An old galaxy in a young Universe

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A mature galaxy has been discovered in an early phase of the Universe apparently too young to contain it. Is this the end of the theorists' favourite cosmology, the Einstein–de Sitter model?

DEEP images from the Hubble Space Telescope and other instruments have provided unprecedented glimpses of the Universe at high redshifts, when it was a small fraction of its present age. Not surprisingly, most of the distant galaxies revealed in these spectacular images bear the signatures of youth, with blue colours dominated by the light of young stars, a striking variety of shapes, and pervasive evidence of interactions and mergers[1]. But these same surveys reveal a handful of red, apparently old galaxies, which tell a different but equally compelling story. On page 581 of this issue[2], Dunlop *et al.* report the discovery of the most perplexing case to date, a galaxy at a redshift of 1.5 with an apparent age of at least 3.5 billion years.

The problem, if conventional cosmological models are correct, is that galaxies that old and that far away simply should not be there. The observation tightens the thumbscrews on the Einstein–de Sitter cosmological model (see box), and offers evidence that at least some galaxies formed at very early epochs, within a billion years after the Big Bang.

The galaxy discovered by Dunlop and colleagues, 53W091, was first identified in a deep survey of faint radio galaxies — radio selection has proved effective in identifying distant galaxies with a range of evolutionary properties[3,4]. Imaging of 53W091 in the visible and infrared revealed extremely red colours, redder than a young galaxy at any plausible redshift and consistent with an evolved galaxy observed at high redshift. A more precise redshift, $z = 1.552$, came from a 5.5-hour spectrum taken with the ten-metre Keck telescope. The successful measurement of the spectrum and redshift of this object is noteworthy in itself: at 26th magnitude, this is one of the faintest galaxies ever observed spectroscopically, and probably the faintest to have its redshift determined using stellar absorption lines.

It is far from being the most distant

A meeting of Hubble constants

ONE of the original goals of the Hubble Space Telescope (HST) was to determine precisely the expansion rate of the Universe, the Hubble constant (H_0). After delays, optics problems and a succession of conflicting H_0 measurements, many have wondered whether the controversy will be settled within the lifetime of HST. Now comes news, presented at a conference last month*, that the measurements of H_0 may be converging at last.

Measuring H_0 is difficult because it requires an accurate distance scale out to at least 100 megaparsecs (300 million light years), far enough to reliably trace the cosmological expansion. There are several secondary standard-candle distance indicators, which must be calibrated against a primary scale provided by Cepheid variable stars in nearby galaxies. But the resulting scales have disagreed by up to a factor of two, mainly due to a dearth of precise Cepheid distances. HST is gradually solving this problem by providing such distances for about 25 galaxies.

Distances are now available for about half of that sample. The H_0 Key Project presented several new distances, including that of NGC1365 in the Fornax cluster (see photograph). Applying these distances to several secondary methods gave an H_0 of 68 to 77 km s^{-1} Mpc^{-1} (J. Mould, Mt Stromlo Obs. and W. Freedman, Carnegie Obs.). A competing group, headed by Allan Sandage, based most of their results on a single secondary method, the apparent brightness of type Ia supernovae, and find H_0 = 55 to 61 km s^{-1} Mpc^{-1} (G. Tammann, Basel Univ. and A. Saha, STScI). These are higher than the 43 to 53 km s^{-1} Mpc^{-1} values reported previously, whereas the latest Key Project results are about 10% lower than their preliminary estimate. The convergence mainly reflects the rapidly improving Cepheid distances from HST.

W. Freedman/HST/NASA

Refinements to other secondary methods were reported, including surface-brightness fluctuation (J. Tonry, MIT), planetary nebula luminosity function (G. Jacoby, Kitt Peak), the Tully–Fisher relation (R. Giovanelli, Cornell Univ.) and other supernova methods (R. Kirshner, Harvard Univ.), all yielding H_0 between 65 and 82 km s^{-1} Mpc^{-1}. Most agree well with the primary Cepheid distances for nearby objects, indicating that systematic errors — long the problem in this field — are being eliminated. These values are still 20 to 30% higher than the 'long' scale favoured by Sandage and colleagues, but that is far from the factor-of-two disagreement that existed only 3 years ago.

As the uncertainty in H_0 decreases, attention turns to its implications for the cosmological age problem. For a Friedmann cosmological model, in which gravity is determined by matter alone, H_0 = 70 km s^{-1} Mpc^{-1} implies a cosmic age of 9 to 14 Gyr, depending on the density of the Universe. For the special-case Friedmann model where the density is just enough to close the Universe — the flat Einstein–de Sitter model favoured by inflationary cosmology — the expansion age is 9 Gyr. This is flatly inconsistent with the ages of Galactic globular clusters, estimated to be about 13–17 Gyr (P. Demarque, Yale Univ.).

How do we solve this conundrum? If the stellar ages are correct, the Einstein–de Sitter model requires a global $H_0 < 40$ km s^{-1} Mpc^{-1}, which now seems unlikely (M. Postman, STScI). The age problem can be avoided, barely, if the density of the Universe is much lower — less than 20% of the closure density — or if most of it is in the form of vacuum energy, the 'cosmological constant' first proposed and later abandoned by Einstein. Current observations cannot discriminate between these alternatives (M. Turner, Univ. Chicago), but there is now hope that HST may finally fulfil the mission for which it was designed 20 years ago. R. C. K.

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