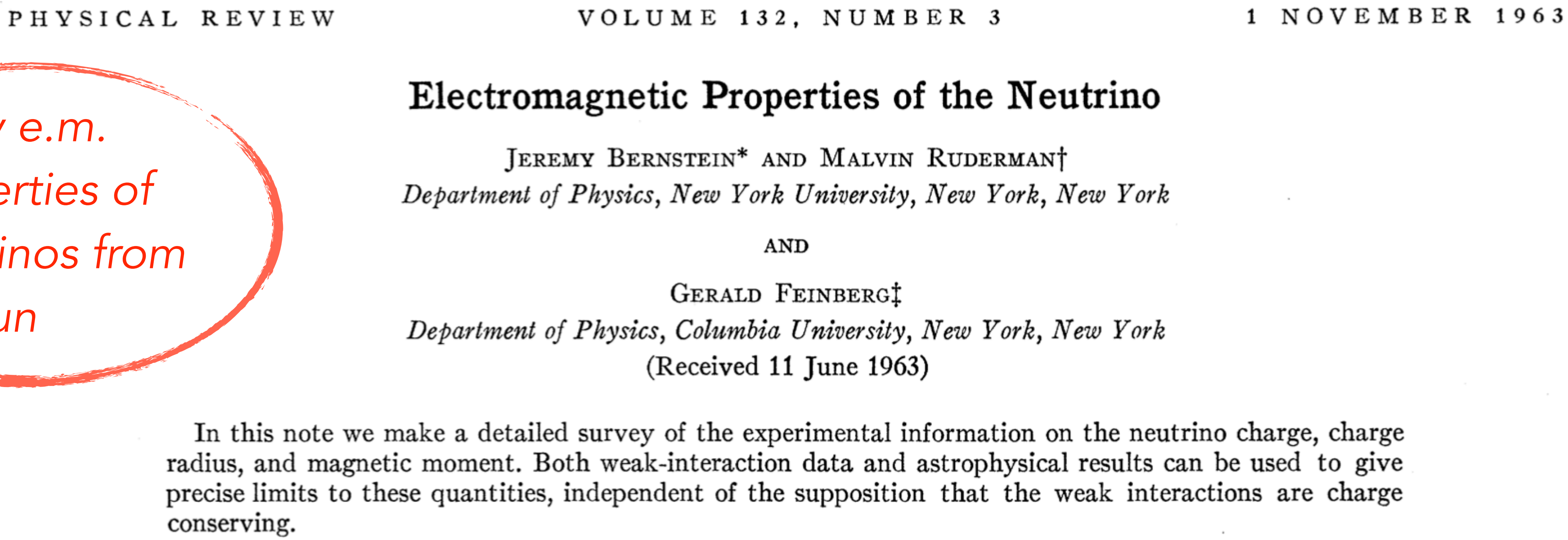
Status of stellar and astrophysics constraints on new (feebly-interacting) physics

Maurizio Giannotti,
Barry University

FIP 2020,
August 31- September 4, 2020

Probing the low energy frontier with stars.

Study e.m. properties of neutrinos from the sun



PHYSICAL REVIEW VOLUME 132, NUMBER 3 1 NOVEMBER 1963

Electromagnetic Properties of the Neutrino

JEREMY BERNSTEIN* AND MALVIN RUDERMAN†
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AND

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Department of Physics, Columbia University, New York, New York

(Received 11 June 1963)

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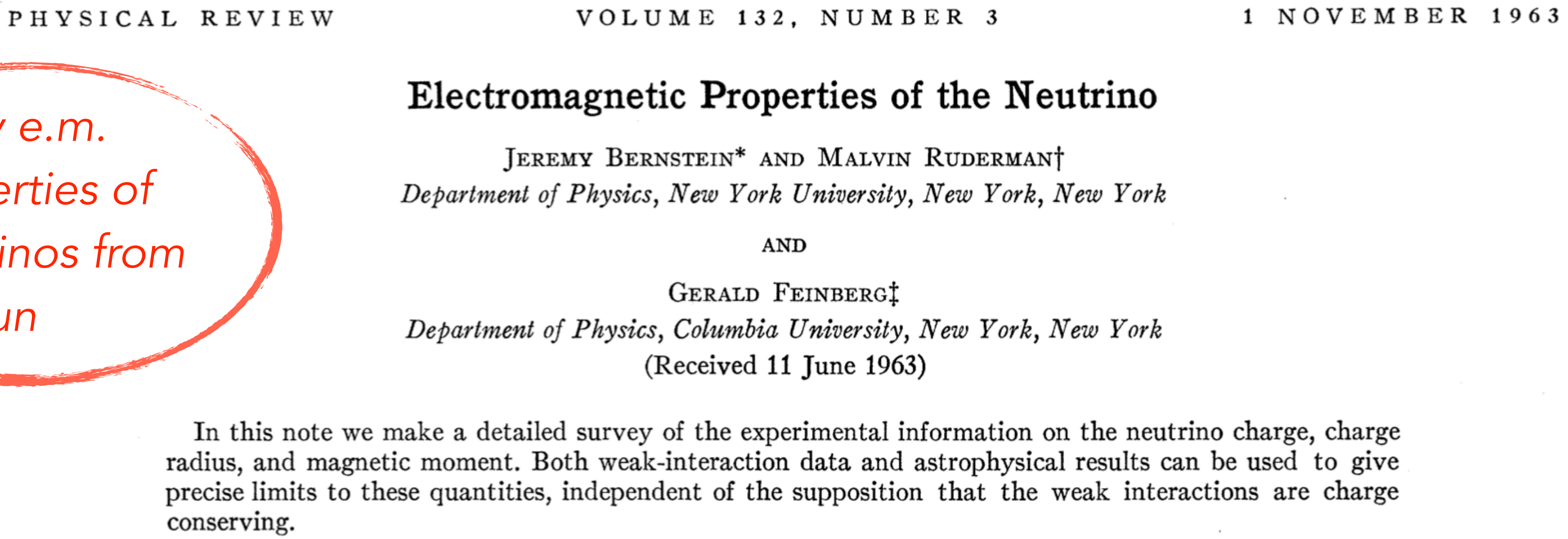

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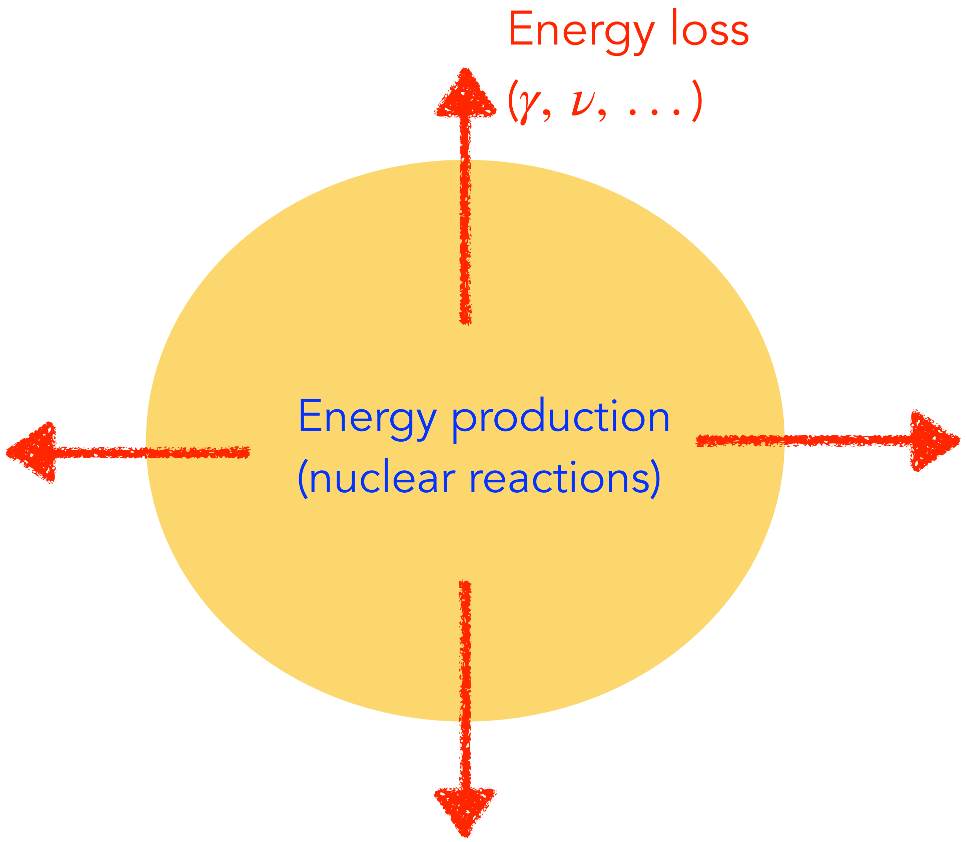
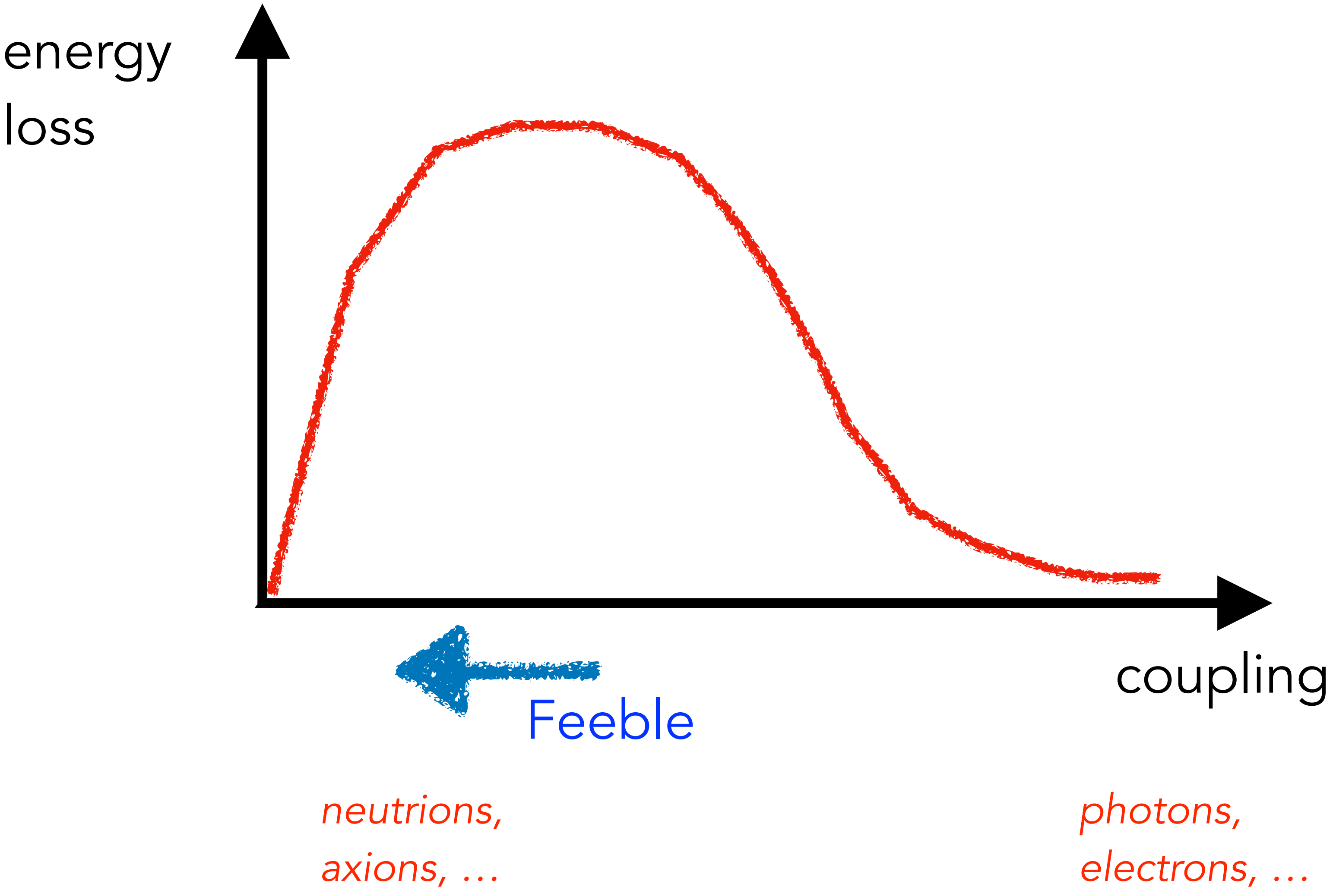
Why are stars such good FIP labs?

Feeble is good!

Light particles, $m \lesssim T$, can be efficiently thermally produced in stellar core

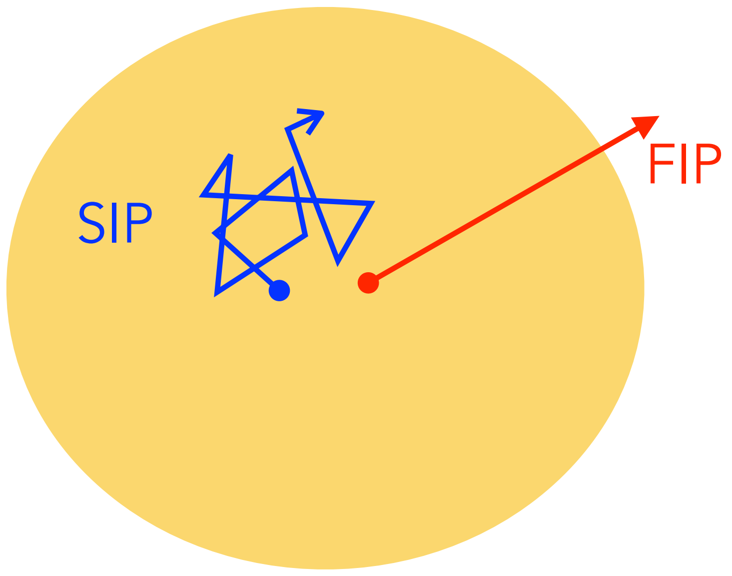


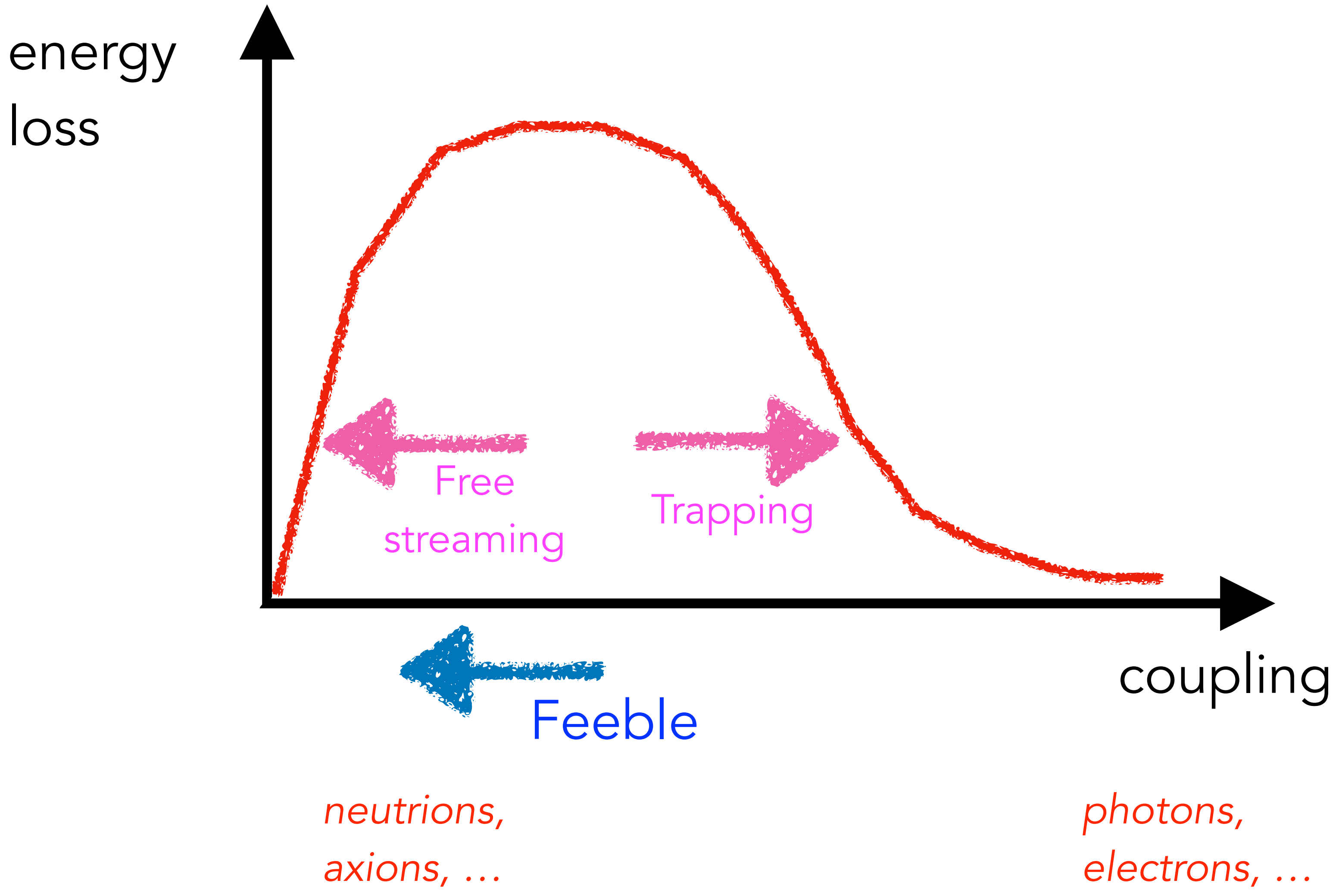


Efficient energy loss
→ fast fuel burning
→ short life
→ few stars

Feeble is good!

Light particles, $m \lesssim T$, can be efficiently thermally produced in stellar core





Efficient energy loss
→ fast fuel burning
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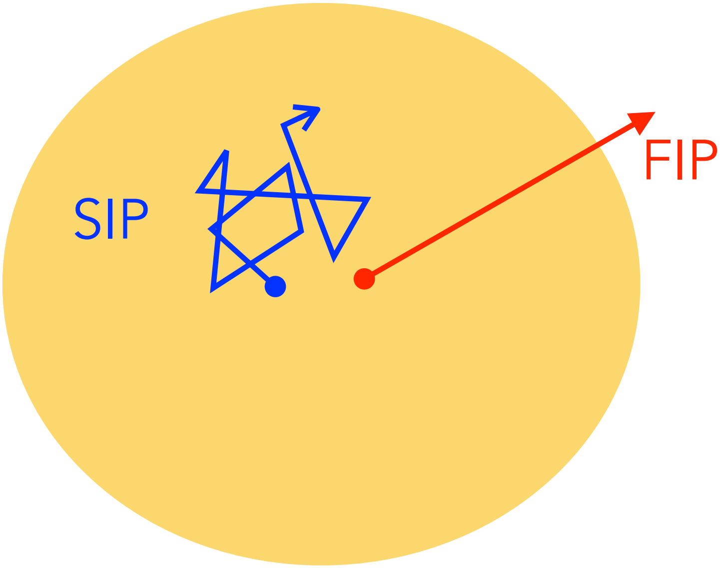
Feeble is good!

Example: the SM process

$$e^+ \, e^- \to \bar{\nu} \, \nu$$

has a branching ratio 10^{-19} times smaller than the process

$$e^+ \, e^- \to \gamma \, \gamma$$



D. D. Clayton, "Principles of Stellar Evolution and Nucleosynthesis", Chicago (1984)

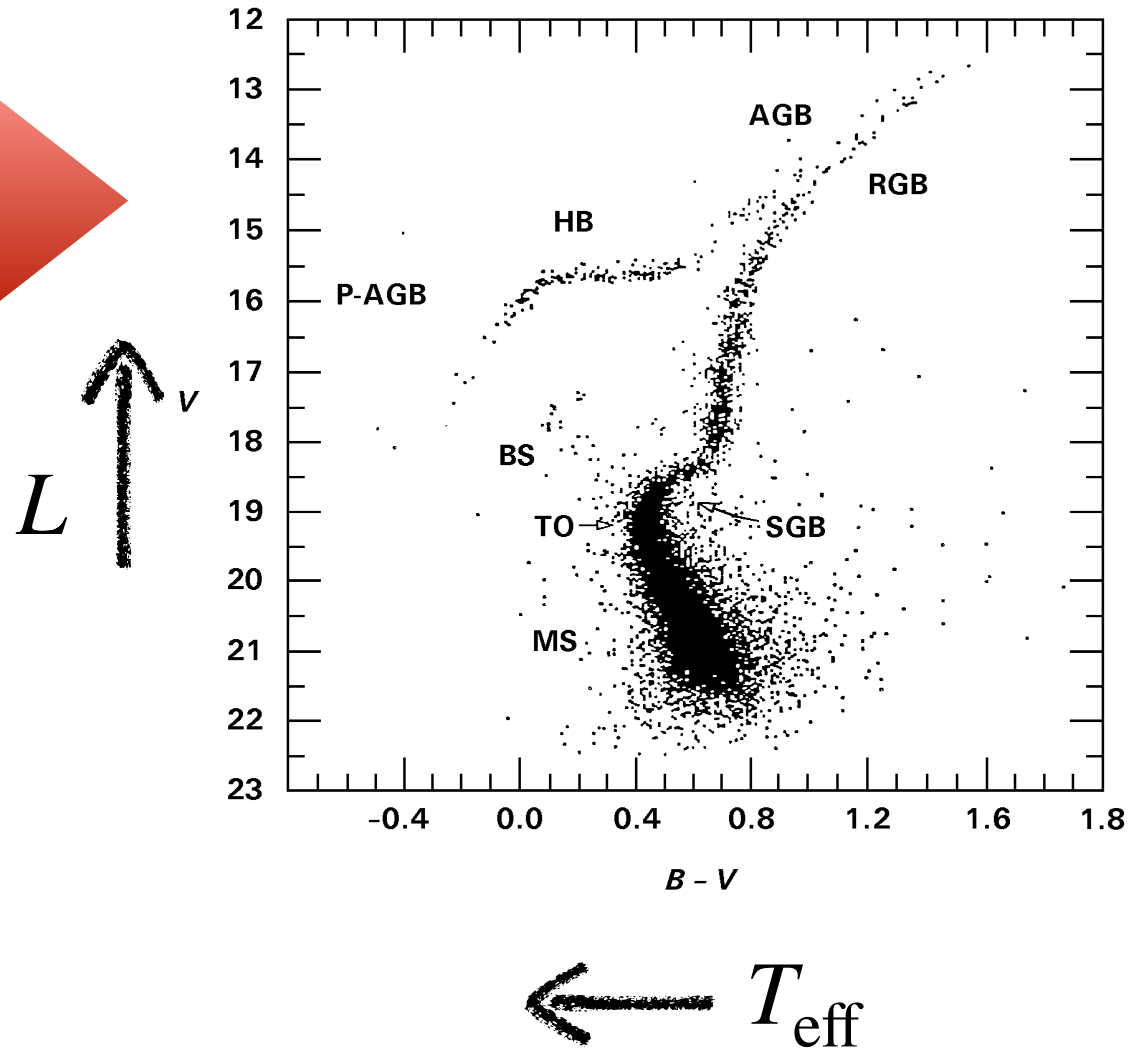
Yet, it controls the evolution of a massive star during the late evolutionary stages.

Another very rare process, $\gamma \to \bar{\nu}\nu$, controls the stellar evolution during the RGB.

Stars as Laboratory for FIPs

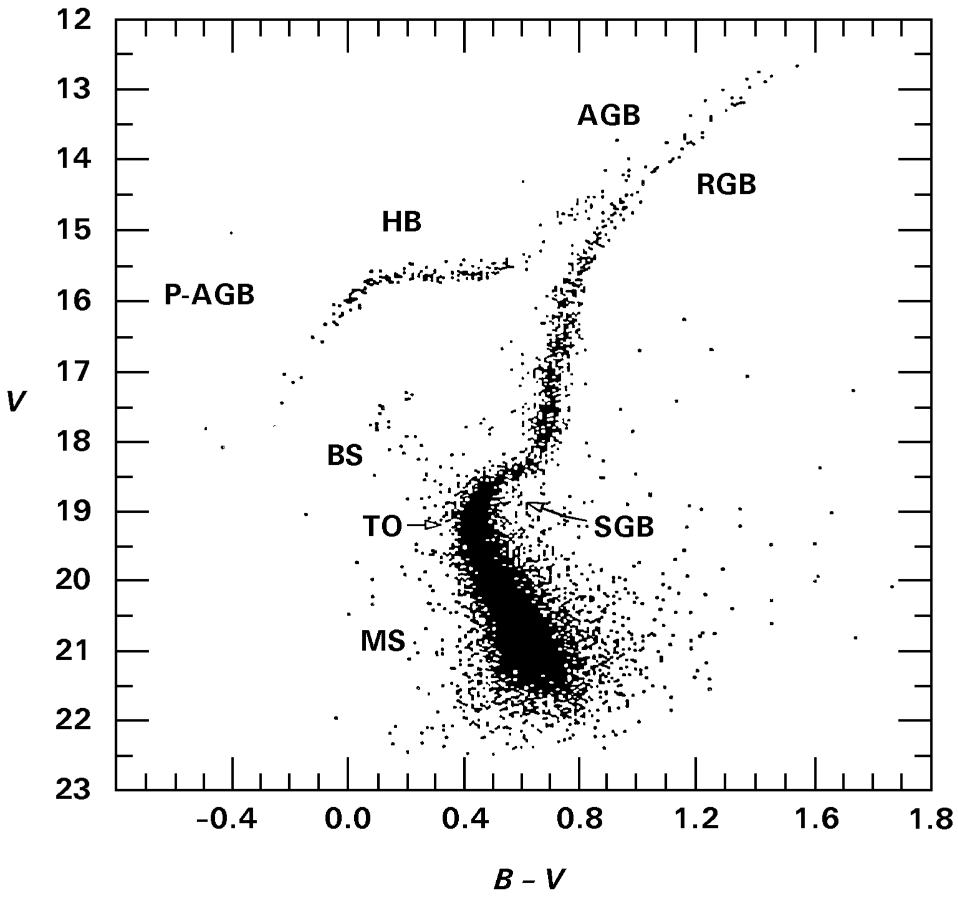
What we observe is stellar populations

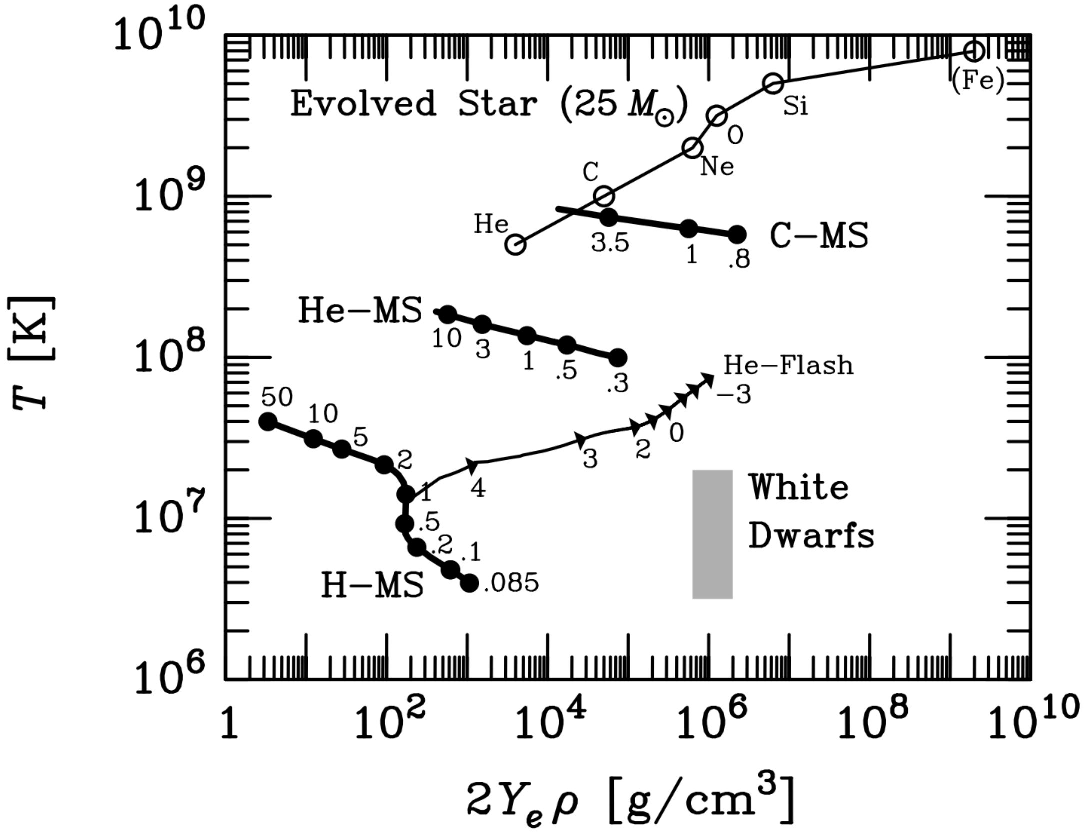
HR or Color Magnitude Diagram (CMD)



Stars as Laboratory for FIPs

What we observe is stellar populations



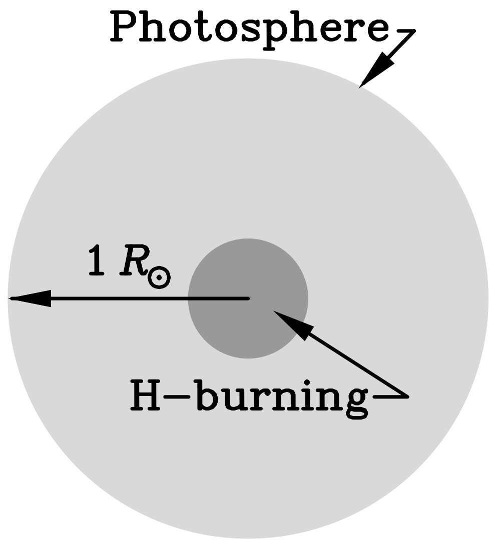


What we need is stellar evolution (especially of the core)

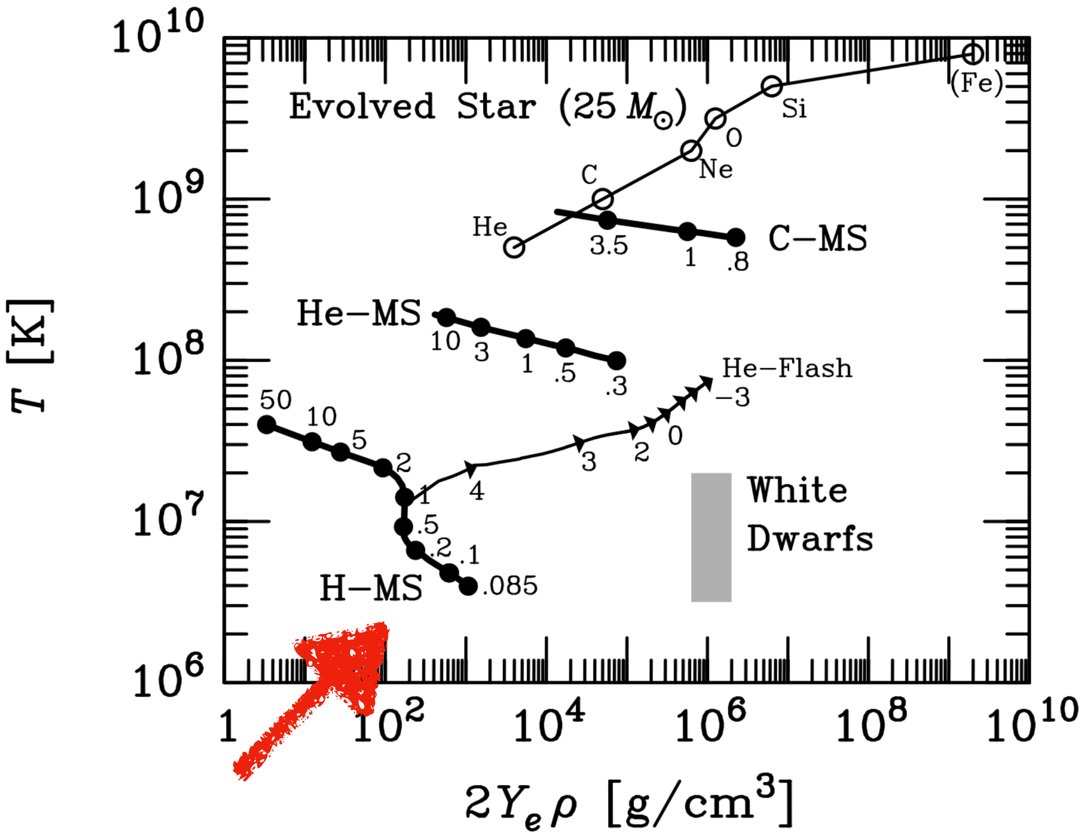
Figures from G. Raffelt, Stars as Laboratories (1996).

