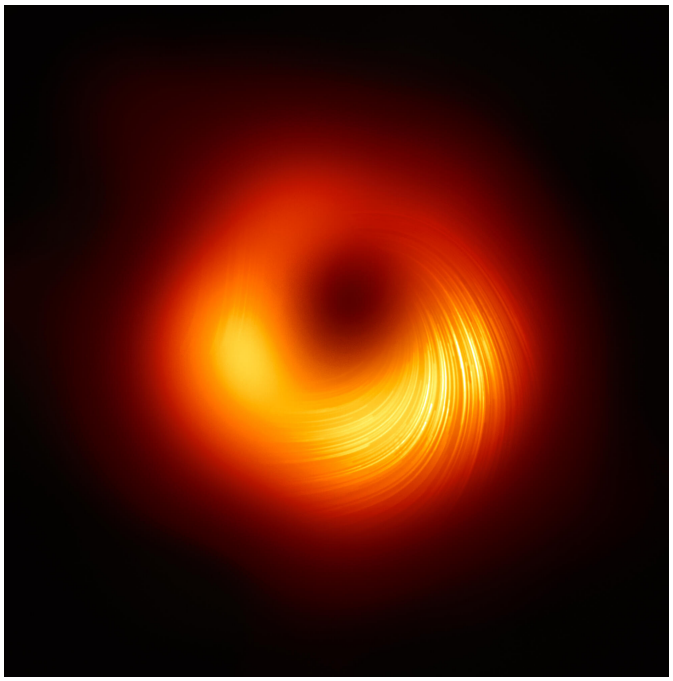
Lecture 22 : Black Holes I

The idea that light may not be able to escape from sufficiently dense bodies dates back to 1783 when the English Pastor John Michell first advanced this notion. This found a prominent mention in the great treatise by the French mathematician Laplace (1798). This conclusion was within the premise of Newton's theory of gravity. Einstein published his new theory of gravity in 1915. Within a couple of months, the great German Polymath obtained an exact solution to Einstein's equations for the gravitational field. This solution,describing the geometry of space-time around a non-rotating star, clearly showed that when a star contracts to a critical radius, no signal would be able to escape from it. Many decades later, the New Zealand mathematician Roy Kerr obtained an exact solution to Einstein's equations describing the geometry of space-time outside a rotating star. This lecture is a historical account of these monumental discoveries, and explains several of the spectacular consequences of Einstein's theory of gravity.

There are two kinds of black holes. The first are formed in supernovae, as the evolutionary end products of the most massive stars. The *stellar* black holes can be as massive as a few tens of solar masses. Then there are the *super-massive* black holes, such as the one sitting at the center of the Milky Way and most other galaxies, which can be more than a million times more massive than the Sun. On 10 April 2019, eighty years after Oppenheimer & Snyder predicted the existence of black holes, scientists of the 'Event Horizon Telescope' (EHT) released the first ever image of a black hole - a black hole of the second kind, the super-massive object at the heart of the M87 galaxy. A follow-up image, published in 2021, shows that a significant fraction of the light around this black hole is polarised.



A polarized view of the black hole in the Messier 87 (M87) galaxy shows the lines marking the orientation of polarization, captured by the EHT collaboration.

Capturing this first image of a black hole has been the result of a gigantic collaboration. The EHT collaboration involves more than 300 researchers from Africa, Asia, Europe, North and South America. The EHT, a virtual Earth-sized telescope, is an effective 'combination' of several individual telescopes - the ALMA, the APEX, the IRAM 30-meter Telescope, the IRAM NOEMA Observatory, the James Clerk Maxwell Telescope (JCMT), the Large Millimeter Telescope (LMT), the Submillimeter Array (SMA), the Submillimeter Telescope (SMT), the South Pole Telescope (SPT), the Kitt Peak Telescope, and the Greenland Telescope (GLT). Supported by considerable international investment, the EHT links these existing telescopes using novel systems creating a fundamentally new instrument with the highest angular resolving power that has yet been achieved.

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