Early high-cadence observations of SNe: revealing features of variability and identifying their diversity

Emmanouela Paraskeva

PhD student

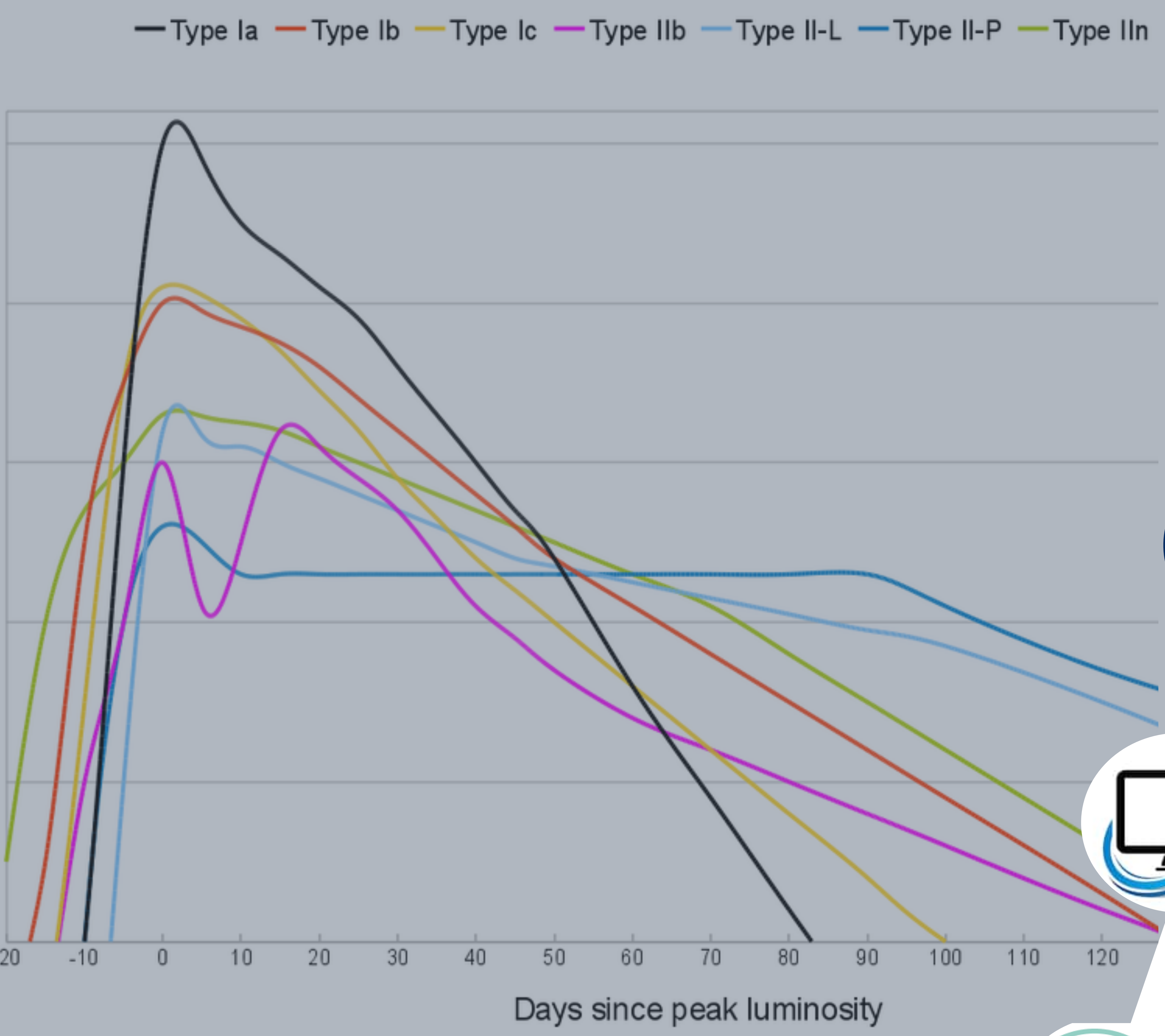
National Observatory of Athens & University of Athens, Greece

Supervisor: Dr. Alceste Bonanos

HELLENIC REPUBLIC
National and Kapodistrian University of Athens

ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ
NATIONAL OBSERVATORY ATHENS

