Evidence for a minimum pulsar ellipticity?

(G. Woan, M. Pitkin, B. Haskell, D. I. Jones & P. Lasky,
ApJLett, **863**, L40 (2018), arXiv:1806.02822)

The P-Pdot diagram

We can plot the period of known pulsars against their period derivative - Pdot (*observed Pdot and true Pdot are not necessarily the same!*)

- lines for different external dipole magnetic field strengths (assuming pure magnetic dipole braking)
- lines for different *characteristic* ages

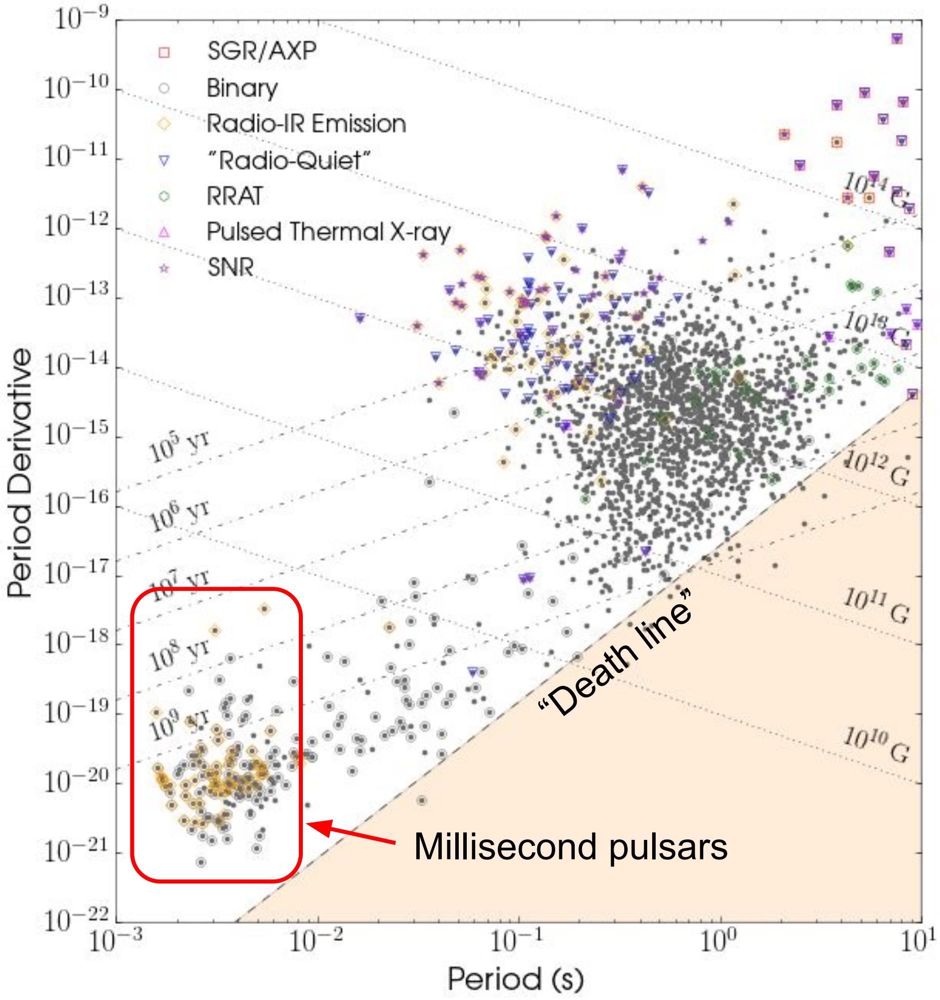
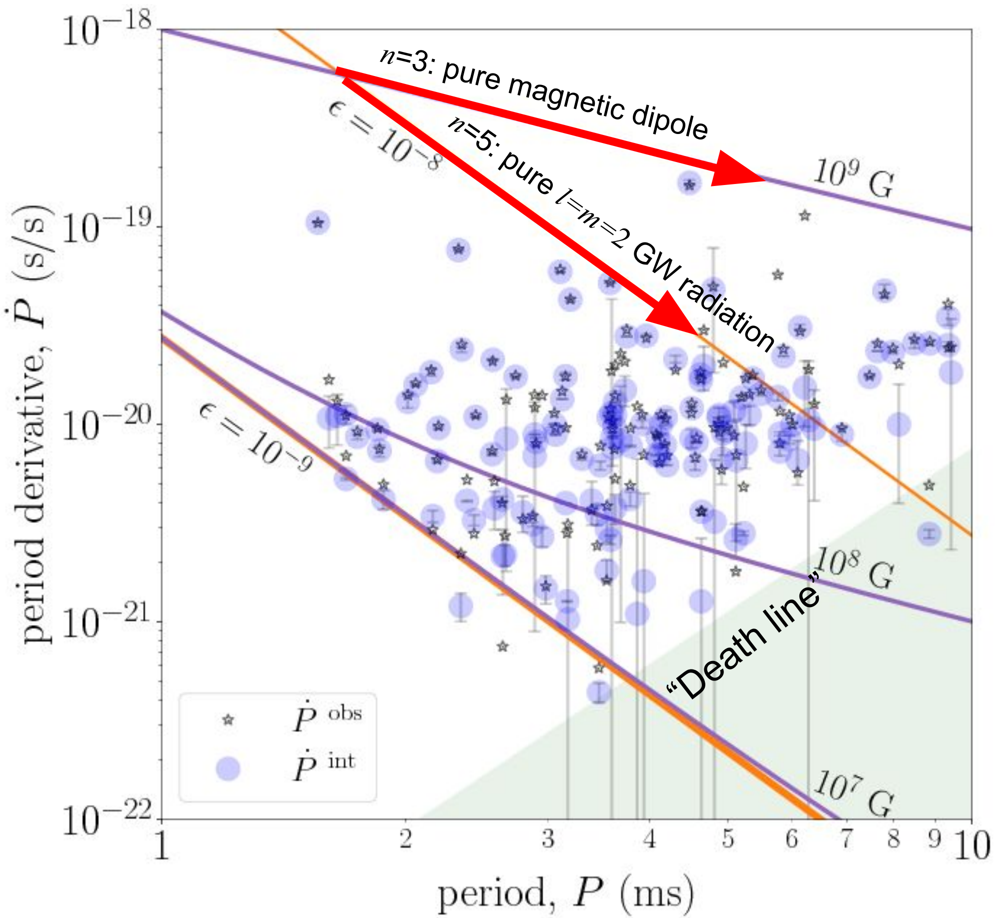


