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Kinematics of RS CVn and W UMa Binaries in the Hipparcos Catalogue

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Abstract

Space motions of RS CVn and W UMa binaries have been calculated using parallaxes and proper motions from Hipparcos catalogue and radial velocities from the literature. We have calculating the mean motions and velocity dispersions. We have excluded those binaries with relative parallax errors $\geq$0.5. The comparison of the asymmetric drift, velocity ellipsoids and vertex deviation with those of main sequence stars given by Dehnen and Binney indicates that both RS CVn and W UMa binaries have kinematics similar to main sequence stars slightly bluer than the Parenago's discontinuity and B-V$\simeq$0.62. Implication of this has been discussed.

1. Introduction

RS Canum Venaticorum (RS CVn) systems are known to be detached binaries with spectral types later than F characterized by strong chromospheric, transition region, and coronal activity (see [1-12]). Another property of these systems is photometric variability, due presumably to large spotted regions (e.g. [1,13-17]).

In the first edition of the Catalogue of Chromospherically Active Binary Stars, Strassmeier et al. [18] included BY Draconis type binaries [19] into the catalogue as most of the properties are similar. RS CVn systems have at least one cool giant component, while BY Dra binaries are late type main sequence objects [20]. In the second edition of the catalogue (here after CABS), Strassmeier et al [21] made no differentiation between RS CVn and BY Dra type binaries.

Related to the RS CVn binaries are W Ursa Majoris (W UMa) binaries which are contact systems with late type main sequence components. The chromospheric and coronal activity properties, as well as the presence of spots seen in RS CVn and BY Dra binaries are also shared by W UMa binaries (e.g. [17, 22, 23] and references therein).

Rotational periods of the components are synchronized with the orbital periods due to strong tidal interaction. Strong stellar activity, i.e. chromospheric and coronal activity, and stellar light variation, in these systems are considered to be manifestations of the coupling of convective motions with fast rotation that derives the dynamo mechanism (e.g. [24]) which gives rise to magnetic activity.

It is an observational fact that RS CVn and W UMa binaries are related but their structure are probably quite different. At present we do not have an adequate theory for the origin and evolution of RS CVn and W UMa binaries and relationship of one to the other. For example, it is not known whether W UMa binaries were formed as contact binaries or started out as detached binaries and became contact due to angular momentum loss via magnetic breaking. It is possible, for example, that short period RS CVn sys tems with P<5 days could lose angular momentum in relatively short time scales to become contact binaries (see [17, 25, 26]).

Determination of the relative ages of RS CVn and W UMa binaries will be an important indication as to their evolutionary connection. Eker [27] has studied the kinematics and age of RS CVn and BY Dra binaries. The purpose of this paper is to study and compare the kinematics of the RS CVn and W UMa binaries with a view to determining the relative kinematic ages.

2. The Astrometric Data

The best source of astrometric data is the Hipparcos Catalogue (HIP) [28] which gives the positions, proper motions, and parallaxes. There are 206 RS CVn and BY Dra systems in the CABS. Of these, we have identified 184 system in HIP. 178 of these systems have published radial velocities collected in CABS. On the other hand, the source of the W UMa systems is the GCVS [29]. We have identified 125 W UMa binaries in the HIP but unfortunately we could find radial velocities for only 32 systems. Although it is in principle possible to use only the proper motions in calculating the mean velocity components, we preferred, however, to work with individual components, even though, number of stars is small.

3. Space Motions

The galactic components U, V, W of a star's space velocity are calculated from

$$\begin{pmatrix} U \\ V \\ W \end{pmatrix} = A_G^{'} \begin{pmatrix} \frac{k\mu_\alpha}{\pi} \\ \frac{k\mu_\delta}{\pi} \\ \rho \end{pmatrix} \tag{1}$$

where U is in the direction of galactic centre, V in the direction of galactic rotation, and W in the direction to the north galactic pole. μ_α and μ_δ are the components of the

