SEARCH FOR ORPHAN GAMMA-RAY BURST AFTERGLOWS IN RUBIN LSST DATA

HOW TO CREATE A MACHINE LEARNING CLASSIFIER TO IDENTIFY THEM

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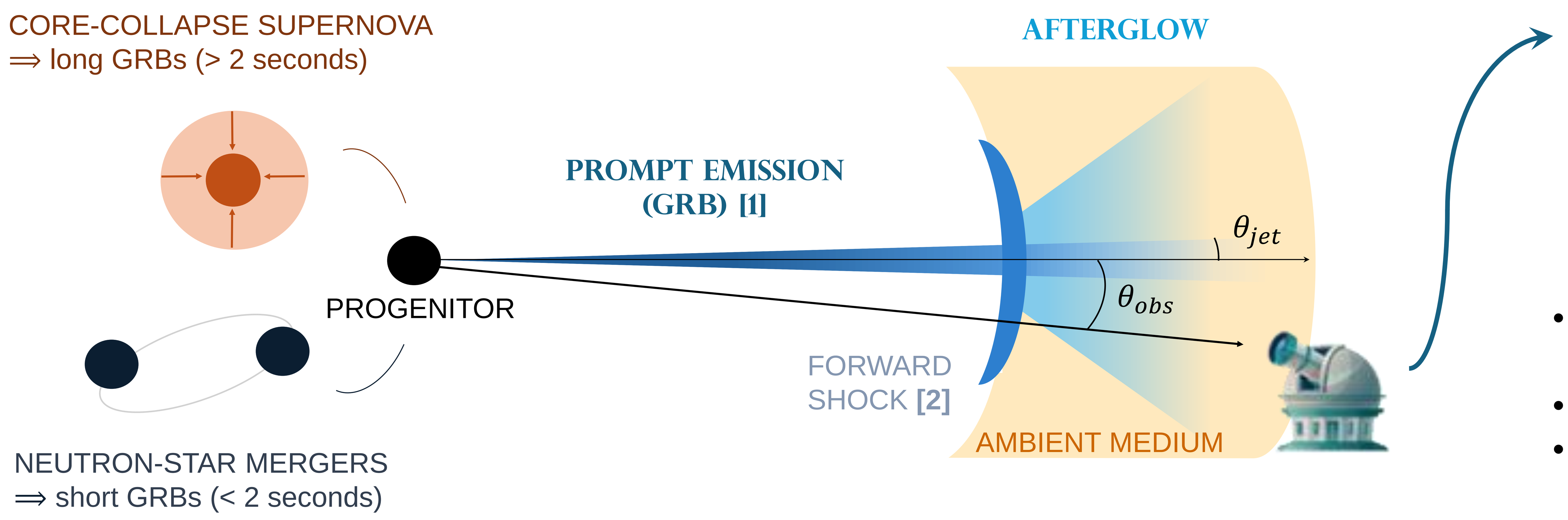
ORPHAN GAMMA-RAY BURST (GRB) AFTERGLOWS: DEFINITION



