Chapter 22

All times are now: black holes and presentism

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Abstract Presentism is the metaphysical doctrine that whatever exists, exists in the present. The compatibility of presentism with the theories of special and general relativity has been much debated in recent years. It has been argued that at least some versions of presentism are compatible with time-orientable models of general relativity. In this paper we confront the thesis of presentism with relativistic physics, in the strong gravitational limit where black holes are formed. We conclude that the presentist position is at odds with the existence of black holes and other compact objects in the universe. A revision of the presentism thesis is necessary, if it is intended to be consistent with the current scientific view of the universe.

Introduction

Presentism is a metaphysical thesis about what there is. It can be expressed as [1]:

Presentism. It is always the case that, for every x, x is present.

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The quantification is unrestricted, it ranges over all existents. In order to make this definition meaningful, the presentist must provide a specification of the term 'present'. Crisp, in the cited paper, offers the following definition:

Present. The mereological sum of all objects with null temporal distance.

The notion of temporal distance is defined loosely, but in such a way that it accords with common sense and the physical time interval between two events. From these definitions it follows that the present is a thing, not a concept. The present is the ontological aggregation of all present things. Hence, to say that 'x is present', actually means that "x is part of the present".

In what follows we shall review the main objections posed to presentism in the framework of both relativities, special and general, and then we shall move on to consider a new type of argument based on the existence of compact objects in the universe. We shall show that the presentist cannot accept the standard physical understanding of these objects, without introducing changes in his ontological views or rejecting current astrophysics.

Presentism and general relativity

Thomas Crisp [2] has proposed a "presentist-friendly" model of general relativity. He suggests that the world is represented by a 3-dimensional space-like hypersurface that evolves in time. This interpretation requires to introduce a preferred foliation of usual space-time, and to consider the $3+1$ usual decomposition for the dynamics of space-time in such a way 'the present' is identified with the evolving hypersurface, as ilustrated in Fig. 22.1.

In order to formulate such a model for space-time, some global constraints must be imposed: there should be a possible foliation into Cauchy hypersurfaces in order to allow for global time-like continuous vector fields that can be used to introduce a "global time coordinate". This is the case, for instance, for the Friedmann-Robertson-Walker-Lemaître metric. General conditions for such a metric requires the absence of Cauchy horizons and the fulfillment of the so-called *energy conditions* [3].

Although a case can be made for general inhomogeneous metrics and massive violations of the energy conditions on the basis of recent cosmological data [4], in what follows we shall focus on local aspects that should be accommodated in any cosmological model compatible with current astrophysics.

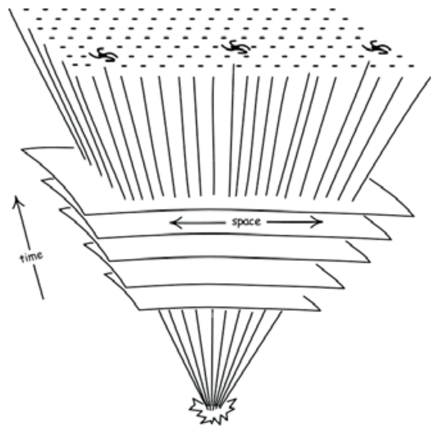

Fig. 22.1 Evolving 3-dimensional space-like surfaces in a space-time with a preferred time-direction.

Black holes and the present

The simplest type of black hole is described by the Schwarzschild metric; this metric characterizes the geometry of space-time outside a spherically symmetric matter distribution. The Schwarzschild metric for a static mass M can be written in spherical coordinates (t, r, θ, ϕ) as:

$$ds^2 = \left(1 - \frac{2GM}{rc^2}\right) c^2 dt^2 - \left(1 - \frac{2GM}{rc^2}\right)^{-1} dr^2 - r^2(d\theta^2 + \sin^2\theta d\phi^2). \quad (22.1)$$

The radius

$$r_{\rm Schw} = \frac{2GM}{c^2}, \quad (22.2)$$

is known as the *Schwarzschild radius*. It corresponds to the event horizon when all the matter that generates the curvature is located at $r < r_{\rm Schw}$.

