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Eclipsing Binaries Observed by LAMOST

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LAMOST has a wide field of view and a very high spectrum acquiring rate. More than 9 millions spectra were obtained by LAMOST till now. Among them, more than 8 millions are stellar spectra. Such huge stellar spectra database will stimulate the deep study of stellar physics and corresponding fields. Eclipsing binaries are very important sources in astrophysics because they provide precise information about absolute parameters of the components. LAMOST observed 12923 eclipsing binary stars, which greatly expanded the spectroscopic information of eclipsing binaries. We provided the eclipsing binary catalogue with stellar atmospheric parameters and spectral types obtained by LAMOST. In this paper, we introduce the different kinds of eclipsing binaries observed by LAMOST. As an example of the follow-up observation, we present the study of the EW-type eclipsing binary NSVS4692753. Combined the complete light curves and the parameters obtained by LAMOST, we analyzed its muli-color light curves.Our results show that NSVS4692753 is a low mass ratio (mass ratio 5.0) and deep contact (fill-out factor 64%) W-type contact binary system. The third light contribution was detected in all bands and the asymmetric light variation detected in the light curve was explained by a dark spot in the secondary. NSVS4692753 is the special system at the late evolutionary stage of contact binaries, and maybe the progenitor of the luminous red nova, which is a rare class of optical transients.

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1. Introduction

LAMOST (Large Sky Area Multi-Object Fiber Spectroscopic Telescope, also called as Guoshoujing Telescope) is a national major scientific project built by the Chinese Academy of Sciences. It has a wide field of view of 5 degrees and can simultaneously obtain about 4000 spectra in one exposure [1, 2]. That means it can collect several ten-thousands of spectra per night. The wavelength range of LAMOST is from 370nm-900nm, which is divided into blue arm (370nm-590nm) and red arm (570nm-900nm). Now, more than 9 millions spectra were obtained by LAMOST. Among them, more than 8 millions are stellar spectra. Such huge stellar spectra database will stimulate the corresponding researches in astrophysics.

Eclipsing binaries are very important sources in astrophysics because they can provide precise absolute parameters (e.g. mass, radius etc.) of the components, based on photometric and spectroscopic observations. According to the shapes of light curves, eclipsing binaries can be divided into three groups, i.e., EA-, EB- and EW-types. EA-type eclipsing systems (EAs) are close binaries with spherical or slightly ellipsoidal stellar components. It is possible to specify the moments of the beginning and the end of the eclipse on their light curves. Out of the eclipses, the light remains almost constant or varies insignificantly that is caused by reflection effects and slight ellipsoidal of binary components, or physical variations. The properties indicate that they are not in contact with each other. EAs could be semi-detached system or detached system. EB-type (EAs) and EW-type (EWs) eclipsing systems are close binaries having ellipsoidal components. Their light variations are continuous and cannot be specified the exact times of onset and the end of eclipses. The depths of the primary and secondary minima of EWs are almost equal, while that of EBs are not. This indicates that the two components of EWs are in thermal contact while EBs are not, though the masses of the two components are different. Generally, EWs are the contact binaries and EBs are semidetached or marginal contact binaries.

According to big photometric surveys, such as the Catalina Sky Survey (CSS; [3, 4]), the asteroid survey LINEAR ([5]), the All Sky Automated Survey (ASAS, [6, 7]), the Northern Sky Variability Survey (NSVS; [8]), Kepler mission ([9, 10]), the HATNet Survey ([11]) and SuperWASP survey ([12]), a large number of light curves of eclipsing binaries were obtained. However, the spectral information of them are insufficient. The enormous amount of data representing stellar spectra from the LAMOST survey provide important information for studying eclipsing binaries.

