Oscillations of non-slender tori in the Hartle-Thorne geometry

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Goals

What?

- To examine the influence of quadrupole moment of neutron stars on the oscillation frequencies of accretion tori.

Why?

- To use in modeling kHz QPO observed in power spectra of low-mass X-ray binaries containing a neutron star.

Previous research

Abramowicz et al. 2003

- Epicyclic frequencies of free test particles in Hartle-Thorne geometry.

Straub and Šrámková 2009

- Pressure corrections on epicyclic frequencies of oscillating tori in Kerr geometry.

Spacetime geometry around neutron stars

Hartle-Thorne metric[1]

$$\mathrm{d}s^2 = g_{tt}\mathrm{d}t^2 + 2g_{t\varphi}\mathrm{d}t\mathrm{d}\varphi + g_{rr}\mathrm{d}r^2 + g_{\theta\theta}\mathrm{d}\theta^2 + g_{\varphi\varphi}\mathrm{d}\varphi^2,$$

$$\begin{aligned}
g_{tt} &= -\left(1-\frac{2M}{r}\right)\left[1+j^2F_1(r)+qF_2(r)\right], \\
g_{rr} &= \left(1-\frac{2M}{r}\right)^{-1}\left[1+j^2G_1(r)-qF_2(r)\right], \\
g_{\theta\theta} &= r^2\left[1+j^2H_1(r)+qH_2(r)\right], \\
g_{\varphi\varphi} &= r^2\sin^2\theta\left[1+j^2H_1(r)+qH_2(r)\right], \\
g_{t\varphi} &= -\frac{2M^2}{r}j\sin^2\theta.
\end{aligned}$$

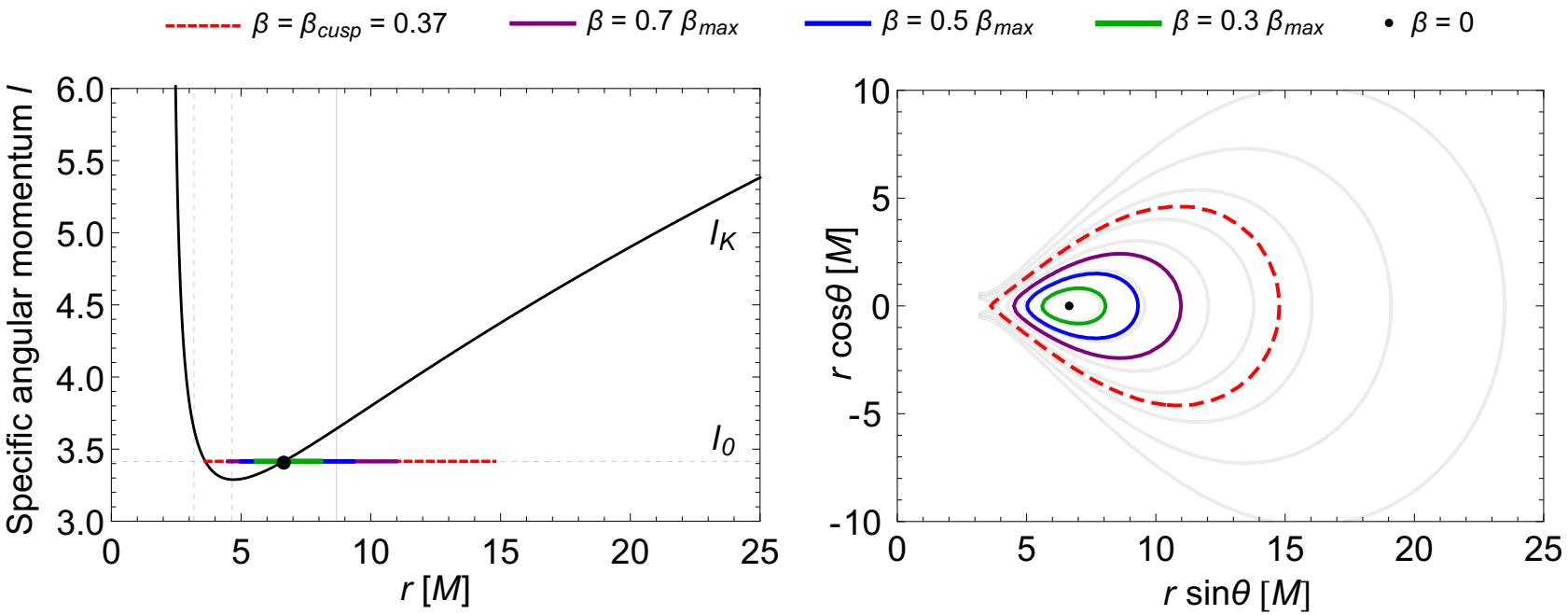
[1] Abramowicz et al. 2003.

