IGR J17354–3255 as a candidate intermediate SFXT possibly associated with the transient MeV AGL J1734–3310

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ABSTRACT

We present spectral and temporal results from INTEGRAL long-term monitoring of the unidentified X-ray source IGR J17354–3255. We show that it is a weak persistent hard X-ray source spending a major fraction of the time in an out-of-outburst state with average 18–60 keV X-ray flux of \( \sim 1.1 \) mCrab, occasionally interspersed with fast X-ray flares (duration from a few hours to a few days) with a dynamic range as high as \( \sim 200 \). From archival Swift/XRT observations, we also show that the dynamic range from non-detection to highest level of measured X-ray activity is \( > 300 \). Our IBIS timing analysis strongly confirms the \( \sim 8.4 \) days orbital period previously detected with Swift/BAT, in addition we show that the shape of the orbital profile is rather smooth and appears to be dominated by low level X-ray emission rather than by bright outbursts, the measured degree of outburst recurrence is \( \sim 25 \% \). The spectral and temporal characteristics of IGR J17354–3255 are highly indicative of a Supergiant High Mass X-ray Binary nature (SGXB). However, our inferred dynamic ranges both at soft and hard X-rays are significantly greater than those of classical SGXB systems, but instead are typical of intermediate Supergiant Fast X-ray Transient (SFXTs). Finally, we note for the first time that the observed fast flaring X-ray behaviour of IGR J17354–3255 is very similar to that detected with AGILE from the spatially associated MeV source AGL J1734–3310, suggesting a possible physical link between the two objects.

Key words: X-rays:binaries – X-rays: individual (IGR J17354-3255)

1 INTRODUCTION

IGR J17354–3255 is an unidentified hard X-ray transient discovered with INTEGRAL on April 2006 (Kuulkers et al. 2006, 2007). Its average flux at that time was \( \sim 18 \) mCrab (20–60 keV) and no information is available on the duration of its X-ray activity because it was in the IBIS/ISGRI field of view (FOV) for only a few hours. The source is located in the direction of the Galactic Center, a region extensively monitored by INTEGRAL during the last \( \sim 8 \) years. As a result, IGR J17354–3255 is reported in the latest 4th IBIS catalog (Bird et al. 2010) with a 18–60 keV average flux of \( \sim 1.7 \) mCrab or \( 2.2 \times 10^{-11} \) erg cm\(^{-2}\) s\(^{-1}\) (1.4 mCrab) and on-source exposure of \( \sim 7.6 \) Ms. It is also listed in the 54 months Swift/BAT hard X-ray catalogue (Cusumano et al. 2010) with a very similar average flux of \( 2.1 \times 10^{-11} \) erg cm\(^{-2}\) s\(^{-1}\) (15–150 keV). The Swift broad band spectrum (0.2–100 keV) is typical of accreting neutron stars in High Mass X-ray Binaries (HMXBs), i.e. an absorbed cutoff power law (D’Ai et al. 2011). In addition, timing analysis of the Swift/BAT light curve showed modulation at \( \sim 8.4 \) days which could be interpreted as the likely orbital period of the binary system (D’Ai et al. 2011).

In the soft X-ray band (0.2–10 keV), to date the region of the sky including IGR J17354–3255 was observed twice by Swift/XRT, on 2008 and 2009 (Vercellone et al. 2009, D’Ai et al. 2011). Only during the observation on April 2009 was a single X-ray counterpart detected inside the \( \sim 1.4 \) arcminutes IBIS/ISGRI error circle, suggesting a transient nature. This X-ray source was also detected by Chandra on February 2009 (Tomsick et al. 2009) at a flux level of \( \sim 1.3 \times 10^{-11} \) erg cm\(^{-2}\) s\(^{-1}\), i.e. similar to that also measured by Swift/XRT. The Chandra 0.2–10 keV spectrum was rather hard (\( \Gamma \sim 0.5 \)) and intrinsically absorbed
(N_H \sim 7 \times 10^{22} \text{ cm}^{-2}), supporting a HMXB nature for IGR J17354−3255. It is worth noting that only one bright 2MASS counterpart is located inside the refined Chandra error circle (0.2 arcseconds radius) while there are no catalogued USNO optical objects (Tomsick et al. 2009). The high inferred optical extinction and the relatively high X-ray column density suggest that the source is probably distant and located at least at the distance of the Galactic Center region (∼8.5 kpc).

