

HOW BIG IS THE WORLD?

EXPLORING THE MULTIVERSE IN MODERN ASTROPHYSICS,
COSMOLOGY, AND BEYOND

Detlev van Ravenswaay via Getty Images

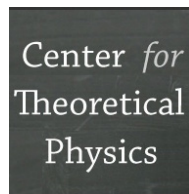
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UC San Diego, Arthur C. Clarke Center for Human Imagination

SPEAKERS



Dr. David Brin
(UCSD)



Prof. Brian Keating
(UCSD)



Dr. Andrew Friedman
(MIT)

CURRENTLY IN ANOTHER UNIVERSE...



Prof. Alan Guth
(MIT)



Prof. Max Tegmark
(MIT)



**The Multiverse
Institute of
Technology**

ARTHUR C CLARKE CENTER FOR HUMAN

IMAGINATION



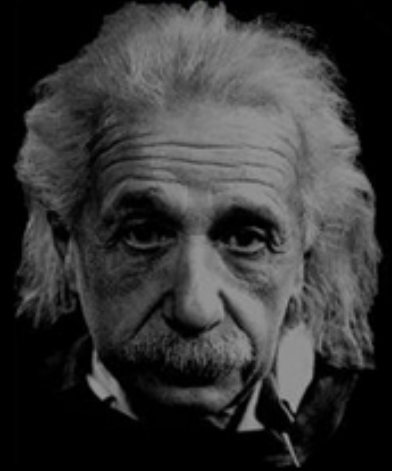
“The only way of discovering the limits of the possible is to venture a little way past them into the impossible.”

Arthur C. Clarke (1917-2008)



“Imagination is more important than knowledge.”

Albert Einstein (1879-1955)



HOW BIG IS THE WORLD?



Olaus Magnus, 1527-39, http://en.wikipedia.org/wiki/Carta_marina

“Here Be Dragons”

🌍 To our ancestors, Earth seemed infinite



http://commons.wikimedia.org/wiki/File:Flammarion_Woodcut_1888_Color_2.jpg

COPERNICAN PRINCIPLE

Center of the Universe?



NO!

LEVELS OF THE MULTIVERSE

I Beyond horizons

II Inflationary bubbles

BRIAN'S
TALK

III Quantum worlds

IV Other laws of physics

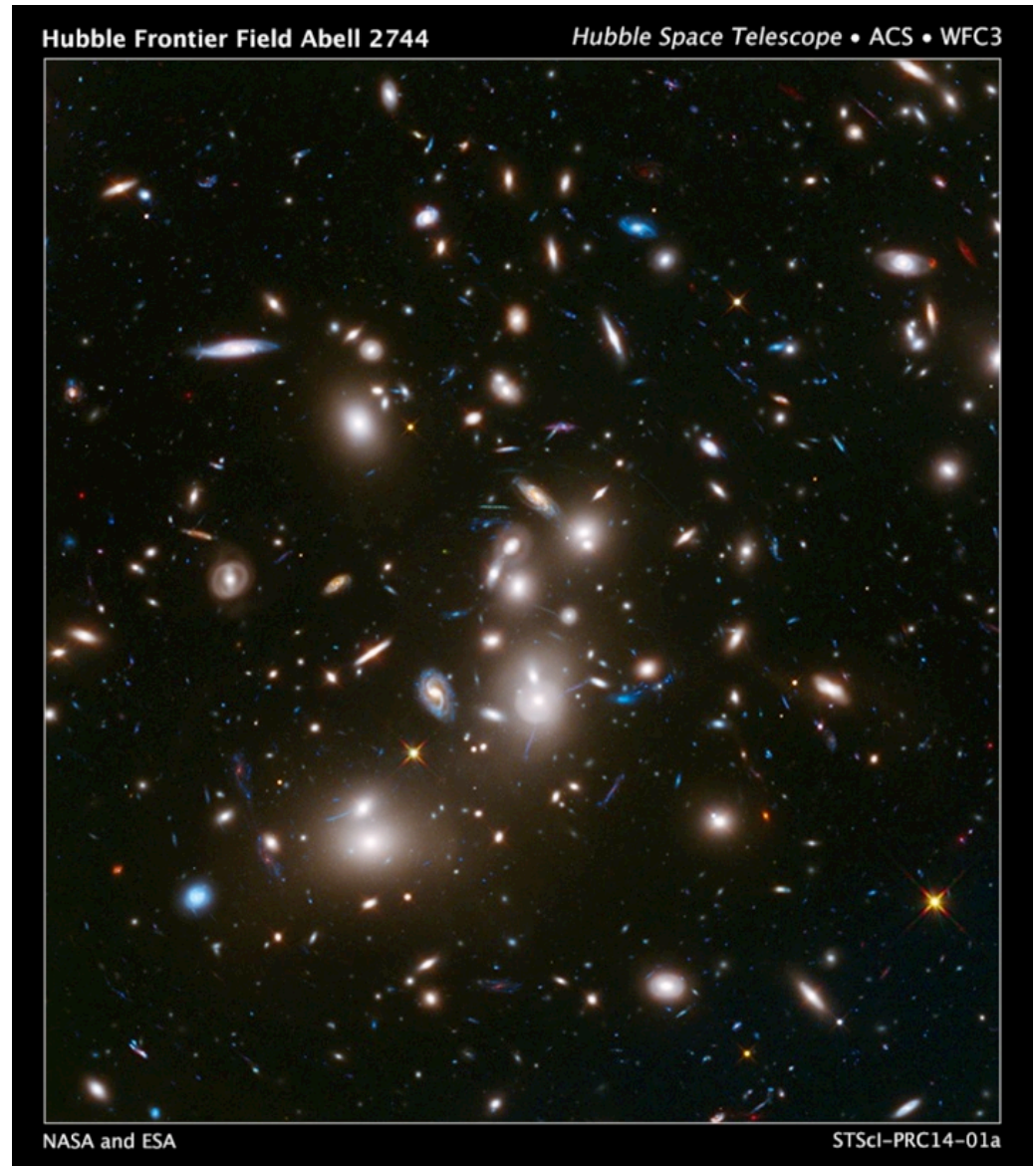
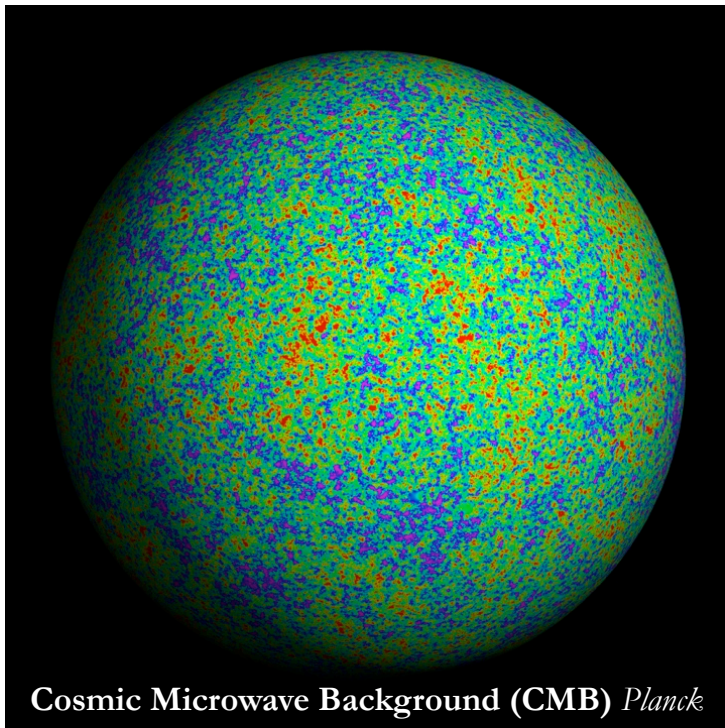
...and many more

