Simultaneous Multi-Color Observations of Planetary Nebulae with ETSI

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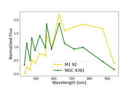
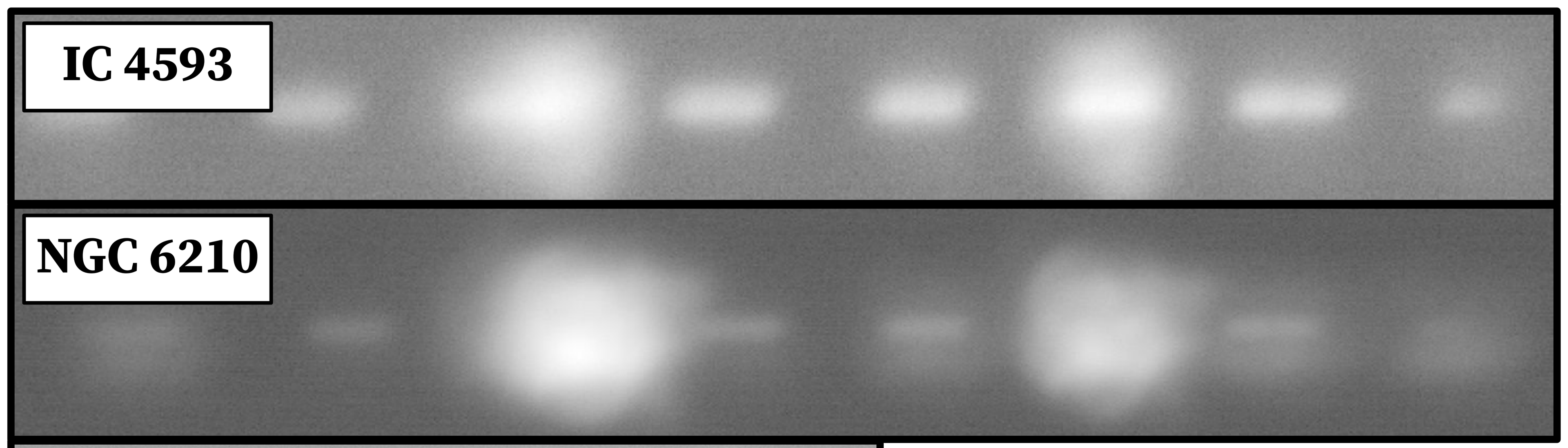


Abstract

We present simultaneous multi-color observations of 9 planetary nebulae taken with the Exoplanet Transmission Spectroscopic Imager (ETSI) on the 2.1m Otto Struve Telescope at McDonald Observatory in the Spring of 2023. These photometric observations are similar to low resolution (R~60) spectroscopic data and provide useful information about the emission features of each nebulae. Additionally, these observations map the morphological features of each element within the nebulae in a single 10 minute observation. We analyze the various emission features of each nebulae and describe a pathway for similar observations using ETSI on a larger telescope.



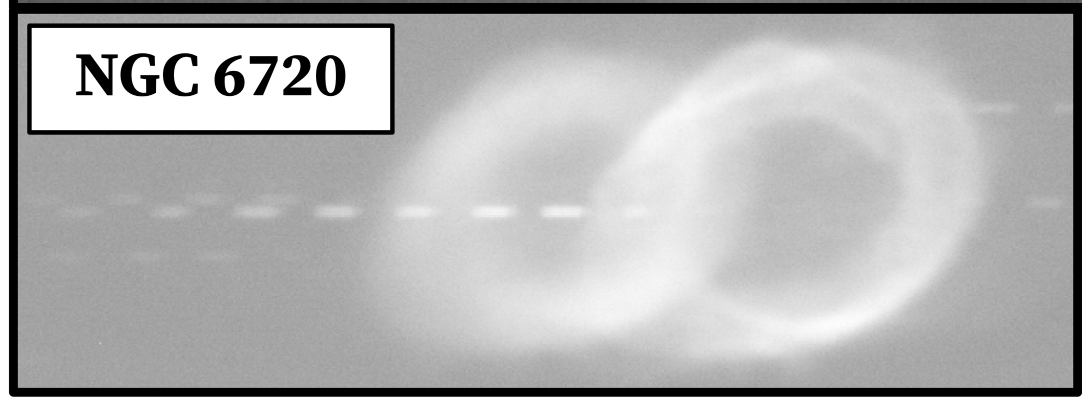


Figure 1: A figure showing three planetary nebulae in a typical ETSI image. The images are *not* blurred, and the objects looks like clouds on the sky. The two bright spots in each image are the Hydrogen alpha and beta spectral features.

