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A SELECTION OF ASTROMETRIC BINARIES FROM GAIA-DR3 THAT COULD BE DOUBLE-LINED SPECTROSCOPIC BINARIES AND ECLIPSING BINARIES

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Abstract. We present a selection of 41 bright astrometric binaries from the 3rd Gaia Data Release (Gaia-DR3) that could also be eclipsing binaries and double-line spectroscopic binaries (SB2s). By adding elements from SB2 orbits and photometric observations of eclipses to the astrometric orbital elements, it should be possible to obtain the masses and radii of the components of these binaries.

Keywords: binaries: spectroscopic, binaries: eclipsing, Astrometry, stars: fundamental parameters

1 Introduction

The masses, luminosities and radii of stars are fundamental parameters for studying the stellar interiors (Serenelli et al. 2021). The masses can be derived from the orbits of double-line spectroscopic binaries (SB2s), when the inclination of the orbit is given by an astrometric orbit. The luminosity ratio is derived from the SB2 orbital elements, the semi-major axis of the photocentric orbit and the trigonometric parallax. When the orientation of the orbit is almost on edge, the binary system can also be eclipsing, and it is possible to deduce the radii of the components. Such systems are rather rare, and generally have components so close together that their masses have been modified by mass exchanges. Fortunately, this situation is set to change thanks to the Gaia satellite.

The 3^{rd} Gaia Data Release (Gaia DR3) includes the orbital elements of nearly 165500 astrometric binaries (Gaia Collaboration et al. 2016; Halbwachs et al. 2023; Holl et al. 2023), most of which were previously unknown. Due to selection effects, the periods of these binaries are essentially between 30 and 2000 days, which puts them in a range where mass transfers are less frequent than in all eclipsing binaries. For these reasons, we decided to select the astrometric binaries of DR3 (i) which could show eclipses, (ii) which could be observed like SB2s with the 193 cm telescope (T193) of the Observatoire de Haute-Provence (OHP) equipped with the "Spectrographe pour l'Observation des PHénomènes des Intérieurs Stellaires et des Exoplanètes" (Sophie), and (iii) that could give masses accurate to 1 % or better.

2 Selection criteria

The objectives listed in the introduction will be translated into selection criteria as follows:

- As we want stars that can be observed from the OHP, we are restricting ourselves to declinations $\delta > 0°$.
- As we want stars that can be observed with T193/Sophie, the magnitude must be bright enough to obtain a good quality spectrum in less than an hour under poor weather conditions. So, $m_v < 10.40$ mag.
- To obtain radial velocities with Sophie, the spectral type must be later than A.

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- To have a chance of getting masses to within 1 %, the astrometric orbit in Gaia DR3 must give $\sin^3 i$ more accurate than 1 % (i is the orbital inclination deduced from the Thiele-Innès elements, as explained in Halbwachs et al. 2023).
- For the binary to show eclipses, the projection of the minimum separation between the components must be less than the radius of the primary component. These radii may be overestimated, since they were derived neglecting the contribution of the secondary component to the total luminosity of the system. On the other hand, we have also overlooked the fact that, due to the size of the secondary component, a partial eclipse can occur when the orbit only grazes the primary component without passing in front of it.
- Stars with a combined astrometric and single-lined spectroscopic (SB1) solution in Gaia DR3 are only retained when a_0/a_1 is not in the range [0.9 , 1.1], in order to exclude the binaries with a component much brighter than the other, since such stars are probably not SB2s.

The masses and radii of the primary components were taken in the Gaia DR3 Main Sources catalogue (Gaia Collaboration et al. 2023). Taken together, these criteria give us a list of 41 targets that will be observed from the OHP starting in the second semester of 2023 to obtain their SB2 orbits.

