Exploring variability in GRS 1915+105 using INTEGRAL, RXTE and radio

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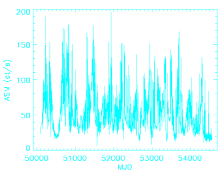
Abstract

GRS 1915+105 is a low-mass X-ray binary hosting a 14-solar mass black hole, which exhibits extreme variability at all wavelengths and is a well-known source of jets. Since March 2003 we have been observing GRS 1915+105 with INTEGRAL. Here we present some of the most recent results - both spectral and temporal - of our monitoring program, especially those for which we have coordinated RXTE and radio coverage. We identify "cycles" of X-ray dips and spikes followed by radio flares and find a possible correlation between the amplitude of the radio flare and the X-ray dip. By performing time-resolved spectroscopy, we show that the ejected medium is probably the coronal material responsible for the observed hard X-rays. We also show results from an observation when the source was in a steady state, in addition to discussing the QPO "spectrum" during this state.

Introduction

GRS 1915+105 has been studied extensively since its discovery in 1992 (Castro-Tirado, Brandt & Lund 1992). It was the first Galactic source to exhibit apparent superluminal motion (Mirabel & Rodriguez 1994). A black hole primary had long been suspected, and Very Large Telescope observations confirmed this, revealing that this X-ray binary hosts a black hole of M (Harlaftis & Greiner 2004). The companion has been identified as being of spectral type K-M III (Greiner et al. 2001), making GRS 1915+105 a low-mass X-ray binary.

Since its launch at the end of 1995, the Rossi X-Ray Timing Explorer (RXTE) has observed GRS 1915+105 extensively.

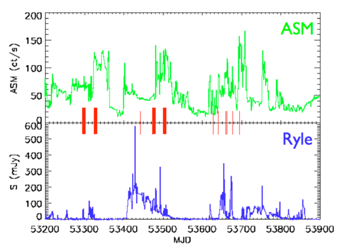


A rich pattern of variability emerged from those data with timescales from years down to 15 ms (e.g. Morgan, Remillard & Greiner 1997). Belloni et al. (2000), analyzing 163 RXTE observations from 1996-1997, classified all the observations into 12 classes (which they labeled with Greek letters) based on count rates and color characteristics. The classes were interpreted as transitions between three basic states, A-B-C, where A and B are softer states, and C the harder state.

We have been conducting a monitoring program on GRS 1915+105 with the European Space Agency's INTErnational Gamma-Ray Astrophysical Laboratory (INTEGRAL) since March 2003. Although the strategy has shifted slightly, the aim remains the same: trying to catch GRS 1915+105 in as many different classes/states as possible. For the large majority of INTEGRAL observations, we also have ground-based radio coverage. In this poster, we show a selection of observations from our monitoring program.

Monitoring GRS 1915+105 with INTEGRAL and RXTE and Ryle

Central to our monitoring program is to try to catch GRS 1915+105 in as many different classes as possible with INTEGRAL. We also had the crucial support of RXTE and the Ryle telescope for radio coverage.



The RXTE/ASM 2-12 keV X-ray and Ryle 15 GHz radio lightcurves. Marked in red are the epochs of some of our INTEGRAL monitoring observations (in bold are the observations dealt with in detail.)

The work in this poster is based on Rodriguez, Hannikainen, Shaw, et al., 2008, 675, 1436 and Rodriguez, Shaw, Hannikainen et al., 2008, 675, 1449

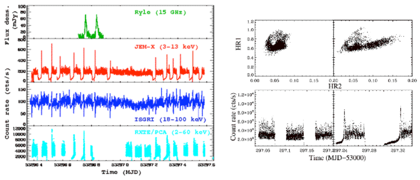
The INTEGRAL observations dealt with in this poster are:

Rev #	Date	Class
246	Oct 2004	ν
255	Nov 2004	λ
305	Apr 2005	χ
315	May 2005	β

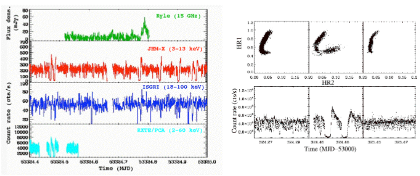
In addition we have noted what class of variability the source mainly was in during the observation.

