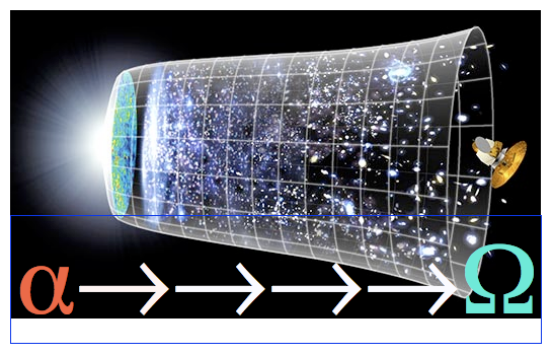
Time, Gentlemen, Please: The Beginning and End

Peter Watson



There was a time in this fair land when the railroad did not run,
When the wild majestic mountains stood alone against the sun,
Long before the white man and long before the wheel,
When the green dark forest was too silent to be real.

But time has no beginnings and the history has no bounds,
As to this verdant country they came from all around.

Gordon Lightfoot Canadian Railroad Trilogy

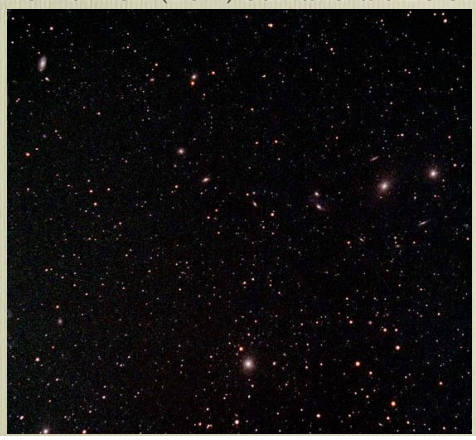
Evidence that it began comes from Hubble (person & telescope!)
Rich cluster of galaxies: Abell S0740.
NASA, ESA, Hubble Heritage Team (STScI / AURA)

In what follows:

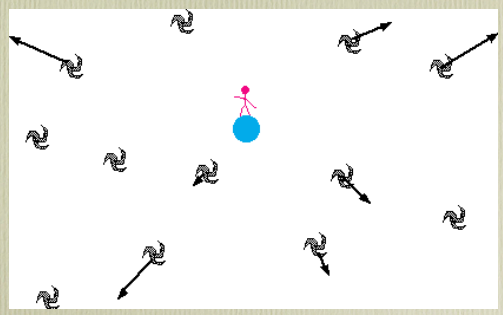
- The smallest things we will talk about are galaxies:
- typically 10 billion (10^{10}) stars and a size of 20 kpc (10^{20} m).

M51 in Can Ven: HST picture

- But most of the time we'll be talking about clusters of galaxies: this is Virgo cluster.
- Typically 1 million billion (10^{15}) Sun and a size of 2 Mpc (10^{22} m).

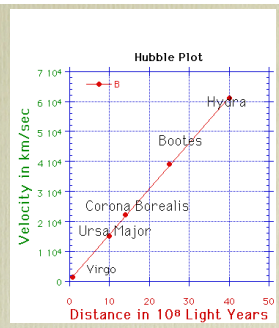


- Found in 1920's (Hubble, Humason, Slipher) that faint galaxies are receding from us:
- fainter the galaxy, faster the recession.



- Hubble was able to measure distances to closer clusters and found that velocity ~ distance

$$v = Hd$$



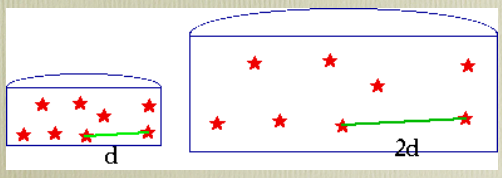
- H is Hubble constant:
- Now we know

$$H \simeq 70 kms^{-1}Mpc^{-1}, 1Mpc = 3x10^{22}\,m$$

i.e. the average galaxy at 100 Mpc is receding at 7000 km/s

Big Bang (once over lightly)

- Note although all galaxies are receding from us, does not imply we are at the centre:
- in the currant cake model all currants see all the others as receding.



RULE 1 in Physics 100: Never mix your units!

$$H = \frac{70.1 \times 10^3}{3.1 \times 10^{22}} = 2.26 \times 10^{-18}\, s^{-1}$$

- We can invert this to give

$$H^{-1} = 4.4 \times 10^{17}\, s = 14 \times 10^9\, yr$$

- What does this time represent?
- Must be age of universe: if expansion does not change.

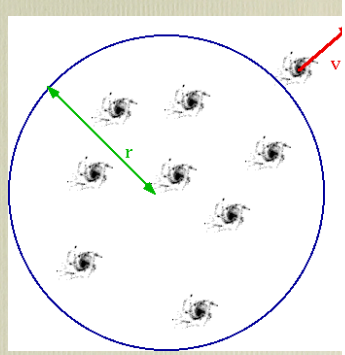
- i.e. $14x10^9$ yr. ago, all the galaxies were in the same place.
- Universe had a beginning, implied by the big bang.
- Can run Hubble expansion back:
- We would like to use this to predict what will happen in the end.