Finally, the position of IGR J17354−3255 is spatially correlated with that of AGL J1734−3310, an unidentified transient MeV source discovered by AGILE on April 2009 during a flare lasting only one day (Bulgarelli et al. 2009). Although the hypothesis of a physical link between the two objects is intriguing, the large positional uncertainty of AGL J1734−3310 (error radius of 0.65") makes this association rather circumstantial and further in-depth studies are needed.

Here we report for the first time on detailed spectral and timing analysis of INTEGRAL data of IGR J17354−3255. In particular, the INTEGRAL long-term monitoring allowed us to discover 15 new hard X-ray flares and properly study the out-of-outburst X-ray emission. Our findings are crucial to understand the nature of the source and the origin of its X-ray emission. Finally we used all the collected information to investigate the possibility of a physical association between IGR J17354−3255 and AGL J1734−3310 and we discuss any possible major implication stemming from this association.

2 DATA ANALYSIS

For the INTEGRAL study, we used all the public data collected with IBIS/ISGRI (Ubertini et al. 2003, Lebrun et al. 2003) and JEM-X (Lund et al. 2003) from the end of February 2003 to the end of October 2008. In particular, the IBIS (JEM-X) data set consists of ∼7050 (∼602) pointings or Science Windows (ScWs, ∼2000 seconds duration) where IGR J17354−3255 was within 12" (5") from the centre of the instruments FOV. A 12" limit was used because the off-axis response of IBIS/ISGRI is not well modelled at large off-axis angles and in combination with the telescope dithering (or the movement of the source within the FOV) it may introduce a systematic error in the measurement of the source fluxes. IBIS/ISGRI images for each pointing were generated in the energy band 18−60 keV using the ISDC offline scientific analysis software version 7.0. Count rates at the position of the source were extracted from all individual images to produce its long term light curve on the ScW timescale.

In addition, we also used data collected with the BAT and XRT instruments on board the Swift satellite (Gehrels et al. 2004). From the Swift/XRT archive, IGR J17354−3255 was observed on March 2008 and April 2009. Here we present a spectral and temporal analysis, the XRT data reduction was performed according to the processes described in Landi et al. (2010). From the Swift/BAT archive, we downloaded the 15−50 keV light curve of IGR J17354−3255 on daily timescale. After filtering for poor quality data flags, short exposures and low coded aperture fractions, the Swift/BAT light curve covers from April 2009 through May 2011 with an effective exposure time of ∼6.4 Ms.

All spectral analysis was performed using Xspec version 11.3; uncertainties are given at the 90% confidence level for one single parameter of interest.

3 TEMPORAL ANALYSIS

3.1 IBIS/ISGRI

3.1.1 Light curve

We performed a detailed investigation of the 18–60 keV IBIS/ISGRI long-term light curve on ScW timescale of IGR J17354−3255 (total on source time ∼10 Ms) to fully characterize for the first time its temporal behaviour. We found that most of the time the source is not significantly detected at ScW level (2σ upper limit of ∼10 mCrab) and it is well below the instrumental sensitivity of IBIS/ISGRI. This is very likely the reason why the source was not reported in the 2nd IBIS catalog (Bird et al. 2006) despite the region of the sky was observed for a total exposure time of ∼1.6 Ms. On the contrary, the source is listed in the subsequent 3rd and 4th IBIS catalogs (Bird et al. 2007, 2010) with a similar 18–60 (20–40) keV average flux of ∼1.7 mCrab (1.4 mCrab); this is very likely due to the significantly longer time intervals analyzed in the 3rd (∼4.5 Ms) and 4th IBIS catalog (∼7.6 Ms) with respect to the 2nd one.

