Photometric classification of supernovae in ZTF

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The Zwicky Transient Facility

- ZTF is a wide-field, optical telescope searching for transients such as supernovae.

- The **Bright Transient Survey (**BTS) is a survey carried out within ZTF, which aims to *spectroscopically* classify supernovae brighter than ~18.5 mag.

Photometric classification of supernovae

- Spectroscopic classification provides high accuracy, but it is not possible to spectroscopically classify every transient detected by ZTF due to the high volume of data.

Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/P. Marenfeld

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→ **Photometric classification will be the future of time-domain astronomy**.

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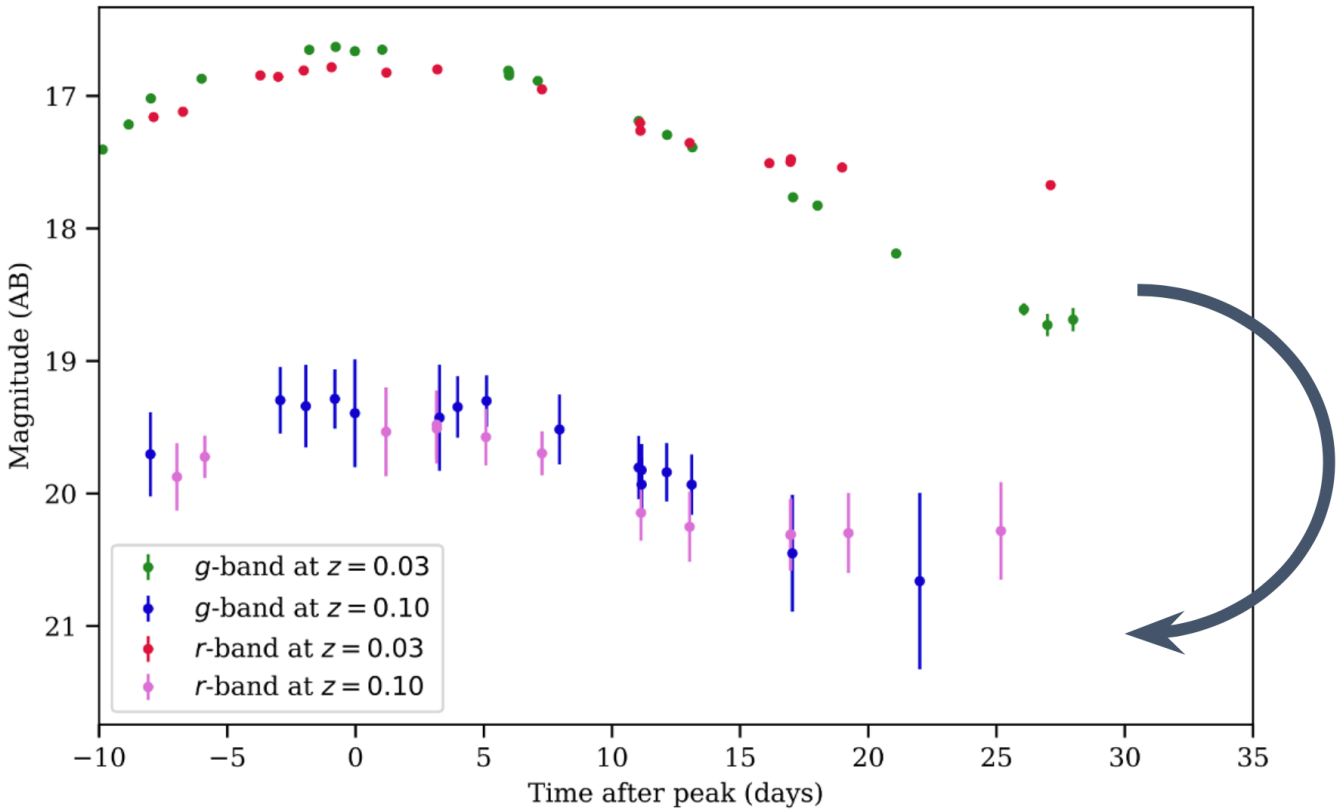
→ Solution: *augment* the training sample by creating copies of the original ZTF data with a *higher redshift* and additional *noise*.

