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UBV-Photometry and 35-day Cycle Model for X-ray Binary HZ Her/Her X-1

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Abstract. Based on the detailed analysis of UBV-photometry of HZ Her obtained in 1972-1994, a model of 35-day cycle is proposed in which both forced precession of a tilted accretion disk and free precession of the neutron star are present.

Mean B-light curve of HZ Her which is folded with the mean precesion period $P_{pr} = 20.5 P_{orb}$ is shown in Fig. 1. A large dispersion of points is clearly seen. The basic idea is to decrease the dispersion on the light curve taking into account real non-stability of the 35-day cycle. We shifted calculated mean precession phases of individual nights so as to keep them as close as possible with the observed main X-ray turn-on moments. The resulting 35-day $O-C$ is plotted in Fig. 2. Individual nights are shown by bars (the length of the bar coresponds to one orbital revolution), empty and filled circles correspond to the observed moments of X-ray turn-on according to X-ray and optical data, respectively. The final B-light curve with much smaller dispersion is shown in Fig. 3 (dots). The basic model is the forced precession of a geometrically thick (semithickness-to-radius ratio $H/r = 0.2$), 15°-tilted to the orbital plane accretion disc. The binary inclination is $i = 87°$. The disc is maximum open at the phase $\phi_{pr} = 95 - 00$. The main turn-on of the source begins at $\phi_{pr} = 80 - 85$. At each precession phase, the upper dashed curve is the pure reflection effect as would be seen if the disc were infinitely thin but has the a finite radius $R_d = 1.8 R_\odot$ (the secondary minimum on the curve is due to the disc passing before the heated face of the star); the bottom solid line shows how the reflection light curve changes considering the disc finite thickness. The best agreement with the observed light curve is achieved when we add the finite disc contribution (horizontal line) and some bright "spots" that appear at some phases. A small modulation of the parameter X-ray-to-optical luminosity ratio L_x/L_{op} with the precession phase might be evidence for the neutron star free precession in the optical light curve. The detailed description of the model will be published elsewhere.

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References

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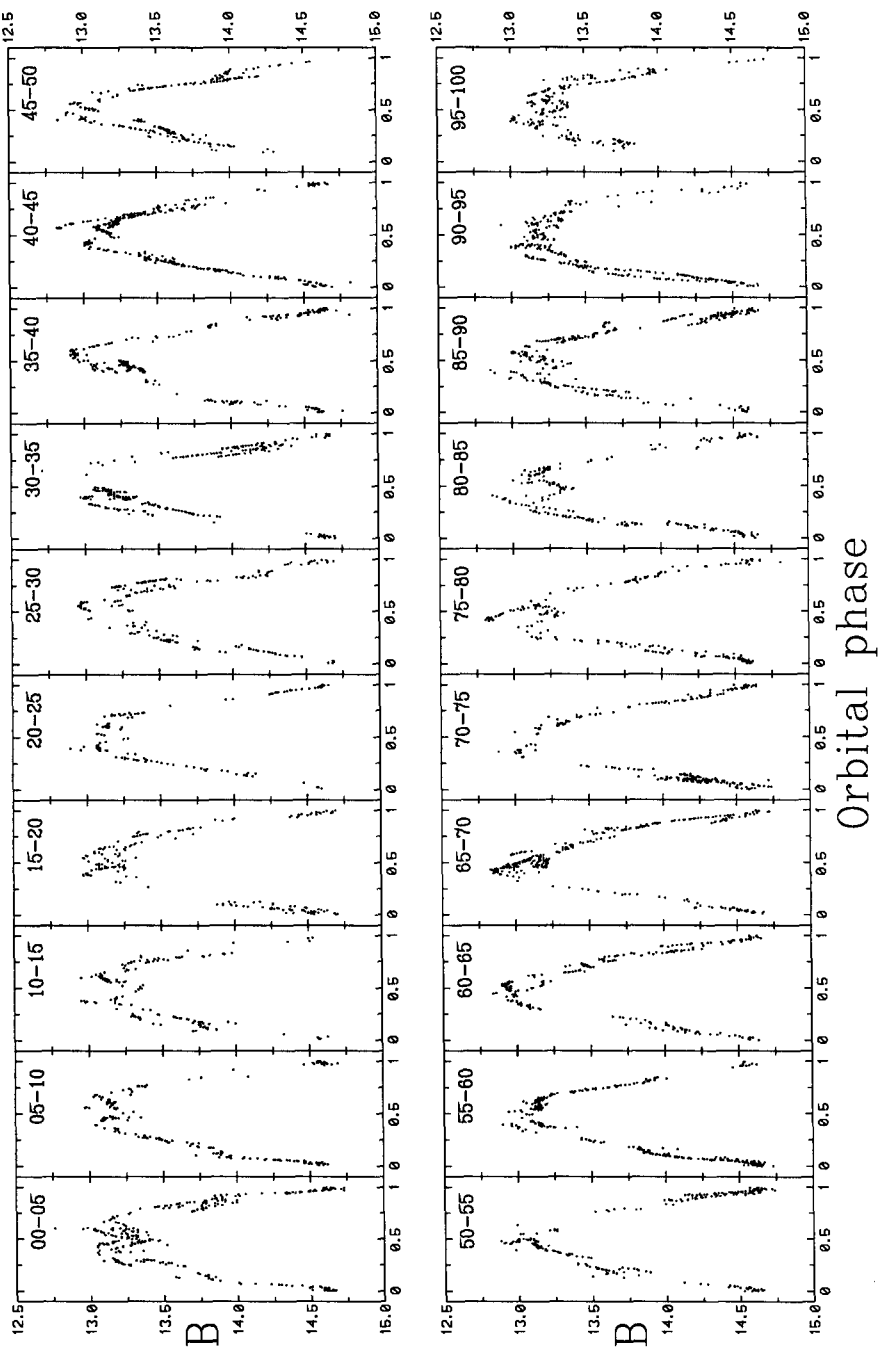

