AS4 Letter of Intent:

A time-domain spectroscopic survey of explosive transients in the MaNGA sample of nearby galaxies

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We propose an AS4 project in which we will follow closely the spectrophotometric evolution of a sample of ~ 1300 transients that explode, during the 5-year survey period, within the 10,000 nearby ($z < 0.05$, $D < 200$ Mpc) galaxies of the SDSS-IV/MaNGA sample. The "discovery engines" for the transients will be an assortment of transient survey telescopes that will be in operation, including: ZTF, ATLAS, BlackGEM, and LSST (2022-), which will monitor at few-night to sub-night cadence, some or all of the footprint of the MaNGA survey, to $\sim 20 - 21$ mag or fainter. The transients will consist of about 1000 core-collapse SNe (CCSNe) of all types, some 250 type Ia SNe (SNe Ia), an uncertain number (0.5-5) of galaxy-nucleus tidal disruption events (TDEs), and likely other rare, or new and unknown, types of transients and variables. Every event will be observed, on average, at several tens of epochs throughout its evolution, resulting in a final dataset consisting of several tens of thousands of spectra, and permitting robust classification and individual characterization of the details of each event. Every event will have pre-existing, pre-explosion, SDSS-IV/MaNGA IFU data of the galaxy host, yielding, both globally and at the specific location of the event: present stellar populations and star-formation rate; dust properties; stellar age distribution (SAD; aka "local star formation history"); gas and stellar metallicity estimates; and kinematics. Furthermore, every event discovered and followed up by the survey will have been discovered in a controlled experiment, that monitors the full, well-defined, mass-selected, MaNGA galaxy sample, with all of the above properties determined for all of the monitored hosts (both SN-hosting and non-SN-hosting ones), and with visibility times and detection efficiencies derivable for each kind of transient. By design, the transients will be young at discovery, and will all be nearby and relatively bright, permitting high S/N and high spectral resolution.

The above attributes of the survey will combine to produce a dataset that is unprecedented in its power to decipher numerous puzzles: what are the rates and delay-time distributions of the different SN types, and how do they depend on local environment? What are the progenitor stellar systems of the different SN types, whether: as seen directly in the MaNGA pre-explosion spectra (as will be possible for some CCSNe, and perhaps in some SNe Ia that may show signs of a pre-explosion accreting WD); or caught via early "flash spectra" of the circumstellar environment; or through shock breakout as revealed by very early photometry, and confirmed by early spectra; or indirectly, by using the local SAD to derive the delay-time distribution of the SN class (as will be possible with the SNe Ia)? How are specific SN types, and subtypes with specific spectral evolutionary behavior and physical element and energy yields, as revealed in the dataset, linked to specific progenitors and specific environments?

To the above sample of transients could be added, if time is available, a comparable number of transient events in non-MaNGA galaxies. Although lacking the pre-existing control data of the MaNGA sample, this sample could still be useful for post-facto studies of the hosts and for diversifying the portfolio of the transient database. Beyond the contribution to the understanding of the physics of cosmic explosions, the project will contribute valuable input to other fields. The spectrophotometric light curves will permit reconstructing the nucleosynthetic-element yield and the kinetic-energy yield of each type of explosion. These yields, together with SN-type demographics and with the rates and delay-time distributions, and their dependences on subtypes and on environmental factors, are all essential factors (but quite poorly known today) in calculations of galaxy and cosmic structure formation. Furthermore, for cosmographic applications, unraveling the subtleties of the correlations between SN Ia luminosity, intrinsic color, dust reddening, extinction, and environment, is required if we are to overcome the systematics that currently challenge the use of SNe Ia in the next stages of precision cosmology. This will be possible only with a massive, highly complete, dataset, well resolved in wavelength and in time, of the kind proposed here.

In the framework of an SDSS-V survey, given the expected SN rates, the proposed observing cadences, and an average visibility time of several months per event, of order 10-20 transients would be observed per night. For a fast reaction time to the discovery engines, of 1 day or so, the planned robotic fiber positioner on the 2.5m telescope is required. There will be only one target/fiber per plate on the 2.5m (see below), and hence all other fibers would be allocated to other programs that have a high target density and need time domain data (e.g. quasars, nearby white dwarfs). Alternatively, the project could be done in single-object spectroscopy mode on the ARC 3.5m, by dedicating a substantial fraction of its time to this project. With a fiber connection between the 3.5m and the 2.5m, the spectra could be obtained on the BOSS spectrograph of the 2.5m.

Ongoing transient surveys, such as PTF, have been obtaining heterogeneous spectroscopic followup for hand-picked transient events. This followup not been done uniformly for any well-defined type of transient candidates, let alone for the full sample of transients occurring in any particular galaxy sample, and let alone in a sample with detailed IFU galaxy information like MaNGA, nor has the followup had the high-cadence planned here. The dataset proposed here would be the first rigorously selected one, but also the largest and most homogeneous one, traits that have always been the power of SDSS.

In terms of synergy with other astronomy of the 2020's, a major goal of the above transient surveys is the discovery and understanding of the transient sky. LSST alone will discover of order millions of SNe per year down to 24.5 mag, with SNe Ia detectable to $z = 1$ and CCSNe to $z = 0.5$. Unfortunately, this wealth of discoveries will be too numerous but also too sparsely distributed to permit its full scientific harvest. At any given time, the surveys will see, all-sky, about 10,000 SNe brighter than 21.5 mag (i.e. amenable to spectroscopy on a medium-aperture telescope), i.e. a sky density of order 0.25 deg^{-2}. The total is orders of magnitude more than can be observed by all single-object spectrographs, while the sky density provides typically just one SN in the field of view of a MOS instrument. It therefore seems certain that the overwhelming majority of the transients from these surveys will remain spectroscopically unidentified, and their scientific benefit is currently uncertain. Our project addresses this problem, even if on a restricted level, by assuring that a well-defined subset of the transients from upcoming surveys will be thoroughly followed up and utilized. Furthermore, the spectral database can serve as a training set to improve photometric-only classification and redshifts of transients, thus enabling science with the millions of LSST transients. The large and complete transient spectral dataset will be of lasting legacy value.