Rainbow

A colorful approach on multi-passband light curve estimation

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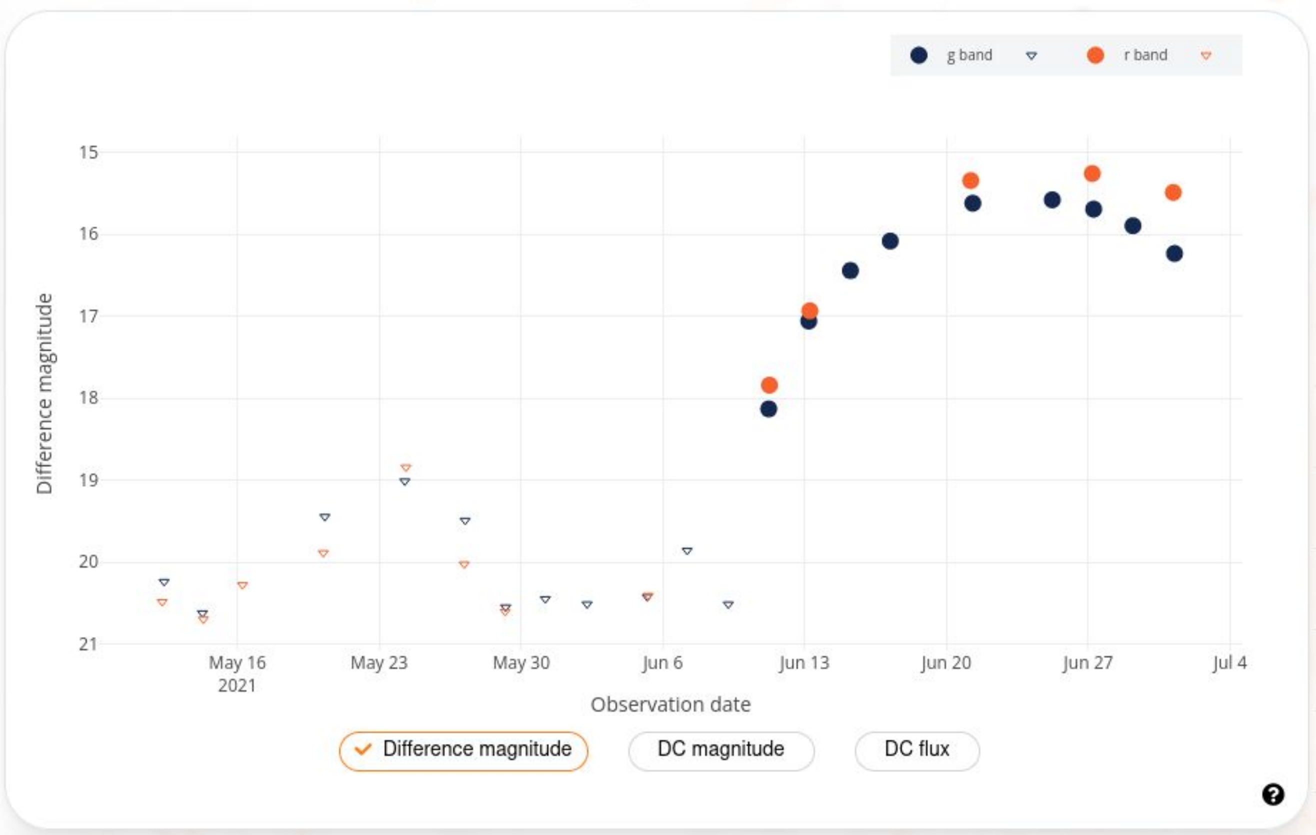
Russeil *et al.*, 2023, submitted to Astronomy & Astrophysics, arXiv:astro-ph: https://arxiv.org/abs/2310.02916

Light curve characterisation

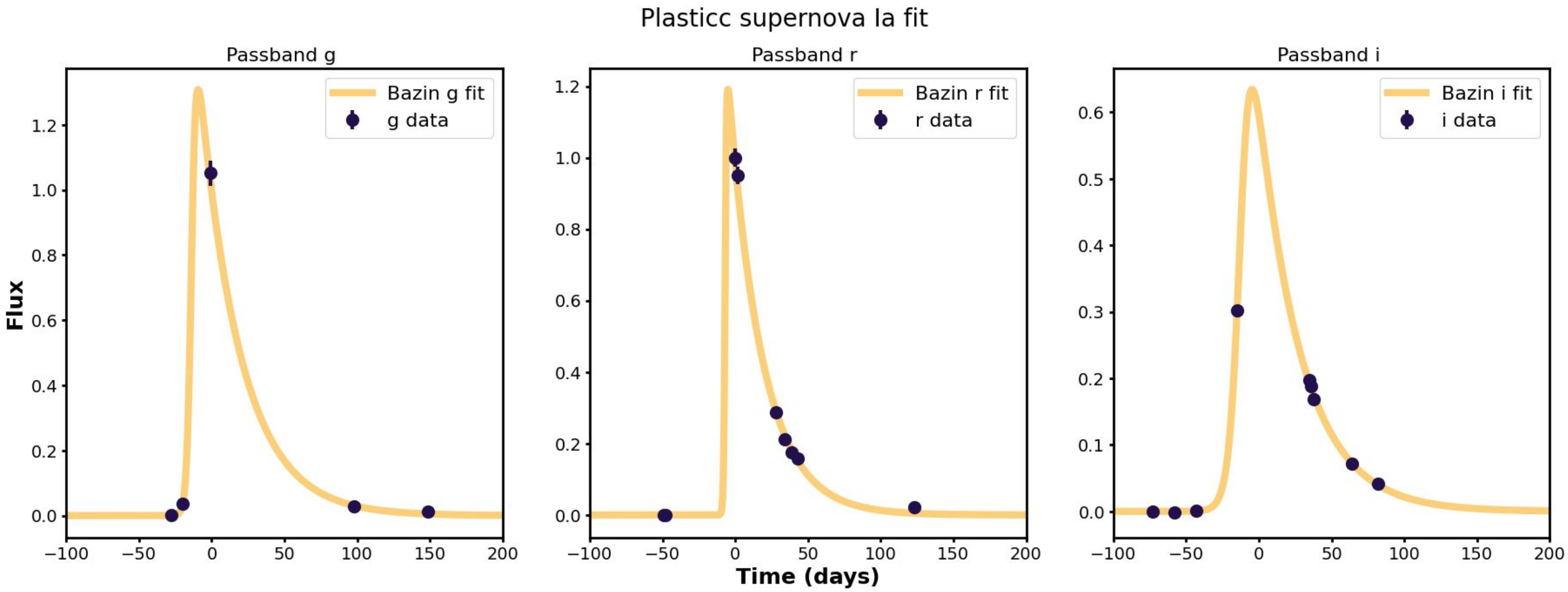


Why produce a fit ?

