

Announcements

- Exploration paper 1 due today at 11:59pm
- Problem 3 due Feb 14 at 11:59pm
- Quiz 2 on Feb 12 (100pts)
 - 1 hr, available from 11am-11:59pm
 - See study goals on Canvas
 - Covers chapter 2 and lecture material

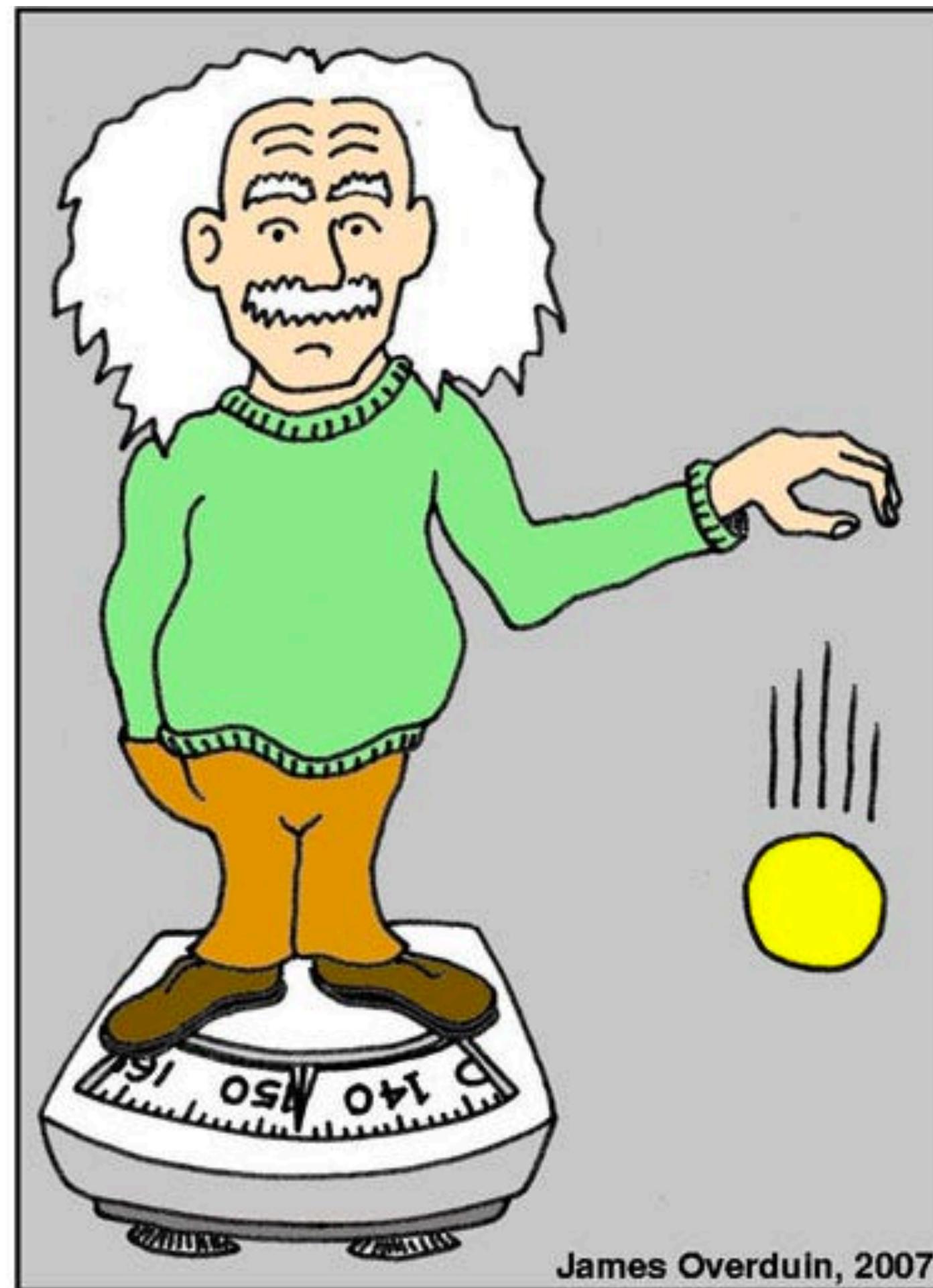
You must return your experimental materials for credit!

Einstein's Equivalence Principle in the Elevator

When the elevator starts or stops, can you tell if you are experiencing an acceleration ... or a change in the force of gravity?



