Binary neutron star population in the Milky Way

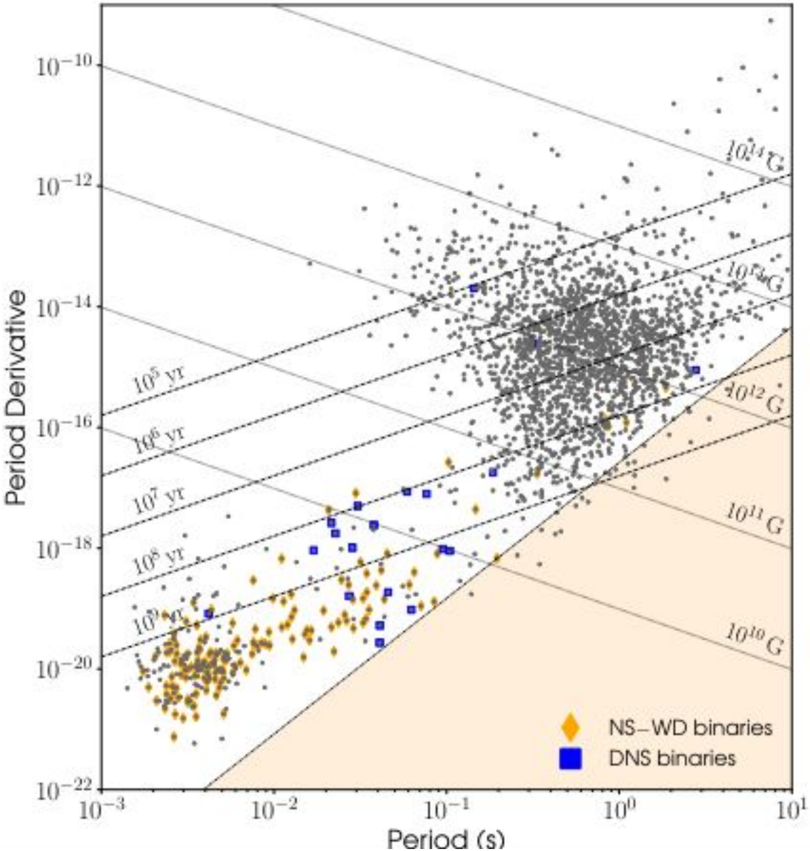
Cecilia Sgalletta

Liege, 19 Jul 2024

SISSA

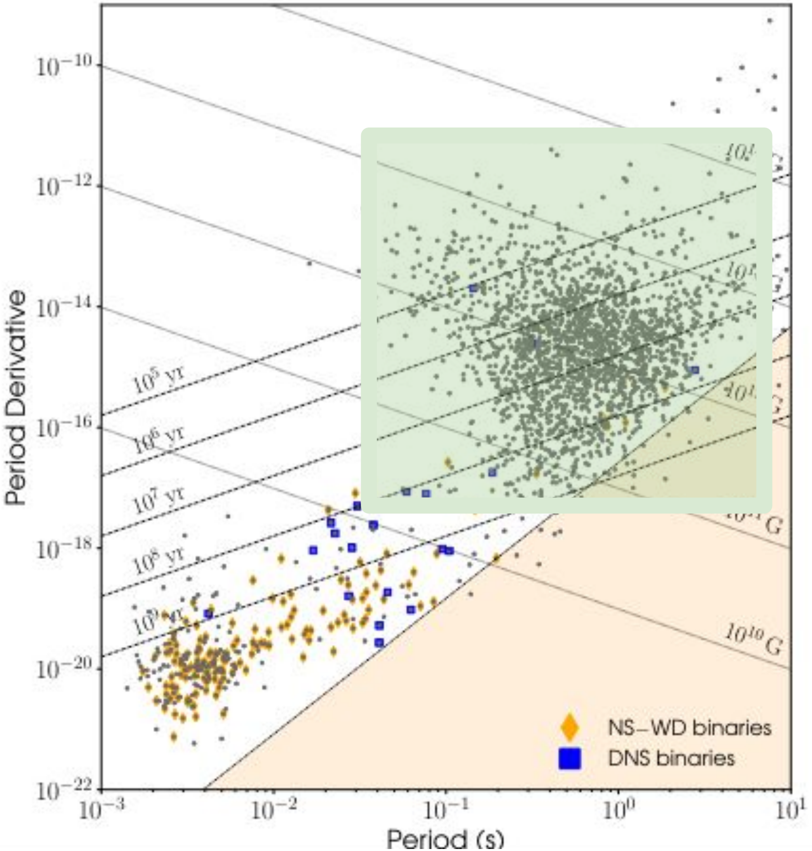
INFN

Pulsars in the MW



Pol et al. 2019,
data from the ATNF catalog,
Manchester et al. 2005

Pulsars in the MW

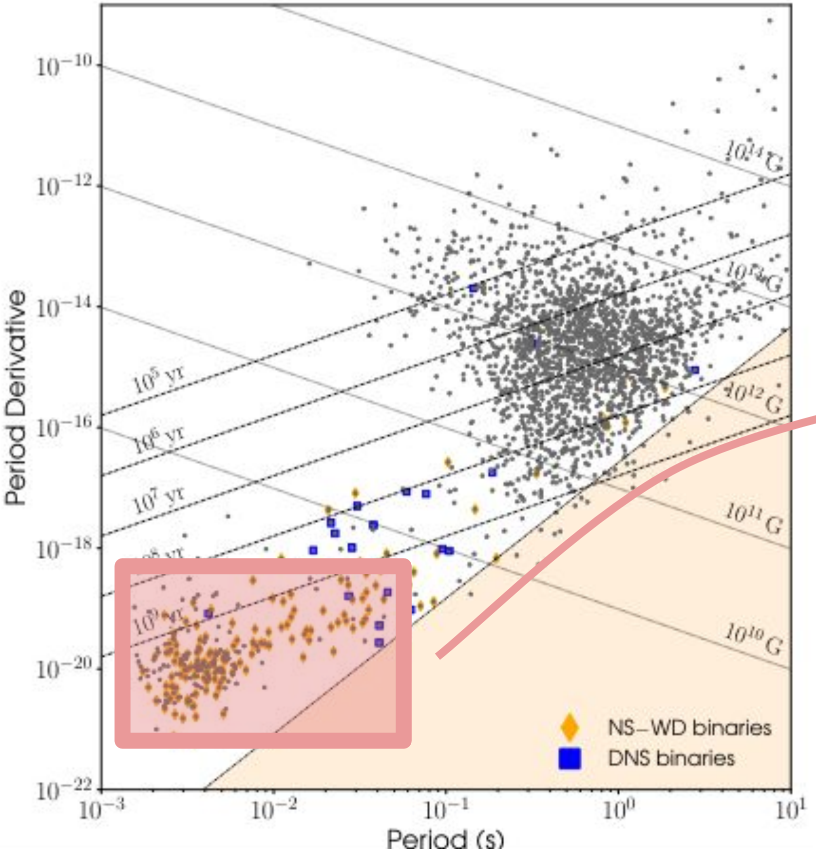


Mostly **isolated pulsars**

