Revista Brasileira de Física, Vol. 5, N.º 3, 1975

Characteristics of Nova Scuti 1975

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Recebido em 10 de Novembro de 1975

Photoelectric observations of Nova Scuti 1975 are presented. From the analysis of the light curve and radial velocity data, we concluded that Nova Scuti 1975 was a fast nova. The estimated distance was 2.6 kpc and the ejected mass was about $10^{-5} M_{\odot}$. The energy of the outburst was about 3 x 10^{44} ergs.

Apresentam-se observações fotoelétricas da Nova Scuti 1975 através de análise da curva de luz e dados da velocidade de expansão do envelope ejetado, conclui-se que Nova Scuti 1975 foi uma "rápida". Estimou-se a distância em 2,6 kpc e, a massa ejetada, em $10^{-5} M_{\odot}$. A energia cinética da explosão foi cerca de 3 x 10^{44} ergs.

1. Introduction

The nova, which appeared in Scutum, was discovered by Wild on June 15 (Wild 1975), when its magnitude was about $m_{pv} \sim 7.9$. Later spectroscopic observations by Bidelman (1975) confirmed the nova nature of the object. Ha and $H\beta$ were observed as strong and broad emission lines of widths about 55 Å and 30 Å respectively, indicating velocities greater than 2000 kms^{-1}. Further spectroscopic observation (Gallagher 1975), on June 25, has shown a strong continuum and Balmer emission lines with P-Cygni profiles indicating an expansion velocity of more than 1400 kms^{-1}.

Considering the interest in the evolution of this object and its favourable position in the sky for southern observers, we have included it in our observational program. Nova Scuti 1975 was observed photoelectrically with the 60 cm telescope, at the Abrahão de Moraes Observatory, since end of June until beginning of August 1975.

In this work, we present the result of these observations as well as some theoretical considerations concerning the light curve. In particular, we have estimated the distance and the mass of the envelope ejected by the nova.

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2. The Light Curve

Since the nova was discovered after maximurn light, our observations referred to latter phases of the expansion.

Our observations indicate an irregular light curve, which sometimes shows magnitude variation of about $0\overset{m}{.}4$ in one night and a more or less steady increase in luminosity of about one magnitude, from July 8 to July 27. This would indicate probably further matter ejection by the star associated with the nova.

In Fig. 1, we show the light curve of Nova Scuti 1975, including not only our own observations, but also some photographic prediscoveries obtained from the IAU circulars.

From Fig. 1, the principal maximum in lumiriosity occurred probably on May 10, when the nova reached a magnitude of about $V \sim 6.1$.

The irregular character of the light curve and the slow decay of the luminosity would indicate that this object was a slow nova and, indeed, this was suggested by Viterwaal and Genderen (1975).

We think, however, that there are two observational facts against this interpretation. The first one concerns the amplitude of the outburst. Shao (1975) discovered a very blue star on the Palomar Sky Atlas with an approximate magnitude $m_{ph} \sim 18.5$, at the position of the nova. If this was the magnitude of the pre-nova object, then the amplitude of the outburst was about 12 mag, since the maximum observed was about 6 mag. This amplitude is typical of a fast nova. A slow nova would have an amplitude of only 9 mag. A second point refers to the ejection velocity which, from thé P-Cygni profiles observed in the Balmer lines, are of the order of 1600 kms^{-1}. This again is characteristic of fast novae, since, we would expect velocities of about 300-500 kms^{-1} for slow novae.

Let us assume tentatively that Nova Scuti 1975 was an "irregular" fast nova, with the principal light maximum occurring on May 10 and with subsequent mass ejection responsible for the irregularities in the light curve.

In what follows, we are going to analyse the consequences of that assumption.

