

Our Place in Space Webinar Series

1. Big Bang Theory

Malte Ebach

Teacher
Earth
Science
Education
Programme Ltd



We wish to acknowledge the Traditional Owners of the land on which we meet today.

We also wish to pay our respects to Elders past, present and future.

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- Sydney Mineral Exploration Discussion Group (SMEDG)



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- Yancoal
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- Australian Rare Earths Ltd
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- VHM Limited



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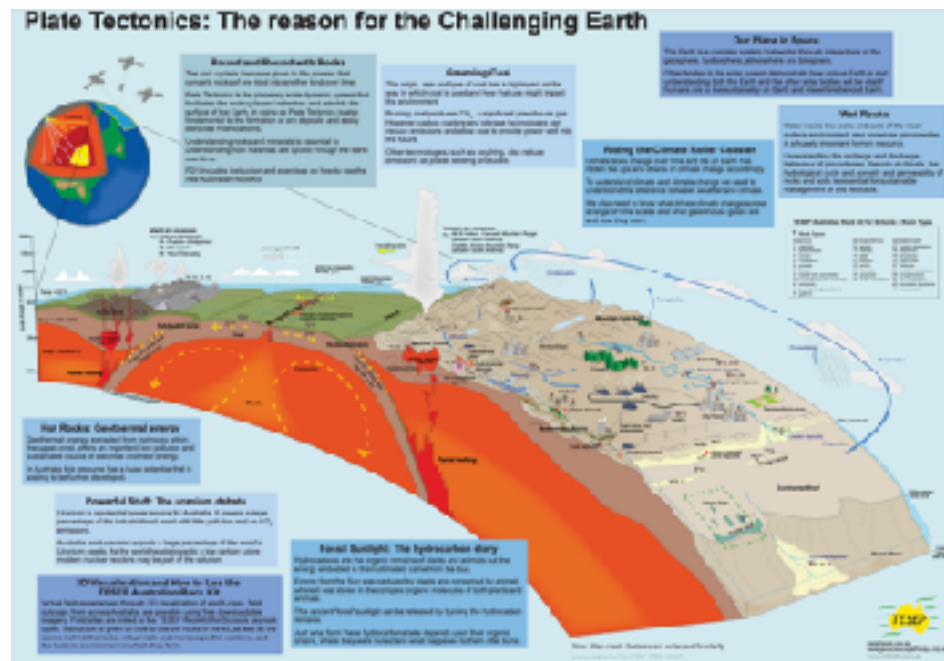
- BHP Olympic Dam
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- Stawell Gold Mine
- Sydney Mineral Exploration Discussion Group (SMEDG)
- Whitehaven Coal
- WIM Resource
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With each School visit we offer a free rock and mineral check:

- To identify specimens no longer useful for teaching (e.g., pebbles, small specimens etc.)
- To identify any misplaced specimens or valuable specimens (for display only)
- To identify any hazardous material (e.g., asbestos, pitchblende etc.)

TESEP Australian Critical Minerals Kit



2 boxes with 26 minerals:

- Critical minerals
- Metallic minerals
- Rock forming minerals
- Moh's scale of hardness
- Online resources include:
 - Mineral Stories
 - Questions for students
 - 3D renders



All TESEP webinars are recorded

After each webinar episode you will be sent a link with:

- access to the slide set for that episode (including any embedded videos and links)
- access to a recording of that episode (YouTube)

After each episode you will also be sent:

- A TESEP Certificate of Attendance (NESA recognised)

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Space Science in the Curricula

Australian Curriculum v.9 (2022)

Stage 3 (Year 6)

- describe the movement of Earth and other planets relative to the sun and model how Earth's tilt, rotation on its axis and revolution around the sun relate to cyclic observable phenomena, including variable day and night length (AC9S6U02) - Covered in episodes 3 and 4.

Stage 4 (Year 7)

- model cyclic changes in the relative positions of the Earth, sun and moon and explain how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides (AC9S7U03) - Covered in episodes 2-4.

Stage 5 (Year 10)

- describe how the big bang theory models the origin and evolution of the universe and analyse the supporting evidence for the theory (AC9S10U03) - Covered in episodes 1 and 2.

<https://v9.australiancurriculum.edu.au/>

Space Science in the Curricula

Victorian Science Curriculum v. 2 (Year 10)

Stage 4 (Year 8)

Cyclic changes in the relative positions of Earth, the Sun and the Moon can be modelled to show how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides (VC2S8U12) Covered in episodes 2-4

Stage 5 (Year 10)

Space exploration seeks to expand knowledge of the origins and structure of the universe and to resolve the challenges of humans travelling and living away from Earth's surface (VC2S10U12) Covered in episode 4

Western Australian Science Curriculum v. 8.1 (Year 10)

Stage 4 (Year 7)

Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the sun, Earth and the moon (ACSSU115) Covered in episodes 2-4

Stage 5 (Year 10)

The universe contains features including galaxies, stars and solar systems, and the Big Bang theory can be used to explain the origin of the universe (ACSSU188) Covered in episodes 1-2



NSW 2026 Syllabus > Science 7-10 >

Stage 5 > Observing the Universe > [Space Science](#) >

- Compare historical and current solar system models to show how models are modified or rejected due to new scientific evidence Covered in episode 1
- Explain that predictable and observable phenomena on the Earth are caused by the relative positions of the Sun, the Earth and the Moon Covered in episodes 2-4
- Use physical models or virtual simulations to explain the cyclic patterns of lunar phases and eclipses of the Sun and Moon Covered in episodes 3-4

Webinar Episodes



1. The Big Bang Theory
2. The Universe and the Solar System
3. Earth and Moon
4. Humans in Space

What is space?



What is space?

- Outer space, commonly shortened to space, is the expanse that exists beyond Earth and its atmosphere and between celestial bodies.
- Outer space is not completely empty;
 - it is a near-perfect vacuum containing a low density of particles, predominantly a plasma of hydrogen and helium, as well as electromagnetic radiation, magnetic fields, neutrinos, dust, and cosmic rays.
 - bits of gas, dust and other matter floats around "emptier" areas of the universe, while more crowded regions can host planets, stars and galaxies.
- In space, sound doesn't carry because there aren't molecules close enough together to transmit sound between them.

Where Does Space Begin?

Space begins at the Kármán line, which is roughly 100 km or 62 miles above the Earth's surface.



sciencenotes.org

Vast distance and deep time

What is a light year?

