Research Training Group
Graduiertenkolleg
Models of Gravity

Newsletter – December 2019

In this issue

Recent habilitation

On 26. June 2019 Eva Hackmann has habilitated at the University of Bremen.

Recent PhDs

Recently four students of the RTG obtained their PhD:

- Christian Knoll, Oldenburg (03.06.19)
- Patric Hölscher, Bielefeld (12.07.19)
- Christian Hoffmann, Oldenburg (28.08.2019)
- Xiao Yan Chew, Oldenburg (06.09.2019)

New PhD Students

Four new students started their PhD in the RTG:

- Roy Barzel works with Claus Lämmerzahl at ZARM
- Felix Willenborg works with Claus Lämmerzahl at ZARM (since 01.06.19).
- Florian Seemann works with Claus Lämmerzahl at ZARM (since 01.08.19).
- Orville Damaschke works with Boris Vertman in Oldenburg (since 01.11.19).

Felix Willenborg

Orville Damaschke

Congratulations: Eva Hackmann has habilitated

Claus Lämmerzahl

In its meeting on 26. June 2019 the faculty council of the Faculty 1 “Physics / Electrical Engineering” of the University of Bremen unanimously approved the habilitation of Eva Hackmann for the area “Theoretical Physics”. She is thus a “Privatdozent” and as such has the official right to award doctorates and to conduct research independently.

Eva studied mathematics in Oldenburg and joined our space sciences group at ZARM of the University of Bremen 13 years ago. After her diploma thesis on a complex mathematical topic in elastiticity theory, she wrote her doctoral thesis on the solution of geodetic equations in Petrov Type D spacetimes. For the first time ever she succeeded in solving hyperelliptic differential equations explicitly. This has been taken up by many groups in the world, which is reflected in a very high citation number for this purely theoretical work in the field of mathematical relativity. For these results she also received the GHT dissertation award of the German Physical Society DPG. This topic is also one focus of the Research Training Group “Models of Gravity”, in which Eva is now also PI. Eva has also applied the developed mathematical methods to other questions in astrophysics such as the motion of particles with charge and spin, as well as to pulsar timing. One of her articles on the latter topic was recently awarded the accolate “Editor’s choice” by the journal “General Relativity and Gravitation”. She has also applied these methods to problems of general relativistic geodesy and to the description of clocks on satellites, where she has developed a proposal for testing a generalized gravitomagnetic clock effect. In recent years she has also familiarized herself with general relativistic hydrodynamics and discussed special configurations of accretion discs.

Eva was also a PI in the now expired Collaborative Research Center “geo-Q” and is planned to be a PI in the new application of the Collaborative Research Center “Terra-Q”. She is also a member of the excellence cluster “Quantum Frontiers” and of the research network “Black Hole Cam”, i.e. she is well networked both nationally and internationally. Eva is strongly involved in teaching and outreach. She is highly appreciated by her colleagues for her helpfulness and competence. She is also Diversity Officer in our Research Training Group.

This is a success of our Research Training Group “Models of Gravity” and we can be very proud to have such an excellent and committed scientist as PI. She conducts research at the highest international level and her work is cited in impressive numbers, thus making a decisive contribution to the visibility of our Research Training Group.

We congratulate Eva on her habilitation. I am convinced that she will soon also receive the title of a professor.

New associated member

Boris Vertman (Uni Oldenburg) is now an associated member of the RTG.

Upcoming events

RTG Colloquia

05.02.20: ZARM, Bremen

22.04.20: Jacobs Uni Bremen

03.06.20: Uni Bielefeld

RTG Workshops

02.-04.03.20: ZARM, Bremen

Publications

A. K. Chatterjee, K. Flathmann, H. Nandan, A. Rudra, *Analytic solutions of the geodesic equation for Reissner-Nordström–(anti–)de Sitter black holes surrounded by different kinds of regular and exotic matter fields*, Phys. Rev. D 100, no. 2, 024044 (2019)

S. Bahamonde, K. Flathmann, C. Pfeifer, *Photon sphere and perihelion shift in weak $f(T)$ gravity*, Phys. Rev. D 100, no. 8, 084064 (2019)