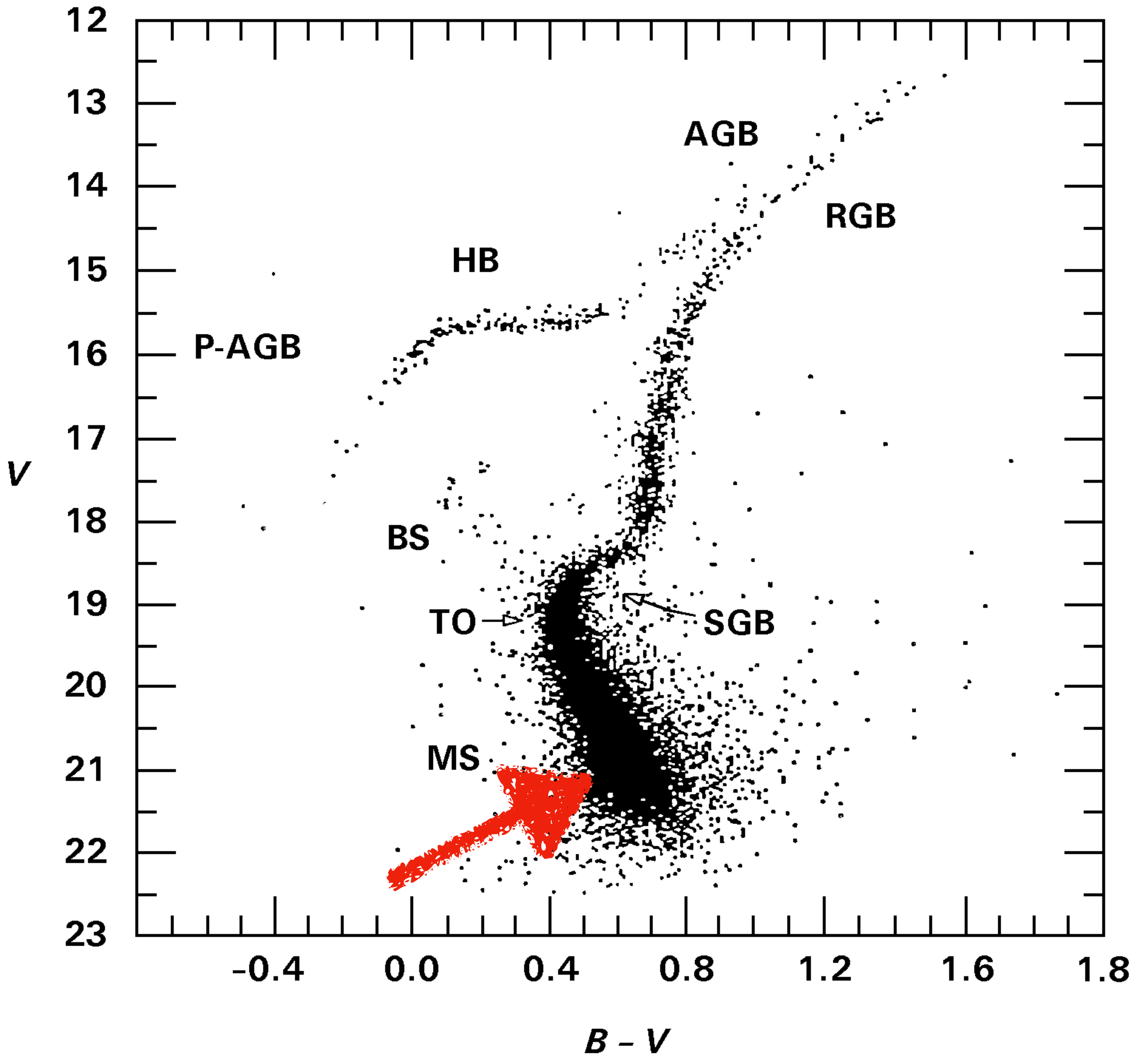
Numerical codes provide the link!

Stellar Evolution



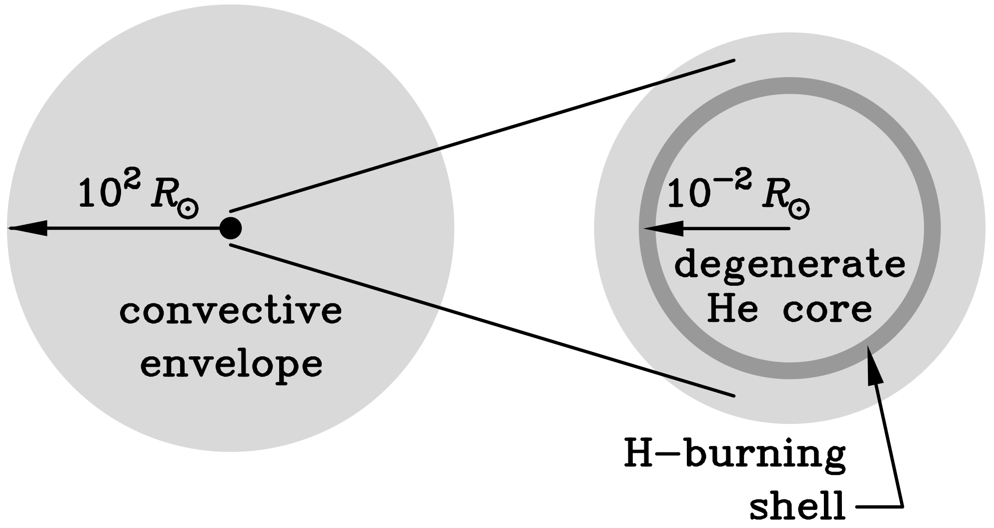
Most of the stellar life is spent burning H into He in the core



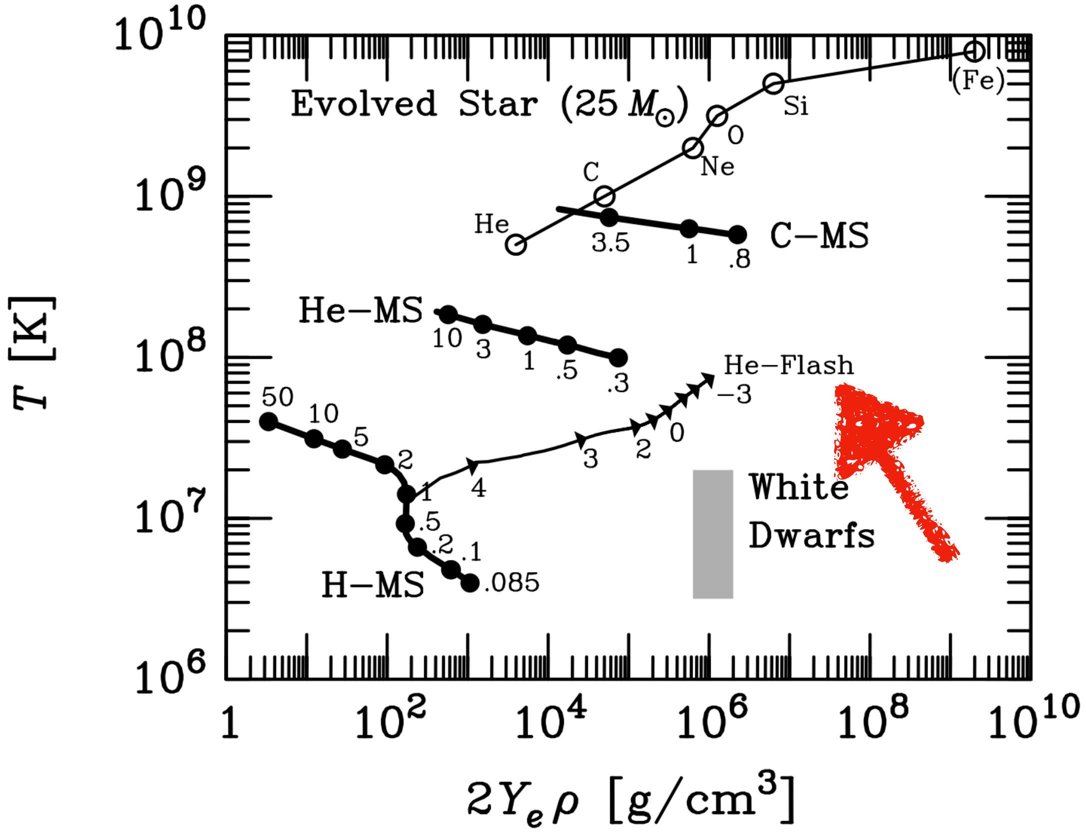


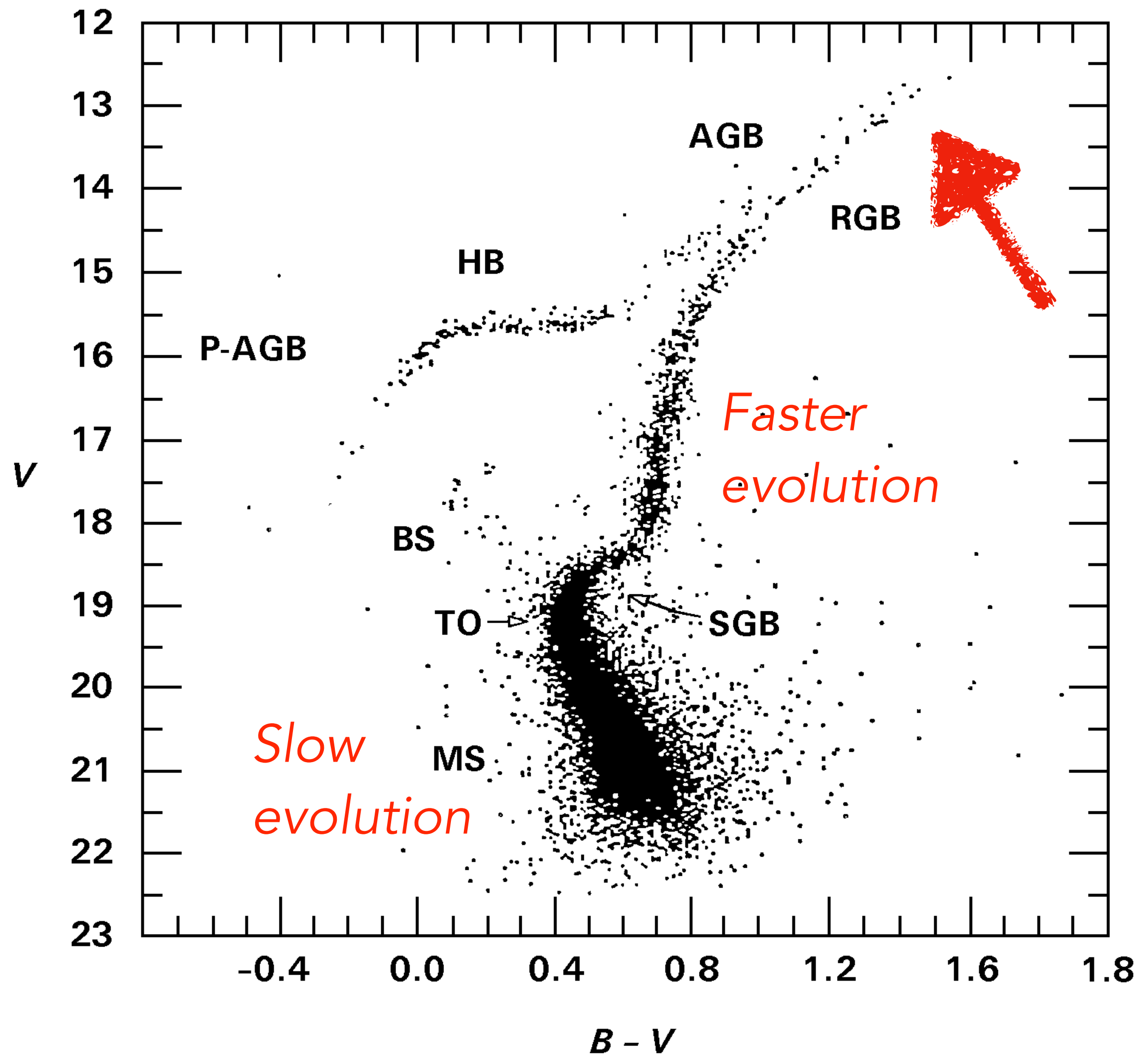
G. Raffelt, Stars as Laboratories (1996).

Stellar Evolution



After the H in the core is exhausted, a light star star moves in the RGB. The surface luminosity keeps increasing, till the He-flash. That is the tip of the RGB





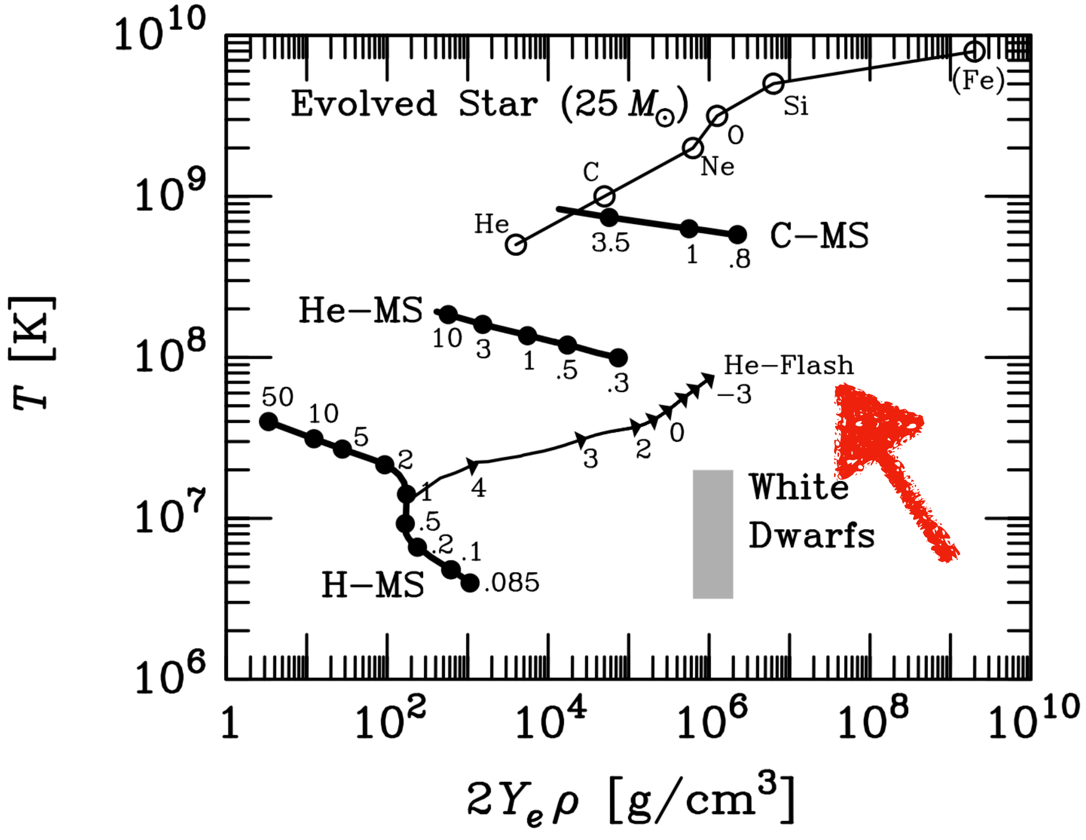
Faster evolution

Slow evolution

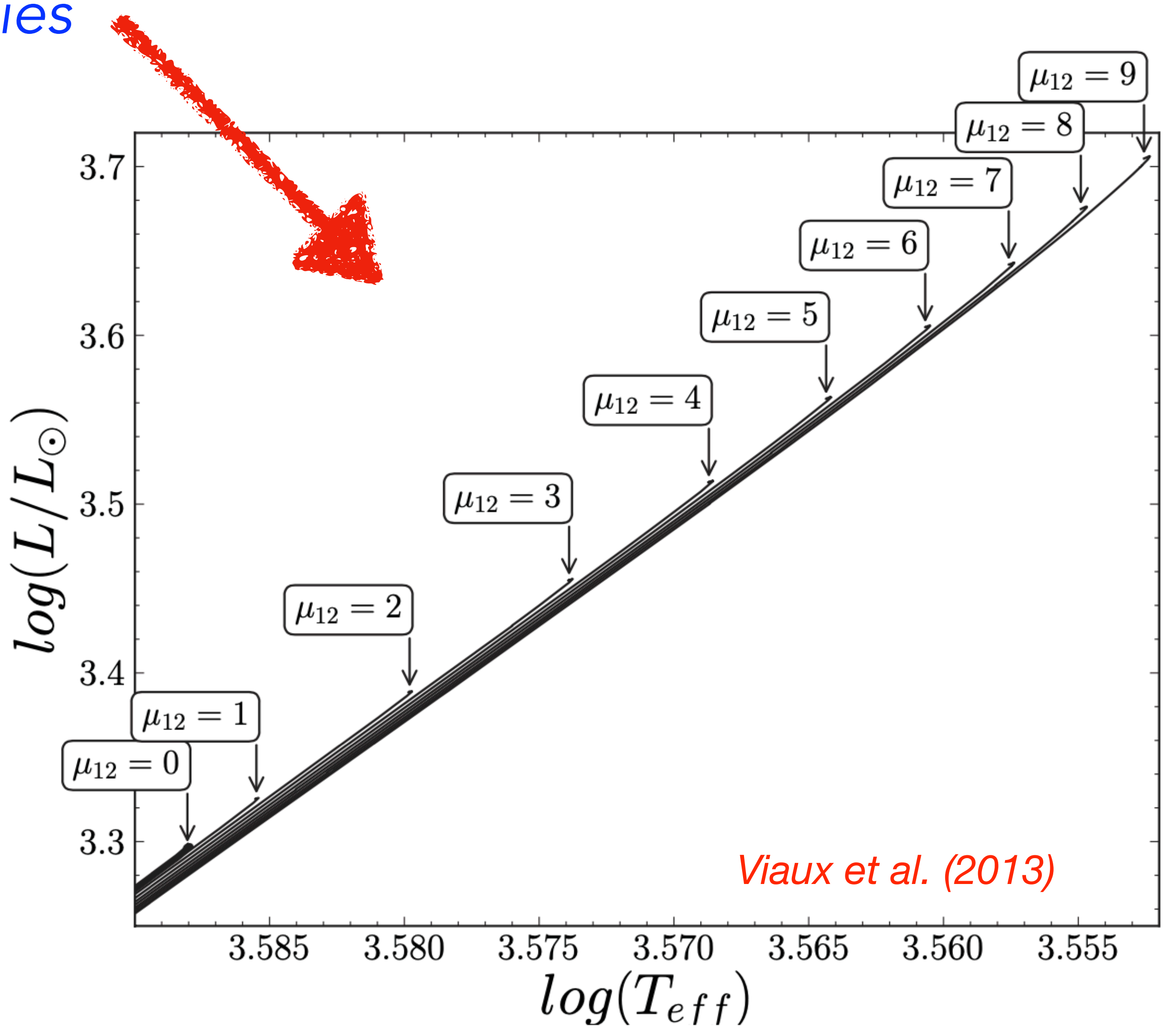
G. Raffelt, Stars as Laboratories (1996).

Stellar Evolution

Additional cooling delays the He-ignition, moving the RGBT to higher luminosities



G. Raffelt, Stars as Laboratories (1996).

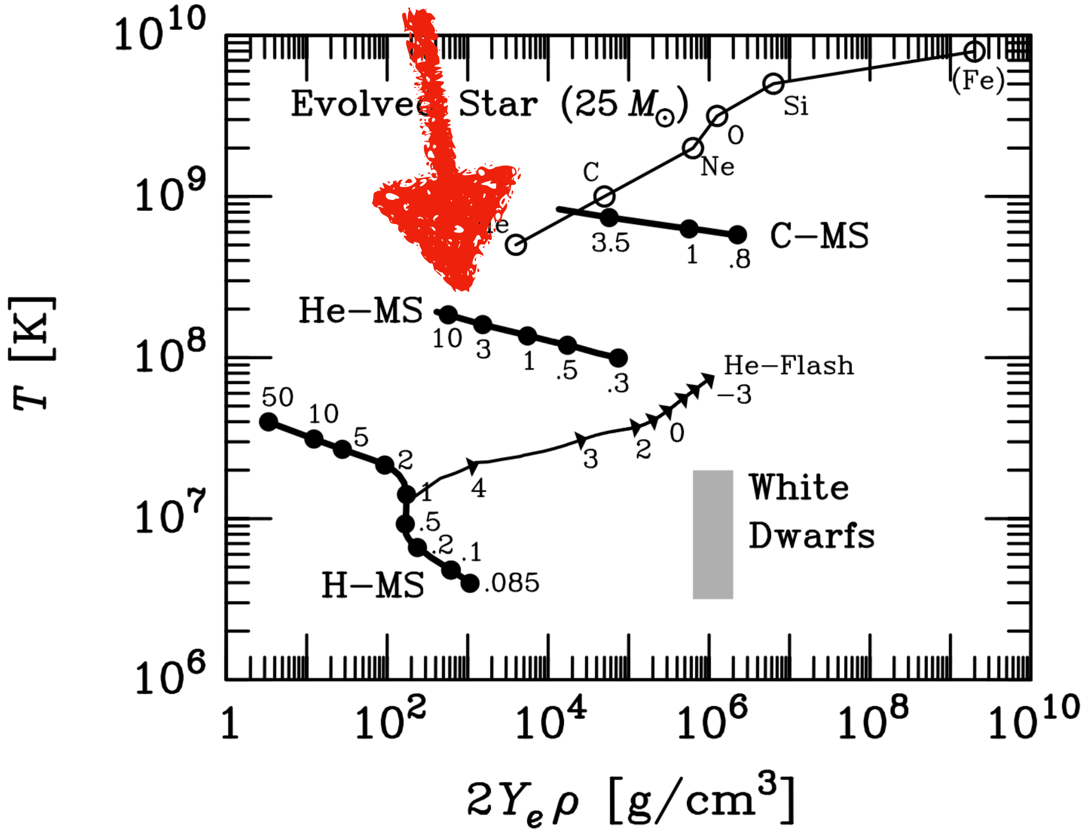


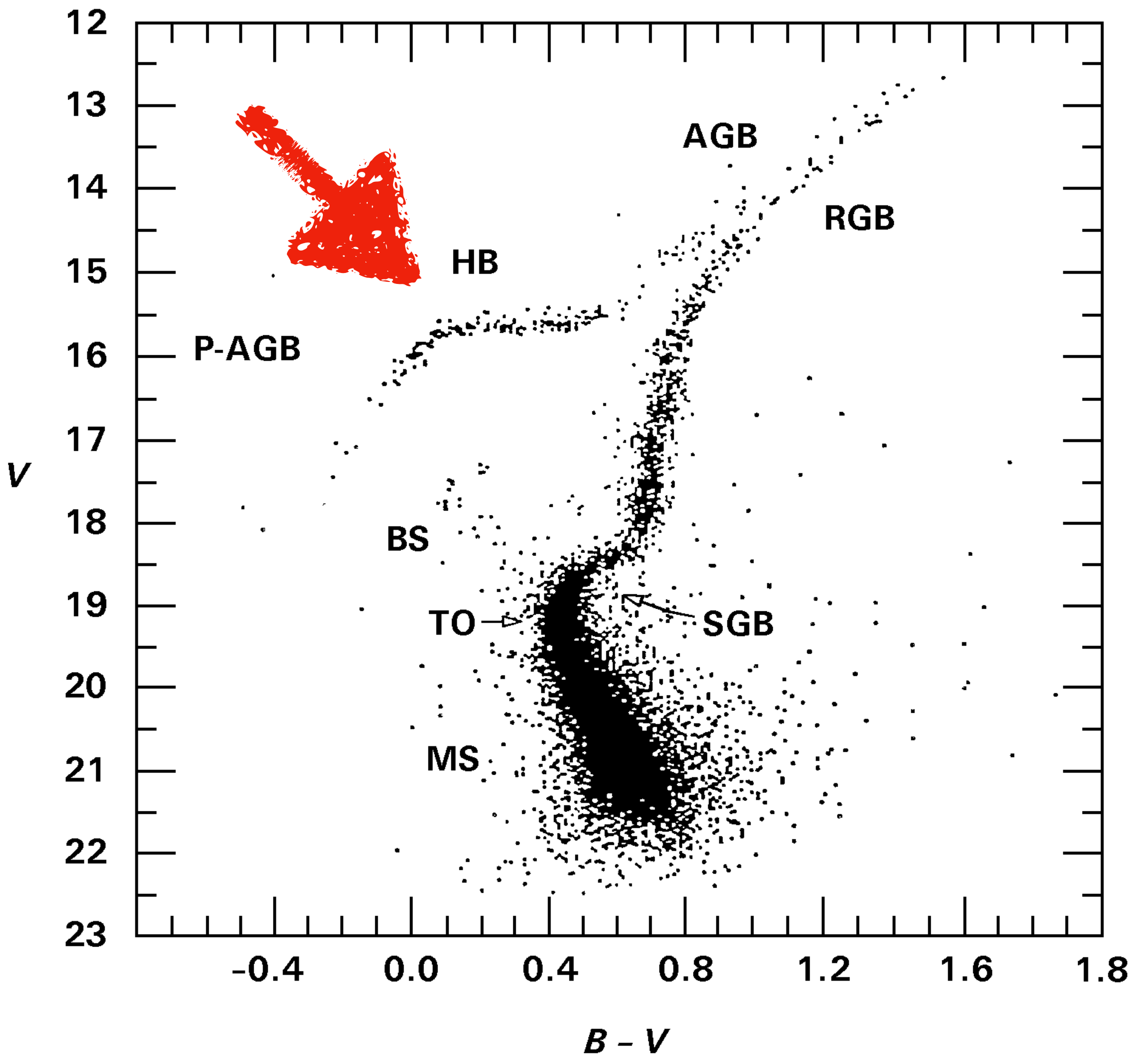
Viaux et al. (2013)

Mild hints of additional cooling have been reported in the past few years.

Stellar Evolution

… after the He-flash, He is ignited and the star moves to the HB.



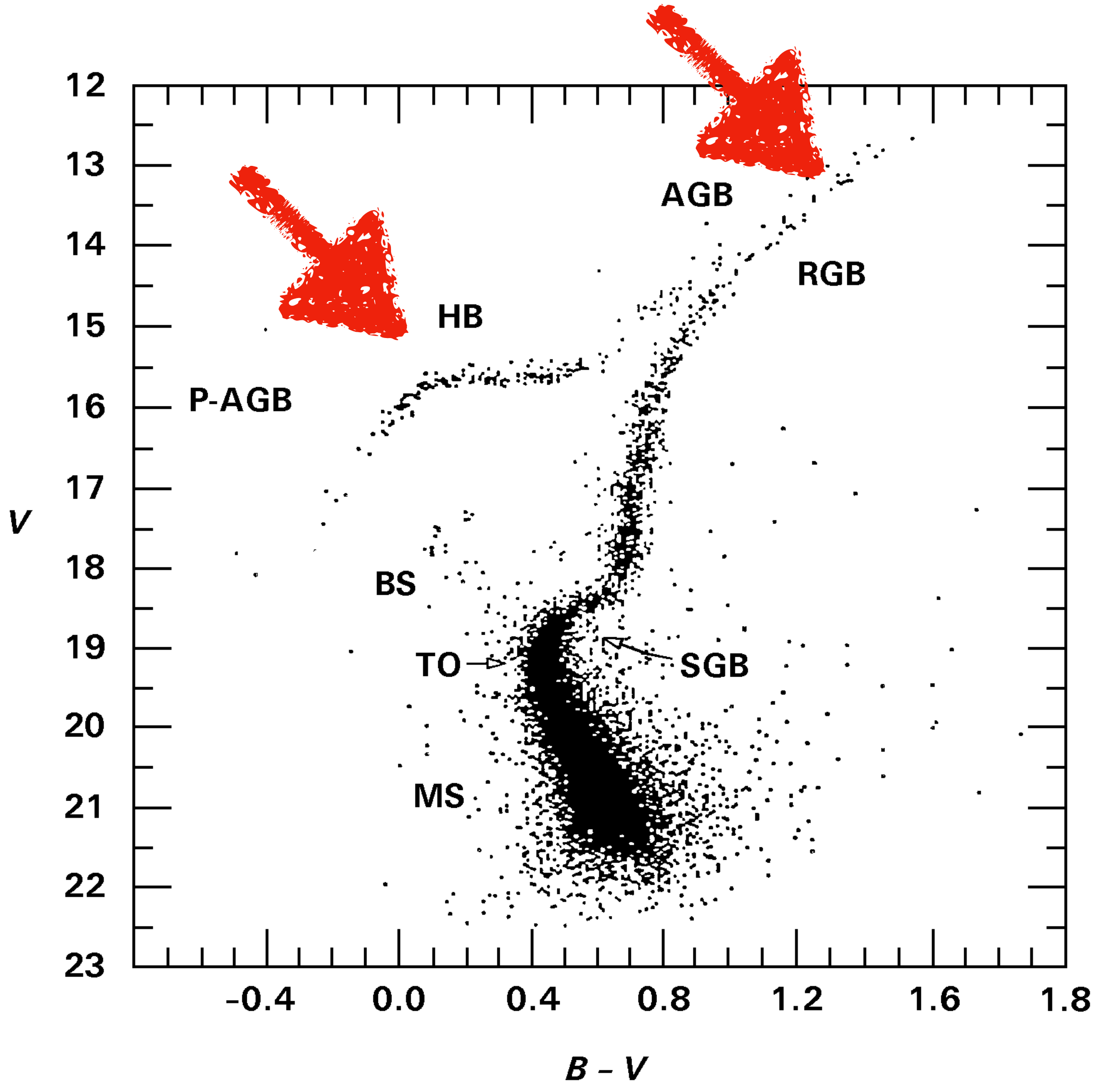


G. Raffelt, Stars as Laboratories (1996).

Stellar Evolution

The number ratio of HB and RGB is the R-parameter

$$R = \frac{N_{\mathrm{HB}}}{N_{\mathrm{RGB}}}$$



Stellar Evolution

The number ratio of HB and RGB is the R-parameter

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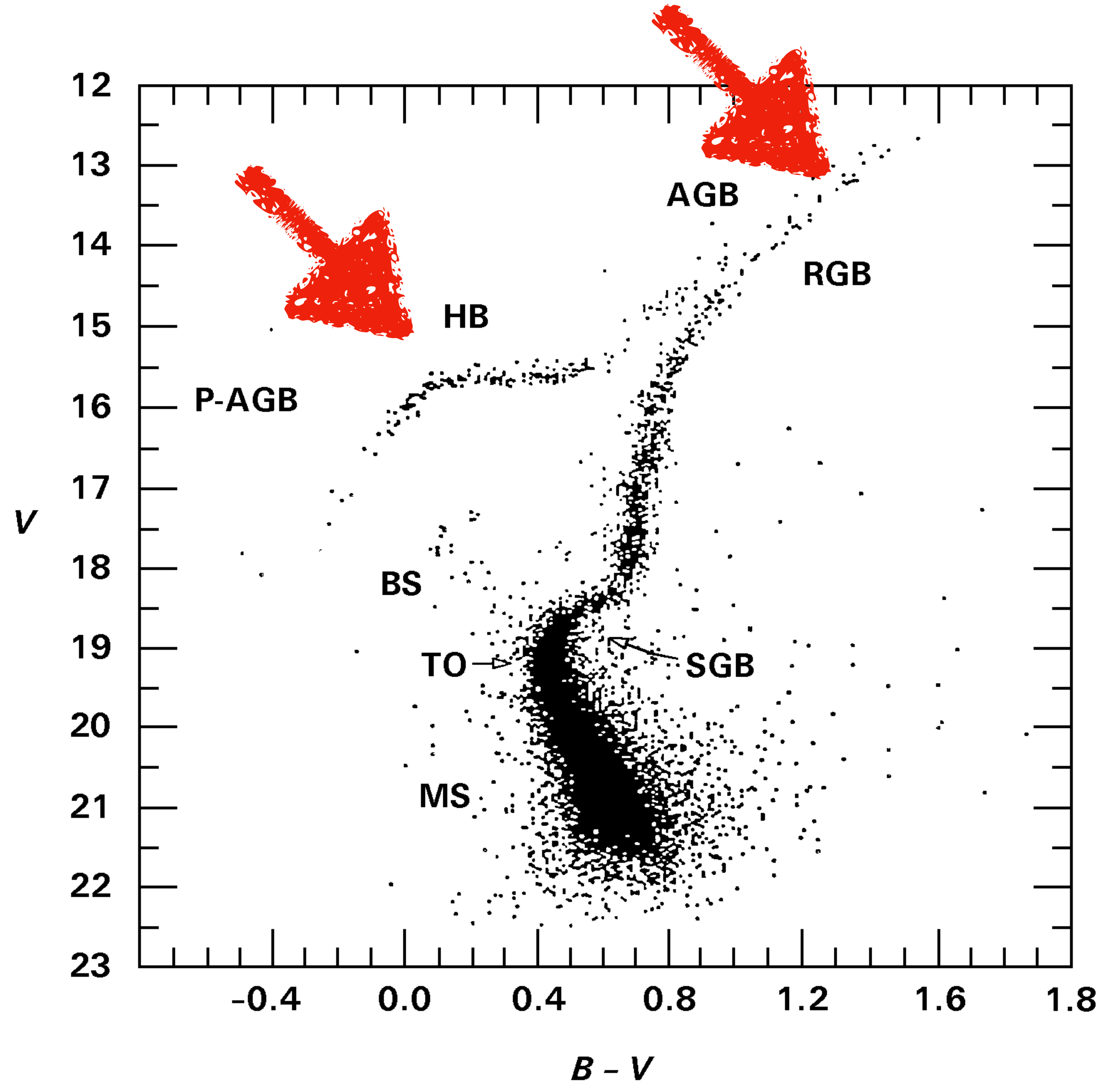
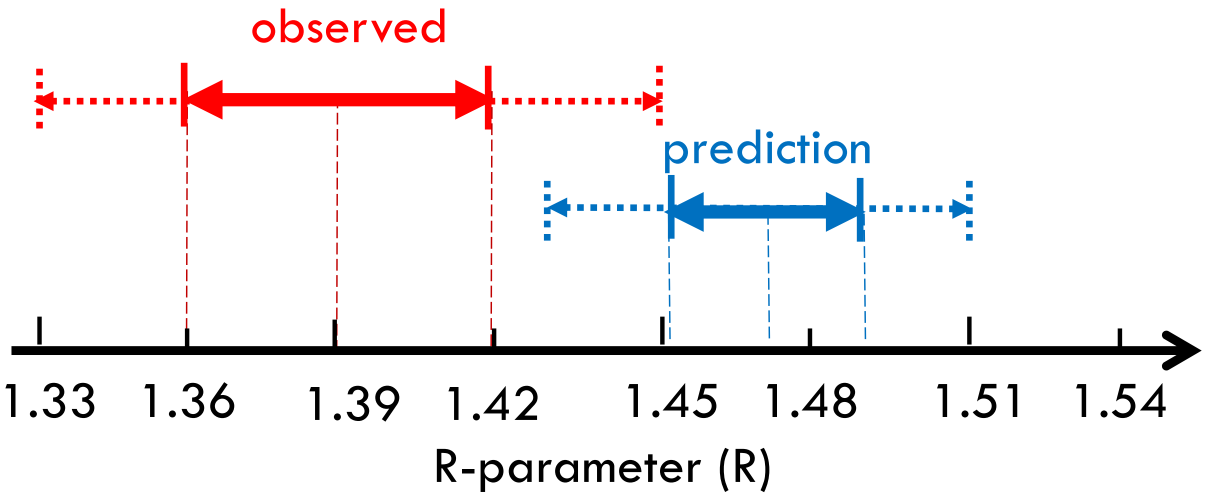


