Using the environment to understand SNe properties

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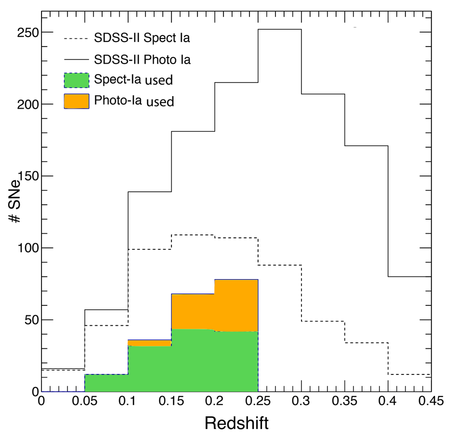
We present here three studies that try to understand supernova (SN) environment in order to use it to constrain SN properties. In the first study we use almost 200 Type Ia supernovae (SNe Ia) at redshifts below 0.25 discovered by the Sloan Digital Sky Survey-II SN Survey, to search for dependencies between SN Ia properties and the projected distance to the host-galaxy center, using the distance as a proxy for local galaxy properties (local star formation rate, local metallicity, etc.). We correlate the light-curve (LC) parameters with several definitions of the distance to the center of the host galaxy, either normalized or not, and look for trends in the mean values of these parameters with increasing distance. In the second analysis, we measure galaxy parameters, such as the age, the mass and the metallicity, from the spectra of the host galaxies of the same SN sample, obtained from SDSS Data Release 9. We look for correlations between the host galaxy parameters and the redshift, SN light-curve parameters, and distance from the core of the host to the SN. We also prove the use of metallicity gradients as a better approximation to the local metallicity. Finally, in the third, we use the galaxies observed by the CALIFA Survey that ever hosted a SN, and look for correlations among the local parameters of the galaxy at the position where the SN exploded. These three studies conform a sequence from an indirect approximation to the local galaxy properties of the SN location to a direct determination of the environmental parameters of the SN.

SNe Ia LC parameters correlated with distance

Sample

From the whole SDSS-II/SNe sample of **1318 Type Ia SNe** (559 spect-Ia and 759 photo-Ia with z-spect of the host galaxy) (1) we selected those with redshifts **z < 0.25** where the detection efficiency of the SDSS-II/SNe survey remains high (~95%). (2) We have matched every SN in this sub-sample to **the closest galaxy within an angular separation of 20 arcsec**, and then obtained multi-wavelength photometric parameters needed for the morphology typing and for the measurement of the separation of the SN from the center of the galaxy.

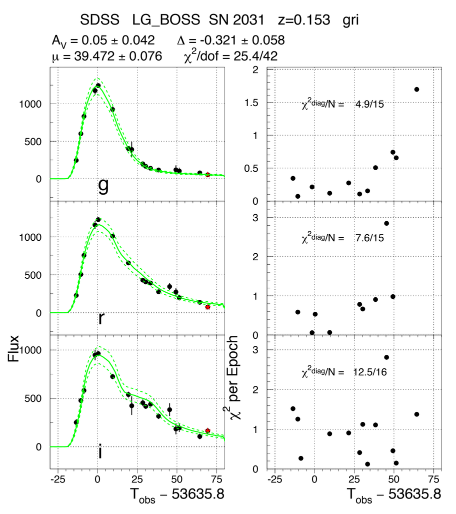


LC fitting

We fit the remaining SN light-curves using the publicly available package SNANA which includes implementations of the **SALT2** and **MLCS2k2** light-curve fitters, and determine color (A_V, c) and light-curve shape (Δ, x_1) parameters for each SN Ia, as well as its residual in the Hubble diagram (HR). (3) We applied the following **selection cuts in the LC** fit:

- 5 obs. in -20d < T_{rest} < +70d (+60d for SALT2) rel. to $T_{B,max}$
- At least 1 obs. T_{rest} < -2d (0d) days before $T_{B,max}$
- At least 1 obs. after T_{rest} < +10d (9.5d) days after $T_{B,max}$
- At least 1 obs. with S/N>5 for each of g, r and i bands.
- P_{fit} > 0.001, light-curve fit probability of being a SN-Ia based on the χ^2/N_{dof}

(4) We also **removed SNe with extreme values** of the LC parameters in order to have a pure sample not affected by those peculiar values. For MLCS2K2 we restricted the sample to Δ>−0.4, and for SALT2 to −0.3<c<0.6, −4.5<x_1<2.0.

