Local DM contributions for young pulsars

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Implications for FRBs

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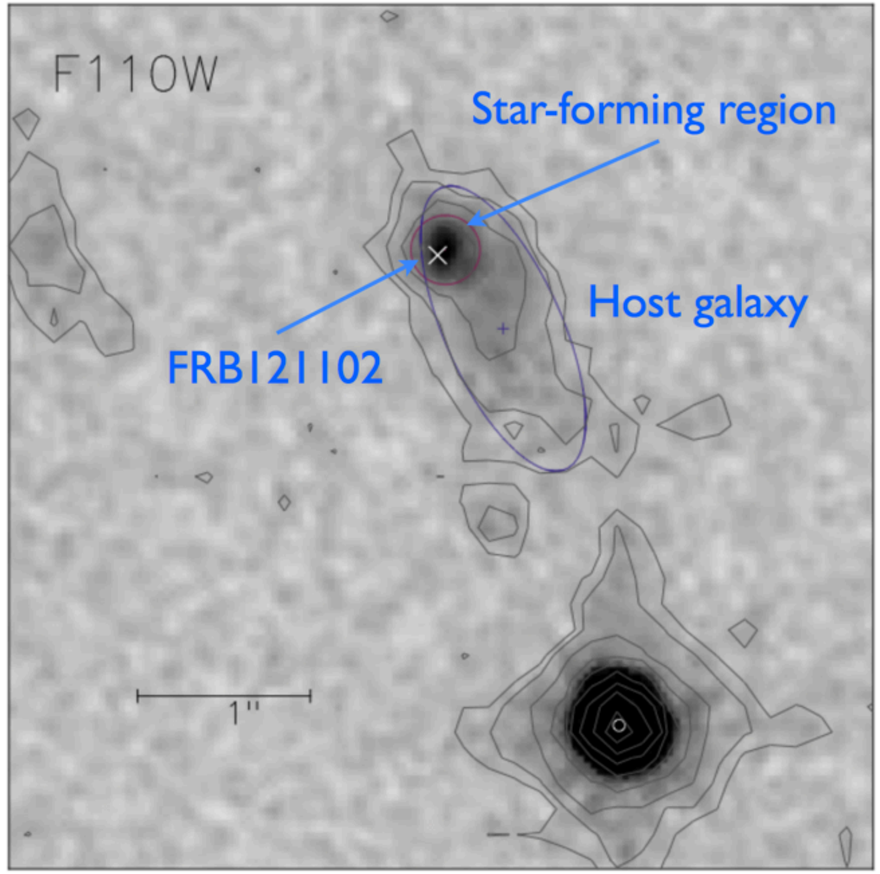
ASTRON

FRB 121102

- ★ Is located in a star-forming region
  (Kokubo+2017, Bassa+2017)
- ★ In an extreme magneto-ionic environment (Michili+2018), resembles the Galactic center magnetar
- ★ Nearly fully linearly polarised, as young pulsars
- ★ Local DM contribution ~ 55 — 225 pc cm^{-3}
- ★ Persistent radio source (Marcote+2017), a PWN?



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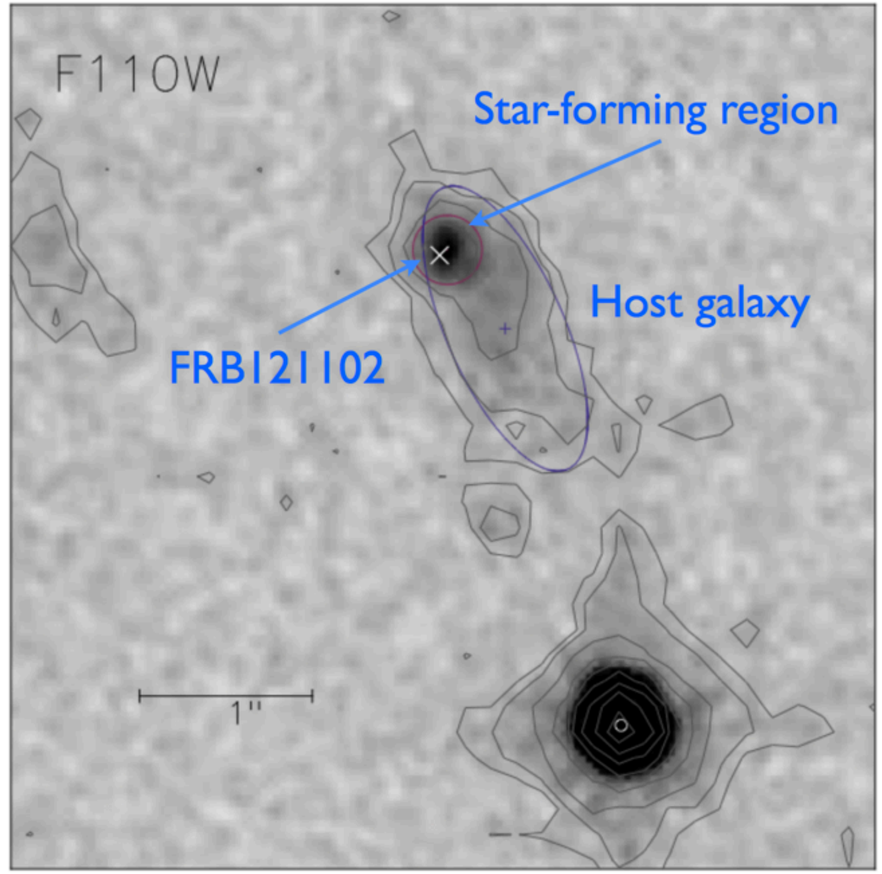


