Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *The age of the universe.*

OK - so you know how the universe is 13.7 billion years old? The 13.7 billion figure is drawn from data collected by the Wilkinson Microwave Anisotropy Probe – or WMAP that's been looking out at the universe from Lagrange point 2 since 2001.

A quick review of the supporting literature for the 13.7 billion figure reveals the following statement (ahem). *Calculating the age of the universe is only accurate if the assumptions built into the models being used to estimate it are also accurate.* That's a not insignificant caveat to this whole ball game.

Don't get me wrong, 13.7 billion years is probably ball park accurate, but some tweaking of the general model seems more-than-likely in the next five or ten years as new data from the Planck telescope come in – and maybe Hubble or even further analysis of data from the now retired WMAP might yet spit out something new.

Leaving WMAP to one side for a moment - a ball park estimate of the age of the universe can be constrained by estimating the age of old stars. In this context, we generally look to globular cluster stars in the Milky Way – which probably are the oldest stars in the galaxy. It's thought that the same stars in the same cluster formed at the same time so there's a good collection of data points available on the luminosity and spectroscopy of those stars. It turns out that the oldest globular clusters in the Milky Way, like M92, are composed of small and hence long-lived stars - being about 0.7 solar masses each and at an evolutionary stage that means they must be between 10 and 20 billion years old.

Now, that's a fairly rough estimate with big margin of error. If we more tightly constrain this estimate with some, well, assumptions - we can narrow it down to between 12 and 16 billion years. Then 13.7 fits neatly in the middle of that – but really all we want from star age estimates is a lower limit for the universe's age – since it can't be younger than the stars it contains. So, by this logic, the universe definitely can't be younger than 10 billion years – and maybe it can't be younger than 12 billion years.

The value of the globular cluster data is that it's drawn from some fairly local objects in the Milky Way and the underlying calculations are based on the data-rich and very reliable Herzsprung-Russell diagram of stellar evolution. There are plenty of other old stars elsewhere in the universe – as well as quasars and other ancient objects - which being very distant, are potentially much older for that reason.

Gamma Ray Burst or GRB 090429B observed in April 2009 currently holds the record for the most distant and most ancient object observed. It may have been a supernova event – and whatever it was, it's estimated to have happened more than 13 billion years ago. But once we try to estimate the age of something that's very distant a collection of assumptions about the universe's density, curvature and expansion rate have to come into play, which are really the same assumptions that complicate the WMAP estimate.

WMAP maps the cosmic microwave background - or the CMB - across the whole sky to a resolution of 13 arc minutes. From there, it’s largely a matter of using redshift as a measure of distance – since the further light has travelled, the older it’s point of origin is. The point of origin of the cosmic microwave background is called the surface of last scattering.

When the universe was about 380,000 years old, the first atoms formed from what was previously a broiling plasma – and suddenly the universe became transparent to radiation so that light could move long distances – whereas previously photons had just been continuously emitted and then re-absorbed (that is scattered) by the broiling plasma. Those first real light rays, the CMB, were emitted but not immediately reabsorbed. So, whatever last emitted it – presumably a collection of very hot ions and electrons – is hence the surface of last scattering.

And in an expanding universe we are currently rushing away from that surface – just like we are rushing away from distant galaxies. But being one unprecedented and never repeated flash of light emitted by the entire universe, the CMB continues to pervade every part of the universe – unlike the flash of light from a single point source, like a supernova. So even though it really was emitted from a surface and at a particular point in time, it’s never really going to move ahead or beyond us like a wave front, because the same entire universe that once emitted it - is the one that we now live in now.

Anyhow... we pretty much know what that temperature was at last scattering – since we can replicate plasma recombination processes in a laboratory. So, the change from that initial universal 3000 Kelvin temperature to the current 2.7 Kelvin of the CMB – is a result of red shift, which gives us the distance and hence the time since the last scattering event occurred.

The timing of all the events that preceded the last scattering event is largely derived from particle accelerator experiments and quantum physics calculations which determine the temperatures and the densities and hence all the steps and the time frame over which the universe got big enough and cool enough to release the CMB.

Then, going forward from the CMB – is pretty much all about Einstein field equations. As well as temperature data, WMAP provides data about the shape of the universe since it maps the CMB across the whole sky. So, if some of it was hotter and hence closer than other bits, it would suggest the universe is either curved outwards or curved inwards. But it’s not, which is why we say that universe is spatially flat. And this is a key finding for the age estimate – since a curved in (or closed) universe would have begun more recently and a curved out (or open) universe would have begun longer ago than our apparently flat one.

So to recap you just have to measure the current temperature of cosmic microwave background , the CMB, since you can see now just how much it's been red-shifted , that is stretched, by the expansion of the universe. Then you can just use your Einstein Field Equations to calculate how the universe has expanded to produce that red shift - because once we can quantify the expansion, we know how long the expansion has been taking place. Then you just add on the extra 380,000 years that it took for the Big Bang to release the CMB and voila you get 13.7 billion years, the age of the universe.

But again, to get an age estimate from an expansion rate, you still need to account for changing energy density and space-time curvature over the evolution of the universe – and the figures we have for these are based on major assumptions about the homogeneity of the universe, dark energy and the equally mysterious early cosmic inflation, required to explain why the universe is homogenous.

The fact that various currently favoured assumptions are mutually supportive of a particular cosmology model is arguably just a case of selection bias – particularly when that model includes something as strange as dark energy, because...(*Han Solo*). But hey, age-wise 13.7 billion is definitely in the ball park.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website helping you enjoy cheaper thought experiments. No ads, no profit, just good science. Bye.