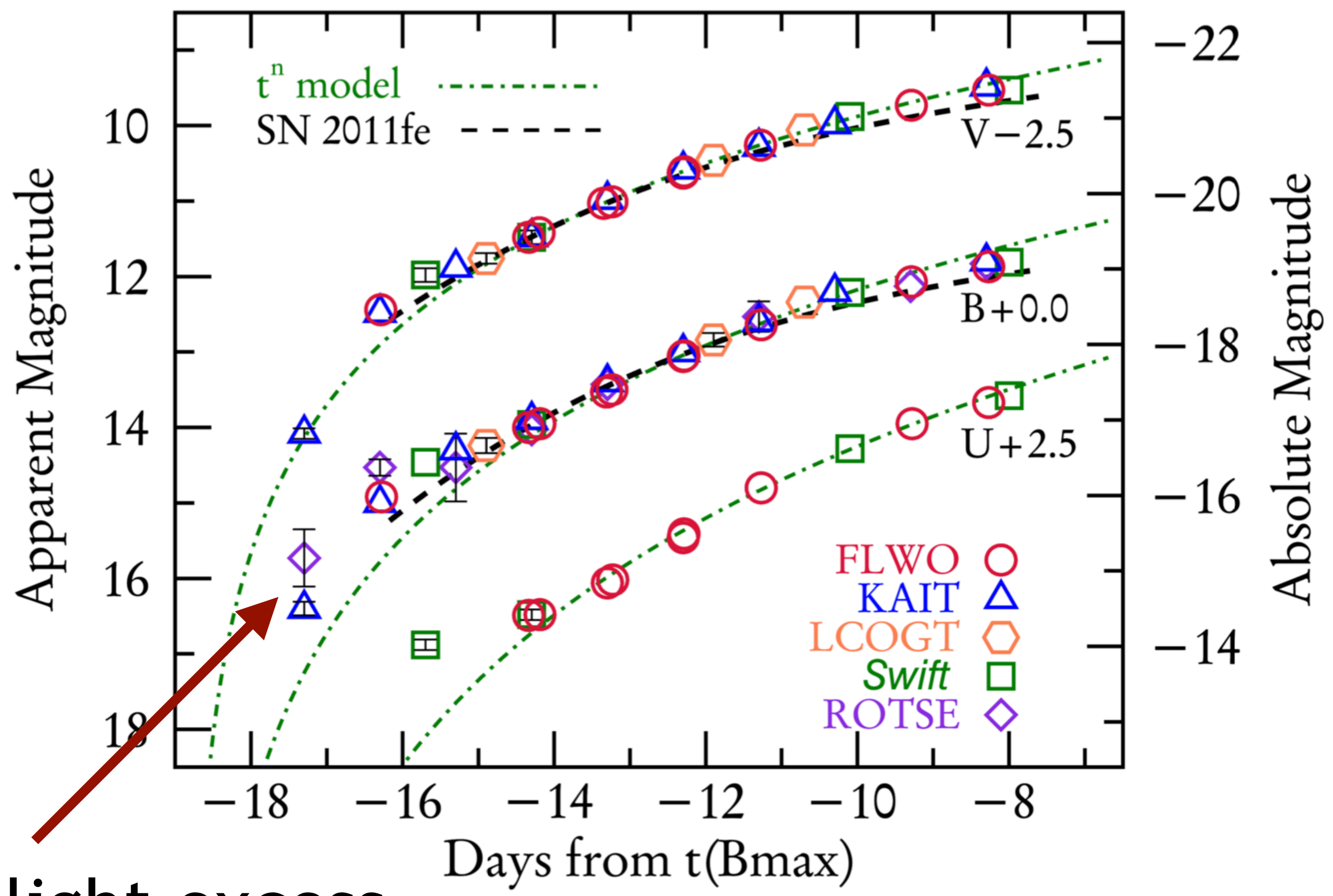
IAASARS



Outline

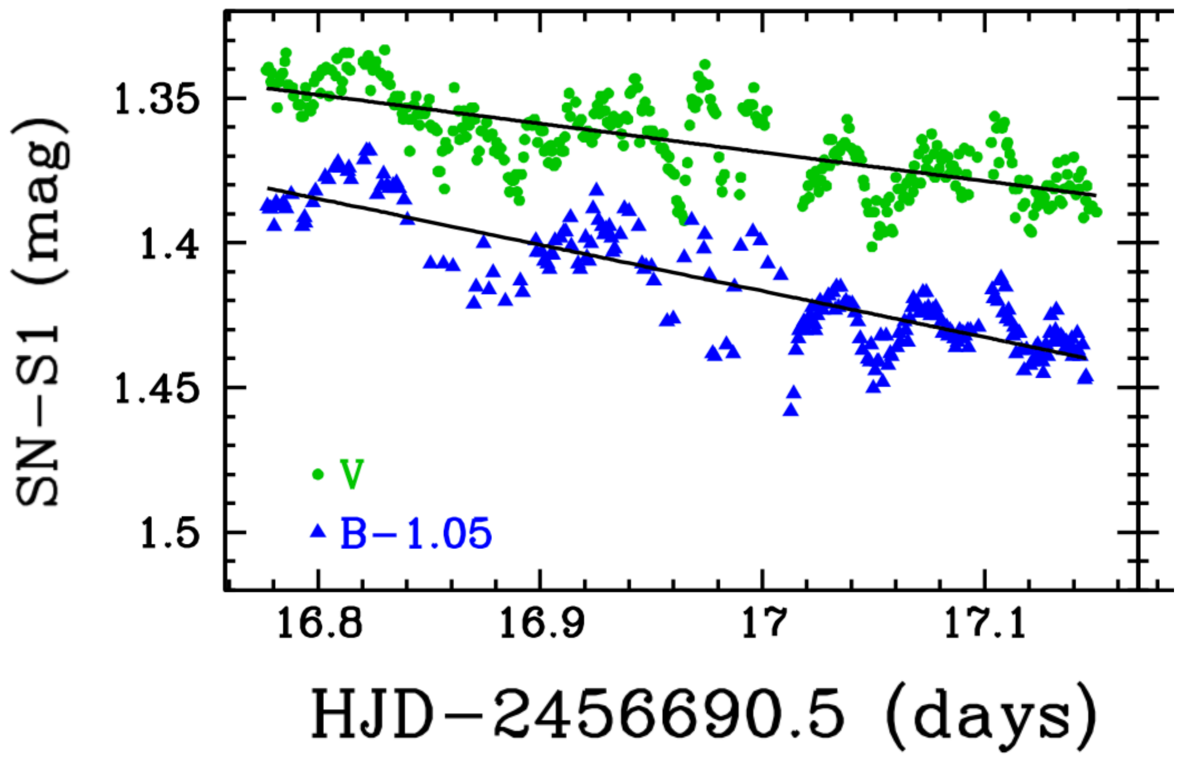
- MOTIVATION
- OBSERVATIONS
- METHODS
- FUTURE PROSPECTS RESULTS

Motivation



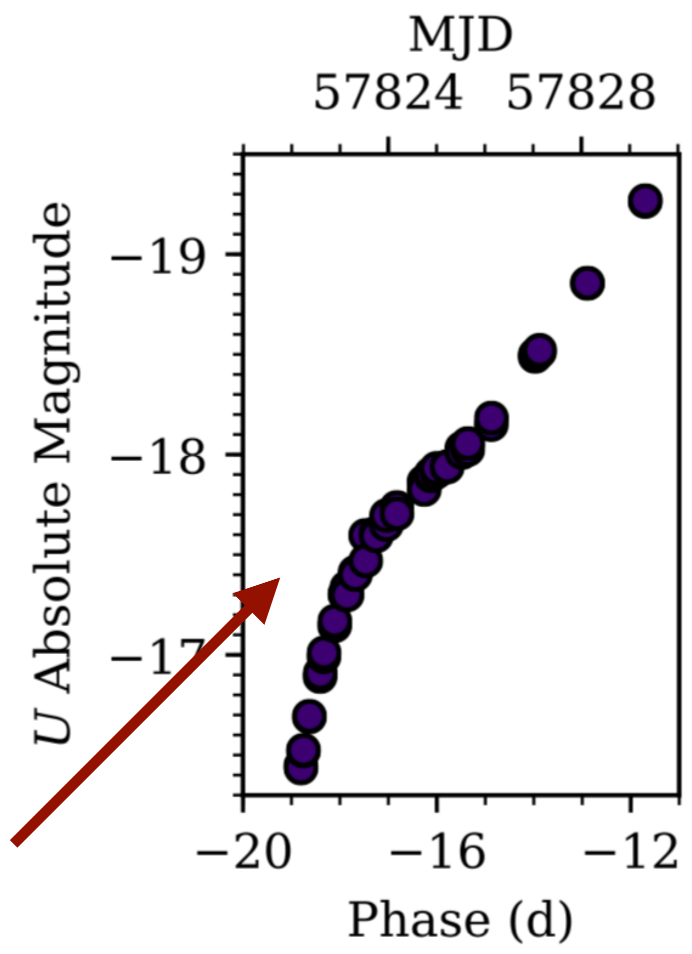
Blue light excess at -15 and -16 days

Marion et al. (2016)



Rapid variability at a scale of 15-60 min at +17 days

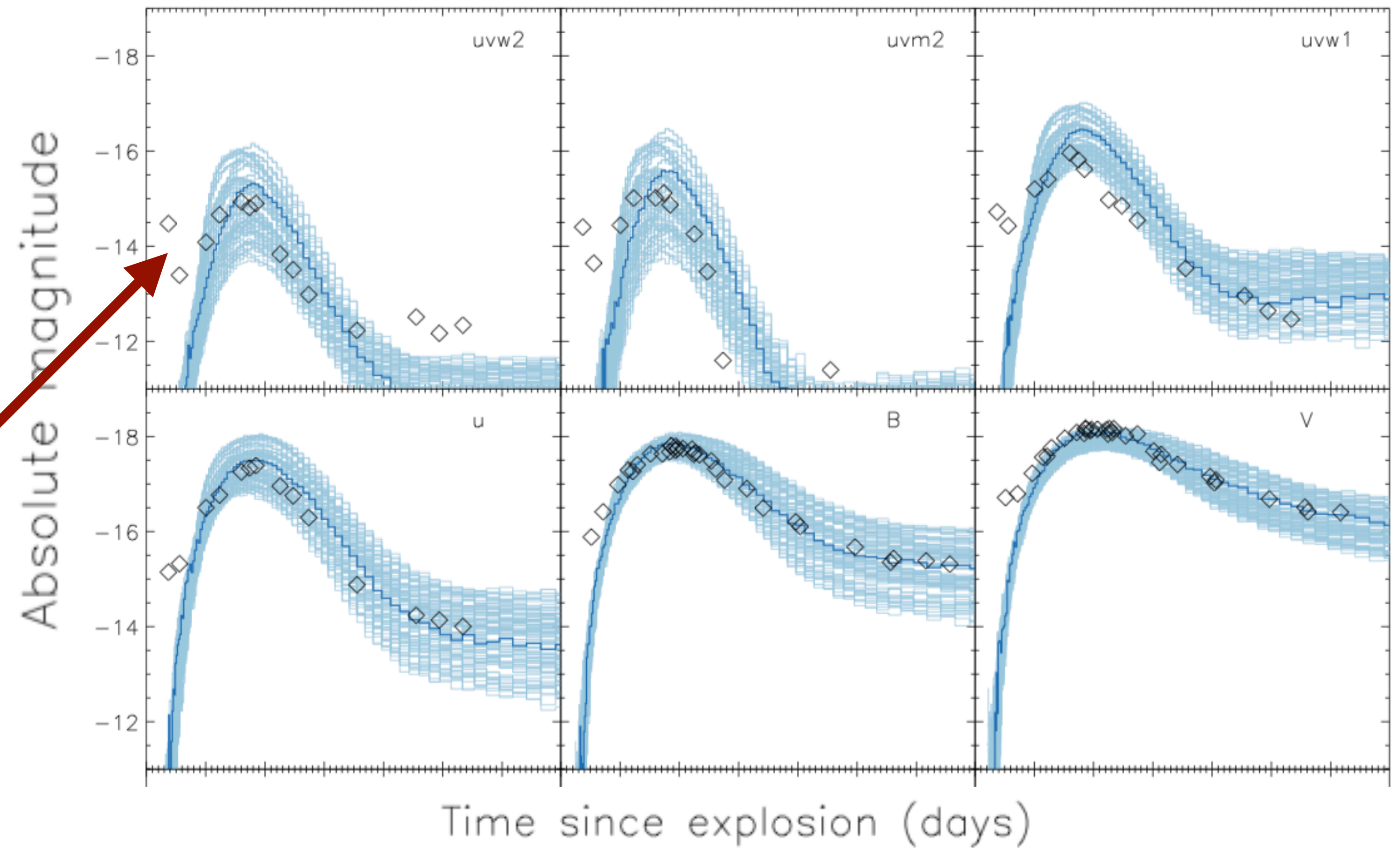
Bonanos et al. (2016)



