UC Irvine
UC Irvine Previously Published Works

Title
Q-(ALPHA) RECONSIDERED

Permalink
https://escholarship.org/uc/item/0rr554tp

Journal
OBSERVATORY, 98(1025)

ISSN
0029-7704

Author
TRIMBLE, V

Publication Date
1978

Copyright Information
This work is made available under the terms of a Creative Commons Attribution License, availalbe at
https://creativecommons.org/licenses/by/4.0/

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

1978Obs....98..163T

References

(1) A. S. Webster & M. Ryle, *M.N.*, **175**, 95, 1976.
(2) R. P. Kirshner, *P.A.S.P.*, **88**, 585, 1976.
(3) B. Elsmore & M. Ryle, *M.N.*, **174**, 411, 1976.
(4) R. W. Hunstead, *M.N.*, **152**, 277, 1971.
(5) L. Helmer & H. J. Fogh Olsen, *A. & A. Suppl.*, **30**, 866, 1977.

$q(\alpha)$ RECONSIDERED

By Virginia Trimble
University of California, Irvine, and University of Maryland

The distribution of mass ratios in spectroscopic binaries, $q(\alpha)$, has been brought up to date and plotted in a slightly more sensible way. All features of the previous determination persist. The most important of these is bimodality: $q(\alpha)$ has peaks near $M_2/M_1 = 0{\cdot}2$–$0{\cdot}3$ and $0{\cdot}9$–$1{\cdot}0$. Every subsample, including unevolved systems, also displays this double-peaked distribution function. It probably implies that binaries are formed by two mechanisms, acting like fission and capture.

The problem of whether the binary stars comprise one, two, or more populations is sufficiently ancient to be considered honourable[1]. It can be tackled theoretically by asking how many different ways one can think of for binaries to form and subsequently evolve. The answers range from zero to many, depending on how rigorous one requires the mathematics to be. Advertised formation mechanisms include fission of a single proto-star, capture of one pre-existing star by another, and separate condensation of two proto-stars which later find themselves to be gravitationally bound. The inevitability of transfer of gas from one star to the other in, at least, close systems, forces one to recognize an evolved and an unevolved population even if there is only one formation mechanism.

The problem can also be tackled observationally by asking how various properties of binaries (separation, period, orbital eccentricity, total mass, mass ratio, orbit orientation) are distributed among known systems. Provided that the available observations are not dominated by selection effects, a single population should show up as a unimodal distribution in the various properties, while multiple populations could produce more complex distribution functions.

Of the distributions that have been studied, that of periastron angle is thought to be dominated by selection effects and that of eccentricity by tidal evolution of the orbits[2]. One study of separations (of binaries in OB associations)[3,4] found a bimodal distribution. Others[1,5], looking at field stars, found a single peak near 20 AU when both visual and spectroscopic systems were included. The period distributions for field B2–5 and F3–G2 IV–V binaries[6,7] similarly have single peaks, occurring at periods of several years, when spectroscopic, visual, and common proper motion pairs are all included.

© The Observatory • Provided by the NASA Astrophysics Data System

1978Obs....98..163T

This slight confusion dissolves into utter chaos when distributions of mass ratio are considered. Abt and Levy[6,7] found a bimodal distribution, mass ratios near unity occurring systematically in close systems, and small ratios in wide (P > 10 years) systems. They attribute these two populations to formation by bifurcation and separate condensation respectively. Wolff's[8] $q(\alpha)$ for late B field spectroscopic binaries is also bimodal; but because only close binaries are included, she attributes the group at $\alpha \sim 0{\cdot}1$–$0{\cdot}2$ to systems originally part of the $\alpha \sim 1{\cdot}0$ group which have passed through a mass-exchange phase, leaving one star as a low-mass white dwarf. It is also possible to search for binaries in open clusters by looking for stars significantly above the main sequence. Two efforts[9,10] in this direction found only a single peak in $q(\alpha)$, at the smallest mass ratio, $M_2/M_1 \sim 0{\cdot}4$–$0{\cdot}5$, to which the method is sensitive. But there is more than one way to decide where the ZAMS is, and several different things can raise stars above it—evolution and rotation as well as a binary companion. Not surprisingly, other analyses of the same data[11,12] found them equally consistent with bimodal distributions of mass ratio, the second peak being near $\alpha = 1{\cdot}0$.

The largest sample of binaries analyzed for $q(\alpha)$, the spectroscopic systems in Batten's *Catalogue*[13] and two supplements thereto[14,15], also showed a bimodal distribution[16,17], small mass ratios being again somewhat correlated with large separations. The bimodality persisted in subsamples chosen by spectral class and luminosity and among both unevolved and evolved systems. The purpose of the present note is to bring this distribution up to date. New data incorporated comprise revised orbits and new systems in a third supplement to the *Catalogue*[18], new systems and orbits obtained from the Cambridge radial-velocity spectrometer[19], and new MK spectral types[20,21], which make possible improved determinations of primary mass and, therefore, of mass ratio, as well as improved division of systems by spectral type and evolutionary state. There are 74 new systems, 193 revised orbits, and about 400 new or revised spectral types.