- young pulsars
- high magnetic field

Pol et al. 2019,
data from the ATNF catalog,
Manchester et al. 2005

Pulsars in the MW



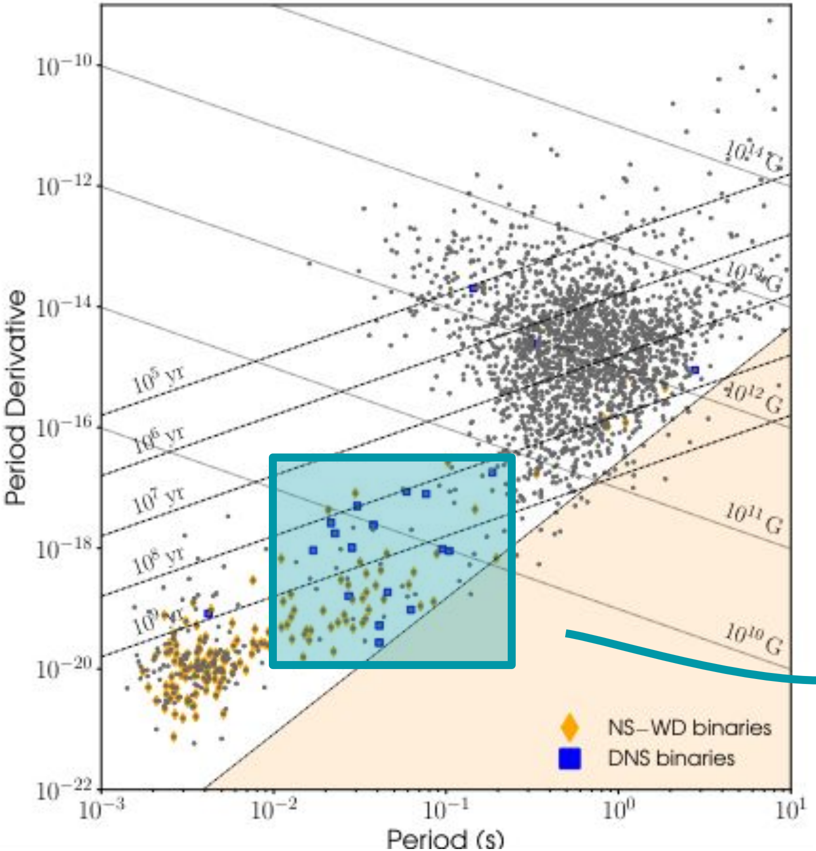
Mostly pulsars in **binaries**

- old/recycled pulsars
- low magnetic fields

Millisecond pulsars

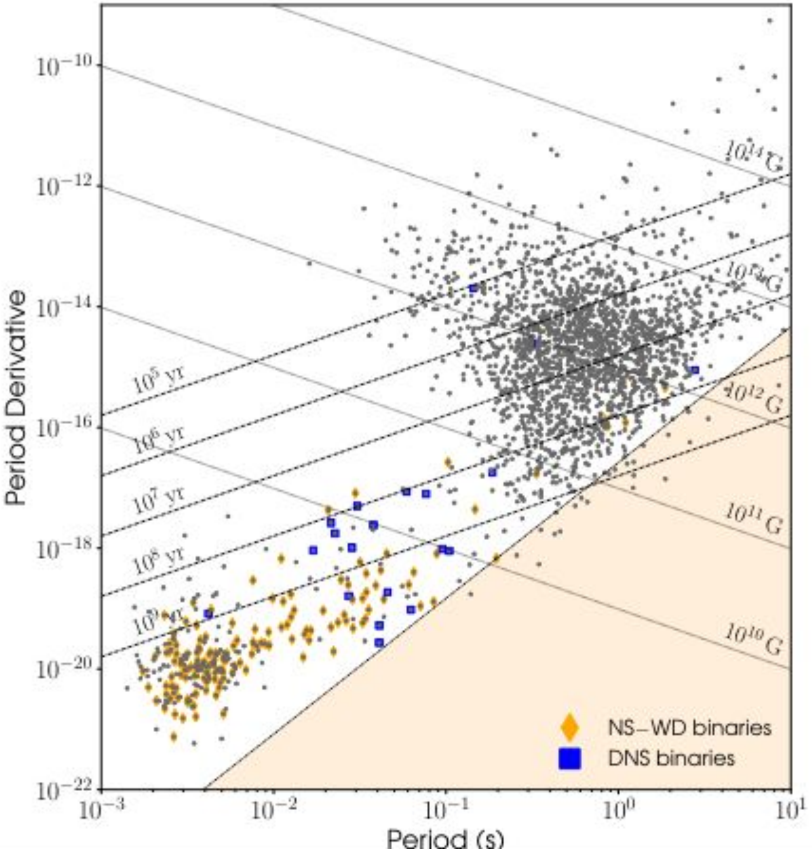
Pol et al. 2019,
data from the ATNF catalog,
Manchester et al. 2005

