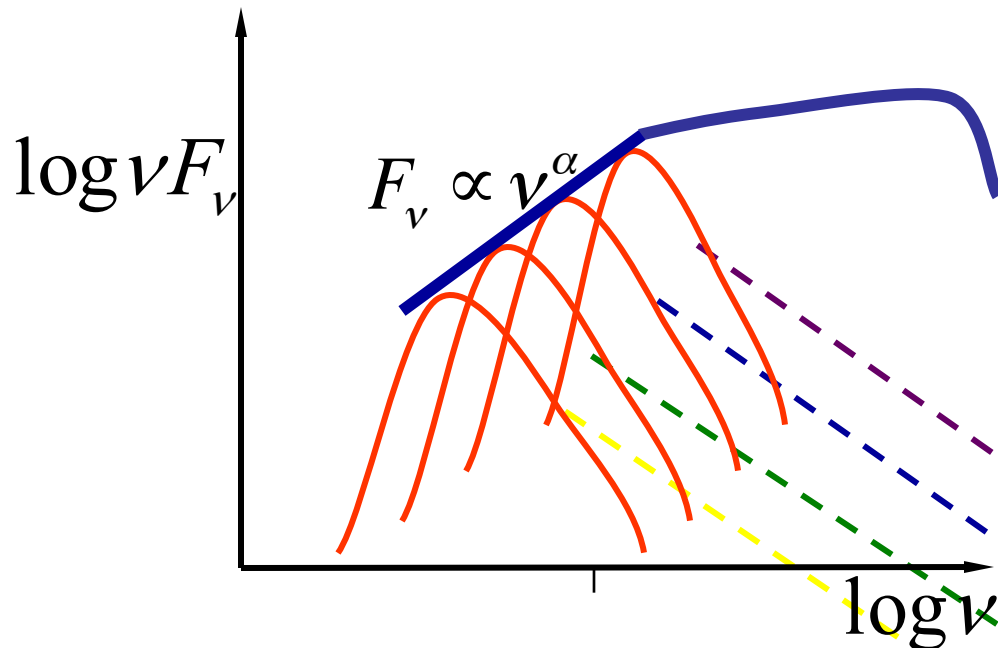
Inhomogeneous accretion flow



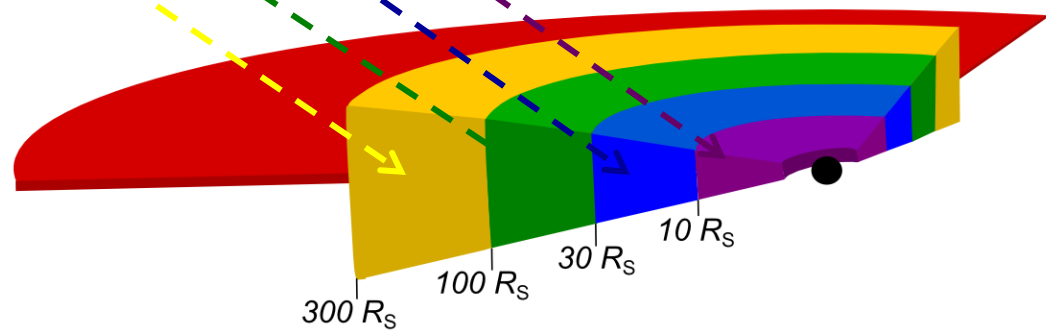
Inhomogeneous accretion flow



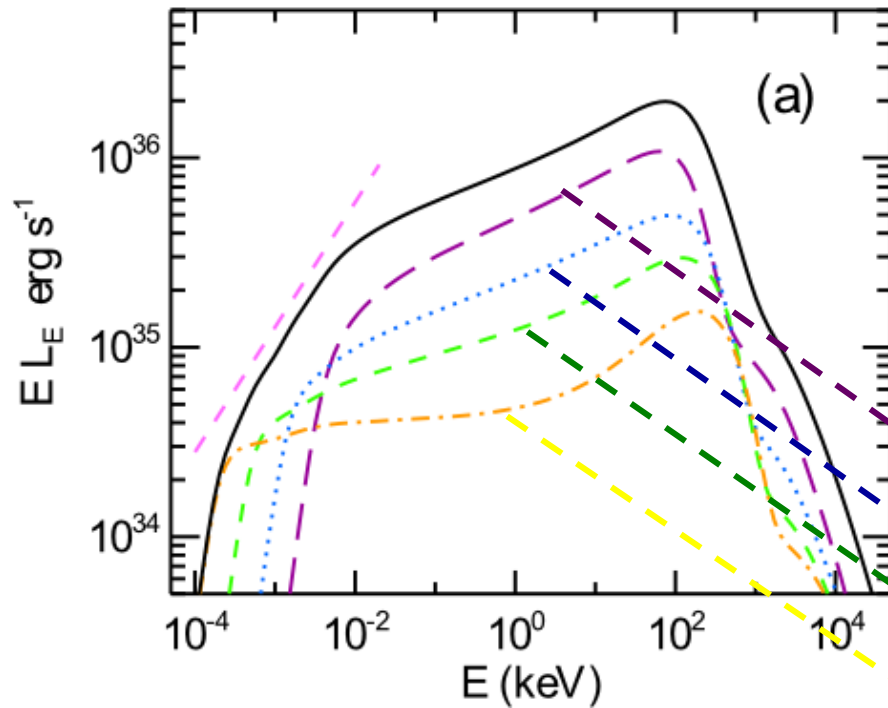
Inhomogeneous accretion flow



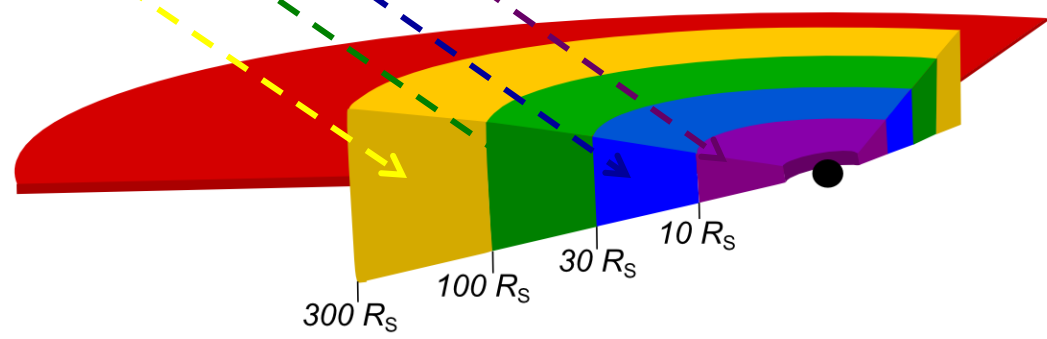
$$\nu_t \approx 10^{15} \left(\frac{R}{10R_s} \right)^{-1} \text{ Hz}$$



