Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Critical density.*

Well, they do say if you don't understand something – you should go and do a podcast about it. Some recent murmurings about anomalous Type 1a supernova observations have raised questions about the reliability of Type 1as as standard candles for measuring cosmic distances and cosmic expansion. So far the answer is that they are still pretty darn reliable – and a couple of outliers don't justify dumping an otherwise very consistent principle.

Measurements of the red-shifts of distant Type 1a supernovae back in 1998 was the first hint that the universe was not only expanding, but expanding at an accelerating rate. But really the reason this line of thinking has gained such a strong foothold is that, around the same time the supernova data was announced, other lines of evidence were coming in that supported the same viewpoint.

Most importantly is the cosmic microwave background, as measured by the WMAP spacecraft and its predecessors. This data tells you about the geometry of the early universe, when it was nearly 400,000 years old and first became transparent to photons. What we find is that the cosmic microwave background is almost isotropic – meaning that everything visible or otherwise detectable is very evenly spread across the whole universe. This was the case 13 billion years ago and still seems to be the case today.

This finding confirms a fundamental assumption of what are called the Einstein field equations, which require that the universe first be isotropic in order to make further sense of it through mathematical modelling. Prior to 1925, Einstein modelled the universe as static, by presuming a cosmological constant called Lambda – which countered the tendency of the mass-energy contents of his modelled static universe to collapse inwards under its own gravity.

Of course, all that went out the window in 1925 with Hubble's finding that the universe was expanding – driving Einstein to say the cosmological constant was his biggest blunder – since the very fact that the universe hasn't collapsed in on itself perhaps should have led him to consider that we must therefore live in an expanding universe.

Given a universe that is expanding outwards, then either the expansive momentum of its energy-mass contents should be strong enough to overcome any backward drag of gravity – or it won't be strong enough to counter gravity and everything will collapse back down into a big crunch, or a gnab gib if you prefer.

What matters here is what's called the critical density. If your universe has a particular size, you can estimate how much energy-mass contents it will need to either expand forever or otherwise collapse back down in on itself – and that tipping point is called the critical density.

Prior to gaining the WMAP data, initial estimates from sky surveys and early microwave background measurements – suggested the energy-mass contents of the universe was only 4% of the critical density and hence the universe should expand forever.

But the energy-mass contents of the universe also has a fundamental effect on the shape of the universe. If the actual density is above the critical density – the universe should be a convex, spherical shape – and if the actual density is below the critical density we should have a concave hyperboloid universe – and if the actual density is the same as the critical density, then the universe should be flat.

This is where you hear people going on about the three angles of a triangle – where they either add up to 180 degrees in flat Euclidean space, add up to more than 180 degrees when you map a triangle onto a convex surface in a spherical universe – or add up to less than 180 degrees when you map a triangle on a concave surface in a hyperboloid universe.

WMAP was apparently unable to detect much curvature one way or the other, because everything observable followed Euclidean geometry and so hooray it seems we live in a flat universe. But how can we account for the universe being flat – if its visible and detectable contents is only 4% of the critical density required to keep it flat – and of course the answer is dark stuff.

Published in 2010, the Wilkinson Microwave anisotropy probe seven year analysis gave an estimate of 72.8% dark energy, 22.7% dark matter and 4.6% baryonic (or ordinary) matter.

This is the current model for the universe, which is sometimes referred to as the Lambda – CDM model. CDM stands for cold dark matter, while Lambda is borrowed from Einstein's field equations, being the term originally posed for the hypothetical cosmological constant, but now representative of the outward push or negative pressure invoked by dark energy.

Compelling evidence for dark matter come from observations of spinning galaxies, which really should fly apart if the only thing gravitationally holding them together is visible matter – as well as galactic clusters and super-clusters which shouldn't really cluster at all unless there is some invisible stuff holding them together.

Cosmic microwave background data collected by WMAP also provides evidence, quite independent of type 1a supernova, to support the proposed accelerating expansion of the universe – and by implication, dark energy. This relates to a WMAP finding called the *Late Time Integrated Sachs Wolfe Effect*.

The WMAP data suggests that photons are red-shifted after moving through large empty voids of space, but blue-shifted after moving across large scale gravity wells, such as those generated by galactic superclusters.

These effects can be explained if the universe is undergoing an accelerated expansion and those gravity wells are being stretched and flattened over the time it takes a photon to cross the well – since a photon gains energy falling into a gravity well, but ends up not losing all that energy climbing back out, because the well has flattened over that time period. Alternatively, when a photon crosses a great void in space, it's a bit like climbing a hill where it loses energy climbing up but then doesn't get all that energy back coming down the other side because the 'hill' has been stretched and flattened over that time period.

So OK, it is all a bit patchy and hypothetical – but this is characteristic of an area of science where the theorists are working way out ahead of the limited observational data that's available with current technologies.

It's possible all this dark stuff may explained away in the future, a bit like how Einstein explained away the need for luminiferous ether by invoking relativity theory. Alternatively, the next generation of cosmic microwave background detecting spacecraft may reveal a whole new picture to interpret. But for now no-one should give up on those Type 1a supernova just yet.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website helping you keep your cosmic balance sheet in order. No ads, no profit, just good science. Bye.