Pulsars in the MW



pulsars in BNSs

Pol et al. 2019,
data from the ATNF catalog,
Manchester et al. 2005

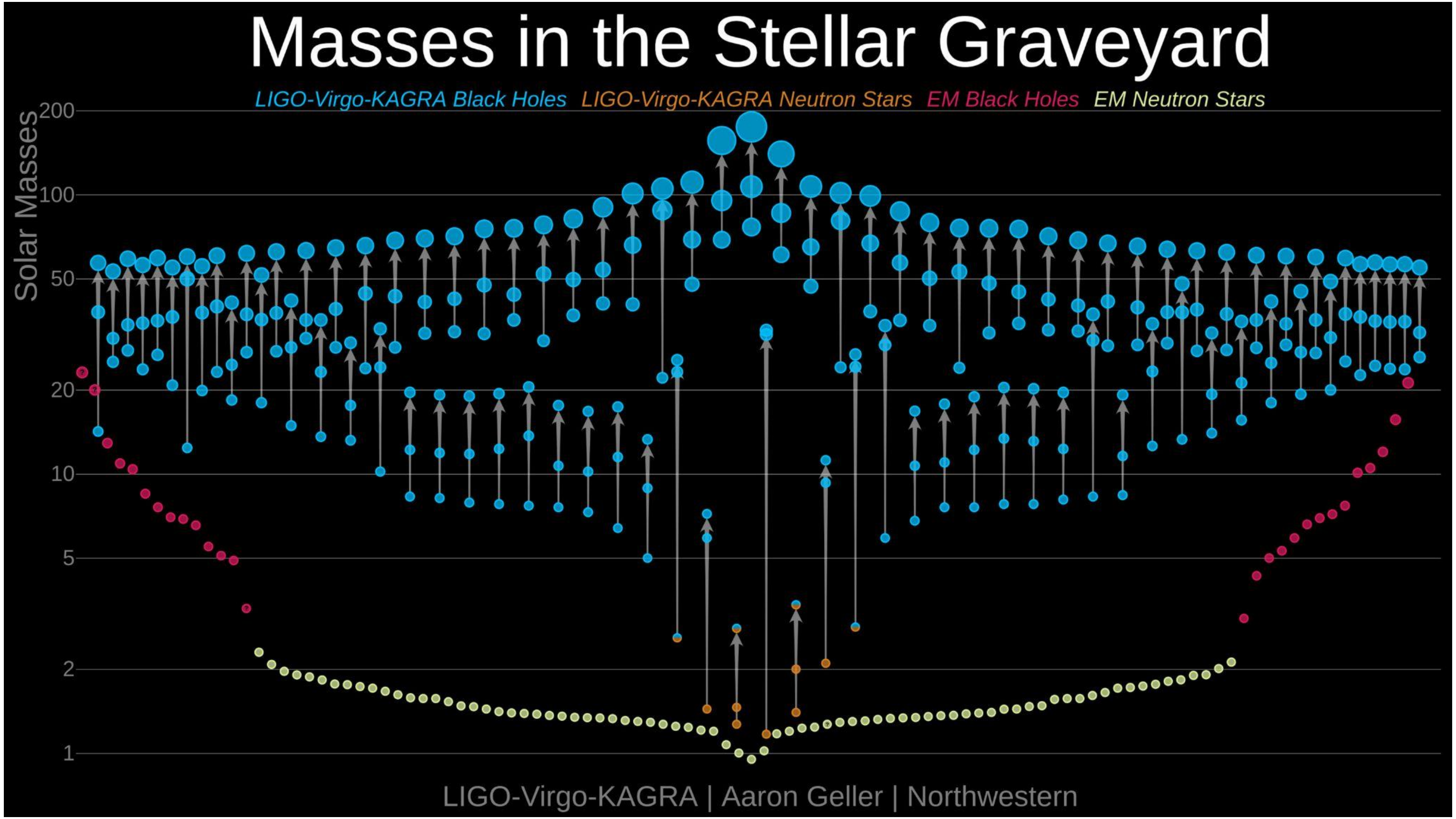


Pulsars in the MW

- Where pulsars are born?
- How do they evolve?

Pol et al. 2019,
data from the ATNF catalog,
Manchester et al. 2005

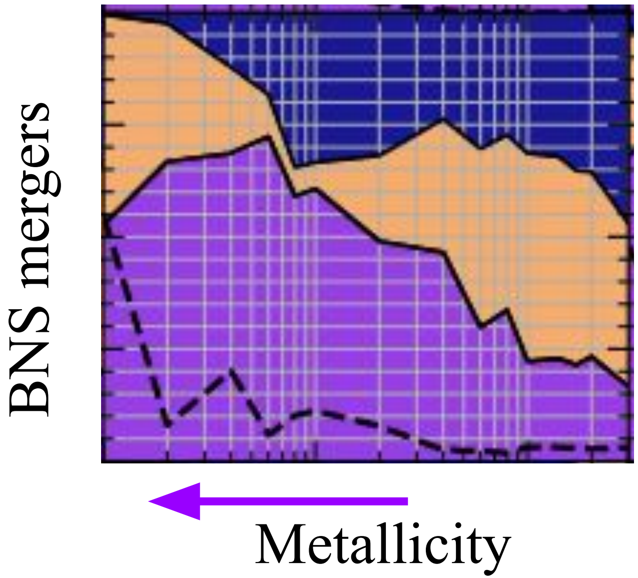
Gravitational Waves

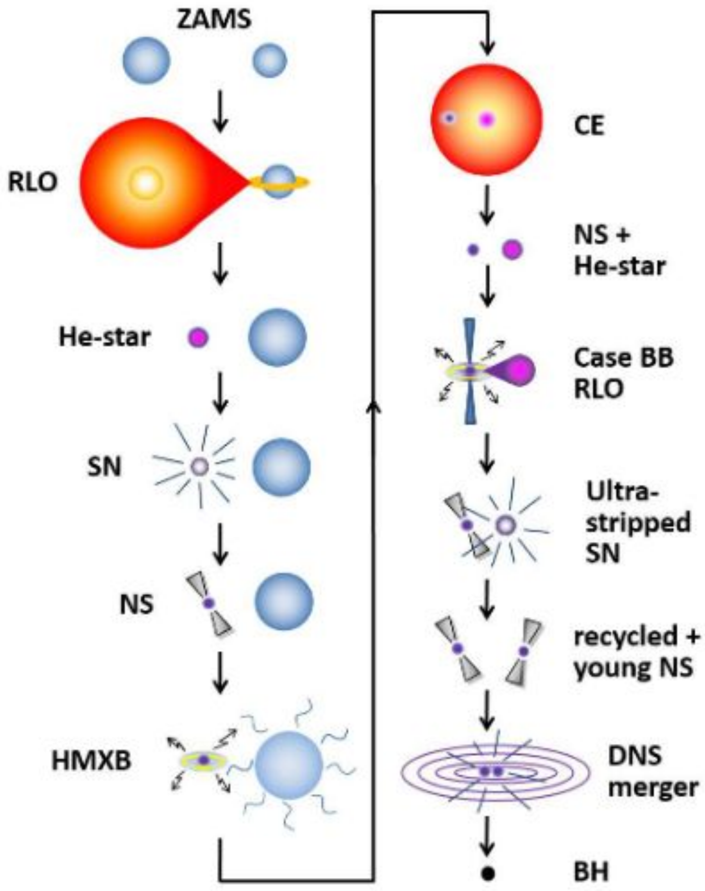


[Masses in the Stellar Graveyard – LIGO (northwestern.edu)](https://northwestern.edu)

