PROBING NEUTRON STAR INTERIORS (INCLUDING THEIR *B*-FIELDS) WITH UV OBSERVATIONS

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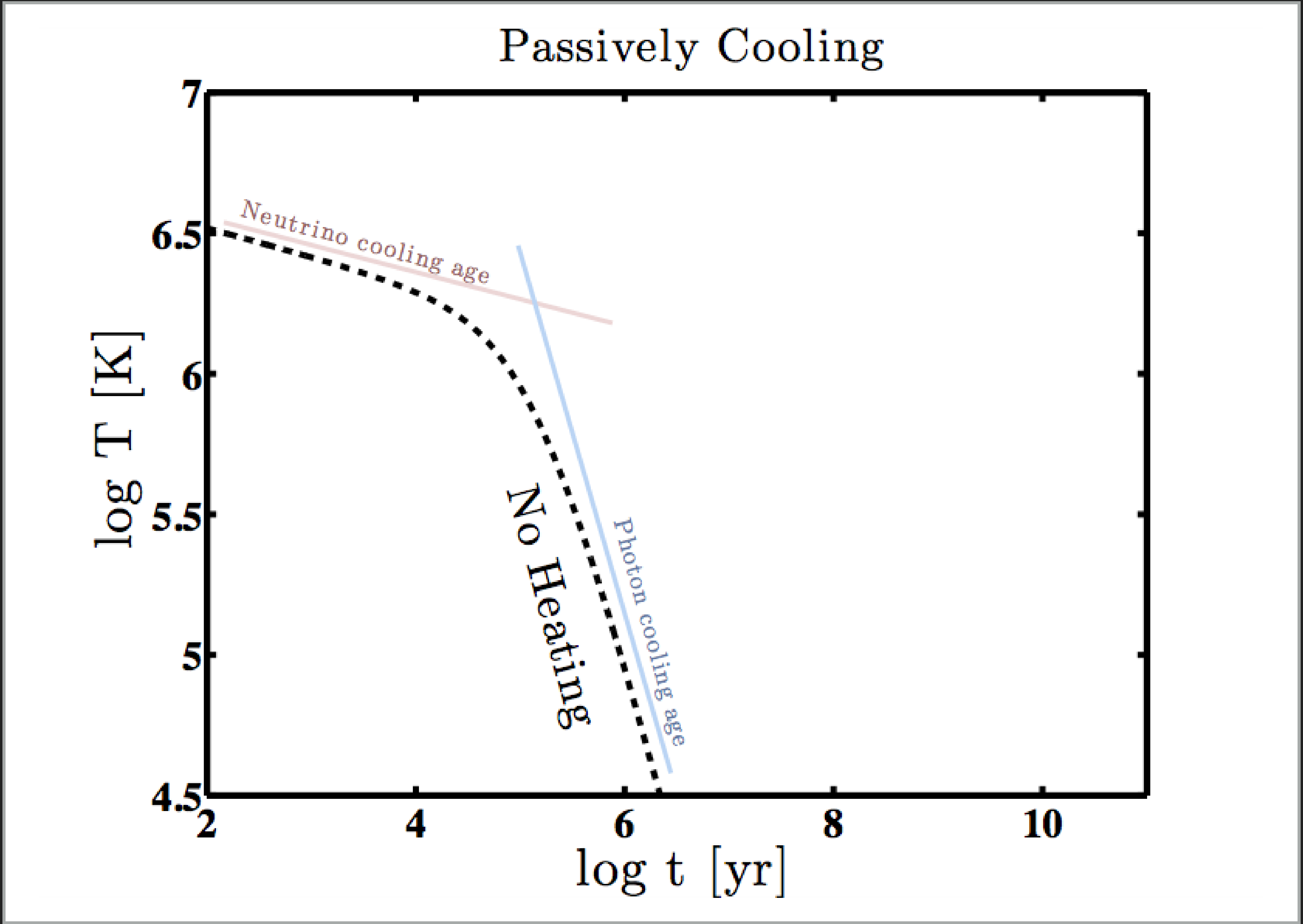
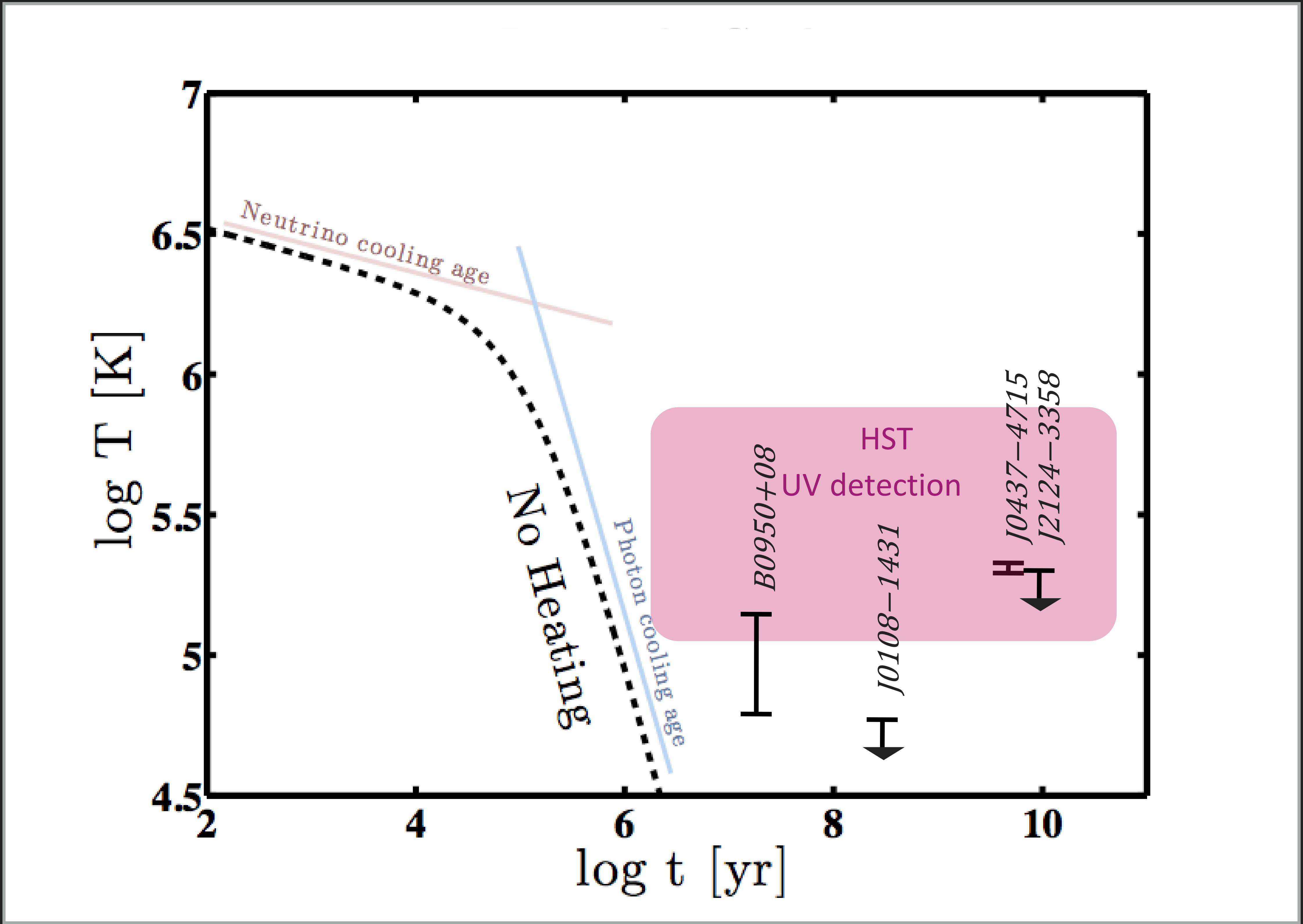
PASSIVELY COOLING NEUTRON STAR



