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

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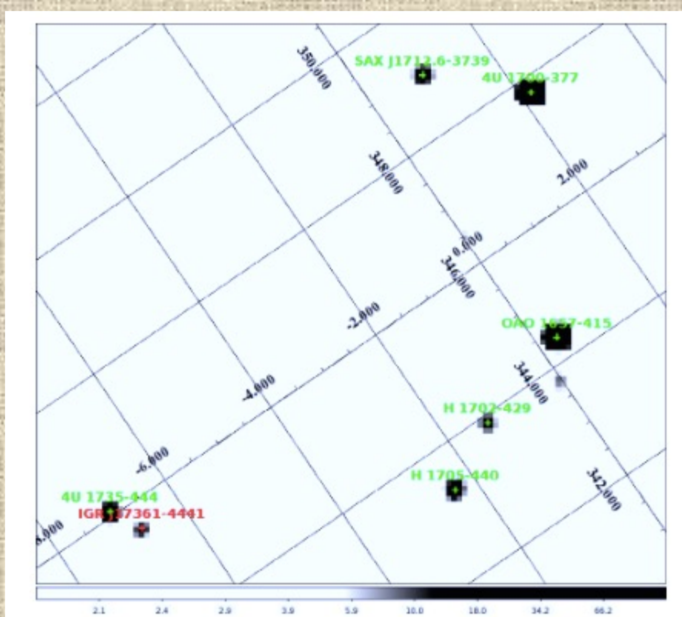
IGR J17361-4441: a new INTEGRAL source in NGC 6388



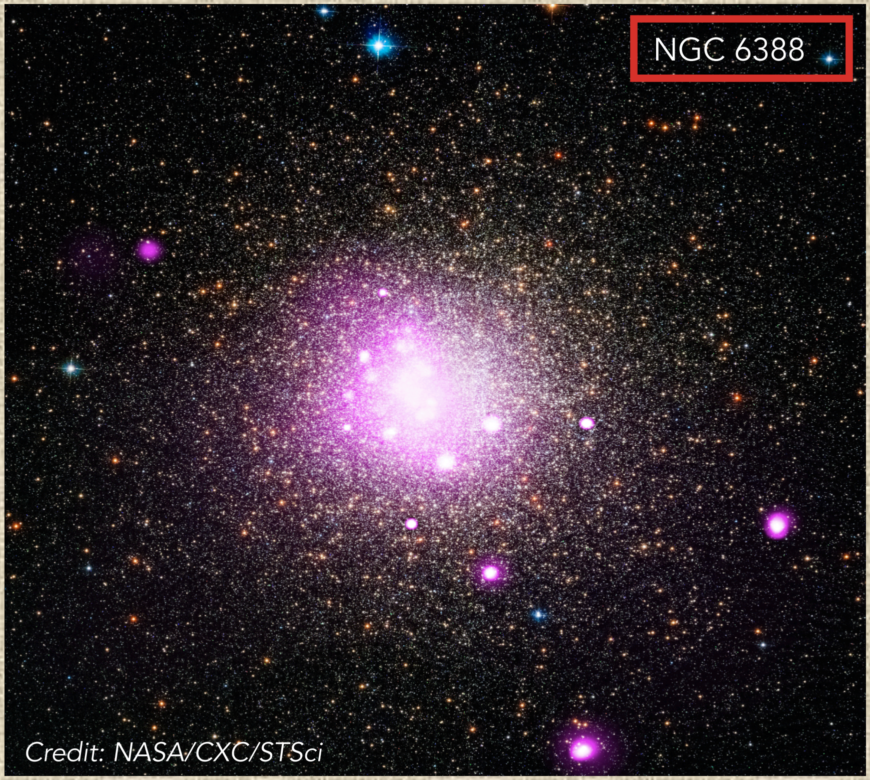
- **2011 August 11th** (Gibaud+11): a new hard X-ray source was discovered by INTEGRAL/IBIS with $F_{20\text{-}40keV}$=7±1 mCrab

- Swift/XRT follow-up (Wijnands+11): refined position consistent with the centre of the globular cluster **NGC 6388,** very flat X-ray spectrum with **Γ≈0.6-1.0**, luminosity peak of **L_X=6-9x10^{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 (4×10^{28} erg s^{-1} @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)

