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ORIGINAL ARTICLE

Radius of the Roche equipotential surfaces

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Abstract In literature, there is no exact analytical solution available for determining the radius of Roche equipotential surfaces of distorted close binary systems in synchronous rotation. However, Kopal (Roche Model and Its Application to Close Binary Systems, Advances in Astronomy and Astrophysics, Academic Press, New York 1972) and Morris (Publ. Astron. Soc. Pac. 106:154, 1994) have provided the approximate analytical solutions in the form of infinite mathematical series. These series expressions have been commonly used by various authors to determine the radius of the Roche equipotential surfaces, and hence the equilibrium structures of rotating stars and stars in the binary systems. However, numerical results obtained from these approximating series expressions are not very accurate. In the present paper, we have expanded these series expressions to higher orders so as to improve their accuracy. The objective of this paper is to check, whether, there is any effect on the accuracy of these series expressions when the terms of higher orders are considered. Our results show that in most of the cases these expanded series give better results than the earlier series. We have further used these expanded series to find numerically the volume radius of the Roche equipotential surfaces. The obtained results are in good agreement with the results available in literature. We have also presented simple and accurate approximating formulas to calculate the radius of the primary component in a close binary system. These formulas give very accurate results in a specified range of mass ratio.

Keywords Methods: analytic · Methods: numerical · Binaries: close · Binaries: general

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1 Introduction

Roche model is widely used to describe the equipotential surfaces (form hereafter we will refer equipotential surfaces as ES and Roche equipotential surfaces as RES) in a close binary system. It is a model in which it is assumed that the total mass of a star is concentrated at its center and this point mass is surrounded by an evanescent envelope in which density varies inversely as the square of the distance from its center. It is also based on the assumptions that the two components of the binary system act as point masses, rotation of the components is uniform, there is synchronism between spin of two components and the orbital motion, orbits are circular and there is no radiation pressure. Despite such assumptions that are not always true in various observed stars, the application of the Roche model has led to considerable progress in our understanding of the structure and evolution of close binary stars, mass transfer in interacting binaries and the orbital stability of satellites in planetary systems.

The calculation of the ES in the close binaries is of importance for determining both the sizes of critical lobes and shapes of the components, and also it is the foundation of all modern day light curve analysis. In literature, certain authors such as Avni and Schiller (1982), Csataryova and Skopal (2005), Eggleton (1983), Kopal (1972), Kruszewski (1963), Kuiper and Johnson (1956), Limber (1963), Lopez Orti et al. (1992), Mochnacki (1984), Morris (1994), Plavec and Kratochvil (1964), Schuerman (1972), Seidov (2004) and