Image produced with psrqpy, Pitkin, JOSS (2018)

P-Pdot diagram

Zoom in on MSPs (showing intrinsic Pdot and uncertainties)

- Lines showing evolution contours for stars spinning-down via
  - pure magnetic dipole radiation
  - pure $l\!=\!m\!=\!2$ GW emission
  - a combination of both
- Lack of pulsars below contour for GW emission assuming pulsars with ellipticities of 10^{-9}!?

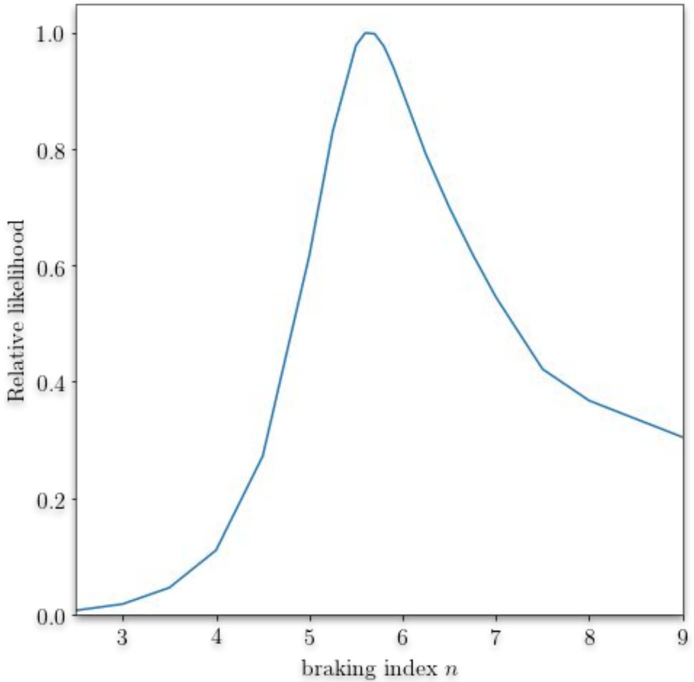


G. Woan *et al.*, arXiv:1806.02822

Ellipticity cut-off

Is the ellipticity cut-off real?