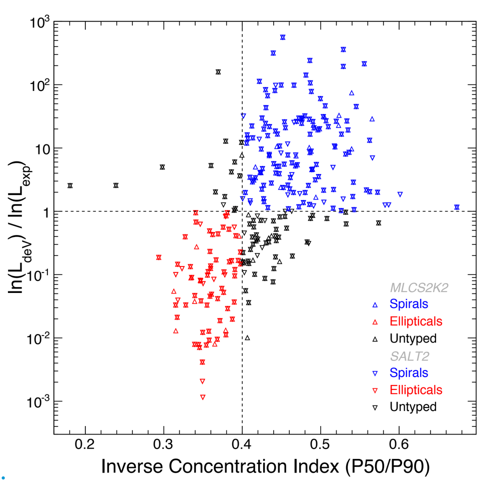


Host typing

(5) The sample is split into two groups depending on the morphology of the host galaxy. (spirals or ellipticals). To do this we consider two photometric parameters: the **inverse concentration index** (CI, ratio between the radii of two circles containing 50% and 90% of the Petrosian flux), and the best likelihood for a fit to a **Sérsic brightness profile** (LH):

$$I(r) = I_0 \exp\left[-a_n \left(r/r_e\right)^{1/n}\right] = I_e \exp\left\{-a_n \left[\left(r/r_e\right)^{1/n} - 1\right]\right\}$$

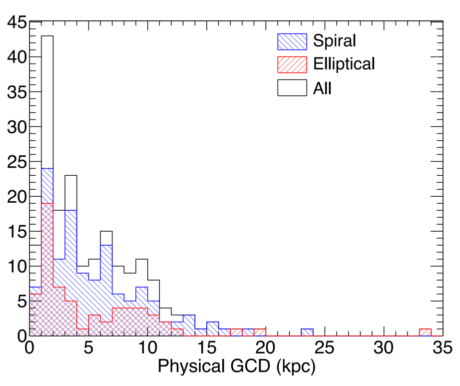
For fitting the brightness profile, two specific patterns are used: An exponential profile (n=1) describes better the decrease in brightness for spiral galaxies, and the de Vaucouleurs profile (n=4) for ellipticals. We consider that a galaxy has elliptical morphology when it has both an CI<0.4, and the LH_{DEV}>LH_{EXP}. A galaxy is assigned a spiral morphology if the CI<0.4, and LH_{EXP}>LH_{DEV}. When both indicators point to different type, the SN is removed from the analysis.

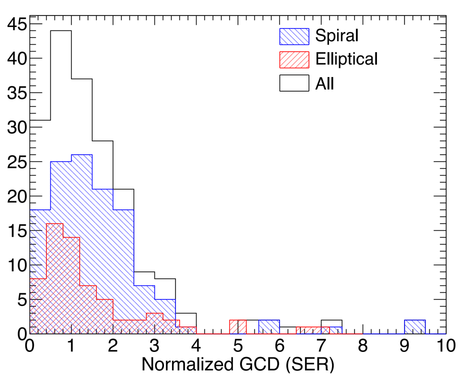


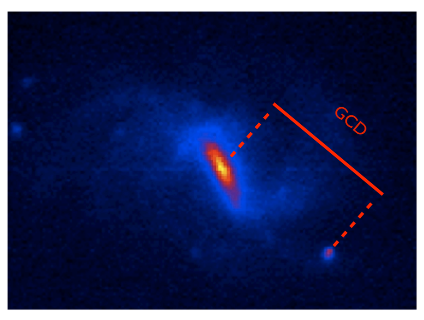
GCD (Galactocentric Distance)

Galaxies vary in morphology and size, thus it makes sense to normalize the SN–galaxy separation in order to be able to compare the LC parameters for SNe in the entire sample. We measured the angular separation between SN and its host, and calculated the physical distance in kpc using the redshift measured. We then used the normalization derived from the shape of the galaxy described by a Sérsic profile ellipse, distinguishing between elliptical galaxies fitted with a **de Vaucouleurs** profile (DEV), and spiral galaxies fitted with a **pure exponential** profile (EXP). All these measurements of the distance are lower limits of the real separation from the center of the host galaxy due to the inclination of the galactic plane with respect to the observer. We therefore refer to these distances as **projected GCD**. (6) In some cases the matched host lacks these parameters, or the SN is too far from the center of the matched host.

The final sample is composed of 190 SNe for MLCS2K2 and 195 for SALT2.





