Astronomy Course Outline

Week 1: The Sky | Week 2: The Planets | **Week 3: The Stars** | Week 4: History of Astronomy | Week 5: Telescopes | Week 6: Deep Sky Objects | Week 7: Cosmology | Week 8: Alien Worlds

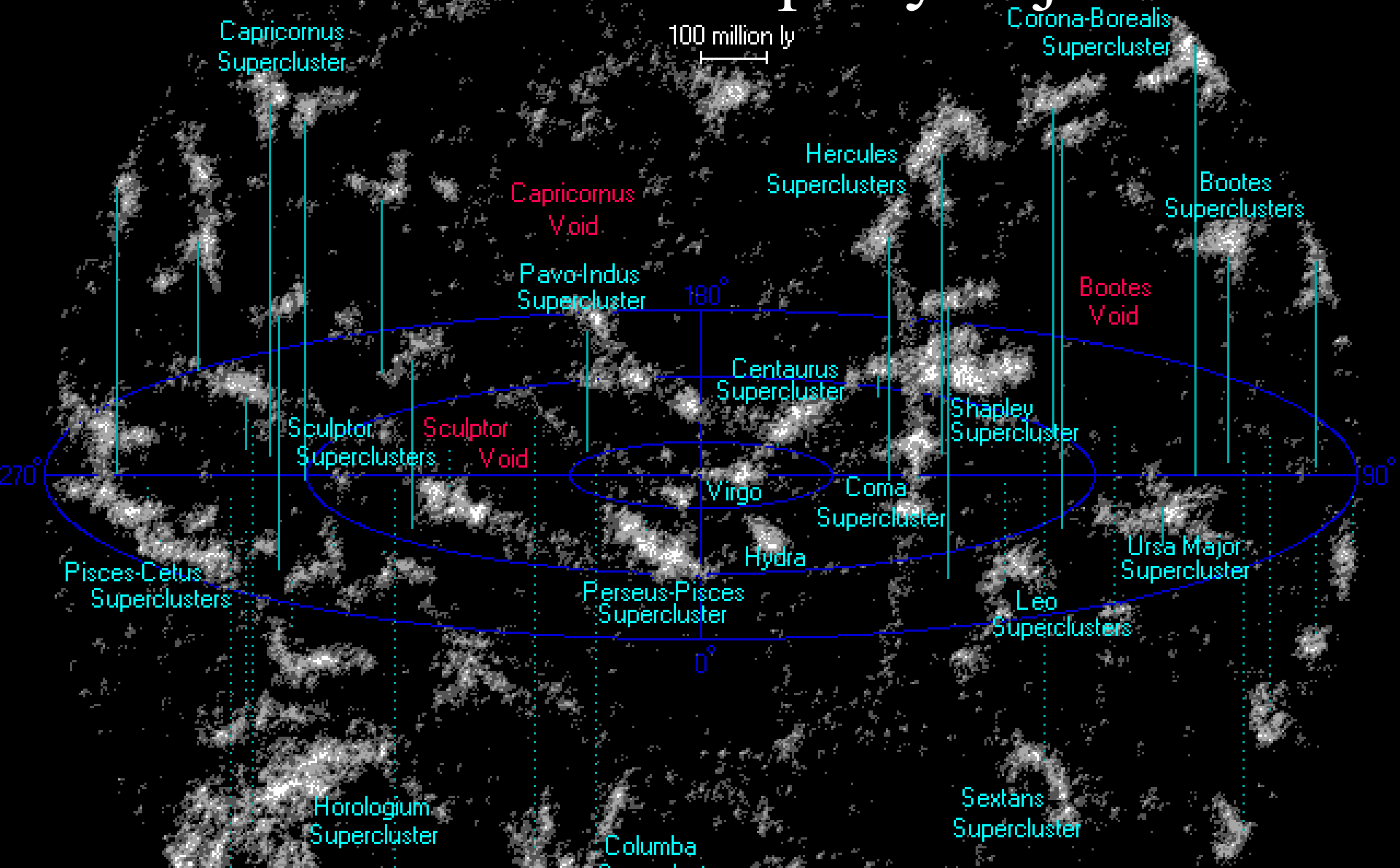
Geminid Meteors This week

In Gemini as name suggestions

(where Jupiter is currently!)

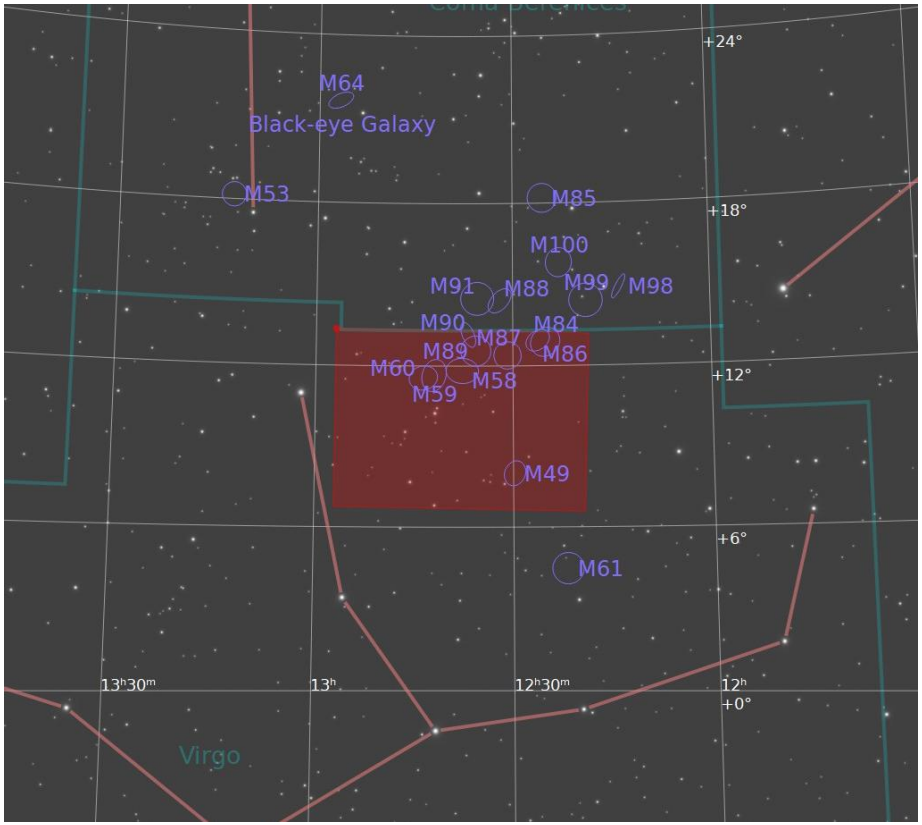
Best viewing on Friday

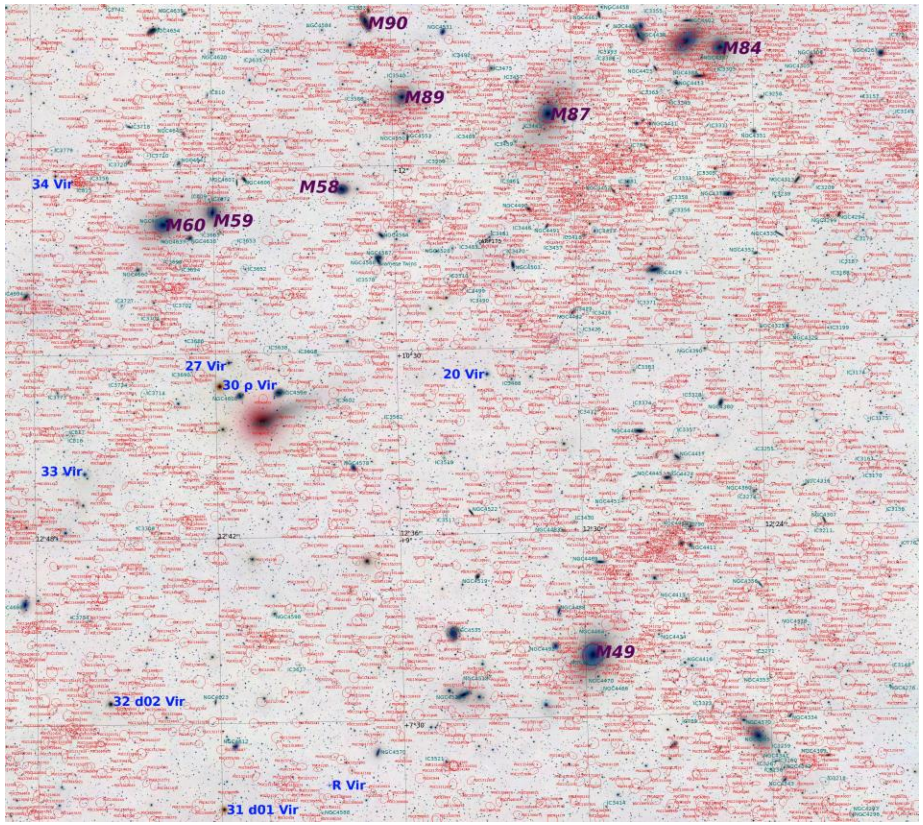
Last Class we finished with this image of the furthest deep sky objects



Superclusters of galaxies,
so distant that this image of
Comet Pons-Brooks,
passing in front of the Virgo
Cluster is like the
Equivalent of imaging a
Single electron with the
inner part of the
solar system visible
in the background

Why do we see the galaxies in clusters at such large scales?



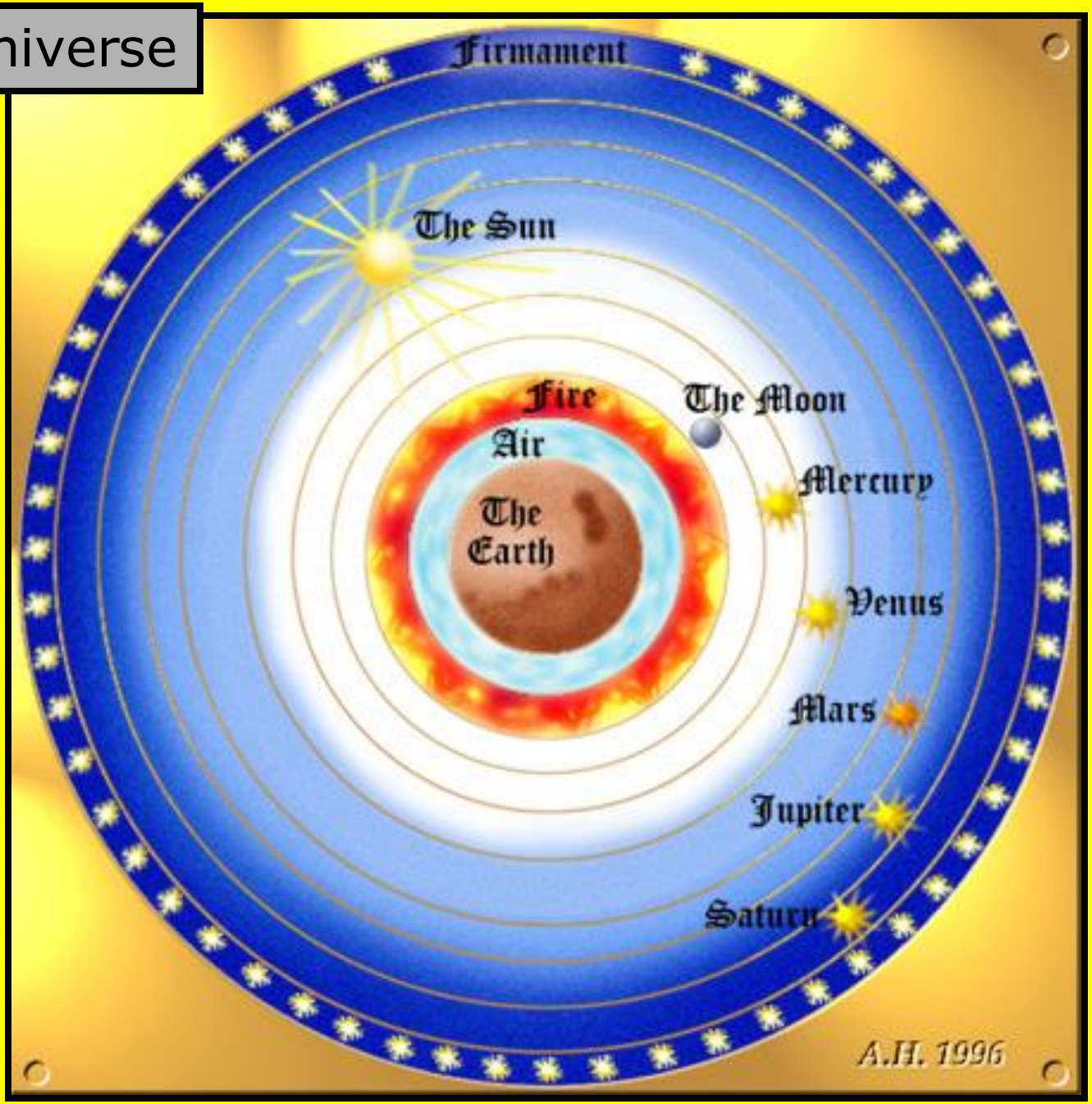


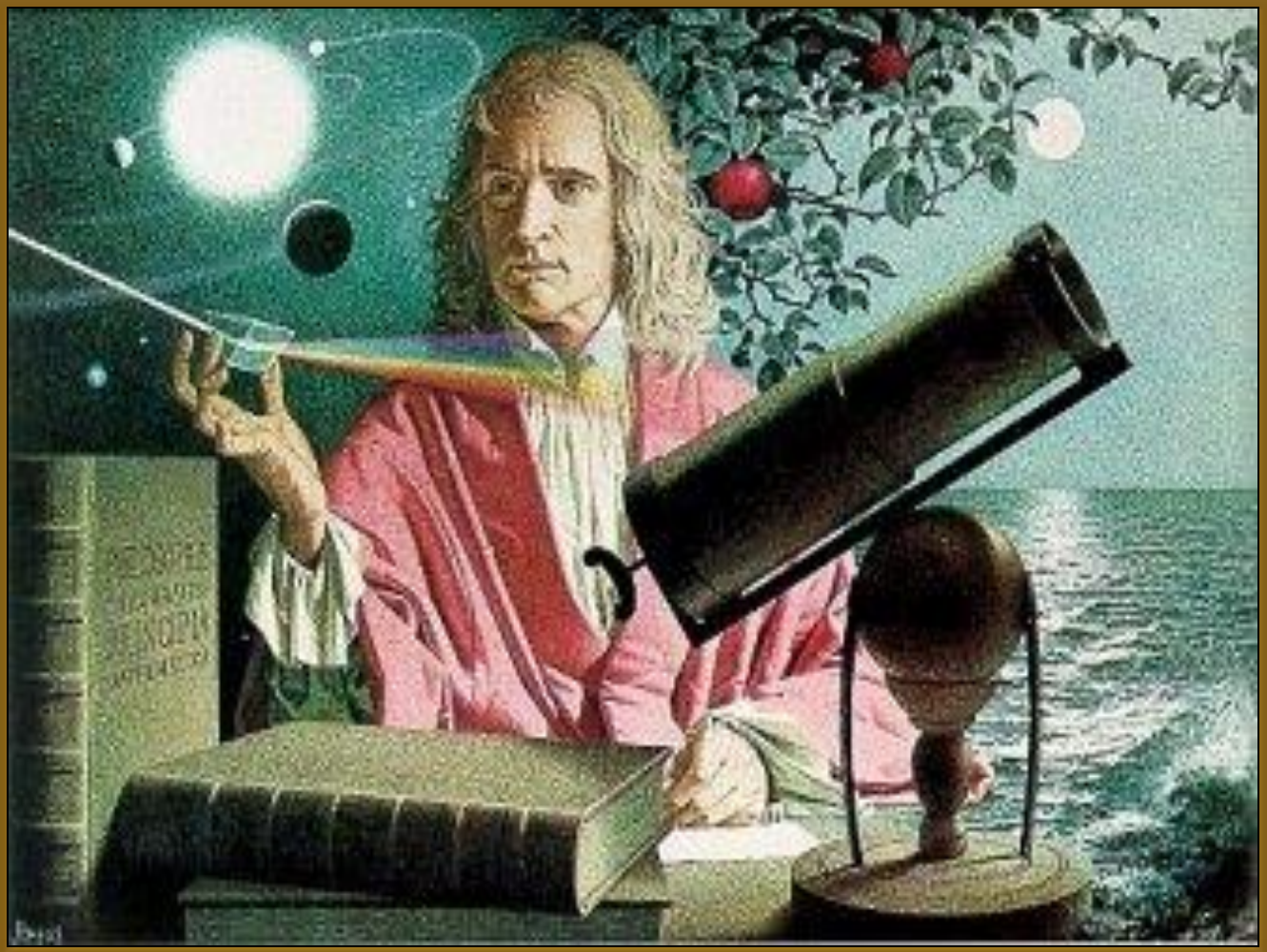
This is the Motivation for the science of Cosmology

Week Six

COSMOLOGY MARCHES ON

The Ancient Universe





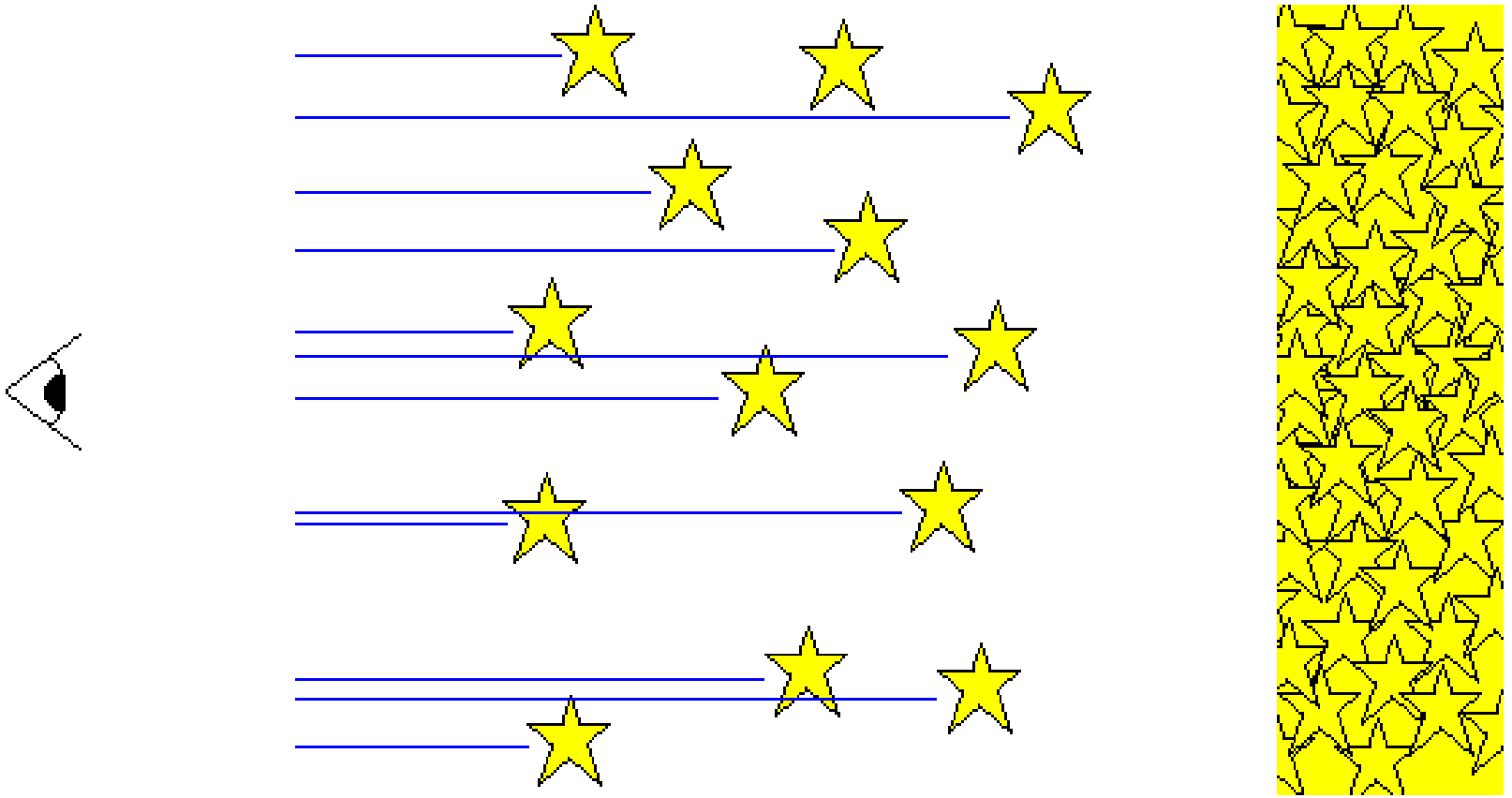
Isaac Newton(1642-1727)


Newton's Universe -
Space & Time are a stage
on which matter acts
out the laws of motion.

