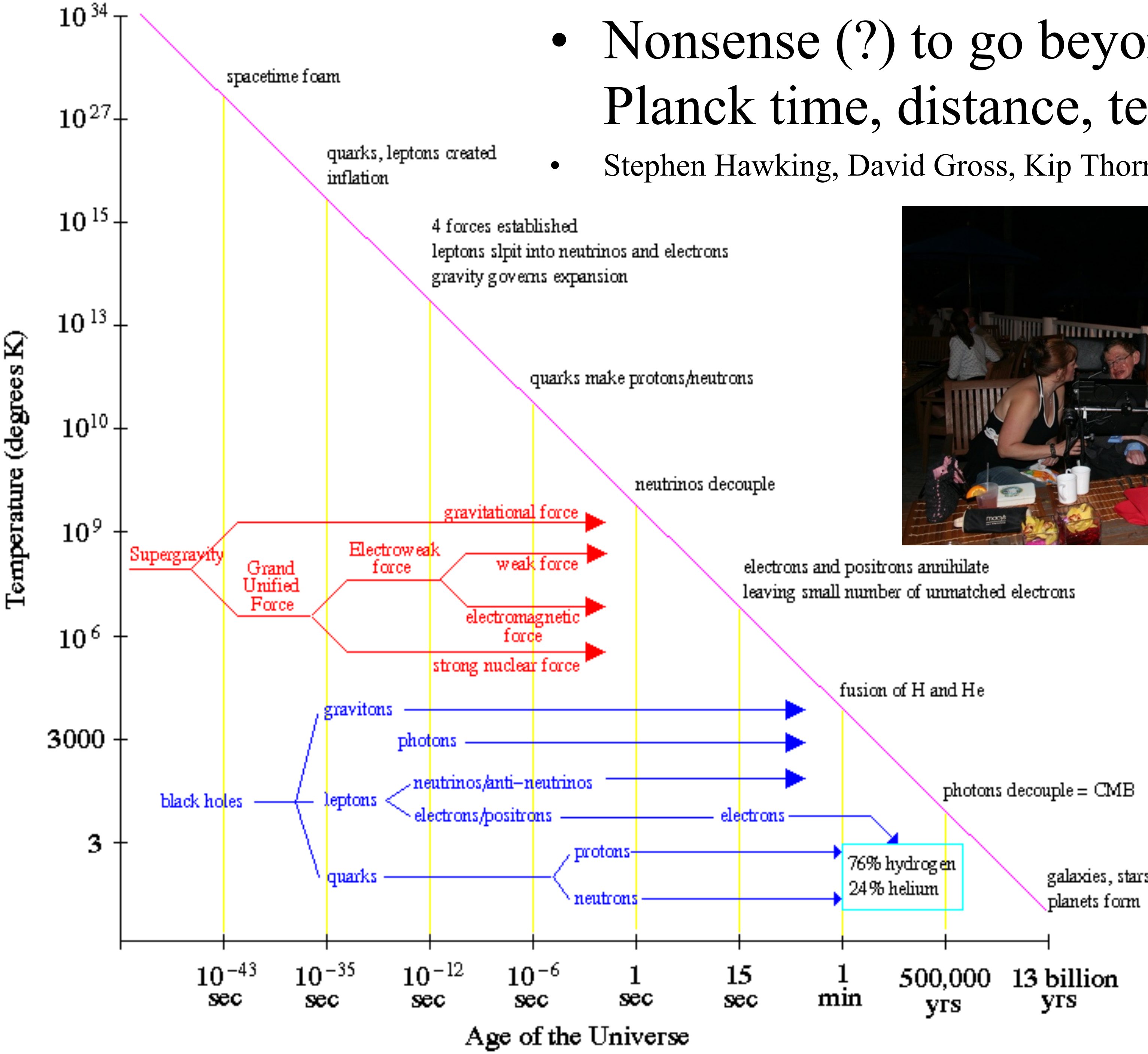
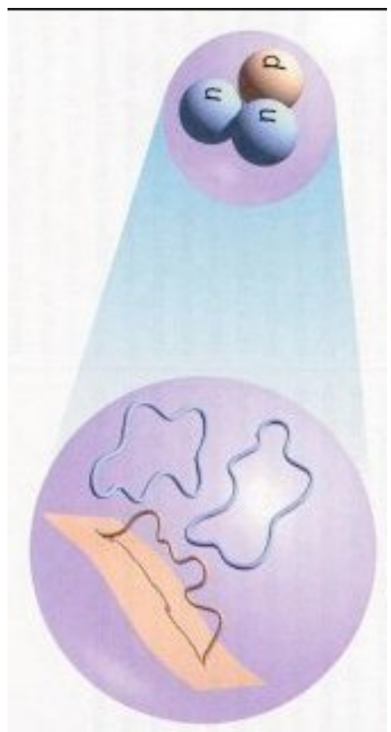
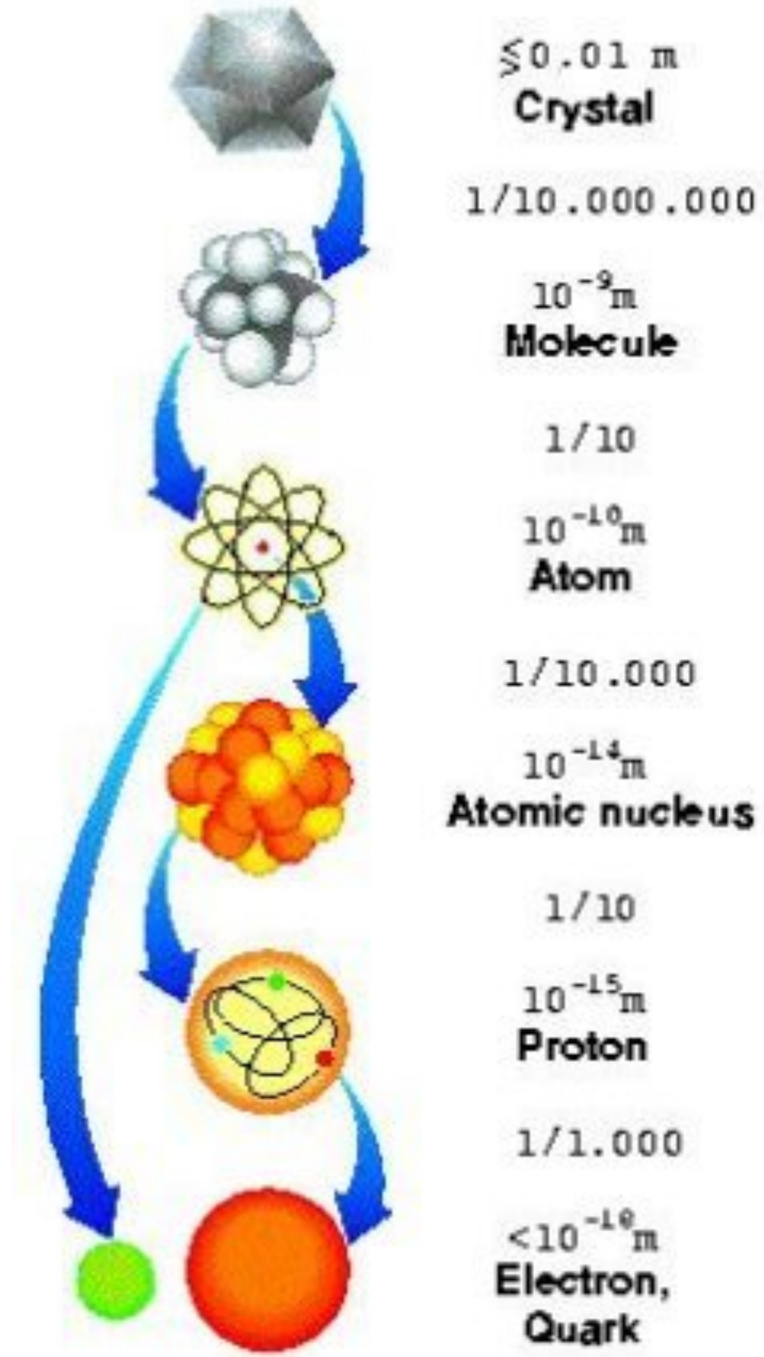
- Nonsense (?) to go beyond the Planck time, distance, temperature
- Stephen Hawking, David Gross, Kip Thorne, Lisa Randall



String Theory: The Unification of Quantum & GR?

