Can we use climate change in neutron stars to detect dark matter?

ArXiv: 1901.0547

Daniel Camargo

CoCo - Cosmologia en Colombia

DARK MATTER AND WEAK INTERACTIONS (DARKWIN) CONFERENCE

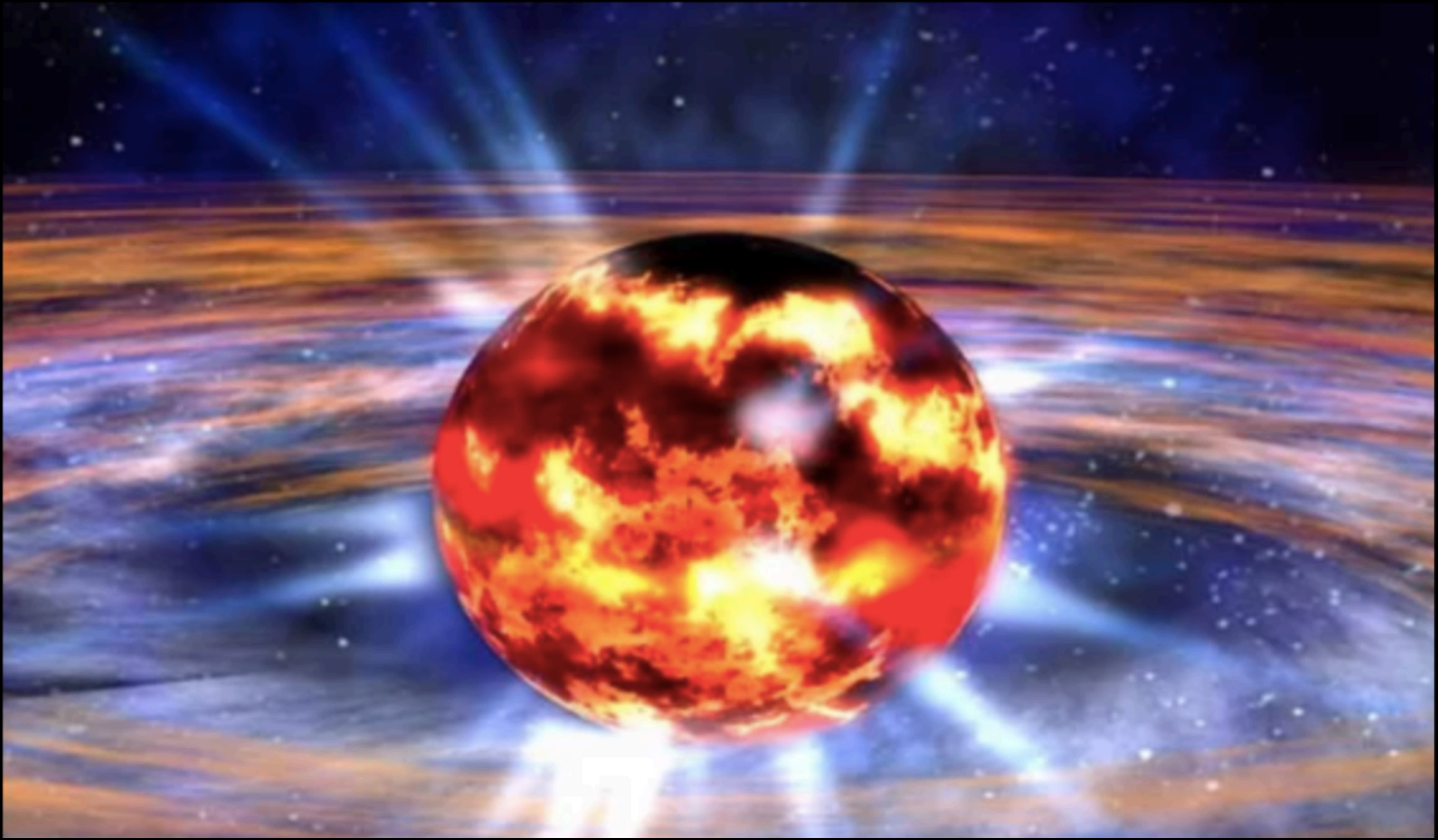
WORKSHOP | MON, SEP 02, 2019 | FRI, SEP 13, 2019

Directors:

Antonio Masiero (INFN)
Farinaldo Queiroz (IIP-UFRN)
Werner Rodejohann (Max Planck Insitute for Nuclear Physics)
Carlos Yaguna (Max Planck Institute)

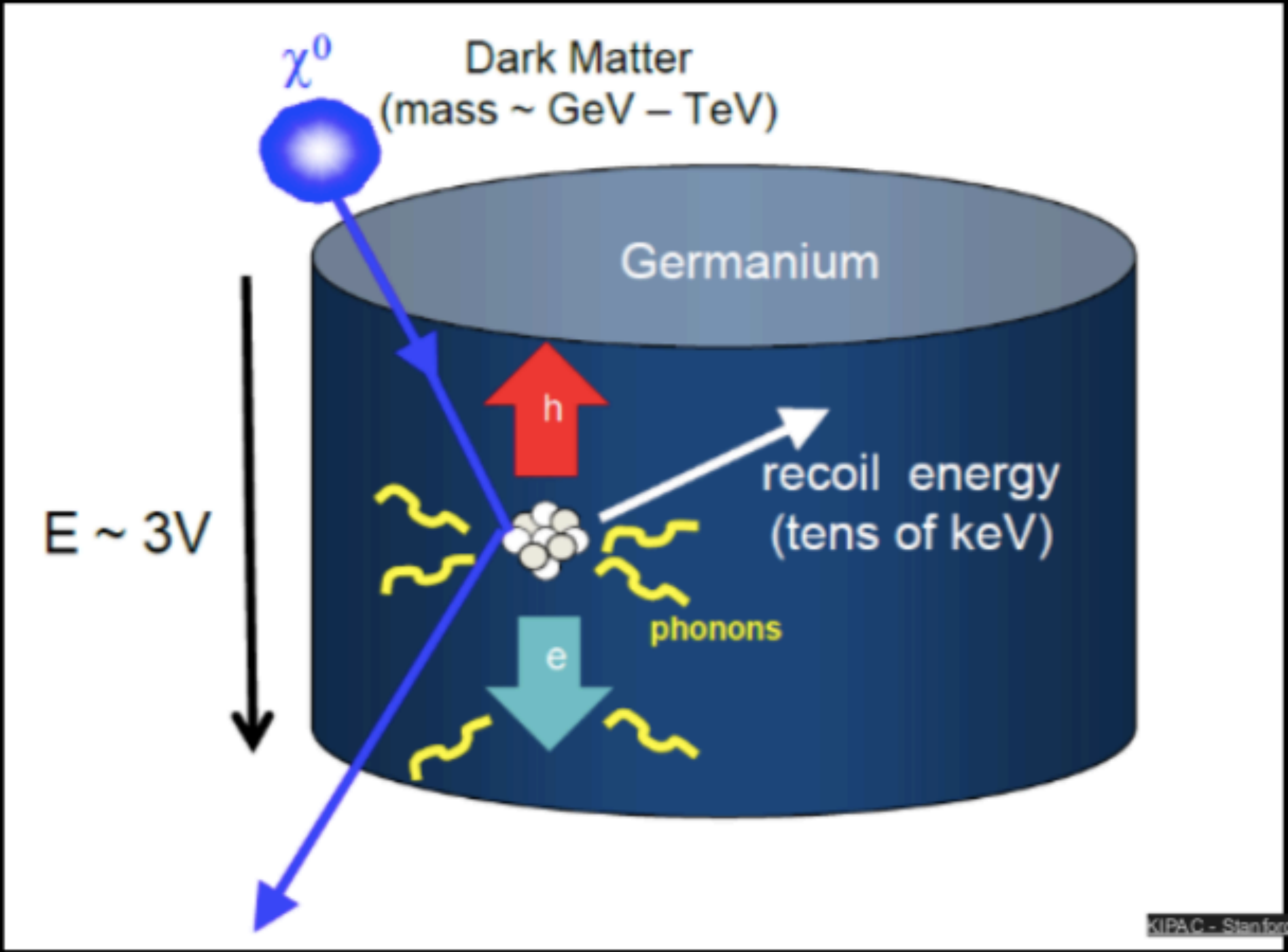
Dark Universe Workshop – Early Universe Cosmology, Baryogenesis and Dark Matter
October 21-25, 2019 **ICTP-SAIFR**

But why Neutron Stars with Dark Matter ?



What happens with direct detection on earth?

What happens on earth?



KIPAC - Stanford Universit

XENON...

A WIMP striking a nucleus will induce a recoil of energy given by

$$E_{\rm recoil} = \frac{|\vec{q}|^2}{2M_{\rm nucleus}} = \frac{2\mu^2 v^2(1-\cos\theta)}{2M_{\rm nucleus}} = \frac{m_X^2 M_{\rm nucleus}\, v^2(1-\cos\theta)}{(m_X + M_{\rm nucleus})^2},$$

where $\vec{q}$ is the WIMP's momentum, v is its velocity, and μ is the reduced mass. For $m_X \gg M_{\rm nucleus}$ and a velocity of $\sim$300 km/s, we expect typical recoil energies of $E_{\rm recoil} \sim M_{\rm nucleus}\, v^2 \sim$ 1-100 keV.

