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)
Variants allow much older dates:
e.g. rubidium-strontium dating

Half-life is 49 billion years

Geologists can combine this with older techniques (e.g. erosion)

Did time begin? Will it end?

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 100,000 light years \((10^{20} \text{ m})\).

- 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 \((10^{22} \text{ m})\).

- 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

\[ H = 70\text{km/s}^{-1}\text{Mpc}^{-1}, 1\text{Mpc} = 3\times10^{22}\text{m} \]

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.

**Where was the Big Bang?**

- i.e. ~14 billion 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.

- A 2-Dimensional analog is the surface of a balloon: Note
- It has no centre in 2-D space.
- Deflating it reduces it to zero size: space and time had no meaning before the Big Bang
- 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.
- Space and Time came into existence at the moment of the Big Bang
3. 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?

• If we know how big the universe is, we know its mass
  We also know how fast the galaxies are moving
  3 lines of Grade-12 maths, and we find the “critical density” of the universe:
  6 Hydrogen atoms in a cubic metre
  Better: if the earth was at this density it would weigh \( \sim 1 \text{ milligram} \)

• We’ll use \( \Omega \): \( \Omega=1 \) means the universe is exactly critical density
  The entire future of the universe is given by this one number!!!!!!!
  \( \text{I am the Alpha and Omega, the Beginning and the End, saith the Lord.} \text{ Revelations I v7.} \)

• if \( \Omega > 1 \) Universe comes to nasty end in \( \sim 50 \text{ billion years} \)

• if \( \Omega = 1 \) Universe expansion slows down but never stops: “critical universe”

• if \( \Omega < 1 \) continues to expand forever

So we need to weigh the universe

• Of more interest to us now:
  • If \( \Omega > 1 \), time began (say) 10 billion years ago, ends in \( \sim 50 \text{ billion yr.} \)
  • 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).
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.

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

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

 Obviously must average over large enough volume such that universe is smooth

- $R > 100 \text{ Mpc}$, and the universe is a very lumpy place!

Density: $\Omega \sim 0.003$

Our “concordance model” agrees with everything we know!

- 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: $\Omega \sim 1.0 (!)$
“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

Conclusion: consistent with all we know

- Time began ~ 14 billion years ago
- Time will not end
- But there are lots of alternative theories

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