Accretion Properties of Outbursting Black Hole Sources

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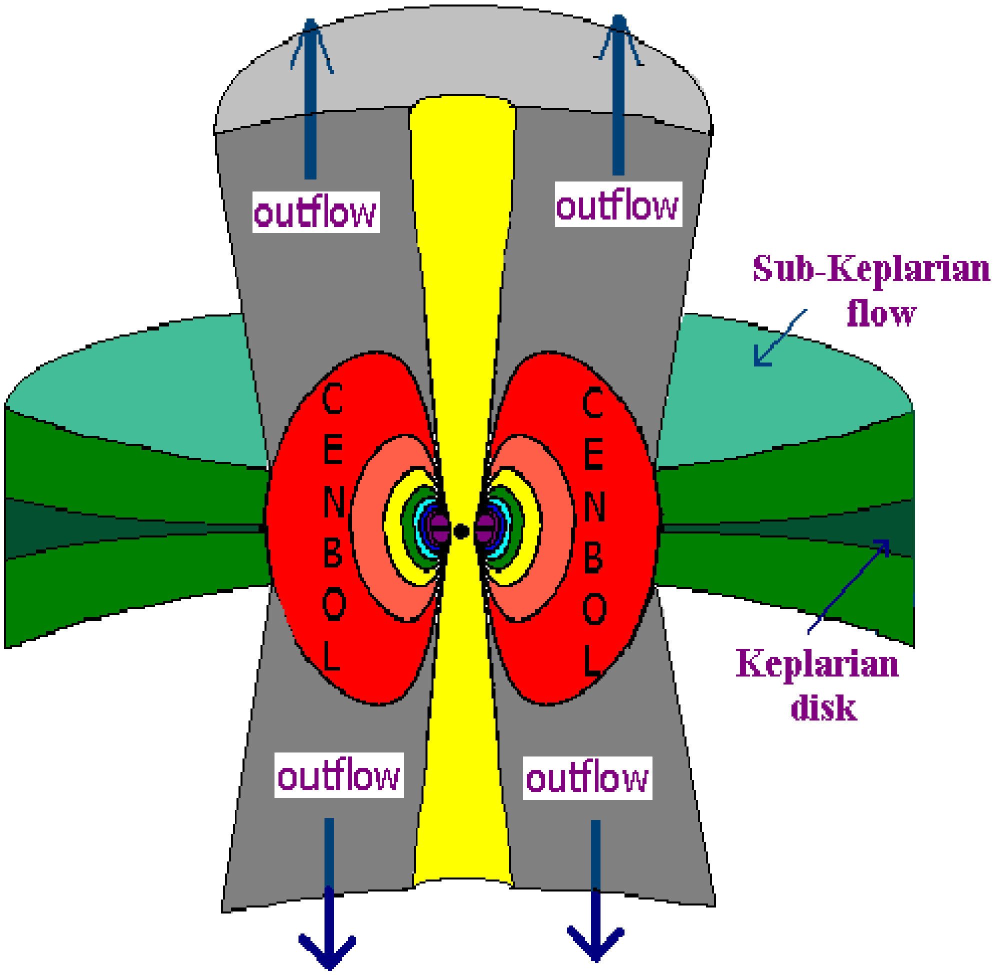
Wide Band Spectral and Timing Studies of Cosmic X-ray Sources, TIFR, (10-13)th January, 2017

Plan of the Talk

- *Two Component Accretion Flow*
- *Radiation Processes*
- *Calculation of Radiation Spectra*
- *Model Fitting in XSPEC*
- *Application Towards Different Outbursting Sources*
- *Conclusions*

Cartoon Diagram of the Model



Units and Governing Equations

- Distance (r_g) = $\frac{2GM_{BH}}{c^2}$
- Velocity = c
- Angular Momentum = $\frac{2GM_{BH}}{c}$

- Radial Momentum Equation:

$$\vartheta \frac{d\vartheta}{dx} + \frac{1}{\rho}\frac{dP}{dx} - \frac{\lambda^2(x)}{x^3} + \frac{1}{2(x-1)^2} = 0$$

- Continuity Equation:

$$\dot{M} = \Sigma \vartheta x$$

- Entropy Generation Equation:

$$\frac{\vartheta\Sigma}{\gamma-1}\left[\frac{1}{\rho}\frac{dP}{dx}-\frac{\gamma P}{\rho^2}\frac{d\rho}{dx}\right]=Q^- - Q^+$$

The angular momentum distribution equation:

$$u\frac{d\lambda(x)}{dx}+\frac{1}{\Sigma x}\frac{d(x^2 W_{x\phi})}{dx}=0$$

v =Radial velocity

ρ=Density

P =Pressure

γ =Adiabatic index

λ =Angular momentum

Σ =Vertical averaged density

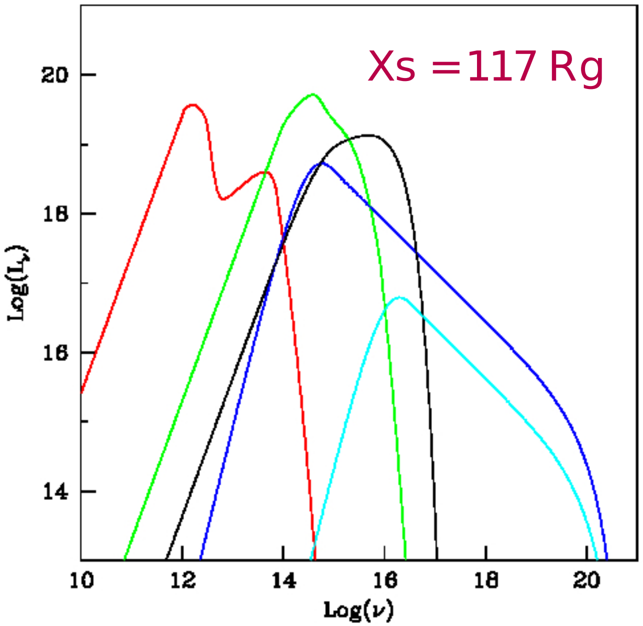
Q^+ =Heat gain

Q^- =Heat loss

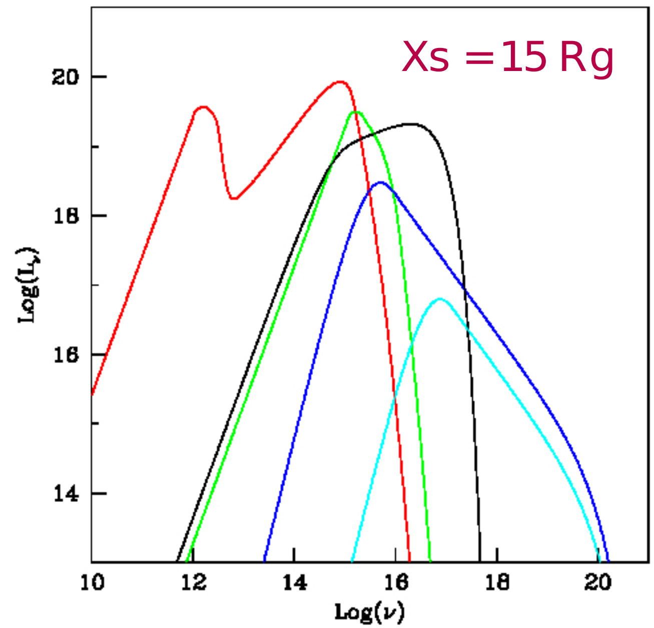
Radiation Processes

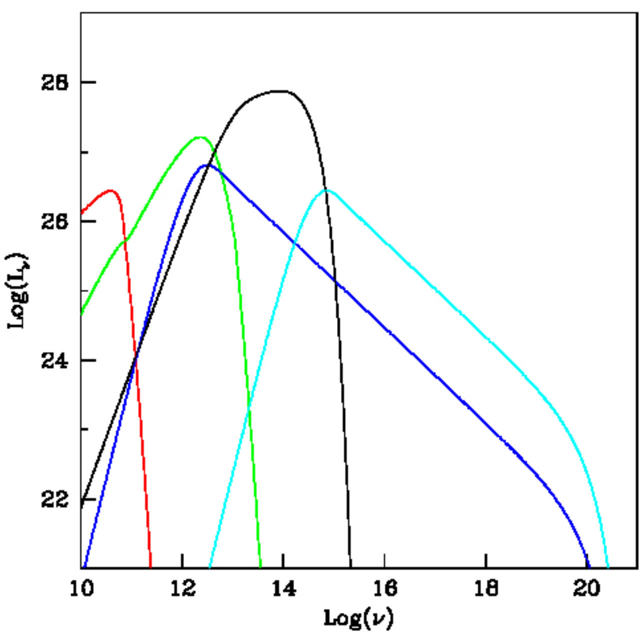
- *Accelerated or decelerated electrons around ions emit bremsstrahlung radiation.*
- *Relativistic electrons moving in a magnetic field emit synchrotron radiation.*
- *Locally soft photons and that supplied by Keplerian disk is inverse-Comptonized by hot electrons in the CENBOL.*
- *Coulomb coupling tries to maintain the temperature difference between electron and proton.*
- *Non-thermal electrons produced by the shock acceleration, are essential in explaining the non-thermal power-law spectrum in high energy.*
- *Pair production and annihilation*

