Astrophysical tests of modified gravity

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Introduction

Neutron stars are one of the best astrophysical candidates for testing the strong field regime of gravity, where there is expectation that deviations from General Relativity could be observed. And, in this context, a scenario still little explored are the tests of modified gravity for neutron stars that are rapidly rotating.

In this work, we study f(R, T) [1] gravity, where the gravitational Lagrangian is an arbitrary function of the Ricci scalar R and of the trace of the energy-momentum tensor T. Our goal is to explore the modifications produced by this theory on the physical quantities associated to rapidly rotating neutron stars.

Rapidly Rotating Stars in f(R,T) Gravity

- The space-time geometry is described by a stationary axisymmetric metric in spherical coordinates.
- The matter of the star is described by a perfect fluid with realistic equation of state.
- The field equations and the equation of hydrostatic equilibrium are obtained for $f(R,T)=R+2\lambda T$.
- We solve the equations using the KEH [2] iterative numerical method.
- Once we have our solutions, we calculate physical quantities such as mass M and radius R_e of the neutron stars and compare our results with observational data.

Results

Consequences of f(R,T) gravity to the physical properties of the neutron stars when compared to General Relativity:

Below Kepler limit*:

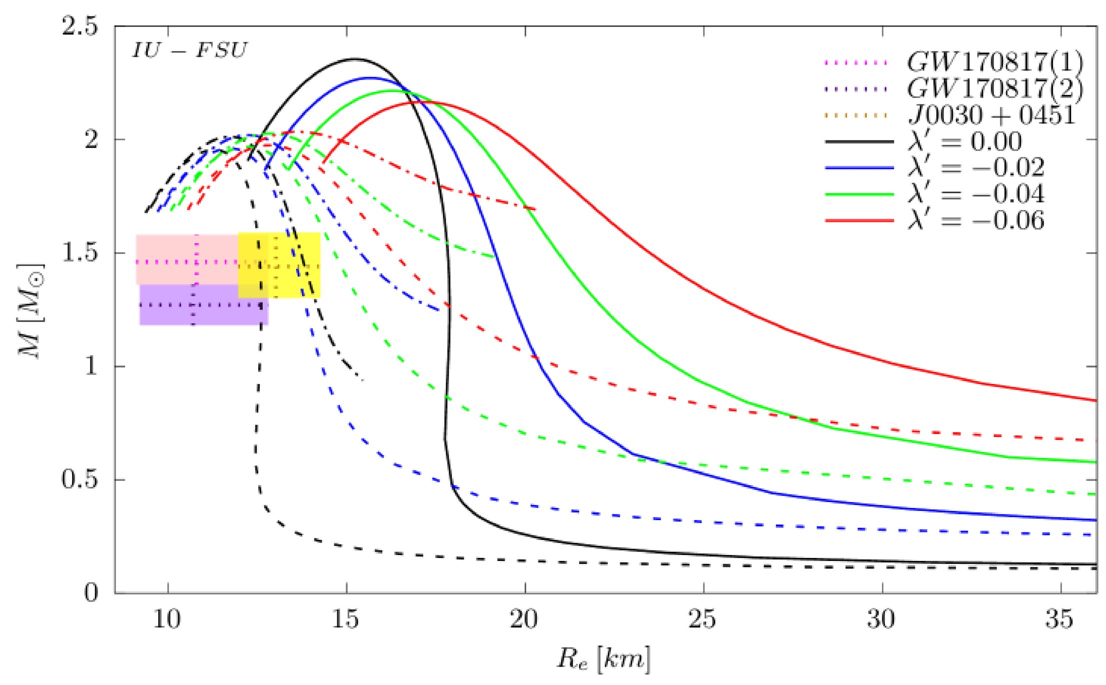
- increases mass M;
- increases moment of inertia I.

At Kepler limit:

- decreases Kepler limit Ω_K;
- decreases mass M;
- decreases moment of inertia I.

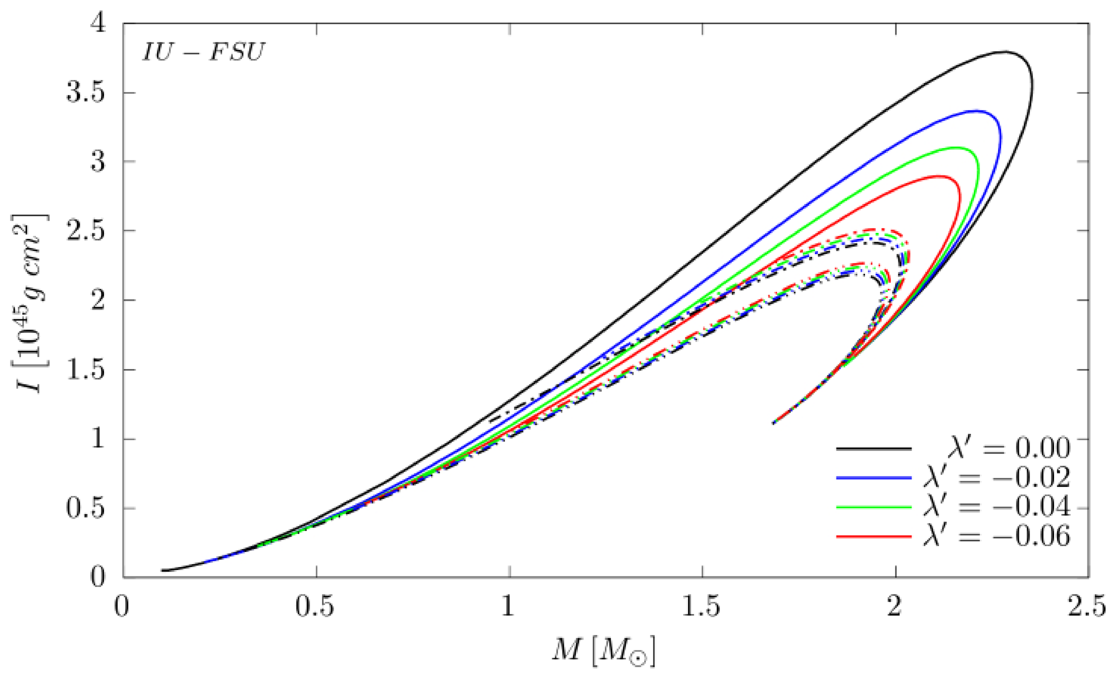
On both cases:

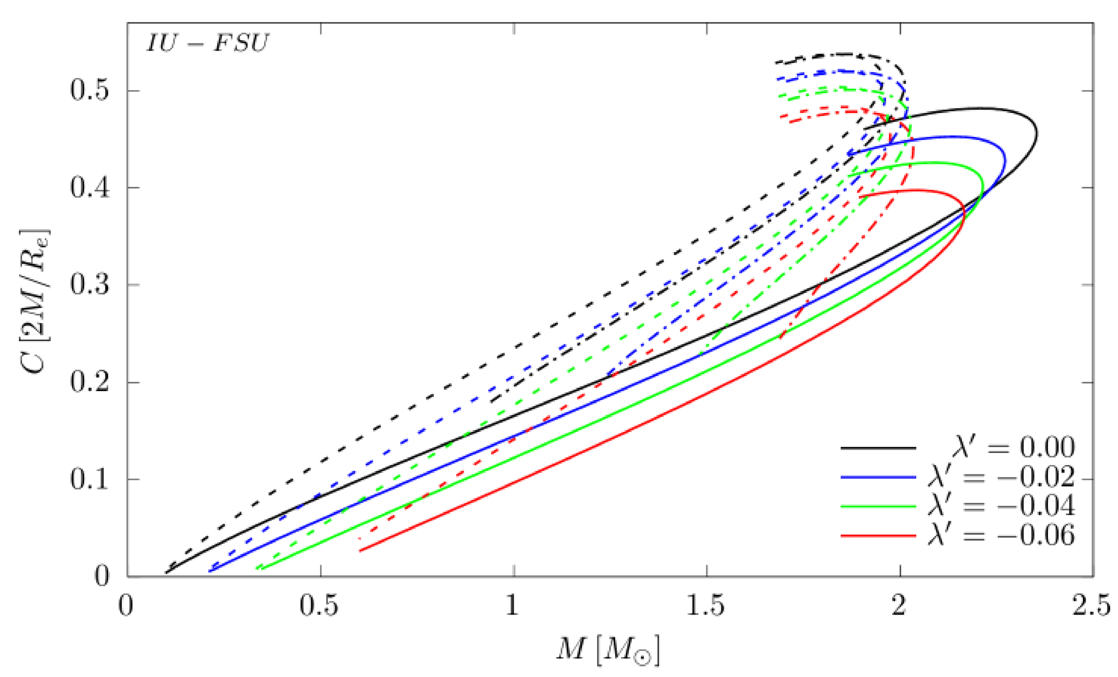
- increases equatorial radius R_e;
- decreases compactness C.



The mass-radius relation for sequences of static stars in dashed curves, stars rotating at 716 Hz in dash-dot curves and stars rotating at the Kepler limit in solid line curves. The curves for $\lambda'=0$ correspond to the General Relativity case.

*The Kepler limit is the maximum velocity that the star can rotate before it starts to lose mass at the equator, so this limit is also known as the mass-shedding limit.





On the left the moment of inertia I and on the right the compactness C as a function of the mass M. Static stars are in dashed curves, the ones rotating at 300 Hz are in dash double-dot curves, the ones rotating at 716 Hz are dash-dot curves and the stars rotating at the Kepler limit are in solid line curves. The curves for $\lambda'=0$ correspond to the General Relativity case.

Conclusions

In this work, we studied the influence of f(R,T) gravity on the physical quantities associated to neutron stars in a fast rotation regime.

Using the mass and radius estimates for GW170817 and PSR J0030+0451 as constraints, our results indicate that this modified theory of gravity gives results that are compatible with observational data if its parameter λ is small ($|\lambda| \leq 0.02$).

In the future, we intend to do further research on the viability of this theory in other contexts, such as geodesic motion of particles near compact objects.

Literature cited

[1]. Harko, Tiberiu, et al. PRD 84.2 (2011): 024020.

[2]. Komatsu, Eriguchi, and Hachisu. MNRAS 237.2 (1989): 355-379.

Acknowledgments

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Further information

Cosmo-ufes page: cosmo-ufes.org

This work is available at: arxiv.org/abs/2206.08469