Superluminous supernovae classification in big data surveys

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Superluminous supernovae

Superluminous supernovae (SLSNe) are extreme supernova events with an absolute magnitude **M < -20**, making them **10 to 100 times more luminous** than standard supernovae. They are rare events for which we still we lack a complete understanding. In particular, the subject of the mechanisms responsible for the excess of energy is an active question. Explainations include **circumstellar interaction** with a thick medium, or the formation of a **magnetar** acting as a central engine. It is also theoretically predicted that population III stars could lead to SLSN through an electron-positron **pair instability** mechanism. Discovering more SLSN is crucial to better understand these events.

The Fink broker

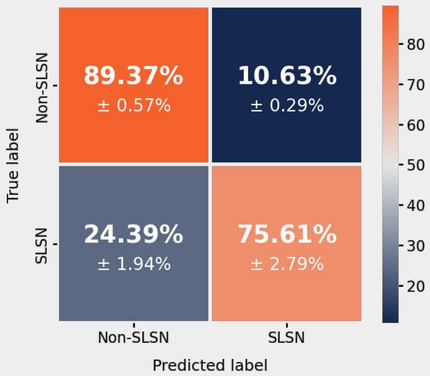
Given the volume of alerts produced every night, both LSST and ZTF rely on **data brokers. Fink** is one of the seven brokers chosen to receive LSST data, and is currently processing ZTF alerts. It has the role of continuously **ingesting, filtering, augmenting** and **distributing** the stream. In this context, **science modules** can be build and attached to broker to produce real time photometric classification. The SLSNe classifier will soon constitute **a new science module**, whose predictions will be **publicly available**.

The classifier

Using the parameters extracted from the **Rainbow fit**, along with a series of **statistical features,** we train a machine learning model to separate SLSN light curves from other transients. The data sample has been chosen for its **spectroscopic high quality labels.**

We train an **XGBoost** model and optimize the hyperparameters to **maximize completeness.** In this way we are able to find rare/unsual SLSN.

We manage to **identify 3/4 of all SLSN alerts**! And this high completeness is achieved while maintaining a **purity of 50%.**



Confusion matrix of the classifier applied on the testing sample. Normalized for completeness

Looking at the events wrongly classified as SLSN, we discover that a large proportion are very **luminous SN-IIn**, for which the question of the **continum** with the **SLSN-II** class is still under debate.

These results are promising and should lead to an efficient method to discover interesting SLSN in the public stream of ZTF, and soon LSST.

Photometric telescopes

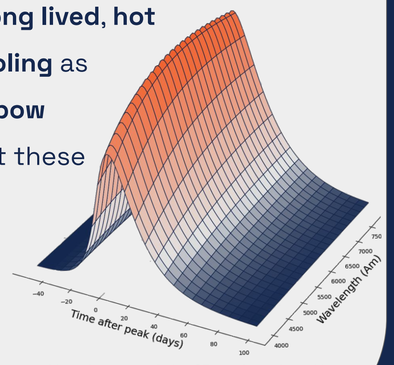
Hundreds of SLSN have been discovered by the **Zwicky Transient Facility (ZTF)**, making it our current best tool to find them. In order to study them live, ZTF triggers an alert everytime a source brightness varies. Currently, ZTF generates **~300k alerts/night**. Extracting information from this amount of data is a true data challenge. Soon, the **Vera Rubin Observatory (LSST)** will start its operation. Using the largest cameraever built, it will produce **~10 million alerts** per night. Among these, we expect to discover **10^4 new SLSNe each year** *(Villar+2018)*, which will drastically increasing our current sample.

The Zwicky Transient Facility located in California has an 1.2 m mirror and a 47 square degrees field of view.

The Vera Rubin Observatory located in Chile has an 8.4 m mirror and a 9.6 square degrees field of view. It will observe with 6 distinct filters

Light curves

Although spectroscopic observation is often required to confidently classify a transient source, the light curve contains information to distinguish various type of events, even **without redshift**. In our case, SLSNe light curves are mostly **long lived**, **hot** and exhibit a **thermal cooling** as they decay. We use **Rainbow** *(Russeil+2024)* to extract these properties. It is a fast **2D parametric fit** which assumes a **blackbody** source and models its **temperature evolution.**



Visualization of the 2D surface fitted by Rainbow on a supernovae.