Probable Nova PNV J17224490-4137160 in Scorpius
(Nova Sco 2023/V1716 Sco)

Abstract

The Large Area Telescope (LAT), one of two instruments on the Fermi Gamma Ray Space Telescope, has detected gamma ray emission from a source positionally consistent with PNV J17224490-4137160, a likely optical galactic nova discovered by Andrew Pearce on 20 April 2023 (ATel #16002). Subsequent optical observations indicate brightening of the transient through 21 April 2023 (AAVSO Alert Notice 821). This Research Note will present the latest optical photometry and spectroscopy.

1.0 Introduction

The AAVSO (Kafka 2021, American Association of Variable Star Observers (https://aavso.org)) Alert Notice 821 and Astronomer's Telegram ATel #16002, ATel #16003, ATel #16004, ATel #16005, ATel #16006, ATel #16007, ATel #16018, and ATel#16019 all have announced the discovery of a probable galactic nova in Scorpius, PNV J17224490-4137160 or Nova Sco 2023/V1716 Sco. The AAVSO VSX (American Association of Variable Star Observers; International Variable Star Index) (Kafka 2021) database for PNV J17224490-4137160 indicates a position of RA = 17:22:45.05, Dec = -41:37:16.3 (J2000.0 coordinates). The probable precursor magnitude (V = 19.6) and location were derived from the Gaia DR3 database (Gaia DR3 5959616875349110656-Alert Notice 821).

Novae are close binary systems with orbital periods from 0.05 to 230 days. One of the components of these systems is a hot white dwarf star that suddenly, during a time interval from one to several dozen to several hundred days, increases its brightness by 7-19 magnitudes in V *(*500-700 nm wavelength), then returns gradually to its former brightness over several months, years, or decades. Small changes at minimum light may be present. Cool components may be giants, subgiants, or dwarfs of K-M type. The spectra of novae near maximum light resemble A-F absorption spectra of luminous stars at first. Then broad emission lines (bands) of hydrogen, helium, and other elements with absorption components indicating the presence of a rapidly expanding envelope appear in the spectrum. As the light decreases, the composite spectrum begins to show forbidden lines characteristic of the spectra of gas nebulae excited by hot stars. At minimum light, the spectra of novae are generally continuous. Only spectra of the most massive systems show traces of cool components. Some novae reveal pulsations of hot components with periods of approximately 100 seconds and amplitudes of about 0.05 magnitude in V after an outburst. Some novae eventually turn out to be eclipsing systems. According to the features of their light variations, novae are subdivided into fast (**NA**), slow (**NB**), very slow (**NC**), and recurrent (**NR**) categories.

2.0 Methods

Alert Notice 821 requests optical observations of all types in multiple bands as well as spectroscopic measurements. The photometry data for PNV J17224490-4137160 was obtained from the database of the ASAS-SN (All-Sky Automated Survey for SuperNova) (Shappee, et al. 2014 and Kochanek, et al. 2017) global network of robotic telescopes and the AAVSO VSX (American Association of Variable Star Observers; International Variable Star Index) (Kafka 2021) database. Specifically, the VSX data is in the Johnson-Cousins BVRI photometric magnitude ranges (Johnson B at 400-500 nm, Johnson V at 500-700 nm, Cousins R at 550-800 nm, and Cousins I at 700-900 nm). The ASAS-SN photometric magnitude range is Sloan g (402.5-551.5 nm). An ASAS-SN light curve was computed for 20 days, combined with the Johnson-Cousins BVRI data, and analyzed with the AAVSO VStar (Benn, D. 2012, “Algorithms + Observations = VStar”, JAAVSO, v40, n2, pp.852-866) software. VStar is a multi-platform variable star data visualization and analysis tool. The composite photometry is shown in Figure 1.

The initial spectroscopic measurements for PNV J17224490-4137160 were performed by the Southern Spectroscopic Project Observatory Team. Preliminary data are shown in Figure 1. Spectroscopic measurements consist of the star’s thermal (blackbody) spectrum, which forms the continuum, with dark absorption lines resulting from atomic energy level transitions. Some types of stars can also have bright emission lines, also corresponding to atomic energy level transitions. The strength of these atomic lines depend on the abundance of each element within the star, as well as the temperature and density of the star’s outer layers. Absorption and emission lines in a star’s spectrum can therefore be used to determine the physical properties of the star, as well as its chemical abundances and composition. The surface temperature of a star can be represented by its spectral type, using the letter sequence: O B A F G K M, from hottest to coolest. This sequence is based on the strength of the absorption lines in the star’s spectrum, primarily hydrogen lines, which strengthen from O to A, then weaken from A onward; the H and K lines of calcium strengthen from A onward, aiding the classification of cooler stars.