DAVID'S
TALK

How many levels?

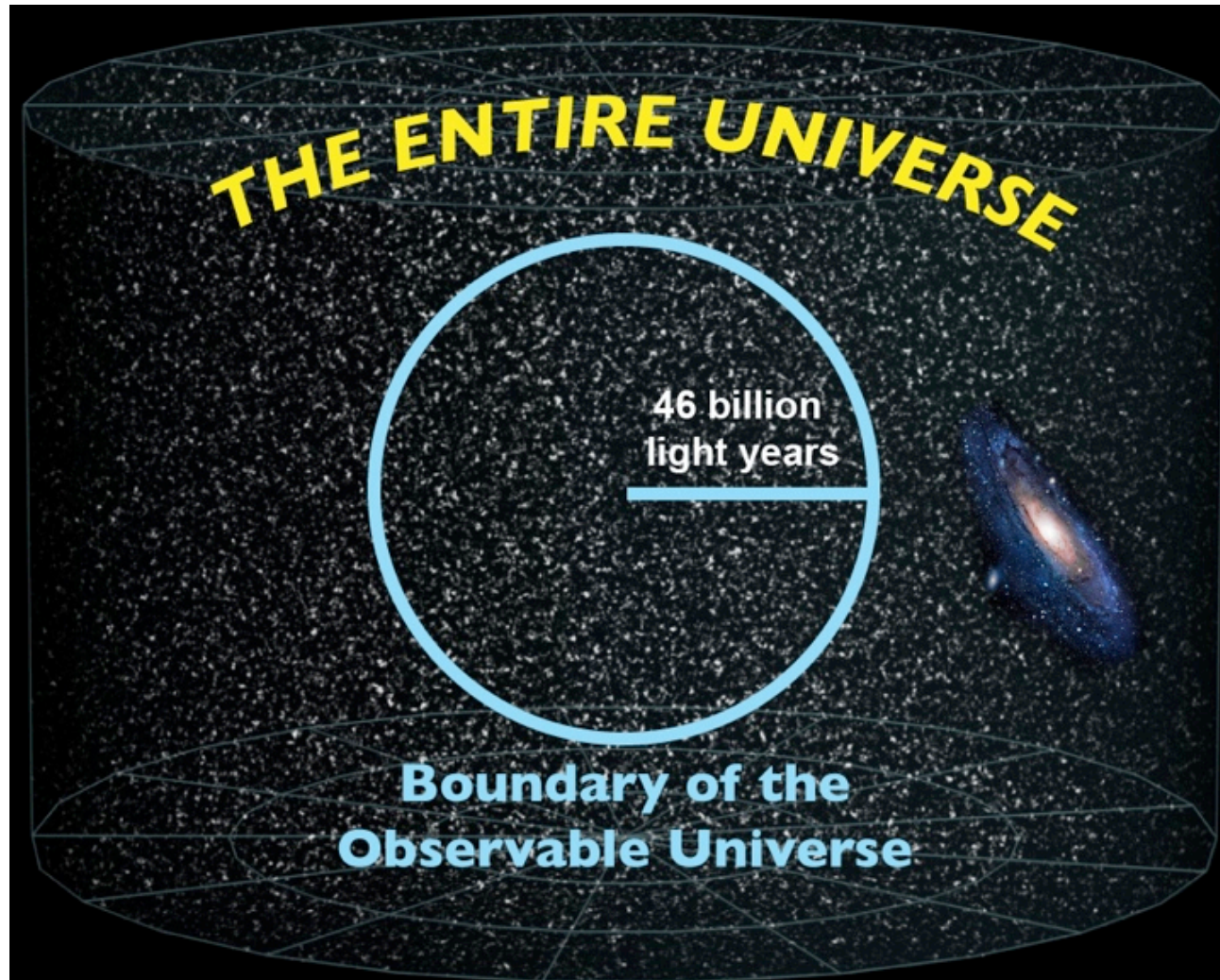
HOW FAR CAN WE SEE?

 **Finite time**
for light to travel
since **Big Bang**



LEVEL I MULTIVERSE

Places Beyond Our Horizon



Modified from S. Larson, <https://writescience.wordpress.com/tag/cosmology/>



What we can see is not everything!

