Early Universe

Professor Katherine Blundell OBE

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What Are Our Horizons? How Far Can We See?

Our horizons are of course determined by where we are and what is in the way of the distant objects we are trying to observe. Anything that is opaque to the light to which our human eyes are sensitive (trees, mountains, buildings) will limit our horizons. Cosmologically, our horizons are limited by similarly opaque blockages (the Earth itself, if we are not looking out to the skies) or intensive (arguably contaminating) sources of light such as the Galactic plane or other galaxies.

How Far Back in Time Can We See?

That rather depends on what is in the way. The oldest thing we can see from Planet Earth is the radiation that was emitted at the earliest times we are sensitive to. So, this is not from nearby objects such as the moon (the light we see when we look at the moon was reflected from it a mere three seconds prior to us looking it. When we capture an image of the sun with a suitably equipped telescope, we are imaging it as it was eight minutes earlier. As we look at increasingly distant objects in the night sky, for example the most distant galaxies, we are looking increasingly further back in time.

What Is the Oldest Thing We Can See from Planet Earth?

The first radiation to be able to traverse across the newly transparent Universe, following its expansion, has been travelling since about 300,000 years after the Big Bang. It is widely believed that the Big Bang happened nearly 14 billion years ago, so this radiation is almost that old (give or take 300,000 years).

How Do You Measure Cosmic “Relic Radiation” From the Earliest Times?

Careful attention needs to be paid to what might attenuate this radiation. The wavelengths at which this radiation is seen most strongly is centred around 1mm (and referred to as “microwave” radiation). At such wavelengths, a lot of attenuation/absorption can occur because of the molecules present in Earth’s atmosphere, specifically water. For this reason, a number of early observations of the cosmic microwave background radiation were made from balloons in dry places such as Antarctica. Modern measurements of the cosmic microwave background radiation have been made with satellites e.g. COBE, WMAP and Planck.

How Much Radiation Is There?

Rather a lot. The number of relic radiation photons in a cubic metre nearby Earth is a few hundred million.

What Does the Cosmic Background Radiation Look Like?

Whichever direction we look in the sky, after subtracting out “foreground emission” such as our own Galaxy and other galaxies, this background radiation is remarkably smooth and uniform. The uniformity of the temperature of this background radiation (close to 270 degrees below the freezing point of water) is remarkable. There are deviations in temperature, albeit subtle ones, which arise from local conditions in the primordial plasma that was the state of matter a few hundred thousand years after the Big Bang.

A Homogeneous and Isotropic Universe?

The high levels of uniformity in the observed cosmic background radiation are very much consistent with the notion that the Universe is homogeneous (the same at all points) and isotropic (the same in all directions). However, this is manifestly not the case on small size scales (a lecture theatre is very different from the desert; the interior of a star is different in density and temperature compared with a region in inter-stellar 2 space). Also, these observations do not preclude inhomogeneities and anisotropies on scales larger than those to which we are sensitive.

What Is The “Horizon Problem”?

The horizon problem is the observation that widely-separated parts of the Universe appear to be in thermodynamic equilibrium even though they cannot have been in causal contact according to the simple original version of the Big Bang model.

What Is Meant by The Expanding Universe?

Consider an array of galaxies, evenly spaced from one another, and then imagine each galaxy starts moving from its nearest neighbour at the same rate as one another. It follows that next-but-one neighbours will move apart at twice that rate, and next-but-two neighbours will move apart at three times this rate. The proportionality between the distance a galaxy is from us and the speed it recedes from us is a strong indicator that the gaps between the galaxies are expanding and, overall, their separation is expanding. It is the increasing separation of most of the galaxies from one another that is referred to as the expansion of the Universe (sometimes termed the Hubble expansion).

How Do We Know the Universe Is Expanding?

This is a straightforward measurement. Light from the gas in a galaxy is often observed via particular features in the spectrum known as emission lines. These distinctive features are observed to move to shorter or longer wavelengths if the galaxy is moving towards us or away from us respectively (this is the Doppler Effect). The shift in wavelength directly gives a measure of the speed of a galaxy relative to us. Apart from a few galaxies in the Local Group, almost all galaxies are moving away from us. The pioneering measurements were made by Vesto Slipher and systematically pursued by Edwin Hubble who identified the fact that the *further* away a galaxy is from us, the *faster* it is moving away from us.

What Determines Whether the Universe Will Continue to Expand or Collapse Back on Itself?

It depends on whether there is enough (or insufficient) gravitational pull to reverse (or not) the expansion.

Will The Universe Expand Forever?

Yes, probably.

What Is Meant by The Flatness – Or the Curvature – Of the Universe?

Flatness or curvature in this context refers to whether the geometry of the Universe, is “flat” (obeys Euclidean geometry, which is the kind we learned about at school) or otherwise (“curved”).

There’s A “Flatness Problem”…?

Yes. This is the problem that given the Universe is very close to being flat today, it would have had to be *extremely* close to being flat at much earlier times. Had circumstances been even a tiny bit different from this extremely limited value, then the Universe would be nowhere near being flat today. Inflation is a good thing (probably). Inflation (cosmological, not economic) was invoked as a solution to both the horizon problem and the flatness problem. It posits that there was an extremely brief period of accelerating expansion in the Universe that inflated regions of the Universe in local thermal equilibrium to size scales which are now expanded to way beyond the size of the observable Universe.

References and Further Reading

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