General Behaviour of Spectra

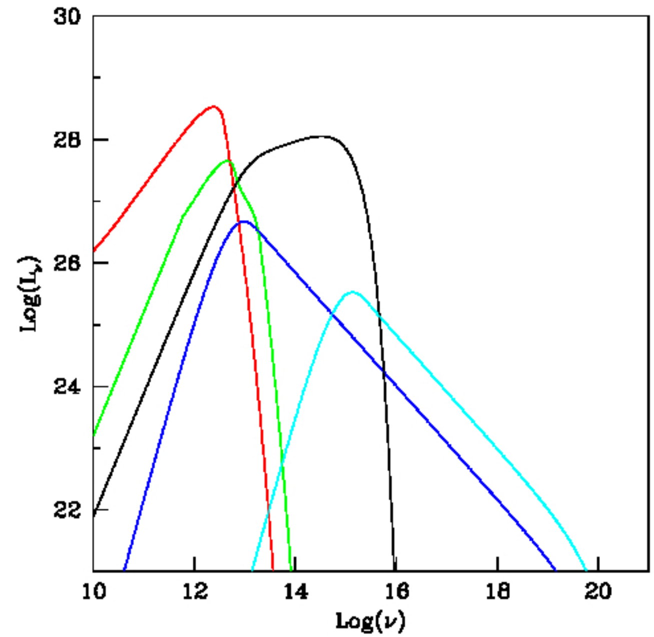


$M = 10\ M_\odot$





$M = 10^8\ M_\odot$



Creating a Local/Table Model for XSPEC

- *Phenomenological model Vs Self-consistent hydrodynamic model*

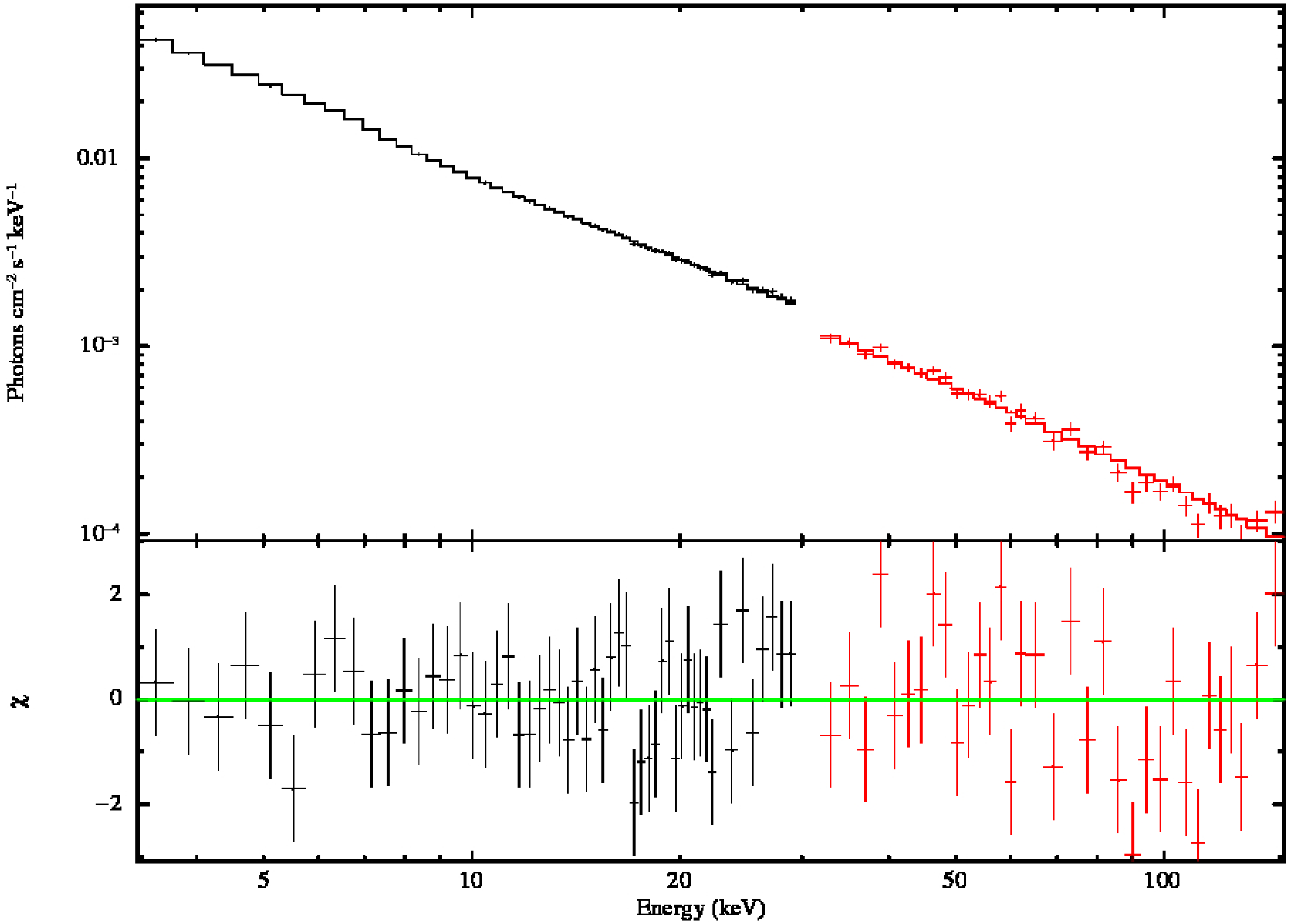
- *Important free parameters: Mass, shock location, sub-Keplerian rate, Keplerian rate*

- *Local model --> Write source code compatible to xspec and link*

- *Table model -->Generate lots of model spectra and create a table. convert the database into a fits model*

