New radial-velocity-curve solution of the eclipsing star HN UMa

Diuana Kjurkchieva, Dragomir Marchev
Astronomical Center, University of Shumen, BG-9700 Shumen
d.kyurkchieva@shu-bg.net; d.marchev@shu-bg.net
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Abstract. High-resolution spectroscopic observations around the H_α line of the W UMa-type star HN UMa covering the whole orbital period are presented. Their analysis and modeling led to the following global parameters: masses M_1=1.78 $M_\odot$ and M_2=0.18 $M_\odot$; radii R_1=1.58 $R_\odot$ and R_2=0.64 $R_\odot$; separation a=2.78 $R_\odot$; equatorial velocities $V_{eq}(1)$=159 km/s and $V_{eq}(2)$=69 km/s. Our results show that HN UMa is contact configuration belonging to A-subtype of the W UMa stars. The most interesting characteristic of HN UMa is the mass ratio q=0.1 that is almost at the lower limit of 0.09 of this parameter for a tidal stability of the W UMa stars.

Key words: Stars: spectroscopic – Stars: fundamental parameters – Stars individual: HN UMa

Ново решение на кривата на лъчевите скорости на затъмнително-двойната звезда HN UMa

Диана Кюркчиева, Драгомир Марчев

Представени са високодисперсни спектрални наблюдения около линията H_α на звездата от W UMa-тип HN UMa, покриващи целия орбитален цикъл. Техният анализ и моделиране доведоха до определяне на глобалните параметри на двойката: маси M_1=1.78 $M_\odot$ и M_2=0.18 $M_\odot$; радиуси R_1=1.58 $R_\odot$ и R_2=0.64 $R_\odot$; радиус на орбитата a=2.78 $R_\odot$; екваториални скорости $V_{eq}(1)$=159 km/s и $V_{eq}(2)$=69 km/s. Нашите резулта-ти показват, че HN UMa е контактна конфигурация от А-подтип. Най-интересната особеност на HN UMa е малката стойност на отношението на масите й q=0.1, което е почти на долната граница q=0.09, теоретично изведена като условие за стабилност на двойни звезди спрямо приливно взаимодействие.

Introduction

Photometric variability of the star HN UMa (BD+38 2220, HIP 55030, V=9.75^m) was discovered by Hipparcos mission (ESA 1997). It was classified as a periodic variable with period 0.38 days and depths of the light minima around 0.102^m and 0.096^m.

Kazarovets et al. (1999) classified the variability of HN UMa as EW type. Pribula et al. (2003) as well as Malkov et al. (2006) included the star in their catalogues of the field contact binaries. Light minima of HN UMa were observed by Drozdz & Ogloza (2005), Krajci (2005), Dvorak (2005, 2008), Nelson (2006, 2007). D'Angelo et al. (2006).

The spectra obtained by Rucinski et al. (2003) allowed to obtain the radial velocity solution of HN UMa and to conclude that the system is A subtype of W UMa type stars.

The proper motion (π=5.8 mas, γ=-37.1 km/s) of the target is comparatively large (Tycho-2 data). Bilir et al. (2005) obtained the position and space velocity of HN UMa (X=-66 pc, Y=1 pc, Z=159 pc, U=63 km/s, V=-11.7 km/s, W=-13.8 km/s) as well as its physical parameters: B-V=0.59, Sp F8V, q=0.14, filling factor f=0.2.

Selam (2004) classified HN UM as EW system and modelled Hipparcos photometry with orbital inclination i=52.5^0 and q=0.1. Zola et al. (2005) modelled their photometric data of HN UMa by the following parameters: fill-out factor f=0.32, i=46.7^0, T_1=6100 K, T_2=6082 K, M_1=1.28 $M_\odot$, M_2=0.18 $M_\odot$, R_1=1.435 $R_\odot$, R_2=0.583 $R_\odot$, L_1=2.55 $L_\odot$, L_2=0.41 $L_\odot$.

The main goal of our H_α observations of this W UMa star was to get a new radial velocity solution and to determine precise value of its mass ratio.

