A tidal disruption of a planet by a white dwarf

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Globular Clusters (GCs) may host Intermediate Mass Black Holes (IMBHs), namely BHs with mass in the range 10^2 - $10^5\,M_{\odot}$. It is the case of NGC 6388 (Baumgardt et al. 2005), whose center has been examined by many authors (Lanzoni et al. 2007, Nucita et al. 2008, Cseh et al. 2010, Lanzoni et al. 2013). Looking for X-ray signatures in NGC 6388, during August 2011, the new high-energy source IGR J17361-4441 was detected close to the GC center (Gibaud et al. 2011). With the aim to define its position and nature, a series of observations were performed using satellites such as Chandra, Swift and INTEGRAL. In the end, Chandra follow-up revealed that the IGR J17361-4441 was consistent neither with the position of the cluster dynamical center nor with other known X-ray sources. The X-ray luminosity $6-9\times 10^{35}\,erg\,s^{-1}$ implies that the source is classified as a Very Faint X-ray Transient (VFXT) (Wijnands et al. 2011). It was also argued that its nature could be related to a neutron star low mass X-ray binary (LMXB) because of its location in a GC. However, the photon index ($\Gamma\simeq 0.6-1.0$) was atypical for LMXBs in this luminosity range. The IGR J17361-4441 outburst went on until 2011 November 5th when it was no longer observable, so Swift/XRT have followed the target for about 200 days (Bozzo et al. 2012) making IGR J17361-4441 the best sampled event of this class. Analyzing the relevant light curve (Fig. 1), we noticed a $\propto t^{-5/3}$ behaviour which pushed us to consider it as a Tidal Disruption Event (TDE). These events, which result into X-ray and UV transients with possible radio jets, are generally due to the disruption of a star (even giant planet) by a Super-Massive Black Hole (SMBH). Sometimes, TDEs are related to smaller objects such as an asteroid accreting on a white dwarf (WD) (Gänsicke et al. 2006, Farihi et al. 2010).

In our case, we first analyzed Swift/XRT observations performed on the target source for a total exposure time of $\simeq 105\,ks$. The relevant data have been analyzed by using the standard procedures described in Burrows et al. (2005) and the latest calibration files. When necessary, we corrected observations affected by pile-up (source count rates above $\simeq 0.5\,ct\,s^{-1}$) and obtained 32 spectra. The fits were performed with XSPEC and errors calculated at 90% confidence level. We have estimated the 1-10 keV unabsorbed fluxes by fitting the aforementioned spectra with a simple power-law. We fit the light curve with a model constituted by the sum of a constant and an exponential law, and obtain a plateau flux value $F_{max}=(4.1\pm0.1)\times10^{-11}erg\,cm^{-2}\,s^{-1}$ and a knee time of $t_k=36\pm1$ days from the INTEGRAL trigger $MJD^{IBIS}=55784.9479$ (about 5 days before the first XRT follow-up observation). Remarkably enough, after the knee the data were well fit with the typical $\propto t^{-5/3}$ TDE trend.

As already mentioned, we also used the low energy IBIS/ISGRI detector (Lebrun et al. 2003) on board INTEGRAL satellite, processing the observations since 2011 August 11th to October 22nd. So, we got a total of 454 science windows (SCW) and $\simeq 1\,Ms$ total time exposure. We performed the analysis by using the Off-line Scientific Analysis (OSA) v. 10.0 distributed by the ISDC (Courvoisier et al., 2003) and the IBIS SCIENCE ANALYSIS task, extracting images in three energy bands: 18–40, 40–80, 80–150 keV. Even if we assembled the 454 images in groups of 38, 39, 61, 63, 130 and 123 items, a significant signal-to-noise value (above $5\,\sigma$) has been obtained only in the first energy band. We got the errors on the IBIS/ISGRI count rate by the significance (signal-to-noise ratio) in output from the OSA software and extracted an averaged spectrum (about $53\,ks$) relating to the flat part of the XRT light curve.

