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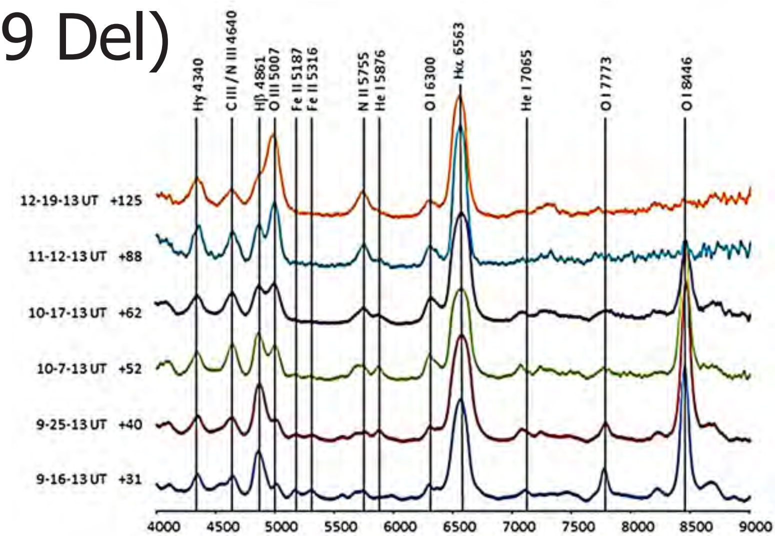
125-Day Spectral Record of the Bright Nova Delphini 2013 (V339 Del)



N Del 2013 spectra for days +31 through +125. The appearance of the forbidden lines of N II and O III accompany the disappearance of O I at the transition to the nebular phase.

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125-Day Spectral Record of the Bright Nova Delphini 2013 (V339 Del)

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Abstract A 125-day spectral record of the evolution of Nova Delphini 2013 (V339 Del), which erupted on 2013 August 14 UT is presented. Spectra were acquired with a low-resolution, 100 line per millimeter grating. Records were acquired beginning one day after discovery and a total of forty-four spectra were analyzed. Despite the low resolution, major phases of evolution of this accreting-white-dwarf nova were recorded. These phases can be readily identified by the oxygen, iron, and nitrogen emission spectra within the range of most commercially available astronomical cameras (e.g. CCD and DSLR).

1. Introduction

The August 14 eruption of the bright Nova Delphini 2013 gave amateur astronomers a rare opportunity to study first-hand the evolution of novae. We present the results of 44 spectra gathered over 125 days with a 100 line per millimeter grating and an inexpensive, commercially-available CCD camera.

The nova was discovered August 14.5 UT by Itagaki (2013) and peaked on 2013 August 16.25 UT at an apparent visual magnitude of 4.3 (Munari *et al.* 2013a). Our first spectrum was acquired 2013 August 15.3 UT (-1 day relative to peak) and nightly thereafter through August 24 UT (+8 days). Additional spectra were acquired every clear night through 2013 December 19 UT (+125 days). After this time Delphinus was too low in the evening sky to image.

Spectra were acquired at SOLO (Studying Old Light Observatory) Observatory, located near Port Wing, Wisconsin. The observatory is a roll-off-roof type featuring a 14-inch Schmidt Cassegrain telescope on an equatorial mount. The system uses a Meade DSI Pro II monochrome CCD camera for image and spectra acquisition.

2. Methods

Spectra were acquired with a Star Analyzer® 100 (Paton Hawksley Education, Ltd. 2014), which is a 100 line per mm diffraction grating, mounted

70 mm from the CCD sensor, which yielded a dispersion of 13.75 Ångstroms/pixel. Dispersion was maximized by spacing the grating at a distance from the image sensor so the zero-order star and first-order spectrum extend across the full width of the sensor. The grating was rotated manually to adjust its horizontal alignment parallel to pixel rows to minimize geometrical artifacts. In addition, care was taken to orient the grating and imager to avoid field contamination from visible zero-order field stars.