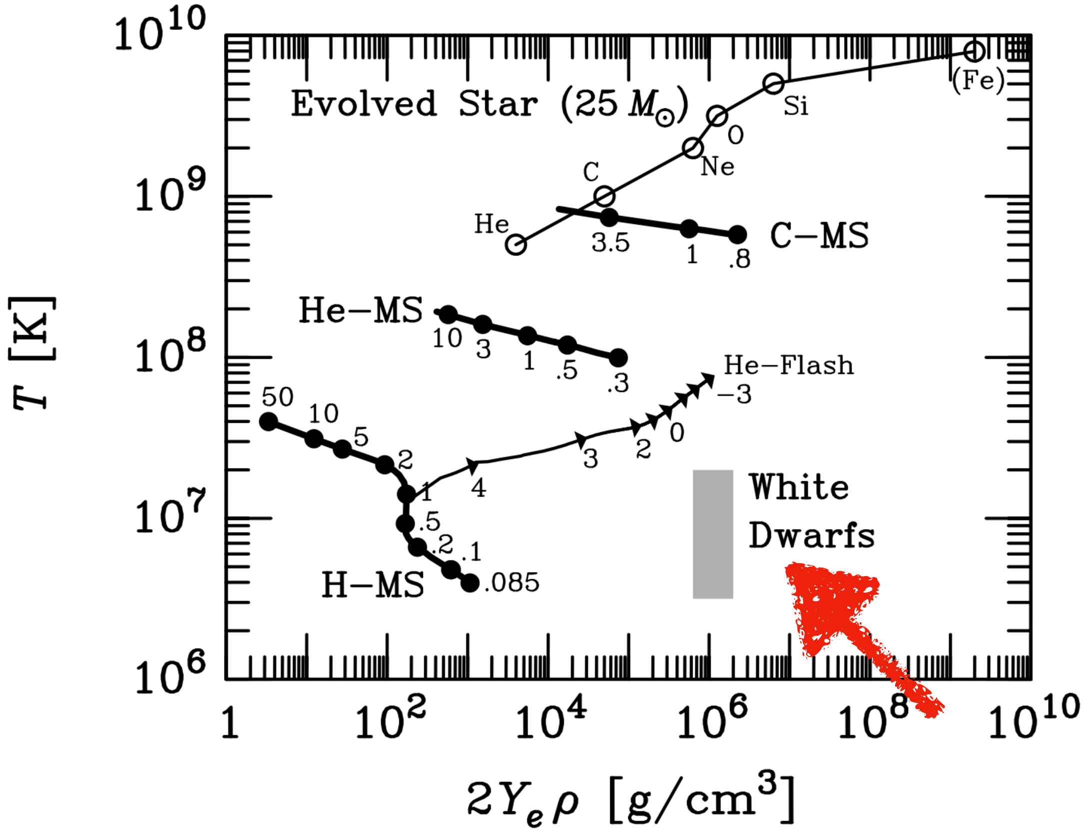
The current analysis shows a slight discrepancy between the predicted and observed R-parameter.



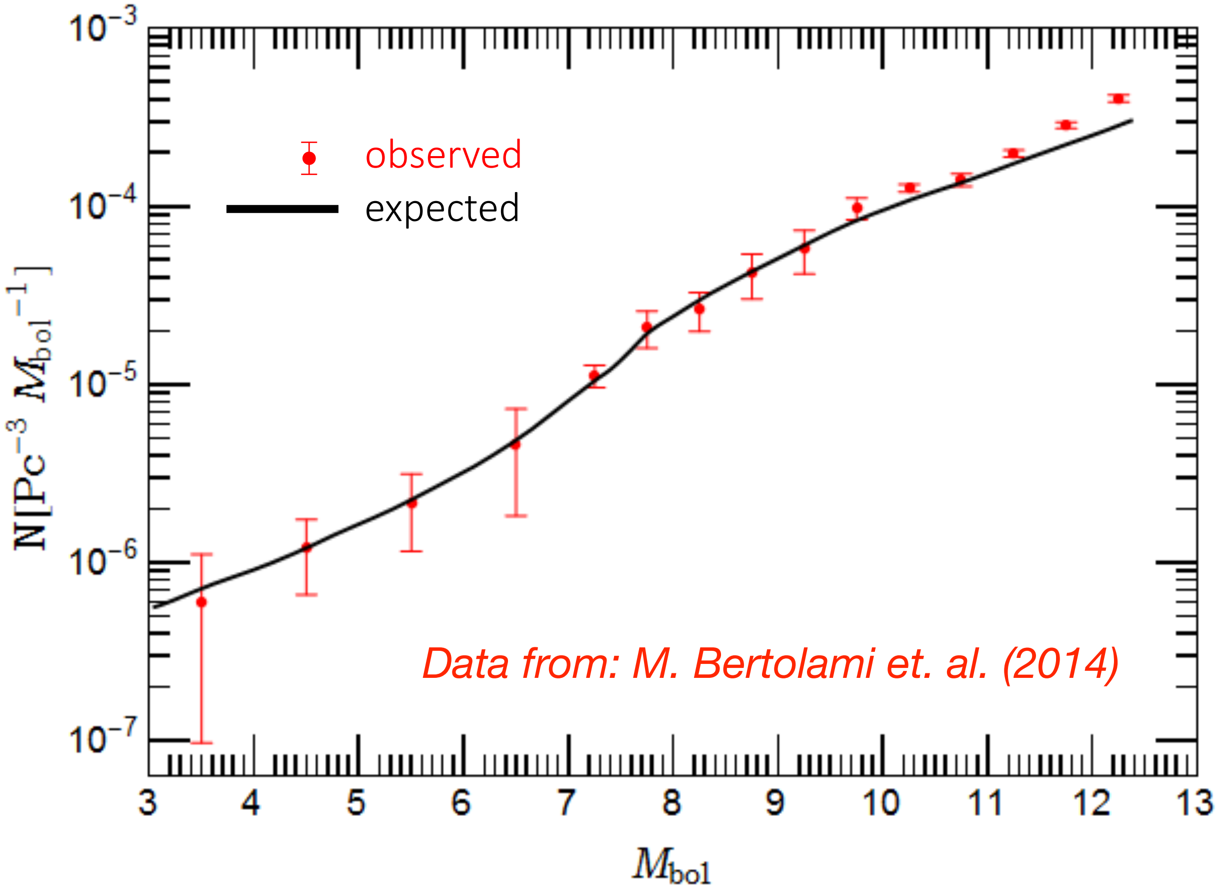
Ayala et al., PRL 113 (2014)

Stellar Evolution

Lighter stars go to the AGB at the end of the central He, and end up as CO White Dwarfs.



G. Raffelt, Stars as Laboratories (1996).



Data from: M. Bertolami et. al. (2014)

The WDLF is a powerful way to measure the cooling efficiency

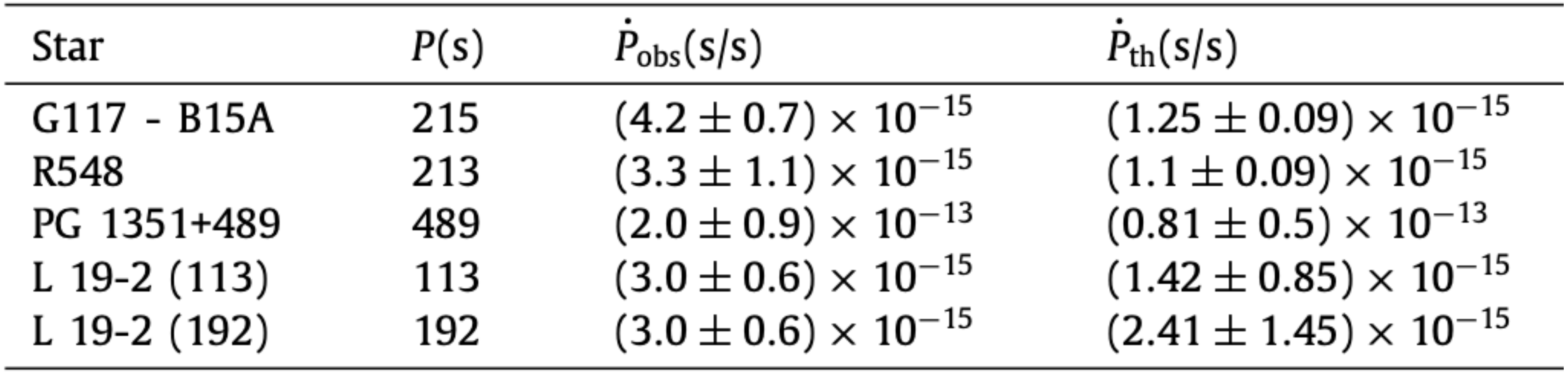
$$\frac{dN_{\rm WD}}{dV\,dL} \propto \frac{1}{L_\gamma + L_\nu + L_x}$$

Stellar Evolution: WD

WD Variables (WDV)

Measures of the period change rate in WD variables offer a way to test the cooling of WDs

$$\dot{P}/P \propto \dot{T}/T$$



Star	P(s)	$\dot{P}_{\rm obs}$(s/s)	$\dot{P}_{\rm th}$(s/s)
G117 - B15A	215	$(4.2 \pm 0.7) \times 10^{-15}$	$(1.25 \pm 0.09) \times 10^{-15}$
R548	213	$(3.3 \pm 1.1) \times 10^{-15}$	$(1.1 \pm 0.09) \times 10^{-15}$
PG 1351+489	489	$(2.0 \pm 0.9) \times 10^{-13}$	$(0.81 \pm 0.5) \times 10^{-13}$
L 19-2 (113)	113	$(3.0 \pm 0.6) \times 10^{-15}$	$(1.42 \pm 0.85) \times 10^{-15}$
L 19-2 (192)	192	$(3.0 \pm 0.6) \times 10^{-15}$	$(2.41 \pm 1.45) \times 10^{-15}$

L. Di Luzio, M.G., E. Nardi, L. Visinelli, Phys.Rept. 870 (2020)

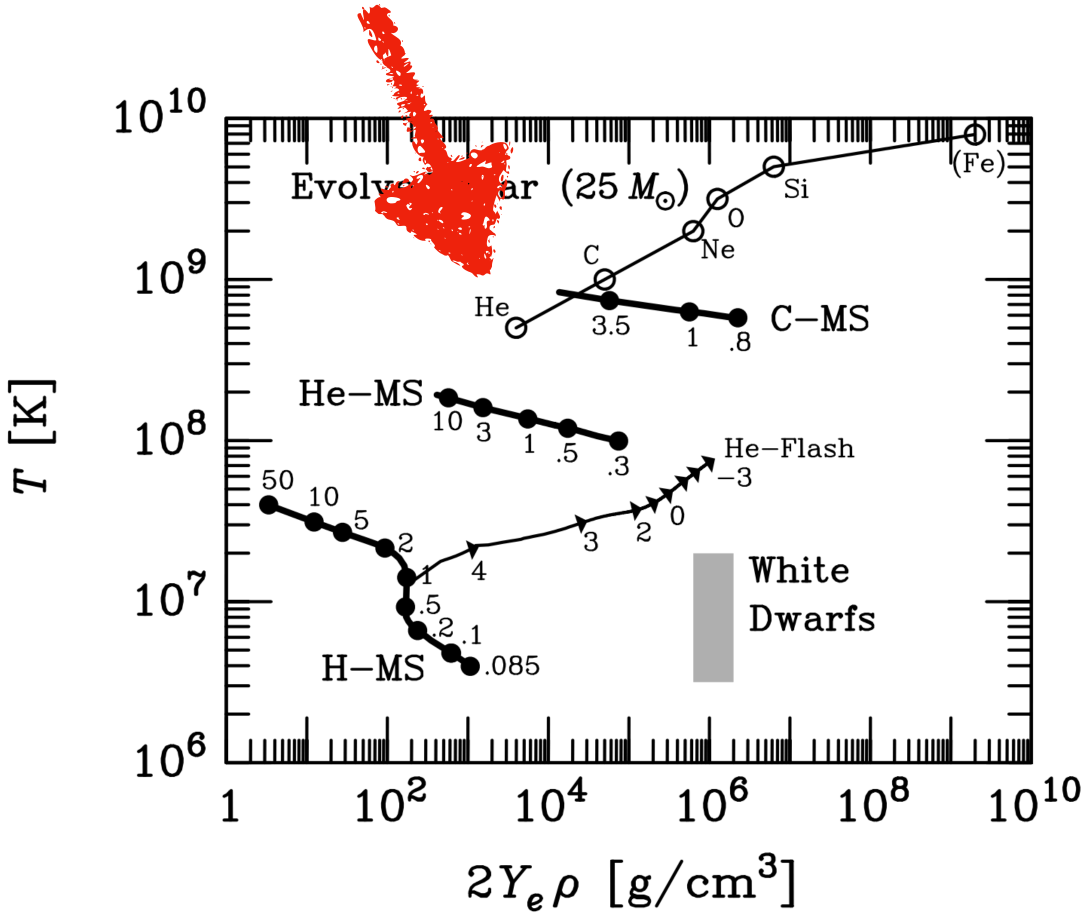
Observations over the past ~30 yr showed consistently $\dot{P}_{\rm obs} > \dot{P}_{\rm th}$, which seems to imply an overly efficient cooling.

Many works starting form Isern, Hernanz, Garcıa-Berro (1992)

Stellar Evolution

More massive stars exhibit blue loops during the He-burning phase.

In later stages, they develop an onion-like structure and may end their life as CCSN.



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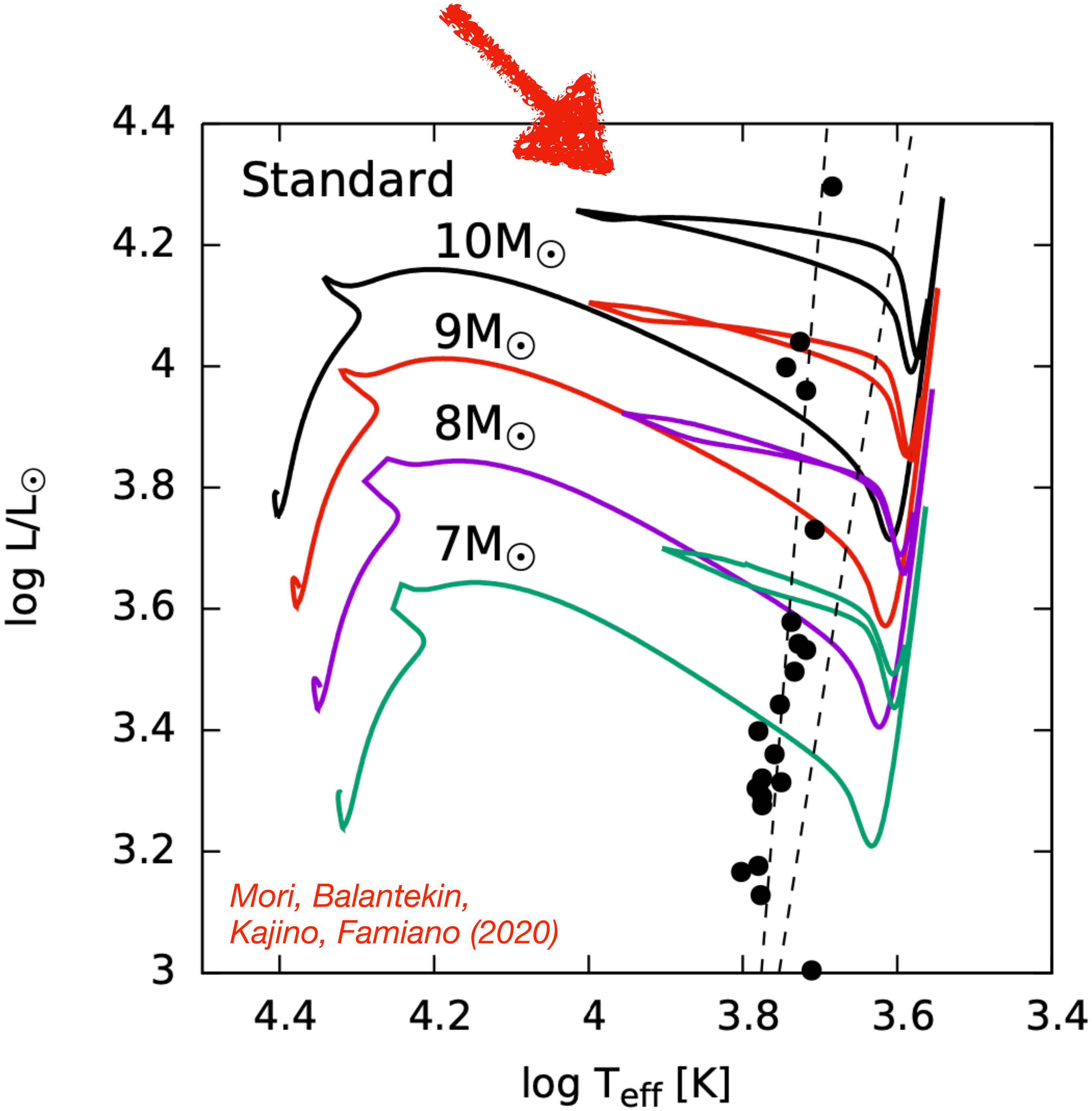


Mori, Balantekin, Kajino, Famiano (2020)

Stellar Evolution

More massive stars exhibit blue loops during the He-burning phase.

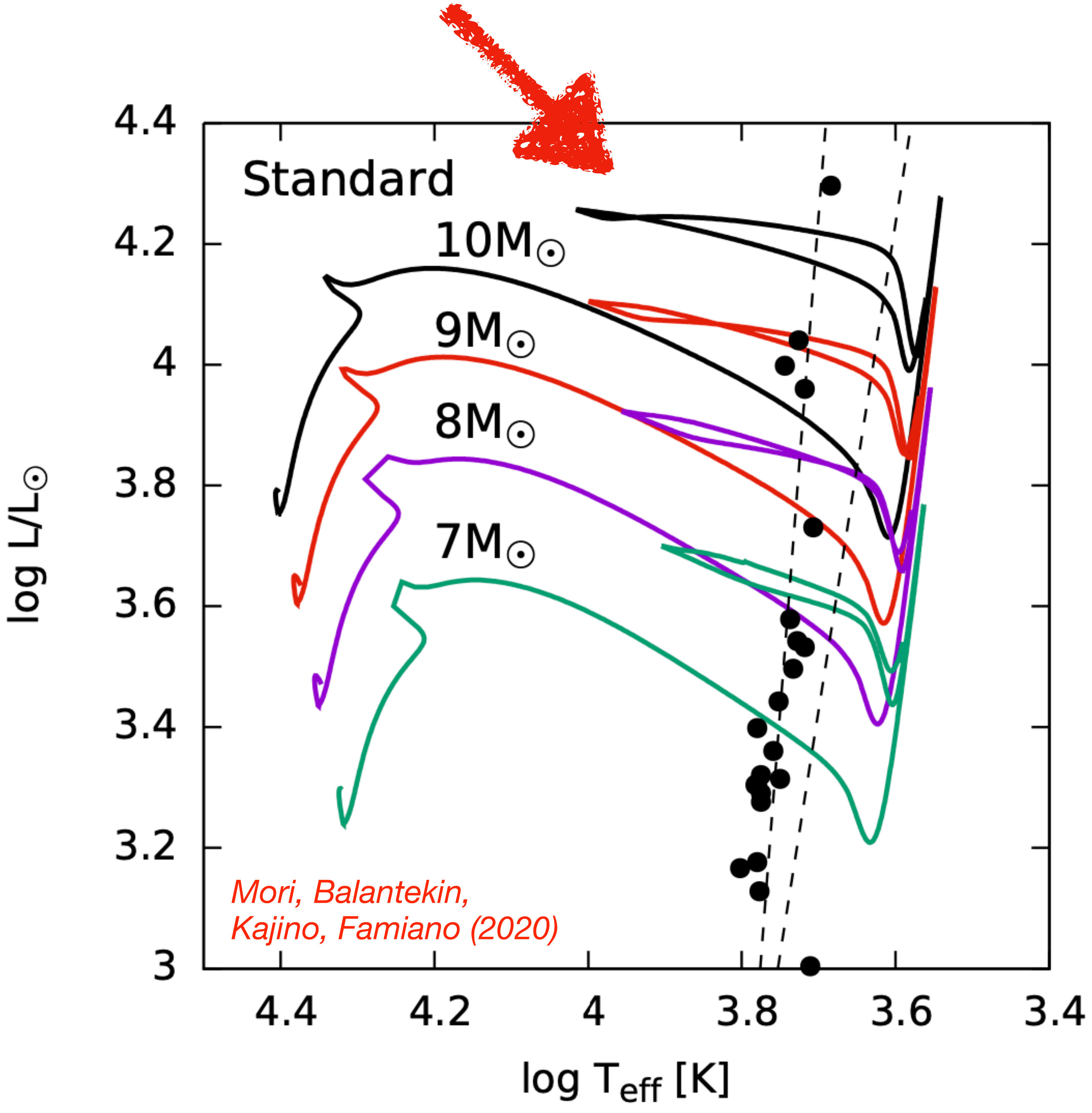
Current observations show:

1) a small red-shift of the bluest point of the blue loop in the high luminosity region of the CMD and

2) too many blue stars (B/R problem).

Additional cooling in the He-burinig stage could alleviate this problem

- *R. C. Dohm-Palmer, E. D. Skillman (2002)*
- *K. B. W. McQuinn et al. (2011)*
- *Friedland, M.G., Wise (2013)*
- *Carosi et al. (2013)*



Mori, Balantekin, Kajino, Famiano (2020)

Stellar Cooling Anomalies: New Physics?

Overly efficient energy loss in stars led to new physics speculation

- Long standing WD hint.

Isern, Hernanz, Garcıa-Berro (1992), Córsico, Althaus, Miller Bertolami, Kepler (2019), and many other works

- Less solid indication of anomalous cooling in RGB

O. Straniero et al., to appear.

- Very recent claim of a possible hint form Red Clumps Stars

Mori, Kusakabe, Balantekin, Kajino, Famiano (2020)

- Indication from HB stars (R-parameter)

Ayala, Dominguez, M.G., Mirizzi, Straniero (2014); Straniero et al. (2015)

- Massive stars (blue loop)

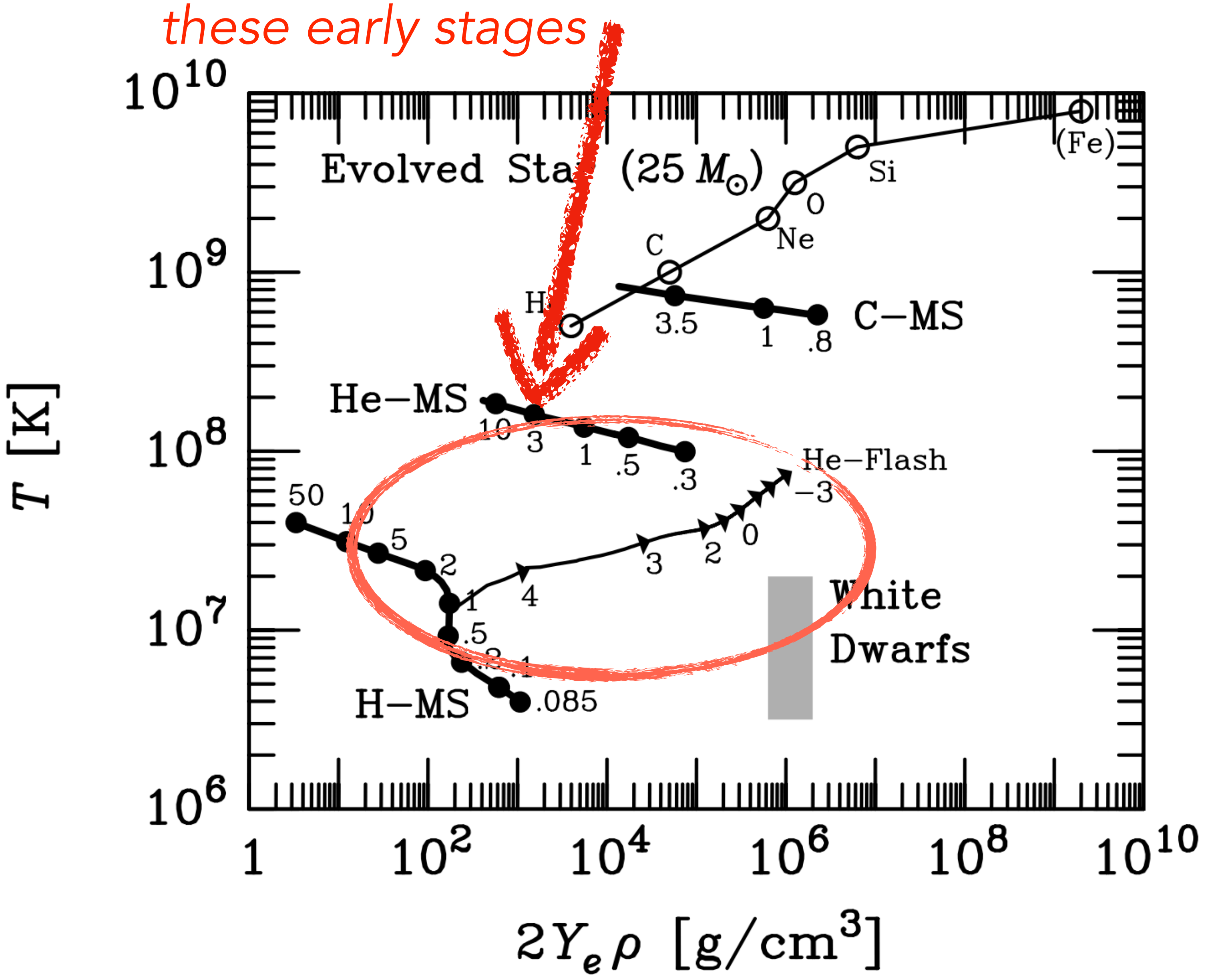
A. Friedland, M.G., M. Wise (2013), Carosi et al. (2014)

ALPs offer the best explanation

M.G., Irastorza, Redondo, Ringwald (2016)

Looking for FIPs in Stars

We can learn a lot from these early stages



During the early evolutionary phases, which are very relevant to the study of FIPs,

$$T_c \sim (1 - 10)\,\mathrm{keV}$$

and

$$\rho_c \sim (10^2 - 10^6)\,\mathrm{g\,cm^{-3}}$$

Other stages, when neutrino cooling dominates, are very fast

Axions and Axion-Like Particles (ALPs)

Axions are among the most well motivated FIPs:

Theoretically motivated by the strong CP problem and as DM candidates.

See Andreas Ringwald's talk (next talk)

$$L_{int} = -i \sum g_{ai}\, a\, \bar{\psi}_i \gamma_5 \psi_i - \frac{1}{4} g_{a\gamma}\, aF\tilde{F}$$

Di Luzio, M.G., Nardi, Visinelli, Phys.Rept. 870 (2020)

QCD axions parameter space restricted from relations among couplings and mass.

