

An Infinity of Worlds

Cosmic Inflation and the Beginning of the Universe

**NATIONAL
ACADEMIES**

*Sciences
Engineering
Medicine*

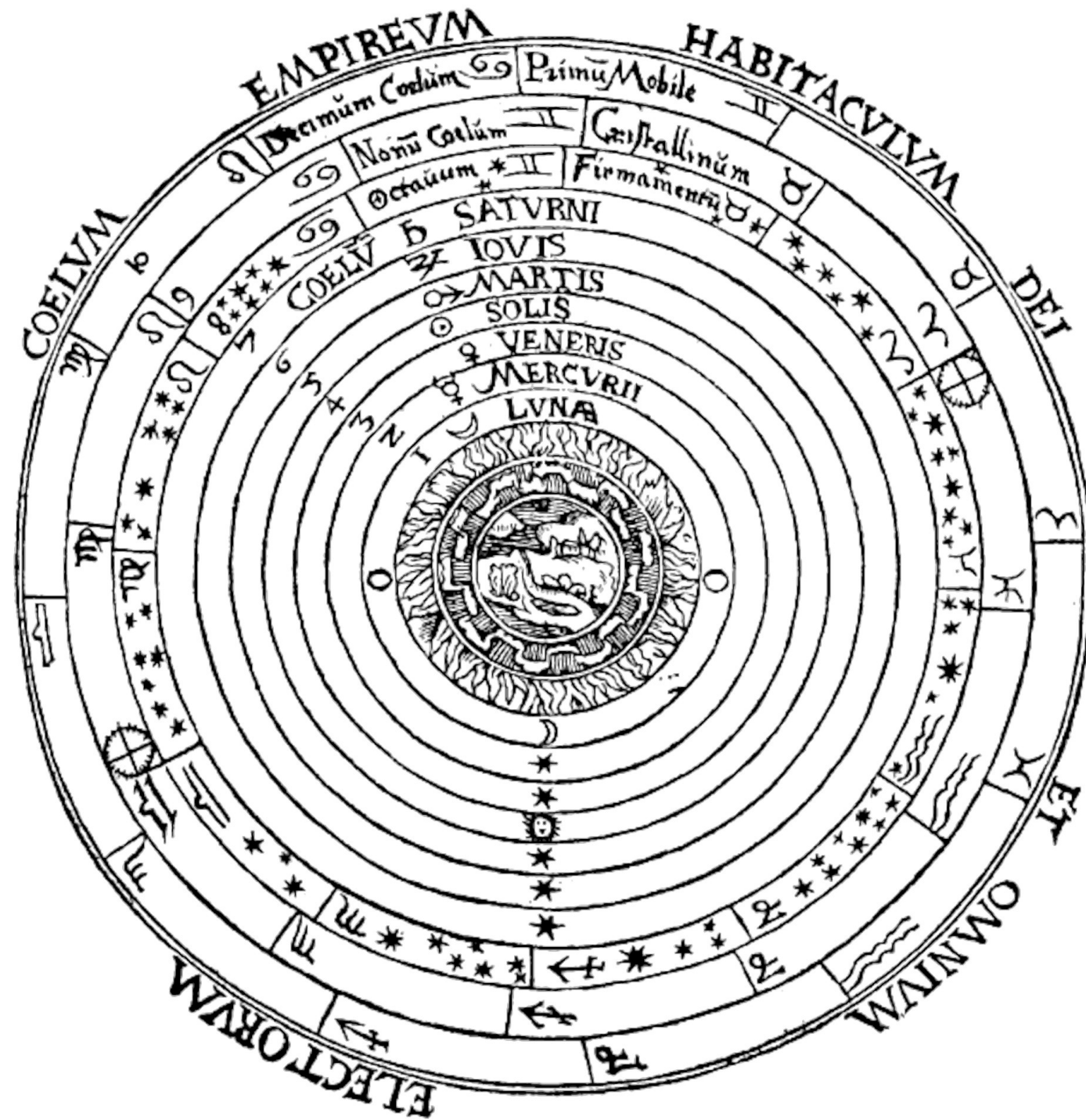


Will Kinney
29 March 2023

The image features a dark, almost black background. On the left side, there is a bright, curved, white-to-gray gradient that resembles a planet's horizon or a celestial body. A thin, dark horizontal line crosses the middle of the image. Below this line, on the left, is a solid black circle. To the right of this circle, the text "The beginning of the world" is written in a bold, white, sans-serif font.

The beginning of the world

Schema huius præmissæ diuisionis Sphærarum.

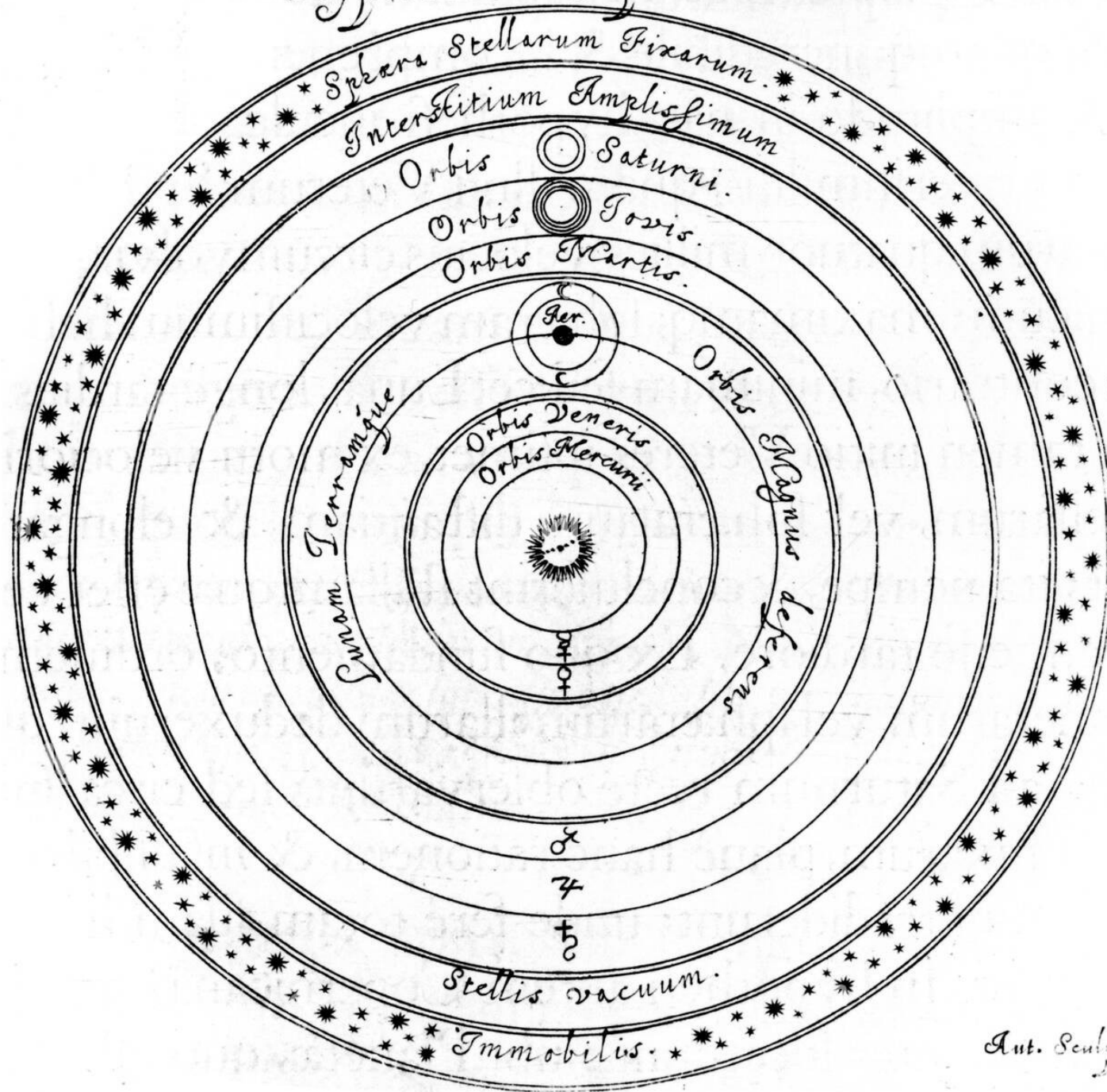




Since everything that is in motion must be moved by something, let us suppose there is a thing in motion which was moved by something else in motion, and that by something else, and so on. But this series cannot go on to infinity, so there must be some First Mover.

Aristotle, "Physics"

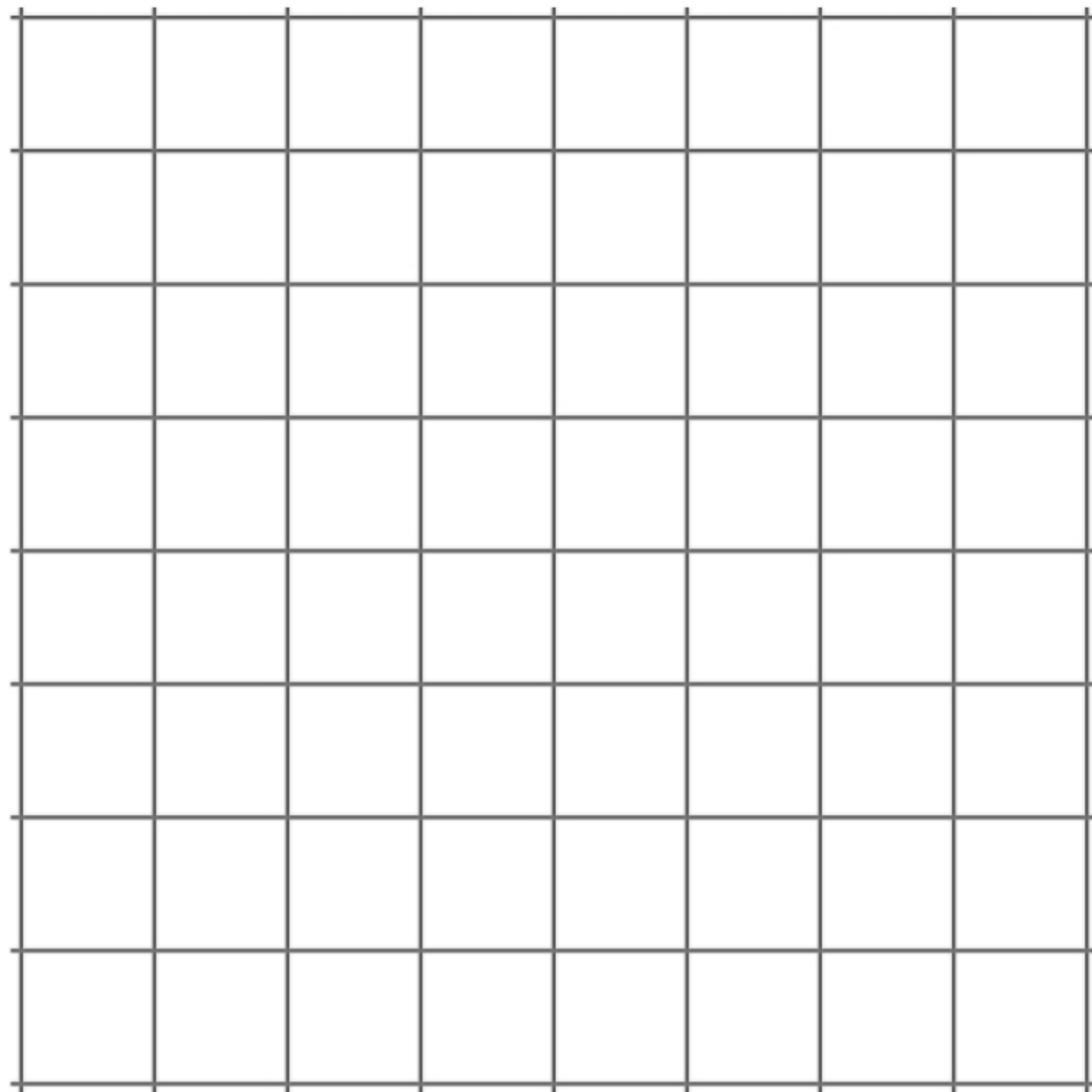
Hypothesis Copernicana.

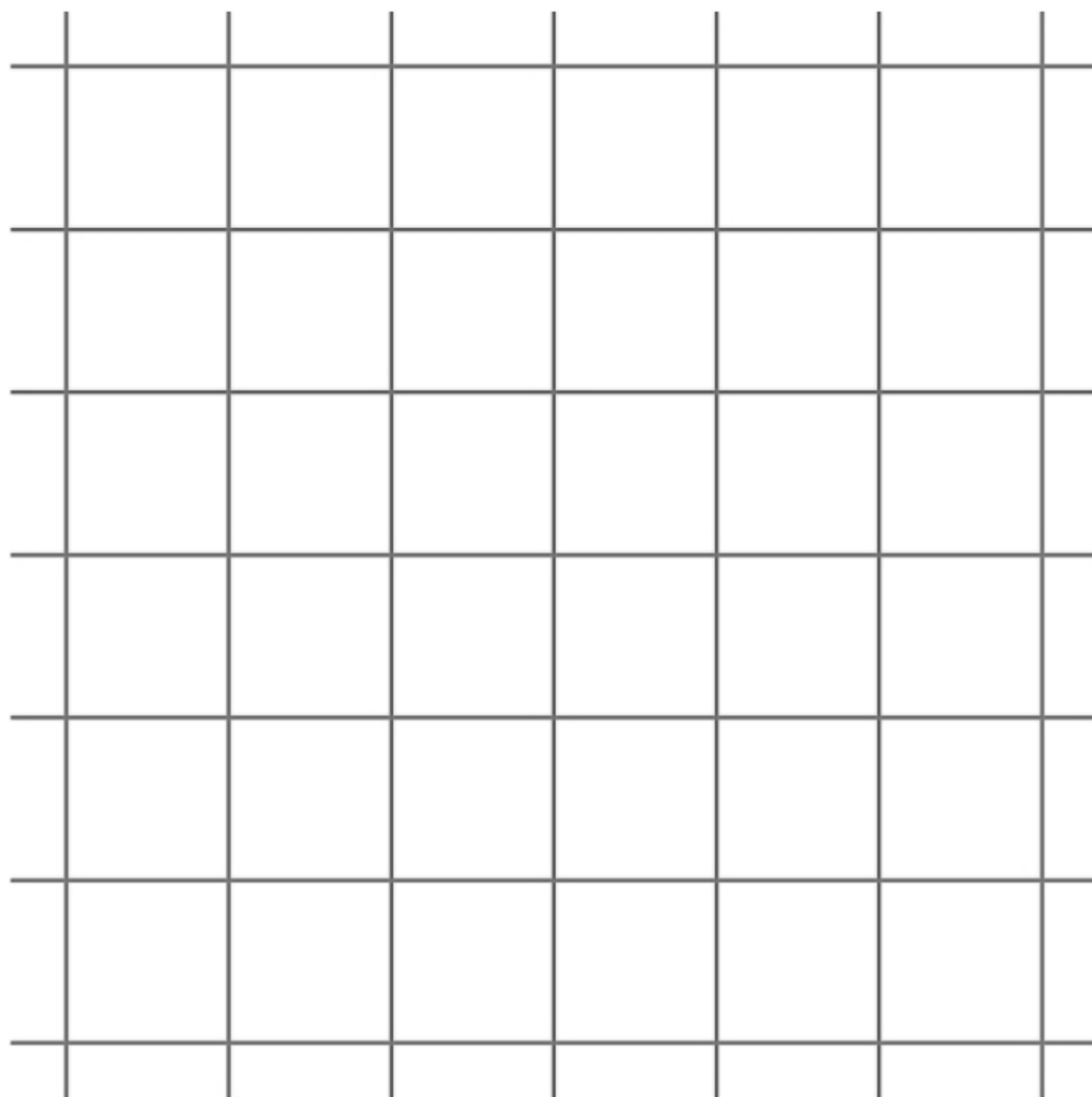


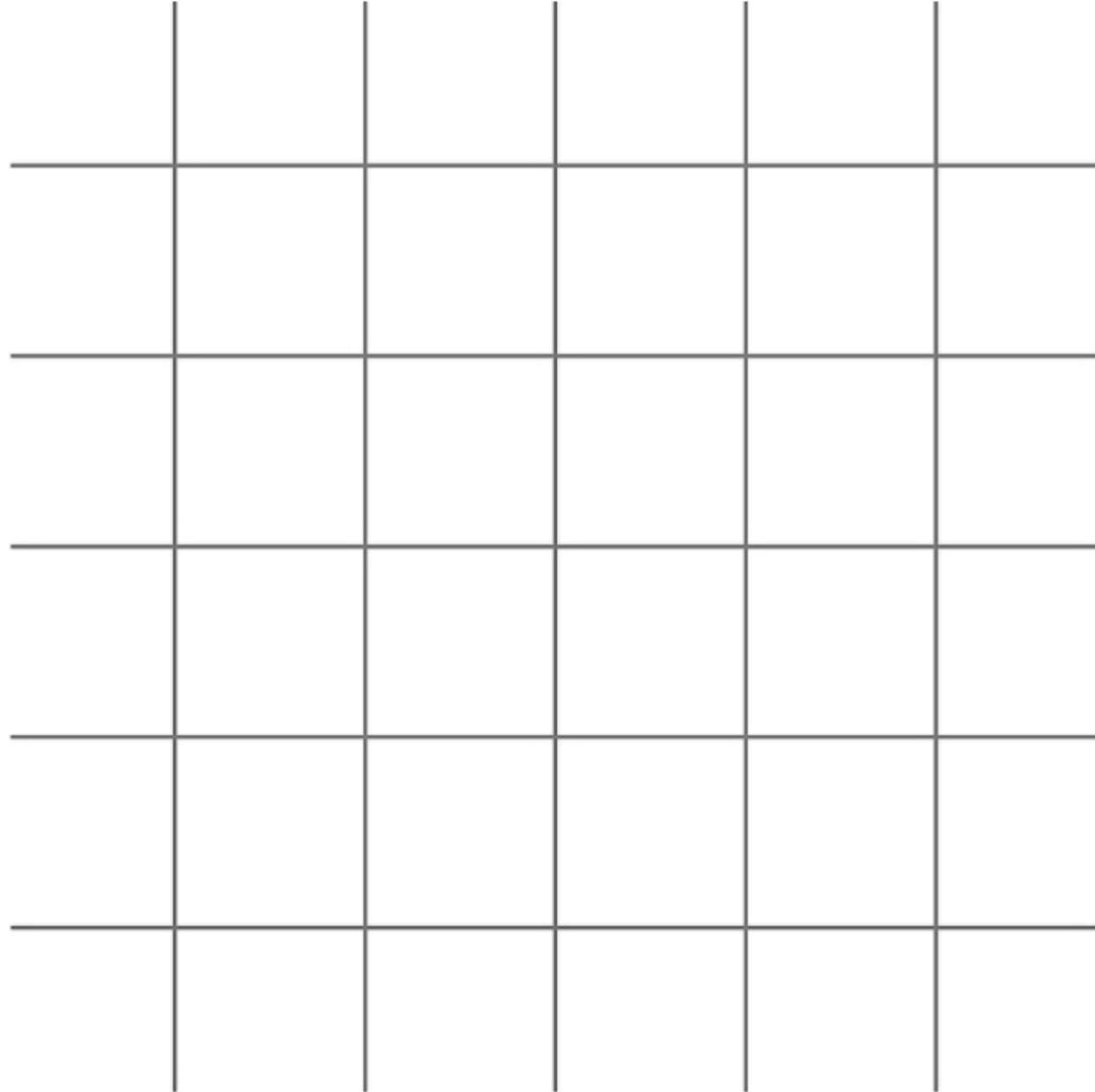


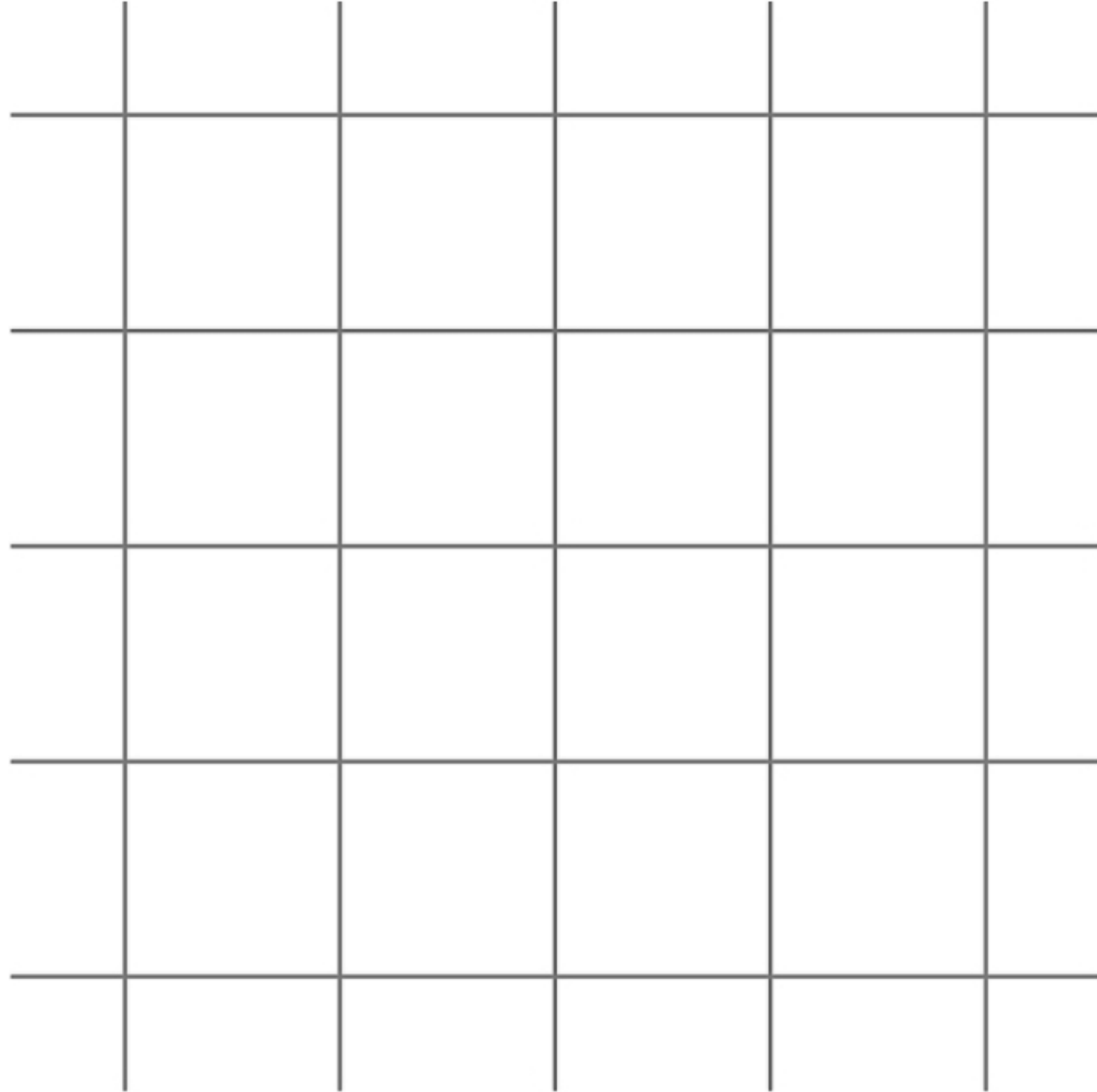
For every apparent change in respect of position is due to motion of the object observed, or of the observer, or indeed to an unequal change of both.