By analyzing Swift/BAT survey data we found that the IGR J17361–4441 outburst started (in

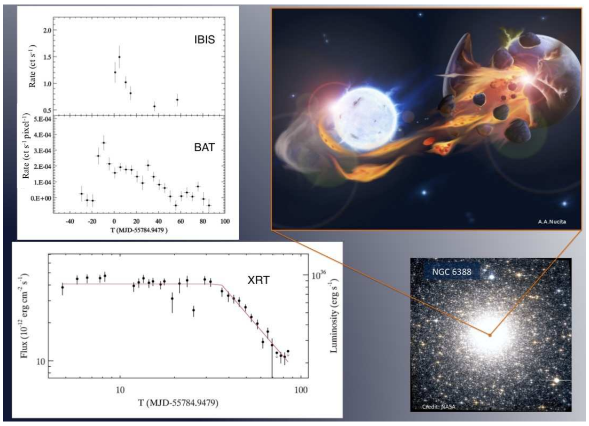

Figure 1. INTEGRAL Picture Of the Month - October 2014 about IGR J17361-4441.

hard X-rays) about 14 days before the INTEGRAL trigger and the event lasted about 99 days, from $MJD^{BAT}_{start} \simeq 55770$ to $MJD^{XRT}_{stop} = 55869.8738$.

When we extended the XRT spectral energy range down to 0.3 keV we added a disc blackbody component to the power-law in order to fit the spectral data. The column density turned out to be $\simeq 0.8 \times 10^{22}\, cm^{-2}$, consistent with that evaluated by Bozzo et al. (2011). We fit the source XRT+IBIS spectrum with a physical model by using a thermal Comptonization model and obtain a bolometric flux (in the range 0.1 - 100 keV) of about $2 \times 10^{-9} erg\, cm^{-2}\, s^{-1}$. Assuming a source distance of 13.2 kpc (Dalessandro et al. 2008), we have estimated the bolometric peak luminosity to be $L_{bol} \simeq 3.5 \times 10^{37}\, erg\, s^{-1}$. The X-ray luminosity L_X of an accreting object corresponds as first approximation to the accretion luminosity $L_{acc} = \epsilon \dot{M} c^2$ (ϵ being the efficiency). So, we evaluated the lower limit of the accreted mass ($M_{acc} \simeq 3.4 \times 10^{23} \epsilon^{-1}\, g$) by integrating the bolometric luminosity over the event duration.

The performed analysis led us to rule out some scenarios, previously proposed, to account for this event. By the way, in spite of its peak luminosity ($L_{2-10keV} = 8.5 \times 10^{35}\, erg\, s^{-1}$) IGR J17361-4441 could not be a VFXT because of its hard X-ray spectrum ($\Gamma \simeq 0.8$) that is unusual for this kind of transient sources. We also excluded the millisecond X-ray pulsar scenario because of the lack of pulsations, the peculiar shape of the light curve and the luminosity whose value was well above the common one. Another rejected possibility was the presence of a BH transient in the hard state in the GC since we identified neither pulsations nor any X-ray (or radio) source in the NGC 6388 gravitational center.

Keeping in mind the constant value of the thermal disc blackbody emission, obtained by fitting the spectra, and the $\propto t^{-5/3}$ slope, we investigated in detail the TDE hypotesis. In such a phenomenon, the accreted mass is half of disrupted object mass which was estimated to be $M_{mb} \simeq 7 \times 10^{23} \epsilon^{-1}\, g$. Following the standard TDE theory, the accretion efficiency turned out to be $\epsilon \simeq 3.5 \times 10^{-4} \left(\frac{M_{\rm Ch}}{M}\right)$, consistent with that expected for a massive WD close to the Chandrasekhar limit. As a consequence, the mass of the disrupted body turned to be $M_{mb} \simeq 1.9 \times 10^{27} \left(\frac{M_{\rm Ch}}{M}\right)\, g$, well within the terrestrial rocky planet mass values.

Finally, although the number of WD and free-floating planets in GCs are uncertain, we have estimated the rate of such a planetary disruption event in NGC 6388 and obtained $\dot{N}_{TDE} \simeq 3 \times 10^{-5}\, yr^{-1}$. Taking into account that there are about 150 GCs in the Milky Way we obtained a total rate of events of about $0.05\, yr^{-1}$, i.e. one every $\simeq 20\, yr$.

This report is based on the paper by Del Santo et al. (2014) to which we refer for more details.

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