Oscillation Modes and Gravitational Waves from Strangeon Stars

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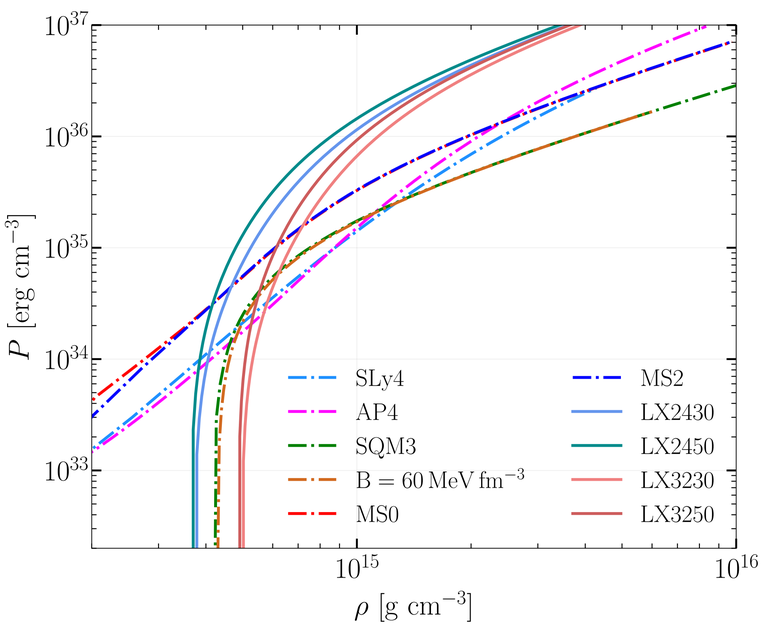
1. Abstract

To characterize the strong-repulsive interaction at short distance and the nonrelativistic nature of strangeons, a phenomenological Lennard-Jones model [1, 2], with two parameters is used to describe the EOS of strangeon stars (SSs). We investigate the oscillation modes of non-rotating SSs and obtain their frequencies for various parameterizations of the EOS. We find that the properties of radial oscillations of SSs are different from those of NSs, especially for stars with relatively low central energy densities. Moreover, we calculate the f-mode frequency of nonradial oscillations of SSs within the relativistic Cowling approximation. Finally, we study the universal relations between the f-mode frequency and global properties of SSs, such as the compactness and the tidal deformability.

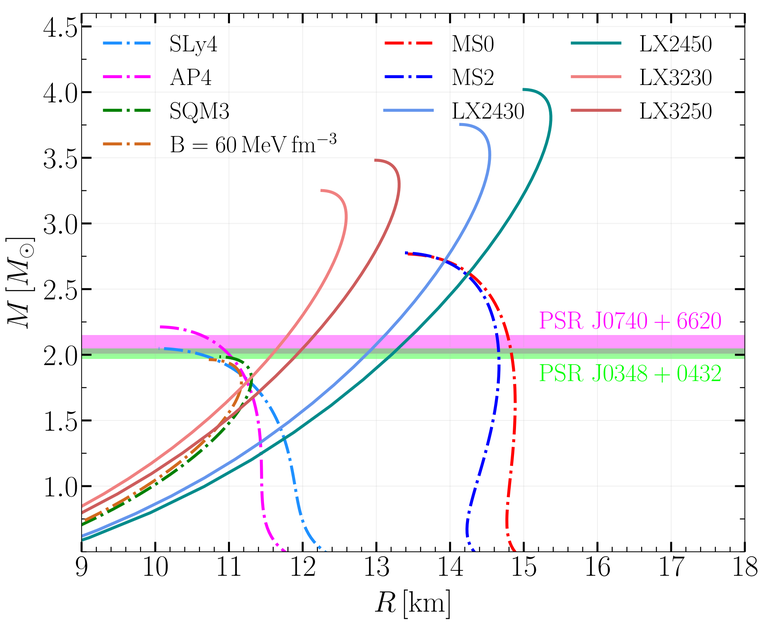
2. EOS of strangeon stars (SSs)

Relations between mass-energy density ρ and pressure P for NSs, QSs, and SSs.



