Aspects of X-ray data analysis for accreting compact objects: theory and results

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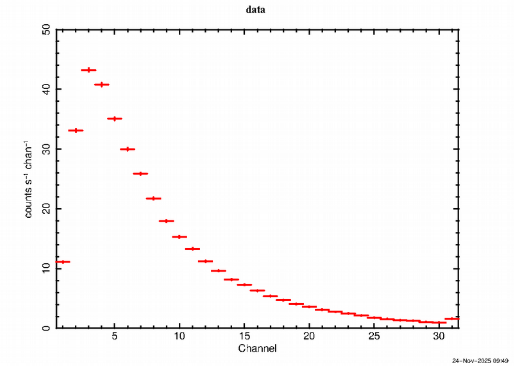
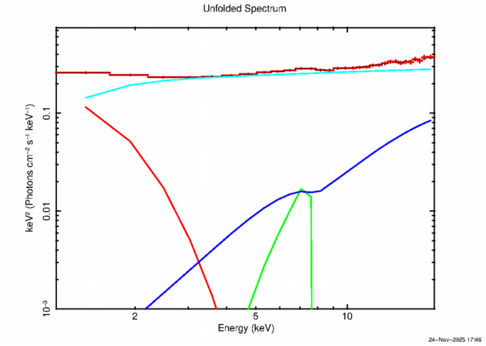
Previous lecture

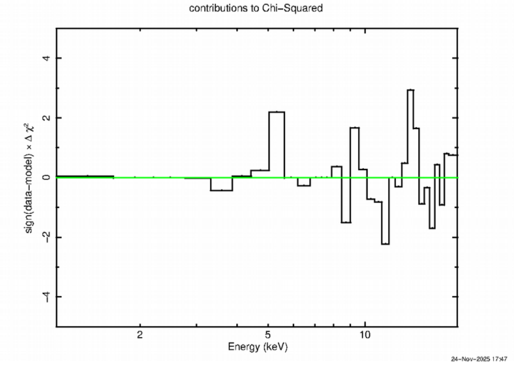
X-ray data, counts, models, model fitting: best fit, parameter uncertainties

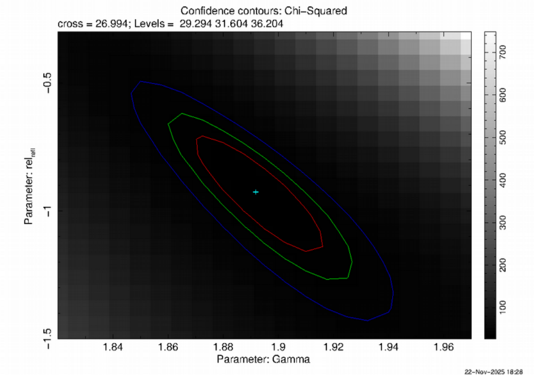
$$\chi^2 = \sum_i \frac{(C_i - M_i(\theta))^2}{\sigma_i^2}$$



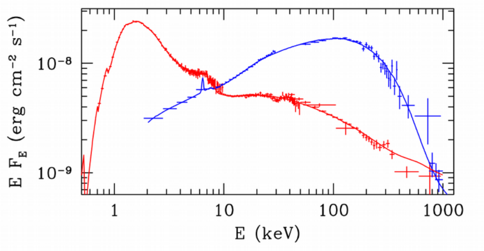


Source flux can be determined when a model is fitted





Color-flux diagramms



These sources are very variable.

Hard state, soft state and everything in between.

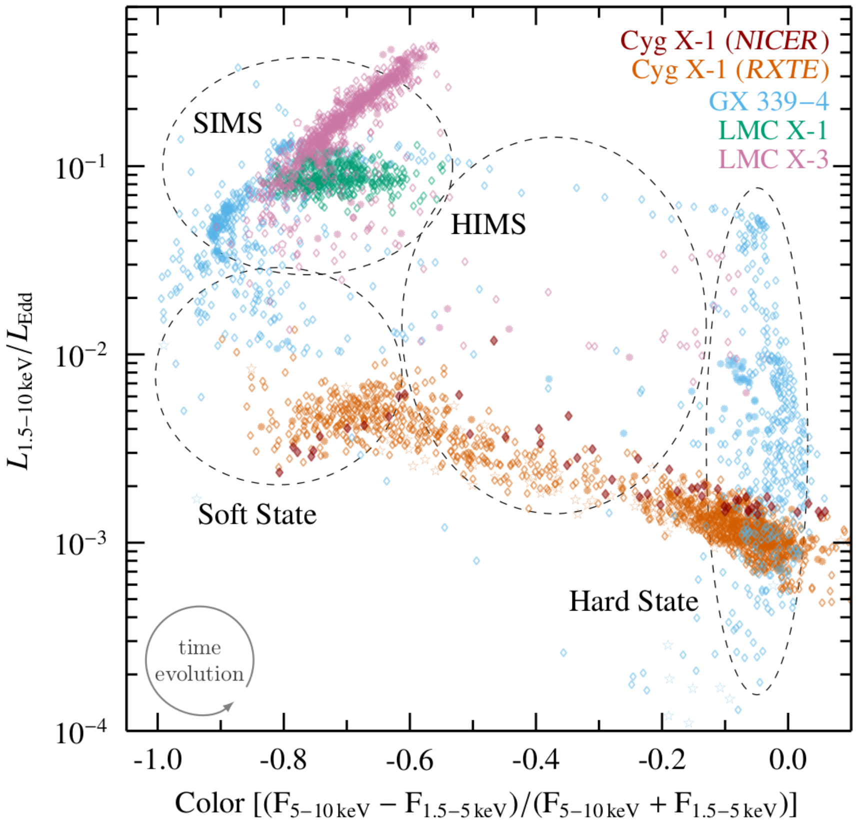
They are also bright – enough counts in a typical observation to construct several spectra.

