On the Accretion, Spin and True Ages of MSPs

Thomas Tauris, Norbert Langer & Michael Kramer (2012)

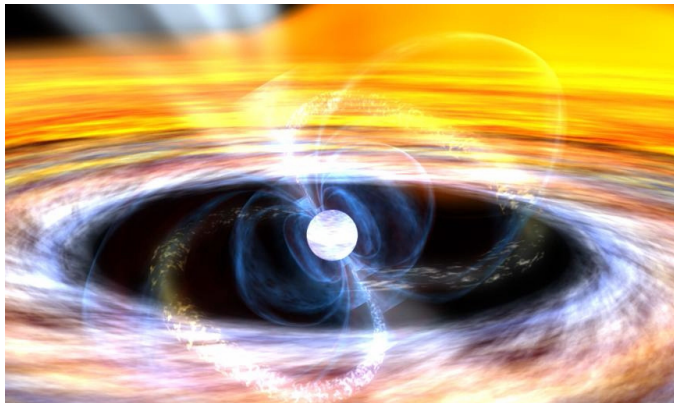
MNRAS, in press

Content

- Recycling pulsars
  - Spin-up line
  - Amount of mass accreted vs pulsar spin period
  - Case BB RLO (post-CE spin-up)
- True ages of recycled pulsars

Congratulations: Dick 70 years

Spin-up line in the PP-diagram:



$$P_{eq} = 2\pi\sqrt{\frac{r_{mag}^3}{GM}}\frac{1}{\omega_c} \quad \wedge \quad r_{mag}(\dot{M}, B) \quad \wedge \quad B(P, \dot{P})$$

$$\dot{P} = \frac{2^{1/6} G^{5/3}}{\pi^{1/3} c^3} \frac{\dot{M} M^{5/3} P_{eq}^{4/3}}{I} \cdot (1 + \sin^2\alpha) \cdot \varphi^{-7/2} \cdot \omega_c^{7/3}$$

spin-up line in $P\dot{P}$ – diagram

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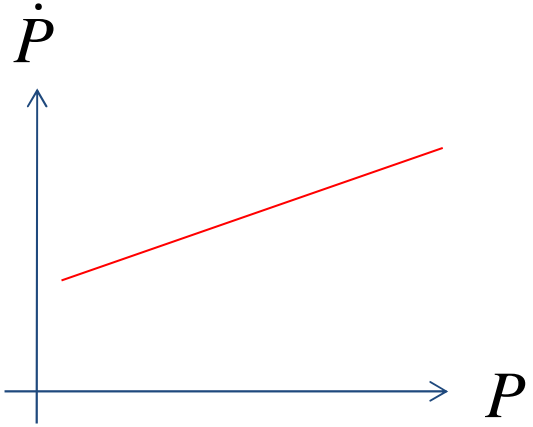
Important!

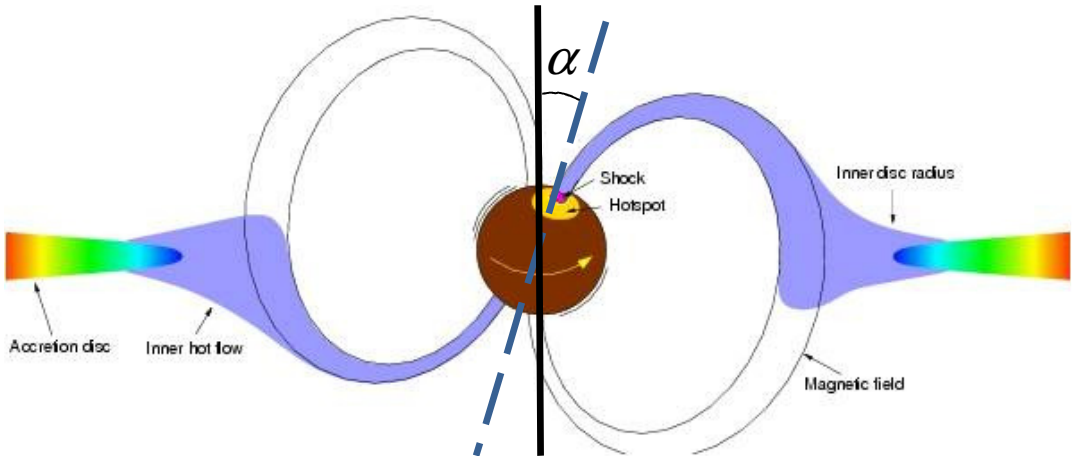
disk –magnetosphere parameters:

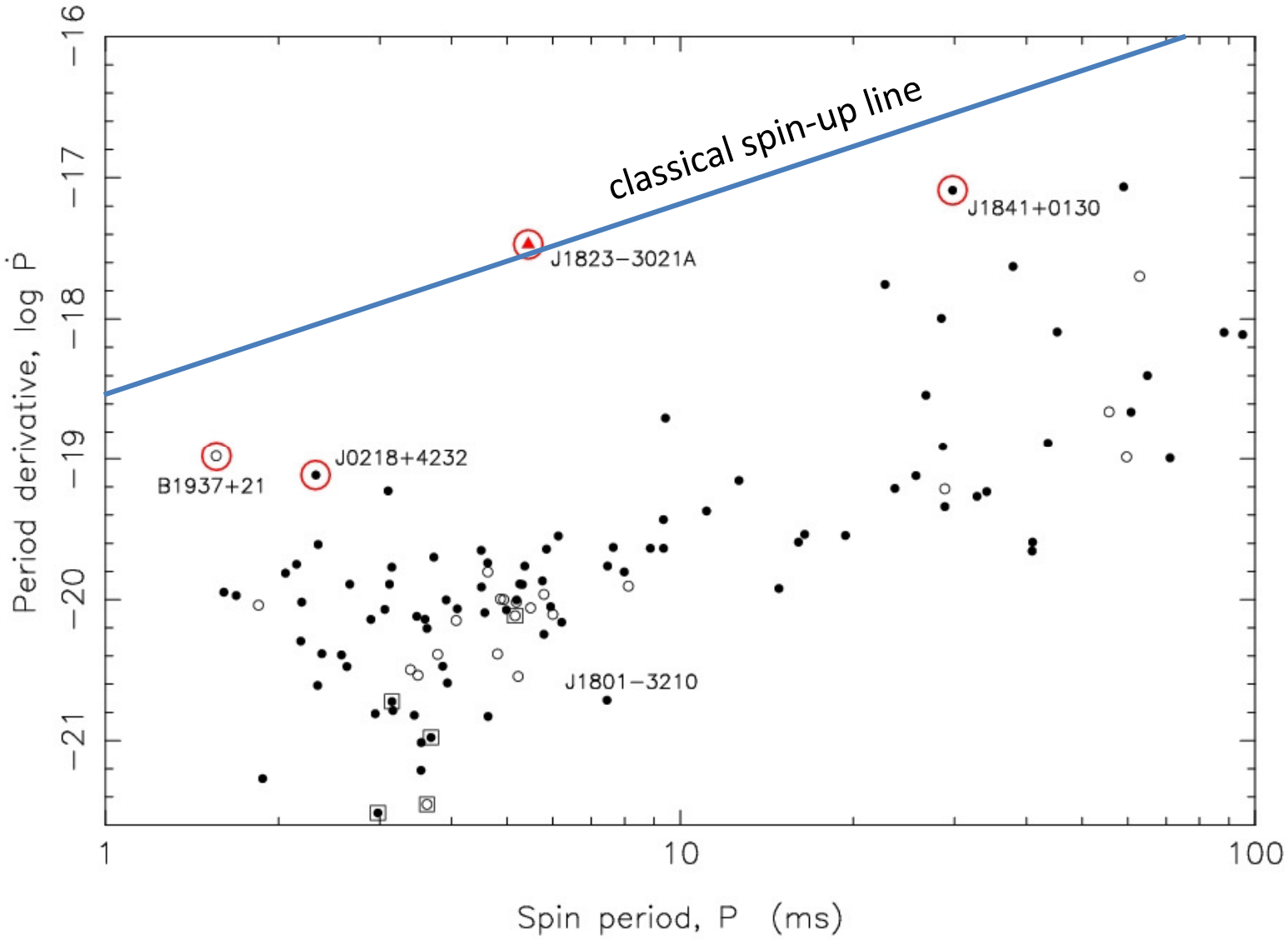
$$R_{mag} = \varphi R_{Alfven}$$

$$\Omega_{NS} = \omega_c \Omega_{mag}^{Kep.}$$



Classical spin-up line
e.g. Bhattacharya & van den Heuvel (1991)

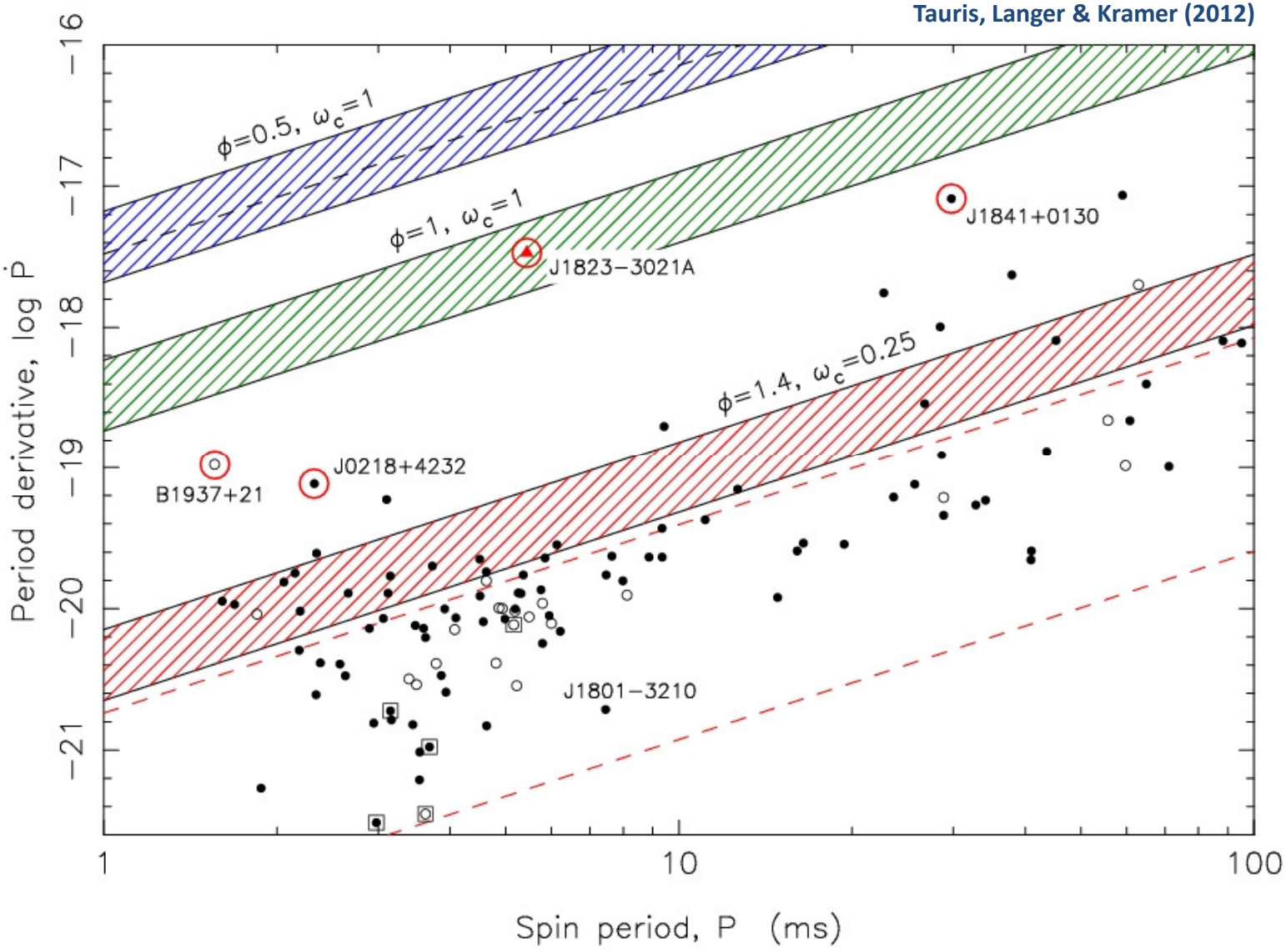



classical spin-up line
J1841+0130
J1823−3021A
J0218+4232
B1937+21
J1801−3210
Period derivative, log Ṗ
−16
−17
−18
−19
−20
−21
1
10
100
Spin period, P (ms)

