A new class of transient flares in Super Massive Black Holes

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The variability of active galactic nuclei in the ultraviolet and optical range is usually at a level of few tens of per cent. Recently, we discovered two transient events located in the centers of galaxies, OGLE17aaj and AT 2017bgt, which showed much more dramatic increase of flux. The optical spectra of these flares exhibit a mix of emission features. Some are typical of luminous, unobscured active galactic nuclei, but others are most likely driven by Bowen fluorescence. The optical spectral features and increased ultraviolet flux show little evolution over a period of at least a year. This disfavors the tidal disruption of a star by the super-massive black hole and other extreme types of active galactic nuclei variability identified in the past. These two objects, together with another similar events, F01004-2237 and Gaia19axp, make a new class of Super Massive Black Hole-related flares.

1 Introduction

In the centers of probably all galaxies reside Super Massive Black Holes (SMBH), with masses over $10^5\,\mathrm{M}_\odot$. Their interaction with the surrounding results in a rapid and energetic burst of emitted energy. A variety of flaring mechanisms have been proposed to explain these events, which range from supernovae, changing-look active galactic nuclei (CL-AGN; e.g. LaMassa et al., 2015), extreme AGN flares of unclear nature (e.g. Graham et al., 2017), or tidal disruption events (TDE, e.g. Arcavi et al., 2014). Here, we present a short history a new class of SMBH-related flares proposed in Trakhtenbrot et al. (2019).

2 F01004-2237

In September 2015, Tadhunter et al. (2017) obtained a spectrum of an ultra-luminous infrared galaxy (URLIG) marked as F01004-2237. This spectrum showed substantial difference when compared with the archival spectrum from 2002 obtained with the Hubble Space Telescope (HST). The emission lines were stronger and a strong double-peaked He II line appeared, which was quite unusual for an AGN, but often seen in TDEs. The examination of the light curve from the Catalina Sky Survey showed a flaring event in 2010. Its maximum corresponded to absolute magnitude $M_\mathrm{V} < -20$ mag. Mass of the black hole was estimated to $M_\mathrm{SMBH} \approx 2 \times 10^7\ \mathrm{M}_\odot$.

The host galaxy showed an intensive star formation and a signature of a population of young and massive Wolf-Rayet (WR) stars in around $10^4\,\mathrm{M}_\odot$ in the central bulge. Synthetic spectrum for a large population of WC- and WN-type Wolf-Rayet stars and a blue-shifted He II component, claimed to originate from the Narrow Line Region (NLR) of AGN, fit very well to the HST spectrum. The 2015 spectrum

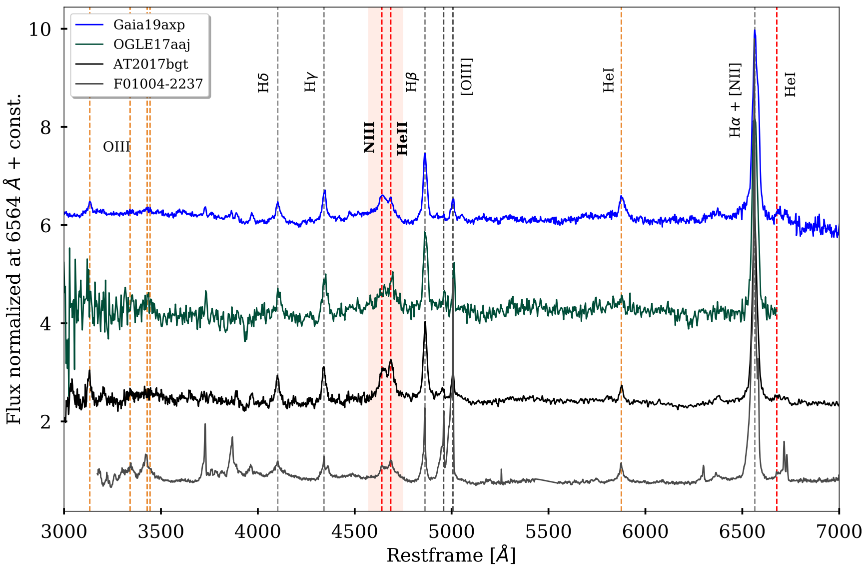

Fig. 1: The comparison of spectra of all known cases of AT 2017bgt-like events (aka Trakhtenbrot events). Spectra of all objects but F0100-2237 were taken close to the maximum of their light curves. Spectrum of F0100-2237 was taken around five years after the maximum. Horizontal dashed lines mark significant emission lines.