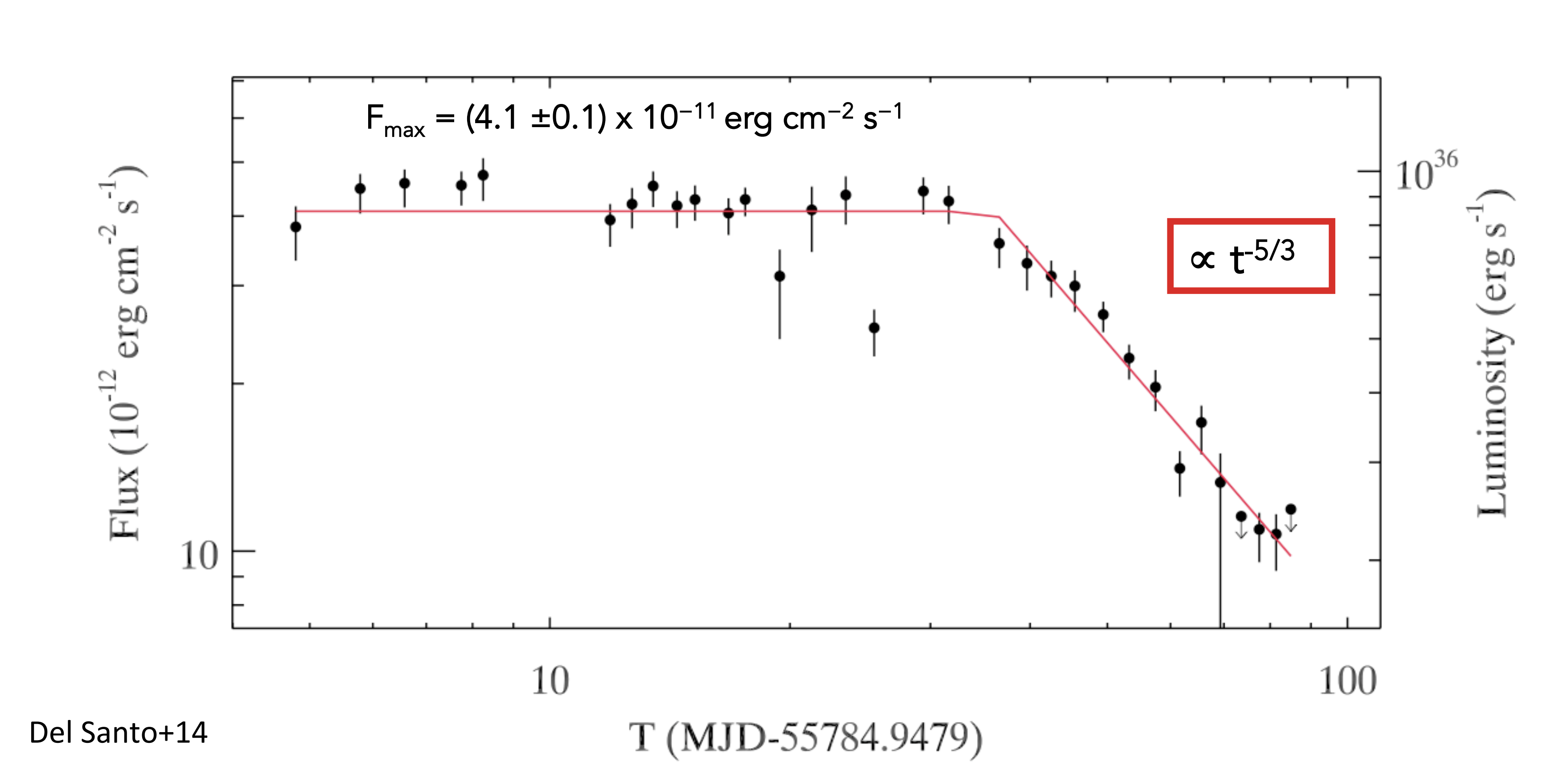
Doubts…

- ✓ 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})