- Understanding of the object
- Interpolation of missing points
- Prediction of the evolution
- Machine learning analysis

Transient feature extraction :

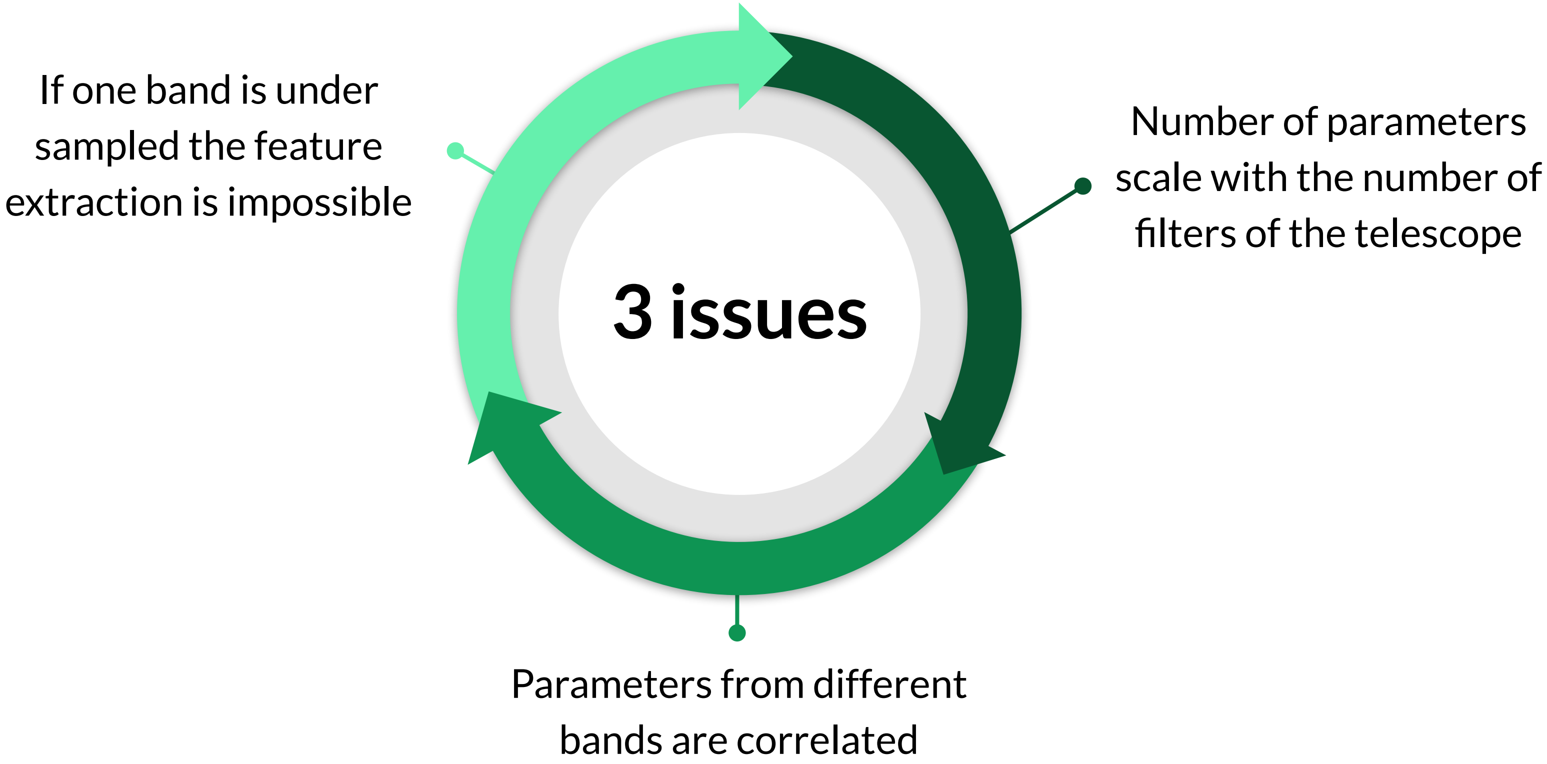
$$F_\nu(t) = A \times \frac{e^{\frac{-(t-t_0)}{t_{fall}}}}{1 + e^{\frac{t-t_0}{t_{rise}}}}$$



A	t0	tr	tf

A	t0	tr	tf

A	t0	tr	tf


3 issues
If one band is under sampled the feature extraction is impossible
Number of parameters scale with the number of filters of the telescope
Parameters from different bands are correlated

I

What is Rainbow

$$F_\nu(t,\nu) = \frac{\pi}{\sigma_{SB}} \times \frac{B_\nu(T,\nu)}{T(t)^4} \times F_{bol}(t)$$

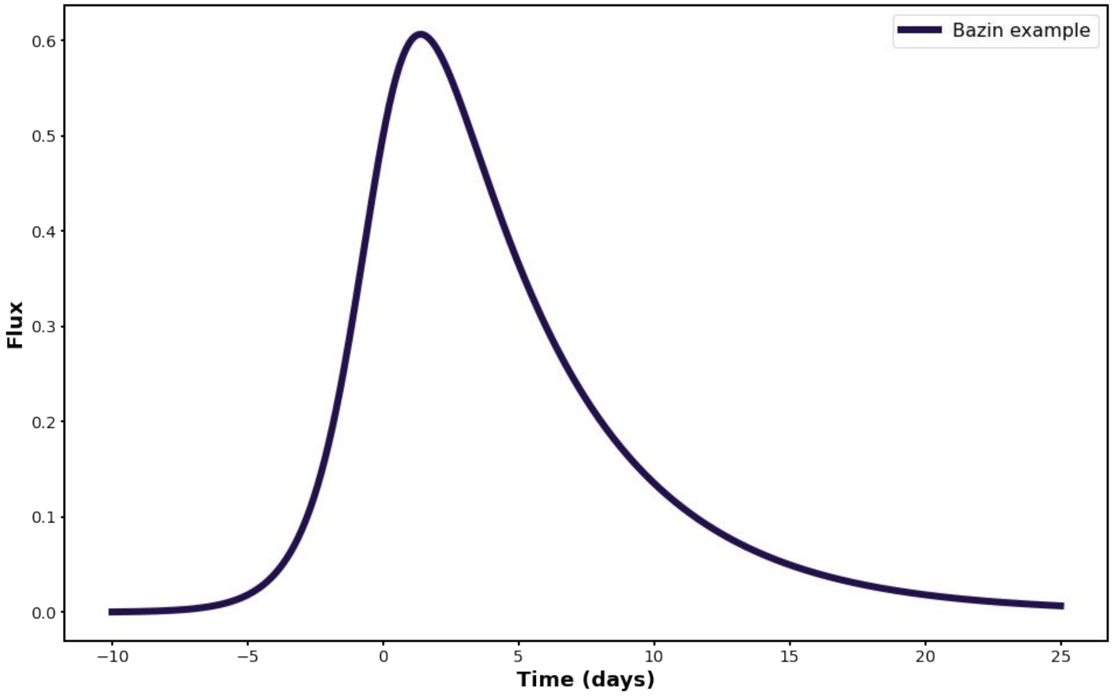
Theoretical solution (assuming that the object is a black body)

$$F_\nu(t,\nu) = \frac{\pi}{\sigma_{SB}} \times \frac{B_\nu(T,\nu)}{T(t)^4} \times F_{bol}(t)$$

We must decide what to use for **T(t)** and **Fbol(t)** ?

Can be adapted to each science case

$$F_\nu(t,\nu) = \frac{\pi}{\sigma_{SB}} \times \frac{B_\nu(T,\nu)}{T(t)^4} \times \boxed{F_{bol}(t)}$$



$$F_{bol}(t) = A \times \frac{e^{\frac{-(t-t_0)}{t_{fall}}}}{1+e^{\frac{t-t_0}{t_{rise}}}}$$

Bazin function : **4** parameters

(here we assume that the baseline is 0)

