Jorge Terol Calvo

Supernova constraints on dark flavoured sectors

Phys.Rev.D 103 (2021) 12, L121301 Jorge Martin Camalich, **JTC**, Laura Tolós and Robert Ziegler

Types of Supernovae

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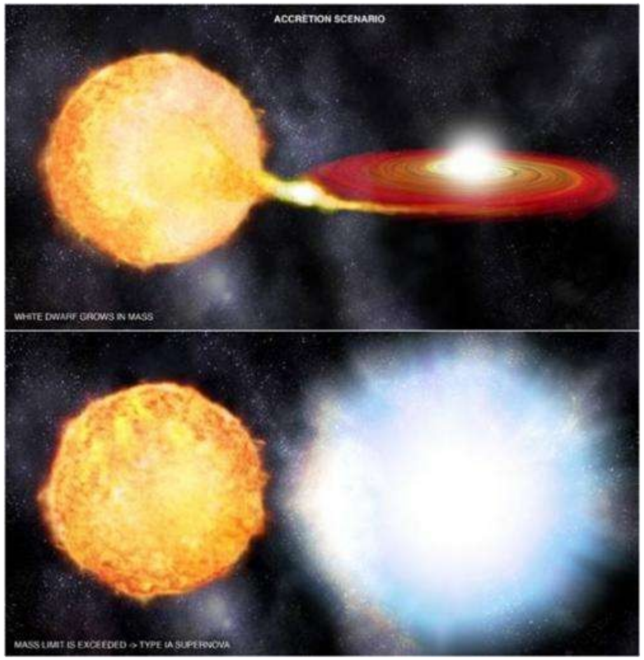
Thermonuclear supernovae



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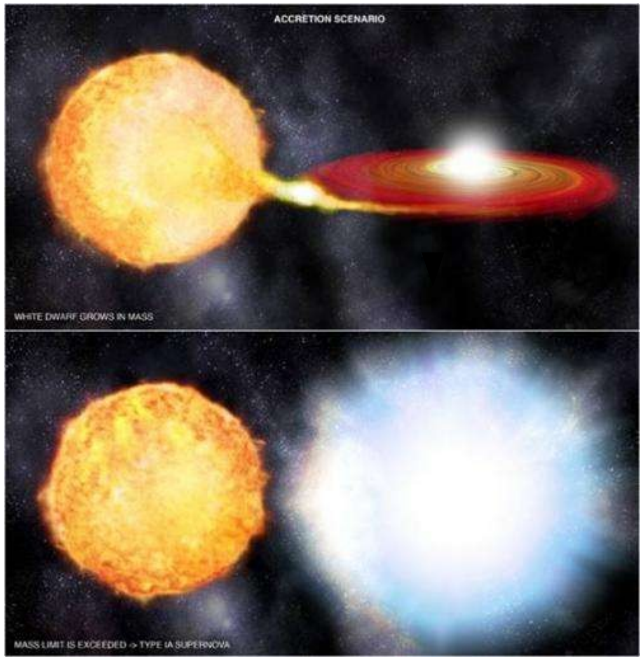
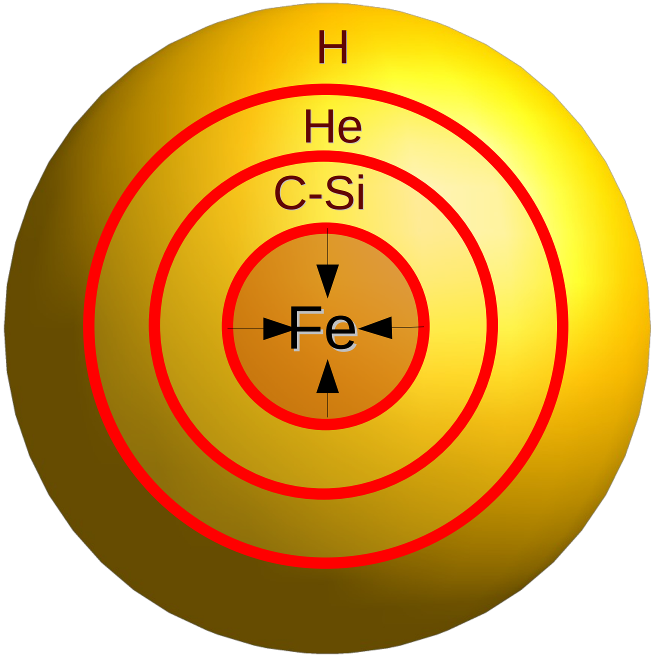


Core collapse supernovae



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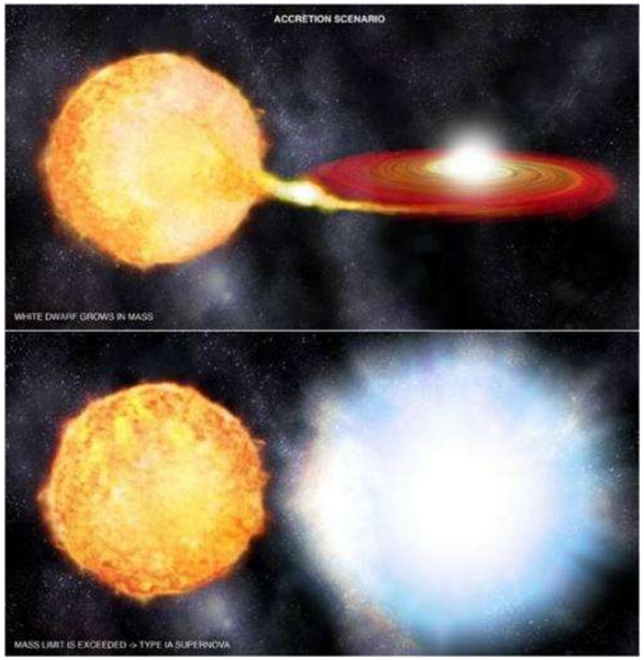

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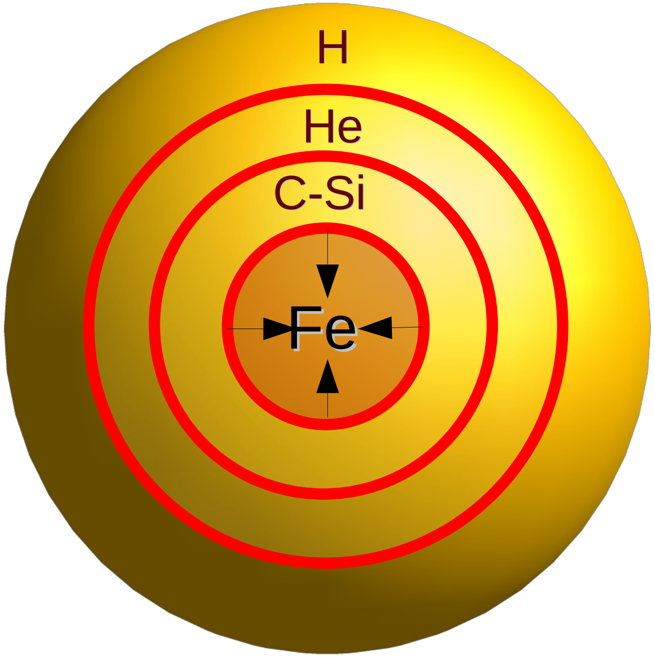
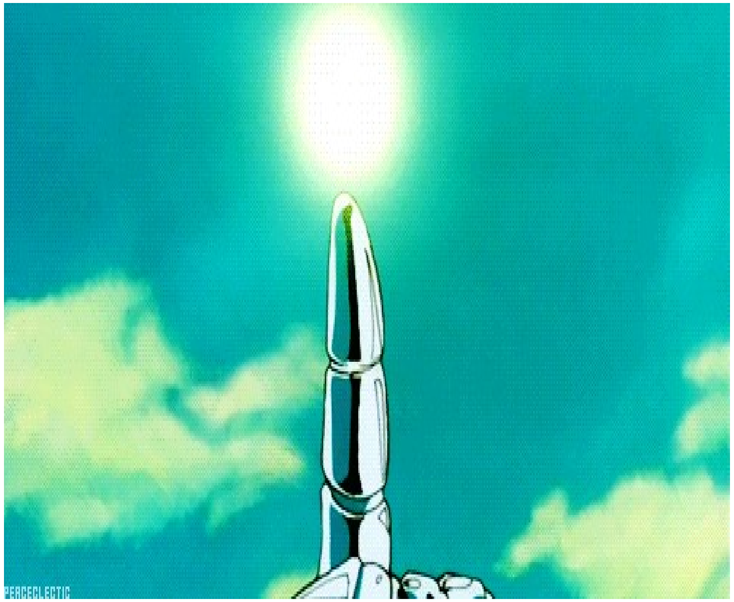


