Astronomy

Distant galaxy observed

R.F. Carswell

THE discovery of a radio galaxy at a redshift $z = 3.395$ is to be published by S. J. Lilly in the October issue of *Astrophysical Journal*. This is the most distant galaxy known and its properties give us some interesting insights into the nature of galaxies soon after they formed: its distance means that we are seeing the galaxy as it was billions of years ago. Only a few quasars with higher redshift ($z \approx 4$), representing more distant objects at an earlier epoch, are known (see the News and Views article by Peter Shaver, *Nature* **330**, 426; 1987). Of particular interest is the presence of a population of stars more than a billion (10^9) years old, suggesting that this galaxy and the stars in it formed very early in the history of the Universe.

The galaxy was selected for study because it is the source of strong radio emission, but it also seems to have some of the usual characteristics of a gas-rich galaxy. It shows short-wavelength continuum radiation indicating that a significant population of young stars is present, as well as line emission from the gaseous component and infrared continuum emission from an older stellar component. The continuum flux indicates that the total mass of stars is about 10^{12} solar masses and the angular size of the object leads to an inferred radius of the order of 10–25 kiloparsecs. Thus the density of material in this galaxy is quite similar to those observed nearby.

Perhaps the most important result of Lilly's observations is that the galaxy contains a significant number of stars likely to be more than a billion years old even when the light we see now was emitted. Thus the galaxy must have formed stars at an early stage in the evolution of the Universe. This is compatible with most models of galaxy formation, although it could constrain some variants of the biased-galaxy-formation picture (see Dekel, A. & Rees, M. J. *Nature* **326**, 455–462; 1987). In models that involve cold, dark matter, for example, galaxies themselves do not form until epochs corresponding to redshift $z \approx 4$ or later, though subgalactic masses could have formed earlier. (The redshift is the relative shift in light from a distant object due to the Doppler effect, which measures the recession velocity and, through the expansion of the Universe, gives an estimate of distance to the object.) If the initial burst of star formation occurs when the galaxy is formed, rather than earlier, it would be difficult to reconcile the presence of this galaxy with a relatively old stellar population with such a model except as a special case. If other similar galaxies are found, models in which most of the galaxies form very early (at high redshifts, $z \gtrsim 30$) from a spectrum of initial perturbations would gain support.

The presence of old stars at such an early stage can also be used to infer a useful lower limit to the age of the Universe. Present estimates of the expansion rate of the Universe give a Hubble constant somewhere around 50–100 km s^{-1} per megaparsec (Mpc), with a preferred value near the middle of the range. Depending on the mass of the Universe, a Hubble constant of 75 km s^{-1} Mpc^{-1} corresponds to an age somewhere in the range $9–13 \times 10^9$ years. The lower value applies if the density in the Universe is critical, that is just enough for the expansion rate asymptotically to approach zero as the time approaches $t = \infty$, because under these circumstances the expansion rate must have been greater in the past. The higher value corresponds to a nearly empty Universe, where the deceleration due to gravity is negligible.

If the smaller value for the age of the Universe now is correct, then at redshift $z = 3.4$ the Universe was about a billion years old. Under these circumstances, it is hard to see how there could be any stellar component with an age of about a billion years or more. Of course, if the Universe is older (and so the expansion rate lower), or its density is lower, this time constraint is less of a problem. But it is difficult to reconcile this new discovery with an age of the Universe less than about 10 billion years even if galaxy and star formation were extremely rapid.

It is, of course, dangerous to draw sweeping conclusions from inferences based on difficult observations of a single faint object, but there is independent evidence suggesting that significant nuclear processing took place in stars at epochs corresponding to redshifts $z \geqslant 3.5$. Quasars are seen at higher redshifts with what seems to be a normal mix of heavy elements, suggesting that nucleosynthesis has occurred in stars rather than some exotic environment, and studies of absorbing clouds in the direction of these quasars also show that significant nuclear processing has occurred at early epochs with the material being returned to the interstellar medium. Taken together, these observations suggest that we should be considering galaxy and star formation on timescales of the order of hundreds of millions of years rather than billions. □

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Daedalus

Shiver my timbers!

FORESTRY is a very inefficient business. Trees grow very slowly and make poor photosynthetic use of the sunlight they intercept; logging and transporting them is very labour-intensive. And after all this, most of the resulting wood is simply torn up into tiny pieces and reassembled into products like paper, laminates and particle boards. Why not use smaller and more convenient plants to start with?

The reason, of course, is that wood is uniquely strong. It has been evolved by large trees, to enable them to spread their leaves as widely and as loftily as possible, despite ferocious side-loading from the wind and the steady pull of their own weight. No smaller plant would have optimized cellulose and lignin into such a structurally splendid material.

So Daedalus is taking the logic a step further. He is breeding dwarf trees with the same structural excellence as their big cousins. They must continue to need the mighty strength of wood, despite being only a few centimetres high. So he is cultivating them in a powerful centrifuge.

Daedalus's centrifugal greenhouse allows seedlings of pine and oak and spruce to be grown under many gravities. A central 'sun' provides light for photosynthesis and gamma-radiation to encourage mutations. The rate of rotation is chosen to collapse most of the seedlings in any generation under their own centrifugal weight; the few tough survivors seed the next generation, which is challenged with higher gravity still. The ultimate product will be a microtree whose wood is still fully as strong as that of its larger ancestors.

A stand of Daedalus's microtrees will resemble a tenacious, bushy grass. The tiny trees will grow rapidly, covering the ground tightly with a photosynthetically efficient canopy a few centimetres above it. They will be readily harvested by mowing — though considerable power will be needed to sever their tough stems. Daedalus is already devising ways of processing the mowings, such as grinding under water to break up the plant structure and separating the little leaves (a useful source of protein) by differential flotation. Further grinding will reduce the wood-fibre feedstock to the size needed for paper, chipboard or any product made of aggregated particles.

A 'wood meadow' of the new trees will be cultivated like any other crop. Once established, it should form a stable and self-sustaining ecology. Herbivores will find the microtrees too tough to eat and digest; weeds will languish under its coherent canopy; regular mowing will keep it in equilibrium. Traditional, expensive forestry will survive only where really needed, to provide big timbers. David Jones