PVLAS and the STARS

PVLAS OPEN DAY
Trieste, October 2006

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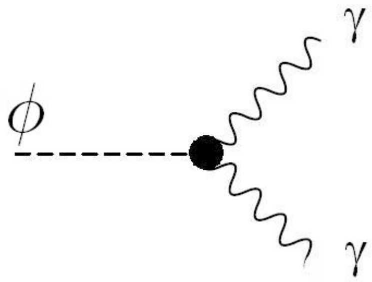
Light bosons coupled to $\gamma\gamma$



- **Pseudoscalar coupled to $\gamma\gamma$**

$$\mathcal{L}_{\phi\gamma\gamma} = \frac{1}{8}\, g_{\phi\gamma\gamma}\; \phi\; \epsilon^{\mu\nu\alpha\beta} F_{\mu\nu} F_{\alpha\beta}$$

two (independent) properties :

m mass

$g_{\phi\gamma\gamma} \equiv \frac{1}{M}$ coupling (notice dimensions)

- **Scalar coupled to $\gamma\gamma$**

$$\mathcal{L}_{\phi\gamma\gamma} = \frac{1}{8}\, g'_{\phi\gamma\gamma}\; \phi\; F_{\mu\nu} F^{\mu\nu}$$

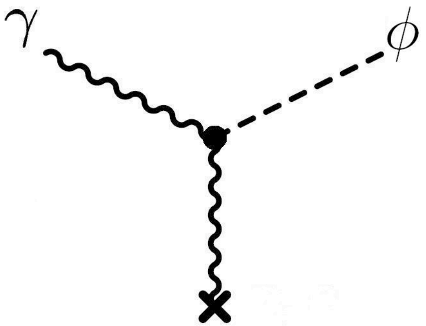
- Similar except for $\mathrm{PS} \rightarrow \vec{E}\vec{B}$, $\mathrm{S} \rightarrow |E|^2 - |B|^2$

Call them AXION-LIKE PARTICLES (ALPs)

ALP production

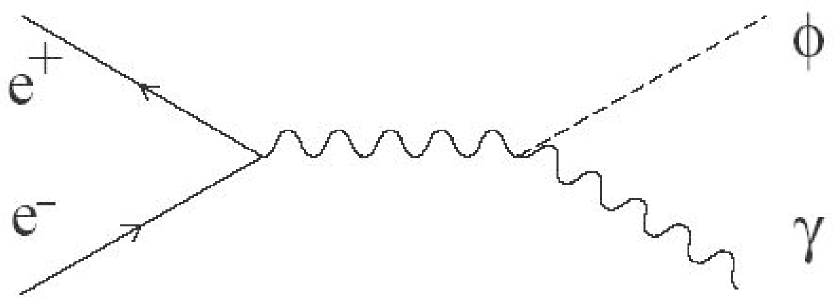
Primakoff-like processes

allows $\gamma \longrightarrow \phi$



(cf. Primakoff process for $\pi^0\gamma\gamma$)

Accelerators



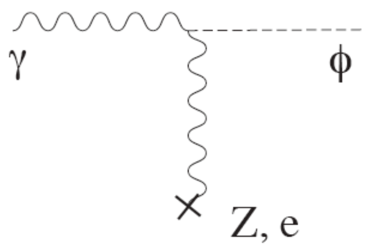
$$M = g_{\phi\gamma\gamma}^{-1} > 10^5 \text{ GeV}$$

EM, Toldrà

Klebart, Rabadan

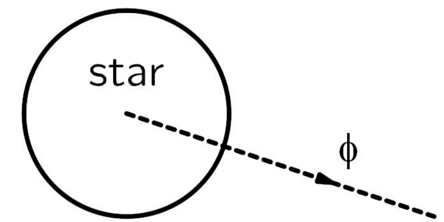
Astrophysical

Production



Primakoff in
the stellar plasma

Emission



Weakly interacting
particles leave the star

New energy loss channel accelerates star evolution

Time-scale observation constrains
exotic energy drain from the star :

