# Unveiling the host extinction of type Ia supernovae with NOTCam


**E. Gallego-Cano[1], L. Izzo[2], F. Prada[1], C. Dominguez-Tagle[1], and E. Pérez[1]**

[1]Instituto de Astrofísica de Andalucía (IAA-CSIC); email: lgc@iaa.es

[2]DARK, Niels Bohr Institute, University of Copenhagen



**Abstract** Type-Ia supernovae (SNe Ia) are among the best standard candles for obtaining an accurate measurement of the Hubble constant ($H_0$) in late times, and can help us to shed light on the reported discrepancy with the estimated value in the opposite edge of the universe, early times. We propose to use NOTCam mounted on the 2.5 m NOT telescope to obtain near-IR photometry of the nearby SNe (z < 0.06) included in our "SN2 Project" sample, and observed in the optical at the Sierra Nevada Observatory (OSN). By including the NIR light curves (LCs) of the SNe we can obtain accurate values of the main luminosity SN parameters. Furthermore, we can determine the extinction curves of the host galaxies for each SN Ia, which is of paramount importance to unravel possible systematics related to their physical properties. The proposed NIR observations and the optical data obtained through the SN2 project allow us to constrain the main physical properties of nearby type-Ia SNe, and provide accurate systematic estimates in the luminosity distance measurements, which will contribute to understanding the origin of the "Hubble tension".


## The SN2 project

Monitoring program of nearby (d < 350 Mpc) type-Ia supernovae from Sierra Nevada Observatory (OSN, Granada, Spain) (http://sn2.iaa.es/)

### Scientific justification

Dependence of type-Ia SN progenitors on their environment?

↓

Correlations between **SN photometric observables** with **intrinsic properties** of their host galaxies (metallicity, star-formation rate, stellar ages and masses—> from spectra)

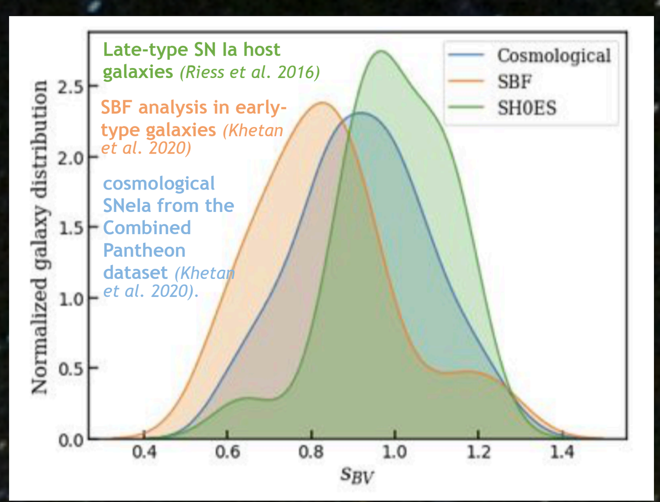



**Figure 1.** The distribution of the stretch-color parameter $s_{BV}$

↓

**Stretch-colour** parameter distribution is related to the **morphological type of the SN host galaxies**

### Main goals

Building a statistically significant and homogeneous photometric sample of about **70 type-Ia SNe** with **host galaxy spectra** (SDSS & DESI)

↓

For each SN a **multi-filter light curve** within the first **50-60 days** of the SN emission, using the **CCDT50** camera mounted on the **T150** telescope at OSN

↓

Anchoring SN luminosity relations with **Cepheids, TRGB and SBF**, and **gravitational wave standard sirens**

↓

Evolution history of **H(z)**—> provide a **GW-calibrated SN luminosity correlation**

### Methodology

- **Photometric data** will be reduced using a customized code developed in **python** *(Izzo et al. in preparation)*
- The **light curves** in the BVRI filters will be analysed using the **SNooPy** package *(Burns et al. 2011)* & **SALT3** *(Kenworty et al. 2021)* LC fitters
- Reconstruct the **intrinsic SED** of each SN with hyerarchical bayesian SED model **BAYESN** *(Mandel et al. 2020)*

### Results

The SN2 sample has already the size of **32 SNe**

#### The Hubble constant from two SNe Ia sibling in the nearby galaxy NGC 4414: SN 1974G and SN 2021J

*(Gallego-Cano, E., et al. 2022, arXiv:2204.10668)*

- Two "sibling" SNe Ia in the same galaxy --> reducing a variety of systematic errors involved in estimating $H_0$.
- NGC 4414: distance measured using Cepheid variables (HST Key Project). It hosts two sibling SNe Ia: SN 2021J and SN 1974G.