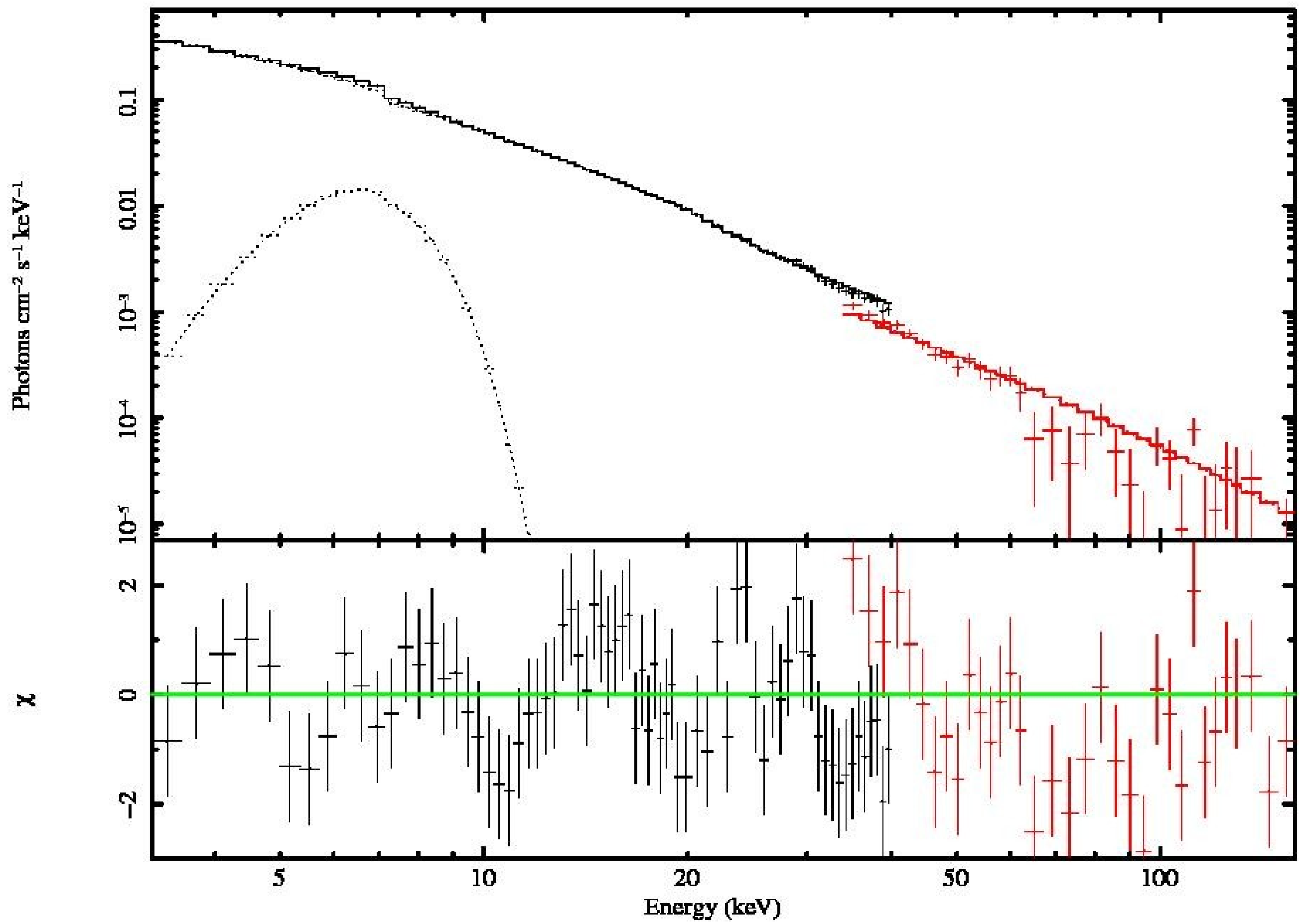
- *MC Table model*

Broadband X-ray spectral modeling: GRO J1655-40



$M = 6.43 \pm 1.05\ M_\odot$ $\dot{m}_h = 0.69 \pm 0.14; \dot{m}_d = 0.31 \pm 0.08; x_s = 44 \pm 14.5$

Broadband X-ray spectral modeling: GRS 1915+105



M=12.7±1.18 M$_\odot$ $\dot{m}_h = 0.3 \pm 0.09 ; \dot{m}_d = 6.26 \pm 0.52 ; x_s = 42.03 \pm 11.25 .$

Montecarlo Model

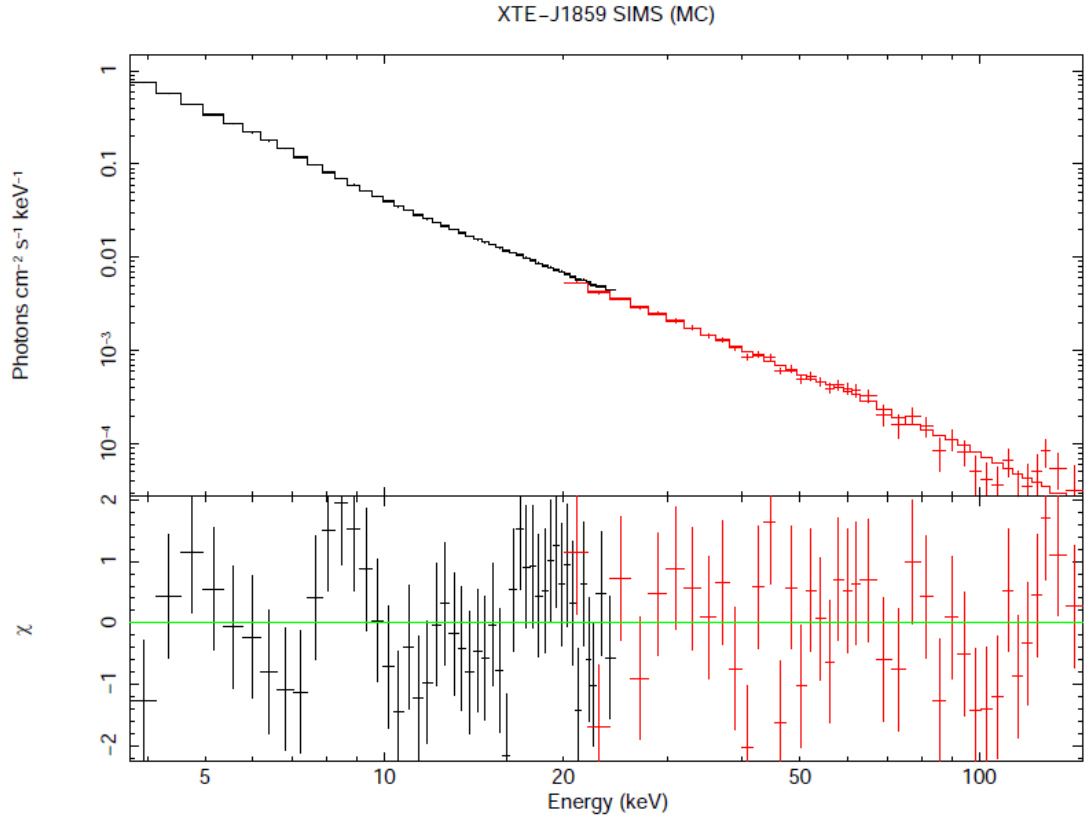
- *Radiation spectrum from analytic calculations works fine in specific situations, namely low and high optical depth or non-relativistic and extreme relativistic cases.*

- *But the most interesting cases are $\tau \sim 1$ and mildy-relativistic plasma. Example may be black hole candidates in intermediate states.*

- *Need to simulate the spactrum using Montecarlo method*

- *We simulate the radiation spectra from two-component accretion flow model using the hydrodynamic solutions.*