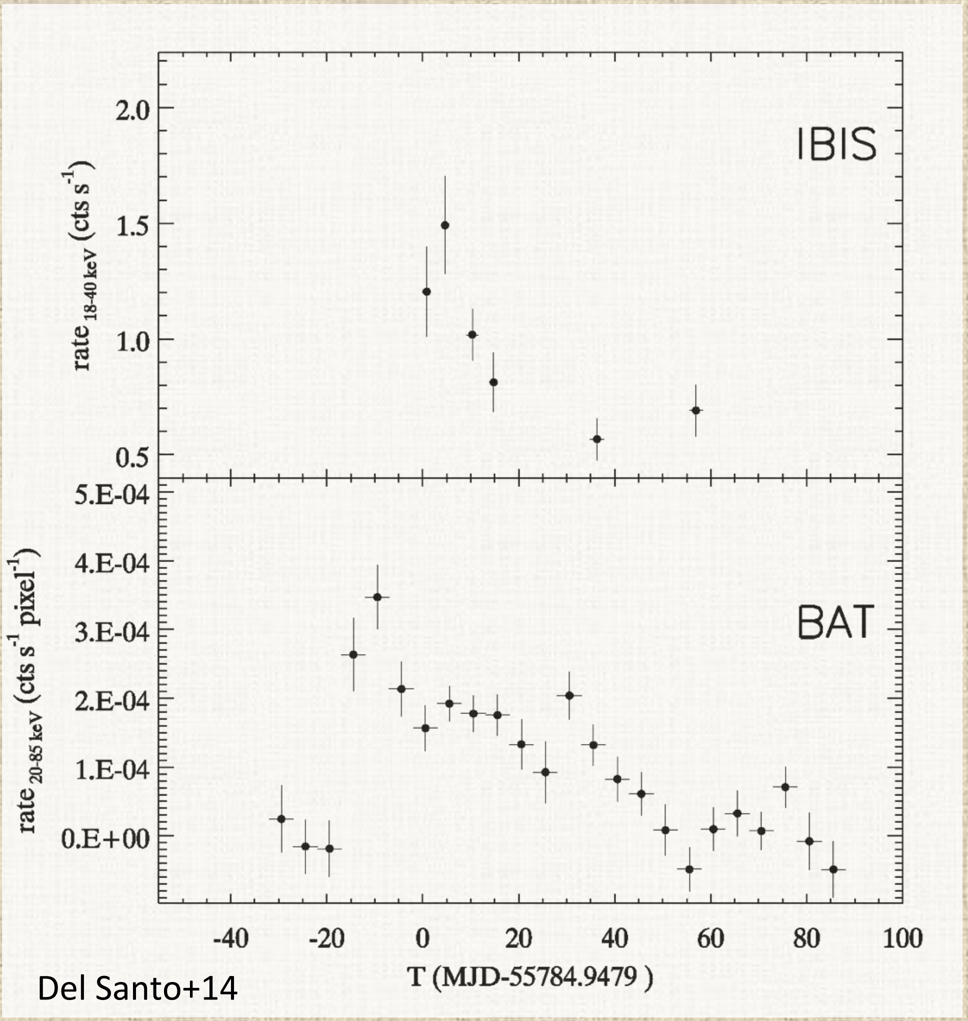
Moreover the BH binary nature seemed unlikely

- ✓ 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 XRT luminosity evolution



The light curve can be well represented by a plateau (t_k=36±1 d) plus a $\propto t^{-5/3}$ law (≈50 days).



BAT data indicated that the event
was started at least 14 days before the discovery.

Total duration ≈ 100 days

Spectral behaviour

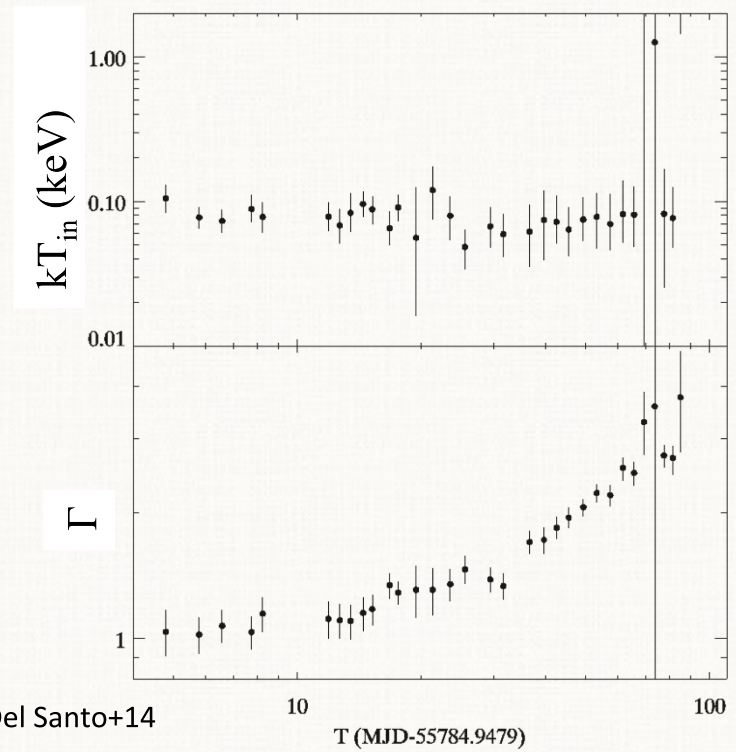
XRT spectra fit with disc

black-body+power-law

Γ increasing

kT_{in} almost constant ≈ 0.08 keV

Del Santo+14



Del Santo+14

XRT+IBIS spectrum in the plateau is well fit by

disc black-body + cutoff power-law (≈40 keV)

A flat slope: Γ = 0.8 ± 0.1

Hints for a Tidal Disruption Event?