$\theta_{obs} > \theta_{jet} \Longrightarrow$ ORPHAN AFTERGLOW

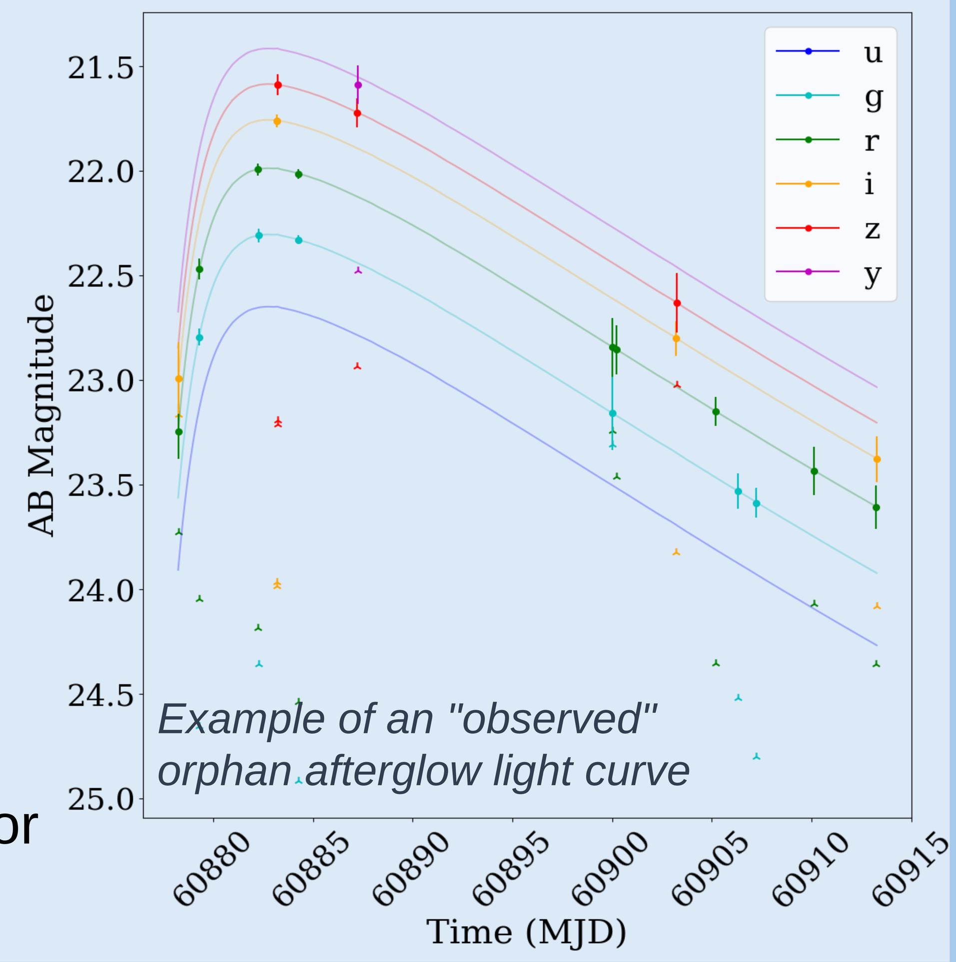
Hard-to-find, faint and slow transients

MOTIVATIONS

- Learn more about GRB physics and their progenitors,
- Help constrain jet structure,
- **Multi-messenger analysis with gravitational waves [3].**

STEP 1: CREATE A POPULATION OF ORPHAN AFTERGLOWS

- Simulation of a **realistic short GRB population** based on the **SBAT4 catalogue**,
- Generation of their **off-axis afterglow multi-wavelength light curves** with **`afterglowpy` [4]**
- **Simulation of their observation** with the **`rubin_sim`** scheduler emulator

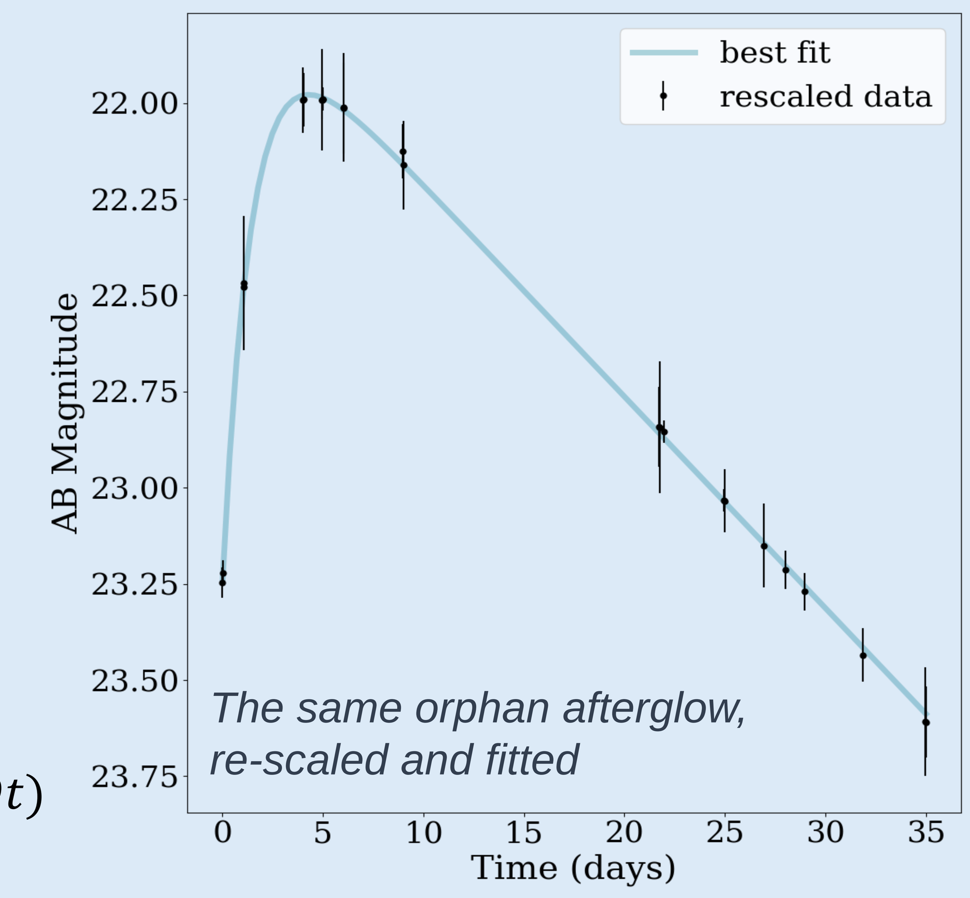


Example of an "observed" orphan afterglow light curve

STEP 2: CHARACTERISE LIGHT CURVES

- **Straightforward features** (colours, rise and fall durations...)
- **Re-scaling** of the point to the r-band using $F_\nu \propto t^{-\beta}$
- Empirical **fit** with:

$$magAB(t) = At + B + C\exp(-Dt)$$



The same orphan afterglow, re-scaled and fitted

STEP 3: DESIGN A MACHINE LEARNING CLASSIFIER AND CHECK ITS PERFORMANCES

Goal: implement a filter in **Fink [5]** to identify the **best orphan afterglow candidates**