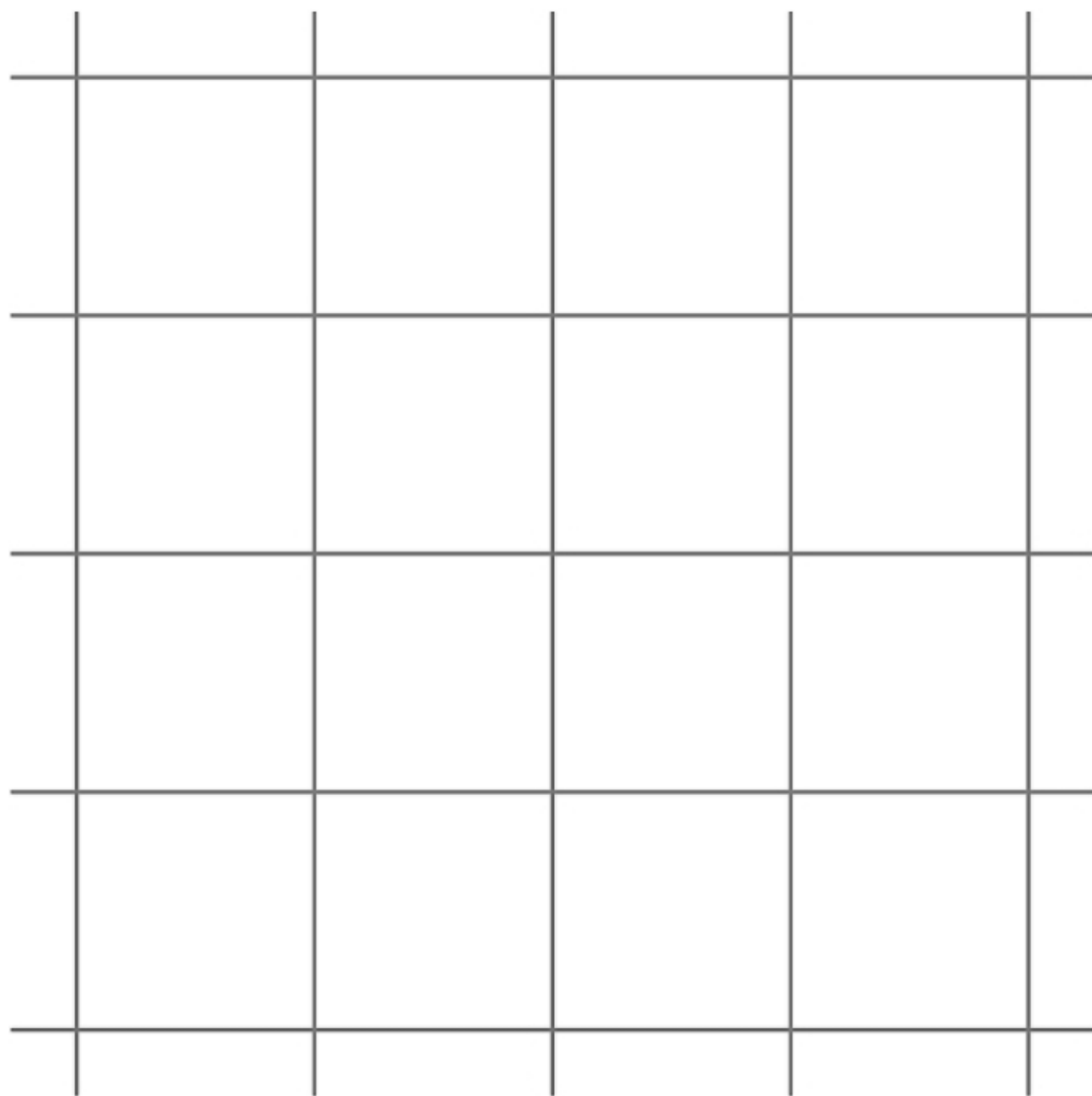
Copernicus, “de Revolutionibus”