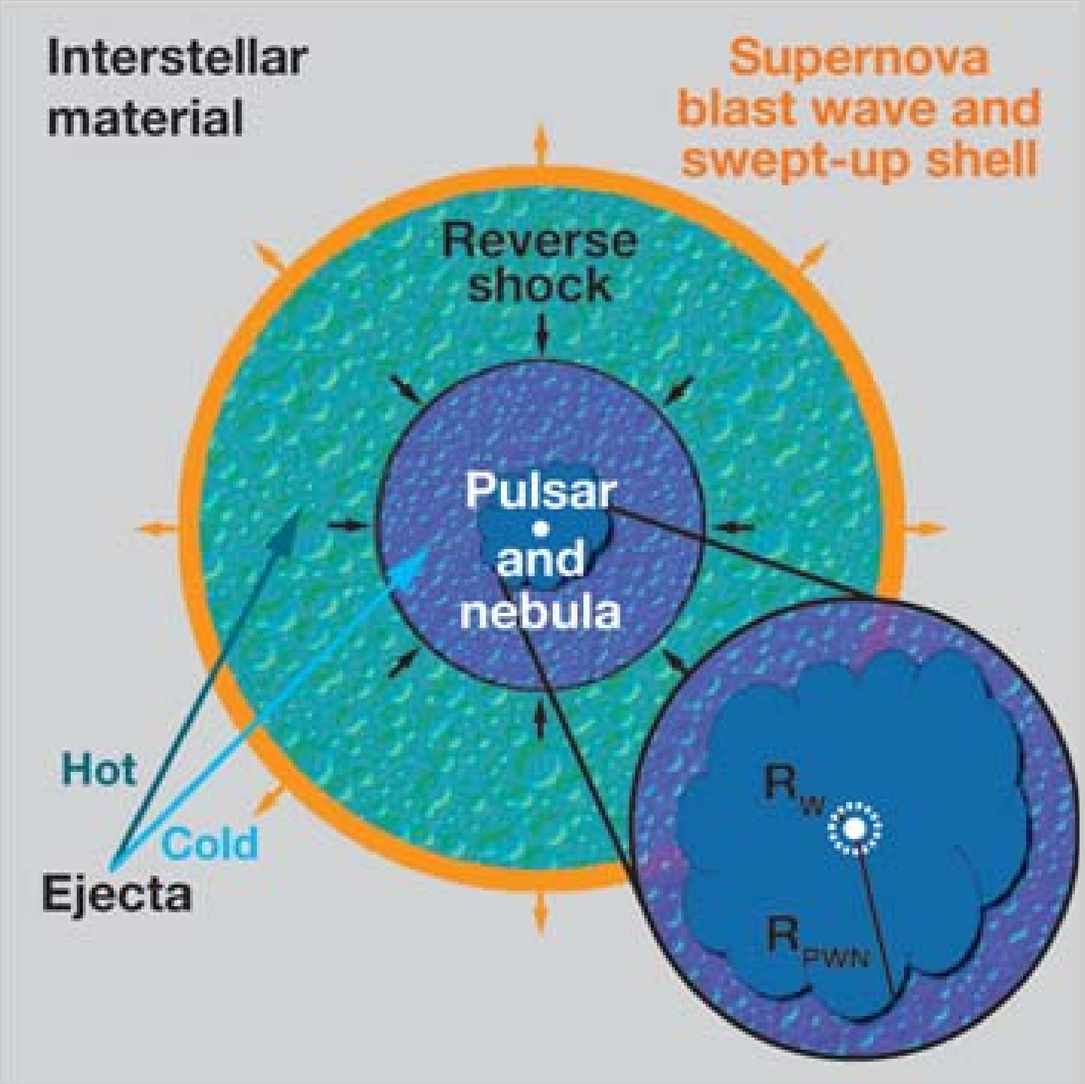
Is the repeater a young energetic neutron star?

FRBs arising from young neutron stars

- Connor+2016 (arXiv:1505.05535)
  FRBs from within young supernova remnants
- Piro 2016 (arXiv:1604.04909)
  Impact of an expanding SNR shell
- Kashiyama & Murase 2017 (arXiv:1701.04815)
  Explanation of the persistent radio emission of the repeater —> PWN
- Metzger+2017 (arXiv:1701.02370)
  Host consistent with those for LGRBs and SLSNe —> ms magnetar
- Dai+2017 (arXiv:1702.05831)
  ms Magnetar in a PWN without an initial SNR
- Cao+2017 (arXiv:1701.05482)
  Constraining the age of a magnetar producing FRBs

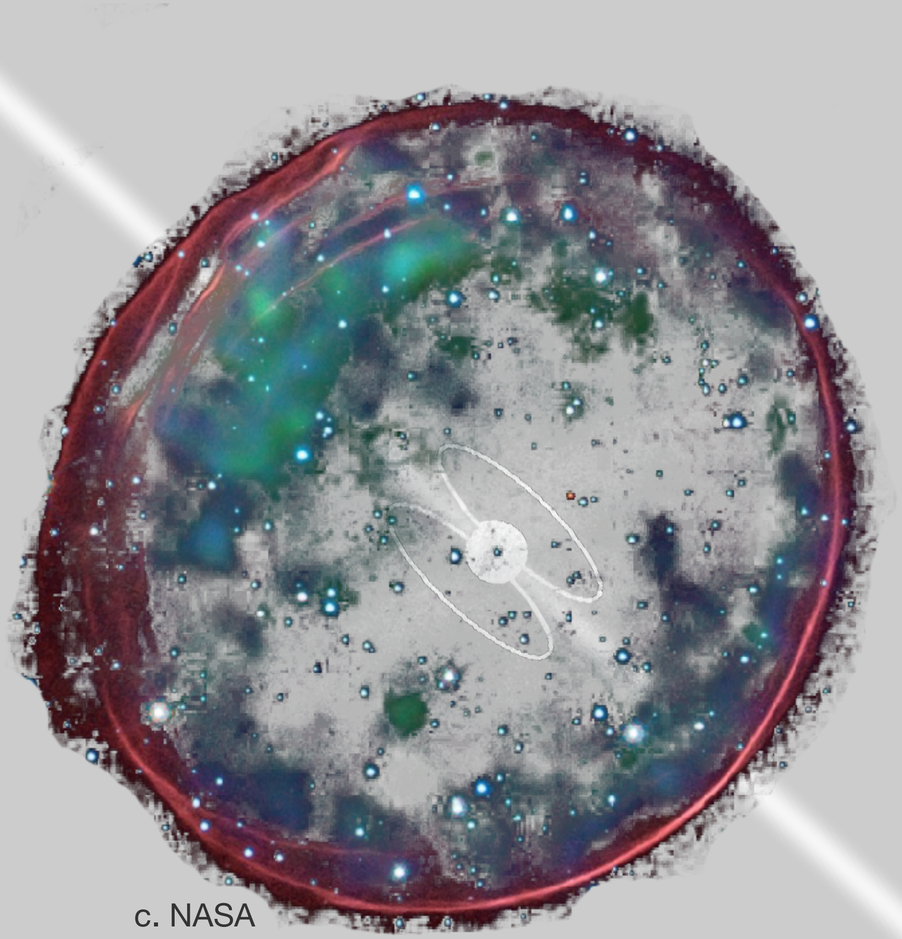
Young pulsars

- Reside in a SNR shell (often)
  - consists of ejecta and swept-up material ionised by the reverse shock
  - shell lives ~ $10^{5\text{-}6}$ years
- High E-dot pulsars ($\gtrsim 10^{36}$ ergs) 'blow' a pulsar wind nebula
  - Relativistic wind existing of $e^{+/-}$ pairs
  - PWN is a turbulent medium