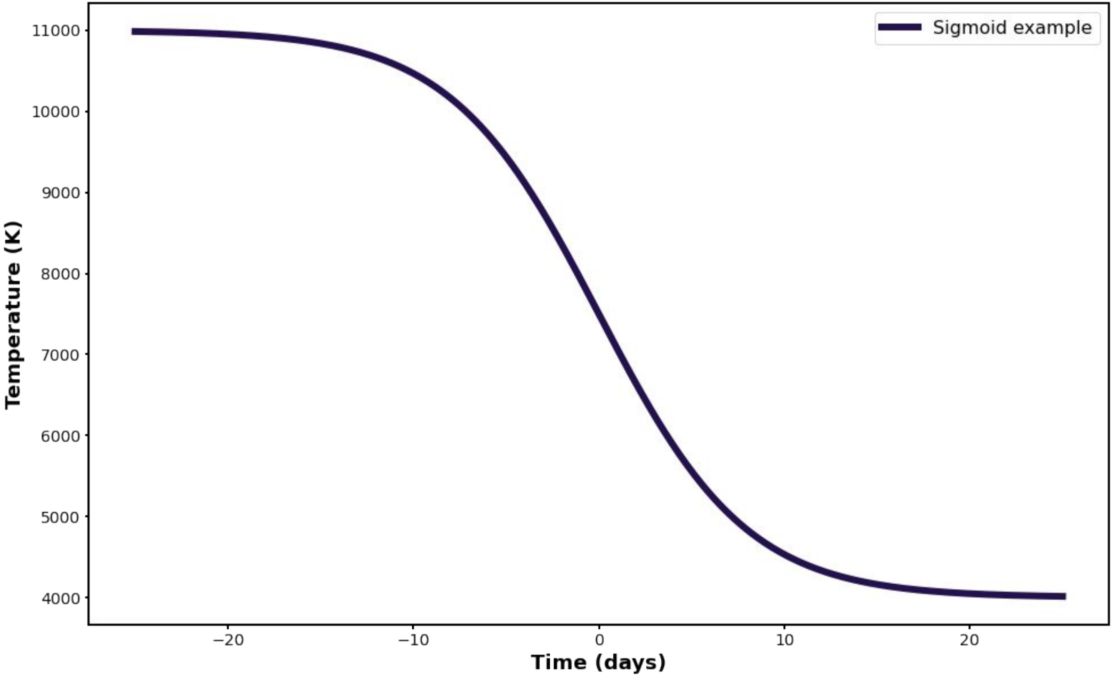
A = 1

t0 = 0

tfall = 5

trise = -1

$$F_\nu(t,\nu) = \frac{\pi}{\sigma_{SB}} \times \frac{B_\nu(T,\nu)}{T(t)^4} \times F_{bol}(t)$$



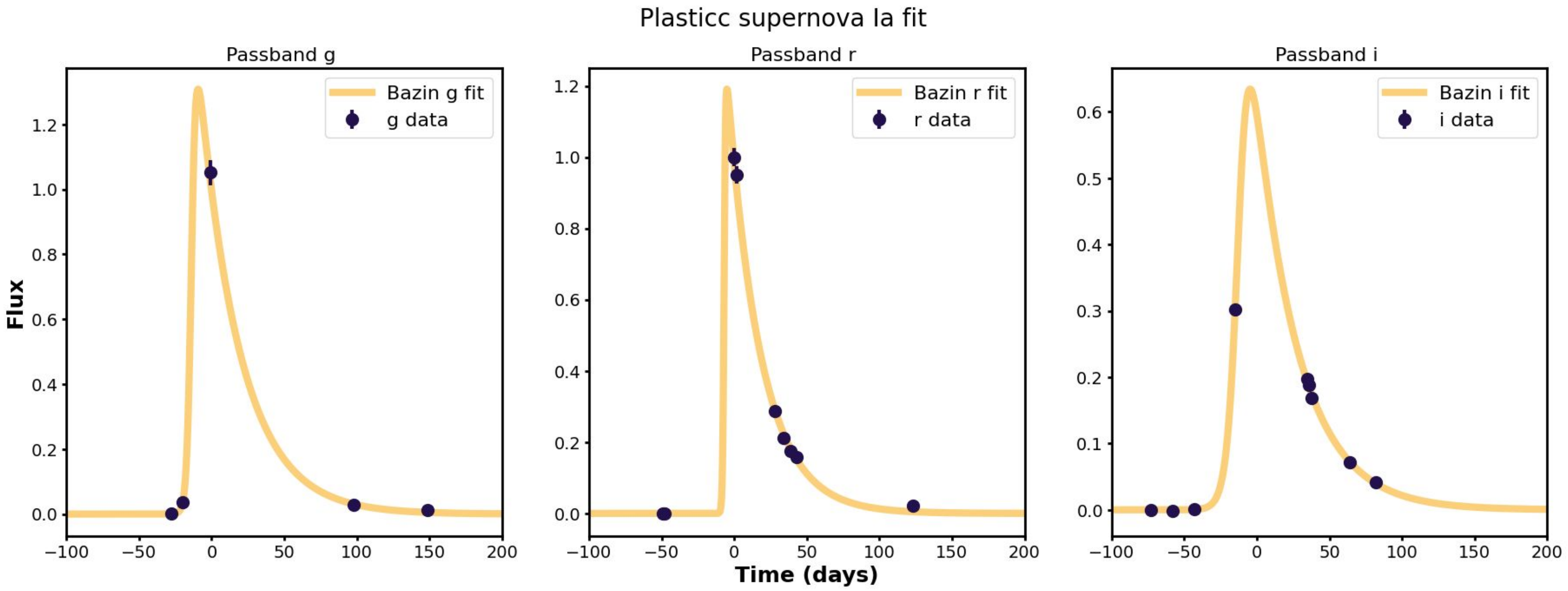
$$T(t) = T_{min} + \frac{T_{var}}{1 + e^{\frac{t-t0}{k_{sig}}}}$$

Sigmoid function : **3** parameters

(t0 is common with Bazin)

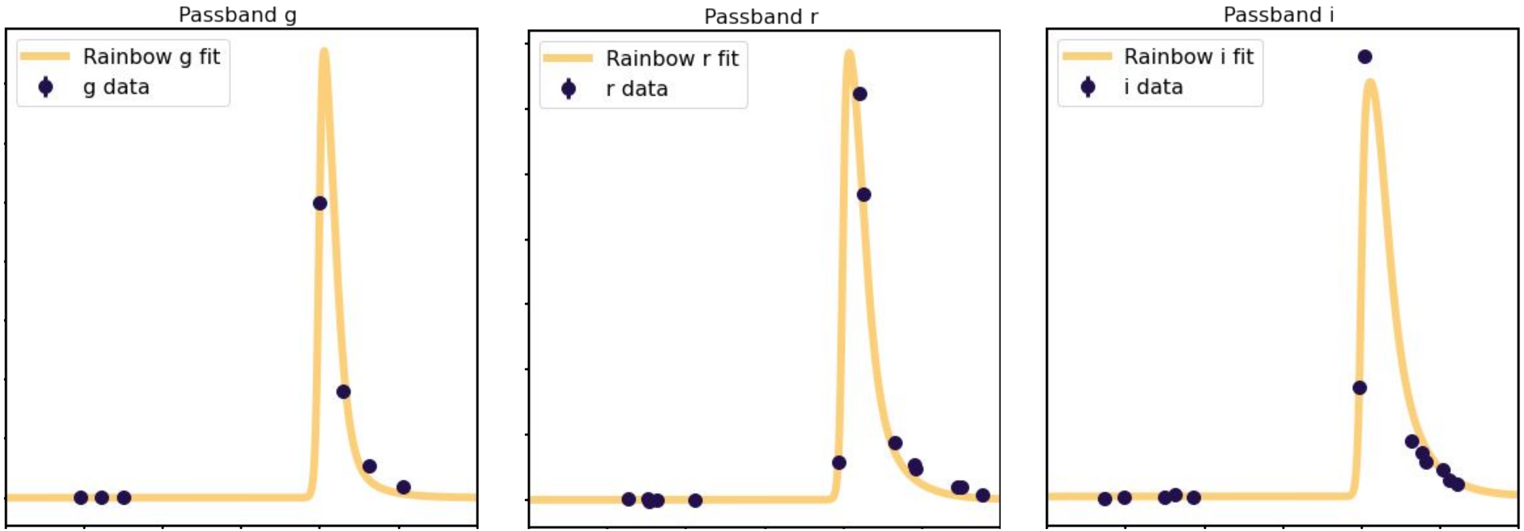
Tmin = 4000
Tvar = 7000
ksig = 4
(**t0** = 0)

