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quencies of the γ rays should be characterized by a 'collective rotational frequency', and a more erratic behaviour ensues.

Indeed, the motion of individual nucleons is principally determined by the average field of all the others, and for rotations about a symmetry axis this field is also unchanged. Thus, in a sense, the nucleons are completely unaware of the rotation and, to some extent, it is meaningless even to speak of the system rotating. It is preferable to say that the total angular momentum of the nucleus is aligned along the symmetry axis.

At much higher angular momenta, fission of the nucleus must eventually occur. Breaking of the nucleus into two distinct fragments clearly corresponds to a prolate configuration. Prior to the fission, therefore, one can expect the matter distribution to reassume a collectively rotating prolate

shape (as in Fig. 1a) with a much increased deformation. Strong evidence for such a 'superdeformed' state in ^{152}Dy has been found in an earlier experiment performed at the Nuclear Structure Facility (Nyako, B.M. *et al. Phys. Rev. Lett.* **52**, 507; 1984).

Both of these experiments owe their success to a unique γ -ray spectrometer, TESSA2 (Twin, P.J. *et al. Nucl. Phys. A* **409**, 343; 1983). This was designed by members of Liverpool University to suppress much of the large γ -ray background produced by Compton scattering in the detectors. The enormous power of such a device has been recognized by many other groups and similar devices are currently under construction in Europe, North America and Scandinavia. $\square$

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Astrophysics

Unsmoothing the Universe

from Virginia Trimble

THE world around us is highly structured on many different scales. On some scales, we think we understand, or at least can reduce, the problem to basic physics: atoms and molecules follow from quantum electrodynamics, the masses of stars are determined by a balance between thermodynamic pressure and gravity. But the origin of the largest structures — galaxies and clusters of galaxies — remains a mystery, and a basic one, for they may be the oldest density fluctuation of all, without which the kinds of stars and planets we now see would have little chance of forming.

Several speakers at the most recent Texas Symposium on Relativistic Astrophysics* suggested ways galaxies might have formed. All sounded about equally plausible, and all required at least two somewhat special circumstances ("tooth-fairies" according to David Schramm, University of Chicago) to yield the observed degree of lumpiness on the right scales at the right time. This suggests that we may still lack the right underlying physics. There were also disputes on precisely what data need to be explained.

The points on which nearly everyone agrees are, first, that galaxies must form before a redshift of 3.5–4 in order for us to see quasars at that epoch. Second, if the universe has passed through an inflationary phase, the luminous matter must be more highly clustered than the dark matter making up most of the critical density. Third, the amplitude of the density fluctuations, $\delta\rho/\rho$, must by now have grown to unity, or larger, on the cluster and supercluster scales. And fourth, the amplitude of fluctuations (at least adiabatic ones) must have been less than a few parts in a thousand at

the time matter and radiation decoupled (redshift ~ 1000) in order not to produce anisotropies in the microwave background radiation larger than the current upper limits, $dT/T = 2 \times 10^{-5}$ over angular scales 1–4 arc min, according to a review by Bruce Partridge (Haverford College).

Some of the possible models and difficulties with them include:

(1) Strings are hypothetical thin tubes of false vacuum left over after a universal phase change to a real vacuum. They connect pairs of monopoles and bound domain walls. They can cross over themselves and reconnect, breaking off loops. Alexander Vilenkin (Tufts University; see also *Nature* **312**, 598; 1984) discussed how oscillating closed loops can act as condensation centres for galaxy formation. A virtue of the idea is that the reconnection process guarantees that lumps formed around loops will have non-random phasing; that is, that galaxies will be more highly clustered than matter as a whole. But the strings themselves contribute nothing to the local mass-density, so that we must still postulate some form of dark, non-baryonic matter that makes up most of the universe.

(2) 'Bias' is the idea that galaxies might form only at extreme points of the density distribution. This yields galaxies that are more clustered than the mass in general, even with a randomly-phased spectrum of primordial perturbations, because galaxy-sized lumps superimposed on larger-scale positive density fluctuations have the best chance of collapsing. An inflationary epoch automatically expands quantum fluctuations to give the requisite initial spectrum (equal power at each scale as it comes within the horizon) and though we cannot currently calculate the amplitude of the fluctuations, the microwave isotropy sets

an upper limit. But the need for some kind of weakly-interacting massive particle to make up most of the energy density constitutes a second tooth-fairy.

James Bardeen (University of Washington, Seattle) and Simon White (University of Arizona) presented biased models of this type. In Bardeen's model, with cold dark matter — axions, super-symmetric particles (see *Nature* **313**, 9; 1985), or other particles of ≥ 2 GeV — either isocurvature or adiabatic fluctuations, together with gravitational interactions, suffice to form galaxies with the observed distribution in the sky. But structures as large as Abell clusters could only have collapsed by the present time if they had much larger density contrasts over the background than observed. White's cold models behave similarly, while those dominated by particles of low mass (for example, neutrinos ≤ 100 eV) or intermediate mass (for example, gravitinos ~ 100 MeV) concentrated much of the matter into 10^{16} – 10^{17} Solar mass structures (larger than we see), and produce excessively high density contrasts on smaller scales, unless galaxy formation is strongly suppressed in high density regions — a sort of inverse bias.

(3) Other possible combinations were addressed by Keith Olive (Fermilab) and David Schramm: a universe dominated by cold massive particles that decay to lower-mass relativistic particles just after galaxy formation ends (so that density contrast stops growing), or a universe dominated by low-mass hot particles, but which only starts with small-scale isothermal perturbations. The former must be very finely tuned whereas the latter cannot be produced by inflation or any other known physical process, so again we need two tooth-fairies.

