COSMOLOGY

The infrared dawn of starlight

Richard S. Ellis

The modest-sized but successful Spitzer Space Telescope has detected fluctuations in cosmic light at infrared frequencies. Is this the signature of the first population of stars that formed in the Universe?

On page 45 of this issue, Kashlinsky *et al.*[1] present observations that reveal clustering in the distribution of cosmic infrared light over and above that expected from the combined effect of known galaxies. This excess signal could conceivably be light from stars that switched on when the Universe was just a tiny fraction of its present age. The authors do not detect any individual sources, nor can they pinpoint precisely when in cosmic history these signals were produced. Nevertheless, their result is likely to provoke much discussion among cosmologists.

Searching for cosmic sources that ignited when the Universe was very young is at the frontier of our current observational capabilities. Deep surveys with space-based telescopes and the larger ground-based telescopes allow us to observe very faint sources that are thought to have originated in early cosmic times. Much progress has been made in tracing how early stellar systems changed and grew to become 'respectable' galaxies such as our own Milky Way. But the results of numerical simulations[2] suggest that the very first stars may have been quite different from those that came later. They probably contained only atoms of light nuclei produced in the Big Bang — so no heavy elements such as carbon and oxygen. They are also likely to have been very massive, over a hundred times more massive than the Sun. When these heavyweights switched on, they would have burnt up their hydrogen in only a few million years, shining intensely and briefly in a brilliant dawn of starlight.

Detecting and studying these first stars will be a specific task for the 6.5-metre-aperture James Webb Space Telescope — successor to the 2.5-metre Hubble Space Telescope — that is projected to enter orbit in 2013. Kashlinsky and colleagues' observations[1] come from a more modest-sized instrument, the Infrared Array Camera (IRAC) on board NASA's Spitzer Space Telescope. The technique they use — that of analysing ripples in the background sky — is well established in cosmology: observations of ripples at microwave frequencies produced soon after the Big Bang (the so-called cosmic microwave background) gave us precise measurements of the constituents and geometry of the Universe. IRAC detects light at infrared wavelengths between 3.6 and 8 micrometres, and is sensitive to the light of young stars that has been redshifted (moved to longer wavelengths) by a factor of between 20 and 50 by the expansion of the cosmos since its emission. This light would have originated at a time when the Universe was only 100 million years old — an infant in terms of its stately 13.7 billion years today.

Spitzer, with its 85-centimetre aperture, does not have the angular resolution to resolve individual sources at these enormous distances. But it might well be capable of detecting distant stars' combined output as structure in the light produced behind that of foreground sources. And here lies the observational challenge: Spitzer's IRAC detectors are also sensitive to diffuse light that is produced within the Solar System, in clouds of cool gas in our Galaxy and, crucially, from galaxies — those close by, as well as those a long way back in cosmic time. Even a minor blunder in removing these foreground signals might lead to a spurious result.

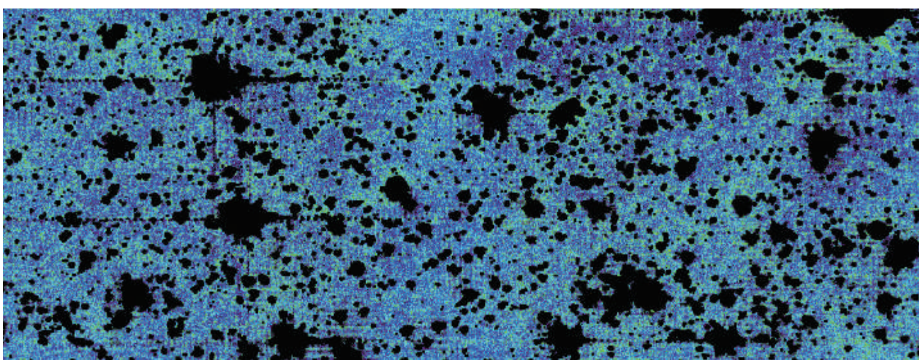

Figure 1 | Sign of the times? A deep infrared exposure taken with the Spitzer Space Telescope. When contributions from the known stars and galaxies are subtracted (black areas), the fluctuations in the background emission show a residual signal over and above that expected from the past history of galaxies. This may arise from the first massive stars that ignited when the Universe was only 100 million years old. (Courtesy of A. Kashlinsky *et al.*[1].)

Although several groups have tentatively claimed to have seen fluctuations from early starlight on the basis of previous infrared space missions[3,4], the increased depth of the IRAC images means that Kashlinsky *et al.*[1] could reduce the confusing signals from foreground galaxies to fainter upper limits (Fig. 1). They present several tests to demonstrate the reliability of their detected signal and the origin they claim for it. The pattern of structure they see, for example, is statistically similar at four different infrared wavelengths, and is consistent across fields whose sky coordinates are very different (so an origin in the Milky Way is unlikely). The signal does not change between two measurements taken six months apart, as would be the case if its origin were 'zodiacal' light reflected by local interplanetary dust in the Solar System.

The authors use various methods to remove the signals coming from faint galaxies, none of which significantly alters their result. Remarkably, however, the total contribution of foreground galaxies, estimated by extrapolating to include those too faint to be resolved in the deepest IRAC images[5], is small compared with the residual signal, which the authors ascribe to primordial stars. Kashlinsky *et al.* argue that this is further proof of their signal's origin, because only a very large error in the amount of foreground galaxy clustering would make the residual signal disappear. Because the clustering observed in the background will be diluted if the first stars switch on gradually over a range in cosmic times, the prominent signal might conceivably arise because it was produced in a very short time interval. But the imbalance still seems a surprising outcome, and a number of untested assumptions involved in allowing for unobserved galaxies could represent a weakness in the analysis.

Kashlinsky and colleagues, perhaps wisely, do not interpret their signal in much detail. Theorists have predicted the level of fluctuations that might be seen in such experiments[6]; but their calculations, too, depend on many imponderables. The genuine excitement in this work lies in the practicality of detecting the stellar radiation from hitherto uncharted distances corresponding to a time when the Universe was barely 100 million years old. Not bad for an 85-centimetre telescope! ■

Richard S. Ellis is at the California Institute of Technology, MS 105-24, Pasadena, California 91125, USA.
e-mail: rse@astro.caltech.edu

1. Kashlinsky, A., Arendt, R. G., Mather, J. & Mosely, S. H. *Nature* **438,** 45–50 (2005).
2. Abel, T. *et al. Science* **295,** 93–98 (2002).
3. Wright, E. L. & Reese, E. D. *Astrophys. J.* **545,** 43–55 (2000).
4. Matsumoto, T. *et al. Astrophys. J.* **626,** 31–45 (2005).
5. Fazio, G. *et al. Astrophys. J. Suppl. Ser.* **154,** 39–43 (2004).
6. Santos, M., Bromm, V. & Kamionkowski, M. *Mon. Not. R. Astron. Soc.* **336,** 1082–1092 (2002).