required an additional He II component with FWHM $\sim$ 6000 km s^{-1}. Tadhunter et al. (2017) interpreted this as a TDE which happened in 2010. They ruled out the CL-AGN because they do not show highly exited He II line. This explanation seemed reasonable, despite the fact that all TDEs exhibited much more broad He II emission lines. Soon after that publication other examples of such narrow He II line events were discovered (Fig. 1).

3 OGLE17aaj

In the beginning of 2017 nuclear transient OGLE17aaj was discovered by the OGLE-IV Transient Search (Wyrzykowski et al., 2014). The spectrum taken with ESO/NTT close to the peak resembled the spectrum of F01004-2237 from five year after its maximum (Gromadzki et al., 2017). The host galaxy of this transient was definitely not an ULIRG, without the enormous number of WR stars and therefore the interpretation of Tadhunter et al. (2017) did not work in this case. SMBH masses in both events were almost identical, but the absolute magnitude of OGLE17aaj was about two magnitudes fainter. Systematic photomeric and spectroscopic follow up in UV and optical range showed that an initial evolution was quite rapid - objects reached its maximum within 60 days and UV photometry suggested maximum temperature of 4×10^4 K. After the peak the light curve evolution slowed down, the brightness decreased slightly (temperature decreased to 2×10^4 K) and the light curve showed a low-level AGN-like typical fluctuations. Due to a relatively large distance (z = 0.116) there was no detection in the X-ray (Gromadzki et al., 2019). Light curves of all discussed events are presented in Fig. 2.

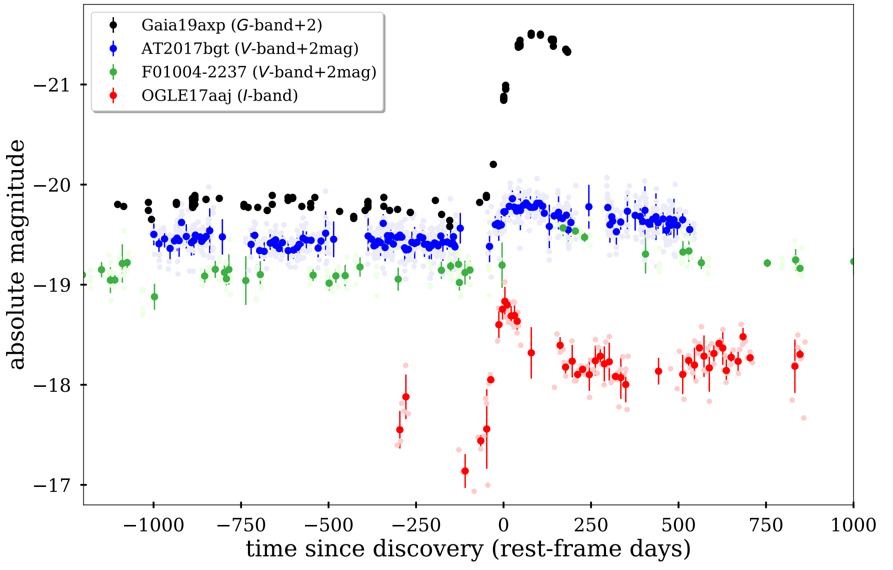

Fig. 2: The comparison of light curve evolution of all currently known AT 2017bgt-like events.

4 AT 2017bgt

Just a month later in February 2017 next transient was found, AT 2017bgt, discovered by the ASAS-SN project (Stanek, 2017). This was the closest of such type of transients discovered until now ($z = 0.064$). Object was also the brightest, which allowed for a detailed multi-band data from X-ray to near-IR (Trakhtenbrot et al., 2019).

