

Graph based Neural Network–Real-Time Classification of Transient Alerts for the LSST Era: A Fink Science Module on the ZTF Alert Stream

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Abstract

The Vera C. Rubin Observatory’s Legacy Survey of Space and Time (LSST) is expected to generate over 10 million transient alerts per night, far exceeding current photometric follow-up capacity and creating an urgent need for reliable, physics-informed photometric classification at the alert level. Using the Zwicky Transient Facility (ZTF) alert stream as a testbed and precursor to LSST-scale operations, we present a Graph based Neural Network (GNN)-based classification pipeline designed for deployment as a Fink science module, targeting the identification of rare, high-value transients — including peculiar Type Ia supernovae and Gravitationally lensed Superluminous Supernovae (SLSNe-I) — while they are still rising in brightness.

Early efforts using standard deep-learning classifiers trained directly on light-curve patterns achieved only moderate reliability, largely because such models learn statistical patterns without capturing the underlying physical structure of the transient. To address this, we developed a two-stage architecture: an invertible deep-learning model that reconstructs spatial structure from photometric image and light-curve data, followed by a GNN that represents multi-epoch photometric and derived structural parameters as graph nodes, enabling correlation discovery across thousands of parameter pairs. This graph-based representation is used both for classification and for probing open questions in transient sub-classification, including empirical relations for Type Iax supernovae.

The resulting pipeline is designed to flag high-confidence candidates in near real time directly from incoming alert packets, enabling spectroscopic resources to be allocated efficiently to the events most likely to be scientifically valuable — including rare lensed transients that have historically been missed due to follow-up constraints. We discuss the pipeline’s architecture, preliminary classification performance on ZTF data, and its scalability toward LSST alert volumes, positioning this work as a step toward physically-grounded, survey-scale transient discovery in the Rubin/LSST era.

Keywords: Transient classification, Graph based Neural Networks, LSST/Rubin Observatory, ZTF alert stream, Fink broker, photometric classification, gravitationally lensed supernovae, Type Iax supernovae, real-time alert processing, time-domain astronomy