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Another theoretical challenge was the elucidation of a new effect which could change the previous estimates for proton decay if monopoles were abundant. It has been known since the last century that the relative angular momentum of an electric and a magnetic charge has a term equal to the product of their charge times the unit vector pointing along the line joining them. If the projectile passes straight through the

target in a collision, then conservation of angular momentum means that the sign of electric charge must reverse in order to balance the reversal of the unit vector. This means the monopole must absorb two units of charge. In a theory including the strong interaction gauge group, baryon number could also be absorbed by the monopole, thereby catalysing proton decay to give a distinctive experimental signature. □

Recent (1981–82) evolution of galactic haloes

from Virginia Trimble

THE halo of our Galaxy is perhaps a bit older, a bit richer in heavy elements, a bit less massive and undoubtedly a bit more complicated than it was before the recent meeting* of the International Astronomical Union in Greece.

A typical spiral galaxy, whose most conspicuous component is a flat, rotating, armed disk, also has a halo of stars which includes the oldest stars in the galaxy, and which bears at least a passing resemblance to the other major class of galaxy, the ellipticals. Many halo stars are still gravitationally bound in globular clusters of 10^5 – 10^6 stars in which they formed. There is also a 'scattered field' star population, generally advertized as consisting of fugitives from the clusters.

Among the things we would like to know about the haloes of our own and other galaxies are (1) the ages of the oldest stars (because this sets a significant lower limit to the age of the Universe), (2) their chemical compositions and how they acquired their heavy elements (since, after all, stars formed out of virgin big bang material should be pure hydrogen and helium, and we see no stars like that), (3) whether the globular cluster and field stars are really part of a single population, (4) whether the dynamical structure of haloes is similar enough to that of elliptical galaxies to suggest a common origin (this would considerably simplify the difficult problem of making galaxies out of lumps in the early Universe) and (5) whether there is anything in the haloes besides the stars we see, and, if so, how much of what (because significant mass there will affect our estimate of the average density of the Universe and so its future evolution). New evidence bearing on these questions appeared at the meeting and in recently published papers.

How old are the stars? Rather older than is entirely convenient! The standard method of measuring the age of a star cluster is to compare the positions of the stars in a graph of brightness against surface temperature or colour (HR

diagram) with calculated versions of what those positions ought to be as a function of the age of the cluster stars (and, unfortunately, their chemical composition and other variables also). The integrated brightness and colour of a cluster can be used somewhat similarly. These methods have yielded values of 7 – 25×10^9 yr in the past. R. Cannon (Royal Observatory, Edinburgh) and B. Carney (University of North Carolina) reviewed eight more-or-less independent recent applications that concur on ages of 15 – 18×10^9 yr, at least for the metal-poor clusters. If stars this old are to be fit into a standard Friedmann model of the expanding Universe, then the Hubble constant, H_0 , must be less than about $65 \text{ km s}^{-1} \text{ Mpc}^{-1}$; and if H_0 is to be ≥ 50 , then the Universe must be a low-density (ever-expanding) one as well. According to Carney, the likely errors go in the direction of making these ages, if anything, underestimates. On a related topic, S. Faber (Lick Observatory) discussed evidence from UV photometry of elliptical galaxies indicating that star formation in them also stopped some billions of years ago (though not necessarily so many as 15).

What is the chemical composition of the halo stars? It varies. There has been agreement for some years that the more metal-poor of the globular clusters have

about 1 per cent of the solar heavy-element abundance. At the other end of the scale, there has been a continuing discrepancy between photometric studies, which found the most metal-rich clusters to come within a factor of three or so of solar abundance (like the oldest disk stars), and spectroscopic studies, which found much lower abundances. G. Gustafsson (University of Uppsala) drew attention to several sources of uncertainty in both methods, and reported spectroscopic work by M. Bessell (Mt Stromlo Observatory) that yields abundances close to the photometric (higher) values. If this is the right answer, then evidently chemical processing (birth and death of stars) continued in the halo until the remaining gas collapsed down into a disk and began forming stars there. This is rather easier to understand than a picture in which there is a large gap in composition between the youngest halo stars and the oldest disk ones.

