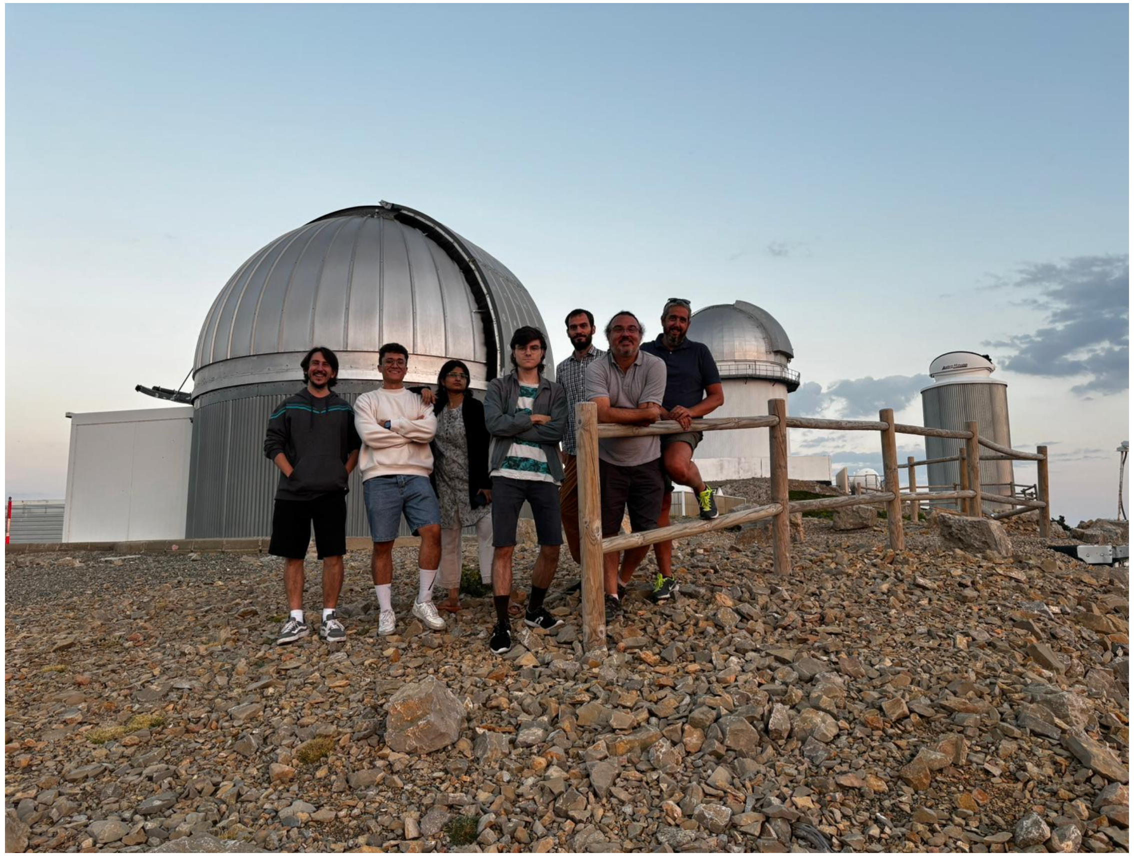
CEFCA

Centro de Estudios de Física del Cosmos de Aragón

My internship in CEFCA



Trip to OAJ :)

Friday lunch 😋

On another day of lunch 🙃

Classification of SNs with J-VAR

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Centro de Estudios de Física del Cosmos de Aragón (CEFCA)

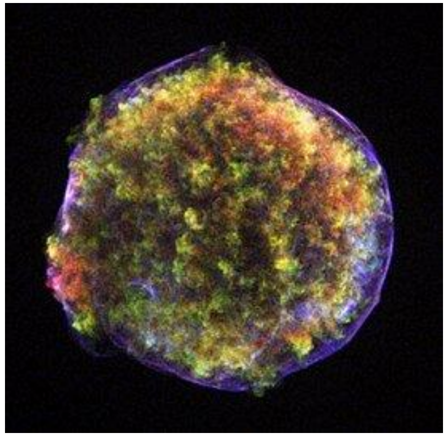
Summer Internship 2024

Introduction – What is a SN?

Supernova comes from *stellae novae*, which means new stars.

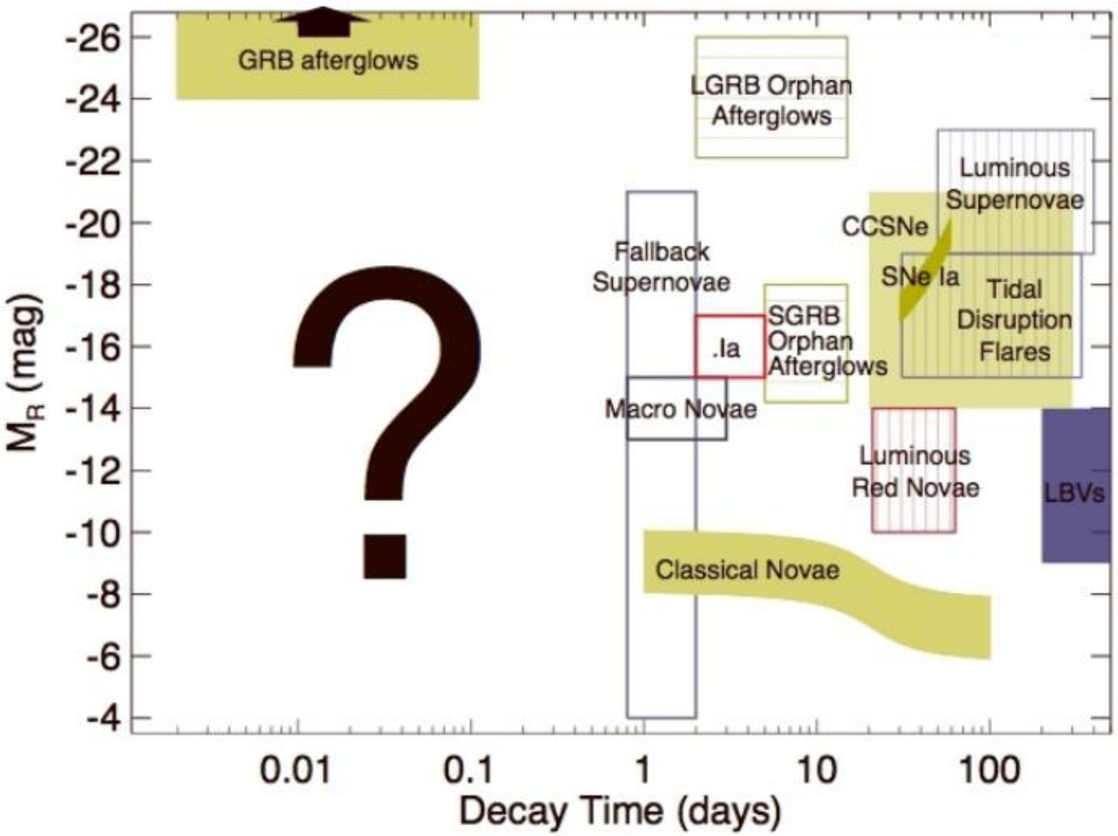
A supernova (SN) is a **powerful and luminous star explosion**. Occurs during the last evolutionary stages of a massive star (core-collapse), or when a white dwarf is triggered into runaway nuclear fusion (thermonuclear).

SNs are a type of transients: objects whose luminosity changes in small scales of time.



SN 1572

AT 2024 slh



Rau (2008)

Introduction – History

The **first discovered SN was the HB9**, recorded in a rock by the prehistoric people in the Indian subcontinent *(other authors say that the first was SN 185).*

Photograph and sketch of stone carving from Burzahom

Until a few years ago, the analysis of a SN was simply **qualitative**:

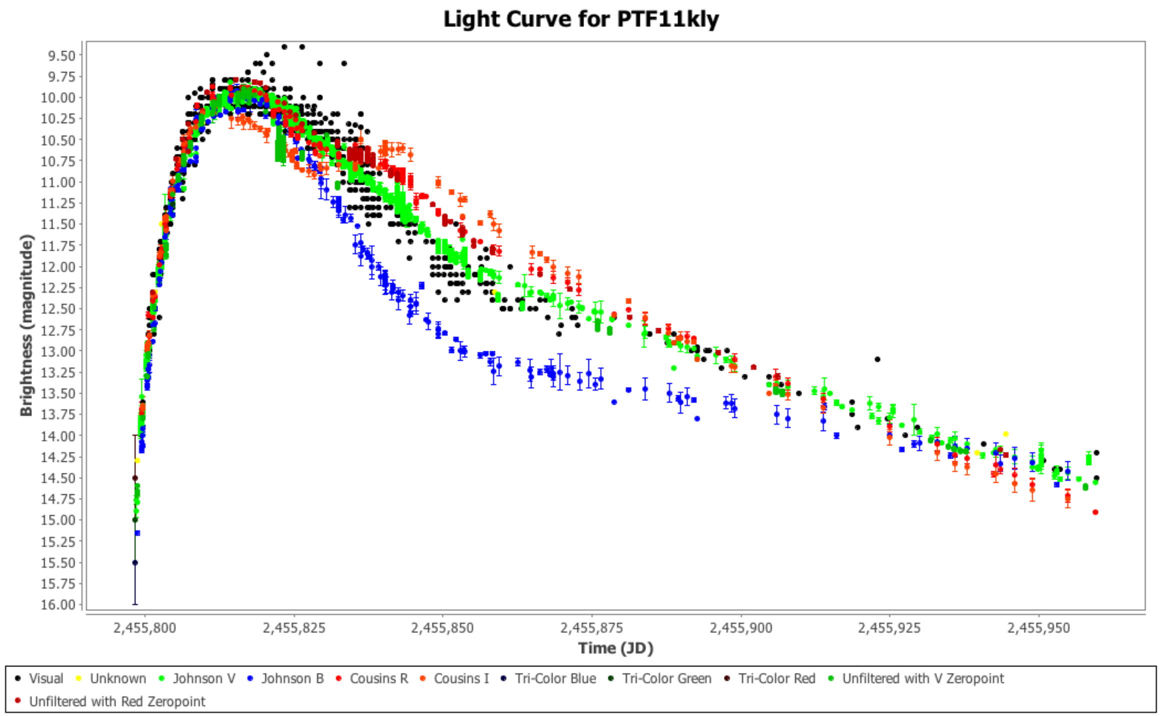
"The size was half a bamboo mat (referring to SN 185). It displayed various colours, both pleasing and otherwise. It gradually lessened. In the 6th month of the succeeding year, it disappeared." (The Book of Later Han)

Nowadays, we can make a **quantitative** study of these transients.

