Long-term spectral changes in GX 1+4

P. Kretschmar (1); A. González Galán (2); E. Kuulkers (1); Konstantin Postnov (3), Mark Finger (4), Stefan Larsson (5)

(1) ESA/ESAC, Madrid, Spain; (2) DFISTS, Universitat d'Alacant, Spain; (3) Sternberg Astronomical Institute, Moscow, Russia
(4) National Space Science and Technology Center, Huntsville, AL, USA (5) Department of Astronomy, Stockholm University, Sweden

Abstract

GX 1+4 is the best known member of the small class of symbiotic accreting X-ray pulsars. It shows strong, irregular luminosity variations typical for this source class. Long-term monitoring indicates significant spectral changes on the orbital timescale in recent years and changes in the behaviour around periastron passages.

GX 1+4

GX 1+4 is an accreting X-ray pulsar discovered in 1970 by a balloon observation at energies above 15 keV [1]. At the time it was one of the brightest X-ray sources in the Galactic centre region. The optical companion was confirmed to be the M giant V2116 Oph in 1997 [2]. With an orbital period of 1161 days with unkown inclination the masses of the binary partners have been estimated as ~1.35 M⊙ for the neutron star and ~1.2 M⊙ for the M giant. This means that the M giant does not fill its Roche lobe and the neutron star is capturing the slow stellar wind of its companion [3].

The X-ray flux is very variable on all timescales, from seconds to decades. In the years after its detection the source remained bright and spun up strongly. During an extended low state in the 1980s the previously strong spin-up reverted to a strong spin-down [4], that has been ongoing ever since, increasing the pulse period from ~110 s to ~160 s in the last three decades [5]. While the source has brightened significantly since the low state of the 1980's it has not yet reached again the average brightness of the 1970's [6].

The spectrum of GX 1+4 is found to be harder than in similar sources, which might indicate an especially strong magnetic field. Observations at hard X-rays found no significant dependence of the spectral shape on intensity, but during a low flux interval in 1996, significant spectral variations in the 2-60 keV band were observed [7].

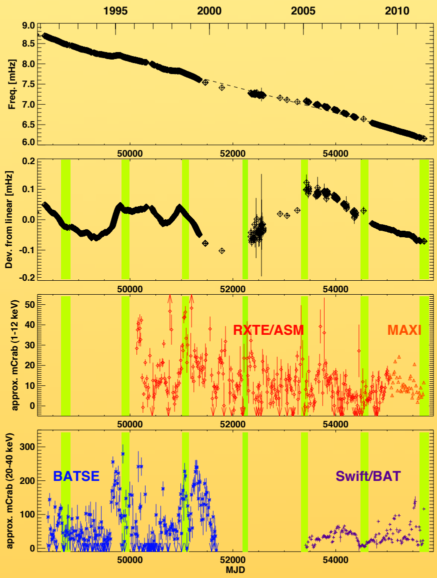

Figure 1: Long-term pulse frequency and flux evolution of GX 1+4 as monitored by different instruments over more than 20 years. Green bars indicate periastron passages as predicted by the ephemeris in [3] (T_0 at MJD 52235.3).

Data & analysis

For this study we have collected monitoring data for GX 1+4 from BATSE, RXTE/ASM, Swift/BAT and MAXI, as provided by the respective teams. Pulse periods for recent data were obtained from the GBM Pulsar Project. Other data from the literature, as compiled in [6].

Since we are interested in long-term trends, the observed light curves have been re-binned to 15 d intervals, using a fixed time grid. For all, but the BATSE data, which was provided in this way, the flux measurements have been converted to rough 'Crab' units for the soft (1-12 keV) and hard (20-40 keV) band, using the measured Crab and correction factors obtained from an analysis of broad-band spectra of GX 1+4 [6,9,10].

Hardness ratios were calculated as *(H-S)/(H+S)* from these 'Crab' ratios where significant fluxes were available in both bands.

Spin frequency trends

In the time period covered in this study, GX 1+4 shows a ***steady spin-up with almost constant change in frequency (-0.12 mHz/y)*** - see Figure 1.

On top of the overall linear trend, there are changes in the pulse frequency on shorter time scales with roughly similar slopes over years. On short timescales a positive correlations between spin-up rate and X-ray luminosity has been found at least occasionally [2,6].

