A non-dissipative tidal evolution of stellar inclination axis in eccentric inclined close binary systems

Pavel Ivanov

Abstract. In this contribution I introduce a new effect of the non-dissipative tidal evolution of stellar rotational axis in inclined eccentric binary systems containing a distributed star and a point-like component. This effect is analogous to the well-know von Zeipel-Kozai-Lidov effect, but, in our case there is no need for a third perturbing body. The effect was discovered in our work together with J. C. B. Papaloizou in 2021 and its theory was later developed in 2023.

Introduction

Tidal interactions play an extremely significant role in the evolution and dynamics of close binary systems and systems containing "Hot" and "Warm Jupiters". Despite the almost 150-year history of quantitative researches in this area, the complexity of phenomena associated with tides still opens up room for an opportunity to find qualitatively new effects. In particular, in our work [1] we showed that there is a possibility of the evolution of the angle between rotation axis of one of the binary components and the normal to the orbital plane (the inclination angle) due to non-dissipative processes associated with tides. Physically, this possibility arises due to misalignment of the symmetry axis of the tidal bulge and the axis directed to the gravitating center induced by rotation. The corresponding torque leads to the evolution of the inclination angle. This effect operates when the axis of rotation is inclined relative to the orbital plane, and the orbit has a non-zero eccentricity. It turns out that the rate of change of the inclination angle is determined by the rate of precession of the apsidal line. In our subsequent work [2], [3], we examined the evolution of the apsidal line due to all potentially important factors operating in an isolated binary system - tides, the Einstein precession and the effects determined by oblateness of the rotating star. The second component of the system was treated as a point-like source of gravity. It was shown, that in the case when the various terms in the equation describing the evolution of the apsidal line almost cancel each other (the so-called evolution near a “critical line”), in addition to the effect of non-dissipative tidal evolution of the stellar rotational axis there must be another qualitatively new effect - instead of the usual, uniform evolution of the apsidal line it librates around an equilibrium value. These effects can be observed in three types of astronomical systems, at least, - in close binary systems with an observed anomalous change of the apsidal line, in systems containing neutron stars, where the orbital inclination and eccentricity can be formed during a supernova explosion (e.g. GX-301-2) and the subsequent kick of the compact component, and in systems containing "Warm Jupiters" on inclined eccentric orbits.In the latter case, the effect can be significant when the planet’s axis of rotation is inclined, and it can potentially be used to find the angle of inclination and rotational frequency of a planet with suitable orbital parameters. A preliminary analysis of the parameter space of the problem was carried out in order to find a region corresponding to the librational dynamics and it was shown that this region is rather large in the case of a sufficiently large eccentricity of the system (say, the eccentricity e is larger than or of the order of 0.5), and the mass ratio is larger than or of the order of unity. Observational detection of this effect would allow one to exploit new methods of determining of the orbital parameters of the systems, it would also provide some additional information about the internal structure of the distributed stars.

Conclusion

We introduced the new effect of non-dissipative tidal evolution of the inclination angle, which may also lead to librations of the apsidal line. We also pointed out a few of potentially interesting systems, where this effect may take place.

References

[1] P. B. Ivanov, J. C. B. Papaloizou, *Monthly Notices of the Royal Astronomical Society*, 500, 3335, 2021.

[2] P. B. Ivanov, J. C. B. Papaloizou, *Monthly Notices of the Royal Astronomical Society*, 526, 3352, 2023.

[3] P. B. Ivanov, J. C. B. Papaloizou, *Astronomical Reports*, 67, 911, 2023.

Pavel Ivanov
Department of theoretical astrophysics and cosmology
PN Lebedev Physical Institute
Moscow, Russia
e-mail: `pavel000astrophysics@gmail.com`