Introduction – Usefulness

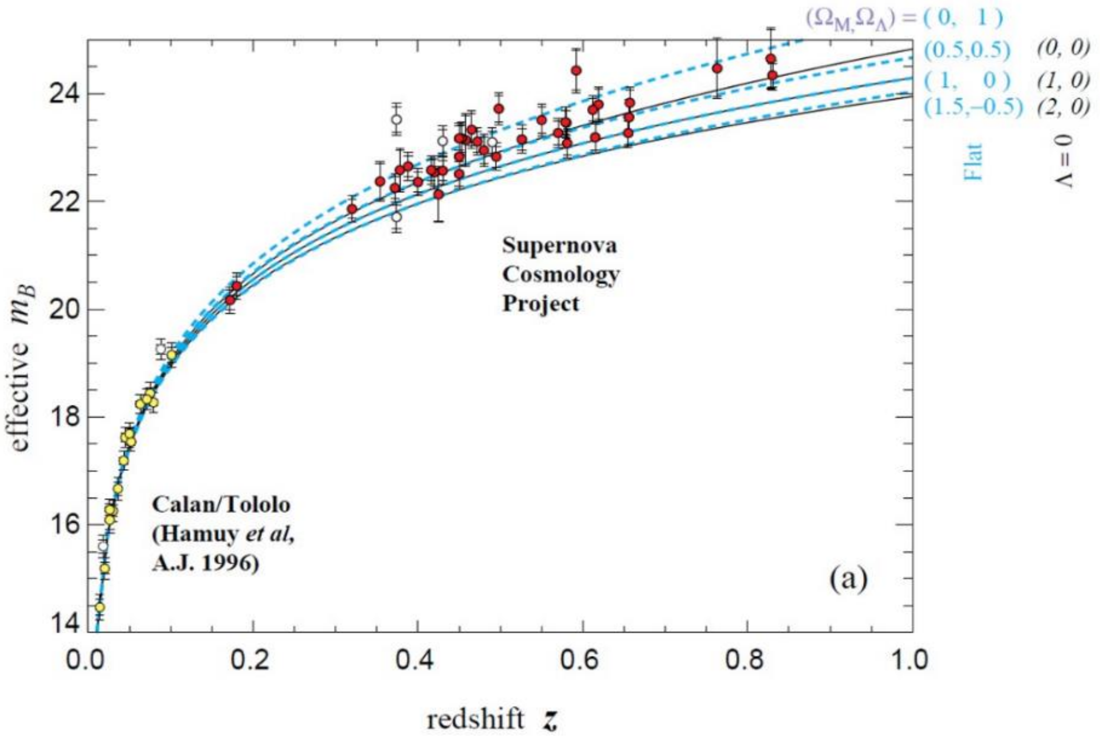
The principal characteristic of an SN is its **light curve** (magnitude vs time). From it, we can **derive some properties**:

Progenitor type (depending on the light curve's shape)



Gouravajhala, S. et al, (2012)

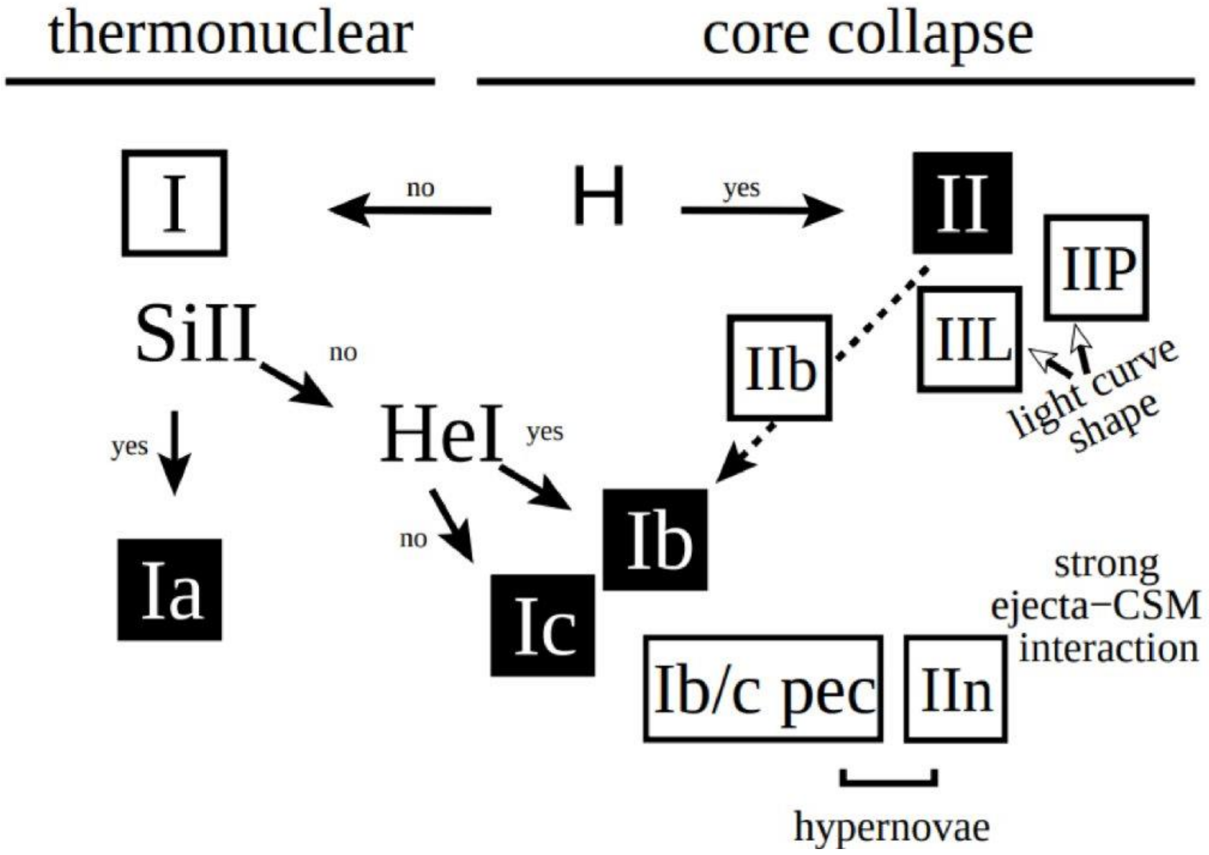
Cosmological distance (depending on the peak's magnitude)



Hamuy, et al, (1996)

Introduction – Types of SNs and objectives

Life is not so simple, and **thermonuclear** and **core-collapse** SNs can be classified into more types (depending on light curves' shapes, lines emissions, etc.



Turatto, Benetti & Pastorello (2007)

The principal **objective** is to answer ...

¿Can we study SNs with J-VAR filters?

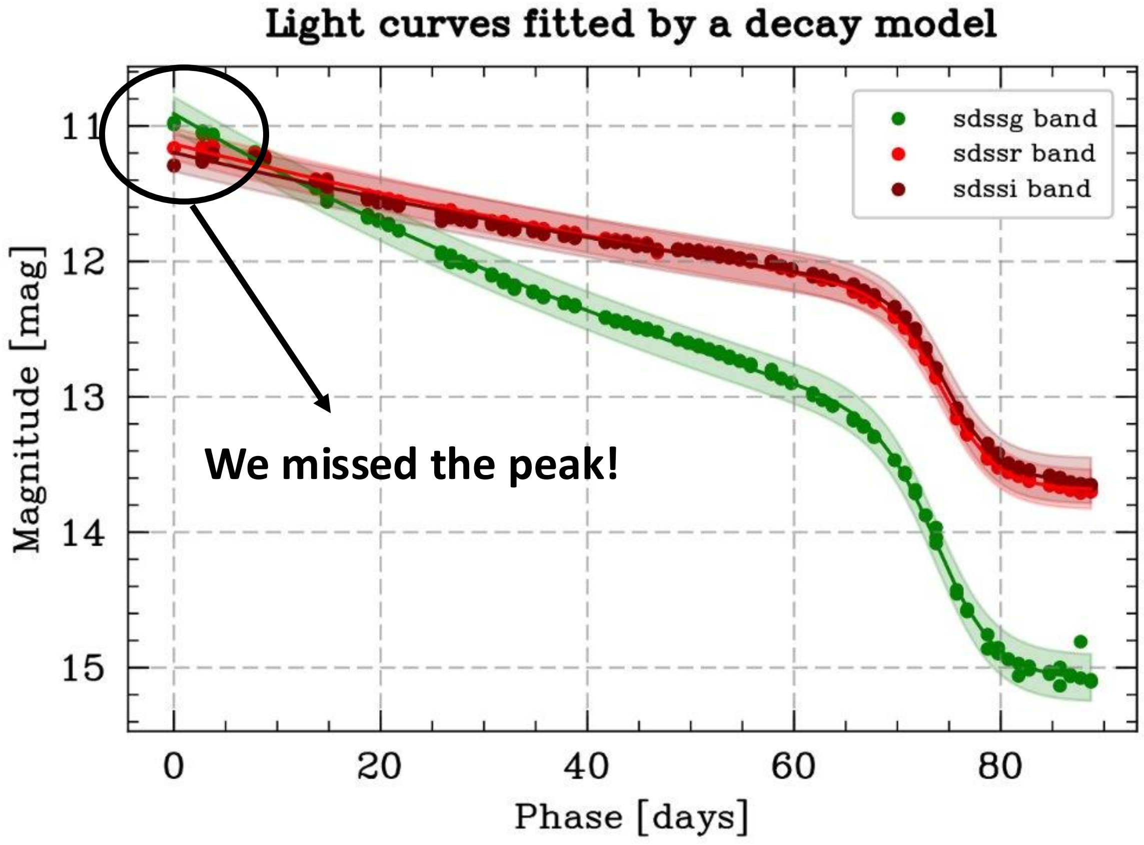
¿Can we create a classification algorithm for J-VAR filters?

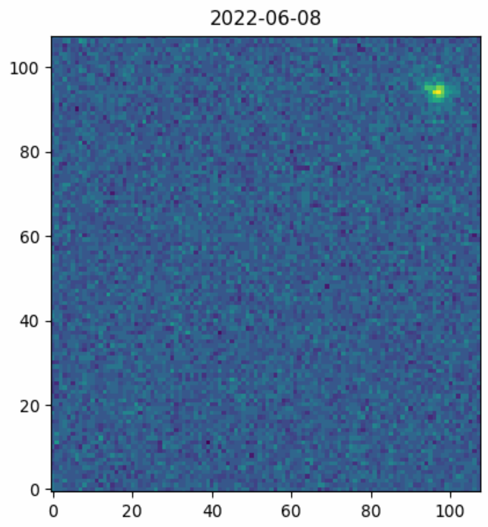
¿Is J-VAR prepared to classify SNs?