Freezer (DBZ) supernovae



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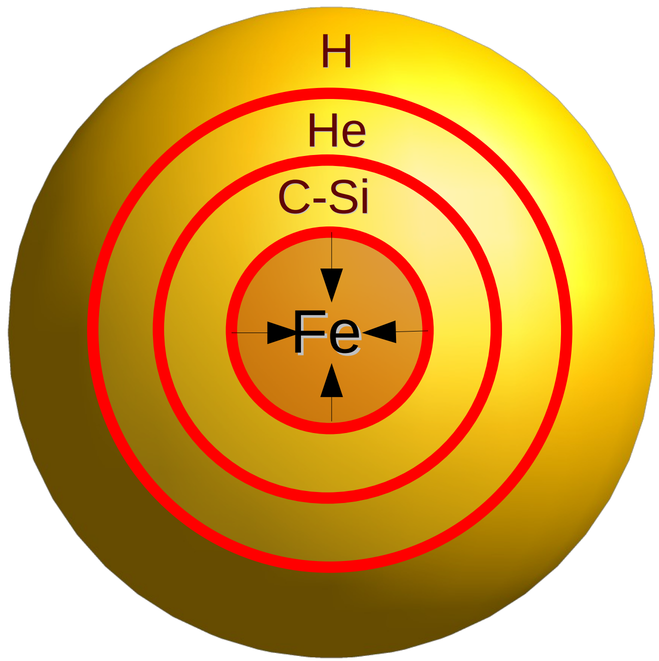

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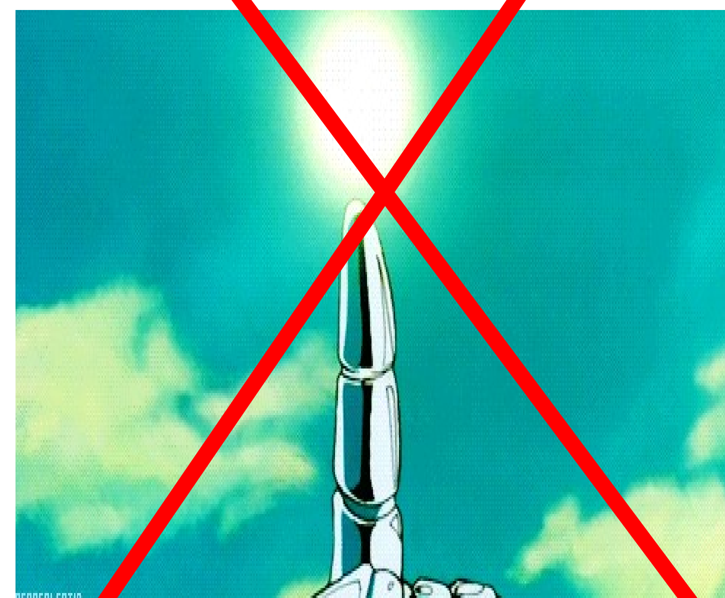

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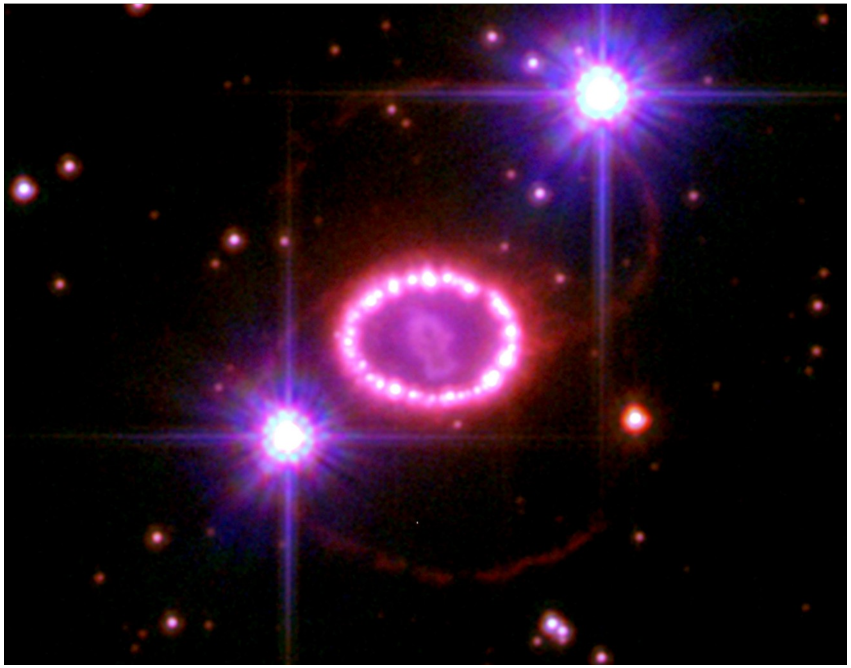

NASA, ESA, P. Challis and R. Kirshner (Harvard-Smithsonian Center for Astrophysics)

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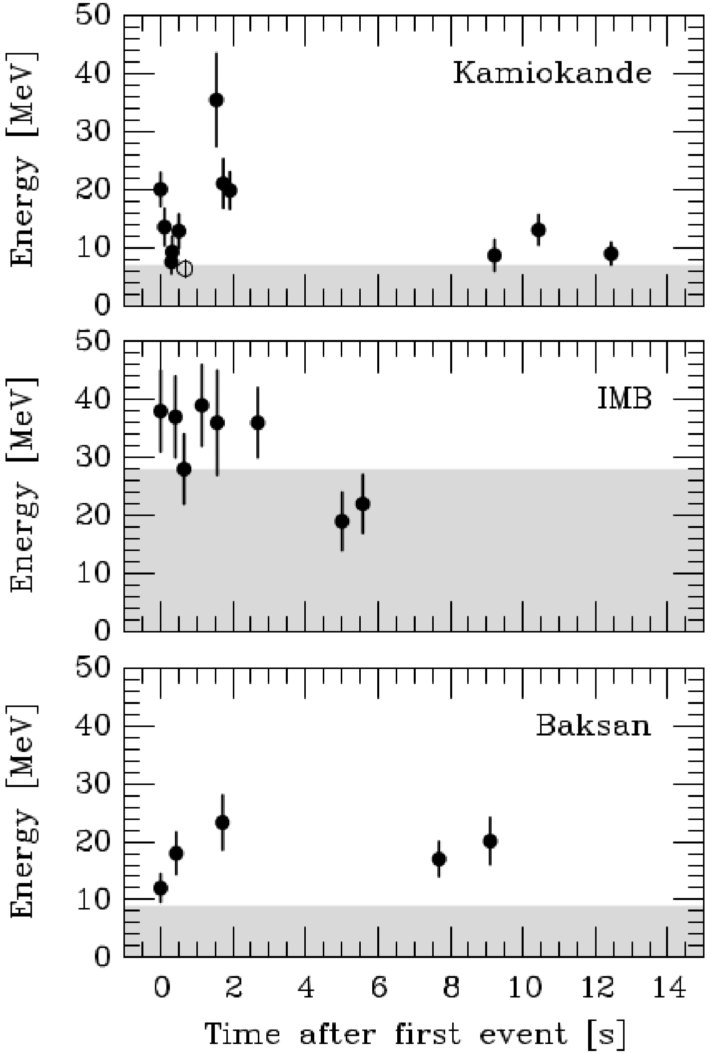

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- **SN1987A cooling bound:** $L_{\rm d} \lesssim L_\nu = 3 \times 10^{52} \;\; {\rm erg\ s^{-1}}$

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Strange cooling mechanism

Strange cooling mechanism: Hyperons!

- PNS reach T and ρ that enables Λ hyperon production.

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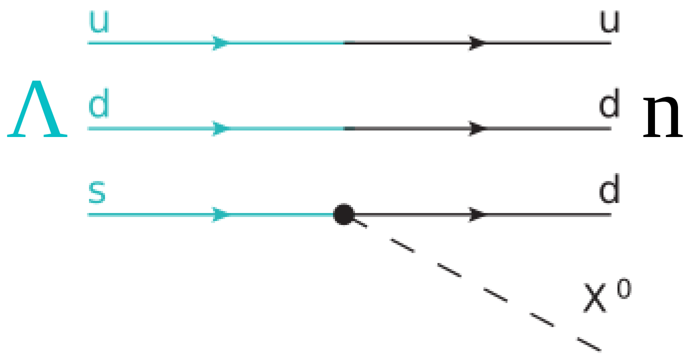

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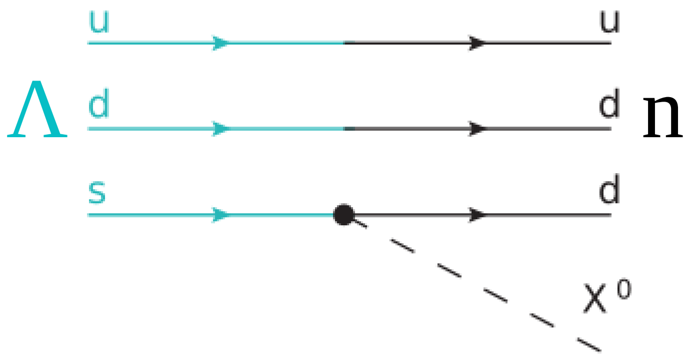

