Extinction laws towards supernova host galaxies with integral field spectroscopy

Alessandro Razza & Santiago González Gaitán & Lluís Galbany

University of Chile/Millennium Institute of Astrophysics

arazza@das.uchile.cl

Abstract

Accurate measurements of the extinction along the line-of-sight of supernovae are essential for determining distances in observational cosmology. Extinction curves, commonly parametrized by the total-to-selective extinction ratio R_V, have been found to be steeper than the standard $R_V = 3.1$, with unusual low values inferred from SN Ia photometric observations, revealing peculiar dust properties of the interstellar medium (ISM) and possible presence of circumstellar dust. Spectroscopy with Integral Field Unit (IFU) allows to spatially resolve different stellar populations within galaxies. Using such observations, we will estimate stellar population extinction and extinction laws by fitting population synthesis models to observations. Accordingly, we select SN host galaxies with IFU data from CALIFA and AMUSING surveys with the scope of mapping dust content and measuring the extinctions at SN sites. For this purpose, the IFU optical spectra and UV/NIR photometry from CSP/GALEX are fitted with the STARLIGHT spectral synthesis code where the best combination of simple stellar populations models is determined together with extinction laws. Results are then compared with those retrieved from SN information alone and from other methodologies such as extinction estimates from HII emission lines (Balmer decrement) and ISM lines (NaI), employed in other works.

Introduction

An important application of the extinction correction is when using supernovae (SNe) as a distance ladder in cosmology. With the increasing number of SNe available for cosmological analysis, it has become of major importance to understand the systematic uncertainties due to host galaxy extinction measurements. To date, Type Ia SN photometry has been extensively used to estimate the extinction (Lampeitl et al., 2010), finding discrepancies with the Galaxy canonical value of R_V (e.g. Folatelli et al., 2010), although the factors leading to it are under debate. In their recent work, Hutton et al. (2015) probed the dust around SN2014J by measuring R_V from pre-explosion data of the host galaxy. They found higher values than those inferred directly from the SN photometric information (Amanullah et al., 2014). This may suggest either a significant change in the dust composition, due to the SN explosion, or presence of circumstellar medium possibly formed by mass loss in the SN progenitor binary system. Observational constraints are thus necessary for understanding the origin of the unusual values of R_V towards some SNe. Moreover, a systematic campaign can show whether the SN progenitor/explosion effect on the ISM is a general trend or it is peculiar of some systems.

Main Objectives and Method

Our scientific goal is to probe the properties of the ISM at SN position through direct measurements of R_V by using Integral Field Unit (IFU) data cubes. A spectral synthesis code (STARLIGHT Cid Fernandes et al., 2009) is used to measure R_V from the best fit to the optical spectra continuum. In this way, the extinction law is estimated from the stellar population contribution to the spectra. Simple stellar population (SSP) spectral features suffer an age-metallicity-extinction degeneracy which we mitigate by fitting a combination of UV photometry and optical spectra (López Fernández et al., 2016). The current phase of the project consists of a series of simulations where a known extinction is added to synthetic spectra from (Charlot and Bruzual, 2007) which are then fitted to measure the expected R_V. The scope is to simulate AMUSING- and CALIFA-like optical spectra to test the capability to recover the added extinction and estimate accurately the extinction law.