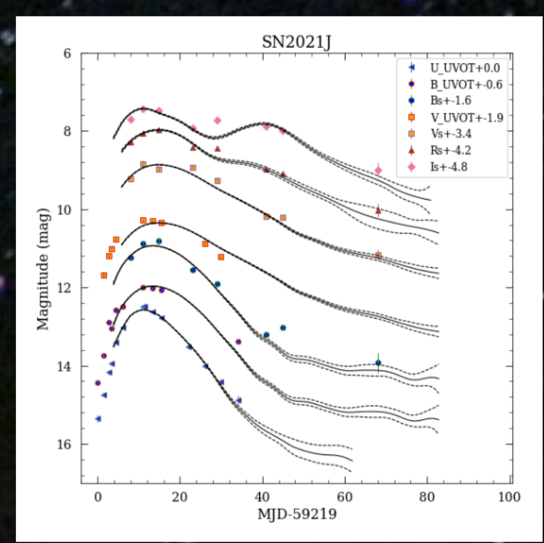



**Figure 2.** SN 2021J LC fits using SNooPy (black lines). The photometry data are obtained from the OSN and Swift. Dashed lines are 1-σ errors.

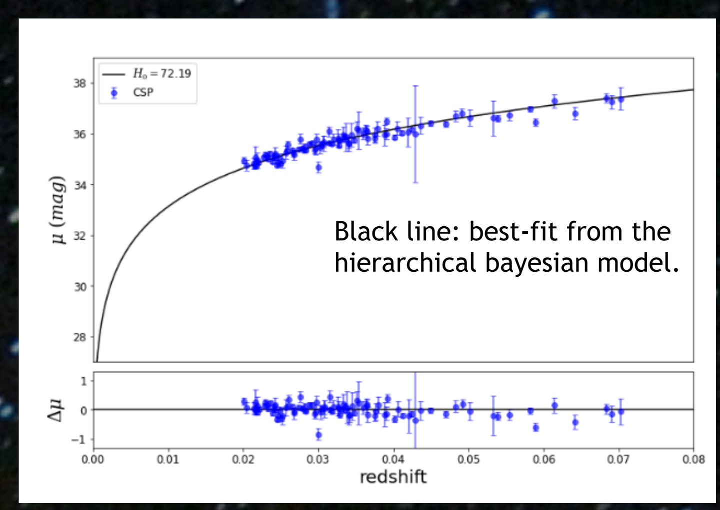



**Figure 3.** Hubble diagram for the cosmological sample of 95 SNe extracted from Pantheon Combined Sample and calibrated using the two sibling type-Ia SNe.

We have significantly reduced the uncertainties of $H_0$

$H_0 = 72.19 \pm 2.32$ (stat.) $\pm 3.42$ (syst.) km $s^{-1}Mpc^{-1}$

## NIR imaging with NOTCam

### Scientific justification

**Dust properties** are **different** for different environments and redshifts —> distance measurements, and hence the cosmological parameters are **biased**

- **Brighter** SNe Ia, **slower** light curves —-> bluer
- **Fainter** SNe Ia, **faster** light curves —-> redder

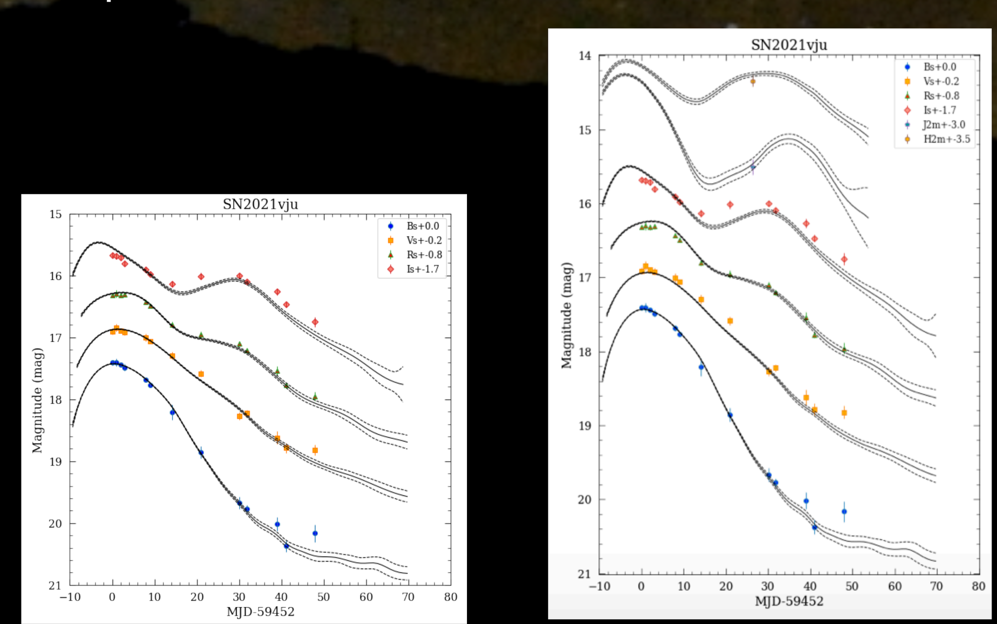
(Phillips, M.; 1993; Riess, A. G., et al. 1996)