Color-color, or color-flux diagrams - a very popular method of analyzing big data (a color – a difference or ratio of fluxes in two energy bands).

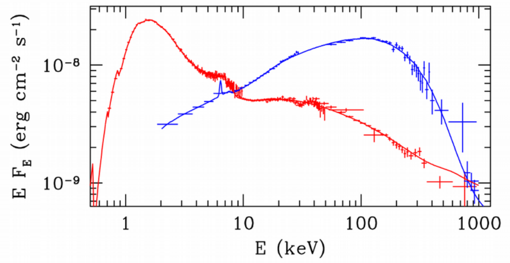
In a simple version these are constructed from counts, but then they are instrument-dependant.

In more sophisticated approach, simple models are fitted to the data, and fluxes determined from these fits.

Color-flux diagrams



O. König, PhD dissertation



Done, Gierliński, Kubota, 2007, A&AR, 1, 66

Permanent vs transient sources

The case of GX 339-4

flux (3-10keV)

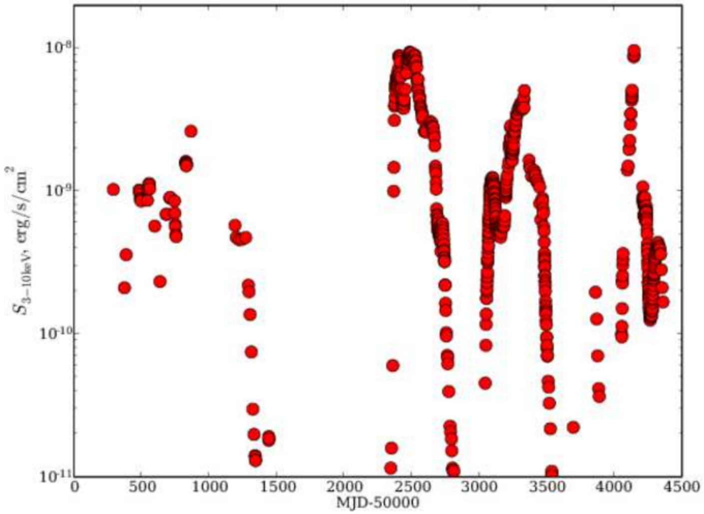
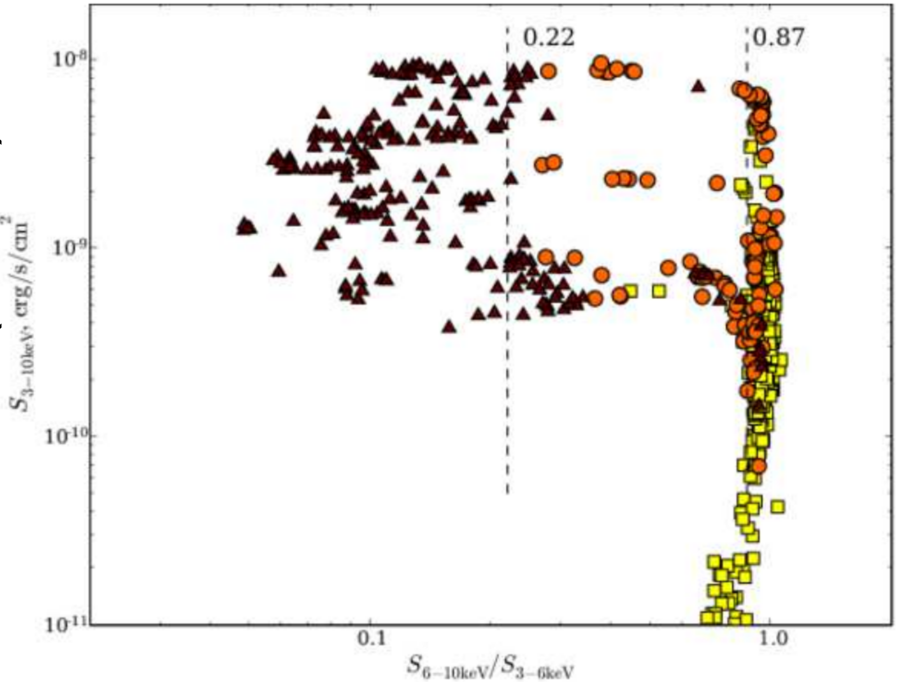


Figure 1. The *RXTE-PCA* lightcurve of GX 339-4 over 11 years. The flux is the absorbed flux between $3-10\,\mathrm{keV}$.

flux (3-10keV)



flux (6-10keV)/flux (3-6 keV)

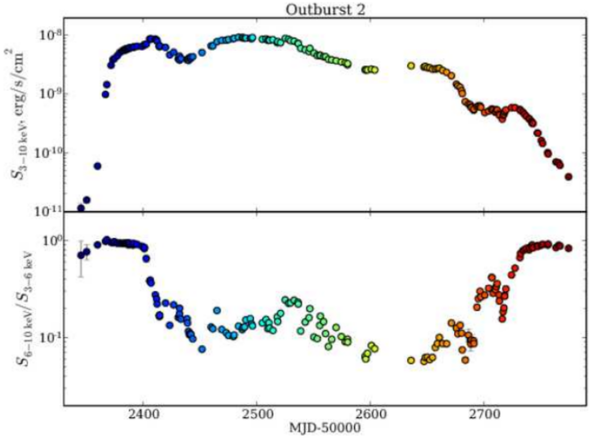
Hysteresis !

