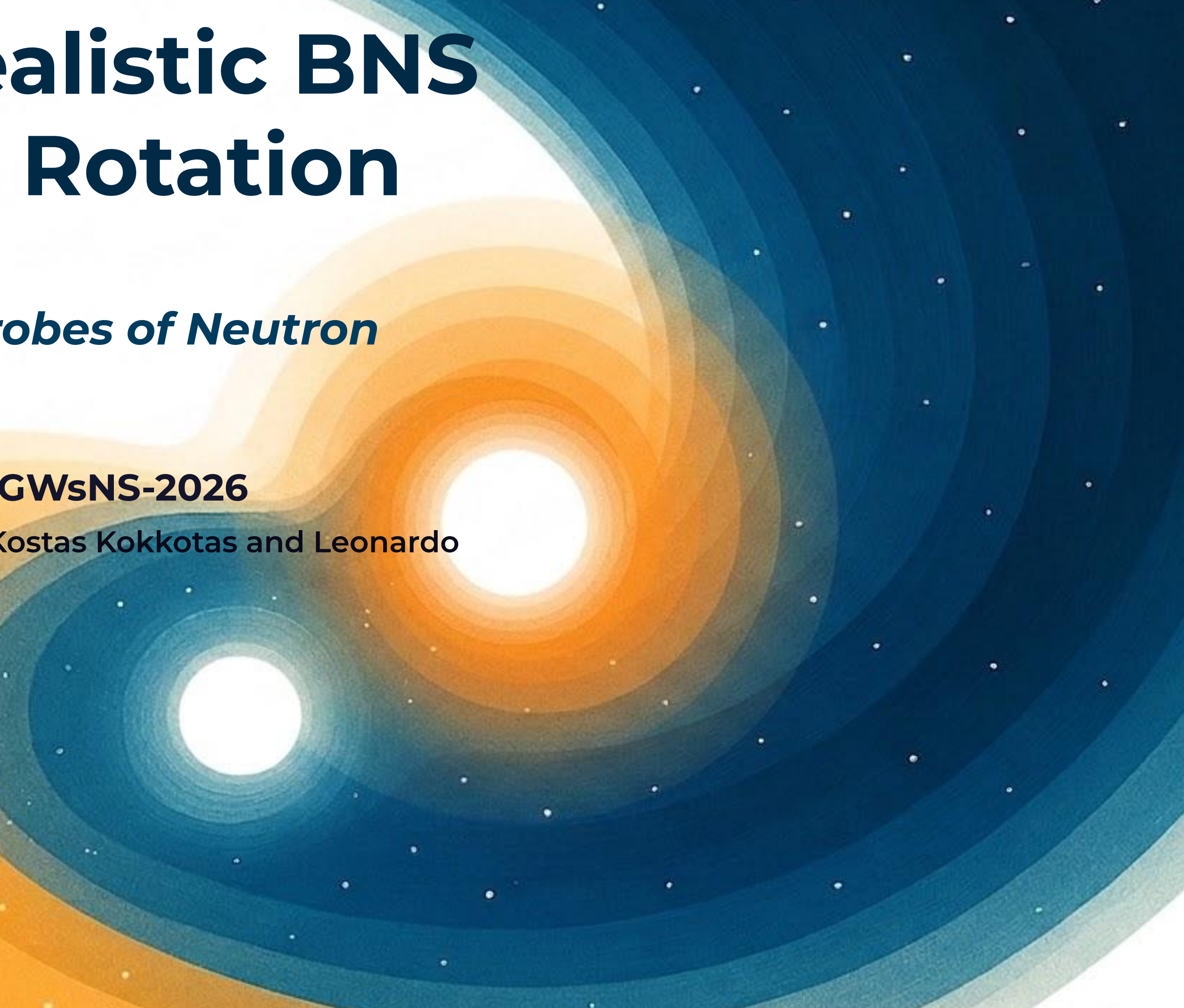
# Building a Realistic BNS Remnant 101: Rotation

*Part of thesis titled*
***'Stellar Oscillations as Probes of Neutron Star Interiors'***

