Snappy Answers to Rather Profound Questions 1: Physics

This resource sheet provides teachers with some considered answers to questions that can arise when discussing the Big Bang. Such questions should be encouraged as the students are trying to get to grips with very profound ideas. In this sheet, we focus on matters directly related to the physics involved.

Where is the centre of the universe?

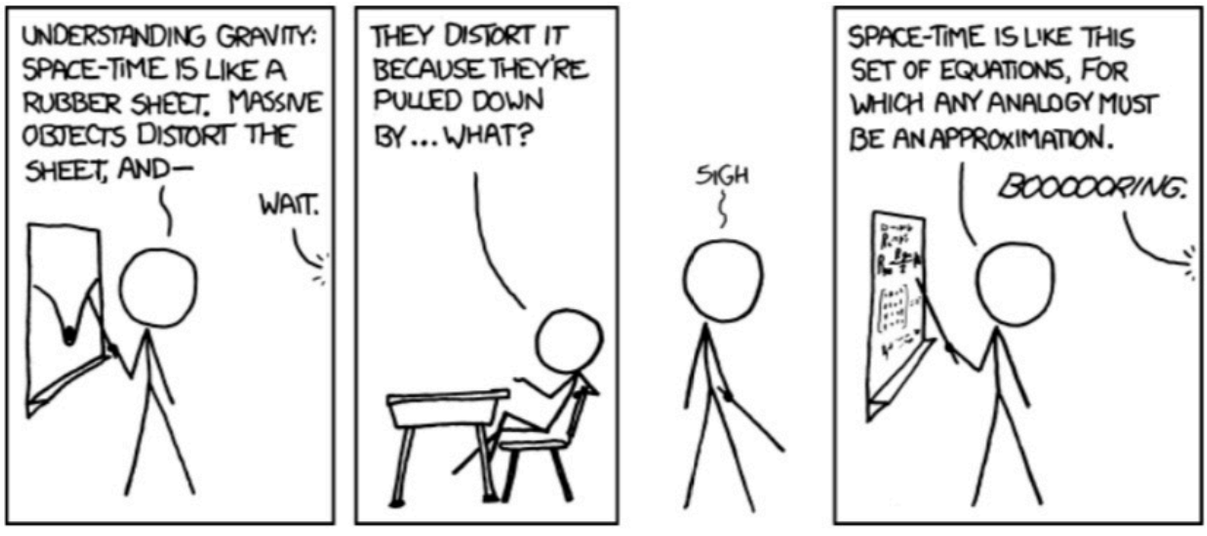
While this is a very natural, and hence common, question it is actually based on a misunderstanding of the Big Bang and the nature of the universe. Either the universe is *infinite* (goes on for ever), in which case any point in the universe can be called the centre (any choice is as good, or as bad, as any other), or it is *finite* but *unbounded* (like the *surface* of a football, to use a two-dimensional analogy) in which case any point is also as good as any other. Unbounded means that you can set off in any direction, and eventually end up where you started from (as you would by sliding over the surface of a football).

1. ### Does the universe have an edge/end?
   This is similar to the first question and has a similar answer. If the universe goes on forever, then there is no edge (hard as that might be to imagine). If the universe is finite, then it is also closed and hence unbounded, like the surface of a football. In this case, there is no edge either.

2. ### Where did the Big Bang happen?
   This question can also be linked to the first and can come as a follow-up. Students are still trying to visualise what might be the centre, as the point where the Big Bang happened. Despite the name, the Big Bang was not an explosion in the conventional sense. When a normal explosion goes off, there is a point at which it happens and a surrounding space into which all the bits fly. As the Big Bang was the start of the universe, there would be no surrounding space for any 'bits' to fly into. Think of it this way, the universe is all the matter and the space that it occupies. If there were any space before the Big Bang, then this space would not have been created in the Big Bang, which would mean that it was not the origin of the universe (where did the space come from?). There was no space or time as we experience them now, before the Big Bang (of course, if there was no time, what do we mean by *before*?). Stephen Hawking used the question 'what is North of the North Pole?' as an illustration of the issues – if you stick to walking over the surface of the Earth, then by definition there is nowhere North of the North Pole. Equally, if time and space are created at the Big Bang, then there is no one place where it happened and no when before it happened. The best answer to where the Big Bang happened is 'everywhere at the same time'.

