Early high-cadence monitoring of supernovae: key to identifying the progenitors

Emmy Paraskeva[1,2] & Alceste Bonanos[1]

[1]IAASARS, National Observatory of Athens, Greece

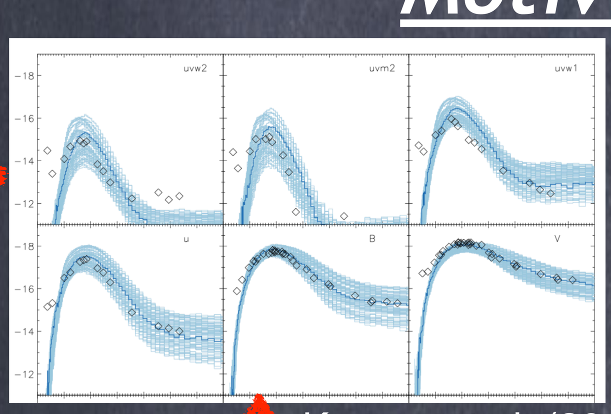
[2]National & Kapodistrian University of Athens, Greece

Abstract

High-cadence photometry on the early evolutionary stage of supernova light curves has the potential to provide a better understanding of nearly every aspect of SNe, from their explosion physics to their progenitors and the circumstellar environment. Given the increasing rate of discovery of bright supernovae before their maximum brightness from modern time-domain optical surveys, we have the opportunity to capture their intraday behaviour near the time of their explosions. We present results of monitoring the optical light curves of 2 out of 8 bright SNe, primarily using the 2.3m Aristarchos telescope and 1.2m Kryoneri telescope. The supernovae were observed over several nights during the early and late evolution with a cadence of 30-120s and high precision differential aperture photometry was derived. Differential light curves with respect to all comparison stars available on each night, as well as reconstructed light curves after implementing the Trend Filtering Algorithm (TFA; Kovacs et al. 2005) are presented. We derive the decline slope of each supernova on each night and quantify the precision of our photometry and variability in the light curves, after accounting for sources of systematic error. We encourage further high-cadence photometric monitoring of bright SNe in the ultraviolet bands with the goal of identifying explosion mechanisms, binary-star interaction, progenitor channels, or properties of the explosion environment.

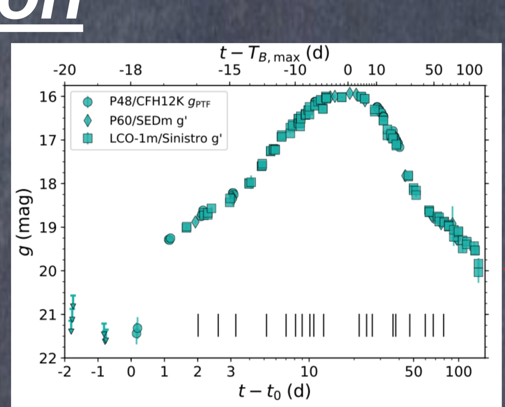
Motivation

Early blue bumps



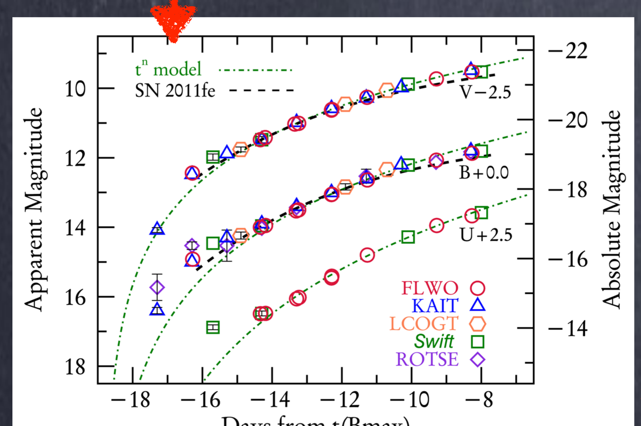
Kromer et al. (2016)

