



Astrophysics

Cosmology

Applicant Study Pack

Cosmology

(d) Cosmology

Students should:

8.13P describe the past evolution of the universe and the main arguments in favour of the Big Bang

8.14P describe evidence that supports the Big Bang theory (red-shift and cosmic microwave background (CMB) radiation)

8.15P describe that if a wave source is moving relative to an observer there will be a change in the observed frequency and wavelength

8.16P use the equation relating change in wavelength, wavelength, velocity of a galaxy and the speed of light:

$$\frac{\text{change in wavelength}}{\text{reference wavelength}} = \frac{\text{velocity of a galaxy}}{\text{speed of light}}$$

$$\frac{\lambda - \lambda_0}{\lambda_0} = \frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

8.17P describe the red-shift in light received from galaxies at different distances away from the Earth

8.18P explain why the red-shift of galaxies provides evidence for the expansion of the universe

What do you need to know about Cosmology?



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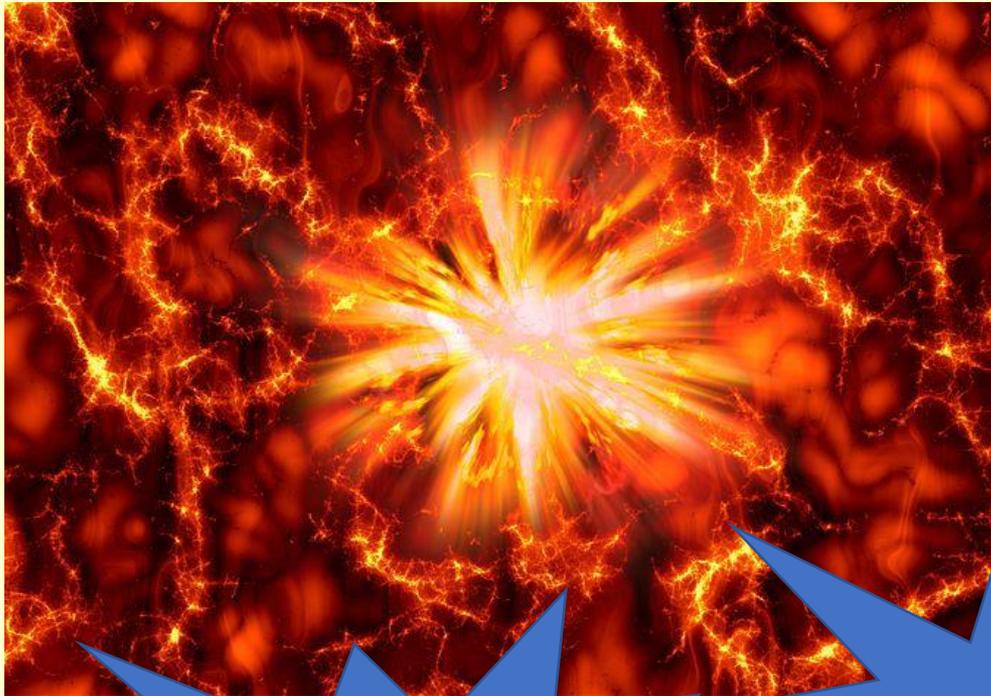
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Let's look at each section in turn

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What happened after The Big Bang?

What evidence is there for The Big Bang?

What was The Big Bang?

So many questions!



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I don't think we mean this 'Big Bang Theory'!



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A long time ago, before the galaxies and star systems were born, all matter in the Universe occupied a very small space.

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This tiny space was
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There was a massive explosion

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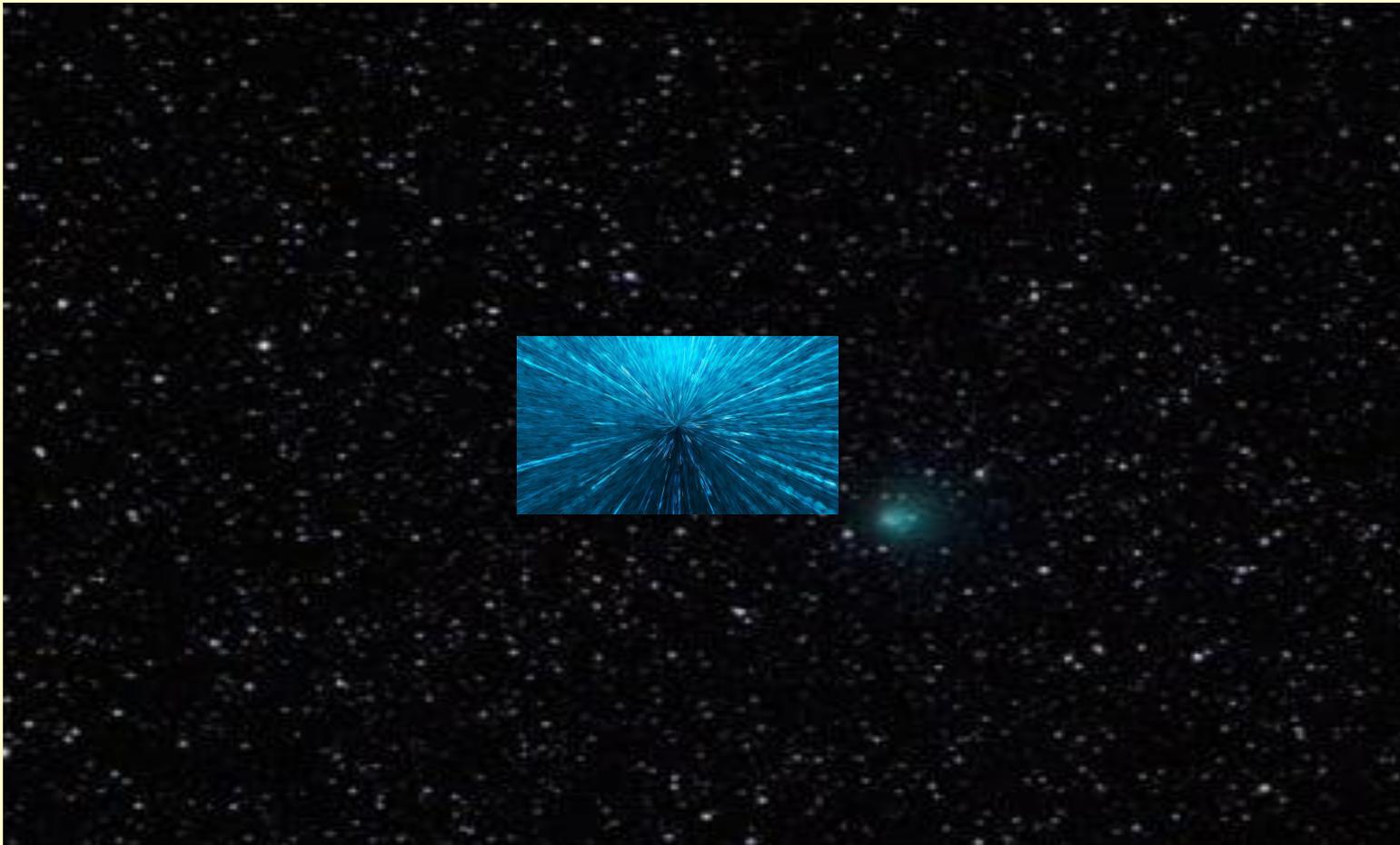
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Space started expanding