Torus model[2]

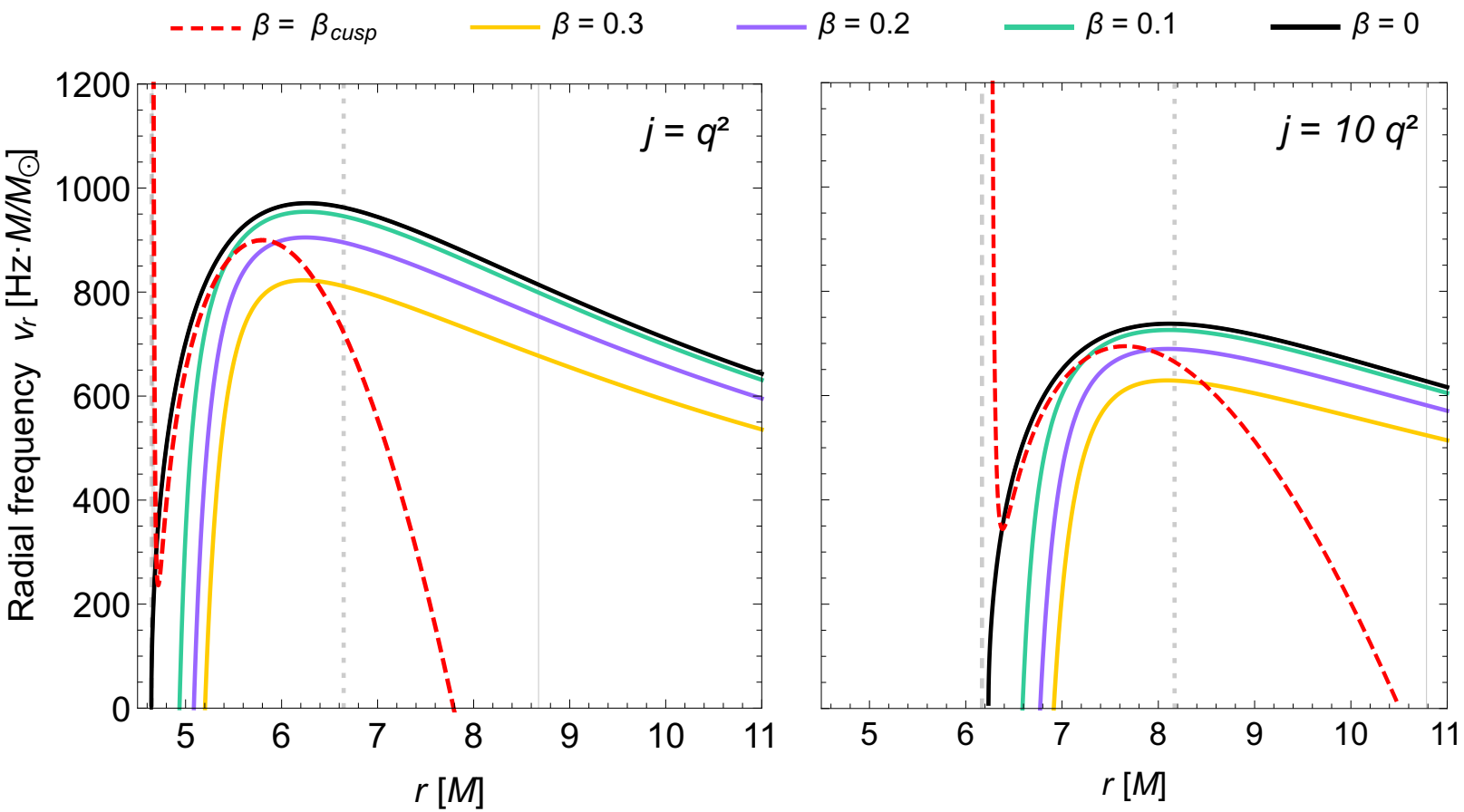
- Perfect polytropic fluid.
- Stationary flow.
- Fluid in a state of pure rotation.
- Constant specific angular momentum.
- Non-self-gravitating.

