The History & Scale of the Universe

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AFFILIATED GROUP

A PARTNER OF THE BRITISH HUMANIST ASSOCIATION

Introduction

I intend to give a very quick overview of the life of the universe and to try to convey a sense of its scale.

I am *not* Professor Brian Cox or Professor Jim Al-Khalili or Professor Stephen Hawking, and I do not claim to understand any of this in depth.

If time permits then we can discuss whether or not it is likely that our planet is the only place in the universe to host life.

But it's tremendous fun to discuss these things, so I hope these slides will prompt some discussion this evening.

A Personal Perspective

I strongly relate to the Humanist assertion that there is only one universe (or multiverse).

Philosophers, theologians, spiritual types and others make various bold claims as to why things are and the meaning of life; but for me an understanding of what and who we are *must* begin with an understanding of the universe that gave us life.

Our universe is mind-blowing, beautiful and terrifying. There is no need to invent metaphysical dimensions and beings. If you seek beauty, complexity or have a need to fear something beyond our control then our universe has it all. Human metaphysical imaginings are woefully feeble in comparison.

Some Number Conventions

Study of the universe necessitates usage of very large numbers.

The definitions of 'billion' and 'trillion' can cause confusion because there are different conventions. The US system has generally been adopted, whereby each 'term' is a factor of 1000 larger than its predecessor.

1 thousand = 1000 = 10 x 10 x 10 = 10^3

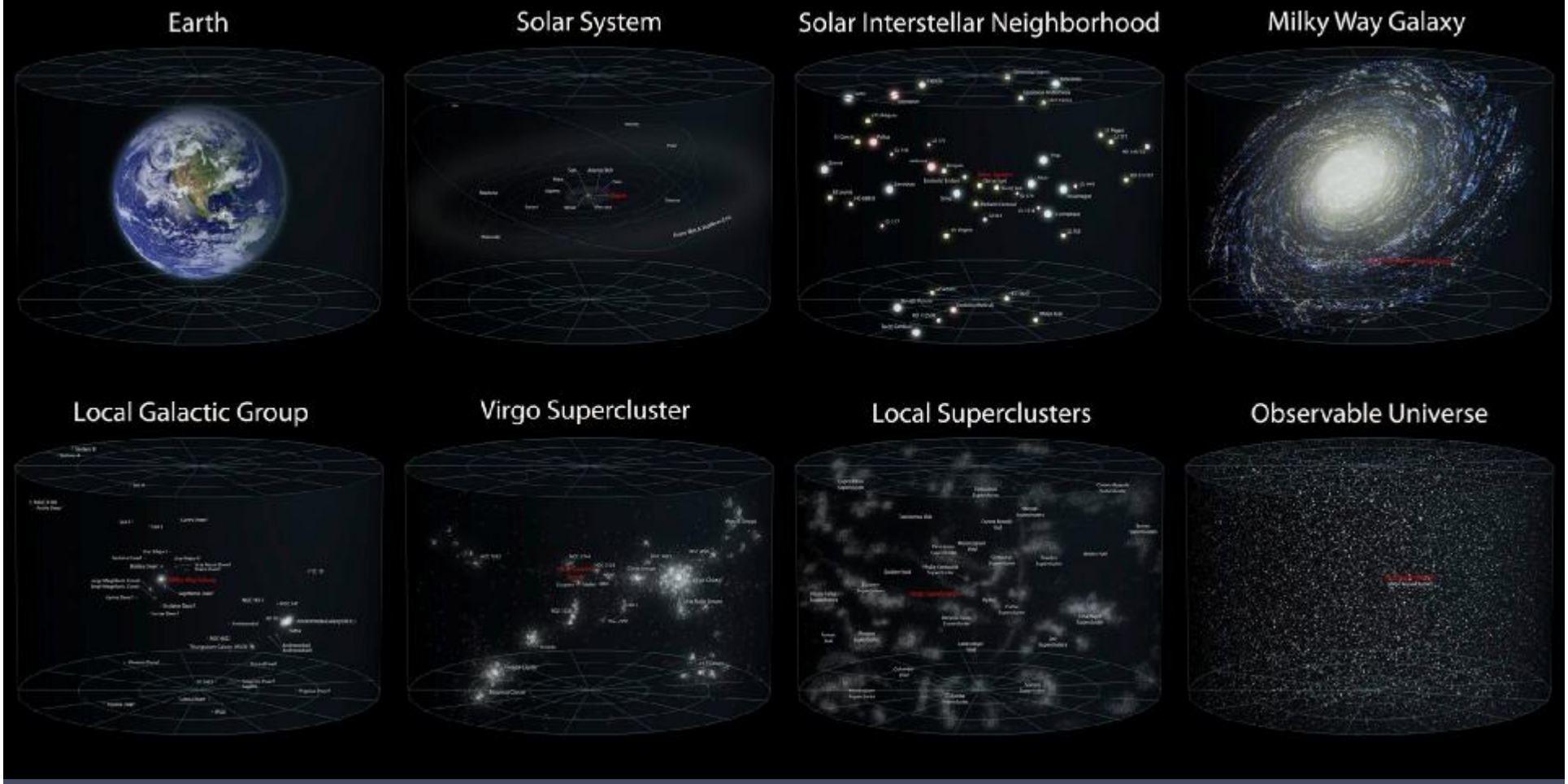
1 million = 1 thousand x 1 thousand = 1,000,000 = 10 x 10 x 10 x 10 x 10 x 10 = 10^6