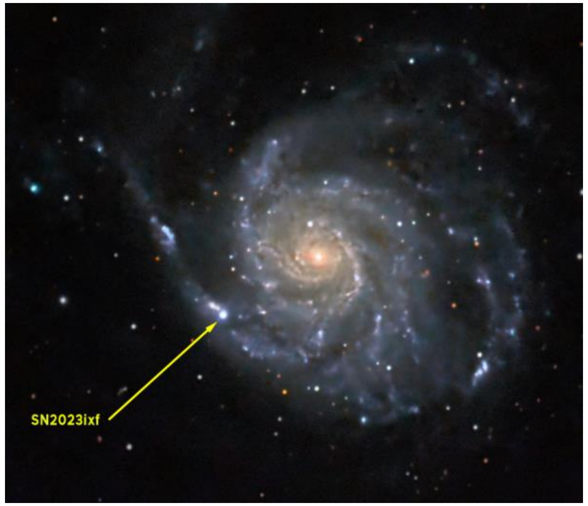
SN2023ixf

The study begins with **SN2023ixf, an SN IIP found in M101.**

The **light curve** was measured with Tx40 (40cm telescope from OAJ) in 3 filters: **gsdss, rsdss, and isdss.**







SN 2023 ixf in gsdss band / multiple bands

The **Bazin's function** was used to make the fit.

$$f(t) = A \cdot \frac{e^{-(t-t_0)/\tau_{fall}}}{1 + e^{-(t-{}_0)/\tau_{rise}}} + B$$

- A, B: normlization and constant parameters
- τ: times of fall or rise
- t_0: related with the peak's time

SN2023ixf – Parameters

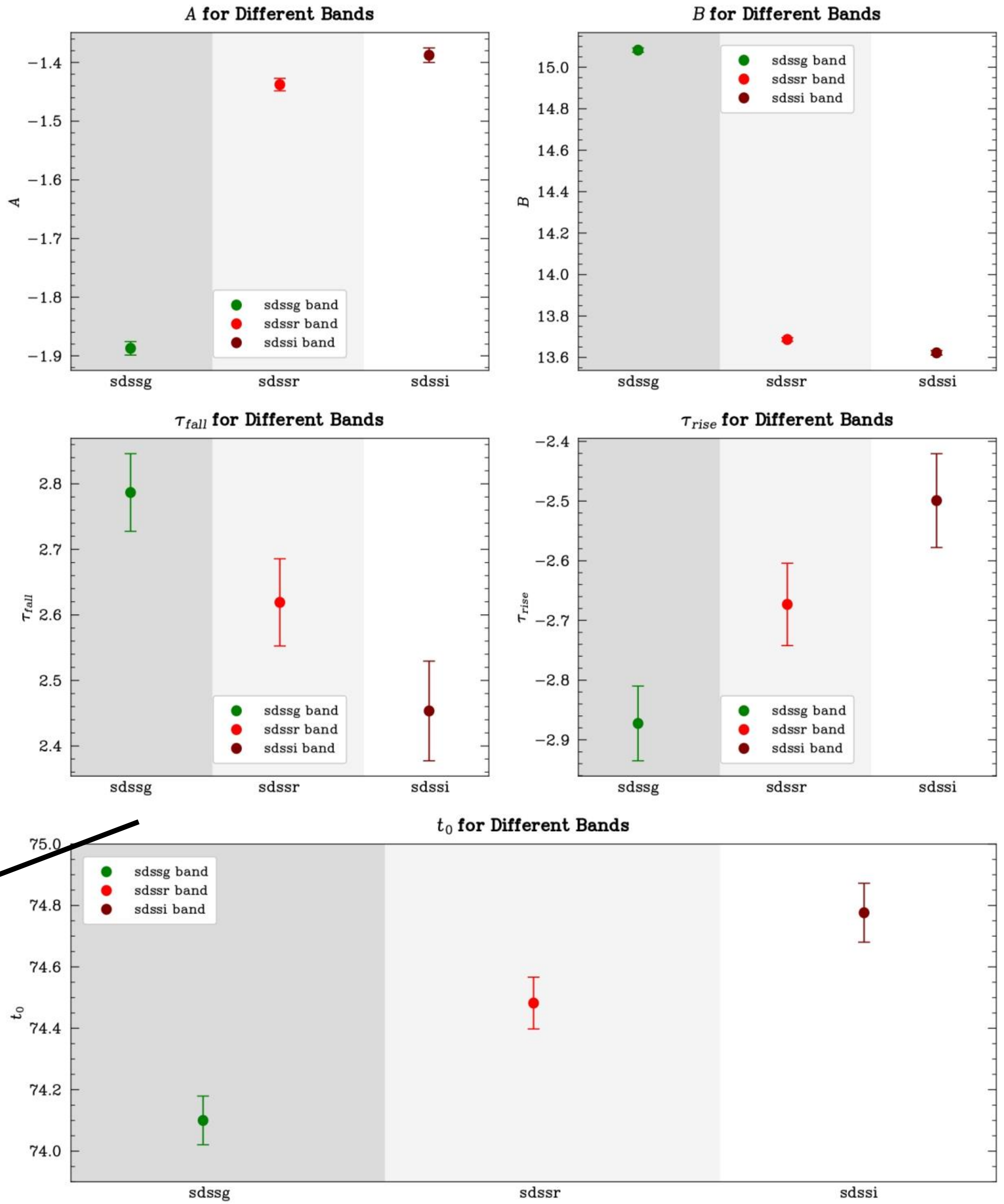
Even then, the **fitted parameters** for SN 2023ixf, using Tx40 data, are the following:

	gsdss	rsdss	isdss
A[mag]	-1.887 ± 0.012	-1.438 ± 0.011	-1.388 ± 0.012
B[mag]	15.083 ± 0.011	13.6866 ± 0.0093	13.622 ± 0.011
τ_{fall}[days]	2.787 ± 0.060	2.619 ± 0.067	2.453 ± 0.076
τ_{rise}[days]	-2.873 ± 0.063	-2.673 ± 0.069	-2.500 ± 0.079
t_0[days]	74.100 ± 0.080	74.482 ± 0.084	74.776 ± 0.096

	gsdss	rsdss	isdss
Δm_{15}[mag]	0.62 ± 0.18	0.28 ± 0.17	0.26 ± 0.20

Some **correlations** between the different parameters and bands are also found.

