[hydrogen-poor] [long-duration]

Connecting SLSNe, GRBs & FRBs to the Birth of ms Magnetars

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TeV Particle Astrophysics

Columbus OH, August 2017

(ms Magnetars and the) SLSN-GRB-FRB Connection

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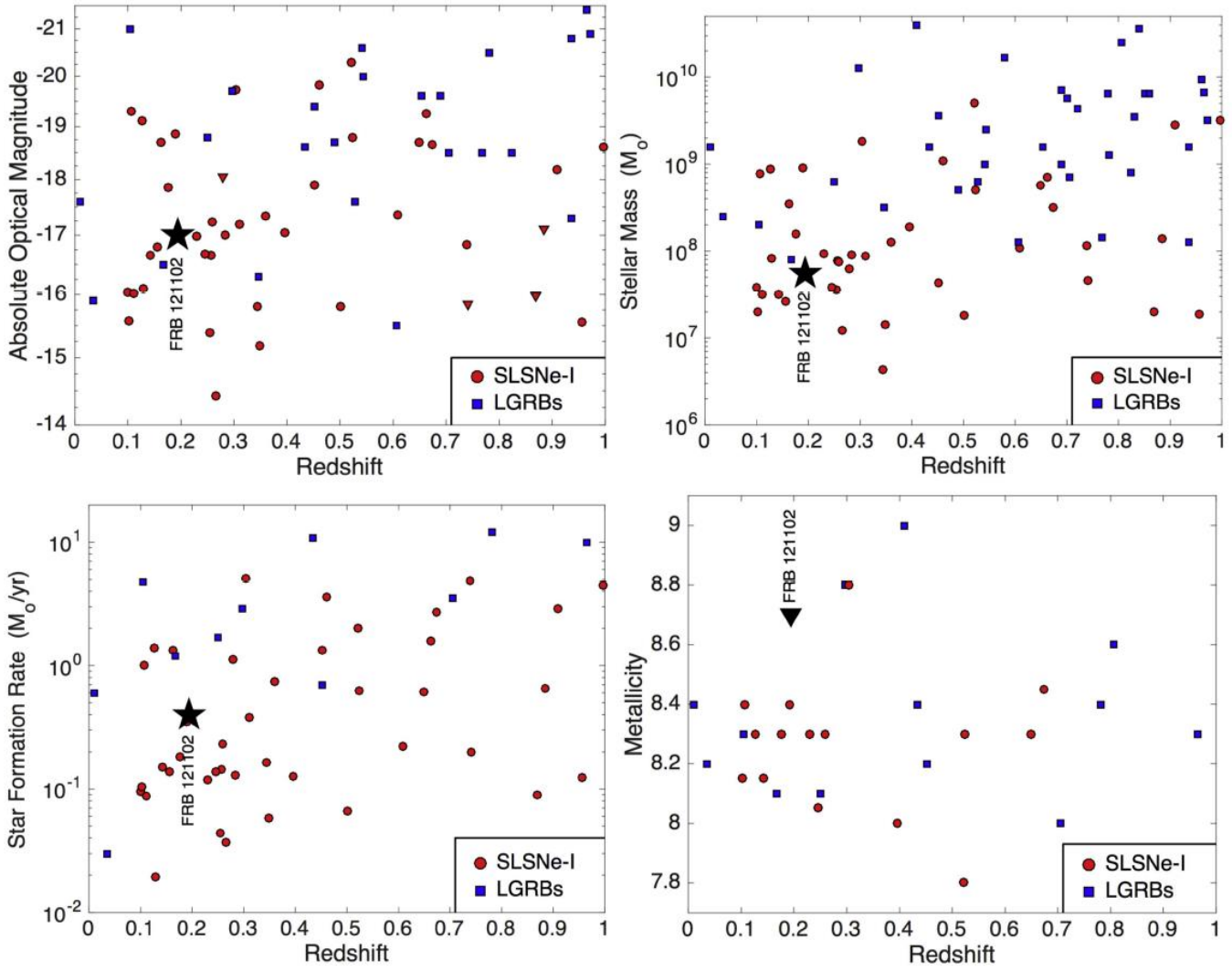
motivation: [evidence for a SLSN-GRB-FRB connection]

- similar (+rare) environment: low-luminosity, metal-poor, star-forming galaxies (e.g. Stanek+06; Lunnan+14; Tendulkar+17; Metzger+17)

- magnetars proposed as engines of GRBs (Thompson+04), SLSNe-I (Kasen&Bildsten10; Woosley10), and FRBs (e.g. Lyubarsky14; Beloborodov17)

Metzger, Berger & BM (2017)