Rapid rise

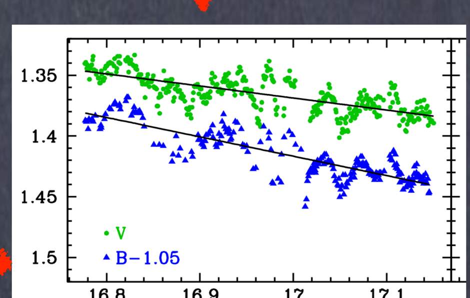


Miller et al. (2018)

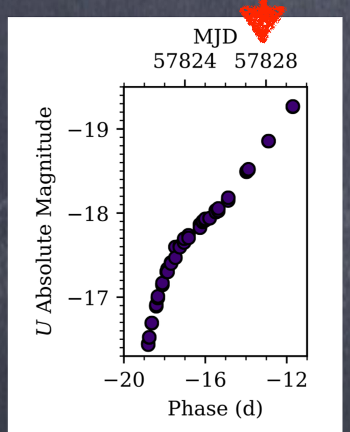
SN 2012cg | iPTF14atg | SN 2014J | iPTF16abc | SN 2017cbv



Marion et al. (2016)



Bonanos & Boumis (2016)



Hosseinzadeh et al. (2017)

Rapid Variability

Observations

Object	RA	DEC	Type	Discovery mag	Filter	Number of frames	Telescope
SN 2016gsn	02:29:17.482	+18:05:16.33	Ia	16.3	VR	4520	Aristarchos
SN 2016gsb	06:04:28.140	-20:20:24.94	Ia	15.9	VR	1892	Aristarchos
SN 2018bq	11:05:59.588	-12:31:37.93	Ia	16.1	V	58	pt5m
SN 2018gv	08:05:34.61	-11:26:16.30	Ia	16.5	R/I	236/236	Kryoneri
SN 2018zd	06:18:03.18	+78:22:00.90	II	17.8	R/I	323/323	Kryoneri
SN 2018hgc	00:42:04.56	-02:37:40.80	Ia	17.9	VR	284	Aristarchos
SN 2018hhn	22:52:32.06	+11:40:26.70	Ia	17.1	VR	296	Aristarchos
SN 2018hna	12:26:12.05	+58:18:51.10	II	16.3	VR	272	Aristarchos

Paraskeva et al. (in prep)