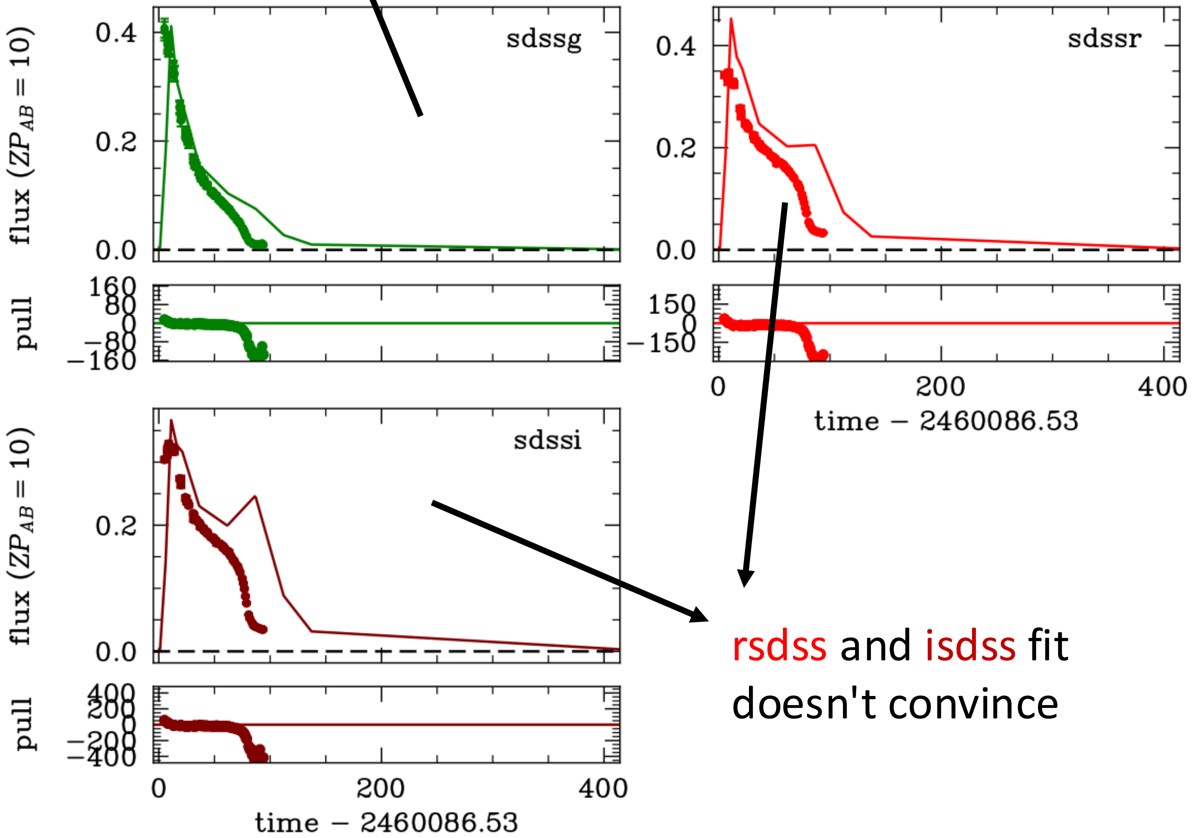
Due to the colour variations



SN2023ixf – sncomo

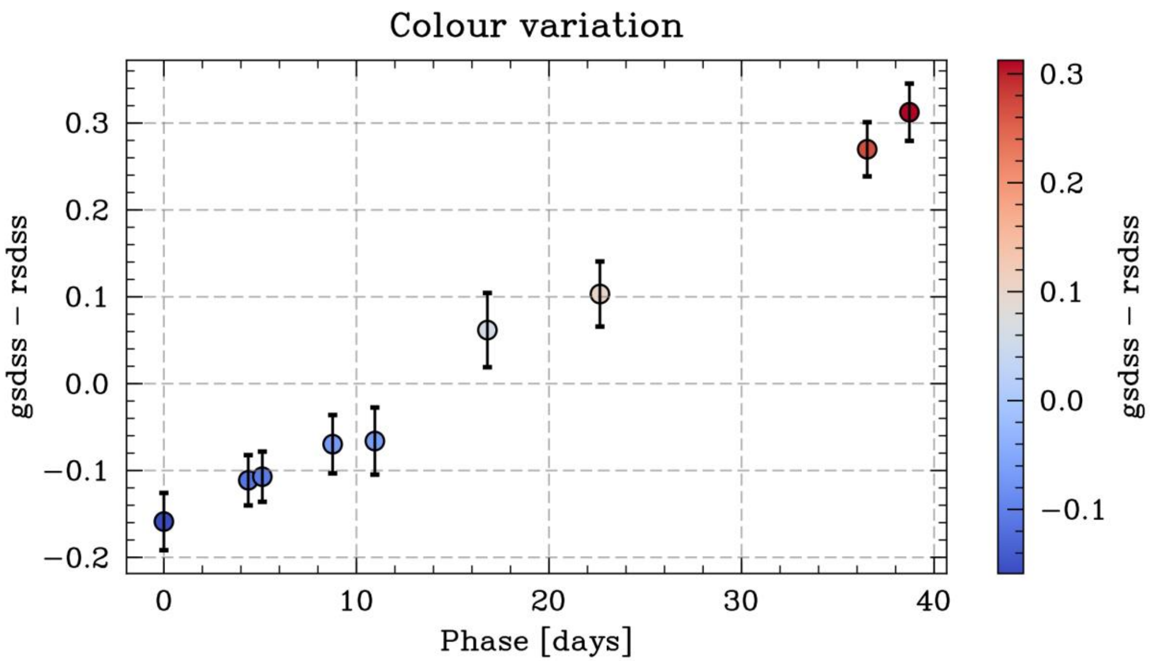
Another way to fit SNs: **sncosmo** (python package)

gsdss fit doesn't seem bad



rsdss and isdss fit doesn't convince

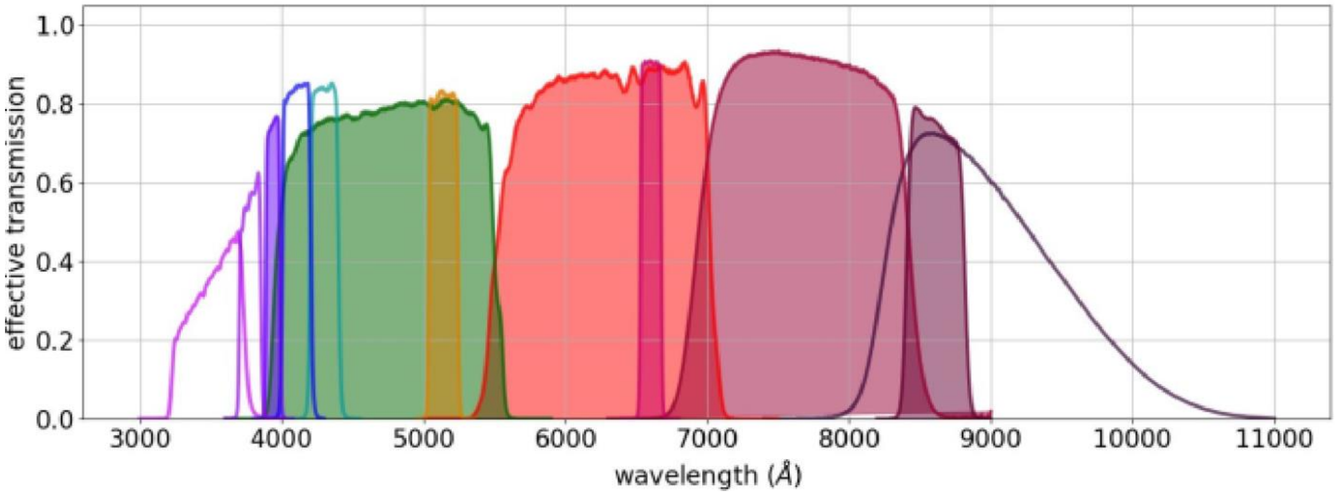
We can also plot the **colour variation**:



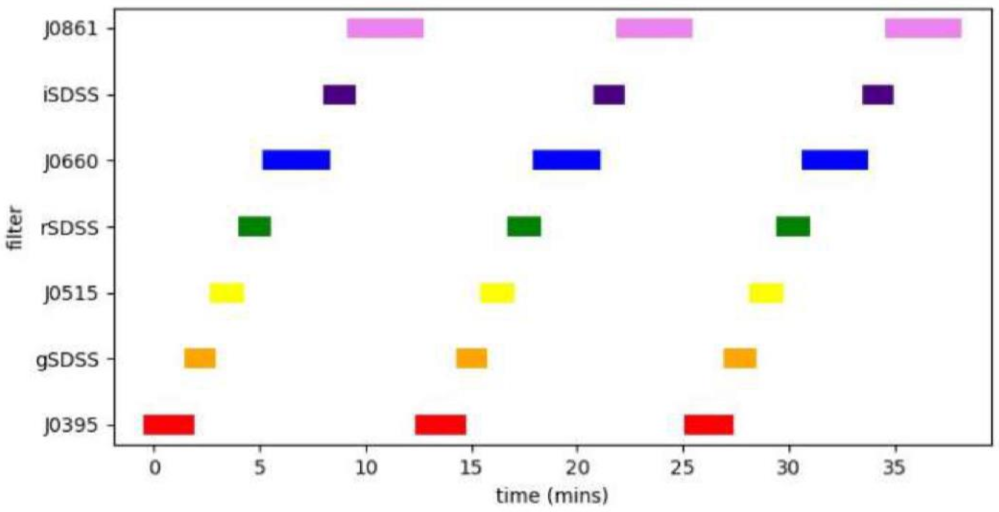
What is J-VAR?

J-VAR = Javalambre VARiablity survey

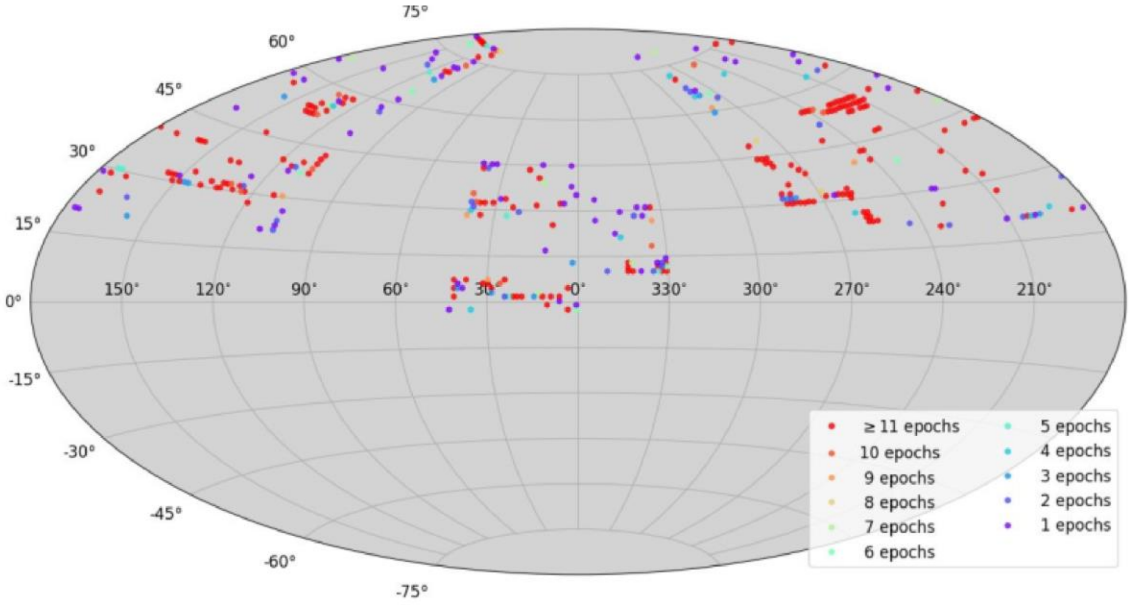
- Wide-field **photometric survey**
- Uses non-photometric nights
- Use J-PLUS as photometric reference
- Has**7 optical filters**
- Objective: **study transients**, classify them, etc



Filters: J0395, gsdss, J0515, rsdss, J0660, isdss, and J0861



Multi-epochs mode

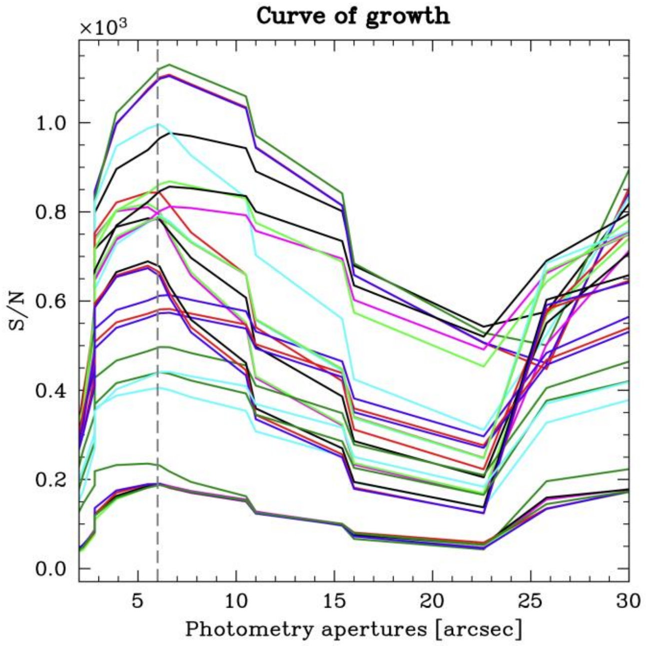


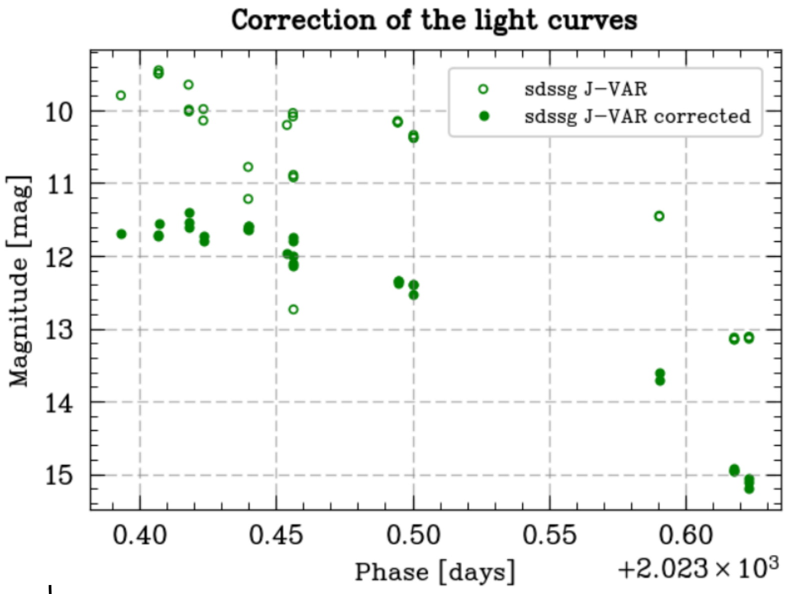
Progress of the survey

SN2023ixf with JAST80

We **repeat the previous process** (obtain light curves with Bazin function a J-VAR) but now **using J-VAR** (collected by the JAST80 telescope of OAJ).