BNS formation

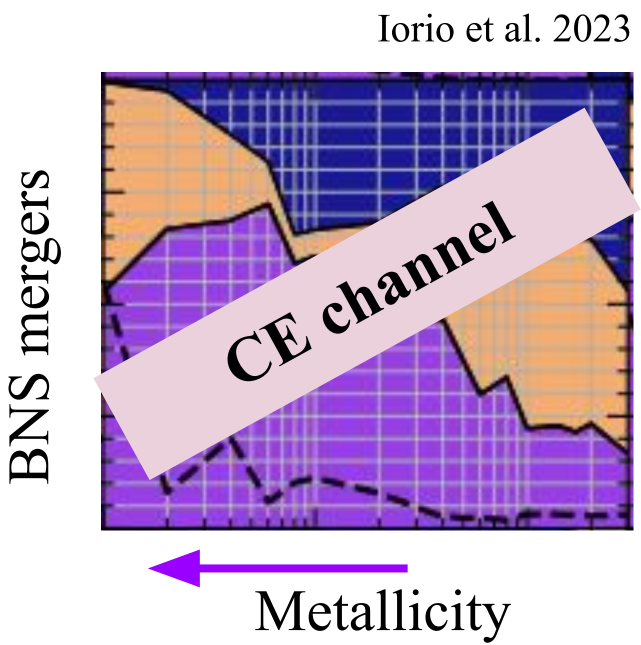
Iorio et al. 2023

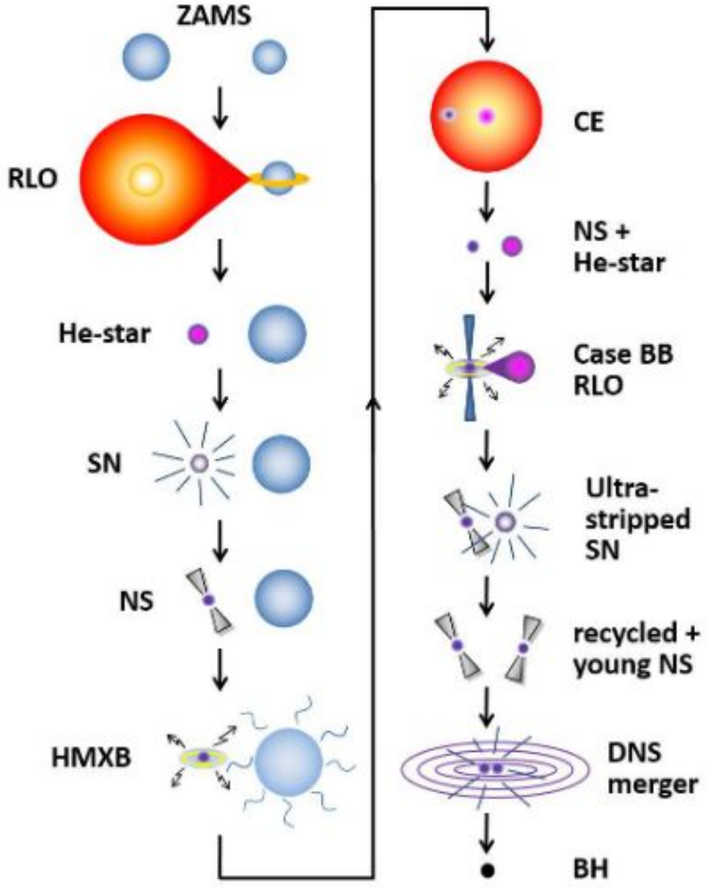




Tauris et al. 2017

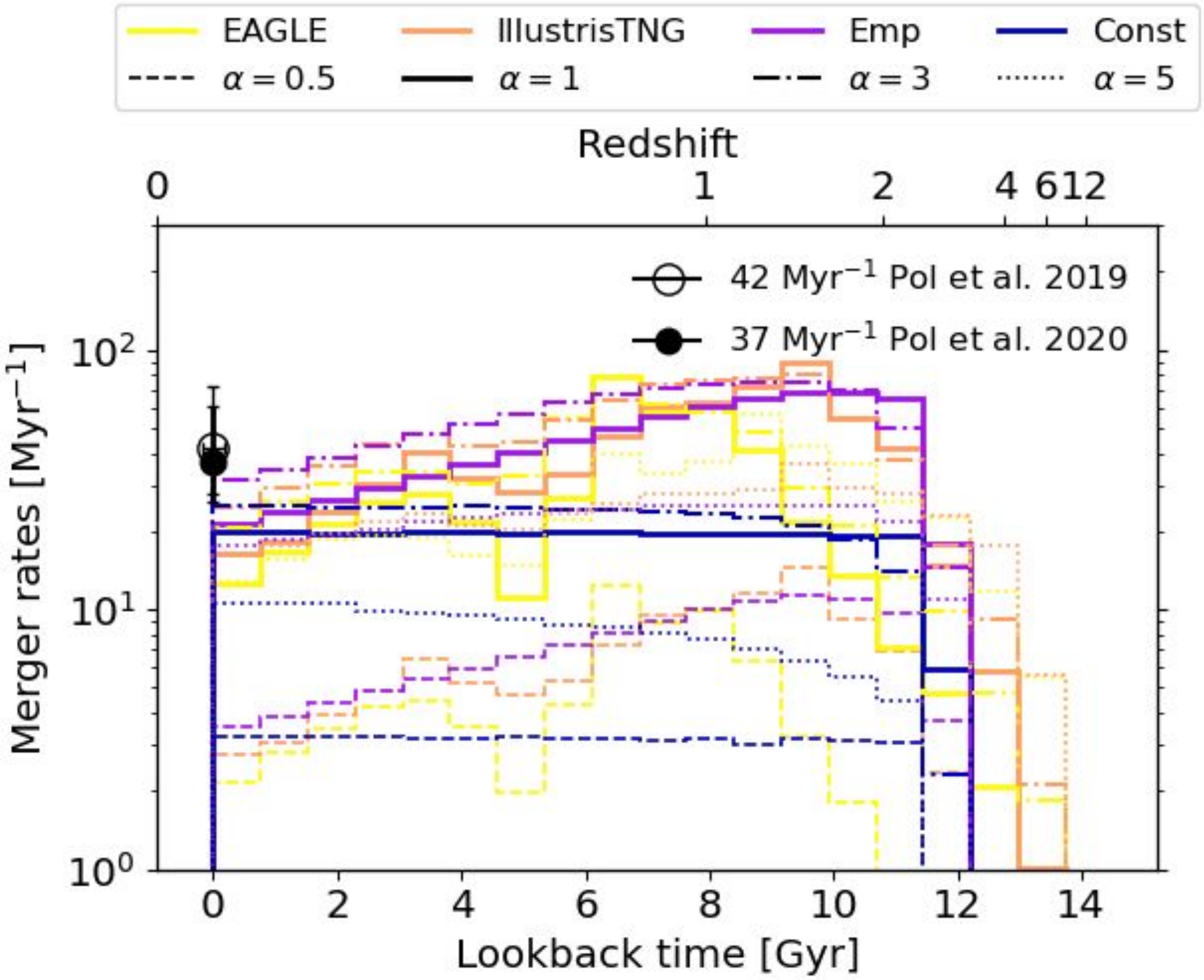
BNS formation





Tauris et al. 2017

- What can we say about the common envelope?
- What are the birth magnetic fields and spin periods?
- Does the magnetic field evolve with time?