In addition, we also investigated the IBIS light curve in order to unveil a possible flaring behaviour of IGR J17354−3255. To this aim, we only considered those flares having a peak-flux greater than ∼20 mCrab or 2.6×10^{-10} mCrab.

| N. | peak-date (MJD) | duration (hours) | sig | peak-flux (18–60 keV) (mCrab) | \( \Gamma \) | ref |
|----|----------------|------------------|-----|-----------------------------|-----|-----|
| 1  | 52741.5        | ∼65\( ^\star \) | 9.0 | 25±5                        | 2.0±0.7 | (1.2,15) | 1  |
| 2  | 53051.9        | ∼0.5            | 5.5 | 108±20                      | 2.2±1.9 | (1.2,15) | 1  |
| 3  | 53114.9        | ∼10             | 5.5 | 35±12                       | 2.3±2.0 | (1.2,15) | 1  |
| 4  | 53452.4        | ∼0.5            | 4.2 | 25±6                        |       |       |     |
| 5  | 53602.9        | ∼0.5            | 4.4 | 35±8                        |       |       |     |
| 6  | 53794.6        | ∼0.5            | 5.0 | 25±5                        | 2.6±2.0 | (1.3,15) | 1  |
| 7  | 53813.8        | ∼60             | 5.6 | 27±6                        | 2.2±1.6 | (0.9,15) | 1  |
| 8  | 53829.8        | ∼36             | 6.6 | 30±4                        | 2.6±0.8 | (0.8,15) | 1  |
| 9  | 53846.2        | ∼5\( ^\star \)  | 8.0 | 28±6                        | 2.0±0.7 | (0.8,15) | 2  |
| 10 | 53975.3        | ∼3              | 4.6 | 32±7                        |       |       |     |
| 11 | 53999.7        | ∼1.5            | 5.2 | 30±7                        | 2.1±1.2 | (1.1,15) | 1  |
| 12 | 54012.6        | ∼5              | 4.2 | 40±9                        |       |       |     |
| 13 | 54340.2        | ∼5              | 6.5 | 25±7                        | 2.5±2.0 | (1.01,15) | 1  |
| 14 | 54345.5        | ∼63             | 7.0 | 21±6                        | 3.2±1.9 | (1.2,15) | 1  |
| 15 | 54539.1        | ∼25             | 6.2 | 21±5                        | 2.1±2.0 | (1.2,15) | 1  |
| 16 | 54547.8        | ∼3\( ^\star \)  | 5.7 | 30±6                        | 2.9±1.0 | (0.9,15) | 1  |
erg cm$^{-2}$ s$^{-1}$ (18–60 keV); we adopted such conservative peak-flux threshold for flare recognition for two main reasons: i) it corresponds to a source significance equal to or greater than $\sim 4\sigma$ in the single ScW containing the peak of the flare, ii) to pick up flares bright enough to extract a meaningful ISGRI spectrum. By applying this criterion, a total of 16 X-ray flares have been detected over a total exposure of $\sim 115$ days though not in sequence, as listed in Table 1 together with the date of the peak emission, approximate duration and significance detection of the entire outburst activity, flux at the peak. We note that all but one are newly discovered flares and are reported for the first time, their typical duration is only a few hours (0.5–5 h), however the source occasionally displays X-ray activity over a period of a few days (1–3 d). The typical peak-flux is in a narrow range $\sim 20–30$ mCrab but also brighter flares occur ($\sim 35–45$ mCrab). The strongest as well as shortest outburst (N.2 in Table 1) was detected only during one ScW lasting half an hour. Such fast X-ray transient behaviour is evident from Fig. 1 and 2 which show the IBIS/ISGRI light curve on ScW timescale and the corresponding sequence of consecutive ScWs significance images, respectively. In particular, the inset in Fig. 1 represents a zoomed view with a bin time of 200 seconds, i.e. significantly smaller than that at ScW timescale. The outburst is characterized by two fast flares lasting a few minutes, the strongest one reached a peak-flux of $108\pm20$ mCrab or $(1.41\pm0.26)\times10^{-9}$ erg cm$^{-2}$ s$^{-1}$.

### 3.1.2 Periodicity analysis

In order to search for any evidence of periodicity, we investigated the IBIS long-term light curve of IGR J17354–3255 using the Lomb-Scargle periodgram method by means of the fast implementation of Press & Rybicki (1989) and Scargle (1982). A clear signal is seen at 8.4474 days as shown in Fig. 3. The 99.999% confidence level was defined at a power of 20.214 by using a randomisation test with 200,000 trials, as outlined in Hill et al. (2005), hence the detected periodic signal is the only significant peak within the power spectrum. Using a variant of the randomisation test as outlined in Drave et al. (2010), the error on this peak was calculated as 0.0017 days. We interpret the periodicity of 8.4474±0.0017 days as the orbital period of the binary system, providing a strong confirmation of the result recently reported by D’Ai et al. (2011) with Swift/BAT data.

