Cosmic Census of Bright Transients

Part I: Summary:

We propose to extend the very successful magnitude limited transient classification program carried out with SEDm during Year 1. Originally proposed as two independent efforts, "*Cosmic Census*" and "*Bright Transient Survey*", both requesting a nearly complete classification of m<18.5 mag transients in the MSIP stream, the adopted program has served the entire ZTF transient community. In addition, as the discoveries and classifications are reported through TNS, the program will have a large legacy value for time-domain astronomy as a whole. Aided by a separate program using Caltech time, the "RCF" program (as it has been called) has been extremely efficient at turning the numerous ZTF discoveries into rich samples of classified SNe, avoiding many of the systematic uncertainties plaguing pre-ZTF surveys.

During Year 1, our SEDm program delivered ~100 SN classifications/month, i.e., about 4 spectra/night, on average. Since the fraction of MSIP fields with references has increased, more transients are expected to be found, thus we are now asking for 5 classifications/night, corresponding to ~60% of the partnership share of P60.

Part II: Team Members / Resources

This program has obtained wide support among (at least) three SWGs: Cosmology & Lensing; Physics of Supernovae; and the neutrino MMA working group. In particular, the two teams behind *Cosmic Census* and *Bright Transient Survey* have joined forces to achieve a well-optimized usage of the common resources. This proposal thus addresses a very large fraction of the ZTF partnership scientific interests.

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Associated Resources (facilities, etc.): As for Year 1, multiple facilities are to be used to complement the SEDm observations when needed (P200, NOT, LT, APO, Keck, TNG, SNIFS, LCO). There are also ongoing discussions with potential external collaborators to further enhance the list of follow-up resources for Year 2.

Part III: Science Objectives (1 page)

With a 47-square-degree camera mounted on the 48-inch Schmidt telescope at Palomar, ZTF improves on its predecessor by nearly an order of magnitude in survey speed. This proposal aims at obtaining spectral identification for transients in the public survey (MSIP), which monitors the entire observable sky in two bands every three nights. ZTF/MSIP detects > 10 new supernovae candidates every night of operation and many thousands each year.

Scientifically crucial questions about the volumetric rates of different transients, the host-galaxy dependences (on age, metallicity, etc.) of different supernova (SN) types and subtypes, or attempts to use SNe as cosmic population probes are greatly complicated by the severe incompleteness of the spectroscopic samples and the impossibility of reconstructing the effect of human-dependent follow-up choices. Qualitative conclusions can sometimes be drawn, but quantified measurements needed to test theories are far more challenging. The SEDM on P60 was built to address this bottle neck. Thanks to several upgrades the SEDM can efficiently classify transients, about 14 per night to about 18.5 mag.

In Year 1, we demonstrated that the P48-P60 combination can undertake a systematic discovery+classification survey of the transient sky. The survey is producing a much needed data-set to address a broad range of topics. These include (but are not limited to) the understanding of the chemical enrichment of galaxies; generating the SNIa sample – with unprecedented early discoveries- to be used to anchor the Hubble diagram for studies of H_0, dark energy and the cosmic flows unveiling the underlying distribution of matter + explore poorly known systematic uncertainties of astrophysical nature, currently limiting all aspects of SN cosmography (e.g., host galaxy extinction, dust in the IGM, "mass-step" in the luminosity function, the nature of the progenitor, etc) ; discovering faint galaxies in the local Universe (e.g., to be used to rank kilonova candidates in coincidence with LIGO-Virgo discoveries); understanding the environmental dependencies of properties of Type II, stripped-envelope and superluminous supernovae; provide the SN sample to cross-correlate with IceCube neutrino signals.

The proposed scheme has worked as a finder and classifier for several transient programmes (Like CCSNe and Type IIn and the ν-multi-messenger association) and - last but not least - the survey is well-suited for searches for exotic transients, including kilonovae, also those not detected in the GW sky (which may be of great importance to understand selection effects), and gravitationally lensed SNe.

Summary: the current magnitude-limited survey allows us to exploit the rich discovery potential of ZTF to produce a legacy sample of classified transients, leading the way to a new era of quantitative studies in time domain astronomy.