We follow these first **steps**, before plotting light curves:





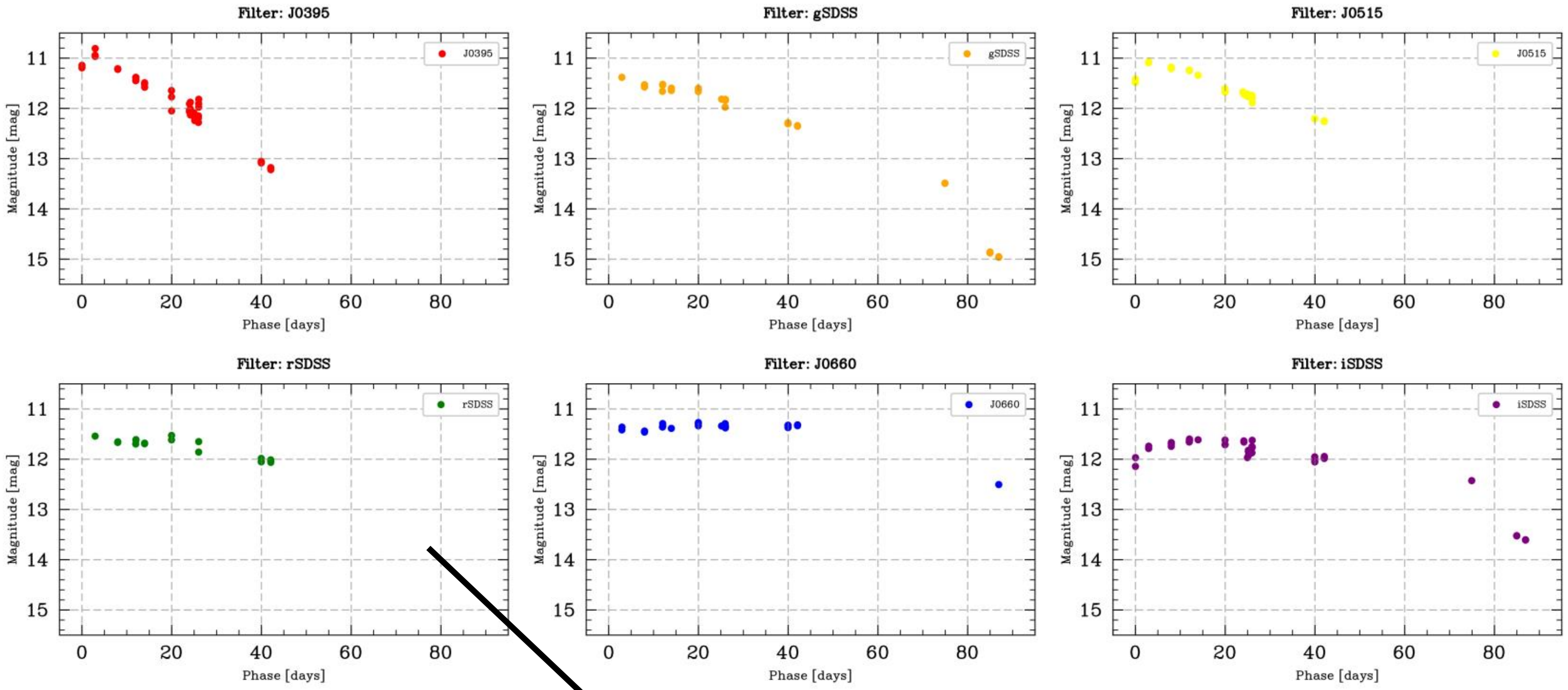
cross-match

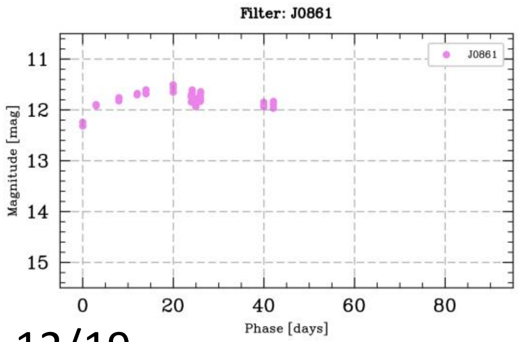
Curve of growth
(S/N vs aperture)

offsets

SN2023ixf with JAST80

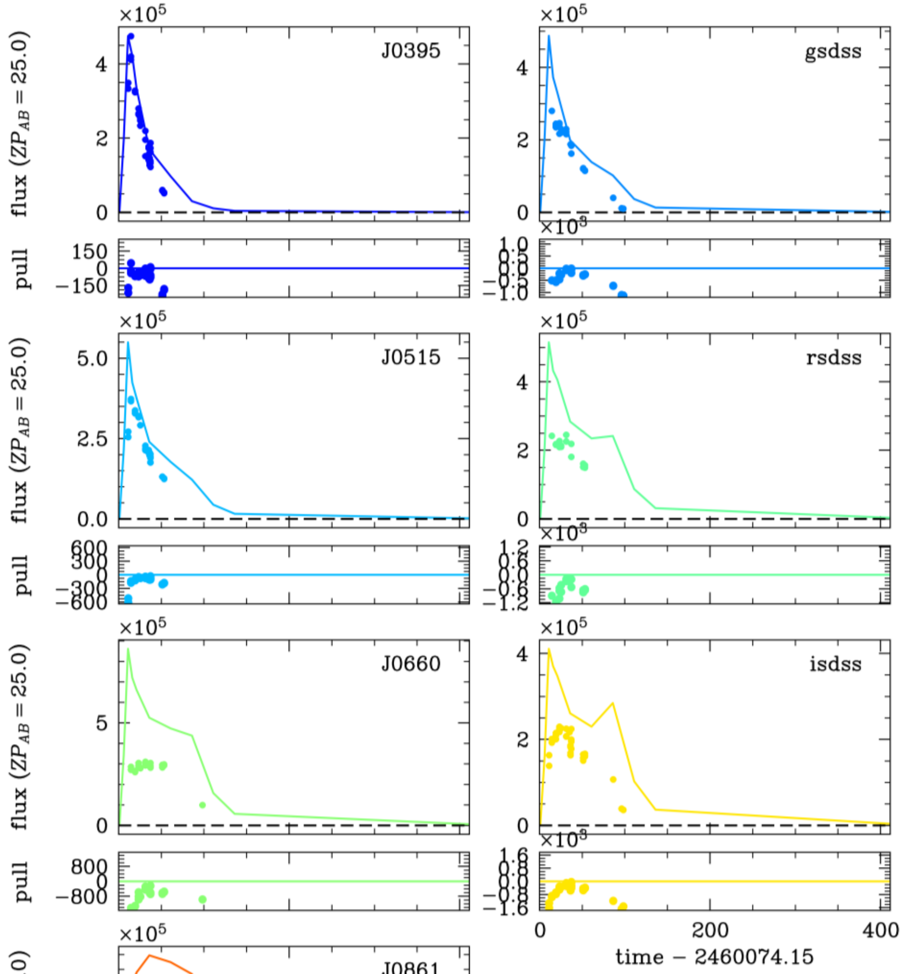
The **light curve** was measured with JAST80 in the 7 J-VAR filters:
J0395, gsdss, J0515, rsdss, J0660, isdss, and J0861.

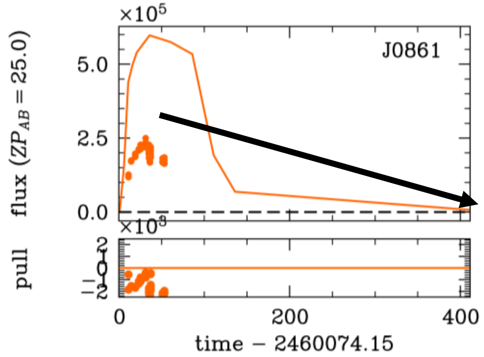




few points! → problems with the convergence of the Bazin's function

The **sncosmo** fits are here:





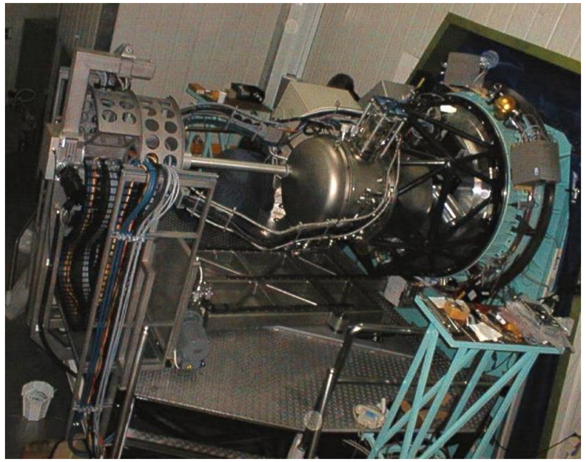
huge discrepancies!
(in redder bands)

PESSTO – What is PESSTO?