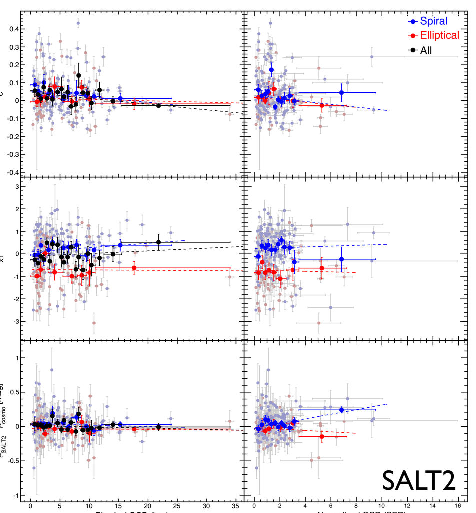


Summary of the number of SN in the sample after each step

	Spec-Ia MLCS	Spec-Ia SALT2	Photo-Ia MLCS	Photo-Ia SALT2	Total MLCS	Total SALT2
SN Ia sample ($z < 0.45$)	559		759		1318	
(1) Redshift < 0.25	376		232		608	
(2) Identified host galaxy	363		228		591	
(3) LC quality cuts	228	217	115	125	343	342
(4) LC parameter cuts	203	209	110	111	313	320
(5) Determined host type	160	164	79	82	239	246
(6) Distance cuts	127	131	63	64	190	195

Method

We examined correlations of the LC parameters (A_V , Δ, x_1, c and HR) with both the physical and the normalized distances to the center of the host galaxy and look for trends in the mean values and scatters of these parameters with increasing distance. We examined correlations for the complete sample, as well as when dividing the sample according to host-galaxy morphology (spiral and elliptical).



Results

- **SNe in elliptical galaxies tend to have narrower LC** (larger Δ, fainter SNe) **if they explode farther from the galaxy core.**

This could be explained by the difficulty to detect faint SNe close to the galaxy center, where the galaxy light is stronger (*selection effect*).

- **Decrease in color (extinction) with distance**.

If most of the variability in color is due to dust, and dust is expected to decrease with distance from the center, this would be expected. Due to the difficulty to observe faint SNe close to the galaxy center, we would expect fewer dust extincted SNe (with high A_V) at small distances. However, this is opposite of what we find, so maybe the *selection effect* is not too large.

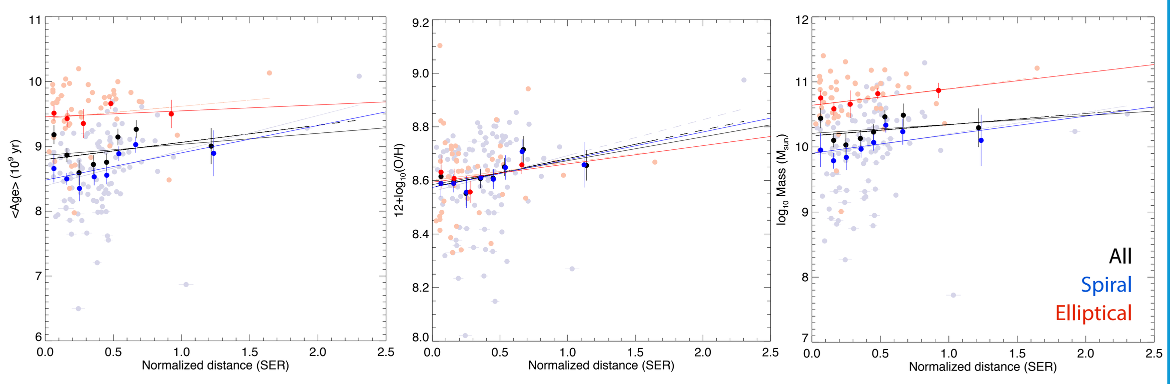
- **No correlation between the Hubble residuals and the GCD**.

Since GCD can be used as a proxy for the local metallicity, this can be seen as an indication of a limited correlation between Hubble residuals and local metallicity.

