Galaxies — Off to a Flying Start?

New Telescopes Tell us Stars Were Made Very Early

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One of the basic questions in astronomy is simply — when did galaxies form? To answer this by observation, astronomers take advantage of the finite speed of light. When we look at the most distant objects in the universe, we also see them as they were when the light started its journey billions of years ago. A study of the geography of faraway galaxies thus becomes a study of their history as well! Two consequences of this long journey have to be kept in mind. These distant objects appear very faint, since the radiation has been spread out over a sphere of radius equal to the distance. And, because of the expansion of the universe, the wavelength of the light received is longer than that emitted. This is the famous redshift, which was the basic observation which led to the idea of an expanding universe. Each quantum of light has a lower frequency and hence a lower energy, further weakening the signal received. But this can actually be turned to advantage. From the ground, we usually do not see the ultraviolet region of the spectrum, since it is absorbed by the earth's atmosphere. A photon which starts out in the far ultraviolet, say at 800 angstroms, would encounter clouds of hydrogen on the way which could absorb it and use the energy to liberate the ground state electron. However, a photon with wavelength longer than 912 angstroms does not have enough energy to do this. There is thus a break in the spectrum we receive at this wavelength (see *Figure 1*).

With this background, one can appreciate the principle of the search for very young galaxies conducted by Lanzetta and colleagues, reported in *Nature* (27 June, 1996). They used data from the Hubble space telescope, which now comfortably detects galaxies which are 10^{11} times fainter than the brightest stars we see in the sky! Such objects are too faint to obtain a spectrum in a conventional sense. But one can get a rough picture of the wavelength distribution of the incoming light by using four filters. In a small fraction of the objects, there was emission in a filter centred at 8000 angstroms but no emission was detectable at shorter wavelengths. This pattern was not seen for the brighter and hence presumably nearer objects in their study. The simplest explanation is as follows. Wavelengths shorter than about 6000 angstroms are being removed from the spectrum of these objects by intervening clouds of hydrogen. The wavelength of the light when it passed these clouds was therefore

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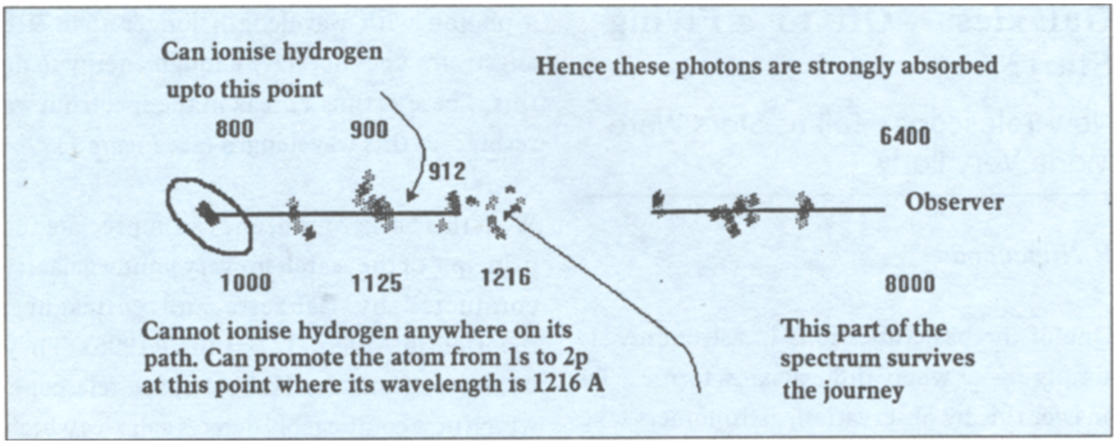

Figure 1 Journey of two ultraviolet photons from a distant source of redshift 7 to the observer. Those with wavelengths shorter than 912 angstroms are absorbed by clouds of hydrogen atoms on the way.

shorter than 912 angstroms. This means that in its journey, the wavelength has got stretched by a factor of seven or eight. Astronomers like to subtract one from this number before calling it a redshift. (This makes sense since no shift corresponds to a wavelength ratio of 1.) Thus, the absorption occurred in clouds at redshift greater than six. These objects were formed at or before a time when the size of the universe was seven times smaller than now! The number of such objects found is also interesting. After scaling up from the small area studied, it roughly corresponds to the number of galaxies seen today. Add to this the fact that the first burst of star formation is expected to give ultraviolet light which would now appear in the 8000 angstrom band, and the overall interpretation becomes attractive.

A few years ago, the simple model in which the density of the universe was very close to the critical value, was quite popular. This value separates the case when the universe recollapses, from the case when it expands forever. In this model, the age at redshift six was fifty times less than the figure of about 12 billion years today. A mere quarter billion years from the big bang and already forming stars? Theoretical cosmologists would regard this as surprising, and would probably look to other models.

The other piece of work bearing on the formation of galaxies is a rather different kind of observation. Dunlop and coworkers report

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in *Nature* (13 June, 1996) their study of a galaxy, bearing the name 53W091, which is about twenty times brighter than the faint members of the previous study. This galaxy would still have been regarded as barely detectable three years ago. Using the biggest ground-based instrument, the W M Keck 10 metre diameter telescope in Hawaii, they were able to obtain a spectrum in just a few hours of observations. And this was a genuine spectrum, not one with four points as in the previous study. It could therefore be compared in detail with the spectra of nearby galaxies and the stars in them. The wavelengths were stretched by about two and a half, which of course makes it a much closer object, at redshift 1.5. It is therefore being seen at a much later phase of the expansion of the universe, compared to redshift 6 of the previous study. Many such objects are already known. But the surprise was that the spectrum strongly suggested a *middle aged* galaxy, at least three and a half billion years old. One finds absorption lines of elements like calcium, very much like those in the sun, which is five billion years old. Most other galaxies spotted at a redshift of one and a half tend to show signs of youth and activity. So this one exception tells us that at least three and a half billion years were needed for the universe to expand from a very small size (the big bang if you like) to a stage when it was two and a half times smaller than it is today. Again, this can be compared with the model of a critical density universe, In which the age increases

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as the square of the expansion factor, the age now is 3.5 billion years, multiplied by 6.25 (i.e. 2.5^2). The result 22 billion years is far too long for comfort! (we quoted 12 billion years earlier). The authors rightly conclude that the critical density model is "in difficulty". Even lowering the density in the model of the universe gives an interesting result. This galaxy formed at redshift greater than four. Combine this with redshift six from the previous study. The overall picture emerging is that the universe is forming galaxies early, even if theoretical cosmologists are not quite sure how. And remember that these magnificent telescopes like Hubble and Keck have only just started looking at the sky. More exciting news from the depths of space and time can be expected.

Suggested Reading

- **Origin (?) of the Universe – V by J V Narlikar, *Resonance*, June 1996 in particular. Further references are available in the same series of articles.**

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