Augmenting the training sample

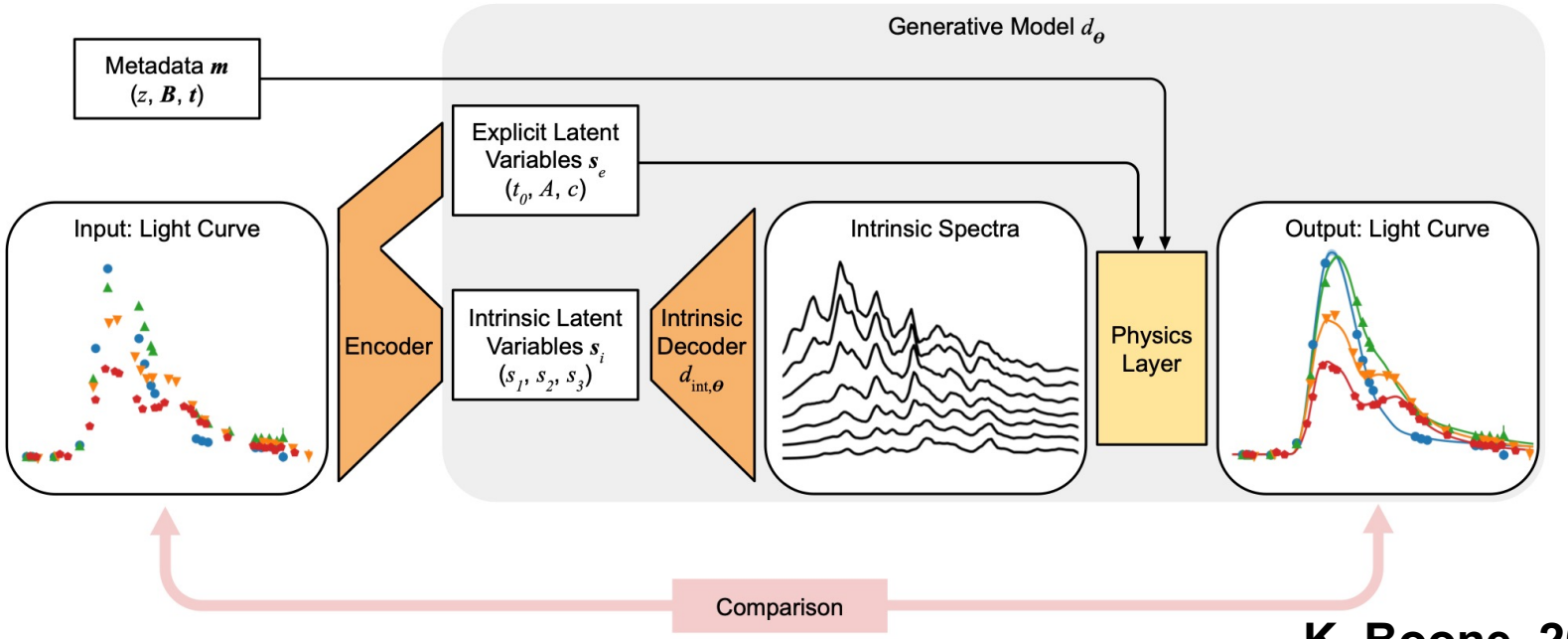


1. **Select new redshift** and scale flux, scatter and errors.
2. **S/N cut** applied.
3. **Drop data points** according to their ‘local density’ first, then drop points randomly.

The number of augmented copies generated is chosen to balance the classes.

