HIPPARCOS ASTROMETRY AND RADIO MAPPING OF PECULIAR BINARY SYSTEMS

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ABSTRACT

We report Hipparcos observations of a number of binary systems, symbiotic stars and bright long period binaries, which are known also for being radio sources. In these systems the matter ejected from the component(s) is generally made visible in the radio by the ionizing radiation of the hot component of the system. Shocks from wind collision may also play a role, especially in those objects which are known for being X–ray sources. Hipparcos has shown that in most cases the astrometric position is very close to the core of the radio source. In particular, in the case of multiple radio sources, the Hipparcos position is close to the central source of CH Cyg, to the brightest source of AG Dra, and to the SiO maser emission of R Aqr.

Key words: radio emission; space astrometry; symbiotic stars; VV Cep stars.

1. INTRODUCTION

Symbiotic stars are long period interactive binary systems, characterized by a late type giant primary (of K or M type, or a Mira variable), and a misterious compact companion a hot subdwarf or a white dwarf powered by the accretion processes. Matter is lost by the system through stellar winds and during violent ejection phases, producing diffuse circumstellar nebulosities of complex shape which are partly ionized by the hot star radiation. The circumstellar region is also the site of interaction of the ejected material with the ambient medium. Extended emitting envelopes are also present in the ζ Aur and VV Cep systems, many of which have in fact been recognized to be radio sources. These systems have a red supergiant primary (of K or M type), and a main sequence early type secondary.

Radio emission has been detected in many of these objects, and it is expected that the situation will largely improve in the next years when more accurate observations will be available. In a number of symbiotic systems, extended radio haloes and jet-like features have been identified which are thought to be associated with matter ejection, both in form of stationary stellar winds, and/or as the result of transient parossistic events (or outbursts) which could have taken place in the past history of the system. Therefore, the link between the radio maps and the astrometric position of the 'central' star at the epoch of the radio observations may help the understanding of the time of formation of the ejecta.

2. HIPPARCOS OBSERVATIONS

Table 1 gives the coordinates as derived from the literature of the barycentre of the radio emission, or of the central radio knot in the case of multiple radio structure. The uncertainty in the radio position given in column 5 of the table was generally derived from the radio beam width, but a more accurate estimate of the precision of the radio position, also taking into account the reference frame to which the radio observations were tied, is in due course, so that some of the conclusions below are to be considered as preliminary. The J1991.25 Hipparcos coordinates (seconds of time and arcsec) were reported to the epoch and equinox of the radio observations using the Hipparcos proper motion determination.

The last column in the table gives the distance (in mas) between the radio and Hipparcos positions and the Hipparcos standard errors. The latter ones take also into account the error introduced by the extrapolation of the J1991.25 Hipparcos coordinates to the time of the radio observations, but not the uncertainty of the radio position given in column 5 of the table.

3. DISCUSSION

Hipparcos has provided a general large improvement of our knowledge on the astrometric positions of these peculiar stars with respect to previous estimates. From Table 1 it is evident that in most cases the radio and optical positions agree within the given uncertainty of the radio observations, which however might be at least in some cases lower than that here reported. We consider the large difference observed in EG And, AG Dra and Z And as due to the larger uncertainty of their radio position because of the weak radio flux of these sources. Also for KQ Pup and

Table 1. Radio and Hipparcos observations of symbiotic and VV Cep systems.

star	epoch	$\alpha_{radio}{}^a$	$\delta_{radio}{}^a$	σ''_{radio}	ref	π	α^s_H	δ''_H	$\Delta_{radio-H}$
EG And	1987.8	00 41 52.70	+40 24 21.8	0.1	12		52.6905	21.783	109±4
KQ Pup	1983.68	07 31 30.082	–14 24 51.94	0.24	1	1.0±0.8	30.0790	51.909	53±6
AG Dra[b]	1986.6	16 01 23.23	+66 56 25.30	0.7	11	<1.0	23.1952	25.229	216±7
AG Dra[c]	1994.94	16 01 40.8	+66 48 08	8_{Xray}	2		41.0188	10.167	2.5″
CH Cyg[b]	1986.12	19 23 14.124	+50 08 30.70	0.1	10	3.7±0.9	14.1264	30.740	46±8
AG Peg	1987.57	21 48 36.164	+12 23 27.42	0.11	6	<1.2	36.1650	27.440	25±7
VV Cep	1983.63	21 55 14.413	+63 23 13.41	0.39	1	<0.9	14.4032	13.419	66±6
Z And	1982.2	23 31 15.27	+48 32 31.20	0.15	9		15.2959	31.386	317±28
R Aqr[b]	1985.03	23 41 14.266	–15 33 43.00	0.07	4	5.1±3.2	14.2513	43.028	214±12
R Aqr[d]	1996.89	23 43 49.4545	–15 17 04.100	0.07	5		49.4545	04.100	16±11

(a) Equinox 1950, except otherwise indicated. (b) Position of central or main radio emission, when multiple. (c) Position of the X–ray source (ROSAT HRI, J2000, Greiner et al. 1997). (d) SiO maser emission at 43 GHz (J2000, Hollis et al. 1997).