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$$\frac{dQ}{d\omega} = \frac{m_\Lambda^2 \Gamma \omega}{2\pi^2 \bar{\omega}} \int_{E_0}^{\infty} dE \, f_\Lambda (1 - f_n)$$

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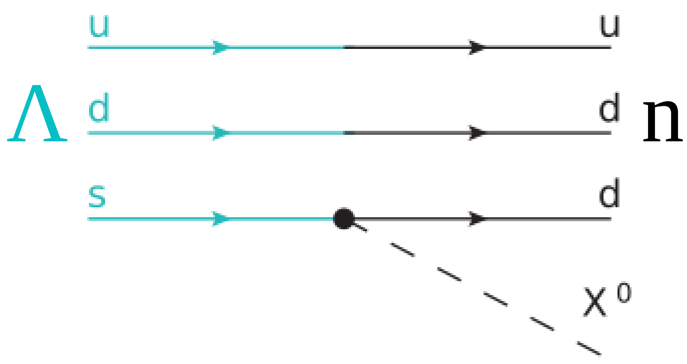

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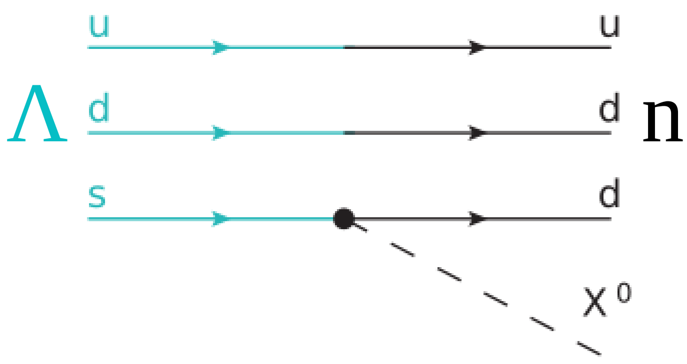

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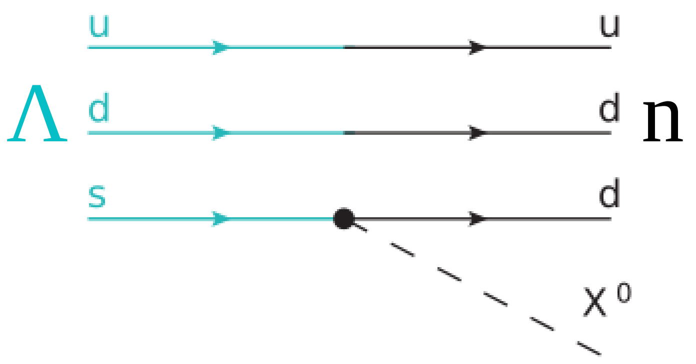

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  - $m_\Lambda - m_n \ll m_n$
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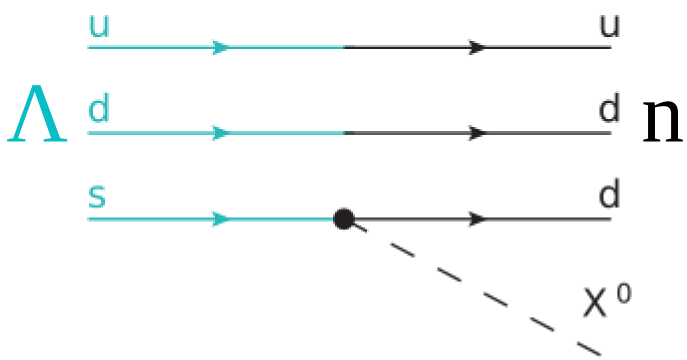

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$$Q \simeq n_\Lambda (m_\Lambda - m_n) \Gamma \simeq n_n (m_\Lambda - m_n) \Gamma e^{-\frac{m_\Lambda - m_n}{T}}$$

Martin Camalich et al. PRD 102 (2020) 1, 015023

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- In the strong coupling limit: $\lambda_\omega << R$

$$L_{\rm d}^{\rm t} = \frac{\pi^3}{30} g_s R_{\rm d}^2 T_{\rm d}^4$$

Supernova simulations and EoS

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  Bollig et al. PRL 125 (2020) 051104

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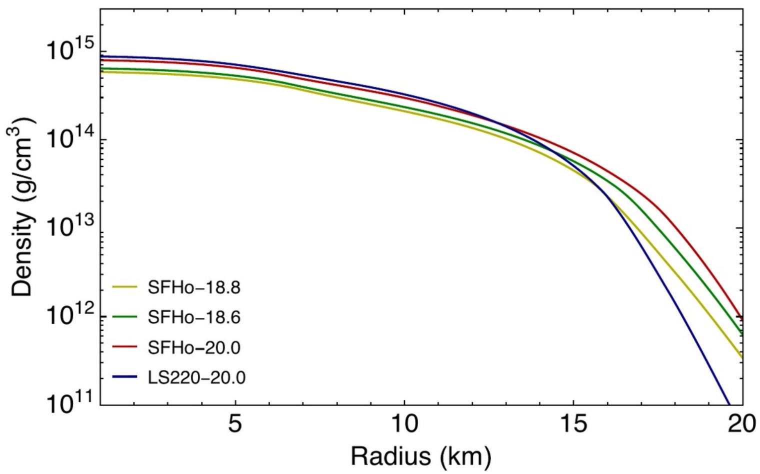

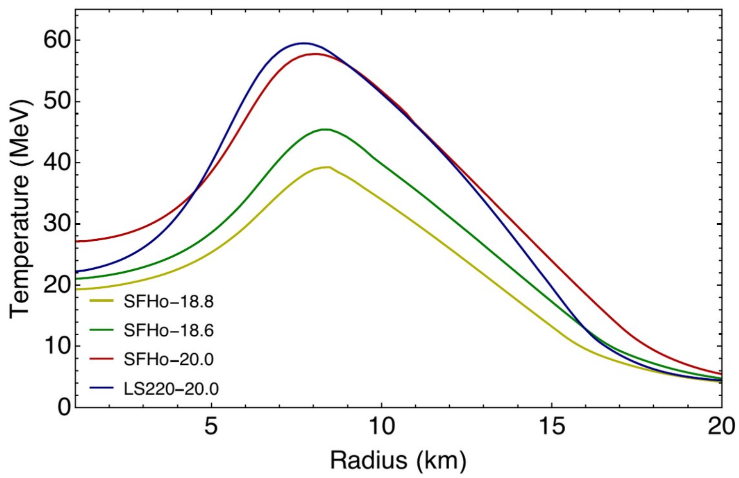

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  - But this EoS not include hyperons

