The nuclear transient AT 2017gge: a tidal disruption event in a dusty and gas-rich environment and the awakening of a dormant SMBH

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ABSTRACT

We present the results from a dense multwavelength [optical/UV, near-infrared (IR), and X-ray] follow-up campaign of the nuclear transient AT 2017gge, covering a total of 1698 d from the transient’s discovery. The bolometric light curve, the blackbody temperature and radius, the broad H and He I λ5876 emission lines and their evolution with time, are all consistent with a tidal disruption event (TDE) nature. A soft X-ray flare is detected with a delay of ~200 d with respect to the optical/UV peak and it is rapidly followed by the emergence of a broad He II λ4686 and by a number of long-lasting high ionization coronal emission lines. This indicates a clear connection between a TDE flare and the appearance of extreme coronal line emission (ECLs). An IR echo, resulting from dust re-radiation of the optical/UV TDE light is observed after the X-ray flare and the associated near-IR spectra show a transient broad feature in correspondence of the He II λ10830 and, for the first time in a TDE, a transient high-ionization coronal NIR line (the [Fe XXII] 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 disc formation, which is instead responsible for the soft X-ray flare, emitted after the end of the circularization process.

Key words: black hole physics – galaxies: active – galaxies: nuclei – infrared: galaxies – X-rays: galaxies – transients: tidal disruption events

1 INTRODUCTION

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 is expelled in unbound orbits, while the rest streams back to the SMBH and circularize to form a new accretion disc (Strubbe & Quataert 2009; Lodato & Rossi 2011). These tidal disruption events (TDEs) manifest themselves as a luminous, short-lived, flares coming from the nuclei of otherwise quiescent galaxies (Hills 1975; Rees 1988; Evans & Kochanek 1989; Phinney 1989) and represent an important tool to study the properties of dormant SMBHs. The emission usually peaks in the UV/optical or in soft X-rays and the bolometric luminosity is expected to follow the bound debris fallback rate, with a power-law decline α r−5.0 on the time-scale of months to years (e.g. Evans & Kochanek 1989; Cannizzo, Lee & Goodman 1990; Rees 1990; Lodato, King & Pringle 2009).

The first TDE candidates were discovered in the X-rays (Komossa & Bade 1999), but thanks to the development of wide-field optical surveys dedicated to the search of transients, the population of observed TDEs has quickly grown and the optical band has become the main discovery channel. Multwavelength monitoring campaigns represents a crucial instrument to identify TDEs among nuclear flares and have revealed an intriguing and puzzling diversity in the observational properties (see the reviews from Saxton et al. 2020; Gezari 2021). The optical spectra are characterized by a strong blue continuum at early times and are dominated by broad (~10^4 km s^-1) H and/or He emission lines with different strengths and relative ratios (Arcavi et al. 2014; Leloudas et al. 2019; Charalamopoulos et al. 2022). A fraction of TDEs have shown broad Bowen fluorescence emission lines (Blagorodnova et al. 2019; Leloudas et al. 2019; Onori et al. 2019) and evidence for Fe II emission lines have been found in a small subset of TDEs (Wevers et al. 2019b; Cannizzaro et al. 2021). Following these discoveries, the TDE population has been divided into three main spectral classes, depending on the appearance or lack of the different broad spectral features (Arcavi et al. 2014; Leloudas et al. 2019; van Velzen et al. 2020). In some TDE candidates, high ionization coronal emission lines have been identified (Komossa et al. 2008, 2009; Wang et al. 2011; Yang et al. 2013; Palaversa et al. 2016), suggesting the presence of a gas-rich environment surrounding these sources. Furthermore, infrared (IR)
echos, resulting from the reradiation of the TDE emission by dust, have been detected thanks to dedicated observations (Mattila et al. 2018), follow-up campaigns or WISE archival searches (see Jiang et al. 2021; van Velzen et al. 2021a, for a recent review). 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 et al. 2022). From photometric analysis, surprisingly low and constant blackbody temperatures of \( \sim 10^2 \) K, which cannot be explained through traditional accretion process, have been derived (Hinkle et al. 2020; van Velzen et al. 2021b). 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 soft X-ray emission, sometimes delayed with respect to the optical peak emission (e.g. ASASSN-14li, ASASSN-15oi, AT 2019dsg, AT 2018fyk, AT 2019giz, AT 2019azh; Holoi et al. 2016; Gezari, Cenko & Arcavi 2017; Wevers et al. 2019b; Nicholl et al. 2020; Cannizzaro et al. 2021; Liu et al. 2022, respectively).

Despite the recent progress in this field, there are many aspects that remain unclear, such as the emission mechanism behind all the observed features, the geometry of the emitting region and the X-ray non-detection of the optically selected TDEs. Different scenarios have been proposed, including the presence of an optically thick atmosphere which reprocess the high-energy radiation emitted during the accretion process (Guillochon, Manukian & Ramirez-Ruiz 2014; Roth et al. 2016; Roth & Kasen 2018), or emission by shocks from intersecting stellar debris streams during the disc formation phase (Piran et al. 2015; Shiokawa et al. 2015; Bonnerot, Rossi & Lodato 2017). However, in these models, the X-rays are expected to show up eventually, once the wind calm down or the circularization process ends. Dai et al. (2018), instead, have explained the X-ray/optical dichotomy in the framework of a TDE unified model in which optically thick winds are produced following the formation of the accretion disc and are responsible for the X-ray obscuration. Inclination effect together with the physical properties of the mass outflow determine the detection of the X-ray emission.

AT 2017gge was first detected on 2017 August 3 (MJD 57 968.35) by the Asteroid Terrestrial-impact Last Alert System survey (ATLAS; Tonry et al. 2018), which reported a discovery magnitude in the ATLAS orange filter of \( a = 18.70 \pm 0.17 \) mag (in the AB system, Tonry et al. 2017). The transient is located within 0′1 (0.1 kpc) from the center of the host galaxy, specifically at the coordinates RA (J2000) = 16:20:34.99 and Dec. (J2000) = +24:07:26.5. The host galaxy has been identified to be SDSS J162034.99 + 240726.5, a spiral galaxy at redshift \( z = 0.0665 \), classified as a star-forming galaxy from the Sloan Digital Sky Survey (SDSS) pre-transient optical spectrum. The field has been observed in the 0.1−2.4 keV energy band by the ROentgen SATellite (ROSAT) within the ROSAT all Sky Survey (RASS) on the 1990 July 30, and no signs of X-ray emission have been detected (only an upper limit of \( F_{\nu, 0.1−2.4 \text{ keV}} = 1.0 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1} \) can be derived). A mid-infrared (MIR) flare in the WISE light curve of AT 2017gge has been recently reported by Jiang et al. (2021). Due to its proximity to the host galaxy core, AT 2017gge is classified as a nuclear transient. The spectroscopic classification reported an uncertain nature for AT 2017gge (Fraser et al. 2017), with a spectrum taken three weeks after the transient’s discovery characterized by a blue continuum and by a broad component at the base of both the narrow Hα and Hβ emission lines, which are not consistent with a SN scenario. Fraser et al. (2017) suggest the possibility of a TDE nature for AT 2017gge, as the smooth evolution of the light curve is atypical for AGN variability. Recently, based on the X-ray and optical analysis, Wang et al. (2022) claimed a TDE nature for this transient.

In this paper, we present the results of our dense multiwavelength follow-up campaign of AT 2017gge, which covers a total of 1698 d from the transient’s discovery. The data set includes optical photometric and spectroscopic data obtained with a number of ground-based facilities, soft X-ray observations delivered by Swift and a series of near-infrared (NIR) spectra obtained after an enhanced MIR emission. Thanks to this dense, long-lasting and multiband data set we have been able to further investigate the nature of this transient, to accurately study the spectroscopic evolution of the broad emission lines and the connection between a delayed soft X-ray flare and the emergence of a broad He i \( \lambda 4686 \) emission line and of a number of high ionization coronal emission lines. Finally, thanks to late-time, high resolution spectroscopy, the activity status of the host galaxy, after the occurrence of the nuclear transient, has been inspected and the black hole (BH) mass has been derived, using two independent methods. In this manuscript, all the times are reported with respect to MJD 57 968.35, which corresponds to the discovery date of AT 2017gge as reported by the ATLAS survey. Throughout the paper we use a luminosity distance of \( d_L = 297.6 \) Mpc, based on a WMAP9 cosmology with \( H_0 = 69.32 \) km s\(^{-1}\) Mpc\(^{-1}\), \( \Omega_M = 0.29 \), and \( \Omega_\Lambda = 0.71 \) (Hinshaw et al. 2013).

### 2 OBSERVATIONS AND DATA REDUCTION

Our monitoring campaign of the nuclear transient AT 2017gge started on 2017 September 14. In order to provide good coverage of the transient’s evolution, we have followed its emission by using different instruments with a multiwavelength approach. In particular, while the X-ray data has been obtained through the XRT instrument on board the Neil Gehrels Swift observatory (Gehrels et al. 2004), the optical/NIR photometric and spectroscopic follow-up has been carried out by using a variety of ground-based facilities together with the UV−optical photometric observations delivered by Swift/UVOT instrument. In the following section, we describe the observational set-up and data reduction for all the instruments used.

