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The Penrose 1965 singularity theorem in historical context of the Black Hole paradigm

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The first mention of a (Newtonian) BH dates back to 1783, when Michell presented a model of a massive "Dark Star", trapping light particles on its surface. The Schwarzschild solution from 1916 entailed two singularities – at the origin and at the Schwarzschild radius; their interpretation has been subject of an intense debate over the 20s-30s. Einstein argued that particle orbits lower than the innermost stable orbit are physically impossible. Moreover, he conceived the central singularity to arise as artifact of idealization in modeling stellar matter by the incompressible fluid ansatz. Eddington argued that quantum properties of matter will, at any scale, exert large enough pressure to impede gravitational implosion. He dismissed Chandrasekhar's rigorous calculations of an upper mass limit for a degenerate matter White Dwarf that sustains a Tolmann-Oppenheimer-Volkoff hydrostatic equilibrium. In 1939 Oppenheimer & Snyder found an evolved solution to the field equations that predicted gravitational collapse of stellar matter, forming a central singularity characterized by geodesic incompleteness and curvature divergence. Finkelstein in 1954 showed that the definition of an event horizon applies to the Schwarzschild radius, his calculation also allowed to introduce a set of coordinates for which the curvature at the Schwarzschild radius is finite. In the early 60s, Khalatnikov and Lifshitz argued that the central singularity is an idealization artifact arising from the spherical symmetry assumption, and that it does not arise under realistic conditions. Penrose's theorem from 1965 showed that the formation of geodesic incompleteness singularities is a generic prediction of General Relativity theory, under the premises that a trapped surface gets formed, the positive energy condition is always respected, and time-like geodesics do not close. The impact of the theorem with regard to the realism-antirealism-debate over the status of spacetime singularities will be discussed, and an outlook given on the cosmic censorship hypothesis.

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