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Evidence for 3XMM J185246.6+003317 as a massive magnetar with a low magnetic field

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Astronomy & Astrophysics

Layers of electron captures in the crust of accreting neutron stars

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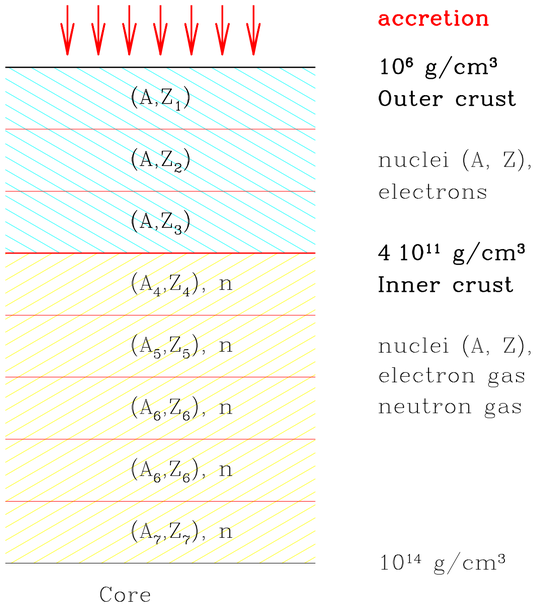
Accretion vs. reactions

Classical approach	Reaction rate vs accretion
Infinite reaction rate	Reaction rate depends on experimental data, pressure and abundance of nuclei
Local equilibrium (t,P)	Matter not in equilibrium - reactions take place
Single nucleus approximation	In the reaction layer mixture of parent and grand-daughter nuclei (A,Z), (A,Z-2)
Reaction layer - infinitesimally thin	Time evolution of reaction layer (finite size)



Reaction Layer

$$(A,Z)+e^- \rightarrow (A,Z-1)+\nu \quad \text{slow}\ ,$$
$$(A,Z-1)+e^- \rightarrow (A,Z-2)+\nu \quad \text{fast}$$

Mixture of two nuclides (isobars)

Parent nuclei N_0 (A,Z). Grand-daughter nuclei N_2 $(A,Z-2)$

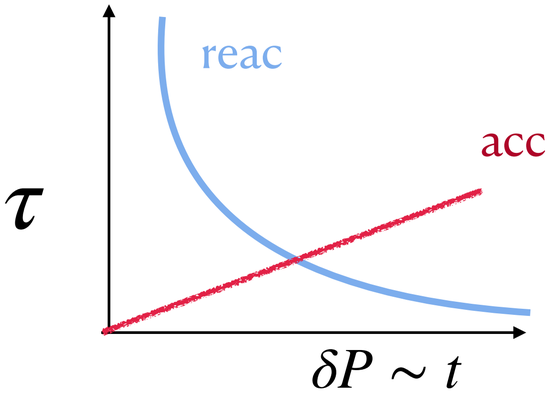
$$X=\frac{N_0}{N_0+N_2}$$

P_{th} threshold pressure - $\mu(P_{th},A,Z)=\mu(P_{th},A,Z-1)$ - corresponds to infinite reaction rate

