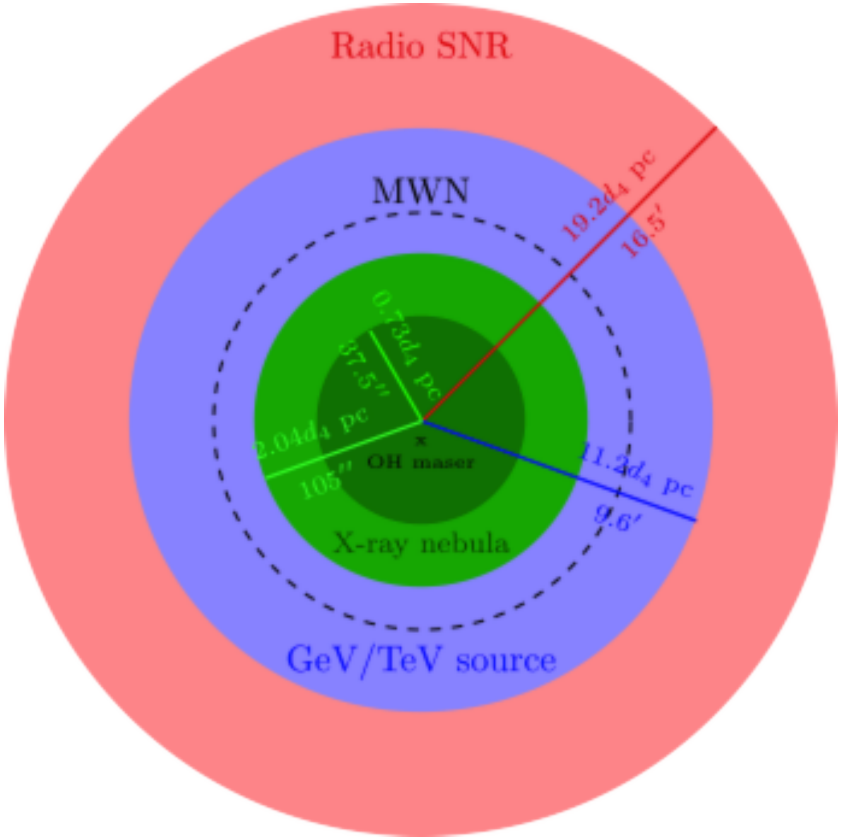
Emission & Detectability of Magnetar Wind Nebulae: Swift 1834.9–0846

- The one known MWN is a good start

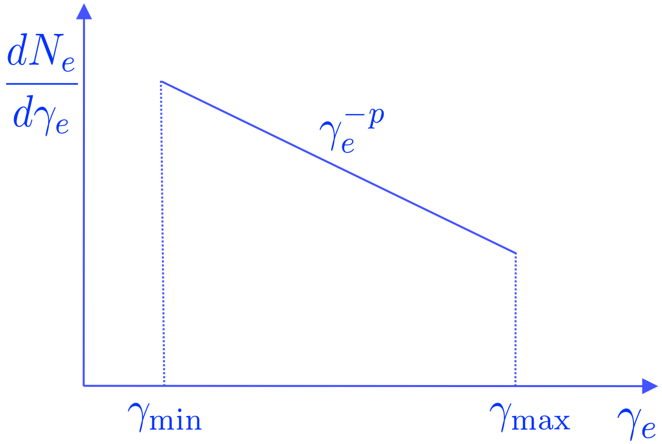


Synchrotron **cooling time** of X-ray emitting electrons (at 2E$_2$ keV) is << system's age ⇒ quasi-steady state:

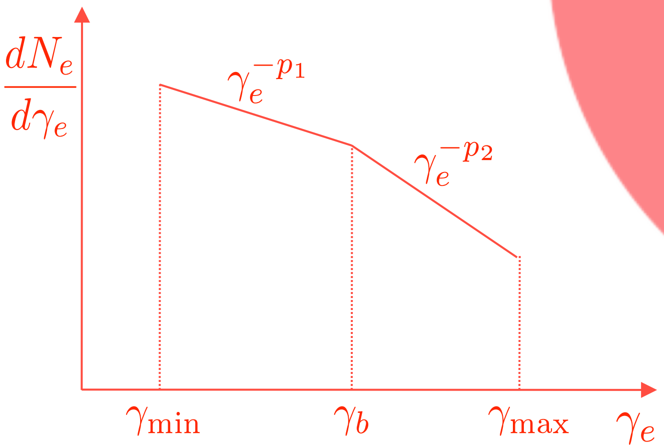
$$t_{\rm syn} = \frac{6\pi m_e c}{\sigma_T B^2 \gamma_e} \simeq 1.02 B_{15\mu{\rm G}}^{-3/2} E_2^{-1/2}\ {\rm kyr}\ .$$

- The spectrum reflects the electron distribution:

single power law?