TRAINING
500 orphans
5000 background events

→ **features** →

ML CLASSIFIER
`scikit.learn` Gradient Boosting Classifier

→

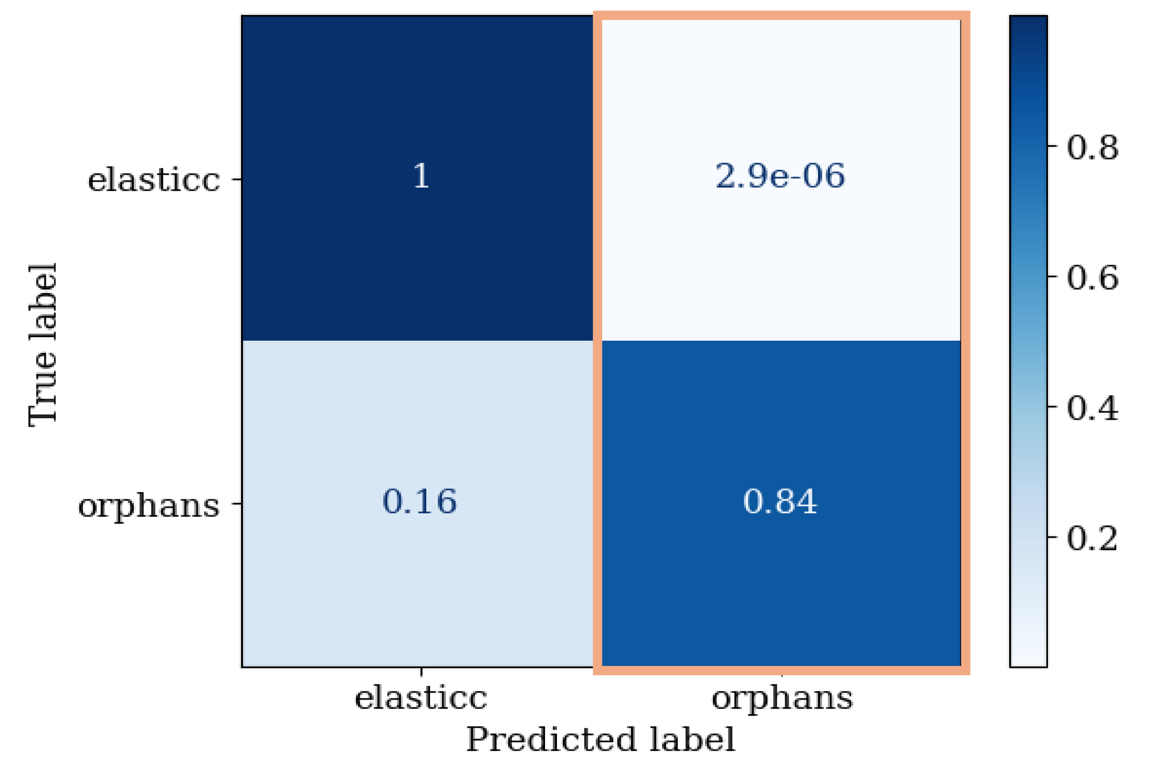
TESTING
1915 orphans
685359 background events

→ **cut = 99.99%** →

84 % of orphans identified
~100% of background rejected
⟹ **99.99% precision**

Background events
ELAsTiCC data set (DESC simulation of synthetic transient light curves for supernovæ, kilonovæ, variable stars... but **not for GRB afterglows**!)

Simulated orphan afterglow population



Confusion matrix of the algorithm

KEY TAKEAWAYS

- We developed a **machine learning algorithm** to identify orphan afterglows in Rubin LSST data, and it manages to **recognise 84% of our simulated orphan afterglow population** and to **reject almost all of the background data [6].**
- Testing filter on-going with ZTF public data and soon with Rubin ComCam DP1 data release

REFERENCES

[1] Sari, R., and T. Piran, 1997, *Ap. J.*, 485, 270+.
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[3] Abbott, B. P. et al., 2017. *Ap. J.*, 848(2):L12.!
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[5] Möller, A., Peloton, J., Ishida, E. E. O., et al., 2020, *MNRAS*, 501, 3272.
[6] Masson, M. and J. Bregeon, 2025, *in prep.*