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Precessions of accretion disks in close binaries

H. Inoue

Institute of Space and Astronautical Science – JAXA, 3-1-1, Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan, e-mail: inoue-ha@msc.biglobe.ne.jp

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, $P_{\rm B}$, to a precession period, $P_{\rm P}$, and that of masses of two stars is predicted as

$$\frac{R}{D} = [2\frac{(1+q)^{1/2}}{q}(\frac{P_{\rm B}}{P_{\rm P}})\frac{1}{\cos\theta}]^{2/3}, \qquad (1)$$

where q is a ratio of the companion star mass to the compact star mass. Fig. 1 shows lines, on which the ratio between $P_{\rm B}$ and $P_{\rm P}$ 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, $R_{\rm L}$, of the Roche lobe is indicated as its ratio to D according to an approximation by Eggeleton (1983).

Send offprint requests to: H.Inoue

2. Super-orbital periods

Superorbital periods have been found in several X-ray binaries (e.g. Priedhorsky & 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 $(R_{\rm L}/D)$ 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.

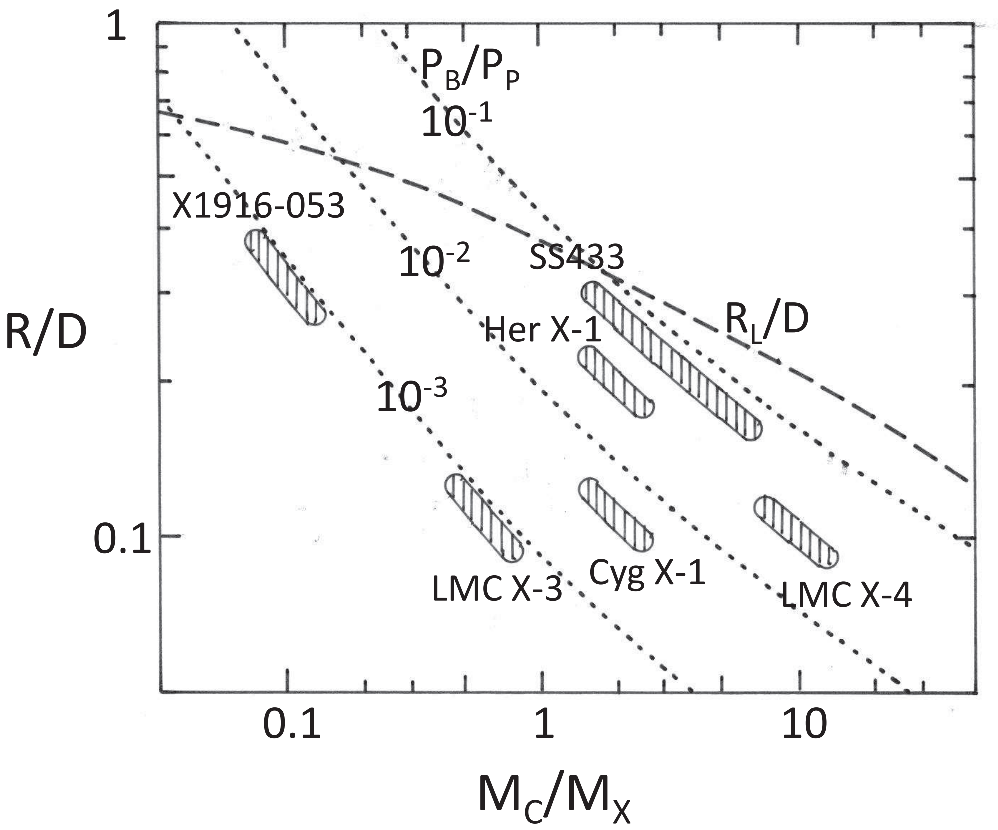

Fig. 1. Ratio of a radius of a precessing ring, R, to a binary separation, D, predicted in the tidal-force induced precession scheme as functions of a ratio between an orbital period, P_B, and a precession period, P_P, and a ratio of a mass of a companion star, M_C, to that of an X-ray emitting compact 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.

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