$\delta P = P - P_{th} > 0$

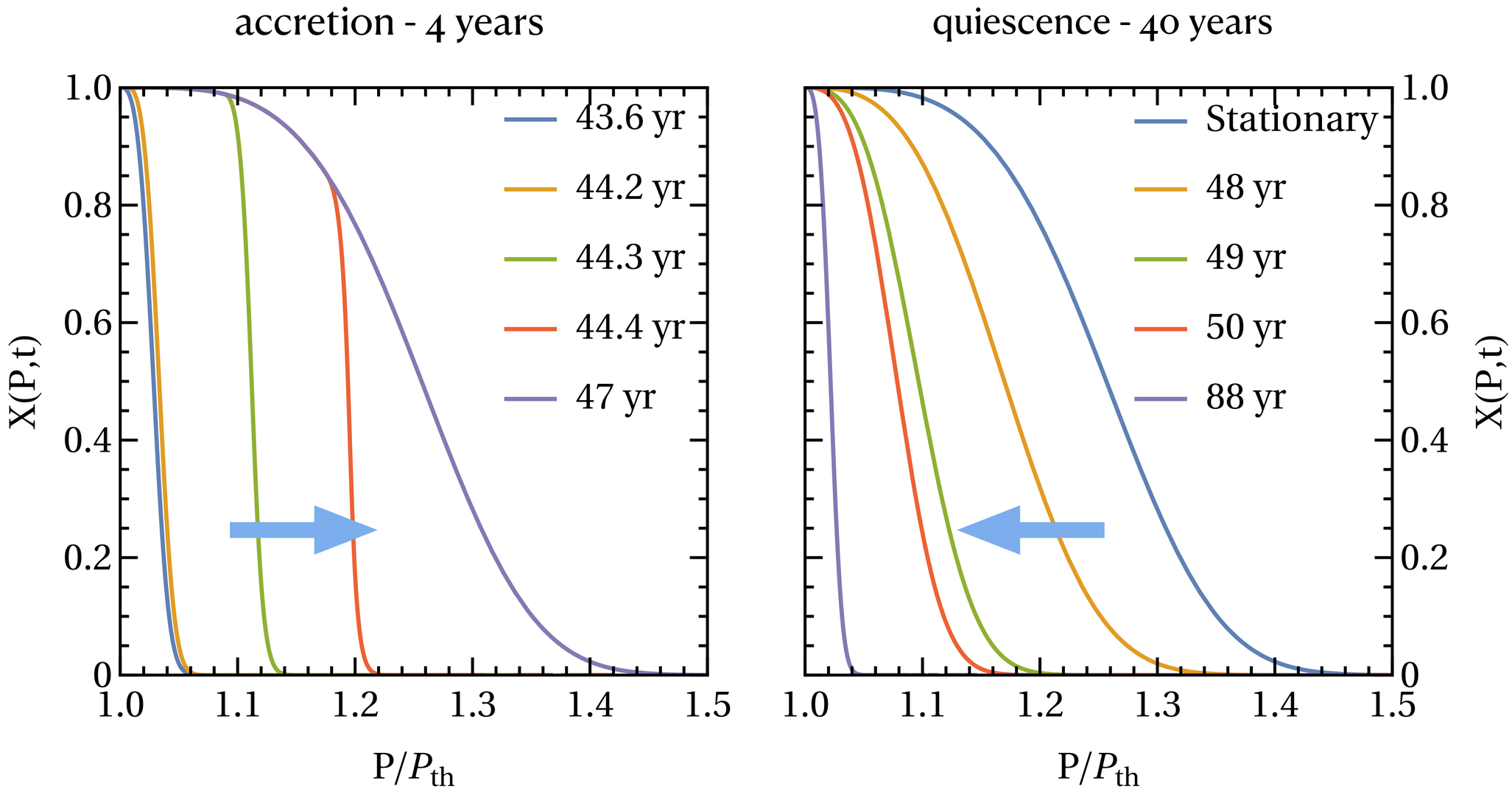
The accretion timescale: $\tau_{acc}(\delta P)=\dfrac{4\pi R^4 \delta P}{GM\dot{M}}$ - increasing function of δP

The reaction timescale: $\tau_{react}=\tau_{react}(\delta P, X;(N,Z))$ - decreasing function of δP



$$\partial_\tau(nX)+\ \partial_z(vnX)=-nX\mathscr{R}_{\rm ec}\ .$$

Evolution of the reaction layer



Conclusions

- The heat sources are time- and pressure- dependent
- The total heat release is a function of astrophysical (active and quiescent time) and microscopic (reaction rate) parameters.
- These parameters should be considered separately and individually for each reaction layer.
- Thickness of the reaction layers: $\delta P = 10^{-7}$ MeV/fm^3 - 10 cm – 10 m
- Shell thickness (between reaction layers) $\Delta P \sim 10^{-5} - 10^{-4}$ MeV/fm^3
- Energy release larger than in the case of instantaneous reaction (by $\sim 20\,\%$)