

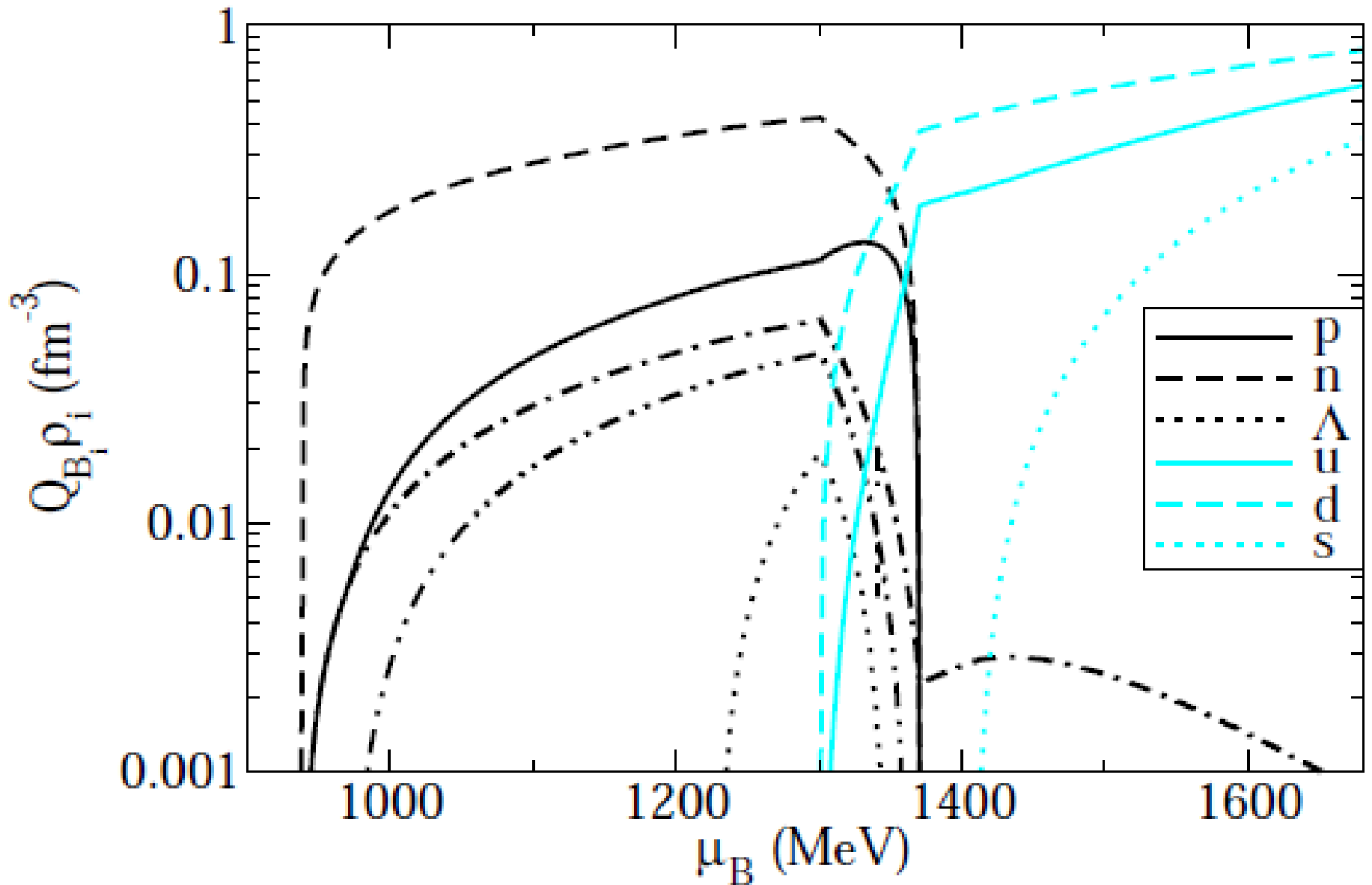
Evolution of Hybrid Stars Modeled With an $SU(3)$ non-linear Sigma Model

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Veronica A. Dexheimer, Stefan Schramm

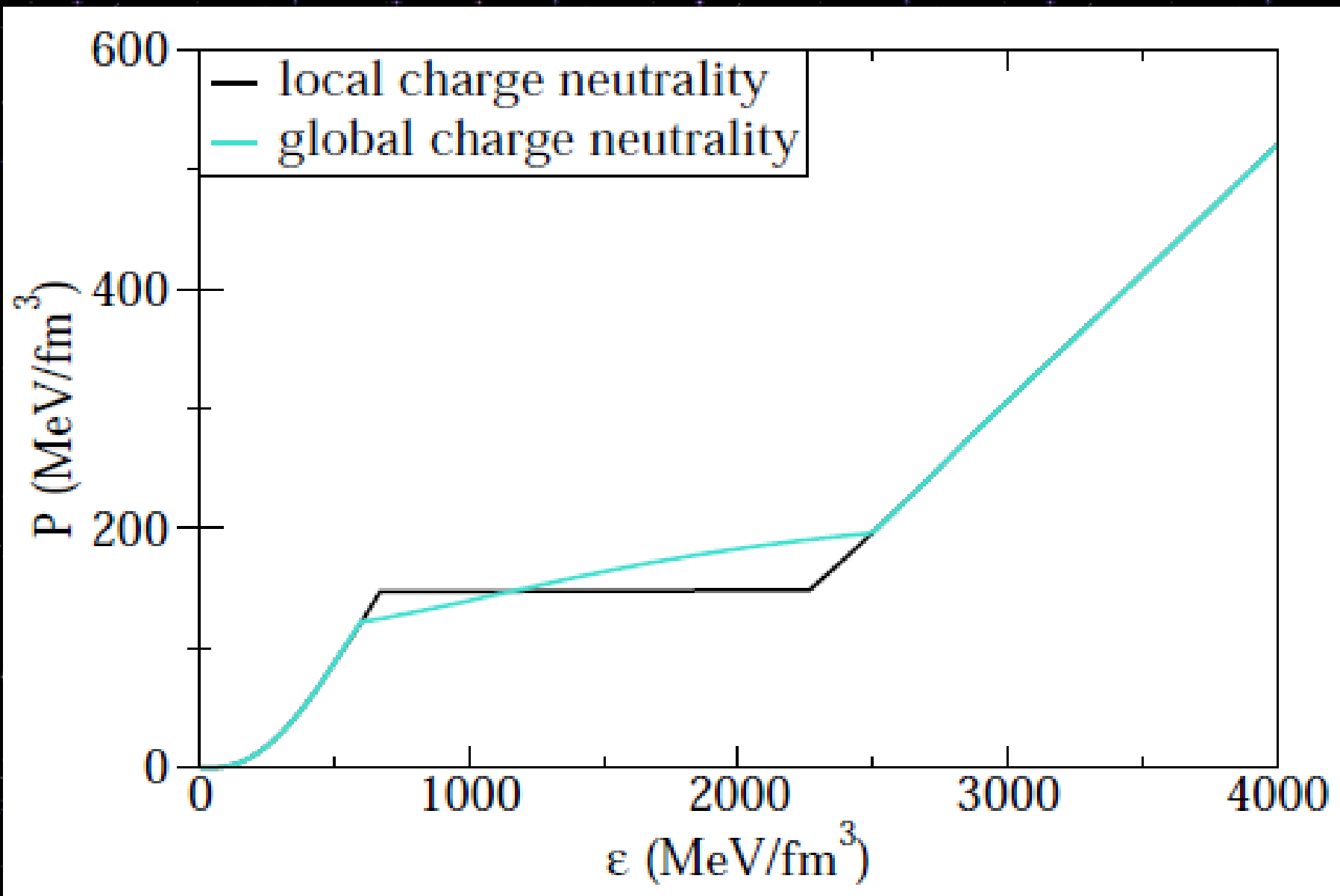
Introduction

- With our approach we can describe quark and hadrons degrees of freedom within the same model.
- Appropriate to describe hybrid stars.
- We investigate the spin-evolution of hybrid stars.
- The thermal evolution of hybrid stars is investigated. Possible effects of spin-down evolution to the cooling is addressed.

Composition



Equation of State



Static Hybrid Stars

Equation of State



Structure
Equations

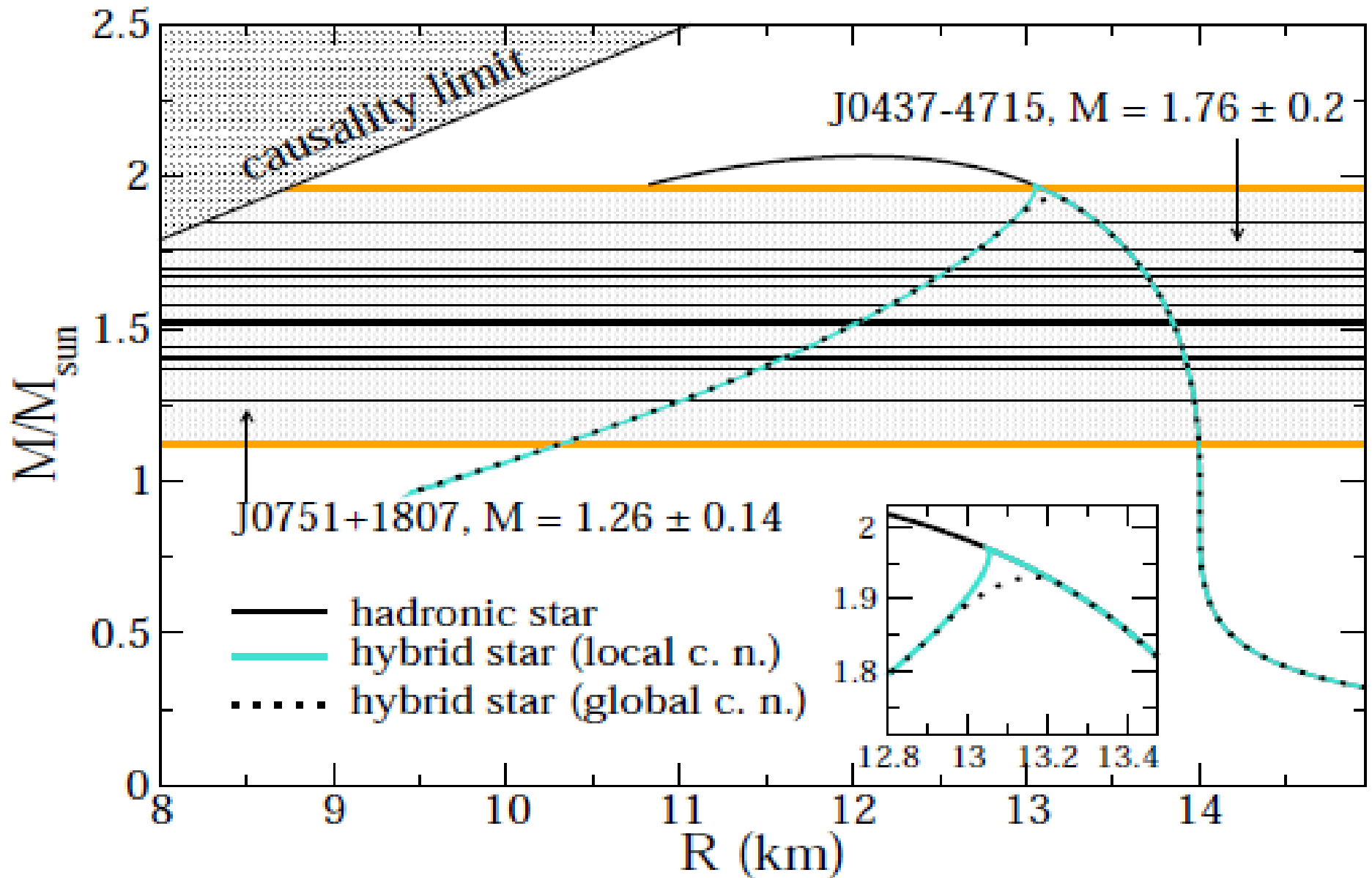
$$\frac{dp}{dr} = -\frac{[p(r) + \epsilon(r)][m(r) + 4\pi r^3 p(r)]}{r(r - 2m(r))}$$