Milky-Way model

+

Stellar EVolution N-body

Population synthesis code written in C++

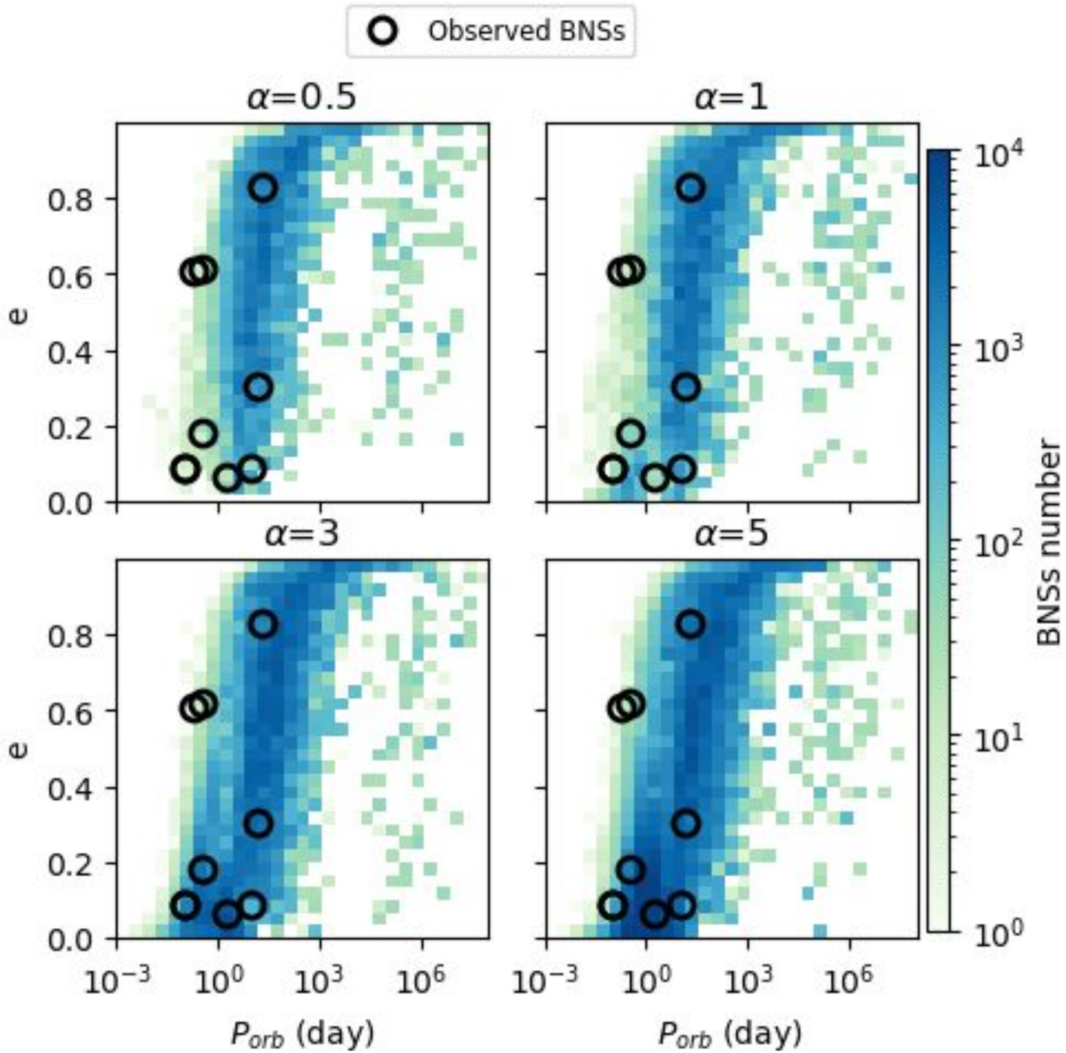
https://gitlab.com/sevncodes/sevn

Iorio et al. 2023

EAGLE: Schaye et al. 2014, the EAGLE team 2017

IllustrisTNG: Nelson et al. 2019, Pillepich et al. 2019

Sgalletta et al 2023: 10.1093/mnras/stad2768



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Iorio et al. 2023

observations from:
Manchester et al. 2005,
Sengar et al. 2022

Sgalletta et al 2023:
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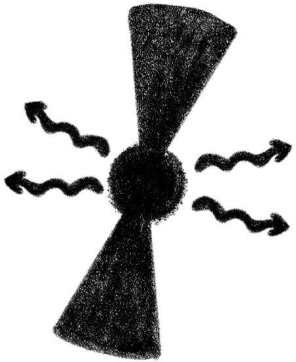
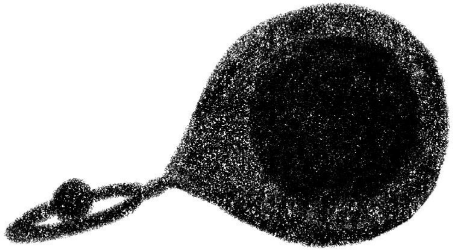


