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EVOLUTION OF CONTACT BINARIES TO RED NOVA: An example of Nova Sco 2008 and its progenitor V1309 Sco

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Abstract. It is accepted that the orbits of close binaries with solar type stars evolve through the angular momentum loss to form contact binaries and then they merge into fast rotating single stars. We present the story of single example of merging contact binary V1309 Sco which was observed in OGLE project before merging process in 2008. The analysis of the light curves of V1309 Sco reveals the properties of progenitor contact binary V1309 Sco.

Keywords: *binary stars: Contact Binary, Nova: Red Nova stars: individual: V1309 Sco*

1. Introduction

Close binary stars with short periods (less than one day) evolve to contact binaries by losing angular momentum through the magnetized stellar winds (Robertson & Eggleton, 1977). Recent studies reveal that the merging of contact binary components are related with a nova like burst known as "red nova" or "V838 Mon type eruptions". Such bursts are different from classical nova, their luminosity reaches maximum $10^6 L_{\odot}$ and they evolve cool supergiant (Tylenda et al., 2011).

V1309 Sco erupted as a red nova in 2008 (Nakano et al., 2008). In this study, we presented the light curve analysis of V1309 Sco which was discovered to be the progenitor of Nova Sco-2008.

2. Photometric observations of V1309 Sco

Nova Sco-2008 was discovered in 2008 by Nakano et al. (2008) as a powerful eruption. It was observed by Rudy et al. (2008) just after the eruption that Nova Sco-2008 was an F-type giant star. Eight months later, the spectral type of the star evolved to K and then to M type giant star (Mason et al., 2010).
The progenitor of Nova Sco-2008 was observed by OGLE III and OGLE IV projects during six years before its eruption. These observations were made using I Cousins photometric filter set and the project obtained about 2000 data points (Figure 1). Standard deviations of the observations are about 0.01 mag (Tylenda et al., 2011). The progenitor came out to be a contact binary, i.e. V1309 Sco.

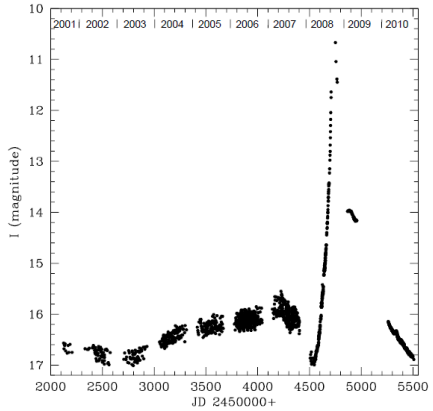

Figure 1. Light variation of Nova Sco-2008 (Tylenda et al., 2011).

During the eruption, V1309 Sco's brightness increased from 17 to 6.8 mag. But this stage was not observed in OGLE project due to technical reasons. Light variation of V1309 Sco obtained in OGLE project is given in Figure 2 (Tylenda et al., 2011).

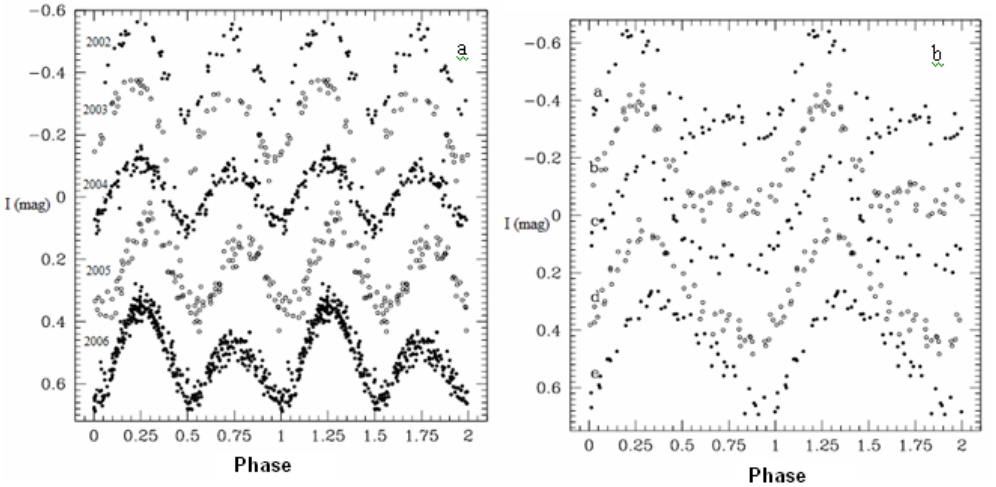

Figure 2. a) Light curves of V1309 Sco in 2002-2006 b) light curves of V1309 Sco in 2007 (Tylenda et al., 2011).