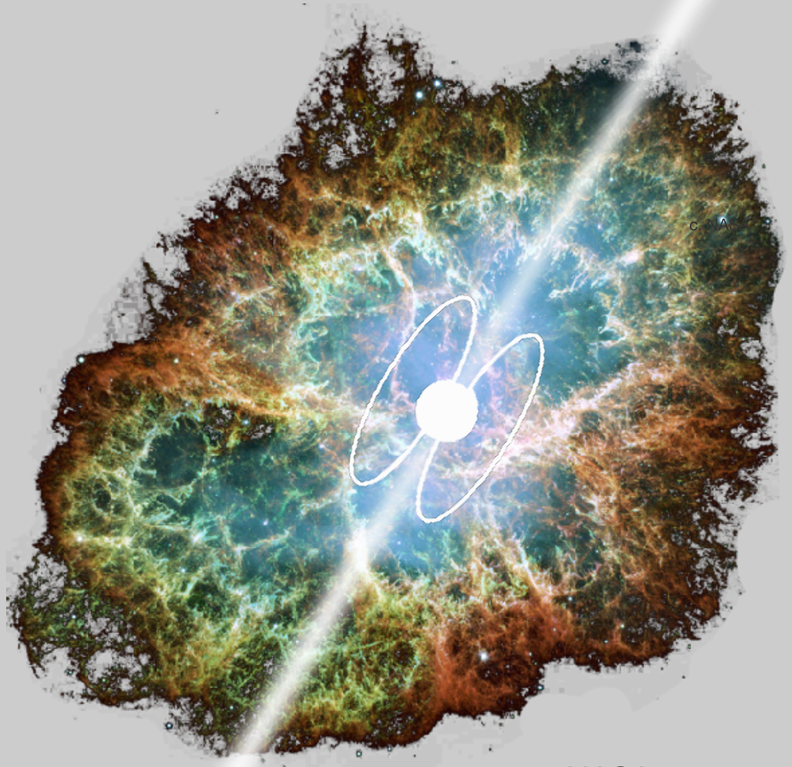


Gaensler & Slane 2006

Excess dispersion from SNRs/PWNe?



c. NASA



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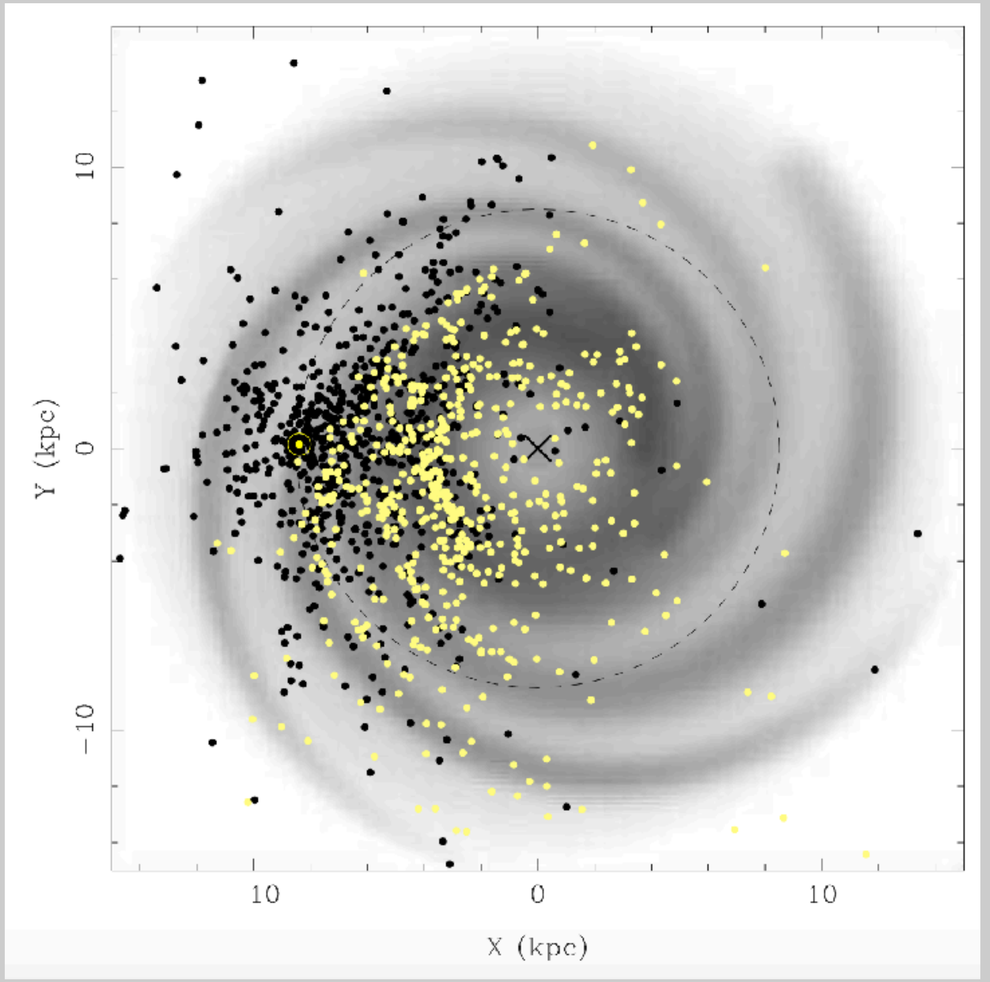
Excess dispersion from SNRs/PWNe?

- NE2001 models clumps of extra electrons for SFRs, SNRs
- PWNe are not modeled
- See if PWN/SNR contribute to DM by:
  - Comparing observed DM to NE2001 DM
  - 2 samples: — Associated (SNR/PWN)
    — Unassociated pulsars

