ASTROPHYSICS

Gravitational waves constrained

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Cosmic gravitational waves could provide unprecedented information on the early Universe. The effects that are of interest are small, but experiments are gradually achieving a sensitivity that will test cosmological models.

Gravitational waves are tiny disturbances in space-time. They can be triggered during cataclysmic events involving stars or black holes, and they could even have been generated in the very early Universe, well before any star formed, merely as a consequence of the dynamics and expansion of the Universe. In the latter case, these waves should provide a 'background' signal of gravitational waves coming from all directions in space — if indeed they can be spotted. One particularly sensitive experiment recruited to the search for gravitational waves is LIGO, the Laser Interferometer Gravitational-Wave Observatory. It has just published the results from its fourth bout (S4) of data-taking in *The Astrophysical Journal*[1].

Gravitational waves are not the only known source of cosmic 'noise'. Most famously, the Universe is filled with a background of electromagnetic radiation left behind by the hot Big Bang; it has now cooled to its present temperature of about 2.7 kelvin by the subsequent expansion of the Universe. The discovery of this 'cosmic microwave background' by Arno Penzias and Robert Wilson in 1964 is a milestone in the history of modern cosmology, and its detailed study provides some of our best information on the early Universe. In 1992, NASA's Cosmic Background Explorer (COBE) satellite reported its measurement of the spectrum of the microwave background and found it to have a perfect 'black-body' form with a characteristic temperature that has tiny variations across the sky — the 'seeds' for galaxy formation[2]. Subsequent experiments, in particular NASA's follow-up WMAP (Wilkinson Microwave Anisotropy Probe) mission, have provided a more detailed picture, and ushered in an epoch of precision cosmology, in which the agreement between experimental data and theoretical models can be at the level of a few per cent.

The discovery of a cosmological background of gravitational radiation would arguably be even more fundamental. Any background of relic particles provides us with a snapshot of the Universe at a very definite time: the time at which these particles decoupled from the primordial plasma. For the photons of the cosmic microwave background, this happened when the Universe was just 270,000 years old. The photons we see today in the cosmic microwave background are a true photograph of the Universe at that age.

LIGO LABORATORY

Figure 1 | Long arms for gravitational waves. The LIGO site at Hanford, Washington.

50 YEARS AGO

An investigation during 1954–56, into hygiene in restaurants and public houses, was then described... In the first survey covering fifty representative kitchens only twenty-seven out of 260 washed utensils examined attained the United States Public Health Standard. Only two from forty-two drying cloths showed less than 500 organisms per square inch. Only seven from forty-two wash and rinse waters yielded less than 500 organisms per ml. 74 per cent of kitchens yielded fæcal *Bacterium coli* from one or more items but no recognized types of food-poisoning pathogens were isolated apart from *Staphylococcus aureus*... Arrangements in many kitchens were poor, the paramount need being for improved ventilation and more hot water at 180° F.

From *Nature* 8 June 1957

100 YEARS AGO

The Origin of Radium by E. Rutherford — In a previous letter to *Nature* (January 17) I gave an account of some experiments which I had made upon the growth of radium in preparations of actinium. ...I think we may [now] safely conclude that, in the ordinary commercial preparations of actinium, there exists a new substance which is slowly transformed into radium. This intermediate parent of radium is chemically quite distinct from actinium and radium and their known products, and is capable of separation from them.

It is not possible at present to decide definitely whether this parent substance is a final product of the transformation of actinium or not. It is not improbable that it may prove to be the long-looked-for intermediate product of slow transformation between uranium X and radium, but with no direct radio-active connection with actinium. If this be the case, the position of actinium in the radio-active series still remains unsettled.

From *Nature* 7 June 1907

50 & 100 YEARS AGO