3. If space is mostly nothing, how can 'nothing' get bigger?

When you are trying to imagine something very difficult, it is natural to look for various analogies to help out. The problem is that these analogies are limited and can convey the wrong ideas as much as they help.



(image credit: XKCD)

One common analogy used for the expansion of the universe, is stretching a rubber sheet. The problem is that the rubber sheet is a physical material that is being stretched. Sometimes the account alludes to a large ball resting on the sheet and distorting the surface, which is supposed to represent the distortion of space-time that is gravity. The problem is that gravity is pulling the ball down into the sheet! Students get worried by such things. In truth, imagining space *itself* stretching is quite a leap of imagination and there is no totally accurate comparison that can be made.

A common technique in science is to use models, analogies and pictures to capture the essence of reality. The most useful tool for doing this has proven to be mathematics. However, this often means that the 'pictures' used to try to convey the mathematics to non-experts are not always consistent with each other, never mind being less than fully accurate.

4. What is the universe expanding into?

When a conventional explosion takes place, it detonates at a specific point and there is some volume surrounding it into which the bits can fly. To think of the Big Bang and the expansion of the universe as being like an explosion implies that there must be a volume of space into which the universe is moving (previously empty space that is slowly being filled with galaxies). This is not what the mathematics tells us.

The Big Bang happened *everywhere* in the universe *at once*. The universe is a self-contained thing: we have no access to anything that may be 'outside' of it. If the universe were two-dimensional, then it might be stretched over the surface of a

balloon. Any flat creatures living in such a universe would have no access to the inside of the balloon nor the volume of space in our 3D universe surrounding the balloon. If we were to inflate the balloon, they would be able to verify that their universe was getting bigger, but would not experience a 'space' into which it was expanding. In the case of our 3D universe, there might be a '*higher dimensional "space"*' in which we are embedded, but we would never have access to it as it would lie outside our dimensionality.

5. **If the universe is expanding, why am I or other things not getting bigger?**
The electrical forces acting between atoms are strong enough to resist the expansion of the underlying space. A spot of paint on a piece of rubber will stretch as the rubber is stretched; however, a piece of blue-tack stuck to the rubber will resist most of the stretch as it has internal forces holding it together. Equally, planets, stars and galaxies have gravity to hold them together. It is only in the vast empty distances between galaxies that we can see the expansion of the universe taking place.

6. **What happened before the Big Bang?**
Time was created with the Big Bang, so there is no time for a 'before' to happen in. Equally, it is hard to give any sense to a 'moment' of creation. St. Augustine was the first to contemplate the creation of the universe in such terms: *'It is idle to look for a time before creation, as if time can be found before time. If there were no motion of either a spiritual or corporeal creature by which the future, moving through the present, would succeed the past, there would be no time at all … we should therefore say that time began with creation, rather than that creation began with time'.*
St. Augustine is pointing out that we experience time via the changes that take place in objects. So, if there are no objects, you can't give a meaning to the passage of time. This argument certainly works if we make an identification between time as we measure and experience it within the universe and time as an abstract concept. However, science is a long way from an understanding of time.

7. **What caused the Big Bang?**
The web of cause and effect is embedded within the universe as we experience it. Take the universe away, and it is not at all clear that the notion of 'cause' has any meaning. As a result, it is possible that the universe has no cause. In a wider view, the Big Bang is clearly governed by laws of nature. These must have pre-existed the universe in some fashion, but here we are speculating about a mode of existence that we do not experience.

8. **How big is the universe?**
The universe that we observe with our telescopes extends in all directions for about 14 billion light years. This is the *visible universe*. The actual universe may well be considerably bigger. As we think that the universe is about 14 billion years old, we can't see any further than the distance that light can travel in this time. Potentially the universe could be infinite in extent.

9. How can something infinite get bigger?

When we think of something getting bigger, we tend to picture the ends of an object getting further away from each other. Something infinite, of course, has no ends, so that picture does not work. A better visualisation would be a series of beads threaded onto a string that extended into the far distance. If the string gets stretched, then the beads get further apart all along their length. This is the sense in which the universe gets bigger, the scale of distance between objects is expanding. Of course, the string/beads picture is in the end limited, as any real string has to have ends.