Precessions of accretion disks in close binaries

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Abstract. Inoue (2012) investigated properties of a precessing motion of a ring, which is circularly rotating around a compact star under an influence of a tidal force from a companion star. Super-orbital periods observed from several X-ray binaries are explained to be the precession periods in the tidal-force-induced precession scheme quite reasonably.

Key words. Binaries – Accretion disks – Compact stars – X-ray observations

1. Introduction

Recently, Inoue (2012) studied a tidal-force-induced precession of an accretion disk in a close binary which was originally discussed by Katz (1973). He examined energetics of a precessing ring around a compact star as a function of the tilting angle of the ring equatorial plane from the binary plane. It is shown that the energy minimum of the ring exists at a state in which it is precessing with a certain tilting angle.

From the arguments by Inoue (2012), precessions are suggested to often take place in X-ray binaries. There, a ratio of a ring radius, $R$, to a binary separation, $D$, in terms of a ratio of an orbital period, $P_B$, to a precession period, $P_P$, and that of masses of two stars is predicted as

$$
\frac{R}{D} = \frac{2(1 + q)^{1/2}}{q} \frac{P_B}{P_P} \cos \theta \left( \frac{1}{2} \right)^{1/3},
$$

where $q$ is a ratio of the companion star mass to the compact star mass. Fig. 1 shows lines, on which the ratio between $P_B$ and $P_P$ has the same value for three cases, on a $q$ and $R/D$ plane. Here, $\cos \theta$ is assumed to be 1 for simplicity. On this figure, the average radius, $R_L$, of the Roche lobe is indicated as its ratio to $D$ according to an approximation by Eggleton (1983).

2. Super-orbital periods

Superorbital periods have been found in several X-ray binaries (e.g. Friedhorsky & Holt 1987; Wen et al. 2006). Inoue (2012) calculated expected ($R/D$) values for six X-ray binaries: the X-ray pulsars, Her X-1 and LMC X-4; the relativistic jet source, SS433; the low mass X-ray binary, X1916-053; the black hole candidates, Cyg X-1 and LMC X-3. The results are plotted in Fig. 1. The $(R/D)$ values are all well below the $(R_L/D)$ locus. This favors the disk-precession scheme. It is interesting to note that two trends seem to exist in this figure; one from X1916-053 to SS433 and the other from LMC X-3 to LMC X-4. The trend with the larger $R/D$ ratio might correspond to cases of accretion due to Roche lobe overflow, while the other could correspond to cases of wind-fed accretion.
Fig. 1. Ratio of a radius of a precessing ring, $R$, to a binary separation, $D$, predicted in the tidal-force induced precession scheme as functions of a ratio between an orbital period, $P_B$, and a precession period, $P_P$, and a ratio of a mass of a companion star, $M_C$, to that of an X-ray emitting compact star, $M_X$. The $R/D$ predictions are plotted in three cases of $10^{-1}$, $10^{-2}$ and $10^{-3}$ for $P_B/P_P$ with dotted lines in a $R/D$ and the mass ratio, $M_C/M_X$ plane. The average radius of the Roche lobe around the compact star, $R_L$, is also indicated as a ratio to the binary separation. Predicted $R/D$ values are calculated for six X-ray binaries on an assumption that their observed super-orbital periods are periods of the tidal-force induced precession.

References
Inoue, H. 2012, PASJ, 64, 40