Dunn, R et al., 2008, MNRAS, 387, 545

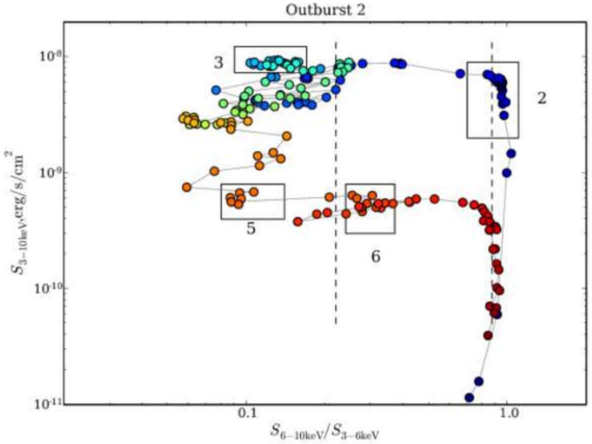
Hysteresis in GX 339-4

flux

color

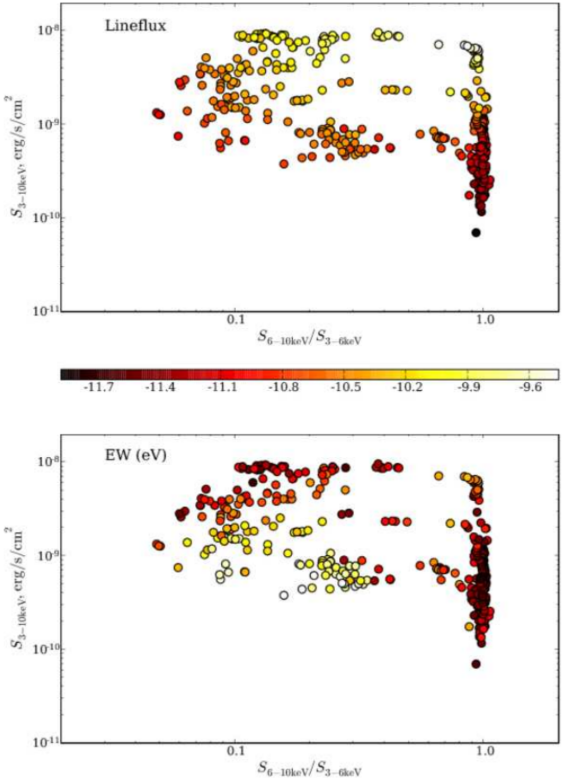


flux (3-10keV)



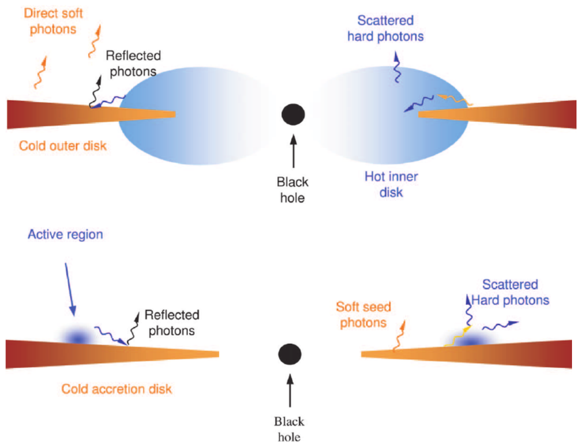
flux (6-10keV)/flux (3-6 keV)

flux (3-10keV)