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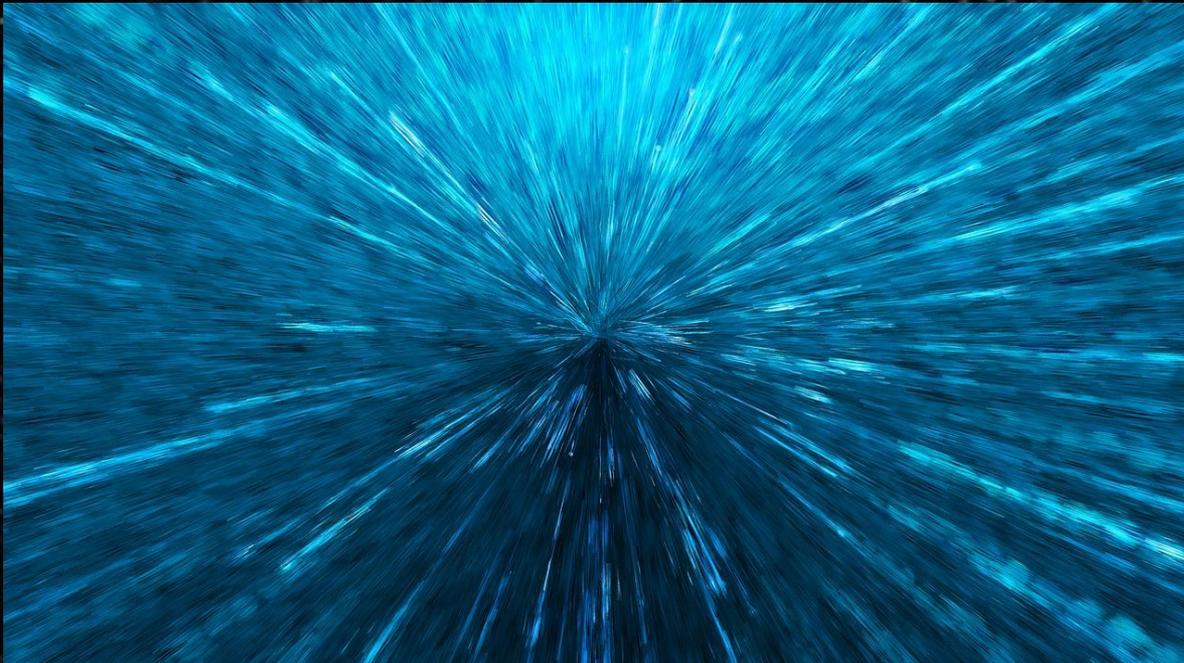
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And it continues to expand

