Galactic evolution

Do globular clusters belong?

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Do the globular star clusters really belong to the galaxies they now inhabit, in the sense of having formed in and with them? Yes, according to some of the results presented at a recent symposium*, and no, according to others. The issue arises because these clusters are a bit like dinosaur teeth — small hard things that could have survived a long time under harsh conditions. Thus, they might, alternatively, have formed separately before their host galaxies or as part of other systems that amalgamated to make those galaxies. The issue is important because the globular clusters, unlike dinosaur teeth, are not just very old, but are actually the oldest subjects in the Universe available for study at close range. They ought, therefore, to tell us something of when and how galaxies and stars began.

Globular clusters have so far been seen in about 40 galaxies (spirals, ellipticals and irregulars) and studied closely in half a dozen. The 125-or-so clusters known in our own Milky Way contain, for instance, about 1 per cent of the stars of the spherical halo. Evidently, indicators are needed to show whether the clusters resemble the stars around them more than they resemble each other, and whether their properties (individually or as populations) are correlated with those of their host galaxies. Resemblance and correlation would suggest formation *in situ*, and the opposite would suggest a more complex process.

The evidence, unfortunately, is contradictory and rather evenly balanced. Starting with our own Galaxy, the globular clusters (according to R. Zinn, Yale University) do generally resemble the other halo stars in their distribution of numbers as a function of radius, in their average heavy-element abundance and its gradient with galactocentric distance, and in their dynamical properties (net rotation, velocity dispersions in three dimensions and average orbital eccentricity). Differences exist, however, in the periods of variable stars as a function of their composition (G. Wallerstein, University of Washington) and in the metallicity distribution, in the sense that the field stars have a larger representation at very high and very low values than do the clusters (J.B. Laird, University of North Carolina).

Other indicators that the clusters 'belong' to their hosts are: the likelihood that galaxies more massive than the Milky Way, including M31, NGC5128 and M87, have redder, more metal-rich clusters (F. Fusi Pecci, University of Bologna; H.C. Harris, US Naval Observatory; J. Huchra, Center for Astrophysics, Cambridge, Massachusetts), though the high value for M87 was disputed by J. Nemec (University of British Columbia); the two-standard-deviation result that central (massive, cD) galaxies in clusters have more than their fair share of globulars (W.E. Harris, McMaster University); and the undisputed fact that gas-rich galaxies, including M33 and the Magellanic Clouds, unlike the Milky Way and similar spirals, are still producing massive clusters (though not quite such massive ones as the true, old globulars; E. Olszewski, Steward Observatory; C. Christian, Canada–France–Hawaii Telescope).

In contrast, several other observations suggest that the clusters did not originate with the galaxies they now inhabit. First, the number of clusters at a given luminosity, the function $N(L)$, seems to be much the same, a gaussian with the same width and a peak at $M_v = -7.4$, in nearly all galaxies examined; at any rate, the assumption that this is so leads to a consistent distance scale out at least as far as the Coma cluster (D.A. Hanes and D.G. Whittaker Queen's University, Ontario; L.A. Thompson and F. Valdes, Institute for Astronomy, Hawaii). Second, the clusters in M31 (Fusi Pecci) and M87 (Huchra) do not show the kind of gradient of abundance from centre to periphery seen in the Milky Way. Both items suggest that the clusters did not know where they were going to end up when they formed.

Finally, and most striking, the clusters in some galaxies differ from the non-cluster stars at the same radial position in a number of related ways. The cluster populations are less centrally condensed than the underlying star light, scaling as $r^{-2.5}$ rather than as r^{-3} in M87, M49 and other large elliptical galaxies[1], where r is the distance from the centre of the galaxy concerned. They are more spherically distributed around the galactic centre than the background stars in disk galaxies including NGC3115, 4594 (the Sombrero) and 7814 (Harris). They are bluer than the star light at the same positions both in M87 (J. Cohen, Caltech, confirming earlier work[2]) and in several dwarf ellipticals[3]. And they display a larger velocity dispersion than the other stars at the same radius in NGC5128[4] and M87[5]. The net impression is that the clusters constitute an older, more primitive population, the bluer colours resulting from lower metal abundancies; and the greater extension, sphericity and velocity dispersion representing a lesser degree of collapse and dissipation.

This could mean that the clusters are pregalactic and primordial[6,7], or that they formed as part of larger units that merged to make modern galaxies (R.B. Larson, Yale University). But it could also mean that the globulars formed *in situ* as galactic halos collapsed, their population statistics having been gradually modified as the most vulnerable clusters were torn apart tidally during close approaches to the galactic centres (J.P. Ostriker, Princeton University; M.J. Rees, Institute of Astronomy, Cambridge; D. Chernoff, Cornell University). Tidal disruption would systematically remove central clusters (hence the shallower density profile) and ones on eccentric orbits. The remaining circular orbits then give the impression of increased velocity dispersion at any given off-centre point. To account for the colour difference, the metal-rich clusters must also have been systematically removed, which is also plausible, at least in galaxies with radial abundance gradients. Apparently, then, all the scenarios can still accomodate all the data and no-one suggested unambiguous clues that might be sought in the near future. □

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1. Harris, W.E. *Astr. J.* **91,** 822 (1986).
2. Strom, S.E. *et al. Astrophys. J.* **245,** 476 (1981).
3. Harris, W.E. *Publ. Astr. Soc. Pac.* **95,** 21 (1983).
4. Hesser, J.E. *et al. Astrophys. J.* **303,** L51 (1986).
5. Mould, J., Oke, J.B. & Nemec, J.M. (in the press).
6. Peebles, P.J.E. & Dicke, R.H. *Astrophys. J.* **154,** 891 (1983).
7. Doroshkevich, A.G., Zeldovich, Ya.B. & Novikov, I.D. *Sov AJ* **11,** 233 (1967).

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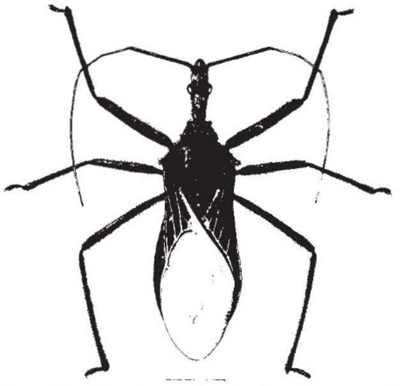
Two new species of the genus *Pristhesancus* are described by M. B. Malipatil in a recent issue of the *Australian Journal of Zoology* (34, 601–610; 1986). The illustration shows a male specimen of *Pristhesancus nigritus*, dorsal view. The scale bar represents 3.2 mm. This bug,



found in Northern Australia, is generally black with two pale distal antennal segments. Like other members of the order Heteroptera, this specimen has two pairs of wings and mouthparts modified for piercing and sucking. Many heteropterous insects are vectors of plant and animal diseases. □