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Photometric typing of normal and peculiar type Ia supernovae

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Abstract. We present a new photometric typing technique for normal type Ia supernovae (SNe Ia) and peculiar SNe Ia such as SN 1991bg-like, type Iax and super-Chandrasekhar SNe Ia. This photometric classifier allows the identification of exclusively normal SNe Ia (with a purity above 99% and an efficiency greater than 80%) in current and future large wide field surveys for cosmological studies.

Keywords. Supernovae: general, methods: data analysis

1. Introduction

Type Ia supernovae have been fundamental for the discovery of the acceleration of the expansion of the universe driven by a yet unknown dark energy component (Riess *et al.* 1998; Perlmutter *et al.* 1999). With the advent of new powerful instruments, current and future surveys are looking to pin down the nature of dark energy with increasing data and better understanding of systematics. These wide field surveys such as SNLS (Astier *et al.* 2006), DES (Sako *et al.* 2011) and LSST (Ivezic *et al.* 2011) generate hundreds to thousands of transients routinely that cannot be followed-up spectroscopically. Photometric classification techniques need to be able to accurately classifiy these objects in order to prioritize certain of them for follow-up or just make their posterior study possible. For cosmology, one can avoid SN spectroscopy using known spectroscopic redshifts from the host galaxy, provided that the object class is known with a photometric method, and even photometric redshifts have shown potential for cosmology (Campbell *et al.* 2013).

2. Methodology

We use a large dataset of ∼500 low-redshift ($z < 0.1$) multi-band light-curves of SNe Ia from the literature, as well as another ∼ 200 core-collapse supernovae (CC SNe) to test for contamination. We fit all these light-curves with SiFTO (Conley *et al.* 2008) to two different spectral template series for normal SNe Ia (Hsiao *et al.* 2007) and 91bg-like SNe Ia (Nugent *et al.* 2002). We find that a simple comparison of the resulting fit quality (χ^2_ν) between these two templates is quite successful at separating normal and 91bg-like objects. Figures 1 and 2 show example fits with the two templates for two SNe: SN 2003fa (Hicken *et al.* 2009) and SN 1999by (Ganeshalingam *et al.* 2010), with better normal and 91bg-like template fits, respectively. From these fits, one can see that most of the difference between the two templates stems from the presence/absence of shoulders and secondary maxima in red filters, but also in the different temporal occurence of the primary maxima in all bands.

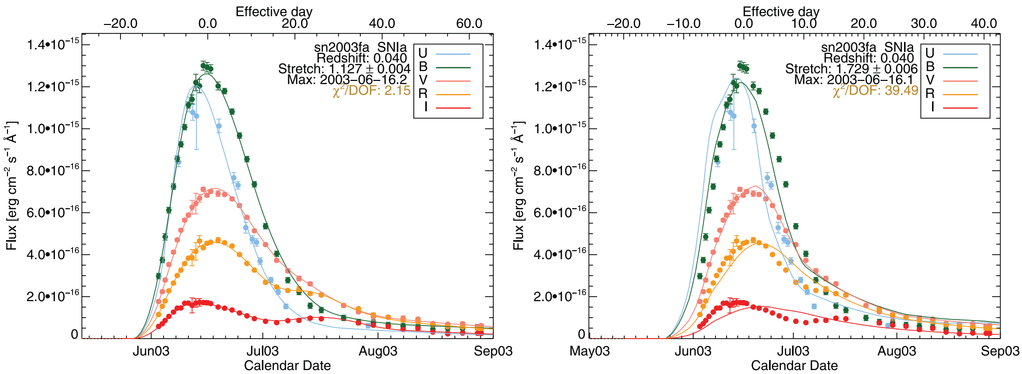

Figure 1. SiFTO fits to SN 2003fa with two templates: normal (left) and a 91bg-like (right) SNIa.

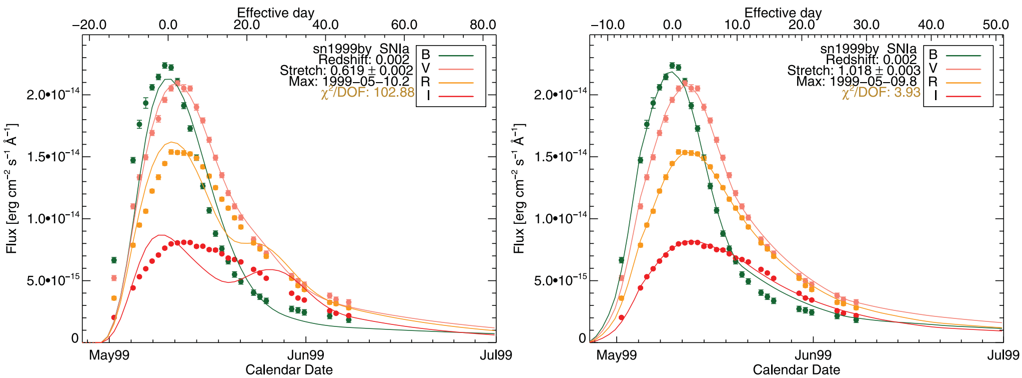

Figure 2. SiFTO fits to SN 1999by with two templates: normal (left) and a 91bg-like (right) SNIa.