2. Eclipsing binaries observed by LAMOST

Till now, there are 12923 eclipsing binary stars were observed by LAMOST. Among them, the spectra of 8729 eclipsing binaries had sufficiently high signal to noise to determine the stellar atmospheric parameters. These stellar atmospheric parameters include the effective temperature T_{eff}, gravitational acceleration log(g), metallicity [Fe/H] and radial velocity (RV) V_r ([13, 14, 15]). They were determined based on the Universite de Lyon spectroscopic analysis software (ULySS) ([16, 17]). When $T_{eff} < 8000K$, the standard deviations are 110 K, 0.19 dex and 0.11 dex for T_{eff}, log(g) and [Fe/H] respectively. For RV V_r, the standard deviations are 4.91 km/s when $T_{eff} < 10000K$ (e.g., [18]). These parameters are tabulated and available online([19, 20]) (e.g. http://search.vbscn.com/CEW.table1.txt, http://search.vbscn.com/CEA.table2.txt), so that one can

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search these LAMOST parameters for specific eclipsing binary easier. The table includes names of the binaries, their coordinates, types of light variation, orbital periods, distance between LAMOST and the input object, observed date, spectral type, the effective temperature T_{eff}, gravitational acceleration log(g), metallicity [Fe/H] and radial velocity (RV) V_r. We will update the table by adding new data obtained by LAMOST in the future.

EWs have the lowest angular momentum and shortest orbital periods among main-sequence binaries. One of the formation scenario of EWs is that from short-period detached binaries through angular momentum loss via magnetic braking (e.g., [22, 23]) and will merge into rapidly rotating single stars ([21, 24]). 8521 EWs were observed by LAMOST. Among them, 5872 have their LAMOST stellar atmospheric parameters. Qian et al.[19] studied the distribution and correlations of these parameters in detail and got some physical properties of EWs. Such as, they found about 80.6% of sample stars have metallicity below zero, indicating that EWs are old stellar populations. EBs are usually the connections of EWs and EAs. Their semidetached or marginal characteristic make them a good astrophysical laboratory to study mass transfer in close binaries. The stellar atmospheric parameters of 424 EBs were obtained among 605 EBs observed by LAMOST. For EAs, the number is 2020 among 3196 systems. The detailed statistics work was done by Qian et al.[20]

3. Follow-up Observations

According to the LAMOST data, not only some new binaries were detected, but also some special eclipsing binaries were found, such as some unusually high metallicities targets which may be caused by contamination of material from the evolution of unseen neutron stars or black holes in the systems etc. The follow-up observations of LAMOST binaries are useful to derive the reliable parameters based on the photometric and spectroscopic data together, and study the structure and evolution of the close binaries. We present here the follow-up observation and investigation of eclipsing binary NSVS4692753 for example.

The light variation of NSVS4692753 was discovered by Hoffman et al.[25]. It was observed by LAMOST twice on December 27, 2015 and May 15, 2016. The spectral type of G2 and the effective temperature T_{eff} of 5800K were determined by LAMOST data. Using 70 cm telescope in Lijiang station of Yunnan Observatories, We obtained the complete muti-color light curves of this system, which are displayed in Fig 1. During the observation, an Andor 2K CCD camera and the standard Johnson−Cousin−Bessel BVR_cI_c filters were used. Employing the WD code ([26, 27, 28]), we analyzed the light curves by fixing the effective temperature of the primary component as 5800 K obtained by LAMOST. The q-search (see Fig 2)result shows the minimal value achieved at 5.0. The corresponding theoretical light curves (solid lines) and the observations (dots) are plotted in Fig 3. Fig 4 shows the geometric structure of NSVS4692753 at phase 0.0, 0.25, 0.5 and 0.75. The asymmetric light variation in its light curve was explained by the dark spot in the secondary component of NSVS4692753. The detail location of the dark spot can be seen clearly in Fig 4.

Our results show that NSVS4692753 is a low mass ratio (mass ratio 5.0) and deep contact (fill-out factor 64%) W-type contact binary system. The third light contribution was detected in all bands. NSVS4692753 is the special system at the late evolutionary stage of contact binaries.

It may evolve from the present low-mass ratio and deep-contact binary into a single rapid-rotation star and produce a luminous red nova like V1309 Sco [24]. The luminous red nova is a new type of stellar explosion. It is a rare class of optical transients. The peak luminosity is higher than the brightest classical novae, but lower than supernovae. NSVS4692753 maybe the progenitor of such stellar explosion.