- The distance traveled by a beam of light in one year
 - The speed of light is 299,792 km/sec
 - In a year that = 9.7 Trillion km (or 6 Trillion miles)

Distance from the Earth to the Sun

- 147,220,000 km = 8 light minutes
- A beam of light leaving the sun takes 8 minutes to reach the Earth
- This distance is known as an Astronomical unit (Au)



Source: <https://i.pinimg.com/originals/9f/6b/7e/9f6b7e0e7fdddfbde29606a565c63aad.jpg>

Vast distance and deep time

The universe is ~13.8 billion years old.

And the Sun is ~4.5 billion years old.

But how do we know?

- One way comes back to the speed of light ...
- Light emitted from the sun takes 8 minutes to reach us – which means the light we see now is a picture of the Sun from 8 minutes ago
- So if a distant star is millions of light years away ... the star must be millions of years old
- An in-built time machine



Source: [Light seconds, light years, light centuries: How to measure extreme distances - Yuan-Sen Ting – YouTube](#) [age of the sun - Bing images](#)

Vast distance and deep time

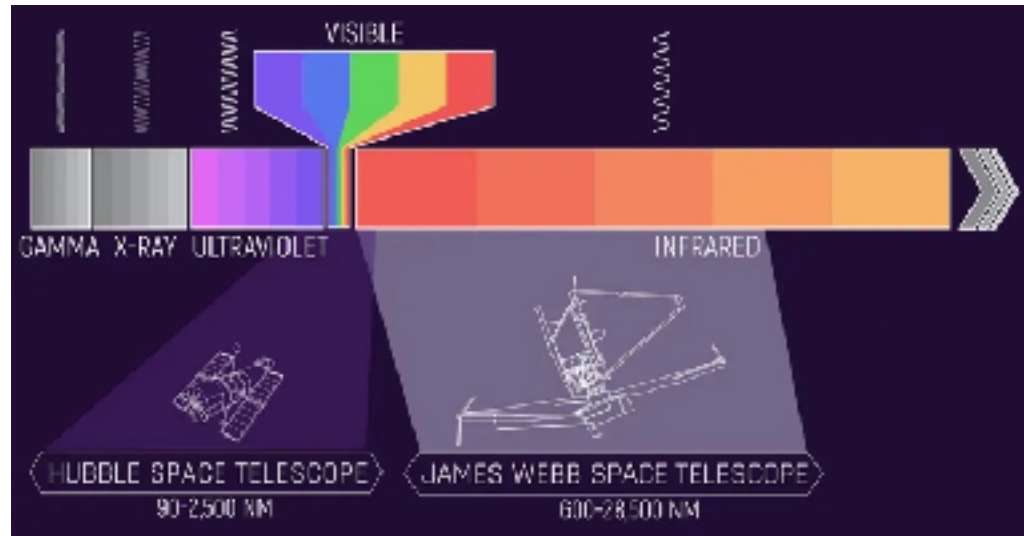
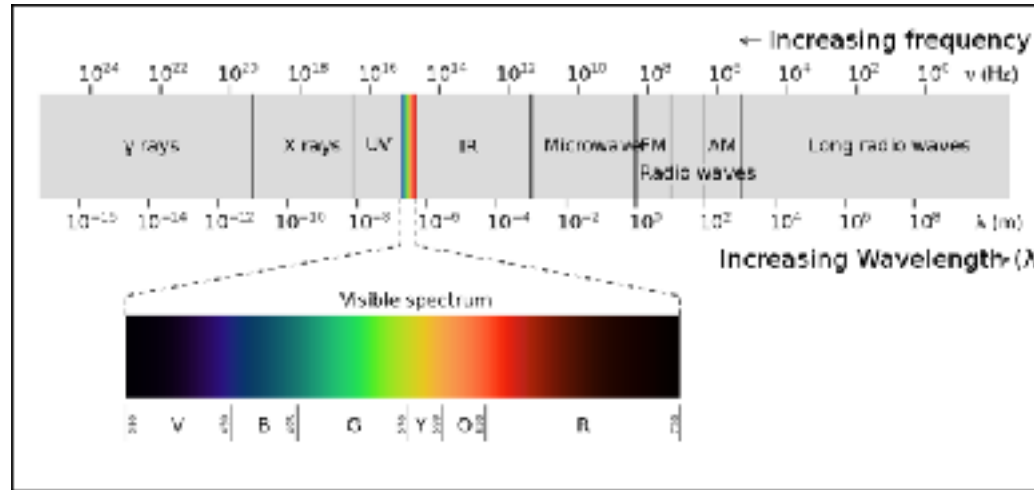
Light is electromagnetic radiation