VV Cep we conclude that the radio and optical position are coincident within the errors. The parallax of KQ Pup is in agreement with current estimates of the distance of this systems (1.4 kpc, e.g. Rossi et al. 1992), confirming the high luminosity of the M2Iab component of the system. The other targets are discussed in more details below.

AG Dra

The high velocity symbiotic star AG Dra is known for the many outbursts occurred in recent years, and for being a supersoft X-ray source (see Viotti et al. 1996, Greiner et al. 1997). Hipparcos has only provided an upper limit to the system's parallax of ≃1 mas, which places AG Dra well far from the galactic plane and suggests for the K-star component a luminosity larger than that of normal K-giants.

The radio source of AG Dra has been resolved by Torbett & Campbell (1987) into two components separated by about 1 arcsec. The Hipparcos observations have shown that the K-star is centred on the main radio component. New higher quality radio observations of AG Dra are strongly desired in order to put in evidence if there is any displacement of the barycentre of the radio main emission with respect to the astrometric position of the red star, displacement which might be associated with an asymmetric ionization of the circumsystem matter by the hot WD companion. The displacement, if confirmed, cannot be attributed to the separation of the hot WD from the K star, since the distance of the system is too large to allow to separate the components of the binary system (orbital period of 554 days).

AG Dra is also known for being a strong ultrasoft X-ray source. The most accurate position of the source (±8 arcsec) which is reported in Table 1 was derived from ROSAT HRI observations (Greiner et al. 1997), and is coincident with the astrometric position within the errors.

CH Cyg

This is one of the most interesting and most studied symbiotic stars for its very rich optical and UV emission line spectrum and the large spectral and photometric variations that have taken place during recent years. The star underwent a 'radio outburst' in 1984 when the optical luminosity declined by more than one magnitude with a simultaneous increase of the ionization of the emission line spectrum. Since then the radio emission had a nova-like evolution on a time scale of about 400 days (Taylor et al. 1988). At high resolution (VLA) the radio emission evolved from a twin source in November 1984 to a three- and five-component structure (January 1985 and February 1986, Taylor et al. 1986, 1988).

The large uncertainty on the astrometric position of the optical counterpart has until the advent of the Hipparcos mission compelled a direct comparison with the position of the radio knots which is an important ingredient for any modeling of the system and of its activity. We have compared the Hipparcos astrometric position of CH Cyg with that of the central radio core at 15 GHz as derived from the radio image of February 1986 reported by Taylor et al. (1988). We estimate from the image that the position error of the radio core be ∼0.1 arcsec or less, although we cannot exclude systematic errors in the reference frame. There is a slight displacement of the radio and optical cores of 46 mas, which is within the assumed radio position error.

CH Cyg is the second nearest symbiotic system, though the distance estimates given in the literature span a rather large range from 100 pc up to 400 pc. The Hipparcos parallax of CH Cyg indicates a distance of 270±66 pc which is slightly larger than most of the previous determinations. At this distance, the above derived 46 mas separation between the radio and optical counteparts, if confirmed, would correspond to ∼12 AU.

AG Peg

The radio emisison from the symbiotic binary AG Peg (M3III+WN6) was observed in 1987 with VLA at 1.5, 5, 12 and 22 GHz. The high resolution observations (HPBW = 0.11 arcsec in the best resolved configuration) confirmed the presence of an unresolved central source, surrounded by an inner shell (D = 2.00±0.06 arcsec), and an outer nebula. The Hipparcos astrometric position of the M star, extrapolated to the time of the 1987 radio observations, is coincident with the position of the radio core within the errors. The lower limit to the distance of ∼0.8 kpc is not in disagreement of current estimates of around 600–800 pc.

R Aqr

R Aqr is a well known symbiotic system containing a Mira-type cool star, and is surrounded by a complex nebulosity which is ionized by the so far unveiled hot companion. High resolution optical, radio and HST observations have revealed a jet–like structure towards about North–East (as well as a weaker counterjet towards South–West). R Aqr is also a weak X–ray source which might be originated in the shock-heated region of the jet (Viotti et al. 1987). VLA observations resolved the central H II region into two components (C1 and C2) separated by ∼0.5 arcsec (Hollis et al. 1986), while HST observations identified a collimated stream of emission nebulae (Paresce & Hack 1994), the most central one being at about 70 mas to the North of the Mira star.

More recently, Hollis et al. (1997) measured the position of the SiO maser emission at 43 GHz and of the central H II radio continuum source, and found a displacement of 55 ± 2 mas (position angle ∼18°) between the two radio sources, which they attribute to the two components of the binary system. At the Hipparcos distance of about 200 pc, this separation would correspond to about 10 AU, in agreement with a 44 year orbital period of the system (Hollis et al. 1997).