**Akshita Mittal | July 01, 2026 | GWsNS-2026**

In collaboration with Andrea Maselli, Kostas Kokkotas and Leonardo Gualtieri



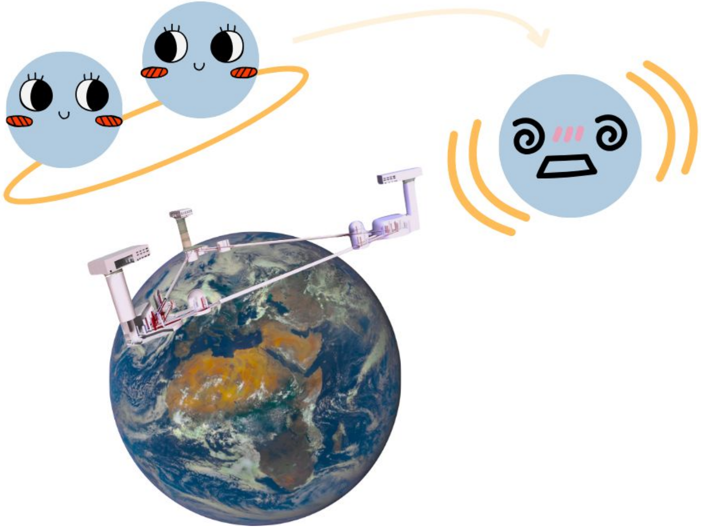
# Why?

Neutron star oscillations hold information about fundamental physics of NSs.

NS oscillations can be studied in linear and non-linear domains.

Post-merger neutron stars are hot, viscous and rapidly, differentially rotating.

Physical effects like finite temperature and rotation alter the spectra.



Gravitational waves from these NSs in detection band of 3G detectors!

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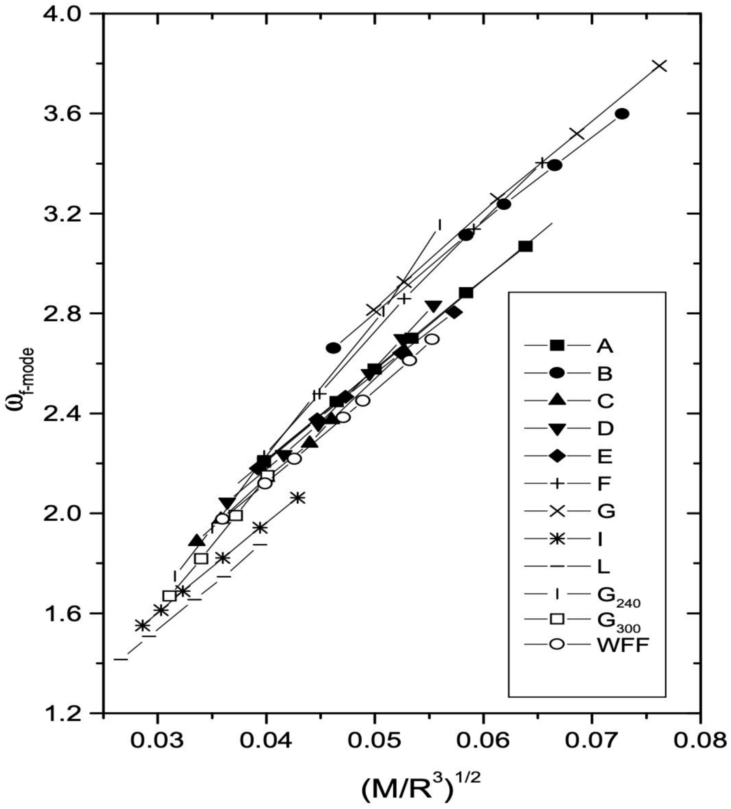
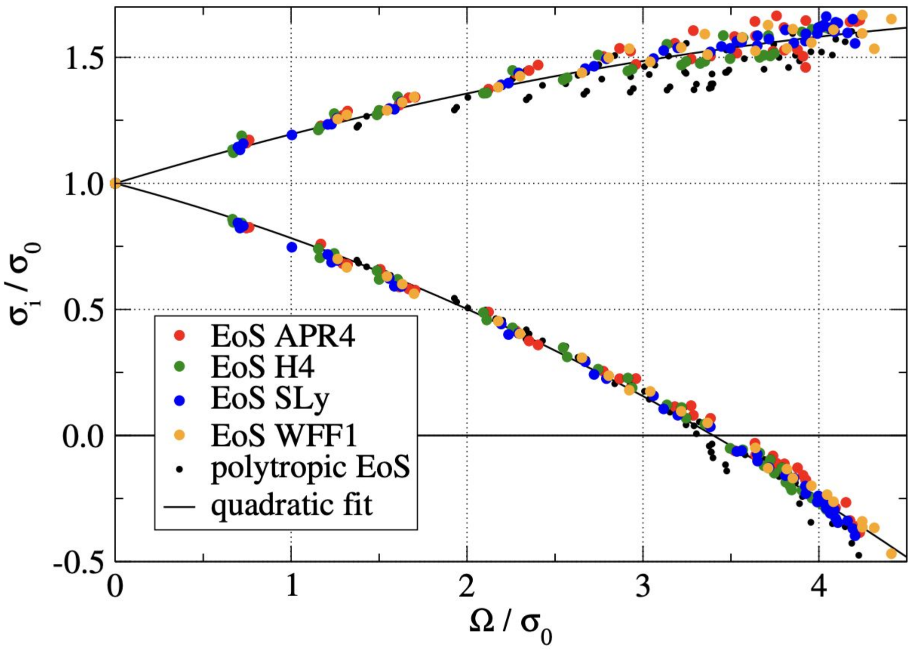
# GW Asteroseismology and Rotation So Far




