GRS 1758-258: A RARE PERSISTENT HARD STATE BLACK HOLE

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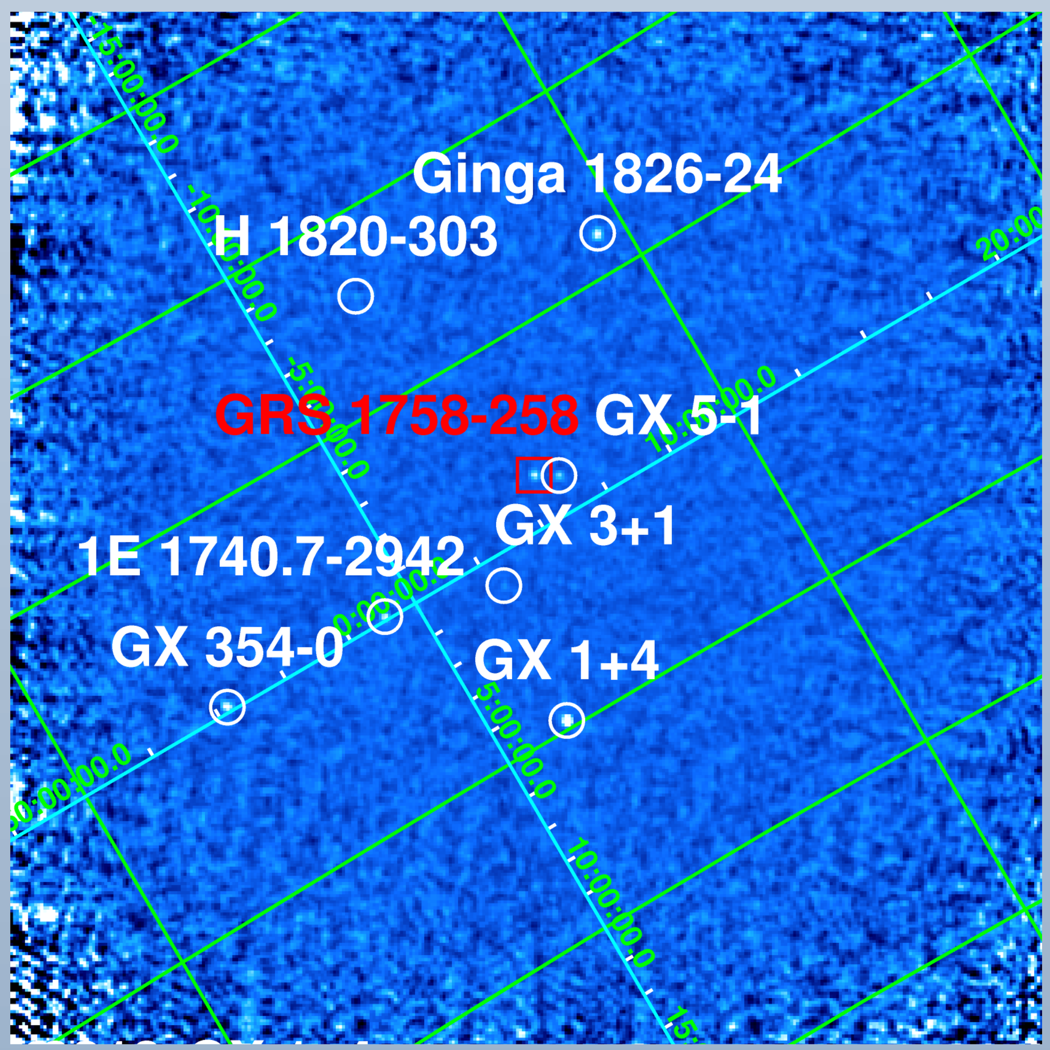
ABSTRACT