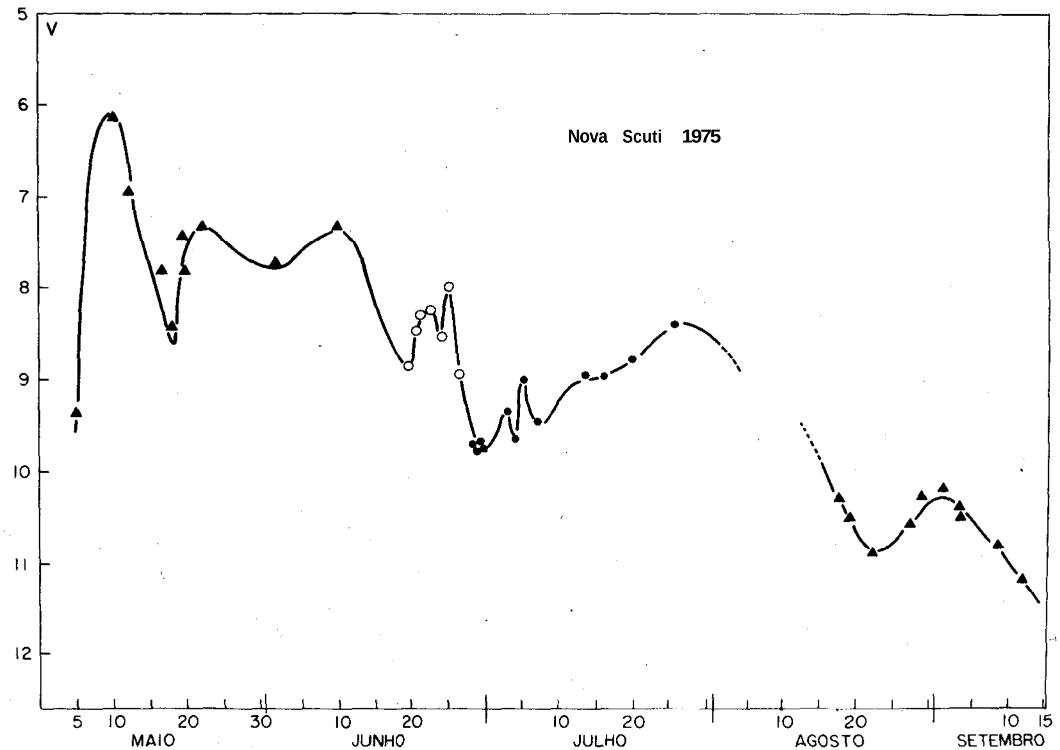

Fig. 1 – The V magnitude of Nova Scuti 1975 in function of time. Filled circles represent photoelectric measurements made at Abrahão de Moraes Observatory. Open circles are photoelectric measurements by Viterwaal and Genderen (see text). Triangles represent photographic measurements (see text).

3. The Distance of Nova Scuti 1975

If, indeed, the principal light maximum occurred on May 10, and if we extrapolate its decay, then the time t_3 necessary for a decline of 3^m from the maximum, is about 10 days, which is again typical for a fast nova. Then, using the empirical relation between the absolute visual magnitude, at maximum light, and t_3, namely,

$$M_V(\max) = -10.5 + 2.2 \log t_3 \tag{1}$$

one obtains

$$M_V(\max) \simeq -8\overset{m}{.}3.$$

From the color excess deduced from the photoelectric observations of SAO 143955 (this star was used as a comparison during our observations), we have estimated an interestellar absorption of about 0.87 mag/kpc in the nova direction, which is a reasonable value for an object near the galactic plane.

Therefore, the distance of the nova can be obtained from the well known relation

$$m_V - M_V = 10 + 5 \log d + 0.87\, d, \tag{2}$$

where d is the distance in kiloparsecs and we have already introduced the numerical value for the extinction in that direction.

Since the magnitude modulus is $14\overset{m}{.}4$, from Eq. (2) one obtains a distance of about 2.6 kpc.

4. The Mass of the Ejected Envelope

The optical depth of the envelope just after the outburst is very large and, therefore, the ejected envelope acts like a "photosphere". The emission in this phase is characterized essentially by a strong continuum with an increasing luminosity as the envelope expands.

Let us assume that, at light maximum, the envelope radiates like a black-body. Assuming also spherical symmetry, we can write

$$L_\lambda(\max) = 4\pi R_*^2\, \pi B_\lambda(T_*)\, \Delta\lambda, \tag{3}$$

where $L_\lambda(\max)$ is the luminosity, at maximum, in the color filter centered at the wavelength Â, with bandwidth AÂ; R, is the radius of the envelope, and $\pi B_\lambda(T_*)$ the Planck-function for the effective envelope temperature, T_*.

