

Fitting of Light Curves for V4641 Sgr

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Abstract

We report the fitting results of theoretical light curves for microquasar V4641 Sgr. In this study, we apply a new accretion disk model that is presented by Fukue (2004) to observed R-band light curves in V4641 Sgr. The new model takes into account the geometrical thickness of the disk, so it may be able to describe the two deep minima of the observed light curves. Best-fit parameters show that the system has a relatively high inclination angle, $i=75^\circ$, and the mass accretion rate is near to the Eddington rate. If our result makes true, the object will be a first eclipsing black-hole binary.

Microquasar & Observation

Microquasars in our Galaxy are a binary system which consists of a stellar mass black-hole and a companion star, and they usually have relativistic well-collimated jets (e.g., GRO J1655-40, GRS 1915+105). V4641 Sgr is one of the microquasars which large X-ray outbursts been detected since 1999. The optical counter part of V4641 Sgr has already discovered by Goranskij (1978), they regarded the object as a variable star. The system contains a black hole with mass of $\sim 10M_\odot$ and secondary star – its spectral type B9III – with $\sim 6M_\odot$, and the distance from the sun is about 13kpc (Orosz et al. 2001). Optical light curves in V4641 Sgr are modeled by Orosz et al. (2001) for the first time with an ellipsoidal model. The ellipsoidal model can roughly reproduce two minima in light curves due to the effect of tidally distorted secondary star. However, their model does not explain the amplitude of the minima and the origin of the asymmetry of the light curves. Here, we try to solve the problem **considering an accretion disk model**.

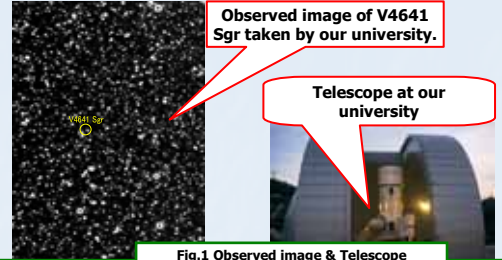


Fig.1 Observed image & Telescope

We observed V4641 Sgr by 51cm Schmidt Cassegrain telescope at Osaka Kyoiku University (hereafter OKU) with the CCD camera. The observed period is from 2004 to 2005 which covers all binary phases. Fig.1 shows the image of V4641 Sgr observed at OKU. Direction of this object is near to the Galactic center.

Critical accretion disk

Critical accretion disk is the super critical accretion disk inside the **critical radius** (boundary for Eddington luminosity) $r_{cr} = \frac{9\sqrt{3}}{8} \frac{r_g}{m} r_g$ ($r_g = 2GM/c^2$), while standard

disk outside the critical radius (Fukue 2004).

Inside r_{cr} the accretion rate decreases with the radius, so as to maintain the critical rate, expelling any excess mass by the radiation-driven wind. Geometrical thickness, H , and the effective temperature, T_{eff} , of disk are a function of accretion rate \dot{m} .

$$H = \begin{cases} \frac{3}{16} (1 - \sqrt{\frac{R_{in}}{R}}) \dot{m} & \text{for } r \geq r_{cr} \\ \sqrt{c_s} r & \text{for } r \leq r_{cr} \end{cases}, \quad \sigma T_{eff}^4 = \begin{cases} \frac{3L_E}{16\pi r^2} \dot{m} & \text{for } r \geq r_{cr} \\ \frac{3}{4} \sqrt{c_s} \frac{L_E}{4\pi r^2} & \text{for } r \leq r_{cr} \end{cases}$$

where $\dot{m} \equiv \dot{M} / \dot{M}_{crit}$, $\dot{M}_{crit} = L_E / c^2$, L_E is the Eddington luminosity.