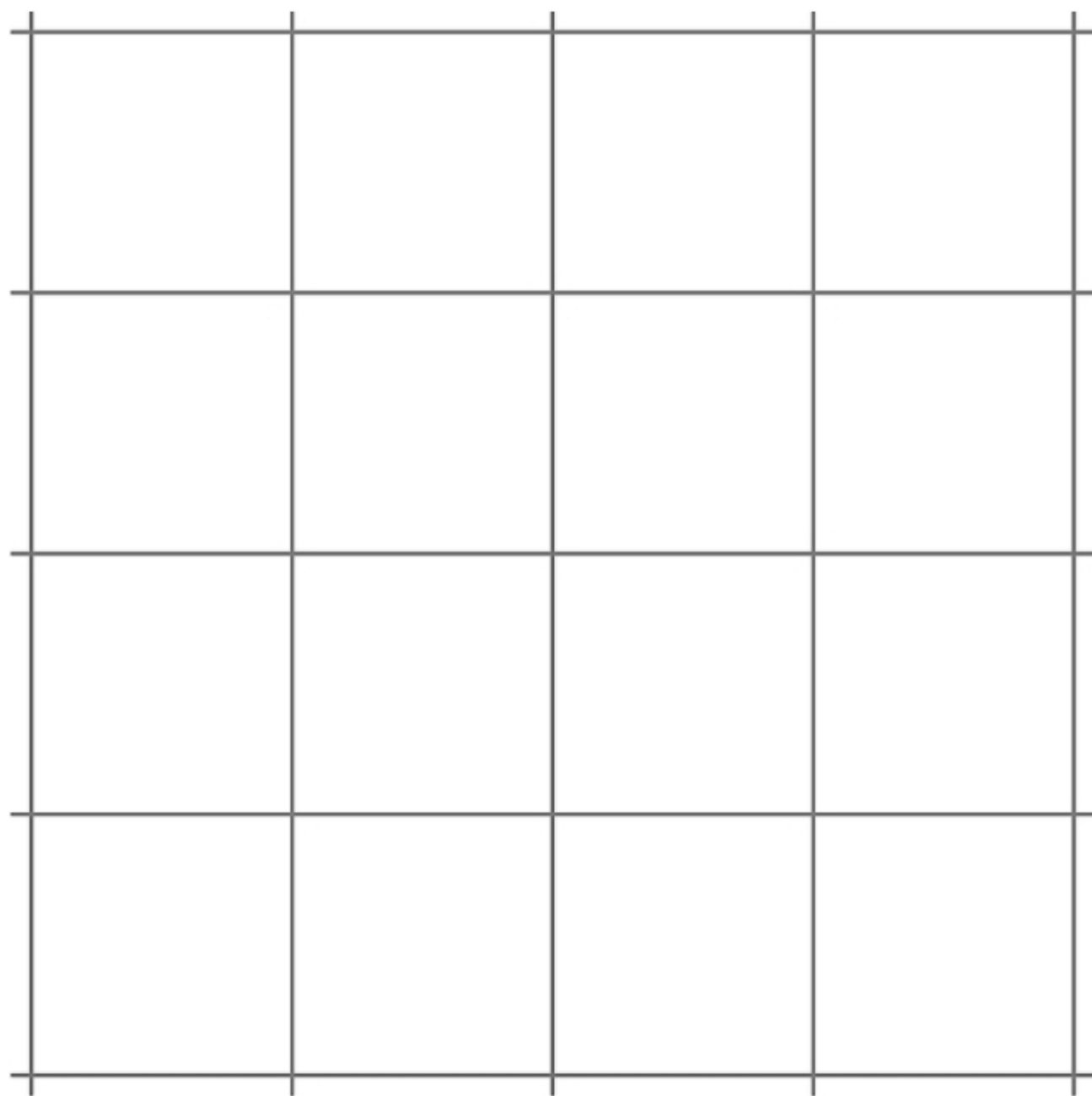


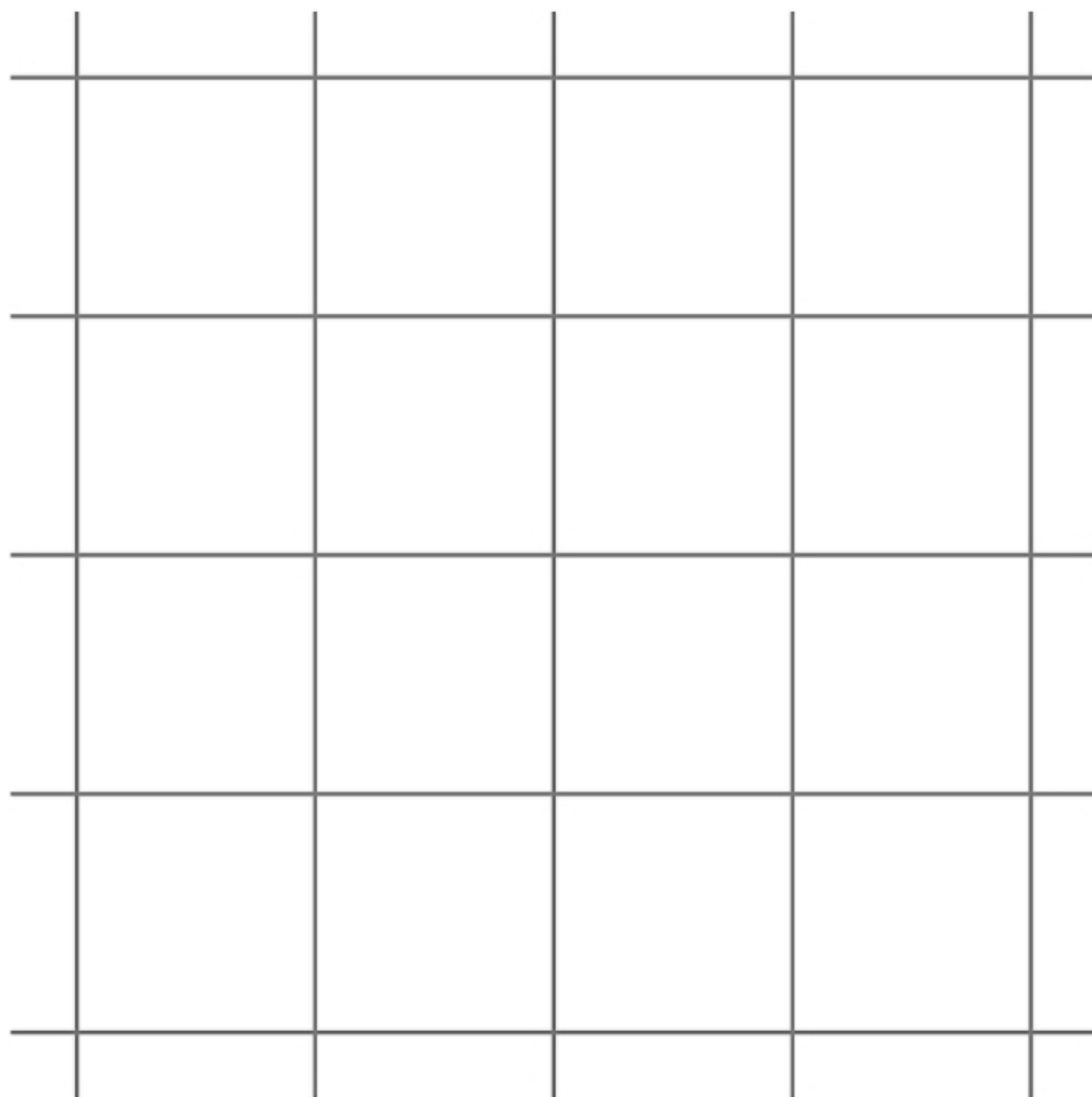


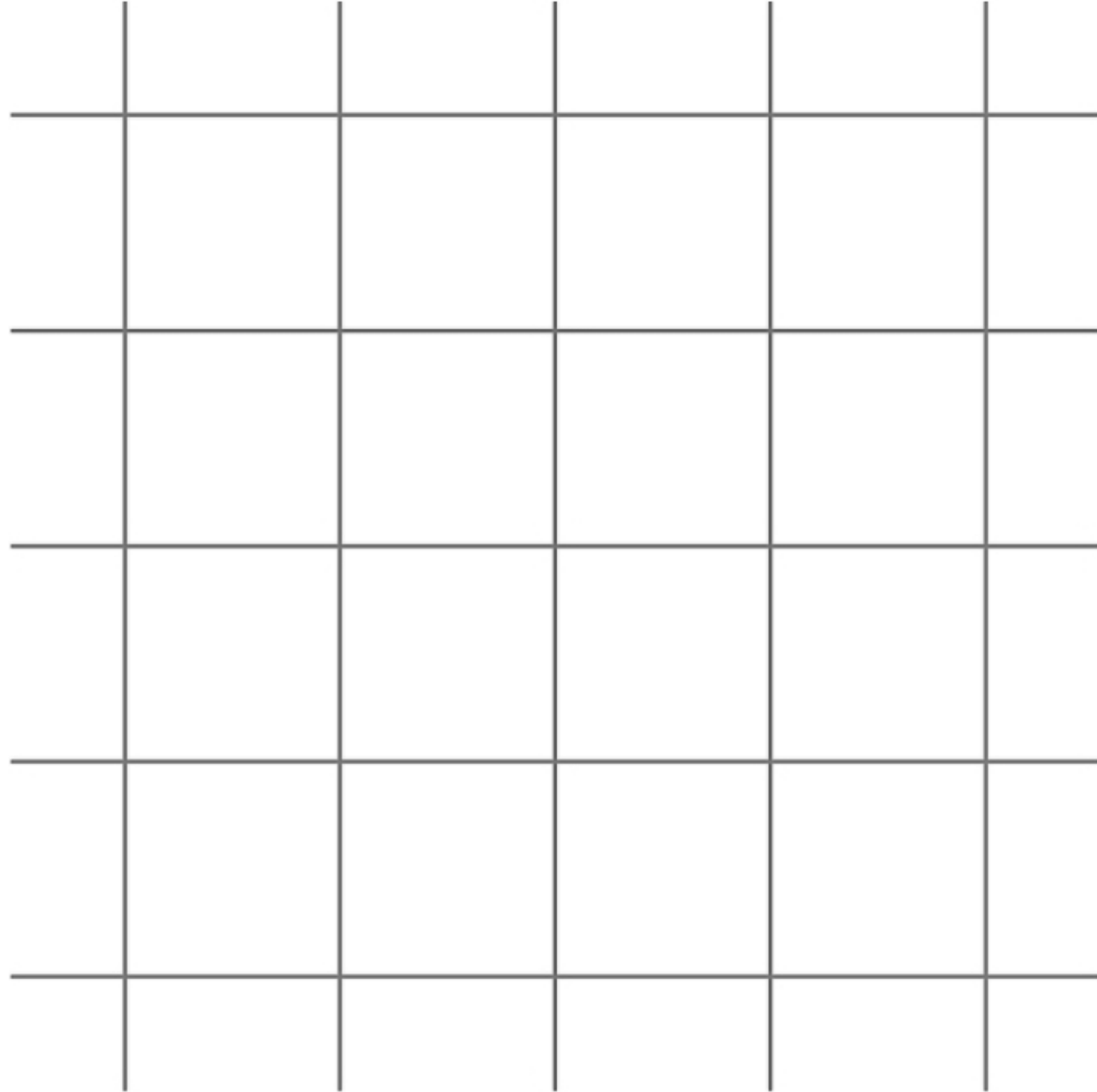


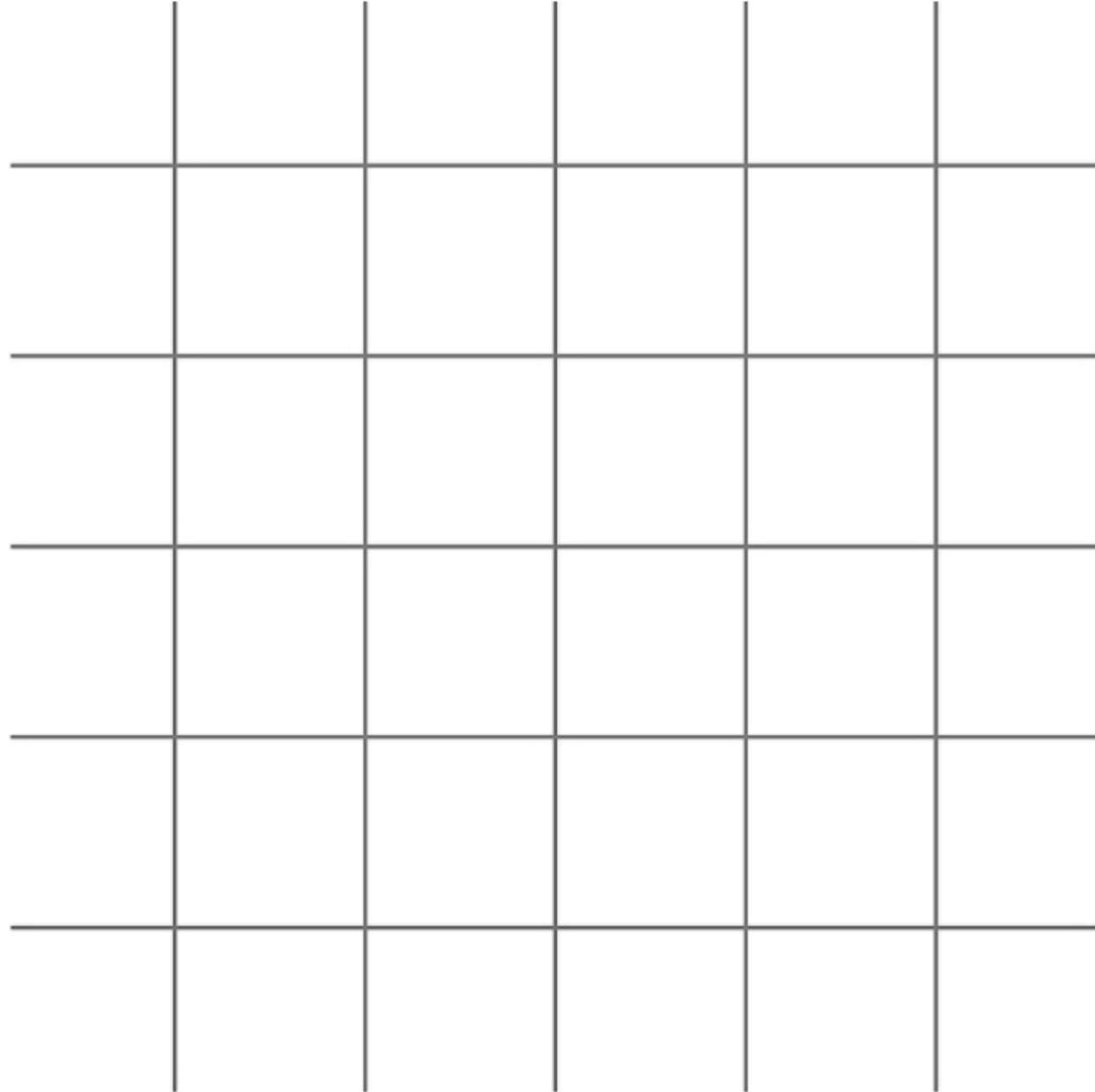


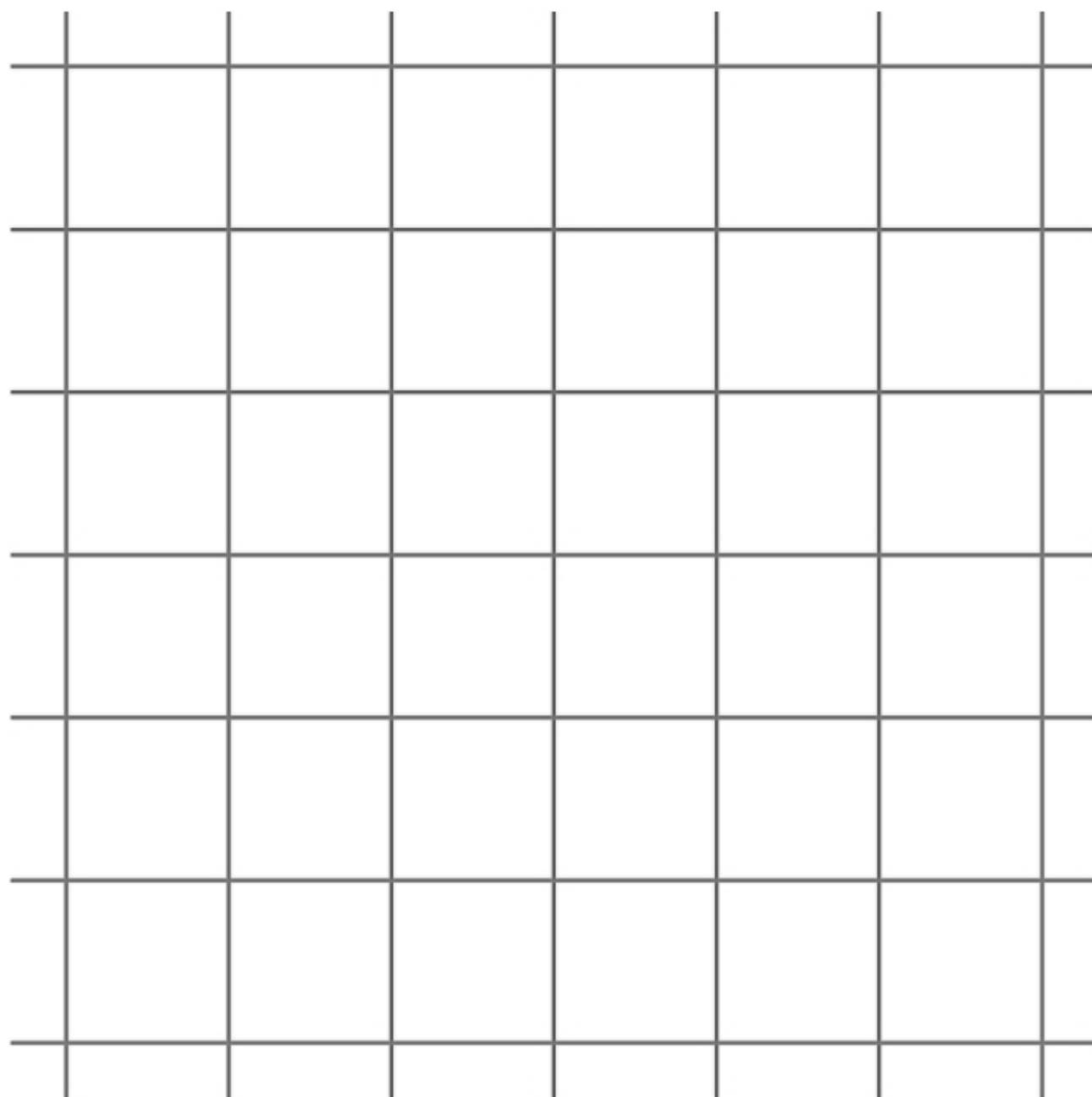


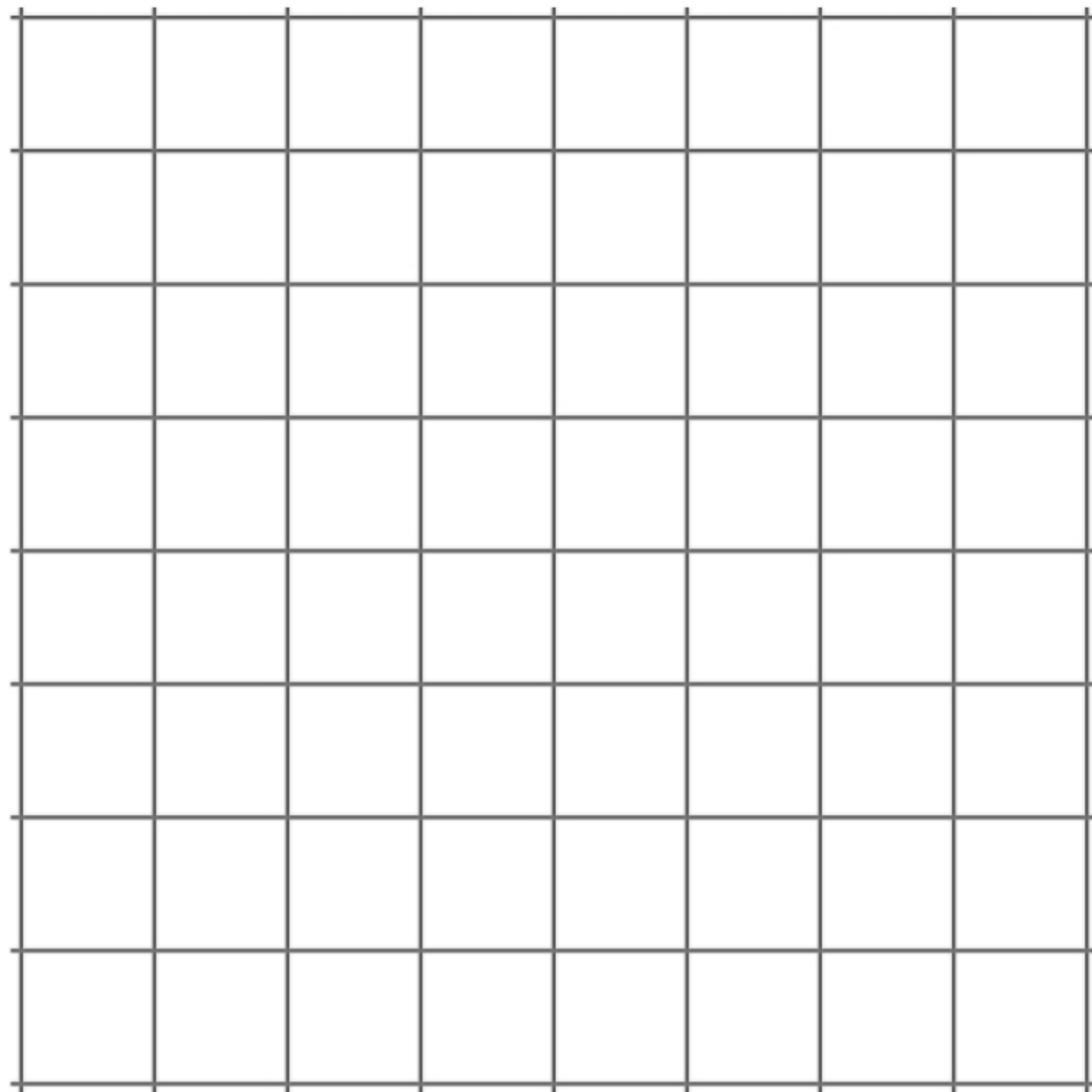


