WHERE IS THE LOVE?

THE DYNAMICAL TIDES OF ROTATING NEUTRON STARS

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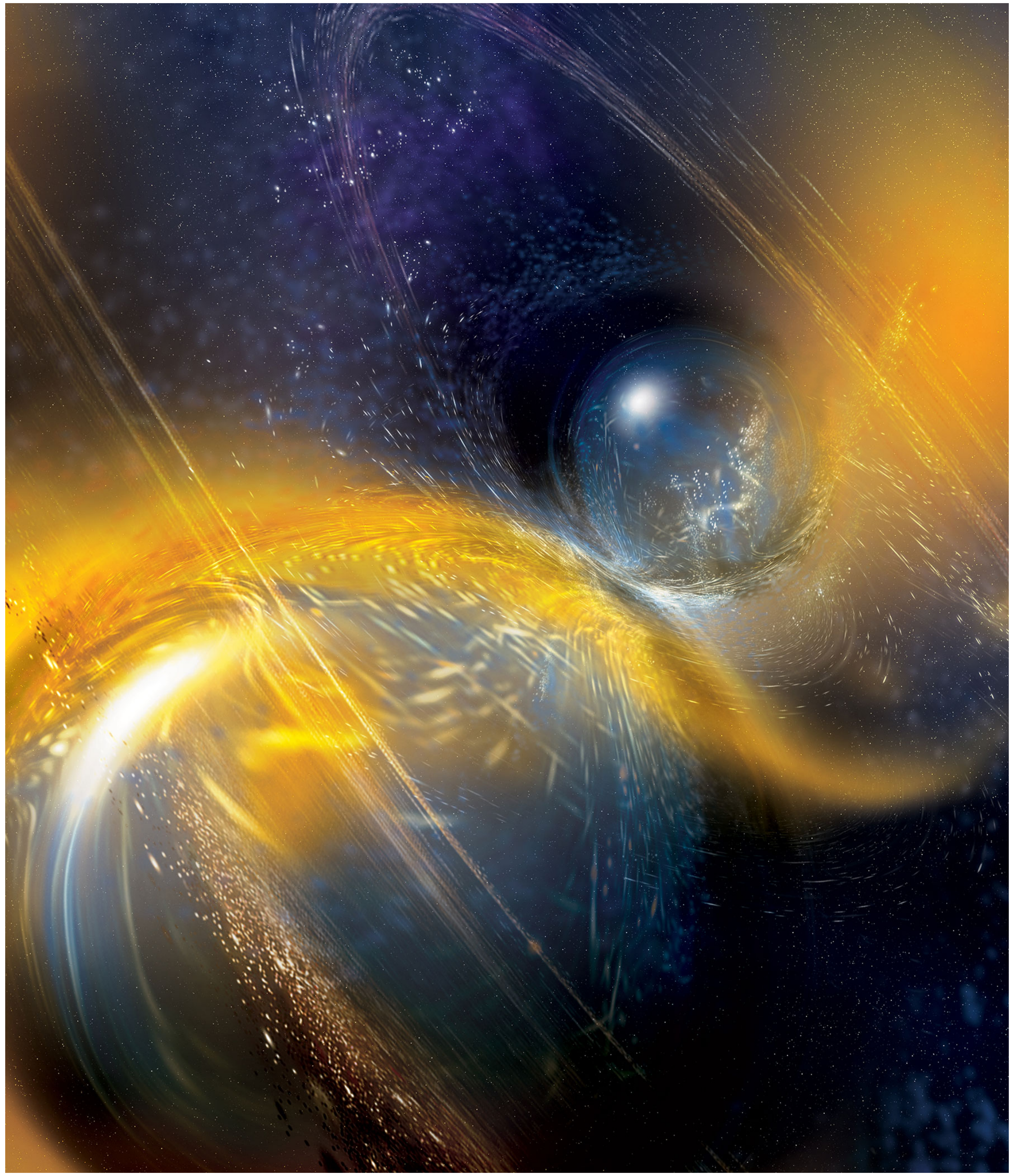