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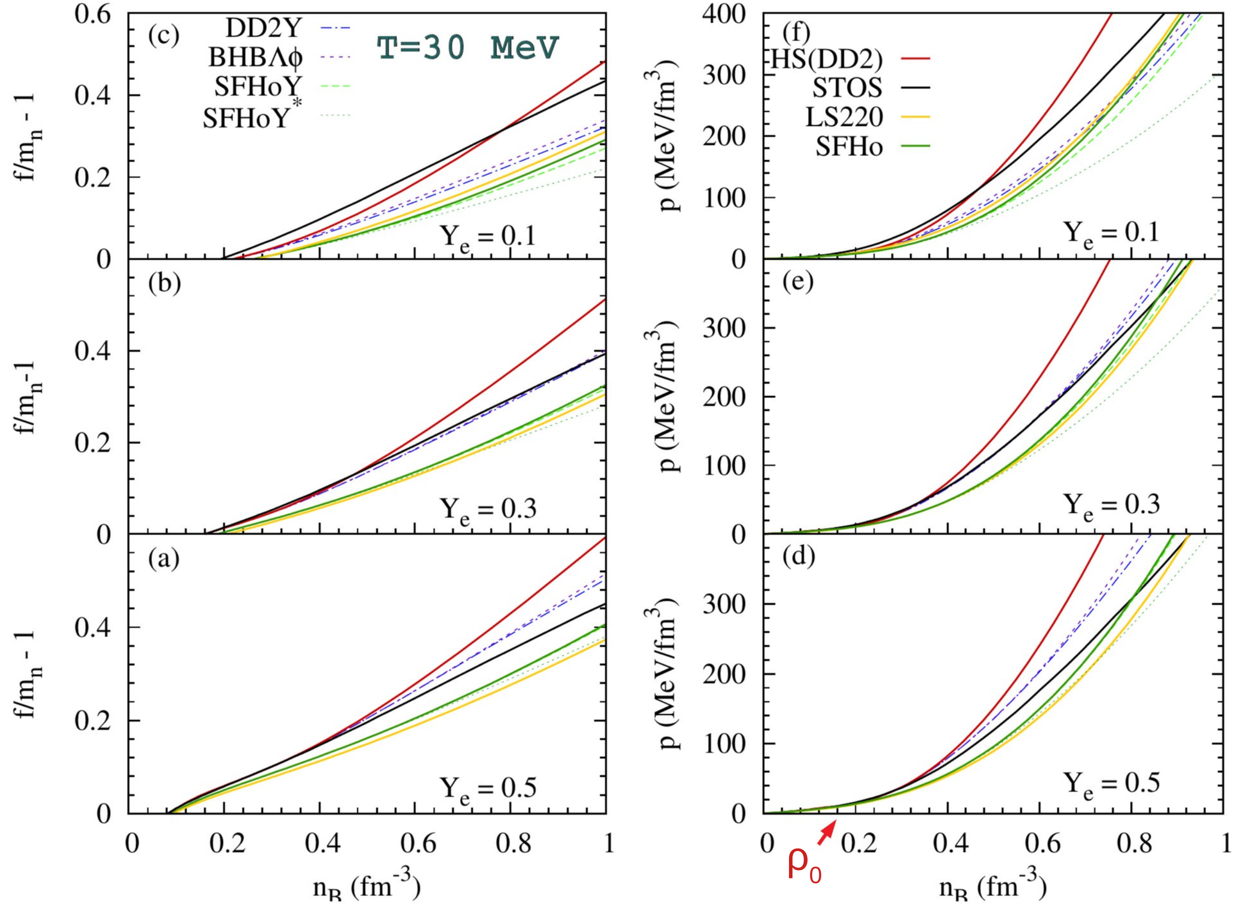
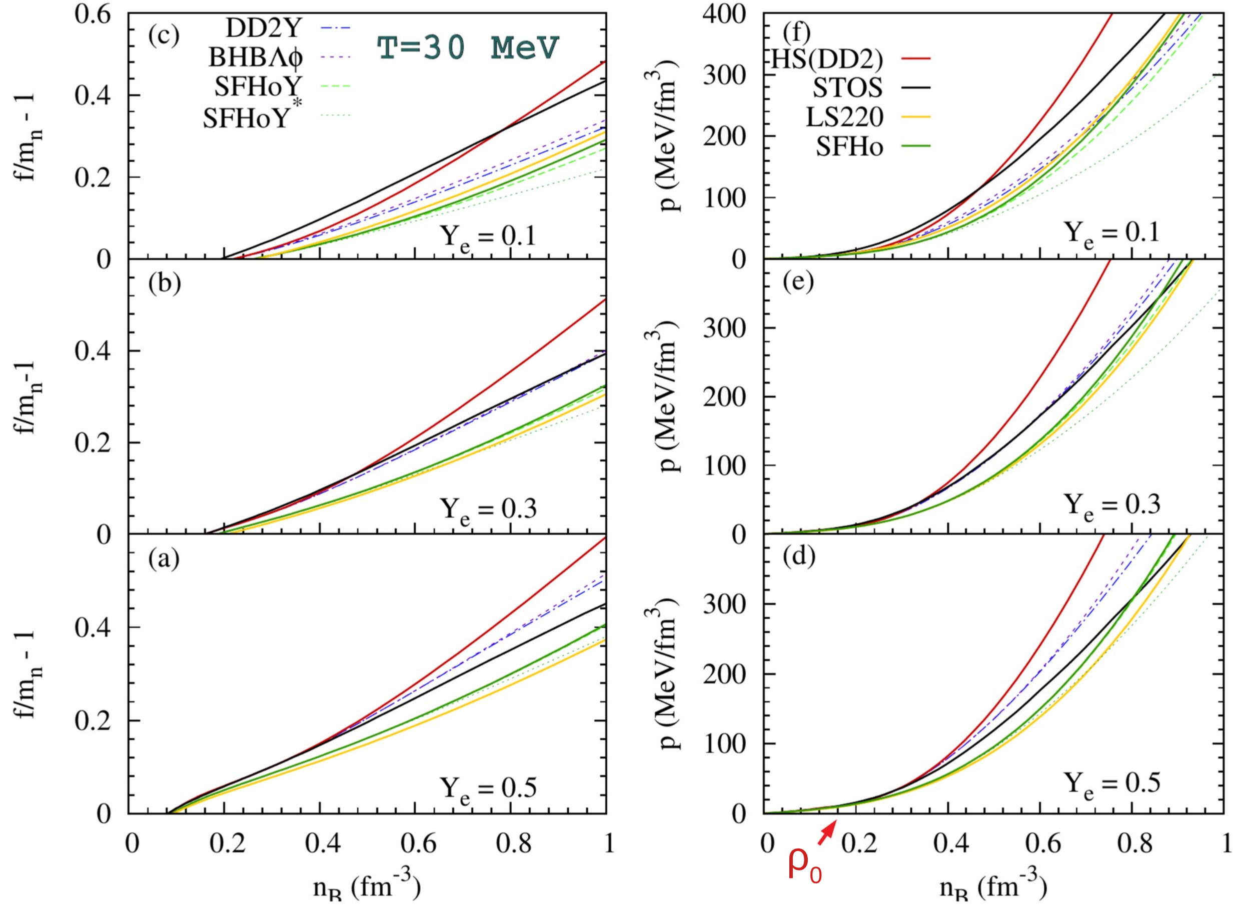


Fortin, Oertel&Providencia, arXiv:1711.09427

Supernova simulations and EoS

CAUTION
Does not reproduce NS observations

- EoS with hyperons: ... and SFHoY
- Consistent with the SN simulations? **YES**



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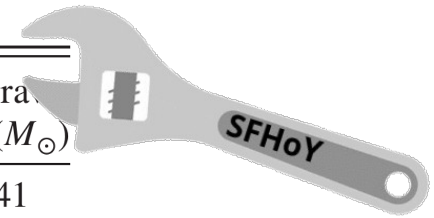

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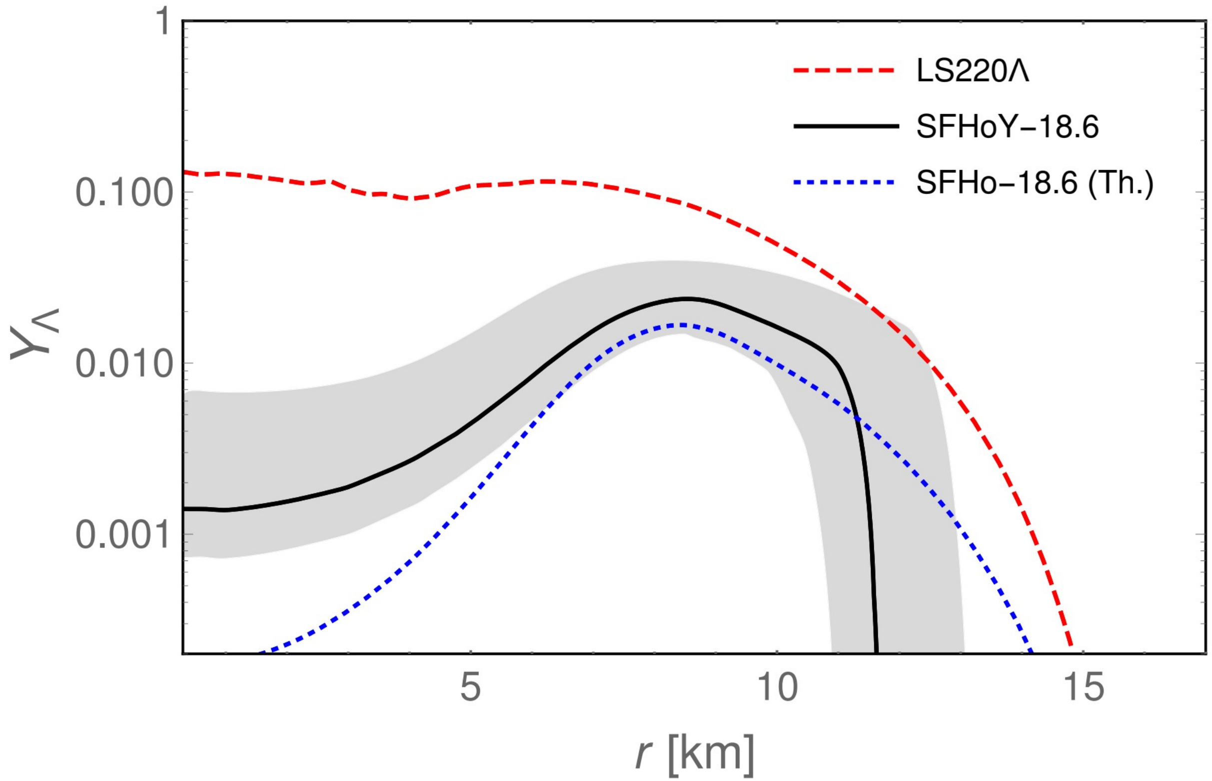
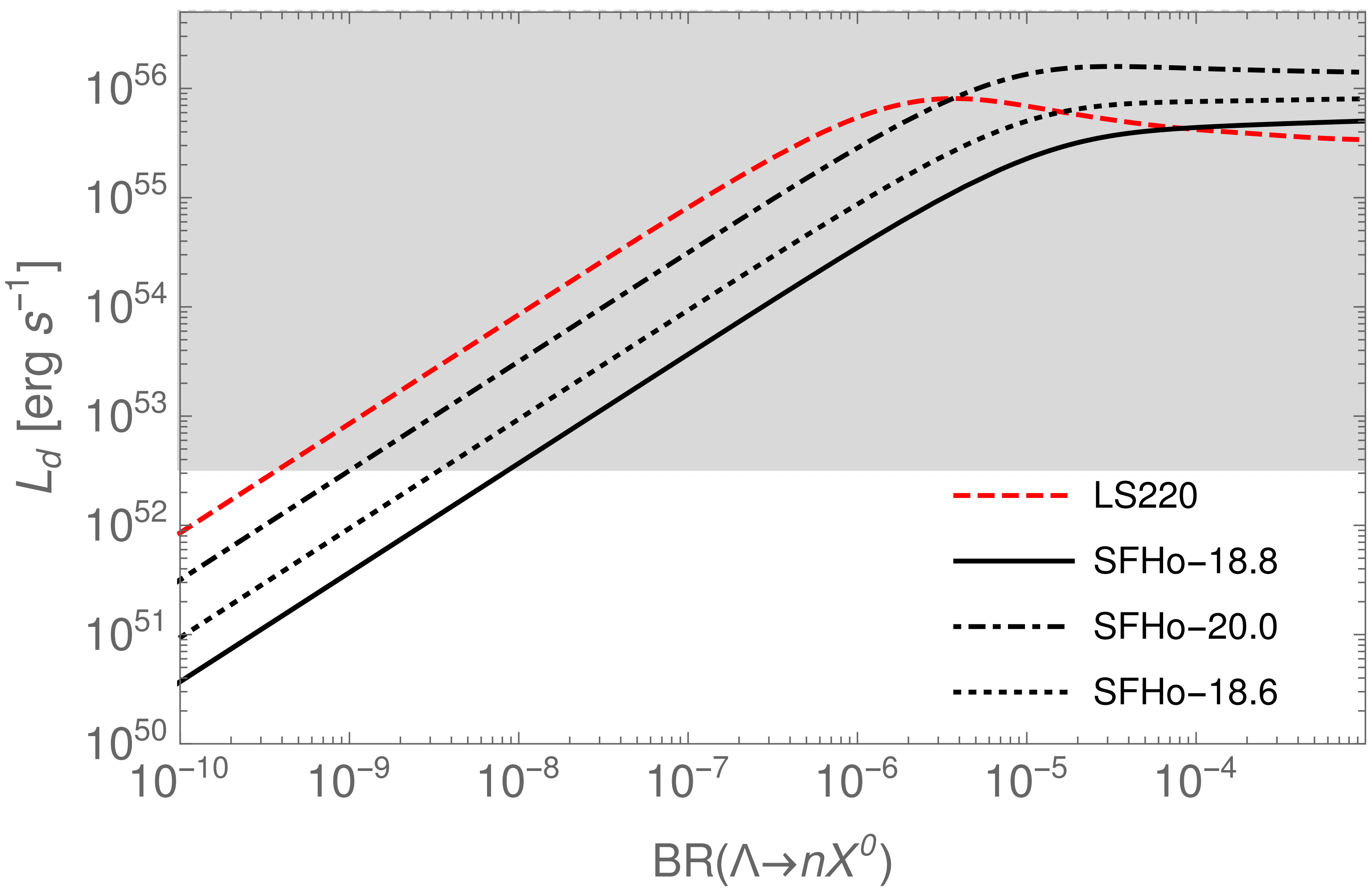
  Bollig et al. PRL 125 (2020) 051104