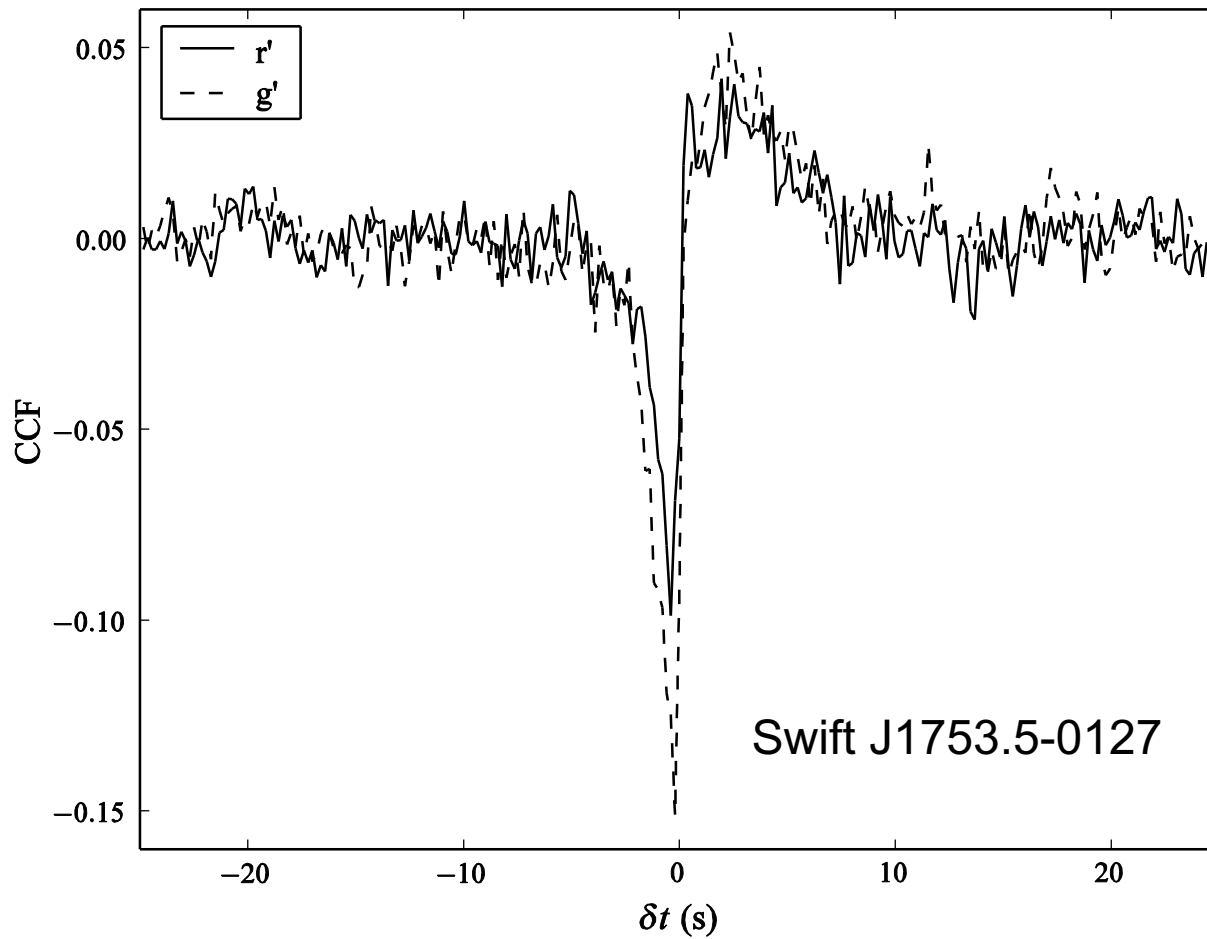
Inhomogeneous accretion flow



$$\nu_t \approx 10^{15} \left(\frac{R}{10R_s} \right)^{-1} \text{ Hz}$$

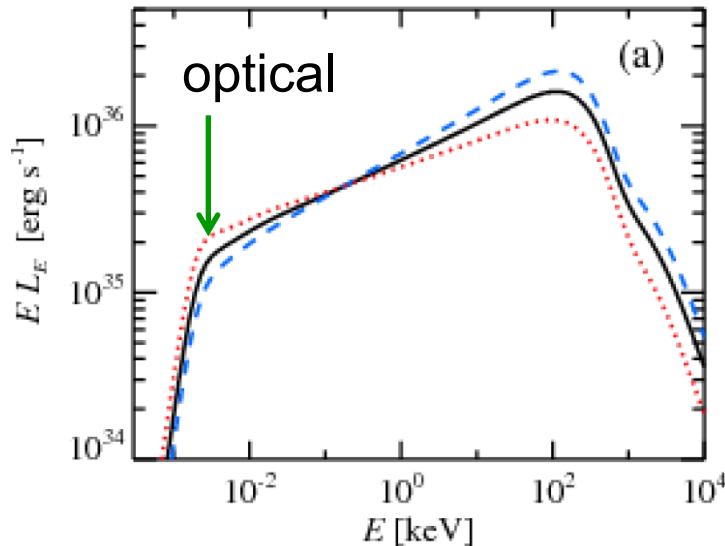


Optical/X-ray cross-correlation



Durant+2010

SSC mechanism in hybrid plasma