- Observational selection effects?
  - No obvious selection effects that we know of
- Statistical sanity check
  - Prior that MSPs are log-uniformly distributed in Pdot, with a lower Pdot cut-off combining a "death line" (for the r.h.s. of the diagram) and a power law braking process cut-off with unknown braking index (slope) and scale; how do fits to the data including different braking index cut-offs compare to no cut-off?
  - Incorporate uncertainties on Pdot values and in pulsar moment of inertia



Cut-off with n=5 (i.e. pure GW emission) favoured over no cut-off by ~6400

Cut-off with n=5 favoured over n=3 (i.e. pure magnetic dipole emission) by ~35

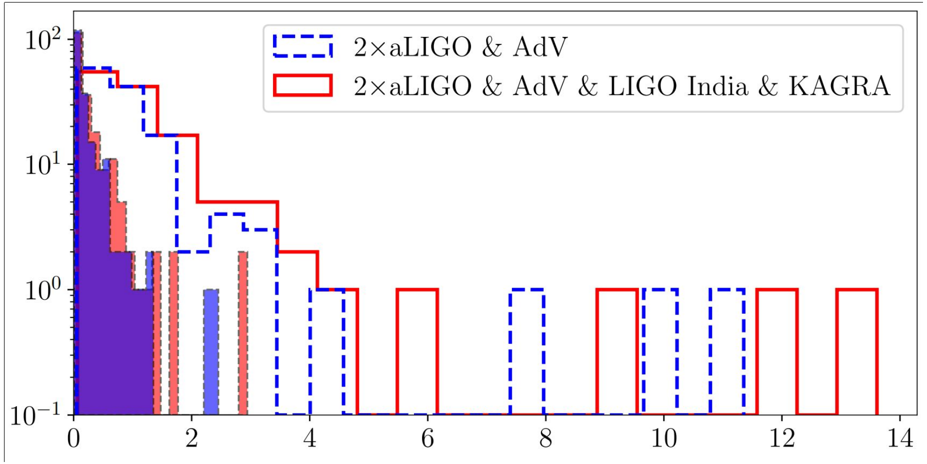
Best fit ellipticity for n=5 is ~10^{-9} (for moment of inertia of 10^{38} kg m^2)

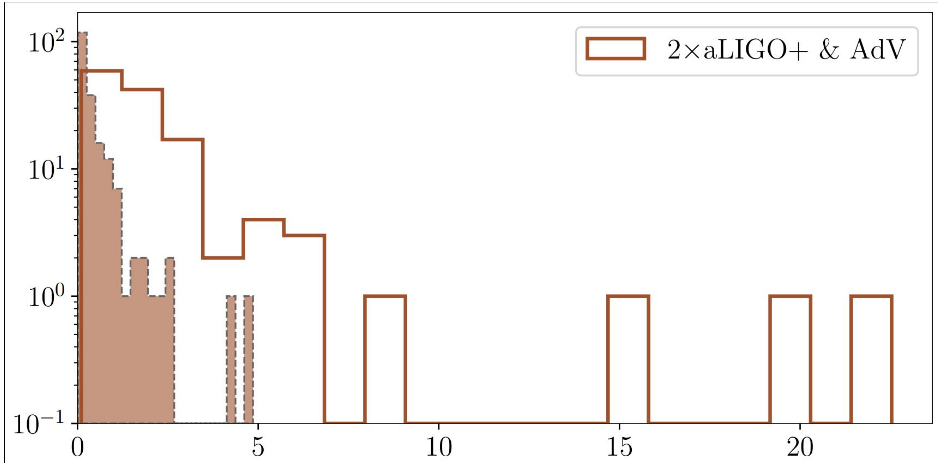
Ellipticity cut-off

What could cause a minimum ellipticity in MSPs?

- MSPs are recycled; they underwent an accretion phase in a binary system to spin them up
  - Small external magnetic field for MSPs (~10^8 Gauss) compared to “young” pulsars ($\gtrsim 10^{11}$ Gauss) suggests field may have been “buried” during accretion (e.g., Vigelius & Melatos, *MNRAS*, 395, 2009)
    - old and cold MSPs may have cores that are type II superconductors, so ellipticity is linear in internal field strength (e.g., Lander, *MNRAS*, 437, 2014) with $\epsilon \sim 10^{-8} (B_i / 10^{12}$ Gauss) - so $\epsilon \gtrsim 10^{-9}$
  - Asymmetric crustal fracturing during spin-up (Fattoyev *et al*., arXiv:1804.04952), or spin-down (e.g., Baym & Pines, AnPhys, 66, 1971), could imprint a similar ellipticity in all MSPs

