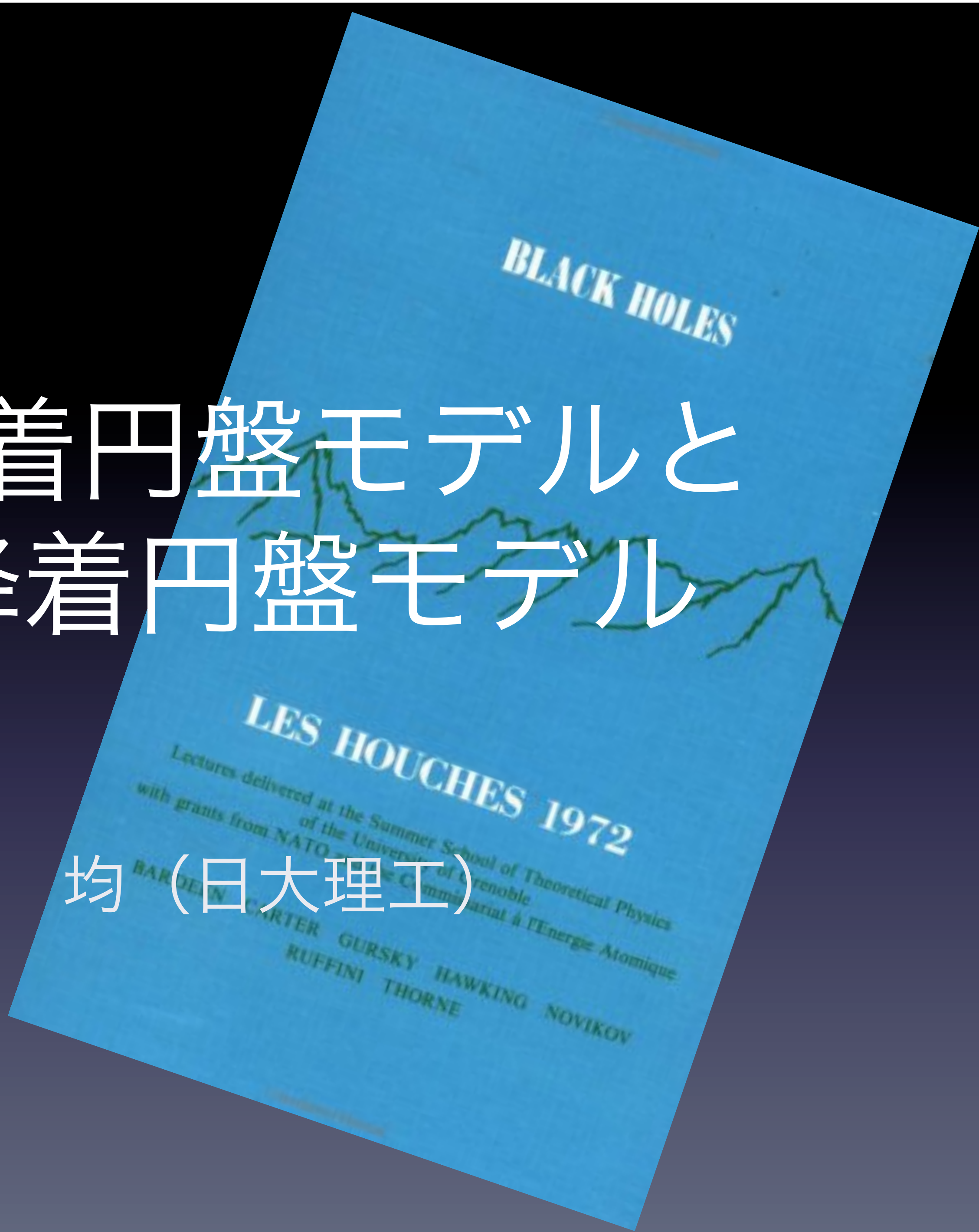
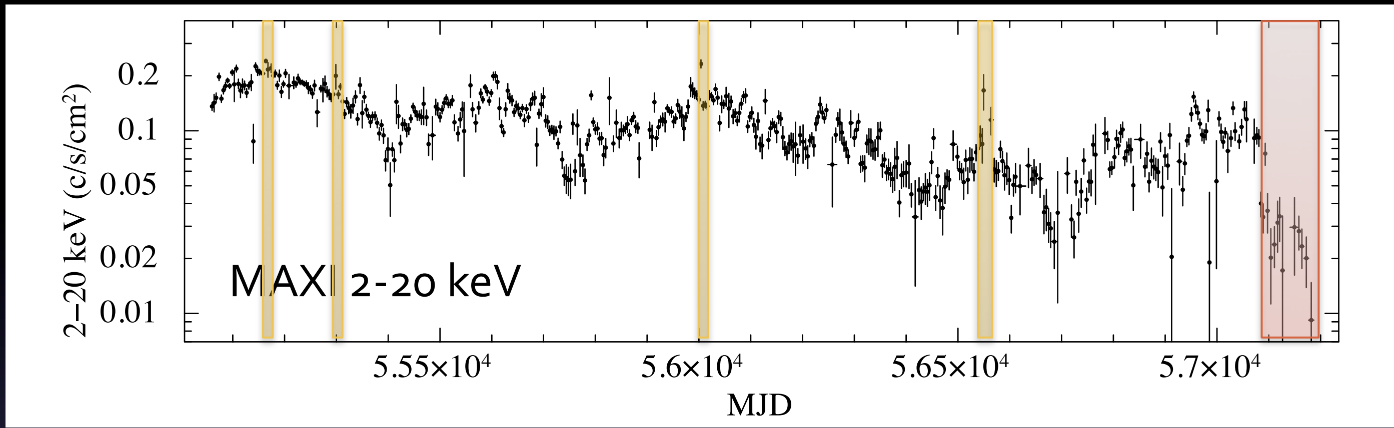
理論降着円盤モデルと観測降着円盤モデル



根來　均（日大理工）

Swift J1753.5-0127 fading away..

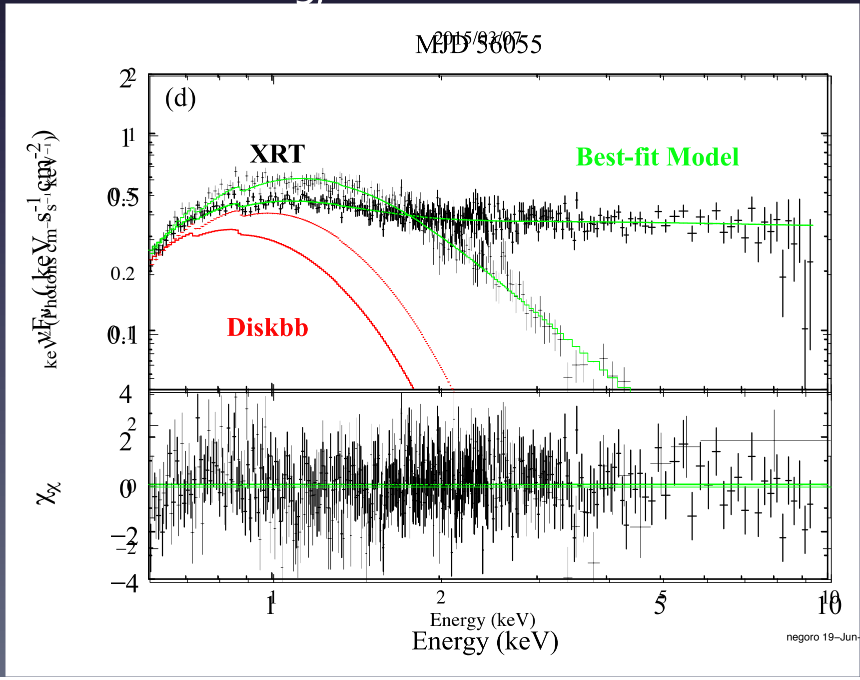
in a soft state ???