$$m(r) = 4\pi \int_0^r dr r^2 \epsilon(r)$$



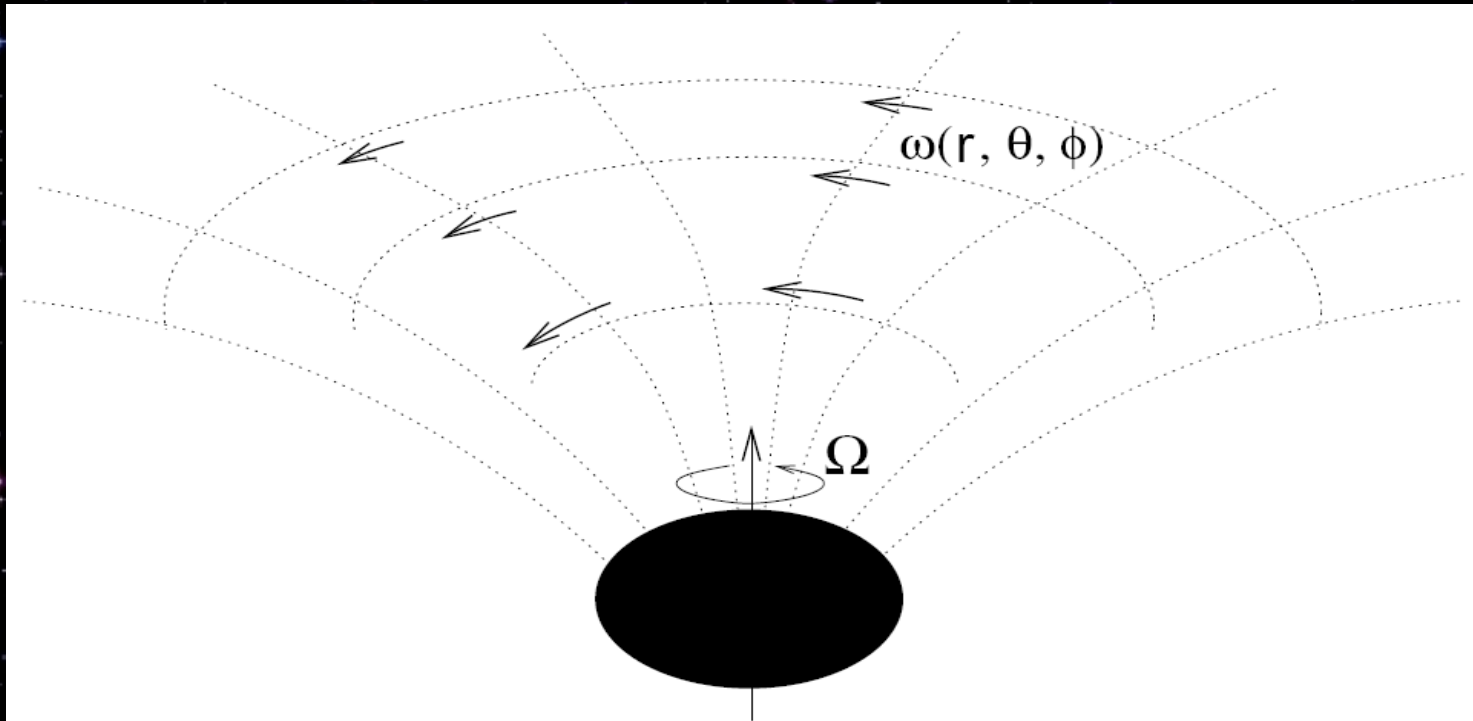
Stellar
Structure

Static Hybrid Stars



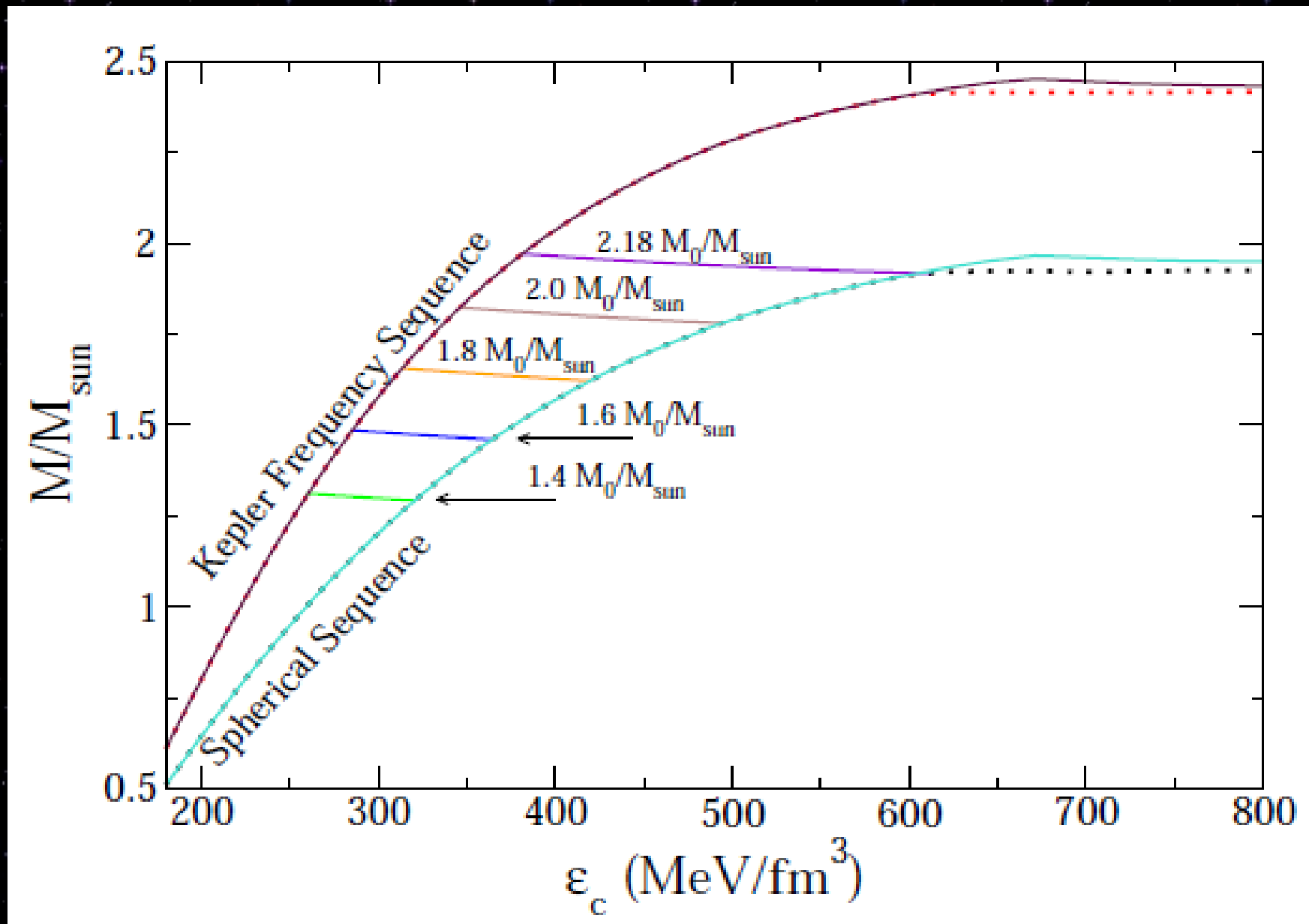
Rapidly Rotating Compact Stars

$$ds^2 = g^{\mu\nu} dx_\mu dx_\nu = -e^{\gamma+\rho} dt^2 + e^{2\alpha} (dr^2 + r^2 d\theta^2) + e^{\gamma-\rho} r^2 \sin^2 \theta (d\phi - \omega dt)^2$$

