Stellar astronomy

The chicken came first

Virginia Trimble

THE hot interiors of massive stars produce most of the elements heavier than hydrogen and helium (metals to astronomers) that we see around us. Conversely, a star's initial small supply (0.01–4 per cent) of heavy elements is a major determinant of its observable properties and evolutionary history. Thus arises a standard sort of 'which came first' problem that now seems to have been answered.

For an aggregate of stars, the single most important property is the initial mass function (IMF), the number of stars formed per unit time as a function of mass from 0.1 to 100 or so times that of our Sun. Knowing the IMF in a group of stars enables us to predict its luminosity, colour, mass-to-light ratio, and the rates of change of these observables and of its chemical composition. Thus, for stellar populations, the chicken-and-egg question can be phrased as, which came first, a particular initial abundance of heavy elements or a particular IMF?

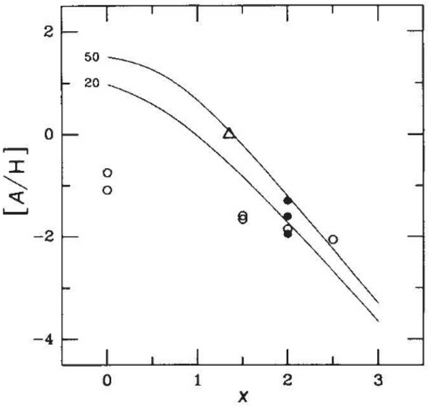
Two Canadian astronomers, Graeme H. Smith and Robert D. McClure of Dominion Astrophysical Observatory, may have answered that question, at least for the stars in the globular clusters of our own Galaxy (*Astrophys. J.* **316**, 206–212; 1987). The IMF came first and determined the metal abundances of the clusters through a process called self-enrichment. Self-enrichment means simply the idea that the most massive (and so shortest-lived) stars in a cluster can complete their evolution and eject their metallic products quickly enough to pollute gas that is still forming the lower-mass stars that live long enough for us to see them today.

The evidence is this: most globular clusters are quite homogeneous. Thus each can be characterized by a single number representing its fractional metal content or metallicity and another number, x, the slope of the IMF, written in the form

$$N(M)\,\mathrm{d}M = N_0\,M^{-x}\,\mathrm{d}M$$

Earlier work by McClure *et al.* (*Astrophys. J.* **307**, L49; 1986) had shown a correlation between metallicity and slope, in the direction of metal-rich clusters having smaller values of x (flatter IMFs), meaning a larger ratio of high-mass to low-mass stars. This could have meant several things. Metal-rich gas might have formed clusters with more big stars (though a best guess at formation mechanisms suggests a correlation in the opposite direction). Or, the most metal-rich clusters might have undergone the most dynamical evolution and so have preferentially lost their low-mass stars through tidal effects (there is perhaps some evidence for this). Or, self-enrichment might have occurred, so that the clusters that began with the largest proportion of massive stars ended up with the most metals in their long-lived, low-mass stars.

Smith and McClure have now gone back and looked at the same clusters again, attempting to estimate how much metal production could be attributed to the numbers of massive stars implied by each of the IMF slopes. Their conclusion is that, for the steepest IMFs and lowest current metallicities, self-enrichment comes out just right. For the flatter IMFs there is an embarrassment of riches, and some of the metals expected from the massive stars must actually have been lost to the clusters. This is not a surprise. When many supernovae explode close together, they will set up winds that can easily expel gas from the shallow gravitational potentials of globular clusters before all the product metals can be incorporated into low-mass stars.



A comparison of the observed and calculated metallicity (A/H) as a function of x, the slope of the initial mass function IMF. The calculations use stellar masses in the ranges of 0.1–20 and 0.1–50 solar masses. The observations were by R. D. McClure *et al.* ○ and R. Lupton, J. E. Gunn and R. F. Griffin ●. △ represents the solar neighbourhood parameters, x=1.35 and (A/H)=0. (From Smith, G. & McClure, R. D. *Astrophys. J.* **316,** 206–212; 1987.)

If the IMF determines metallicity in globular clusters, then we have to ask what determines the IMF. Smith and McClure suggest that it is the average initial density of the gas that forms a cluster (low densities yielding steep IMFs). The degree of turbulence or rotation could also be important; few globular clusters today show evidence of rotation, but they are mostly metal-rich ones.

It should be possible to extend Smith and McClure's argument by asking whether the same correlation and probable mechanism applies to the nearby dwarf elliptical galaxies. Because these are further away than the globular clusters, it will be difficult, but perhaps not impossible, to measure the slope of the IMF by counting individual stars. The average metallicities are already reasonably well known. For larger galaxies, there is no doubt that the present metal content reflects many generations of self-enrichment. And so, if metallicity is not the primary determiner of IMF, Smith and McClure's work predicts that the two should not be correlated in younger star clusters in our own and other galaxies. ☐

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Protein toxins

Closing in on ricin action

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RICIN, a toxic plant protein, is widely used to arm monoclonal antibodies for targeted cell killing (immunotoxins). Despite this extensive use, the mechanism of its action at the molecular level has long remained obscure. Now, work by Endo, Tsurugi and co-workers demonstrates that the A-chain of ricin is a highly specific *N*-glycosidase that removes a single adenine residue from ribosomal RNA. Another striking new observation is that cytotoxins made by bacteria involved in enteric and renal diseases are functionally and structurally related to ricin.

The general mechanism of ricin intoxication has been known since the 1970s (see ref. 1 for review). The toxin consists of two disulphide-linked polypeptides termed A and B. The B-chain binds to galactose-containing structures at the cell surface and facilitates entry of the A-chain into the cytosol, where it inactivates the 60S ribosomal subunits, causing disruption of protein synthesis and cell death. It was soon discovered that the toxin inactivates the 60S ribosomal subunits catalytically and that no cofactor is required, leading to the suspicion that ricin has endonuclease activity, like two other ribosome-inactivating proteins, colicin E3 and the fungal toxin α-sarcin. But despite many attempts, nucleolytic activity of