Broken power law?



- Other relevant quantities: wind/outflow composition & Lorentz factor or pair multiplicity, minimal & maximal Lorentz factor, power-law index/es

Total emitted power (0.5 – 30 keV)	The spin-down power	X-ray efficiency of MWN
$L_{\rm x,tot} = 2.74\times 10^{33} d_4^2\ {\rm erg\ s^{-1}}$	$L_{\rm sd} = 2.05\times 10^{34}\ {\rm erg\ s^{-1}}$ ⟶	$\eta_X = \frac{L_{\rm X,tot}}{L_{\rm sd}} = 0.13 d_4^2$

If energy injection is not dominated by spin-down: $\langle\dot{E}\rangle = g L_{\rm sd} \Longrightarrow \eta_{X,\rm true} = \frac{L_{X,\rm tot}}{\langle\dot{E}\rangle} = \frac{\eta_X}{g} = \frac{0.0026 d_4^2}{g_{50}} < 0.042 \frac{\sigma}{1+\sigma} d_4^{-1} E_{M,30}^{-\frac{7}{2}} f^{-\frac{7}{2}}$

Observed Size & Spectral Softening: Role of Diffusion

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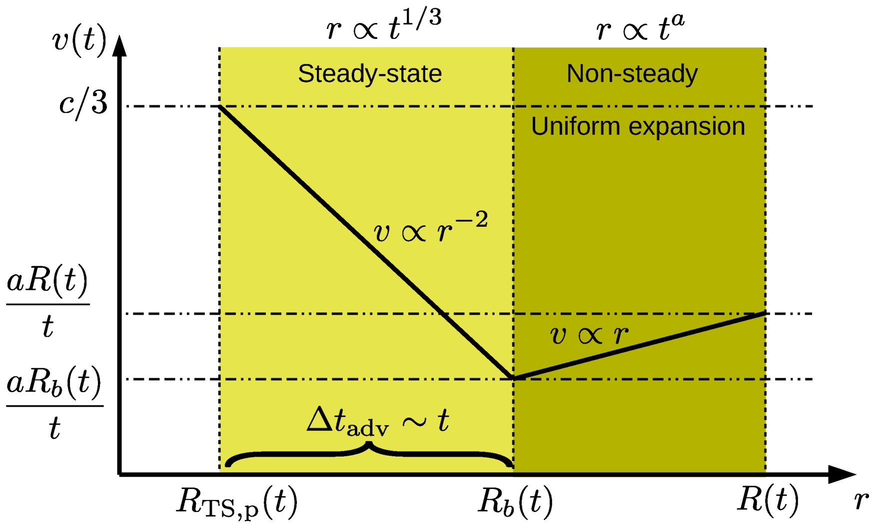
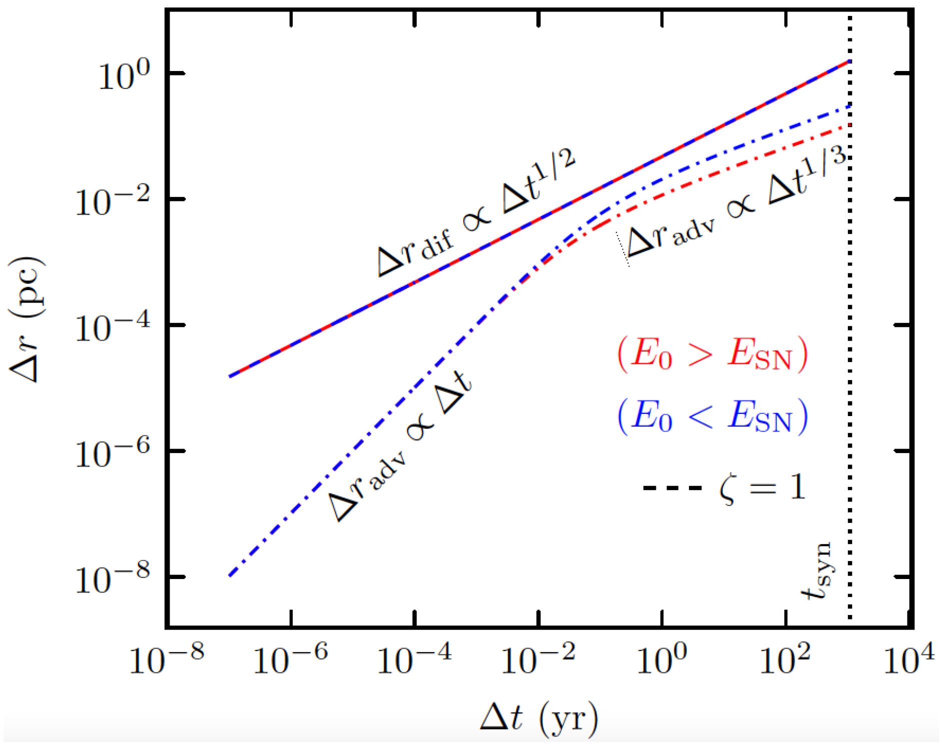


