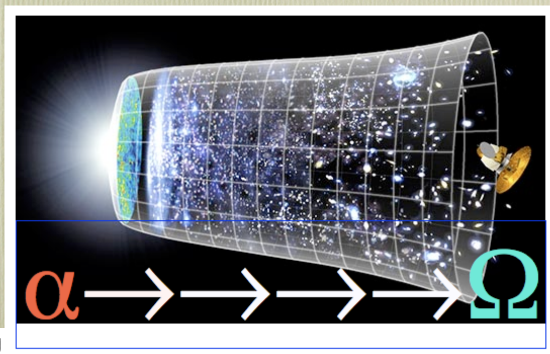
Time, Gentlemen, Please: The Beginning and End

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

- And the angel whom I saw standing on the sea and on the land raised his right hand to heaven and swore by the One living for ever and ever, who created heaven and the things in it, and the earth and the things in it, and the sea and the things in it, that there shall be no more time.
- Revelations Chap 10.

Deep Time

- Mostly we have concentrated on short times
- How about long times?

Human history

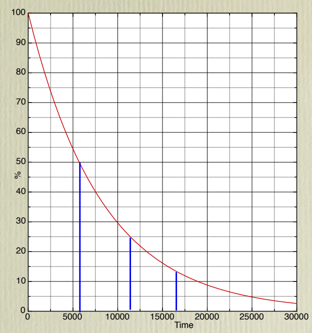
- written records from China ~2100 BC
- Mesopotamia ~3000 BC
- egypt~3200 BC: Namur palette from ROM
- (dispute over what was writing)

Radioactive Dating

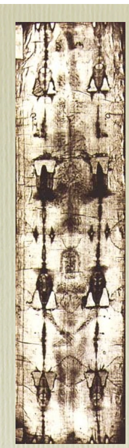
- All radioactive decays have a similar behaviour. The decay occurs totally at random, hence the probability of observing a decay is proportional to the number of nuclei.
- Half life: time after which half the nuclei have decayed
- carbon dating: In the atmosphere, some of the $^{14}N \Rightarrow {}^{14}C$ by cosmic rays.
- This gets incorporated in living things, substituting for ^{12}C : When the object dies, no more ^{14}C is absorbed, and what is already there decays

Carbon Dating

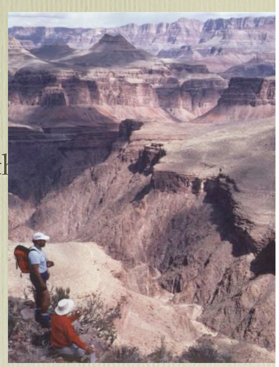
- 50% of atoms are left after 5700 years
- 25% after 11400
- 12.5% after 16100 etc



e.g. the Turin Shroud, (supposedly used to wrap Christ in when he was lowered from the Cross)
Proportion of ^{14}C which is 89.5% of that of current materials.
Dates to around 1300 AD

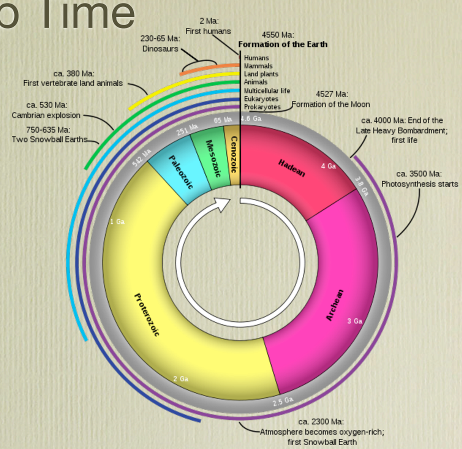


- Variants allow much older dates: e.g rubidium-strontium dating
- Half-life is 49 billion years
- Geologists can combine this with techniques (e.g. erosion)



Deep Time

- Consider the Earth's history as the old measure of the English yard, the distance from the King's nose to the tip of his outstretched hand. One stroke of a nail file on his middle finger erases human history



- Did time begin? Will it end?
  Evidence that it began comes from Hubble (person & telescope!)
  Rich cluster of galxies: Abell S0740.
  NASA, ESA, Hubble Heritage Team (STScI / AURA)

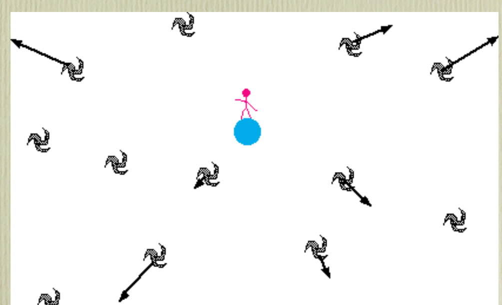
In what follows:

- M51 in Can Ven: HST picture

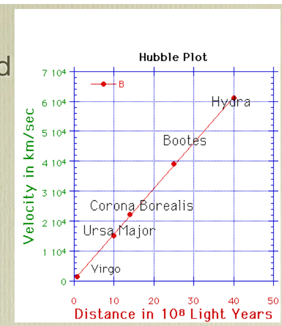
- The smallest things we will talk about are galaxies:
- typically 10 billion (10^{10}) stars and a size of 20 kpc (10^{20} m).

