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Modelling of stellar surfaces in single and binary star systems

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Abstract. A precise and time effective method for generating stellar surfaces is a crucial step in creating the light curves of single and binary star systems. In the case of rotationally deformed components of single star systems and tidally deformed components of close binaries, spherical symmetry is no longer usable for generating stellar surfaces, which increases complexity of the task. However, exploitation of axial and planar symmetries of such stellar components proved to be a powerful tool in reducing overall computational time necessary to generate a stellar surface. We present one of the possible approaches to this issue that includes usage of symmetry vectors that enabled us to effectively perform the surface discretization and calculation of surface parameters such as the local effective temperature or gravity acceleration.

Key words: binary stars – single stars – computational astrophysics

1. Introduction

Stellar surface in hydrostatic equilibrium can be described as the equipotential surface defined by the appropriate potential function. Hovever, especially in the case of components of binary systems, the solution of such potential function for the equipotential surface has to be found implicitly. Such approach is computationally demanding and thus the number of surface points evaluated should be minimized.

2. Construction of the stellar surfaces

Axial and planar symmetries of single and binary stellar surfaces enabled us to greatly reduce the surface area of the star that needs to be evaluated. It is especially important in the case of components of binary systems where surface points have to be solved implicitly. Moreover, triangulation of such reduced surface becomes much more efficient since the computational time of the Delaunay triangulation (Barber et al., 1996) scales with the square of the number of triangulated points.

Symmetries of stellar surfaces can be also utilized to avoid calculation of quantities characterizing stellar surface on the whole surface. Such quantities as

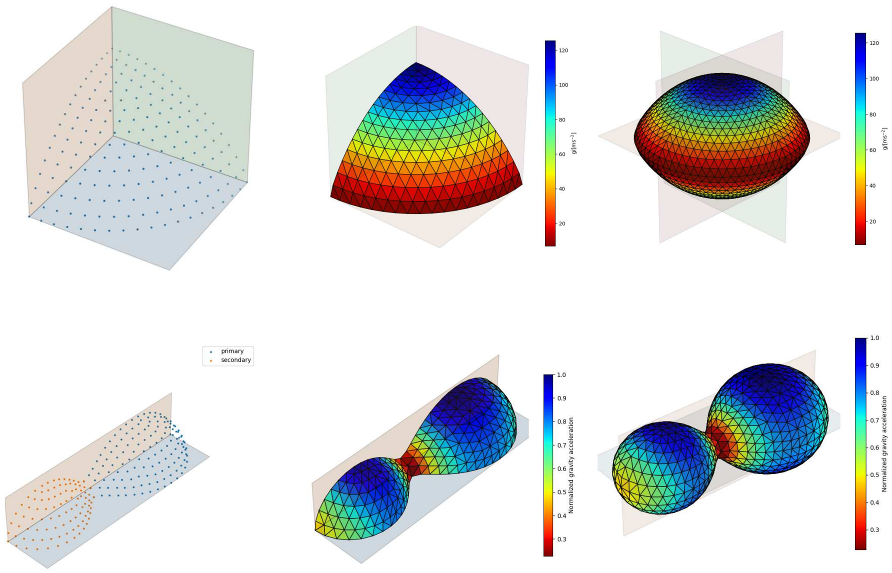

Figure 1. This set of figures illustrates construction of the stellar surface for a rotationally deformed single star (top row) and an over-contact binary system (bottom row) utilizing displayed planar symmetries. The left column shows the equipotential surface points that were subsequently triangulated (middle column) using the Delaunay triangulation. The rest of the surface is completed using before mentioned planar symmetries (right column).

gravity acceleration, gradient of surface potential, local effective temperature, etc. need to be evaluated only on the one eighth resp. one quarter of the surface and then mirrored to the rest of the surface faces using the "symmetry vector" which maps evaluated surface faces to all its symmetrical counterparts on the rest of the surface.

3. Triangulation of over-contact binary surfaces

One of the limitations of the Delaunay triangulation is the ability to triangulate only convex surfaces. However, the neck of the over-contact system is not a convex surface. We solved this problem by equalizing the radial component of the surface points which effectivelly transformed the surface point mesh into a convex spherical surface (Fig. 2b,c) which was triangulated and resulting faces were then remapped into the original concave point mesh (Fig. 2d).The main advantage of this transformation is that it maintains relative positions of surface points which is crucial during the triangulation process.

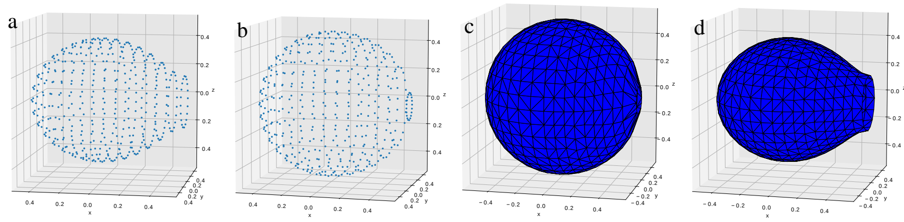

Figure 2. This series of figures illustrates an approach to triangulation of over-contact binary systems. Figures a) and b) show surface points of the component before and after the transformation which enabled us to use the Delaunay triangulation method (figure c)). The resulting surface of the over-contact component is on display in figure d).

4. Conclusions

This approach utilizes a novel approach to the problem of generation of the single and binary stellar surfaces. Compared to the other algorithms utilized in software packages such as PHOEBE (Horvat et al., 2018) and ROCHE (Pribulla, 2012), this approach requires far less evaluations of surface points and faces in order to produce the stellar surface with the same resolution. This algorithm will be implemented in the upcoming software package dedicated to a modelling of eclipsing binaries with pulsating components.

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