Know your partner

The mass-ratio distribution of spectroscopic binaries along the main-sequence

Henri M.J. Boffin[1] & Dimitri Pourbaix[2]

[1]ESO, Karl-Schwarzschild-str. 2, 85748 Garching, Germany [2]FNRS, Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, C.P. 226, Campus Plaine, Bd du Triomphe, 1050 Brussels, Belgium

BINARITY IS NOW A WELL-ESTABLISHED QUALITY AFFECTING A LARGE FRACTION OF STARS AND RECENT STUDIES HAVE SHOWN THAT THE FRACTION OF BINARIES IS A FUNCTION OF THE SPECTRAL TYPE OF THE PRIMARY STAR, WITH MOST MASSIVE STARS BEING MEMBER OF A CLOSE BINARY SYSTEM. BY CROSS-MATCHING TGAS WITH THE S_B^9 DATABASE, WE WENT ONE STEP FURTHER AND DERIVED THE MASS RATIO DISTRIBUTION OF BINARY SYSTEMS AS A FUNCTION OF THE SPECTRAL TYPE OF THE PRIMARY STAR. THIS, COMBINED WITH THE BINARY FRACTION, PROVIDES VERY STRONG CONSTRAINTS ON STAR FORMATION AND CRITICAL INPUT FOR STELLAR POPULATION MODELS.

1. Aims and methods

The distribution of orbital elements can reveal much about the formation mechanisms of binary systems as well as their subsequent evolution. In the same vein, the distributions of the masses of the two components, M_1 and M_2, or similarly, of M_1 and the mass ratio, $q=M_2/M_1$, are clues to critical questions related to binaries: did the binaries form through random pairing? Does the mass ratio distribution depend on the primary mass (as does the multiplicity of stars)? How will the systems evolve (the existence of some systems being possible only if the mass ratio is close to one? How do families of stars compare to each other? Several studies have tried to address these questions. We aim here to derive the mass ratio distribution as a function of the primary mass, thanks to TGAS.

We use the S_B^9 catalogue (Pourbaix et al. 2004; *http://sb9.astro.ulb.ac.be* – accessed in Oct. 2016) that contains a large set of spectroscopic binaries gathered from the literature – it should be more than 2/3 complete. Our systems are divided into single-lined spectroscopic binaries (SB1), for which we only have the spectroscopic mass function, and double-lined spectroscopic binaries (SB2), for which we already have the mass ratio.

2. The TGAS H-R Diagram of S_B^9 Binaries

We have cross-correlated the TGAS catalogue with the S_B^9 catalogue to select all binary systems containing a main sequence primary, for which the relative error on the parallax was below 16%. We then queried from *CDS Simbad* the *V* and *B* magnitudes as well as the spectral type and coordinates, which combined with the analytical extinction models of Arenou et al. (1992) allowed us to compute the visual extinction, A_V. This enabled us to put all our objects in the colour-magnitude diagram, B-V vs. M_V (see Fig. 1). As we want to bin the stars in their spectral types, and we want to have a representative sample for each spectral class, we were finally left with 142 K, 340 G, 421 F, 369 A, and 153 B stars, i.e. 1425 stars. There were too few systems with spectral types M or O to be considered.

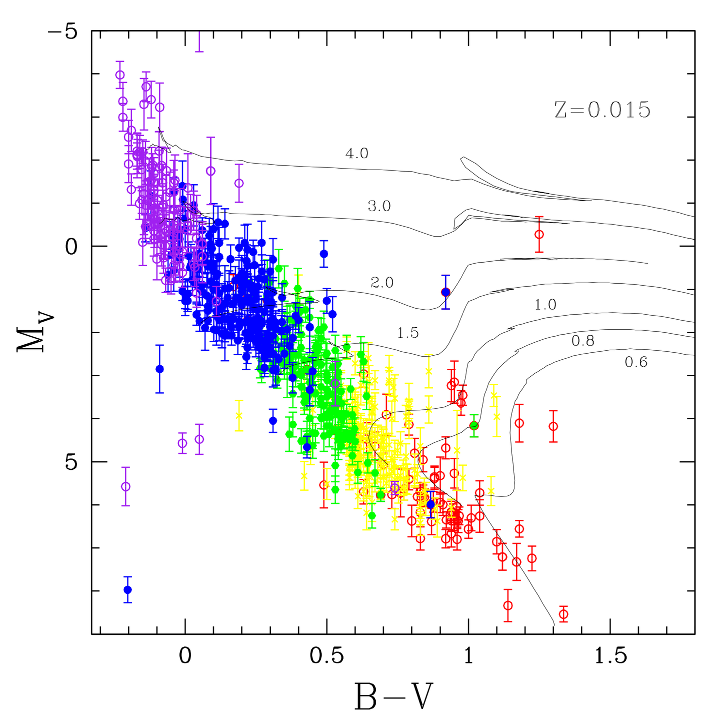


Fig. 1: Colour-magnitude diagram for our selected SB1 binary systems, based on TGAS data. The colour and symbol are related with that of the spectral type of the primary: K (red), G (yellow), F (green), A (blue), and B (purple). Also shown are the PARSEC evolutionary tracks for solar metallicity stars of various (labelled) masses.