- With CompOSE database we include this EoS with hyperons in the simulations



Dark luminosity



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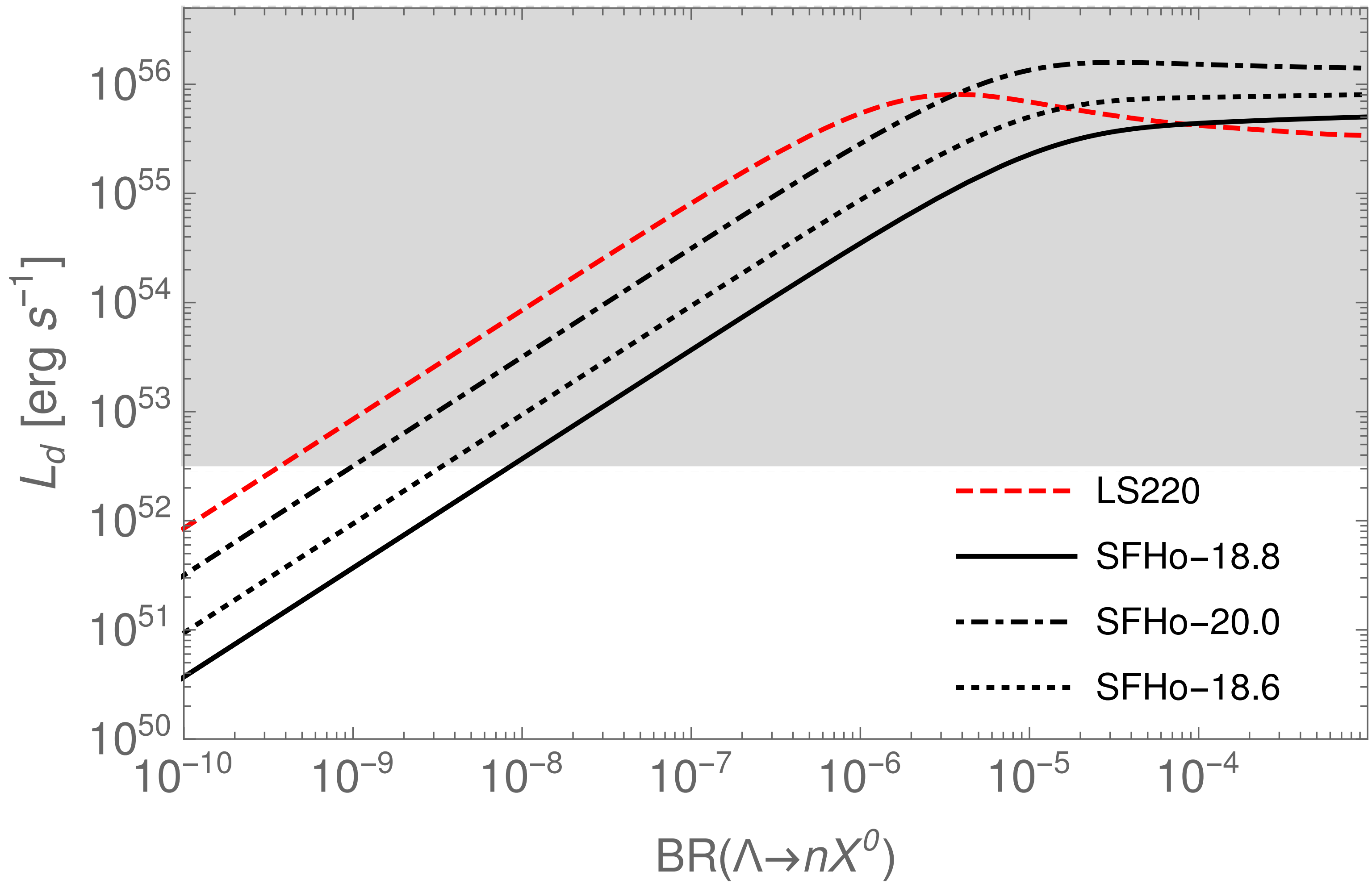

