CONSTRAINING DARK MATTER with ASTEROSEISMOLOGY

CoRoT 3 - KASC 7

Jordi Casanellas

in coll. with

Ilídio Lopes: Casanellas J. & Lopes I., ApJL 765 (2013) arXiv: 1212.2985

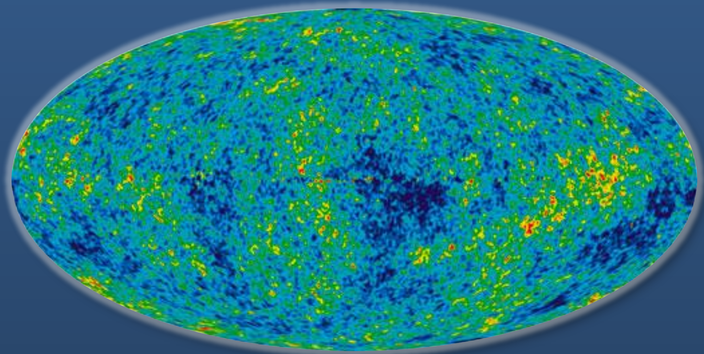
Isa M. Brandão: Casanellas J. & Brandão I., in preparation

Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut)

Unterstützt von / Supported by Alexander von Humboldt Stiftung / Foundation

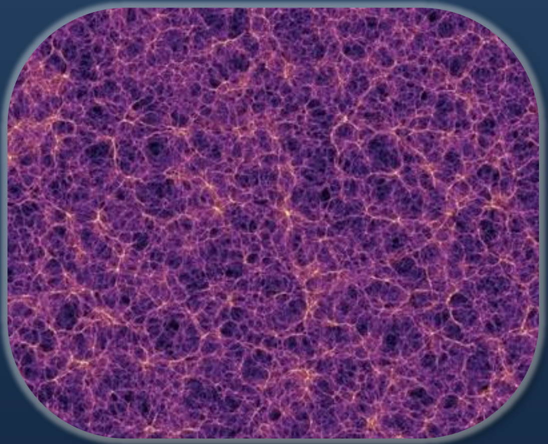
The Space Photometry Revolution, Toulouse 2014

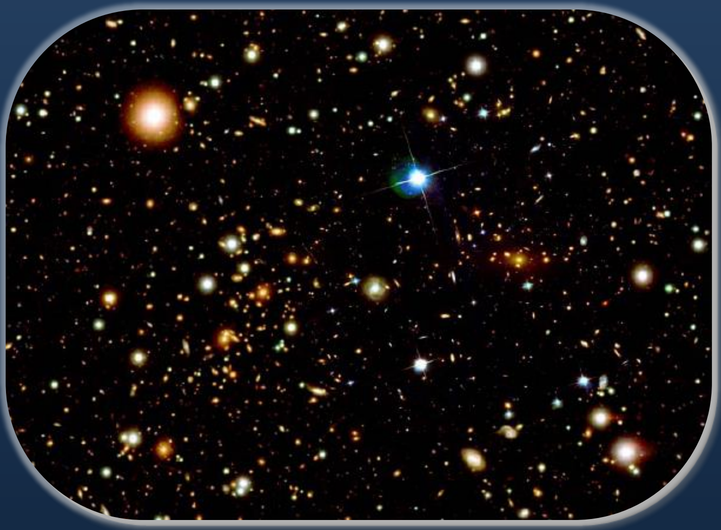
Dark Matter??

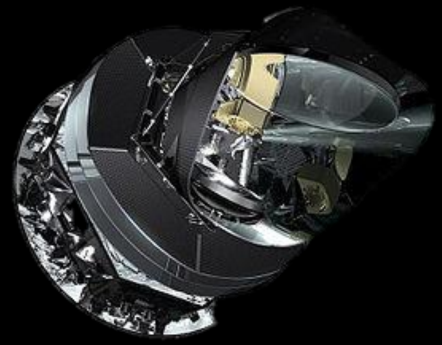


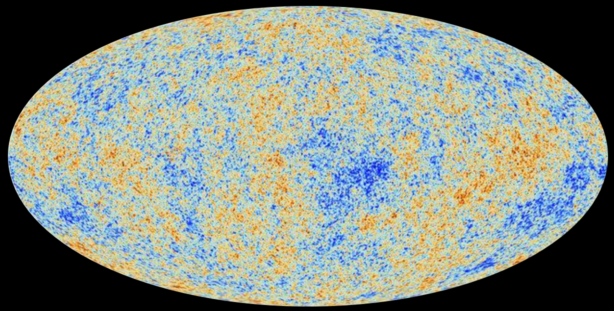
~ **80%** of all the matter exists in an **unknown form**

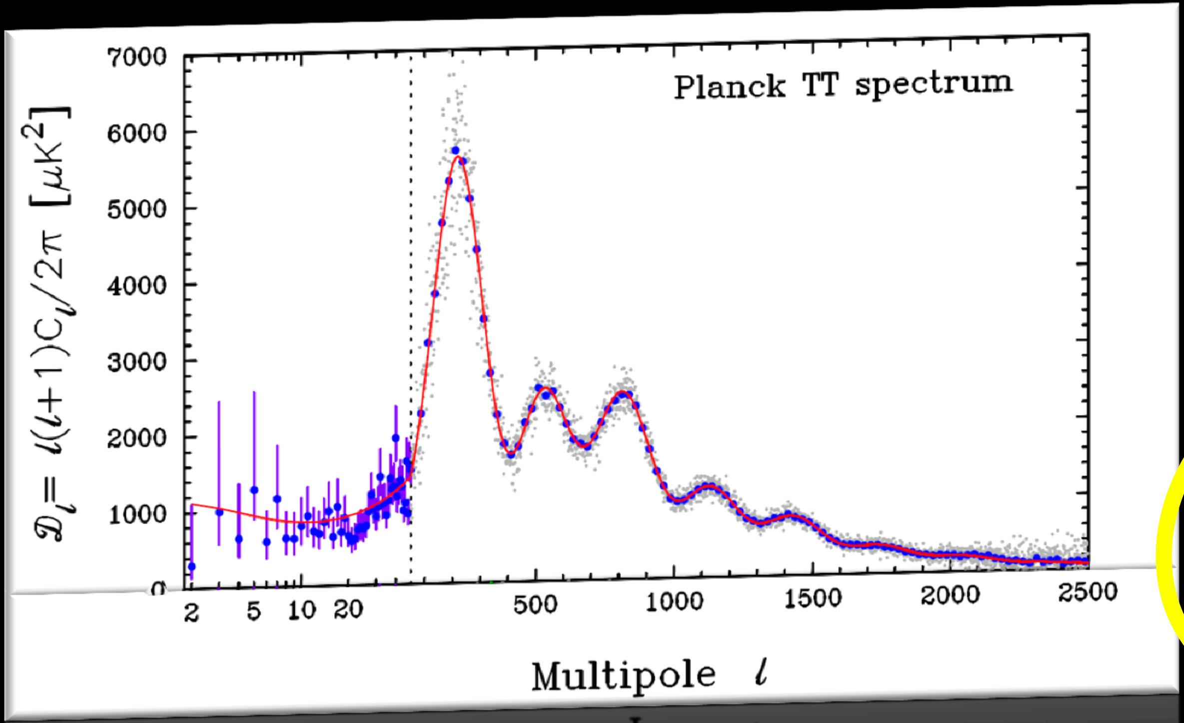
- Massive
- Abundant
- Stable
- Weakly interacting with photons (neutral) and baryons











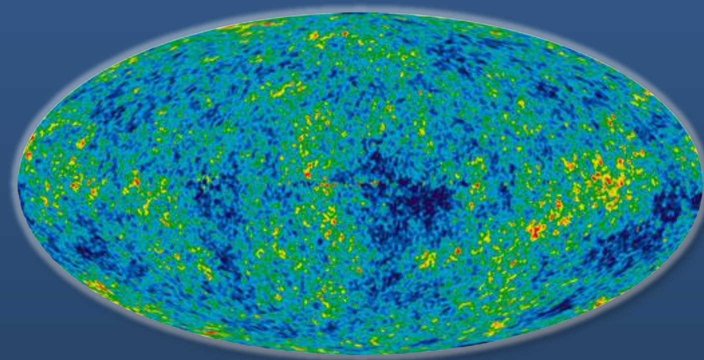
ting

$\Omega_m = 0.315$

$\Omega_b = 0.049$

[PLANCK coll., arXiv:1303.5076 (2013)]

Dark Matter??



