THE SURFACE DISTRIBUTION OF CHEMICAL ANOMALIES OF Ap COMPONENTS IN DETACHED CLOSE BINARIES

M. Kitamura
Tokyo Astronomical Observatory
University of Tokyo, Mitaka
Tokyo 181, Japan

ABSTRACT

By estimating the orbital inclinations of non-eclipsing detached close binaries with Ap spectra, a marked statistical preference is obtained on the frequency distribution of the inclination which suggests that the abundance anomalies of Ap components tend to concentrate towards the stellar polar region.

1. INTRODUCTION

It is well known that no eclipsing system has been discovered in spectroscopic binaries with Ap spectra, except for AR Aur, for which Dworetsky (1975) reported that it is an Ap star of the Hg-Mn type.

Suppose that the orientations of the orbital planes of the binary systems are at random in space; then the relative frequency ratio of observable eclipsing and spectroscopic binaries may be written as

$$R = f_{ecl}/f_{sp} \qquad (1)$$

where f_{ecl} is the probability of discovery of eclipsing binaries and f_{sp} the probability of discovery of spectroscopic binaries. The Seventh Catalog of spectroscopic binaries (Batten et al. 1978) lists 978 systems, of which 378 are eclipsing binaries. Kitamura and Kondo (1978) made a statistical study of spectroscopic binaries of Am spectral features with periods less than 12 days and showed that 11 of the 45 systems are eclipsing. Thus, the probability of discovery of eclipsing binaries in spectroscopic ones should about to 25 $\sim$ 40% generally.

Therefore, the actual lack of eclipsing systems in spectroscopic binaries with Ap spectra might suggest any particular reason.

M. J. Plavec, D. M. Popper and R. K. Ulrich (eds.), Close Binary Stars: Observations and Interpretation, 95–99.

https://doi.org/10.1017/S0074180900064664 Published online by Cambridge University Press

2. Ap CLOSE BINARIES WITH PERIODS LESS THAN 13 DAYS AND THEIR ORBITAL INCLINATIONS

It is customary to divide the Ap stars into two groups, the Hg-Mn type and the magnetic type. So far, 14 close binaries of the Hg-Mn type and 5 of the magnetic type are known. Of these, 9 are double-lined and the remaining are single-lined (Kitamura, 1980).

For a non-eclipsing double-lined binary, the orbital inclination can be estimated from the $m_1 \sin^3 i$ value with the assumed m_1 value corresponding to its spectral type as the main sequence. For a non-eclipsing single-lined binary, the orbital inclination can be given from the mass function as

$$\sin^3 i = (m_1/m_2 + 1)^2 \cdot f/m_2 \qquad (2)$$

In view of the invisibility of the fainter component on spectrograms, we may put a condition that

$$m_1/m_2 > 1.5 \qquad (3)$$

Also, the lowest mass for the secondary component may be put as

$$m_2 > 0.3 \qquad (4)$$

Substituting conditions (3) and (4) into (2), it follows that the orbital inclination of a single-lined binary should fall within the two limiting values as

$$(10\ m_1 + 3.3)f > \sin^3 i > 9.4\ f/m_1 \qquad (5)$$

From expression (5) we can find the value of orbital inclination of a non-eclipsing single-lined binary with a certain limit, which enables us to make a statistical study of the frequency distribution of the inclinations.

3. STATISTICS

In order to find the frequency distribution of the orbital inclinations of 19 spectroscopic binaries with Ap features, numbers of binaries within intervals of 0°-15°, 15°-30°, 30°-45°, 45°-60°, 60°-75°, and 75°-90° in the orbital inclination were counted. If the range of the inclination deduced for a single-lined binary was spread over more than one interval, a weight reduced reciprocally to the number of the relevant intervals was applied. For example, the orbital inclination of 21 Her is given to be 10°-21° spreading over two intervals of 0°-15° and 15°-30°. In such a case a reduced weight of 0.5 was applied

https://doi.org/10.1017/S0074180900064664 Published online by Cambridge University Press

to each of the relevant intervals. The results of the counts are given in the second line of Table 1.