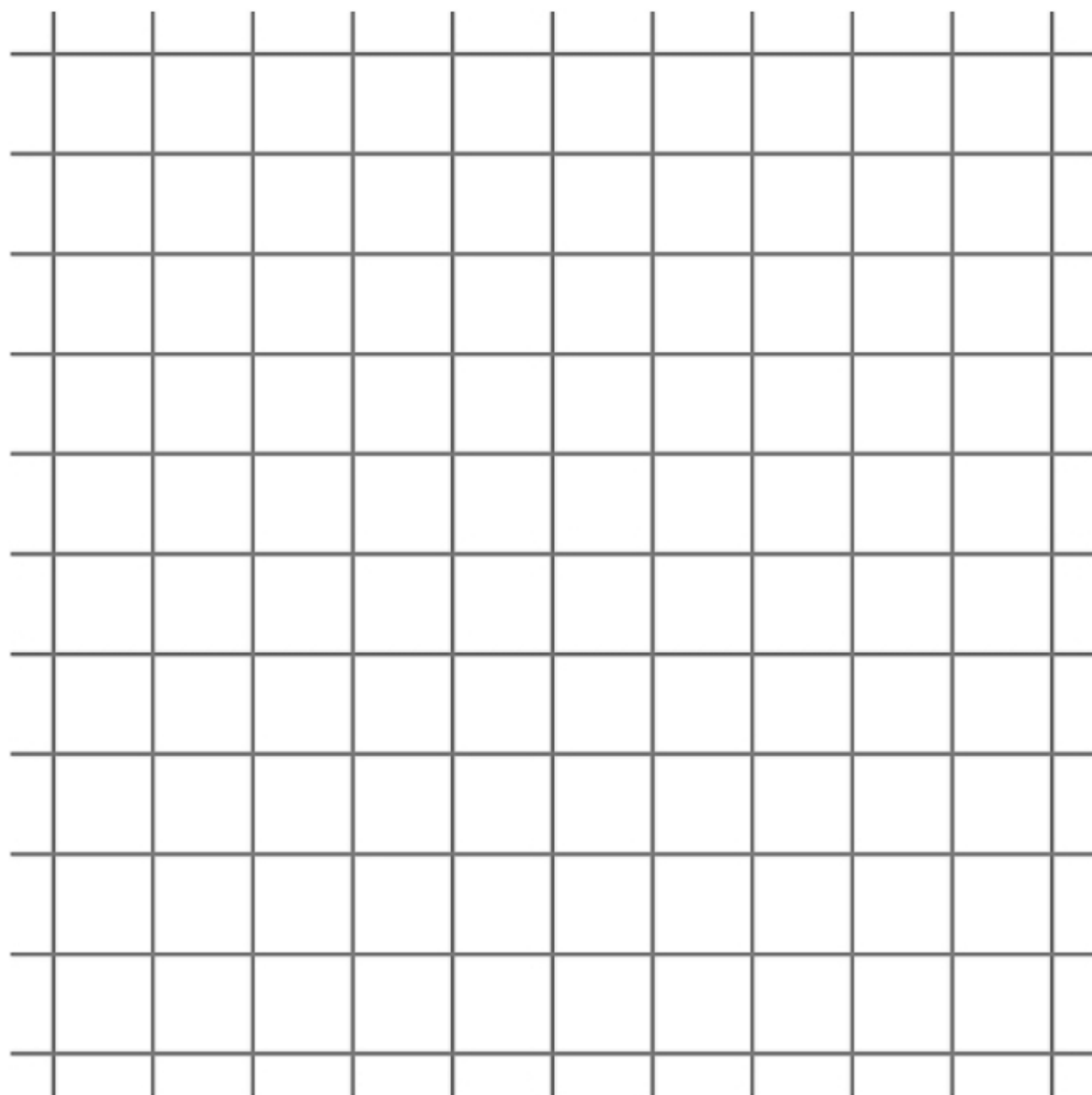


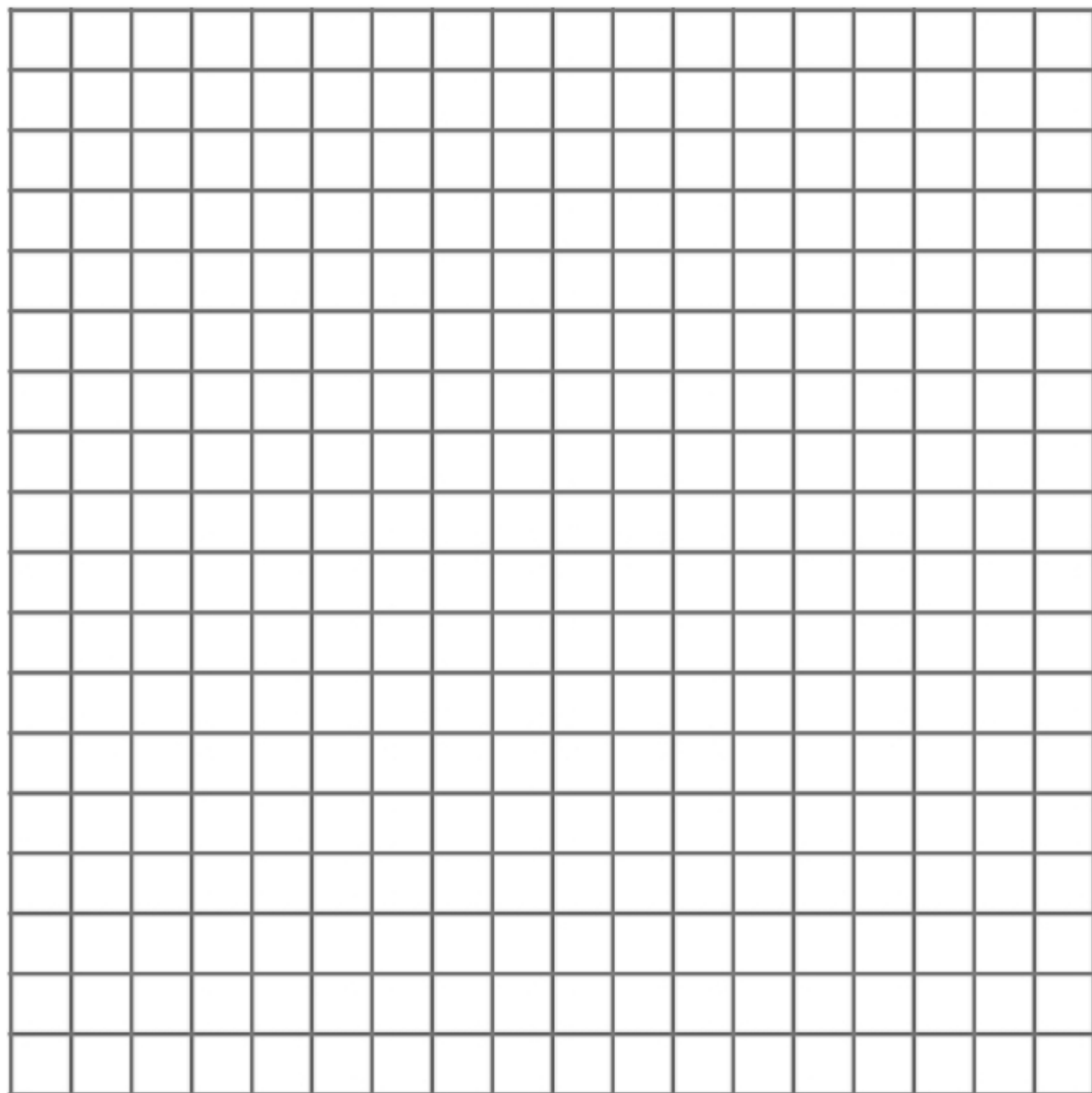




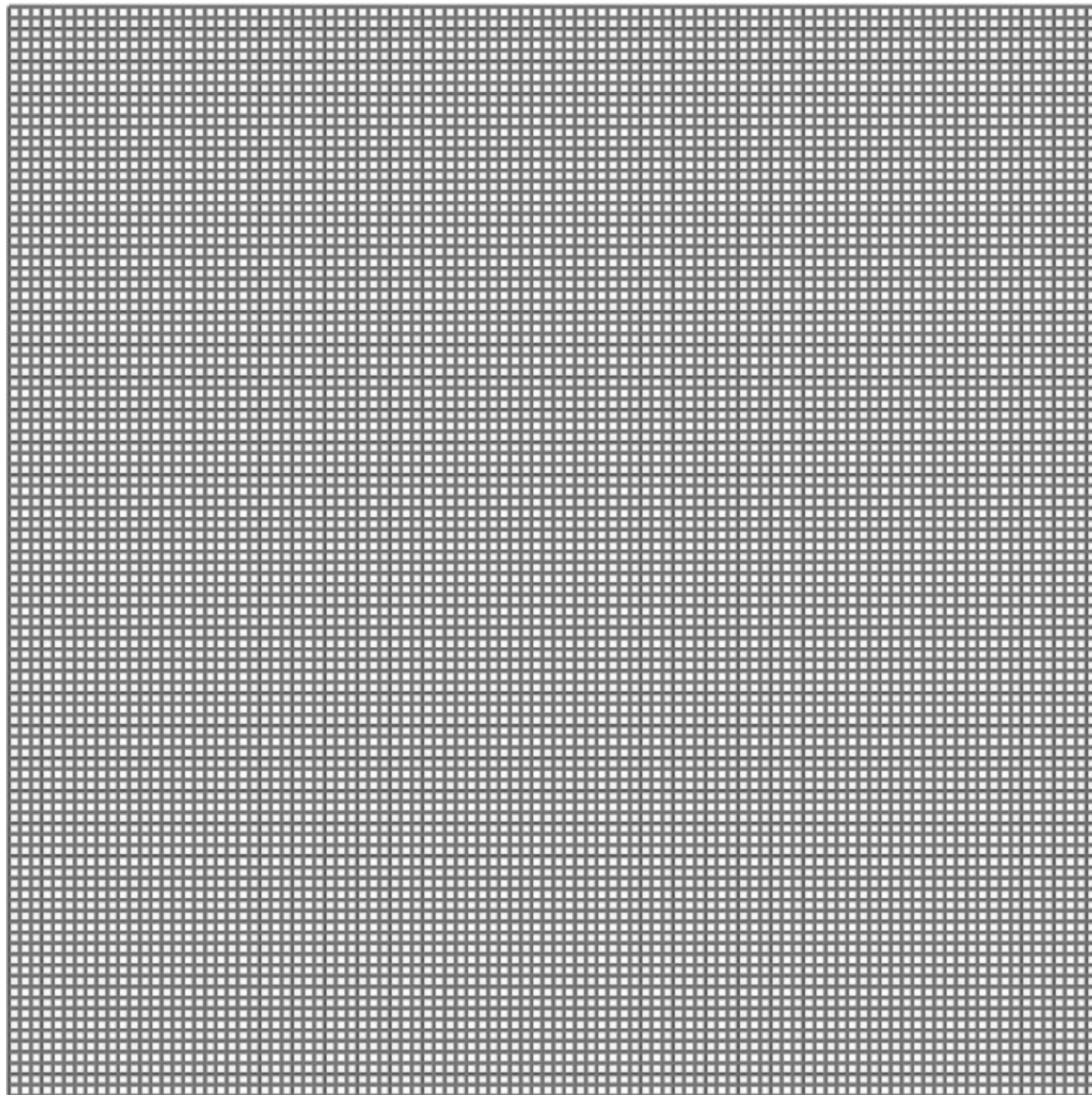


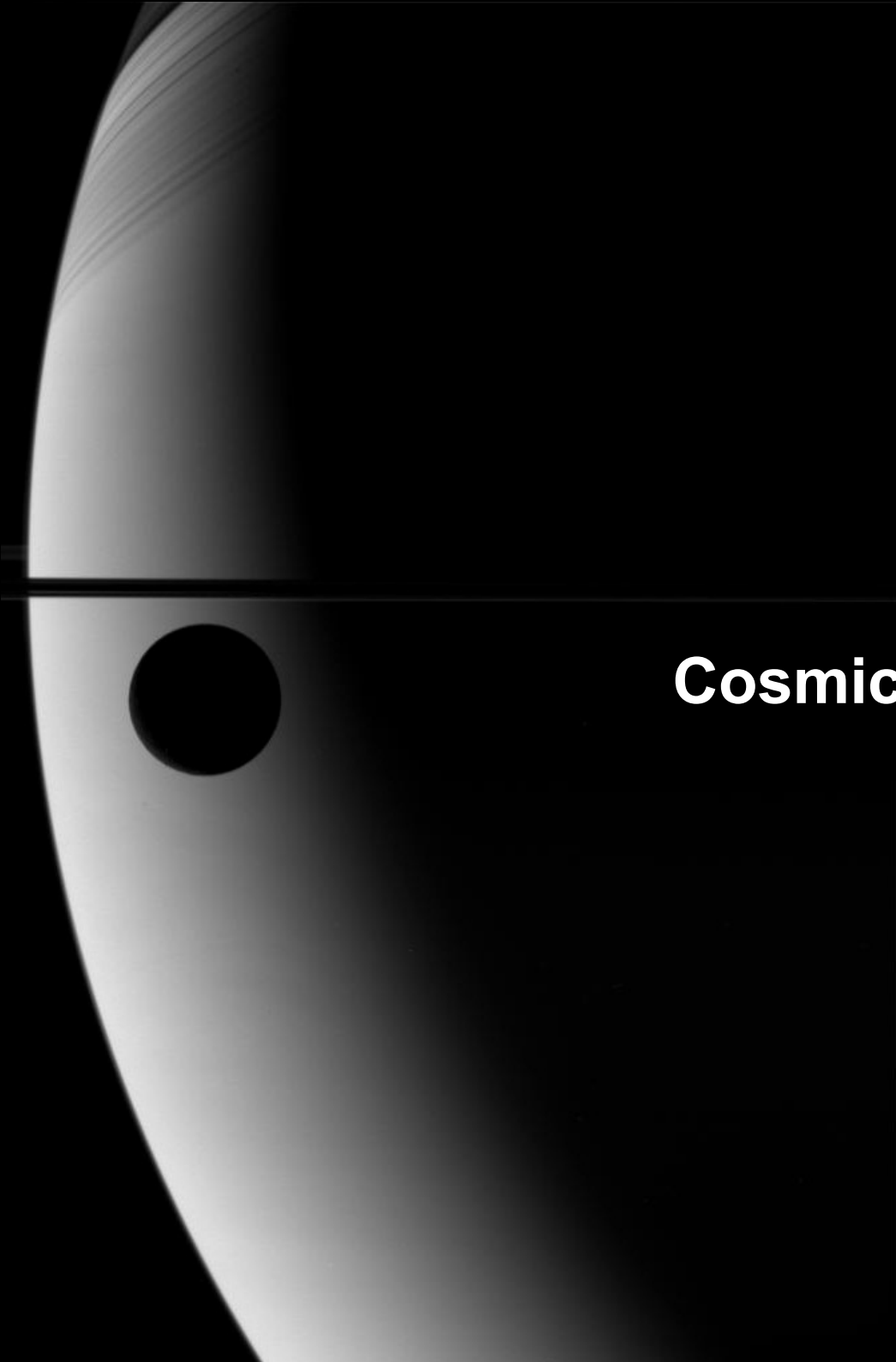






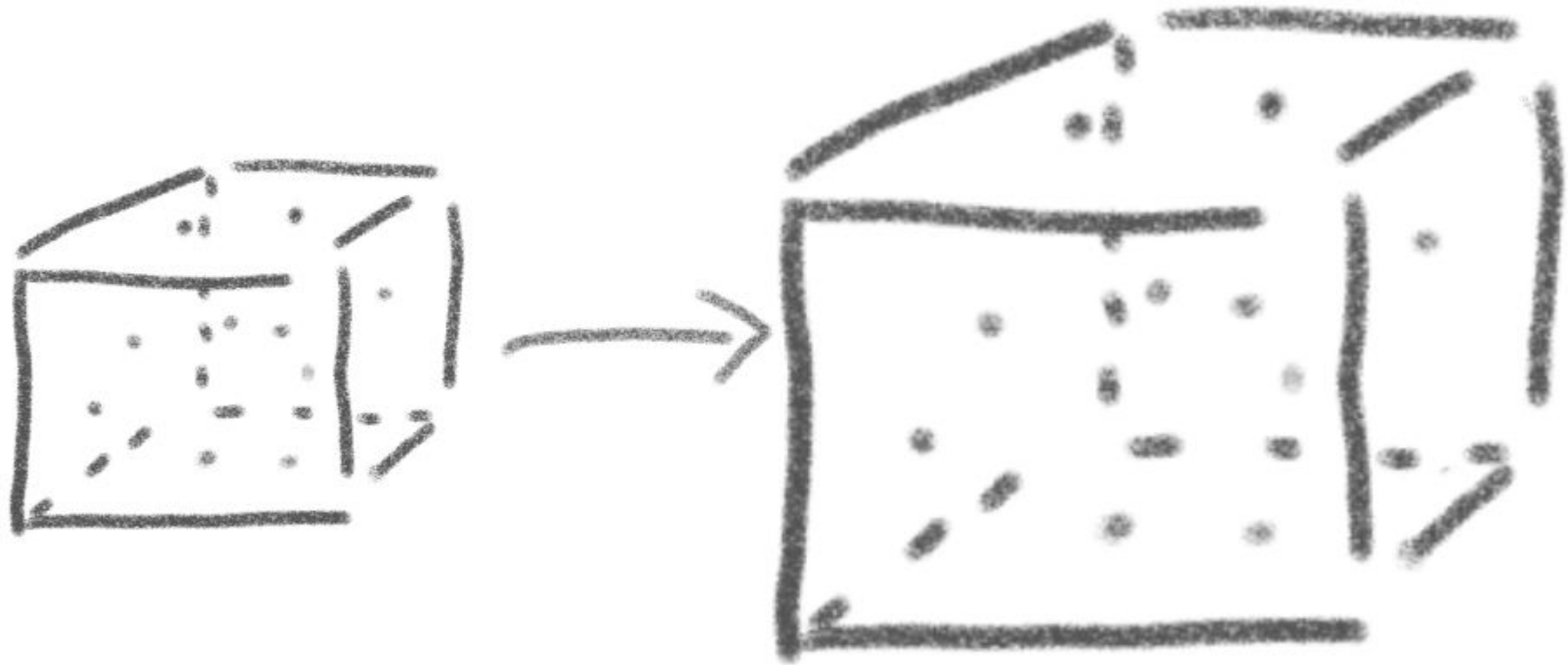
BANG!





