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Recent PhD

Isabel Oldengott obtained her PhD on 14.07.17 at the University of Bielefeld.

New PhD Students

Three students started their PhD at ZARM.

Sandro Gödtel (since 16.10.17) works with Claus Lämmerzahl.



Sandro Gödtel

Roberto Tanzi (since 01.10.17) and Dennis Stock (since 01.11.17) work with Domenico Giulini.



Roberto Tanzi



Dennis Stock

New Postdoc

Christine Gruber is a new postdoc at the Hanse Wissenschaftskolleg (HWK) in Delmenhorst (since 07.11.17). She works with Jutta Kunz and Domenico Giulini.



Constraints on particle properties from the cosmic microwave background

Isabel Oldengott

In this doctoral project, we derived constraints on various particle properties from observations of the cosmic microwave background (CMB).

In our first project, we considered a decaying dark matter component as a source of reionization in addition to the reionization process caused by astrophysical objects. Both of these reionization sources impact the angular power spectrum of the CMB in a similar way. We took into account two different parametrizations for the astrophysical reionization process. Using Planck 2015 data, we constrained the effective dark matter decay rate to $\Gamma_{\text{eff}} < 2.9 \times 10^{-25} / \text{s}$ at 95% CL. This limit is robust, as it only weakly depends on the chosen parametrization of astrophysical reionization. We also applied our results to a keV-mass sterile neutrino as a specific dark matter candidate and obtain constraints on its mixing angle and mass.

In a second project, we studied and constrained the impact of non-standard neutrino interactions on the CMB angular power spectrum. In the first part of this project, we derived the Boltzmann hierarchy for neutrinos including interactions with a scalar particle. We studied two limits of the scalar mass, an extremely massive scalar that only plays the role of a mediator for neutrino self-interactions, and a massless scalar that can be produced in abundance and demands its own Boltzmann hierarchy. In contrast to the Boltzmann hierarchy for photons, our interacting neutrino/scalar Boltzmann hierarchies are momentum dependent, which reflects non-negligible energy transfer in the considered neutrino interactions.

In the second part of this project, we focused on the massive scalar case and implemented the Boltzmann hierarchy for interacting neutrinos into the Boltzmann solver CLASS. We compared our results with known approximations in the literature, finding thereby a good agreement between our exact approach and the relaxation time approximation (RTA). The popular $(c_{\text{eff}}^2, c_{\text{vis}}^2)$ -parametrization however does not reproduce the correct signal in the CMB angular power spectrum. Using the RTA, we furthermore derived constraints on the effective coupling constant G_{eff} from currently available cosmological data. Our results revealed a bimodal posterior distribution, where one mode represents the standard Λ CDM limit, and the other a scenario of neutrinos self-interacting with $G_{\text{eff}} \simeq 3 \times 10^9 G_{\text{F}}$.



In a third project, we considered a cosmic lepton asymmetry η_l , which affects the CMB angular power spectrum through a modified helium abundance and an increased expansion rate in the early Universe. We derived constraints on the neutrino chemical potentials from the Planck 2015 data and found $\xi = -0.002_{-0.111}^{+0.114}$ (95% CL) for the chemical potentials, corresponding to $-0.085 \leq \eta_l \leq 0.084$. Our constraints on the lepton asymmetry are significantly stronger than previous constraints from CMB data analysis and more robust than those from primordial light element abundances.



Upcoming events

RTG Colloquia

13.12.17: University of Oldenburg

17.01.18: ZARM, Bremen

RTG Workshops

19.-21.02.18: Jacobs University

Other

03.-04.05.18: 13. Kosmologietag,
ZiF Bielefeld

Publications

Z. Altaha Motahar, J. L. Blázquez-Salcedo, B. Kleihaus and J. Kunz, *Scalarization of neutron stars with realistic equations of state*, *Phys. Rev. D* **96**, 064046 (2017)

L. G. Collodel, B. Kleihaus, J. Kunz, *Excited Boson Stars*, *Phys. Rev. D* **96**, 084066 (2017)

V. Witzany, C. Lämmerzahl, *Pseudo-Newtonian Equations for Evolution of Particles and Fluids in Stationary Space-times*, *Astrophys. J.* **841**, no. 2, 105 (2017)

C. Markakis, K. Uryū, E. Gourgoulhon, J.-P. Nicolas, N. Andersson, A. Pouri, V. Witzany, *Conservation laws and evolution schemes in geodesic, hydrodynamic and magnetohydrodynamic flows*, *Phys. Rev. D* **96**, 064019 (2017)

V. Witzany, *Exploiting the hidden symmetry of spinning black holes: conservation laws and numerical tests*, *MNRAS*, **stx2520** (2017)

K. Schroven, E. Hackmann and C. Lämmerzahl, *Relativistic dust accretion of charged particles in Kerr-Newman spacetime*, *Phys. Rev. D* **96**, 063015 (2017)

I. M. Oldengott, D. J. Schwarz, *Improved constraints on lepton asymmetry from the cosmic microwave background*, *Europhys. Lett.* **119** no.2, 29001 (2017)

Best paper award for Dennis Philipp

In June Dennis Philipp presented his recent work on “The Relativistic Geoid” at the special session on “Relativistic Metrology” at the 2017 Metrology for Aerospace conference in Padua, Italy:

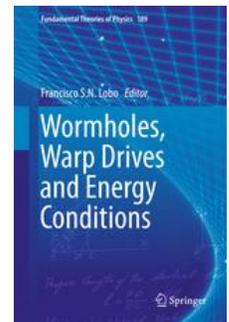
D. Philipp, V. Perlick, D. Puetzfeld, E. Hackmann, C. Lämmerzahl, *Definition of the relativistic geoid in terms of isochronometric surfaces*, *Phys. Rev. D* **95**, 104037 (2017).