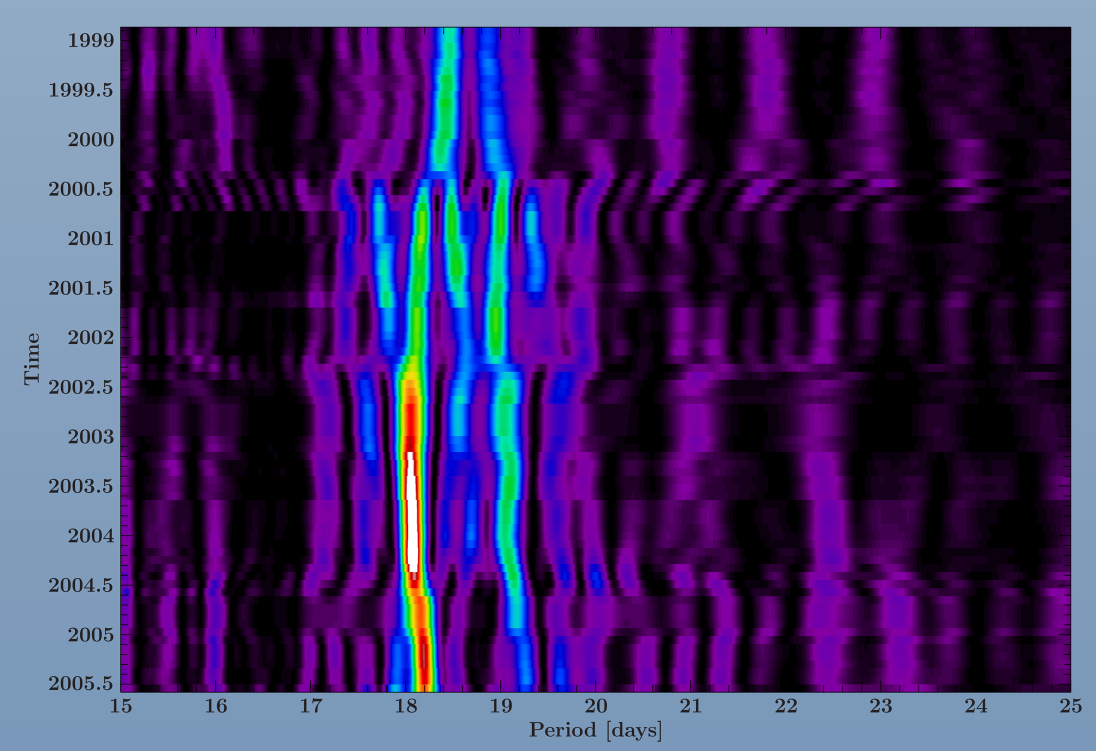
We present the spectral and timing evolution of GRS 1758-258, one of only three known persistent black hole binaries in our Galaxy, based on 11 years of RXTE-PCA observations. During this time, GRS 1758-258 entered a thermally dominated soft state seven times, showing a strong decline in the 3-20 keV flux rather than an increase. There is only one other source that displays this behavior. In its hardness intensity diagram below 20 keV, GRS 1758-258 shows a hysteresis of hard and soft state fluxes like transient sources in outburst, but with deviations from their typical q-tracks. The spectral flux light curve does not contain any orbital modulations in the range of 1 to 30 days, but in the dynamic power spectrum significant peaks are drifting between 18.47 ± 0.25 and 18.04 ± 0.22 days.

GRS 1758−258



The intermediate mass black hole binary GRS 1758−258 was discovered in 1990 during observations of the Galactic Center Region by the Granat satellite. An *INTEGRAL*-ISGRI count rate mosaic image in the 20–40 keV band, obtained during Galactic Center Region Key Programme observations performed in spring 2007 (Lohfink et al., 2010), shows the position of GRS 1758−258. The companion star in the system is probably an early A-type main sequence star, but with unusual colors (Muñoz-Arjonilla et al., 2010). As one of only few persistent sources, GRS 1758−258 has been observed in many energy ranges. Since radio observations are showing a double lobed counterpart and on basis of the spectra, GRS 1758−258 is assumed to be a microquasar. Generally it can be found in the hard state. However, in some respects it still displays a behavior typical for transient sources (hysteresis, rare decay-type soft states; Pottschmidt et al., 2006; Smith et al., 2001, 2002; Soria et al., 2011).