Cosmic History

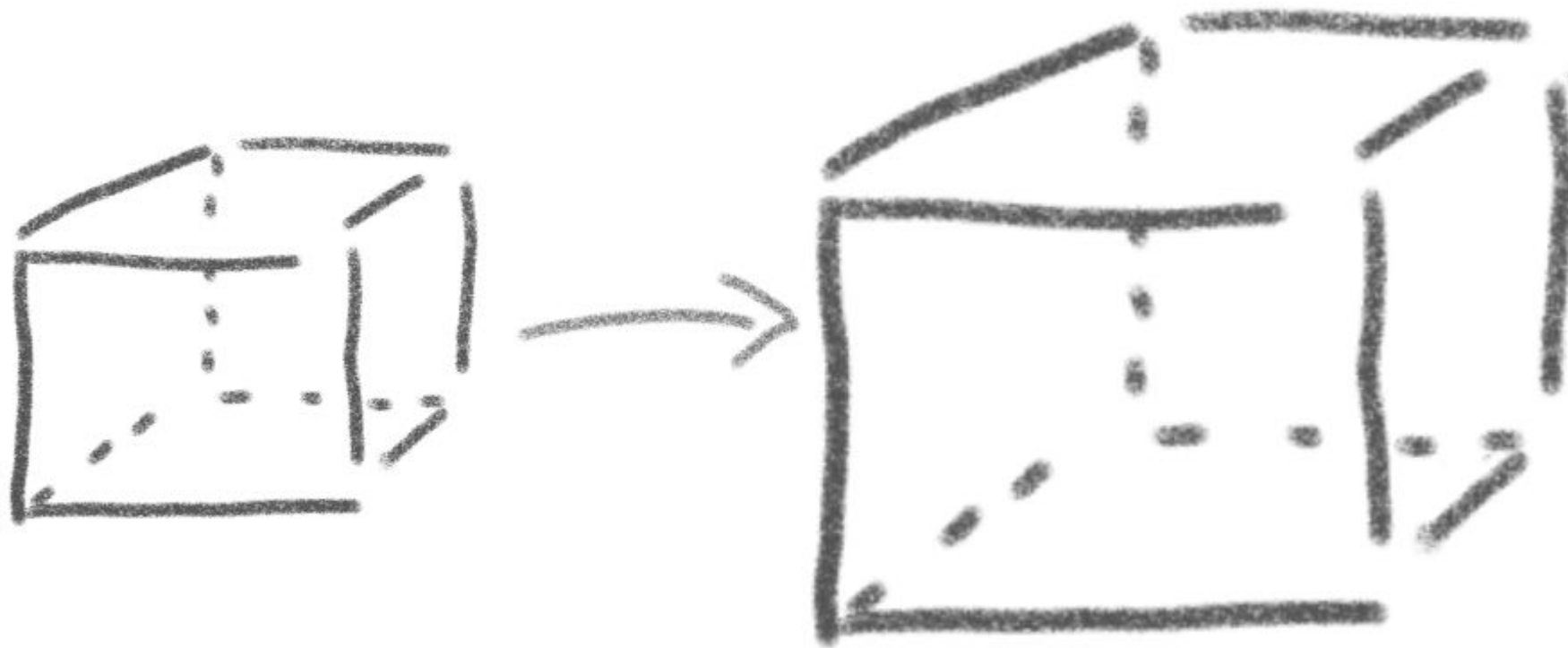
The cosmic cocktail: matter



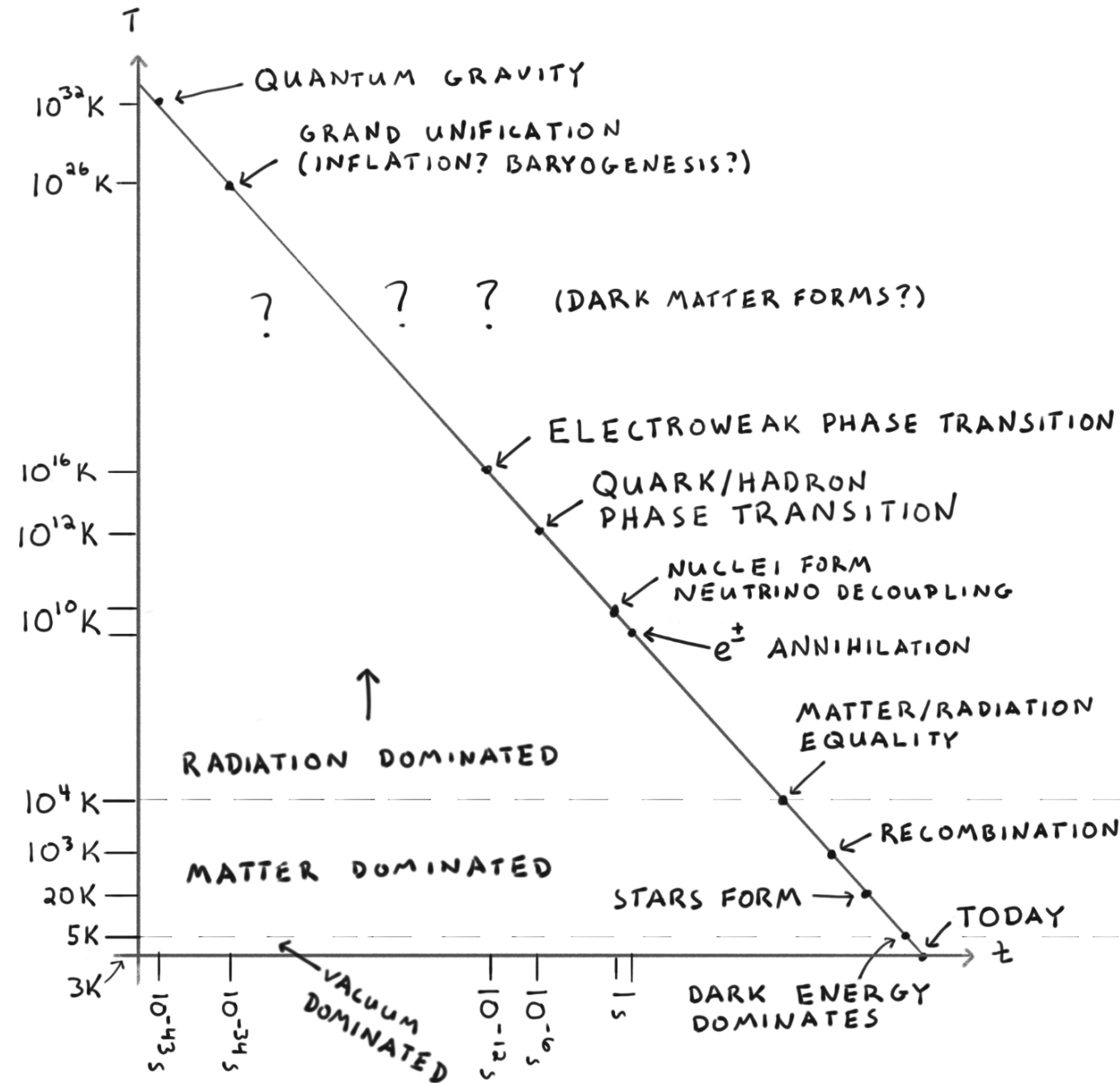
The cosmic cocktail: radiation

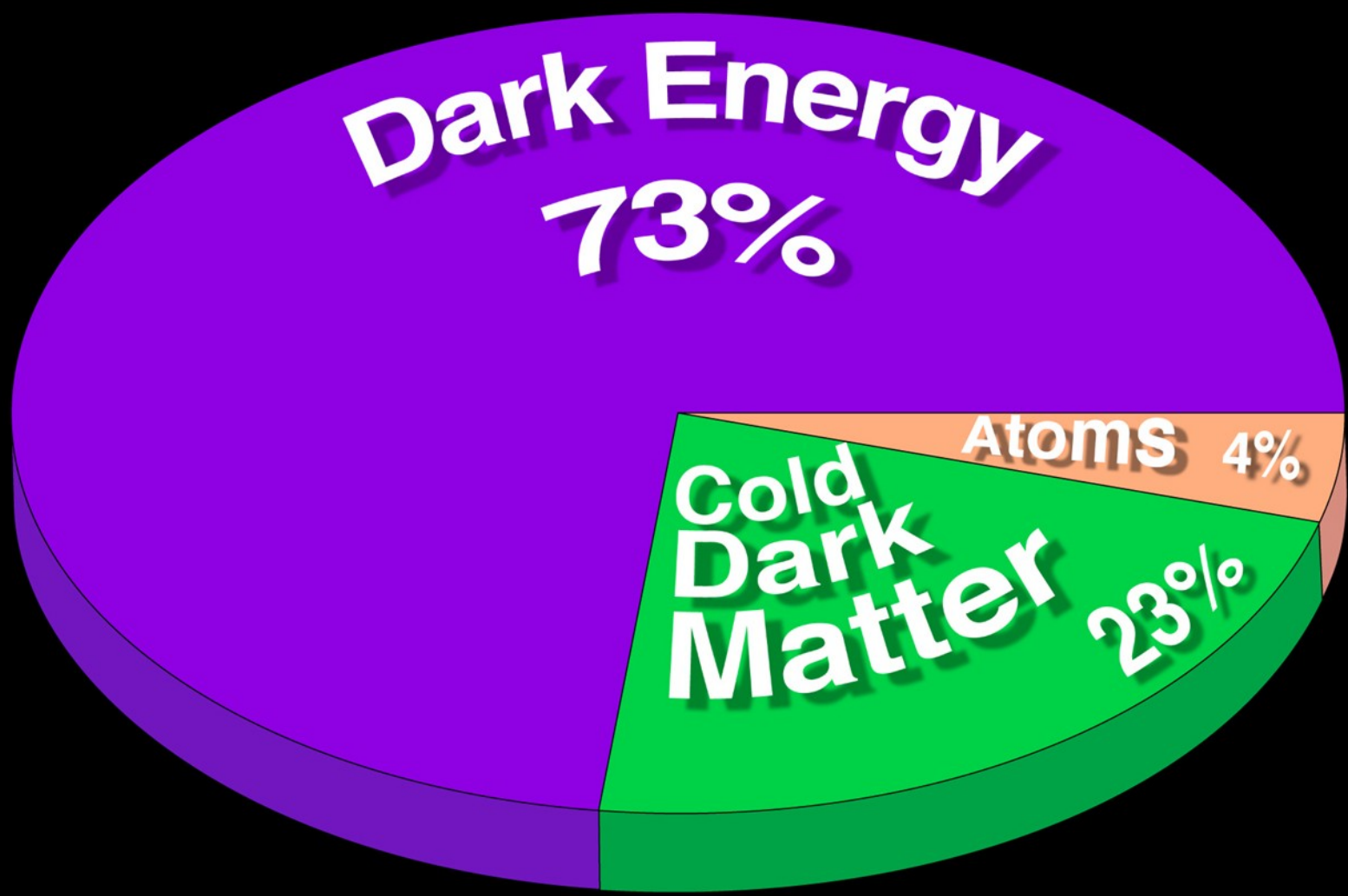


The cosmic cocktail: vacuum

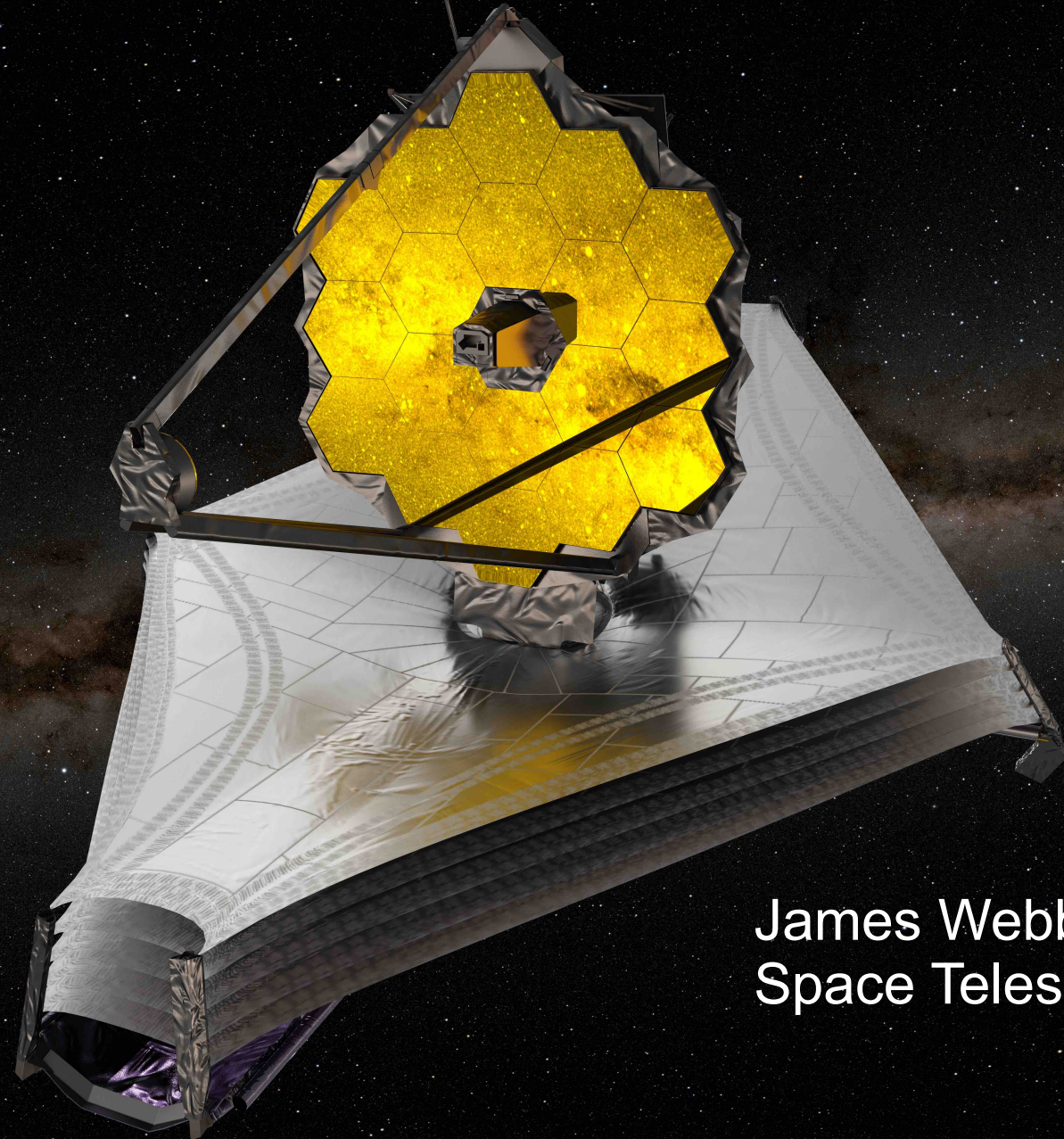


History of the universe: abridged





Looking out in space = looking back in time



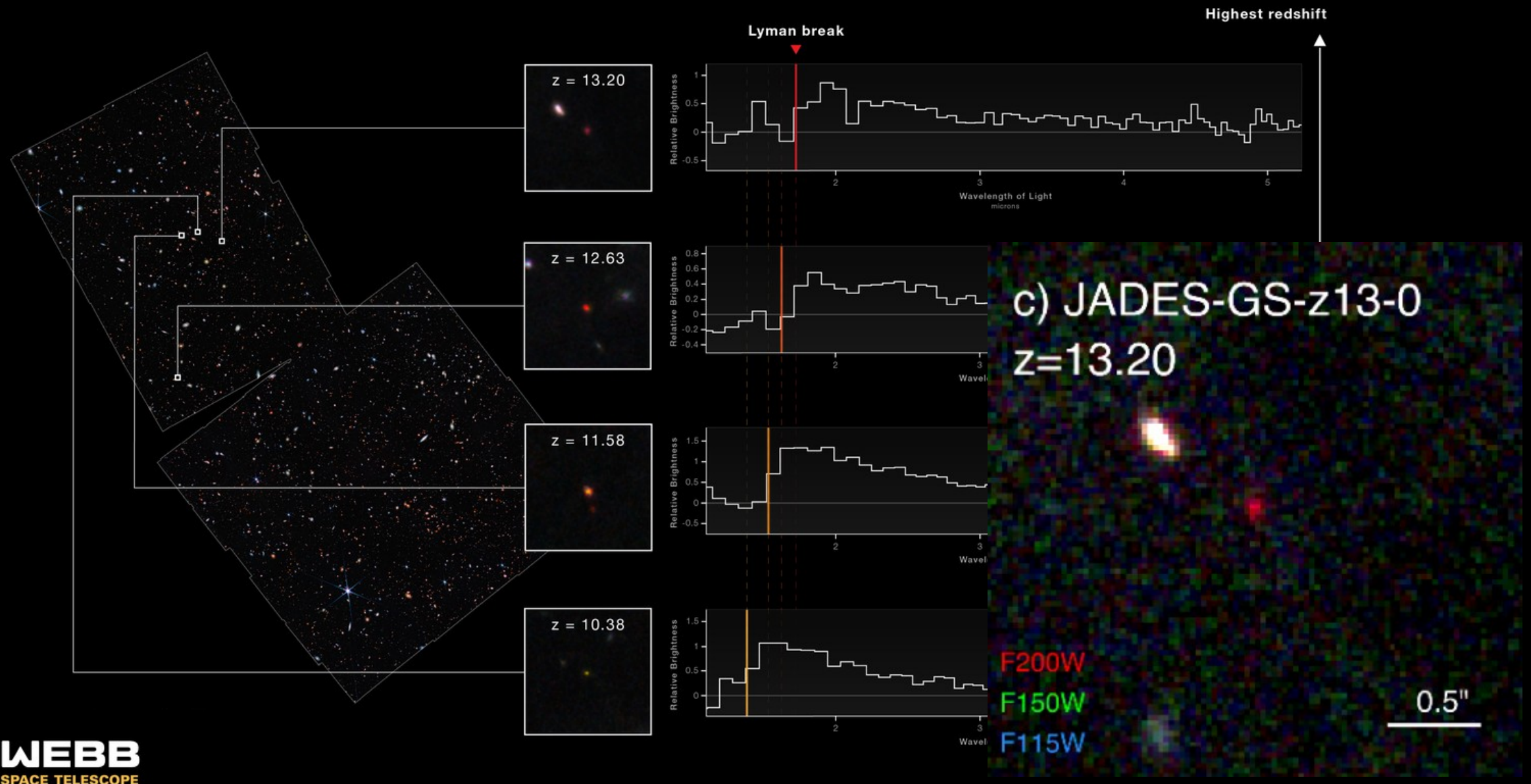
James Webb
Space Telescope

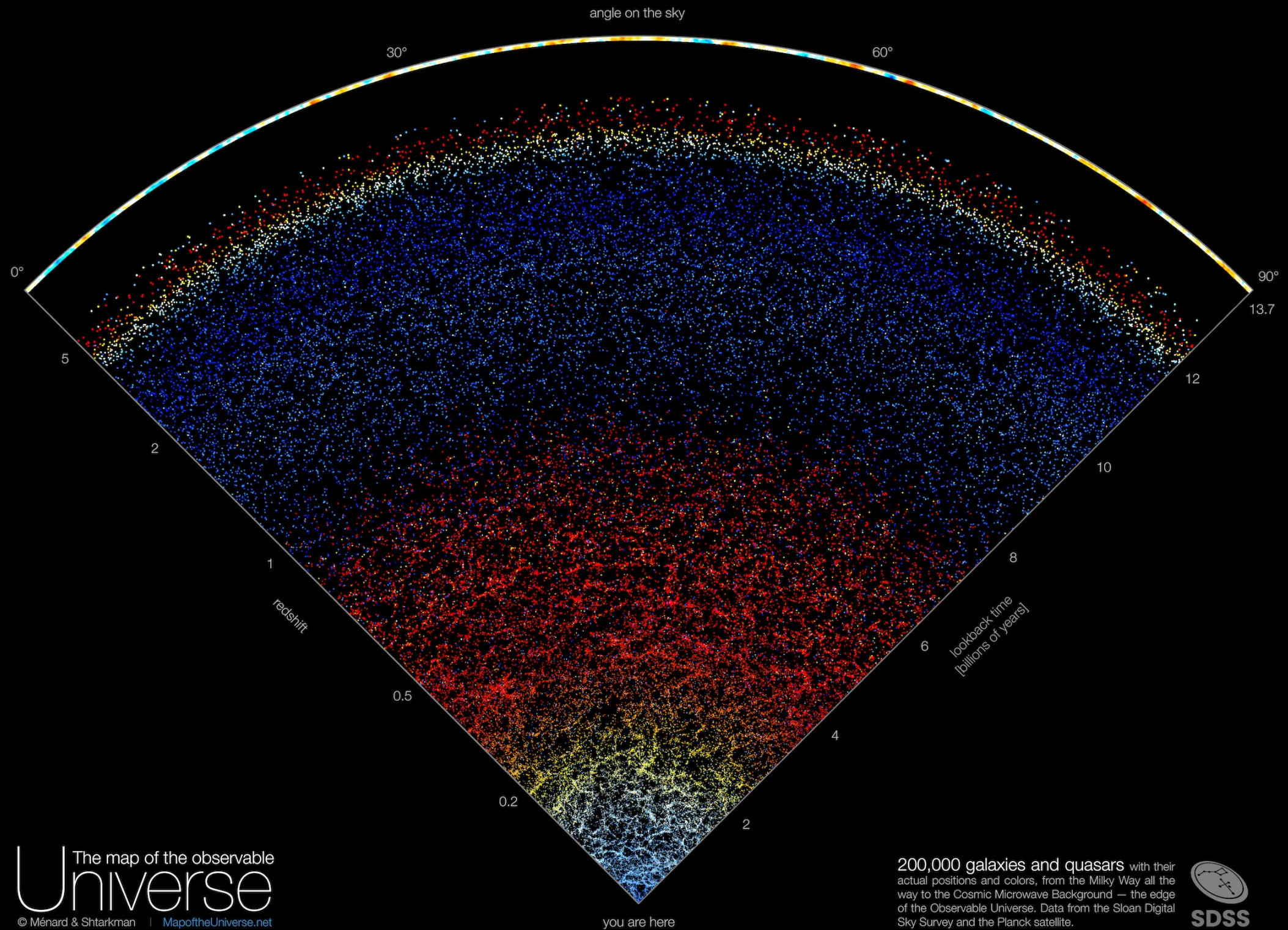


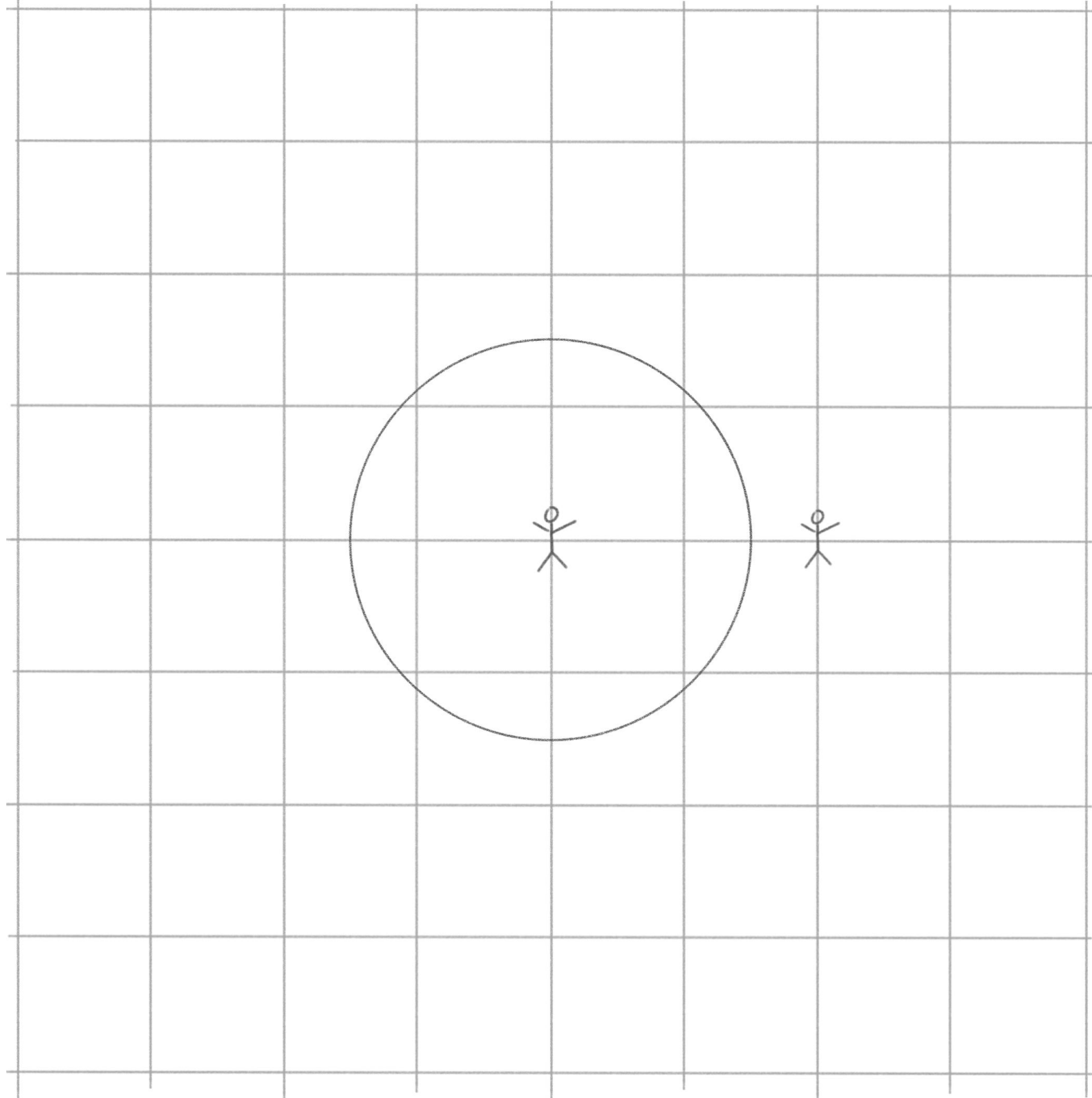
WEBB SPECTRA REACH NEW MILESTONE IN REDSHIFT FRONTIER

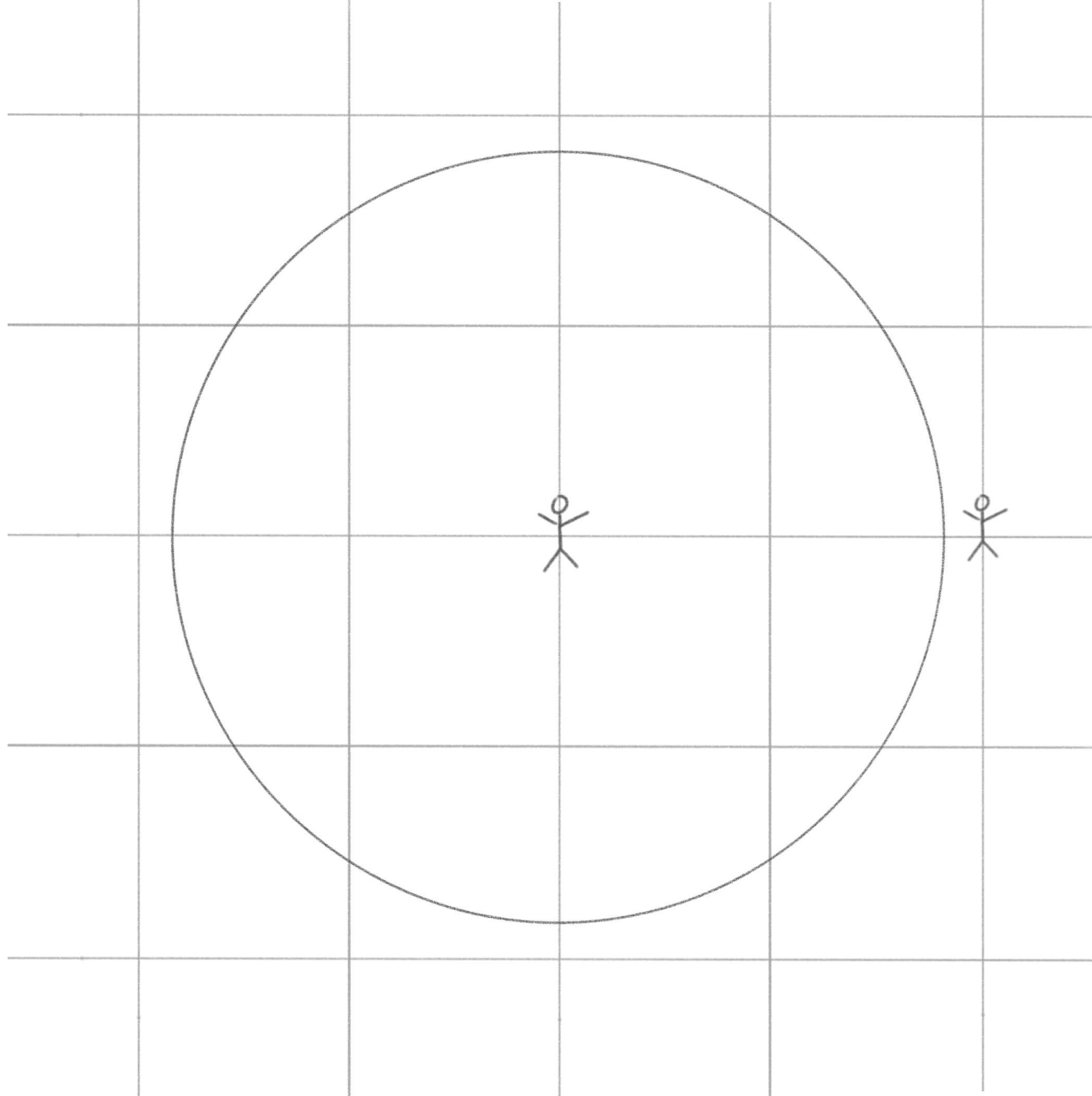
NIRCam Imaging

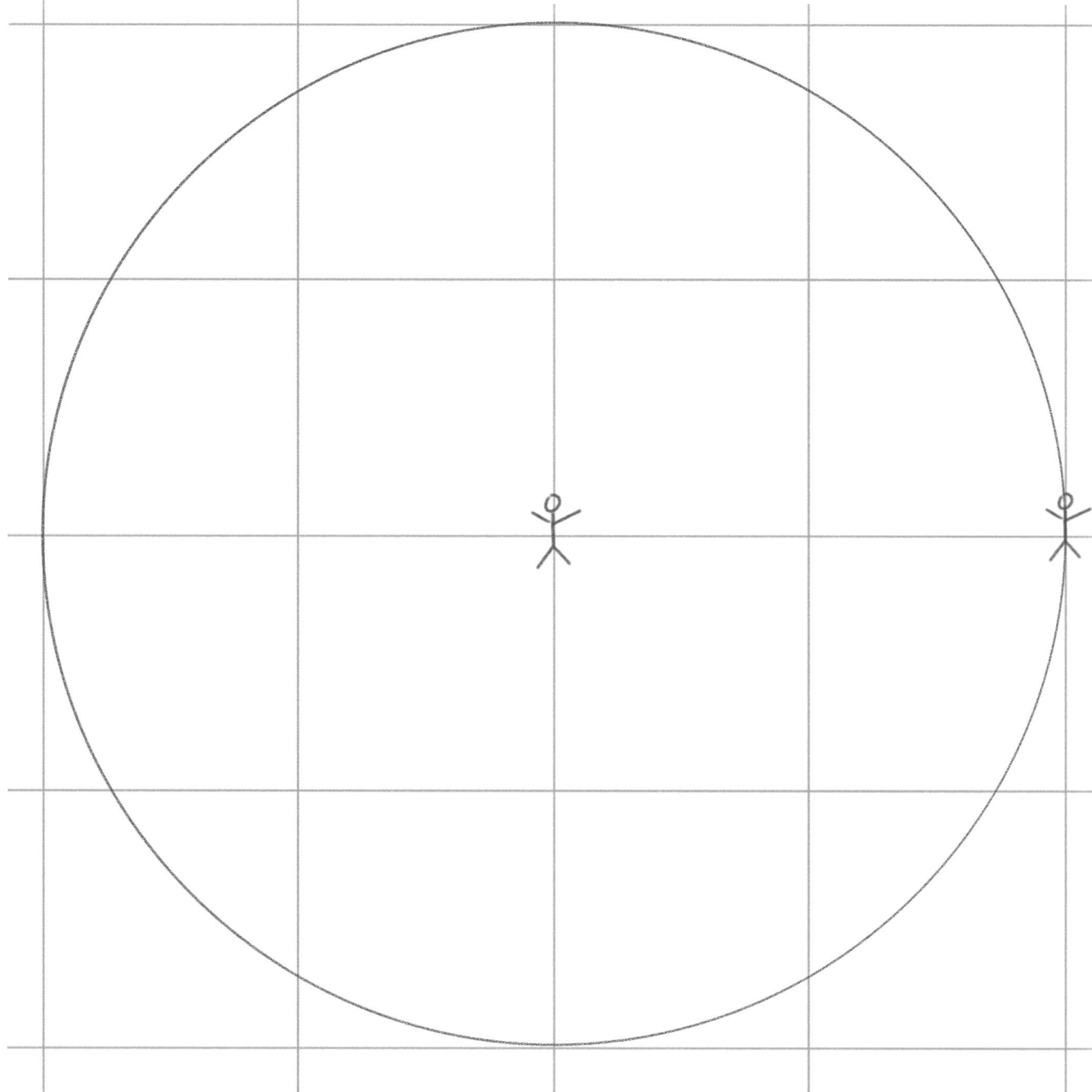
NIRSpec Microshutter Array Spectroscopy

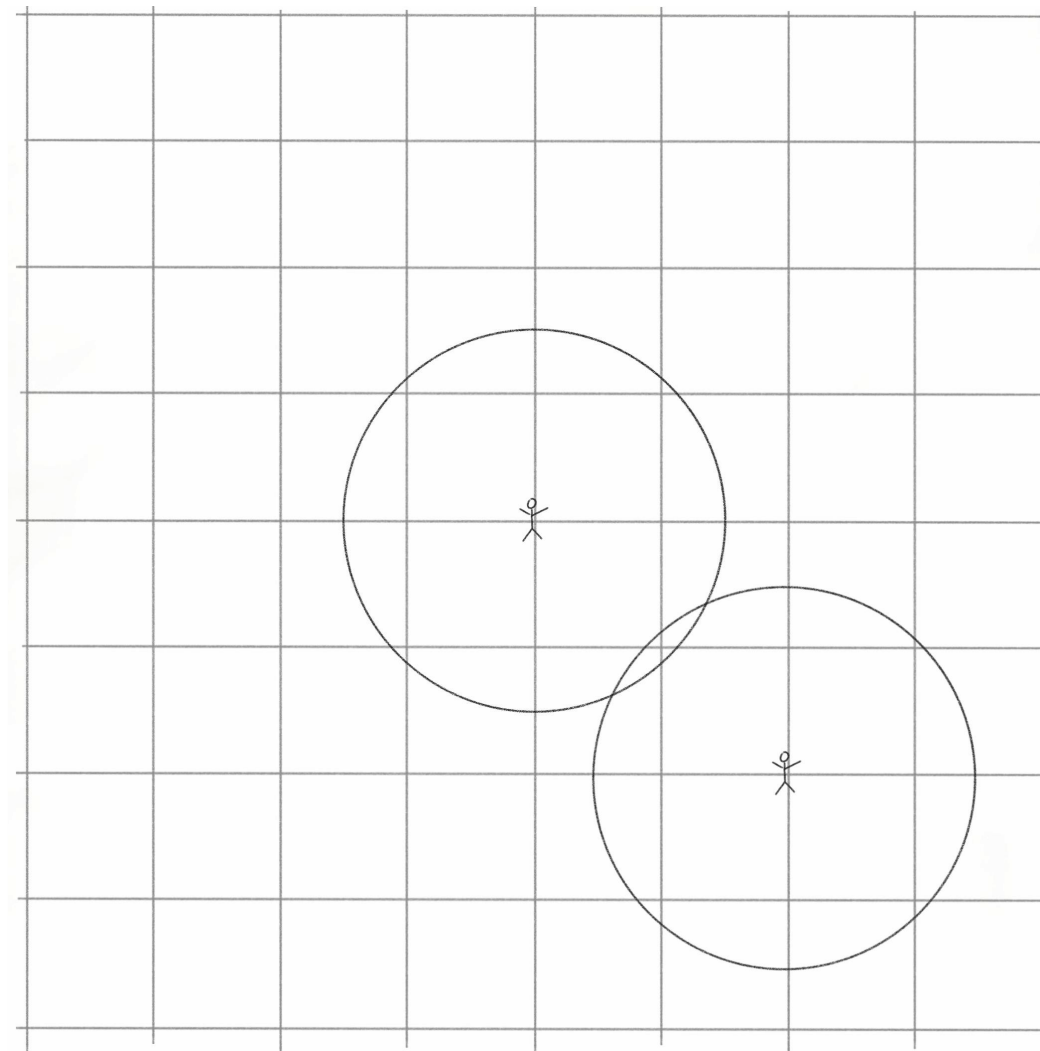
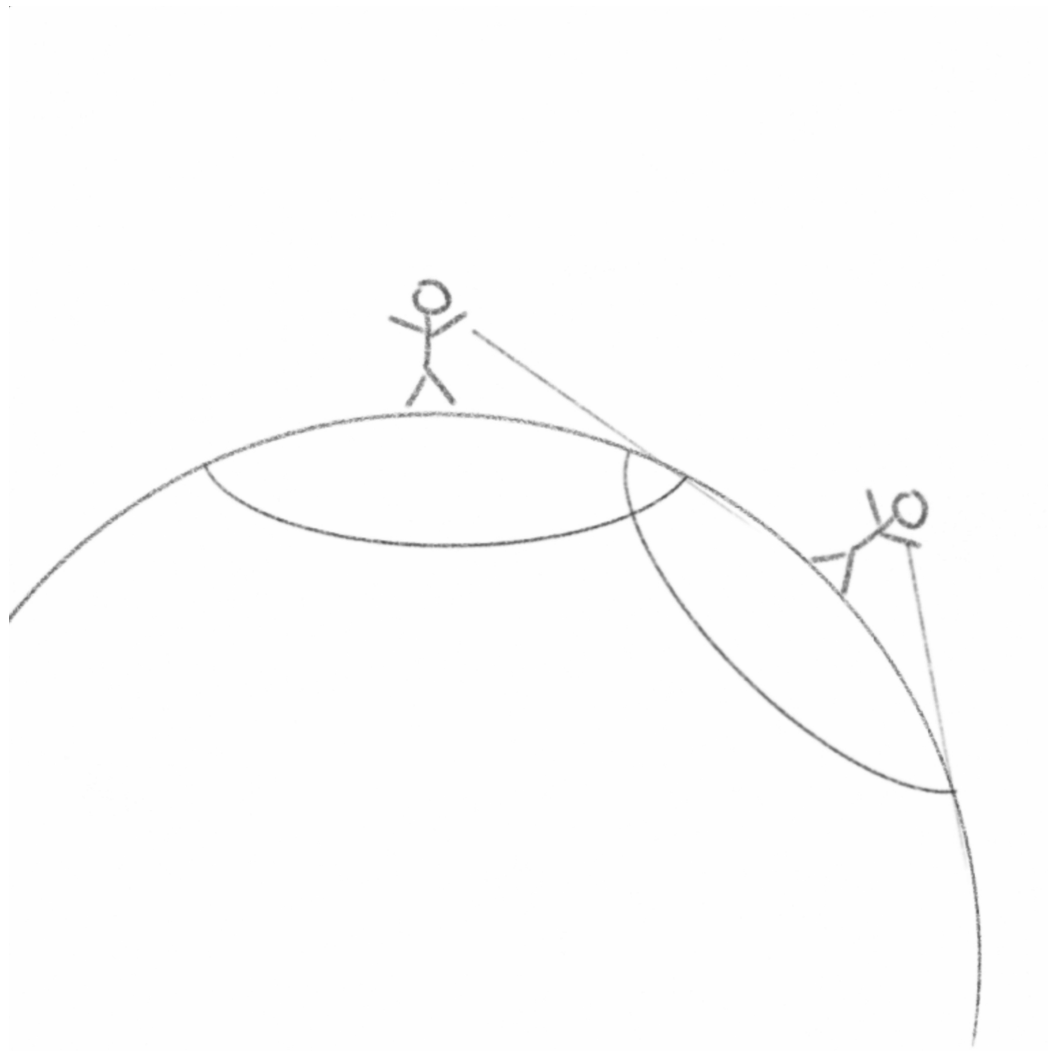