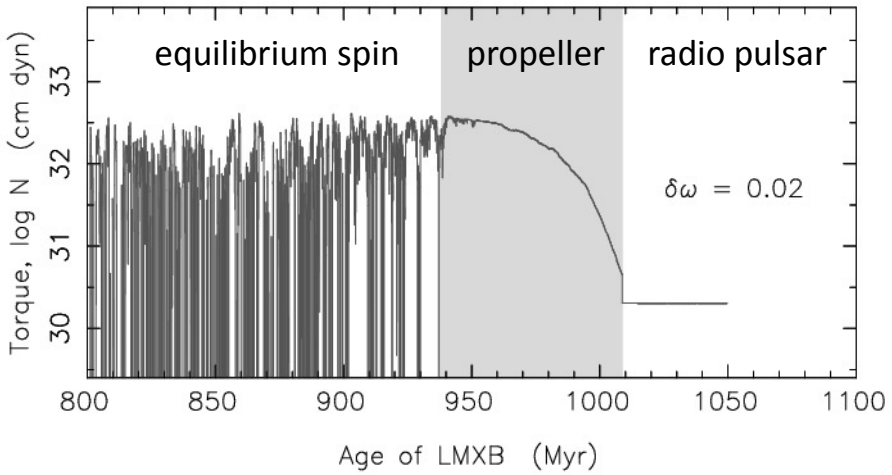
All spin-up lines shown here are calculated for $\dot{M} = \dot{M}_{Edd}$

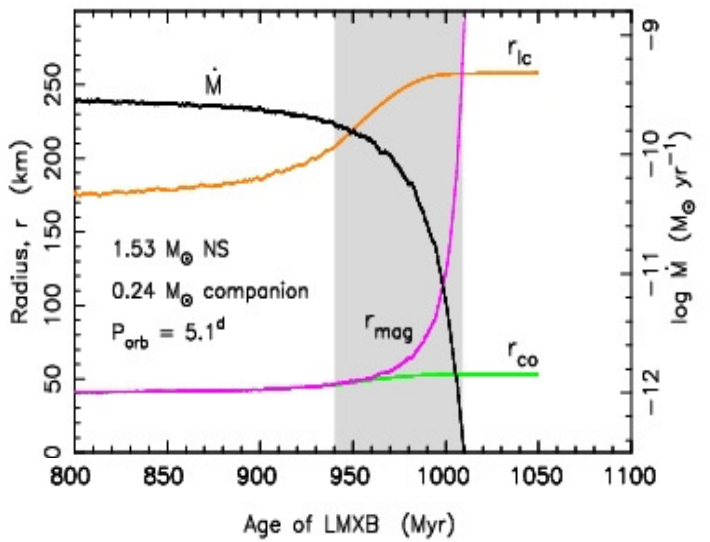
The width of each ”line” is caused by (M, α)

Tauris, Langer & Kramer (2012)



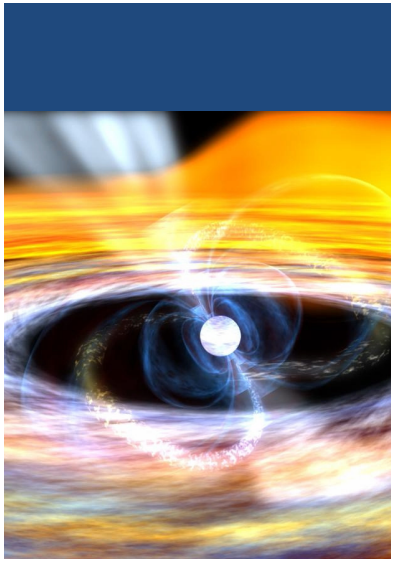
$r_{mag} \simeq r_{co}$ $r_{mag} > r_{co}$ $r_{mag} > r_{lc}$

