Winds of Stars and Exoplanets
Proceedings IAU Symposium No. 370, 2023
A. A. Vidotto, L. Fossati & J. S. Vink, eds.
doi:10.1017/S174392132200388X

Planet migration in accretion discs in binary systems

A.D. Nekrasov[1,2], S.B. Popov[1,2] and V.V. Zhuravlev[2]

[1]Department of Physics, Lomonosov Moscow State University, 119991, Moscow, Russia

[2]Sternberg Astronomical Institute, 119234, Universitetski pr. 13, Moscow, Russia

Abstract. We model evolution of exoplanets of S-type in close binary systems at the stage when the companion starts to lose mass via a slow stellar wind. At this stage an accretion disc is formed around the planets' host. Detailed structure of such discs is calculated in quasi-stationary and non-stationary approaches. We model migration of planets embedded in these discs.

Keywords. planetary systems, binaries: close, accretion disks

1. Introduction

An accretion disc can be formed around a secondary non-evolved star in a binary system when the primary companion leaves the Main sequence and starts to lose mass with an enhanced rate via a slow stellar wind. We analyze accretion disc evolution and planetary migration in such discs around solar-like Main sequence stars in binary systems with evolved companions. As the disc is formed from the stellar wind matter, its properties depend on the mass loss rate by the donor and parameters of the binary. In this study we advance the analysis initiated by Kulikova et al. (2019). We use a numerical model to calculate properties of non-stationary discs (NSD) with a variable mass inflow on the whole disc surface within the Bondi radius during late stages of the primary evolution. Then, the migration path of a single planet embedded in such a non-stationary disc is determined by the migration rate varying in the course of the disc evolution. The case of quasi-stationary discs (QSD) is also modeled for comparison.

2. Model and results

Discs discussed in this note can exist for a comparable period of time (or even longer) than usual protoplanetary discs due to an external source of mass. This leads to similar, but usually more significant migration compared to migration in protoplanetary discs. Our code allows to model discs in the mass range from 10^{-10} up to 10^{-2} $M_\odot$.

We consider binary systems with major semi-axis $a < 100$ AU. Primaries have initial masses, M_1, below 8 $\mathrm{M}_\odot$, which guarantees evolution of the star with smooth envelope loss at late stages (i.e., without a supernova explosion) and formation of a white dwarf. The secondary component in each system under consideration is formed as a Sun-like star: $M_2 = \mathrm{M}_\odot$ whith $M_2 < M_1$ and evolves slower than the primary. Slight variations of the secondary mass would not change our main conclusions. It is assumed that just one planet is formed around the secondary on a dynamically stable orbit. Thus, any possible interactions in a multi-planetary system are ignored. Properties of the donor are calculated using the code MESA (Paxton et al. 2011).†

† MESA tracks were calculated by A. Andryushin, whom we thank for providing these data.

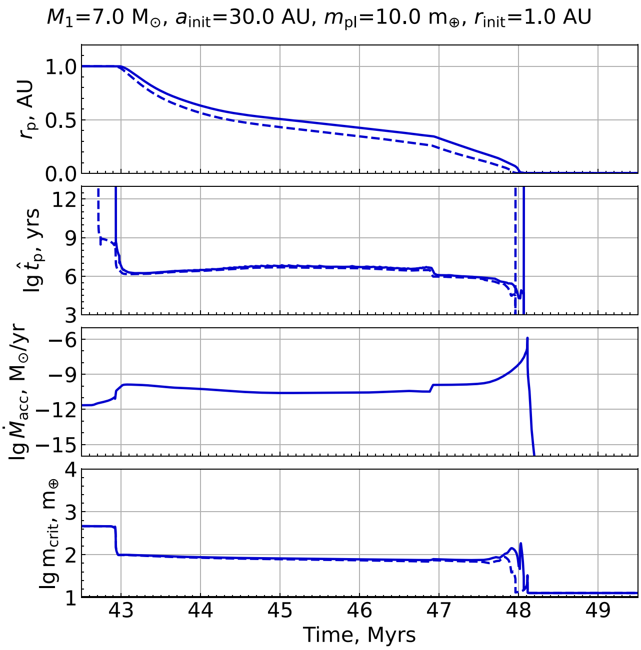

Figure 1. Orbital radius evolution and characteristic migration time for planet with mass $m_{pl} = 10$ $m_\oplus$ and initial orbital radius $a_{pl} = 1$ AU, total accretion rate and critical planet mass for gap opening at radius of the planet for system $M_1 = 7.0$ $M_\odot$, $a = 30$ AU. NSD curves are solid, QSD curves are dashed.

In binary systems with an initial separation $a \lesssim 80 - 100$ AU (we take into account orbital evolution due to mass loss from the donor star) gas giants efficiently migrate in such discs and typically approach short distances from the host star where tidal forces become non-negligible. Neptune-like planets can reach these internal parts of the system in cases when a donor is a relatively massive star (5-8 $M_\odot$) or in binaries with $a \lesssim 20$ AU. An example of our calculations is given in the Figure. Complete set of calculations and detailed description of the model will be published elsewhere.

We conclude that in binaries, mass loss from the primary at late evolutionary stages can significantly modify structure of a planetary system around the non-evolved secondary component, probably resulting in mergers of massive planets with the host star.

Acknowledgements

This study was supported by the Ministry of Science and Higher Education of the Russian Federation grant 075-15-2020-780 (N13.1902.21.0039). The work of A. Nekrasov and V. Zhuravlev was also partly supported by the Foundation for the Advancement of Theoretical Physics and Mathematics 'BASIS'.

References

Kulikova, O,, Popov, S. B., Zhuravlev, V. V., 2019, MNRAS, 487, 3069
Paxton, O., Bildsten, L., Dotter, A., et al., 2011, ApJS, 192, 3