Mass ratios were found in the same manner as before[16]. For double-lined systems, M_2/M_1 is just the ratio of the amplitudes of the two velocity curves. For single-lined systems, M_1 is taken from a calibration of mass versus two-dimensional spectral type, and M_2 calculated from the observed mass function, using the known values of $\sin^3 i$ for eclipsing systems, or the average value (0·68) appropriate to a population of orbits which is randomly distributed in space, but for which discovery probability is proportional to velocity amplitude.

Fig. 1 illustrates the results of this operation. The points, plotted at intervals of 0·01 in $\alpha = M_2/M_1$, are running means. That is, for each point, q represents the fraction of all systems ($N = 900$) having M_2/M_1 within $\pm 0{\cdot}05$ of α. This prevents the problem normally encountered in histograms that choosing large bins may conceal structure in a distribution, while choosing small ones ruins the statistics. There are clearly two peaks, near $\alpha = 0{\cdot}3$ and 1·0, and a sharp minimum near $\alpha = 0{\cdot}7$. The sharp cut-off on the right-hand edge of the Figure reflects the relative rarity of systems in which the less luminous star is the more massive. The few binaries for which this seems to be the case have already been over-discussed[22]. The cut-off on the left reflects partly the real absence of systems with negative mass ratio, and partly strong observational selection effects against the discovery of pairs with small mass ratio, velocity amplitude being roughly proportional to α for small α.

© The Observatory • Provided by the NASA Astrophysics Data System

1978Obs....98..163T

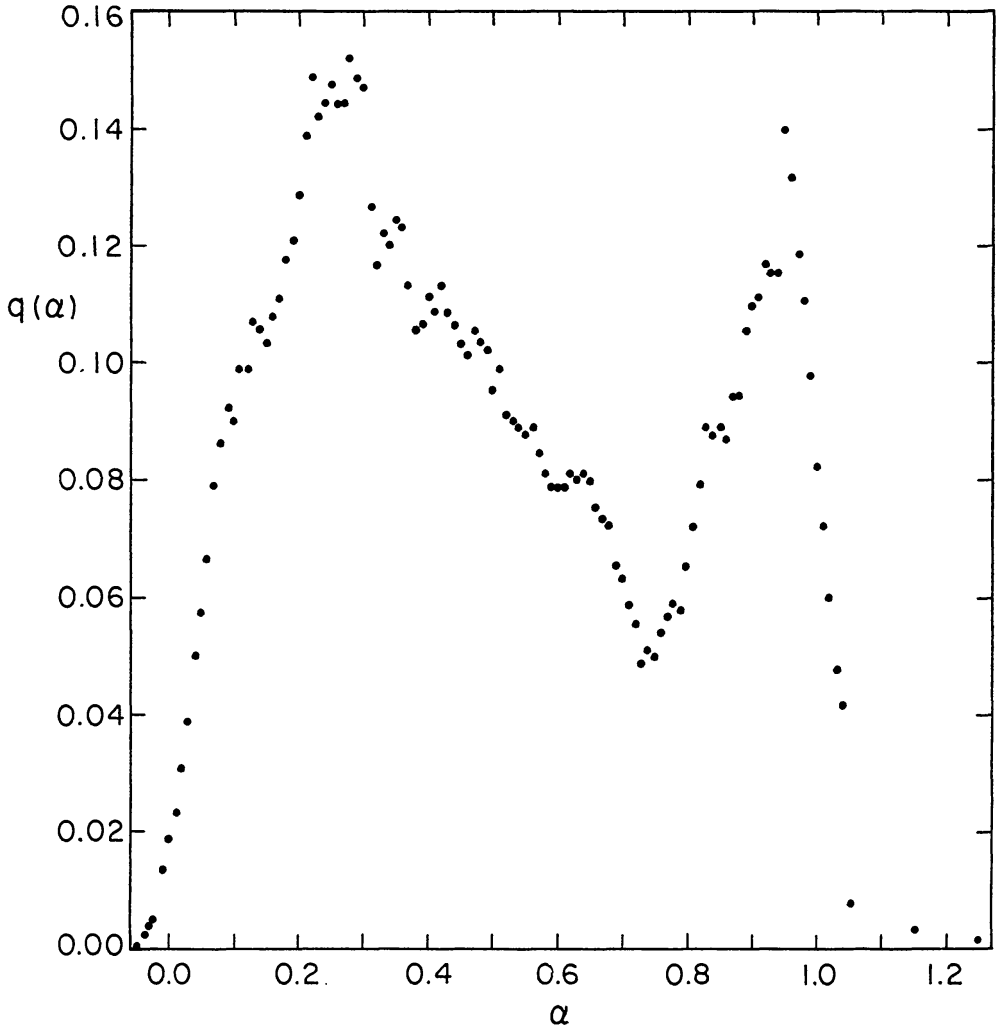

FIG. 1

Distribution of mass ratio, $\alpha = M_2/M_1$, for 900 spectroscopic binaries with published orbits. Points are running means, that is, each value of q is the fraction of all systems with mass ratio within $\pm 0{\cdot}05$ of its value of α. The cut-off at small values of α can be attributed largely to observational selection, as the radial velocity amplitude, and therefore discovery probability, is roughly proportional to α for small α. The cut-off above $\alpha = 1{\cdot}0$ indicates that very few systems have the less luminous star the more massive. The most important feature of this distribution function is its bimodality, which persists in all reasonable subsamples, and apparently indicates that binaries can be formed by more than one physical process.