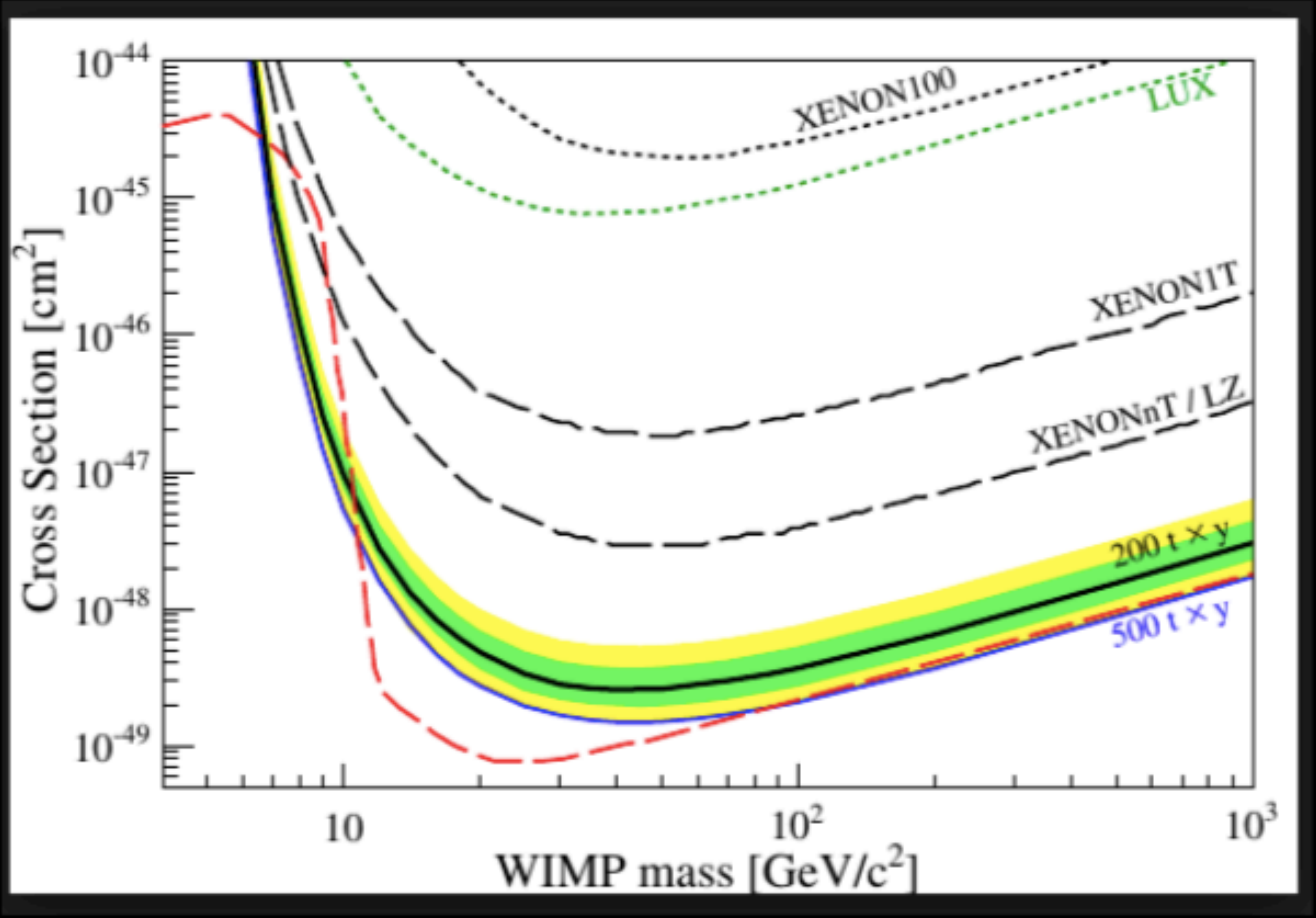
WIMPs scatter with nuclei in a target at a rate given by

$$R \approx \int_{E_{\rm min}}^{E_{\rm max}} \int_{v_{\rm min}}^{v_{\rm max}} \frac{2\rho}{m_X} \frac{d\sigma}{d|\vec{q}|}\, v\, f(v)\, dv\, dE_{\rm recoil},$$

where ρ is the dark matter density, σ is the WIMP-nuclei elastic scattering cross section, and $f(v)$ is the velocity distribution of WIMPs. The limits

How E is distributed ?

What happens on earth?



https://darwin.physik.uzh.ch/news.html

What happens on earth?

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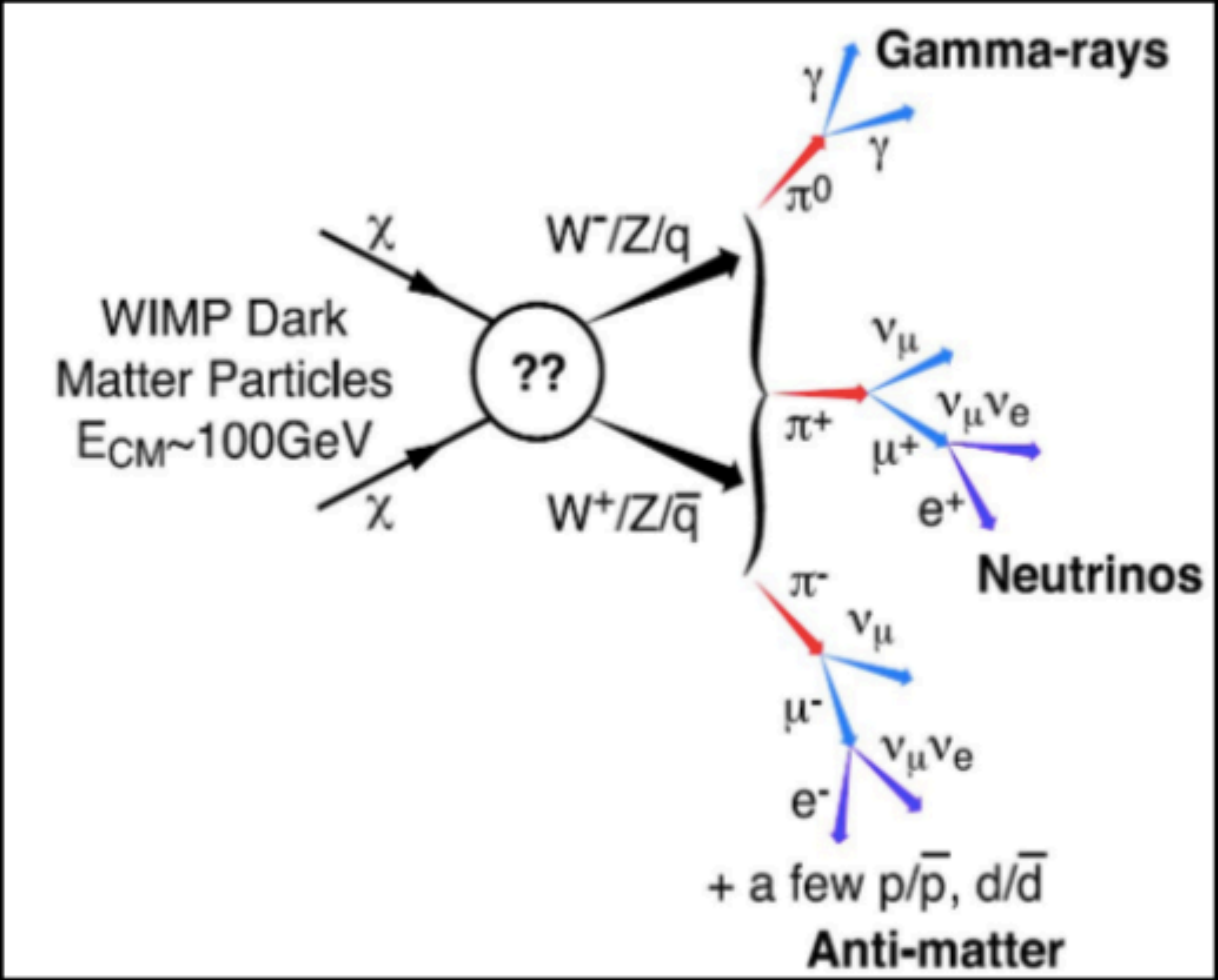

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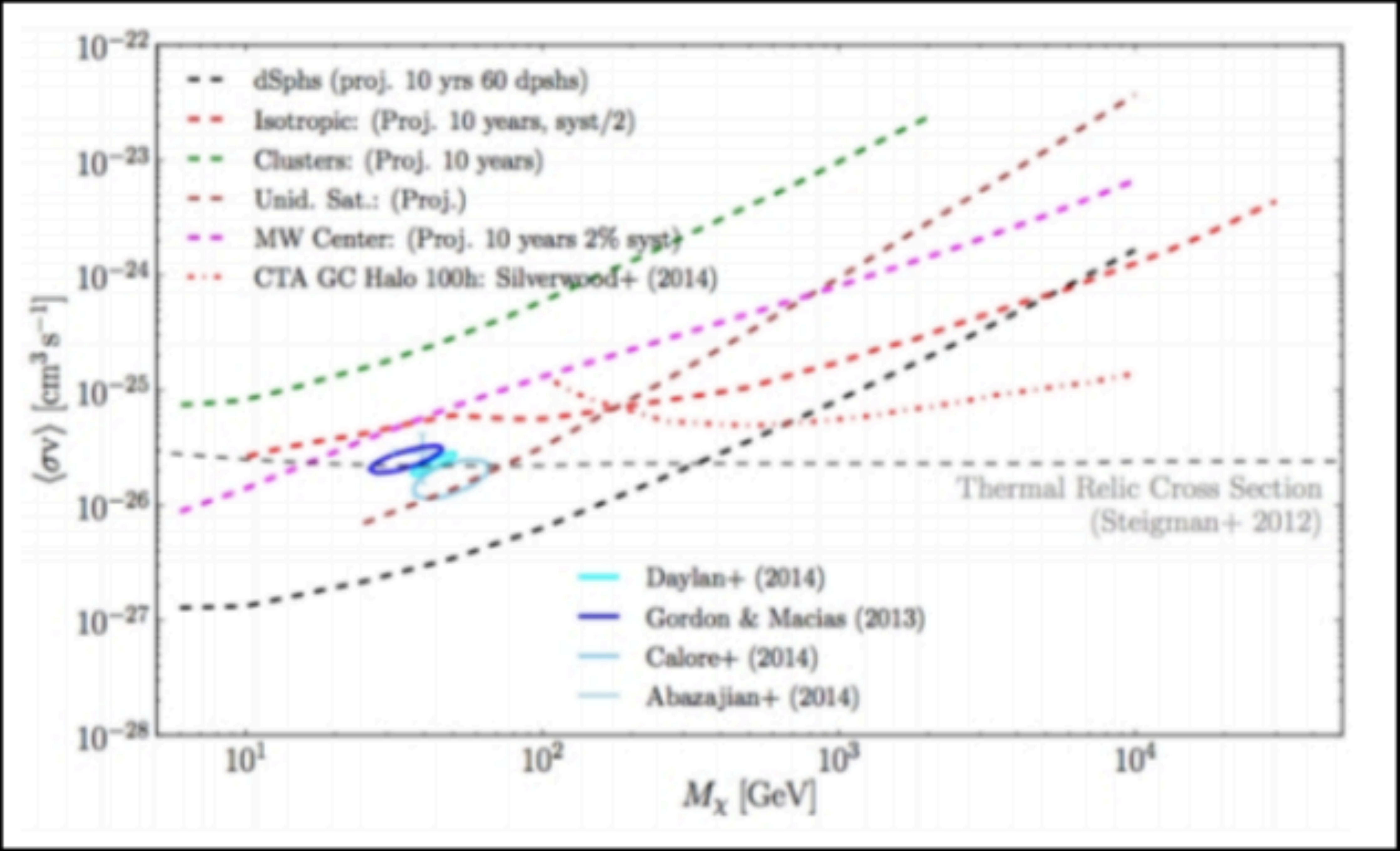

