The nuclear transient AT2017gge: a TDE in a dusty and gas-rich environment

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Abstract

We present the results from a dense and long-lasting multi-wavelength (X-ray, UV/Optical and NIR) follow-up campaign of the TDE AT2017gge, covering 1698 days from the transient's discovery. A soft X-ray flare is detected with a delay of ~200 days with respect to the optical/UV peak and it is rapidly followed a number of spectroscopic features, including long-lasting high ionization coronal emission lines. This indicate for the first time ***a clear connection between a TDE flare and the late-time appearance of extreme coronal emission lines***. An IR echo, resulting from dust re-radiation of the optical/UV TDE light is observed after the X-ray. The associated near-IR spectra show a transient broad feature in correspondence of the He I λ10830 and, for the first time in a TDE, a transient high-ionization coronal NIR line (the [Fe XIII] λ10798) is also detected. The data are well explained by a scenario in which a TDE occurs in a gas and dust rich environment and its optical/UV, soft X-ray, and IR emission have different origins and locations. The optical emission may be produced by stellar debris stream collisions prior to the accretion disk formation, which is instead responsible for the soft X-ray flare, emitted after the end of the circularization process. The emitting region of the observed broad lines is consistent with a symmetric and stratified photosphere and an absorbing dust with a covering factor of ~0.2 surrounds the whole system, masking a large proportion of the UV radiation emitted by the TDE.

The importance of Tidal Disruption Events (TDEs)

When an unlucky star wanders too close to a supermassive black hole (SMBH) it is ripped apart by the strong tidal forces. In this process, approximately half of the stellar material streams back to the SMBH, building a new accretion disc (Strubbe & Quataert 2009 ; Lodato & Rossi 2011) and powering a tidal disruption events (TDEs; Hills 1975 ; Rees 1988). These transient phenomena represent an important tool to study dormant low-mass SMBH, otherwise not detectable. Multiwavelength monitoring campaigns represents a crucial instrument to identify and characterize TDEs and have revealed an intriguing and puzzling diversity in their observational properties (Arcavi+14; Leloudas+19; Onori+19 Saxton+20; vanVelzen +20; Gezari 2021).

The TDE Nature of AT2017gge

AT2017gge was first detected on 2017 August 3 (MJD 57968.35) by ATLAS (Tonry et al. 2018) with a discovery magnitude of o=18.70±0.17. The transient is located at 0.1 kpc from the center of the spiral galaxy SDSSJ162034.99 + 240726.5, classified as star-forming galaxy at z = 0.0665. A mid-infrared (MIR) flare in the WISE light curve of has been reported (Jiang+21).

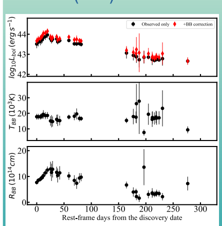

Figure 1 *Top:* Evolution of the bolometric luminosity during the first 300 from the discovery; *Middle:* Black body (BB) temperature evolution; *Bottom:* BB radius evolution.

The results from our analysis, such as the bolometric light-curve, the BB temperature and radius evolution (**Figure 1**) , the broad (FWHM~10^4 km/s) H and He emission lines and their time evolution (**Figure 2**), are all consistent with a TDE nature

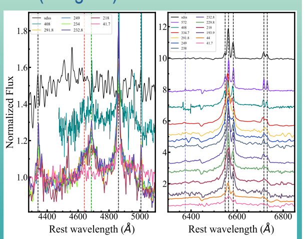

Figure 2: Sequence of normalized spectra starting from 42 d from the TDE discovery for the Hβ and Hα region (left and right, respectively). Vertical black dashed lines show the main emission lines (O, H, [N II] and [S II]). Red and green dashed lines indicate the position of the Bowen lines at 4640Å and the He II λ4686, respectively. Grey dashed line shows the position of the coronal emission line [Fe X] λ6374.

Based on the detection of very broad Hβ and Hα emission lines and on the delayed appearence of a broad HeII λ4686 emission line, we classify AT2017gge as a H-rich TDE (TDE-H) in transition toward the H + He TDE (TDE H + He) subclass.

Swift detection of a delayed X-ray flare in AT2017gge

Despite what is expected in the case of emission from a newly formed accretion disc, TDEs selected in the optical are typically not detected in the X-rays. Only few exceptions have been discovered, with some events showing also a soft X-ray, sometimes delayed with respect to the optical peak (e.g ASASSN-14li, ASASSN-15oi, AT2019dsg, AT2018fyk, AT2019qiz, AT2019azh; Holoien+16; Gezari+17 ; Wevers+19; Nicholl+20; Cannizzaro+21; Liu+22). These discoveries have led to questions about the origin of the TDE emission mechanism and the properties of the emitting regions. Different theoretical scenarios have been proposed, which are still under debate (Piran+15; Guillochon+14; Metzger & Stone 2016; Dai+18).

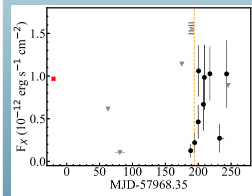

Figure 3: The X-ray light curve in the 0.3–10 keV band from the XRT observations. The grey triangles represent upper limits. The orange vertical dashed line indicates the first detection of the broad He II λ4686 emission lines in the optical spectra. The pre-transient upper limits from the RASS observations are shown with a red cross.

