COST STSM Report: Minimal dilatonic gravity in full GR
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Host: Prof. Luciano Rezzolla

The purpose of this STSM is to place the foundations for the use of the minimal dilatonic gravity (MDG) in physically realistic models of compact relativistic stars. The first application of MDG field equations was recently presented in Fiziev (2014) /arXiv:1402.2813 [gr-qc]/ for the case of relativistic static spherically symmetric stars. There, the field equations for this metric have been used to find the properties of neutron stars with the equation of state (EOS) of an ideal Fermi neutron gas at zero temperature. The so obtained results demonstrated the potential of MDG as an alternative description of the effects of dark matter and dark energy in models of relativistic compact stars. It also exposed some numerical problems which need to be addressed, in particular, it exposed the need of new numerical implementation of the equations governing the problem, independent of the software package MAPLE, where it is difficult to reach the mass of the dilaton required by the Solar System observations. In contrast to general relativity, the exterior solution for stars in MDG is not known analytically. Therefore, it has to be obtained via numeric integration of the exterior equations under proper boundary conditions, consistent with the de Sitter space-time geometry far enough with respect to the single star.
As part of this visit, the following has been done:
1. The problem of extending the MDG model to rotating neutron stars has been discussed with the host, prof. Rezzolla, focusing on different numerical codes for rotating neutron stars and the prerequisites needed for the use of MDG in such codes.
2. The static TOV equations was implemented in a FORTRAN code using the Rosenbrock method for integrating the system and it was used to study the numerical behavior of the MDG equations. The code was applied to the case of equation of state describing relativistic white dwarf, and the results were compared with the those obtained with MAPLE. The resulting code is currently able to integrate up to 7-10 star radii.
3. As part of the visit, and following the discussions with prof. Rezzolla, it has been decided to implement the MDG equations in the COCAL code's static TOV solver. This has been done in collaboration with Dr. Antonios Tsokaros from the ITP whose knowledge of the COCAL routines facilitated significantly the successful implementation of the equations in the specific form COCAL uses. Also, the details on the MDG theory have been discussed with prof. Fiziev from JINR, Dubna. First numerical results have been obtained in the case of gamma=2 non-rotating neutron star.
This step is extremely important with respect to the future use of the MDG theory for the cases of rotating neutron-stars. In order to be able to use COCAL in the rotating neutron stars case, one needs a 3+1 formulation of the MDG theory. However, since the static TOV solver is used for the evolution of the rotating case, implementing the MDG equations in it and studying both their numerical behavior and their physical interpretation is critical for the future 3+1 implementation of the MDG.
4. The results have been presented on a Astro-Coffee seminar at the ITP. The seminar consisted in presenting the astrophysical background for the MDG theory, the theoretical formulation of the MDG theory as well as the numerical results obtained with MAPLE, Fortran and COCAL. The fruitful discussion during and after the seminar gave interesting suggestions on possible developments of the theory and it will aid a clearer presentation of the results in future works.

Beyond its short-term scientific goal, this STSM is a part of a larger project to foster collaboration between the numerical groups at the ITP, Frankfurt, Germany led by prof. Rezzolla, the INRNE, Bulgaria and the Joint Institute for Nuclear Research (JINR), Dubna, Russia, led by prof. Plamen Fiziev. The fruitful work between those groups can lead to numerous publications, and on the possibility of using MDG in different physical configurations and also, with more realistic equation of states. This collaboration has the potential for future exchanges and common projects.
As a direct result of this STSM, an article on the case of use of the static COCAL TOV solver applied to the case of white dwarfs in MDG is in preparation.