The Detailed Light Curve Evolution of V1674 Her (Nova Her 2021)

R. M. Quimby, A. W. Shafter, and H. Corbett

1Department of Astronomy and Mount Laguna Observatory
San Diego State University, San Diego, CA 92182, USA
2Kavli Institute for the Physics and Mathematics of the Universe (WPI)
The University of Tokyo Institutes for Advanced Study
The University of Tokyo, Kashiwa, Chiba 277-8583, Japan
3Department of Physics and Astronomy
University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3255, USA

ABSTRACT

We report high-cadence photometry of the ultra-fast ($t_2 \sim 1.2$ d) nova V1674 Her during its rise to maximum light ($V \sim 6.3$) and the beginning of its subsequent decline. These observations from Evryscope and the Mount Laguna Observatory All-Sky Camera reveal a plateau in the pre-maximum light curve at $g \sim 14$ ($\sim 8$ mag below peak) that lasted for at least three hours. Similar features (so-called pre-maximum halts) have been observed in some novae near maximum light, but to our knowledge the detection of a plateau in the light curve $\sim 8$ mag below peak is unprecedented.

Keywords: Classical Novae (251) — Light Curves (918) — Time Domain Astronomy (2109)

1. INTRODUCTION

V1674 Her (Nova Her 2021) was discovered by Seiji Ueda (Kushiro, Hokkaido, Japan) on 2021 June 12.5484 UT near magnitude 8.4. The object subsequently rose to reach a peak visual brightness of $V \equiv 6$ on 2021 June 12.9 UT according to observations reported to the AAVSO. The nova then faded rapidly, declining by $\sim 2$ mags in approximately a day. Novae with $t_2$ times this short are extremely rare, and the object has been monitored at multiple wavelengths since its discovery (e.g., Page et al. 2021; Woodward et al. 2021; Sokolovsky et al. 2021; Aydi et al. 2021; Munari et al. 2021). The quiescent counterpart has been identified and a recent analysis has revealed an 8.4-min period in the progenitor binary that likely reflects the rotation period of the accreting white dwarf (Mroz et al. 2021). In addition, recent spectroscopic observations by Wagner et al. (2021) have revealed strong [Ne V] 342.6 nm and the [Ne III] pair at 386.9, 396.8 nm, which establish the object as a member of the class of “Neon Novae” (Gehrz et al. 1998).

In this Research Note we report photometric observations of V1674 Her obtained with unprecedented coverage and temporal resolution using the Evryscope and the All-Sky Camera (ASC) at the Mount Laguna Observatory (MLO). The Evryscope consists of an array of 20 6.1-cm aperture telescopes that monitor $\sim 7400$ square degrees simultaneously and continuously every two minutes (Law et al. 2014). There are two Evryscopes currently in operation: Evryscope South at Cerro Tololo, Chile (CTIO), and Evryscope North at MLO. With a limiting magnitude reaching $g \sim 14$, the Evryscope is a useful instrument to monitor bright transients such as classical novae. In the case of V1674 Her, which just reached naked-eye brightness, the object proved to be too bright for the Evryscope, with all measurements with $g \lesssim 9$ being saturated. Fortunately, MLO is equipped with an ASC that is nominally used to monitor the weather during remote observing runs. The MLO-ASC is an Alcor-System OMEA 8M that records FITS images with 10 s integrations followed by $\sim 5$ s for readout and processing. The ASC detector was cooled to $-3^\circ$ C, but dark current subtraction and flat-fielding have not yet been implemented. However, by stacking raw ASC images into roughly 5-min
Figure 1. The complete light curve of V1674 Her based primarily on our preliminary Evryscope and ASC observations. The data have been augmented by photometric measurements from the AAVSO, CBAT and ASAS-SN. The Evryscope observations reveal pre-maximum plateau, lasting for \( \sim 3 \) hr, that is highlighted in the insert. Details of the various symbols and fits to the light curve are given in the figure legend.

bins (\( \sim 20 \) frames), we can mitigate these signals and reach limiting magnitudes of \( \sim 9 \) mag calibrated to the Gaia band. Thus, the ASC nicely complements our Evryscope observations.

2. THE LIGHT CURVE

Figure 1 shows our combined Evryscope and ASC light curve for V1674 Her. The most striking feature is the plateau seen near \( g = 14 \) in the pre-maximum light curve. The aperture photometry may include some light from neighboring objects, but no source has been significantly detected at this position in 150 previous nights of Evryscope observations and visual inspection of the images suggest the appearance of a faint source between MJDs 59377.248 and 59377.275. The existence of the plateau is further supported by two photometric points from the All-Sky Automated Survey for Supernovae (ASAS-SN, Shappee et al. 2014) database – the first on MJD 59377.1956 at \( g = 16.2 \), and the second on MJD 59377.1968 at \( g = 16.4 \) – that together with our Evryscope observations constrain the length of the pre-maximum plateau to be less than 3 hr. We are unaware of any additional photometry that would help constrain the evolution of the nova prior to reaching the plateau.