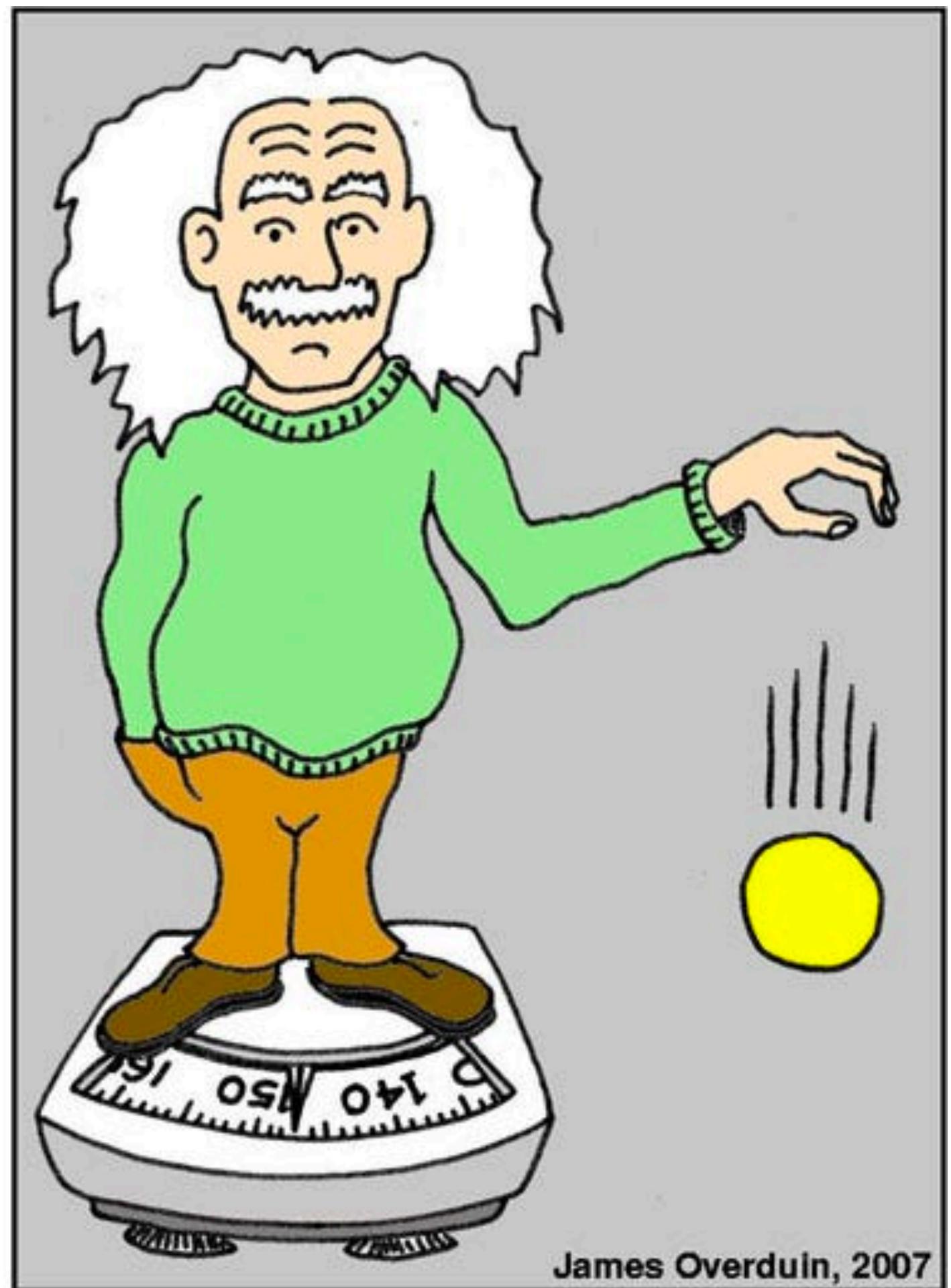
Einstein's Equivalence Principle in the Elevator



Results: 780 measurements
in 16 different elevators

Spring 2024: $a = (0.096 \pm 0.002) \times g$

Einstein's Equivalence Principle in the Elevator



Results: 780 measurements
in 16 different elevators

Spring 2024: $a = (0.096 \pm 0.002) \times g$

Fall 2023: $a = (0.093 \pm 0.001) \times g$

Spring 2023: $a = (0.106 \pm 0.001) \times g$

CMU elevators impart $\sim 0.1g$

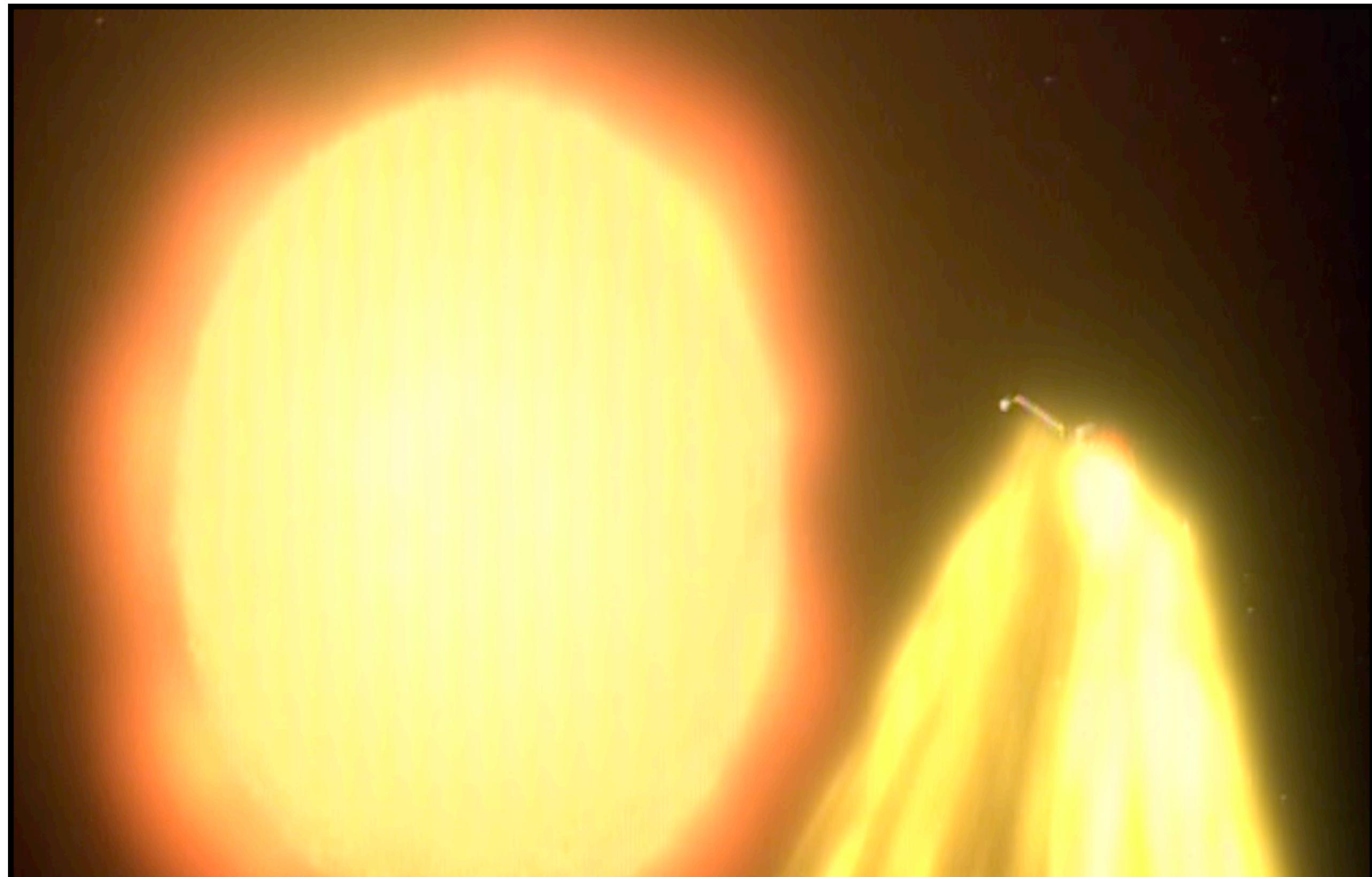
More detailed results next week!



