

Investigating the nature of an unusual supernova: Spectroscopic classification, light curve modeling, and dust formation

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This project investigates the unusual supernova ZTF25aatclux, a transient that has received extensive follow-up observations through the RAT survey. The primary goal is to classify this supernova and determine its physical properties, including whether it is forming dust, the nature of its progenitor star, and the mechanism powering its unusual light curve. To accomplish this, spectroscopic observations and optical and infrared light curves were analyzed and compared with those of more typical supernovae. Light curve modeling was performed using tools such as REDBACK to constrain the physical processes responsible for the observed emission, while infrared observations were used to search for evidence of dust formation in the supernova ejecta. By characterizing ZTF25aatclux and comparing it with normal supernovae, this project aims to improve our understanding of supernova evolution, dust formation, and the diversity of stellar explosions, contributing to a broader understanding of the life cycles of massive stars and their impact on the interstellar medium.

The influence of planetary mass on mean-motion resonance type in Kepler and TESS multi-planet systems

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This work investigates how the type of mean-motion resonance (MMR) occupied by neighboring planets depends on planetary mass, using a combined sample of confirmed planets and planet candidates from the Kepler and TESS missions. Compact multi-planet systems frequently exhibit orbital period ratios near small-integer values, whose resonant structure can preserve dynamical signatures of planetary formation and evolution. We identify neighboring planet pairs across nearly 10,000 systems and estimate planetary masses from radii using a standard mass–radius relation. To classify resonant pairs, we develop an adaptive tolerance scheme based on Farey-sequence mediant theory, in which the tolerance decreases as resonances become more closely spaced, avoiding the limitations of a single fixed tolerance. We find that lower-mass planet pairs preferentially occupy tighter resonances (e.g., 5:4 and 3:2), whereas higher-mass pairs preferentially occupy wider resonances (e.g., 2:1), with high statistical significance (Kolmogorov–Smirnov tests, $p < 0.01$). Standard resonance-capture theory, which depends primarily on the mass ratio of the planets, does not predict this dependence on absolute planetary mass. We therefore test a scaling relation predicted by resonant overstability and find that the observed trend agrees with the predicted direction, although its magnitude is weaker than predicted. An analytic two-body chaos criterion applied to systems with reliable eccentricity measurements further indicates that higher-mass planets at their observed 2:1 spacing are dynamically stable, but would become unstable at tighter separations given their typical eccentricities. This provides a possible dynamical explanation for the observed mass-dependent resonance distribution. Our results suggest that the present-day distribution of resonance types retains signatures of mass-dependent dynamical processes, particularly resonant overstability, that shaped compact planetary systems during and after their formation.

Understanding the cataclysmic variable population in the globular cluster 47 Tucanae

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We search for new cataclysmic variables (CVs) and characterize previously known CVs in the globular cluster 47 Tucanae using ~400 days of HST WFC3/UVIS F300X imaging. We identify several new CV candidates on the basis of variability, CMD position, and X-ray brightness. We also measure a period of 173.7 minutes for the suspected magnetic CV W62, providing evidence against a magnetic classification. Finally, we observe dwarf nova outbursts in two sources, W25 and W36. Our data provide the first well-sampled coverage of an outburst in W25 and the first coverage of the DN decline

in W36. We model both events and interpret them in the context of various statistical relations between DN features, as well as the thermal-viscous accretion disk instability model. We also discuss how W36 departs from standard CV behaviour because its companion is a subgiant rather than a main sequence star.

Identifying and characterizing dipper stars in Taurus

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Dipper stars are a subclass of young stellar objects that exhibit frequent dimming events caused by the dust in the circumstellar disk obscuring the observer's view of the stars' light. The processes that cause dipper behavior in these stars lift the dust above midplane in the innermost part of the disk, enabling us to characterize dust properties where terrestrial planets are expected to form. In this work, we analyze a multifilter photometric dataset from Las Cumbres Observatory's 0.4-meter network of telescopes. The sample of dipper stars comes from the nearby Taurus star-forming region, which hosts a $\lesssim 3$ Myr population of young stars. Here, we determine the stars exhibit dipping behavior during the observing seasons in the Taurus region, then model the dust grain size distributions of each star. We then look for correlations with stellar and disk parameters to identify whether dipper behavior is linked to specific physical conditions.

Detecting short period transiting brown dwarfs in ZTF

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Conventional stellar models predict that in fully convective stars such as low mass M-dwarfs (MDs) and brown dwarfs (BDs) magnetic braking—main mechanism of angular momentum loss—is weakened, suggesting that BD-MD binaries with orbital period less than 10 days are extremely rare. However, recent discoveries of BD-MD binaries ZTF J2020+5033 (2 hour orbit) and ZTF J1239+8347 (57 minute orbit) at relatively close distances suggest that such systems may be more common than was initially believed. We present a pipeline to detect short period BD-MD binaries in ZTF Variability Archive (ZVAR) in order to measure the occurrence rate of ultrashort period BDs. First, we perform a cut that selects eclipsing binaries within a certain range of orbital period, color, and absolute magnitude. We use an ELLC light curve modeling tool coupled with Markov Chain Monte Carlo algorithm to perform parameter estimation and produce a list of objects whose light curves are consistent with BD-MD systems. After obtaining a list of potential candidates we plan to conduct follow up spectroscopy and radial velocity observations to increase confidence in our candidates.

