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

MPIK Particle and Astroparticle Theory Seminar, Heidelberg

30-05-2022

The Quest for new physics

The Quest for new physics

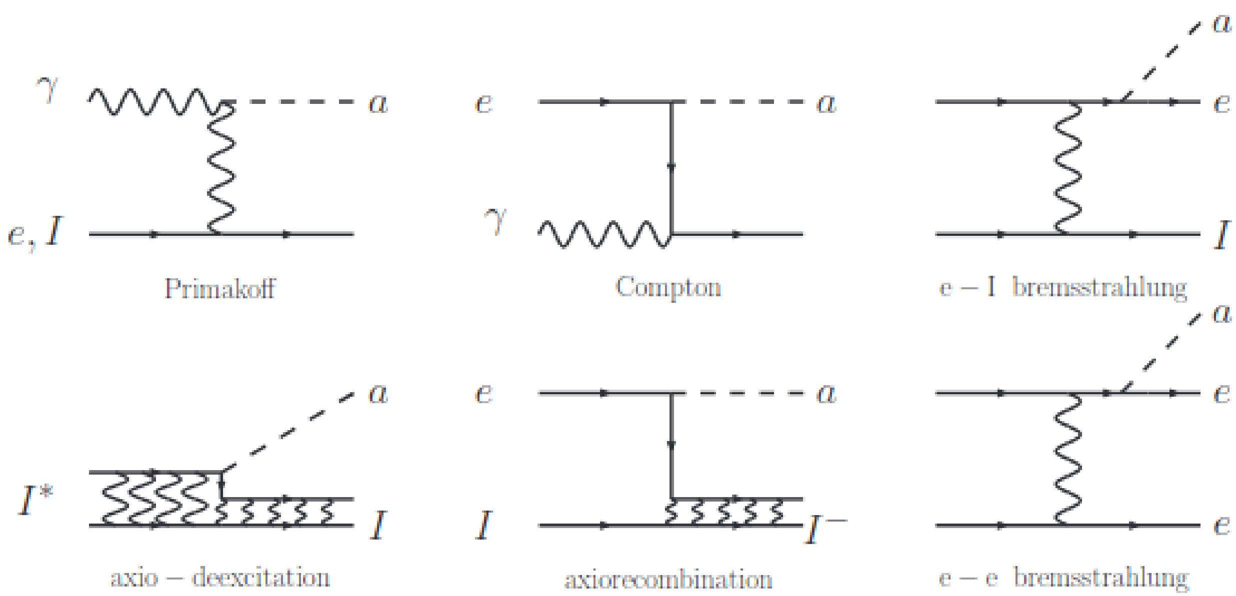
- Neutrino masses
- Dark matter
- BAU
- Dark energy
- Experimental Anomalies
- Flavour structure
- Hierarchy/naturalness
- Unification

Stars are good particle laboratories

- Energy Loss arguments allow us to prove BSM scenarios in stars:

Stars are good particle laboratories

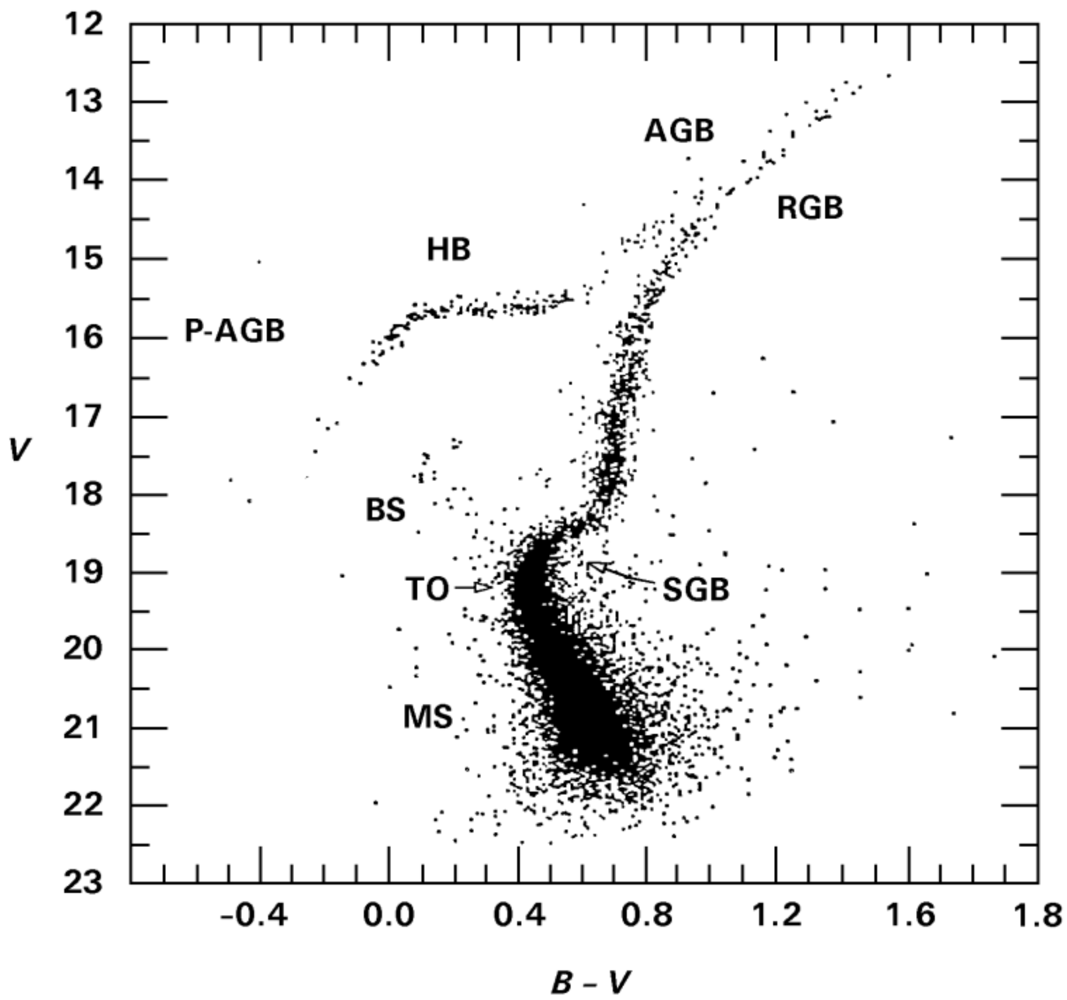
- Energy Loss arguments allow us to prove BSM scenarios in stars:
  - Direct search of sun emission



Redondo, 1310.0823

Stars are good particle laboratories

- Energy Loss arguments allow us to prove BSM scenarios in stars:
  - Direct search of sun emission
  - Tip of the Red Giant Branch brightness



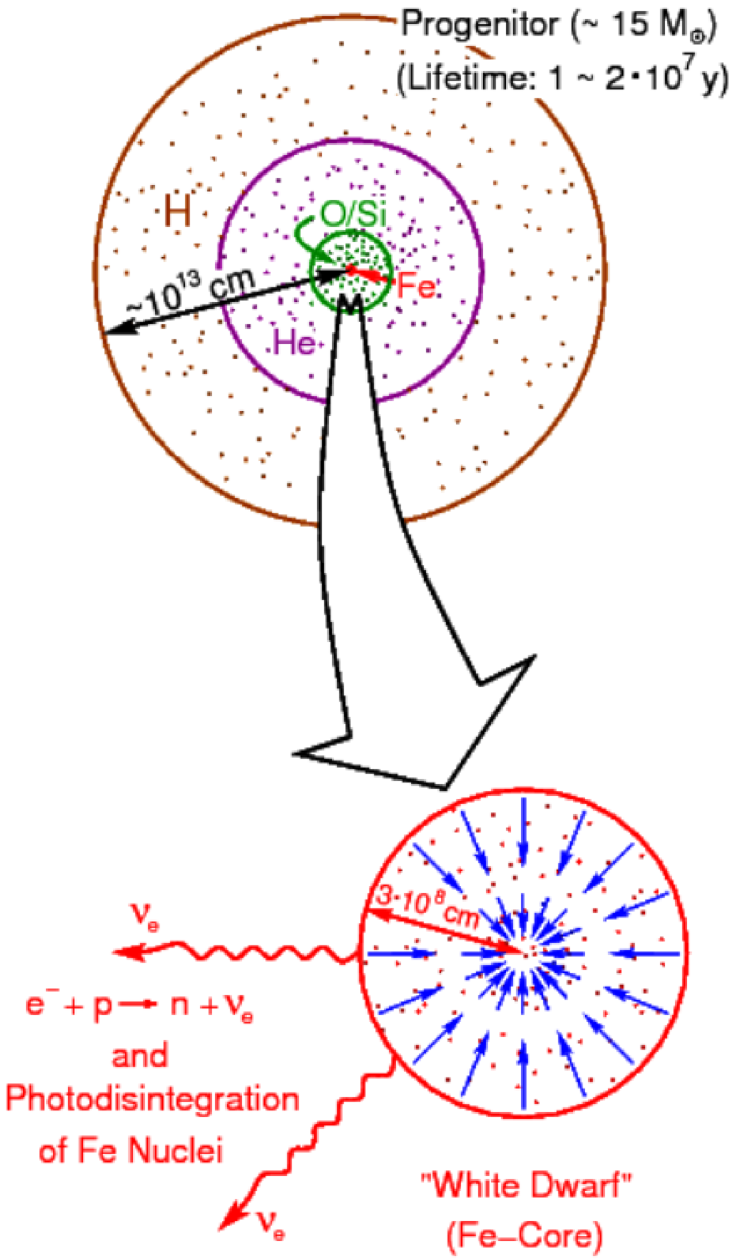
Capozzi & Raffelt, 2007.03694

Stars are good particle laboratories

- Energy Loss arguments allow us to prove BSM scenarios in stars:
  - Direct search of sun emission
  - Tip of the Red Giant Branch brightness
  - Core-Collapse Supernovae

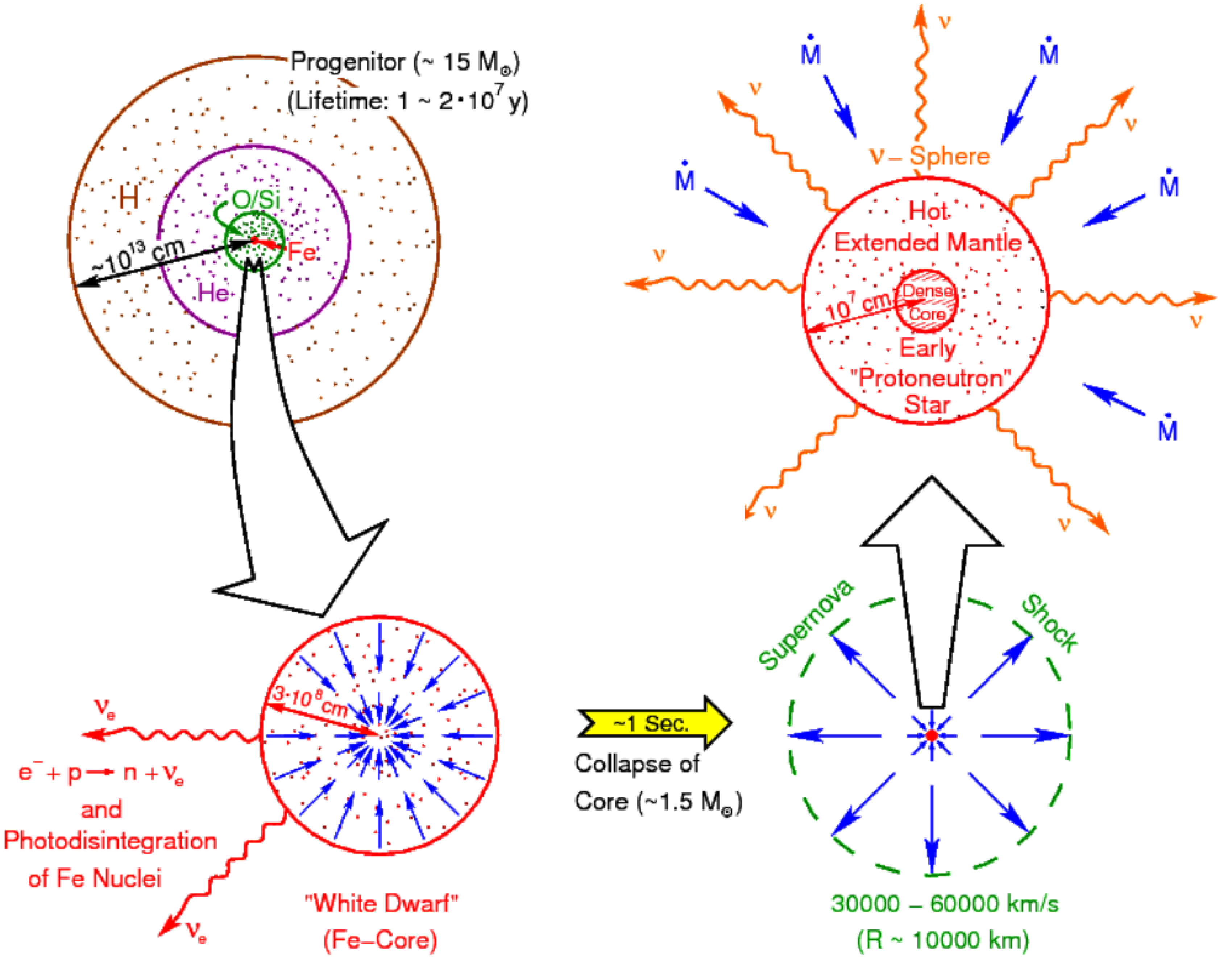
NASA, ESA, P. Challis and R. Kirshner
(Harvard-Smithsonian Center for Astrophysics)

