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Nova Circini 2018 - Star of the Year

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There are a number of types of eruptive variables, collectively called novae (from the Latin "nova stellorum", or new star), that appear suddenly and without warning in the sky. They are not really new stars - most involve white dwarfs approaching the end of their lives - but they increase dramatically in brightness, often appearing where no star has been seen before.

The most spectacular, and rarest, are the supernovae, powered by gravitational collapse of either a massive stellar core or a Chandrasekhar-mass white dwarf. Type Ia supernovae (white dwarf supernovae) reach absolute magnitude -19, increasing in brightness to rival their host galaxies. It is estimated that a supernova occurs once every 50-100 years in galaxies like the Milky Way.

The most common eruptive variables are the dwarf novae, a variant of cataclysmic variables (CVs). In these interacting binary systems an instability in the accretion disk causes the disk to collapse and drain onto the white dwarf, releasing half its potential energy in heating the disk. Their brightnesses increase by a few magnitudes for a few days to weeks. Examples include GK Per and SS Cyg.

In the middle are the galactic novae - neither super nor dwarf. These are the manifestations of thermonuclear runaways - basically hydrogen bombs - in accreted material on the surfaces of white dwarf stars in accreting binary systems.

All accreting white dwarfs, including all cataclysmic variables, will experience nova explosions, with recurrence rates depending on the mass of the white dwarf and the mass accretion rate. All dwarf novae (notably GK Per and V392 Per) undergo nova explosions when the mass of accreted hydrogen-rich material accumulated from many dwarf novae events reaches critical mass. And if novae gain mass over time (a question to which the answer is a definite maybe), some may reach Chandrasekhar mass and die spectacularly as type Ia supernovae.

Novae are important for the galactic ecosystem because they recycle low-atomic-number elements into the interstellar medium (ISM). Nucleosynthesis in novae is a major source of the ^{13}C, ^{15}N, and ^{17}O in the Galaxy, and may be responsible for most of the Lithium present in the Galaxy today. A large fraction of novae form dust, and disperse it into the ISM at velocities of a few hundred to a few thousand km/s. Some novae are transient sources of gamma-rays, and many become super-soft X-ray sources when the surface of the hot white dwarf becomes visible.

About 50 times a year a nova appears in our Galaxy, brightening by between about 6 and 20 magnitudes before fading away, on timescales of a few days to a few years (only about half of these novae are discovered). Most novae are far, far away in the galactic bulge, and shine at V~10, but every few years one or two reach naked eye brightness. The brightest nova of 2018 to date was discovered in the southern constellation of Circinus on 19 January by amateur astronomer John Seach of Australia.

N Cir 2018 (PNV J13532700-6725110, 5.8V–17.3G, RA 13h 53m 27.59s (J2000), Dec –67° 25′ 00.9″) was discovered at about 9th magnitude and brightened steadily for about 8 days to V~6. Such an early discovery is rare, because novae are generally discovered at or past peak brightness. Early discovery offers the opportunity to study the physical processes as the nova expands and starts to interact with the local ISM.

N Cir is an exceptionally slow nova, which facilitated the pre-maximum discovery. Like most very slow novae, it has a complex light curve, with a slow fading trend superposed on irregular fluctuations of up to +/- 1.5 mag in all bands (B through K). In fact, the peak observed brightness of V=5.77 mag was not reached until 61 days after discovery, some 53 days after its initial peak.

The visible nova early-on is called a fireball - an expanding opaque surface (a photosphere). Spectroscopically, the nova at this phase resembles the photosphere of an F supergiant (effective temperature about 8000K), but one expanding at a typical velocity of about 600 km/s. The line profiles combine blue-shifted absorption from gas on the line of sight with unshifted emission lines - called a P Cygni profile - a clear signature of a strong wind blowing outward from the star. Near maximum light the emission lines, with exception of H-alpha, disappear, while the blue-shifted absorption lines remain. As the fireball starts to fade, emission lines of hydrogen, oxygen, sodium, and singly ionized iron and calcium return. With each large fluctuation in the optical brightness, new absorption systems (cool absorbing gas at discrete velocities) appear, likely indicating newly ejected shells of material.