Rainbow fit examples

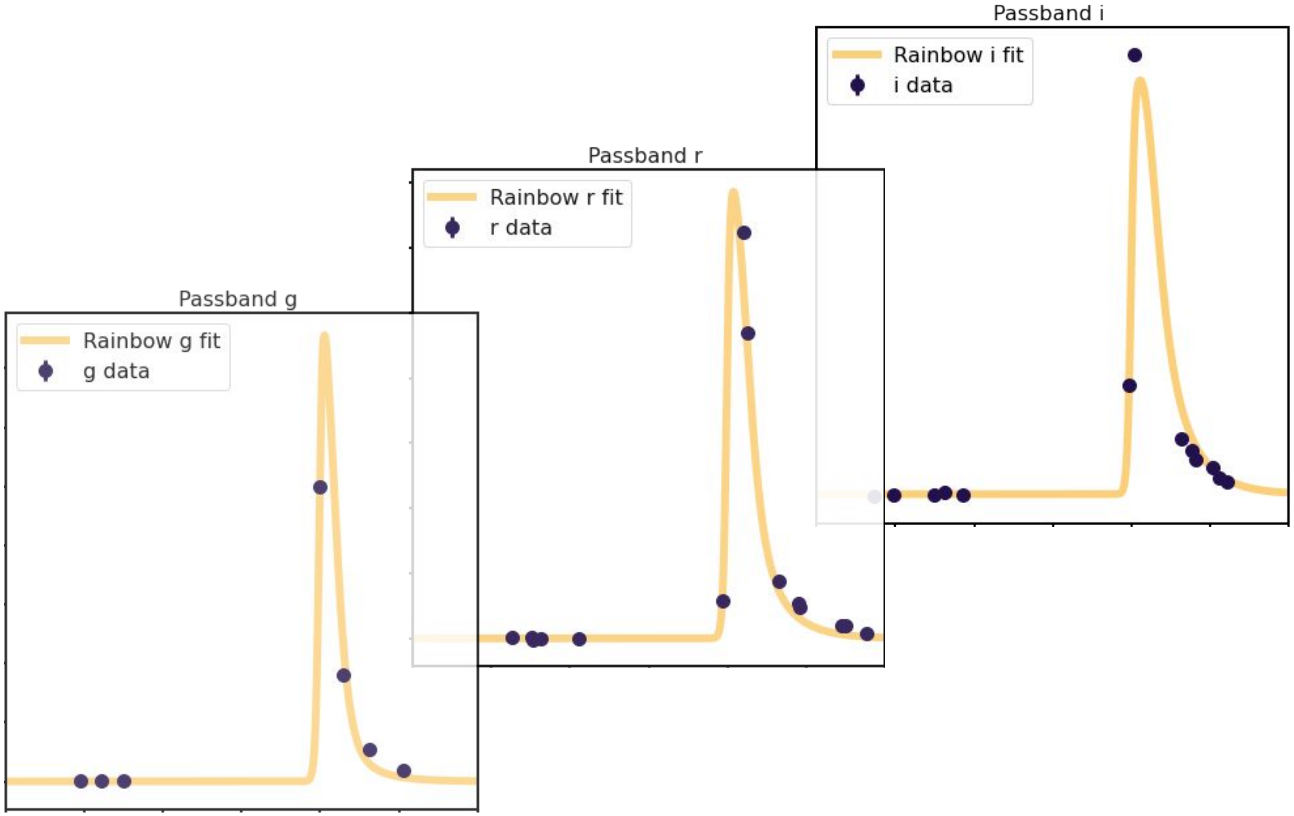


A	t0	tr	tf	Tvar	Tmin	ksig

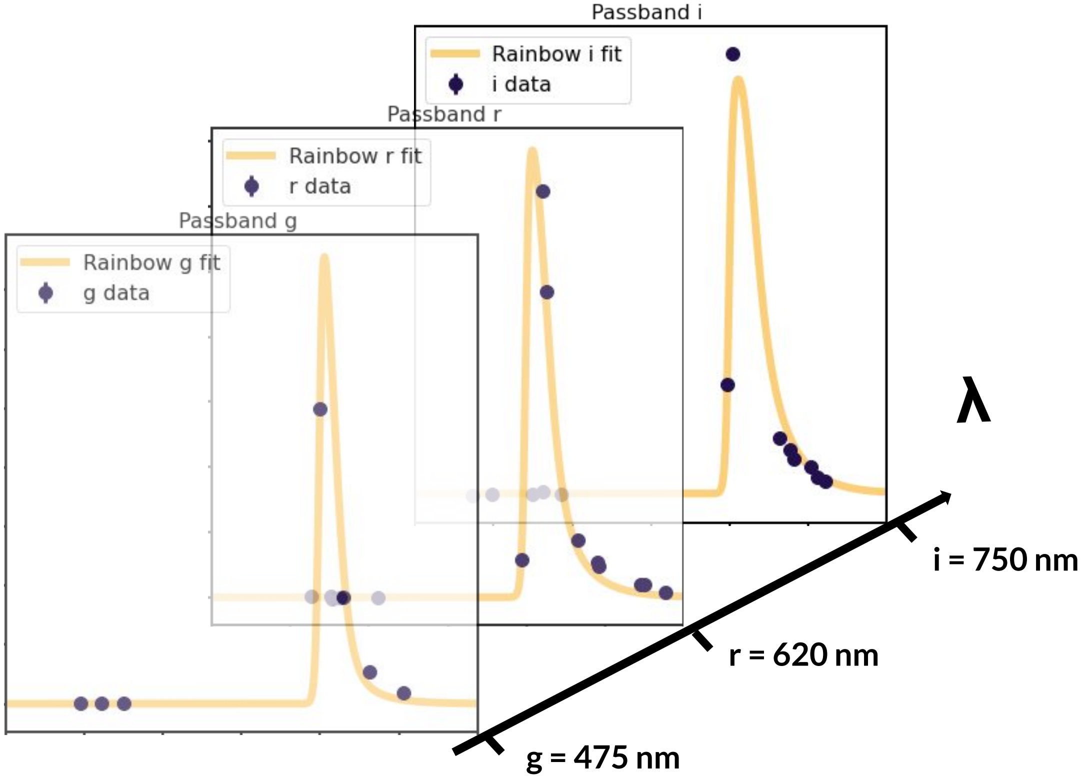
3D visualisation



3D visualisation

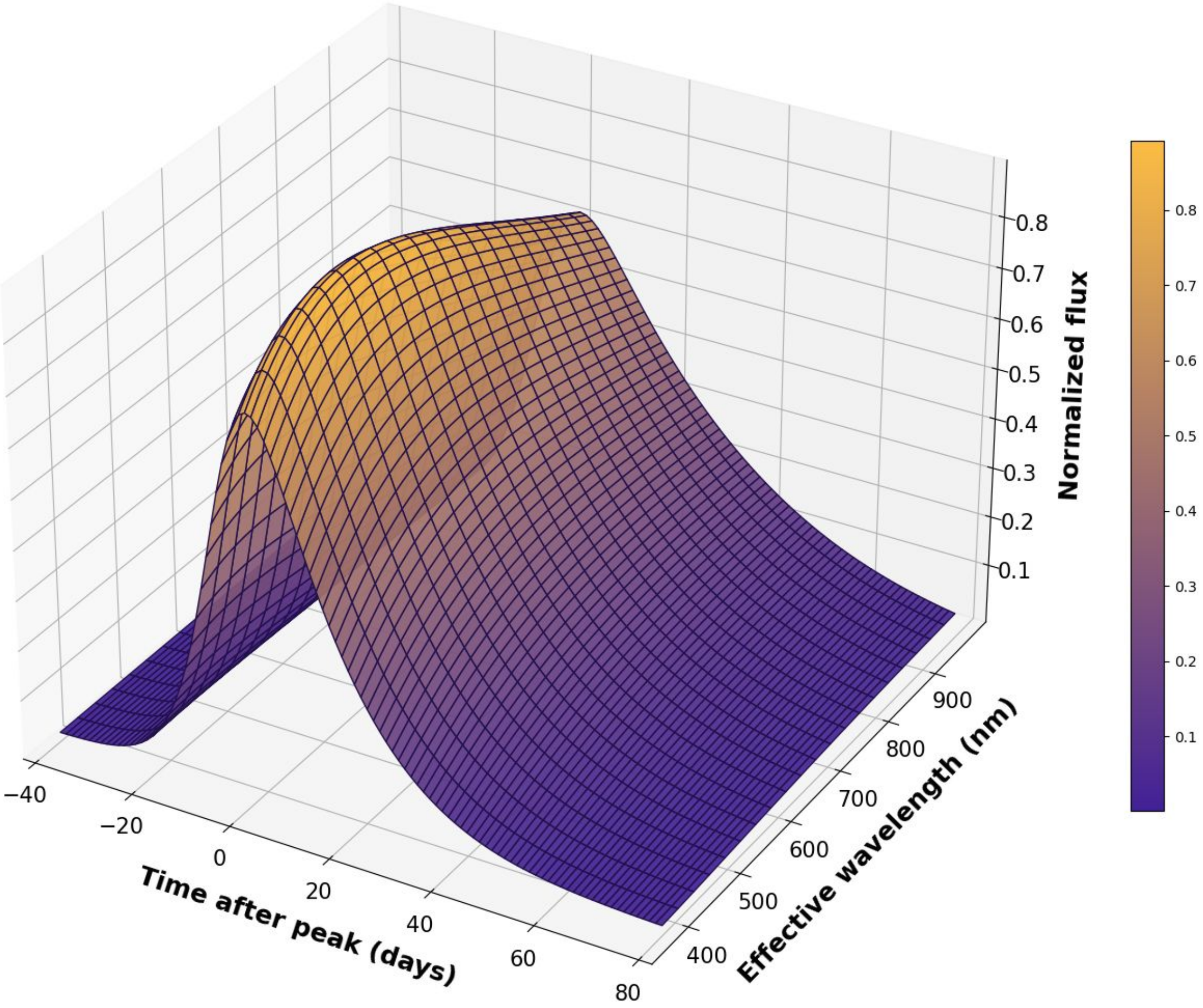


3D visualisation

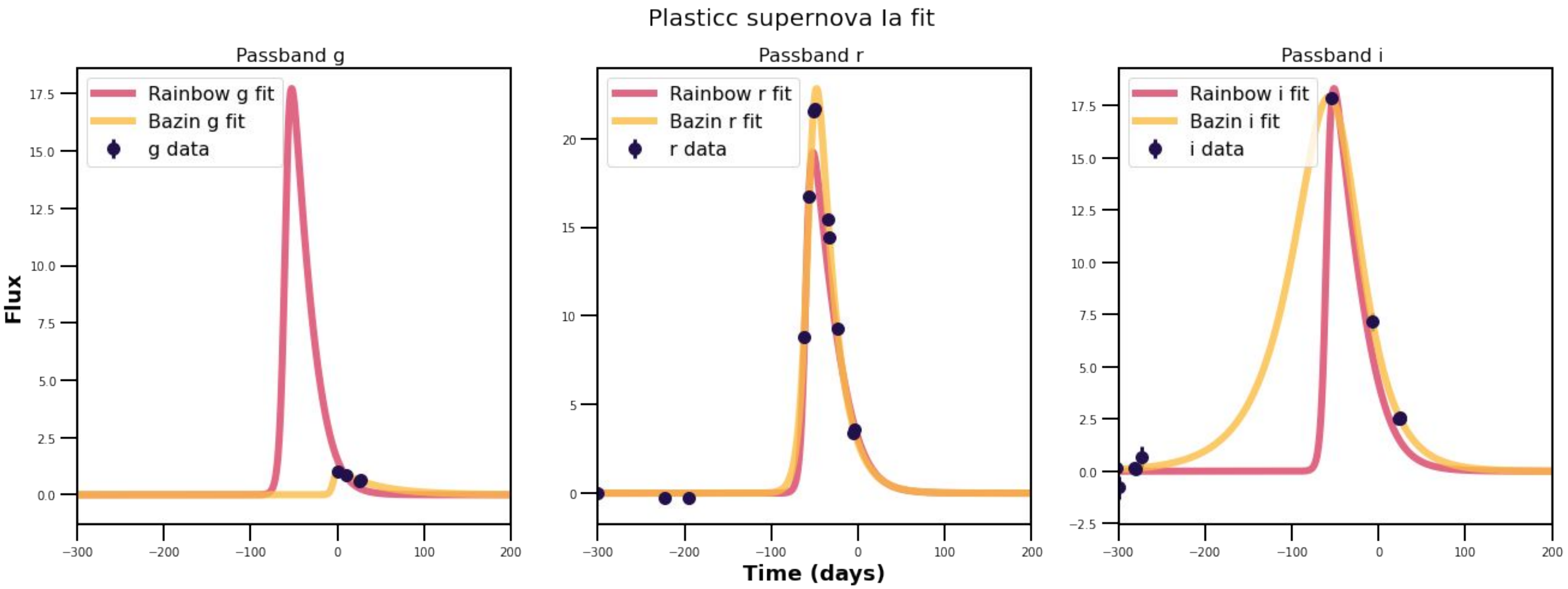


3D visualisation

RAINBOW:



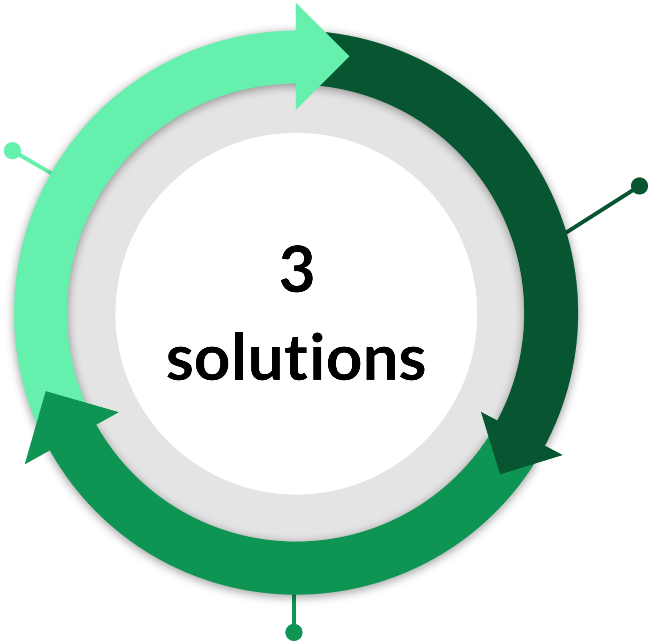
Typical behavior



II

Rainbow efficiency

Consider all points available at once. An undersample passband doesn't matter