[2] Abramowicz et al. 2006.

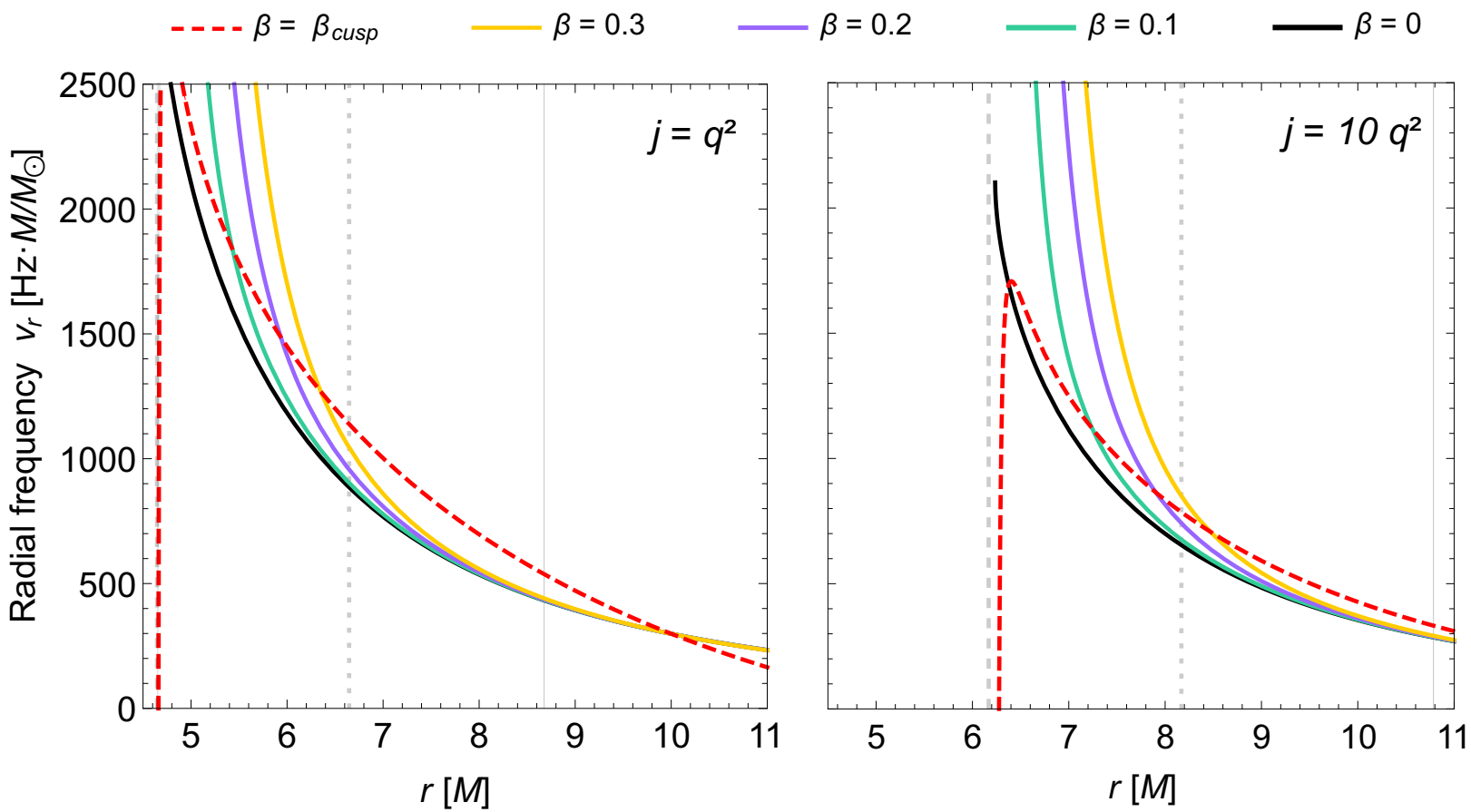
Torus construction