Core-Collapse SN



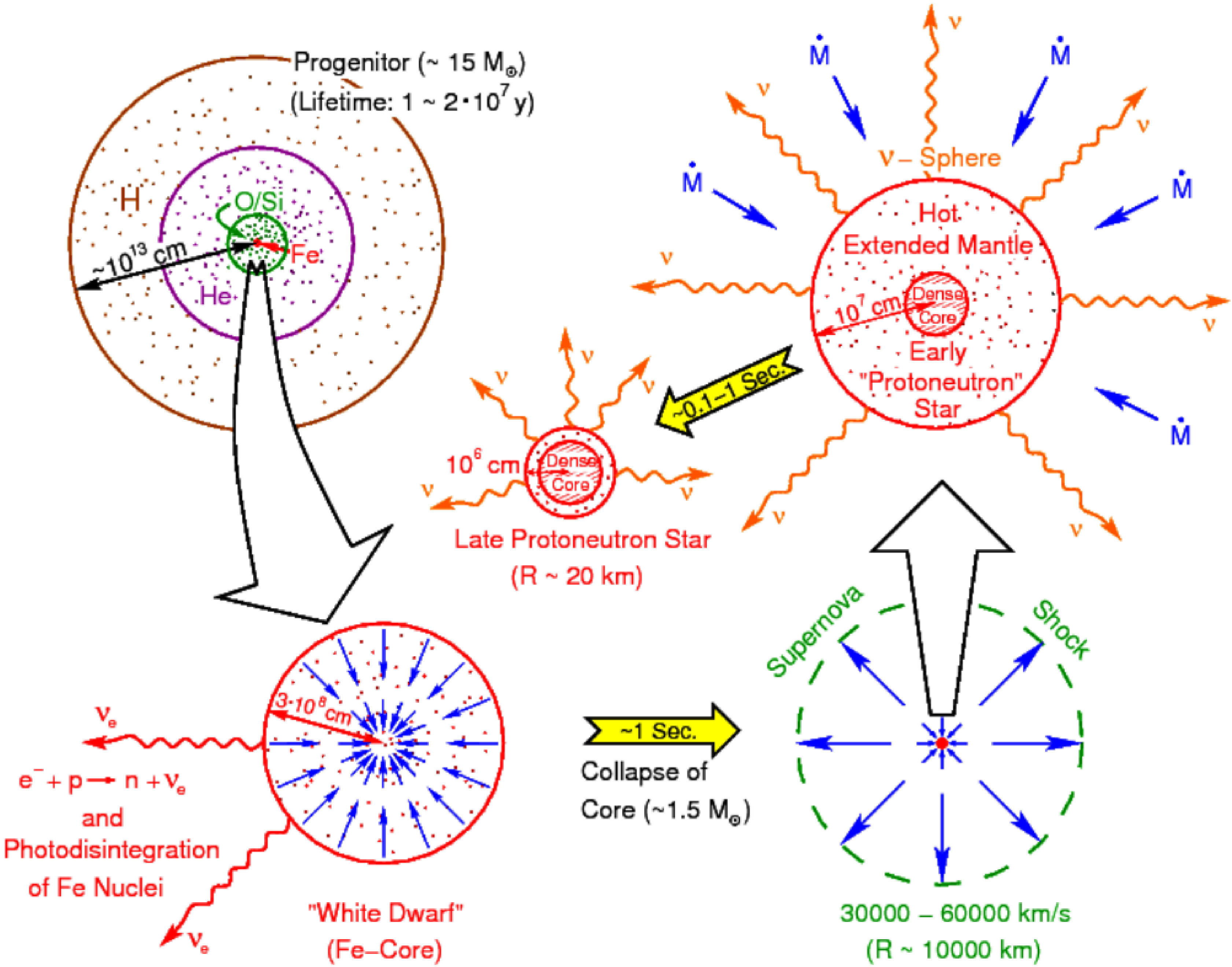
adapted from A. Burrows (1990)
Janka, https://indico.cern.ch/event/1037035/

Core-Collapse SN



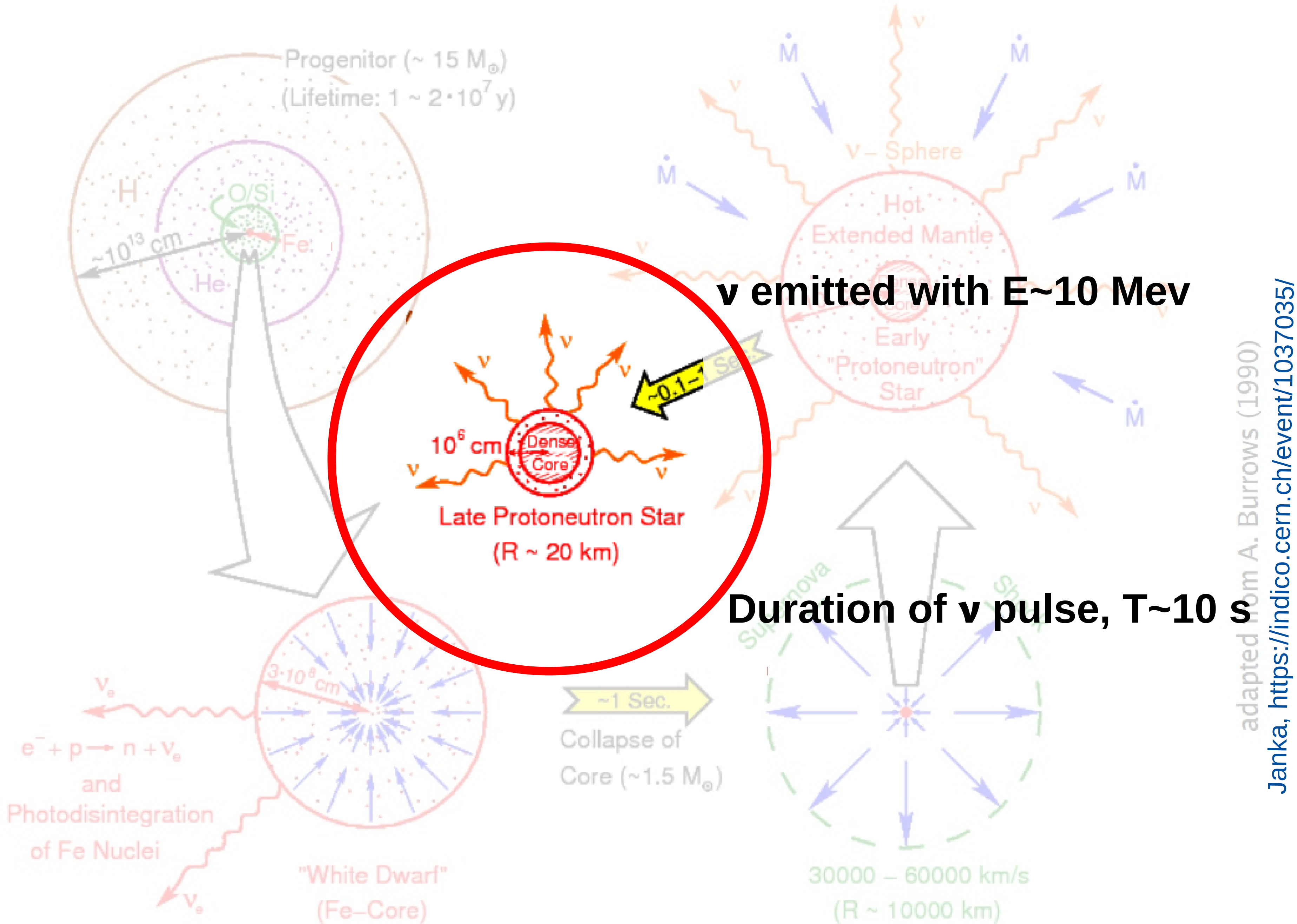
adapted from A. Burrows (1990)
Janka, https://indico.cern.ch/event/1037035/

Core-Collapse SN



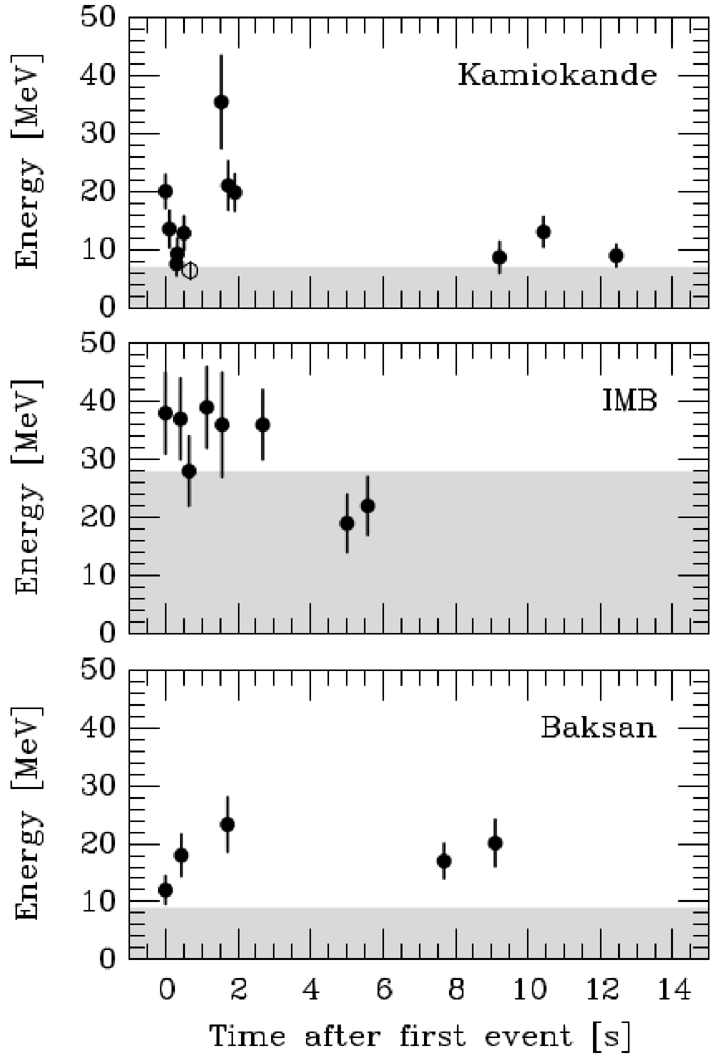
adapted from A. Burrows (1990)
Janka, https://indico.cern.ch/event/1037035/

Core-Collapse SN



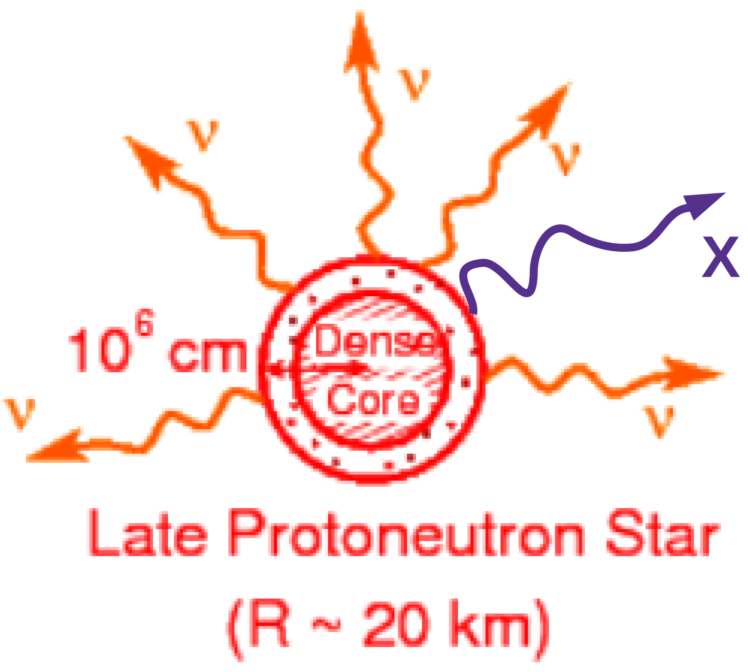
Core-Collapse SN: SN1987A

- Observed ν's: Average energy ~10 MeV, duration of pulse ~10 s
  Koshiba, M. Phys. Rept. 220, 229 (1992)