T. M. Siewert, C. Hale, N. Bhardwaj et al., *One- and Two-point Source Statistics from the LOFAR Two-metre Sky Survey First Data Release* arXiv:1908.10309

K. Flathmann, M. Hohmann, *Post-Newtonian Limit of Generalized Scalar-Torsion Theories of Gravity*, arXiv:1910.01023

J. L. Blázquez-Salcedo, S. Kahlen, J. Kunz, *Quasinormal modes of dilatonic Reissner-Nordström black holes*, arXiv:1911.01943

Diversity at GR22

Eva Hackmann

This years's 22nd International Conference on General Relativity and Gravitation in Valencia hosted two rather unusual events, both aimed to broach the issue of diversity in our field. On Tuesday, July 9, the conference hosted a Diversity and Inclusion lunch. It was intended as a social-peer platform to celebrate diversity, discuss challenges, and collaborate on strategies to bolster diversity and inclusion. After everyone got their meals, a moderated discussion on diversity was initiated. Unfortunately, most of the people in the large room seemed to be much more interested in their meals and private conversations. This effectively spoiled the intended central discussion of diversity issues. A positive aspect was the opportunity to share personal views and life experiences on specific issues with other lunch attendees.

In the evening of the same day, a one-hour long round-table discussion about women in the fields of STEM took place at the Museum MuVIM in downtown Valencia. A particular emphasis was of course on women in physics. The high-ranked panel consisted of Prof. José Adolfo de Azcárraga (President of the Spanish Royal Physical Society), Prof. Pascuala García Martínez (President of the Specialized Group on Women in Physics of the Spanish Royal Physical Society), Prof. Ruth Lazkoz (University of the Basque Country), Prof. Virginia Trimble (University of California Irvine), and Prof. Francesca Vidotto (University of Western Ontario). The event started with a statement of each panel member emphasizing different aspects of the underrepresentation and (subconscious) discrimination of women in physics. In the following a lively and interesting discussion evolved, with partly very different opinions and solution approaches discussed among the panel and the audience. The event could have continued much longer than the planned one-hour, which was in my view too short for the complex topic. I am looking forward to see similar events on other conferences!

Massive Spin 1/2 Fermions in curved Spacetimes

Thesis summary of Christian Knoll

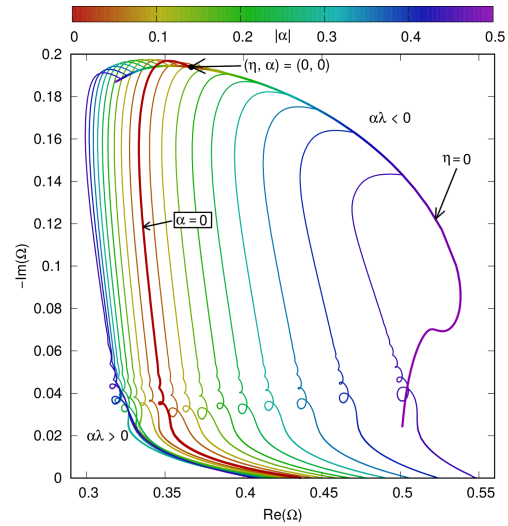
In this thesis we have studied (non-quantized) Dirac fermions in curved spacetimes.

In the first part of the project, we calculated the quasinormal modes for the massive Dirac field in the background of the Schwarzschild-Tangherlini black hole, from four to nine spacetime dimensions. Some studies already considered the limit case when the frequencies have large imaginary parts. Hence we have focused on modes lying close to the real axis in the complex plane. For the calculation we used the Leaver continued fraction method with Nollert improvement. Additionally we used the WKB approximation to cross-check the calculations. With the WKB approximation we also determined an eikonal approximation for the frequencies valid for all mass values with very satisfactory accuracy.

Comparing with the literature it became clear that the modes of the Dirac field share many similarities with the modes from other fields of other spin values (scalar, vector fields, etc). For example, we showed that Dirac fields also possess quasiresonances: modes lying very close to the real axis with very long damping times that grow with the mass. Additionally, we found a loop-like behaviour in the complex plane for the frequency as a function of the mass, which is quite characteristic of the quasinormal mode spectrum of several classes of fields.