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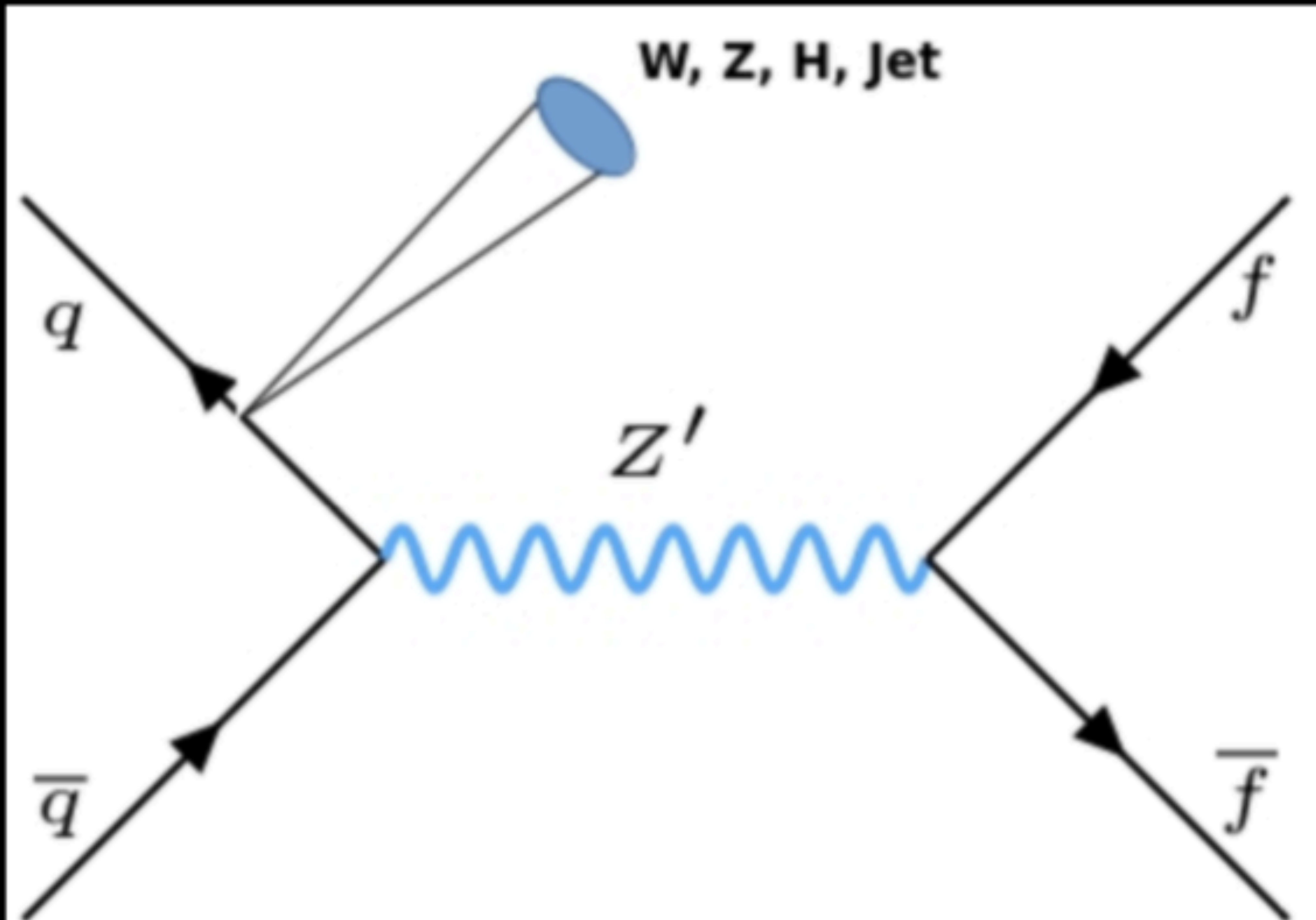


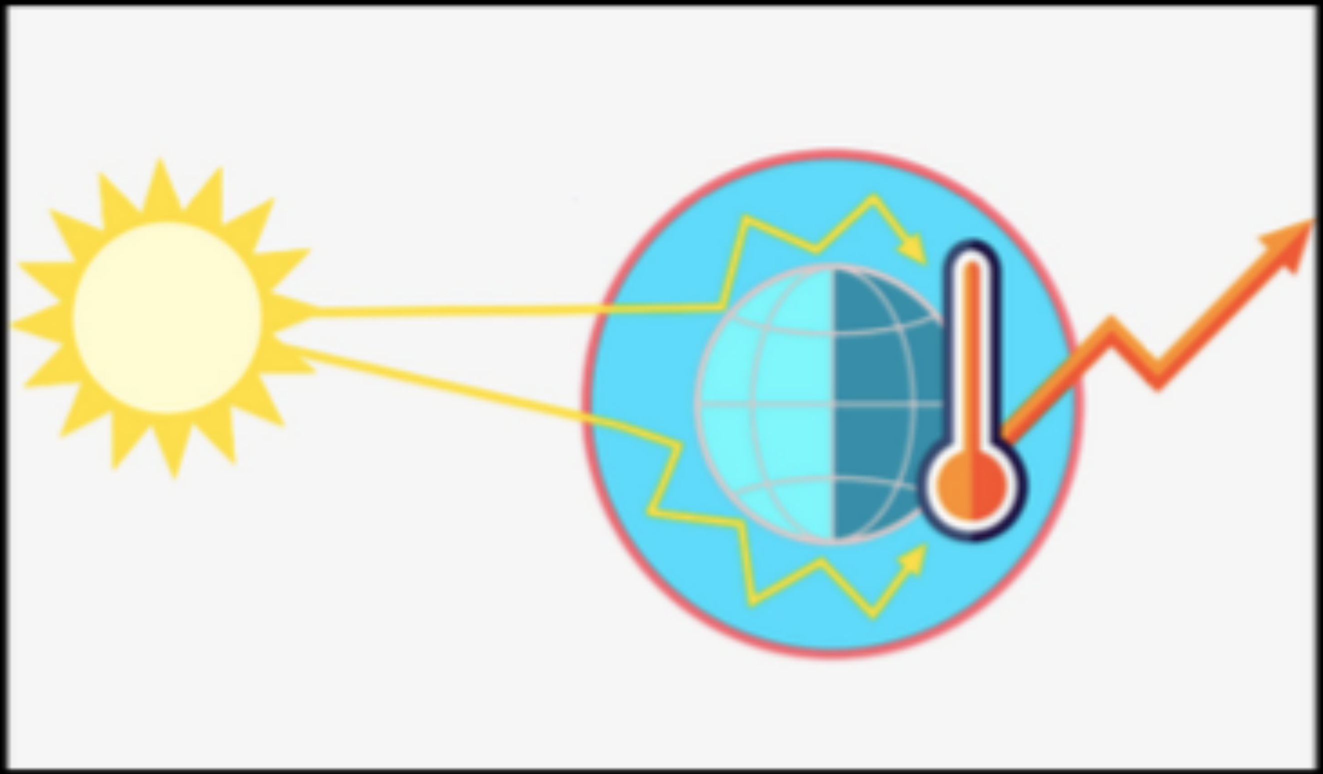
F. Queiroz Conference: C16-03-12, p.427-436

What happens on earth?

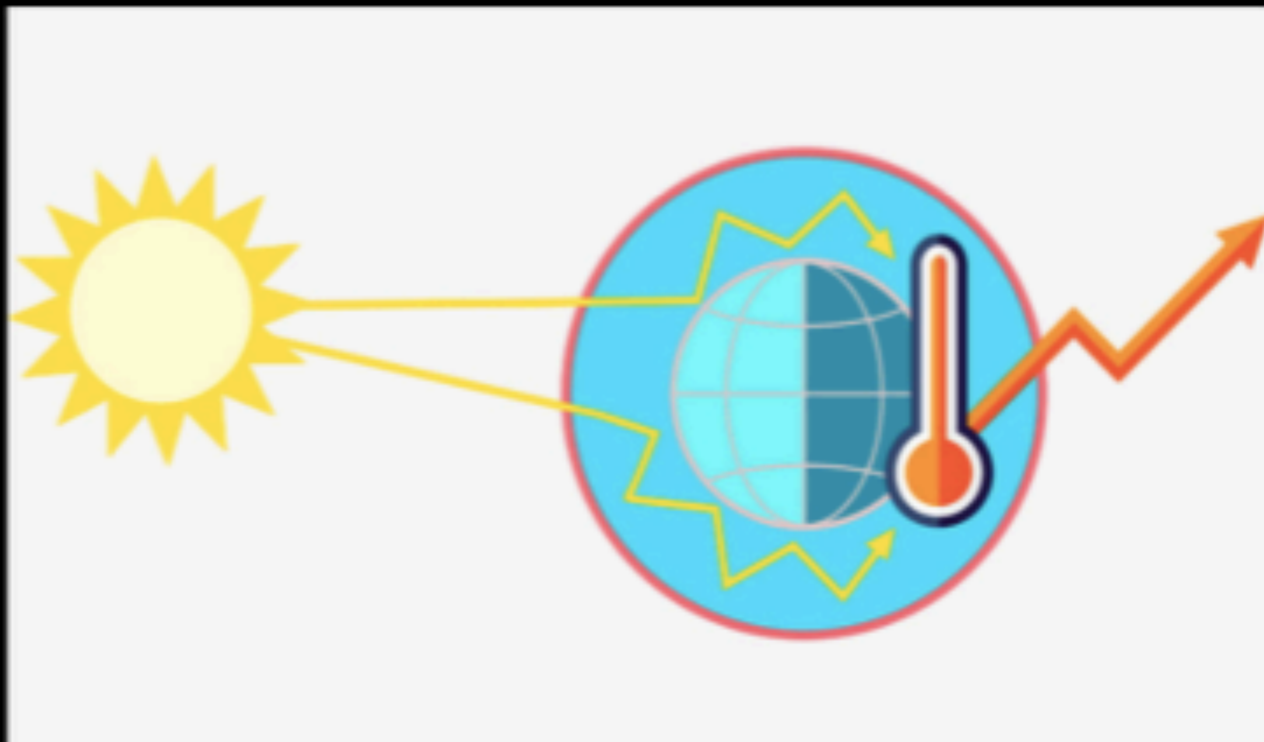
What happens on earth?

