Research Training Group
Graduiertenkolleg
Models of Gravity

Newsletter – August 2018

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Recent PhDs

Keno Eilers obtained his PhD on 02.03.18 at the University of Oldenburg.
Stephan Reimers obtained his PhD on 09.07.18 at the University of Oldenburg.
Paul Jefremov obtained his PhD on 10.07.18 at the University of Bremen.

New PhD Students

Kai Flathmann

Matheus Teodoro

Five students started their PhD recently.
Kai Flathmann and Matheus C. Teodoro (since 01.04.18) work in Oldenburg with Jutta Kunz.
Schokoufe Faraji (since 01.04.18) works at the ZARM with Eva Hackmann.
Nitesh Bhardwaj (since 01.06.18) and Bilel Ben Salem (since 15.06.18) work in Bielefeld with Dominik Schwarz and Joris Verbiest respectively.

Nitesh Bhardwaj

Bilel Ben Salem

Geodesics in Higher-Dimensional Rotating Spacetimes

Stephan Reimers

In this thesis, we investigated five-dimensional spacetimes by the means of the geodesic motion of massive and massless test particles. The considered spacetimes are

- The five-dimensional Myers-Perry spacetime,
- The five-dimensional Myers-Perry-Anti-de Sitter spacetime,
- The five-dimensional EMCS Kerr-Newman spacetime,
- The five-dimensional EMCS Gödel spacetime.

The first two spacetimes are solutions of the higher-dimensional Einstein field equations describing five-dimensional generalizations of the four-dimensional Kerr spacetime and Kerr-Anti-de Sitter spacetime, respectively. They describe five-dimensional black holes parametrized by the black hole's mass, two independent rotational parameter and, in the latter case, a negative cosmological constant. The remaining spacetimes are solutions of the Einstein-Maxwell-Chern-Simons field equations generalizing the Kerr-Newman and the Gödel spacetime solutions of the four-dimensional Einstein field equations. The corresponding generalizations of the higher-dimensional Einstein field equations have not yet been found in closed form. While the EMCS Kerr-Newman spacetime describes a five-dimensional black hole parametrized it's mass, charge and two independent rotational parameter, the Gödel spacetime describes a globally rotating, five-dimensional universe of a homogeneous and pressureless mass distribution.
In a first step we investigated the possible horizons and the singularities of these spacetimes. The 5D Myers-Perry, Myers-Perry-AdS and EMCS Kerr-Newman spacetime contain a curvature singularity enclosed by a Cauchy horizon and an event horizon. We could show that the singularity differs significantly from the four-dimensional ring singularity of the Kerr spacetime. In the five-dimensional case, it describes a three-dimensional, non-traversable surface. The geodesic equations of this spacetime were derived and separated by the Hamilton-Jacobi formalism using the constants of motion. These are given by the test particles rest mass, energy, two independent angular momenta and a separation constant, which is related to a second order Killing Tensor. The geodesics of these spacetimes were investigated by the means of parametric diagrams as well as effective potentials and the possible orbit types for massive and massless test particles, related to timelike and lightlike geodesics, were categorized.

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Upcoming events

RTG Colloquia

07.11.18: Jacobs University, Bremen

05.12.18: Leibniz University, Hannover

16.01.19: ZARM, Bremen

RTG Summer School

03.-07.09.18: ZARM, Bremen

RTG Autumn Workshop

10.-12.09.18: ZARM, Bremen

22. German Conference of Women in Physics

27.-30.09.18: Oldenburg

Publications

V. Perlick, O. Y. Tsupko, G. S. Bisnovatyi-Kogan, *Black hole shadow in an expanding universe with a cosmological constant* Phys. Rev. D 97, 104062, (2018)

S. Schneider, V. Perlick, *The shadow of a collapsing dark star* Gen. Rel. Grav. 50, 58 (2018)

L. G. Collodel, B. Kleihaus and J. Kunz, *Static Orbits in Rotating Spacetimes* Phys. Rev. Lett. 120 (2018) 201103

X. Y. Chew, B. Kleihaus and J. Kunz, *Spinning Wormholes in Scalar-Tensor Theory* Phys. Rev. D 97 (2018) no.6, 064026 arXiv:1802.00365 [gr-qc]

J. Grover, J. Kunz, P. Nedkova, A. Wittig and S. Yazadjiev, *Multiple shadows from distorted static black holes* Phys. Rev. D 97 (2018) no.8, 084024

O. Lechtenfeld and G. Zhilin, *A new construction of rational electromagnetic knots* Phys. Lett. A 382 (2018) 1528

(continued from page 1)