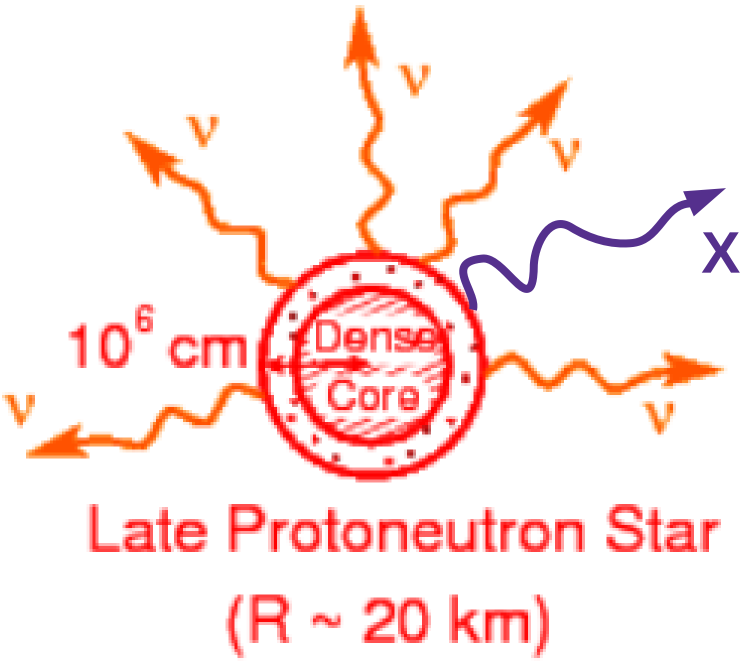


G. Raffelt "Stars as Laboratories of Fundamental Physics" (1995)

Limit on new cooling mechanisms



Limit on new cooling mechanisms

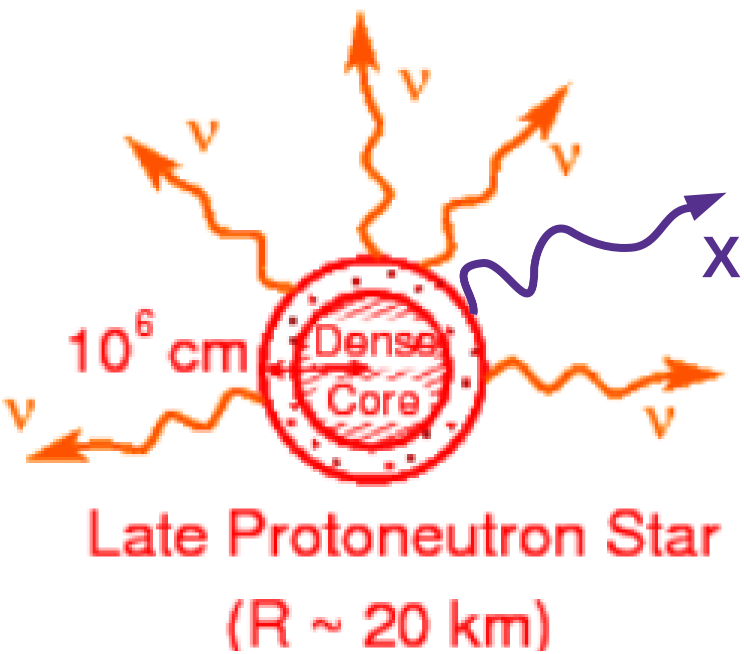


$$L_\mathrm{d} \lesssim L_\nu = 3 \times 10^{52} \ \ \mathrm{erg\ s^{-1}}$$

Raffelt, G.G. Phys. Rept. 198, 1 (1990)

Used in the litearture to constrain many models

Limit on new cooling mechanisms

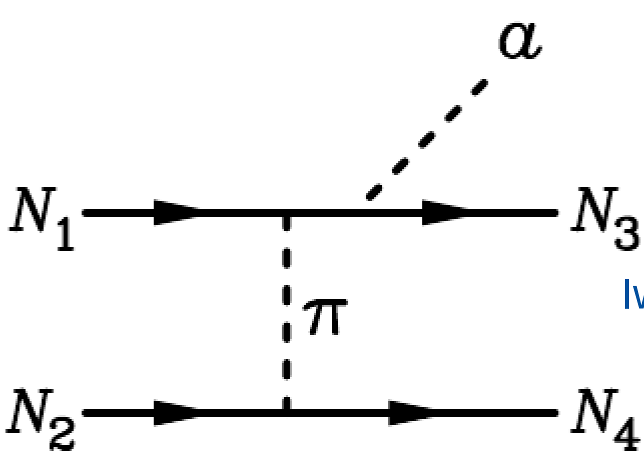


$$L_{\mathrm{d}} \lesssim L_\nu = 3 \times 10^{52} \quad \mathrm{erg\ s^{-1}}$$

Raffelt, G.G. Phys. Rept. 198, 1 (1990)

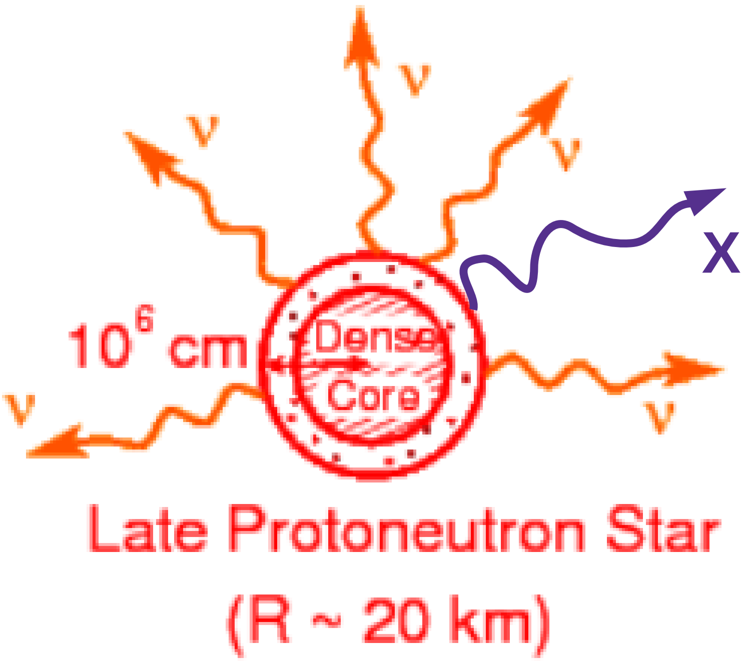
Used in the litearture to constrain many models

- Axion couplings
  - Nucleons



Iwamoto PRL53 (1984) 1198, Giannotti&Nesti PRD72 (2005) 063005

Limit on new cooling mechanisms



$$L_\mathrm{d} \lesssim L_\nu = 3 \times 10^{52} \quad \mathrm{erg\ s}^{-1}$$

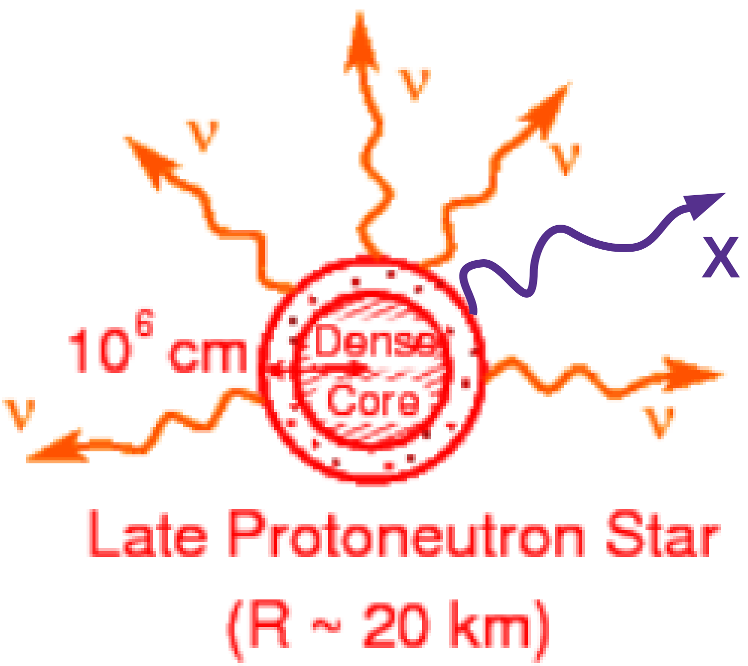
Raffelt, G.G. Phys. Rept. 198, 1 (1990)

Used in the litearture to constrain many models

- Axion couplings
  - Nucleons
  - Muons

Bollig et al. PRL 125 (2020) 051104,Croon et al. JHEP 01 (2021) 107

Limit on new cooling mechanisms



$$L_d \lesssim L_\nu = 3 \times 10^{52} \ \ \mathrm{erg\ s^{-1}}$$

Raffelt, G.G. Phys. Rept. 198, 1 (1990)

Used in the litearture to constrain many models

- Axion couplings
  - Nucleons
  - Muons
- Neutrino properties

Raffelt and Seckel Phys. Rev, Lett. 60 (1988) 1793.

Strange cooling mechanism

Strange cooling mechanism: Hyperons!

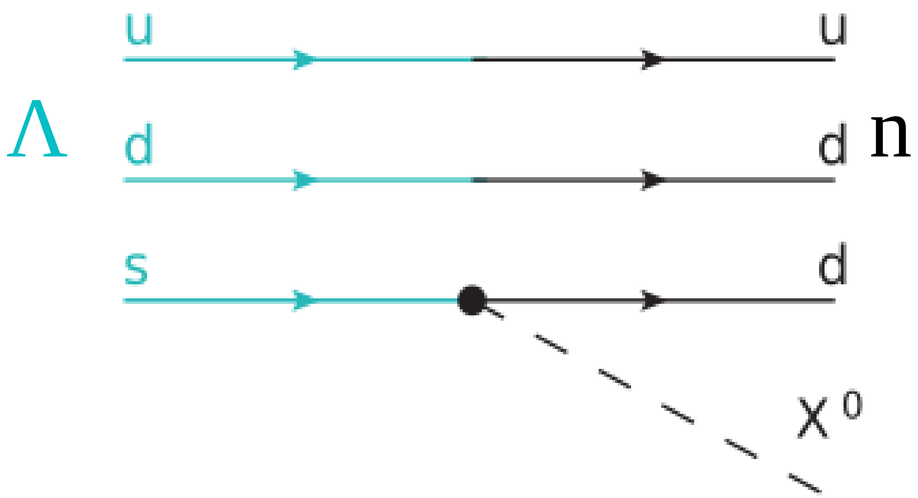
Strange cooling mechanism: Hyperons!

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

  M. Oertel et al. Rev. Mod. Phys. 89, 015007

Strange cooling mechanism: Hyperons!

- PNS reach T and ρ that enables Λ hyperon production.
  M. Oertel et al. Rev. Mod. Phys. 89, 015007
- Λ decay to a massless dark boson X^0

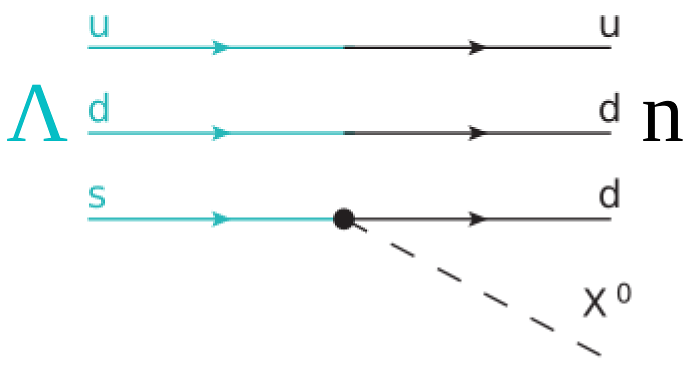


Strange cooling mechanism: Hyperons!

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

  M. Oertel et al. Rev. Mod. Phys. 89, 015007

- Λ decay to a massless dark boson X^0



- Spectrum of dark cooling rate

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

$\Gamma : \Lambda \to n\, X^0$ rate in vacuum

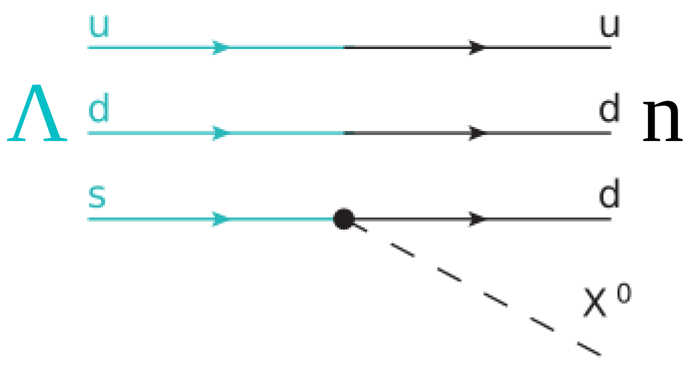
f : Fermi-Dirac distributions

E_0 : Minimum energy to produce X^0 with ω

$\bar{\omega}$: Energy of X^0 in Λ rest frame

Strange cooling mechanism: Hyperons!