Can Dark matter scattering with nucleons heat up the earth?

caracteristicas.co



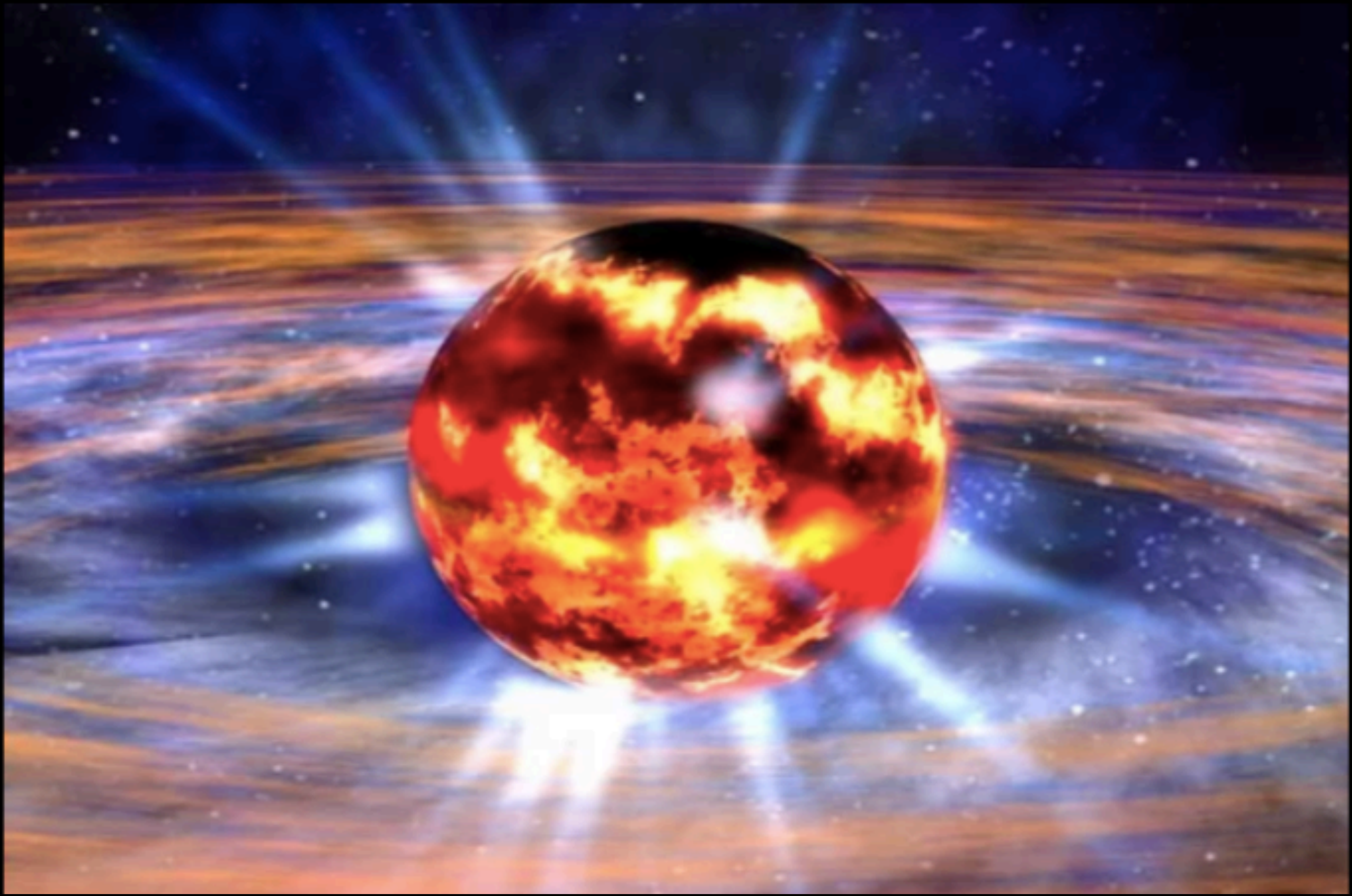
In general, a lot of “events”



A lot of interactions!

Dodecahedron Books

What about more compact objects?



Neutron Stars

The smallest and densest stars

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Typical radios 10 km and 1.4-2.6 solar mass

They can be easily detected if they are pulsar or part of a binary system

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Neutron stars have overall densities of 3.7×10^{17} to 5.9×10^{17} kg/m^3 (2.6×10^{14} to 4.1×10^{14} times the density of the Sun),