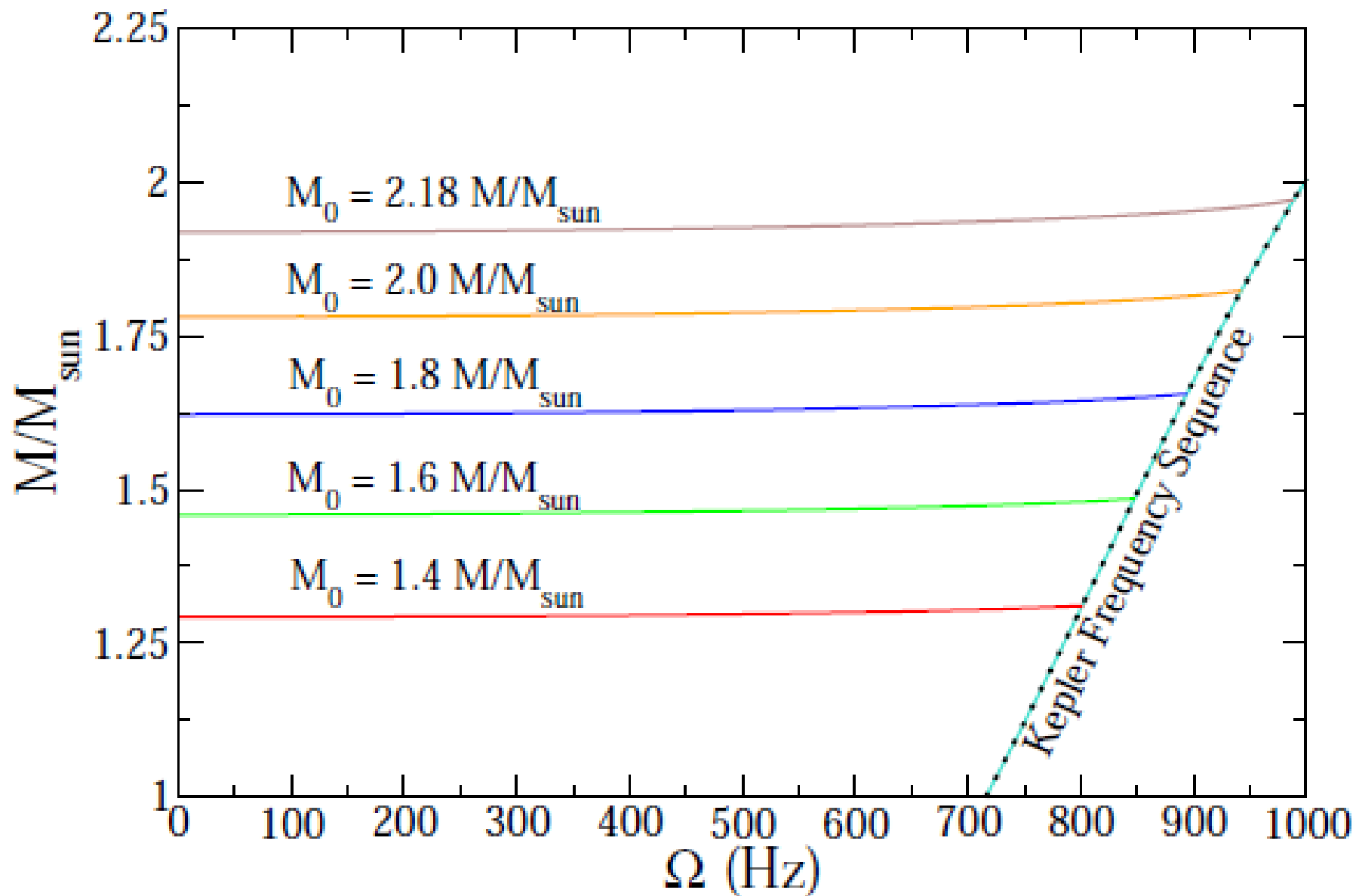


$$G^{\mu\nu} = R^{\mu\nu} - \frac{1}{2} g^{\mu\nu} = 8\pi T^{\mu\nu}$$

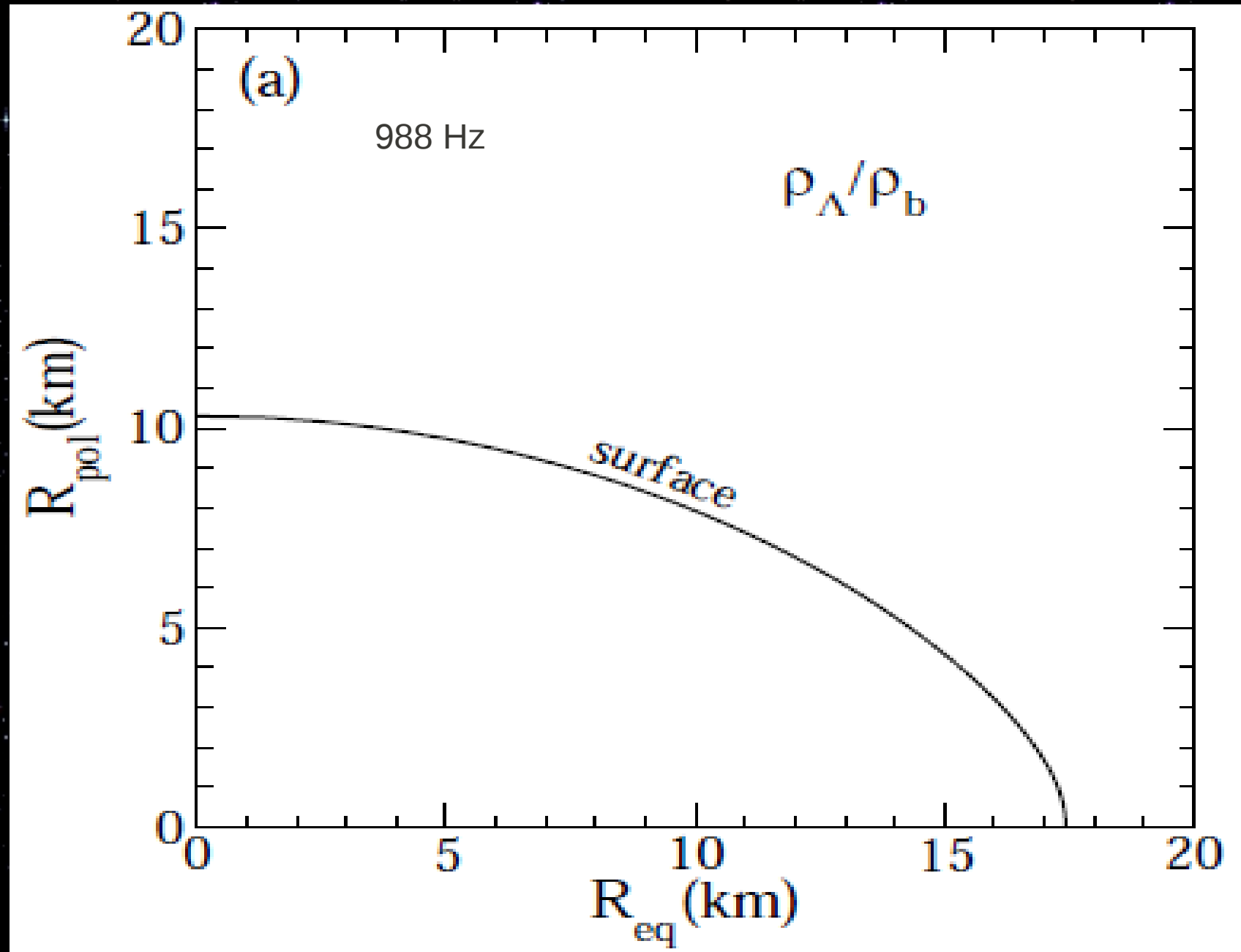
Constant Baryon Mass Sequences



Constant Baryon Mass Sequences

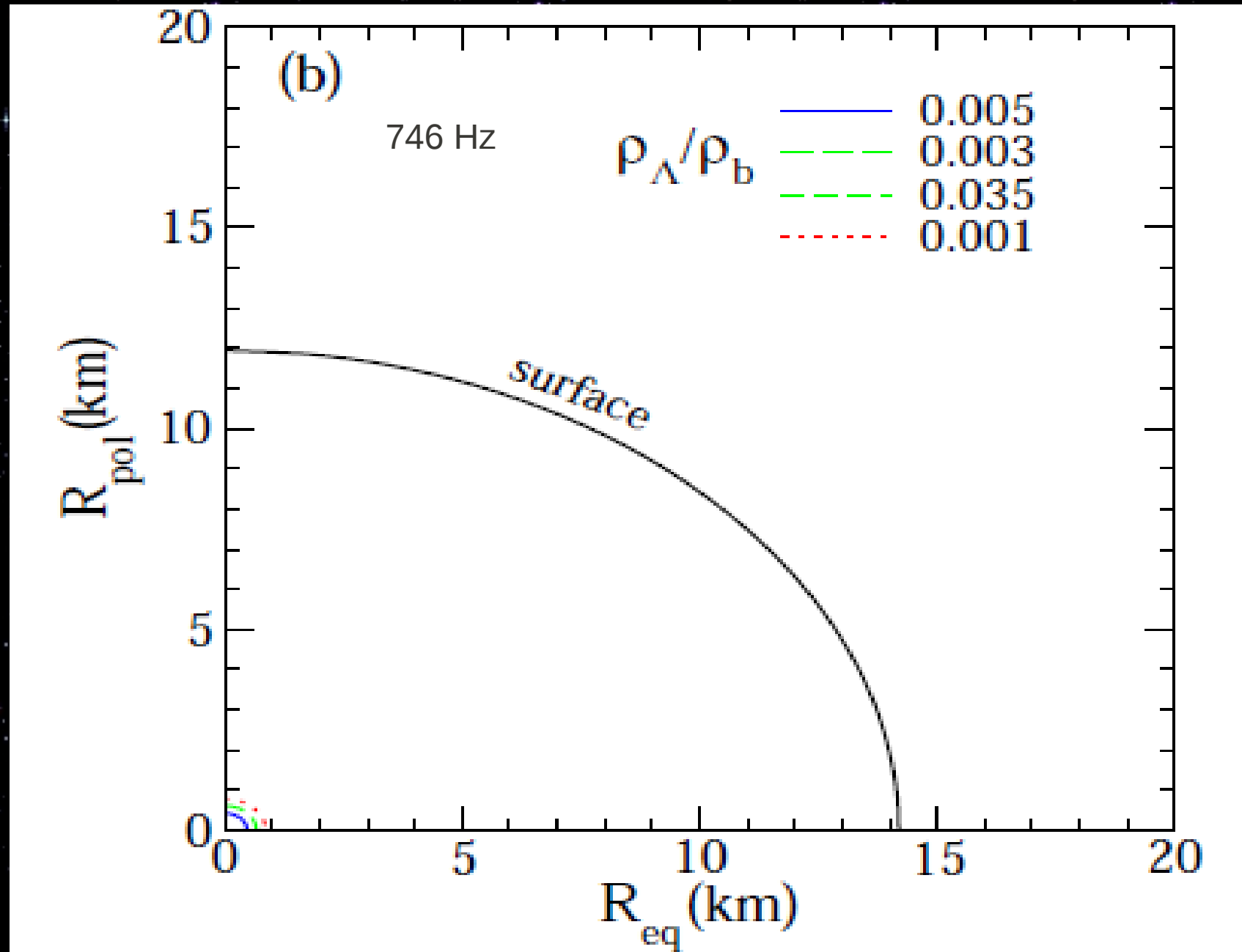


Composition Changes Caused by Spin Evolution

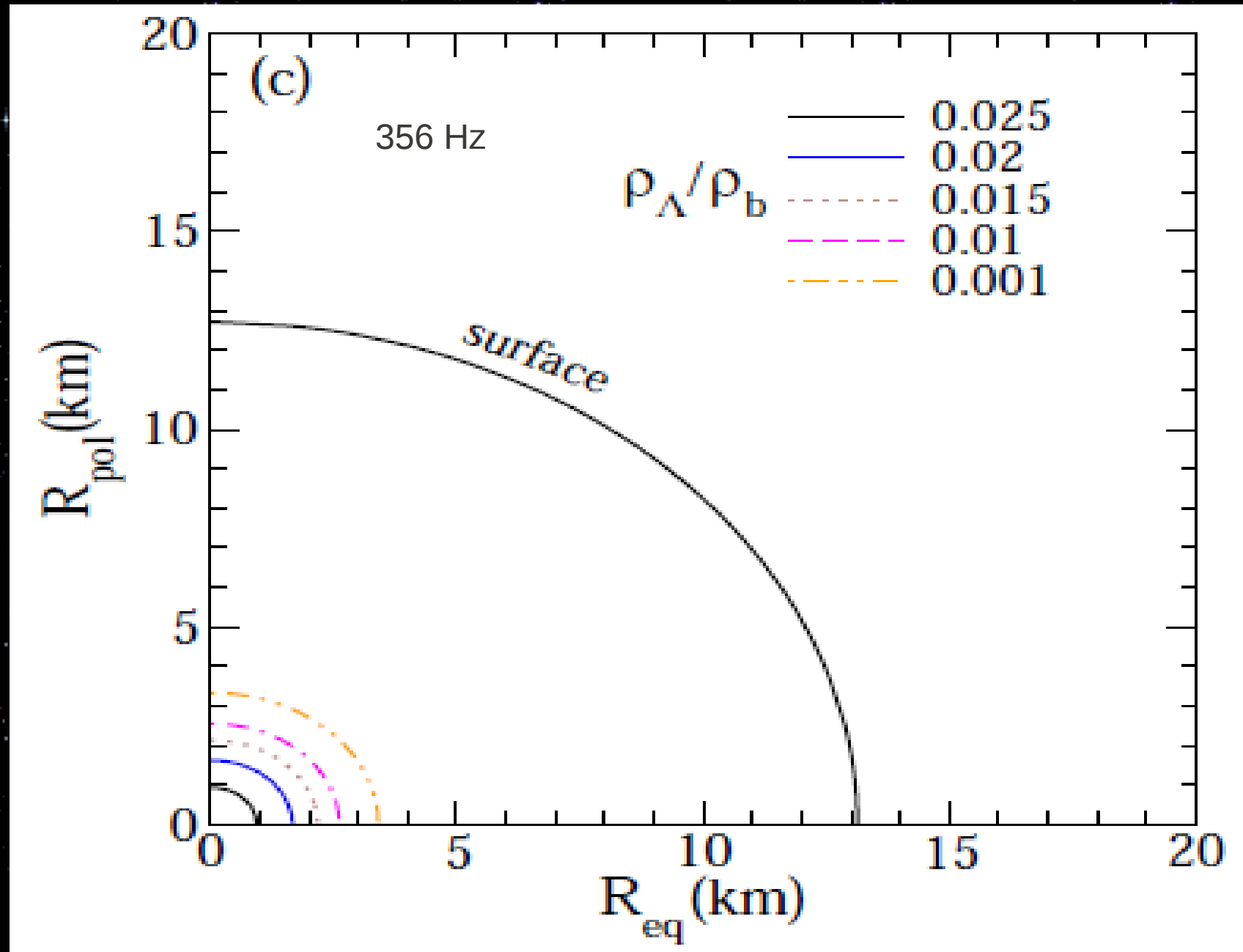


Hybrid Star

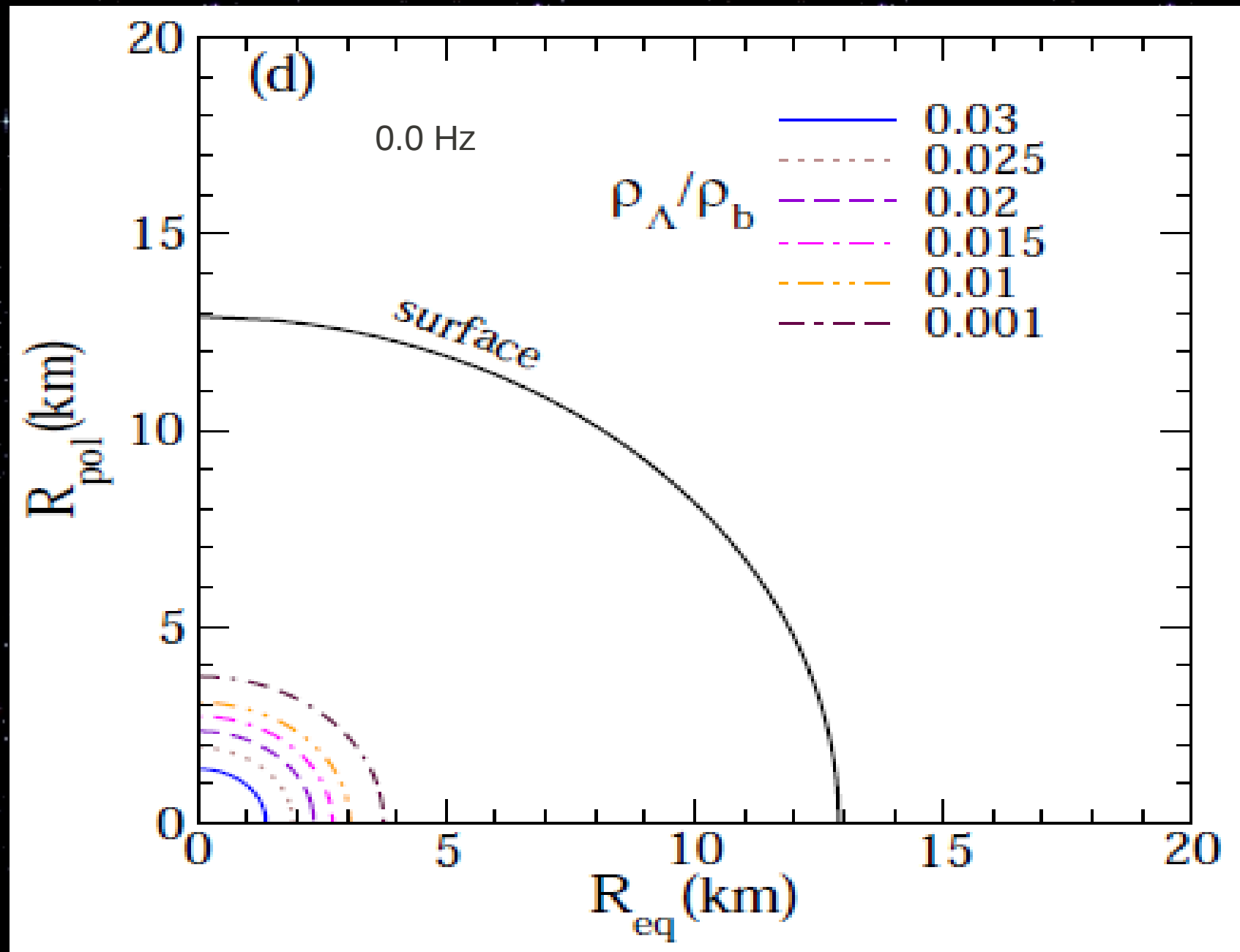
Composition Changes Caused by Spin Evolution