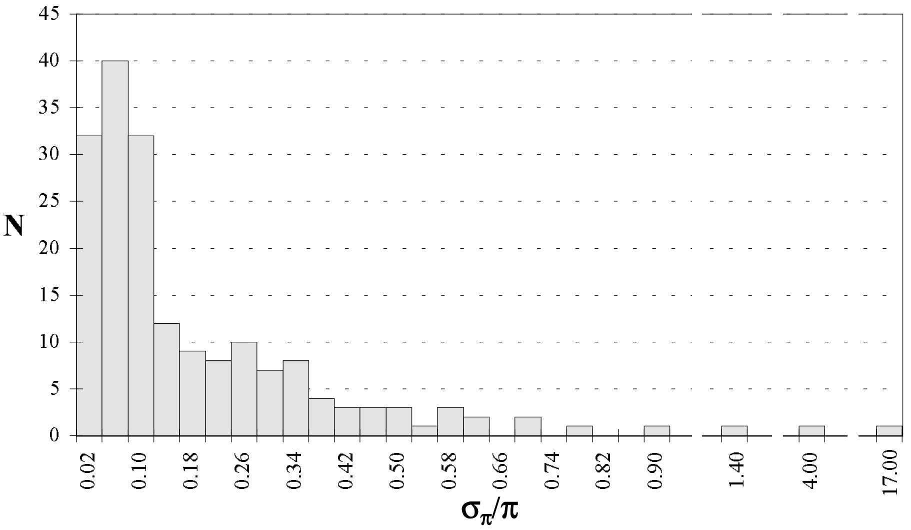

Figure 1. Frequency distribution of relative parallax errors for RS CVn systems

observed proper motion in right ascention and declination, π the parallax. The constant $k = 4.74047\,\mathrm{km\ yr\ s^{-1}}$ converts the proper motion units to km/s. ρ is the observed radial velocity, allegedly referred to the centre of gravity of the binary. The conversion matrix A_G from the equatorial coordinates to the galactic coordinates is taken from HIP.

Although negligibly small, we have corrected the velocity components for the differential galactic rotation using the values of the Oort constants A=14.82 $\mathrm{kms^{-1}kpc^{-1}}$, B=-12.83 $\mathrm{kms^{-1}kpc^{-1}}$ given by Feast and Whitelock [30]. For the propagation of errors in the proper motions and radial velocities, we have used the covariance matrix of the astrometric parameters given in HIP and the standard error of the radial velocity taken from the radial velocity source or adopted depending on the spectral type, ranging from 1.2 km/s to 4 km/s.

The distribution of the relative errors of the parallaxes of RS CVn and W UMa binaries are given in Figures 1 and 2, respectively. We, however, arbitrarily excluded from the solutions those binaries with relative parallaxes $\sigma_\pi/\pi \geq 0.5$. This amounted to 13 RS CVn and 11 W UMa binaries being excluded. Also excluded from the mean motion is HD 149414 (HIP 81170), which has a large space motion (U, V, W)=(-88.9 ± 4.5, -173.1 ± 10.3, -135.2 ± 4.2) with respect to the Sun, (see Figure 3). The mean motions with respect to the Sun and velocity dispersions are summarized in Table 1. We have also included in Table 1, the solution for RS CVn stars with more accurate parallaxes, i.e. for $0 < \sigma_\pi/\pi < 0.1$. It is seen that there is no statistically significant effect. It should be noted that the velocity dispersions have been corrected for the formal observational errors, so that dispersions in Table 1 should refer to the true cosmic dispersions.

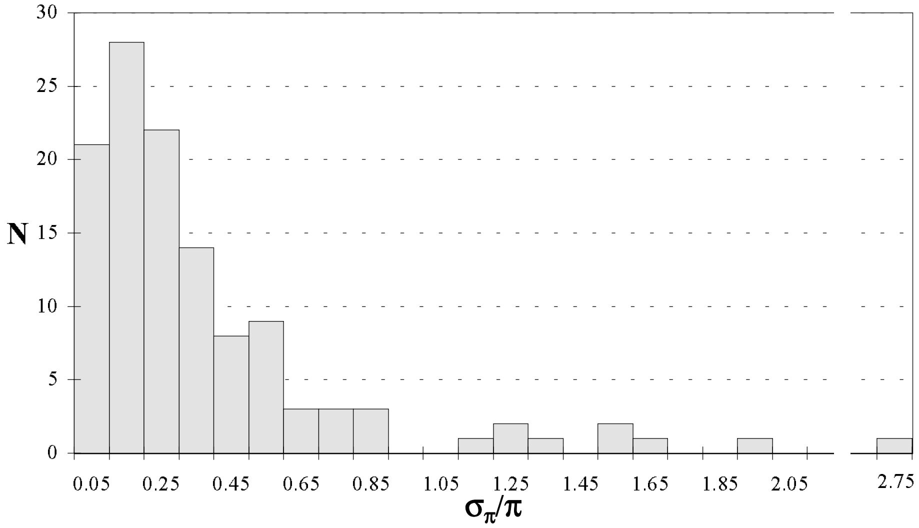

Figure 2. Frequency distribution of relative parallax errors for W UMa systems

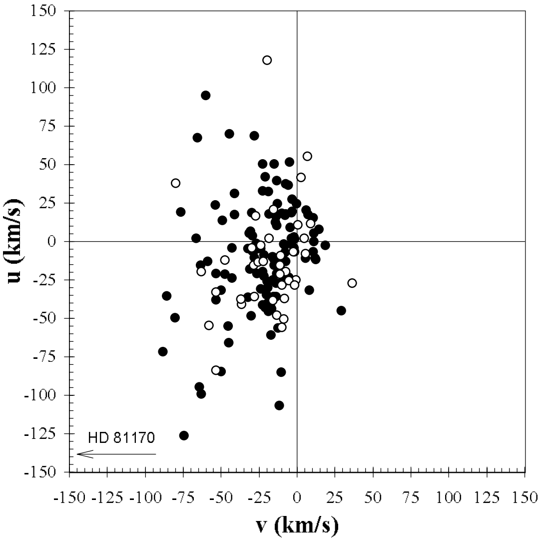

Figure 3. Distribution of RS CVn binaries in the $u-v$ plane. Filled circles: $0\leq \sigma_\pi/\pi < 0.2$, open circles: $0.2\leq \sigma_\pi/\pi < 0.5$

