Tidal disruption event in NGC 4845

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In January 2011, INTEGRAL discovered a hard X-ray flare (IGR J12580+0134) in the centre of NGC 4845, a Seyfert 2 galaxy never detected at high-energy previously. The flare was seen around 6 months and it was also observed by XMM-Newton, Swift satellites and MAXI detector onboard ISS. Analysis of light-curve of the source points out the tidal disruption event by supermassive black hole (BH) of an object with a mass of 14-30 Jupiter. It could be a giant planet or a brown dwarf. The hot corona has been observed. The variable flux may suggest appearing of an quasi-periodic oscillation (QPO).

1 Observations

The hard X-ray flare was discovered by INTEGRAL satellite during an observation performed in the period January 2-11, 2011. A few days later, a position of the flare was determined based on the *Swift* and *XMM-Newton* observations. Both observations were performed on January 12-13 and 22, 2011, respectively. The source was associated to NGC 4845. Observations made by MAXI covering $\sim$ 1 year and by *Swift* taken on June 29, 2012, were added. IGR J12580+0134 was detected at a peak flux higher by a factor of $\sim$ 100 than an intrinsic diffuse emission of NGC 4845, and showing a flux variability with a factor $>$ 100, which is very unusual for a Seyfert 2 galaxy. NGC 4845 was observed in 1980 using *Einstein* satellite (Fabbiano et al., 1992). The authors estimated only 3σ upper limit in the 0.2-4.0 keV energy band of $\nu F_\nu(0.2-4.0\mathrm{keV}) < 2.5 \times 10^{-13}$ erg cm^{-2} s^{-1}.

2 Analysis

We extracted the *XMM-Newton* Epic-pn light-curves of the flare in the 0.1-2 keV (soft) and 2-10 keV (hard) energy band with time bins of 10s. We also performed analysis of its spectrum in the wide range 0.1-80 keV using INTEGRAL, Swift, and *XMM-Newton* observations. The source emits mainly the hard flux than the soft X-ray flux. Mean count rate equals to $\sim$6 versus 0.3 cts/s, respectively. The hardness ratio HR = (hard - soft)/(hard + soft) does not show any significant variability in time of the observation. It suggests that the spectral shape does not vary with flux on short-time scales. The spectrum could be fitted by an absorbed power law and the diffuse emission of the host galaxy. A common fit of the INTEGRAL/ISGRI and *XMM-Newton*/Epic-pn data could be obtained, leading to the column density $\mathrm{N_H} = (7.39 \pm 0.10) \times 10^{22}\mathrm{cm}^{-2}$, the photon index $\Gamma = 2.22 \pm 0.03$, the flux $\nu F_\nu(2-10\mathrm{keV}) = (6.09 \pm 0.02) \times 10^{-11}$ erg cm^{-2} s^{-1}, and $\nu F_\nu(17.3-80\mathrm{keV}) = (5.41 \pm 0.02) \times 10^{-11}$ erg cm^{-2} s^{-1} (see Nikołajuk & Walter, 2013, for details).

