Indian group proposes radical new way to settle universe expansion dispute

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Premium

The precise rate of the universe’s expansion remains a point of crisis in modern cosmology.

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Sayantan Datta

The light from faraway galaxies becomes redshifted by the time it reaches an observer, in this case the James Webb Space Telescope. | Photo Credit: ESA/Webb, NASA, and CSA, A. Martel

About 13.8 billion years ago, a really small, really dense, and really hot spot lying beyond spacetime began to expand. Its expansion and cooling – in an event that scientists have called the Big Bang – produced the universe as we know it.

The universe continued to expand, at first really rapidly before slowing down to a great degree. Then, about five or six billion years ago, dark energy – an unknown and largely uncharacterised form of energy – accelerated its expansion again.

Scientists confirmed that the universe was indeed expanding at an accelerating rate in 1998.

Euclid space telescope begins quest to study dark universe

A crisis

In 1929, American astronomer Edwin Hubble provided the first mathematical description of the universe’s expansion in an equation called Hubble’s law. Yet the precise *rate* of this expansion, called the Hubble constant, remains a point of crisis in modern cosmology.

In a move that could eventually help resolve this crisis, researchers at the International Centre for Theoretical Sciences (ICTS), Bengaluru; the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune; and the University of California, Santa Barbara (UCSB) have proposed a new way to determine the Hubble constant.

Their study was published in the journal *Physical Review Letters*in June.

While the study's predictions may only be tested in the 2040s, their method "will provide an independent measurement of cosmological parameters," Jasjeet Singh Bagla, an astrophysicist at the Indian Institute of Science Education and Research (IISER), Mohali, said.

Measuring the Hubble constant

Two details are required to calculate the value of the Hubble constant: the distance between the observer and astronomical objects, and the velocity at which these objects are moving away from the observer as a result of the expansion of the universe.

So far, scientists have used three methods to get these details:

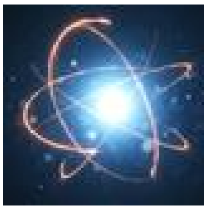
1: They compare the observed brightness of a stellar explosion, called a supernova, with its expected brightness to figure how far away it could be. Then they measure how much the wavelength of the light from the star has been stretched by the expansion of the universe – i.e. the redshift – to figure how much it's moving away.

2: They use changes to the cosmic microwave background (CMB) – radiation leftover from the Big Bang event – to estimate the Hubble constant.

3: They use gravitational waves, ripples in spacetime produced when massive astronomical objects – like neutron stars or black holes – collide with each other. Detectors that observe gravitational waves record the data in the form of curves.

Using the shape of these curves, astronomers can calculate the amount of energy that the collision released. Comparing this with the amount of energy the waves had when they reached earth allows researchers to estimate the distance between these objects and earth. They use the redshift to get the moving-away speed.

Scientists tested an electron's response to a magnetic field with extreme accuracy. Why?



The discrepancy

Measurements from the first method has reported a Hubble constant about two units higher than the one derived by the second method; the third method hasn't yet matured enough to provide a precise measurement.

Parameswaran Ajith, an author of the new study and an astrophysicist at ICTS, said this discrepancy could be due to a mistake in the methods used – or it could indicate that the Hubble constant is itself evolving with time.

This possibility arises because the three methods estimate the Hubble constant today based on information from *different stages* of the universe. The CMB way is based on a much younger universe while the other two are based on an older universe (i.e. closer to the one today).

Lensed gravitational waves

In 1919, as a total solar eclipse rendered the sky dark, Arthur Eddington led a group of astronomers to an island off Africa's west coast to photograph a star cluster for the duration of the eclipse. Back in England, he analysed these photographs and found something remarkable: the Sun's gravitational field was bending starlight passing through it.

Eddington had observed the *gravitational lensing* of light. Based on the idea that gravitational waves could be lensed as well, in 2021, researchers working with three gravitational-wave detectors in the U.S. and Italy conducted one of the first searches for such lensed waves in existing data.

Infographic explaining lensing of gravitational waves. | Photo Credit: Parameswaran Ajith

Scientists are yet to find lensed gravitational waves but there’s good reason to believe that they will in the next two decades. This is because the upcoming generation of gravitational-wave detectors are expected to be able to sense about a million gravitational waves a year, per the authors of the current study.

The rationale is that while lensed gravitational waves are expected to occur around 0.1% of the time, a decade’s worth of observations should turn up thousands of them.

Detectors ‘see’ lensed gravitational waves as multiple copies of the same wave with a time delay. The current study began when Shasvath J. Kapadia, a postdoctoral fellow with Prof. Ajith in 2019-2022 and currently a faculty member at IUCAA, wondered if analysing a collection of all lensed waves and their time delays could contain an “imprint of the rate of expansion of the universe”.

He built a preliminary model. Souvik Jana, a doctoral student with Prof. Ajith and the lead author of the current study, built on it, factoring in the fact that the *number* of lensed gravitational waves observed would depend on the *rate of expansion* of the universe.

The universe linked by cosmic information

An independent probe

The strength of the method, Prof. Ajith said, is its ability to independently estimate the Hubble constant from the intermediate stages of the universe's expansion. Mr. Jana added that the method could also help determine other cosmological parameters, such as the density of matter.

A.R. Rao, an astrophysicist who retired from the Tata Institute of Fundamental Research, Mumbai, called the study "fascinating". According to him, it provides an important cosmological use of gravitational waves.

"Gravitational waves were detected in the last decade as a curio. This is one of the first papers to propose their astronomical use to measure something else," he said.

Signal-to-noise ratio

Prof. Bagla lauded the study as well but said that for the method to be successful, future research will have to account for a possibly low signal-to-noise ratio when identifying the source of the gravitational waves.

This, according to him, is especially important since Jana et al. in their method don't use any electromagnetic-wave counterpart – the traditional method of identifying the distance of sources from the earth and their moving-away speeds.

Meanwhile, the team is exploring other uses of their method – including an attempt to investigate the "nature of a dark matter particle", according to Tejaswi Venumadhav, a co-author and an assistant professor of physics at UCSB.

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- In 1929, American astronomer Edwin Hubble provided the first mathematical description of the universe's expansion in an equation called Hubble's law. Yet the precise *rate* of this expansion, called the Hubble constant, remains a point of crisis in modern cosmology.

- Two details are required to calculate the value of the Hubble constant: the distance between the observer and astronomical objects, and the velocity at which these objects are moving away from the observer as a result of the expansion of the universe.

Sayantan Datta (they/them) are a queer-trans freelance science writer, communicator and journalist. They currently work with the feminist multimedia science collective TheLifeofScience.com and tweet at @queersprings.

Note: This article was updated at 7.45 am on July 18, 2023, to further clarify some of the technical aspects of techniques to estimate the universe's expansion rate and the lensing of gravitational waves.

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