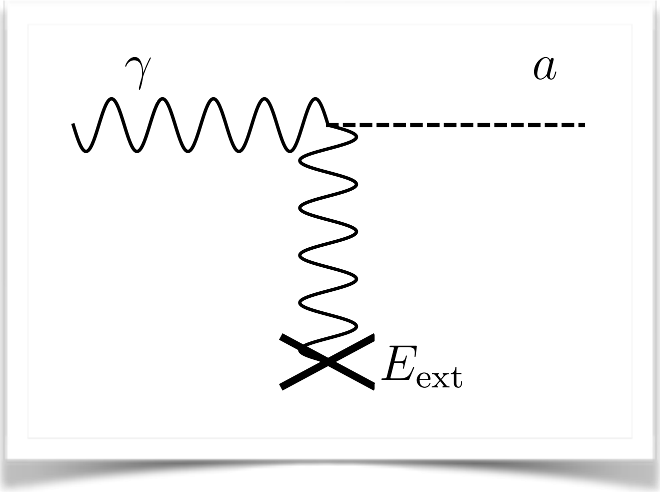
See Prateek Agrawa's talk (later, this morning)

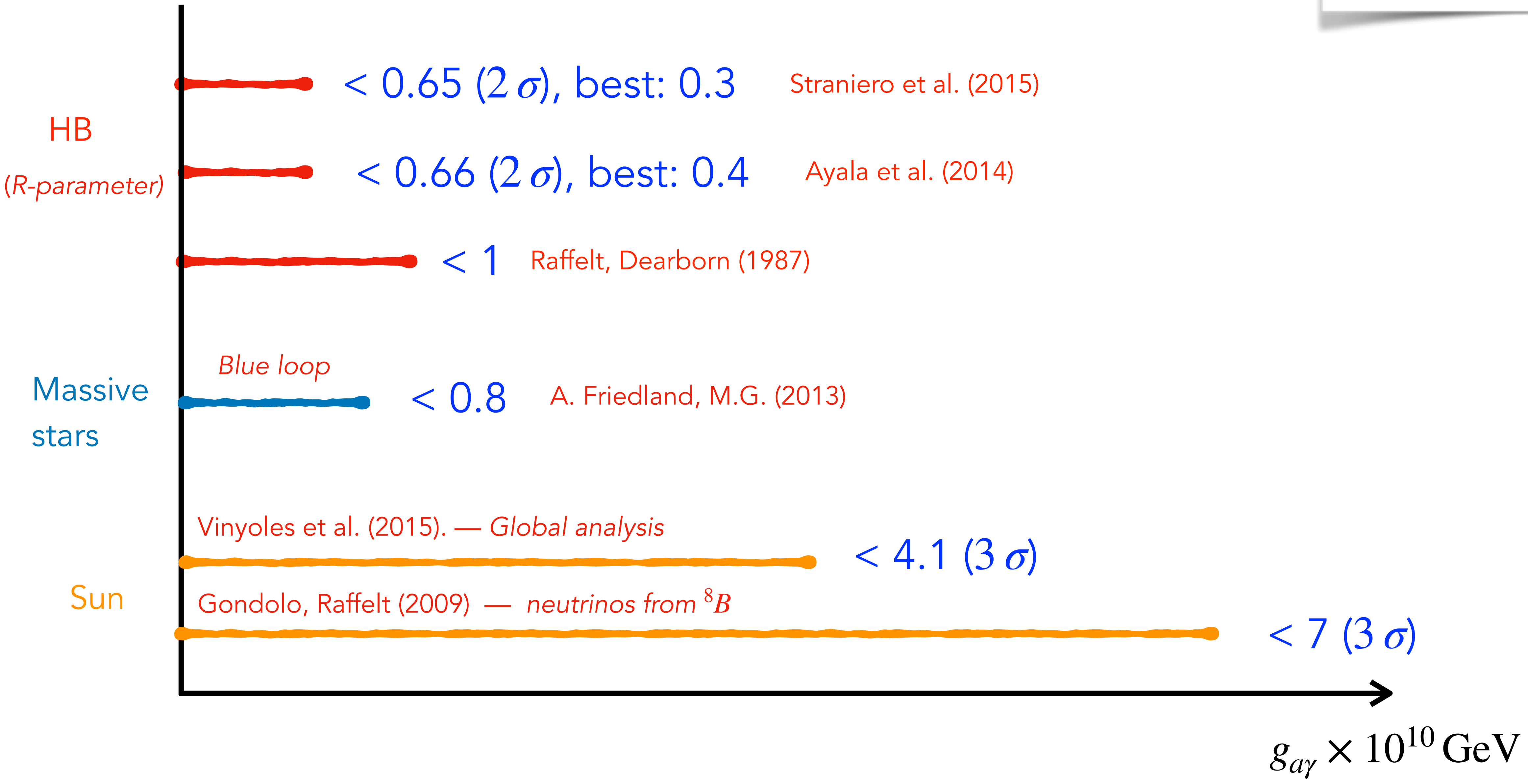
ALPs: no restrictions in the parameter space

Axion-photon coupling ($g_{a\gamma}$)

$$L_{a\gamma} = -\frac{1}{4} g_{a\gamma}\, aF\tilde{F}$$

Most relevant process in stars:
Primakoff





HB
(R-parameter)

< 0.65 ($2\,\sigma$), best: 0.3 Straniero et al. (2015)

< 0.66 ($2\,\sigma$), best: 0.4 Ayala et al. (2014)

< 1 Raffelt, Dearborn (1987)

Massive stars

Blue loop

< 0.8 A. Friedland, M.G. (2013)

Sun

Vinyoles et al. (2015). — *Global analysis*

< 4.1 ($3\,\sigma$)

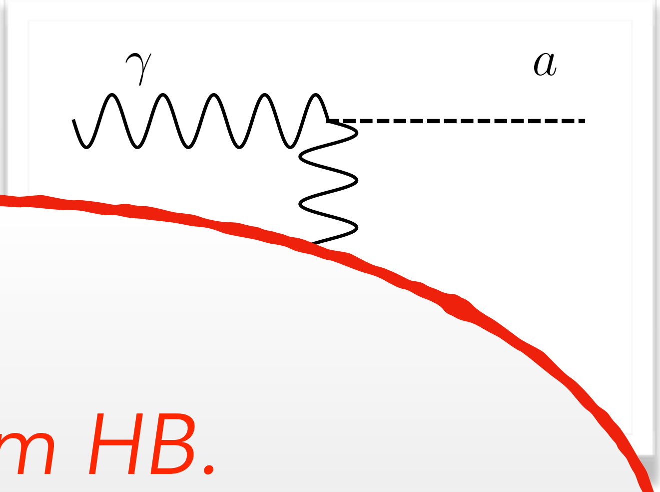
Gondolo, Raffelt (2009) — *neutrinos from* ^{8}B

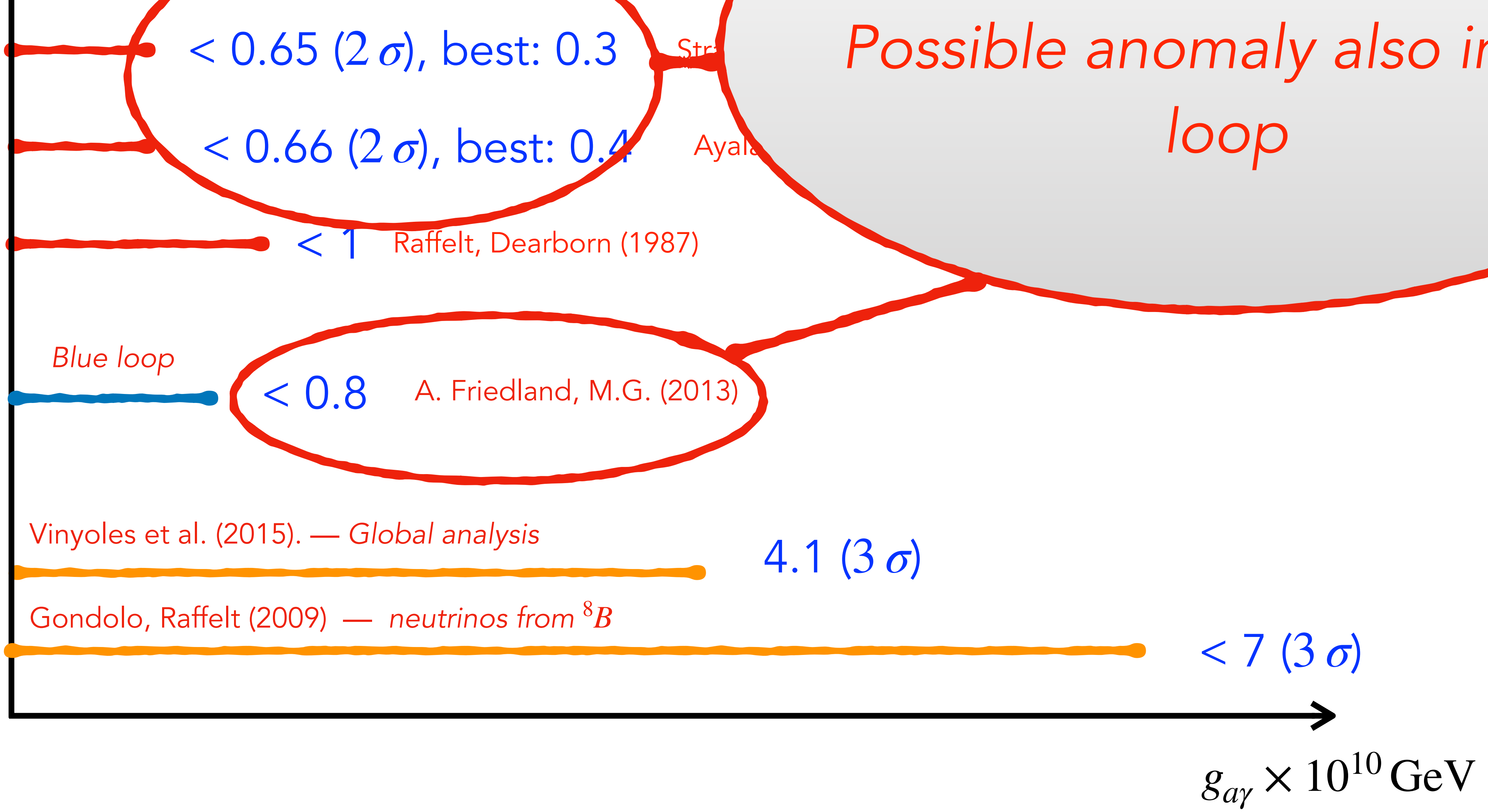
< 7 ($3\,\sigma$)

Axion-photon coupling ($g_{a\gamma}$)

Most relevant process in stars:

Prima ff





Hint from HB.

Possible anomaly also in blue loop

HB

(R-parameter)

< 0.65 (2 σ), best: 0.3 Str

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< 1 Raffelt, Dearborn (1987)

Massive stars

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Vinyoles et al. (2015). — *Global analysis*

4.1 (3 σ)

Gondolo, Raffelt (2009) — *neutrinos from* ^8B

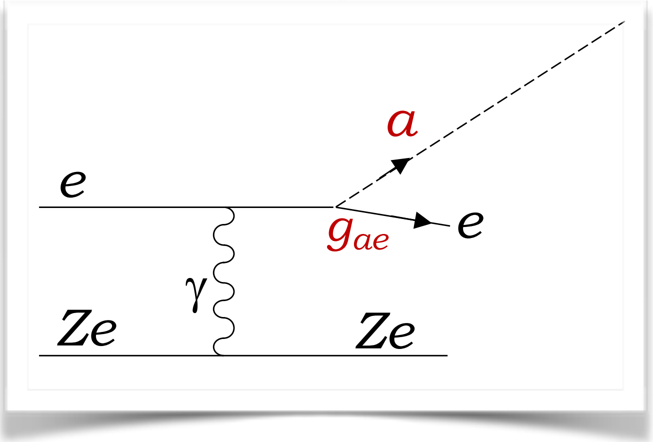
< 7 (3 σ)

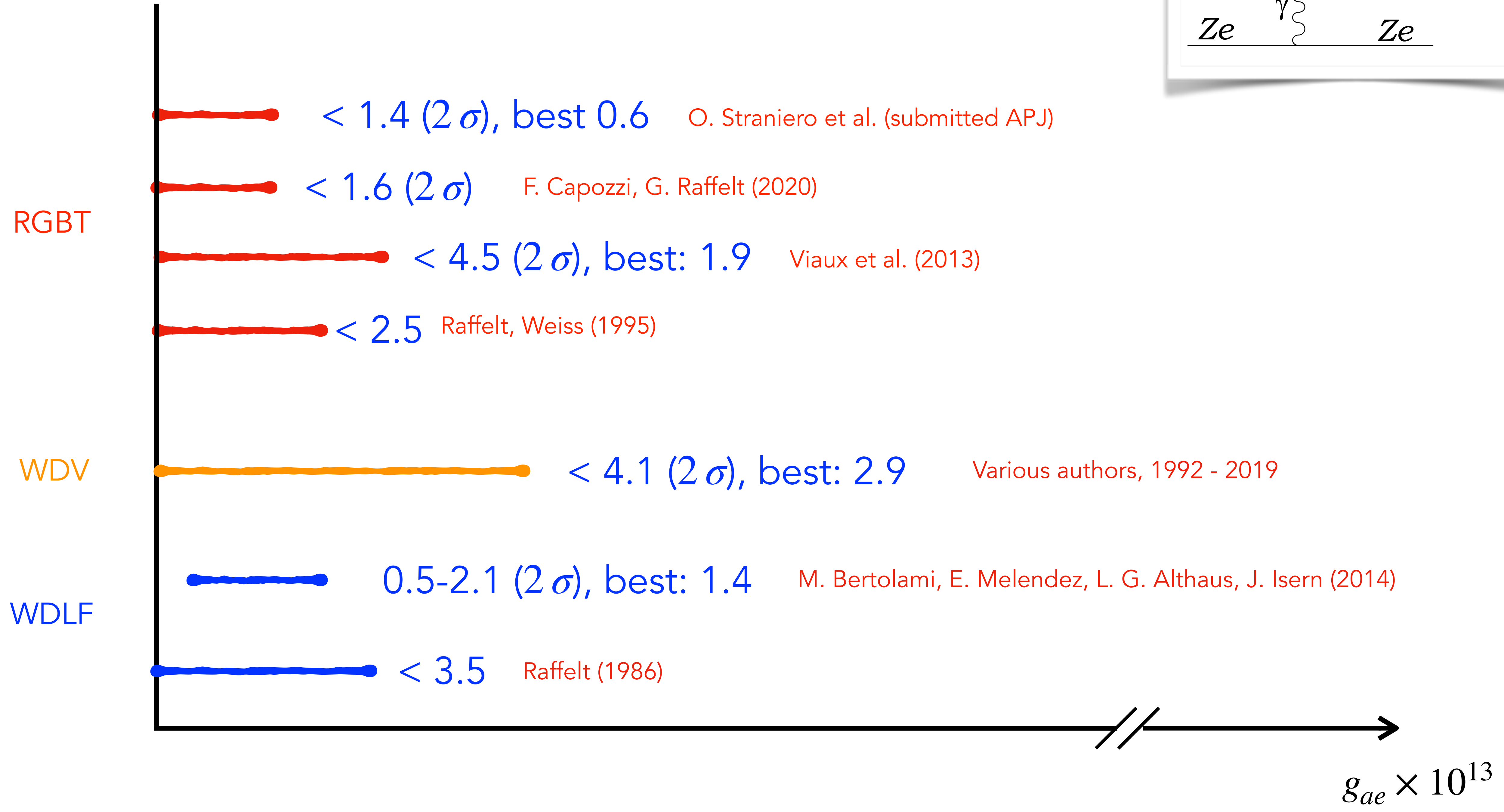
$g_{a\gamma} \times 10^{10}\,\mathrm{GeV}$

Axion-electron coupling (g_{ae})

$$L_{a\gamma} = -\, i g_{ae}\, a\, \bar{e}\, \gamma_5\, e$$

Most relevant process in stars:
bremsstrahlung





RGBT

< 1.4 ($2\,\sigma$), best 0.6 O. Straniero et al. (submitted APJ)

< 1.6 ($2\,\sigma$) F. Capozzi, G. Raffelt (2020)

< 4.5 ($2\,\sigma$), best: 1.9 Viaux et al. (2013)

< 2.5 Raffelt, Weiss (1995)

WDV

< 4.1 ($2\,\sigma$), best: 2.9 Various authors, 1992 - 2019

WDLF

0.5-2.1 ($2\,\sigma$), best: 1.4 M. Bertolami, E. Melendez, L. G. Althaus, J. Isern (2014)

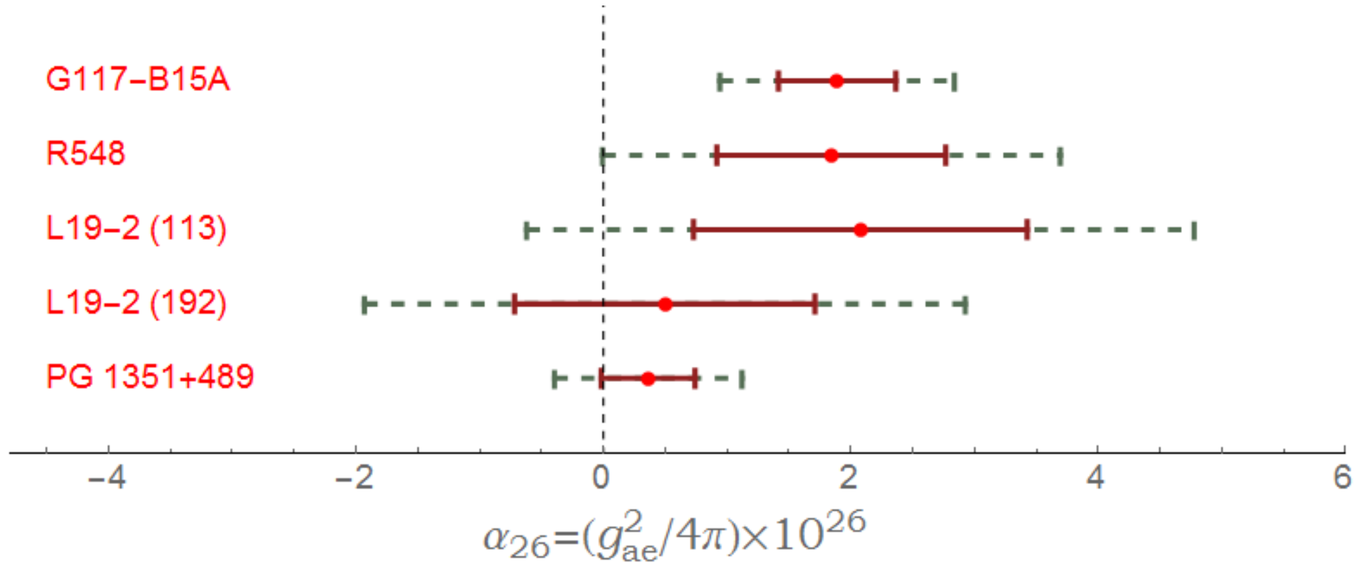
< 3.5 Raffelt (1986)

Axion-electron coupling (g_{ae}): Hints from stars?

Long standing hint from WDV.

WDLF also shows excess energy loss, interpretable as:

- *ALPs good fit;*
- *HP good fit*
- *μ_ν very bad fit*



M.G., Irastorza, Redondo, Ringwald, Saikawa, (2017)

Less solid evidence for a hint from RGBT

No hint from Capozzi, Raffelt (2020) [arXiv:2007.03694]

Preliminary

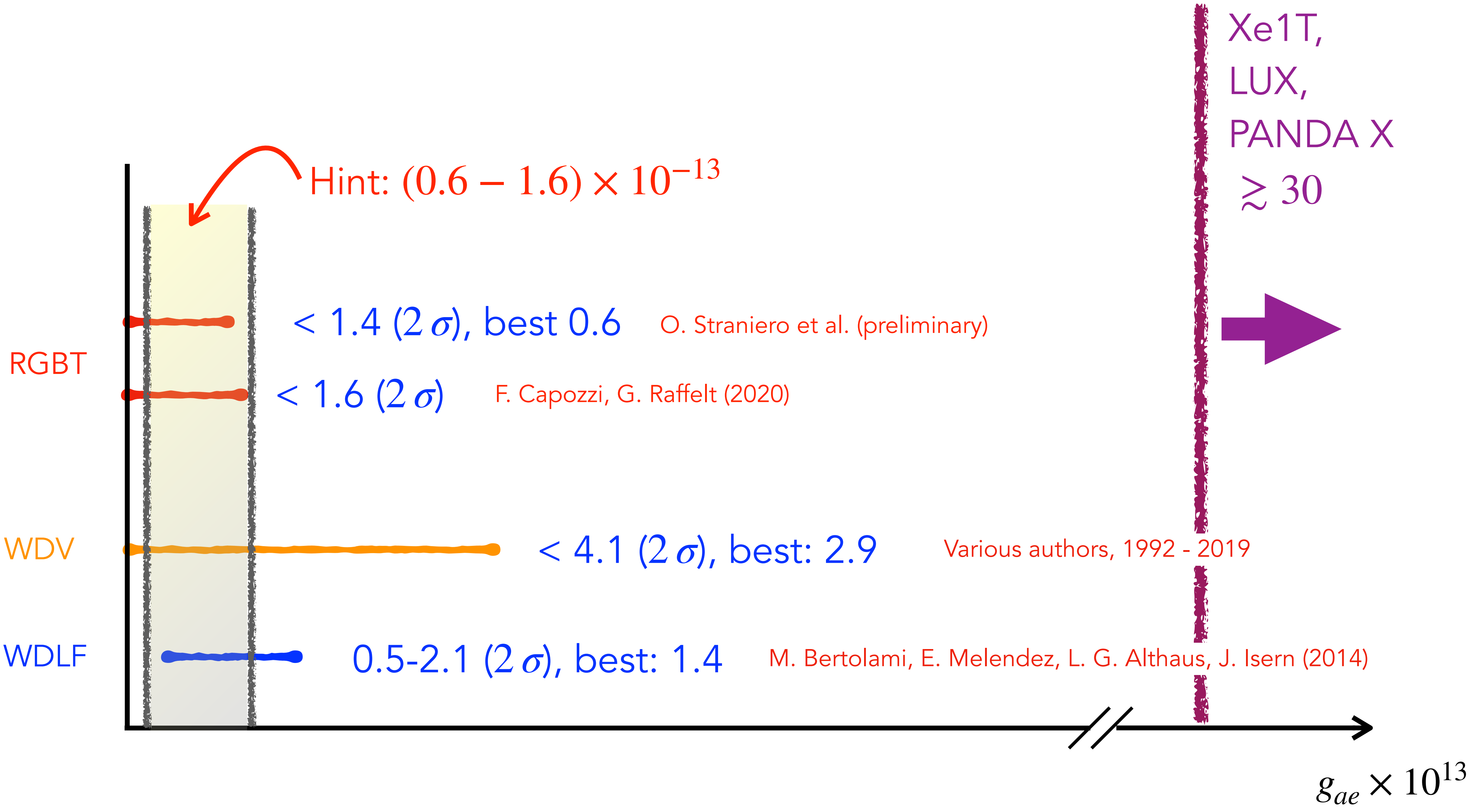
	photometric sample	distance scale	g_{13} best value	g_{13} bound
M5	VI+JK	ZAHB	0	2.30
47 Tuc	VI+ JK	parallax	0.45	1.87
NGC 362	VI+JK	parallax	0	1.37
22 GCs	JK	ZAHB	0.60	1.38
16 GCs	JK	KINEMATIC	0.35	1.05

Straniero et al., to appear

Updated Vlaux et al. (2013) result.

Axion-electron coupling (g_{ae})

Still insufficient experimental sensitivity for direct detection of solar ALPs



Hint: $(0.6 - 1.6) \times 10^{-13}$

Xe1T,
LUX,
PANDA X
$\gtrsim 30$

RGBT

< 1.4 ($2\,\sigma$), best 0.6 O. Straniero et al. (preliminary)

< 1.6 ($2\,\sigma$) F. Capozzi, G. Raffelt (2020)

WDV

< 4.1 ($2\,\sigma$), best: 2.9 Various authors, 1992 - 2019

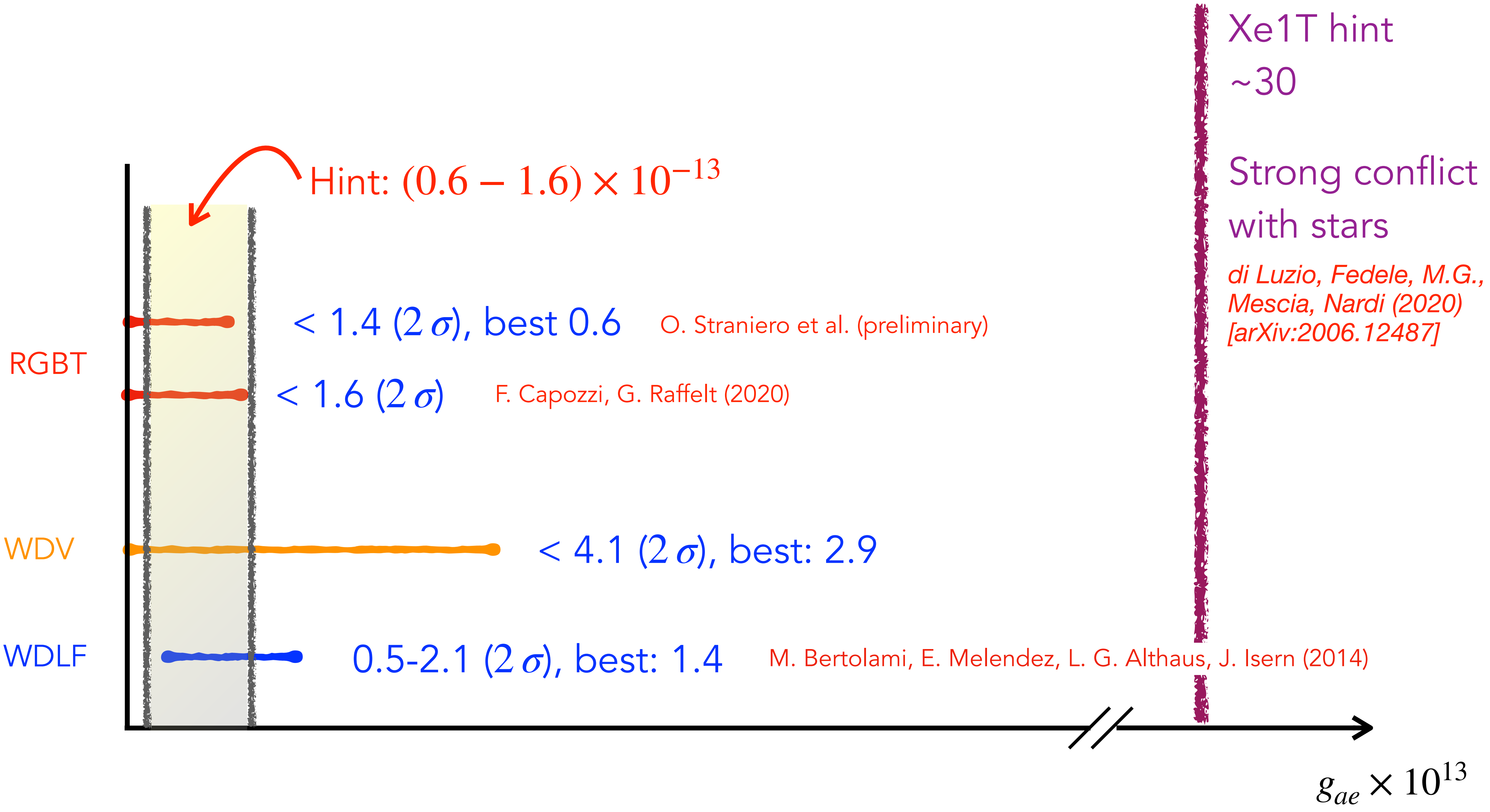
WDLF

0.5-2.1 ($2\,\sigma$), best: 1.4 M. Bertolami, E. Melendez, L. G. Althaus, J. Isern (2014)

$g_{ae} \times 10^{13}$

Axion-electron coupling (g_{ae})

Xenon 1T did not observe solar ALPs…



Xe1T hint

~30

Strong conflict with stars

di Luzio, Fedele, M.G., Mescia, Nardi (2020) [arXiv:2006.12487]

Hint: $(0.6 - 1.6) \times 10^{-13}$

RGBT

< 1.4 ($2\,\sigma$), best 0.6 O. Straniero et al. (preliminary)

< 1.6 ($2\,\sigma$) F. Capozzi, G. Raffelt (2020)

WDV

< 4.1 ($2\,\sigma$), best: 2.9

WDLF

0.5-2.1 ($2\,\sigma$), best: 1.4 M. Bertolami, E. Melendez, L. G. Althaus, J. Isern (2014)

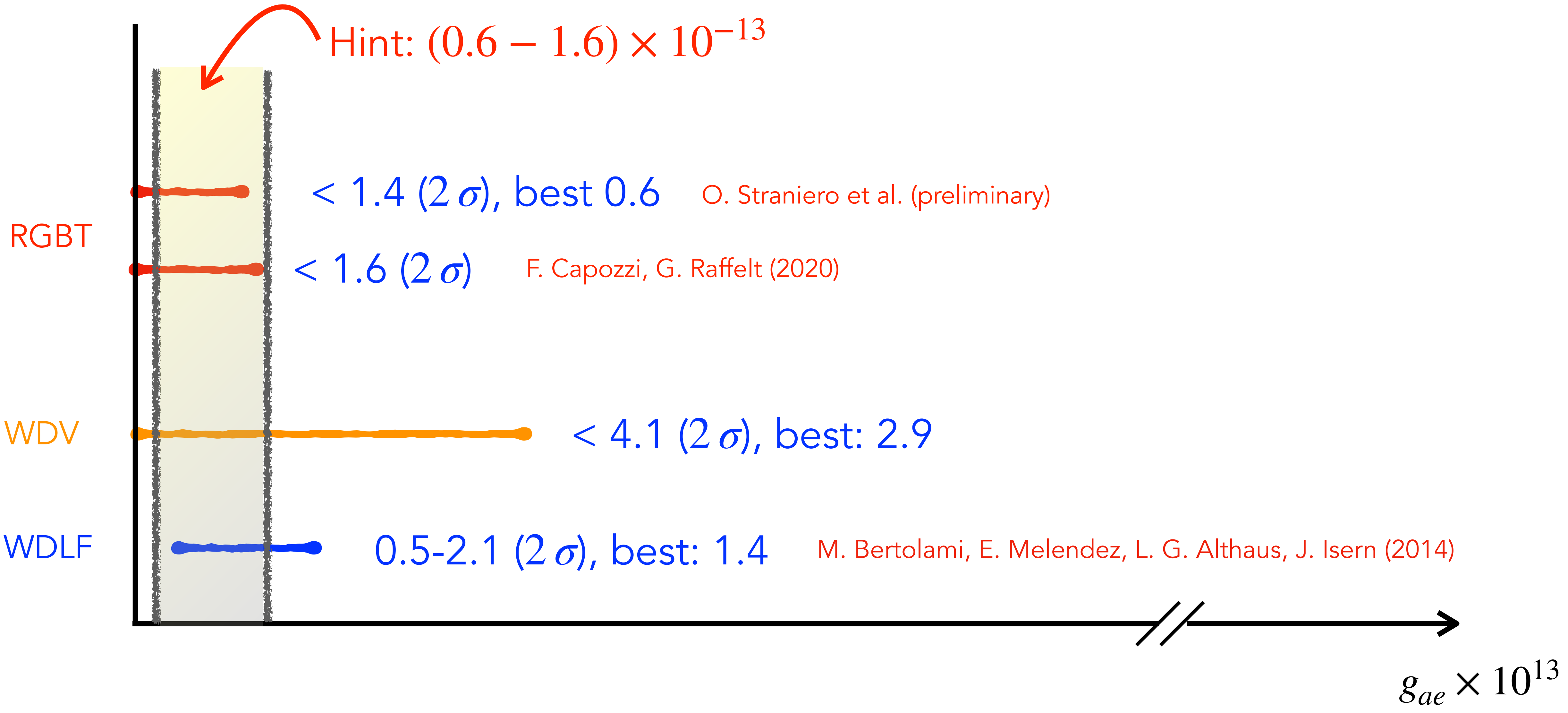
$g_{ae} \times 10^{13}$

Axion-electron coupling (g_{ae})

Xenon 1T did not observe solar ALPs…

… However, it might have observed DM ALPs, with $g_{ae} \sim (0.5 - 0.7) \times 10^{-13}$ *(RGB hint), mass a few keV, and weakly coupled to photons*

Takahashi, Yamada, Yin (2020) [arXiv:2006.10035]



Hint: $(0.6 - 1.6) \times 10^{-13}$

RGBT

< 1.4 ($2\,\sigma$), best 0.6 O. Straniero et al. (preliminary)

< 1.6 ($2\,\sigma$) F. Capozzi, G. Raffelt (2020)

WDV

< 4.1 ($2\,\sigma$), best: 2.9

WDLF

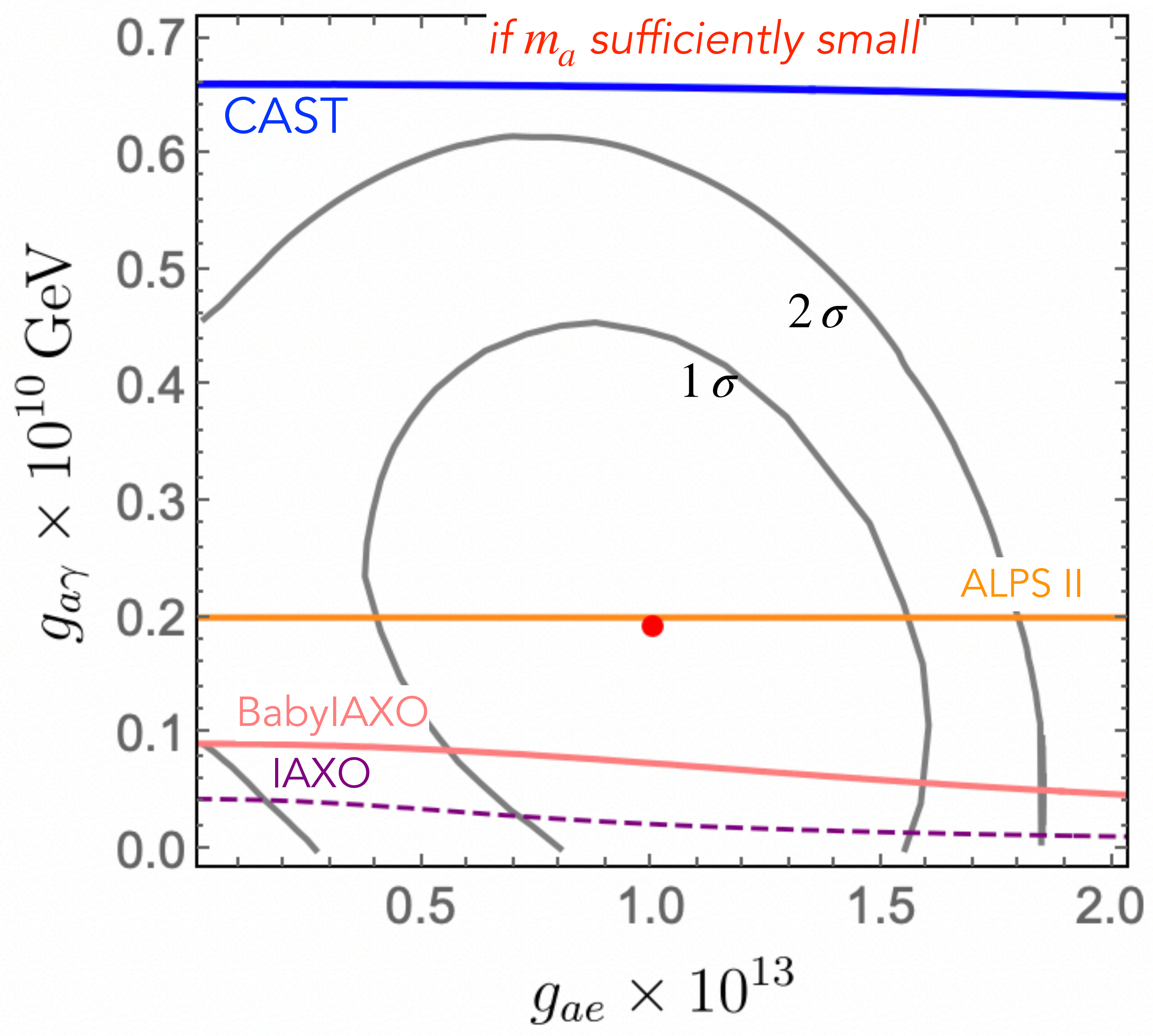
0.5-2.1 ($2\,\sigma$), best: 1.4 M. Bertolami, E. Melendez, L. G. Althaus, J. Isern (2014)

Stellar hints on axion couplings (g_{ae}, $g_{a\gamma}$)

A global analysis of RGB, WDLF, WDV and R-parameter gives a preference to some energy loss unaccounted in the SM and explainable by axions coupled to photons and electrons.