(ms Magnetars and the) SLSN-GRB-FRB Connection

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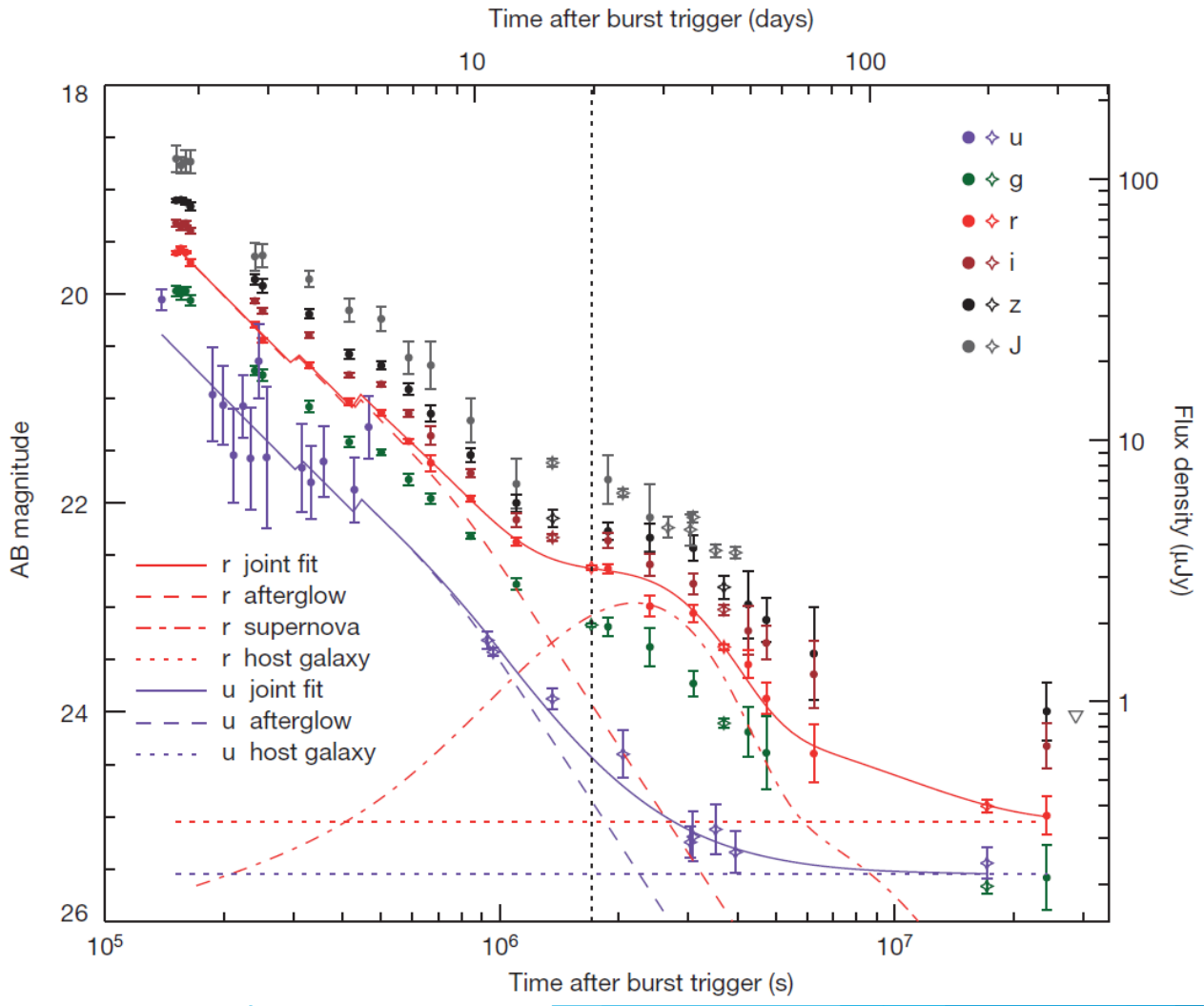
motivation: [evidence for a SLSN-GRB-FRB connection]

- comparable (beaming-corrected) GRB & SLSN rates
  + plausibly consistent with FRB rate
  (Nicholl+17)

- direct evidence? ULGRB 111209A and the associated luminous SN 2011kl
  (Greiner+15)

Greiner et al. (2015)



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follow-up questions: [or… outline]

- what distinguishes the engines responsible for these different phenomena?
- can a single engine power a GRB, a luminous SN, and an FRB in the same event? if so:
  - how is the engine energy partitioned between these components?
  - when can a jet successfully burrow out of the SN ejecta?
  - what are the observable consequences?
  - what is the ejecta's ionization-state, and how does it affect propagation of an FRB?

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[can a single engine power both a GRB & SLSN?]

$\hat{\Omega} \cdot \hat{\mu}$, or mis-aligned magnetars:

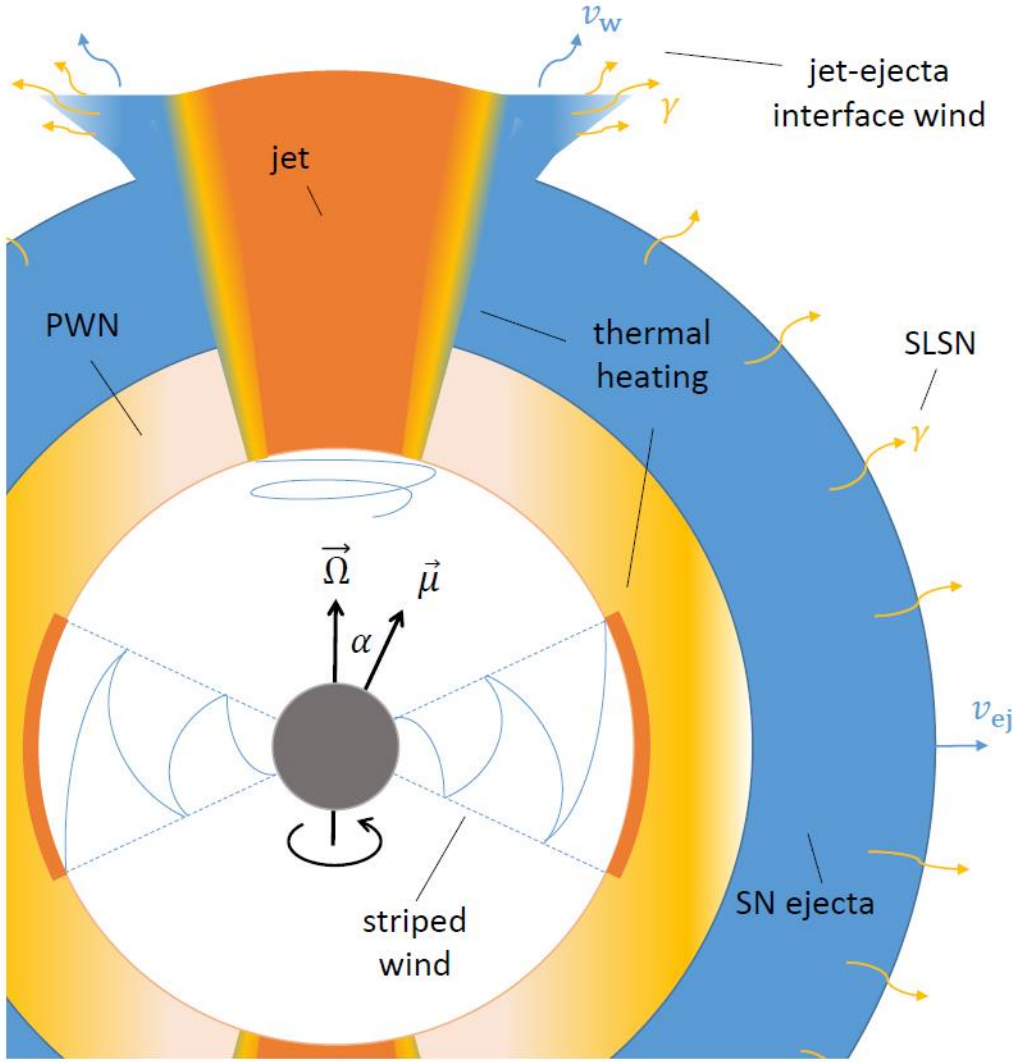
BM et al. (2017)

- dissipation by forced reconnection of 'striped-wind' (Lyubarsky03; Komissarov13)
  ⇒ energize ejecta
  ⇒ power SN

- remaining ordered poloidal field
  ⇒ power collimated jet
  (e.g. Bucciantini+09; Bromberg&Tchekhovskoy16)

- quantitative prescription for energetic partitioning,

$$f_{\rm th}(\alpha) \approx 1.025\alpha(0.636 + \alpha^4)^{-1/4}$$



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[what distinguishes engines responsible for different phenomena?]

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landscape of engine-powered transients:

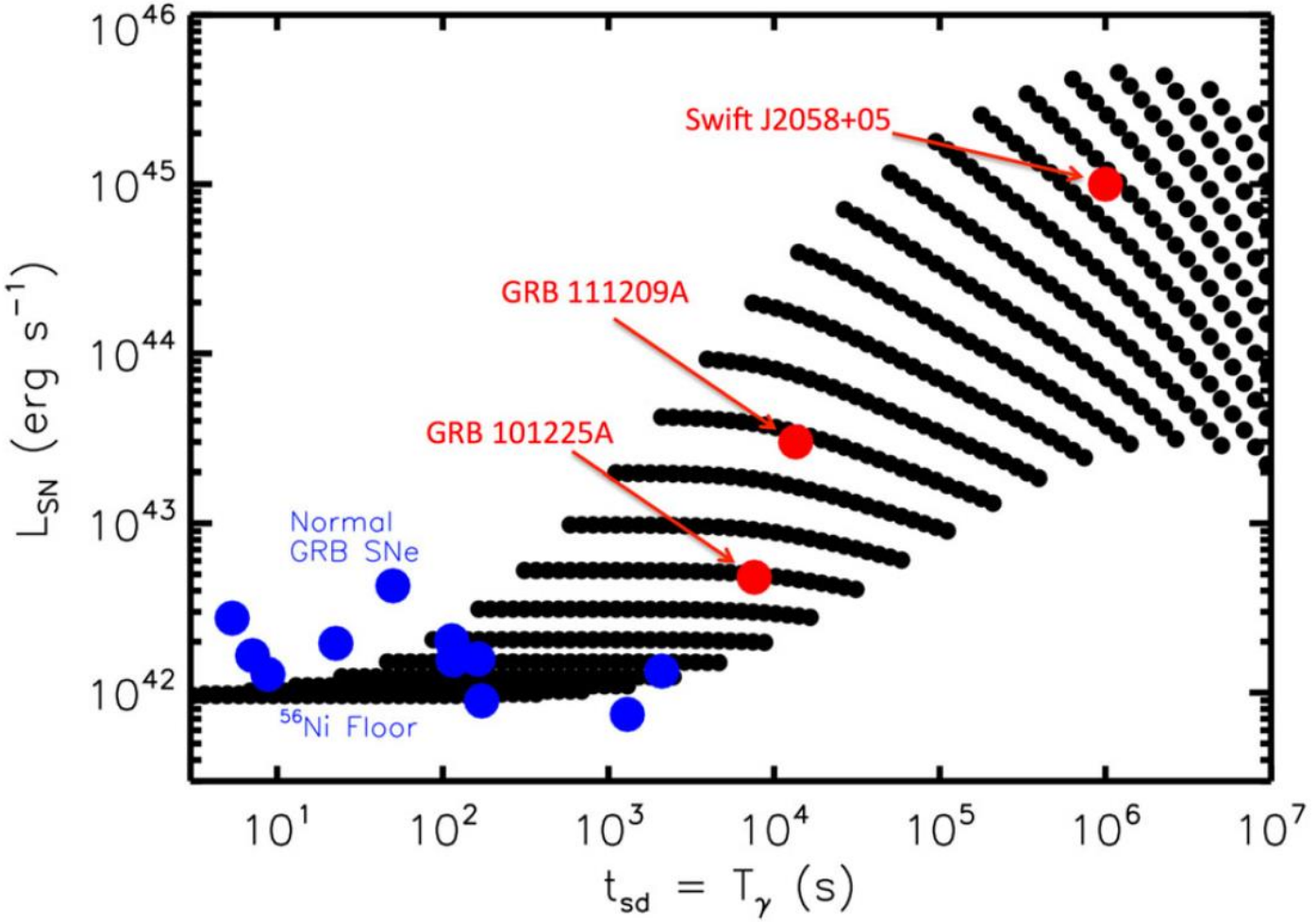
- engine time-scale is key!