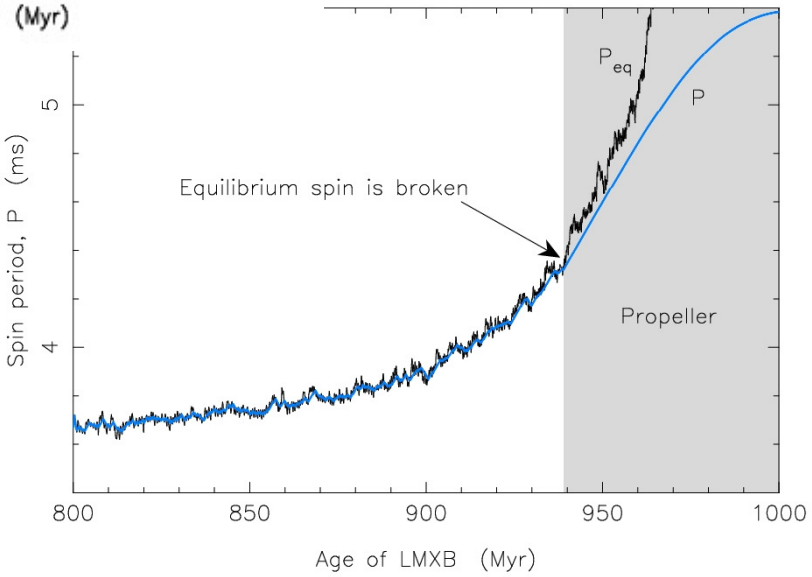


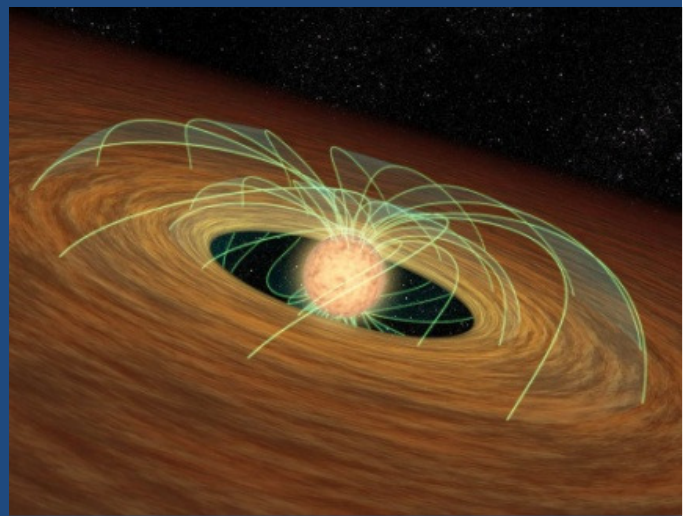


$$N(t) = n(\omega)\left[\dot{M}(t)\sqrt{GM\, r_{mag}(t)}\,\xi + \frac{\mu^2}{9r_{mag}^3(t)}\right] - \frac{\dot{E}_{dipole}(t)}{\Omega(t)}$$

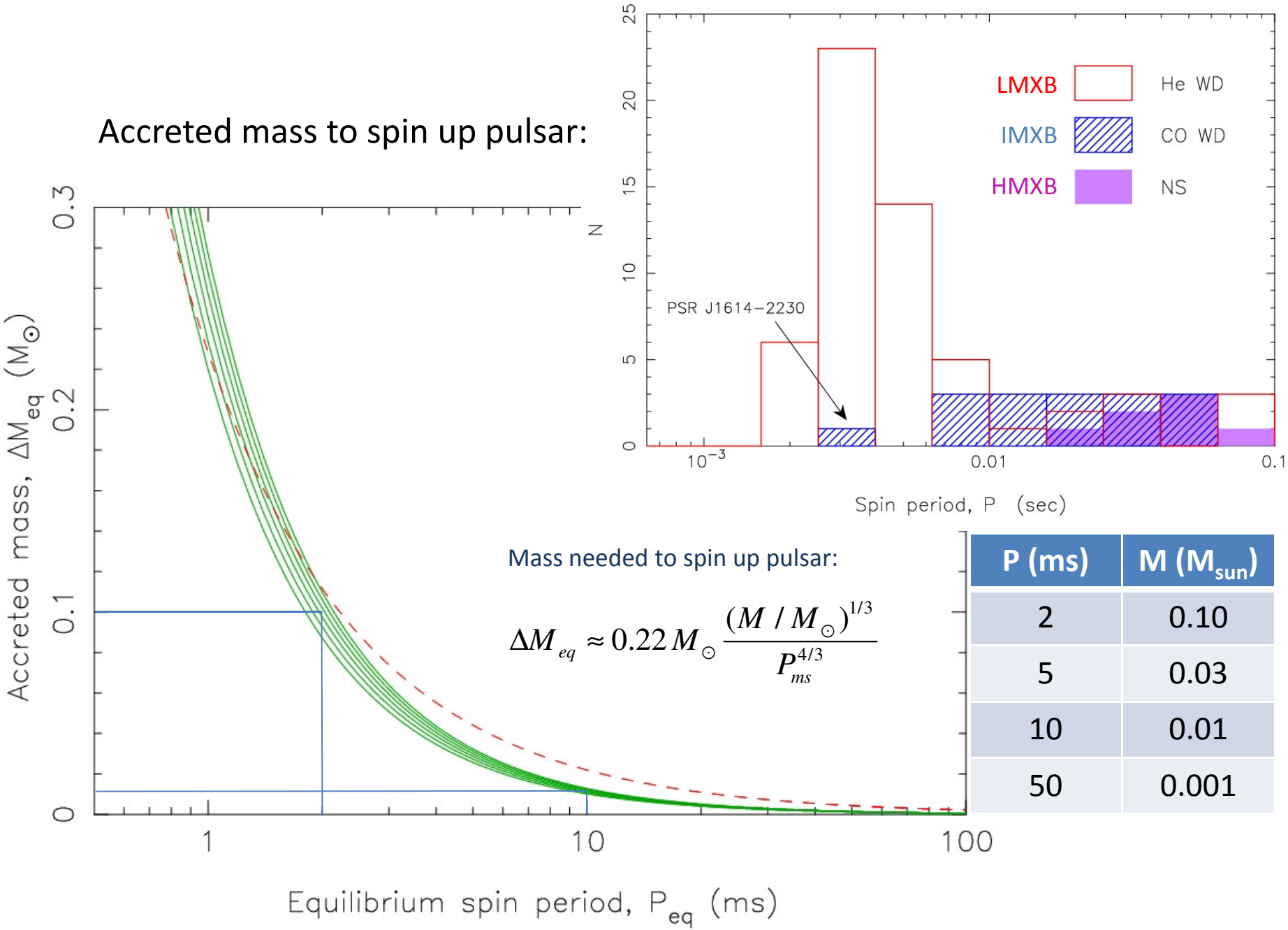
Tauris (2012), Science 335, 561







Accreted mass to spin up pulsar:

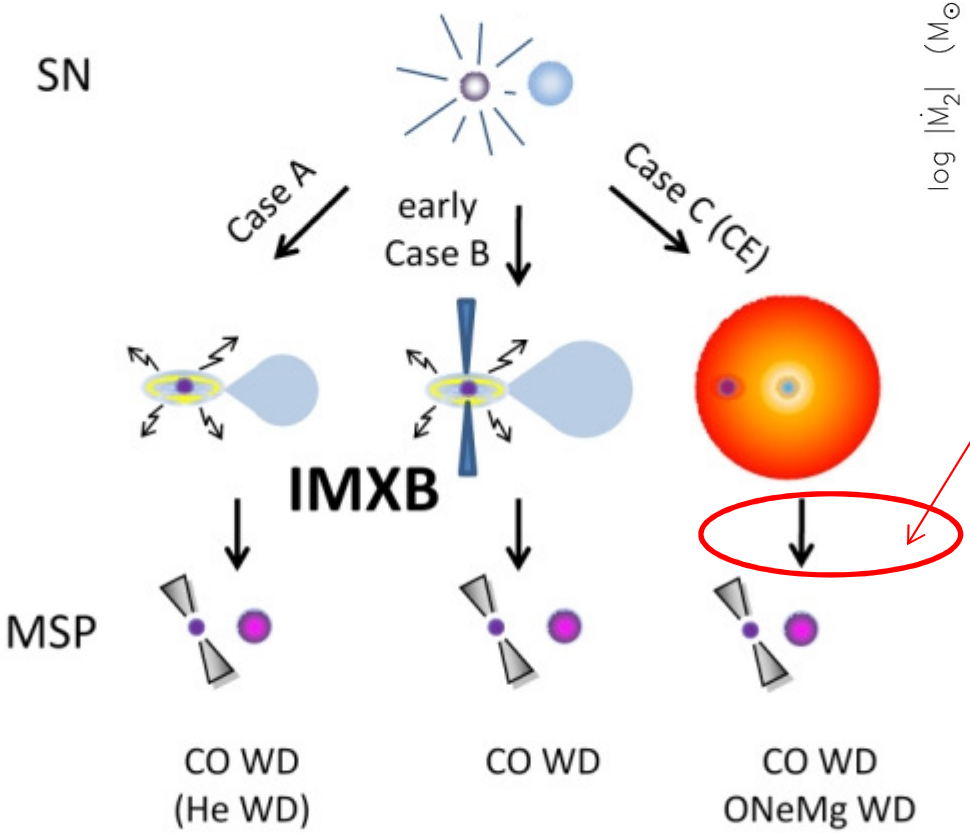


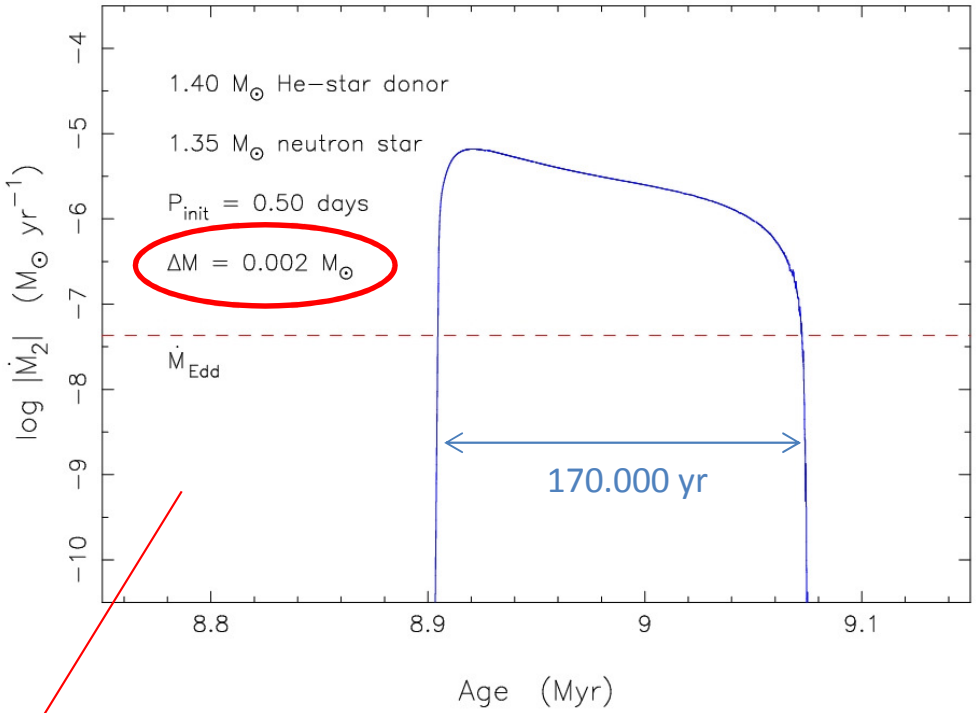
Mass needed to spin up pulsar:

$$\Delta M_{eq} \approx 0.22\, M_\odot \frac{(M/M_\odot)^{1/3}}{P_{ms}^{4/3}}$$

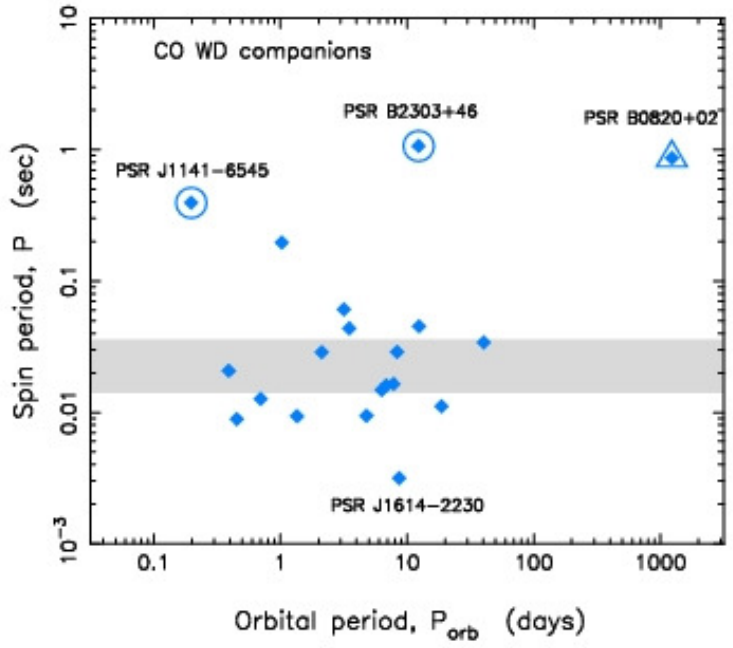
P (ms)	M (M_{sun})
2	0.10
5	0.03
10	0.01
50	0.001