Fig. 4 shows the phase folded light curve where it is evident a smooth orbital modulation of the flux; it peaks during the periastron passage and becomes consistent with zero around apastron. We note that the feature at phase $\sim 0.5$ is due to the binning and is not taken as being of physical origin. The red crosses indicate the outbursts detected by IBIS (listed in Table 1) within these orbital ephemerides. As clearly evident their occurrence is consistent with the region of orbital phase around periastron. The shape of the orbital profile shown in Fig. 4 is rather smooth and appears to be dominated by lower level X-ray emission rather than by the outbursts. To test this assumption we employed the recurrence analysis technique which searches for periastron detections (Bird et al. 2009) by summing the X-ray emission during each periastron passage within a set window of 3 days (periastron $\pm 1.5$ days). The source could then be detected even though a significant detection is not achieved in the individual ScWs. The same process was performed for each apastron passage and the distributions compared. Fig. 5 shows the recurrence analysis results, there is a clear excess in detections above $3\sigma$ during the periastron passages, corresponding to detectable emission on about 26% of periastron passages covered by the data set. This value is taken as a lower limit as there may still be emission that is occurring during other periastron passages that is below the sensitivity of IBIS/ISGRI. On the contrary no detections above $3\sigma$ are recorded during apastron passages.

Our recurrence analysis suggests that the 16 individual outbursts detected by IBIS/ISGRI cannot explain the smooth shape seen in the phase folded light curve. Assuming a source distance of 8.5 kpc (see section 1) these outbursts all have X-ray luminosities in excess of $10^{36}$ erg s$^{-1}$ and represent the most luminous outburst events. Hence we would not expect these events to define the orbital emission profile over the extent of these long baseline observations. Instead we attribute the shape to lower level emission that is below the instrumental sensitivity of IBIS/ISGRI in an
individual ScW (i.e. ~ 10 mCrab). However when the whole data set, covering about 300 orbital cycles of 8.4 days, is folded this emission sums to a significant detection and reveals the smooth profile shown in Fig. 4. This emission could be either smoothly varying following a similar profile during each orbit or the super position of many low intensity flares at fluxes of ~ \(10^{33} - 10^{35} \text{ erg s}^{-1}\). Such flaring activity was demonstrated occurring in the SFXT IGR J18483–0311 by Romano et al. (2009) who estimated the probability of observing the source in a non-flaring state (i.e. < \(10^{33} \text{ erg s}^{-1}\)) as only ~ 25% through observations covering an entire orbital period with Swift/XRT. Due to the sensitivity limits of IBIS/ISGRI and the different observing strategy however it is not possible to define which of these processes is occurring in this system and draw any conclusions as to the stellar wind configurations that could be responsible for this effect.

3.2 Swift

The 15–50 keV Swift/BAT light curve on daily timescale was inspected searching for outbursts. We considered only those detected with a significance greater than 5\(\sigma\). Only one significant outburst was clearly found (see Fig. 6), peaking at MJD 55145 (10 November 2009) with a flux of \((2.8 \pm 0.54) \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1}\) or ~ 220 mCrab (15–50 keV). The total outburst duration was ~ 6 days, for a significance detection of ~ 6.5\(\sigma\). Swift/BAT observations covered April 2009 through May 2011 and they are not overlapped with those performed by INTEGRAL/IBIS which on the contrary covered February 2003 through October 2008. The apparent incongruence between the number of flares seen by IBIS (16) and BAT (1) in almost the same energy band could be reasonably explained by the significantly different dataset as well as instrumental capabilities. In fact, BAT observations had an effective exposure time of ~ 6.4 Ms which is significantly smaller than that of INTEGRAL/IBIS (~ 10 Ms). In addition, Table 1 clearly shows that about 70% of the outbursts detected by IBIS/ISGRI have typical duration and flux of few hours and 20–40 mCrab, respectively. Longer flares (i.e. few days duration) are rarer. Clearly IBIS/ISGRI is particularly suited to the detection of short events thanks to its high instantaneous sensitivity for short observations on ~ 2000 seconds ScW lengths (i.e. ~ 10 mCrab) which match very well the duration of the flares. On the contrary, BAT is more suited to long-term monitoring thanks to its much more continuous coverage but could eventually miss the detection of shorter flares (i.e. few days duration) which, if close to the IBIS sensitivity, are very likely not detectable by BAT due to its poorer instantaneous sensitivity. In fact, the minimum detectable flux by BAT depends on both the exposure and the position of the source in the sky. For the median BAT pointing duration of ~ 1000 seconds the minimum detectable flux is ~ 60 mCrab. In the daily averages it corresponds to approximately 15 mCrab (Krimm et al. 2006).

