

Scientific Method & Black Hole History

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Evolution of modern science: pre-Einstein

~1500 ~1500 to ~1650: foundations of modern science
Copernicus, Tycho Brahe, Kepler, Galileo:
observation and experiment essential.

1687 Newton: modern classical mechanics formulated
(including theory of gravity).

1783 Michell: first suggestion of black hole (BH) idea

1794 Laplace: suggests BH in 'Le Système du Monde'

1854 Riemann: develops mathematics for *curved* spaces. Pythagorus modified

$$ds^2 = dx^2 + dy^2 \quad (\text{Euclid}) \quad \longrightarrow \quad ds^2 = g_{\mu\nu} dx_\mu dx_\nu$$

1865 Maxwell: develops unified theory for magnetic and electrical phenomena;
→ predicts E/M waves with velocity (c) a constant.

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Evolution of modern science: post Einstein

1905 Einstein: publishes **Special relativity (SR)** theory, among other things,
 $E = Mc^2$, ..., really $E = \gamma(Mc^2)$

1911 Rutherford: energetic α radiation (^4He nuclei) scattered by matter.

1915 Astronomers: identify **white dwarfs** as unusual.

1915 Einstein publishes **general relativity (GR)** - new theory of gravity:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = (8\pi G/c^4)T_{\mu\nu}$$

which means: **space-time** curvature ← **mass-energy** density, and
particles and light follow paths in curved **space-time**

1916 Schwarzschild discovers first **BH** solution -
part of the Schwarzschild metric for an isolated, nonrotating spherically symmetric mass.
Schwarzschild radius (event horizon) is:

$$R_g = 2GM_\star/c^2$$

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Science evolution (continued)

1917 Rutherford: nitrogen nuclei “split” by α particles from radioactive decay.

1919 Eddington: measures bending of starlight around Sun, predicted by GR.

~1925 Schrodinger, Heisenberg, Pauli, ... quantum mechanics developed.

1926 Fowler: uses quantum mechanics (QM) to develop a WD theory – electron degeneracy pressure prevents gravitational collapse.

1932 Chandrasekhar: combines SR with QM to get a WD theory that predicts a maximum mass ($\sim 1.5M_{\star}$)

1932 Cockcroft & Walton (and Rutherford): ${}^7\text{Li} + \text{p} \rightarrow {}^4\text{He} + {}^4\text{He}$

1932 Chadwick: discovers neutron

1935 Landau: develops theory of stellar mass with mainly neutrons (a NS), and independently discovers WD maximum mass.

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Science evolution (continued)

1936 Oppenheimer & Volkoff: NS model investigated, including predicted maximum mass.

1939 Oppenheimer & Snyder: GR theory used to investigate BHs and very compact stars.

~1963 Astronomers: quasars discovered - BHs proposed as energy source.

1963 Kerr: exact GR solution for rotating BH – the Kerr metric.

1967 Bell & Hewish: pulsars (accidentally) discovered.

1968 Gold: rotating magnetic NS “lighthouse” model of pulsar proposed.

1968 Wheeler: coins term ‘black hole’

1975 Hulse & Taylor: The binary pulsar (PSR 1913+16) discovered.

2007 Physicists & astronomers: “accept” observational evidence for reality of BHs.

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