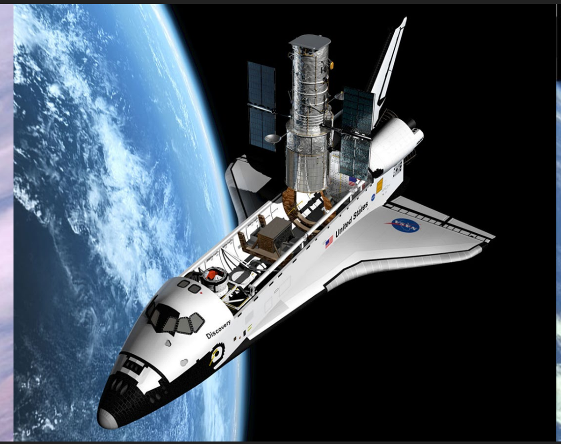
PASSIVELY COOLING NEUTRON STAR



SUMMARY OF THE OBSERVATIONS

Pulsar	*P* [ms]	log B [G]	log P/2P* [yr]	log $T_S^{\infty}/(10^5 K)$ [K]
J0437-4715	5.75	8.45	9.82	2.39-2.10
J2124-3358	4.93	8.2	10	<1.8
B0950+08	253	11.38	7.24	0.6-1.2
J0108-1431	808	11.36	8.29	<0.6
J2144-3943	8510	12.3	8.43	<0.3