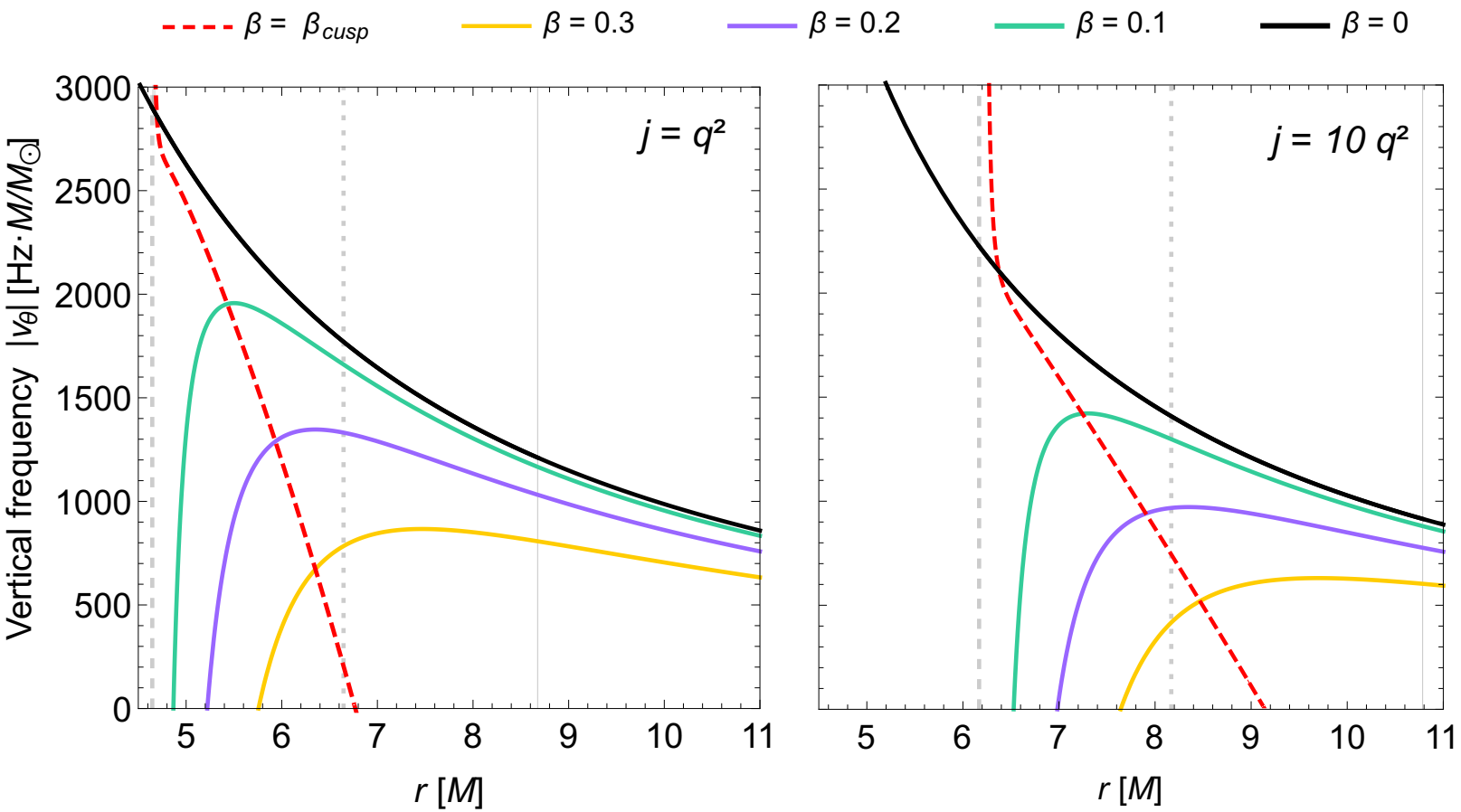
Radial oscillation, $m = 0$, $j = 0.4$