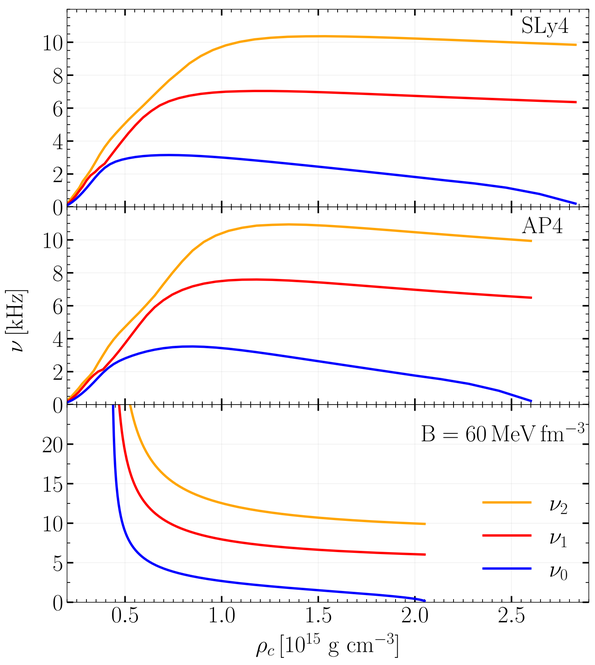
3. Mass and radius relation

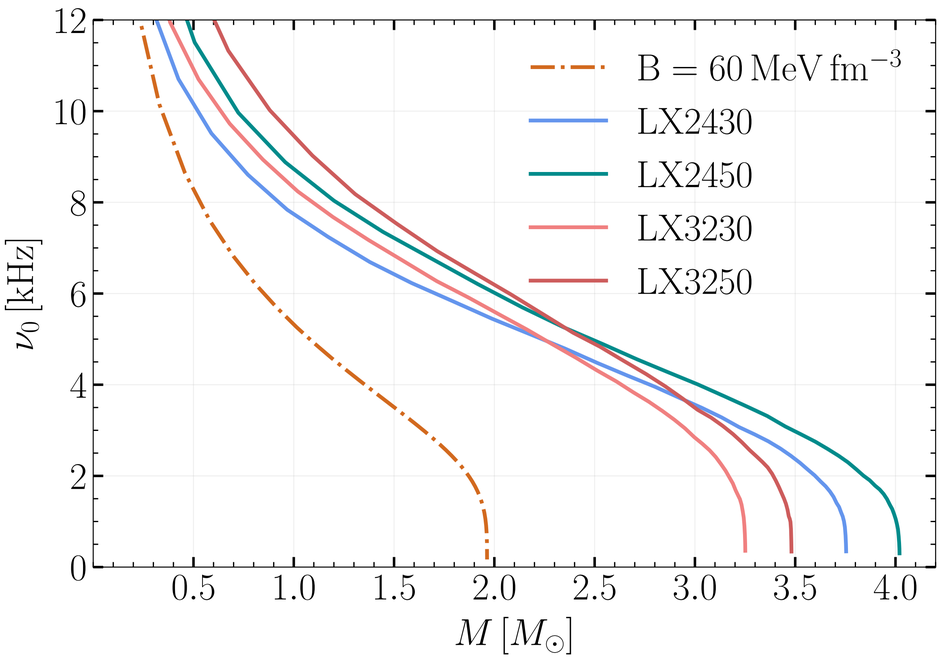
Mass-radius relations of SSs with different combinations of the surface baryonic density n_s and the potential depth ϵ. For comparison, we also show the mass-radius relations for selected NSs and QSs. The 1-σ regions of the mass measurements in PSRs J0348+0432 [3] and J0740+6620 [4] are illustrated.



4. Radial oscillation:Dynamical stability

We show the ordinary frequency ν_0 of the f-mode versus the mass of the stars for SSs and one EOS of QSs. The curves of SSs have the same trend as that of QSs, with ν_0 going to zero at their maximal masses. However, ν_0 for SSs is larger than that of QSs for a given mass, which arises from the fact that SSs' EOSs are much stiffer than that of QSs.



