LETTERS TO THE EDITOR

ASTROPHYSICS

Possibility of an Accelerated Process of Collapse of Stars in a Very Dense Centre of a Cluster or a Galaxy

THE recent discoveries of extremely luminous and very distant objects, indicating a collapse of vast masses of dimensions of galaxies, suggested to one of the authors a re-examination of the problem of collisions in a multiple star system. The recently accumulating evidence of the association of the novæ phenomena with binary or multiple star systems also revived this question. Some of the ideas were then discussed with G. and M. Burbidge.

According to G. Burbidge, the possibility is not to be excluded that the density of stars in the centre regions of certain galaxies may attain the value of 10^7 and 10^8 per cubic parsec. Assume then the assemblage of such stars to be in conditions satisfying the virial theorem. The question arises whether after some collisions between a few stars the process of encounters may become accelerated; more and more collisions will occur increasingly fast so that a large proportion of the stars in the central region of such a condensation will coagulate and, so to say, the 'gas' of stars will, as it were, change phase and become something of a 'liquid' of these objects.

Very crude, purely dimensional estimates would give for the times involved and the energies liberated by collisions between stars the following figures:

Assume a galaxy with $\sim 10^{11}$ stars, and a central region of the dimension of a cubic parsec with 10^8 stars.

In this region the average distance between nearest neighbours is then $d \cong 5 \times 10^{15}$ cm.

We take a total mass of the galaxy as $\cong 10^{44}$ g.

The mass M of the central region is $M \cong 10^{41}$ g.

At a distance of ~ 1 light year from the centre the orbital velocities of the stars may have an average value of $\bar{v} \cong 2 \times 10^8$ cm/sec.

If a collision between the stars is central, the loss of a large fraction of kinetic energy will liberate an amount of energy in a different form of the order of $\varepsilon = 2 \times 10^{49}$ ergs per star.

The collisions between most of the 10^8 stars would yield $E \cong 10^{57}$ ergs.

If the process of collisions should become accelerated, as suggested here, the time T for the eventually complete collapse of the central region would be of the order of:

$$T \cong \frac{2 \times 10^{18} \text{ cm}}{2 \times 10^8 \text{ cm/sec}} = 10^{10} \text{ sec} \cong 300 \text{ years}$$

The energy production due to conversion of kinetic energy would be then at a rate of $\frac{10^{57} \text{ ergs}}{10^{10} \text{ sec}} \cong 10^{47}$ ergs/sec.

Thus we see that the total energy obtained from the kinetic energy of the motions of stars would be of the order 10^{57} ergs in a period of, say, 300 years.

It is also conceivable that in certain multiple star systems consisting, say, of two massive stars in a binary system, plus a third smaller body or plus several smaller stars, there would be periodic collisions of the smaller masses with one or the other of the binary systems, giving rise to flare-ups or large explosions producing a nova-like behaviour.

In order to begin testing quantitatively such a possibility, we have considered a number of problems which were studied numerically on computing machines. These problems involved four or five stars, initially in quasi-stable configuration, illustrating the virial theorem, and we followed by computation the development of such systems. A typical problem was to take, say, four stars of approximately equal masses, consisting of two rather close pairs, and revolving around each other with the distance between the pairs taken to be four to six times larger than the distance between members of each pair. The size of each star was taken as 1/20th to 1/50th of the distance between the close pair. The motion of such a system was followed on the computing machine with a view to observe whether, after some two of the multiple star systems have collapsed, the next collapse will occur rather sooner afterwards. One might perhaps suspect that this could be the case, on general grounds, since, if one considers such a system as a 'gas', the inelastic collision between two stars (which, in order to make the calculations practicable, we assume to lead to a single object of double mass moving so that the momentum is conserved) will lead to a 'cooling' of this system and shrinking of a part of it. Also, since the total energy after loss of some kinetic energy (which is assumed to be transformed into internal energy of the composite stars or dissipated in form of radiation or ejection) will become more negative, further collisions may seem more likely.

In most of our cases, examined numerically on the computer, this was indeed the case—after a first collision, the next collision occurred in a shorter interval of time and the fourth star then proceeded to go out farther, forming with a triple star mass a larger double star system. In subsequent problems we have considered five stars and then eight stars, and a similar behaviour was observed. Most of the problems were studied in the plane. A few truly three-dimensional initial conditions were considered, mostly in the following form: a set of two binaries, each performing Keplerian motions as a binary in the same plane, were superimposed on a motion of the two binary systems around each other in a plane perpendicular to the plane of the motions of each binary. This was, of course, only the initial condition. After periods of several revolutions, the motion became complicated in three dimensions—it seemed that in this non-plane case, also, the process of further collapse became accelerated. We plan to perform many more calculations of this sort, with somewhat more realistic initial conditions, to try to strengthen the evidence for the statistical likelihood of such an accelerated process of collapse. The calculations were performed in intervals of what would be one part in several hundred of a single full period of revolution between two close stars. The numerical work used the Runge–Kutta method and the usual checks of energy and momentum were satisfactorily observed. These quantities were preserved, after periods of dozens or more of full revolutions, to better than 1 per cent.

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The Sun's Electrical Charge

IN a recent communication to *Nature*[1] I have shown that the interplanetary magnetic fields measured by means of the space probes *Pioneer* 5, *Explorer* 10, *Mariner* 2 and *Explorer* 12 all verify the predictions about these fields which were published in 1960[2,3] as tests of the hypothesis that the Sun carries a large net negative electric charge.