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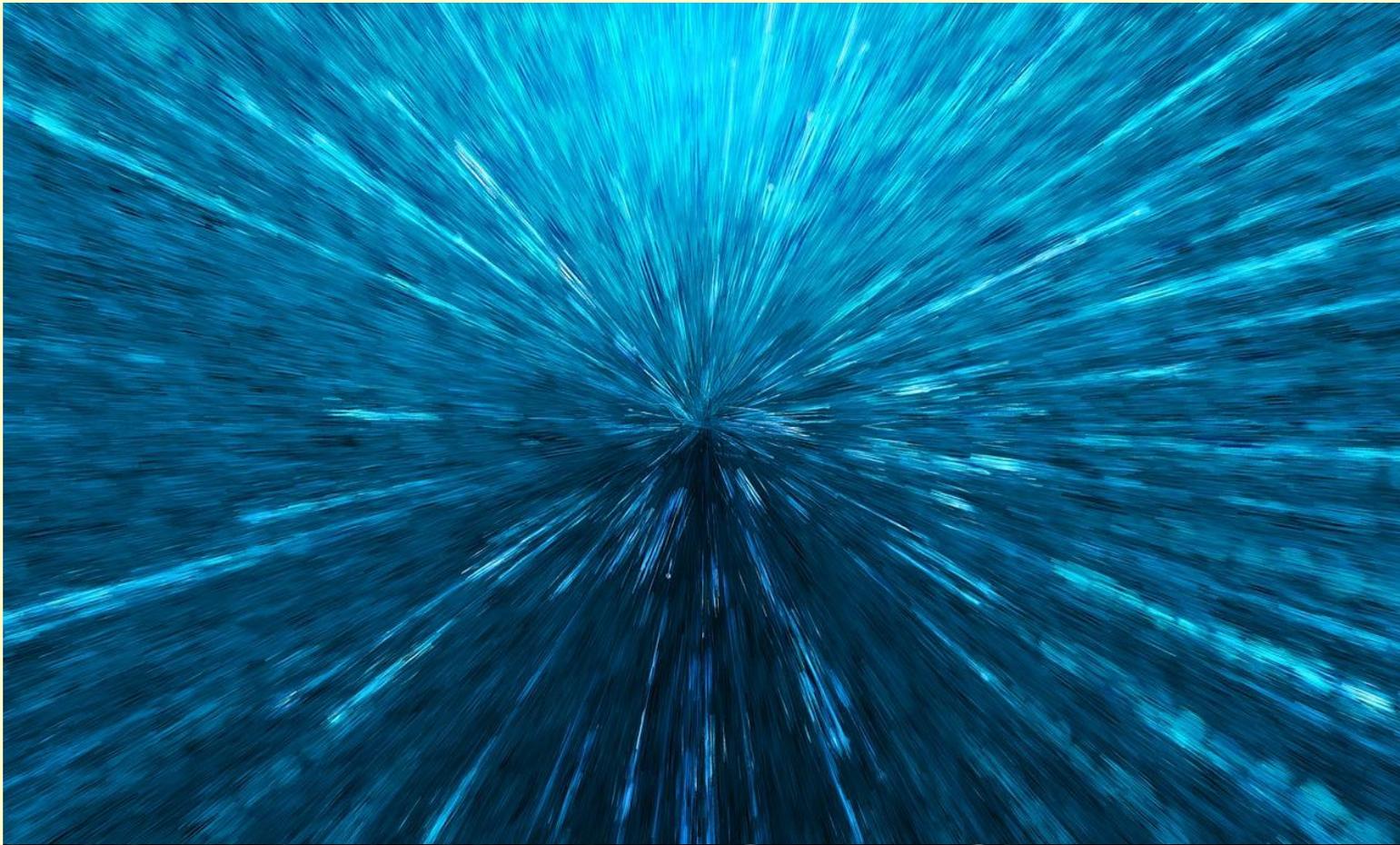
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The Big Bang theory is the best guess we have so far, but we need to collect more evidence



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Two of the best bits of evidence we have so far are Red Shift and Cosmic Microwave Background (CMB radiation)



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Let's have a look at red-shift. You'll have to hang on to your hat for this one!



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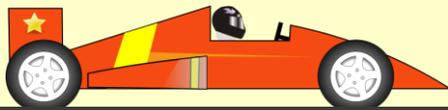
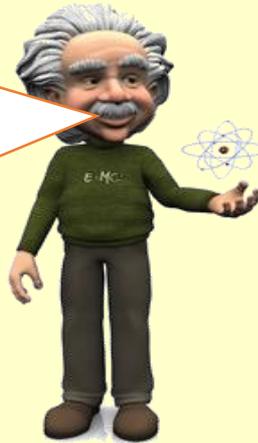
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Suppose you are standing at the side of the track and a racing car whizzes past you.



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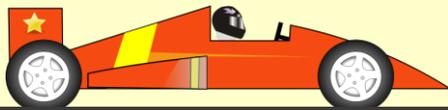
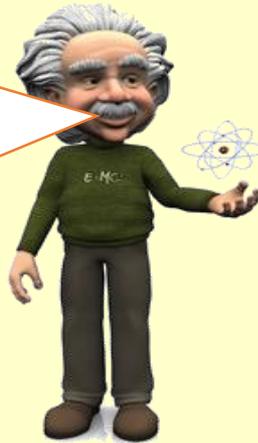
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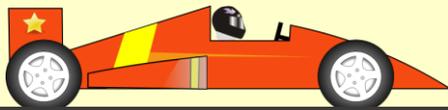
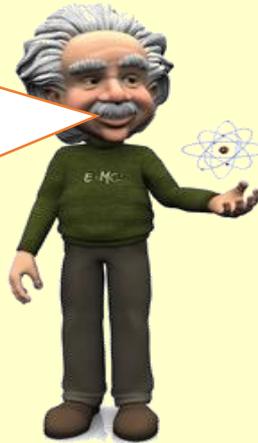
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What do you hear?