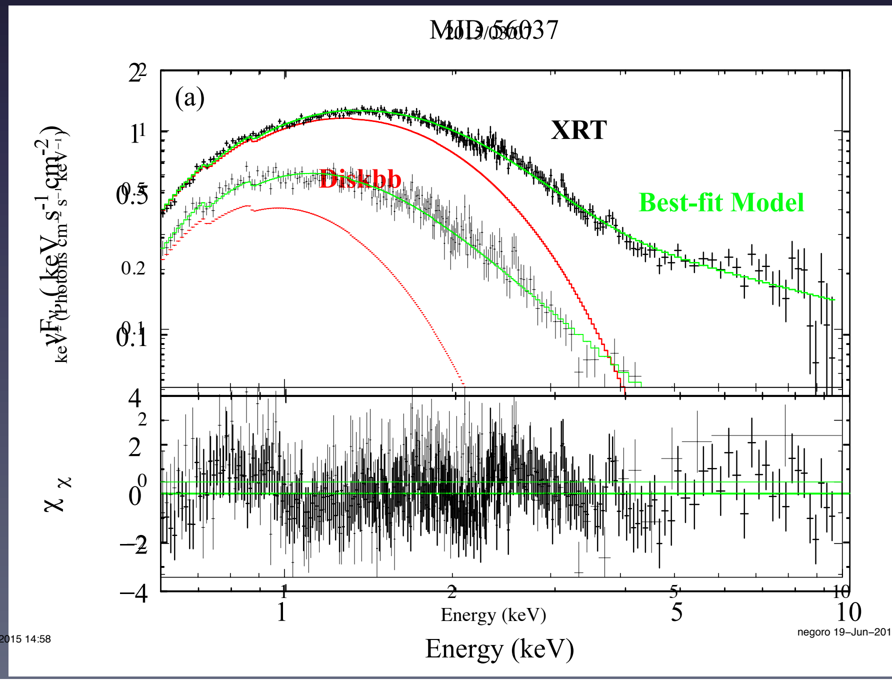


MAXI J1910
Nakahira's
talk

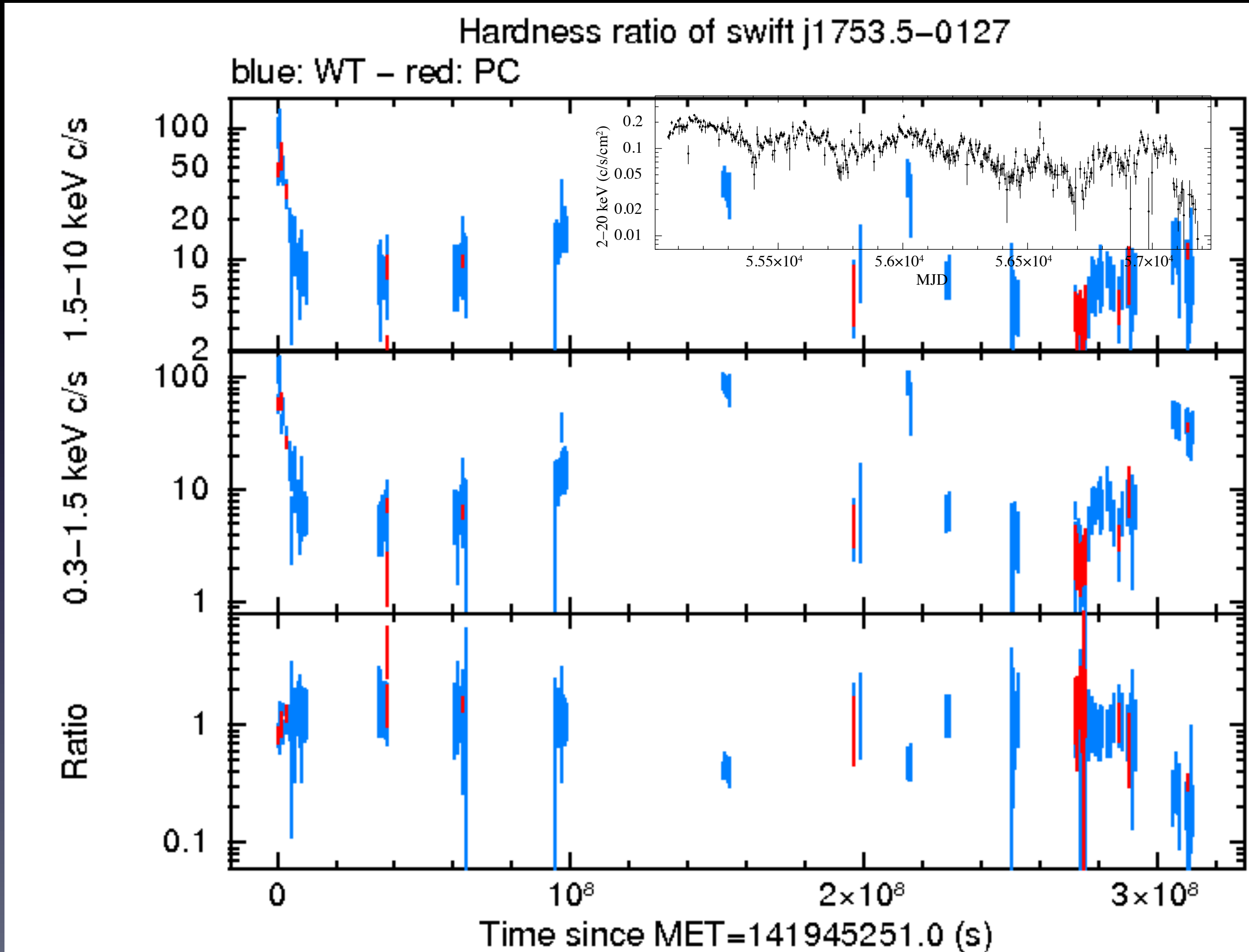
Yoshikawa+ 2015, PASJ

Onodera+ ATel 7196



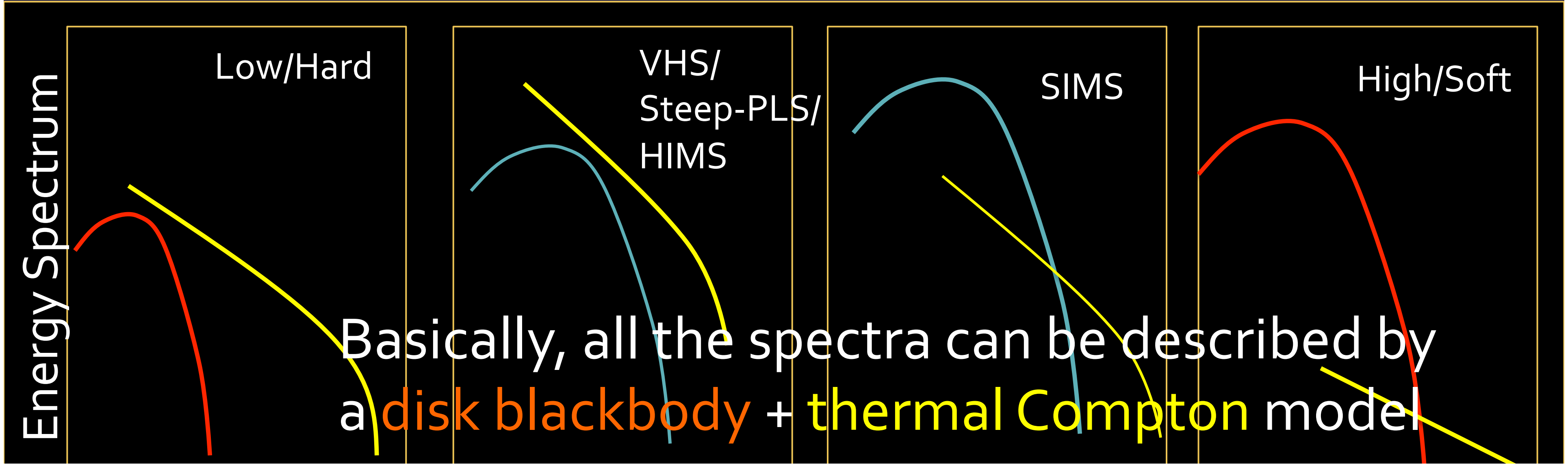


Swift J1753.5-0127 Swift/XRT



Observations vs Theories

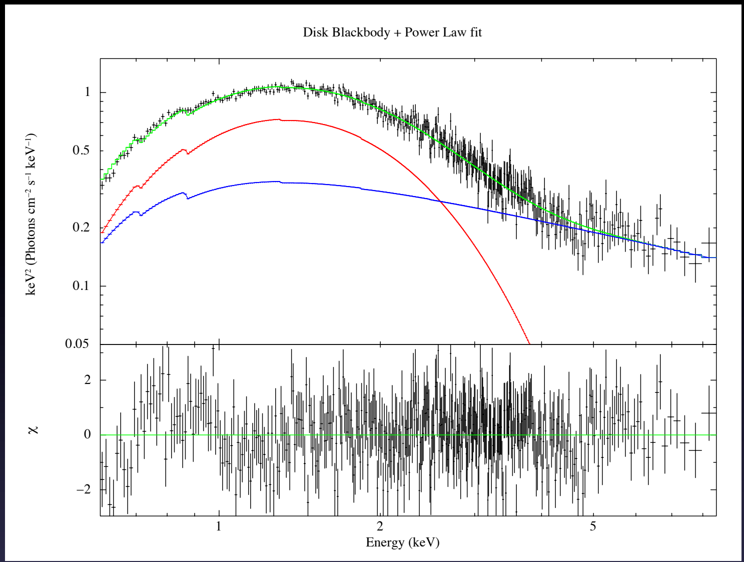
- Low/Hard State
  - Power-Law (= Advection Flow, Corona or jet ?)
  - Flickering (= Advection)
- Intermediate State
  - Steep Power-Law dominant (= Corona Dominant Disk ?)
  - QPOs (=inner boundary instability, disk warp, Lense-Thirring ??)
- High/Soft State
  - Thermal Disk (= S-S Standard Disk) + Power-Law tail (= Corona ?)

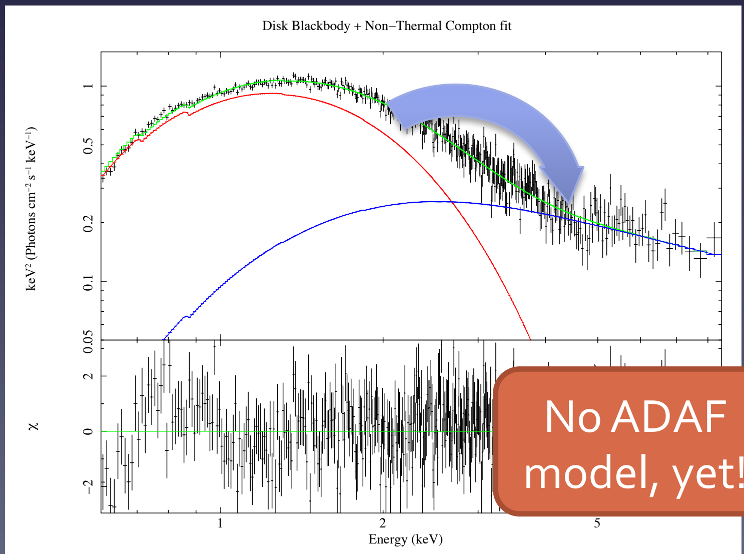


Basically, all the spectra can be described by a disk blackbody + thermal Compton model

Power-Law: Corona, ADAF, or Jet ?

Swfit J1753.5-0127/Swift (Yoshikawa+ 2015)





No ADAF model, yet!

Empirical Models

power-law , exp-cut power-low, ..

Comptonization Models

nthcomp (Tdbb/bb, Te, Γ : Zdziarski+96, Zycki+99)
simpl(*diskbb) (Γ, fraction : Steiner 09)
comptt (Tbb, Te, τ : Titartuck+ 94, 95, 96)
compbb (Tbb, Te, τ : Nishimura+ 86)
..

→ Good fits, but no geometry info

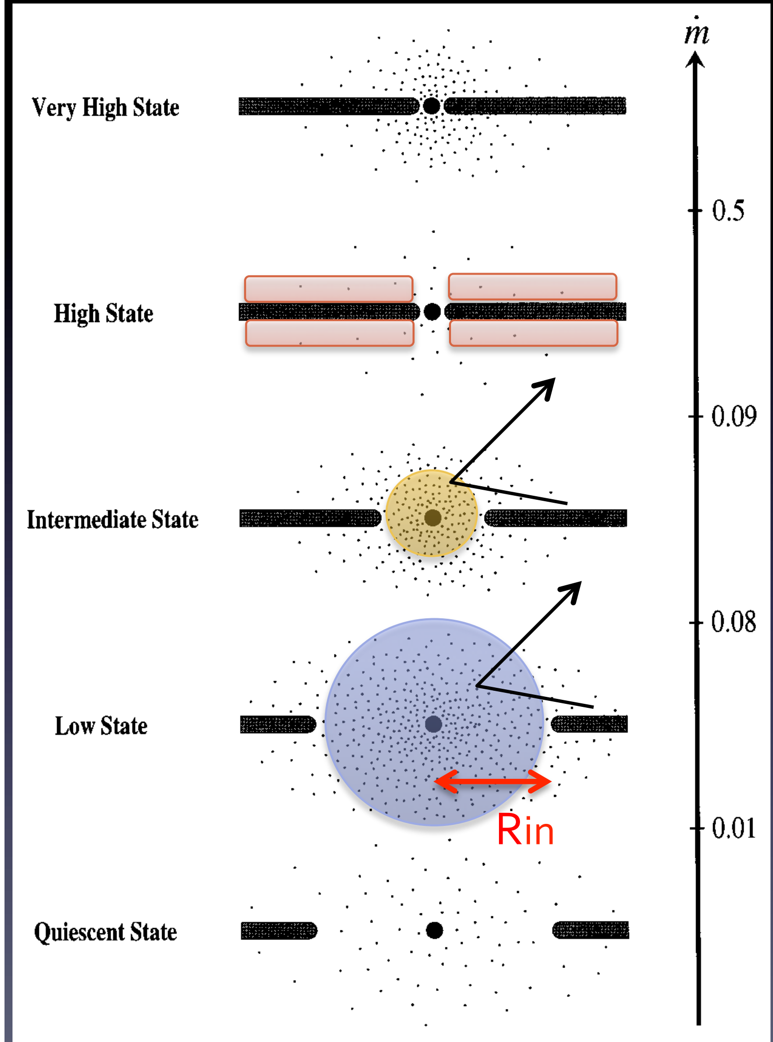
Complex Models

eqpair (Coppi 02?)
compps (Poutanen+ 96)

→ Too many (~20) parameters

Compton Cloud?