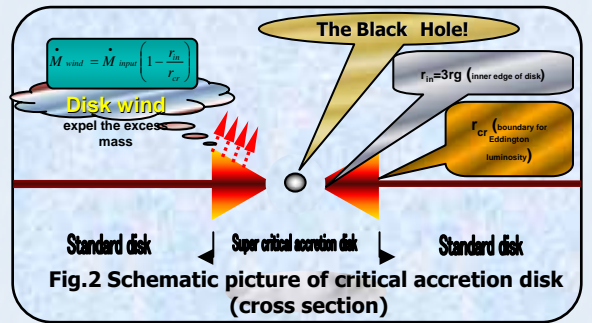


Fig.2 Schematic picture of critical accretion disk (cross section)

Simulation of Binary Light Curves

Our binary calculation code can calculate the observed images and light curves including the secondary star and the disk model under the Roche potential. We obtained the binary luminosity as sum of the local region using the mesh-method (total mesh number is $\sim 240 \times 240 \times 240$). Main parameters are inclination angle i , and mass accretion rate \dot{m} . Mass ratio was determined by Orosz et al. Temperature of companion star and orbital period were fixed at 10500 K and 2.8173 day. We take into account not only canonical standard disk model but also the disk thickness and temperature distribution in critical disk model.

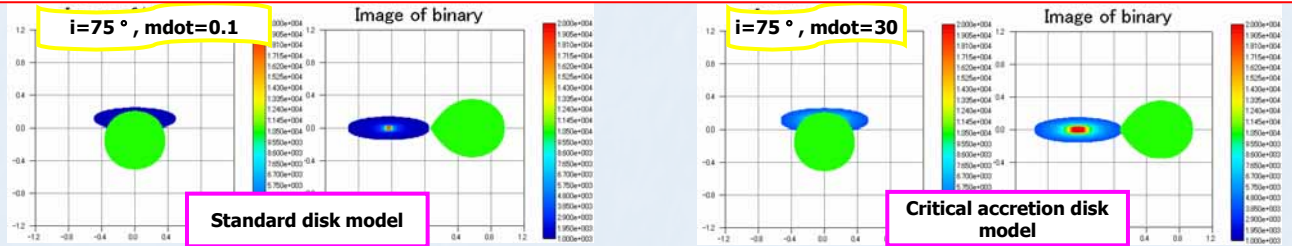
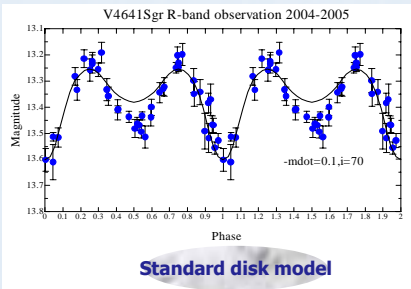
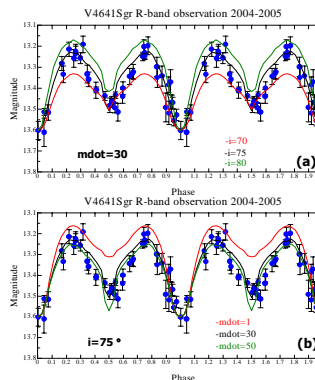


Fig.3 Observed temperature images of V4641 Sgr simulated by our code. They show the temperature of accretion disk and companion star. Note that they don't show the optical images.

Fitting Results



Thin disk model cannot explain secondary minimum! (at the phase 0.5 or 1.5)



Fitting Results

Fitting results of light curves using critical accretion disk model.

In these cases (a) and (b), mass ratio fixed 0.778 (mass of disk and companion star $9M_\odot, 7M_\odot$, respectively). Inclination angle related to the depth of primary minimum, shown by (a). Increasing of the disk mass accretion rate makes a deep secondary minimum, seen in (b). Then we decided the best fit parameter are $\dot{m}=30, i=75^\circ$.

Conclusion

We observed light curves of V4641 Sgr in a quiescence state with OKU telescope, and have done the model fitting using a critical accretion disk model. In this study, we show the deeper sub- minimum light-curve which cannot be reproduced the standard model. That is because the disk became bright as comparable as the companion star. The best fit parameters are, mass of black-hole and companion star are $9M_\odot$ and $7M_\odot$, and inclination angle is 75° , \dot{m} is 30. We note that the canonical ellipsoidal model cannot explain the sharp sub-minimum in the light-curve, thus the geometry (thickness) of the accretion disk should be important in this object for reproducing the complete light-curve.