Hi this is Steve Nerlich from Cheap Astronomy, www.cheapastro.com and this is *One crowded second.*

This is the first of two podcasts on the timeline of the Big Bang and subsequent events in the formation of the cosmos.

Zero – the Planck epoch

Any period up to 10 to the power minus of 43 of a second is a Planck unit of time, essentially the smallest unit of time there can be – meaning that it's indivisible. So there's no point talking about a sequence of events taking place in a unit of Planck time – since you can't say in the first half of the Planck unit this happened and in the second half of the unit that happened. There isn't really enough time for anything to happen. So, let's just say that in the Planck epoch a potential universe sat poised and ready.

Ten to the power of minus 43 seconds – the grand unification epoch

Suddenly, something happened. Quantum physics suggests that gravity split out from the other fundamental forces - the strong, weak and electromagnetic forces - which still remained in a state of unified equilibrium. General relativity, preferring to maintain that there is no such thing as a force of gravity, suggests that a singularity began to unravel into space-time. A yet to be articulated theory of everything would presumably say both those things, but perhaps in a whole different way.

In any case, from here, both space and time begin to mean something as the primordial universe begins to occupy a larger volume in a progressively sequential manner – or to put it another, it begins to expand over time.

Ten to the power of minus 36 seconds – the electroweak epoch

Expansion reduces the energy density of the still utterly tiny primordial universe, which means it begins to cool sufficiently to break the symmetry (or the previous state of unified equilibrium) of the strong, weak and electromagnetic forces.

The strong force separates first - which is hypothesised to coincide with an also hypothesised cosmic inflation. And it's, well, hypothesised that this is something analogous to a phase transition.

For example, at the moment a pond of water in liquid phase freezes into a pond of ice in solid phase, there is a detectable release of energy called latent heat.

So, it's hypothesized that the splitting off the strong force from the remaining unified forces is analogous to a phase transition resulting from the ongoing cooling of the primordial expanding universe – and a preposterously large amount of expansive energy, roughly analogous to latent heat, is produced.

Or, to put it another way (*makes explosion sound*)

Ten to the power of minus 35 seconds – the inflationary epoch

In this epoch, the latent heat type of expansive energy, also known as negative-pressure vacuum energy – increases the volume of the universe at an exponential rate. Indeed in this period it seems clear that space-time expanded at a rate exceeding speed of light – which is OK since the rule is that you can't move through space-time at a velocity exceeding the speed of light. No-one said anything about how fast space-time could move.

By 10 to power of minus 34 seconds, it's thought the radius of the universe expanded from ten to the power of minus 50 meters up to 1 full metre and kept going from there. By ten to the power of minus 32 seconds, exponential inflation was petering out, but by then the universe was becoming truly cosmic in scale.

It's this sudden explosive expansion that is thought to have given the universe the qualities it possesses today, which are that it is isotropic and flat. Isotropic means it looks pretty much the same everywhere you look – indeed when you measure the cosmic microwave background, its temperature is pretty much the same everywhere you look. Flat means that it's spread out wide, kind of like a spread-out tablecloth, except not really. There's some great Astronomy Cast episodes in this area if you enjoy hearing people trying to explain hyperspatial geometry in plain English.

Quantum physicists enjoy explaining everything in terms of particles and so propose that cosmic expansion was driven by inflatons – indeed an inflaton scalar field, which is what underwent the phase transition mentioned earlier, reducing to a lower (almost zero energy state) and as a consequence releasing gargantuan amounts of energy, which becomes the current energy-mass content of the universe – being all that heat and light and stars and galaxies and stuff.

As well as inflatons, other exotic – and as yet undetected - particles such as the Higgs boson are thought to appear in this epoch. There is some anticipation that the Large Hadron Collider will be able recreate energy densities equivalent to the state of the universe at the end of cosmic inflation and perhaps identify the Higgs boson.

Ten to the power of minus 32 seconds – the desert epoch

There's bit of as pause immediately after the end of inflation when the energy density of the universe is still too high for anything new to form out of it, although it is still expanding and hence also cooling. If you want make a coffee or something, this is a good time to do that.

Ten to the power of minus 12 seconds – the quark epoch

From here we begin to move into the better understood territory of a primeval universe composed of particles that can be recreated in today's particle accelerators.

Needless to say, in the quark epoch, there are lots of quarks – as well as some leptons (like electrons and neutrinos), gluons (which mediate the strong force), w and z bosons (which mediate the weak force) and photons (which mediate the electromagnetic force). Essentially everything that builds our current universe had come into existence, but the universe was still too hot and dense and all these particles are in a state of constant interaction and thermal equilibrium. But remember, the universe is still expanding and cooling – so…

Ten to the power of minus 6 seconds – the hadron epoch

Suddenly the universe is cool enough for neutrinos to decouple from the rest of the interacting plasma and begin to move freely through the universe at almost the speed of light, which is what they proceed to do – creating the, as yet undetected, cosmic neutrino background.
Also, it is cool enough for hadrons to begin to form from quarks by becoming bound together by gluons (which mediate the strong force). However, most of them don't last long as roughly equal numbers of hadrons and anti-hadrons form and begin to annihilate each other, by the end of which, only a small residue of hadrons, including some familiar protons and neutrons, remain.

And that is the first second (*exhale*).

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where cheapness is a cosmological constant. No ads, no profit, just good science. Bye.