Star Trek IV:
The Voyage Home

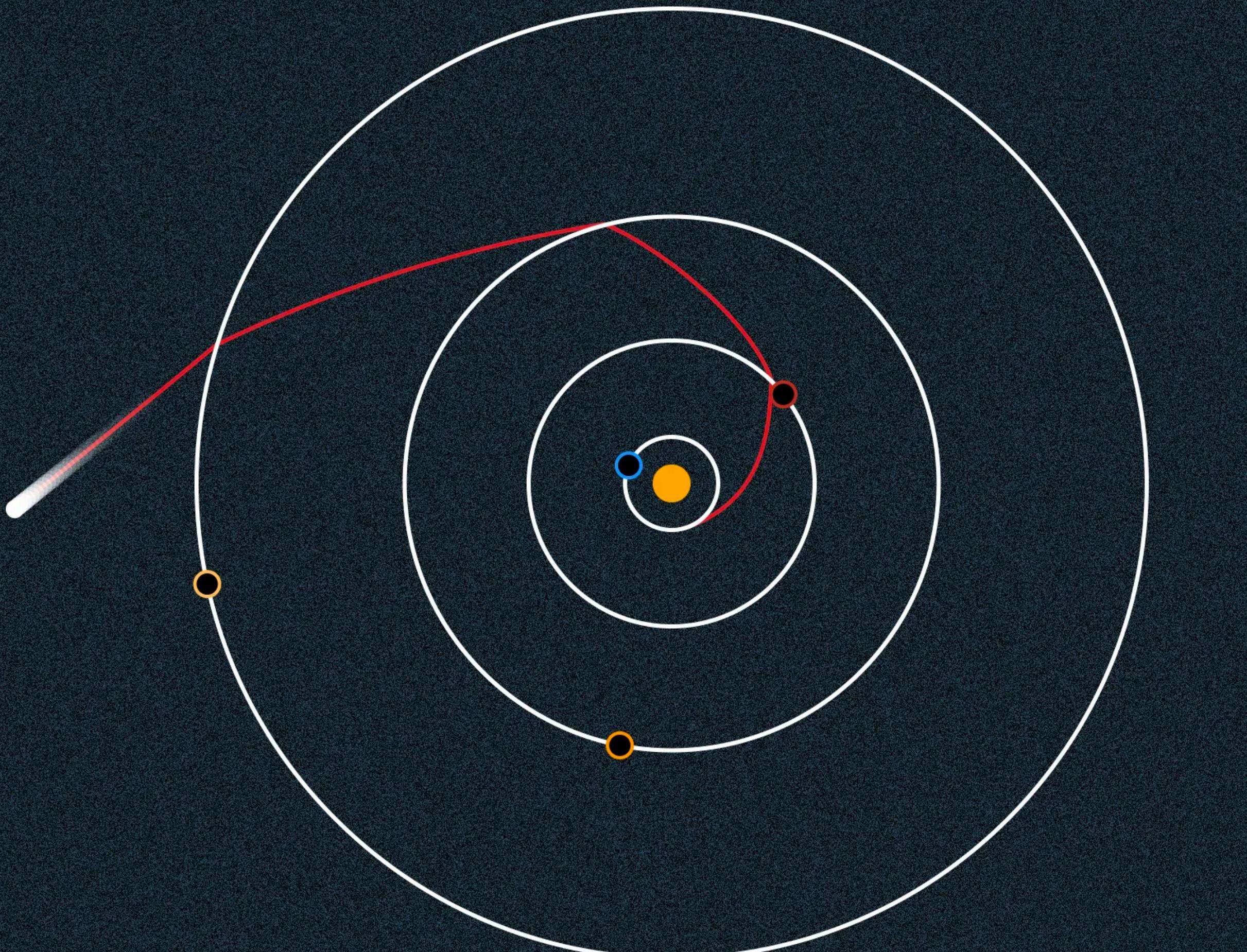
Directed:
Leonard Nimoy

Paramount (1986)



A gravity assist from the Sun's curved spacetime while at warp speed to go back in time?

Definitely not possible with current general & special relativity descriptions



Gravity assists with
Newtonian gravity are used
with most spacecraft!