The equation of state → QCD+ Superfluidity + Superconductivity

Neutron Stars and Dark Matter

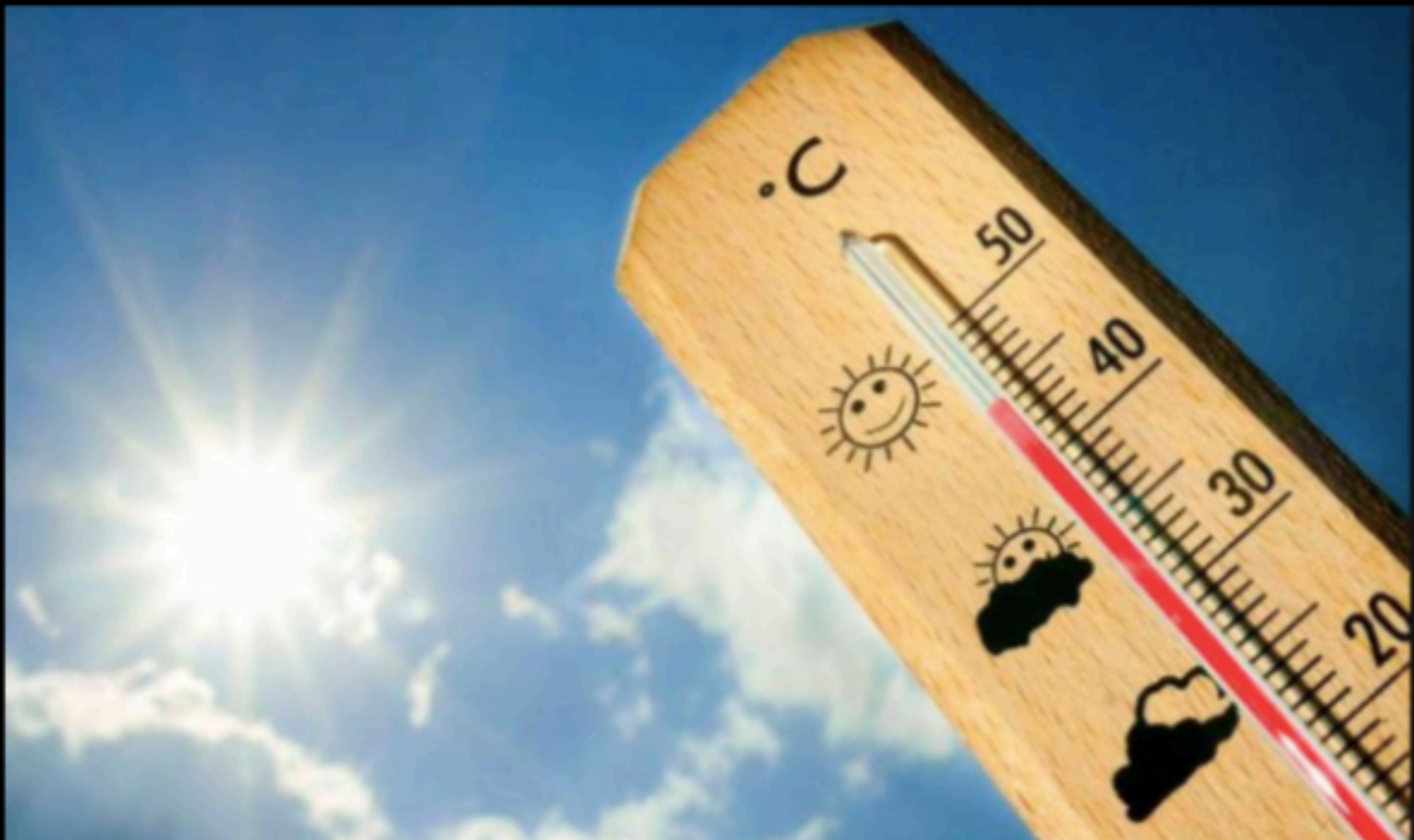
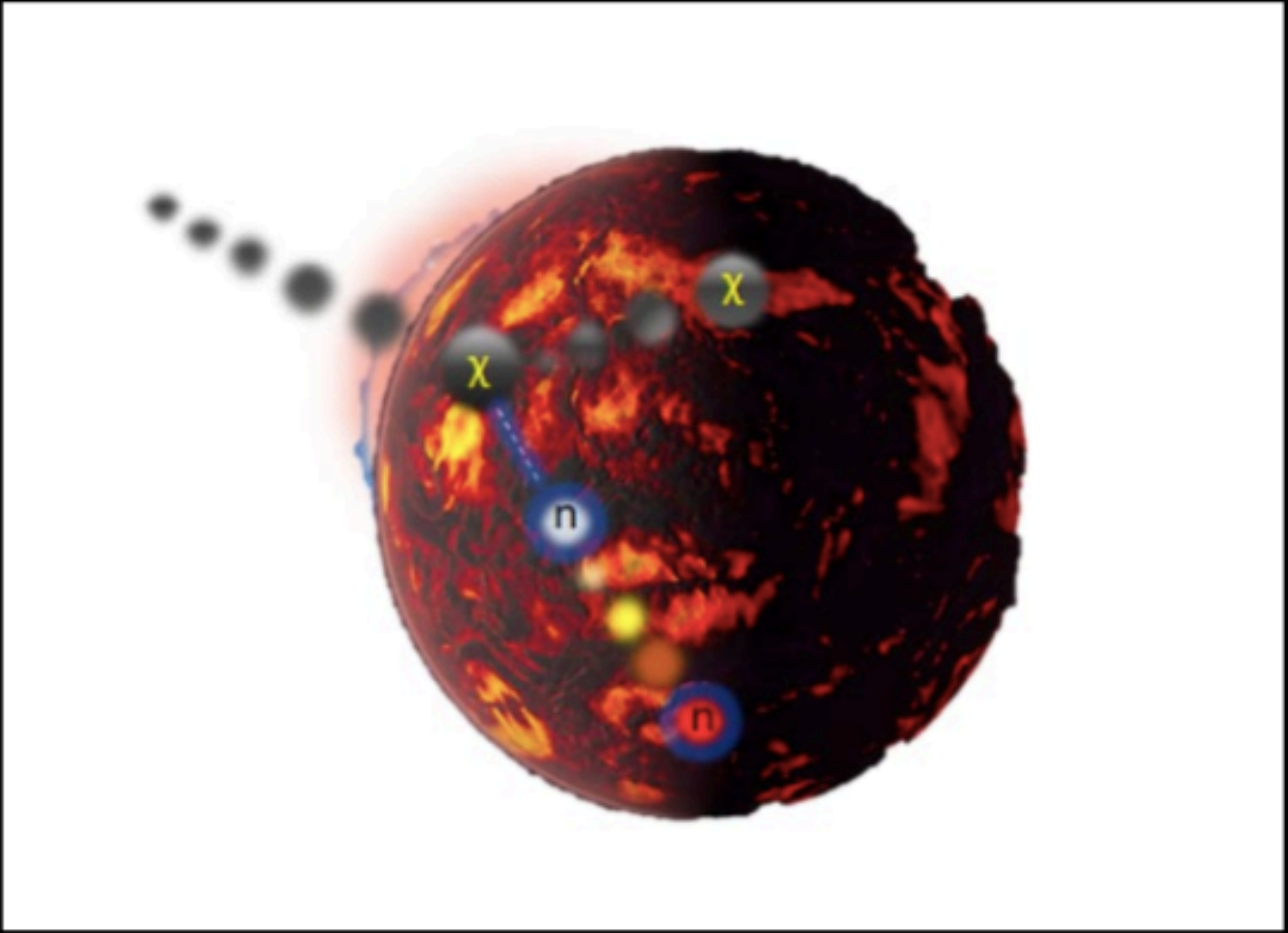
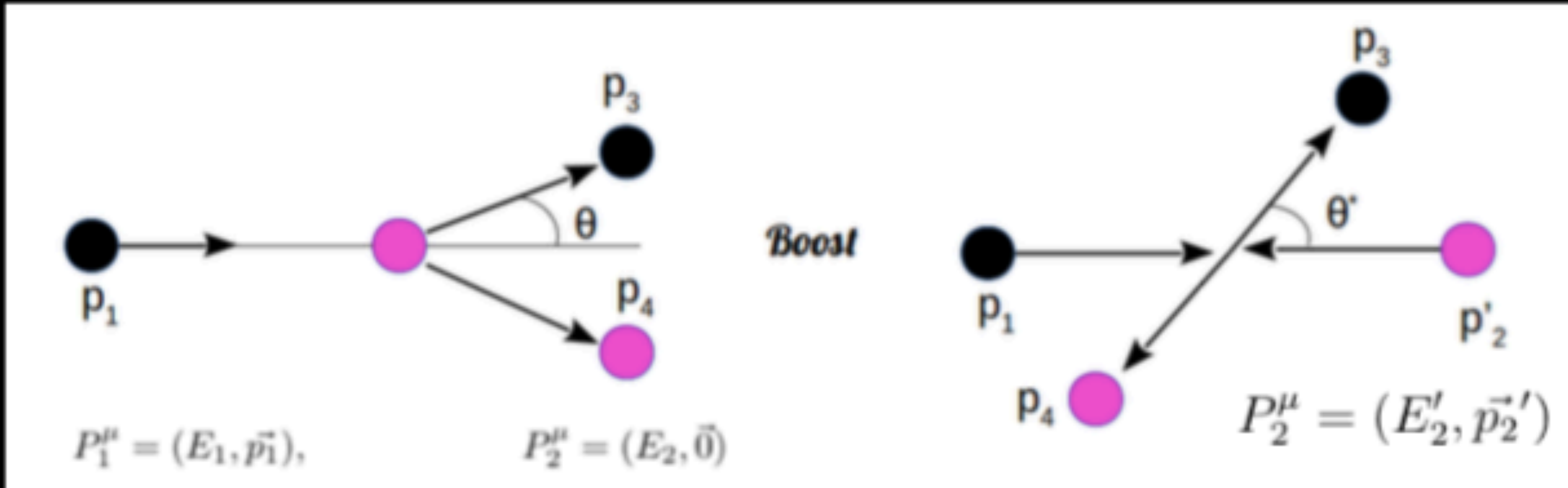


Foto: ARCHIVO / END Ampliar.

let’s see!



Neutron Stars and Dark Matter



$$\Delta E_\chi = E_4 - E_2$$

$$\Delta E = \frac{\gamma^2 m_1^2 v_1^2 (1 - cos\theta^*)}{m_1^2 + m_2^2 + 2\gamma m_1 m_2} E_2$$

Neutron Stars and Dark Matter

So what?

Neutron Stars and Dark Matter

$$E_\chi = m_\chi + K_\chi = \gamma m_\chi \longrightarrow K_\chi = m_\chi(\gamma - 1)$$

$$K_\chi^\infty = k_\chi^R - \frac{GMm_\chi}{R}$$

$$m_\chi(\gamma^\infty - 1) = m_\chi(\gamma^R - 1) - \frac{GMm_\chi}{R}$$

$$\gamma^R = \gamma^\infty + \frac{GM}{R}$$

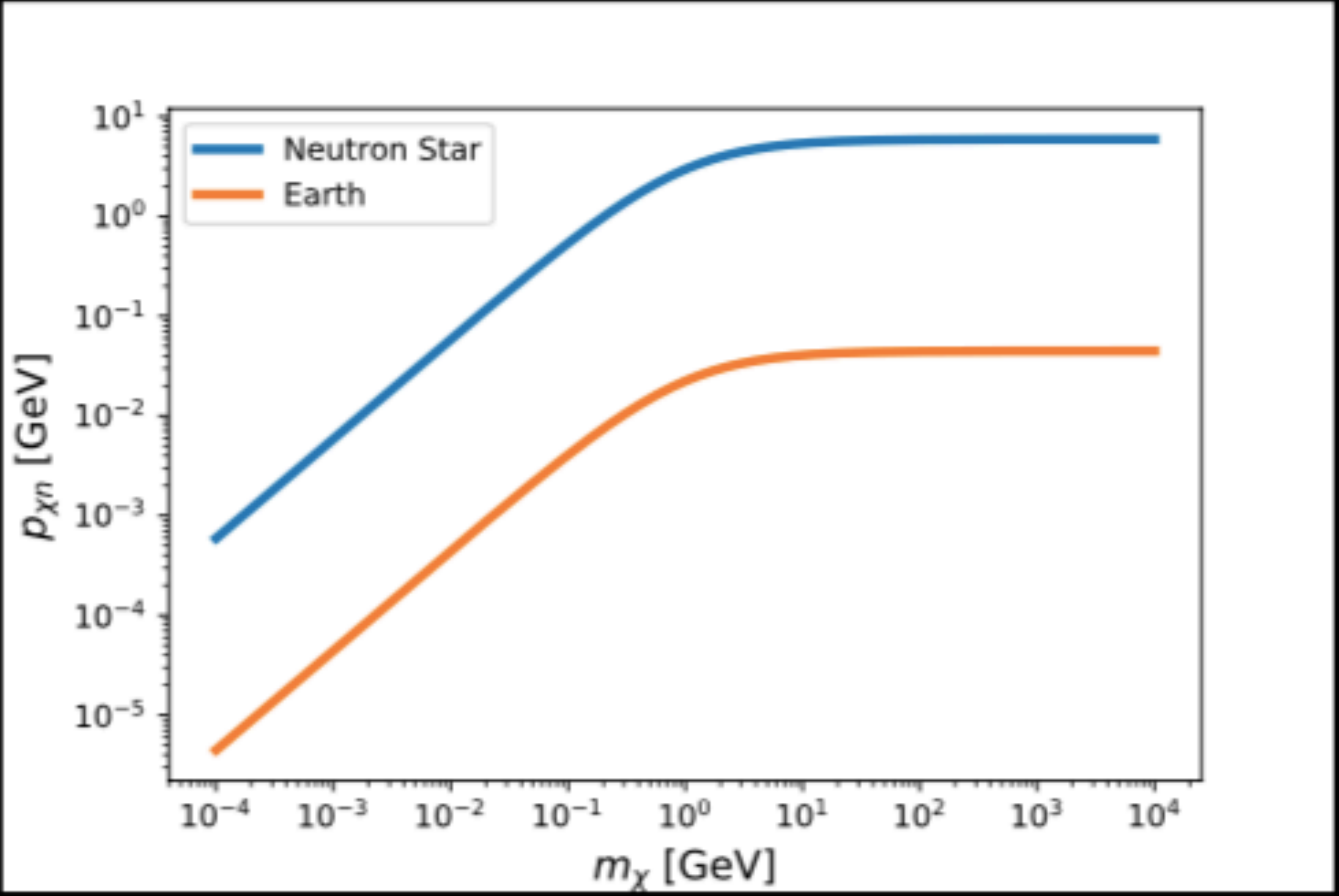
Neutron Stars and Dark Matter

$$v_\chi^2 = v_\infty^2 + \frac{2GM}{R} = v_\infty^2 + v_{esc}^2$$

$$\Delta E = \frac{\gamma^2 m_1^2 (v_\infty^2 + v_{esc}^2)(1 - cos\theta^*)}{m_1^2 + m_2^2 + 2\gamma m_1 m_2} E_2$$