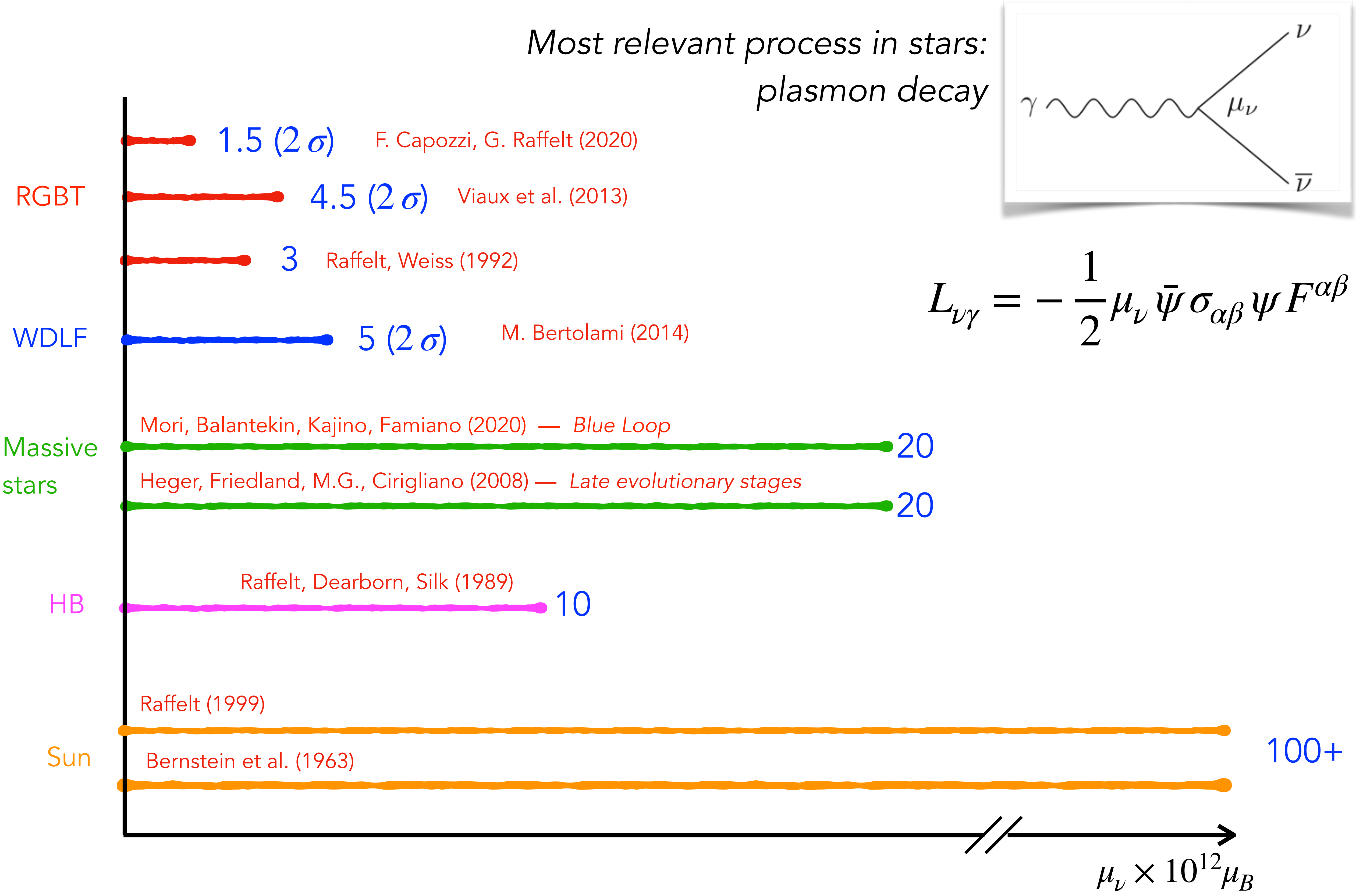
- *M.G., Irastorza, Redondo, Ringwald, Saikawa, (2017)*
- *Di Luzio, Fedele, M.G., Mescia, Nardi (in preparation)*

Couplings accessible to next gen. experiments (ALPS II, BabyIAXO), if m_a sufficiently small



Interlude: Neutrino magnetic moment (μ_ν)

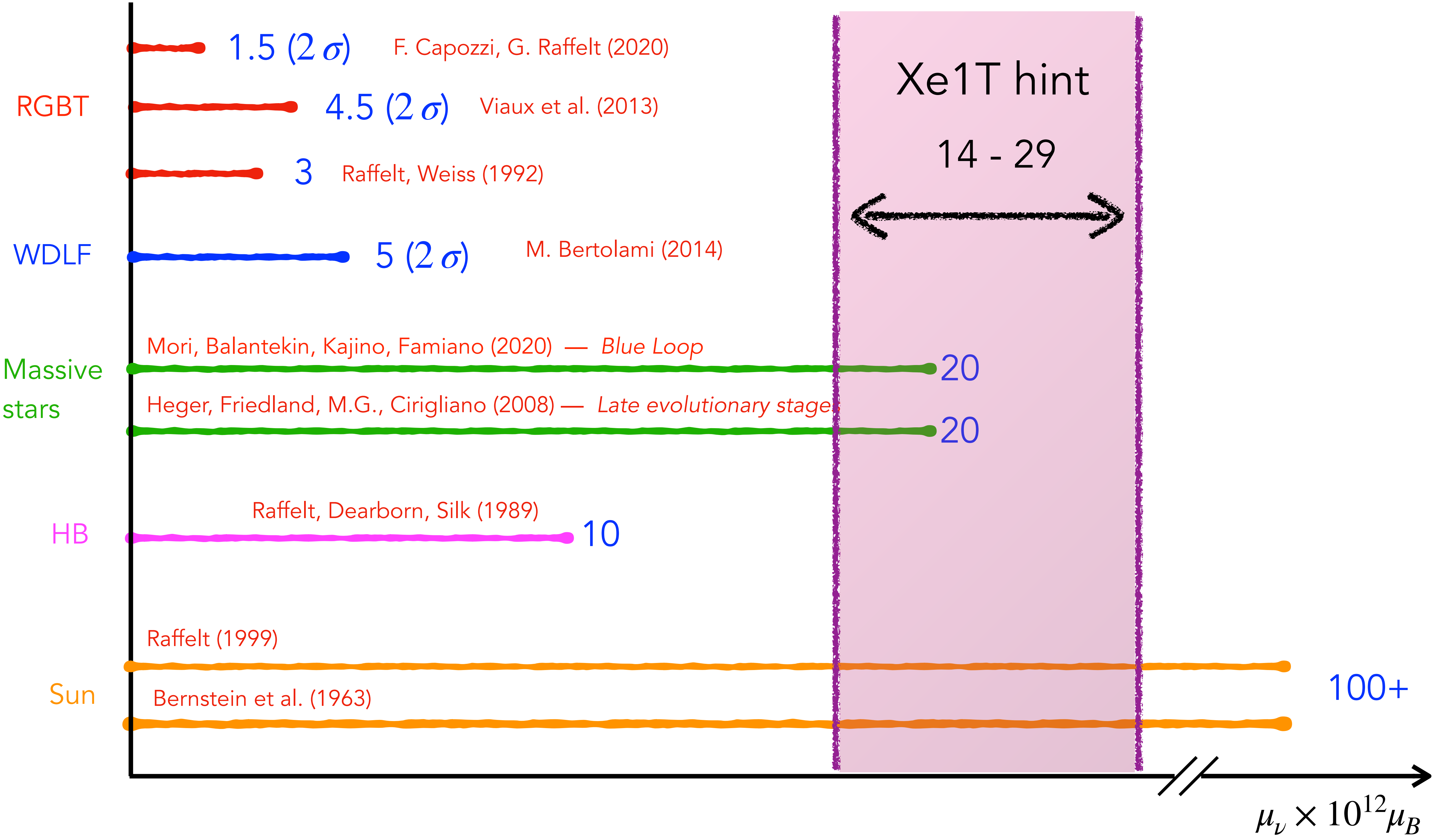
Most relevant process in stars:
plasmon decay



$$L_{\nu\gamma} = -\frac{1}{2}\mu_\nu \bar{\psi}\sigma_{\alpha\beta}\psi F^{\alpha\beta}$$

Interlude: Neutrino magnetic moment (μ_ν)

A $\mu_\nu \neq 0$ *would help the neutrino detection*
(ν *scattering on electrons and nuclei)*



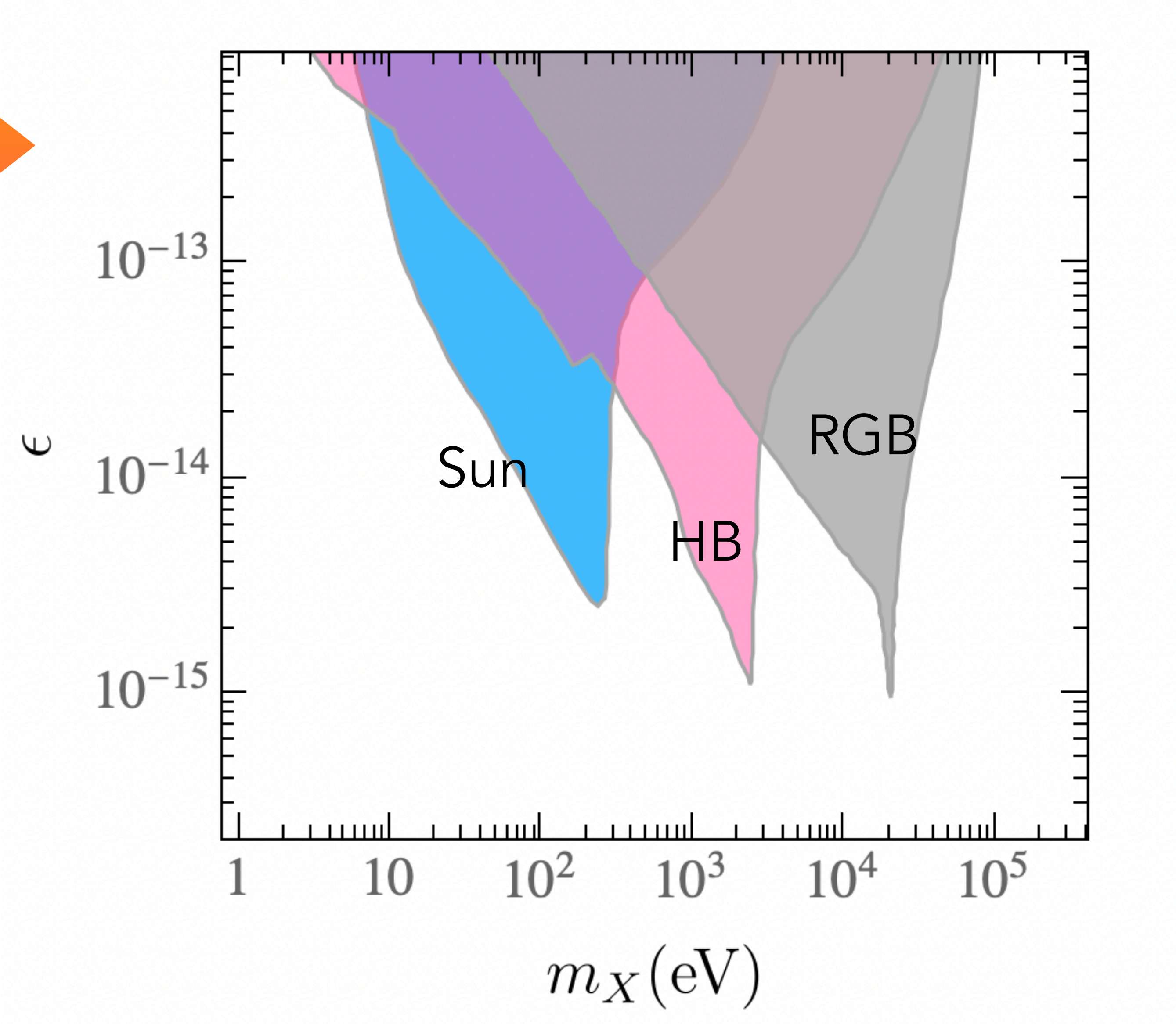
Dark-Photons (X_μ)

$$L = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}X_{\mu\nu}^2 - \frac{\epsilon}{2}F_{\mu\nu}F^{\mu\nu} + \frac{m_X^2}{2}X_\mu X^\mu + e\,J^\mu_{\rm em}A_\mu$$

M. Fabbrichesi, E. Gabrielli, G. Lanfranchi (2020) [arXiv:2005.01515]

Stellar bounds

An, Pospelov, Pradler, Phys.Lett.B 725 (2013);
An, Pospelov, Pradler, Ritz, Phys.Lett.B 747 (2015)



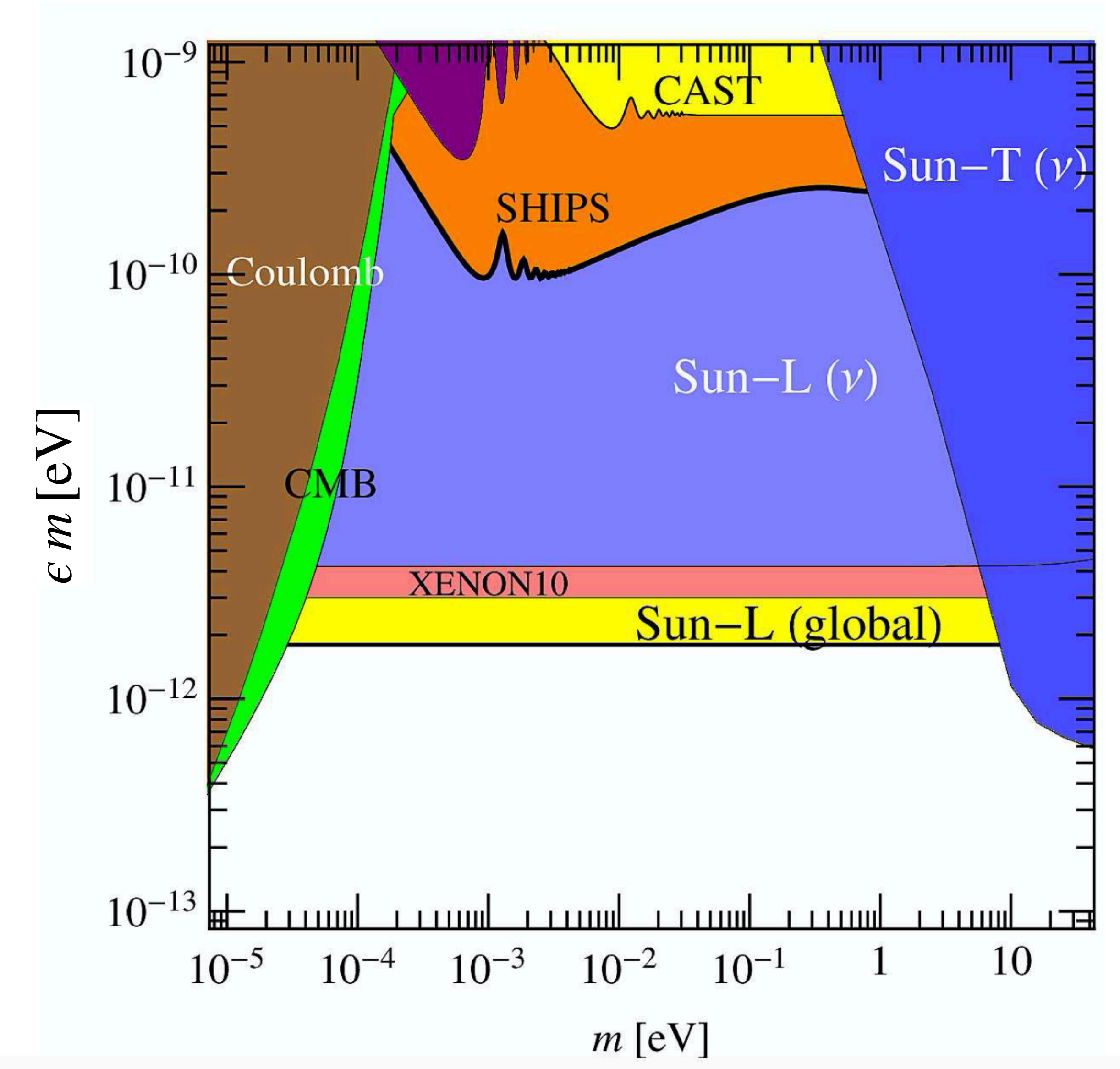
Sun $\rightarrow$ $\omega_{\rm pl}(r=0) \sim 300\,\mathrm{eV}$
HB $\rightarrow$ $\omega_{\rm pl}(r=0) \sim 2.6\,\mathrm{keV}$
RGB $\rightarrow$ $\omega_{\rm pl}(r=0) \sim 25\,\mathrm{keV}$

Dark-Photons (X_μ)

$$L = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}X_{\mu\nu}^2 - \frac{\epsilon}{2}F_{\mu\nu}F^{\mu\nu} + \frac{m_X^2}{2}X_\mu X^\mu + e\,J^\mu_{\rm em}A_\mu$$

Solar bound

Vinyoles et al., JCAP 10 (2015)



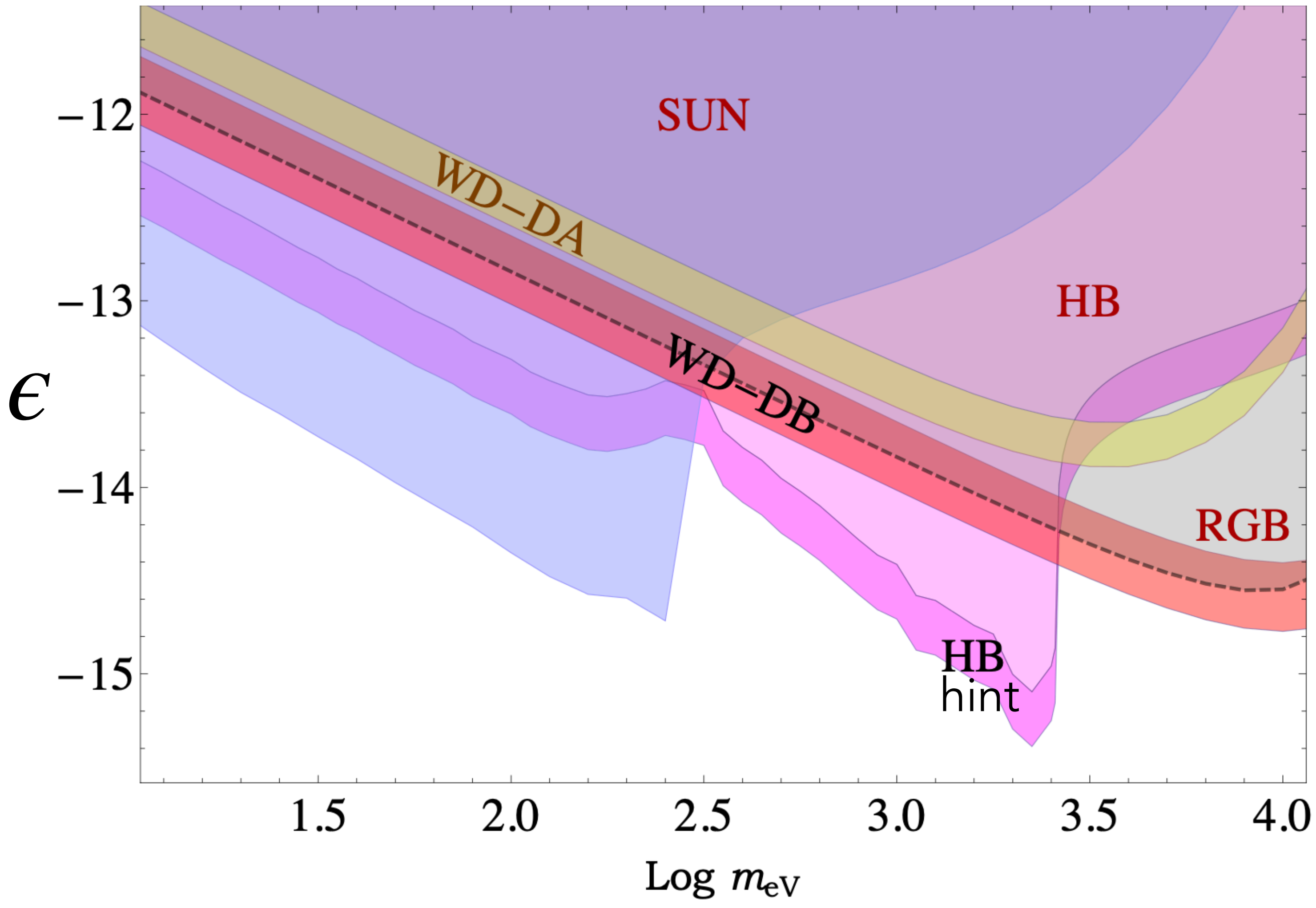
At lower masses the bound weakens. Solar L-mode dominates:

$$\epsilon \cdot m_X \leq 1.8 \times 10^{-12}\,\mathrm{eV}, \quad m_X \lesssim 1\,\mathrm{eV}$$

Dark-Photons (X_μ)

$$L = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}X_{\mu\nu}^2 - \frac{\epsilon}{2}F_{\mu\nu}F^{\mu\nu} + \frac{m_X^2}{2}X_\mu X^\mu + e\,J_{\rm em}^\mu A_\mu$$

Stellar hints



HP can fit well the WDLF

However, conflict btw WDV and other stellar bounds

M.G., I. Irastorza, J. Redondo, A. Ringwald, JCAP 1605 (2016)

Dark-Photons (X_μ)

$$L = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}X_{\mu\nu}^2 - \frac{\epsilon}{2}F_{\mu\nu}F^{\mu\nu} + \frac{m_X^2}{2}X_\mu X^\mu + e\,J_{\rm em}^\mu A_\mu$$

Xenon 1T did not see solar HP.

Their spectrum is too soft…

An, Pospelov, Pradler, Ritz (2020) [arXiv:2006.13929]

Dark-Photons (X_μ)

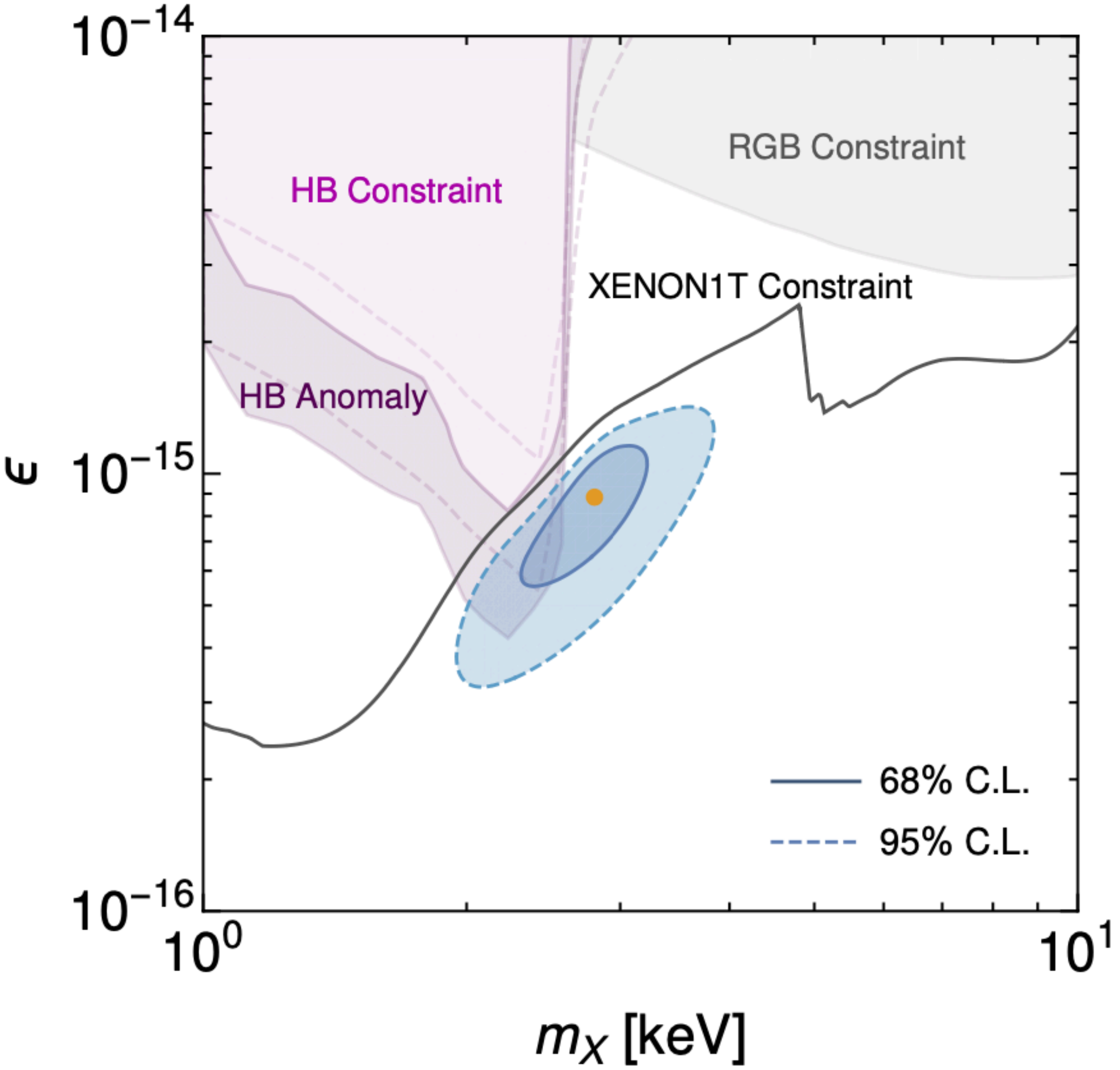
$$L = -\frac{1}{4}F_{\mu\nu}^2 - \frac{1}{4}X_{\mu\nu}^2 - \frac{\epsilon}{2}F_{\mu\nu}F^{\mu\nu} + \frac{m_X^2}{2}X_\mu X^\mu + e\,J^\mu_{\rm em}A_\mu$$

Xenon 1T did not see solar HP.
Their spectrum is too soft…

An, Pospelov, Pradler, Ritz (2020) [arXiv:2006.13929]

… However, the signal is consistent with DM HP, with couplings overlapping the HB hints

Alonso-Alvarez, Ertas, Jaeckel, Kahlhoefer, Thormaehlen (2020) [arXiv:2006.11243]



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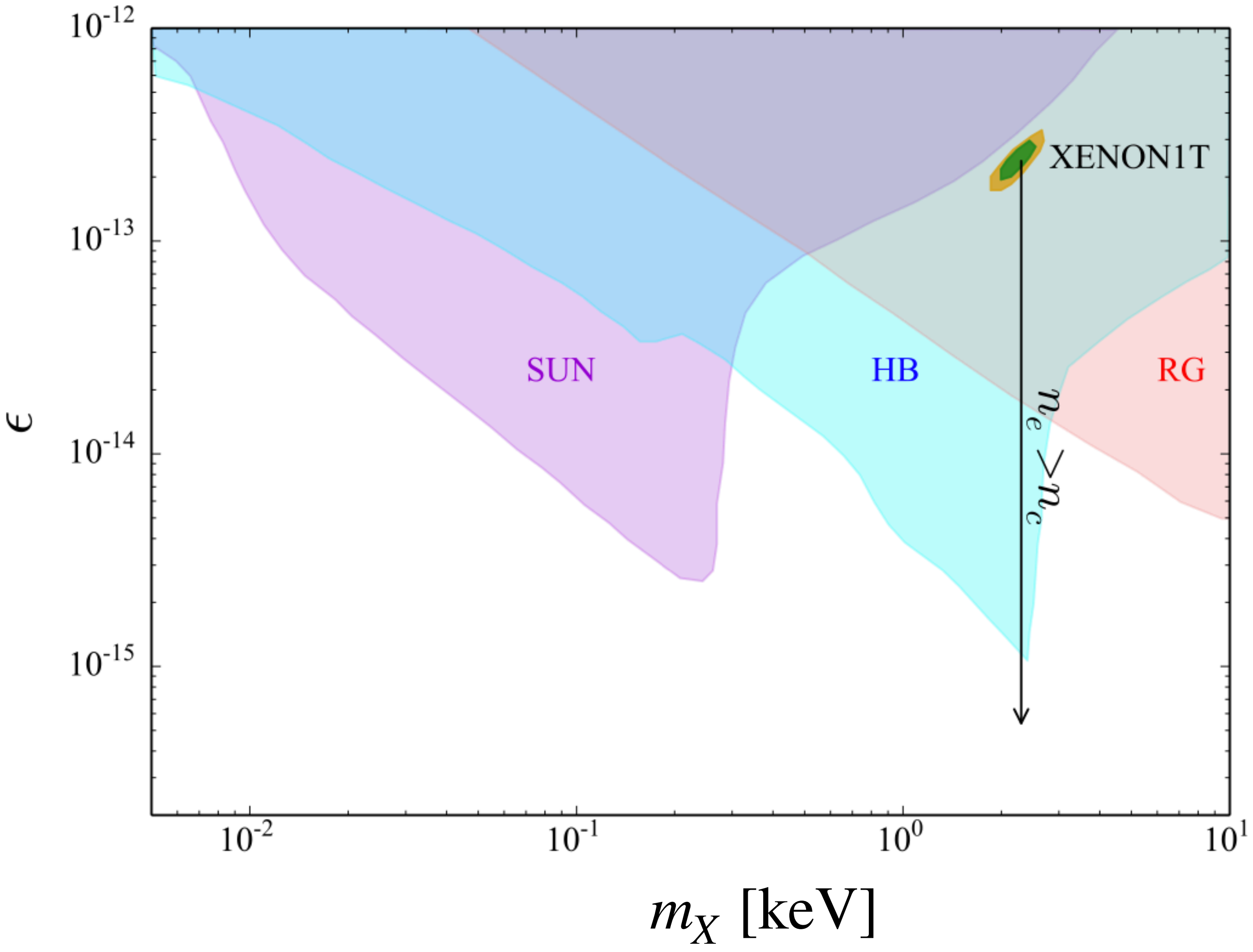
Xenon 1T did not see solar HP.
Or did it?

non-minimal scenarios may suppress production in HB and RGB stars but not in the sun. Environmental effects are induced through dynamical kinetic mixing, emerging through interaction with a scalar field.