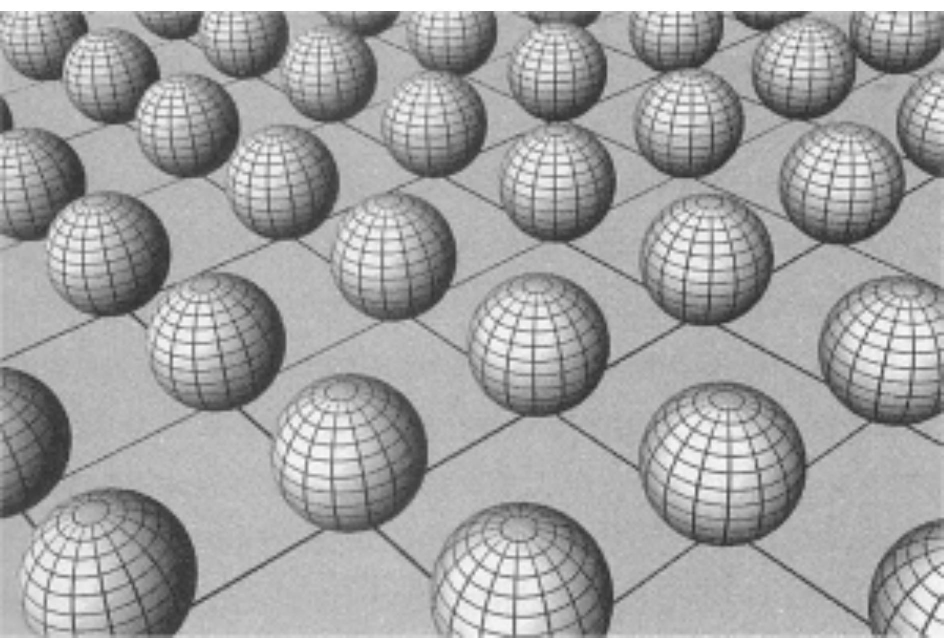
- The subatomic particles are pieces of superconducting string
- Vibrating in different modes for different particles

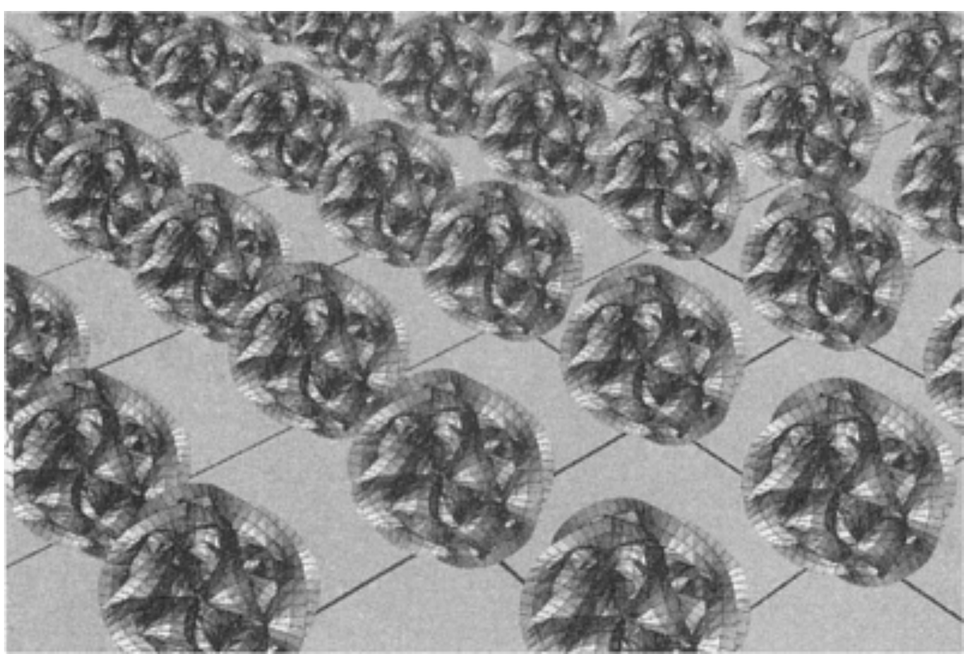




String Theory: requires more dimensions

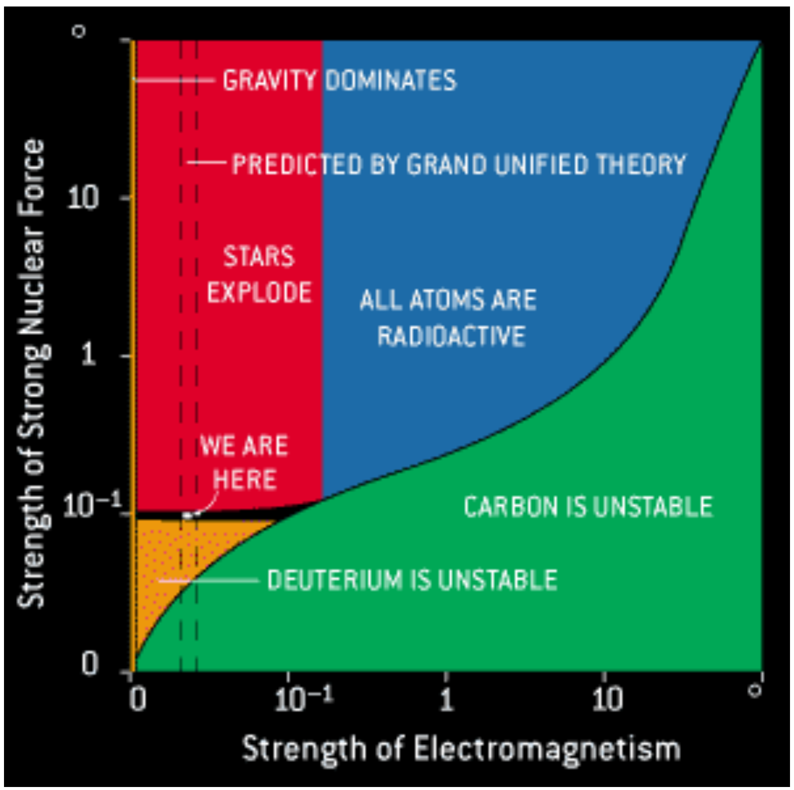
- The ant on the 1-D string is really 3-D string when magnified
- Similarly each point in 2-D surface could be 5-D
- And each point in 2-D could be 10-D ?????

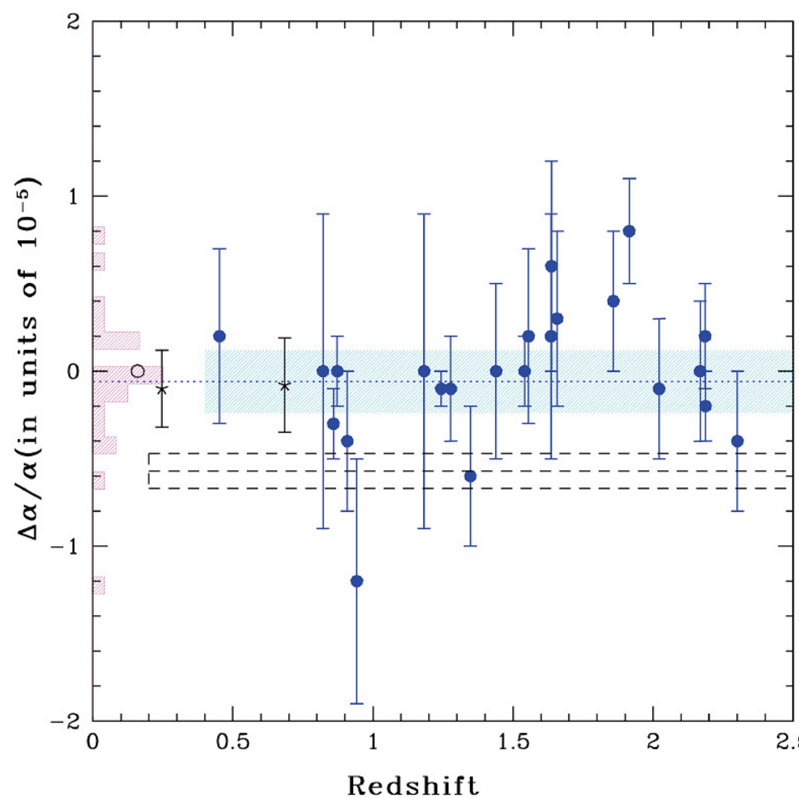




Constant Constants?

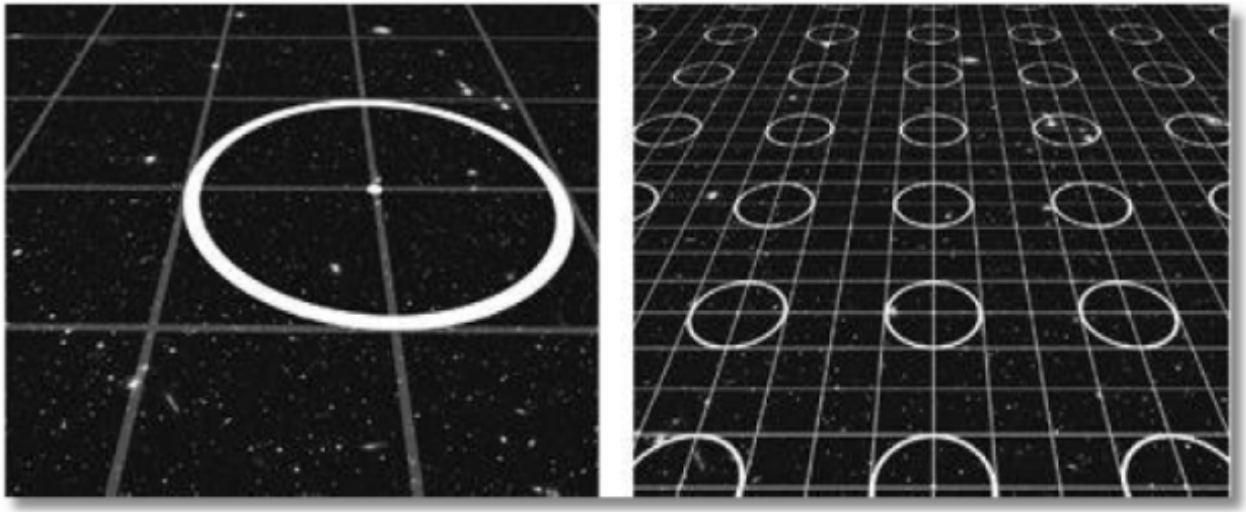
- Could the physical constants be changing?