Comparison: Analytical model and MC model



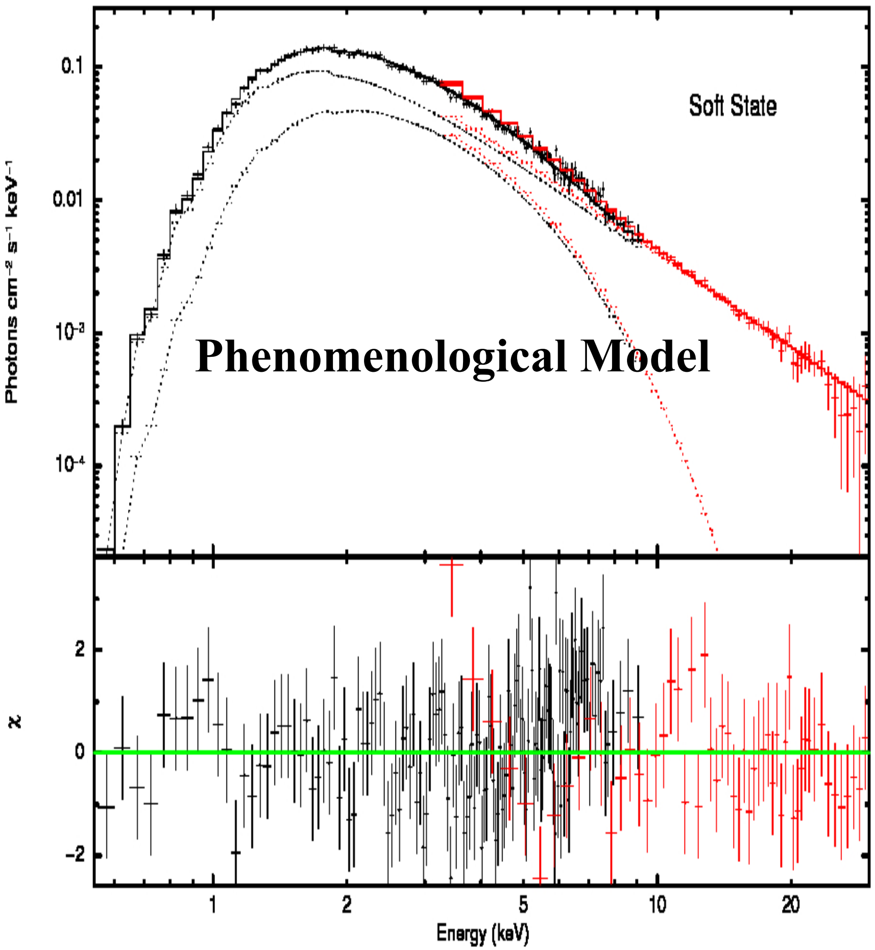
stant<4> Source No.: 1 Active/On

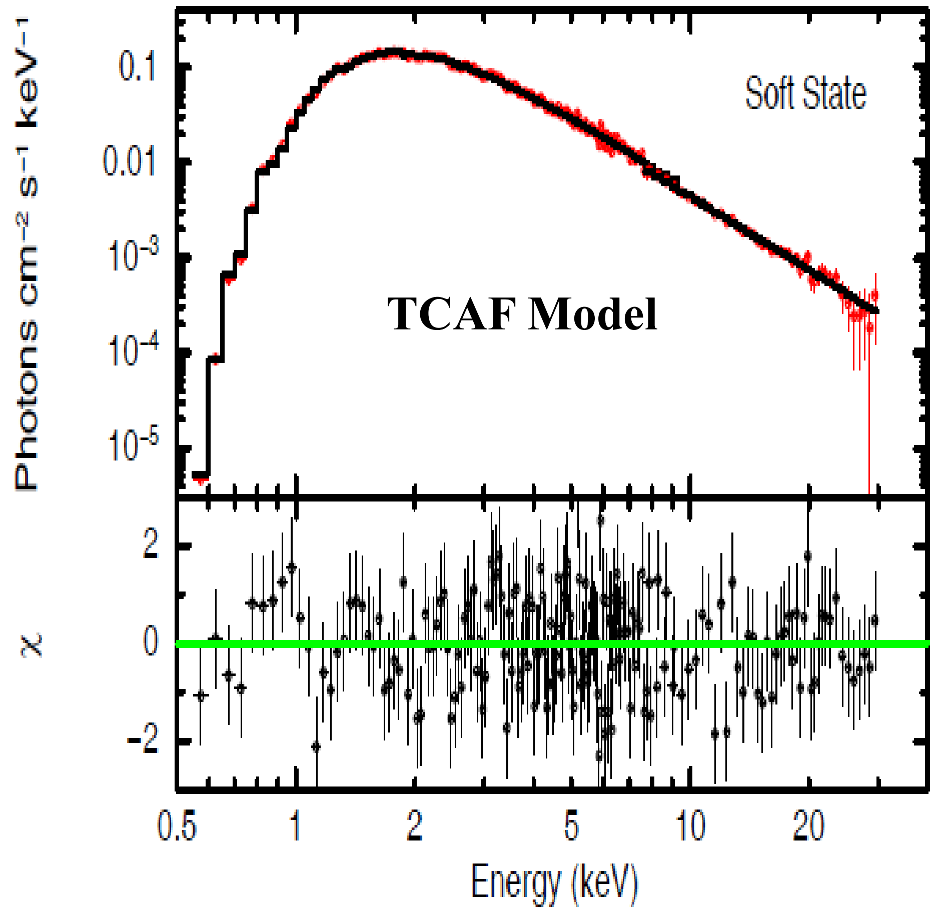
odel par	Model comp	Component	Parameter	Unit	Value	
			Data group: 1			
1	1	phabs	nH	10^22	0.100000	frozen
2	2	CT-TCAF-MC	embh		8.09647	+/- 0.417547
3	2	CT-TCAF-MC	xs		16.0220	+/- 0.551865
4	2	CT-TCAF-MC	emdoth		8.35935E-02	+/- 9.05202E-04
5	2	CT-TCAF-MC	emdotdsk		1.98999	+/- 0.711512
6	2	CT-TCAF-MC	norm		20.2012	+/- 1.93592
7	3	smedge	edgeE	keV	6.80000	frozen
8	3	smedge	MaxTau		9.36953	+/- 24.9980
9	3	smedge	index		-2.60000	frozen
10	3	smedge	width		61.1646	+/- 162.782
11	4	constant	factor		1.00000	frozen

: 1 Active/On

odel par	Model comp	Component	Parameter	Unit	Value	
			Data group: 1			
1	1	phabs	nH	10^22	0.100000	frozen
2	2	Test	embh		9.13167	+/- 34.2171
3	2	Test	xs		19.0107	+/- 6.25177
4	2	Test	emdoth		0.312114	+/- 4.61061E-02
5	2	Test	emdotdsk		2.27283	+/- 2.44517
6	2	Test	norm		7.59177	+/- 20.4159
7	3	smedge	edgeE	keV	6.83748	+/- 0.116432
8	3	smedge	MaxTau		9.37167	+/- 20.4504
9	3	smedge	index		-2.67000	frozen
10	3	smedge	width		44.6115	+/- 98.0623
11	4	constant	factor		1.00000	frozen

Broadband Spectral Modeling: IGR J17091-3624
(2011 outburst)

