Charge Conservation, Entropy Current, and Gravitation
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Charge conservation, entropy current and gravitation

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We propose a new class of vector fields to construct a conserved charge in a general field theory whose energy–momentum tensor is covariantly conserved. We show that there always exists such a vector field in a given field theory even without global symmetry. We also argue that the conserved current constructed from the (asymptotically) timelike vector field can be identified with the entropy current of the system. As a piece of evidence we show that the conserved charge defined therefrom satisfies the first law of thermodynamics for an isotropic system with a suitable definition of temperature. We apply our formulation to several gravitational systems such as the expanding universe, Schwarzschild and Banãdos, Teitelboim and Zanelli (BTZ) black holes, and gravitational plane waves. We confirm the conservation of the proposed entropy density under any homogeneous and isotropic expansion of the universe, the precise reproduction of the Bekenstein–Hawking entropy incorporating the first law of thermodynamics, and the existence of gravitational plane wave carrying no charge, respectively. We also comment on the energy conservation during gravitational collapse in simple models.

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Rapid Communications

Unruh effect for fermions from the Zubarev density operator

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Using the Zubarev quantum-statistical density operator, we calculated the corrections to the energy-momentum tensor of a massless fermion gas associated with acceleration. It is shown that when fourth-order corrections are taken into account, the energy-momentum tensor in the laboratory frame is equal to zero at a proper temperature measured by a comoving observer equal to the Unruh temperature. Consequently, the Minkowski vacuum is visible to the accelerated observer as a medium filled with a heat bath of particles with the Unruh temperature, which is the essence of the Unruh effect.

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I-Love-Q: Unexpected Universal Relations for Neutron Stars and Quark Stars