The Hipparcos parallax is however very uncertain because of the very red colour of the Mira star, and for its large luminosity variations (V from 6 to 12). Another negative point is the fact that the pulsation period is of nearly one year, which might have introduced systematic errors in the parallax measurements. New direct estimates of R Aqr distance are strongly needed to solve the problem of its binary nature.

The Hipparcos astrometric positions are reported in Figure 1 where they are compared with the recent radio and HST observations. In the figure we give the extrapolated positions of the Mira at the time of the 1985 and 1996 radio observations. The line marks the large proper motion of the star during 1985.0–1996.9. For the sake of completeness, we also report in the figure the position of the closest nebulae from the 1991 HST imagery (Paresce & Hack 1994).

Since the HST positions are relative to the Mira star, they were transformed into absolute positions by adopting for the Mira the Hipparcos coordinates at the time of the HST observations. We find that

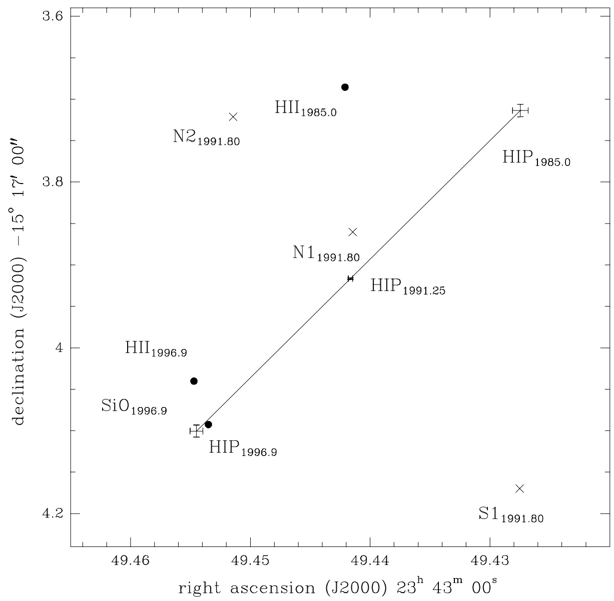

Figure 1. Hipparcos astrometry of the R Aqr Mira compared with the position of the structures identified by the radio and HST observations in different epochs.

the November 1996 Hipparcos position of the Mira is coincident within the errors with SiO maser. This supports the idea of a molecular shell surrounding the Mira, as suggested by Hollis et al. (1997).

We also note from the figure that the relative position of the nearest H II nubecula $N1$ is the same in the VLA and HST observation made five years apart, so the source may well be the same without a significant motion. On the other end the 15 GHz VLA position of the barycentre of the radio knot C_1 in January 1985 is displaced by 0.21 arcsec to the East with respect to the extrapolated astrometric position of R Aqr.

This large displacement could be easily explained if we assume, having taken into account the uncertainty in the radio position, that the C_1 knot is the same as the 1991 HST $N2$ nubecula, and that the weaker $N1$ feature is unresolved in the 1985 radio observations. The slight elongation towards SW of the C_1 radio knot seems to favour this hypothesis. If this is the case the two Hα structures C_1 and C_3 found by the speckle interferometric observations of Hege et al. (1991), should be coincident with the HST $N2$ and $N1$ features, respectively.

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REFERENCES

Florkowski, D.R., Johnston, K.J., Wade, C.M., de Vegt, C., 1985, AJ, 90, 2381

Greiner, J., Bickert, K., Luthardt, R., Viotti, R., Altamore, A., González-Riestra, R., Stencel, R.E., 1997, A&A, in press

Hege, E.K., Allen, C.K., Cocke, W.J., 1991, ApJ, 381, 543

Hollis, J.M., Michalitsianos, A.G., Kafatos, M., Wright, M.C.H., Welch, W.J., 1986, ApJ, 309, L53

Hollis, J.M., Pedelty, J.A., Lyon, R.G., 1997, ApJ (Letters), in press

Kenny, H.T., Taylor, A.R., Seaquist, E.R., 1991, ApJ, 366, 549

Paresce, F., Hack, W., 1994, A&A, 287, 154

Rossi, C., Altamore, A., Baratta, G.B., Friedjung, M., Viotti, R. 1992, A&A 256, 133

Seaquist, E.R., Taylor, A.R., 1990, ApJ, 349, 313

Taylor, A.R., Seaquist, E.R., Kenyon, S.J., 1988, The Symbiotic Phenomenon, J. Mikolajewska et al. (eds.), Kluwer, Dordrecht, 231

Torbett, M.V., Campbell, B., 1987, ApJ, 318, L29

Torbett, M.V., Campbell, B., 1989, ApJ, 340, L73

Viotti, R., Piro, L., Friedjung, M., Cassatella, A., 1987, ApJ (Letters), 319, L7

Viotti, R., Gonzalez-Riestra, R., Montagni, F., Mattei, J., Maesano, M., Greiner, J., Friedjung, M., Altamore, A., 1996, Proc. Workshop on 'Supersoft X-ray Sources', Garching, 28 February-1 March 1996, J. Greiner editor, Lecture Notes in Physics, Springer Verlag, p. 259