SEDm Whitepaper: A Complete Spectroscopic Sample of Bright TDEs.

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Science: Tidal Disruption Event (TDE)

The fast cadence and wide FOV of the ZTF camera will allow the assembly of the first statistical sample (32 per year through the MSIP survey) of TDEs from one single survey. 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 detailed 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 and 1 proposal under review (described below) that will shed light on the emission mechanism operating in optically bright TDEs with imaging and spectroscopic observations across the electromagnetic spectrum.

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. From the iPTF g+R experiment in 2016, we have formalized an efficient TDE selection strategy (e.g. cuts on the spatial separation, host galaxy color, transient color, variability amplitude...etc) to reduce the contamination rate from 250:1 to 4.5:1 (see Fig 4 in Hung et al. 2017b; arXiv:1712.04936). This selection strategy will yield a manageable number of candidates for a complete spectroscopic classification in ZTF.

End-to-End planning

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

HST (PI Cenko; Accepted)

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

VLA (PI van Velzen; Accepted)

15 FAST triggers for newly discovered TDEs to look for radio emission. If radio emission is detected in the FAST trigger, we will trigger 5 multi-frequency SED observations.

XMM (PI Gezari; Accepted)

We will observe 2-6 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.

Spitzer DDT (PI Yan; Accepted)

We will obtain high cadence mid-IR light curves for 7 TDEs (5 epochs each) that have redshift < 0.2 and the discovery phases no later than 20 days post-maximum light.

Swift (PI Hung; Pending)

Observe 2 rising TDEs with magnitudes accessible by SEDM. We will use Swift to sample TDE light curves on a daily cadence with XRT and 6 filters of UVOT (UV + optical) to map reverberation in TDEs.

Expected outcome

We simulated the number of triggers expected with realistic data from the 4-month g+R experiment in 2016. We employed less stringent selection criteria than in Hung et al. (2017b; arXiv:1712.04936) by selecting all blue nuclear transients that are not caused by AGNs and are accessible by SEDm in our simulation. Our estimated rate of TDE candidates is 5 per operating week (excluding weather loss or diurnal interruptions). In one year of our SEDm program, we will expect to have discovered 6 TDEs. This SEDm sample will be spectroscopically **complete** down to 19 mag, and will provide classifications for ~20% of the total TDE ZTF sample, including 2 TDEs discovered 30 days before peak. 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 ~6 bonafied TDEs classified by SEDm, we will trigger our panchromatic follow-up program (HST, Gemini, XMM, VLA, Spitzer, Swift).**

Triggering criteria

Following the strategies in Hung et al. (2017b), 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, or CRTS.
6. The amplitude of variability (Δm) is greater than 0.5 mag.
7. The transient has a g-r < 0

According to the exposure time recommendations for SEDM. We propose the following times for a S/N of 7:

- Transients with r <18 - 1800s
- Transients with 18 < r < 18.5 - 2100s
- Transients with 18.5 < r < 19 - 2400s

Publication plan + manpower

Tiara will automate the selection process by setting up filters in the GROWTH marshal and cross-matching transients to AGN catalogs.
The PIs of each ToO program will be in charge of triggers and analysis.
Nadia Blagorodnova will automate the SEDm trigger process, data reduction and fast classification of the transients..

Expected list of publications:
-- Rate of TDEs in ZTF Year 1
-- Host Galaxy Properties of TDEs in ZTF Year 1
-- Multiwavelength properties of 6 individual TDEs (6 papers)
-- UV and optical spectroscopy synthesis paper
-- Radio synthesis paper
-- X-ray synthesis paper
-- Infrared dust echo synthesis paper
-- light curve synthesis paper