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Detection of two-armed spiral shocks on the accretion disk of V1494 Aql

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Abstract. We have modeled the unusual orbital light curve of V1494 Aquilae (Nova Aquilae 1999 No.2) and found that such an unusual orbital light curve can be reproduced when there exist two-armed spiral shocks on the accretion disk. In particular, triple-wave patterns are naturally obtained. This result strongly suggests the existence of two-armed spiral shocks on the accretion disk in the late phase of the nova outburst.

1. Introduction

Angular momentum transport plays an essential role in accretion disks of cataclysmic variables. Two mechanisms have been proposed so far: one is the turbulent viscosity as adopted in the standard accretion disk model of Shakura & Sunyaev (1973), and the other is the direct dissipation by tidal spiral shocks on the accretion disk as first demonstrated by Sawada, Matsuda, & Hachisu (1986). The turbulent viscosity is a local physical process while the tidal spiral shocks have a global structure on the accretion disk. Therefore, we have a chance to observe global spiral shock structures when they play an essential role in the angular momentum transport of the accretion disk. Such observational evidence first came from the Doppler maps of the dwarf nova IP Peg outburst Steeghs, Harlaftis, & Horne (1997). We have long believed that tidal spiral structures can be detected even in orbital light curves of cataclysmic variables if the spiral patterns are prominent. At last we find such evidence of spiral patterns on the accretion disk from the orbital light curves of V1494 Aquilae.

2. The light curve model

Our binary model and the corresponding orbital light curve are illustrated in Figure 1, which consists of a 0.3 $M_\odot$ main-sequence (MS) star filling its Roche

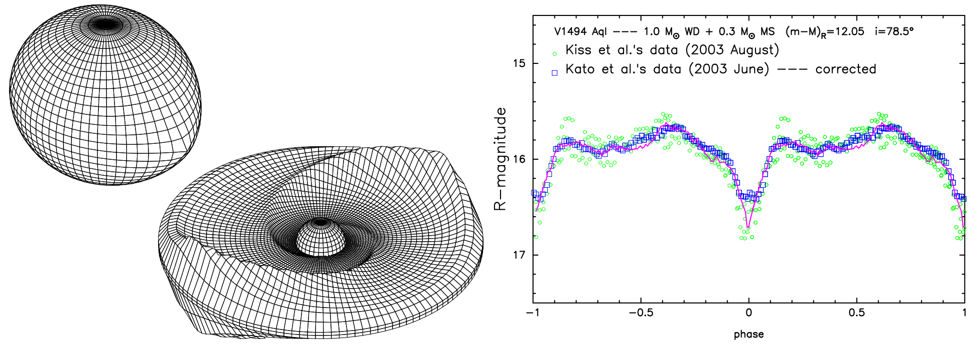

Figure 1. Left: Our V1494 Aql model. The farther cool component is an main-sequence (MS) companion (0.3 $M_\odot$) filling up its inner critical Roche lobe. The north and south polar areas of the cool component are irradiated by the nearer hot component (1.0$\mathrm{M}_\odot$ white dwarf (WD), right). The separation is $a = 1.21$ $\mathrm{R}_\odot$; the effective radii of the inner critical Roche lobes are $R_1^* =$ 0.59 $\mathrm{R}_\odot$ and $R_2^* = R_2 = 0.34$ $\mathrm{R}_\odot$ for the primary WD and the secondary MS companion, respectively. A two-armed spiral pattern is shown on the accretion disk. The WD surface is artificially enlarged so as to easily see it. Right: calculated R_c light curves plotted against the binary phase (binary phase is repeated twice from −1.0 to 1.0) together with the observational points of Kato et al. (2004, squares) and of Kiss, Csák, & Derekas (2004, circles). A thick solid line denotes the R_c light curve for the best fit model. The apparent distance modulus is $(m - M)_R = 12.05$ for the WD luminosity of $L_\mathrm{WD} = 3000$ $\mathrm{L}_\odot$.

lobe, a 1.0 $\mathrm{M}_\odot$ white dwarf (WD), and a disk around the WD. The triple-wave structure of the out-of-eclipse orbital light curve is reasonably and naturally reproduced with our spiral shock pattern model. See Hachisu, Kato, & Kato (2004) for more details. Both the thickness of the accretion disk and the pitch angle of spirals adopted here are roughly consistent with the three-dimensional simulations (e.g., Makita, Miyawaki, & Matsuda 2000). The present results strongly support the two-armed spiral pattern on the accretion disk. We hope for a spectroscopic confirmation of this spiral pattern by Doppler maps for V1494 Aql.

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