Kent Yagi* and Nicolás Yunes

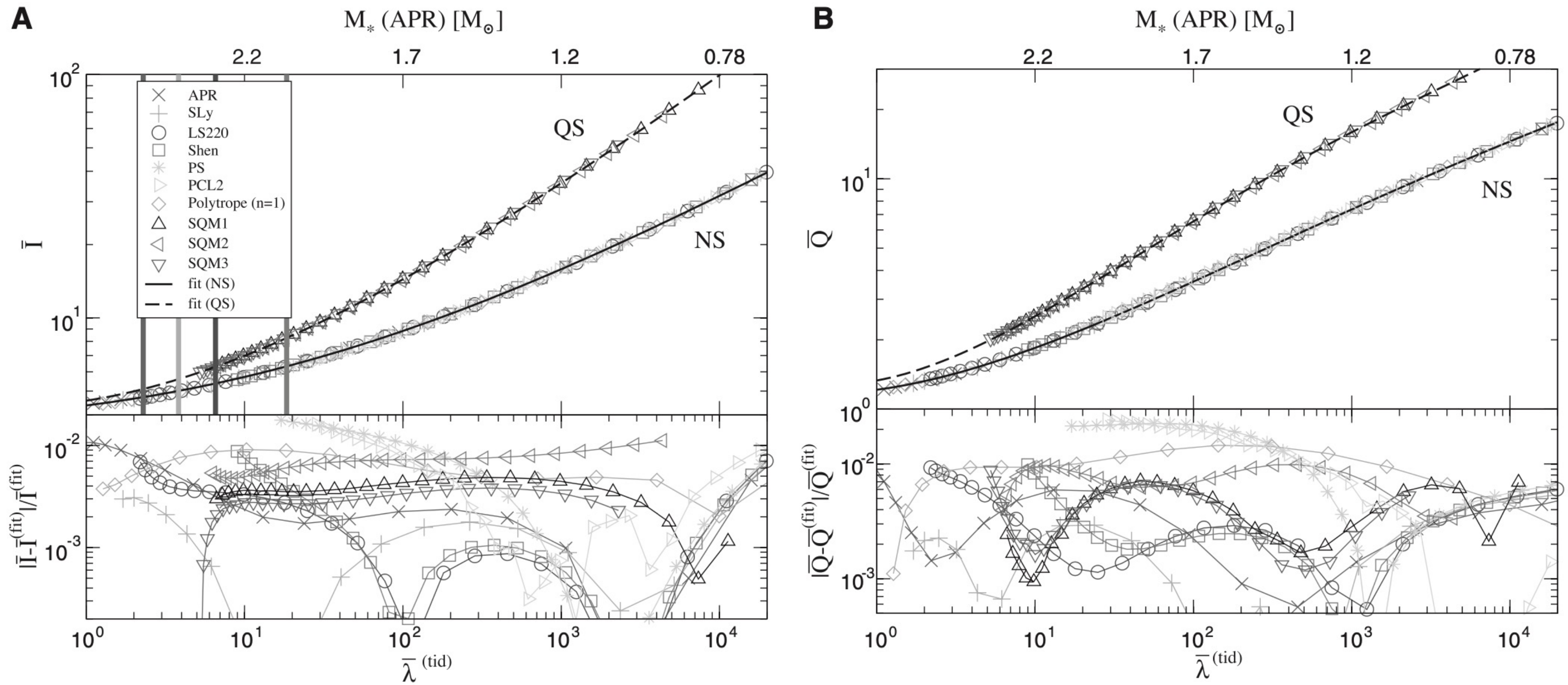
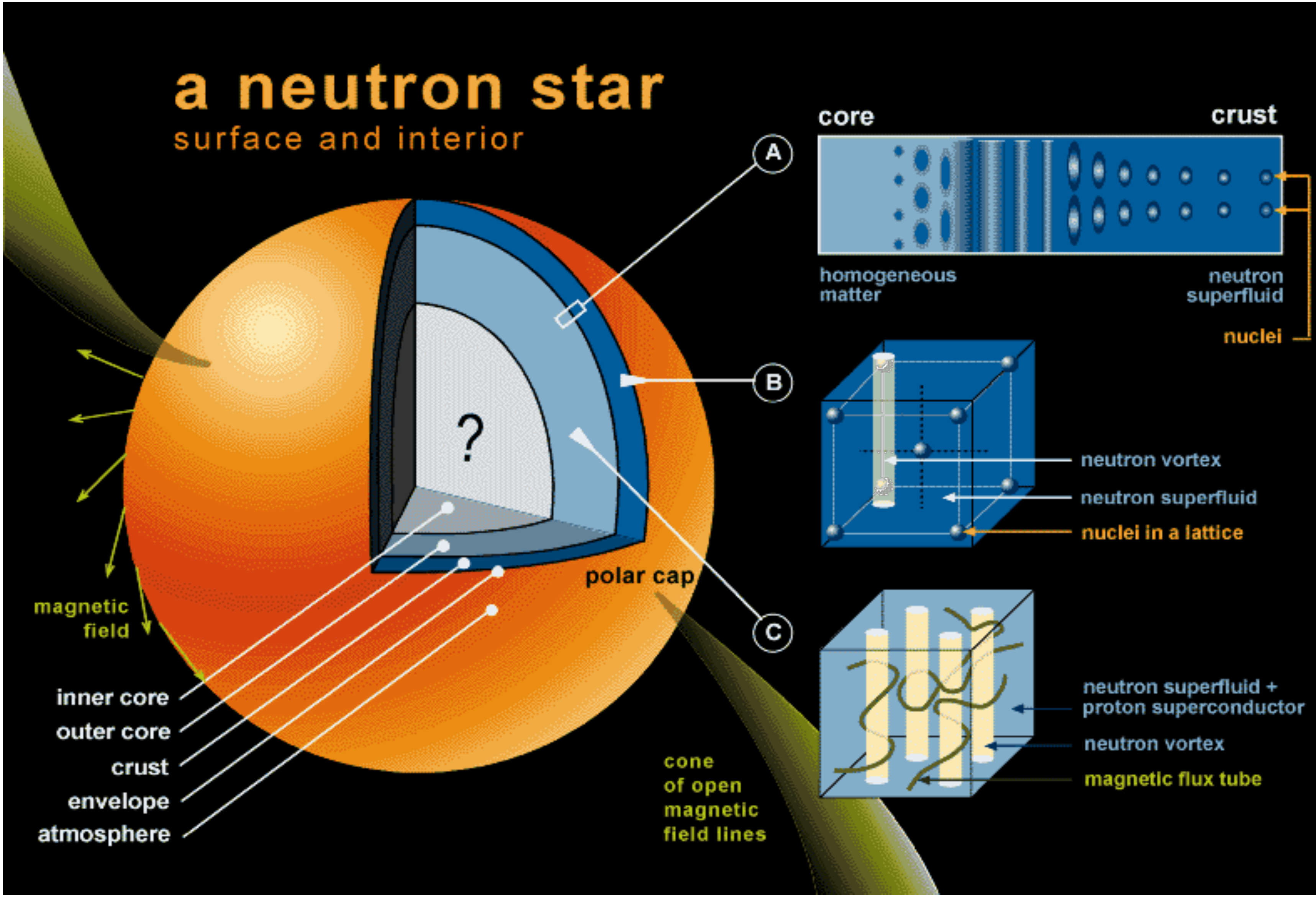