#### 2.1 Ground-based observations

A dense photometric coverage of the first \( \sim 40 \) d of AT 2017gge have been performed in the \( o \) and \( c \) filters by the ATLAS survey (Smith et al. 2020) and in the \( i' \) filter by the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS; Huber et al. 2015; Chambers et al. 2016). Additional \( w \) images have been obtained by Pan-STARRS between 600 and 700 d from the transient discovery. The spectroscopic monitoring was carried out mainly by using the ESO Faint Object Spectrograph and Camera (EFOSC2; Buzzoni et al. 1984), mounted on the 3.58 m New Technology Telescope (NTT) as part of the ePESSTO ESO public survey (Smartt et al. 2015) and the Andalucía Faint Object Spectrograph and Camera (ALFOSC), mounted on the 2.56 m Nordic Optical Telescope (NOT), as part of the NOT Unbiased Transient Survey (NUTS). Additional optical observations and late-time images have been obtained with the Device Optimized for the LOW RESolution (DOLORES) installed at the 3.58 m Telescopio Nazionale Galileo (TNG), the Auxiliary-port CAMERA (ACAM) mounted on the 4.2 m William Herschel Telescope (WHT) and the Optical Wide Field Camera (IO-O) at

\(^1\)http://csp2.lco.cl/not/
the Liverpool Telescope (LT; Steele et al. 2004), respectively. Higher resolution spectra were obtained with the Gemini North Multi-Object Spectrographs (GMOS-N), mounted on the 8.1 m Frederick C. Gillett Gemini North telescope, with the Optical System for Imaging, the low-Intermediate-Resolution Integrated Spectroscopy (OSIRIS), mounted at the 10.4 m Gran Telescopio CANARIAS (GTC) and the X-shooter spectrograph (Vernet et al. 2011), mounted on the UT3 the Very Large Telescope (VLT), located at the ESO Paranal observatory. NIR spectra and images in the J, H, and Ks bands have been obtained with the infrared spectrograph and imaging camera Son of ISAAC (SoFI Moorwood; Cuby & Lidman 1998), mounted on the NTT. After the transient light had faded below the detection levels, host galaxy spectra and images were taken for each ground-based facility and with the same observational set-up used during the follow-up.

All the spectroscopic observations have been carried out with the slit oriented at the parallactic angle. In Table 1, the main observing information, such as the observing date, the grism used, the exposure time, the slit width, the airmass and seeing condition, are reported for each instrument. The sequence of the optical spectra is shown in Fig. A1, the SoFi NIR spectra are shown in the lower panel of Fig. 5, while we show the whole X-shooter spectrum (UVB, VIS, and NIR arms) in Fig. A3.

2.1.1 NTT/EFOSC2 + SoFI

As shown in Table 1, a total of 16 spectra have been taken with EFOSC2 instrument by using the grism Gr #13, which covers a wide wavelength range (3685–9315 Å) with a resolution of \( R = \lambda / \Delta \lambda \sim 300 \), calculated for a 1′0 slit (a slightly higher resolution is achieved in case of seeing better than 1′0). In order to perform more detailed observations in the He II λ4686 region, we also used the grism Gr#18, which provides a resolution of \( R = \lambda / \Delta \lambda \sim 750 \) (calculated for a 1′0 slit and for a 1′0 seeing) in the wavelength range 4700–6770 Å. Two NIR spectra have been obtained with the SoFI instrument in nodding mode with the BG grism, which covers the wavelength range 9500–16400 Å and provides a resolution \( R = \lambda / \Delta \lambda \sim 1000 \), calculated for a 0′6 slit. We use the two instruments also in imaging mode in order to obtain images of the field in the g and r filters (with EFOSC2) and in the J, H, and K filters (with SoFI).

All these spectra and images have been reduced using the ePESTTO NTT Pipeline v.2.4.02 (in spectroscopic and imaging mode, respectively), which is based on standard IRAF tasks, such as bias, flat-field, and cosmic rays correction. The spectroscopic wavelength and flux calibration are performed using arc lamps and standard stars, respectively. Multiple spectra taken on the same night are averaged in order to increase the SNR. The photometric zero-points of the images are calculated using SDSS stars for the Sloan filters, while the stars in the 2MASS catalogue are used for the SoFI images.

2.1.2 NOT/ALFOSC

A total of 5 spectra of AT 2017gge were obtained with the ALFOSC instrument mounted on the NOT at days 193.9, 231.8, 232.8, 310.7, and 556.9. For these observations we first used the grism Gr#4, which covers the wavelength range 3200–9600 Å with a resolution \( R = \lambda / \Delta \lambda \sim 360 \), calculated for a 1′0 slit under seeing conditions of 1 arcsec or larger. We performed more detailed observations in the He II λ4686 region by using the grism Gr#19, which provides a resolution of \( R = \lambda / \Delta \lambda \sim 970 \) (for a 1′0 slit under seeing conditions of 1 arcsec or larger) over the 4400–6950 Å wavelength range.

We reduced the spectra by using the fosgcul 1.7 pipeline,\(^3\) which is based on standard IRAF reduction tasks (Tody 1986), including bias and flat-field correction, cosmic ray cleaning, wavelength calibration by using arc lamps and flux calibration with a standard star.

We used ALFOSC also to obtain images of the transient field in g and r filters. These images have been reduced with the fosgcul 1.7 pipeline in imaging mode, which is based on standard IRAF reduction tasks and includes bias, flat fields and cosmic rays correction. It also provides the World Coordinate System calibration using SDSS stars. The photometric zero-points are derived using SDSS stars in the field of view.

2.1.3 WHT/ACAM

We observed AT 2017gge with the low-resolution spectrograph of ACAM on three nights. In particular, we used the V400 grating which provides a nominal wavelength coverage of 3950–9400 Å and a resolution \( R = \lambda / \Delta \lambda \sim 430 \) for a 1′0 slit, under seeing conditions of 1 arcsec or larger. We reduced the data by using a the standard IRAF tasks including bias, flat-field and cosmic ray correction. The spectroscopic wavelength and flux calibration are performed by using arc lamps and standard stars, respectively.

2.1.4 TNG/DOLORES

A total of three spectra of AT 2017gge were obtained with the low-resolution spectrograph and camera DOLORES. In the spectroscopic mode we used the the LR-B grating which provides a wavelength coverage of 3000–8430 Å and a resolution \( R = \lambda / \Delta \lambda \sim 580 \) for a 1′0 slit and under seeing condition of 1′0 or larger. We used DOLORES also in imaging mode in order to obtain u, g, and r images of the field of the transient. The data have been reduced by using the standard IRAF tasks which includes bias, flat-field, and cosmic rays correction. The spectroscopic wavelength and flux calibration are performed by using arc lamps and standard stars, respectively.

2.1.5 LT/IO-O

We observed AT 2017gge with the IO-O at the Liverpool Telescope in order to obtain images of the transient field in the u, g, and r filters. The images were reduced with the IO-O pipeline\(^4\) and the zero-points calculated using stars in the the American Association of Variable Star Observers (AAVSO) Photometric All-Sky Survey (APASS) catalogue (Henden 2019).

2.1.6 GTC/OSIRIS

Two spectra of AT 2017gge have been taken 338.6 d after the transient discovery with the OSIRIS instrument, located at the Nasmyth-B focus of GTC. We use the spectrograph in the long-slit mode and with the R500B grism, which covers the 3600–7200 Å wavelength range with a resolution \( R = \lambda / \Delta \lambda \sim 540 \), calculated for a 0′6 slit under seeing condition of 0′6 or larger. The data have been reduced by

\(^2\)https://github.com/svalenti/pessto

\(^3\)fosgcul is a graphical user interface aimed at extracting spectroscopy and photometry obtained with FOSC-like instruments. It was developed by E. Cappellaro. A package description can be found at http://sangroup.oapd.inaf.it/fosgcul.html.

\(^4\)https://telescope.livjm.ac.uk/TelInst/Pipelines/#ioo
using the dedicated GTCMOS pipeline (Gómez-González, Mayya & Rosa-González 2016), which is an IRAF-based script and performs bias, flat-field, cosmic rays correction. It also delivers wavelength-calibrated 2D spectral images (calibrated by using arc lamps) and flux calibration is applied on the extracted spectra by using a standard star for reference. The spectra taken on the same night are then combined together, in order to increase the S/N.

2.1.7 Gemini/GMOS-N

Two additional late-time, higher resolution spectra of AT 2017gge have been obtained with the Gemini Multi-Object Spectrograph (GMOS) mounted at Gemini North telescope, in single long slit mode (1″ slit) and using the B600 grism. This configuration allows to approximately cover the 4400–7500 wavelength range with a resolution $R = \lambda/\Delta\lambda \approx 844$, achieved with a slit width of 1″ under seeing condition of 1" or larger. The science data was obtained through dithering in the spatial and spectral direction to avoid contamination from bad pixels and columns. Data have been reduced with the Gemini iraf package, including bias subtraction, flat-field, wavelength calibration. The flux calibration was performed with the spectra of the standard stars EG 131 and Hilt 600. Four individual exposures were combined into each final spectrum.