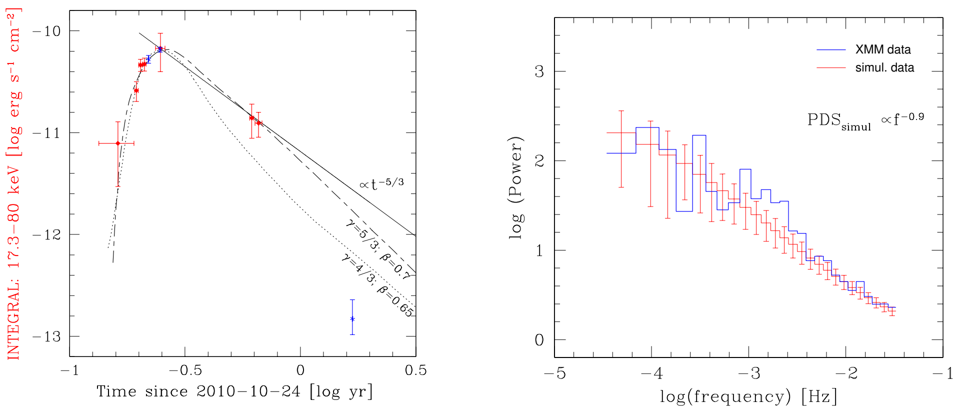

Fig. 1: (Left panel): The light-curve of the flare observed in the 17.3-80 keV energy band. Red squared points refer to INTEGRAL data, blue crosses show *Swift* and *XMM-Newton* observations. The solid line show a model of the form $t^{-5/3}$. The long-short dash and dotted lines indicate the predictions of simulations for the disruption of a sub-stellar object ($\gamma = 5/3$; $\beta = 0.7$) and, respectively of a star ($\gamma = 4/3$; $\beta = 0.65$). (Right panel): The 19.1 ks *XMM-Newton* power spectrum (blue histogram) versus simulated 10 000 powers with a slope of -0.9 (red histogram with error bars). An excess in the observed power near frequency $= 10^{-3}$ Hz may suggest a presence of the QPO.

The mass of the supermassive black hole in NGC 4845 can be estimated using the X-ray excess variance method (Nikołajuk et al., 2006). The fast variable flux of the source and the mean value of the normalized excess variance ($\sigma^2_{\rm nxs} = 0.12$) indicate the BH mas equals to $2.3^{+1.1}_{-1.0} \times 10^5 M_\odot$. The errors, related to the red noise leak and aliasing, are larger and the black hole mass could range in the interval $10^4 - 10^6 M_\odot$.

3 Tidal disruption event

The fast and large increase of the hard X-ray luminosity occurred in inactive X-ray galaxy points out the tidal disruption event (TDE). The hydrodynamic simulations of tidal disruptions were performed by Guillochon & Ramirez-Ruiz (2013). We compare our data to the simulations. We assume that the disrupted object is either a star or a sub-stellar object with polytropic index $\gamma = 4/3$ and $5/3$, respectively. The simulations gives as a result the decline in the flux, the mass of the disrupted object, $M_\star$, and the impact parameter, $\beta = r_{\rm T}/r_{\rm P}$, where $r_{\rm T}$, and $r_{\rm P}$ are the tidal and the pericentric radii, respectively.

The observational constraints such as the time from the initial tidal disruption to the peak accretion, and the peak accretion rate, are sufficient to constrain the mass of the disrupted object. For a black hole mass of $2.3 \times 10^5 M_\odot$, the mass $M_\star$ is either 14-16 $M_{\rm Jupiter}$ (for $\gamma = 5/3$) or $10 - 15 M_\odot$ (for $\gamma = 4/3$). The later is very unlikely when someone compares the simulated decline of the flux with observed data (see Fig.1, left panel). For a black hole mass increasing to $10^6 M_\odot$, the mass $M_\star$ = 25-28 $M_{\rm Jupiter}$ (up to 75 $M_{\rm Jupiter}$ in the case of $10^7 M_\odot$) for a sub-stellar object. Regardless of how massive the BH in NGC 4845 would be the tidally disrupted object is not a main sequence star. The object was a giant planet or a brown dwarf. This is the first notice of the tidal disruption of a low massive object by BH.

The observed by INTEGRAL peak luminosity $L_{\rm peak} = 1.5 \times 10^{42}$ erg s^{-1}. Most of luminosity of a tidal disruption event is expected to be released in the soft X-rays. Up to today, the hard X-rays were only seen in three TDEs (excluding IGR J12580+0134). In all three cases, we have a production of the relativistically beamed jets, and therefore, the brightening of the source. The isotropic luminosity is higher than 10^{47} erg s^{-1}, whereas the luminosities of TDEs without jets are in the range 10^{41}-10^{45} erg s^{-1}. It would be theoretically possible to have a jet production and see low luminosity, however, the observer should look at the flare with high inclination and the bulk Lorentz factor $\Gamma \gtrsim 20$. A typical value of Γ inferred from VLBI measurements is around 10 (Vermeulen & Cohen, 1994) and for TDE Swift J164449.3+573451 is around 2 (Zauderer et al., 2011). Therefore, we suggest that the hard X-ray emission in IGR J12580+0134 should come from a corona forming around the accretion disc.

4 Quasi-periodic oscillation

The power spectrum density (PSD) spectrum of the X-ray light-curve shows an excess in the range 0.001-0.005 Hz (see Fig.1, right panel). This frequency corresponds to the innermost stable circular orbit (ISCO) around a black-hole of $3 \times 10^5 M_\odot$. The coincidence is not larger than 5% that this excess is formed by chance for power law or broken power law shaped PSD. Low time resolution of the Epic-pn detector could not corroborate the QPO presence. Longer and more sensitive X-ray observations are needed to follow the last moments of a super-Jupiter's life.

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