- enhancing SN luminosity requires energy deposition at right time, near $t_{\rm diff} \sim \sqrt{3\kappa M_{\rm ej}/4\pi c v_{\rm ej}}$

  - $t_{\rm e}$ ~minutes-hours
    ⇒ GRB (+Ic-bl?)

  - $t_{\rm e}$ ~days-months
    ⇒ SLSN (+ULGRB?)

Metzger, BM, Kasen, Quataert (2015)



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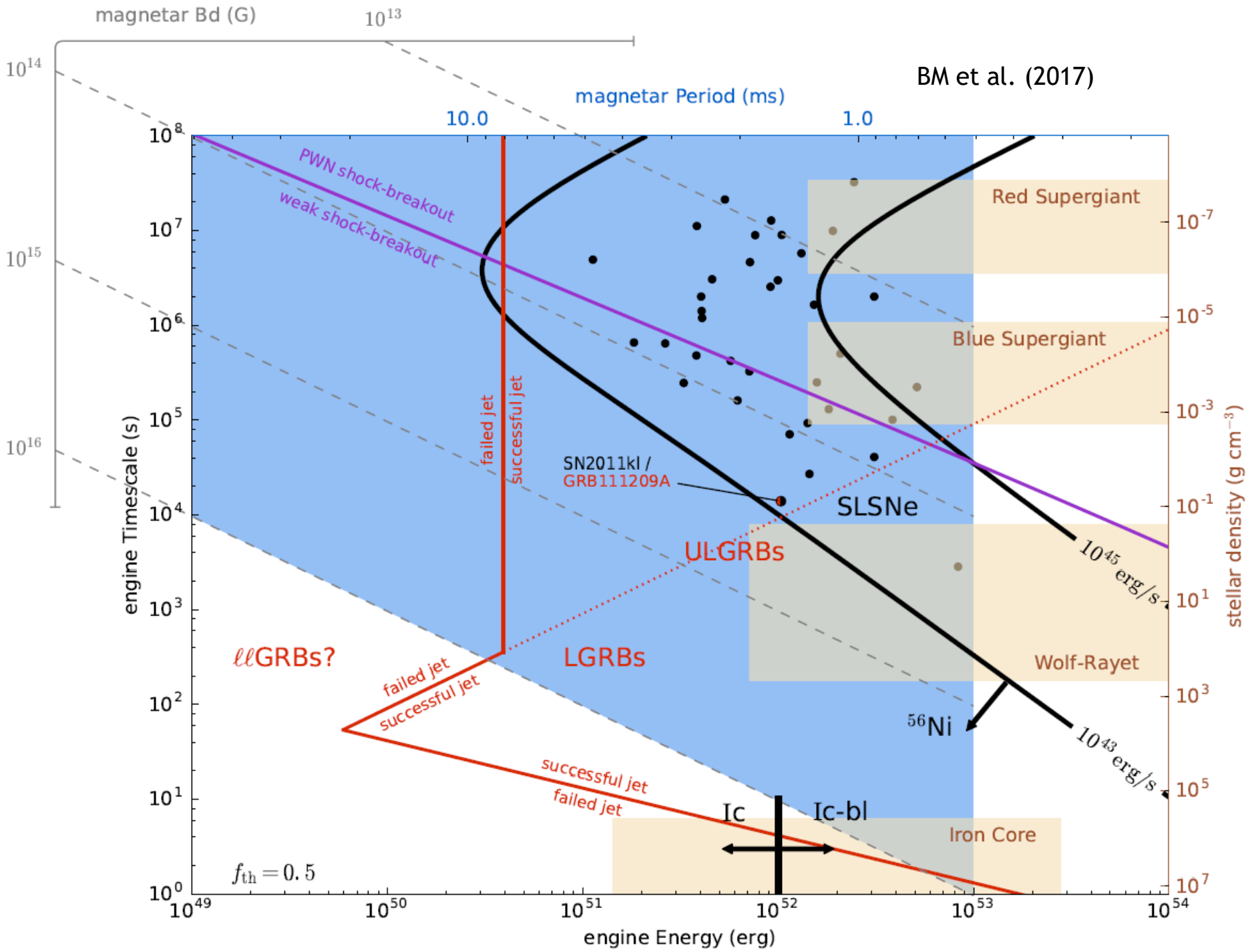

landscape:

- unless $f_{\rm j} \ll 1$, jets may ubiquitously accompany SLSNe

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[consequences for off-axis observers?]