- PNS reach T and ρ that enables Λ hyperon production.
  M. Oertel et al. Rev. Mod. Phys. 89, 015007
- Λ decay to a massless dark boson X^0



- Spectrum of dark cooling rate

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

$\Gamma : \Lambda \to n\, X^0$ rate in vacuum

f : Fermi-Dirac distributions

E_0 : Minimum energy to produce X^0 with ω

$\bar{\omega}$: Energy of X^0 in Λ rest frame

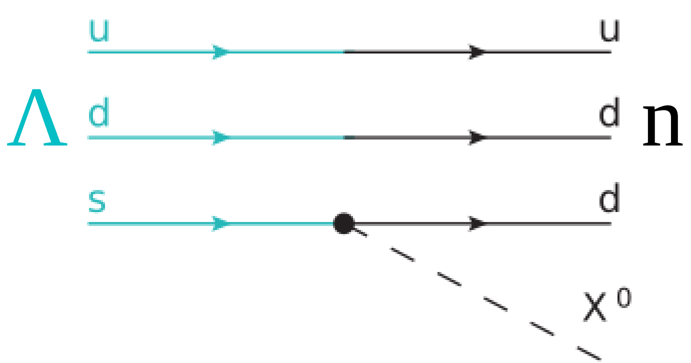
- Approximations:
  - Nonrelativistic
  - Ignore Pauli blocking
  - $m_\Lambda - m_n \ll m_n$
  - Free Fermi gas approximation

Strange cooling mechanism: Hyperons!

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

  M. Oertel et al. Rev. Mod. Phys. 89, 015007

- Λ decay to a massless dark boson X^0



- Spectrum of dark cooling rate

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

$\Gamma : \Lambda \rightarrow n\, X^0$ rate in vacuum

f : Fermi-Dirac distributions

E_0 : Minimum energy to produce X^0 with ω

$\bar{\omega}$: Energy of X^0 in Λ rest frame

- Approximations:
  - Nonrelativistic
  - Ignore Pauli blocking
  - $m_\Lambda - m_n \ll m_n$
  - Free Fermi gas approximation

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

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

Reabsorption and trapping

- X^0 could be absorbed by the inverse process.

Reabsorption and trapping

- X^0 could be absorbed by the inverse process.
- From the detailed balance analysis we get the mean free path and the optical depth.

$$\lambda_\omega^{-1} = \frac{m_\Lambda^2 \Gamma}{\bar{\omega}\omega^2} \int_{E_0}^{\infty} dE (1 - f_\Lambda) f_n \qquad \rightarrow \qquad \tau(\omega, r) = \int_r^{\infty} \lambda_\omega(r')^{-1} dr'$$

Reabsorption and trapping

- X^0 could be absorbed by the inverse process.

- From the detailed balance analysis we get the mean free path and the optical depth.

$$\lambda_\omega^{-1} = \frac{m_\Lambda^2 \Gamma}{\bar{\omega}\omega^2} \int_{E_0}^{\infty} dE (1 - f_\Lambda) f_n \qquad \rightarrow \qquad \tau(\omega, r) = \int_r^\infty \lambda_\omega(r')^{-1} dr'$$

- This affects the total luminosity

$$L_\mathrm{d} = \int d^3\vec{r} \int_0^\infty d\omega \frac{dQ(r)}{d\omega} e^{-\tau(\omega,r)}$$

Reabsorption and trapping

- X^0 could be absorbed by the inverse process.

- From the detailed balance analysis we get the mean free path and the optical depth.

$$\lambda_\omega^{-1} = \frac{m_\Lambda^2 \Gamma}{\bar{\omega}\omega^2} \int_{E_0}^{\infty} dE (1 - f_\Lambda) f_n \qquad \rightarrow \qquad \tau(\omega, r) = \int_r^\infty \lambda_\omega (r')^{-1} dr'$$

- This affects the total luminosity

$$L_\mathrm{d} = \int d^3\vec{r} \int_0^\infty d\omega \frac{dQ(r)}{d\omega} e^{-\tau(\omega,r)}$$

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

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

Supernova simulations and EoS

- We use latest 1D SN1987A simulations

  Bollig et al. PRL 125 (2020) 051104

Supernova simulations and EoS

- We use latest 1D SN1987A simulations

  Bollig et al. PRL 125 (2020) 051104

Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS grav. mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707

- Two EoS: Lattimer & Swesty and Steiner, Hempel & Fischer

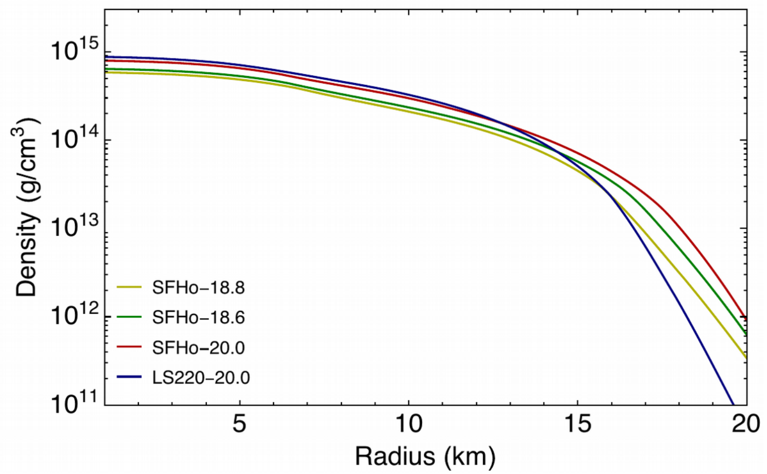
Supernova simulations and EoS

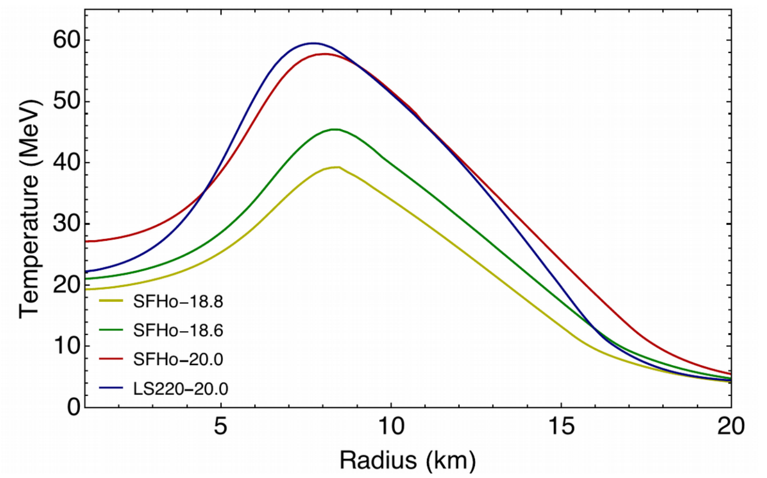
- We use latest 1D SN1987A simulations

  Bollig et al. PRL 125 (2020) 051104

Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS grav. mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707

- Two EoS: Lattimer & Swesty and Steiner, Hempel & Fischer





Supernova simulations and EoS

- We use latest 1D SN1987A simulations

  Bollig et al. PRL 125 (2020) 051104

Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS grav. mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707

- Two EoS: Lattimer & Swesty and Steiner, Hempel & Fischer
  - But this EoS do not include hyperons

Supernova simulations and EoS

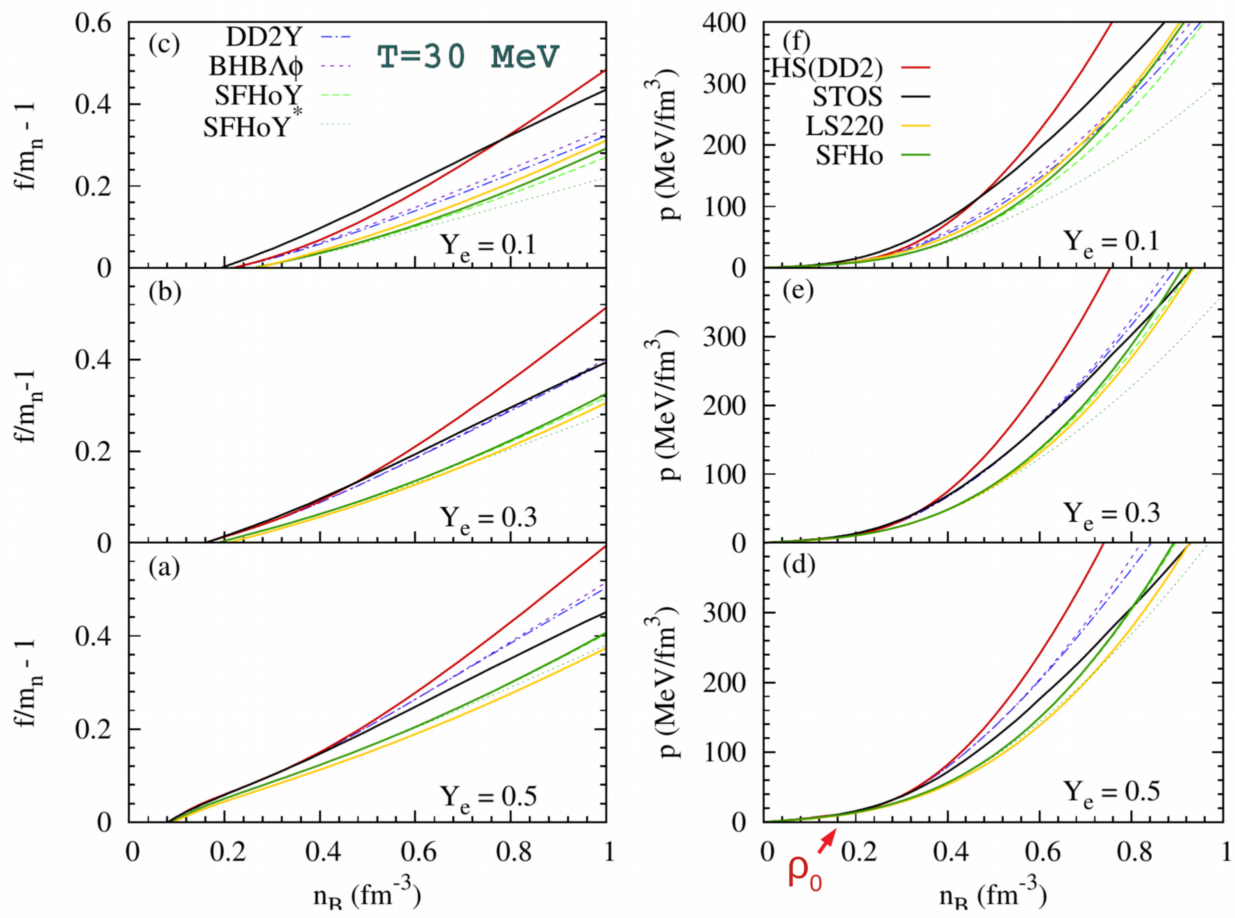
- EoS with hyperons: LS220Λ and SFHoY

Supernova simulations and EoS

- EoS with hyperons: LS220Λ and SFHoY
- Consistent with the SN simulations? **YES**

Supernova simulations and EoS

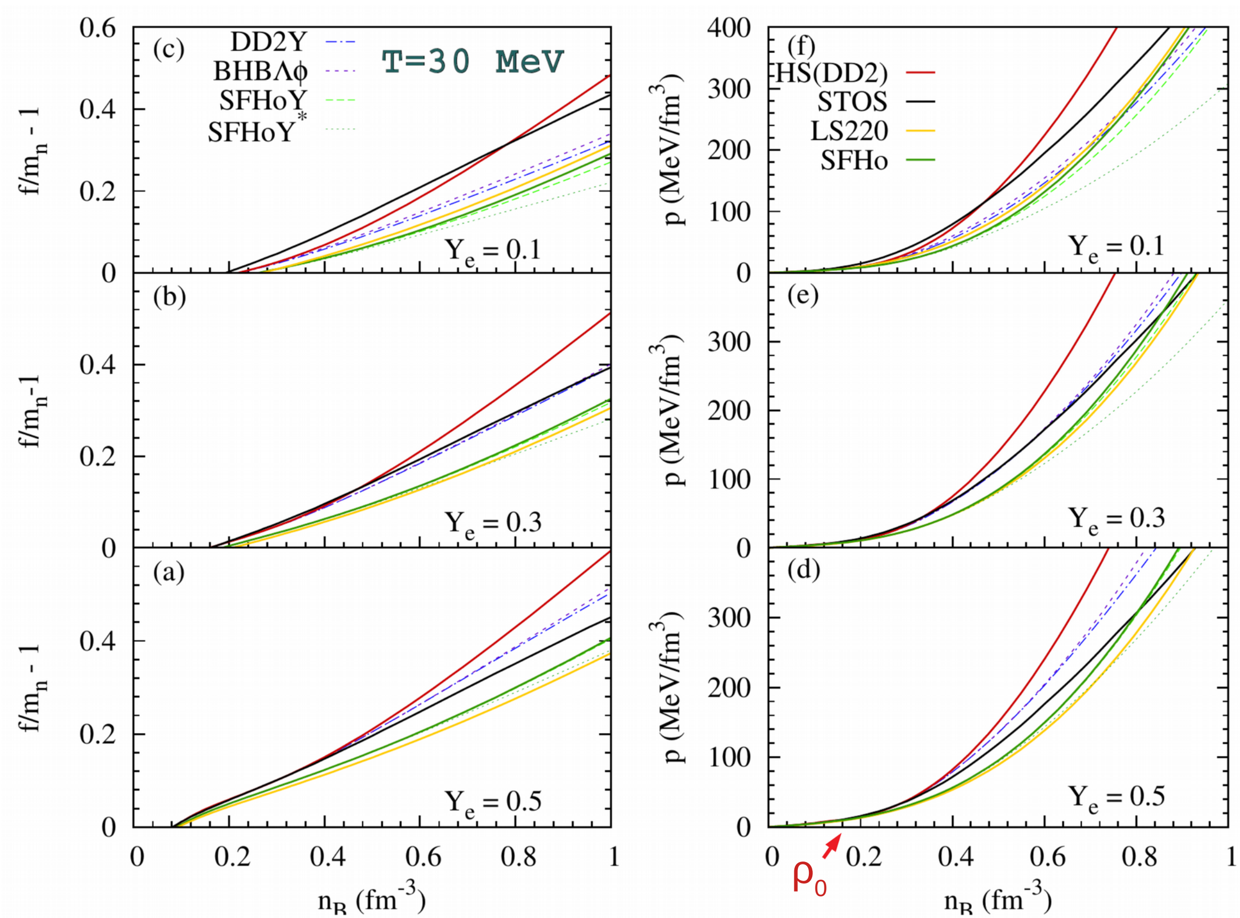
- EoS with hyperons: LS220Λ and SFHoY
- Consistent with the SN simulations? **YES**



