THE ASTROPHYSICAL JOURNAL, 204:L89–L90, 1976 March 1

THE POSITIONS AND PROPER MOTIONS OF HZ HERCULIS AND 12 NEIGHBORING STARS

GEORGE GATEWOOD
Allegheny Observatory, University of Pittsburgh
AND
SABATINO SOFIA
National Aeronautics and Space Administration, Washington
Received 1975 October 20

ABSTRACT

The positions and proper motions of HZ Her, the optical counterpart of the X-ray source Her X-1, and 12 field stars are determined in the system of the FK4. The proper motion of HZ Her is consistent with that expected from a relatively low peculiar velocity object located at the ~3 kpc distance estimated for Her X-1.

Subject heading: X-rays: sources

I. PROPER MOTIONS AND PHOTOMETRY

The distance of the binary system containing HZ Her and the X-ray source Her X-1 is not known with a high degree of confidence; and although the currently preferred value, based on photometric and spectroscopic evidence, is about 3 kpc (Crampton 1975), estimates between 2 and 6 kpc can be found in the literature (cf. Blumenthal and Tucker 1974).

In a preliminary measurement of the proper motion of HZ Her carried out by L. W. Luyten on a pair of plates taken with the Palomar 48 inch (1.2 m) Schmidt telescope 12.86 years apart, the following result was obtained (Crampton 1975):

$$\mu_\alpha = +0''.015 \pm 0''.020\,,$$
$$\mu_\delta = -0''.041 \pm 0''.020\,.$$

At a distance probably in excess of 2 kpc, the proper motion of the object indicates a tangential velocity of over 400 km s^{-1}, a datum of considerable implications regarding the supernova mechanism and age estimates for the source. However, because of the rather large formal errors of the measurements, and the fact that the radial velocity of HZ Her (corrected for solar motion) is only about 40 km s^{-1} (Crampton 1975), it is highly desirable to redetermine this proper motion with much higher accuracy. It is the purpose of this *Letter* to report the results of such a study.

The plate material available for this work is listed in Table 1. The early plates were obtained from the Harvard College Observatory plate file and measured on the Harvard digitized two-coordinate comparator. The current plates were obtained with the Allegheny Observatory 30 inch (76 cm) photographic Thaw refractor. Four of these plates, 107851–2 and 107853–4, form an overlap pattern such that the image of HZ Her appears in a different corner of each plate. Plates 107850 and 107861 are centered on the X-ray source. This pattern allowed the images of 17 AGK-3 stars to be measured on the Thaw plates, which cover less than one square degree per plate. The recent plates were measured on the Allegheny Observatory two-screw Mann comparator.

TABLE 1

PLATES OF HERCULES X-1

Plate Number	Telescope (inches)	Plate Scale (arcsec mm^{-1})	Epoch	M_{pg} Her X-1
A7271....	Bruce 24	60	1905 April 25	11.7
MC 8454..	Metcalf 16	98	1915 April 20	14.5
MC 18657.	Metcalf 16	98	1922 April 25	14.3
MC 35345.	Metcalf 16	98	1947 March 30	14.2
MC 38198.	Metcalf 16	98	1955 April 17	14.4
107850....	Thaw 30	14.6	1975 May 7	14.1
107851....	Thaw 30	14.6	1975 May 7	14.1
107852....	Thaw 30	14.6	1975 May 7	14.1
107854....	Thaw 30	14.6	1975 May 7	14.3
107855....	Thaw 30	14.6	1975 May 7	14.3
107861....	Thaw 30	14.6	1975 May 8	12.7

All plates were reduced by a restricted plate overlap technique (Eichhorn 1960) into the system of the AGK-3, ostensibly that of the FK4. The positions and proper motions of HZ Her and 12 field stars are given in Table 2 for the epoch and equinox 1950.0. The standard error of the proper motions is 0''.004 while the internal standard error of the positions at their 1975 epoch is 0''.03 in each coordinate.

The weighted mean of the proper motion components found here and independently by Luyten are

$$\mu_\alpha = +0''.001 \pm 0''.004\,,$$
$$\mu_\delta = -0''.005 \pm 0''.004\,.$$

It is useful to note that these values are within the errors of those predicted by effects of the differential galactic rotation in the region of the sky occupied by HZ Her, which are approximately $\mu_\alpha = +0''.001$, $\mu_\delta = -0''.003$. This coincidence, if meaningful, implies that the distance to the source is large enough so that its peculiar tangential velocity can be ignored by comparison with the tangential velocity due to the differential