INFLATION

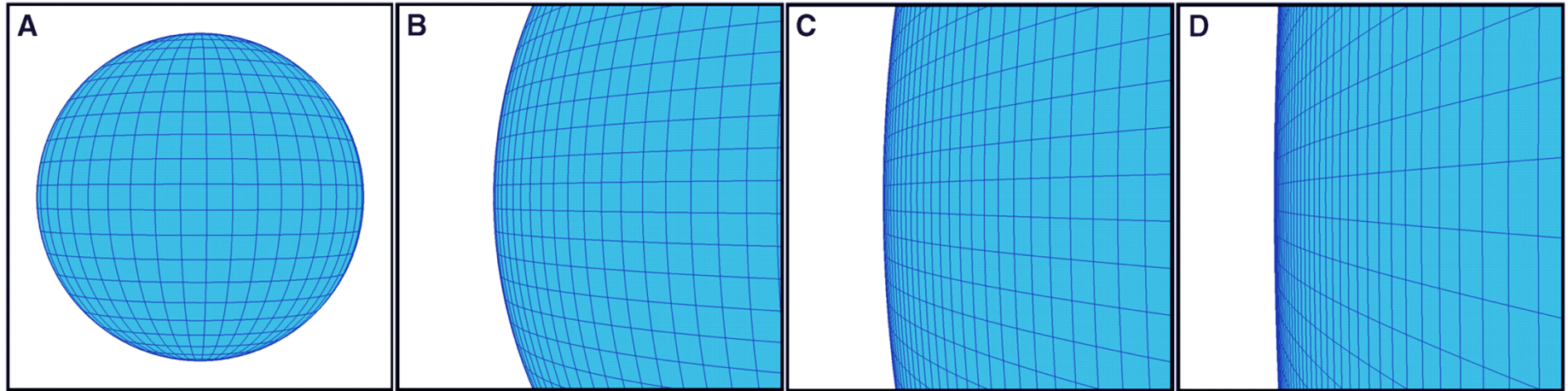


Image Credit: Ned Wright, UCLA

 Solves cosmological problems

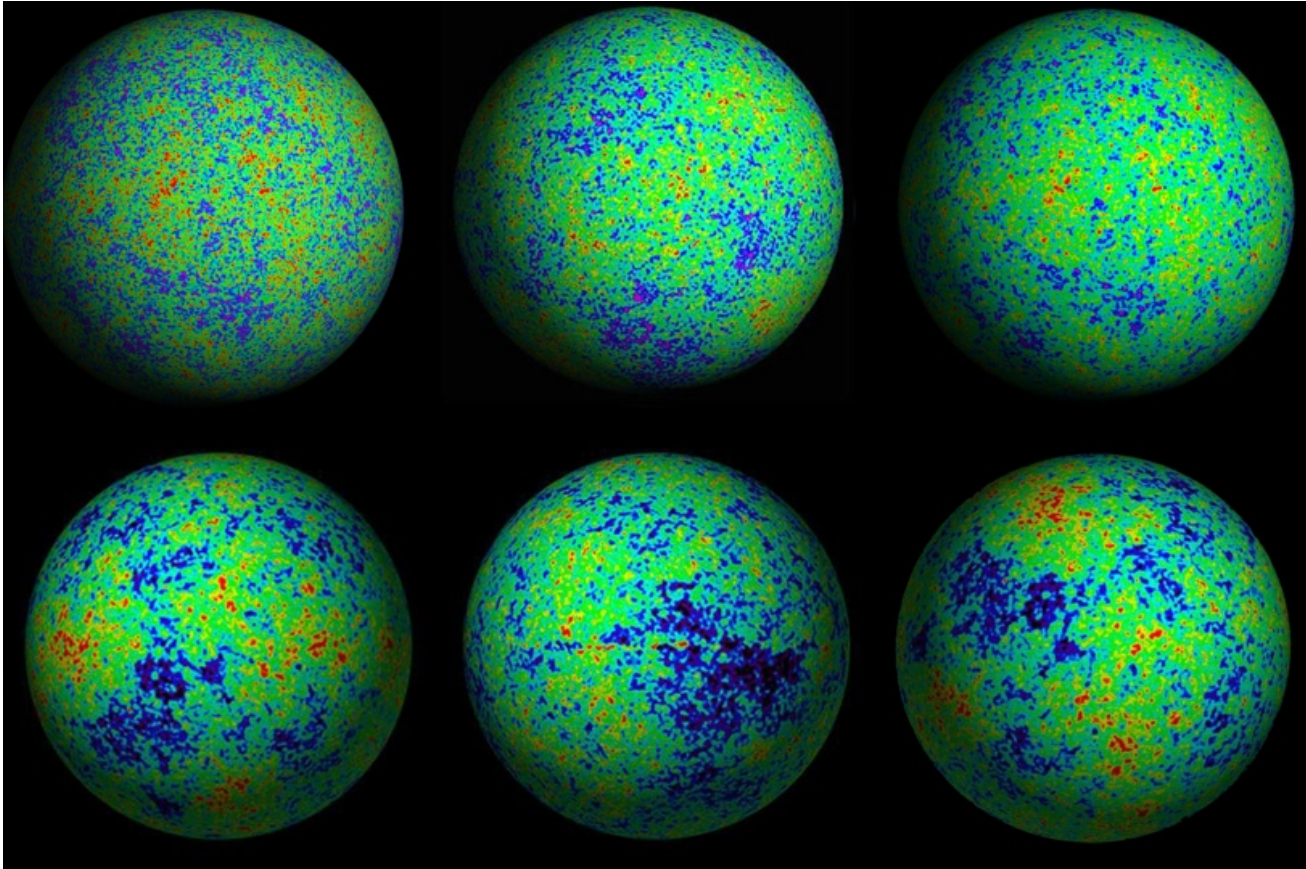
 Many testable predictions

BRIAN'S
TALK

Space much larger than part we see!

LEVEL I MULTIVERSE

- Same laws, constants
- Different *initial conditions*, outcomes

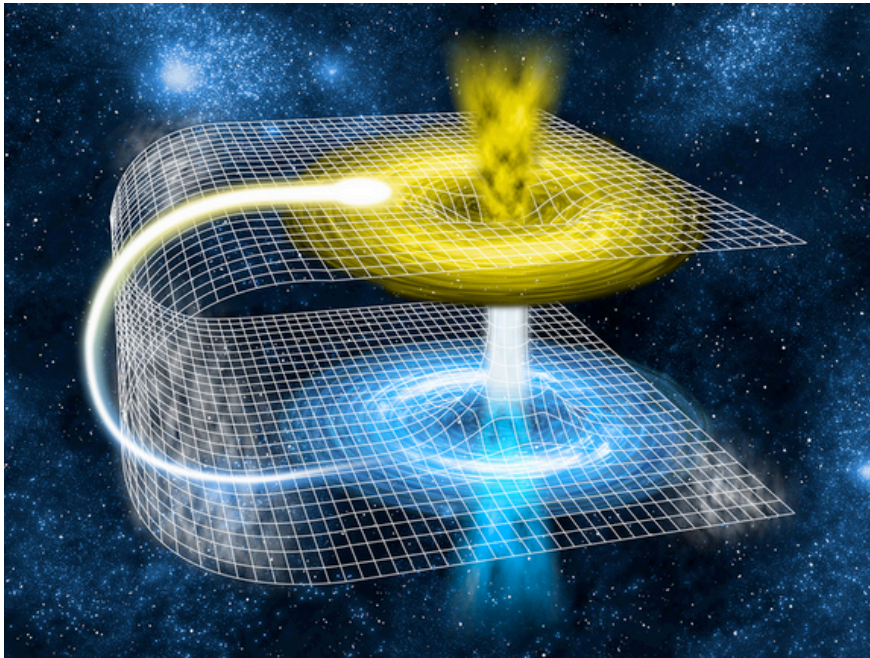


Evidence: CMB, inflation

BLACK HOLES

🌍 What's inside?