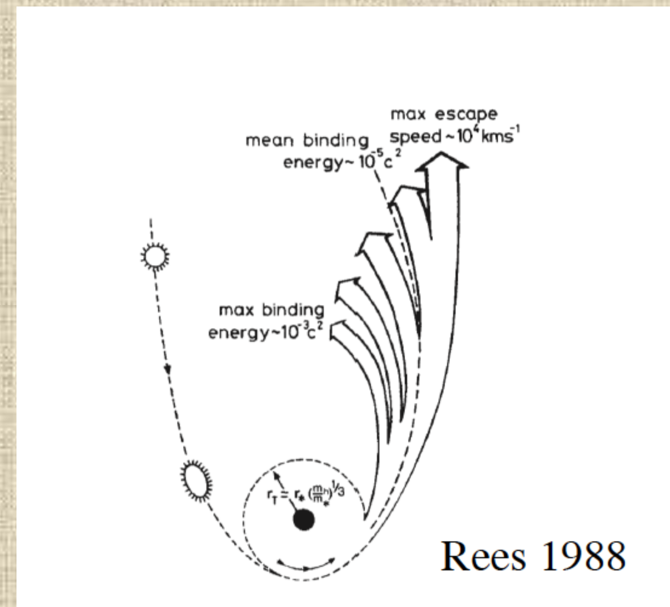
There are two empirical evidences that point in this direction:

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

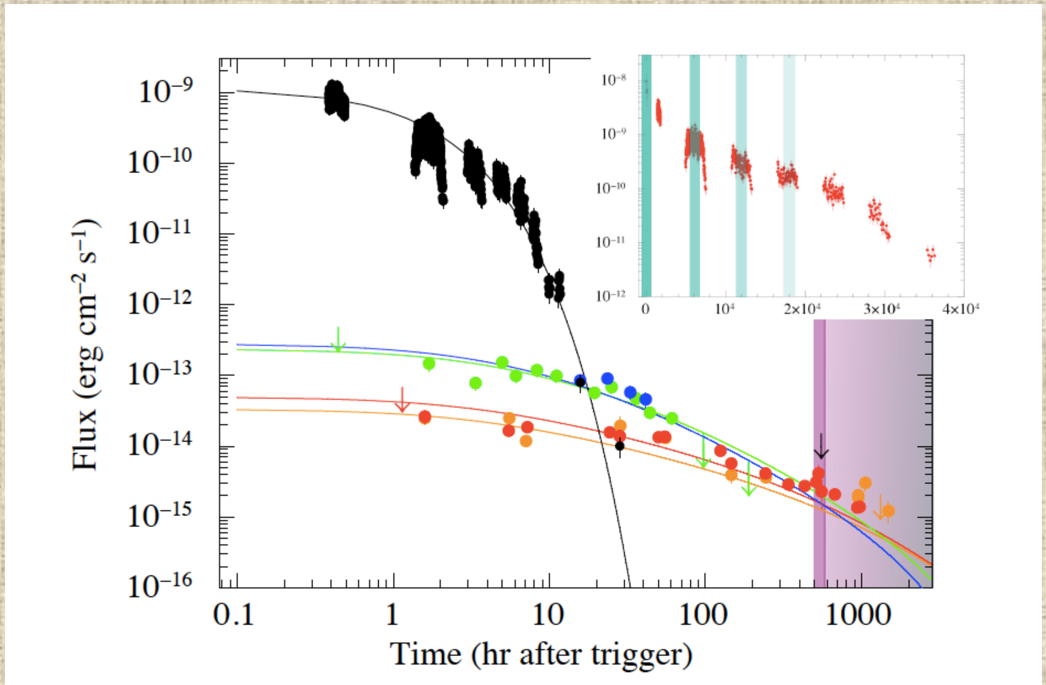
Half of the original stellar debris falls back onto the hole, half escapes on a hyperbolic orbit