Humans can only see a small spectrum of wavelengths – visible light

And not all ranges of light pass through the Earth's dense atmosphere

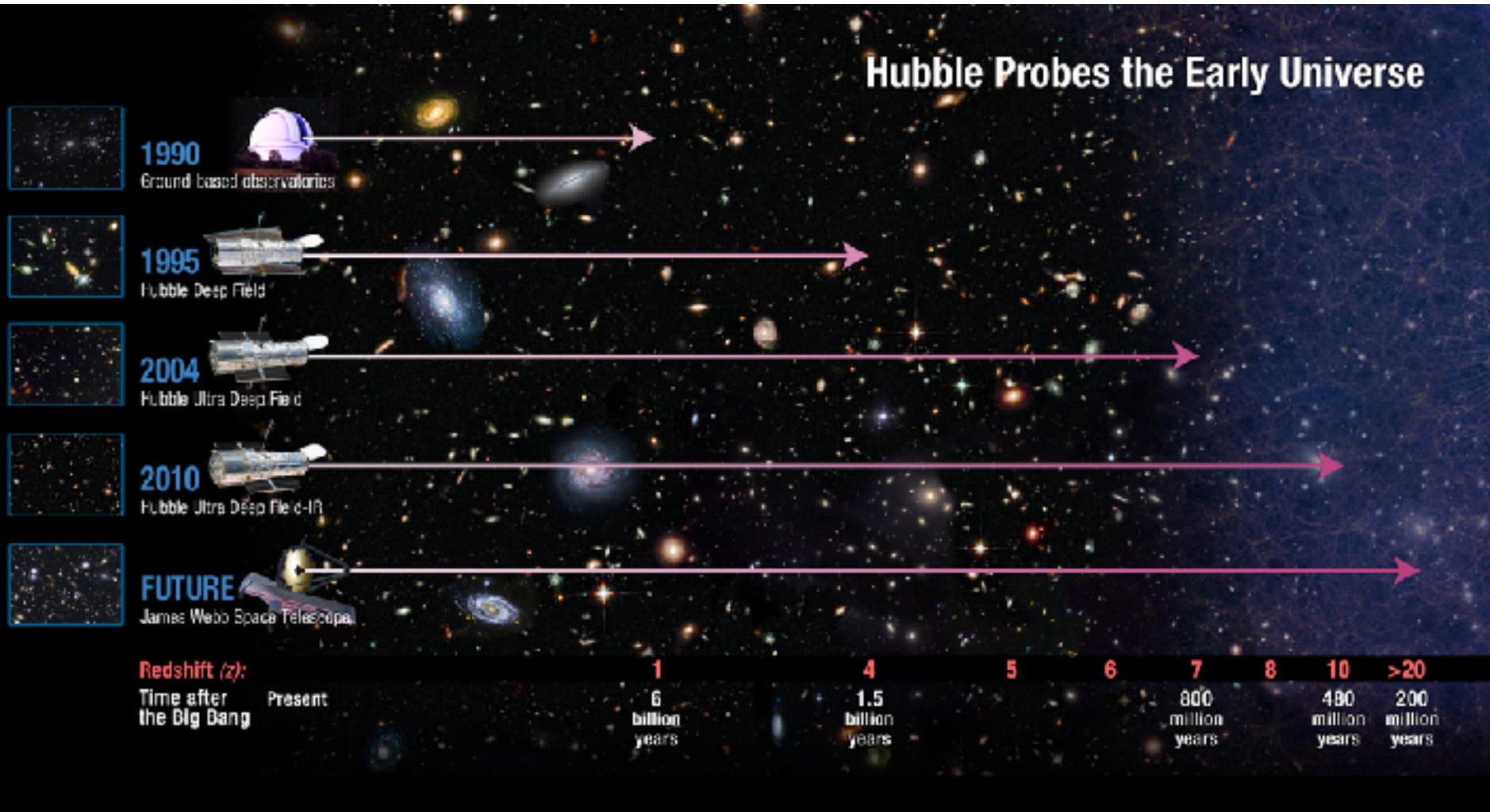
The Hubble Space Telescope and the James Webb Space Telescope allow us to see different wavelengths

- So we can see further away – and further back in time



Source: https://upload.wikimedia.org/wikipedia/commons/thumb/f/f1/EM_spectrum.svg/1280px-EM_spectrum.svg.png The James Webb Space Telescope Is Like a Cosmic Time Machine. Here's Why : ScienceAlert

Vast distance and deep time



https://www.nasa.gov/images/content/512584main_j1105bw.jpg

What was the Big Bang?

An explosion *of* space, not an explosion *in* space

- Occurred everywhere at once
- The beginning of time: occurred 13.8 billion years ago

An infinitely hot and dense point (a singularity) existed 13.8 billion years ago.

The singularity violently expanded (inflation) rapidly everywhere

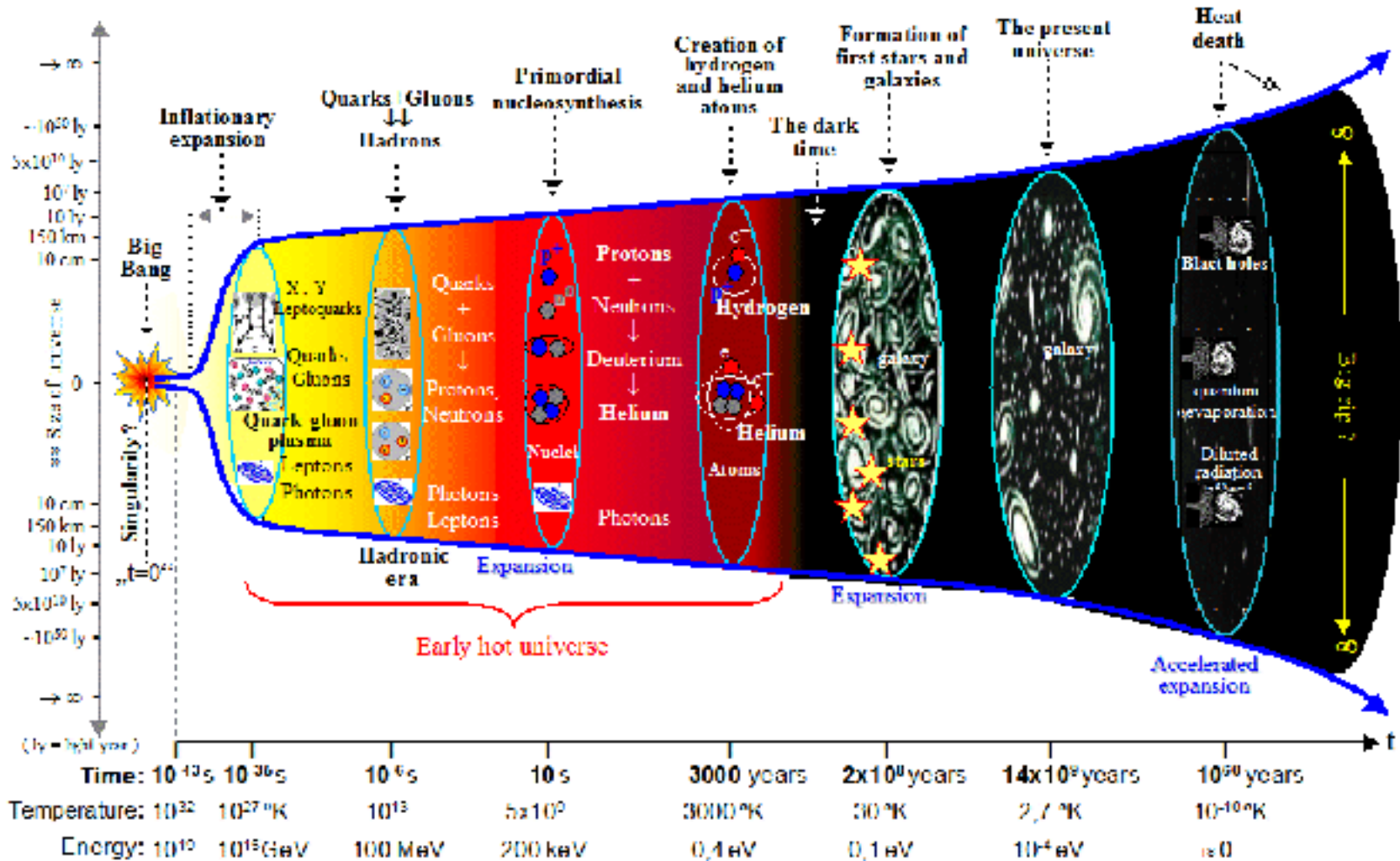
- The Big Bang

As space cooled down and became less dense

- Energy (cosmic radiation)
- Matter (quarks – protons / neutrons / electrons – atoms)

Source:

The Big Bang



The Big Bang



Singularity ($t = 0$)

The Big Bang



Super hot fog ($t = 10^{-43}\text{s} - 10\text{s}$)

Quarks, protons and neutrons created.

