Astropartículas: Mensajeros de lo visible y lo invisible (2)

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Astropartículas=Mensajeros

A) Mensajeros de un universo violento

B) Mensajeros de un universo temprano

C) Mensajeros de un universo invisible

Cuando piensen en una astropartícula (mensajero), piensen en sus tres ingredientes básicos

Producción

Propagación

Detección

Recuerden en cada uno de esos procesos, hay mecanismos que requiere del conocimiento de las propiedades fundamentales de las partículas involucradas: Modelo estándar de las partículas elementales

Vimos un ejemplo: Neutrinos solares

$$N_{Obs}^{th} = \sum_i \phi_i \times t \times N_e \times \int dE_\nu \int dT \lambda_i(E_\nu) \times \frac{d\sigma(E_\nu, T)}{dT} \times P(\Delta m^2, \theta, \mu_\nu, \epsilon, \varepsilon' \ldots)$$

Producción: Reacciones
Nucleares dentro del Sol

Detección

Propagación: Interacción del mensajero
Con el medio o propiedades fundamentales
(decaimiento, oscilación etc...)

Vimos un ejemplo de como calcular una sección eficaz

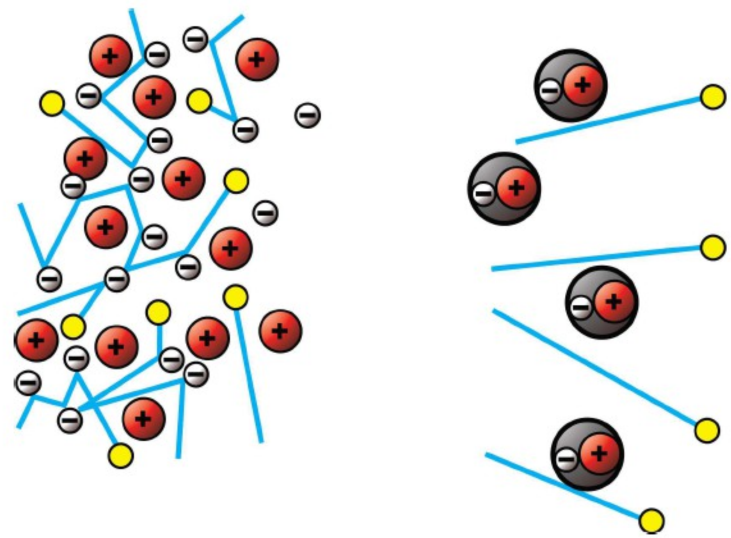
Plan de hoy:

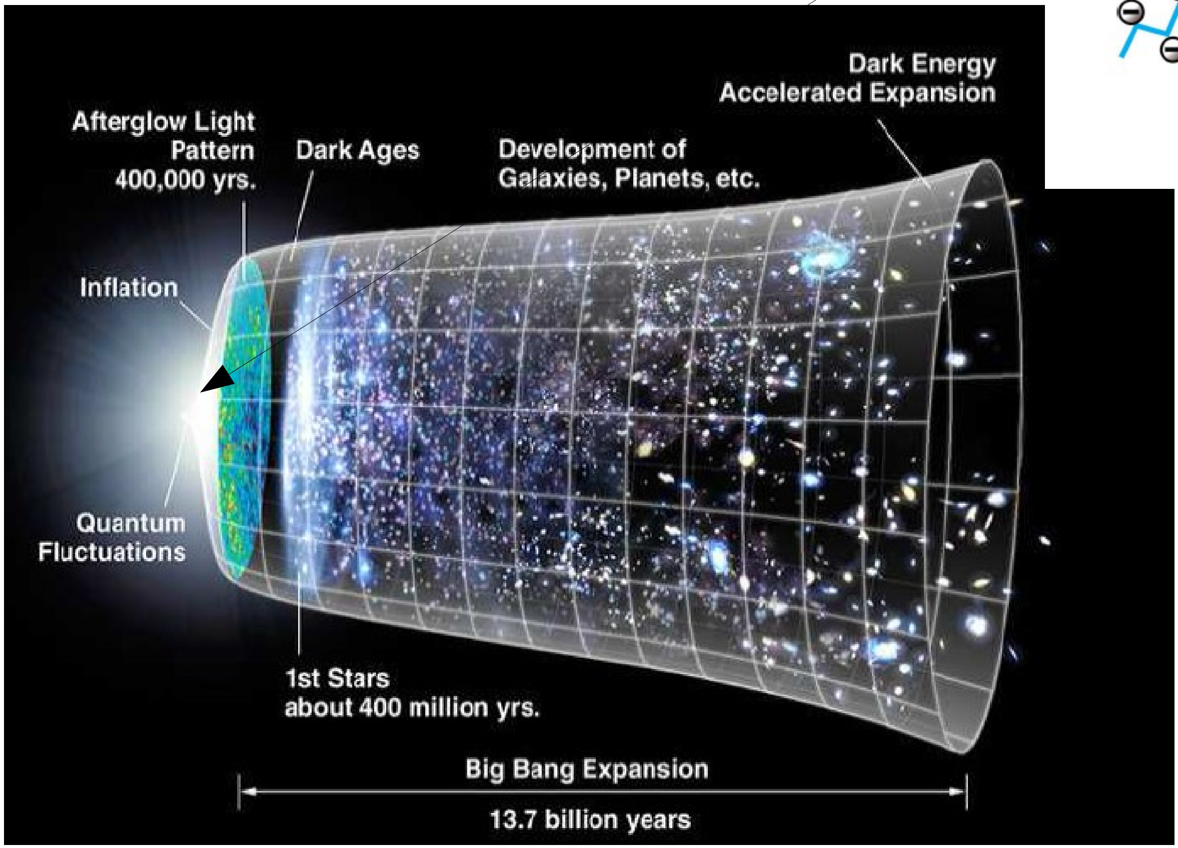
Vamos a mostrar ejemplos de como las astropartículas son mensajeros de lo visible y lo invisible del universo temprano, violento e invisible

Indicaciones de nueva física (propiedades nuevas de las partículas o nuevos estados de la materia)

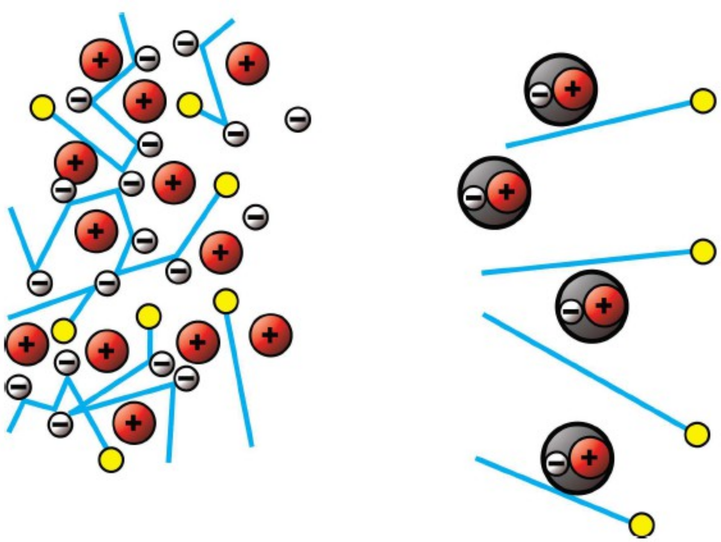
Mensajeros de un universo temprano

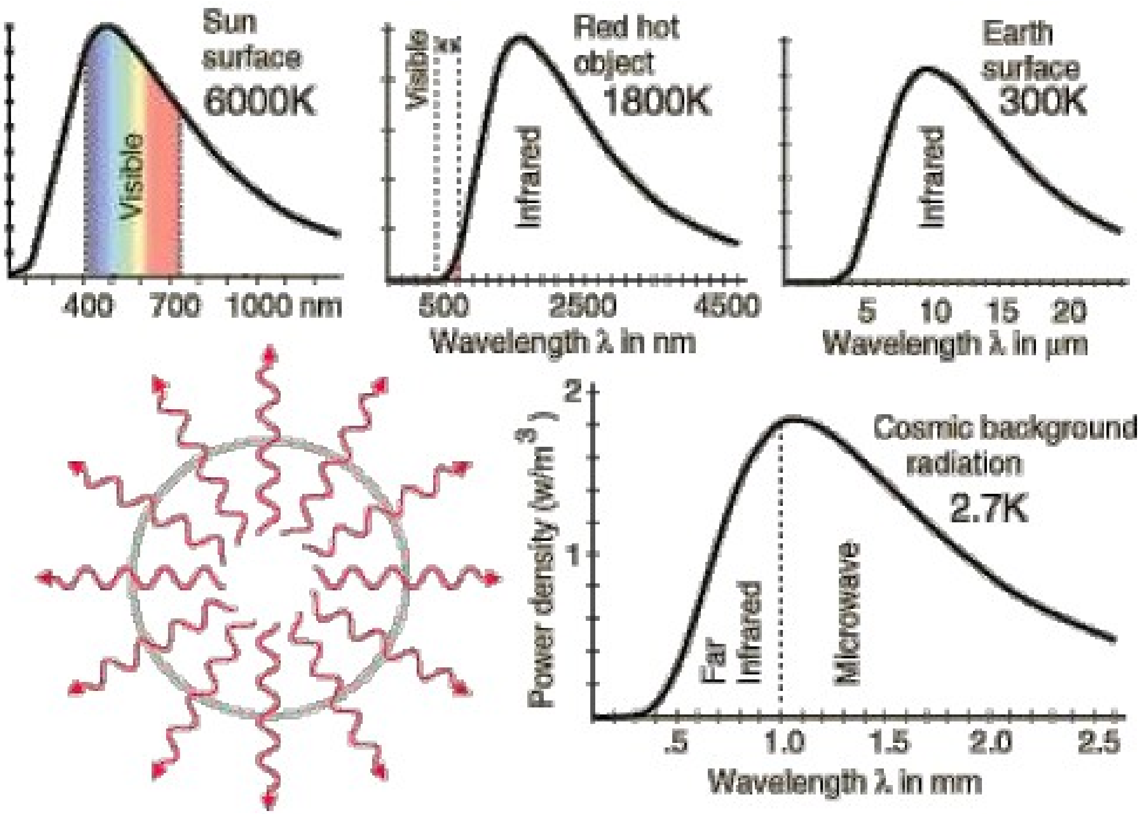
- Modelo Estándar Cosmológico
  - Relatividad general





Producción



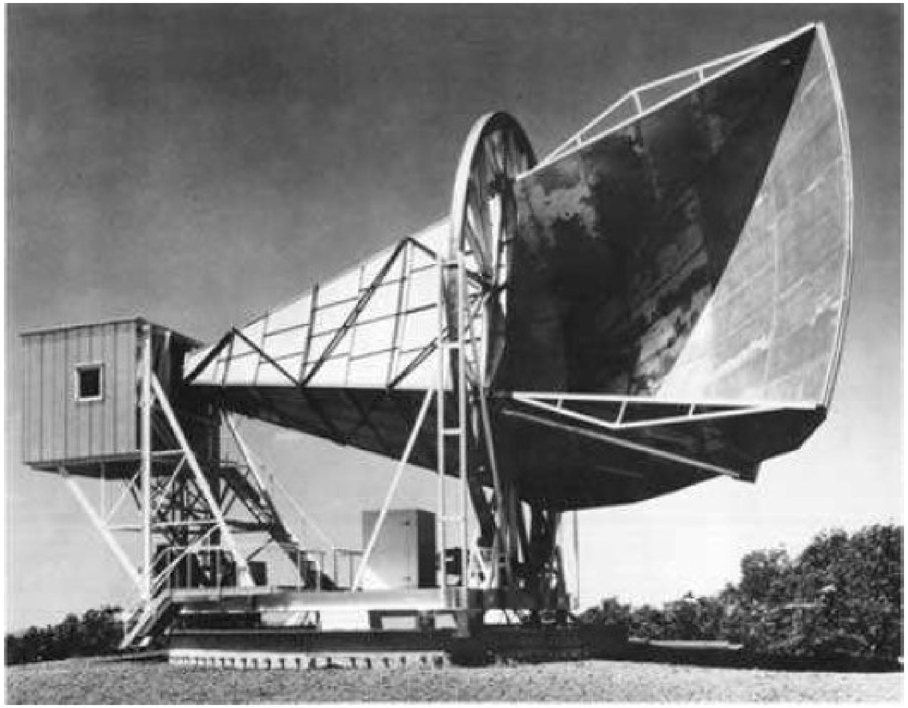

Sun
surface
6000K
Visible
400
700
1000 nm
Red hot
object
1800K
Visible
Infrared
500
2500
4500
Wavelength λ in nm
Earth
surface
300K
Infrared
5
10
15
20
Wavelength λ in μm
Cosmic background
radiation
2.7K
Power density (w/m³)
2
1
Far
Infrared
Microwave
.5
1.0
1.5
2.0
2.5
Wavelength λ in mm

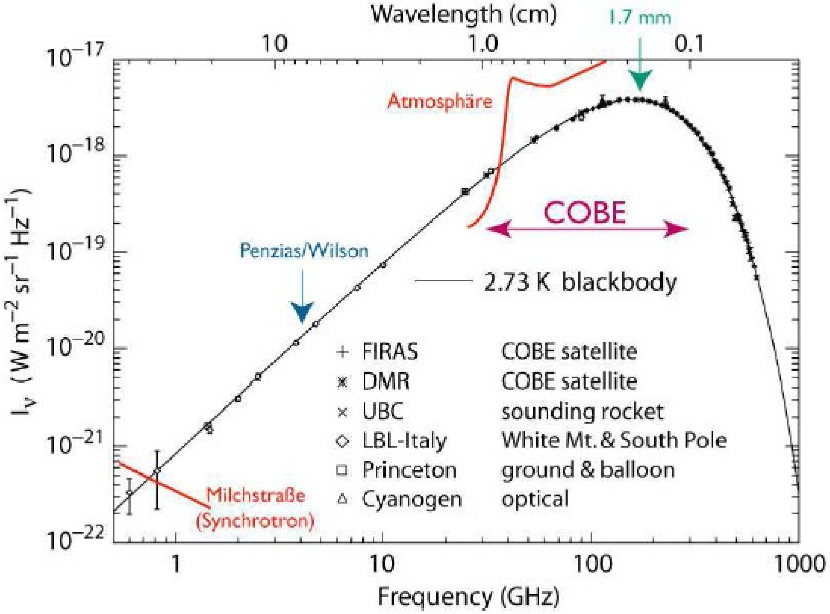
Propagación

Mientras que la expansión del universo extiende la longitud de onda de la luz emitida desde la superficie de última dispersión, también disminuye la densidad del fotón, y por lo tanto la intensidad disminuye.

Estos dos efectos se cancelan de modo que se conserva la distribición característica del cuerpo negro.

Detector: Antena



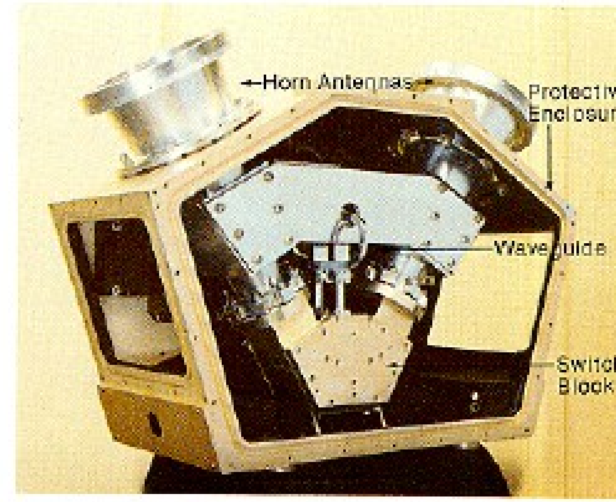


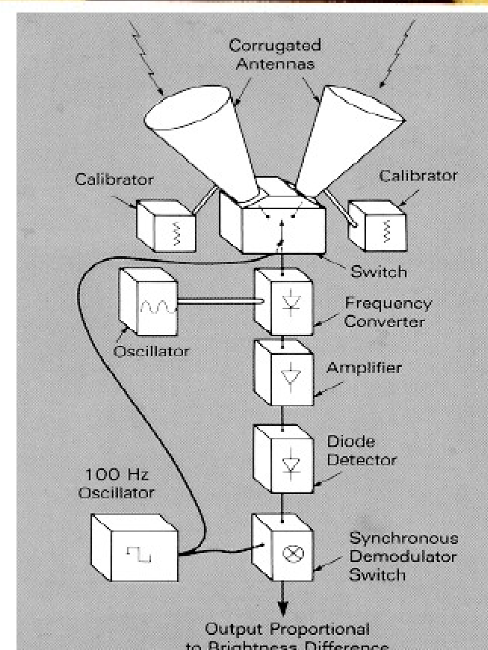
1964: Penzias y Wilson

El CMB no tiene complicaciones en su producción ni en su propagación: la dificulatd técnica es la detección:

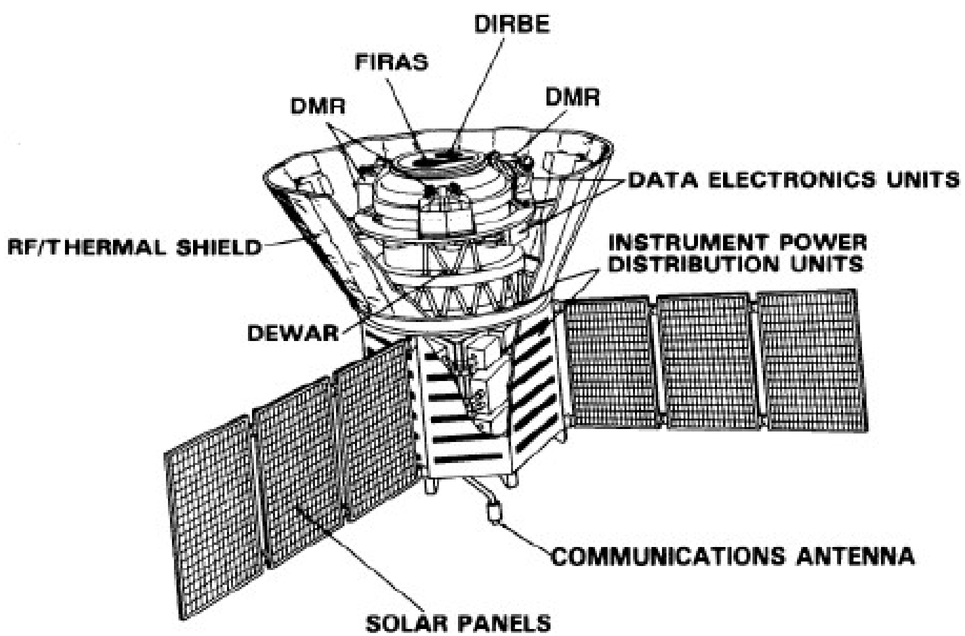
Radiómetro

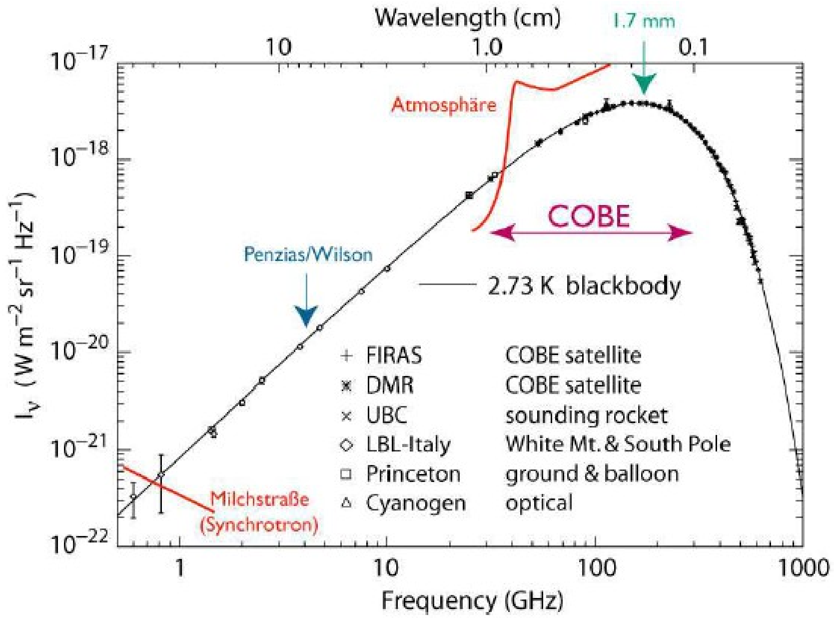
Radiómetro diferencial





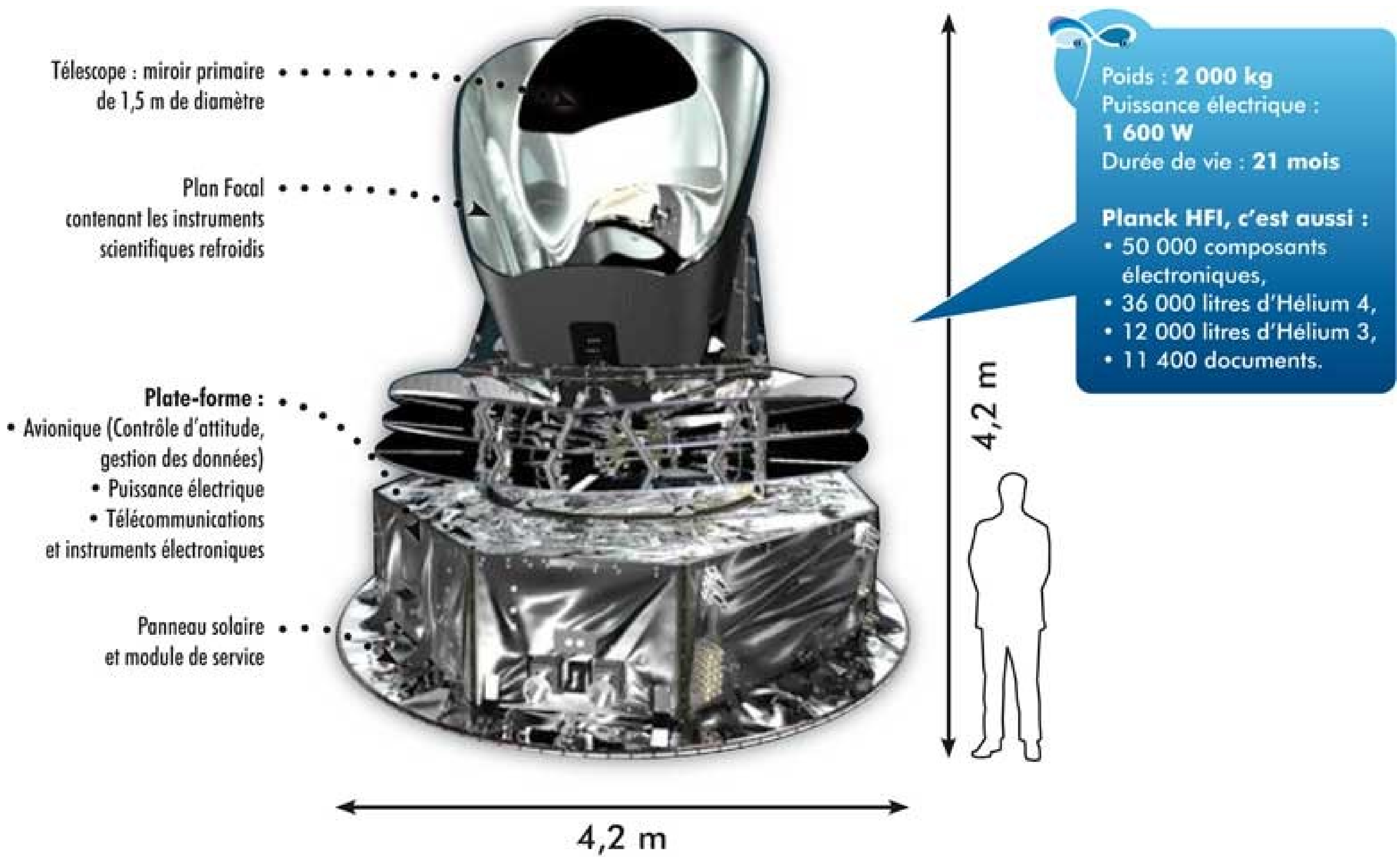
COBE: Cosmic Background Explorer



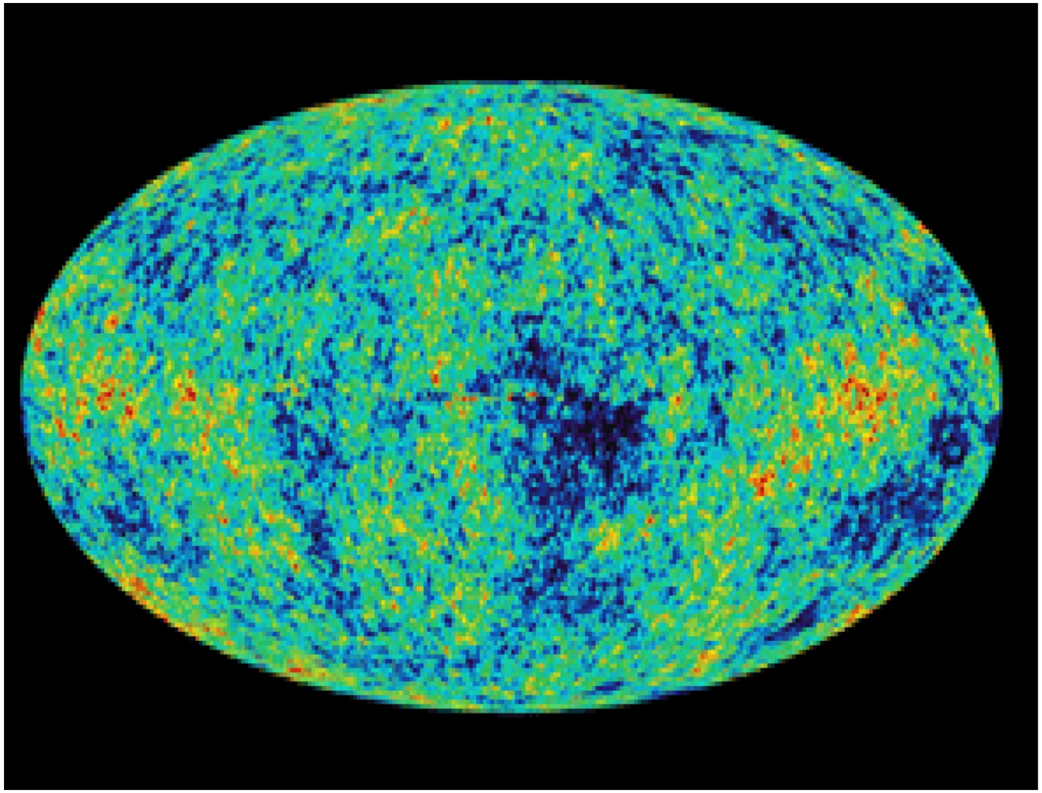


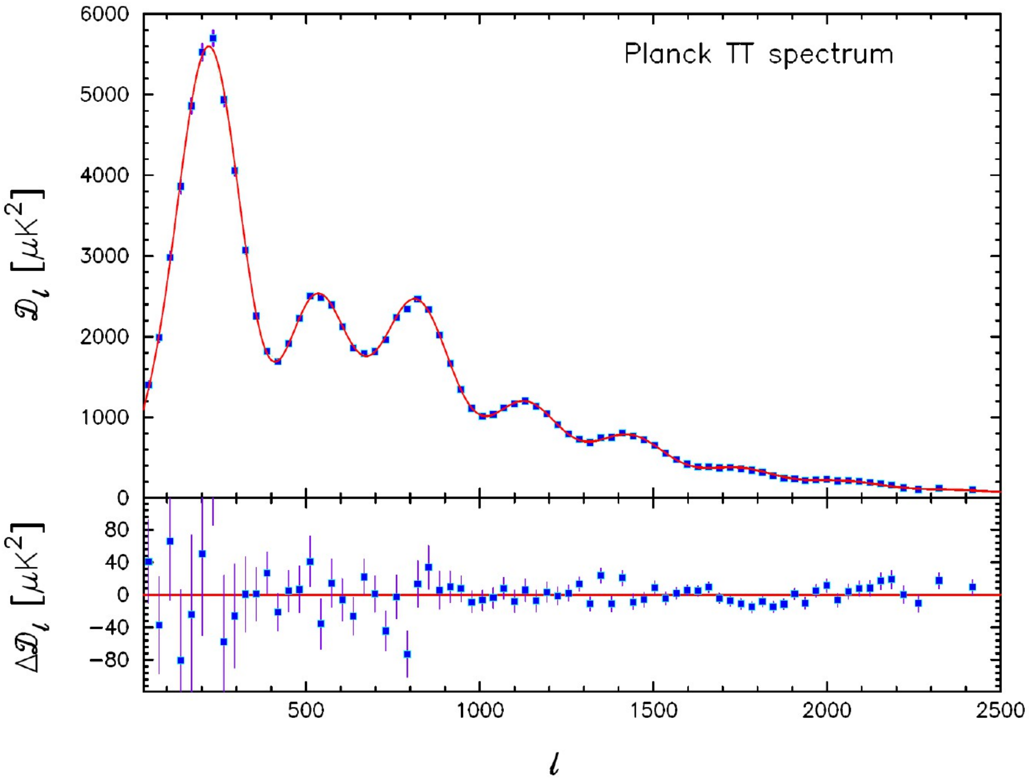
El radiómetro diferencial de COBE consite de SEIS radóometros diferenciaesl de micro-ondas que operan a tres distintas frecuencias: 31.5, 53, and 90 GHz.
El Satelite gira a una raz'on de 0.8 rpm y precesa. De tal forma que se obtiene una cubierta total del cielo en un período de seis meses.

Mejoras en el detector: PLANCK



Diferencias de temperatura de 10^(-5) Kelvin





- A escalas cosmológicas

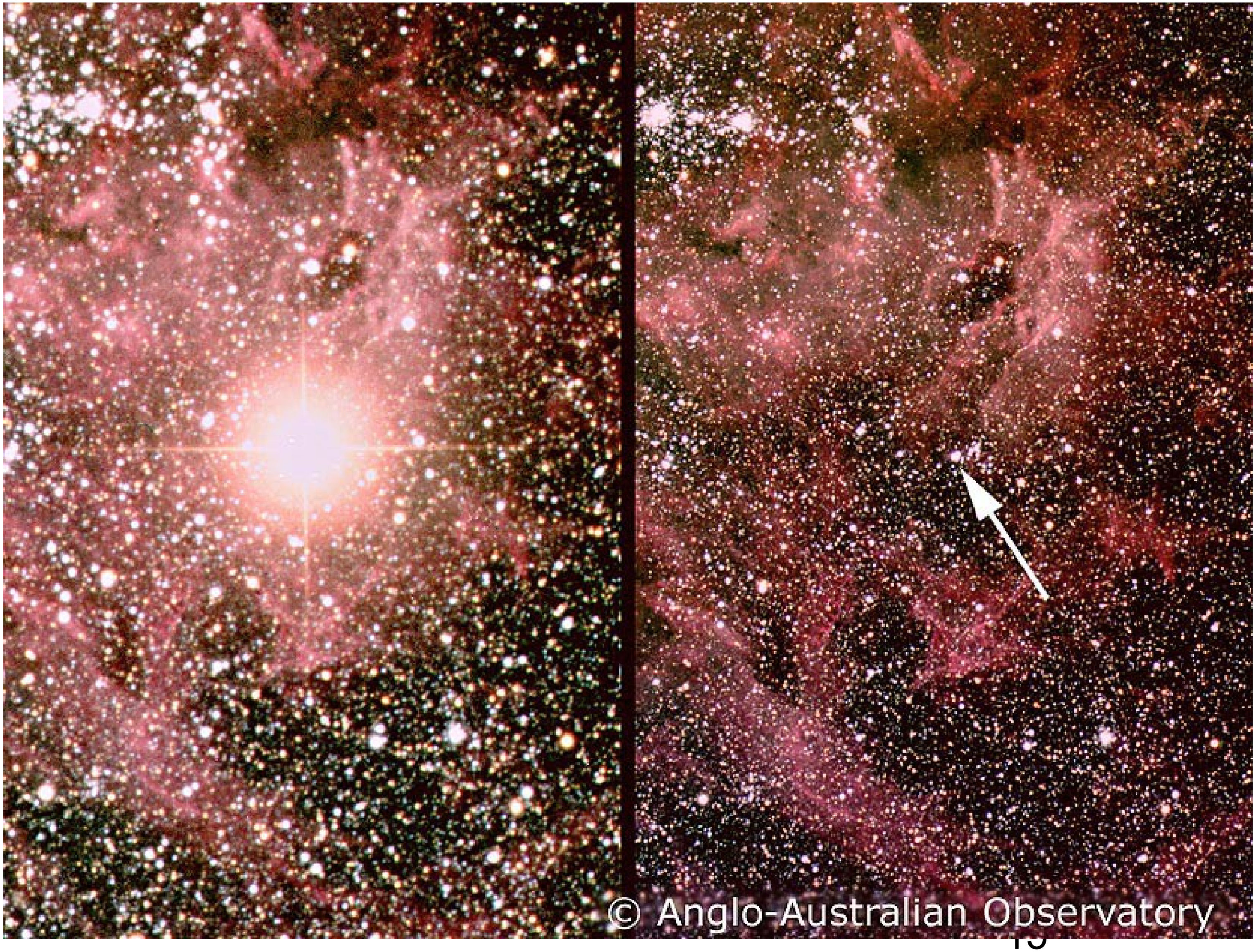
  Se parte de un modelo cosmológico, que tiene un número fijo de parámetros, y utilizando los datos del espectro del CMB, el conjunto de valores del modelo son aquellos que dan el mejor ajuste a los datos experimentales.

  - El análisis de WMAP:

    $\Omega_b h^2 = 0{,}024 \pm 0{,}001 \quad , \Omega_M h^2 = 0{,}14 \pm 0{,}02.$

Mensajeros de un universo violento: Supernovas

Supernova neutrinos



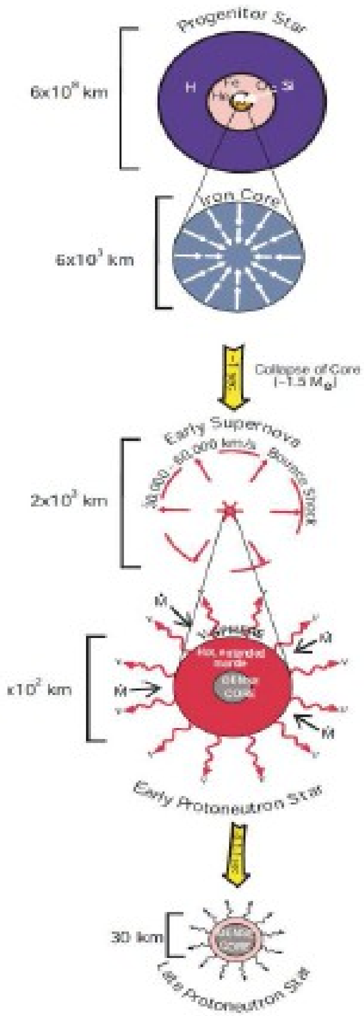
First observation of extragalactic neutrinos

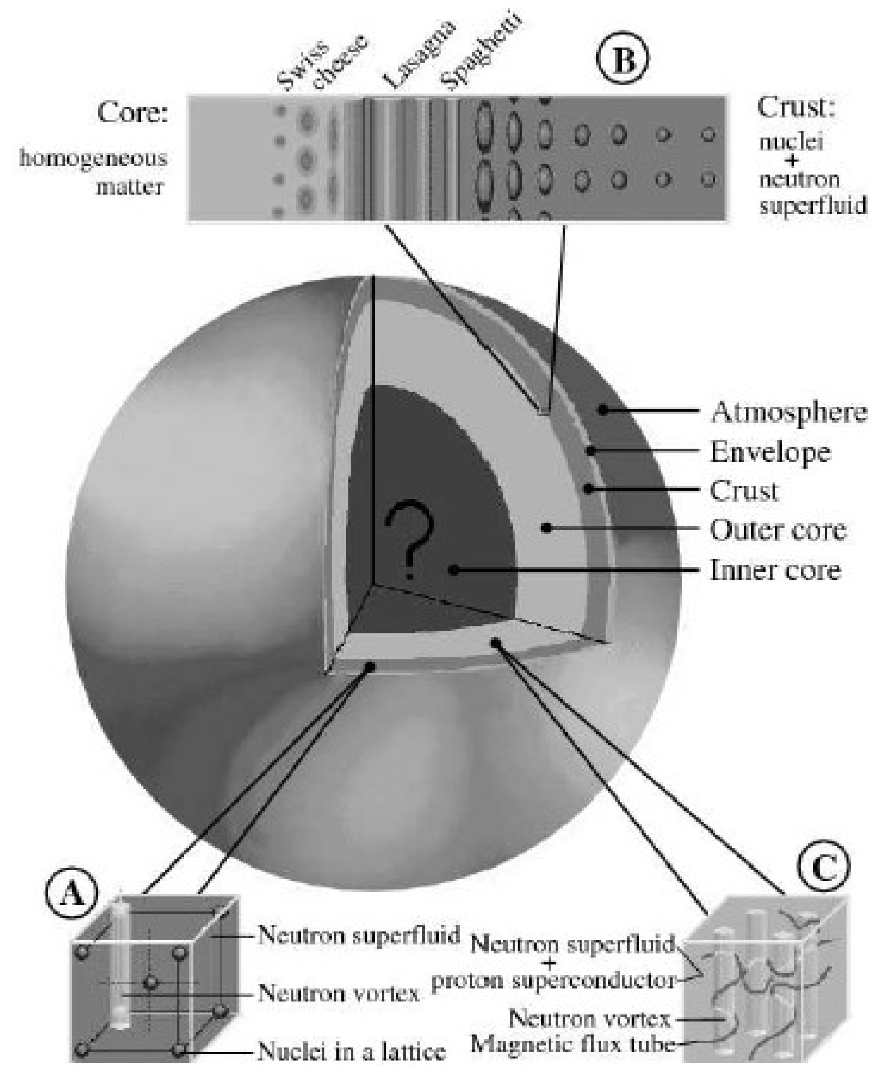
Neutrino data

Time (UT) February	Detector (threshold[a]/size)	Number of events (*E*-range/duration)
23 2h 52m	Mt. Blanc (7 MeV/90t)[b]	5 (6–10 MeV/7 s)
23 2h 52m ± 1 min	Kamioka (8 MeV/2.14 kt)	1 (7 MeV/10 s) (consistent with background)
23 2h 52m ± 1 min	IMB (30 MeV/6 kt)	none reported
23 2h 52m ± 1 min	Baksan (11 MeV/130 t)[b]	none reported
23 7h 35m (± min)	Kamioka (7 MeV/90 t)	11 (7–35 MeV/13 s)
23 7h 35m	IMB (30 MeV/6 kt)	8 (20–40 MeV/4 s)
23 7h 35m	Baksan (11 MeV/130 t)[b]	3 (12–17 MeV/10 s)[d]
23 7h 35m	Mt. Blanc (7 MeV/90 t)[b]	2 (7–9 MeV/13 s)
sum of pulses	Homestake ν_e (0.7 MeV/615 t)[c]	0
	optical	
23 9h 25m	lack of sighting	$m \gtrsim 8$ mag
23 10h 40m	photograph	$m = 6$ mag
24 10h 53m	discovery	$m = 4.8$ mag

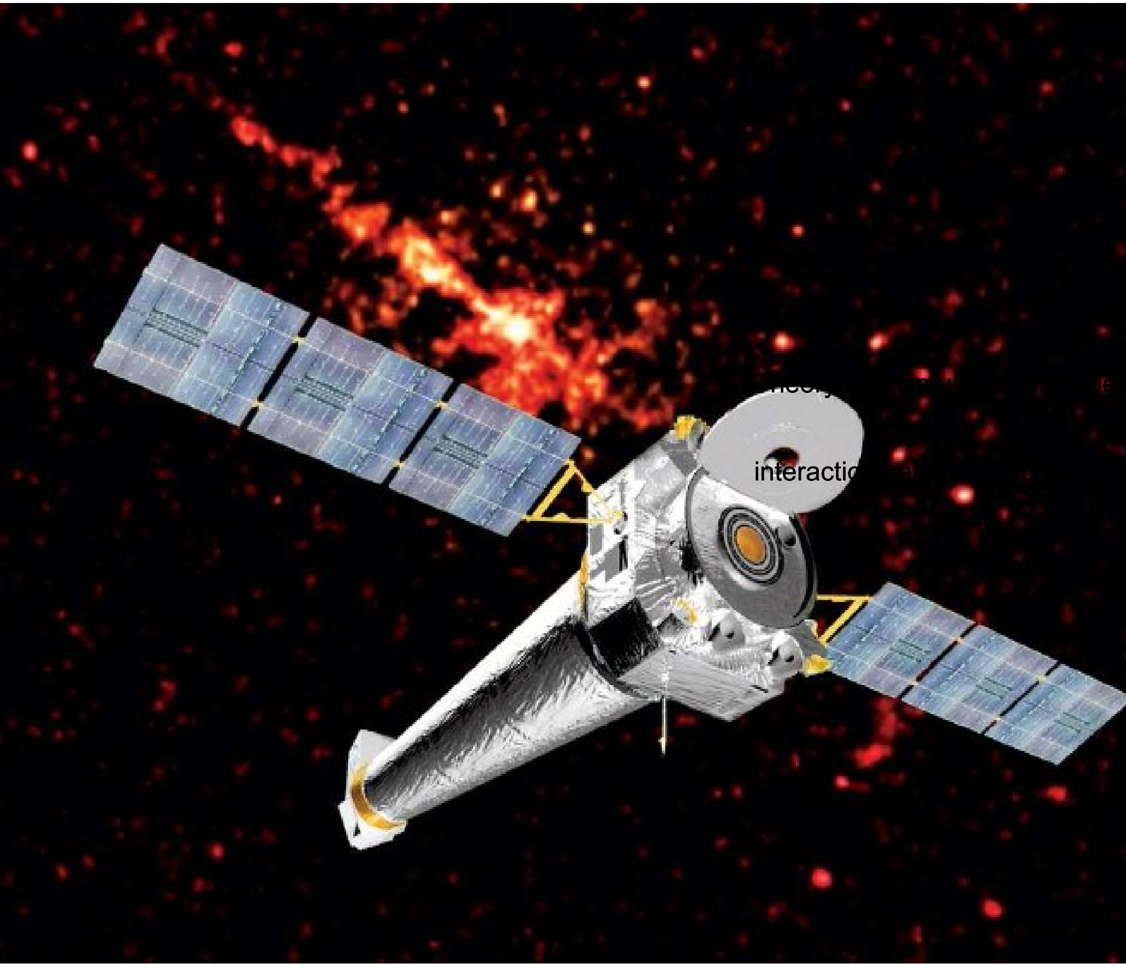
Producción de fotones y de neutrinos en una estrella de neutrones