1 billion = 1 million x 1 thousand = 1,000,000,000 = 10^9

1 trillion = 1 billion x 1 thousand = 1,000,000,0000,000 = 10^{12}

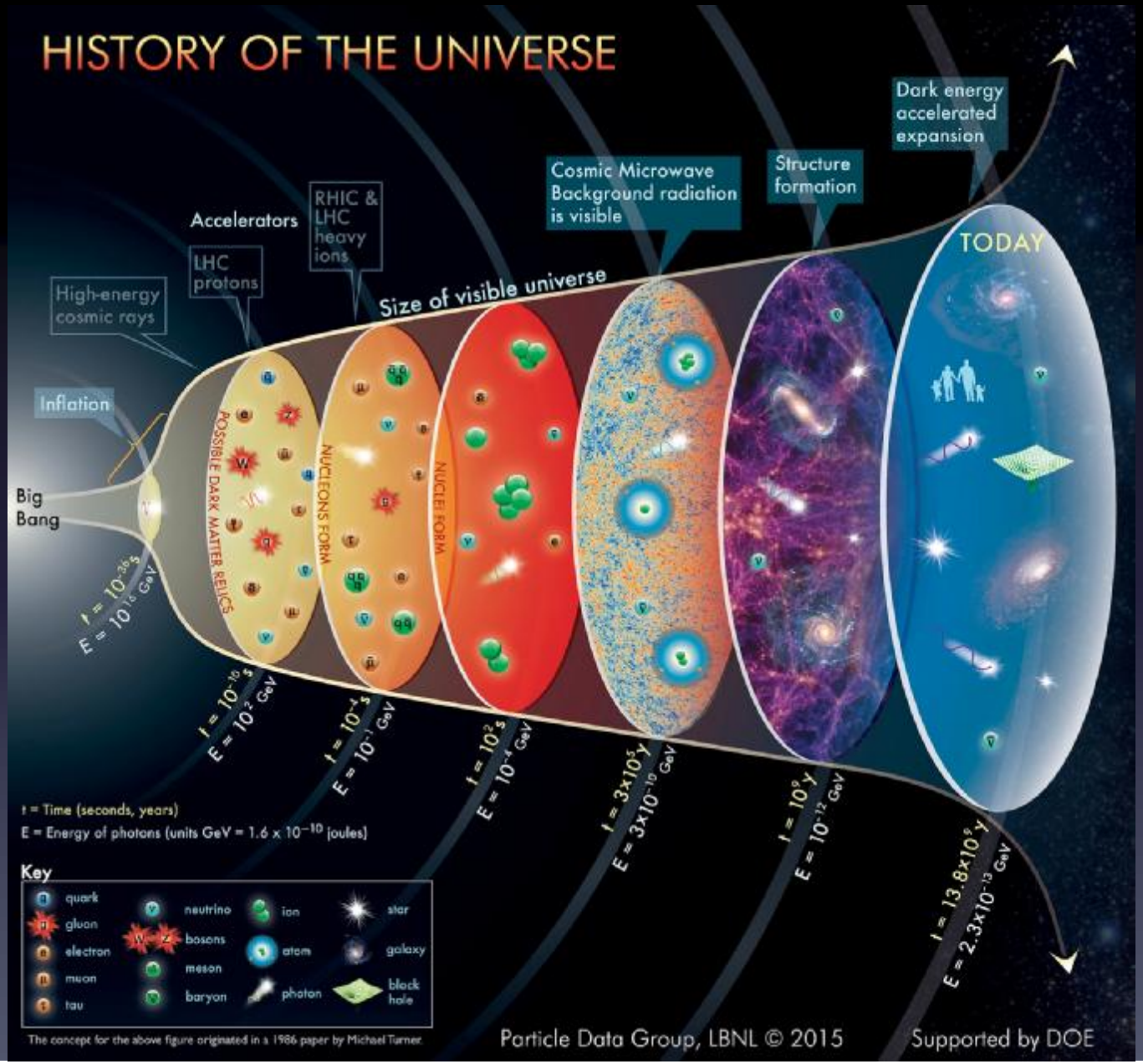
1 quadrillion = 1 trillion x 1 thousand = 10^{15}