3 Properties of the selected targets

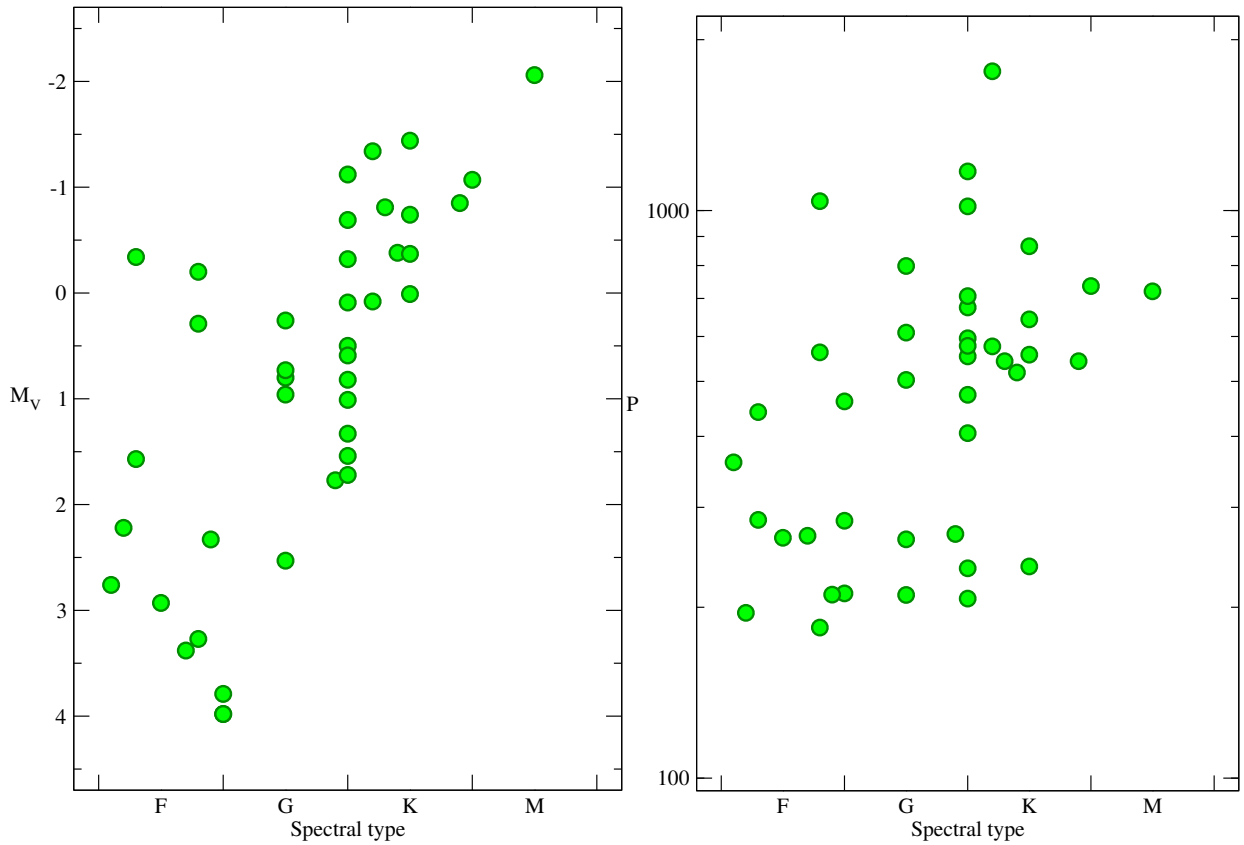

Fig. 1. Properties of the 41 binaries possibly eclipsing. **Left:** HR diagram. **Right:** Spectral type vs period diagram.

The main characteristics of our targets are shown in Figure 1. Their positions in the HR diagram (figure on the left) shows several types of stars: a dozen or so F-G dwarfs or sub-giants and about thirty or so giants, distributed between the clump, the asymptotic giant branch and the horizontal branch.

The periods of these binaries are shown in the figure on the right. We can see that the late–type stars, which are giants, have periods of several hundred days, which suggests that many of them have not been affected by mass transfer.

4 Programme organisation

First of all, we need to be sure that we can determine the masses of the components of these binaries, so that these stars are SB2s. For each star, this will require 1 or 2 observations from the OHP with the T193/Sophie. To be as effective as possible, these observations will be made at carefully chosen phases. Now that our project has been accepted*, observations begin this autumn 2023.

As soon as an SB2 has been detected, we will propose it for photometric observations with a view to observing eclipses. For this, we hope to be able to count on well-equipped amateur astronomers. To cover eclipses effectively, we will need observers spread out different longitudes, and working in the same wavelength ranges if possible. We will produce ephemerides announcing the corresponding epochs; because of the uncertainties affecting the periods of the DR3 orbits, these epochs will be at the beginning of time intervals of several days. Subsequently, once the orbits have been revised on the basis of radial velocity measurements, these intervals should narrow.

5 Conclusions

We have selected 41 targets whose spectra will be observed from OHP to detect SB2s, and then photometrically to detect eclipses. We hope that many amateur astronomers will be able to take part in this final part of the programme. Individuals or organisations wishing to join us are invited to contact us at jean-louis.halbwachs(at)astro.unistra.fr to receive eclipse ephemerides.

After a few years and the publication of DR4, it should be possible to produce a list giving the masses, magnitudes and radii of a few dozen stars of all types.

This work has made use of the SIMBAD database and of the Vizier facility, both operated at CDS, Strasbourg, France.

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