Chakraborty, Jung, Loladze, Okui, Tobioka (2020) [arXiv:2008.10610]



Exploring higher masses: Supernovae

Supernovae have an internal temperature of ~30 MeV and density of $\sim 10^{14}\,\mathrm{g\,cm^{-3}}$.

In this conditions more massive FIPs can be created.

However, a reliable description of the FIP production in SN is difficult

Several recent improvements and revisitations

- *C. Hanhart, D. R. Phillips, S. Reddy (2001)*
- *Chang, Essig, McDermott (2018);*
- *Chang, Essig, McDermott (2019);*
- *P. Carenza et al. (2019);*
- *Ertas and Kahlhoefer (2020)*
- *G. Lucente et al. (2020)*
- *…*

Supernova 1987A

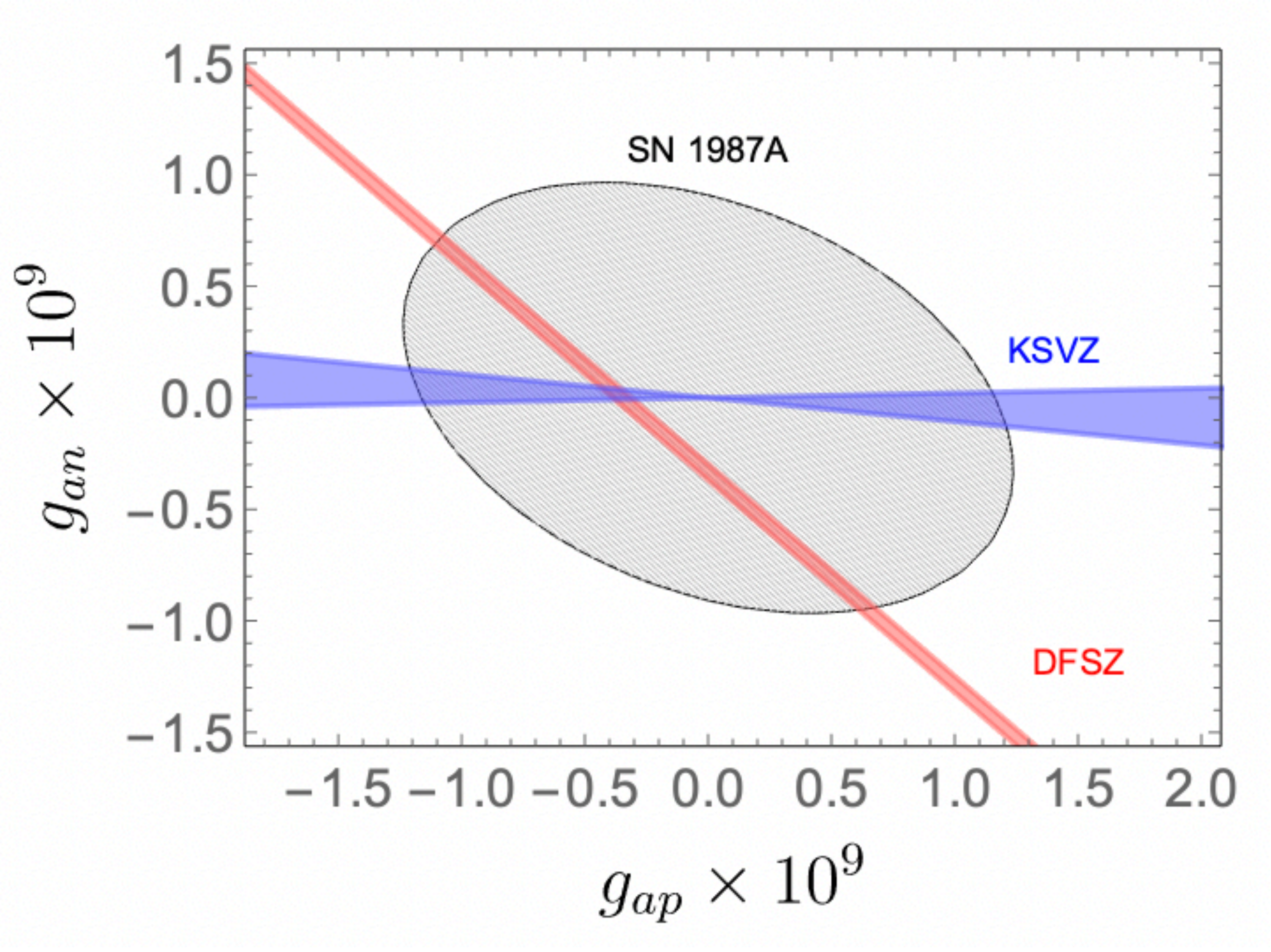
SN1987A: SNe cannot cool too fast (ν-signal).
Roughly, $L_a \lesssim L_\nu$

Very old bounds however:
- Emission rate is hard to calculate
- Very few data

Several recent revisitations

- *C. Hanhart, D. R. Phillips, S. Reddy (2001)*
- *Chang, Essig, McDermott (2018);*
- *Chang, Essig, McDermott (2019);*
- *P. Carenza et al. (2019);*
- *Ertas and Kahlhoefer (2020)*
- *G. Lucente et al. (2020)*
- *…*

Axion-like particles (g_{aN})



- *Carenza, Fischer, M.G., Guo, Martinez-Pinedo, Mirizzi (2019);*
- *Di Luzio, M.G., Nardi, Visinelli Phys.Rept. 870 (2020)*

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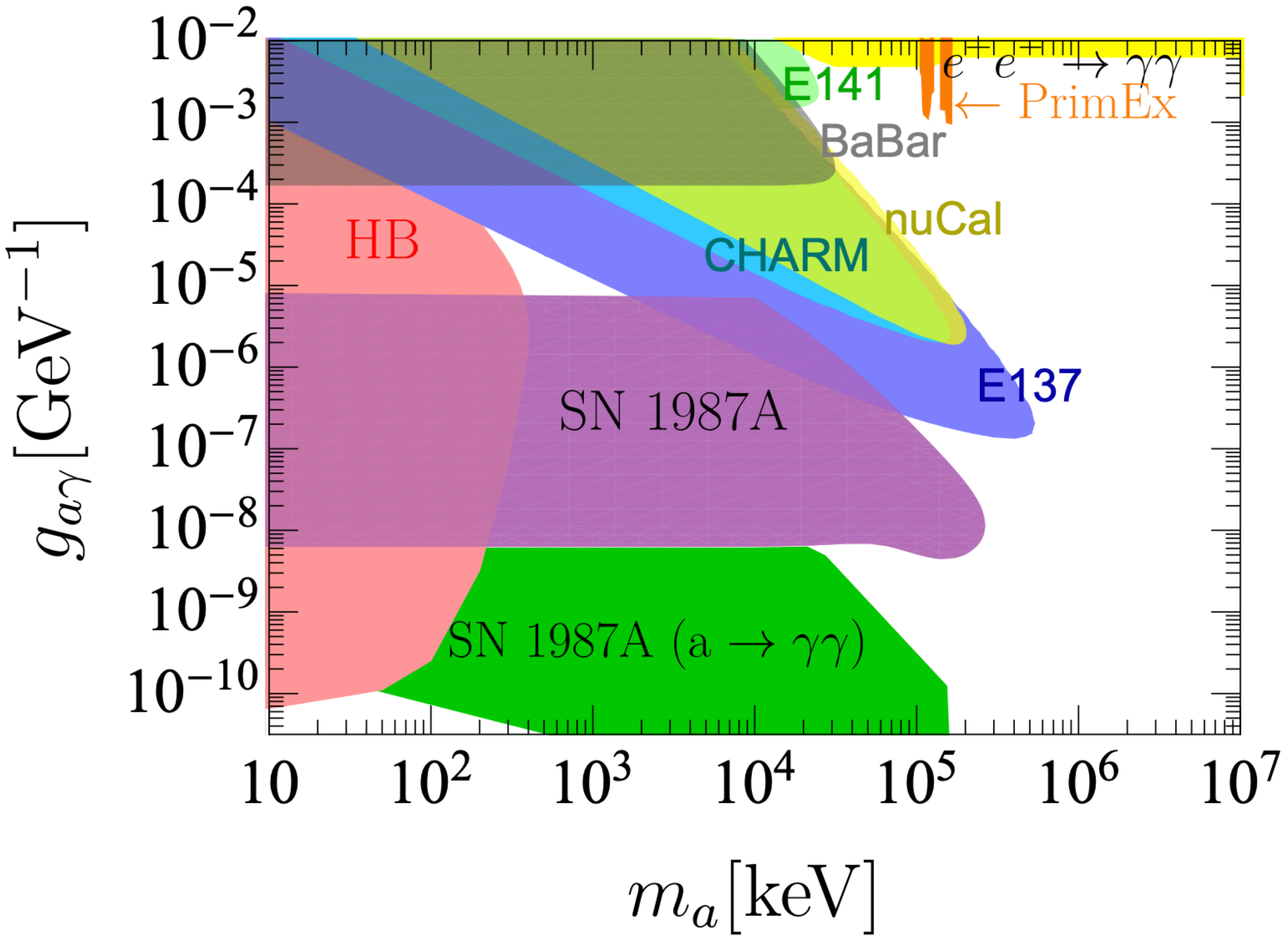
- *Ertas and Kahlhoefer (2020)*
- *G. Lucente et al. (2020)*
- *…*

Axion-like particles ($g_{a\gamma}$)



- *Jaeckel, Malta, Redondo (2017);*
- *Ertas and Kahlhoefer (2020);*
- *G. Lucente et al. (2020);*

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- *P. Carenza et al. (2019);*
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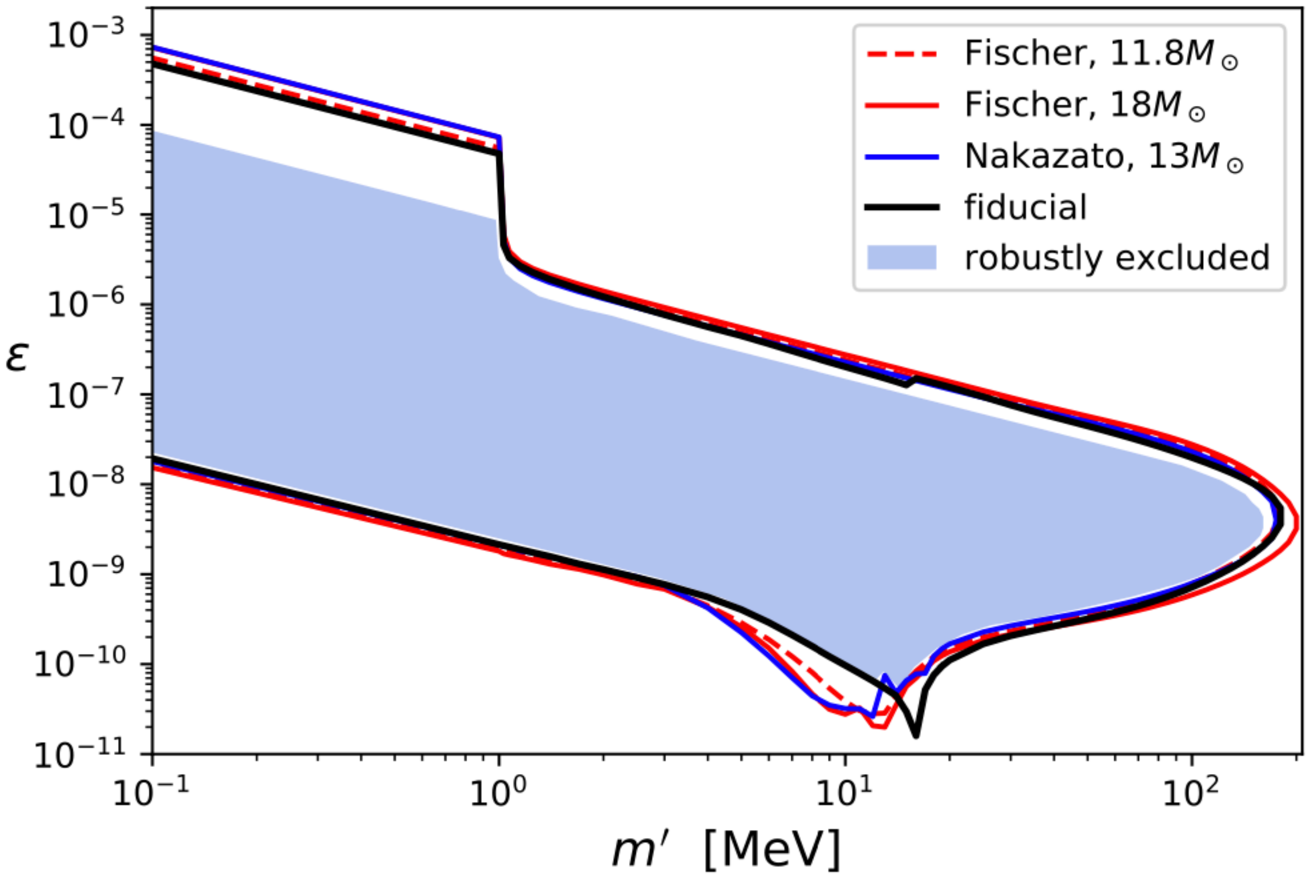
- *…*

Dark Photons



Chang, Essig, McDermott (2019);

Stars as FIP Factories

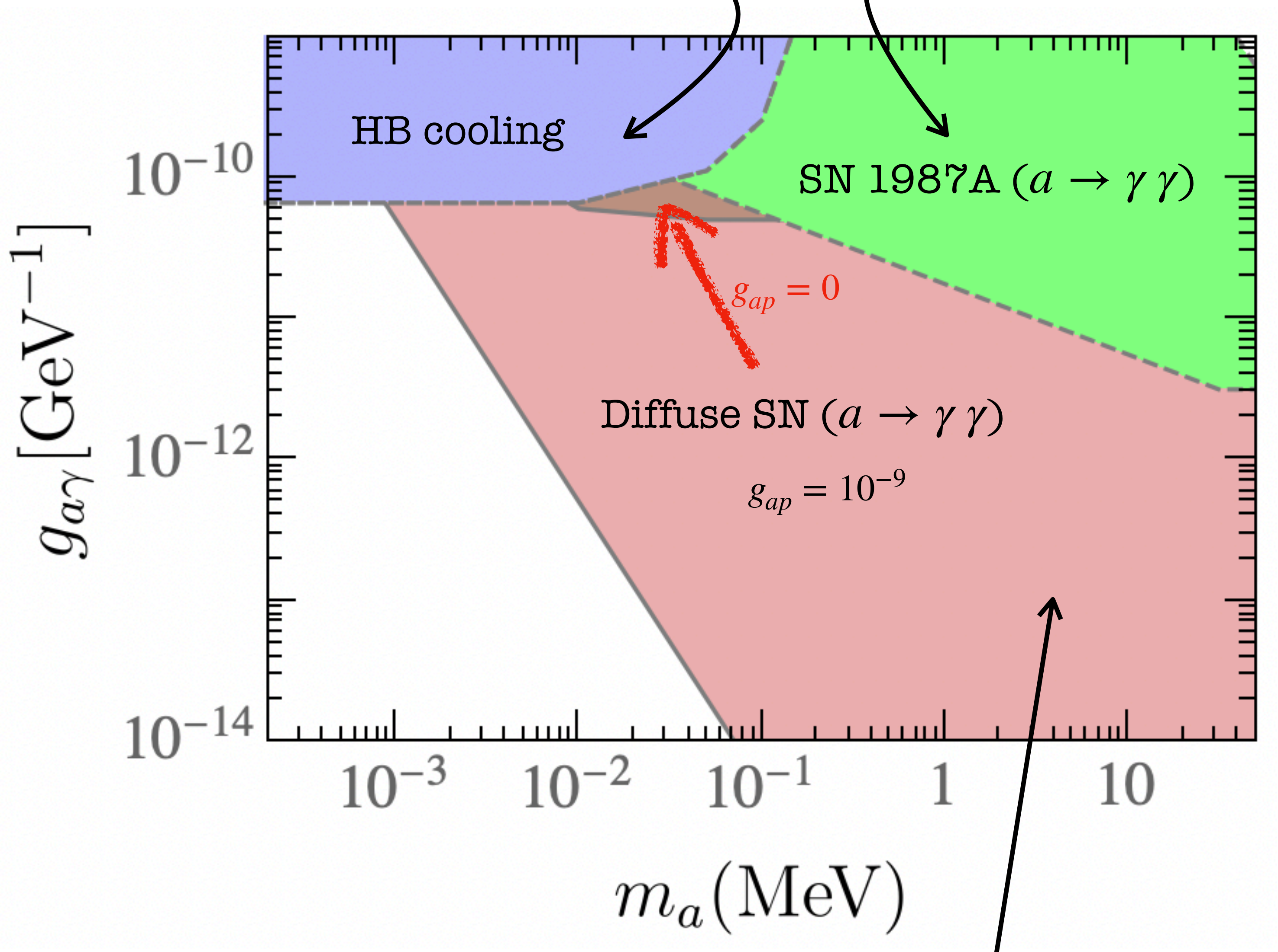
Stars may produce FIPs copiously.

- Solar ALPs and HP are searched by terrestrial experiments.
- SNe can produce enormous quantities of FIPs ($\sim 10^{52}$ erg/s).
- Very strong limits from SN 1987A

[Payez et al. (2015), De Rocco et al. (2020)]

- and from diffuse gamma ray from all past SNe

[Calore et al. (2020), De Rocco et al. (2020)]



Carenza, Dobrich, Lucente, M.G., Mirizzi, Straniero (2020)

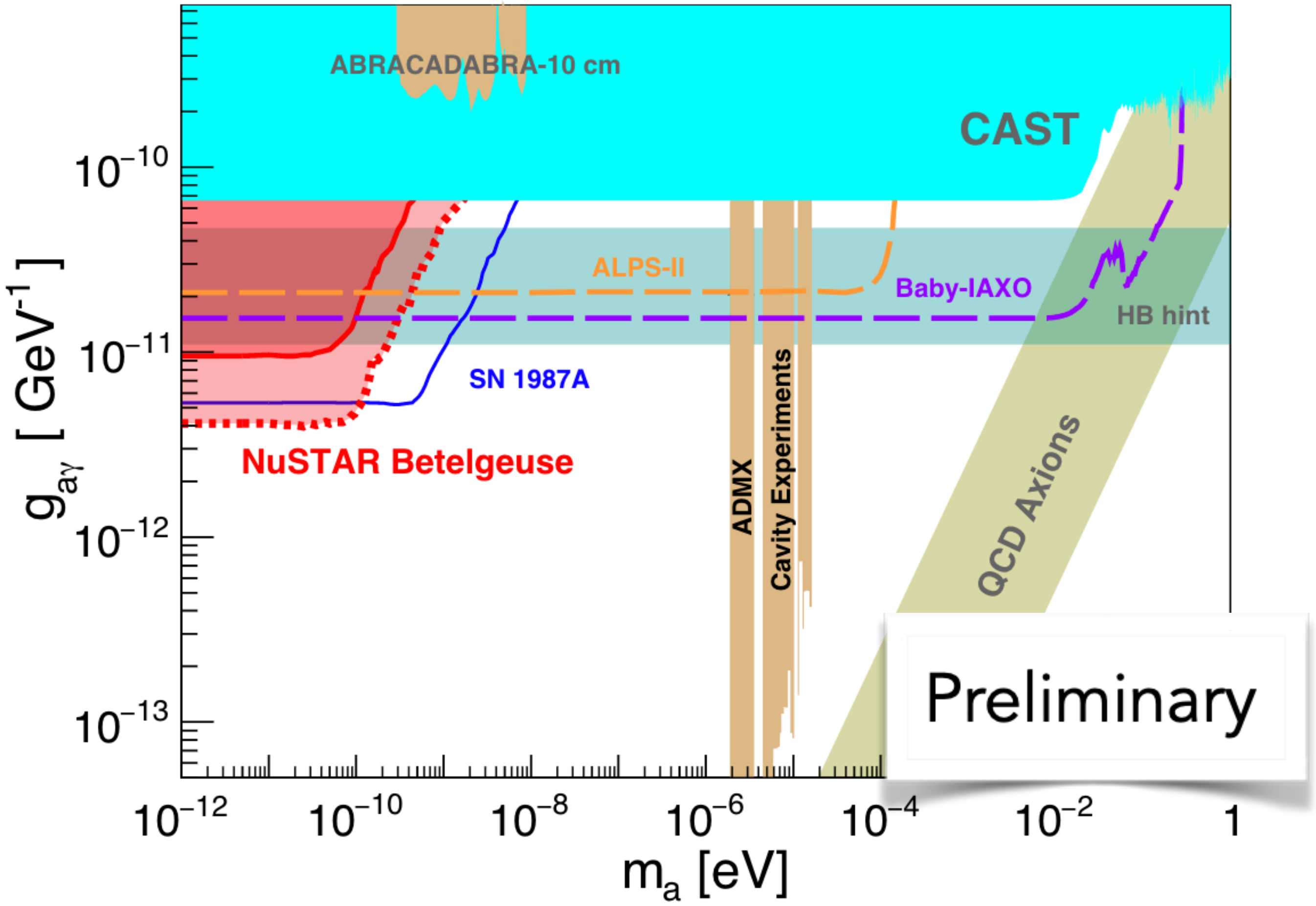
Jaeckel, Malta, Redondo (2017)

- Calore, Carenza, M.G., Jaeckel, Mirizzi (2020)
- DeRocco, Graham, Kasen, Marques-Tavares, Rajendran (2020)

Stars as FIP Factories

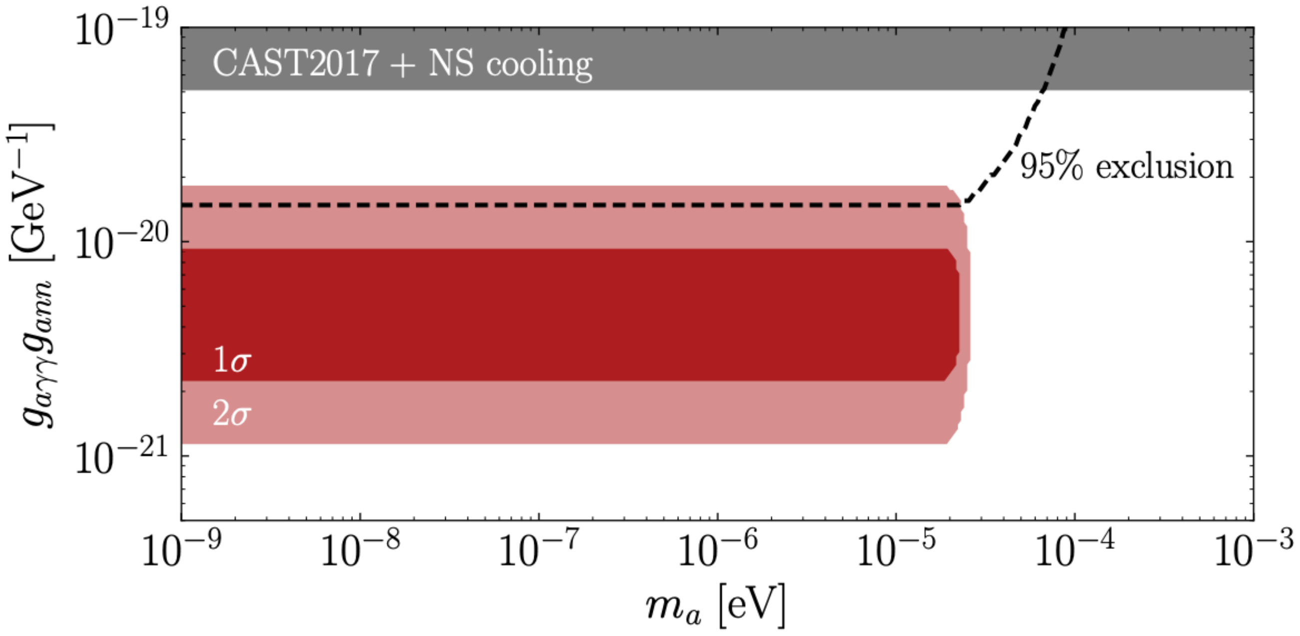
Surprisingly strong bounds on ALPs from other stars too, particularly form supergiants. ALPs oscillate into X-ray photons. Bounds from NuSTAR

- *M. Xiao et al. Nustar bounds from Betelgeuse, (in preparation);*
- *Dessert, Foster, Safdy, X-ray Searches for Axions from Super Star Clusters (2020)*



A few NS, observed by XMM- Newton and Chandra, exhibit an unexplainable excess. Is it due to $a \to \gamma$?

Buschmann, Co, Dessert, Safdy, X-ray Search for Axions from Nearby Isolated Neutron Stars (2019)



Stars as FIP Factories

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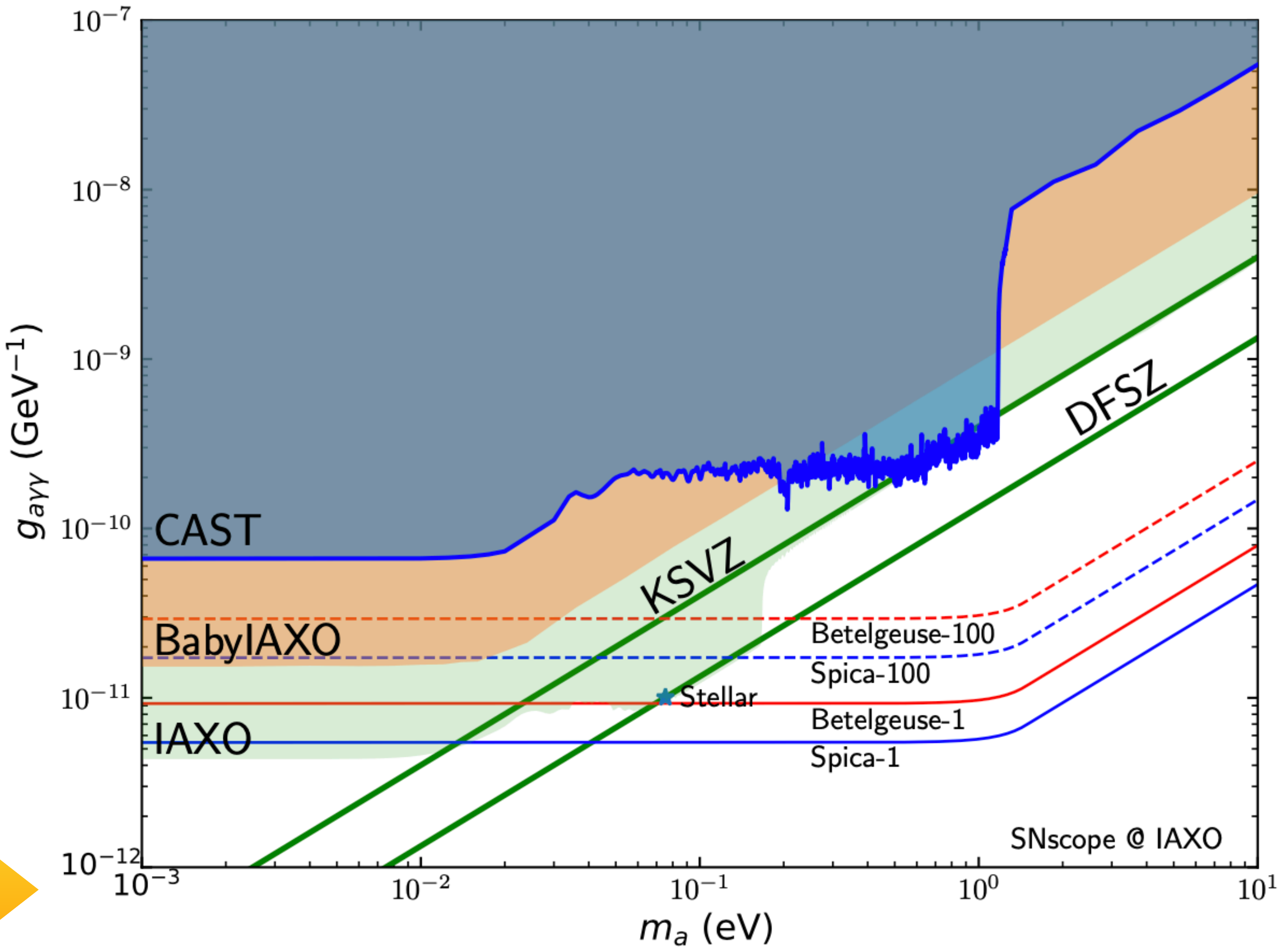
Direct detection of SN ALPs?

