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HISTORICAL AND NEW SPECTRAL INDICATORS FROM THE NEARBY SUPERNOVA FACTORY

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Abstract. From a sample of 58 SNe Ia spectra obtained by the Nearby Supernova Factory with the SuperNovae Integral Field Spectrograph (SNIFS), we present measurements of spectral indicators proposed in the literature. In addition, we probe the direct correlation of spectral indicators to the Hubble diagram residuals and the relevance of such indicators as substitutes to stretch and colour.

1 The SNe Ia sample

The data presented here has been obtained by the Nearby SNF collaboration with SNIFS on the UH 2.2 m (Aldering et al. 2002). The light curves in synthetic BVR filters are reconstructed from the absolute spectra of each SN. The present study is performed on a sample of 58 SNe Ia selected for the quality of their SALT2 (Guy et al. 2007) light-curve fit, the phase coverage, and for which a spectrum in a window of ± 2.5 days around the peak luminosity was obtained. The parameters of the fit (stretch ($x1$), colour (c)) are also used in this analysis.

2 Classical spectral indicators

Two regions of interests between 3500 and 4200 Å and between 5500 and 6500 Å have been shown to exhibit calcium and silicon features correlated to the supernova intrisic parameters (Nugent et al. 1995; Bongard et al. 2005). They defined the following classical spectral indicators :

$$R_{Ca} = \frac{F^{3950}_{max}}{F^{3650}_{max}} \quad RSi = \frac{\mathrm{depth}_{5800}}{\mathrm{depth}_{6200}} \quad RSiSS = \frac{\int_{5500}^{5700} F(\lambda)d\lambda}{\int_{6200}^{6450} F(\lambda)d\lambda}$$

where $F(\lambda)$ is the flux ($[erg/cm^2/s/A]$), F^{λ}_{max} is the flux at the peak position found around the given wavelength, and depth_{λ} is the difference between the continuum flux and the real minimum flux of the absorption feature. Computing these indicators in an objective way requires an automatic smoothing procedure which preserves spectral extrema, as shown in Fig. 1.

Other spectral indicators such as equivalent widths (EW) (Hachinger et al. 2006; Bronder et al. 2007) were computed in relevant regions of the SN Ia spectrum. In our sample, $EW_{SiII}(4000)$ (shown in Fig. 1 on the top right of the control plot) was found to correlate strongly with the SALT2 $x1$ parameter . The general definition of EW is:

$$EW = \sum_{i=1}^{N} \left(1 - \frac{f_{\lambda}(\lambda_i)}{f_c(\lambda_i)}\right) \Delta\lambda_i$$

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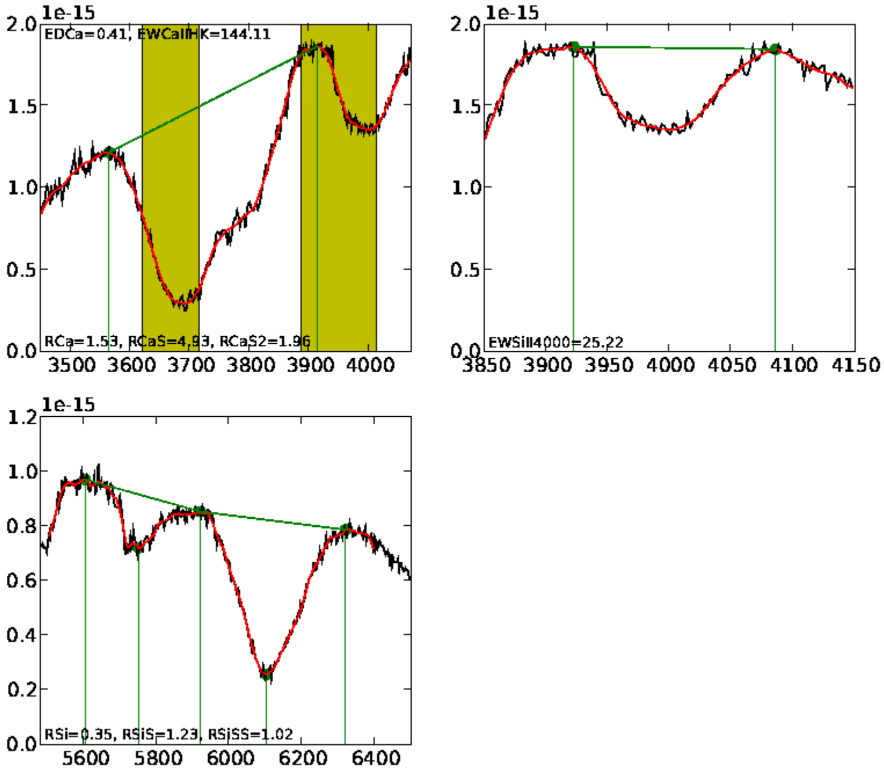

Fig. 1. Automatic control plot for a spetrum of the sample.