Spin-down

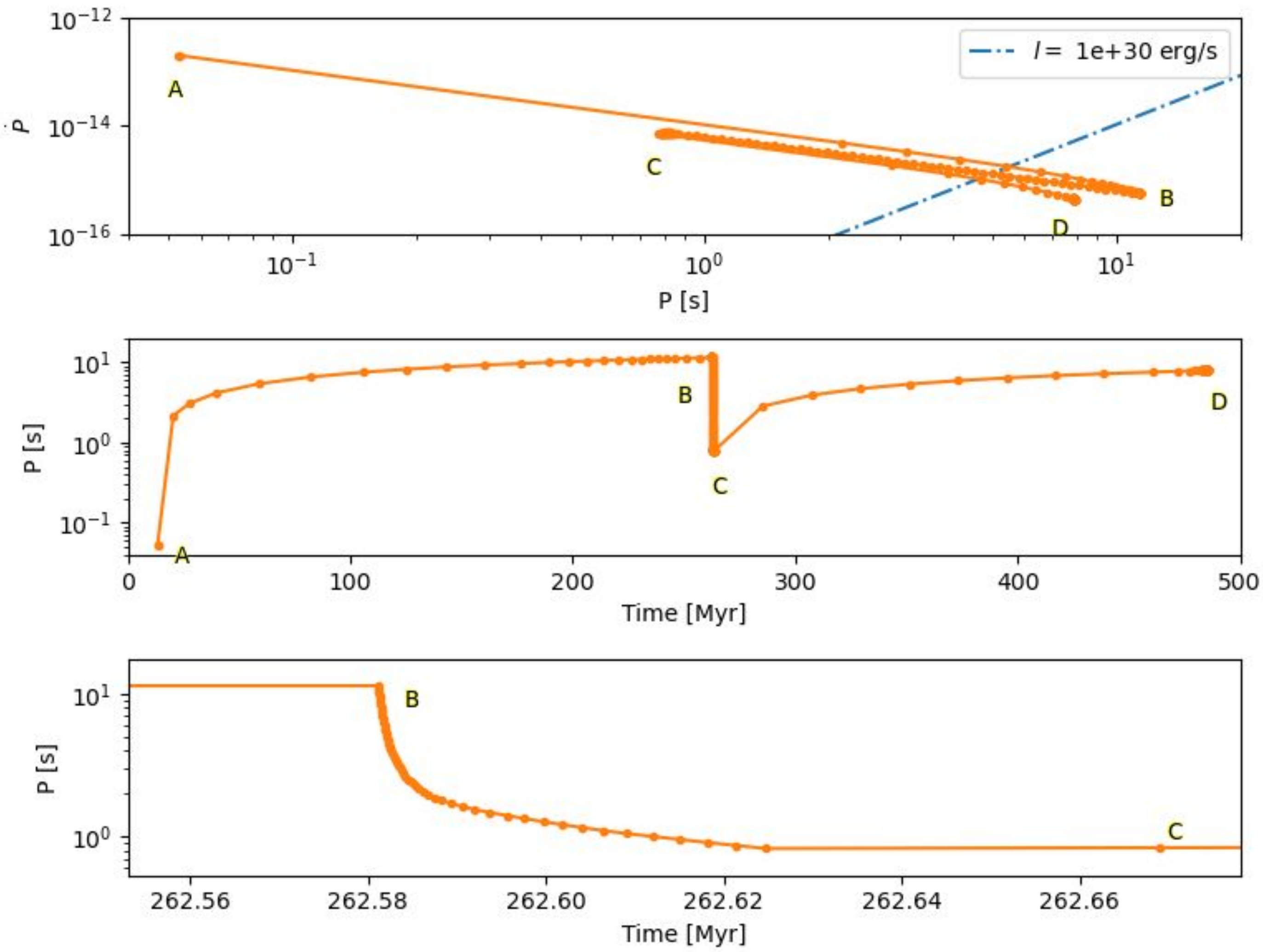


Spin-up

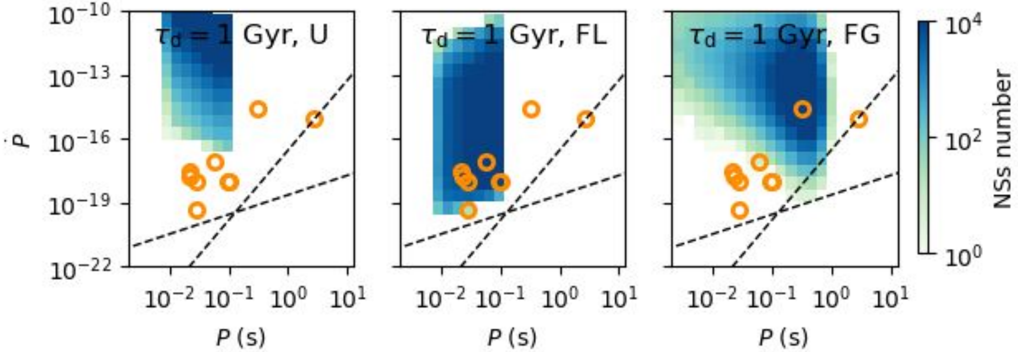
Radio Selection Effects

psrpoppy

Lorimer et al. 2011,
Bates et al. 2014

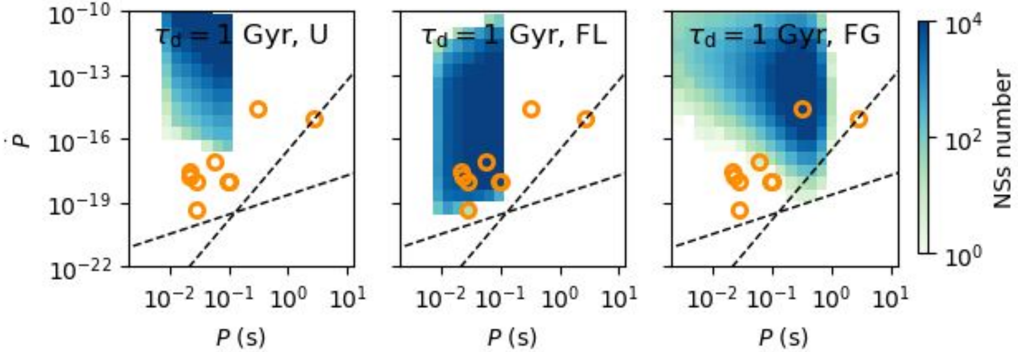


- A. First NS
- B. Roche Lobe Overflow
- C. End of Roche Lobe Overflow
- D. Second Compact object



Initial distributions

Faucher-Giguère & Kaspi 2006,
Chattopadhyay et al. 2020, 2021,
Rudak & Ritter 1994



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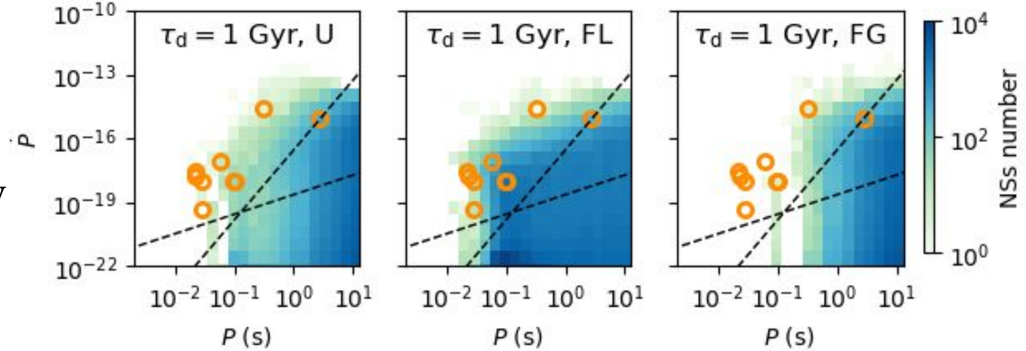
Evolution in the MW



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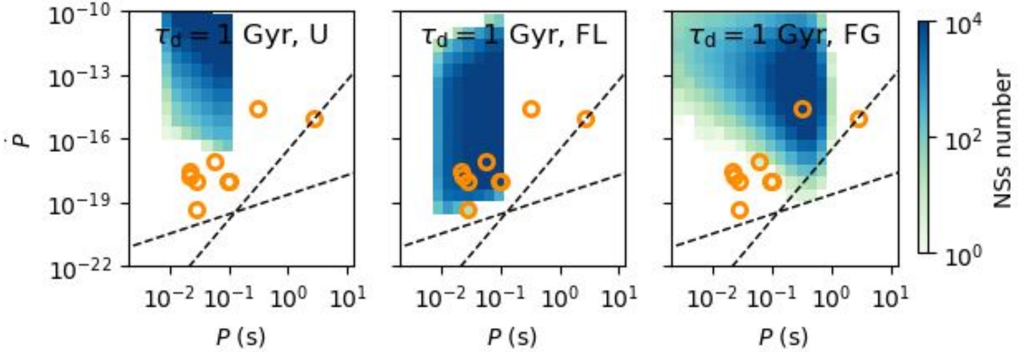
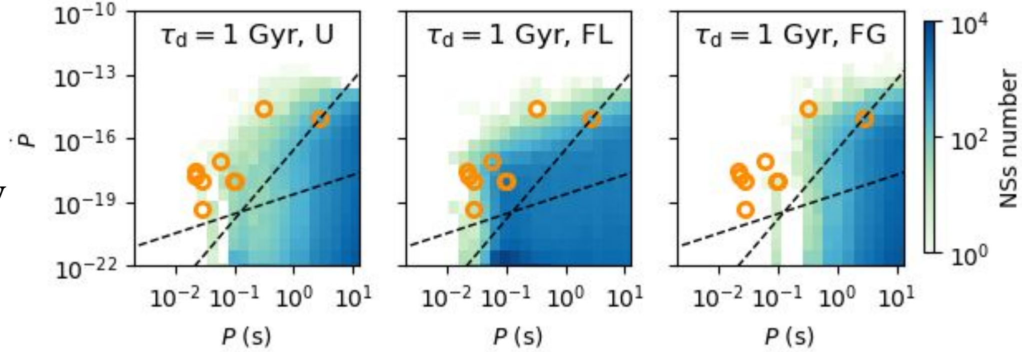
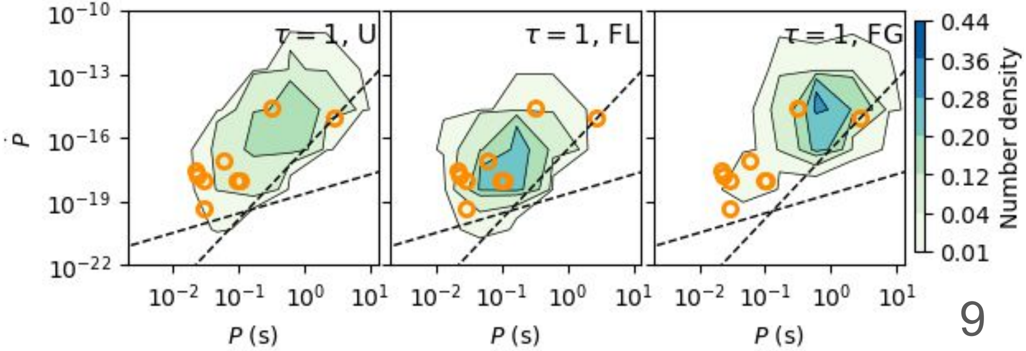


