STRONG QPOS AND HIGH ENERGY TAIL IN SIMULTANEOUS RXTE/INTEGRAL OBSERVATIONS OF GRS 1915+105

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ABSTRACT

We present the first results of the timing analysis of our RXTE/INTEGRAL monitoring campaign on GRS 1915+105. Over the 6 already performed RXTE observations, we study the presence of Low Frequency QPO (LFQPO), and their energetic dependences. In a view to understand the QPO phenomenon, we compare the QPO properties to the spectral behaviour of the source. We propose that part of the compact jet detected during multi-wavelength observations, could produce a significant amount of hard X-rays, and hence explain the energy dependence of the amplitude of the QPOs.

Key words: accretion, accretion disks — black hole physics — stars: individual (GRS 1915+105) — Gamma-rays:observations.

1. MONITORING CAMPAIGN ON GRS 1915+105

The log of the RXTE observations analysed in this paper is reported in Table I. All of them were simultaneous with INTEGRAL and other ground based observations. The first observation shows a new class of variability (Hannikainen et al. 2003), while during Obs. 2,3,4, the source has a steady flux in the X/Gamma rays. It shows a strong QPO, a powerful compact jet during Obs. 2 (Fuchs et al. 2003), and a high level of radio emission during the 2 other observations (Hannikainen et al. 2004, these proceedings).

2. CLASS OF VARIABILITY OVER THE CAMPAIGN

The study of the RXTE colour-colour diagrams allowed us to classify the class of variability of the source following Belloni et al. (2000) classification:

- Observation #1: as shown in Hannikainen et al. (2003) and discussed in these proceedings, this observation belongs to a new class of variability
- Observations #2,3,4: these three observations belong to the steady class $\chi$. The high level of radio emission allows to further classify them as $\chi_1 - \chi_3$, a.k.a radio loud hard state (Muno et al. 2001), or type II state (Trudolyubov 2001). See Fuchs et al. (2003) for a presentation of the whole multi-wavelength campaign during Obs. 2.
- Observation #5: a high level of solar activity renders the analysis of this observation delicate. It will be presented elsewhere
- Observations #6: this last observation of our RXTE AO-8 campaign belongs to the steady class $\phi$.

3. CLASS $\chi$ PRELIMINARY SPECTRAL ANALYSIS

Fits of the PCA 2-25 keV spectra with a standard model of (absorbed) multi colour disc black body plus power-law leads to unrealistic values of the disk parameters ($kT \sim 4$ keV) as already reported in the literature for such radio loud states (e.g. Muno et al. 2001). When restraining to the 3-25 keV (PCA only), a cut-off power-law (with $\Gamma = 1.8$) fits the spectra as shown in Fig. II for both Obs. 2 and Obs. 3.
Table 1. log of the RXTE observation and contemporaneous INTEGRAL revolutions reported in this paper

| Obs. sequence # | Date (MJD)                  | Good times (s) | Revolution # (INTEGRAL) | INTEGRAL ref.                           |
|-----------------|-----------------------------|----------------|-------------------------|-----------------------------------------|
| 1               | 6-7 March 2003 (52704-05)   | 15768          | Rev. 48                 | Hannikainen et al. 2003                 |
| 2               | 2 April (52731)             | 9300           | Rev. 57                 | Fuchs et al. 2003                       |
| 3               | 9-10 April (52738-39)       | 25360          | Rev. 59                 | Hannikainen et al. 2004                 |
| 4               | 9 May (52768)               | 14000          | Rev. 69                 | Hannikainen et al. 2004                 |
| 5               | 2 November (52945)          |                | Rev. 122                | Solar Flares                            |
| 6               | 22-23 November (52965-66)   | 36100          | Rev 135                 | Hannikainen et al. 2004                 |

Figure 1. PCA 2–25 keV spectra from Obs. 2 and Obs. 3, with the best fit model superimposed.

The disc parameters are then closer to what is usually observed in other black hole systems (kT 0.5-0.8 keV depending on N_H). This model does not fit the spectra well when including energies above 25 keV (Fig. 4 left panel). The 20-300 keV spectra are well fitted by a power-law with Γ ≈ 3.5 (Fig. 4 right panel). A broken power law with a break energy of ≈ 15 keV (Γ_1 = 2.5, Γ_2 = 3.5), is the best model for the broad band spectrum. Whether the second power-law is evidence or not for a 3rd emitting media during radio loud hard state is thus an open question (as already pointed out by Trudolyubov 2001).

4. TIMING ANALYSIS: LFQPOS

In Obs. 1 a QPO feature is clearly detected in the dynamical power spectra (Fig. 8). Its frequency is clearly correlated to the PCA flux as widely reported in the literature for such features (e.g. Markwardt et al. 1999; Rodriguez et al. 2002). In Obs. 2,3,4 a steady QPO is clearly detected in the power spectra (e.g. Fig. 8 right). The feature has a constant frequency over the whole observing time during Obs. 2 and 3. In Obs. 4 however two distinct frequencies are identified. Due to long exposure we could study the energy dependence of the QPO amplitude with the highest possible accuracy (Fig. 4).

Although the three observations show that the source is in the same class of variability, the energy dependence of the QPO amplitude is quite different from one observation to the other. The main difference is the presence of a turn-over in the amplitude vs. energy relation in Obs. 2 which is not obvious in the other ones (although a flattening is always detected). Obviously, this is not related to the frequency of the feature: e.g. the 2 features observed in Obs. 4 have a similar energy dependence of their amplitude, although they have different frequencies.

5. DISCUSSION

We found that the radio loud hard state (a.k.a. Class χ1-χ3) does not lead to sensible parameters when fitted with a multi colour disc black body and a power-law (see Muno et al. 2001, Trudolyubov 2001). A broken power-law represents the 3-300 keV spectra well. During the 3 steady observations high level of radio emission is observed (see Fuchs et al. 2003, Hannikainen et al. these proceedings). The hard X-rays above 20 keV may originate from the jet (as expected see Markoff et al. 2003; Corbel et al. 2003). The spectra of GRS 1915+105, would then fit better in the standard picture of micro-quasars states. Our analysis of the spectra of LFQPOs confirms the presence of a cut-off in their energy dependence (Tomsick & Kaaret 2001; Rodriguez et al. 2002), with an evolving energy from ≈ 15-20 keV in Obs. 2 to a value > 25 keV in the remaining Obs. (Fig. 9).
Figure 2. Left: Simultaneous fitting of RXTE (PCA+HEXTE) and INTEGRAL (ISGRI+SPI), with a simple model consisting of (absorption) multi-colour disc black body + cutoff power-law. The deviation at high energy is clear. Right: High energy (HEXTE+ISGRI+SPI) fit with a simple power-law with $\Gamma \sim 3.5$.

Figure 3. Left: Dynamical power spectrum of a sample of Obs. 1. Right: power spectrum of Obs. 2 showing the strong QPO. Obs. 3 and Obs. 4 have similar power spectra, although in the latter case two different features are found (at different times).
Although the QPO cut-off is needed at some point (otherwise its amplitude would grow indefinitely), its evolution is unclear. It can be easily understood, however, if the jet contributes significantly to the hard X-ray, and its flux is not modulated on such a short time scale.

The fact that a high level of radio emission (at 15 GHz) is found during obs.2, when the cut-off is clearly detected in the QPO spectrum, is compatible with this interpretation. We thus propose that a part of the hard X-ray is emitted by the compact jet, explaining both the spectral behaviour of the source and the QPO “spectra”.

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