The Doppler shift affects the spectrum of a star with relative motion toward (blue shift) or away from (redshift) Earth. By comparing the wavelength of a line in a stellar spectrum to its known rest wavelength value, the star’s relative radial velocity (Doppler shift) can be determined. If an object is rotating, then light from one side is red shifted and light from the other side is blue shifted. This causes spectral lines to be rotationally broadened.

3.0 Results and Analysis

The composite photometric light curve and preliminary spectroscopy data for PNV J17224490-4137160 are shown in Figure 1. The upper left hand corner of Figure 1 is the composite light curve from ASAS-SN and AAVSO photometry. The light curve is essentially flat in Sloan g through 18 April 2023 (JD 2460052.92454) at approximately magnitude 14.5 and brightens to magnitude 10.917 in Sloan g by 20 April 2023 (JD 2460054.9146). The maximum Sloan g magnitude is 7.002 on 22 April 2023 (JD 2460057.10872). The first AAVSO Johnson-Cousins BVRI data occurs on 20 April 2023 with magnitude 8.475 in Johnson B and reaches maximum in Cousins I with magnitude 5.284 on 22 April 2023 (JD 2460057.13323). All of the other data points (Johnson V and B and Cousins R) have a maximum value on 22 April 2023. The composite light curve begins to fade thereafter. The total magnitude increase is over nine magnitudes.

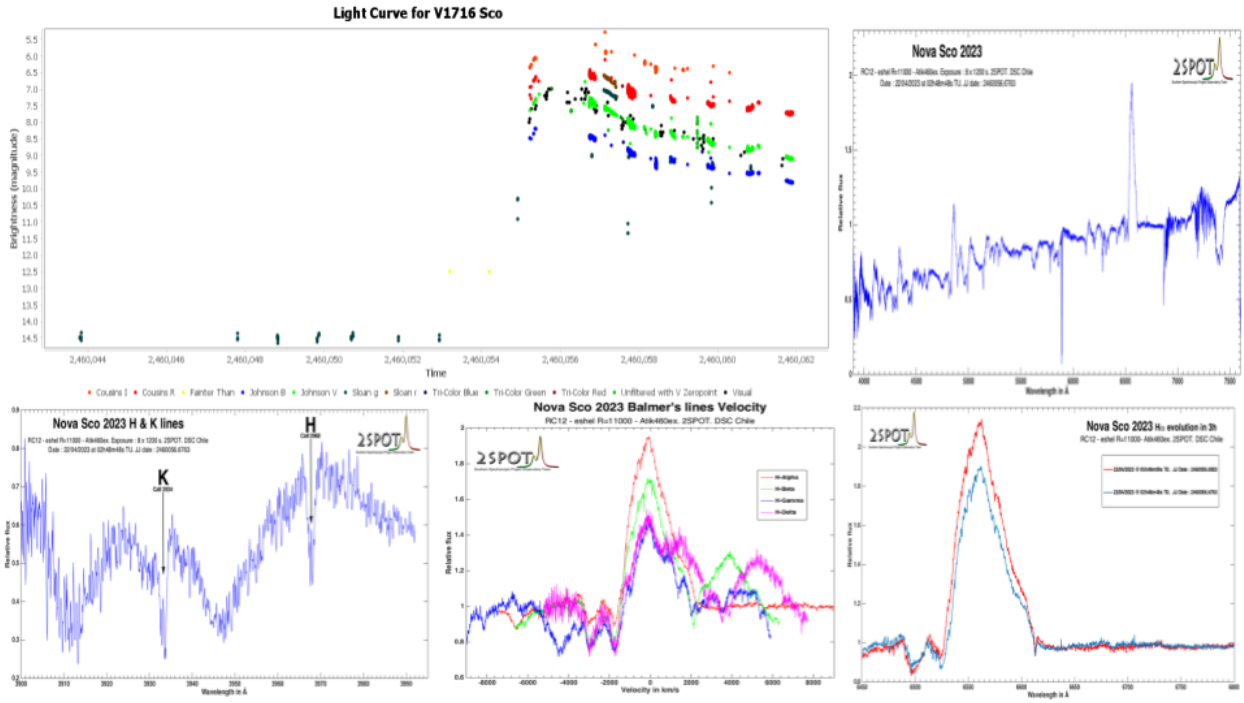

Figure 1: Composite Photometric Light Curve and Preliminary Spectroscopy Data for PNV J17224490-4137160