🌍 Wormholes?



https://deepuniversetruth.files.wordpress.com/2014/06/wp-id-shutterstock_25016035.jpg

🌍 Other universes?

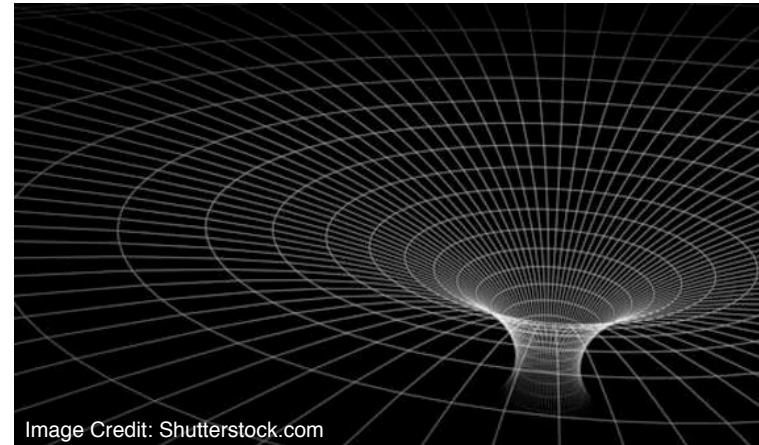
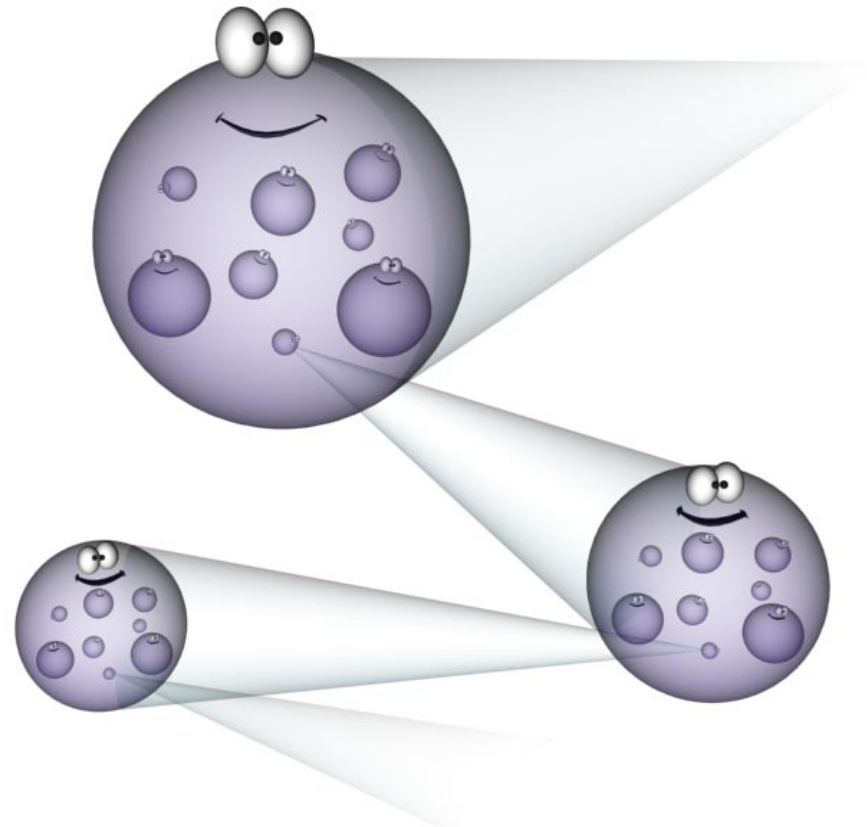