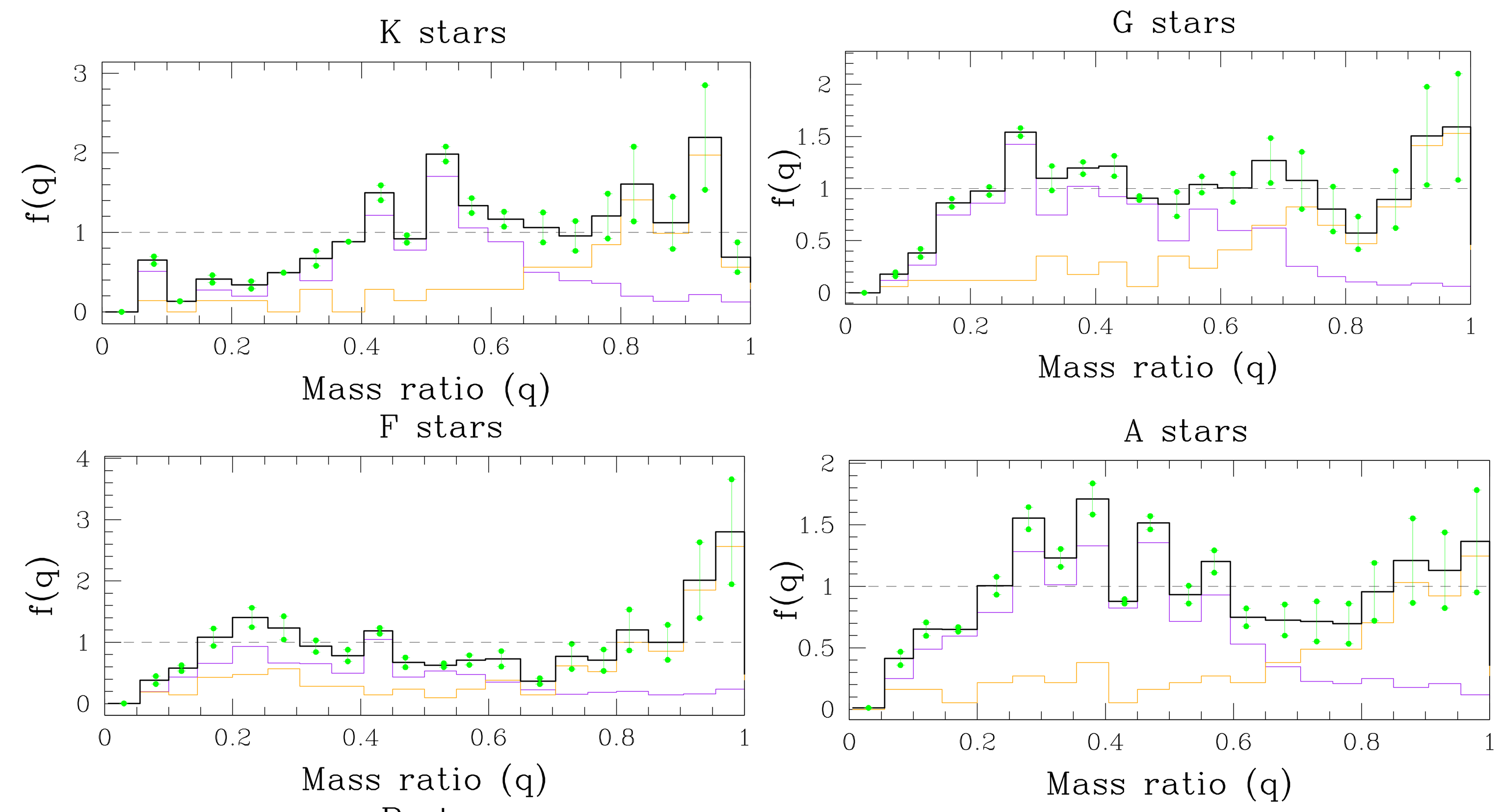
3. Mass of SB1 Primary

Having been able to place our SB1 systems in the HRD, we can now move forward and determine their mass from a comparison with the PARSEC stellar evolutionary tracks (Bressan et al. 2012; see Fig. 1). This was done with a weighting scheme that takes into account the error bars as well as the time a star of a given mass spends at a certain location of the colour-magnitude diagram. The mode's mass of our samples is, resp., 0.85 (K stars), 1.05 (G), 1.2 (F), 1.8 (A), and 4.0 (B) solar masses.