Part IV: Past Usage (1 page)

In our previous proposals, we used simulations to estimate that we should discover approximately 650 SNe brighter than 18.5 mag during the first six months of the survey. A majority of these (70%) are Type Ia with the rest being core-collapse.

We started the principal surveys in late March. Despite bad weather and continued commissioning problems (for both the P48 camera and SEDM), during the first months, the SN yield and the SEDM performance has been, as can be seen from the Figure 1, on track. Up until 2018 Dec. 4th we had successfully classified a total of 622 SNe, in excellent agreement with the simulations by Ulrich Feindt.

The discoveries and spectral identifications have been made publically accessible through TNS and has thus been a very welcome contribution to the transient community. Figure 2 shows the quality of the SEDm spectral identifications, as compared with other (larger) facilities. The obtained spectra are in excellent agreement with others from higher resolution instruments.

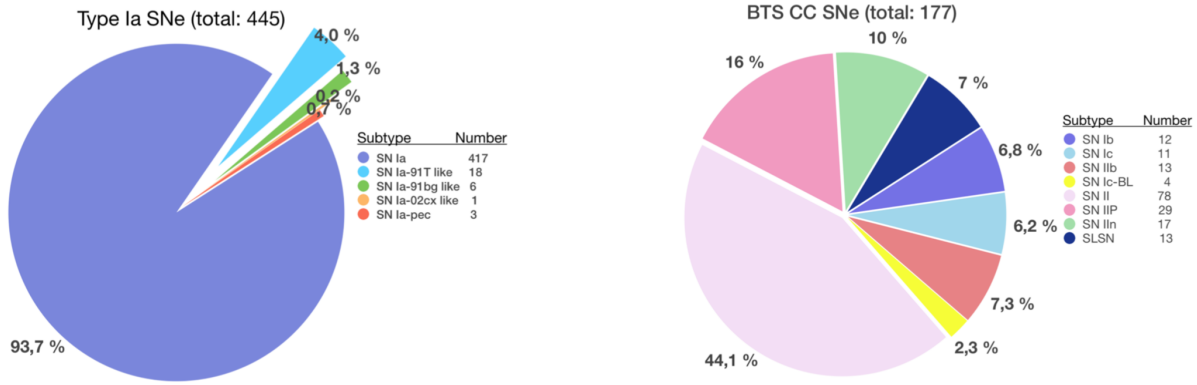

Figure 1: The yield of the Year 1 survey (6 months worth of observations) that we propose to extend. The total rate of SNIa an CCSNe matched very well the predicted rates from simulations, which allowed us to generate realistic plans to realize a complete survey.

