# STSM Report: Importing Elasticity to WhiskyTHC

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**Purpose of STSM** The goal of this week-long visit was to discuss the details of importing a conservation law formulation for elasticity into the WhiskyTHC code, and to identify the next steps that need to be taken to move this project forward. The trip also gave me an opportunity to present my work on elasticity and interfaces to the group in Frankfurt.

**Summary of Work Completed** Over the course of the week, we conducted meetings to discuss the specifics of importing the elasticity formulation into the WhiskyTHC code. We discussed specific scientific questions that we would like to answer using the code, as well as technical challenges that we will need to face. We also identified two possible routes that the project could take, as well as several funding options for the project. During the trip, I also gave a 50 minute, seminar-style talk.

**Summary of Main Results** The main result of the visit is a clearer plan as to how to proceed with this project. This includes a clearer scientific question, possible technical challenges and ideas as to how to solve them, as well as ideas for funding the work.

Through this project, we hope to quantify the upper limit of the effect that an elastic crust could have on the tidal deformations of neutron stars in a binary merger system, and therefore the upper limit of the influence of these tidal distortions on the phase evolution of the gravitational wave signal. Because the goal of the project is to simply produce an upper limit, a simulation where the entire star is made of an elastic solid capable of sustaining shear strain should be sufficient.

A number of challenges were identified; most of which will be relatively simple to overcome. For example, we thought about how we might encounter problems with an elastic atmosphere, and how we might encounter problems with higher-than-second-order evolutions because we lack the analytical solution to the eigenproblem for elasticity in relativity. However, the most concerning issue is the slow speed of the current elasticity code.

The code for elasticity is roughly 8 time slower than a similar hydrodynamic code, partially because it has 19 evolved variables instead of 5, and partially because it must use a 4-dimensional root finder for calculating the primitive variables from the conserved variables, where a 1-dimensional root finder is used for relativistic fluids. This slowness of this code could potentially mean that doing a fully relativistic 3D simulation is not feasible.

Because of this, we are considering two options for moving forward with this project. The first option is to simply import elasticity into WhiskyTHC and do fully relativistic simulations of binary neutron star mergers. However, as mentioned above, this may prove to be infeasible because of the slowness of elasticity calculations. Another option, which would be less computationally intense, would be to import elasticity into a LORENE-like code to find a series of equilibrium orbits of the two stars to achieve the same results.

In addition to this plan, we also identified possible funding sources for me to go to Frankfurt to carry out this work. One option is the Alexander von Humboldt Foundation, which offers fellowships for early career postdoctoral researchers to carry out research at German universities. There is no deadline for this, as applications are continuously reviewed, but the next selection committee meeting (the final step of the selection process) is in November. Another option is the Marie Skłodowska-Curie Action Individual Fellowship; the deadline for this is 11 September 2014.

**Future Collaborations** The hope is that I will go to Frankfurt to carry out the work of importing elasticity into a binary neutron star merger code in order to determine the maximum effect that this could have on the phase evolution of gravitational waves emitted from that system. However, this plan is entirely subject to funding.

**STSM Grant Information**

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| **COST Action** | MP1304 |
| **STSM Title** | Importing Elasticity to WhiskyTHC |
| **Reference** | ECOST-STSM-MP1304-210714-047891 |
| **STSM Dates** | from 21-07-2014 to 26-07-2014 |
| **Location** | Institute for Theoretical Physics<br>Frankfurt am Main<br>Germany |
| **Host** | Professor Luciano Rezzolla<br>Institute for Theoretical Physics<br>luciano.rezzolla@aei.mpg.de |