2.1.8 VLT/X-shooter

One spectrum of the AT 2017gge host galaxy has been taken at day 1697.9 with the X-shooter instrument which is an intermediate resolution spectrograph covering a wide wavelength range. In particular, it spans the 3000–25 000 Å range in a single observation, thanks to the presence of three arms (UVB, VIS, and NIR) working simultaneously. Specifically, the UVB arm covers the 3000–5595 Å wavelength range, the VIS arm spans the 5595–10 240 Å and the NIR arm ranges from 10 240–24 800 Å. We used the 1.0′, 0.9′, and 0.9′ slit widths configuration for the UVB, VIS, and NIR, respectively, which deliver the respective nominal resolutions of $R = \lambda/\Delta\lambda = 5400, 8900$, and 5600. Data have been reduced by using the X-shooter pipeline in the EsoReflex environment (Freudling et al. 2013) and telluric corrections were performed by using the molecfit V.4.2 software (Kausch et al. 2015; Smette et al. 2015).

2.2 Swift observations

AT 2017gge was monitored by the Neil Gehrels Swift observatory over a period spanning ~200 d, starting from ~60 d after the transient discovery. A total of 19 XRT and UVOT observations have been obtained. In particular, we were awarded six epochs of Swift ToO
observations between 2018 March 9 and 2018 April 7 for late-time follow-up of the source. In Table 2, a list of the Swift observations for AT 2017gge are reported, together with the main properties (date of observation, time after the transient discovery and instruments exposure times). All the XRT observation have been executed in photon-counting mode.

| MJD  | Time  | XRT exp. time | UVOT exp. time |
|------|-------|---------------|---------------|
| (d)  | (d)   | (s)           | (s)           |
| 58031.12 | 62.8  | 1631          | 1555          |
| 58041.75 | 73.4  | 1604          | 1532          |
| 58046.29 | 77.9  | 1403          | 1338          |
| 58051.78 | 83.4  | 2084          | 2020          |
| 58055.04 | 86.7  | 2232          | 2180          |
| 58143.57 | 175.2 | 1532          | 1480          |
| 58156.93 | 188.6 | 2153          | 2104          |
| 58162.98 | 194.6 | 1504          | 1480          |
| 58168.35 | 200.0 | 2109          | 2058          |
| 58174.28 | 205.9 | 564           | 536           |
| 58177.72 | 209.4 | 1432          | 1387          |
| 58186.15 | 217.8 | 908           | 906           |
| 58193.72 | 225.4 | 490           | 489           |
| 58200.76 | 232.4 | 379           | 378           |
| 58211.60 | 243.3 | 560           | 559           |
| 58213.85 | 245.5 | 535           | 534           |
| 58215.98 | 247.6 | 576           | 578           |
| 59651.84 | 1683.5| 3574          | 3502          |
| 59655.29 | 1686.9| 2283          | 2210          |

### 3 PHOTOMETRIC ANALYSIS

#### 3.1 Differential photometry

In order to analyse the photometric properties of AT 2017gge, we first have carried out differential photometry procedures against the host galaxy for each images of our data set. This has allowed us to subtract the host galaxy contribution and thus to obtain images where only the nuclear transient’s emission is present. To this purpose we used the pre-transient host galaxy images available in the Pan-STARRS1 data archive (DR2) in the $g$ and $r$ filters, and the host cataloged $u$ image available on the SDSS archive (DR16; Doi et al. 2010; Ahumada et al. 2020). For the data in the NIR taken with NTT/SofI, we have used the host galaxy images obtained with the same instrument at very late times, 1346 d from the AT 2017gge discovery.

For each images we subtracted the host galaxy contribution by using hotpants V5.1.11 software (Becker 2015). We have then applied aperture photometry on the resulting images by using the sextractor software with apertures of variable size, depending on the seeing conditions. In Table A2, we report the measured host-subtracted optical and IR magnitudes of AT 2017gge, not corrected for foreground extinction and in their common systems (AB for Sloan filters and Vega for Johnson filters). In the case of the UVOT filters, we have used the host contribution as determined from the photometric analysis performed on the very late time observation (taken at ~1680 d from the transient discovery). The resulting light curves, including also the host-subtracted UVOT, ATLAS, and PS1 data, are shown in Fig. 2.

#### 3.2 Bolometric light curve

From the multicolour photometry derived from our analysis, together with the values from the ATLAS and PS1 surveys, we computed the bolometric luminosities for AT 2017gge. We used the python routine superbol (Nicholl 2018), all the input magnitudes have been corrected for the Galactic extinction from Schlafly & Finkbeiner (2011), which assumes a reddening law with $R_V = 3.1$, and $K$-correction (Oke & Sandage 1968) has been applied. When needed,
we extrapolated the photometry assuming a constant colour evolution for the light curve. Subsequently, we have integrated over the spectral energy distribution (SED) inferred from the multiband data (for each epoch) and, finally, we fitted the SED with a single blackbody model. The best-fitting blackbody at each epoch was then used to compute the additional flux bluewards of the UVW2 band and redwards of the K band. In Fig. 3, we show the results for the first ~300 d from the transient’s discovery: the bolometric luminosity evolution (upper panel, black circles for the luminosity calculated by integrating over observed fluxes only, the red diamonds show the luminosity derived using a single blackbody model to fit the SED); the blackbody temperature and radius evolution are shown in the central and lower panel, respectively. While the blackbody temperature is characterized by no significant evolution over time, being consistent with a constant value of $T_{BB} \sim 1.8 \times 10^4$ K, the blackbody radius show a first phase of expansion from $R_{BB} = (7.7 \pm 0.8) \times 10^{14}$ cm to a maximum value of $R_{BB} \sim (12.9 \pm 2.8) \times 10^{14}$ cm, reached at ~25 d from the transient’s discovery, followed by a phase of decline finally reaching a value of $R_{BB} = (7.3 \pm 2.7) \times 10^{14}$ cm after ~300 d from the transient’s discovery.

In Fig. 4, we show the bolometric luminosity of AT 2017gge (derived using the blackbody correction, filled black square) in comparison with the bolometric light curves derived for other TDEs\(^5\) by applying the same method used for AT 2017gge data (coloured dashed lines). After PS1-10jh (Gezari et al. 2012), AT 2017gge is the second brightest object in the plot, with a luminosity and an evolution notably similar to what observed for AT 2018hyz. Moreover, for the first ~100 d it shows a light-curve behaviour comparable to the one observed for AT 2019qiz. From the bolometric luminosity evolution we estimate that the emission reached its peak value of $L_{bol} = (1.4 \pm 0.5) \times 10^{44}$ erg s\(^{-1}\) at MJD 57989.26, which corresponds to ~20 d from the transient’s discovery. The rise of the light curve is consistent with a $t^{5/3}$ power law, while in decline it is better represented by a $t^{-1.1}$ power law (red dot–dashed line) rather than the $t^{-5/3}$ trend (light-blue dot–dashed line), when considering ~600 d of emission. We note that during the first ~200 d the light curve decline can be well represented also by the $t^{-5/3}$ power law. The

\(^5\)Photometric data retrieved from The Open TDE Catalog https://tde.space.
total energy radiated \( (E_{\text{rad}}) \) is derived by integrating the bolometric luminosity over time and it results \( E_{\text{rad}} = (1.0 \pm 0.1) \times 10^{51} \text{ erg} \). In their recent letter on AT 2017gge, Wang et al. (2022) independently derived the bolometric light curve, together with the blackbody temperature and radius by using all the UVOT data but V filter and only the ATLAS o band data. Although their values are consistent with our results, they found a declining trend for the bolometric light-curve luminosity compatible with the \( t^{-5/3} \) powerlaw. This discrepancy can be explained with the use of a more complete and well-sampled photometric data set in our analysis.

The photometric properties, such as the steep rise to the peak luminosity, reached after \( \sim 20 \text{ d} \) from the transient’s discovery, the power-law decay of the bolometric luminosity the constant blackbody temperature at \( T_{\text{BB}} \sim 1.8 \times 10^4 \text{ K} \) and the blackbody radius \( R_{\text{BB}} \sim 10^{15} \text{ cm} \) evolving with time, are all commonly observed in TDEs (Hinkle et al. 2020; van Velzen et al. 2020, 2021b; Zabludoff et al. 2021, and reference therein), and thus are indicative of the TDE nature of AT 2017gge.

### 3.3 IR emission

Interestingly, AT 2017gge is listed in the Mid-InfraRed Outburst in Nearby Galaxies (MIRONG) sample (Jiang et al. 2021), which includes a total of 137 low-redshift SDSS galaxies that have experienced recent MIR flares of at least an amplitude of 0.5 mag in their WISE light curves. In Fig. 5, we show the AT 2017gge WISE light curves for the W1 and W2 filters (with half a year sampling) and the epochs of the two SofI spectra. The MIR flare is detected at \( \sim 197 \text{ d} \) from the transient’s discovery in both filters and the first SofI spectrum has been obtained 178 d after the MIR flare, when the MIR emission is still \( \sim 0.6 \text{ dex} \) higher than during the quiescent phase.