Image Credit: Shutterstock.com



ETERNAL INFLATION

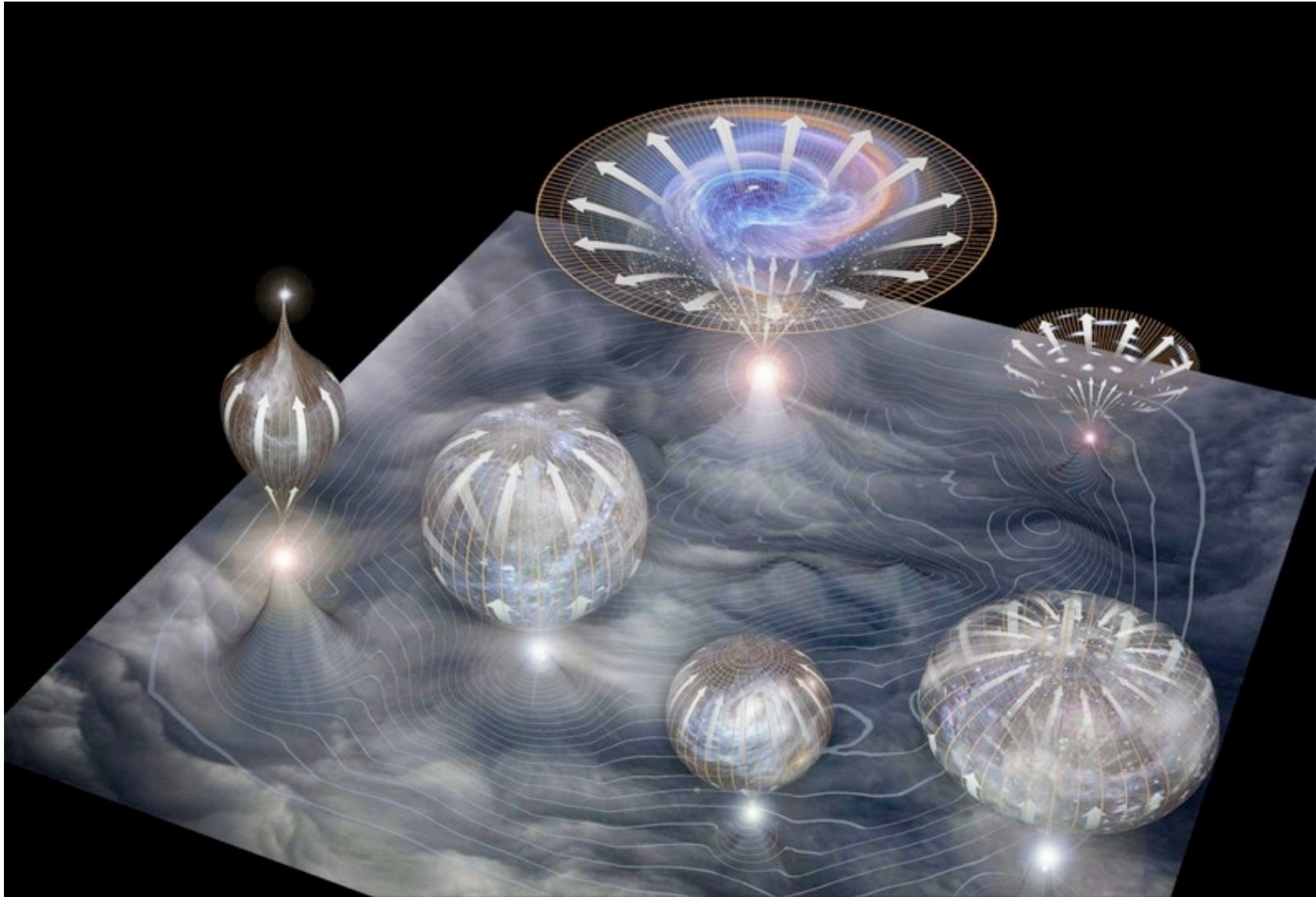
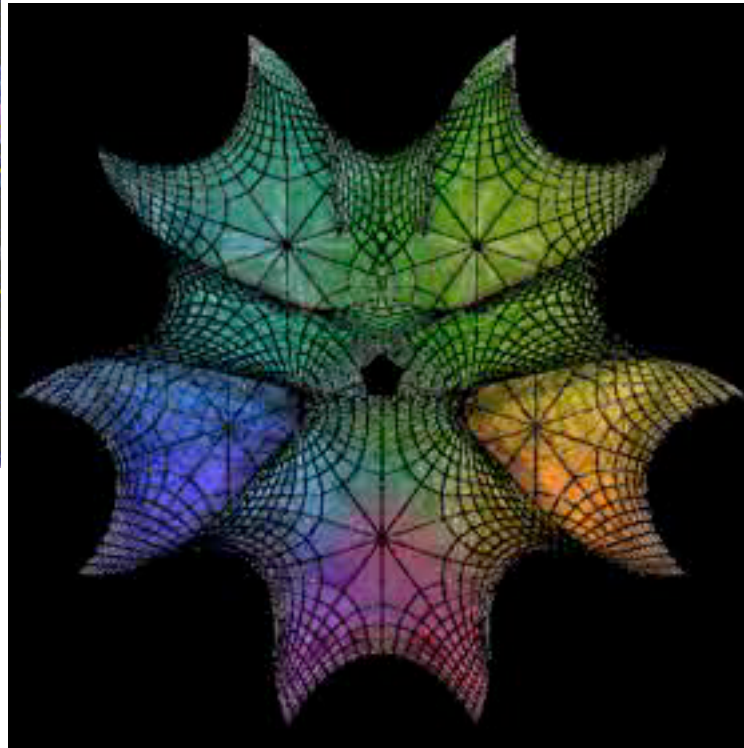
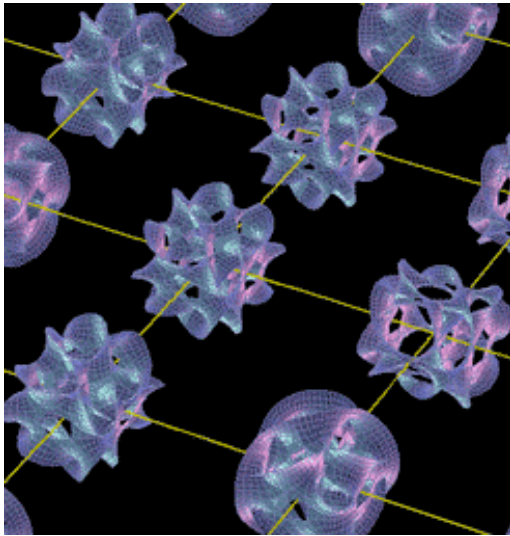


Image credit: Moonrunner Design, via <http://news.nationalgeographic.com/news/2014/03/140318-multiverse-inflation>

 **Hard for inflation to only happen once!**

STRING THEORY LANDSCAPE

- Many possible universes
- Eternal Inflation populates landscape!



<http://universe-of-waves.tumblr.com/post/14284019593/calabi-yau-manifold-small>
<https://nylander.wordpress.com/2008/08/25/cross-section-of-the-quintic-calabi-yau-manifold/>
<http://hopebeyondreason.com/2012/11/15/multiple-universes-fine-tuning-and-well-aimed-bullets/>

LEVEL II MULTIVERSE

Different Post-Inflationary Bubbles

- Same equations
- Different “constants”

Evidence:

CMB,
inflation

Explains fine-tuning!

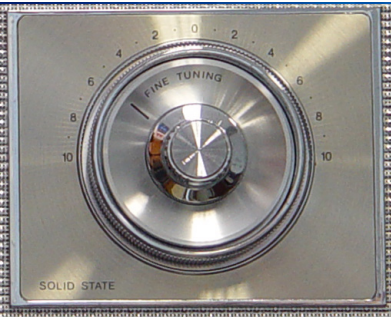


Detlev van Ravenswaay via Getty Images

<http://i.huffpost.com/gen/1688758/thumbs/o-BUBBLE-UNIVERSES-facebook.jpg>

FINE TUNING FOR LIFE?

Small changes make life impossible!