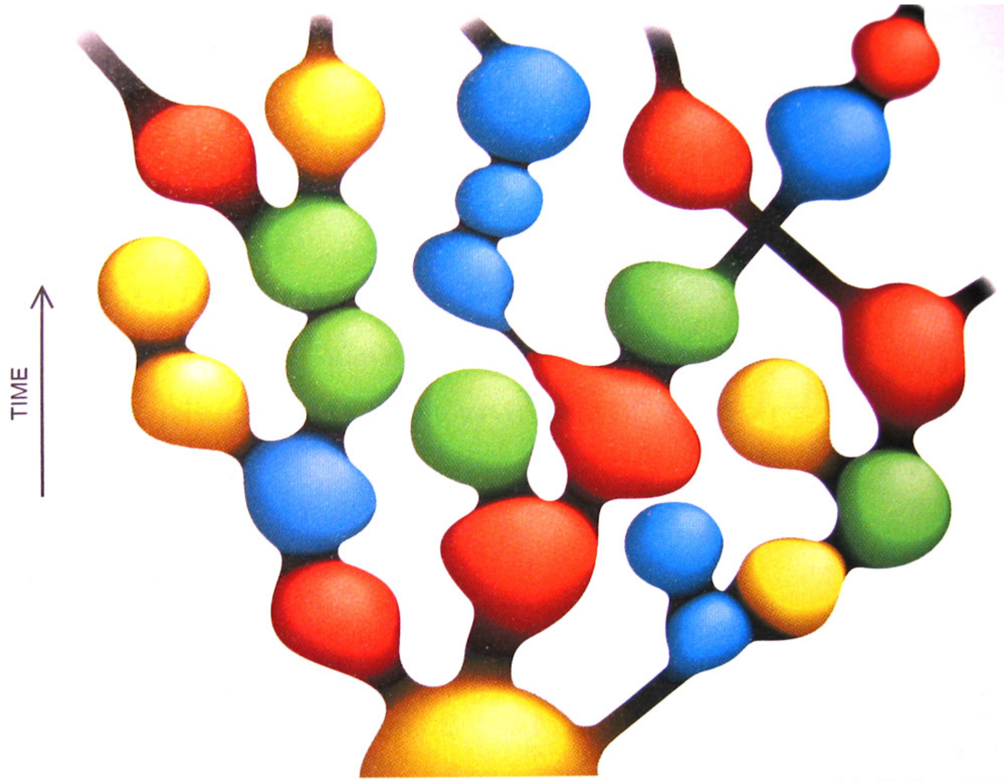
Other Universe**s**; Multiverse?

- Cosmological Principle requires no end to universe but could it be finite but unbounded? Quilted?
- Is this Science? Falsifiable? Predictions?

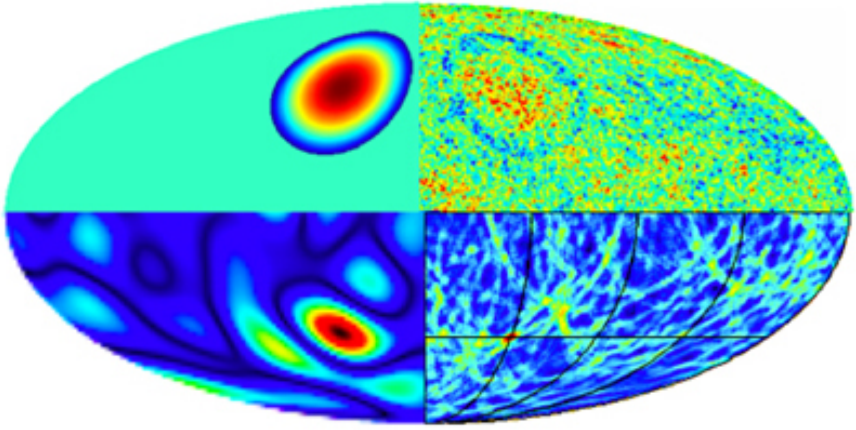


Many Inflations?

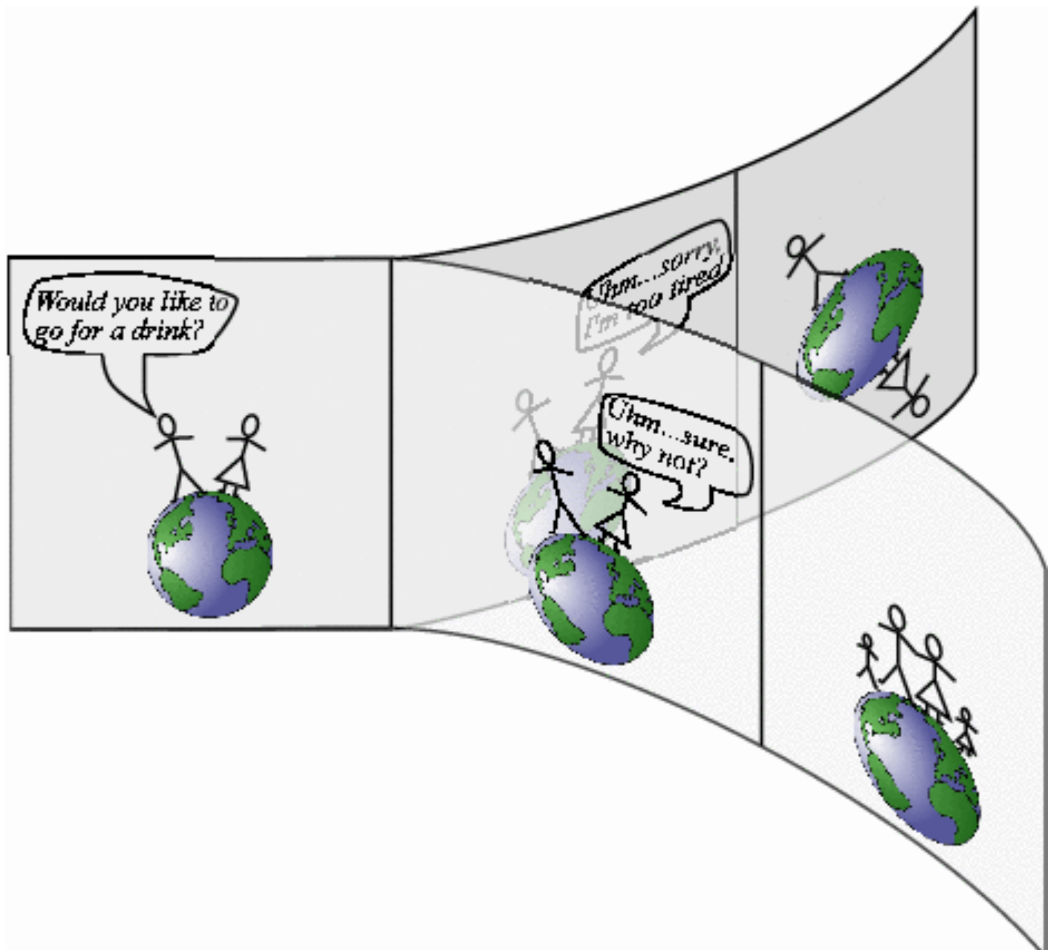
- Could our Universe just be one of many?
- Could they touch each other?



SELF-REPRODUCING COSMOS appears as an extended branching of inflationary bubbles. Changes in color represent "mutations" in the laws of physics from parent universes. The properties of space in each bubble do not depend on the time when the bubble formed. In this sense, the universe as a whole may be stationary, even though the interior of each bubble is described by the big bang theory.