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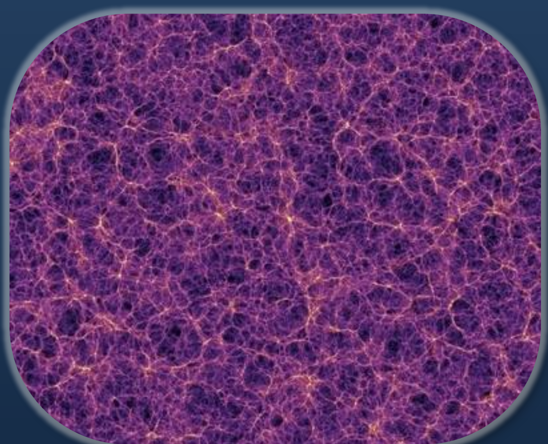

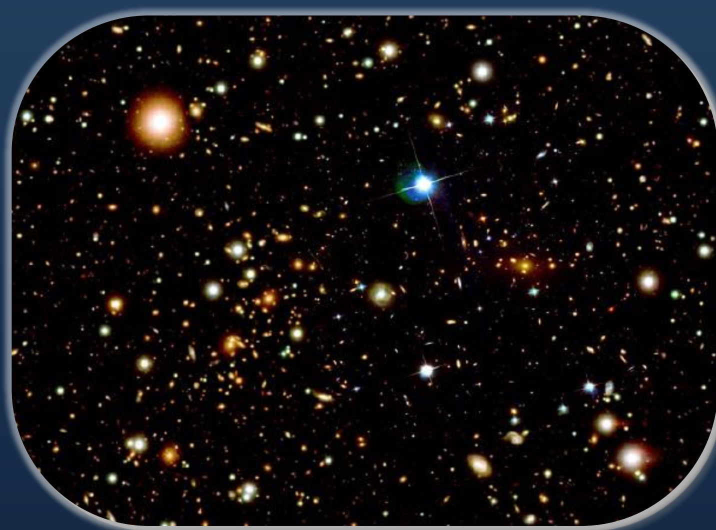

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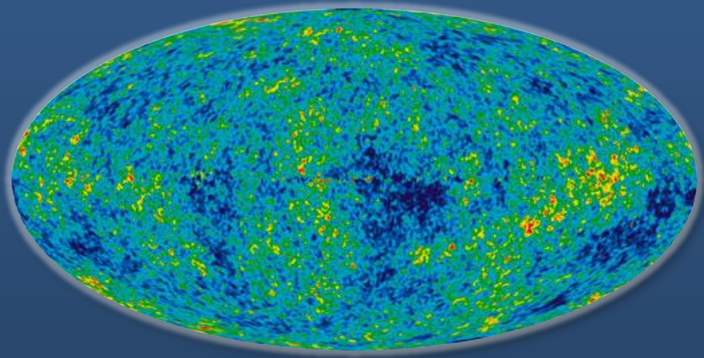

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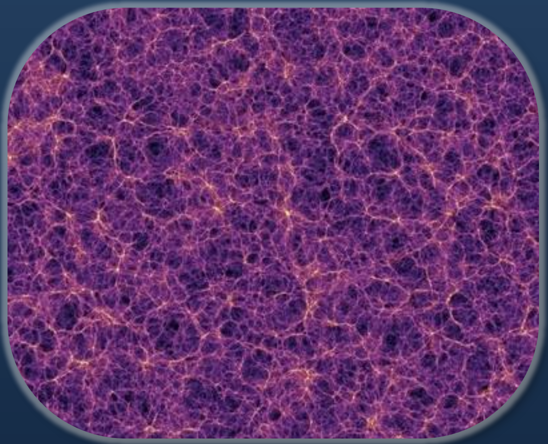

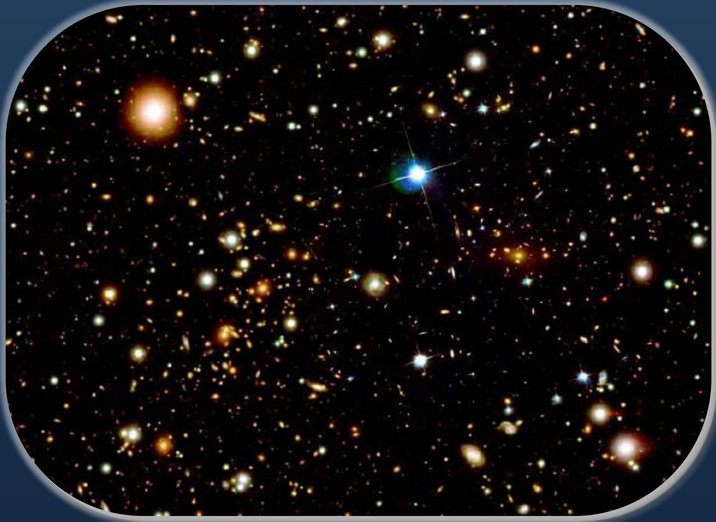

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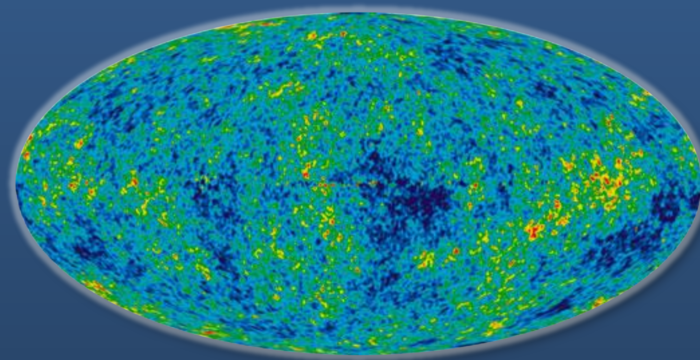

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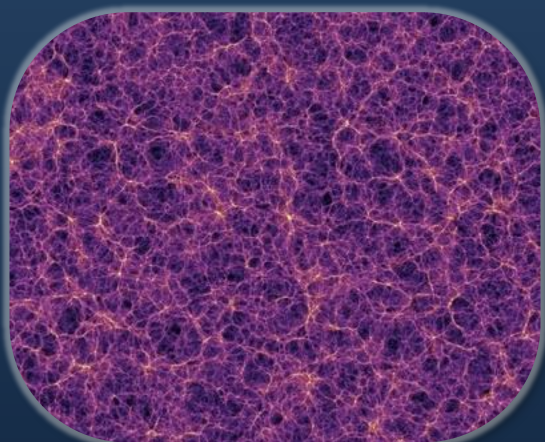

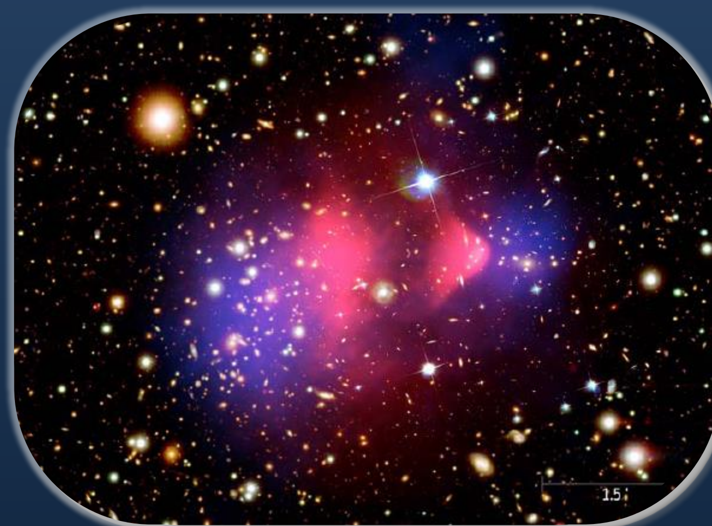

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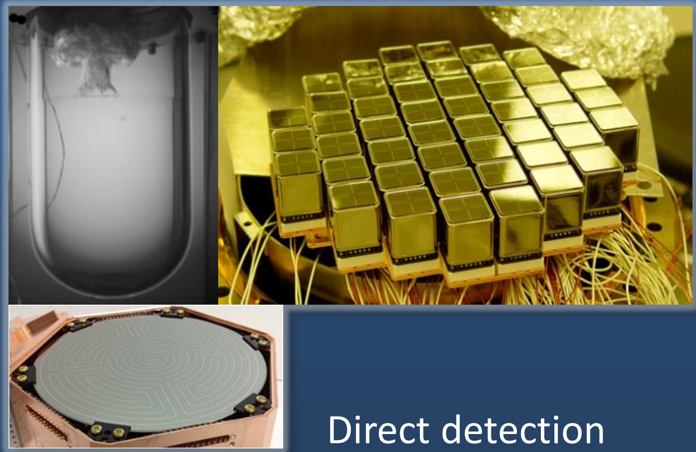
→ **WIMPs !**

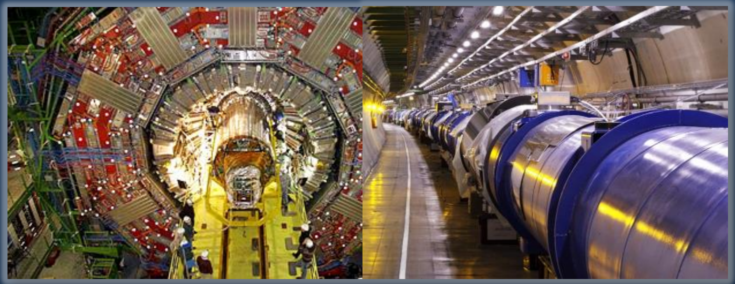
axions,
sterile neutrinos,
gravitinos ...