- 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



$$v = Hd$$

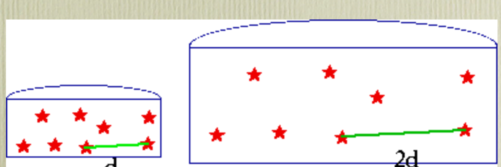
- H is Hubble constant:
- Now we know

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

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!

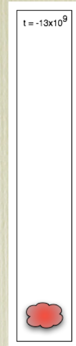
$$H = \frac{70.1 \times 10^3}{3.1 \times 10^{22}} = 2.26 \times 10^{-18} s^{-1}$$

- 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. 14×10^9 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.

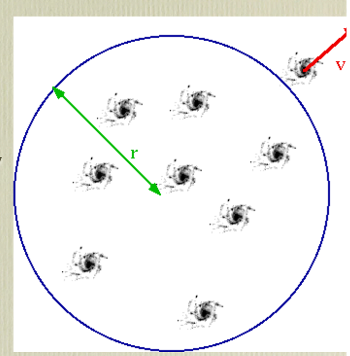


Where was the Big Bang?

- 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.



- Energy must be conserved:

$$\frac{1}{2}mv^2 - \frac{GMm}{r} = 0$$

But $v = Hr$ and total mass "inside" depends on the density

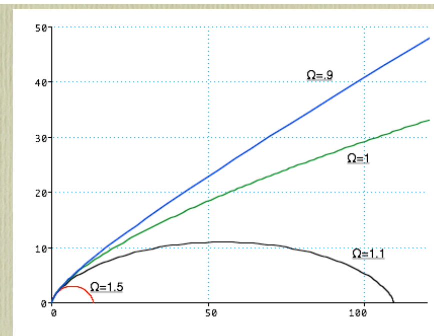
$$M = \frac{4\pi}{3}\rho r^3$$

So $$H^2 r^2 = 2G\frac{4\pi}{3}\rho r^2$$

- (we got lucky: the r cancels out!).
- We can turn this round and write it as an equation for ρ

$$\rho_0 = \frac{3H^2}{8\pi G}$$

- 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.

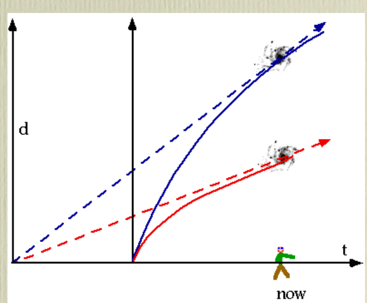


- So if $\Omega > 1$ Universe comes to nasty end in ~ 50 billion yr.
- So if $\Omega = 1$ Universe expansion slows down asymptotically : "critical universe"
- So if $\Omega < 1$ continues to expand forever

- Of more interest to us now:
- If $\Omega > 1$, time began (say) 10 billion years ago, ends in ~ 50 billion yr.
- If $\Omega = 1$, time began 14 billion years ago, does not end.
- If $\Omega \approx 0$, time began 18 billion years ago, does not end.
- More important: if $\Omega \leq 1$ we live forever (well maybe).

- Note that this implies that the rate of expansion must change.
- Gravity will slow down expansion in the early stages, so Hubble's constant isn't a constant...
- when the universe was smaller, v was larger so H must have been bigger.

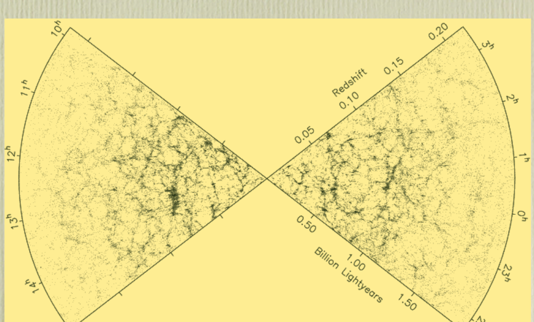
- Better "the Hubble parameter".



So how do we weigh the universe?

- Can only see luminous matter
- How much Dark Matter is there?
- First Guess: What you see is what you get!
- Count number of galaxies in a region of space, assume they consist of stars much like the sun.

- Obviously must average over large enough volume such that universe is smooth
- R > 100 Mpc, and the universe is a very lumpy place!



Density: Ω ~.003

But wait a moment...

