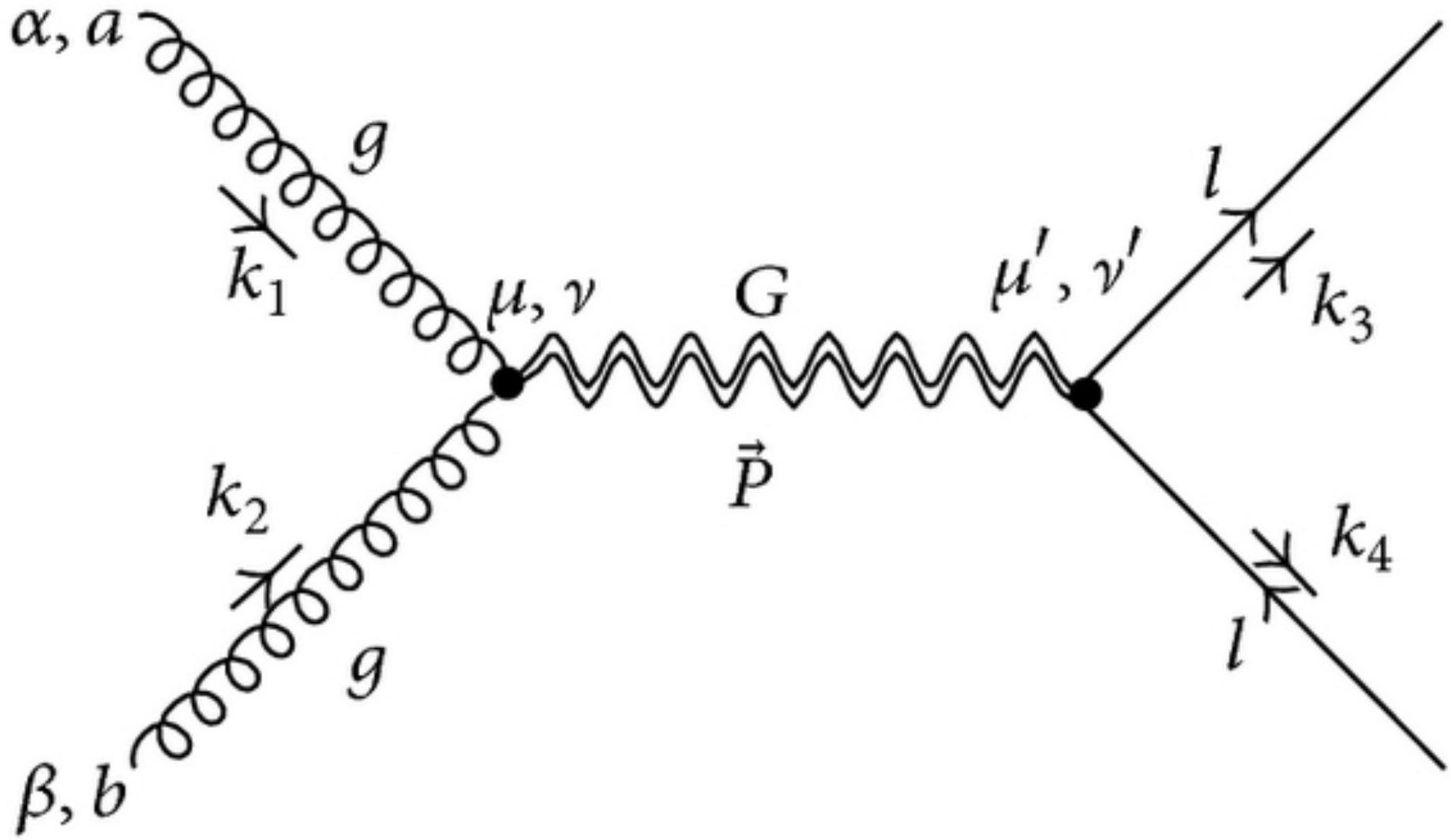
Constraining the mass of the graviton using low-frequency gravitational waves and Gaia



