COSMOLOGY

Ripples of early starlight

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After all known sources are accounted for, puffy blobs of infrared light persist on deep-field telescope images. Evidence is mounting that these could be the signatures of stars in early 'protogalaxies'.

About a year ago, Kashlinsky *et al.* found evidence for fluctuations in background infrared light from far-off cosmological sources larger than would be expected from unresolved galaxies in known populations[1,2]. In two papers to be published in *The Astrophysical Journal*, the same authors now confirm the effect in different and larger sections of the sky[3,4]. They argue that the most plausible interpretation is fluctuations in the light emitted by an early generation of stars. If so, this is the oldest starlight yet detected, and dates from long before modern giant galaxies formed.

In the conventional model of early cosmic evolution, small primordial concentrations in the density of unseen 'dark matter' had, about 100 million years after the Big Bang, finally grown large enough to cause the gravitational collapse of gas towards them. This process created pockets of gas dense enough to collapse of their own accord and form the first stars. By the time the Universe was about 200 million years old, stellar burning in small, pregalactic systems was widespread. After this time, stars formed in successively larger, hierarchically assembled systems. After a few billion years, this evolution culminated in the formation of the giant galaxies that we see all over the Universe today.

Detailed, direct observations of pregalactic starlight from the Universe's first billion years would allow astronomers to probe many aspects of the early evolution of the cosmos that are obscure or untested. These include the formation of the first clumps, or 'minihaloes', of dark matter; the collapse of the first clouds of gas on small scales; the formation and explosion of the first stars, and the end of the cosmic 'dark ages'; the chemical enrichment and ionization of the early cosmos; and the energy feedback that apparently kept most gas from ever forming stars.

Kashlinsky and colleagues' latest analysis[3] was performed, as before[1], on deep-field exposures made by NASA's Spitzer Space Telescope. After identifiable sources are masked out and digitally cleaned from the data, a background of fuzzy blobs remains (Fig. 1) that is not consistent with randomly distributed 'shot' noise from unresolved sources. The images show additional fluctuations on scales of about 1 to 10 arcminutes (1/60th to 1/6th of a degree), this upper limit being set by the size of the surveyed fields.

The authors' favoured interpretation[4] of this effect is that the blobs represent a fractional fluctuation of a few to about ten per cent in a rather intense background of starlight originating in the first 1.2 billion years of the Universe's existence. This equates to sources at redshifts (z) of between about 5 and 20 (where $1 + z$ is the factor by which the Universe has expanded since the source emitted the light). Individual, collapsed star-forming systems associated with early protogalaxies are small and numerous, so their random shot noise is small, and in the absence of other perturbations their light should be relatively smoothly distributed. But standard cosmology predicts that these systems are clustered non-randomly owing to the larger-scale and smaller-amplitude primordial fluctuations in matter density that eventually become giant galaxies and groups of galaxies. Summed along the line of sight, these fluctuations give rise to the detected blobs. (The brighter, uniform, non-fluctuating component of the background is not directly detectable in these data, because it cannot be distinguished from other sources of noise and emission.)

That this starlight should appear as puffy blobs at infrared wavelengths is entirely expected[5]. In everyday life, distant things — whose light has travelled further to reach us — look smaller. But looking back to redshifts greater than about 1.6, systems in our expanding Universe start appearing larger, not smaller. This odd effect is caused by the expansion itself, which not only shifts the visible spectrum of starlight to longer, infrared frequencies, but also means that older objects at higher redshift were 'closer' at the time they emitted the light. Thus, an object has about the same angular size at redshift 10 as it does at redshift 0.3. At redshift 10, the angular size of the observed blobs, about 100 arcseconds, corresponds to a size of some 1.3 million light years. This size is typical of the dark-matter haloes that eventually collapse into giant galaxies and groups of galaxies (but, at the time the light was emitted, were yet to collapse).

At present, the data are not specific enough to allow us to tell where the light is coming from, but a high-redshift interpretation works if the emitting stars are hot, massive and bright. Alternatively, the light might be coming from lower redshifts, but in this case its smooth distribution, and the fact that more starlight has not been seen at optical wavelengths, are puzzling.

Either way, the much more powerful telescopes on the way, especially NASA's James Webb Space Telescope, which is scheduled for launch within the next decade, will have plenty to study. This telescope's much larger primary mirror will allow it to resolve the small regions of protogalactic star formation, perhaps find spectroscopic clues as to the redshift of the light, and maybe even detect supernova explosions as the first stars die in the regions surveyed. The evidence seems to be growing that there is more than just a dark sky between the galaxies: ripples of infrared starlight glow in every direction. ■

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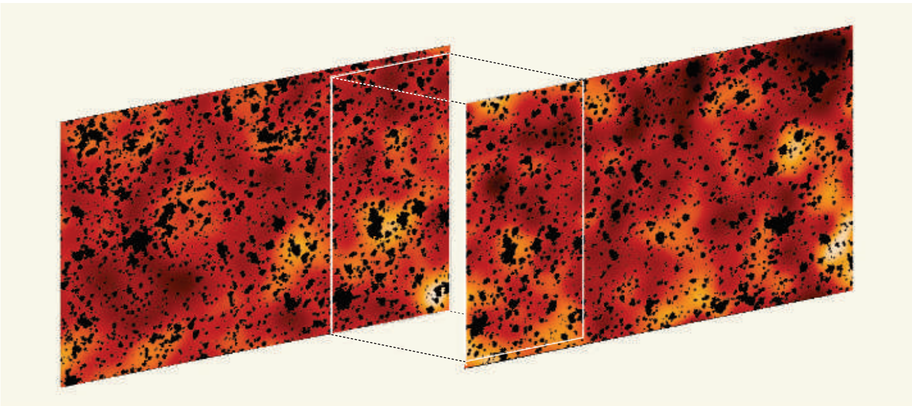

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Figure 1 | Infrared map. These images of a portion of the sky in the Hubble Deep Field North are based on data from NASA's Spitzer Space Telescope at two different infrared wavelengths, 3.6 μm and 4.5 μm, including an overlapping region as shown. The black pixels are close to bright sources and are masked off. The remaining pixels are cleaned of point sources, leaving extended fuzzy blobs glowing in the background that show up in both bands. These could be fluctuations, due to nascent cosmic structure, in a bright pregalactic infrared background.

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3. Kashlinsky, A., Arendt, R. G., Mather, J. & Moseley, S. H. *Astrophys. J.* (in the press); preprint available at www.arxiv.org/astro-ph/0612445 (2006).
4. Kashlinsky, A., Arendt, R. G., Mather, J. & Moseley, S. H. *Astrophys. J.* (in the press); preprint available at www.arxiv.org/astro-ph/0612447 (2006).
5. Bond, J. R., Carr, B. J. & Hogan, C. J. *Astrophys. J.* **306,** 428 (1986).