Case BB RLO
(recycling in post-CE binaries)





P_{orb} < 3 days



True ages of MSPs

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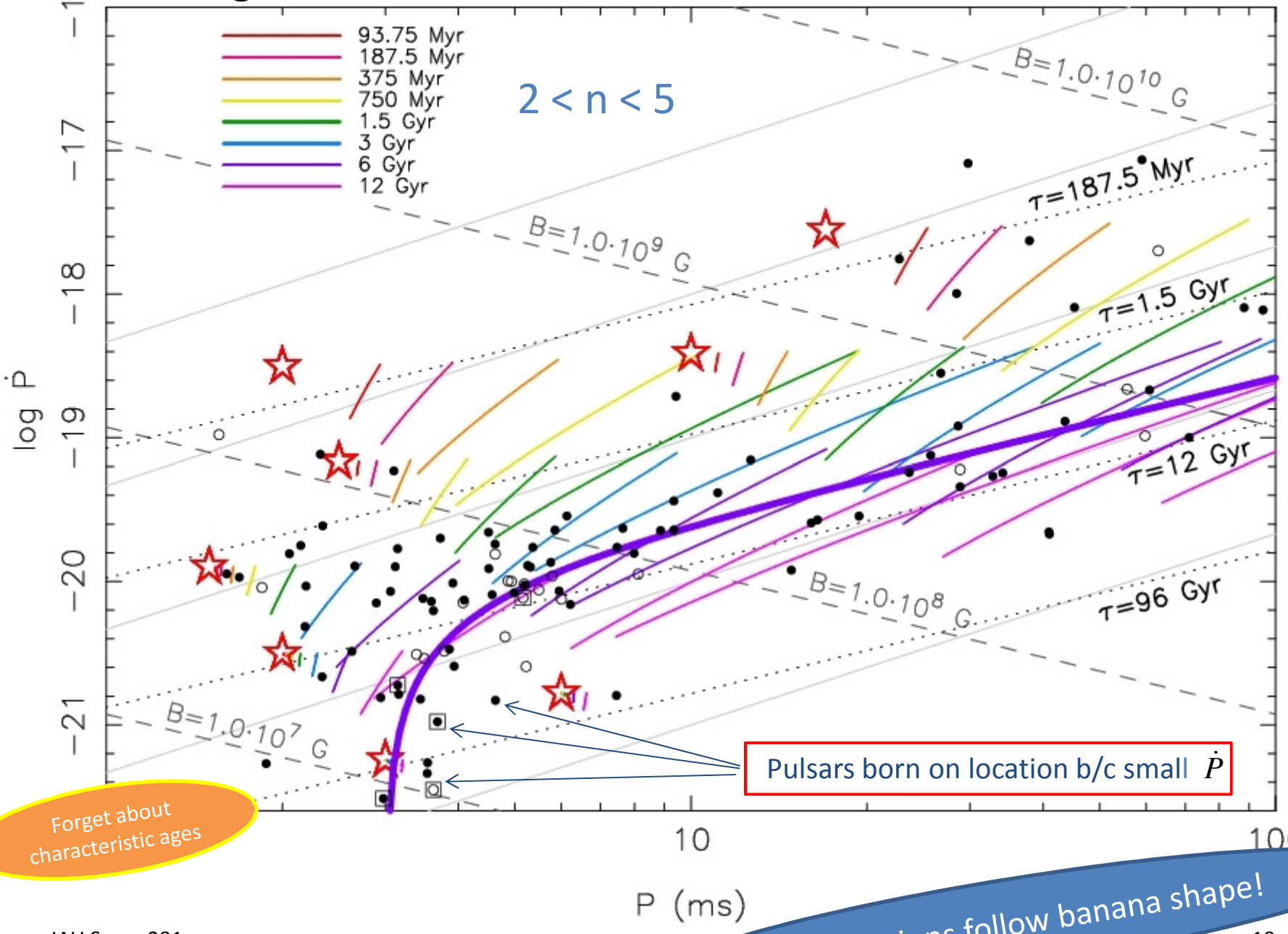
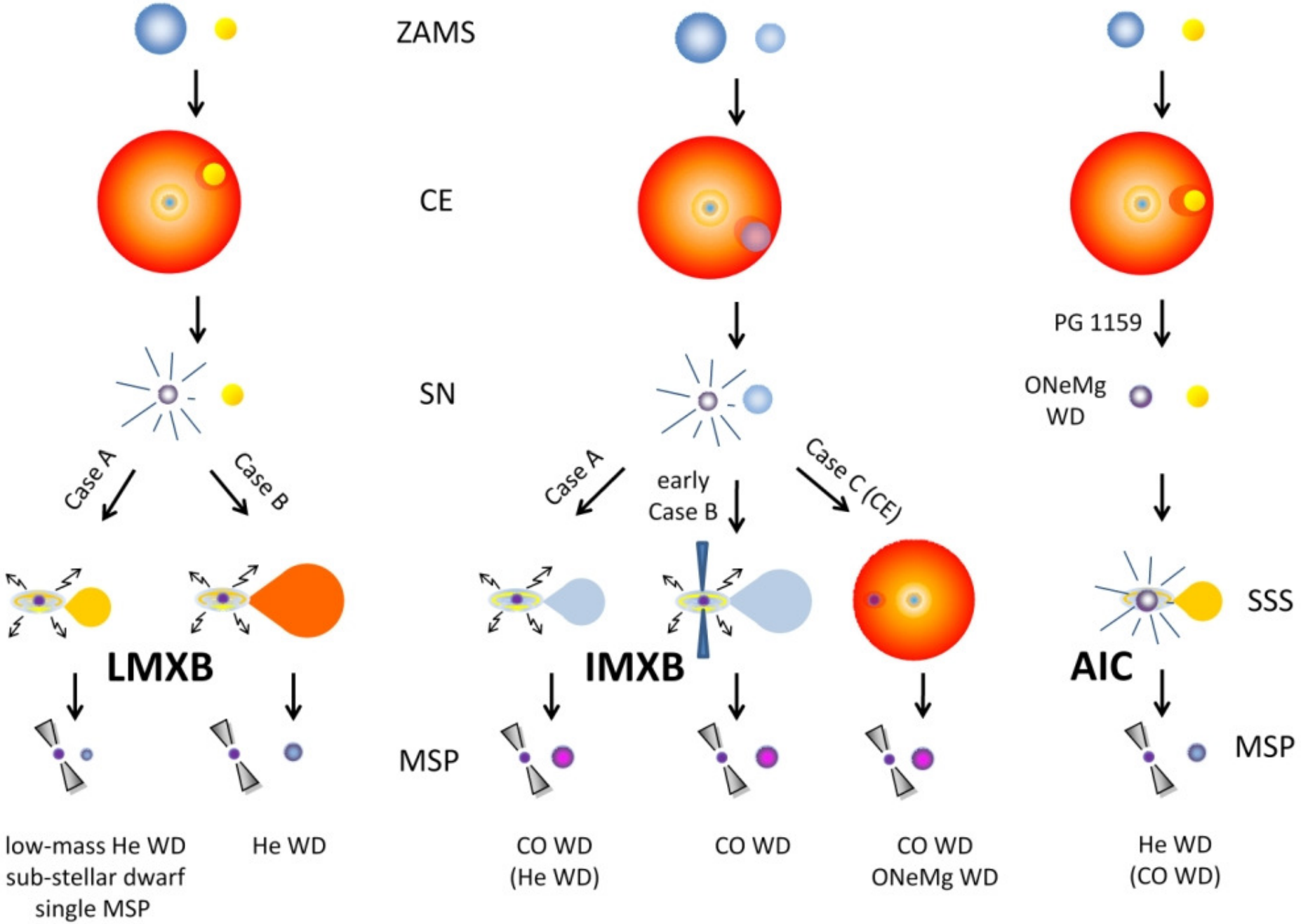


