NaCl (Nouveaux Algorithmes de Courbes de Lumières) : A new framework for training type Ia supernova lightcurves

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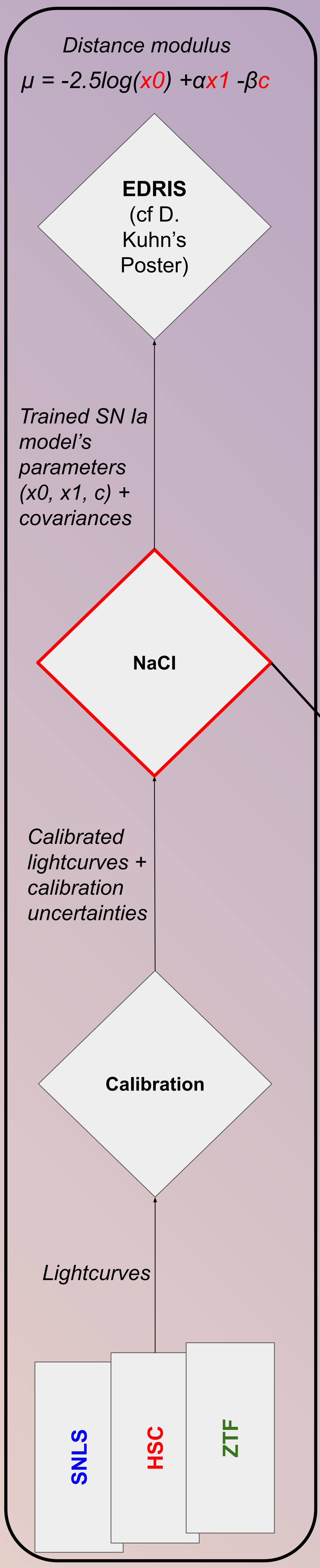
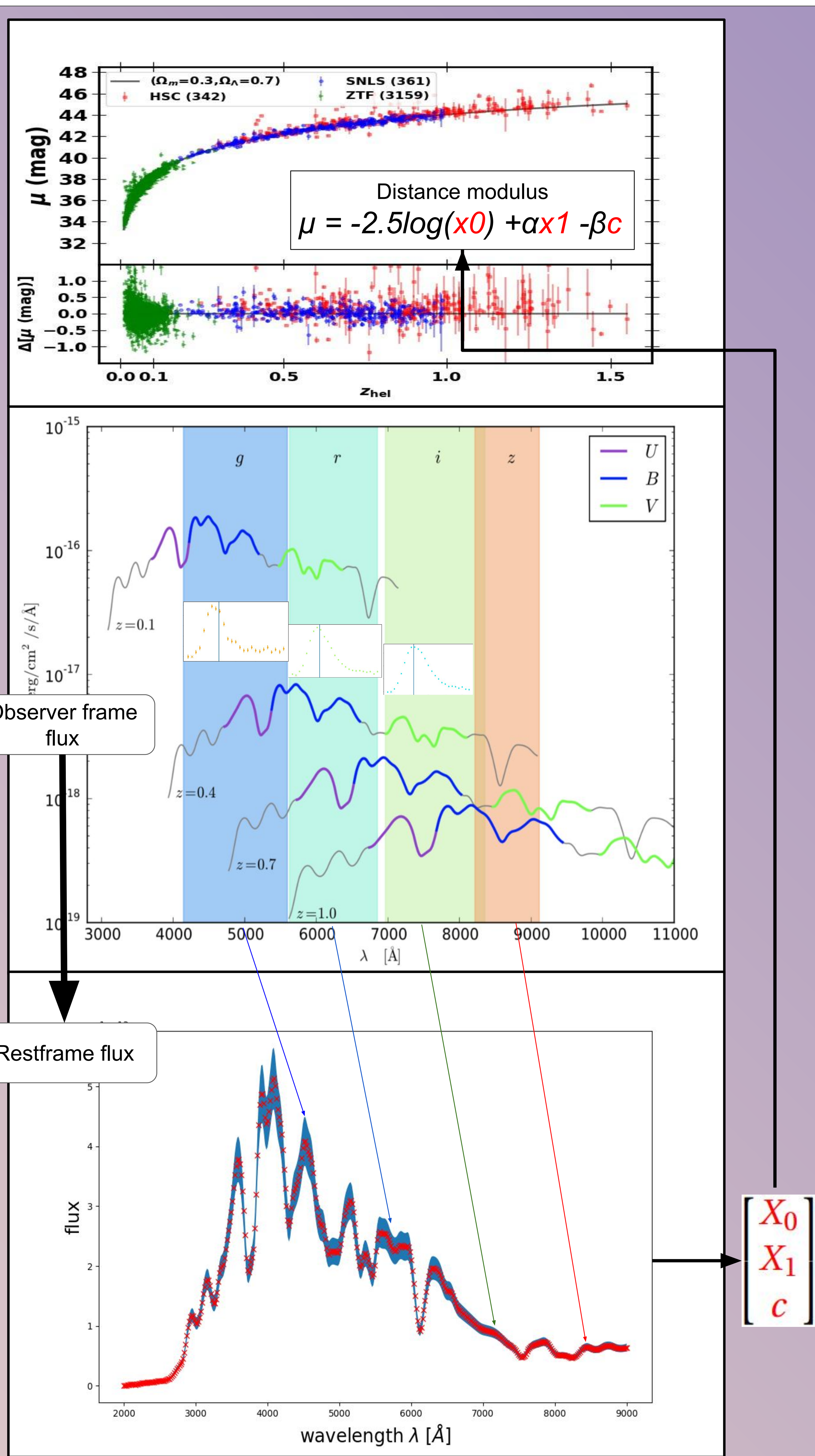
CONTEXT:

Precision measurements of the **expansion history** of the Universe depends on the determination of type Ia supernovae (SN Ia) **standardized luminosity distances**. Theses distances are determined using SN Ia lightcurves [1]. SN restframe peak luminosities in the B band present a natural dispersion of roughly 40% which can be reduced to ~10% using correlations of peak luminosities with SN shapes and colors. SN empirical models are used to extract restframe luminosities and standardization parameters from the observer frame lightcurves.





LEMAITRE:

The **LEMAITRE** project aims at measuring parameters of cosmic expansion using a dense and independent SN Ia dataset (~O 4000 SN). The **LEMAITRE** inference pipeline is comprised of multiple steps : the full calibration of 3 independent datasets (ZTF, SNLS & HSC), the retrieval of standardized fluxes with **NaCl** and finally the determination of standardized distances with **EDRIS** (cf D. Kuhn's poster).

NaCl:

What does NaCl do?

NaCl describes the **restframe** spectrophotometric evolution of SN Ia which is how one can measure distances. This is done by training an empirical spectrophotometric model

What makes NaCl different?

The NaCl framework aims to train SN Ia spectrophotometric models and to fit individual SN standardization parameters. The design is driven by the following requirements:

- Speed: The NaCl framework fits all of its parameters (training + standardization) using a single log likelihood minimization.
- Calibration errors : The calibration uncertainties are propagated in the training. Indeed NaCl trains its model using the same dataset on which the cosmological analysis is being done which means the propagation of calibration uncertainties can be well understood.
- Model independent : NaCl is designed to be model independent. New models can be easily developped and plugged in the NaCl machinery.

