Optically thick disc wind in GRO J1655-40?

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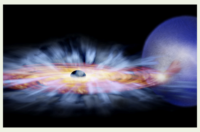
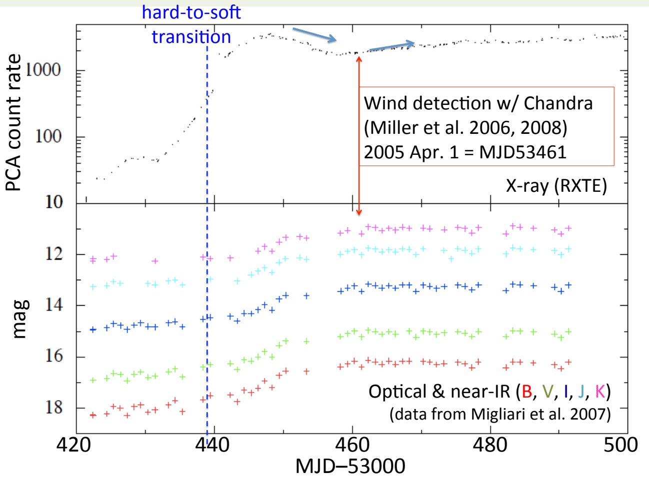


Abstract

Many disc winds observed in black hole binaries can be explained as thermally or radiation-pressure driven winds. An exceptional case is the disc wind of GRO J1655-40 detected with Chandra in 2005, whose launching radius was estimated to be much smaller than the Compton radius. Here we revisit the GRO J1655-40 wind, using RXTE X-ray data and simultaneous optical photometric data which trace the outer disc emission. We find that the optical flux was monotonically increasing around the Chandra epoch, while the X-ray flux started decreasing ~10 days before. The optical and X-ray spectral energy distribution at the Chandra epoch is well modelled by a disc emission and optically-thick Comptonisation, both of which are heavily absorbed. High frequency variability at the Chandra epoch was greatly reduced from the levels in the normal high/soft state, likely due to strong Compton scattering. These results suggest that the wind was optically thick to Compton scattering, and that the intrinsic X-rays are strongly scattered and absorbed by the wind. These effects, which have been ignored in previous studies, must be taken into account for accurate estimation of the wind launching radius and determination of the driving mechanism of the wind.

1. Long-term X-ray, optical & near-IR behaviour

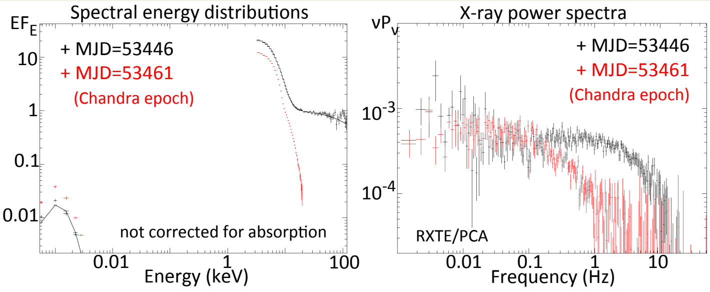


Wind detection w/ Chandra
(Miller et al. 2006, 2008)
2005 Apr. 1 = MJD53461

Optical & near-IR (B, V, I, J, K)
(data from Migliari et al. 2007)

- Optical flux = outer disc emission (disc blackbody + irradiation)
  + emission from the companion star
- Delay of the X-ray rise with respect to the optical/near-IR rise
  → rapid increase of the optical/near-IR fluxes would be caused by irradiation, instead of the intrinsic increase of Mdot
- Similar lag was observed in the previous outburst (Orosz et al. 1997)
- **The Optical/near-IR fluxes are monotonically increasing, whilst X-ray flux is decreasing just before the Chandra observation**
  → large fraction of X-ray flux is lost by absorption and/or suppressed by scattering out of the line of sight?
  Then intrinsic Lx is larger than observed Lx.

2. Comparison between the normal soft state and the hypersoft state with the wind

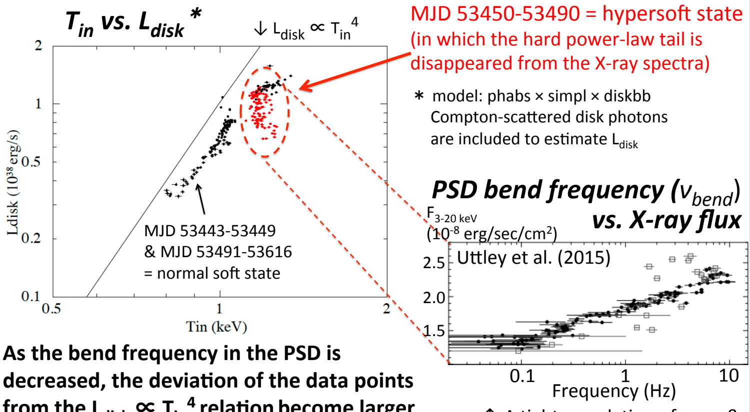


+ MJD=53446
+ MJD=53461
(Chandra epoch)
not corrected for absorption

- a large difference in the hard X-ray spectral shape, whilst the optical & near-IR SEDs are largely unchanged
- optical/near-IR fluxes have gone up but X-rays have gone down!
  This is not possible, since optical and near-IR track either Mdot through outer disc or irradiation from X-rays

