Complete SEDM Follow-up of Bright TDEs and CLAGN

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Science: Tidal Disruption Events (TDEs)

The fast cadence and wide FOV of the ZTF camera has enabled the assembly of the first statistical sample (20 in the first 2 years of the MSIP survey) of TDEs from one single survey (van Velzen et al. 2020). Our goal is to use the SED machine (SEDm) to make timely identification of bright TDEs (<19 mag) discovered by ZTF in order to trigger multiwavelength follow-up observations to study the physical mechanisms operating in TDEs.

As shown by recent theoretical work, the two fundamental parameters of a black hole — mass and spin — are imprinted on the light-curves of TDEs. However, observations of optical TDEs in the past decade have shown inconsistent results from the classical prediction where the emission is dominated by an optically thick accretion disk peaking in the soft X-ray. To summarize, the temperature of the optically discovered TDEs is too cold (a few x 10^4 K vs 10^6 K) and remains constant blackbody temperature instead of cooling with time. These result in an optical emitting region that is orders of magnitude larger in size (10^{14} cm vs 10^{12} cm) and shrinking with time.

These discrepancies have motivated a number of second generation models with increased sophistication. Some works argue that a gaseous envelope could reprocess the X-ray photons produced by the accretion disk and re-emit in the UV and optical. Alternatively, the optical emission may originate from energy dissipated in stream-stream collision shocks caused by relativistic apsidal precession. Currently we have 4 approved ToO programs across the electromagnetic spectrum and 2 proposals under review (described below) that will shed light on the emission mechanism operating in optically bright TDEs, and connect the spectroscopic class of the TDE with its physical parameters.

The SEDm, given its flexibility in scheduling, will serve to optimize the usage of these follow-up programs through making prompt classification of the TDE candidates. The brightness limit (19 mag) of the SEDm will also ensure the classified TDEs to be bright enough for high S/N observations with ground and space-based telescopes. Using our systematic filtering, archival contextual information, and light curve parameterization, we have demonstrated an efficient end-to-end TDE selection strategy (e.g. cuts on the spatial separation, host galaxy color, transient color, variability amplitude...etc), yielding TDEs at a rate of ~10 per year brighter than 19, and a contamination rate of 4:1. Our selection strategy will continue to yield a manageable number of candidates (~1 photometric TDE candidates per week) for a **complete** spectroscopic classification in ZTF of TDEs brighter than 19th mag. This complete sample, with no bias towards host galaxy color or morphology, will enable a rigorous study of the host galaxy preferences of TDEs and their black hole demographics.

End-to-End planning

The following programs are available to us for multi-wavelength follow-up of ZTF TDEs.

Swift (PI Gezari; Accepted)

Observe 10 rising TDEs (g < 19 mag) confirmed with SEDm in Cycle 16. We will use Swift to sample TDE light curves on a cadence of week, with higher cadence observations (2 days) for our low-redshift TDEs (z < 0.07) with XRT and 6 filters of UVOT (UV + optical).

LDT (PI Gezari; Accepted)

Observe ~10 TDEs and CLAGN per month (both new SEDm-confirmed candidates and monitoring of known ZTF TDEs and CLAGN) with optical spectroscopy on the 4.3m Lowell Discovery Telescope (LDT).

HST (PI Cenko; Pending)

We will obtain a sequence of UV (HST) and optical (Gemini/GMOS) spectra for a sample of 5 TDEs in Cycle 28.

VLA (PI van Velzen; Accepted)

We have an approved VLA program for radio follow-up of 8 ZTF-selected TDEs. For this program, early radio observations are more valuable hence early TDE classification is key and SEDM provides the crucial first step

XMM (PI Gezari; Accepted)

We will observe 6 TDEs that are discovered pre-peak in the X-rays. Take an initial observation within a week of discovery (t1) , plus up to two more epochs at t1+1 month and t1+3 months.

Expected outcome

Our rate of bright (g < 19 mag), photometrically selected TDE candidates from Years 1-2 of ZTF is ~1 per operating week (excluding weather loss or diurnal interruptions), for a total of 26 triggers in this 6 month SEDm call (April - September). This SEDm sample will be spectroscopically **complete** down to 19 mag. Provided that our filtering on the candidates is minimal (all g<19 mag nuclear transients with g-r < 0), we can achieve a spectroscopically complete flux-limited sample of TDEs, which will allow us to measure rates and host galaxy properties in an unbiased manner. Among our non-TDE blue nuclear transients, we expect 50% to be SNe Ia, 33% to be AGN, and a few % to be core-collapse SNe. **For the ~5 bonafied TDEs classified by SEDm in this 6 month period, we will trigger our panchromatic follow-up program (HST, DCT, XMM, VLA, Swift).**

Triggering criteria

Following the strategies of van Velzen et al. (2020), we will trigger SEDm on transients that satisfy the following criteria

1. g or r < 19 mag

2. The transient is spatially coincident with an extended galaxy.
3. Separation from the host centroid is less than 0.8".
4. The transient has not been reported as an AGN.
5. The position of the transient has no variability history in PTF, PS1, CRTS, or WISE
6. The amplitude of variability (Δm) is greater than 0.5 mag.
7. The transient has a g-r < 0 and no color evolution

So, for 20 TDE candidate triggers, we require 26 x 2430s = 17.55 hours of exposure time, plus we expect 2 CLAGN candidates per month (another exciting discovery from our systematic follow-up of nuclear transients, and published in Frederick et al. 2019) requiring 12 x 2430s = 8.10 hours, resulting in a total request of **26 hours in this 6-month period**, corresponding ~6% of the total time allocation to the ZTF Partnership.

Publication plan + manpower

We have already automated our selection process using filters in AMPEL, that are then ingested into the GROWTH marshal, cross-matched with AGN catalogs, and the shape of their light curves systematically characterized, and then ranked TDE candidates for daily visual scanning by our ZTFbh science working group.
The PIs of each ToO program will be in charge of triggers and analysis.

Expected list of publications:
-- Rate of TDEs in ZTF Years 1-3
-- Host Galaxy Properties and BH Demographics of TDEs in ZTF Years 1-3
-- Multiwavelength synthesis paper