Blue excess over 5 days

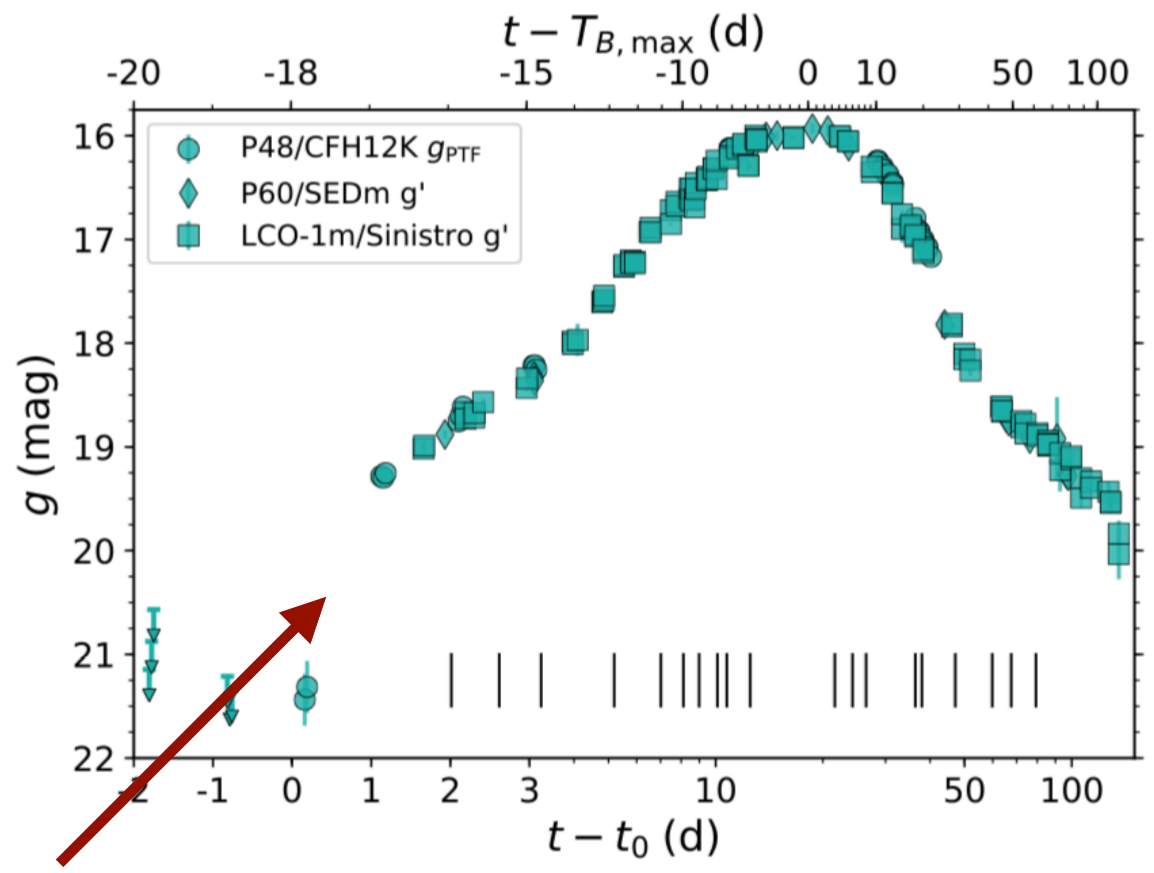
Hosseinzadeh et al. (2017)

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



A strong UV flash 4 days past explosion followed by a steep decline lasting about 1 day

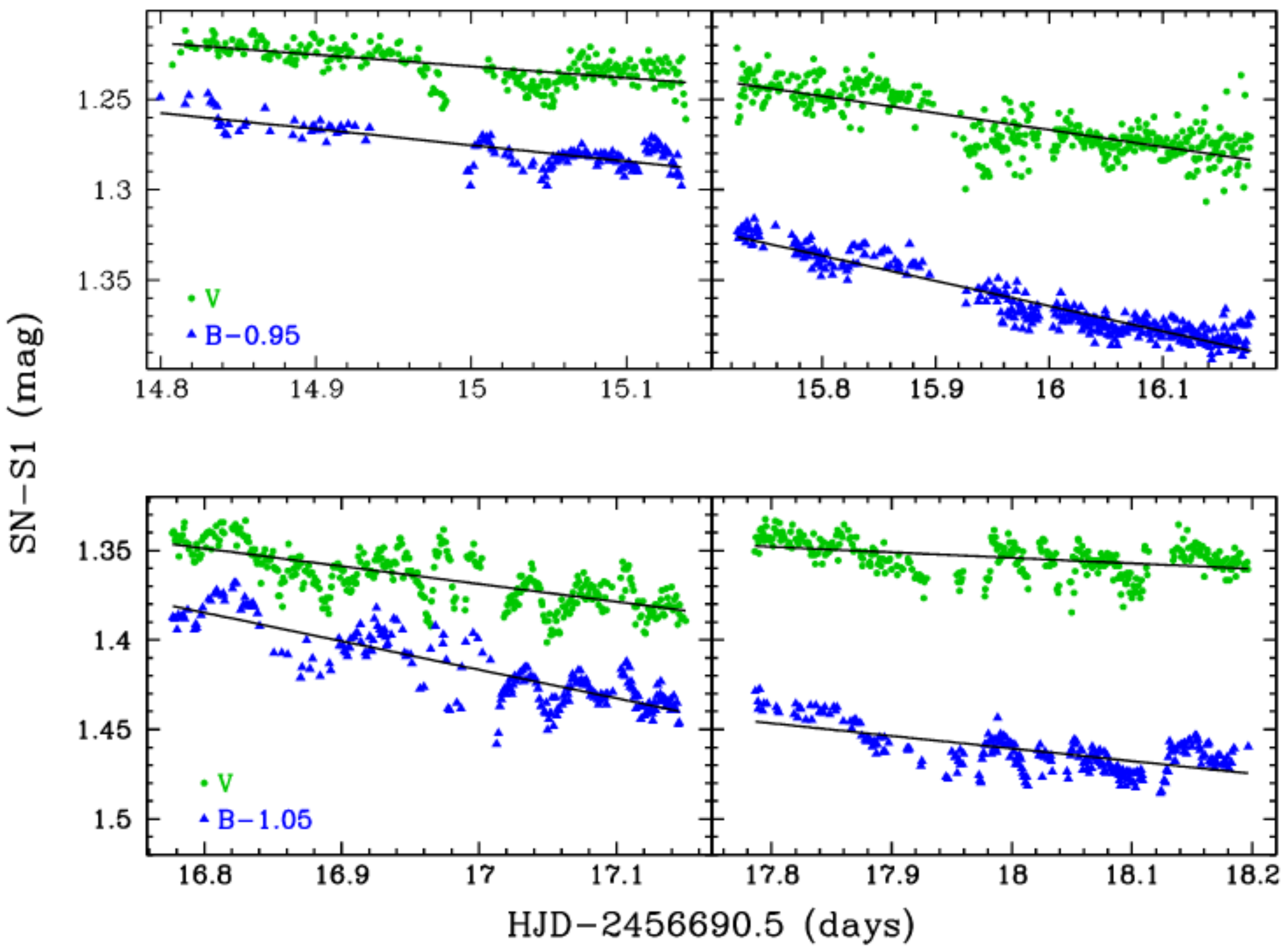
Kromer et al. (2016)



2 mag rise within 24 hours

Miller et al. (2018)

Motivation - SN 2014J



Evidence for rapid variability of 0.02-0.05 mag on a timescale of 15-60 min peaking on 3rd night

<u>Scenarios for the origin of micro-variability:</u>

➡clumping of the ejecta (Hole et al. 2010)
➡ interaction of the ejecta with circumstellar material (Foley et al. 2014)
➡ asymmetry of the ejecta (Wang & Wheeler 2008)
➡the onset of the secondary maximum (Pinto & Eastman 2000)

- 15-18 days after peak
- 2 min cadence

Bonanos & Boumis (2016)