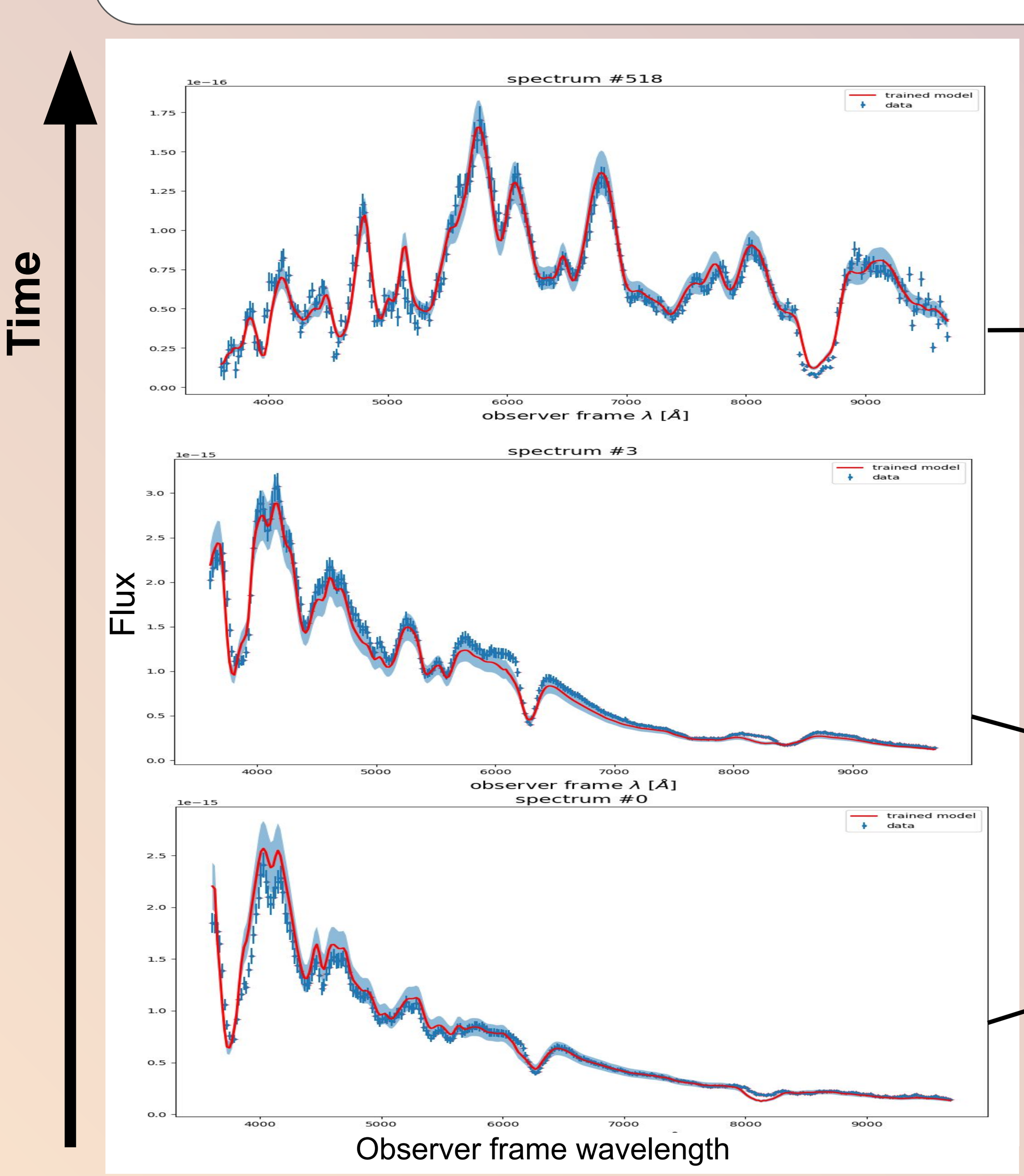
What do we get from NaCl?

