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DID EINSTEIN STUMBLE? THE DEBATE
OVER GENERAL COVARIANCE

ABSTRACT. The objection that Einstein's principle of general covariance is not a relativity principle and has no physical content is reviewed. The principal escapes offered for Einstein's viewpoint are evaluated.

1. INTRODUCTION

...the general theory of relativity. The name is repellent. Relativity? I have never been able to understand what that word means in this connection. I used to think that this was my fault, some flaw in my intelligence, but it is now apparent that nobody ever understood it, probably not even Einstein himself. So let it go. What is before us is Einstein's theory of gravitation. (Synge 1966, p. 7)

The magnitude of Einstein's success with his theories of relativity brought its own peculiar problem. His success attracted legions of cranks to his work, all determined to show where Einstein had blundered and anxious to accuse him of the most fundamental of misconceptions. On first glance, you might well imagine that the sentiments quoted above were drawn from this tiresome crank literature. However you would be mistaken. These remarks were made by J. L. Synge, one of this century's most important and influential relativists. They reflect the growth of a tradition of criticism of Einstein's views on the foundations of general relativity. The tradition began with the theory's birth in the 1910s as a minority opinion. Over the decades following, it refused to die out, instead growing until it is now one of the major schools of thought, if not the majority view amongst relativists.

The deep reservations of this tradition do not apply to the theory itself. The general theory of relativity is nearly universally hailed as our best theory of space, time and gravitation and a magnificent intellectual achievement - although followers of Synge might prefer a different name for the theory. What is questioned is the account that Einstein gave of its fundamental postulates. His account has been criticized in many of its aspects. The one that has attracted the most criticism is the prominence he accorded the requirement of general covariance, which Einstein saw as the crowning achievement of his theory. Through it, Einstein proclaimed, the theory had extended the principle of relativity to accelerated motion. Einstein's critics responded that general covariance had nothing to do with a generalization of the principle of relativity. Worse, general covariance was physically vacuous, a purely mathematical property.

My purpose in this paper is to review some of the principal positions advanced in this debate. I will pursue two themes: whether covariance...
principles have physical content and whether they express a relativity principle. First, in Sections 2 and 3, I will review the role Einstein claimed for covariance principles in the foundations of relativity theory and the ensuing objection, originating with Kretschmann in 1917, that the principle of general covariance is physically vacuous. Then, in Section 4, I will outline the stratagems that have been proposed to restore physical content to the principle. I will conclude that they succeed only in the degree to which they deviate from a simple reading of the original principle. In Section 5, I will review the development of the modern view that covariance principles are not relativity principle and that relativity principles express a symmetry of a spacetime. Finally, in Section 6, I will review Anderson's notion of absolute object. This notion provides our best attempt to reconcile Einstein's view of the connection between covariance and relativity principle and the modern view of relativity principles as symmetry principles.

2. COVARIANCE IN EINSTEIN'S ACCOUNT OF THE FOUNDATIONS OF RELATIVITY THEORY

For Einstein, covariance principles were the essence of his theories of relativity. For a theory to satisfy a principle of relativity, the equations expressing its laws needed to have a particular formal property. They needed to remain unchanged in form – covariant – under a group of coordinate transformations characterizing the principle of relativity at issue. This was the clear moral of his famous 1905 special relativity paper (Einstein 1905). The emphasis in that paper was to discover the correct form of the group of coordinate transformations associated with the relativity of inertial motion. These, he argued, were the Lorentz transformation equations. It then followed that Maxwell's electrodynamics satisfied the principle of relativity of inertial motion since the basic equations of Maxwell's theory remained unchanged in form under Lorentz transformation. Einstein (1940, p. 329) later summarized his approach:

The content of the restricted relativity theory can accordingly be summarized in one sentence: all natural laws must be so conditioned that they are covariant with respect to Lorentz transformations.

That the laws of a theory have the appropriate covariance is something that must be demonstrated by calculation, often by quite arduous manipulation. The mechanical exercise of establishing the Lorentz covariance of Maxwell's theory occupies a significant part (§§6, 9) of Einstein's 1905 paper.

Einstein's algebraic approach to the principle of relativity was quite different from that soon introduced by Minkowski (1908, 1909). He formulated the special theory of relativity in terms of the geometry of what we now know as a Minkowski spacetime. Satisfaction of the principle of