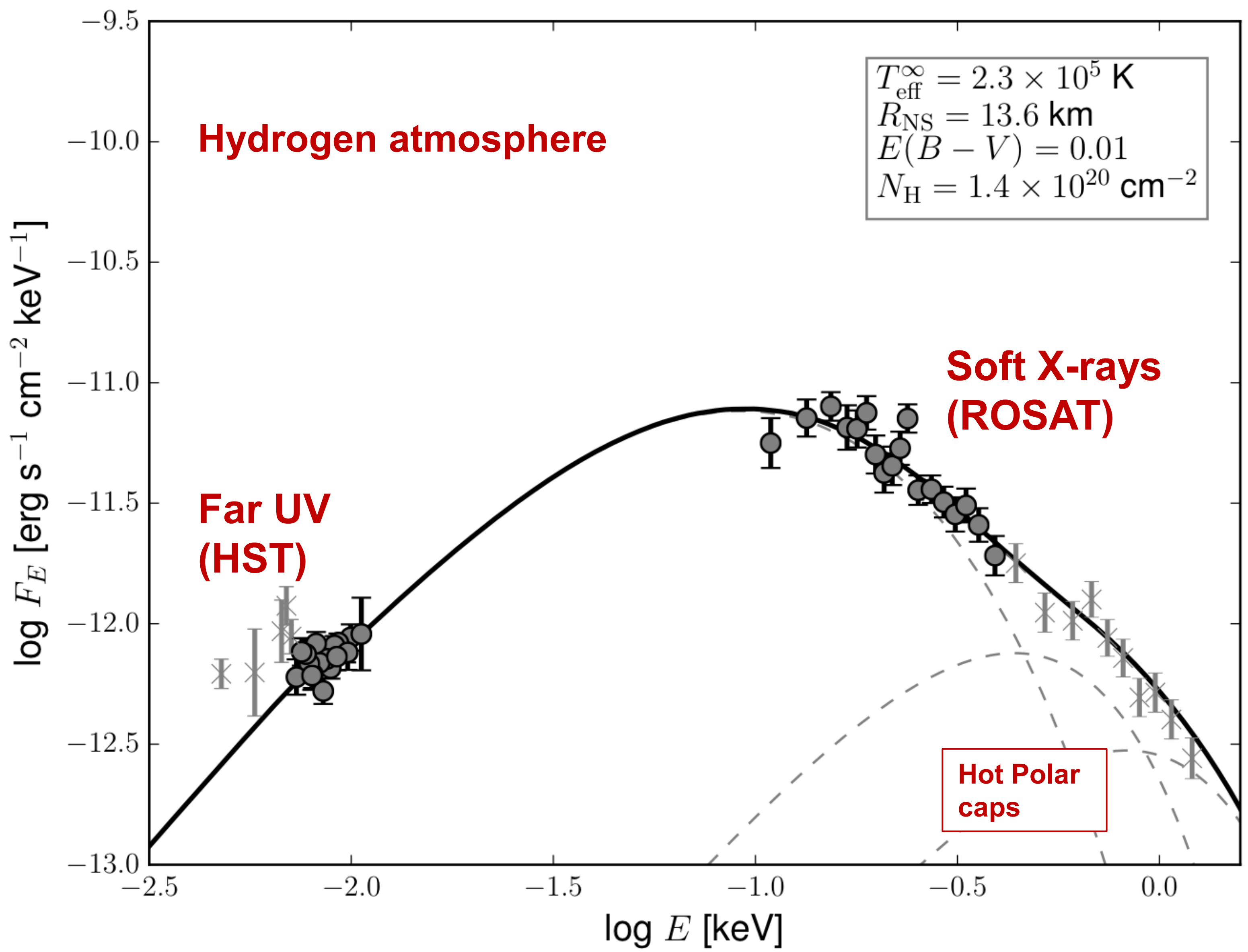
J0437-4715 Gonzalez-Caniulef et al. 2019
J2124-3358 Rangelov et al. 2017
B0950+08 Pavlov et al. 2017
J2144-3943 Guillot et al. 2019
J0108-1431 Abramkin et al. 2017

Spectral Fit of PSR J0437-4715

González-Caniulef, Guillot, and Reisenegger (2019)

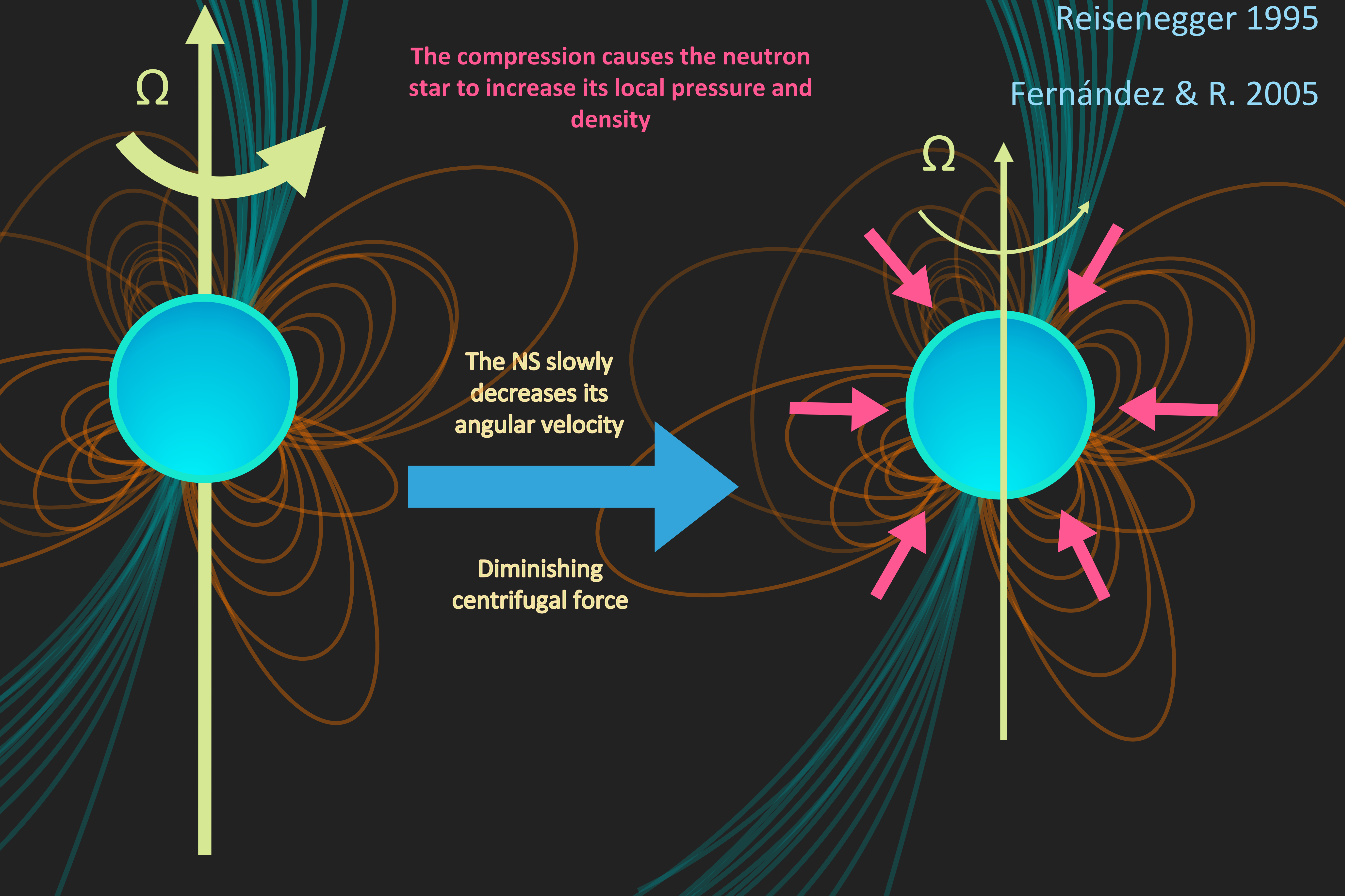
- We modelled the cool thermal component observed in the UV (HST) and soft X-rays (ROSAT), considering non-magnetic atmosphere models of neutron stars for H, He, Fe composition, as well as blackbody emission
- We perform an MCMC analysis with four parameters: radius, temperature, dust extinction, and neutral H column density.
- We found that a **hydrogen atmosphere** yields the best spectral fits.