The initial spectroscopic measurements for PNV J17224490-4137160 were performed by the Southern Spectroscopic Project Observatory Team and follow-on measurements were added by the High Accuracy Radial velocity Planet Searcher North (HARPS-N). The lines, in the range 3850 - 7600 angstroms, are all complex and the ejecta are still optically quite opaque. The spectrum is dominated by a bright H-alpha line. The source is a classical (Fe II) nova near maximum light. The brightest non-Balmer lines are Fe II 501.8 nm (multiplet 42) and Fe II 614.8/624.8 nm (multiplet

74). The Balmer lines are also seen in emission through H-alpha, H-beta, H-gamma, and H-delta and indicate the velocity and Doppler shift. The K and H calcium absorption lines are 3934 and 3968 angstroms, respectively. There are no detected neutral helium transitions (e.g, He I 4471, 5896, 6678, 7065). The upper right hand corner of Figure 1 is the complete spectrum showing H-alpha and Na (sodium). The lower left hand corner shows H and K calcium lines, while the lower middle of Figure 1 shows the Balmer lines for H-alpha, H-beta, H-gamma, and H-delta. The lower right hand corner shows the evolution of the H-alpha line over a three hour period.

Additionally, NuStar (Nuclear Spectroscopic Telescope Array) observed the nova in the hard 3-78 keV X-rays between 2023-04-21.89 and 2023-04-23.42. While the NuSTAR images were affected by stray light, likely from the nearby neutron-star-hosting low mass X-ray binary 4U 1708-40, the nova was clearly detected. Its background-subtracted count rate was smoothly increasing from 0.02 to 0.04 counts/second per focal plane module over the course of the NuSTAR exposure. Preliminary analysis suggests that the X-ray spectrum is consistent with that of a heavily absorbed thermal plasma with kT= 31 +/-13 keV and N_H= (8.2 +/-1.5) x10^23 cm^-2 (assuming solar abundances). The derived kT is higher than values found in all novae previously observed by NuSTAR. The unabsorbed 3-78 keV flux is 3.1 x10^-12 erg/cm^2/s (luminosity 2.4 x10^34 * (d / 8 kpc)^2 erg/s).

The IceCube Collaboration reports that IceCube has performed a search for track-like muon neutrino events arriving from the direction of the classical nova PNV J17224490-4137160. The search was performed using a time window of three days approximately centered on the highest energy photon detected by Fermi-LAT (2023-04-20 09:36:00 to 2023-04-23 09:36:00 UT), during which IceCube was collecting good quality data. IceCube derived a time-integrated muon-neutrino flux upper limit for this source of E^2 dN/dE = 5.9e-1 GeV cm^-2 at 90% CL, under the assumption of an E^-2 power law. 90% of events IceCube would detect from a source at this declination with an E^-2 spectrum have energies in the approximate energy range 90 TeV to 20 PeV. The IceCube Neutrino Observatory is a cubic-kilometer neutrino detector operating at the geographic South Pole, Antarctica.

4.0 Conclusions

The Fermi Large Area Telescope has detected gamma ray emission from a source positionally consistent with PNV J17224490-4137160, a likely optical galactic nova discovered on 20 April 2023. Subsequent optical observations indicated brightening of the transient through 21 April 2023 (AAVSO Alert Notice 821). Spectroscopic measurements commensurate with the photometry have confirmed that

this is a nova and this has been supported by X-ray observations as well as detection of neutrino events. This nova has been assigned the permanent designation V1716 Sco.

References

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Kafka 2021, American Association of Variable Star Observers (AAVSO) International Variable Star Index (VSX) (https://www.aavso.org/vsx/). This research has made use of the International Variable Star Index (VSX) database, operated at AAVSO, Cambridge, Massachusetts, USA.

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