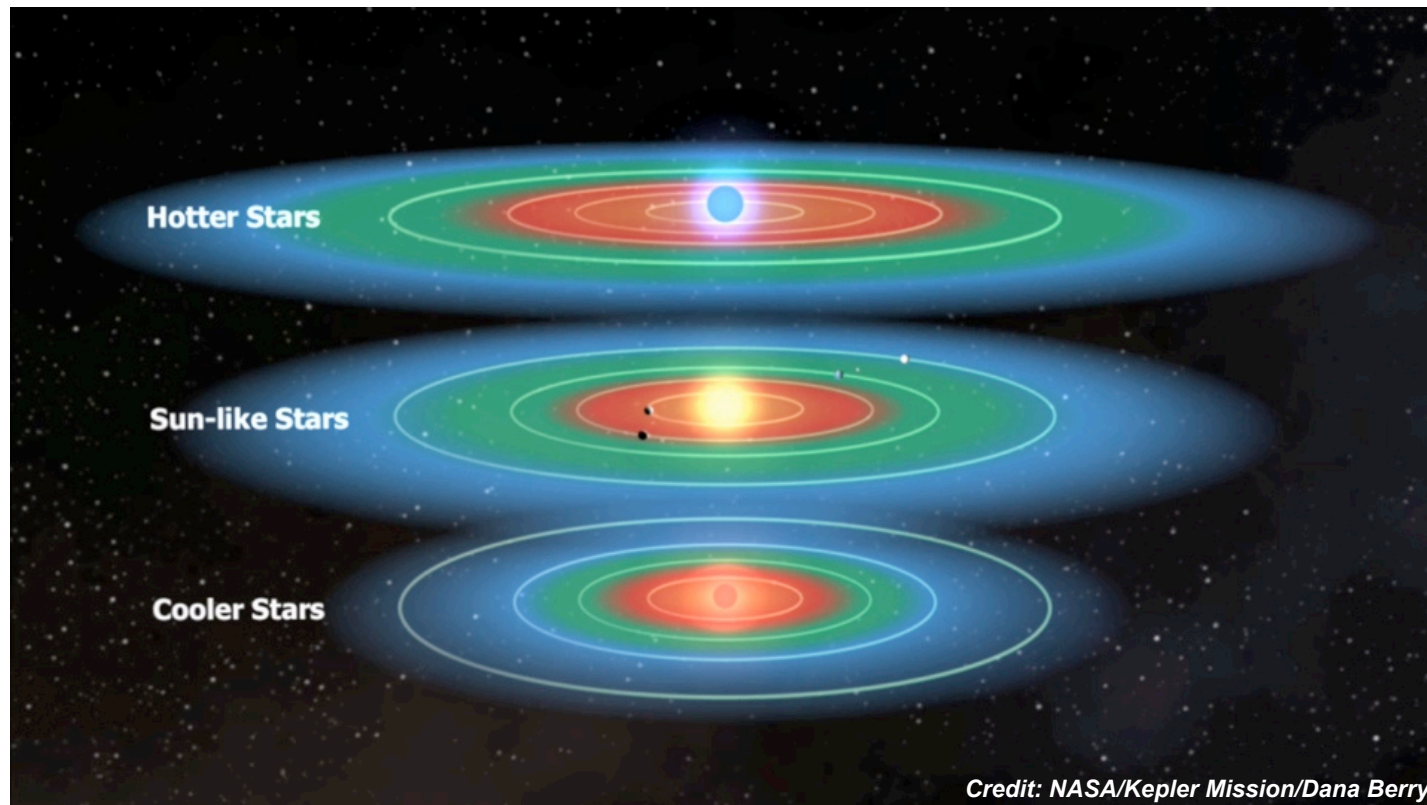


Many universes...

...at least one “just right”

ANTHROPIC PRINCIPLE

- Physical constants allow **our existence**
- **Many universes**, different constants
- e.g. Earth-Sun Distance