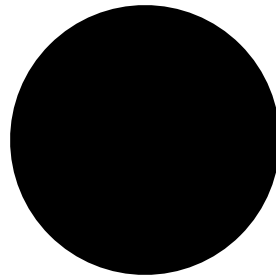
The Big Bang



Super hot fog ($t = 10\text{s} - 3000\text{ years}$)

Creation of hydrogen and helium atoms.

The Big Bang



Dark age ($t = 3000 \text{ years} - 2 \times 10^8 \text{ years}$)

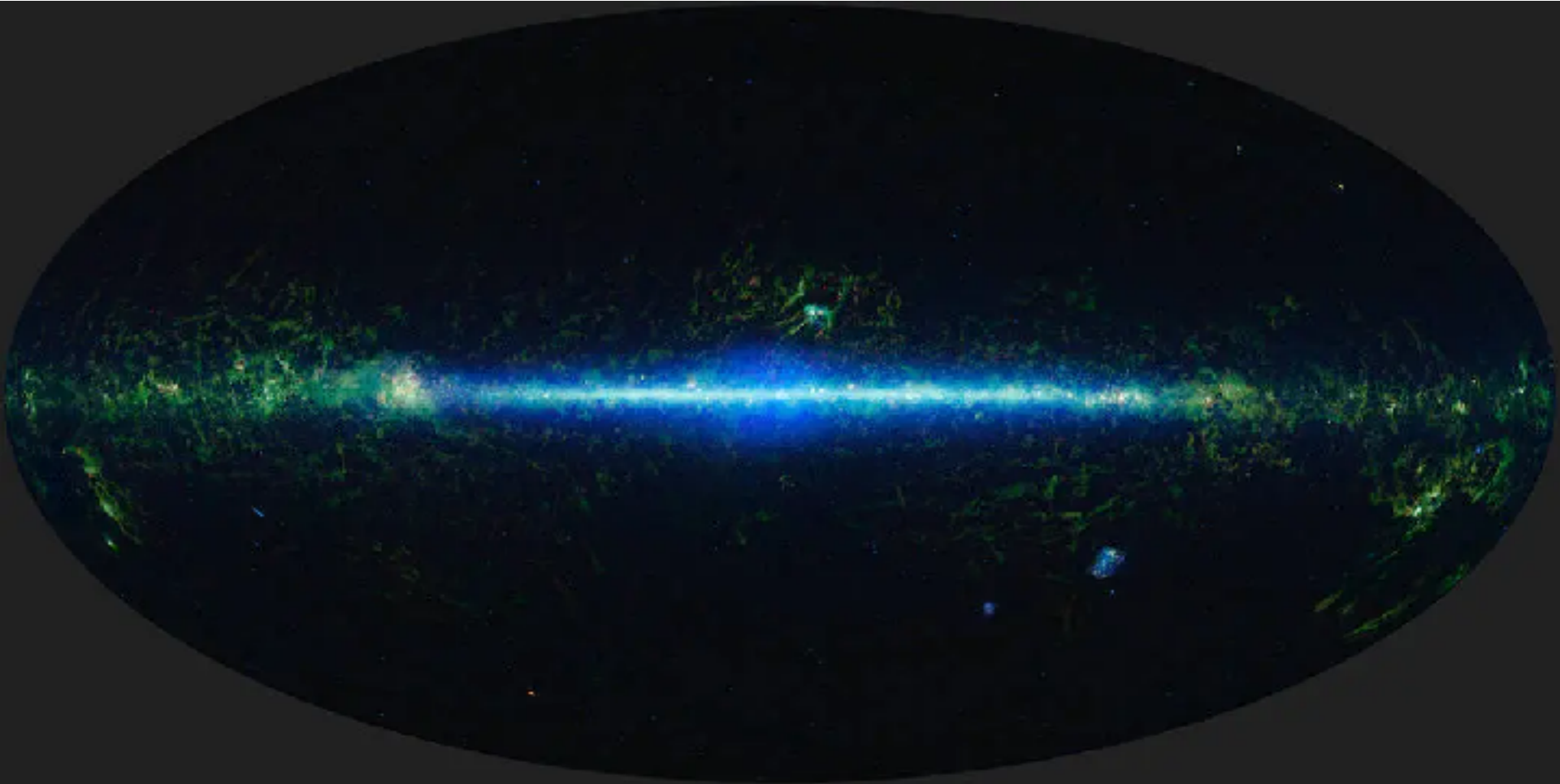
The Big Bang



Early Universe (2×10^8 years)

Galaxy formation.

The Big Bang



Present Universe (14×10^9 years)

What was the Big Bang?



Development of the Big Bang Theory

Up until the early 1900s ... the Static Universe model

- 1500s: Thomas Digges proposed the Static Universe model: the universe is both spatially and temporally infinite, and space is neither expanding nor contracting.
- 1700: Issac Newton proposed that space is infinitely old and will exist forever without changes
- 1917: Albert Einstein proposed a temporally infinite but spatially finite model (his theories of relatively were that time and space are related)

Some big discoveries:

- 1912: Vesto Slipher measured the first Doppler Shift and discovered spiral nebula (galaxies) were receding from Earth
- 1922: Alexander Friedmann used Einstein's equations to propose the universe may be expanding
- 1924: Edwin Hubble measured distance to nearest galaxy, and then to other galaxies
- 1927: Georges Lemaitre proposed that the recession of the nebulae was due to the expansion of the universe – and the universe started as a single point
- 1929: Hubble-Lemaitre Law – the farther away a galaxy is, the faster it is moving away from Earth

Development of the Big Bang Theory

After World War II – two main models ...

The Steady State model (Fred Hoyle)

- Whereby new matter would be created as the universe seemed to expand. In this model the universe is roughly the same at any point in time.