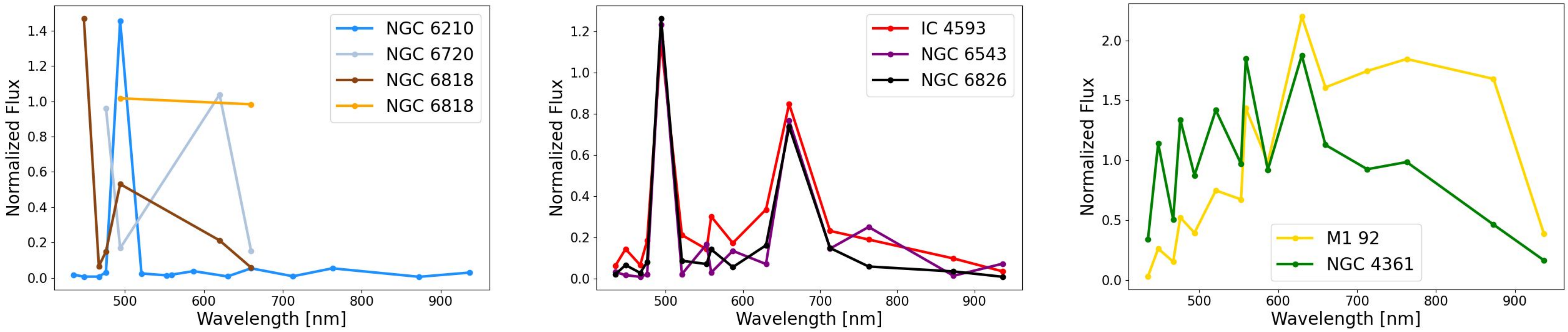


Figure 2: Each observed planetary nebula was categorized into three groups. Irregular (*left*), strong Hydrogen features (*center*), and a smooth spectrum (*right*).

Motivation

Planetary nebulae (PNe) form at the end of an intermediate-mass star's life as the star sheds its outer atmospheric layers in a attempt to remain at hydrostatic equilibrium. PNe consist of ionized gases which help contribute to further enriching the interstellar medium with heavier elements which in turn help to enrich the next generation of stars. By studying PNe, we can dive in depth into stellar evolution studies (DePoy et al. 1994).

We sought to classify several PNe using follow-up observations with ETSI on the 2.1m telescope at McDonald Observatory. ETSI provides simultaneous multi-color observations using a common-light path allowing for super precise relative photometry and color comparisons (~0.01%, Limbach et al. 2020). This instrument is unique because it can classify elements within PNes in a single 10 minute exposure without precise wavelength calibration, greatly simplifying the identification process.

References

1. DePoy, D. L. and Pogge, R. W., 1994, AJ, 433, 725-728
2. Limbach, M. A., Schmidt, L. M., DePoy, D. L., et al. 2020, SPIE, 11447, 114477D

Methods and Discussion

A list of potential PNe was generated from known objects based on their brightness and observability. Next, notable emission features were identified and cataloged for future comparison. Each PNe was then observed using the ETSI instrument on the 2.1m at McDonald Observatory during an observing run in late April and early May of 2023. Each PNe was observed for approximately 10 minutes with exposure times ranging from 1 to 10 seconds. Figure 1 shows real ETSI images obtained on sky. The light from the PNe is split at known wavelengths thanks to a unique multi-color filter.

A `PYTHON` script was written and implemented to generate a summed "master" image for each PNe. The flux of each spectral wavelength was then extracted using the ds9 software with uniquely fit apertures. The background flux was then subtracted from each wavelength's flux and all wavelengths were normalized by the flux from the mean of the 660nm and 494nm bandpasses, which are the closest to Hydrogen alpha and beta - the two brightest features in each panel of Figure 1.

We then cataloged each PNe into one of three groups, as shown in Figure 2: irregular (left panel), strong Hydrogen features (middle panel), and a smooth spectrum (right panel).

Our next steps include a more robust estimation of spectral features.

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