Unimaginable Distances



And the universe is expanding at a phenomenal rate.

Timeline


HISTORY OF THE UNIVERSE
Dark energy accelerated expansion
Cosmic Microwave Background radiation is visible
Structure formation
TODAY
Accelerators
RHIC & LHC heavy ions
LHC protons
High-energy cosmic rays
Size of visible universe
Inflation
Big Bang
POSSIBLE DARK MATTER RELICS
NUCLEONS FORM
NUCLEI FORM
t = Time (seconds, years)
E = Energy of photons (units GeV = 1.6 x 10−10 joules)
Key
quark
gluon
electron
muon
tau
neutrino
bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
The concept for the above figure originated in a 1986 paper by Michael Turner.
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Looking Back in Time

Light travels at a speed of 3×10^8 m/s, or 186,000 miles per second.

When we view distant objects then we are seeing those objects as they were when the photons of light left the object.

Distance = Speed x Time

1 light-year = 3×10^8 x 1 year = 9.461 quadrillion metres = 9.461×10^{15} m

When we look at the moon , we see it as it was 1.3 seconds ago.

When we look at the sun, we see it as it was 8.3 minutes ago.

When we loot at Alpha Centauri (our nearest star), we see it as it was 4.4 years ago.

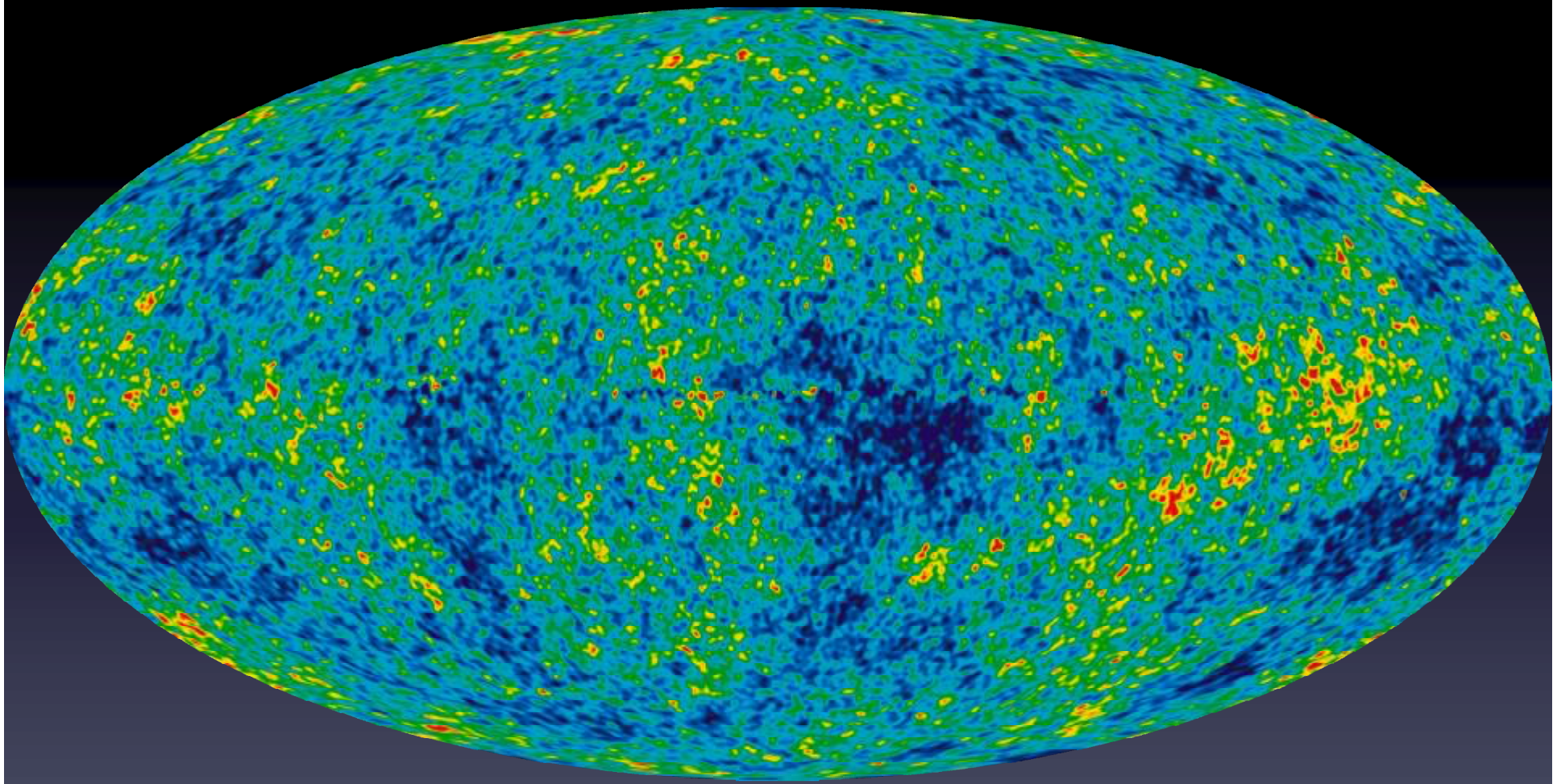
When we look at the Andromeda Galaxy (our nearest non-dwarf galaxy), we see it as it was 2.5 million years ago.

