Doomsday scenarios are frequently portrayed in film and literature, but these man-made or natural disasters—ones that wipe out the human race either in the blink of an eye, or over a longer and usually very painful period—pale when considering the ultimate fate of the universe. Doomsday is terrifying because it indulges our anthropocentric selfishness, but comprehending the complete obliteration of the totality of everything—space, time, matter, energy, all governing physical laws—is existential absurdity that the typical inward-looking nihilist cannot grasp. Therefore, it is left to the cheerful among us to look beyond our meager biological form and attempt to comprehend the true meaning of absolutely nothing.

*—Russell Quinn*

# THE ULTIMATE FATE OF THE UNIVERSE

*Start here*

## THE SHAPE OF THE UNIVERSE?*

### DARK ENERGY

The universe appears to be expanding at an accelerating rate, and dark energy (DE)—not to be confused with dark matter—is the theoretical source of energy used to explain this phenomenon. According to most cosmological models, DE accounts for 73 percent of the total mass-energy ($E=mc^2$) of the universe. The actual form of DE is the biggest unknown when speculating about the universe's ultimate fate. The density of DE in space could grow until it dominates all other forces, tearing apart gravitationally bound structures and eventually atoms ("The Big Rip"), or it could dissipate over time, leaving gravity to rule and causing the universe to contract and collapse ("The Big Crunch"). The best guess, however, is the Lambda-CDM model in which the density of DE stays fixed, the Milky Way eventually collapses to a black hole, and it all ends with "The Big Freeze."

**OPEN** — *Less DE* / *More DE*

**FLAT** — *More DE* / *Less DE*

**CLOSED** — *Less DE* / *More DE*


*Fate reached slower* / *Fate reached faster*

### BIG BOUNCE

*Asking what happens after the Big Crunch is much the same as asking what happened before the Big Bang. Einstein briefly considered the possibility of a cyclic universe with an infinite number of oscillations, each starting with a bang and ending with a crunch. More recently, loop quantum cosmology has proposed that a universe does not crunch into an absolute singularity, but to a point where gravitational forces become repulsive, triggering a bounce.*

### BIG CRUNCH

*A closed universe of finite size will continue expanding for another 50 billion years—until its radius has just about doubled—before it reverses and begins to contract at the same rate. After about 60 billion more years, background radiation will rise, eventually killing all life, before the galaxies merge with one another, the stars collide, and finally neutrons and protons are ripped from nuclei. All matter will collapse into a tiny entity of near-infinite density.*

### BIG FREEZE

*The second law of thermodynamics states that heat flows unidirectionally from hot to cold. Given enough time, the universe will reach a point where all energy is evenly distributed as zero-temperature black holes. Since there will be no matter outside of these black holes to fall into them, and there will be no temperature differentials to be exploited to do work, nothing will happen in this maximum-entropy universe. This is also known as "heat death."*

### BIG RIP

*In an infinitely expanding universe, where dark-energy density increases with time, the rate of expansion, and therefore the scale, is also infinite. Eventually galaxies and solar systems will become gravitationally unbound. Millions of years later, stars and planets will be torn apart. An instant before the end, all matter will disintegrate into either radiation or fundamental particles without substructure.*

### FALSE VACUUM

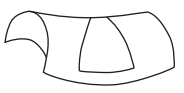
*It's possible that there is a lower energy state than the vacuum of space, which is simply a temporarily stable, local minimum. If a bubble of lower energy was instantiated, our current vacuum might tunnel into it, changing all physical constants, and therefore matter, energy, and space-time. Without warning, all structures could be instantly destroyed.*

## *WHAT SHAPE IS THE UNIVERSE?

Will the universe continue to expand forever, or will it eventually slow and contract? Assuming the basic validity of the general theory of relativity and the homogeneity of the universe, there are three theoretical shapes the universe can take: open, closed, or flat. These are called the Friedmann Models, and they inform the possible end scenarios.

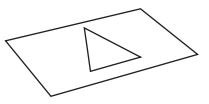
### OPEN (INFINITE)

There is not enough matter in the universe for it to be able to stop itself from expanding forever. Space is infinite, can be described by hyperbolic geometry, and would resemble a three-dimensional, infinitely extended saddle shape.



### FLAT (INFINITE)

The mass of the universe is just sufficient to stop continual expansion, meaning the rate will slow so that, given an infinite amount of time, expansion will eventually cease completely. Traditional Euclidean geometry is valid throughout this model.



### CLOSED (FINITE)

Spherical in shape, the universe may either continue expanding indefinitely, given enough dark energy, or could eventually reach a maximum scale and then start to contract. It would be possible to circumnavigate.

*Recent academic thought makes a closed universe without dark energy seem unlikely, and in 2001 the Wilkinson Microwave Anisotropy Probe found—with a 0.5 percent margin of error—that we're inhabiting a universe that is either flat or so close to flat that we cannot detect the difference yet. However, while the Big Crunch and the Big Bounce seem no longer supported, they are not ruled out.*

**Compiled and designed by Russell Quinn**

**Scenario illustrations by Holly Wales**