All the subsamples I have been able to think of—first and last half of the data by HD number, single versus double-lined systems; known versus assumed $\sin^3 i$; or groupings by temperature, luminosity, mass or evolutionary state implied by the spectra—also show two peaks. The low-α peak is relatively most prominent and occurs at the smallest value of α for the bluest and most massive systems; the $\alpha = 1{\cdot}0$ peak is most prominent in double-lined systems; and a larger fraction of evolved than unevolved systems have α less than the minimum near 0·7, consistent with Wolff's[8] result. Large αs tend to go with small separations.

© The Observatory • Provided by the NASA Astrophysics Data System

1978Obs....98..163T

There is nothing new in all this: it agrees quite precisely with the distribution function found the first time[16,17], implying that $q(\alpha)$ is rather stable to moderate changes in orbit parameters, sample size, and values chosen for M_1. This increases the probability that the double-peaked structure is a feature of the real world and not an artifact of the data-processing.

The obvious implication is that unevolved binaries constitute (at least) two populations, presumably formed in different ways, and that some of the differences between the populations persist through evolution by mass transfer. The correlation of small α with large $a \sin i$ means that the two formation processes act the way one would expect for fission of a single, rotating proto-star and for separate formation of the two components, followed by capture or the discovery that they are gravitationally bound.

Acknowledgements. My interest in binary-star astronomy is largely a result of interaction with participants in IAU Colloquium No. 6 (Copenhagen, 1969) on mass loss and evolution in close binaries. Dr J. P. Ostriker suggested, on theoretical grounds, looking for correlations of $q(\alpha)$ with system mass.

References

(1) G. P. Kuiper, *P.A.S.P.*, **47**, 38, 1935.
(2) A. H. Batten, *Binary and Multiple Systems of Stars* (Pergamon, Oxford), 1973.
(3) A. Blaauw & T. S. van Albada, *The Determination of Radial Velocities and Their Application* (IAU Symp. no. 30) (Academic Press, New York), 1967, p. 215.
(4) A. Blaauw & T. S. van Albada, unpublished.
(5) A. Beer, *Vistas in Astronomy*, **2**, 1387, 1956.
(6) H. A. Abt & S. G. Levy, *Ap. J. Suppl.*, **30**, 273, 1976.
(7) H. A. Abt & S. G. Levy, *Ap. J. Suppl.*, **36**, 241, 1978.
(8) S. C. Wolff, Ap. J. **222**, 556, 1978.
(9) C. L. Bettis, *P.A.S.P.*, **87**, 707, 1975.
(10) C. Jaschek, *A. & A.*, **50**, 185, 1976.
(11) J. P. Dabrowski & W. R. Beardsley, *P.A.S.P.*, **89**, 225, 1977.
(12) V. L. Trimble & J. P. Ostriker, *A. & A.*, **63**, 433, 1978.
(13) A. H. Batten, *P.D.A.O.*, **13**, 119, 1967.
(14) A. Pédoussaut & N. Ginestet, *A. & A. Suppl.*, **4**, 253, 1971.
(15) A. Pédoussaut & J. M. Carquilat, *A. & A. Suppl.*, **10**, 105, 1973.
(16) V. Trimble, *A.J.*, **79**, 967, 1974.
(17) V. Trimble & C. Cheung, *Structure and Evolution of Close Binaries*, IAU Symp. no. 74 (D. Reidel, Dordrecht), 1976, p. 369.
(18) A. Pédoussaut & R. Nadal, *A. & A. Suppl.*, **27**, 55, 1977.
(19) G. A. Radford & R. F. Griffin, *The Observatory*, **97**, 235, 1977, and 16 previous papers.
(20) P. M. Kennedy & W. Buscombe, *MK Spectral Classifications* (Northwestern University, Evanston), 1974.
(21) W. Buscombe, *MK Spectral Classifications* (Northwestern University, Evanston), 1977.
(22) V. Trimble & K. S. Thorne, *Ap. J.*, **156**, 1013, 1969.

PHOTOELECTRIC PHOTOMETRY OF BRIGHT SOUTHERN GALAXIES

By M. R. Green and K. L. Dixon
Department of Astrophysics, Oxford

In this paper we present the results of photoelectric photometry, using circular apertures, of 17 bright southern galaxies. As in two previous papers[1,2]

© The Observatory • Provided by the NASA Astrophysics Data System