PESSTO = Public ESO Spectroscopic Survey for Transient Objects

- **Transient catalogue survey** that uses the ESO New Technology Telescope (**NNT**) and the **EFOSC2** (optical) and **SoFi** (NIR) spectrographs
- Covers 7 years (2012-2019) of observations
- Classification target range: **r < 20 mag**

- Objective: **classify transients**



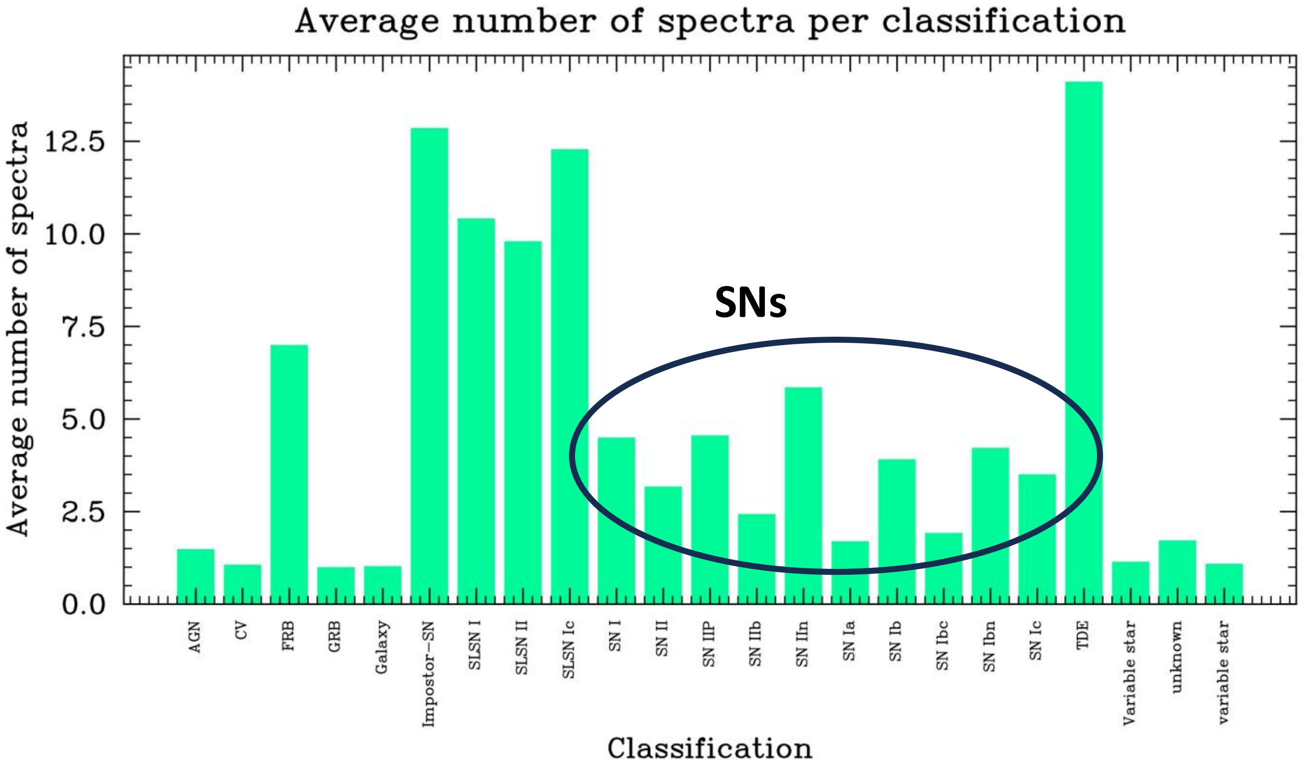
SoFi

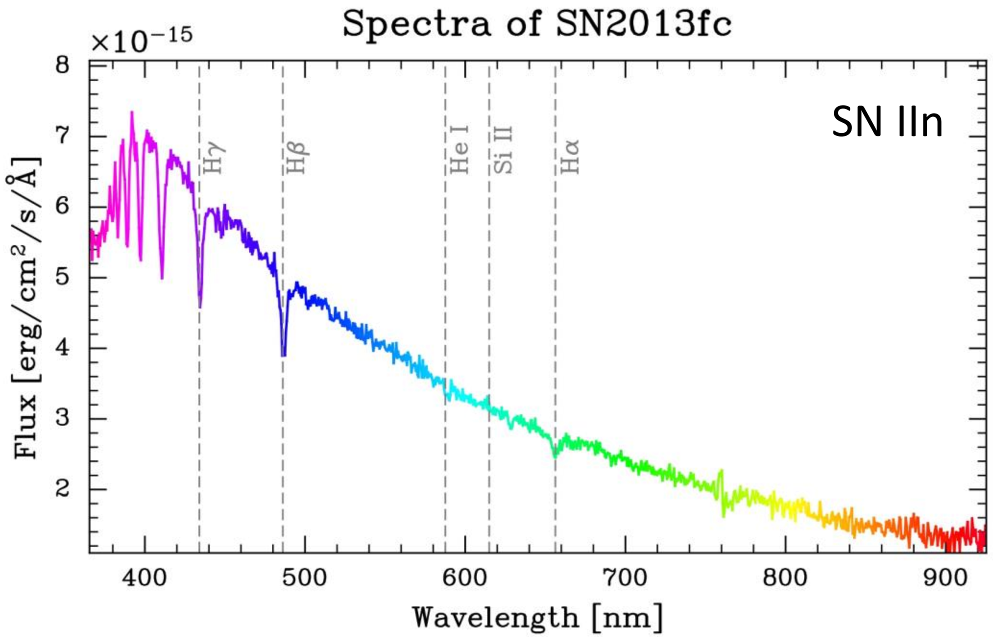
EFOSC2

NTT

PESSTO – First analysis

- PESSTO **collects different types of transients**. Most of them are SNs.
- Each transient has **spectra vs time data**.
- **Most of the objects has only 1 observation** (= 1 spectra) → *1 spectrum is enough to classify (PESSTO's objective)*