Figure 1. Observed B-light curve folded with the mean precession period (20.5 orbital periods)

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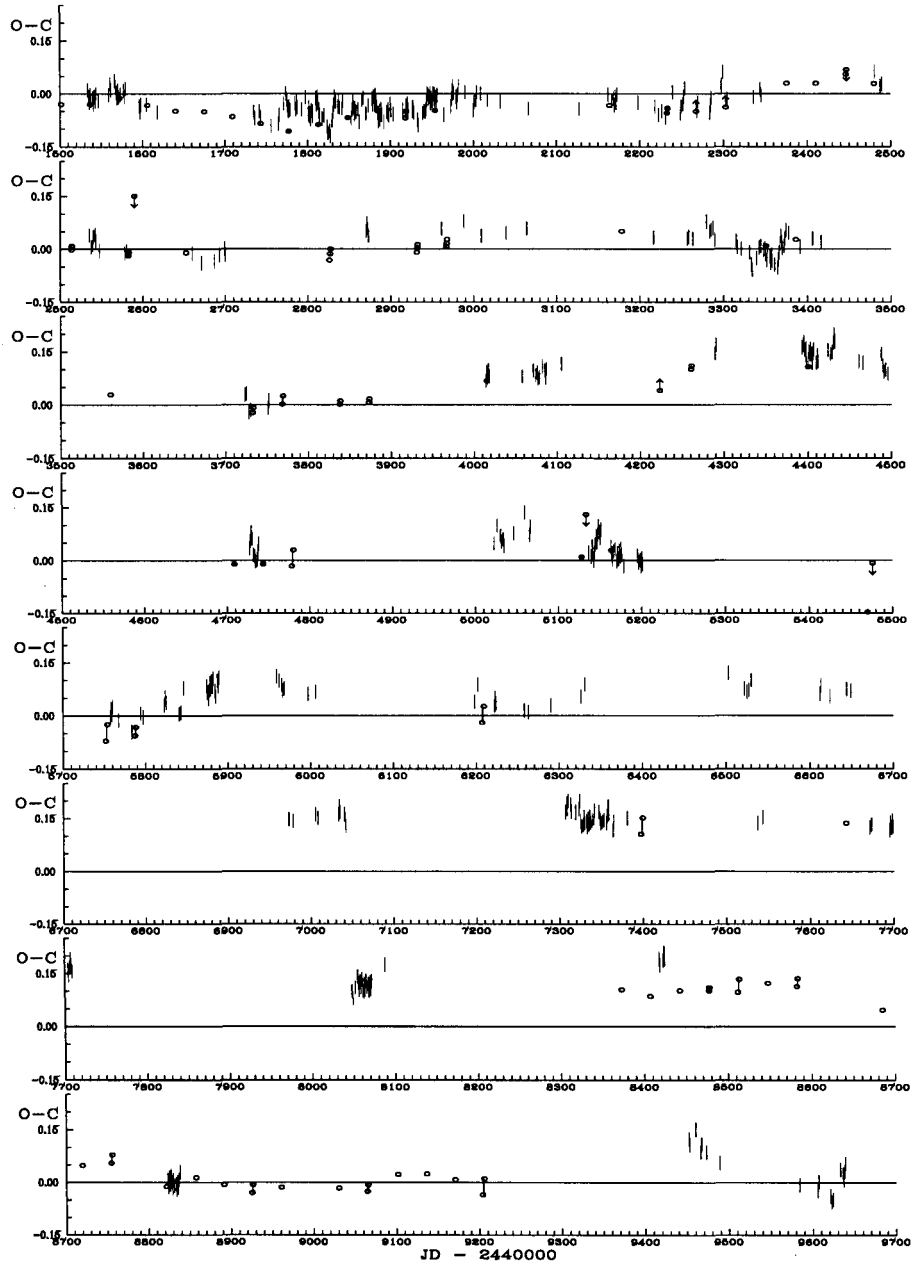

