GR 6: Black Holes I

Time: Tuesday 16:15–17:30 Location: KH 02.012

GR 6.1 Tue 16:15 KH 02.012

Interplay of evaporating black holes with BSM particle physics — •Jens Boos and Christoph Borschensky — Karlsruhe Institute of Technology

Evaporating black holes emit Hawking radiation. The precise radiation rate depends on (i) the geometrical backreaction, described by greybody factors, and (ii) the particle spectrum of the universe. We demonstrate that both aspects of modified gravity and beyond-the-standard model particle physics need to be taken into account to model a realistic black hole lifetime. In doing so, we outline the main corrections one thereby obtains to the emitted photon spectrum (including secondary photons) that is relevant to constrain the abundance of such evaporating black holes and links them to (a part of the) dark matter relic density.

GR 6.2 Tue 16:30 KH 02.012

Microlensing of non-singular black holes at finite size: a ray tracing approach — •Hao Hu and Jens Boos — Institute for Theoretical Physics, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We study the gravitational microlensing of various static and spherically symmetric non-singular black holes (and horizonless, non-singular compact objects of similar size). For pointlike sources we extend the parametrized post-Newtonian lensing framework to fourth order, whereas for extended sources we develop a ray tracing approach via a simple radiative transfer model. Modelling non-relativistic proper motion of the lens in front of a background star we record the apparent brightness as a function of time, resulting in a photometric lightcurve. Taking the star radius to smaller values, our numerical results approach the theoretical predictions for point-like sources. Compared to the Schwarzschild metric in an otherwise unmodified lensing geometry, we find that non-singular black hole models (and their horizonless, non-singular counterparts) at finite size tend to feature larger magnifications in microlensing lightcurves, contrary to the point-source prediction.

GR 6.3 Tue 16:45 KH 02.012

On the formation of black-hole mimickers within General Relativity — •Daniel Jampolski[1] and Luciano Rezzolla[1,2,3] — [1]Institut für Theoretische Physik, Max-von-Laue-Str. 1, 60438 Frankfurt, Germany — [2]School of Mathematics, Trinity College, Dublin 2, Ireland — [3]CERN, Theoretical Physics Department, 1211 Geneva 23, Switzerland

Regular black holes and horizonless black-hole mimickers offer mathematically consistent alternatives to address the challenges posed by standard black holes. However, the formation mechanism of these alternative objects is still largely unclear and constitutes a significant open problem since understanding their dynamical formation represents a first step to assess their existence. We here investigate, for the first time and without invoking deviations from general relativity, the dynamical formation of a well-known horizonless black-hole mimicker, namely, a gravastar. More specifically, starting from the collapse of a uniform dust sphere as in the case of the Oppenheimer-Snyder collapse, we demonstrate that, under suitable conditions, a gravastar can form from the nucleation and expansion of a de-Sitter region with initial zero size at the center of the collapsing sphere. Furthermore, the de-Sitter expansion naturally slows down near the Schwarzschild radius, where it meets the collapsing dust surface and gives rise to a static equilibrium. Interestingly, we also find a maximum initial compactness of the collapsing star of $\mathcal{C} = 3/8$, above which the collapse to a black hole is inevitable.

GR 6.4 Tue 17:00 KH 02.012

Formation and Time Evolution of Primordial Black Holes — Hans-Otto Carmesin[1,2,3] and •Lina Jarck[3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

In the very early universe, the density has been sufficiently large, so that black holes have formed. Simultaneously, these can decay as a result of Hawking radiation.

(1) For various densities, the amount of primordial black holes is derived as a dynamical equilibrium value.

(2) A population-based simulation is developed in Python. The simulation models processes in the early universe: Photons move randomly within a defined space. When two photons meet, they can fall into the Schwarzschild radius and form a black hole. Its lifetime is determined. The black hole then decays back into two photons through Hawking radiation.

(3) The results are compared with primordial black holes observed by the James Webb Space Telescope.

Carmesin, H.-O. (2020): The Universe Developing from Zero-Point Energy - Discovered by Making Photos, Experiments and Calculations. Berlin: Verlag Dr. Köster.

GR 6.5 Tue 17:15 KH 02.012

The observer-invariant end of spacetime at the horizon of Schwarzschild black holes — •René Friedrich — Strasbourg

Time is not absolute but observer-dependent: This groundbreaking insight of Einstein in 1905 has the potential to settle the famous disagreement between external observer Bob and infalling observer Alice:

At first sight, the fact that Alice reaches the event horizon of a black hole within finite proper time prevails over Bob's "mere" observation that infalling matter does never reach the horizon. However, all external observers (even including Alice who is an external observer, too, before reaching the horizon) agree without exception that the horizon represents the ultimate simultaneity line (t = infinity), the temporal border of the spacetime manifold. Since spacetime is observer-dependent and thereby mere observation, this "concordant observation shared by all observers of the universe of spacetime" is perfectly adapted for determining the extent and the boundaries of spacetime.

As a result, there can't exist any spacetime beyond observation, and when Alice - subject to infinite gravitational time dilation - reaches the event horizon, she is leaving our observer-dependent spacetime manifold. Consequently, the mass of a Schwarzschild black hole is not inside the horizon but outside, in the approximate form of a nearby membrane, avoiding the unsolvable dilemma of a central spacetime singularity. More: Quantum gravity without trouble.