The tidal disruption event AT2017eqx: spectroscopic evolution from hydrogen rich to poor, through an atmosphere and outflow

AT2017eqx was discovered by the PanSTARRS and ATLAS surveys. We classified it spectroscopically as a TDE in a post-starburst galaxy using the MMT and Magellan telescopes.

Photometry from Swift, FLWO and Swope show a typical $L \approx 10^{44}$ erg/s and constant $T \approx 25000$ K.

The early spectra show broad lines of H I and He II 4686. After a few months, He II / H$\alpha$ ratio changes from $\approx 2$ to $>10$, with H lines no longer detectable.

Simultaneously, He II becomes blueshifted by 5000-8000 km/s.

The late-time spectrum resembles He-strong TDEs such as PS1-10jh, PTF09ge and ASASSN-15oi.

This proves that a H-poor spectrum does not indicate the disruption of a stripped star. Instead, the He II / H ratio must be a sensitive function of physical conditions.

The evolving He II / H$\alpha$ ratio can be explained by changes in the physical size of the emitting region. For a more compact configuration, H$\alpha$ is optically thick throughout (Roth et al 2016).

Contraction of a thermally-emitting envelope is also consistent with the decline in luminosity at constant colour temperature.

However, the blueshifted He II line indicates outflowing material: the geometry of the TDE debris must include both inflowing and outflowing regions.

This is shown in the schematic below: a quasi-spherical envelope undergoing slow contraction under gravity, and an outflow confined to a narrow angular range. This applies regardless of underlying power source (accretion, A, vs circularisation, B).

Implication: our viewing angle towards TDEs determines when, if ever, the blueshifted lines are revealed.
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We modelled the light curve using the TDE model in the MOSFiT package (Guillochon et al. 2018, Mockler et al. 2019). The model assumes a fallback rate dM/dt (M_\text{h}, M_\text{\ast}) derived from simulations, with a simple prescription for viscous delays and a blackbody SED.

Assuming a typical TDE rise time, we found a SMBH mass log(M_\text{h}/M_\odot) ≈ 6.3. This value is larger by ~0.5 dex if the rise time is left unconstrained. The disrupted star mass was found to be ≈ 0.9 M_\odot. The impact parameter indicates a close encounter (full disruption).

We found no evidence for viscous delays, possibly favouring a collisional (rather than accretion) origin for the luminosity.

We fit the host galaxy SED using Prospector (Leja et al. 2017). The total stellar mass indicates an SMBH mass log(M_\text{h}/M_\odot) ≈ 6.8, consistent with our light curve modelling.

A host spectrum reveals it to be a post-starburst galaxy, overabundant within the TDE sample (French et al. 2016). However, it is fainter, and has a lower stellar mass surface density than any other TDE host except for PS1-10jh (Graur et al. 2018).
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We carried out deep X-ray observations using the Neil Gehrels Swift Observatory and Chandra X-ray observatory. No X-rays were detected down to a deep limit of $< 10^{41}$ erg/s, one of the deepest limits among TDEs (Auchettl et al 2017).

The lack of X-rays indicates either:

- An optically-thick reprocessing layer, if the TDE is powered by accretion (A). Comparing this to our schematic model, X-rays may have been visible in this case for viewing angles closer to the pole.
- A TDE powered by stream-stream collisions/circularisation, rather than direct accretion. In this scenario, a disk may or may not form at late times. If this occurs, a more isotropic emission is expected (B), though it may be faint.

We argue that if most TDEs are powered by accretion, there should exist a correlation between X-ray-bright TDEs and blue-shifts in their emission lines, because both are more visible for polar viewing angles.

In a stream-powered scenario, no such correlation exists. Therefore a combination of deep X-ray observations and optical spectroscopy key to revealing the TDE power source.

Radio observations with the VLA rule out an on-axis relativistic jet, but may allow a weaker outflow comparable to that seen in ASASSN-14li (Alexander et al 2016, van Velzen et al 2016).

Future radio observations should determine whether this TDE could have launched an off-axis jet.

References
van Velzen S., et al., 2016, Science, 351, 62