Veledina+2011

$$R \propto \dot{m}^{-4/3} \quad \text{Rozanska \& Czerny 2000}$$

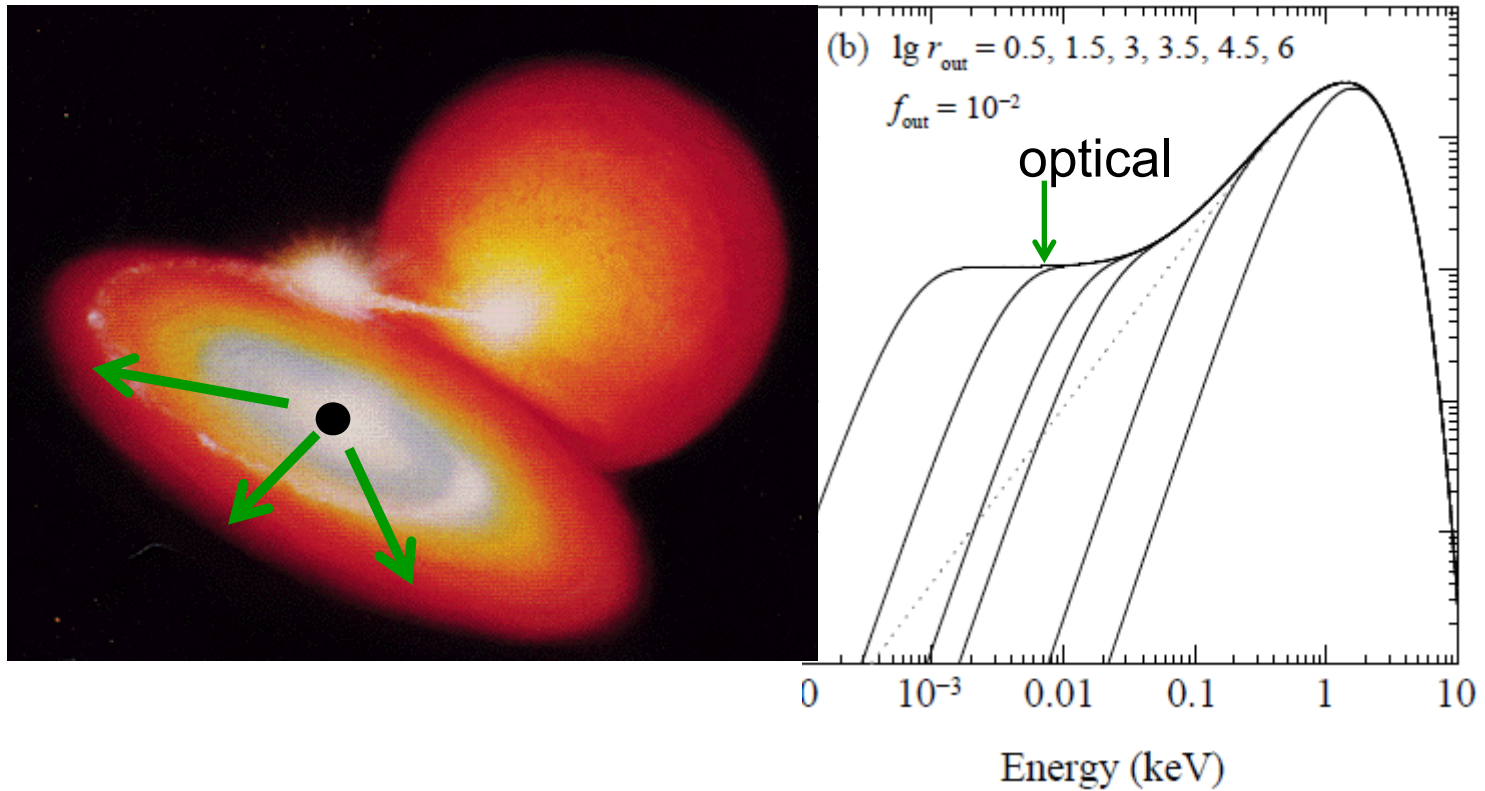
$$L \propto \dot{m}$$

$$\tau \propto \dot{m}$$

$$B = \text{const}$$

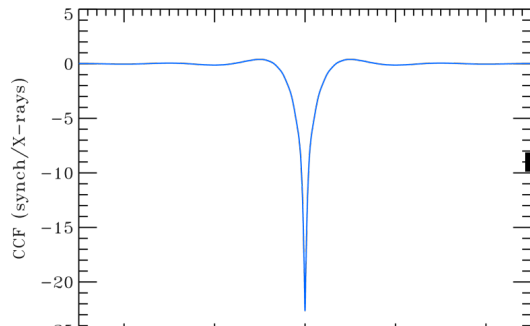
The optical and the X-rays
are anticorrelated