Regarding Swift/XRT, the region of the sky including IGR J17354–3255 was observed on 17 April 2009 (~ 5.3 ks exposure). Fig. 4 clearly shows that the observation took...
place during the periastron passage. A single bright X-ray counterpart was clearly detected inside the IBIS error circle (see inset in Fig. 7). The 0.2–10 keV light curve (200 seconds bin time) of this X-ray counterpart is shown in Fig. 7. It is evident that at the beginning the source count rate was very low, after which several fast X-ray flares occurred and the strongest one reached a peak-flux of \(8.7 \times 10^{-11}\) erg cm\(^{-2}\) s\(^{-1}\). Throughout the entire Swift/XRT observation, lasting \(\sim 8\) hours, the source was strongly variable displaying a dynamic range of \(\sim 50\).

4 X-RAY SPECTRAL ANALYSIS

4.1 Flaring activity

4.1.1 INTEGRAL

To date no spectral information above 20 keV on X-ray flares from IGR J17354–3255 has been available. The number of flares reported in Table 1 allows a spectral study for the first time. We were able to extract a meaningful IBIS/ISGRI spectrum only from the flares having a significance detection > 5\(\sigma\). Due to the limited statistics we performed a fit by using only a simple power law model whose spectral parameters are listed in Table 1 (photon index, \(\chi^2_p\), d.o.f.). The photon indices are not well constrained because of the limited statistics, however their best fit values fall in the range \(\Gamma=2\pm3\) and this could suggest a rather constant soft spectral shape from flare to flare. Bearing this in mind and to improve the statistics, the IBIS/ISGRI spectra from all flares were summed up together and fit with a power law model (\(\chi^2_p=1.4\), 15 d.o.f.), providing a much better constrained photon index of \(\Gamma=2.4\pm0.4\) (see Fig. 8, top spectrum).

During just two flares (N. 8 and 9 in Table 1) the source was inside the FOV of the X-ray monitor JEM-X, although for very short time (\(\sim 1\) ks and 0.5 ks, respectively) because of its much smaller FOV with respect to that of IBIS/ISGRI. The source was not detected, providing a loose 3\(\sigma\) upper limit of \(5\times10^{-11}\) erg cm\(^{-2}\) s\(^{-1}\) in both 3–10 and 3–20 keV energy bands.

4.1.2 Swift/XRT

IGR J17354–3255 was detected by Swift/XRT data on 17 April 2009 during an observation lasting \(\sim 5.3\) ks. The X-ray spectrum is best fit by an absorbed power law model (\(\chi^2_p=1.28\), 16 d.o.f.) with \(\Gamma=1.7\pm0.4\) and \(N_H=8^{+4.4}_{-2.6} \times 10^{22}\) cm\(^{-2}\). The expected Galactic absorption along the line of sight is \(1.18\times10^{22}\) cm\(^{-2}\) (Kalberla et al. 2005). The unabsorbed average flux is \((1.6\pm0.14)\times10^{-11}\) erg cm\(^{-2}\) s\(^{-1}\) (0.2–10 keV). In addition, an absorbed black body model gave a reasonable description of the data as well (\(\chi^2_p=1.4\), 16 d.o.f.) with \(kT=1.4^{+0.4}_{-0.3}\) keV and \(N_H=5^{+2.2}_{-1.6} \times 10^{22}\) cm\(^{-2}\). Such spectral parameters are in fair agreement with those previously reported by using the same Swift/XRT dataset (Vercellone et al. 2009, D’Ai et al. 2011).

