

Multi-wavelength studies of Gamma-ray detected Novae

Background

A nova eruption results from a thermonuclear runaway at the base of a hydrogen-rich shell on the surface of an accreting white dwarf (WD) in a binary system (Gallagher & Starrfield, 1978; Starrfield et al., 2016). The released nuclear energy leads to a dramatic expansion of the WD atmosphere that is eventually ejected at velocities of $\sim 500\text{--}5000\text{ km s}^{-1}$ (Barlow et al., 1981; Yaron et al., 2005; Aydi et al., 2020), expelling $\sim 10^{-7}\text{--}10^{-3} M_{\odot}$ of material (Gehrz et al., 1998; Nelson et al., 2014). The expanding envelope causes the optical brightness of the system to increase by 8–18 mag, reaching peak absolute magnitudes in the range $M_V = -4$ to -10 mag. As the ejected envelope dissipates, the system brightness declines on timescales of days to months. Approximately 30 novae erupt in the Galaxy each year, with only ~ 10 typically observed while others remain hidden by dust (Rector et al., 2022; Kawash et al., 2022; Zuckerman et al., 2023). Novae emit across the electromagnetic spectrum from TeV and GeV γ -rays to meter-wave radio wavelengths (Della Valle & Izzo, 2020; Chomiuk et al., 2021a).

Galactic novae are now routinely detected in GeV γ -rays, with 23 systems detected by the Large Area Telescope (LAT) on the *Fermi Gamma-ray Space Telescope* since 2010. Most of these are classical novae: systems with main-sequence donors and very low density circumstellar material (CSM). The luminous γ -rays trace the presence of shocks that for dwarf-donor novae must be internal to the ejecta. The shocks accelerate particles to relativistic velocities, and it is thought that the relativistic hadrons produce γ -rays, while the relativistic leptons produce radio synchrotron (Marti-Devesa et al., 2025). Novae therefore serve as real-time laboratories for particle acceleration in shocks, and enable a comparison of hadronic and leptonic acceleration efficiency. Radio observations may directly trace these shock fronts and regions of particle acceleration. Meanwhile, free-free thermal emission traces the bulk of the ejected mass, which enables estimates of the density of the shock and the overall energetics of the eruption. Gamma-ray luminosities of novae are observed to vary by at least three orders of magnitude. Only 10 classical novae have been both observed in the radio and detected by *Fermi*, and their behaviour is diverse at both wavelengths (Chomiuk et al., 2021b).

Radio observations have the potential to trace an intriguing new correlation that has been noticed in comparing radio and optical/IR light curves of novae. In several systems that formed dust, the time of peak dust obscuration (which shows as a dramatic dip in the optical light curve) corresponds in time precisely with a dramatic synchrotron flare in the radio (Chomiuk et al., 2021b). The interpretation of this correlation is still in its early days, but seems to be hinting that dust formation and shocks are tied together, perhaps because dust forms in the cool, dense, post-shock region (Derdzinski et al., 2017). The sample of high-quality radio light curves of dust-forming novae remains small (~ 4), though, so to more thoroughly understand this phenomenon, we need to grow the sample.

Project outline

In this project, student will engage in the comprehensive reduction and analysis of optical and radio observations of novae V462 Lup and V572 Vel, utilizing data collected from both MeerKAT and MeerLICHT. These observations will be supplemented by data from ASAS-SN and ATLAS all-sky surveys. If time permits, the resulting images can be used for commensal transient searches using existing pipelines such as TRAP and TRON.

Requirements

Basic Python coding and familiarity with the Linux environment are a must. Access to a laptop is required.

Expected outcome

- Basic knowledge/background in thermonuclear eruptions
- Use of CASA package to analyse radio data from MeerKAT
- Measure flux densities from the targets
- Determine the type of emission detected
- Compare radio observations with optical, infrared and Gamma-ray observations

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