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Frequency

high

low

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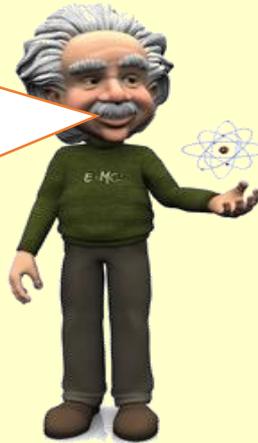
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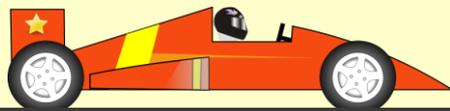
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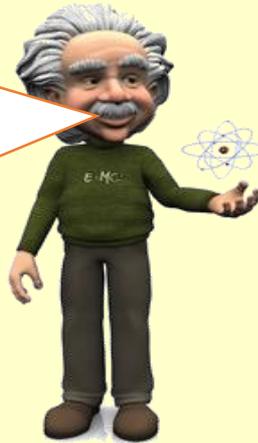
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This apparent change in frequency is called the **Doppler effect**.



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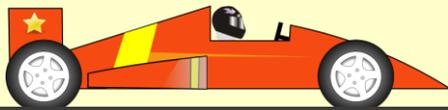
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The faster the car is moving, the greater the change in frequency

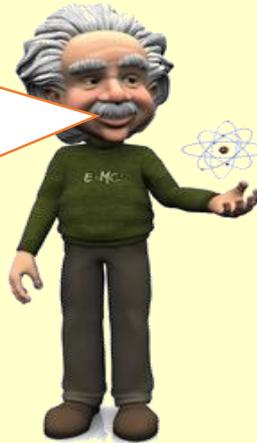
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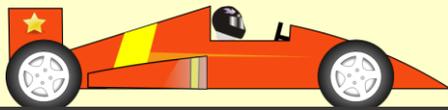
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The Doppler effect is a property of all waves, including light.

The faster the car is moving, the greater the change in frequency



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When astronomers are looking at the spectra of light from distant galaxies and stars they are seeing the Doppler effect



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This is the light spectrum from a nearby star. The dark lines we can see are called **absorption lines**.



Absorption lines = frequencies of light absorbed by hydrogen.

Cosmology



This is the light spectrum from a nearby galaxy. Note that the lines have moved towards the red end of the spectrum.



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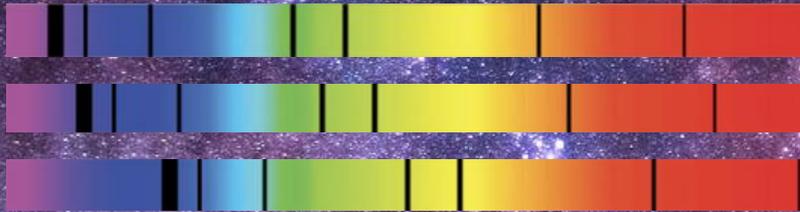
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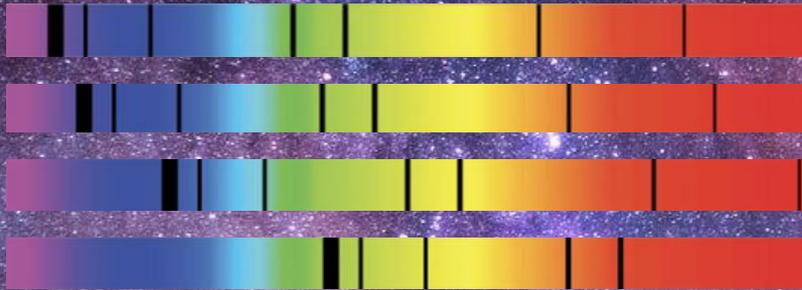
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This spectrum is from a distant galaxy. The lines have moved even further towards the red end.



Absorption lines = frequencies of light absorbed by hydrogen.

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Here is a spectrum from a very, very distant galaxy. See how the lines have shifted the furthest towards the red end.



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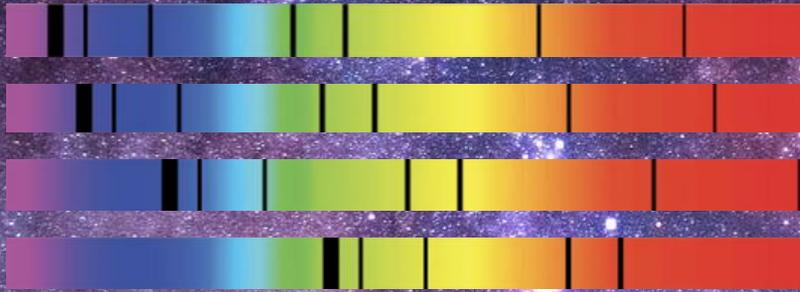
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This displacement of the lines is called 'red shift'.

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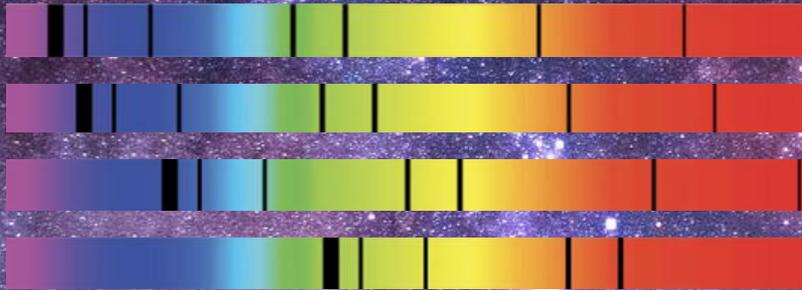
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Like the change in frequency and the racing car, red-shift indicates that the source of the light waves is moving away from the observer.