Figure 2. O-C diagram showing the 35-day phase-shifts of individual nights (bars) in accordance with the turn-on moments (circles)

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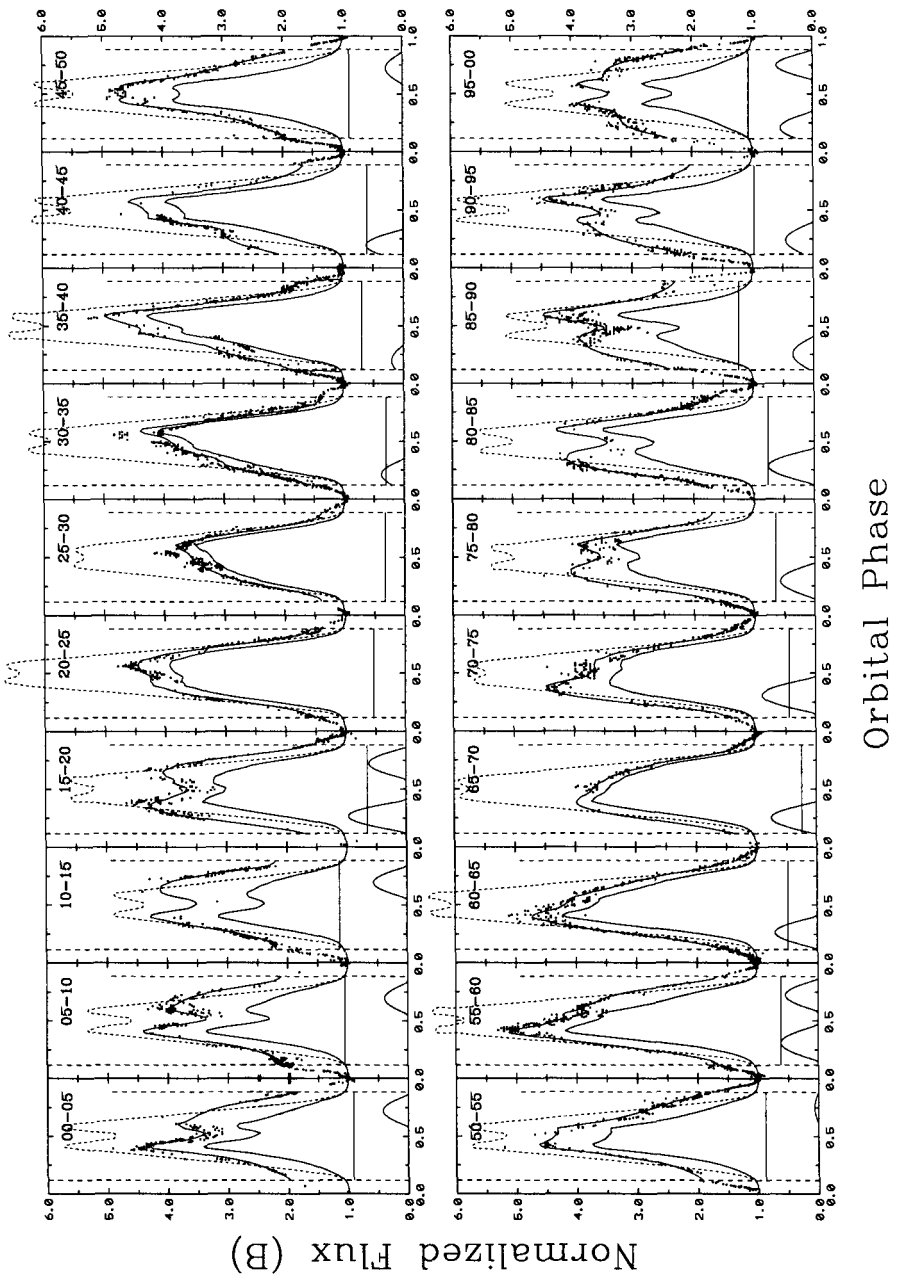

Figure 3. The resulting 35-day B-light curve and the model fit

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Discussion

R. Webbink: Does your model offer an explanation for the variation in turn-on phase?

N. Shakura: Yes. The dynamical action of the gaseous streams on the accretion disk that are moving at an inclination to the plane of the binary system.

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