Old ('70s) and New problem
- "corona" or "inner region
(2 temperature SLE model)"



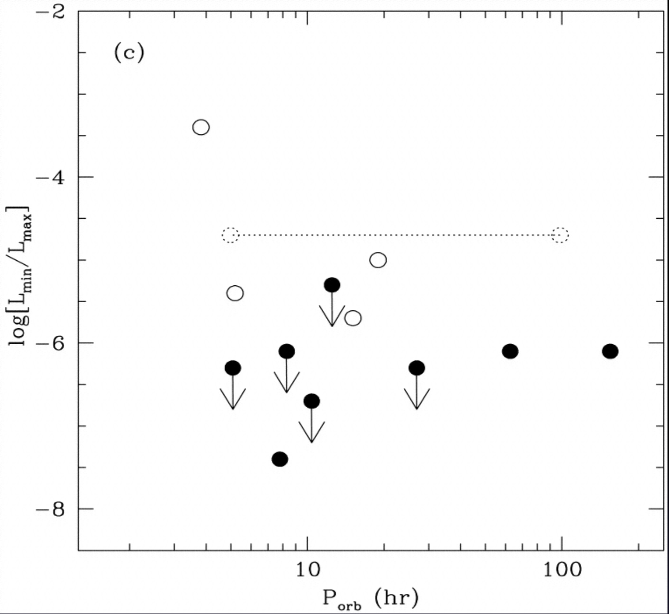
Fitting gives
Electron Temperature: Te, τ (Γ)
Disk parameters: Tbb, Rin
Compton Fraction: fc

if Corona, a real vertical structure?
soft state : Rin <= color temperature correction
Tcolor/Teff ~ 1.7-1.9 (Shimura+ 1995),
~ 1.5-1.6 (e.g., Devis+ 2005)
AND competing with Corona!
hard state: rapid time variations?

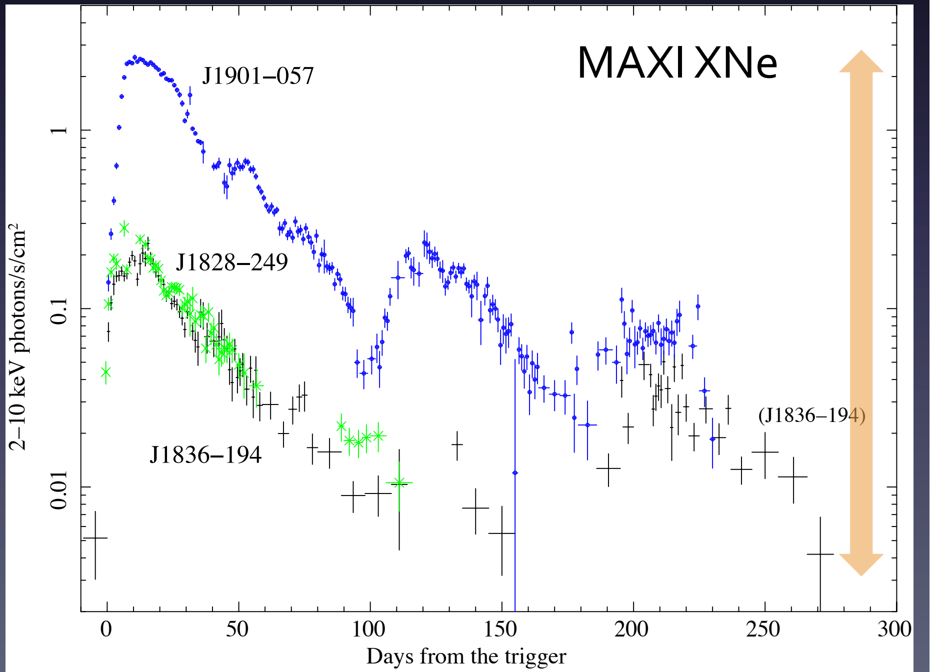
Assuming a spherical region, fc ≤ 20% (indep. of Rin)
hard state : fc > 20%
-> simple model N.G.
-> seed photon: synchrotron, brems?, e.g.,ADAF
(or jet!)

ADAF?

Menou+ 1999



Negoro 2014



Cabanac+ 2009

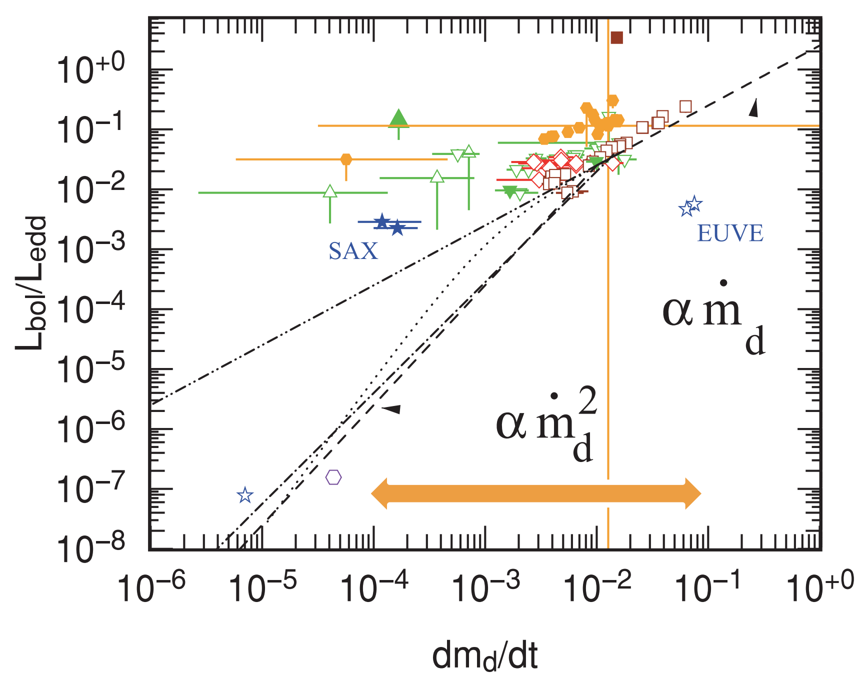
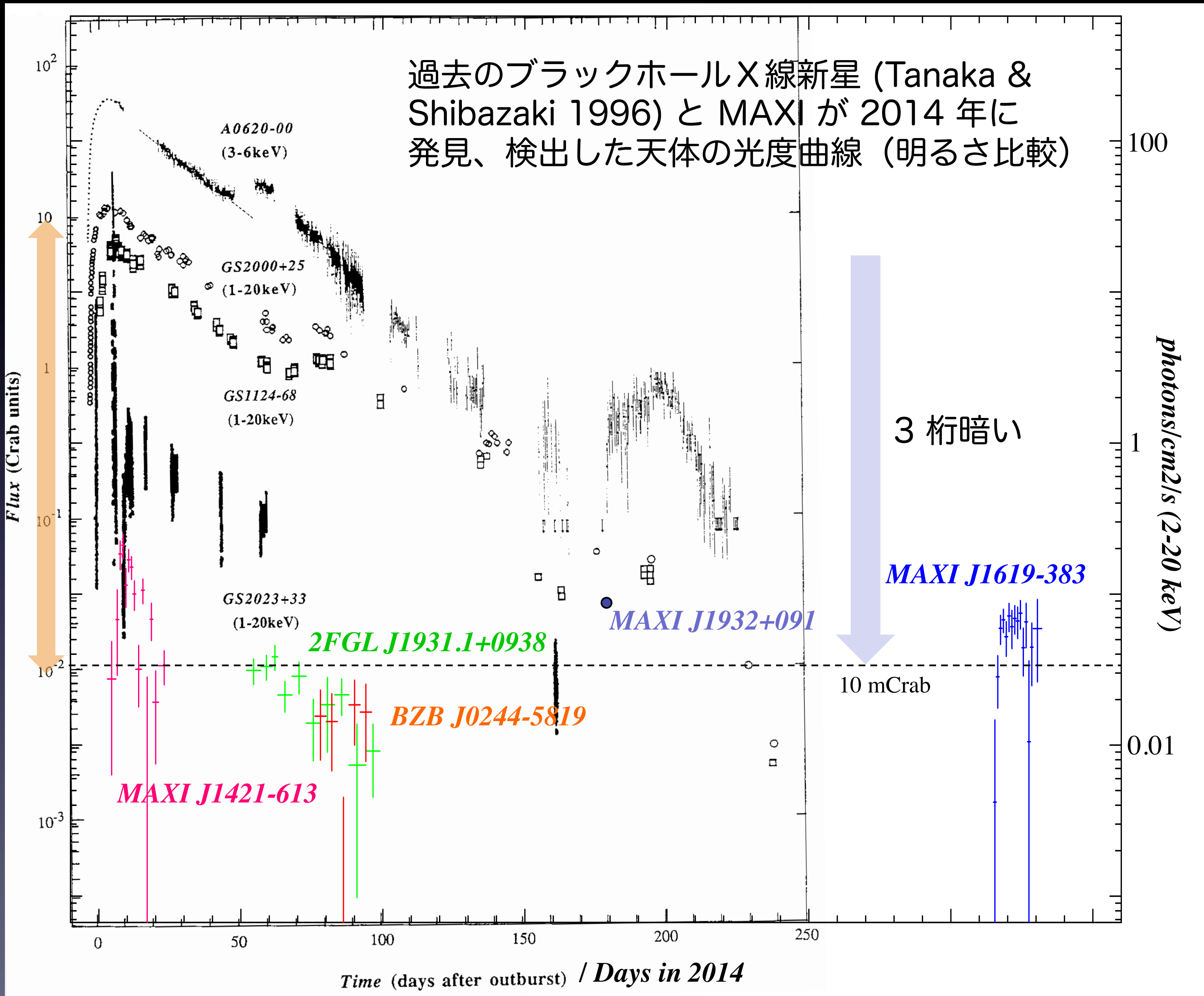


Figure 14. Bolometric luminosity as function of the accretion rate in the optically thick disc $\dot{m}_{\rm d}$ obtained for our sample, using equation (7). Points are subject to global horizontal shifts due to the actual Eddington efficiency value used. The set of curves shows theoretical relations. Dashed: $L_{\rm bol} \sim L_{\rm disc} \propto \dot{m}_{\rm d}$ when $R_{\rm in} = 6R_{\rm g}$ and the efficiency at Eddington luminosity $\eta_{\rm Edd} = 0.1$. Under $\sim 10^{-2} L_{\rm Edd}$, continuing relationship when $L_{\rm bol} \propto \dot{m}_{\rm d}^2$. Supposing $\dot{m}_{\rm total} \sim \dot{m}_{\rm d}$ we have ADAF solutions (dotted), MH02 (Dot-dot–dashed) and RC00 (Dot–dashed). The value of α and β are the same as in Fig. 16. Errors on $\dot{m}_{\rm d}$ were computed by propagating those on the temperature and the inner radius only. Colour/symbol code is the same as in Fig. 9.