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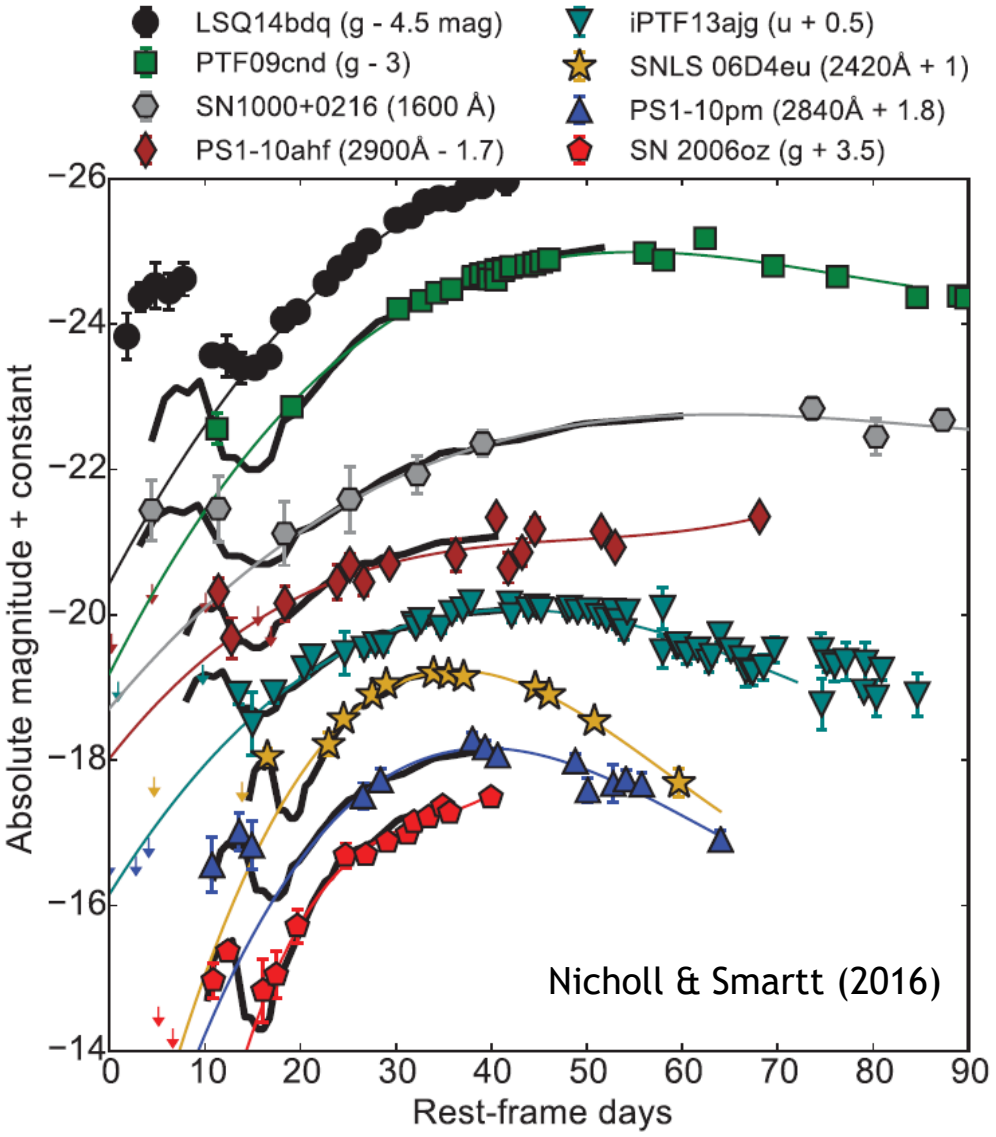
observational tests:

- predict population of "jetted SLSNe"
- SLSNe should be accompanied by:
  - orphan radio afterglows (currently two non-detections; Nicholl+16; Bose+17)
  - UV 'cocoon breakout' emission peaking at $\sim 10^{44} - 10^{45}$ erg s^{-1} on $\sim$ hr timescales (see also Nakar&Piran17)
    - will be observable by ULTRASAT
  - early optical/UV peak from jet-ejecta interaction
    - novel explanation for early-time maximum observed in some SLSNe light-curves (Nicholl&Smartt16)



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[can a single engine power both SLSN & FRB?]