Motivation - SN 2017cbv

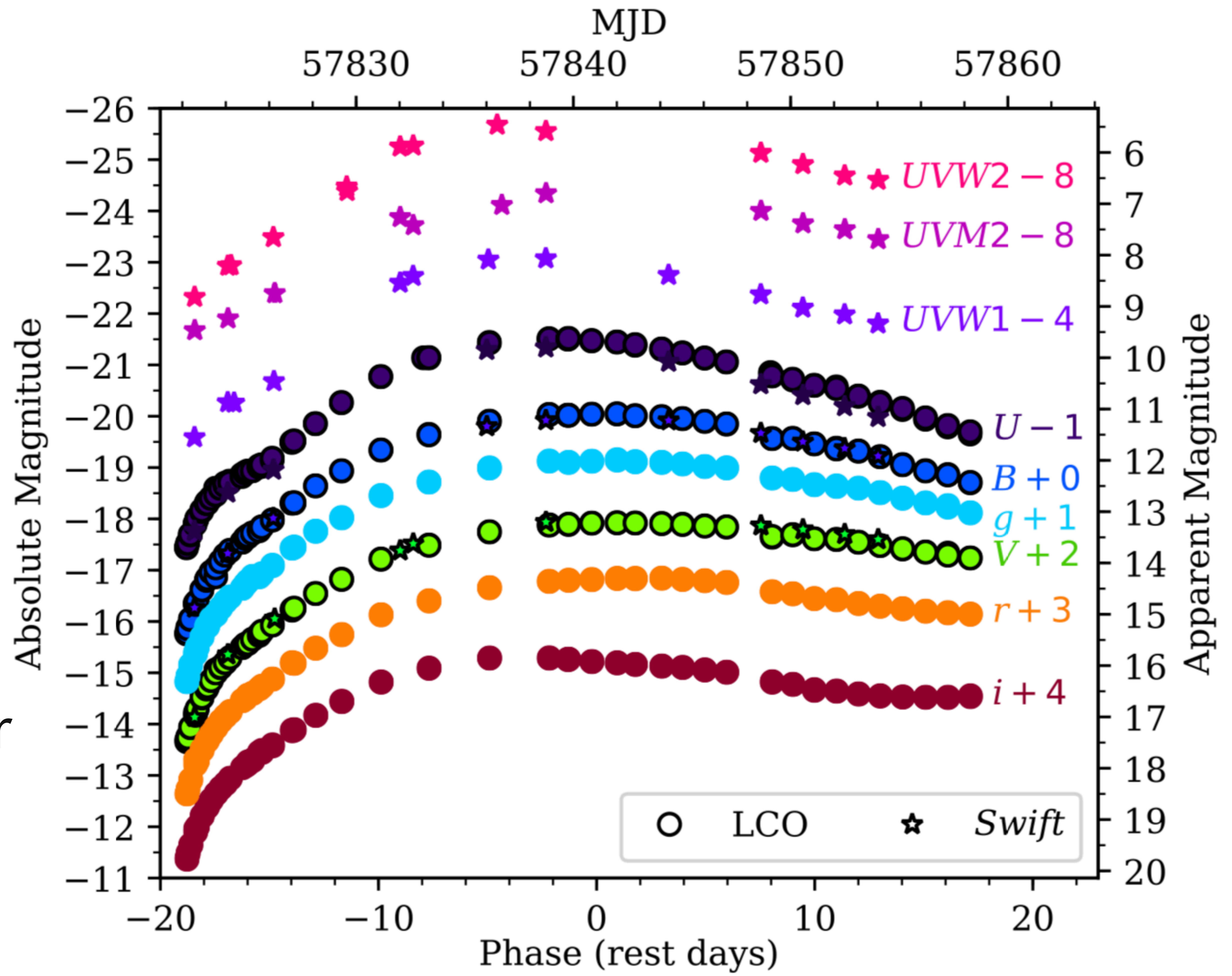
- Blue excess during the first 5 days of observations
- Good fit between UBVgri data and models of binary companion shocking from Kasen (2010)
- Fit overpredicts UV luminosity at early times

<u>Scenarios for the origin of the bump:</u>

➡Interaction with CSM

➡The presence of radioactive Nickel in the outer ejecta

➡Connection between an early light curve bump and unburned carbon-clue about SNe Ia progenitors?



Hosseinzadeh et al. (2017)

High-cadence survey

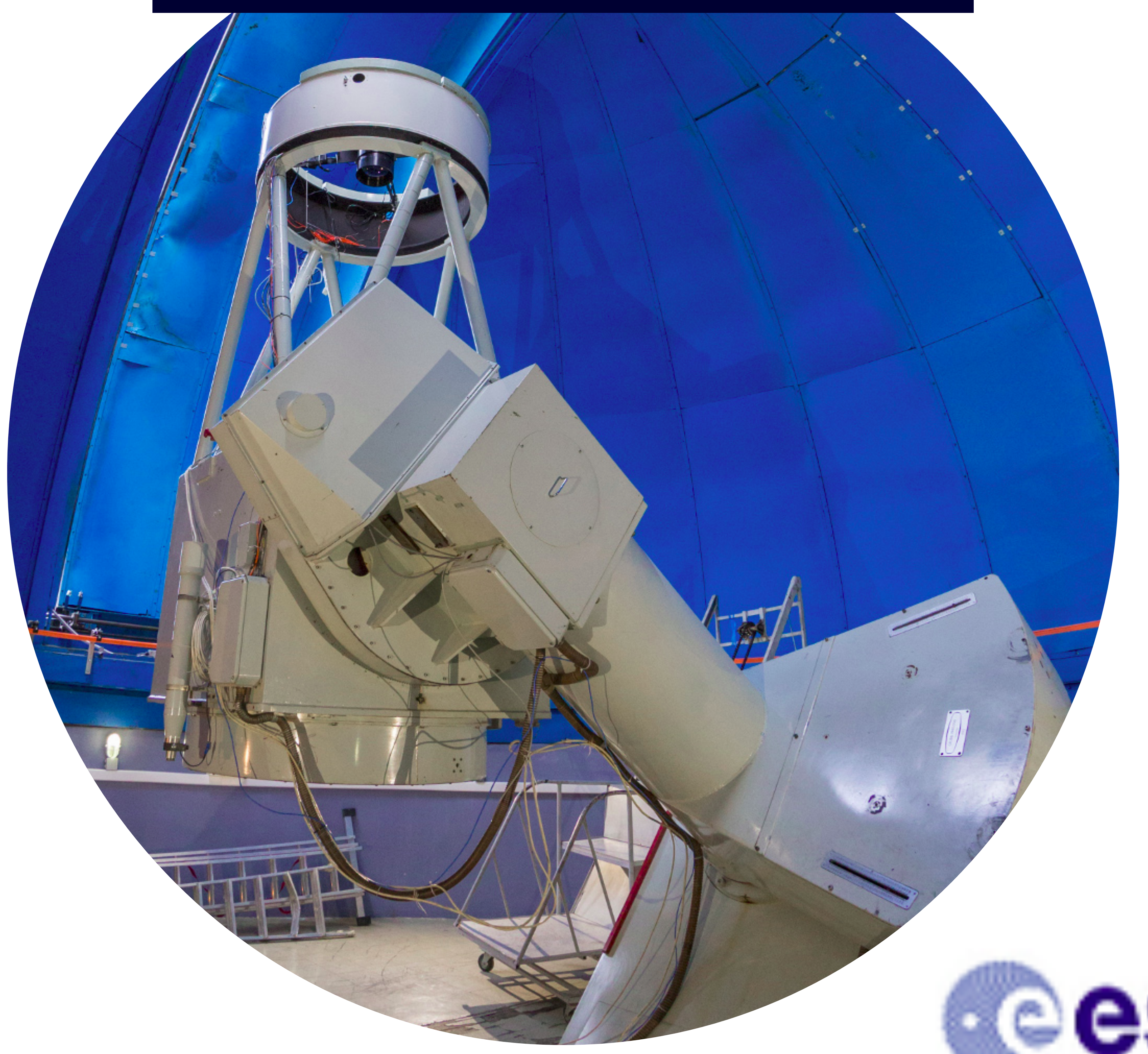
Aim

Obtain high-cadence observations to search for variability and characterise early evolution, with the goal of identifying SN progenitor channels.

ARISTARCHOS TELESCOPE
HELMOS OBSERVATORY

- 2.3 m telescope
- RISE2 camera (10’x10’ FOV, broad-VR filter)
- High cadence (10-180s) photometry

Kryoneri Observatory
1.2m Telescope



- 1.2 m telescope
- Two fast frame sCMOS Zyla 5.5 cameras, 17’x14’ FOV
- Dichroic beam splitter
- R & I filters

OPTICON esa neliota

Observations

Late time photometry

Object	RA	DEC	Type	Discovery Date	Discovery mag	Filter	Number of frames	Telescope
★ SN 2016gsn	02:29:17.482	+18:05:16.33	Ia	2016-09-29 11:02:24	16.3	VR	4520	Aristarchos
SN 2016gsb	06:04:28.140	-20:20:24.94	Ia	2016-09-29 06:43:12	15.9	VR	1892	Aristarchos
AT 2018gpn	03:37:45.260	+72:31:58.70	–	2018-08-22 13:42:14	15.9	VR	4201	Kryoneri
SN 2018bq	11:05:59.588	-12:31:37.93	Ia	2018-01-08 08:52:48	16.1	V	58	pt5m
★ SN 2018gv	08:05:34.61	-11:26:16.30	Ia	2018-01-15 16:21:06	16.5	R/I	236/236	Kryoneri
SN 2018zd	06:18:03.18	+78:22:00.90	II	2018-03-02 11:40:16	17.8	R/I	323/323	Kryoneri
★ SN 2018hgc	00:42:04.56	-02:37:40.80	Ia	2018-10-10 00:57:36	17.9	VR	284	Aristarchos
SN 2018hhn	22:52:32.06	+11:40:26.70	Ia	2018-10-13 20:48:28	17.1	VR	296	Aristarchos
SN 2018hna	12:26:12.05	+58:18:51.10	II	2018-10-22 19:33:07	16.3	VR	272	Aristarchos