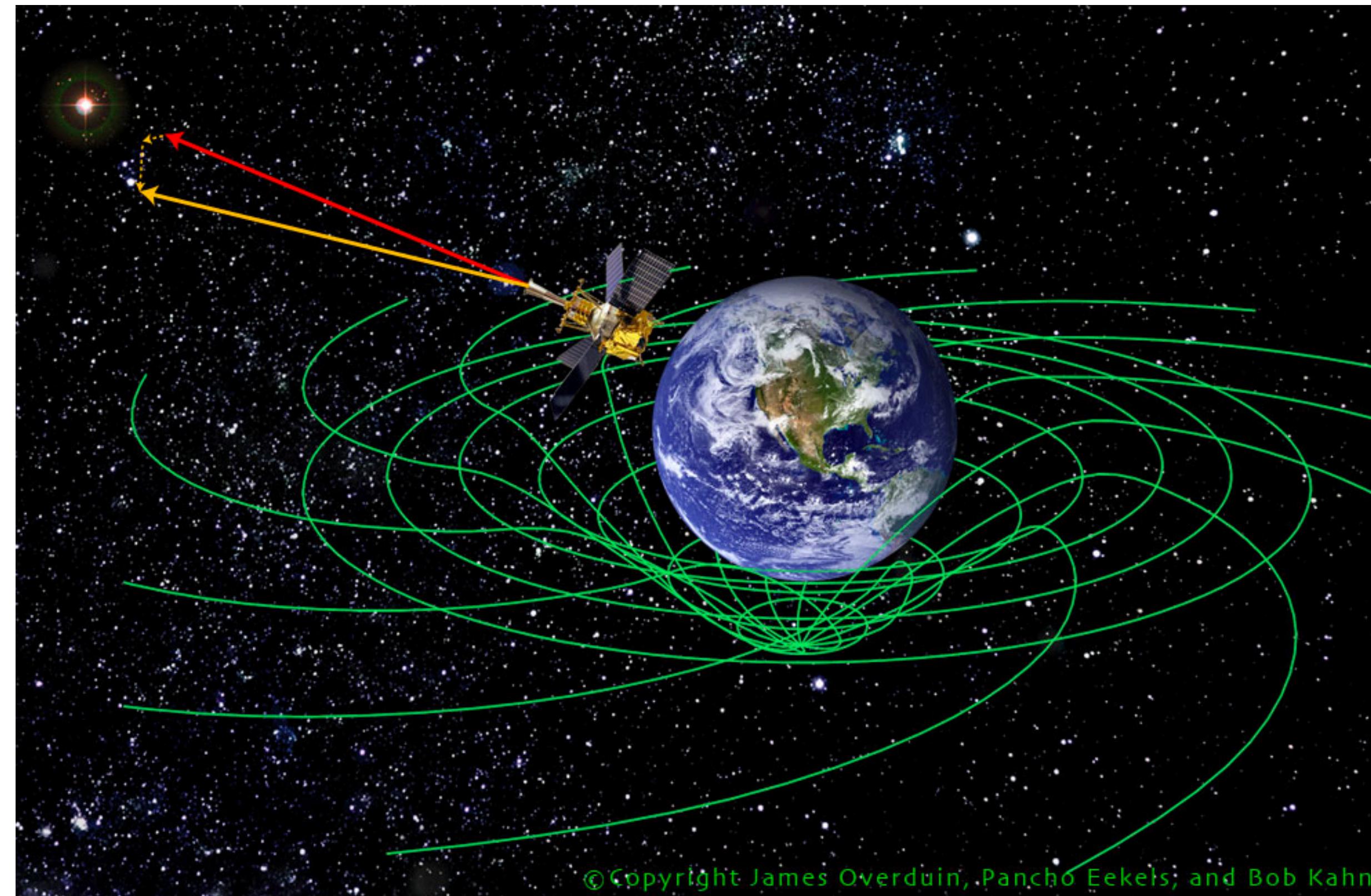
New Horizons was
launched toward Pluto 15
years ago and used Jupiter's
gravity as an assist in it's
travel

Gödel Universe

A spinning Universe which can allow for “closed timeline curves” in which the past and the future intersect

No current evidence for a spinning Universe but it is allowed mathematically





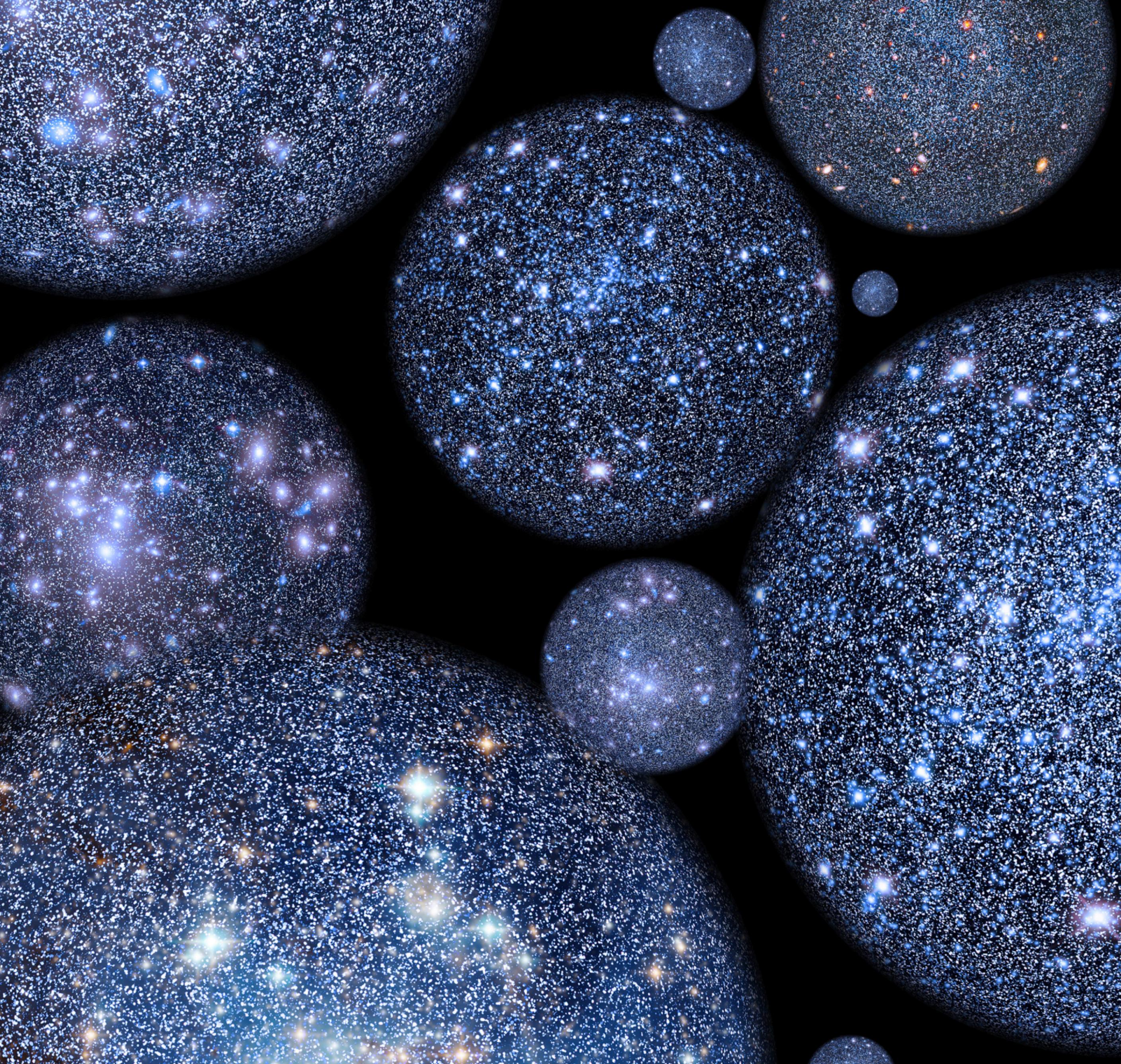
There is evidence for spinning spacetime due to massive spinning objects — “frame dragging”

Gravity Probe-B measures this effect while it orbits the Earth!