The Big Bang Theory (Georges Lemaitre, George Gamow, Ralph Alpher, Robert Herman)

- The further in the past the smaller the universe was, until at some finite time in the past all the mass of the universe was concentrated into a single point, a "primeval atom" where and when the fabric of time and space came into existence

Ironically, Hoyle introduced the term 'The Big Bang' in a radio broadcast in 1949 – though it was not really used until the 1970s

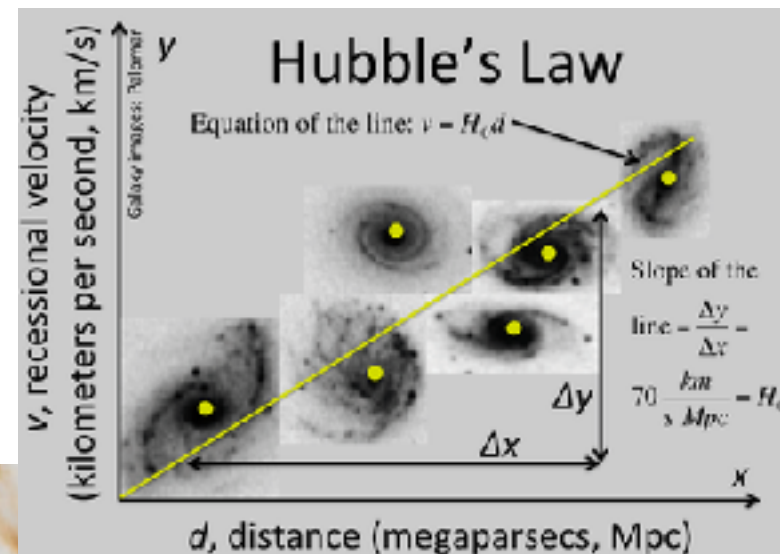
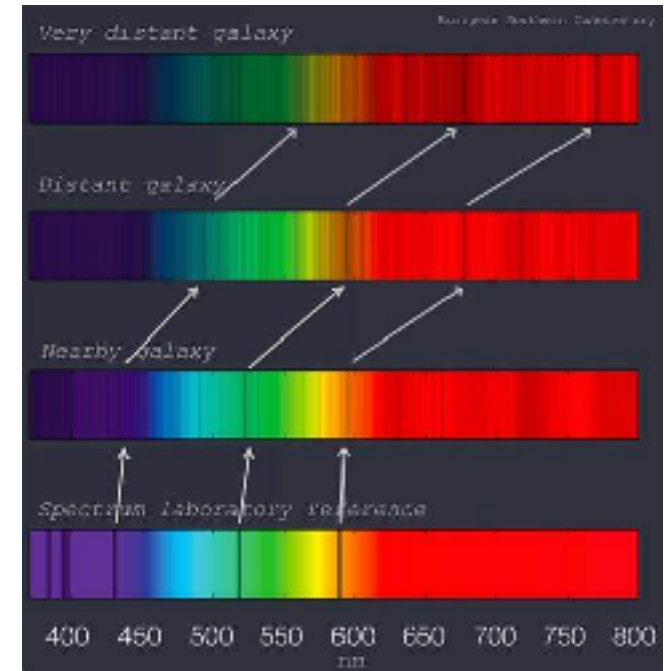
Source: [What Is the Big Bang? | NASA Space Place – NASA Science for Kids](#), [Big Bang - Wikipedia](#)

Big Bang evidence: observed recession of galaxies

If an object emitting light recedes away from an observer, the light reaching the observer will shift towards the red, increasing the wavelength and decreasing the frequency (redshift)

- Edwin Hubble noticed the further away a galaxy, the greater their redshift
- Hubble postulated that these distant galaxies were traveling away from our own
- Hubble eventually determined that the velocity at which these galaxies were receding was proportional to how far away they were; the further away the galaxies were, the higher their redshift was.
- i.e. the farther away a galaxy is, the faster it is moving away from Earth

They can all be extrapolated back in time – shows all matter was touching in a very small space

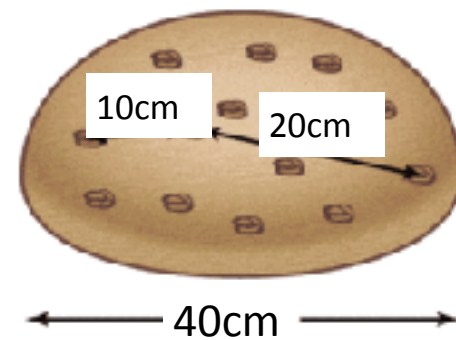
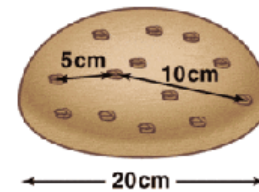


Source: [Astronomical Redshift | Imaging the Universe - The University of Iowa \(uiowa.edu\)](https://www.uiowa.edu/~astronomy/education/redshift/)

Big Bang evidence: observed recession of galaxies

Analogy

- Think of a loaf of raisin bread baking in an oven
- Pretend the loaf is all of the Universe, and the raisins are individual galaxies.
- As the bread bakes, the loaf expands, and every raisin moves apart from every other raisin.
- The raisins furthest from each other move away from each other the most quickly.

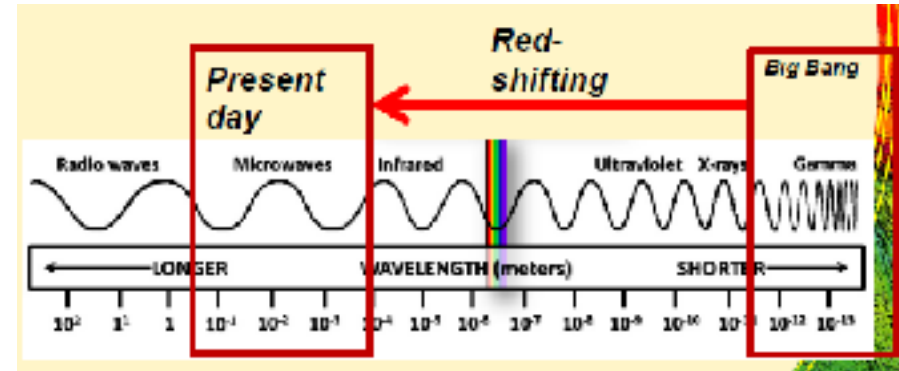


Source: [Astronomical Redshift | Imaging the Universe - The University of Iowa \(uiowa.edu\)](https://www.uiowa.edu/~astronomy/teaching/astrophysics/astrophysics.html)

Big Bang evidence: cosmic radiation

Discovered accidentally by Penzias and Wilson in 1964 at the Bell Labs (telephone company) – radio noise they couldn't explain

Its presence had been predicted by George Gamow as part of the Big Bang theory



High energy radiation emitted during Big Bang

- Space expands for 13.7 billion years
- Oldest radiation is red-shifted to the microwave spectrum
- 1% of static picked up on an analogue TV is cosmic radiation!