DYNAMIC POWER SPECTRUM

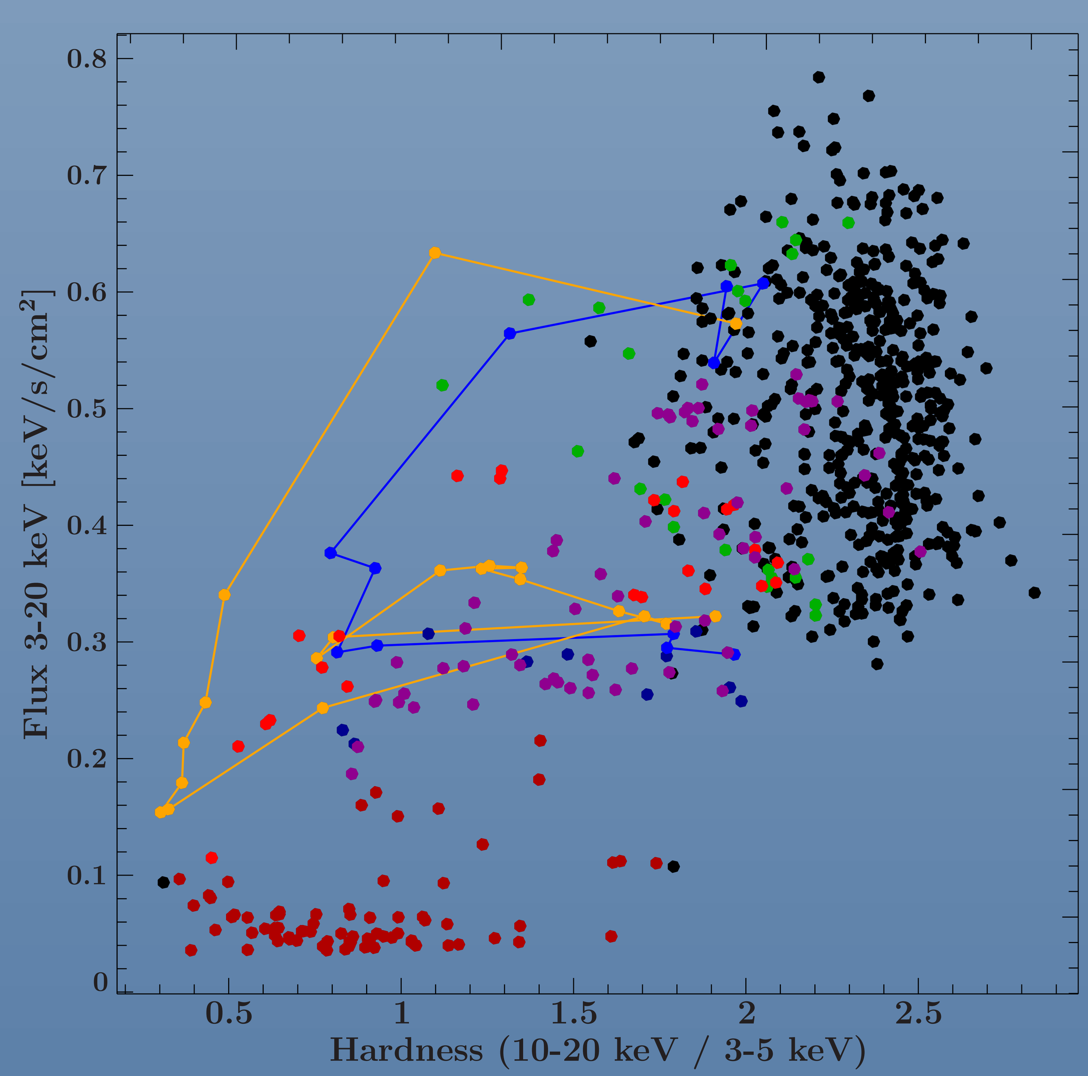


In search of an orbital period the model flux light curve was analyzed. We had to use the algorithm for generalized periodograms after Lomb, N. R. (1976) and Scargle J. D. (1982) due to many gaps and unevenly spacing of the data points. The light curve was first highpass-filtered by subtracting a smoothed version of the light curve. Using only observations where GRS 1758−258 is in the hard state (i.e., $\Gamma < 2$), we are within our errorbars able to confirm the results of Smith et al. (2001), who find a peak at 18.45 ± 0.10 days within the first five years of data. Calculating a dynamic power spectrum however shows that this peak at 18.47 ± 0.25 days is drifting to lower values up to a minimum of 18.04 ± 0.22 days in 2003. Towards the end of the light curve, the period of the main peak is rising again. Simulations show that a peak in this period range is caused neither by red nor by white noise. Monte Carlo Simulations of 10000 white noise light curves with a dynamic power spectrum calculated for each of them gives significances between 99.9% and 100.0% for the respective periods of the drifting peak.