19th Century Problems with Newton's Universe

- Olber's Paradox
- 2nd Law of Thermodynamics
- Michaelson-Morely Experiment

Olber's paradox



observer

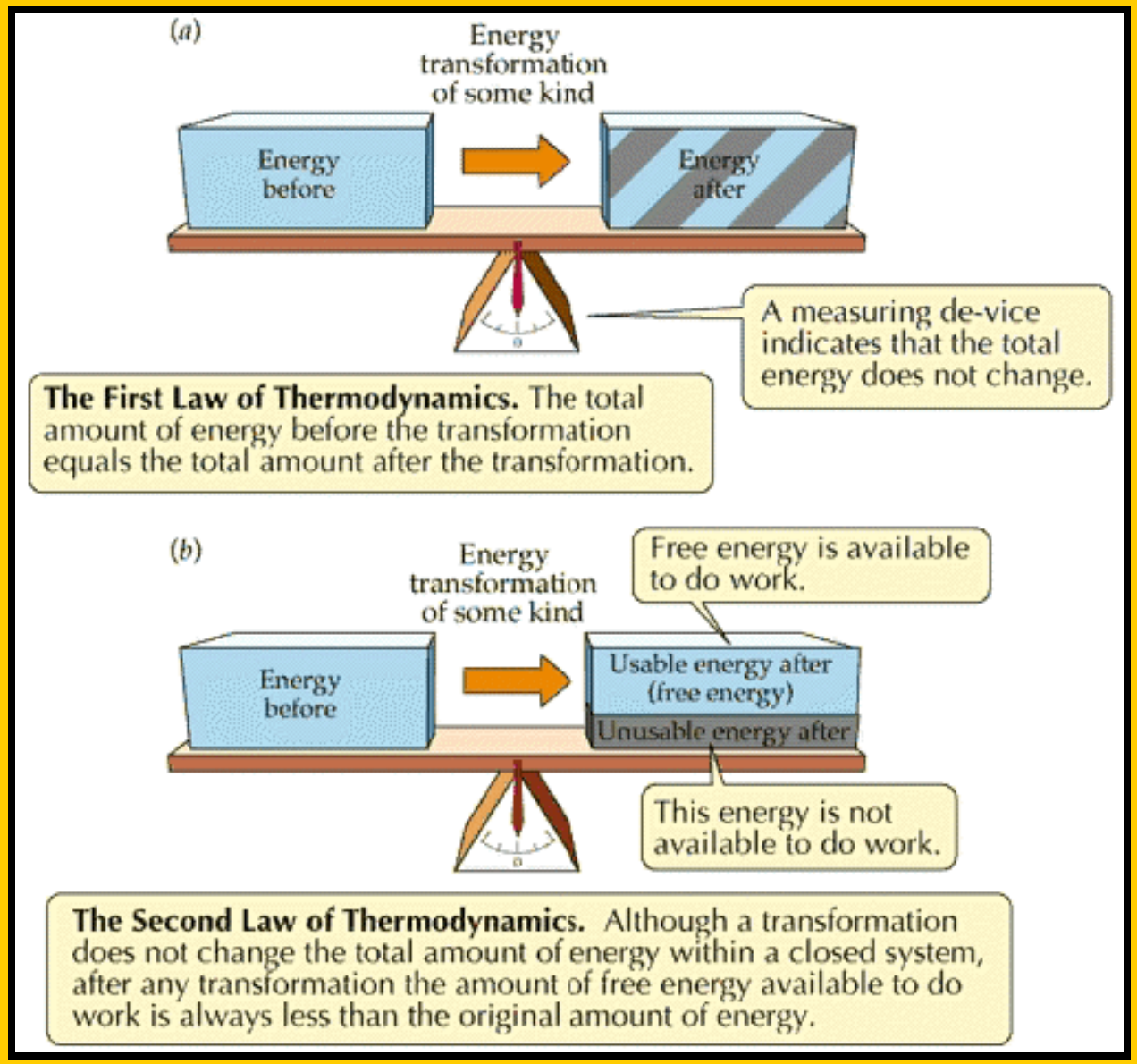
Universe of stars

night sky

19th Century Problems with Newton's Universe

- Olber's Paradox
- 2nd Law of Thermodynamics
- Michaelson-Morely Experiment

2nd Law of Thermodynamics



19th Century Problems with Newton's Universe

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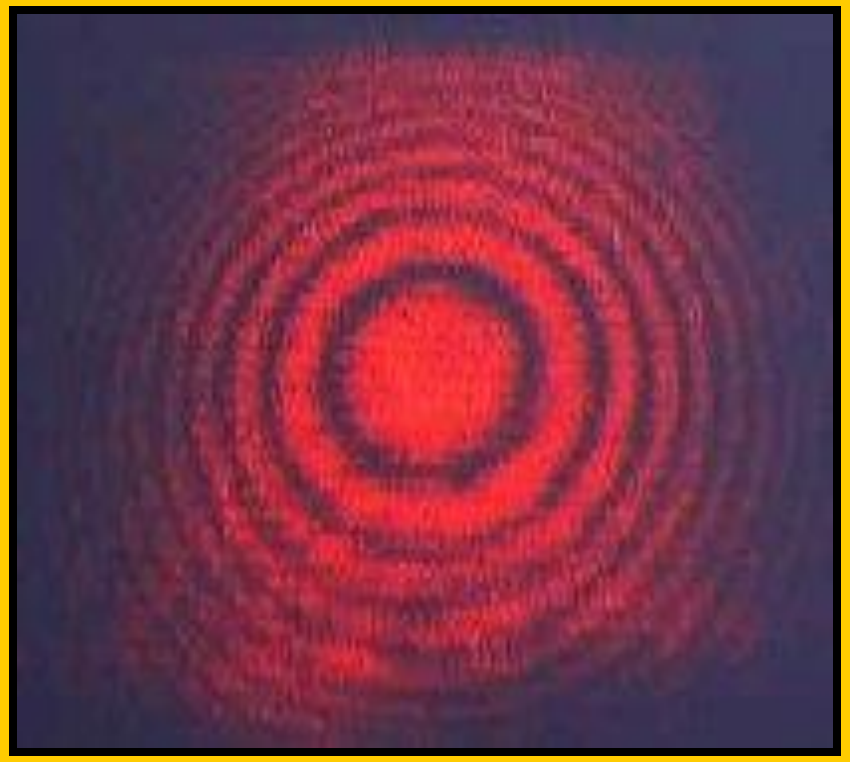
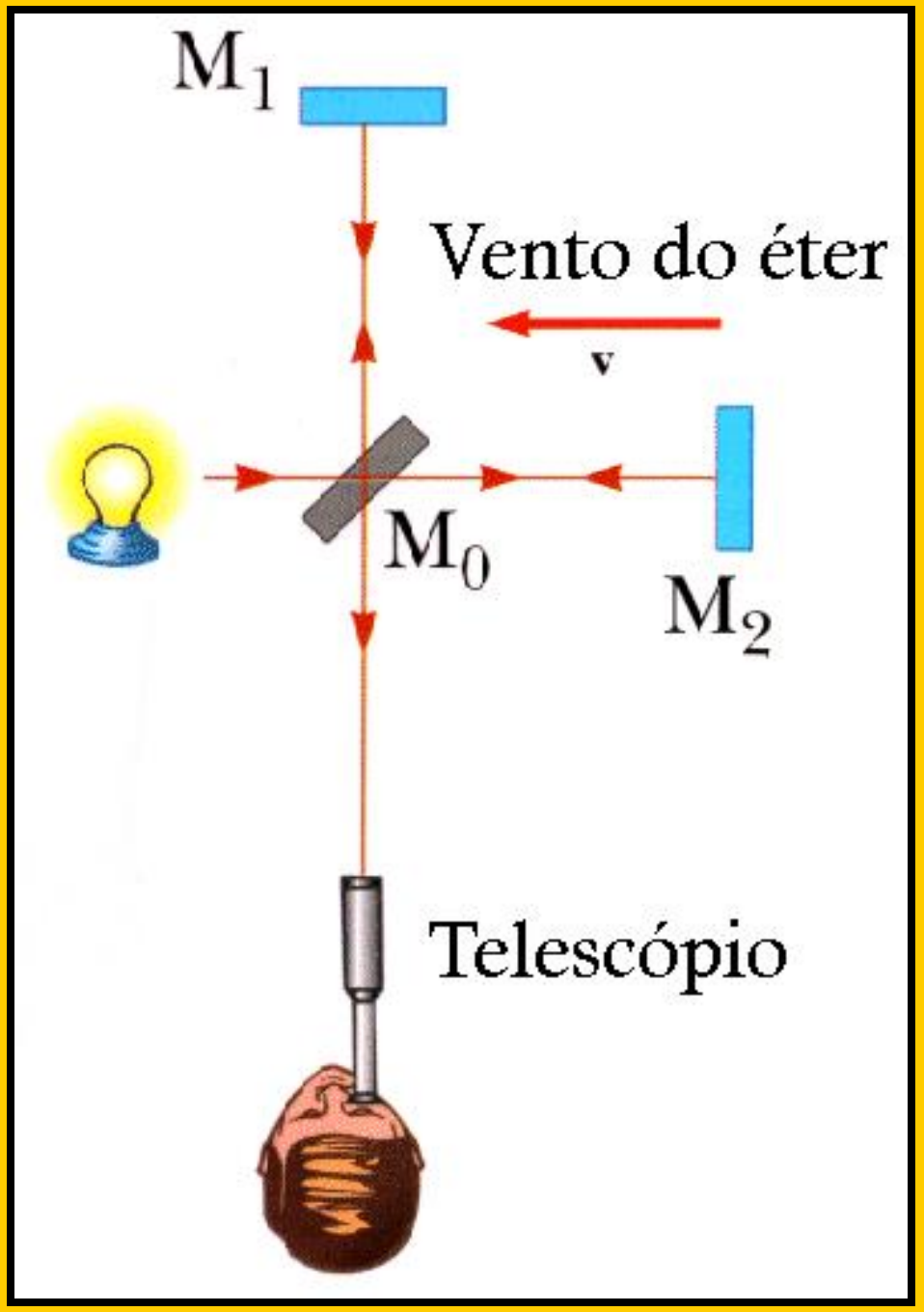
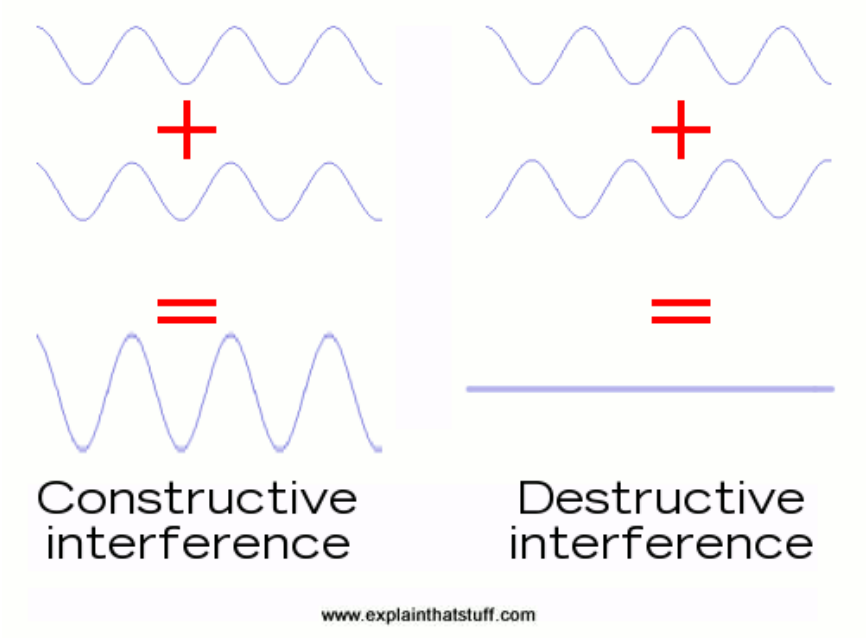
Michaelson-Morely Experiment

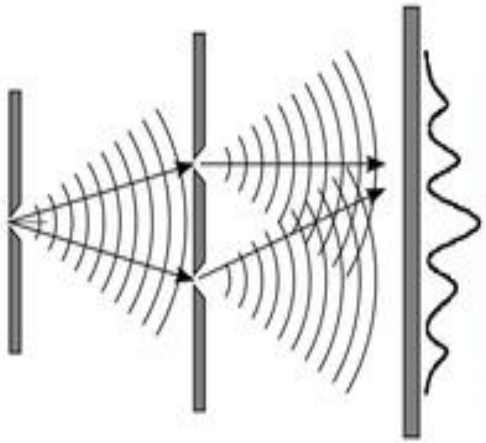


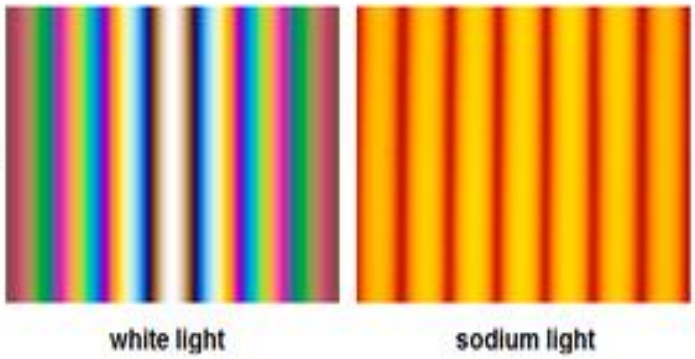




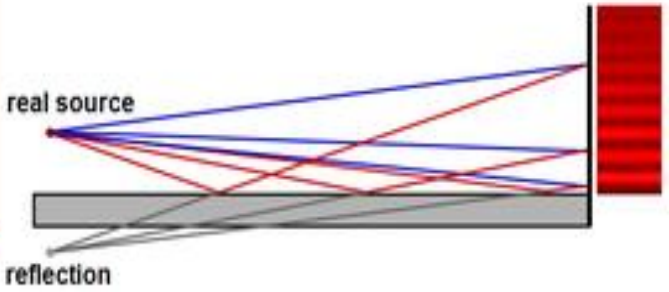
Basics of Interferometry

- Many other types, e.g. Sagnac, Mach-Zehnder
- All attempt to control or induce a phase-shift to "measure" or "manipulate" light.

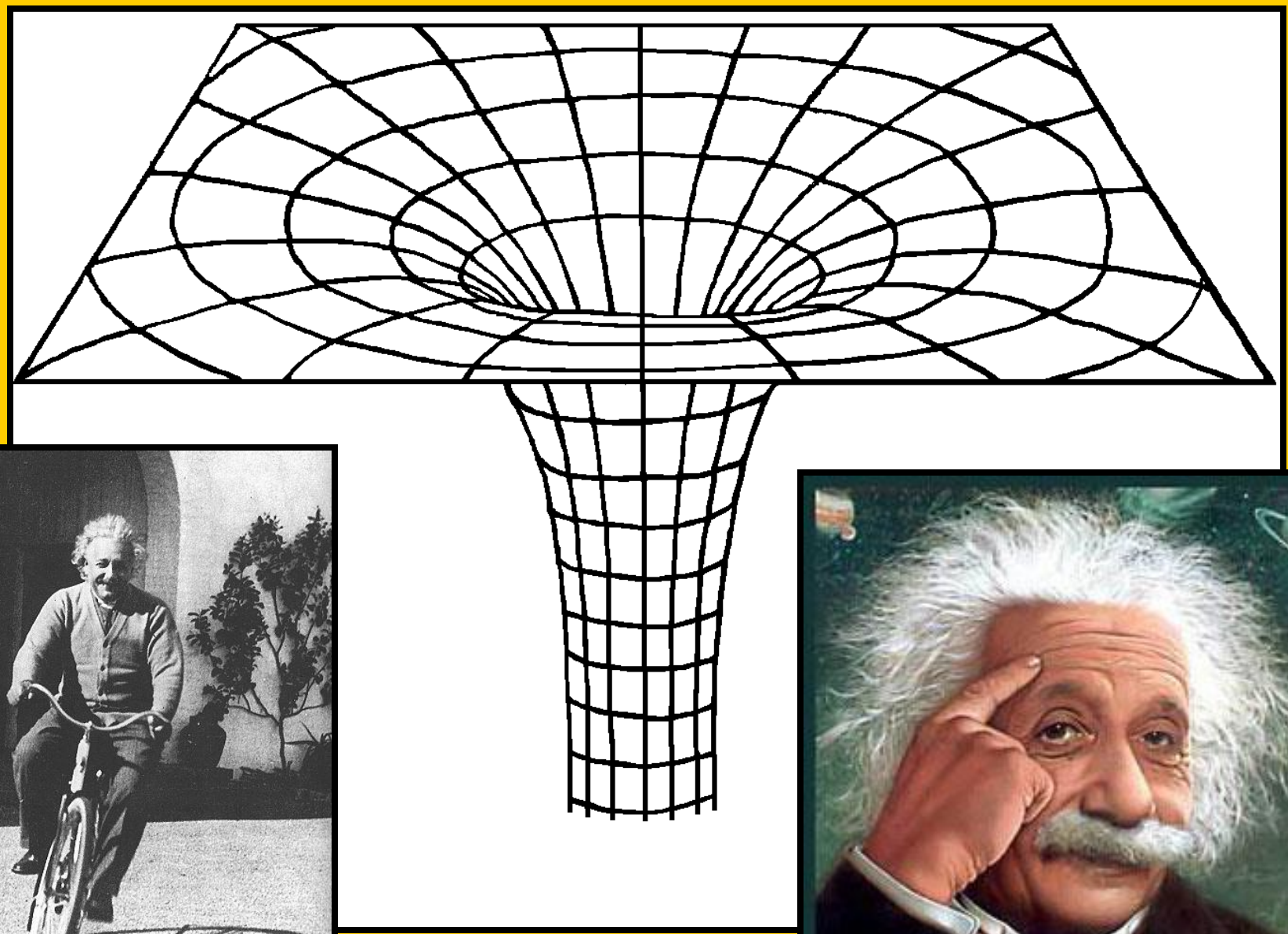

Young's Two-slit Experiment



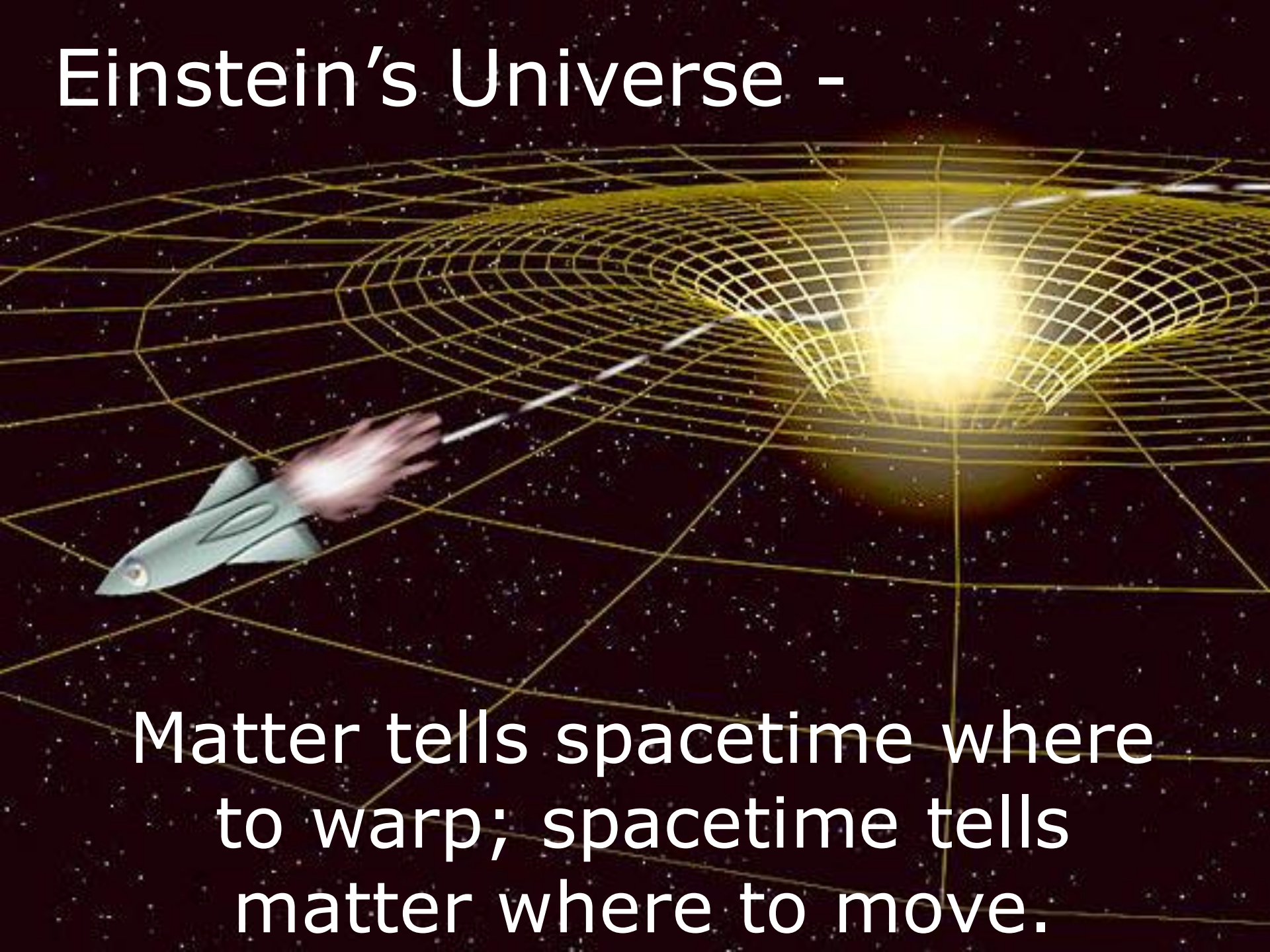
Two-slit Diffraction Patterns



Lloyd's Mirror



Einstein's Universe -



Matter tells spacetime where to warp; spacetime tells matter where to move.

Properties of our Universe

Cosmological Principle - The Universe is smooth on the large scale (100s of light-years).

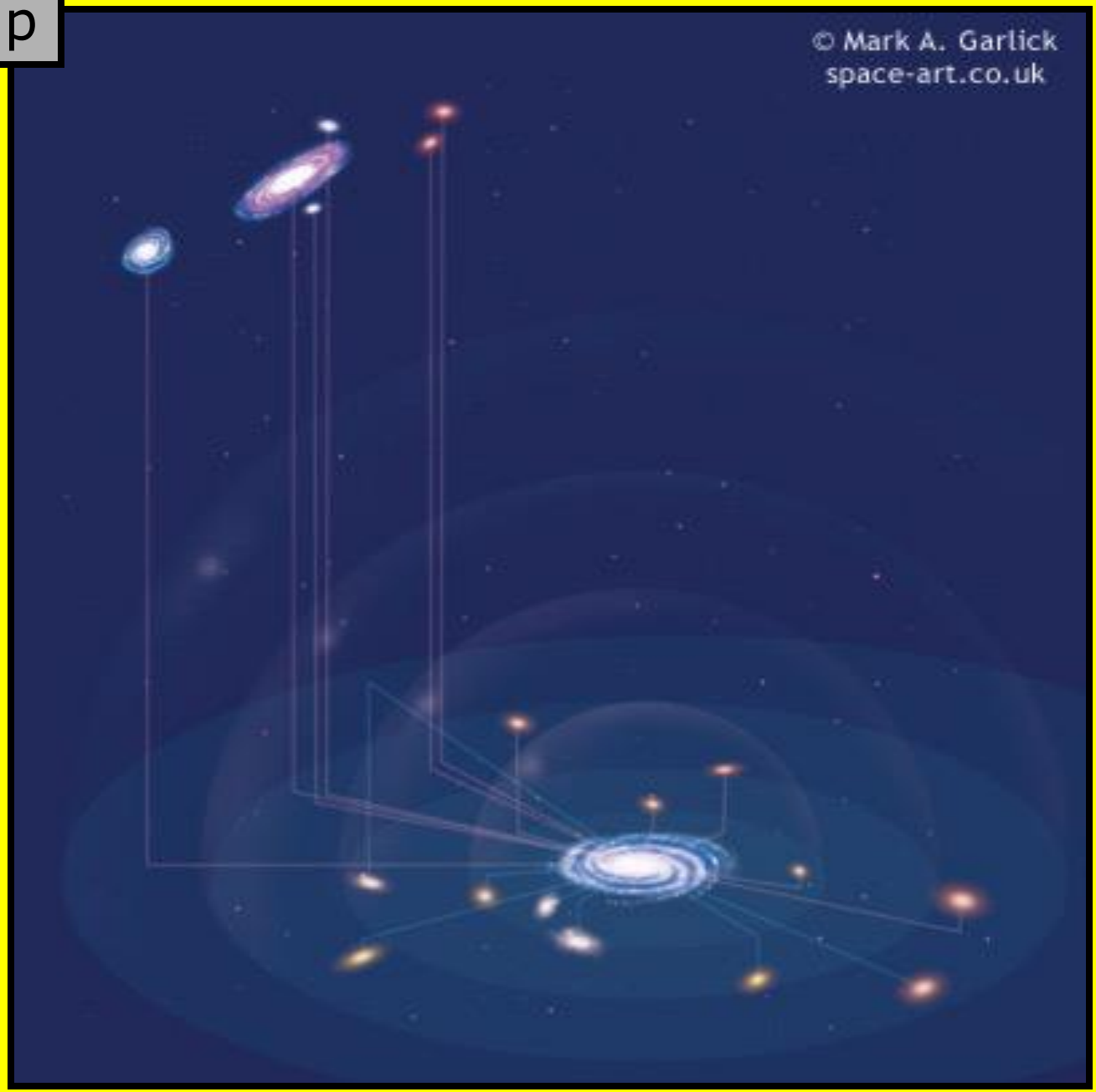
Homogeneity - The Universe looks the same at every *location*.

Isotropy - The Universe looks the same in every *direction.*

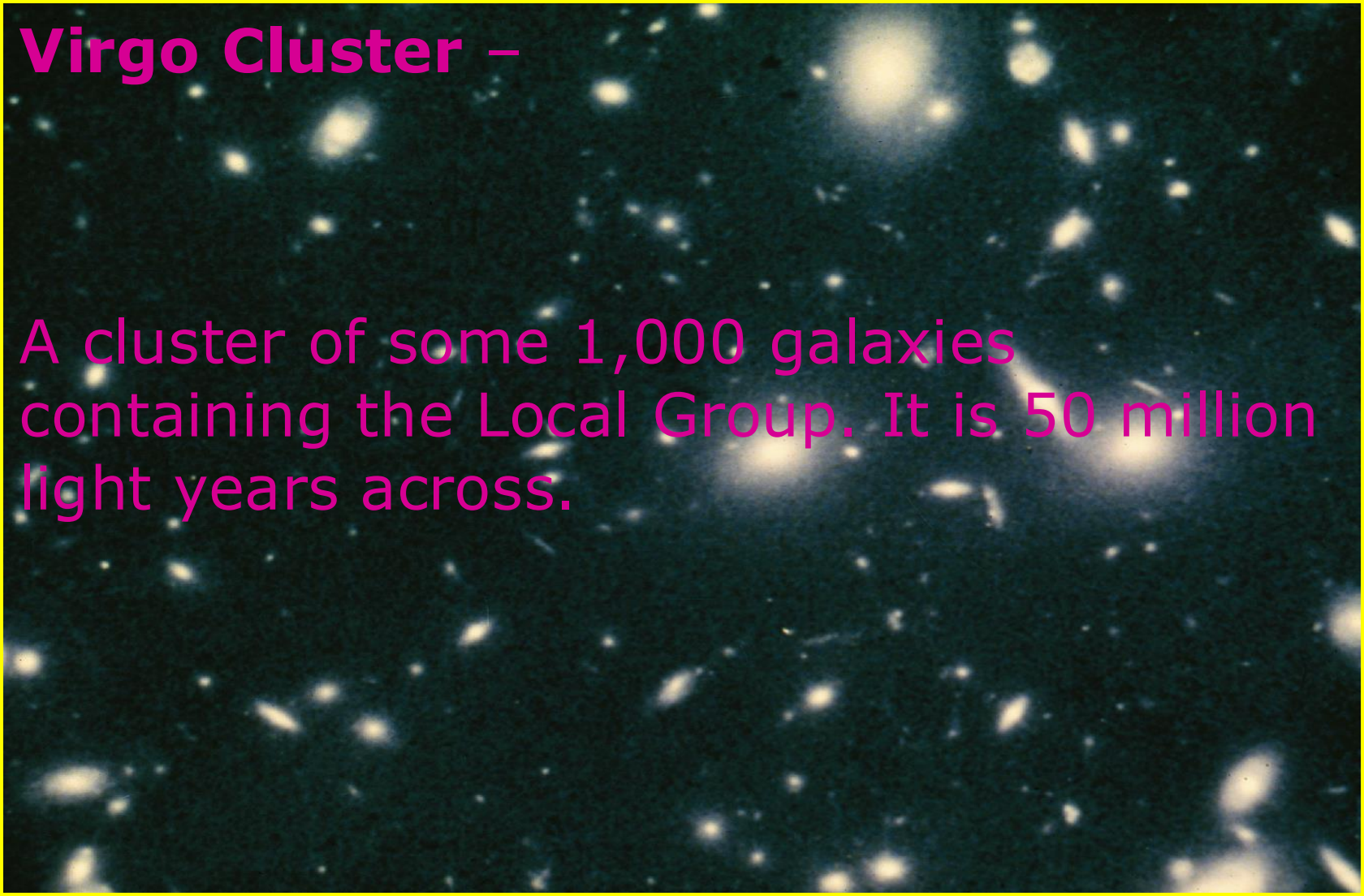
Omni-recessionality - On the large scale, everything is rushing away from everything else.