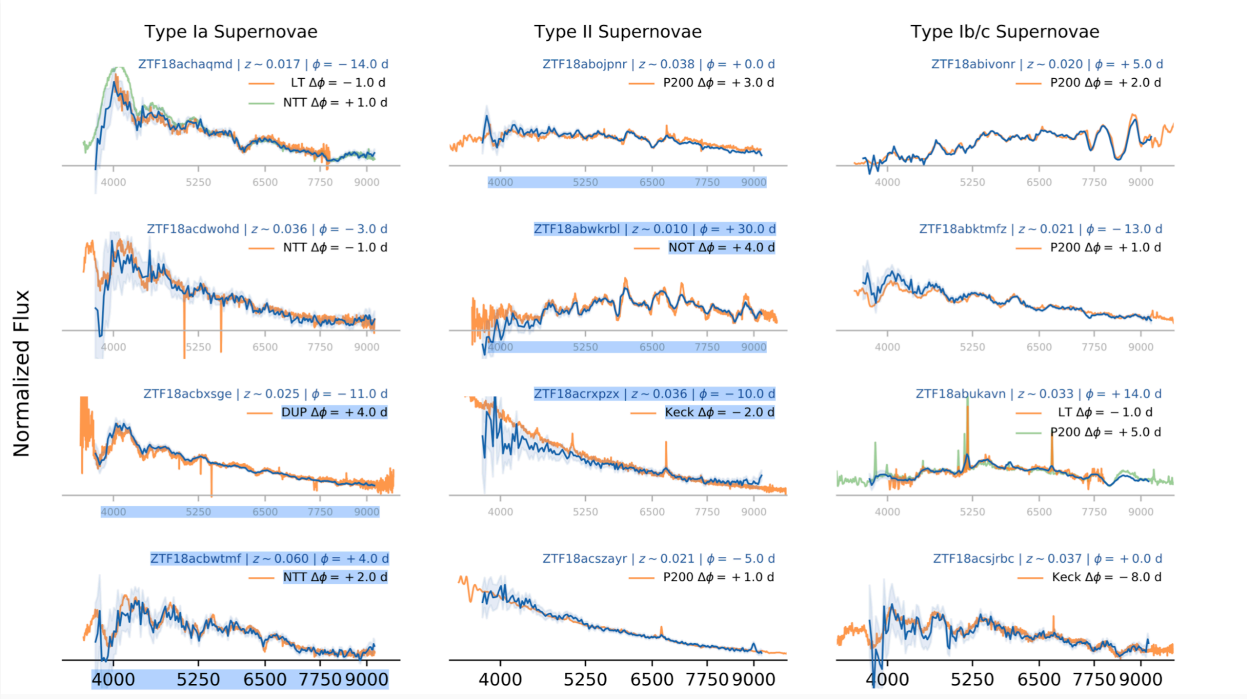

Figure 2. SEDm spectral comparisons for a variety of SN types and brightness, as prepared by Mickael Rigault for a forthcoming paper.

Part V: Observing Details (1 page)

Triggering Criteria: a threshold of m<18.5 mag on MSIP transient alerts has been set not to saturate the use of SEDM, especially considering other critical needs for P60 usage among the partnership SWGs. However, would the planned enhancement lead to considerable shorter exposure times, we would attempt to increase the depth by a few more tenths of mag. The latter would be very valuable for SNe Ia in the i-band footprint, increasing the reach of the ZTF SNIa Hubble diagram to completeness up to z~0.1, the design target for the cosmology survey.

Trigger Method: So far, two channels have been used coherently to trigger: a tuned RCF Growth filter, as well as a separate stream based on AMPEL. The idea is to gradually phase out the manual intervention as much as possible.

Observing Sequence: Single spectrum when the transient passed the adopted threshold, avoiding stellar objects and AGNs.

Total Time Request: Based on the Year 1 observations, the *average* exposure length is 2100 sec + 180 sec OH x 5 exposures/ night = 3.2 hs /night, i.e., just about 60% of the partnership share, assuming 8 hs/night.

Part VI: Publication Plans (0.5 page)

The RCF project is currently preparing a letter presenting the Redshift Completeness of local galaxy catalogs using SNe Ia up to z=0.1, to be submitted in the first quarter of 2019 (Fremling, et al.). Following this, full data releases of the RCF spectra (Fremling et al.) and lightcurves (Miller et al.) are planned for late 2019 (for SNe found starting from June 2018). A paper investigating SN host galaxy properties is being prepared by K. Taggart and D. Perley.
Plans to combine the RCF with the Census of the Local Universe (CLU) project in order to constrain the faint end of the luminosity function of core collapse SNe are also in motion for 2019 (Fremling et al.).

The Cosmology working group is planning for several 2019 publications based on the 2018 RCF sample, as well as the proposed extension. These include constraining the SNIa early lightcurve rise, first estimates on bulk flow and structure variations using peculiar velocities and a study of the relative SN brightness in different host galaxy environments. These studies and the RCF programme further motivates the WG investment in calibration, where we are now readying the first star flat correction maps.

The ZTF, and thereby RCF, completeness, will be addressed in the AMPEL introduction paper (Nordin et al), where we investigate whether candidates reported by other surveys should have been found also by ZTF and RCF. This study will also include a comprehensive comparison of different supernova detection channels, which can form the baseline for more automated and faster detection.

The luminosity functions and relative rates of SNe (of all kinds) are also being investigated by members of the Cosmology SWG in the context of designing photometric typing algorithms with view on LSST.