IGR J17361-4441 lies in a Galactic Globular Cluster at 13.2 kpc

Tidal Disruption of minor body

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

- $L_{Bol} \simeq 3.5 \times 10^{37}$ erg s^{-1} ⇨ $M_{acc} = 3.4 \times 10^{23}\ \varepsilon^{-1}$ g
- Mass of the disrupted object $M_{mb} \approx 7 \times 10^{23}\ \varepsilon^{-1}$ g
- Fall-back time $t_{min} \approx 68$ days

$$t_{min} = \frac{C^3\pi}{2^{1/2}}\left(\frac{M}{M_{mb}}\right)^{1/2}\sqrt{\frac{3}{4\pi G\rho}} \approx 1.4 \times 10^4 \left(\frac{C}{2}\right)^3 \left(\frac{M}{M_{Ch}}\right)^{1/2} \epsilon^{1/2} \mathrm{d},$$

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

- $\varepsilon \approx 3.5 \times 10^{-4}\ (M_{Ch}/M)$ accretion efficiency of a WD close to the Chandrasekhar limit
- $M_{mb} \approx 1.9 \times 10^{27}\ M/M_{Ch}$ g (Terrestrial-icy planetary regime)

The planetary TDE rate

$$\dot{N}_{\mathrm{TE}} \simeq \frac{4\pi r_{\mathrm{c}}^3}{3} N_{\mathrm{FFP}} N_{\mathrm{WD}} \Sigma \sigma_{\mathrm{pl}},$$

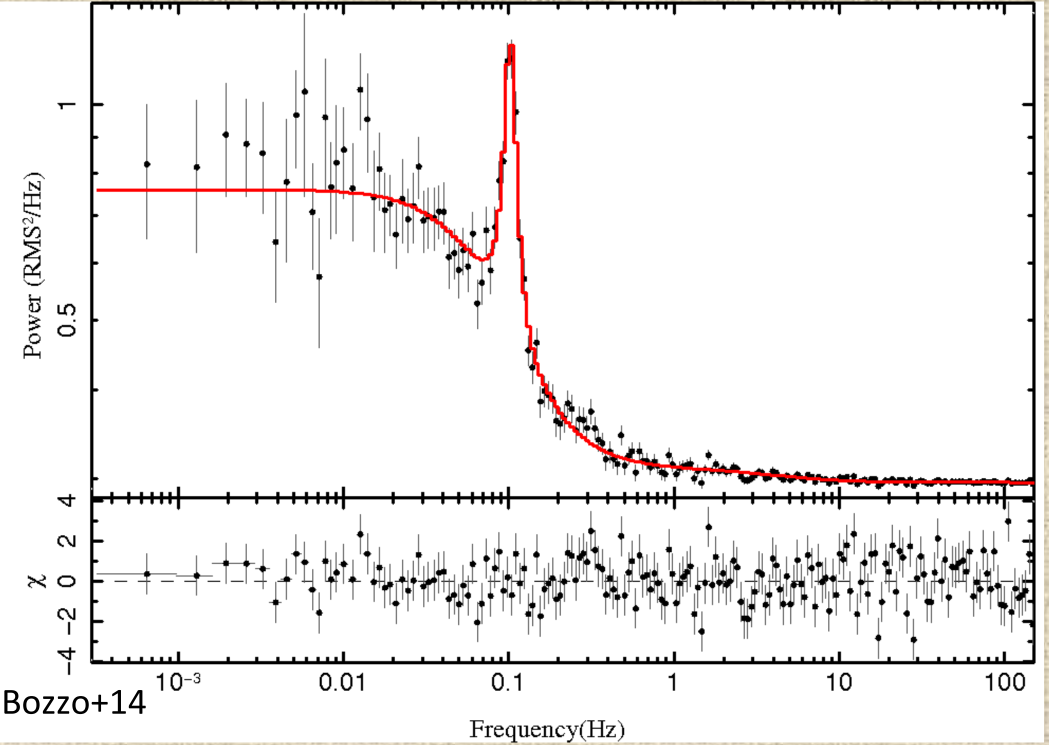
Soker+01; Binney&Tremaine08

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 σ_{star}=13 km/s (Lanzoni+13)
4. $\sigma_{pl} \approx 2.5\ \sigma_{star}$
5. cross section of the interaction $\Sigma = \pi r_t^2 \left(1 + \frac{2GM}{\sigma_{pl}^2 r_t}\right)$

$$\dot{N}_{\mathrm{TE}} \simeq 10^{-6}\text{–}10^{-4}\ \mathrm{yr}^{-1}$$

XMM-Newton Power Density Spectrum

- 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)



Bozzo+14

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