↓

powering FRBs with magnetars:

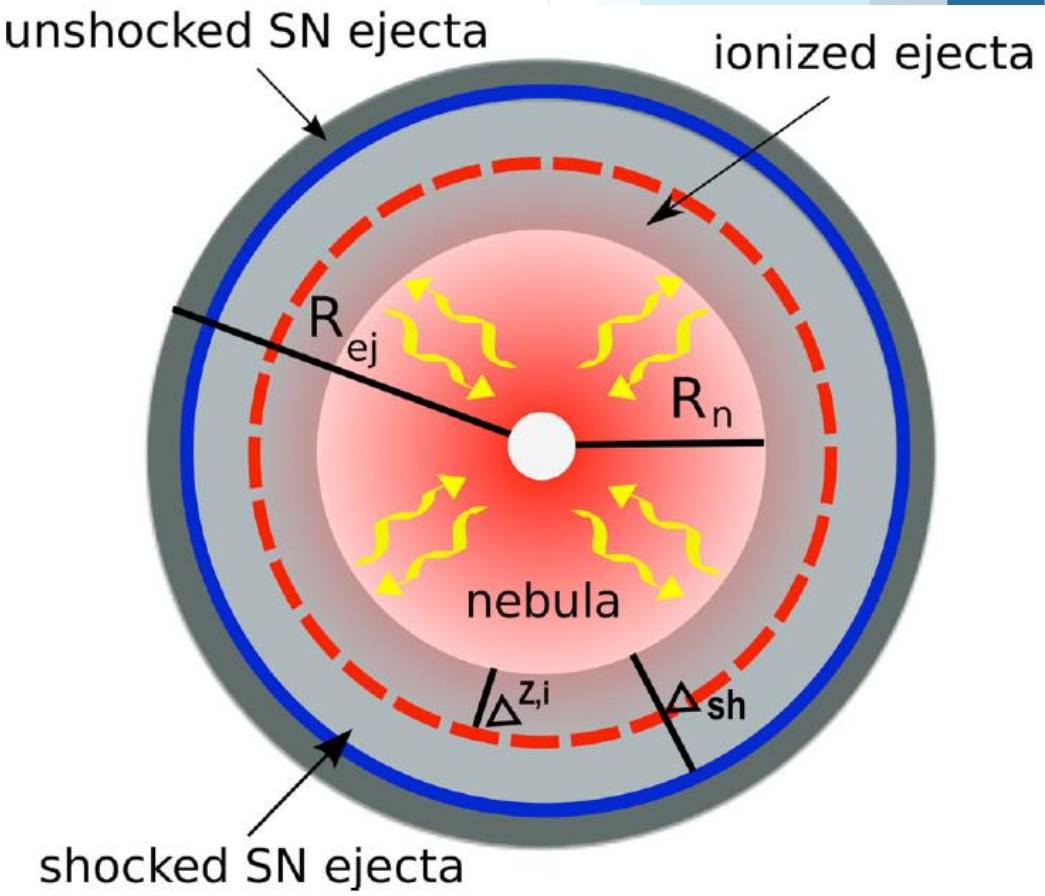
- repeater energetics disfavor spin-down powered models (Lyutikov17; Metzger,Berger&BM17)
- but – could be magnetically powered (e.g. Lyubarski14; Beloborodov17)

- FRB must propagate through dense SN ejecta (Connor+16; Piro16; Murase+17; Metzger,Berger&BM17)

  ⇒ free-free absorption + local DM constrain repeater's age

- photo-ionization by magnetar-wind-nebula

Metzger et al. (2014)



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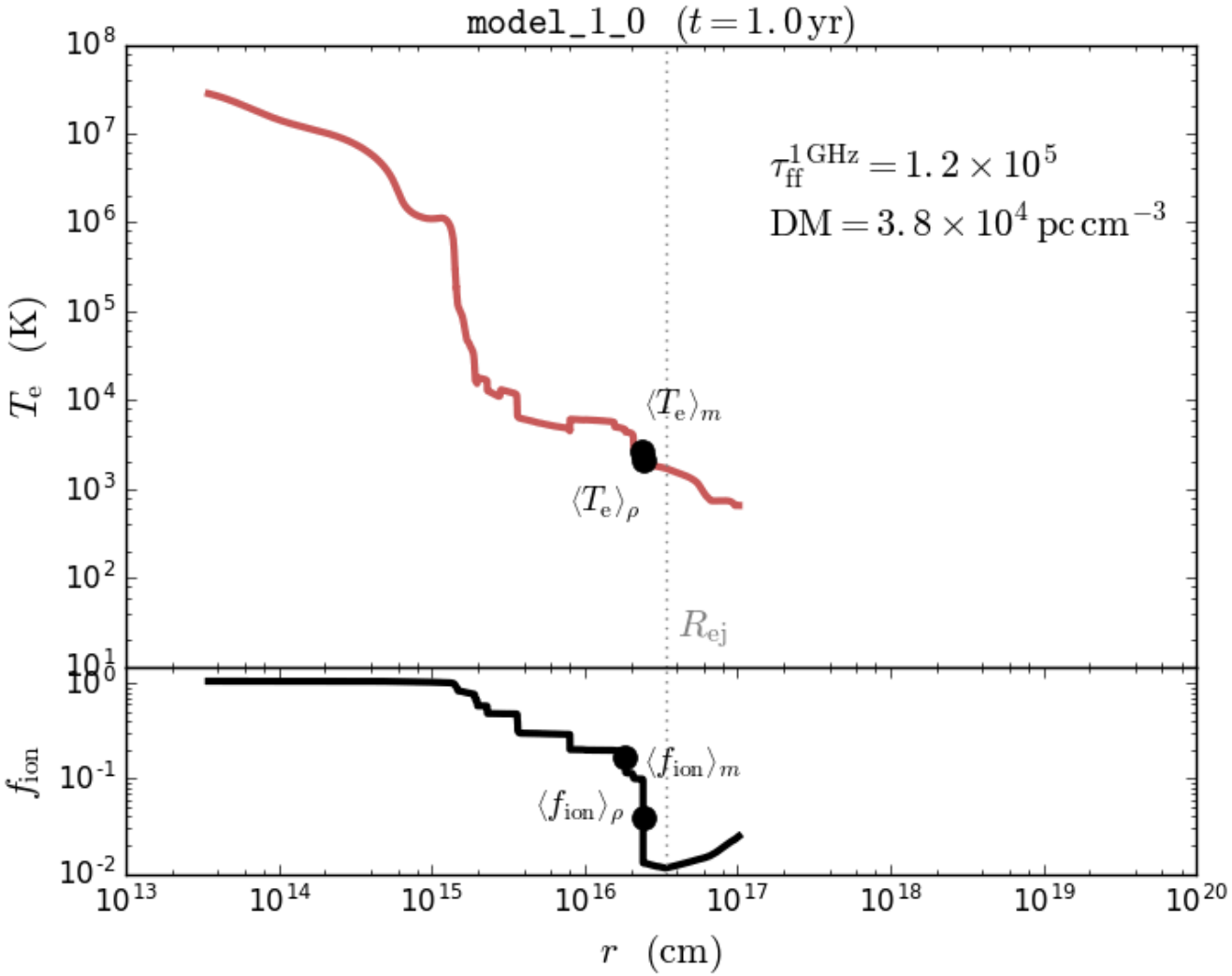
[what is the ejecta's ionization state?]