Irradiated discs

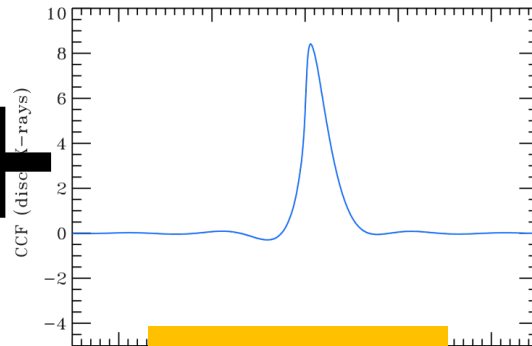


Gierlinski+2009

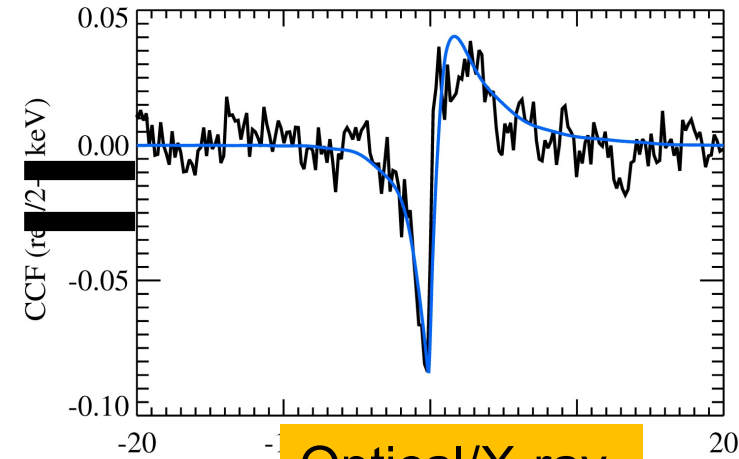
Optical/X-ray cross-correlation



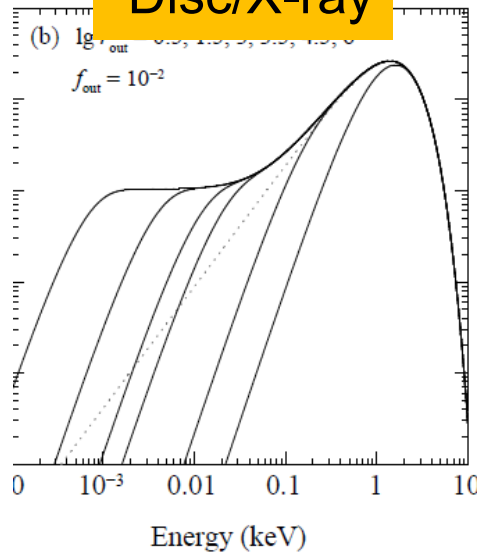
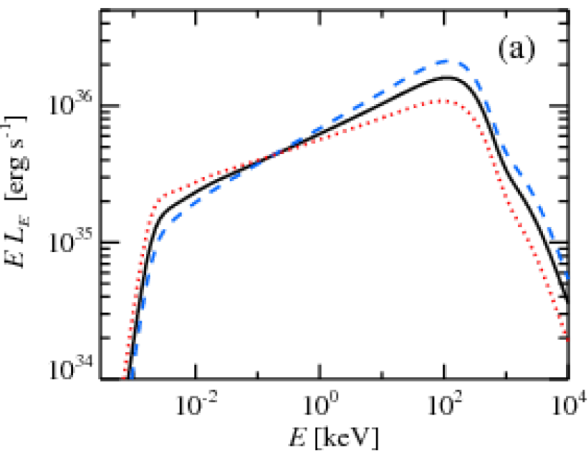
Synchrotron/X-ray