The structure of the Universe

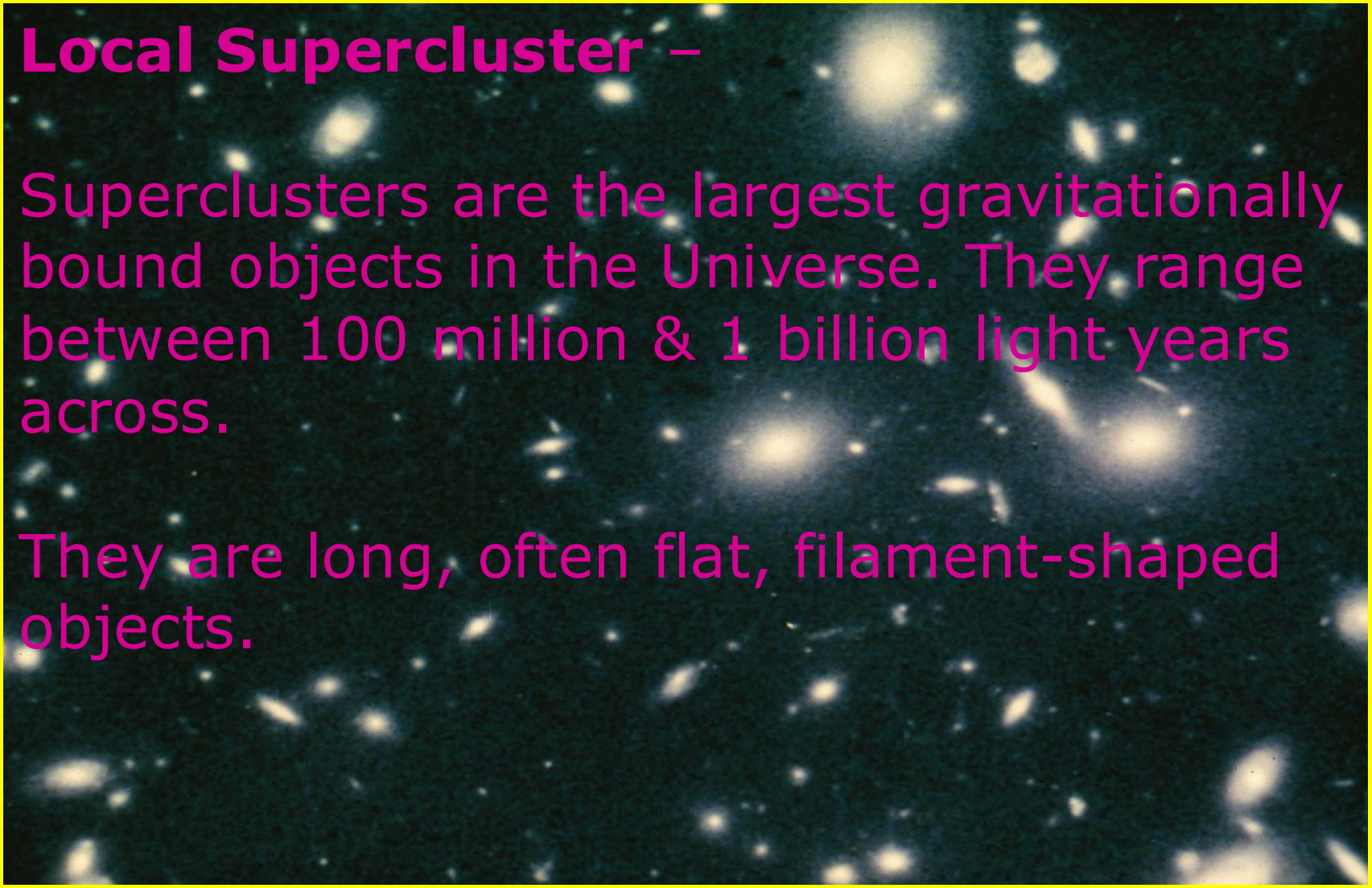
The Local Group



The structure of the Universe

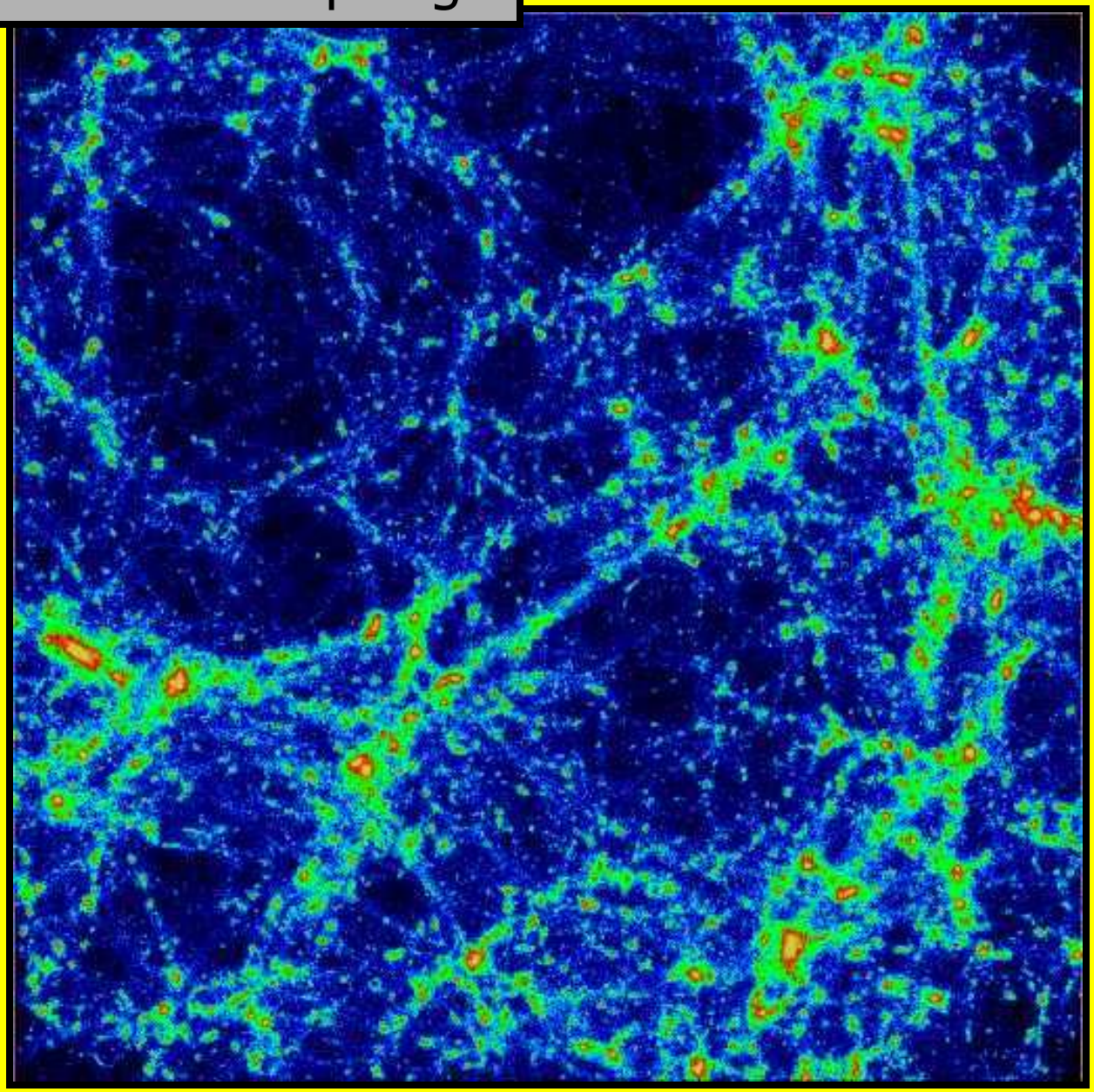


The structure of the Universe



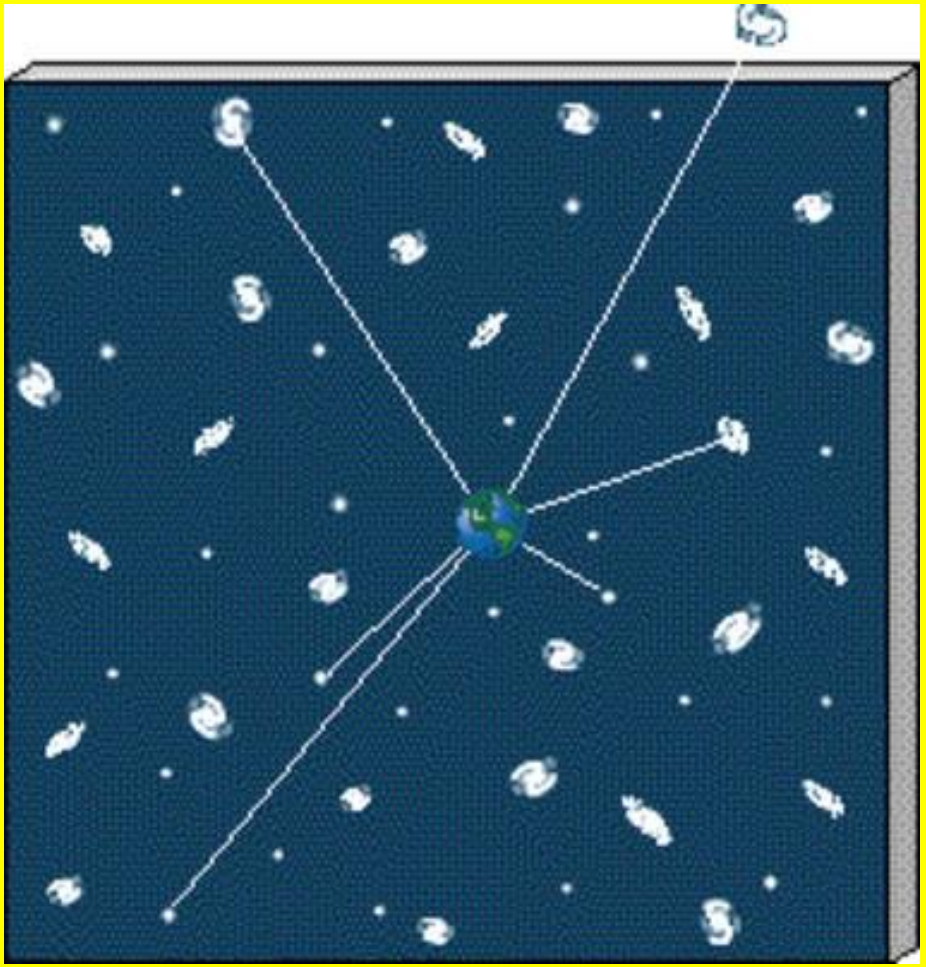
The structure of the Universe

Our Universe is a cosmic sponge

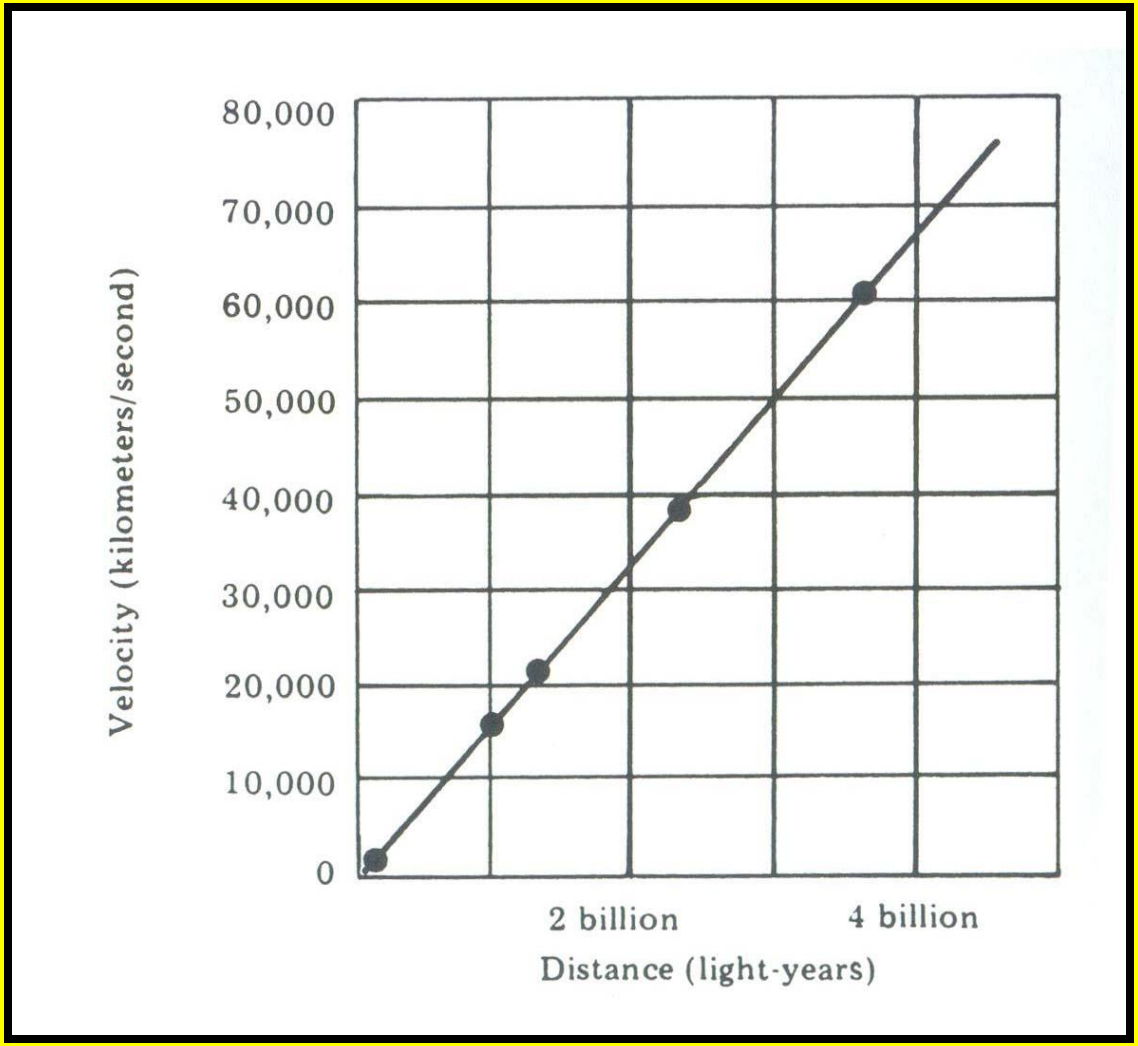


Hubble's Law - A galaxy's speed of reccesion from us is directly proportional to its distance.

Edwin Hubble



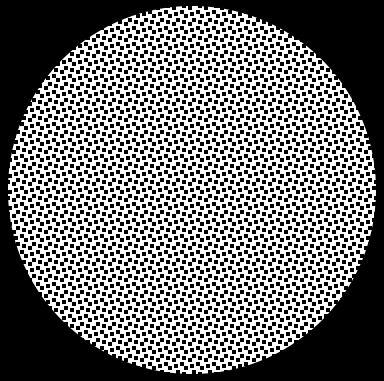
This linear relation is observed from all places - the Universe has no centre.



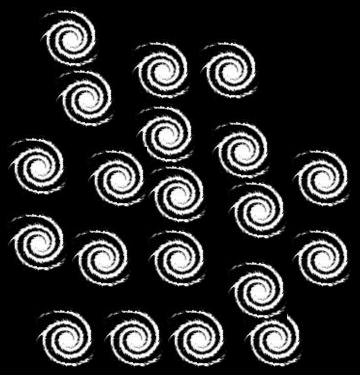
The Big Bang - Universe is Born

The Big Bang - Universe Expands & Cools

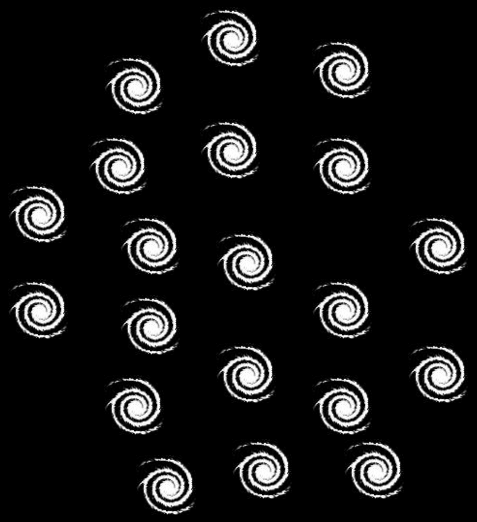
1/2 million years - Matter & Radiation Separate

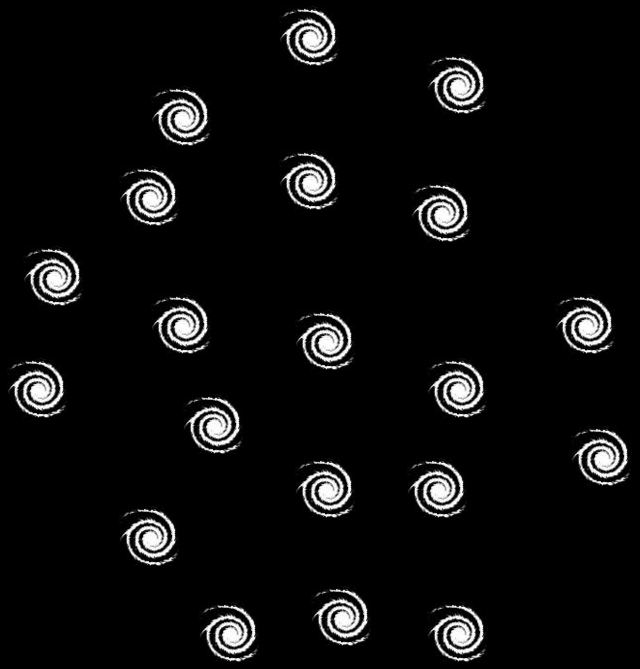


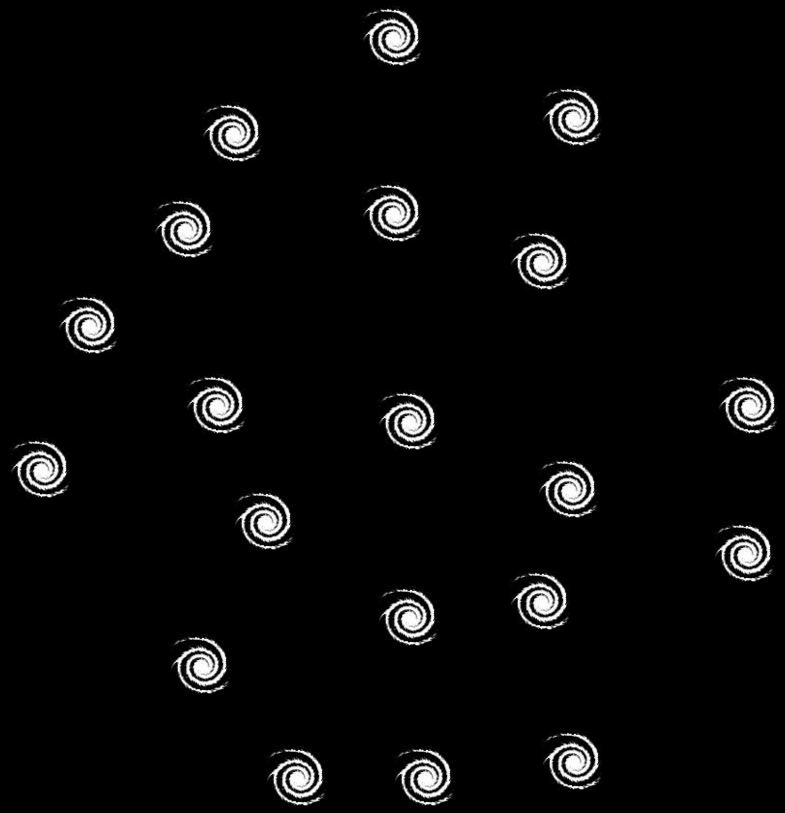
1 billion years - Galaxies Form

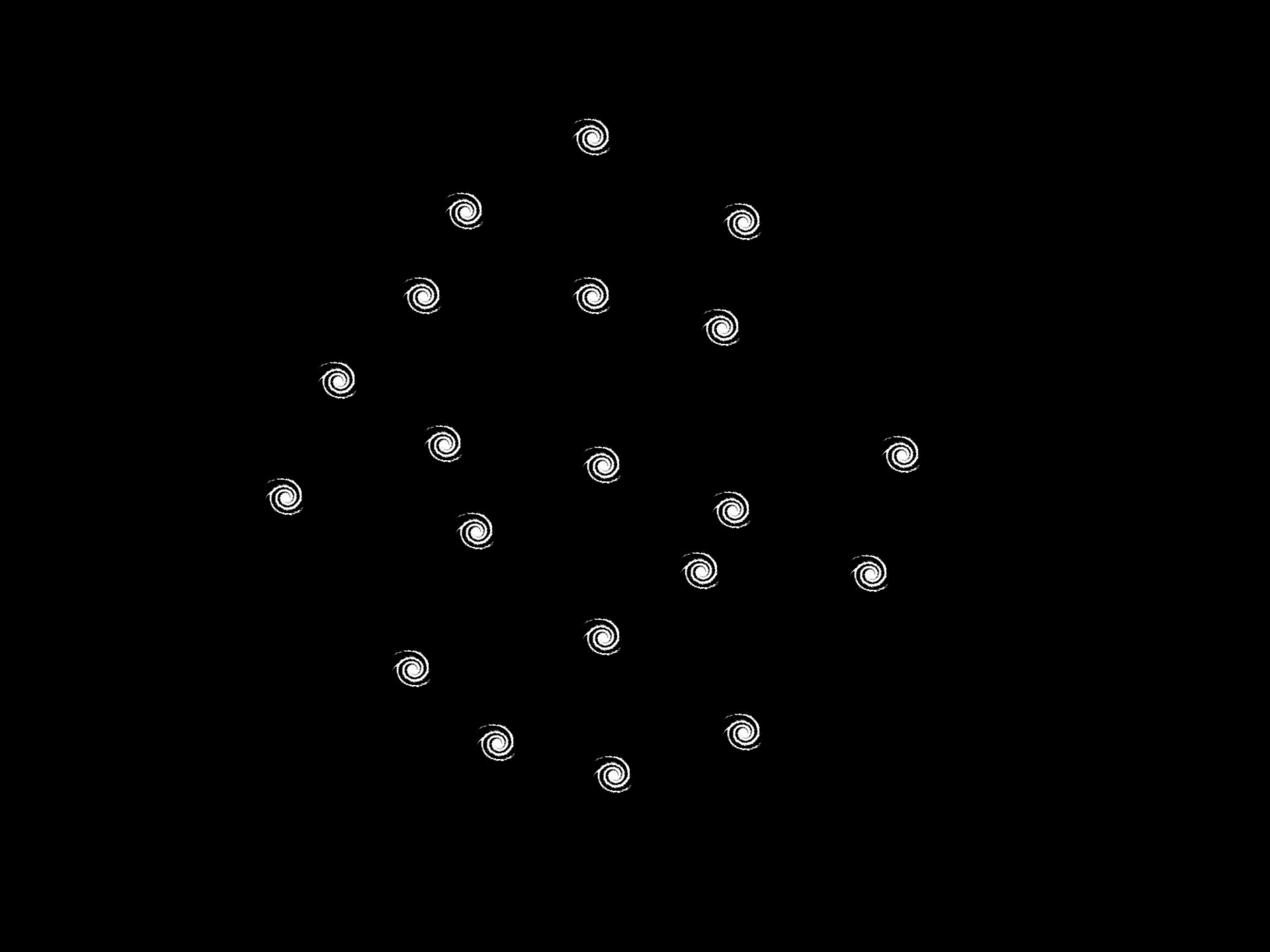


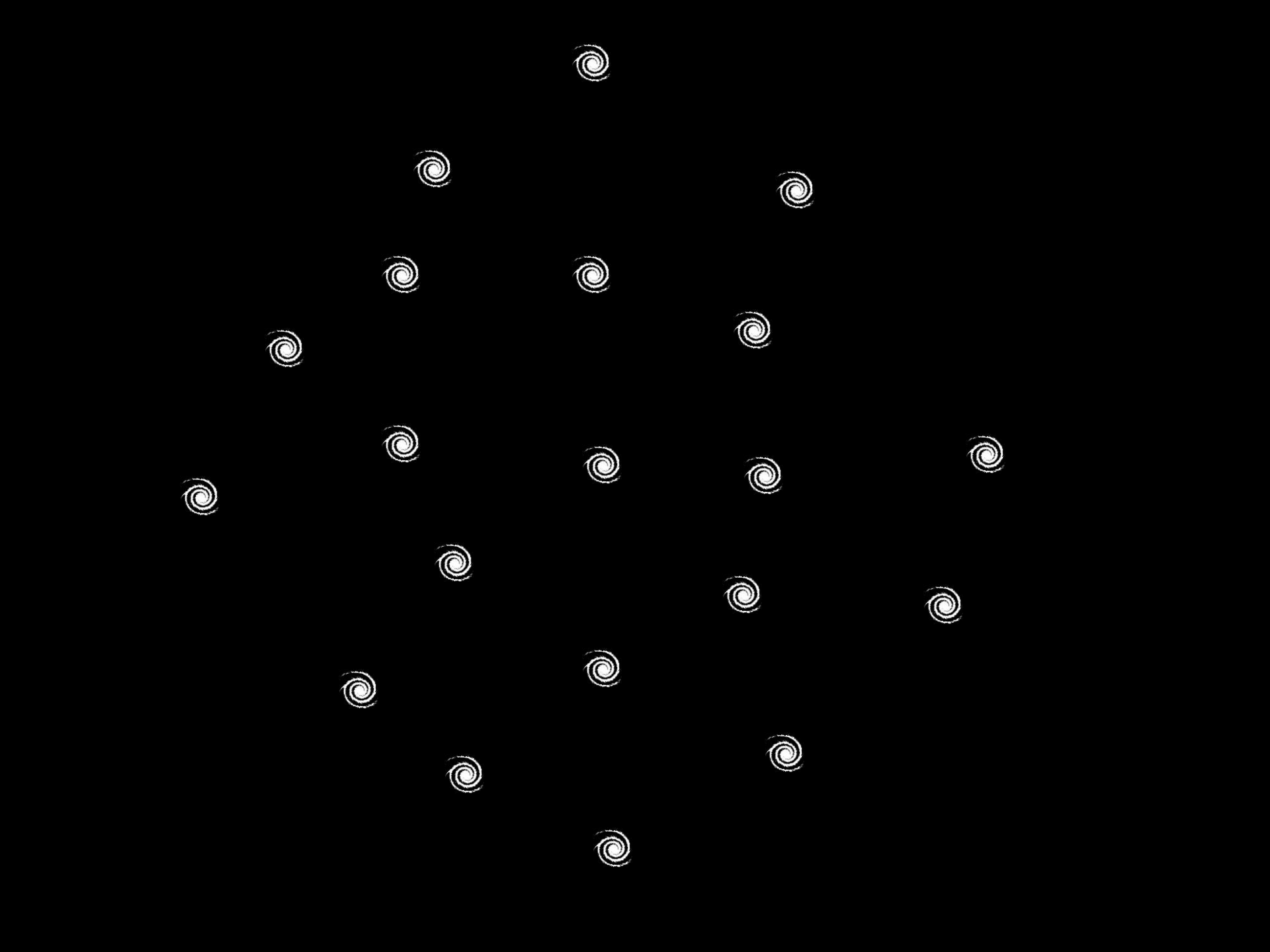
As the Universe expands, galaxies appear to rush away from each other