Paraskeva et al. (in prep)

Early time Photometry

Methods

1 ***Photometry:***

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

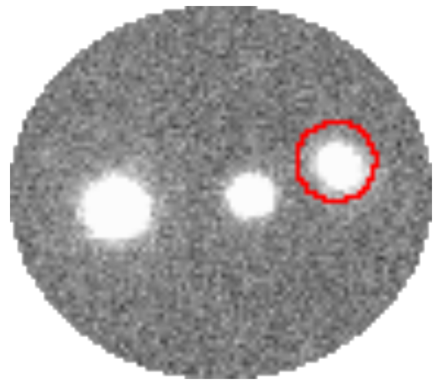
2 ***Analysis:***

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

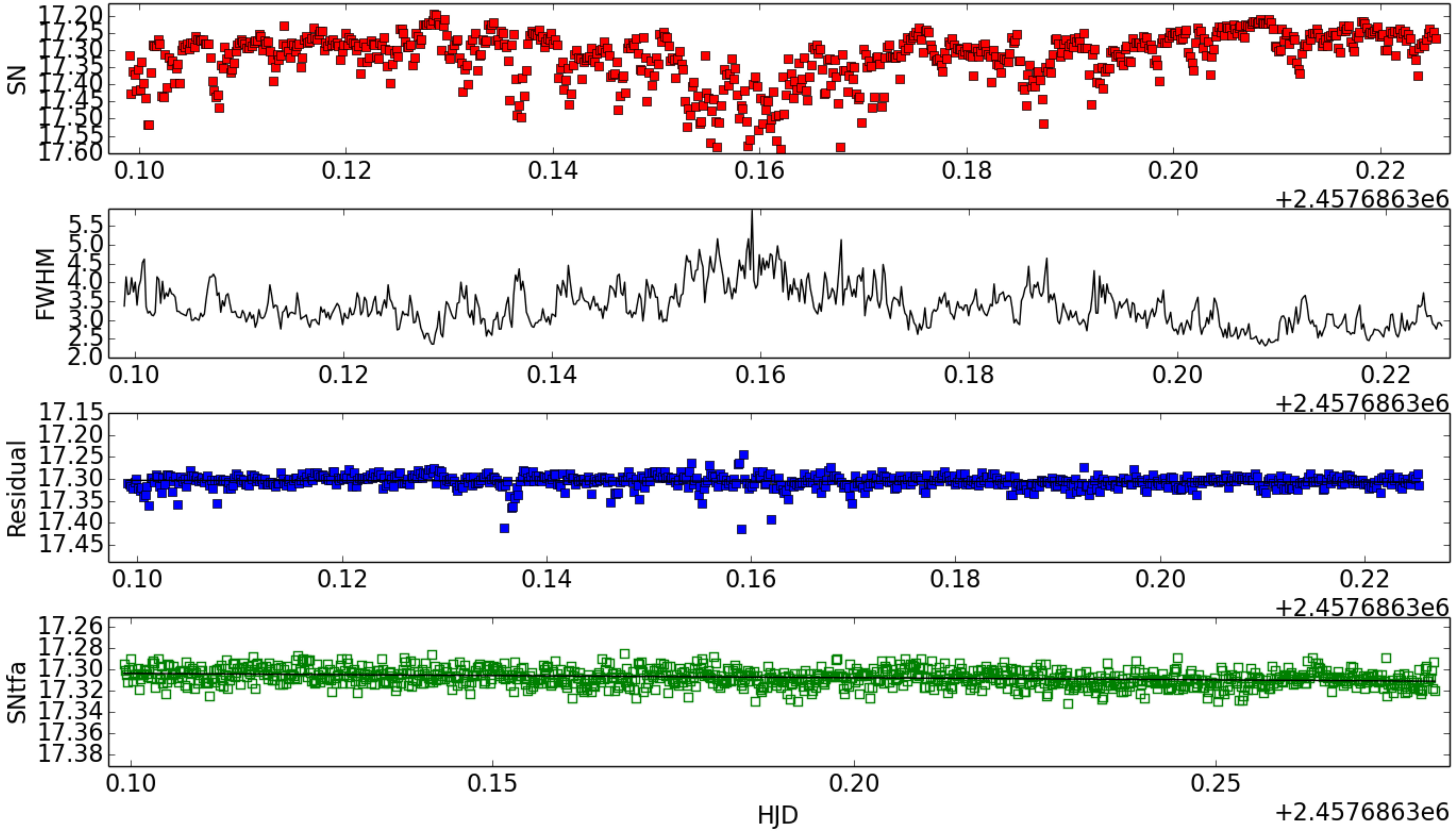
3 ***SNe light curve analysis:***

- Photometric light curve data fitting to calculate the redshift and the time-of-zero-phase with **SALT2**, Nugent's templates, sncosmo

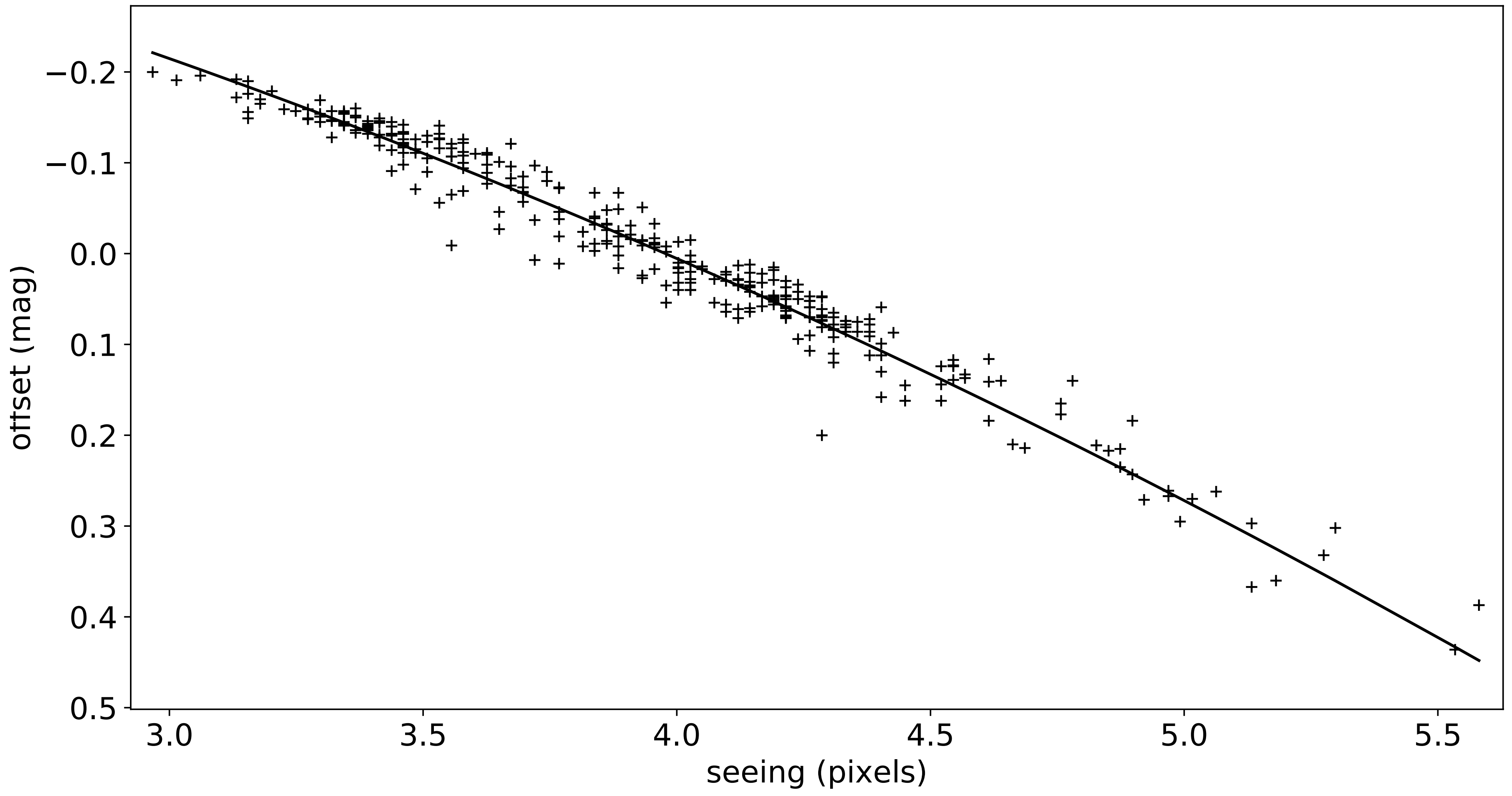
Results - SN 2016gsn



Type Ia



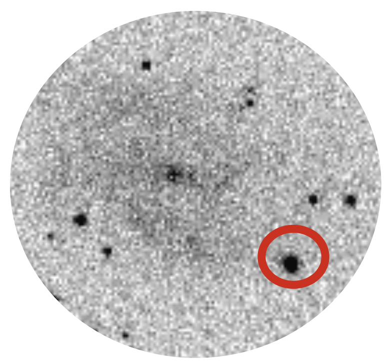
Late time photometry of SN 2016gsn: **1050 frames** obtained on the 3rd night of observations with 2.3-m Aristarchos telescope, using an exposure time of **10s**. The rms improved from 0.072 mag to 0.016 mag.



