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Students Modelled the Discovery of Gravitational Waves with Computer Experiments Developed by Themselves

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The *goal* of this project was that students of an astronomy club reproduce the emission and propagation of the gravitational waves discovered this year[1,2]. These students ranging from class 5 to 12 reproduced the above observations with computer experiments.

The *modelling* was established progressively and comprehensively at four levels. At the basic level, the students constructed trajectories on squared paper. This construction is in accordance with a discretized version of Newton's axioms. With this method, a formula 1 game and a basketball trajectory game as well as planetary orbit simulations were performed. At a second level, the students determined trajectories using Excel or Java programs. With these tools, they simulated orbits according to the Schwarzschild metric and general relativity dynamics. On this basis, they modelled the perihelion precession, the relativistic deflection of light as well as the spiral trajectories typical for the coalescence of binary black holes. At a third level, the students derived the Schwarzschild metric in a simple and exact manner[3]. Moreover, they discovered equations for the propagation of light in curved space by using Huygens' principle in a new way. On this basis, they established equations for massive particle trajectories. At a fourth level, the students derived formulae for spiral trajectories as well as for the emission and propagation of gravitational waves[4].

[1] B. P. Abbott et al. (2016): Observation of Gravitational Waves from a Binary Black Hole Merger. Physical Review Letters, 116, 061102-1-16.

[2] B. P. Abbott et al. (2016): Observation of Gravitational Waves from a 22-Sun-Mass Binary Black Hole Coalescence. Physical Review Letters, 116, 241103-1-14.

[3] Carmesin, H.-O. (2012): Schüler entdecken die Einstein-Geometrie mit dem Beschleunigungssensor. PhyDid B, 2012, ISSN 2191-379-DD15p06.