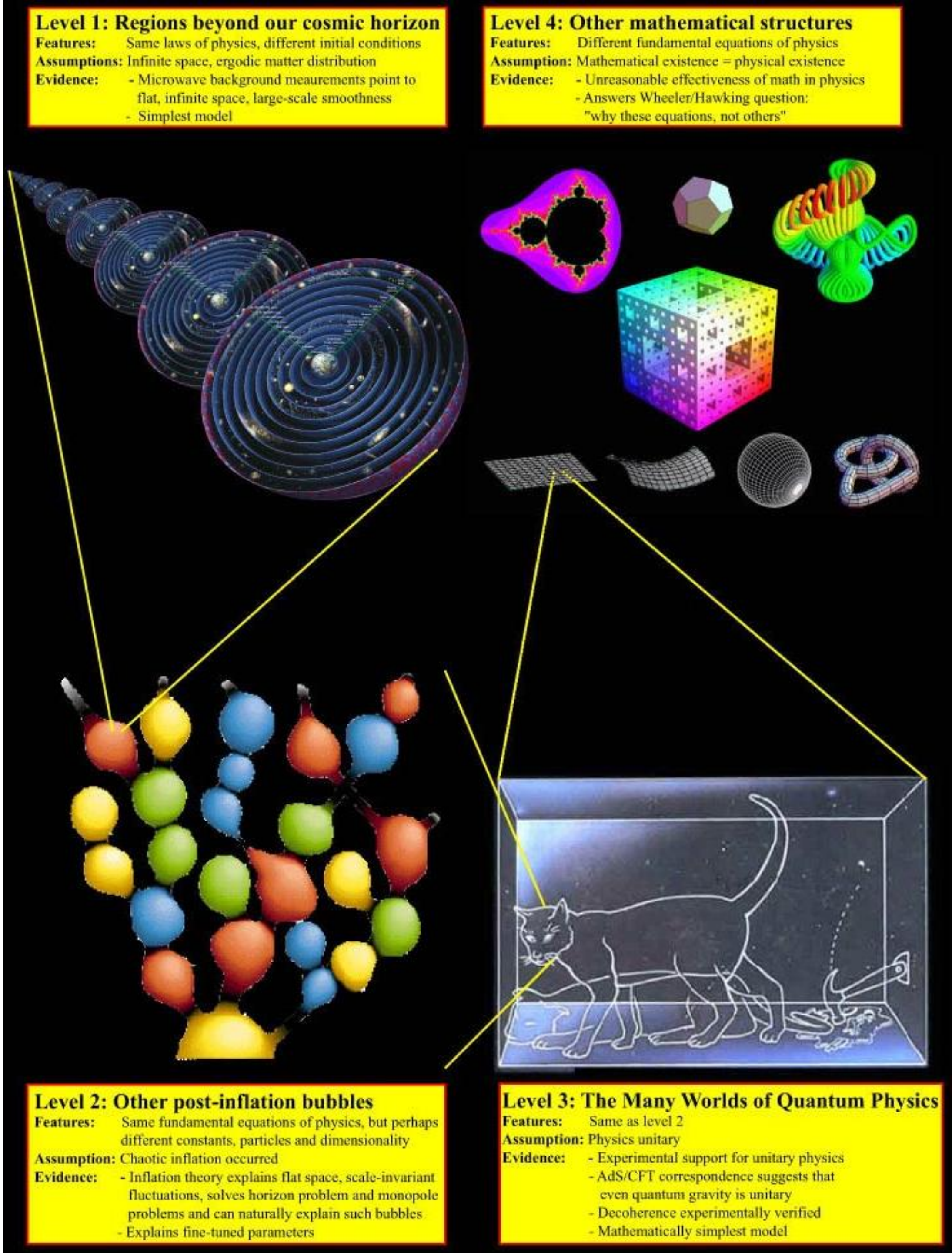


Multiverse –Quantum Physics



Levels of Multiverse

- Why not different physics equations and different numbers of dimensions??

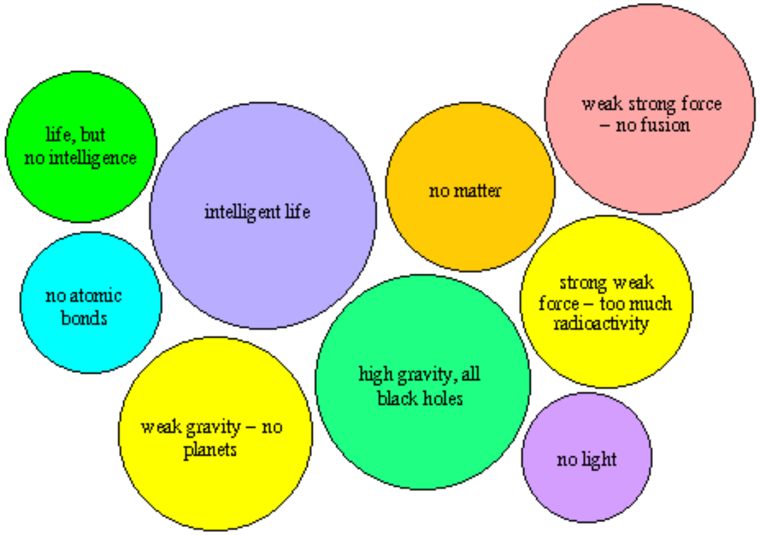


Anthropic Principle

- "Observers will only observe conditions which allow for observers"
- A universe with physical laws which do not allow intelligent beings to exist will not be observed
- A dodge to not do the hard work of understanding the universe?

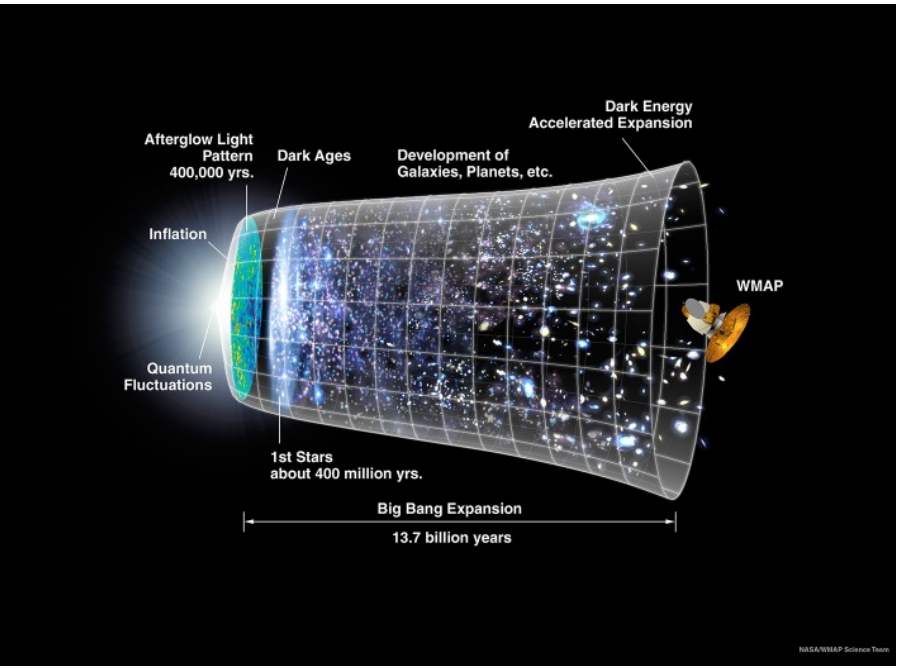
Anthropic Bubbles

one possible solution to the anthropic dilemma is the numerious bubble universes produced by inflation. Each bubble universe may have its own physical constants, which determine the evolution within the bubble



the evolution of intelligent life is extremely sensitive to the initial conditions, but since number of bubble universes is also large, the possibility is finite and our existence is not a big mystery

And What is the Fate of the Universe?

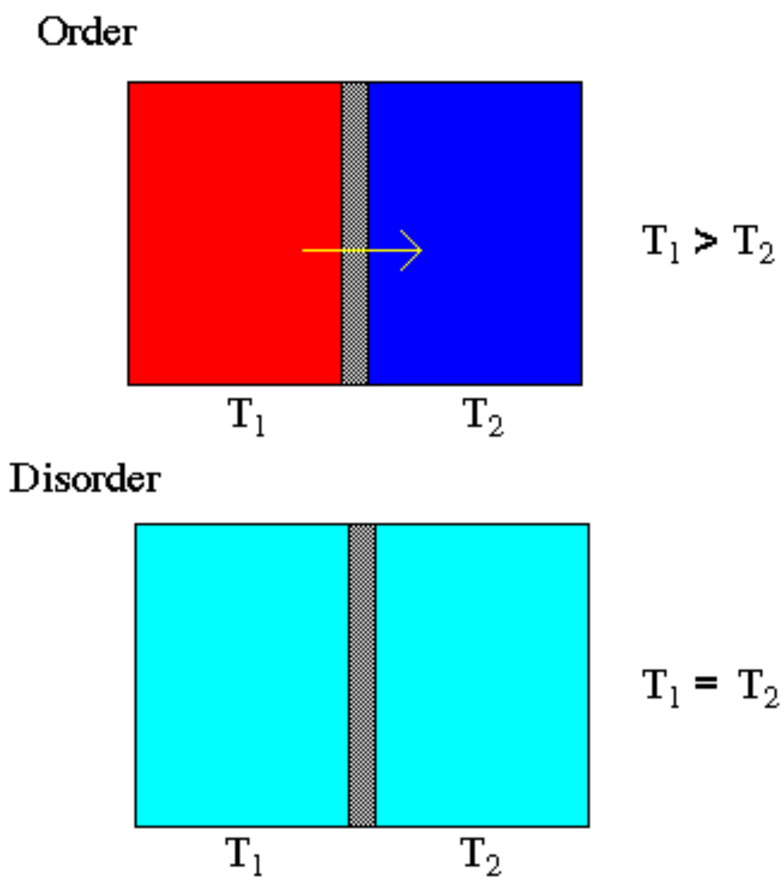


a) Expand forever with stars galaxies etc
b) Contract into big crunch
c) Expand forever composed of photons slowly cooling
d) Explode in new period of inflation
e) Expand forever with everything collected into black holes