Classifier

- We use *ParSNIP* (Parametrization of SuperNova Intrinsic Properties, *Boone 2021*) to produce models for the transients.
- ParSNIP is a a modified version of a variational autoencoder (VAE), it uses:
  - a neural network to model the unknown **intrinsic** diversity of transients (latent variables; s_1, s_2, s_3)



K. Boone, 2021

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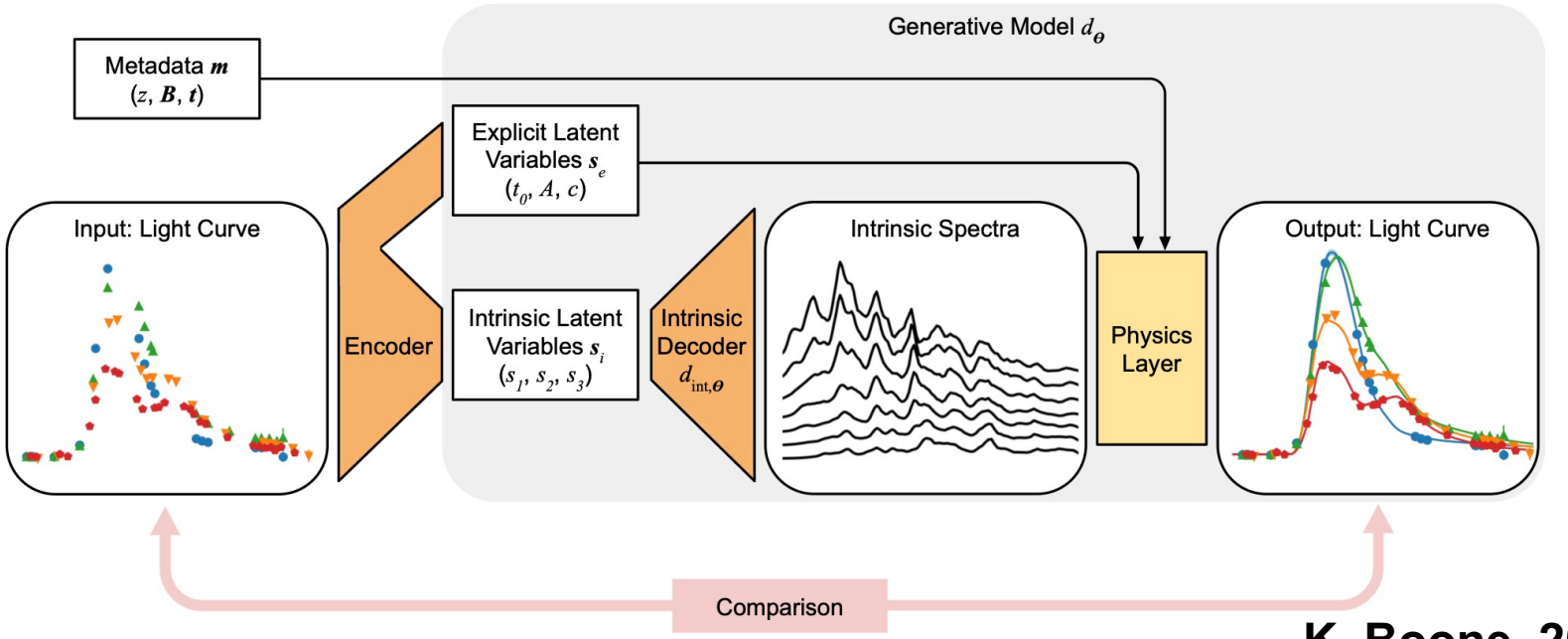
  - a neural network to model the unknown **intrinsic** diversity of transients (latent variables; s_1, s_2, s_3)
  - an **explicit** physics-based model of how light travels through the universe and is observed (A, c, t_0).