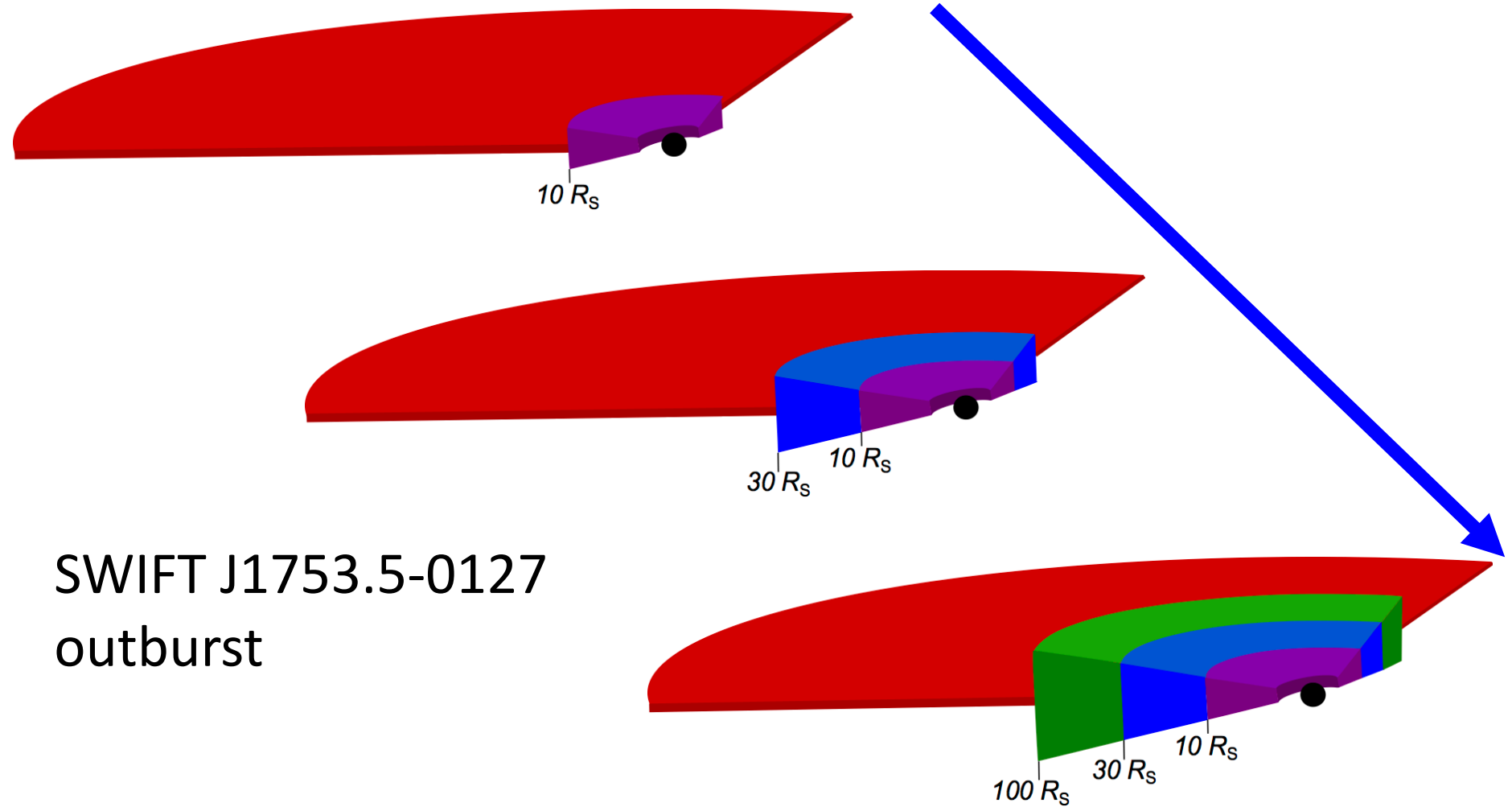
Disc/X-ray



Optical/X-ray

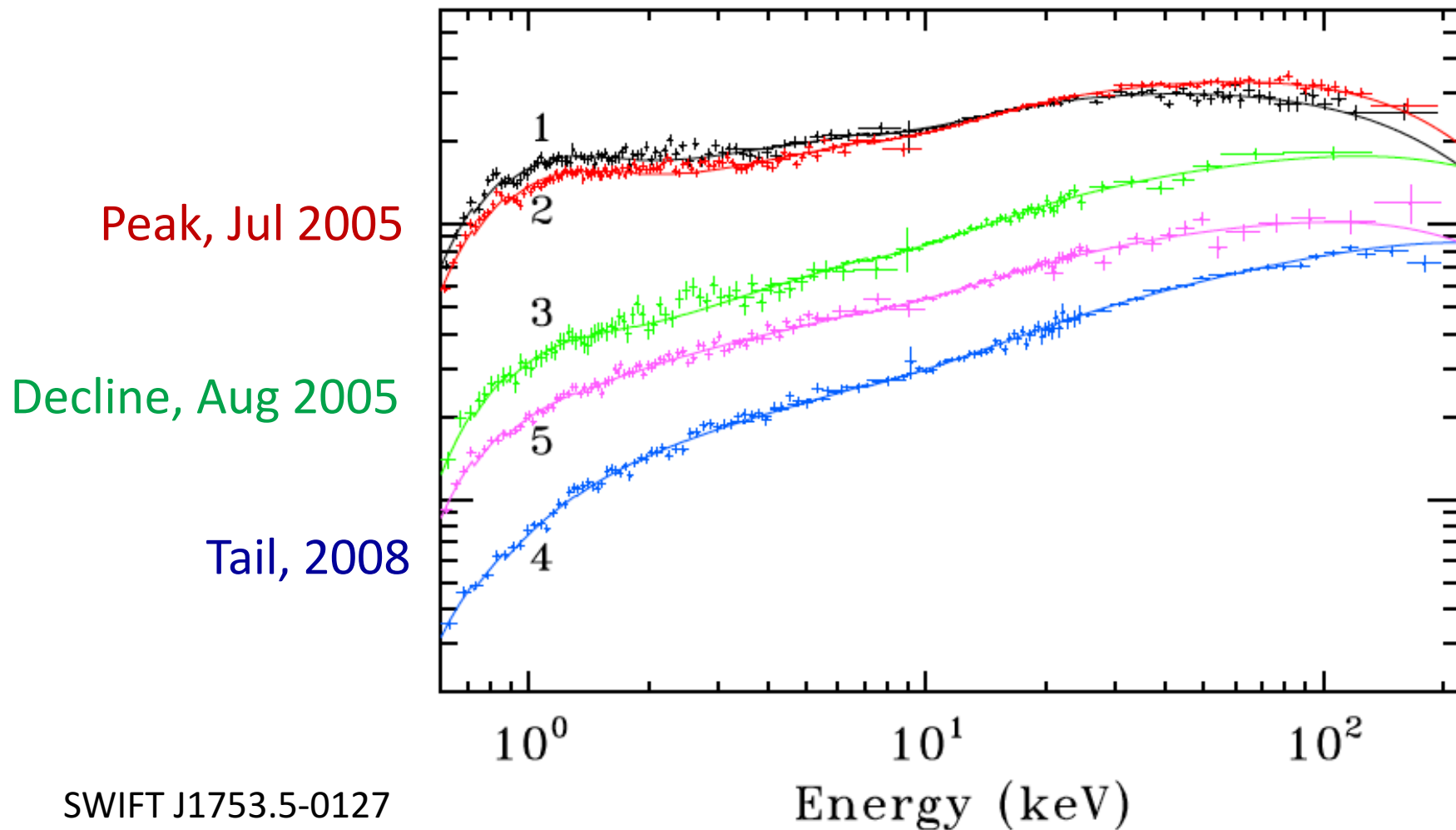


Outburst decline – receding disc

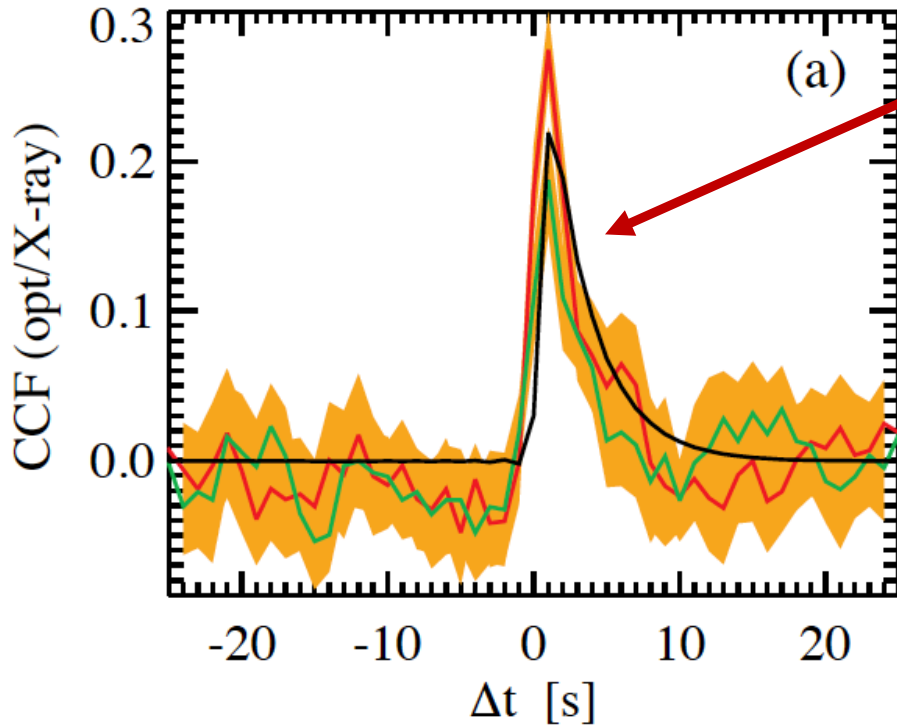


Outburst decline – changing spectrum

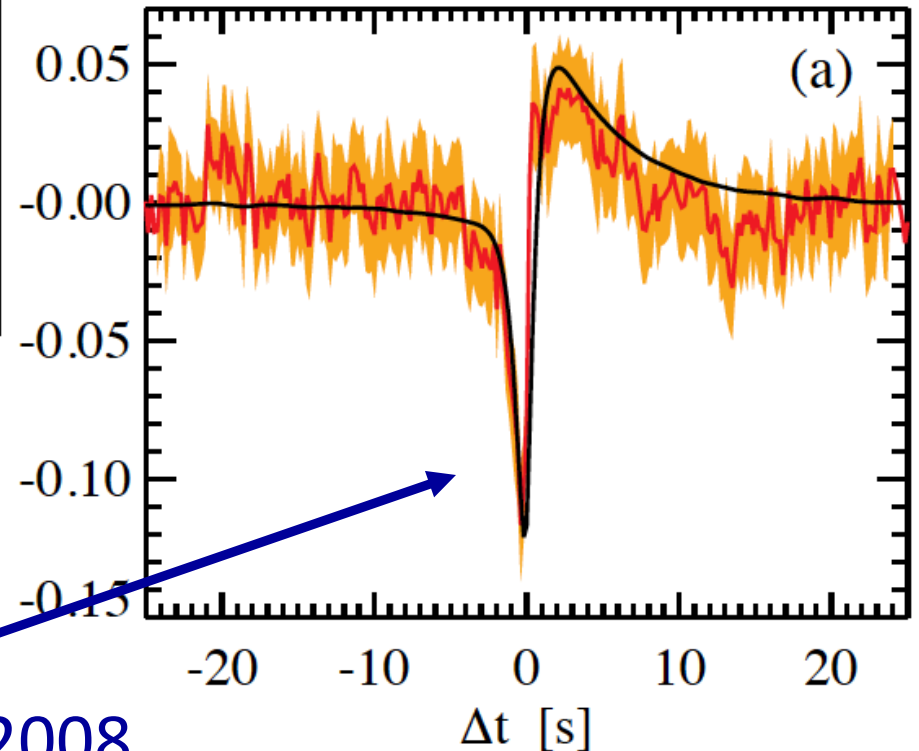
SWIFT J1753.5-0127 outburst



