SEDM WP from the *Cosmology & Lensing SWG*:

Cosmic census of supernova rates and the Hubble diagram with ZTF/SEDm

Science case:

Through this SEDm proposal we aim at producing the first controlled sample of transients in the local universe, including both thermonuclear and core collapse supernovae. Over a period of 6 months we expect ZTF to find nearly 700 supernovae in the MSIP fields for a triggering threshold at g=18.5 mag, as shown in the table below. Spectroscopic identification of these will enable a careful assessment of 1) the chemical enrichment of galaxies; 2) the feed-back mechanisms regulating the growth of galaxies and star formation; 3) the rate by which black holes and neutron stars are born. Furthermore, an unbiased spectroscopic identification of supernovae will generate detailed information of relative rates of the various explosion subtypes and shed clues onto many questions of the final stages of stellar evolution. The proposed spectroscopic follow-up will feed into important cosmological studies; especially for the Hubble diagram of Type Ia supernovae used to measure the H_0 and the properties of dark energy. It will also yield key knowledge on rates and luminosity functions needed for photometric classification of transients in the future.

As clearly demonstrated by the most recent compilation of SNe Ia ("*Pantheon*", Scolnic et al., arXiv:1710.00845), systematics in the current low-z anchoring sample, collected from many different surveys, dominates the uncertainty in the estimates of dark energy and may be causing the "Hubble tension", a claimed >3 σ discrepancy between the local and global estimate of the expansion of the universe. Aside from the Hubble tension, a well calibrated single survey controlled low-z sample will be essential for increasing the power of high-z SNe Ia to discern between models of dark energy. The *Cosmology and Lensing SWG* is also planning to explore other techniques to measure cosmological parameters with ZTF. With the proposed data-set, and follow-up higher resolution spectroscopy for selected objects from NOT, we will be able to measure H_0 with an independent technique: using Type II supernovae as distance estimators, a still poorly exploited tool in cosmology, see Gall et al, arXiv:1705.10806, for a state of the art result. The survey will also help to search for lensed SNe, for reference iPTF16geu (Goobar et al, 2017, *Science*) peaked at ~19 mag. Lensed SN studies is an exciting path to explore the expansion rate of the universe probing a distance scale in between the local tests and the CMB/BAO extrapolation. The proposed sample will also allow us to measure the structure in the nearby universe and determine whether it is consistent with the predictions from ΛCDM structure formation. This is done by using the correlations of the Hubble residuals of SNe Ia. Examples of this technique include the determination of lower-order peculiar velocity moments, bulk flow and shear (Feindt et al. 2013) and measurement of the growth of structure factor $f\sigma_8$, see e.g. Howlett et al. 2017 for a higher-z case.

Uniqueness:

Only the combination of ZTF and the SEDM can realistically collect the data-set needed to explore the outlined science. We are securing other follow-up telescopes (NOT, TNG, SNIFS) to cover for potential inefficiencies to reach our completeness. Our proposal shares the same

triggering criteria as the SEDm WP by Kulkarni et al, thus we should be able to coordinate resources optimally.

Expected outcome and publication plan:
One of the key SWG goals is to publish a robust measurement of SN rates, where this sample would form the backbone. Transient rate studies requires very good control of survey depths and detection efficiencies, and it is thus not realistic to finish this before late 2019. However, right from the start, the sample obtained through this programme would form a background data-set, which will be used as reference for all forthcoming ZTF cosmology publications, the key projects of the Cosmology & Lensing SWG.

Manpower available:
Nordin and Brinnel in the HU Berlin group are already implementing an alert management pipeline ("Ampel"). Through this we could provide nightly target lists of all untyped transients with predicted brightness above the final magnitude threshold. The rates analysis will be led by OKC postdoc Biswas, who is also the current co-convener for the LSST DESC SN group, for which the current study will become a pillar of their survey planning. The entire SWG is engaged in producing the cosmology results, including four postdocs at OKC, two at Berlin and the new group led by Mickael Rigault in France. Several graduate students in the three main institutions will be involved. For the cosmology with Type II SNe, the group at WEI, as well as the CC group at OKC and Peter Nugent in Berkeley will be involved.

Triggering criteria:
We propose to trigger on all transients passing a threshold g=18.5 mag on the MSIP footprint. The forecasted statistics over six months of survey is summarized in the table below:

SN Type	SNe in 6 months	Median redshift
Ia	440	0.06
Ibc	84	0.05
IIP/L	110	0.03
IIn	43	0.05
Total	237 CC/440 Ia=677	

Assuming 1 hour exposures and 8 hs/night, the program above requires nearly 50% of total the SEDM usage. At this depth, the ½ year program would yield a sample roughly corresponding to the current nearby well-observed sample but with a known selection function. A shallower survey would yield a sample smaller than what is exists today, and thus not have a similar immediate impact.