Phenomenology 2019 Symposium
Cosmology session
6 May 2019

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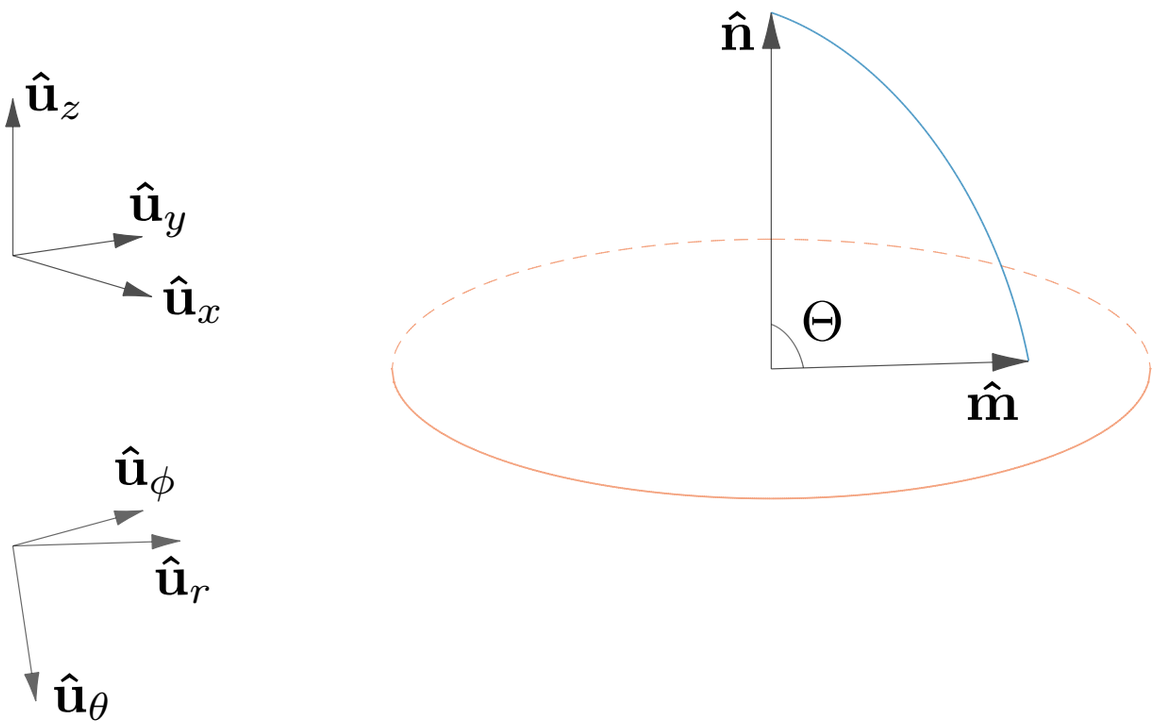
Cambridge / UPitt

NanoGrav
EPTA
PPTA
Gaia
$\log_{10}$ (Strain amplitude)
$\log_{10}$ (Frequency / Hz)
−11.0
−11.5
−12.0
−12.5
−13.0
−13.5
−14.0
−14.5
−8.5
−8.0
−7.5
−7.0
−6.5
−6.0