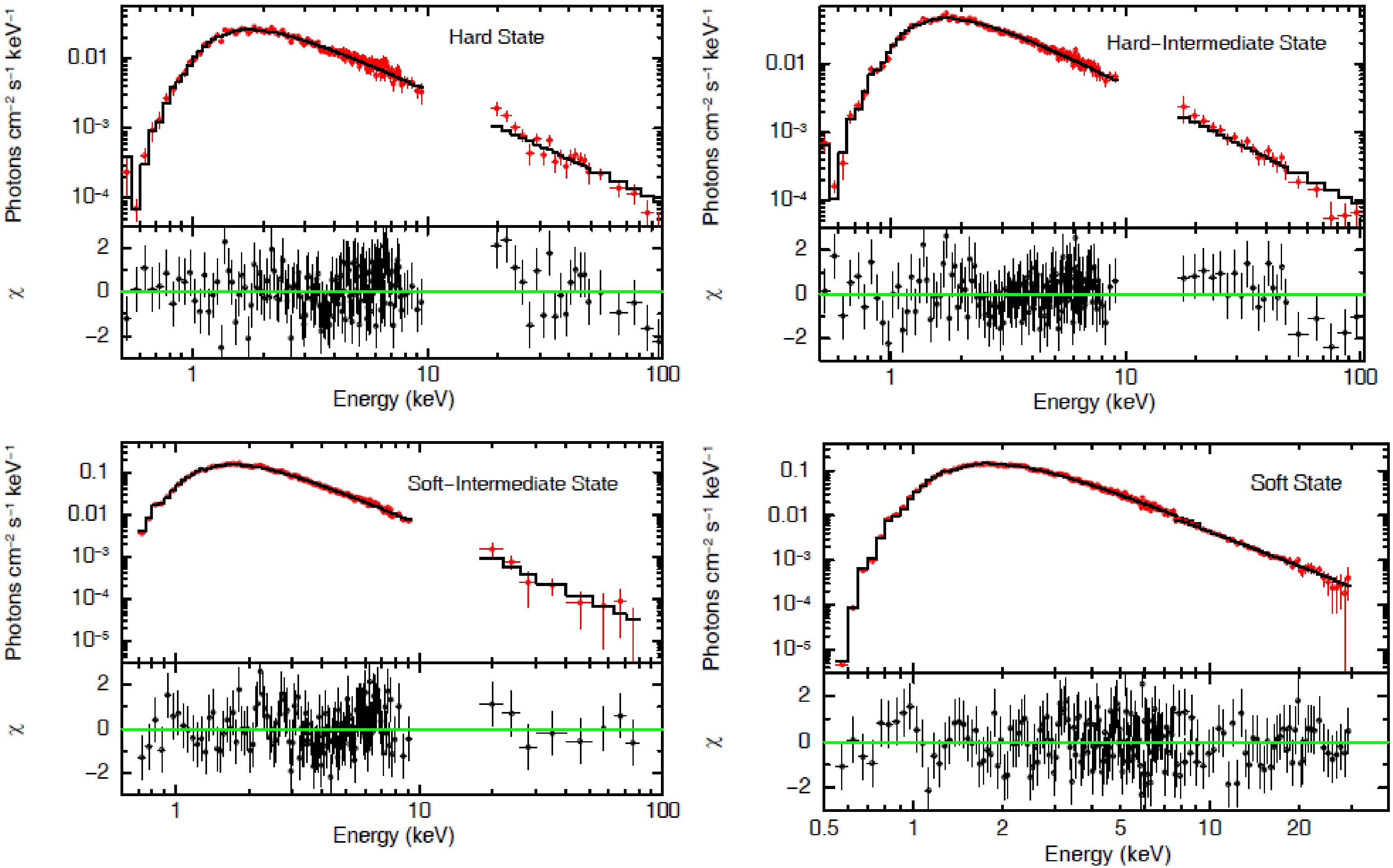




Data: Swift XRT and INTEGRAL

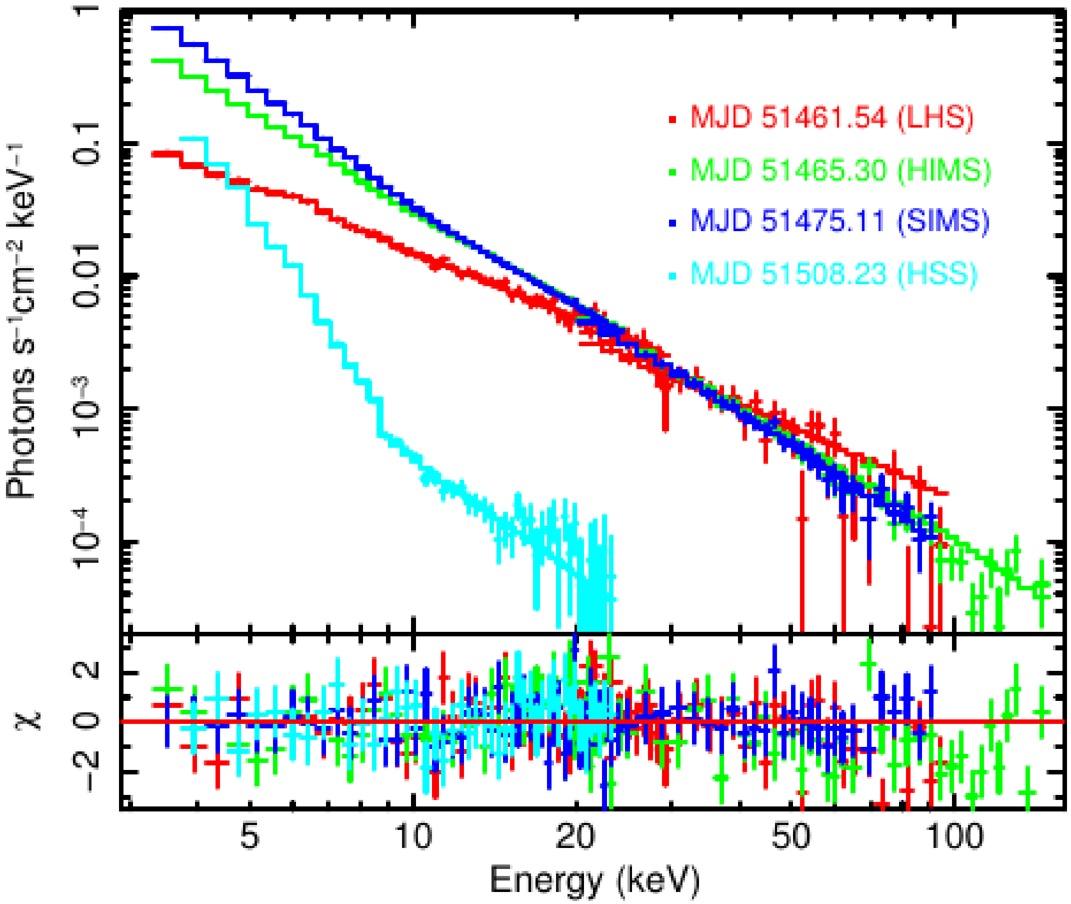
Iyer, Nandi & Mandal 2015

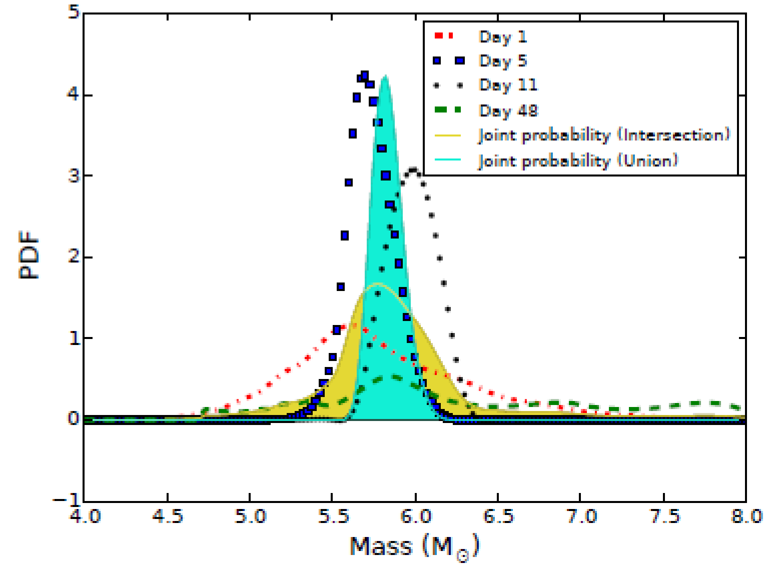
IGR J17091-3624 (2011 outburst)



Mass of the central source: $11.8\,M_\odot - 13.7\,M_\odot$

Spectral Modeling of XTE J1859+226 (1999 outburst)

