Ontology of Gravitational Singularities

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Ontology of Gravitational Singularities

Peter Bokulich and Erik Curiel (Curiel and Bokulich 2018) assert that general relativity (GR) allows singularities, and that we need to understand the ontology of singularities if we want to understand the nature of space and time in the present universe. Although some physicists believe that singularities indicate a failure of GR, others believe that singularities open a new horizon in cosmology, with real physical phenomena that can help deepen our understanding of the world.

From the definitions of singularities, most known are the possibility that some spacetimes contain incomplete paths (most accepted), the missing points, and the pathology of curvature. A spacetime path is a continuous chain of events. The paths of the most important singularity theorems represent the possible trajectories of particles and observers ("world lines"). An incomplete and inextendible path assumes that, after a finite period of time, the subject of that path "goes out of the world", disappears; or vice versa, may emerge from nothingness. (Curiel and Bokulich 2018) Although there is no logical or physical contradiction in these situations,(Sfetcu 2018) the disappearance or sudden appearance of an entity in space-time is a "singularity." It is what can happen in the case of an incomplete and inextendible path of finite length and a finite existence interval. Peter Bokulich and Erik Curiel propose that, in order to achieve conclusive results, we will have to limit the spacetime class in question to spacetime that is *maximally expanded* (or only *maximal*).

Regarding the type of incompleteness of the path that is relevant to singularities, there is a lot of controversy. Geroch(Geroch 1968) demonstrates that a spacetime can be completely geodesic and still possess an incomplete temporal path of a limited total acceleration - meaning, an unparalleled traversable spacetime path along which an observer could only experience a finite amount of proper time. By exploiting this idea, Earman (Earman 1995, 36) combines it with the notion of "generalized affine length" to give a semiofficial definition of singularities: "A maximal spacetime is singular if and only if it contains an inextendible path of finite generalized affine length."

Many discussions about the singular structure of relativistic spacetime start from the idea that singularity is a point or a set of points that in some sense or else is "missing" from spacetime, that spacetime has a "hole" in it. Thus, Peter Bokulich and Erik Curiel suggest that we define a spacetime with missing points from it if and only if it contains incomplete and inextendible paths, and then try to use these incomplete paths to build points located properly in spacetime, making the paths extendible. These points would then be our singularities.

Many physicists and philosophers believe that GR needs such a construction, and a construction is currently being sought to give a clear ontological status to singularities as entities.

Ontology of black holes

Gustavo E. Romero considers spacetime as the emergence of the ontological composition of all events, being able to be represented by a concept. The source of the gravitational field in the GR equations, the tensor field T_{ab}, represents the physical properties of material things, the energy and momentum of all non-gravitational systems. In the case of a point mass M and assuming spherical symmetry, the solution of the equation is a Schwarzschild black hole. A black hole is conceived as a spacetime area disconnected causally from the rest of spacetime; what characterizes the black hole is its measure and hence its curvature. No events in this region can influence events outside the region. Events in the black hole are, however, causal due to past events, so a black hole is not a deviation from classical causality.

Determinism is an ontological assumption that all events are given. Determinism does not require causality and does not imply predictability. The current state of the Universe is the effect of its past and the cause of its future. Romero believes that GR assumes the existence of all events represented by a variety, so it is a deterministic theory from an ontological point of view, but still unspecified epistemologically. The existence of singularities in space-time does not imply a failure of ontological determinism, only a failure in predictability, but they are not the elements of spacetime itself.

Presentism claims that the future and the past exist only as changes that have taken place or will take place today and do not have a real existence. Eternalism implies that the past and the future exist in a real sense, not just as changes that have taken place or will take place today. Presentism is incompatible with the existence of singularities. (Romero 2014) In this sense, Romero argues that black holes can be used to show that presentism gives a faulty image of the ontological substrate of the world.

The hole argument

The hole argument[1] first appeared in Einstein's work on general relativity in 1913. The hole argument exploits a property of GR, its general covariance. Substantivists consider that the variety of events has an existence independent of the fields defined therein; events have their identities irrespective of metric properties, so the difference between spacetimes is a real physical difference, although nothing observable distinguishes the two spacetimes. Moreover, all the differences appear only inside. This is considered by John D. Norton(Norton 2012) a serious failure of determinism; the hole may be specified as small, and no spacetime specification outside the hole can fix the properties inside. It follows that the differences between the two spacetimes are only differences in the mathematical description, both describing the same physical reality. Norton concludes that a substantivalism of the manifold is inconceivable.

There are no singularities

Singularities are usually considered to be a deep defect of GR. Singularities can lead to determinism failures, as laws "break down" in a certain sense. Christopher Smeenk and George Ellis (Smeenk and Ellis 2017) state that this concern applies only to certain types of singularities. Relativistic spacetimes that are hyperbolic globally have Cauchy surfaces, and the corresponding initial data on these surfaces fixes a unique spacetime solution. The threat to determinism is more

[1] In a common field equation, knowing the source of the field and the boundary conditions determines the field everywhere. However, they do not determine the vector potential. Einstein found that if the gravitational equations are generally covariant, then the metric can not be determined uniquely by its sources as a function of spacetime coordinates. Some philosophers of physics call for argument to raise a problem of manifold substantiality, according to which the manifestation of events in space is a "substance" that exists independently of the metric field defined on it or its matter. Others consider the argument to be a confusion in terms of gauge.

qualified: laws do not apply to "singularity itself", even if the subsequent evolution is completely deterministic and there are some types of singularities that more seriously threaten determinism. The presence of singularities determines that GR is incomplete. The presence of a singularity in a cosmological model indicates that spacetime, as described by GR, ends: there is no way to expand spacetime through singularity without breaking the mathematical conditions necessary to ensure that field equations are well defined. Any description of “'before the big bang' must be based on a theory that supersedes GR and allows for an extension through the singularity."

Gustavo E. Romero argues that there are no physical singularities in space-time. Singular models with spacetime do not belong to the world's ontology, because they are defective solutions of Einstein's field equations. The complexity of the non-linear equations of the field, and the interpretation of the metric tensorial field, have led to concerns about the ontological hypotheses of the theory. The spacetime concept was introduced by Minkowski (1908) and belongs more to ontology than to physics. A formal spacetime construction can be obtained from an ontological basis of each thing (Bergliaffa, Romero, and Vucetich 1997) or events.(Romero 2013). Romero starts from the underlying ontological hypothesis that spacetime is the ontological composition of all events, so an emerging entity represented by a concept.

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