Neutron Stars and Dark Matter

$$\Delta E = \frac{\gamma^2 m_1^2 (v_\infty^2 + v_{esc}^2)(1 - cos\theta^*)}{m_1^2 + m_2^2 + 2\gamma m_1 m_2} E_2$$



Neutron Stars and Dark Matter

$$\mathcal{L}_\star = \dot{E} = \frac{E_\chi^R \dot{m}}{m_\chi} f = 4\pi\sigma_B R^2 T_\star^4$$

$$f = min(\sigma_{\chi n}/\sigma_S, 1)$$

Neutron Stars and Dark Matter

$$\mathcal{L}_\star = \dot{E} = \frac{E_\chi^R \dot{m}}{m_\chi} f = 4\pi\sigma_B R^2 T_\star^4$$

$$T_{NS} = T_\star \sqrt{1 - \frac{2GM_\star}{R}}$$

$$T_{NS} = \left[\frac{(\gamma^R - 1) b_{max}^2 v_\chi \rho_\chi}{\sigma_B R^2}\right]^{1/4} \left(1 - \frac{2GM_\star}{R}\right)^{\frac{1}{2}} f^{1/4}$$

$$T_{NS} \sim 1750 f^{1/4} [K]$$

Neutron Stars and Dark Matter

Test some particle models :)

Neutron Stars and Dark Matter

$$L \supset g\bar{\chi}\chi\phi + g\bar{q}q\phi$$

$$L \supset g\bar{\chi}\chi\phi + g\bar{q}\gamma^5 q\phi$$

$$L \supset g\bar{\chi}\gamma^5\chi\phi + g\bar{q}\gamma^5 q\phi$$

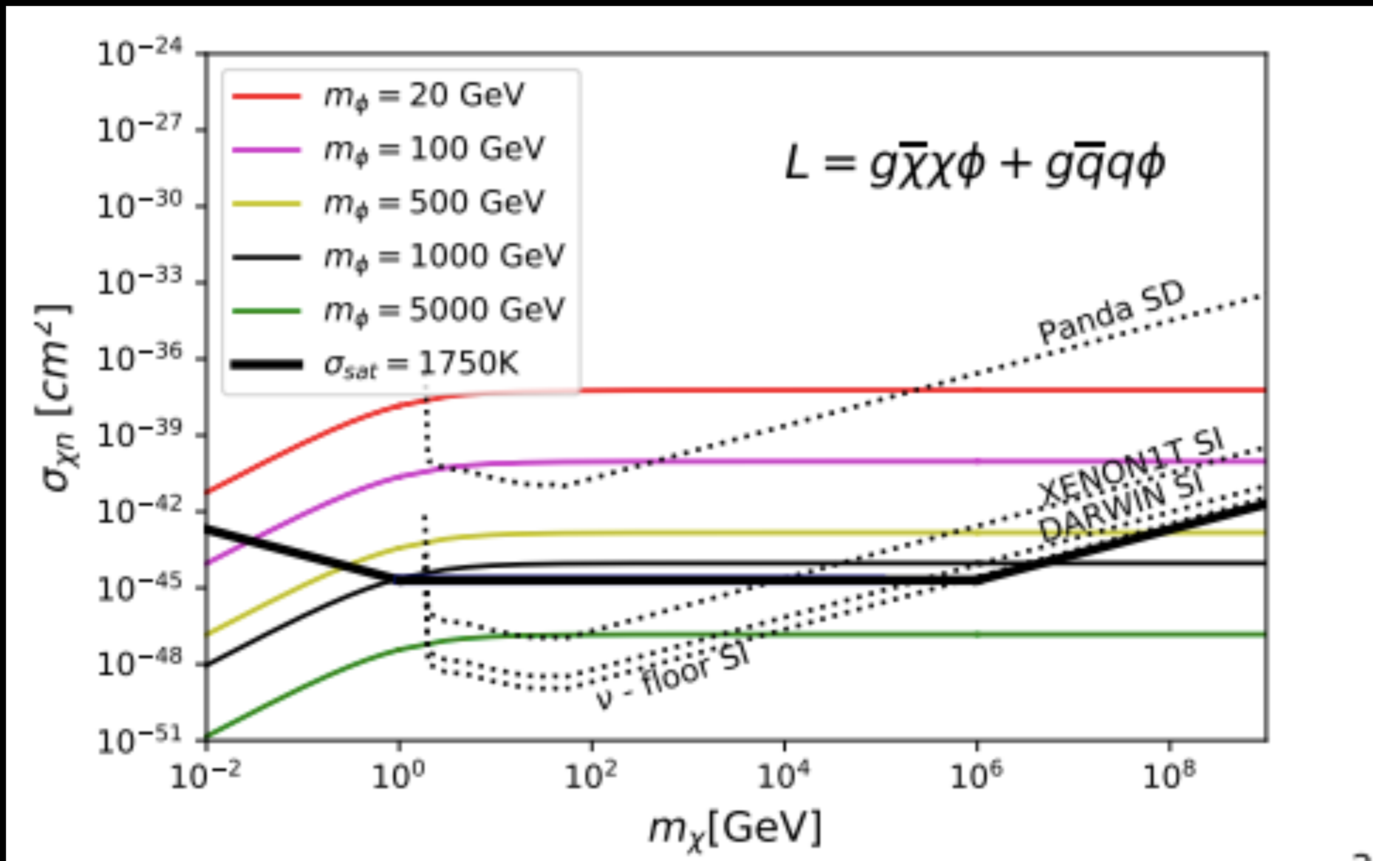
Neutron Stars and Dark Matter

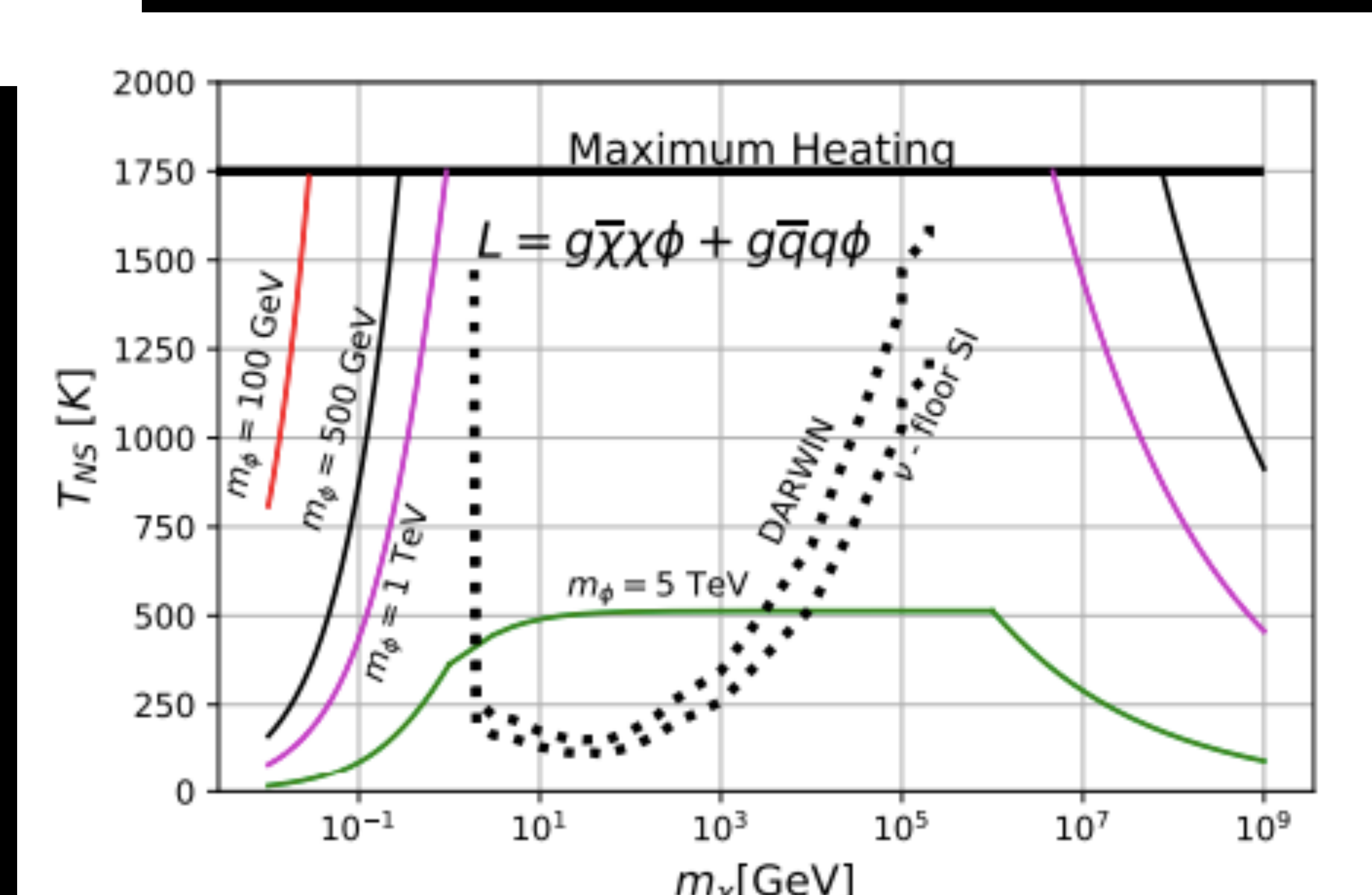
$$\frac{d\sigma_{\chi n}}{d\Omega}_S \rightarrow \frac{d\sigma_{\chi q}}{d\Omega}_S c_N^S,$$

$$\frac{d\sigma_{\chi n}}{d\Omega}_{SP} \rightarrow \frac{d\sigma_{\chi q}}{d\Omega}_{SP} c_N^S,$$