1 Observations

We obtained 18 spectra of HN UMa on May 27 2008 in the spectral range 6470-6670 A (around the H_α line) with resolution 0.19 A/pixel. We used a CCD Photometrics AT200 camera with the SITe SI003AB 1024x1024 pixels chip mounted on the Coude spectrograph (grating B&L632/14.7^0) on the 2-m telescope of the Rozhen National Astronomical Observatory. The exposure time was 15 min and our spectra cover well the whole orbital cycle of the star. We used β Vir as a radial velocity standard.

The bias frames and flat-field integrations were obtained at the beginning and at the end of the night. All stellar integrations were alternated with Th-Ar comparison source exposures for wavelength calibration. The mean ratio S/N for our observations is around 60-70. The spectral data were reduced in a standard way using the PCIPS (Smirnov et al. 1992) software packages by bias substraction, flat-field division and wavelength calibration.

Our data were phased according to the ephemeris of Kreiner (2004)

HJD(MinI)=2452500.103+0.382609*E.

The normalized spectra of HN UMa are shown in Fig. 1.

2 Analysis of the spectra

The H_α lines of the two stellar components of HN UMa are in absorption and the H_α line of the secondary star is weaker and narrower than that of the primary one (Fig. 1). On the base of the used ephemeris we will call "primary" the star that is eclipsed at phase 0.0.

In order to measure the radial velocities of the wide H_α lines of HN UMa we fitted their profiles with sums of two Lorenzians.

The obtained radial velocity data were fitted with circular orbits with parameters (Fig. 2): $K_1 \sin i$=25.3±3.9 km/s; $K_2 \sin i$=252.0±7.1 km/s; V_0=-26.7±6.3 km/s; q=0.100±0.018; $(M_1 + M_2) \sin^3 i$=0.84 $M_\odot$; $a \sin i$=2.095 ±0.083 $R_\odot$.

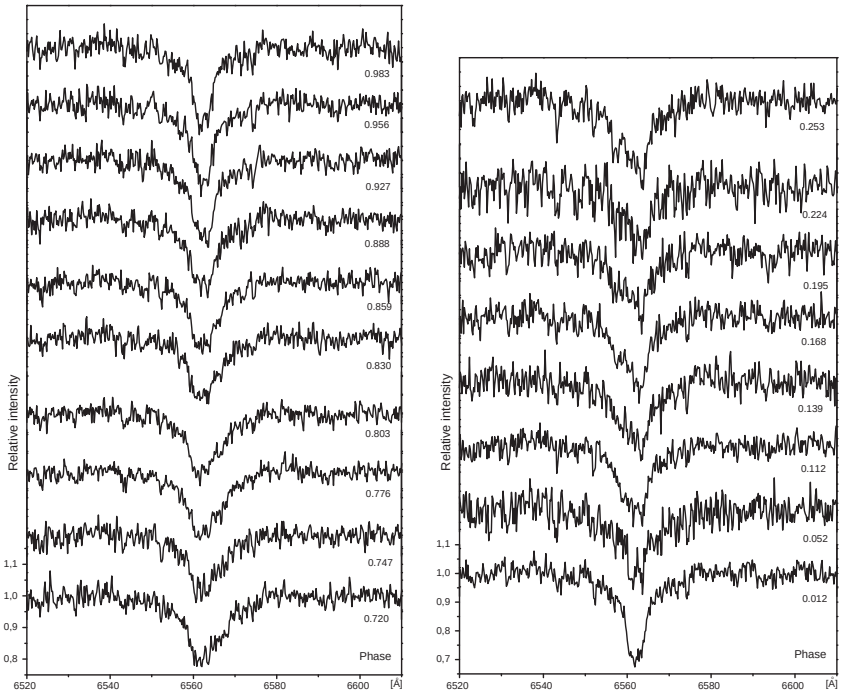

Fig. 1. The spectra of HN UMa from May 27 2008

The obtained value q=0.1 of HN UMa is out of the range 0.2-0.5 of the usual values of the mass ratio for W UMa stars. The mass ratio of HN UMa is very close to the lower limit 0.09 of this parameter for W UMa stars that is derived theoretically as a requirement for a tidal stability of binaries. It is supposed that binaries with $q < 0.09$ are not stable and they should merge to single fast-rotating stars. There are only several binaries with $q < 0.1$ that are useful targets for the study of the final stages of the binary stars.