Notably, in their work, Jiang et al. (2021) propose IR echoes (i.e. optical/UV light absorbed and reradiated by dust) of emission originating from the accretion on to SMBHs as the main source of the detected MIR outbursts and they derive some physical properties of the dust responsible for the detected emission, such as the temperature, luminosity, mass, and its distance from the central heating source. Specifically, for the case of AT 2017gge they infer a distance of the dust of \( \log R_{\text{dust}} = -1.51 \pm 0.12 \text{ pc} \) or \( \log R_{\text{dust}} = -1.01 \pm 0.16 \text{ pc} \), depending on the considered absorption coefficient, which correspond to \( R_{\text{dust}} \sim 10^{17} \text{ cm} \). We independently computed the time lags \( (\tau) \) between the optical and MIR data using two different methods, the interpolated cross-correlation function (ICCF; White & Peterson 1994) and the javelin tool (Zu et al. 2013, 2016). From the ICCF method, the time-lag \( \tau \) for W1 band is estimated to be \( \tau = 204.6^{+170.8}_{-41.2} \text{ d} \), which is consistent with that computed applying the javelin method \( (\tau \approx 207.6^{+34.7}_{-31.7} \text{ d}) \). These methods are commonly used in active galactic nuclei (AGNs) reverberation mapping studies and are based on the tight correlation between the IR luminosity and the dust radius of ordinary AGNs (size–luminosity relation). Thus, it is possible to infer the luminosity of a possible AGN from the estimated time lag. In particular, by using the size–luminosity relation from Lyu, Rieke & Smith (2019), we found \( L_{\text{AGN}} \approx 10^{45} \text{ erg s}^{-1} \).

Our estimated peak bolometric luminosity for AT 2017gge from the observed optical and UV fluxes was \( (1.4 \pm 0.5) \times 10^{44} \text{ erg s}^{-1} \), but we can infer that the true peak was larger than this due to the presence of the IR echo. Therefore, it is not unreasonable to assume that the intrinsic TDE luminosity was large enough to be consistent with this estimate. The time-lag measurements above also provide values for the distance to the dust producing the IR echo, which are \( 0.161^{+0.061}_{-0.034} \text{ pc} \) for CCF, and \( 0.163 \pm 0.019 \text{ pc} \) for javelin.

These values are similar to the dust sublimation radius of 0.15 pc found for the TDE PTF-09ge by van Velzen et al. (2016), implying that is reasonable for AT 2017gge to have also sublimated dust out to this radius. The estimates for the dust radius in Jiang et al. (2021) are somewhat smaller than this, and precise measurements require a more involved model. It is possible to use the infrared light echo to estimate the required luminosity of the flare needed to sublimate the dust to the sublimation radius. In particular, we have obtained a flare peak luminosity of \( L_{\text{dust}} = 1.14 \times 10^{45} \text{ erg s}^{-1} \) by using the the equation (1) reported in van Velzen et al. (2016), the (independently derived) sublimation radius of 0.16 pc and assuming a sublimation temperature of 1850 K for the dust. Notably, this value is consistent with the luminosity inferred by using the AGN size–luminosity relation of Lyu et al. (2019) \( (L_{\text{AGN}} \approx 10^{45} \text{ erg s}^{-1}) \) and thus further support the hypothesis of an intrinsic TDE luminosity larger than what derived from the observed optical and UV fluxes. Interestingly, from the the MIR luminosity analysis, Wang et al. (2022) derived a covering factor of \( \sim 0.2 \) for the dusty environment. As already discussed by the authors, such a high value is comparable with what is usually observed for the AGN torus. However, prior to the transient occurrence, an AGN classification has been excluded given: (a) the X-ray non-detection in the RASS observations, (b) the quiescent WISE colour \( (W1-W2 \sim 0.6, \text{ Stern et al. 2012}) \), and (c) the the SDSS spectrum based location in the Baldwin, Phillips &
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The RASS pre-transient upper limit of $F_{0.3-10\,\text{keV}} = 1.0 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, corresponding to observation taken at MJD 48102, is also shown before the transient detection for comparison (red cross in Fig. 6). The detected X-ray emission has a transient nature, with only upper limits (grey triangles in the figure) for the first 170 d from the discovery of AT 2017gge and showing the peak around 200 d. Furthermore, no X-rays have been detected in the recent XRT observations taken at $\sim$1684 d (see Wang et al. 2022). Such a delayed X-ray brightening with respect to the optical/UV peak has already been observed in some TDEs, specifically, ASASSN-14li (Gezari et al. 2017; Pasham et al. 2017), ASASSN-15oi (Gezari et al. 2017; Holoien et al. 2018), AT 2019ahz (van Velzen et al. 2021b; Liu et al. 2022), and OGLE16aaa (Kajava et al. 2020; Shu et al. 2020), who have shown $\sim$30 d, 1 yr, 200 and 140 d of delay in the X-ray emission, respectively. In all these cases, the authors investigate the different scenarios for the origin and location of the optical/UV emission and the delayed X-ray flare, including the stream–stream collision and reprocessing photosphere/winds hypothesis. Among these, a two-process scenario, where the UV/optical emission is produced by the stellar debris streams during the circularization phase, whereas a delayed formation of an accretion disc is responsible for the X-rays, has been suggested and, in some cases, has been even preferred (i.e. ASASSN-15oi, ASASSN-14li, OGLE16aaa, AT 2019ahz; Gezari et al. 2017; Pasham et al. 2017; Kajava et al. 2020; Liu et al. 2022).

4.2 The X-ray spectral analysis

The spectrum of the source is very soft, with the emission detected only between the 0.3 and 1 keV energy range. We modelled the data with an absorbed power law by the model \texttt{TBABS+ZAShift+POWERLAW} (solid blue line, left-hand panel) and we obtain a photon index of $\Gamma = 6.0 \pm 0.8$ and a \texttt{c-stat}/d.o.f. = 11.74/12. The unabsorbed flux in the 0.3–10 keV band results to be $F_{0.3-10} = (0.18 \pm 0.05) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, which corresponds to an X-ray luminosity of $L_X = (2.4 \pm 0.7) \times 10^{32}$ erg s$^{-1}$, calculated for the distance of AT 2017gge. These spectral features are usually observed in the X-ray emission of non-jetted TDEs, which show very soft spectra well represented either by a single power law with a photon index value $\Gamma > 4$ or by a blackbody model with temperatures between 10 and 100 eV (Auchettl, Guillochon & Ramirez-Ruiz 2017; Saxton et al. 2020). Therefore, we also modelled the X-ray spectrum using a blackbody model \texttt{TBABS+ZAShift+BODYRAD} (middle panel of Fig. 7, magenta solid line). In this case, we obtain $c$-\texttt{stat}/d.o.f. = 7.24/12. The inferred temperature and radius are $kT = 70 \pm 10$ eV and $R = (1.4^{+0.5}_{-0.5}) \times 10^{10}$ cm. These values are consistent with a TDE nature for this transient. The unabsorbed flux in the 0.3–10 keV band is $F_{0.3-10} = (0.15 \pm 0.04) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, which corresponds to a luminosity of $L_X = (1.8 \pm 0.5) \times 10^{32}$ erg s$^{-1}$. The results of the spectral analysis are reported in Table 3 and are shown if Fig. 7. These results are all consistent with the X-ray analysis already presented in the recent discovery paper of AT 2017gge (Wang et al. 2022). Additionally, in order to investigate the origin of the delayed X-ray flare as produced by a newly formed accretion disc, we have modelled the data with the \texttt{TBABS+ZAShift+DISKBB} model (right-hand panel of Fig. 7, red solid line). In this case, we obtain $c$-\texttt{stat}/d.o.f. = 7.76/12, a temperature at the inner disc radius of $T_{in} = 83 \pm 10$ eV, an unabsorbed flux of $F_{0.3-10} = (0.15 \pm 0.04) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, which corresponds to a luminosity of $L_X = (1.9 \pm 0.5) \times 10^{32}$ erg s$^{-1}$. We note that although it is difficult to discriminate between
these two models given the very similar c-stats values, the accretion disc model is able to represent well the data. Thus, given the derived X-ray properties, we can conclude that the AT 2017gge X-ray emission resembles what is usually seen in non-jetted TDEs, as it is characterized by a very soft emission and a steep spectrum well modelled either by an absorbed power law, by a blackbody or by an accretion disc model.

5 OPTICAL AND NIR SPECTROSCOPIC ANALYSIS

The rest-frame optical spectra of AT 2017gge taken with the different ground-based facilities described in Section 2 are shown in Fig. A1, while the rest-frame SoFi NIR spectra and the UVB, VIS and NIR X-shooter spectra are shown in the lower panel of Fig. 5 and in Fig. A3, respectively. We corrected all the reduced spectra for the foreground extinction by using the Cardelli function (Cardelli et al. 1989) with $A_V = 0.193$ mag and $R_V = 3.1$. In this section, we discuss the spectroscopic features detected in the optical and NIR spectral sequence.

5.1 The optical spectra and the detection of high ionization coronal emission lines

The first spectra of our data set (taken $\sim 42–45$ d from the transient’s discovery) are characterized by broad $H\beta$, $He\lambda 5876$, and $H\alpha$ emission lines superimposed on a blue continuum. However, from the
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Lundqvist, Lundqvist & Shibanov 2022). As most of these coronal lines are first detected 218 d from the transient’s discovery and are not detected at the resolution of the pre-transient SDSS spectrum, we conclude that these features have a transient nature. These findings are remarkable as, together with the TDE AT 2019qiz (Nicholl et al. 2020), they represent the first time in which high ionization coronal emission lines are detected in the optical spectra of a TDE soon after the occurrence of the X-ray flare (see Short et al., in preparation, for an accurate study on the detection of the high ionization coronal emission lines in the optical spectra of AT 2019qiz). This strongly suggests a close connection between the TDE X-ray outburst and the presence of high ionization coronal emission lines in the TDE late-time spectra and host galaxy.