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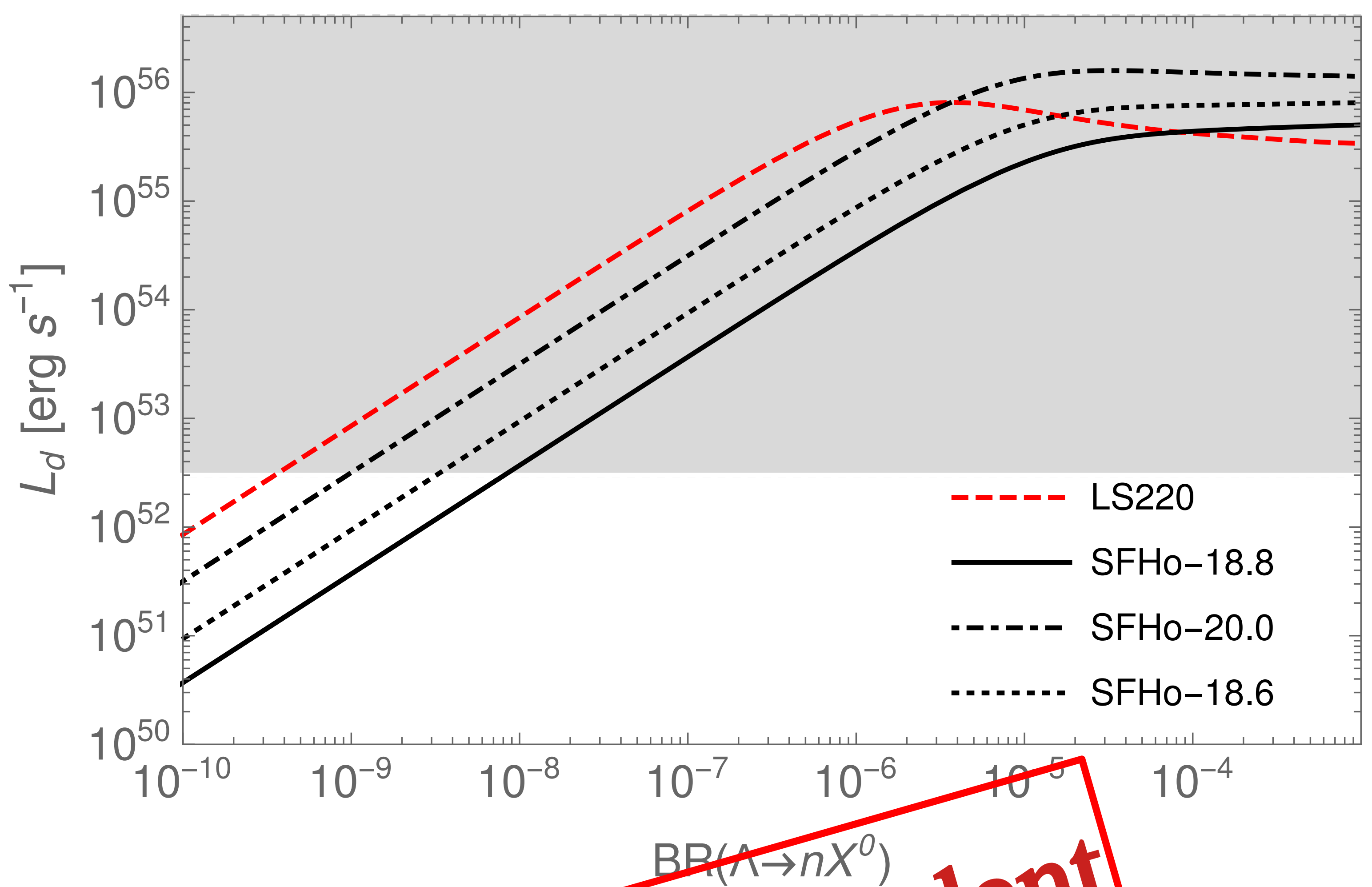

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Model independent

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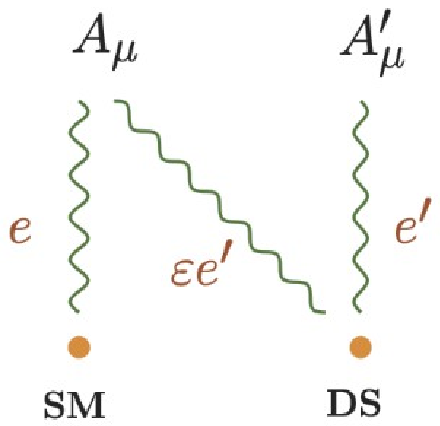

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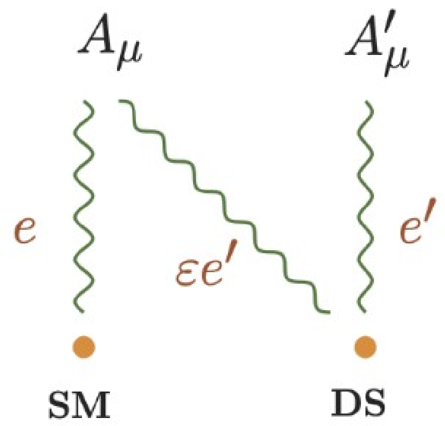

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- Couples through higher dimension operators

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Dobrescu, PRL 94 (2005) 151802

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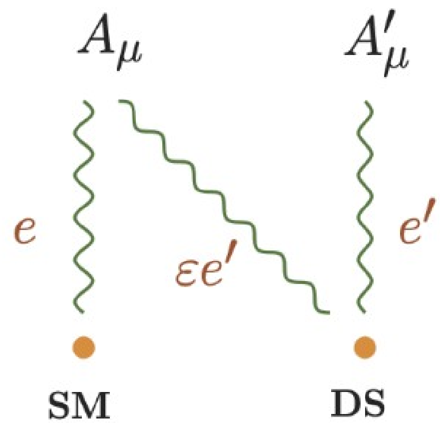

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Dobrescu, PRL 94 (2005) 151802

- Can arise in models with a natural origin for flavor.

  Fabbrichesi et al. PRL 119 (2017) 031801

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Di Luzio et al. Phys.Rept. 870 (2020) 1-117

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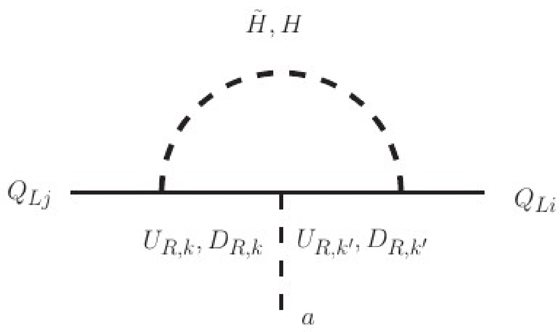
  - Radiative SM corrections generate flavour violation



Martin Camalich et al. PRD 102 (2020) 1, 015023

The QCD axion

- $\mathcal{L}_a = \frac{\partial_\mu a}{2 f_a} \bar{\psi}_i \gamma^\mu (c_{ij}^V + c_{ij}^A \gamma_5) \psi_j$ with $F_{sd}^{V,A} \equiv 2 f_a / c_{sd}^{V,A}$

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$$F_{sd}^V \gtrsim 7.1 \times 10^9 \text{ GeV} \qquad F_{sd}^A \gtrsim 5.2 \times 10^9 \text{ GeV}$$

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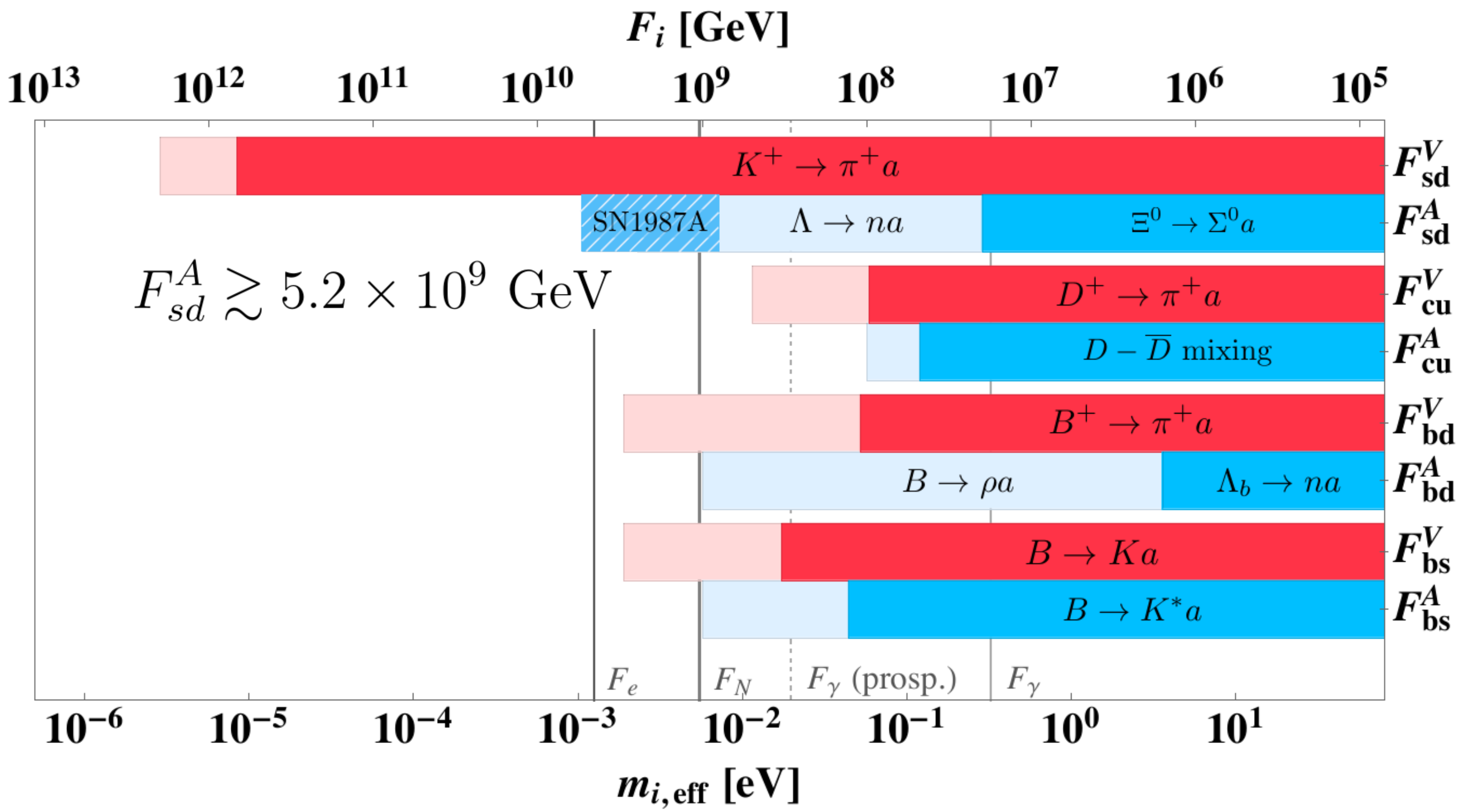