In the second part of the project, we studied the quasinormal modes for a family of Myers-Perry black holes. Although the symmetries decreased compared to the spherically symmetric Schwarzschild-Tangherlini case, due to the addition of rotation, the field equations can be decoupled and solved numerically. This is possible due to hidden symmetries.

We studied in detail the quasinormal modes of the Dirac field in the four dimensional Kerr metric and the five dimensional Myers-Perry metric with equal angular momenta. We were able to solve the angular part of the equations in the case of the five dimensional Myers-Perry metric analytically. Due to this we had an analytic expression for the angular eigenvalue of the field an had to solve only the radial part numerically. For this we used the Leaver continued fraction method with Nollert improvement. We found many similarities for the Dirac quasinormal modes compared to fields of other spins. In particular, we showed again the existence of quasiresonances, a loop-like behaviour of the modes in the complex plane, and the existence of modes with vanishing real part. In the background of the four dimensional



Kerr metric there is a simple relation between modes with positive real part and negative real part of the frequency. This is not the case for quasinormal modes in the five dimensional Myers-Perry metric with non-vanishing field mass and angular momentum of the black hole.

In addition, we studied in detail the behaviour of the perturbation in the near horizon geometry of the five dimensional Myers-Perry black hole with equal angular momenta. We showed that several analytical solutions are available, and we studied their physical properties (the behaviour of their flux at the horizon).

In the last part of the thesis, we have studied solutions with back-reaction of the Dirac field onto the geometry. For this we wanted to treat the simplest case first: stationarity and spherical symmetry configurations. For this we needed a field configuration compatible with these assumptions. These were successfully constructed for dimensions greater then three, by constructing an Ansatz that combines an even number of Dirac fields (for example, two fields in 4 and 5 dimensions, etc). This results into a simplified system of differential equations that can be integrated numerically in order to construct Dirac stars (self-gravitating soliton solutions).

The research done in the thesis has opened several lines of research. In particular, regarding the last direction, we recently showed that the Ansatz for spherically symmetric configurations allows to obtain several analytical solutions. In particular, wormholes that are supported by the Dirac fields.

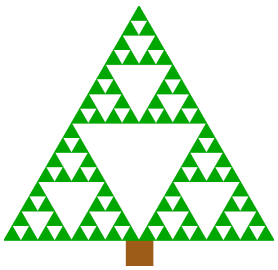
Explore Science 2019

Where on earth has the time gone? No one can answer that better than scientists from the Research Training Group "Models of Gravity". At this year's Science Festival, 5-7 September 2019, in Bremen's Bürgerpark with 9000 visitors, everything revolved around the topic of "time", and Eva Hackmann and Claus Lämmerzahl had space and time for a lecture.

Eva explained to the audience why pulsars work like high-precision clocks in space. Pulsars are fast-rotating neutron stars that emit light like a lighthouse, which we receive as regular light signals. Due to their compactness, the rotation is very stable, making these pulsars a very accurate clock. And with these clocks you can do a lot: e.g. you can measure the properties of black holes, you can detect gravitational waves and also the accelerated expansion of the universe.

Claus was investigating why time doesn't run backwards. But what would it mean if time could run backwards? And are there phenomena in nature that define a certain direction of time? For a part of nature it doesn't matter whether time runs backwards or forwards. But there are a number of phenomena that show that time can only run in one direction. This also limits the possibility of time travel or of a recurring universe.

In addition to the talks on the main stage, the Research Training Group together with the Olbers Society offered hands-on experiments and interactive presentations of topics such as time on the edge of a black hole, light years, sidereal day and constellations. Since 2006, the Klaus Tschira Foundation has been organizing the "Explore Science" week. The aim is not to "serve" ready-made answers to families, children, young people and all inquisitive people, but to give them the opportunity to discover scientific phenomena themselves together with experts.



We wish you a happy Christmas time and a good start to the New Year!

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