Dark Matter searches



Direct detection

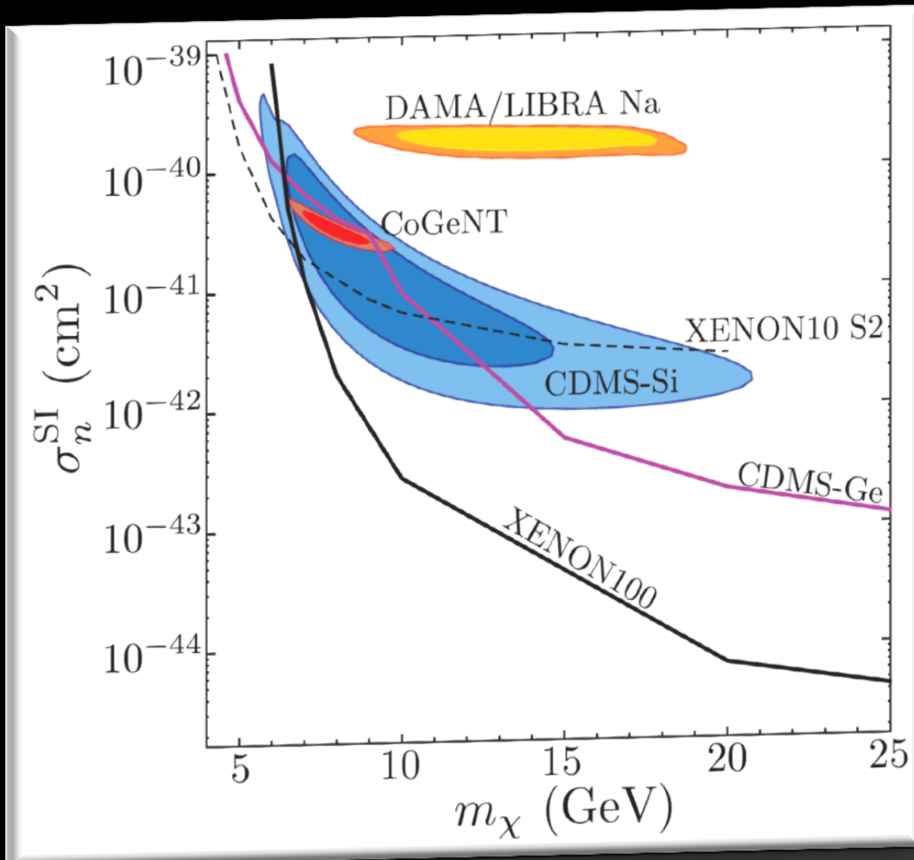
Indirect detection



Colliders

Astrophysical probes
(**STARS**)

Detection of Low-mass WIMPs ??



[Buckley M. & Lippincott W. H., Phys. Rev. D 88 (2013)]

