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OBSERVED AND INTRINSIC PROPERTIES OF BINARY STAR ORBITS

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RESUMEN

Hemos analizado los efectos que el proceso de detección de binarias espectroscópicas introduce en las estadísticas conocidas de dichas estrellas. Por medio de una simulación numérica, hemos estudiado la posibilidad de que exista un 100% de binaridad en un grupo estelar. Mostramos los efectos de selección en las distribuciones de períodos y cocientes de masa introducidos por la búsqueda de binarias dentro de nuestra población.

ABSTRACT

We have analyzed the effects that the process of spectroscopic binary detection can introduce on the known statistics of these stars. Performing a Monte Carlo simulation, we have studied the possibility of having a 100% spectroscopic binarity. We show the biases in the period and mass ratio distribution introduced by a search for binaries on such a population.

Key Words: **STARS: BINARIES: SPECTROSCOPIC — STARS: KINEMATICS**

1. INTRODUCTION

One of the basic quantities in astronomy that still proves difficult to find is the number of binary systems among stars. There is an overall agreement for a frequency lying in the range of 30 to 60% out of the total number of stars observed, as found in Garmany et al. (1980) and Mason et al. (1998). Several selection effects inherent to the process of binary detection are biasing the statistics of the observed binaries. In this contribution, we present a numerical simulation of a population of binary stars, combined with the simulation of the observation process. This allows us to establish statistical properties of the sample and to check for the differences found between the intrinsic and the observed ones.

2. THE BINARY POPULATION

The population has the following characteristics: (i) all stars in our sample are binary systems, where both components are main sequence stars; (ii) as we are dealing with spectroscopic binaries, we consider that the mass estimated from photometry is more related to the total mass of the binary system. This total mass follows a normal Salpeter distribution (Salpeter 1955); (iii) the mass ratio $Q = M/m$, being M the most massive star of the pair, is distributed between 1 and Q_{max}. The “observed” Q distribution (Garmany et al. 1980) is not used, as this is most probably affected by an observational bias; (iv) orbits have random inclination i to the observer's plane, as there is no evidence for any preferred direction, even in clusters; (v) orbital periods are

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distributed between 1 day and P_{max}. The value of the maximum period depends on the time span of the observations; (vi) we have calculated for each orbit the maximum possible eccentricity, from the restriction introduced by the minimum allowed periastron distance. The eccentricity is then chosen randomly between 0 and e_{max}; (vii) the semi-major axis a are hence calculated for each orbit through Kepler's third law.

We calculate then the radial velocity for each brightest star of the pair (assuming it is the most massive), at a randomly chosen position within its orbit (we distribute the anomaly to the periastron, ν_0, to be random), by means of:

$$V_r = 1.1574 \times 10^{-5} \frac{\mu\, a\, m}{(M+m)\sqrt{1-e^2}} sin(i)\, [cos(\nu_0 + \nu) + e\, cos(\nu_0)] \,, \tag{1}$$

where the numerical factor is the number of days in a second.

3. THE OBSERVATIONS

The observed distribution of periods is quite uniform in log(P) over a large range of periods. However, the process of detecting a spectroscopic binary favors the identification of stars with large amplitude in their radial velocity changes. These, in turn, are favored in short period binaries, as they have larger spatial velocities than the longer period ones. We have estimated the influence of the detection process by observing our binary sample. How do we *detect* a binary star? The same way as it would be done when searching for them observationally. From equation 1, we can introduce different observation times as $\nu = \nu(t)$. The observing times were selected to match the ones of a typical search for spectroscopic binaries.

The next step is to look for changes in the observed radial velocity. The largest change is found comparing the maximum and minimum radial velocities within the observed interval. Although the uncertainty in our determinations of V_r is very small, this is not the case for real observations. According to the spectral resolution of the studies mentioned before, particularly those by Levato et al. (1991) and Bosch et al. (1999). we can estimate a threshold value for the amplitude of velocity change for the binary star to be detected of 50 km s^{-1}.

In the case of the period distribution we have looked for a detected distribution that matches the one shown by Abt (1983). If we assume an intrinsic distribution which is uniform in log(P), equivalent to a period distribution function $\Pi(P) \propto P^{-1}$, we obtain an observed distribution that does not match the published one. An intrinsic distribution which follows $\Pi(P) \propto P^{-\frac{2}{3}}$ yields a detected distribution quite uniform in log(P).

The Q distribution was found only from the normalization factor, which indicates that only 35% of the sample should be detected. We choose half a Gaussian profile, which allowed to fit the 'concentration' degree by changing the value of the profile dispersion. A value close to 35% was achieved for $\sigma_Q = 5$. We have also analyzed the effects of the detection process, which shows that the detected sample has a distribution more concentrated towards Q = 1 than the intrinsic one.

4. SUMMARY

By means of a MonteCarlo simulation, we have shown that a 100% binary population *is possible*. We have also shown that the same observational bias introduces changes in the statistics of orbital characteristics, such as the period and mass ratio distributions. Although we do find that the period distribution favors orbits with short periods and that the mass ratio distribution favors values towards unity, we find that the observation and detection process introduces an enhancement of those tendencies.

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