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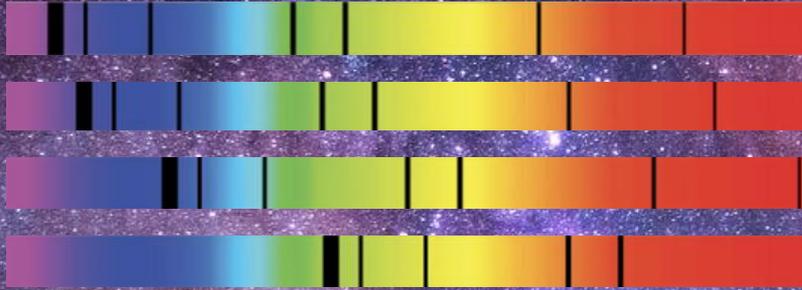
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Here is a spectrum from a very, very distant galaxy. See how the lines have shifted the furthest towards the red end.



Cosmology



(d) Cosmology

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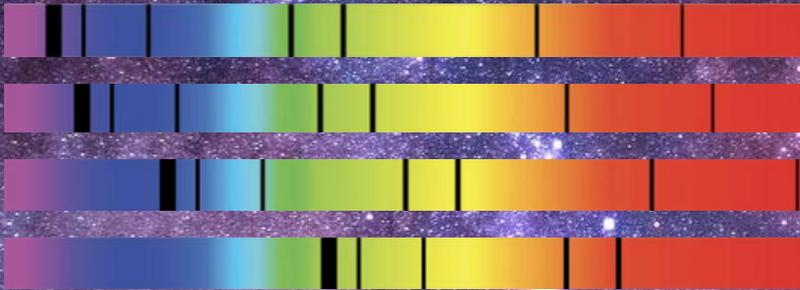
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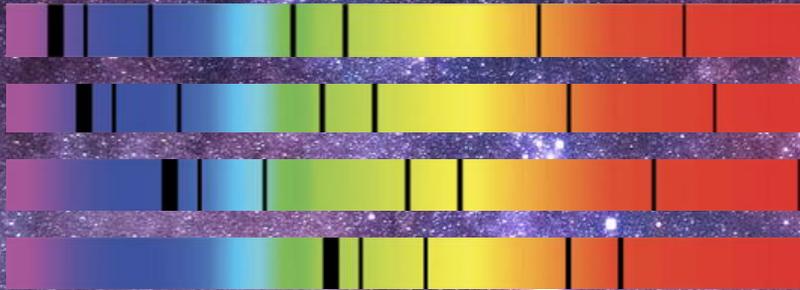
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Most distant galaxies have greater red-shifts than nearer ones. The conclusion?

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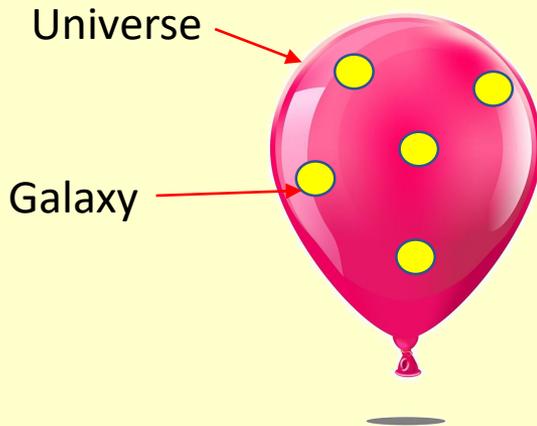
Measurements of the red-shift indicate that distant galaxies are moving away from us the fastest in all directions.

Most distant galaxies have greater red-shifts than nearer ones. The conclusion?

The Universe must be expanding!

Cosmology

The 'expanding Universe' model



Imagine a balloon covered in dots.



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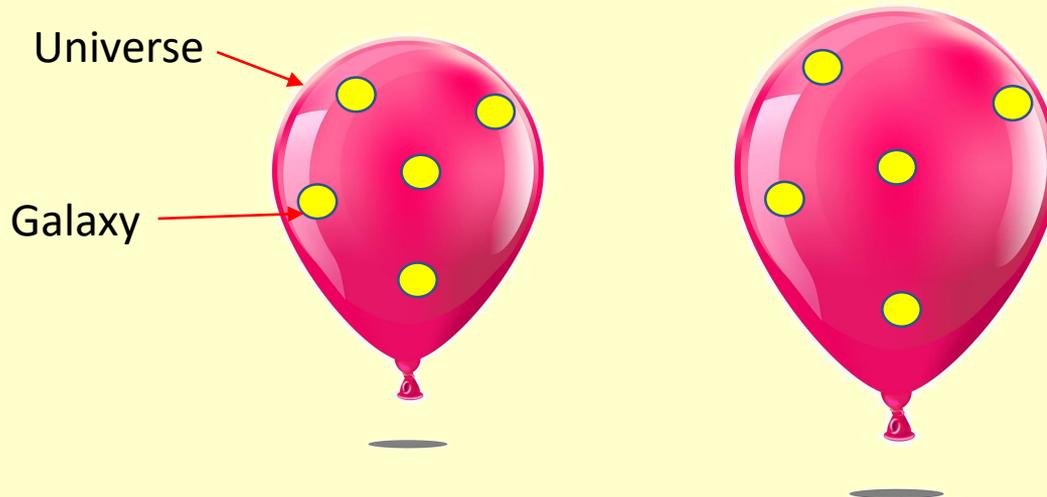
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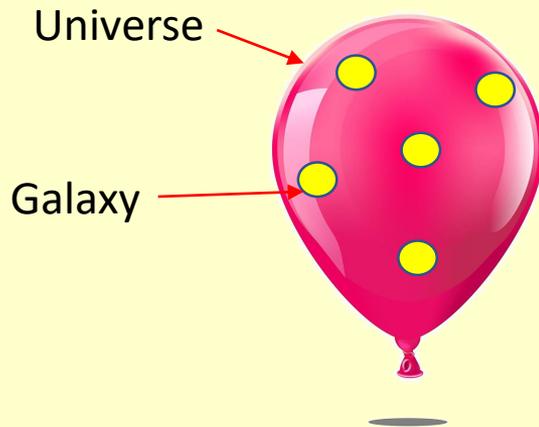
As the balloon inflates, the dots move away from each other



Cosmology

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Imagine a balloon covered in dots.



