**UBV Photometry of the Post-AGB Star**

**IRAS 22272+5435=V354 Lac in 1990-2008**

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**Abstract**

New *UBV*-photometry obtained in 2000-2008 is presented for the post-AGB star IRAS 22272+5435=V354 Lac. The star showed semi-regular light variations with varying amplitudes. The maximal amplitude did not exceed: \(\Delta V=0.5\), \(\Delta B=0.7\) and \(\Delta U=1.0\). For 2000-2008, we have found a photometric period near 128 days. The analysis of long-term observations in 1990-2008 reveals variations with two close periods: 128 and 131 days, causing amplitude modulation. The \(V-(B-V)\) diagram shows a clear correlation: the star is generally bluer when brighter. From our *UBV* data, we derive \(E(B-V)=0.5\) and conclude that the spectral type of the star varies between K1 to K7 during pulsations. The mean *UBV*-data of V354 Lac have not changed during the past 19 years: \(V=8.60, \ B-V=2.06\) and \(U-B=2.14\).

**INTRODUCTION**

The IR source IRAS 22272+5435 is identified with the bright star BD+54\(^{\circ}\)2787=HD 235858 (22\(^{h}\)29\(^{m}\)10\(^{s}\)+54\(^{\circ}\)51\('\)06\('\)′(2000)). It is one of the most reliable protoplanetary nebula candidates.

The spectral energy distribution of IRAS 22272+5435 show a characteristic double peak, with about the same amounts of energy emitted in the visible plus near-infrared (from the reddened photosphere) and in the mid-infrared (re-emission from circumstellar dust) (Hrivnak and Kwok 1991).

The chemical composition of IRAS 22272+5435 is typical of carbon post-AGB stars. Začs, Klochkova and Panchuk (1995) found the star to be iron poor: \([\text{Fe/H}]=-0.49\). The elements of the \(\alpha\)-process are overabundant relative to the solar compositions and the carbon abundance is \(C/O\approx 12\). In the spectra of IRAS 22272+5435 strong molecular bands of \(\text{C}_3\) and \(\text{C}_2\) are found (Hrivnak and Kwok 1991).

In the survey of protoplanetary nebulae candidates with Hubble Space Telescope, Ueta et al. (2000) discovered an elongated low-surface-brightness reflection nebulosity around IRAS 22272+5435. These authors believe that the multilobed nebulosity may be a progenitor of a complex planetary nebula.

The spectral classification of V354 Lac is a difficult problem because of its peculiar spectrum. In the HD catalog, HD 235858 has the spectral type K5. McCuskey (1955) classified the object as M0III and Hrivnak and Kwok (1991), as GpIa. The atmospheric parameters of IRAS 22272+5435, \(T_{\text{eff}}=5600\ \text{K}\) and \(\log g=0.5\), correspond to a G2 supergiant (Začs, Klochkova and Panchuk, 1995).

The brightness variability of BD+54\(^{\circ}\)2787 was discovered by Strohmeier and Knigge (1960). They list it as a possible short-period variable with an amplitude of \(0.5\). Filatov (1961) reported irregular variability of the star with an amplitude of \(1.5-2.0\). In the 62nd GCVS Name-List (Kukarkin et al., 1977), BD+54\(^{\circ}\)2787 got the designation V354 Lac. The GCVS variability currently listed for the star is LB (a slow irregular variable).

The light-curve and radial-velocity studies of V354 Lac were carried out by Hrivnak and Lu (2000) respectively in 1994-1996 and 1991-1995. They found brightness and radial-velocity variability with the period \(P=127^d\).
The radial-velocity monitoring of V354 Lac performed by Začs et al. (2009) confirmed regular variations with a peak-to-peak amplitude of about 10 km s\(^{-1}\) and a period of about 131.2 days.

UBV OBSERVATIONS OF V354 Lac

Our UBV photometry of IRAS 22272+5435 was performed in 1990-2008 with the 0.6-m telescope of the Crimean Station of the Sternberg Astronomical Institute. The measurements were obtained using a pulse-counting photometer with an EMI 9789 photomultiplier, and a filter set consistent with the Johnson system. All observations were made with respect of the comparison star BD+54\(^{°}\)2793 (\(V = 8.\text{m}54, B = 10.\text{m}45, U = 12.\text{m}79\)). The typical photometric uncertainties range from 0.\(\text{m}01\) in the V band and to 0.\(\text{m}05\) in the U-band. The observations obtained in 1990-1999 were published earlier (Arkhipova et al., 1993 and Arkhipova et al., 2000). The light and color curves of V354 Lac for 1990-2008 are presented in Fig.1.