DAMA, CoGeNT, CRESST, CDMS

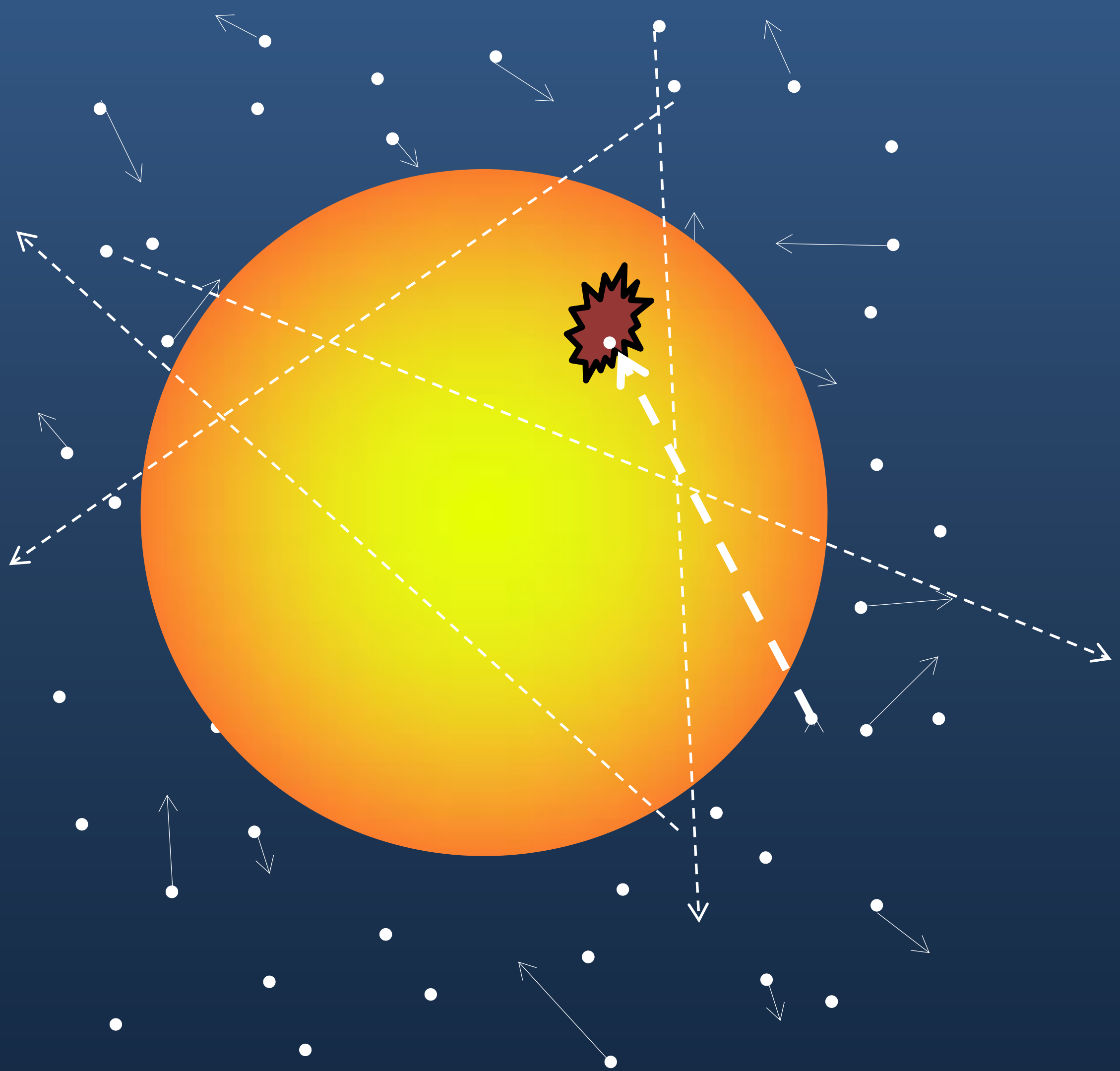
$m_\chi \sim 10\ GeV$

$\sigma_{\chi,SI} \sim 10^{-41}\ cm^2$

$\sigma_{\chi,SD} \sim 10^{-36}\ cm^2$

Tension with null results of XENON100, EDELWEISS

Impact of Dark Matter on stars



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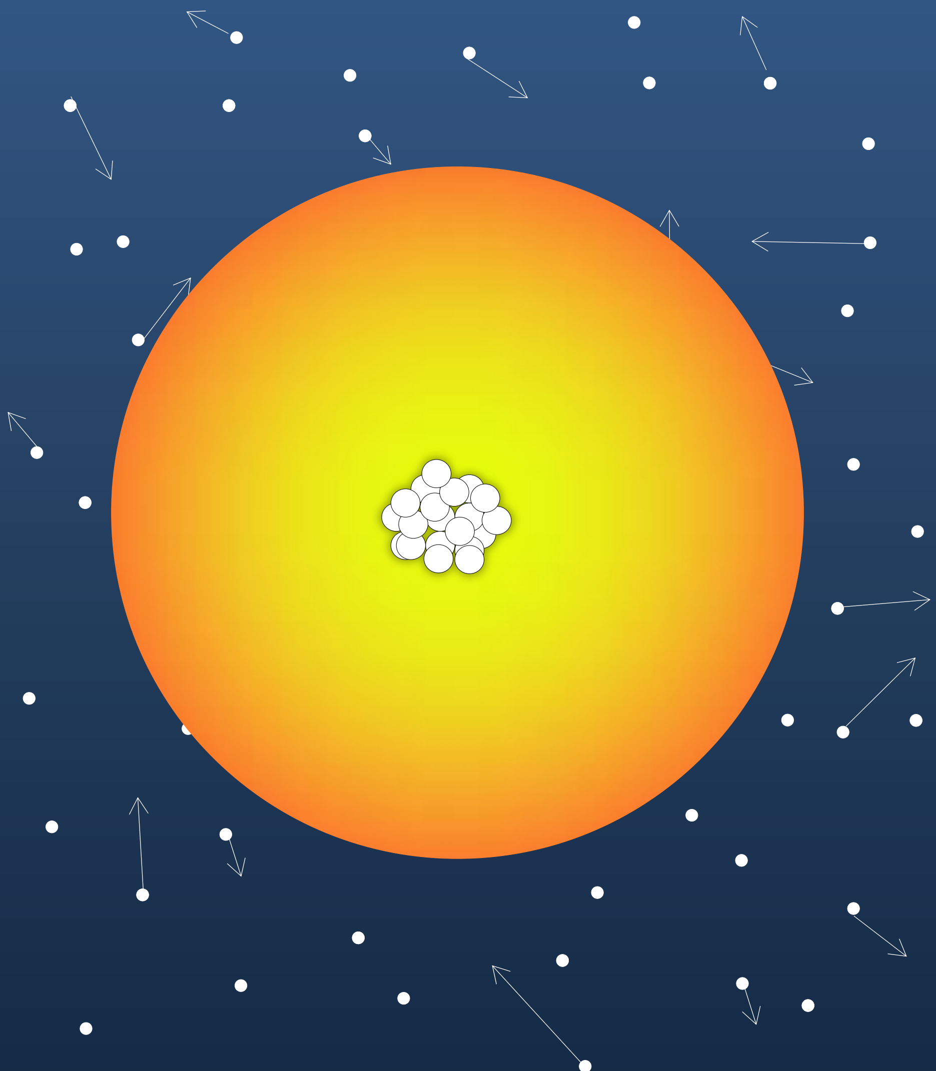

DM Capture [Gould, ApJ 321 (1987)]

Impact of Dark Matter on stars

DM Capture [Gould, ApJ 321 (1987)] + DM energy transport [Gould & Raffelt ApJ 352 (1990)]

Impact of asymmetric Dark Matter on stars

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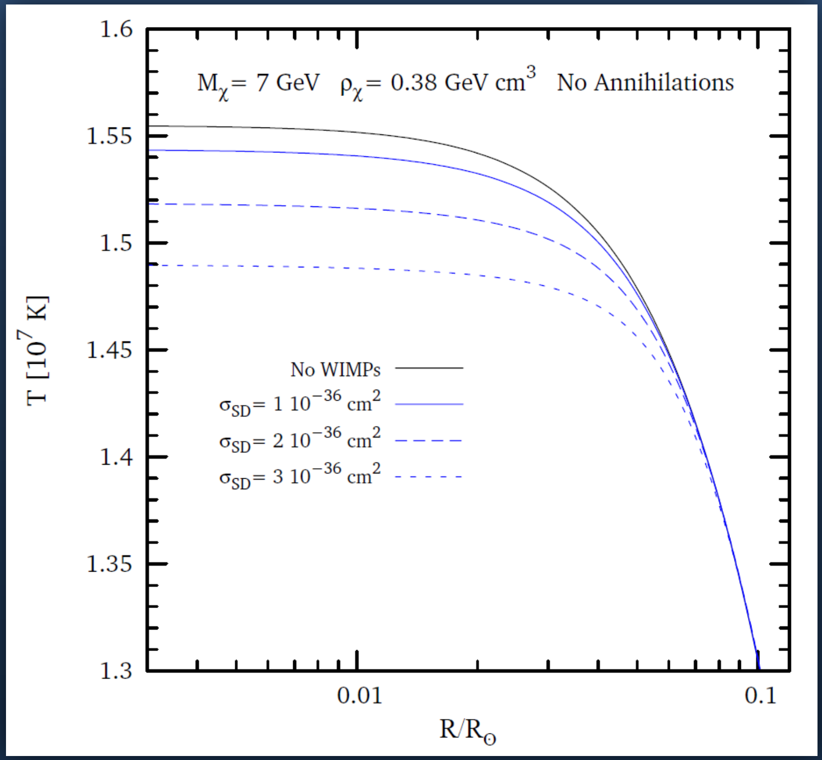
Impact of asymmetric Dark Matter on stars

DM energy transport

[Gould & Raffelt ApJ 352 (1990)]

Reduction central temperature

SUN: [Spergel and Press, ApJ 294 (1985)
Lopes, Bertone & Silk, MNRAS 337 (2002)...]

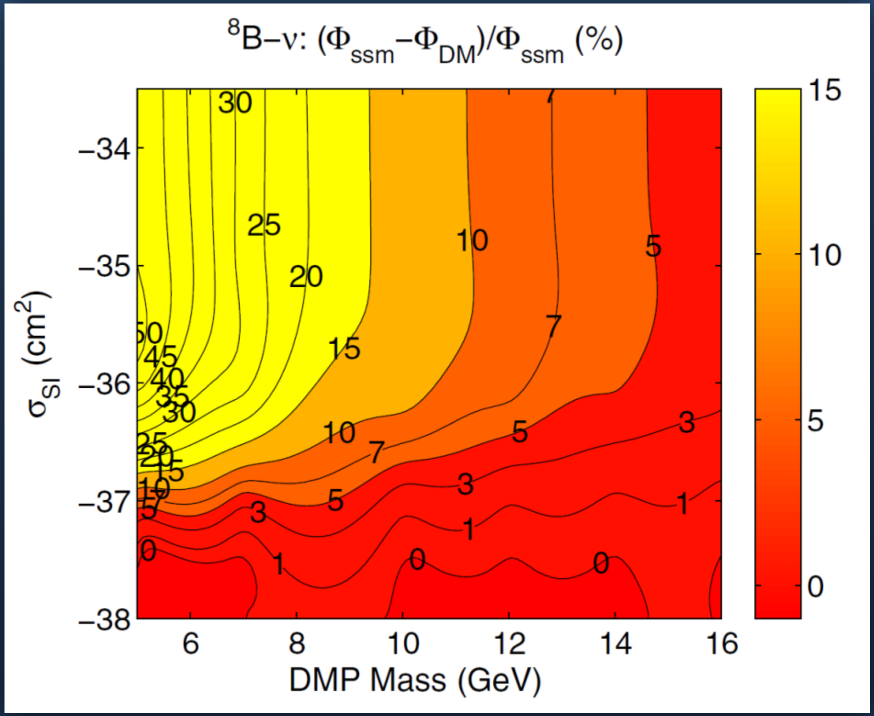


[Taoso *et al*. Phys. Rev. D 82 (2010)]

Impact of asymmetric Dark Matter on stars

Reduction central temperature

SUN: solar neutrinos, helioseismology



[Lopes & Silk, ApJL 752 (2012), Science (2012)]

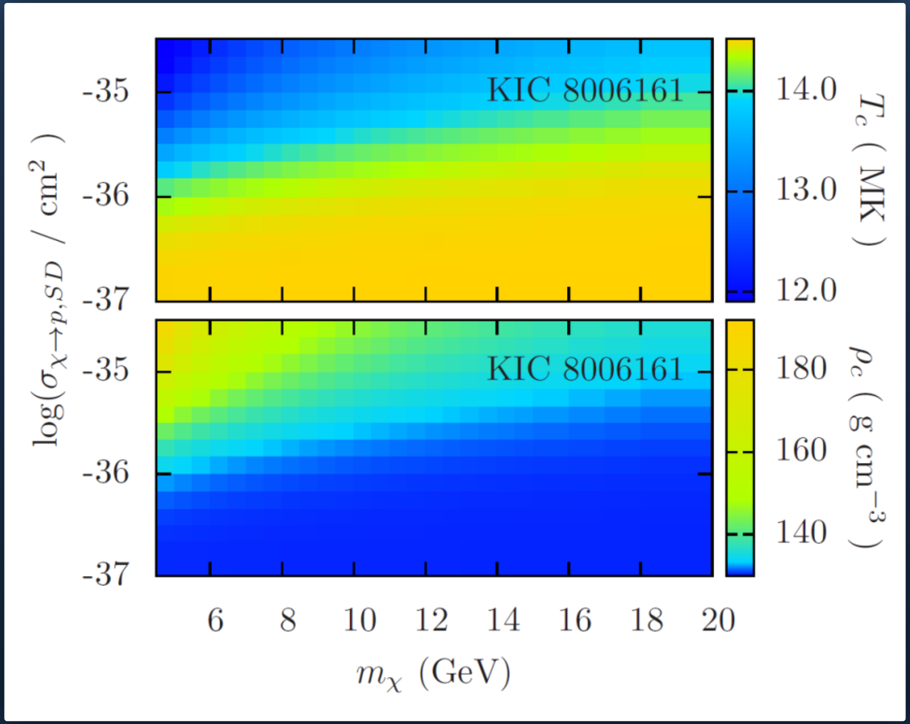
Impact of asymmetric Dark Matter on stars

