Interpretation
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Interpretation

THE JOURNAL WELCOMES MANUSCRIPTS IN POLITICAL PHILOSOPHY AS WELL AS THOSE IN THEOLOGY, LITERATURE, AND JURISPRUDENCE.

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Kip S. Thorne, *Black Holes & Time Warps: Einstein's Outrageous Legacy* (New York: W. W. Norton & Company, 1994), ii + 619 pp., $30.00

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Professor Thorne has written a remarkable book, the detailed history by a participant for three decades in an unfinished scientific odyssey in search of an astrophysical object called a "black hole." He describes the origin of the concept; what its structure is in a Newtonian world-view; and how it becomes a necessary consequence of Einstein's Theory of General Relativity (GRT). He describes this in great detail in terms of the accomplishments (and background) of the contributors to the evolution and refinement of this concept.

As well as a history it is by remarkable coincidence an example of the anthill-like activity and agitation of scientists in the presence of an interesting problem. The coincidence resides in the circumstance that the book is a volume in the "Commonwealth Fund Book Program" under the editorship of Lewis Thomas. Dr. Thomas, since deceased, described just such activity in his essay "Natural Science" in the *Lives of a Cell* (New York: Penguin Books, 1974).

A black hole is the result predicted by GRT as the ultimate fate of a sufficiently massive star (at least twice the mass of our sun) which has exhausted its fuel and no longer can support its mass against its own self-gravitational attraction. A catastrophic implosion occurs, and if insufficient mass is blown away in the process, the result is an object of unimaginably huge density contained in a (usually) spherical surface of very small size. This surface has a oneway property; anything—literally anything—may pass through it, but nothing—literally nothing—may emerge. This includes radiation of any kind. Hence, the name black hole.

If GRT is correct, and with the accumulating evidence over the years since its announcement almost eighty years ago there are very few physicists who doubt its correctness, then there must be such objects "out there." But a black hole is singularly elusive. This is manifested in the theorem "black holes have no hair," which is a way of stating colloquially that the only external manifestations of a black hole are gravitational and electric fields due to its mass and charge, respectively. It is also very small: a black hole with a mass four times that of the sun would have a radius of only about three kilometers.

Once it became clear that the Einstein theory predicted its existence, the search has been to determine its properties and to figure out how to find so singular an object. To see it directly is not possible; it emits absolutely no

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radiation whatsoever. It can only be detected by its effect on another astrophysical object in its vicinity, and it is these effects on which the search has been centered. There are several very promising candidates for black-hole-hood, but the laying on of hands has not yet been vouchsafed. The search continues.

Although intended for the same audience as Stephen Hawking's *A Brief History of Time* (New York: Bantam, 1988) or Roger Penrose's *The Emperor's New Mind* (New York: Oxford, 1989), *Black Holes & Time Warps* is distinctly more demanding. There is a substantial amount of technical background woven into the history, and although Professor Thorne provides a very carefully constructed didactic underpinning, it helps to have had an introductory college-level physics course. The background material includes a brief history of gravitation theory beginning with that of Isaac Newton. This includes outlines of the basic concepts of both the Principle of Special Relativity and the Theory of General Relativity.

It is helpful to be aware of the proper relationship of the three intellectual domains encompassed by Newtonian mechanics and gravitation, the Principal of Special Relativity, and the Theory of General Relativity. Newtonian mechanics is an abstract structure set in a flat three-space with a distinct absolute time. It is a template for the construction of *any* theory. A separate and distinct postulate is required for each dynamical structure; the precise form of the force law must be specified. The one of interest here is the law of gravitational attraction of masses. It may be observed tangentially that among the fundamental problems of physics in the nineteenth century was the determination of the proper form of the electrodynamic forces, and it was largely the failure to find a solution to this problem that led inexorably to formulation of the Principle of Special Relativity (SRT). Here, too, SRT is a *principle* for the construction of theories. It postulates a different view of space and time than the Newtonian scheme and fuses the two into space-time. It provided a satisfactory solution to the nineteenth-century problem of the proper formulation of the electrodynamic forces and electromagnetic fields. It is not that such forces and fields were not quite well understood; it was that they did not fit into a Newtonian scheme without substantial ad hoc shoehorning. SRT worked so well in this regard that it soon supplanted the Newtonian scheme.

The situation was now turned topsy-turvy. Although the electrodynamic problems were solved, the beautiful Newtonian gravitational scheme would no longer fit. It had been known since early in the nineteenth century that there was a problem with the gravitational force law even within the Newtonian scheme. Despite considerable effort, success proved completely elusive. The advent of SRT led to the hope that within this framework the solution to the gravitational force problem would be found. It was not. The resolution was provided by GRT. The Theory of General Relativity is *not* a generalization of SRT. It is a theory of gravitation; it is the successor theory to the Newtonian

scheme of combined abstract dynamical structure and specific force law and contains it in appropriate approximation.

The *Time Warps* of the title refers to some highly speculative material on "wormholes" and time travel by means of them. A wormhole is a species of tunnel between two widely spatially separated regions of the universe. Its length is a minute fraction of the external distance between the two domains. An excellent (if unphysical) example of the concept appears as a major feature of the science fiction television program "Deep Space Nine," where it provides the passageway between two widely separated parts of our galaxy. Such objects can be constructed as solutions of the Einstein equations. It should be kept in mind that there exist thousands of solutions to the Einstein equations of which fewer than half a dozen can be demonstrated to possess physical significance. Professor Thorne, ever meticulous, takes great care to ensure that his presentation doesn't violate any established physical laws and notes that the material is written from his "own personal viewpoint."

For those interested in Natural Philosophy in the ancient and honorable tradition, Professor Thorne's book promises great rewards.