RADIAL VELOCITY AND LIGHT CURVES ANALYSIS OF THE ECLIPSING BINARY NN VIR

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ABSTRACT. The eclipsing binary NN Vir is a short period system showing an EW-type light curve. Photometric Observations of NN Vir were done by Gomez-Ferrellad & Garcia-Melendo (1997) at Esteve Duran Observatory. We used photometric Data of NN Vir for light curve analysis.

The available spectroscopic data of NN Vir is new and we also used the first radial velocity Data of this system obtained by Rusinski & Lu (1999) for analysis.

The radial velocity and light curves analysis was made with the Latest version of Wilson program(1998) and the geometric and physical elements of the system are derived. By searching the simultaneous solutions of the system, we have determined the masses and radii of the components : $1.89(M_\odot)$ and $1.655(R_\odot)$ for the primary component; $0.93(M_\odot)$ and $1.230(R_\odot)$ for the secondary component. We estimated effective temperatures of 7030(K) for the primary and 6977(K) for the secondary component.

Key words: Stars: binary: eclipsing binary: NN Vir.

1. Introduction

NNVir (=HD 125488 =BD +06°2869 =GSC 323.930) is one of the stars whose variability has been detected by the Hipparcos satellite. An analysis of the photometric data from the Tycho Mean Photometric Catalogue and the Tycho Photometric Observations Catalogue performed by Woitas (1997), yielded a list of 43 new bright variables. NN Vir was one of them and according to Woitas, this object is an RR Lyr variable with a 0.20 day period.

Photometric Observations of NN Vir were done by Gomez-Ferrellad & Garcia-Melendo (1997) in the V band for 6 nights, from 13 to 21 March 1997, using a CCD camera and a 6-cm refracting telescope at Esteve Duran Observatory. Their Observations showed that HD 125488 is not an RR Lyr star but an eclipsing binary system with a period of 0.48 days and the following ephemeris was computed:

$$MinI = HJD2450525.6434 + 0^d.48069 \times E \qquad (1)$$

The radial velocity variations on NN Vir have been observed by Rucinski & Lu (1999) for the first time. They found that this system has a spectral classification F_0/F_1 and a relatively large mass ratio, $q_{sp} = 0.491 \pm 0.011$, which is rather infrequent among the A-type contact systems.

As CCD data in V-color bandpass (329 points) as well as Radial velocity Data (46 points) of this system proved to be highly precise and reliable, we utilized the same data for analysis.

Based on ephemeris (1), radial velocity and light curves are shown in Figure 1 and Figure 2.

2. Radial Velocity and Light Curves Analysis

Photometric and spectroscopic solutions of the NN Vir were obtained by means of the latest version of the Wilson program (1998) which includes an option to work with either observed times or phases, additional solution parameters (initial epoch, T_0, orbital period at initial epoch, P_0, first time derivative of the orbital period, dP/dt, and first time derivative of the argument of periastron, $d\omega/dt$), inclusion of the Marquardt λ factor (1963) in differential corrections solutions and conversion of the entire program to double precision. In the new version of Wilson program the adjusted parameters were divided into subsets whose members were not strongly correlated. The DC program output provided a table of correlation coefficients. Each subset consists of the largest number of adjusted parameters which were uncorrelated. The adjustments from the subset with the smallest predicted $\sum wr^2$, the sum of the weighted squares of the residual, were applied to the parameters of next run of the program. The run continued until adjustments were exceeded by their probable errors.

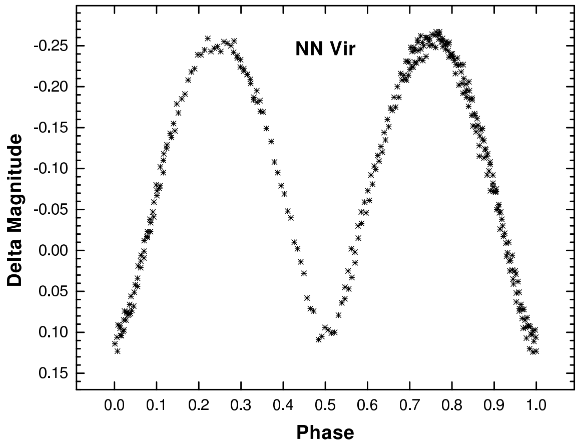

Figure 1: Light curve of NN Vir plotted vs. orbital phases were obtained at Esteve Duran Observatory.