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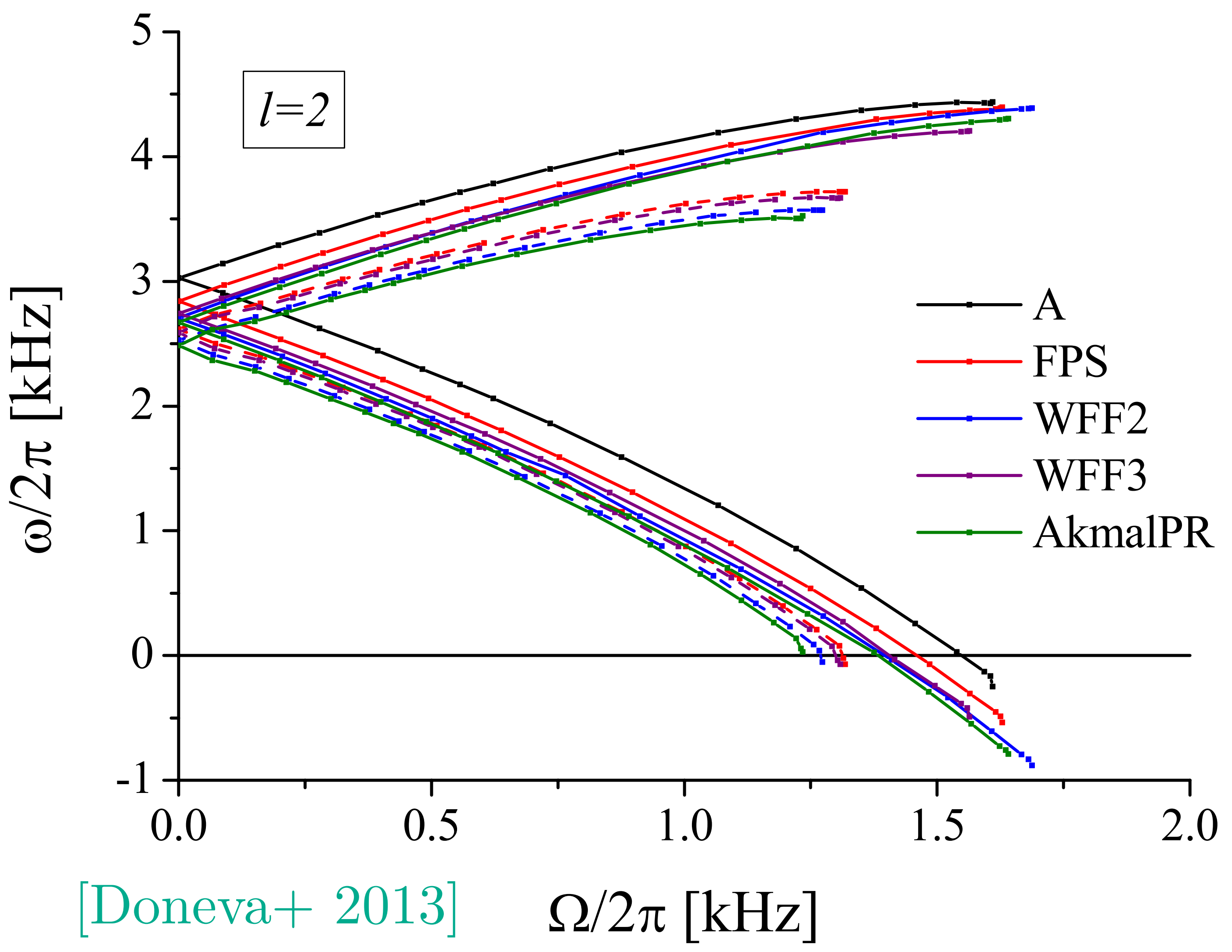
STAG RESEARCH CENTRE

neutron-star seismology

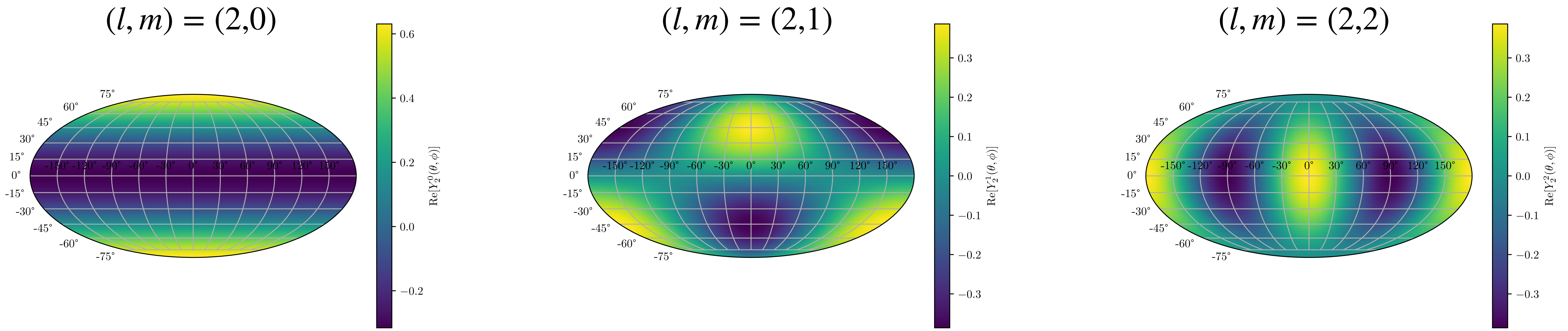
- Due to their intricate structure, neutron stars possess a rich spectrum of *oscillation modes*.
- The quantitative features of the modes depend on the elusive nuclear-matter *equation of state*.



[Doneva+ 2013]

Eigenfrequencies of the $(l, m) = (2, \pm 2)$ *f*-modes for different equations of state.