Interpreting AGN and star-formation diagnostics in 5MUSES: A sampling-aware comparison of PAH equivalent width and optical/infrared variability

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Infrared-emitting galaxies can be powered by star formation, accretion onto supermassive black holes, or both. Using the 5 Millijansky Unbiased Spitzer Extragalactic Survey, I examined how spectroscopic and time-domain measurements distinguish these processes. Because the 6.2- μm polycyclic aromatic hydrocarbon (PAH) complex traces star formation whereas the 6.2- μm continuum is associated with emission by dust heated by BH accretion, its equivalent width formed the spectroscopic basis of the analysis. I remeasured it by applying a modern twist to long-established local-continuum approaches, combining spectral decomposition with consistent treatment of weak and undetected features. I then placed these measurements within a broader analysis of galaxy properties and multiwavelength variability, drawing on redshift, mid-infrared continuum slope between warmer and cooler dust emission, optical variability from the Zwicky Transient Facility, and infrared variability from the Wide-field Infrared Survey Explorer and its NEOWISE extension. Infrared-variable sources were concentrated among galaxies with weaker PAH emission, consistent with a stronger active-galaxy

contribution, although not every galaxy with weak PAH emission varied. Considering these relationships together, while accounting for differences in observational sampling, provides a framework for interpreting what combinations of spectral and variability behavior reveal about the connections and co-evolution of star formation and black-hole accretion.

Searching for rare transients from complementary views: A multi representation normalizing-flow framework for astronomical surveys

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The Vera C. Rubin Observatory's Legacy Survey of Space and Time will transform time-domain astronomy by producing millions of transient alerts each night. Its greatest scientific promise includes the discovery of rare, rapidly evolving, and potentially unknown phenomena, yet only a small fraction of these events can receive detailed follow-up. Supervised classifiers alone cannot solve this problem: rare classes are poorly represented during training, entirely new classes have no training examples, and unknown objects may be confidently assigned to known common categories. Anomaly detection provides a way to prioritize such events by identifying light curves that do not conform to the learned population. However, the anomalies recovered by a model depend strongly on how the light curves are represented. Here, we develop a light-curve-only, multi-representation anomaly-detection framework based on normalizing flows. Separate flows learn the distributions of normal transients in two complementary spaces. The first uses physically interpretable light-curve features extracted from parametric and probabilistic reconstructions of multiband photometry. The second uses learned light-curve embeddings produced by the photometric encoder in the AppleCiDER TEMPO pipeline. Both branches operate exclusively on light-curve information, without using spectra or images. Objects with low likelihood under either normal-transient distribution receive high anomaly scores. Because extracted features and learned embeddings encode different geometries of light-curve behavior, their scores provide complementary rather than interchangeable evidence. Using archival Zwicky Transient Facility light curves as a testbed, we find that the two branches reveal different aspects of rarity. Extracted light-curve features provide physical interpretability and expose the effects of sparse sampling, observational coverage, and reconstruction quality, while learned light-curve embeddings provide stronger separation of rare events in the current experiments. The final framework is designed to combine the calibrated scores from both branches, producing a candidate ranking that is not dependent on any single light-curve representation. This approach aims to improve the scientific diversity and reliability of rare-transient prioritization under limited follow-up resources and establishes a scalable methodology for anomaly-driven discovery in the Rubin era.

Characterizing dust from extragalactic Wolf-Rayet binary candidates with the James Webb Space Telescope

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Wolf-Rayet stars are hot and aging stars that have lost their hydrogen layer, exposing the helium-rich interior. Many Wolf-Rayet stars exist in binary systems, and systems with a carbon-rich (WC) Wolf-Rayet star and a massive companion sometimes exhibit episodic dust production regulated by their orbit. While dust-producing WC binaries have been studied extensively in the Milky Way, few extragalactic candidates have been studied. We use the python package `space_phot` to analyze JWST infrared imaging, performing photometry on two dust-producing WC candidates identified in SPIRITS, a time-domain survey with the Spitzer Space Telescope. We then test two approaches to model dust emission, DUSTY and modified black-body fitting. We obtained an optical spectrum of the candidate SPIRITS 14bqe with the Palomar 200-inch Telescope, which ruled out a WC designation. While not a WC system, SPIRITS 14bqe is shown to be dust-producing, and we are exploring alternative explanations of its nature. The second candidate, SPIRITS 16ln, is a confirmed WC star with an observed spectral energy distribution that can be fit by dust modeling techniques. Our analysis demonstrates that JWST observations are ideal for investigating dust production from extragalactic sources like SPIRITS 14bqe and SPIRITS 16ln.