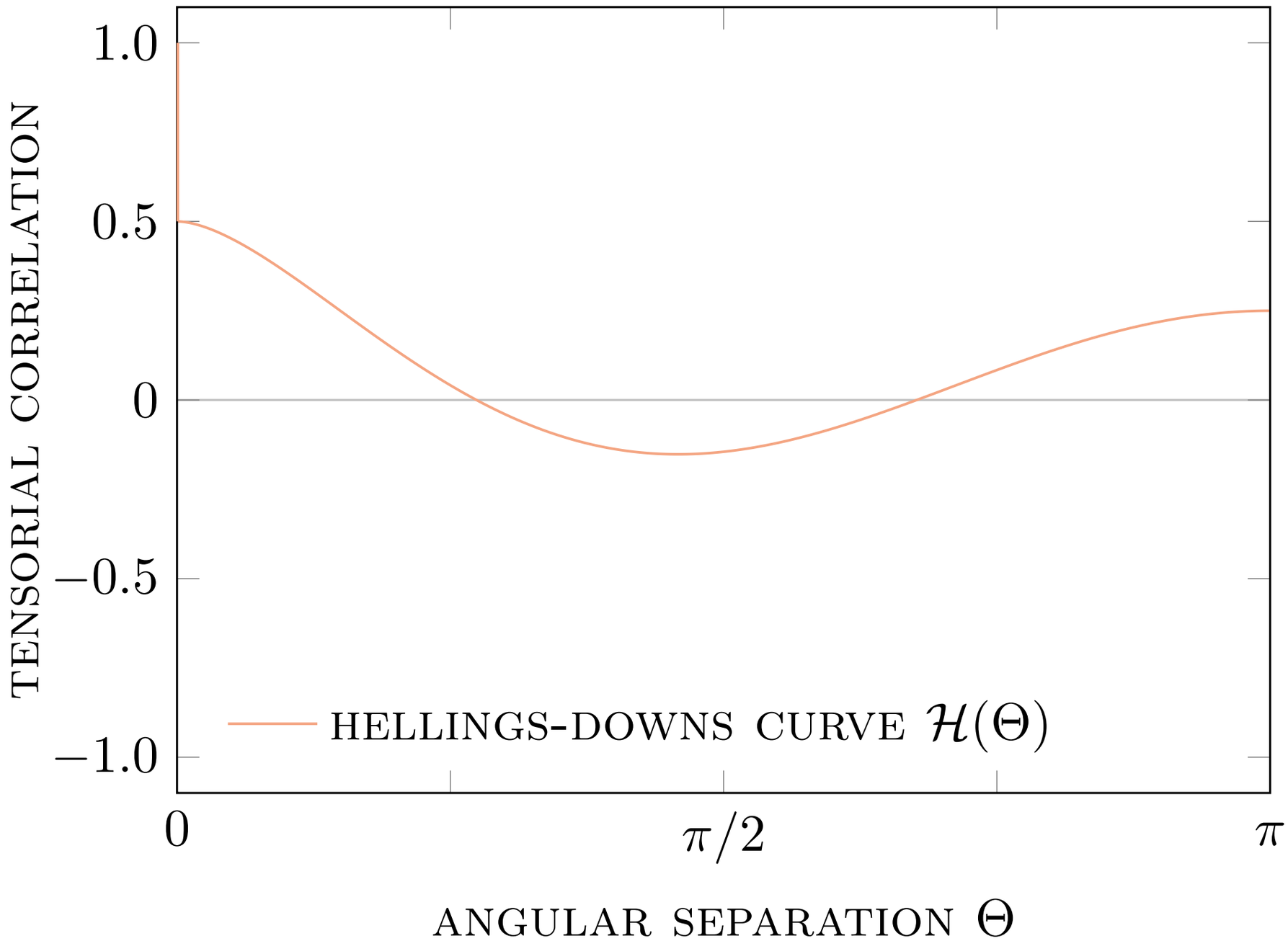
The astrometric equivalent of the Hellings-Downs curve depends on the background polarization content and the mass of the graviton

Hellings-Downs curve



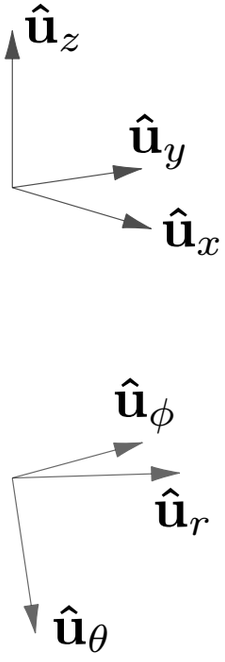
$$z = \frac{n^i n^j}{2\left(1 - n_k q^k\right)} \left[h_{ij}(\text{OBS}) - h_{ij}(\text{SOURCE})\right]$$