Evolution in the MW

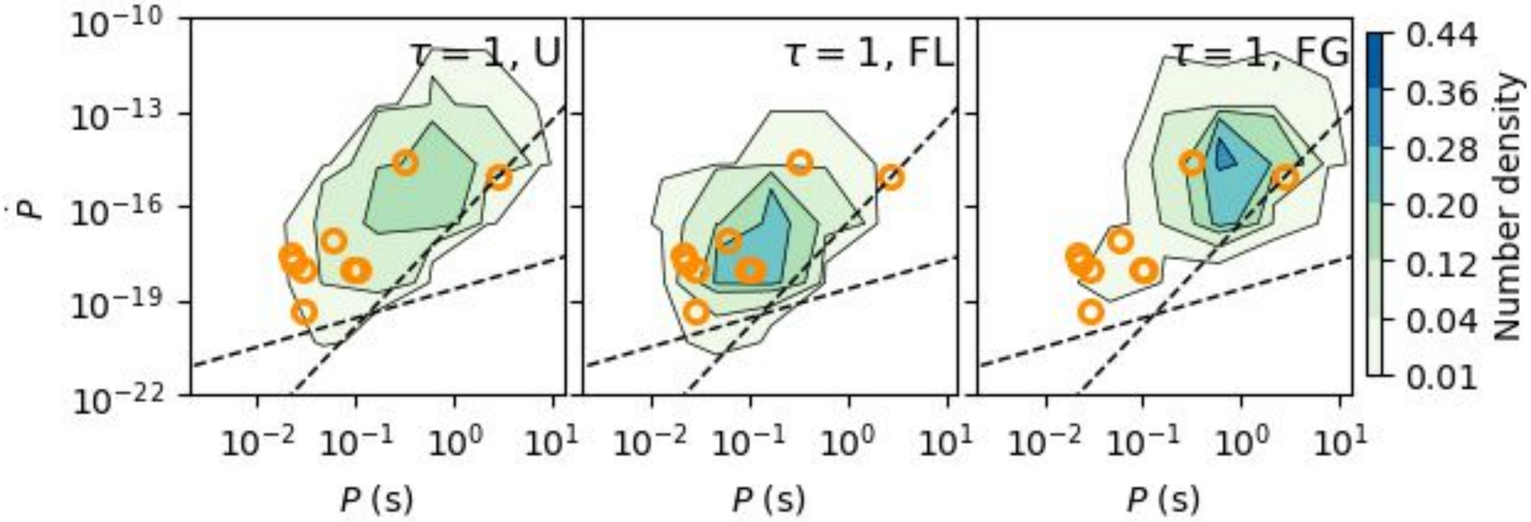


Radio selection effects



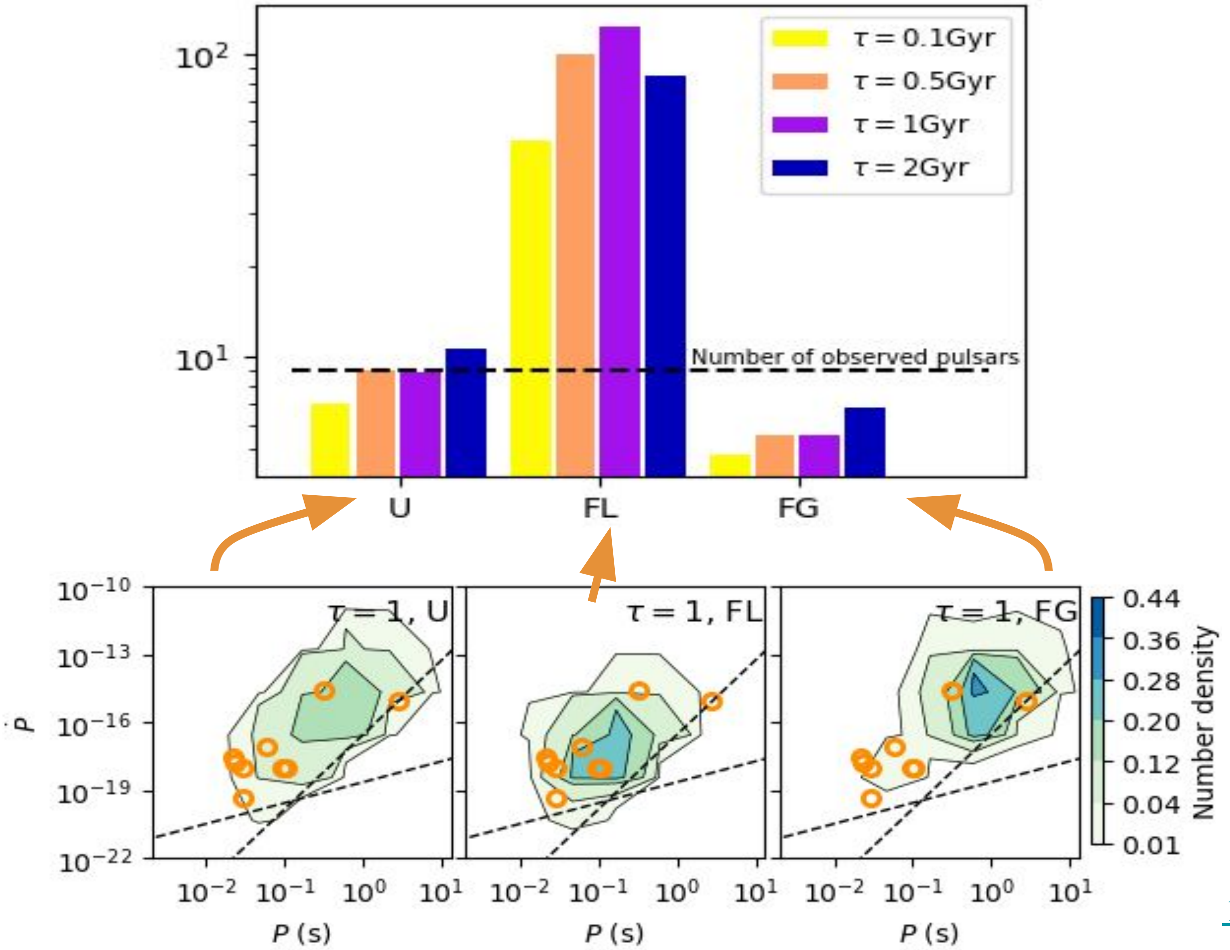
The effect of initial distributions

Sgalletta et al 2023: 10.1093/mnras/stad2768



observations from:
Manchester et al. 2005,
Sengar et al. 2022

The effect of initial distributions



Sgalletta et al 2023:
[10.1093/mnras/stad2768](https://doi.org/10.1093/mnras/stad2768)

Conclusions

- We are able to **reproduce the merger rates, orbital and pulsars properties** in a self-consistent fashion
- Solid statistical framework to evaluate the different models, however **too large uncertainties due to the small sample of pulsars**
- The **initial distributions** of magnetic field and spin period at pulsar formation play a critical role
- We predict **SKA** to observe about 20 new pulsars in BNSs