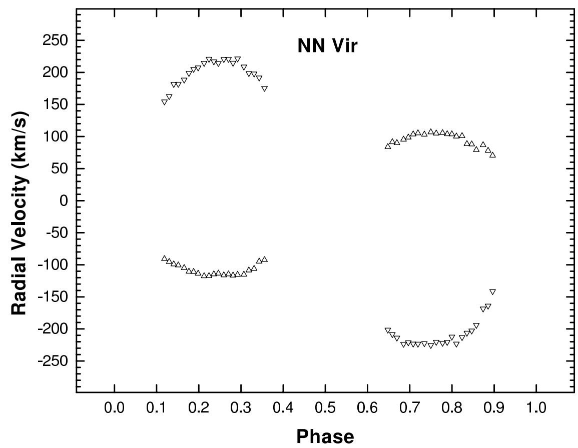

Figure 2: Radial velocity curve of NN Vir plotted vs. orbital phases were obtained at David Dunlap Observatory.

Based on V colors of Gomez-Ferrellad & Garcia-Melendo (1997), individual observations the magnitude differences were converted to intensities and used as a photometric input data. For radial velocity analysis we used all 46 points data were given by Rucinski & Lu (1999). Two radial velocity and one light curves were employed simultaneously for determination of the geometric and physical elements of the system.

For detailed analysis mode 3 of Wilson program, suitable for contact binaries with difference in the component's surface brightness, was used with constrains for gravity-darkening exponents $g_1 = g_2$, the bolometric albedos $A_1 = A_2$, the modified surface potentials of two components $\Omega_1 = \Omega_2$, the limb darkening coefficients $x_1 = x_2$, $y_1 = y_2$ and the luminosity of the secondary component coupled to its temperature. Because the photoelectric light curve of NN Vir has a normal shape, we supposed that there are neither a third light, $l_3 = 0.0$, nor spots.

Table 1: The elements of the binary system NN Vir (most quantities are defined in the text).

Element	Value
i	66.270 ± 0.834
q	0.491 ± 0.005
$a(R_\odot)$	3.642 ± 0.053
$V_\gamma(km/s)$	-6.11 ± 0.002
$\Omega_1 = \Omega_2$	2.801 ± 0.027
$A_1 = A_2$	0.500
$g_1 = g_2$	0.320
l_3	0.00
$T_1(K)$	7730
$T_2(K)$	6977 ± 174
$x_{1(bol)}=x_{2(bol)}$	0.641
$y_{1(bol)}=y_{2(bol)}$	0.255
$r_{1(pole)}$	0.426 ± 0.004
$r_{2(pole)}$	0.309 ± 0.005
$r_{1(side)}$	0.450 ± 0.006
$r_{2(side)}$	0.328 ± 0.006
$r_{1(back)}$	0.480 ± 0.007
$r_{2(back)}$	0.372 ± 0.012
$(\sum wr^2)$	0.054

For both components, we used bolometric linear, logarithmic and square root law in Wilson program and the best result was obtained for bolometric logarithmic limb darkening law of Klinlesmith and Sobieski (1970) of the form:

$$I = I_0\,(1 - x + x\cos\theta - y\cos\theta\ln(\cos\theta)) \qquad (2)$$

and both x and y parameters of both components were fixed to their theoretical values, interpolated from Vh-limb program of Van Hamme (1993). Because of spectral type of system, F_0/F_1, the temperature of primary component was adopted to be $T_1 = 7030$ (K). The following parameters were free to be adjusted: the orbital inclination i, the mass ratio $q = m_2/m_1$, the mean surface temperature of secondary component T_2, the potential function Ω_1 (or Ω_2), the monochromatic luminosity of primary component L_1, the semi-major axis a and the systemic velocity V_γ. These parameters were varied until the solution converged.