Distinguishing gap transients from Type Ia and II supernovae using photometric classification

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Gap transients are rare events, dimmer than supernovae and brighter than novae. They consist of luminous red novae, thought to be stellar mergers, intermediate-luminosity red transients (ILRTs), which may be due to electron capture supernovae, and other subclasses. Subclass assignment can be difficult. With the advent of Rubin Observatory's Legacy Survey of Space and Time (LSST), many more gap transients will be discovered, making a better classification increasingly important and requiring reliable differentiation between gap transients and frequently detected supernovae. We collected photometric data – measurements of an object's brightness through filters – for a sample of literature and Zwicky Transient Facility gap transients. Using Gaussian processes, we interpolate the photometric data and resample rare subclasses to generate more lightcurves. For comparison with supernovae, we simulate a sample of type Ia and type II lightcurves. We then use two methods: training a Random Forest classifier on photometric features, and transforming lightcurves into 2D histograms for classification with convolutional neural networks. This work explores machine learning methods that may be useful for LSST classification of gap transients.

Variability in broad emission line components of potential intermediate-mass black holes

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Supermassive black hole (SMBH) formation could greatly impact galactic growth and formation since a SMBH lays at the center of each large galaxy we know in the local universe. Studying IMBH behavior could reveal much about SMBH formation and thus galactic growth and formation. Blue compact dwarf galaxies (BCDs) are not massive enough to host SMBHs, so if they have active galactic nuclei (AGN) they would be intermediate-mass black holes (IMBHs). However, relatively few IMBH candidates have been identified. We are looking for variability in the broad components of visible spectroscopic emission lines to identify IMBH candidates. Broad emission components are generated by high velocity gas creating a doppler effect. Looking primarily at BCDs with previously identified broad components, we will examine how they have changed over time. We will compare the flux percentage from data taken using the Magellan Echellette (MagE) Spectrograph in spring 2026 to percentages reported in 2007. Variability was identified in one of the five galaxies in our sample by comparing the percent of flux from the broad component of the H α line of J1143 over time. A significant change was found, indicating J1143 is a likely host of an IMBH. Identifying variability in the broad components of other galaxies would indicate a likely IMBH candidate.

Aluminum among the meteors: Quantifying and tracking the rising impact of space debris reentries

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The increasing frequency of spacecraft reentries may introduce substantial quantities of Aluminum and other anthropogenic materials into the upper atmosphere, yet these events remain difficult to observe systematically from the ground. This study develops a multispectral method for identifying candidate Aluminum-rich space debris reentry events using synchronized Ultra-Violet (UV), Blue, and broadband Visible Light imaging. Aluminum has a strong, discrete atomic emission near-UV line at 396 nanometers when thermally excited; therefore, comparisons among the three channels may help distinguish the narrow-band signature of candidate artificial objects from the continuous blackbody radiation of meteors and other optical phenomena. The instrument combines a UV-sensitive industrial camera with Blue and broadband Visible Light reference cameras and adapts the Global Meteor Network detection and astrometric-calibration framework for multispectral observations. Broadband Visible Light measurements provide star-field calibration, while synchronized Blue observations serve

as a spectral control. Observational validation is still required to establish the system's detection sensitivity and its ability to distinguish reentries from natural events. The long-term goal is a low-cost citizen-science network for monitoring the frequency, trajectories, and atmospheric effects of space debris reentries.

Spatially resolved star formation histories of fast radio burst host galaxies using Keck Cosmic Web Imager

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Fast radio bursts (FRBs) are millisecond-duration extragalactic radio transients whose progenitor systems remain uncertain. Although their host galaxies provide important clues to their origins, measurements integrated across an entire galaxy combine distinct stellar populations and may not represent the environment in which a burst source formed. In this work, we use integral field spectroscopy from the Keck Cosmic Web Imager to study the local environments of twelve FRBs in nearby host galaxies. We developed a spectral analysis pipeline that uses stellar population synthesis and emission-line diagnostics to map stellar ages, metallicities, and recent star formation across each galaxy. These measurements will be used to reconstruct spatially resolved star formation histories and evaluate candidate delay-time distributions, which describe the interval between the formation of a stellar population and the onset of FRB activity. Convolving each galaxy's star formation history with these distributions produces maps of the expected burst rate under different progenitor scenarios. These predictions, when compared to the observed burst locations, provide a direct test of whether FRBs arise promptly from young massive stars or through evolutionary pathways that operate over longer timescales.

Searching for successes and failures of the latest high-redshift galaxy models

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Astronomers' first look at high-redshift galaxies is often in the form of photometry. For decades, astronomers have assumed that the light from high-redshift galaxies is akin to that from local, low-redshift, Milky Way-like galaxies and have used this to infer their properties, leading to inaccurate predictions of stellar mass, redshift, spectral energy distributions, and other properties. To resolve these inaccuracies, astronomers have developed new models that account for the early-universe environments in which these galaxies formed. This project aims to test how well our latest models predict galactic properties of the most distant objects by pinpointing not only where these new models excel but also where they fail to give us an accurate idea of the object we are observing.