The most distance galaxy observed to date is called GN-Z11, found by the Hubble Telescope this year, is (was!) 13.3 billion light years away.

The universe is 13.7 billion years old, so why can't we look back in time to a distance of 13.7 billion light-years, and simply observe the big bang, or God himself, at work?

Answer: the Cosmic Background Microwave Radiation (CMBR) gets in the way.

CMBR



The universe existed as a plasma when it was 300,000 years old. The plasma is impenetrable to light – so we cannot see beyond it in time. When we look at the CMBR we are actually seeing the end state of the plasma as it reformed from a 'soup' of uncombined protons and electrons into Hydrogen atoms.

Are We Alone?

Most scientists think not: as evidenced by the investment in exploring our own solar system for signs of life, and seeking out exo-planets that might be suitable for sustaining life.

We know that the laws of physics are consistent throughout the observable universe.

We know that the physics gives rise to the same chemistry from the stars in all observable galaxies.

What we do ***not*** yet know is whether the consistent chemistry gives rise to similar biology, but a simple analysis of the numbers of the universe would suggest that it is reasonable to assume that we are not alone.

Let's "do the maths" based on the assumptions that our solar system is typical and our galaxy is typical.

(number of planets and moons per solar system) x (number of stars per galaxy) x (number of galaxies)

= 150 x 400 billion x 100 billion = 6×10^{28} possible locations for life!

So, even if the odds of biology arising from chemistry are '1 in a trillion' in any particular location, then one would expect

$6 \times 10^{28} / 10^{15} = 6 \times 10^{13}$ locations in the obersvable universe where life exists.

And of course, on cosmological timescales, stars and planets die and form, with each new generation providing fresh opportunities for new biology.

- I am ignoring star types that cannot support life and I am not factoring in so-called 'goldilocks' regions of solar systems
- A more through probabilistic approach is expressed in the 'Drake Equation', proposed by Frank Drake in 1961, and expressed as $N = R_* \times fp \times ne \times fl \times fi \times fc \times L$

How Does it End?

Galaxies in our local galactic group will merge together (Andromeda hits us first in about 5 billion years).

Galaxies further away will recede away as the space between us expands due to dark energy.

The CMBR will fade away as its wavelength expands.

So there will be no evidence remaining of the 'big bang'.

The universe will continue to expand and cool, an eventually all that will be left will be photons and black holes in an unimaginably enormous, dark universe. Then even the black holes will evaporate that's after about 10^{100} years !! There will be no matter any more.

Probably...

So no matter, no temperature changes, and nothing happens, forever.

And if there is no matter, then distance has no meaning and time has no meaning, because Einstein tells us that photons must travel at the speed of light, and for anything travelling at the speed of light there is no time.