As the balloon inflates, the dots move away from each other



As time goes on, **space stretches** and expands, moving **galaxies away from each other**.



Cosmology



We can use the **Doppler equation** to work out the speed at which a galaxy or star is moving away from us.

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Q. The Sun emits light at a wavelength of 434nm. A galaxy far away gives off the same light but has a wavelength of 492nm (because of the Doppler effect). Calculate the speed at which the galaxy is moving away from us. (Remember: 1 nm = 10⁻⁹m)

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$$\text{Velocity of galaxy} = v$$

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Because the apparent wavelength is **longer** (red-shift) the galaxy is moving away from us at 40 200 km/s

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Cosmology

So that's the red-shift bit.
What about the Cosmic
Microwave Background
(CMB) bit?



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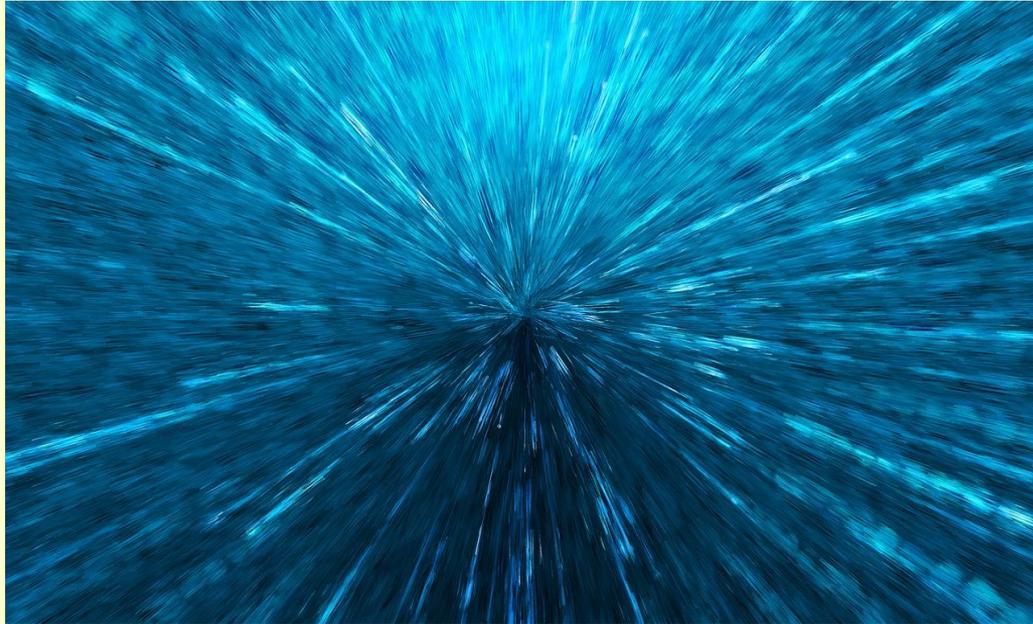
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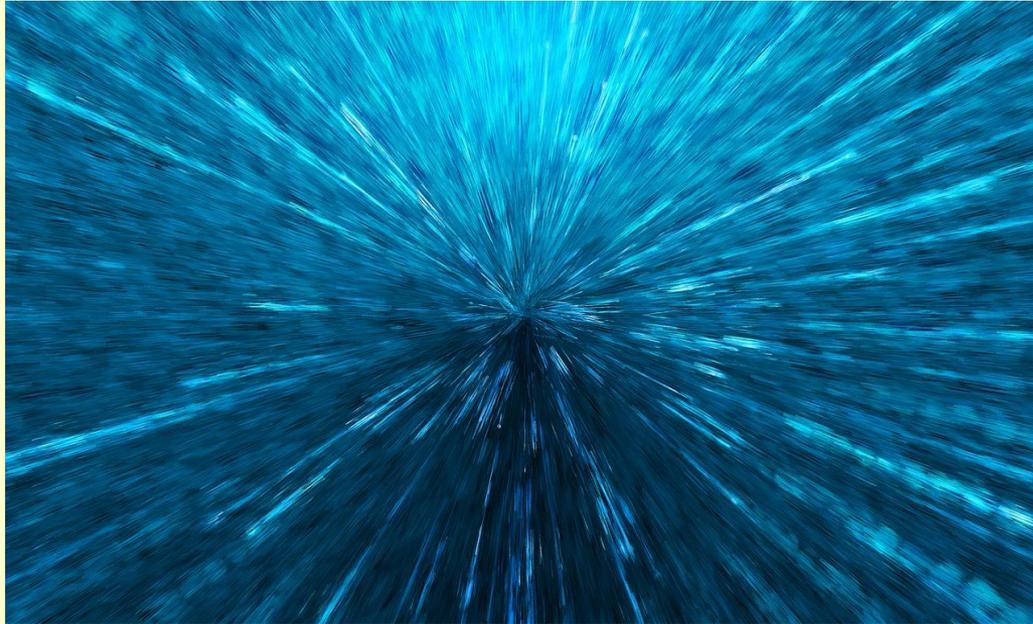
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As the Universe expands, so it releases energy in the form of waves.