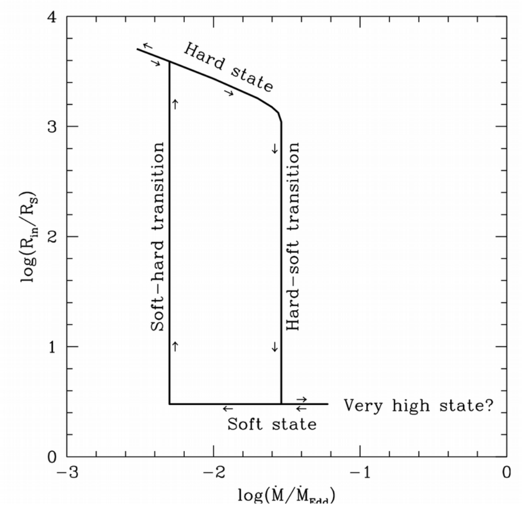


Dunn, R et al., 2008, MNRAS, 387, 545

Mechanism of the hysteresis



Truncation radius



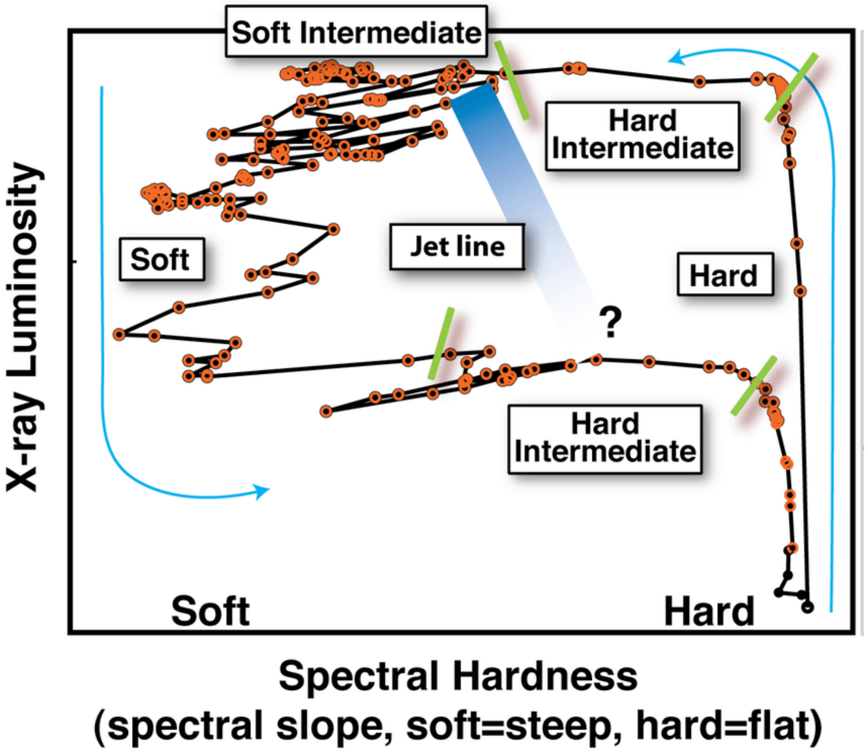
Accretion rate

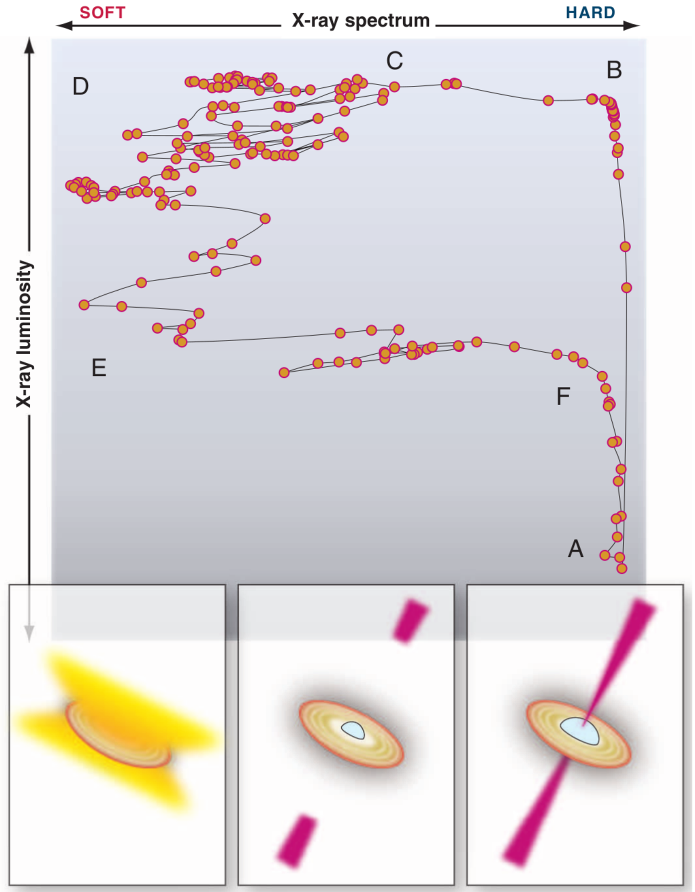
Hard-to-soft: need a lot of extra mass (so, high accretion rate) to cool down the hot plasma, so that it collapses to a standard disk.

Soft-to-hard: need to significantly decrease the mass flow through the disk (so, low accretion rate), so that the hot plasma has a chance to evaporate the disk

E. Meyer et al., 2005, A&A, 432, 181

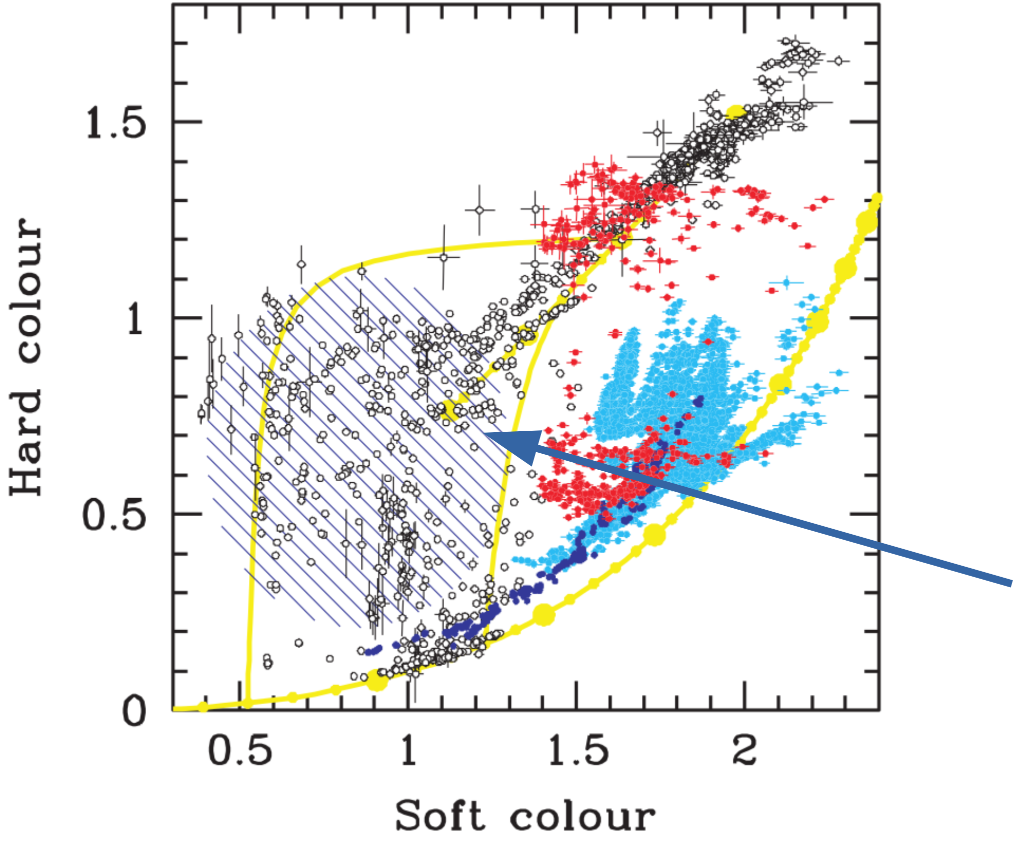
More general color-flux diagram





T. Belloni, R. Fender, other works

Color-color diagram for black holes vs neutron star systems



soft color = F(4–6.4)/F(3–4)

hard color = F(9.7–16)/F(6.4–9.7)

