Final Report, “Systematic Effects in Type-1a Supernovae Surveys from Host Galaxy Spectra’

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This project explored the relationship between the physical nature of Type Ia supernovae, and the host galaxies in which they lie. Type Ia supernovae are used as a key cosmological probe: their observed brightness as a function of redshift is one of the key pieces of evidence that we live in an accelerating Universe dominated by Dark Energy. This discovery resulted in the awarding of the 2011 Physics Nobel Prizes to Adam Riess, Saul Perlmutter, and Brian Schmidt. Understanding the physical nature of these supernovae, and in particular, determining whether they change with cosmic epoch, is important for controlling systematic errors in their use as a cosmological probe.

My colleagues and I studied the spectral properties of galaxies that have hosted Type Ia supernovae, to see what their stellar populations can tell us about the physical nature of the progenitors of those supernovae. There is growing evidence that these progenitors fall into two types, associated with younger and older stellar populations, respectively, corresponding to supernovae triggered either by a white dwarf with a massive star companion (for which mass transfer makes the object exceed the Chandrasekhar limit, setting off the explosion), or a pair of white dwarfs (whose merger would then cause it to explode). Given the rather different physics of these two scenarios, it is reasonable to ask whether the subsequent light-curve evolution of the two would be identical in the two cases. The light curves are of course used as a distance indicator which gives us our best measure of the expansion history of the universe, therefore it is critical to test the universality and robustness of the light curve evolution of supernovae.

We tackled this problem by examining the spectral properties of host galaxies, and correlating them with the light curve properties of the supernovae. This grant supported visits of Professors Raul Jimenez (of the University of Barcelona) and Éric Aubourg (of the University of Paris) to Princeton, and have also supported a graduate student, Tim Brandt. This grant has resulted in two papers, both with over 50 citations to date. They are:

Evidence of short-lived SN Ia progenitors, by Éric Aubourg et al. This was published in *Astronomy & Astrophysics* 2008, Volume 492, issue 3, pages 631–636.

Abstract: We use the VESPA algorithm and spectra from the Sloan Digital Sky Survey to investigate the star formation history of the host galaxies of 257 type Ia supernovae. We find 5σ evidence of a short-lived population of progenitors with lifetimes of less than 180 Myr, indicating a type Ia supernova channel arising from stars in the mass range $\sim 3.5 - 8M_{\odot}$. As standardizable candles, type Ia supernovae play an important role in determining the expansion history of the Universe, but to be useful for future cosmological surveys, the peak luminosity needs to be free of uncorrected systematic effects at the level of 1-2%. If the different progenitor routes lead to supernovae with even moderately small differences in properties, then these need to be corrected for separately, or they could lead to a systematic bias in future supernovae surveys, as the prompt route is likely to increase in importance at high redshift. VESPA analysis of hosts could be a valuable tool in this, by identifying which progenitor route is most likely.

The Ages of Type Ia Supernova Progenitors, by Timothy Brandt et al. Published in *The Astronomical Journal* 2010, volume 140, issue 3, pages 804-816.

Abstract: Using light curves and host galaxy spectra of 101 Type Ia supernovae (SNe Ia) with redshift $z < 0.3$ from the Sloan Digital Sky Survey Supernova Survey (SDSS-SN), we derive the SN Ia rate as a function of progenitor age (the delay time distribution, DTD). We use the VESPA stellar population synthesis algorithm to analyze the SDSS spectra of all galaxies in the field searched by SDSS-SN, giving us a reference sample of 77,000 galaxies for our SN Ia hosts. Our method does not assume any a priori shape for the DTD and is therefore minimally parametric. We present the DTD in physical units for high-stretch (luminous, slow declining) and low-stretch (subluminous, fast declining) supernovae in three progenitor age bins. We find strong evidence of two progenitor channels: one that produces high-stretch SNe Ia < 400 Myr after the birth of the progenitor system, and one that produces low-stretch SNe Ia with a delay > 2.4 Gyr. We find that each channel contributes roughly half of the Type Ia rate in our reference sample. We also construct the average spectra of high-stretch and low-stretch SN Ia host galaxies, and find that the difference of these spectra looks like a main-sequence B star with nebular emission lines indicative of star formation. This supports our finding that there are two populations of SNe Ia, and indicates that the progenitors of high-stretch supernovae are at the least associated with very recent star formation in the last few tens of Myr. Our results provide valuable constraints for models of Type Ia progenitors and may help improve the calibration of SNe Ia as standard candles.