The CCD camera was mounted at prime focus with no focal reducer. Images were shot at f/11 with a focal length of 4,086 mm. The CCD imaging camera is a 16-bit Meade DSI Pro II with a Sony ICX429ALL monochrome, front-illuminated, interline CCD image sensor with no coating or UV enhancement and has a sensitivity range of approximately 3900–10,000Å. Dimensions of the sensor are 752 (H) × 582 (V) effective pixels with pixel size of 8.6 (H) × 8.3 (V) µm, yielding a chip size of 7.4 × 5.95 mm and a plate scale of 0.429 arcsec per pixel.

Spectra were recorded by stacking 20 one-second exposures during the early phases of the nova evolution; as the magnitude faded exposure time was increased to 5.7 sec. All exposures were dark-frame subtracted. No bias or flat-field correction was done. After acquiring each spectrum the star 29 Vul, a type A0V star (strong H-Balmer absorption lines) located close to the nova, was imaged.

Spectra were analyzed with the RSPEC® software from Field Tested Systems, LLC (Field 2014), which when coupled with the Star Analyzer 100 provides an easy, very low-cost way for beginners to learn spectroscopy. Wavelength calibration was then done using a two-point method: the nova was used as the

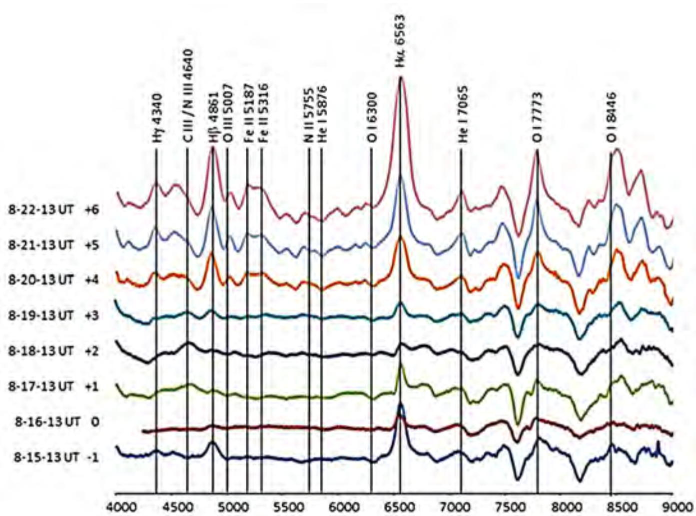

Figure 1. N Del 2013 spectra for days -1 through +6.

zero-order point and the hydrogen alpha emission line at 6563Å was used as the second point. Spectra were then corrected for instrument response using a reference curve generated from the star 29 Vul and were normalized for graphing.

Resolution (R) of the spectra is given by

$$R = \lambda/\Delta\lambda, \tag{1}$$

where λ is the wavelength of interest and $\Delta\lambda$ the smallest difference in wavelength that can be distinguished. The FWHM was determined for the Hβ line from several images and the average was 105Å. Using this value as $\Delta\lambda$ yields a spectral resolution of 46.3.

3. Results and discussion

The 44 normalized spectra were aligned, combined, and labeled in Universal Time and Day relative to peak magnitude of Nova Del 2013. These spectra are plotted for the interval 4000–9000Å and were combined into a single figure. This figure, although extremely helpful in characterizing the phases of evolution, is too large for the format or this journal but can be viewed at http://www.d.umn.edu/~hmooers/NovaDel2013CompositeSpectra.jpg.

Our spectra start at –1 day relative to maximum visible brightness (Munari *et al.* 2013a) during the fireball phase. At this time Hα and Hβ are the only prominent emission lines. By day +2, however, H emissions have all but disappeared but are again prominent by day +3 (Figure 1). On day +5, Fe II at 5187Å and 5316Å, He I at 7065Å, and O I at 7773Å appear.