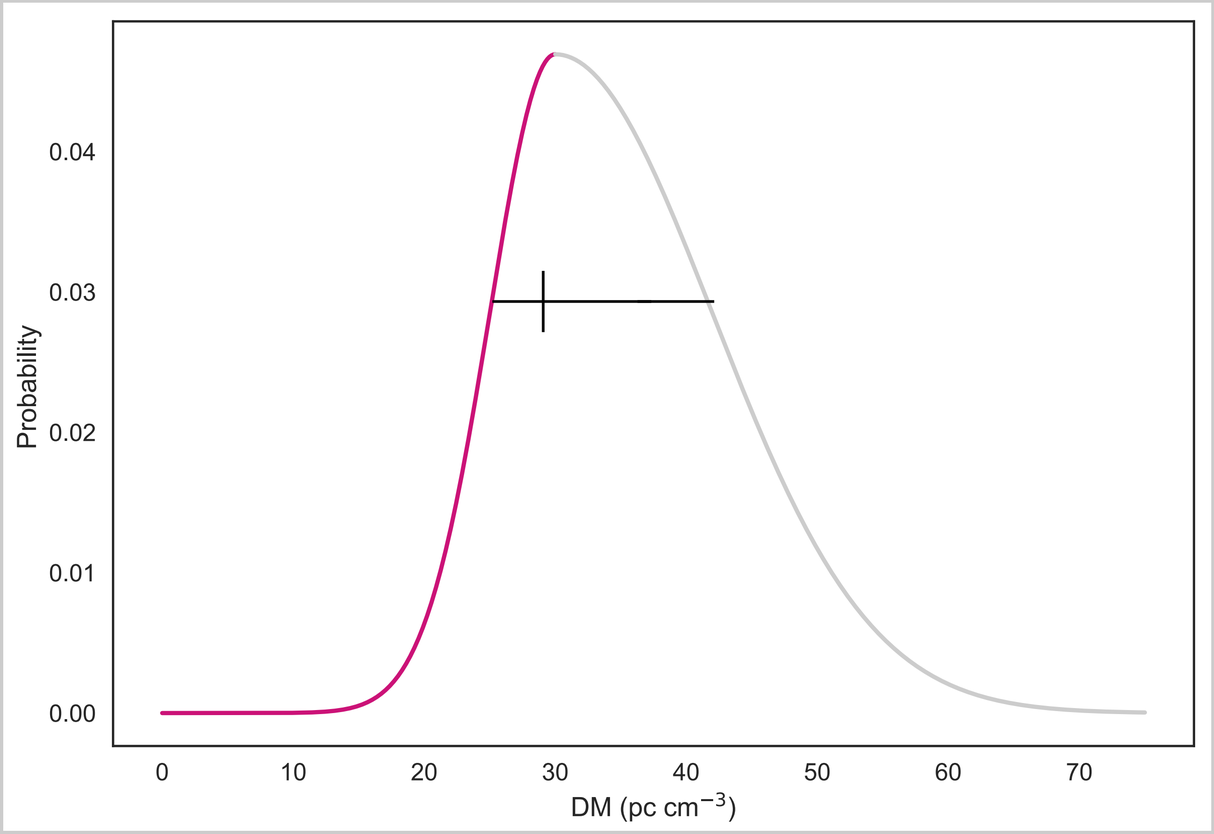


The Handbook of Pulsar astronomy, Lorimer & Kramer

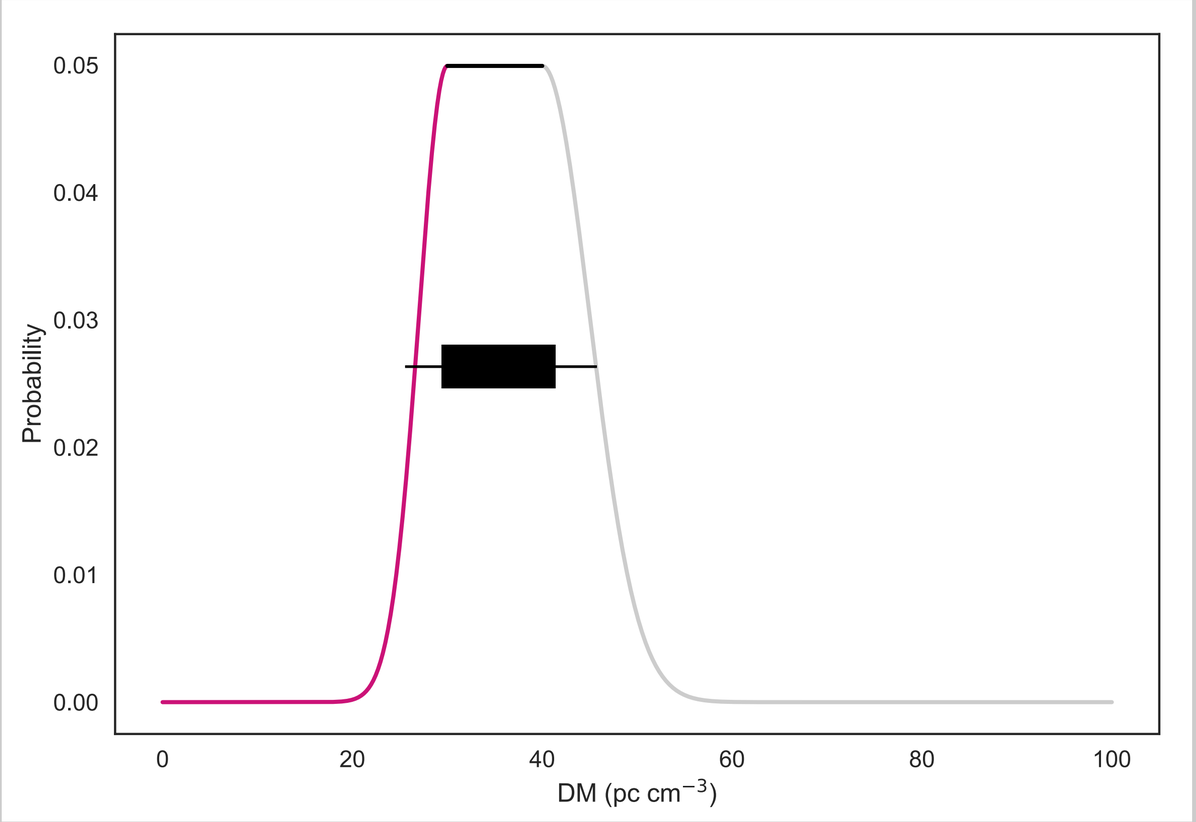
Excess dispersion from SNRs/PWNe?

- Distances from HI-line velocity or parallax translated to expected DM and error
- Errors are not Gaussians, perform Bayesian fit for any excess
  - Performed an MCMC fitting using their proper probability density functions