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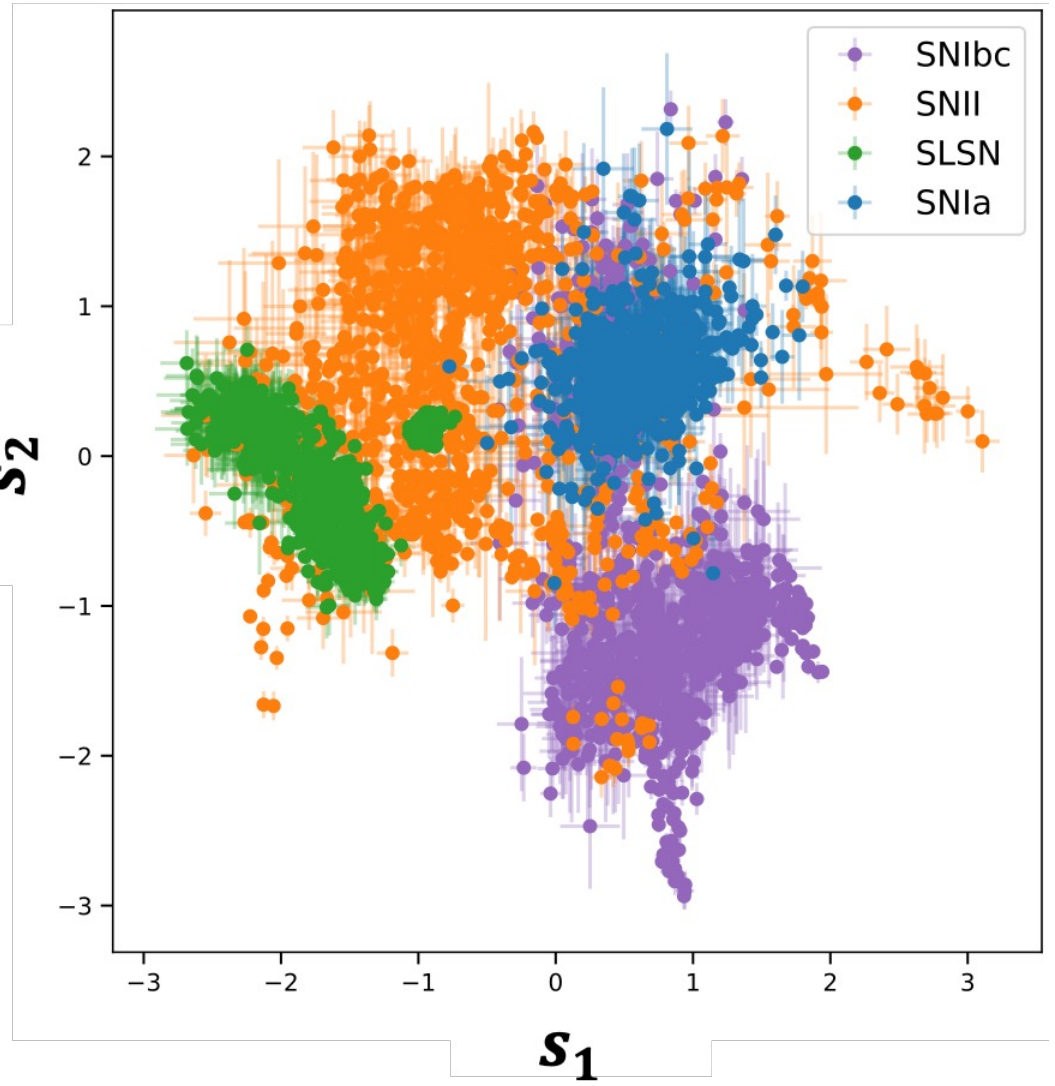
Classifier

- We extract the features from ParSNIP.
- These features are used to train a gradient-boosting decision tree, which is the **classifer.**

An example of how two of the ParSNIP features (intrinsic latent variables s_1 and s_2) vary for the classes.