AT2017gge was monitored by Swift for ∼200 d, starting from ∼60 d after the TDE discovery. We detected a transient X-ray flare with a delay of ∼200 d with respect to the UV/optical peak emission, followed by the development of a broad He II λ4686 and by high ionization coronal emission lines (**Figure 3, Figure 2, Figure 7, Figure 8**). The X-ray spectral analysis show a good agreement with an accretion disc model (**Figure 4**).

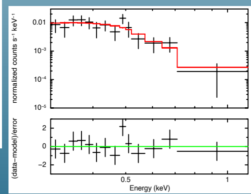

Figure 4: Swift /XRT spectrum extracted from deep stacked data (∼22 ks, by combining 17 observations). The result using the *TBABS∗ZASHIFT∗DISKBB* model is shown (red solid line). Bottom: residuals with respect to the model.

A two-process scenario for the AT 2017gge emission

The results from the UV/optical and X-ray analysis suggests a different origin for the two signals. The AT2017gge emission is well described by a scenario where the optical emission is produced by the collision of intercepting stellar debris streams during the initial phase of the stellar disruption, while the X-ray flare is emitted following the formation of an accretion disc, after the end of the circularization process (**Figure 5**).

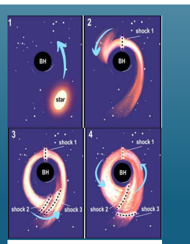

Figure 5: Toy model for the TDE emission adapted from Liodakis+23

The delayed MIR echo and the appearence of the NIR Coronal Emission Line

The interaction of the TDE flare with the host galaxy's environment can result in reverberation signals such as IR echoes and transient long-lasting high ionization coronal emission lines (Lu+16; van Velzen+16; Jiang+21), which trace the circumnuclear hosting environment and can be used as additional discovery channels. Indeed, recent findings suggest that some TDEs are expected to be so highly dust enshrouded that they could have remained out of the reach of optical or X-ray surveys due to the large column densities of obscuring dust and gas (Reynolds+22). Furthermore, the detection of transient extreme coronal emission lines in the spectra of a sample of non-active galaxies as been explained as a possible signature of the occurrence of a TDE in the past (i.e. extreme coronal lines emitting galaxies (ECLEs); Komossa+08; Komossa+09;Wang+12).

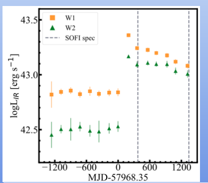

Figure 6: WISE W1 and W2 MIR light curves for AT 2017gge, covering a range of ∼2400 d around the transient's discovery. Grey dashed vertical lines indicate the phase at which IR SofI spectra have been taken.

In AT2017gge, a MIR flare is detected in the WISE light-curves with a delay of ∼200 d from the optical peak (**Figure 6**), corresponding to a distance of the dust of ∼0.16 pc, as derived in this work by using two cross-correlations methods. This value is similar to the sublimation radius obtained for the TDE PTF-09ge (van Velzen+16) and suggests that AT2017gge may have sublimated the pre-existing in situ dust out to this radius. A covering factor of ∼0.2 (Wang+22) for this surrounding absorbing dust suggests that a large portion of the TDE UV radiation could still be unobserved.

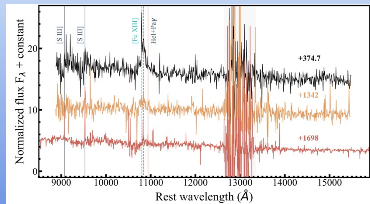

Figure 7: Rest-frame NIR spectra of AT 2017gge taken with SofI at two different epochs from the transient's disco v ery (374.7 and 1342 d, respectively) in comparison with the NIR X-shooter spectrum taken at 1698 d. The detected emission lines are indicated by vertical lines.

For the first time in a TDE, we present a spectroscopic follow-up in the NIR band (**Figure 7**). A broad component (FWHM~7600 km/s) in the He I λ10830 and the high ionization coronal emission line [Fe XIII] λ10798 are detected. The spectral sequence show their transient nature.

The detection of high ionization coronal emission lines in a TDE

Our dense and long lasting follow-up campaign of AT2017gge have revealed the formation of transient high ionization coronal emission lines in the optical and NIR spectra (**Figure 7**; **Figure 8**). This is the first time that the these features are observed in a TDE. Their appearence soon after the X-ray outburst and in a star-forming hosting galaxy strongly indicates a close connection between the two phenomena and a gas-rich hosting environment. Furthermore, this finding strongly supports the hypothesis that the extreme coronal line emitter (ECLE) galaxies may have indeed experienced a TDE in the past.

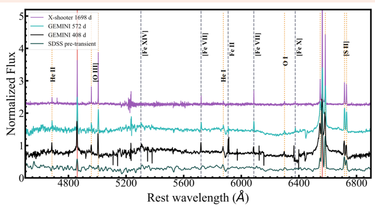

Figure 8: Comparison between the SDSS spectrum of AT 2017gge host galaxy taken before the transient first detection (in grey) and the late-times Gemini and X-shooter spectra taken at days 408, 572, and 1698 (black, cyano, and purple, respectively).

AT2017gge: the suggested picture

A TDE occurred in a dusty and gas-rich environment, in which the UV/optical emission is produced by the collision between intercepting streams of stellar debris during the initial phase. After ∼200 d, the circularization ends and a newly formed accretion disc released a soft X-ray flare. The emitting region of the broad lines is consistent with a symmetric and stratified photosphere. Finally, placed at ~0.16 pc, an absorbing dust surrounds the whole system with a covering factor of ∼0.2.

Scan me!

Onori, Francesca et al., 2022, MNRAS, 517, 76; arXiv:2206.00049;

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