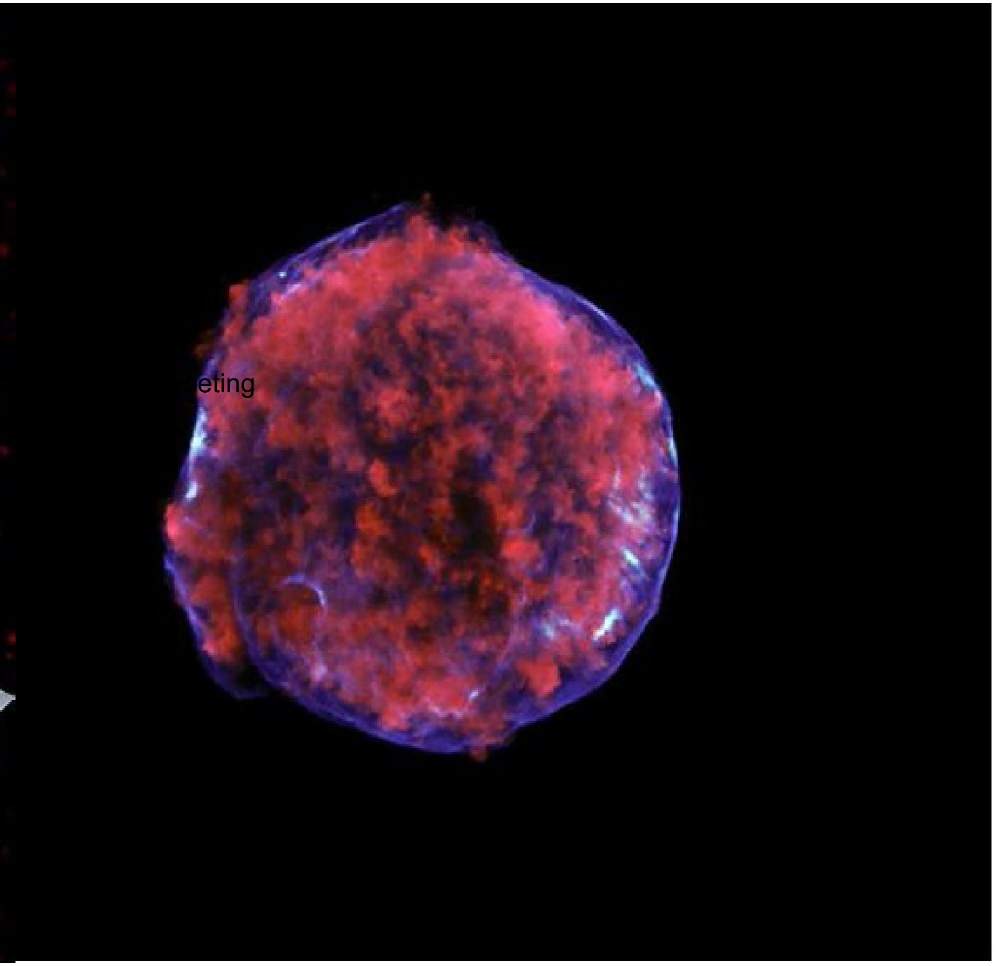
The death of a star





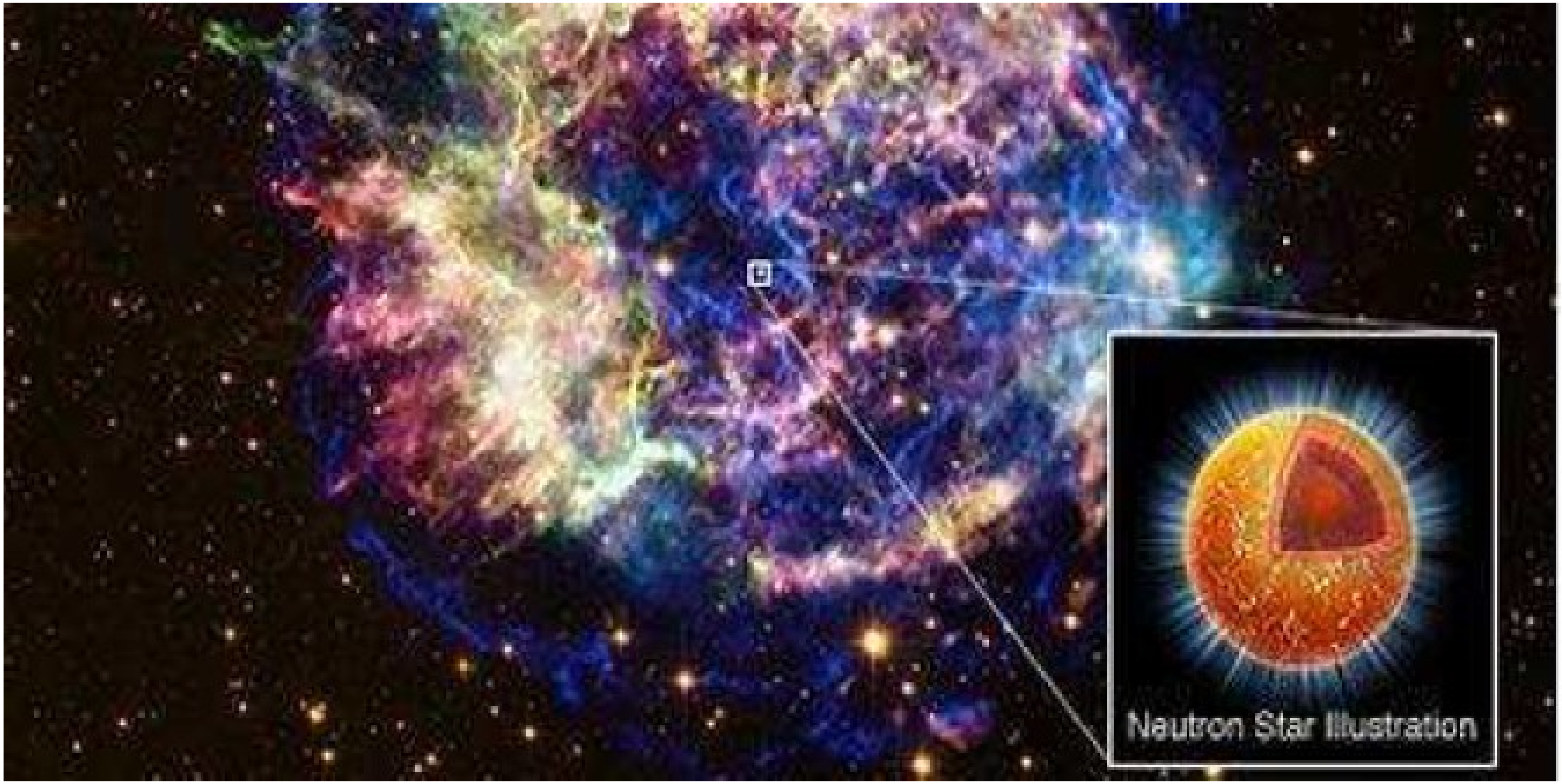
Supernova remmants





The place where ultra high energy cosmic rays are accelerated

El remanente de una supernova



Una estrella que se enfría

Assume the star's interior is isothermal and neglect GR effects.

Thermal Energy, E_{th} ,balance:

$$\frac{dE_{th}}{dt} = C_v \frac{dT}{dt} = -L_\gamma - L_\nu + H$$

⇒ 3 essential ingredients are needed:

- C_v = total stellar specific heat
- L_γ = total surface photon luminosity
- L_ν = total stellar neutrino luminosity

H = "heating", from B field decay, friction, etc ...

Procesos para el enfriamiento de una estrella de neutrones

The Murca-Bremsstrahlung family and Durca

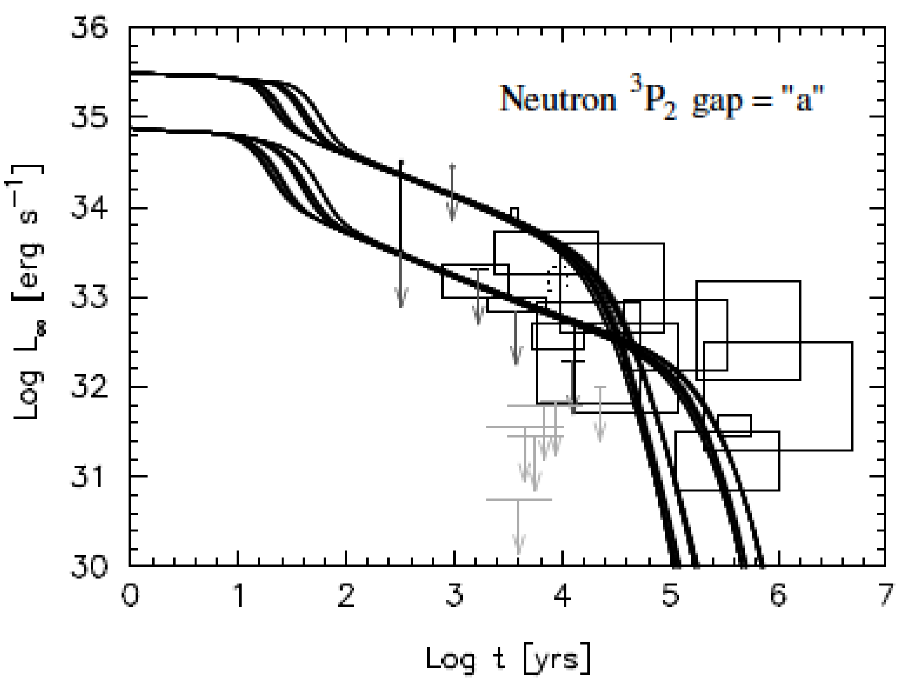
Name	Process	Emissivity (erg cm^{-3} s^{-1})	
Modified Urca cycle (neutron branch)	$n+n \rightarrow n+p+e^- + \bar{\nu}_e$ $n+p+e^- \rightarrow n+n+\nu_e$	$\sim 2\times10^{21}\, R\, T_9^8$	Slow
Modified Urca cycle (proton branch)	$p+n \rightarrow p+p+e^- + \bar{\nu}_e$ $p+p+e^- \rightarrow p+n+\nu_e$	$\sim 10^{21}\, R\, T_9^8$	Slow
Bremsstrahlung	$n+n \rightarrow n+n+\nu+\bar{\nu}$ $n+p \rightarrow n+p+\nu+\bar{\nu}$ $p+p \rightarrow p+p+\nu+\bar{\nu}$	$\sim 10^{19}\, R\, T_9^8$	Slow
Direct Urca cycle	$n \rightarrow p+e^- + \bar{\nu}_e$ $p+e^- \rightarrow n+\nu_e$	$\sim 10^{27}\, R\, T_9^6$	Fast

El modelo mínimo de enfriamiento

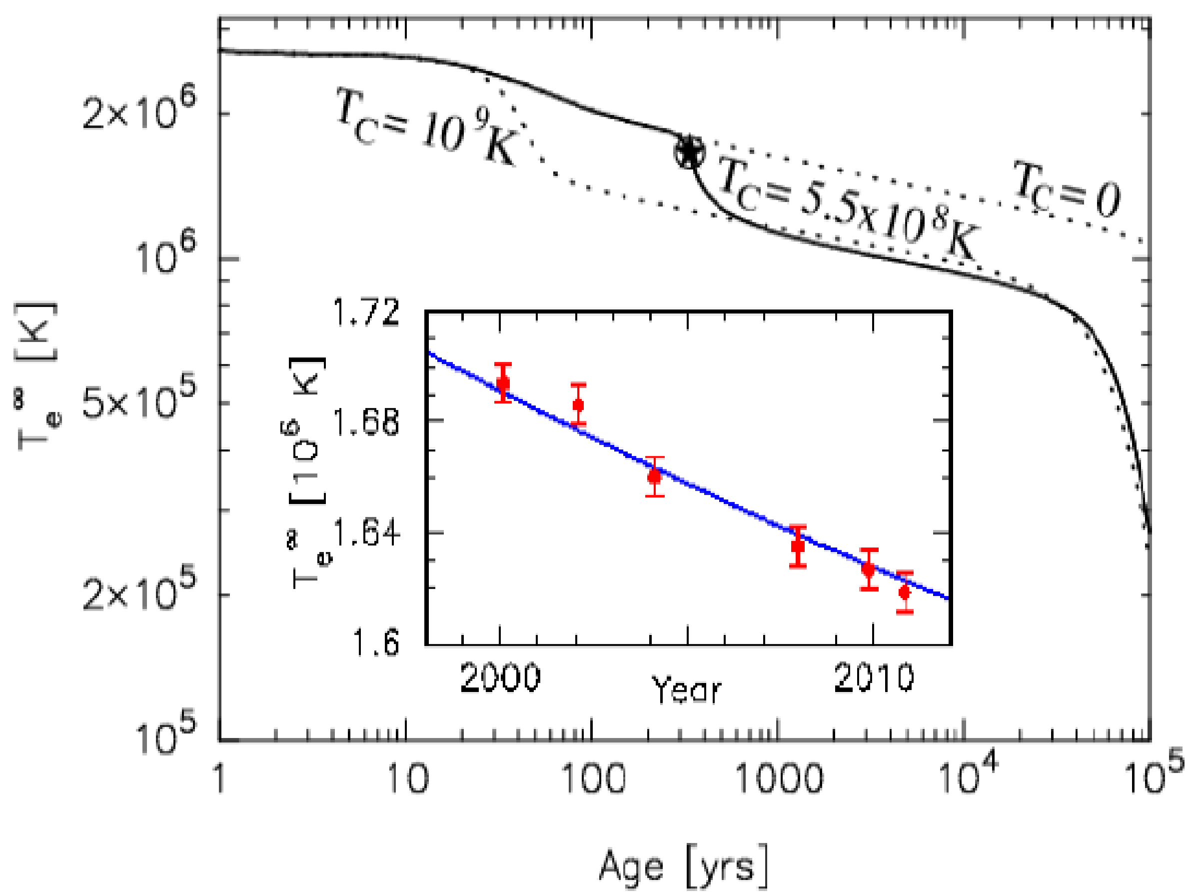
Standard (minimal) cooling of NS..

$$\frac{e^{-\lambda-2\Phi}}{4\pi r^2}\frac{\partial}{\partial r}\left(e^{2\Phi}L_r\right) = -Q + Q_{\rm h} - \frac{c_T}{e^{\Phi}}\frac{\partial T}{\partial t},$$
$$\frac{L_r}{4\pi\kappa r^2} = e^{-\lambda-\Phi}\frac{\partial}{\partial r}\left(T e^{\Phi}\right),$$

+ stellar structure



Comparación con los datos de Cassiopea A: ¡Debe existir superfluidez en el interior!

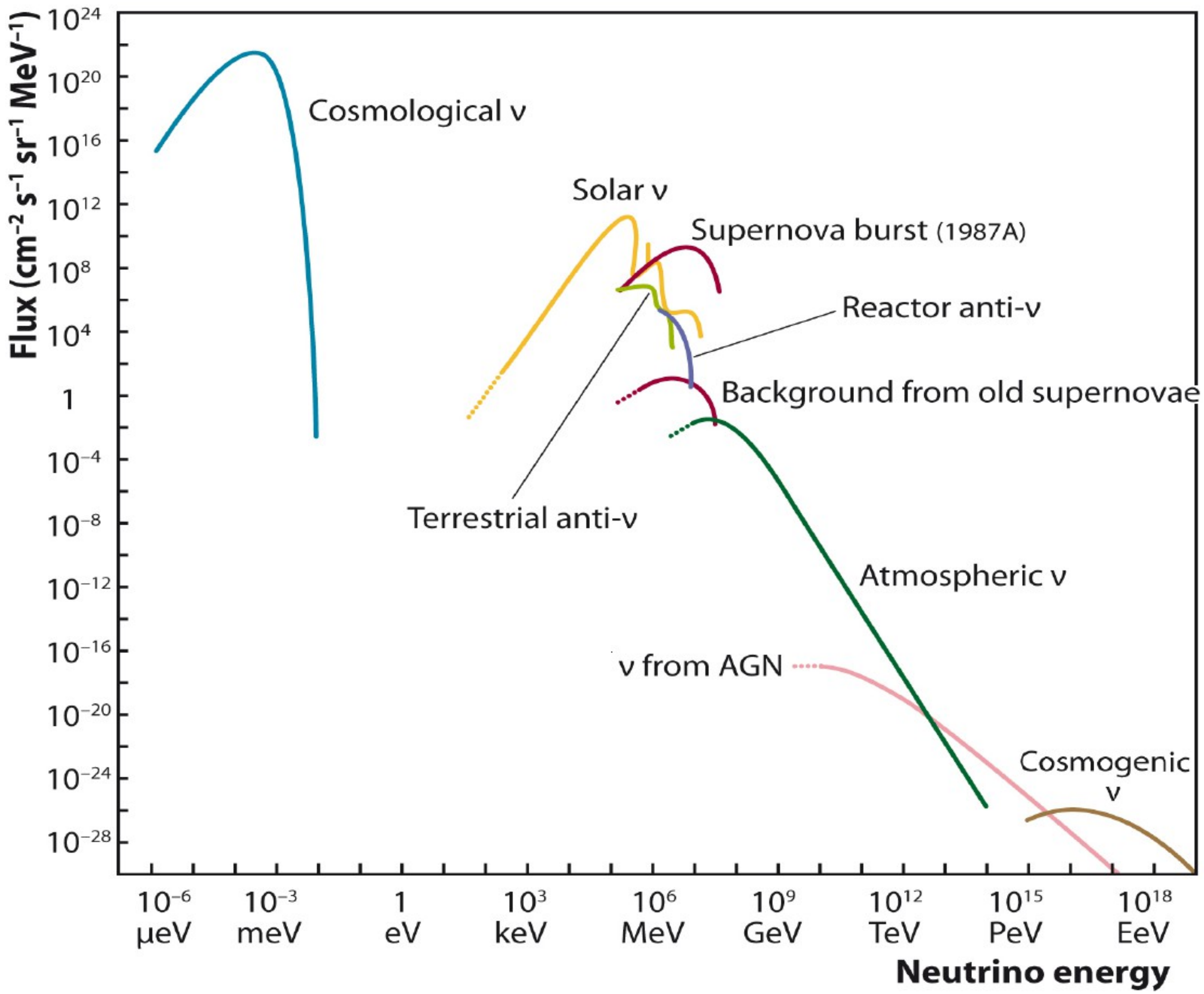


Rapid Cooling of the Neutron Star in Cassiopeia A Triggered by Neutron Superfluidity in Dense Matter

Dany Page, Madappa Prakash, James M. Lattimer, Andrew W. Steiner

Phys.Rev.Lett. 106 (2011) 081101

Más de las supernovas: Neutrinos



Still waiting for the next galactic supernova:

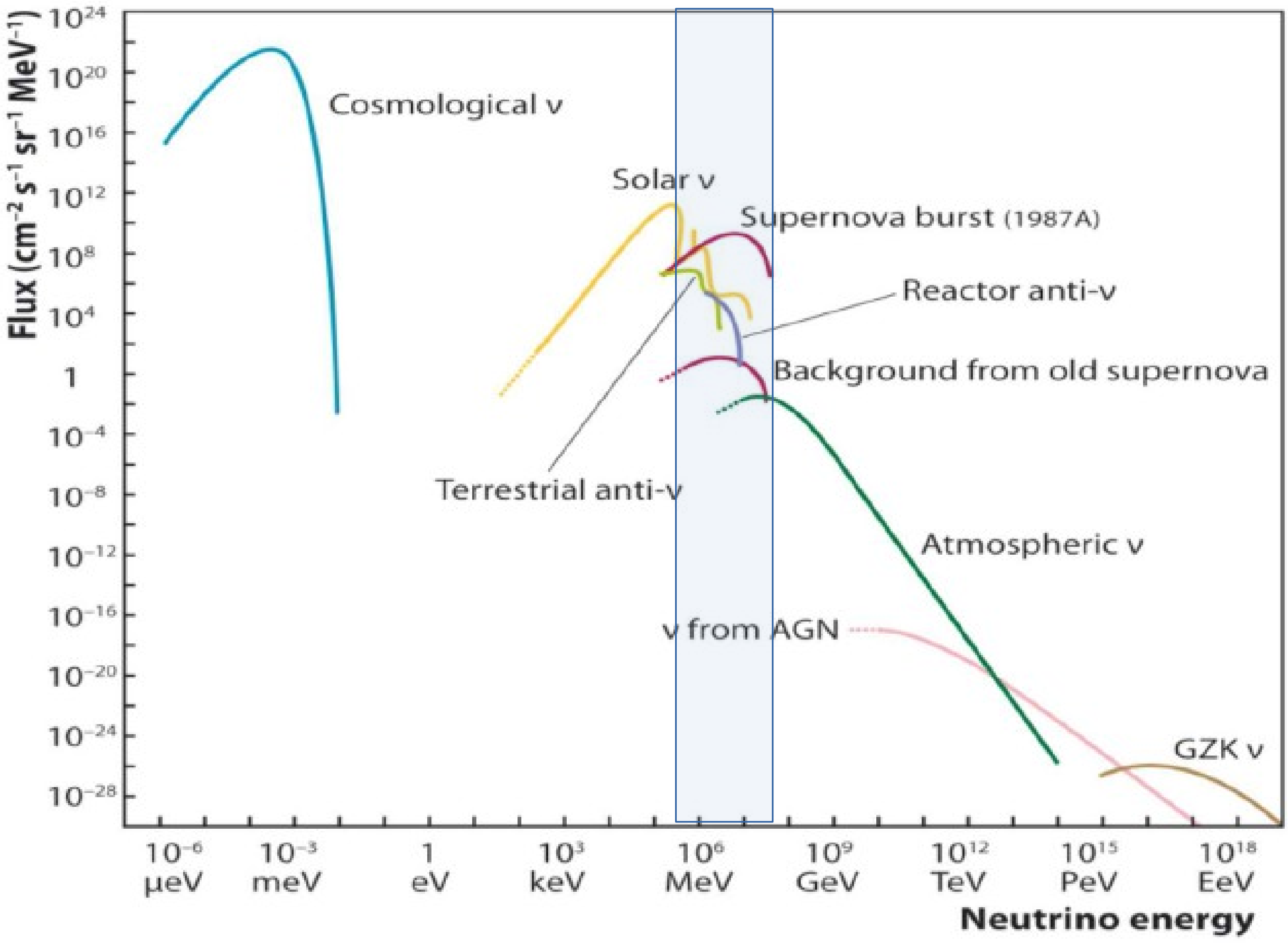
one or two per century per galaxy

the cumulative neutrino flux from all past SN in the Universe

→

Diffuse neutrino Supernova Background

Los neutrinos de supernovas



Computing the DSNB

$$\frac{d\phi^{DSNB}}{dE} = \int R_{CCSN}(z) \frac{dN(E)}{dE} \left| \frac{dt}{dz} \right| dz$$

R_{CCSN} is the core collapse SN rate.