FRBs & ejecta photo-ionization:

- calculate time-evolving photo-ionization state of ejecta (w/ CLOUDY)
- find free-free transparency time and DM evolution

`model_1`: O-rich ejecta,
$P_0 = 1\,\mathrm{ms}$, $B_\mathrm{d} = 10^{14}\,\mathrm{G}$,
$M_\mathrm{ej} = 10 M_\odot$, $\epsilon_\mathrm{ion} = 10^{-3}$



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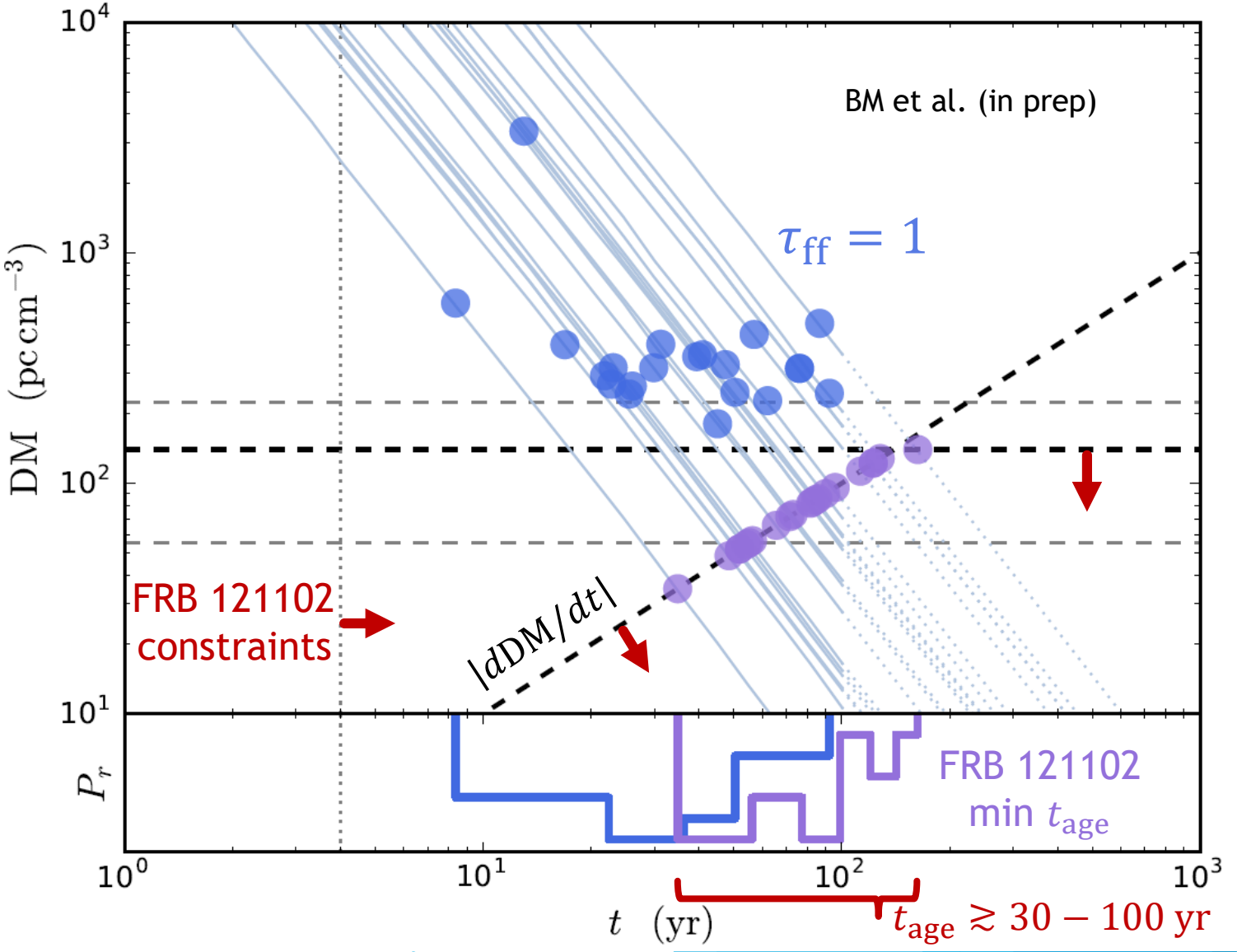
[how is FRB affected by propagation through ejecta?]