Fitting synthetic spectra with added extinction

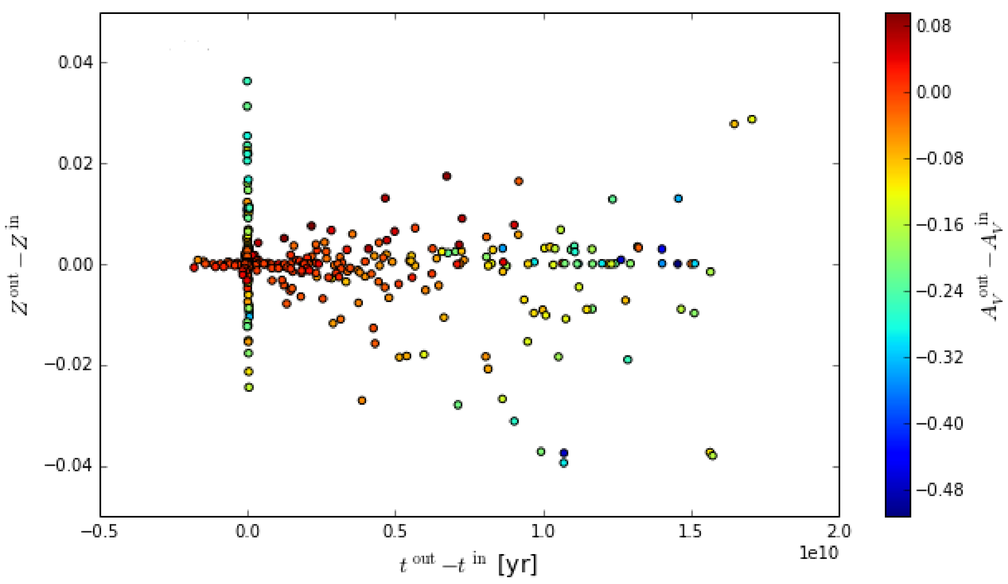

Figure 1: Fitted values of total extinction, metallicity and age (i.e. $A_V^{\rm OUT}$, $Z^{\rm OUT}$ and $t^{\rm OUT}$, respectively) are compared with those known for the models ($Z^{\rm IN}$, $t^{\rm IN}$) and the extinction we added ($A_V^{\rm IN}$). The colour bar shows the level of underestimation of the extinction as computed by STARLIGHT.

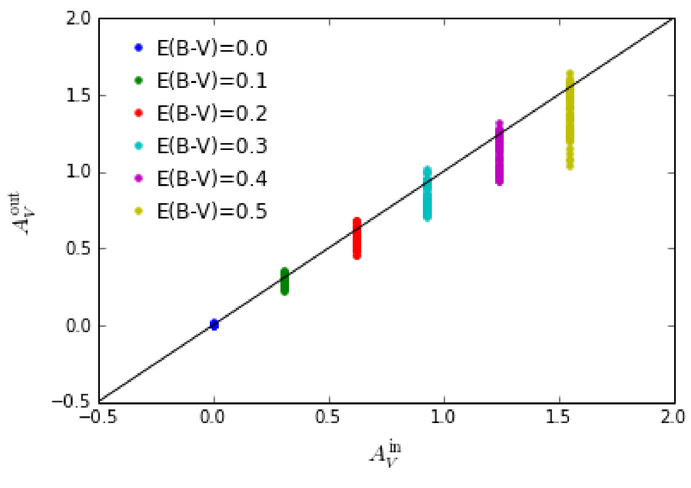

Figure 2: The plot shows the extinction $A_V^{\rm OUT}$ as fitted by STARLIGHT versus the simulated values $A_V^{\rm IN}$ for a grid of values for the colour excess $E(B-V)$. $R_V = 3.1$ was assumed.

We added extinction to 66 synthetic spectra models from Charlot & Bruzual (2007), each of them representing a SSP with different age and metallicity, and fitted them with STARLIGHT to test whether it was possible to recover the simulated reddening. We observed that STARLIGHT compensates the extinction (underestimated) with a combination of more metal-rich and older stellar populations, as shown in Figure 1. From the colour of scatter points it is possible to see the degeneracy between A_V and both the age and the metallicity. Specifically, Figure 2 shows that A_V is more underestimated for higher values of simulated input colour excess.