Number of parameters is constant independently of the number of filters

We obtain only one set of parameters : get rid of the correlations

Paper conclusion : simpler and better !

Goodness of fit
Light curves with points randomly removed

Classification

Multiclass supernova like event classification

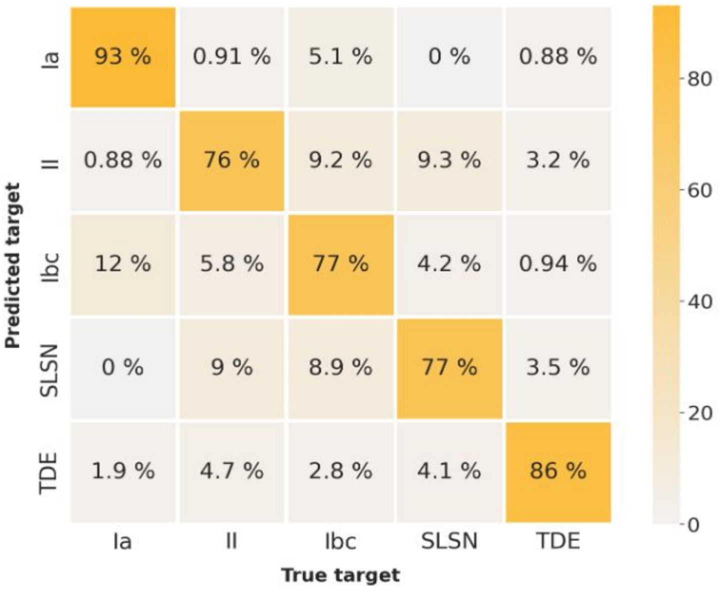
Peak time prediction

Machine learning prediction and direct computation.