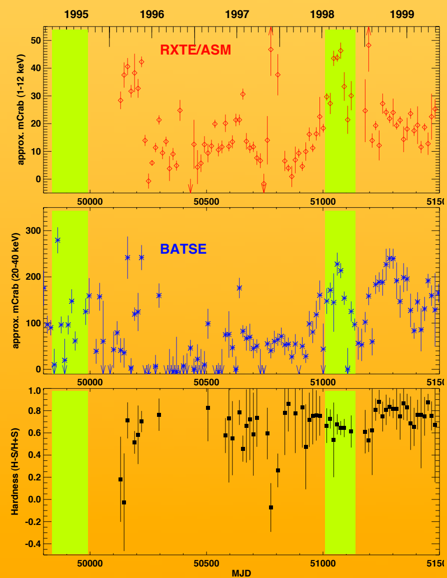

Figure 2: Zoom-in on fluxes and hardness ratio for the time period with BATSE and RXTE/ASM monitoring.

Flux & spectral evolution

In contrast to the stable spin-down, we find no firm pattern in the flux and spectral variations.

In the late 1990s the spectral hardness remained rather constant, regardless of the luminosity variations, except for brief intervals of 'soft flares' (see Fig. 2).

More recently, from 2006 to end 2007 the spectral hardness increased steadily, dropping abruptly during a perigee passage period, due to a drop in hard flux. Other variations seem to happen on timescales of several months.

Conclusions

From the quasi-spherical accretion model, which has been invoked to explain the long-term pulse period evolution of GX 1+4 [5,11], we would actually expect a correlation between flux and hardness, because increased Compton cooling leads to higher accretion rates.

But as the historical data shows, the source behaviour is more complex. There are intriguing indications for accretion state changes triggered at periastron passages, but with contrasting results for different passages.

These results emphasize the necessity of long-term consistent monitoring in order to truly understand accreting X-ray sources.

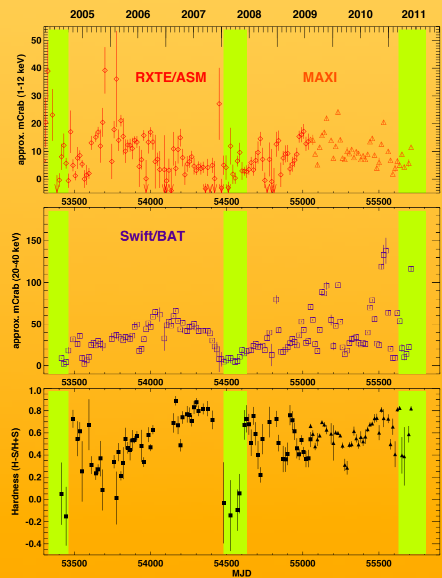

Figure 3: Zoom-in on fluxes and hardness ratio for the time period with Swift/BAT and RXTE/ASM and MAXI monitoring.

References

[1] Lewin, W.H.G., Ricker, G. R., & McClintock, J.E. 1971, ApJ, 169, L17
[2] Chakrabarty, D. & Roche, P. 1997, ApJ, 489, 254
[3] Hinkle, K. H., Fekel, F. C., Joyce, R. R., et al. 2006, ApJ, 641, 479
[4] Hall, R. & Davelaar, J. 1983, IAU Circ., 3872
[5] González-Galán, A., Kuulkers, E., Kretschmar, P., et al. 2011, PoS(INTEGRAL 2010)016, arXiv:1105.1907
[6] González-Galán, A., Kuulkers, E., Kretschmar, P., et al. 2011, *in prep.*
[7] Mony, B., Kendziorra, E., Maisack, M., et al. 1991, A&A, 247, 405
[8] Greenhill, J.G., Sharma], D.P., Dieters, S.W.B., et al. 1993, MNRAS, 260, 21
[9] Ferrigno, C., Segreto, A., Santangelo, A., et al. 2007, A&A, 462, 995
[10] Naik, S., Paul, B., & Callanan, P. J. 2005, ApJ, 618, 866
[11] Postnov, K., Shakura, N., González-Galán A. et al. 2011, PoS(INTEGRAL 2010)015