Fitting UV photometry with optical spectra

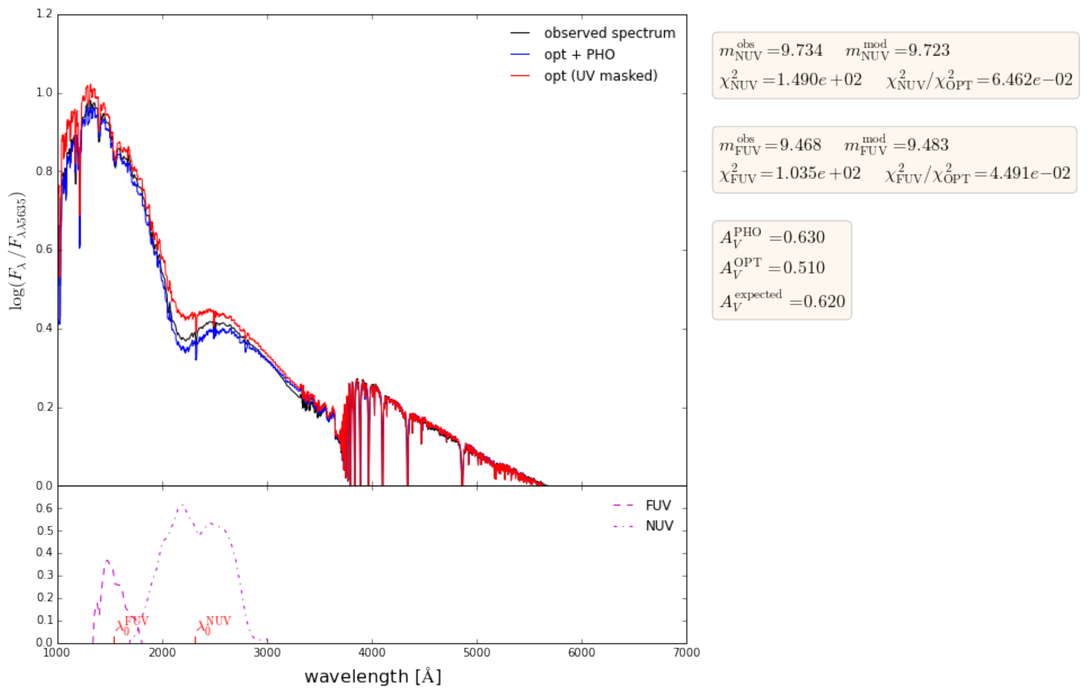

Figure 3: Fit of a single synthetic spectrum where an extinction of $A_V = 0.620$ was added. Black line shows the spectrum to fit, the red line represents the fit with the optical part only, whereas the blue line is the improved fit with optical spectrum and UV photometry. The bottom panel shows the two GALEX filter transmission curves employed for the convolution. Text box on left side: (two upper panels) magnitudes as computed by means of our convolution with the GALEX filters ($m^{\rm obs}$), the magnitudes as computed by STARLIGHT fit for each filter and the comparisons between χ^2 of the fit for optical part only and photometric part only; (lower panel) our simulated $A_V^{\rm expected}$, compared with those obtained with and without UV photometry ($A_V^{\rm PHO}$ and $A_V^{\rm OPT}$, respectively).

As a first step toward breaking the age-metallicity-extinction degeneracy, preliminary fits with the new version of STARLIGHT (López Fernández et al., 2016) have been performed. UV photometry from GALEX broad-band filters is used, in combination with optical spectra, after convolving the synthetic spectra with the profile of each filter to compute synthetic magnitudes. Figure 3 shows a fit for a single model for which we added an extinction of $A_V = 0.620$. It is apparent how the fit where only the optical part of the spectrum was used overestimates the UV flux and therefore leads to the wrong age/metallicity estimation. Otherwise, the combined optical spectra and UV photometry allowed to attain a better fit with a more accurate estimate of A_V (text box in Figure 3).

Outlook

- We added 5 levels of extinction to 66 synthetic spectra and fitted them with STARLIGHT. We observed an underestimation of A_V toward higher extinctions if we include only the optical range covered by CALIFA/AMUSING surveys.
- First tests with the new version of STARLIGHT, that allows to include photometric data from other survey as GALEX, are promising. New fits seem to constrain better the flux in UV thus breaking the age-metallicity-extiction degeneracy, typical of SSPs.

Forthcoming Research

- Charlot and Bruzual (2007) synthetic spectra will be fitted by including UV photometry, as done already in the first tests.
- Although STARLIGHT does not have R_V as free parameter, a final step to set up the method will be to fit with different extinction laws and estimate the values of R_V by minimizing χ^2.
- In a future implementation, infrared photometry will be used self-consistently to model the levels of UV-optical extinction and reprocessed thermal dust emission. This is expected to minimize the degeneracy between extinction, age, and metallicity.
- Finally, our results will be compared with R_V inferred from SN photometry and from other methodologies.

References

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