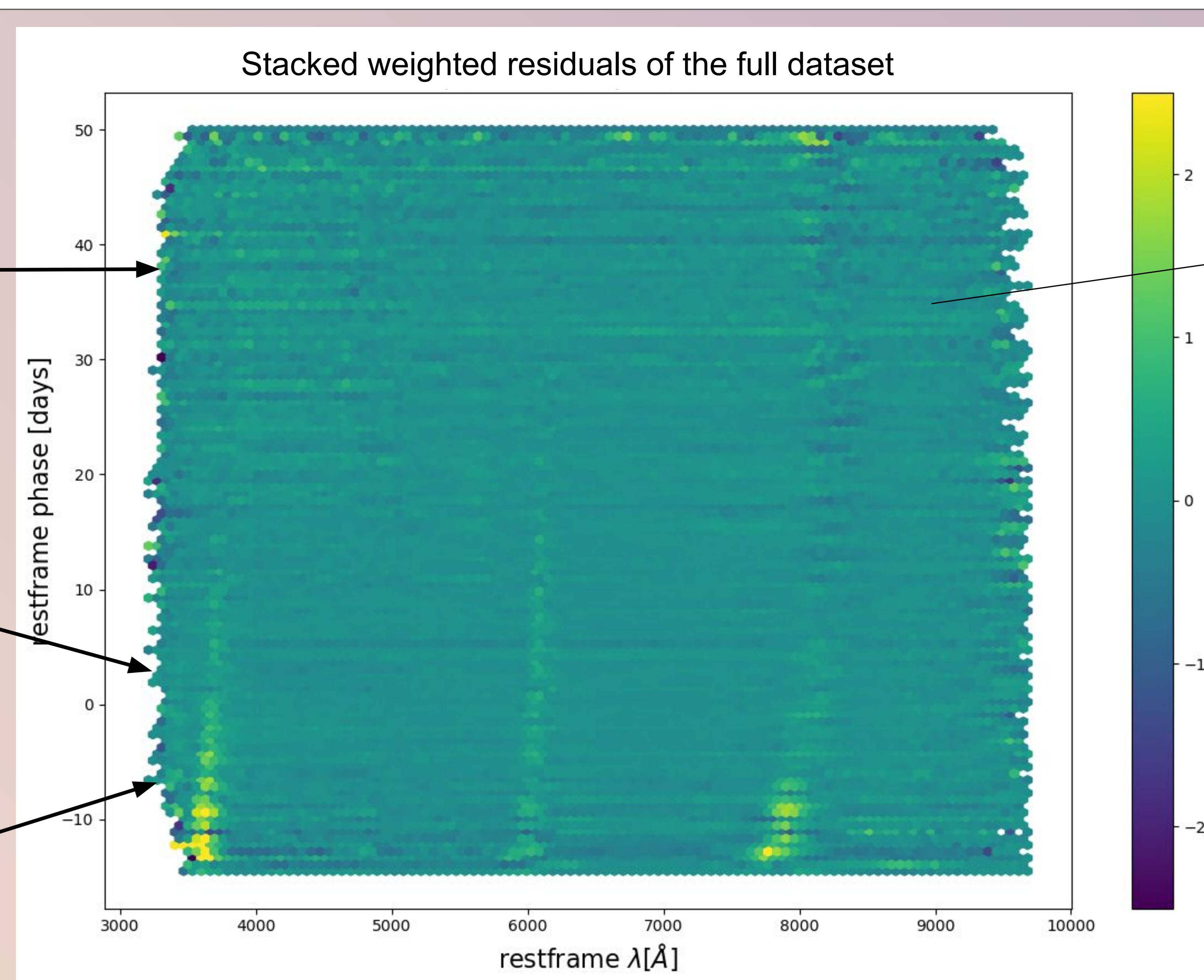
After a full training we obtain a list of the **standardization parameters** and their **covariance matrix** which are then used by EDRIS (cf D. Kuhn's poster) to calculate the standardized distances.

NaCl on real data : SNFactory:

NaCl was trained on the dataset of SNFactory [2] which contains 224 SNe and over 3000 well calibrated spectra. The training was done using the state of art spectrophotometric model parameterization SALT2 [3].

$$S(\lambda, p) = X_0 \times \left[M_0(\lambda, p) + X_1 \times M_1(\lambda, p)\right] \; 10^{0.4cCL(\lambda)}$$





Results shows in large parts agreements between the model and the data!

Only in three spectral regions the model doesn't capture the SN Ia variability (UV, Ca, Si II peaks)

Future work:

Train the SALT model with NaCl on larger datasets such as ZTF DR2 (~3000 SNe) and eventually LEMAITRE. Explore a method that may improve the speed of the training and maybe a new parameterization of the model.

Reference:

[1] - Goobar, A. and Leibundgut, B. (2011). Supernova cosmology: Legacy and future. Annual Review of Nuclear and Particle Science, 61(1):251–279

[2] - Aldering, G., Adam, G., Antilogus, P., et al. (2002). Overview of the Nearby Supernova Factory. In Tyson, J. A. and Wolff, S., editors, Survey and Other Telescope Technologies and Discoveries, volume 4836, pages 61 – 72. International Society for Optics and Photonics, SPIE.

[3] - Guy, J., Astier, P., Baumont, S., et al. (2007). SALT2: using distant supernovae to,improve the use of type Ia supernovae as distance indicators.,A&A 466(1):11–21