Teacher notes

Karl Schwarzschild

In November of 1915 Einstein published his four papers on the General Theory of Relativity. In them he put forward the radical idea that matter and energy in space-time determine the geometry of space-time. In turn, the geometry of space-time determines the motion of material bodies and light in space-time. Einstein's field equations were complex non-linear differential equations. Einstein did not supply any solutions to these equations. Within a month of the publication of the papers a wrinkled, muddy, blood-stained envelope arrived at Einstein's home in Berlin. It was from an officer on the Russian front (World War I was in full swing) by the name of Karl Schwarzschild. To Einstein's immense surprise, Schwarzschild provided, in the letter, the very first solution to the Einstein equations for the case of a single, electrically neutral, spherical non-rotating mass, M.

The letter closed with the words: "As you can see the war treated me kindly enough, in spite of the heavy gunfire, to allow me to get away from it all and take this walk in the land of your ideas".

Einstein was shocked. He was the one who discovered the equations but could not provide any solutions himself!

The solution included a special radius, the Schwarzschild radius $R_S = \frac{2GM}{c^2}$. If the radius of the star was less than the Schwarzschild radius, then no light from the star would escape to an observer far away. The escape speed from the star would be larger than the speed of light. The star would become what more than 50 years later John Wheeler would call a black hole. The solution was presented in terms of the metric of space-time (the space-time interval) in spherical co-ordinates:

$$ds^2 = -(1-\frac{R_S}{r})c^2dt^2 + (1-\frac{R_S}{r})^{-1}dr^2 + r^2d\Omega$$

and was published as "Über das Gravitationsfeld eines Massenpunktes nach der Einstein'schen Theorie", (On the gravitational field of a point mass according to Einstein's theory) in Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften, 1 (1916), 189.

The idea that a man working under brutal battle conditions (bloody attacks and counter attacks with continuous artillery bombardments and constant fear of poison gas) and without access to any books would be able to work out a solution to very complicated equations is surely an extraordinary achievement. He was a child prodigy and published his first scientific paper on the motion of binary stars at the age of 16!

Schwarzschild contracted a rare skin disease while on the Russian front. Two months later, in May 1916, at the age of 42 and at the height of his creative abilities he died.

In 1960 an observatory in Tautenberg was founded in his honor, named the Karl Schwarzschild Observatory, dedicated to "the greatest German astronomer of the last 100 years" and the "Karl Schwarzschild Medal" was inaugurated in 1959. Fittingly, the first recipient was Martin Schwarzschild, Karl's son, a professor of Astrophysics at Princeton.