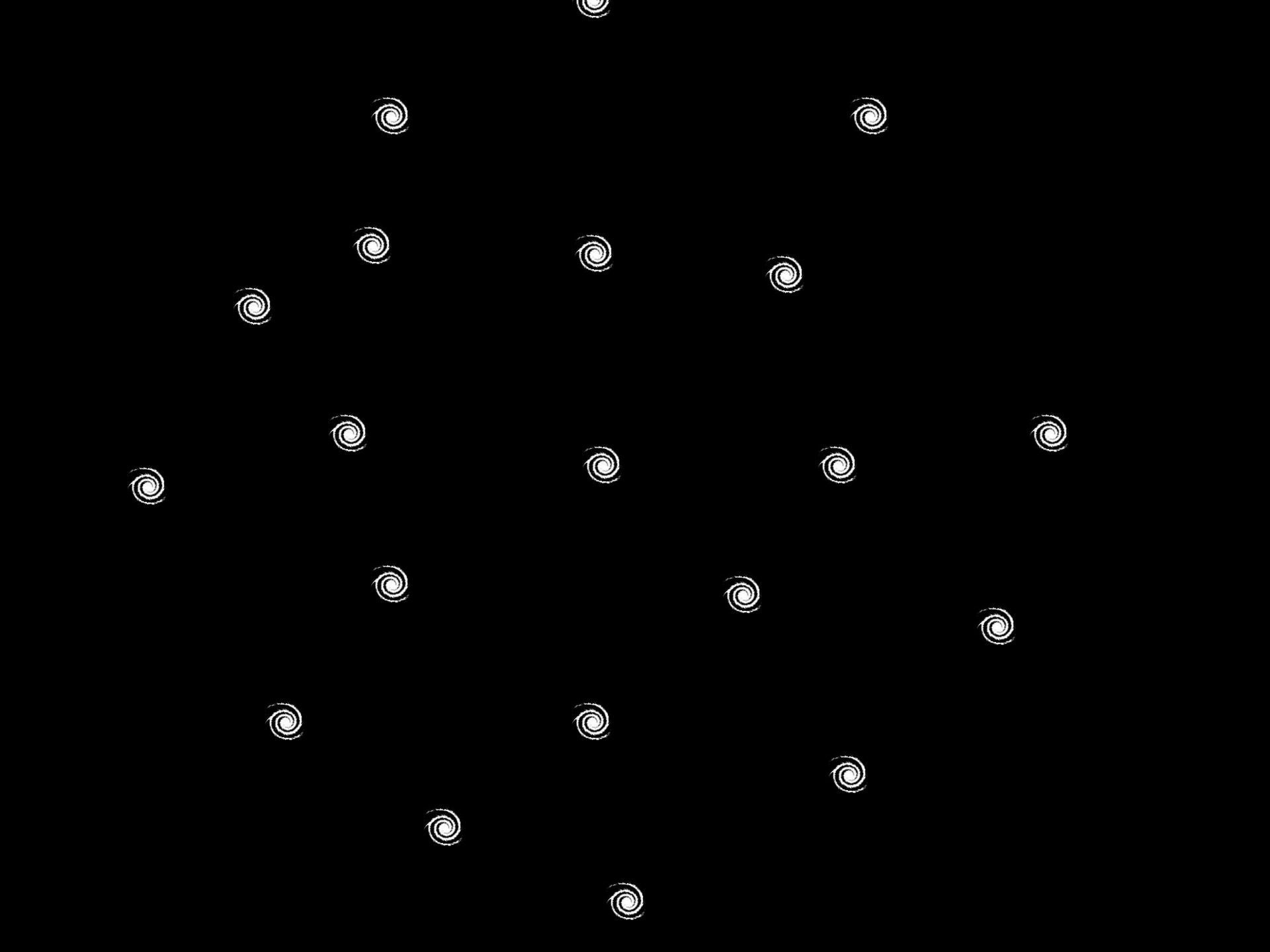


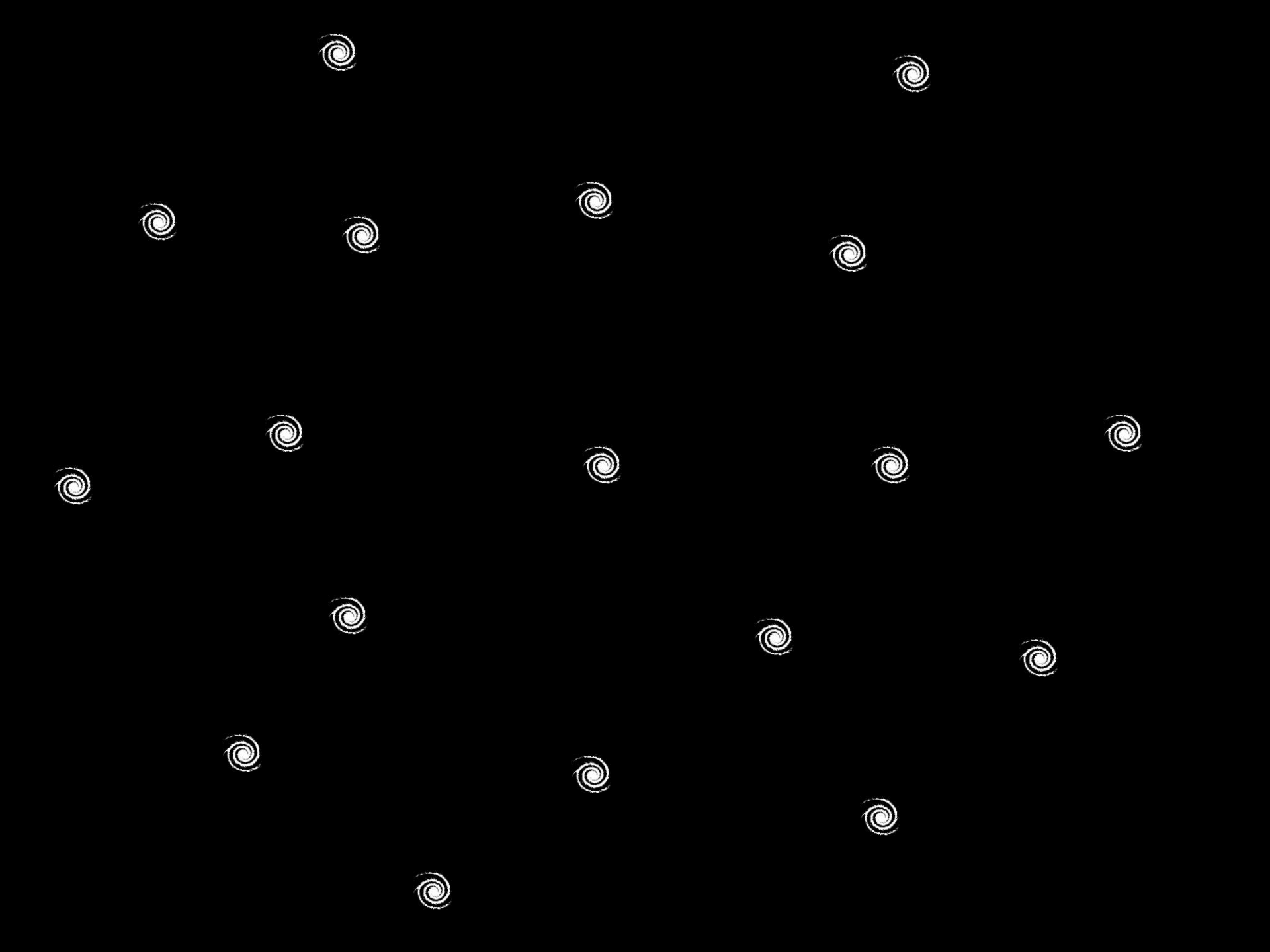


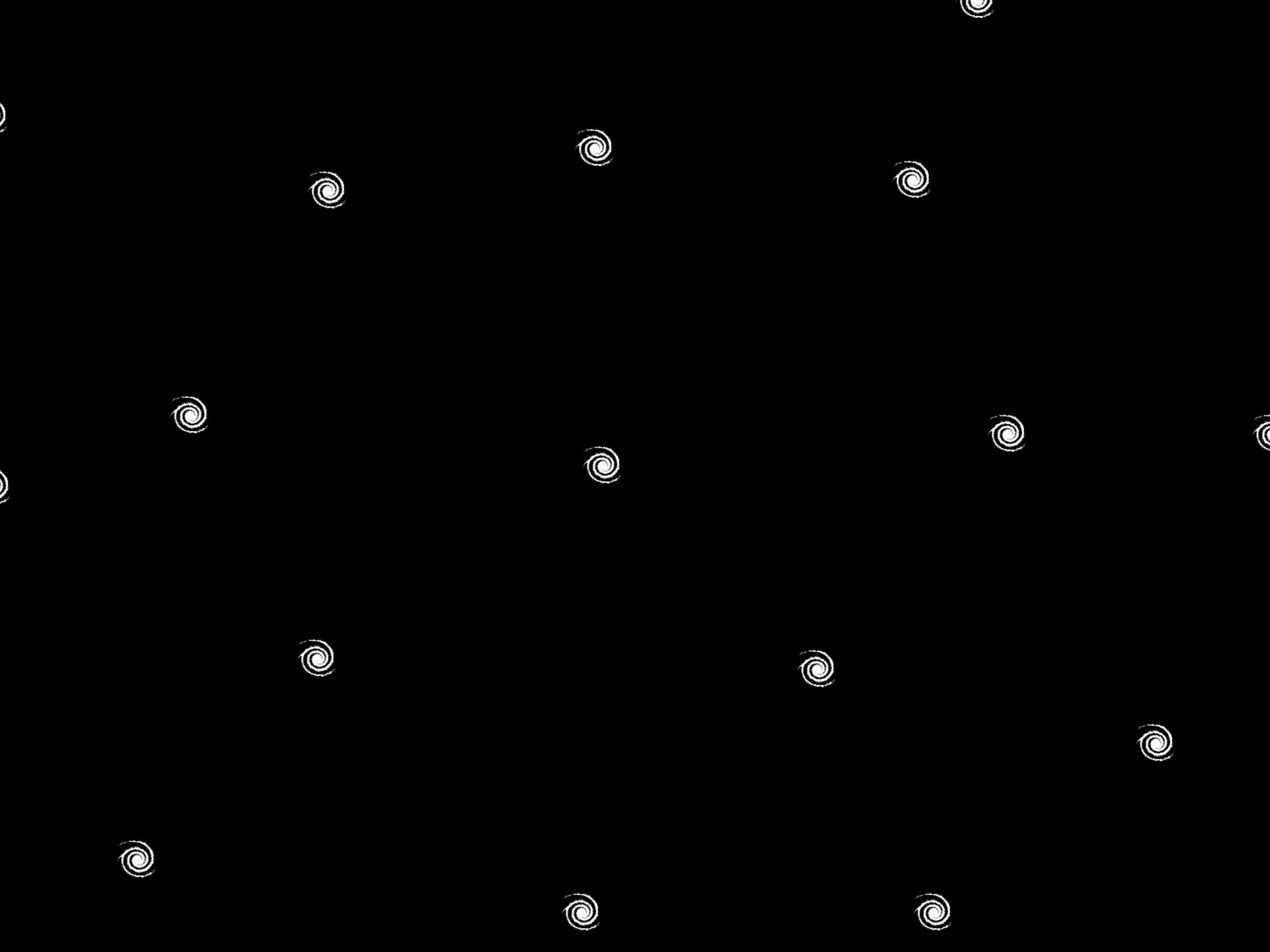




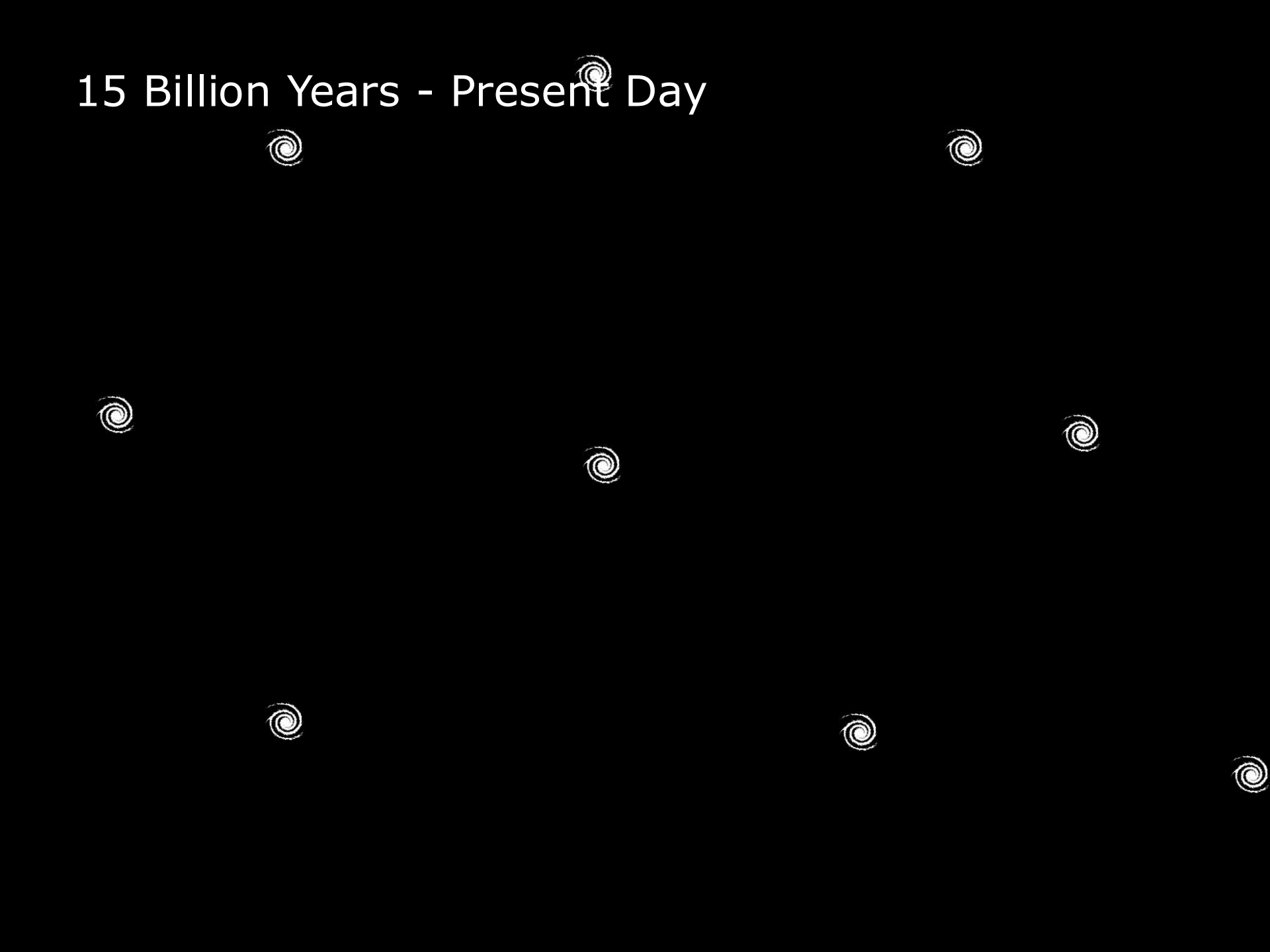






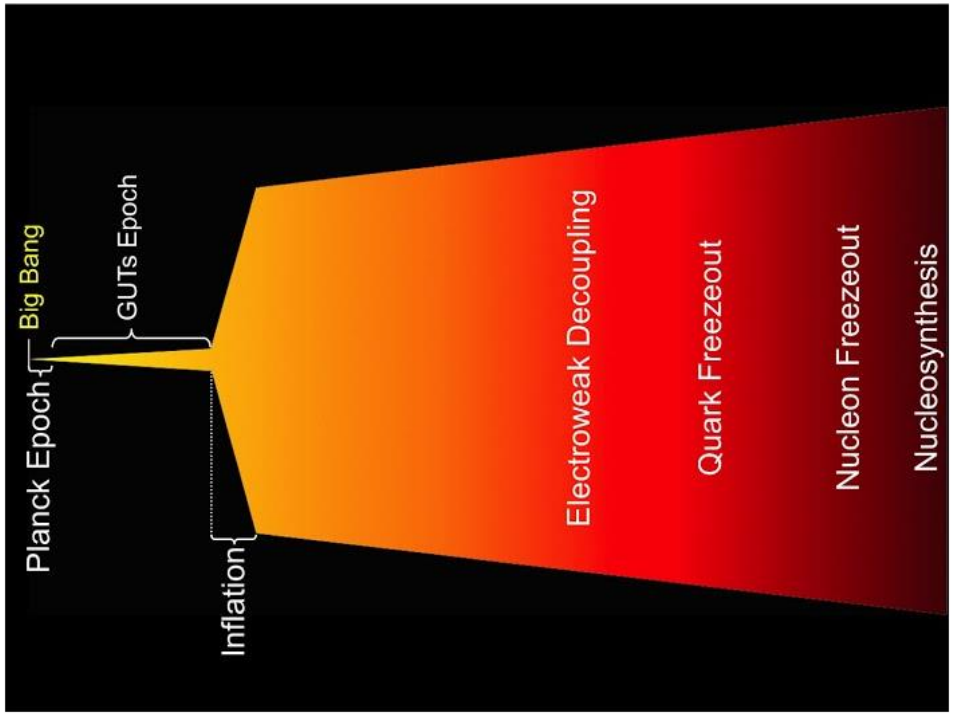


15 Billion Years - Present Day

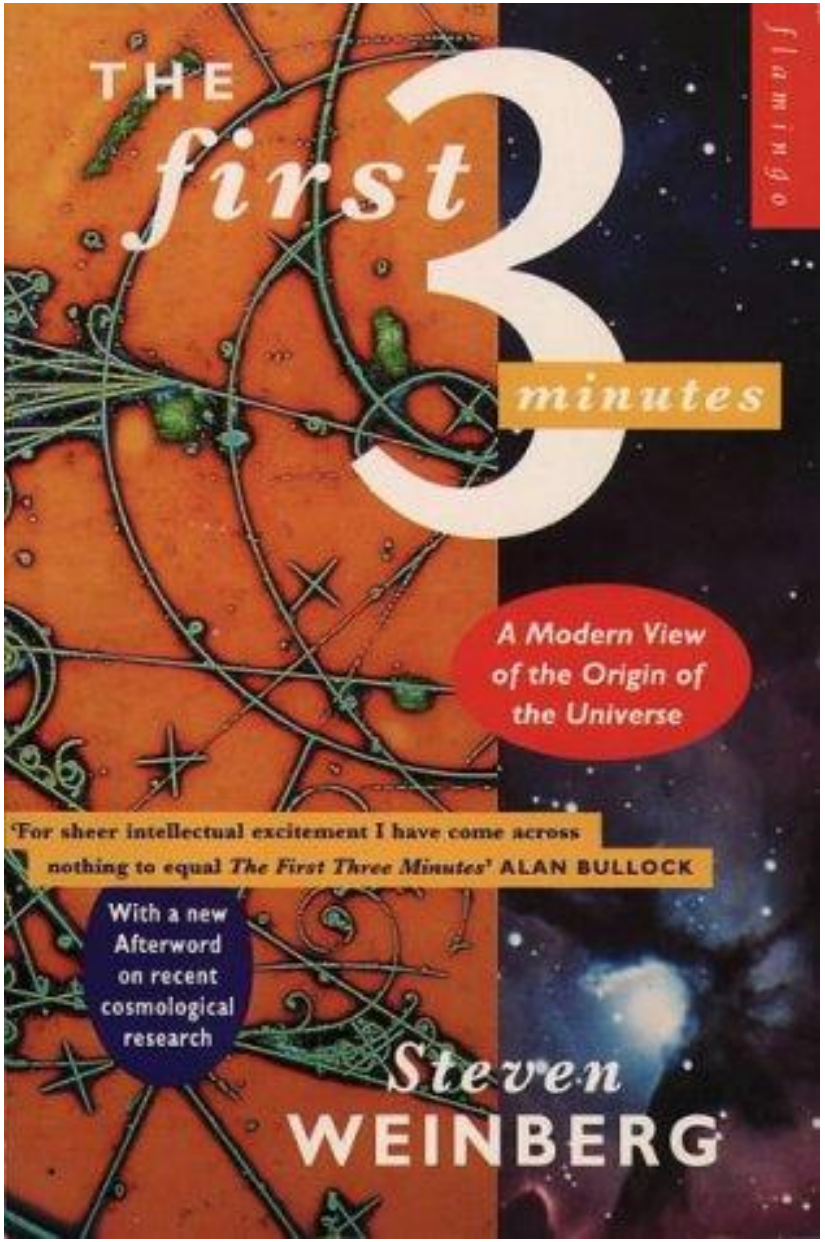


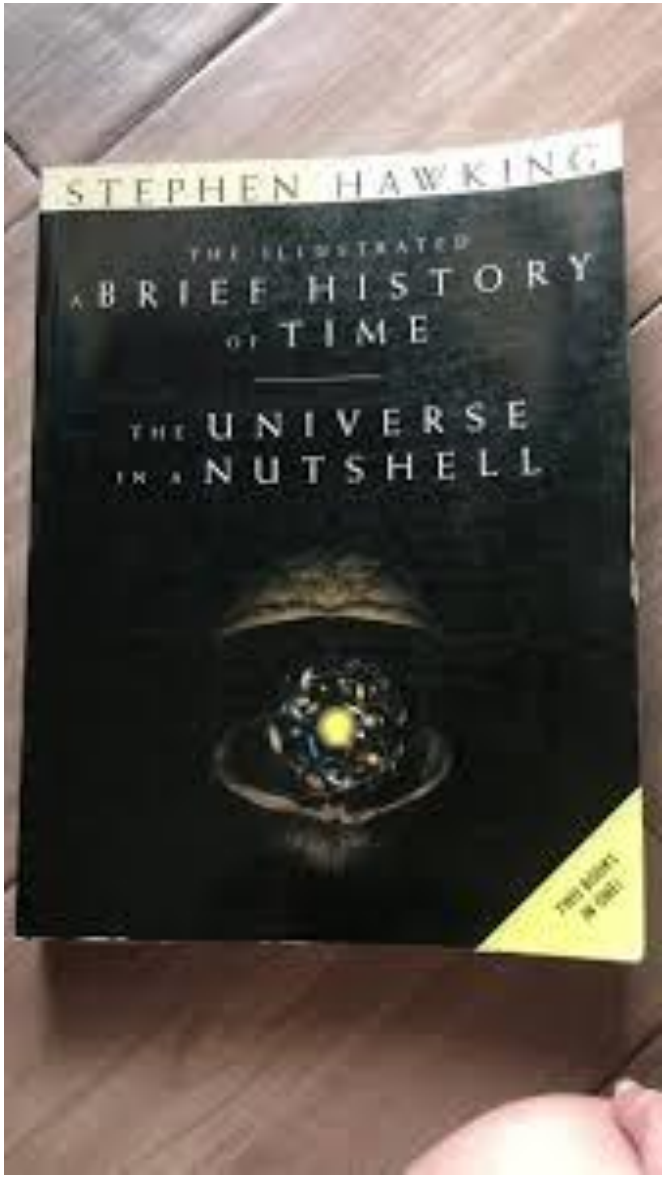

At this scale we ironically need particle physics/quantum mechanics to describe the universe

