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Redshift evolution of the SN stretch distribution

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ABSTRACT

Context. Type Ia supernovae (SNe Ia) allow for the construction of the Hubble diagram, giving us information about the Universe's expansion and its fondamental components, one of which is dark energy. But systematic uncertainties are now starting to be limiting in our ability to measure those parameters. In particular, the physics of SNe Ia is still mostly unknown, and is thought not to change in time/with the redshift.
Aims. In an attempt to reduce those uncertainties, we try to find an empirical law describing SNe Ia's length of explosion (stretch) evolution with the redshift.
Methods. We started by getting a complete sample representing all of the stretch distribution that Nature can give us, before using LsSFR measurments, an age tracer which evolution with redshift is known, that has been shown to have a strong correlation with the stretch. We compare their AICc, an estimator of the relative quality of statistical models that includes the number of free parameters, to determine which ones describe besto the data.
Results. Models with an evolution of the stretch with the redshift have a better AICc than the ones without.
Conclusions. We find that implementing these models allows us to fit the data better than models without stretch evolution.

Key words. Cosmology – Type Ia Supernova – Systematic uncertainties

1. Introduction

Type Ia supernovae (SNe Ia) are now well-known for their capacity to determine cosmological parameters: their study led to the discovery of the accelerated expansion of the Universe (Riess 98, Perlmutter 99) through the name of "dark energy", and they have been used continuously for better measurments since then (Betoule 2014). They are acquired through their lightcurves, giving the evolution of their luminosity from the time of explosion, in different wavelength. 3 parameters are used to describe those: an amplitude, a width (named "stretch") and a color (magnitude difference in the B and V bands).

The simple use of those is not enough for our aim, as SNe Ia have an intrinsec dispersion of their luminosity of ≈ 0.4 mag that gives a huge uncertainty on the determination of their distance modulus. Henceforth they are standardized using the "brigther-slower" and "brighter-bluer" relations (Philipps 93, Riess 96, Tripp 98) in the SALT2 algorithm (Guy 2007, 2010) that fits the distance modulus which is expressed as

$$\mu = m_b + \alpha x_1 - \beta c - M$$

with m_B the logarithm of their flux, x_1 their stretch, c their color and M their intrinsec magnitude. This relation lowered their magnitude dispersion to ≈ 0.15 mag, allowing for previously mentioned accelerated expansion to be discovered.

This Tripp estimator lies on the idea that this standardization doesn't change with the redshift. However, Rigault 2015 showed that SNe Ia depend on their environments, and these environments' properties evolve with the redshift. In this Letter, we try to determine whether a stretch evolution with the redshift allows for a better description of the collected data.

2. Sample

We use data from 5 different surveys: Hubble Space Telescope (HST, REF), Supernova Nearby Factory (SNf, REF), Supernova Legacy Survey (SNLS, REF), Sloan DSS (SDSS, REF) and Panstarr-1 (PS1, REF). 3 of which had selection effects that we tried to remove with a statistical approach in lack of precise data concerning the instruments' capacity to acquire fluxes. Here it is:

3. Method

We used LsSFR measurments which evolution with the redshift is analytically known (references) and stretch measurments made by SNf to try an correlate these to parameters. We fit different model, and compare their AICc.

4. Results

We find that every model lacking an evolution of the stretch with the redshift is systematically worse than those that implement it.

5. Conclusion

Stretch evolution with the redshift is a thing. Need to see if it has an impact on the cosmology though.