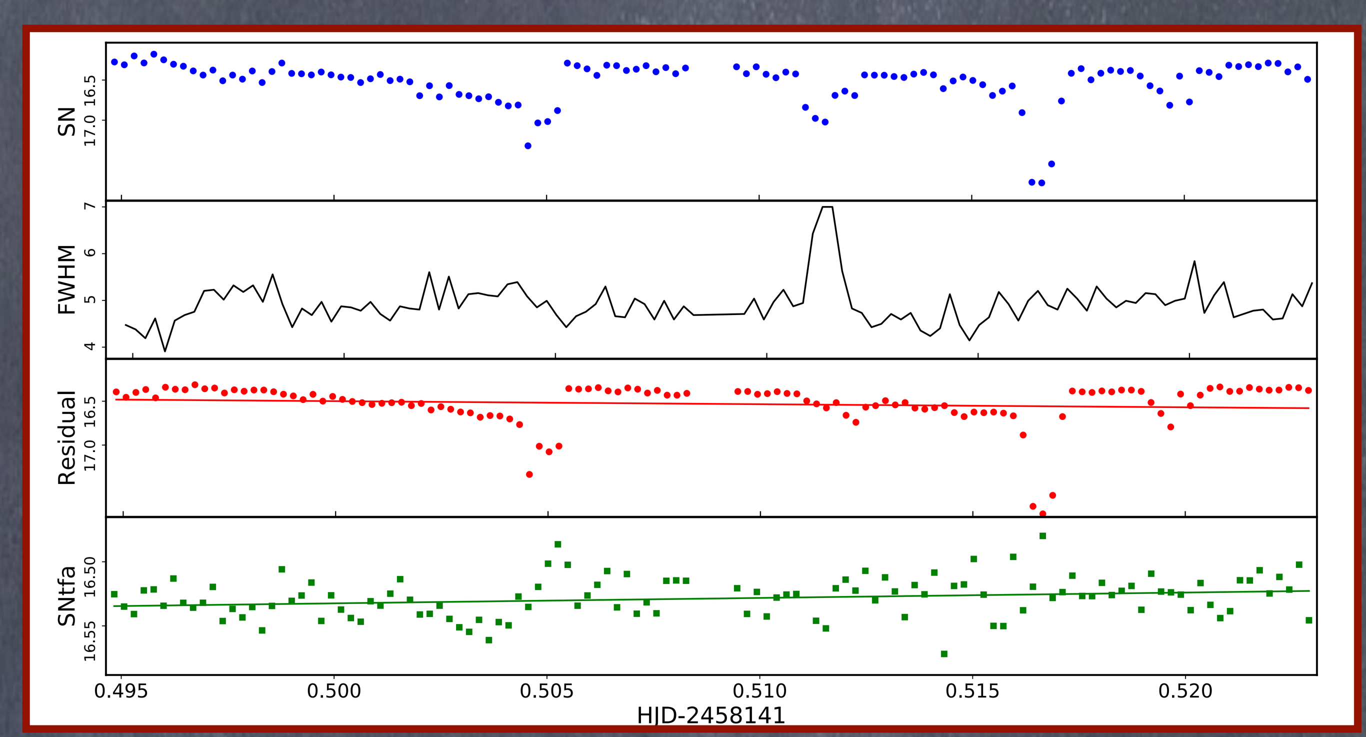
Methods

Photometry:

- Optimal photometry with VAPHOT (Deeg et al. 2013)
- PSF photometry with DAOPHOT
- ISIS Image Subtraction (Alard 2000)

Analysis:

- Remove seeing effects following Irwin et al. (2006)
- Trend-Filtering Algorithm (TFA, Kovacs et al. 2005) from VARTOOLS
- Estimation of white & red noise with a MCMC analysis following Winn et al. (2007)



object	rms_{tfa}	a_{SNtfa}	σ_w	σ_r
SN 2018gv	0.02	-0.0421	0.0038	0.0078

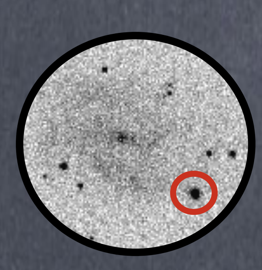
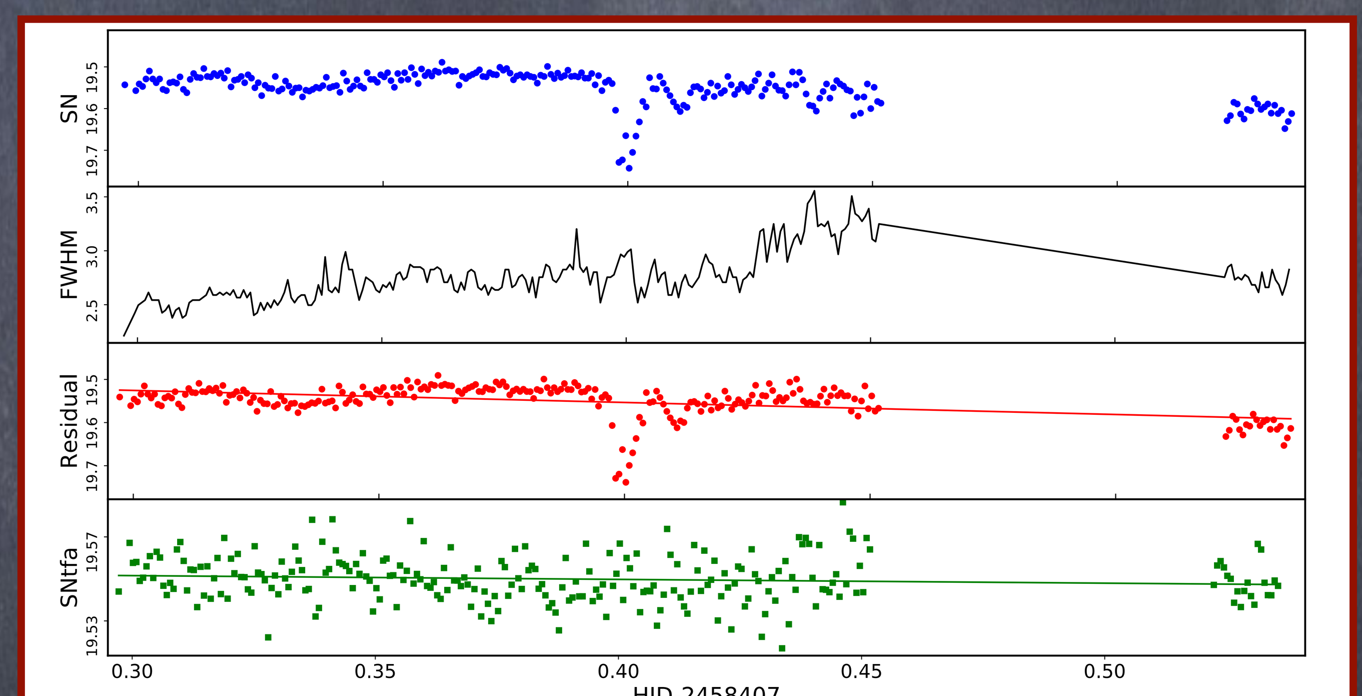