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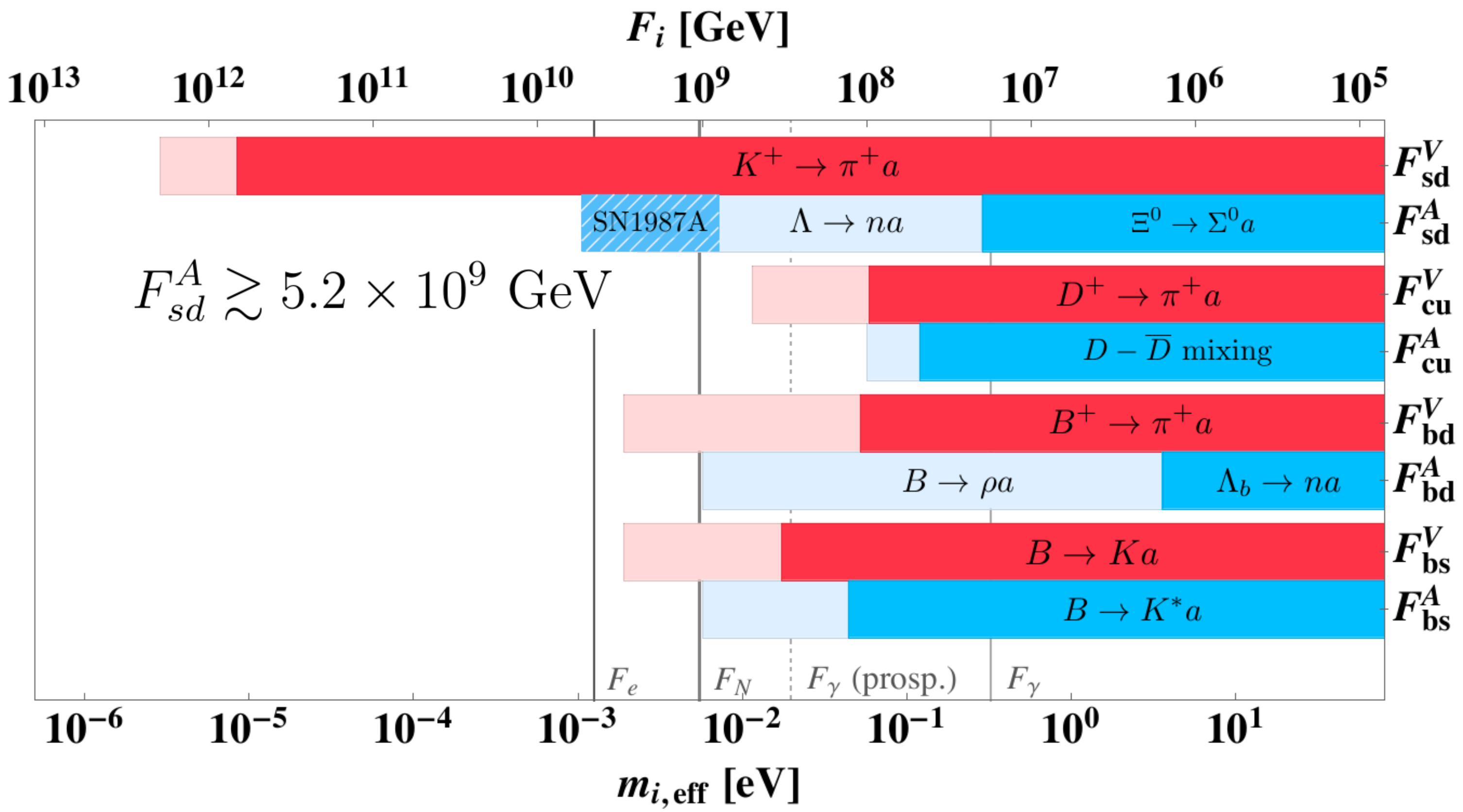

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- **Strongest limit on the axial couplings of axions to SM fermions!**

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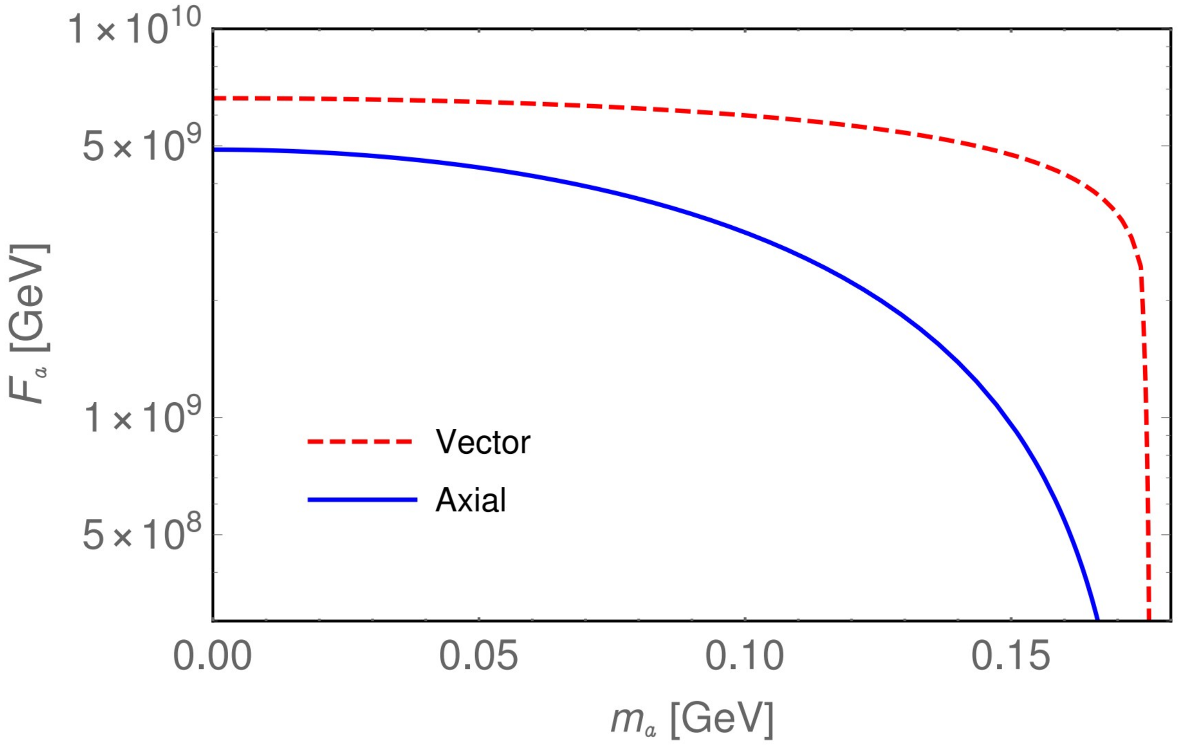

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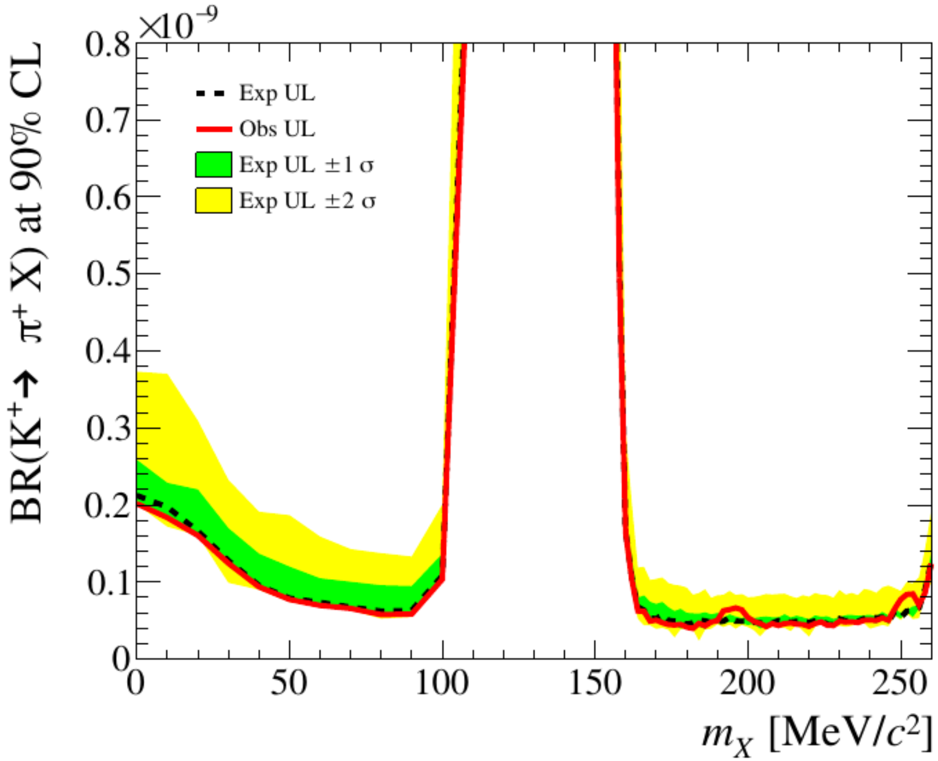
- In the region 100 MeV≤ m_a ≤ 150 MeV SN gives a more competitive bound (Vectorial)