- How much matter is there we that we can't see?
- This assumes $\rho_{\text{dark matter}} \sim 0$
- Can use this gravitational lensing trick to measure the amount of matter

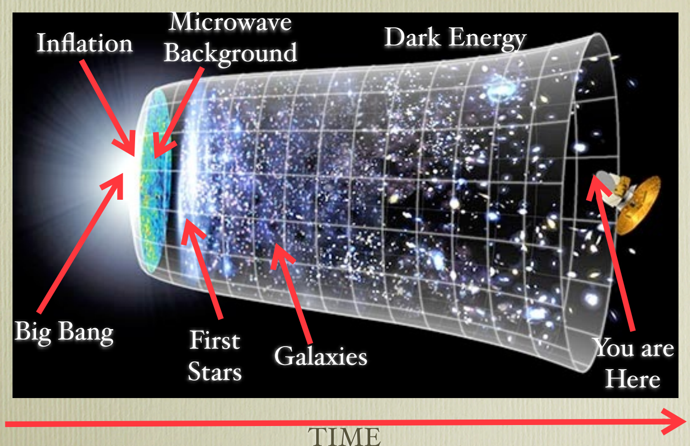
- Allows us to estimate the mass. For Abell 2218 we seem to have at least 300 times as much dark matter as luminous matter.

Density: Ω ~1.0 (!)

Let's pretend:

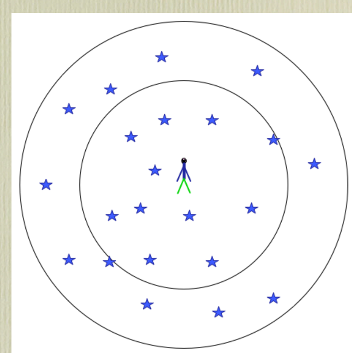
- We live in an open universe.
- Time began 14 billion years ago, but has no end.
- Laws of physics don't change.
- We know (or suspect) all the ones that matter.
- This is often the way it is in physics: our mistake is not that we take our theories to seriously, but that we do not take them seriously 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

- Our "concordance model" agrees with everything we know!

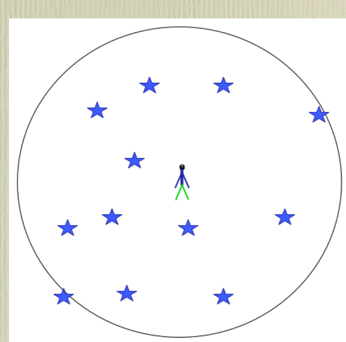


"Open" implies

- 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 = 4×10^9 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!

To His Coy Mistress

Had we but world enough, and time,
This coyness, Lady, were no crime
We would sit down and think which way
To walk and pass our long love's day.
Thou by the Indian Ganges' side
Shouldst rubies find: I by the tide
Of Humber would complain. I would
Love you ten years before the Flood,
And you should, if you please, refuse
Till the conversion of the Jews.
My vegetable love should grow
Vaster than empires, and more slow;
An hundred years should go to praise
Thine eyes and on thy forehead gaze;
Two hundred to adore each breast,
But thirty thousand to the rest;
An age at least to every part,
And the last age should show your heart.

But at my back I always hear
Time's wingèd chariot hurrying near;
And yonder all before us lie
Deserts of vast eternity.
.....
Now let us sport us while we may,
And now, like amorous birds of prey,
Rather at once our time devour
Than languish in his slow-chapt power.
The grave's a fine and private place,
But none, I think, do there embrace.
....
Thus, though we cannot make our sun
Stand still, yet we will make him run.

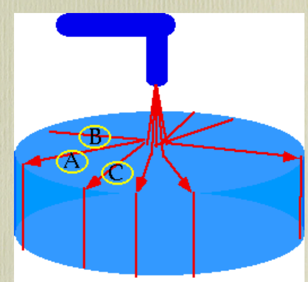
Did it work?

But .....

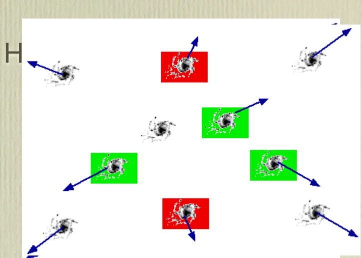
- There are other theories which have been tried
- E.g. Dark energy might rip the universe apart
- or

Steady state theory of Bondi, Hoyle, Gold

- Basic assumption is that universe is not only isotropic in space, but also in time: i.e. No beginning , so it always looked much the same.
- How can this be squared with expansion?
- Imagine a stream of water falling into full bucket:
- (A) will see (B) and (C) receding even though the situation does not really change.



- Requires creation of new Matter.
- approx. 10^{-35} gm cm^{-3}/sec averaged over space, or 1 H atom/c.c. every 10,000 yr., which is undetectable.
- Does not conserve energy (in usual sense).
- Also predicts expansion should be accelerating.

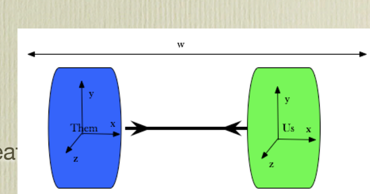


- Doesn’t work in detail.

A much more dramatic idea:

The Ekpyrotic Universe

- If we take the idea of extra dimensions seriously .....
- Ordinary particles (forces and matter) live in 3-D mem**brane**.
- If we have two branes (physics needn't be the same) these can attract gravitationally in a 5th dimension
- Big bang is brane collision
- See Steinhardt
- Note a "large" universe is crea inflation to be dropped.



So are we ready to summarize things?

- First we should look at how time and culture have interacted over the last 100 years.