Reduction central temperature

SUN: solar neutrinos, helioseismology

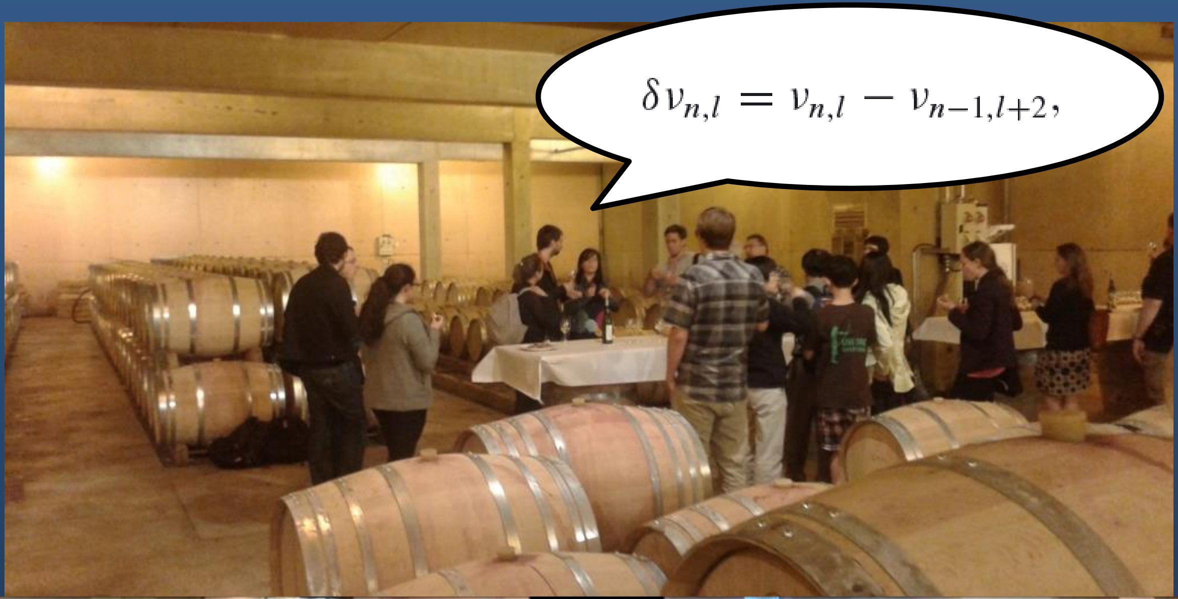
WHY OTHER STARS ?

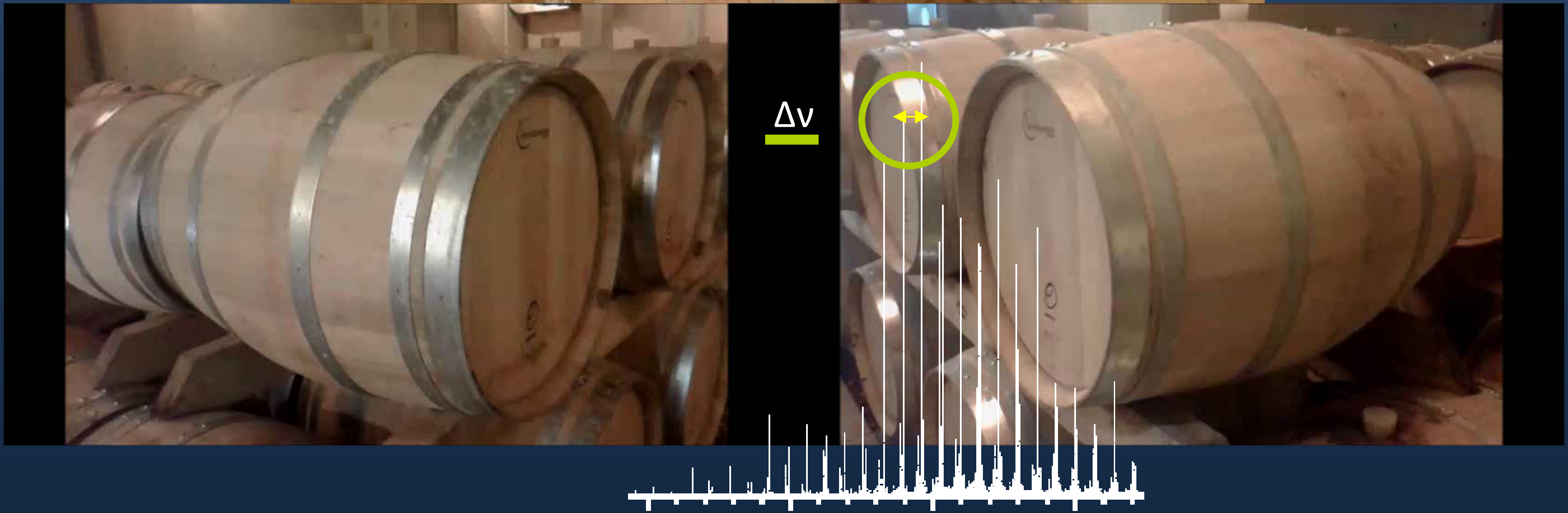
- $M_\star \downarrow \Rightarrow$ stronger DM impact



[**Casanellas** & Lopes , ApJL 765 (2013)]

How can asteroseismology constrain Dark Matter?





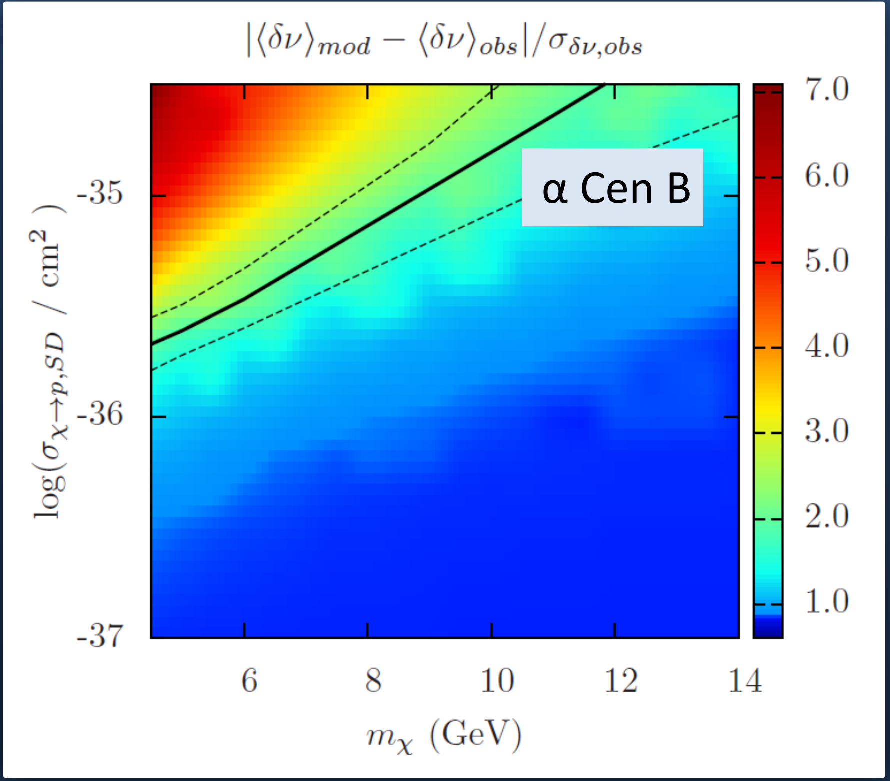
Constraining asym Dark Matter with asteroseismology

- Modelling of **α Cen B**

⇨ $M_\star \downarrow$, closest, binary

[**Casanellas** & Lopes , ApJL 765 (2013)]

$$\delta\nu_{n,l} = \nu_{n,l} - \nu_{n-1,l+2},$$



Asymmetric DM candidates with

$m_\chi = 6$ GeV and

$\sigma_{\chi,SD} \geq 3 \cdot 10^{-36} \mathrm{cm}^2$

excluded at 95% confidence level.