Cosmology



These waves have become stretched, and are much longer than before. They are in fact in the microwave part of the electromagnetic spectrum.

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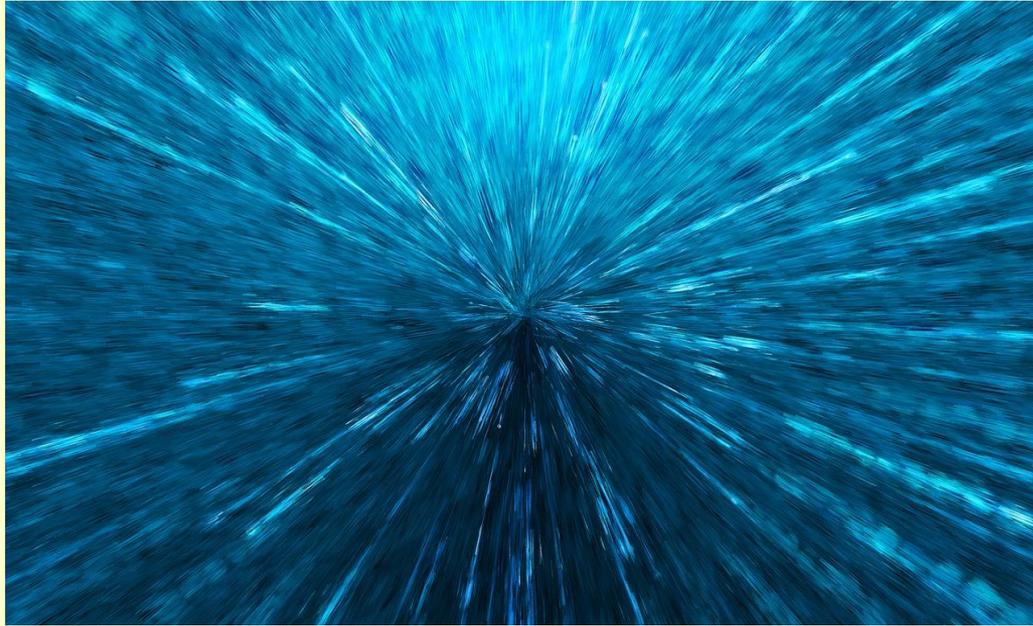
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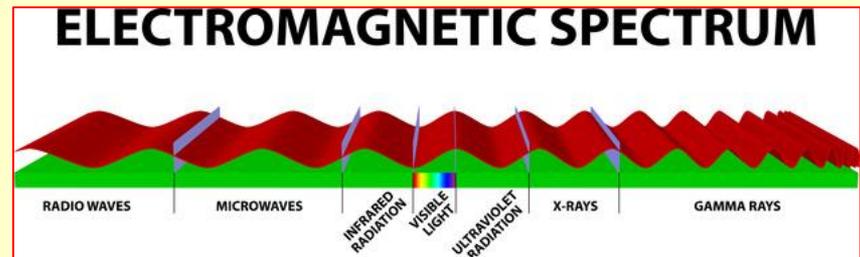
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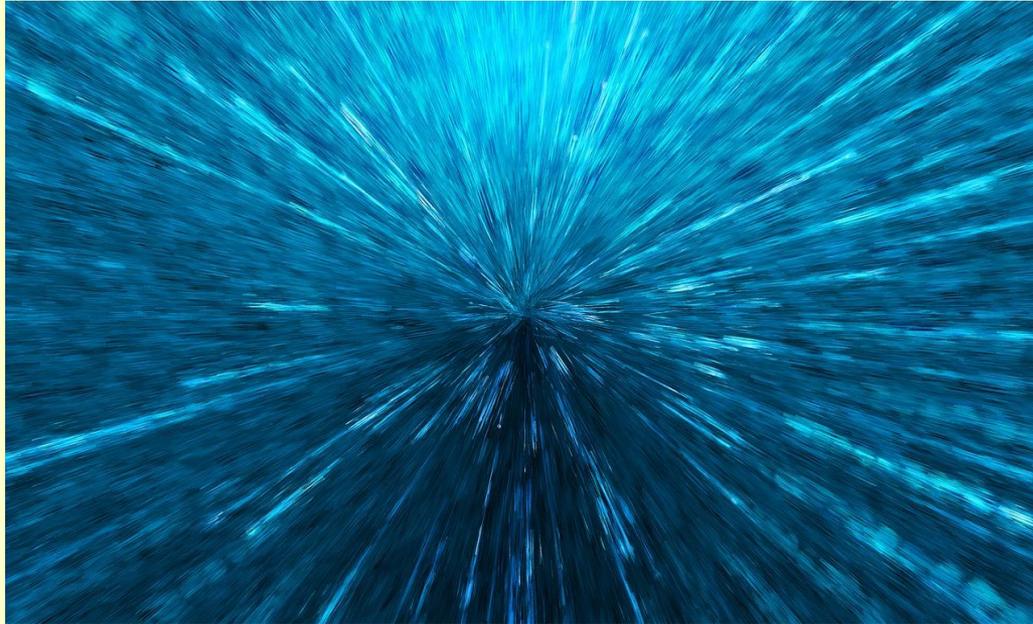
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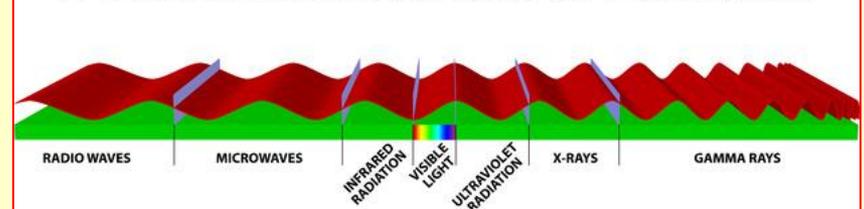
8.17P describe the red-shift in light received from galaxies at different distances away from the Earth