Implications for GW detections

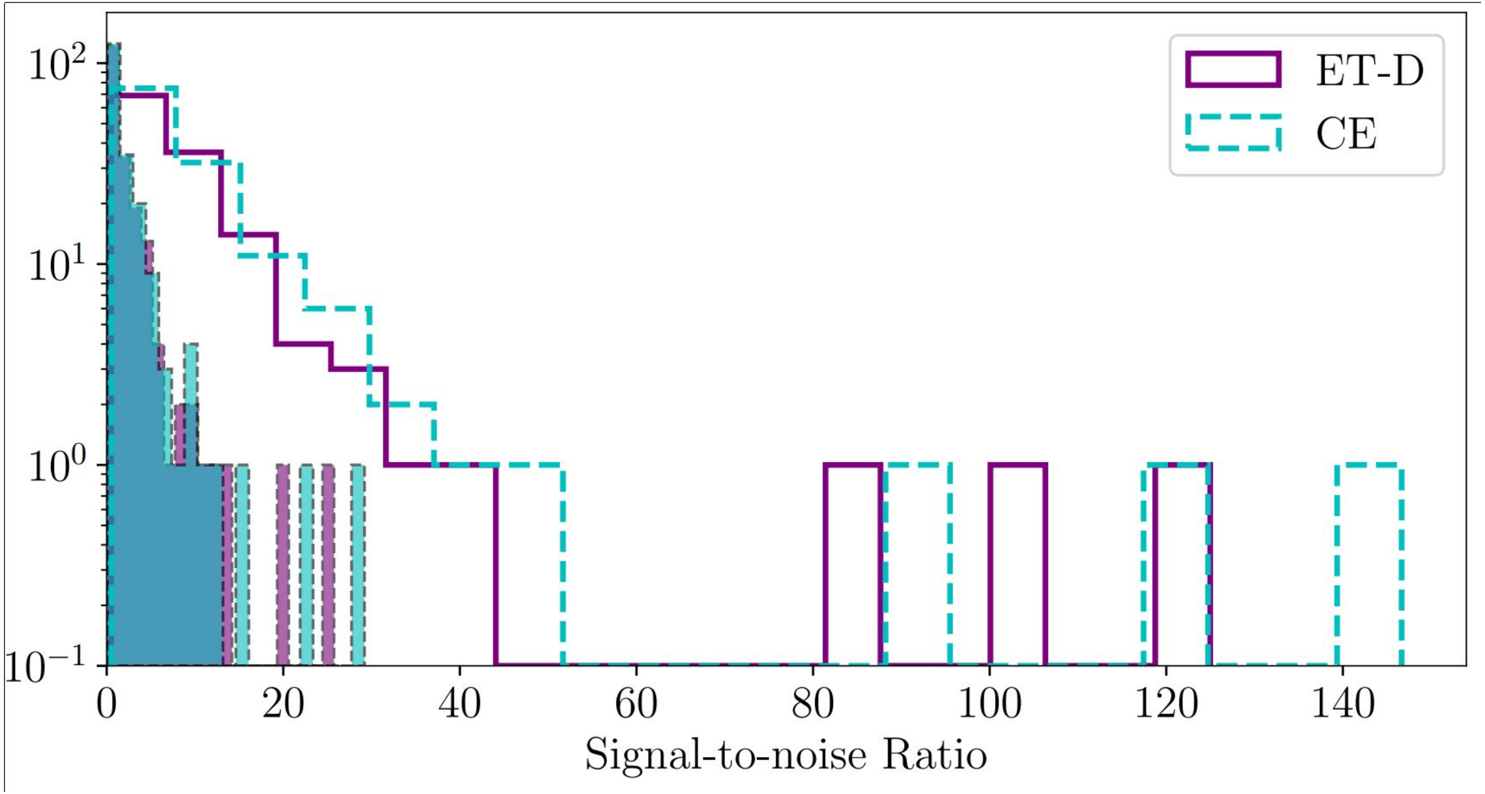




Expected SNR for one year coherent observations of pulsars with various detector networks:

- Filled histograms - all pulsars with ellipticities of 10^{-9}
- Unfilled histograms - all pulsars emitting at their spin-down limits

Implications for GW detections



Assuming all have $\epsilon=10^{-9}$

ET:
- SNR > 20: **2**
- SNR > 15: **2**
- SNR > 10: **5**
- SNR > 8: **9**
- SNR > 5: **15**

CE:
- SNR > 20: **2**
- SNR > 15: **3**
- SNR > 10: **6**
- SNR > 8: **9**
- SNR > 5: **18**