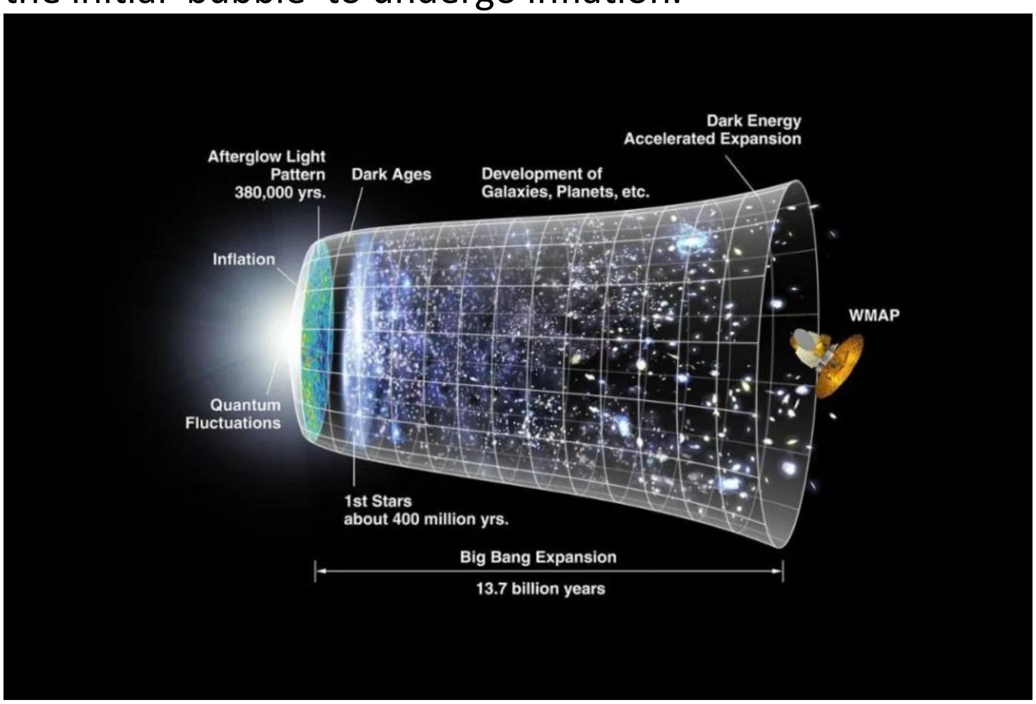
Gravity and Dark Energy: Who Will Be the Terminator of the Universe?

Abby Fan 2023,10,21

Beginning

"So, can these 'bubbles' just linger comfortably in space? Our universe surely can't just be a bubble in the end. Gravity would pull them together, causing all matter to collapse eventually. Therefore, these 'bubbles' can only escape rapid collapse caused by the gravitational field by expanding rapidly through a process called inflation. As a result, these 'bubbles' grow larger and eventually become universes, ours being just one of them, and physical theories only apply to this one. Has your view of the universe been overturned? However, I regret to inform you that humanity still cannot prove the truth of this theory because we cannot find 'inflationary particles,' which are particles that could cause the initial 'bubble' to undergo inflation."



By this point, your minds must be buzzing: What inflation? What vacuum? What quantum mechanics? Seriously, is there any straightforward way a regular person could think of to explain the birth and expansion of the universe?

Let's forget about quantum mechanics and go back to a time when physics wasn't this complex (those were some happy times)...

In fact, physicists observed long ago that it seemed like most stars were moving away from us, leading to two hypotheses: either we're the center of the entire universe or the whole cosmos is expanding. Obviously, the former idea was a bit far-fetched compared to the latter, so we widely accepted the theory of the universe expanding. Now, if the universe is expanding, it must have started from somewhere, right? Hence, scientists proposed that the universe "exploded" from an infinitely small and extremely dense point—that's the Big Bang theory mentioned earlier.

As for how the universe will end, it undoubtedly depends on how fast the universe is expanding; and this, in turn, is the result of a showdown between two mysterious forces...

Endgame

"In our first year of kindergarten, we learned that gravity attracts all objects with mass. In the second year, we learned that mass and energy can be converted into each other (conservation of mass-energy). So, in our third year, we could infer: energy attracts other forms of energy, pulling the entire universe together—um, did we learn this in kindergarten? Anyway, thus, the expansion of the universe was slowing down due to the influence of gravity. But now, we've discovered something astonishing: the universe is actually accelerating in its expansion?! Isn't this like bringing back a long-dead argument? Even though many scientists try to explain this issue by suggesting that radiation might repel objects, the overall amount of radiation is still too weak to counteract gravity. So, what now?

Since there's no known form of matter or energy that can patch up this loophole, astronomers straightforwardly employed their vast imagination, conjuring up a concept out of thin air: they called the energy capable of pushing the universe apart 'dark energy.' This approach is quite reminiscent of staring at the solution to a math problem and imagining the steps involved...