Assuming an average value i=50^0 from the previous photometric studies of HN UMa (Selam 2004, Zola et al. 2005) we obtained masses M_1=1.78±0.19 $M_\odot$ and M_2=0.18±0.04 $M_\odot$ of the components and separation a=2.78 $R_\odot$. These values mean that the more massive star is eclipsed at the primary eclipse, i.e. HN UMa belongs to the A-subtype of the W UMa stars.

For comparison the parameters of the radial velocity solution obtained by Rucinski et al. (2003) are: K_1=29.6 km/s, K_2=212.2 km/s; q=0.14, $(M_1 + M_2)\sin^3 i$=0.562 $M_\odot$. Although Rucinski et al. (2003) suspected presence of third component in HN UMa later Pribula & Rucinski (2006) stated that they did not find such a component.

The measured rotational broadenings of the H_α lines of the two components of HN UMa correspond to $V_{eq}(1)\sin i$=120 km/s and $V_{eq}(2)\sin i$=52

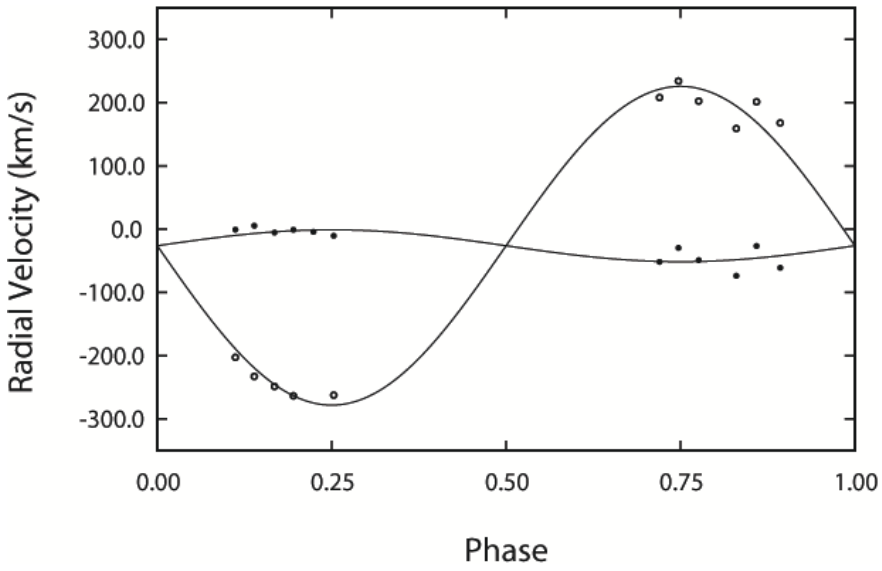

Fig. 2. Radial velocity curves of HN UMa and their fits

km/s. Adopting orbital inclination of 50^0 we calculated the equatorial velocities of the components $V_{eq}(1)$=159 km/s and $V_{eq}(2)$=69 km/s. The fast rotation of W UMa stars is a natural consequence of the spin-orbit synchronization due to the strong tidal interactions between the components of HN UMa.

On the basis of the values of the relative stellar radii r_1=0.57 and r_2=0.23 from the light curve solution of Zola et al. (2005) and our value of the orbital separation a we obtained for the radii of HN UMa' components R_1=1.58 $R_\odot$ and R_2=0.64 $R_\odot$. These values reveal that the secondary component of HN UMa is considerably oversized for its mass in respect to the mass-radius relation for MS stars.

3 Conclusion

The main results of our high-resolution spectral observations of HN UMa might be summarized as follows.

(1) The new radial velocity solution based on the measurements of the H_α lines led to the following global parameters of the system: masses M_1=1.78 $M_\odot$ and M_2=0.18 $M_\odot$; radii R_1=1.58 $R_\odot$ and R_2=0.64 $R_\odot$; separation a=2.78 $R_\odot$. These values mean that HN UMa belongs to the A-subtype of the W UMa stars and its secondary component is considerably oversized for its mass.

(2) The measured equatorial velocities of $V_{eq}(1)$=159 km/s and $V_{eq}(2)$=69 km/s revealed fast rotation of the components of HN UMa.

(3) The mass ratio of HN UMa is very close to the lower limit 0.09 of this parameter for a tidal stability of the W UMa stars. Thus HN UMa is between the several binaries with $q < 0.1$ that are important targets for the study of the final stages of binary stars (probably before coalescence).

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