4.2 Out-of-outburst X-ray emission

4.2.1 INTEGRAL

With the aim of investigating the hard X-ray state of IGR J17354–3255 outside its bright flaring behaviour, we selected all the available ScWs during which the source was within the fully coded FOV of IBIS/ISGRI with a significance value less than 4\(\sigma\) (18–60 keV), i.e. not undergoing a bright outburst. The relative extracted average spectrum (see Fig. 8, bottom spectrum) is fit by a power law with \(\Gamma=2.4\pm0.4\) (\(\chi^2_p=0.6\), 5 d.o.f.). Fig. 8 clearly shows the source spectral constancy in shape, but not in flux, from flaring state (top) to out-of-outburst emission (bottom). The average 18–60 keV flux is \((1.4\pm0.1)\times10^{-11}\) erg cm\(^{-2}\) s\(^{-1}\) or \(1.1\pm0.1\) mCrab, such measurement represents the lowest detectable hard X-ray state of the source to date. When assuming the lowest and highest source flux in outburst, as measured by INTEGRAL/IBIS and Swift/BAT, we can infer a dynamic range in the interval 20–200.

Next, we also used all the available ScWs during which the source was within the fully coded FOV of JEM-X1 and JEM-X2. As in the previous case, we intentionally excluded those pointings during which it was in outburst. A mosaic
JEM-X2 providing a 3σ signification (bottom). Both spectra, fit with a simple power law model, have been rebinned for display purposes.

The significance map was generated in the energy band 3–20 keV, for a total on-source exposure of \( \sim 650 \) ks (JEM-X1) and \( \sim 330 \) ks (JEM-X2). IGR J17354–3255 was not detected by JEM-X2 providing a 3σ upper limit of \( \sim 2 \times 10^{-12} \) erg cm\(^{-2}\) s\(^{-1}\) (3–20 keV). Conversely, it was weakly detected by JEM-X1 at \( \sim 6 \)σ level, likely thanks to the longer time interval analyzed, with an average flux of \( \sim 1 \times 10^{-12} \) erg cm\(^{-2}\) s\(^{-1}\) (3–20 keV). Unfortunately, the insufficient JEM-X statistics did not allow us to extract a meaningful spectrum and light curve of this out-of-outburst state.

### 4.2.2 Swift/XRT

From analysis of archival Swift/XRT data, IGR J17354–3255 was not detected during an observation on 11 March 2008 lasting \( \sim 4.4 \) ks. Fig. 4 clearly shows that it took place very close to the apastron passage. We infer a 3σ upper limit of \( \sim 2.8 \times 10^{-13} \) erg cm\(^{-2}\) s\(^{-1}\) (0.2–10 keV) by assuming the same spectral model as in the Swift/XRT detection on 2009. When considering the highest source flux as measured by Swift/XRT in the same energy band, we can infer a dynamic range > 311.

### 5 ASSOCIATION WITH AGL J1734–3310?

AGL J1734–3310 is an unidentified transient MeV source discovered by AGILE on 14 April 2009 during a flare lasting only one day (Bulgarelli et al. 2009). It was detected at \( \sim 4.5 \)σ level only in the energy band 100–400 MeV with a flux of \( \sim 3.5 \times 10^{-6} \) photons cm\(^{-2}\) s\(^{-1}\) and 95% confidence error circle radius of 0.65 (Bulgarelli et al. 2009). We note that three hard X-ray sources listed in the 4th IBIS catalog (IGR J17354–3255, GX 354–0, 4U 1730–335) are spatially associated with AGL J1734–3310 in view of its large positional uncertainty.

After the discovery of AGL J1734–3310, extensive searches for further flaring gamma-ray emission have been carried out by the AGILE team. As result, several additional MeV flares have been discovered in the AGILE data archive related to the period 2007–2009, all of them have a similar duration (about one day) and gamma-ray fluxes in the range \((1.3–2.3) \times 10^{-6} \) photons cm\(^{-2}\) s\(^{-1}\) (Bulgarelli et al. in preparation, private communication). This clearly shows that AGL J1734–3310 is a recurrent transient MeV source. The sum of all flaring episodes detected by AGILE allowed the determination of a source position centered at Galactic coordinates \( l = 355^\circ 805 \) and \( b = -6^\circ 26 \), with a significance detection of 6.6σ and with statistical and systematic error radius of 0.46 degrees (95% confidence). We note that now IGR J17354–3255 is the only hard X-ray source unambiguously located within such refined AGILE position. This is clearly evident in Fig. 9 which shows the 18–60 keV IBIS/ISGRI significance mosaic map (\( \sim 7.6 \) Ms exposure) of the sky region surrounding IGR J17354–3255 with superimposed the refined positional uncertainty of AGL J1734–3310. Moreover, we point out that IGR J17354–3255 is also the only soft X-ray source (3–10 keV) detected by JEM–X1 (\( \sim 650 \) ks exposure) to be located inside the AGILE error circle. The spatial association between IGR J17354–3255 and AGL J1734–3310 is further strengthened by our reported findings which show for the first time that IGR J17354–3255 occasionally displays hard X-ray flares on short timescale, i.e. a temporal behaviour similar to that observed by AGILE from AGL J1734–3310.