Is there a single halo population? Apparently not. The field and globular cluster stars seem to have the same dynamical characteristics, ages and range of metal abundances, but there are detailed differences. R. Kraft (Lick Observatory) suggested that the field stars have, on average, smaller amounts of nitrogen, larger amounts of carbon and a narrower range of abundances of both than do cluster members. This implies either that the field stars are less highly evolved (less thoroughly mixed), meaning that they are younger or less rapidly rotating or something, or that the cluster members have been more thoroughly contaminated by heavy elements made in supernovae in the clusters themselves. Differences between field and cluster stars in the ratio of barium to iron¹ at least weakly support the first, evolutionary, sort of hypothesis. A difference between cluster and field stars in the maximum metal abundance to be found among RR Lyrae and type II Cepheid (pulsating variable) stars is not easily explained by either mechanism². Thus, if the field stars have merely escaped from the clusters, they have not done so at random.

Are elliptical galaxies and the spheroidal parts of spirals the same sort of thing? Again, apparently not. The general shape and ranges of compositions and ages are similar, but there are significant differences. Spiral bulges (the central part of the spheroidal component) have fewer globular clusters per unit luminosity than do ellipticals³. This could only be fit into a unified model if clusters were somehow torn apart by the process of disk formation, which seems unlikely. In addition, ellipticals typically show a steeper gradient of composition, from metal-rich at

A typical spiral galaxy contains two basic components: a flat, rotating armed disk and a spherical halo of stars which, at their most concentrated, form the central bulge of the disk.

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*The meeting was held in Patras, Greece on 16–26 August 1982.

the centre to metal-poor at the edges, than do spiral bulges⁴. This might just mean that chemical evolution operated longer or more efficiently in them. But, finally, well studied haloes show overall net rotation⁵, which is not found in most elliptical galaxies and could not very well have been introduced after galaxy formation was complete.

Finally, what, if anything, is in the haloes besides the stars we see? Probably, though not certainly, up to 90 per cent of the mass of the Universe. J. Ostriker (Princeton University) reviewed observational evidence of measured galactic masses that increase roughly linearly with the radius out to which the measurement is made, from the inner 10 kpc sampled by rotation curves, through the 20–100 kpc range sampled by orbits of globular clusters and satellite galaxies, out to the 1–3 Mpc sampled by dynamics of rich clusters (see ref. 6 for another recent summary).

The implication is that a typical large galaxy has associated with it about $10^{12} M_{\odot}$ (mass of the Sun) in some form, of which we can see only about 10 per cent in disk and halo stars. D. Schramm (University of Chicago) reviewed the arguments indicating that the invisible material is quite likely to be in the form of exotic particles such as non-zero-rest-mass neutrinos, photinos, or gravitinos. This evidence is largely negative — adequate amounts of ordinary matter could not have escaped detection, either directly or through their influence on big bang synthesis of helium and deuterium.

But two noteworthy arguments against extensive invisible mass, at least in some galaxies, surfaced at the meeting. First, J. Hunter (University of Florida; see also ref. 7) presented a rotation curve for the barred spiral NGC3992 showing $2 \times 10^{11} M_{\odot}$ within the inner 19.7 kpc (on the de Vaucouleurs 'short' distance scale) and velocities of satellite galaxies around 3,992 indicating at most $4 \times 10^{11} M_{\odot}$ within 59 kpc, so that $M(R)$ must increase much less steeply than linearly with R , and might stop increasing entirely beyond about 20 kpc. The most relevant response to this is that other galaxies with satellites do show rising $M(R)$, and that even H_I profiles (roughly, rotation curves) yield masses of order $10^{12} M_{\odot}$ for some galaxies, when the data extend out far enough, as witness the line widths near 800 km s⁻¹ for NGC5635 and IC4553 (ref.8).