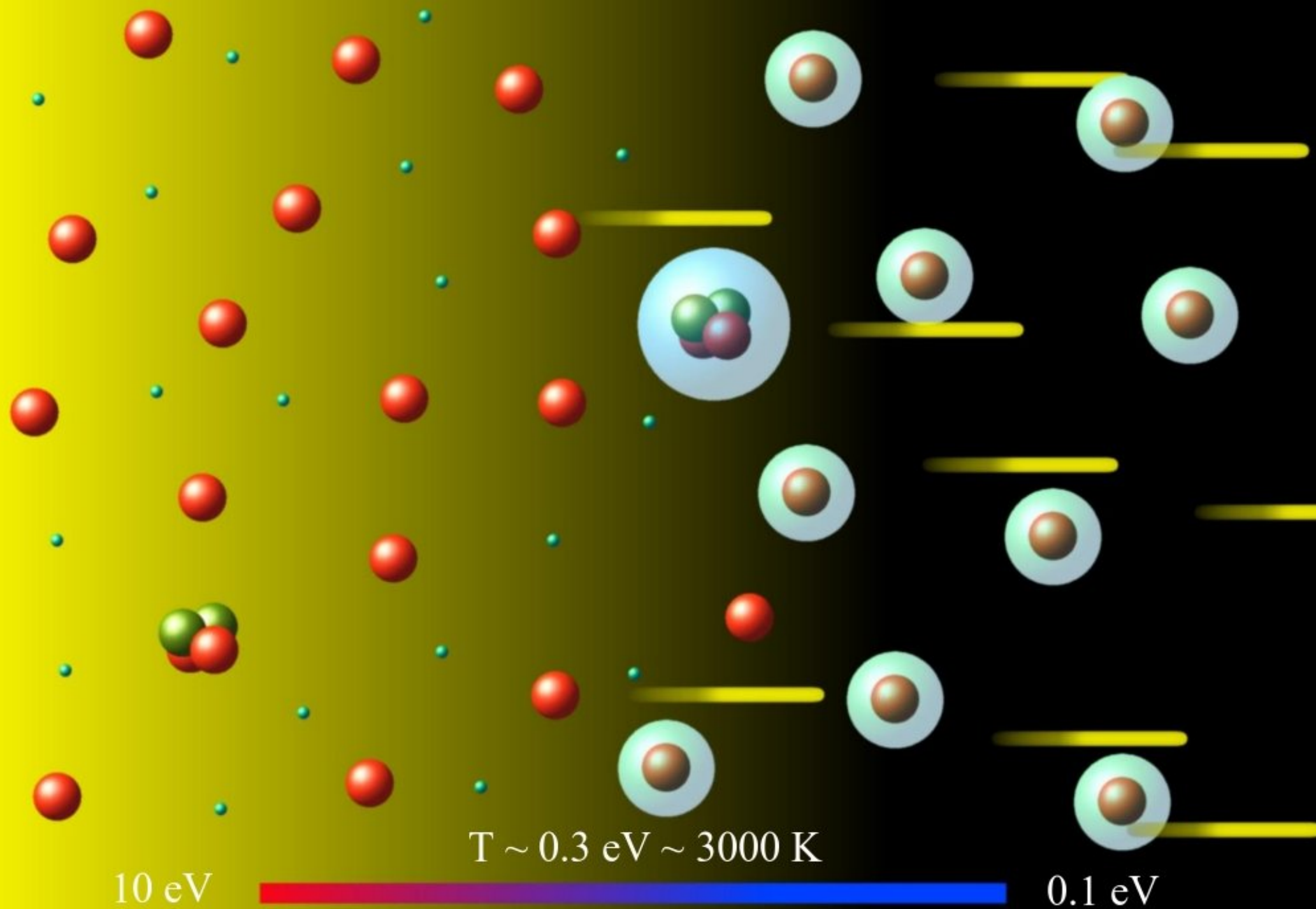








Recombination



Cosmic Microwave Background

Lookback Time
[Billion Years]

0.0

5.0

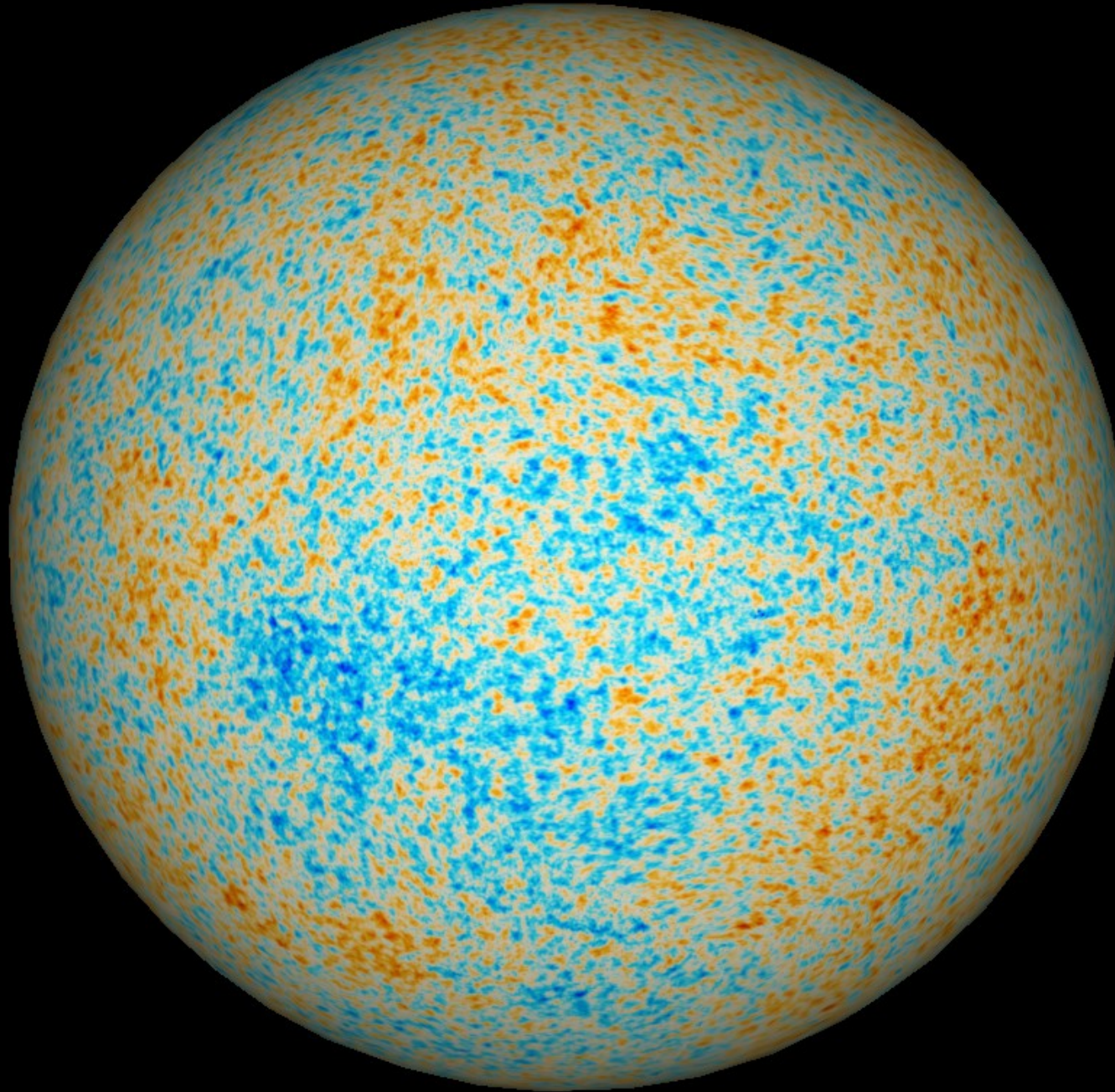
10.0

12.0

13.5

13.8

The Cosmic Microwave Background



(Image: ESA and the Planck collaboration)

COBE

W-band temperature anisotropy

WMAP

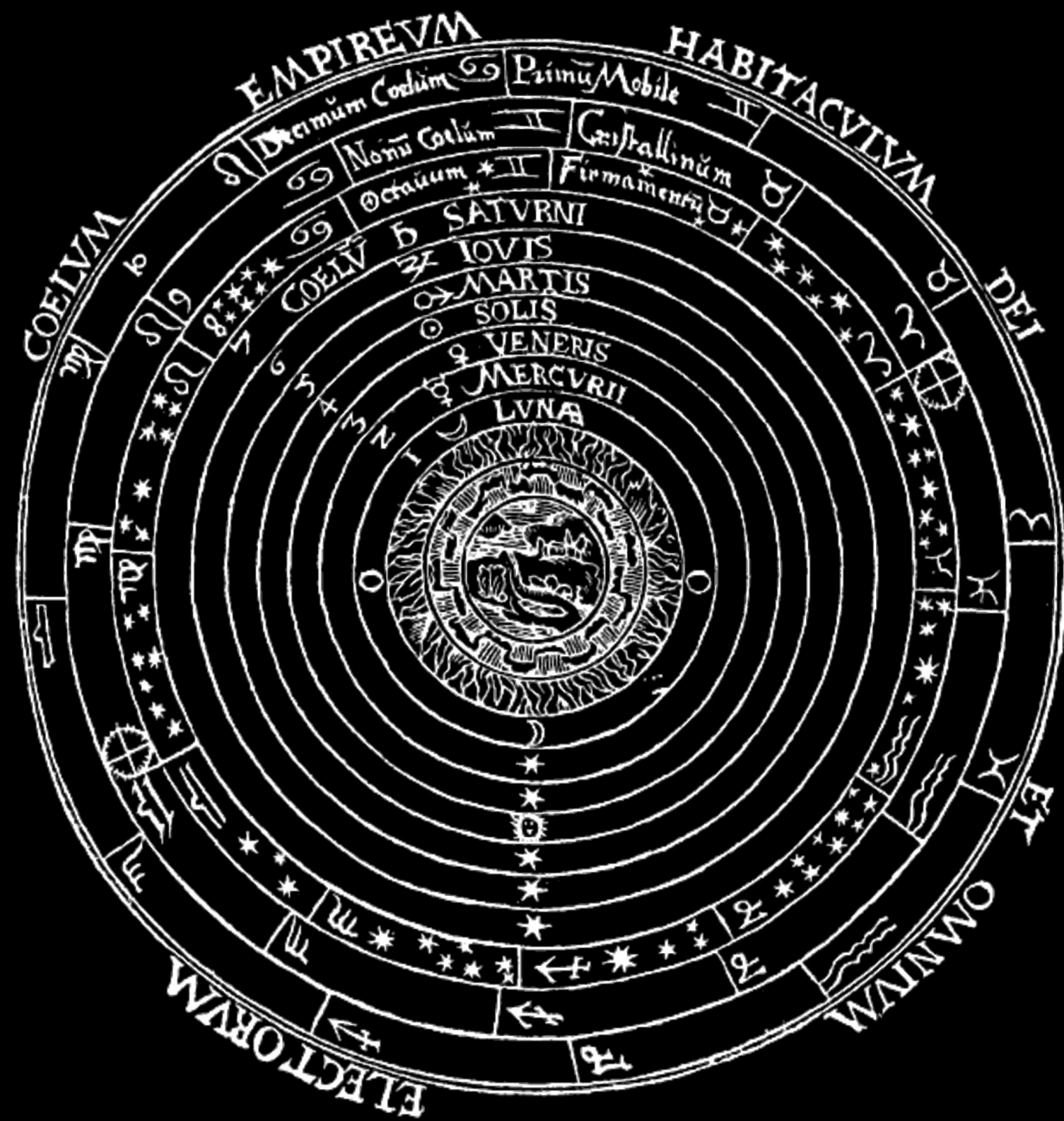
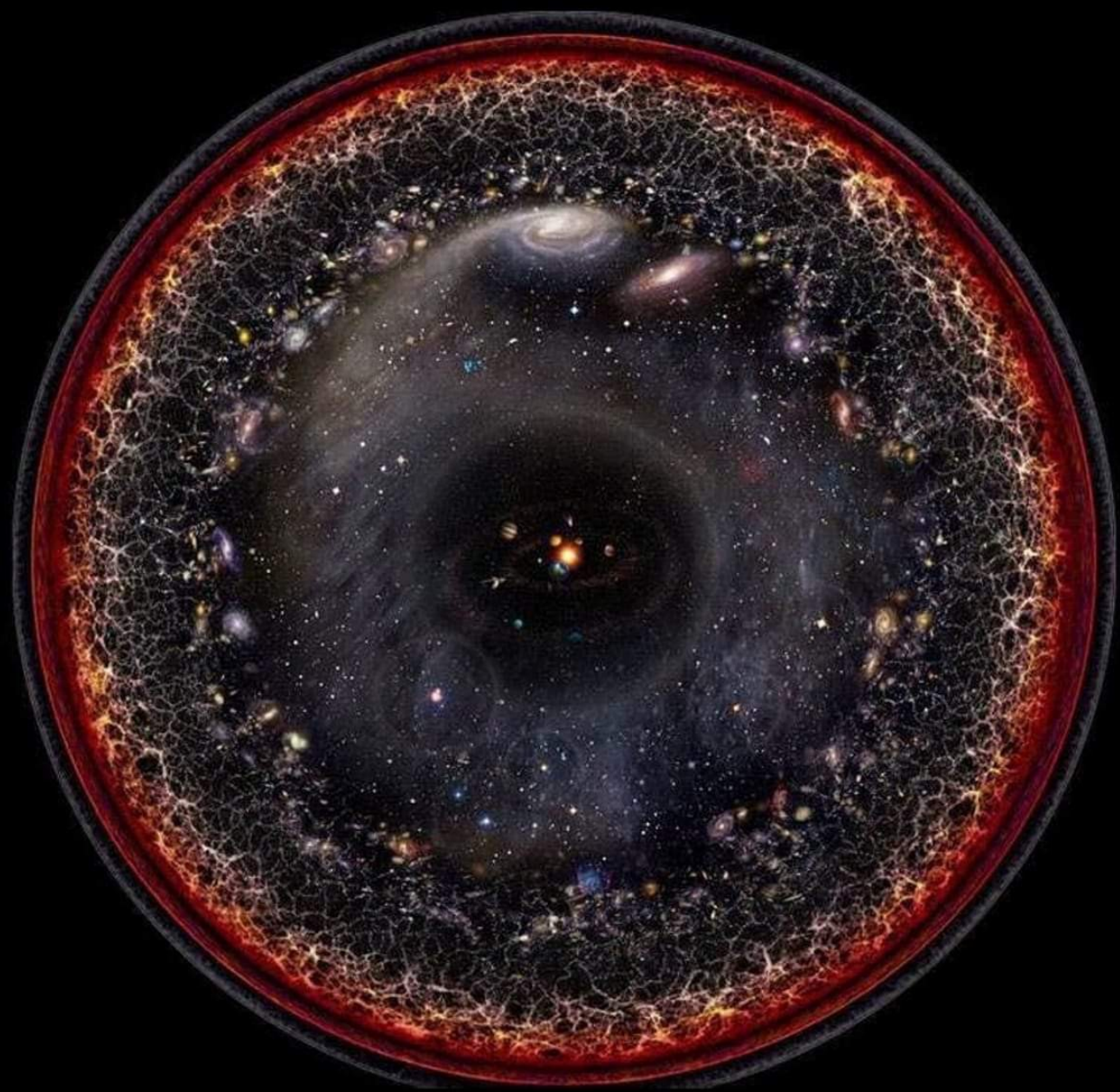
Internal Linear Combination of 5 bands, smoothed

Simulated temperature anisotropy

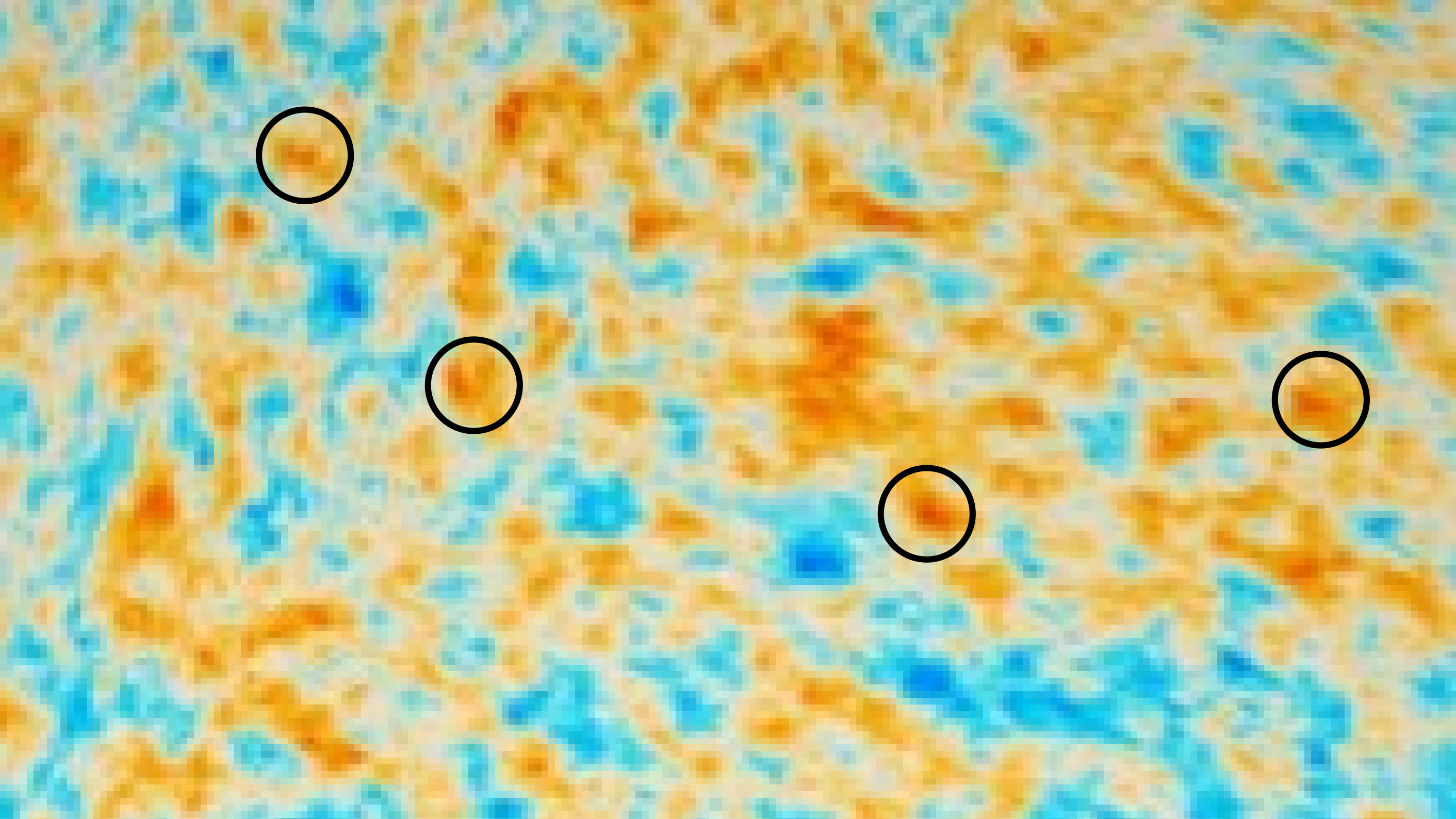
PLANCK

Simulated temperature and polarization anisotropy





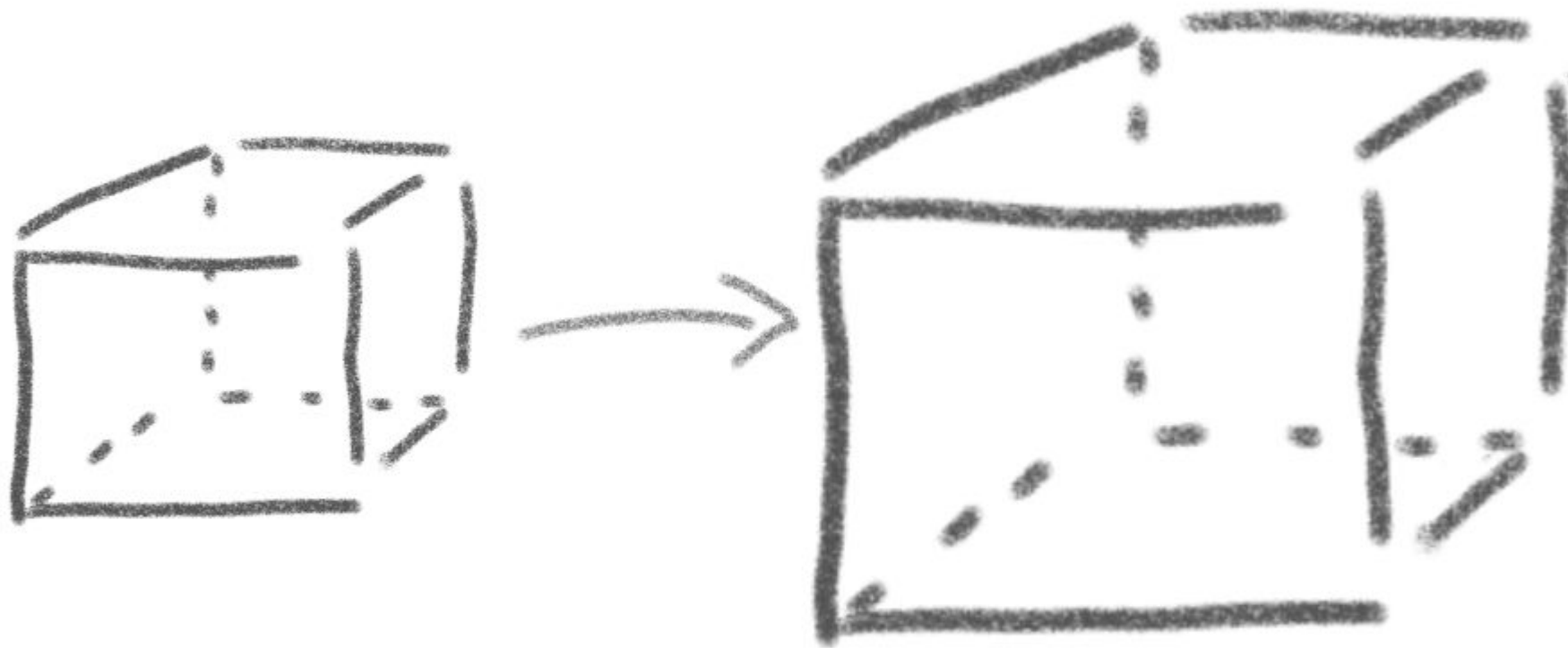
(Image: Pablo Carlos Budassi)