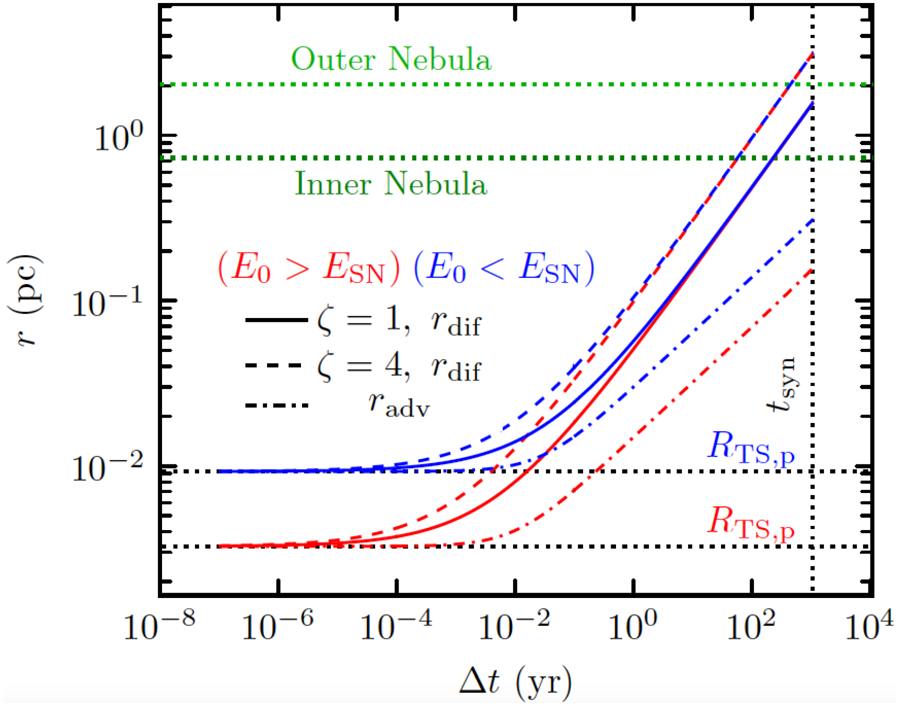
- Diffusion dominates over advection in whole MWN

$$r_{c,{\rm dif}} \approx \sqrt{2\lambda_{\rm def} c t_{\rm syn}(\gamma_e)} \approx 1.57\, B_{15\mu{\rm G}}^{-3/2}\zeta^{1/2}\ {\rm pc}$$

$$\zeta \equiv \lambda_{\rm def}/R_L \gtrsim 1\ (\zeta = 1 \text{ corresponds to Bohm diffusion})$$

- Resulting cooling length ~ observed nebula size R$_X$ ⇒ may also explain the spectral softening





The Detectability of Magnatar Wind Nebulae

- Is Swift J1846.9–0846 unique in any way (J1935?)? What helps produce a detectable MWN?
- It is currently ~1-2 MWNe around ~30 known magnetars (small number statistics)

- What makes the difference? Intrinsic vs. External properties:
- Initial spin period P_0 & rotational energy E_0
- Initial surface dipole field B_0
- Pair multiplicity & wind Lorentz factor
- Natal kick velocity

Small kick velocity: magnetar remains inside its SNR, which confines a MWN (traps the outflows & results in a relatively bright, easier to detect emission)

$$\mathrm{offset} \lesssim (0.05 - 0.1)\mathrm{R_{SNR}} \Longrightarrow \mathrm{v_{\perp,SGR}} \lesssim (30 - 60)\mathrm{d_4}(\mathrm{t_{SNR}}/10^{4.5}\ \mathrm{yr})^{-1}\ \mathrm{km\ s^{-1}}.$$

Large kick velocity: magnetar exits its SNR & forms a bow-shock containing much less energy (most of the outflow escapes, leading to weaker, harder to detect emission)

$$\mathrm{SGR\ 1806-20:\ v_{\perp,SGR}} \approx 580\mathrm{d_{15}\ km\ s^{-1}}\ ,\quad \mathrm{SGR\ 1900+14\ v_{\perp,SGR}} = 130 \pm 30\ \mathrm{km\ s^{-1}}$$

- External medium density (SNR & MWN evolution) + composition (bow shock X-ray efficiency)