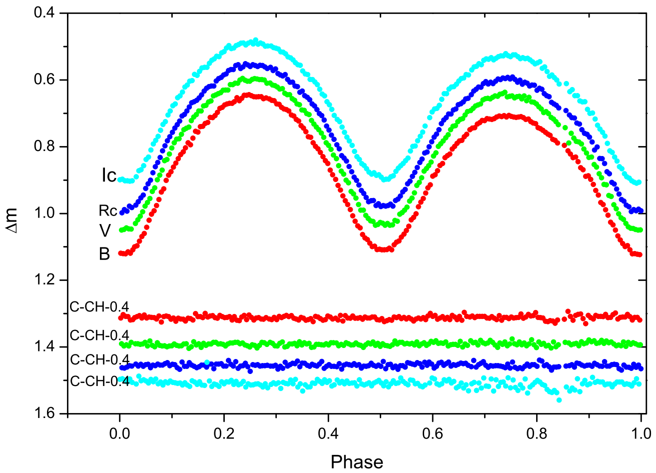

Figure 1: The muti-color light curves of NSVS4692753 observed by 70 cm telescope.

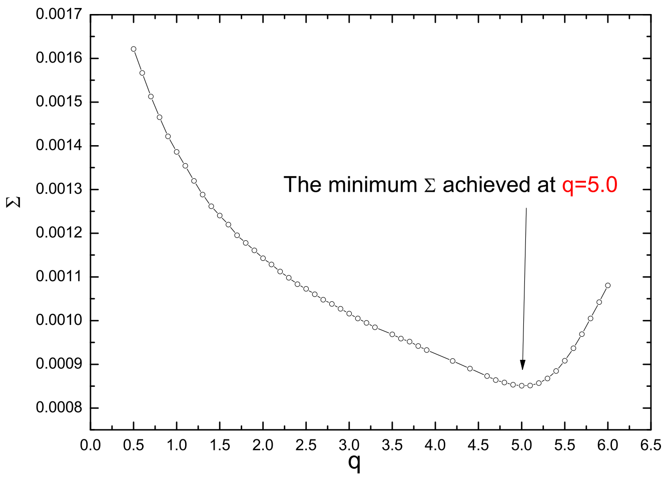

Figure 2: The $\Sigma - q$ curve for NSVS4692753.

4. Conclusion

A huge amount of stellar spectra obtained by LAMOST is very useful for the field of eclipsing binary. We provided the eclipsing binary catalogue with stellar atmospheric parameters and spectral types obtained by LAMOST, which is a great information expansion of eclipsing binaries. Many interesting studies are aroused and need for follow-up in the future.

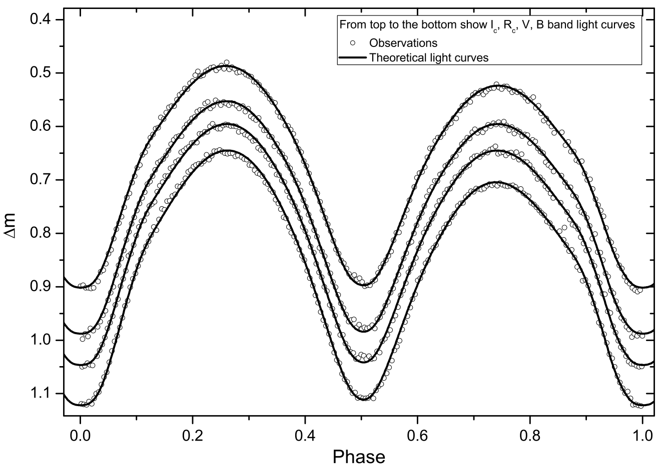

Figure 3: Observed and theoretical light curves of NSVS4692753.

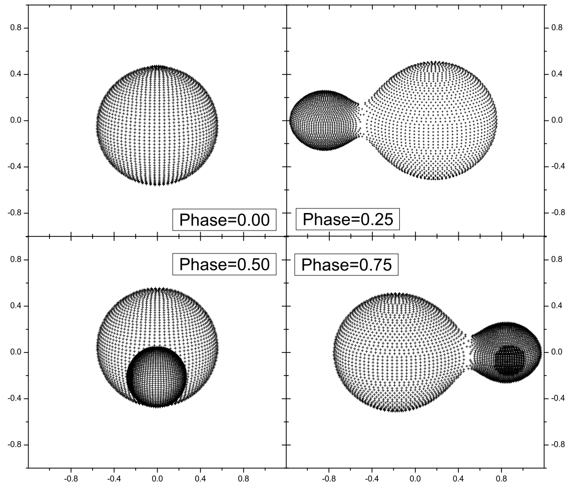

Figure 4: Geometrical structure of NSVS4692753 at phase 0.0, 0.25, 0.5 and 0.75.

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