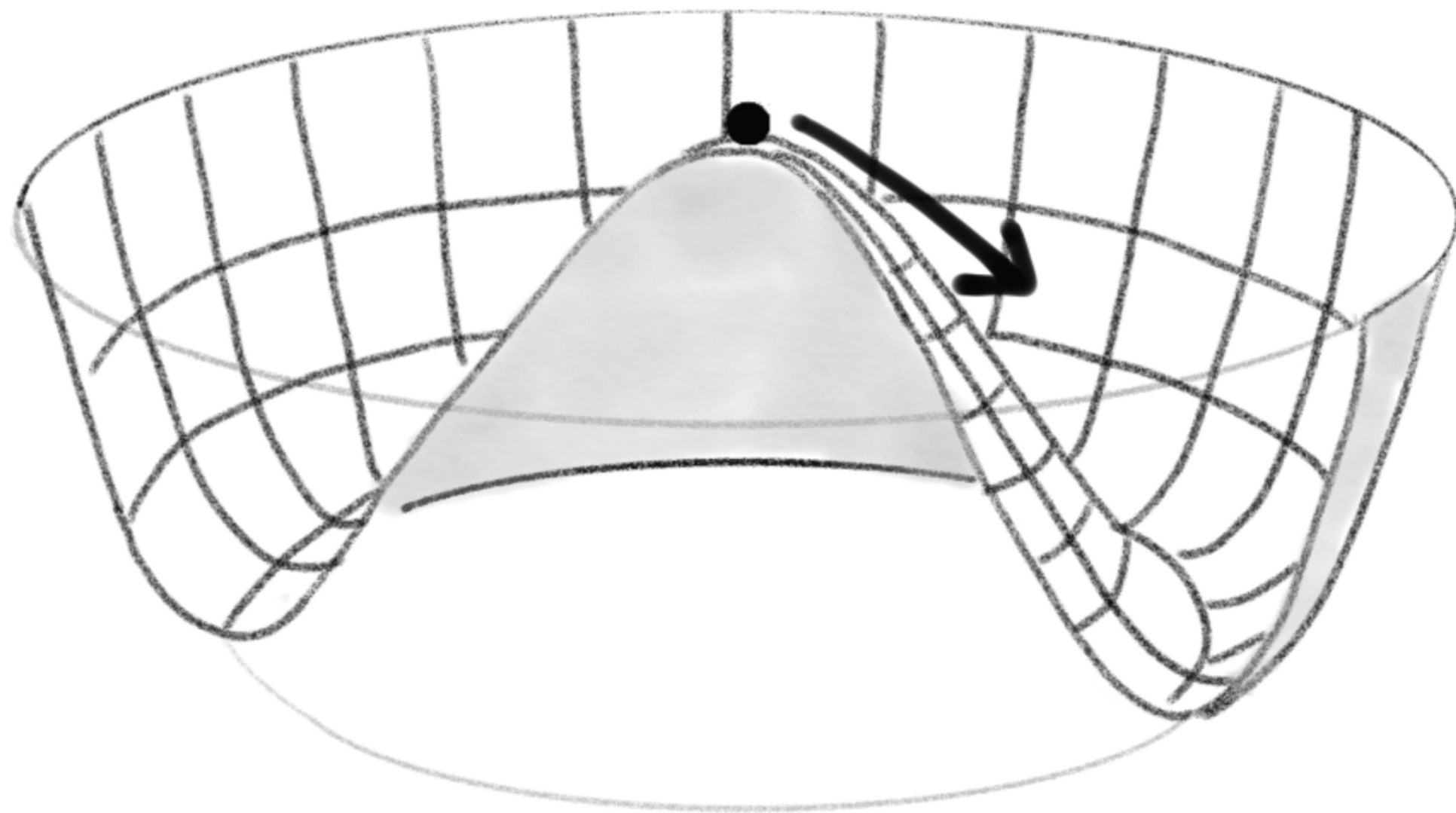


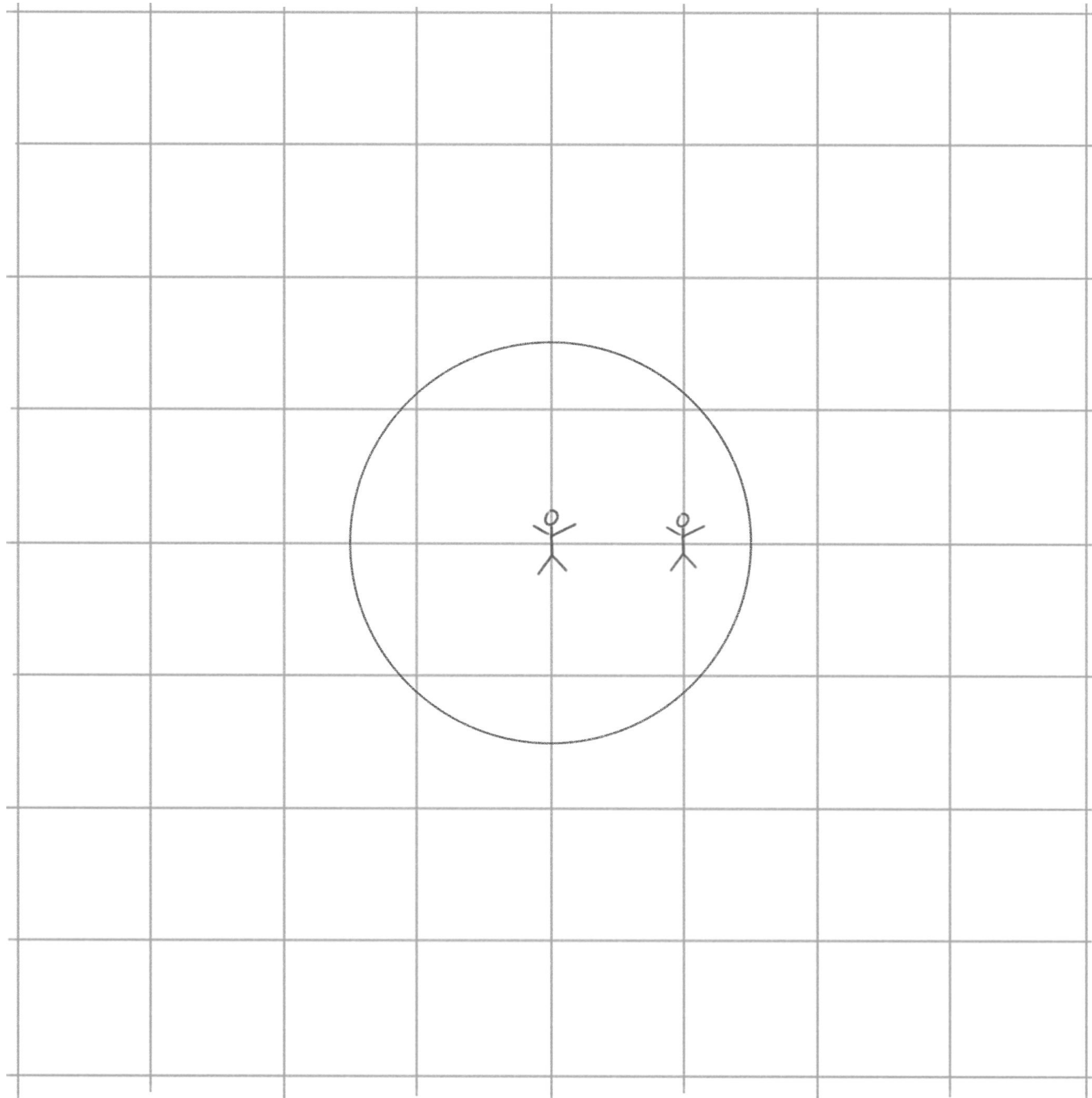


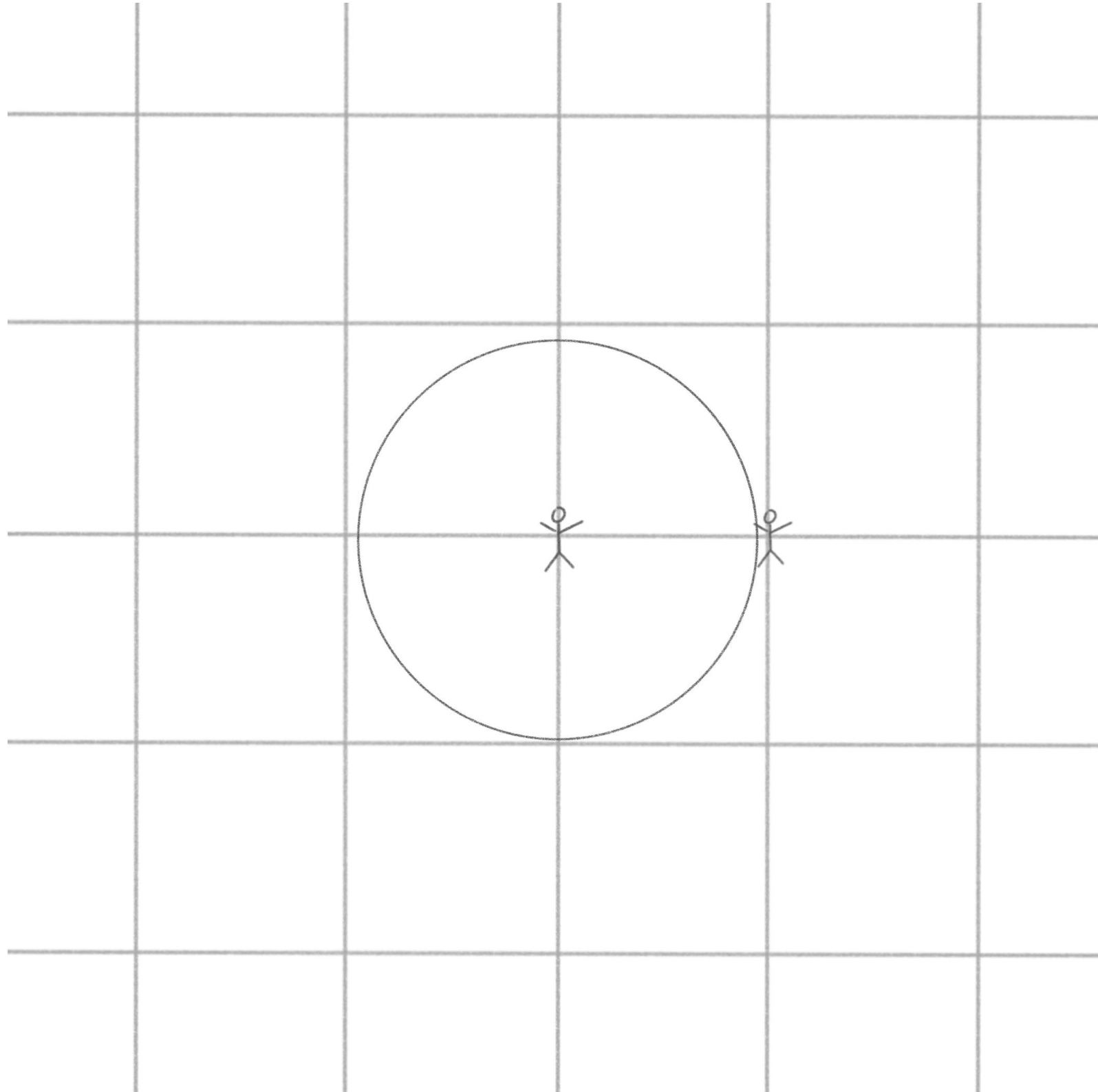
Inflation

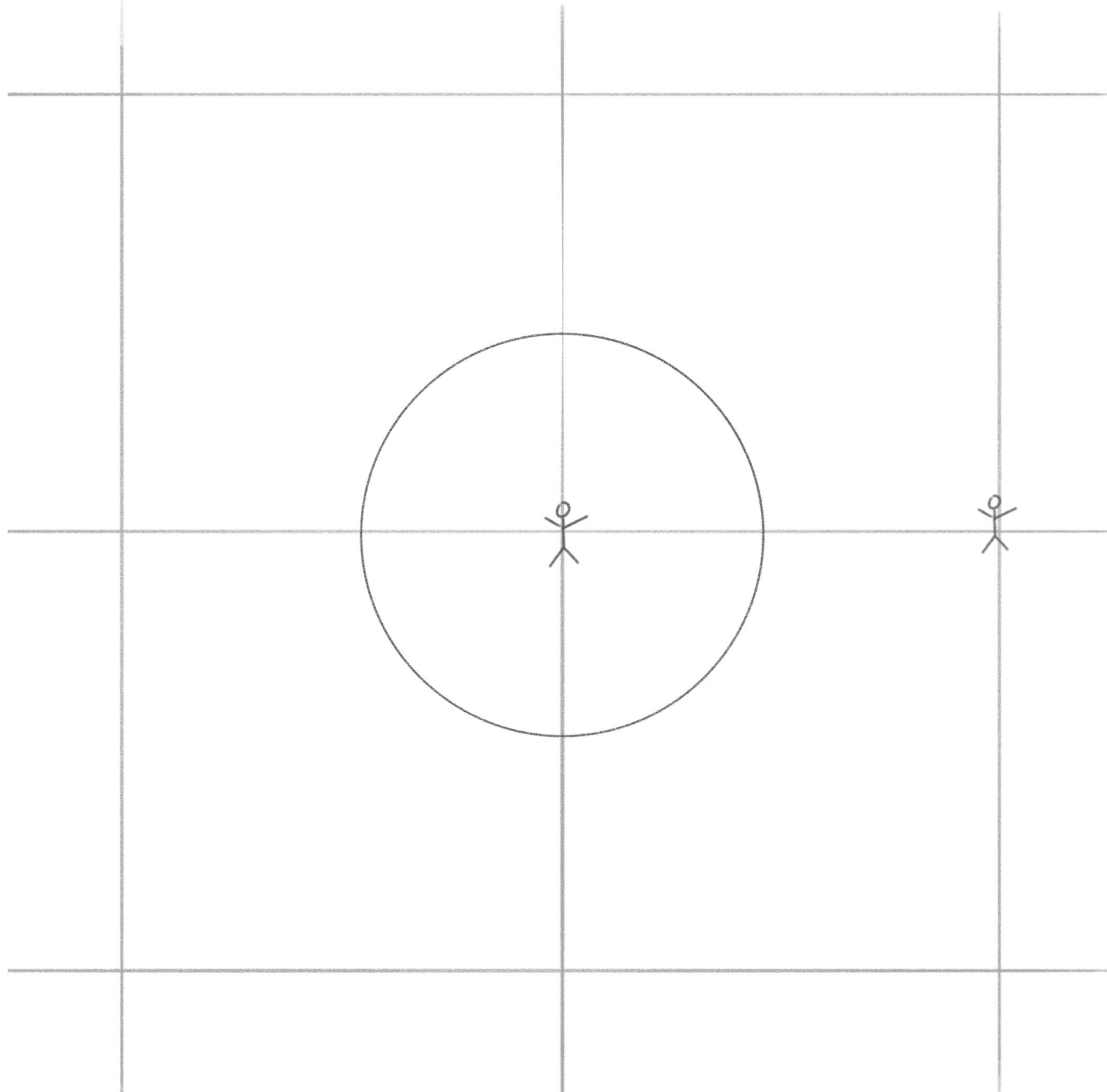
Vacuum energy and inflation



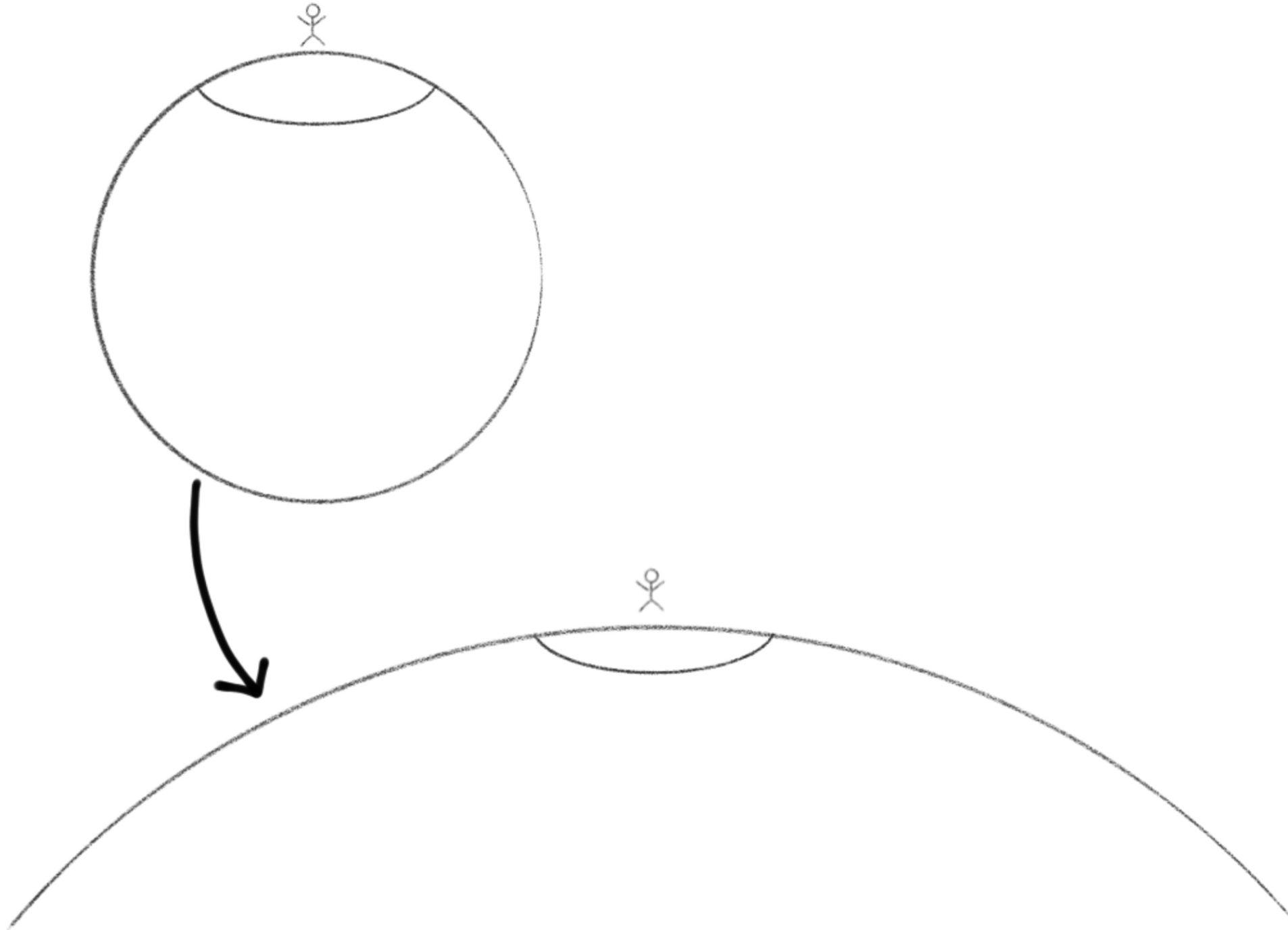




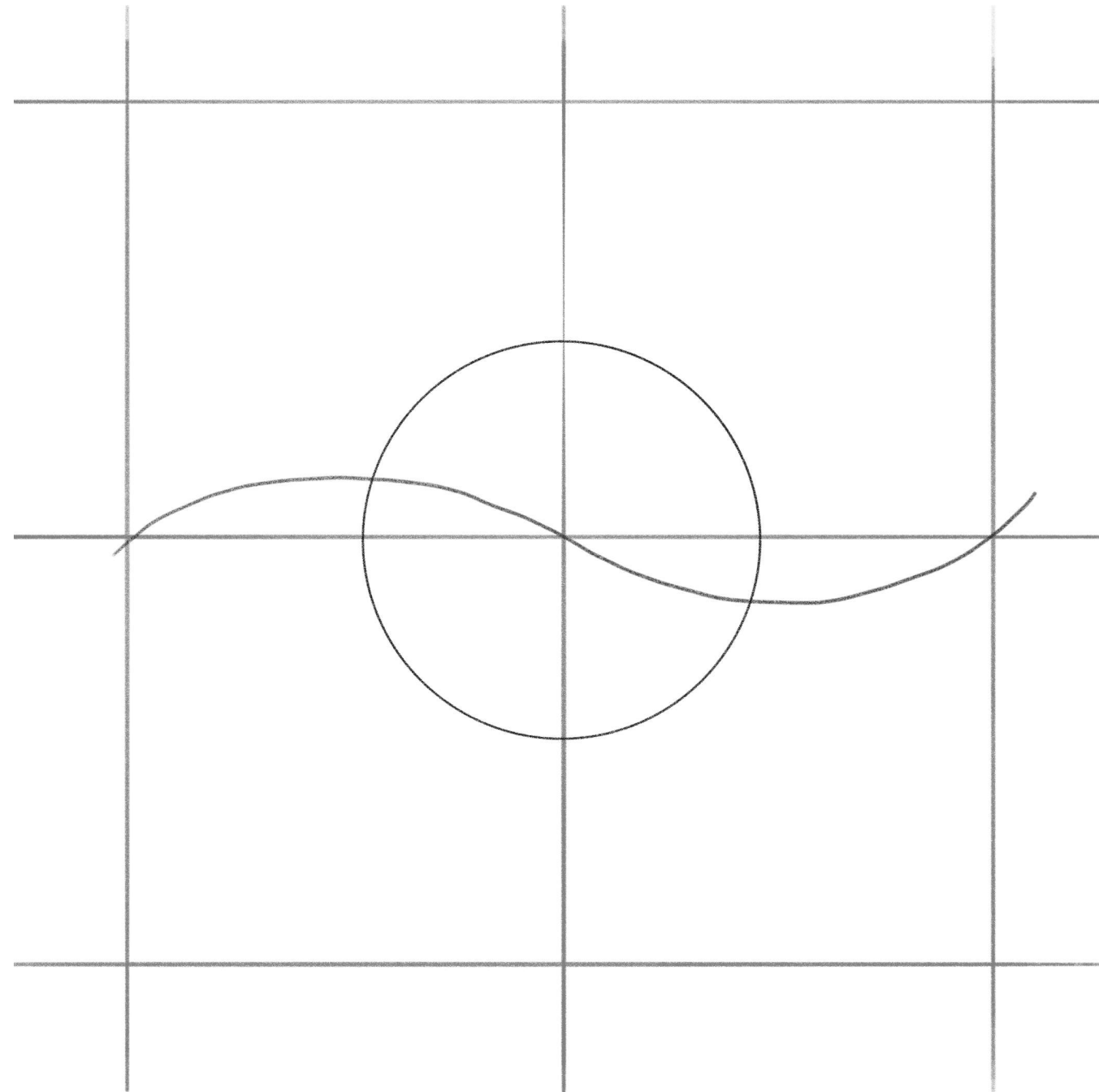
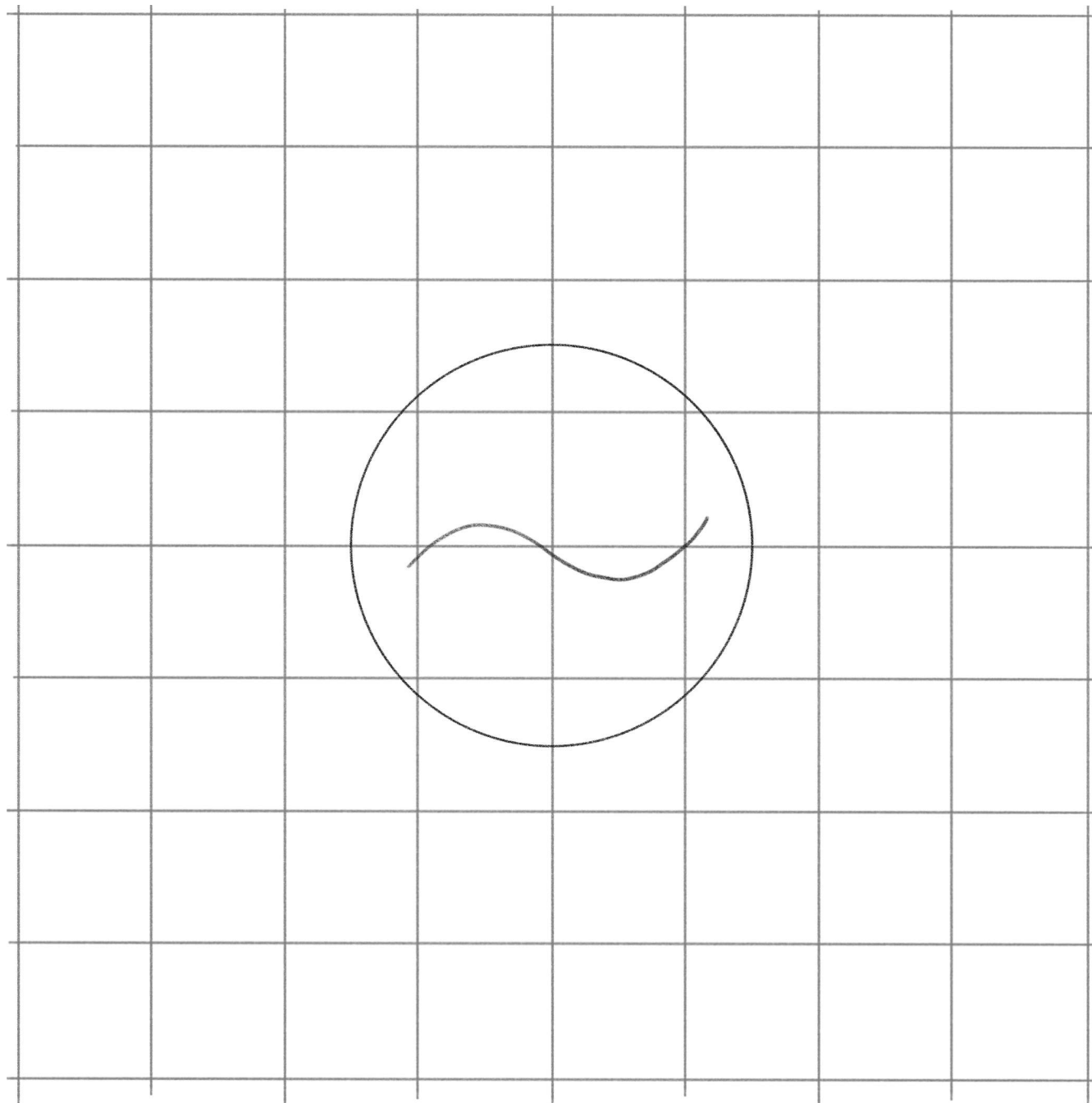