Outburst decline – changing CCF

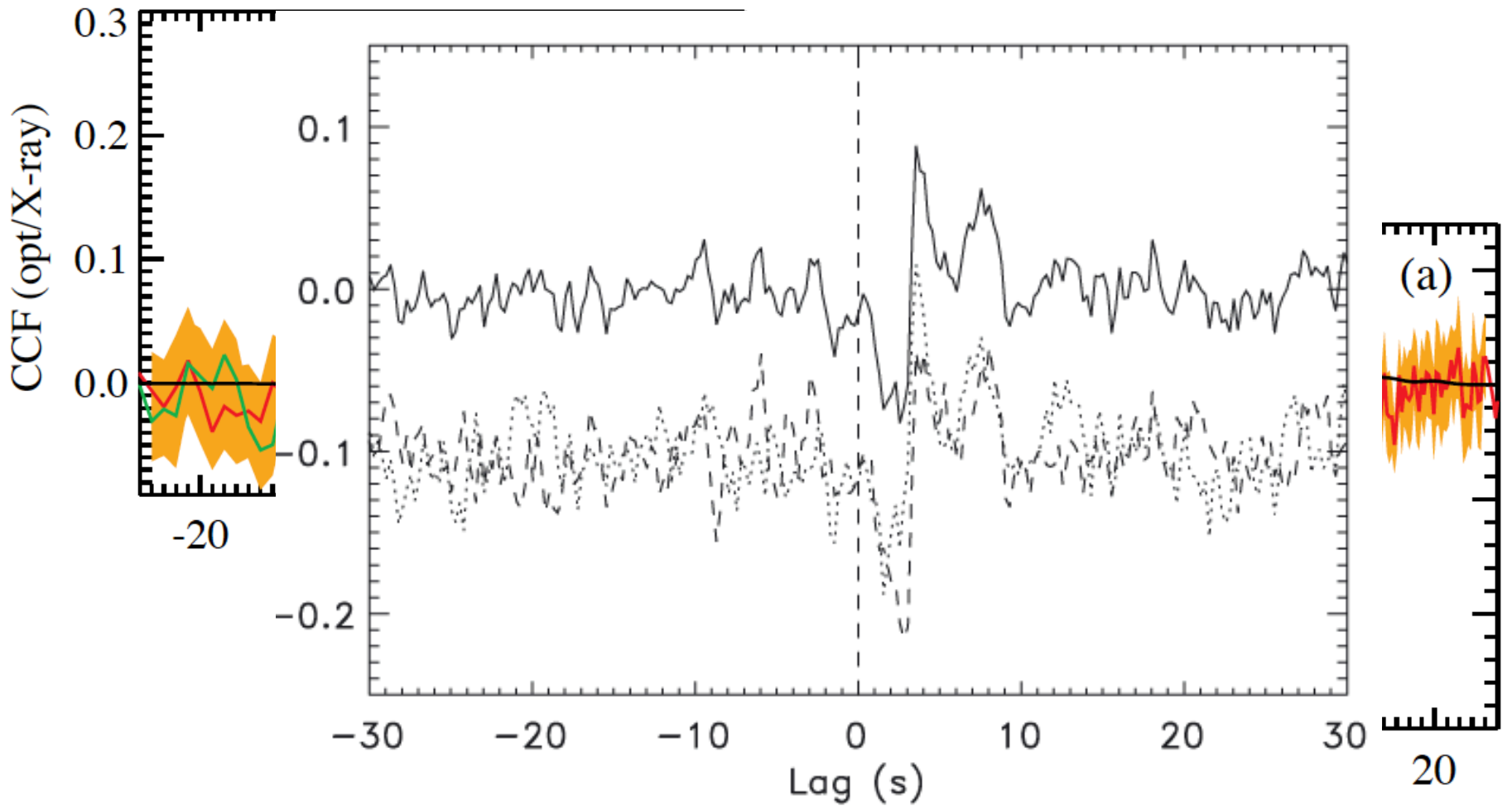


Outburst peak, Jul 2005



Outburst tail, 2008

Outburst decline – changing CCF



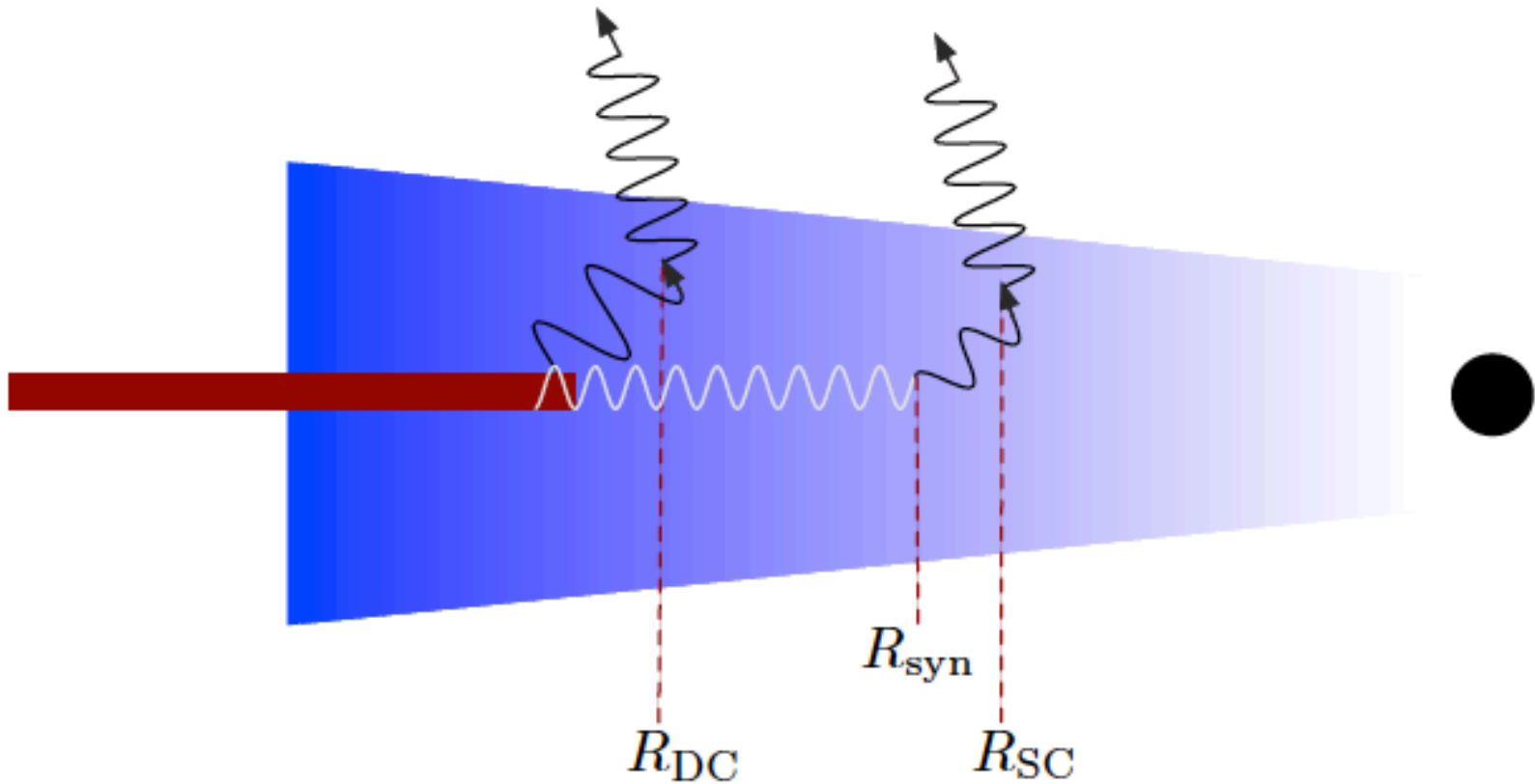
CCF

Decline, Aug 2005

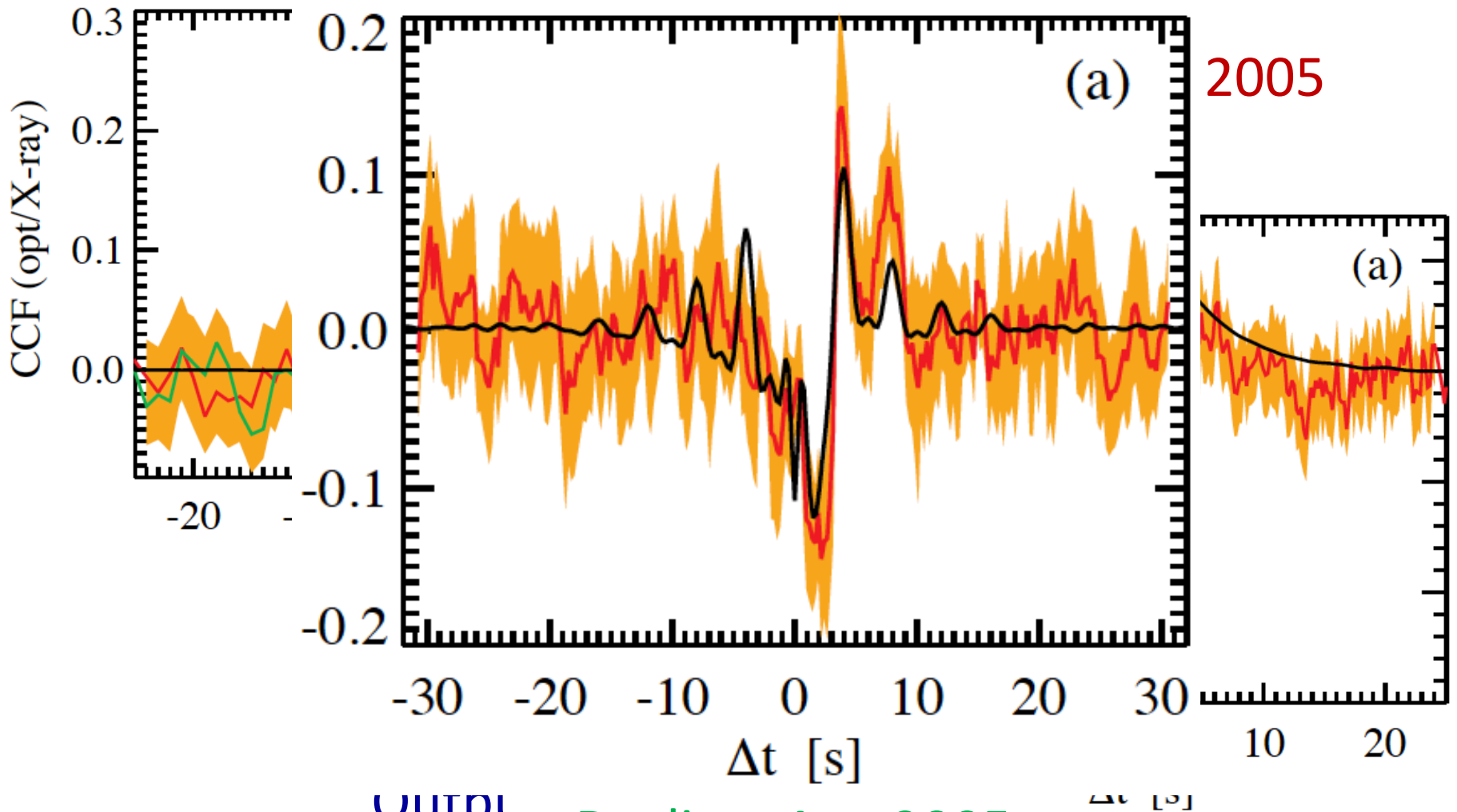
Hynes+09