Table 1. The Frequency Distribution of the Orbital Inclinations

i	90°-75°	75°-60°	60°-45°	45°-30°	30°-15°	15°-0°
No.	2.28	3.28	2.78	3.95	3.20	3.50
f_{Ap}	0.120	0.173	0.146	0.208	0.168	0.184
f_{Am}	0.312	0.196	0.188	0.133	0.107	0.064
f_{Ap}/f_{Am}	0.38	0.88	0.78	1.56	0.57	2.88

In the third line of Table 1, the corresponding fraction is given. F_{Am} in the fourth line is taken from Kitamura and Kondo's statistical study (1978) on Am spectroscopic binaries. According to Abt and Bidelman (1969), the A2-FO type stars as the components of close binaries are all Am stars and therefore the frequency distribution of orbital inclinations of Am binaries may be considered to represent the ordinary A-type spectroscopic binaries. The values of f_{Am} and f_{Ap} are shown in Figure 1 as well.

3. DISCUSSION

In general the discovery of spectroscopic binaries is easier the larger their velocity variations are. As the orbital inclination is larger, the velocity variations should be larger. For the random orientations of the orbital planes of binary systems in space, the frequency distribution of the orbital inclination for observable spectroscopic binaries should increase with increasing orbital inclinations, as in the case of Am spectroscopic binaries. However, as is evident in Figure 1, the distribution of f_{Ap} and f_{Am} are quite different.

Next we shall correct for the discovery probability in order to find out the real relative frequency distribution of the orbital inclinations of Ap binaries in space. This can be done by dividing the observed frequency of Ap binaries with the relative frequency for Am binaries, because f_{Am} may be regarded as representing the relative discovery rate of the general spectroscopic binaries. The ratio f_{Ap}/f_{Am} should represent the relative frequency distribution of the orbital inclinations of the 19 Ap binaries in space, corrected with the discovery probability.

Figure 2 shows the distribution of f_{Ap}/f_{Am} with the inclination. As is evident from this figure, the frequency distribution in space of orbital inclinations of Ap spectroscopic binaries has a considerable preference towards the smaller orbital inclinations. What does this mean?

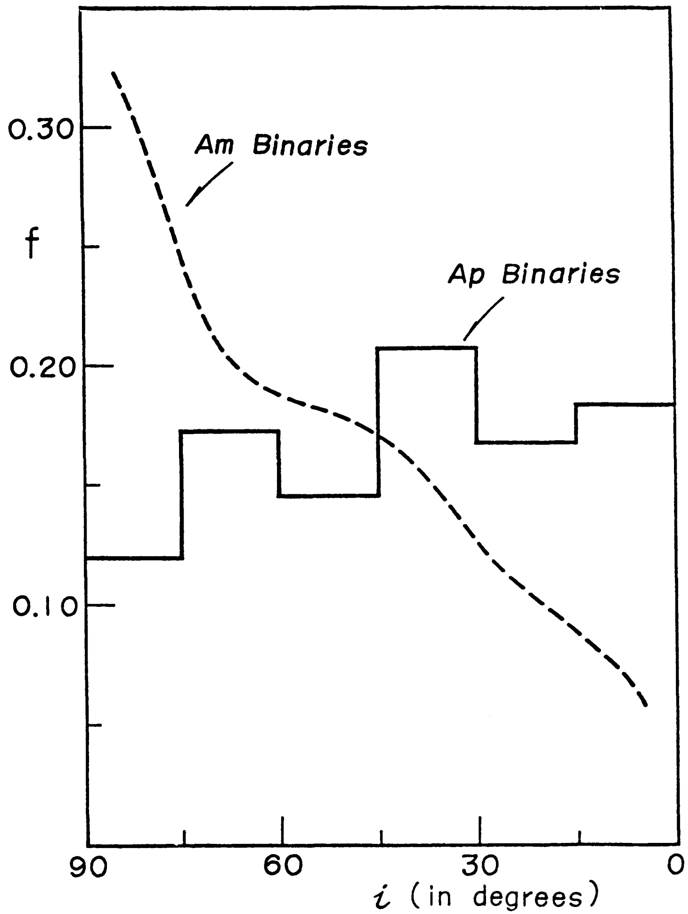

Figure 1. Histogram for the frequency distribution of the orbital inclination for the 19 Ap binaries of the Hg-Mn type and the magnetic type. The dotted curve represents the corresponding smoothed frequency distribution for the Am spectroscopic binaries with periods less than 12 days.