Helioscopes as SN-scopes



Ge, Hamaguchi, Ichimura, Ishidoshiro, Kanazawa (2020) [arXiv:2008.03924]

Keeps coherence up to higher masses because of much higher energy

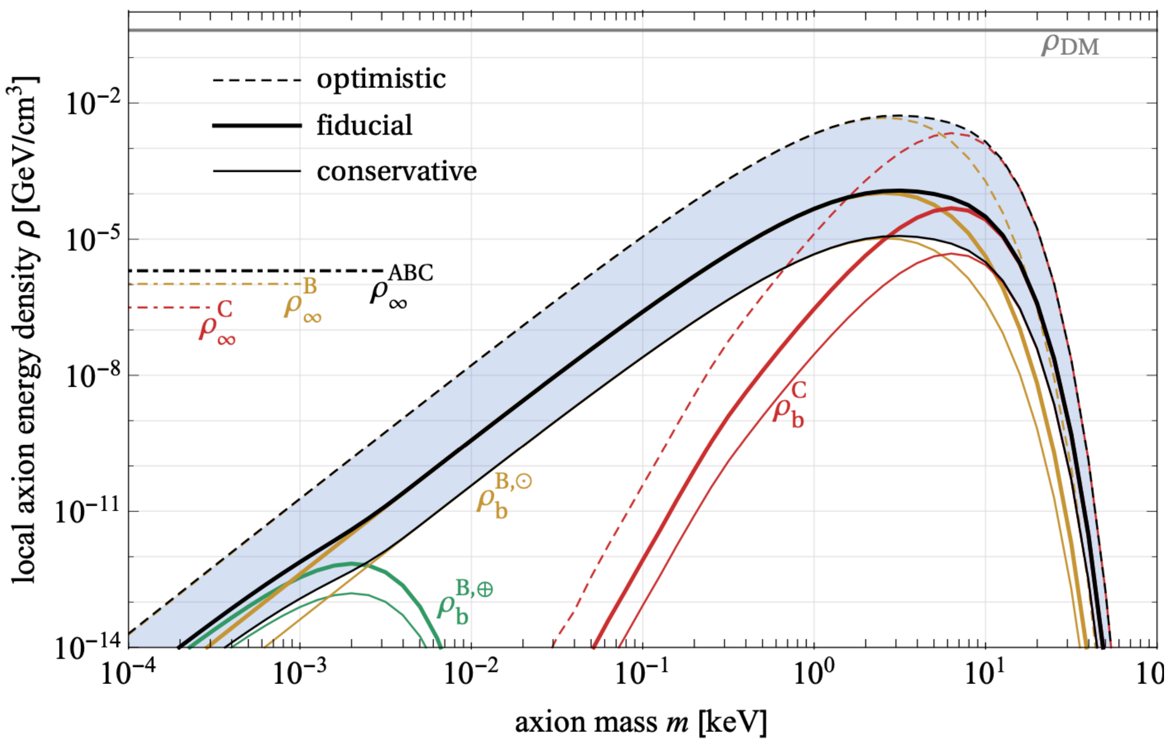
Stars as FIP Factories

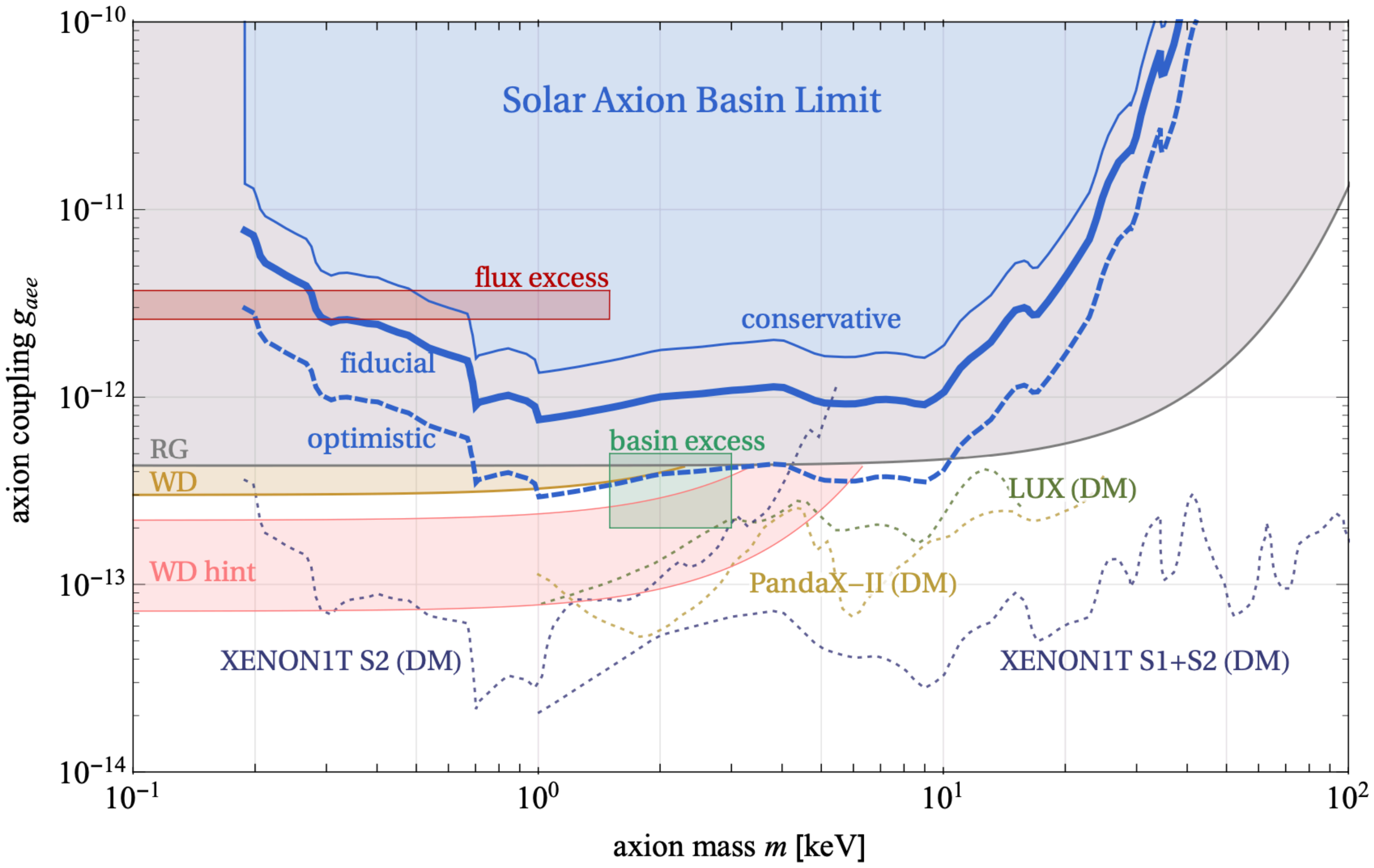
Stellar basins for FIPs?

Ken Van Tilburg (2020)
[arXiv:2006.12431]

FIPs trapped in stellar gravitational field. Does it matter?

Perhaps so. A FIP basin would build up during the stellar lifetime, assuming the depletion time is slow enough





Stars as FIP Factories

Stellar basins for FIPs?

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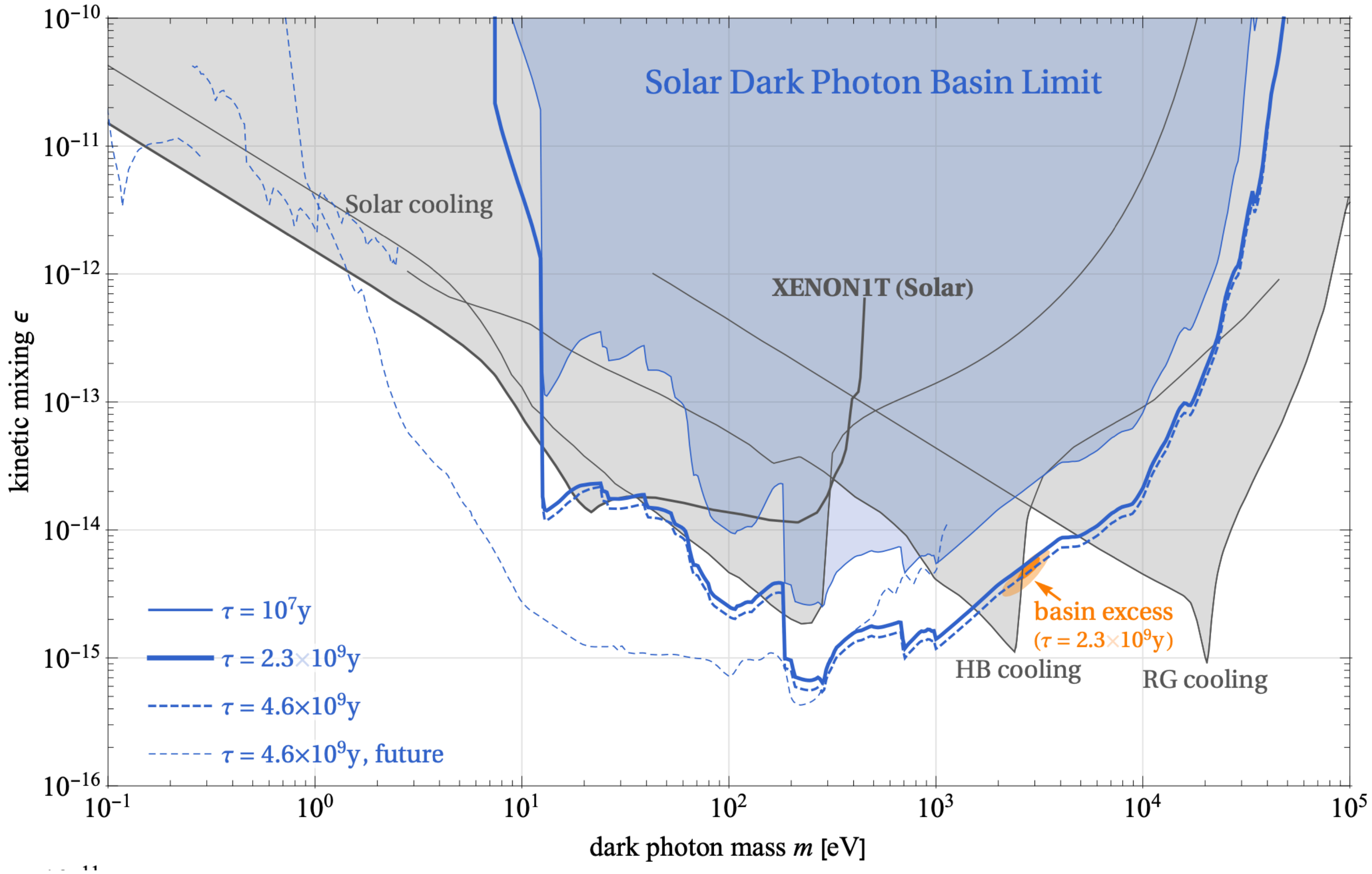


Did Xenon 1T observe Dark Photons in solar basin?

Robert Lasenby, Ken Van Tilburg (2020)
[arXiv:2008.08594]

The Roaring Twenties

An exciting decade for FIPs astrophysics!

Great improvements in stellar census, photometry, astrometry,…

GAIA, since 2014, Data Release 3 expected soon.

JWST, launch scheduled for Oct. 31, 2021

Vera Rubin Telescope (LSST), beginning of operation schedule for 2021.

In addition: XRISM, soft X-ray 0.4-13 keV, early 2020s

Perhaps, less improvements in the 0(10-100) MeV γ-ray detectors, although possibly better resolution.

Gamma 400, starts in 2026. Other proposals: eAstrogam, Amego (not yet approved)

GAIA DR3: https://www.cosmos.esa.int/web/gaia/earlydr3

https://www.jwst.nasa.gov

LSST DM group (Alex Drlica-Wagner et al.) (2019) [arXiv:1902.01055]

Fantin, Cote, McConnachie (2020) [arXiv:2007.01312]

https://heasarc.gsfc.nasa.gov/docs/xrism/

Conclusions

Stars are (excellent) FIPs labs + FIPs factories.

Stellar anomalies have stimulated research in stellar evolution and FIPs models.

Several new bounds, proposals and ideas in stellar FIPs this year.
In part motivated by the Xenon 1T anomaly.

A lot of progress expected in the near future. Stay tuned!

Backup Slides

SNe and other monsters

Supernovae, Neutron Stars, and even Black Holes offers unique ways to study FIPs.

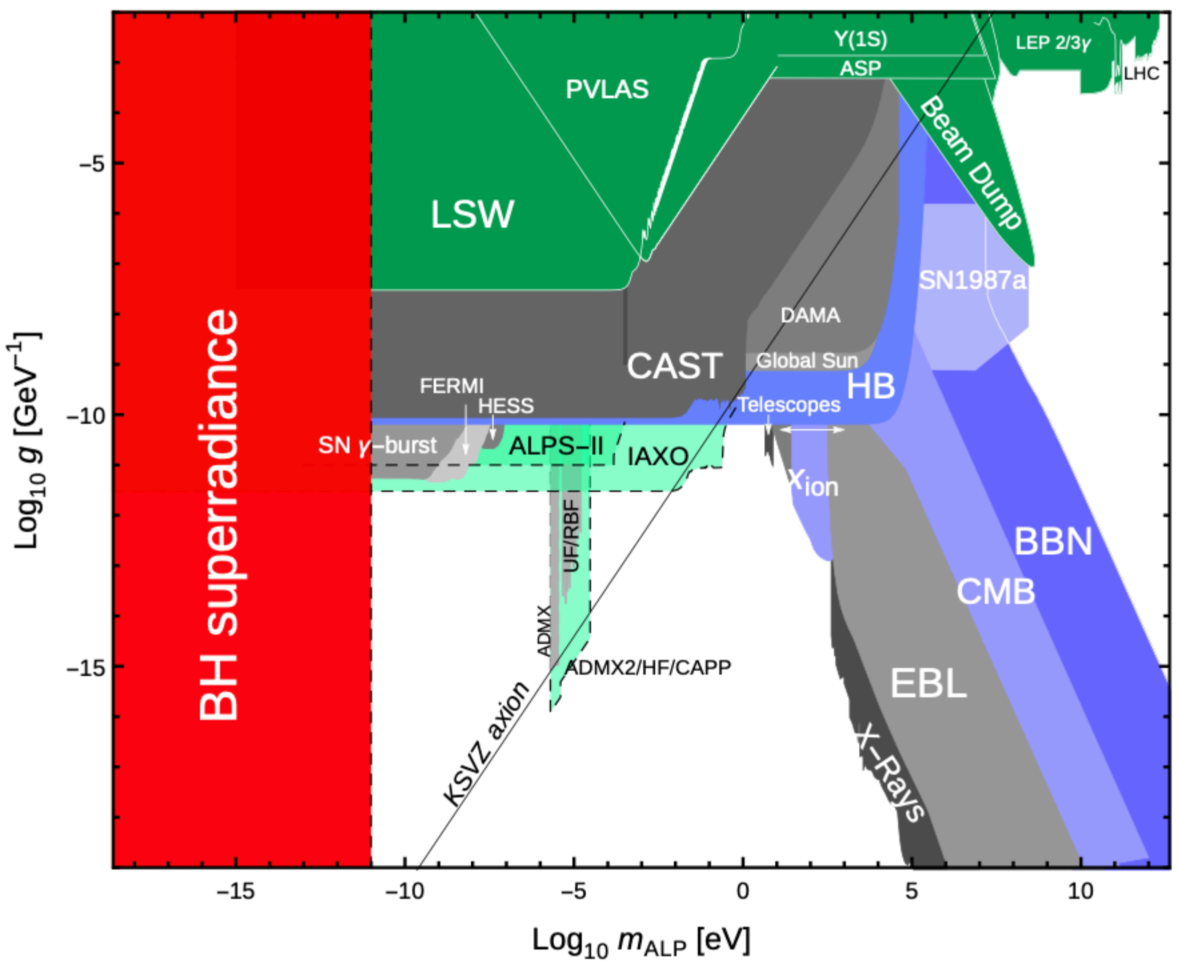
Application of these monster stars to the physics of FIPs is relatively recent.

Several recent revisitations for ALPs and HP.

- *C. Hanhart, D. R. Phillips, S. Reddy (2001)*
- *Chang, Essig, McDermott (2018);*
- *Chang, Essig, McDermott (2019);*
- *P. Carenza et al. (2019);*
- *G. Lucente et al. (2020)*
- *…*

BH superradiance

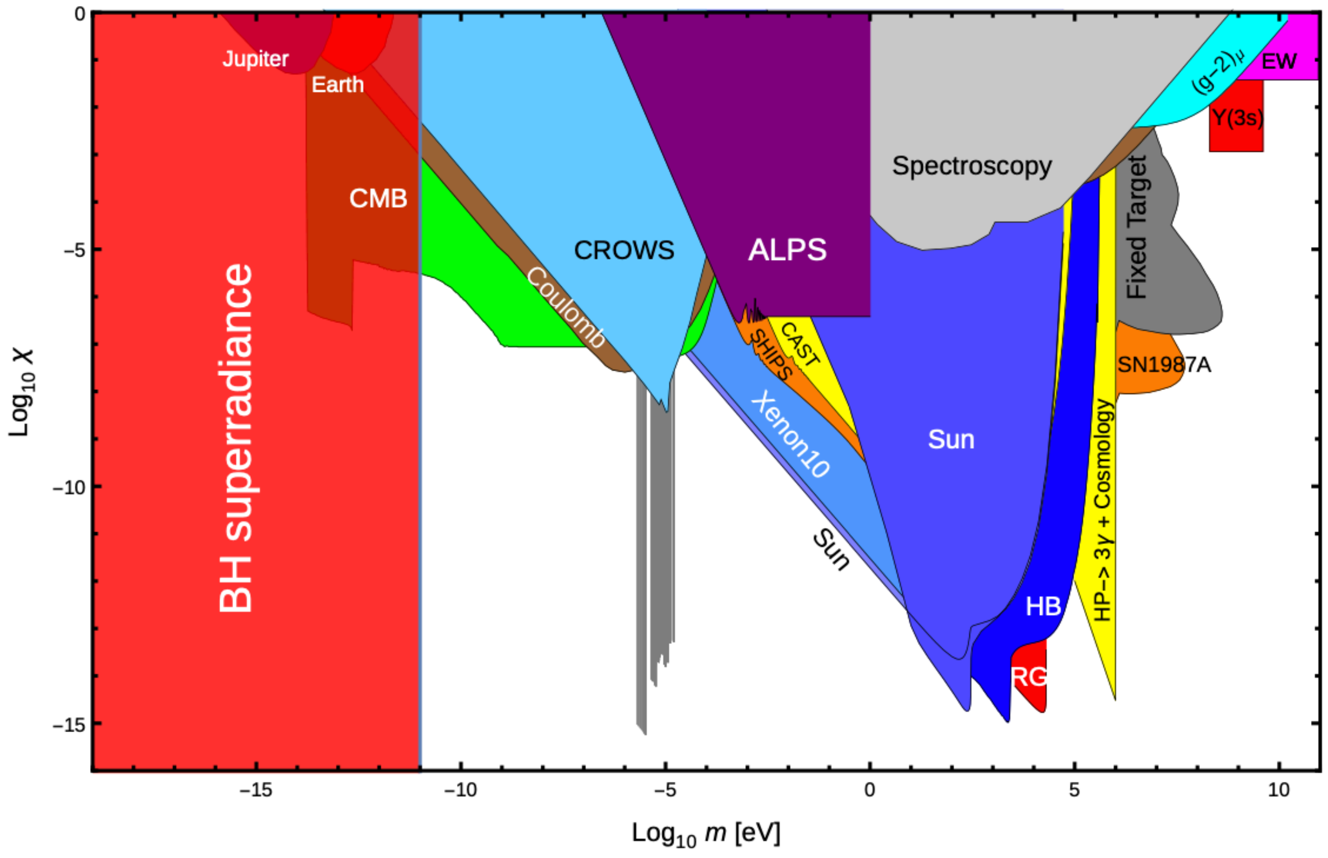
Tests coupling to gravity. No assumption that the boson is initially present, i.e. there is no requirement for the boson to be the DM.



A. Arvanitaki, S. Dubovsky, PhysRevD.83.044026 (2011);

A. Arvanitaki, M. Baryakhtar, X. Huang, PhysRevD.91.084011 (2015)

V. Cardoso et al. JCAP 1803 (03) (2018)



Figures form V. Cardoso et al. JCAP 1803 (03) (2018)

SN Factories

Calore, Carenza, M.G., Jaeckel, Mirizzi (2020)

- Diffuse gamma spectrum from ALPs and HP

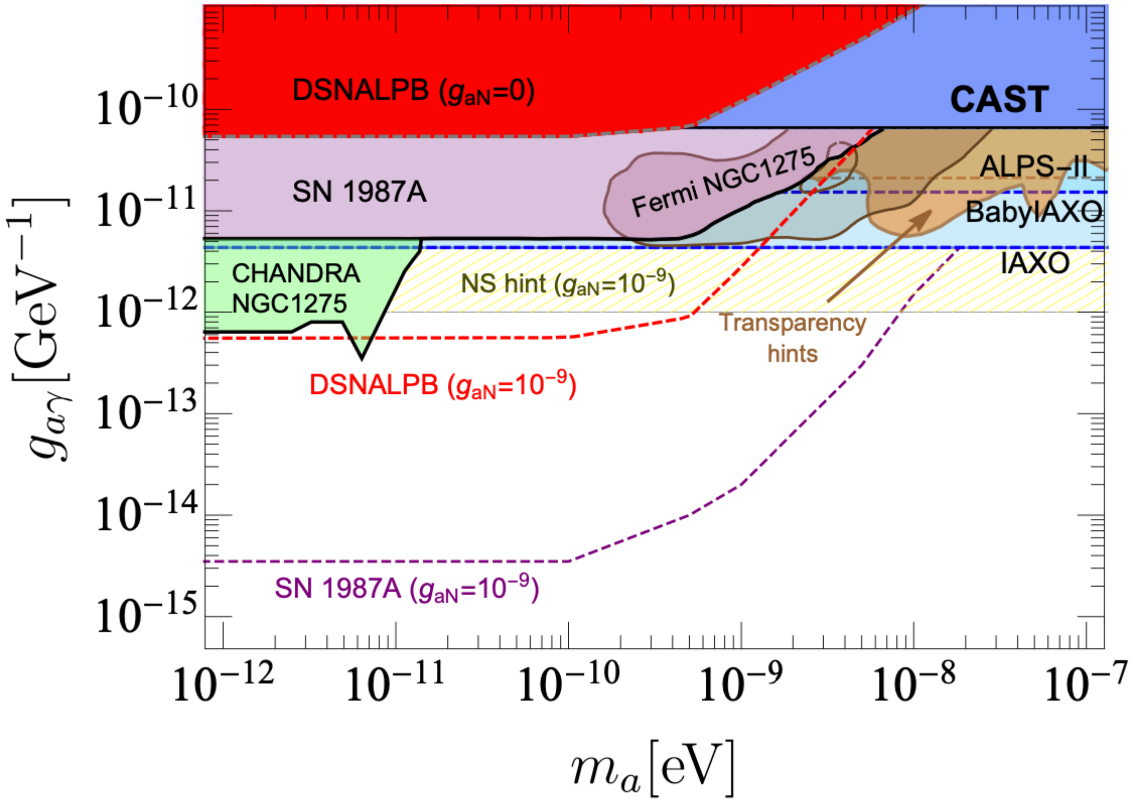
DeRocco, Graham,Kasen,
Marques-Tavares, Rajendran (2020)

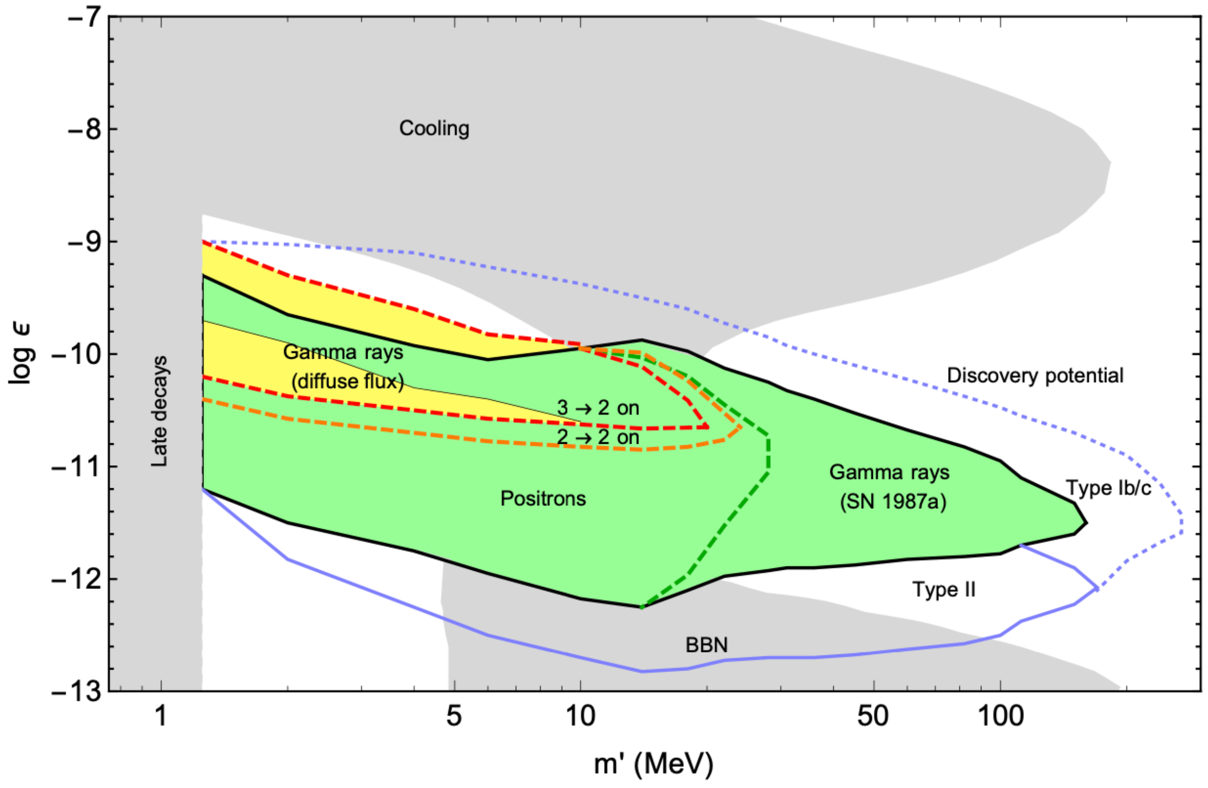
- Bounds from gamma ray from SN 1987A

Payez, et al., JCAP 02 (2015)

- Excess of galactic positrons from HP

DeRocco, Graham,Kasen,
Marques-Tavares, Rajendran (2020)





SN-scope

Table 1: List of SN progenitor candidates with having a mass $\gtrsim 10\ M_\odot$ and within 250 pc from the Earth. We basically use the values listed in the Hipparcos catalogue [78]; otherwise, we show the reference for the source.

HIP	Common Name	Distance (pc)	Mass ($M_\odot$)	RA (J2000)	Dec (J2000)
65474	Spica/α Virginis	77(4)	11.43 ± 1.15 [79]	13:25:11.58	-11:09:40.8
81377	ζ Ophiuchi	112(3)	20.0 [80]	16:37:09.54	-10:34:01.5
71860	α Lupi	142(3)	10.1 ± 1.0 [81]	14:41:55.76	-47:23:17.5
80763	Antares/α Scorpii	170(30)	11–14.3 [82]	16:29:24.46	-26:25:55.2
107315	Enif/ϵ Pegasi	211(8)	11.7(8) [81]	21:44:11.16	$+09$:52:30.0
27989	Betelgeuse/α Orionis	222^{+48}_{-34} [83]	$11.6^{+5.0}_{-3.9}$ [84]	05:55:10.31	$+07$:24:25.4

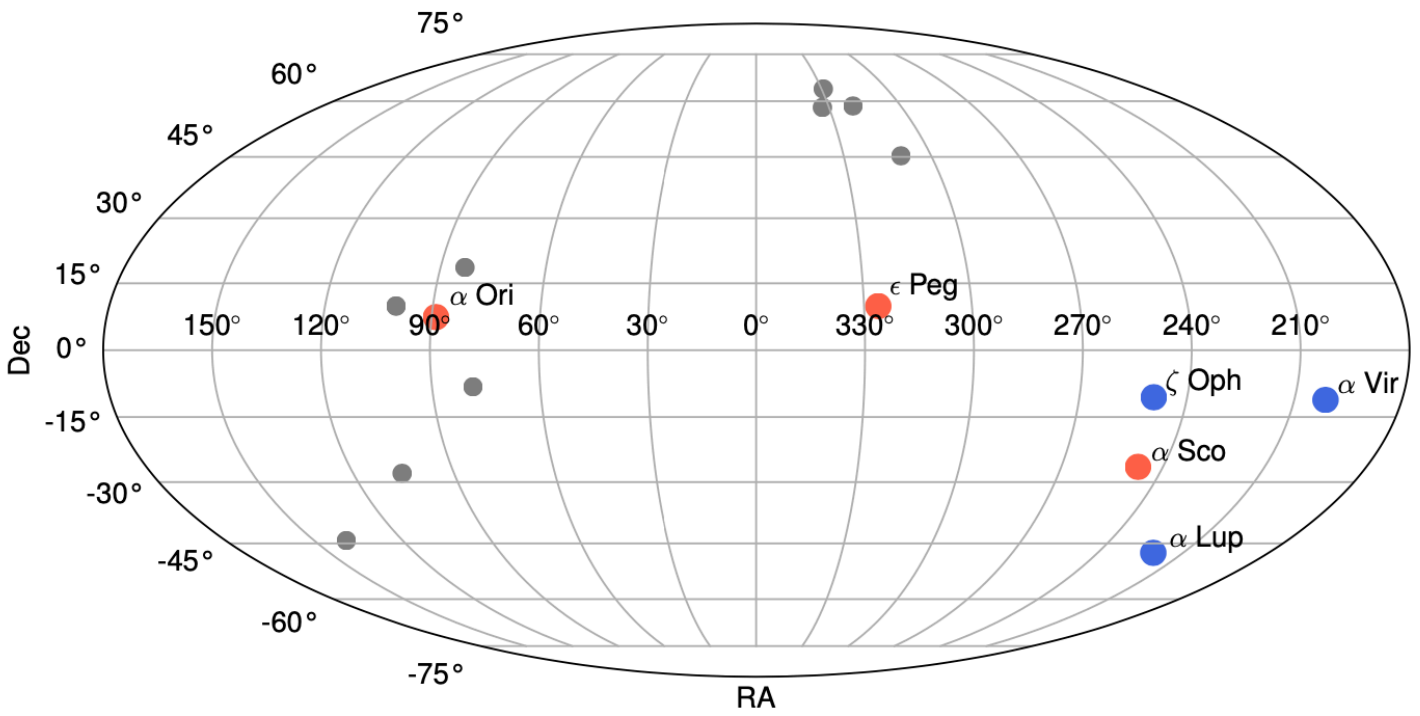
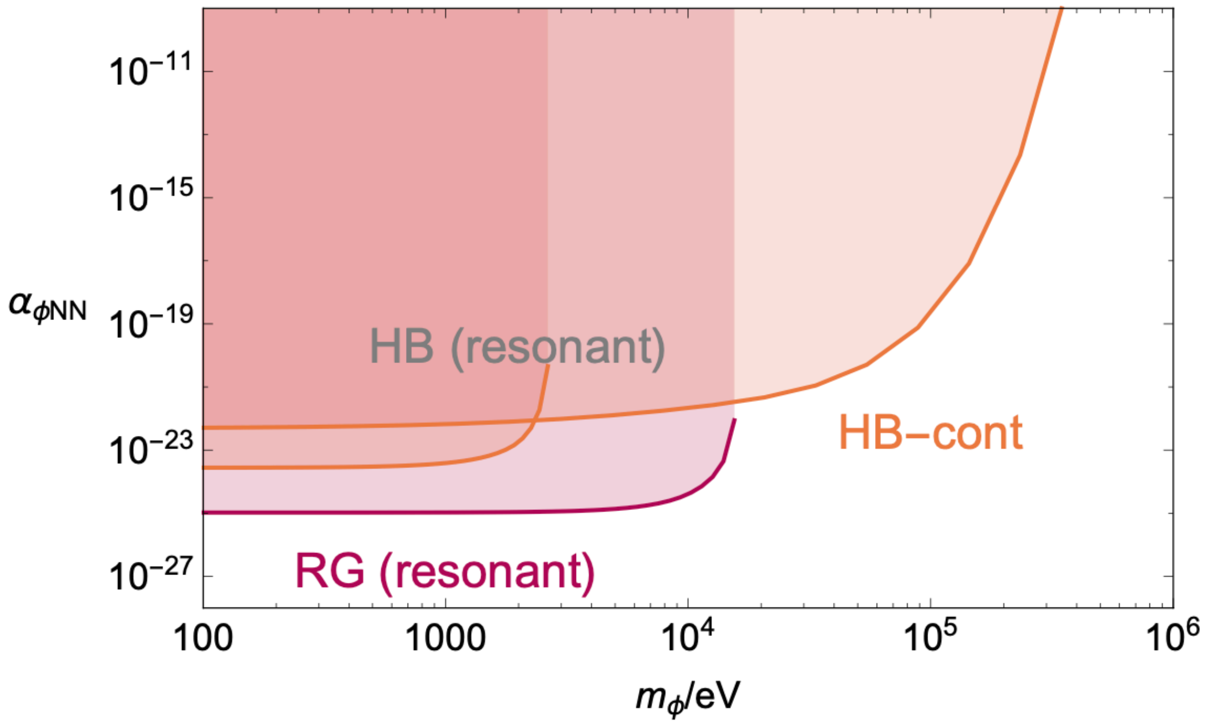


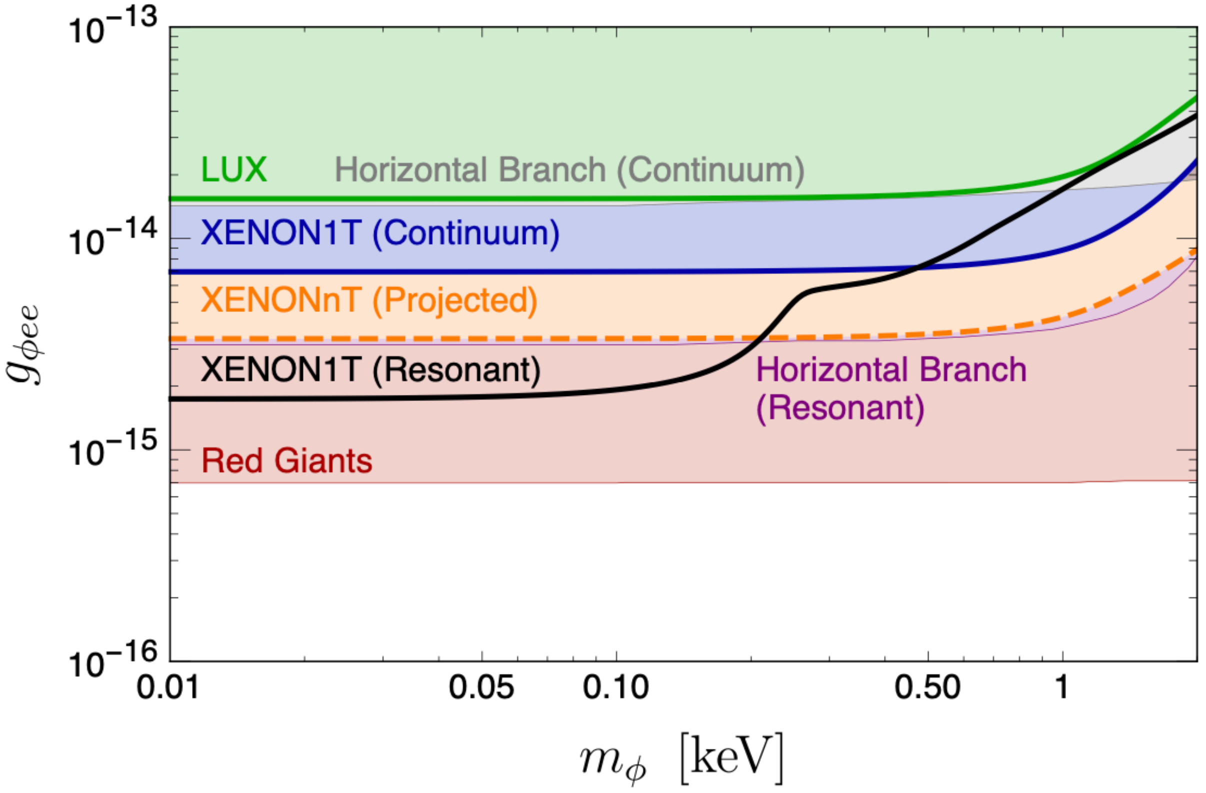
Figure 1: The position of the SN progenitors in Table 1 on the Mollweide projection of the celestial sphere, where the red and blue dots correspond to the spectral types of K/M and O/B, respectively. We also show by the gray dots the progenitors with $d > 250$ pc and $M \gtrsim 10\ M_\odot$ listed in Table A1 in Ref. [87].