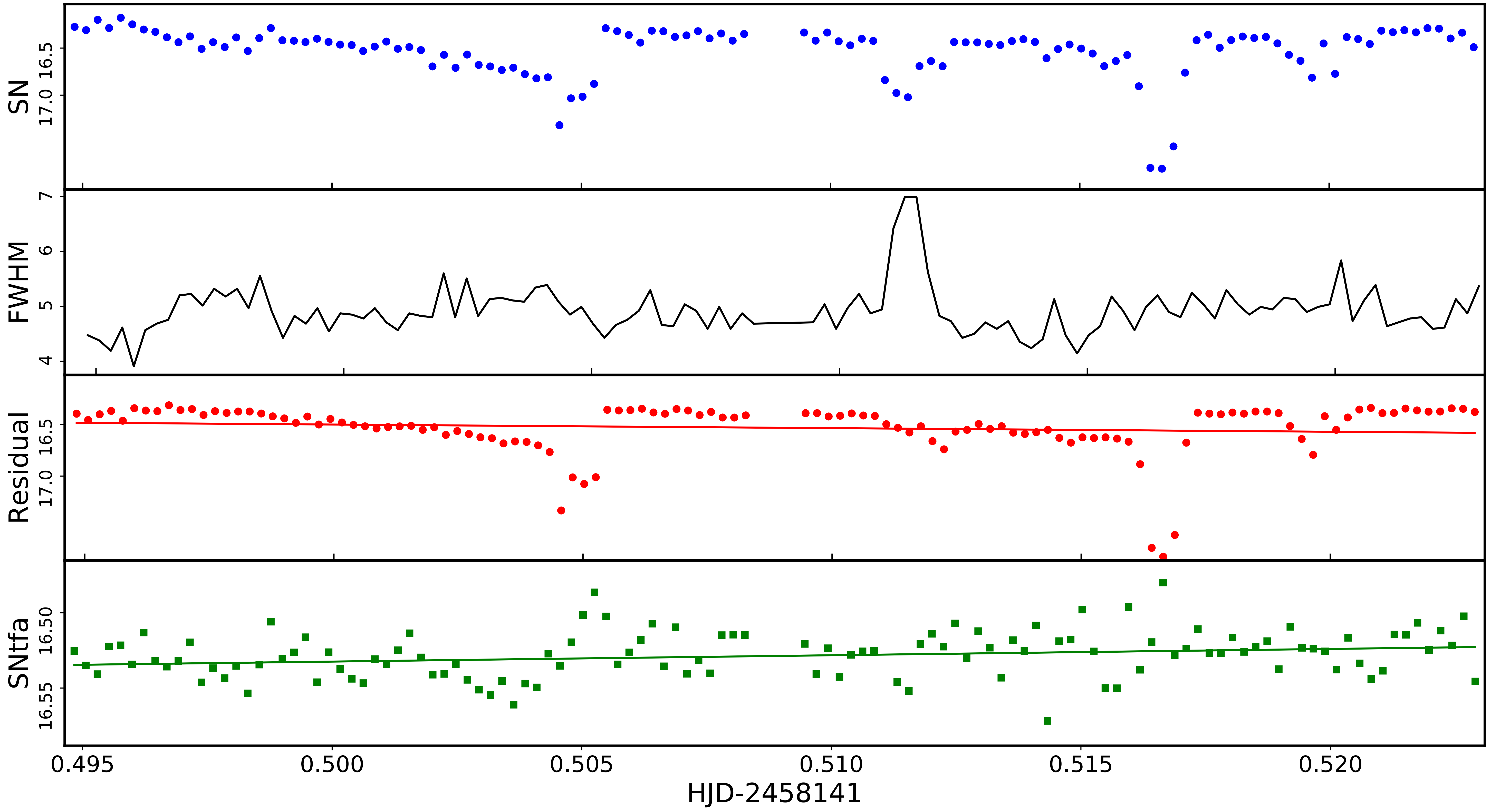
Paraskeva et al. (in prep)

- 21-32 days after peak
- 4520 frames
- 10-20s exposure time
- Discovery mag: 16.3mag
- Redshift: 0.018

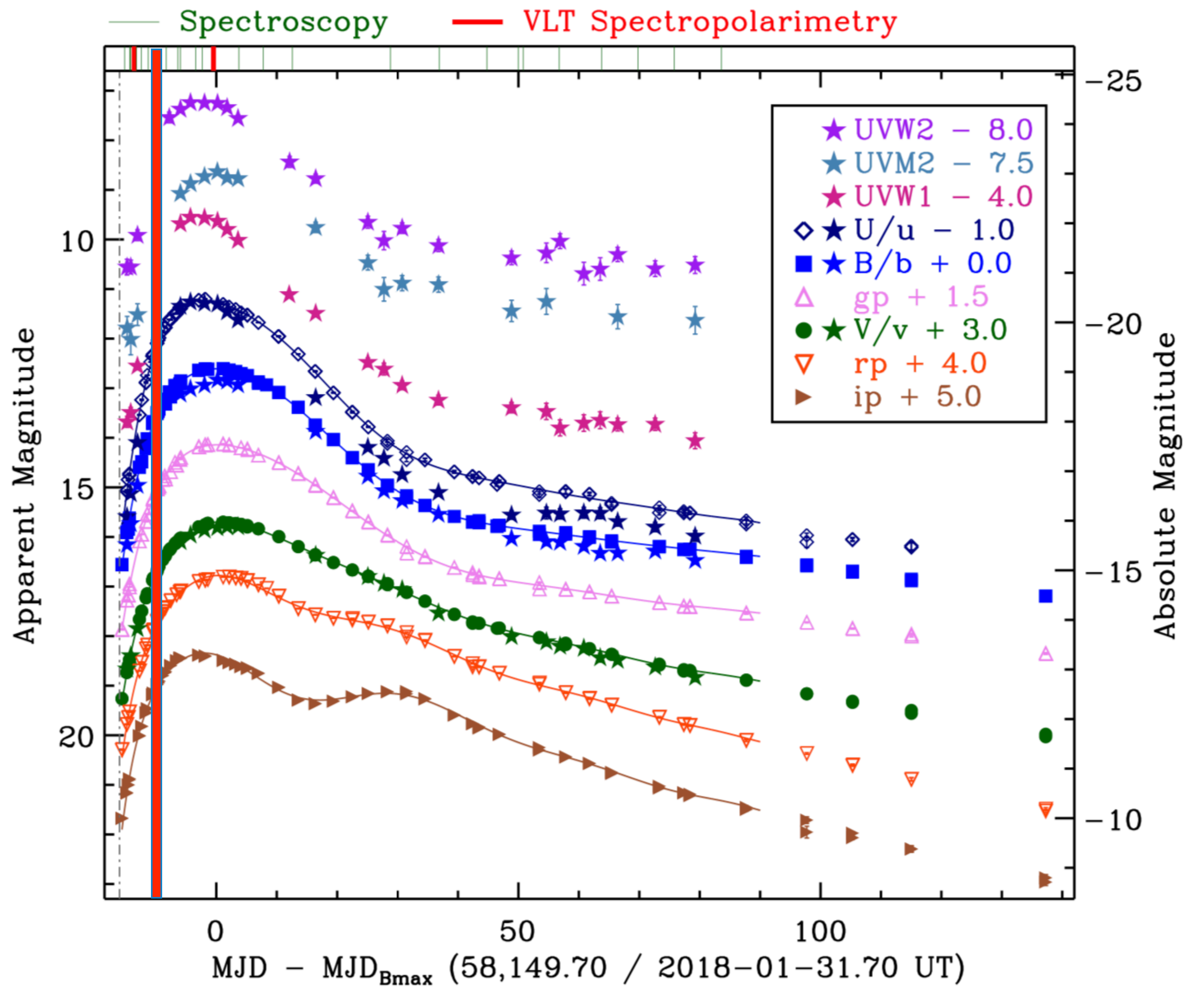
Results - SN 2018gv



Type Ia



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



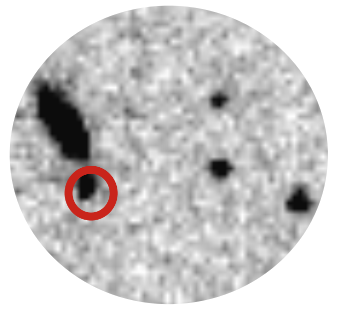
Early time photometry of SN 2018gv: **120 frames** obtained with 1.2-m Kryoneri telescope in R band, using an exposure time of **30s**.