5.2 The NIR spectra

In the lower panel of Fig. 5 we show the NIR spectra taken with SofI at two different epochs from the transient’s discovery, specifically at 374.7 d (in black) and 1342 d (in orange) in comparison with a part of the NIR X-shooter spectrum taken after 1698 d (in red). Although our NIR data set is composed of only three spectra, a spectral time evolution is visible also in this wavelength range. Indeed, the first SofI spectrum shows a prominent and composite emission line in the HeI λ10830 region, with a very broad component and a narrower one (FWHM = 7660 ± 1500 km s⁻¹ and FWHM = 1639 ± 330 km s⁻¹, respectively), blended with the Paγ in which we also detect an intense narrow emission line consistent with the high ionization coronal line [Fe XIII] λ10798 (see the upper right panel of Fig. 5). This finding is particularly notable as it represents the first detection of a transient high-ionization coronal NIR line in a TDE. Indeed, such a broad and complex feature becomes less prominent in the second SofI spectrum, where the broad component becomes fainter, the Paγ starts to emerge and the narrow [Fe XIII] λ10798 is not detected anymore. Finally, this broad feature has completely disappeared in the X-shooter spectrum, the HeI λ10830 and the Paγ are well detected and show only narrow components. Also in this case, the narrow [Fe XIII] λ10798 is not detected.

6 THE SUBTRACTION OF THE HOST GALAXY CONTRIBUTION

In order to isolate the nuclear transient spectral features, we have first subtracted the host galaxy contribution from each spectrum of our data set by using the penalized pixel fitting (pPXF) method (Cappellari & Emsellem 2004; Cappellari 2017). In this way, it has been possible to model the host galaxy spectral features present in the AT 2017gge spectra through convolution with a host-galaxy template spectrum. Subsequently, the best-fitting host-galaxy model is subtracted from the observed transient + host spectrum, resulting in the final transient-only spectrum. During the fitting procedure, we excluded all the spectral regions where intense emission lines were present (with particular care for the Hα and Hβ regions) and the areas affected by telluric absorption (see also Onori et al. 2019, for an application of this method).

Based on our photometric analysis, the transient’s emission can be considered exhausted (or at least faded beyond the detection in the optical bands) after ~500 d from its discovery. Thus we used the spectra taken after this phase as the host galaxy templates in our host-subtraction procedure. In particular, in order to have a host galaxy spectrum with the same observational set-up as the one used for the transient + host spectra taken during our follow-up campaign, we have collected late-time spectra with different...
7 THE TDE BROAD EMISSION LINES

In this section, we describe the method used for the emission line fitting and the results from the spectral analysis of the AT 2017gge host-subtracted spectra.

7.1 Fitting of the emission lines

In order to investigate the properties and evolution of the main spectral features observed in the host-subtracted spectra of AT 2017gge (see Fig. A2 for the entire sequence), we modelled them with Gaussian functions by using the python packages `curvefit` and `leastsq`. In the case of simultaneous presence of broad and narrow components in the line profiles, a multicomponent Gaussian fit has been applied. During the fitting procedure, a wavelength window of $\sim 1100$ Å has been selected, in order to include both the spectral features of interest and the local continuum. A narrower fitting window has been selected in late time spectra, when the width of the broad emission lines became smaller. The same fitting procedure has been applied also in the case of host-subtracted spectra, such as the SDSS, SofI, Gemini, and X-shooter spectra. In Fig. 11, the application of the multicomponent Gaussian fit for the $H\beta$ and $H\alpha$ region in the Gemini and X-shooter spectra is shown, while in the upper right panel of Fig. 5 it is shown for the $He\alpha \lambda 10830$ region of the SofI spectrum of day 374.

7.2 The time evolution of the optical broad emission lines

We analysed the evolution of the emission line properties, such as the full width at half maximum (FWHM), the equivalent width (EW), and the EW ratio of the main broad emission lines detected in the host-subtracted spectra of AT 2017gge. Specifically, we focus on the properties of the $He\beta \lambda 4686$, $H\beta$, $He\alpha \lambda 5876$, and $H\alpha$ emission lines, as derived from the fitting procedure described in Section 7.1. In Fig. 12, the results from this analysis are shown. Broad components in the $H\beta$, $He\alpha \lambda 5876$, and $H\alpha$ are detected starting from the first spectra of our data set, taken 41.7 and 44.4 d from the transient’s discovery, and they last until phase 291 (for $He\beta$), 408 (for $H\beta$), and 572 (for $H\alpha$). As shown in the upper panels of Fig. 12, all these three features have high values of the FWHM in the initial phases of the transient emission with FWHM $\sim (1.3-2.0) \times 10^4$ km s$^{-1}$, which are consistent with the broad emission lines widths typically observed in...
steady decline from the initial value of FWHM = (1.8 ± 0.1) × 10^4 km s^{-1}, as measured at phase 41.7 d, to an FWHM = (0.23 ± 0.01) × 10^4 km s^{-1} as derived at 572.2 d. It is worth noting that a broad H α component of FWHM = (0.12 ± 0.01) × 10^4 km s^{-1} is still detected in the X-shooter spectrum (at day 1698), while any other broad feature is not present anymore.

The H β evolution is quite fast, with a rapid change of the line width in ~150 d, from a value similar to what is observed in the H α, FWHM = (2.0 ± 0.2) × 10^4 km s^{-1} at 41.7 d, to a narrower broad component of FWHM = (0.56 ± 0.06) × 10^4 km s^{-1} at 193.9 d. Finally, a broad He II λ4686 is first detected only after ~193.9 d from the transient’s discovery, it is characterized by smaller value of FWHM with respect to H β, He I, and H α, with a nearly constant value at FWHM ~ 0.6 × 10^4 km s^{-1} until its last detection at 338.6 d, in which an FWHM = (0.56 ± 0.05) × 10^4 km s^{-1} is measured. Later time spectra show only a narrow He II emission line.

### 7.2.2 The EW time evolution

The middle panels of Fig. 12 show the EW time evolution of the He II λ4686, H β, He I λ5876, and H α broad components. As for the FWHM, the EW of these features follows a declining trend, with the H α characterized by the higher values (from an initial EW ~ 120 Å to EW ~ 30 Å as measured at 572 d) with respect to the other lines during the whole monitoring campaign. Indeed, the H β shows a trend similar to what is observed in the H α, but at EW values one order of magnitude lower, while the He I is characterized by an initial growing phase until 193.9 d, followed by a very rapid declining trend which ends at 291.8 d. Also in this case the EW values are one order of magnitude lower than what measured for the H α. The behaviour of the He II is instead completely different from the aforementioned lines. In fact, it is characterized by a late-time development and by a rapid variation of the EW, which oscillates between different values (from EW ~ 8 Å to EW ~ 30 Å) within a time interval of ~20 d.

### 7.2.3 The broad line ratios

In the bottom left panel of Fig. 12 we show the time evolution for the H α/H β and of the He II/He I line ratios. In particular, the H α/H β line ratio is consistent with the value of 2.86, expected for the theoretical Case B recombination (black dashed line Osterbrock & Ferland 2006) but with two remarkable exceptions. Indeed, the H α/H β line ratio is greatly enhanced around day 200, when it changes from a value of 1.7 ± 0.2 at 41.7 d to the values of 4.9 ± 0.8 and 6.5 ± 1.4 at 193.8 and 218 d, respectively. After ~10 d, it comes back to values in agreement with the Case B recombination. This consistency with the Case B recombination value lasts for ~80 d, when the line ratio gradually increases again toward the value of 6.7 ± 1.1 at 407.9. It is interesting to note that the high H α/H β line ratio values detected at days 193.8, 218, and 407.9 are all consistent with the line ratio value expected if the emission is dominated by an AGN broad line region (BLR, red dotted–dashed line, Osterbrock & Ferland 2006). This variation in the H α/H β is mainly due to the broad H β declining more rapidly than the broad H α, which started around 194 d.

The He II/He I line ratios, instead is characterized by a steep and rapid rising trend, from an initial values of 0.32 ± 0.15, as measured at 193.9 d, to a final value of 3.67 ± 1.52 as measured at 292.8 d. This behaviour has been already observed in the recent spectroscopic study on a sample of 16 TDEs performed by Charalamopoulos et al. (2022). In their paper, the authors ascribe the observed temporal
rising of the He ii/He i line ratio with a photoionization increase in the helium line emitting region. In AT 2017gge, the development of the He ii soon after the X-ray flare and the simultaneous disappearance of the He i suggests that they are emitted from the same region which is being further ionised probably as a result of the delayed X-rays. However, we stressed that although our results can be explain within this scenario, they are not strong enough to extend such a delayed X-ray photoionization of He ii broad component model to the general TDE behaviour. Indeed, we outline that other events characterized by a multwavlength behaviour similar to that of AT 2017gge, have shown broad He ii emission line in the early time spectra, well before the X-ray detection (i.e. ASASSN-15oi and AT2019anzh Gezari et al. 2017; van Velzen et al. 2021b; Hinkle et al. 2021).

In the bottom right panel of Fig. 12 the time evolution of the He ii/He i and He ii/He α line ratios in comparison with the value expected in the case of a nebular environment for a solar helium abundance (black dotted line, Hung et al. 2017) are shown. The He ii-to-He α line ratio is in agreement with the nebular argument for all the duration of the monitoring campaign. This behaviour has been also shown to hold for many others TDEs (see fig. 9 of Charalampopoulos et al. 2022).