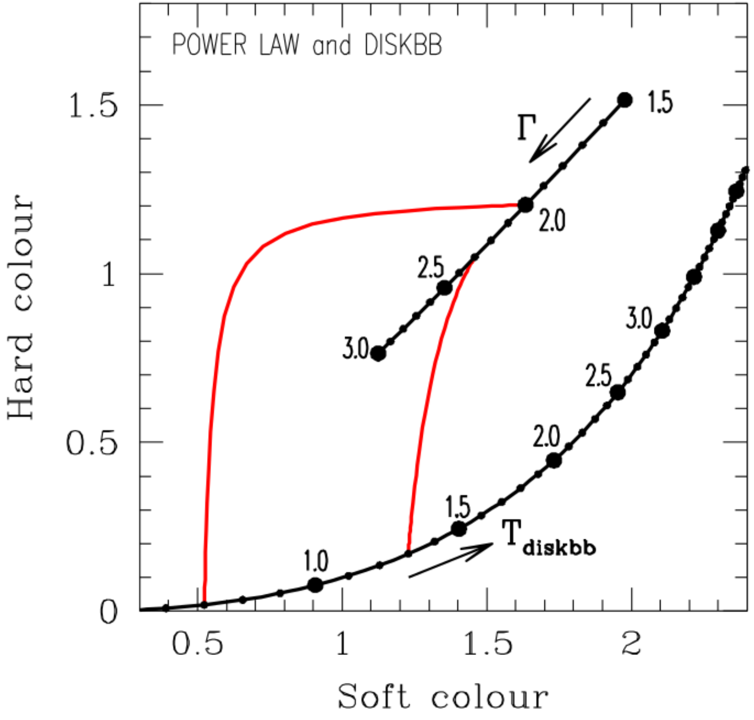
Open, black circles – BH;

Colored points – NS

only BH here!

Done & Gierliński, 2003, MNRAS, 342, 1041

Color-color diagram for black holes vs neutron star systems



soft color = F(4–6.4)/F(3–4)

hard color = F(9.7–16)/F(6.4–9.7)