NA62 Collab. JHEP 03 (2021) 058

The Dark Photon

- $$\mathcal{L}_{\gamma'} = \frac{1}{\Lambda_{\text{UV}}} \bar{\psi}_i \sigma^{\mu\nu} \left(\mathbb{C}^{ij} + i\, \mathbb{C}_5^{ij} \gamma_5 \right) \psi_j F'_{\mu\nu}$$

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$$\boxed{\Lambda_{\rm UV} \gtrsim 1.2 \times 10^{10}\ \text{GeV}}$$

(Assuming $\left(|\mathbb{C}^{ds}|^2 + |\mathbb{C}_5^{ds}|^2\right) \sim 1$)

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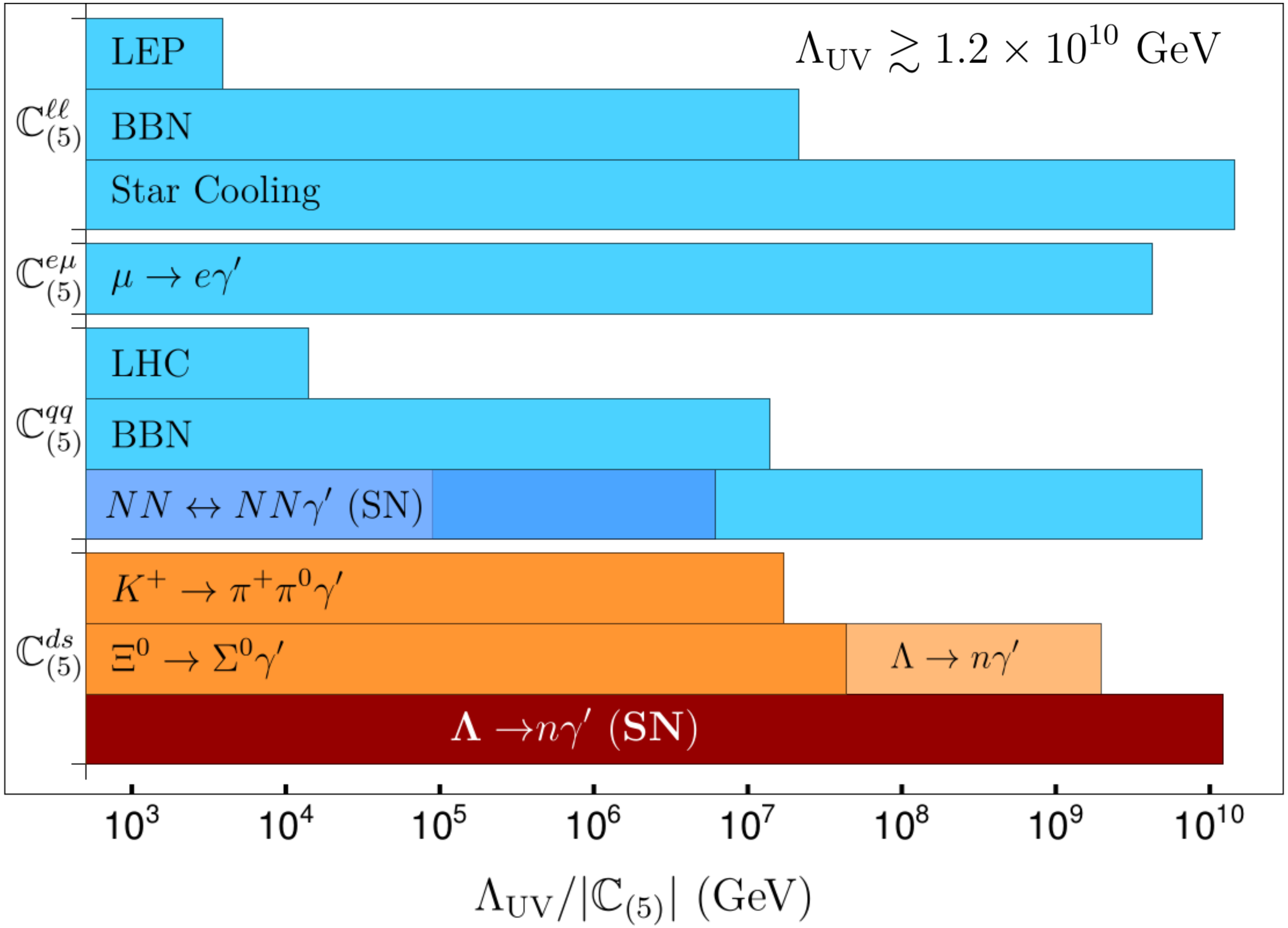

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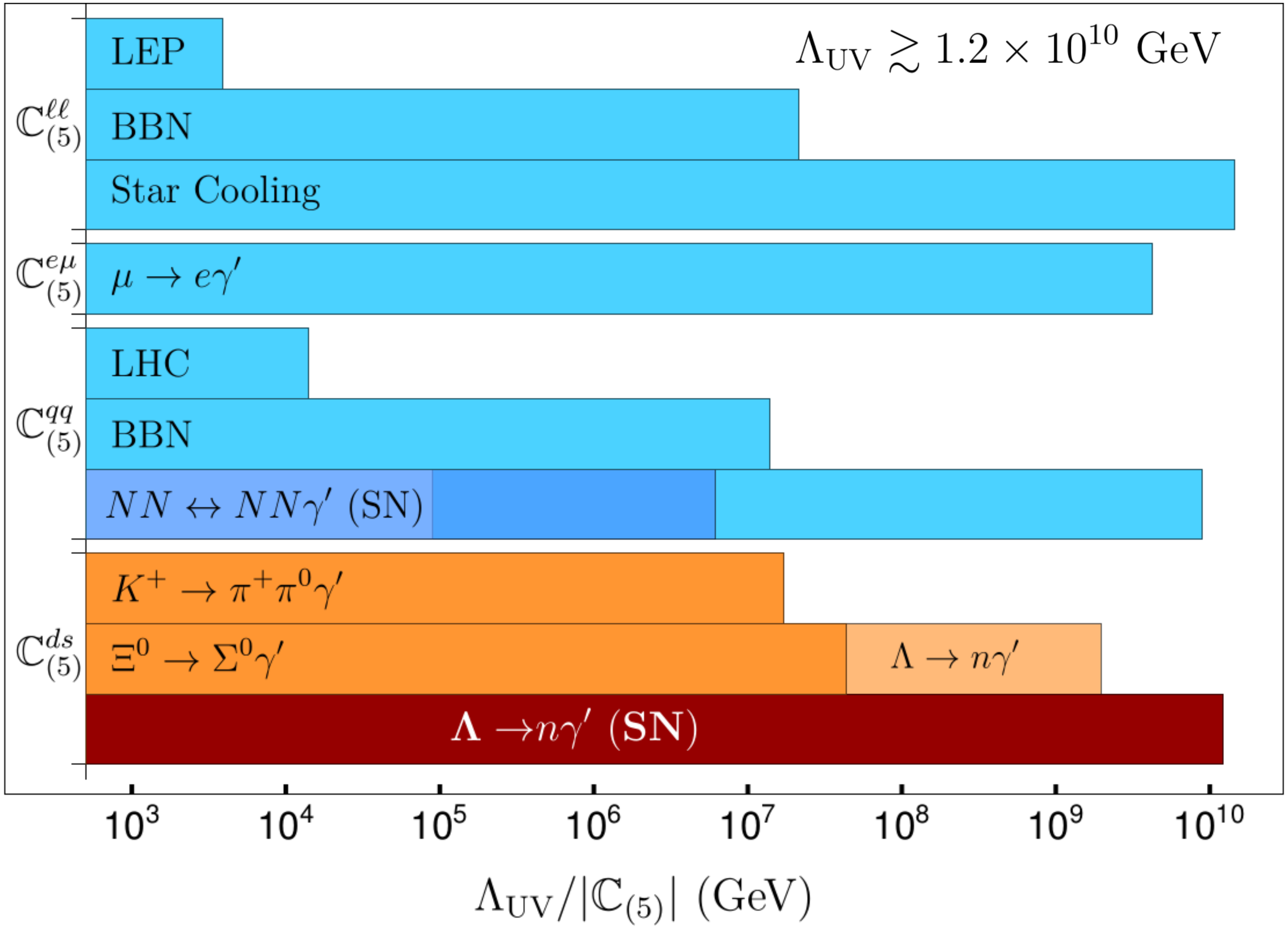

Strongest limit on quark couplings!

Takeaway message

- **Astrophysics can be a great source of information on new physics scenarios including flavour**

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Thank You!