Composition Changes Caused by Spin Evolution

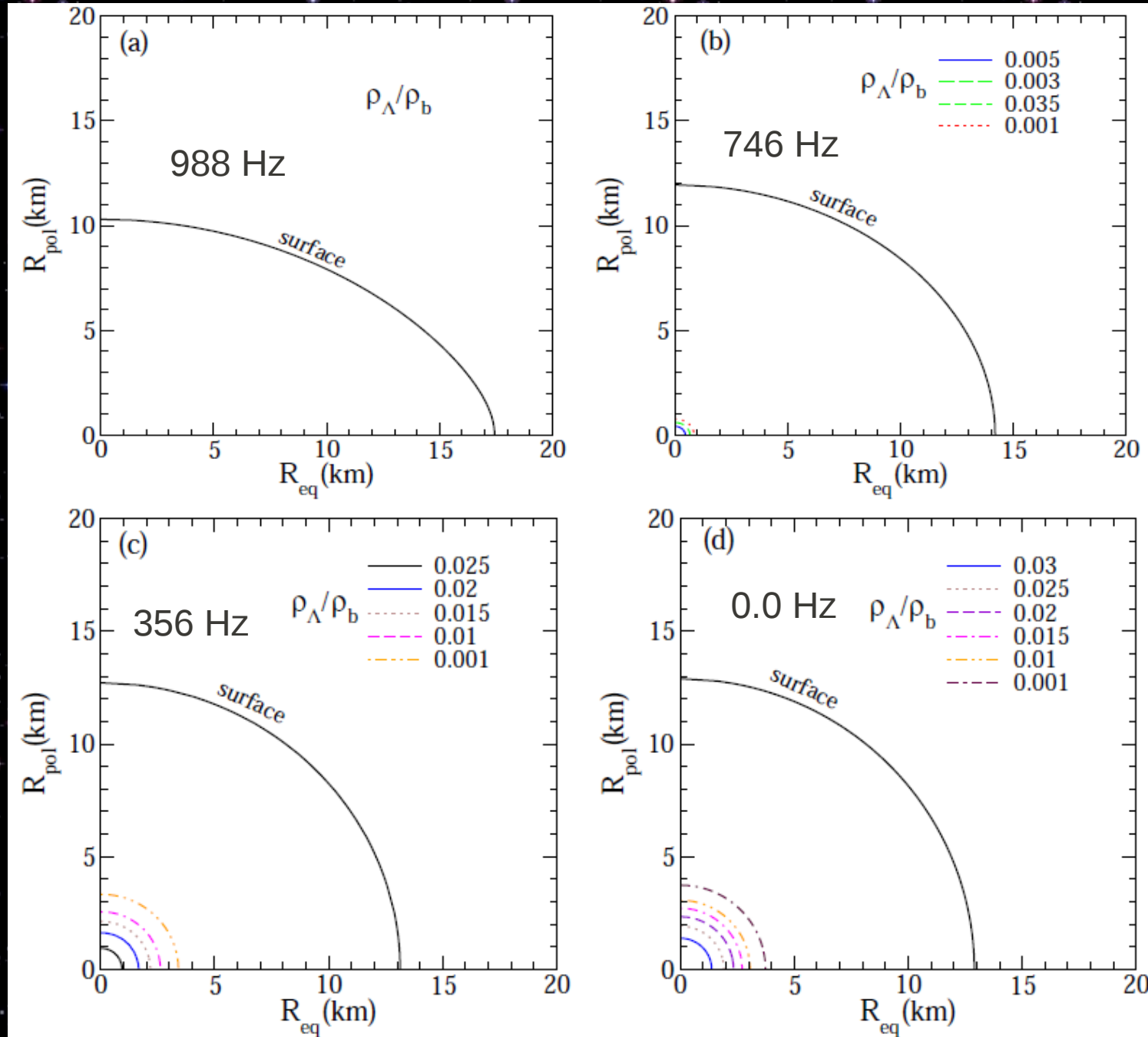


Composition Changes Caused by Spin Evolution



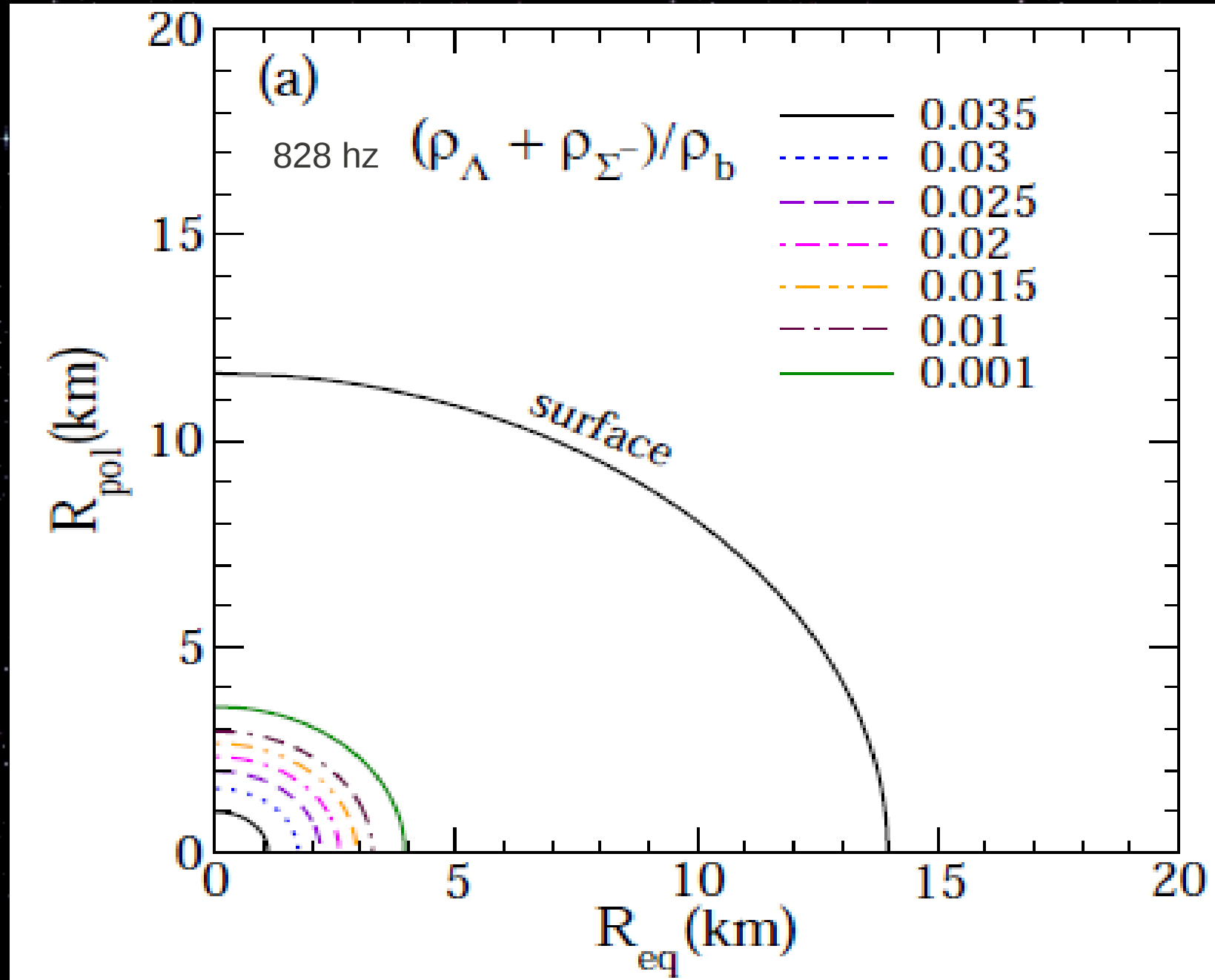
Hybrid Star

Composition Changes Caused by Spin Evolution



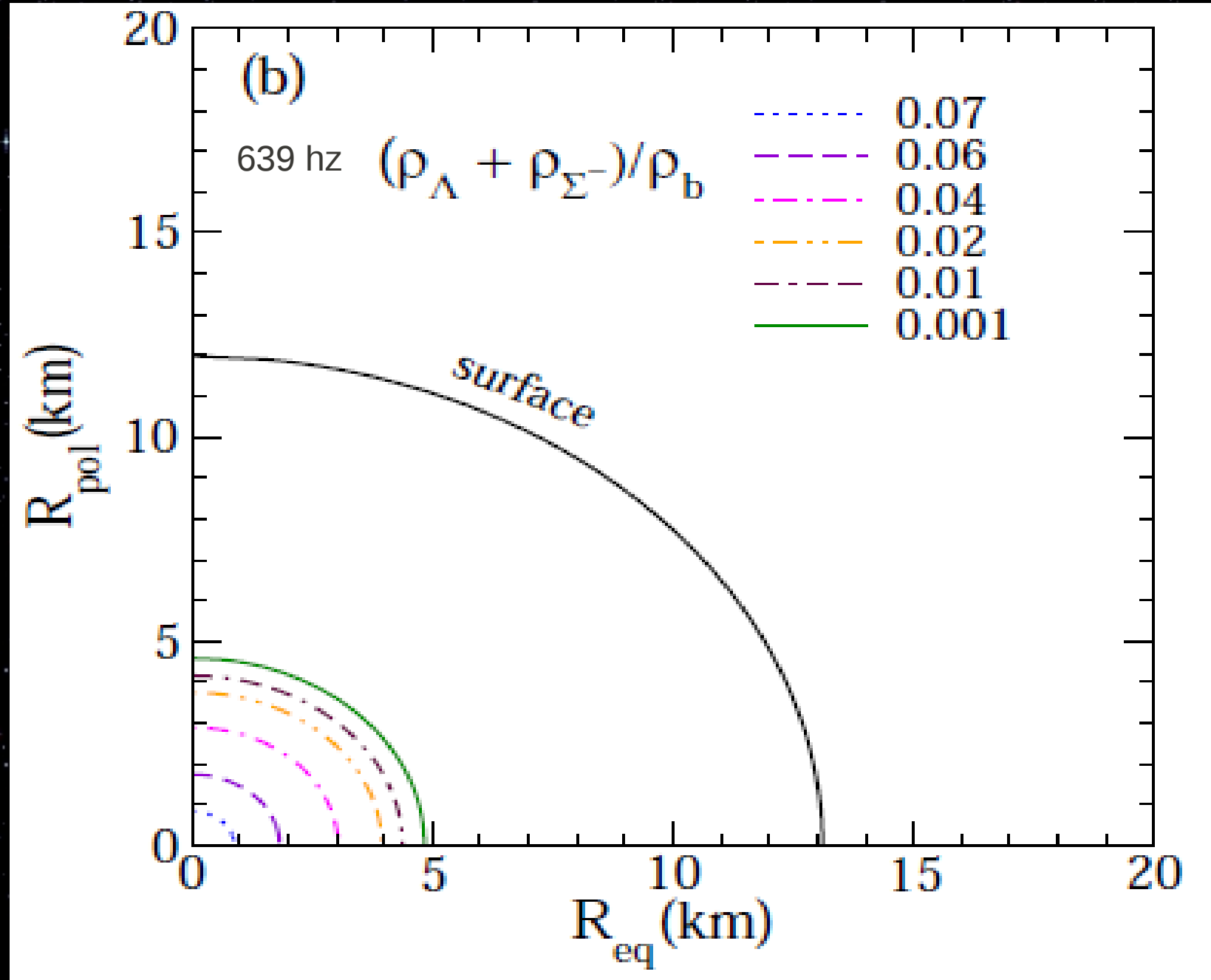
Hybrid Star

Composition Changes Caused by Spin Evolution



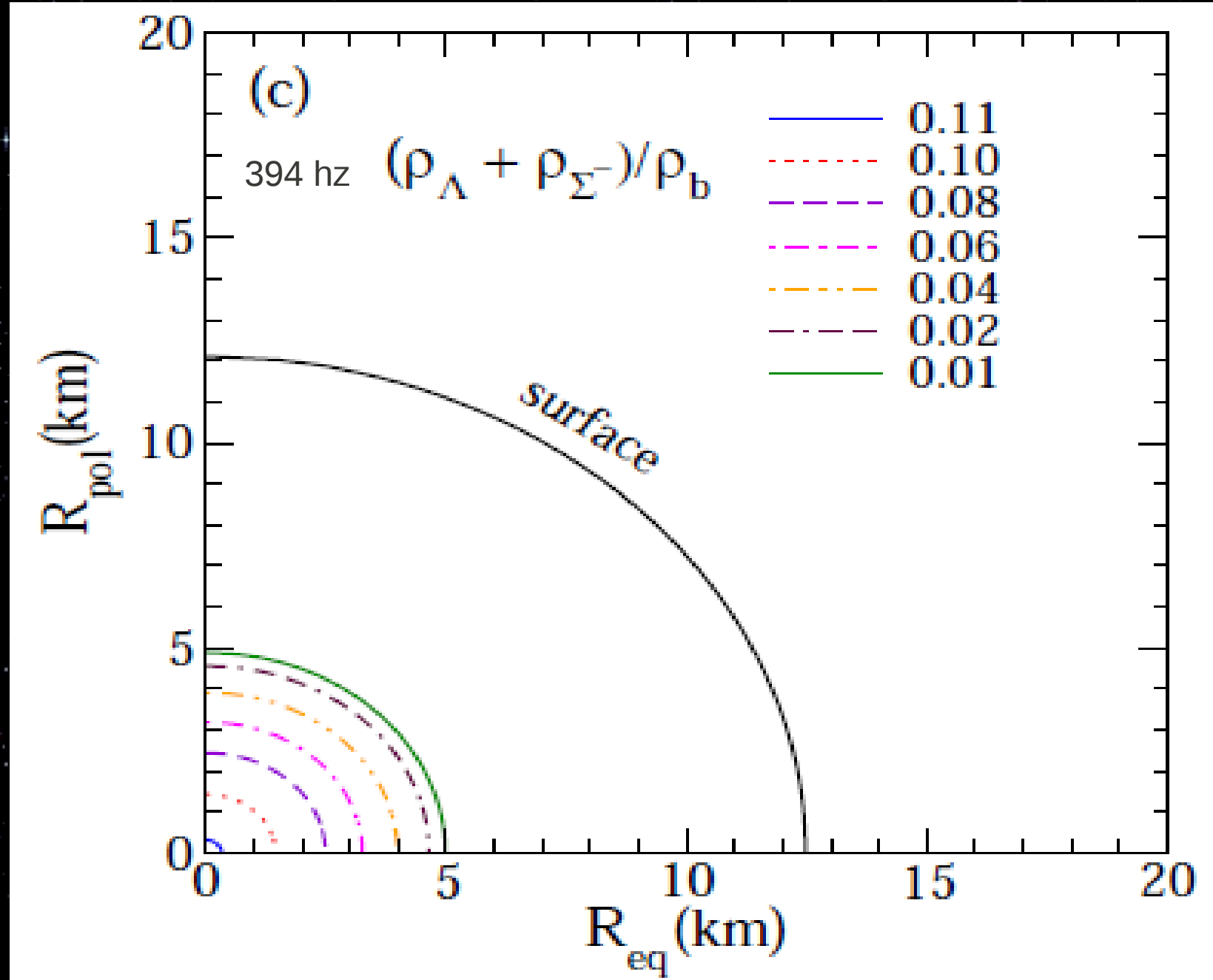