8.18P explain why the red-shift of galaxies provides evidence for the expansion of the universe

As the Universe expands, so it releases energy in the form of waves.

These waves have become stretched, and are much longer than before. They are in fact in the microwave part of the electromagnetic spectrum.

ELECTROMAGNETIC SPECTRUM



In the 1960s scientists detected this afterglow of energy from the Big Bang, and the term Cosmic Microwave Background (CMB) radiation was used to describe it.

Cosmology

(d) Cosmology

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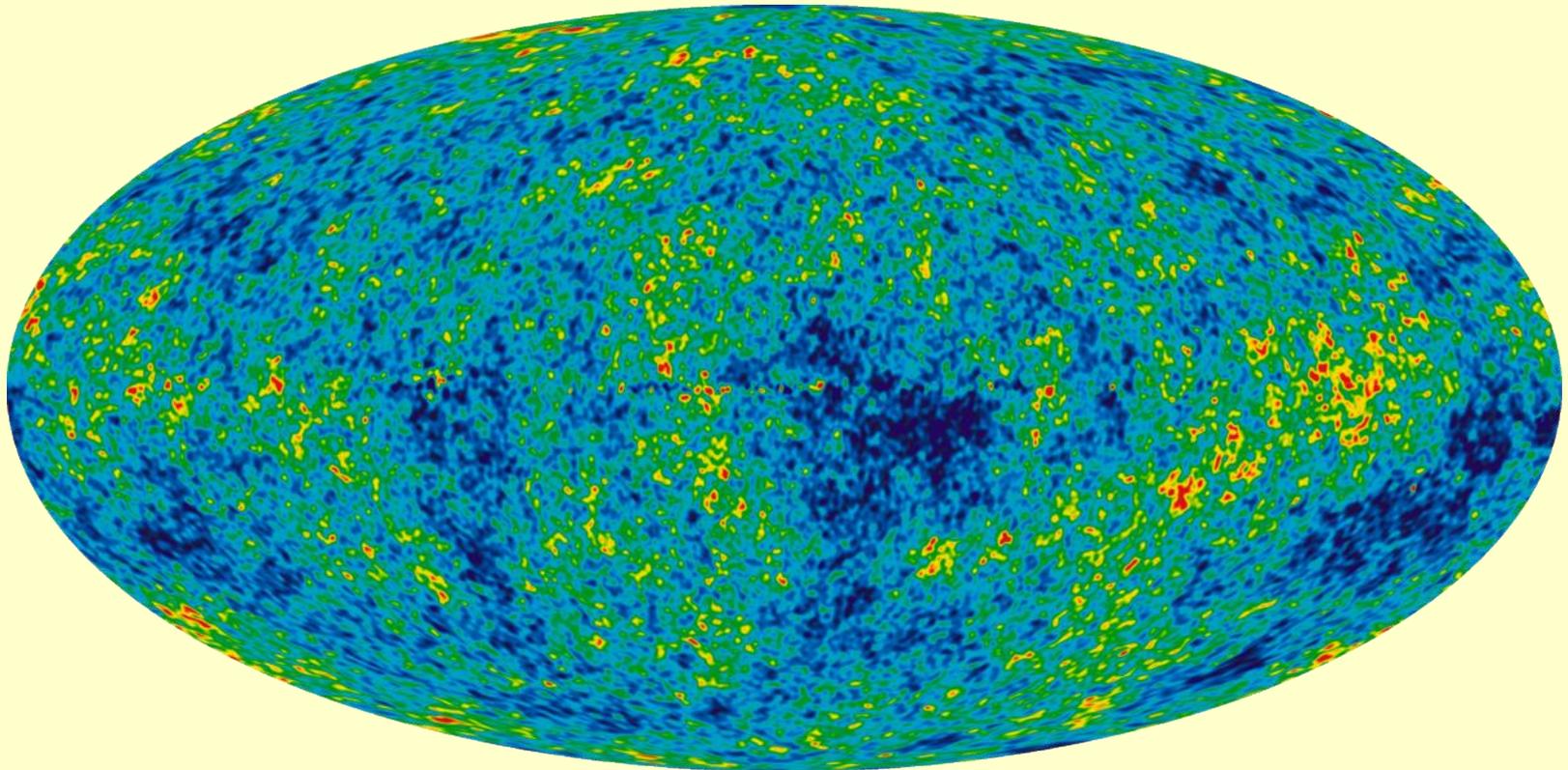
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This all-sky view provides a map of the Cosmic Microwave Background (CMB) radiation

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Absolutely!



PHYSICS
CLASS

$$E = m \cdot c^2$$

$$P = \frac{F}{A}$$

$$V = a \cdot t$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$



Cosmology