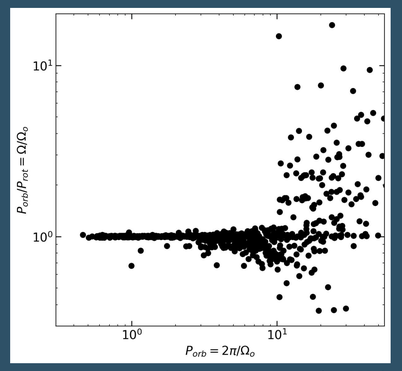
Tidal torque balance in stars and gaseous planets

Janosz Dewberry | CITA

Dewberry J. 2024, ApJ, 966, 180 (arxiv:2403.06979)

Background

Tidal torques cause rotation and orbital periods to evolve toward synchronization

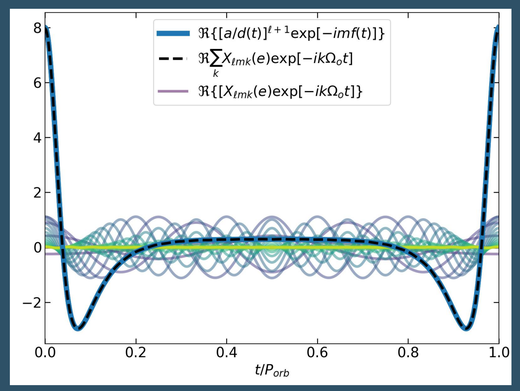


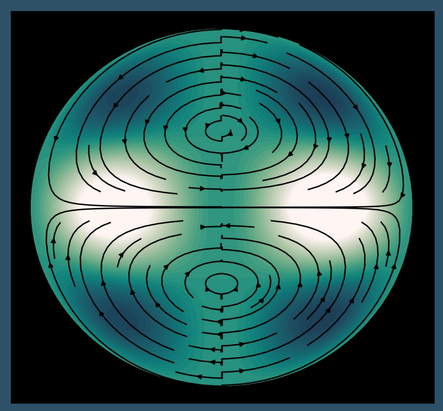
(data: Lurie et al. 2017)

Eccentric orbits drive tides at many simultaneous tidal frequencies

Tidal potential:

$$U_{\ell m} \propto \left(\frac{a}{d(t)}\right)^{\ell+1} \exp[-imf(t)]$$





Inertial modes enhance tidal torques at frequencies proportional to a star or planet's rotation rate

(e.g., Dewberry & Lai, 2021)

Results

Inertial mode frequency scaling

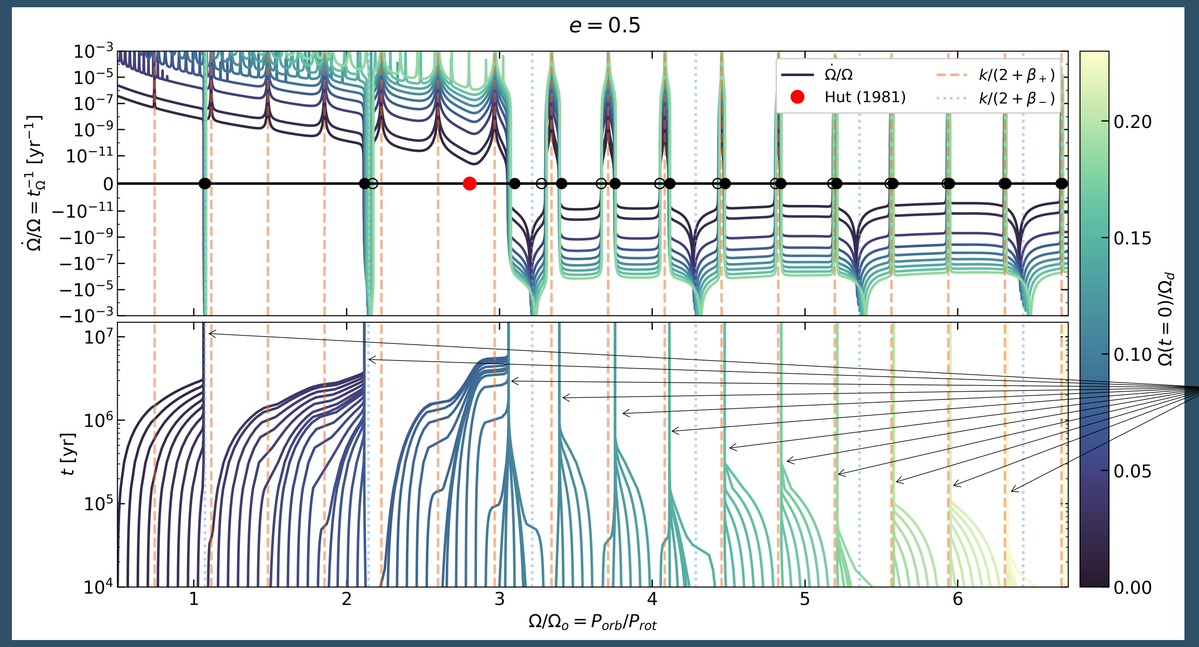
$$\omega \approx \beta\Omega$$

Vanishing total tidal torques at numerous ratios of orbital to rotation period:

$$\frac{\Omega}{\Omega_o} \approx \frac{k}{2+\beta},\ k = 1, 2, 3, \ldots$$

Period *ratios* of torque balance are ~independent of:

- Rotation period
- Orbital period
- Eccentricity
- Internal dissipation
- Internal structure (barring disappearance of a convective envelope)

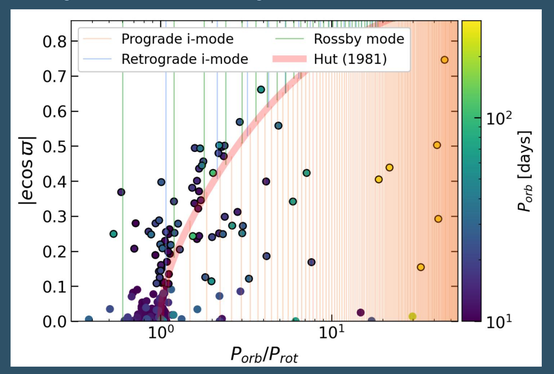


Fixed points ("synchronization traps") in tidal spin evolution (while orbit remains eccentric)

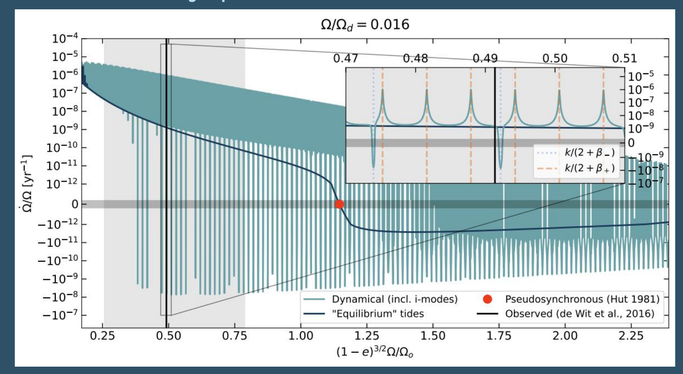
Takeaways

Inertial modes can inhibit tidal spin (pseudo-)synchronization in eccentric systems

May affect binary stars



And/or hot jupiters!



References:
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Dewberry J. 2024, ApJ, 966, 180
de Wit J. et al. 2016, ApJL, 820, L33
Hut P. 1981, A&A, 99, 126
Lurie J. C. et al. 2017, AJ, 154, 250