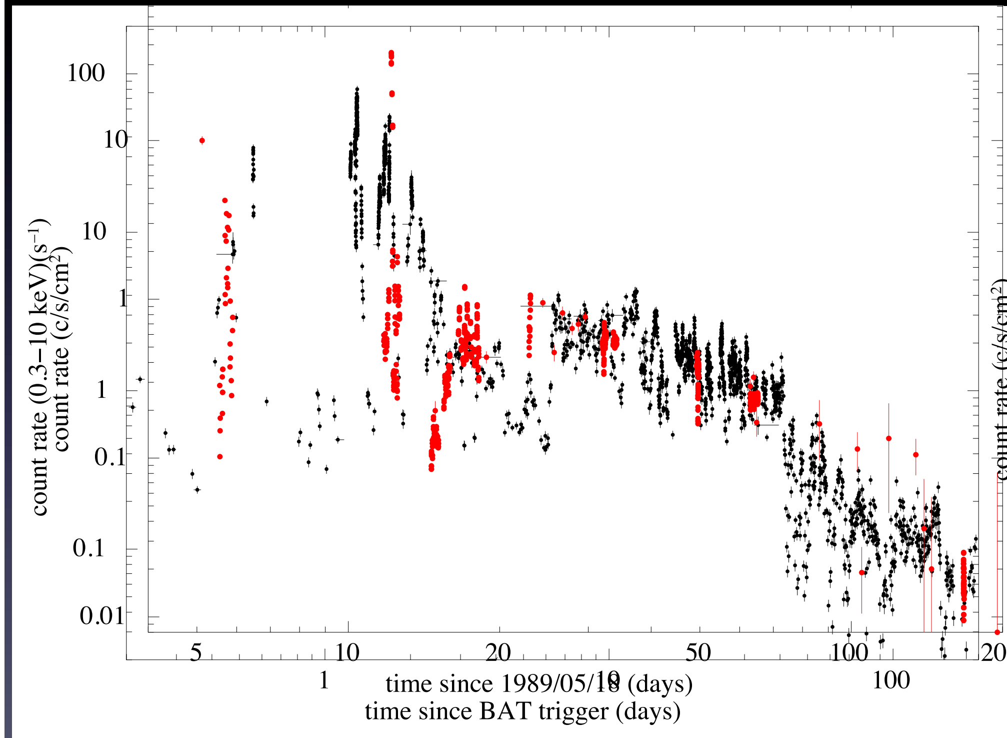
Near future by MAXI..

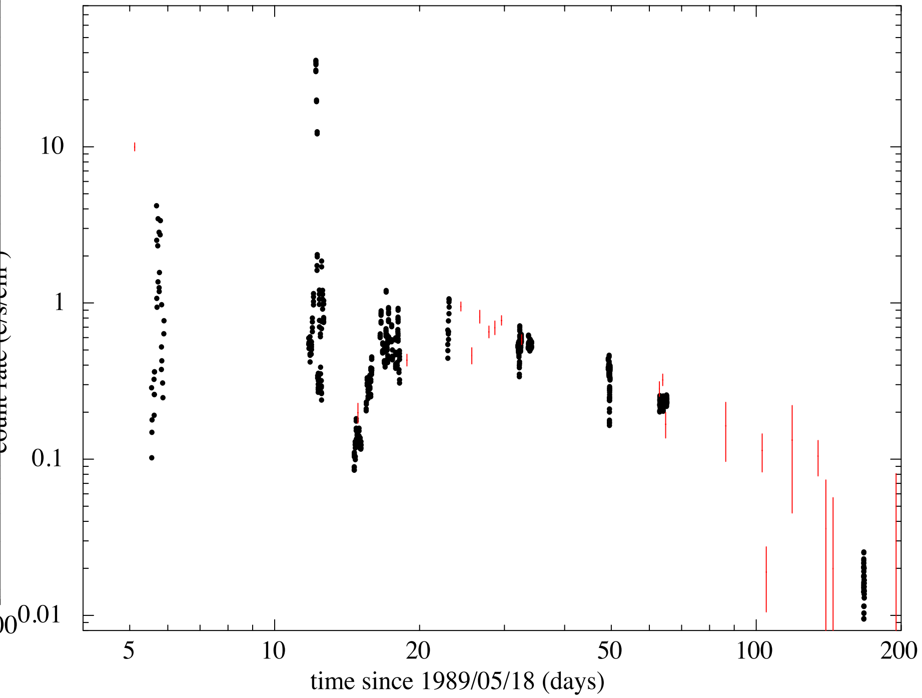


Q: Successive Sporadic Flares ?

Swift J164449.3+573451

GS 2023+338 (404 Cyg)





swift.ac.uk

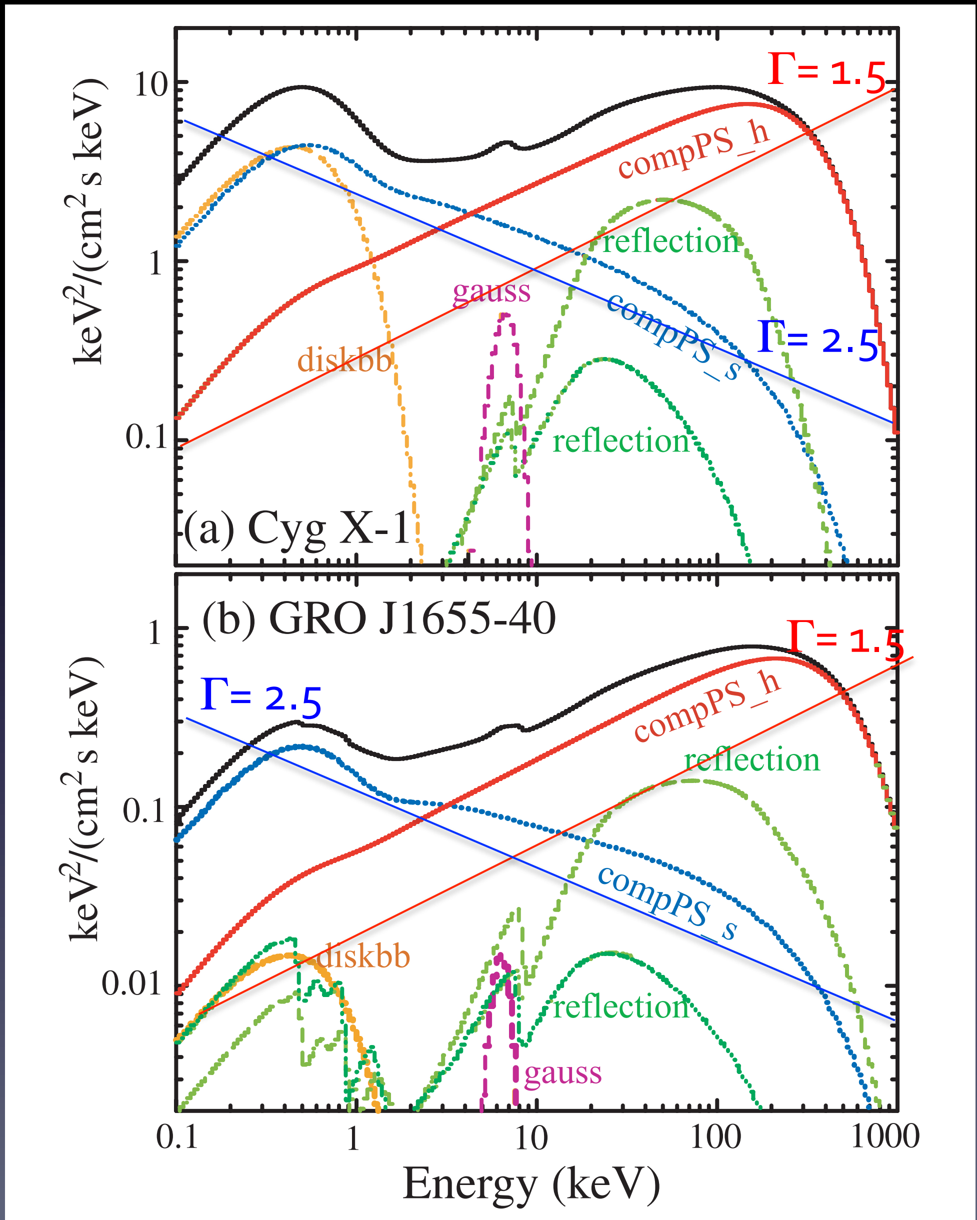
Courtesy of K. Terada (1994)

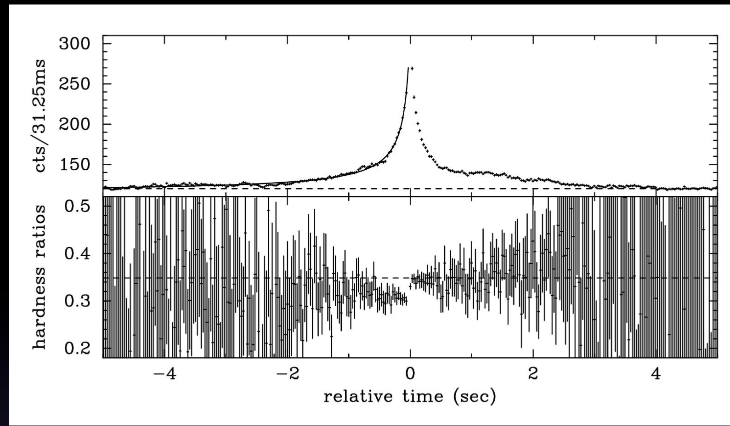
2015/06/15~ renewed outburst!

Barthelmy+ GCN 17929, Negoro+ ATel 7646

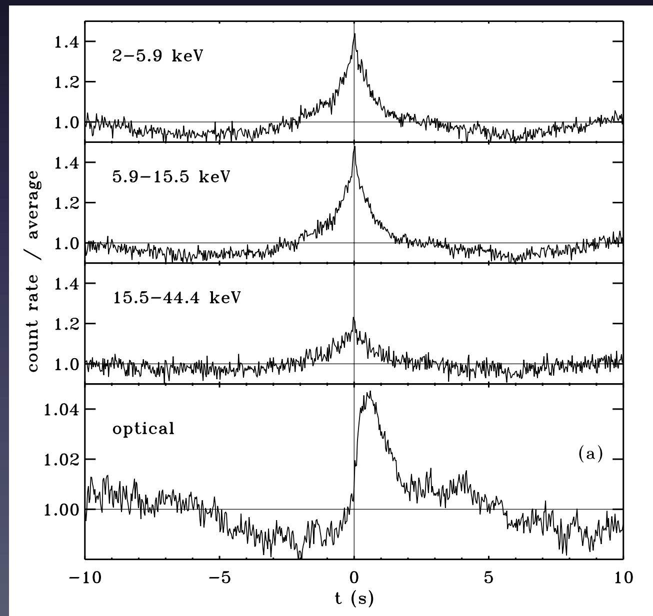
More complex..