ROTOCHEMICAL HEATING

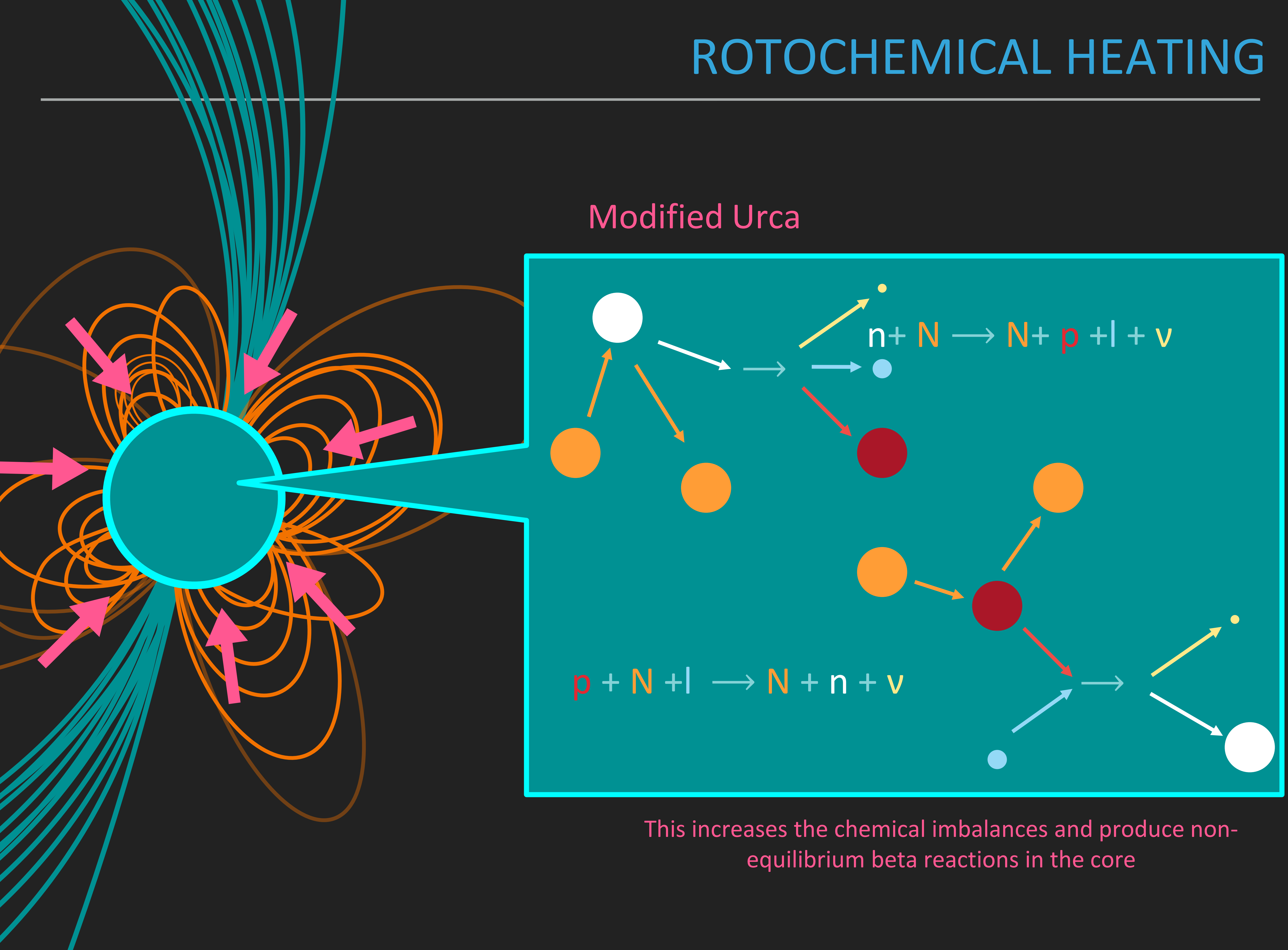
Reisenegger 1995

Fernández & R. 2005



ROTOCHEMICAL HEATING

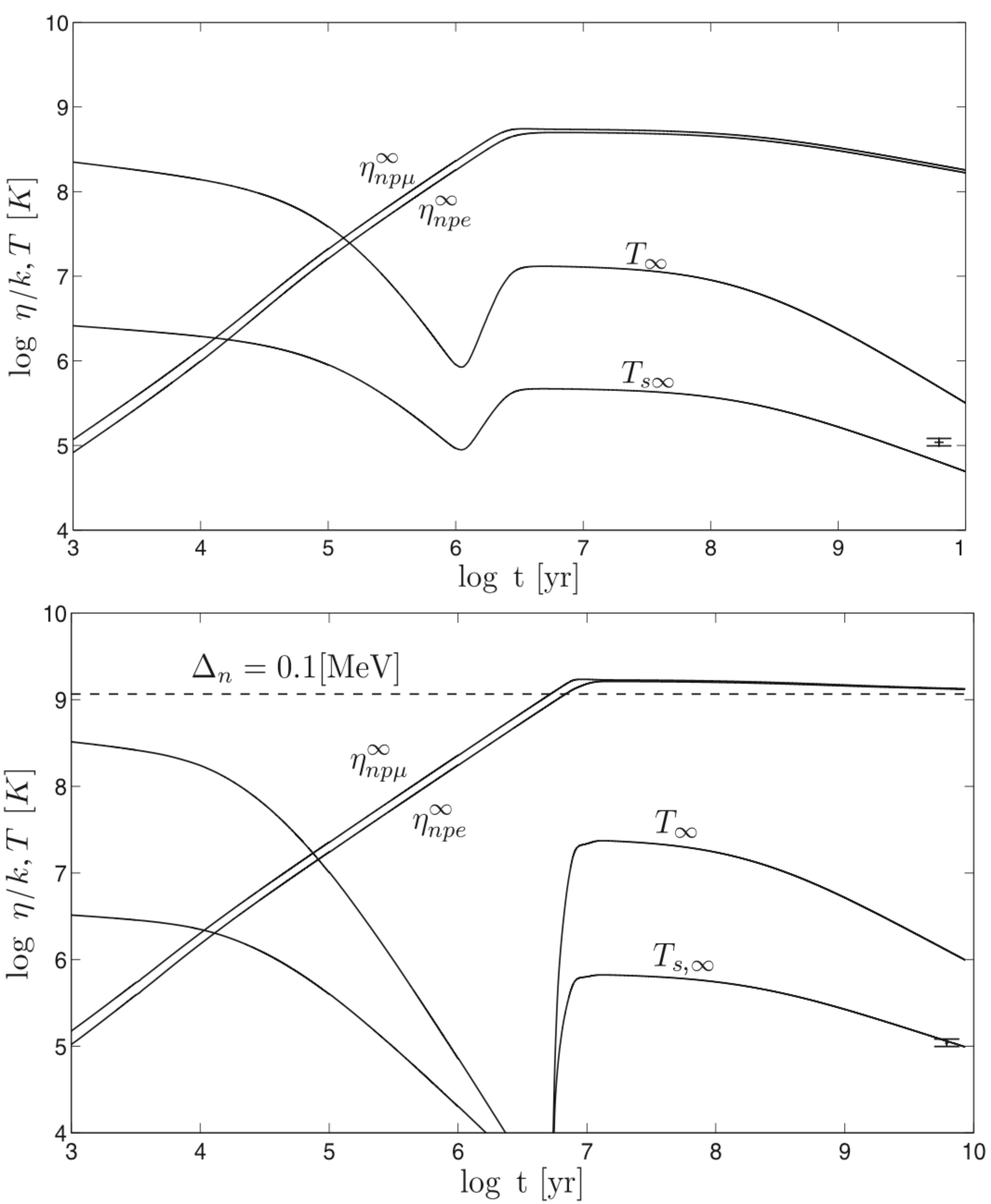
Modified Urca



This increases the chemical imbalances and produce non-equilibrium beta reactions in the core