From S. F. Ge et al., IAXO as SN-scope (2020) [arXiv:2008.03924]

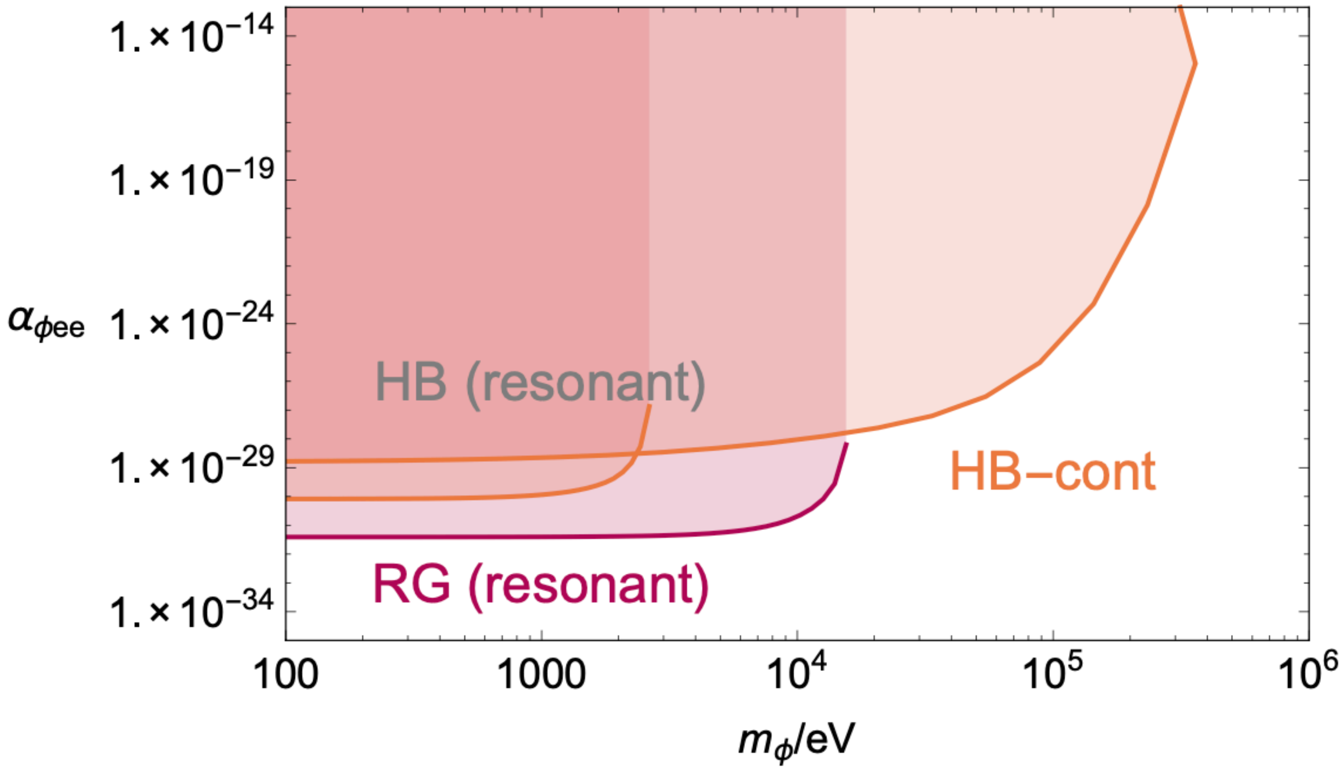
Scalars

Bounds on scalar particles produced in stellar plasma have been recently revised





Budnik, Davidi, Kim, Perez, Priel (2020) [arXiv:1909.02568]



E. Hardy, Lasenby JHEP02(2017)033

Stars as FIP Factories

Surprisingly strong bounds on ALPs from other stars too, particularly form supergiants. ALPs oscillate into X-ray photons. Bounds from NuSTAR

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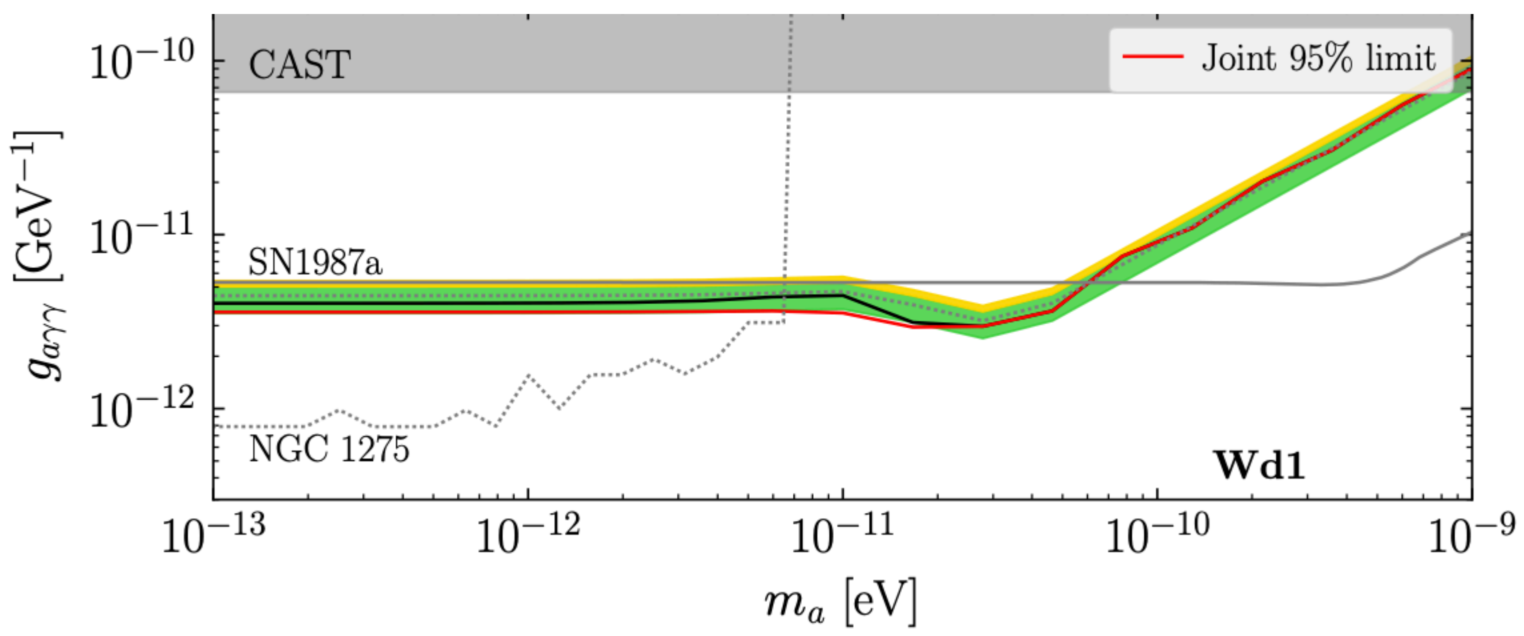
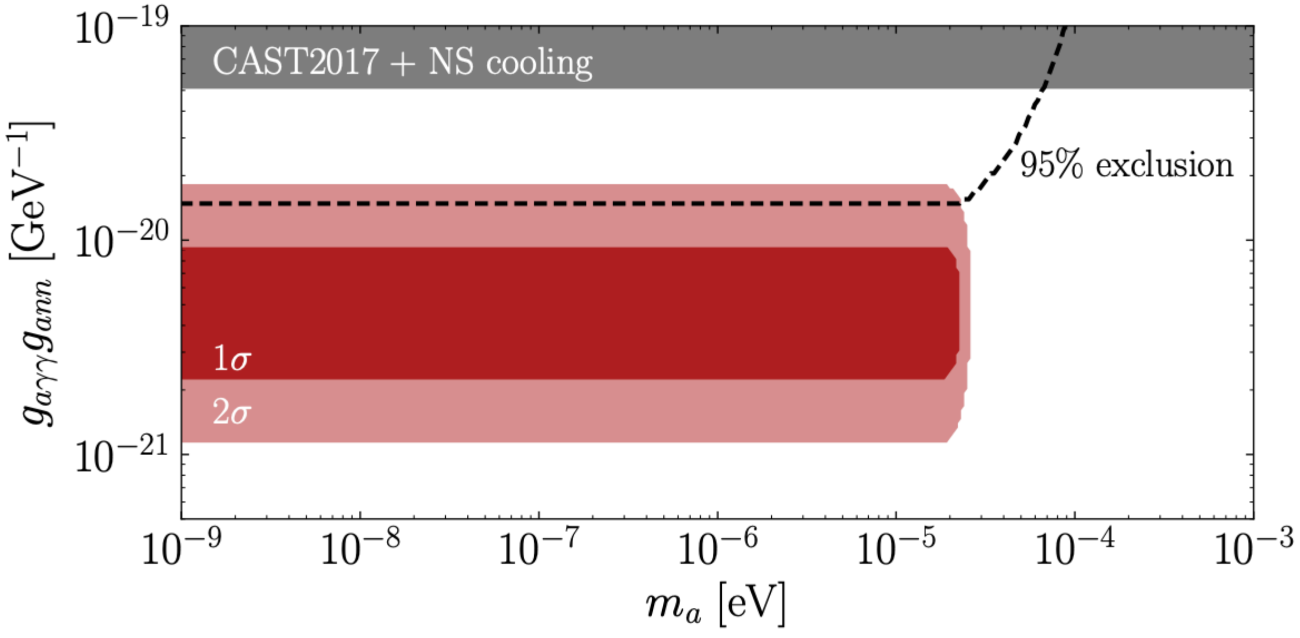


A few NS, observed by XMM- Newton and Chandra, exhibit an unexplainable excess. Is it due to $a \rightarrow \gamma$?

Buschmann, Co, Dessert, Safdy (2019)



Draft version September 2, 2020
Typeset using LaTeX **twocolumn** style in AASTeX63

White Dwarfs in the Era of the LSST and its Synergies with Space-Based Missions

Nicholas J. Fantin,[1,2] Patrick Côté,[2] and Alan W. McConnachie[2]

[1] *Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada*
[2] *National Research Council of Canada, Herzberg Astronomy & Astrophysics Research Centre, 5071 W. Saanich Rd, Victoria, BC, V9E 2E7, Canada*

(Received September 2, 2020)

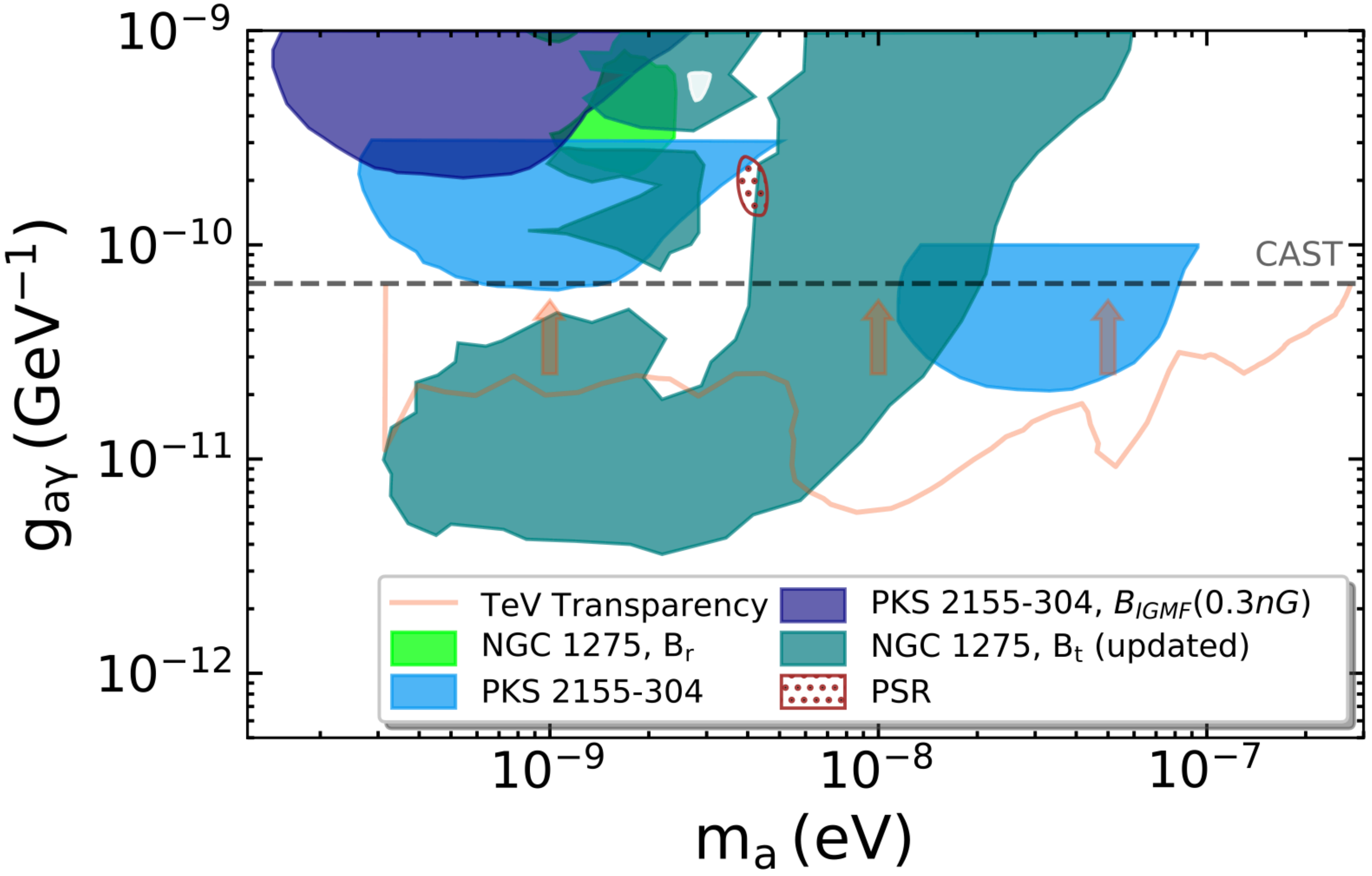
Submitted to ApJ

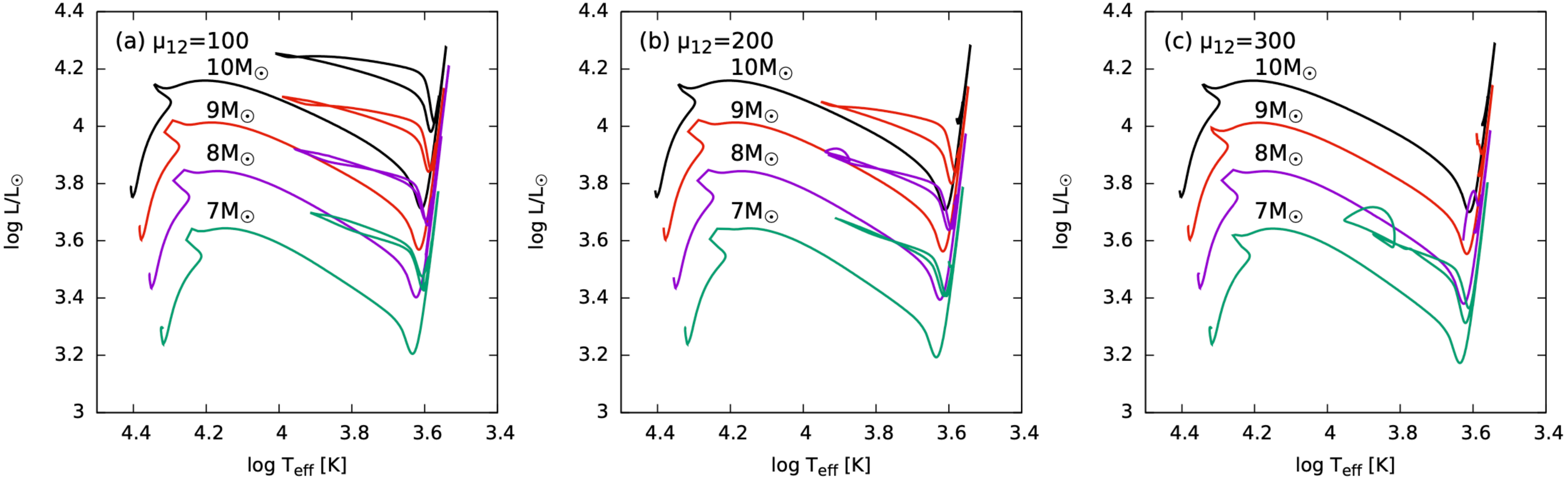
Can stellar bounds be evaded?

see, e.g., De rocco et al. (2020) [arXiv:2006.15112]. Chakraborty, et al (2020) [arXiv:2008.10610]

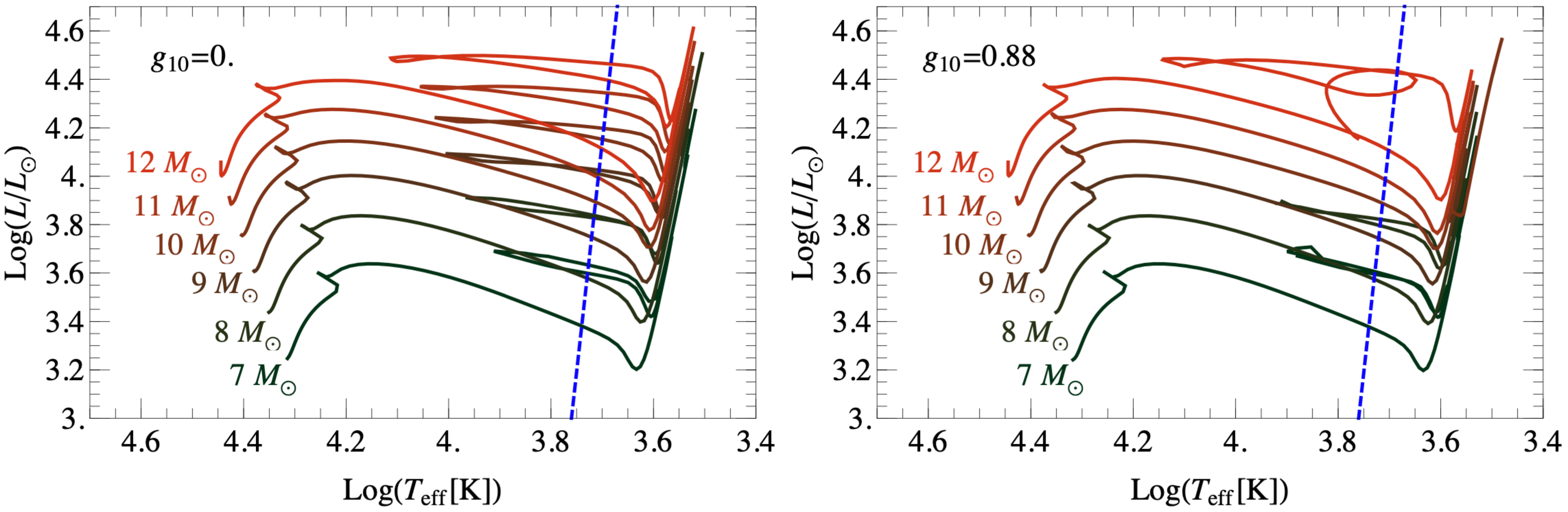
If so, it may open the way to the interpretation of more astrophysical anomalies in terms of FIPs.

see, e.g., Pallathadka et al. (2020) [arXiv:2008.08100].





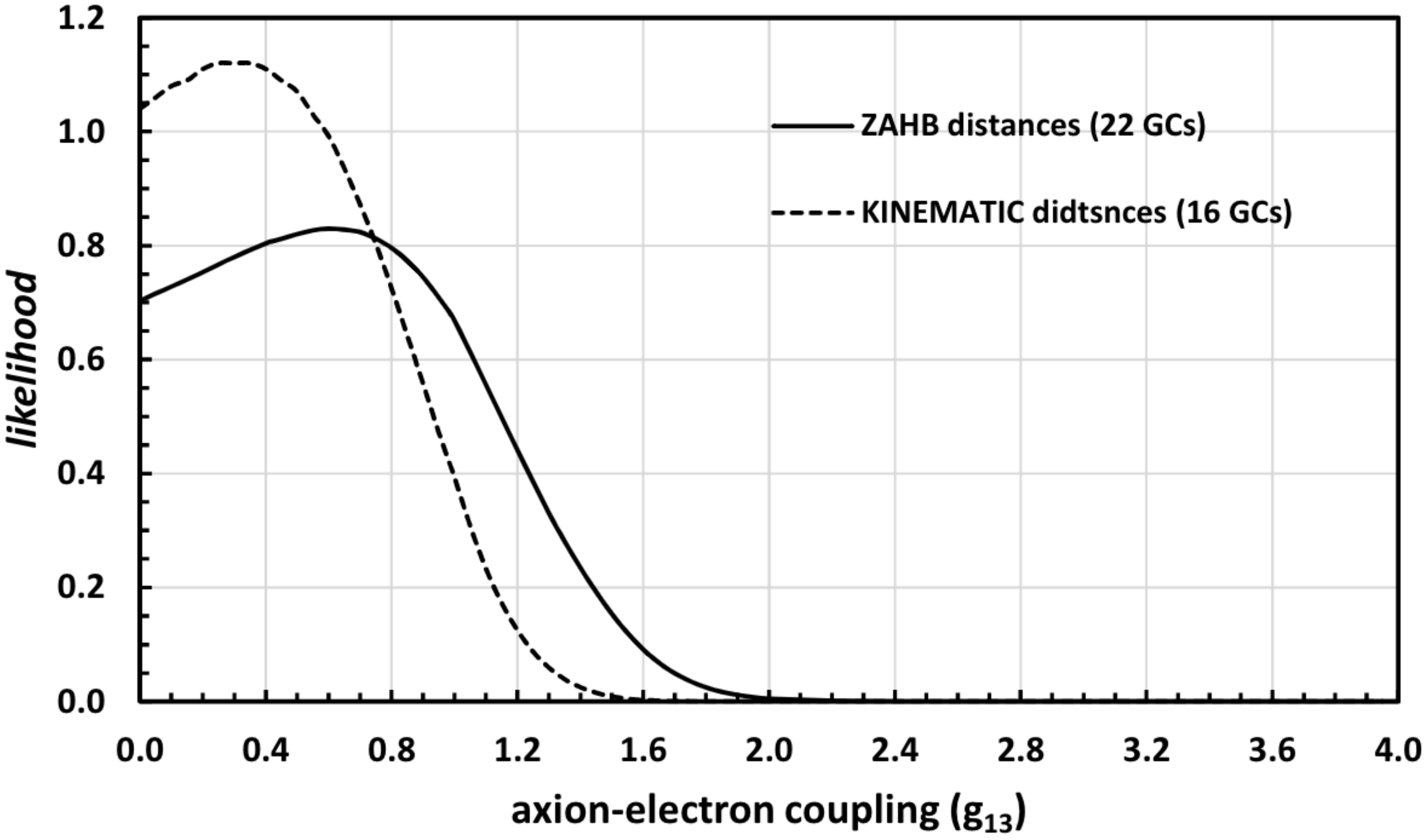
Mori, Balantekin, Kajino, Famiano (2020)



A. Friedland, M.G., M. Wise (2013)

	photometric sample	distance scale	g_{13} best value	g_{13} bound
M5	VI+JK	ZAHB	0	2.30
47 Tuc	VI+ JK	parallax	0.45	1.87
NGC 362	VI+JK	parallax	0	1.37
22 GCs	JK	ZAHB	0.60	1.38
16 GCs	JK	KINEMATIC	0.35	1.05

Capozzi Raffelt: $\mu_{12} < 0.77\,(1.50)$ at $68\,\%\,(95\%)$ CL

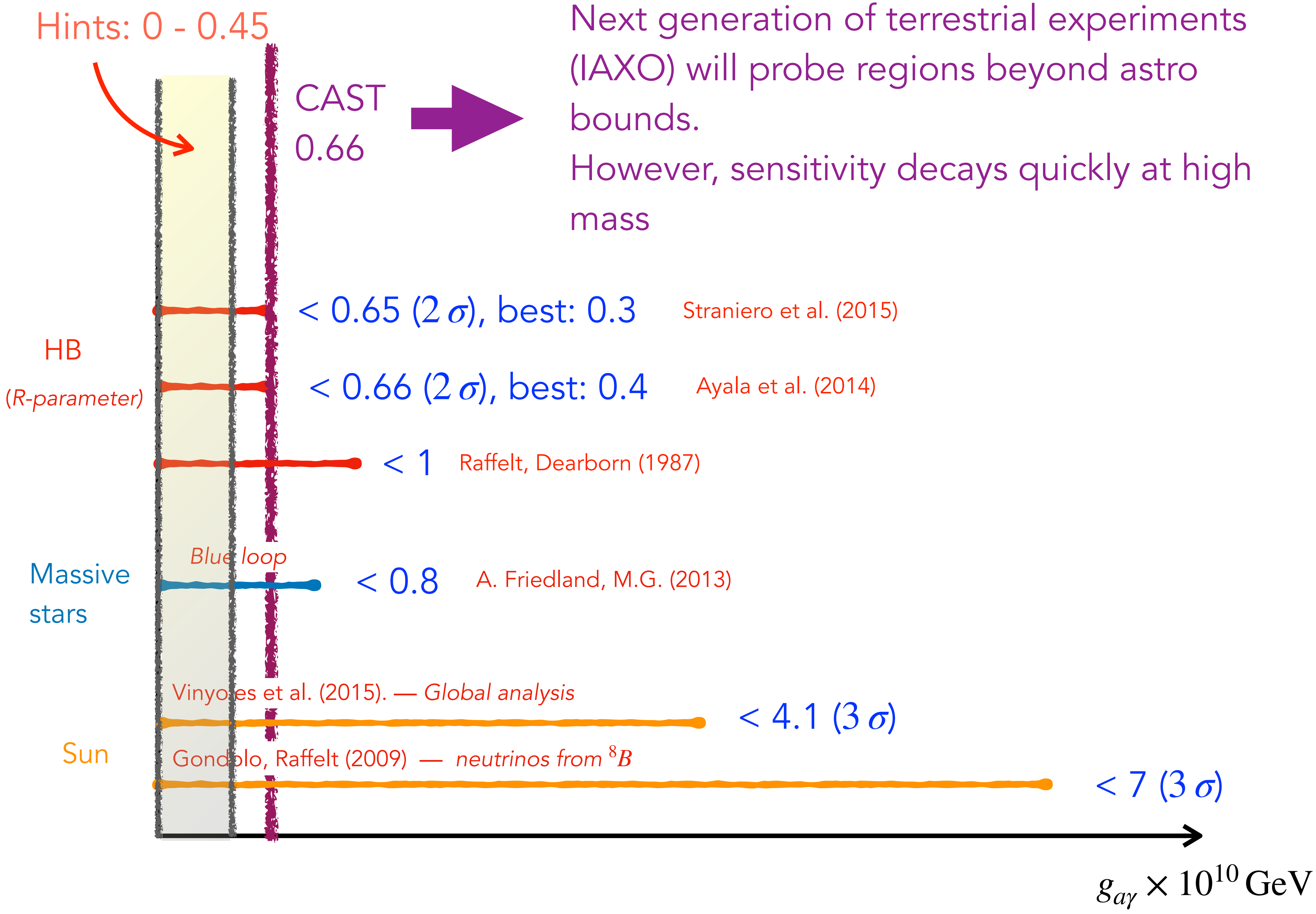


Straniero et al. (2020)

$$g_{ae} = 0.60^{+0.33}_{-0.53}$$

Axion-photon coupling ($g_{a\gamma}$)

Next generation of terrestrial experiments (IAXO) will probe regions beyond astro bounds.
However, sensitivity decays quickly at high mass



Hints: 0 - 0.45

CAST
0.66

HB
(R-parameter)

< 0.65 ($2\,\sigma$), best: 0.3 Straniero et al. (2015)

< 0.66 ($2\,\sigma$), best: 0.4 Ayala et al. (2014)

< 1 Raffelt, Dearborn (1987)

Massive stars

Blue loop

< 0.8 A. Friedland, M.G. (2013)

Sun

Vinyoles et al. (2015). — *Global analysis*

< 4.1 ($3\,\sigma$)

Gondolo, Raffelt (2009) — *neutrinos from* ^8B

< 7 ($3\,\sigma$)

$g_{a\gamma} \times 10^{10}\,\mathrm{GeV}$