Makishima+ 2008, Yamada+2013



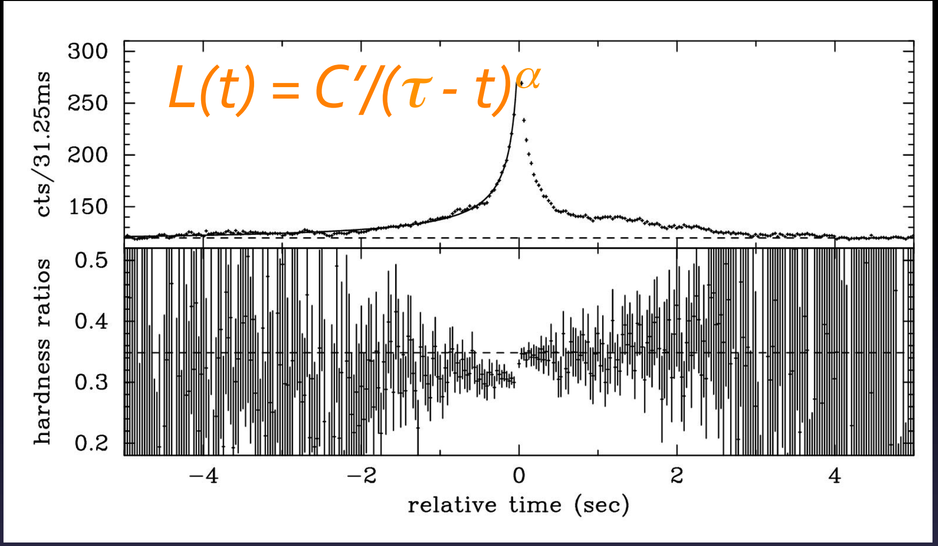


Cyg X-1 (Negoro+ 1994, Yamada+ 2013)



XTE J1118+480 (Malzac+ 2003)
also GX 339-4 (Gandhi+ 2010)

Rapid Variation, Shot - *Density Fluctuation on ADAF*

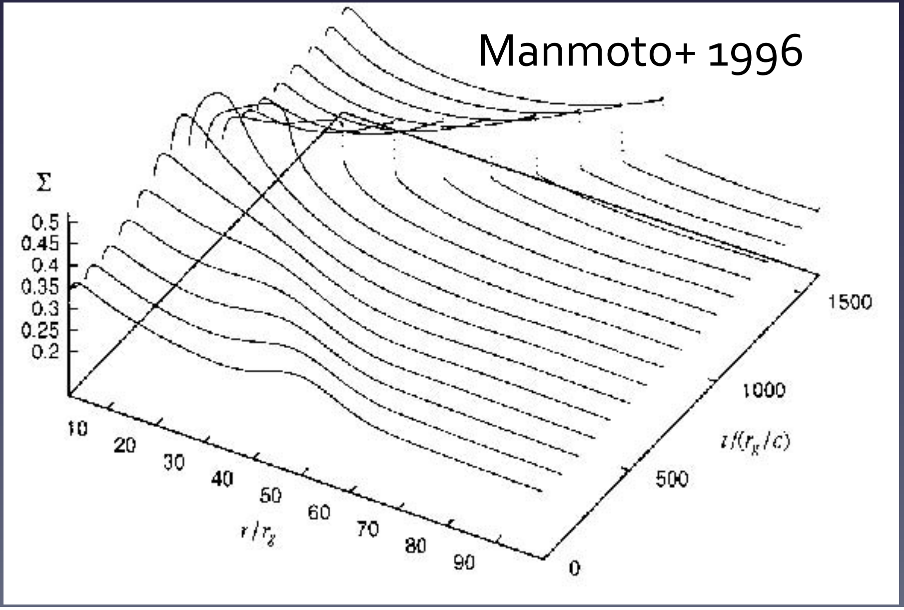


radial velocity

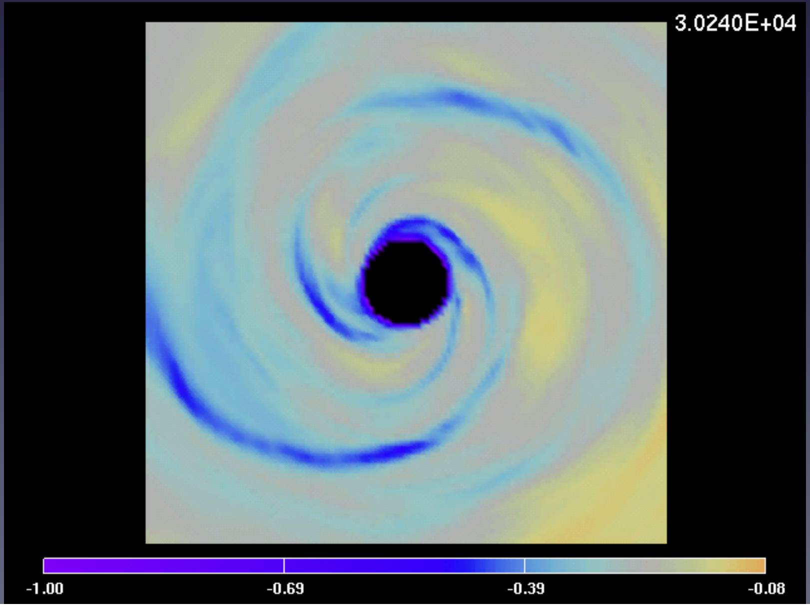
$dr/dt = - C\, r^{-1/2}$

released energy

$L = GMm/2r^2\, (-dr/dt)$

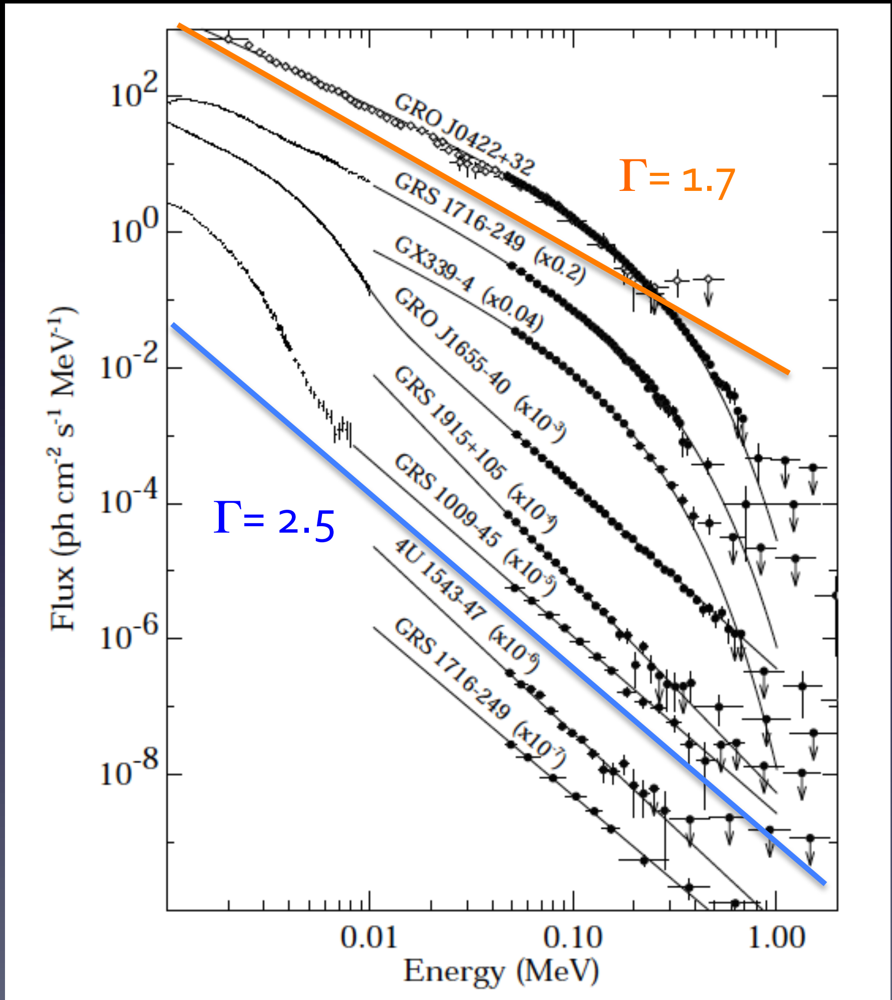


Machida+2002

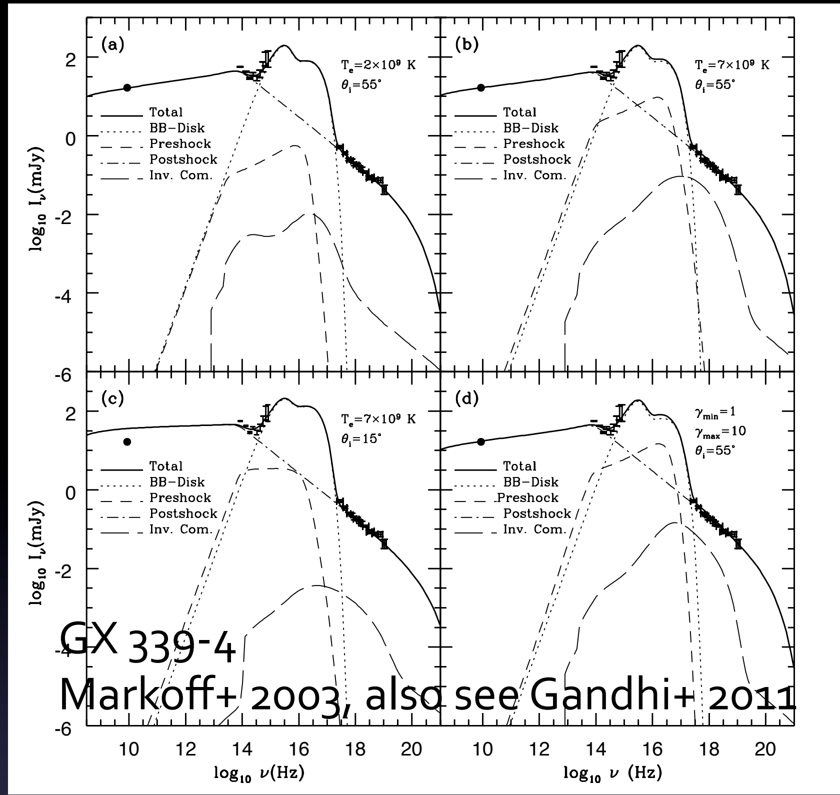


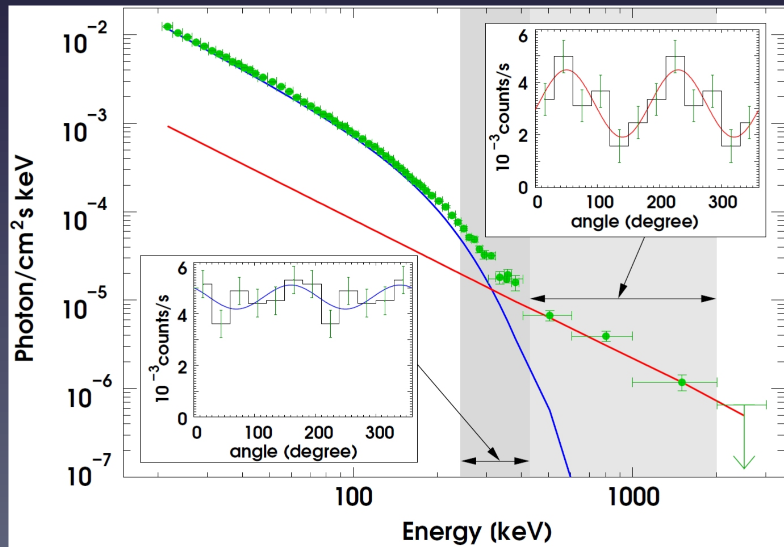
Jet as the origin of the PL?