We have fit the early rise with a model of the early fireball as a uniformly expanding spherical blackbody of radius \( R(t) \) and (assumed constant) effective temperature, \( T_{\text{eff}} \). The time evolution of the observed flux in such a model is given by:

\[
f(t) = \left[ \frac{\theta(t)}{d} \right]^2 \sigma T_{\text{eff}}^4,
\]

where \( \theta(t) = R(t)/d \) is the angular radius of the expanding photosphere.

Assuming that the fireball expands with constant velocity (i.e., \( R \propto t \)), we see that \( f \propto t^2 \). This simple model, which is shown as the dotted line in Figure 1, allows us to estimate the time of the initial explosion to be at approximately MJD 59377.1575. We note that this time is \( \sim 3 \) hr earlier than one would estimate based on an extrapolation of the later, post-plateau, rise recorded by Evryscope between MJDs 59377.2793 and 59377.3278. The best-fit power-law over this range is \( f \propto t^{1.2} \) (dashed line in Fig. 1).

To estimate the time and magnitude at peak we have fit a 6th-order polynomial to a combination of the ASC time-series and the AAVSO and CBAT data points. The fit shows that peak brightness reaches \( m \sim 6.3 \) (pseudo V magnitude) at MJD 59377.722, and fades by two magnitudes in 1.18 d. This value is comparable with other estimates
of $t_2$ (e.g., Aydi et al. 2021, $t_2 \lesssim 1$ d), and suggests that V1674 Her is arguably the fastest nova on record [the recurrent nova U Sco also has a $t_2$ time reported to be $\sim 1.2$ d (Schaefer 2010)].

3. CONCLUDING REMARKS

V1674 Her is the first nova where the pre-maximum rise has been observed in great detail thanks to the availability of modern automated sky patrols (e.g., Evryscope and ASAS-SN). Observations made possible by these instruments have allowed us to discover a pre-maximum plateau in the light curve of V1674 Her well below maximum light. The plateau appears to exhibit fluctuations of order 15 min that may be related to the 8.4 m periodicity reported by Mroz et al. (2021). The plateau is reminiscent of the pre-maximum halts observed just below peak in some novae (e.g., Hounsell et al. 2010, 2016), although in V1674 Her the feature occurs relatively early in the eruption and well below maximum light. The physical process or processes causing the plateau is currently unclear, but may be related to radiation from a precursor UV flash or the result of changes in the structure of the convective zone in the nova’s expanding photosphere (e.g., see Hillman et al. 2014). Further modeling will be required to fully understand the nature of the pre-maximum plateau in V1674 Her.

REFERENCES

Aydi, E., Sokolovsky, K. V., Chomiuk, L., et al. 2021, The Astronomer’s Telegram, 14710, 1
Gehrz, R. D., Truran, J. W., Williams, R. E., & Starrfield, S. 1998, PASP, 110, 3, doi: 10.1086/316107
Hillman, Y., Prialnik, D., Kovetz, A., Shara, M. M., & Neill, J. D. 2014, MNRAS, 437, 1962, doi: 10.1093/mnras/stt2027
Hounsell, R., Bode, M. F., Hick, P. P., et al. 2010, ApJ, 724, 480, doi: 10.1088/0004-637X/724/1/480
Hounsell, R., Darnley, M. J., Bode, M. F., et al. 2016, ApJ, 820, 104, doi: 10.3847/0004-637X/820/2/104
Law, N. M., Fors, O., Wulfken, P., Ratzloff, J., & Kavanaugh, D. 2014, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 9145, Ground-based and Airborne Telescopes V, ed. L. M. Stepp, R. Gilmozzi, & H. J. Hall, 91450Z, doi: 10.1117/12.2057031
Mroz, P., Burdge, K., Roestel, J. v., et al. 2021, The Astronomer’s Telegram, 14720, 1
Munari, U., Valisa, P., & Dallaporta, S. 2021, The Astronomer’s Telegram, 14704, 1
Page, K. L., Orio, M., Sokolovsky, K. V., & Kuin, N. P. 2021, The Astronomer’s Telegram, 14747, 1
Schaefer, B. E. 2010, ApJS, 187, 275, doi: 10.1088/0067-0049/187/2/275
Shappee, B. J., Prieto, J. L., Grupe, D., et al. 2014, ApJ, 788, 48, doi: 10.1088/0004-637X/788/1/48
Sokolovsky, K., Aydi, E., Chomiuk, L., et al. 2021, The Astronomer’s Telegram, 14731, 1
Wagner, R. M., Woodward, C. E., Starrfield, S., Banerjee, D. P. K., & Evans, A. 2021, The Astronomer’s Telegram, 14746, 1
Woodward, C. E., Banerjee, D. P. K., Wagner, R. M., Starrfield, S., & Evans, A. 2021, The Astronomer’s Telegram, 14728, 1