- We can look for signatures of modes in gravitational-wave signals — *e.g.*, continuous gravitational-wave emission from unstable modes, mode excitation in tidal interactions.



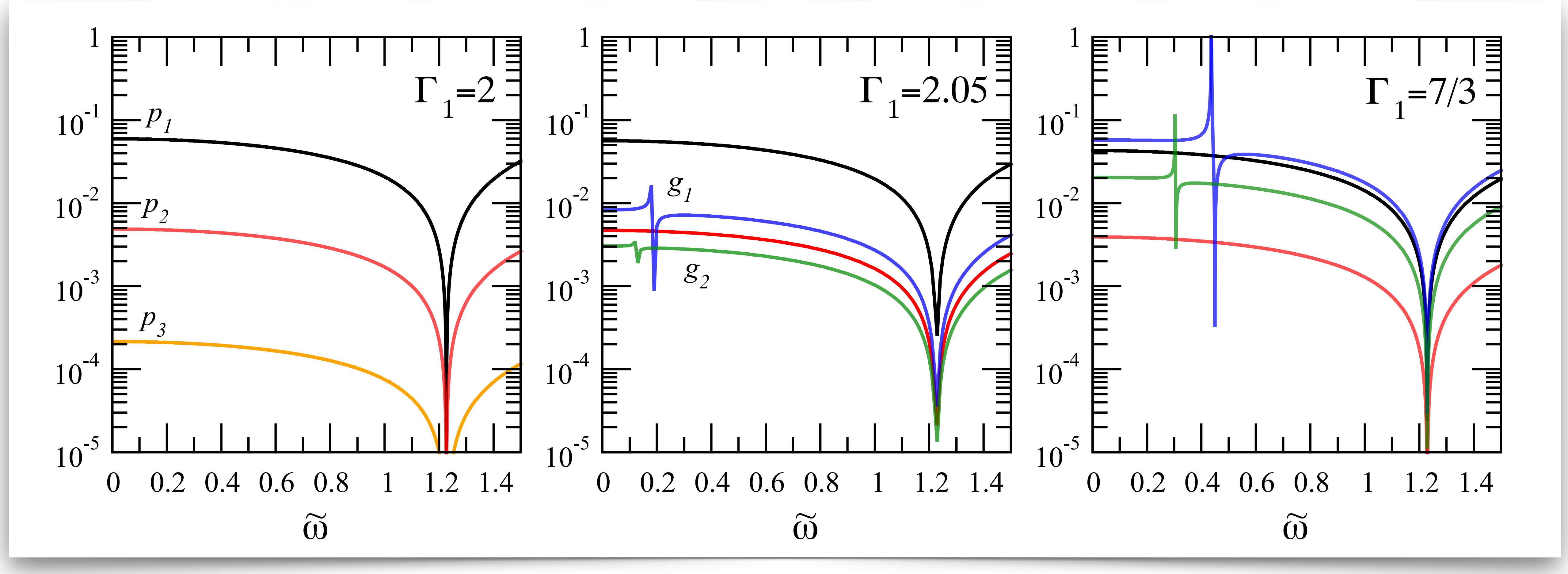
Angular behaviour of the $l = 2$ modes of a spherical star, given by $\mathrm{Re}(Y_l^m)$.

Love numbers: non-rotating stars

- The Love numbers quantify the multipolar response of a star to a given tidal potential. Away from resonance, one finds

$$k_{lm} = \frac{2\pi G}{(2l+1)R^{2l+1}} \sum_{\alpha} \frac{I_\alpha^2}{\omega_\alpha^2 - (m\Omega_{\rm orb})^2}.$$

- Therefore, each mode α with an (l, m) dependence will be excited by the corresponding (l, m) component of the tidal field.



[Andersson+Pnigouras 2020]

Relative contributions to the tidal Love number compared to the f-mode for $l = 2$.

Love numbers: rotating stars

- The modes are no longer identified by a single l. Rotation also couples the pro- and retrograde modes.

- The Love numbers are therefore

$$k_{lm} = \frac{2\pi G}{(2l+1)R^{2l+1}} \frac{1}{K_{lm}} \sum_{l'} K_{l'm} \left[\sum_{\alpha} \frac{I^*_{\alpha l'} I_{\alpha l}}{\omega_\alpha + m(\Omega - \Omega_{\rm orb})} + \sum_{\beta} \frac{I_{\beta l'} I^*_{\beta l}}{\omega_\beta - m(\Omega - \Omega_{\rm orb})} \right].$$

- The static tides of a spinning star deviate from the spherical case at second order in rotation,

$$k_{lm} = \frac{2\pi G}{(2l+1)R^{2l+1}} \sum_{\alpha} \left(\frac{I^0_\alpha}{\omega^0_\alpha} \right)^2 + \mathcal{O}(\Omega^2).$$

challenges

Calculations will need to be done in full general relativity.

opportunities

At this level, more realistic physics can be incorporated (like the equation of state, crustal properties, superfluidity *etc.*).