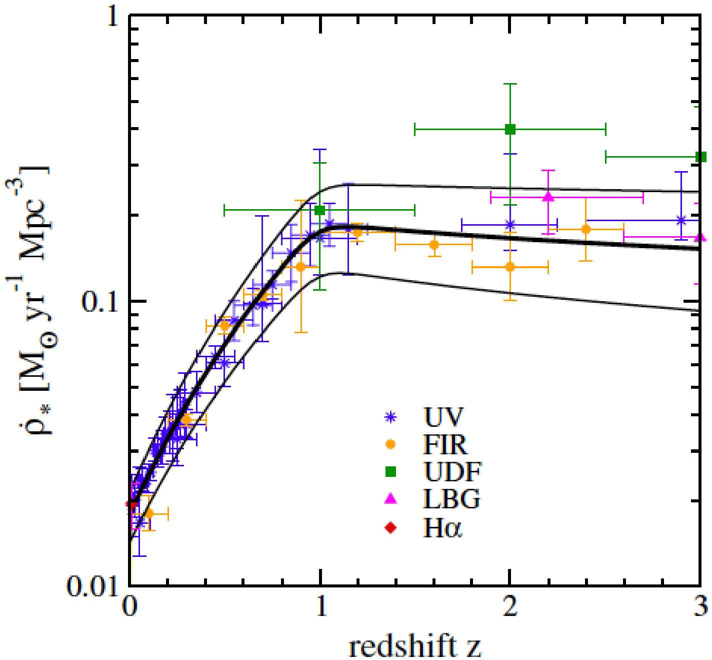
$\frac{dN(E)}{dE}$ is the time integrated neutrino spectrum

$\left| \frac{dt}{dz} \right|$ is related to the Hubble parameter $H(z)$

Core collapse supernova rate

$$R_{CCSN}(z) = \frac{\int_8^{50} \psi(M)dM}{\int_{0.1}^{100} M\psi(M)dM}\psi_*(z)$$

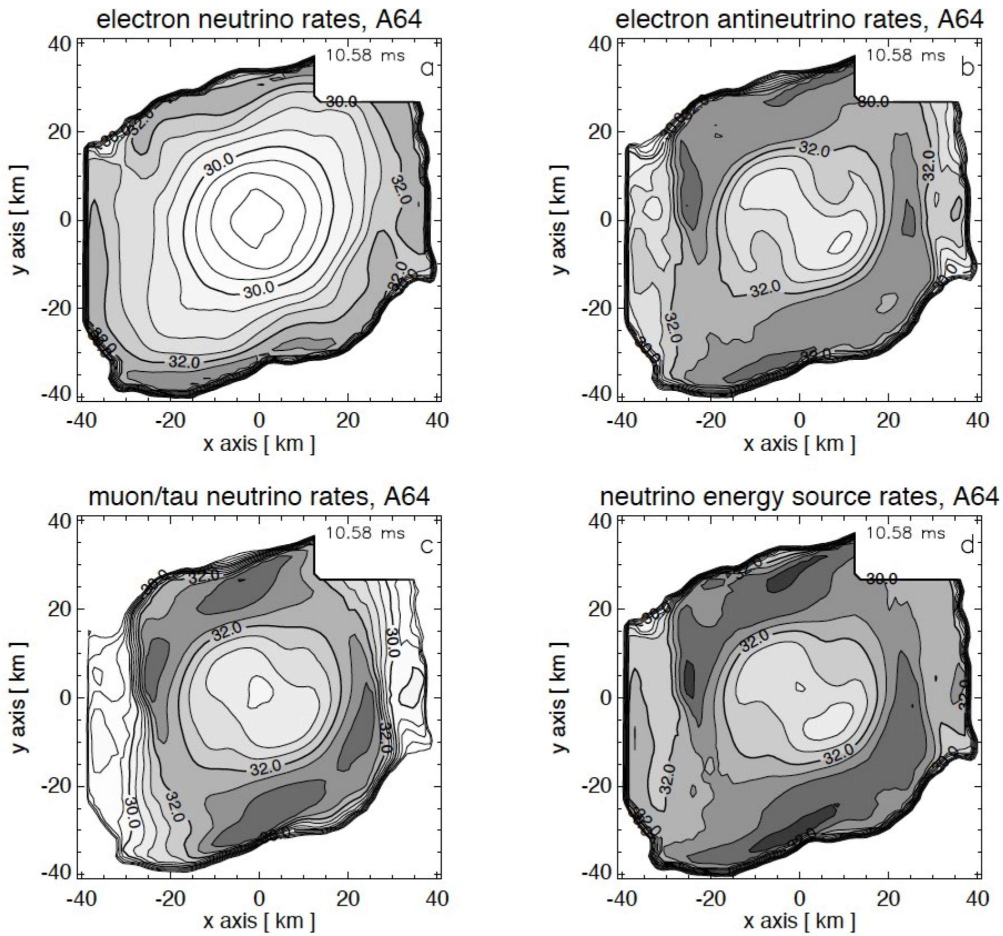
The star formation rate

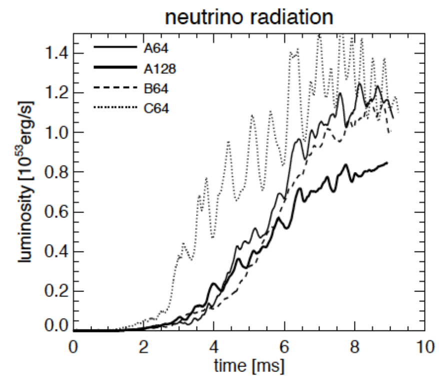


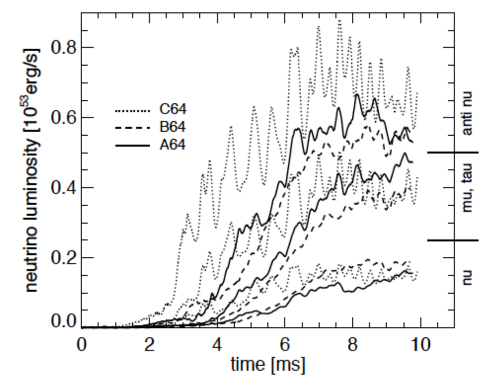
$$\psi_*(z) = \dot{\rho}_0 \left[(1+z)^{\alpha\eta} + \left(\frac{1+z}{B}\right)^{\beta\eta} + \left(\frac{1+z}{C}\right)^{\gamma\eta} \right]^{1/\eta}$$

The neutrino energy spectrum

$$\frac{dN(E)}{dE} = \frac{(1+\alpha)^{1+\alpha} E_{\mathrm{tot}}}{\Gamma(1+\alpha)\bar{E}^2} \left(\frac{E}{\bar{E}}\right)^{\alpha} e^{-(1+\alpha)E/\bar{E}}$$







The expansion rate of the universe

$$\left|\frac{dz}{dt}\right| = (1+z)H(z)$$

The Friedmann eqs:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2}\rho$$

$$\dot{\rho}_m + 3H\left(\rho_m + \frac{p}{c^2}\right) = 0$$

Λ-CDM model

$$\rho = \rho_m + \rho_\Lambda$$

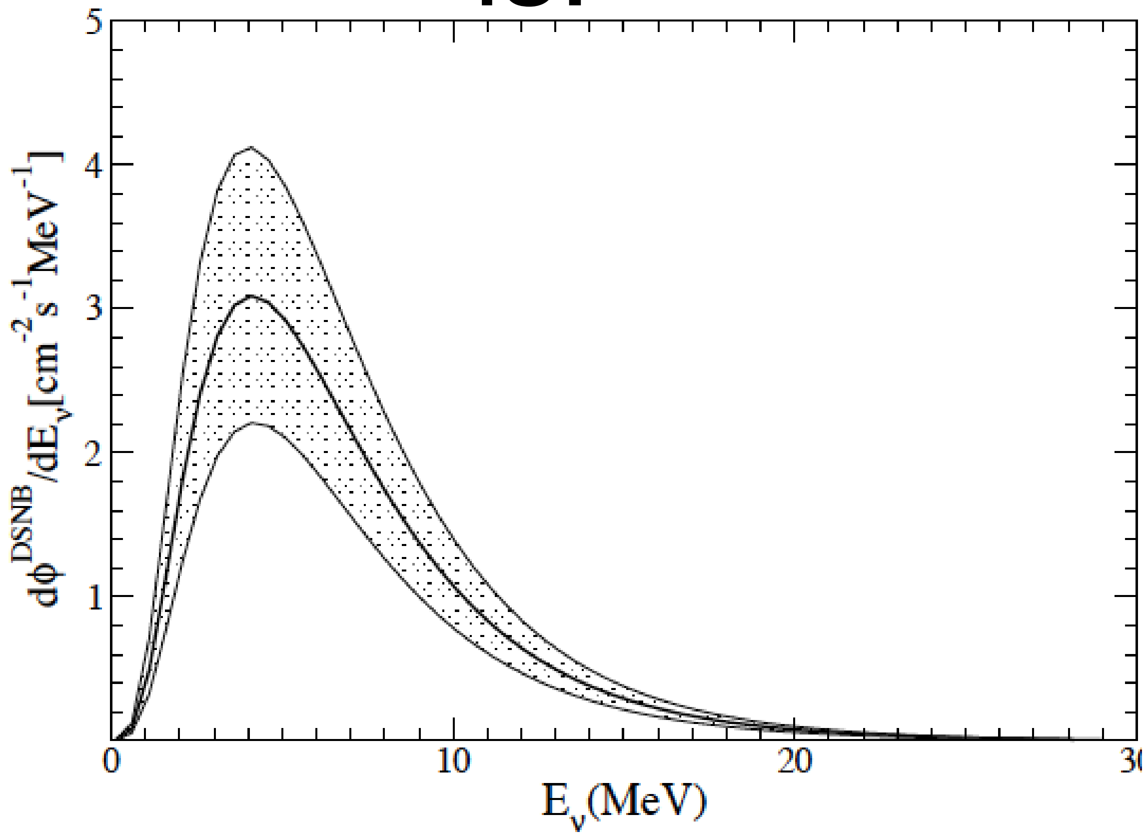
$$p = 0$$

$$H(z) = H_0\sqrt{(\Omega_\Lambda + (1+z)^3\Omega_m)}$$

where

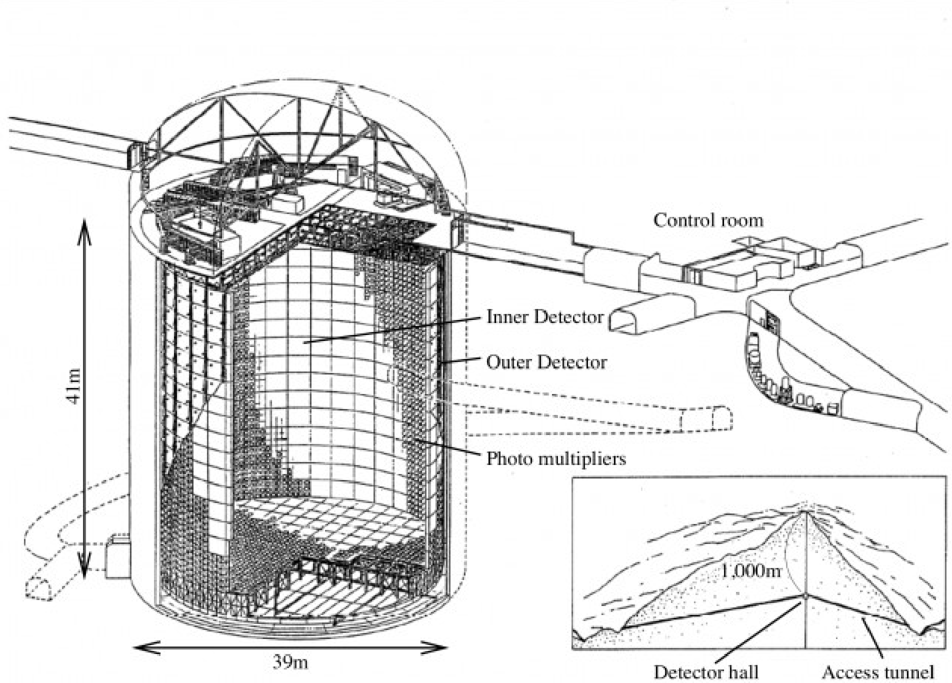
$$\Omega_\Lambda = \rho_\Lambda/\rho_c,\ \Omega_m = \rho_m/\rho_c \text{ and } \rho_c = \frac{3H^2}{8\pi G}$$

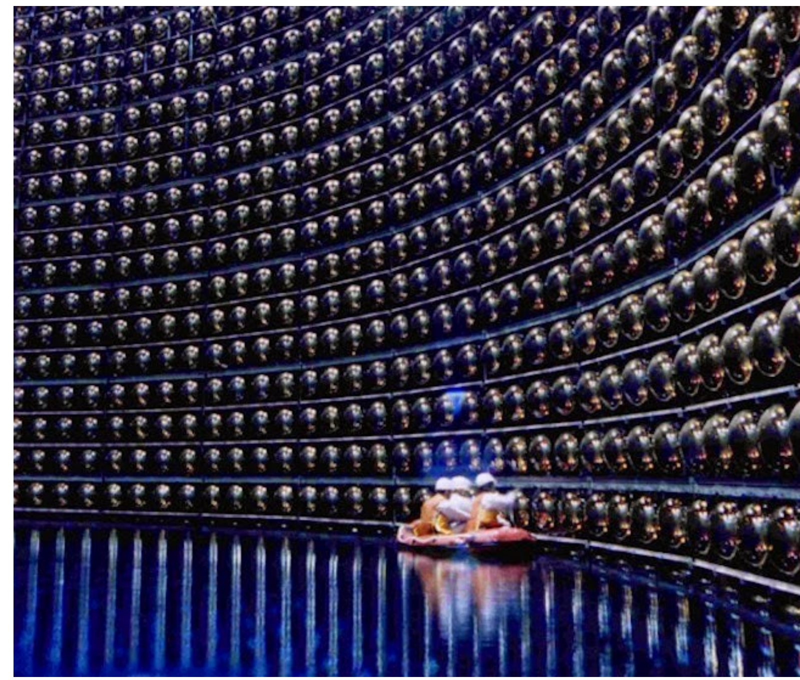
The diffuse neutrino background flux is:



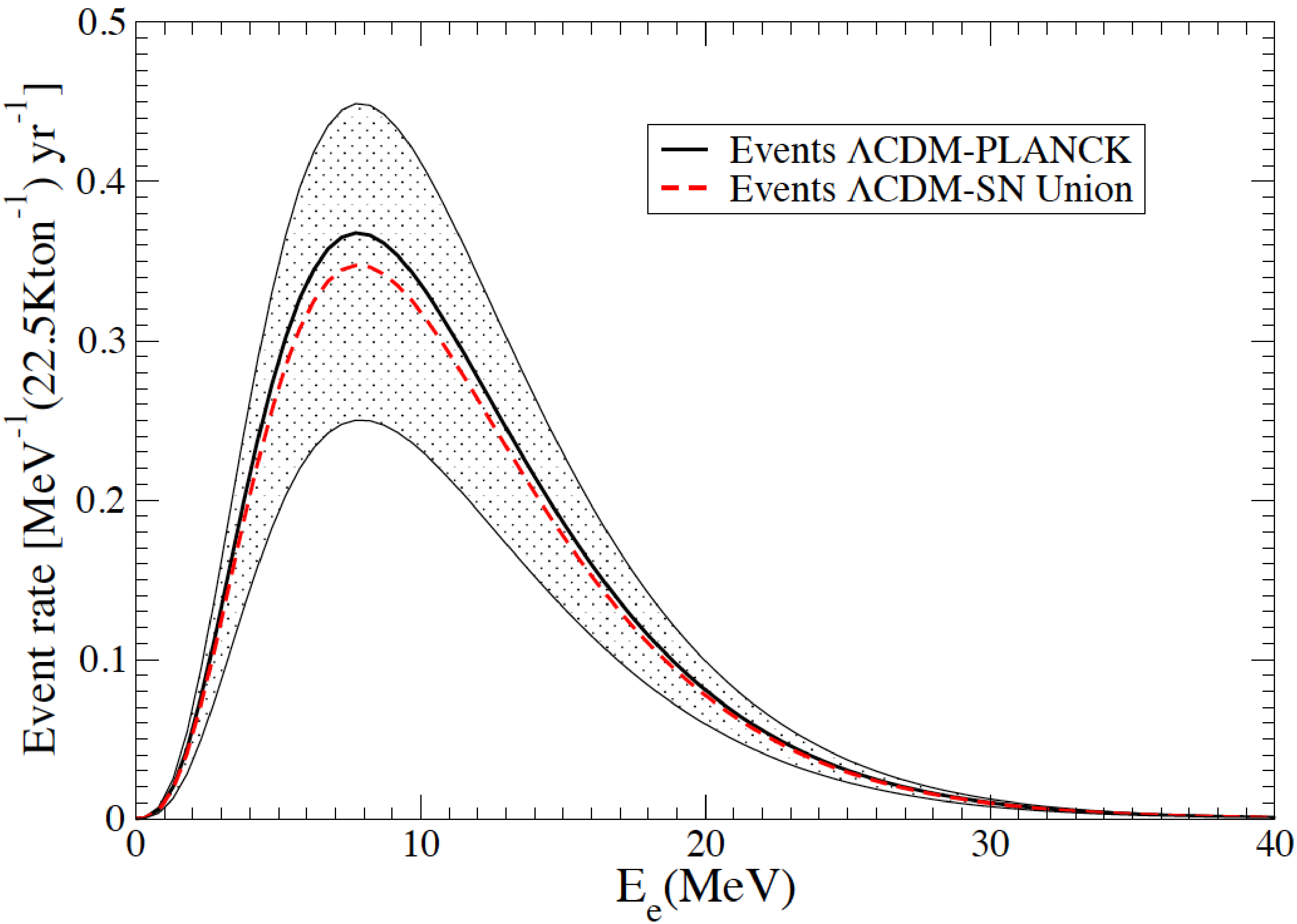
Its detection is inevitable...

inverse beta decay $\bar{\nu}_e + p \to n + e^+$





$$\frac{dN}{dE_e} = N_p \sigma(E_\nu) \frac{d\phi^{DSNB}}{dE_\nu}$$



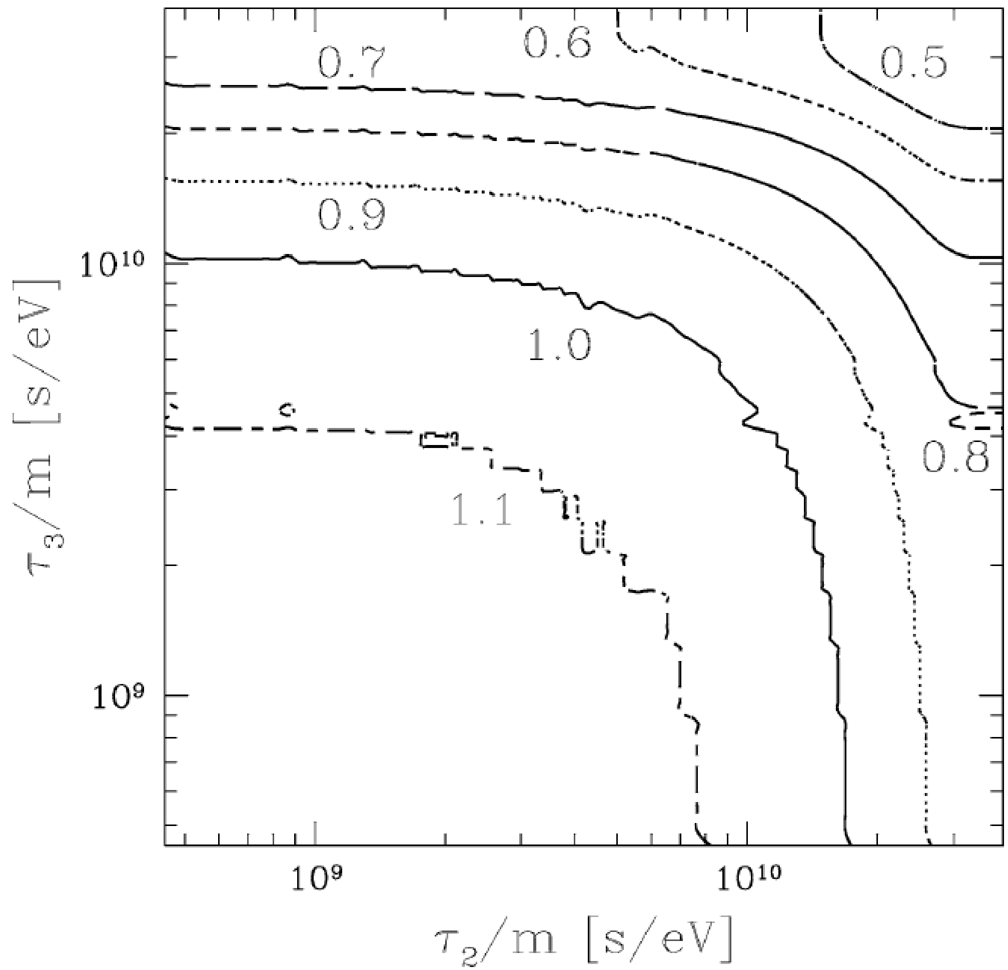
SK has not observed DSBN

$$\phi_{\bar{\nu}_e} < 2.9\ \bar{\nu}_e s\ \mathrm{cm}^{-2}\mathrm{sec}^{-1}\ \mathrm{for}\ E_\nu > 16.\ \mathrm{MeV}$$