Where was the Big Bang?

- A 2-D analog is the surface of a balloon: Note the following:
- It has no centre in 2-D space.
- Deflating it reduces it to zero size:

- The galaxies are not receding from us: space is expanding.
- We require a curved 2-D (really 3-D) surface embedded in a 3-D really 4-D)volume.
- What's going to happen in the end?
- The sky becomes black, Earth sinks into the sea From Heaven fall the bright stars The sea ascends in storm to Heaven It swallows the Earth, the air becomes sterile. From the Hyndluljod (Iceland)
- Will the universe will expand forever?

- As a model, consider this as an escape velocity problem.
- How hard do we need to throw a galaxy on the "outside" so that it escapes?
- Note: our calculation had better not depend on r! The universe doesn't really have a radius.



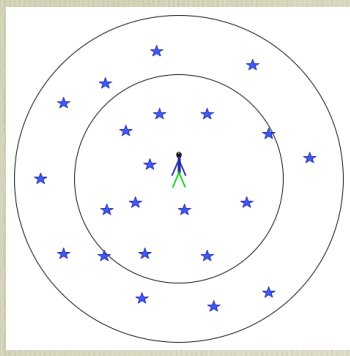
- Hence the critical density
- ρ_0~6 Hydrogen atoms m^{-3} (Number is slightly flaky).
- Will mostly use $\Omega = \frac{\rho}{\rho_0}$ because some errors cancel out.
- The entire future of the universe is given by this one number!!!!!!!!</P>
- I am the Alpha and Omega, the Beginning and the End, saith the Lord. Revelations I v7.

Let's pretend:

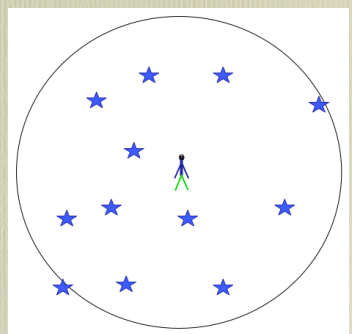
- We live in an open universe.
- Time began 14 billion years ago, but has no end.
- Laws of physics don't change.
- We know (or suspect) all the ones that matter.
- This is often the way it is in physics: our mistake is not that we take our theories to seriously, but that we do not take them seriously enough. It is hard to believe that the numbers that we play with at our desks have something to do with the real world. Steven Weinberg The First Three Minutes

"Open" implies

- expanding (into what? Remember the balloon analogy)
- Possibly infinite, but finite in what we can see.
- Note that we would expect to see more as the universe expands



- Not necessarily: can be that the galaxies recede so fast we see the same number



Dyson's three questions

- Does the universe totally freeze? — No
- Is it possible for life and intelligence to survive? — Yes
- Is it possible to communicate across the expanding universe? — Maybe

Time Scales

- Life cycle of large stars (formation to supernova)
- 10 million years = 10^7 yr.
- Current age of sun
- 4.5 billion years ~ 10^9 yr
- Time since Big Bang
- 14 billion years ~ 10^{10} yr
- Statutory warning: none of the numbers from now on are going to be very accurate

- Life cycle of small stars (formation to white dwarf)
- 10 trillion years = 10^{13} yr
- Hydrogen runs out (so no new stars)
- 100 trillion years = 10^{14} yr
- Detachment of planets by near collision
- 1000 trillion years = 10^{15} yr.
- Destruction of galaxies (black holes form at centre, stars drift off)
- 1 million-trillion years = 10^{18} yr.

- Decay of orbits by gravitational radiation
- 1 trillion-trillion years = 10^{24} yr
- Lifetime of proton (possibly)
- 1 trillion-trillion-trillion years = 10^{36} yr.
- Decay of black holes (Hawking radiation)
- 1 trillion-trillion-trillion-trillion-trillion years = 10^{60} yr.
- Note that on these time scales, solid matter is liquid (!)

Biological Time Scales

- Based on the earth
- Time to evolve species (e.g.humanity)
- 1 million years = 10^6 yr.
- Time to evolve class (e.g. Mammals)
- 100 million years = 10^8 yr.
- Time to get from nothing to humans
- 4 billion years = $4x10^9$ yr.
- So we have plenty of time to react

What is basis of consciousness?

- Organic molecules
- Then we are dead when the stars die!
- Matter in general (e.g. Silicon chips, black clouds)
- Then we last much longer.

- Dyson argues that we can calculate the "complexity" of a living organism: effectively how low its entropy is.
- Humans dissipate 200 W at 37°C (=310°K) and have a "now" of ~ 1 s.
- Complexity $Q \sim 10^{23}$ bits.
- (means it would take a billion years to transmit the info to build a human at broad-band speeds!)
- If we want to maintain the same complexity, we need to slow down our thinking!

- Life must have source of energy, must maintain low entropy state, must be able to radiate energy into space.
- As universe cools, must slow down, so subjective time decreases:
- i.e. our “now” needs to become much longer.
- Maybe this was what Marvell had in mind!

So are we ready to to do the hard problem?

Can We Time-Travel?