Dips and spikes in the lightcurves: cycles

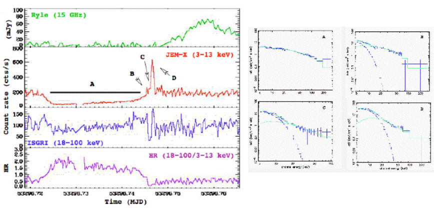
The lightcurves from Rev 246 (ν) and



Rev 255 (λ) and the accompanying color-color diagrams that allowed for the class identification



Decomposing the lightcurves



A zoom of the lightcurves from Rev 246 (ν) and the corresponding JEM-X + ISGRI spectra. The spectra were fit with wabs x (diskbb + comptt). This same procedure - chopping the lightcurve to identify different features for spectral extraction and then fitting the resulting spectrum - was also undertaken for Revs 255 (λ) and 315 (β). The results of the fits (only Rev 246 and 315 tabulated)

Interval	kT^a (keV)	R_{in}^b ($\times R_G/[\cos(i)]^{1/2}$)	kT_e (keV)	τ	χ^2_ν (dof)	Unabs. Fluxes ($\times 10^{-8}$ erg cm^{-2} s^{-1}) 3–50 keV disk	3–50 keV comptt
Rev 246 class ν							
A	0.7 (frozen)	...	33^{+6}_{-4}	0.6 ± 0.1	1.49 (88)	...	1.4
B	1.33 ± 0.09	$12.1^{+2.2}_{-1.7}$	14^{+8}_{-3}	$1.5^{+0.6}_{-0.7}$	1.42 (44)	2.42	1.9
C	$1.5^{+0.3}_{-0.2}$	$7.6^{+2.0}_{-0.6}$	90^{+57}_{-12}	0.01 (frozen)	1.30 (31)	2.66	0.86
D	$2.10^{+0.06}_{-0.07}$	6.2 ± 0.3	110^{+17}_{-14}	0.01 (frozen)	1.52 (68)	7.9	1.5
Rev 315 class β							
A	0.8 ± 0.2	28^{+64}_{-14}	15^{+32}_{-5}	$1.5^{+0.5}_{-1.2}$	1.11 (43)	0.77	1.2
B	0.9 ± 0.4	21^{+100}_{-13}	181^{+65}_{-31}	0.01 frozen	1.20 (39)	0.89	1.6
C	1.5 ± 0.1	$6.2^{+1.2}_{-1.4}$	$> 124^c$	0.01 frozen	1.13 (31)	1.4	0.24

show that

a) the disk approaches the black hole monotonically during the cycles

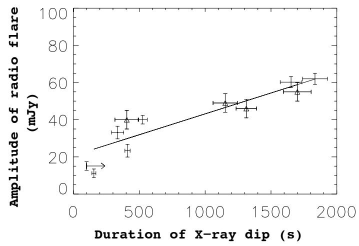
b) the flux of the disk increases throughout the whole sequence

c) looking at Rev 246: the flux of the corona increases from A -> B, decreases from B -> C, then slowly recovers in C -> D

We speculate that Dip C following the precursor spike B indicates the disappearance of the corona, which ultimately constitutes the ejecta

(similar spectral evolution throughout the cycles is seen for Revs 255 and 315)

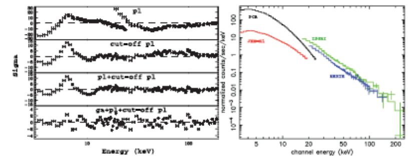
X-ray dip duration vs radio flare amplitude



A positive correlation is found between the duration of the X-ray dip and the amplitude of the subsequent radio flare. One explanation might be that matter and energy, which later emerge as an ejection event, are accumulated during the X-ray dip. Thus, the longer the dip, the more energy and/or matter available for the ejection, and hence the larger the amplitude of the radio flare.

Class χ

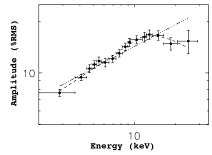
Class χ (Rev 305) corresponds to the hardest steady state of GRS 1915+105. In the radio domain, a relatively bright and steady emission is detected and attributed to the presence of a compact jet (eg Fuchs et al. 2003). We noted that in addition to a Comptonizing component, an extra powerlaw was also needed in fitting the X-ray spectrum (as mentioned in Vadawale et al. 2003)..



The figure shows the residuals in terms of σ between the models used to fit the RXTE spectra. From top to bottom the reduced χ^2 are 25.2 (132 dof), 7.3 (131 dof), 5.5 (129 dof) and 1.8 (126 dof).

The origin of the extra powerlaw is much speculated about, but it could be due the signature of Comptonization on a hybrid thermal/nonthermal population of electrons (eg Poutanen & Svensson 1996). Other scenarios invoke eg the jet as the source of the hard tail.

As expected for this class, a strong low-frequency QPO was detected. This feature is always present when a Comptonizing component in the energy spectrum is also present.



The spectrum of the LFQPO from RXTE data. A good fit is obtained with a powerlaw model with cutoff (dashed line). As the spectrum is not well fit by a pure powerlaw (dashed-double-dotted line), this indicates that the origin of the LFQPO is probably not in the hard tail.

Conclusions

Monitoring with INTEGRAL and RXTE and Ryle has shown that GRS 1915+105 continues to baffle with its bewildering variability. However, intense monitoring has allowed us to distinguish certain patterns in the lightcurves and subsequent spectral analyses show that the ejected material is most probably the Comptonizing medium, ie the corona. An interesting positive correlation between the duration of the X-ray dip and the amplitude of the subsequent radio flare was found.

References

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