Star	M ($M_\odot$)	R ($R_\odot$)	L ($L_\odot$)	T_{eff} (K)	$(Z/X)_s$	$\langle\Delta\nu_{n,0}\rangle^a$ (μHz)	$\langle\delta\nu_{02}\rangle^a$ (μHz)
α Cen B							
Observ. [24, 25]	0.934 ± 0.006	0.863 ± 0.005	0.50 ± 0.02	5260 ± 50	0.032 ± 0.002	161.85 ± 0.74	10.94 ± 0.84
Stand. mod./DM mod.[c]	0.934	0.868	0.51	5245/5230	0.031	162.56/162.45	10.23/8.95

Impact of asymmetric Dark Matter on stars

Reduction central temperature

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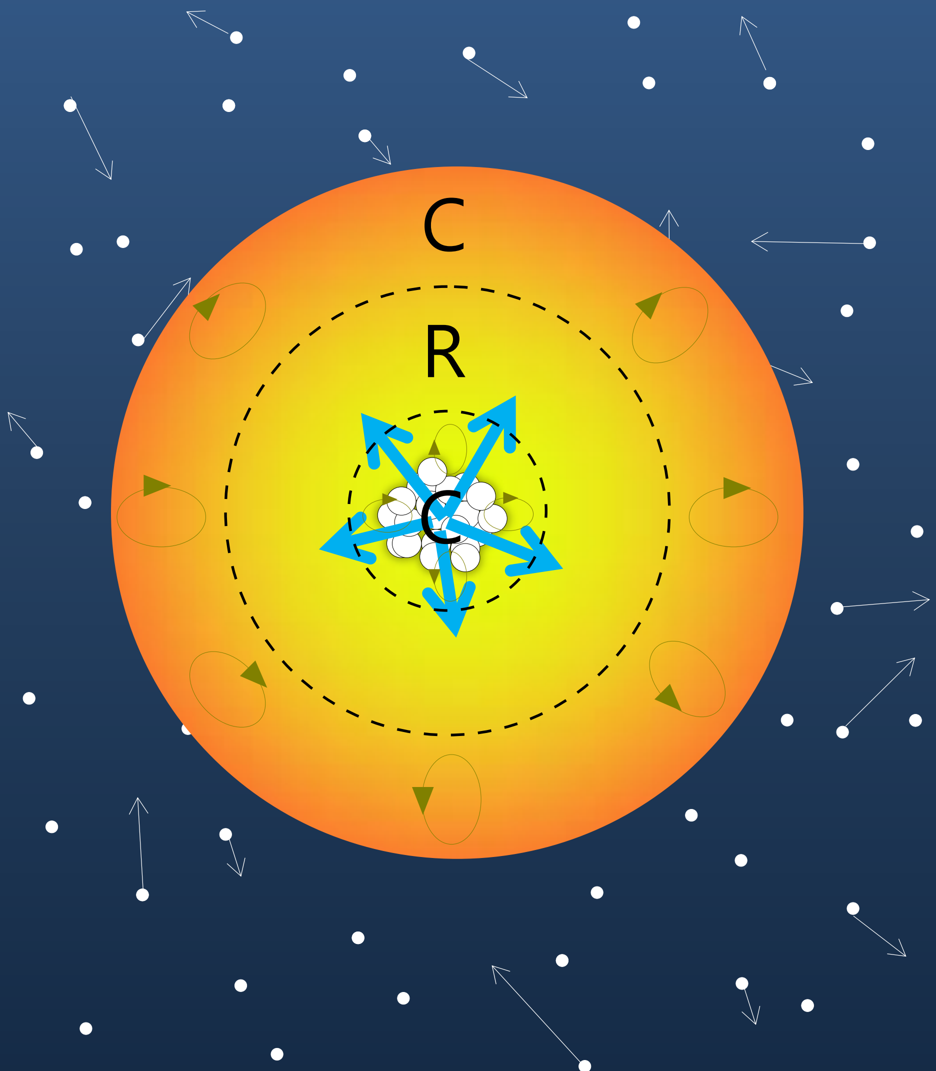
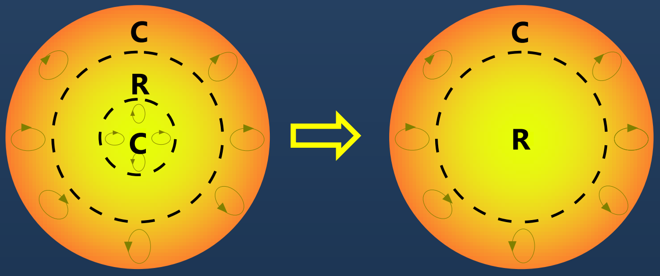


Reduction central temperature

SUN: solar neutrinos, helioseismology

WHY OTHER STARS ?

- $M_{\star}\downarrow$ ⟹ stronger DM impact
- Suppression of **convective core** in 1.1-1.3 Ms stars



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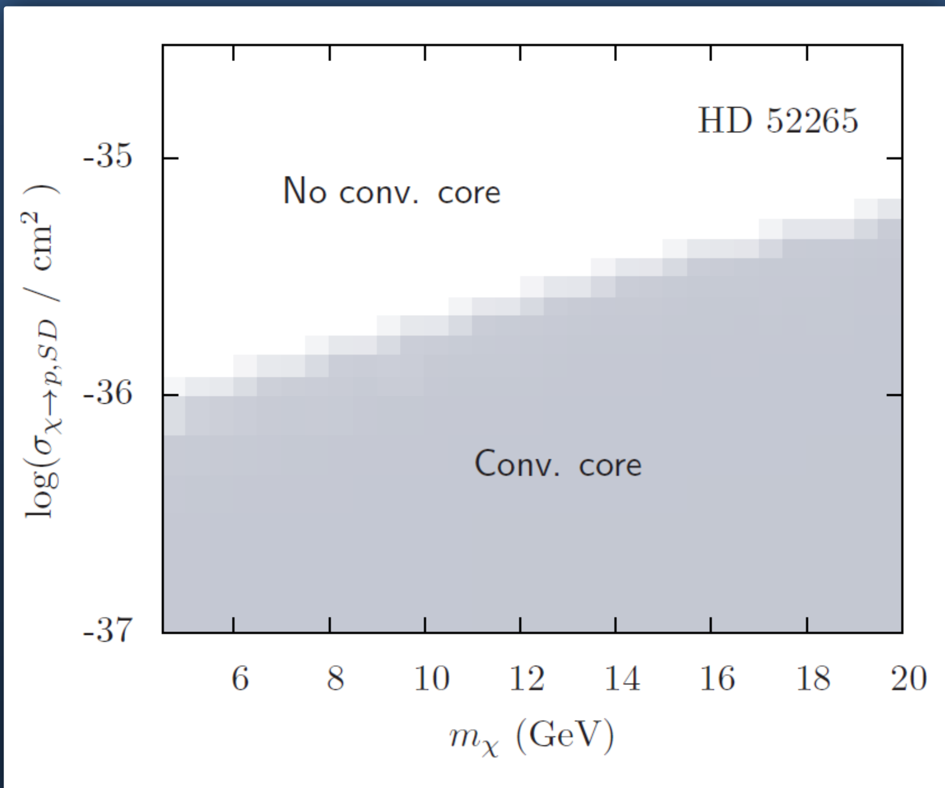

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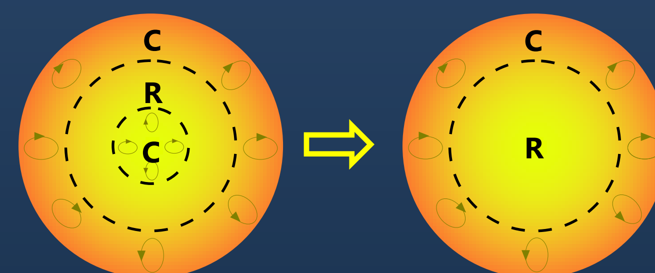


Convective Core in HD 52265 ??

[Ballot *et al.*, A&A 530 (2011), Escobar *et al.*, A&A 547 (2012)]

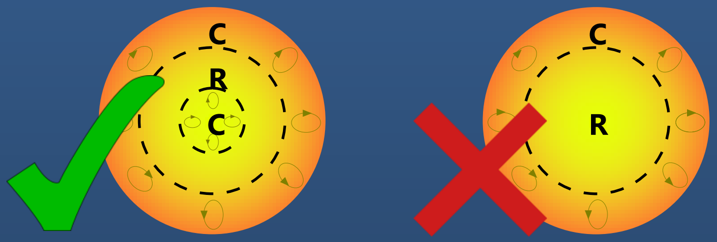
[**Casanellas** & Lopes , ApJL 765 (2013)]