The talk of Dennis Philipp and his contribution, which was one of 110 paper contributions to the conference, was awarded the *best paper presented by a young researcher* with a certificate and an exclusive silver plaque.

Wormholes, Warp Drives and Energy Conditions

A while ago the book “*Wormholes, Warp Drives and Energy Conditions*” was released in the series “Fundamental Theories of Physics” of Springer International Publishing AG. In the book researchers in the field of gravity present recent topics ranging from the stability of rotating wormholes supported by ghost scalar fields, modified gravity applied to wormholes, the study of semi-classical and non-linear energy conditions, to the applications of quantum effects and the superluminal version of the warp drive in modified spacetime. Burkhard Kleihaus and Jutta Kunz, contributed to the book with a chapter on “*Rotating Wormholes*”.



In this chapter rotating wormholes in General Relativity in four, and five dimensions are presented. Their nontrivial topology is supported by a phantom field. The wormhole solutions depend on three parameters, which are associated with the size of the throat, the magnitude of the rotation and the symmetry of the two asymptotic regions. The physical properties of these wormholes are discussed in detail. Their global charges are derived, including mass formulae for the symmetric and nonsymmetric cases. Their geometry is discussed, a definition of their throat in the nonsymmetric case is presented, and their ergoregions are investigated. The authors demonstrate the existence of limiting configurations, which correspond to extremal rotating vacuum black holes. Since a stability analysis of rotating wormholes in four dimensions is very involved, a stability analysis of five-dimensional rotating wormholes with equal magnitude angular momenta is performed, restricting the investigation to the unstable radial modes. Interestingly, when the rotation is sufficiently fast, the radial instability disappears for these five-dimensional wormholes.

Lobo F. (eds), *Wormholes, Warp Drives and Energy Conditions*, *Fundamental Theories of Physics*, vol. 189, Springer (2017), ISBN 9783319551814



Publications

I. M. Oldengott, T. Tram, C. Rampf, Y. Y. Y. Wong, *Interacting neutrinos in cosmology: exact description and constraints*, [arXiv:1706.02123](https://arxiv.org/abs/1706.02123)

K. Eilers, *Rosenhain-Thomae formulae for higher genera hyperelliptic curves* [arXiv:1707.08855](https://arxiv.org/abs/1707.08855)

Ž. Marojević, E. Göklü, H. Uecker, C.s Lämmerzahl, *Life time of topological coherent modes of a Bose–Einstein condensate in a gravito optical surface trap*, [arXiv:1708.04443](https://arxiv.org/abs/1708.04443)

D. Philipp, F. Wöske, L. Biskupek, E. Hackmann, E. Mai, M. List, C. Lämmerzahl, B. Rievers, *Modeling approaches for precise relativistic orbits I: Analytical, Lie-series, and pN approximation*, [arXiv:1708.04609](https://arxiv.org/abs/1708.04609)

J. L. Blázquez-Salcedo, C. Knoll, *Slowly damped quasinormal modes of the massive Dirac field in d-dimensional Tangherlini spacetime*, [arXiv:1709.07864](https://arxiv.org/abs/1709.07864)

C. Hoffmann, E. G. Charalampidis, D. J. Frantzeskakis, P. G. Kevrekidis, *Extreme events in near integrable lattices*, [arXiv:1710.04899](https://arxiv.org/abs/1710.04899)

S. Grunau, H. Neumann and S. Reimers, *Geodesic motion in the five-dimensional Myers-Perry-AdS spacetime*, [arXiv:1711.02933](https://arxiv.org/abs/1711.02933)

L. G. Collodel, B. Kleihaus and J. Kunz, *Static Orbits in Rotating Spacetimes*, [arXiv:1711.05191](https://arxiv.org/abs/1711.05191)

D. Philipp, E. Hackmann and C. Lämmerzahl, *Redshift and frequency comparison in Schwarzschild spacetime*, [arXiv:1711.01237](https://arxiv.org/abs/1711.01237)

Static Orbits in Rotating Spacetimes

In a recent paper ([arXiv:1711.05191](https://arxiv.org/abs/1711.05191)) Lucas Collodel, Burkhard Kleihaus and Jutta Kunz showed that under certain conditions an axisymmetric rotating spacetime contains a ring of points in the equatorial plane, where a particle at rest with respect to an asymptotic static observer remains at rest in a static orbit. It is worth mentioning that this phenomenon of static orbits is a purely inertial one. The physical conditions to be met in order to allow for such static orbits

require, that besides a precise balance between the angular momentum and the frame dragging, the gravitational potential contained in the metric component g_{tt} should possess a maximum, such that a particle sitting at the corresponding radius r_{st} is neither pulled towards the center nor pushed away from it. Clearly, the extremum of g_{tt} and the extremum of the effective potential must therefore coincide at r_{st} .

The emergence of static orbits is illustrated for boson stars in the paper. However, such orbits arise not only for boson stars but also for Ellis wormholes immersed in rotating bosonic matter, as well as for hairy black holes or Kerr-Newman solutions.

While one might argue that it might be unlikely to expect nature to produce such a fine tuned scenario, it can be verified that geodesics followed by particles initially at rest near the (stable) static radius are characterized by slow motion. The closer they start from r_{st} the smaller are their maximal radial and angular velocities. This opens the possibility of observing this phenomenon, if rotating compact objects such as the above examples would indeed exist in nature.

Therefore, observing static, or quasi-static, astrophysical objects in a region which otherwise indicates the presence of a strong gravitational field could offer support for the presence of a type of compact object that differs from the Kerr black hole.