The First Three Minutes

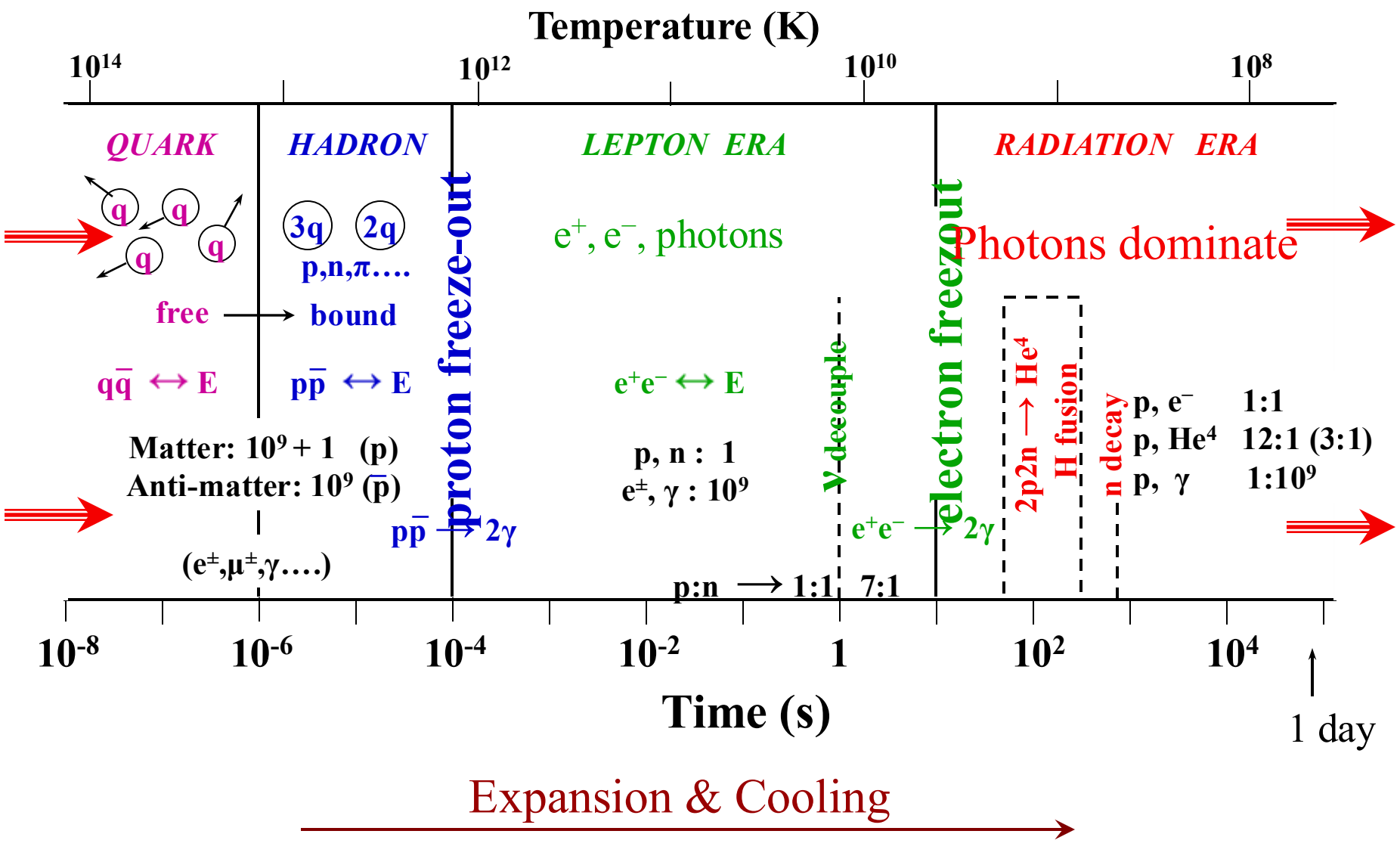


Astronomy 1101


THE first 3 minutes
flamingo
A Modern View of the Origin of the Universe
'For sheer intellectual excitement I have come across nothing to equal *The First Three Minutes*' ALAN BULLOCK
With a new Afterword on recent cosmological research
Steven WEINBERG


STEPHEN HAWKING
THE ILLUSTRATED
A BRIEF HISTORY OF TIME
THE UNIVERSE IN A NUTSHELL

The First Day



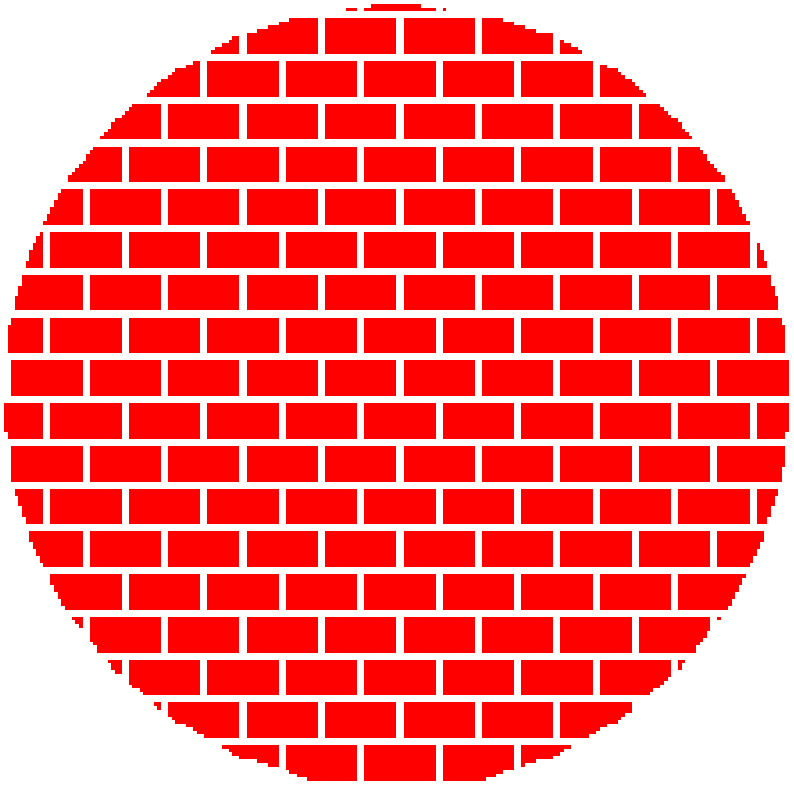
Expansion & Cooling

Predictions of Big Bang Theory

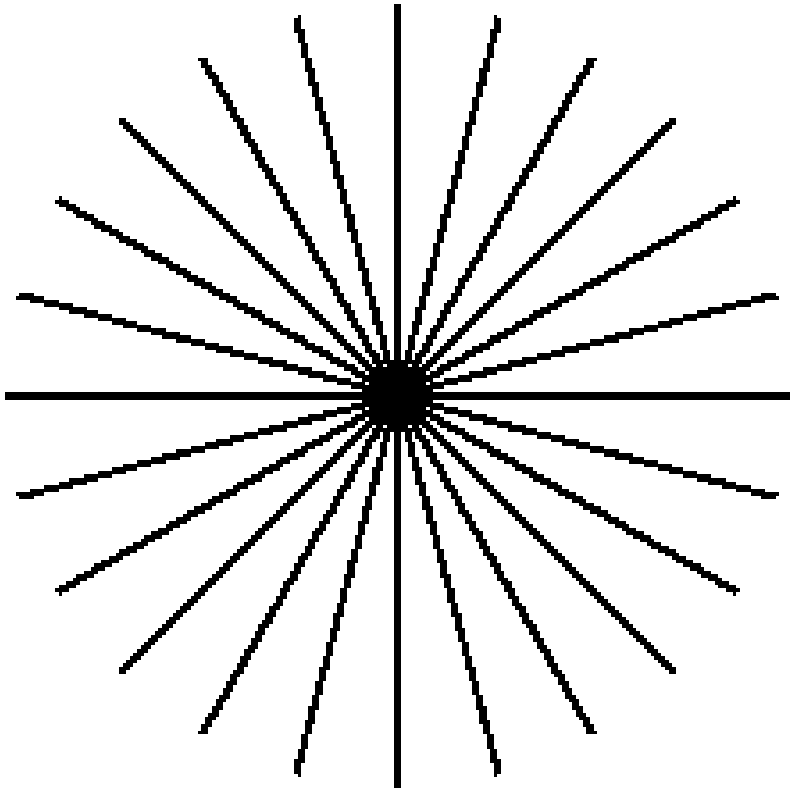
- The Universe is homogeneous and isotropic (very smooth)
- But not too smooth…
- The ratio of H/He (about 75% H, 25% He)
- Trace abundances of D, ^{3}He, Li, Be
- The cosmic microwave background radiation


Georges LeMaitre
George Gamow
Ralph Alpher
YLEM
LIQUEUR
COINTREAU

The Universe is Homogeneous and Isotropic

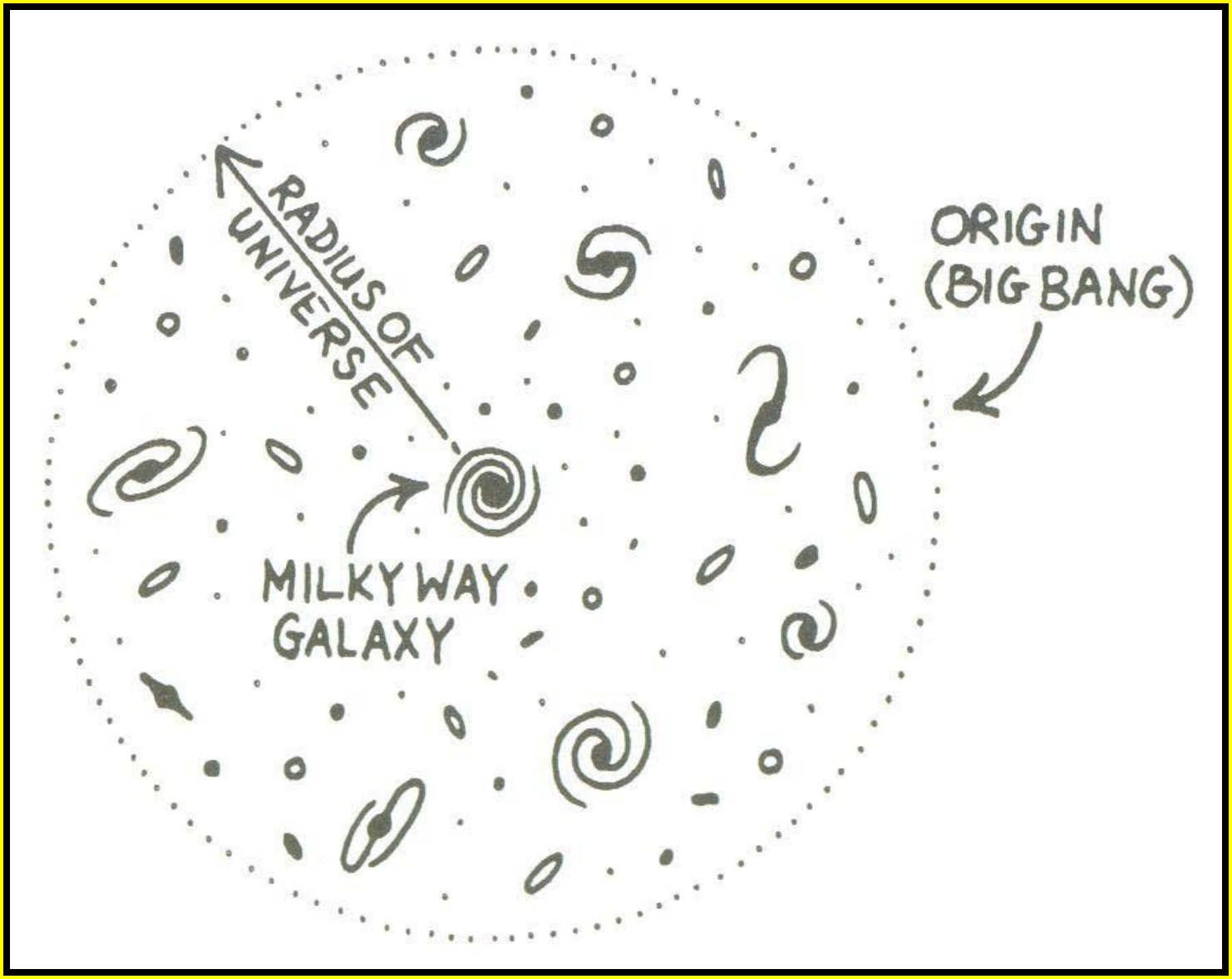


Homogeneous: looks the same at all locations
Not isotropic

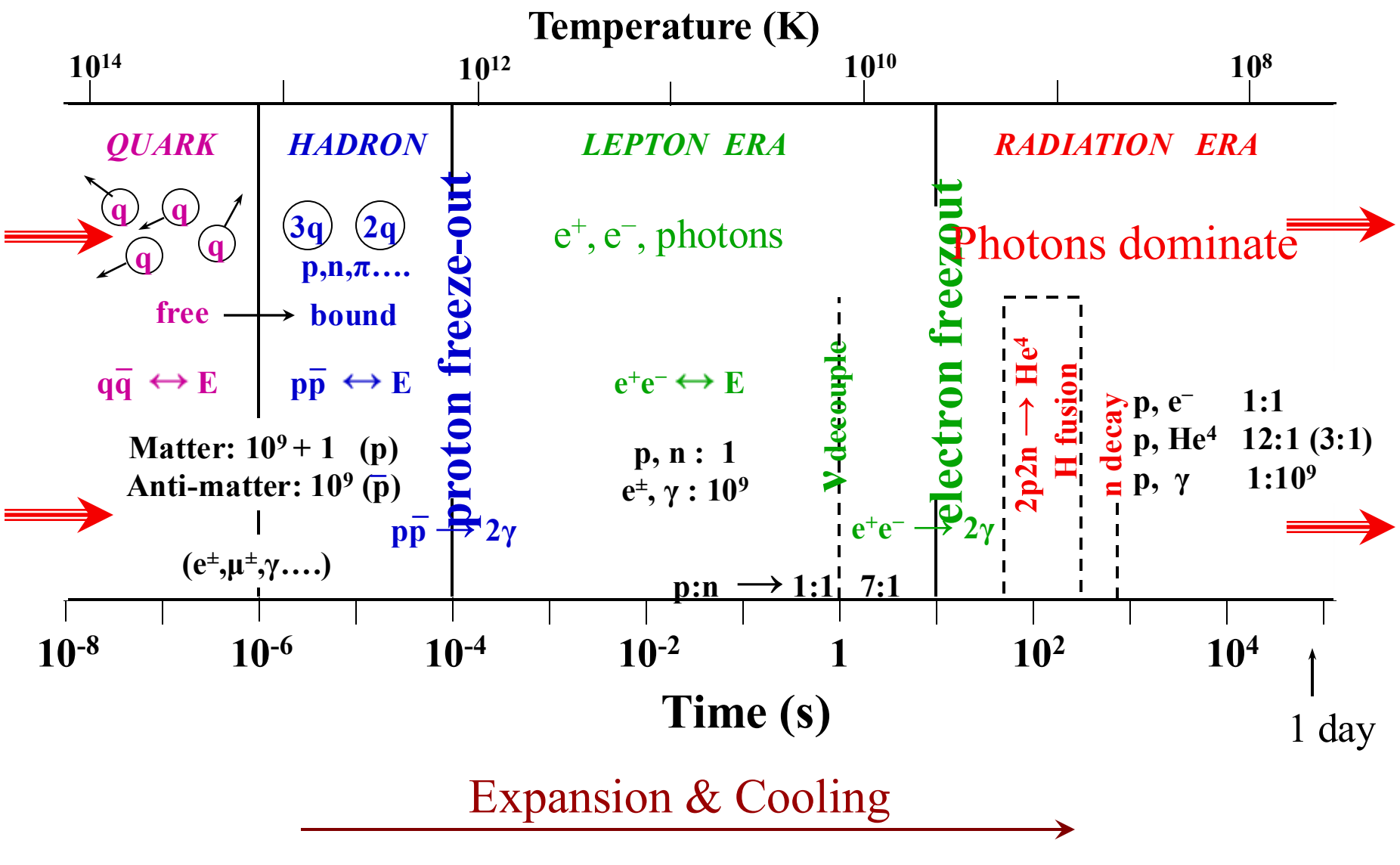


Isotropic: looks the same in all directions
Not homogeneous

Looking afar is looking far back in time



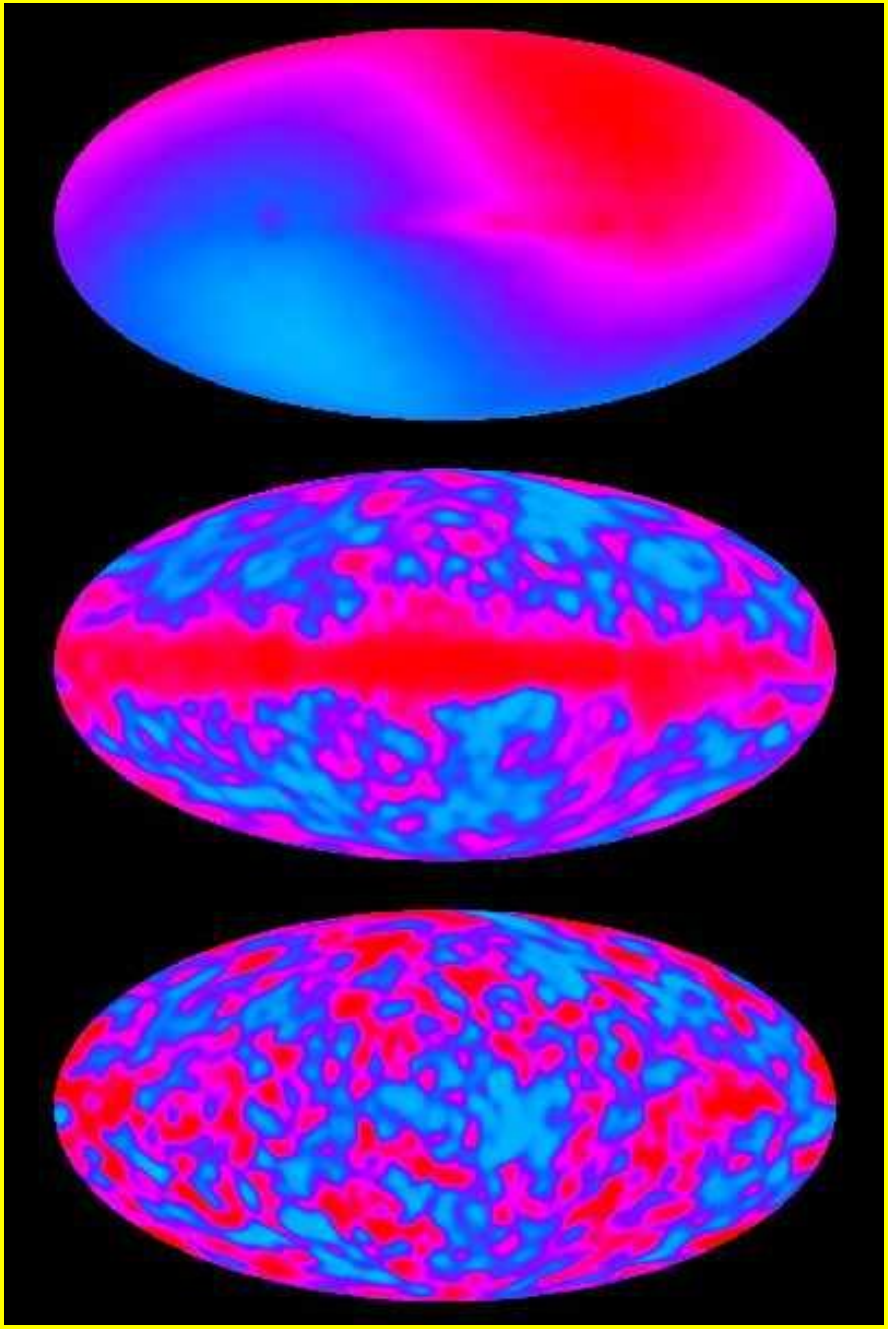
The First Day

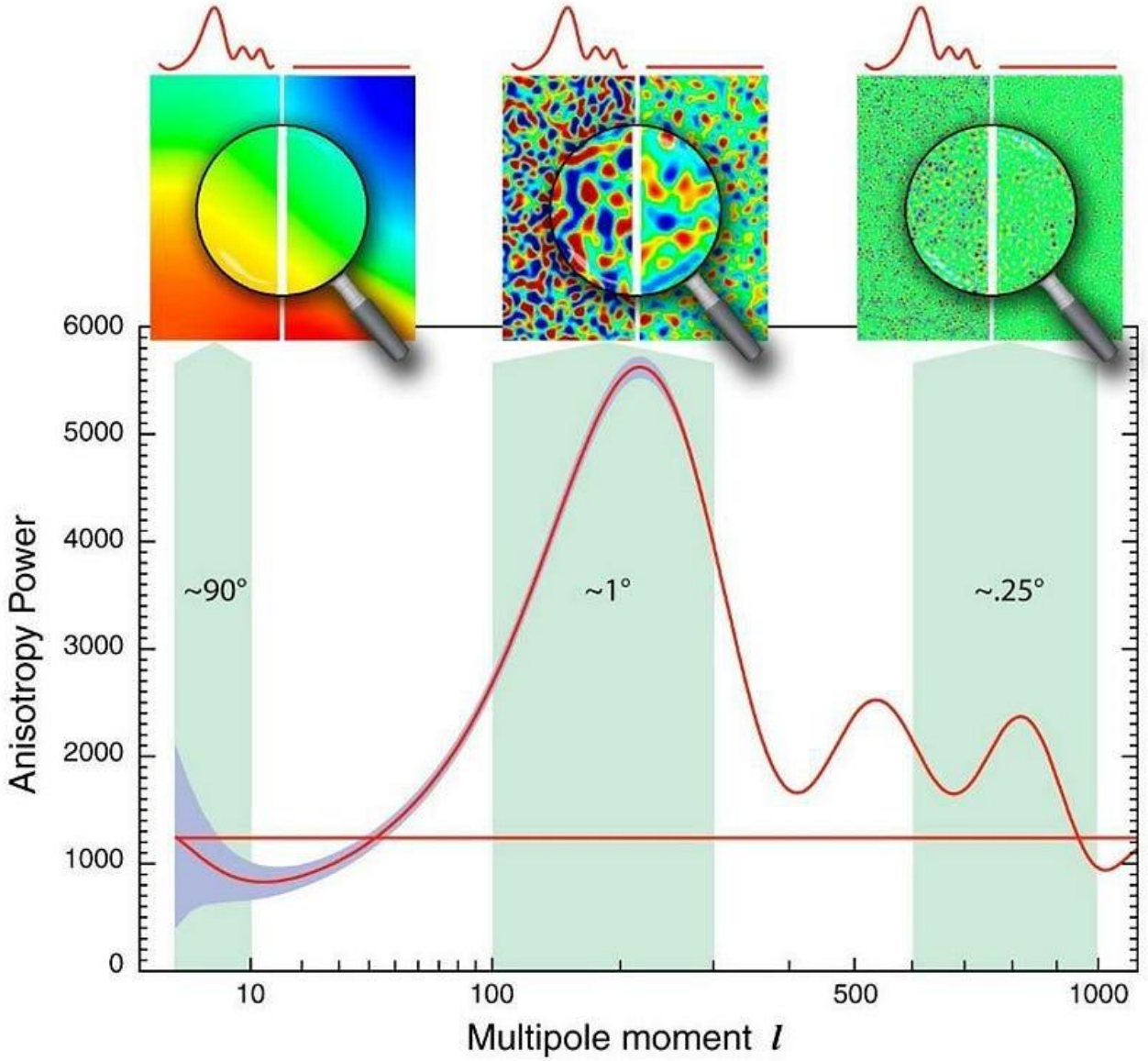


Expansion & Cooling

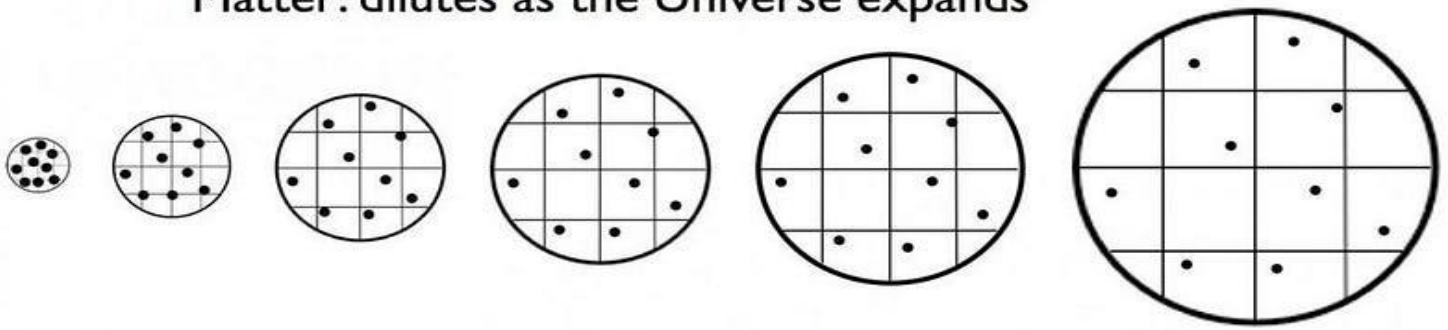
How did the Universe get *clumpy* on the small scale?