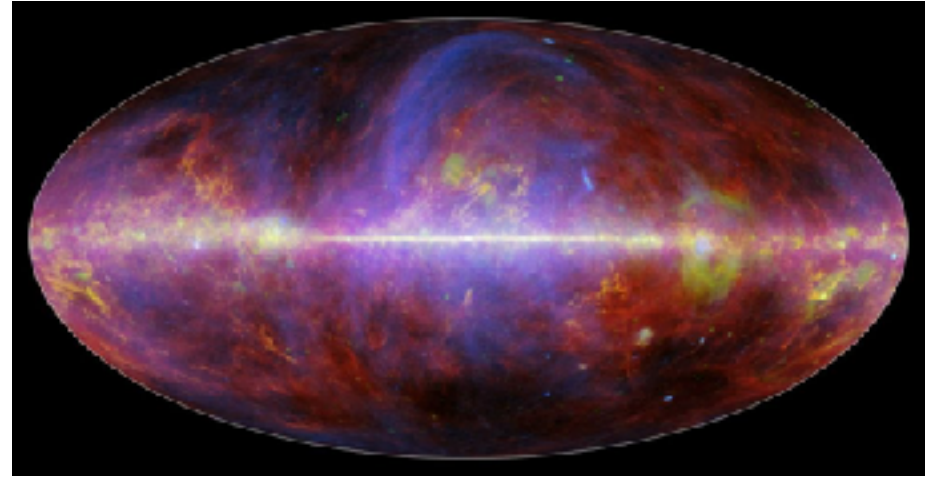
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Source:

Big Bang evidence: age of the universe (using cosmic radiation)

The universe is constantly expanding.

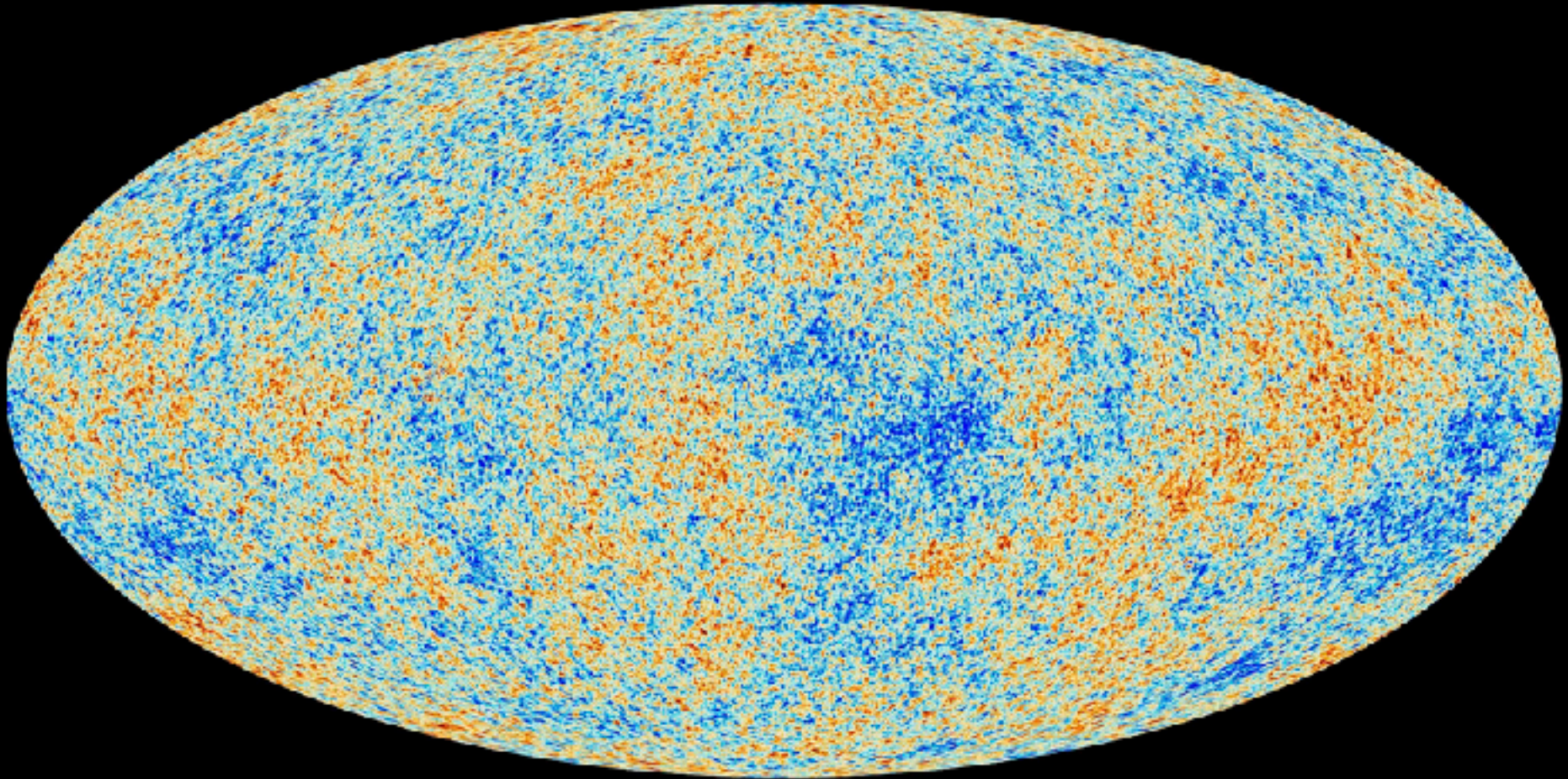
- If we know the rate of expansion (known as the Hubble constant), we can work out how long the universe has been expanding
- By measuring radiation left over from the big bang (cosmic microwave radiation), we can determine the density, composition and expansion rate of the universe
- Radiation mapped and the age of the universe calculated by:
 - NASA's Wilkinson Microwave Anisotropy Probe (WMAP) in 2012
 - 13.772 billion years
 - The European Space Agency's Planck spacecraft in 2013
 - 13.82 billion years



A view of the Milky Way galaxy in microwaves, captured by the European Space Agency's Planck satellite. The different colours correspond to different elements, including gas, dust, and energetic particles.

