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IGR J17361-4441: a possible planetary tidal disruption event unveiled in NGC 6388

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2011 August 11th (Gibaud+11): a new hard X-ray source was discovered by INTEGRAL/IBIS with $F_{20-40\text{keV}} = 7 \pm 1$ mCrab

Swift/XRT follow-up (Wijnands+11): refined position consistent with the centre of the globular cluster NGC 6388, very flat X-ray spectrum with $\Gamma \approx 0.6-1.0$, luminosity peak of $L_X = 6-9 \times 10^{35}$ erg/s

Is an Intermediate Mass Black Hole responsible for this emission?
Multi-wavelength follow-up

ATCA ToO (Ferrigno+11; Bozzo+11): lack of radio emission, rms noise level of 19.0 μJy @ 9 GHz (4x10^{28} \text{ erg s}^{-1} \text{ @8.5 GHz})

Chandra revealed that the position was not consistent with the gravitational centre of the cluster (Pooley+11).
A possible Very Faint X-ray transient

- X-ray sources in Globular Clusters are most-likely Low Mass X-ray Binaries with Neutron Star
- X-ray binaries with luminosity peak as $L_X=10^{34}-10^{36}$ erg/s are Very Faint X-ray Transients (VFXT)

IGR J17361-4441 was proposed being a LMXB with NS accreting at very low rate (Wijnands+11)
Flat X-ray spectra are unusual in LMXB-NS which show X-ray spectra with indices of 1.6-2.2.

No type-I bursts nor pulsation have been detected in IGR.

NS transients show (usually) quiescent luminosities of about $10^{32-33}$ erg s$^{-1}$ (Rea+11) higher than the upper limit of IGR (few $10^{31}$ erg s$^{-1}$).
Moreover the BH binary nature seemed unlikely

- Based on the fundamental plane (Merloni+03; Kording+06), the radio flux upper limit would imply a BH mass lower than solar (Ferrigno+11)
- Only a few stellar-mass black hole survive in GC since most of them are likely ejected through dynamical interactions.
- VFXT with BH show X-ray spectra with $\Gamma \approx 1.5-2$ (Armas-Padilla+13)
The light curve can be well represented by a plateau ($t_k=36\pm1$ d) plus a $\propto t^{-5/3}$ law ($\approx50$ days).
BAT data indicated that the event was started at least 14 days before the discovery.

Total duration $\approx 100$ days
**Spectral behaviour**

XRT spectra fit with disc black-body + power-law

\[ \Gamma \text{ increasing} \]

\[ kT_{\text{in}} \text{ almost constant } \approx 0.08 \text{ keV} \]

XRT+IBIS spectrum in the plateau is well fit by disc black-body + cutoff power-law (\( \approx 40 \text{ keV} \))

A flat slope: \[ \Gamma = 0.8 \pm 0.1 \]
Hints for a Tidal Disruption Event?

There are two empirical evidences that point in this direction:

1. The XRT light curve declines as $\propto t^{-5/3}$
2. Thermal emission component does not evolve significantly with time

Which kind of object was captured and tidally disrupted, and by what?
Tidal Disruption Events (TDE)

Star tidally disrupted by a SMBH

Tidal field of the BH exceeds the star's self-gravity

Half of the original stellar debris falls back onto the hole, half escapes on a hyperbolic orbit

IGR J17361-4441 lies in a Galactic Globular Cluster at 13.2 kpc
While in the Solar System comets fall directly onto our Sun, if the star is a compact object, the minor body can be tidally disrupted.

‘Christmas’-ray burst (GRB 101225A10) can be explained by a tidal disruption event of a minor body around a Galactic isolated neutron star (Campana+11).

The presence of heavy elements in the 4% of White Dwarfs atmospheres originates from disrupted rocky bodies such as asteroids or minor planets.

Ex.: White Dwarf G29-38 (Gänsicke+06)
TDE scenario for IGR J1736

- $L_{\text{Bol}} \approx 3.5 \times 10^{37} \text{ erg s}^{-1}$
  - $M_{\text{acc}} = 3.4 \times 10^{23} \varepsilon^{-1} \text{ g}$

- Mass of the disrupted object $M_{\text{mb}} \approx 7 \times 10^{23} \varepsilon^{-1} \text{ g}$

- Fall-back time $t_{\text{min}} \approx 68 \text{ days}$

$$t_{\text{min}} = \frac{C^2 \pi}{212} \left( \frac{M}{M_{\text{mb}}} \right)^{1/2} \sqrt{\frac{3}{4\pi G \rho}}$$

$$\approx 1.4 \times 10^4 \left( \frac{C}{2} \right)^3 \left( \frac{M}{M_{\text{Ch}}} \right)^{1/2} \varepsilon^{1/2} \text{d},$$

- $t_{\text{min(\text{obs})}} = t_{\text{min(\text{theory})}}$ (Rees et al. 1998; Lodato et al. 2009)

- $\varepsilon \approx 3.5 \times 10^{-4} (M_{\text{Ch}}/M)$ accretion efficiency of a WD close to the Chandrasekhar limit

- $M_{\text{mb}} \approx 1.9 \times 10^{27} M/M_{\text{Ch}} \text{ g}$ (Terrestrial-icy planetary regime)
1. WD density in GC is estimated in the range $10^4$–$10^5$ pc$^{-3}$ (Raskin+09, Ivanova+06).

2. Free Floating Planets density could exceed $10^6$ pc$^{-3}$ (Soker+01) up to $10^8$ pc$^{-3}$ (Fregeau+02, Hurley&Shara 2002, Ida+03).

3. The NGC 6388 core radius is 0.5 pc (Lanzoni+07) and the star velocity dispersion $\sigma_{\text{star}} = 13$ km/s (Lanzoni+13).

4. $\sigma_{\text{pl}} \approx 2.5 \sigma_{\text{star}}$

5. Cross section of the interaction $\Sigma = \pi r_i^2 \left( 1 + \frac{2GM}{\sigma_{\text{pl}}^2 r_i} \right)$

\[ \dot{N}_{\text{TE}} \simeq \frac{4\pi r_c^3}{3} N_{\text{FFP}} N_{\text{WD}} \Sigma \sigma_{\text{pl}}, \]

Soker+01; Binney&Tremaine08

\[ \dot{N}_{\text{TE}} \simeq 10^{-6} - 10^{-4} \text{ yr}^{-1} \]
• Found a 100 mHz quasi-periodic oscillation in the X-ray emission (0.6-12 keV)
• Confirmed the soft thermal component ($kT_{in} \approx 0.08$ keV)

Similar to Dwarf Novae Oscillations (DNOs)
Motion of material close to the inner boundary of the accretion disk surrounding a WD
Conclusion

✓ Based onto two empirical evidence, we proposed a TDE nature for IGR J1736

✓ The disrupted object mass is of the order of a third Earth mass, while the compact object is a WD to the Ch. limit

✓ In the optimistic case the rate of such TDEs is $10^{-4}$ yr$^{-1}$

✓ Considering 150 globular clusters into the Galaxy, the total rate of this kind of events is one every 20 years

✓ This is comparable with the lifetime of INTEGRAL and Swift

Thanks for your attention