During our observations, V354 Lac showed semi-regular brightness variations with varying amplitudes. Its largest amplitudes do not exceed \(\Delta V=0.\text{m}5, \Delta B=0.\text{m}7, \Delta U=1.\text{m}0\).

We searched for periodicity in the observations obtained in 1990-2008 using the DFT (Discrete Fourier Transforms) package by Dr. V.M.Lyuty.

In the power spectrum (Fig.2), triplet frequencies are dominating: \(\nu_1=0.00781, \nu_2=0.00763, \nu_3=0.00800\). The ratios \(\nu_1/\nu_2\) and \(\nu_3/\nu_1\) are close to 1.024. The periods \(P_1=1/\nu_1=128^d\) and \(P_2=1/\nu_2=131^d\) have approximately the same amplitudes, about 0.\(\text{m}18\) in the V band.

A single period, \(P = 128 \pm 2\) days, was found in the observations of 2000-2008. The corresponding power spectra and the V-band phased light curve are shown in Fig.3.
Figure 2. The power spectrum of V354 Lac for observations of 1990-2008.

Figure 3. The power spectrum (top panel) and the phased V light curve (bottom panel) of V354 Lac for observations of 2000-2008.

Considering the radial-velocity variations (Začs et al., 2009) together with our light curve (Fig.4) confirms the conclusion of Hrivnak and Lu (2000) that V354 Lac "is brightest when it is at its average size and expanding and faintest when at its average size and contracting". Hrivnak and Lu interpreted this variability as due to pulsation in the star rather than its binary nature.

The V-(B-V) diagram shows a clear correlation: the star is generally bluer when brighter (Fig.5).

V354 Lac is located at a low galactic latitude (b = −2°52). The interstellar extinction in the direction of V354 Lac from maps of Neckel and Klare (1980) is 1.62 < AV < 1.69 at r=1 kpc. From UBV data, we conclude that E(B-V)=0.5 and AV = 1.55. Thus, practically all the color excess can be caused by interstellar extinction.

In the (U-B)-(B-V) two-color diagram (Fig.6), the star moves along the sequence of supergiants in the course of its fluctuations. Correction of the color indices for reddening with E(B-V)=0.5 put the star on the sequence of supergiants, where the spectral type of the star varies during pulsations from K1 to K7.
Figure 4. The radial-velocity variations of V354 Lac (black filled circles) with a sinusoid fit ($P=131.2$ days; black line) and $V$ light curve (red filled circles) with a sinusoid fit ($P=128$ days; red line).

Figure 5. The color-brightness diagram for V354 Lac.

CONCLUSIONS

Our long-term $UBV$ photometry of the post-AGB star V354 Lac permitted to study its variability character. V354 Lac showed semi-regular light variations with varying amplitudes. The maximal amplitudes did not exceed: $\Delta V=0.\text{m}5, \Delta B=0.\text{m}7, \Delta U=1.\text{m}0$. The observed behavior of V354 Lac is explained with beating of two closely spaced pulsation modes with the period ratio 1.02. The other post-AGB stars with amplitude modulation are IRAS 19386+0155=V1648 Aql (Arkhipova et al., 2009) and IRAS 08544-4431 (Kiss et al., 2007). The period ratio for them is 1.04. Some pulsating red variables on the asymptotic giant branch (AGB) show pulsations with two close periods. Such a phenomenon is detected, for example, for RX UMa and RY Leo (Kiss et al., 2000). The authors of the cited paper assumed that the period ratios assumed that the period ratios found for these stars (1.03-1.10) suggested either high-order overtone or radial+non-radial oscillation.

The mean $UBV$ parameters of V354 Lac has not changed during the past 19 years: $\overline{V}=8.\text{m}60$, $\overline{(B-V)}=2.\text{m}06$ and $\overline{(U-B)}=2.\text{m}14$.

The brightness and the colors change in phase: the star is generally bluer when brighter. The temperature variations during pulsations correspond to the changes of the spectral type from K1 to K7.

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Figure 6. V354 Lac in the $(U - B)$-$(B - V)$ two-color diagram. The solid curve is the supergiant sequence according to Straičys (1977); the dots represent our observations and the open circles represents de-reddened data with $E(B - V) = 0.5$.

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