Therefore, now we have gravity provided by mass and energy, and repulsion provided by radiation and dark energy. So, which one prevails will determine the ultimate fate of the universe. When repulsion outweighs gravity, the universe accelerates its expansion. When repulsion is less than gravity, the universe starts to contract. 'You and me, heart to heart, getting closer and closer, closer and closer, closer and... boom!' No, can't go off-track again! In other words, how the universe's expansion will develop is essentially a battle between gravity and repulsion."

Cosmologists also proposed a physical quantity, the cosmic density (Ω), to describe the relative strengths of these two forces. But what exactly is this cosmic density? It might sound sophisticated, but in reality, it's quite simple—it's the total mass divided by the total volume. However, there's a catch: most of the matter in the universe exists in an invisible form, so we can only measure the approximate mass of this dark matter through gravitational effects. By combining the visible and invisible masses together, we arrive at the total mass and thus calculate an approximate density.

So here's the basic model in cosmology (<u>in simpler terms</u>):

When Ω is far less than 1, gravity is weaker than repulsion. When Ω equals 1, the two forces are evenly matched. When Ω is far greater than 1, gravity dominates the scene.

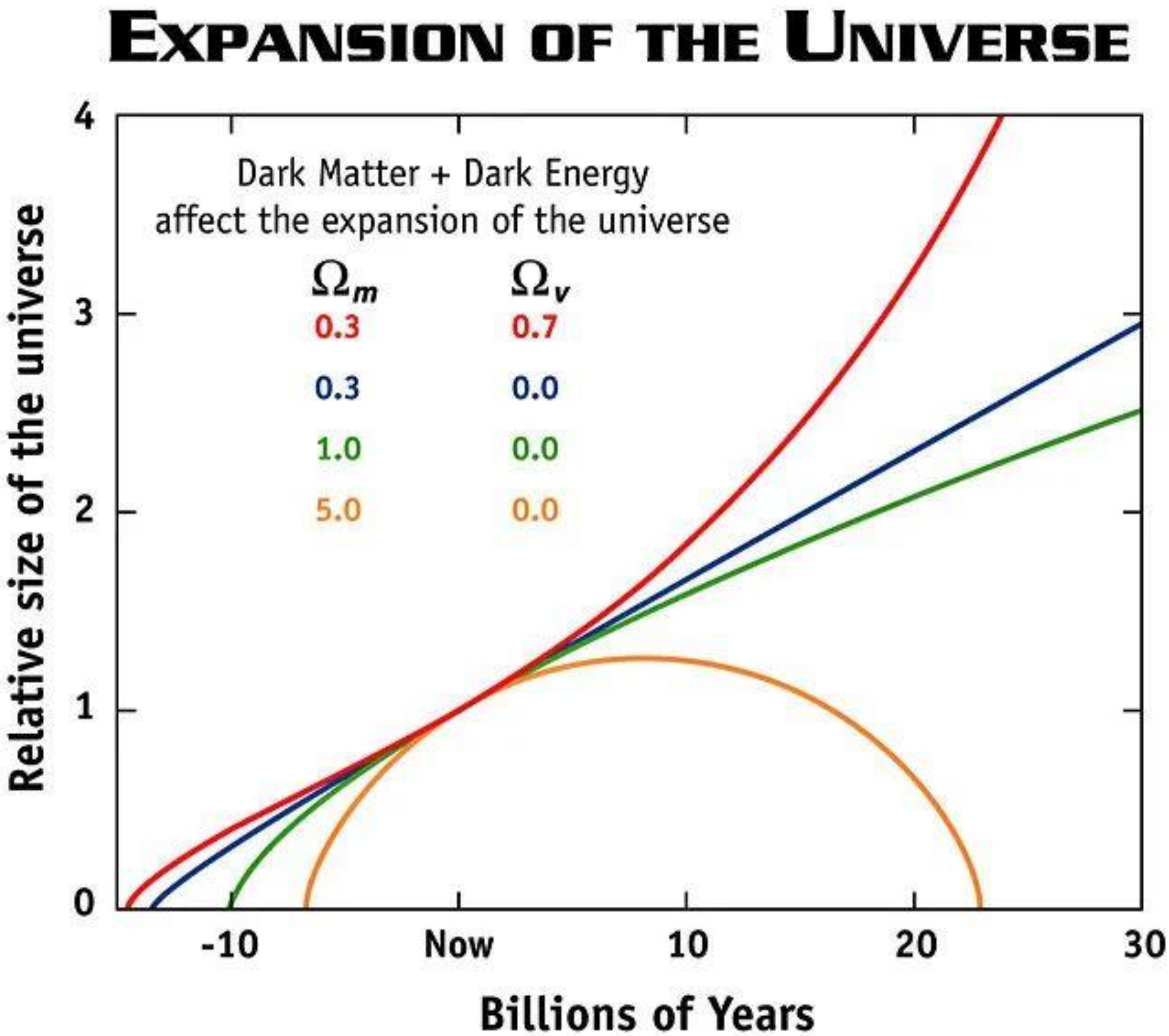
The ending

"Oh, not bad, I've finally set the stage! So, there are three generally recognized theories now: the Big Crunch, the Open Universe, and the Big Rip. Well, just from their names, it's evident that all these endings are bleak...