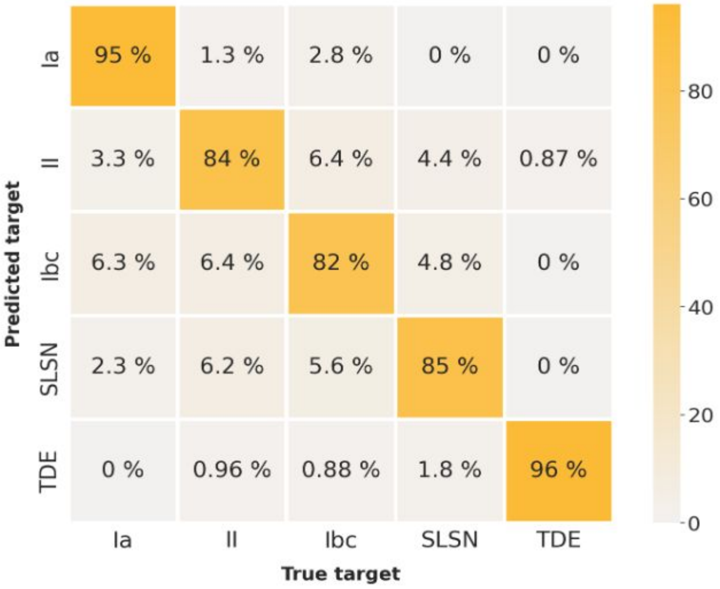
Russeil et al., 2023. Rainbow: a colorful approach on multi-passband light curve estimation, arXiv:cs https://arxiv.org/abs/2310.02916

Paper teaser: PLAsTiCC transient classification

Independent fit

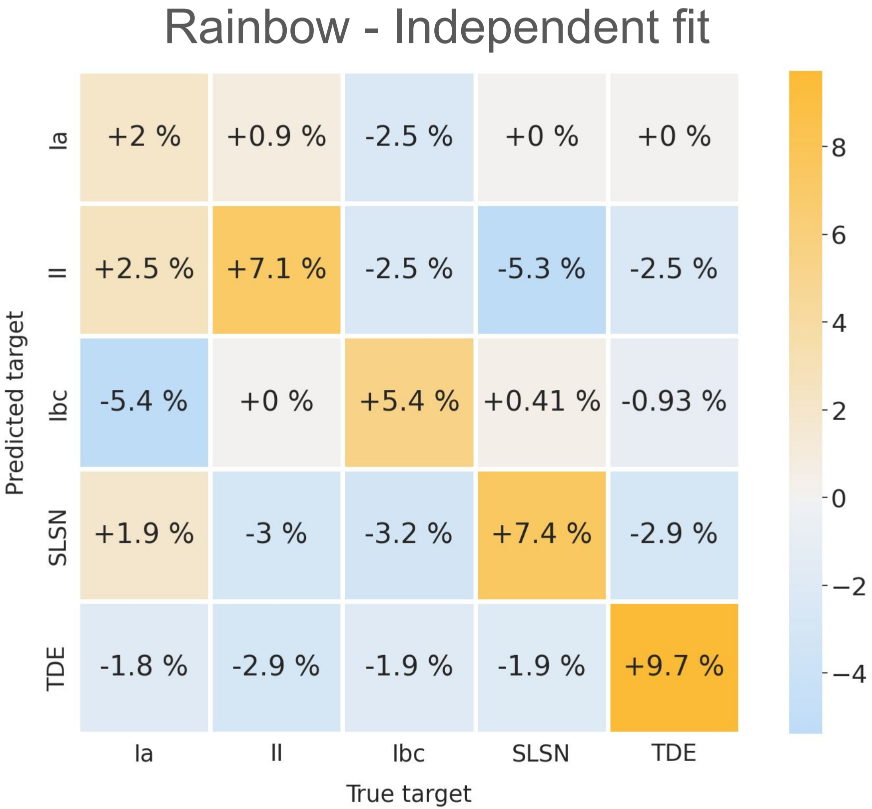


Rainbow



Balanced dataset (300 objects per class)

Paper teaser: PLAsTiCC transient classification



II

Fink applications

Science modules

- **Active galactic nuclei**
- **Anomaly detection**
- **Early SNIa**
- **Super Luminous Supernovae**
- **Tidal disruption event**
- *More to come ?*

All require a parametric fit at some point

Science modules

- **Active galactic nuclei**
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All require a parametric fit at some point

Need to adapt from 2 to 6 passbands with a low lower cadence for LSST !

Current work using Rainbow

Early SNIa

- Fit only rising light curves
- Details to presented by Emille

Early TDE

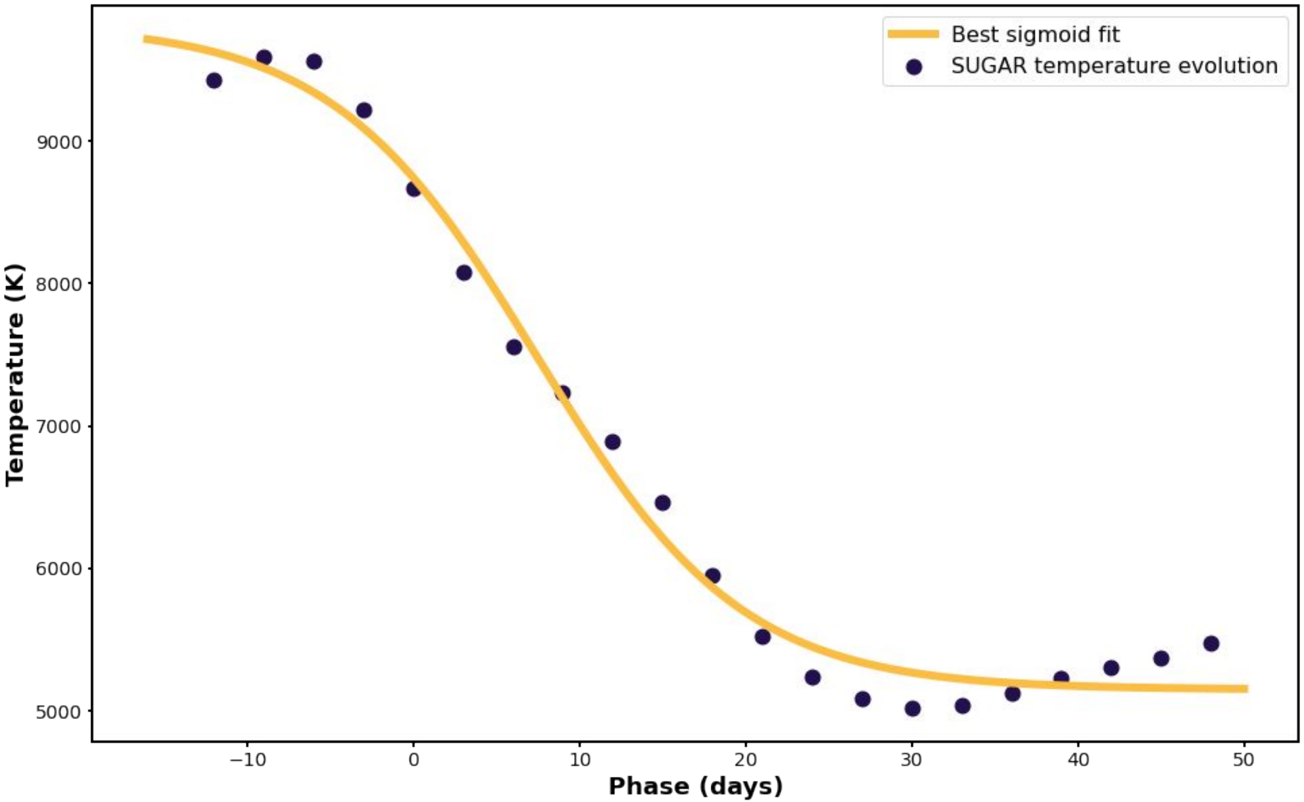
- Fit only rising light curves
- Use a constant temperature
- Work in progress

