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Jerzy Lewandowski – Spacetime, structures, equations and solutions

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When I met Lionel at Syracuse in the winter of 1991, he was interested in null structures, the spacetimes that admit them and the equations they may satisfy. Some of these, along with a few others and new results, will be discussed in this lecture.

For curved spacetime, the twistor equation relates the local twistor connection to the Chern-Moser connection of the CR structure and the corresponding conformal Fefferman geometry. The Fefferman family of metric tensors contains examples of spacetimes that are flat in the Bach sense but not conformally Einstein.

The CR structures appear in a larger class of spacetimes as null shear free geodesic congruences. Einstein equations imply their realisability while the spacetimes are algebraically special.

In the case of Petrov type D, the spacetimes admit 2-dimensional groups of isometries. When the NUT parameter does not vanish, two Killing vectors are distinguished, each defining a space of orbits free of the conical singularity. This property was used to construct globally defined, singularity-free Kerr-NUT-(A)dS spacetimes. Some of them are globally hyperbolic, while others contain Killing horizons of the Hopf fibration structure.

Quasi-local generalisation of Killing horizons leads to isolated horizons. Geometric structure of the isolated horizons is subject to equations implied by Einstein's equations. The solution space of the equations of an isolated horizon has many properties analogous to those proved in the global black hole theory: the topology of connected components of sections must be spherical, the rigidity, no-hair, uniqueness.

In the theory of gravitational radiation through a non-expanding horizon, the symmetry group is the BMS group extended by one more generator. The canonical fluxes vanish to first order, the energy flux is positively definite to second order.