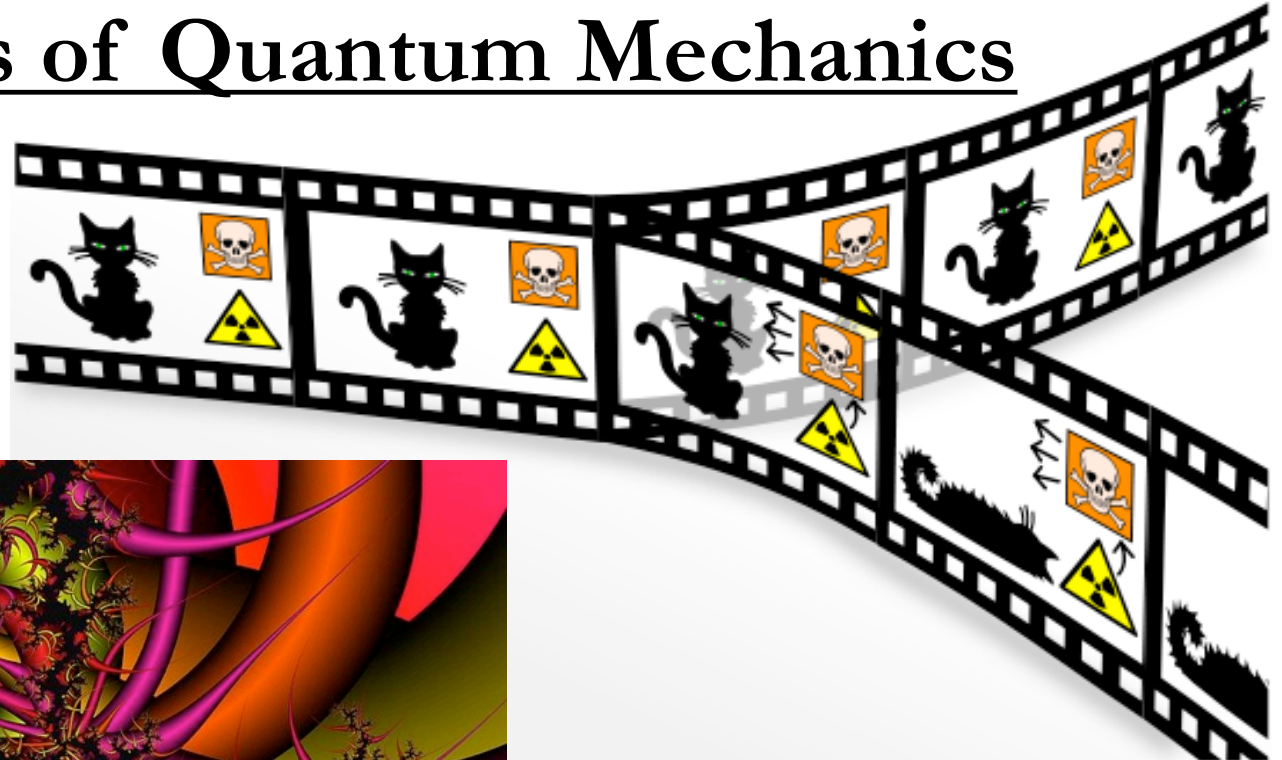


Credit: NASA/Kepler Mission/Dana Berry

<http://kepler.nasa.gov/multimedia/artwork/diagrams/?ImageID=29>

LEVEL III MULTIVERSE

Many Worlds of Quantum Mechanics



https://en.wikipedia.org/wiki/File:Schroedingers_cat_film.svg



<http://fineartamerica.com/featured/chaos-theory-christy-hodgin.html>

● Observer
splits every
quantum event

LEVEL III MULTIVERSE

Many Worlds of Quantum Mechanics

Evidence:

- Double slit experiment
- Quantum Computers?

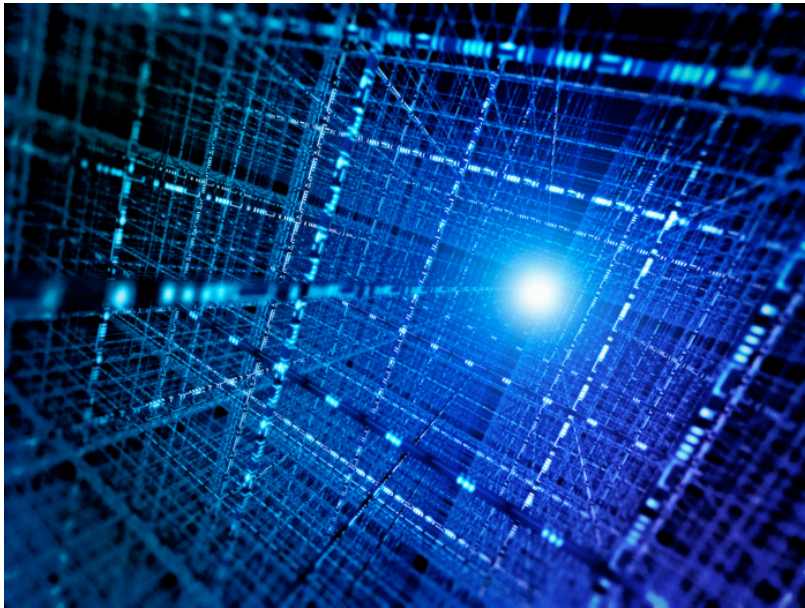
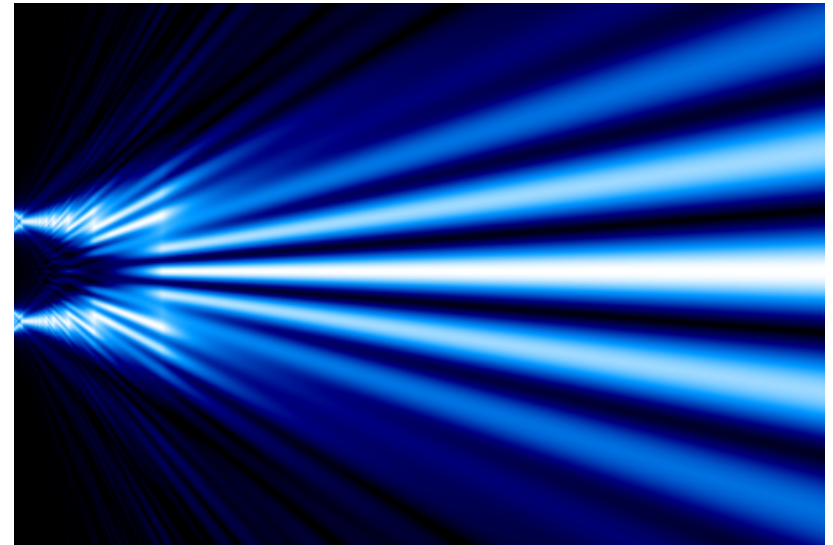


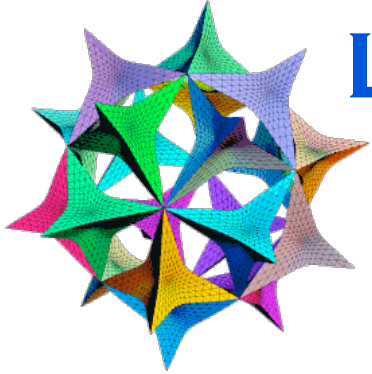
Image Credit: iStockphoto/Henrik Jonsson



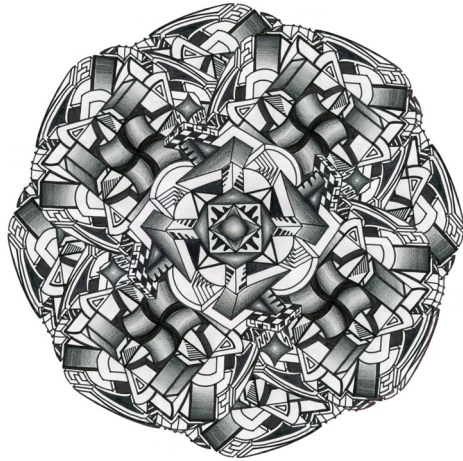
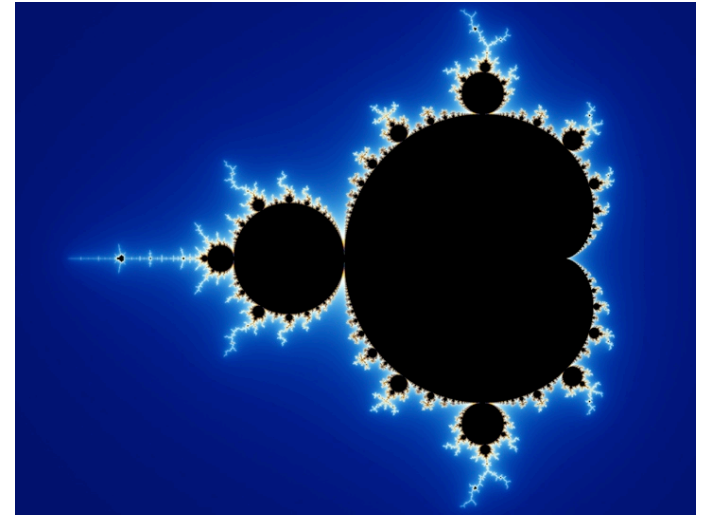
http://www.iop.org/news/13/mar/page_59670.html

But: Other
interpretations
give same
predictions!