ROTOCHEMICAL HEATING MODELS

Fernández & R. 2005, Petrovich & R. 2010



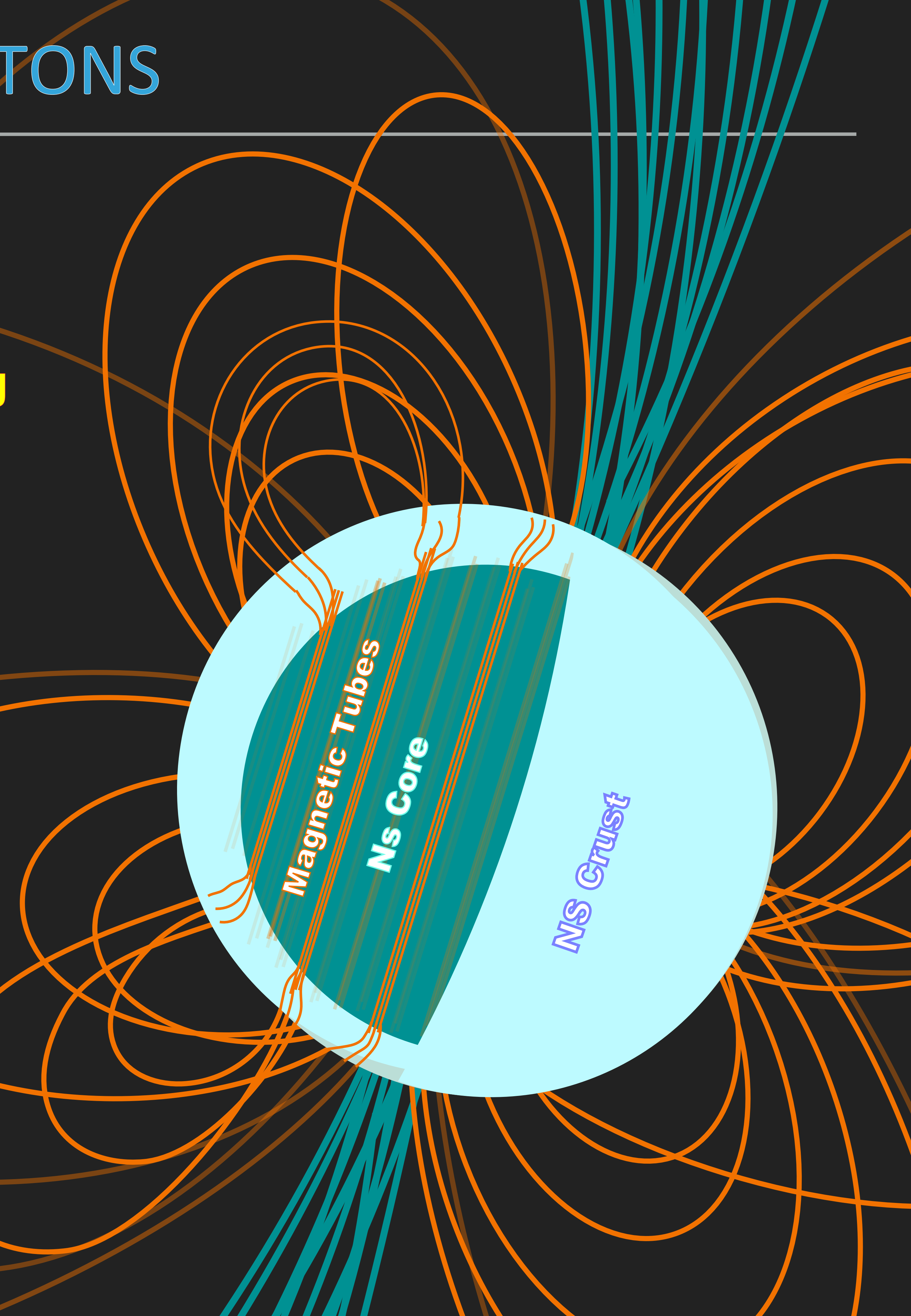
“Normal” matter

Superfluid neutrons:
energy gap suppresses reactions until chemical imbalance threshold is reached (similar for superconducting protons)

SUPERCONDUCTING PROTONS

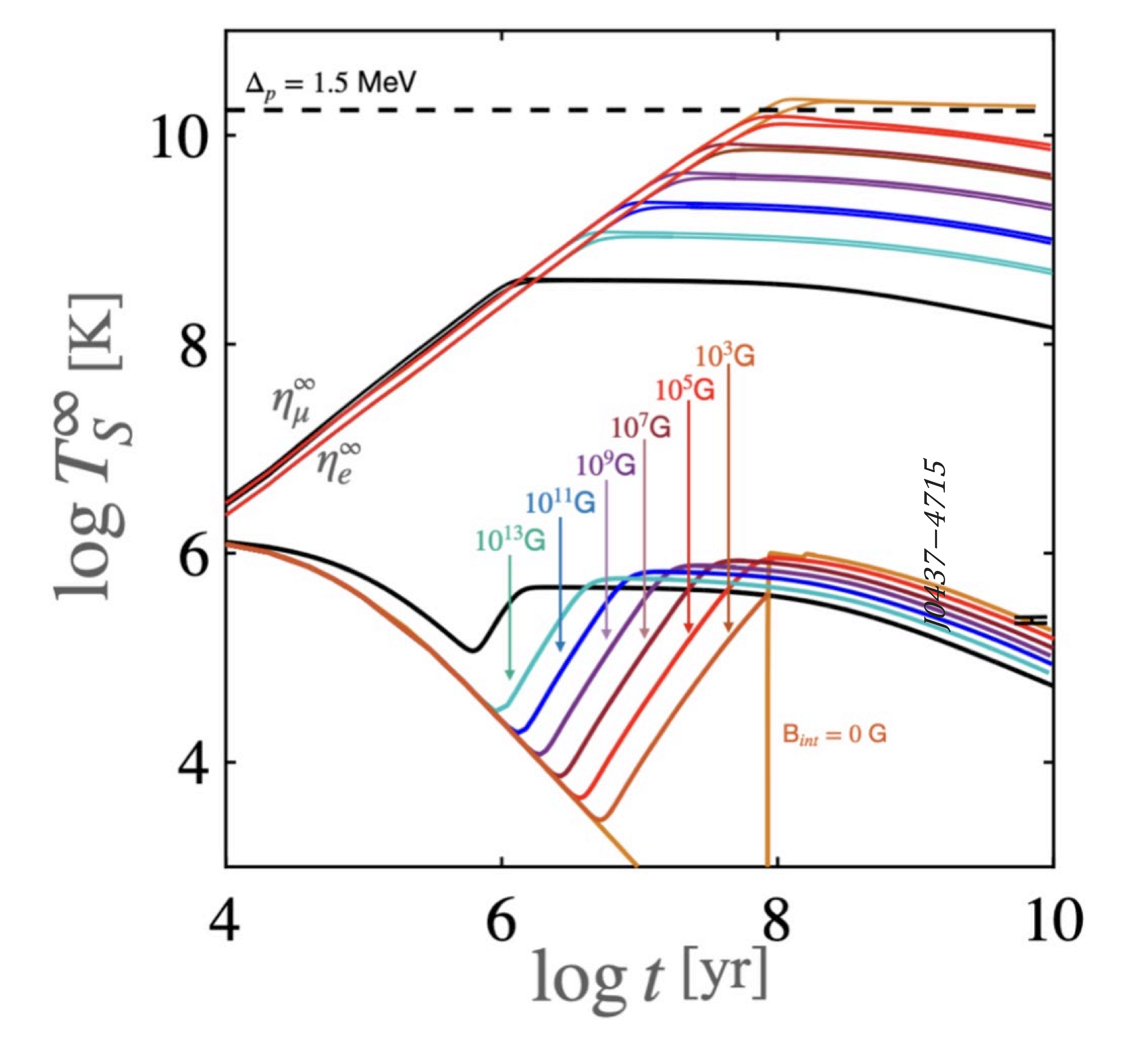
Protons remain non-superconducting inside the flux tubes cores