Time travel summary:

Time travel into the future is ***very*** possible with both special and general relativity

Time travel into the past is ***very much not*** possible with either special or general relativity **unless you can figure out how to make a long-lived wormhole!**

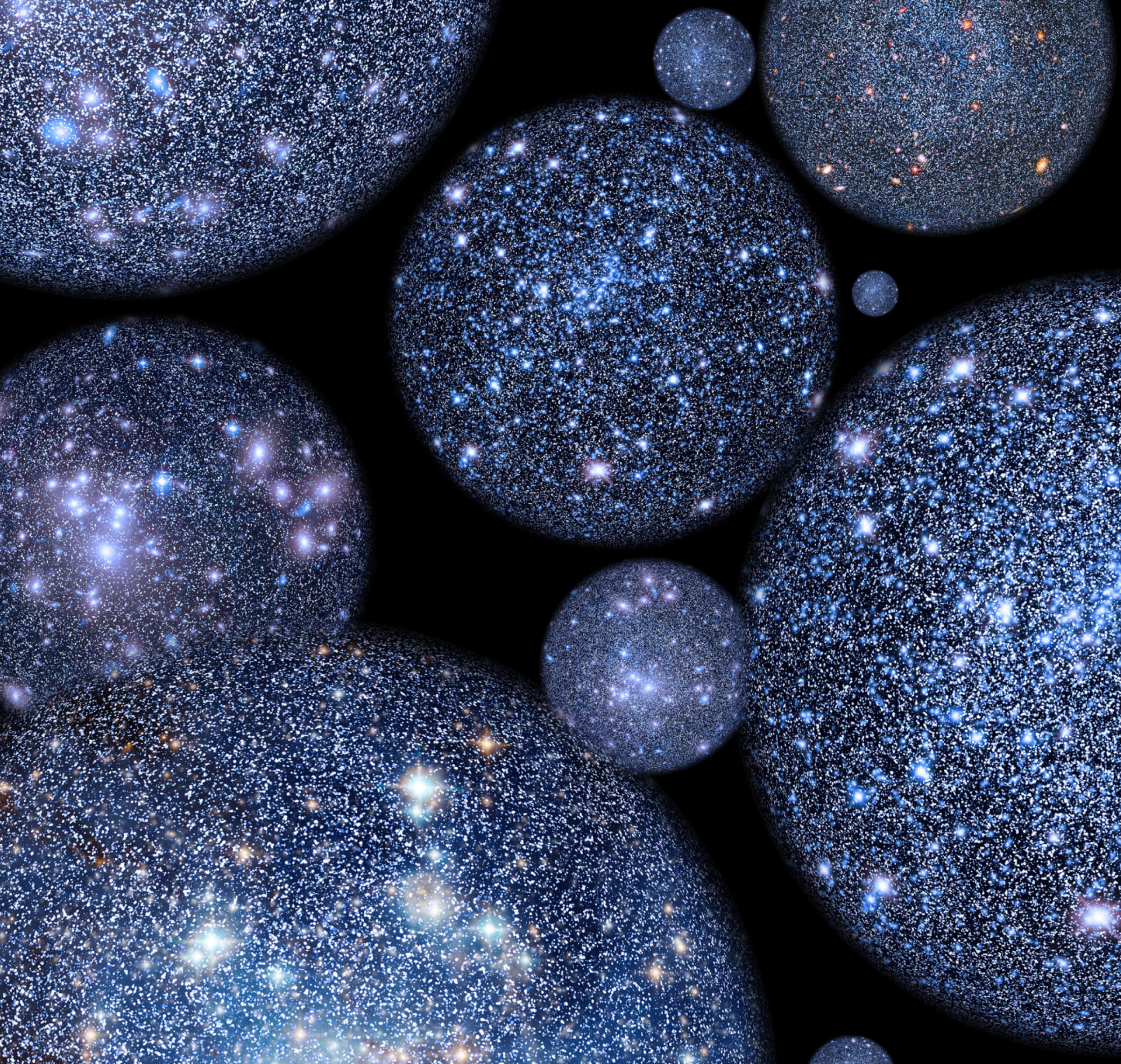


The Multiverse Hypothesis

Is our Universe the
only universe?

How do we know?

Can we know?