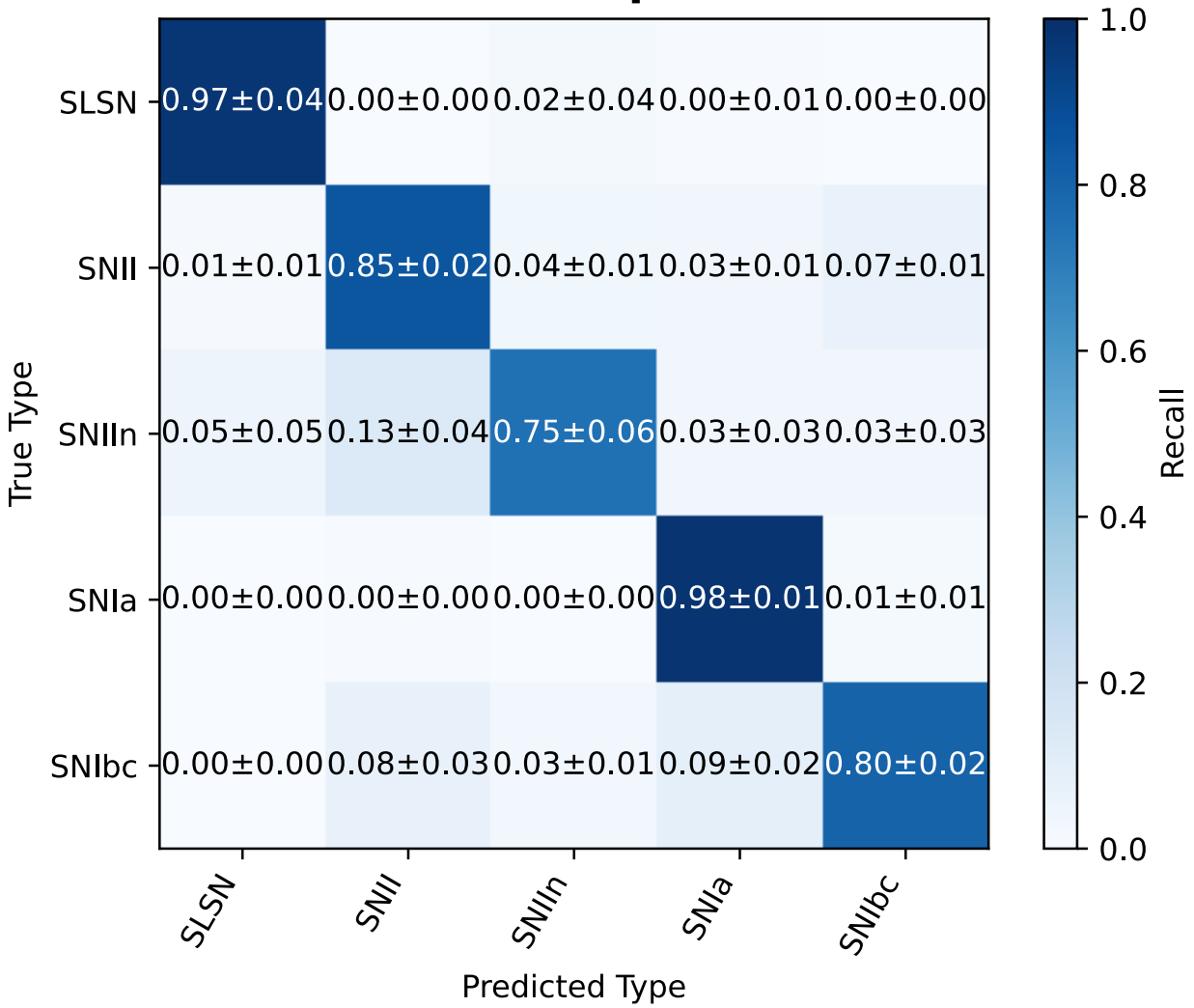
Results

Multi class classifier – for live follow-up

Test set is also augmented to represent the real faint unclassified ZTF sample.

A threshold probability of p(class) > 0.7 is applied. This means that approx. ~10% of test sample is unclassified.

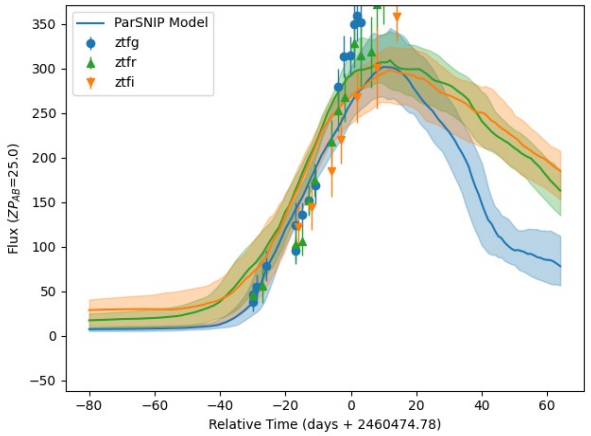
Peculiar objects not included!