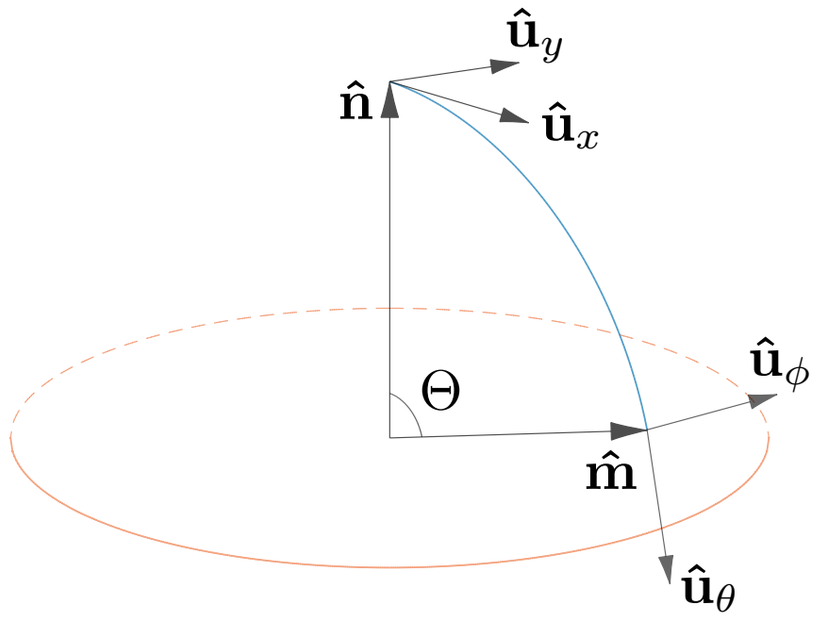
Hellings-Downs curve



Astrometric equivalent

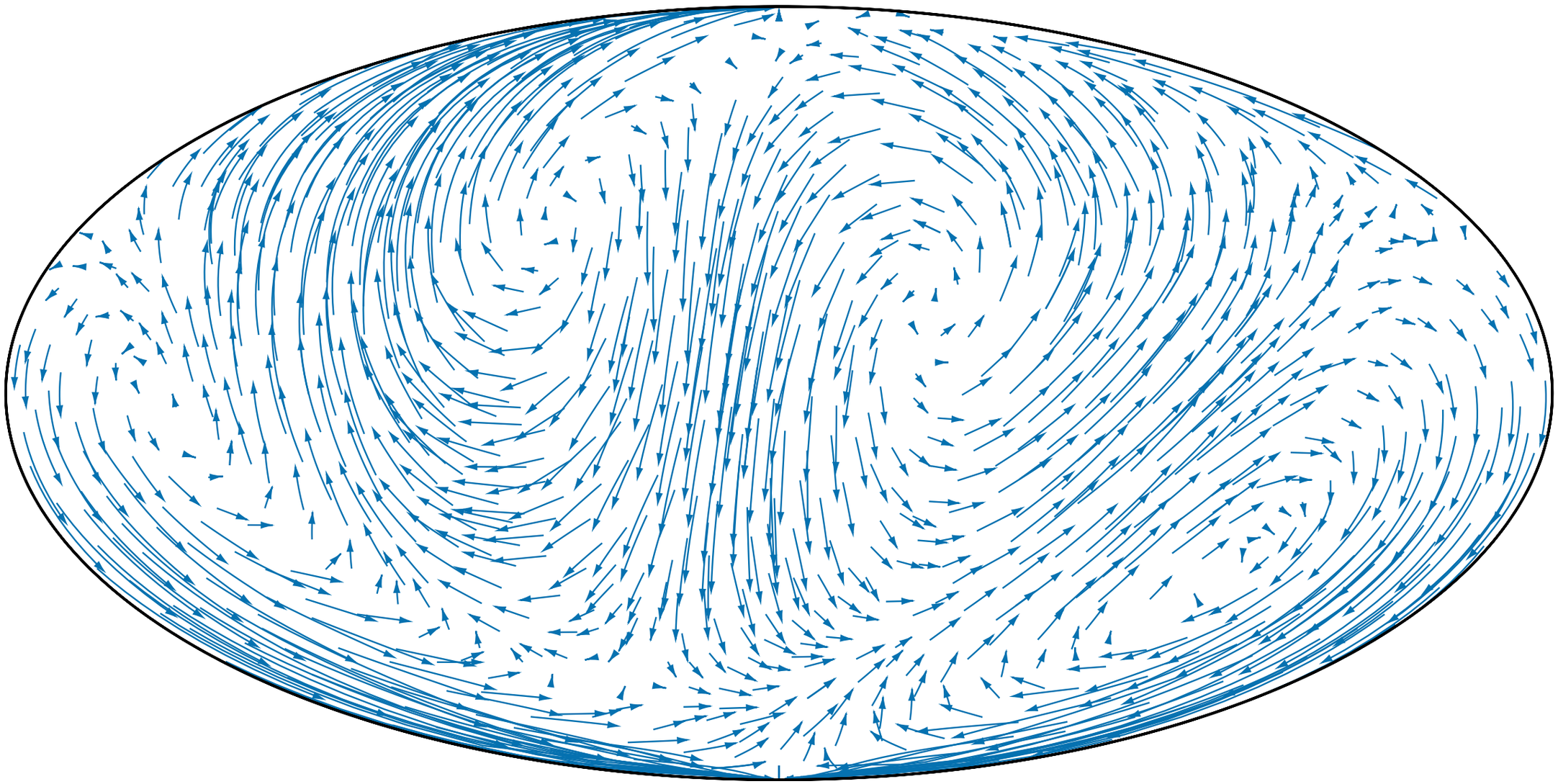
$$\Gamma^P_{ij}(\Theta) \propto \int_{S^2} \mathrm{d}\Omega_{\mathbf{q}}\, \delta n_i(n_k, t)\, \delta m_j(m_\ell, t),$$