Source: [How Old is the Universe? | Space](#) [Gallery: Planck Spacecraft Sees Big Bang Relics | Space](#)

Temperature map of the universe (370,000 years)

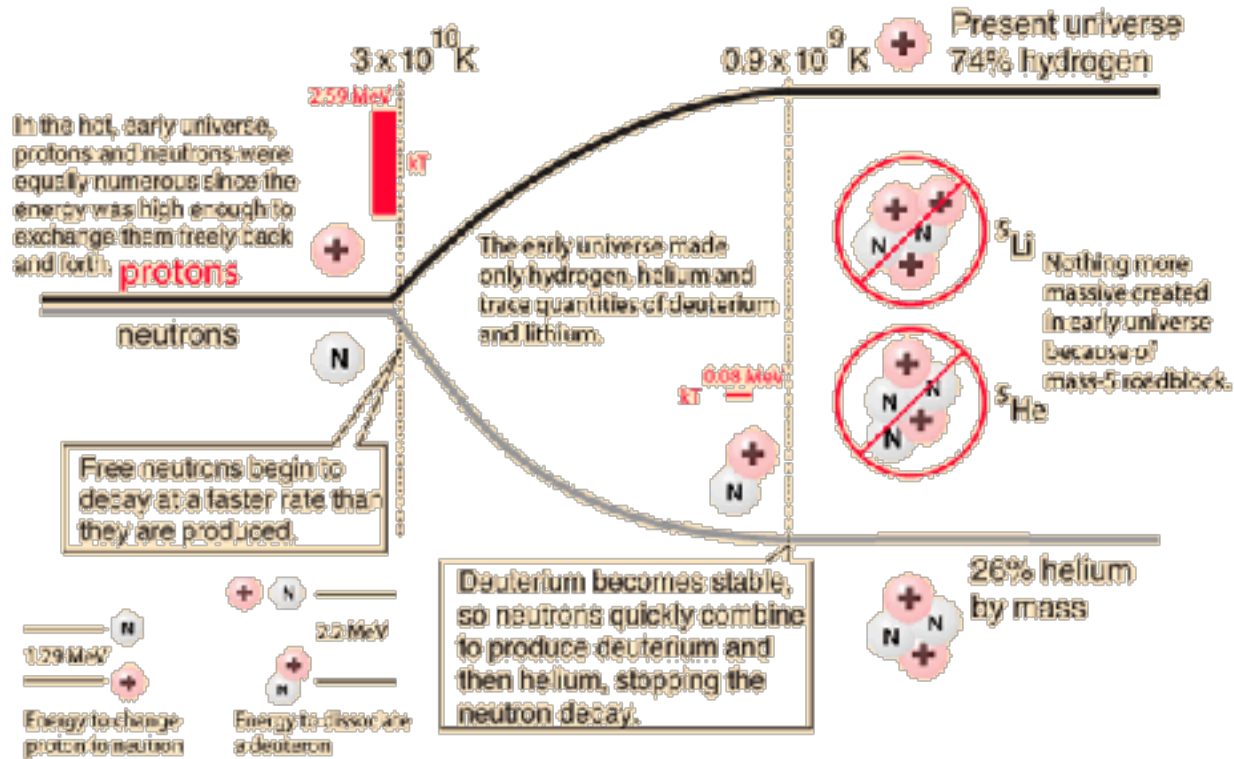


Temperature range between hot (red) and cold (blue) is ± 200 microKelvin (very small $<1\text{c}$)

Big Bang evidence: nucleosynthesis

Using nuclear theory, the Big Bang model predicts 25% of all matter, by mass, will exist as 4He (Helium - 4) – the most stable light isotope

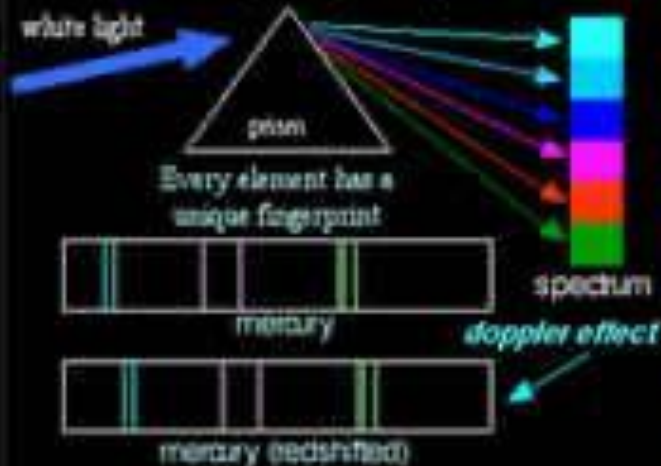
- 4He should constitute 25% of all mass in primitive (i.e. unchanged) gas bodies.
- Observations of such primordial gas clouds show that they contain 25% 4He
- The agreement between observations and predictions support the Big Bang model!



Source: [Big Bang Nucleosynthesis \(gsu.edu\)](http://Big_Bang_Nucleosynthesis_(gsu.edu))

Expanding Universe

Spectral Analysis has determined that nearly all stars and galaxies are moving away from us. This is the genesis of **The Big Bang Theory**



Radio Astronomy



Background Radiation

it's so cold out there

After the Bang, the universe cooled down. The Big Bang Theory predicts that there would be a background radiation of about 2.7°K above absolute zero

10¹⁰ years **Silicon-based Life Forms**

Carbon-based Life Forms

Planet Formation

Star Formation

Galaxy Formation

Hydrogen matter era

1 year **Protons**

Electrons

Quarks

radiation era

The Biggest in Bang the Universe

The Big Crunch?

What's the mass?

What's all the fuss about this Inflationary Universe?

Galaxy Formation

How did the galaxies and super galactic structures of the universe come about?

COBE discovers a slight temperature gradient thru-out the universe

Bubbles (Super Galactic Structures) and Voids are now explained within The Big Bang Theory.