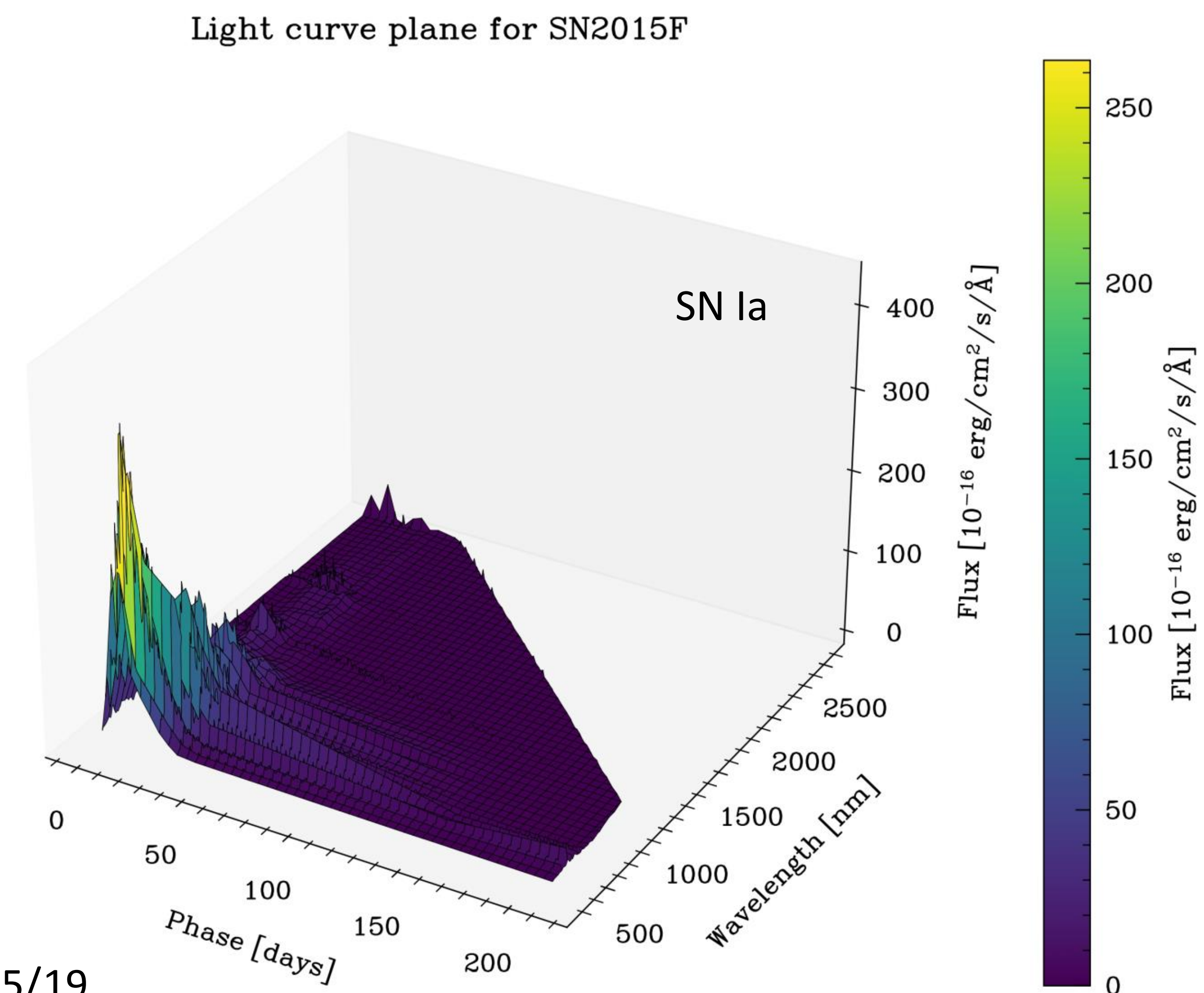


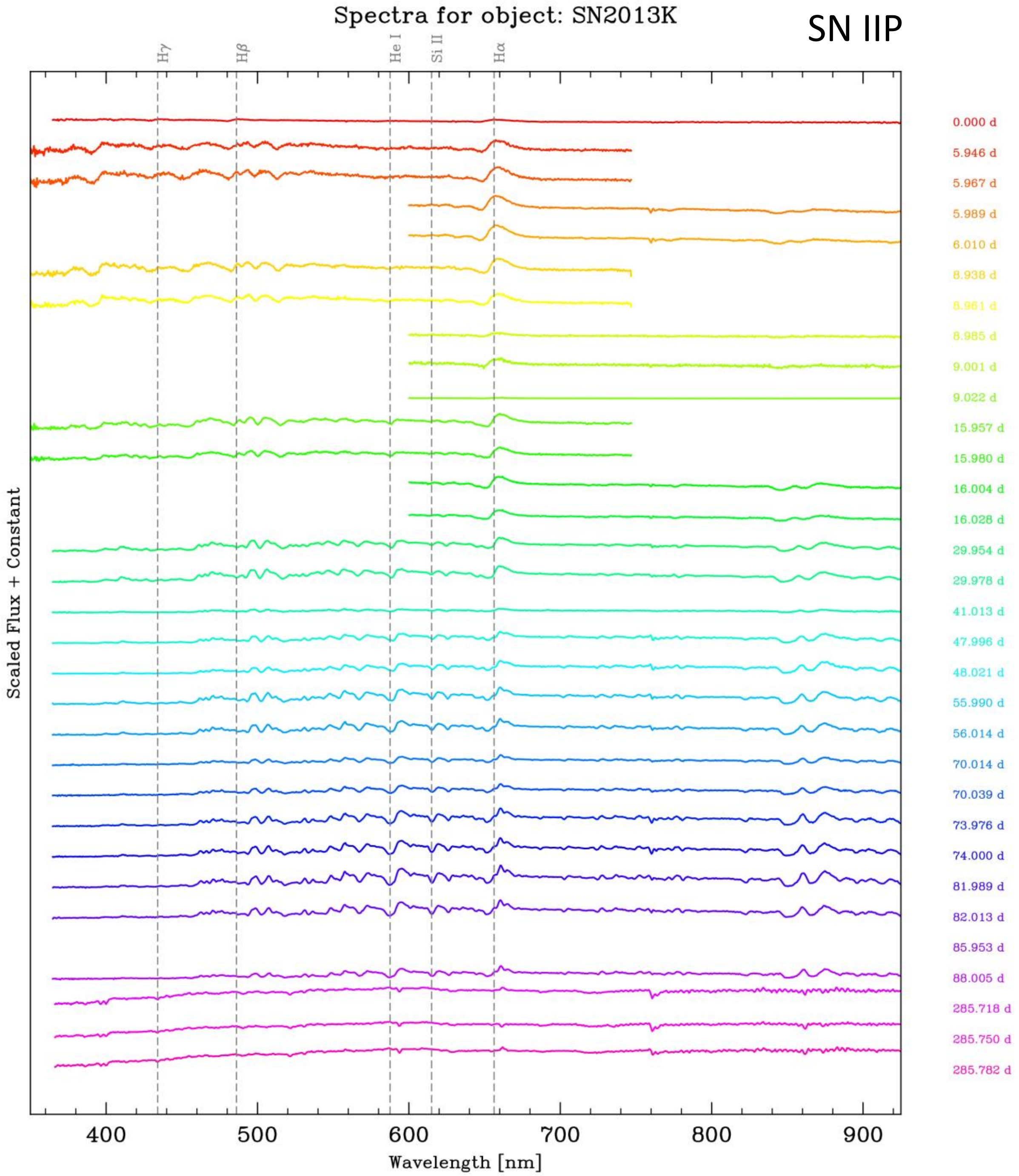


OBJECT	RA	DEC	WAVE	FLUX	ERR	TMID
str27	float64	float64	float32[1024]	float32[1024]	float32[1024]	float64
2MASXJ06192755-6553079	94.8647916667	-65.8855277778	3638.2922 .. nan	1.395055e-16 .. nan	2.8425602e-17 .. nan	58036.36231421185
2MASXJ14044671-2511433	211.194583333	-25.1955555556	3640.1067 .. nan	1.7322726e-16 .. nan	3.4845784e-17 .. nan	58185.3571207153
2MASXJ14044671-2511433	211.194583333	-25.1955555556	3641.5295 .. nan	9.69944e-17 .. nan	9.296269e-18 .. nan	58201.22991676621
ASASSN-14fo	308.5268	-1.96766388889	3653.0413 .. nan	2.3290977e-15 .. nan	4.184733e-17 .. nan	56886.0857349
ASASSN-14fw	357.278	-7.04905555556	3632.1172 .. nan	0.0 .. nan	1.1300342e-16 .. nan	56894.3634558
ASASSN-14gs	249.046541667	-26.2007722222	3654.3696 .. nan	5.682665e-15 .. nan	1.5203112e-16 .. nan	56915.983769
...	...	...	...	...	...	...

PESSTO – Some spectra

The **evolution of the spectra** can be plotted in different ways

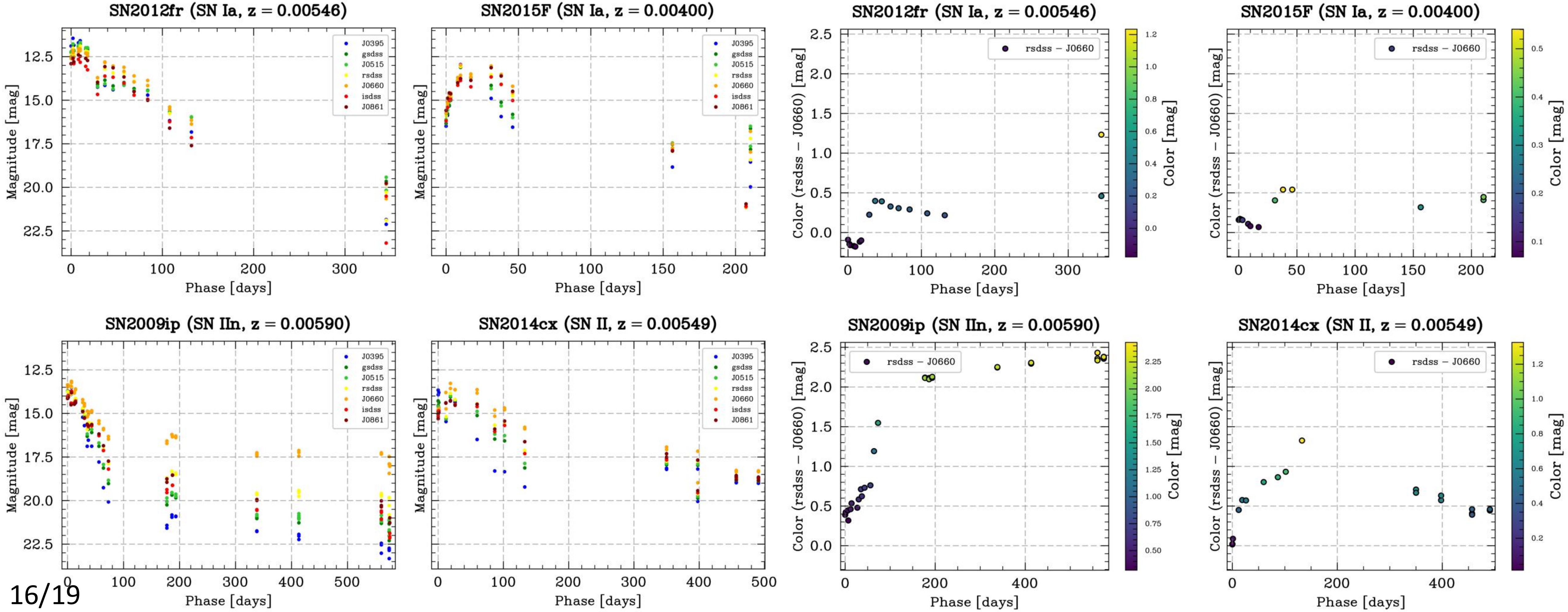




PESSTO – Light curves

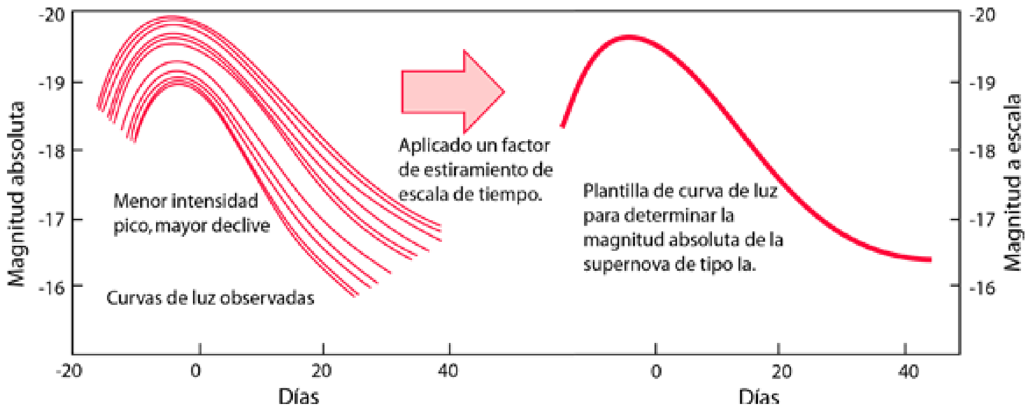
From the evolution of the spectra, we can **derive the light and colour curves → synthetic photometry** (using **sncosmo** package)

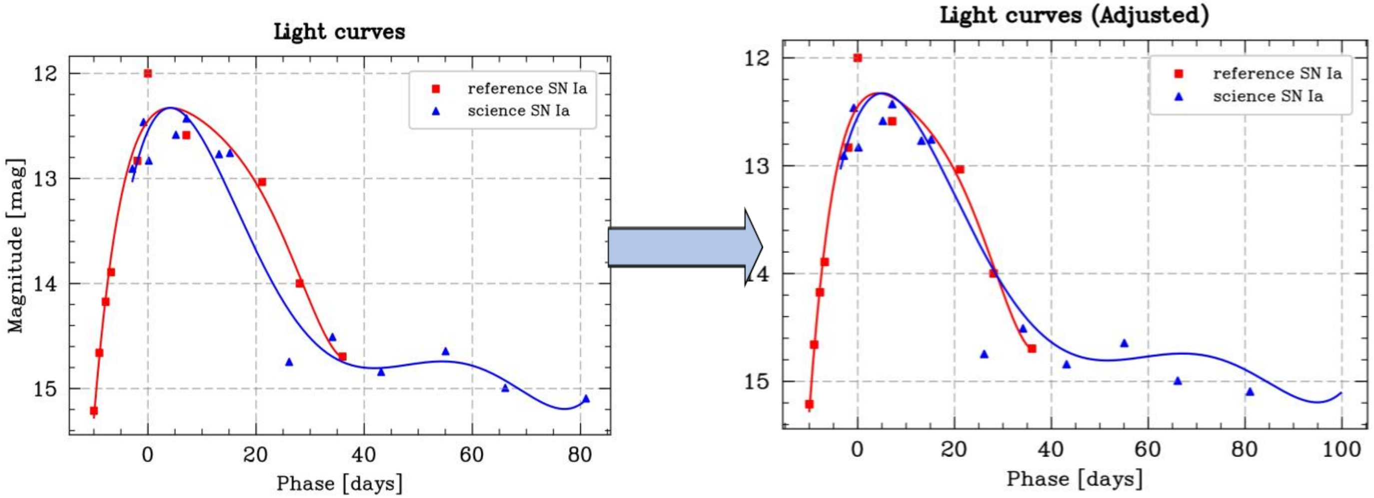
$$m = -2.5\,\log_{10}\frac{\int_{\lambda_i}^{\lambda_f} f(\lambda)\ \frac{\lambda}{h\,c}\ T(\lambda)\ \mathrm{d}\lambda}{\int_{\lambda_i}^{\lambda_f} f_r(\lambda)\ \frac{\lambda}{h\,c}\ T(\lambda)\ \mathrm{d}\lambda}$$