Heat Death

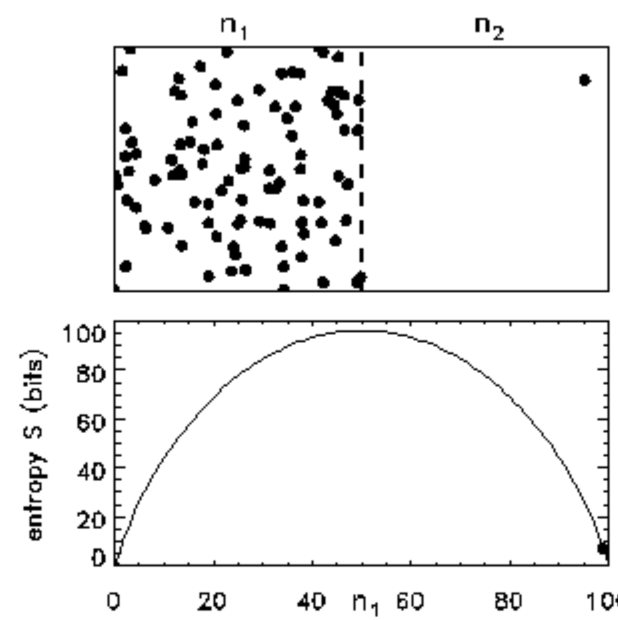
Heat Flow

energy flows from high temperature regions to low temperature regions



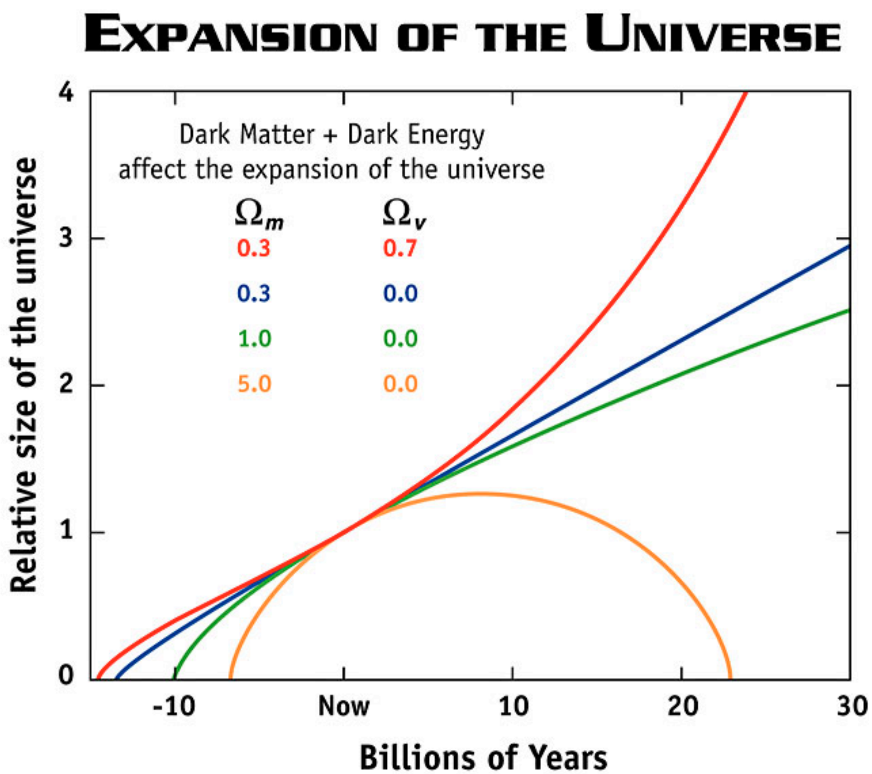
heat flow is the process that converts a low entropy region into a maximal entropy region

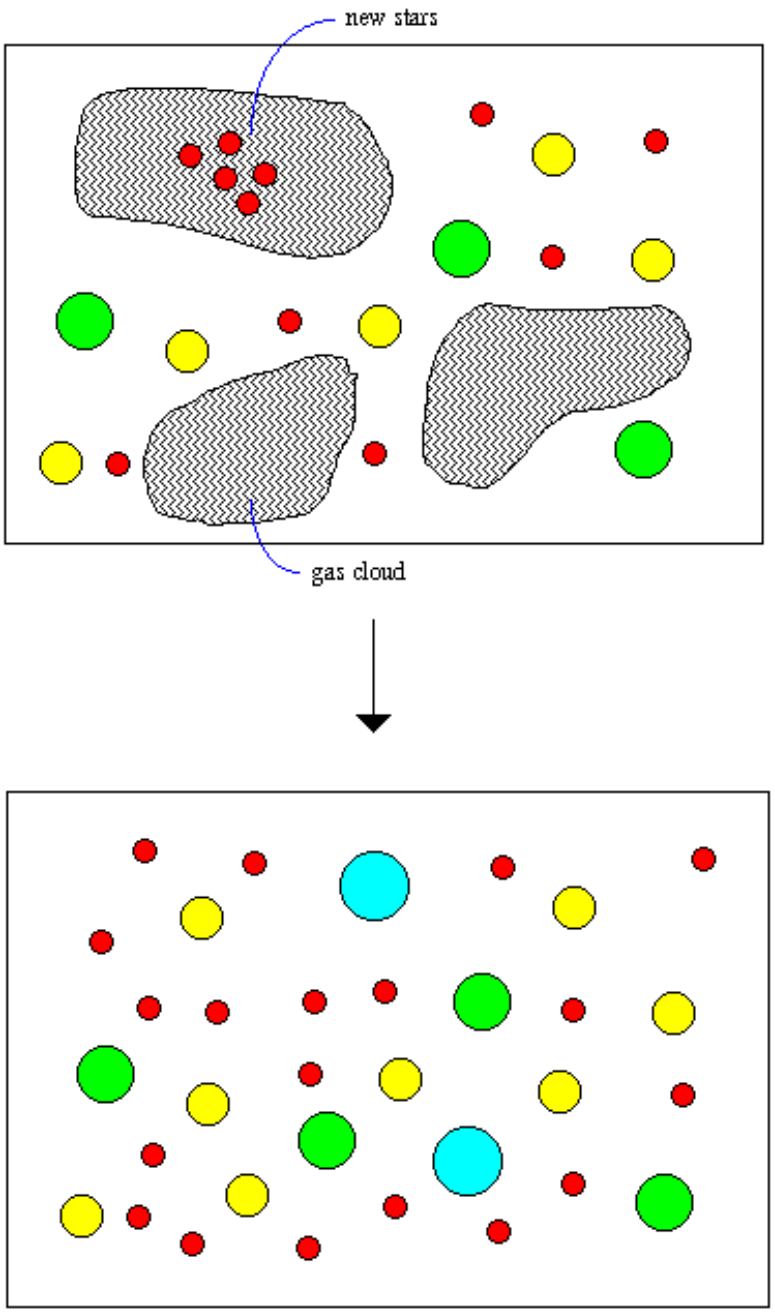
- “Some say the world will end in fire, others say in ice” Robert Frost



Dark Energy/Cosmological Constant

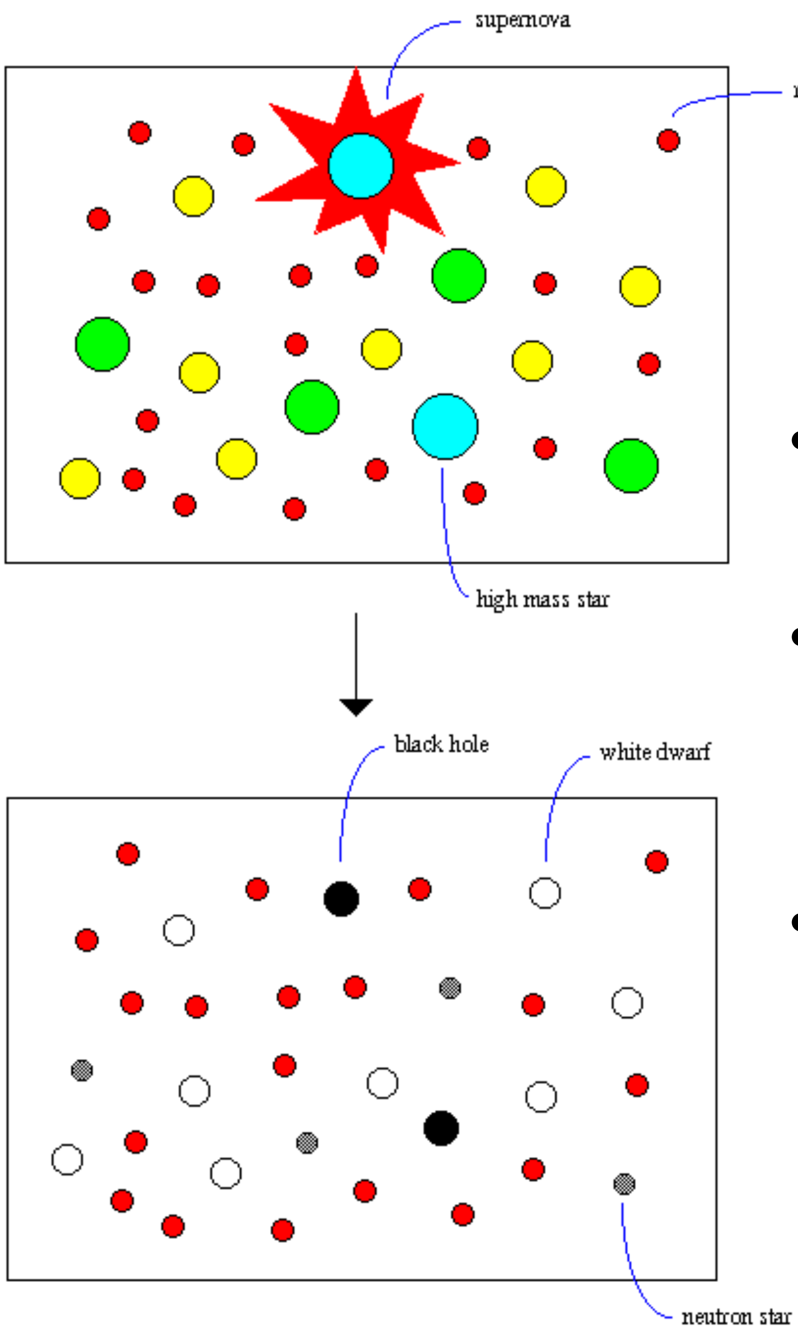
- Dark Energy = Cosmological Constant then its a property of space; so more space more expansion
- Due to Dark Energy universe expands faster & faster
- Eventually we lose sight of the distant galaxies