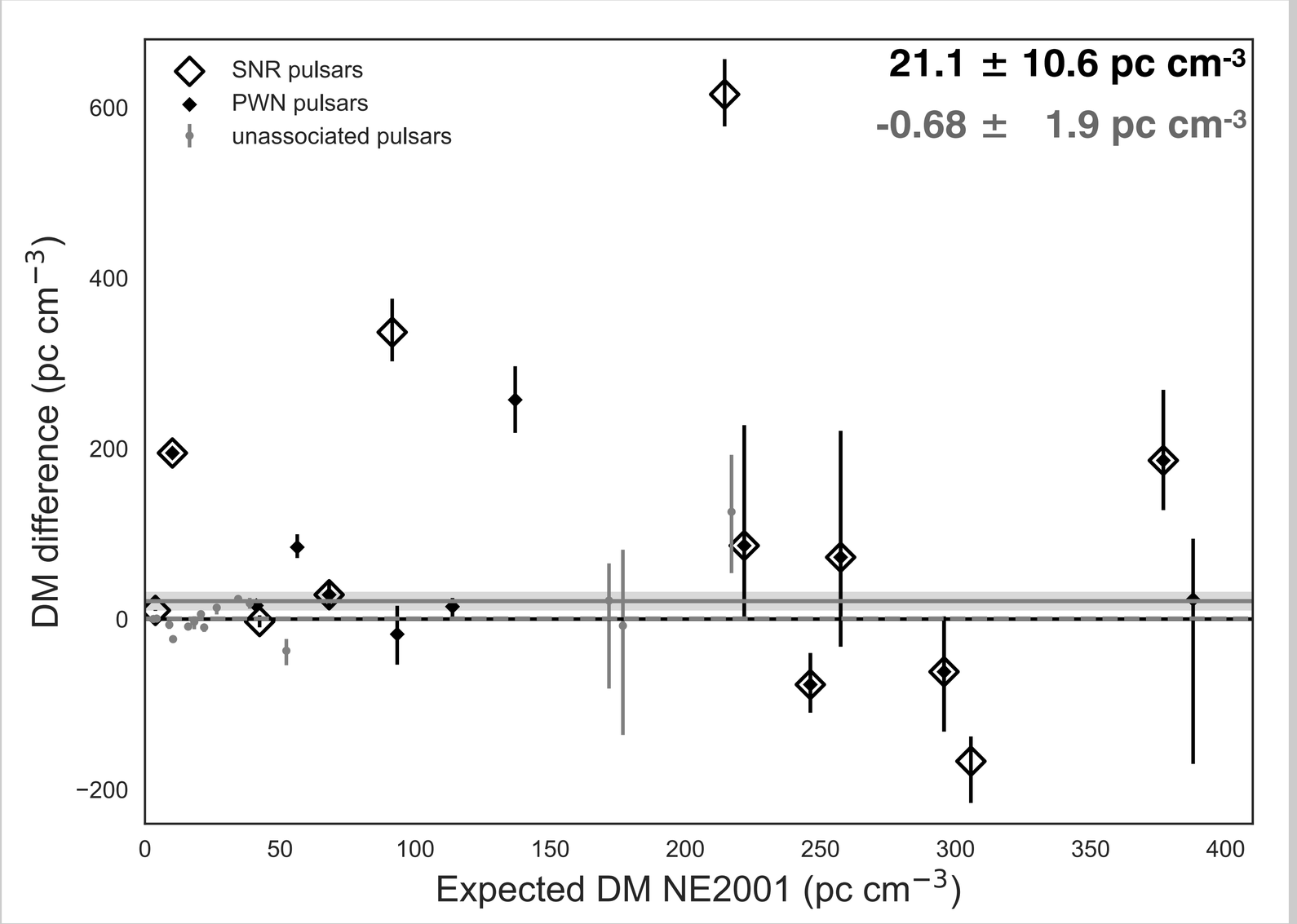
Parallax — Asymmetric errorbars



HI distances — Tophat with Gaussian drop-off



Excess dispersion from SNRs/PWNe



Straal et al. submitted

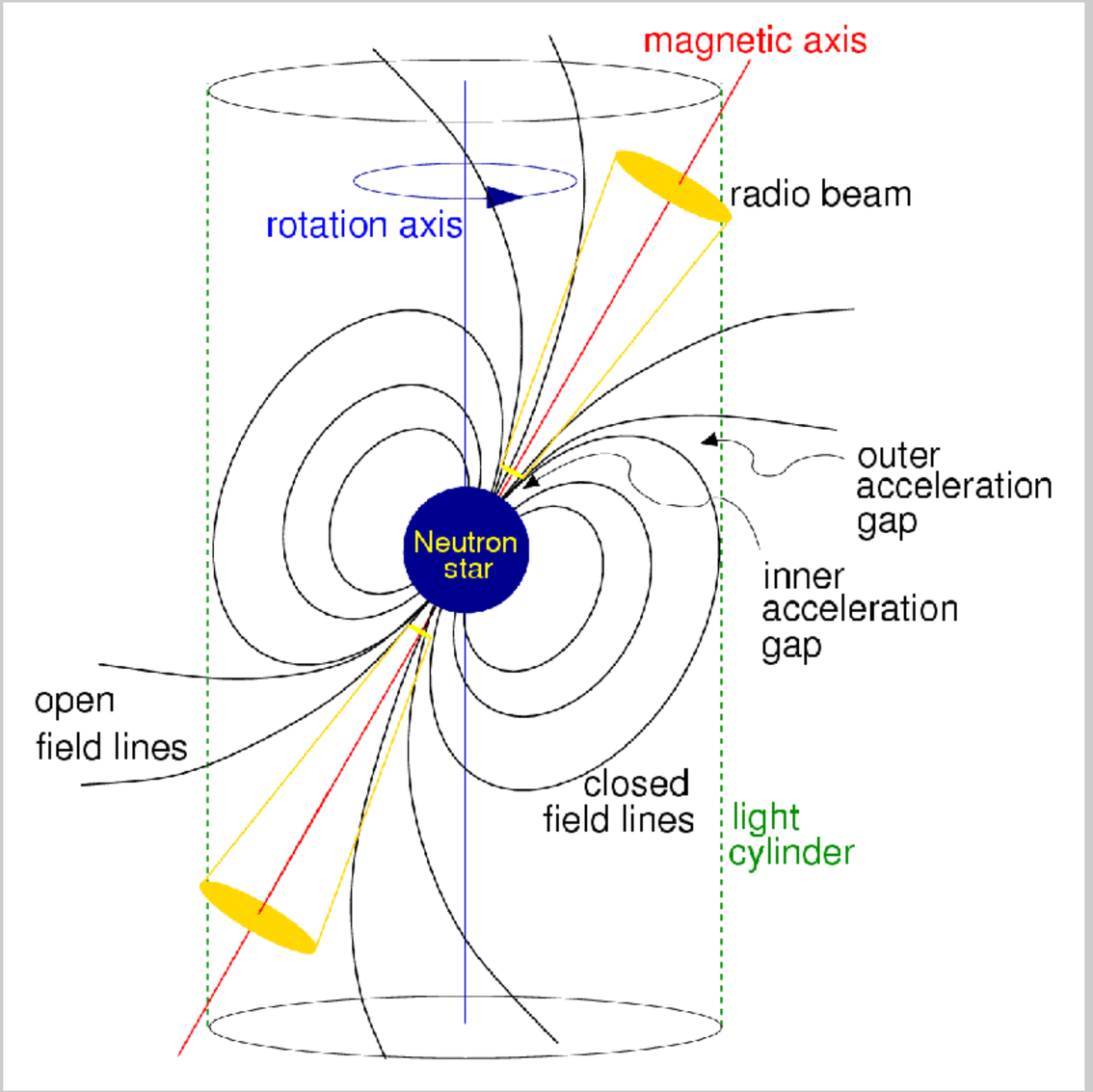
SNR and PWN contribution to DM

- ★ DM excess of 21.1±10.6 pc cm^{-3}
- ★ SNR after t = 10^3 years adds ~3 pc cm^{-3}

$$n_e = f_i \frac{3M_{ej}}{4\pi r^3 \mu_e m_p} \, cm^{-3}$$

- ★ Doppler boosted PWN (Cao+2017) adds for mean of sample ~11 pc cm^{-3}

$$DM_W = 6 \times \left(\frac{B}{10^{13}\,G}\right)^{4/3} \left(\frac{P}{100\,ms}\right)^{-11/3} \left(\frac{\kappa}{10^4}\right)^{2/3} pc\,cm^{-3}$$