Fortin, Oertel&Providencia, arXiv:1711.09427

Supernova simulations and EoS

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



Fortin, Oertel&Providencia, arXiv:1711.09427

Supernova simulations and EoS

- We use latest 1D SN1987A simulations

Bollig et al. PRL 125 (2020) 051104

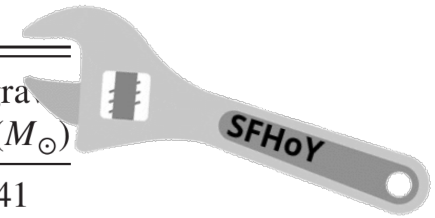
Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS gra mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707

Supernova simulations and EoS

- We use latest 1D SN1987A simulations

Bollig et al. PRL 125 (2020) 051104

Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS gra[illegible] mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707



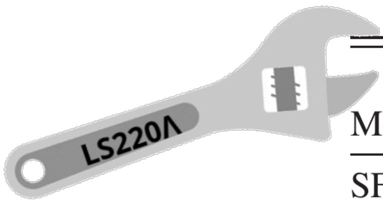
- Medium effects: SFHoY

$$E^*_{\mathfrak{B}} = \sqrt{\vec{p}^2 + m^{*2}_{\mathfrak{B}}} + V_{\mathfrak{B}}$$

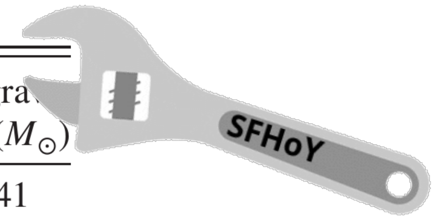
Supernova simulations and EoS

- We use latest 1D SN1987A simulations

Bollig et al. PRL 125 (2020) 051104



Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS gra mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707



- Medium effects: SFHoY

$$E^*_{\mathfrak{B}} = \sqrt{\vec{p}^2 + m^{*2}_{\mathfrak{B}}} + V_{\mathfrak{B}}$$

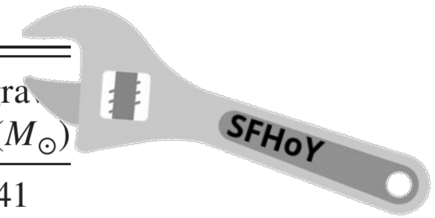
Effective mass

Supernova simulations and EoS

- We use latest 1D SN1987A simulations

Bollig et al. PRL 125 (2020) 051104

Model name	Equation of state	Progenitor mass ($M_\odot$)	NS bary. mass ($M_\odot$)	NS gra mass ($M_\odot$)
SFHo-18.8	SFHo	18.8	1.351	1.241
SFHo-18.6	SFHo	18.6	1.553	1.406
SFHo-20.0	SFHo	20.0	1.947	1.712
LS220-20.0	LS220	20.0	1.926	1.707



- Medium effects: SFHoY

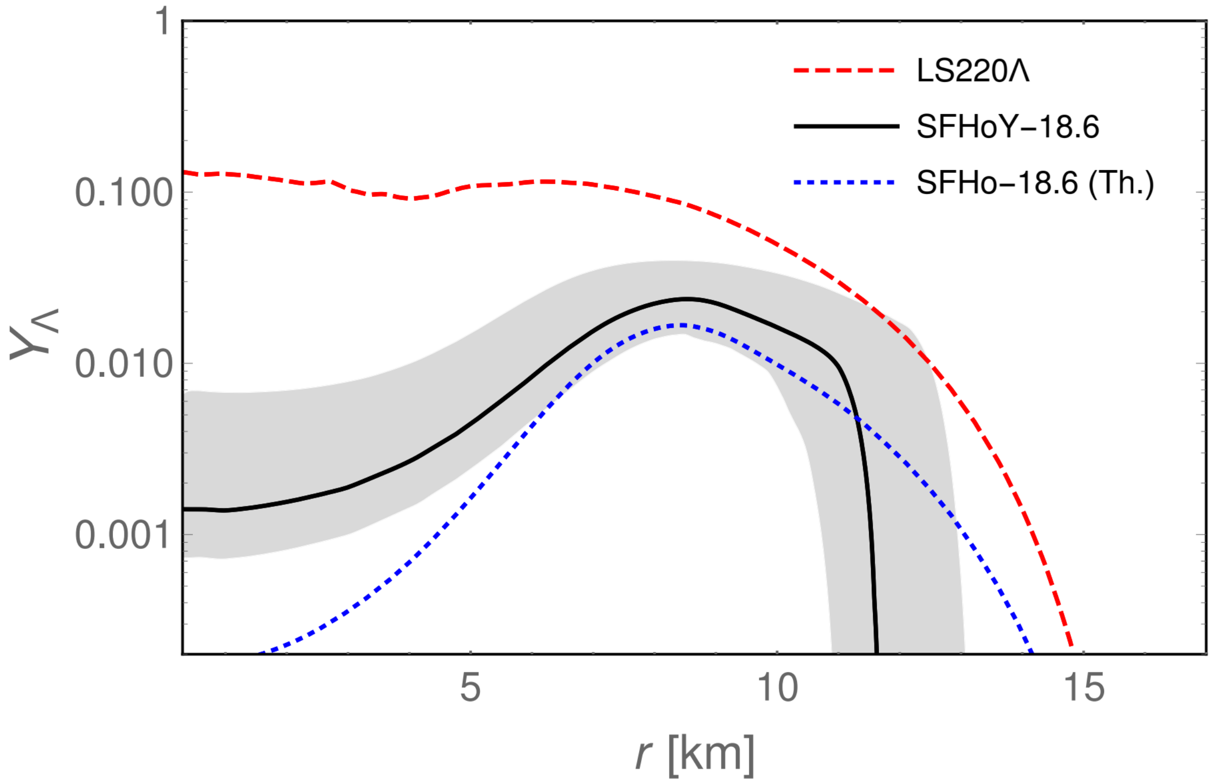
$$E^*_{\mathfrak{B}} = \sqrt{\vec{p}^{\,2} + m^{*2}_{\mathfrak{B}}} + V_{\mathfrak{B}}$$

Effective mass   Self energy

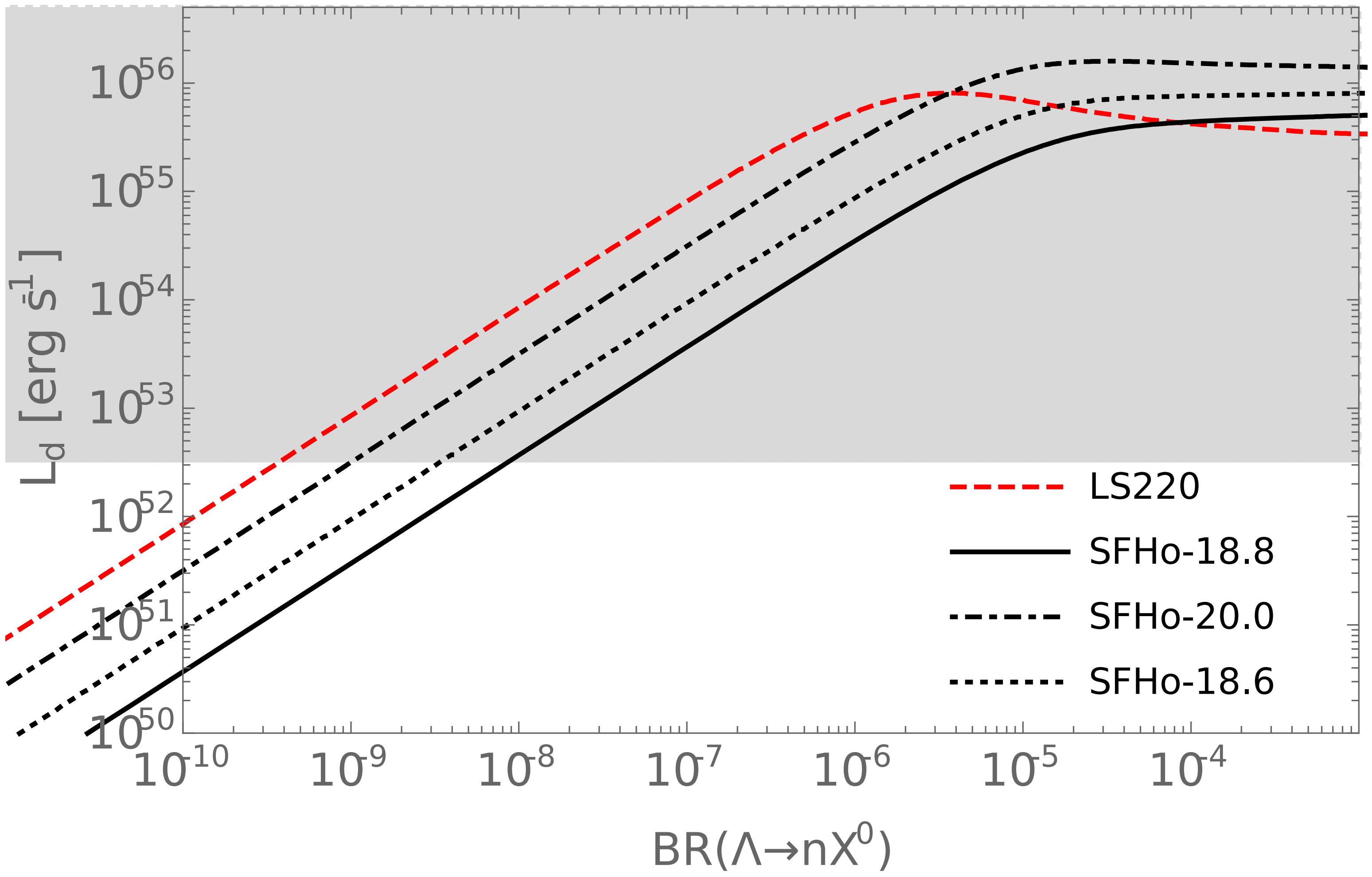
Supernova simulations and EoS

- We use latest 1D SN1987A simulations
  Bollig et al. PRL 125 (2020) 051104

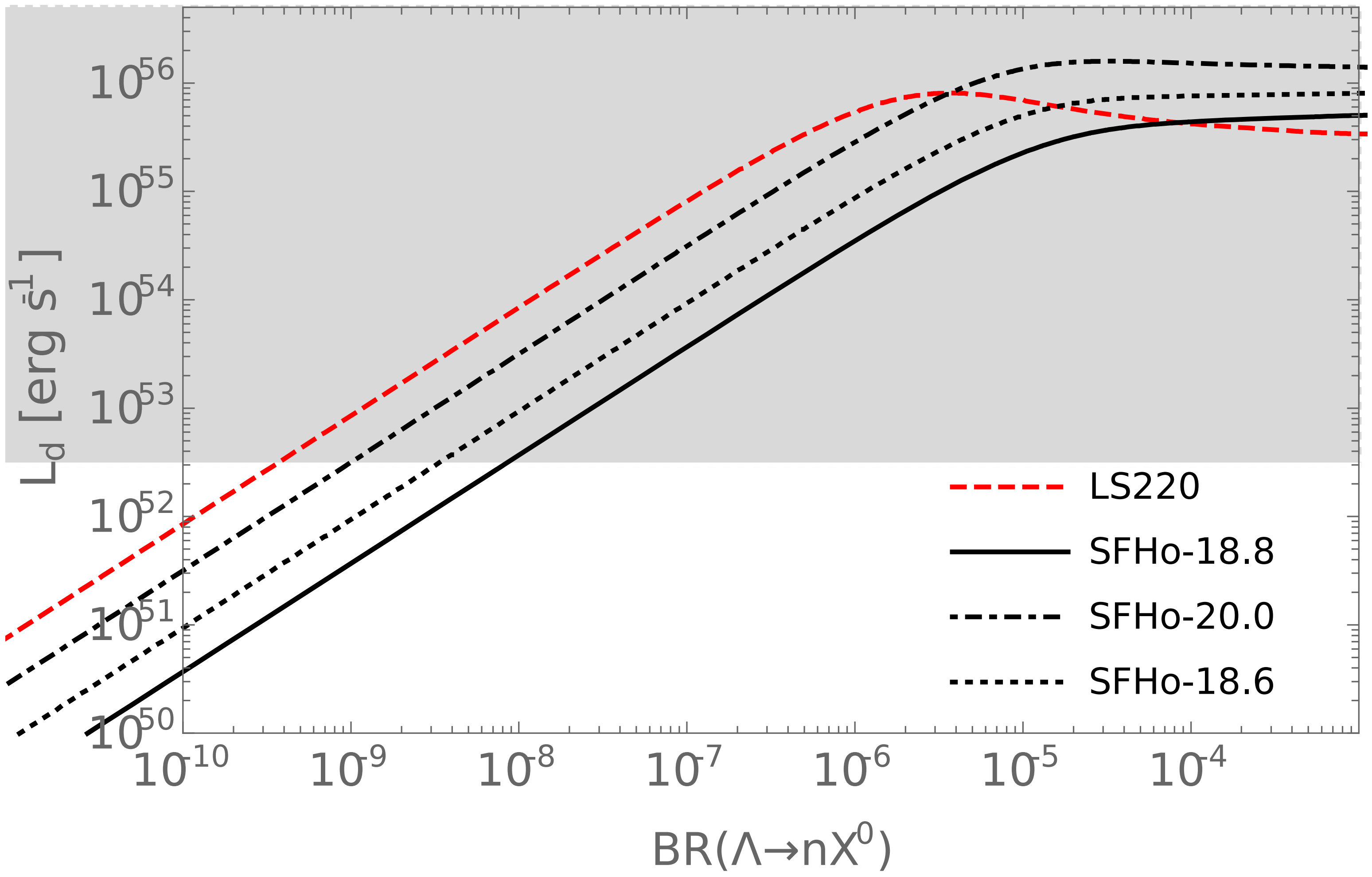
- With CompOSE database we include this EoS with hyperons in the simulations



