COSMOLOGY

Hydrogen was not ionized abruptly

When and how the first stars and galaxies ionized the primordial hydrogen atoms that filled the early Universe is not known. Observations with a single radio antenna are opening a new window on the process. SEE LETTER P.796

JONATHAN PRITCHARD & ABRAHAM LOEB

Four hundred thousand years after the Big Bang, the Universe had cooled sufficiently for hydrogen atoms to form. Hundreds of millions of years later, the first stars and galaxies had produced ionizing ultraviolet radiation that broke the hydrogen atoms into their constituent electrons and protons. This process, termed reionization, marks a major cosmological phase transition. When and how rapid this transition was are important open questions[1]. On page 796 of this issue, Bowman and Rogers[2] implement a new technique that allows them to rule out models in which reionization occurs abruptly.

Their approach uses a simple radio antenna operating at low frequencies to measure the absolute radio intensity of the sky. Cosmic hydrogen atoms can emit or absorb light with a wavelength of 21 centimetres, a signal that is stretched (redshifted) on its way to Earth through the expansion of the Universe[3]. The redshifted 21-cm hydrogen signal, which falls within the radio regime, is expected to cut off at short, observed wavelengths that correspond to later times when the Universe was ionized. The authors' experiment to detect the global reionization step (EDGES) searches for the associated spectral step in the sky's intensity[4].

Our knowledge of the epoch of reionization is surprisingly limited. The lack of ultraviolet (UV) absorption by diffuse neutral hydrogen along the line of sight to the most distant quasars[5] (accreting black holes) indicates that the Universe is largely ionized at a redshift of less than about 6 — a billion years after the Big Bang. Yet observations of the cosmic microwave background[6] — radiation left over from the Big Bang — indicate that the Universe was filled with neutral hydrogen at much earlier times. Clearly, a transition must have occurred from a neutral to an ionized Universe, but even recent observations of high-redshift galaxies with the Hubble Space Telescope tell us little

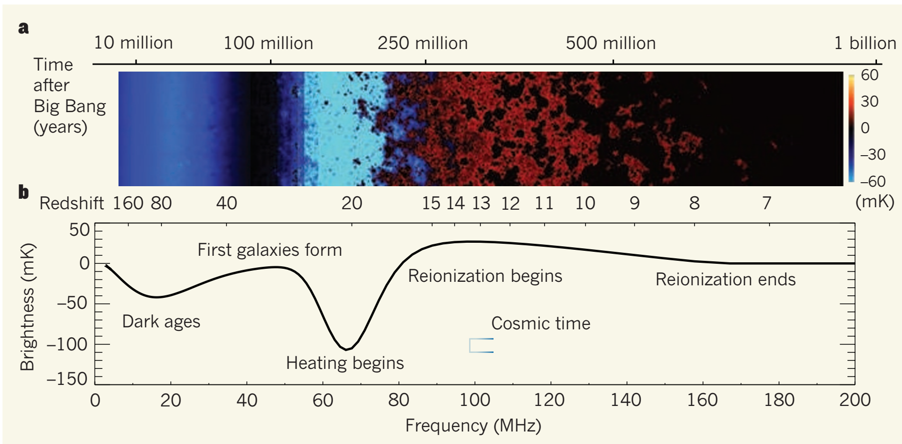

Figure 1 | The 21-centimetre cosmic hydrogen signal. a, Time evolution of fluctuations in the 21-cm brightness from just before the first stars formed through to the end of the reionization epoch. This evolution is pieced together from redshift slices through a simulated cosmic volume[9]. Coloration indicates the strength of the 21-cm brightness as it evolves through two absorption phases (purple and blue), separated by a period (black) where the excitation temperature of the 21-cm hydrogen transition decouples from the temperature of the hydrogen gas, before it transitions to emission (red) and finally disappears (black) owing to the ionization of the hydrogen gas. **b,** Expected evolution of the sky-averaged 21-cm brightness[8] from the 'dark ages' at redshift 200 to the end of reionization, sometime before redshift 6. The frequency structure within this redshift range is driven by several physical processes, including the formation of the first galaxies and the heating and ionization of the hydrogen gas. There is considerable uncertainty in the exact form of this signal, arising from the poorly understood properties of the first galaxies. Bowman and Rogers[2] study the final phase, in which the progressive ionization of the gas cuts off the signal.

NATURE

50 YEARS AGO

The July issue of *Man* contains several articles of general interest … A. D. Lacaille illustrates a number of very large British Acheulean coups de poing, and a puzzling rock-carving from the Val Camonica is discussed by Dr. Anati of Paris. The site is near where the great glacial valley debouches on to the north Italian plain, and many rock-carvings there have been known for a long time. They include animals and humans treated in a conventional manner somewhat recalling the Copper Age paintings of Las Figuras in south-west Spain. The little group in question seems to indicate either a phallic or a ritual scene. The author suggests a date for this art group somewhere towards the start of the first millennium B.C. Is not this somewhat too early?
From *Nature* 10 December 1960.

100 YEARS AGO

The Anatomy of the Honey Bee. By R. E. Snodgrass. — In this modest pamphlet the author has given to entomologists an original, trustworthy, and excellently illustrated account of the structure of the honey bee … Many volumes have been written on the honey bee, yet no surprise can be felt that Mr. Snodgrass has been able to add new points to our knowledge and to correct errors in the work of his predecessors … He expresses scepticism as to certain positive statements that have been made on controverted details of physiology and reproduction; for example, "concerning the origin of the royal jelly or of any of the larval food paste … we do not know anything about it." There is a present-day tendency unduly to disparage the results obtained by former workers, and such a statement will strike many readers as extreme.
From *Nature* 8 December 1910.