Like most slow novae, N Cir seems to have formed dust. This occurs when the temperature of the ejected material cools enough that molecules can form. If the densities are high enough, these can stick together and form silicate or carbonate grains. Novae are a laboratory for the real-time analysis of dust-formation processes. After 5 months the blue and visible light faded relative to the K-band brightness. It is not yet clear whether this is due to absorption of optical light by cool dust on the line of sight, or emission from warm dust in a shell surrounding the nova, or both.

The complexity of the optical/near-IR light curve, and of the detailed evolution of the optical spectra, belie the textbook description of a nova as a simple explosion, after which all that is left is an expanding, cooling envelope. Because the properties of novae depend on the parameters of the underlying CV (especially the mass of the white dwarf), and the ejecta are not spherically-symmetric (novae seem to have fast bi-polar outflows and slower equatorial tori), all novae appear different, despite their underlying commonality.

Because its evolution has been so slow, N Cir may be an explosion on a low mass white dwarf. The complexity of the light curve, and the optical spectra, suggest that we may be observing N Cir near its equatorial plane, through a slowly-expanding equatorial torus.

As of early September 2018, N Cir is entering the next phase of its evolution. The X-ray brightness is slowly increasing, suggesting that the hot surface of the white dwarf left behind is now becoming visible through the expanding, thinning ejecta. The white dwarf may not yet be done burning up its accreted Hydrogen layer.

We are fortunate that N Cir 2018 was discovered by attentive observers early in its observing season. We will have observed over 8 months of its evolution before it slips behind the Sun. What will come out the other side when we can get back to it in December? Will we still be peering through an optically-thick envelope, or will the clouds have parted to reveal a nova in the nebular phase, with transparent gas shells heated by the revealed hot white dwarf?

Novae have a way of surprising us, and a lot can happen in 2 months.

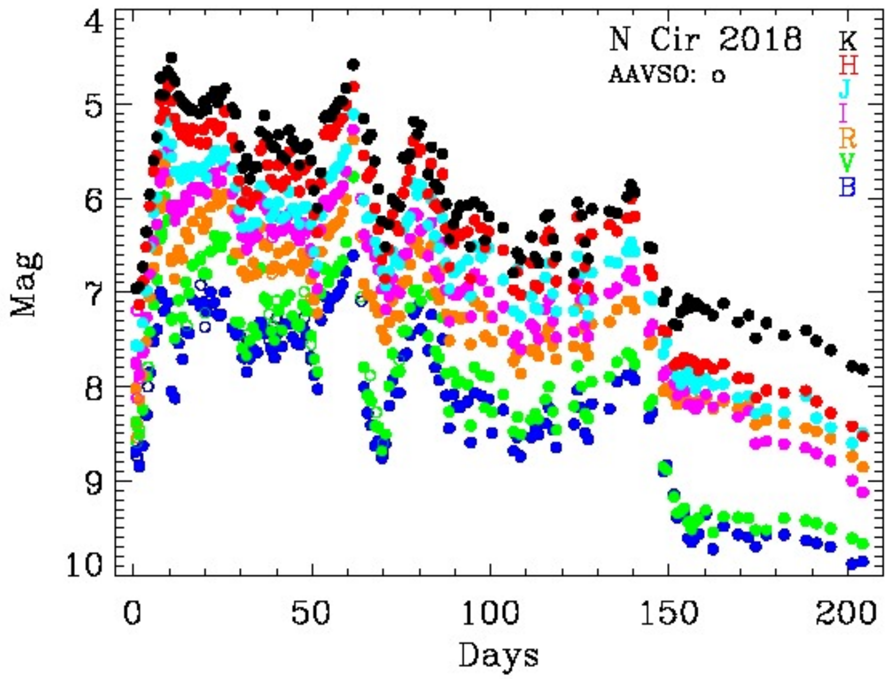

Figure 1. Multicolor light curve of N Cir 2018 (data from FMW and AAVSO). Possible dust event is evident around day 150, but the light curve is unusual.

