Monitoring the Continuing Spectral Evolution of Nova Delphini 2013 (V339 Del) with Low Resolution Spectroscopy

Howard D. Mooers
William S. Wiethoff
Department of Earth and Environmental Sciences, University of Minnesota Duluth, Duluth, MN 55812; send email correspondence to hmooers@d.umn.edu

Alexander Evich
Department of Physics and Astronomy, University of Minnesota Duluth, Duluth, MN 55812

Received December 7, 2015; accepted December 31, 2015

Abstract The continuing spectral evolution of Nova Delphini 2013 (V339 Del) is presented with low-resolution spectroscopy collected with a 100 line per millimeter diffraction grating. Spectra were collected on 3 July 2014, and 14 September 2015, 321 and 759 days after peak visible brightness on 16 August 2013. An imaging system was mounted on an equatorially–mounted, 14-inch Schmidt-Cassegrain telescope. The continuum is no longer visible in the spectra, however, OIII (5007 Å) and Hα (6563 Å) are prominent and NII (5755), Hγ (4340 Å) and CIII/NIII (4640 Å) can still be discerned at +759 days.

1. Introduction

Nova Delphini 2013 (V339 Del) erupted on 14 August 2013 UT (Itagaki 2013) and reached a peak magnitude of 4.3 (Munari *et al*. 2013) on 16 August 2015 UT. Mooers and Wiethoff (2014) presented a 125-day, low-resolution spectral record of the nova acquired with relatively modest equipment available to nearly any amateur astronomer. Here we update the spectral evolution of this bright nova with additional low resolution spectra collected on 3 July 2014 UT and 14 September 2015 UT, 321 and 759 days after maximum visible brightness, respectively. In particular, we emphasize the capabilities for this type of observation that have become available to the amateur astronomer. Although this low resolution spectral analysis will not lend significantly to the understanding of nova evolution, it does provide a mechanism for the amateur to study variable stars in a rigorous way and learn the techniques of professional observational astronomy. There are, however, many ways that the amateur community plays a critical role in variable star research, and their contributions have been recognized for many years (Lankford 1981; Percy 1998). The professional community is limited in the number and availability of equipment, particularly large telescopes, as time on them is typically reserved for "deep" objects. For many projects the professional astronomers rely on the amateur community and smaller telescopes that are relatively abundant. In fact, the AAVSO was founded in the idea of forging strong collaborations between amateur and professional astronomers (for example, the Citizen Sky Program (https://www.aavso.org/citizensky); see also the AAVSO Vision/Mission Statement (https://www.aavso.org/visionmission)).

In the study of variable stars, the contribution of photometric observations of the amateur community is critical given the large number of variable star candidates. With the proliferation of very capable backyard telescopes and the rapidly decreasing cost of high-quality astronomical cameras, filters, and software, the professional astronomers have come to rely on amateurs to produce reliable, high-quality data. Variable stars are an important tool in astrophysics for the understanding of stellar origin and evolution including stellar properties, such as mass, radius, luminosity, temperature, internal and external structure, and composition. Much of this information would be difficult or impossible to obtain in other ways.

2. Methods

The imaging system is mounted on a 14-inch Schmidt Cassegrain telescope on an equatorial mount. As with the spectra described by Mooers and Wiethoff (2014) the spectrum reported here was acquired with a STAR ANALYZER® 100 (Paton Hawksley Education, Ltd. 2014), a 100-line-per-mm diffraction grating. The grating was mounted 70 mm from the sensor of a Meade DSI Pro II CCD camera, which has a Sony ICX429ALL CCD with dimensions of 752 (H) × 582 (V) pixels of 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. Spectral dispersion was 13.75 Å/pixel. The camera was mounted at prime focus with no focal reducer. Images were shot at f/11 with a focal length of 4,086 mm. Spectral resolution is 46.3.

Images were acquired on 3 July and 14 September 2015 UT. Photometry was measured using AIP4WIN software (Berry and Burnell 2000) and the spectrum was analyzed with RSPEC® software (Field Tested Systems 2014).

3. Results

Figure 1a shows N Del 2013 at its maximum magnitude of 4.3 (Munari *et al.* 2013) on 16 August 2013. Figure 1b was taken on 14 September 2015 with a calculated apparent visual magnitude of 13.61 and 13.25 using AIP4WIN software and the GSC and USNO A 2.0 catalogues, respectively, for calibration magnitudes. Figure 1c shows the spectrum of N Del 2013 acquired on 14 September 2015. The continuum is no longer visible, however, the OIII (5007 Å) and Hα (6563 Å) emission