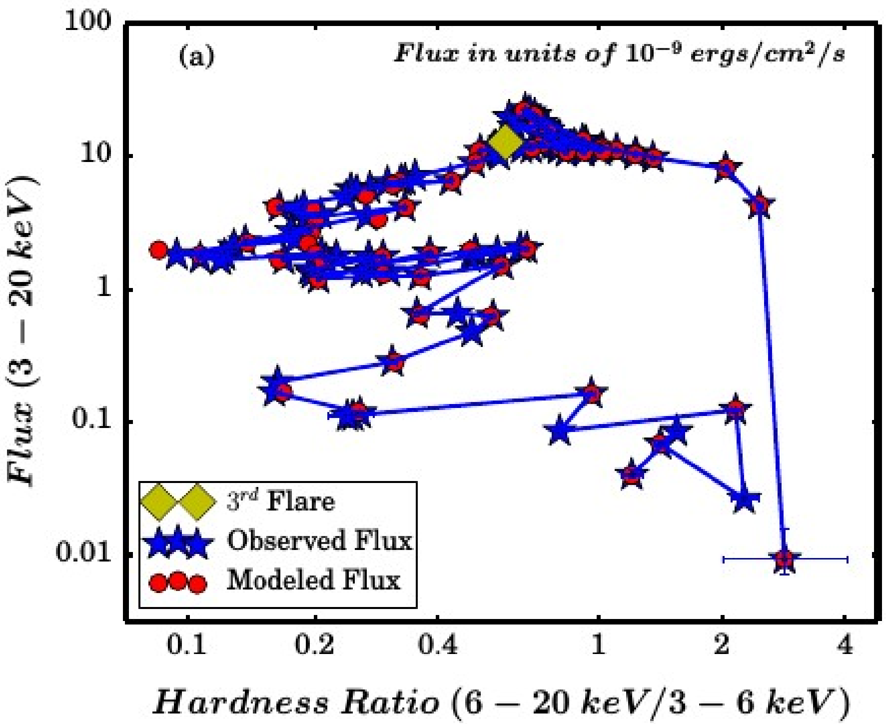


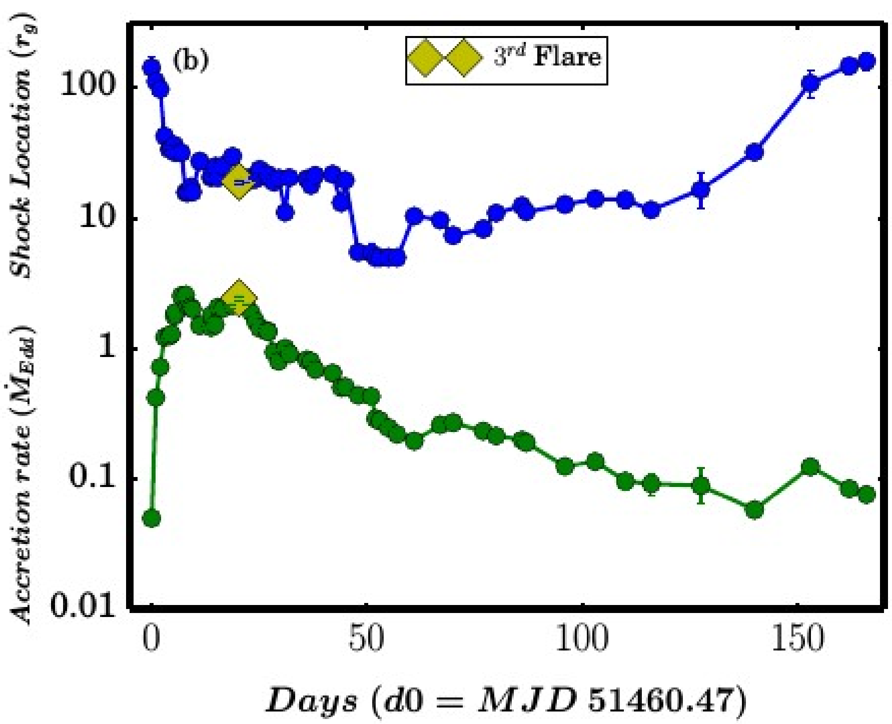


Spectral modeling provides mass of the source: 5.2 − 7.9 $M_\odot$

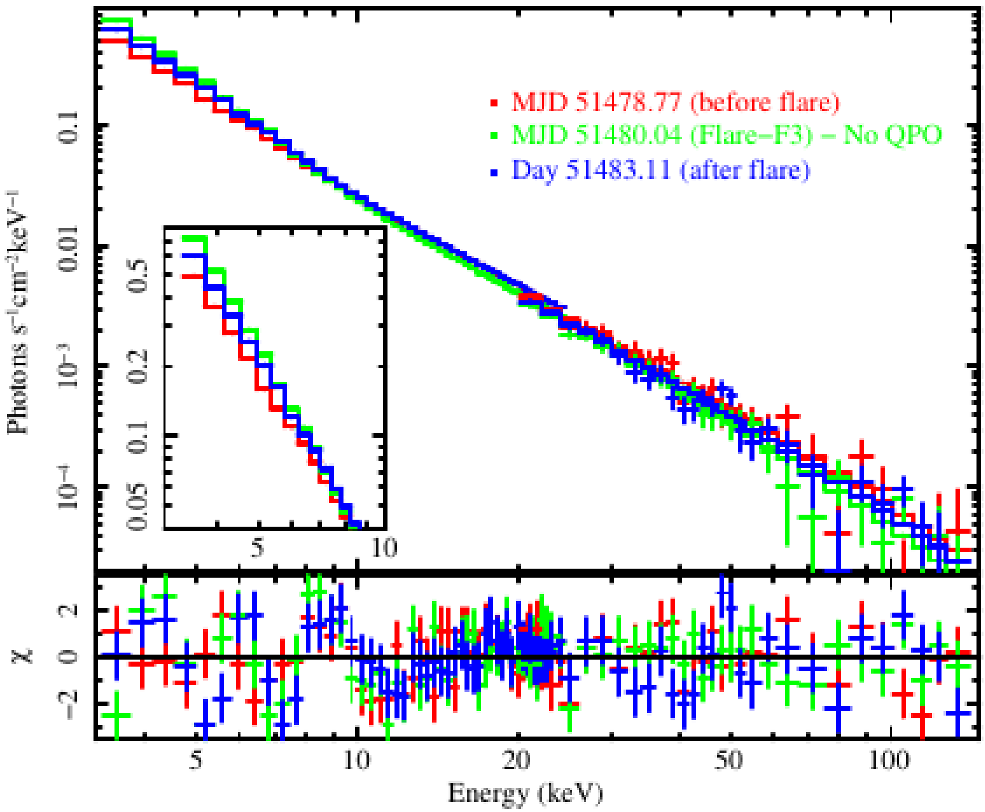
Data: PCA + HEXTE of RXTE

Spectral Modeling of XTE J1859+226 contd....





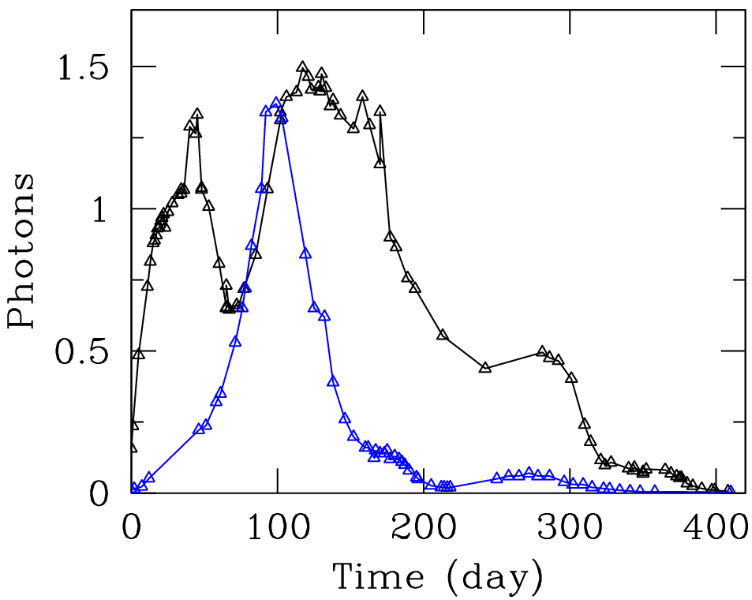
Spectral Signature of Radio Flare: XTE J1859+226

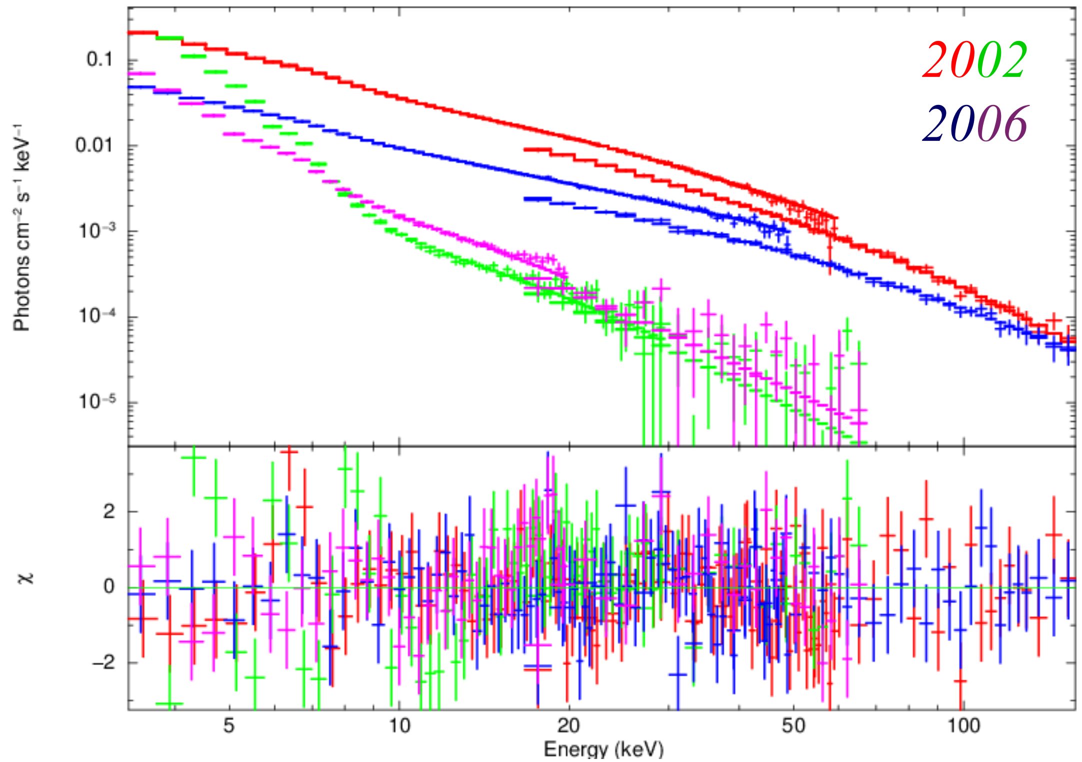


Calculate jet kinetic power from observed radio luminosity provides a mass outflow rate 7−14% of the accretion rate. This is consistent with the change in accretion rate required to fit the broadband spectra before and during the jet ejection