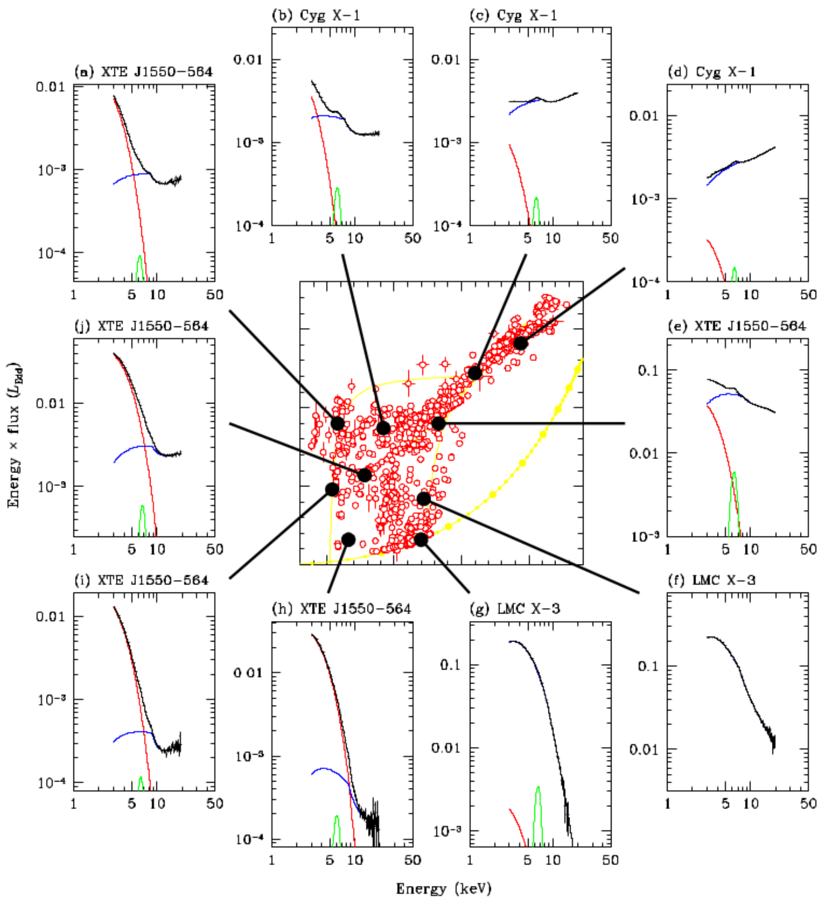
Disk black body + power law

kT = 0.7 keV, $\Gamma = 2$

kT = 1.3 keV, $\Gamma = 2.3$

Done & Gierliński, 2003, MNRAS, 342, 1041

Color-color diagram for black hole systems



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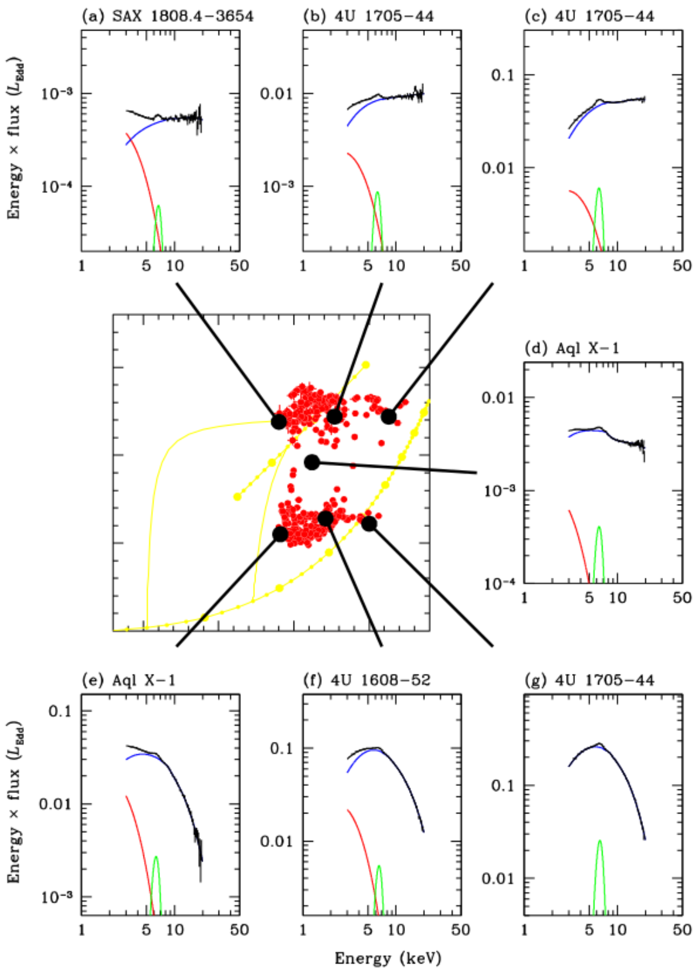
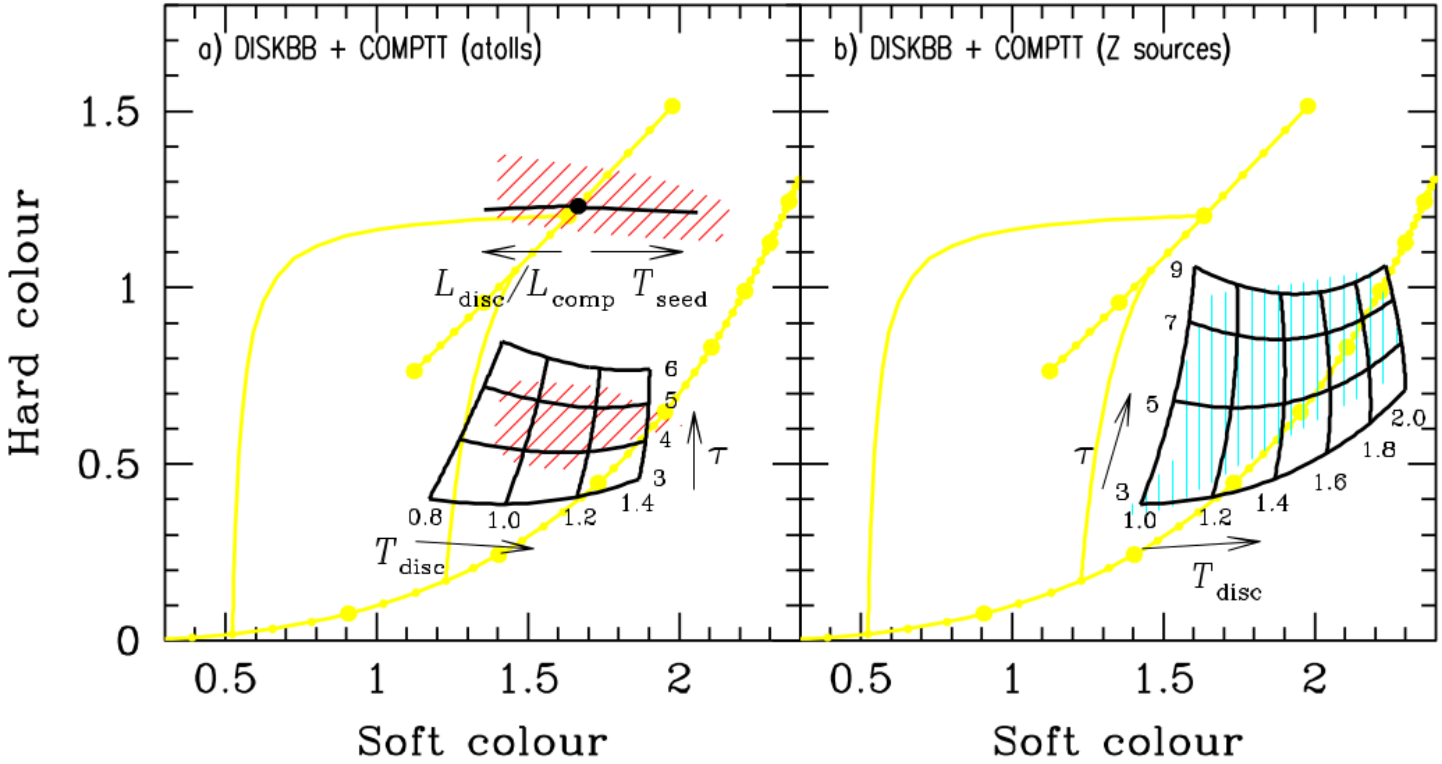
Color-color diagram for neutron star systems



