BLACK-HOLE REMNANTS IN GLOBULAR CLUSTERS

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Many presentations at this meeting have discussed the phenomenon of "core collapse", and it seems agreed that a stellar system like a globular cluster will, within a few half-mass relaxation times, undergo a runaway increase in central density and achieve a nearly singular density distribution with a logarithmic gradient slightly steeper than -2. The collapse is halted by the formation of binaries when the core has shrunk to contain only a small number of stars, and the system subsequently expands gradually while maintaining a density profile approximating that of a singular isothermal sphere. Light profiles resembling the predicted nearly singular form have been found in a small number of globular clusters (Djorgovski, this meeting), but a puzzle remains in that many more clusters should have undergone core collapse, yet they show quite flat light profiles in their cores.

A plausible resolution of this discrepancy would be to assume that the cores of globular clusters contain remnants more massive than the visible stars; these remnants could then have the predicted nearly singular density distribution, while the lighter visible stars would have a flatter density profile because of approximate equipartition of energy. In this case the observed core properties of globular clusters would be determined by the properties of the central subcluster of heavy remnants. In order to see whether such a model can successfully explain the core structure of globular clusters, and to estimate what kind of population of heavy remnants would be required, some very simple two-component models of globular cluster cores have been calculated, and the predicted surface density profiles of the lighter objects have been compared with the observed light profiles of a number of well-studied globular clusters.

The heavy objects are assumed to form a collapsed core with a singular density distribution, and both heavy and light objects are assumed to have velocity dispersions that vary with radius according to $v^2 \propto r^{-n}$. Various numerical simulations of pre-collapse evolution have suggested values for the exponent n in the range $\sim 0.2 - 0.5$, while a singular isothermal sphere would have $n = 0$. By adjusting the assumed

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mass ratio, it is possible to fit the observed light profiles of typical globular cluster cores with any value of n between 0 and 0.5; therefore it has been attempted to constrain the parameter n better by using the available information on velocity dispersions in globular clusters. A value for n of 0.5 has been found to allow a good fit to all of the available data.

With models of this type, the core light profiles of typical globular clusters are well reproduced if the assumed mass of the heavy remnants is about 3 times the mass of the visible stars, or about 2.5 $M_\odot$. Thus the heavy remnants are probably mostly black holes, although neutron stars and binaries will contribute. The anomalous cusped light profile of M15 can be fitted closely with a heavy-remnant mass that is somewhat smaller, about 1.7 $M_\odot$. The fraction of the cluster mass that is required to be in heavy remnants varies from about 1 to 5 percent, and is typically about 3 percent. There is some evidence that this fraction correlates inversely with the slope of the main-sequence luminosity function, as would be expected if these differences reflect differences in the initial mass function.

It is not implausible that 3 percent of the mass of a typical globular cluster would be in the form of remnants whose representative mass is $\sim$ 2.5 $M_\odot$. In the absence of any firm knowledge about the final evolution of massive stars it is not possible to say exactly what initial population of massive stars this corresponds to, but if it is assumed that the initial mass function is like that of the solar neighborhood, then a remnant population with the required properties would be produced if stars leave remnants whose mass is either 0.6 $M_\odot$ or 15 percent of the initial stellar mass, whichever is larger. These assumptions would also imply a large mass spread for the remnants, in which case the two most massive ones would almost certainly form a dominant central binary of two black holes.

The best evidence for, or constraints on, a central subcluster of heavy remnants will probably come from accurate measurements of velocity dispersions near the centers of globular clusters. Some of the data presented at this meeting show unexpectedly high velocity dispersions in the cores of 47 Tuc and ω Cen, apparently indicative of a substantial amount of unseen mass. Deviations from a gaussian distribution of velocities may also be an important indicator of core structure. Gunn and Griffin found two stars with anomalously high velocities in the core of M3; such high-velocity stars are in fact predicted by models of the type discussed here, since a few stars whose orbits pass close to the center will gain unusually high velocities by interaction with the heavy remnants. Thus the presence of such stars may be a sensitive test for the presence of a condensed core of heavy remnants.

A more complete account of this work is to be published in Monthly Notices of the Royal Astronomical Society.