Galbany et al. 2012, ApJ 755 125

SNe Ia correlations with host galaxy parameters

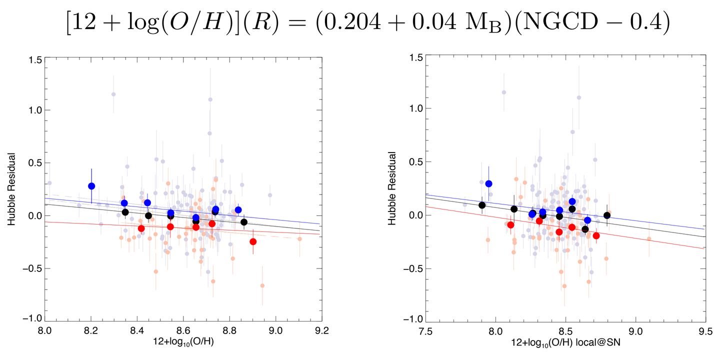
We measure galaxy parameters, such as the **age**, the **mass**, the **metallicity**, the **Hα emission,** and the **specific star formation rate** from the spectra of the host galaxies of those SNe in this sample that have the host galaxy spectrum available in SDSS Data Release 9 (153 MLCS, 157 SALT2). We look for correlations between these host galaxy parameters and the galactocentric distances.



- We find that, for spiral galaxies, **SNe in more massive, old, and with high-metallic, tend to explode farther for the center**.

We also considered the use of metallicity gradients as a better approximation to the local value at the SN position. We combine the expression in Boisser+09 with our own measurement of the NGCD.

$$[12 + \log(O/H)](R) = (0.204 + 0.04\ \mathrm{M_B})(\mathrm{NGCD} - 0.4)$$



We **do not find a significant difference** when using a metallicity gradient as an approximation to the local metallicity @SN position

Galbany et al., in prep.

SNe environment observed by CALIFA Survey IFS

We aim to study the properties of the environment where SNe exploded, using the **integral filed spectroscopic (IFS)** information of ~600 galaxies of any morphological type and distributed across the entire Color-Magnitude diagram in the Local Universe (**0.005 < z < 0.03**) provided by the Calar Alto Legacy Integral Field Area (**CALIFA**) Survey. With this approach we are going further than using simply an aperture spectrum centered at the galaxy core, or a spectrum from a slit positioned at a SN explosion.

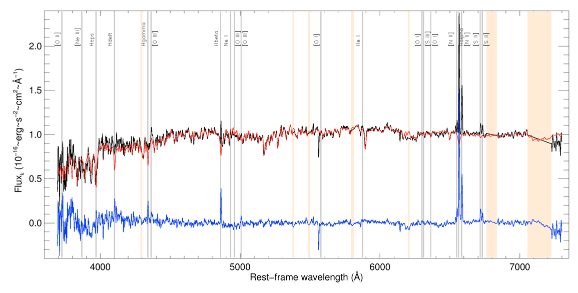
Sample

We make use those galaxies within the CALIFA sample that ever hosted a SN. At this point, we have IFS information of 27 galaxies that hosted 33 SNe (17 II, 9 Ibc, 7 Ia).

Analysis

The final product of CALIFA observations is a 3D-datacube for each galaxy, containing some thousands spectra, one for each 1″X1″ in RA and DEC (the FoV of the images is 1.3′X1.3′, so far ~4000 spectra).

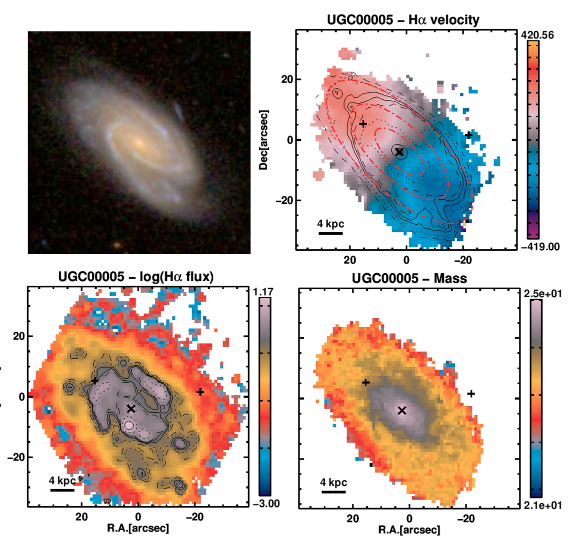
We first fit all the spectra with **STARLIGHT** (Cid-Fernandes +2000) in order to subtract the continuum emission.



Then we measure the ionized gas emission lines, with which we are able to measure useful parameters such as metallicity, star formation rate, or ionization.

From the continuum we cam also obtain the same parameters but from the stellar populations present in the galaxy.