As expected, no stable bound orbits for massive and massless test particle could be found outside the event horizon of the black hole spacetimes without cosmological constant. Nevertheless, stable bound orbits were found for both types of test particle inside the Cauchy horizon, revolving around the curvature singularity. This means, these orbits are hidden behind the event horizon and cannot be observed from the outside. In the 5D Myers-Perry and the 5D EMCS Kerr-Newman spacetime escape orbits, which approach the black hole from radial infinity and eventually leave to radial infinity again, were found for timelike and lightlike geodesics. Furthermore, many-world bound orbits, which cross both horizons periodically or two-world escape orbits, which repass both horizons and escape to radial infinity, exist for massive and massless test particles. Due to causality, these orbits need to continue into another universe when leaving the event horizon and thus are part of multiverse theories.
In the 5D Myers-Perry-AdS spacetime, the influence of the cosmological constant is different for timelike and lightlike geodesics, so a case differentiation was necessary. For timelike geodesics, stable bound orbits outside the event horizon and many-world bound orbits were found, but no such orbits which reach radial infinity. These escape orbits or two-world escape orbits only exist for lightlike motion. In return, no such bound orbits were found for lightlike motion, but many-world bound orbits still exist in this case. Furthermore, spacelike geodesics were considered, as they play an important role in the AdS/CFT correspondence. Escape orbits, two-world escape orbits, many-world bound orbits and bound orbits inside the Cauchy horizon could be identified. Incomplete geodesics, describing terminating orbits of test particles, which finally end in the singularity, were found in all of the black hole spacetimes as well.
In the 5D EMCS Gödel spacetime, the geodesic equations of electrically charged test particles were derived by a modified Hamilton-Jacobi formalism including the gauge field. The effective potentials revealed that only bound orbits and escape orbits exist in this spacetime, while escape orbits solely exist for certain values of the test particle's charge. Assuming that massless test particles are uncharged, there are no such escape orbits in case of lightlike motion.
The analytic solutions of the geodesic equations were given in terms of Weierstraß $\wp$-, ζ- and σ-functions in the case of the black hole spacetimes and in terms of inverse trigonometric functions in the case of the 5D EMCS Gödel spacetime. These analytic expressions were used in order to display planar orbits as well as three-dimensional projections of the actual four-dimensional motion.

Recent paper recieved additional attention

It seems like our last newsletter was not the only source very excited about a recent paper (arXiv:1711.05191) by Lucas Collodel, Burkhard Kleihaus and Jutta Kunz. Lisa Zyga of Phys.org picked it up in May, where she focussed on the frame dragging by a massive astrophysical object and how it was shown that a particle might stand perfectly still in a static orbit.

Publications

N. Kozyrev, S. Krivonos, O. Lechtenfeld, A. Nersessian, and A. Sutulin, *N=4 supersymmetric mechanics on curved spaces* Phys. Rev. D 97, 085015 (2018)

E. Castellanos, J. C. Degollado, C. Lämmerzahl, A. Macias, and V. Perlick, *Bose-Einstein condensates in charged black-hole spacetimes* J. Cosm. Astropart. Phys. 2018, 043 (2018)

V. Dzhunushaliev, V. Folomeev, B. Kleihaus and J. Kunz, *Dispersion relations for gravitational waves in different models of dark energy* Int. J. Mod. Phys. D26 (2017) 1750157

S. Grunau, H. Neumann, and S. Reimers, *Geodesic motion in the five-dimensional Myers-Perry-AdS spacetime* Phys. Rev. D 97, 044011 (2018)

C. Hoffmann, T. Ioannidou, S. Kahlen, B. Kleihaus, and J. Kunz, *Wormholes Immersed in Rotating Matter* Phys. Lett. B 778 (2018) 161

V. Dzhunushaliev, V. Folomeev, B. Kleihaus, and J. Kunz, *Wormhole solutions with a complex ghost scalar field and their instability* Phys. Rev. D 97 (2018) no.2, 024002

S. Fedoruk, E. Ivanov, O. Lechtenfeld, and S. Sidorov, *Quantum SU(2|1) supersymmetric Calogero-Moser spinning systems* J. High Energ. Phys. (2018) 2018: 43

Z. A. Motahar, J. L. Blazquez-Salcedo, B. Kleihaus, and J. Kunz *Axial quasinormal modes of scalarized neutron stars with realistic equations of state* Phys.Rev. D98 (2018) no.4, 044032

Relativistic accretion onto compact objects

Paul Jefremov

This thesis focussed on results on accretion obtained during my studies from 2014 to 2018. The main restriction that framed the direction of this research was to proceed as far as possible analytically. The major result of the thesis was the new ansatz for the specific angular momentum-angular velocity dependence for the perfect fluid in circular motion around the Kerr black hole, presented first in our recent paper (Witzany & Jefremov, 2018).

This new ansatz enables one to obtain new solutions for toroidal configurations. The resulting ansätze have more free parameters and allow to derive the known Polish Doughnuts and Fishbone-Moncrief tori as their special combinations. The dynamical properties of these configurations and the results of their application as initial conditions for accretion simulations within 2-D HARM code were discussed in detail.

The already well-studied Polish Doughnuts with constant specific angular momentum are potentially useful for gaining key ideas on accretion in exotic spacetimes. In the second part of the thesis the characteristic changes in this accretion pattern caused by the gravitomagnetic parameter in the NUT spacetime was investigated. The most significant one of them is the fact that the tori there are lifted from the equatorial plane where they lie in the Schwarzschild or Kerr spacetimes.

The last part of the work presents a pre-study of accretion of spinning particles and fluids onto Kerr black holes. Here the spin-induced advance in radii of circular orbits and the changes in the thin-disk efficiency was discussed.

22. German Conference of Women in Physics

We would like to invite you to the 22nd Women in Physics Conference that will take place September 27 - 30, 2018, in Oldenburg.

The conference will be a forum for women in physics and offers physicists of all fields and from all stages in their career the opportunity to present their work and exchange experiences and perspectives benefitting their career planning. Additionally, highly experienced female experts to emphasize the importance of role models for young physicists are participating. We consider it to be an important task of this conference to help build connections between physicists and representatives of the industry.

Further information about the conference and its background can be found at www.physikerinnentagung.de. You can also register there and submit an abstract. We are looking forward to seeing you at the DPT 2018!