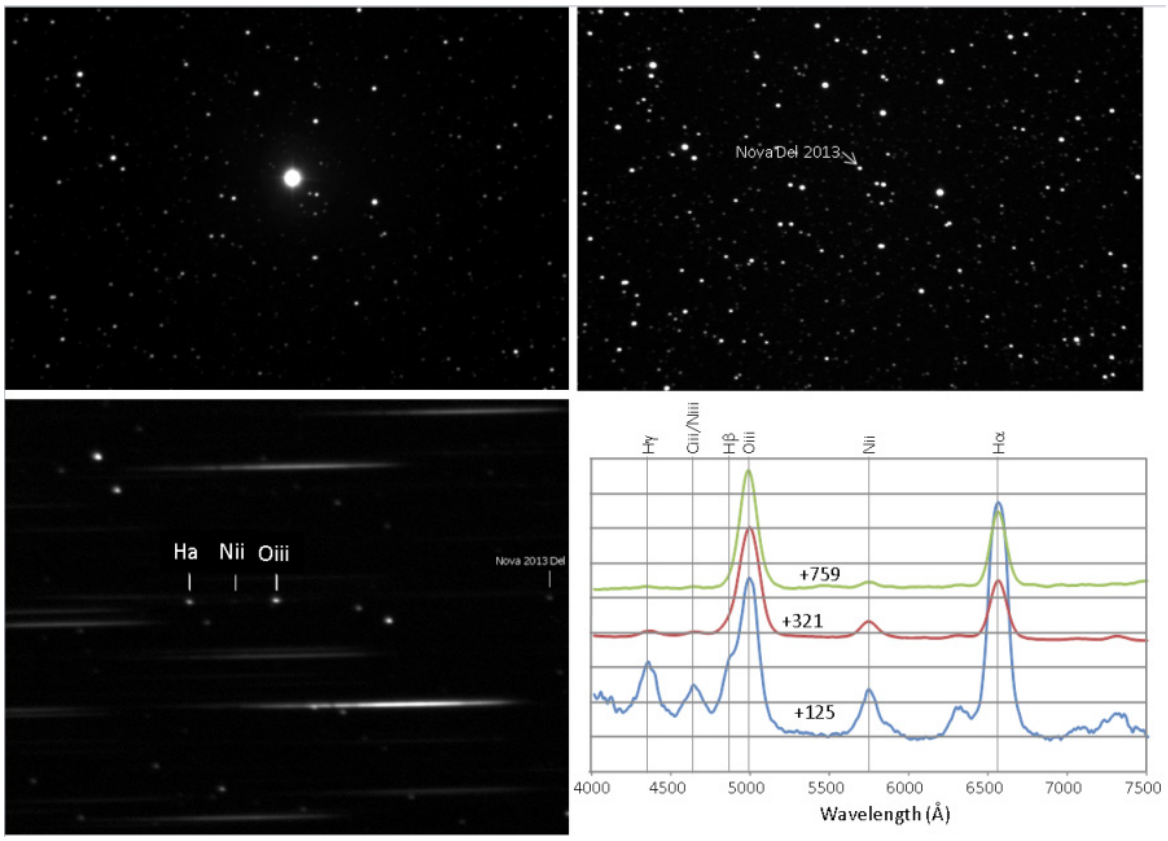

Figure 1. N Del 2013 (V339 Del): a) at maximum magnitude of 4.3 on 16 August 2013; b) calculated apparent visual magnitude of 13.61 and 13.25 on 14 September 2015; c) spectrum acquired on 14 September 2015, continuum no longer visible but the OIII (5007 Å) and Hα (6563 Å) emission lines are prominent and the NII (5755) emission line is also faintly visible; d) the calibrated, normalized spectra acquired on 3 July 2014 and 14 September 2015, along with the spectrum from day +125 (Mooers and Wiethoff 2014). Hγ (4340 Å) and CIII/NIII (4640 Å) that were clearly visible at +125 days can still be discerned at +759 days.

lines are prominent and the NII (5755) emission line is also faintly visible (Figure 1c). Figure 1d shows the calibrated, normalized spectra acquired on 3 July 2014 and 14 September 2015, along with the spectrum from day +125 (Mooers and Wiethoff 2014). Hγ (4340 Å) and CIII/NIII (4640 Å) that were clearly visible at 125 days can still be discerned at 759 days.

4. Discussion and conclusions

The amateur astronomical community has played a significant role in data collection for the professional community. Often amateurs are captivated by the prospect of producing fabulous astrophotography and along the way learn the techniques of professional image processing. However, the knowledge and tools of the amateur community are easily applied to problems of variable star research. The study of Mooers and Wiethoff (2014), and this continuation and update of the evolving spectrum of N Del 2013, illustrate potential for furthering the development of the amateur astronomical community (Percy 1998). Although the nebular phase of classical novae continues to evolve over many years (Krautter and Williams 1989; Slavin *et al.* 1995), most of the spectral evolution is beyond the capabilities of low-resolution spectroscopy. However, this kind of study piques the interest, develops the analytical skills, and demonstrates the capabilities of the amateur astronomer.

References

Berry, R., and Burnell, J. 2000, Astronomical Image Processing, Willman-Bell, Richmond, VA.

Field Tested Systems, LLC. 2014, RSPEC® software (http://www.rspec-astro.com).

Itagaki, K. 2013, *IAU Cent. Bur. Astron. Telegrams Transient Object Followup Rep.* 2013, 08 14.584 (http://www.cbat.eps.harvard.edu/unconf/followups/J20233073+2046041.html).

Krautter, J., and Williams, R. E. 1989, *Astrophys. J.*, **341**, 968.

Lankford, J. 1981, *Social Stud. Sci.*, **11**, 275.

Mooers, H. D., and Wiethoff, W. S. 2014, *J. Amer. Assoc. Var. Star Obs.*, **42**, 161.

Munari, U., Dallaporta, S., Cherini, G., Valisa, P., Cetrulo, G., Milani, A., and Ghirotto, L. 2013, *Astron. Telegram*, No. 5304, 1 (http://www.astronomerstelegram.org/?read=5304).

Paton Hawksley Education, Ltd. 2014, STAR ANALYZER® 100, 100 line per mm diffraction grating (http://www.patonhawksley.co.uk/staranalyser.html).

Percy, J. R. 1998, in *New Trends in Astronomy Teaching*, eds. L. Gouguenheim, D. McNally, J. R. Percy, IAU Colloquium 162, Cambridge Univ. Press, Cambridge, 205.

Slavin, A. J., O'Brien, T. J., and Dunlop, J. S. 1995, *Mon. Not. Roy. Astron. Soc.*, **276**, 353.