8 THE HOST GALAXY ACTIVITY STATUS AND THE BLACK HOLE MASS

In Fig. 9, we show the late time high resolution spectra of AT 2017gge taken with Gemini (after 408 and 572 d from the transient’s discovery) and X-shooter (taken at 1698 d) in comparison with the pre-transient SDSS spectrum. It is clearly visible how the host galaxy spectrum has been modified after the nuclear transient took place. Indeed, in the SDSS spectrum only narrow H α and H β emission lines are present, with no signs of broad components or outflows, and the [O iii] λ5007 is barely detected. In contrast, the Gemini spectra are characterized by H β and H α line profiles similar to those usually observed in AGN (Osterbrock & Ferland 2006), with broad components clearly visible in both lines in the spectrum taken at day 408, and only the broad component in the H α detected at 572 d. In the X-shooter spectrum, only a faint broad H α emission line is detected, together with a clear enhancement of the [O iii] λ5007 emission line. Furthermore, as already discussed in Section 5, a narrow He ii λ4686 and many high ionization emission lines compatible with iron transitions are present only in the Gemini and X-shooter spectra, but are not detected in the pre-transient SDSS spectrum.

8.1 The host galaxy activity status

We investigated on the activity status of the AT 2017gge host galaxy by using the BPT diagrams (Baldwin, Phillips & Terlevich 1981) and the EW of the narrow H α, H β, [O iii] λ5007, [N ii] λ6583, and [S ii] λλ6716,6731 lines detected in these spectra. The lines profiles have been modelled following the method described in Section 7.1.

The line ratios derived from the SDSS spectrum are log([N ii]/H α) = −0.27 ± 0.01, log([O iii]/H β) = −0.40 ± 0.33 and log([S ii]/H α) = −0.45 ± 0.10. Despite the faint [O iii] λ5007 emission line, these values place the galaxy on the boundary between the H ii and composite regions in the BPT diagram shown in the left-hand panel of Fig. 13 and well inside the star-forming region in the BPT diagram shown in the right-hand panel of Fig. 13. We note that the location on the extreme starburst line may indicate that an additional ionizing component is required to explain the line ratios.
The line ratios obtained from the Gemini spectrum of day 408 are log([N II]/H α) = −0.04 ± 0.08, log([O III]/H β) = −0.08 ± 0.11, and log([S II]/H α) = −0.09 ± 0.12. While the line ratios obtained from the Gemini spectrum of day 572 are log([N II]/H α) = −0.03 ± 0.06, log([O III]/H β) = −0.2 ± 0.10, and log([S II]/H α) = 0.01 ± 0.07. In this case, the derived line ratios values are consistent between each other and place the galaxy well inside the LINER region and on the boundary between the composite and the AGN regions (cyan square and magenta triangle in Fig. 13), indicating an increase in the activity of the galaxy nucleus after the nuclear transient took place. Finally, the line ratios obtained from the X-shooter spectrum (taken at 1698 d) are log([N II]/H α) = −0.36 ± 0.03, log([O III]/H β) = −0.08 ± 0.03, and log([S II]/H α) = −0.54 ± 0.04 and place the galaxy inside the composite and the star-forming regions in the BPT diagrams of Fig. 13 (green star in the left-hand and right-hand panels, respectively), indicating a further variation in the host galaxy activity, which come back to values in agreement with what derived from the pre-transient spectrum of SDSS. A similar variation in the activity status of a TDE host galaxy has been observed also in AT 2019giz (Short et al., in preparation).

The discovery of AT 2017gge in a star-forming galaxy make this TDE particularly interesting as it probes a host galaxy population (the blue galaxies) poorly represented in most optically and X-ray selected TDE host galaxies samples which result to be dominated by green valley galaxies (Hammerstein et al. 2021; Sazonov et al. 2021).

8.2 The SMBH mass

The detection of AGN-like features in the Gemini optical spectra, their location in the BPT diagnostic diagrams (see Fig. 13) and the evolution of the H α/H β line ratio, suggest an AGN-like behaviour of the AT 2017gge host galaxy after the TDE occurrence. This led us to use these two spectra and a single epoch (SE) relation to test a different and independent method for the SMBH mass derivation, beside the commonly used $M$−$σ$, scaling relations. Recently, Ricci et al. (2017) derived an SE relation based on the AGN X-ray luminosity in the 2–10 keV band and on the width of H β and/or H α broad components. If the broad H emission lines detected in the Gemini spectra are emitted in a virialized photosphere (similar to an AGN-like BLR), then we can use this SE relation to estimate the mass of the black hole.

To this scope we first have derived the unabsorbed X-ray luminosity in the 2–10 keV band from the Swift/XRT spectral analysis of $L_X = (6 \pm 3) \times 10^{39}$ erg s$^{-1}$. Then we have fitted the H broad emission lines detected in the Gemini spectra. In particular, the broad components detected in the H β and H α emission lines of the Gemini spectrum taken at 408 d result to be centred at $λ_c = 4857.30 \pm 1.40$ Å and $λ_c = 6559.10 \pm 0.62$ Å and are characterized by an FWHM = 2318 ± 268 km s$^{-1}$ and FWHM = 2760 ± 69 km s$^{-1}$, for the H β and the H α, respectively. In the Gemini spectrum of 572 d the only H α broad component is detected, which results centred at $λ_c = 6556.08 \pm 0.49$ Å and with an FWHM = 2274 ± 38 km s$^{-1}$.

By using the virial estimator presented in table 4 of Ricci et al. (2017) with the zero-points constants valid for all the classes of host galaxies we derived a black hole mass of $log M_{BH} = 5.5 \pm 0.3$ when using the width of the broad H β, a log $M_{BH} = 5.8 \pm 0.3$ and $log M_{BH} = 5.4 \pm 0.3$ when using the width of the broad H α measured in the Gemini spectra of 408 and 572 d, respectively. Finally, we derive the BH mass of the host galaxy by using the $M_{BH}$−$σ$, scaling relation of McConnell & Ma (2013) and Gültekin et al. (2009), following the method illustrated in Wevers et al. (2017, 2019a) for a sample of TDEs. To this purpose, we measured the stellar velocity dispersion of the host galaxy of AT 2017gge by applying the ppxf fitting procedure to the X-Shooter UVB and VIS spectra. We derive a stellar velocity dispersion of $σ_v = (97 \pm 3)$ km s$^{-1}$, which correspond to a $log M_{BH} = 6.55 \pm 0.45$ or to a $log M_{BH} = 6.80 \pm 0.43$, when using the $M_{BH}$−$σ$, scaling relation of McConnell & Ma (2013) or the relation of Gültekin et al. (2009), respectively. We note that by using the SE relation of Ricci et al. (2017), we obtain values for the BH mass that are ~one order of magnitudes lower than what is derived with the $M_{BH}$−$σ$, relation. Moreover, given the bolometric luminosity of $L_{bol} = 4.6 \times 10^{44}$ at peak, the BH masses derived with the SE relation would imply a super-Eddington accretion (with an Eddington ratio ~10). Instead, a Eddington limited accretion would requires a BH mass of $∼4 \times 10^6 M_\odot$, which is consistent with the values obtained with the $M_{BH}$−$σ$, relations. Thus, we favour the BH mass as derived from the $M_{BH}$−$σ$, scaling relation for AT 2017gge and we suggests that the region emitting the broad lines in this TDE is not virialized as in the case of the AGN BLR.

9 DISCUSSION

The nuclear transient AT 2017gge was first discovered by the ATLAS survey on MJD 57 968.35 and was alerted as a possible TDE by the ePESSTO spectroscopic classification (Fraser et al. 2017). A first claim on the TDE nature for this transient was recently presented by Wang et al. (2022), who investigated on its properties following the detection of an NIR flare in the WISE light curve (Jiang et al. 2021). The optical/UV photometric evolution, the properties of the X-ray emission and the dense spectroscopic sequence as presented in this work, not only confirm the TDE nature of AT 2017gge, but have also allowed us to accurately investigate on the observational properties and their evolution with time in a multiwavelength approach. This led us to the finding of a strong connection between the TDE flare and the appearance of extreme coronal line emission (ECLEs), to the the first detection of a transient high-ionization coronal NIR line in a TDE and to the suggestion a possible scenario for the emission mechanism and the geometry of the emitting region.
9.1 AT 2017gge as a gas-rich TDE surrounded by a dusty environment

The detection of very broad (FWHM \( \sim 10^4 \) km s\(^{-1}\)) H emission lines in the optical spectra place AT 2017gge among the H-rich TDEs subclass (Arcavi et al. 2014; van Velzen et al. 2020; Charalampopoulos et al. 2022). Notably, in correspondence of a delayed X-ray flare, a broad (FWHM \( \sim 10^3 \) km s\(^{-1}\)) He\textsc{ii} \( \lambda4686 \) emerges after 194 d from the transient discovery, indicating a transition toward a TDE H + He subclass. Together with the He\textsc{ii} \( \lambda4686 \), also a number of high ionization coronal emission lines appear. These spectral features and the IR echo, strongly indicate the presence of a gas-rich and dust-rich environment surrounding the source, consistent with the star-forming nature of the host galaxy.