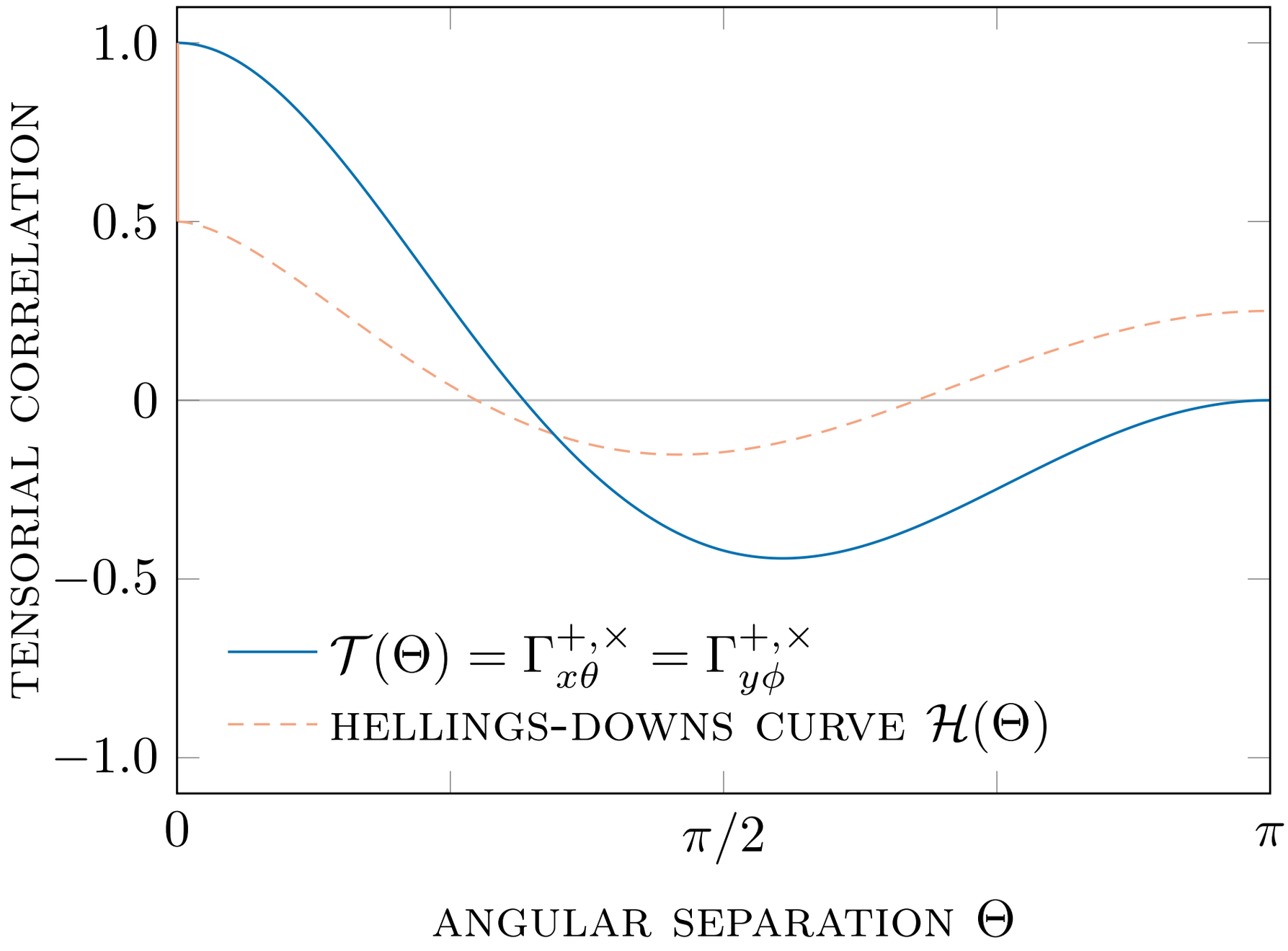


$$C = \left(\begin{array}{c|c} \Gamma_{x\theta} & \Gamma_{x\phi} \\ \hline \Gamma_{y\theta} & \Gamma_{y\phi} \end{array}\right)$$