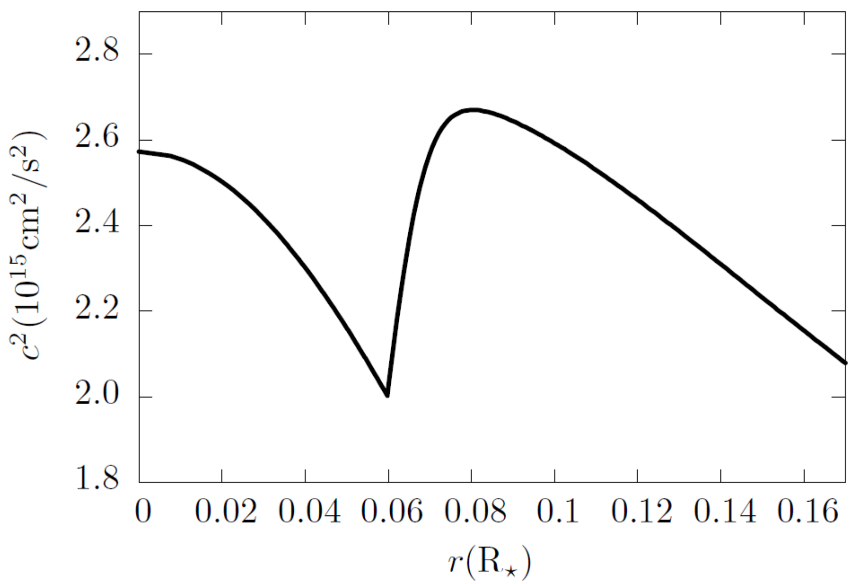
Star	M ($M_\odot$)	R ($R_\odot$)	L ($L_\odot$)	T_{eff} (K)	$(Z/X)_s$	$\langle\Delta\nu_{n,0}\rangle^a$ (μHz)	$\langle\delta\nu_{02}\rangle^a$ (μHz)
HD 52265							
Observ. [19, 23]	1.18-1.25[b]	1.19-1.30[b]	2.09 ± 0.24	6100 ± 60	0.028 ± 0.003	98.07 ± 0.19	8.18 ± 0.28
Stand. mod./DM mod.[c]	1.18	1.30	2.22	6170	0.028	97.92/98.05	8.16/7.65

Constraining asym Dark Matter with asteroseismology

- Presence or abscence of a **convective core** in KIC 12009504 (Dushera)

[Silva Aguirre *et al.*, ApJL 769 (2013)]





$$dr_{0213} = 6\left(\frac{D_{02}}{\Delta\nu_{n-1,1}} - \frac{D_{13}}{\Delta\nu_{n,0}}\right)$$

$$\text{where } D_{l,l+2} \equiv \delta\nu_{n,l}/(4l+6)$$

[Cunha M.S. & Metcalfe T.S. (2007), Cunha M.S. & Brandão I.M (2014)]

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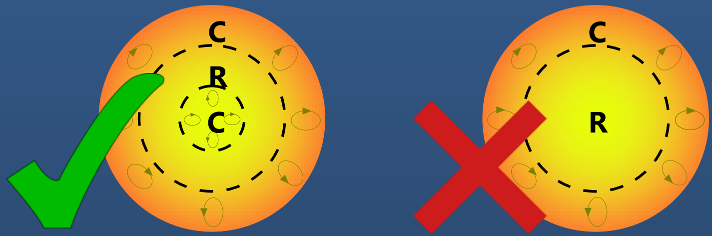

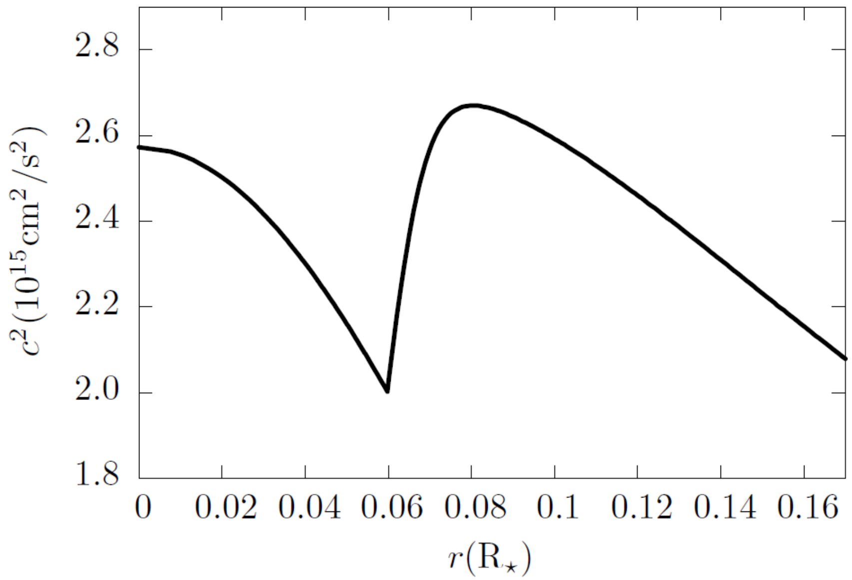

$$|S\{\Delta\nu\ r_{010}\}|$$

$$r_{01} = \frac{d_{01}}{\Delta\nu_{n,1}}, \qquad r_{10} = \frac{d_{10}}{\Delta\nu_{n+1,0}},$$

where

$$d_{01} = \frac{1}{8}(\nu_{n-1,0} - 4\nu_{n-1,1} + 6\nu_{n,0} - 4\nu_{n,1} + \nu_{n+1,0}),$$

$$d_{10} = -\frac{1}{8}(\nu_{n-1,1} - 4\nu_{n,0} + 6\nu_{n,1} - 4\nu_{n+1,0} + \nu_{n+1,1}).$$

[Roxburgh I. W. &Vorontsov S. V. (2003), Brandao I., Cunha M. &.Christensen-Dalsgaard J, MNRAS 438 (2014)]

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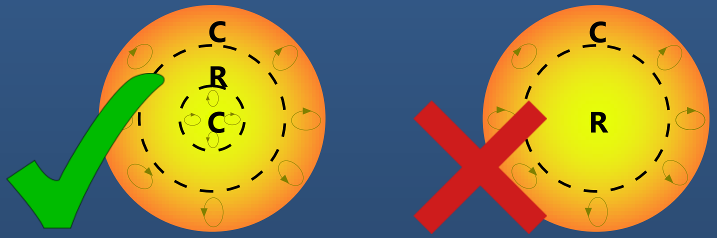

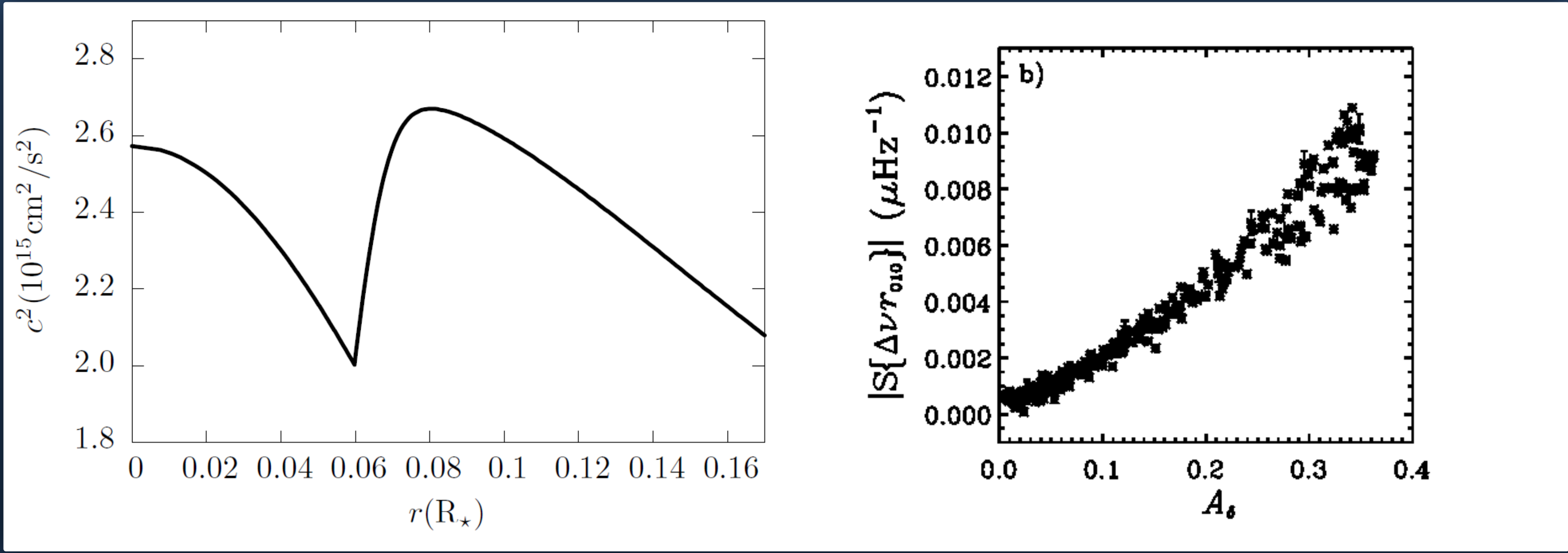

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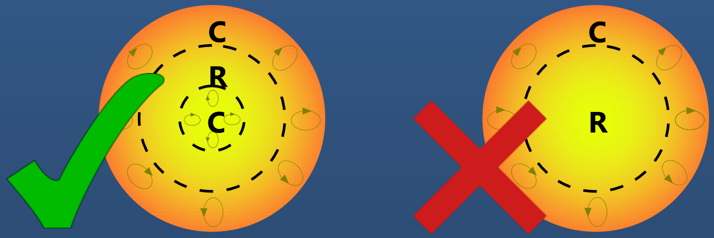

- Modelling of Dushera: Grid with CESAM (M, Z, age, α_{CONV}, α_{OV}) +

  [**Casanellas** & Brandão , in prep.]