Sensitivity to neutrino physics

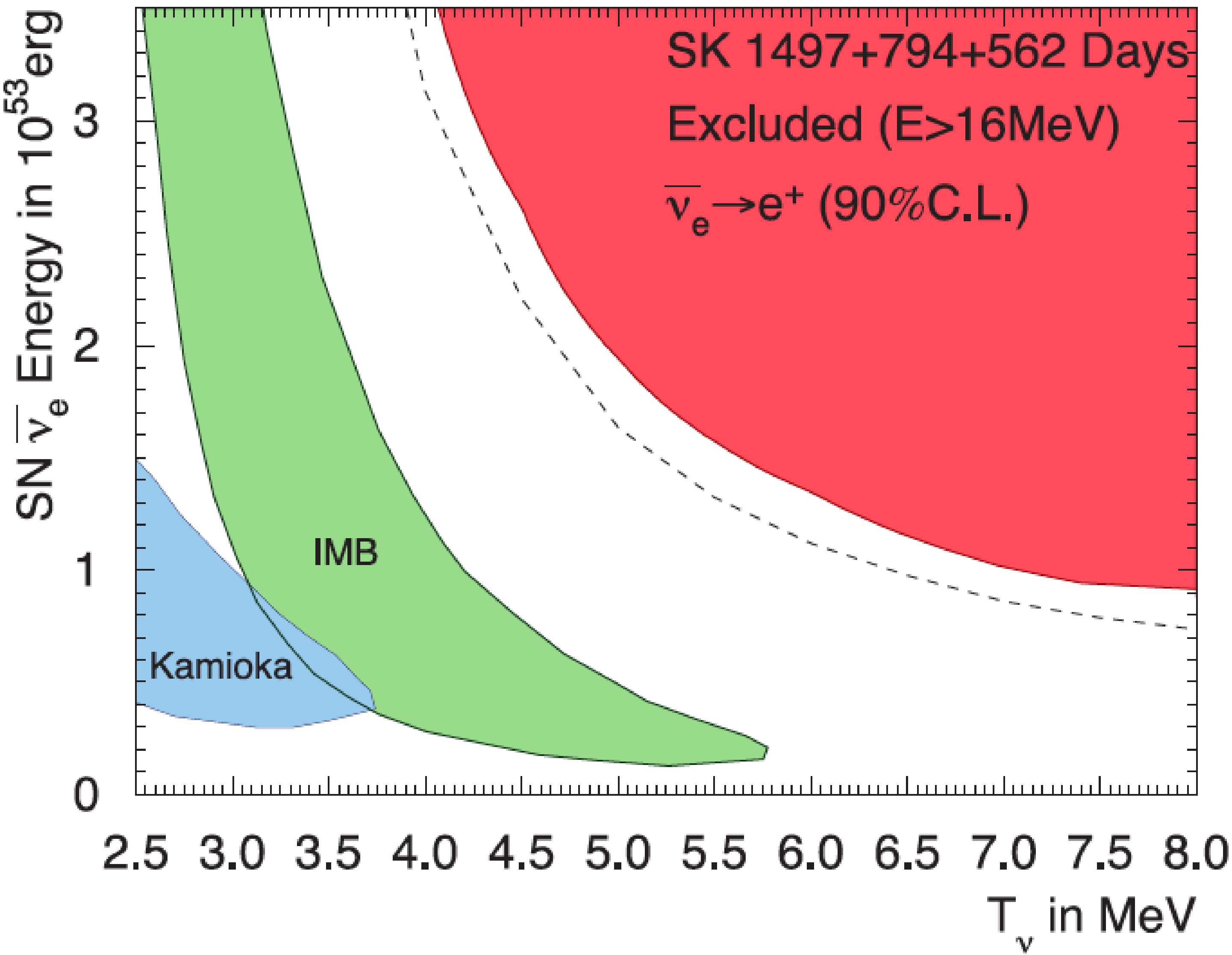
Neutrino lifetime

S. Ando / Physics Letters B 570 (2003) 11–18



Sensitive to supernova spectra

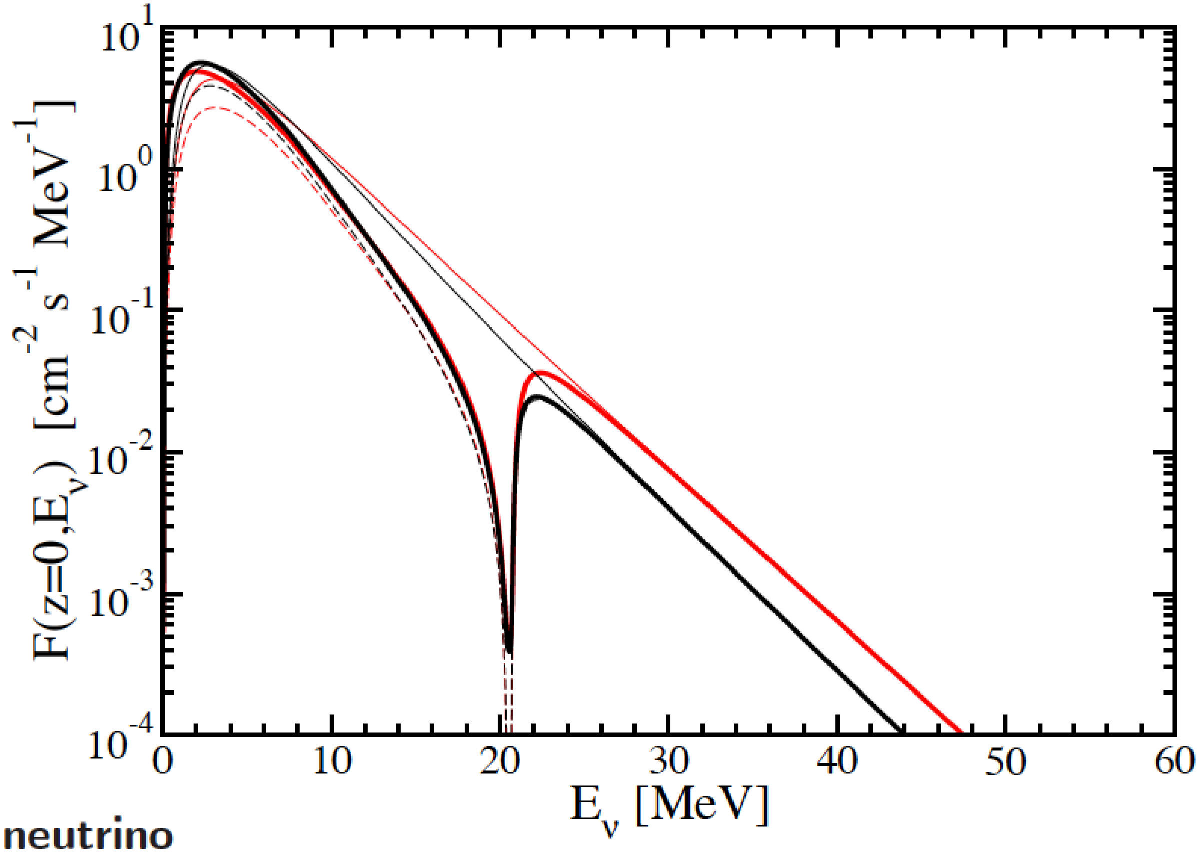
C. Lunardini / Astroparticle Physics 79 (2016) 49–77



New physics

$gN_R^\dagger \nu_L \phi$

$m_\phi = m_{\rm DM} = 1\,\rm MeV$

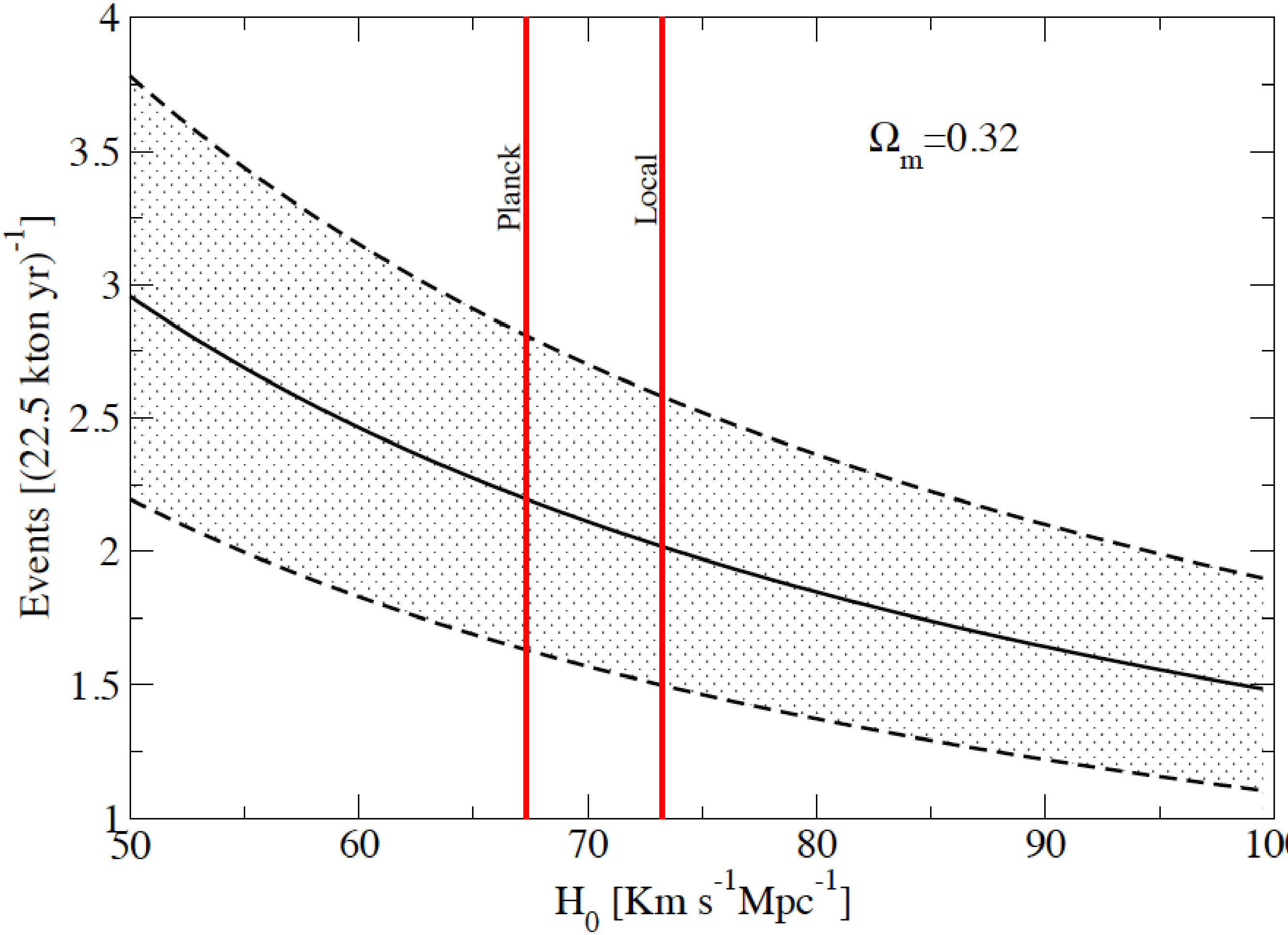


Dips in the diffuse supernova neutrino background

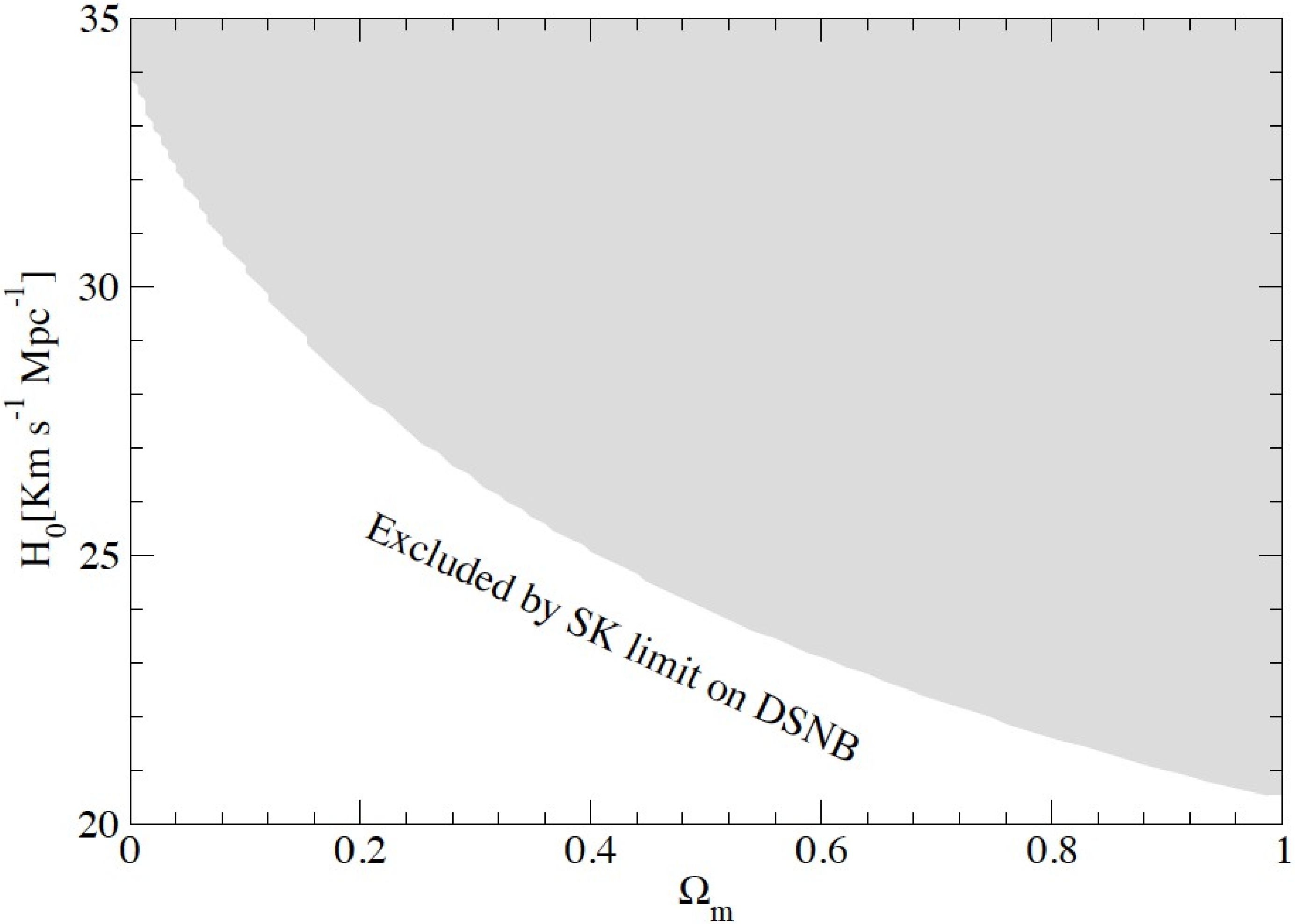
Yasaman Farzan[a] and Sergio Palomares-Ruiz[b]

What about cosmology?

$$\frac{d\phi^{DSNB}}{dE} = \int R_{CCSN}(z) \frac{dN(E)}{dE} |\frac{dt}{dz}| dz \qquad |\frac{dt}{dz}| = 1/(1+z)H(z)$$



SK limits already constrains CDM



$H_0 > 21.5$ Km/sec/Mpc independently of the content of dark matter Ω_m

Alternative models

The cosmological constant, which correspond to the energy density of the vacuum, is the simplest model to explain an accelerating expansion of the universe. Nevertheless, two problems arise:

(i) a huge discrepancy between its predicted value and the observed value and

(ii) the "*cosmic coincidence problem*", i.e. the problem that we are living in a time when the matter density in the Universe is of the same order than the dark energy density.

Two examples:

a) The logotropic universe

b) Bulk viscous matter dominated universe

Logotropic

$$P = A \log(\rho/\rho_P)$$

$$H(z) = H_0\sqrt{\Omega_{m0}(1+z)^3 + (1-\Omega_{m0})(1-3B\log(1+z))}$$

Bulk viscous matter dominated universe

$$T_{\mu\nu} = \rho_{\mathrm{m}}\, u_\mu u_\nu + (g_{\mu\nu} + u_\mu u_\nu) P^*_{\mathrm{m}}$$

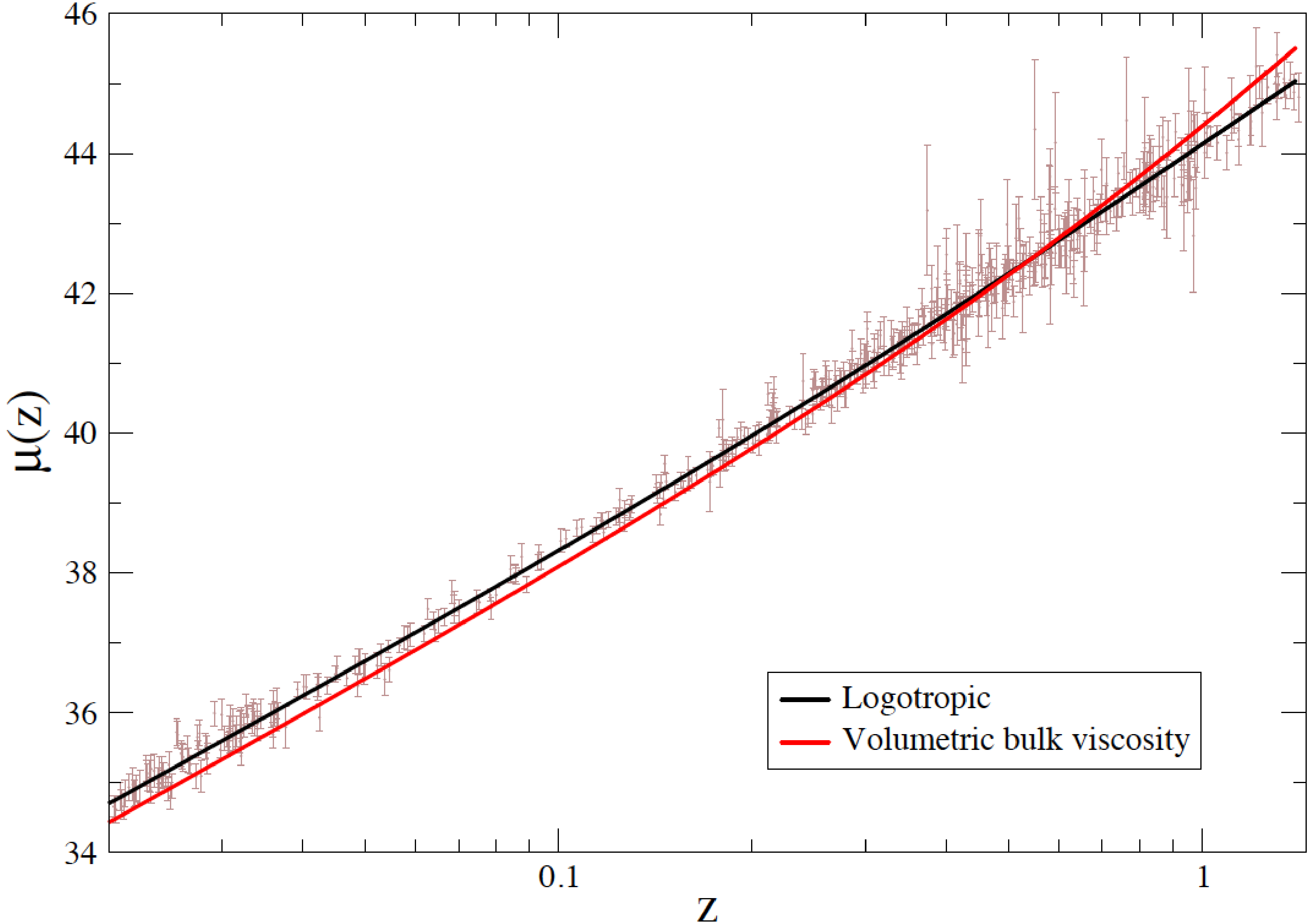
$$P^*_{\mathrm{m}} \equiv P_{\mathrm{m}} - \zeta \nabla_\nu u^\nu$$

$$\zeta \;=\; \zeta_0 + \zeta_1 H$$

$$\frac{d\rho_{\mathrm{m}}}{da} + \frac{(3-\bar{\zeta}_1)}{a}\rho_{\mathrm{m}} - \frac{3H_0}{(24\pi G)^{1/2}}\frac{\bar{\zeta}_0}{a}\rho_{\mathrm{m}}^{1/2} = 0$$

$$H(z) = H_0\left(\left(1-\frac{\bar{\zeta}_0}{3-\bar{\zeta}_1}\right)(1+z)^{(3-\zeta_1)/2} + \frac{\bar{\zeta}_0}{3-\bar{\zeta}_1}\right)$$

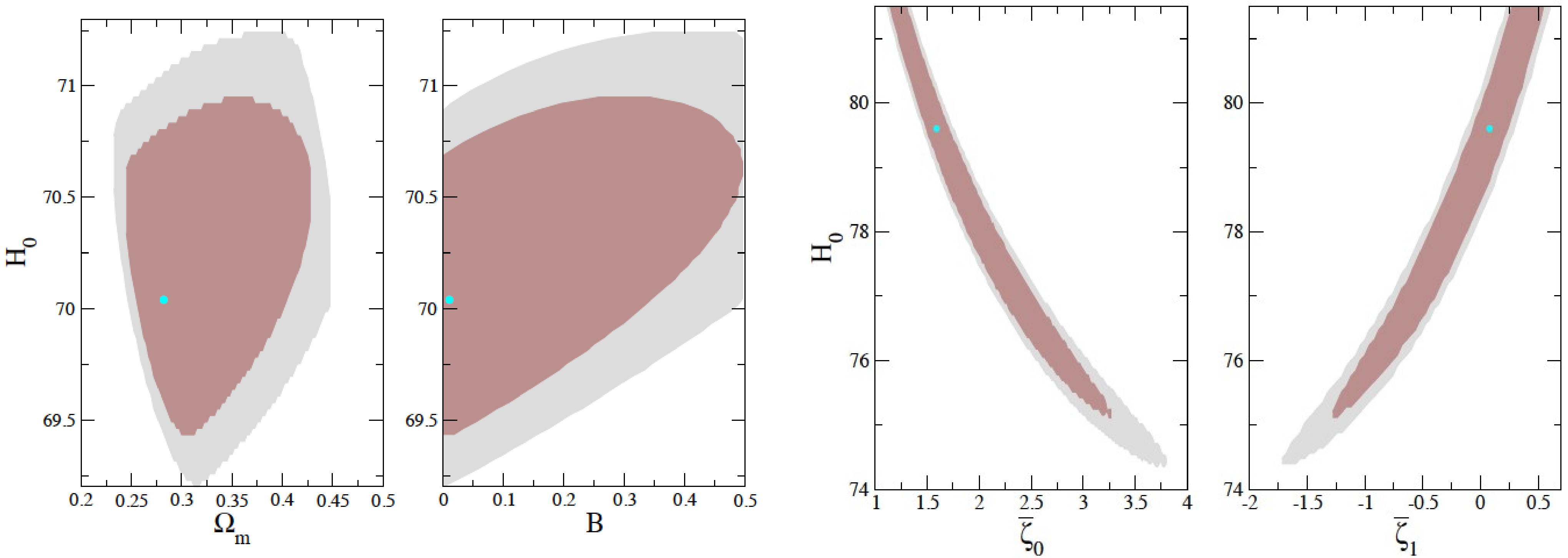
Model	Best fit parameters			$\chi^2_{\text{min}}/\text{d.o.f.}$
Volometric	$H_0 = 79.05^{+3.85}_{-1.77}$	$\bar{\zeta}_0 = 1.73^{+1.35}_{-0.89}$	$\bar{\zeta}_1 = 0.03^{+0.90}_{-1.26}$	$\chi^2_{\text{min}}/\text{d.o.f.} = 0.971$
Logotropic	$H_0 = 70.25^{+0.69}_{-1.05}$	$\Omega_{m0} = 0.28^{+0.15}_{-0.13}$	$B = 0.00^{+0.47}_{-0.20}$	$\chi^2_{\text{min}}/\text{d.o.f.} = 0.973$
ΛCDM	$H_0 = 70.04^{+0.68}_{-0.64}$	$\Omega_m = 0.28 \pm 0.04$		$\chi^2_{\text{min}}/\text{d.o.f.} = 0.971$