After maximum, absorption lines appear, indicating that the light emitted by the star is reaching us. This means that the optical depth, at maximum, is near unity. Thus, we can write

$$\tau = \kappa_0 \, \rho_*^2 \, T_*^{-9/2} \, E R_* \sim 1, \tag{4}$$

where $\kappa_0 = 7.68 \times 10^{30}$ (cgs) is a constant, p, the envelope density, and E the fractional thickness of the envelope. We have considered only "bound-free" transitions in the opacity.

Since

$$\rho_* = M_* (4\pi E R_*^3)^{-1}, \tag{5}$$

where M_* is the envelope mass, from Eqs. (4) and (5) the radius, at maximum, is given by

$$R_* \sim (\kappa_0 / 16\pi^2 E)^{1/5} \, M_*^{2/5} \, T_*^{-9/10}. \tag{6}$$

If we substitute Eq. (6) into (3), and use the definition of magnitude, we obtain

$$M_\lambda(\max) = 4.75 - 2.5 \log 4\pi \left[4\pi (\kappa_0/16\pi^2 E)^{2/5} \, (M_\odot^{4/5}/L_\odot) \times \right.$$
$$\left. \times \, (\pi B_\lambda(T_*) \, \Delta\lambda / T_*^{9/5})\right] - 2 \log(M_*/M_\odot). \tag{7}$$

We now assume E = 0.3 (the final result is not sensitive to this parameter) and $T_* = 7300$°K, since at light maximum the average color index of novae is about $(B - V) \simeq +0^m\!.2$. With the absolute visual magnitude obtained previously, from Eq. (7) the mass of the envelope is

$$M_*/M_\odot \sim 1.3 \times 10^{-5}. \tag{8}$$

Since the velocity of the ejected material is about 1600 km s^{-1}, the kinetic energy of the outburst was about 3.3×10^{44} ergs.

These figures are typical of novae outbursts.

The radius and density, at maximum, can be estimated now using Eqs. (6) and (5), respectively. One obtains

$$R_* \sim 770 \, R_\odot \tag{9}$$

and

$$n_* \sim 2.6 \times 10^{10}\,\mathrm{cm}^{-3}. \tag{10}$$

Since we do not have enough observations to estimate the contribution of the subsequent activity of the star, these estimates should be considered only in order of magnitude. However, our estimative of the envelope mass can be checked in the following way: The [N II] λ 5755 line was detectecl, for the first time, in the spectrum, on June 22 (Mc Croskey *et* al. 1975), i.e., 42 days after maximum. This means that the time for collisions of second kind is comparable with the lifetime of the excited state, namely,

$$A \sim (8.63 \times 10^{-6}\,\Omega/g\,T_e^{1/2})\,n_e, \tag{11}$$

where $A = 1.08\,\mathrm{s}^{-1}$ is the Einstein transition probability for the line, $\Omega = 0.376$ the collisiori strength, $g = 1$ the statistical weight of the upper level, and n_e rhe electron density of the envelope. With $T_e \sim 1000°\mathrm{K}$, from (11) the electron density is

$$n_e \sim 3.5 \times 10^7\,\mathrm{cm}^{-3}. \tag{12}$$

Assuming that, at this phase, the envelope is totaly ionized, then its mass is given by

$$M, \sim 4\pi E(vt)^3\,m_H n_e\,. \tag{13}$$

With $v = 1600\,\mathrm{km\,s}^{-1}$ and $t = 42$ days, one obtains an envelope mass of about $2 \times 10^{-5}\,M_\odot$. This figure is in excellent agreement with that derived above from a different method.

5. Conclusions

In spite of the irregular character of the light curve, we think that Nova Scuti 1975 was a. fast nova, since the amplitude of the outburst, the expansion velocity and the time for 3 mag decline are typical for that class of novae.

The distance is about 2.6 kpc and the uncertainties in this estimate are due to possible errors in our evaluation of the interstellar absorption and, of course, to the assumption that Nova Scuti 1975 was a fast nova.

The mass of the main envelope is approximately $10^{-5}\,M_\odot$ and the energy of the outburst was about 3×10^{44} ergs.

Since this object presented peculiarities in its light curve, which would indicate an extended state of activity, more observations of this object would be required in order that a more detailed analysis could be done.

I thank very much Dr. Sayd Codina for his participation in the observations of this program.

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