BIG BANG SINGULARITY AS A METRIC ARTEFACT

Jan-Åke Schweitz, Dept of Engineering Sciences, Uppsala University, Sweden

'Metric' is a broad concept. In our limited context it is a way of defining 'distance' between two points in 3-dimensional space or between two events in 4-dimensional spacetime. There is no unique way of defining the metric of spacetime. A metric is not a 'natural' property of any space; it is a feature given by us, usually for practical reasons. We are free to choose another metric anytime we find it appropriate – just for the sake of convenience.

This freedom can be illustrated by a very simple example. The shape of a banana can be described in two ways; either as a bent body in straight space or a straight body in bent space. Which way one chooses is a matter of convenience. Both ways are correct and equivalent.

This is what Einstein did when he generalized his flat-metric theory of Special Relativity into curved-metric General Relativity. By changing the metric representation of spacetime he found a new and elegant way of expressing gravity, not easily achievable in flat-metric theory. This is a great achievement, which however easily may lead to misconceptions. It is often said that gravity 'curves spacetime' and that a freely moving particle 'is compelled to follow the curvature' of spacetime – as if there exists a compelling physical interaction between the particle and spacetime. No such interaction exists. Einstein's field equation is just an aid to adapt our choice of local metric to the local energy-momentum contents (and to Newton's law of gravity through the correspondence principle), with the practical result that particles follow the curved geodesics of spacetime in free fall. Hence this metric is purposely designed by Einstein to eliminate forces in curved motion. This metric is *not* a compelling fact of nature. In flat metric exactly the same curved motion occurs due to non-vanishing gravitational forces. Both metric representations are correct and equivalent.*

In the standard expansion theory of cosmology (the ΛCDM theory) the choice of spacetime metric is of profound consequence to the interpretation of the primordial Big Bang singularity. The metric of choice is the FLRW metric, which is an exact solution of Einstein's field equation in the case of homogeneous and isotropic expansion (or contraction) of the universe. In this metric, the spatial part is made time-dependent by the scale factor $a(t)$, ranging from $a(0) = 0$ to $a(\infty) = \infty$, meaning that any choice of volume unit initially is zero (initially being proportional to $a(0)^3$). This, in turn, means that the density of the cosmic medium (the amount of medium per volume unit) at the defining instant must be infinitely high. *Hence the Big Bang singularity is not some physical abnormity, but a consequence of our choice of spatial metric.*

Had we chosen a metric where $a(0) \neq 0$ we would have no Big Bang singularity. But is this possible, given that the expanding universe is an observed fact, and that Einstein's field equation in that case indicates $a(0) = 0$? Yes, it is possible. It is frequently pointed out in the literature that the field equation probably is not valid in the limit $t = 0$. Furthermore, another cosmological model exists, allowing of solutions with $a(0) \neq 0$ [1].

Hence the Big Bang singularity should be seen as a *metric* artefact rather than a physical model artefact.

*In 1919 Eddington found that photons passing close to the Sun were deflected more than predicted by Newton's orbital mechanics, but in agreement with the prediction of Einstein's theory of General Relativity. This is due to the fact that in General Relativity a photon is *postulated* to travel at constant speed of light *c* along the full length of the trajectory, while in Newton's orbital mechanics the photon is accelerated to superluminal speed as it passes close to the Sun, and then is decelerated back to the initial speed of light *c* as it leaves the Sun. Hence Einstein's photon spends longer time than Newton's photon in the field of gravity, and therefore is more deflected. This difference has nothing to do with our choice of curved or flat metric, but rather is a consequence of Michelson-Morley's speed limit for light being postulated in General Relativity but not in Newton's theory.

[1] Schweitz, J-Å, 2014, *Does the Planck unit system relate to a non-singular primordial universe?,* DiVA archive: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-247245