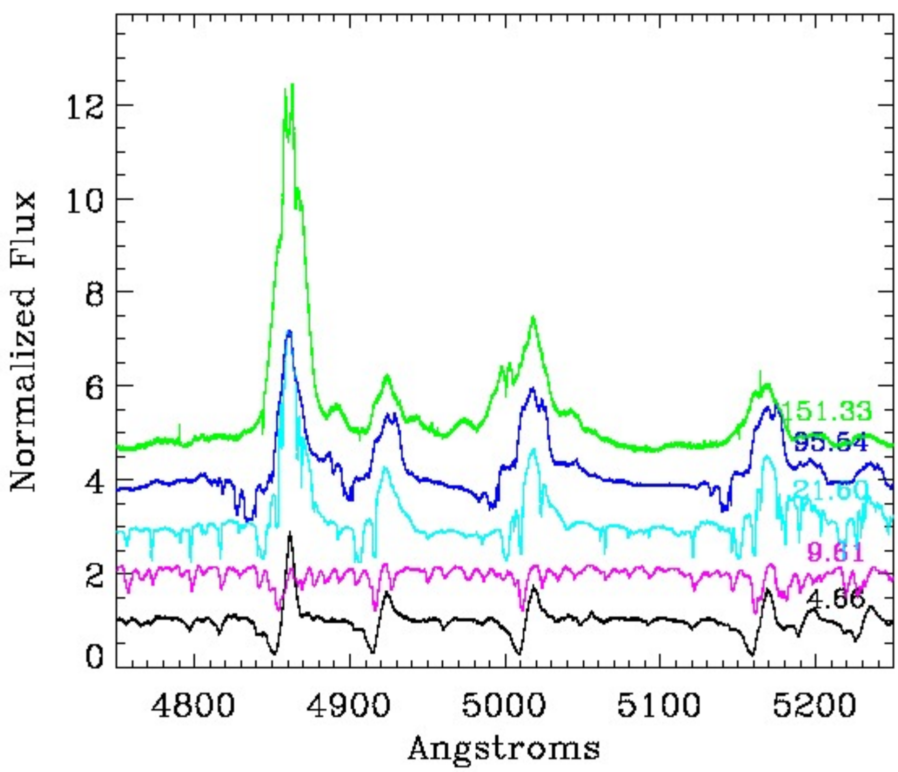

Figure 2. Five spectra of N Cir 2018 in the region of the Hβ and Fe II multiplet 42 lines. These spectra were taken with the SMARTS 1.5m with the Chiron fiber-fed echelle spectrograph, at a resolution of 78,000. The continua are set to 1, and offset by one unit from the previous

spectrum. The day of observation (in days after discovery) is shown on the right side of the plot. Hβ (4861 Angstroms) and the three strong Fe II (singly-ionized iron) multiplet 42 lines have P Cygni line profiles for the first few months. This is strong evidence for mass outflow on the line of sight. The emission lines are centered near zero velocity, and disappear near maximum light (day 9). Strong P Cygni profiles, with absorption at many discrete velocities from a few hundred to two thousand km/s, reappeared after a few days. By 5 months (the uppermost spectrum) the continuum has faded, the P Cygni absorption has disappeared, and the brightness is dominated by emission lines from the ejected envelope. The nova has not yet entered its nebular phase when the strongest emission lines will be those of highly ionized forbidden lines.

Create finder charts with comparison star sequences for stars in the AAVSO observing program using the AAVSO Variable Star Plotter (VSP) (https://www.aavso.org/vsp).

Submit observations of stars in the AAVSO observing program to the AAVSO International Database using WebObs (https://www.aavso.org/webobs).

Observing Recommendations

- For N Cir 2018 (and Novae in general) and for Supernovae: Nightly photometric observations should be made using standard BVRcIc filters and transformed to the standard system. Visual estimates are welcomed and encouraged. High- or low-resolution spectroscopy is also of interest. If a significant dust dip appears, a nova may fade by up to 10 mag at B and V (and much less at R and I). Observers should not give up – the nova will recover in a month or so.

- For Dwarf Novae: When at minimum, one observation every clear night is sufficient. When an outburst is beginning, a few observations per night until at maximum. During the outburst, the frequency of observation depends on the type of dwarf nova: for U Gem-type (example SS Cyg) and Z Cam-type, one observation per night; for SU UMa-type, one observation per night if regular outburst, a few observations per night to time series, depending on mode of observing.