PARALLAXES AND PROPER MOTIONS OF PROTOTYPES OF ASTROPHysiCALLY INTERESTING CLASSES OF STARS

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ABSTRACT

Hipparcos data are presented for 13 stars belonging to six different evolutionary types that present various puzzles. There are three FK Comae stars, one Wolf-Rayet binary, the “galloping giant” FG Sagittae, two high-velocity B stars, two runaway T Tauri stars, and four cataclysmic variables. Most of the numbers are of limited statistical significance, because even the best-known examples of rare classes of stars are likely to be distant and faint. In most cases, the stars are confirmed as being more or less what was expected. A few are not. We present these data primarily to call attention to the fact that the 118,226 stars in the Hipparcos Catalogue include some that are of individual, as well as of statistical, interest.

Key words: astrometry — stars: distances — stars: kinematics

1. INTRODUCTION

In 1982, the present senior author and G. H. Herbig responded to an announcement of opportunity from the Hipparcos Programme Selection Committee by asking that about 30 stars be placed on the observing program because they were the brightest members or prototypes of classes of stars whose physical properties or evolutionary status were quite uncertain. Some of the flavor of the process can be recovered by noting (1) that the coordinates for the stars being proposed could be submitted on magnetic tape or punched cards and (2) that, when V. T. prematurely threw away all her preliminary data after the apparent launch failure, they were in the form of file cards.

About two-thirds of our stars made it into the Hipparcos Input Catalogue (ESA 1992). The failures were, for the most part, highly variable and thought likely to be too faint for observation during the mission. These nonstarters included (1) FU Ori and the FU Orionis star V1057 Cyg, (2) proto—planetary nebula candidates HM Sge, V1016 Cyg, and V1329 Cyg, (3) the massive contact binary SV Cen, (4) the recurrent nova RS Oph, (5) the nova-like variable TT Ari, and (6) the prototypes of two main classes of dwarf novae, U Gem and Z Cam. The stars for which we eventually received early release data in 1997 January included seven R Coronae Borealis variables, discussed elsewhere (Trimble & Kundu 1997). The other 13, belonging to six classes, are presented here.

2. RESULTS

Table 1 shows the parallax and proper-motion values and their standard errors as received, plus Hipparcos magnitudes during the mission and the derived transverse velocities and absolute magnitudes discussed in the following subsections. The stars are listed in the order in which they are discussed. For the most part, references cited are those mentioned in the 1982 proposal as indicating why the stars were of interest. It is striking that many of the same questions can still be asked, and we do not attempt a complete review of present understanding of the various types. CI Cyg appears as a symbiotic star (Kenyon et al. 1982), although it was originally proposed as possibly similar to FG Sge (Audouze et al. 1981). Sadly, SS Cyg appears in the Input Catalogue but was not, in fact, observed (J. Mattei 1997, private communication).

2.1. FK Comae Stars

These are G–K giants with rotation much too rapid to represent conservation of angular momentum from a single, main-sequence precursor. Thus they have often been attributed to recent binary mergers, probably of W Ursae Majoris stars (Collier 1992). This interpretation “predicts” $M_r = 1 \pm 1$, and the primary intent in including these stars was to check this prediction. Two of the three have distances of 200–330 pc and $M_r = 0.8$ and $1.4 \pm 0.5$ (neglecting absorption), very much as expected. Their transverse velocities are $2–6$ and $46–77$ km s$^{-1}$, the latter aimed roughly toward the Galactic plane.

The third star, HD 36705, at a distance of only 15 pc, has $M_r = 6.1$ and $(v, \mu)$ a modest 11 km s$^{-1}$. It is clearly a K main-sequence star, not a K giant. Events here overtook our long-term program. Rucinski (1985) had already degraded it to a subgiant on the basis of optical and ultraviolet (IUE) spectra and debated whether the rapid rotation was more likely to be that of a post–T Tauri star or that of a low mass ratio, tidally locked binary. Because the star is a point radio source (White et al. 1988), it has become important for linkage of radio and optical coordinate systems, and Innes et al. (1985) reported a ground-based parallax of $0.05$ (distance range 15–25 pc) and degraded its spectral type still further to G8 V. Single radio stars are rare, and one might be tempted to attribute the 0.5 day period ($v \sin i = 70 \pm 10$ km s$^{-1}$) to tidal locking. There is, however, no real evidence of an orbit (White et al. 1988). Given its youth (the star has detectable lithium) and proximity, neither the rapid rotation nor the radio emission of AB Dor is really anomalous. It is also an X-ray source and certainly astrophysically interesting, but it is not an FK Comae star.