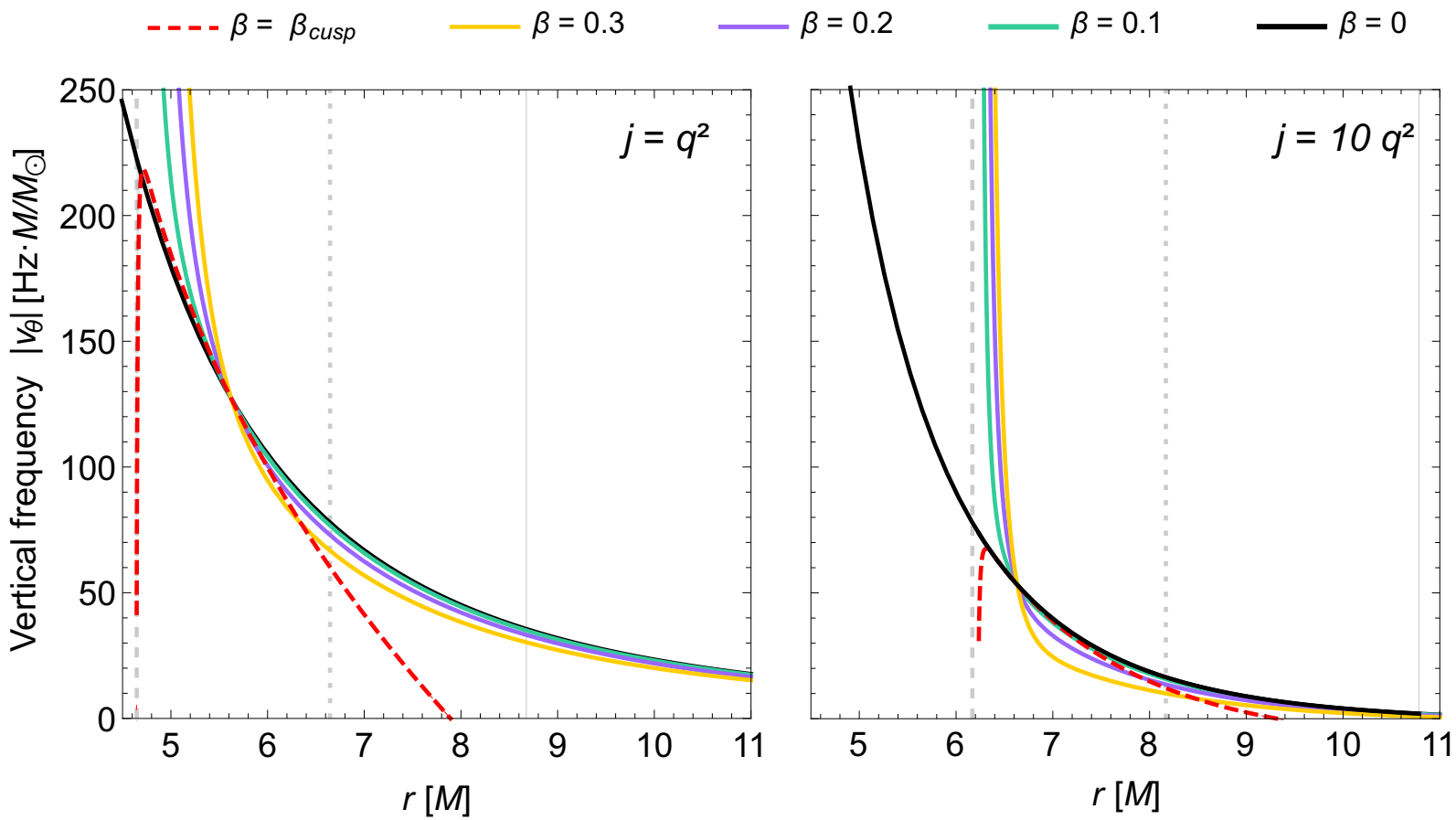
Radial oscillation, $m = -1$, $j = 0.4$



Vertical oscillation, $m = 0$, $j = 0.4$