### 6 DISCUSSIONS

In this work we report for the first time detailed temporal X-ray results on IGR J17354–3255. The long-term INTEGRAL monitoring allows us to show that it is a weak persistent hard X-ray source spending a major fraction of the time during out-of-outburst X-ray state with average 18–60 keV flux of \( \sim 1.4 \times 10^{-11} \) erg cm\(^{-2}\) s\(^{-1}\). Occasionally, the source undergoes short flaring activity whose duration ranges from a few hours (0.5–5 h) to a few days (1–3 d) while the peak-fluxes are in the interval \((3–28) \times 10^{-10} \) erg cm\(^{-2}\) s\(^{-1}\) (18–60 keV). Hence, the highest inferred dynamical range is \( \sim 200 \).

In the soft X-ray band (0.2–10 keV), the dynamic range of IGR J17354–3255 from non-detection to highest level of activity is > 311. When active, the source is strongly variable (factor of \( \sim 50 \) on timescales of a few hours.

Our above findings, both at soft and hard X-rays,
strongly resemble those of Supergiant Fast X-ray Transients (SFXTs), a new subclass of supergiant HMXBs discovered by INTEGRAL (Sguera et al. 2005, 2006) and characterized by short and bright X-ray flares on top of longer and fainter periods of X-ray emission level. In this respect, IGR J17354−3255 could well belong to the SFXT class. However, we point out that whereas classical SFXTs have a remarkable dynamical range of $\sim 10^{3}−10^{4}$, we found for IGR J17354−3255 significantly lower values, in the range $21–200$ (18–60 keV) and $>$311 (0.2–10 keV). Although IGR J17354−3255 cannot be considered a classical SFXT, still its dynamical range is significantly greater than that of classical persistent supergiant HMXBs known to display variability of factors lower than $\sim 20$ (Walter & Zurita 2007). Therefore, we suggest that IGR J17354−3255 is an intermediate SFXT system, much like several similar cases reported in the literature (Clark et al. 2010, Walter & Zurita 2007, Sguera et al. 2007).

In addition, our IBIS timing analysis of the source identified an orbital period of 8.4474±0.0017 days, strongly confirming the previous detection with Swift/BAT (D’Ai et al. 2011). The occurrence of the outbursts detected by IBIS is consistent with the region of orbital phase around periastron. The calculated lower limit on the recurrence rate of the source (i.e. detected outbursts when predicted by the $\sim 8.4$ days period) is $\sim 26\%$, this is the second highest value of any known SFXT after that of SAX J1818.6−1703 ($\sim 50\%$, Bird et al. 2009). We suggest that IGR J17354−3255 is a SFXT system similar to SAX J1818.6−1703 (Bird et al. 2009), but with a shorter orbit and a lower eccentricity of $\sim 0.1–0.2$ to account for the reduced recurrence rate. The shape of the orbital profile is very smooth, conversely that of other known SFXTs is sharper. Our recurrence analysis suggests that the sixteen individual outbursts detected by IBIS/ISGRI, which all have X-ray luminosities in excess of $10^{36}$ erg s$^{-1}$ and represent the most luminous outburst events, cannot explain such smooth shape. Instead we attribute it to a lower level x-ray emission that is below the instrumental sensitivity of IBIS/ISGRI in an individual ScW. This emission could be either smoothly varying following a similar profile during each orbit or the super position of many low intensity flares at X-ray luminosities of $\sim 10^{33}−10^{34}$ erg s$^{-1}$. Unfortunately, due to the sensitivity limits of IBIS/ISGRI in such short period, it is not possible to define which of these processes is occurring in this system and draw any conclusions.

