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Spacetime Structure and Rotation Profile of Binary Neutron Star Remnant

Neutron stars are among the most compact objects known to exist in the universe, reaching densities a few times (~3) larger than that of an atomic nucleus. In these extreme conditions, Newton's theory of gravity is no longer sufficient and general relativistic effects must be taken into account. The evolution of a NS is therefore governed by curved spacetime phenomena as well as fluid and magnetic field dynamics. Among the resulting phenomena is gravitational frame-dragging, a relativistic effect, in which a spinning mass causes its surrounding spacetime to rotate.

When two neutron stars merge, they form a rapidly rotating, massive remnant with a unique internal rotation profile. In particular, the angular velocity reaches a minimum near the centre and a maximum in the outer layers of the star. The origin of this distinct feature is not fully understood. To study these systems, neutron star mergers have been simulated numerically by solving the coupled Einstein and magnetohydrodynamic equations.

As part of a Master's thesis, this work analyses simulation data of a binary neutron star merger produced in previous research. We examine the spacetime structure of the binary neutron star remnant approximately 100 ms after the merger. Employing a transformation of the metric to cylindrical coordinates, we show that the spacetime is approximately axisymmetric (i.e. symmetric around the rotation axis). Furthermore, we fit a radial conformally flat metric – a flat metric multiplied by a radial scalar function (the conformal factor) – to the spatial metric, finding deviations of only at most 16%. Finally, using the conformal factor we employ a second coordinate transformation that uses the proper distance to the origin as a radial coordinate. This framework allows us to interpret the rotation profile of the fluid, decomposing it into frame-dragging effects and physical fluid movement. We find that at the centre the physical fluid angular velocity tends to zero, therefore the central angular velocity appears to be governed by the gravitational frame-dragging. In the further course of this work, we aim to investigate the origin of the observed rotation profile by analysing how it changes when we resolve smaller-scale fluid turbulence less accurately.