2.2. Wolf-Rayet Binary

The (unrealistic) goal here was to learn whether WRs with close companions arise from the same range of masses as single WRs. HD 90657 (Niemala & Moffat 1982) is a
unsurprisingly, brighter than of at least 300 pc and an absolute magnitude, fairly typical example with an OB companion. Its parallax about 7 mas yr$^\text{-1}$. This B4–K2 star needs no introduction (Herbig & Boyarchuk 1968). It was relatively bright during the Hipparcos mission ($m = 9.5$). The proper motion of 4.6 mas (standard error 2.8 mas) is of very limited significance. The proper motion of 8.5 mas yr$^\text{-1}$ is, however, more than 3 times its standard error. If the star is as bright and distant as is usually suggested (e.g., 3900 pc), then the transverse velocity is about 120 km s$\text{-1}$, adding some support for its membership in an old and highly evolved population. The original goal of identifying the evolutionary state of this star has been largely accomplished, partly by the star itself continuing to change and partly through interpretation since 1982. It has probably experienced its last helium flash within the last century and may be on the way to becoming an R Coronae Borealis star (Stone, Kraft, & Prosser 1993; Iben & Livio 1993).

2.5. Runaway T Tauri Stars

RW Aur (Herbig 1973) and RK Ser (Jones & Herbig 1979) were, in 1982, the only known examples of this category remotely bright enough for Hipparcos. They are (two-dimensional) members of nearby star formation regions whose proper motions, as determined from the ground, are quite different from the other stars in the regions. The parallaxes are marginally significant and confirm that the stars could be three-dimensional members of their regions. RW Aur is at 48–136 pc (1 σ) and its cluster is at 140 pc. FK Ser is at 64–303 pc (1 σ), its cluster at 220 pc. Table 2 shows the proper-motion data in comparison with the ground-based values. Curiously, the declination values agree (within the errors), but those in right ascension are wildly discordant. We do not feel we understand Hipparcos well enough to offer even a tentative explanation (G. H. Herbig 1997, private communication). In either case, the stars do not share the motions of their neighbors and are moving fast enough to leave the regions in 10$^7$ yr and eventually turn up as weak-lined T Tauri stars and X-ray sources outside the main cluster cores.

| Star (HIC) | Name     | $n^a$ | $\mu$(R.A.)$^b$ | $\mu$(decl.)$^b$ | $m^c$ | $M_\odot^d$ | $V_p^e$ |
|------------|----------|-------|----------------|-----------------|-------|------------|---------|
| 65915 ...... | FK Com   | $+4.27 \pm 1.00$ | $-52.7 \pm 1.0$ | $-19.8 \pm 0.6$ | 8.3–8.4 | 1.35       | 46, 77  |
| 23106 ...... | HD 32198 | $+3.43 \pm 0.61$ | $-4.0 \pm 0.6$ | $-2.5 \pm 0.8$ | 8.1–8.3 | 0.8        | 2, 6    |
| 25647 ...... | HD 36705 | $+66.92 \pm 0.54$ | $+32.1 \pm 0.5$ | $+151.0 \pm 0.7$ | 7.0–7.1 | 6.1        | 11, 11  |
| 51109 ...... | HD 90657 | $+1.72 \pm 1.18$ | $-6.9 \pm 1.5$ | $+3.2 \pm 1.1$ | 9.7–9.8 | 0.9        | 6, 54   |
| 99527 ...... | FG Sge   | $+4.60 \pm 2.78$ | $+0.1 \pm 2.9$ | $-8.5 \pm 2.5$ | 9.2–9.7 | 2.5        | 4, 30   |
| 1511 ......  | FB 5080  | $+0.37 \pm 2.82$ | $-4.4 \pm 2.9$ | $-34.3 \pm 1.5$ | 11.6–11.7 | $\leq 4.2$ | 47      |
| 1703 ......  | FB 5121  | $+1.78 \pm 2.75$ | $+4.2 \pm 2.6$ | $-3.3 \pm 1.7$ | 11.5–11.7 | $\leq 4.1$ | 3       |
| 23873 ...... | RW Aur   | $+14.18 \pm 6.84$ | $+9.7 \pm 7.4$ | $-21.9 \pm 3.9$ | 9.9–11.1 | 5.7        | 4, 19   |
| 89874 ...... | FK Ser   | $+9.42 \pm 6.17$ | $+9.4 \pm 8.4$ | $-32.6 \pm 5.9$ | 10.6–10.8 | 5.5        | 8, 62   |
| 101991 ...... | AE Aqr   | $+9.80 \pm 2.84$ | $+75.2 \pm 3.2$ | $+11.5 \pm 2.4$ | 10.9–11.9 | 5.9        | 27, 54  |
| 89886 ...... | AR Pav   | $+3.37 \pm 2.47$ | $-1.0 \pm 1.5$ | $-11.3 \pm 2.1$ | 10.1–12.4 | 2.7        | 7, 72   |
| 107848 ...... | AG Peg   | $-0.30 \pm 1.17$ | $+0.3 \pm 1.8$ | $-2.7 \pm 0.9$ | 8.4–8.9 | $\leq 0.8$ | 3       |
| 97594 ...... | CI Cyg   | $-0.18 \pm 1.5$ | $-2.9 \pm 1.5$ | $-2.9 \pm 1.5$ | 10.5–11.1 | $\leq 2.9$ | 3       |

$^a$ Parallax and standard error in milliarcseconds, from Hipparcos (ESA 1997).

