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THE STATISTICAL EFFECT OF ENCOUNTERS ON WIDE BINARIES

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RESUMEN

Resultados previos de Ambartsumian y de Cruz-González se combinan en una ecuación de Fokker-Planck que describe la evolución en el tiempo de la distribución de las dimensiones orbitales de un conjunto de binarias abiertas, cuando encuentros con estrellas de paso cambian estadísticamente las órbitas. Se encuentra una solución que predice la distribución de separaciones mayores que aproximadamente 3000 UA.

ABSTRACT

Previous treatments by Ambartsumian and by Cruz-González are combined into a Fokker-Planck equation that describes the time evolution of the distribution of orbit sizes of a set of wide binaries, as encounters with field stars statistically change the orbits. A solution can be found that predicts the distribution of separations greater than about 3000 AU.

The effect of stellar encounters on the components of a binary star was first considered by Ambartsumian (1937), who correctly recognized that the dominant encounters are not distant tidal ones but rather encounters in which the passing star comes much closer to one component of the binary than to the other. An independent study by Chandrasekhar (1944) was based on the tidal approach and therefore does not seem to be a valid treatment. Still another study was made by Cruz-González (1965), who used the same basic approach as Ambartsumian but treated the statistics of the encounters in a quite different way. Whereas Ambartsumian had followed the *systematic* energy change up to the eventual dissolution of the pair, Cruz-González considered the random walk in energy instead. Each of them arrived at a similar formula for the dissolution time, even though their statistical points of view were so different.

The apparent disagreement between these two authors is easily explained: each treatment is correct, but each tells only a part of the complete story. A fuller treatment can be developed, in which these two contributions become the friction and diffusion terms of a Fokker-Planck equation that describes the evolution of the distribution function of orbital energies. (An examination of the detailed circumstances shows that the many-small-increments assumption of the Fokker-Planck equation is reasonably well satisfied.) The equation has a very simple form, because the low orbital velocity in a wide binary allows an approximation that makes the encounter integrals independent of the orbital energy.

This Fokker-Planck equation has two equilibrium (i.e., time-independent) solutions, but neither is astronomically acceptable. What is needed instead is a time-dependent solution, in which encounters gradually erode the initial distribution of orbit sizes. The orbit distribution of closer binaries remains virtually unchanged, but the distribution of separations of wide binaries is determined completely by the statistical effect of encounters. The proper mathematical treatment is a similarity solution of the Fokker-Planck equation. Fitting of this solution to the orbit distribution of close pairs then gives a prediction of the distribution of separations of wider binaries —roughly speaking, those with $a > 3000$ AU.

(*Note*: As presented at the Colloquium, this study was incomplete, and the paper did not then refer to a satisfactory solution of the problem. Work has progressed since that time, however, and a full paper will be submitted to a future issue of the *Rev. Mex. Astron. Astrof.* It is a pleasure to record that this project was begun when the author was a guest at the Instituto de Astronomía, Universidad Nacional Autónoma de México. Further support has come from NSF Grant MPS73-04674).

REFERENCES

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DISCUSSION

Hénon: In principle one should be able to derive directly from your last equation the fact that the distribution function *f* is practically invariant for small *a*. Is this actually possible?

King: If we think of the change of the energy distribution as a process of biased diffusion, then we can say that the diffusion coefficient is independent of E. This means that if a binary has a large $|E|$, its diffusion to zero energy takes proportionally longer; in terms of *a*, the time goes as $1/a$.

Huang: You have mentioned that Professor Chandrasekhar made a physical error. I wonder whether you could kindly enlighten me on this point. I ask this question because Chandrasekhar wrote his paper in 1944 after Ambartsumian's work. Being a very careful investigator, Chandrasekhar must have examined Abartsumian's paper thoroughly before he undertook his own study. So I have the feeling that Chandrasekhar could not make the error, where Ambartsumian before him was right.

King: This surprised me very much too. An essential point in Ambartsumian's analysis was to recognize that distant encounters, whose effect is only tidal, are relatively unimportant and that the important effect comes from encounters in which the field star comes much closer to one component of the binary than to the other. (This point is elaborated upon in my written manuscript). I believe that he also did not combine the effects of successive encounters correctly. To look at the effect of tidal passages myself, I used Spitzer's theory of tidal shocks on a galactic cluster and verified that tidal passages have a total effect much less than that of close encounters.

Abt: If you put in typical distances for visual binaries, say 20-50 parsecs, you predict that there should be few binaries with separations greater than several minutes of arc. Have you looked at the literature to see if many such systems exist?

King: I have not looked myself, but one of my reasons for presenting this subject at this meeting is to stimulate double-star observers to investigate such questions more carefully. As I undestand it, selection effects in the existing data are very serious.

Napier: Might disruption by galactic tidal forces be important at more than 10^4 AU?

King: One can answer this quantitatively by noting that for a star cluster to be stable against galactic tidal forces, the limiting density is of the order of 0.1 solar mass per cubic parsec. For a binary this would correspond to a separation of more than a parsec; so I do not think that galactic tidal forces matter.

Poveda: Can you make a guess as to whether your formula will give longer dissolution time than Arbartsumian's? The persistence of the comet cloud suggests longer time.

King: One should not think of the "dissolution time" as a sharp cutoff. It is rather a characteristic time for strong changes in the distribution. My theory has a time scale that is the same as Ambartsumian's; therefore I would conclude that the outer parts of the comet cloud have been quite severely depleted since the time of their origin.

Dommanget: In spite of probable selection effects in the distribution curve of log *a*, did you compare your results with the observed curve found by W. J. Luyten on the basis of visible (common proper motion) pairs?

King: I am embarrassed that I did not make it clear that I do not have quantitative results to compare with *any* curve. But a good reliable observed distribution might serve as a guide to the theory.

Poveda: A very nice illustration of the effect of dissolution on binary stars is shown in work I have done with C. Allen. We found that the proportion of H emission among binaries in the solar vicinity is larger when the separation is larger, showing that wide binaries, on the average, are young (because the old ones have dissolved).

King: This is extremely interesting and would appear to be a good confirmation.