Einsteins ripples: Your guide to gravitational waves

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Hey Einstein, surf's up! Researchers from the BICEP2 telescope in Antarctica today announced the clearest detection yet of gravitational waves, ripples in space-time first predicted by the iconic physicist. The particular ripples the team detected were caused by inflation, the period immediately after the big bang, giving us a glimpse further back in our universe's history than ever before. That should help us piece together the exact sequence of events that led to our universe's birth, as well as a collection of other cosmic secrets. But what exactly is a ripple in space-time, anyway?

What are gravitational waves?
Long predicted but never directly seen, gravitational waves are ripples in the fabric of the universe.

Albert Einstein compared the universe's shape to a single fabric, hewn from space and time. According to his theory of general relativity, the force of gravity is the result of curvature in this space-time: gravitational waves are ripples in it. The ripples are produced by accelerating objects, just as an accelerating electric charge emits electromagnetic waves.

Colliding black holes and stars create modern-day gravitational waves. But cosmologists also believe the big bang itself produced primordial waves that still reverberate through space-time. It is these ripples, dating back to a fraction of a second after the birth of the universe, that the BICEP2 researchers have detected.

(Gravitational waves should not be confused with gravity waves, a term used in the study of fluids to refer to waves on a surface that propagate because of gravity.)

If the big bang's waves have been hanging around for so long, why haven't we found them until now?
Despite being produced by massive disturbances in space-time, even the largest gravitational waves are tiny. BICEP2 detected them by looking for patterns in the cosmic microwave background, the remnants of the first light in the universe. Gravitational waves squeeze space-time as they pass, leaving a small but meaningful fingerprint in this first light that the researchers could detect, but only after years of data analysis.

Has anyone tried to see them before?
BICEP2 has seen the first evidence for primordial gravitational waves – but the telltale signs of modern-day waves have been glimpsed before. In 1974, astronomers Russell Hulse and Joseph Taylor detected a binary pulsar, a pair of two dead stars emitting pulses of radio waves. Hulse and Taylor realised that the two pulsars were losing energy and slowly spiralling towards each other in a way that was exactly consistent with Einstein's equations of general relativity: the missing energy is thought to be emitted as gravitational waves. The finding earned the pair the Nobel prize for physics in 1993.

If we've found modern gravitational waves, and primordial ones, is the hunt now over?
Not quite. Physicists still hope to surf a passing gravitational wave, which would amount to the first direct detection of these entities, in contrast to the indirect effects seen by BICEP2 and Hulse and Taylor.

So how do you surf a gravitational wave?
Like light waves, gravitational waves come in many different frequencies depending on how they are produced (see diagram, below).

Experiments like LIGO, which is spread over two sites in Washington state and Louisiana in the US, and VIRGO, in Cascina, Italy, look for high-frequency waves, caused by modern-day black hole mergers or exploding stars. These should cause slight disturbances on Earth that can be measured – although none of the detectors has yet reported such an event.

Detectors in space, meanwhile, can detect lower frequency waves – next year the European Space Agency plans to launch LISA Pathfinder, a test mission that will lead to a trio of spacecraft in 2034 intended to hunt for gravitational waves emitted by black holes.