Hadronic Star

Composition Changes Caused by Spin Evolution



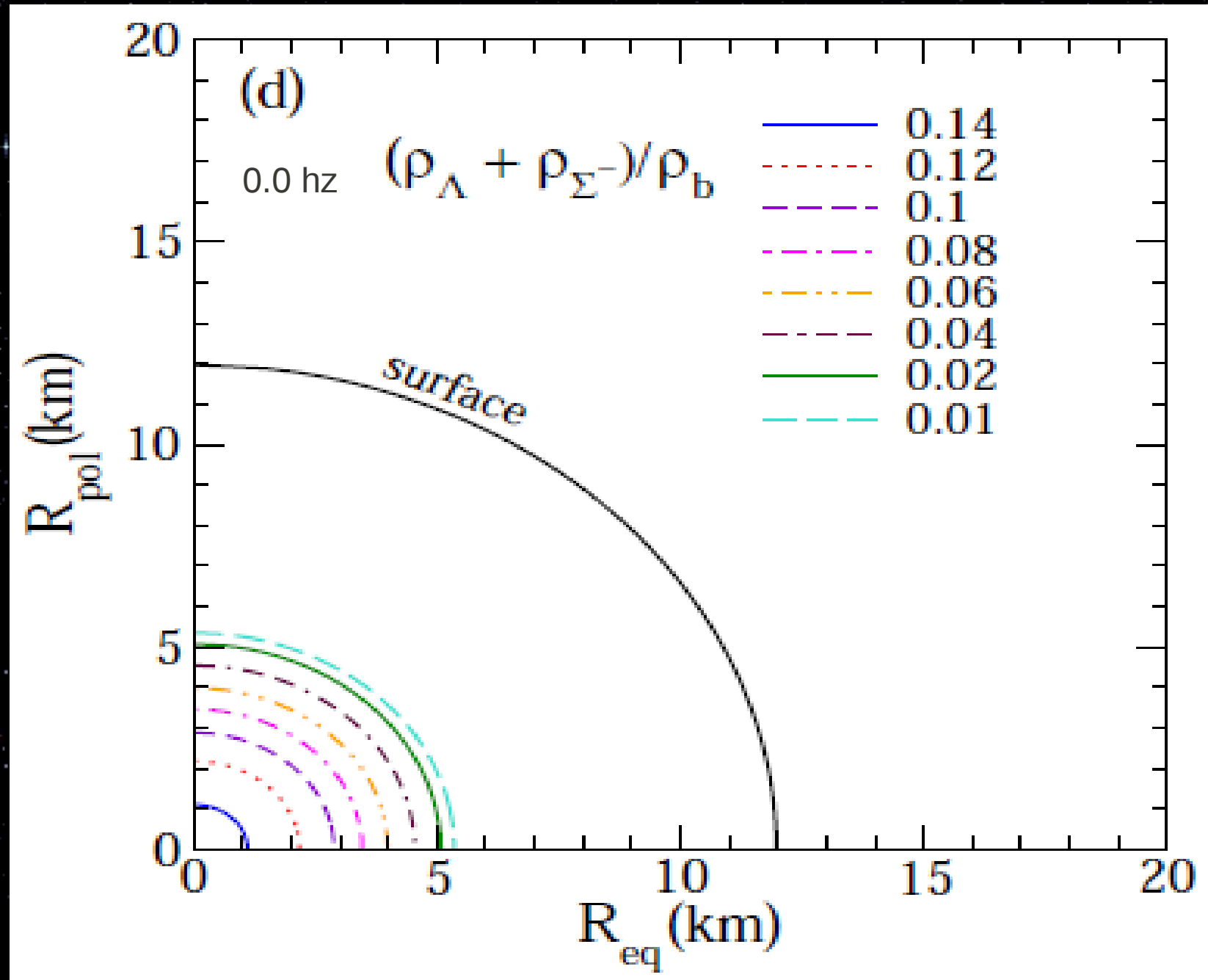
Hadronic Star

Composition Changes Caused by Spin Evolution



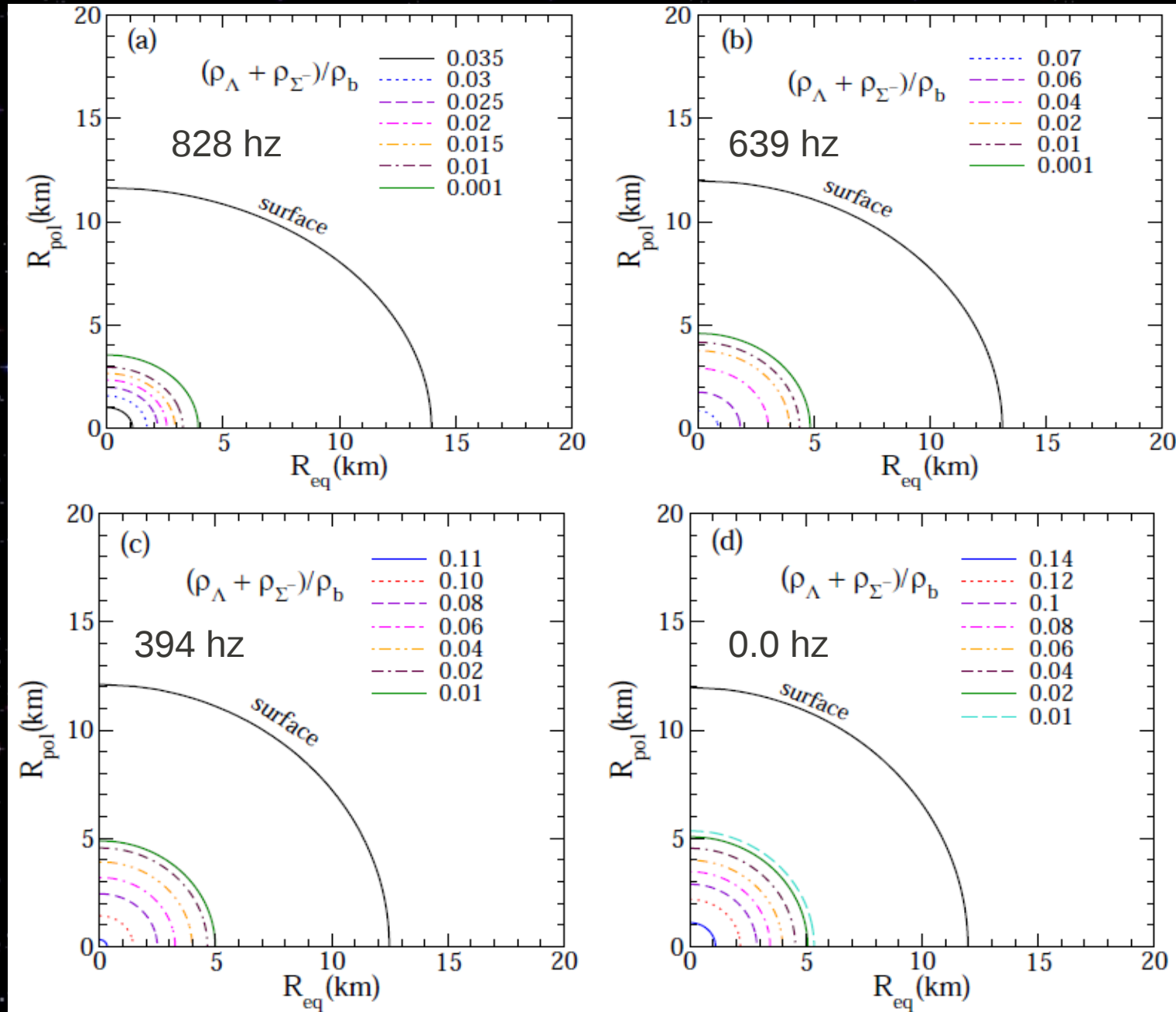
Hadronic Star

Composition Changes Caused by Spin Evolution



Hadronic Star

Composition Changes Caused by Spin Evolution