Star Era

- Stars begin forming 200 million years after Big Bang
- ~1 billion years galaxies form
- 10 Billion $=10^{10}$ years is now
- Sun =>redgiant: end of Earth
- At a trillion years gas is 20% hydrogen, 60% helium, 20% heavy elements
- Last stars burn out 10^{14} years = 100 trillion years
- Galaxies beyond local group redshifted to be invisible



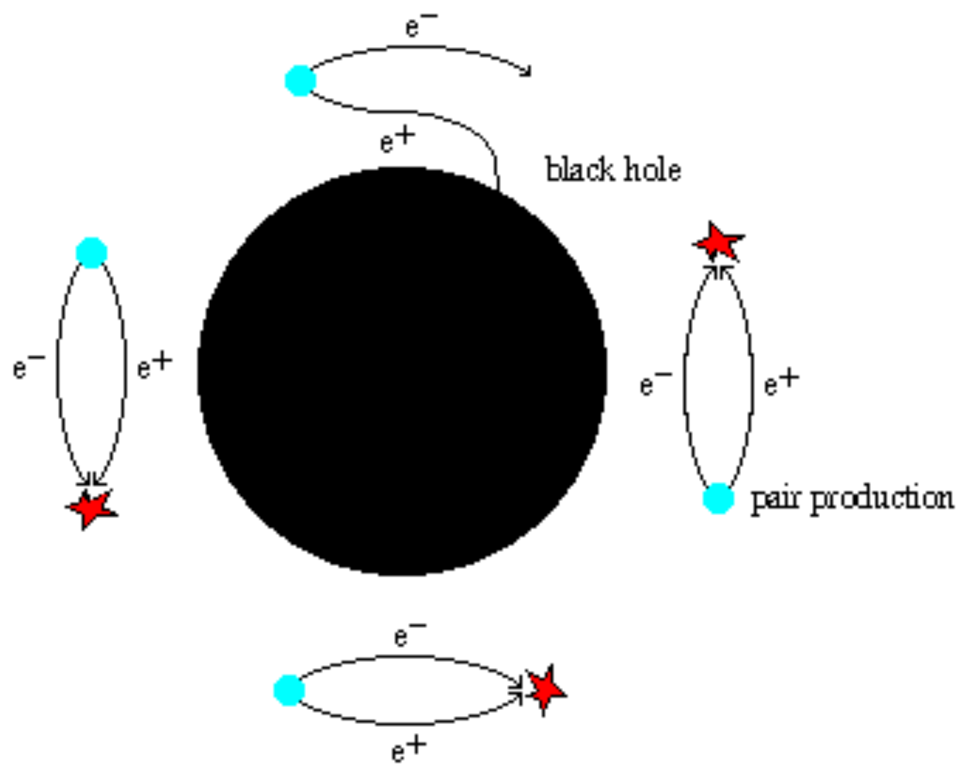
Degenerate Era

- 10^{16} years most planets detached from stars
- 10^{30} years Black Holes, absorb most white dwarfs & neutron stars, growing bigger and bigger
- 10^{37} years?? Proton decay?? destroys anything that got away

Hawking Radiation

Hawking Radiation

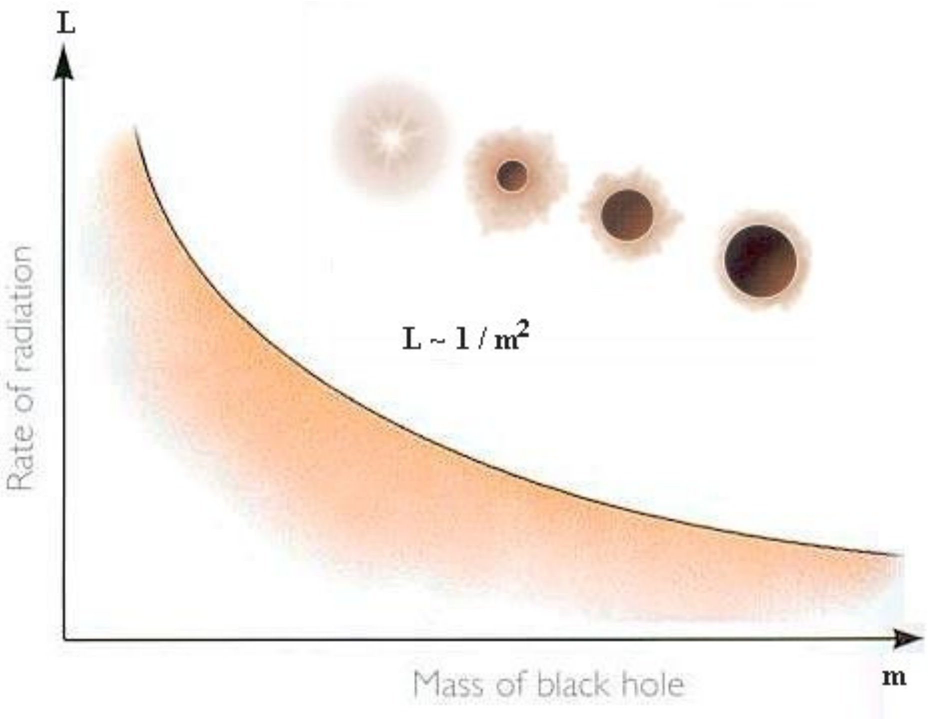
the strong gravitational field around a black hole causes pair production

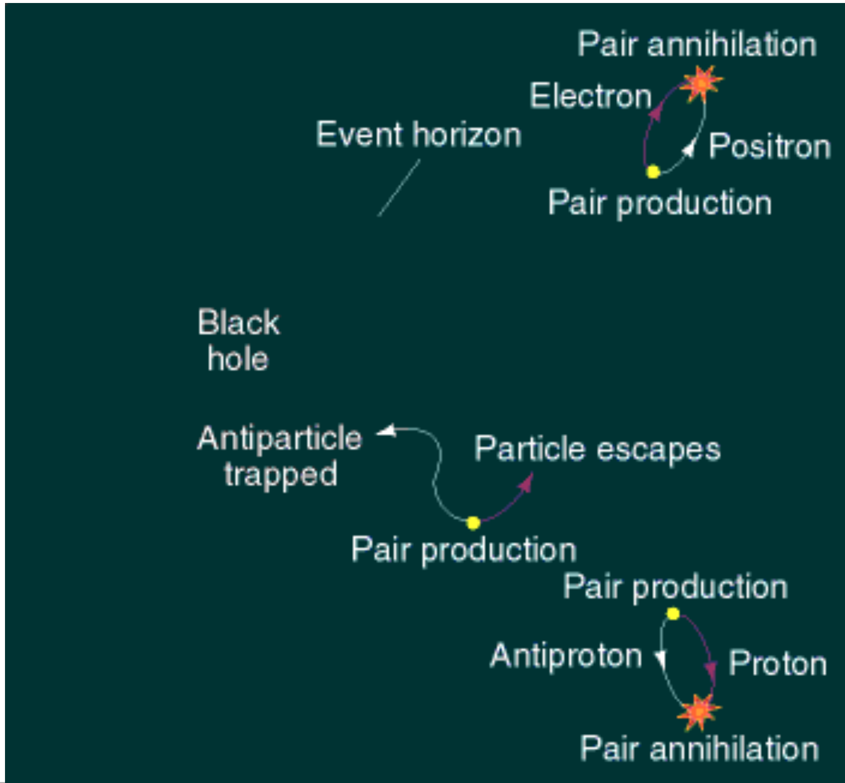


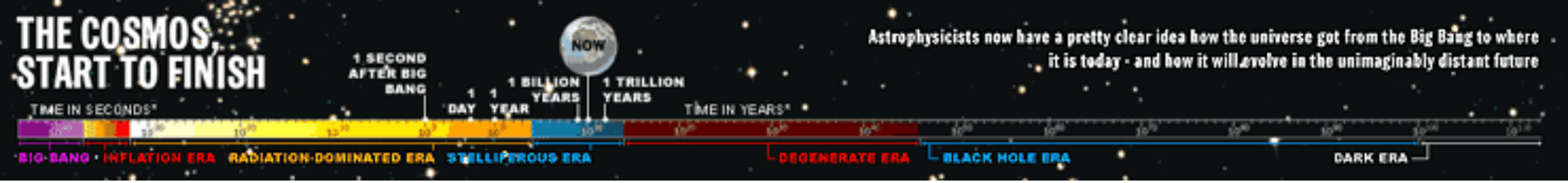
if a pair is produced outside the event horizon, then one member will fall back into the black hole, but the other member will escape and the black hole loses mass