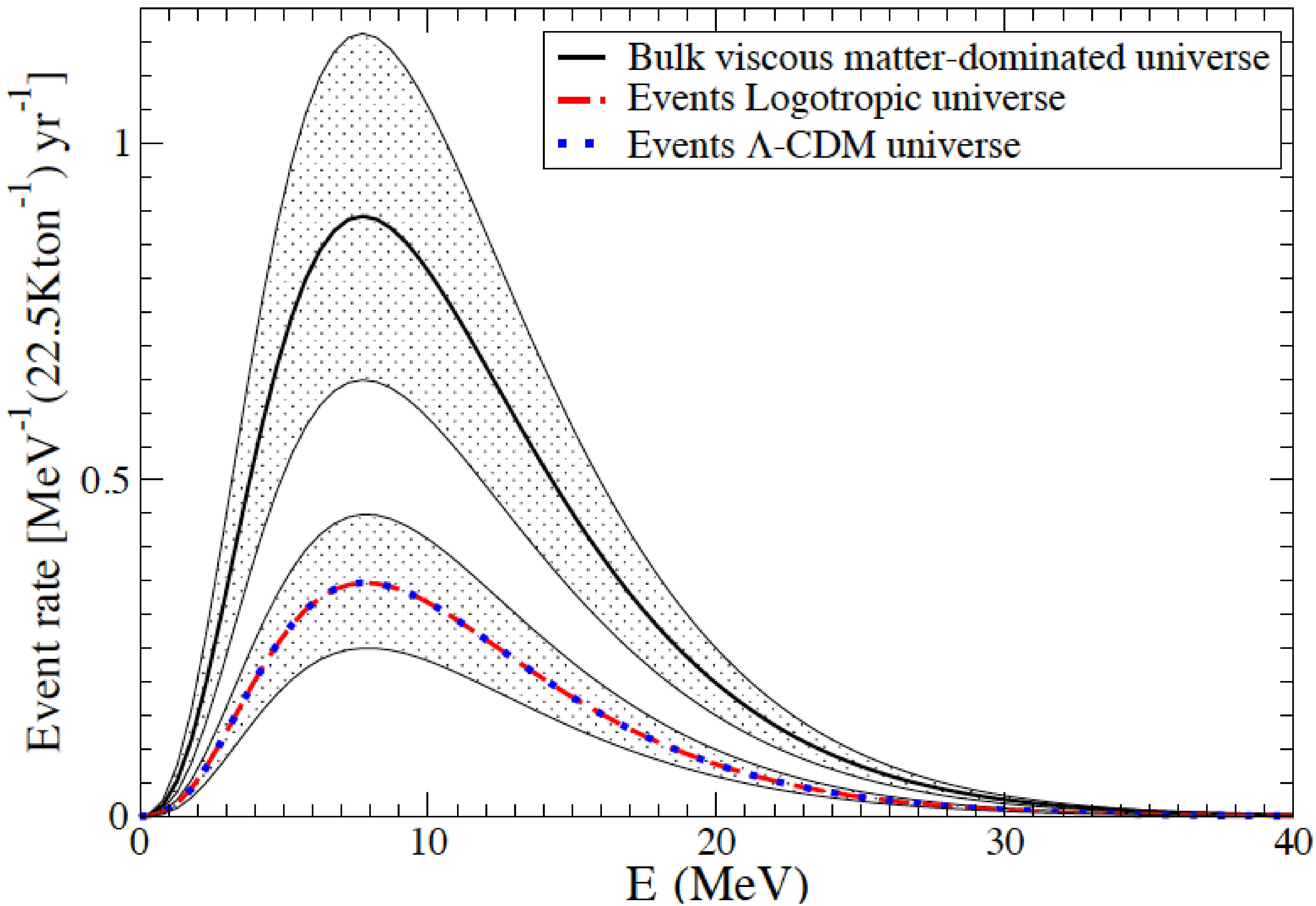
$$\chi^2 = \sum_i \left(\frac{\mu^{Th}(z_i) - \mu^{Exp}(z_i)}{\delta \mu_i^{Exp}} \right)^2$$

$$\mu^{Th}(z) = 5\log\left[\frac{d_L(z)}{\mathrm{Mpc}}\right] + 25$$

$$d_L(z) = c(1+z)\int_0^z \frac{dz'}{H(z')}$$



Predicted number of events



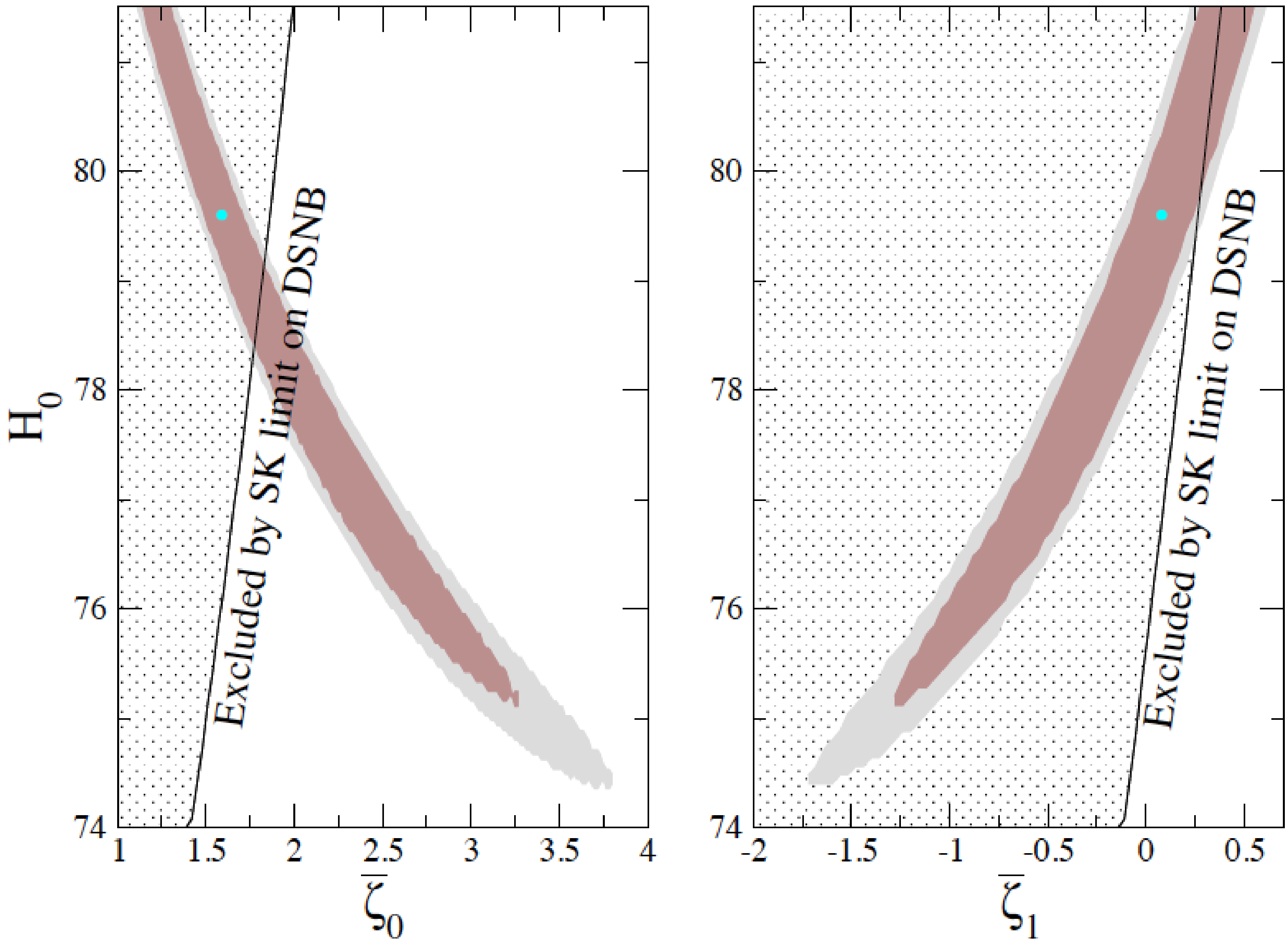


Figure 8. Allowed regions for the $H_0, \bar{\zeta}_0$ and $\bar{\zeta}_1$ constrained with the Union 2.1 data set at 68% and 90% C.L. and the excluded region obtained by imposing that $\phi^{DSNB}(H_0, \Omega_m) < 2.9\,\bar{\nu}_e \text{cm}^{-2}\text{sec}^{-1}$ for $E_\nu > 16$ MeV.

DSNB is sensitive to the cosmological model

(assuming the alternative cosmological model predicts a similar SFR as LCDM)

Neutrinos astrofísicos y su naturaleza Dirac o Majorana

Propagación y detección

Is the neutrino a Dirac or a Majorana particle?

1) To show that the neutrino-electron scattering with polarized neutrinos might have different cross sections for the Dirac or the Majorana case

2) Use that fact to constrain the neutrino magnetic moment

What is the relevance of being Majorana?

I. The equation that dictates the dynamics is different
II. The neutrino will be its own antiparticle
III. There will be another processes like the Neutrinoless double beta decay

There is a crucial difference between Dirac and Majorana neutrinos if we consider neutrino-electron scattering. At low energies, the effective Lagrangian is:

$$\mathcal{L}_{\nu e} = \frac{G_F}{\sqrt{2}}[\bar{u}_{\nu_\ell}\gamma^\mu(1-\gamma^5)u_{\nu_\ell}][\bar{u}_e\gamma_\mu(g_V^\ell - g_A^\ell\gamma^5)u_e]$$

If the neutrino is a Majorana particle, then the following identity holds:

$$\bar{v}^f_{\nu_\ell}\gamma_\mu(1-\gamma^5)v^i_{\nu_\ell} = \bar{u}^f_{\nu_\ell}\gamma_\mu(1+\gamma^5)u^i_{\nu_\ell}$$

Then, the amplitudes for each case are:

Dirac case:

$$\mathcal{M}^D(\nu_\ell e \to \nu_\ell e) = -i\frac{G_F}{\sqrt{2}}[\bar{u}_e^f \gamma^\mu (g_V^\ell - g_A^\ell \gamma^5) u_e^i][\bar{u}_{\nu_\ell}^f \gamma_\mu (1-\gamma^5) u_{\nu_\ell}^i]$$

Majorana case:

$$\mathcal{M}^M(\nu_\ell e \to \nu_\ell e) = i\frac{2G_F}{\sqrt{2}}\left[\bar{u}_e^f \gamma^\mu (g_V^\ell - g_A^\ell \gamma^5) u_e^i\right]\left[\bar{u}_{\nu l}^f \gamma_\mu \gamma^5 u_{\nu l}^i\right]$$

If amplitudes are so different: why are not the cross sections for Majorana and Dirac cases different?

A: Neutrinos have negative helicity. An extra factor

$$(1-\gamma_5)/2$$

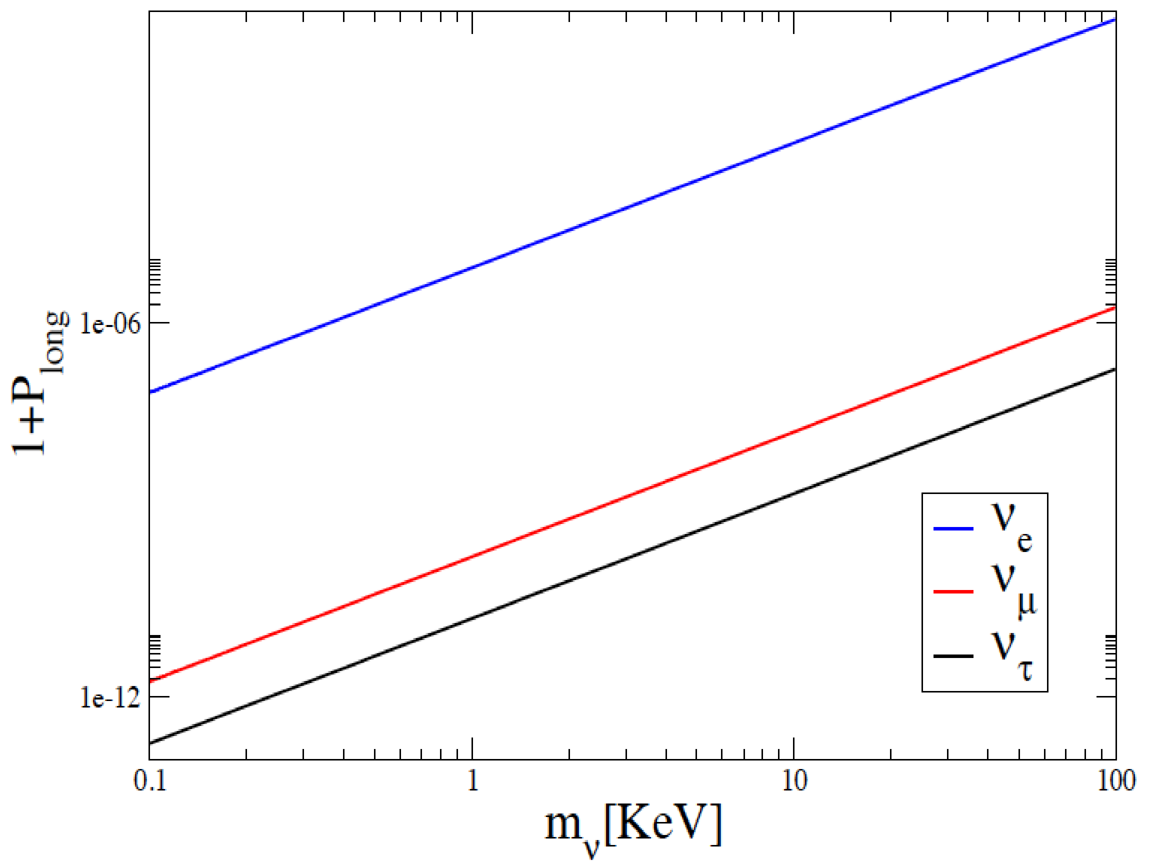
should be added and both amplitudes become identical

Neutrinos are almost completely left handed.
Consider the pure leptonic deacy of a pseudoscalar meson:

$$P^+ \rightarrow \ell^+ + \nu_\ell$$

The neutrino longitudinal polarization: $P_{\rm long} = \frac{(E-W)|\vec{k}|}{WE - |\vec{k}|^2}$,

Here $\vec{k}$ is the neutrino moment and E,W the lepton energies



In any case...forget for a moment the value of the neutrino polarization and compute:

neutrino-electron scattering $\nu_\ell(p_\nu, s_\nu) + e(p_e) \to \nu_\ell(p'_\nu) + e(p'_e)$

$$s_\nu = (0, s_\perp, 0, s_{||})$$

For the Dirac case (in CM) [B. Kayser, R. Schrock PLB 112 (1982) 137]

$$\begin{aligned}
\frac{d\sigma^D}{d\Omega} &= \frac{G_F^2}{8\pi^2 s}((m_e^2(E_\nu - p^2\cos\theta)({g_A^\ell}^2 - {g_V^\ell}^2) \\
&+ (E_\nu E_e + p^2)(g_V^\ell + g_A^\ell)^2 + (E_\nu E_e + p^2\cos\theta)^2(g_V^\ell - g_A^\ell)^2 \\
&- p[s^{1/2}(E_\nu E_e + p^2)s_{||}(g_V^\ell + g_A^\ell)^2 + (E_\nu E_e + p^2\cos\theta) \\
&\times ((E_e + E_\nu\cos\theta)s_{||} + m_\nu s_\perp \sin\theta\cos\phi]) (g_V^\ell - g_A^\ell)^2 \\
&+ m_e(E_\nu(1-\cos\theta)s_{||} - m_\nu|s_\perp|\sin\theta\cos\phi)({g_A^\ell}^2 - {g_V^\ell}^2))),
\end{aligned}$$

For the Majorana:

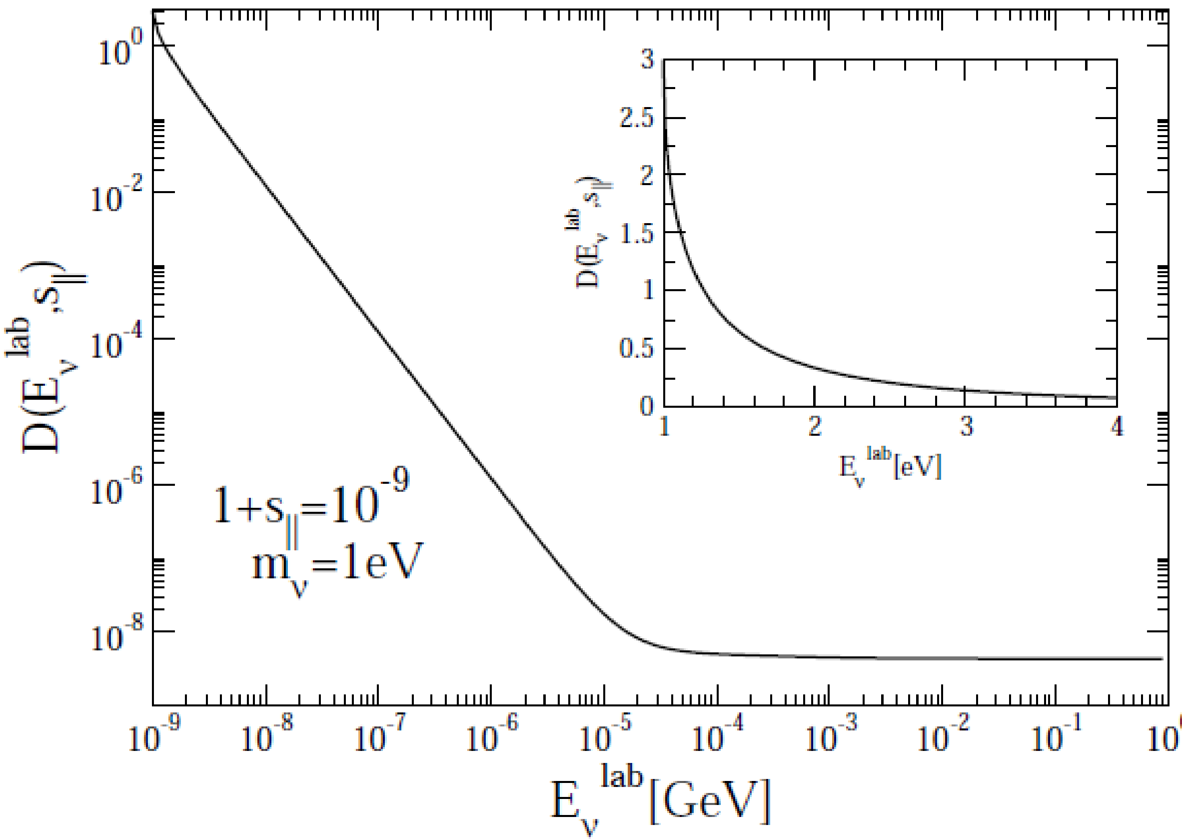
$$
\begin{aligned}
\frac{d\sigma^M}{d\Omega} &= \frac{G_F^2}{4\pi^2 s}(((E_\nu E_e + p^2)^2 + (E_\nu E_e + p^2\cos\theta)^2 \\
+ & \quad m_\nu (E_\nu^2 - p^2\cos\theta))({g_V^\ell}^2 + {g_A^\ell}^2) + m_e^2(E_\nu^2 - p^2\cos\theta + 2m_\nu^2) \\
\times & \quad ({g_A^\ell}^2 - {g_V^\ell}^2) - 2 g_V^\ell g_A^\ell p (2E_\nu E_e + p^2(1+\cos\theta)) \\
\times & \quad (E_\nu s_{||}(1-\cos\theta) - m_\nu |s_\perp| \sin\theta\cos\phi))\,.
\end{aligned}
$$

They are different!!!!

Seriously?

$$D(E_\nu^{\rm lab}, s_{||}) = \frac{|\sigma(\nu^D_{pol} e) - \sigma(\nu^M_{pol} e)|}{\sigma(\nu^D_{pol} e)},$$

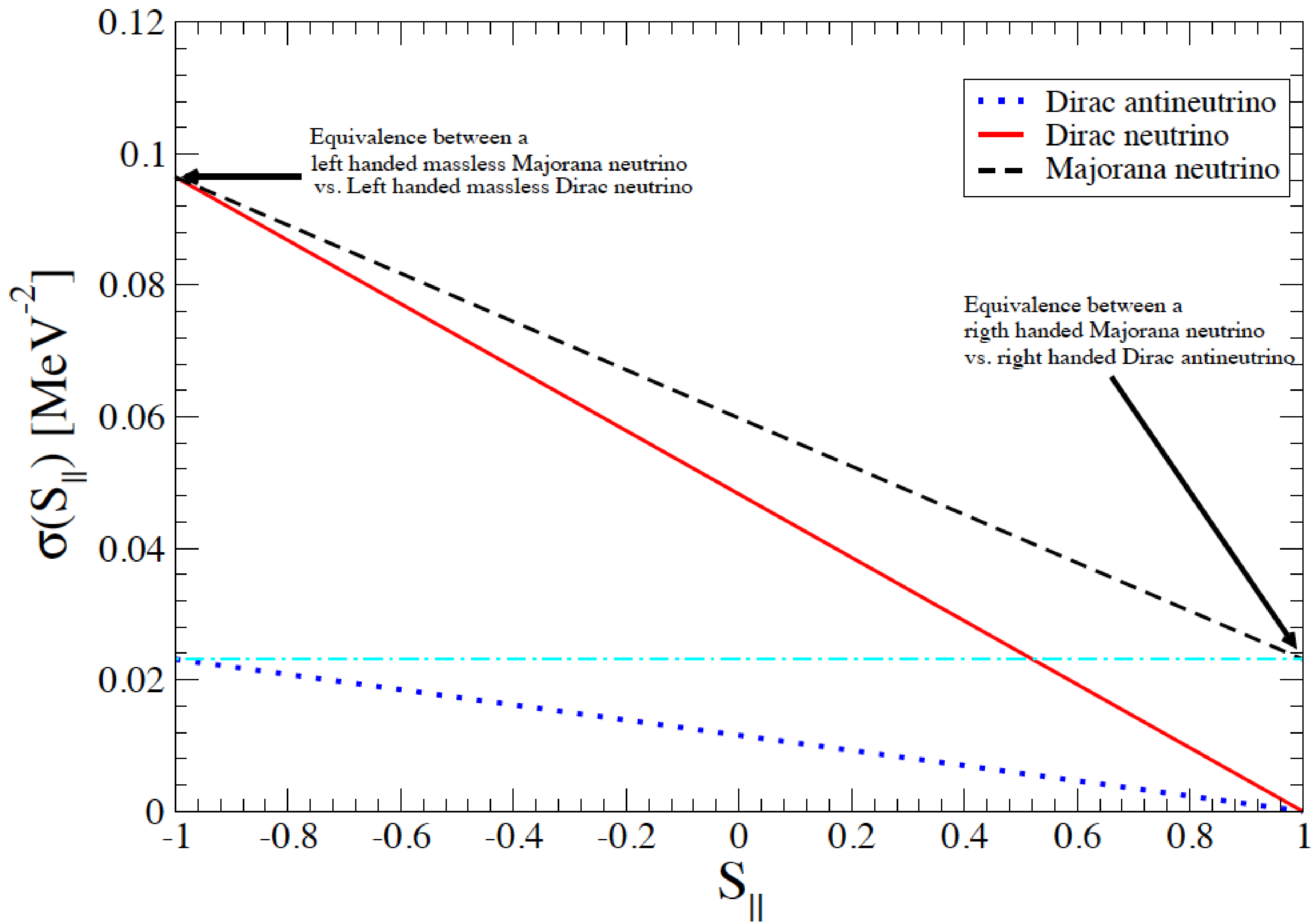
For man made neutrinos, which are produced via charged currents, it is extremely difficult to have significant differences between Dirac and Majorana neutrinos.



Don't lose your faith...