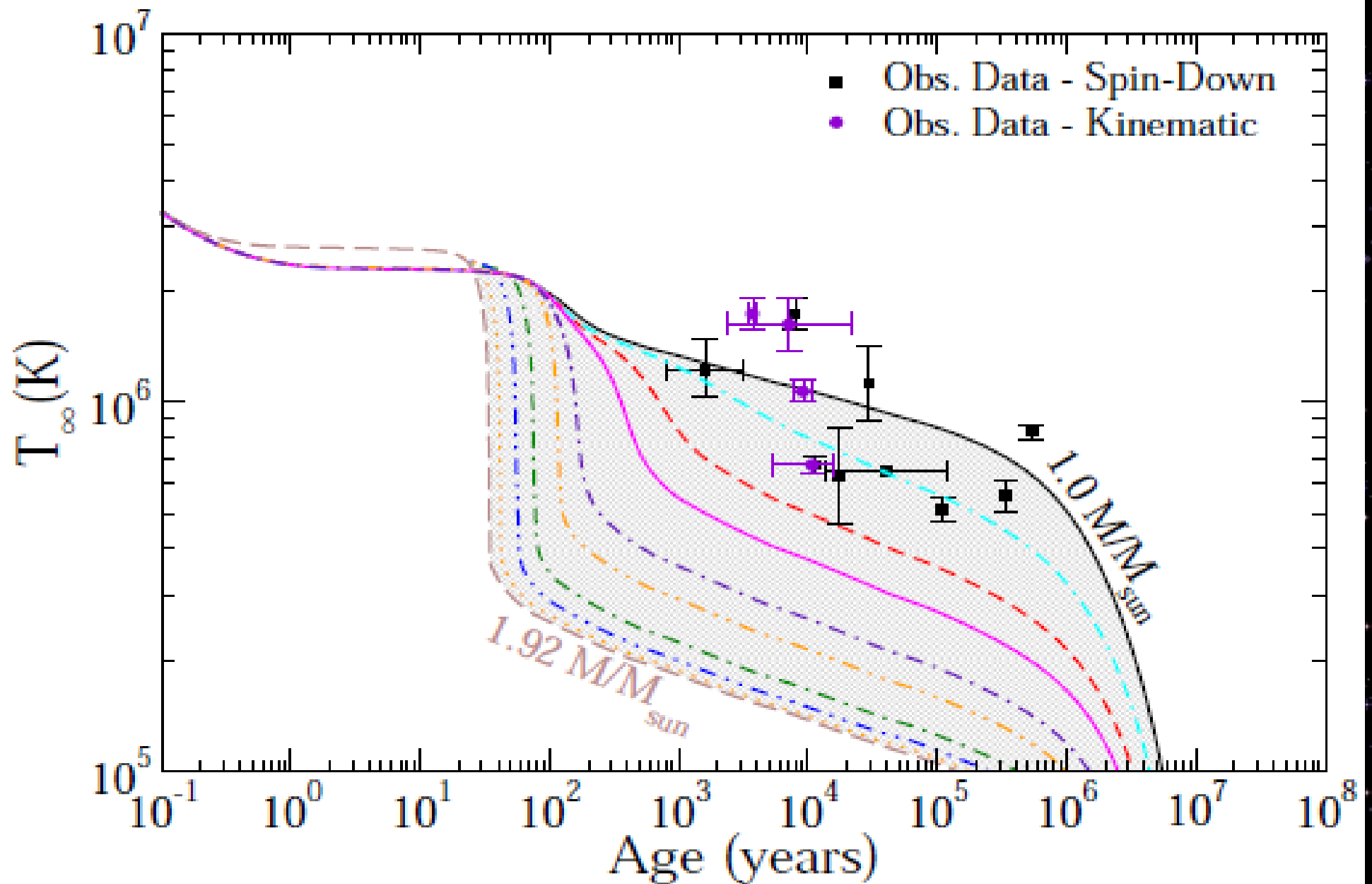


Hadronic Star

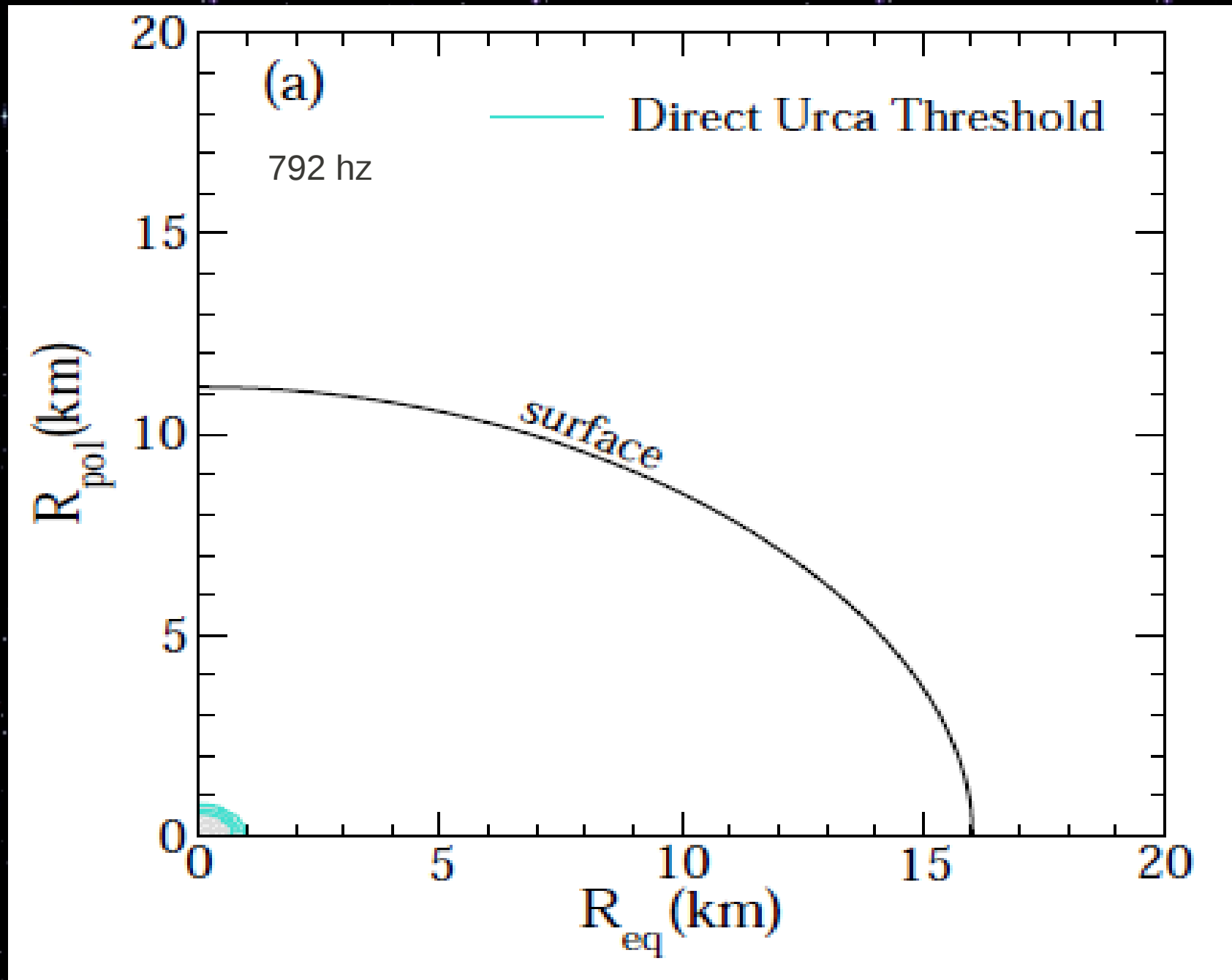
Thermal Evolution

$$\frac{\partial(Le^{2\phi})}{\partial m} = -\frac{1}{\epsilon\sqrt{1-2m/r}} \left(\epsilon_\nu e^{2\phi} + c_v \frac{\partial(Te^\phi)}{\partial t} \right)$$
$$\frac{\partial(Te^\phi)}{\partial m} = -\frac{(Le^{-\phi})}{16\pi^2 r^4 \kappa \epsilon \sqrt{1-2m/r}},$$