*See: Andersson, Kokkotas (1996, 1998, 2001)*

- Quasi-universal relations obtained for non-rotating relativistic stellar models.
- Stepping stones of **GW asteroseismology**.

# GW Asteroseismology and Rotation So Far




*See: Gaertig and Kokkotas (2011), Krüger and Kokkotas (2019)*

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- Been done from slow-rotating approximations, Cowling approximation to full GR.

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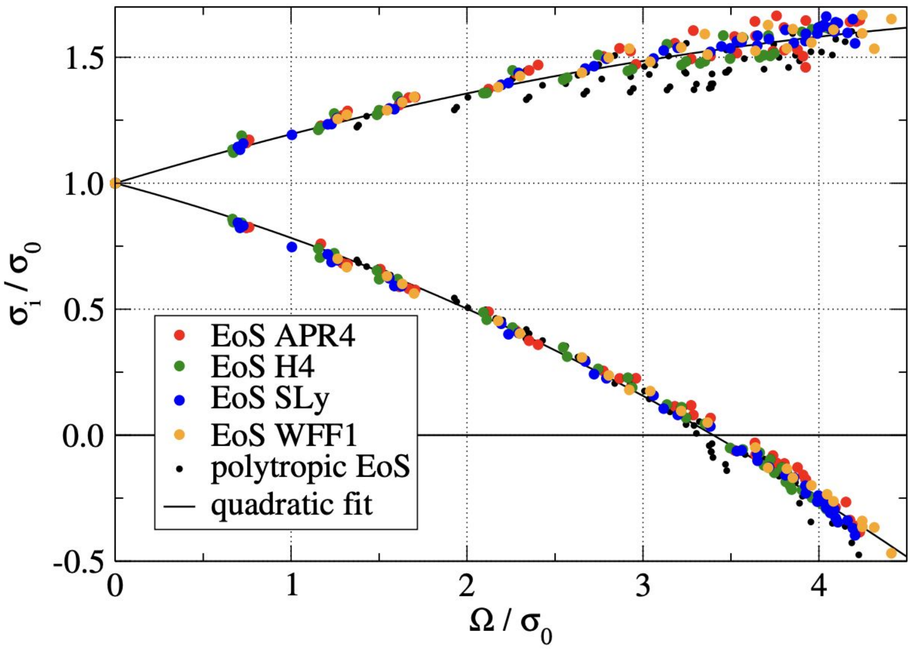


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With rotation:

- Instabilities
- Shifting of frequencies and damping times.... and more

# GW Asteroseismology and Rotation So Far

***Post-merger remnants do not rotate uniformly.***

# Differentially Rotating Neutron Stars

## KEH Law

- Simple, computationally convenient.
- A>0 determines length scale on which $\Omega$ changes within star.
- Widely used in literature, but not accurate for PM remnants!

$$\Omega(r,\theta) = \frac{\Omega_c}{1 + \left(\frac{r\sin\theta}{A}\right)^2}$$

*See: Komatsu et al (1989), Bauswein & Stergioulas (2015), Endrizzi et al (2018), Kiuchi et al (2018)*