Consider the integrated cross section in a Borexino type detector

$$\sigma(s_{\|}) = \int dT \int dE_\nu \lambda(E_\nu) \frac{d^2\sigma}{dE_\nu dT}$$



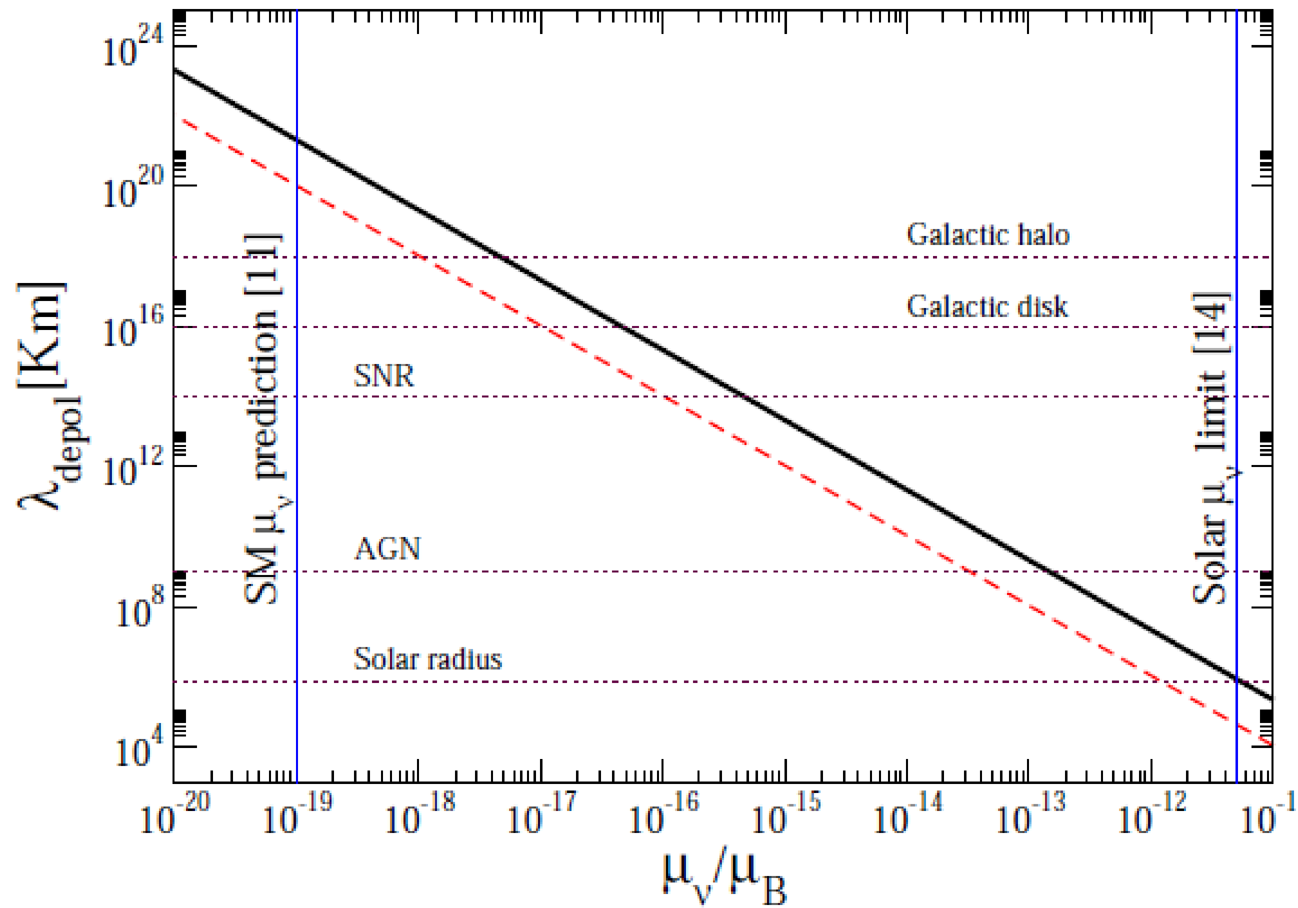
Can we (or nature) change the neutrino initial polarization?

Yes, we (nature) can...
Bargmann-Michel-Telegdi:

$$\frac{dS^\mu}{d\tau} = 2\mu(G^{\mu\nu}S_\nu - u^\mu G_{\alpha\beta}u_\alpha S_\beta) + 2\varepsilon(\tilde{G}^{\mu\nu}S_\nu - u^\mu \tilde{G}_{\alpha\beta}u_\alpha S_\beta)$$

What is the magnetic field needed in order to have such changes in the neutrino's helicity? In order to estimate this, we recall previous studies where the depolarization rate of neutrinos was calculated [15, 16, 17]. In the case of a random distribution of electromagnetic fields, the average neutrino's helicity $\langle h \rangle$ changes as dictated by the equation $\langle h(t) \rangle = exp(-\Gamma_{depol})\langle h(0) \rangle$, where

$$\Gamma_{depol} = 0.0132\mu_\nu^2 T^3 \,, \tag{11}$$



J. Barranco, D. Delepine, V. G. Macias, C. Lujan-Peschard and M. Napsuciale, Phys. Lett. B **739**, 343 (2014) [arXiv:1408.3219 [hep-ph]].

Not fully polarized, but partially polarized neutrinos.

1. Consider a model for the magnetic field of the Sun:

Solutions to magnetostatic Equations
[O.G. Miranda et al.
Nucl.Phys. B595 (2001) 360-380]

$$B_r^k(r,\theta) = 2\hat{B}^k \cos\theta \left[1 - \frac{3}{r^2 z_k \sin z_k}\left(\frac{\sin(z_k r)}{z_k r} - \cos(z_k r)\right)\right],$$

$$B_\theta^k(r,\theta) = -\hat{B}^k \sin\theta \left[2 + \frac{3}{r^2 z_k \sin z_k}\left(\frac{\sin(z_k r)}{z_k r} - \cos(z_k r) - z_{\cdot}\right.\right.$$

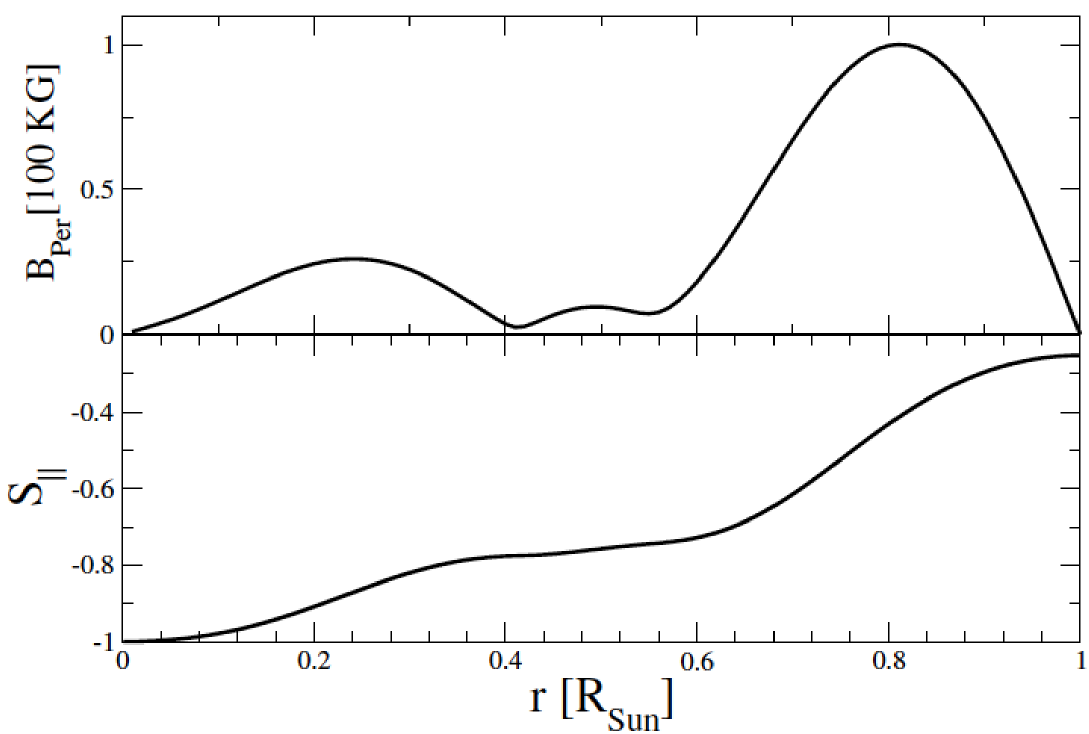
$$B_\phi^k(r,\theta) = \hat{B}^k z_k \sin\theta \left[r - \frac{3}{r z_k \sin z_k}\left(\frac{\sin(z_k r)}{z_k r} - \cos(z_k r)\right)\right],$$

$$B_\perp = \sqrt{B_\phi^2 + B_\theta^2} = B_{core}\frac{\sin\theta}{r} f(r)$$

2. With this magnetic field, solve the BMT equation:

$$\frac{ds_\parallel}{dr} = -2\mu_\nu B_\perp s_\parallel$$

For a given magnetic field, and a neutrino magnetic moment, the final $s_\parallel \neq -1$



Possible differences between Dirac and Majorana neutrino observable with astrophysical fluxes

1. A neutrino magnetic moment
2. External magnetic field
3. Massive neutrinos

Then, we expected number of neutrinos change from:

$$N_{Obs}^{th} = \sum_i \phi_i \times t \times N_e \times \int dE_\nu \int dT \lambda_i(E_\nu) \times \frac{d\sigma(E_\nu, T)}{dT} \times P(\Delta m^2, \theta)$$

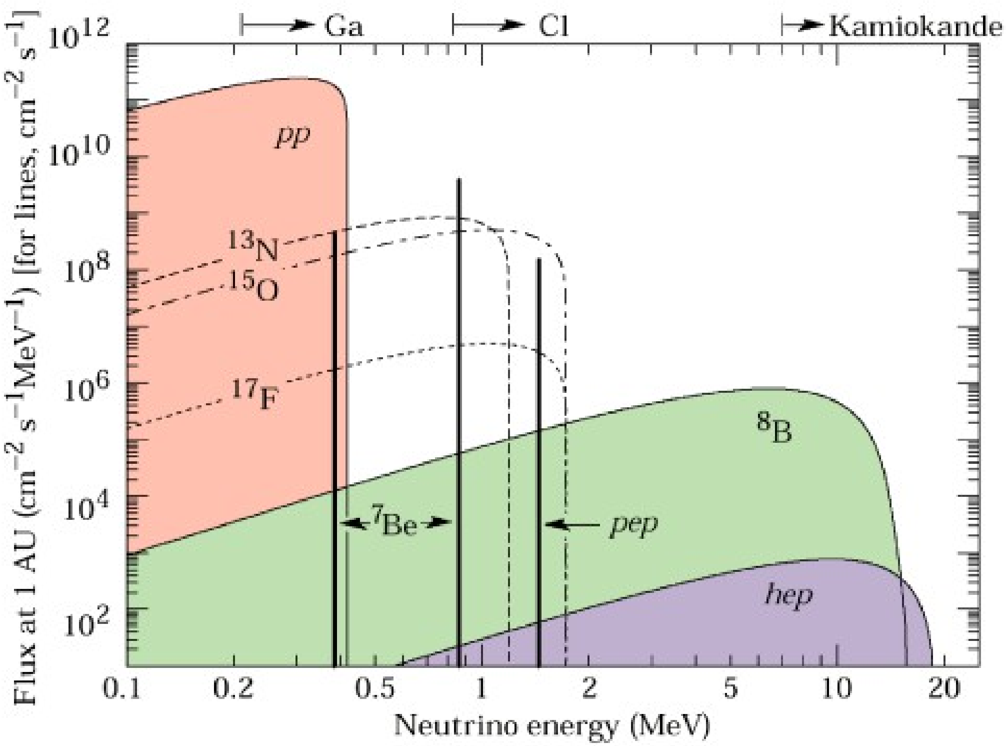
to...

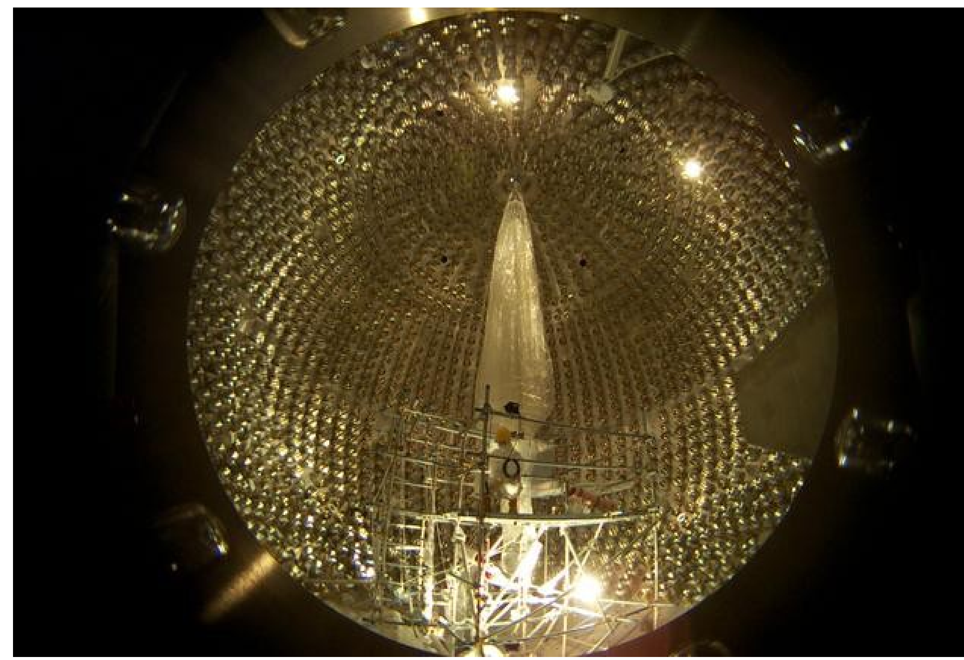
$$N_{Obs}^{th}(\mu_\nu, s_{||}) = \sum_i \phi_i \times t \times N_e \times \int dE_\nu \int dT \lambda_i(E_\nu) \times \frac{d\sigma(E_\nu, T, \mu_\nu, s_{||})}{dT} \times P(\Delta m^2, \theta, \mu_\nu)$$

Borexino

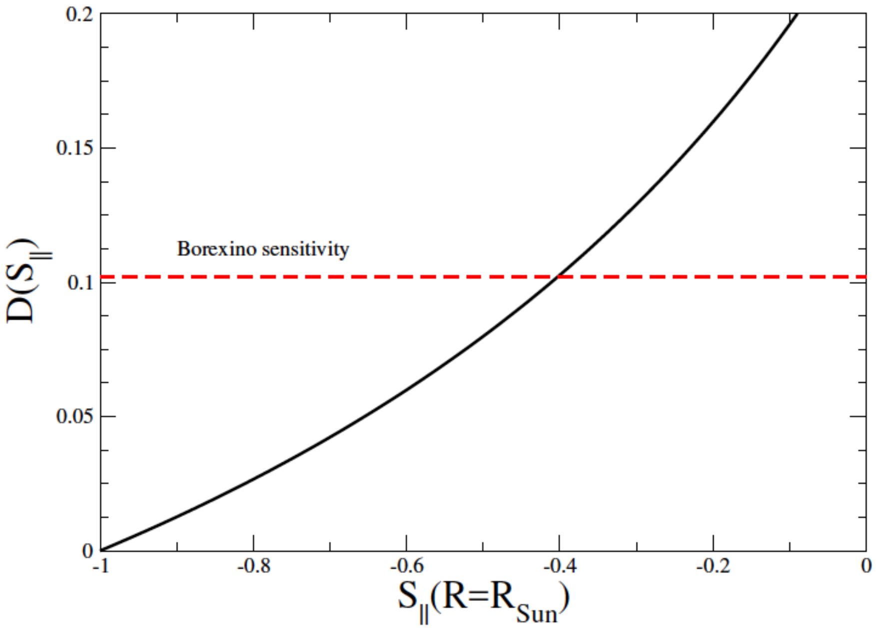
PRL **101,** 091302 (2008) PHYSICAL REVIEW LETTERS week ending 29 AUGUST 2008

Direct Measurement of the ^{7}Be Solar Neutrino Flux with 192 Days of Borexino Data



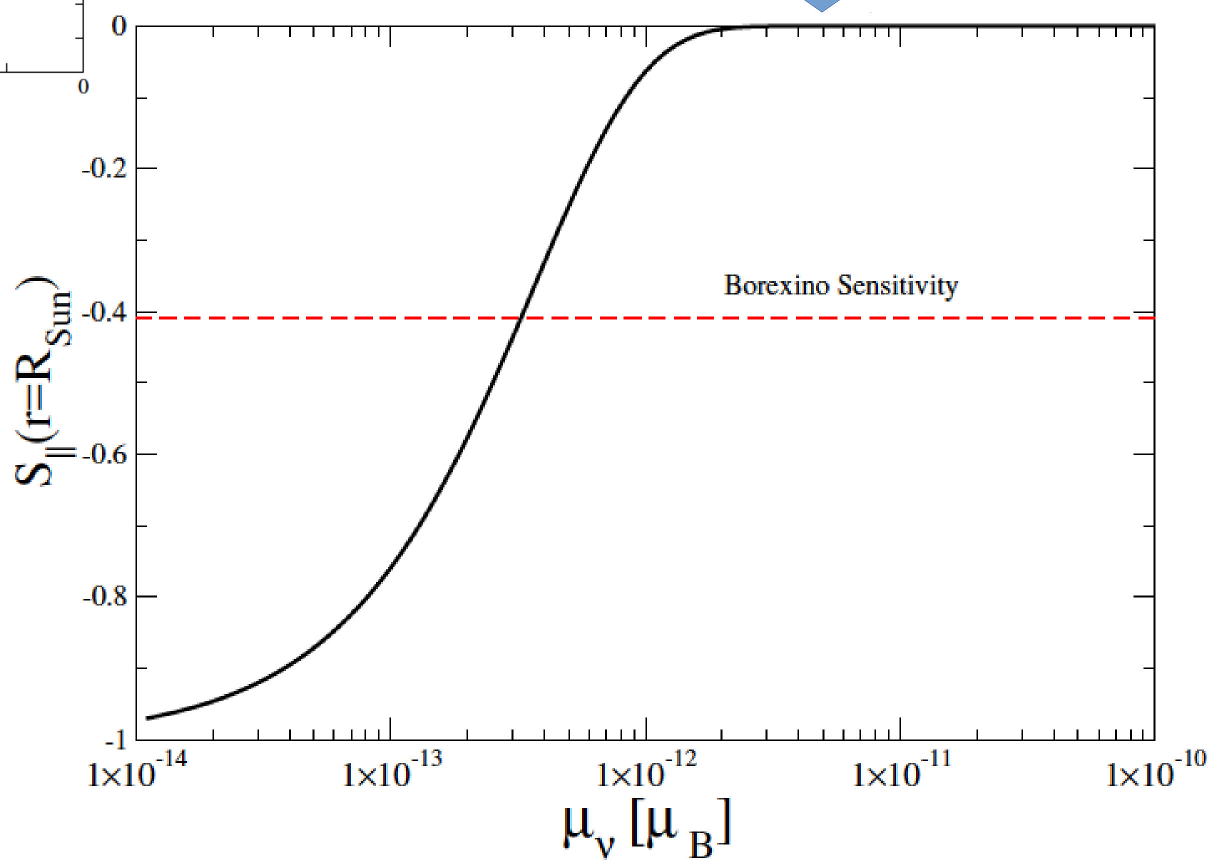


$$\text{Borexino's relative error} = \frac{|N^M - N^D|}{N^D} = \frac{|\sigma^M - \sigma^D|}{\sigma^D} = D(s_{||})$$



Borexino relative error = 4%
It implies a maximum value for the Neutrino polarization at the surface of the Sun

Maximum polarization implies an Upper bound on the neutrino magnetic moment



$$\mu_\nu < 3.3 \times 10^{-13} \mu_B.$$

J. Barranco, D. Delepine, M. Napsuciale, A. Yebra arXiv:1704.01549

Is it possible to obtain more information about's neutrino nature using astrophysical neutrinos? YES

Magnetic field amplification and magnetically supported explosions of collapsing, non-rotating stellar cores

M. Obergaulinger[1], H.-Th. Janka[2], M.A. Aloy Torás[1]
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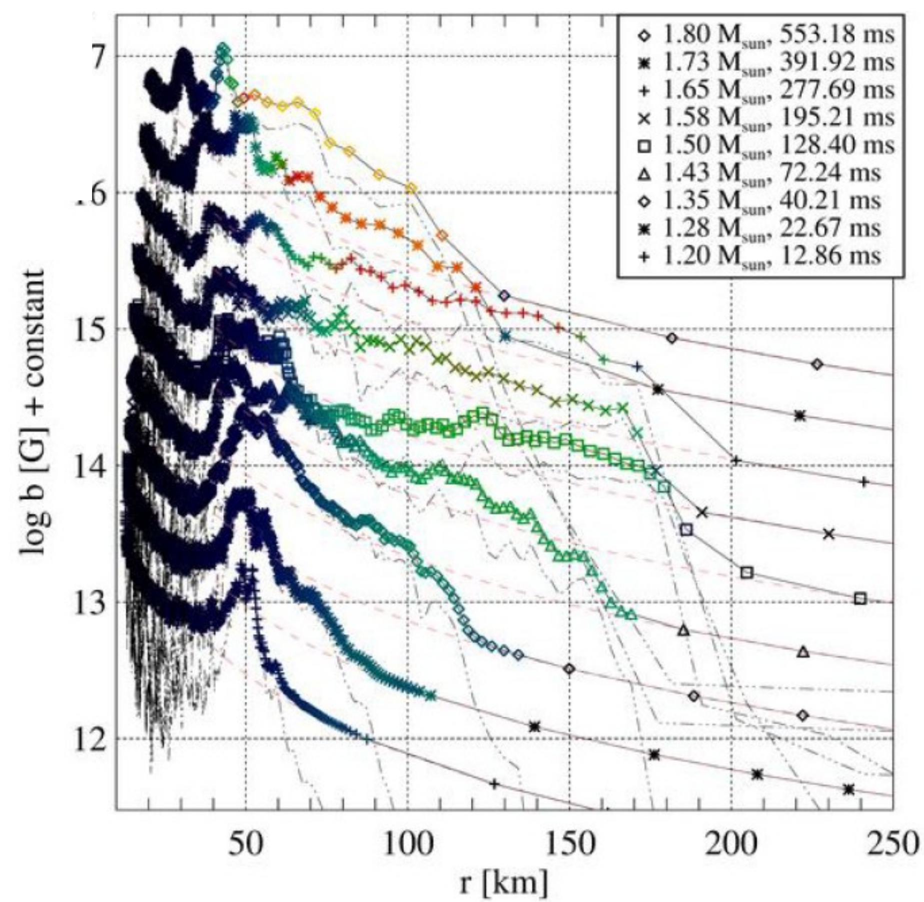
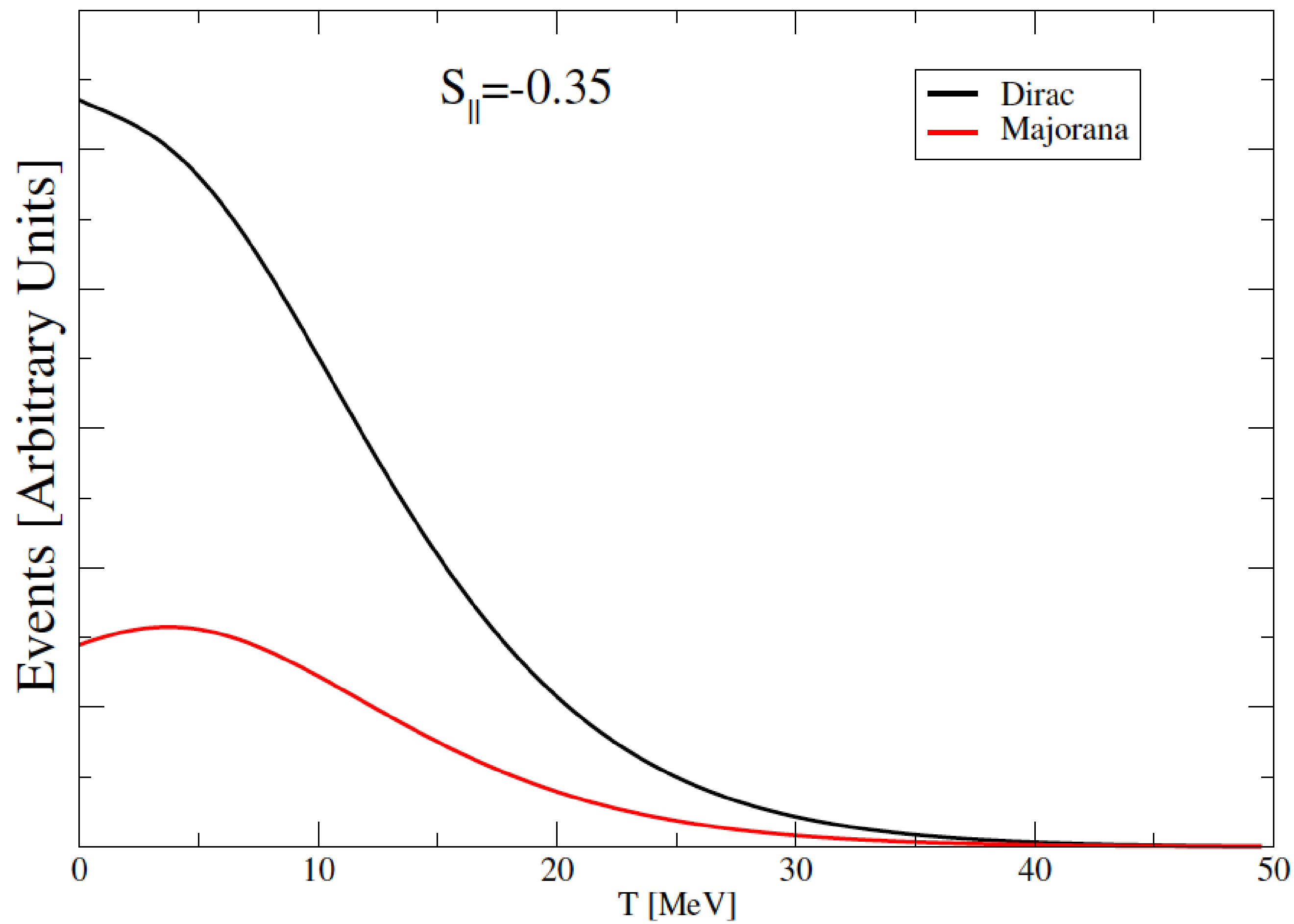
[2] *Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85748 Garching, Bavaria, Germany*