Nandi et al., 2017 in preparation

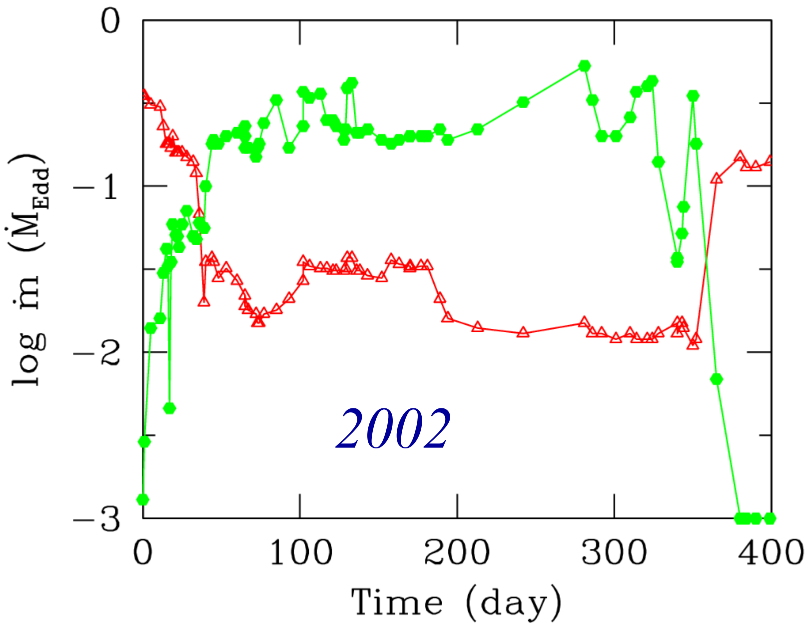
GX 339-4 Outburst (2002; 2006)

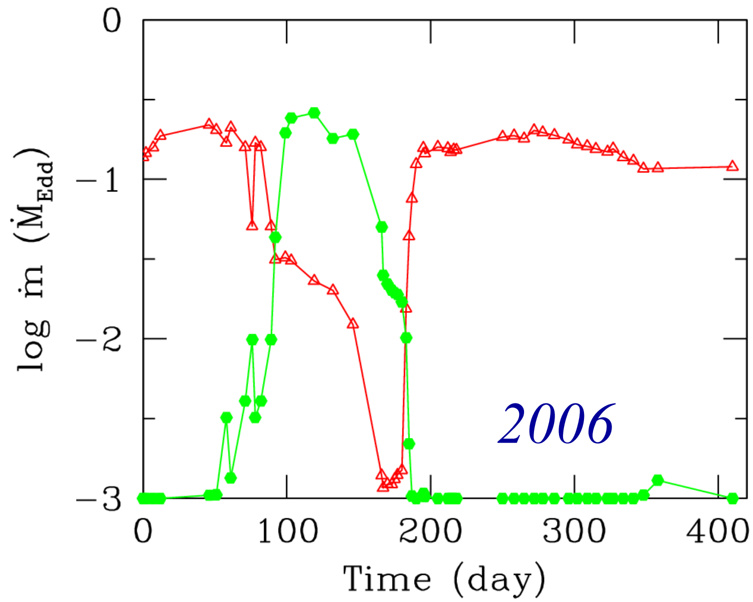


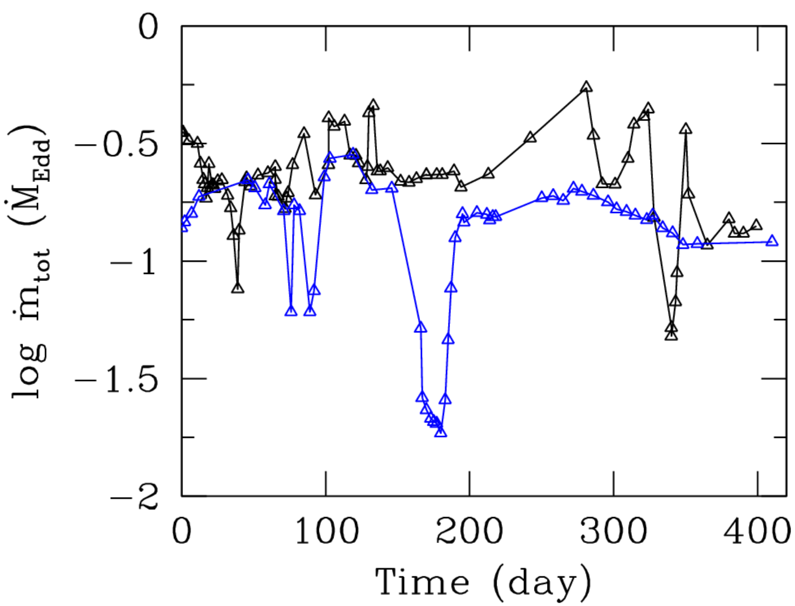


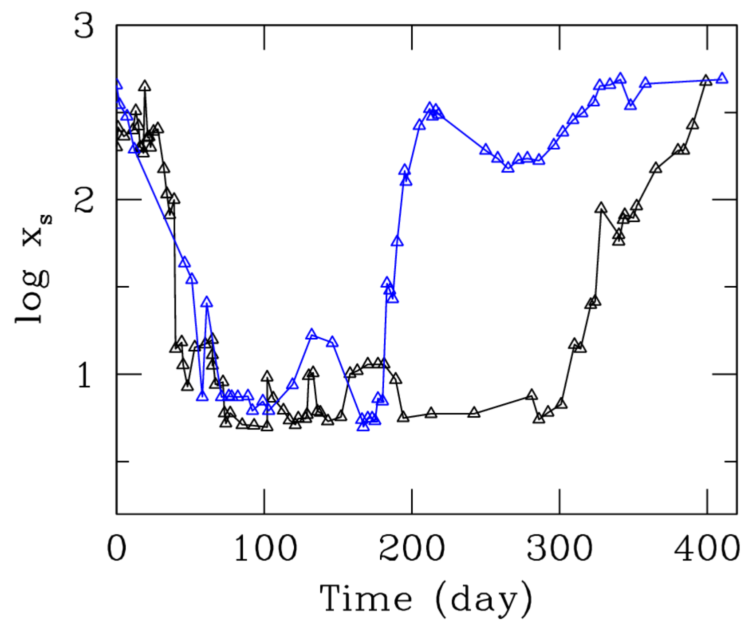
Data: PCA + HEXTE of RXTE

GX 339-4 Outburst (2002; 2006)