The MIR reverberation signal is detected with a delay of \( \sim 200 \) d from the optical peak emission and corresponds to a distance for the dust producing the IR echo of \( \sim 0.16 \) pc, as derived in this work by using two cross-correlations methods. This value is similar to the sublimation radius obtained for the case of the TDE PTF-09ge (van Velzen et al. 2016) and suggests that AT 2017gge may have sublimated the pre-existing \textit{in situ} dust out to this radius. Our estimation of the total (optical/UV + IR) radiated energy of \( 2 \times 10^{51} \) erg is significantly lower that the \( 10^{52} \) erg that has been theoretically predicted for the case of the disruption of a solar mass star, despite the large covering factor of \( \sim 0.2 \) derived by Wang et al. (2022). This could be explained by a large proportion of far-UV emission remaining unobserved, as potentially indicated by the large intrinsic luminosity required to produce the delay time we observe in the IR. This can be compared with TDEs in galaxies with a very high covering factor for the SMBH such as the IR-luminous, highly obscured TDE Arp 299-B AT1, where a direct integration over time of the IR SED yielded a total radiated energy of \( \sim 2 \times 10^{52} \) erg (Mattila et al. 2018; Reynolds et al. 2022).

We have presented three NIR spectra taken after the IR echo and we report the detection of a broad feature in the He\textsc{ii} \( \lambda10830 \) and an intense Fe\textsc{xiii} coronal emission line, both gradually disappearing in the subsequent spectra. This is the first time that a broad feature and a high-ionization coronal line are detected in the NIR spectra of a TDE taken following an IR echo from surrounding dust (but see the case of the candidate TDE AT 2017gb1 in which NIR spectra have been presented, Kool et al. 2020).

The presence of the luminous and transient high ionization coronal emission lines in the spectra obtained soon after the detection of the soft X-ray emission implies a strong correlation with the soft X-ray emission and a gas-rich environment of the TDE, as expected from the star-forming nature of the host galaxy. These high ionization coronal lines are long-lasting as, together with a narrow He\textsc{ii} \( \lambda4686 \), are still present in the X-shooter medium-resolution spectrum taken after 1698 d from the transient discovery. Together with the TDE AT 2019qiz (Short et al., in preparation), this is the first time that high ionization coronal emission lines are detected in the optical spectra of TDEs following the X-ray outburst. This strongly indicates a close connection between the two phenomena and support the hypothesis that the extreme coronal emission lines detected in the spectra of a sample of non-active galaxies could be a signature of the occurrence of a TDE in the past (as suggested by Wang et al. 2012).

9.2 The broad line emitting region

We study the evolution of the EW, the FWHM and the line ratios of the broad H\textbeta, He\textsc{ii} \( \lambda4686 \), H\alpha, and He\textsc{i} \( \lambda5876 \) emission lines detected in the host-subtracted spectra of AT 2017gge. With the exception of the He\textsc{ii} emission line, all the other broad lines are detected starting from the very first spectra (at day \( \sim 40 \)) with FWHM \( \sim 10^4 \) km s\(^{-1}\) and show a declining trend with time. In particular, the H\textbeta have a different behaviour with respect to the H\alpha and He\textsc{i} \( \lambda5876 \), being characterized by a faster decline before becoming undetectable after \( \sim 400 \) d from the transient discovery. Instead, the broad H\alpha is characterized by a slow declining trend and it is long-lived as it is still detected in the X-shooter spectrum, after 1698 d from the transient discovery, when all the other broad lines are no longer detectable. Contrary to what observed in the H\alpha, the broad He\textsc{i} \( \lambda5876 \) keeps constant high values of the FWHM for \( \sim 250 \) d and soon after this phase it starts a very rapid decline, which last only \( \sim 50 \) d. Notably, this almost coincides with the appearing of the broad He\textsc{ii} \( \lambda4686 \) emission line. This feature is first detected at 194 d, soon after the delayed X-ray flare, and it does not show a particular declining trend. Instead it keeps an almost constant width of FWHM \( \sim 6 \times 10^3 \) km s\(^{-1}\) (one order of magnitude smaller than what measured for the broad H and He\textsc{i}) until its last detection at 338.6 d.

The observed different behaviour of the various broad emission lines is indicative of a stratified photosphere where different lines are produced at a different distance from the continuum source. Moreover, the time evolution of the various lines ratios can give us more insight in the properties of the region emitting the broad lines. In particular, the observed rising trend of the He\textsc{ii}/H\alpha line ratio can be ascribe to an increase in the photoionization of the broad helium emitting region. Given that the He\textsc{ii} line is known to be produced by photoionization due to (soft) X-ray photons, we suggests that the observed delayed X-ray flare could be responsible for this phenomenon. Furthermore, the observed evolution of the H\alpha/H\beta line ratio, which experiences variation from a values consistent with the Case B recombination to values predicted for homogeneous AGN BLR models, is mainly due to the faster decay of the broad H\beta with respect to the H\alpha.

9.3 A two-process scenario for the AT 2017gge emission

The X-ray peak brightening detected with a delay of \( \sim 200 \) d with respect to the UV/optical peak emission, followed by the development of a broad He\textsc{ii} \( \lambda4686 \), suggests a different origin for the two signals in AT 2017gge. A delayed X-ray emission is not new in the TDE field. It has been predicted to eventually occur in some models of TDE emission (i.e. reprocessing envelope model, the stream–stream collision scenario and the TDE unified model, Guillchon et al. 2014; Piran et al. 2015; Dai et al. 2018) and it has been already observed in some TDEs (i.e. ASASSN-14li, ASASSN-15oi, AT 2019azh, and OGLE16aa, Pasham et al. 2017; Gezari et al. 2017; Holoien et al. 2018; Liu et al. 2022; Kajava et al. 2020; Shu et al. 2020). Recently, Hayasaki & Jonker (2021) proposed an interesting two emission scenario in order to explain such a delay between the two signals, observed in a sub-sample of optically selected TDEs. In particular, in this picture, 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.

As suggested also by Wang et al. (2022), the AT 2017gge observed emission can be well described by this scenario. Indeed, the results from the optical photometry, the X-ray spectral analysis and even from the optical spectroscopy, are in line with this picture. In fact, while the optical/UV blackbody radius results ranging between \( R_{BB} = 7–13 \times 10^{14} \) cm, from the X-ray spectral fitting we derive a much smaller value for the blackbody radius, \( R_{BB} \sim 1.4 \times 10^{11} \)
cm, suggesting a different location for the source of the two signals. Moreover, an accretion disc model is able to represent well the X-ray spectrum.

The non-detection of the He II in the optical spectra taken prior to the X-ray flare may indicate the absence of the X-ray emission at these epochs, as the He II line is known to be correlated with the soft X-ray photons (Pakull & Angehault 1986; Schaerer, Fragos & Izotov 2019; Cannizzaro et al. 2021). However, we note that in the case of the TDE ASASSN-15oi and AT 2019ah a broad He II feature is detected well before the onset of a delayed soft X-ray flare (Gezari et al. 2017; Hinkle et al. 2021; van Velzen et al. 2021b). Additionally, in the recent work of Nicholl et al. (2022), where the light curves of 32 optically bright TDEs have been thoroughly analysed, it has been found that the events without He II were consistent with a stream-crossing origin for the luminosity, while those with He II were more consistent with forming accretion discs. The late-time developing of the He II observed in AT 2017gge could further support this scenario as this TDE seems to transition between these two regimes. However, we caution that there are also alternative explanations connecting both the optical/UV and X-ray emissions to the accretion phenomena, such as the lowering of the optical depth of an outflowing wind or of a reprocessing region, that cannot be excluded from our study. In particular, the delayed X-ray brightening observed in AT 2017gge could still be explained within a reprocessing scenario in which the decreasing of the optical depth of a reprocessing material at later times finally reveals the gas-rich circumnuclear environment from the flare and release the soft X-rays photons, allowing them to power the the narrow He II and iron coronal lines.

9.4 The awakening of the host galaxy activity

In order to understand the impact that a TDE can have on the host galaxy nucleus, we have used the pre-transient SDSS and the Gemini and X-shooter late-time optical spectra (taken after ∼408, 572, and 1698 d from the AT 2017gge discovery, respectively) to investigate on the activity status of host galaxy through the BPT diagrams. From this analysis a variation on the host galaxy activity clearly emerges. In particular, while the line ratio measured from the pre-transient SDSS spectrum are consistent with the star-forming classification (although its location on the the extreme starburst line suggests the presence of an additional ionizing component), the values derived from the Gemini spectra place the galaxy at the border between the composite and the AGN region and well inside the LINER region, suggesting an AGN-like activity between 400 and 600 d from the transient discovery. Finally, the galaxy activity status has come back to the initial values at 1698 d, as derived from the X-shooter spectrum. All this evidence suggests the possibility that the occurrence of the TDE resulted in the enhancement of the activity of the SMBH, which passes from quiescent to an AGN-like, with the formation of a transient stratified photosphere, similar to a BLR, surrounding the source.