$^b$ Proper motions (right ascension and declination) and standard errors in mas yr$^\text{-1}$ from Hipparcos.

$^c$ Range of apparent brightness during the mission, in the Hipparcos magnitude system.

$^d$ Absolute magnitude at the distance implied by parallax, if it exceeds its standard error even slightly, or limit assuming distance of at least 300 pc.

$^e$ Velocity perpendicular to the line of sight; 1 σ (on both distance and proper motion) limits or lower limit assuming $d = 300$ pc, in km s$^\text{-1}$.
2.6. Cataclysmic Variables

SS Cyg, a well-known dwarf nova from our list, appears in the Input Catalogue (ESA 1992). Unfortunately, a nearby 9th magnitude star was observed instead (J. Mattei 1997, private communication). The nova-like variable AE Aqr (Crawford & Kraft 1956; Mallama & Trimble 1978) is therefore the only low-luminosity cataclysmic variable represented. Both parallax and proper motion exceed 3 standard errors. The distance is 102 (79–144) pc, and the apparent magnitude ranged between 10.9 and 11.0 during the mission. Hence the absolute magnitude in the Hipparcos system was 5.9 ± 6.9 (with some slight preference for the bright end of the range, allowing for an appropriate Lutz-Kelker correction; Lutz & Kelker 1973; I. R. King 1997, private communication; assuming $A_V = 0$ at $l = -28\degree$). Thus, the system is not enormously brighter than its K5 IV–V secondary would be alone. This is just a little surprising, given that nova-like variables are supposed to be exempt from dwarf nova–type outbursts because their mass transfer rates are large as cataclysmic variables go (cf. Barrett 1996, who suggests $155 \pm 55$ pc).

The symbiotic stars AR Pav, AG Peg, and CI Cyg all have a reasonable chance of being (on the basis of infrared, spectroscopic, and other data) the mainstream kind, with giants transferring material to white dwarfs (Zuckerman 1980). None of the parallaxes are significant, confirming the bright, evolved status of the donors. Two of the three proper motions are less than about 5 mas yr$^{-1}$ (11 mas yr$^{-1}$ for AR Pav). These are not high-velocity stars at any reasonable distance.

3. CONCLUSIONS

We have not revolutionized stellar astrophysics as a result of acquiring these data. The main surprises were the dwarf nature of one purported FK Comae star (discovered from the ground in the interim), the relatively large transverse velocities of a couple of stars, and the marginal faintness of the nova-like variable AE Aqr. On the other hand, it is worth reiterating that there are individual stars of considerable importance within the Hipparcos (ESA 1997) sample. Another example is the group of hydrogen-deficient carbon stars considered by Cottrell & Lawson (1997). We urge anybody who has a favorite star between $m = 8$ and $m = 13$ to look into the Hipparcos database and see whether your star is there.

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REFERENCES

Audouze, J., Bouchet, P., Fehrenbach, C., & Woszczyk, A. 1981, A&A, 93, 1
Barrett, P. 1996, PASP, 108, 412
Collier, A. C. 1982, MNRAS, 200, 489
Cottrell, P. L., & Lawson, W. A. 1997, preprint
Crawford, J. A., & Kraft, R. P. 1956, ApJ, 123, 44
ESA. 1992, The Hipparcos Input Catalogue (ESA SP-1136) (Noordwijk: ESA)
———. 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200) (Noordwijk: ESA)
Fehrenbach, C., & Burnage, R. 1982, A&AS, 49, 483
Herbig, G. H. 1973, ApJ, 182, 129
Herbig, G. H., & Boyarchuk, A. A. 1968, ApJ, 153, 397
Iben, I., & Livio, M. 1993, ApJ, 406, L75
Innes, J. L., Robinson, R. D., Coates, D. W., & Thompson, K. 1985, Proc. Astron. Soc. Australia, 6, 151
Jones, B. F., & Herbig, G. H. 1979, AJ, 84, 1872
Kenyon, S. J., Webbink, R. F., Gallagher, J. S., & Truran, J. W. 1982, A&A, 106, 109
Lutz, T. E., & Kelker, D. H. 1973, PASP, 85, 573
Mallama, A. D., & Trimble, V. 1978, QJRAS, 19, 430
Niemala, V. S., & Moffat, A. F. J. 1982, ApJ, 259, 213
Rucinski, S. M. 1985, MNRAS, 215, 391
Stone, R. E. M., Kraft, R. P., & Prosser, C. F. 1993, PASP, 105, 775
Trimble, V., & Kundu, A. 1997, PASP, 109, 1089
White, G. L., Jauncey, D. L., Barry, M. J., Peters, W. L., & Gulkis, S. 1988, PASP, 100, 825
Zuckerman, B. M. 1980, ARA&A, 18, 263