FRBs & ejecta photo-ionization:

- assume FRB engine similar to SLSNe magnetars
- what can we learn about FRB 121102 from population of observed SLSNe?
- repeater's $t_{\rm age} \gtrsim 30 - 100$ yr



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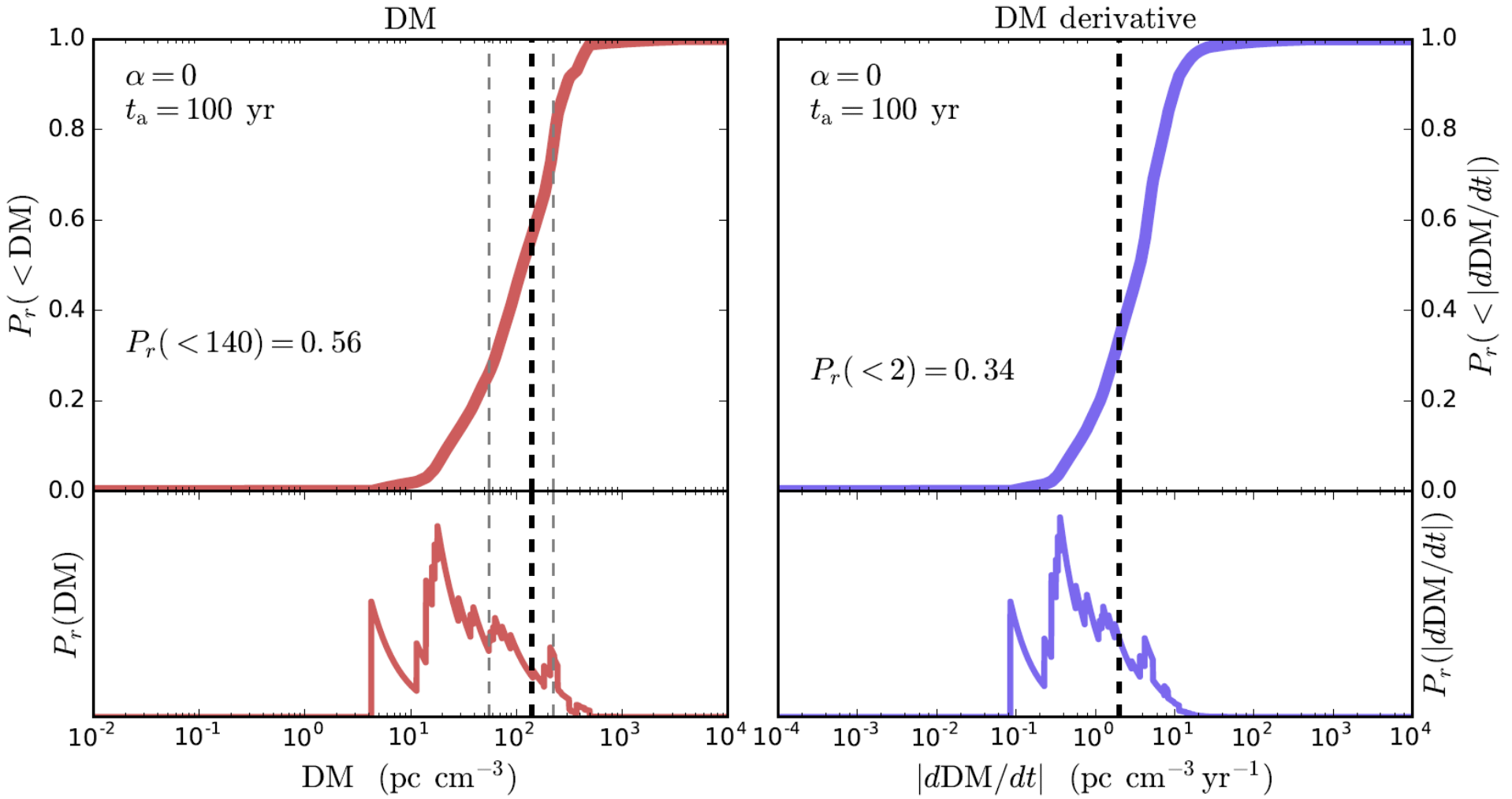
[how is FRB affected by propagation through ejecta?]

FRBs & ejecta photo-ionization:

- FRB 121102's DM, $d\mathrm{DM}/dt$ "typical" within SLSN population

BM et al. (in prep)



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summary: [or finally – putting the pieces together]

- mis-aligned ms magnetars can simultaneously power both jetted (GRB) & thermal (SN) transients
- weak ($\sim 10^{46}\ \mathrm{erg\ s^{-1}}$) jets can generically escape from expanding SN ejecta as long as $E_{\rm j} \gtrsim 0.2 E_{\rm sn}$

  $\Rightarrow$ jets may ubiquitously accompany SLSNe
- jet-ejecta interaction may explain early-time 'bumps' in SLSNe light-curves
- FRB 121102 age $\sim 30 - 100\ \mathrm{yr}$
- repeater's properties "typical" for SLSN population magnetars/ejecta