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## Uryu+ Law

- Not simple, 4-parameter law.
- Rotational profile has maximum away from the center.
- First implementation and comparison in *Iosif and Stergioulas (2020).*

$$\Omega(j) = \Omega_c \frac{1 + \frac{j}{B^2\Omega_c}}{1 + \left(\frac{j}{A^2\Omega_c}\right)^4}$$

*See: Uryu et al (2017)*

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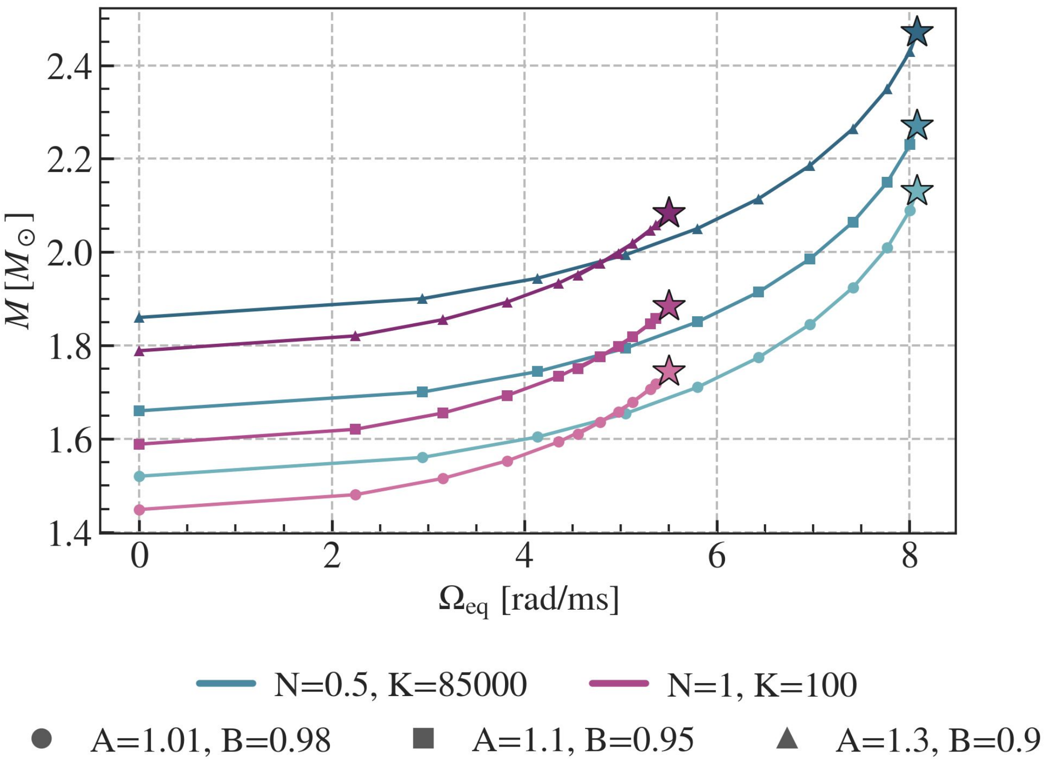