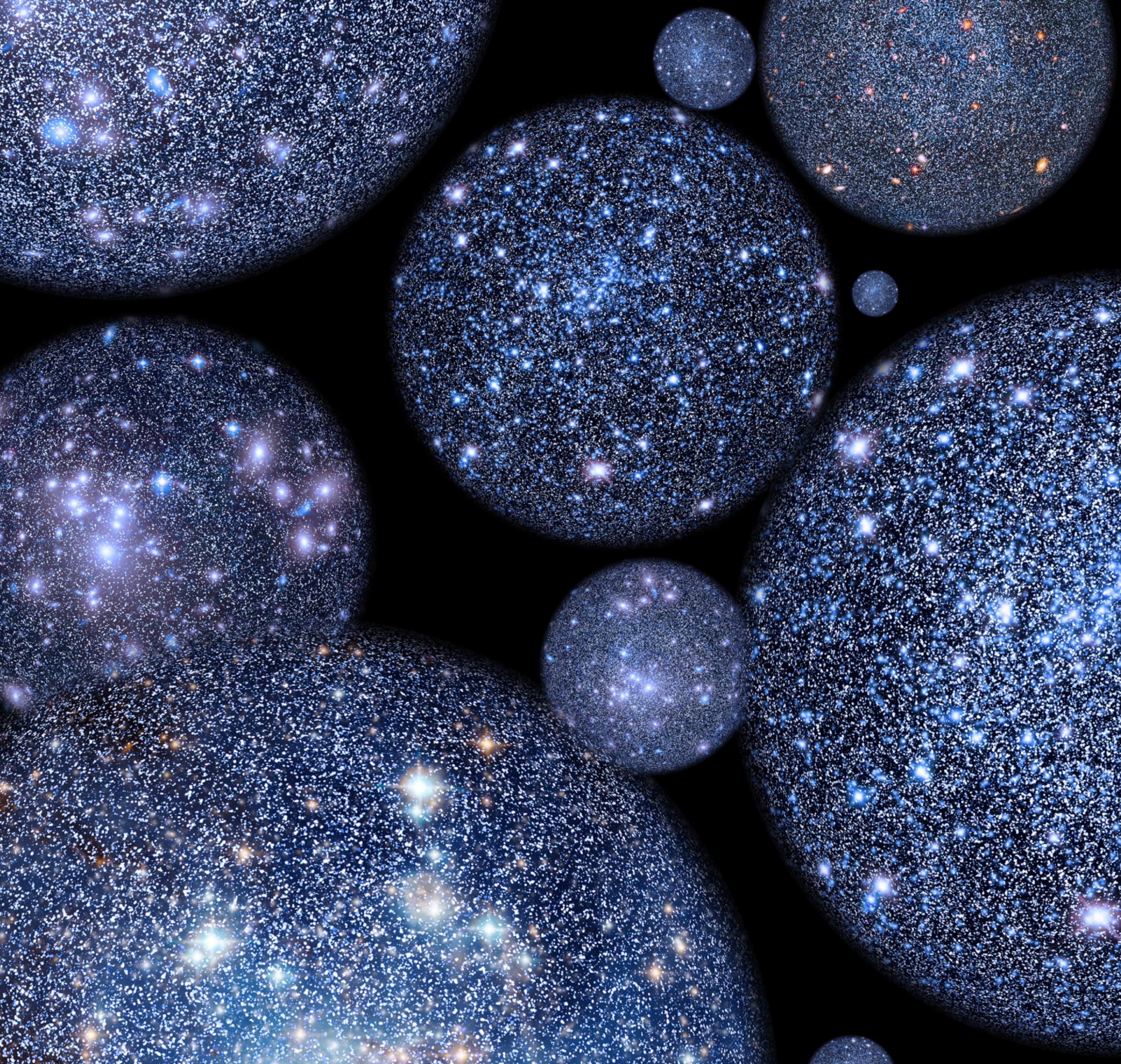


Why does the multiverse hypothesis exist?

No single reason; it's been
theorized since the
ancient Greeks!

Fairly hotly debated by
proponents and critics

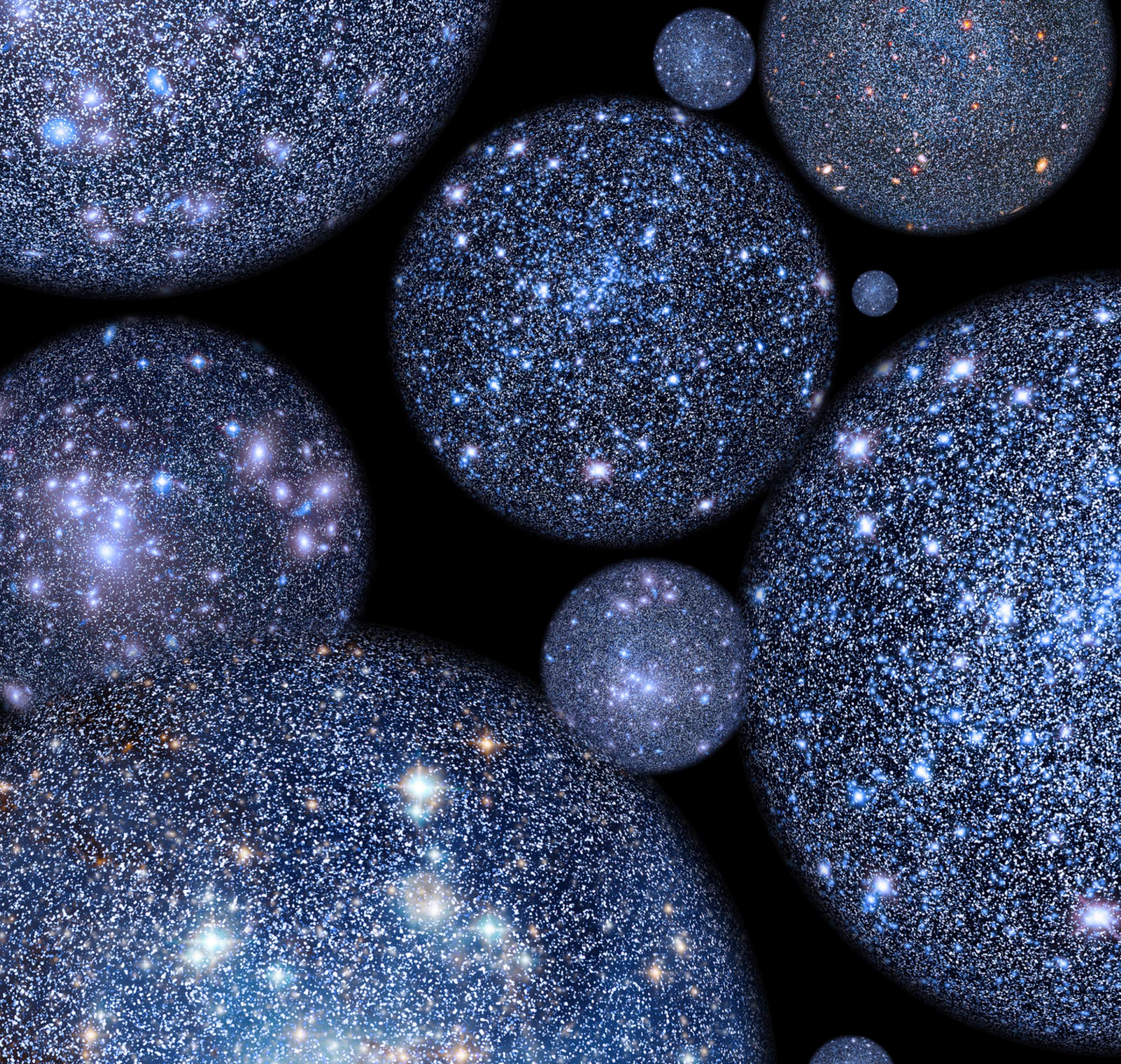
Could be an explanation for our
Universe's seemingly arbitrary
physical constants