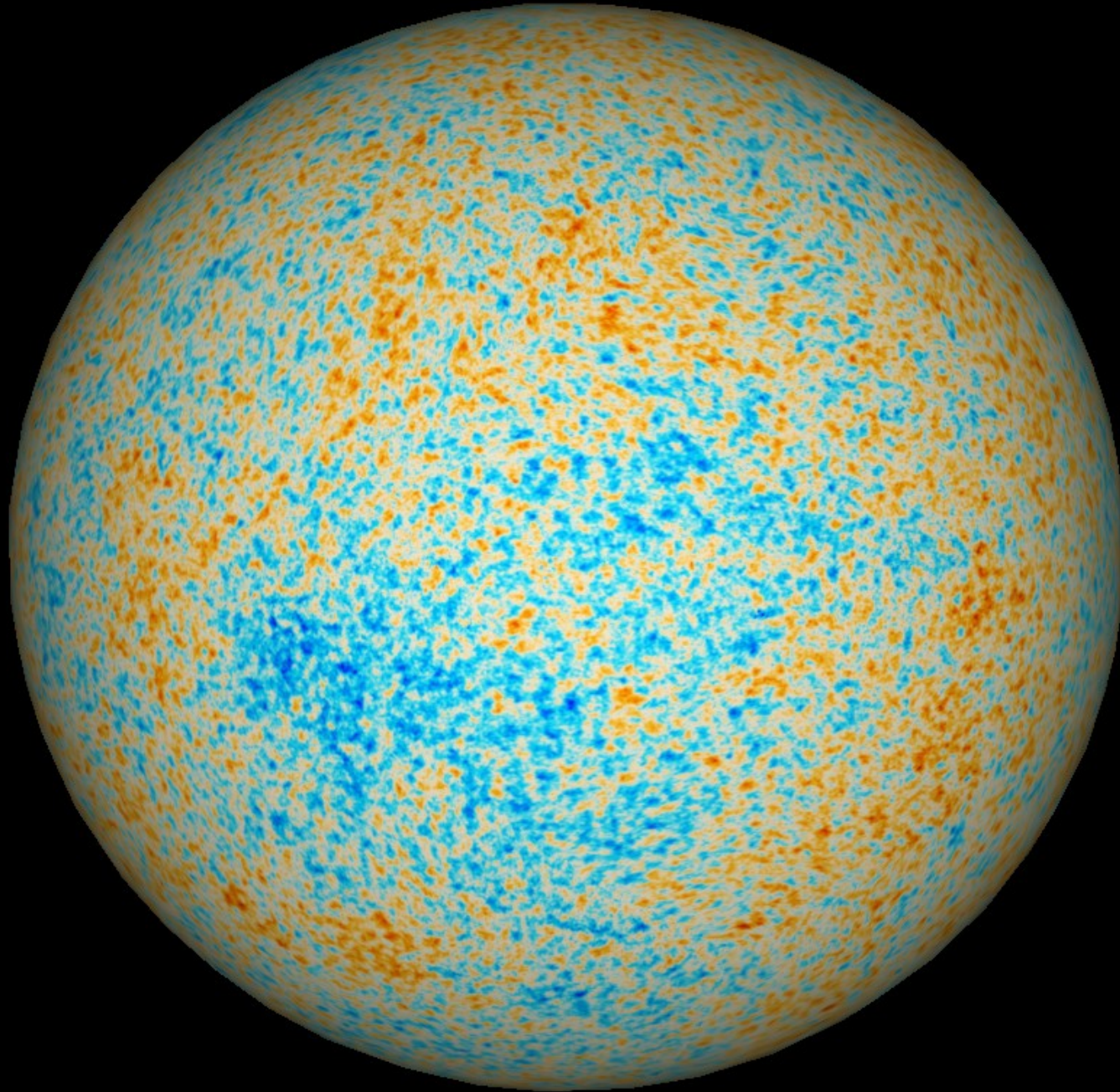
Inflation makes the universe flat and smooth



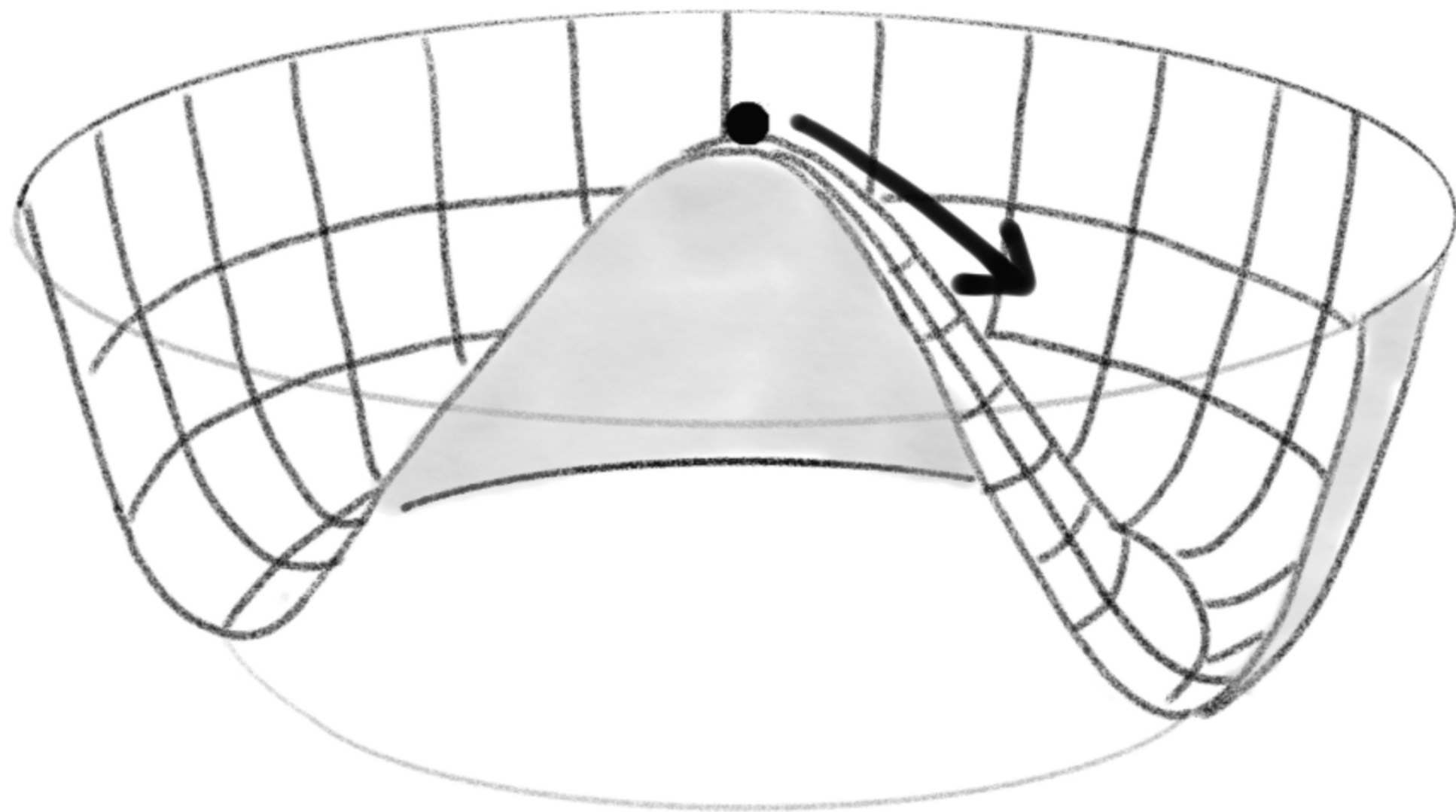
Quantum fluctuations source structure

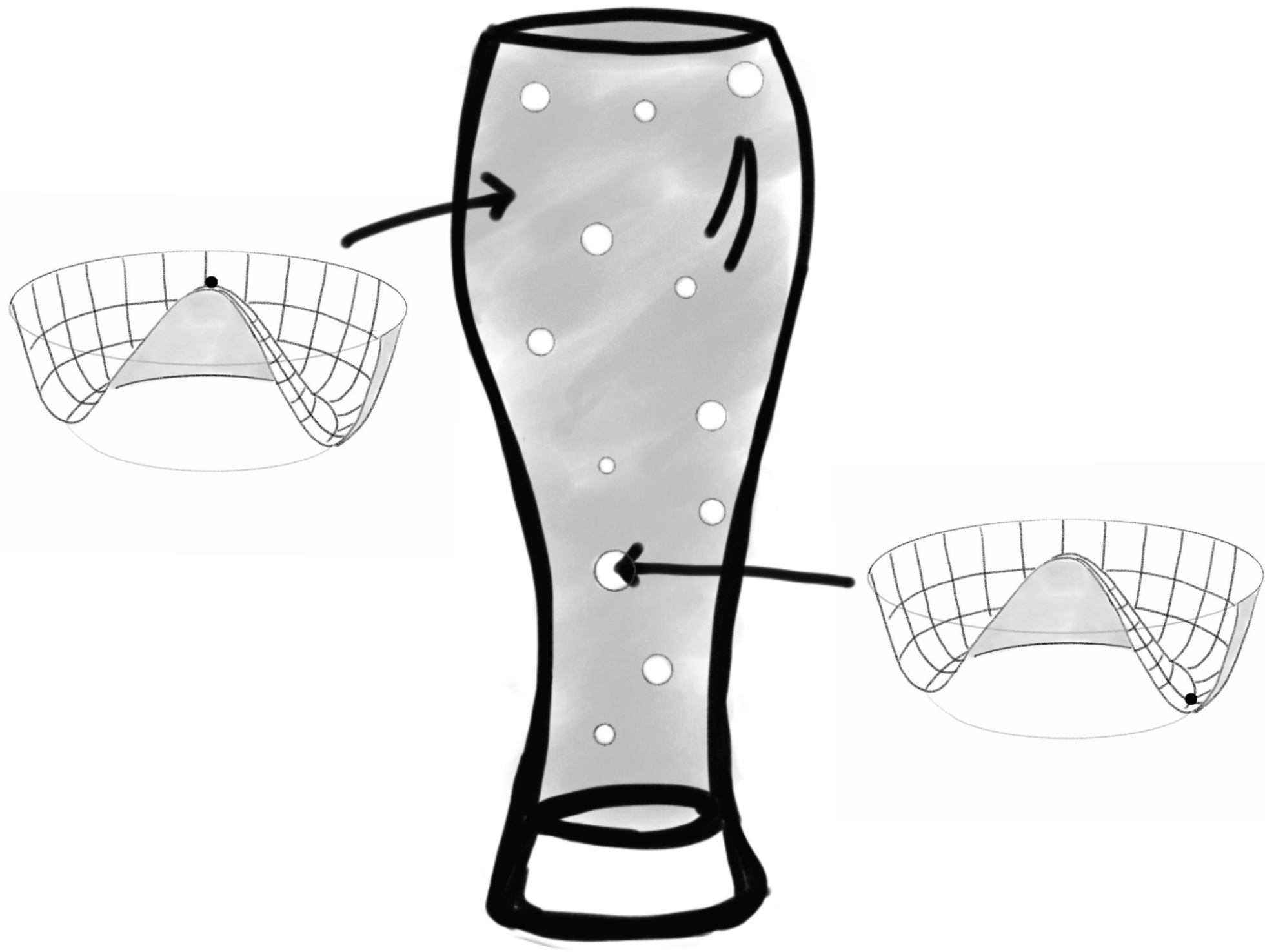


Primordial perturbations

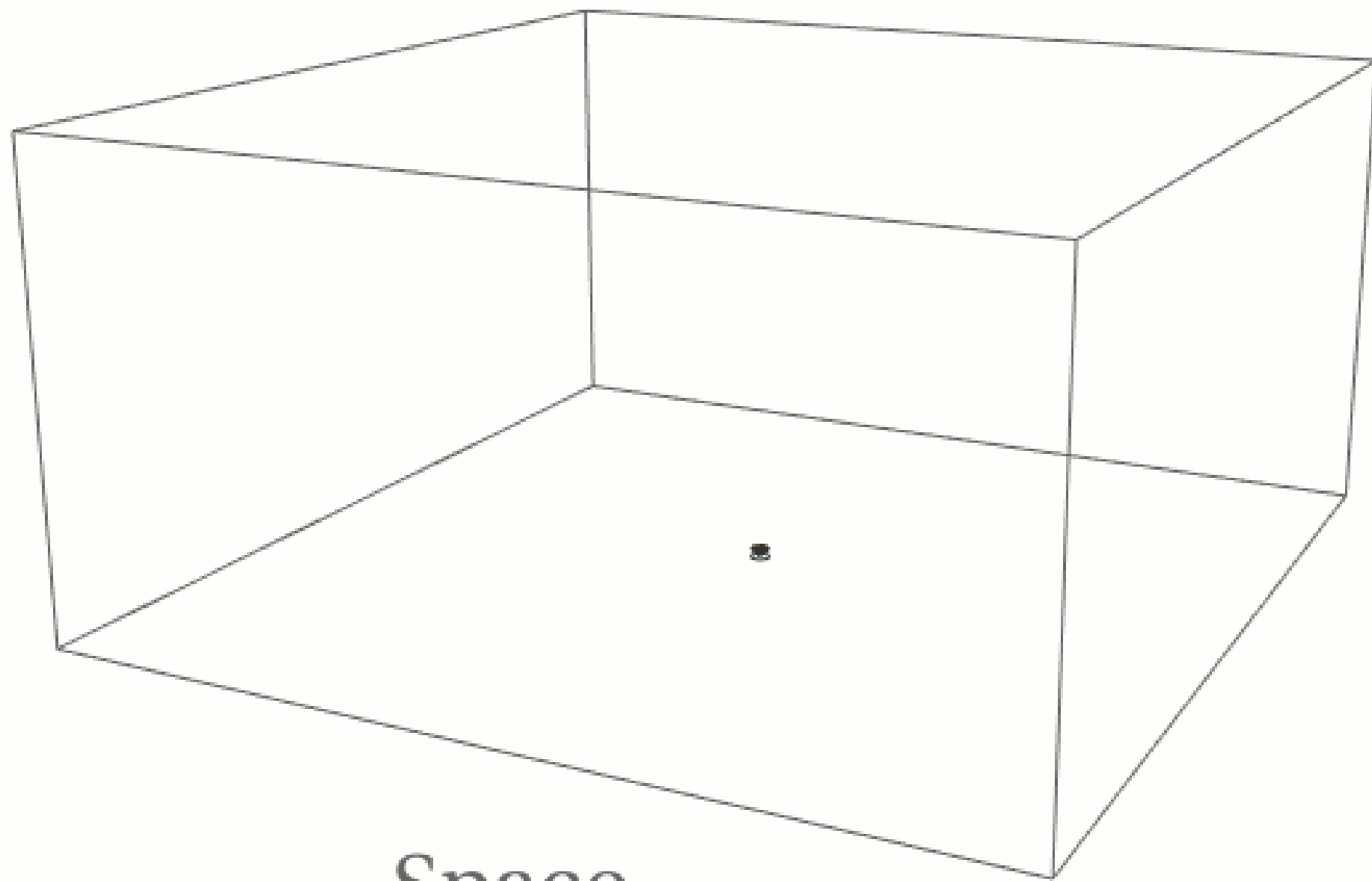


(Image: ESA and the Planck collaboration)

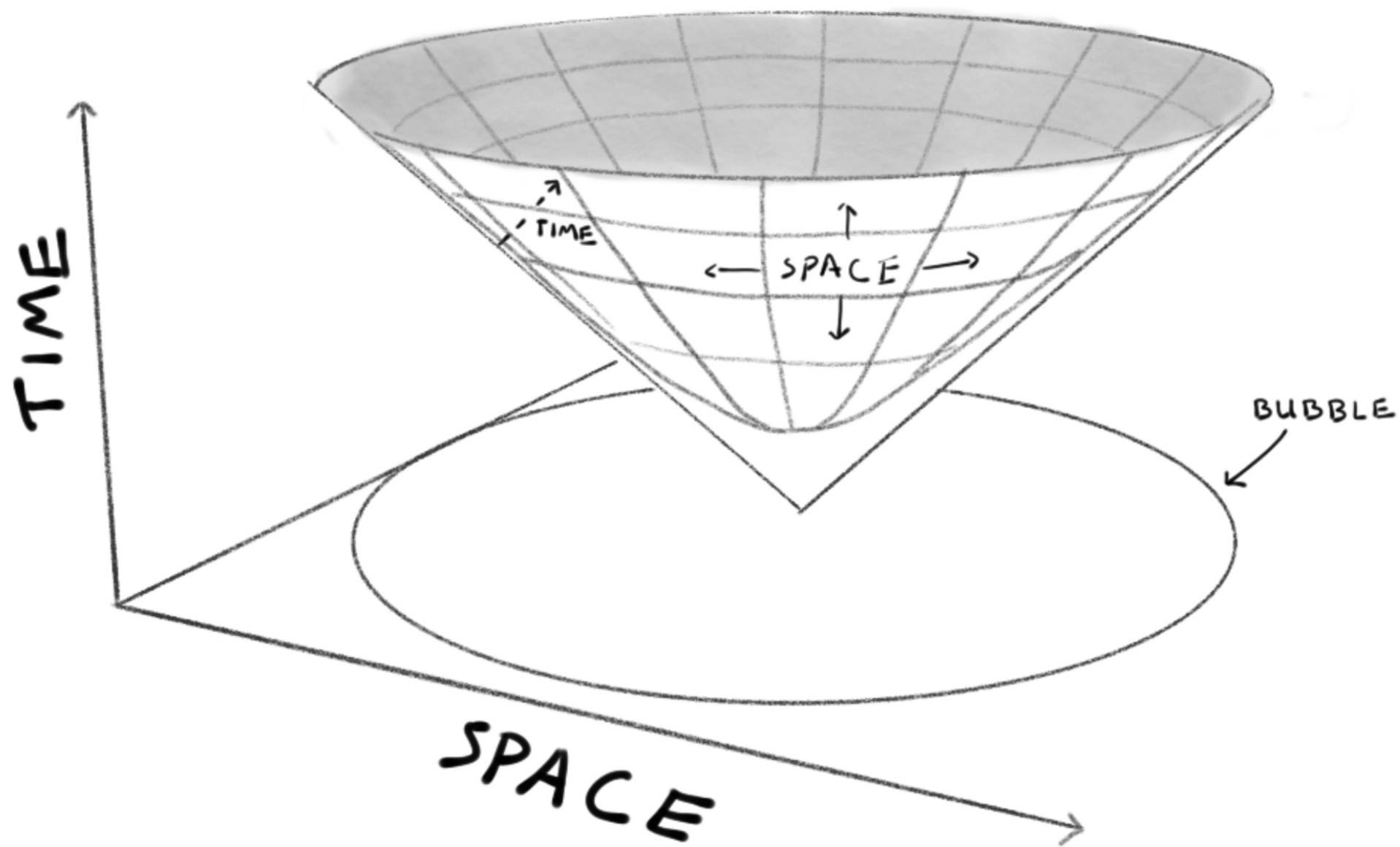




Time



Space



*God is infinite, so His universe must be too...
He is glorified not in one, but in countless
suns; not in a single earth, a single world, but
in a thousand thousand, I say in an infinity
of worlds.*

-- Giordano Bruno, 1584