Supernova neutrinos

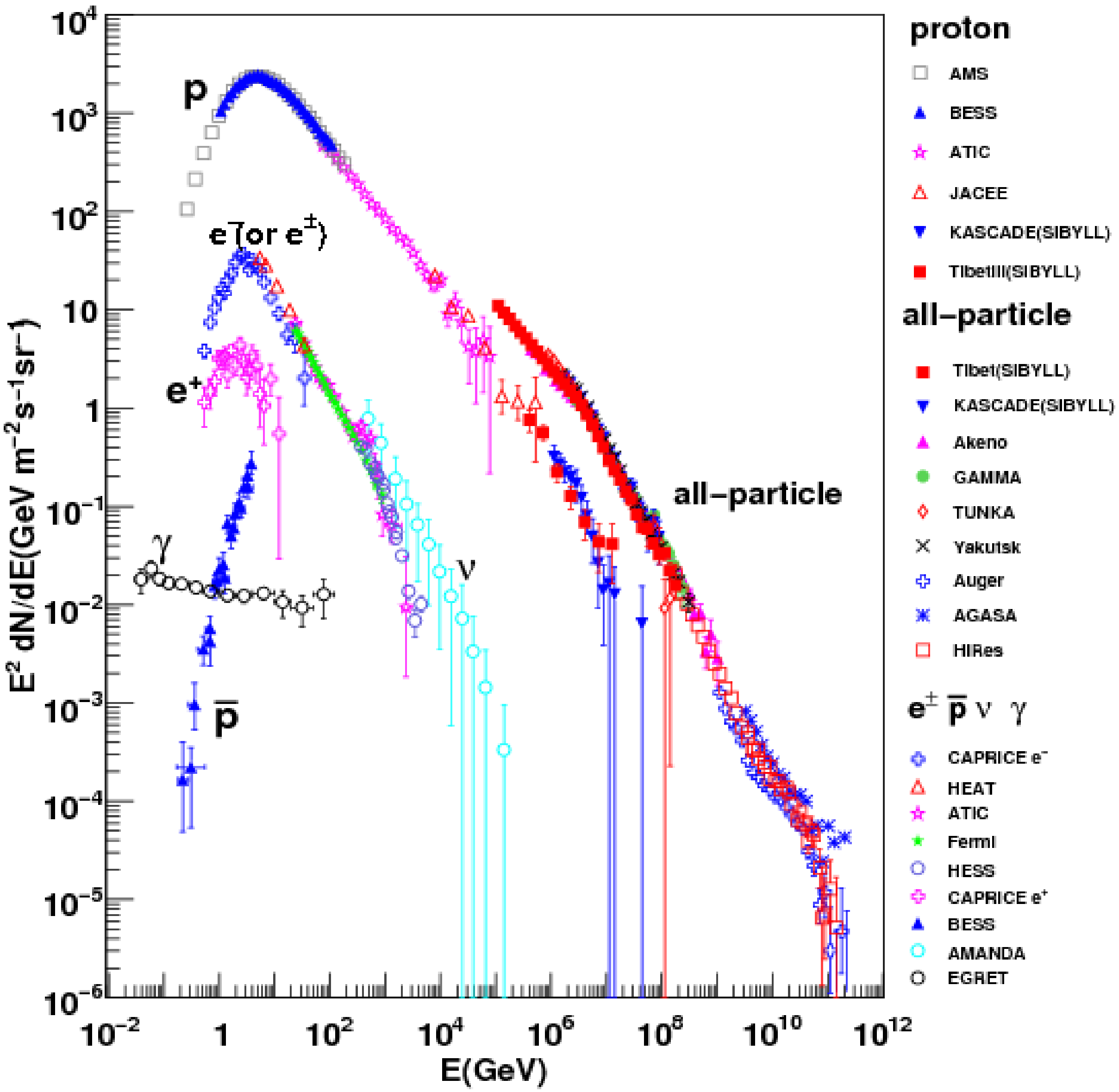


Difference between Majorana and Dirac with SN neutrinos

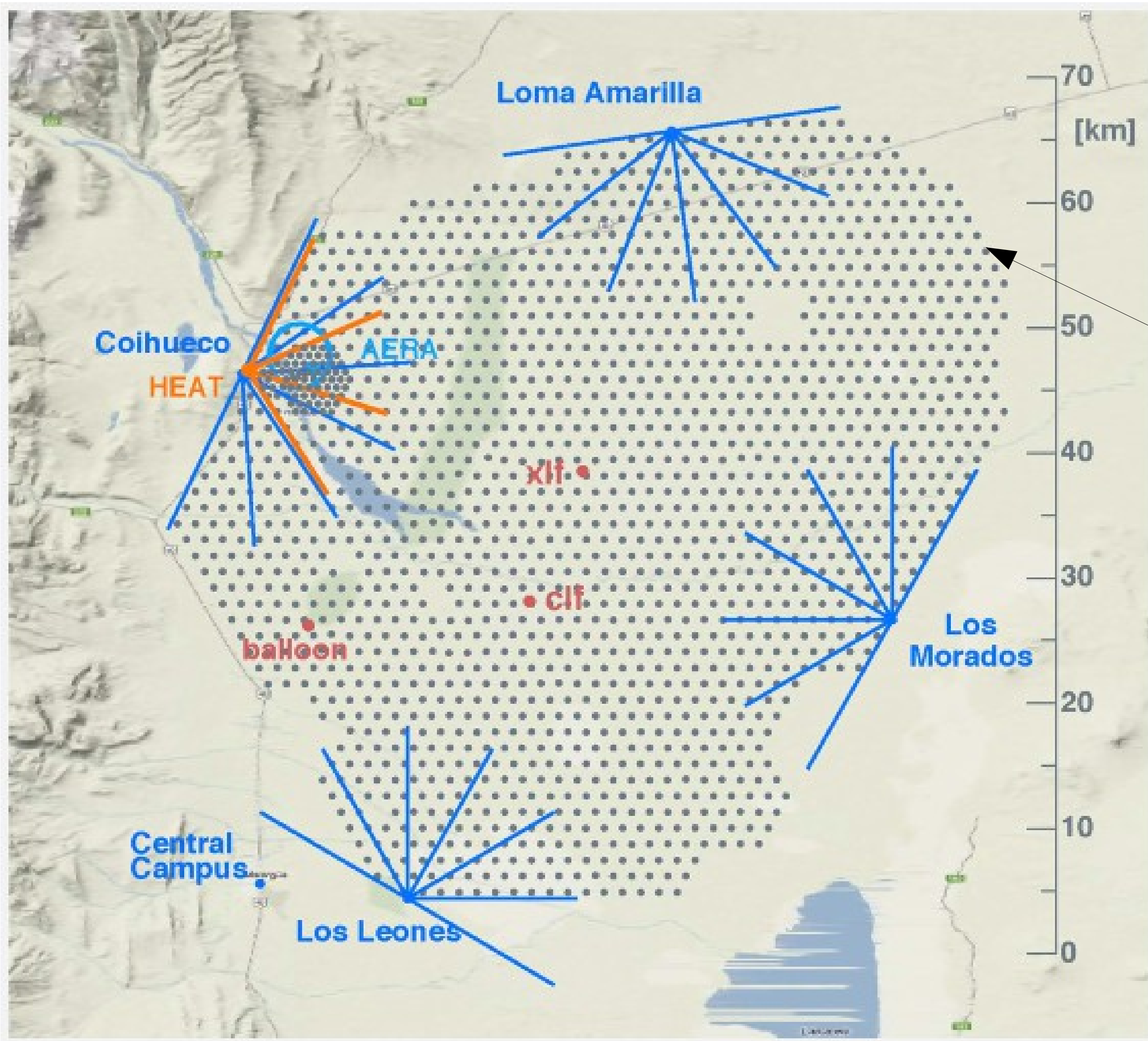
Even with a neutrino magnetic moment as small as the predicted by the standard model, the Huge magnetic fields In the SN explosions might generate observable differences in both spectra and number of neutrinos.



Fotones, neutrinos, rayos cósmicos



Detector


Loma Amarilla
Coihueco
HEAT
AERA
xlf
clf
balloon
Los Morados
Central Campus
Los Leones
70
[km]
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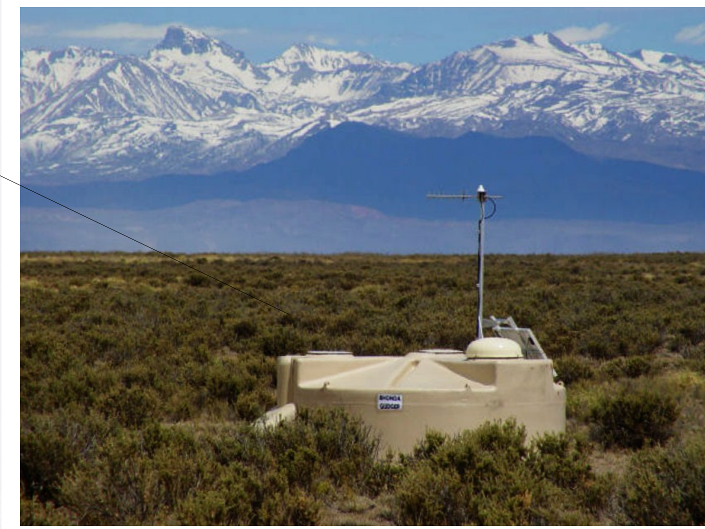
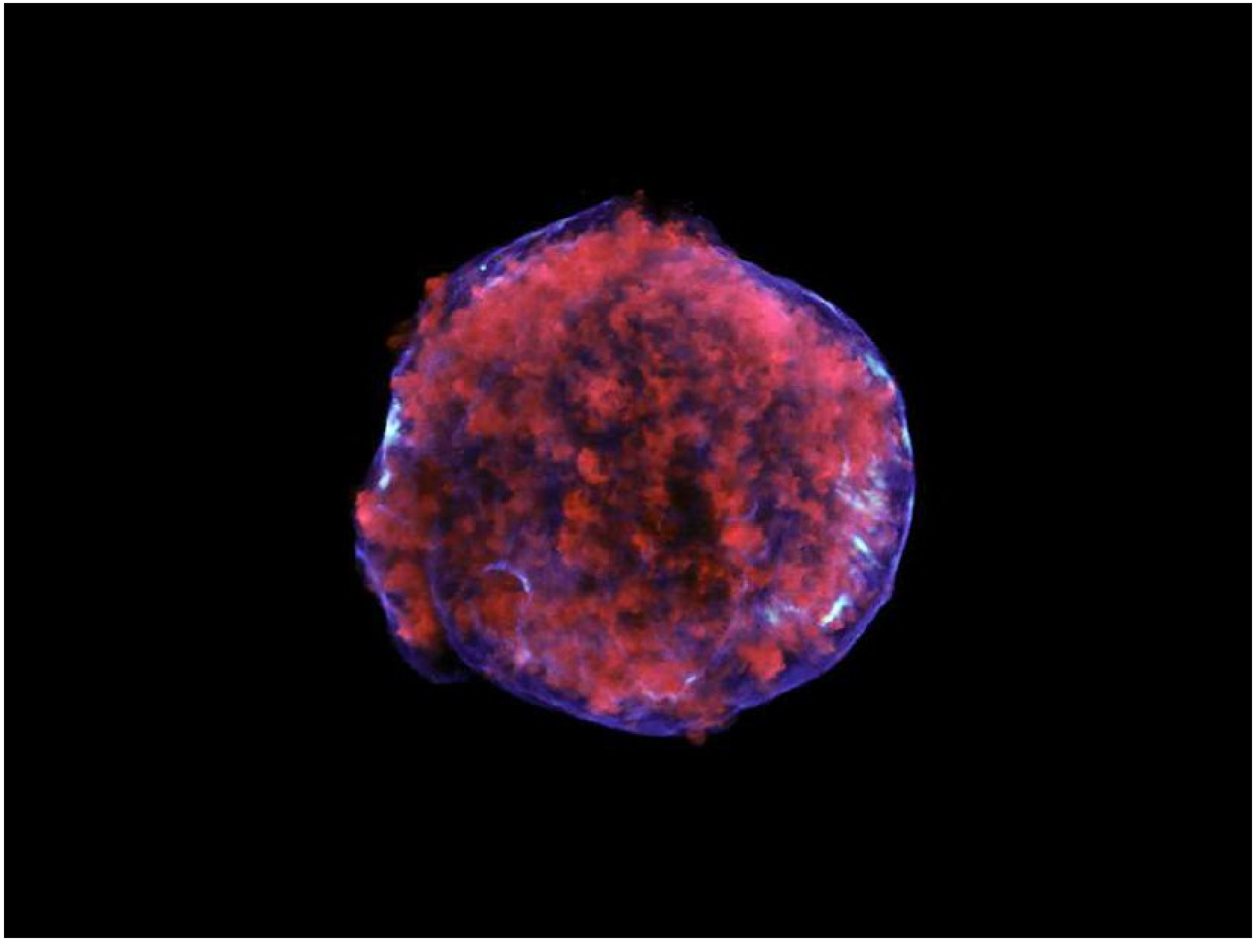
40
30
20
10
0



¿De donde provienen?



¿remanente de supernovas?

Universo invisible

DM does not have Interactions with SM

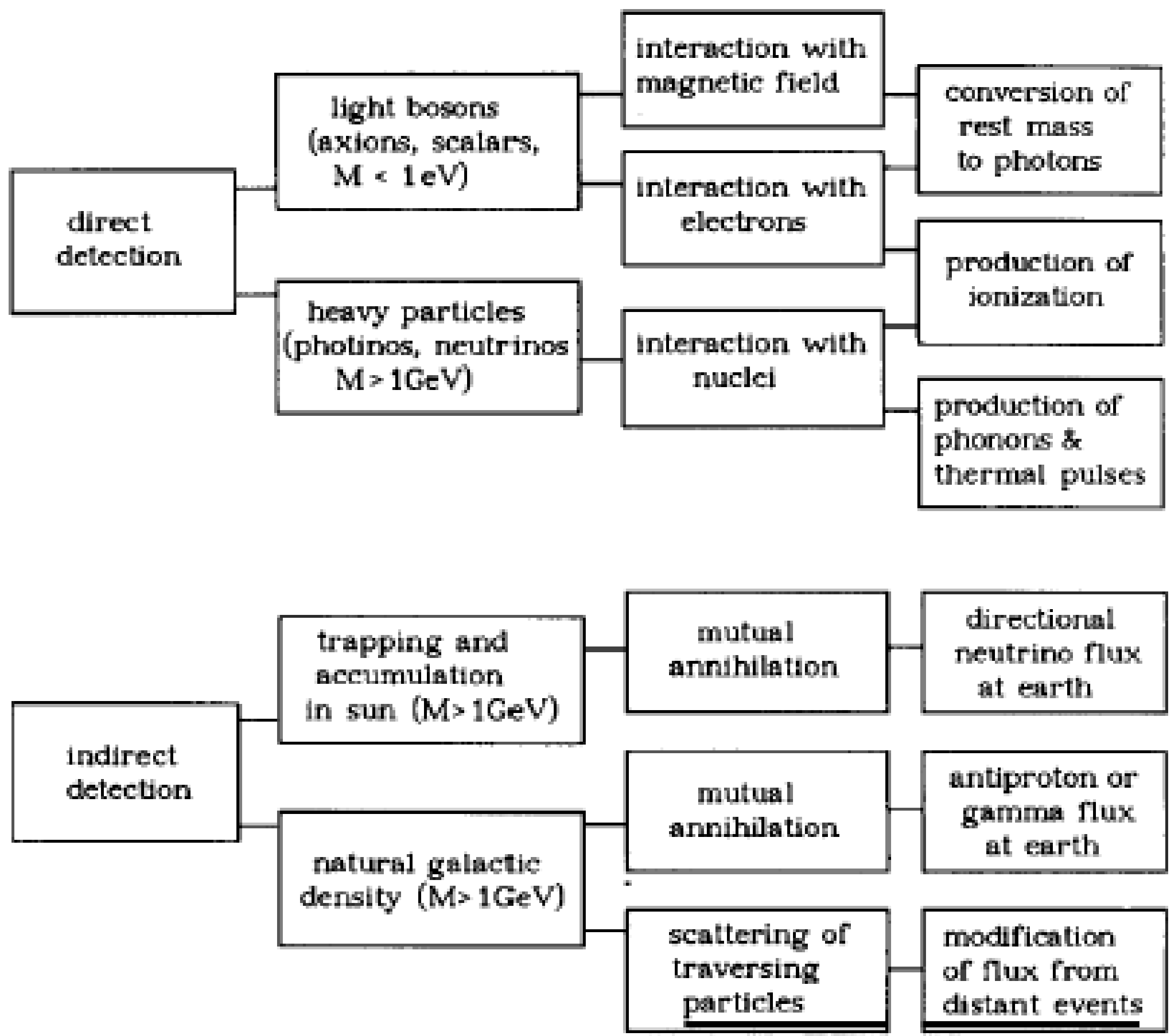
It is inferred form its Gravitational interaction with Visible matter (Rotation curves, SN1a)

How to detect directly the DM?

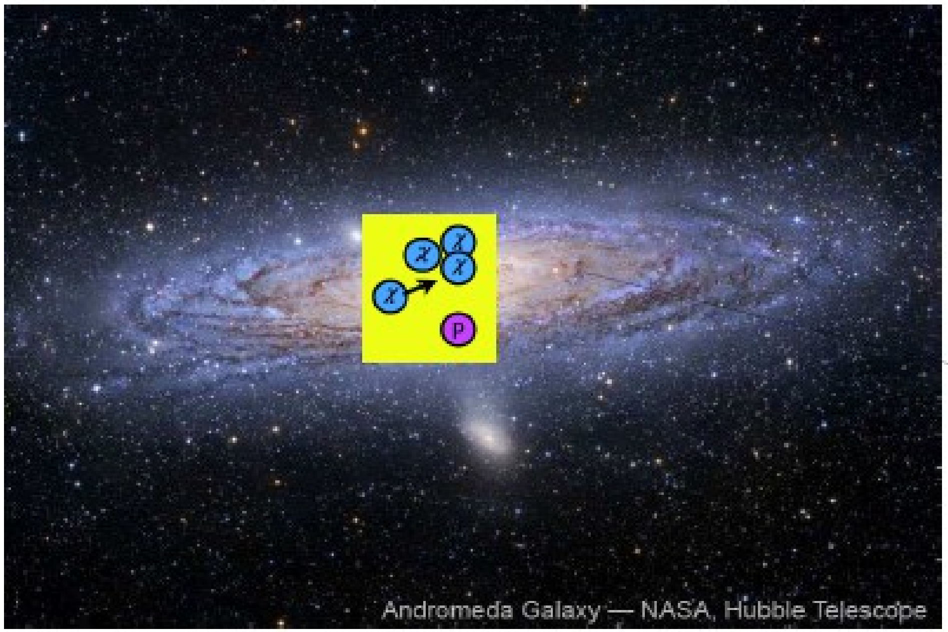
DM candidates SHOULD Couple to baryonic matter:
Neutralino (SUSY)
Axion

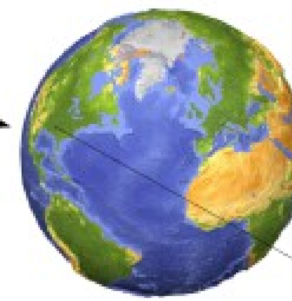
It is an interesting exercise to Couple DM with SM!!!

Detección de materia oscura



Detección indirecta





$$\frac{dN}{dt} = C - C_A N^2 \begin{cases} C \propto \sigma_{SD}\, \rho_{DM} \\ C_A \propto \langle \sigma v \rangle \end{cases}$$

Resumen

- Es una rama de la física de partículas que estudia a las partículas elementales de origen astronómico y su relación con astrofísica y cosmología.
- La física de astropartículas es un nuevo campo que surge de la intersección de:
  - Física de partículas
  - Astronomía
  - Astrofísica
  - Física de detectores
  - Cosmología
  - Física del estado sólido
  - Relatividad