III

Conclusion

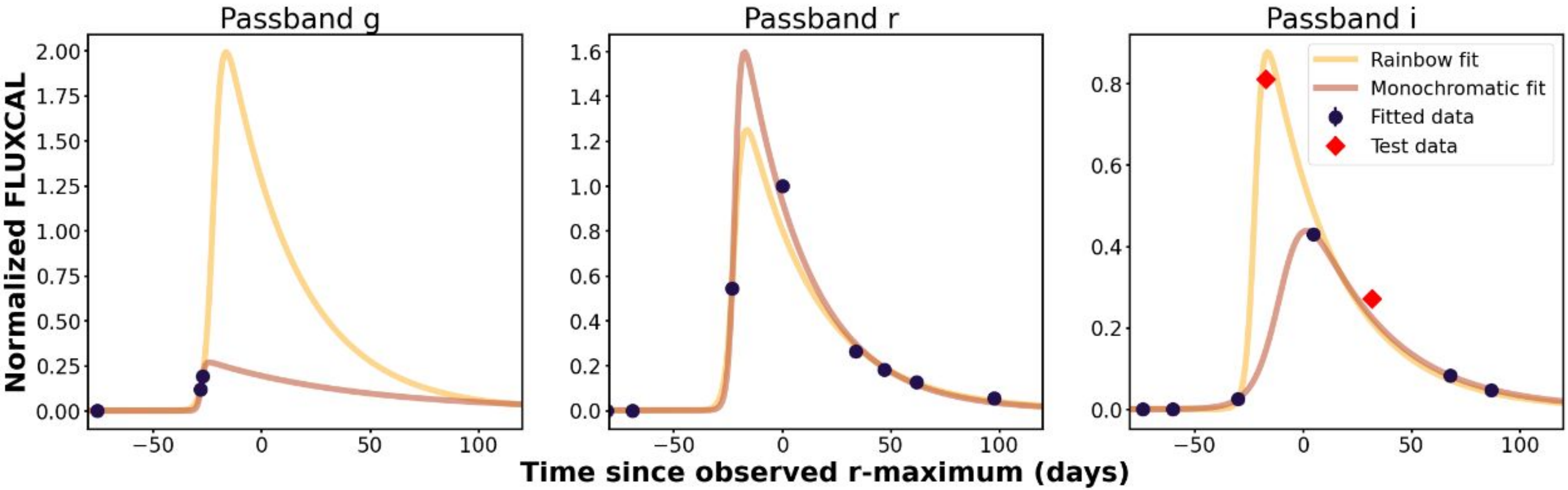
- Rainbow is displaying excellent results, see paper
- Offers a good transition from ZTF to LSST
- An implementation is available for easy use here: https://github.com/light-curve/light-curve-python
- Adaptable to future science cases ! Need to choose bolometric flux and temperature evolution
- If you are interested in using Rainbow don’t hesitate to contact me

Why sigmoid ?



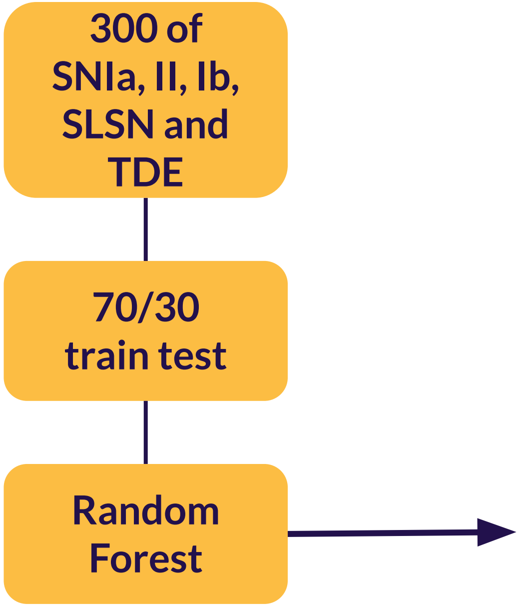
Best sigmoid fit
SUGAR temperature evolution
Temperature (K)
9000
8000
7000
6000
5000
−10
0
10
20
30
40
50
Phase (days)

Goodness of fit : random points removal

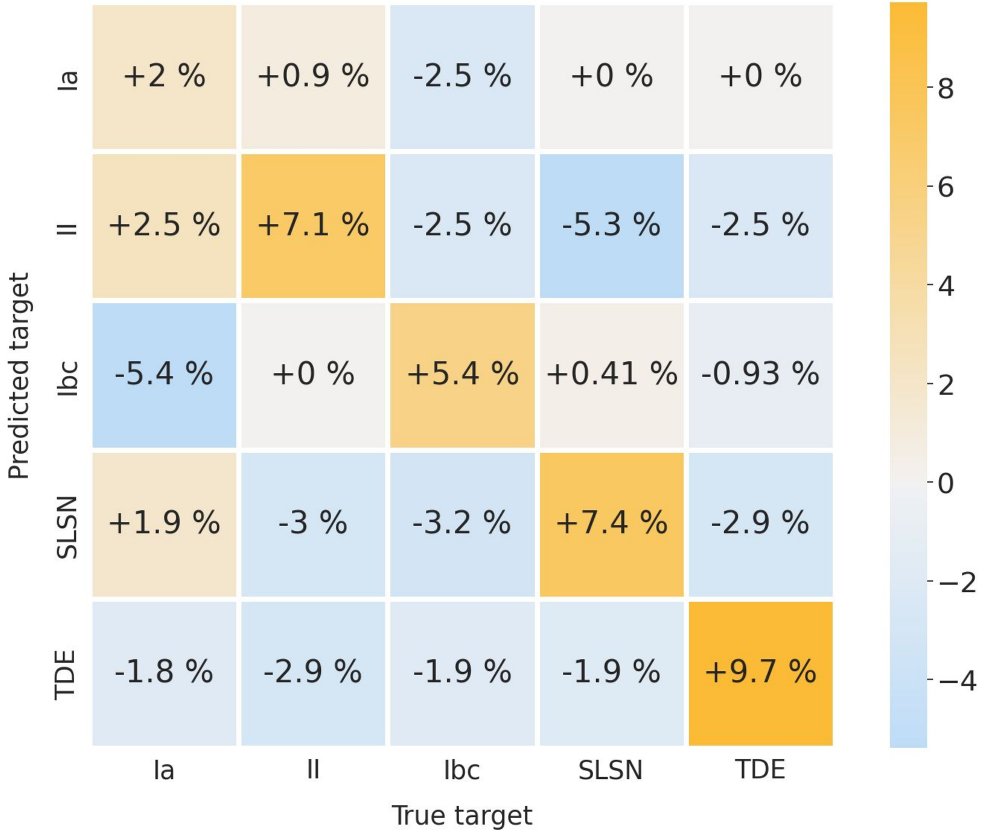


$$\text{nRMSEo} = \sqrt{\frac{1}{m}\sum_i\left[\frac{(y_i-\mu(t_i))^2}{2\epsilon_i^2}\right]},$$

