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Static and radiative cylindrically symmetric spacetimes

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A simple setup for discussing both mathematical and physical aspects of spacetimes with extended sources, like cosmic strings or cosmic filaments of galaxies and dark matter extending across hundreds of millions of light years is provided by cylindrical symmetry. Investigating cylindrically symmetric configurations is also a suitable precursor to the study of axial symmetry. Unlike in the spherically symmetric case, the cylindrically symmetric vacuum is not unique. The Einstein–Rosen cylindrically symmetric vacuum solutions in GR include wavelike behaviours, allowing for both standing wave and approximate progressive wave solutions, discovered analytically in the very early days of general relativity by Einstein and Rosen. Both solitonic waves and impulsive wave solutions were also identified in this class. The canonical quantization of cylindrically symmetric gravitational waves by Kuchar was the earliest example of the midisuperspace approach. A cylindrically symmetric, static background on which the ylindrical gravitational waves propagate, could be the Levi-Civita spacetime, the static limit of the Einstein–Rosen class. Although well studied earlier in a variety of coordinates, certain aspects of the Levi-Civita spacetime concerning its physical and geometrical interpretation were not well clarified. In order to do so, we suitably defined the Komar mass density of its infinite axis source to explore it as a metric parameter. Among the advantages we enlist that it eliminates double coverages of the parameter space, vanishes in flat spacetime and when small, it corresponds to the mass density of an infinite string. As expected, the Newtonian gravitational force is attractive and it increases monotonically with positive Komar mass densities, asymptoting to the inverse of the proper distance in the radial direction. The tidal force between nearby geodesics (gravity in the Einsteinian sense) however has a maximum, after which it decreases asymptotically to zero with increasing Komar mass density. Hence, from a physical point of view the Komar mass density of the Levi-Civita spacetime encompasses both Newtonian gravity and acceleration effects. Its increase eventually drags the field lines parallel, transforming Newtonian gravity through the equivalence principle into a pure acceleration field and the Levi-Civita spacetime into a flat Rindler-like spacetime. In a geometric picture the increase of the Komar mass density deforms the planar sections of the spacetime into ever deepening funnels, eventually degenerating into cylindrical topology in an appropriately chosen embedding. The Einstein-Rosen vacuum waves propagating on this background have been generalised both to be sourced by radiation in the geometrical optics limit and to Brans-Dicke vacuum. Preliminary results on further generalisations will also be reported.

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