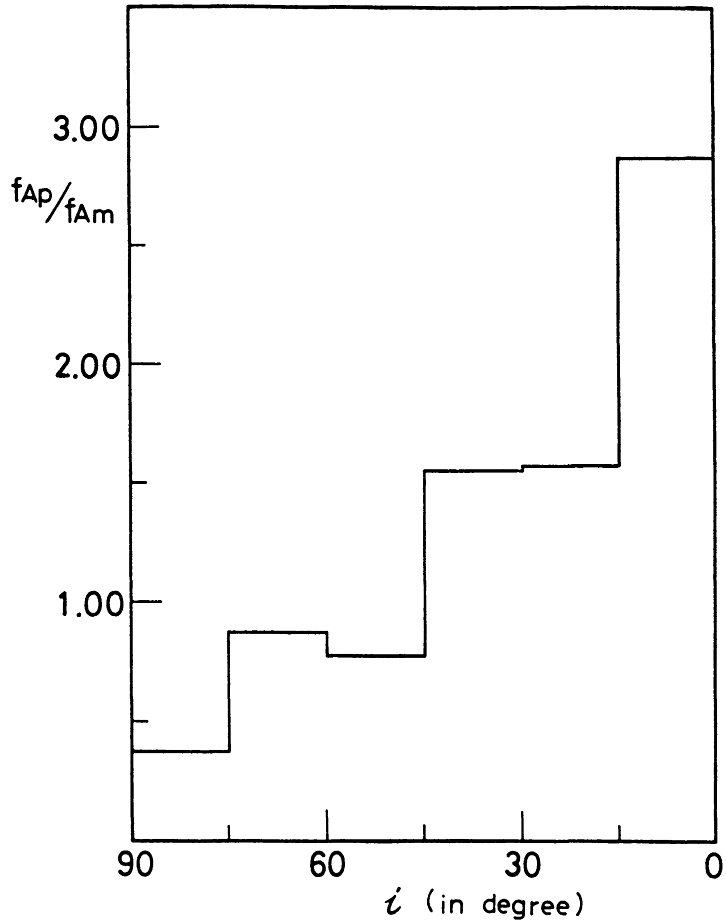

Figure 2. Relative frequency distribution of the orbital inclinations of the 19 Ap binaries, corrected for the discovery probability.

https://doi.org/10.1017/S0074180900064664 Published online by Cambridge University Press

In close binaries, the components may be considered to rotate around the axes perpendicular to their orbital planes, and therefore the inclinations should correspond to the angle between the line of sight and the rotation axis of either component. Therefore, the present result indicates that the surface distribution of Ap chemical anomalies should have a marked preference towards the pole of the Ap star.

It has been conventional to divide the Ap stars into two distinct groups, the Hg-Mn type and the magnetic type. However, the present statistics reveal that both types have a similar nature. The full discussions will be published in Ap. Sp. Sci. soon.

REFERENCES

Abt, H.A. and Bidelman, W.P.: 1969, Astrophys. J., 158, 1091.
Batten, A.H., Fletcher, J.M. and Mann, P.J.: 1978, Publ. Dominion Astrophys. Obs., 13, No.8, 119.
Dworetsky, M.: 1975, In W.W. Weiss, H. Jenkner and H.J. Wood (ed.), Physics of Ap Stars (IAU Coll. No. 32), Wien Univ. Obs., p. 228.
Kitamura, M. and Kondo, M.: 1978, Astrophys. Sp. Sci., 56, 341.
Kitamura, M.: 1980, Astrophys. Space Sci., 68, 283.

COMMENTS ON KITAMURA

Nariai

The paper puts the Hg-Mn stars into the group of Ap-type stars. It is probably better to separate the Hg-Mn stars from the Ap stars, because the Hg-Mn stars seem to form the hot extension of the Am-type stars (cf. S. Wolff, IAU Coll. No. 32, Vienna, 1975, p. ...).