$$V_{norm} = \frac{B_{int}}{B_{crit}}$$



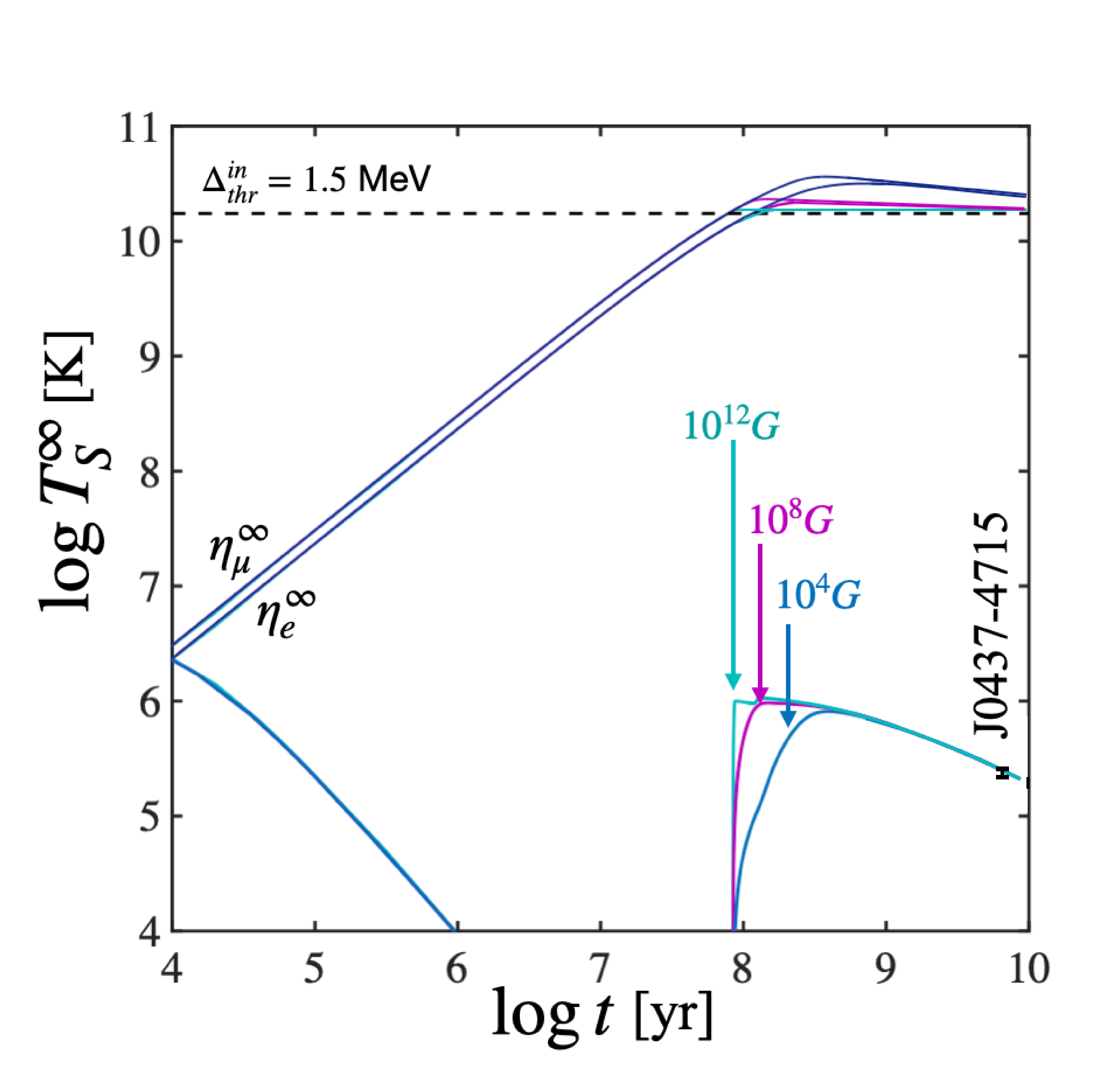
ROTOCHEMICAL HEATING WITH SUPERCONDUCTING PROTONS AND NORMAL NEUTRONS

MILLISECOND PULSARS



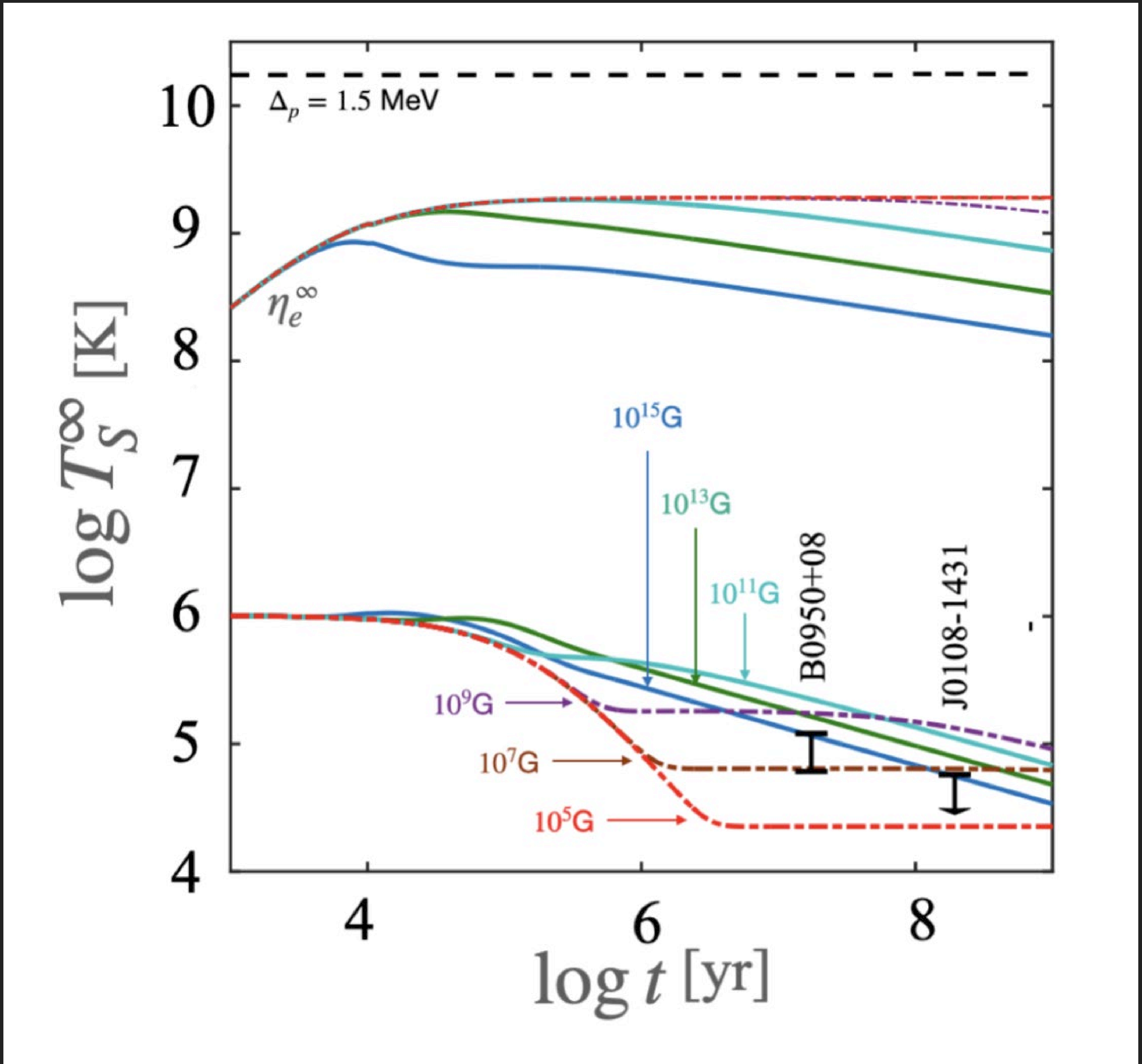
ROTOCHEMICAL HEATING WITH SUPERCONDUCTING PROTONS AND SUPERFLUID NEUTRONS

MILLISECOND PULSARS



ROTOCHEMICAL HEATING WITH SUPERCONDUCTING PROTONS AND NORMAL NEUTRONS

CLASSICAL PULSARS



SUMMARY AND CONCLUSIONS

No magnetic flux tubes

To explain the inferred temperature for MSP J0437, a gap of **1.5 MeV** is necessary, either for **superconducting protons** or **superfluid neutrons**.

The chemical imbalances reach the threshold of **1.5 MeV** if the initial period is short, which makes it very unlikely that RH dominates in CLPs.

Considering magnetic flux tubes

The inclusion of flux tubes makes it possible to explain the temperatures for MSPs and CLPs by modulating the **internal magnetic field**. Both kinds of pulsars should have a 1.5 MeV gap for superconducting protons and a very small (or null) gap for **superfluid neutrons**. MSPs require a **weak internal magnetic field**, while CLPs could be fitted with strong or weak magnetic fields.

Many uncertainties remain!

Ongoing HST observing program will provide more data:

Kargaltsev et al., *"The legacy UV survey of 28 pulsars"*