Done & Gierliński, 2003, MNRAS, 342, 1041

Phenomenological models for neutron star systems



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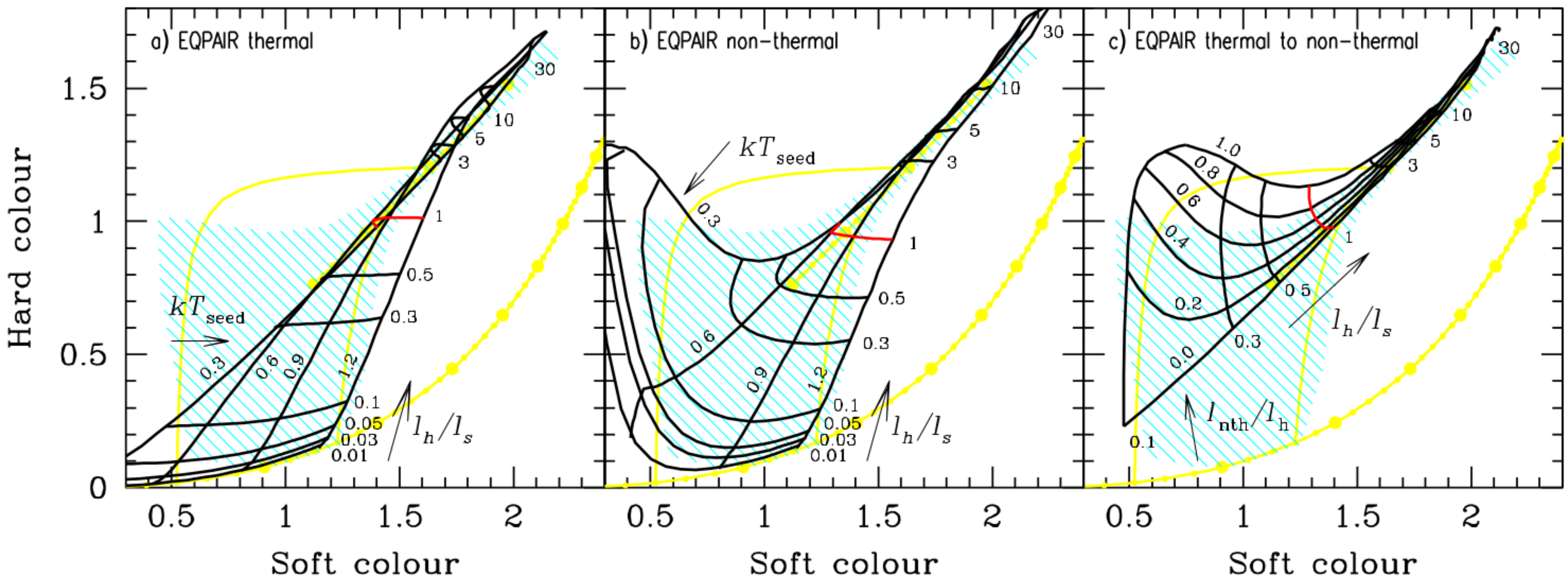
Physical models for black hole systems



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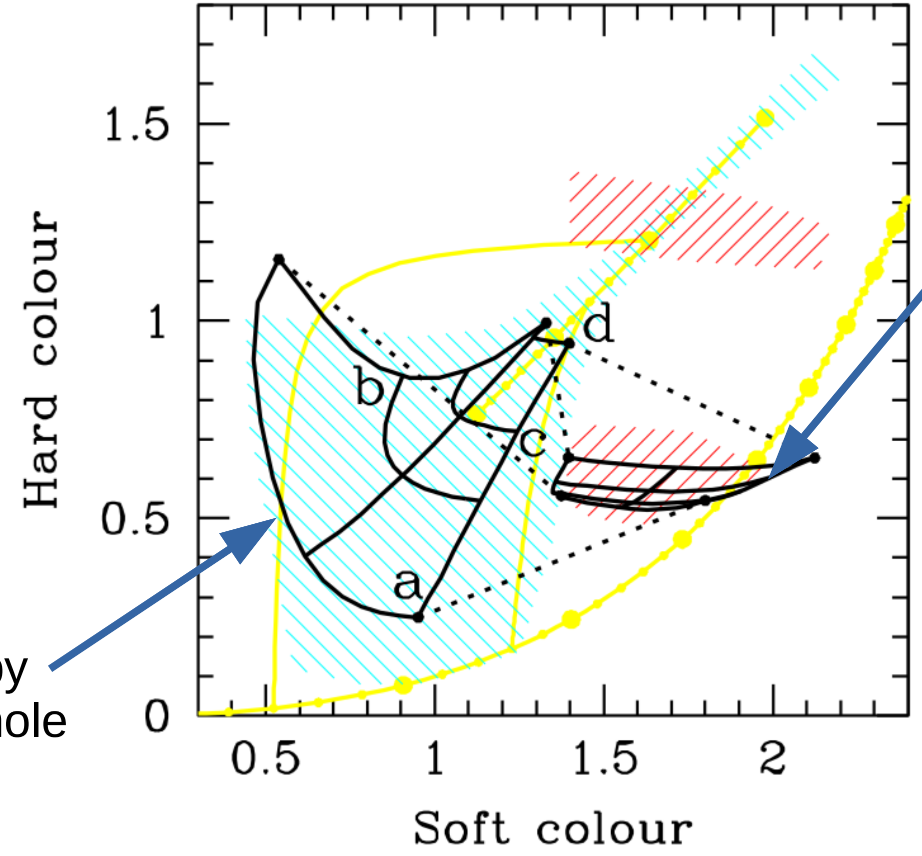
Physical models for black hole and neutron star systems