The light cones can be calculated from the metric (22.1) imposing the null condition $ds^2 = 0$. Then:

$$\frac{dr}{dt} = \pm\left(1 - \frac{2GM}{r}\right), \quad (22.3)$$

where we made $c = 1$. Notice that when $r \to \infty$, $dr/dt \to \pm 1$, as in Minkowski space-time. When $r \to 2GM$, $dr/dt \to 0$, and light moves along the surface $r = 2GM$, as shown in Fig 22.2. The horizon is therefore a *null surface*. For $r < 2GM$, the sign of the derivative is inverted. The inward region of $r = 2GM$ is time-like for any physical system that has crossed the boundary surface.

There is a very interesting consequence of all this: an observer on the horizon will have her present *along* the horizon (see Fig. 22.3). All events occurring on the horizon are simultaneous. The temporal distance from the observer at any point on the horizon to any event occurring on the horizon is zero (the observer is on a null surface $ds = 0$ so the proper time interval is necessarily zero). If the black hole has existed during the whole history of the universe, all events on the horizon during such history (for example the emission of photons on the horizon by infalling matter) are *present* to the observer on the horizon. These events are certainly not all present to an observer outside the black hole. If the outer observer is a presentist, she surely will think that some of these events do not exist because they occurred or will occur either in the remote past or the remote future. But if we accept that what there is cannot depend on the reference frame adopted for the description of the events, it seems we have an argument against presentism here.

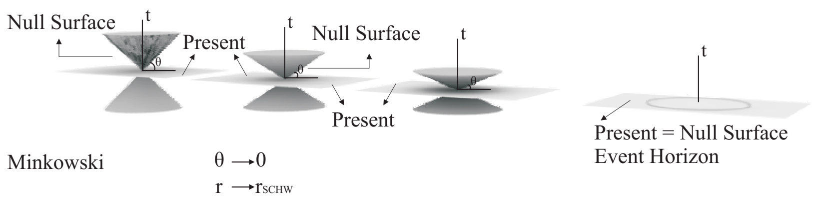

Fig. 22.2 The closer the light cones are to the event horizon, the smaller the angle between the cones and the surface of the present. In the event horizon, both surfaces coincide.

Ontological implications

In a world described by special relativity, the only way to cross a null surface is by moving faster than the speed of light. As we have seen, this is not the case in a universe with black holes. We can argue against presentism along the following lines.

Argument $A1$:

- $P1$: There are black holes in the universe.

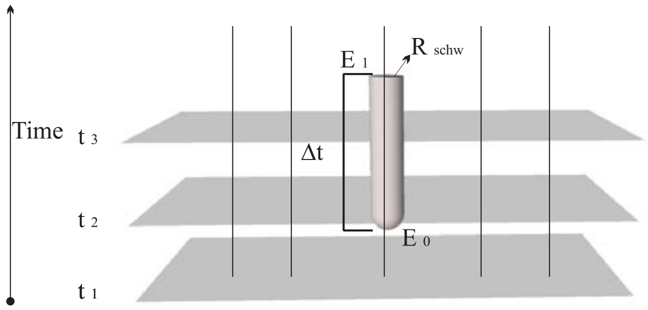

Fig. 22.3 Foliation of a temporally-oriented space-time with a black hole. All the events occuring on the horizon are simultaneous, such as E_0 (birth of the black hole) and E_1. Outside the black hole, these two events have a non-zero temporal distance Δt.

- *P*2: Black holes are correctly described by general relativity.
- *P*3: Black holes have closed null surfaces (horizons).
- Therefore, there are closed null surfaces in the universe.

Argument *A*2:

- *P*4: All events on a closed null surface are simultaneous with any event on the same surface.
- *P*4*i*: All events on the closed null surface are simultaneous with the birth of the black hole.
- *P*5: Some distant events are simultaneous with the birth of the black hole, but not with other events related to the black hole.
- Therefore, there are events that are simultaneous in one reference frame, and not in another.

Simultaneity is frame-dependent. Since what there exist cannot depend on the reference frame, we conclude that there are non-simultaneous events. Therefore, presentism is false.

Final remarks

What kind of ontological view is compatible with black hole astrophysics? We suggest that one where what we call 'present' has a local rather than a global character. The intuitive ontology adopted by most practising astrophysicists is one where there are things, and these things change relative to each other. One can speculate that space-time is an emergent property of the system of all things [5] [6]. The exact formulation of such an ontological theory to encompass a relativistic view of the world, taking into account the peculiarities of non-local effects in quantum mechanics, is an open problem.

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