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Testing stellar evolution models

Seblu H. Negu and Solomon Belay Tessema

Ethiopian Space Science and Technology Institute (ESSTI), Entoto Observatory and Research Center (EORC), Astronomy and Astrophysics Research and Development Division, Box 33679, Addis Ababa, Ethiopia
emails: seblu1557@gmail.com; tessemabelay@gmail.com

Abstract. In this study, we have investigated the stellar evolution models using the open-source software instrument Modules for Experiments in Stellar Astrophysics. We examine the evolution of angular momentum and the stability of mass transfer in the evolution of Algol-type binaries through the inner Lagrangian point via the Roche lobe overflow. Also, we have determined the ongoing challenge of chemical mixing and exhibit improvements that make easier the simulation of Algol-type binaries evolution.

Keywords. Binary systems, Algol-type binaries, stellar models, mass transfer, method-numerical.

1. Introduction

The development of a relatively complete and quantitative picture of evolution of binary stars is of great interest in astrophysics. The comprehensive and detailed stellar models of various processes involved in binary systems evolution are lacking and suffer many theoretical uncertainties associated with mass transfer, chemical reactions, and orbital evolution, especially in the domain of low-mass stars (Nelson & Eggleton 2001). Based on the binary stars evolution code such as Modules for Experimental Stellar Astrophysics, MESA (Paxton *et al.* 2015), we investigate the stability of mass transfer in Algol-type binaries by using the binary stars evolution models and mass-radius exponent relations. Algol-type binaries are one of the semi-detached binary systems, which are formed from detached binaries by exchanging mass between their components. In semi-detached binaries, mass transfer proceeds from low-mass subgiant to more massive main-sequence stars in circular orbit (Peters 2001). Hence, as noted by Negu & Tessema (2018), here we examine the theoretical models of mass transfer in semi-detached binaries and its stability by using the evolution of orbital and stellar parameters through the physical principle of Roche lobe overflow, RLOF (Hilditch 2001).

2. Analysis

We considered the MESA version 7624 in our simulations of semi-detached binary systems evolution taking into account different stellar masses. For numerical calculations we applied the Eggleton (1983) formula:

$$\frac{R_{Ld}(q)}{a} = \frac{0.49q^{2/3}}{0.6q^{2/3} + \log(1+q^{1/3})}, \tag{2.1}$$

where R_{L_d}, a, and $q = \frac{M_d}{M_a}$ are the Roche lobe radius of the donor star, semi-major axis, and mass ratio of the semi-detached binary system, respectively. This is a basic mathematical model that can be used to compute the evolutionary phases of semi-detached binary systems and its chemical composition. Hence, we determine the stability of mass

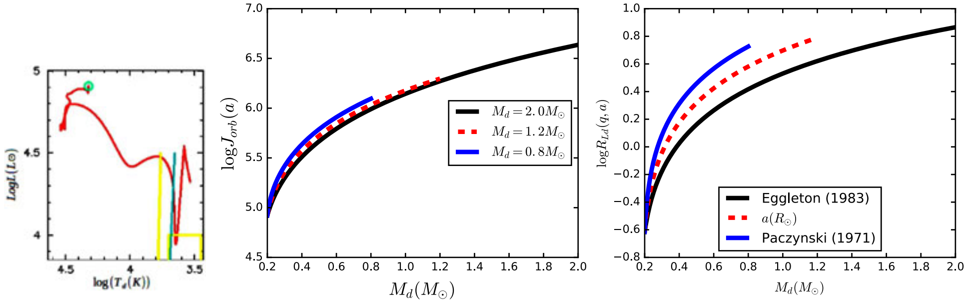

Figure 1. Left plot: relation between L and T_{eff} for different chemical composition of semi-detached binary systems. **Middle plot:** evolution of J_{orb} with M_d. **Right plot:** evolution of the R_{L_d} with Md.

transfer in these systems using the orbital and stellar parameters due to the distribution of orbital angular momentum, J_{orb}, which is given by:

$$J_{orb}(a) = \left(\frac{q\sqrt{GM^3 a}}{(1+q)^2}\right), \tag{2.2}$$

where G and $M = M_a + M_d$ are the universal gravitational constant and the sum of mass of the accretor, M_a, and donor, M_d, respectively. The components of semi-detached binary systems should also satisfy the Stefan-Boltzmann law that the stellar luminosity, L, is related to the stellar radii, R, and effective temperature, T_{eff}:

$$L = 4\pi R^2 \sigma T_{eff}^4, \tag{2.3}$$

where σ is the Stefan-Boltzmann constant. In Figure 1 (left plot) we show the core helium (red line) and hydrogen (yellow line) shell burnig for different values of L and T_{eff}. Numerical solution of the system is showed with cyan line. Middle and right plot of Figure 1 show the relation of J_{orb} and R_{L_d} with the stability of mass transfer, respectively.

3. Conclusion

In this study, we have tested the binary star evolution code MESA to determine the stable mass transfer in semi-detached binary systems with the evolution of orbital angular momentum.

Acknowledgment

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