We note that the $\sim 8.4$ days orbital period of IGR J17354−3255 is significantly longer than those typical of Low Mass X-ray Binaries ($<0.5$ d) and it is significantly shorter than those of Be HMXBs ($>30$ days). On the contrary, it is more typical of SGXBs (2–12 d) providing further strong support to the hypothesis that the companion donor is a supergiant star. In this respect, only one bright 2MASS counterpart is located inside the Chandra error circle of IGR J17354−3255 while there are no catalogued USNO optical objects. Spectroscopy of this infrared counterpart is essential to fully characterize it. The high inferred optical extinction and the relatively high X-ray column density suggest that IGR J17354−3255 is located at a relatively large distance, i.e. near the Galactic Center region (d=8.5 kpc). If we assume such a distance, then the source displays typical outbursts X-ray luminosities of $10^{36}−10^{37}$ erg s$^{-1}$ (18–60 keV) while its lowest X-ray luminosity state is $<2.4\times10^{33}$ erg s$^{-1}$ (0.2–10 keV). Such values are very similar to those of known firm SFXTs.

Our deep INTEGRAL significance mosaic maps both at soft (3–10 keV) and hard X-rays (18–60 keV), combined with a refined AGILE positional uncertainty, revealed that IGR J17354−3255 is the only X-ray source unambiguously located inside the error circle of the unidentified transient MeV source AGL J1734−3310. This spatial association is enforced by our temporal findings which unveiled for the first time the recurrent X-ray flaring behaviour of IGR J17354−3255 on short timescale (from few hours to few days), i.e. a characteristic similar to that observed with AGILE from AGL J1734−3310. We took into account the possibility of a chance coincidence and to this aim we calculated the probability of finding a supergiant HMXB, such as IGR J17354−3255, inside the AGILE error circle by chance. Given the number of supergiant HMXBs detected by IBIS within the Galactic plane (Bird et al. 2010), defined here as restricted to a latitude range of $\pm 5$ degrees, we estimated a probability of $\sim 1\%$, i.e. $\sim 0.5$ chance coincidences are expected.

It is noteworthy that the possible association between IGR J17354−3255 and AGL J1734−3310 might not be a unique and rare case. So far three HMXBs (LS 5039, LSI +61 303, PSR B1259−63) have been unambiguously detected both at MeV and TeV energies as persistent and variable sources, where the variability is modulated by the orbital period (Paredes et al. 2008, Hill et al. 2010). In addition, the two HXMBs Cygnus X-3 and Cygnus X-1 have been detected at MeV energies as transient sources displaying fast flares with a short duration of a few hours/days (Sabatini et al. 2010, Tavani et al. 2009, Abdo et al. 2009). Different theoretical models have been proposed to explain the emission mechanism at such high energies in HMXB systems (Bosch-Ramon et al. 2006, Paredes et al. 2006, Romero et al. 2003, 2005, Maraschi & Treves 1981, Tavani & Arons 1997). Similarly, SFXTs have all the ingredients to possibly be MeV/TeV emitters since they host a compact object (black hole or neutron star) and a massive supergiant star which could be the source of seed photons (for the inverse Compton emission) and target nuclei (for hadronic interactions). However, due to their transitory nature, MeV/TeV emission from SFXTs must be in the form of fast flares which are not easy to detect. Despite this, a few SFXTs have been proposed in the literature as best candidate counterparts of unidentified transient MeV sources located on the Galactic Plane (Sguera et al. 2009a, 2009b). In this respect, we propose the candidate intermediate SFXT IGR J17354−3255 as best candidate counterpart of AGL J1734−3310. Although we are aware that the reported evidences are so far circumstantial, the eventual confirmation of a common nature would have very major implications: the SFXTs could represent a new class of MeV/GeV emitting Galactic transients. To this aim, further and deeper multiwavelength studies of IGR J1734−3255 and AGL J1734−3310 are strongly needed especially in radio and at gamma-rays. In particular, a periodicity analysis of the MeV emission from AGL J1734−3310 is essential to support a secure identification with IGR J1734−3255. These kind of temporal studies can be performed by the current gamma-ray instrumentations, such as Fermi/LAT or AGILE, as amply proved by the LAT detections of periodic MeV emission from several HMXB systems.
systems (e.g. Hill et al. 2010). On-going regular and frequent scannings of the Galactic Bulge and Plane with INTEGRAL, together with observations from Fermi/LAT and AGILE, could likely shed new light on the proposed association.

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