Live follow-up

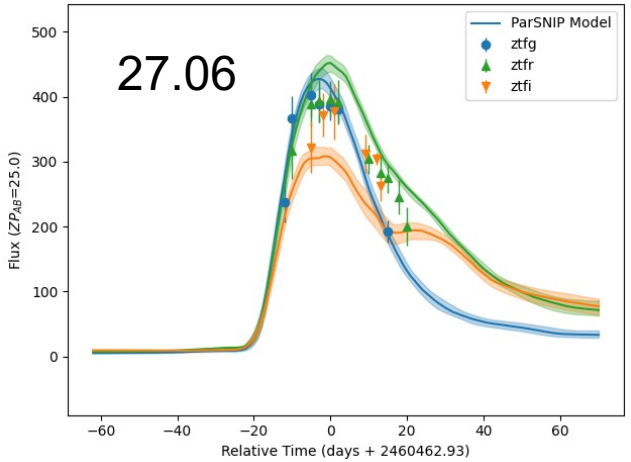
We had a live classification project ongoing with the ePESSTO+ collaboration (using NTT telescope in La Silla).

ZTF24aaowjlw

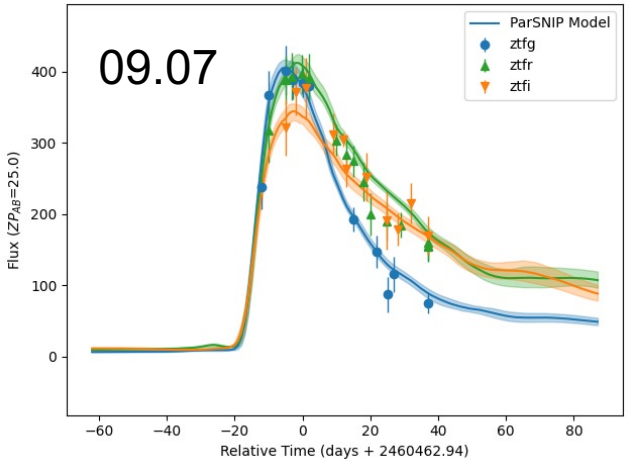


P(SLSN) = 86%
Classified as SLSN-I

ZTF24aaooxcd



P(SNIa) = 82%

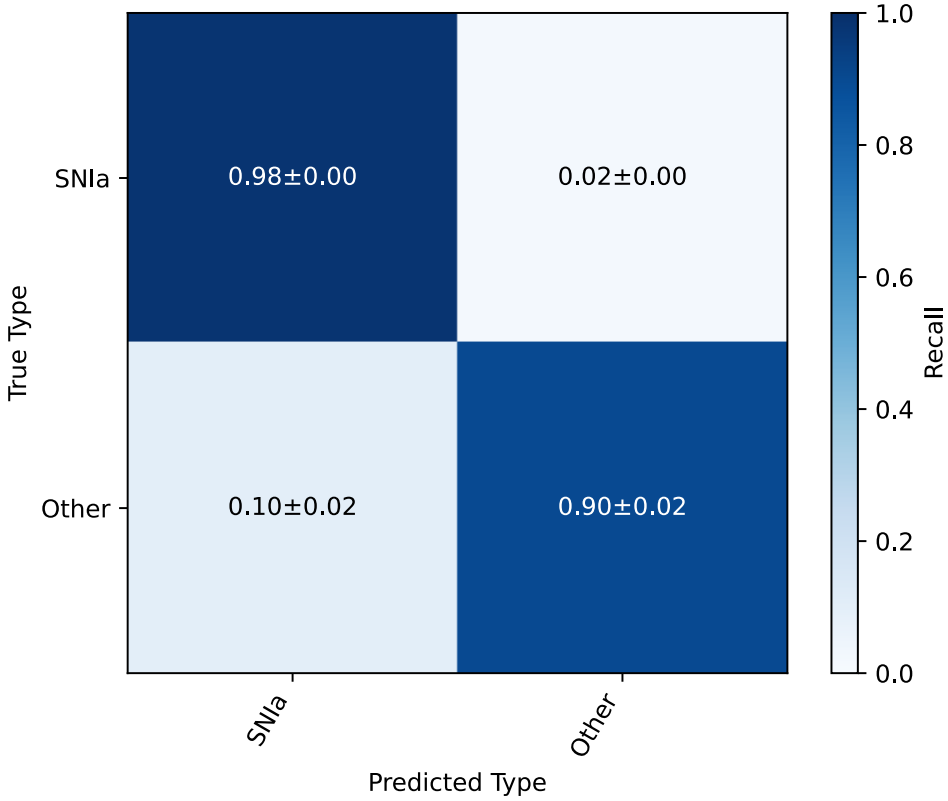