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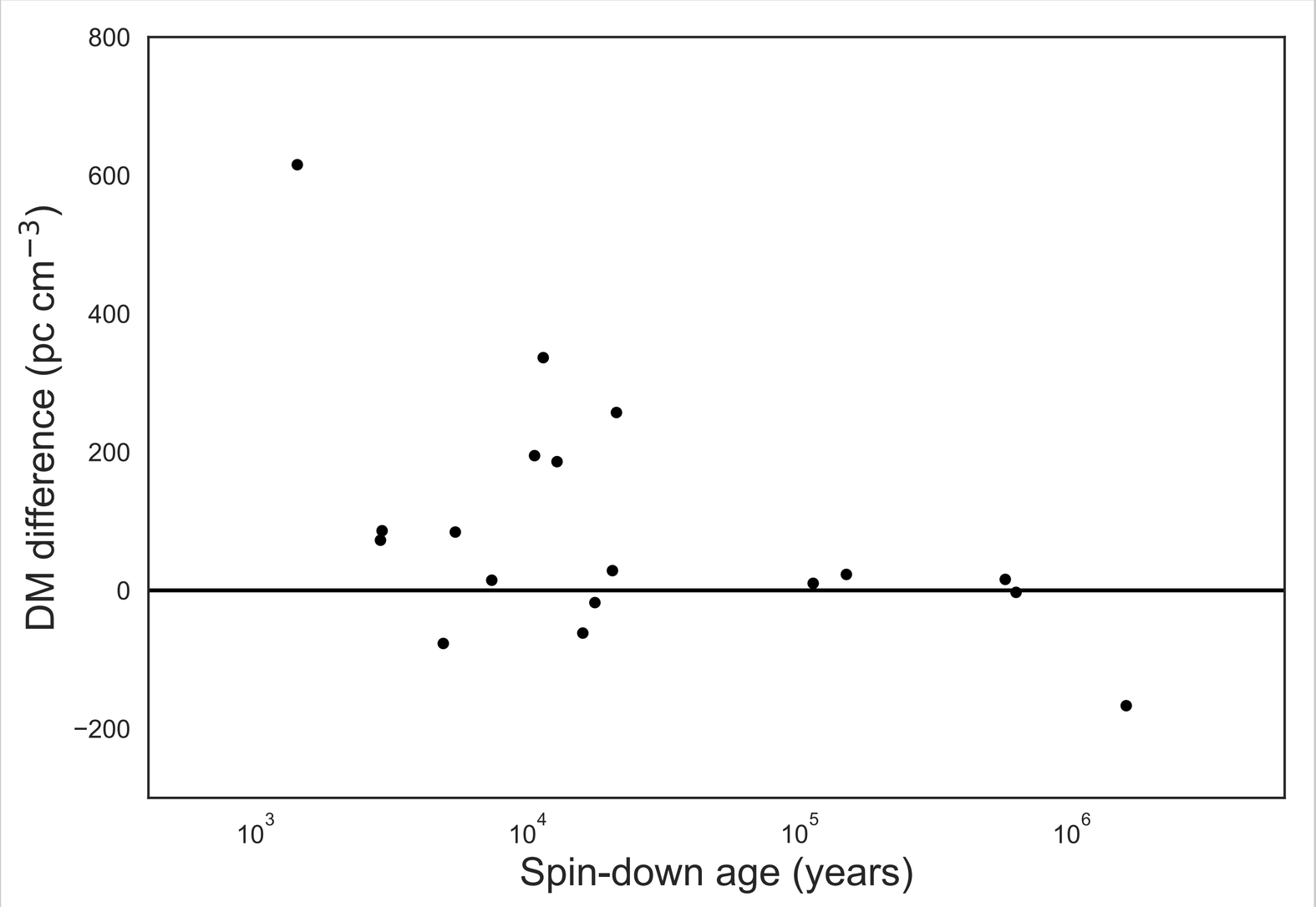
Age-correlation of DM excess



Straal et al. submitted

DM contribution in a young system

- ★ P_i = 10 ms
- ★ P_{dot} = 5 x 10^{-13} s s^{-1}
- ★ B = 10^{12} G
- ★ M_{ej} = 8 M_{sun}

SNR shell of 0.1pc thick

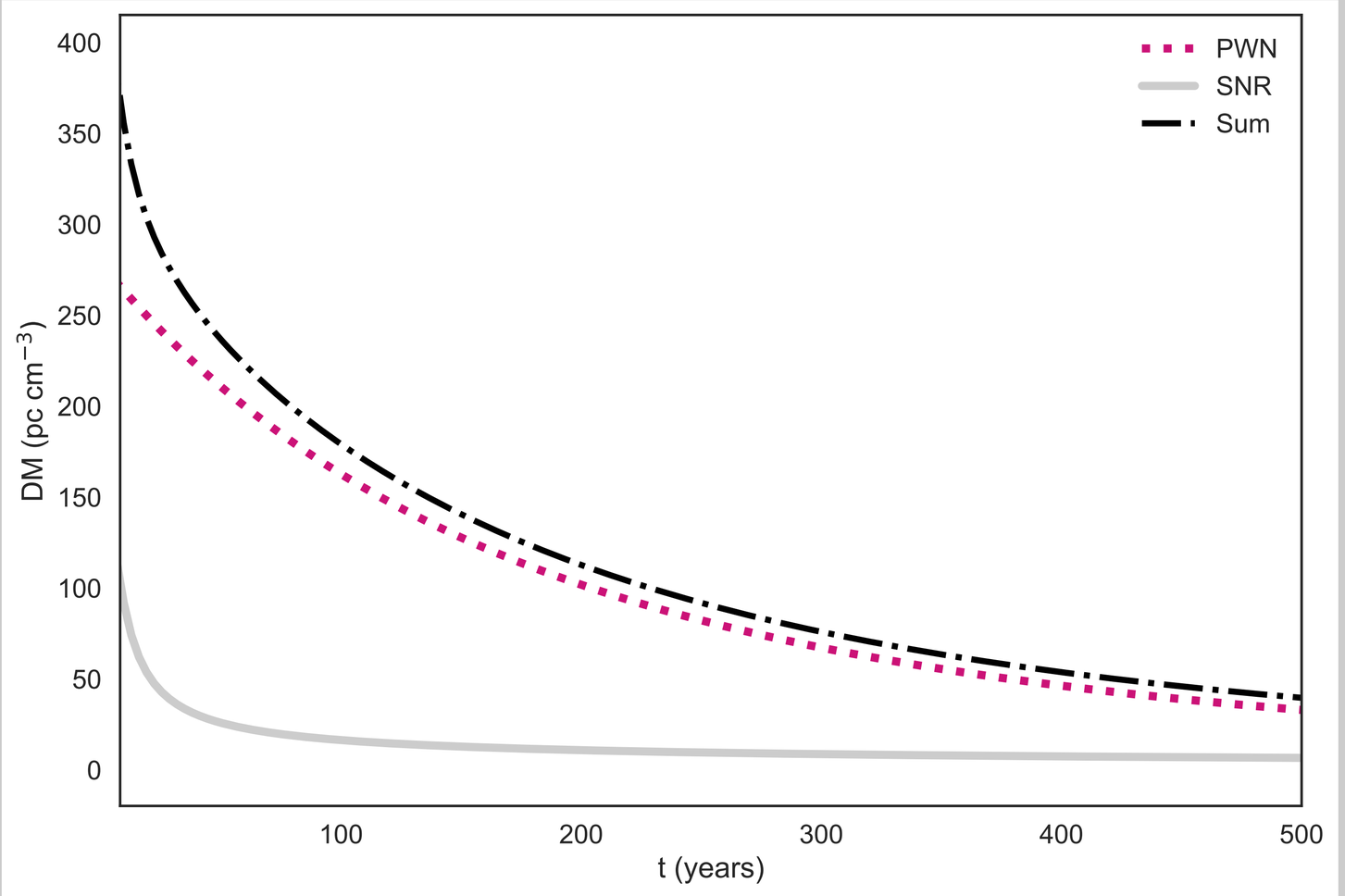
$$n_e = f_i \frac{3M_{ej}}{4\pi r^3 \mu_e m_p} \, cm^{-3}$$