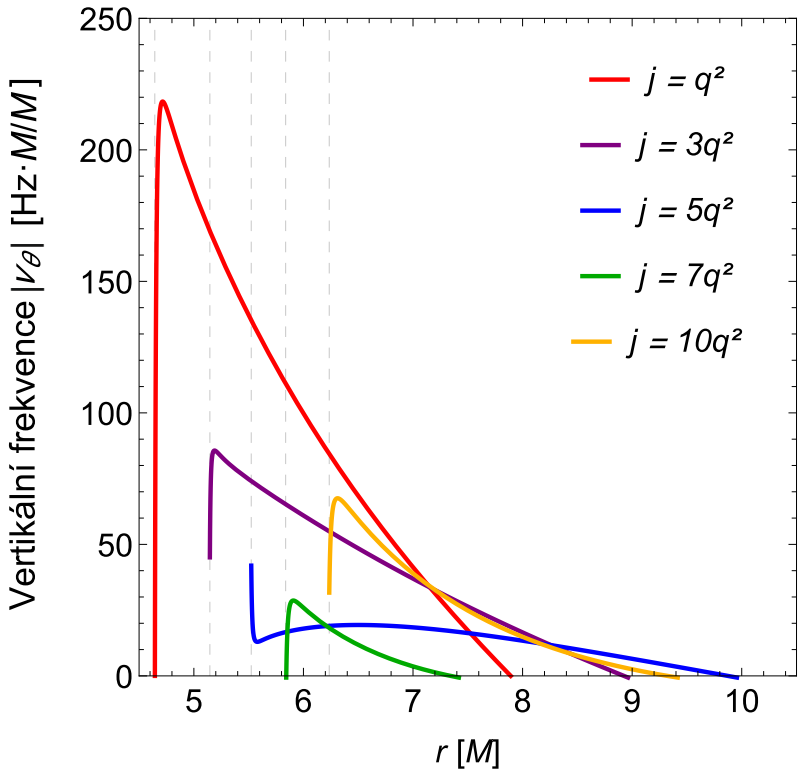
Vertical oscillation, $m = -1$, $j = 0.4$