e.g., Markoff+2001



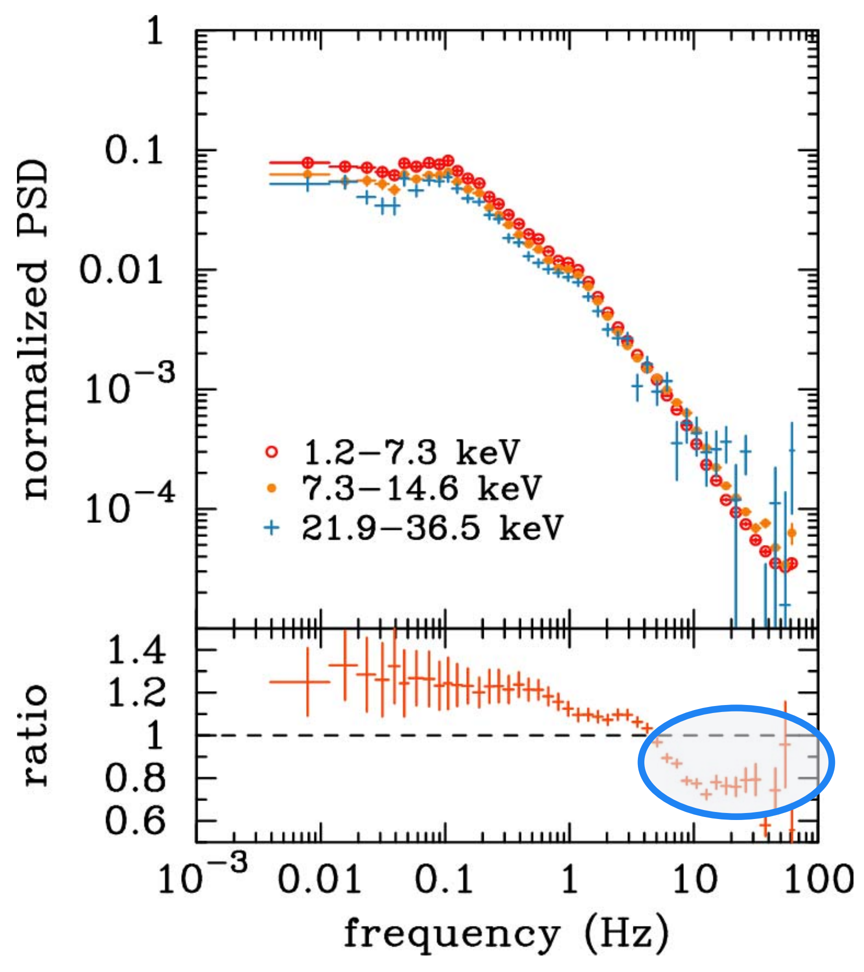
Grove+ 1998





Cyg X-1 (Laurent+ 2011, Rodriguez+ 2015)

Compton?



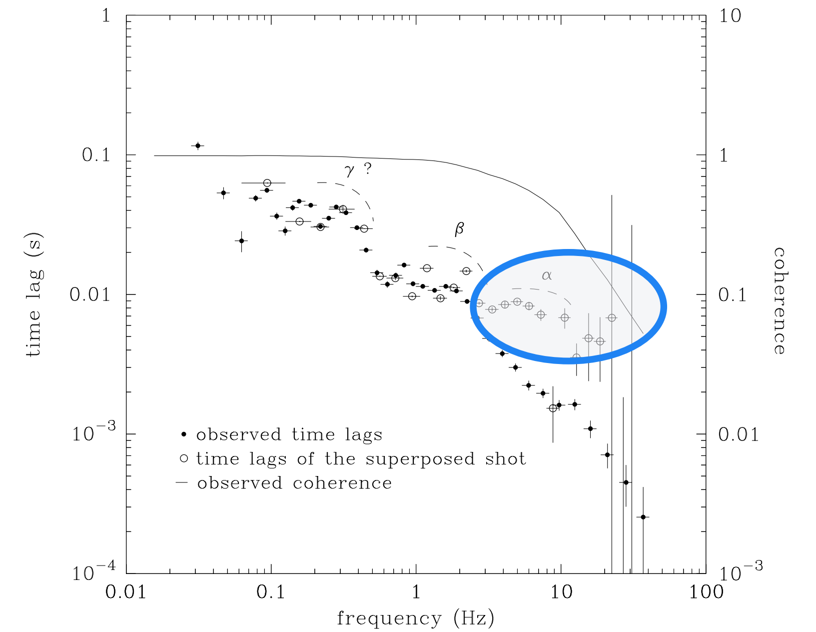
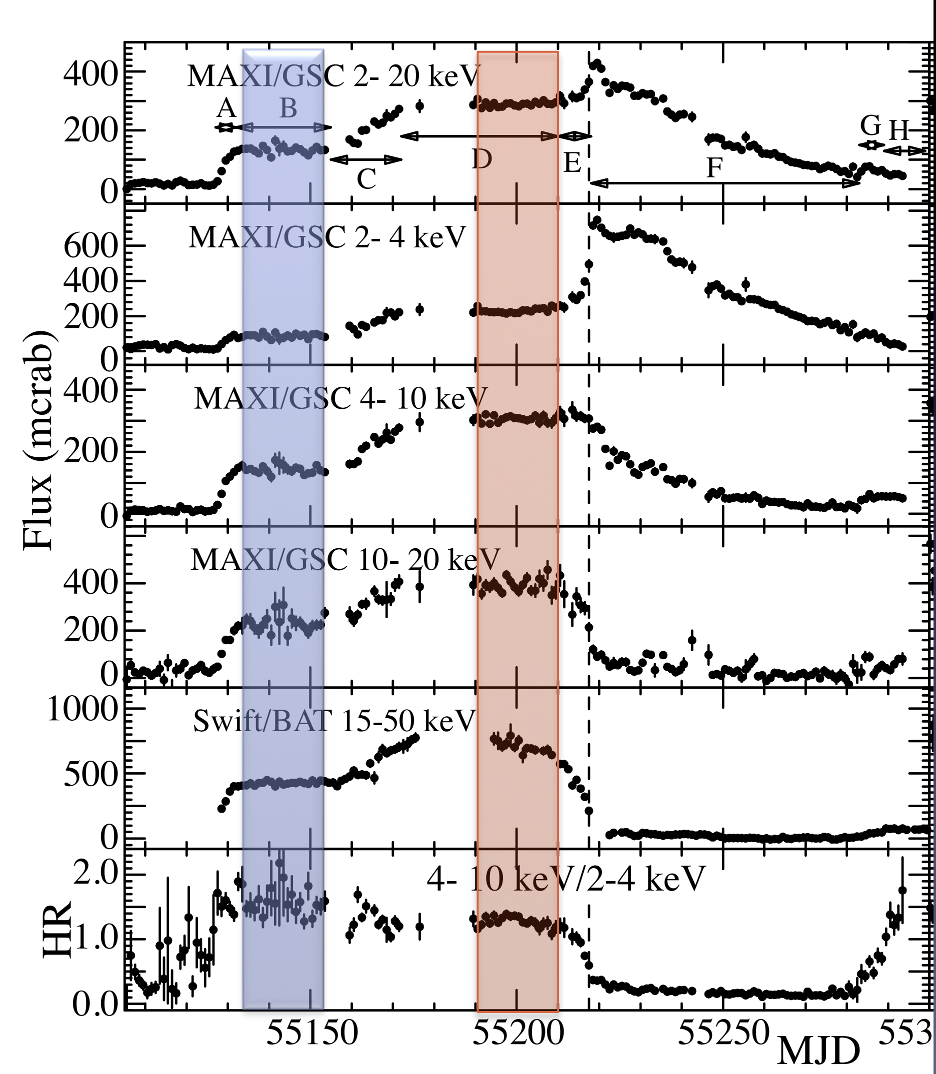
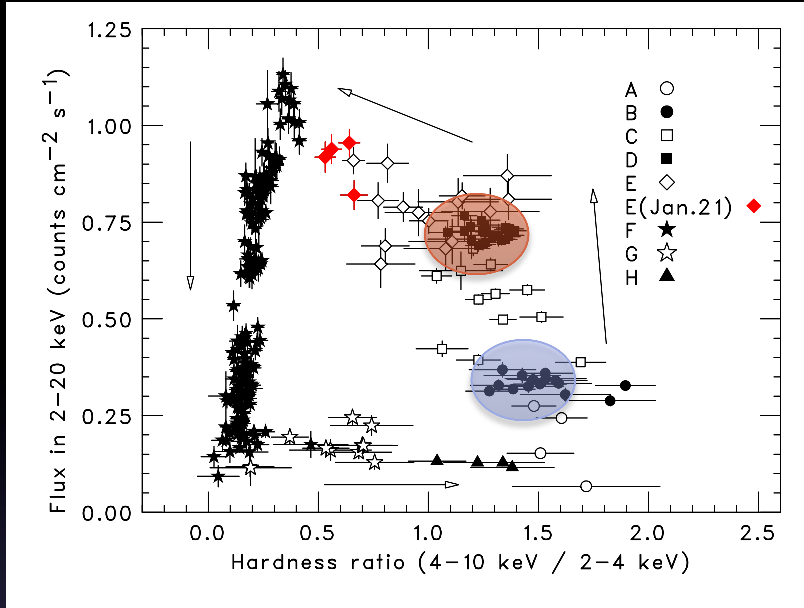


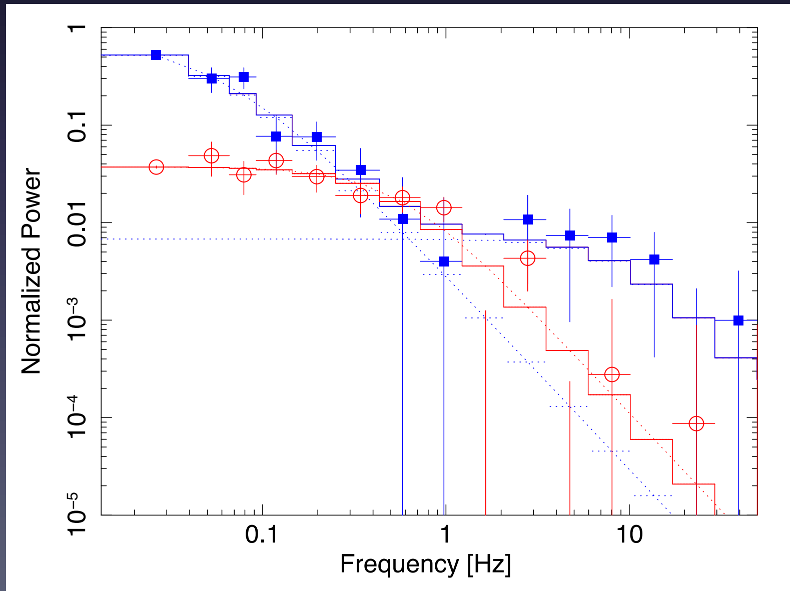
FIG. 3.—Coherence function (*solid line*, *right axis*) and time lags of the hard X-rays (7.3–14.6 keV) behind the soft X-rays (1.2–7.3 keV) against frequencies (*filled circles*, *left axis*). (All these crosses indicate hard X-ray lags behind soft X-ray.) Time lags of the superposed shot are denoted by the open circles, which show common behavior below a few Hz, where the coherence is high.