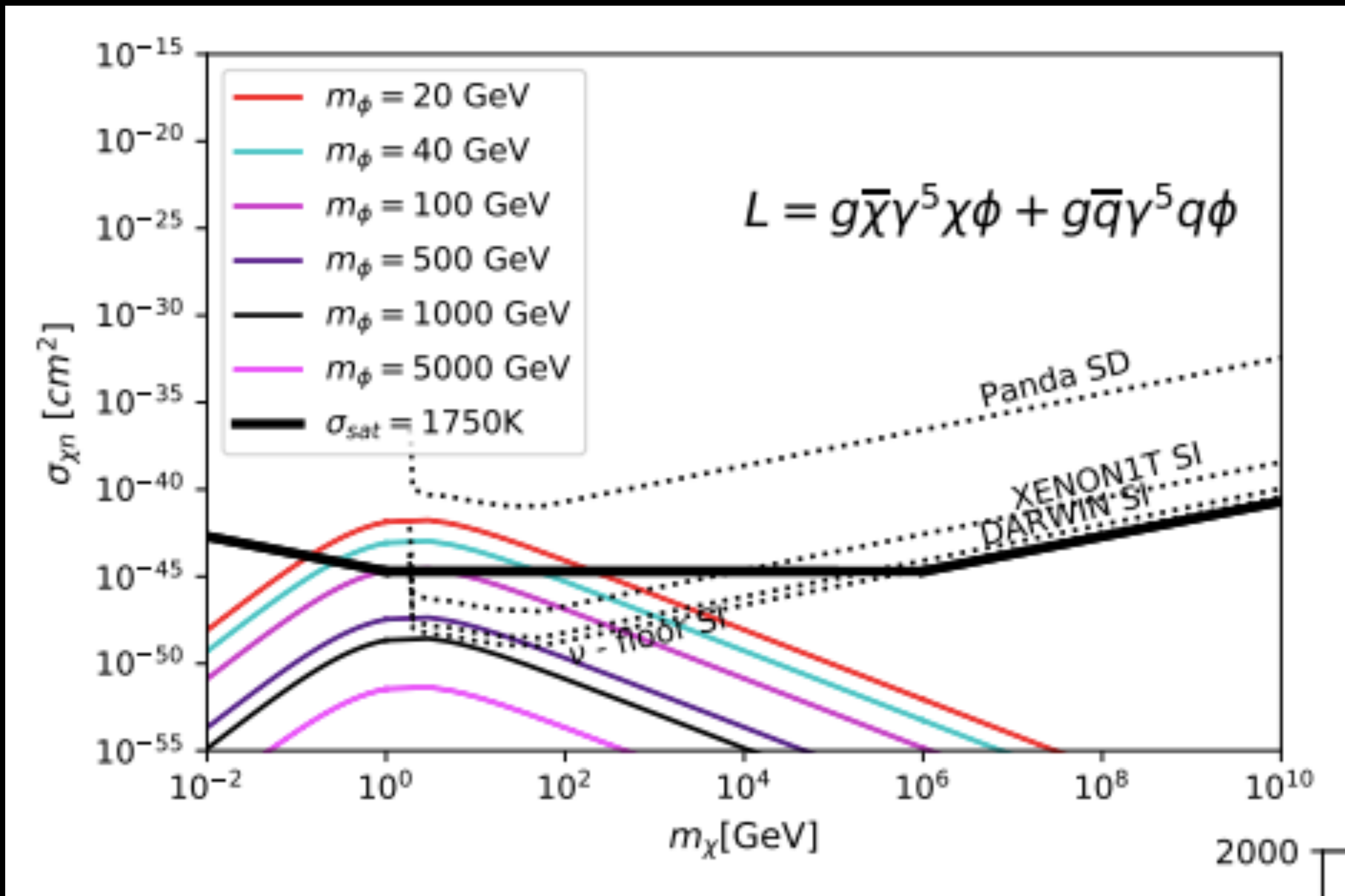
$$\frac{d\sigma_{\chi n}}{d\Omega}_{PP} \rightarrow \frac{d\sigma_{\chi q}}{d\Omega}_{PP} c_N^P,$$