Evolution of the light curve was very slow and similar to the two previous cases. It resembled more a jump in to a higher activity level than a classical flare. During over 2 years the spectrum did not change significantly and its light curve declined very slowly. In X-rays the object showed a photon index $\Gamma \sim 2$ and an increase in flux by more than 50 compared to the historical detection. Near-IR spectrum was very similar to an AGN spectrum with addition of a narrow He II line.

Most important part of this study was the identification of N III and O III emission lines. Their FWHM suggested that they originated from Broad Line Region (BLR) of the AGN and were produced by Bowen fluorescence mechanism proposed already by Netzer et al. (1985). In the Bowen mechanism the Ly-α photons from He II λ303.789 excite certain states of O III and N III. The excited states lead to a cascade of transitions, which can be observed as prominent emission lines in UV-optical regime. This effect can be particularly strong in O III λ3133, N III λ4640 and He II λ4686 emission. This mechanism is well established in planetary nebulae but has been rarely seen in AGNs. The mass of the SMBH was similar as in previous cases to around $\sim 2 \times 10^7$ $M_\odot$ but the absolute magnitude at V-band at peak was brighter at -21.3 mag.

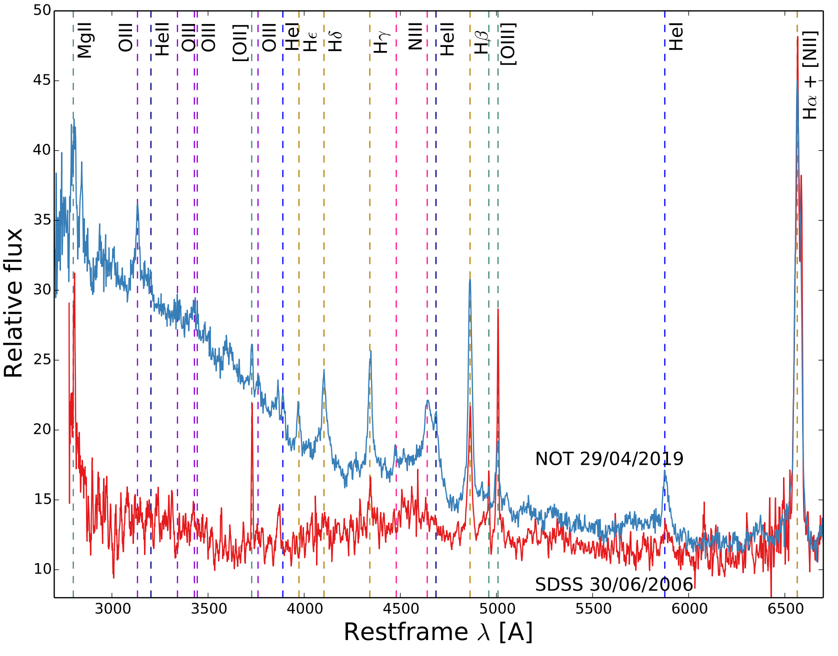

Fig. 3: The comparison of the archival SDSS (red) and peak NOT (blue) spectra of Gaia19axp.

5 Gaia19axp

In March 2019 we identified a new member of the Trakhtenbrot class in an event discovered by the Gaia Science Alerts system (Delgado et al., 2019), Gaia19axp/AT 2019brs. This one is the most distant and the brightest of all, with $z = 0.37$ and $M_{\rm V} = -22.3$ mag. Thanks to the high redshift we can see the Bowen cascade and UV excess which are shifted to the optical range (see Fig.3). Detailed analysis of this transient will be presented in Ihanec et al. (in prep.).

6 Summary

Detection of Bowen fluorescence in AGNs indicates that the Bowen cascade is triggered by a sudden X-ray/UV flare which then illuminates BLR matter, but the details of this mechanism are still mysterious. Distribution of released energy at maximum peak is quite wide $M_{\rm V} \sim -18.3 \div -22.3$ mag but masses of SMBHs are very similar in all four known events ($\sim 2 \times 10^7$ M$_\odot$). AGN component of the optical spectra in all cases could be classified as NLSy1 and photometric and spectroscopic evolution also look similar. Despite many unanswered questions, the four transients reported here form a new class of SMBH-related flares. Although, number of objects in this class remains low and new discoveries are needed.

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