↓

**Host galaxy extinction** correction for **each** SN?

### Methodology

- Build a **spectral energy distribution** with **SNooPy/EBV-model** to disentangle the host galaxy dust extinction and the intrinsic color variation.
- Implement a **global population analysis** using **BayeSN,** to compare with the SNooPY results.




```
SN  SN2021vju
Fit results (if any):
   DM = 36.002  +/-  0.033  +/- 0.091 (sys)
   dm15 = 0.844  +/-  0.049  +/- 0.060 (sys)
   EBVhost = 0.125  +/-  0.021  +/- 0.060 (sys)
   Tmax = 59453.795  +/-  0.536  +/- 0.340 (sys)
```

```
SN  SN2021vju
Fit results (if any):
   DM = 35.987  +/-  0.031  +/- 0.092 (sys)
   dm15 = 0.844  +/-  0.047  +/- 0.060 (sys)
   EBVhost = 0.131  +/-  0.020  +/- 0.060 (sys)
   Tmax = 59453.737  +/-  0.521  +/- 0.340 (sys)
```

**Figure 4.** The multi-filter light curve fit analysis of the type-Ia SN 2021vju made with **SNooPy.** We used **optical data** obtained within the **SN2 project** and 1 epoch of **NIR data** obtained with **LBT** (J and H filters). The EBV-model and the δm-15 shape parameter have been used to estimate the **host dust extinction.**

### Main goals

Complement the SN2 optical sample with **near-IR data** observed with **NOTCam**

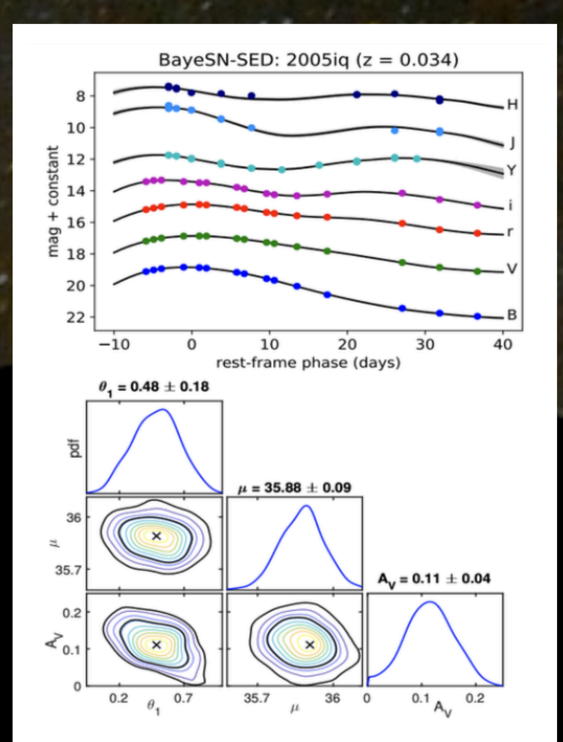
↓

For each SN, **NIR** observations between the peak brightness and **20-30 days**

↓

Unravel the **extinction** of the **interstellar** medium (dust), and the **intrinsic color** of the SN

**Figure 5.** **BayeSN** light curve fit of optical and NIR observations of SN 2005iq. The posterior distribution for the parameters of light curve fit to observations of SN 2005iq are shown in the lower panel. The SED parameters (θ1 and **host galaxy dust extinction** $A_V$) *(Mandel et al. 2020)*.




**Preliminary results for SN 2021vju**

✓Improved host dust extinction E(B − V ): 0.125 vs 0.131 mag

✓z = 0.04 (from galaxy spectrum) vs z = 0.0267 (NED, TNS)

### Observational strategy

- Redshift range 0.001 ≤ z ≤ 0.06 —> H: 16-18.8 mag (see Fig 7 in *Weyant et al. 2013*)
- 2 NIR filters (**H and J**) x **2 epochs** for each SN.
- **Telescope time:** ~0.7 hours per SN with H≤17 mag and ~1.33 hours per SN with H≤18.8.
- **Three SNe** Ia per month.
- Observational period for proposal covers **6 months.**

Total telescope time at the NOT ~ **20 hours** (~ 2.5 nights)

### Summary

✴ Building a homogenous sample of SNe Ia:

- Obtain accurate values of Δm15(B) and the main luminosity SN parameters.
- Link the measured SN properties to their local environments.
- Resolve the degeneracy between intrinsic SN color variations and extrinsic dust extinction.

‣ Improve estimates of the systematic uncertainties.

**Optimising SN Ia distance measurements** and understand the origin of the **"Hubble tension"**


**Ref:** Burns, C. R., et al. 2011 AJ,141,19; Kenworthy, W. D., et al. 2021, ApJ, 923(2), 265; Riess, A., et al., 2016, ApJ, 862, 56; Khetan, N., et al. 2021, A&A, 647, A72; Mandel, K. S., et al. 2022, MNRAS, 510(3), 3939-3966; Gallego-Cano, E., et al. 2022, arXiv:2204.10668; Weyant, A., et al. 2014; AJ, 784(2), 105; Krisciunas, K., et al. 2017; AJ, 154(5), 211, Phillips, M. M.; 1993; ApJL, 413, 105; Riess, A. G., et al. 1996, ApJ, 473, 88.