This is the big-question in cosmology today

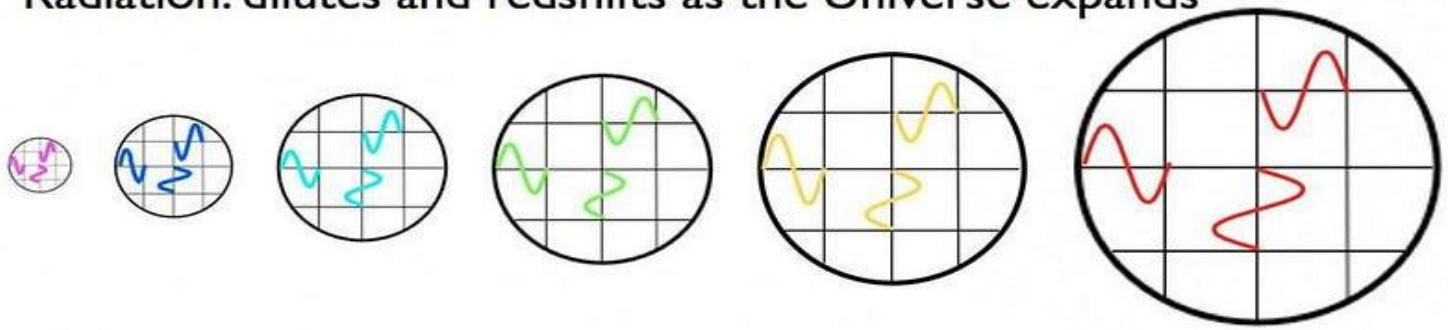


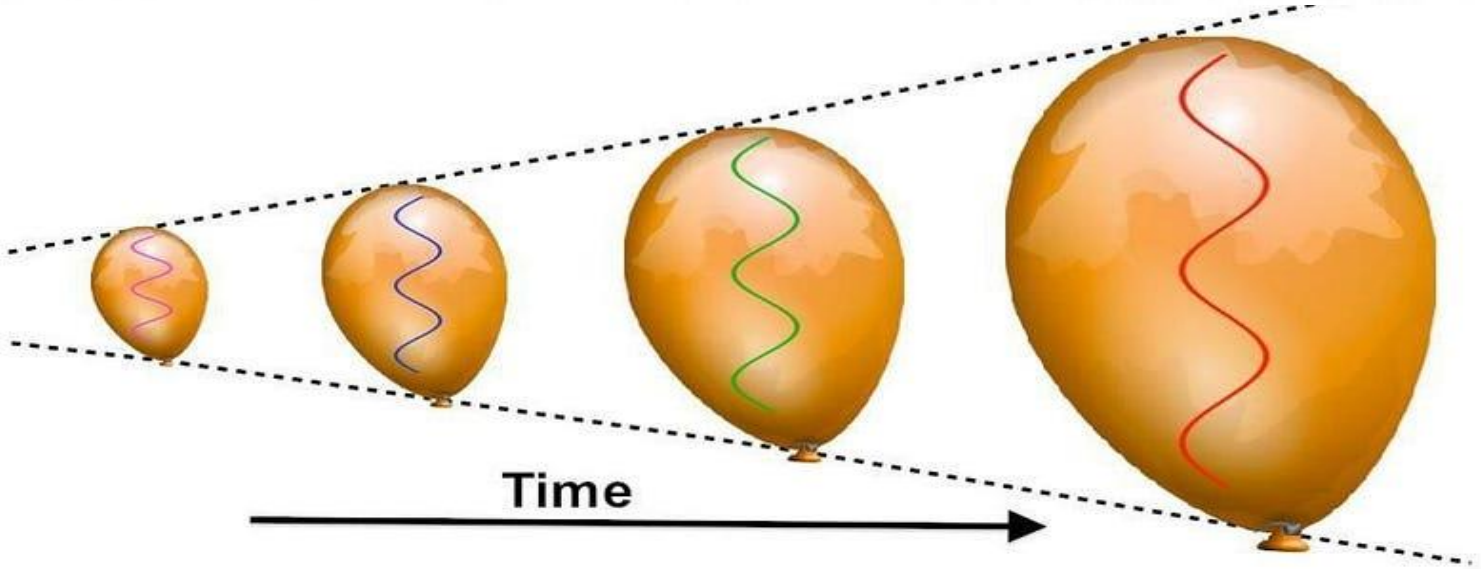

6000
5000
4000
3000
2000
1000
0
Anisotropy Power
~90°
~1°
~.25°
10
100
500
1000
Multipole moment l

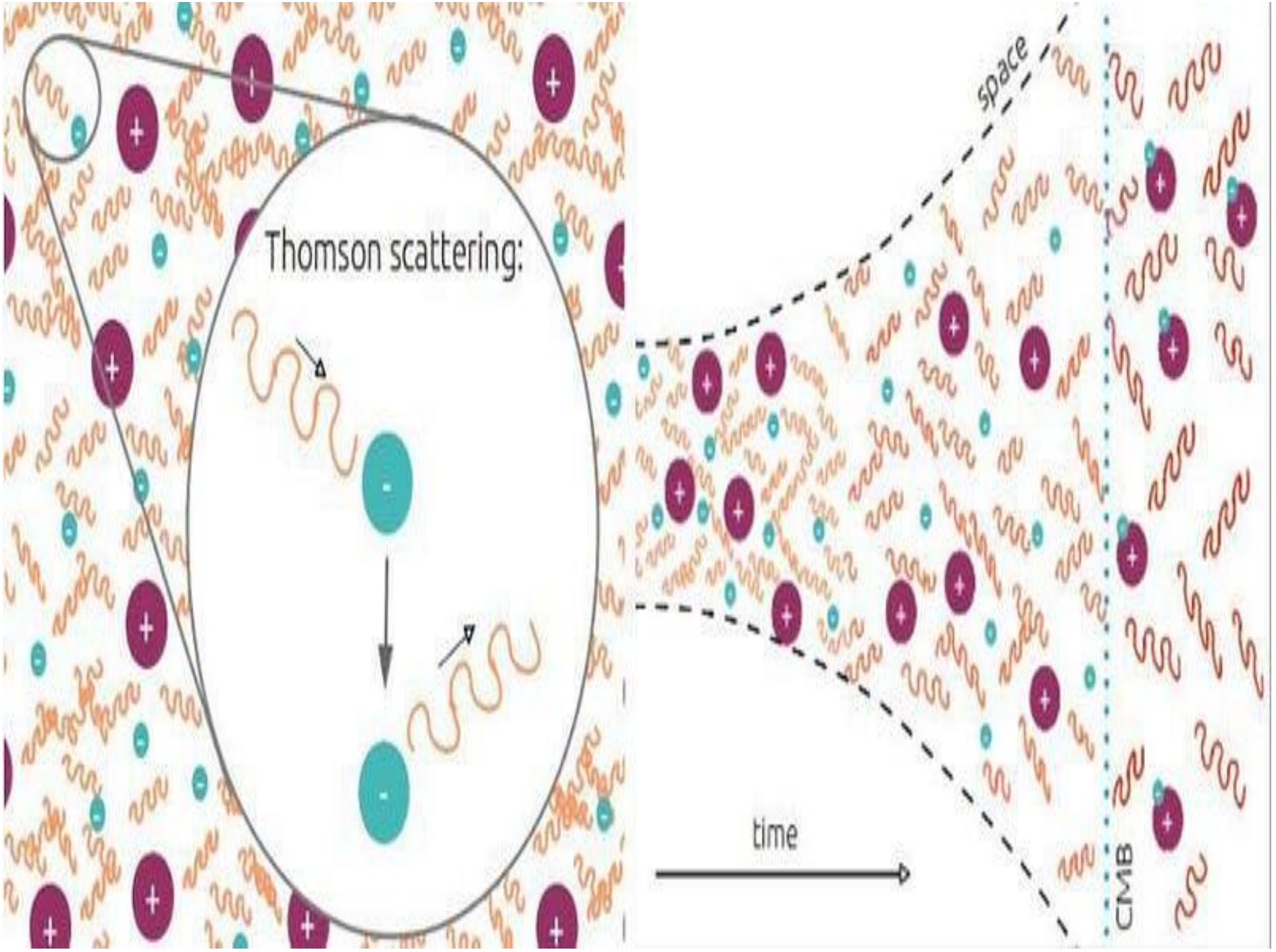
Matter: dilutes as the Universe expands

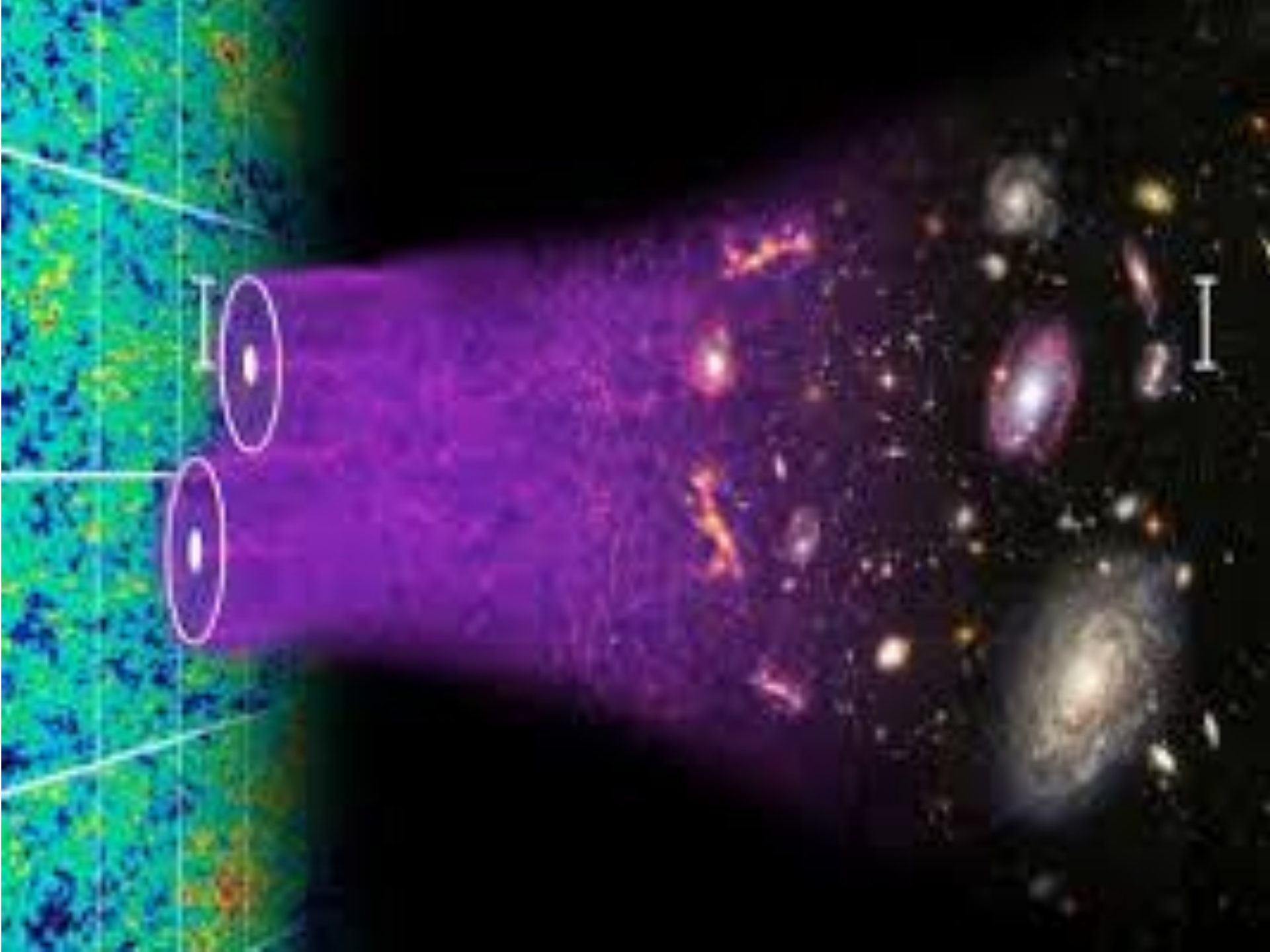


Radiation: dilutes and redshifts as the Universe expands

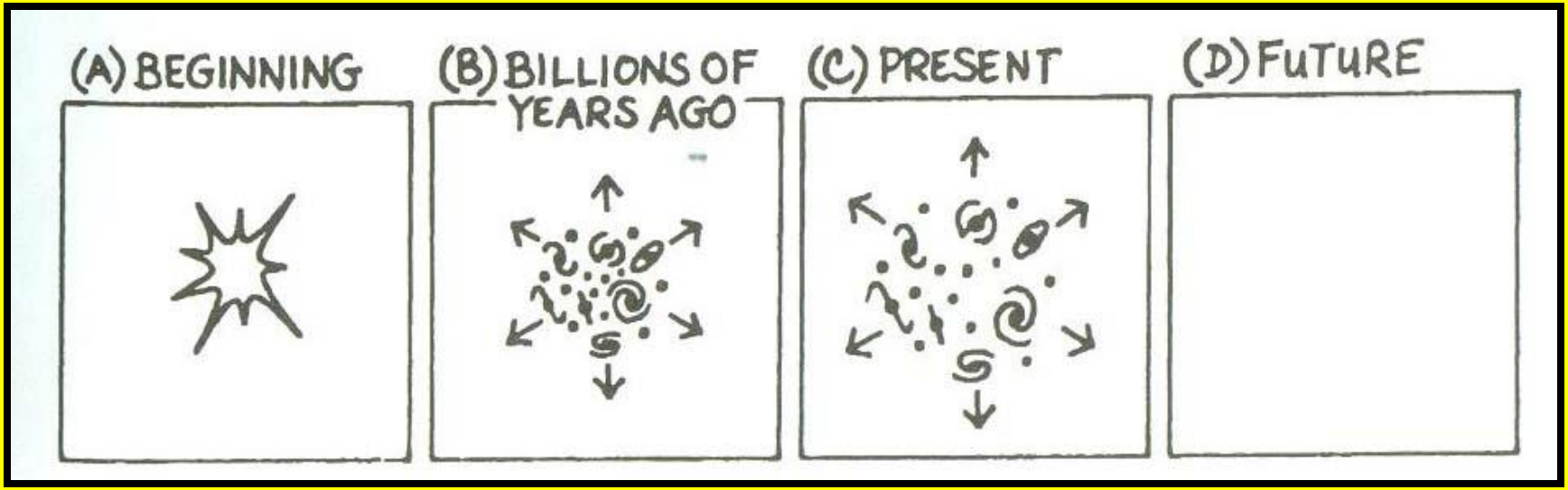





Thomson scattering:
space
time
CMB



An ‘Open Universe’…

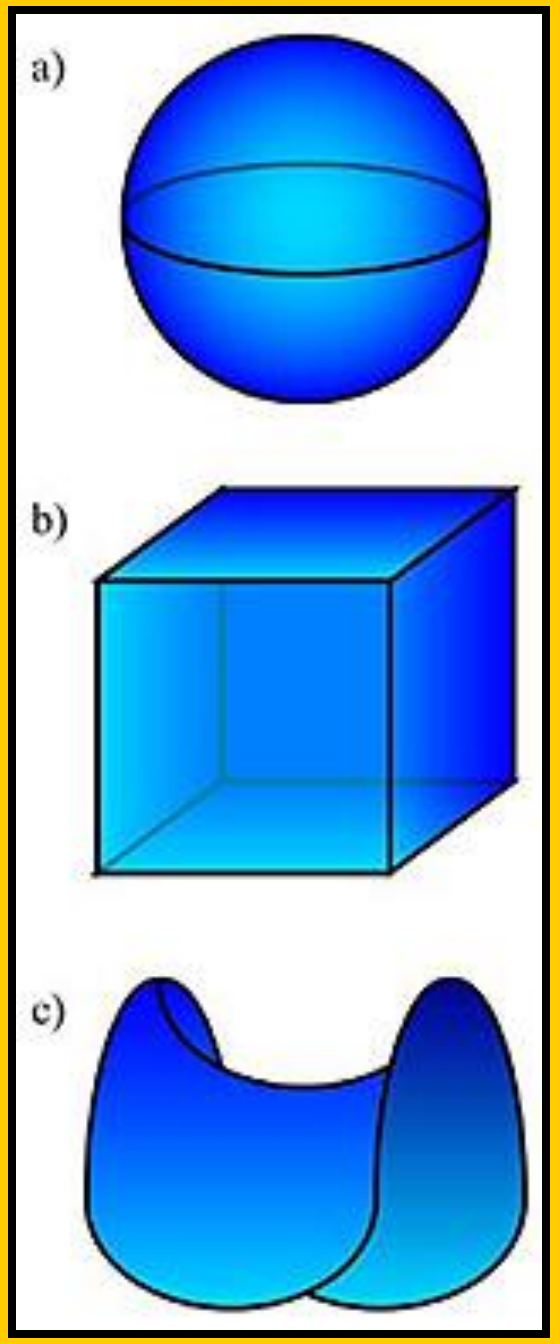


…the expansion goes on forever.