Dark luminosity

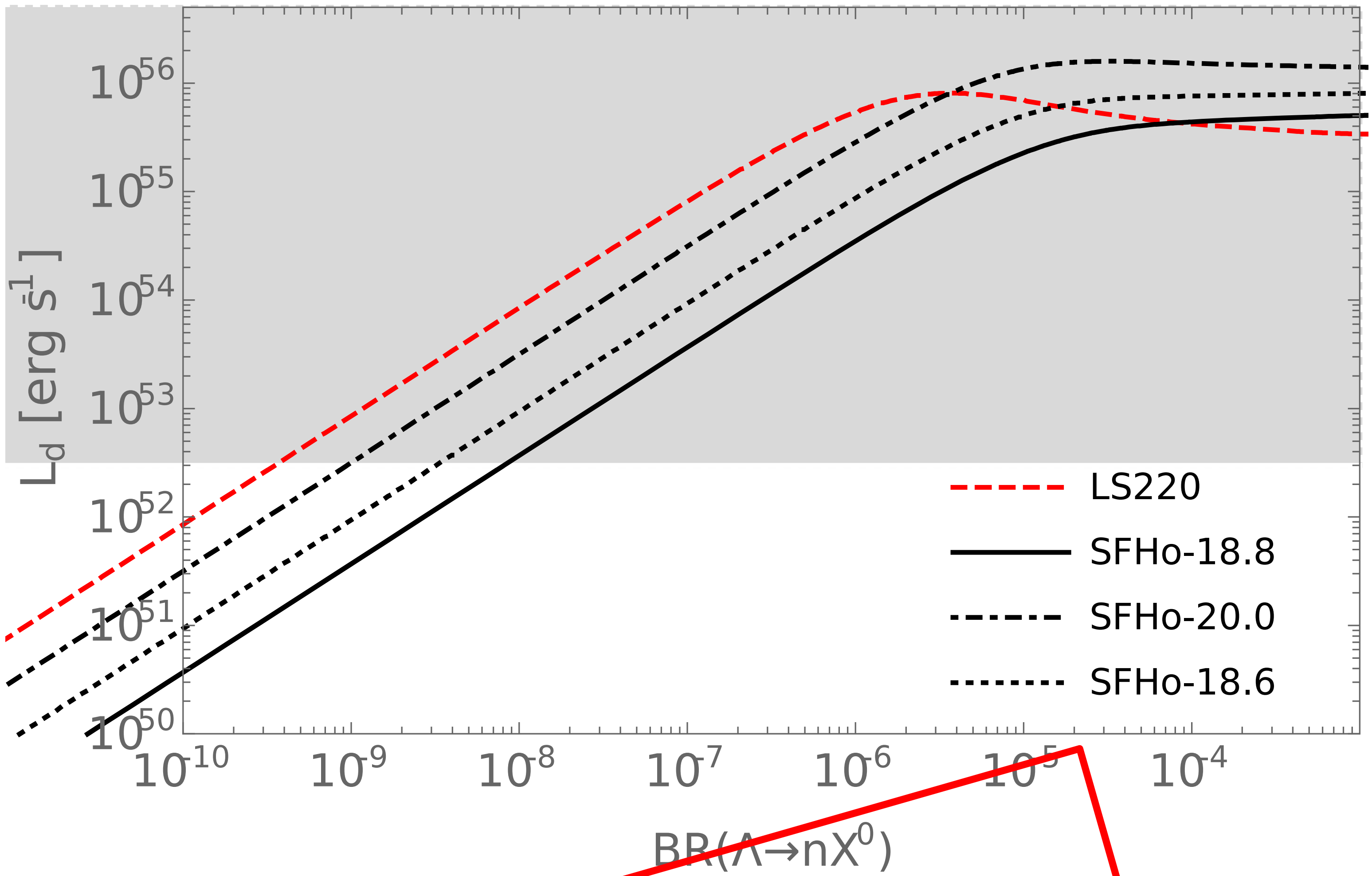


Dark luminosity



$$\mathrm{BR}(\Lambda \to nX^0) \lesssim 8.0 \times 10^{-9}$$

Dark luminosity

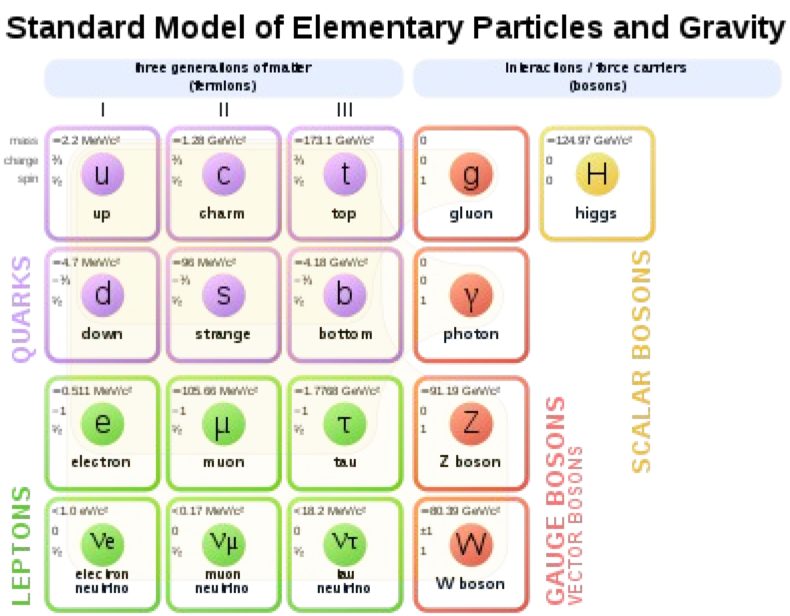


$$\mathrm{BR}(\Lambda \to nX^0) \lesssim 8.0 \times 10^{-9}$$

Model independent

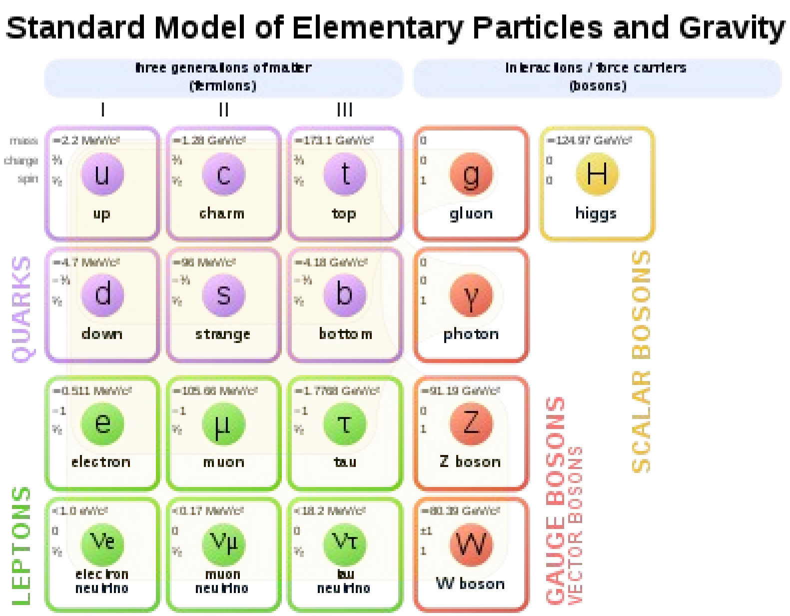
Flavoured dark sector

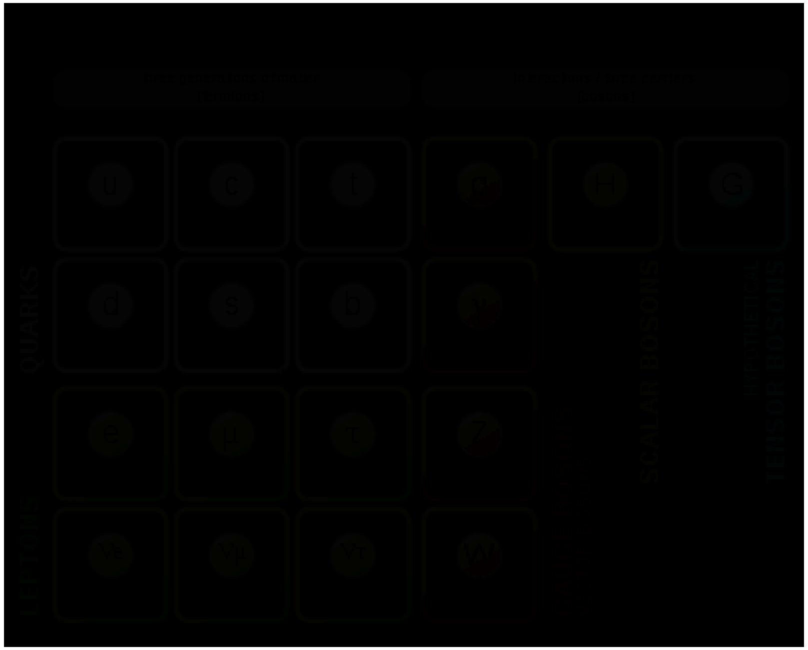
- Portals connect the SM with dark sectors



Flavoured dark sector

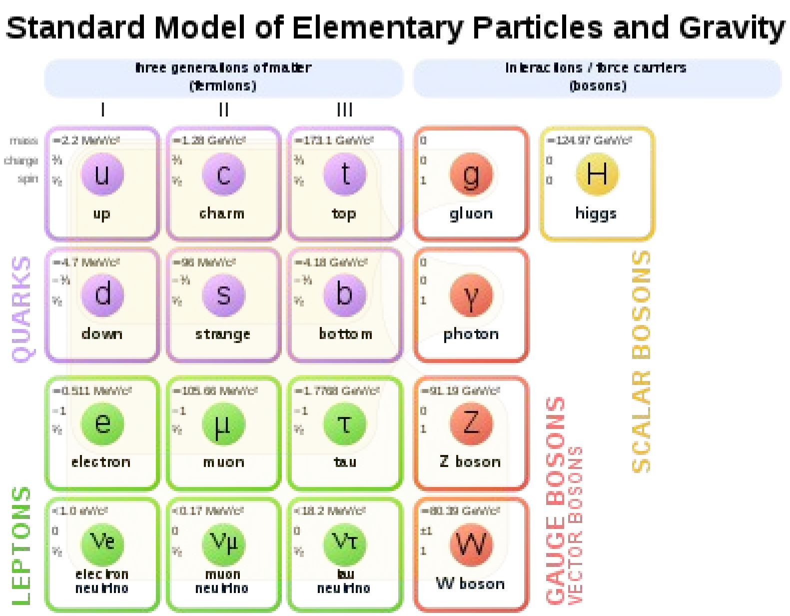
- Portals connect the SM with dark sectors

