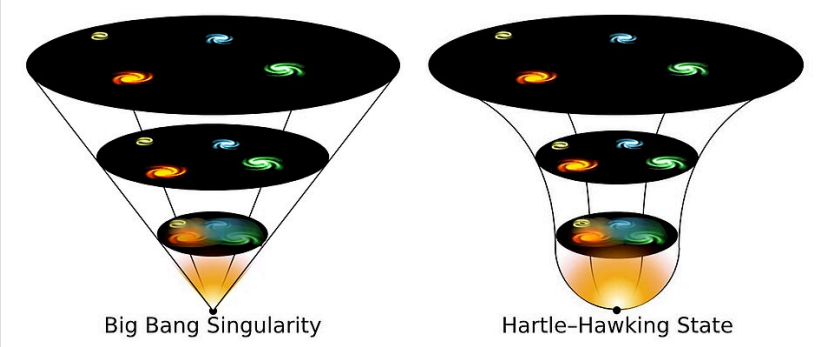
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Hartle–Hawking proposal

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The **Hartle–Hawking state**, also known as the **no-boundary wave function**, is a cosmological model that applies quantum mechanics to the Big Bang.[2]:769 It is named after James Hartle and Stephen Hawking, who first proposed it in 1983.[3][4] The concept can also be considered as an initial condition for models of quantum cosmology.[5]:14



Comparison of the Big Bang concept (left) and a Hartle–Hawking state concept (right) as they are extrapolated to time zero. Diagram shows two space dimensions horizontally and one time dimension vertically.[1]

Ingredients

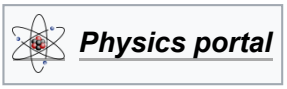
The Hartle-Hawking proposal includes several ingredients. First it uses Richard Feynman's path integral formulation of quantum mechanics. In this approach every possible path a particle can take through spacetime contributes to the solution with its own amplitude and phase. Technical challenges with those sums lead to the second ingredient, a transformation to Euclidean space-time: a geometry which combines 3 space dimensions with an imaginary time dimension.[6]:172 This is related to the Wick rotation, $\tau = it$, and it converts the spacetime metric in to a Euclidean metric, $ds^2 = d\tau^2 + dx^2 + dy^2 + dz^2$. In Hawking's approach, this rotation is applied to every path, not to the background space of the paths as in Wick's approach, and therefore the sum of histories becomes a quantum superposition of spacetimes.[2]:769 This curved Euclidean spacetime can be analogous to a sphere in being both finite in extent and yet have no boundary.[6]:174

History

The original 1983 paper by Hartle and Hawking grew out of a summer visit by Hawking to UC Santa Barbara where Hartle worked. Hawking was exploring the idea that the boundary condition for space time was simply no-boundary at all. With Hartle this idea was converted in to a proposal and published.[6]:175 In 1998 Hawking worked with Neil Turok to expand the Hartle-Hawking concept to include a hyperbolic or open geometry.[7][2][8][1]

See also

- Imaginary time
- Multiple histories
- Signature change



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