As it can be seen in Figure 2, the light curves exhibit two maximum and two minimum like in contact binary stars but the level of second maximum drops down in time from 2002 to 2006. At the end the second maximum disappears when the components of V1309 Sco merge into a single star (Tylenda et al., 2011).

3. Light curve analysis

We analysed the light curves of V1309 Sco obtained in 2002, 2004 and 2006. Before the light curve analysis we made mass ratio search by using 2002 light curve. It was found to be q≈0.1. Then, the

progenitor light curve analysis was made using Wilson-Devinney program (Wilson & Devinney, 1971). The 2002 and 2004 light curves were analyzed through Wilson-Devinney code mode 3, the 2006 light curve was analyzed by mode 6. In these analysis the effective temperature of the primary component was adopted as 4500 K (Tylenda et al., 2011) and it was fixed through out the analysis. Details and other selected parameters for the solution can see Soydugan et al. (2011) study. Decreasing level of the secondary maxima is most probably caused by cool material accumulated around phase 0.75. In the light curve analysis we represented such cool material effect by the cool spot which produce similar effect on the light curve. Size increase of the cool spot was seen from 2002 to 2006 in the light curves of the V1309 Sco. The result of the light curves analysis of V1309 Sco was given in Table 1. The consistency between the computed light curves and observational data can be seen in Figure 3.

Table 1. Results of the light curves analysis of V1309 Sco.

Parameter	2002 Light Curve	2004 Light Curve	2006 Light Curve
q	0.107 (30)	0.099 (23)	0.178 (17)
T_1 (K)	4500*	4500*	4500*
T_2 (K)	4822 (68)	4781 (35)	5128 (28)
i (^{o})	62.72 (54)	62.57 (95)	63.51 (82)
Ω_1, Ω_2	1.911 (260), 1.911	1.932 (144), 1.932	2.176 (98), 2.176
$L_1/(L_1+L_2)$	0.82 (11)	0.85 (7)	0.73 (4)
Fill-out	25	34	100
Colatitude (^{o})	90	90	90
Longitude (^{o})	330	330	270
Radius (^{o})	32.1	43.2	129.6
T_{spot}/T_{local}	0.76	0.76	0.76

* fixed parameters

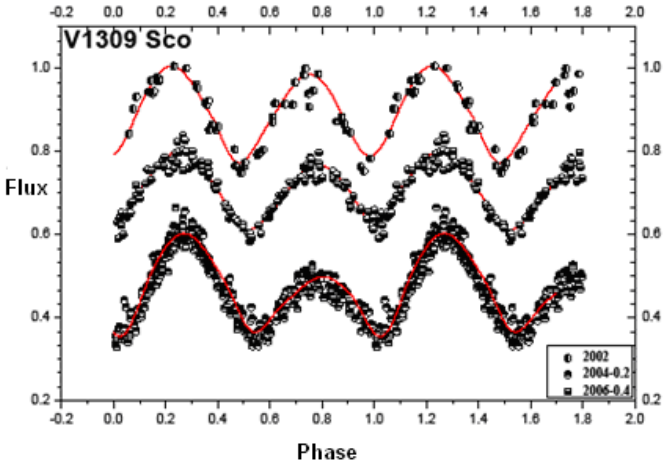

Figure 3. OGLE light curves of V1309 Sco and theoretical light curves.

4. Discussion

In 2008, Nova Sco-2008 eruption occurred and investigations showed that its progenitor was a contact binary; V1309 Sco. Before the eruption, the OGLE project monitored progenitor V1309 Sco for six years. In this study, we used OGLE's data of V1309 Sco and analyzed its light curves. Our goal in this study is to monitor the variation of the binary elements just before merging process. Results of our analysis present the phases of the merging process in the contact binary V1309 Sco. The most interesting parameter change between 2002 and 2006 was expected in mass ratio: it diminishes first and then increases suddenly. If this change is real it may be caused by sudden mass loss from the third Lagrange point which causes the mass loss from primary and thus the increasing mass ratio. Large increase of the fill-out parameter from 34 to 100 in two years supports the picture. Decrease in the level of the secondary maximum is probably due to light absorption by cool material accumulated around phase 0.75. Such material accumulation around phase 0.75 provided by the loss mass from L_3 point through the coriolis force. Further decrease of the secondary maximum level and its disappearance is probably due to further accumulation of mass and its engulfing the small secondary which may spirale into merging with the primary component.

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