The adopted solution for NN Vir are summarized in Table 1 and Table 2 and the theoretical radial velocity and light curves are shown in Figure 2. The configuration of NN Vir calculated with the Roche model is shown in Figure 3.

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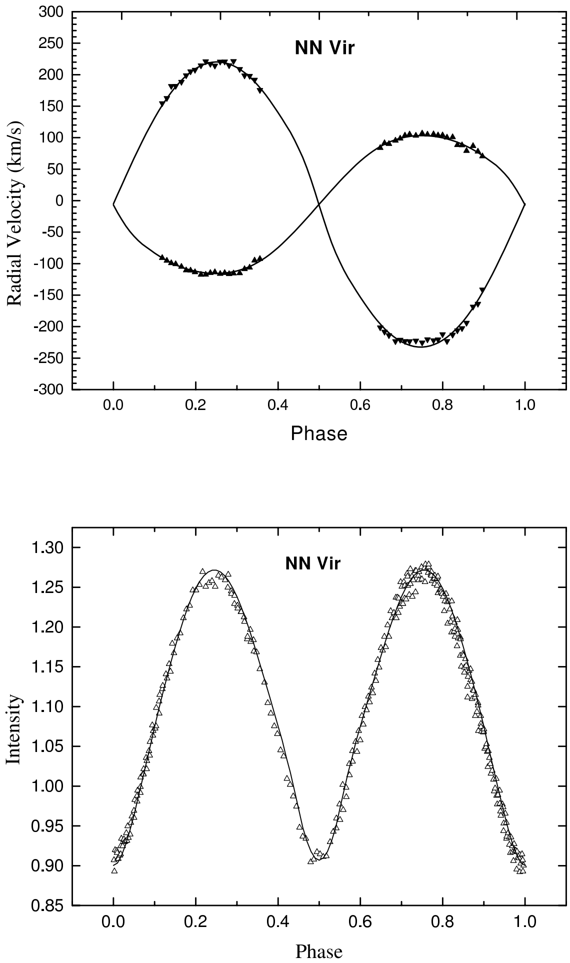

Figure 3: Up & down triangles show the observed points of NN Vir and model fit are shown by continuous lines.

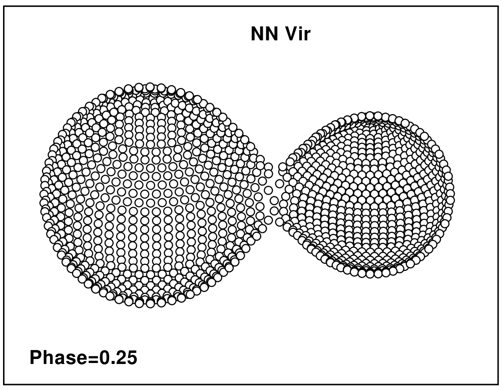

Figure 4: A three dimensional model of NN Vir for phase 0.25.

Table 2: Geometric and physical parameters of NN Vir (notes to the Table: a= distance of the centers of components in solar radii, R_1 and R_2 are radii of the primary and the secondary components , respectively, in solar radii, M_1 and M_2 are masses of components in units of solar mass, L_1 and L_2 are luminosities in unit of solar luminosity, T_1 and T_2 are effective temperatures of components, $(M_{bol})_1$ and $(M_{bol})_2$ are absolute bolometric magnitudes of components).

element	Value
a($R_\odot$)	3.64
$R_1(R_\odot)$	1.65
$R_2(R_\odot)$	1.23
$M_1(M_\odot)$	1.89
$M_2(M_\odot)$	0.93
$L_1(L_\odot)$	6.00
$L_2(L_\odot)$	3.22
T_1(K)	7030
T_2(K)	6977
$(M_{bol})_1$	2.84
$(M_{bol})_2$	3.52

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