Two kinds of HSs?

Nakahira+2010



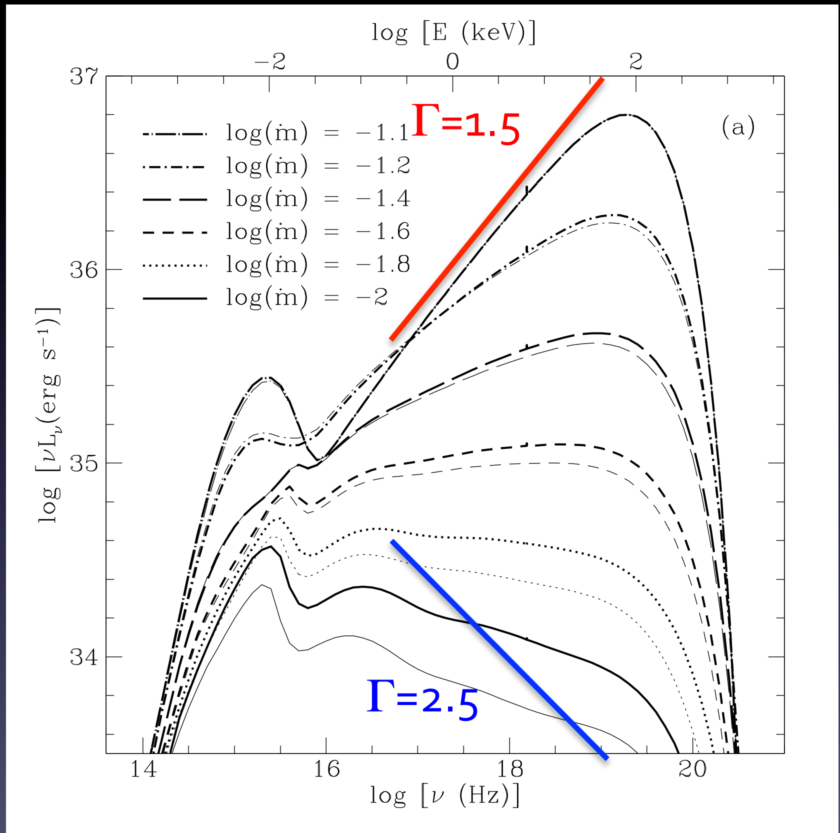




鈴木 日大修論 2015

Precise models provide..

ADAF



Esin+ 1997

Plasma Pair..

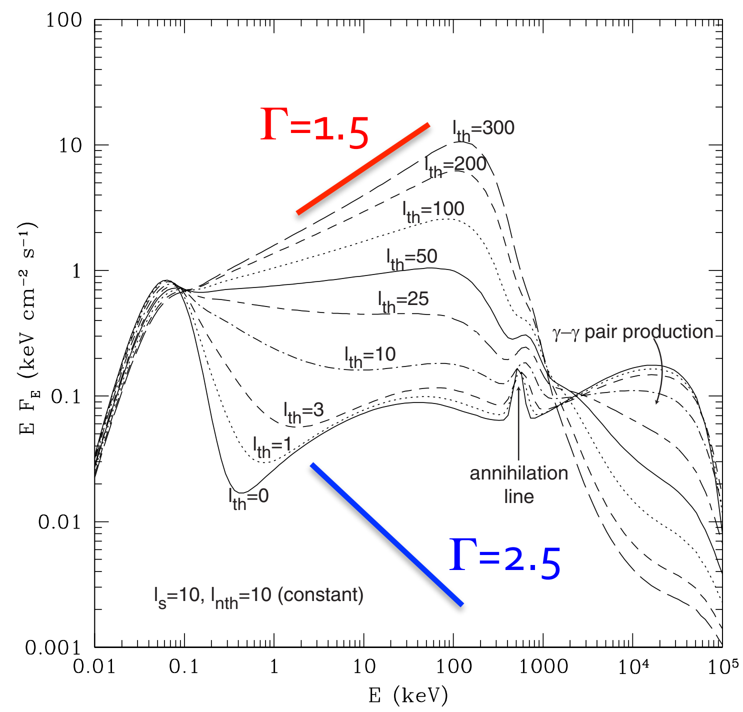


Figure 1. The transition from a non-thermal plasma ($l_{th} = 0$) to a thermally dominated plasma ($l_{th}/l_{nth} = 30$). The soft input into the source has a compactness $l_s = 10$ and has a blackbody spectrum with $T_{bb} = 15$ eV. The assumed source radius is $R = 10^{14}$ cm, and a background plasma is present with optical depth $\tau_p = 0.1$.

Coppi 2002?

観測と一致するようには思えない。。

Mass and spin : Inner region of the standard disk

simple multi-color disk model: *diskbb* (Mitsuda+ 1984)
+ general relativity: *grad* (Hanawa 1989, Ebisawa+ 1991),
diskpn (Gierlinski+ 1999)..
+ spin: *kerrbb* (Shafee+ 2006)
+ metal opacities : *bhspec* (Davis+ 2006)
+numerical simulation (Kularni+ 2011)
-> advection, viscos dissipation at risco (radial pressure gradient ?)

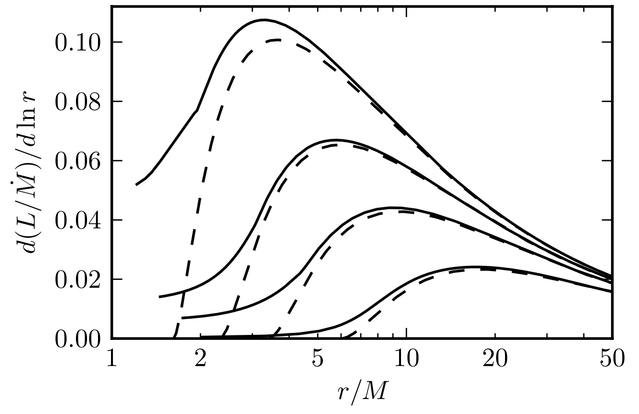


Figure 1. Luminosity profiles from the GRMHD simulations (solid lines) compared with those from the NT model (dashed lines) for $a_* = 0, 0.7, 0.9$ and 0.98 (bottom to top). The disc thicknesses are $|h/r| = 0.05, 0.04, 0.05$ and 0.08 respectively for these runs. The ISCO is located at the radius where the NT disc luminosity goes to zero.

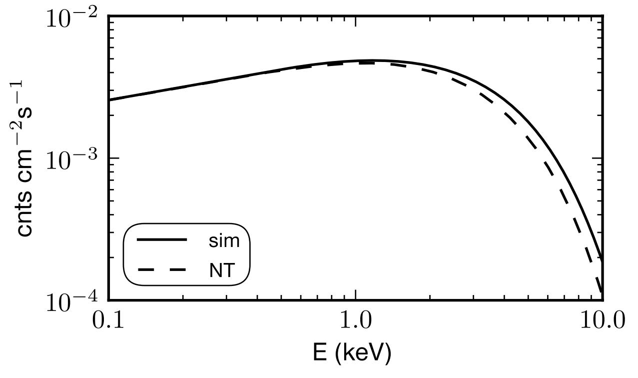


Figure 2. Spectra from the simulated (solid line) and NT (dashed line) discs, for $a_* = 0.9$ and $i = 75°$.

Kulkarni+ 2011

ブラックホール物理学2
もう一つの重要な半径

innermost stable circular orbit (ISCO)

有効ポテンシャル ($E_{eff} = E - mc^2$)

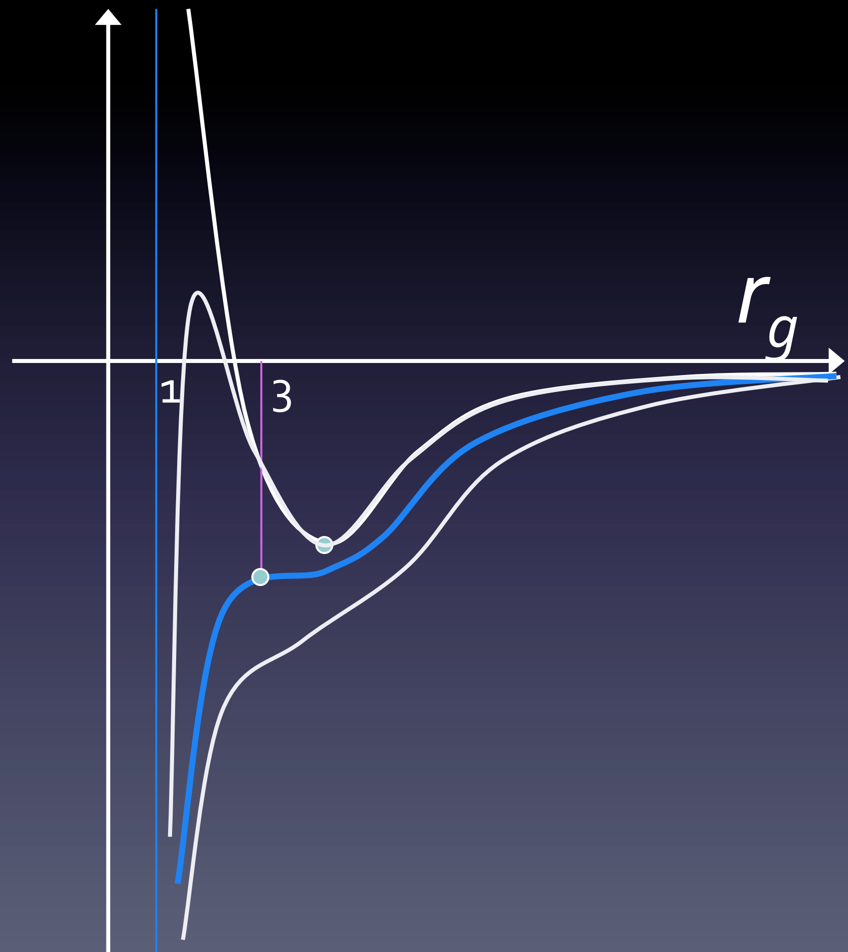
$$E_{eff} \approx \frac{L^2}{2r^2} - \frac{GM}{r}\left(1 + \frac{L^2}{c^2 r^2}\right)$$

