GALAXY FORMATION

Struggling with hieroglyphics

Leo Blitz

IT appears that astronomers are witnessing for the first time the birth of an entire galaxy similar to the Milky Way. The gestation is largely hidden from the view of optical telescopes, and is straining the limits of what is measurable with current instruments. In a series of six articles published in the 20 September and 10 October issues of the *Astrophysical Journal*[1–6], separate groups of European, American and Japanese astronomers have been struggling to interpret observations of an extraordinary object that defies conventional understanding.

Last year, Rowan-Robinson *et al.*[7] announced the discovery of a galaxy brighter than any known object in the Universe. Although the galaxy, known by its catalogue number F10214+4724, emits about 1,000 times as much radiation as the entire Milky Way, it is optically inconspicuous; it was initially identified at infrared wavelengths. Shortly after the discovery, Brown and vanden Bout[8] looked for emission from the CO molecule and found it. CO is a tracer of the much more abundant H_2 molecule, and although the initial estimates of the mass of H_2 were too high[9], the mass of molecular gas alone in F10214+4724 was found to be about 10^{12} solar masses, more than the total mass of the Milky Way (which contains only about 10^9 solar masses of H_2).

Because molecular hydrogen is the raw material from which new stars form, and because the mass of gas alone is more than enough to form an entire galaxy, these two sets of observations strongly suggested that F10214+4724 is a primaeval galaxy, one still in the initial stages of formation. The luminosity of the galaxy is probably due to an early generation of massive stars still enveloped in their nascent dust cocoon. The intense visible and ultraviolet stellar radiation would be largely absorbed by the surrounding dust (itself from yet an earlier generation of star formation) and reradiated in the infrared.

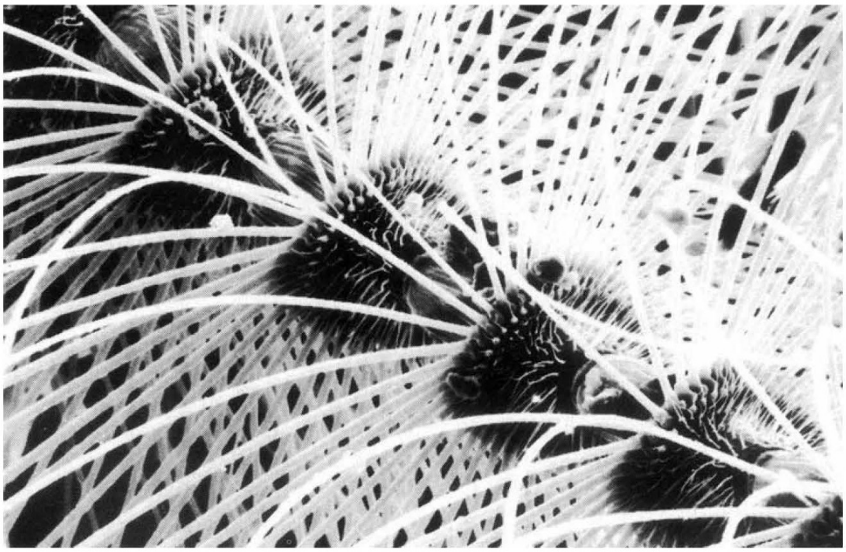
The initial excitement was followed by a dose of healthy scepticism. The high luminosity of the galaxy is inferred from its infrared brightness and from the large redshift (implying great distance) of 2.236 measured for its proposed optical counterpart. How do we know that the infrared source and the optical galaxy are the same? The positional uncertainty of the infrared source is one minute of arc, and there are seven optical sources that could plausibly be responsible. Most, but not all, have been ruled out, but there is not yet a published confirmation that the galaxy which has the large optical redshift is the infrared source.

Serious questions have also been raised about the detection of CO. Although the detection itself looks fairly convincing, the width of the observed spectral line is almost unbelievably narrow. The width is determined by the total mass of the galaxy and the inclination of the gas orbits to our line of sight. How could a galaxy with that much mass (the initial mass estimates were 10–100 times that of the Milky Way) have a line much narrower than would the Milky Way or other galaxies of similar mass? It is not clear that a primaeval galaxy would have developed into a disk, no less be highly inclined to the line of sight.

This is where the new observations play a conclusive role in verifying the identity and uniqueness of F10214+4724, as well as imposing some new difficulties. Aperture-synthesis observations with the Nobeyama array[3,4], a technique fundamentally different from Brown and vanden Bout's single-dish observations, greatly improved the resolution of the CO sighting and show that the emission is real and is centred within 1 arcsecond of the galaxy identified by Rowan-Robinson *et al.*. Yet, the spectral line detected is even narrower than that of the original CO detection. The galaxy would still have to be nearly face on, deviating at most by 8–18° from the line of sight. Furthermore, the Japanese did not detect the highest-velocity components of Brown and vanden Bout's spectrum suggesting that either this gas is very extended, covering more than about 30 arcseconds, or the original spectrum is corrupted.

Brown and vanden Bout's more recent work[2] argues that the CO emission is indeed extended, because the line is barely brighter when observed with a larger telescope, the 30-m IRAM telescope in Spain, than with the 12-m telescope in Arizona that they used initially. However, if the galaxy is as large as they require, then it would have an extent of at least 100–200 kiloparsecs; the galaxy would be uniquely large. For comparison, the Milky Way (itself rather macho as spiral galaxies go), has a diameter of about 40 kiloparsecs. But the flux density (a measure of the surface brightness) recorded at the Nobeyama array implies that the Japanese are observing all of the emission seen with the IRAM telescope, and that all of the emission detected at IRAM is concentrated within a radius comparable to the size of the Milky Way. That is, the galaxy is not uniquely large. Thus it

Tuned into good vibrations



MALE mosquitoes, unlike females, boast large and elaborate antennae which aid them in their quest for mates. The antennae also helped Gregory Paulson of Washington State University to gain the overall first prize in this year's International Photomicrography Competition sponsored by Polaroid. The familiar whining sound of female mosquitoes in flight reflects the wing-beat frequency of the species and causes the antennae of males of the same species to resonate. Directional cues are detected by massive sense organs at the base of the antennae. Paulson's micrograph, reproduced here, shows the rings of fibrils encircling the shaft of a male's antenna (magnification, × 340). P.T.