By day +12, O I emission is increasing rapidly at 6300Å, 7773Å, and 8446Å and Fe II becomes more prominent (Figure 2). As the ejecta thins, however (Bhatia and Kastner 1995), O I 7773Å emission begins to drop and by day +52

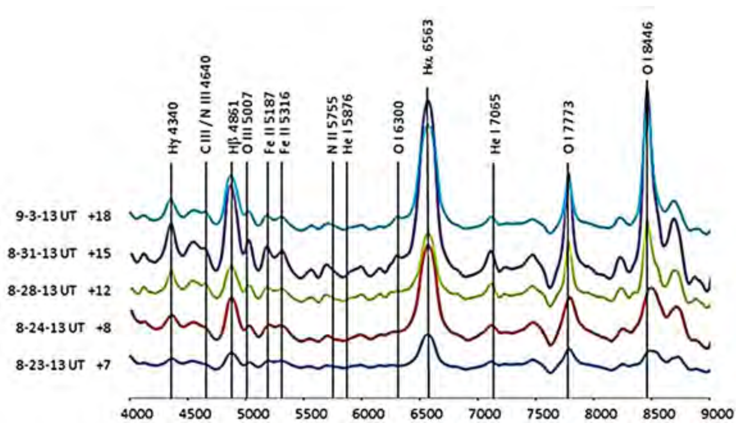

Figure 2. N Del 2013 spectra for days +7 through +18 with the appearance of neutral oxygen (8446Å) and strengthening of the iron lines.

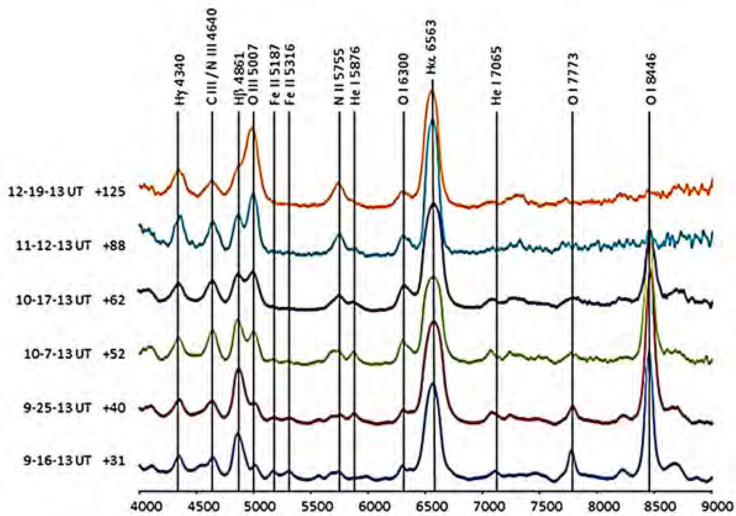

Figure 3. N Del 2013 spectra for days +31 through +125. The appearance of the forbidden lines of N II and O III accompany the disappearance of O I at the transition to the nebular phase.

is no longer discernible (Figure 3). Also at this time (day +52) the nebular lines of the C III/N III complex at 4640Å and particularly O III at 5007Å appear (Figure 3). The appearance of the forbidden transitions O III 5007Å and N II 5755Å accompany the thinning of outer ejecta, which is characteristic of the late stages of the expansion (Shore 2012, p. 10). By day +62 the O III 5007Å line has equaled Hydrogen β in intensity and corresponds to the flattening of the visible light curve around day +65 (Teyssier 2013) (Figure 3). The increasing intensity of OIII emission is commonly considered to be the beginning of the nebular phase (the optically thin regime of Munari *et al.* (2013b)). Fe II emissions are no longer discernible by this time (Figure 3).

The last several spectra (after day +62) acquired in this study show a curious upturn in the continuum above 9000Å and appear slightly noisier. We do not know the origin of these artifacts but speculate they may result from sky glow, because of the low altitude of Delphinus at this time (below 45° altitude) or other atmospheric effects. These artifacts do not, however, affect the overall utility of the spectra or the identification of emission lines.

4. Conclusions

Low resolution spectra obtainable by nearly any amateur astronomer with relatively modest equipment can be used to study the evolution of novae or investigate a host of other astronomical phenomena. Resolution of spectra is greatly improved by using larger imaging sensors but requires longer exposures because of decreased photon flux per pixel.

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