

Astrowatch

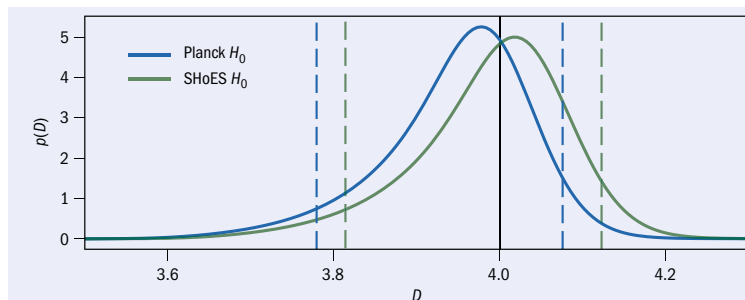
COMPILED BY MERLIN KOLE, DEPARTMENT OF PARTICLE PHYSICS, UNIVERSITY OF GENEVA

Gravitational hunt for extra dimensions

General relativity predicts very accurately how objects fall from a table and how planets move within the solar system. At larger scales, however, some issues arise. The most glaring is the theory's prediction of the motion of stars within a galaxy and of the acceleration of galaxies away from each other, both of which are at odds with observations. Models containing dark matter and dark energy can solve these two problems, respectively. Another potential solution is that space–time contains additional dimensions, modifying general relativity. Such additional dimensions are not observable with electromagnetic waves, but new information gleaned from gravitational waves (GWs) are allowing such models to be tested for the first time.

Some modifications of general relativity, such as the Dvali–Gabadadze–Porrati (DGP) model, involve the addition of extra dimensions accessible to gravity. If such extra dimensions are large, and thus not rolled up to a microscopic size as predicted by some beyond-Standard Model theories, part of the gravitational field would “leak” into the extra dimensions. Therefore, GWs arriving at detectors such as those of the LIGO and VIRGO observatories would be weaker than expected.

The first GWs detected, in September 2015, came from distant black-hole binaries. For such objects, there is no electromagnetic-wave counterpart, so the only information astronomers have about their distance from Earth is from the GWs themselves, making it impossible to check if some of the wave's intensity was lost. However, GW170817, the first observed merger of binary neutron stars, produced both GWs and electromagnetic radiation, which was measured by a wide range of instruments (CERN Courier



The probability p as a function of the number of spacetime dimensions D for two different values of the Hubble constant.

December 2017 p16). As a result, we know in which galaxy the merger took place and therefore have a good measurement of the distance the GWs travelled. Using this distance measurement and the measured strength of the GW signal, one can test whether the signal follows general relativity or a model with additional dimensions.

Doing exactly this, a group led by Kris Pardo from Princeton University has found that the results are most compatible with the standard 3+1 space–time–dimensions picture. Assuming two values for the Hubble constant, as required due to a large discrepancy between values obtained by two different methods (CERN Courier May 2018 p17), the researchers show that, regardless of the value assumed, the results allow for a total of 4.0 ± 0.1 dimensions (see figure).

The authors also obtained an upper limit on the graviton's lifetime of 450 million years. As is the case with a potential leakage of gravity into extra dimensions, the decay of gravitons propagating towards Earth would also cause the strength of the GW signal to decrease.

These findings are just the beginning of the physics studies made possible by gravitational-wave astronomy. As the authors make clear in their paper, the results only affect theories with finite but large-scale extra dimensions. That may change, however, as more GWs are expected to be measured, with increased precision, in the future. One promising parameter capable of probing a larger set of models is the polarisation of the GWs. For the GW170817 system, polarisation information was not available at the time of observation owing to the limited number of GW detectors. Any higher-dimensional model allows for extra GW polarisation modes, which can be studied with the help of additional GW detectors such as the planned KAGRA and INDIGO facilities.

With a future global array of GW detectors, we can look forward to more studies in this field of physics which, until now, has been almost inaccessible.

● Further reading

KPardo et al. 2018 *J. Cosmol. Astropart. Phys.* **7** 48.

Picture of the month

This slightly blurry distorted image of a rocky surface is more interesting than it might first appear. The small instrument responsible for the picture is the first of several robot “hoppers” to be deployed to an asteroid called Ryugu by the Japanese probe Hayabusa2, before the spacecraft itself will land on the asteroid surface to take samples back to Earth. The asteroid consists mainly of nickel, iron, cobalt, water, nitrogen, hydrogen and ammonia. It's slightly less than 1 km in diameter and weighs 450 million tonnes. The image was taken as the robot, which is about the size of a shoebox, jumped several metres high – a journey that, owing to a gravitational acceleration of just 0.0001 m s^{-2} , takes about 15 minutes.



JAXA



Introducing...Best Cyclotron & Best Particle Therapy Systems from TeamBest® Companies!

Best Cyclotron Systems provides 15/20/25/30/35/70 MeV Proton Cyclotrons as well as 35 & 70 MeV Multi-Particle (Alpha, Deuterons & Protons) Cyclotrons

- Currents from 100uA to 1000uA (or higher) depending on the particle beam
- Best 20u and 30u are fully upgradeable on site



Installation of Best 70 MeV Cyclotron at Italian National Laboratories (INFN), Legnaro, IT

Cyclotron	Energy (MeV)	Isotopes Produced
Best 15	15	^{18}F , $^{99\text{m}}\text{Tc}$, ^{11}C , ^{13}N , ^{15}O , ^{64}Cu , ^{67}Ga , ^{124}I , ^{103}Pd
Best 20u/25	20, 25–15	Best 15 + ^{123}I , ^{111}In , $^{68}\text{Ge}/^{68}\text{Ga}$
Best 30u (Upgradeable)	30	Best 15 + ^{123}I , ^{111}In , $^{68}\text{Ge}/^{68}\text{Ga}$
Best 35	35–15	Greater production of Best 15, 20u/25 isotopes plus ^{201}Tl , $^{81}\text{Rb}/^{81}\text{Kr}$
Best 70	70–35	$^{82}\text{Sr}/^{82}\text{Rb}$, ^{123}I , ^{67}Cu , ^{81}Kr + research



Proton-to-Carbon High Energy Particle Delivery System:

- Intrinsically small beams facilitating beam delivery with precision
- Small beam sizes – small magnets, light gantries – smaller footprint
- Highly efficient single turn extraction
- Efficient extraction – less shielding
- Flexibility – protons and/or carbon, future beam delivery modalities



ion Rapid Cycling Medical Synchrotron (iRCMS)

