Death by gamma-ray bursts may place first lower bound on the cosmological constant

7 March 2016, by Lisa Zyga

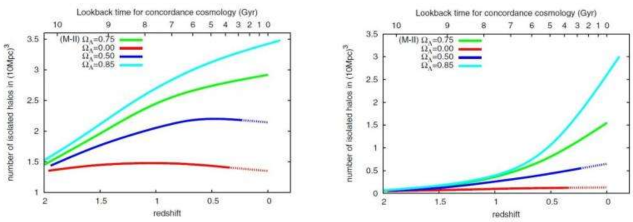
Artist's illustration of a gamma-ray burst. Energy from the explosion is beamed into two narrow, oppositely directed jets. Credit: NASA/Swift/Mary Pat Hrybyk-Keith and John Jones

(Phys.org)—Sometimes when a star collapses into a supernova, it releases an intense, narrow beam of gamma rays. Gamma-ray bursts often last just a few seconds, but during that time they can release as much energy as the Sun will produce in its entire lifetime, making gamma-ray bursts the most powerful explosions ever observed in the universe. They are so intense that, if pointed at the Earth from even the most distant edge of our galaxy, they could easily cause a mass extinction, possibly obliterating all life on the planet. It's thought that a gamma-ray burst may have caused the Ordovician extinction around 440 million years ago, which wiped out 85% of all species at the time.

Clearly, the farther away a planet is from gamma-ray bursts, the better its chances of harboring advanced forms of life. In a new paper, scientists have shown that the gamma-ray burst risk to life favors a universe where all objects (like planets and gamma-ray bursts) are relatively far apart. And the main factor that tells how far apart everything is in the universe—or in other words, how things are spreading out and moving away from each other—is dark energy or the cosmological constant.

One of the biggest unanswered questions in cosmology is why does the cosmological constant have the particular value that scientists observe? Einstein initially devised the cosmological constant to be like an "anti-gravity" force, so that a larger value means that the universe is expanding very rapidly and objects are being pushed farther apart from each other. A smaller value means that the universe itself is smaller and objects are somewhat closer together.

Currently, the value of the cosmological constant is estimated to be about 10^{-123}. Researchers have placed upper bounds on this value (it can't be more than 10^{-120} or else galaxies and other structures could not form because their matter could not have gotten close enough together). But so far, no research has been able to place a lower bound on the value.



The number of protective halos increases as the value of the cosmological constant increases (different colors of lines represents different values of the constant). The two graphs represent two different sizes of halos, though they give similar results: for example, both show that few halos existed more than 7 billion years ago, which fits with the age of the Earth being about 4.5 billion years old. Credit: Piran, et al. ©2016 American Physical Society

By showing that the chances of advanced life existing is extremely small when planets are close to gamma-ray bursts, the new study makes an argument for placing the first lower bounds on the value of the cosmological constant. The scientists estimate that, when the value gets below 10^{-124}, the number of protective "halos" of space (regions where planets stand a chance of avoiding gamma-ray bursts for long periods of time) sharply decreases. In other words, it would be pretty unlikely for humans to exist if the value were smaller than this number.

"We have found a lower limit on the cosmological constant," coauthor Tsvi Piran at The Hebrew University in Jerusalem told Phys.org. "As you know it is very small, 10^{-123}. If it is so small, then why not zero? Zero is a 'round' number and one can look for a basic law of physics that will force the cosmological constant to vanish. Additionally, why not a negative value?"

By showing that the cosmological constant is very unlikely to be zero or negative, and much more likely to be close to its observed value, the results may help explain where this value comes from.

"This is important as it gives clues to the question of what is the origin of this constant," Piran said. "It is generally believed that the value of the cosmological constant is determined by some quantum process, and understanding its relevant range is important to have a clue on its origin."

The full analysis is more complicated, as the researchers had to account for other factors, such as the age of the universe—it can't be too young nor too old for advanced life. It can't be too old because planets need to orbit around a hydrogen-burning star like our Sun, which is young enough that it has not yet reached the end of its lifetime. But the universe also can't be too young because a galaxy (where protective halos reside) must have time to undergo chemical evolution to produce metal elements. A high metallicity decreases the odds of having a nearby gamma-ray burst, since the stars that cause these bursts have relatively low metal concentrations.

It's not surprising that Earth seems to occupy a favorable point in the researchers' simulations: a place with minimal exposure to gamma-ray bursts, and at a time with many hydrogen-burning stars like the Sun, along with a high average metallicity. This special place and time may help researchers search for other possible locations of life in the universe.

"We would like to further refine this limit and extend the range of parameters (beyond just the cosmological constant) that influence the rate of gamma-ray bursts, and investigate their implications for the possible locations of planets that can harbor life," Piran said.

More information: Tsvi Piran, et al. "Cosmic Explosions, Life in the Universe, and the Cosmological Constant." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.116.081301. Also at: arXiv:1508.01034 [astro-ph.CO]

APA citation: Death by gamma-ray bursts may place first lower bound on the cosmological constant (2016, March 7) retrieved 13 March 2016 from http://phys.org/news/2016-03-death-gamma-ray-bound-cosmological-constant.html