The first "deathly" scenario, the Big Crunch, was the most prominent in the 20th century and was somewhat idolized by numerous renowned scientists, including Einstein and Hawking. It describes a hypothetical future state of the universe: when gravity becomes extremely strong, continuously pulling everything together, the expansion of the universe halts. Then, a phase of "rejuvenation" begins, leading to a re-collapse into a singularity, possibly exploding again to form a new universe. So, one might conclude that the Big Crunch is a sort of rebirth for the universe! Now, considering the mathematical model I mentioned earlier, with $\Omega > 1$, gravity significantly surpasses repulsion, allowing the universe to "shrink." However, currently, most cosmologists believe the universe's density is only around 0.25 to 0.3—far from collapsing! In that case, let's turn to the second, more plausible possibility: the Open Universe—an outcome entirely contrary to the Big Crunch.

Another interpretation of the Open Universe is termed the "Big Freeze." In fact, this outcome is still a hypothetical state, occurring when $\Omega = 1$, where gravity in the universe exactly matches repulsion. It's not exactly dreadful, just enormously unfavorable: the distances between stars grow, galaxies drift away at a constant pace, matter disperses further apart. Eventually, stars extinguish one by one, but matter becomes too distant to reassemble via gravitational collapse into discs or stars. So, while the universe may generate stars due to random events, due to the vastness of space and the scattered distribution of energy, the universe, overall, loses its vitality. Essentially, the universe gradually enters the era of neutron stars and white dwarfs, but as time progresses, neutron stars decay massively, leading to the dark era of black holes. Yet, even these "giants" won't endure indefinitely—having evaporated due to consuming no material, they leave behind naked singularities, and subsequently, the universe becomes utterly "void," reaching a state of 'existence' without "substance": this is the "heat death." Rather than a fiery conclusion, the universe faces an end amid endless frigidity. Frankly, that's not death, it's more like a "zombie state," devoid of any possibility of revival. In short, with no energy sources left, the universe essentially enters an eternal "ice age," so the name "Big Freeze" fits quite literally. Alright, at this point, there's not much more to say—my heart's freezing, feeling a chill in the future...

Finally, there's the "Big Rip," where dark energy (also known as repulsion) takes center stage. In reality, scientists calculate that 68% of the universe consists of dark energy, which we simply cannot perceive, yet it continually influences the universe's evolution. For instance, there's a type of dark energy called 'phantom dark energy', capable not only of accelerating the expansion rate but even causing the acceleration itself to perpetually increase. The consequence is that the universe expands at a geometric rate, faster and faster, akin to a ghostly manifestation, eventually leading to the so-called "Big Rip." The intense repulsion from dark energy and rapid expansion are no longer governed by mutual gravitational attraction, meaning $\Omega < 1$—gravity significantly less than repulsion: galaxies drift farther apart, the Earth and the Sun part ways, even atomic attractions cease. Thus, in the final moments of destruction, from atoms to the entire universe, everything tears apart, including time and space themselves. The Milky Way was destroyed 6 million years before the "Big Rip," the Sun obliterated 28 minutes ago, the Earth exploded 16 minutes ago, and atoms were torn apart in the last 10 to the power of -19 seconds... terrifying, right? Feels quite frightening, but it all depends on the extent of this tearing. If spacetime survives because a black hole is a singularity with infinite smallness, infinite density, and warping spacetime itself, then it manages to persist... but that's practically no different from nonexistence!"



(Horizontal axis represents time, and the vertical axis represents the size of the universe. The red line depicts the Big Rip, where the universe rapidly expands; the green line represents the Big Freeze, while the yellow line signifies the Big Crunch.

Conclusion

Feeling quite despairing? Take a deep breath now, because a turning point is about to unfold!

Firstly, we have yet to observe dark energy, so dark energy is currently only a form of energy "created" in theory. We have no way of understanding its nature, and therefore, we cannot know how it will change in the future or affect the expansion of the universe.

Secondly, even if our universe is heading towards one of the tragic endings, the time span involved is immensely long: the current age of the universe compared to the time when all stars die is as fleeting as an hour in a person's lifetime, so there's no need to worry about the ultimate fate of the universe.

In fact, the fate of the universe has long been a source of inspiration for scientists, both as a physics problem and a philosophical question, motivating countless researchers to continuously explore the essence of the cosmos. Vast stars glitter in the night sky, shrouded in endless secrets behind a veil, and each step humanity takes to uncover these mysteries signifies a milestone in natural science. The destiny of the universe is the ultimate question of this world. For human civilization, still in its cradle on Earth, it inspires us to continually explore with curiosity and reverence for nature: if civilization is a ship in the fog, then the boundless charm emitted by the universe is undoubtedly the dazzling light of a distant lighthouse, guiding us firmly towards the future in pursuit of science and truth!

Citing:

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