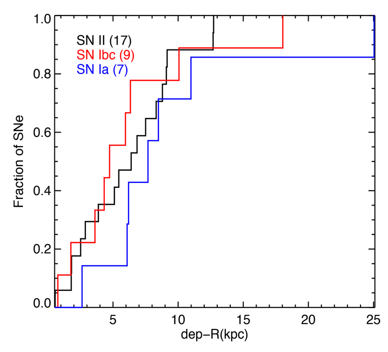
We then, have spatial maps of all those parameters and we can correlate the values at the SN position.



Results

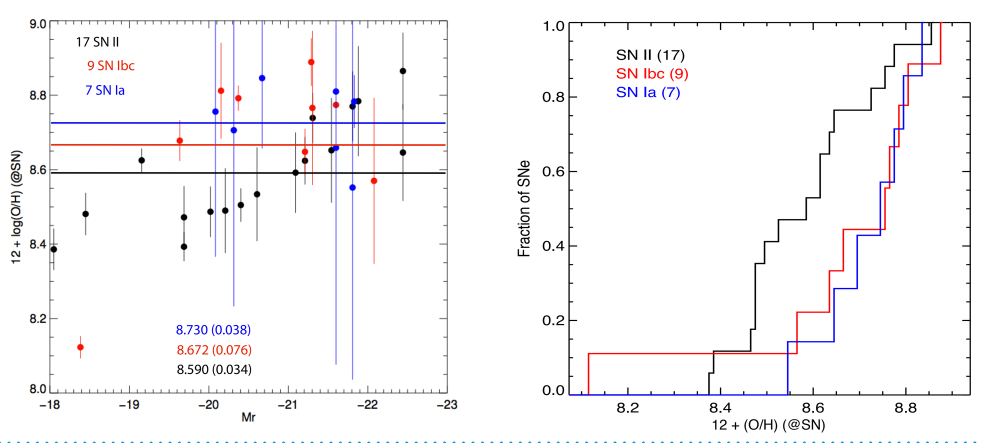
Distance

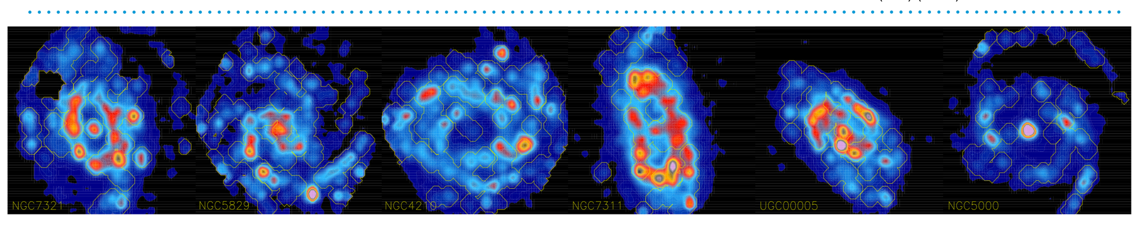
We correlated the SN type with the separation (projected and deprojected) from the galactic core. We find slight indications that points to a trend on type Ibc SNe exploding closer to the center of the galaxy than type II, and those closer than type Ia SNe.



Metallicity

We correlated the SN type with the local metallicity @SN position. We find a slightly difference (~0.1 dex) between the local metallicity of type Ibc and Ia SN environments, compared to type II SN environemts, being the former lower.





HII regions

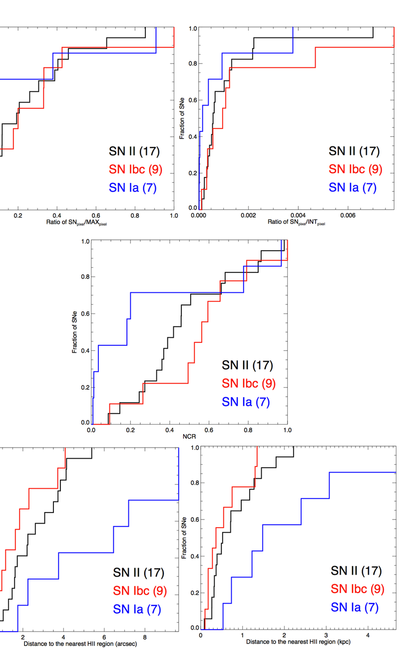
We correlated the SN type with the location where the SN explode in terms of Hα emision.

-Hα @SN position compared to both, maximum Hα and total Hα of the galaxy

-Normalized cumulative rank value function (NCR, Anderson+06) @SN position

-Distance to the closest HII region using HII-explorer (Snachez+12)

In all methods we find a sequence in association to HII regions ranging from type Ibc, type II and finally Ia SNe, being those, less associated with HII regions.



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