Fig. 1. I-Love and Q-Love relations. (A and B) (Top) The neutron star (NS) and quark star (QS) universal I-Love and Love-Q relations for various EoSs, together with fitting curves (solid and dashed curves). On the top axis, we show the corresponding NS mass with an APR EoS. The thick vertical lines show the stability boundary for the APS, SLy, LS220, and Shen EoSs from left to right. The parameter varied along each curve is the NS central density, or equivalently the NS compactness, with the latter increasing to the left of the plots. (Bottom) Fractional errors between the fitting curves and numerical results. $M_\odot$ indicates the mass of the Sun.

I-Love-Q - Unexpected Universal Relations for Neutron Stars and Quark Stars
Kent Yagi, Nicolás Yunes - Science 26 Vol. 341, Issue 6144, pp. 365-368 (2014)

Superdense objects – what is inside?



Computing the love number/tidal deformability

Extension of a standard TOV solver (i.e. numerically an integration of coupled ODEs):

Ansatz for the metric including a l=2 perturbation

$$
\begin{aligned}
ds^2 &= -e^{2\Phi(r)}\left[1+H(r)Y_{20}(\theta,\varphi)\right]dt^2 \\
&\quad +e^{2\Lambda(r)}\left[1-H(r)Y_{20}(\theta,\varphi)\right]dr^2 \\
&\quad +r^2\left[1-K(r)Y_{20}(\theta,\varphi)\right]\left(d\theta^2+\sin^2\theta d\varphi^2\right)
\end{aligned}
$$

Following Hinderer et al. 2010

Integrate standard TOV system:

$$
\begin{aligned}
e^{2\Lambda} &= \left(1-\frac{2m_r}{r}\right)^{-1}, \\
\frac{d\Phi}{dr} &= -\frac{1}{\epsilon+p}\frac{dp}{dr}, \\
\frac{dp}{dr} &= -(\epsilon+p)\frac{m_r+4\pi r^3 p}{r(r-2m_r)}, \\
\frac{dm_r}{dr} &= 4\pi r^2\epsilon.
\end{aligned}
$$

EoS to be provided ε(p)

And additional eqs. for perturbations:

$$
\frac{dH}{dr} = \beta \tag{11}
$$

$$
\begin{aligned}
\frac{d\beta}{dr} &= 2\left(1-2\frac{m_r}{r}\right)^{-1} H\left\{-2\pi\left[5\epsilon+9p+f(\epsilon+p)\right]\right. \\
&\quad \left. +\frac{3}{r^2}+2\left(1-2\frac{m_r}{r}\right)^{-1}\left(\frac{m_r}{r^2}+4\pi rp\right)^2\right\} \\
&\quad +\frac{2\beta}{r}\left(1-2\frac{m_r}{r}\right)^{-1}\left\{-1+\frac{m_r}{r}+2\pi r^2(\epsilon-p)\right\}.
\end{aligned}
$$

(K(r) given by H(r))

Note: Although multidimensional problem – computation in 1D since absorbed in Y20

