Self-force as probe of internal structure

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Self-force as probe of internal structure

The self-force is the result of a nonlocal interaction between the field created by an electric charge and the spacetime curvature.

In principle the self-force depends on all aspects of the spacetime, both local and remote.

In the case of a static charge outside a spherical distribution of matter, the self-force depends on the body's internal structure.

What does the self-force tell us about this internal structure?

Static charges in static, spherically-symmetric spacetimes

Key works:

- Smith and Will (1980): Schwarzschild black hole
- Unruh (1976): Inside a thin shell
- Burko, Liu, and Soen (2001): Inside and outside a thin shell
- Drivas and Gralla (2011): Outside a matter distribution

Drivas and Gralla showed that

$$F^r = \frac{e^2 M}{r^3} + O(r^{-5})$$

for any matter distribution; the self-force is universal to leading order in r^{-1}.

They showed also that the dependence on internal structure occurs at order r^{-5}, but did not explore this dependence.

This work

To explore the dependence on internal structure, we compute the self-force acting on a static electric charge outside a static, spherically-symmetric, relativistic polytrope.

The rest-mass density ρ, pressure p, and thermodynamic energy density ϵ satisfy the equations of state

$$p = K\rho^{1+1/n}, \qquad \epsilon = np$$

with K a scaling constant and n the polytropic index.

For given K and n, polytropic stellar models form a family parameterized by the central density ρ_c.

They have a total mass M and a radius R.

Self-force outside a polytrope

Following Drivas and Gralla, we compute the self-force difference

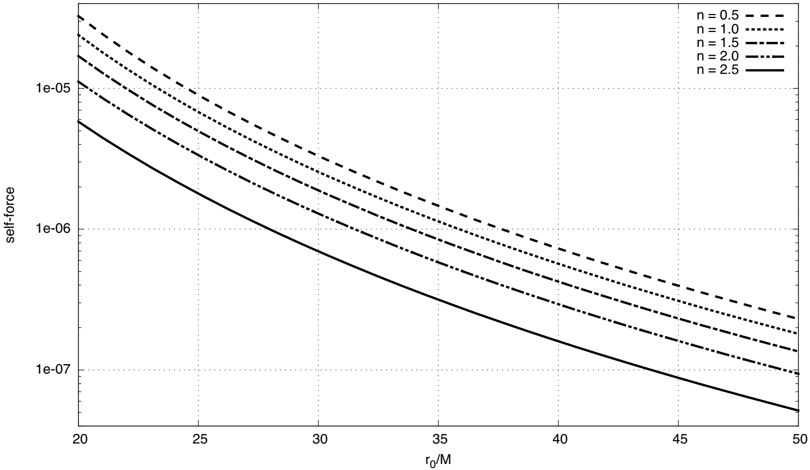
$$\Delta F^r = F^r_{\text{polytrope}} - F^r_{\text{black hole}}$$

where

$$F^r_{\text{black hole}} = \frac{e^2 M}{r^3}(1 - 2M/r)^{1/2}$$

with an exponentially-converging mode-sum method.
We analyze the dependence of ΔF^r on the equation of state.

Self-force outside a polytrope



The self-force difference is plotted as a function of r/M; all polytropes have $R/M = 15$.