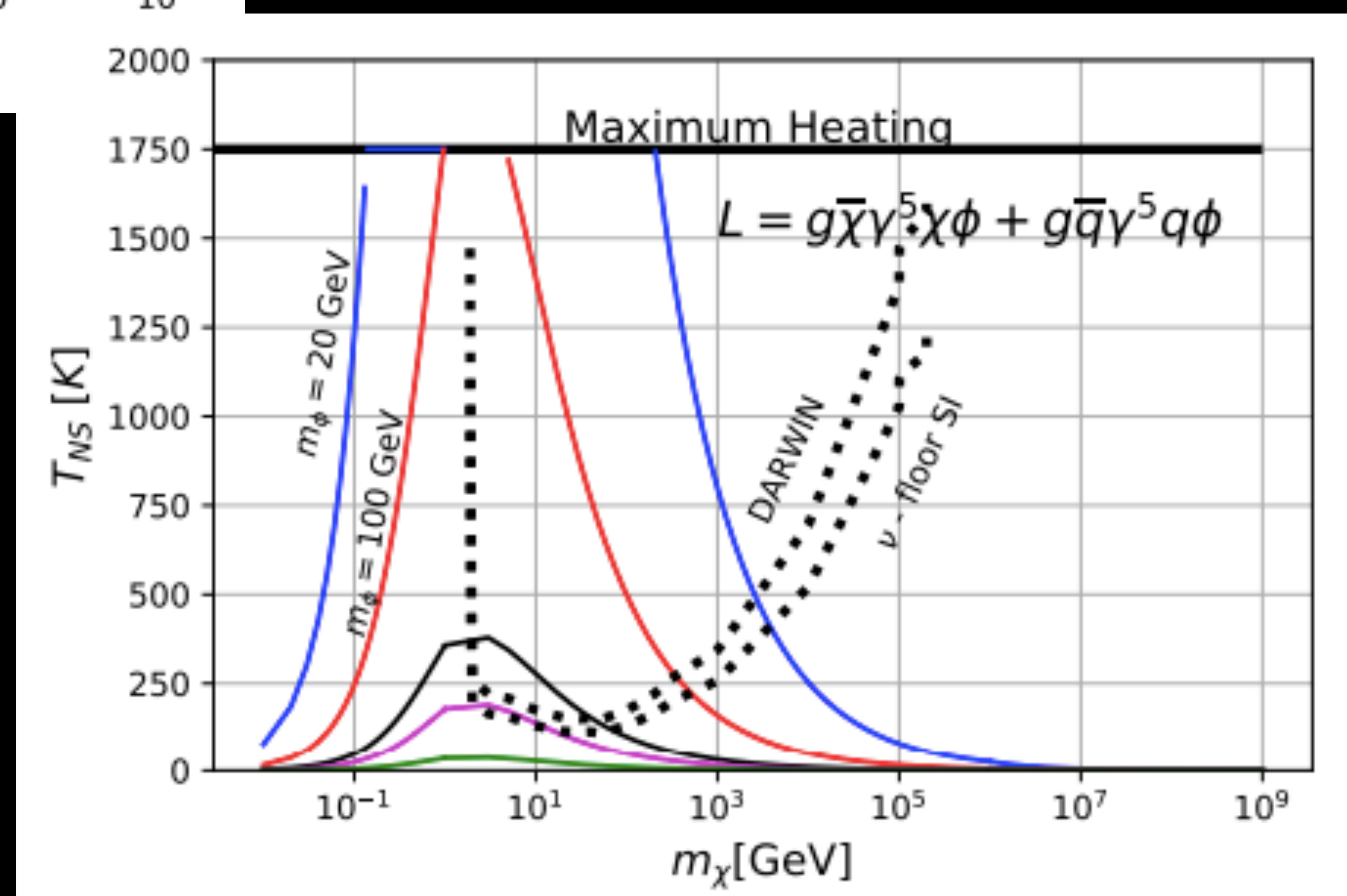
Dark Matter and Neutron Stars



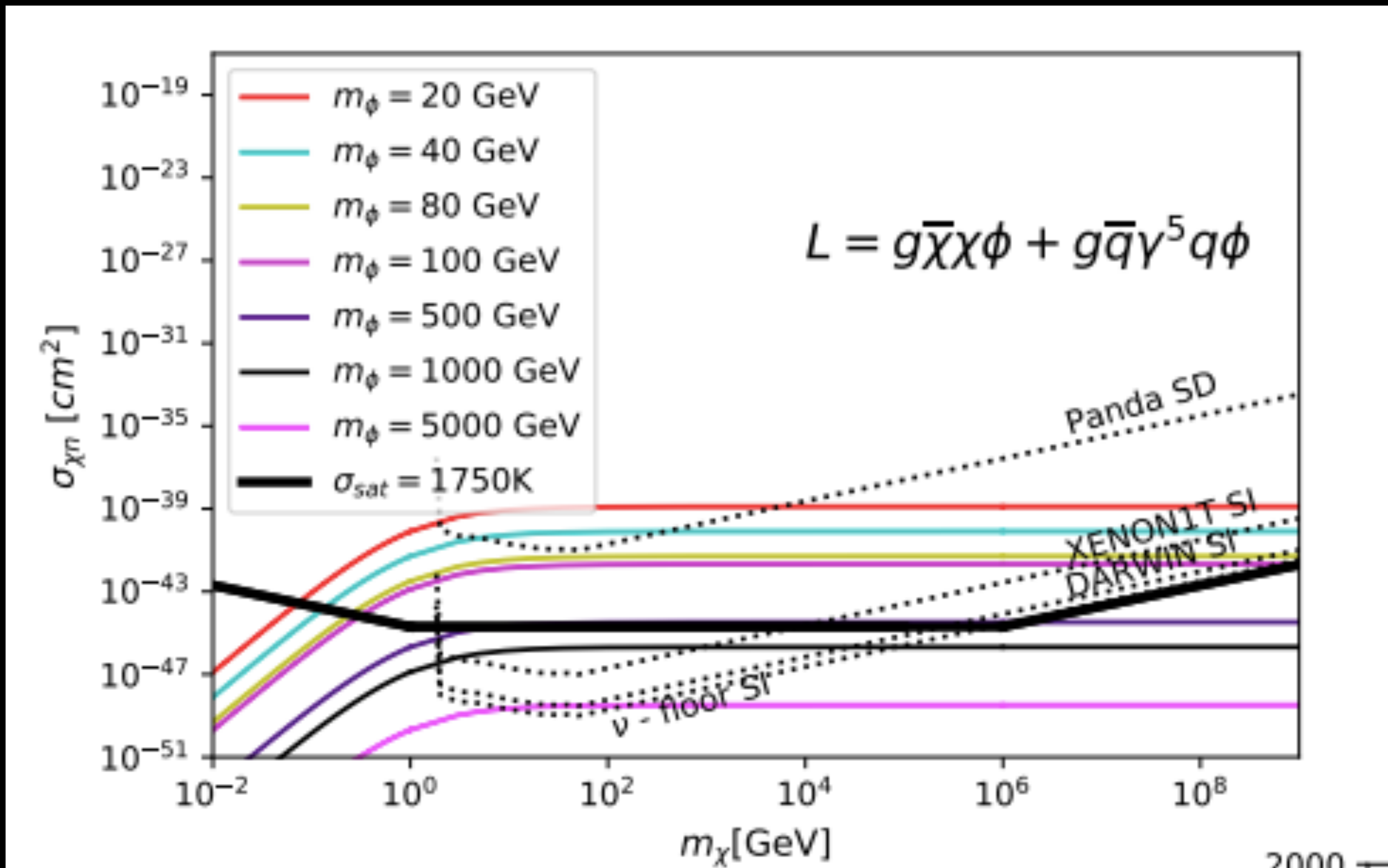


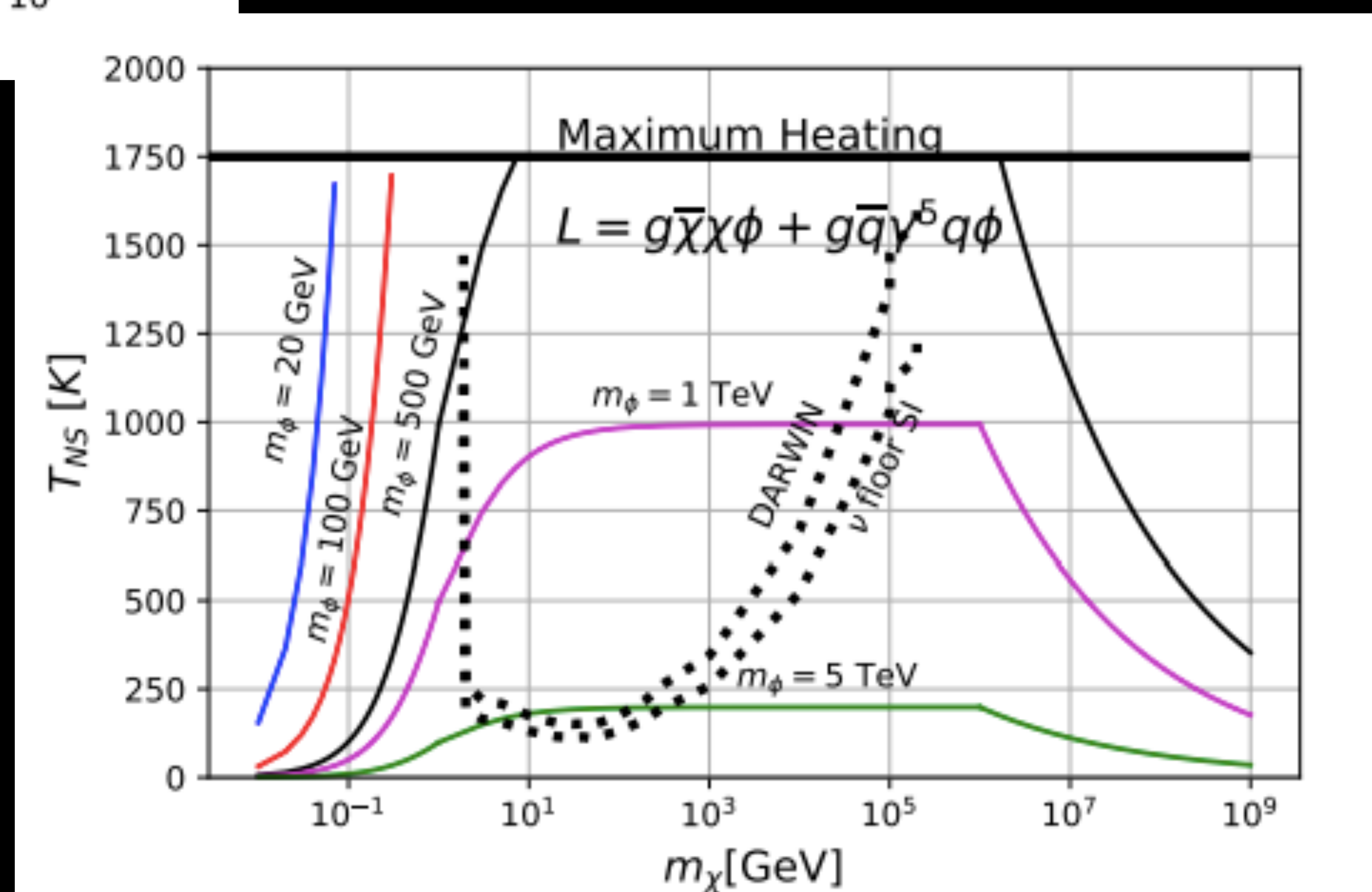
Dark Matter and Neutron Stars



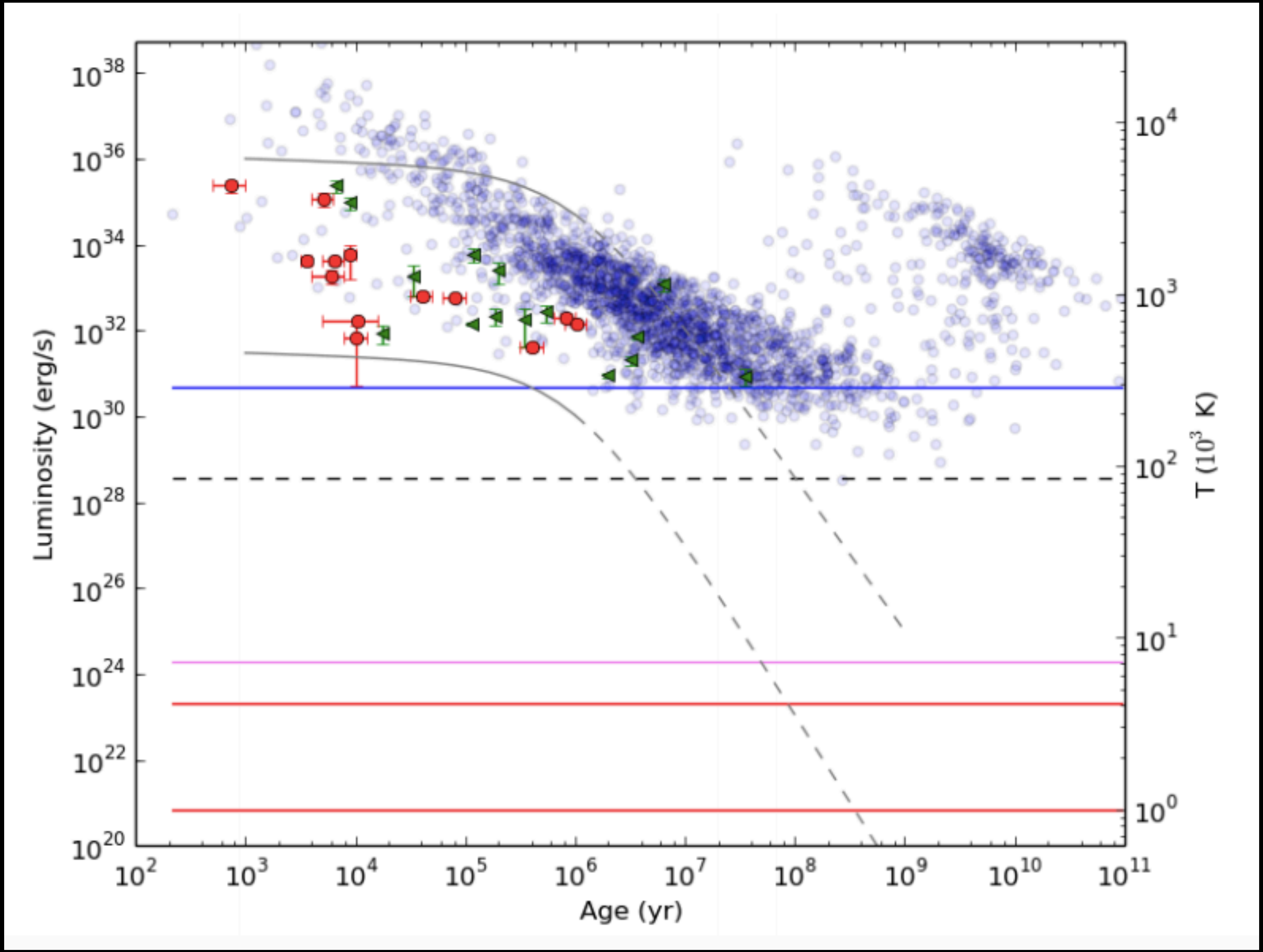


Dark Matter and Neutron Stars





Dark Matter and Neutron Stars



Take to home!

Dark matter its still an OPEN question in physics

We need more observations