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Black Hole Acrobatics: The Somersaults and Backflips of IGR J17091-3624

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Introduction

IGR J17091-3624 and GRS 1915+105 are both galactic Black Hole LMXBs; the former is known to accrete at close to its Eddington limit, and the latter is suspected to also be accreting close to this threshold. Many LMXBs show periodic or quasi-periodic variability in their flux and spectra over time, but IGR J17091 and GRS 1915 are remarkable for the complexity and variety of X-Ray lightcurve patterns they display on timescales of seconds to minutes (see upper panels in Figures 1 and 2). Belloni et al. categorised all RXTE observations of GRS 1915 before 2000 into 12 (later expanded to 14) distinct variability classes, interpreted as being caused by rapid transitions between quasi-stable emission states. These transitions are in turn interpreted as being caused by instabilities in the accretion disk. Many physical models for these instabilities have been proposed, but none are as yet able to explain the full breadth of variabilities seen in GRS 1915.

Here we perform the first model-independent classification of all available observations of IGR J17091 into a full independent set of variability classes. With this framework in place, we can directly compare IGR J17091's behaviour with that of GRS 1915, and thus check that models designed to explain GRS 1915's behaviour are consistent with both objects.

Identifying Variability Classes

To identify variability classes, we created power spectra, lightcurves, Hardness-Intensity Diagrams (HID)s and Colour-Colour Diagrams (CCDs), using standard colours, for every available RXTE observation of IGR J17091. To identify hysteresis patterns in HIDs and CCDs, we folded data from a given observation on a period we inferred from low-frequency peaks in its power spectrum.

Results

In all 256 RXTE observations of IGR J17091, we find 11 distinct variability classes; all of which appear at least broadly consistent with classes seen in GRS1915, with some appearing nearly identical.

We find that hysteretic loops are present in the HIDs of several of these variability classes. In particular, we find a clockwise loop in the HIDs of 18/30 observations of the ρ class, and an anticlockwise loop in the HIDs of 25/38 observations of the ν class (see Figure 1). In the remainder of observations of these variability classes, we were unable to confirm or exclude the presence of loops due to poor statistics associated with the low count rate of IGR.

References

Altamirano, D. *et al.* 2011, ApJ, 742, 17 ● Belloni, T. *et al.* 2000, A&A, 355, 271 ● Neilsen, J. *et al.* 2011, ApJ, 737, 69

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IGR J17091-3624

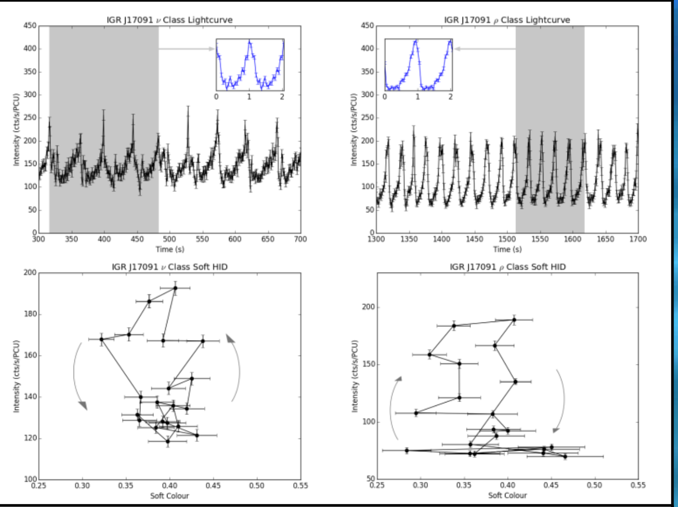

Figure 1: Lightcurves and HIDs for observations of IGR J17091 identified as ρ and ν class. Soft colour is defined as intensity in the 6.5-15keV band divided by intensity in the 2-6.5 keV band. HIDs were created from folded data; the regions folded over are highlighted on the lightcurves and the resultant folded lightcurves are shown in inset.

GRS 1915+105

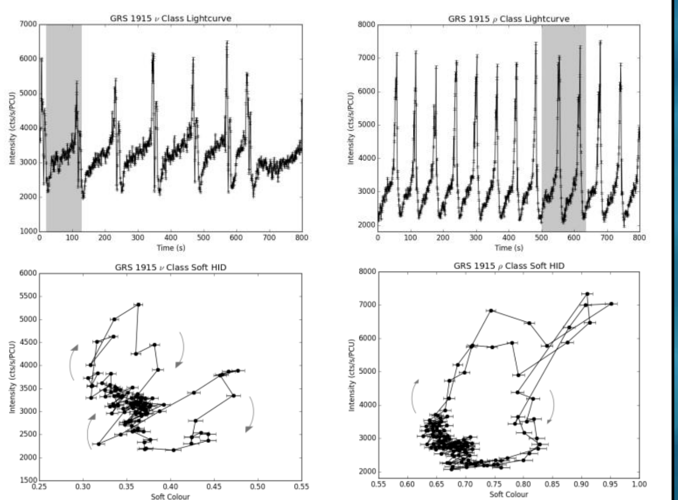

Figure 2: Lightcurves and HIDs for observations of GRS 1915 identified as ρ and ν class. Soft colour is defined as intensity in the 5-10keV band divided by intensity in the 2-5 keV band. HIDs were created the regions of data highlighted on the lightcurves .

Comparison with GRS 1915+150

The first apparent difference between variability classes in GRS and IGR is the direction of the hysteretic loop in the soft HID in the ν class; a variability class present in both GRS 1915 and IGR J17091. **We also find that this loop reversal is absent from other classes:** the ρ class of IGR J17091 shows a HID loop which occurs in the same direction as in GRS 1915.

In all states in GRS 1915 that exhibit HID hysteresis, the loop is executed in the same direction (Figure 2). This is due to a lag between the soft emission, associated with disk winds, and hard emission, associated with jets, in these states (Neilsen et al.). This suggests that fluctuations in the hard emission are caused by fluctuations by the soft emission. However, **the differing HID loop directions in Figure 1 suggest that the hard-soft lag can take both signs in IGR J17091.** This shows either that **different mechanisms drive the seemingly similar ρ and ν variabilities, or that both hard and soft emission are driven by changes in some third parameter.**