3 The correlation of spectral indicators with SNe Ia parameters

The relative standardization power of these indicators were studied with their correlations with $x1$, colour and a proxy to their absolute magnitude, ΔM_B: the latter was derived from the residual of a fit to the Hubble diagram for a flat ΛCDM.

The Table 1 shows the correlation coefficients between parameters and spectral indicators. A SALT2 colour cut is applied on the sample ($c < 0.1$), to study the intrisic part of the SN Ia variability. 44 over our 58 SNe pass the cut. Fig. 2 shows the correlation between $EW_{SiII}(4000)^{cut}$ and ΔM_B after the colour cut.

	ΔM_B	$x1$	colour	ΔM_B^{corr}	phase
R_{Ca}	0.55	-0.45	0.35	0.17	0.05
R_{Si}	0.26	-0.60	0.04	0.00	0.06
R_{SiSS}	-0.77	-0.57	-0.54	-0.16	0.27
$EW_{SiII}(4000)$	0.33	-0.76	-0.01	0.17	0.23
$EW_{SiII}(4000)^{cut}$	**0.80**	**-0.84**	0.01	0.28	0.21

Table 1. Correlation coefficients between spectral indicators and other SN Ia parameters.

The $EW_{SiII}(4000)$'s correlations with Hubble residuals and x1 **increase after the colour cut** (see Table 1 and Fig. 2). $EW_{SiII}(4000)$ is independant of colour (the correlation coefficient is 0.01) and can be a good proxy for x1, it thus proves to be particularly useful for standardizing SNe Ia.

4 Corrected Hubble residuals

In the SALT2 approach, the luminosity is corrected for stretch and colour with α and β tuned to minimize the residuals to the cosmological fit to the data: $\Delta M_B^{corr} = \Delta M_B + \alpha \times x1 - \beta \times c$. The spectral correction can be

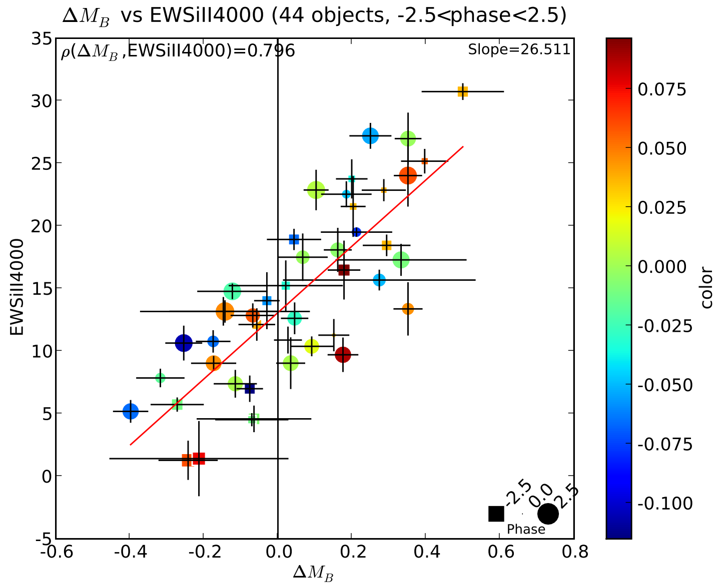

Fig. 2. Correlation between ΔM_B and $EW_{SiII}(4000)^{cut}$, after the colour cut ($c < 0.1$)

used in the similar way. Table 2 gives the RMS of the Hubble diagram residuals uncorrected and corrected with spectral indicators. The Hubble residual with colour and $EW_{SiII}(4000)$ corrections are as effective as colour and $x1$ before the colour cut and perform better after. $EW_{SiII}(4000)$ is then an excellent candidate for the estimate the intrinsic part of the SN Ia variability and replaces or strengthens the $x1$ parameter.

Correction	None	c & x1	c & $EW_{SiII}(4000)$	None	c & x1	c & $EW_{SiII}(4000)$
RMS	0.406	0.161	0.164	0.217	0.153	0.123
nMAD	0.264	0.159	0.177	0.243	0.139	0.148

Table 2. Standard deviation and normalized median absolute deviation of hubble diagram residual without any cut (left values) and with a colour cut (right values).

5 Conclusion

Traditional spectral indicators are correlated to the SNe Ia absolute luminosity, and some of them such as $EW_{SiII}(4000)$ are strongly correlated to the intrinsic variability of SNe Ia. Another spectral indicator presented in (Bailey et al. 2009) using the same sample of SNe Ia from the SNFactory collaboration also shows a very strong correlation (0.95) between the spectral ratio R(642/443) and ΔM_B even without any colour cut. It proves to be a strong competitor of x1 and colour for the luminosity standardization and reaches a final RMS on the hubble diagram of 0.128 ± 0.012.

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