TABLE 2

THE POSITIONS AND PROPER MOTIONS OF 13 STARS IN THE REGION OF HERCULES X-1

No.	m_{pg}	R.A.$_{1950}$	μ_α(seconds yr^{-1})	Decl.$_{1950}$	μ_δ (arcsec yr^{-1})
218.....	12.0	$16^h54^m0^s.959$	+0.0002	+35°23′06″.19	−0″.004
219.....	11.8	16 54 28.270	+0.0005	34 59 11.14	−0.001
220.....	12.3	16 54 37.981	−0.0009	35 11 42.96	−0.007
221.....	12.6	16 54 40.259	−0.0009	35 10 22.91	−0.011
222.....	9.6	16 55 22.420	−0.0001	35 21 46.40	−0.004
223.....	14.6	16 55 44.407	−0.0004	35 17 53.10	−0.011
224.....	14.3	16 55 46.297	+0.0004	35.26 30.74	−0.002
225.....	11.0	16 55 52.620	+0.0022	35 20 43.34	+0.008
226.....	14.3	16 55 58.684	+0.0003	35 31 42.02	−0.001
227.....	Var.	16 56 01.676	0.0000	35 25 04.84	−0.004
228.....	14.4	16 56 11.144	0.0000	35 20 29.23	+0.019
229.....	14.1	16 56 18.183	−0.0010	35 26 04.09	−0.013
230.....	14.2	16 56 39.507	+0.0009	35 27 18.45	−0.002

NOTE.—The star numbers in this table are part of a continuing sequence of stars studied at Allegheny by the plate overlap technique. Star No. 227 is HZ Her. Dr. Bruce Stephenson reports that star 222 is K3 III, and notes in its spectrum a weak g-band.

galactic rotation, and it is in this regard that Her X-1 is very probably a relatively low peculiar velocity object. In any event, the large tangential velocity first suggested for the object is not confirmed.

Besides HZ Her, five field stars (Nos. 218, 219, 222, 224, and 226) have proper motions which also fall within their standard errors of the differential galactic rotation value. Three of these stars (Nos. 222, 224 and 226) are among the seven program stars (Table 3) that were included in a recent photometric study of this region by Boynton (1975). Star No. 222 has been classified by B. Stephenson as a K3 III. If we assume that stars 224 and 226 are also K III, then their distance would be about 3 kpc, just as suggested for HZ Her. Of course, this evidence is extremely weak, and whether these stars form a coherent group must await further spectroscopic work.

The photometric results for star 221 are suggestive of a B2 V star; however, both the proper motion and the galactic coordinates of the object argue against this interpretation, and the star may be a hot white dwarf. Further spectroscopic work is definitely warranted for this star.

TABLE 3

PHOTOELECTRIC PHOTOMETRY OF PROGRAM STARS

No.	m_V	$v-r$	$B-V$	$U-B$
221.....	12.82	−0.12	−0.19	−0.80
222.....	8.12	1.02	1.42	1.64
224.....	13.21	0.83	1.11	1.00
225.....	9.93	0.76	1.07	0.98
226.....	13.16	0.79	1.13	0.93
229.....	13.46	0.55	0.67	0.15
230.....	13.44	0.63	0.76	0.22

II. CONCLUSIONS

The proper motion derived here resolves the conflict between the usually accepted value of the distance of Her X-1 and the available astrometric data without having to invoke an enormous tangential velocity for the object. While no value of the distance of Her X-1 can be determined from the small proper motion found here, we note that this value is the one predicted by differential galactic rotation. In other words, our proper motion is consistent with the hypothesis that the system has both a normal peculiar tangential velocity and a distance of several kiloparsecs.

Five of the field stars in this study also have proper motions similar to that predicted by differential galactic rotation. Spectral classifications might indicate that some of these stars are at the distance that has been suggested for Her X-1.

Finally, a low-dispersion spectrum of star 221 would resolve the identity of this interesting object.

We would like to thank Dr. Paul Boynton, of the University of Washington, for making the photoelectric photometry listed here available to us before publication. We would also like to express our gratitude to Dr. and Mrs W. Liller, of the Harvard College Observatory, for their interest and suggestions, and Dr. Bruce Stephenson, of the Warner and Swasey Observatory, for classifying star 222. One of us (G. G.) acknowledges partial support for this study by an NSF grant. Finally, we wish to acknowledge the assistance of Miss Jane Russell.

REFERENCES

Blumenthal, G. R., and Tucker, W. H. 1974, *Ann. Rev. Astr. and Ap.*, **12**, 23.
Boynton, P. 1975, private communication.
Crampton, D. 1975. *Ap. J.*, **187**, 345.
Eichhorn, H. K. 1960, *Astr. Nachr.*, **285**, 233.

GEORGE GATEWOOD: Allegheny Observatory, University of Pittsburgh, Pittsburgh, PA 15214
SABATINO SOFIA: National Aeronautics and Space Administration, Code SA, Washington, DC 20546