Second, A. Kalnajs (Mt Stromlo Observatory) showed results of his calculations of the rotation curves

produced by various sorts of mass distributions. The result most impressive to his audience is that it is quite possible to get a flat rotation curve, in which velocity versus radius does not drop off at large radius, without invoking a massive, unseen halo component. The secret is a model in which halo and disk have the same constant ratio of mass to luminosity (3–7 in solar units for the galaxies he fit) out to the last measured point, where both end sharply, so that we cannot measure the rotation curve out where we would expect velocity to be dropping with increasing radius in a keplerian way. The four galaxies fit in this way have data extending out to 5, 8, 12 and 25 kpc from their centres; and the fits do

not much constrain what is going on outside that. The mass distributions may, indeed, end sharply as in the models or may continue out to 100 kpc or more without distorting the rotation curve near the centre. Which is right must be determined from data that probe further out, such as those from satellite galaxies, binary galaxies and rich clusters, invoked by Ostriker and others in support of massive haloes. Many participants nevertheless came away feeling that the evidence for massive haloes had largely disappeared. This is, perhaps, a natural over-reaction to having had the arguments in favour presented so vigorously at so many previous meetings! □

Human monoclonal antibodies

from Karol Sikora and A. Munro Neville

Now that the application of monoclonal antibodies to the diagnosis and treatment of human disease has become the major goal of many investigators, a limiting factor is the availability of human rather than mouse or rat monoclonals. Human monoclonal antibodies are particularly needed for administration to patients for diagnosis and therapy in order to minimize the problems of administration of a foreign animal protein, with the risks of anaphylaxis and the clinical manifestations of immune complex formation, as well as abrogation of the antibody's effects.

The short history of human monoclonal antibody production has been fraught with technical difficulties but several novel systems now hold out promise. Initial attempts used available mouse and rat myeloma lines for fusion^{1–3}. Unfortunately the resulting hybridomas preferentially lose human chromosomes, eventually eject the chromosomes coding for immunoglobulin production and thus lose the ability to produce monoclonal antibodies. Although early and repetitive cloning of the hybrids can reduce the shedding of human chromosomes, the development of more stable human-human hybridoma systems seems desirable.

Accordingly several groups have developed human systems from which hybridomas may be created. Unfortunately many human myelomas are difficult to grow in tissue culture and have low growth rates and poor immunoglobulin secretion. Nonetheless, certain lines have been 'adapted' to grow in culture in genetic selection conditions in which the growth of the myeloma is suppressed but the hybridomas continue to propagate. There have, however, been difficulties with mycoplasma infection in myeloma stocks. Indeed many investigators have been unable to obtain any hybridomas at all with

lines donated by certain laboratories, causing considerable controversy.

The use of several human myeloma or lymphoblastoid lines was discussed at a recent workshop in Cambridge held under the auspices of the Ludwig Institute for Cancer Research (LICR). The ideal properties of such a cell system include high fusion frequency, high cloning efficiency, the ability to grow rapidly in non-stringent serum conditions, no secretion of myeloma or lymphoid cell immunoglobulin, and yet the production of large amounts of immunoglobulin after fusion to suitable lymphocyte donors. M. O'Hare (LICR, London) described his experience with the cell line LICR-LON-HMy2 (ref.4) — a derivative of the human 'myeloma' ARH77 (ref.5). This lymphoblastoid line expressing Epstein-Barr virus (EBV) antigens appears to be the best available system. Reasonable fusion frequencies have been obtained from a variety of human lymphocytes but the immunoglobulin secretion rate is low at 0.2–8.0 $\mu\text{g ml}^{-1}$ in 24 h.

K. Sikora (LICR, Cambridge) reported that use of the same line. Intra-tumoral and regional node lymphocytes from the tumour-draining nodes of 180 patients resulted in the successful production of new immunoglobulin-producing hybrids in 24 cases⁶. When these were screened for antitumour antibody activity, weak binding was detected in only nine hybridoma supernatants. More success was achieved when fusing intra-tumoral lymphocytes from patients with malignant glioma, and three monoclonal antibodies to lung cancer were obtained by fusing lymphocytes from intra-thoracic lymph nodes removed at the time of surgical

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