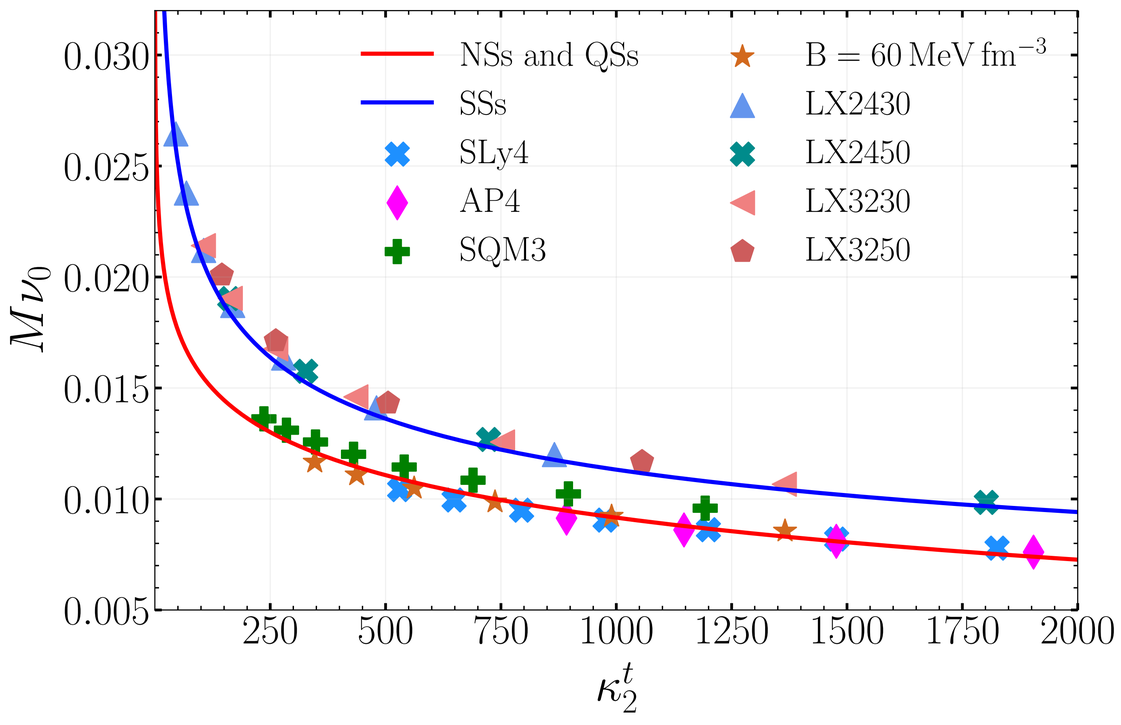


5. Nonradial oscillation: Universal relation

For binary NSs of masses M_a and M_b, the dimensionless tidal coupling constant is defined as,

$$\kappa_2^t = 2\left[q\left(\frac{X_a}{C_a}\right)^5 k_2^a + \frac{1}{q}\left(\frac{X_b}{C_b}\right)^5 k_2^b\right]. \quad (1)$$

Scaled frequency of the f-mode $M\nu_0$ as a function of the tidal quadrupolar ($l = 2$) coupling constant κ_2^t for NSs, QSs and SSs. The solid line represents the best power law fit in κ_2^t to the scaled frequencies of the NSs, QSs and SSs.



6. Conclusions

We use the Lennard-Jones model to describe the EOS of SSs with two parameters, the number density at the surface of the star n_s and the potential depth ϵ.

1. We study the radial and non-radial oscillations of non-rotating SSs.
2. The radial oscillation of SSs is different from the NSs, especially for the lower central energy density.
3. We study the universal relations between the f mode and the tidal deformability. The universal relations for QSs and SSs will complement that of NSs, and play a role in GW data analysis.

7. References

[1] J. E. Jones. On the Determination of Molecular Fields. II. From the Equation of State of a Gas. *Roc. Roy. Soc. Lond. A*, 106(738):463–477, October 1924.

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[3] John Antoniadis et al. A Massive Pulsar in a Compact Relativistic Binary. *Science*, 340:6131, 2013.

[4] E. Fonseca et al. Refined Mass and Geometric Measurements of the High-mass PSR J0740+6620. *ApJL*, 915(1):L12, 2021.