Neutrino trapping in rotating and non-rotating compact objects

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Overview

Motivation

- Photons, gravitational waves or neutrinos move along null-geodesics (NG)
- Gravitational waves from ultracompact stars (Abramowicz, et al., 1997)
- Neutrino trapping in extremely compact objects (Stuchlík et al., 2008)
- Cooling of neutron stars (NS) is driven by neutrino emission

Presentation is based on:

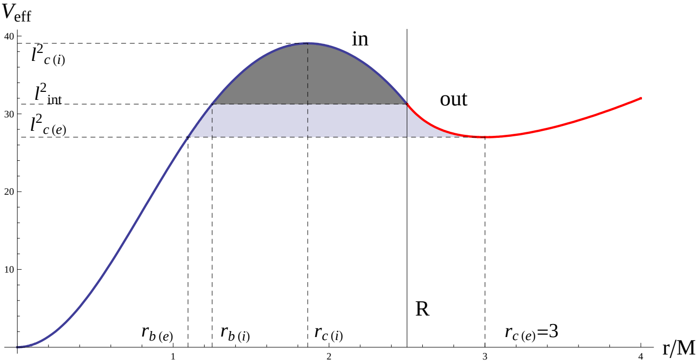
- *Trapping of null geodesics in slowly rotating spacetimes*; Vrba J., Urbanec M., Stuchlík Z., Miller J. C.; EPJC; 2020
- *Neutrino trapping in extremely compact Tolman VII spacetimes*; Stuchlík Z., Hladík J., Vrba J., Posada C.; EPJC; 2021
- *Trapping of null geodesics in slowly rotating extremely compact Tolman VII spacetimes*; Stuchlík Z., Vrba J.; EPJP; 2021

- Given $\rho(r)$ - constant or quadratic (Schwarzschild or Tolman VII)
- Ultra compact object $R/M \approx 3$ (NS, Strnge or Quark Stars)
- Isotropic emission of neutrinos throughout the object
- Free path of neutrino in NS is much greater than object radius
- Rigid rotaion
- Hartle-Thorne approximation of rotating compact objects

- Schwarzschild spacetime
- Slowly rotating Schwarzchild - first order Hartle-Thorne approximation
- Tolman VII spacetime
- Slowly rotating Tolman VII - first order Hartle-Thorne approximation

Effective potential

- Effective potential gives insight into the behavior of spacetime, re-turning points
- Trapping areas appear if exists local maximum and minimum of effective potential (if unstable circular photon orbit is above the surface of the object)



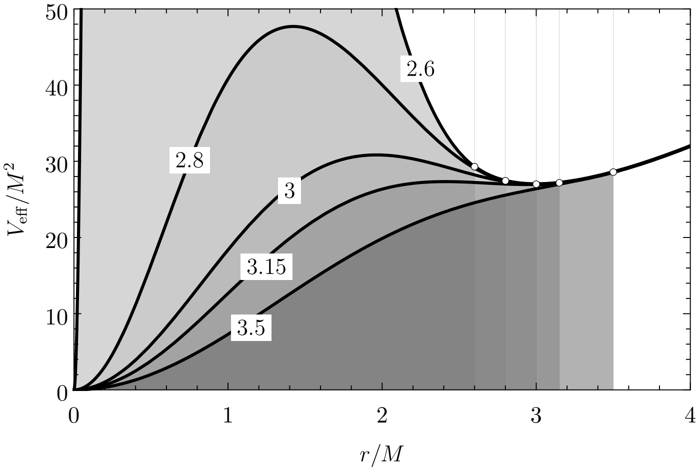


Figure: Effective potentials of non-rotating Tolman VII spacetimes.

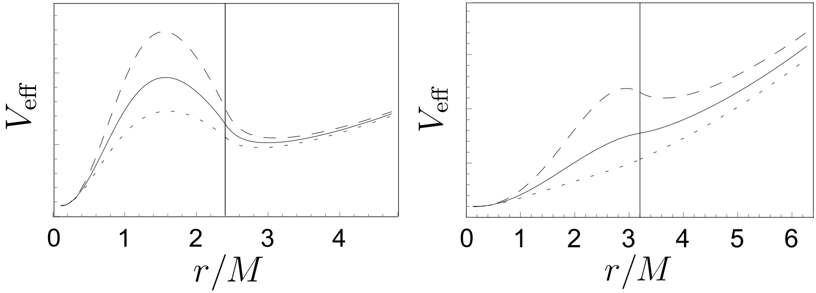


Figure: Effective potentials of null-geodesic for configuration with $R/M = 2.4$, $j = 0.1$ and $\theta = \pi/2$ on the left and effective potentials of null-geodesic for configuration with $R/M = 3.2$, $j = 0.7$ and $\theta = \pi/2$ on the right. Where solid line is non-rotating, dashed counter-rotating and dotted co-rotating part of effective potential.