Black Hole Evaporation

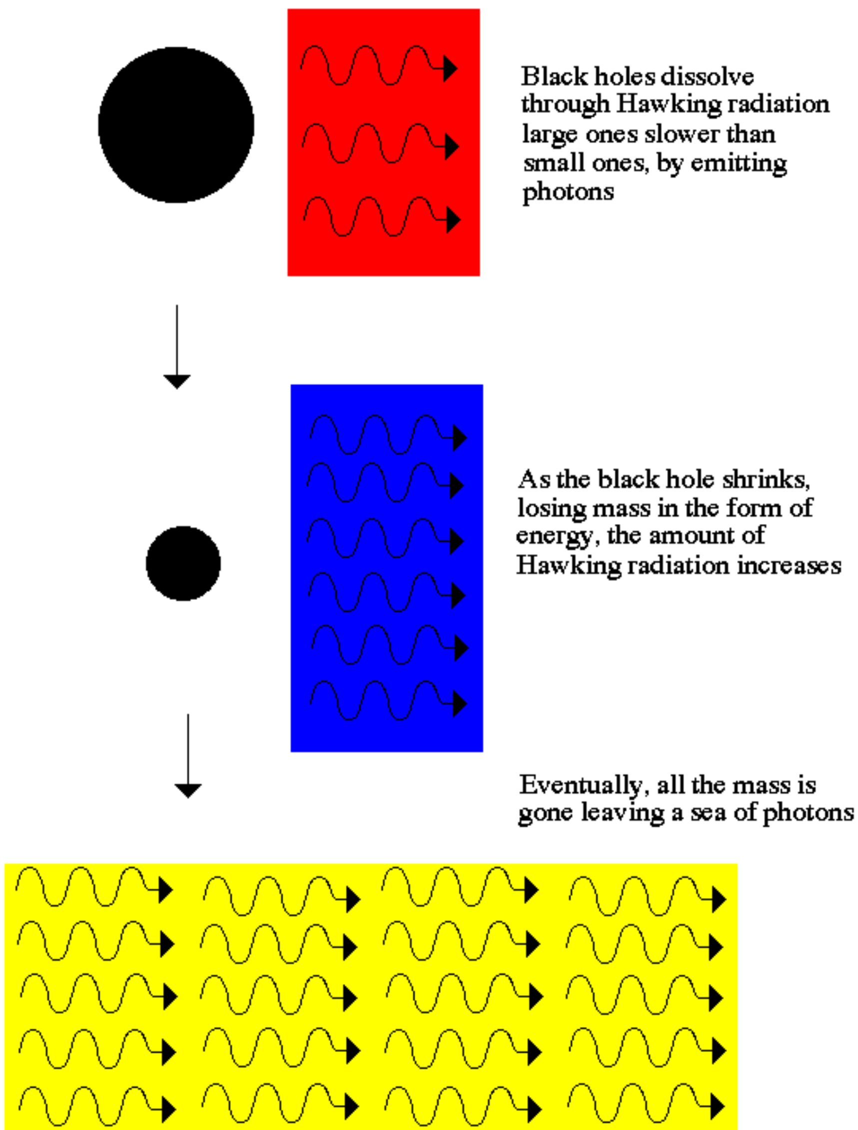
- Black Holes seem to radiate energy
- The smaller the hole the hotter it appears
- Black Holes made in Large Hadron Collider will evaporate faster than they grow
- A 1 Solar mass black hole will last ~10^{70} years





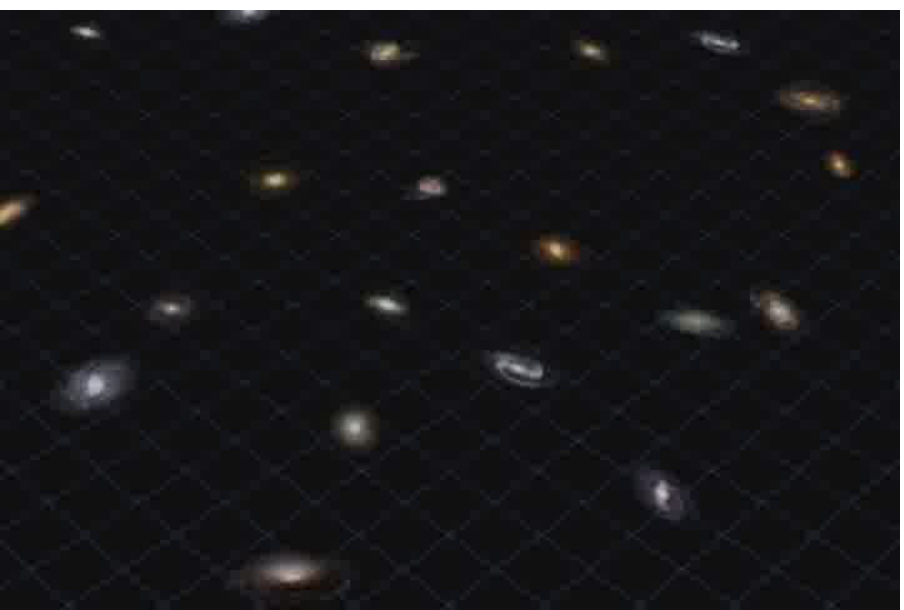


Black Hole Era



- 10^{65} years Stellar Mass black holes evaporate
- 10^{83} years Million solar mass black holes evaporate
- 10^{100} years largest black holes evaporate
- Heat death – everywhere is the same temperature

The **Big Rip**?