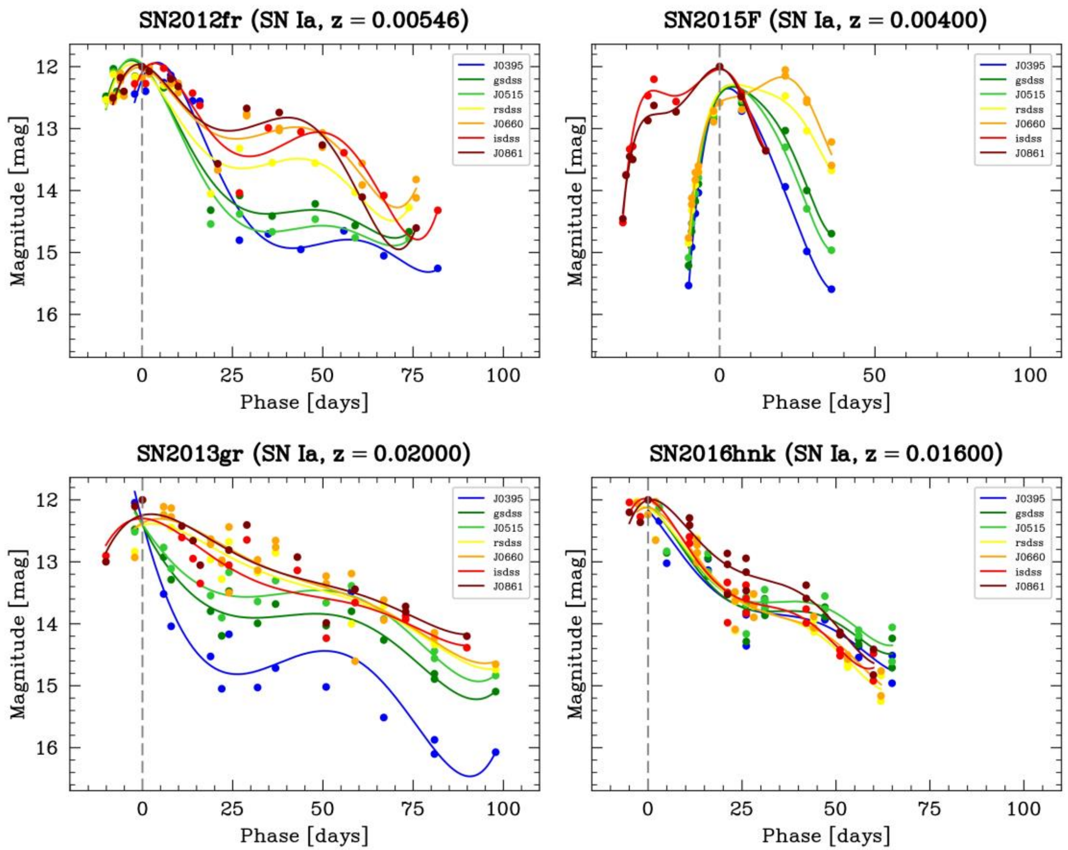
PESSTO – Stretch factor

Stretch factor (**re-scales the time-axis)** + normalize magnitudes
→ **light curve template**



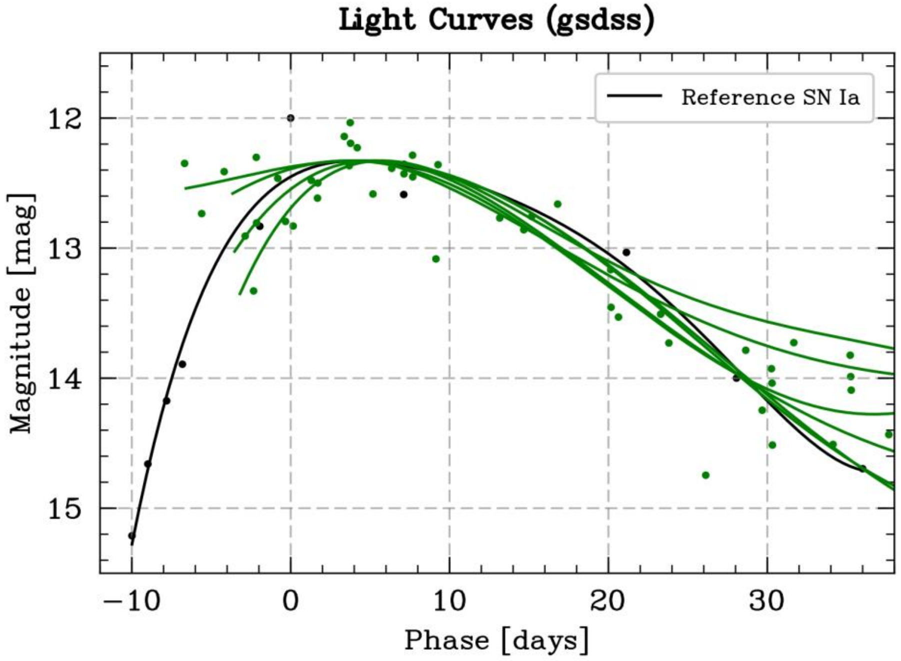


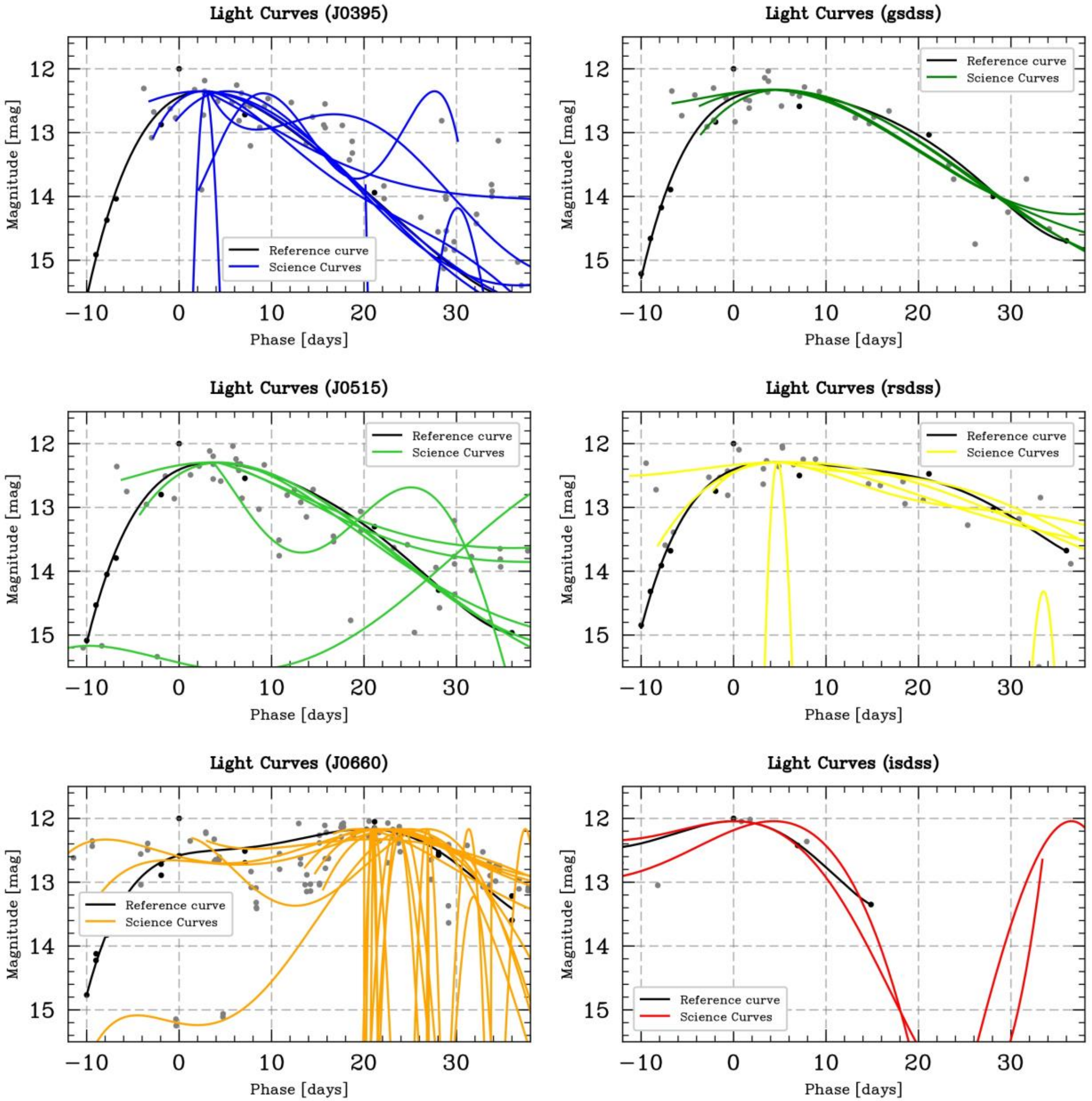
But first, light curves must be fitted: **splines**



PESSTO – Template for SN Ia light curves

Finally, by fitting the different light curves **for the 7 filters** for all the SN Ia, it is time to **apply the stretch method.**





gsdss was the band taken as a reference. Once this was done, we **extrapolated the method to the rest of the filters**. But some **problems appear**.

Same problem appears with other transients.

Conclusions

OAJ

SN 2023ixf

- The light curves obtained with Tx40 are fine, but **sncosmo seems to have problems in redder bands**.
- The light curves obtained with JAST80 have **fewer points** → Bazin function doesn't work and sncosmo also has problems in redder bands.

Possible solutions: have **more observation** (after and before the peak; difficult) with J-VAR for the next SNs and find **alternative fit models to sncosmo**.

PESSTO

- Despite all the SNs that PESSTO collects, most of them **do not have enough points to estimate the light curves + do not collect the peak** → creating a **template for SNs light curves is not viable**

Observing these objects in detail (with enough data points before and after the peak) **using J-VAR, will enable us to create empirical light curve templates that can be used to classify the different transients detected in OAJ.**