Connor+2016

Doppler boosted PWN

$$DM_W = 6 \times \left(\frac{B}{10^{13}\,G}\right)^{4/3} \left(\frac{P}{100\,ms}\right)^{-11/3} \left(\frac{\kappa}{10^4}\right)^{2/3} pc\,cm^{-3}$$

Cao+2017



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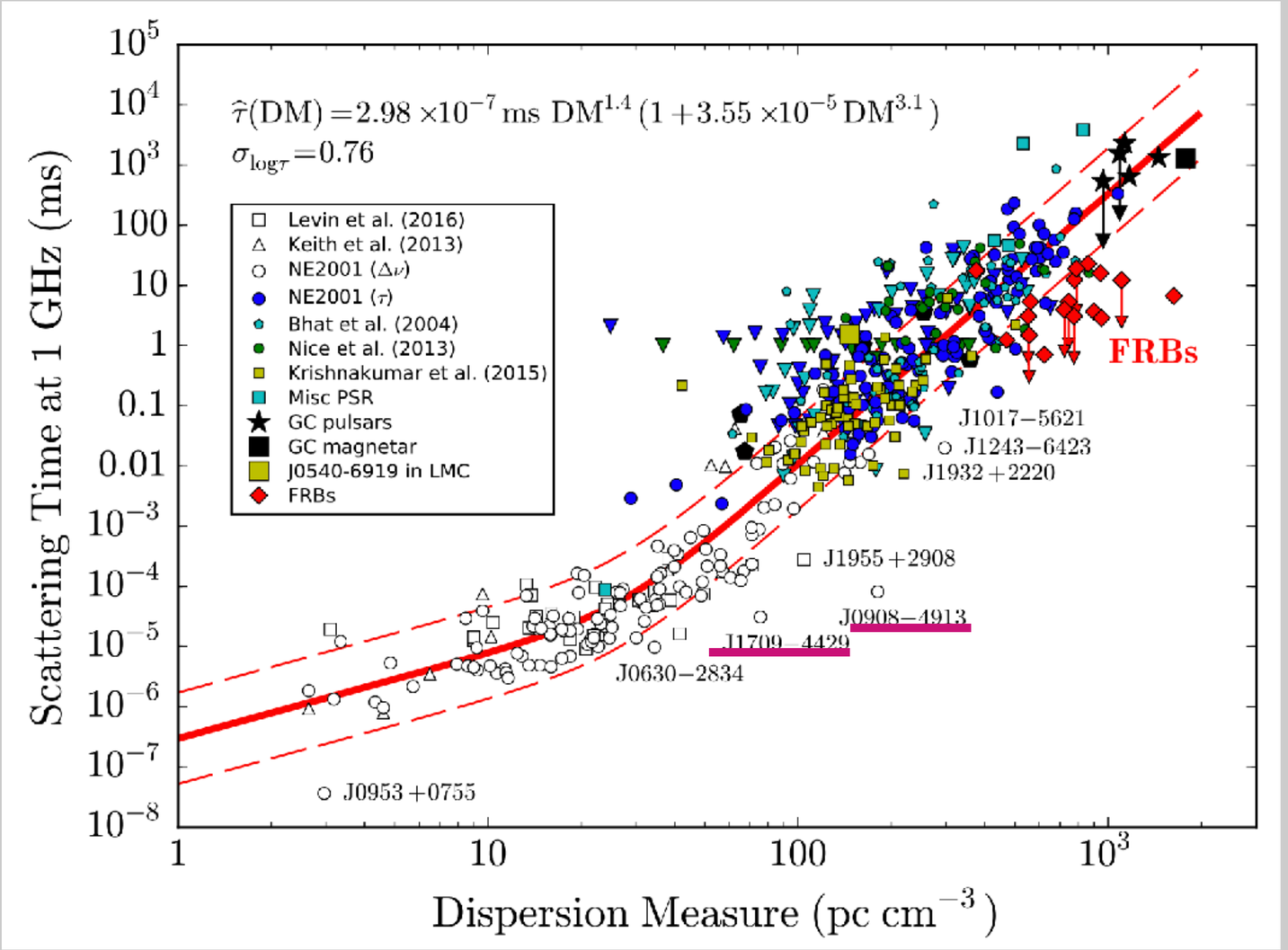
DM — Scattering relation

- FRBs tend to be under-scattered
  - Overly dispersed?
- 2 PWN pulsars also under-scattered
- Are all PWN pulsars under-scattered overly-dispersed?