Using a different metallicity would imply a different mass, but this has negligible impact on the mass ratios we determine.

4. Mass-Ratio Distributions (MRD)

To determine the MRD of our SB1, we make use of their spectroscopic mass function and the primary mass derived above and apply the Richardson-Lucy deconvolution technique (see Boffin et al. 2010 for the details of the method). This can be done for our 5 samples and the result is shown in Fig. 2. The final MRD is then obtained by summing up the MRD coming from the SB1 with that of the SB2 (obtained directly). The main issue is whether we are suffering from observational biases, i.e. if the S_B^9 catalogue contains relatively too few or too many SB2 compared to SB1. Our large samples and the fact that the data come from various, independent sources, should ensure that any bias, if present, is quite small. For illustration purpose, we show in Fig. 2 what we would have if we added only half (resp. twice) the distribution of SB2.



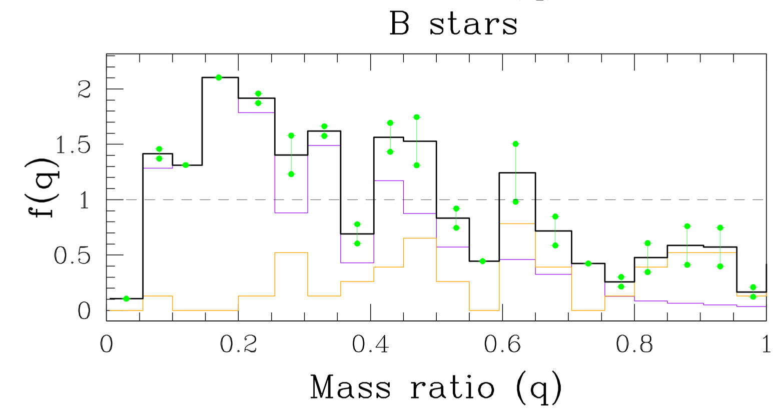


Fig. 2 : Mass-ratio distributions for the stars in the S_B^9 catalogue per their spectral type. The purple histogram is the MRD obtained for SB1 by deconvolution, while the orange line shows the MRD for the SB2. The final, heavy black line, MRD is the sum of both, with the green dots showing the variations if we count only half of the SB2 or twice the SB2. For illustration purpose, the dashed line shows the uniform distribution.

Our results clearly indicate that the MRD is a (continuous?) function of the spectral type of the primary, and thus of its mass, although (except for B stars) the general trend is to have a MRD that is relatively flat.

5. Companion's Mass Distribution

Using our primary mass distribution as well as our MRD, we can of course obtain also the distribution of the companion's mass as a function of the primary's spectral type. This is shown in Fig. 3. It appears that up to a given value, around 0.4 Msun, the distributions are peaked towards lower masses, but in a much less steep way than would be expected from the Salpeter or Chabrier IMF.

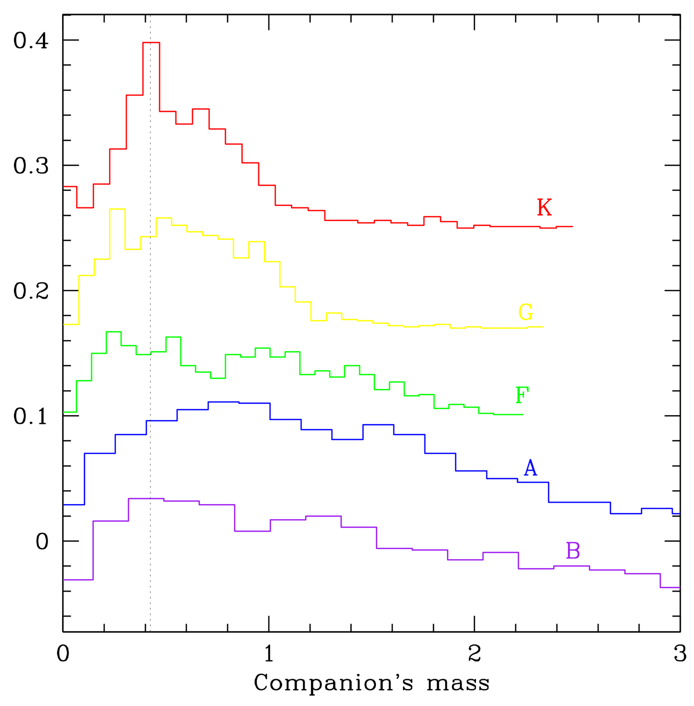


Fig. 3: The distributions of the companion's mass as a function of the spectral type of the primary star.

References

Arenou, F. et al. 1992, A&A 258, 104
Boffin, H.M.J. 2010, A&A 524, A14
Bressan, A. et al. 2012, MNRAS 427, 127
Pourbaix, D. et al. 2004, A&A 424, 727

Read the poster online