Max Tegmark's 'level' classification

Level 1: An extension of our own Universe

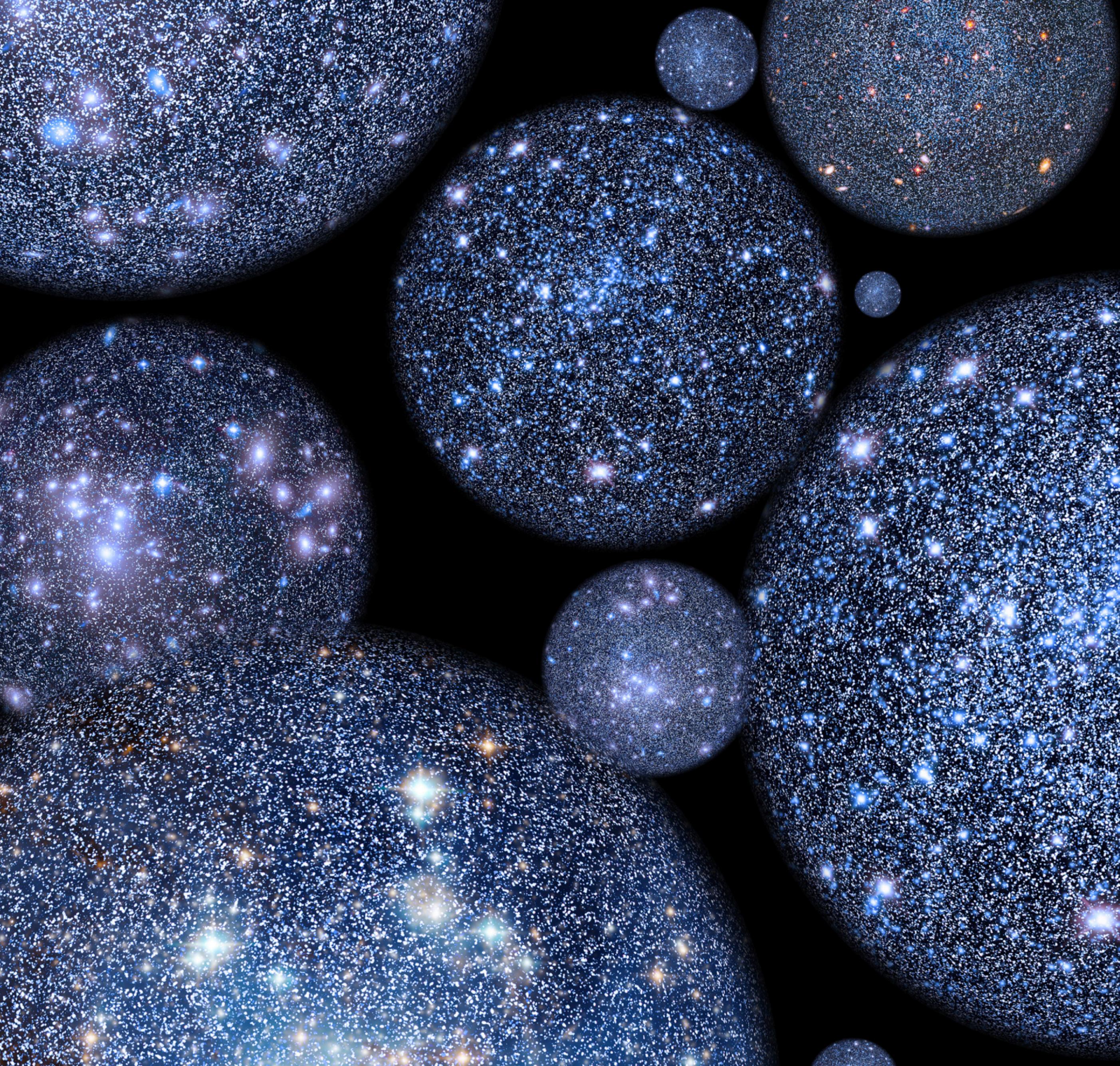
Other universes extend beyond the horizon of what we can observe from the light that first emitted in our own Universe — a different you in a different universe



Max Tegmark's 'level' classification

Level 2: universes with different physical constants

Other universes extend beyond the horizon of our own Universe and have *different laws of physics*



Max Tegmark's 'level' classification

Level 3: many worlds

Anything that can occur with nonzero probability does occur just in other universes



Fringe

“Peter”

Teleplay:
Jeff Pinker, J.H. Wyman,
Josh Singer

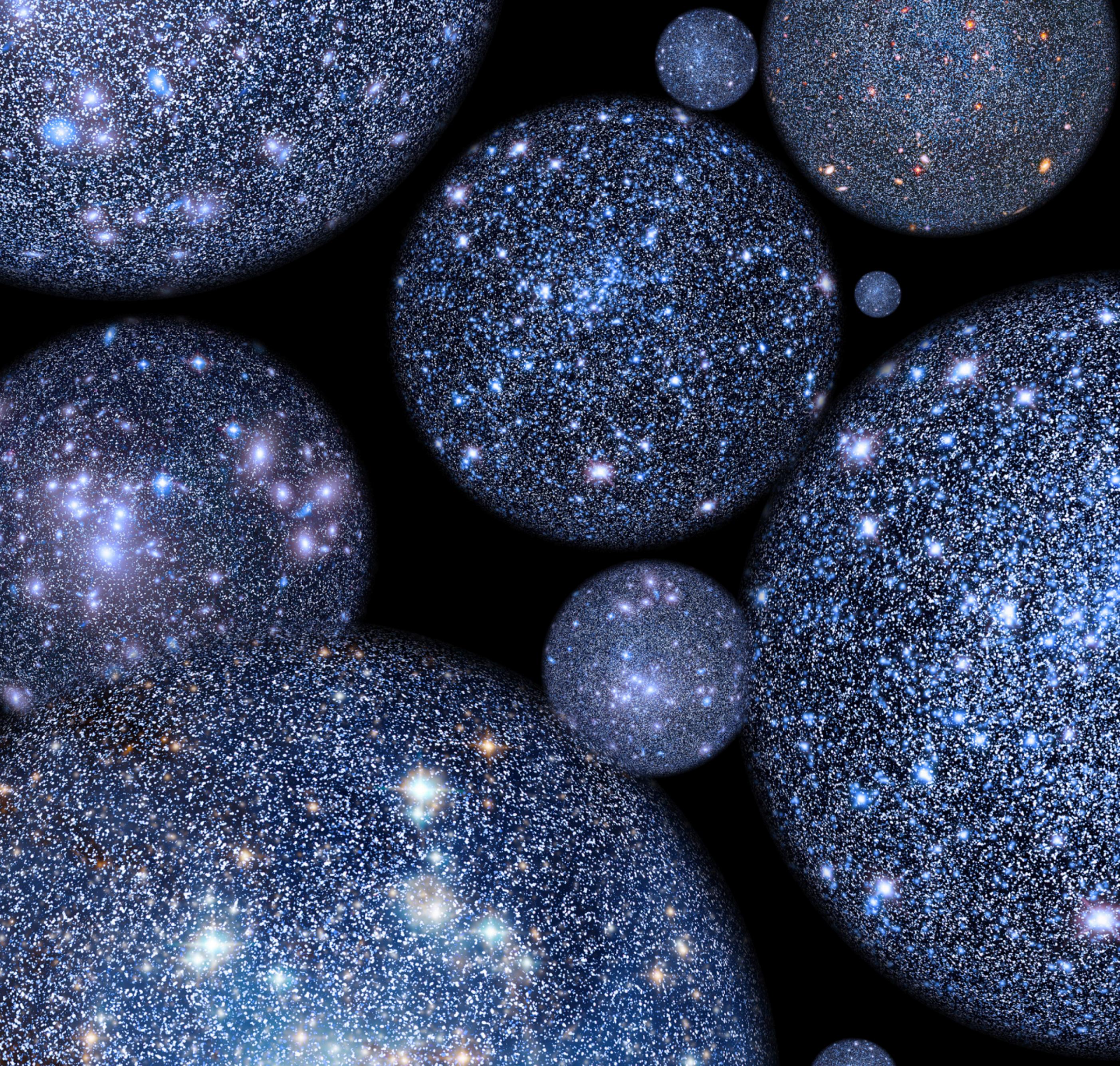
Warner Brothers (2010)