Element Abundance

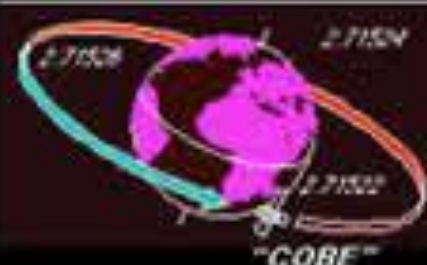
gravity



All the elements in the universe were made in the stars then expelled through Supernova explosions



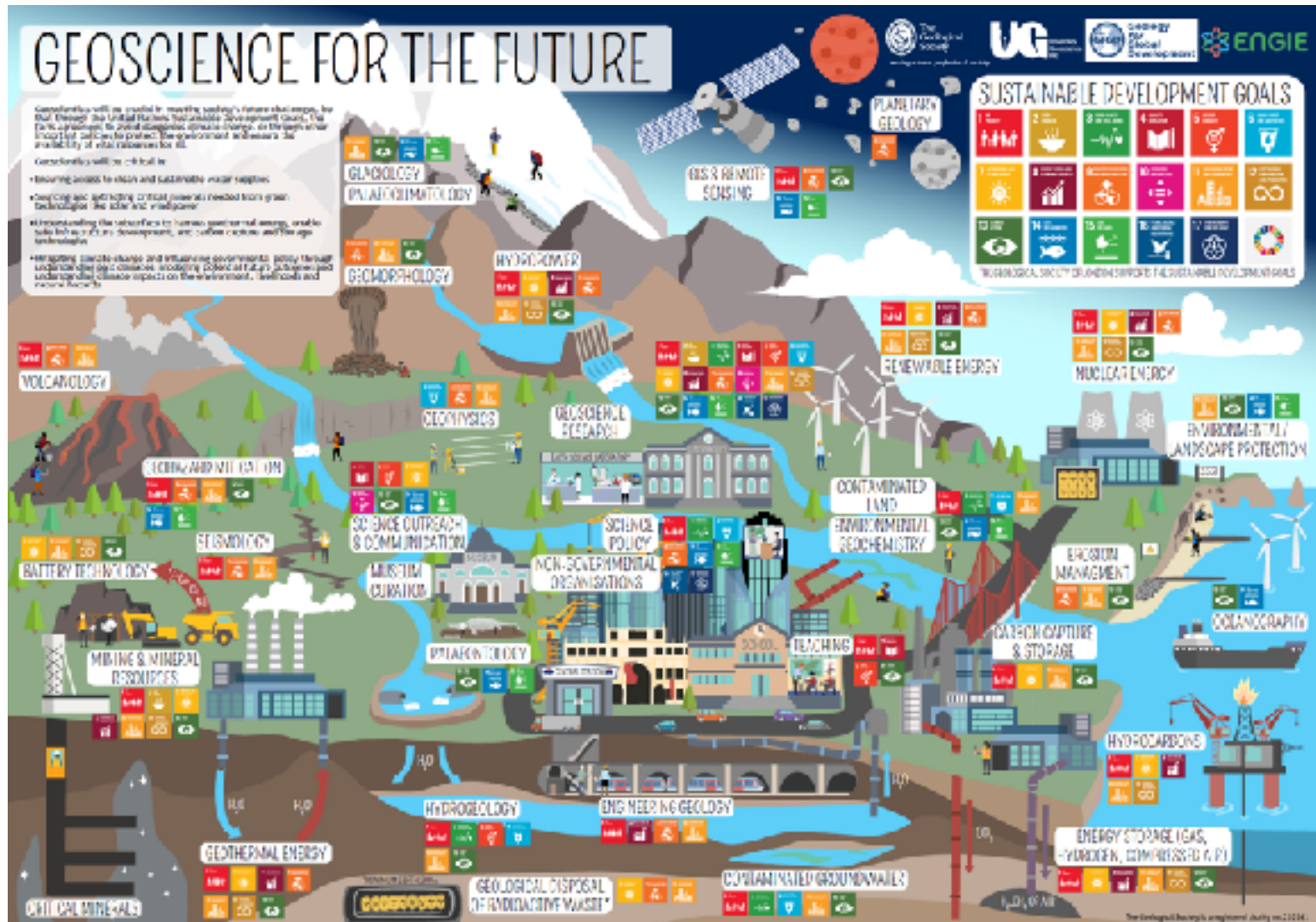
There is more helium and lithium in the universe that can be accounted for by stellar nucleosynthesis alone. Some must have been created at *The Big Bang*





Slides for further resources ...

So many aspects of geoscience!



So many aspects of geoscience!




Biology



Maths



Resources

Data scientist	Resource geologist	Environment	Palaeontologist
Geochronologist	Exploration geologist	Rehabilitation	Anthropology
Spatial analyst	Commodity analyst	Soil science	Astrobiologist
3D modeller	Climate	 Geoscientist	Space
Petrography	Geotourism	Geomorphology	Volcanologist
Geochemist	Medical geology	Geotechnical	Astronomer
Mineralogist	Community liaison	Forensic geology	Geodynamics
Geometallurgist	Land access		Seismologist
			Geophysicist

Chemistry



Community



Physics



Geoscience Australia – Education Centre

Online resources and classroom activities for Australia's geology, minerals, energy, natural hazards and more



Australian Government
Geoscience Australia

Visit them!

- Purpose built Education Centre in Canberra
- Student-activity education
- Earthquake and tsunami monitoring
- Touch the only piece of the Moon in the Southern Hemisphere
- Geological time walk with representative Australian rocks
- National rock, mineral and fossil display – including meteorites

<https://www.ga.gov.au/education>



Links to online resources

Not for profit organisations ...

TESEP:

<http://www.tesep.org.au>

SACOME STEM Digital Technology Program Data Science Challenges

agrigg@sacome.org.au

Geoscience Pathways Project

www.geosciencepathways.org.au

Aus Earth Ed:

<https://ausearthed.com.au/>

CoRE Learning Foundation

<https://www.corefoundation.com.au/>

Ore Some Resources:

<https://www.oresomeresources.com/>

Geological Surveys and professional groups ...

Geoscience Australia:

<https://www.ga.gov.au/education>

British Geological Survey – Education

<http://www.geomag.bgs.ac.uk/education/home.html>

United States Geological Survey

<https://www.usgs.gov/educational-resources>

Kentucky Geological Survey (classroom activities):

<https://www.uky.edu/KGS/education/classroom-activity.php>

Minerals Council of Australia (Australian minerals facts):

<https://minerals.org.au/about/mining-facts/>

NSW Mining (Hunter Valley Mine Tours):

<https://miningdialogue.com.au/engagement/school-tours>

Opportunities for keen and talented students

Olympiads and Fairs ...

Australian Science Olympiads

<https://www.asi.edu.au/program/australian-science-olympiads/>

International Earth Science Olympiad

<https://www.igeoscienced.org/>

Australian Science and Engineering Fair

<https://aussef.com.au/>

International Science and Engineering Fair

<https://www.societyforscience.org/isef/>

Local geology and earth science societies ...

Geotrails in Australia (AGC)

<https://www.agc.org.au/geoscience-in-australia/geotourism/inventory-of-geotrails-in-australia/>

Geological Society of Australia (talks and field trips across Australia)

<https://www.gsa.org.au/>

Field Geology Club of SA

<https://fieldgeologyclubsa.org.au/>

Amateur Geological Society of the Hunter Valley

<https://agshv.com/>