We find that this simple classification based on fits to the entire light-curve with two templates is able to differentiate properly between spectroscopic normal and 91bg-like SNe Ia (see figure 3). Additionally, we find that the method consistently picks up other peculiar SNe Ia such as SN 2002cx-like SNe (Iax) and even super-Chandrasekhar SNe. Taking a closer look at their light-curves, one sees that in fact they also lack secondary maxima in their redder filters, similarly to 91bg-like objects. To disentangle these objects from classical 91bg-like, we perform SiFTO fits with the two templates to only blue (u or U, B and g) and only red (V, r or R and i or I) light-curves. In this way, SNe Iax and super-Chandrasekhar have better 91bg-like template fits in their red but not in their blue light-curves, as opposed to real 91bg-like objects for which the 91bg template fit is always better. This behaviour is interesting and could point towards physical similarities between those sub-groups despite the diversity in other characteristics. More importantly, it opens up the possibility to obtain pure samples of normal SNe Ia for different studies, particularly cosmology.

To study this further, we apply the technique to all low-redshift SNe available, including non-Ia SNe. We perform SIFTO fits with the two templates for the entire light-curves but also for red and blue light-curves. To avoid CC contamination, we additionnally make cuts on the χ^2_ν as shown in figure 4. The final purity we obtain is above 99% for normal SNe Ia (with only one false positive) with an efficiency above 80%. This competes with other classification techniques (e.g Sako *et al.* 2011) with the additional advantage that it

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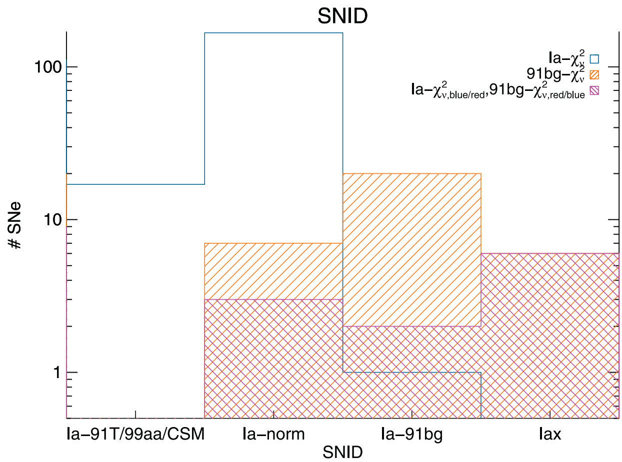

Figure 3. Comparison of our photometric classifier with the spectroscopic classifier SNID (Blondin & Tonry 2007). SNID subclasses are put in different bins in the x-axis. Our photometric normal candidates are shown in blue, 91bg-like according to the overall fit are shown in orange and 91bg-like according to only blue or red band fits are shown in purple.

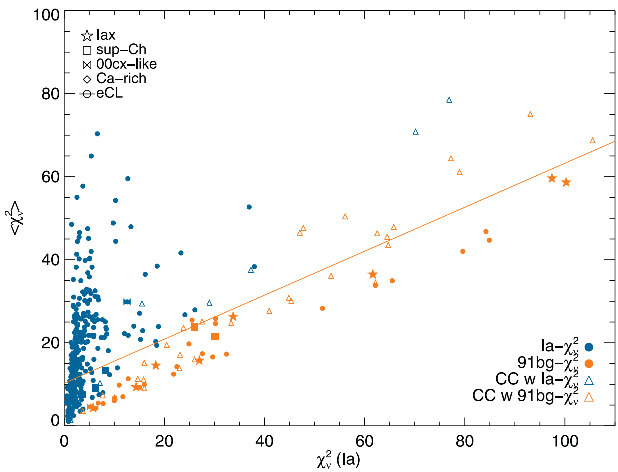

Figure 4. Average overall χ^2_ν of normal and 91bg template fits versus χ^2_ν for the normal template. Circles (normal and 91bg-like), stars (Iax) and squares (super-Chandra) represent SNe Ia whereas triangles are CC SNe. Blue are orange are normal and 91bg-like candidates according to the overall light-curve fits. The dividing line separates SNe Ia from CC contaminants.

is also free of peculiar SNe Ia, which are unfit for cosmology. The method is capable also of selecting peculiar objects such as 91bg-like or SNe Iax, although with a lower purity due to contamination from SNe Ibc.

We have presented a robust technique to identify SNe Ia of different sorts without the need of spectroscopy. Such algrithms are essential for upcoming large wide field surveys and future cosmological work with SNe Ia.

References

Riess, A. G., *et al.* 1998, *AJ*, 116, 1009
Perlmutter, S. *et al.* 1999, *ApJ*, 517, 565

Astier, P. *et al.* 2006, *A&A*, 447, 31
Sako, M. *et al.* 2011, *American Astronomical Society Meetings*, 217, 205
Ivezic, Z. *et al.* 2011, *American Astronomical Society Meetings*, 217, 252
Campbell, H. *et al.* 2011, *ApJ*, 763, 88
Conley, A. *et al.* 2008, *ApJ*, 681, 482
Hsiao, E. Y. *et al.* 2007, *ApJ*, 663, 1187
Nugent, P. *et al.* 2002, *PASP*, 114, 803
Hicken, M. *et al.* 2009, *ApJ*, 700, 331
Ganeshalingam, M. *et al.* 2010, *ApJS*, 190, 418
Blondin, S. & Tonry, J. L. 2007, *ApJ*, 666, 1024
Sako, M. *et al.* 2011, *ApJ*, 738, 162