Love number

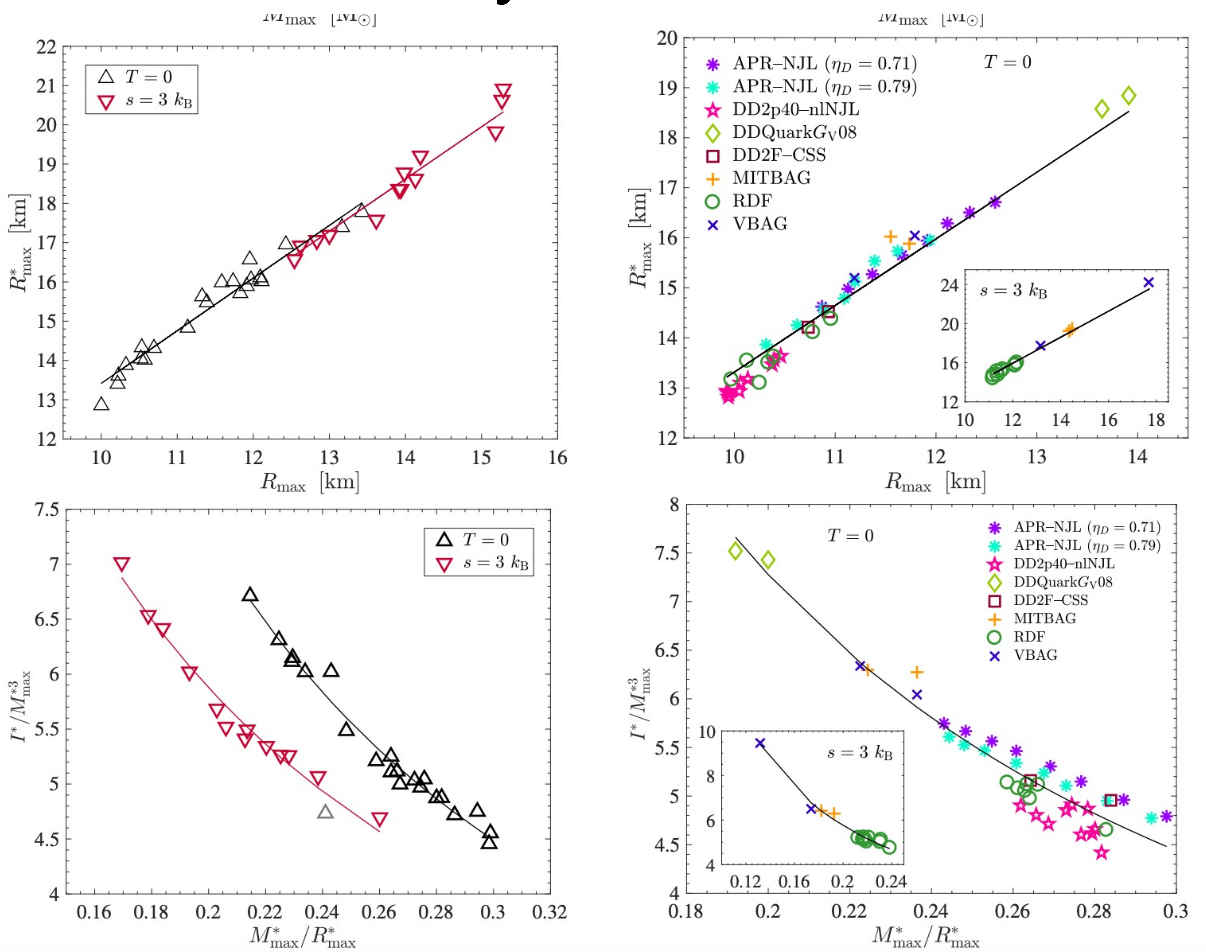
$$y = \frac{R\,\beta(R)}{H(R)}$$

$$\Lambda \equiv \frac{2}{3} k_2 \left(\frac{R}{M}\right)^5$$

$$\begin{aligned} k_2 = {} & \frac{8C^5}{5}(1-2C)^2[2+2C(y-1)-y] \\ & \times \Big\{ 2C[6-3y+3C(5y-8)] \\ & + 4C^3[13-11y+C(3y-2)+2C^2(1+y)] \\ & + 3(1-2C)^2[2-y+2C(y-1)]\ln(1-2C) \Big\}^{-1} \end{aligned}$$

where $C = M/R$ is the compactness of the star.

Universal relations for rapidly rotating cold and hot hybrid stars



Noshad Khosravi Largani, Tobias Fischer, Armen Sedrakian, Mateusz Cierniak, David E. Alvarez-Castillo, David B. Blaschke - arXiv: 2112.10439

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