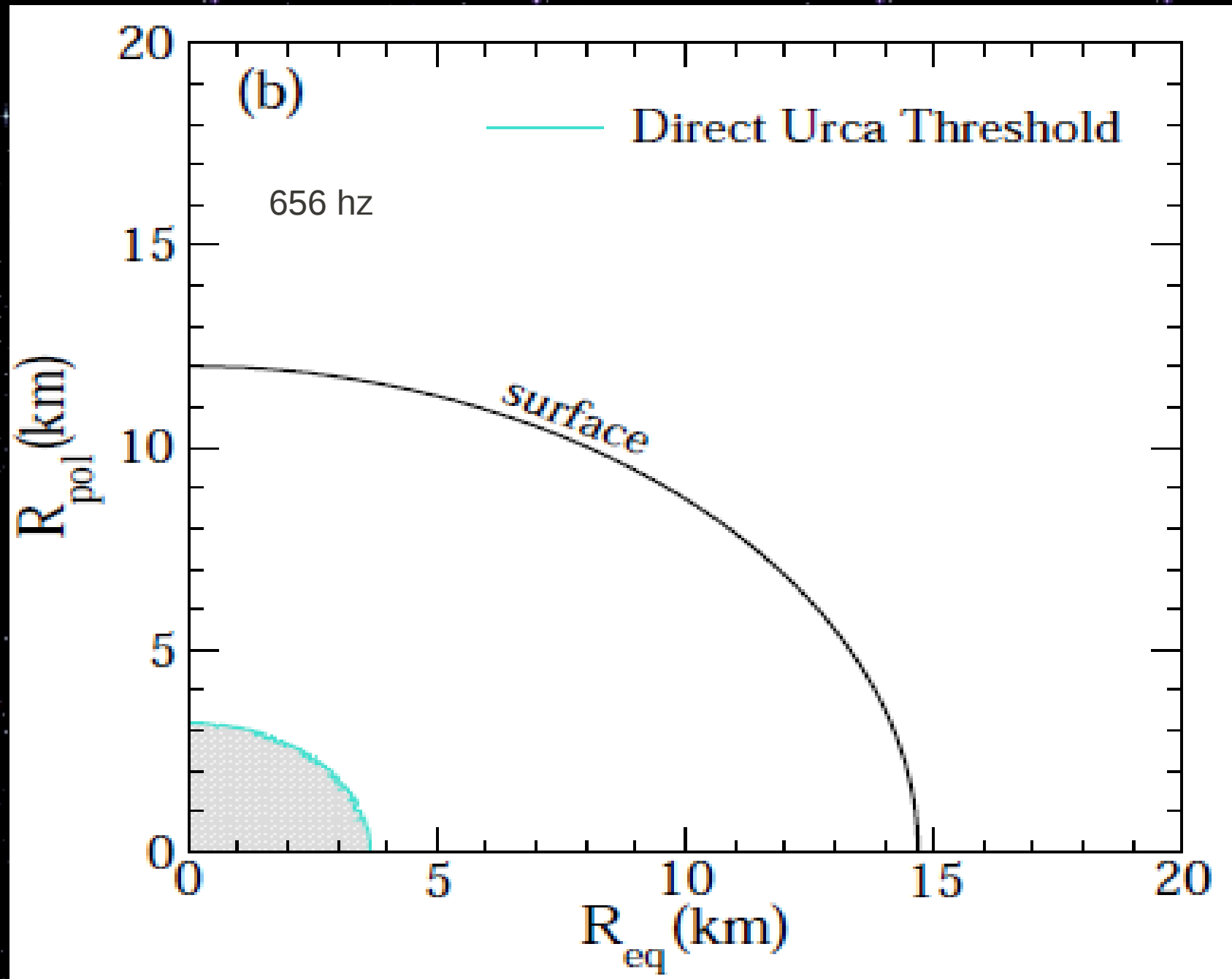
Thermal Evolution



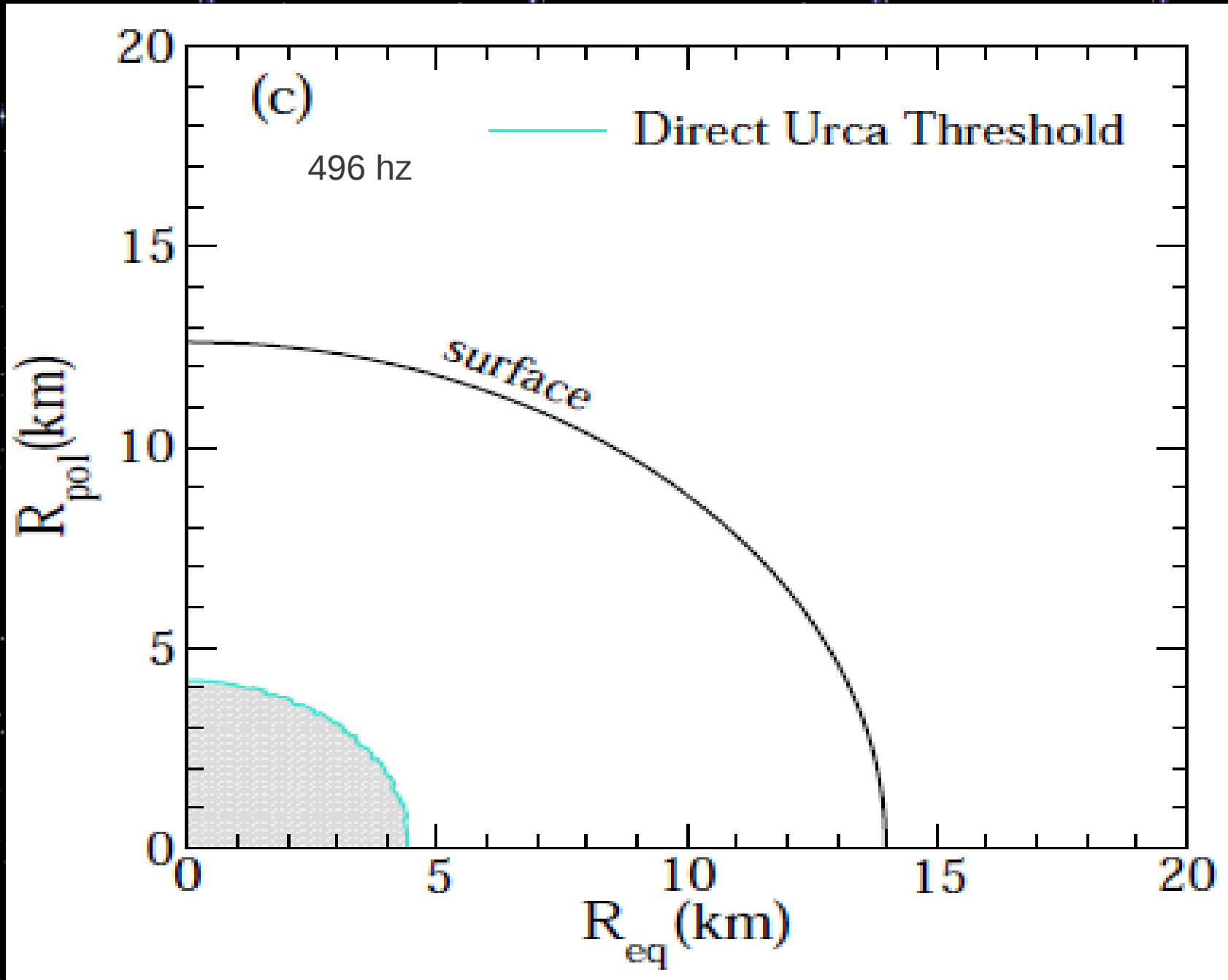
Possible Effects of Spin-Evolution on Cooling



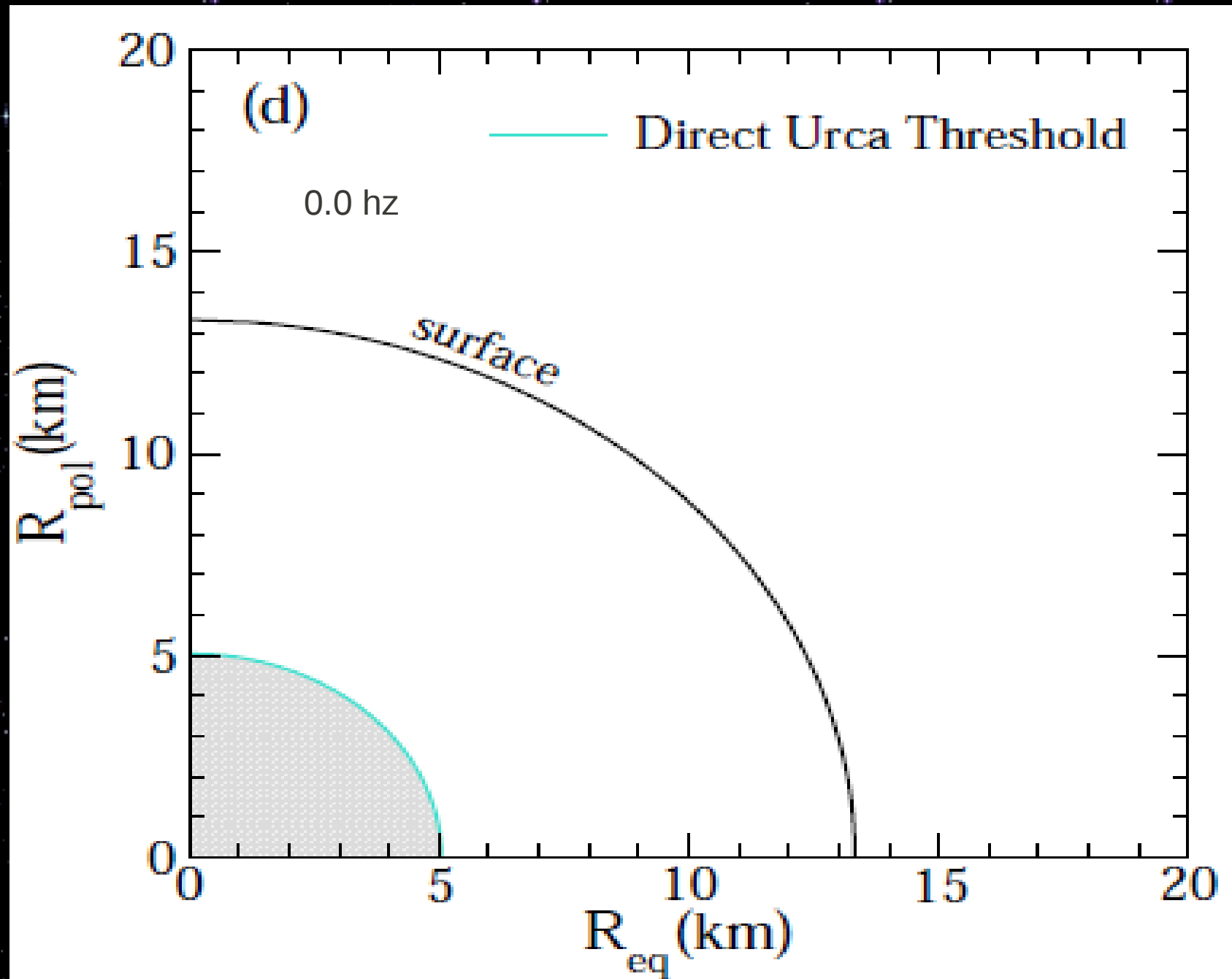
Possible Effects of Spin-Evolution on Cooling