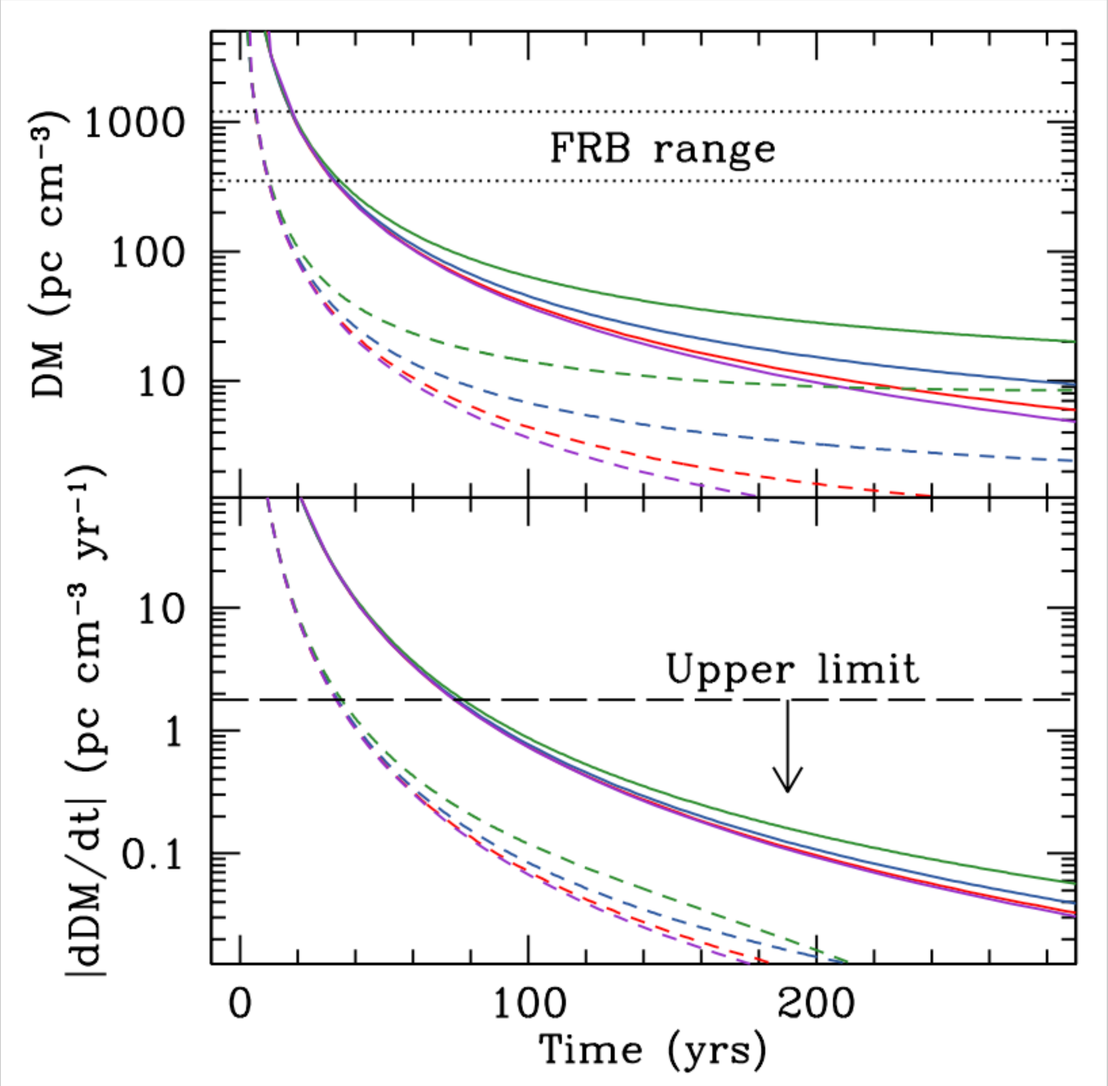
Cordes+2016

Summary

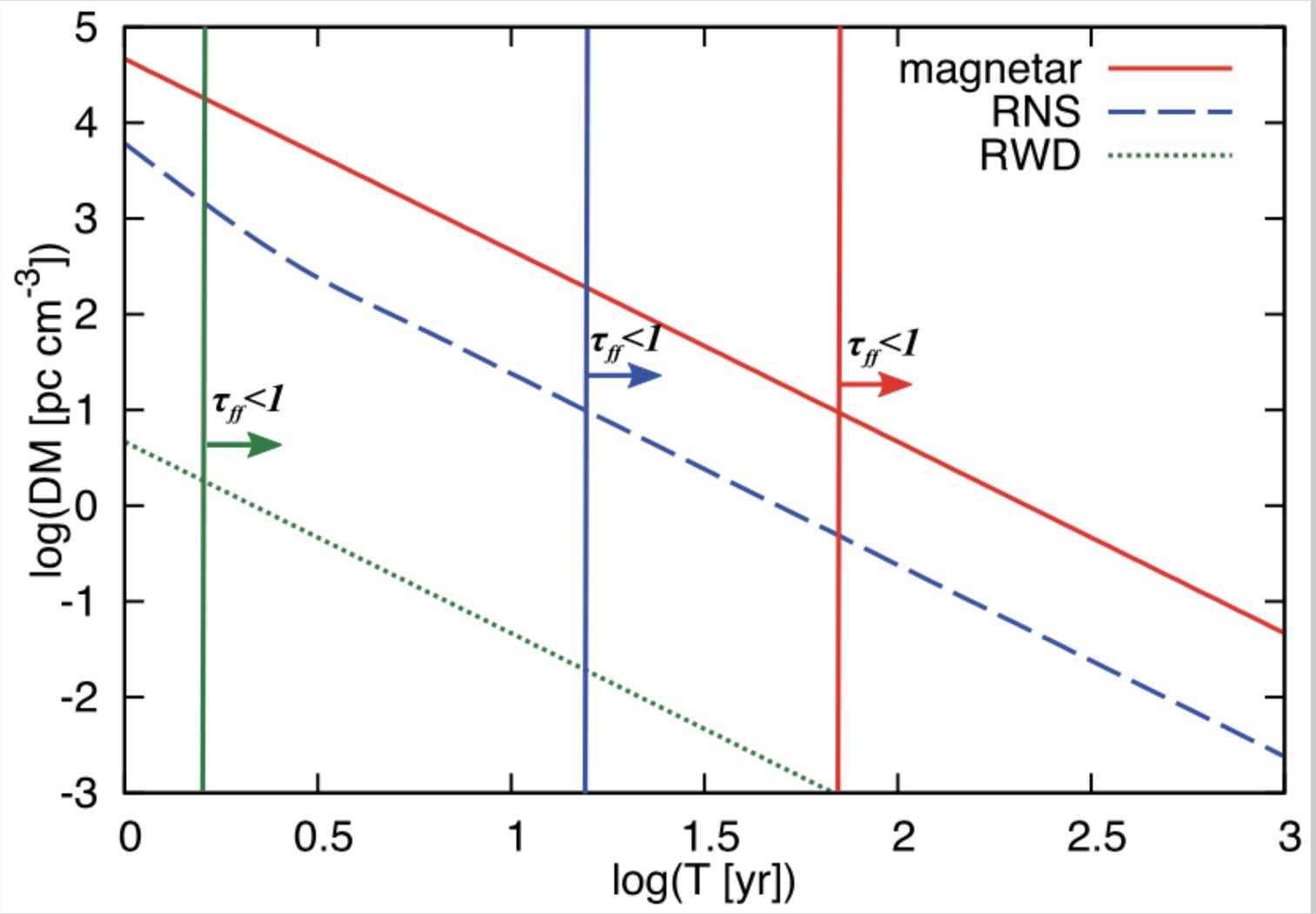
- Young pulsars show
  - Large fraction linear polarisation (as does FRB 121102, Michilli+2018)
  - DM excess = 21.1 ± 10.6 pc cm^{-3} with mediate age of ~10^4 years
- For FRBs can contribute ~300 pc cm^{-3} in early years
- Investigate scattering properties of nebulae
- Study FRB hosts, dwarf galaxies home to SLSNe
- Find younger Galactic sources to study and understand emission mechanism

c. SKA — Artist impression

Piro 2016


DM (pc cm^{-3})
1000
100
10
FRB range
|dDM/dt| (pc cm^{-3} yr^{-1})
10
1
0.1
Upper limit
0
100
200
Time (yrs)

Murase+2016


magnetar
RNS
RWD
$\tau_{ff}<1$
$\tau_{ff}<1$
$\tau_{ff}<1$
log(DM [pc cm^{-3}])
log(T [yr])
5
4
3
2
1
0
-1
-2
-3
0
0.5
1
1.5
2
2.5
3

Metzger+2017