Photon orbit

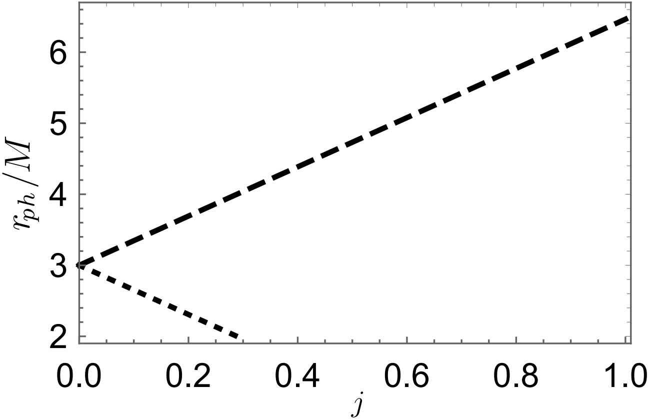


Figure: Dependence of unstable circular photon orbit for co-rotation (dotted) and counter-rotation (dashed) directions on rotation parameter j.

Example of escape cone

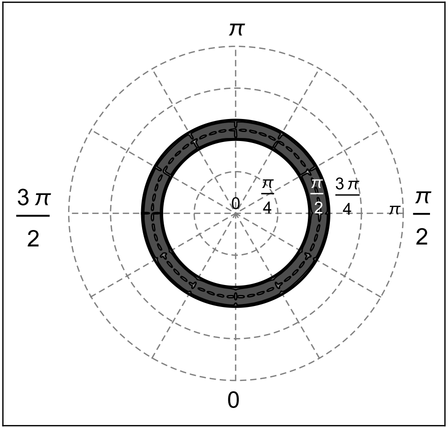


Figure: The escape cone non-rotating configurations at the maximum of the effective potential for $R/M = 2.8$. A shaded part depicts trapped neutrinos.

Cones for compactness 2.4

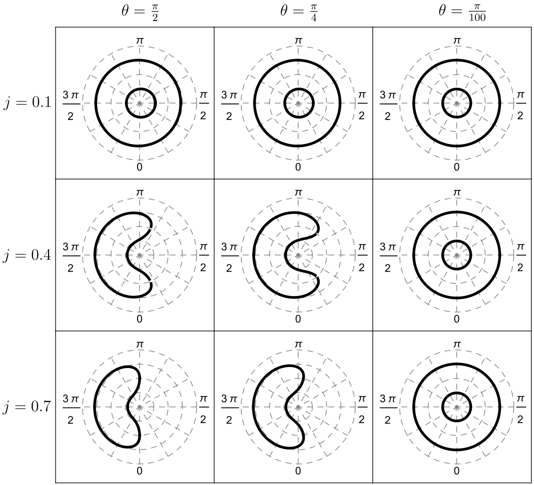


Figure: The escape cone produced at the maximum of the effective potential for $R/M = 2.4$.

Cones for compactness 3.2

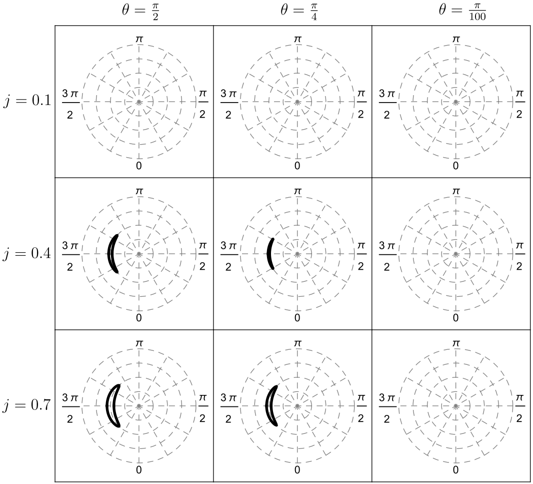


Figure: The escape cone produced at the maximum of the effective potential for $R/M = 3.2$.