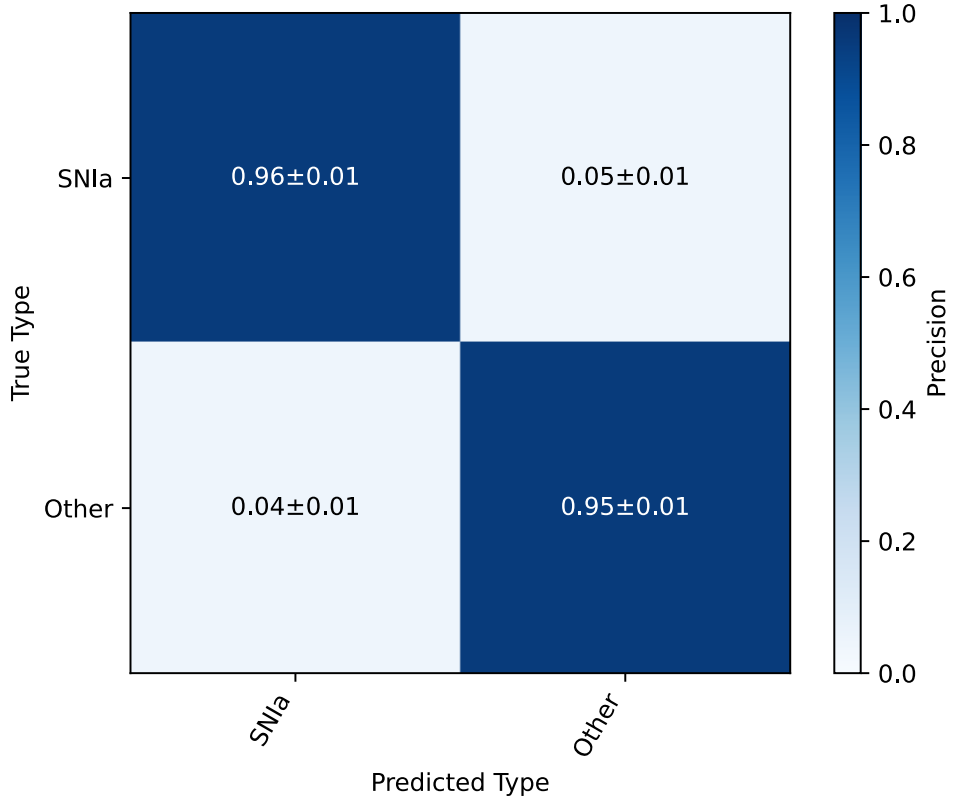
P(SNII) = 65%

Classified as SNII

Results

SN Ia binary classifier – for cosmology

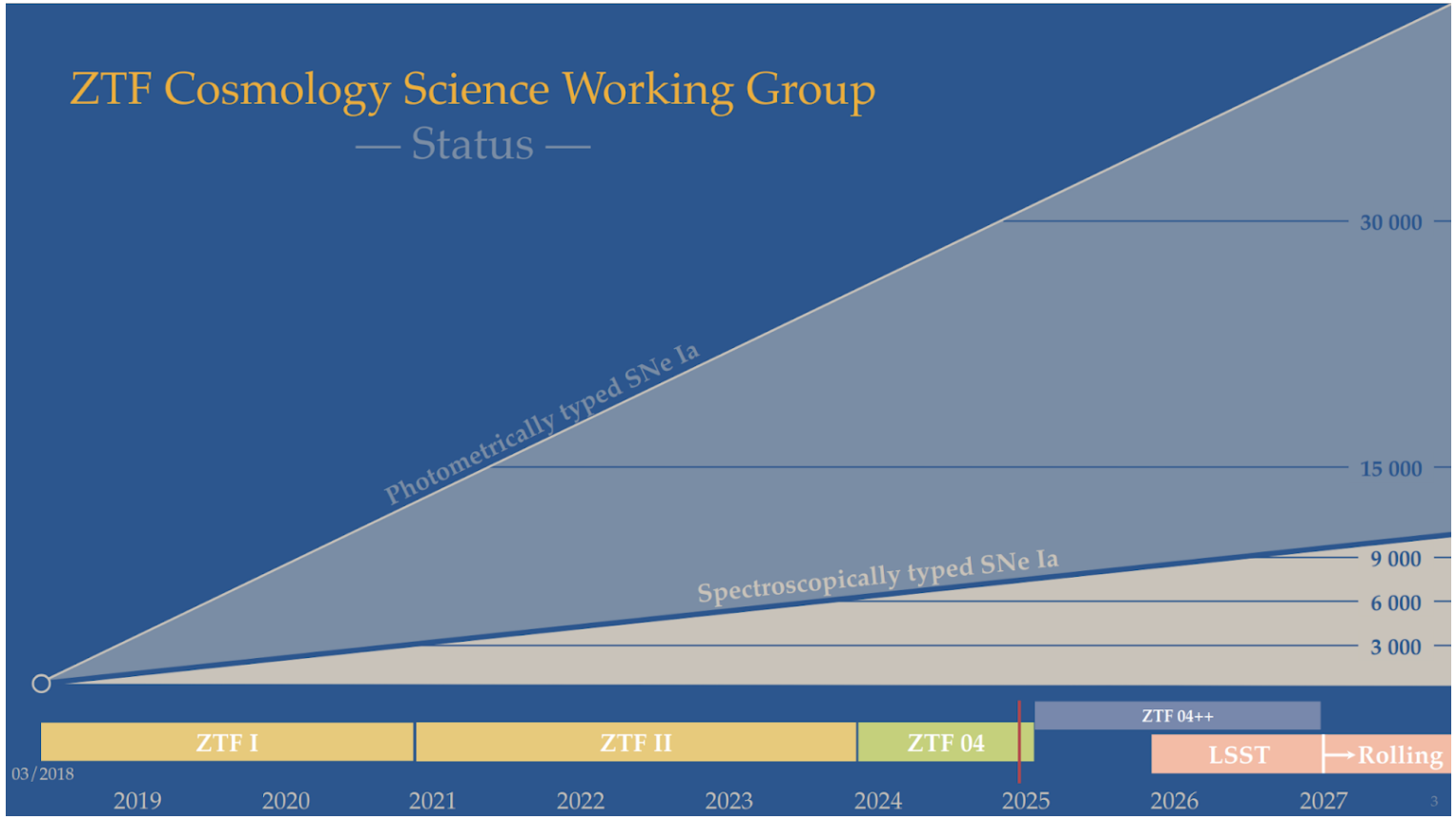




For SN Ia cosmology, maximising the SN Ia recall is biggest priority. Although we want a high precision too, this contamination can be modelled and removed before the Hubble diagram.

Future plans for cosmology

- Photometrically classify the entire ZTF dataset, leading to ~ 30,000 SNe Ia to use for cosmology.
- This large sample of SNe Ia will reducing statistical uncertainties, enabling more precise measurements of H_0.



Credit: Mickael Rigault