Perhaps the greatest surprise to most participants was a suggestion from Margaret Geller (Center for Astrophysics) that the supposed data these simulations are designed to match are not as secure as we had thought. She has re-examined details of the Shane-Wirtanen galaxy counts, a major source of published statistics which shows how the distribution of galaxies in the sky differs from randomness. It is based on plates that were taken under a wide range of observing conditions and counted by two different people over some period of time. Shane and Wirtanen attempted to compensate for the inevitable non-uniformities by forcing the closest possible matches in regions of plate overlap. One result is to push down the numbers in plates surrounding a bad one.

Geller finds that these and other problems in the original data not only create artificial features in the galaxy distribution but also hide real ones. For instance, a conspicuous filamentary feature traces down the edges of a group of plates counted by Wirtanen rather than Shane; a bad plate near the Coma cluster has suppressed nearby areas and makes the cluster look very isolated; and there is a shift between counts done on single plates and those done across plate

*The Twelfth Texas Symposium on Relativistic Astrophysics, 17–21 December 1984, Hebrew University, Jerusalem.

boundaries at just about the scale where one might have expected to see a real change in the slope of the correlation function. Thus only effects that have been seen in more than one survey should be taken seriously, such as the slope of the correlation function ($r^{-1.8}$), but not its precise amplitude, the length scale at which it turns over (if it does), or whether it goes negative at some large distance.

Clusters of galaxies are, themselves, even more strongly clustered than the galaxies, according to Neta Bahcall (STScI). Rich clusters are more clumped than poorer ones. That is, the amplitude of the rich-cluster correlation function exceeds that of the galaxy correlation function by a factor of about 30, at a scale length of 5Mpc; the amplitude for smaller clusters falls in between; and the slope of all three correlation functions is $r^{-1.8}$. Bahcall interprets this to mean that a large fraction of galaxies form outside clusters. But Schramm pointed out that, when the correlation functions are renormalized to scale length as a fraction of the average separation of the objects concerned (a technique adopted from condensed-matter physics), rich and poor clusters look the same, while the galaxies are more strongly clustered, reflecting the action of an extra factor, presumably gravity. If this is correct, then the galaxy correlation function should go negative at about 40 Mpc and that of the cluster at 400 Mpc. As Geller noted, some surveys show such a turn-over but others do not.

Finally, Bahcall remarked that clustering on still larger scales should reveal itself through large velocity deviations from smooth expansion. A hint of the predicted peculiar velocities has recently turned up at another meeting[†]. Marc Aaronson (University of Arizona) and Jeremy Mould (California Institute of Technology) have analysed redshift data for 10 nearby clusters, the distances of which have been determined from the correlation of infrared luminosity with 21 cm line width (the Tully-Fisher relation). Scatter in the derived value of the Hubble constant is minimized if the Local Group of galaxies has a velocity of 788 ± 188 km/s in the direction of galactic latitude $18^\circ \pm 13^\circ$ and longitude $255^\circ \pm 17^\circ$. This is in reasonable agreement with the 600 ± 30 km/s in about the same direction that seems to be our velocity relative to the 3 K microwave radiation. But, more to the point, it can be broken up into a vector sum of an infall of the Local Group toward the centre of our (Virgo) supercluster at about 300 km/s plus a somewhat larger motion of the supercluster towards the adjacent Hyades-Centaurus supercluster. The best-fit value of the Hubble constant from this analysis is about 90 km/s/Mpc, which presents its own problems. But that's another story. □

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[†]The 165th meeting of the American Astronomical Society, 14-16 January 1985, Tucson, Arizona.

Mutants without mutations

THE *Drosophila* embryo shown on the left is an example of a *Krüppel* mutant, the result of a mutation in the *Krüppel* gene. This embryo is short relative to the normal embryo shown in the middle, because it lacks all thoracic and several abdominal segments, so that the head is directly connected to one of the more posterior abdominal segments. The embryo on the right, which resembles the *Krüppel* mutant, in fact has normal *Krüppel* genes, but is the dramatic result of the injection of the embryo, at a very early stage in its development, with a large dose of what is known as *Krüppel* 'antisense' RNA, as described on page 703 of this issue.

Krüppel 'antisense' RNA, which is synthesized *in vitro* from the 'wrong' strand of *Krüppel* cDNA, is complementary in sequence to *Krüppel* 'sense' (natural) RNA and so is able to pair with it to form double-stranded RNA. Although the precise fate of *Krüppel* antisense RNA in injected embryos is unknown, it is thought to pair with *Krüppel* sense RNA and so prevent it from being translated into the normal *Krüppel* gene product. Direct evidence that antisense RNA (for beta globin) works in this way in microinjected frog oocytes has recently

been reported by D.A. Melton (*Proc. natn. Acad. Sci.* **82**, 144; 1985).

The ability to 'phenocopy' mutants in this way is of more than academic interest. An example of the kind of problem to which the technique might be applied comes from some recent work on the *engrailed* locus of *Drosophila*, which was discussed by Peter Lawrence in these pages three weeks ago (24 January, p.268). *Engrailed* has some characteristics of a homoeotic gene, and, like the better known homoeotic genes of the bithorax and Antennapedia complexes, it contains a homoeo-box sequence. Close by the *engrailed* gene there is a second homoeo-box sequence, which identifies the *engrailed-related* gene. What does this gene do? Nobody knows, for as yet no mutations mapping in this region of the *Drosophila* genome have been identified. The use of antisense RNA offers a direct way to test what effect the loss of *engrailed-related* gene function has on development. Antisense RNA should also be useful in dissecting the activities of genes involved in the regulation of development by preventing their expression at specific times and in discrete regions of the embryo.

Geoffrey North