- rapid variability above ~0.1 Hz is considerably reduced around the Chandra epoch (due to scattering?)
- the PSD shape has only little energy dependence (see Uttley+ 2015)
  → the decline of variability is not just caused by the disappearance of the power-law tail in the SED

4. Evolution of disc spectrum & X-ray power spectrum



MJD 53450-53490 = hypersoft state (in which the hard power-law tail is disappeared from the X-ray spectra)

* model: phabs × simpl × diskbb
Compton-scattered disk photons are included to estimate L_{disk}

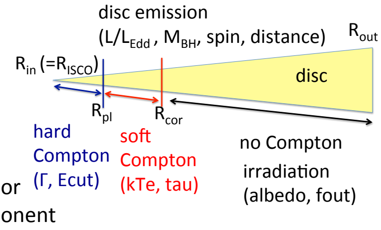
MJD 53443-53449
& MJD 53491-53616
= normal soft state

As the bend frequency in the PSD is decreased, the deviation of the data points from the $L_{disk} \propto T_{in}^4$ relation become larger likely due to wind absorption/scattering

↑ A tight correlation of ν_{bend} & Fx during hypersoft state

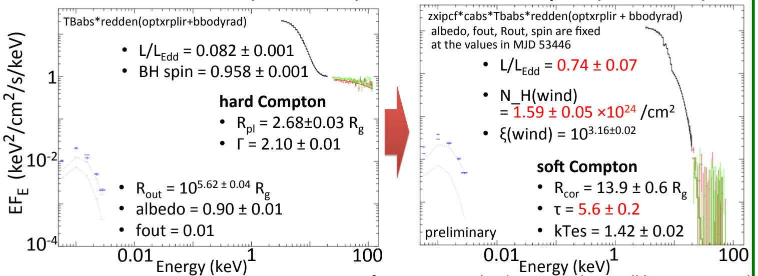
3. SED analysis with a new irradiated disc model

the **optxrplir** model
= intrinsic disc emission + Comptonisation + irradiation



- $L_{irrad} \propto R^{-12/7}$ (not R^{-2})
  Veledina et al. (2013)
- Comptonisation:
  = hard component (cutoff power-law)
  + soft excess
- the radial dependence of the color-temperature correction factor is taken into account in the disc component
- we assume irradiation by total X-ray flux, not only hard X-rays, because the optical SED shape is largely unchanged despite the large difference in the hard X-ray band

the normal soft state (MJD=53446) **Chandra epoch (MJD=53461)**



TBabs*redden(optxrplir+bbodyrad)

- $L/L_{Edd} = 0.082 \pm 0.001$
- BH spin = 0.958 ± 0.001

hard Compton

- $R_{pl} = 2.68 \pm 0.03\ R_g$
- $\Gamma = 2.10 \pm 0.01$

- $R_{out} = 10^{5.62 \pm 0.04}\ R_g$
- albedo = 0.90 ± 0.01
- fout = 0.01

zxipcf*cabs*Tbabs*redden(optxrplir + bbodyrad)
albedo, fout, Rout, spin are fixed at the values in MJD 53446

- $L/L_{Edd} = 0.74 \pm 0.07$
- N_H(wind) = $1.59 \pm 0.05 \times 10^{24}$ /cm^2
- ξ(wind) = $10^{3.16 \pm 0.02}$

soft Compton

- $R_{cor} = 13.9 \pm 0.6\ R_g$
- $\tau = 5.6 \pm 0.2$
- kTes = 1.42 ± 0.02

soft Compton with a large τ and a small kTe is required

system parameters (Greene+ 2001)

- MBH = 6.3 Msun
- D = 3.5 kpc
- Tstar (companion) = 6500 K
- Rstar (companion) = 5.0 Rsun
- N_H(interstellar) = 7.4×10^{21} /cm^2

If the fast variability is suppressed by scattering
ν_{bend} = ~c/(2 τ R) Zdziarski et al. (2008)
=> the scattering cloud is located at R ~ 10^{10} cm
(ν_{bend} = ~0.2 Hz, τ = ~5.6)