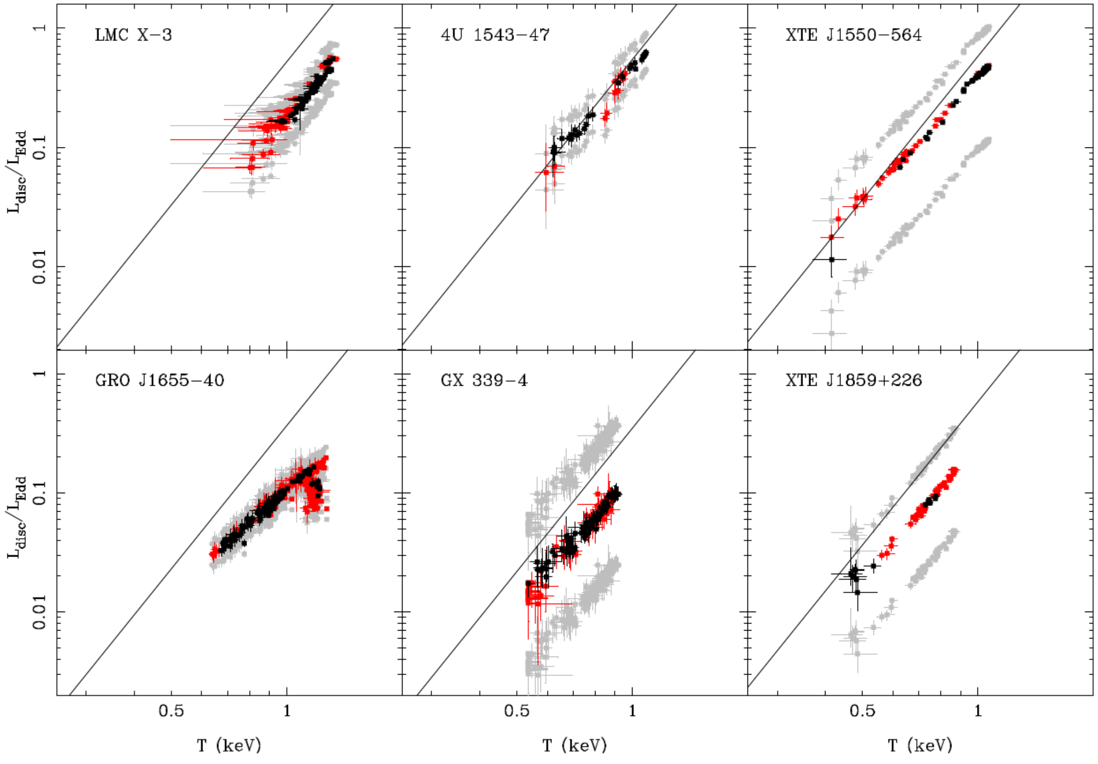
A range covered by models for black hole systems ...

… is transformed into a range covered by neutron star systems, when **additional emission from NS surface/boundary layer is added**

Done & Gierliński, 2003, MNRAS, 342, 1041

Temperature-luminosity relation

Disk luminosity (rel. to Eddington)

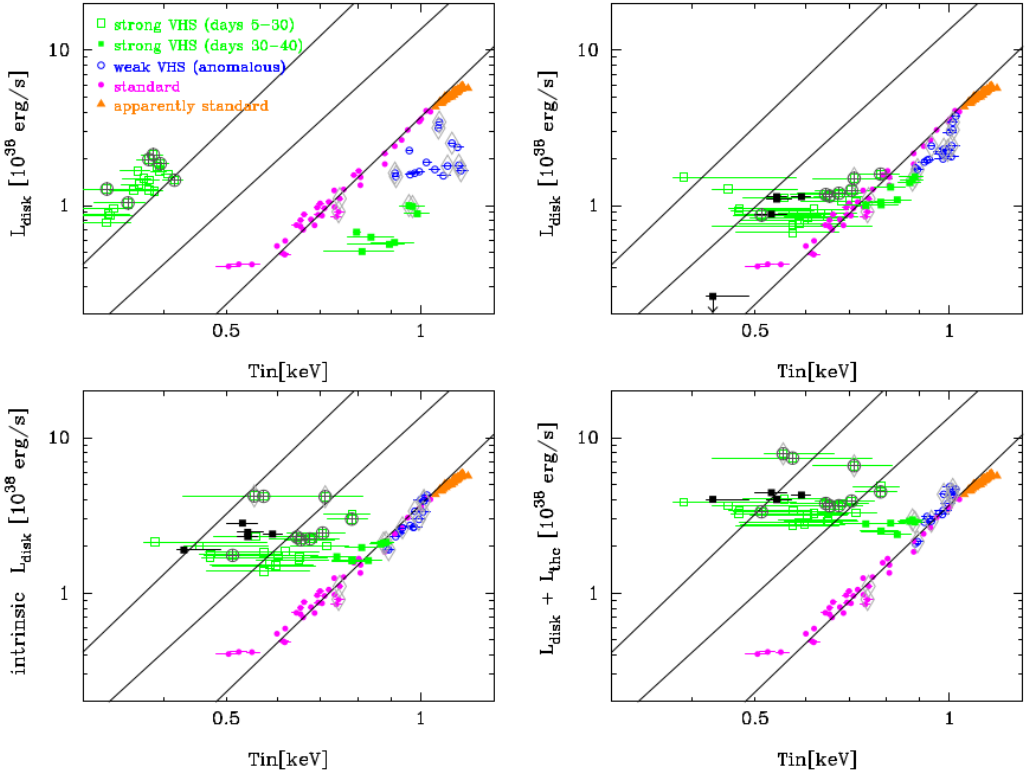


Temperature (keV)

$$L \propto T^4$$

Done, Gierliński, Kubota, 2007, A&AR, 1, 66

Temperature-luminosity relation



Disk luminosity (rel. to Eddington)

Temperature (keV)

Deviations from the standard relation → change of geometry? Change of the structure of the disk?

Done, Gierliński, Kubota, 2007, A&AR, 1, 66