In the hypothesis of the formation of a virialized BLR-like photosphere, we test an independent method to derive the SMBH mass by using the SE relation developed by Ricci et al. (2017) and the broad Hα and Hβ as measured in the Gemini spectra (which correspond to the phase of the increased activity of the host galaxy in the BPT diagrams). We derive an SMBH mass which is one order of magnitude smaller than what derived by using the canonical $M_{\text{BH}}=\sigma^{*}$, scaling relations developed by McConnell & Ma (2013) and Gültekin et al. (2009) and the stellar velocity dispersion as measured from the X-shooter spectrum ($\log M_{\text{BH}} = 5.4-5.7$ and $\log M_{\text{BH}} = 6.6-6.8$, respectively). Given the peak bolometric luminosity of $L_{\text{bol}} = 1.4 \times 10^{44}$ erg s$^{-1}$, an Eddington limited accretion would requires a BH mass of $\sim 4 \times 10^{6}$ $M_{\odot}$, consistent with the values obtained from the $M_{\text{BH}}-\sigma^{*}$ relation. Thus, we consider this method more trustworthy and we suggest that the broad lines emitting region is not virialized.

10 CONCLUSION

We have presented the results from our dense, long-lasting and multiwavelength follow-up of the nuclear transient AT 2017gge. Based on the on the detection of very broad Hβ and Hα emission lines in the optical spectra and on the results from the bolometric light curve and the X-ray analysis, we confirm the TDE nature of this transient and we classify this object as a H-rich TDE (TDE H) in transition toward the H + He TDE (TDE H + He) subclass. The SMBH mass as derived from the $M_{\text{BH}}-\sigma^{*}$ relation results to be $\log M_{\text{BH}} = (6.55 \pm 0.45)$ or $\log M_{\text{BH}} = (6.80 \pm 0.43)$ (depending on the scaling relation used) and is consistent with the typical values derived for the TDEs host galaxies.

The occurrence of the TDE have an impact on the activity of the host galaxy which passes from a quiescent star-forming galaxy to a composite/AGN in the BPT diagram, to come back to quiescence after 1698 d. The photoionization induced by the delayed X-ray flare is responsible for the production of a number of high ionization coronal emission lines, which also indicate that the TDE occurred in a gas-rich environment.

The picture that we suggest from our analysis is that of a TDE occurred in a dusty and gas-rich environment, in which the UV/optical emission is produced at a distance of $R \sim 10^{15}$ cm from the SMBH by the collision between intercepting streams of stellar debris during the initial phase of the stellar disruption. After $\sim 200$ d from the transient discovery, the circularization process ends and a newly formed accretion disc released a soft X-ray flare. However, we caution that the reprocessing scenarios are still able to explain the delayed X-ray brightening observed in AT 2017gge. The emitting region of the observed broad lines is consistent with a symmetric and stratified photosphere. Finally, placed at a distance $R \sim 10^{15}$ cm, an absorbing dust surrounds the whole system. The covering factor of $\sim 0.2$ suggests that a large proportion of UV radiation could still be unobserved in both the optical and IR bands and could be behind the observed total (optical/UV + IR) energy radiated being significantly lower than the energy expected to be released by the disruption of a solar mass star.

Our dense and long-lasting monitoring campaign of AT 2017gge have revealed a remarkable TDE which have induced a variety phenomena in the host environment, allowing us to build a picture describing both the geometrical and the physical properties of the system. Moreover, its occurrence in a star-forming galaxy suggests a close connection between a gas-rich environment, the soft X-ray flare and the production of long-lasting high ionization coronal emission lines, strongly supporting the idea that extreme coronal line emitter galaxies may have indeed experienced a TDE in the past. This demonstrate the importance of such dense multiwavelength follow-up campaigns of TDEs in the study of accretion processes around quiescent SMBHs.

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**DATA AVAILABILITY**

The data underlying this article are available in the article and in its online supplementary material. The NTT spectra and images are publicly available through the PESSTO SSDR4 ESO Phase 3 Data Release (see the ESO archive search and retrieve interface). The NOT, TNG, WHT, GTC data are public and available through the corresponding telescope archives. The processed data underlying this article will be shared on request to the corresponding author.

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SUPPORTING INFORMATION

Supplementary data are available at MNRAS online.

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APPENDIX: SOME EXTRA MATERIAL
Table A1. Swift/UVOT photometric measurements.

| MJD (1) | Phase (2) | U/VW2 (3) | U/VM2 (4) | U/VW1 (5) | U (6) | B (7) | V (8) |
|---------|-----------|-----------|-----------|-----------|-------|-------|-------|
| 58 031.12 | 62.8 | 18.03 ± 0.08 | 17.86 ± 0.08 | 17.66 ± 0.09 | 16.51 ± 0.12 | 17.26 ± 0.14 | 16.62 ± 0.17 |
| 58 041.75 | 73.4 | 18.23 ± 0.09 | 18.02 ± 0.08 | 18.00 ± 0.11 | 16.81 ± 0.15 | 17.77 ± 0.21 | 16.93 ‡ |
| 58 046.29 | 77.9 | 18.18 ± 0.08 | 18.14 ± 0.08 | 17.98 ± 0.10 | 17.97 ± 0.14 | 17.83 ± 0.17 | 17.20 ± 0.22 |
| 58 051.78 | 83.4 | 18.42 ± 0.09 | 18.11 ± 0.08 | 17.99 ± 0.11 | 16.84 ± 0.16 | 17.48 ± 0.17 | 16.84 ‡ |
| 58 055.04 | 86.7 | 18.34 ± 0.09 | 18.17 ± 0.09 | 18.18 ± 0.11 | 16.65 ± 0.14 | 17.84 ‡ | 16.85 ‡ |

Notes. (1) MJD date of observations; (2) Phase (days) with respect to the discovery date MJD 57 968.35; (3), (4), and (5), apparent magnitudes and uncertainties for the UVOT filters U/VW2, U/VM2, U/VW1, in AB system; (6), (7), and (8), apparent magnitudes and uncertainties for the UVOT filters U, B, and V, in the Vega system. The values indicated with ‡ are upper limits. All the magnitudes reported are uncorrected for foreground extinction. With --- we indicate epochs with no data available (no observations). The full table including photometric measurement until MJD 59 655.29 is available online.

Table A2. Optical photometric measurements.

| MJD (1) | Phase (2) | c (3) | o (4) | u′ (5) | g′ (6) | r′/i′ (7) | i (8) | Telescope (9) |
|---------|-----------|-------|-------|--------|-------|----------|------|--------------|
| 57 968.35 | 0.00 | --- | 18.70 ± 0.17 | --- | --- | --- | --- | ATLAS |
| 57 971.32 | 2.97 | --- | 18.48 ± 0.17 | --- | --- | --- | --- | ATLAS |
| 57 972.30 | 3.95 | --- | --- | --- | --- | --- | 18.57 ± 0.04 | PS1 |
| 57 975.32 | 6.97 | --- | 18.38 ± 0.13 | --- | --- | --- | --- | ATLAS |
| 57 977.30 | 8.95 | --- | 18.24 ± 0.07 | --- | --- | --- | --- | ATLAS |
| J | H | Ks | | | | | |
| 58 347.043 | 374.75 | 19.96 ± 0.16 | 17.50 ± 0.09 | 16.12 ± 0.09 | --- | --- | NTT |

Notes. (1) MJD date of observations; (2) Phase (d) with respect to the discovery date MJD 57 968.35; (3) and (4) host-subtracted apparent magnitudes and uncertainties for the ATLAS filters c and o, respectively; (5) and (6) host-subtracted apparent magnitudes and uncertainties for the filters u′ and g′ obtained in the framework of our monitoring campaign; (7) host-subtracted apparent magnitudes and uncertainties for the filters r′ obtained in the framework of our monitoring campaign and for the PS1 filter w′; (8) host-subtracted apparent magnitudes and uncertainties for the filter i′, obtained by PS1; (9) telescope used. NIR magnitude from SoFI/NTT observations is reported in the last row of the table. All the optical magnitudes are uncorrected for foreground extinction and are in the AB system, while the NIR data are in the Vega system. With --- we indicate epochs with no data available (no observations). *PS1 data in w′ band central wavelength correspond to the r′ one (Smith et al. 2020). The full table including photometric measurement until MJD 58 696.32 is available online.
Figure A1. Sequence of the rest-frame optical spectra of AT 2017gge taken with different facilities: EFOSC2/NTT (in blue), ALFOSC/NOT (in red), DOLORES/TNG (in orange), ACAM/WHT (in green), OSIRIS/GTC (in black), and GMOS/Gemini (in purple). All the spectra have been corrected for reddening. The time of the observation in days since the transient discovery and the main emission lines are indicated. The location of telluric absorption lines is indicated by grey bands.
Figure A2. Sequence of the host-subtracted spectra of AT 2017gge. In the left-hand panel the He II + Hβ region is shown, while in the right-hand panel the Hα region. The host-subtracted spectra obtained for the EFOSC2 Gr#18 and the ALFOSC Gr#19 are shown in green in the left-hand panel only (as they do not cover the Hα region). The position of the H lines and of the [O II] λ3727 are shown with black vertical dashed lines, while the He II and the position of the Bowen blend at λ4640 are indicated by green ad red dashed lines, respectively. The solid grey vertical lines indicates the position of the high ionization coronal lines [Fe X] λ6374. For each spectrum, the days from the transient discovery are also indicated.
Figure A3. Rest-frame X-shooter spectrum (UVB, VIS, and NIR) of the AT 2017gge host galaxy taken 1648 d after the transient discovery. The spectrum has been corrected for reddening. The main emission lines are indicated with dashed vertical lines, while red solid vertical lines indicate the position of the H lines. The region affected by telluric absorption lines is indicated by grey bands.
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