Stellar Multiplicity and Large Spectroscopic Surveys

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Abstract

Stellar multiplicity is a key parameter for many astrophysical questions. Several interesting phenomena, such as gravitational waves and gamma-ray bursts, arise from binary stars, and the knowledge of multiplicity can provide constraints on possible channels of star formation and evolution in the Galaxy.
However, little is known about the binary frequency in Milky Way field stars, particularly outside the Solar neighbourhood. *Gaia* will bring a new era in astronomy: millions of binary systems will be observed and detected by this project. In addition for ongoing and coming large spectroscopic surveys, such as *RAVE*, *APOGEE*, *Gaia – ESO* and *4MOST*, it is important to identify the binaries to clean the survey products from potentially faulty results.
I will present our models of the effect of binaries on high-resolution spectroscopic surveys, in order to determine how many binaries will be observed, whether unresolved binaries will contaminate measurements of chemical abundances, and how we can use spectroscopic surveys to better constrain the population of binaries in the Galaxy. As an application we model binary stars that mimic APOGEE red giants in the Galactic disc.

Binary Star Evolution Model

Binary and single star evolution is performed by the rapid binary-star evolution (BSE) algorithm presented in Hurley, Tout & Pols (2002). In our model initially more massive stars have the masses: $0.7 \leq m1 \leq 100\ M_\odot$ and the IMF drawn from Kroupa et al. (1993). The companion stars are drawn from the same distribution and have masses: $0.1 \leq m2 \leq m1\ M_\odot$. The initial age of the stars is drawn uniformly in [0:10] Gyr and stars have solar metallicities (z = 0.019). The orbital eccentricity is taken from thermal (dynamically relaxed) distribution: f(e)=2e (Heggie, 1975). The distribution of the orbital periods of stellar population is symmetrical and follows Gaussian-type relation where $\overline{logP}$ = 4.8, σ_{logP} = 2.3, and P is in days (Duquennoy & Mayor, 1991).
This is an initial model with a simple stellar population. We are testing the effects of more complicated metallicity and age distributions, but their effect on the binary population is relatively small.

BSE provides the stellar luminosity L, radius R, mass M etc. for each of the component star as they evolve. For a star of a given parameters we calculated stellar absolute *2MASS* magnitudes and hence colours using *BC* tables provided by Padova group (Marigo et al., 2008).

Resolved binary:

- *Two stars separated in the sky by ≥6″.*

Unresolved binary:

- *Two stars have angular separation ≤ 6″.*
- *The flux ratio ≥ 10: single line spectroscopic binary (SB1).*
- *The flux ratio ≤ 10: double line spectroscopic binary (SB2).*

APOGEE Red Giants

The APOGEE is high-resolution (R∼22,500), high signal-to-noise infrared spectroscopic survey. In APOGEE stars were observed in multiple visits (Zasowski et al, 2013). We selected the Galactic disc red giants from DR 12:

- $24° \leq l \leq 240°$, $|b| \leq 16°$.
- *$(J\text{-}K_s)_0 \geq 0.5$ mag; $H \leq 13.2$ mag.*
- *log(g) ≤ 3.5.*
- *S/N of individual spectra ≥ 20.*
- *N visit ≥ 3.*

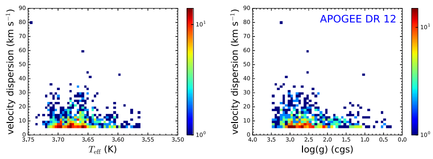

Figure 1. Effective temperature and surface gravity versus velocity dispersion in the selected APOGEE giants. Selected stars are with the velocity dispersion ≥ 5 km s^{-1} much larger than the typical RV uncertainty.

Model

The stars are randomly distributed in a Galaxy model (See Fig.2). The Galactic disc is exponential with the radial scale length h_R = 3.0 kpc and the vertical scale height h_z = 0.3 kpc. The Sun is located at 8 kpc from the center of the Galaxy. We consider only the thin disc since the APOGEE sample in the Galactic plane is dominated by thin disc stars.

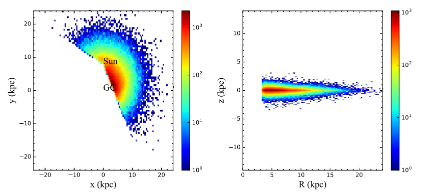

Figure 2. Position of stars in the Galactocentric x-y and R-z plane.

In order to mimic the APOGEE observations we are using the same stars selection function. We looked at the same binary in the model at a set of times, took snapshots of the radial velocity, and investigated the distribution of velocities in those snapshots (see Fig.3). We choose to pick the observation schedule for a random star in the APOGEE red giant sample.

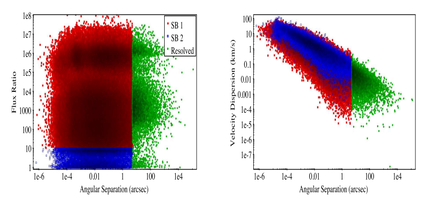

Figure 3. Angular separation versus flux ratio and predicted velocity dispersion. Red - SB1, blue - SB2 & green - resolved binary stars.

Results

The unresolved binary stars inflating the velocity measurements in a multiple visit observations are shown in Fig. 4. & 5.

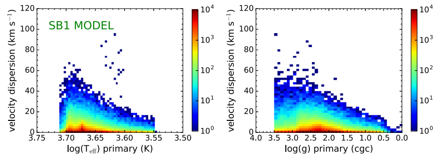

Figure 4. T_{eff} and log g versus predicted velocity dispersion in the primary star.

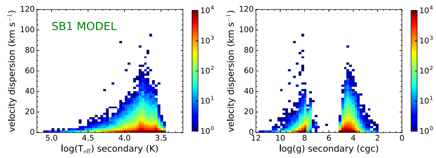

Figure 5. T_{eff} and log g versus predicted velocity dispersion in the (unseen) secondary.

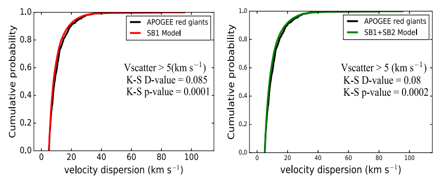

Figure 6. Cumulative distribution function of the velocity dispersion for SB1 & SB1+SB2 models.

Although the predicted and observed radial velocity variations have very similar distributions, our model systematically under-predicts the observed radial velocity scatter. We find that an additional dispersion of about 2 km s^{-1} is required to account for the discrepancy. Possible astrophysical origins of the additional scatter include a different underlying binary population, the presence of triple stars and higher-order multiples, and brown dwarf companions.

We intend to investigate to what extent we can constrain the frequency and separation distribution of binaries, and whether we can detect any systematic variation with metallicity or position within the Galaxy.

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