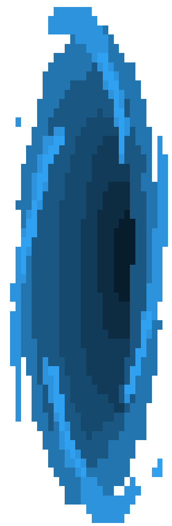


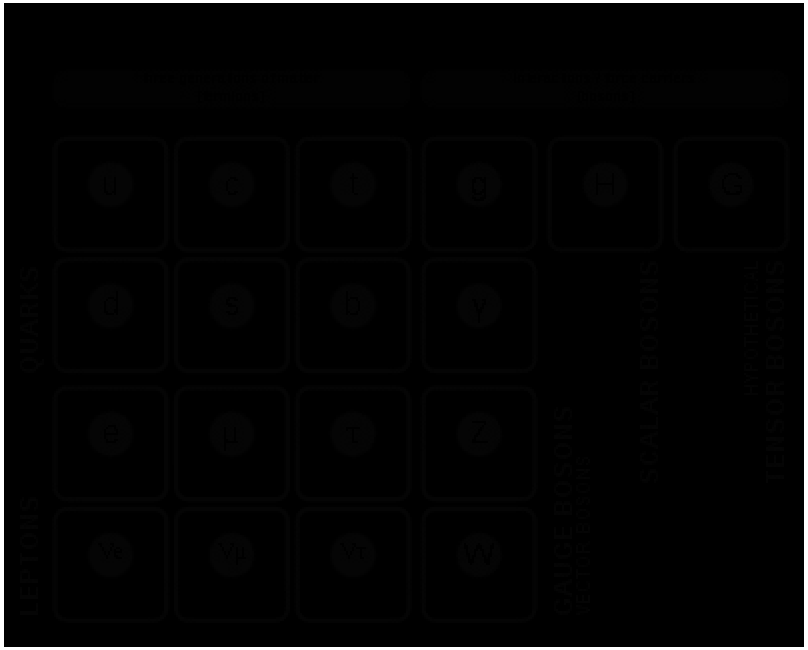


Flavoured dark sector

- Portals connect the SM with dark sectors

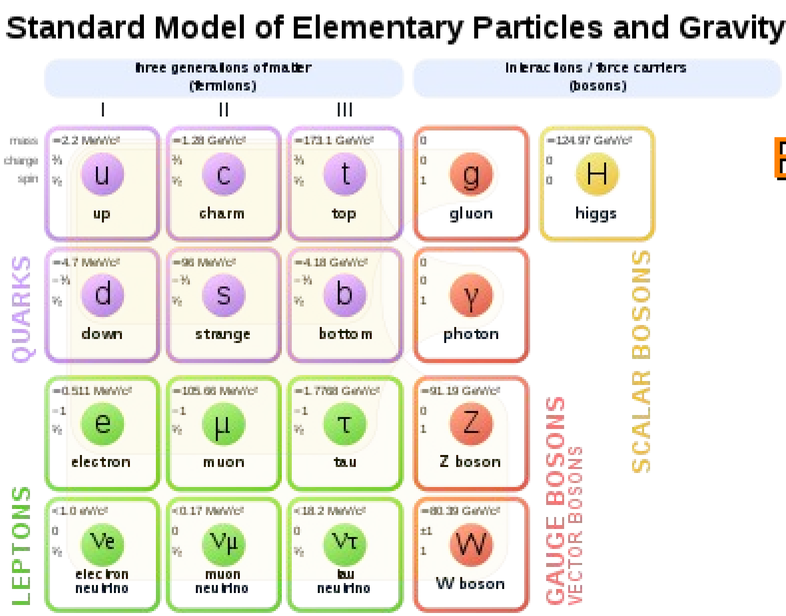






Flavoured dark sector

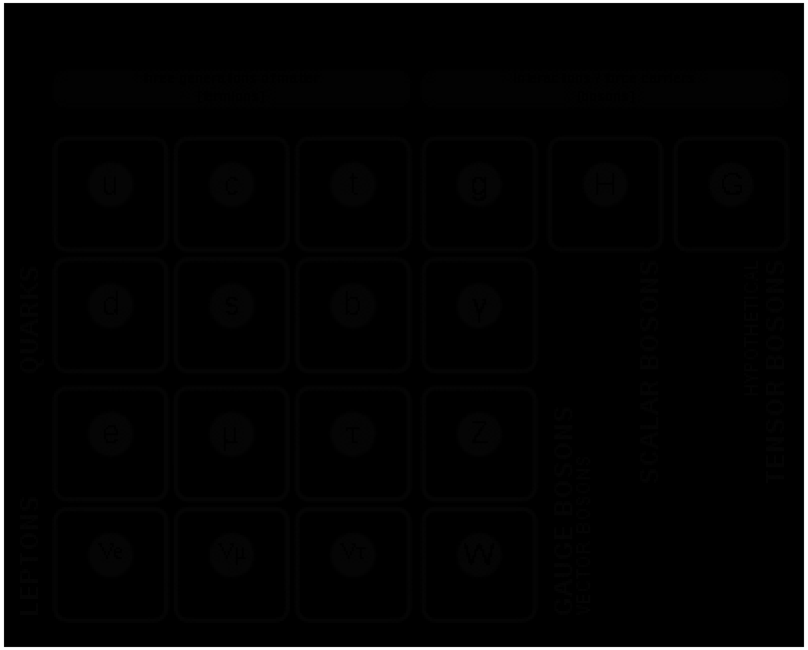
- Portals connect the SM with dark sectors



Bosonic portals:

Axions

Dark photon



Flavoured dark sector

- Portals are usually assumed to have universal couplings to SM

Flavoured dark sector

- Portals can have a rich flavour structure.

Flavoured dark sector

- Portals can have a rich flavour structure.
  - Dark Flavour exists:

Flavoured dark sector

- Portals can have a rich flavour structure.
  - → Dark Flavour exists:
- The axion

Flavoured dark sector

- Portals can have a rich flavour structure.
  - ➔ Dark Flavour exists:
- The axion
  - ➔ The axiflavon → solution to flavour puzzle + QCD axion

    Wilczek PRL 49 (1982) 1549, Calibbi et al. PRD 95 (2017) 095009

Flavoured dark sector

- Portals can have a rich flavour structure.
  - Dark Flavour exists:
- The axion
  - The axiflavon → solution to flavour puzzle + QCD axion

    Wilczek PRL 49 (1982) 1549, Calibbi et al. PRD 95 (2017) 095009
  - QCD axion with non universal PQ charges

$$\mathcal{L}_a = -\frac{\partial_\mu a}{2 f_a} \frac{1}{N} \left[\bar{f}_L \left(U_L^{f\dagger} \boldsymbol{X}_{f_L} U_L^f \right) f_L + \bar{f}_R \left(U_R^{f\dagger} \boldsymbol{X}_{f_R} U_R^f \right) f_R \right]$$

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

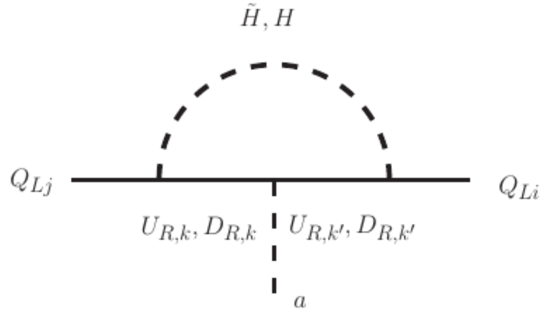
Flavoured dark sector

- Portals can have a rich flavour structure.
  - Dark Flavour exists:
- The axion
  - The axiflavon → solution to flavour puzzle + QCD axion

    Wilczek PRL 49 (1982) 1549, Calibbi et al. PRD 95 (2017) 095009
  - QCD axion with non universal PQ charges

$$\mathcal{L}_a = -\frac{\partial_\mu a}{2f_a}\frac{1}{N}\left[\bar{f}_L\left(U_L^{f\dagger}\boldsymbol{X}_{f_L}U_L^f\right)f_L + \bar{f}_R\left(U_R^{f\dagger}\boldsymbol{X}_{f_R}U_R^f\right)f_R\right]$$

    Di Luzio et al. Phys.Rept. 870 (2020) 1-117
  - Radiative SM corrections generate flavour violation



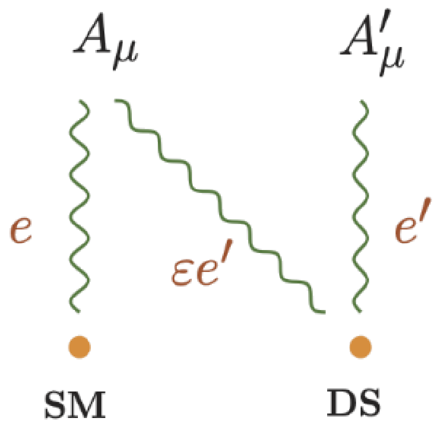
Martin Camalich et al. PRD 102 (2020) 1, 015023

Flavoured dark sector

- Portals can have a rich flavour structure.
  - Dark Flavour exists:
- The massless dark photon

Flavoured dark sector

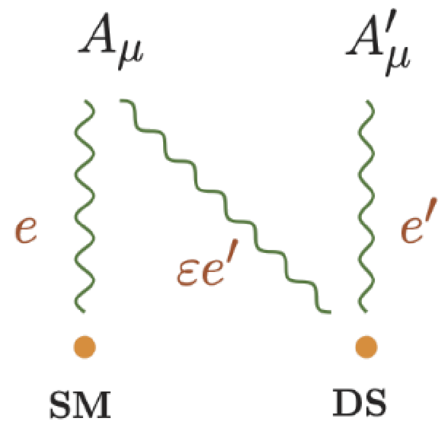
- Portals can have a rich flavour structure.
  - Dark Flavour exists:
- The massless dark photon
  - Not tree level couplings to SM fermions
    Holdon, PLB 166 (1986) 196, del Águila et al. NPB 456 (1995) 531



Fabbrichesi et al., arXiv: 2005.01515

Flavoured dark sector

- Portals can have a rich flavour structure.
  - Dark Flavour exists:
- The massless dark photon
  - Not tree level couplings to SM fermions
    Holdon, PLB 166 (1986) 196, del Águila et al. NPB 456 (1995) 531



Fabbrichesi et al., arXiv: 2005.01515

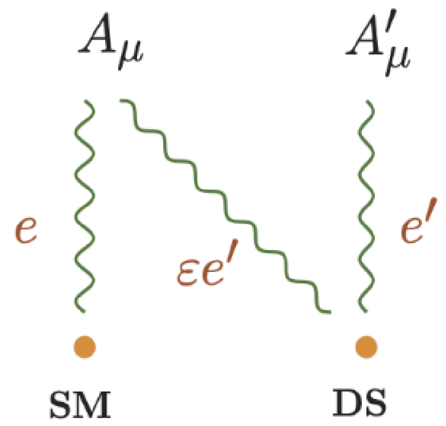
- Couples through higher dimension operators

$$\frac{1}{M^2} P_{\mu\nu}(\overline{q}_L \sigma^{\mu\nu} C_u \widetilde{H} u_R + \overline{q}_L \sigma^{\mu\nu} C_d H d_R + \overline{l}_L \sigma^{\mu\nu} C_e H e_R + \text{H.c.}).$$

Dobrescu, PRL 94 (2005) 151802

Flavoured dark sector

- Portals can have a rich flavour structure.
  - Dark Flavour exists:
- The massless dark photon
  - Not tree level couplings to SM fermions
    Holdon, PLB 166 (1986) 196, del Águila et al. NPB 456 (1995) 531



Fabbrichesi et al., arXiv: 2005.01515

- Couples through higher dimension operators

$$\frac{1}{M^2} P_{\mu\nu}(\overline{q}_L \sigma^{\mu\nu} C_u \widetilde{H} u_R + \overline{q}_L \sigma^{\mu\nu} C_d H d_R + \bar{l}_L \sigma^{\mu\nu} C_e H e_R + \text{H.c.}).$$

Dobrescu, PRL 94 (2005) 151802

- Can arise in models with a natural origin for flavor. Fabbrichesi et al. PRL 119 (2017) 031801