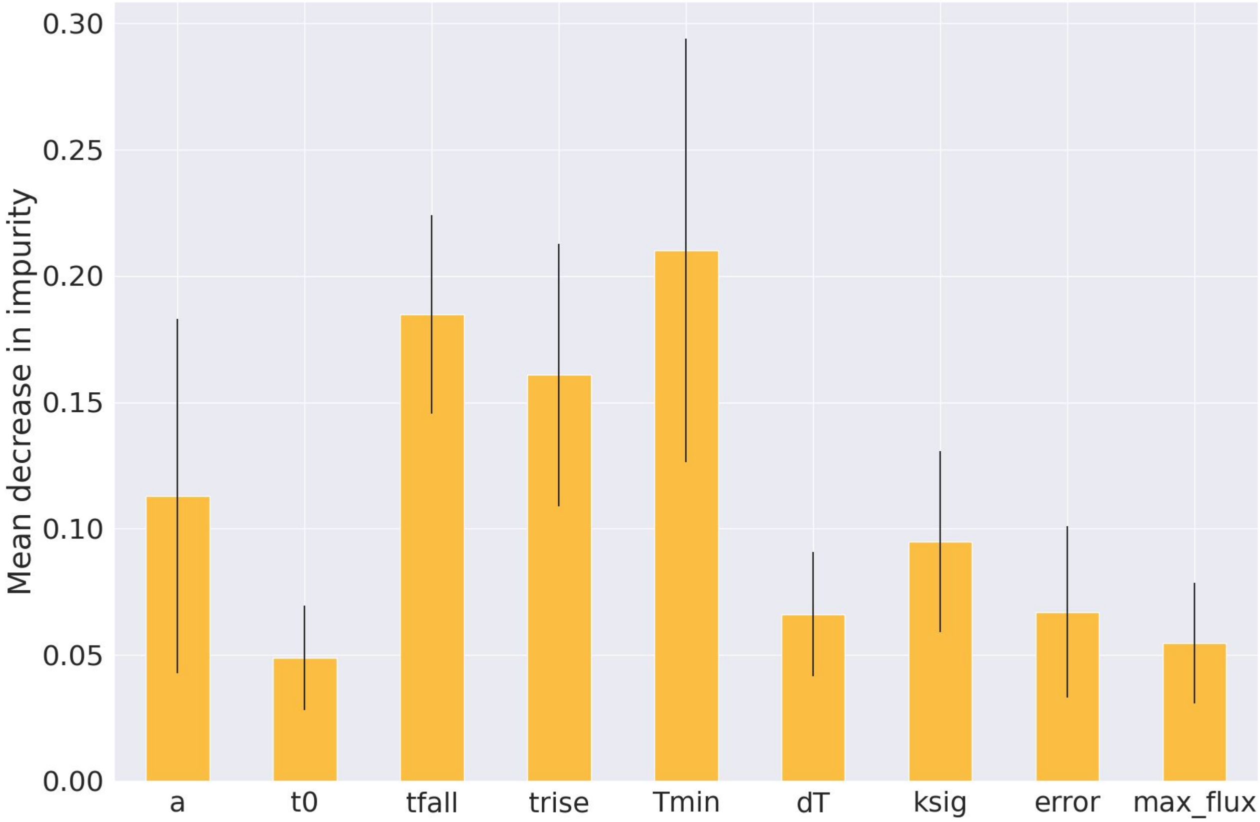
Classification task



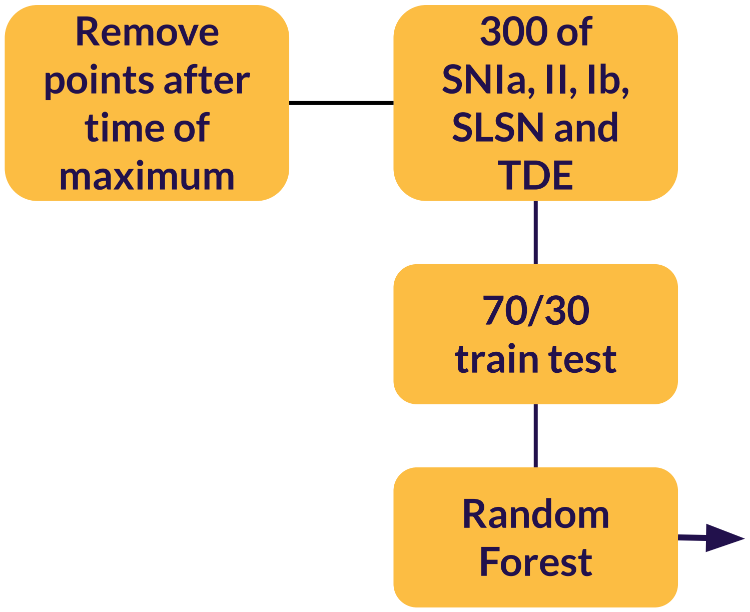
Rainbow - Monochromatic



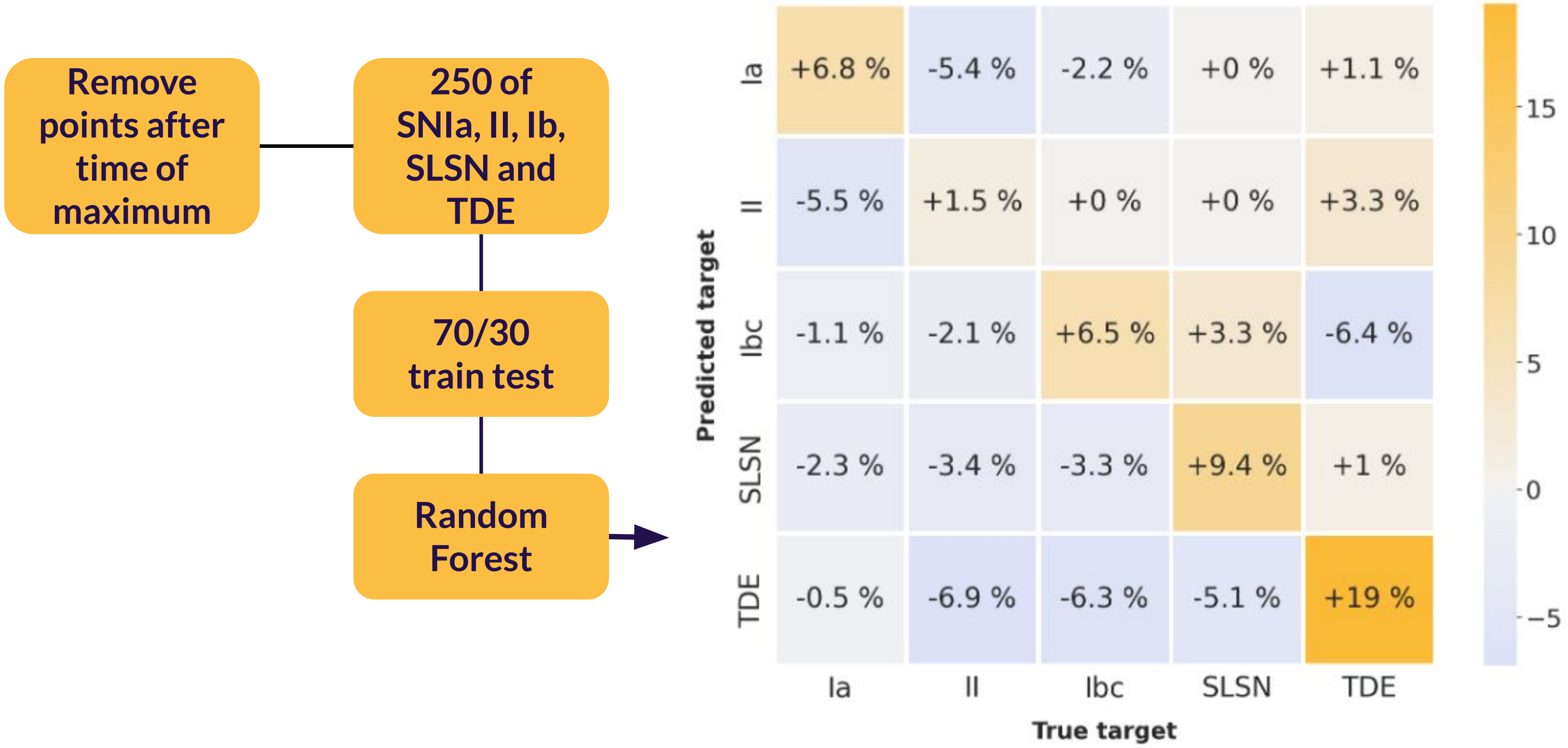
Classification task



Classification rising light curves



Classification rising light curves



$$F_\nu(t,\nu) = \frac{\pi}{\sigma_{SB}} \times \frac{B_\nu(T,\nu)}{T(t)^4} \times F_{bol}(t)$$

Planck's law

$$B_\nu(\nu,T) = \frac{2h\nu^3}{c^2} \times \frac{1}{exp(\frac{h\nu}{k_B T}) - 1}$$