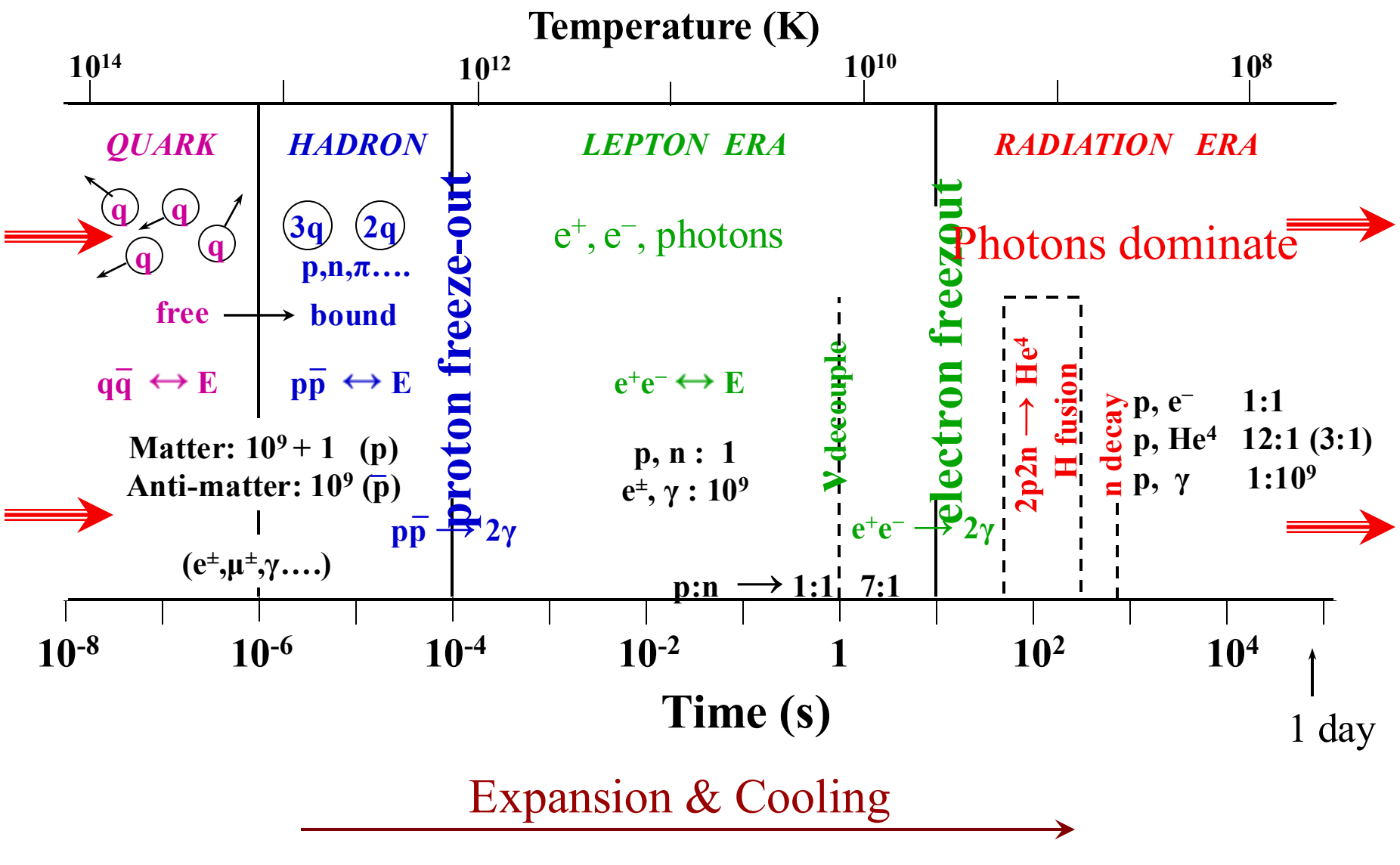
Closed Universe

Flat Universe

Open Universe

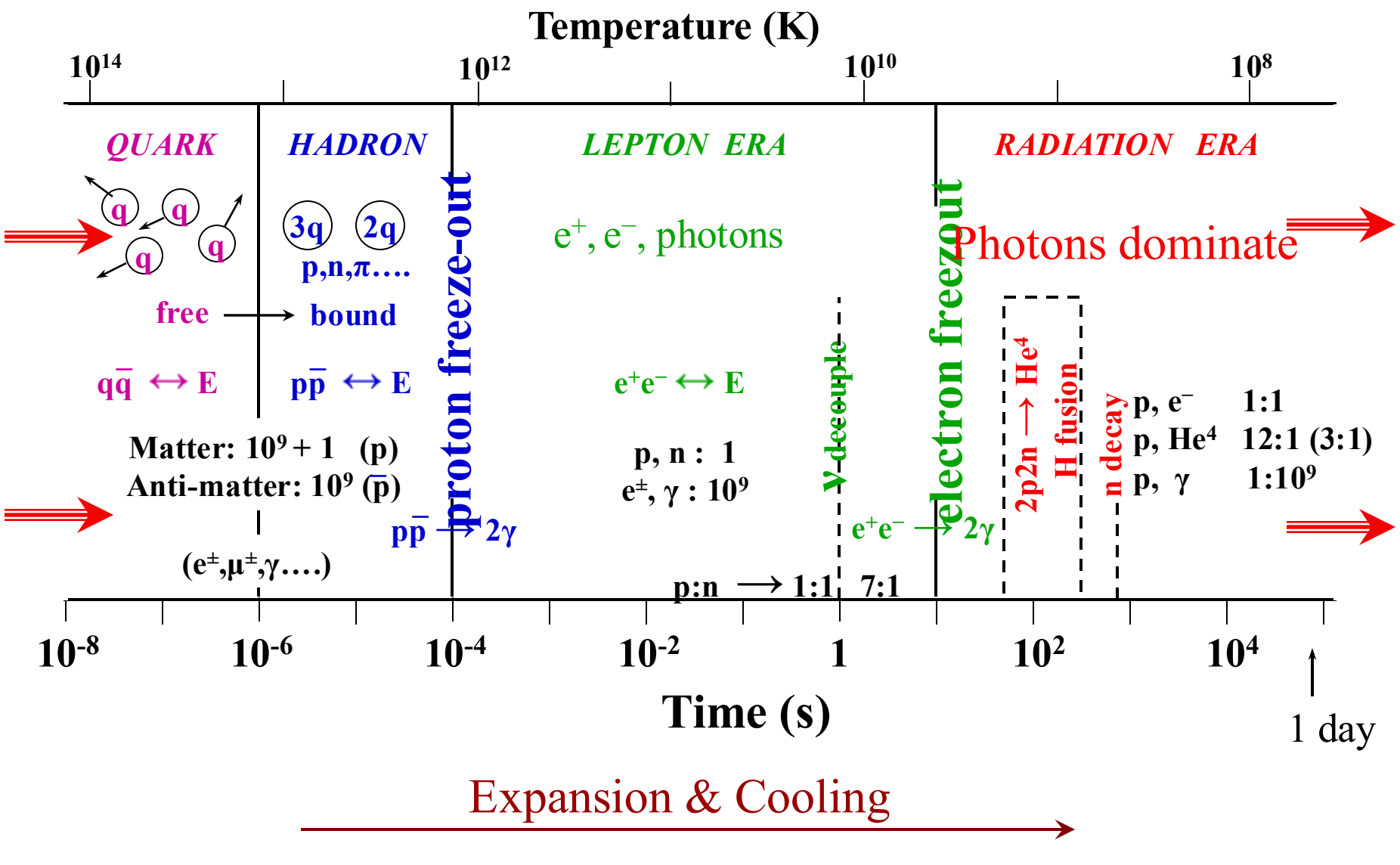


The First Day



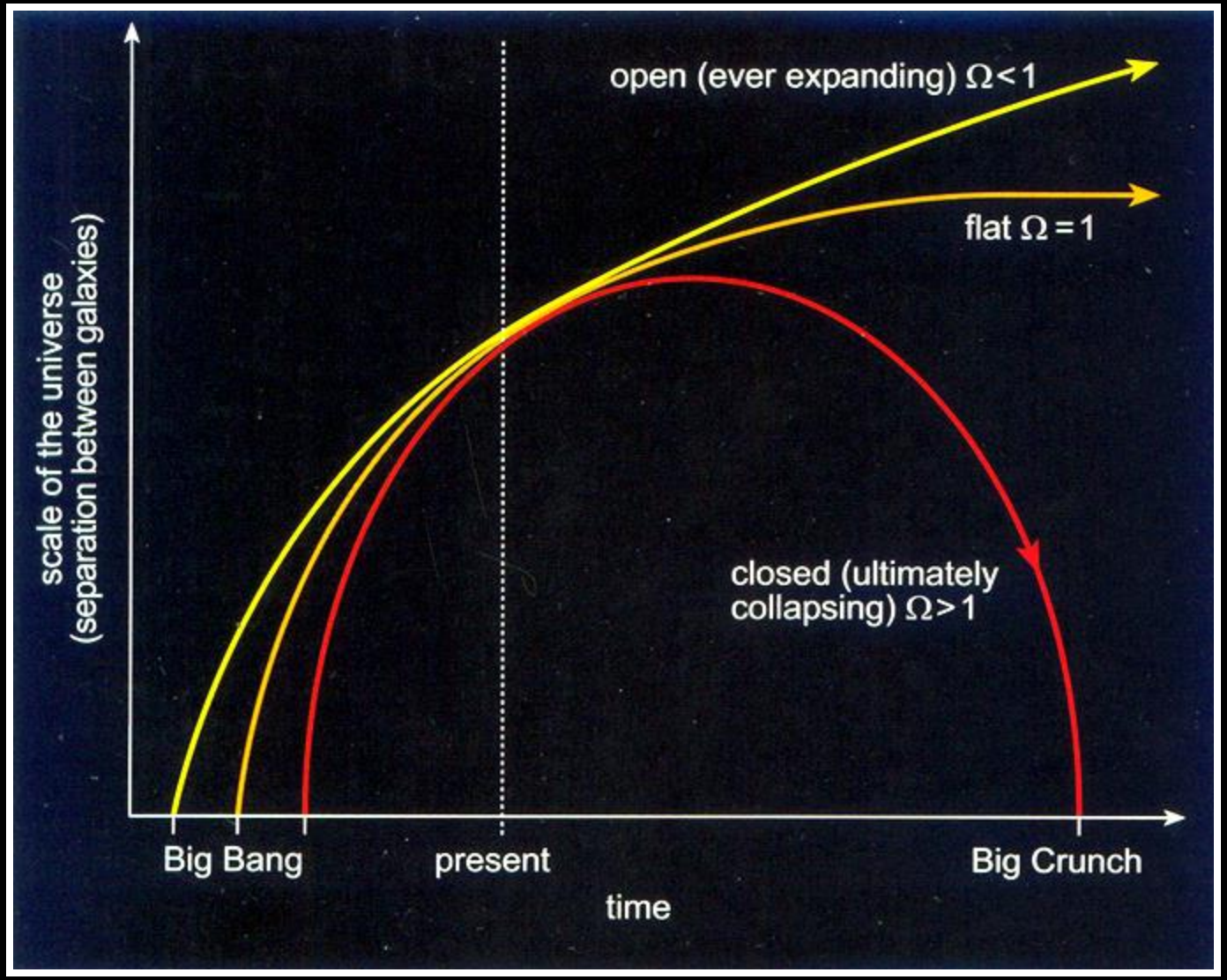
Expansion & Cooling

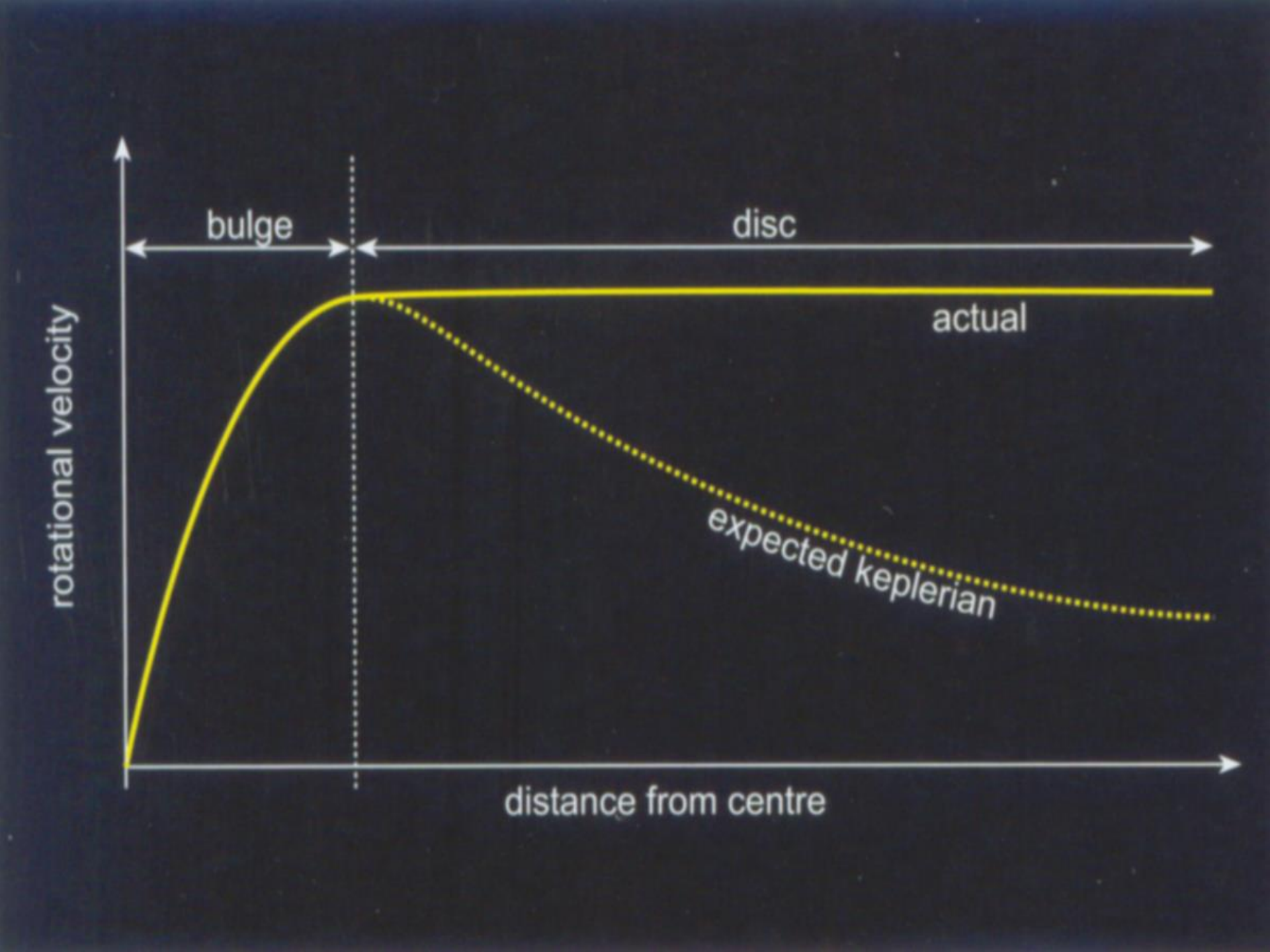
The First Day

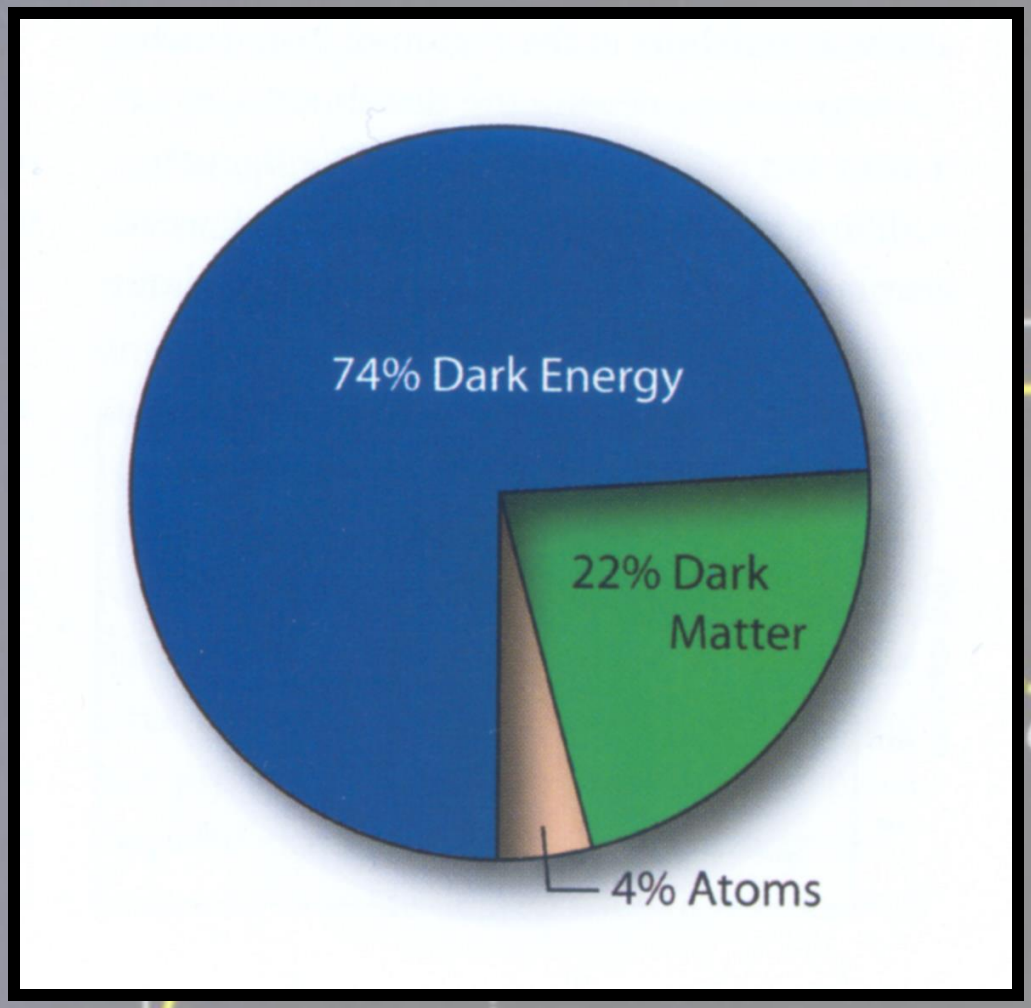


Expansion & Cooling

Traditional view of the fate(s) of the Universe




bulge
disc
actual
expected keplerian
rotational velocity
distance from centre



disc

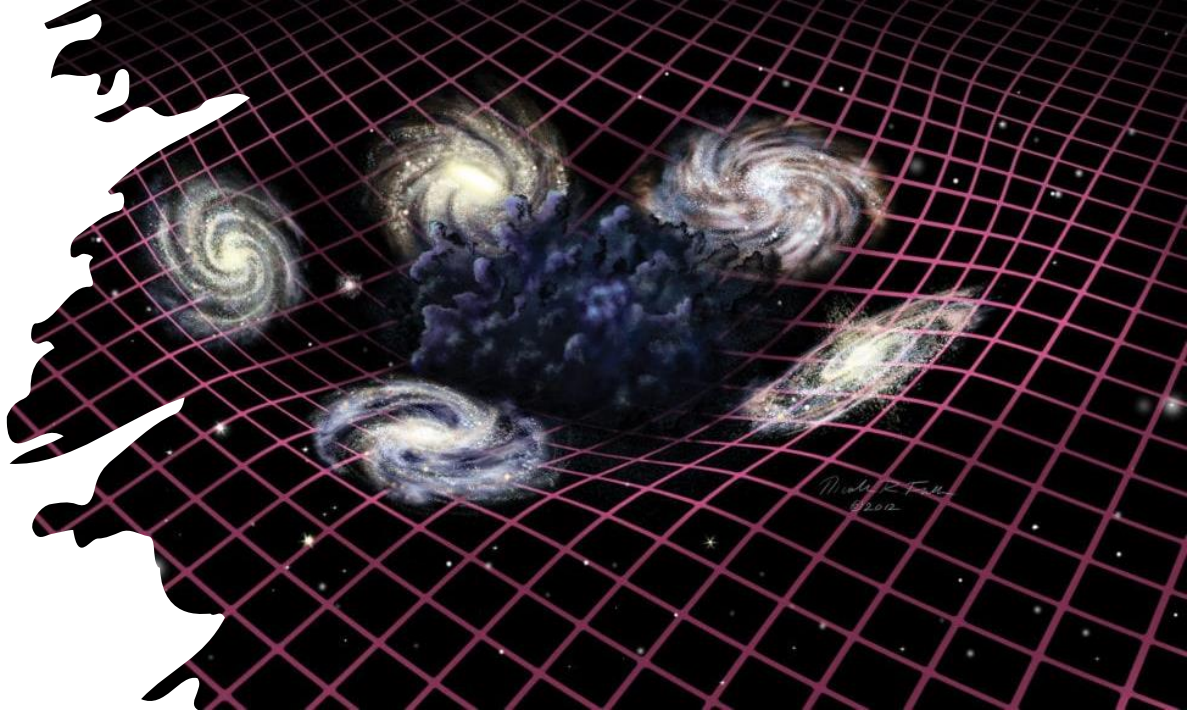
actual

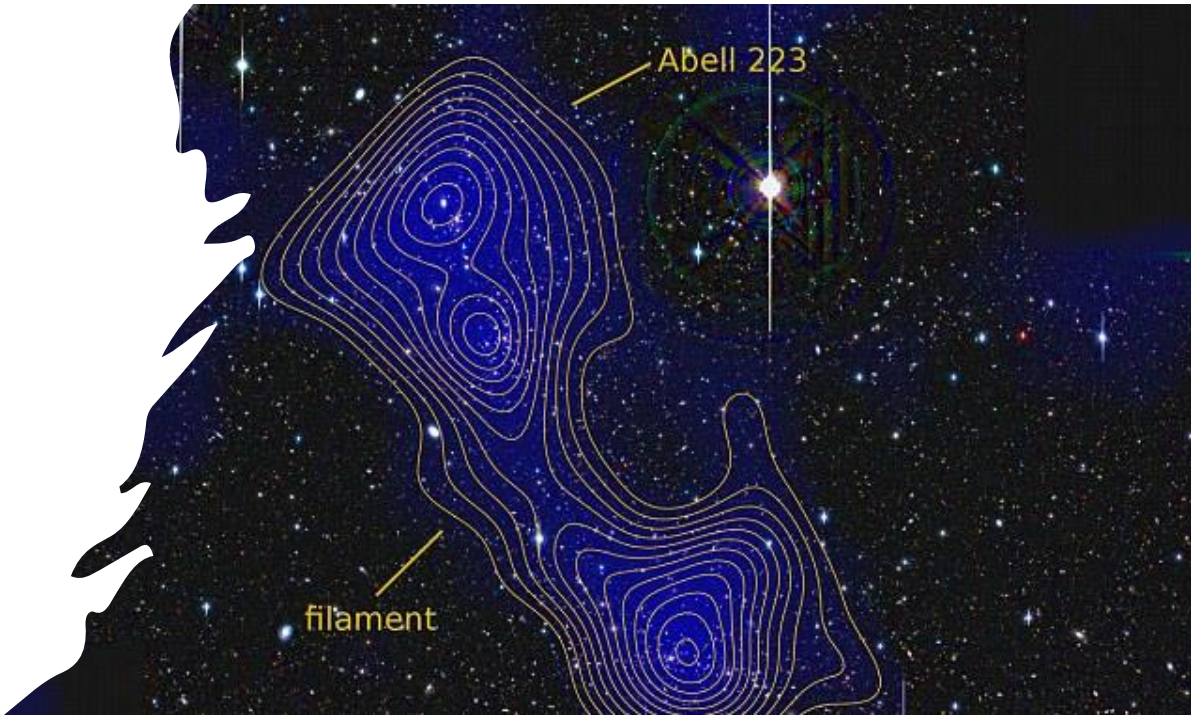
expected keplerian

distance from centre

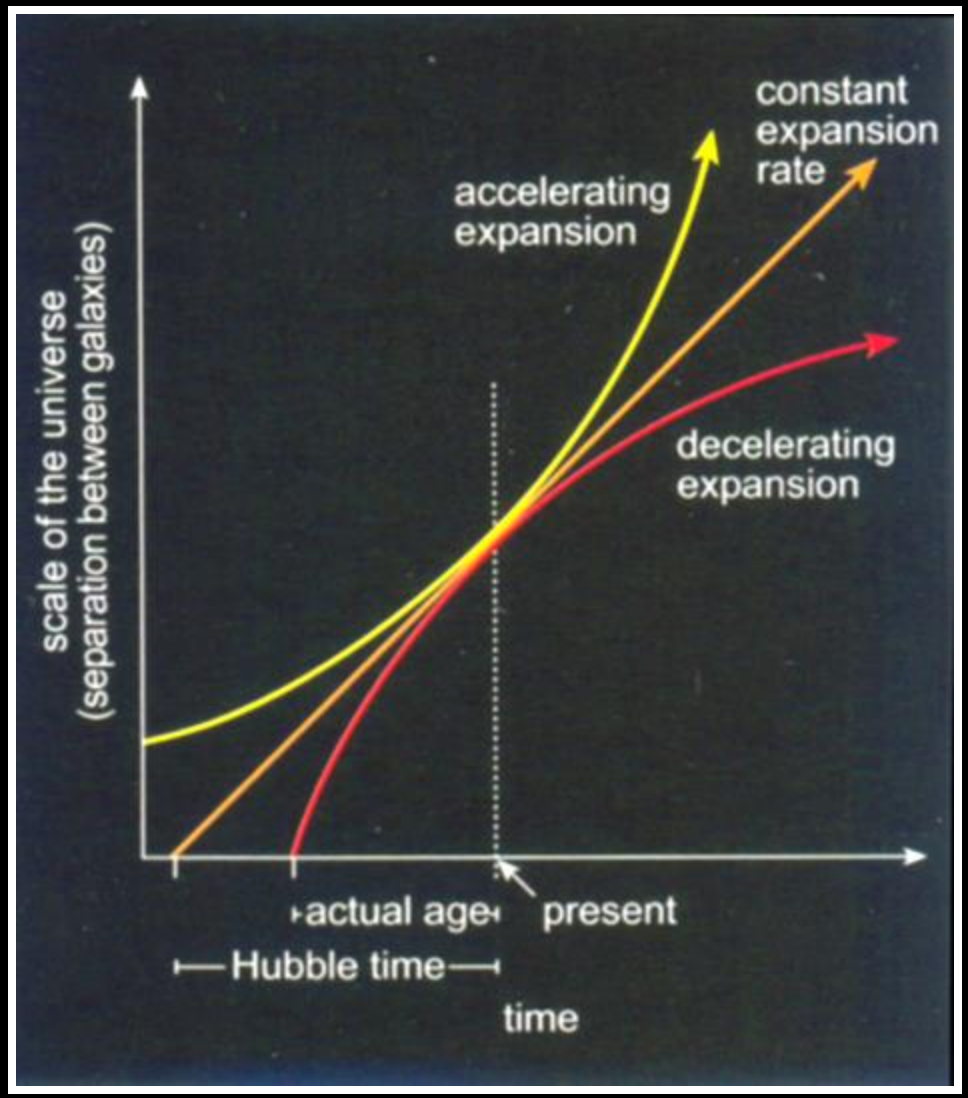
Dark Matter, in filaments, may be the reason for large scale galaxy clusters having a relatively stable structure over 100s of millions of light years

Surveys have revealed some of the "shape" of the filaments but it is still unknown what particle physics governs Dark Matter – are they a form of neutrino, or new particles beyond the standard model? Who knows?

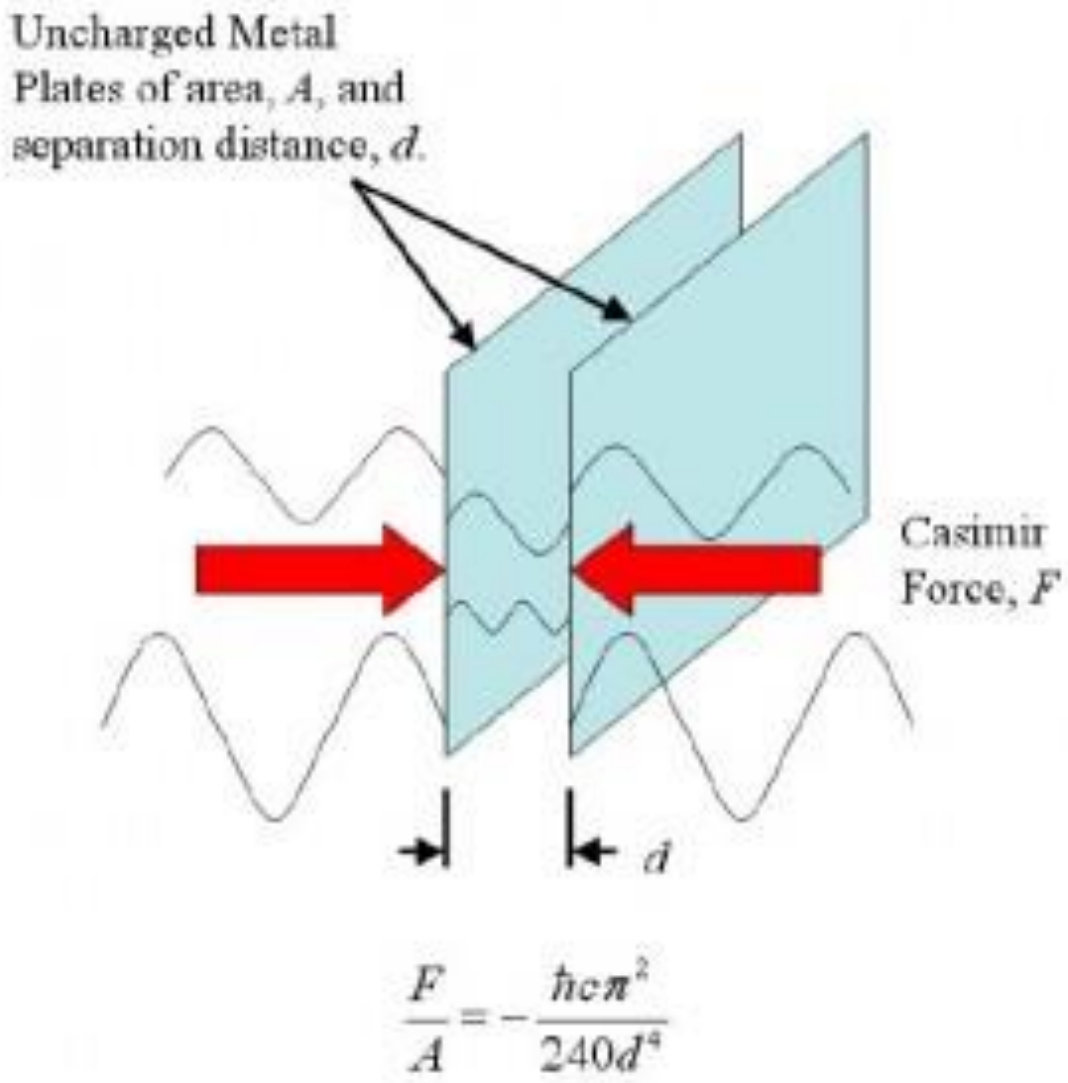




In 1998 it was discovered that the rate of expansion is accelerating.