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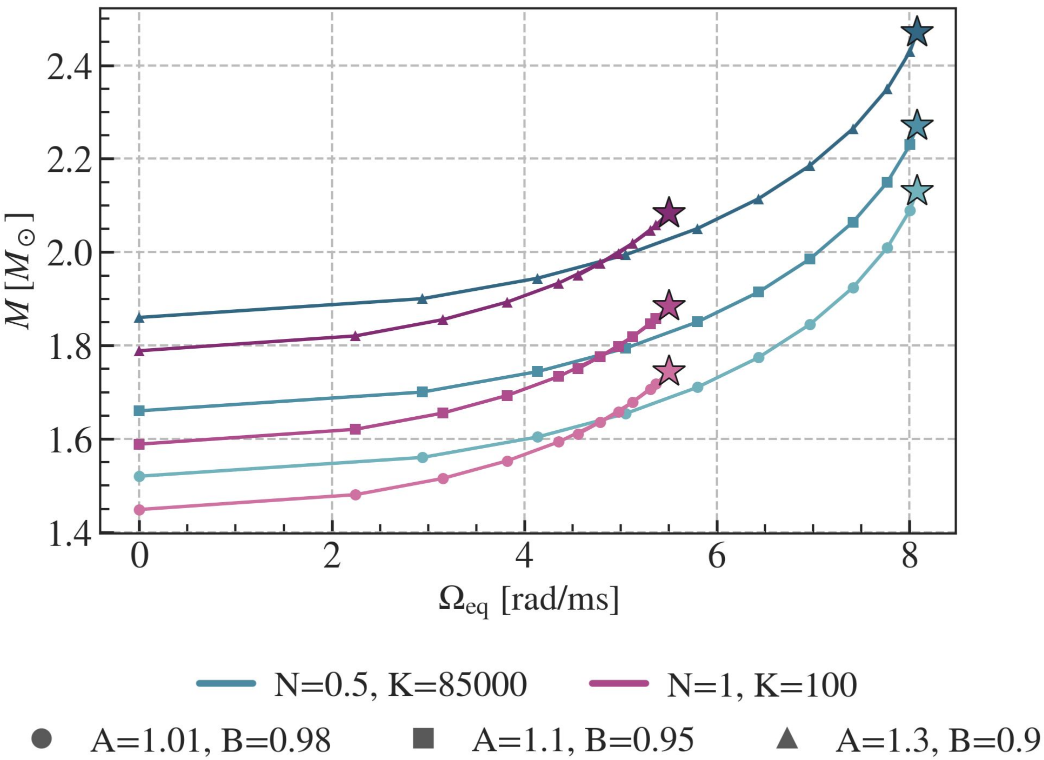


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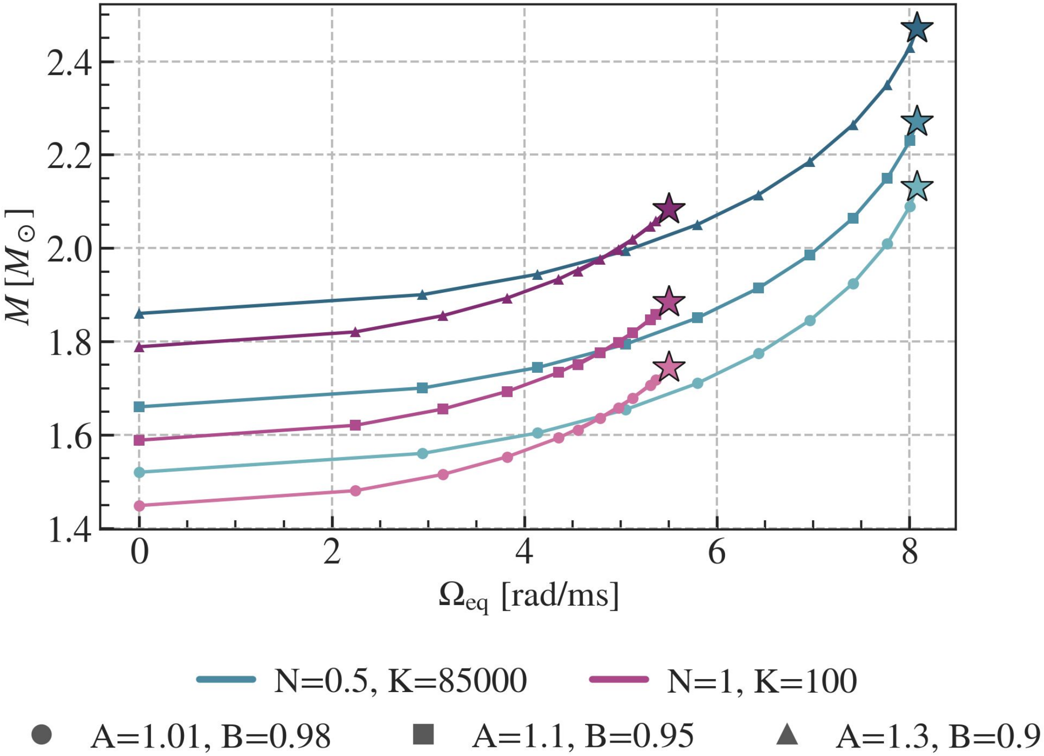


- Differential rotation within Einstein Toolkit for polytropic and tabulated EoSs.
- Introduce a perturbation and study time evolution of oscillations.
- Finite temperature (hot EoSs), viscosity etc. to be added for a **realistic BNS remnant**.

*“just a modest introduction to a story which promises to be long, complicated, and fascinating”*

Thorne and Campolattaro

# Thank you!