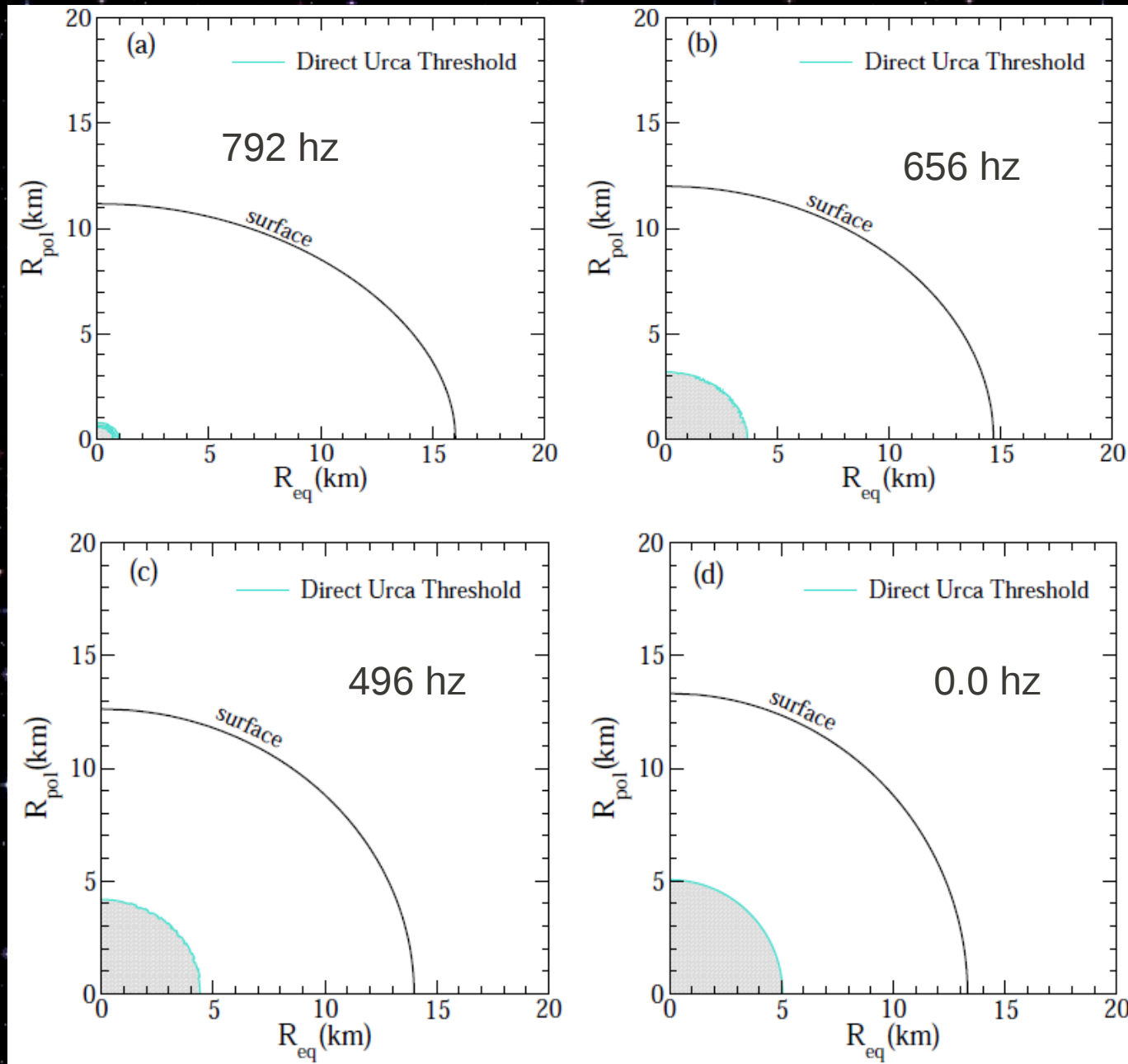
Possible Effects of Spin-Evolution on Cooling



Possible Effects of Spin-Evolution on Cooling



Possible Effects of Spin-Evolution on Cooling



Conclusions

- Our model seems to be an appropriated method to investigate the evolution of hybrid stars.
- The phase transition to quark matter signals the transition to the unstable branch of the stellar sequence.
- If global charge neutrality is assumed one can obtain a mixed phase of quarks and hadrons, even for $T=0$. For static stars a mixed phase core of 2 km is obtained.
- The onset of quarks suppresses the presence of Hyperons.
- Our results seem to be consistent with observed data on compact stars.

The Model

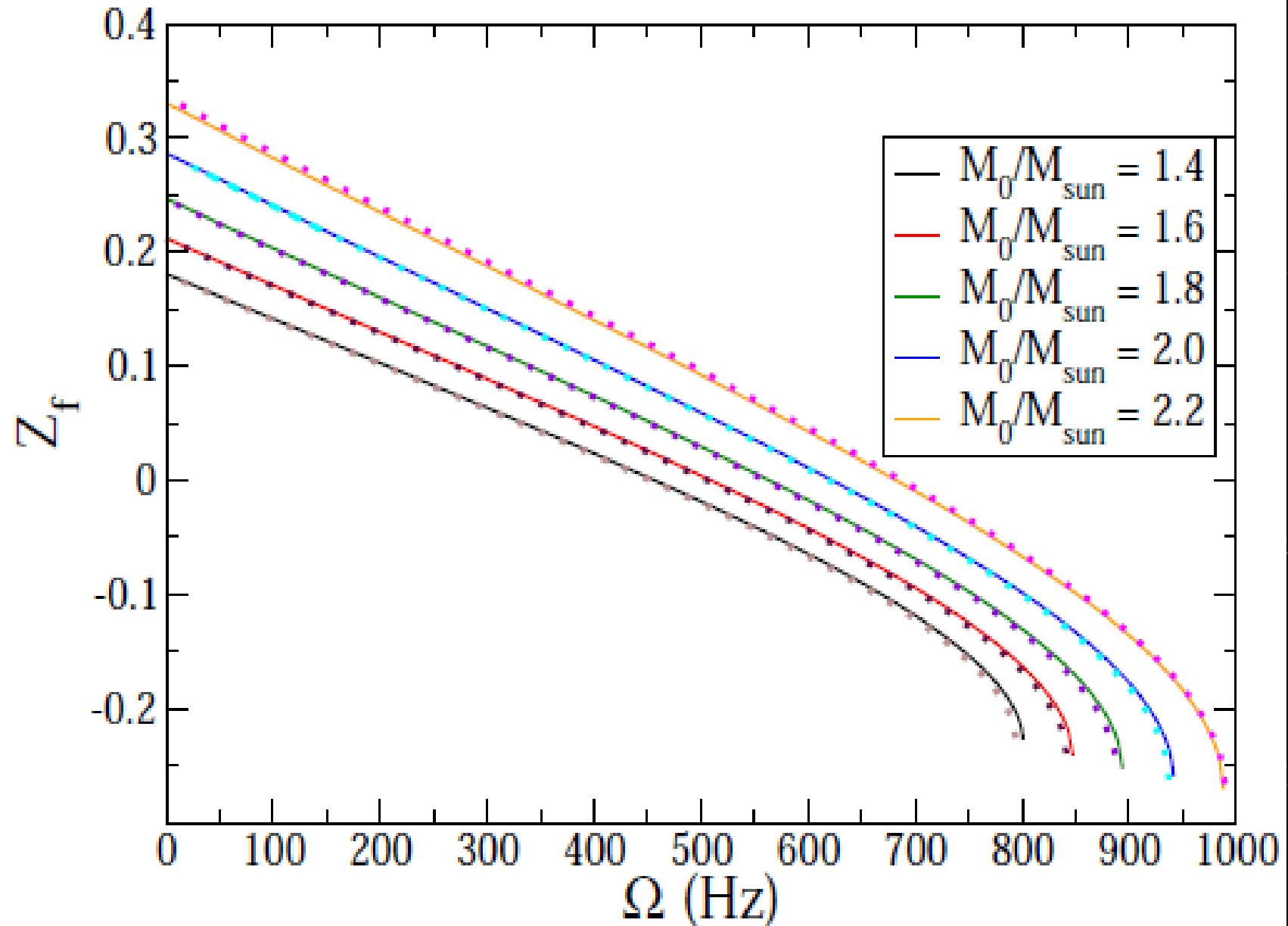
$$L = L_{Kin} + L_{Int} + L_{Self} + L_{SB} - U,$$

$$L_{Int} = - \sum_i \bar{\psi}_i [\gamma_0 (g_{i\omega} \omega + g_{i\phi} \phi + g_{i\rho} \tau_3 \rho) + M_i^*] \psi_i$$

$$\begin{aligned} L_{Self} = & -\frac{1}{2} (m_\omega^2 \omega^2 + m_\rho^2 \rho^2 + m_\phi^2 \phi^2) \\ & + k_0 (\sigma^2 + \zeta^2 + \delta^2) + k_1 (\sigma^2 + \zeta^2 + \delta^2)^2 \\ & + g_4 \left(\omega^4 + \frac{\phi^4}{4} + 3\omega^2 \phi^2 + \frac{4\omega^3 \phi}{\sqrt{2}} + \frac{2\omega \phi^3}{\sqrt{2}} \right) \\ & + k_2 \left(\frac{\sigma^4}{2} + \frac{\delta^4}{2} + 3\sigma^2 \delta^2 + \zeta^4 \right) + k_3 (\sigma^2 - \delta^2) \zeta \\ & + k_4 \ln \frac{(\sigma^2 - \delta^2) \zeta}{\sigma_0^2 \zeta_0} \end{aligned}$$

$$L_{SB} = m_\pi^2 f_\pi \sigma + \left(\sqrt{2} m_k^2 f_k - \frac{1}{\sqrt{2}} m_\pi^2 f_\pi \right) \zeta$$

Constant Baryon Mass Sequences



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