Astrometric equivalent

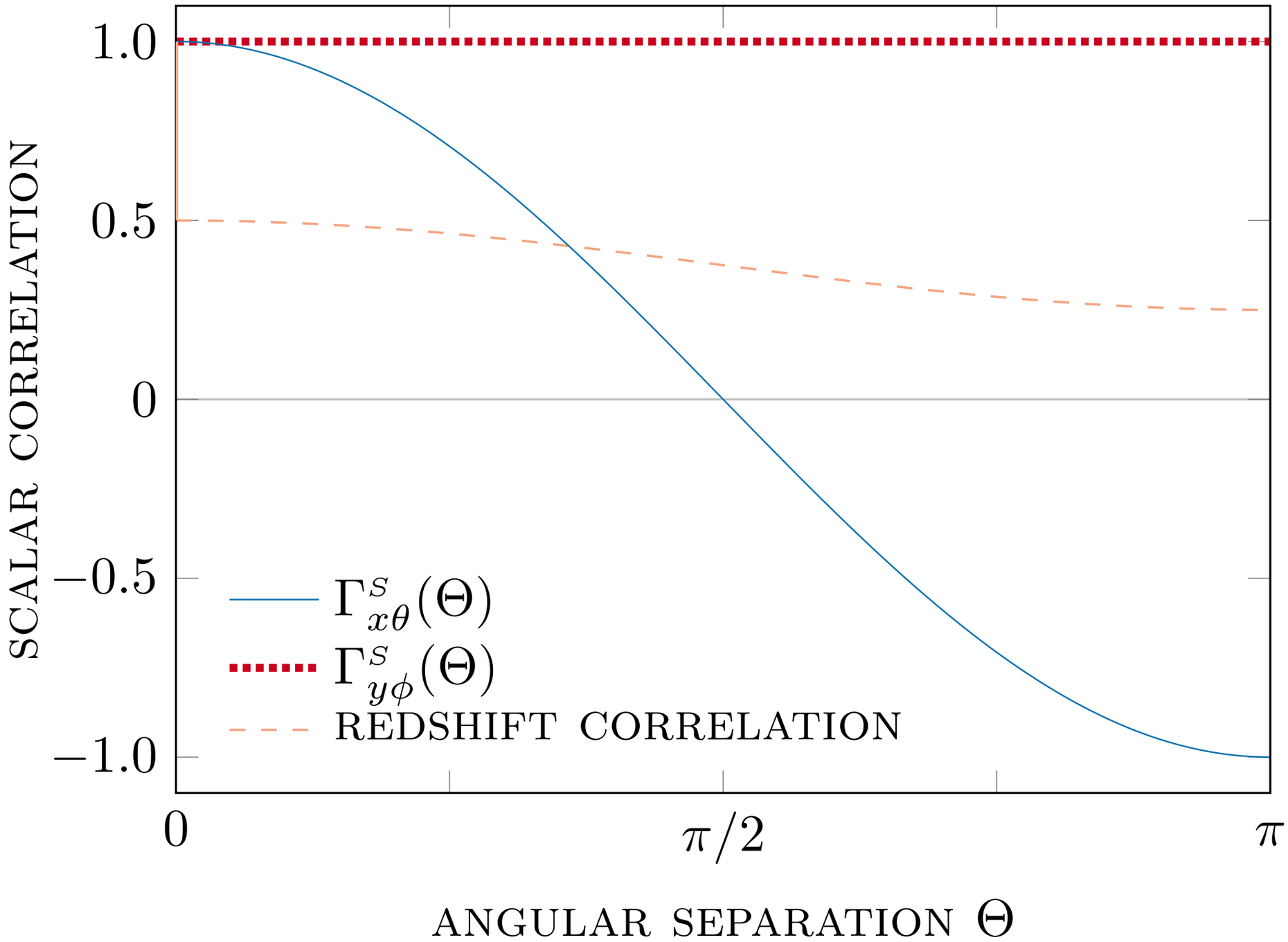


Astrometric equivalent

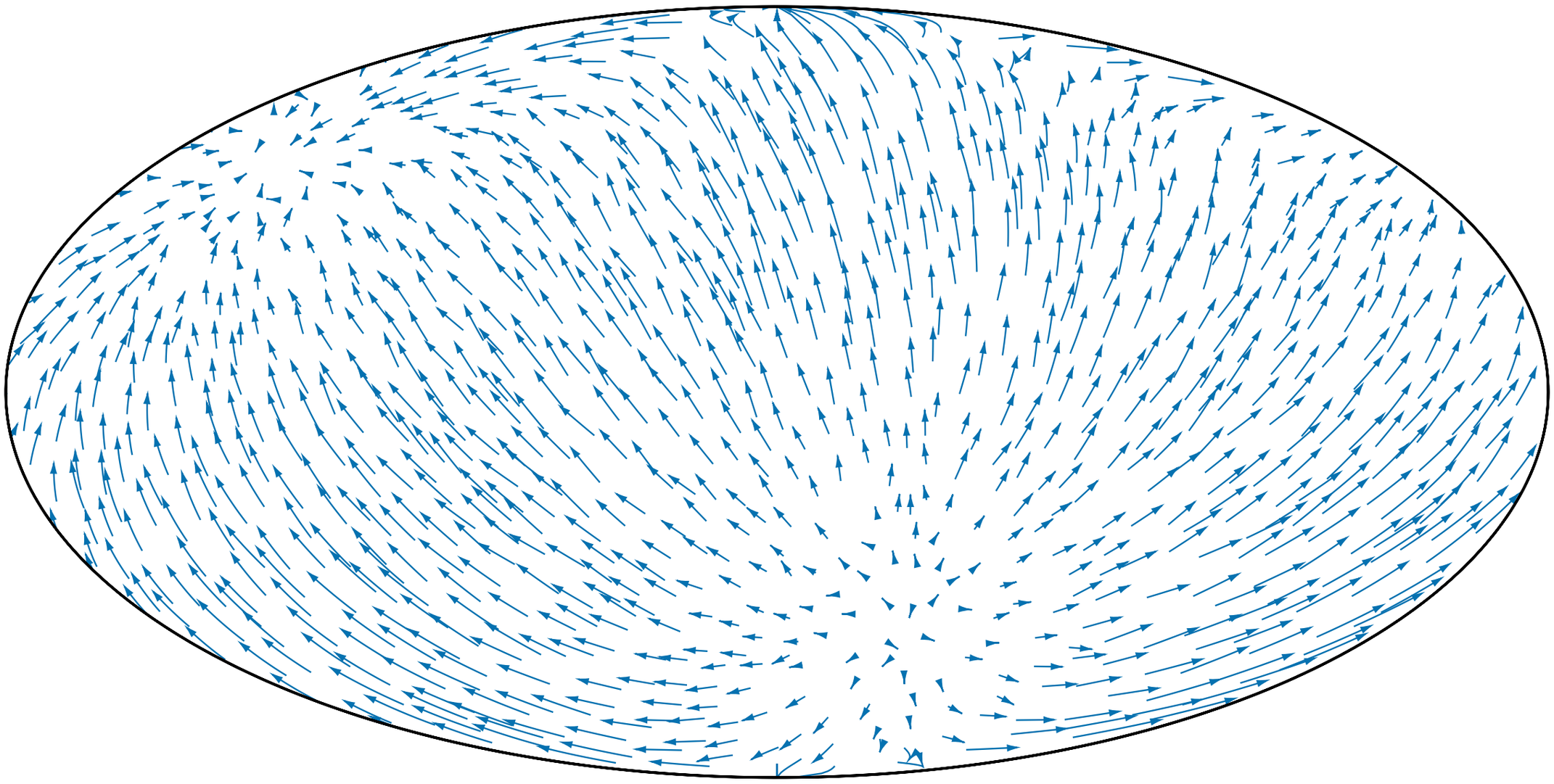


Cf. Book and Flanagan, 2001

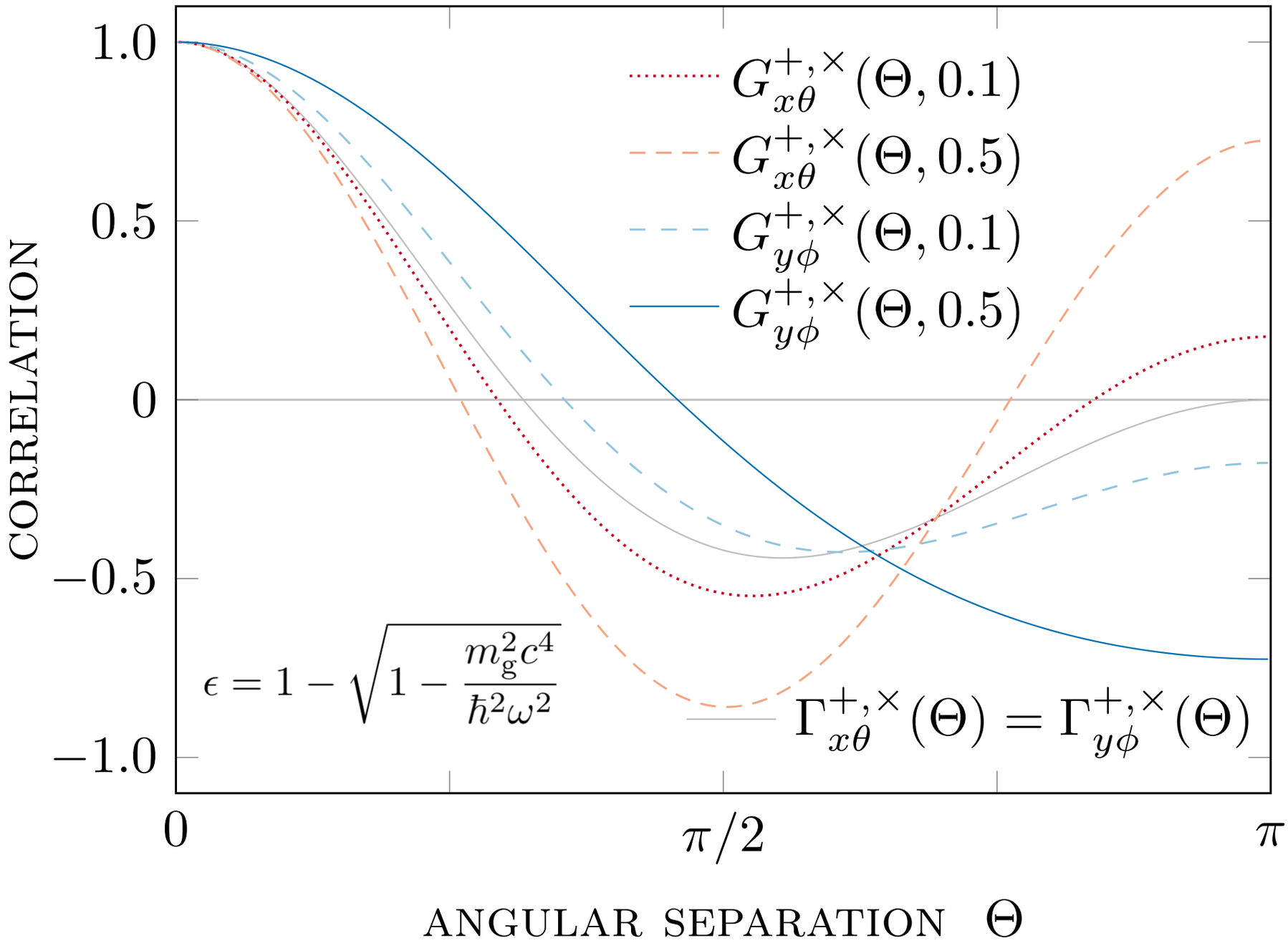
Breathing mode background



Breathing mode background



GR MODES WITH MASSIVE GRAVITON CORRECTIONS



Conclusions

1. GWs induce periodic perturbations in the astrometric measurements of stars

2. GW backgrounds induce correlated astrometric patterns

3. Gaia is the ideal tool to study these effects

4. Each GW polarization has a distinct correlation curve

5. The mass of the graviton can be constrained using its effect on the correlation

arXiv:1707.06239

arXiv:1804.00660