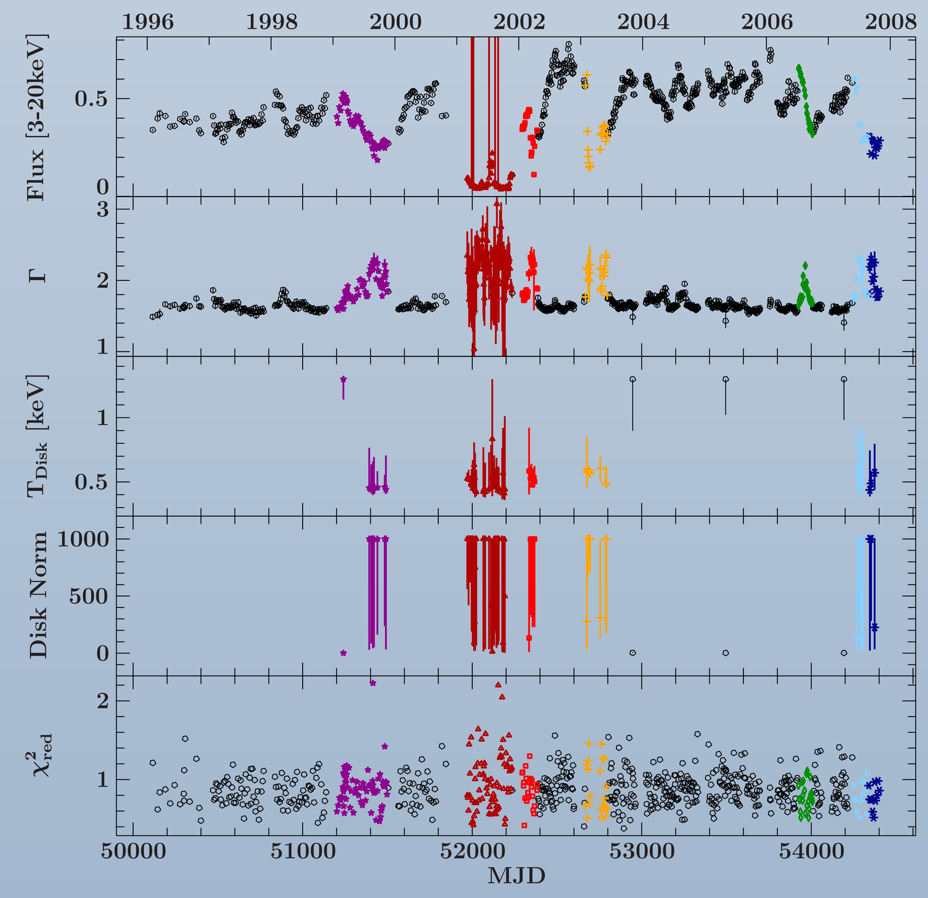
Even though we did not find an orbital period, a time-varying peak in the dynamical PSD could still be close to the orbit if it is caused by superhump behavior of the disk.

HARDNESS INTENSITY DIAGRAM

For energies below 20 keV, the Hardness Intensity Diagram (HID) of GRS 1758−258 shows a clear hysteresis for hard and soft state fluxes. However, GRS 1758−258 does not follow the q-shaped track typical for black holes during outbursts (Fender et al., 2004) but starts at the upper right edge. No brightening is seen before the softening of the spectrum, GRS 1758−258 immediately fades into its dim, almost off state.



SPECTRAL EVOLUTION



GRS 1758−258 was monitored by *RXTE* in 1-1.5 ks pointed snapshots regularly from 1996 to 2007 (Obst et al., 2013). As GRS 1758−258 is a rather faint source located close to the Galactic Center, the *RXTE* PCA spectra contain not only source counts but also a strong background component caused by the Galactic Ridge emission. A 13 ks background observation was performed by *RXTE* in 1999. We modeled the spectrum taken 1.5° off GRS 1758−258 with two bremsstrahlung components and an iron line complex according to Ebisawa et al. (2007) and the best-fit model added as a constant to the source model.

The spectra were fitted with an absorbed powerlaw continuum with an additional weak iron $K\alpha$ line. The column density due to interstellar absorption in the direction of GRS 1758−258 was kept fixed to the canonical value of $1.5 \times 10^{22}\,\mathrm{cm}^{-2}$ (Mereghetti et al., 1997). The photon index varies between 1.5 and 3. Most of the time, GRS 1758−258 is in the hard state. However, 7 dim soft states (highlighted in the figure above) clearly appear in the data. This behavior is typical for transient, not persistent sources. During the 2001 soft state, the 3-20 keV flux drops by about 85% but is generally still at least 10σ above the background for the individual monitoring observations.

Some spectra also required a black body disk component at a Monte Carlo significance level of 99.0%. This disk only becomes visible when GRS 1758−258 is in the dim, soft state with photon indices above 2. The low flux in the soft states increases the error bars.

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