$r_{ms} = 3r_g$

r_{ms}以下では、自由落下

→ エネルギー損失小

→ 観測されない！？



佐藤文隆 「相対論と宇宙論」

Landau & Lifshitz 「場の古典論」

Shapiro & Teukolsky “Black Holes, White Dwarfs, and Nutron Starts”

Accurate measurements of Rin

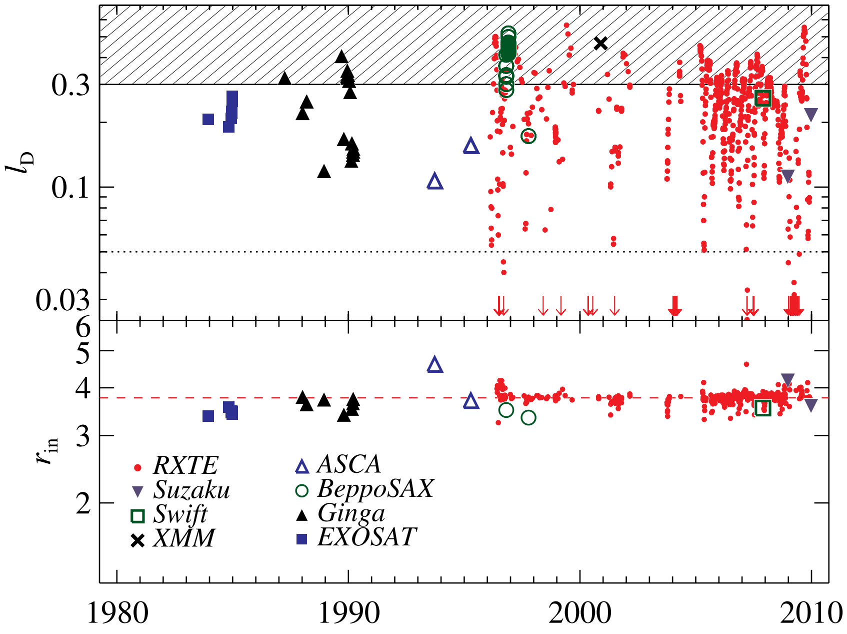


Figure 1. Top: accretion disk luminosity in Eddington-scaled units ($M = 10\ M_\odot$) vs. time for all the data considered in this study (766 spectra). Red arrows show *RXTE* data which are off scale. Data in the unshaded region satisfy our thin-disk selection criterion ($H/R < 0.1$, which implies $l_D < 0.3$; McClintock et al. 2006). The dotted line indicates the lower luminosity threshold (5% L_{Edd}) adopted in Section 3.1. Bottom: values of the dimensionless inner-disk radius r_{in} are shown for thin-disk data in the top panel that meet all of our selection criteria (411 spectra; see Section 3.1). Despite large variations in luminosity, r_{in} remains constant to within ≈4% over time. The median value for the *RXTE* data alone ($r_{in} = 3.77$) is shown as a red dashed line.

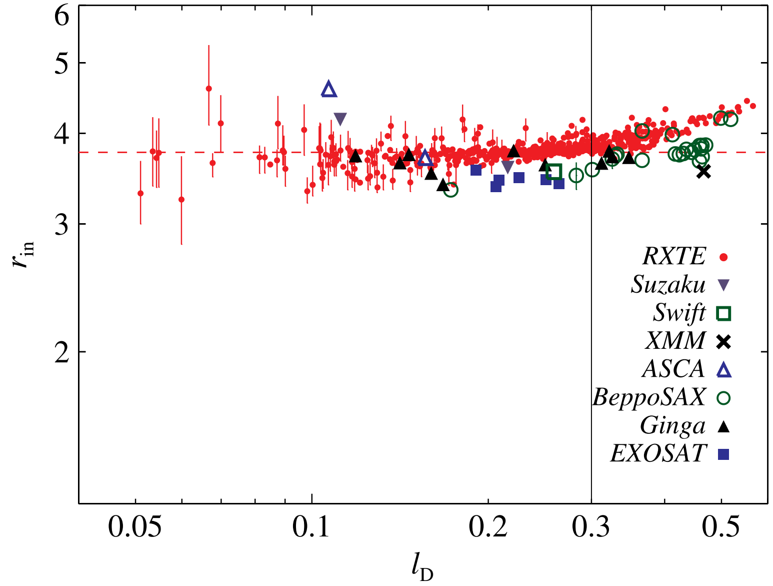
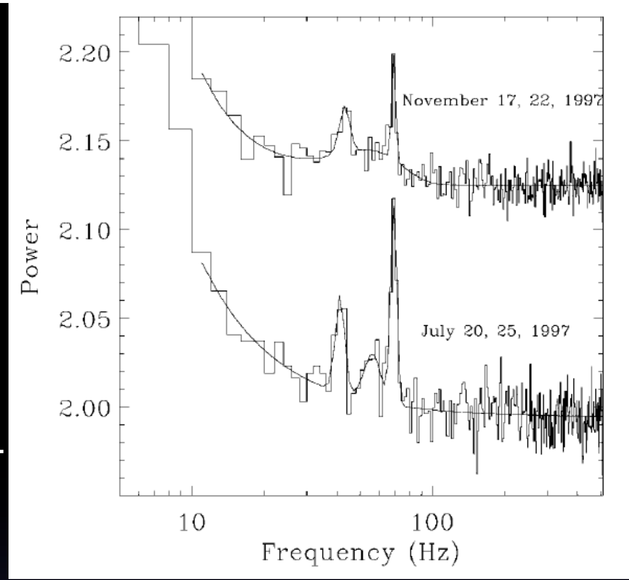


Figure 2. Dimensionless inner-disk radius r_{in} vs. luminosity for the filtered data (Section 3.1) and our baseline model. The vertical black line shows our adopted thin-disk upper limit, $l_D = 0.3$. As in Figure 1, the red dashed line shows the *RXTE* average below this limit.

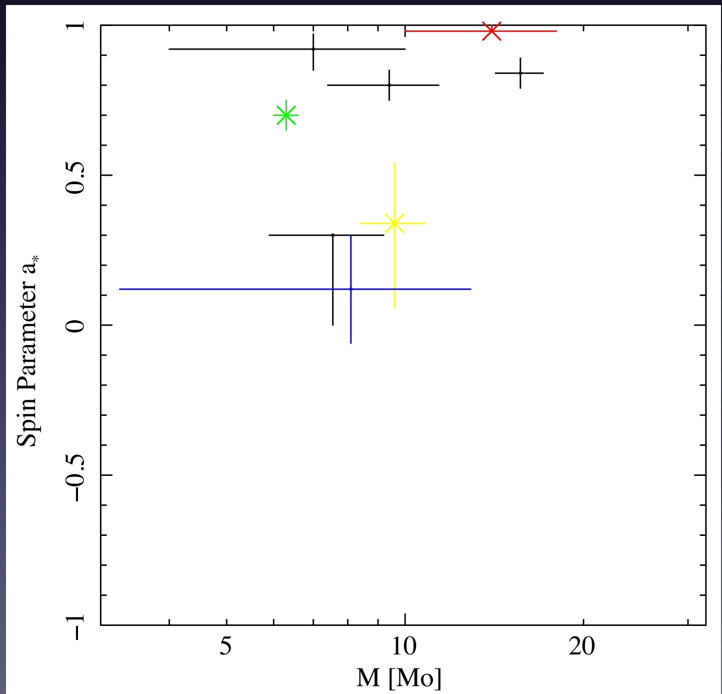
Steiner+ 2010

BH spin parameters from 2 different methods



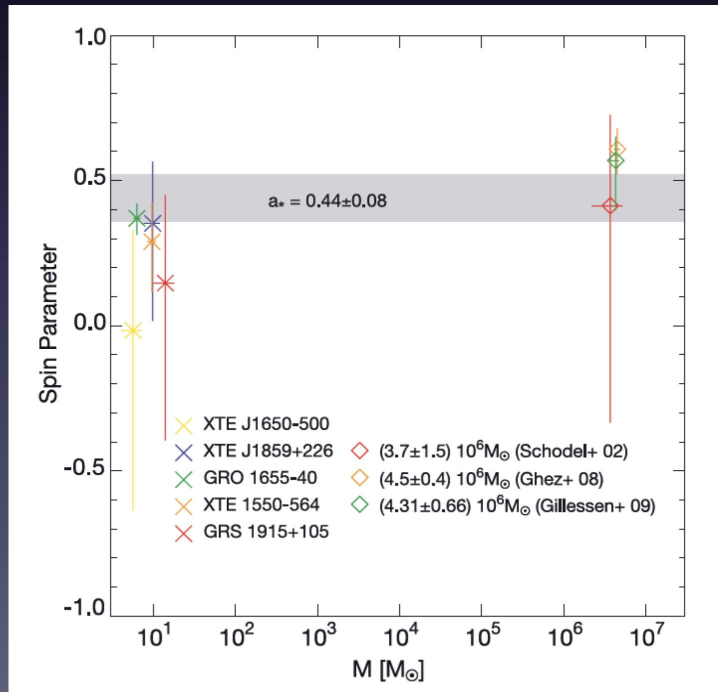
GRS 1915+105
Strohmayer+01

from Thermal Spectrum Fits



Values are from McClintock et al. 2011

from High Freqeuency -QPOs



Kato et al. 2010

まとめ

- ブラックホール降着円盤からのスペクトルは（光学的に厚い）熱的円盤成分とべき型成分からなる
- Low/Hard State
  - べき成分は、単純なコンプトン散乱ではない
    - （熱的成分）内縁半径の見積もりには注意（色温度補正, 散乱成分の割合など）
    - シンクロトロンジェットの寄与もあるはず
    - ADAF の検証はまだ半ば
    - ガス圧、磁気圧で支えられた２種のハードステートの観測的違いは？
- High/Soft State
  - 熱的成分は、相対論、inflow に考慮して、モデル化はかなり進んでいる
    - （質量, 距離が分かれば）スピンも決められる。HF-QPO と一致しない
    - べき成分との関係？そもそもべき成分の起源は？
    - 単純な diskbb モデルとの関係は？ (常に bhspec がベスト?)
  - 鉄輝線
    - 光源の起源、連続成分の寄与、モデル化にまだ不確定性が多い
- Jet, (Low/High frequency) QPO は理論的にはまだ未解決