➡Residual undulations ~0.05 mag, 7 days before peak brightness

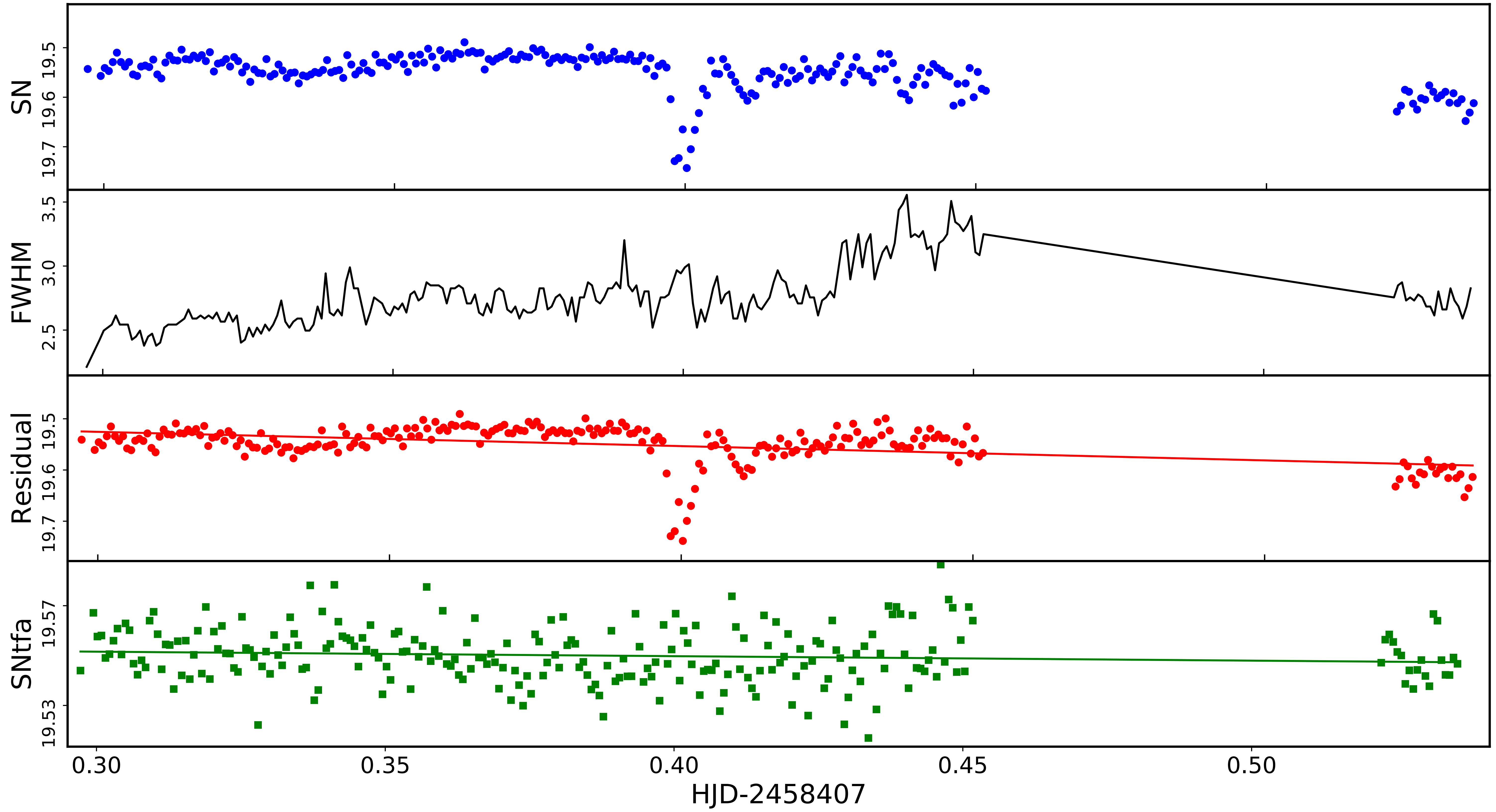
Paraskeva et al. (in prep)

Yang et al. (2019)

Results - SN 2018hgc



Type Ia

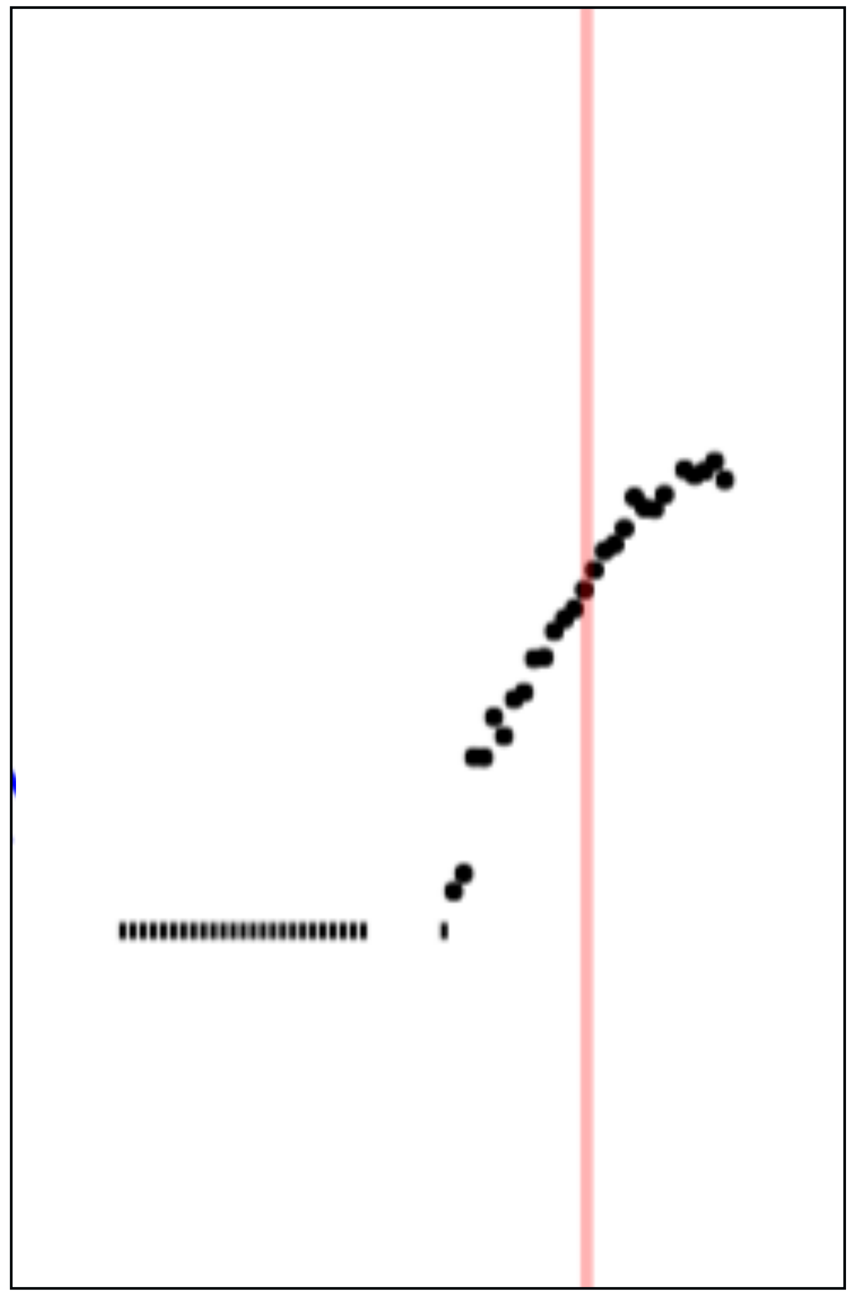


Early time photometry of SN 2018hgc: **180 frames** obtained on the 2nd night of observations with 2.3-m Aristarchos telescope, using an exposure time of **90s**.