SWIFT J1753.5-0127

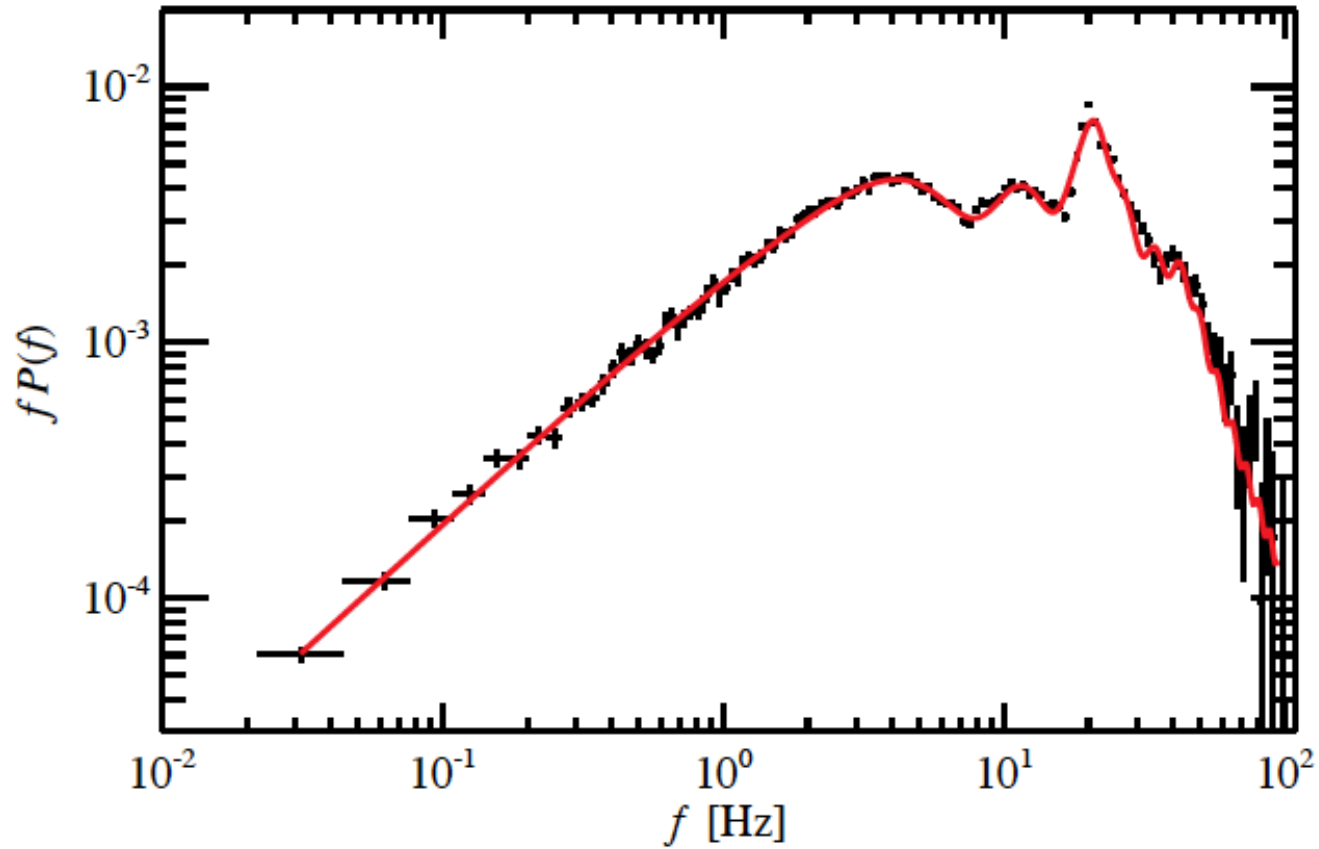
Outburst decline – changing CCF



Outburst decline – changing CCF



Interference in the power spectrum



Conclusions

- Presence of non-thermal particles in the media of accreting black holes dramatically changes cooling conditions and emerging spectra
- Non-thermal electrons produce optical/infrared emission via synchrotron
- Accretion flows with non-thermal electrons can explain many observed phenomena: flat optical/infrared spectra, optical/X-ray CCF, optical QPOs, humps in the X-ray power spectra

Thanks!