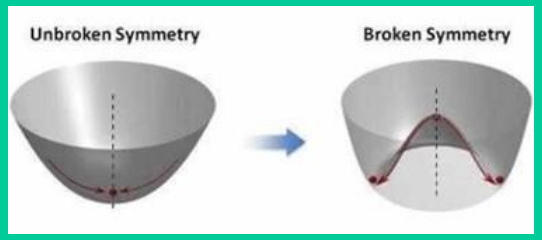


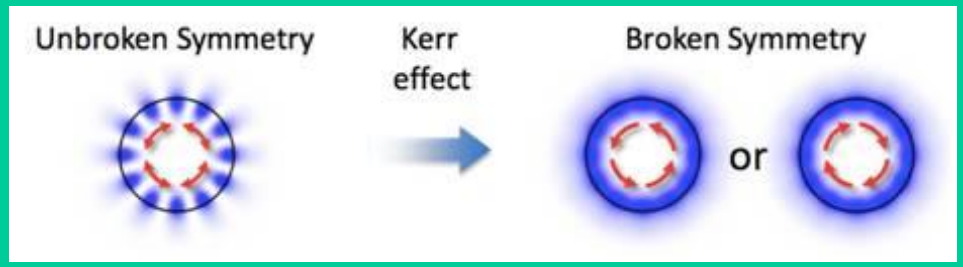
Dark Energy is Somewhat similar to the Casimir Effect, again in small-scale physics

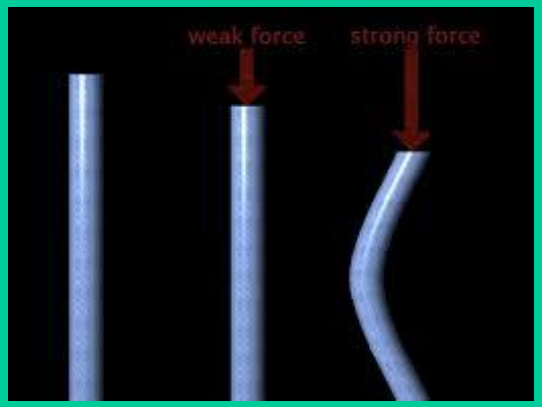


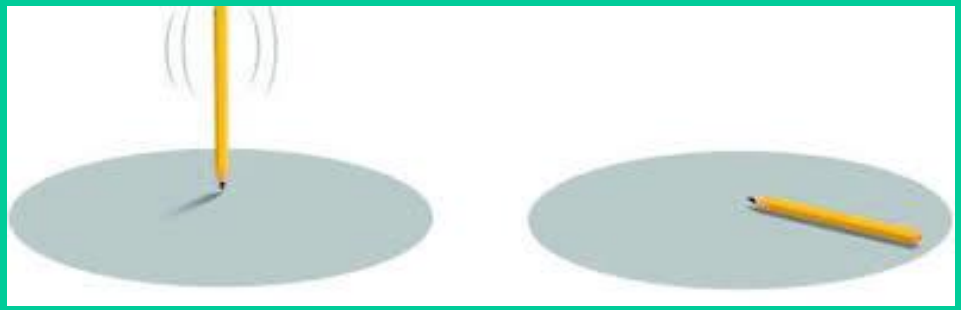
- When Symmetries in a physical system break, some force must emerge or be involved

- Symmetry breaking occurs in dynamic systems undergoing phase transitions, like a crystal melting forming cracks for example.
- Or water evaporating forming chaotic clouds of vapor

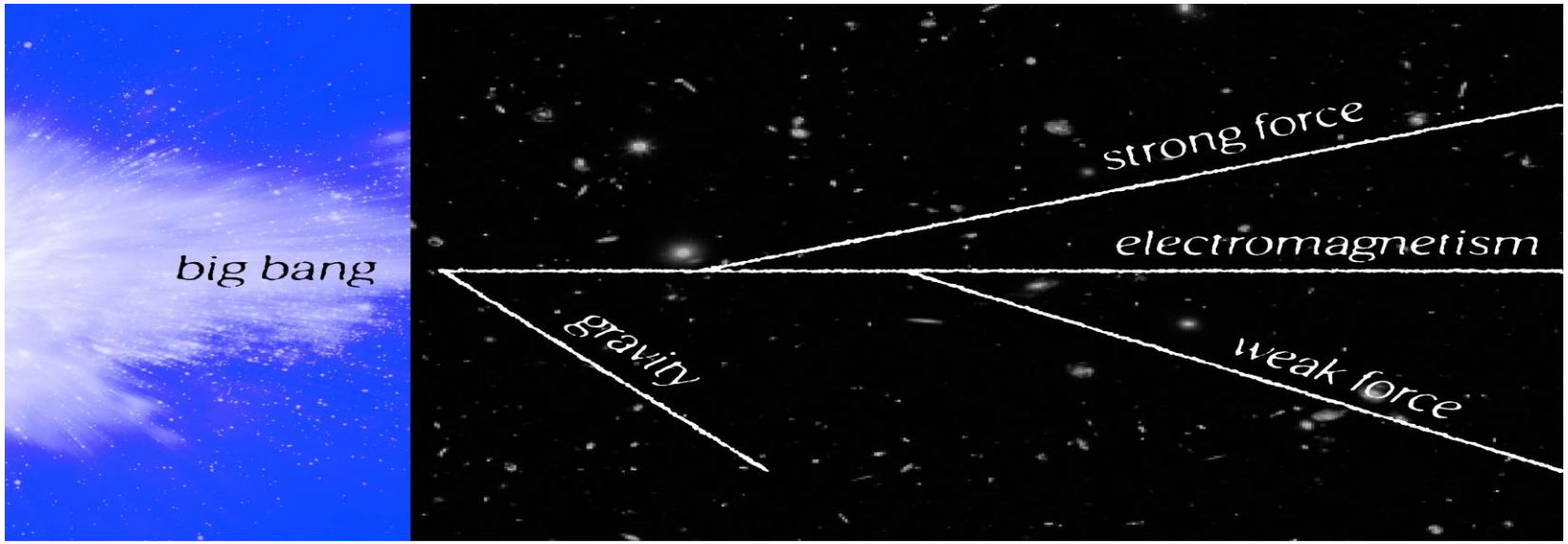

Unbroken Symmetry
Broken Symmetry


Unbroken Symmetry
Kerr
effect
Broken Symmetry
or


weak force
strong force

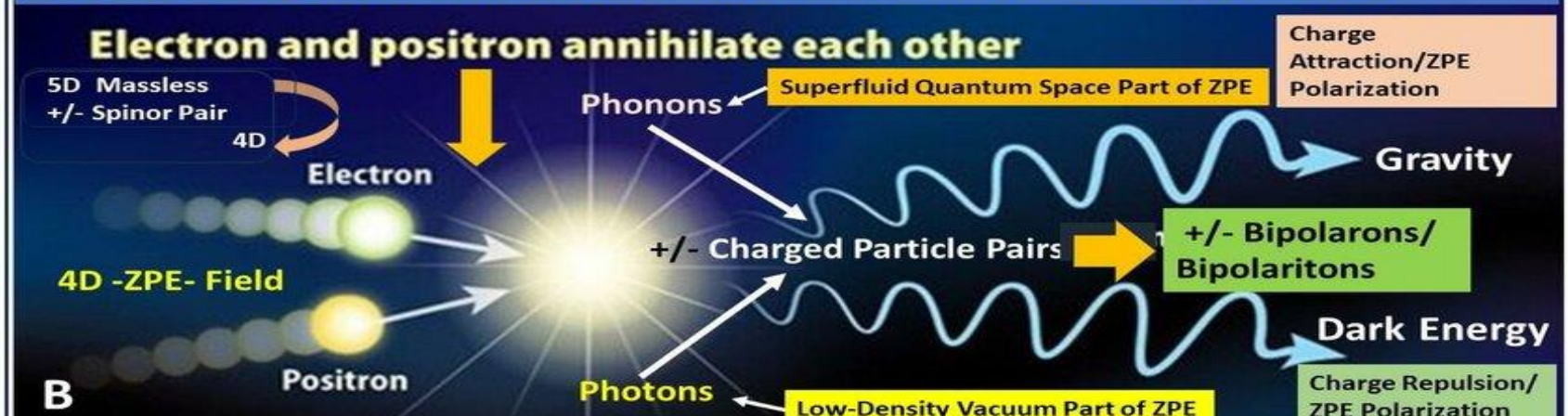


Symmetry-Breaking as a principle of nature repeating itself?

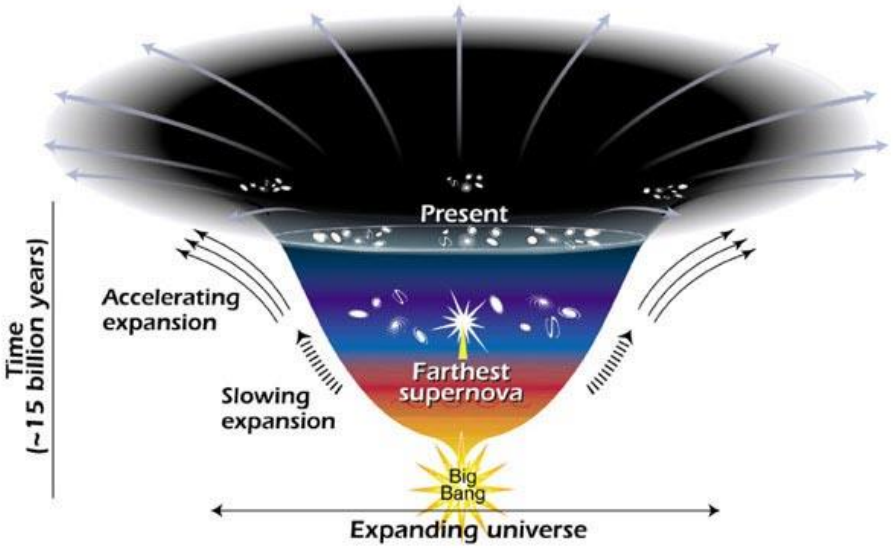


Dark Energy and Gravity Created from Phonons/Photons and Electron/ Proton Pairs Gravit. Bipolar(it)ons

Electron/Positron Pairs Undergo Collision, Producing either Phonons or Photons, at ZPE Superfluid or Vacuum Conditions. They than form Quasi-Particles by Covering (-) Electrons and (+) Protons or Positrons. This Yields Dual Polarons and Bipolaritons. Repulsive or Attractive Charge Interactions of Bipolarons Induce, either, Dark Energy or Gravity

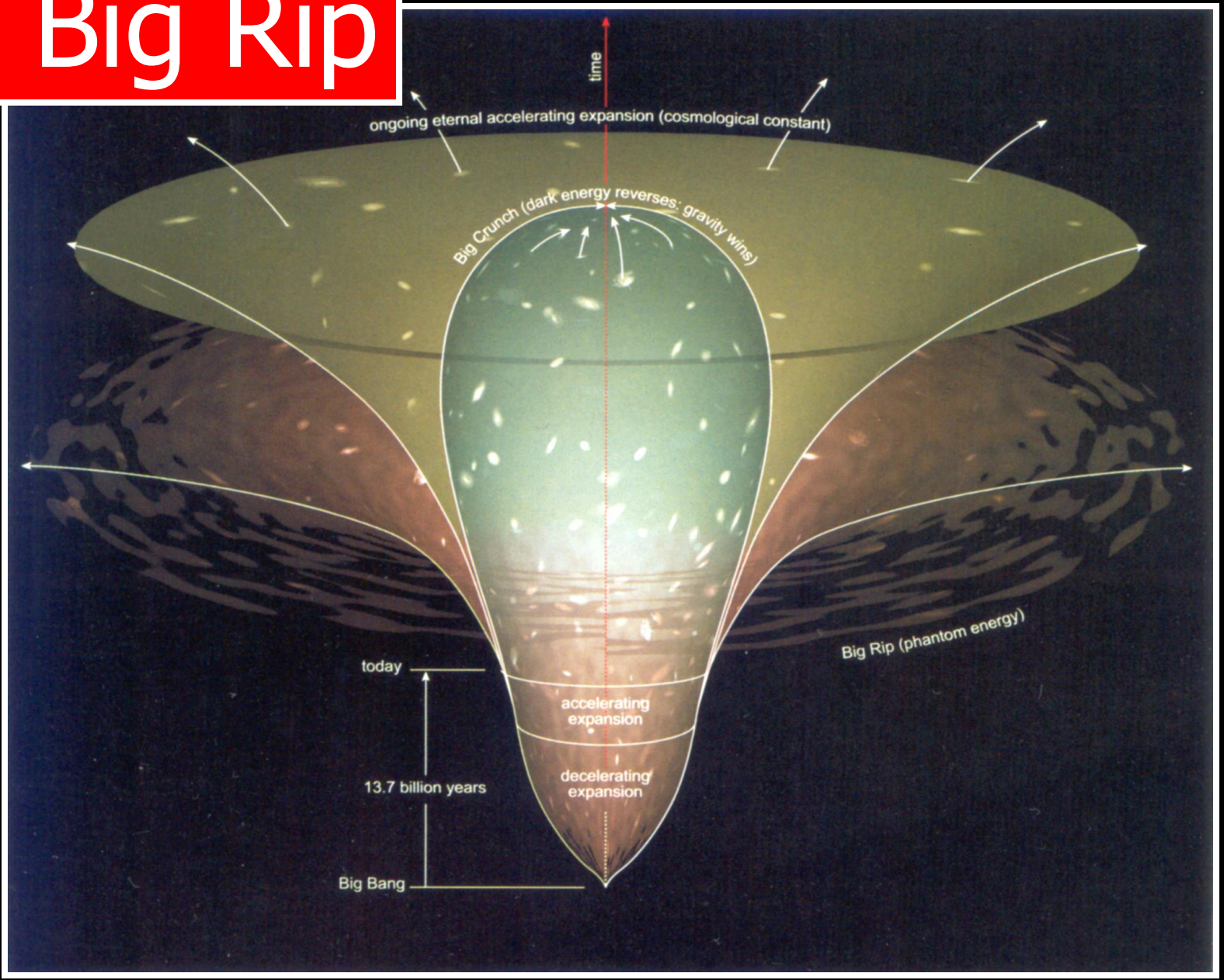


The Far Future of the Universe



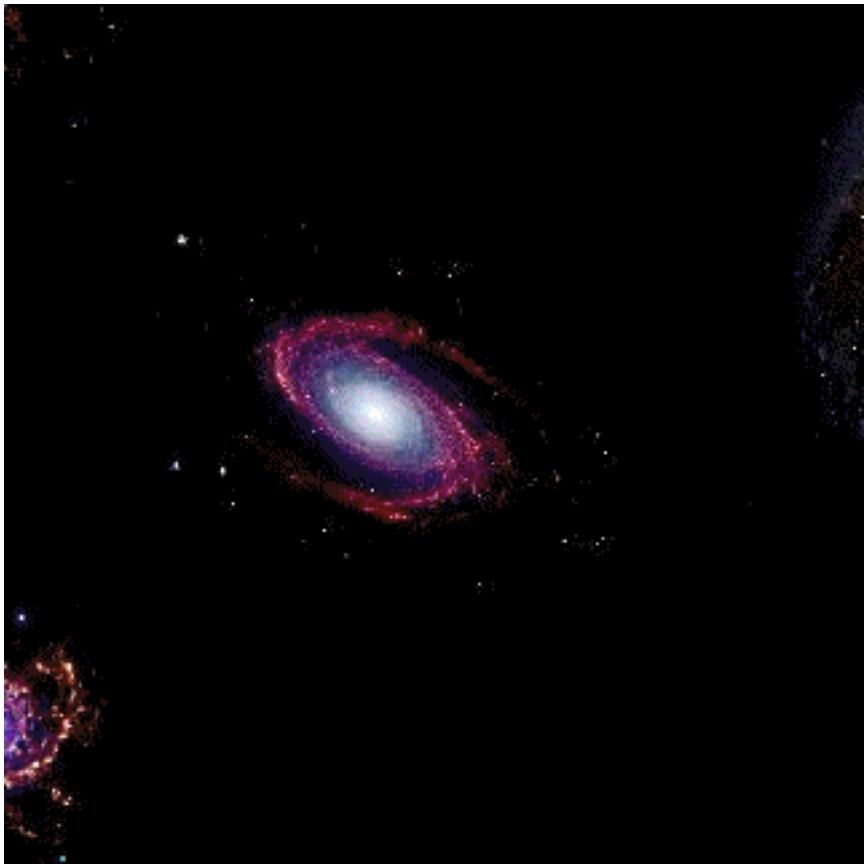
- Three major theories
  - Big Rip
    - Open universe: expansion of the universe accelerates
    - Comes to dominate over attractive forces
    - Local forces no longer dominate
    - Eventually pulls the universe apart

The Big Rip


time
ongoing eternal accelerating expansion (cosmological constant)
Big Crunch (dark energy reverses: gravity wins)
Big Rip (phantom energy)
today
accelerating expansion
decelerating expansion
13.7 billion years
Big Bang

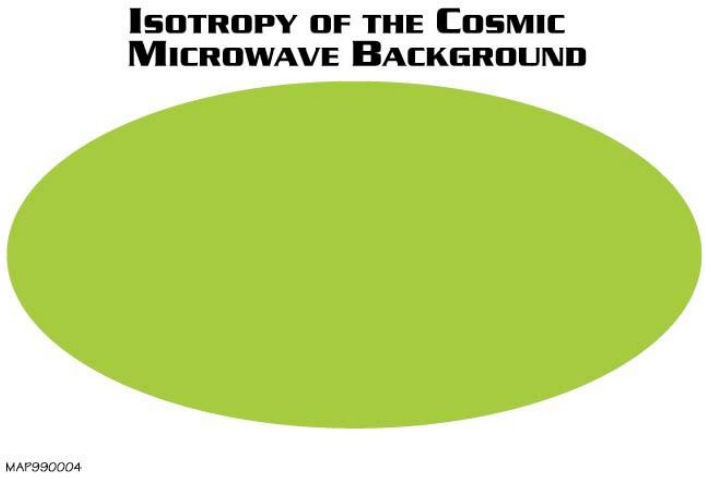
The Future of the Universe

- Three major theories
  - Big Crunch
    - Closed universe: expansion slows down
    - Attraction comes to dominate over expansion
    - Eventually universe collapses
    - Reverse of the Big Bang (occasionally called Gnab Gib)
    - May lead to Big Bounce and oscillating Universes



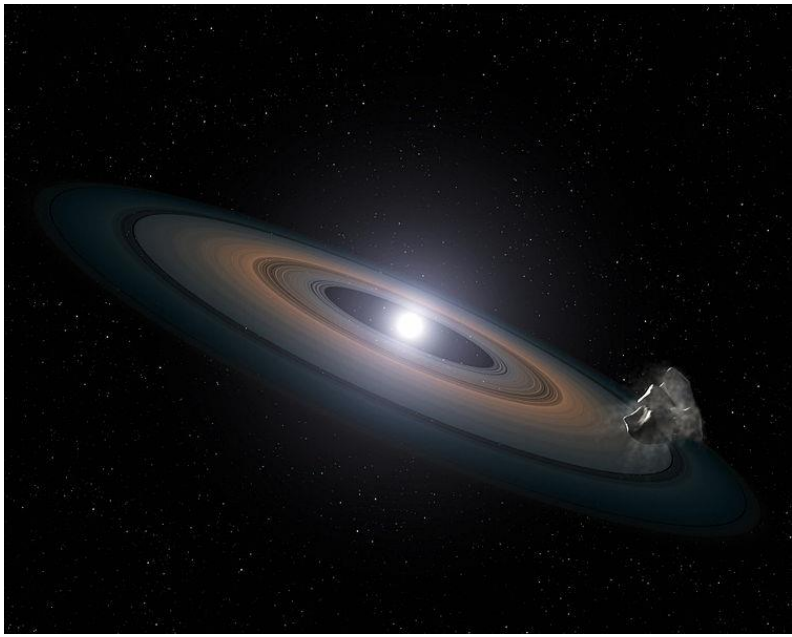
The Future of the Universe

- Three major theories
  - Big Freeze
    - Flat universe continues until energy runs out
    - Universe is smooth over very large scale
    - Current leading theory
    - Measurements suggest universe is flat to within 0.4%
    - Curvature of universe at most comparable to observable universe



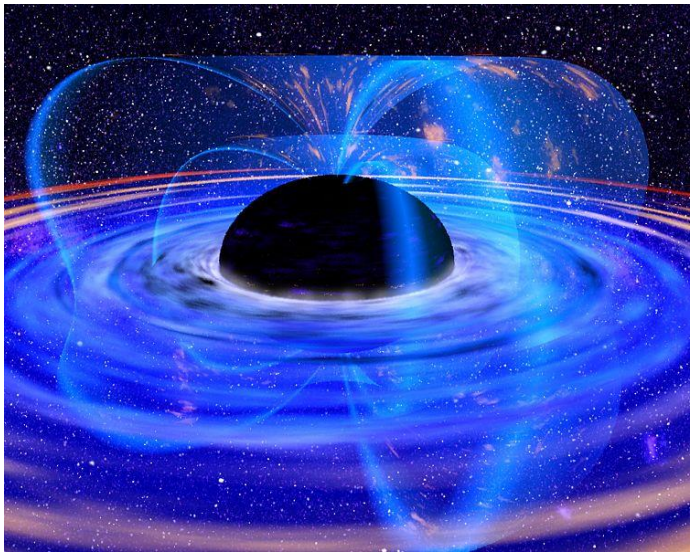
The Future of the Universe

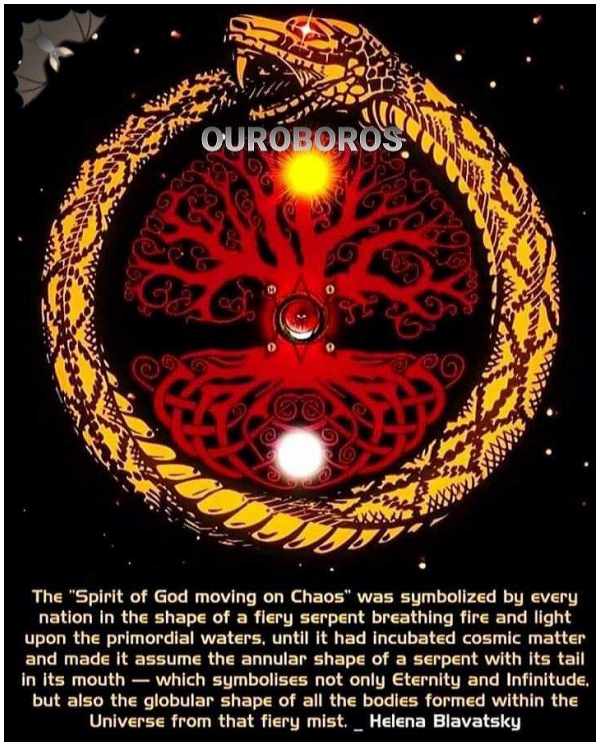
- Stelliferous Era (Star Forming)
  - Cycle of life, death and rebirth uses more and more fuel each time
  - After ~10^{14}years (10,000 times the current age of the universe) the last hydrogen will be consumed in the last red dwarf stars
  - The remaining matter is in White dwarfs which slowly cool to black dwarfs

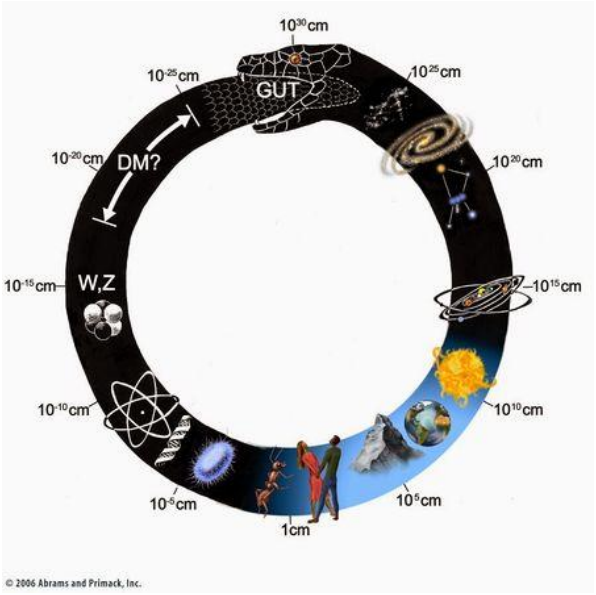


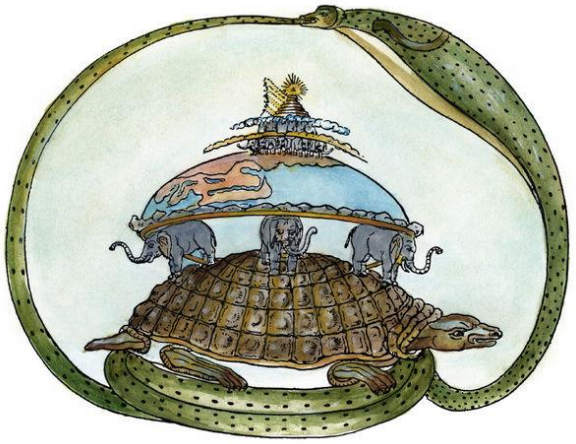
Future of the Universe

- The End of Matter
  - Nucleons decay (~10^{34} yr - 10^{40} yr)
    - Protons and neutrons may decay over extremely long timescales
  - Black Hole Era (~10^{40} yr - 10^{100} yr)
    - Universe dominated by black holes
    - Black holes slowly evaporate via Hawking Radiation
    - More massive black holes last longer









The End...or beginning?

The End?!?