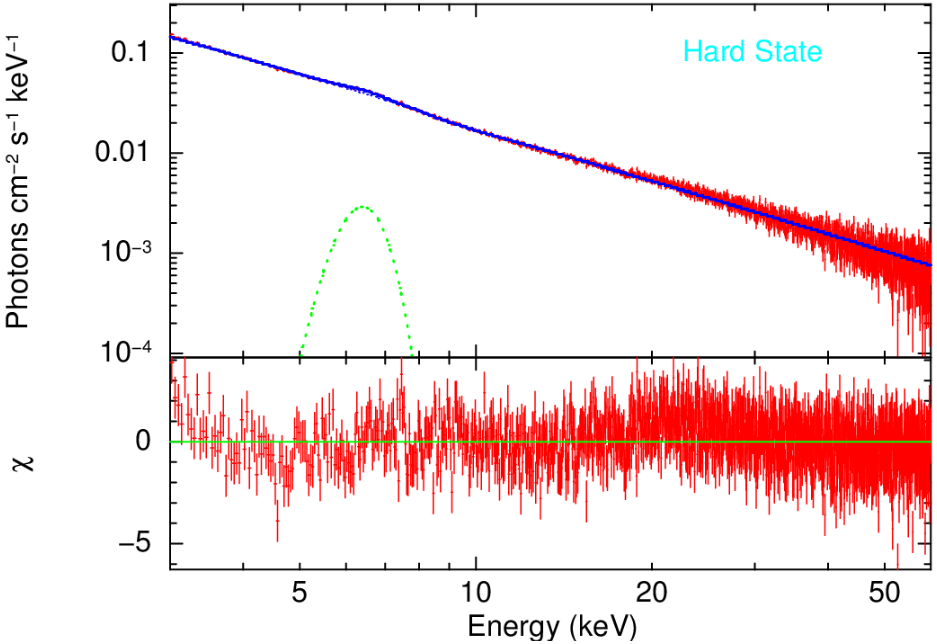


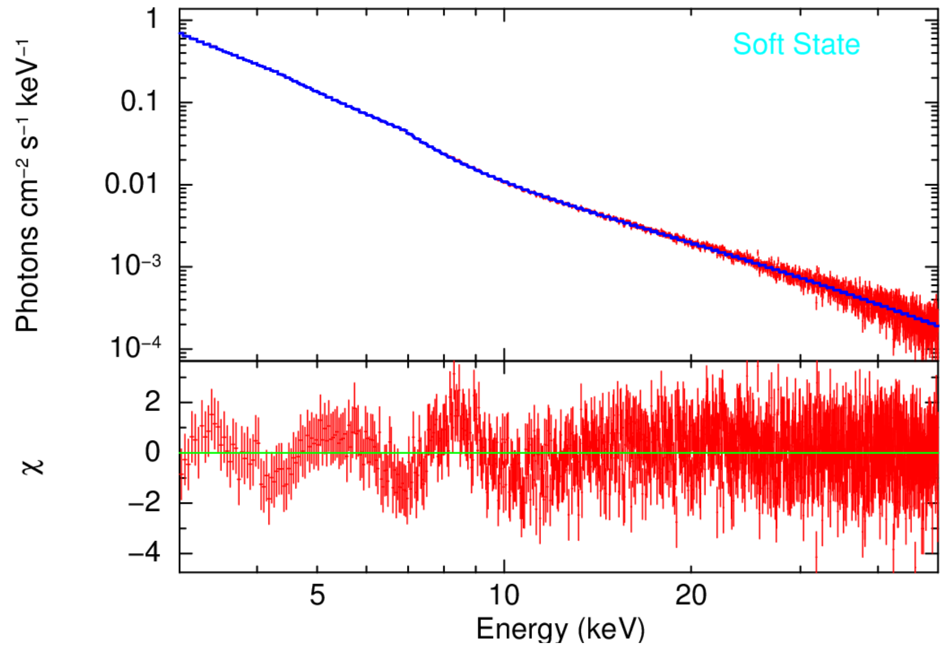






GX 339-4 Outburst (2015)

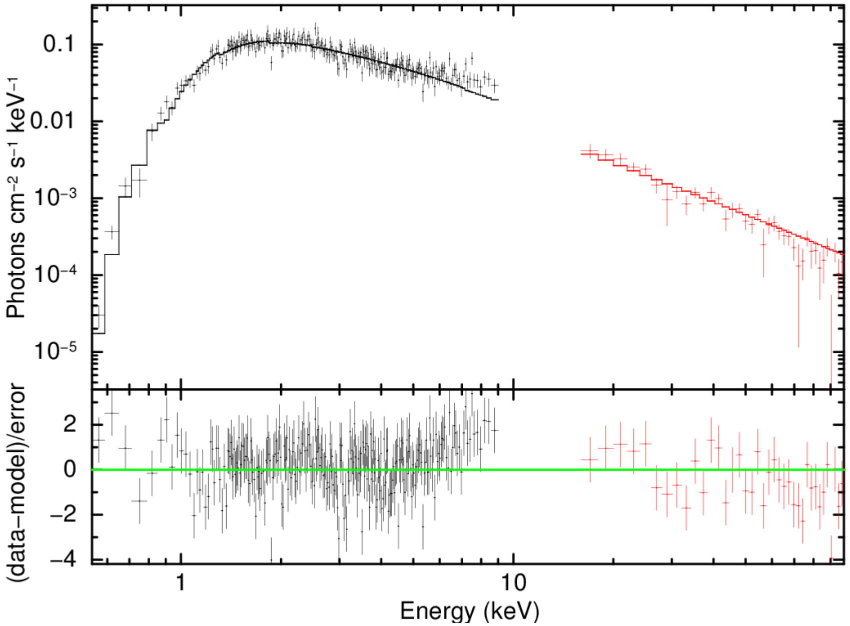




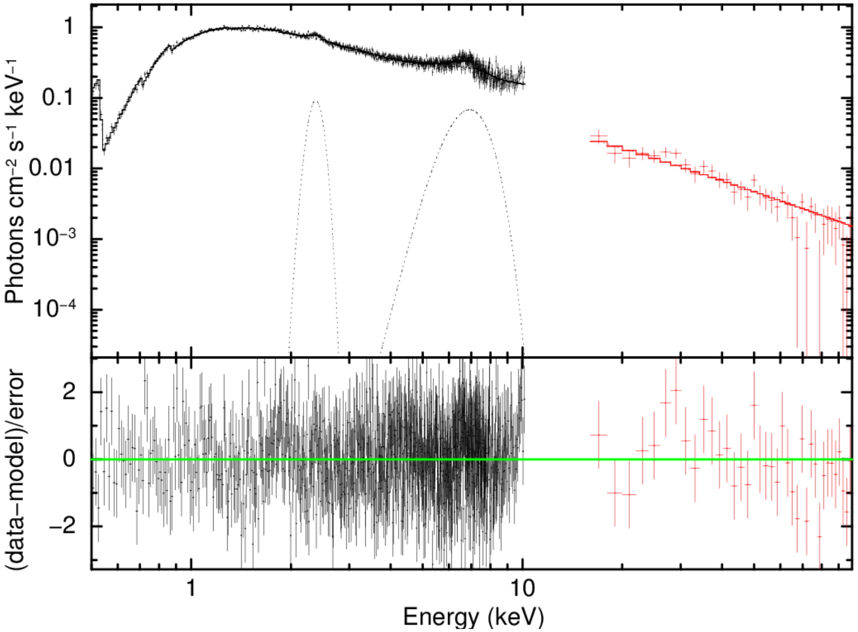
Data: NuSTAR

2015 outburst of GS 2023+338 (V404 Cyg)

Hard State (57191.03)



Intermediate State (57196.34)



1	pcfabs	nH	10^22	16.0566	+/-	4.92065
1	pcfabs	CvrFract		0.195113	+/-	3.32536E-02
2	wabs	nH	10^22	1.32142	+/-	4.11392E-02
3	CT-TCAF	embh		12.0567	+/-	1.32092
3	CT-TCAF	xs		487.495	+/-	3.62094
3	CT-TCAF	emdoth		0.203651	+/-	1.04867E-02
3	CT-TCAF	emdotdsk		1.12469E-03	+/-	9.51651E-05
3	CT-TCAF	norm		1000.00	frozen	
4	constant	factor		1.00000	frozen	

2	pcfabs	nH	10^22	49.2403	+/-	1.79402
2	pcfabs	CvrFract		0.591510	+/-	7.69862E-03
3	phabs	nH	10^22	0.547881	+/-	5.29433E-03
4	CT-TCAF	embh		11.5218	+/-	0.154766
4	CT-TCAF	xs		211.732	+/-	7.73220
4	CT-TCAF	emdoth		0.308622	+/-	8.73444E-03
4	CT-TCAF	emdotdsk		5.11114E-03	+/-	1.24647E-04
4	CT-TCAF	norm		1000.00	frozen	
5	constant	factor		1.00000	frozen	
6	gaussian	LineE	keV	6.91778	+/-	5.91099E-02
6	gaussian	Sigma	keV	0.800000	frozen	
6	gaussian	norm		0.136374	+/-	1.02485E-02
7	gaussian	LineE	keV	2.37642	+/-	4.64546E-02
7	gaussian	Sigma	keV	0.100000	frozen	
7	gaussian	norm		2.31495E-02	+/-	3.64453E-03

Data: SWIFT (XRT + BAT)

Conclusions

- *A two-component hydrodynamic model implemented into xspec to fit the observed data*

- *Outbursting events may trigger due to change in accretion of matter at the outer boundary or due to internal change in viscosity.*

- *A Montecarlo model is necessary to fit the radiation from mildly relativistic and $\tau \sim 1$ plasma.*

- *A self-consistent transonic flow xspec model is required for a better understanding of the realistic physical picture.*

Thank You

National Conference on
Recent Trends in the Study of Compact Objects - Theory and Observation (RETCO - III)

5-7 June, 2017

Indian Institute of Space Science & Technology

Thiruvananthapuram

Recent Trends in the Study of Compact Objects - Theory and Observation (RETCO) is a biannual conference dedicated towards the science around compact objects.

The third meeting of the series (RETCO-III) is going to be hosted by IIST. The goal of the conference is to bring together the researchers (scientists, post doctoral fellows and Ph.D students) in the field across the country and share the knowledge about the current development of the subject.

Broad topics to be discussed

* Theoretical and observational studies of galactic X-ray binaries, outbursting high energy sources, X-ray transients
* Science related to AGNs, blazars
* Multi-wavelength study of compact astrophysical sources
* Numerical and theoretical studies of high magnetic field compact systems
* Gamma Ray Bursts, Supernovae and gravity wave

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Articles submitted in the conference will be peer reviewed and accepted articles will be published in Journal of Astrophysics and Astronomy (JAA) as a special issue.

Local hospitality will be provided by IIST. Very limited travel support (by train 3AC) is available only to Ph.D students who do not have support from their host institutes.