Star Trek: The Next
Generation
“Parallels”

Written:
Brandon Braga

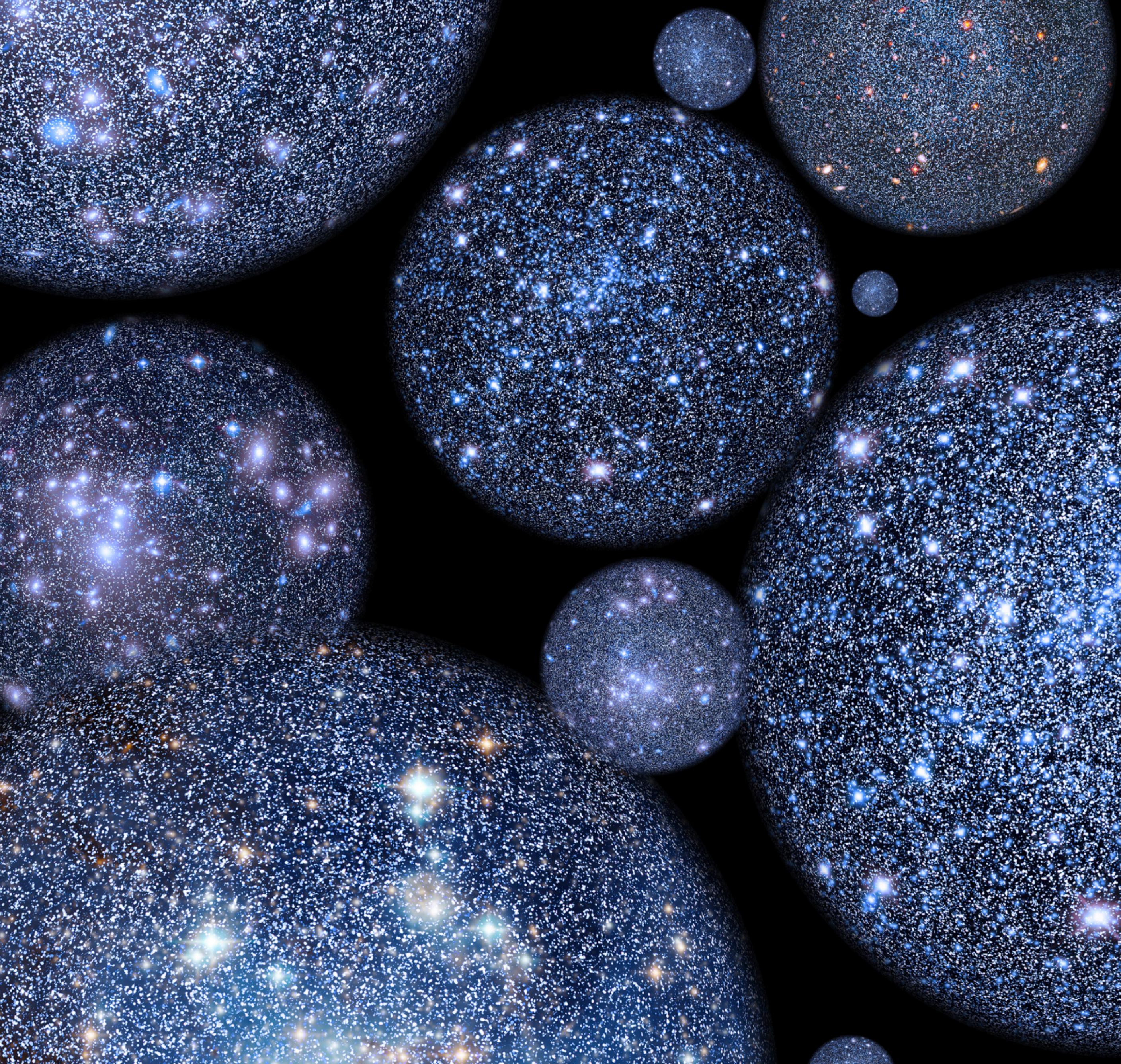
Paramount (1993)



Can the multiverse
hypothesis be tested?

Some critics say: no.

If the universes are not
causally connected —
verification is not
possible



Can the multiverse hypothesis be tested?

Some proponents say:
it's worth checking.

Observations of the early Universe may have weird features that are unexplainable

About as likely as opening a worm hole

Next time:

- ▶ Begin 2nd big question:
What is the Universe made of?