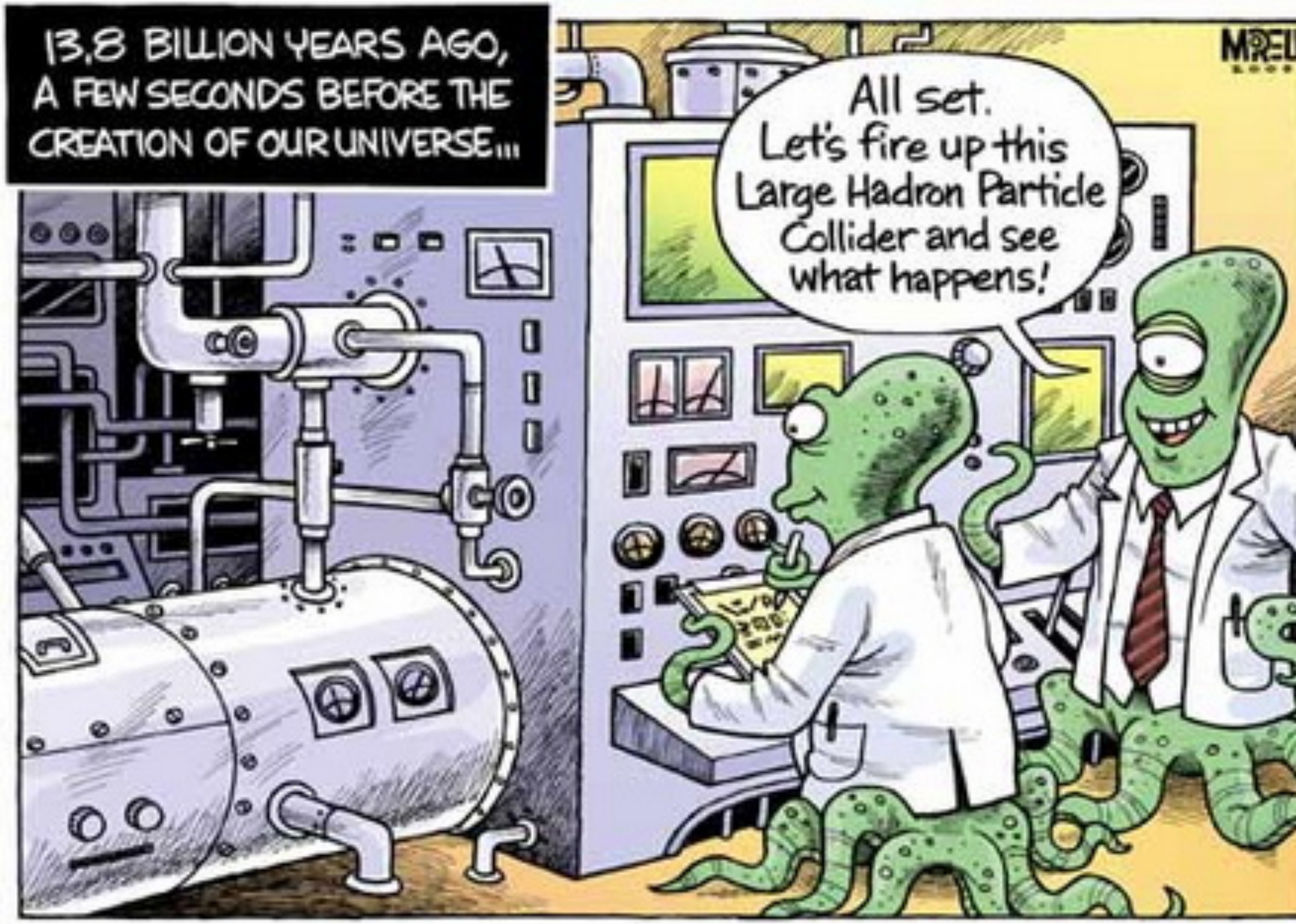


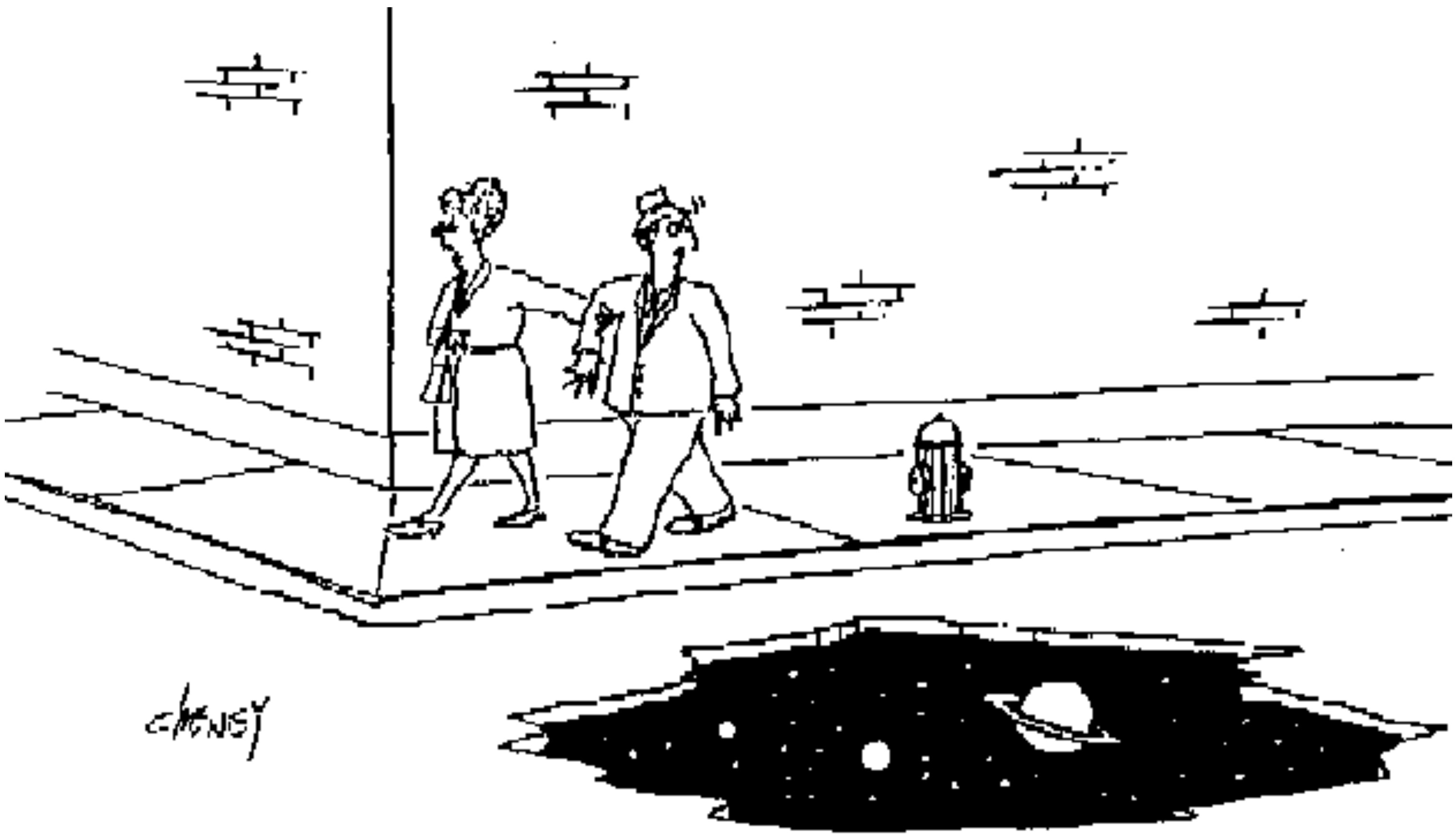
- If cosmological constant / Dark Energy is too large
- 0 Big Bang
- 3 min Helium forms
- 380,000 yr atoms form
- $200X10^6$ yr stars form
- +15Gyr today
- +20Gyr Sun becomes WD
- +49Gyr = -1Gyr destroy Galaxy Clusters
- -60Myr destroy Galaxy
- -3months solar system
- -30min Earth explodes
- -10^{-19} sec atoms dissociate
- +35 Billion years Big Rip

Why is there Something Rather than Nothing?

- "… the darkest question in all philosophy." (William James)
- This problem "can tear the individual's mind asunder." (A. C. B. Lovell)
- Each of us is "grazed by [this question's] hidden power." (Martin Heidegger)
- "What is it that breathes fire into the equations and makes a universe for them to describe? Why does the universe go to all the bother of existing?" (Stephen Hawking)

Where did it all come from?


13.8 BILLION YEARS AGO, A FEW SECONDS BEFORE THE CREATION OF OUR UNIVERSE...
All set. Let's fire up this Large Hadron Particle Collider and see what happens!
MOREU



- Oh, for goodness sakes Norman! You act like you have never seen a hole in the space-time continuum before.

[ENTROPY OF A GAS]

WHAT GRAVITY DOES TO ENTROPY

What qualifies as low entropy or high entropy depends on the situation. Physicists identify the high-entropy state of a system based on how the system evolves over time. For example, if a diffuse and sufficiently cool gas feels the tug of gravity, it evolves to a clump. The law of entropy increase then implies that the clump has a high entropy, even though at first glance it might appear to be orderly (low entropy).

- **Gravity shut off**
- **Volume fixed**

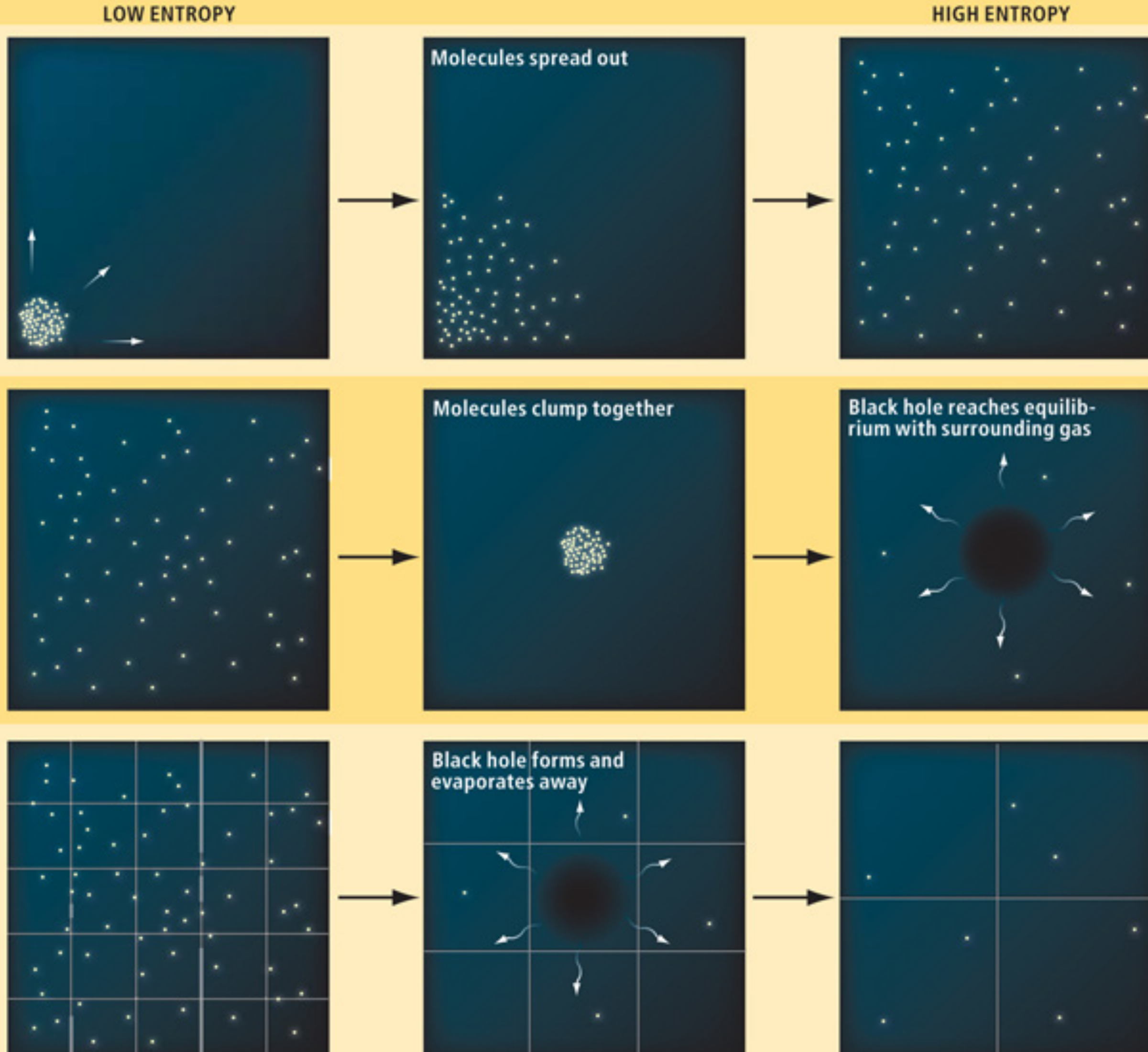
When gravity is negligible, a gas in a box has low entropy if it sits neatly in one corner and high entropy if it sprawls out. Thus, sprawl it does.

- **Gravity turned on**
- **Volume fixed**

Where gravity is significant, the opposite is true: the gas maxes out its entropy by collapsing to a black hole. Thus, a gravitating gas tends to clump rather than spread. The hole can survive forever in equilibrium with its surroundings.

- **Gravity turned on**
- **Volume expanding**

If the box is growing in size, the gas initially clumps and forms a black hole, but then the hole evaporates away. The gas it leaves behind continues to increase in entropy forever by spreading into an ever thinner gruel.



Planck Length 10^{-35}m; **Time** 10^{-43} sec

- Particles have a wavelength due to quantum mechanics $E=hc/\lambda=mc^2$
- A very tiny black hole will have an event horizon equal
- To its wavelength at distance of 10^{-35} meters = Planck Length
- At that size singularity would not stay inside event horizon
- Need to have Quantum + General Relativity = **Theory of Everything**