Pulsars born on location b/c small $\dot{P}$

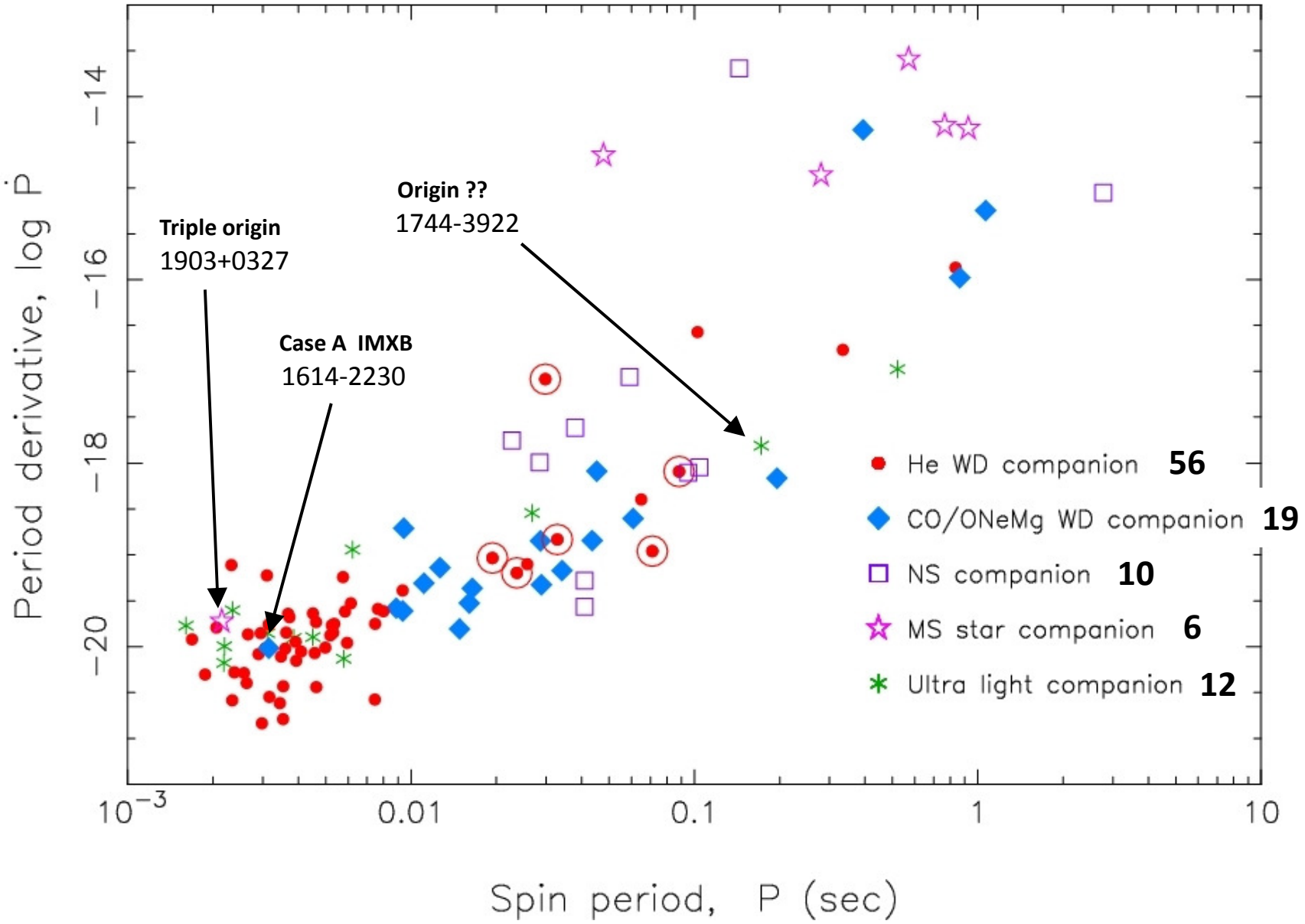
Forget about characteristic ages

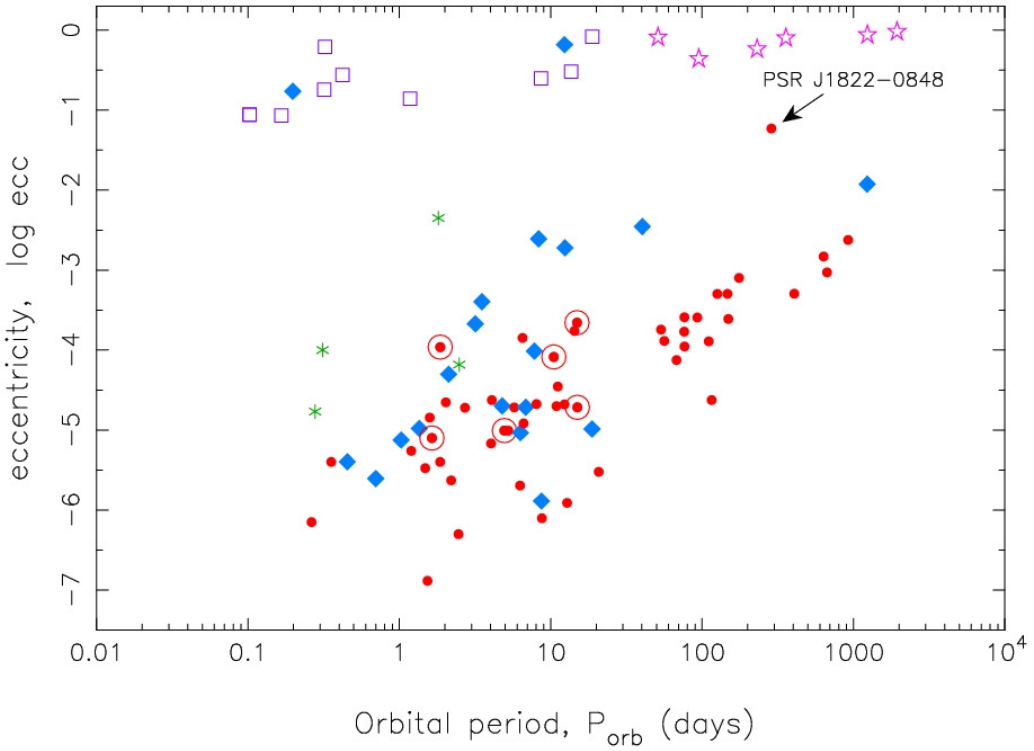
Observations follow banana shape!

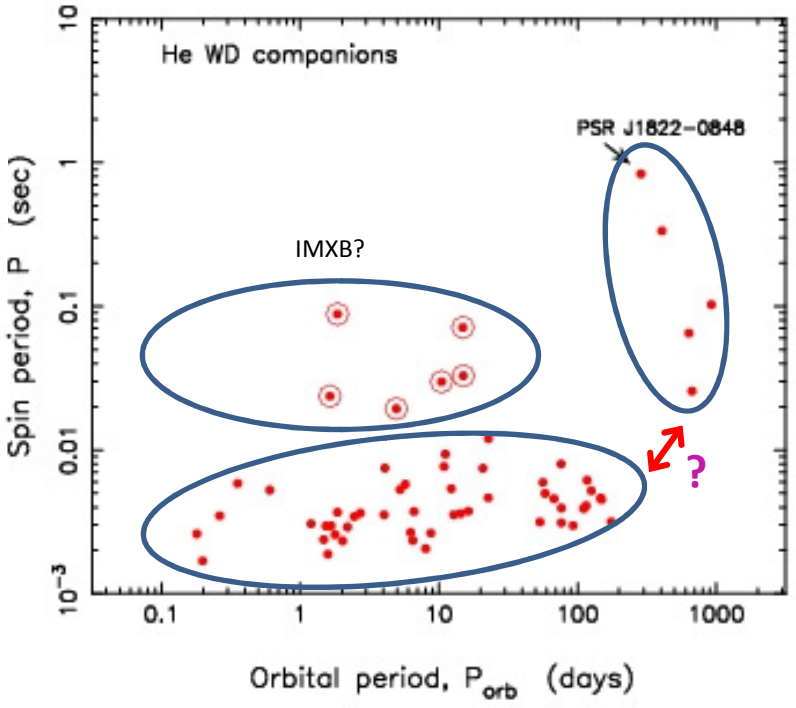
Tauris (2011)


ZAMS
CE
SN
Case A
Case B
LMXB
MSP
low-mass He WD
sub-stellar dwarf
single MSP
He WD
Case A
early
Case B
Case C (CE)
IMXB
CO WD
(He WD)
CO WD
CO WD
ONeMg WD
PG 1159
ONeMg
WD
AIC
SSS
MSP
He WD
(CO WD)

103 binary pulsars in the Galactic disk with measured $\dot{P}$ (186 in total)




PSR J1822−0848
eccentricity, log ecc
Orbital period, P_{orb} (days)


He WD companions
PSR J1822−0848
IMXB?
?
Spin period, P (sec)
Orbital period, P_{orb} (days)

Summary

- The spin-up `line´ is quite broad !!
- Recycled pulsar spin and mass accreted ⟷ binary stellar evolution √
  - Lifetimes of Case A/B/C RLO in LMXBs and IMXBs
- Case BB RLO can explain recycled pulsars with a CO WD and $P_{orb} < 3$ days
- The banana-shape distribution of recycled pulsars in the PP_{dot} –diagram can be understood as simple accumulation over time
- The true ages of recycled pulsars $t \ll \tau$

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Thank you!

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