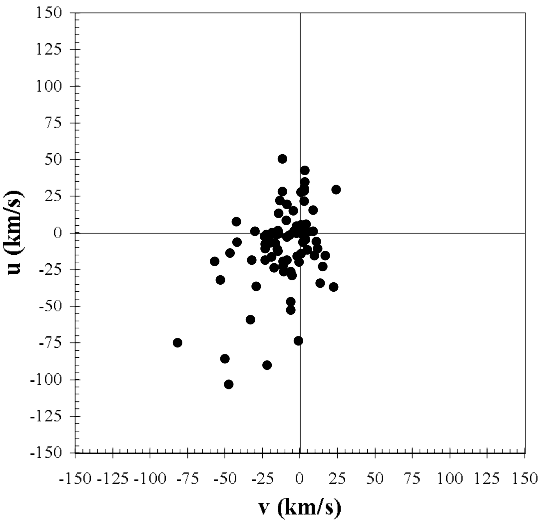

Figure 4. Distribution of W UMa binaries in the $u - v$ plane.

Table 1. Mean motions and velocity dispersions (km/s). l is the value of the vertex deviation obtained and N is the number of stars.

	RS CVn	RS CVn	W UMa
	0< σ_π/π <0.1	0< σ_π/π <0.5	0< σ_π/π <0.5
U	-12.8±3.6	-11.8±2.8	-9.0±6.2
V	-21.3±2.4	-20.5±2.0	-20.7±3.7
W	-5.9±2.0	-6.4±1.6	-9.3±2.6
σ_U	33.4	35.8	35.1
σ_V	22.7	22.4	21.1
σ_W	18.5	18.2	14.6
l	-	10°	20°
N	87	165	32

4. Discussion

As judged by Figures 3 and 4, there is no suggestion of non-homogeneity in the velocity dispersions. We have not found any significant differences between subsamples of RS CVn system, although there is some indication that the main sequence RS CVn binaries have smaller velocity dispersions, indicating smaller ages, but this has to be confirmed by a more detailed study.

Dehnen and Binney ([31], DB hereafter) using the Hipparcos data, calculated the mean motions and velocity dispersions of main sequence stars as a function of B-V. They found that U and W components show no trend with colour but the V component follows the asymmetric drift relation. DB obtained u_0=10.00±0.36, v_0=5.23±0.62 and w_0=7.17±0.38 km/s for the components of the solar motion with respect to the local standard of rest (LSR) and the asymmetric drift relation approximately given by $v = -k^{-1}\sigma_u^2$, where k=80±5 km/s. Adopting these values for the components of the peculiar motion of the Sun, we find the average space motion of the 32 W UMa binaries in our sample to be 20 km/s relative to the LSR. This is rather different from 61 km/s obtained by Guinan and Bradstreet [22] for almost the same sample. Also they found the dispersions in the velocity components to be σ_u=51, σ_v=36 and σ_w=18 km/s, which are much larger than our results in Table 1. As the samples of the stars used are almost the same, these differences should be attributed to the errors in distances and proper motions used by Guinan and Bradstreet.

On the other hand, Eker [27] found (U, V, W)=(-10, -20, -5) km/s for the motion of 145 RS CVn and BY Dra systems relative to the Sun and $(\sigma_u, \sigma_v, \sigma_w)$=(37, 25, 23) km/s for the dispersions. These are not much different from the present results given in Table 1, taking into account the larger errors in the distances and proper motions used by Eker.

We see from Table 1 that, within the errors, mean U and W components of both RS CVn and W UMa systems do not differ from the reflected components of the Sun. On the other hand, we find the asymmetric drift to be v=-15.3±2.1 and v=-15.5±3. 7 for the RS CVn and W UMa systems, respectively, which, with the values of σ_u in Table 1, fit well the asymmetric drift of the main sequence stars found by DB quoted above.

Comparisons of the asymmetric drift, velocity ellipsoids and the vertex deviation given in Table 1 with those of the main sequence stars given by DB show that both RS CVn and W UMa binaries fall at a main sequence colour slightly bluer than Parenago's discontinuity at B-V≈0.62 and that, as judged by the ratios of the dispersions, W UMa binaries correspond to slightly bluer main sequence colour than the RS CVn binaries, presumably indicating that W UMa binaries can not be older than the RS CVn systems. This means that W UMa binaries could not have evolved from the RS CVn binaries by angular momentum loss from magnetic breaking unless the time to reach contact and the duration of contact stage is very short. According to Guinan and Bradstreet [22], stars with initial orbital period of 5 days would take ≈17 Gyr to reach contact, whereas for a short period system with P=1 day, contact would occur in 30 Myr. If this time scale is correct, then W UMa binaries could not have evolved from detached binaries with orbital periods much longer than 2 days.

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