Jets at all Scales
Proceedings IAU Symposium No. 275, 2011
G. E. Romero, R. A. Sunyaev & T. Belloni, eds.

doi:10.1017/S1743921310016303

Spectral evolution of the galactic microquasars XTE J1550-564 and GRO J1655-40 during outbursts

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Abstract. We present results of a broadband spectroscopy of the galactic microquasars and black hole candidates XTE J1550-564 and GRO J1655-40, performed with the INTEGRAL and RXTE observatories during strong outbursts in 2003 and 2005, respectively. The spectral parameters evolution was traced during brightening and fading phases of each outburst to search a possible hysteresis and transitions from state to state. We estimated a size and optical depth of different regions around XTE J1550-564, like a hot plasma zone and optically thick accretion disk. Upper limits to the annihilation 511 keV line emission were obtained for both sources using data of the SPI spectrometer onboard the INTEGRAL observatory.

Keywords. X-ray transients, black holes, microquasars, jets

Light curves. Both sources were regularly monitored with the INTEGRAL observatory during 7 years of its operation at the orbit. Two relatively bright outbursts with the flux maximum of $\sim$ 300 mCrab were detected from GRO J1655-40 in 2005, but only one outburst was detected from XTE J1550-564 in 2003 (Fig.1). The total duration of the last in the standard X-ray energy range was about 50 days, and the shape of its light curve proved to be asymmetric with a $\sim$ 10-days rise in intensity to the peak value followed by a $\sim 35-40$-days smooth decay (see, e.g., Arefiev *et al.*, 2004).

Spectra. During both outbursts GRO J1655-40 demonstrated very hard X-ray emission, practically without any cutoff till $>$ 200 keV. The source spectra for 4 extended epochs were presented by Caballero-Garcia *et al.* (2007). Here we made a detailed analysis of its hard X-ray emission ($>$ 20 keV) and found, that the source spectrum could be well

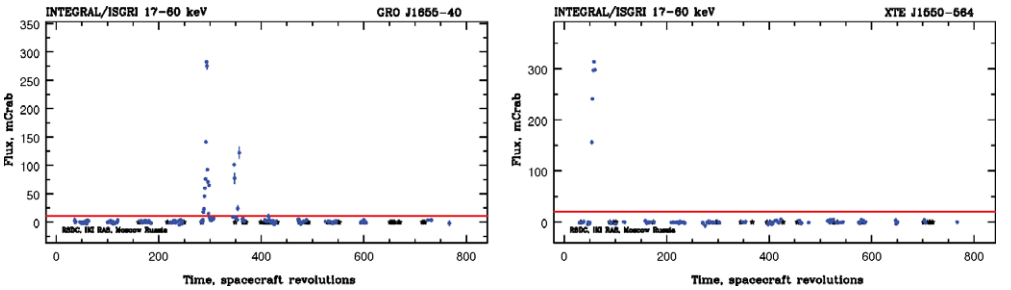

Figure 1. Light curves of GRO J1655-40 (left) and XTE J1550-564 (right) as they were measured by the INTEGRAL observatory in 2003-2009. Strong outbursts are clearly seen. The horizontal axis is given in the INTEGRAL revolutions, starting from Oct 17, 2002. See http://hea.iki.rssi.ru/integral/survey/catalog.php for details.

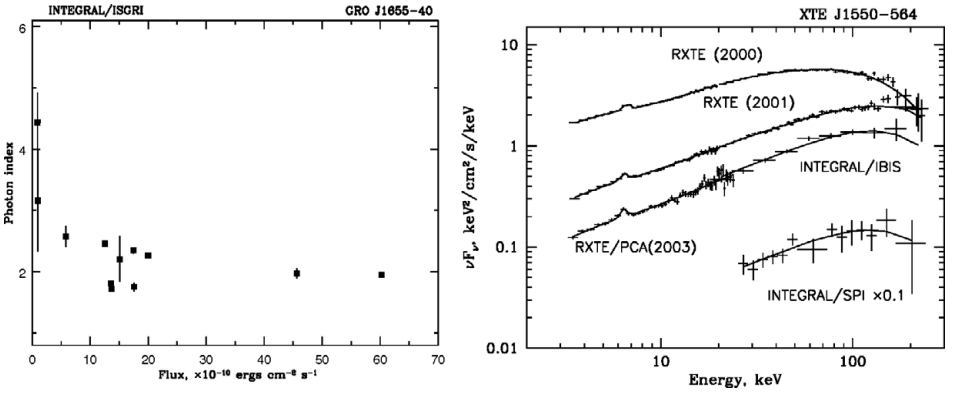

Figure 2. (*left*) The 20-200 keV photon index dependence on the flux measured during outbursts from GRO J1655-40. (*right*) INTEGRAL and RXTE broadband spectrum of XTE J1550-564 obtained during 2003 outburst. Source spectra collected during hard state of 2000 and 2001 outbursts are shown for comparison.

described by a simple powerlaw with a relatively stable photon index ~ 2 during the high state. A some steepening of the spectrum was revealed in the low state (Fig.2, left).

Because XTE J1550-564 demonstrated only subtle spectral variability during the outburst, we averaged its spectrum over all our observations. Figure 2(right) shows the XTE J1550-564 broadband spectra obtained during outburst of 2000, 2001 and 2003. It is seen that both 2001 and 2003 outbursts had much harder spectra than that the 2000 outburst. To describe spectrum, we used the Comptonization model by Poutanen & Svensson (1996), which includes the reflection of a hot radiation from a cold neutral medium. Best-fit parameters are summarized below. The large optical depth may reflect the fact that the source has a rather large inclination, and we look at the central source through the entire thickness of the central cloud (see Arefiev *et al.*, 2004 for details).

kT, keV	τ	R, $\Omega/2\pi$	$\mathrm{EW_{line}}$, eV	Flux, erg/s/cm^2	$\chi 2$/d.o.f.
50 ± 10	5 ± 1	0.25 ± 0.13	120 ± 30	3.8×10^{-10}	1.20

The analysis of SPI/INTEGRAL data shown, that the maximum significance of the flux variability in the 511-keV line was observed near the Galactic plane at a Galactic latitude of $\sim 30°$. This is the most interesting feature, since the microquasar GRO J1655-40 can be a potential source of this outburst. The observed outburst in the $508-514$ keV energy band coincides in time with an intense outburst in the X-ray energy band (see Fig. 1). But the most conservative upper limit for the 511-keV emission does not exceed $\sim 2 \times 10^3$ phot cm^{-2} s^{-1} (see Tsygankov & Churazov, 2010, for details).

This work was supported by the program of Russian Academy of Sciences "Origin, Structure and Evolution of Objects in the Universe" and grant NSh-5069.2010.2.

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https://doi.org/10.1017/S1743921310016303 Published online by Cambridge University Press