T_{eff}	$\log(g)$	Z/X_s [1]	$\langle\Delta\nu\rangle_{012}$
6200 ± 200	4.30 ± 0.2	0.023 ± 0.09	88 ± 0.6

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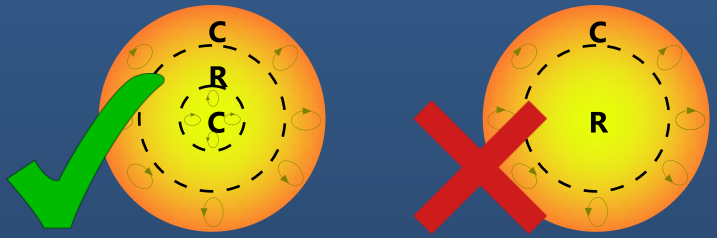

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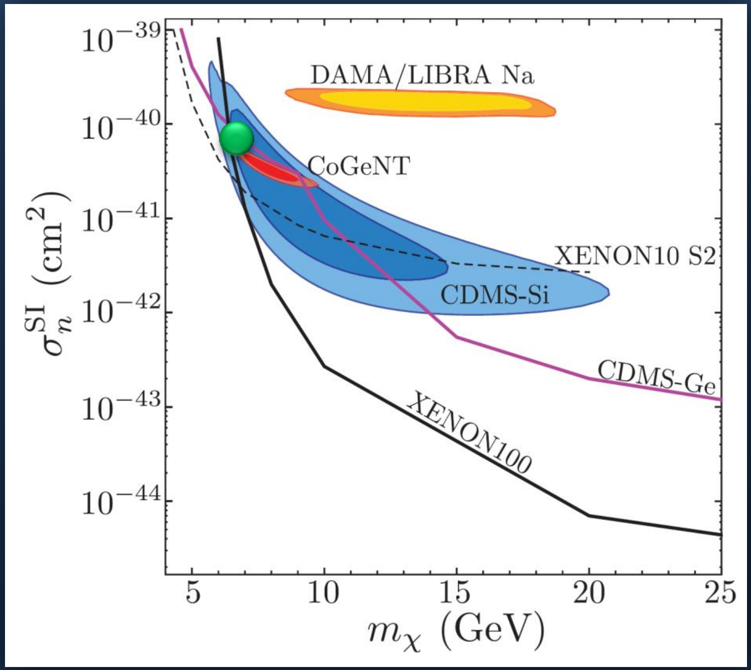
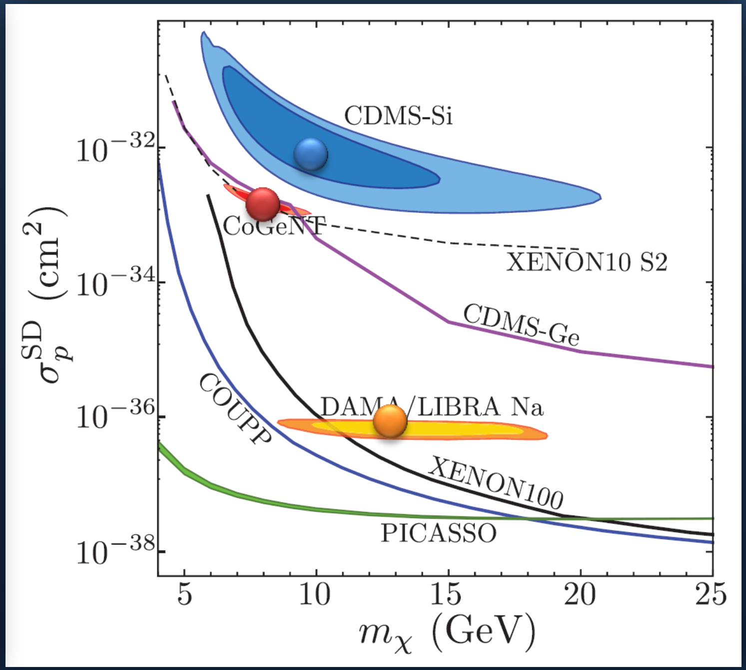
- DM model 1 (SI best fit)
- DM model 2 (DAMA)
- DM model 3 (CDMS)
- DM model 4 (CoGeNT)





[Buckley M. & Lippincott W. H., Phys. Rev. D 88 (2013), Arina , arXiv:1310.5718, (2013)]

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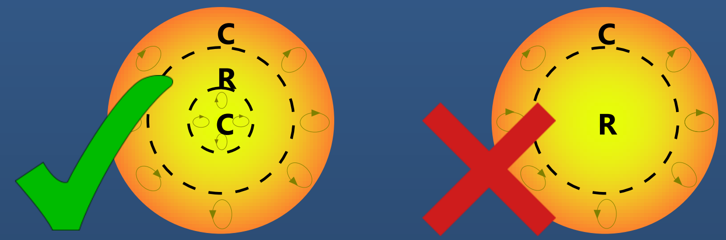

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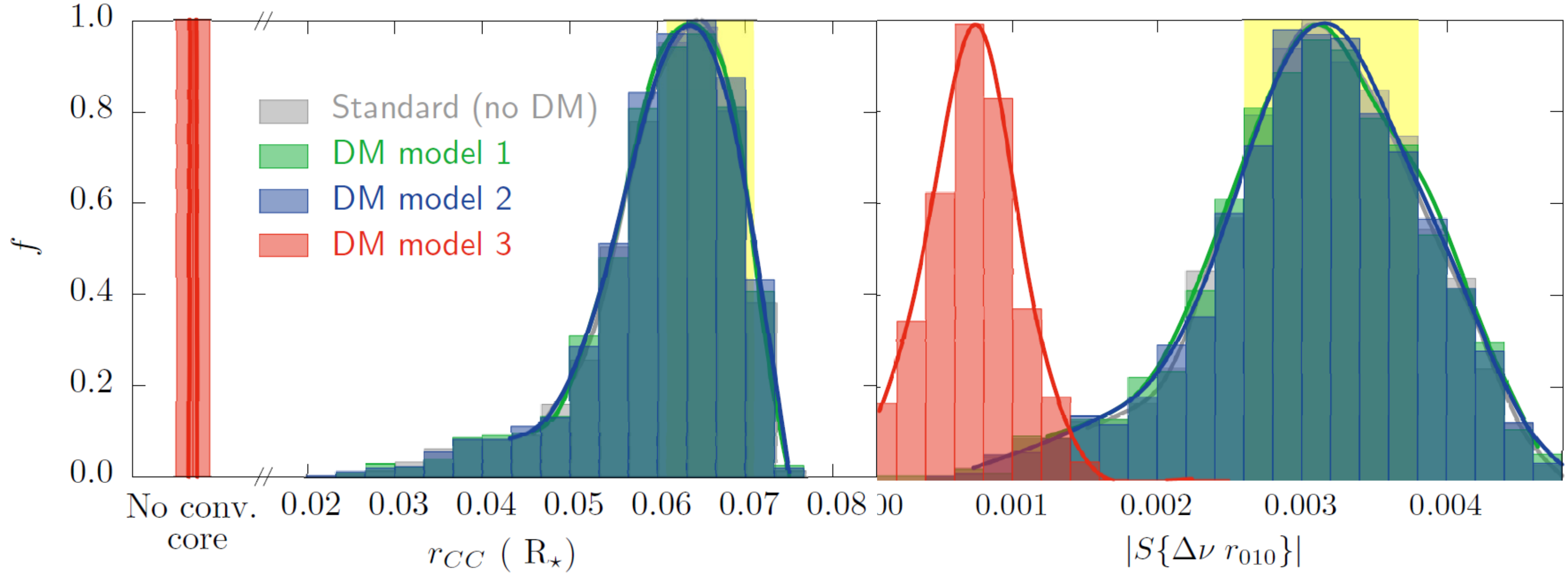

WORK IN PROGRESS, see also POSTER #40

Conclusion:

ASTEROSEISMOLOGY can be used to investigate **DARK MATTER**

Future directions:

- Solar-like oscillations in **low-mass stars** (0.7 Ms?) observed with high precision (detached eclipsing binaries?)
- Gravity modes in **Red Giants**
- Environments with **high Dark Matter densities**: the Galactic Center, Globular Clusters, dwarf Sph Galaxies