Paraskeva et al. (in prep)

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

➡Residual undulations ~0.04 mag



Fausnaugh et al. 2019

Future prospects

High cadence and high precision monitoring campaigns of future nearby and bright SNe in the ultraviolet and blue

ZTF

MOU with ZTF

gaia

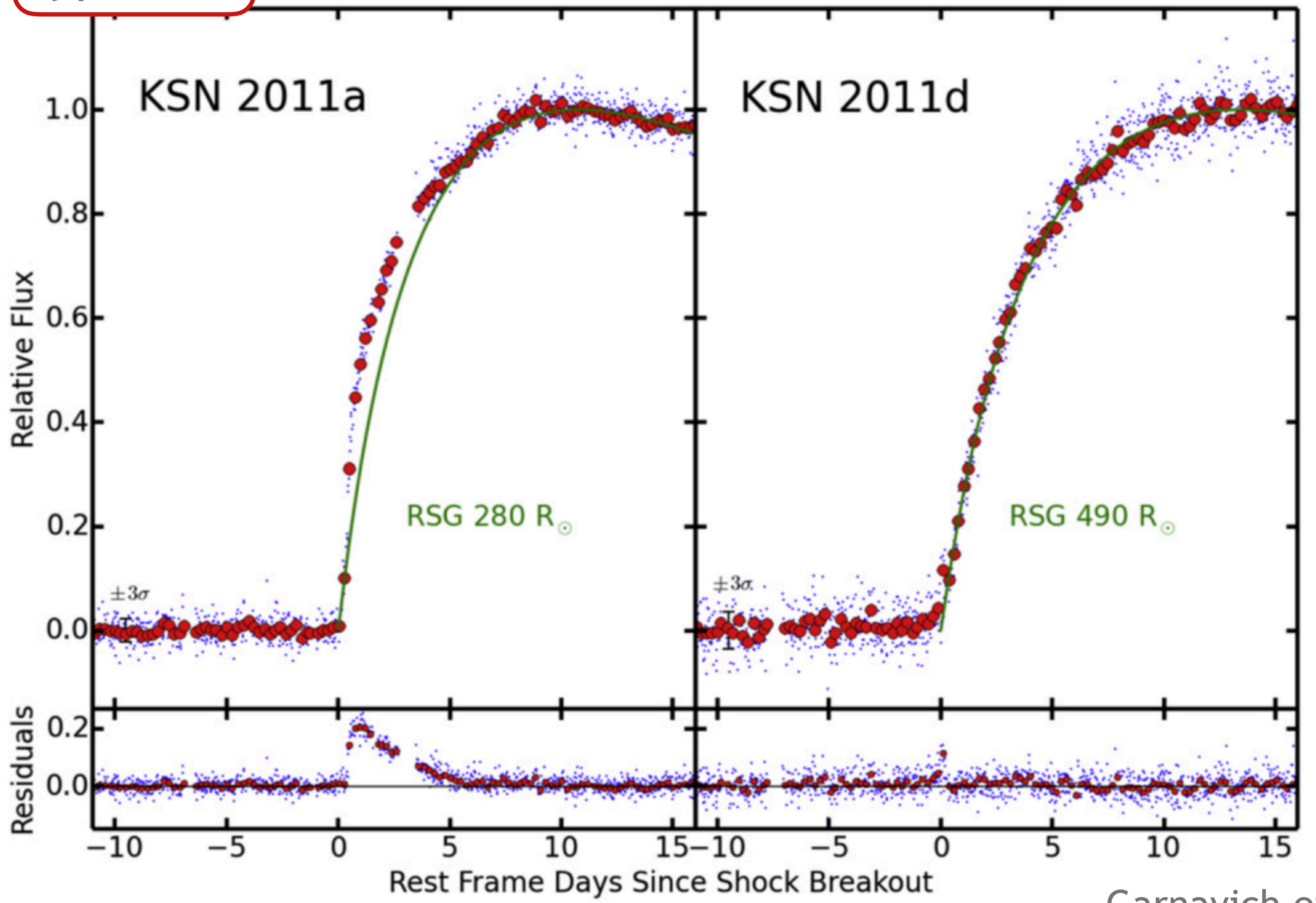
Gaia Science alerts follow-up network

IAASARS

2.3 m Aristarchos telescope
1.2 m Kryoneri telescope

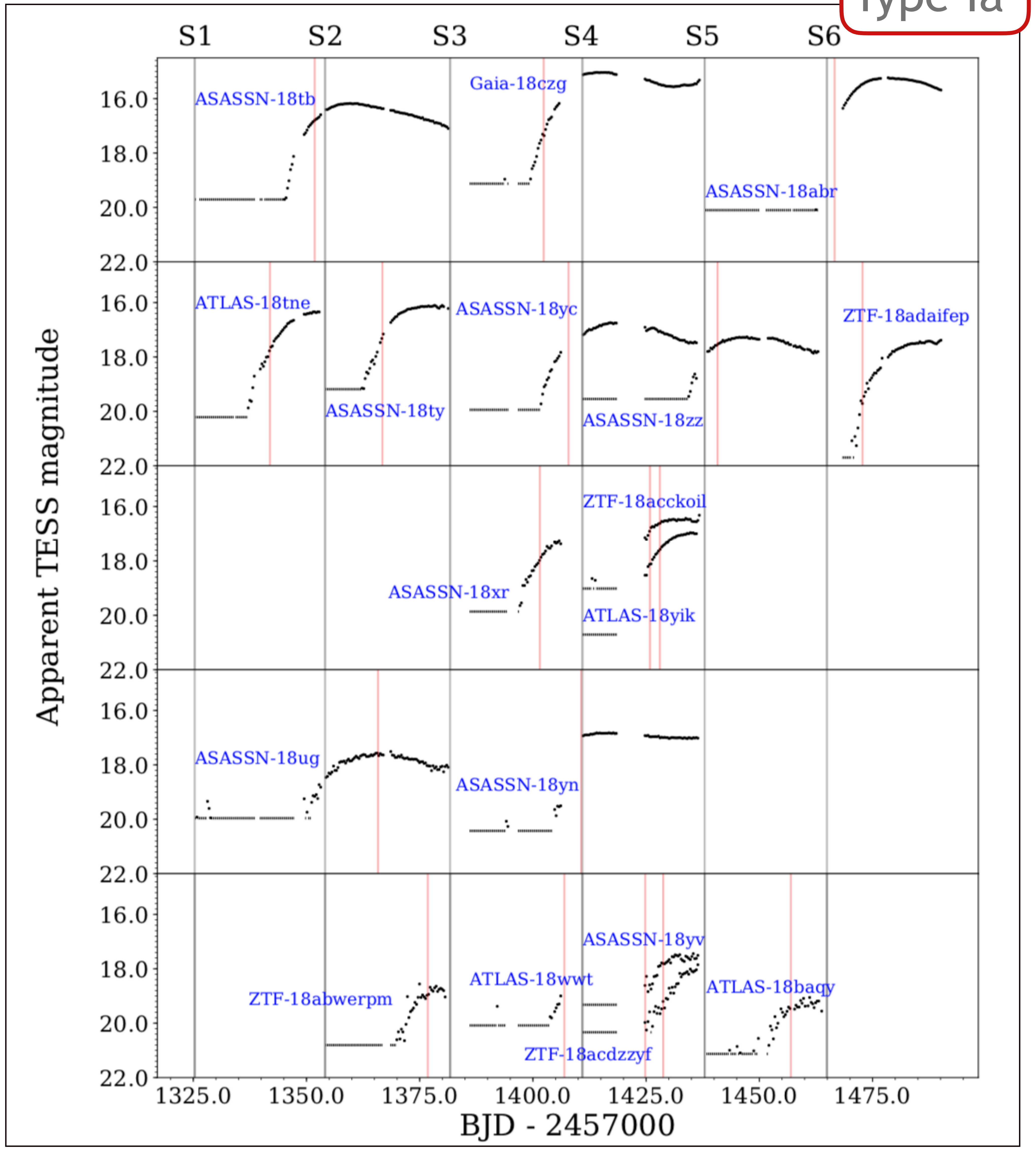
Future prospects

Type II-P



Garnavich et al. 2016

Type Ia



Fausnaugh et al. 2019

- Radius of the explosion object (Nugent 2011, Garnavich et al. 2016)
- Constraints on the companion star (Kasen 2010, Fausnaugh et al. 2019)
- Explosion time (critical for color evolution, photospheric velocity evolution and light curve slope)

Conclusions

1 We present results of a pilot study of high cadence photometry, which is a powerful tool for probing supernova physics

2 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.

3 Residual undulations in two SNe (2018gv & 2018hgc, Fig 1 & 2) remain after trend filtering and seem significant when compared to red/white noise estimations.

4 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

Thank you!