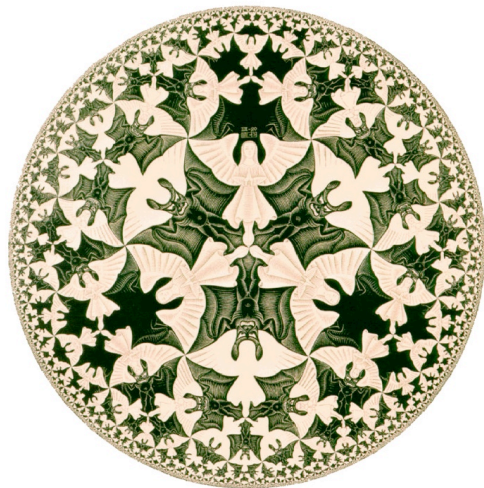
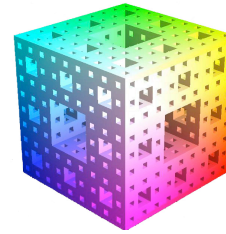
LEVEL IV MULTIVERSE



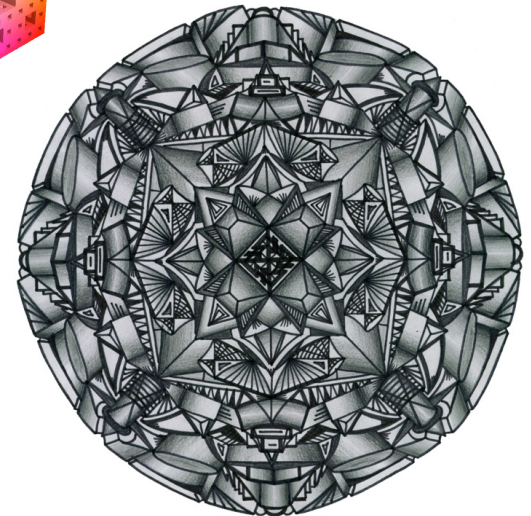
● Different laws



● Other mathematical structures



● Why does math work?



SCIENCE OR “JUST” PHILOSOPHY?

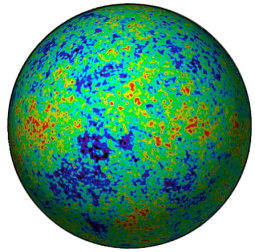
- Parallel universes
Not a theory!
- Predictions
of theories
- No need to test
all predictions.
Only some



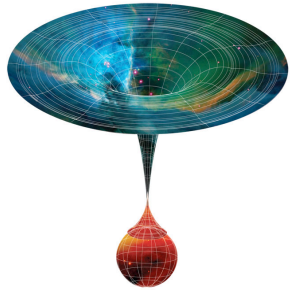
Must take all predictions seriously,
even ones you can't test (yet)

Tegmark 2009

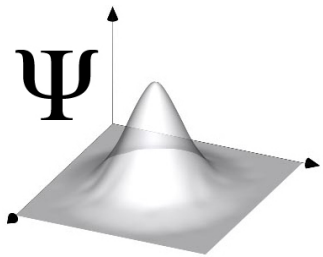
WHICH LEVELS EXIST?



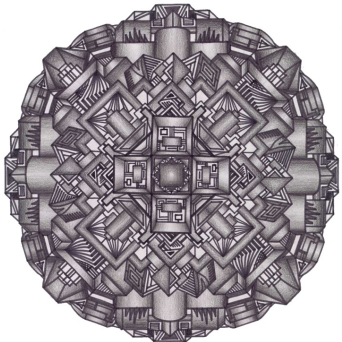
I. We can't see everything



II. Best physical theories



III. Quantum theory



IV. World is mathematical?

...How many more?



NEXT TALKS



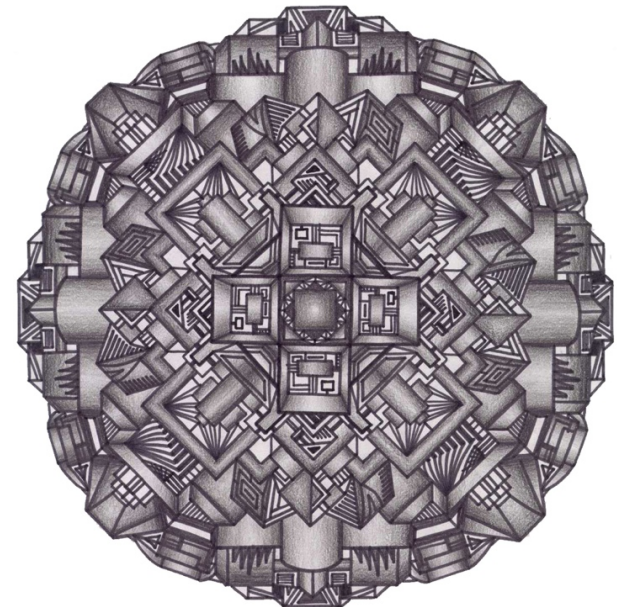
**Prof. Brian Keating
(UCSD)**

- Evidence for inflation
- BICEP2 Telescope



**Dr. David Brin
(UCSD)**

- Life in the Multiverse
- Implications for humanity



REFERENCES

Greene, Brian, “The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos”, Knopf Doubleday Publishing Group (2011)

Guth, Alan, “The Inflationary Universe”, Reading, MA: Addison-Wesley (1997)

Tegmark, Max, “The Multiverse Hierarchy”, in *Universe or Multiverse?*, ed. Bernard Carr, pp. 99-126. New York: Cambridge University Press (2009)

Tegmark, Max, “Our Mathematical Universe: My Quest for the Ultimate Nature of Reality”, Random House/Knopf, (2014)

Vilenkin, Alex, “Many Worlds in One: The Search for Other Universes”, Hill and Wang (2007)