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Non-Smoothness of Event Horizons of Robinson–Trautman Black Holes

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Abstract. It is shown that generic "small data" Robinson–Trautman space-times cannot be C^{123} extended beyond the "$r = 2m$ Schwarzschild-like" event horizon. This implies that an observer living in such a space-time can determine by local measurements whether or not he has crossed the event-horizon of the black-hole.

1. Introduction

Perhaps the two most striking predictions of Einstein's theory of gravitation are the existence of gravitational radiation and of black holes. There are known four classes of asymptotically flat space-times containing gravitational radiation, the global structure of which is reasonably well understood: the Christodoulou–Klainerman metrics [7], the Friedrichs metrics [13], the boost-rotation symmetric metrics [2] and[1] the Robinson–Trautman (RT) metrics [17]. On the other hand known examples of space-times which contain a black hole are given by the Kerr–Newman space-times, the static Einstein–Maxwell Majumdar–Papapetrou multi-black hole solutions, the Tolman–Bondi perfect fluid metrics, Christodoulou's collapsing scalar field black-holes [6] (for these last two classes of space-times the metric in the vacuum region is the Schwarzschild metric) and the RT space-times. The privileged role of the Robinson–Trautman space-times stems from the fact that they provide an arena in which both gravitational radiation and black-hole formation can be studied simultaneously, in the vacuum. These space-times were orignally

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[1] It seems that Christodoulou's scalar field space-times [5, 6] should not be considered as containing gravitational radiation, since by Birkhoff's theorem the metric is the Schwarzschild one wherever the scalar field ϕ vanishes. Moreover, the $1/r$ part of the Riemann tensor, usually thought of as the manifestation of gravitational radiation, vanishes for these metrics (D. Christodoulou, private communication)