The QCD axion

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

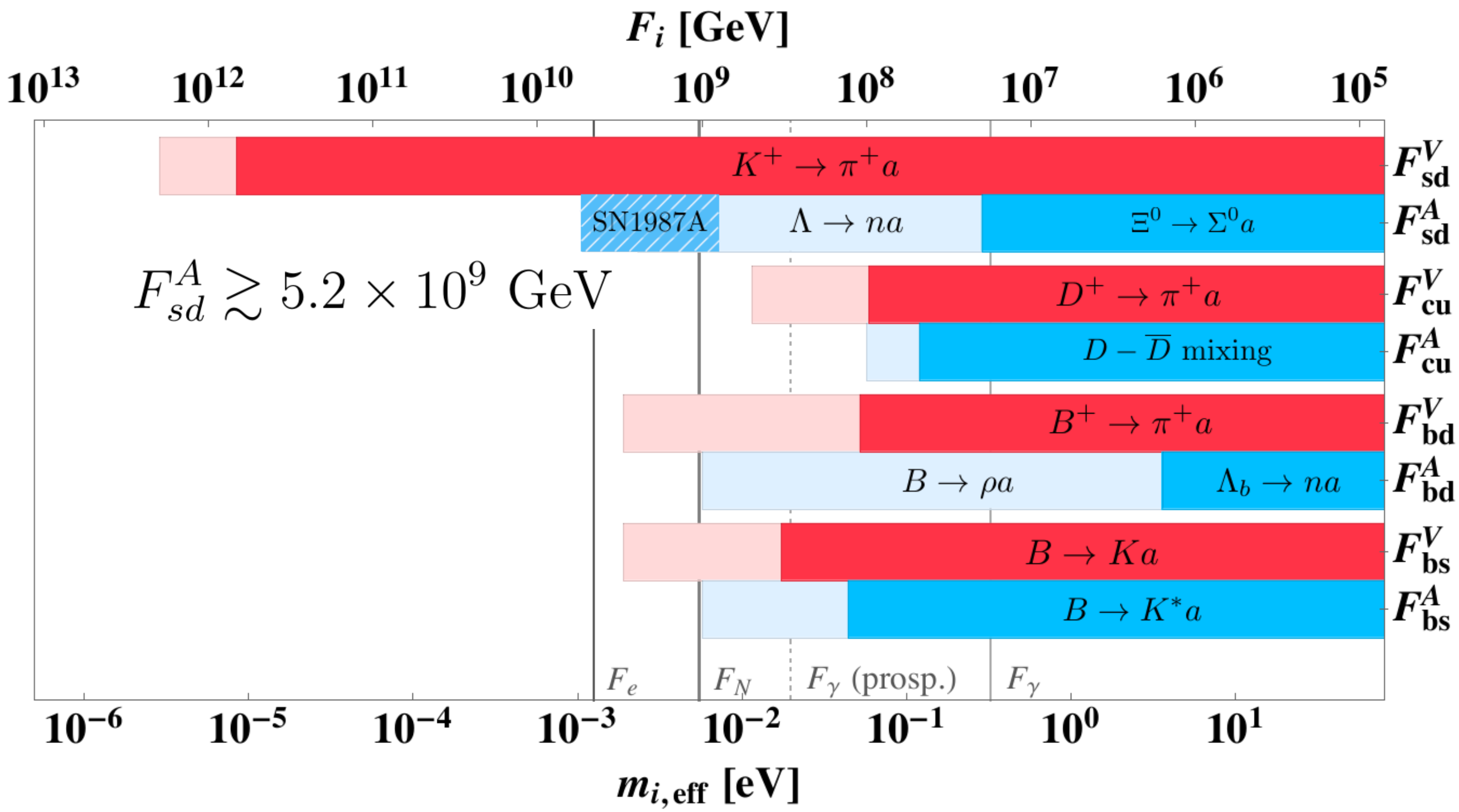
The QCD axion

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

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

The QCD axion

$$\mathcal{L}_a = \frac{\partial_\mu a}{2f_a}\,\bar{\psi}_i\gamma^\mu(c^V_{ij} + c^A_{ij}\gamma_5)\psi_j \quad \text{with} \quad F^{V,A}_{sd} \equiv 2f_a/c^{V,A}_{sd}$$



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

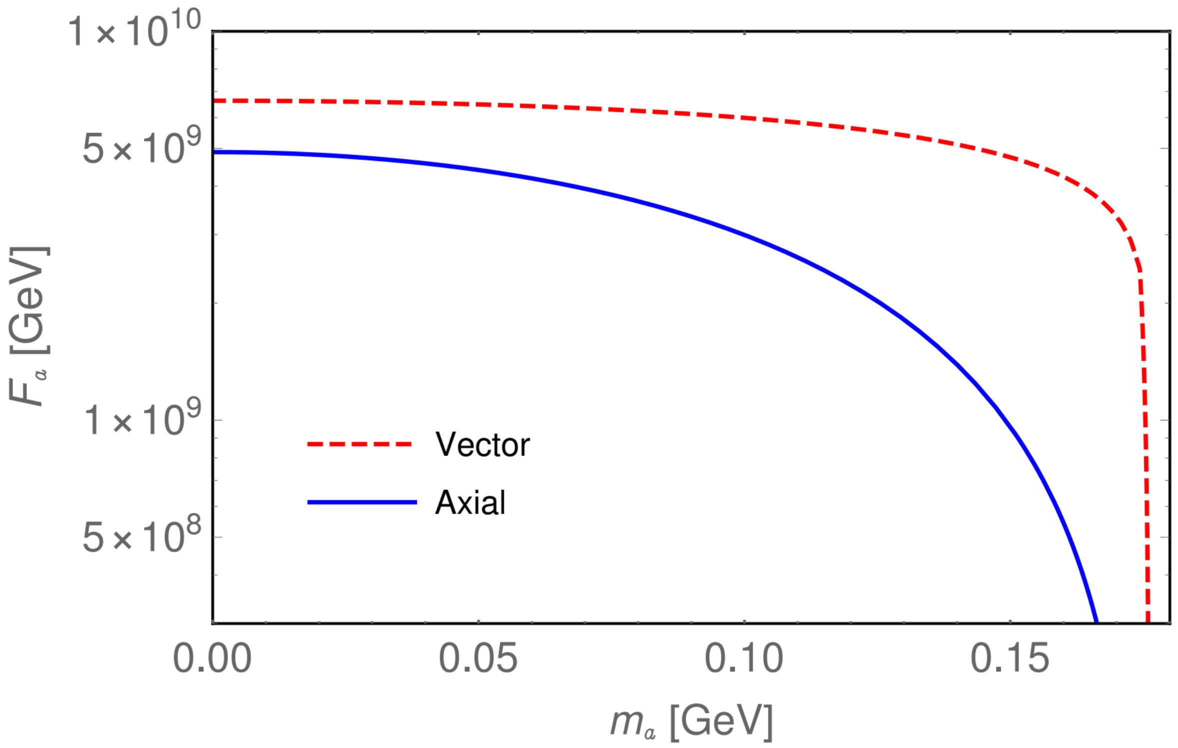
The ALP

$$\mathcal{L}_{\mathrm{ALP}} = \mathcal{L}_a + \frac{1}{2} m_a^2 a^2$$

The ALP

$$\mathcal{L}_{\rm ALP} = \mathcal{L}_a + \frac{1}{2} m_a^2 a^2$$

- Approx. the same bound as QCD axions except for $m_a \simeq m_\Lambda - m_n$



The Dark Photon

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

The Dark Photon

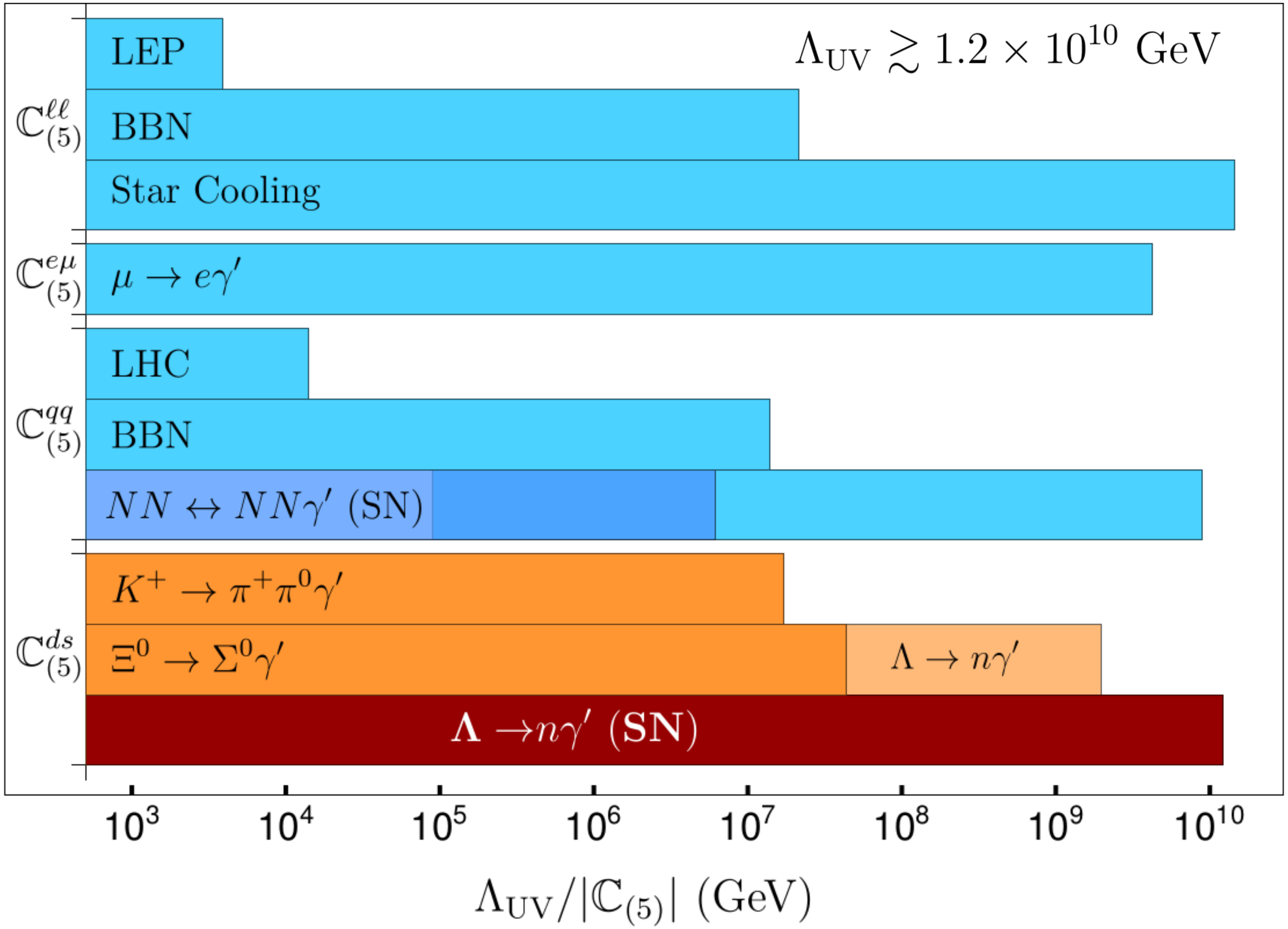
- $$\mathcal{L}_{\gamma'} = \frac{1}{\Lambda_{\rm UV}} \bar{\psi}_i \sigma^{\mu\nu} \left(\mathbb{C}^{ij} + i\,\mathbb{C}_5^{ij}\gamma_5\right) \psi_j F'_{\mu\nu}$$

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

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

The Dark Photon

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



The Dark Photon

- Future experiments should reach higher sensitivities

The Dark Photon

- Future experiments should reach higher sensitivities

Kaons		Hyperons	
Decay mode	Max branching ratio	Decay mode	Max branching ratio
$K^+ \to \pi^+\pi^0 A'$	1.3×10^{-7} $\left(7.8 \times 10^{-11}\right)$	$\Lambda \to nA'$	1.4×10^{-5} $\left(8.0 \times 10^{-9}\right)$
$K^+ \to \pi^+\gamma A'$	3.2×10^{-8} $\left(1.9 \times 10^{-11}\right)$	$\Sigma^+ \to pA'$	8.3×10^{-7} $\left(4.9 \times 10^{-10}\right)$
$K_L \to \pi^0\gamma A'$	5.9×10^{-8} $\left(3.4 \times 10^{-11}\right)$	$\Xi^0 \to \Sigma^0 A'$	5.2×10^{-6} $\left(3.0 \times 10^{-9}\right)$
$K_L \to \pi^+\pi^- A'$	5.6×10^{-7} $\left(3.2 \times 10^{-10}\right)$	$\Xi^0 \to \Lambda A'$	2.4×10^{-6} $\left(1.4 \times 10^{-9}\right)$
$K_L \to \gamma A'$	6.8×10^{-5} $\left(4.0 \times 10^{-8}\right)$	$\Xi^- \to \Sigma^- A'$	6.1×10^{-6} $\left(3.6 \times 10^{-9}\right)$
$K_L \to$ inv.	1×10^{-4} $\left(6.5 \times 10^{-10}\right)$	$\Omega^- \to \Sigma^- A'$	6.1×10^{-5} $\left(3.6 \times 10^{-8}\right)$

E. Goudzovski et al. ArXiv: 2201.07805

The Dark Photon

- Future experiments should reach higher sensitivities

Kaons		Hyperons	
Decay mode	Max branching ratio	Decay mode	Max branching ratio
$K^+ \to \pi^+\pi^0 A'$	1.3×10^{-7} (7.8×10^{-11})	$\Lambda \to nA'$	1.4×10^{-5} (8.0×10^{-9})
$K^+ \to \pi^+\gamma A'$	3.2×10^{-8} (1.9×10^{-11})	$\Sigma^+ \to pA'$	8.3×10^{-7} (4.9×10^{-10})
$K_L \to \pi^0\gamma A'$	5.9×10^{-8} (3.4×10^{-11})	$\Xi^0 \to \Sigma^0 A'$	5.2×10^{-6} (3.0×10^{-9})
$K_L \to \pi^+\pi^- A'$	5.6×10^{-7} (3.2×10^{-10})	$\Xi^0 \to \Lambda A'$	2.4×10^{-6} (1.4×10^{-9})
$K_L \to \gamma A'$	6.8×10^{-5} (4.0×10^{-8})	$\Xi^- \to \Sigma^- A'$	6.1×10^{-6} (3.6×10^{-9})
$K_L \to$ inv.	1×10^{-4} (6.5×10^{-10})	$\Omega^- \to \Sigma^- A'$	6.1×10^{-5} (3.6×10^{-8})

E. Goudzovski et al. ArXiv: 2201.07805

Takeaway message

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

Takeaway message

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


Thank you!