Florida Institute of Technology

Senior Capstone Project 2026

Research Proposal:

Mapping Nebular Gas Structure Through Stellar Population Filtering in the Orion Nebula.

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INTRODUCTION

Star-forming nebulae such as M42 offer a rare opportunity to investigate the transition between molecular gas and ionized plasma under the influence of newly formed massive stars. The interplay between feedback and gas kinematics defines the architecture of the surrounding interstellar medium (ISM) and regulates subsequent star formation.

In the Orion Nebula Cluster (ONC), the dominant O- and B-type stars within the Trapezium have carved a cavity of ionized gas within the molecular cloud. However, disentangling stellar light from nebular emission remains a key challenge: continuum from thousands of stars, reflected and scattered light, and spatially variable extinction all complicate direct measurement of the gas emission.

This project therefore focuses on producing **clean, color magnitude diagrams** and **correlated molecular gas and dust distributions**. These color–magnitude diagrams (CMDs) will serve as a diagnostic tool to remove stellar contaminants and quantify spatial distribution maps, allowing accurate recovery of nebular surface brightness. The ultimate goal is to quantify the gas distribution, magnitude, and ionization across the ONC, relating them to the structure of the molecular cloud using their locations on the color-magnitude diagram to guide us.

Methods

Overview This project integrates optical photometry, imaging, and astrometric data to characterize the nebular gas structure in M42. Cam's developed Neural Networks will remove stars, making this methodology applicable to other nebulae.

Data Acquisition Broadband photometry (B, V, or Gaia G/BP/RP) will be used to construct CMDs for spatial distribution. These data will be acquired through the Skynet and FIT telescope networks. All data will be registered on a **World Coordinate System (WCS)** to allow multi-instrument comparison and overlay with external surveys.

Image Processing and Calibration All images will undergo bias, dark, and flat-field corrections, via Cam's Neural Network, with additional photometric calibration derived from standard stars or cross-matched Gaia magnitudes.

CMD Mapping CMDs will be constructed to estimate gas color and magnitude. Rather than serving as a stellar classification tool, the CMD analysis will provide:

- a map of $(B-V)$ and V across the field;
- identification of foreground (blue) and embedded (red) stellar populations for masking or weighting in extinction interpolation;

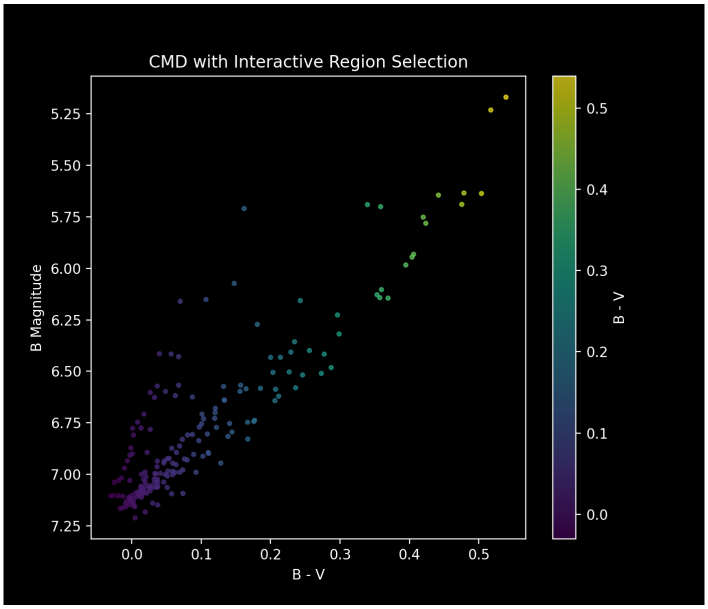

Figure 1: CMD of M42 in B, V Filters

- a spatially smoothed distribution of luminosity and magnitudes map.

Nebular Analysis After stellar and continuum subtraction, The CMB's will further be utilized:

1. **Surface Brightness and Emission Measure (EM)**

2. **Spatial Correlations** — cross-correlation between ionized-gas brightness, and dust optical depth to quantify feedback-driven structures.

Expected Outcomes This project will deliver:

1. Color Magnitude Diagrams of M42.

2. Stellar-subtracted, continuum-corrected images in WCS coordinates suitable for multiwavelength overlay;

3. Spatial distribution analysis between ionized gas, molecular gas, and dust emission;

4. A documented, reproducible pipeline for CMD-based extinction correction and nebular mapping applicable to other Nebula.

Scientific Impact By shifting the CMD's role from direct stellar classification to a tool for extinction and contamination correction, this work bridges stellar and nebular analyses. The resulting maps will provide new insights into how massive-star feedback sculpts the surrounding ISM, and how color and magnitude of nebular gas reveal interesting features.

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