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Backup slides

Spin-down

$$\dot{\Omega} = \frac{8\pi B^2 R^6 \sin^2(\alpha)\Omega^3}{3\mu_0 c^3 I}$$

$$B = (B_0 - B_{min})e^{-\Delta t/\tau} + B_{min}$$

Spin-up

$$\dot{J} = V_{diff} R_A^2 \dot{M}_{NS}$$

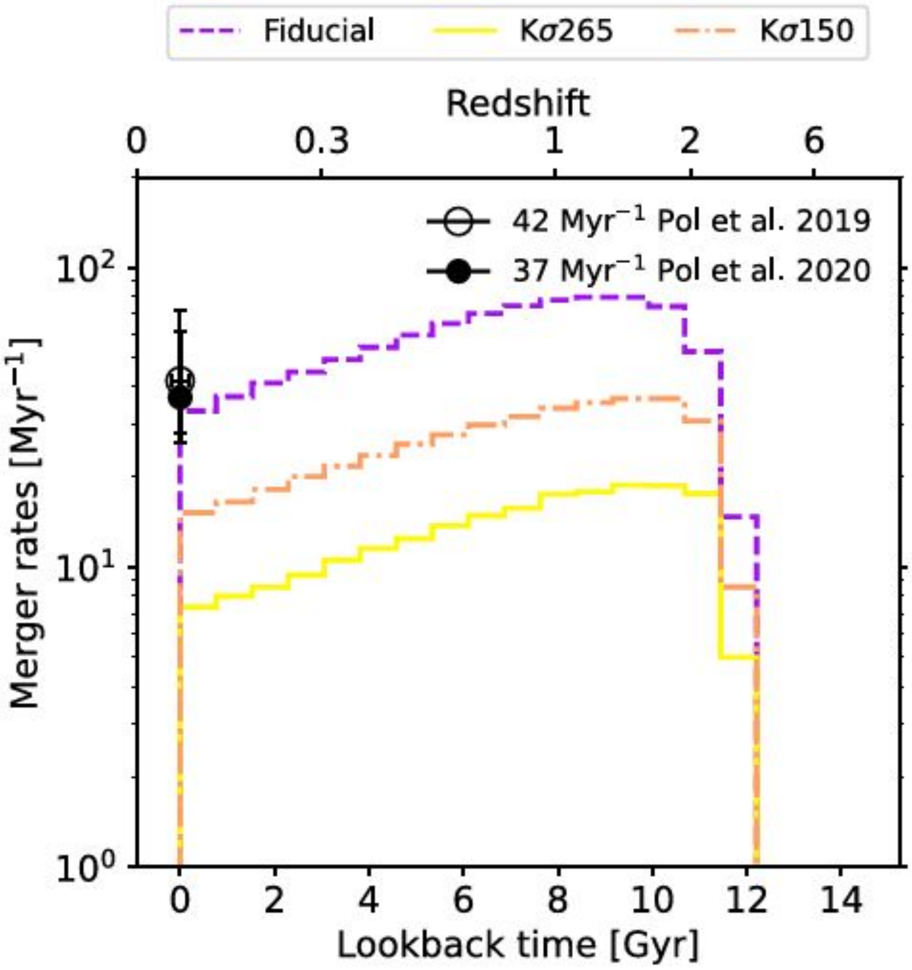
$$V_{diff} = \Omega_K - \Omega_{NS}$$

$$B = (B_0 - B_{min})e^{-\Delta M_{NS}/\Delta M_d} + B_{min}$$

$$R_{Alfven} = \left(\frac{2\pi^2}{G\mu_0^2}\right)^{1/7} \left(\frac{R^6}{\dot{M}_{NS} M_{NS}^{1/2}}\right)^{1/7} B^{4/7}$$

Chattopadhyay et al. 2020, 2021

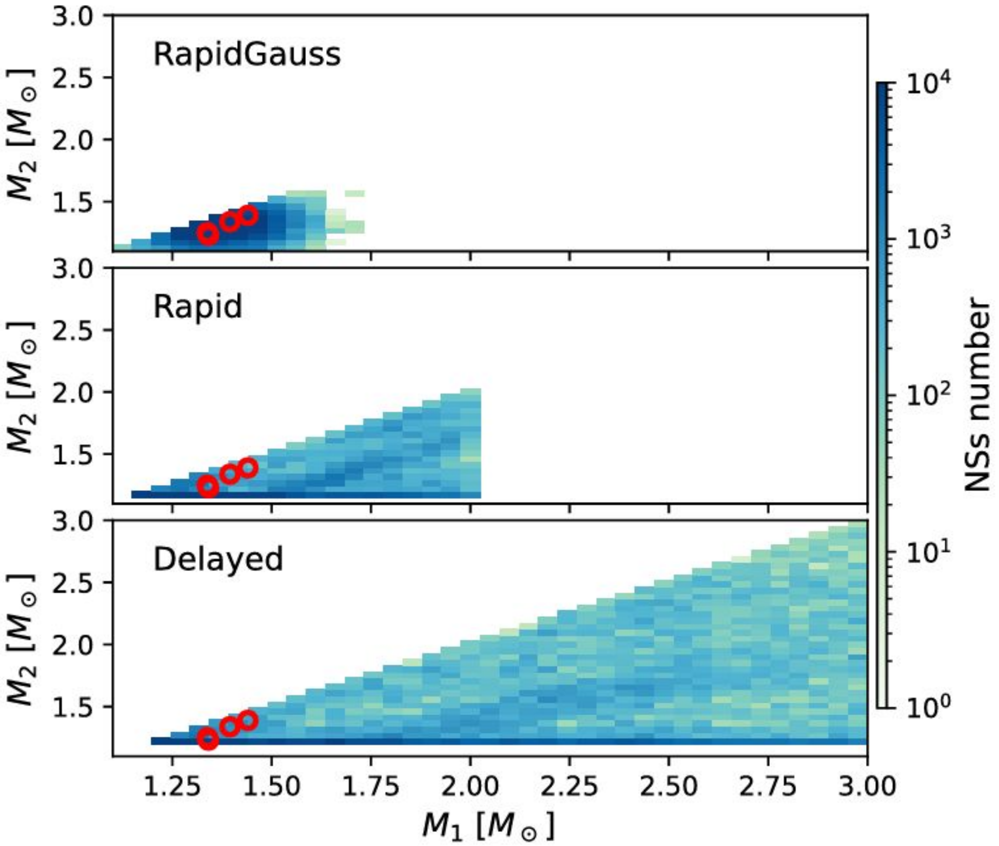
SN kicks



Giacobbo & Mapelli 2020,
Hobbs et al. 2005,
Atri et al. 2019

Figure A1. BNS merger rate in the MW as a function of the look-back time for different natal kick models. Purple dashed line: Fiducial model (Ua3t1Emp); pink dot–dashed line: Kσ265 model, yellow solid line: Kσ150 model. The circles show the BNS merger rate in the MW inferred from observations, as in Fig. 1. All simulations shown in this figure assume our fiducial model parameters: $\tau_d = 1$Gyr, the U distribution for initial spins and magnetic fields, the Emp MW model and $\alpha = 3$. The natal kick model has a dramatic impact on the MW merger rate. Our fiducial model is the only one that matches the observed rate.

Neutron stars masses



Observations based model, Ozel et al. 2016

State-of-the-art theoretical SN models in population synthesis codes, Fryer et al. 2012