Fig. 1: Light curve of SN 2018gv (top panel) obtained with the 1.2-m Kryoneri telescope during the second run. The second panel shows the corresponding variations in the seeing. The third panel shows the supernova's light curve after the subtraction of the FWHM features. The reconstructed light curve after the subtraction of the systematic effects with TFA appears on the bottom panel. A residual undulation is apparent at a level of 0.05 mag.



object	rms_{tfa}	a_{SNtfa}	σ_w	σ_r
SN 2018hgc	0.01	0.286	0.0041	0.0086

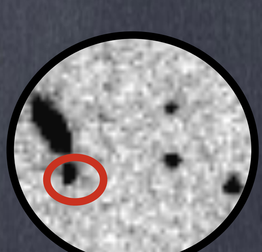


Fig. 2: Same as Fig. 1, but for the early time light curve of SN 2018hgc obtained with the 2.3-m Aristarchos telescope. A residual undulation is apparent at a level of 0.04 mag.

Conclusions

- We present results of a pilot study of high cadence photometry, which is a powerful tool for probing supernova physics
- Trend Filtering algorithm was key to subtracting the systematic noise. A future goal will be to improve the systematic error subtraction in order to confidently identify any structure in the early time light curves.
- Residual undulations in two SNe (2018gv & 2018hgc, Fig 1 & 2) remain after trend filtering and seem significant when compared to red/white noise estimations.
- We plan to monitor future bright supernovae (e.g. from ZTF) in the blue using the 1.2-m Kryoneri and 2.3-m Aristarchos telescopes & Gaia science alerts follow-up network.

References

Bonanos A. Z., & Boumis P., 2016, A&A, 568, A22
Deeg, H. J. 2013, VAPHOT: Precision differential aperture photometry package, Astrophysics Source Code Library
Hosseinzadeh, G., Sand D. J., Valenti S., et al. 2017, MNRAS, ApJ, 845, L11
Irwin J., Irwin M., Aigrain S., et al. 2007 MNRAS, 375, 1449
Kovacs G., Bakos G., & Noyes R. W. 2005, MNRAS, 356, 557
Kromer, M., Fremling, C., Pakmor, R., et al. 2016, MNRAS, 459, 4428
Marion, G. H., Brown, P. J., Vinko, J., et al. 2016, ApJ, 820,92
Miller, A. A., Cao, Y., Piro, A. L., et al. 2018, ApJ, 852, 100
Winn, J. N., Holman, M. J., Bakos G. Á., et al. 2007, AJ, 134, 1707

Acknowledgements

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