Summary

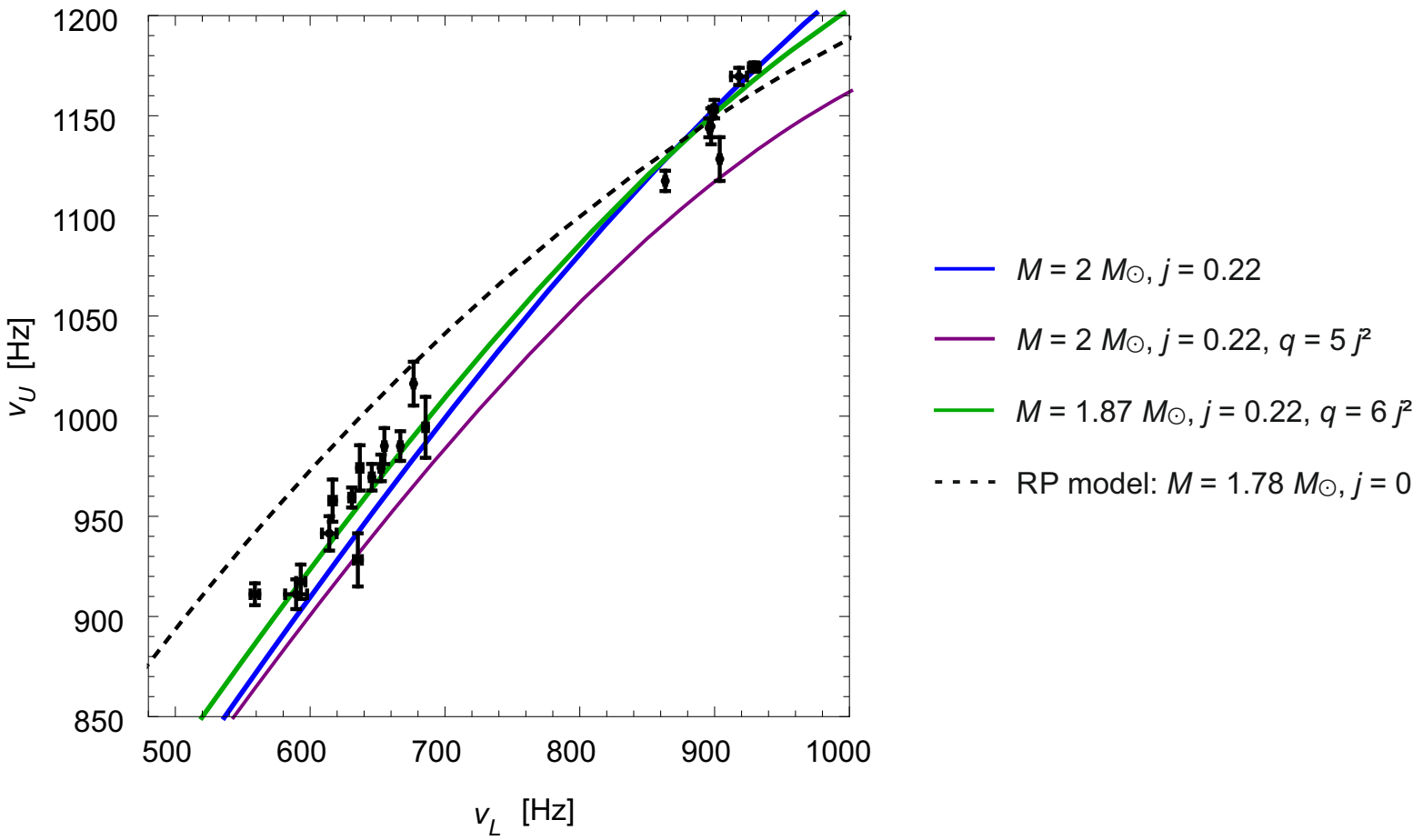
Influence of quadrupole moment

- With increasing q decrease of maximum frequency values.
- Change of permissible torus position (r_{ms}, r_{mb}).
- Different behavior of the vertical non-axisymetric mode $(m = -1)$.



Modeling kHz QPO

Cusp model - Török et al. 2015 (source 4U 1636-53)



References

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