Trapping

- Trapping efficiency coefficient = trapped/produced
- Local trapping efficiency coefficient
- Global trapping efficiency coefficient

Local trapping for compactness 2.4

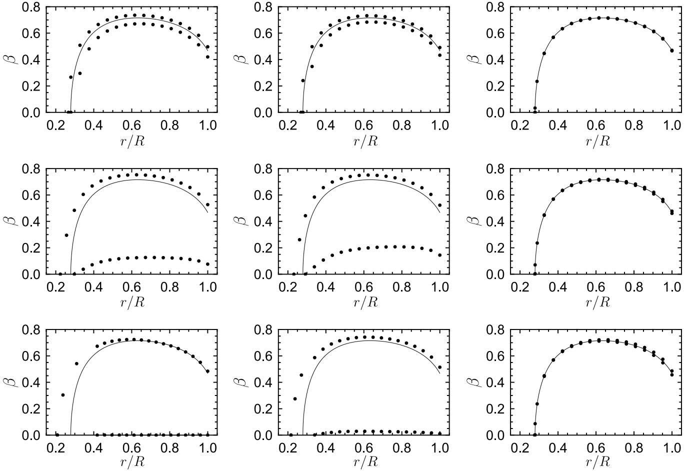


Figure: Local trapping efficiency coefficient β for $R/M = 2.4$. In first column $\theta = \pi/2$, in second $\pi/4$, and in third $\pi/1000$. In first line is $j = 0.1$ in second 0.4 and in third line $j = 0.7$.

Local trapping for compactness 3.2

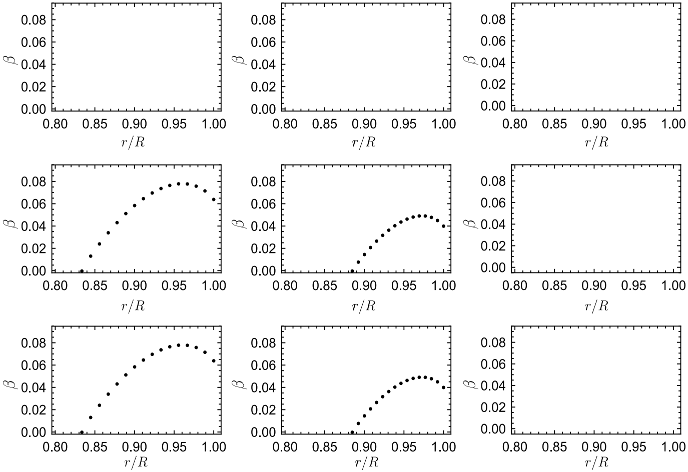


Figure: Local trapping efficiency coefficient β for $R/M = 3.2$. In first column $\theta = \pi/2$, in second $\pi/4$, and in third $\pi/1000$. In first line is $j = 0.1$ in second 0.4 and in third line $j = 0.7$.

Global trapping efficiency coefficient

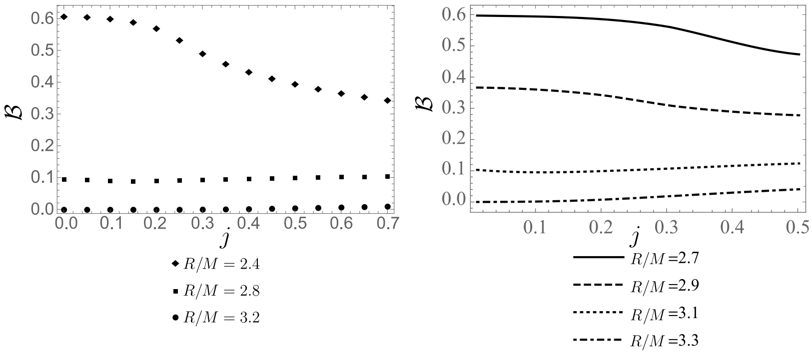


Figure: Global trapping efficiency coefficient $\mathcal{B}$ for Schwarzschild rotating NS (right panel) and Tolman VII rotating (left panel) NS.

Future

- Realistic EOS - Polytropic EOS
- More realistic spacetime - Higher orders of Hartle-Thorne approximation

Thank you

THANK YOU for your attention!