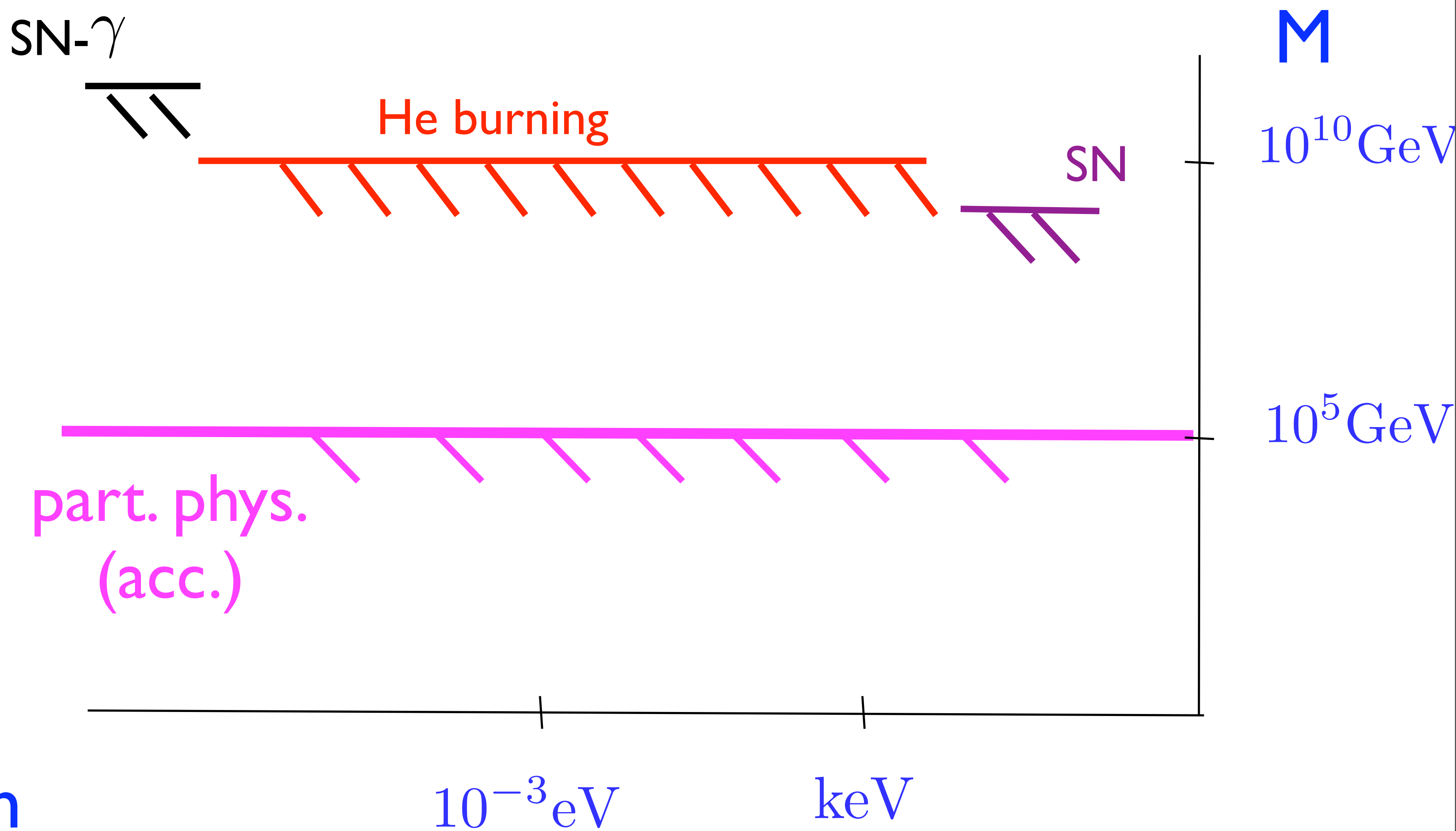
$$M > 2 \times 10^{10}\ \text{GeV}\ (m < 10\ \text{keV})$$

Raffelt

Horizontal
Branch Stars

Also SN87 A $M > 10^{9}\ \text{GeV}\ (m < 50\ \text{MeV})$

Constraints on $\phi\gamma\gamma$



EM, Toldrà
Klebart, Rabadan

photon-ALP mixing

in external B-field

$$\mathcal{L}_{\text{int}} = \mathcal{L}_{\phi\gamma\gamma} \Rightarrow g_{\phi\gamma\gamma}\ \phi\ \vec{\epsilon} \cdot \vec{B}$$

strength of interaction

photon polarization

Interaction states $\neq$ Propagation states

Sikivie

Raffelt, Stodolsky

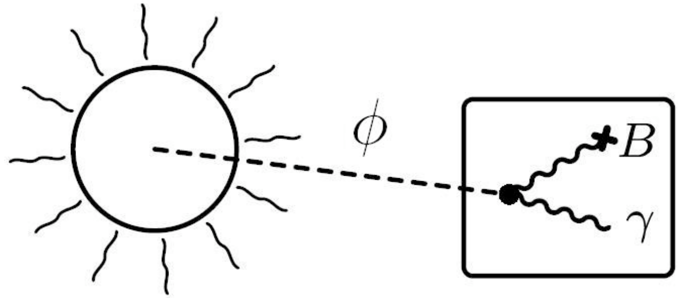
$$|\phi'\rangle = \cos\theta\,|\phi\rangle - \sin\theta\,|\gamma\rangle$$
$$|\gamma'\rangle = \sin\theta\,|\phi\rangle + \cos\theta\,|\gamma\rangle$$

transition probability
after traveling a distance L

$$P(\gamma \rightarrow \phi) = \frac{1}{4}\, g_{a\gamma}^2\, B_T^2\, L^2$$

New experimental results

CAST



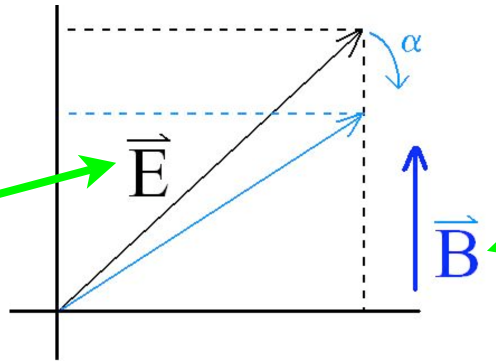
Helioscope
Sikivie

$$M > 0.9 \times 10^{10}\ \text{GeV}$$
$$(m < 0.02\ \text{eV})$$

K. Zioutas et al.
PRL (2005)

PVLAS

Light polarization



External field

Observe selective absorption
(dichroism)

$$\alpha = (3.9 \pm 0.5)\ 10^{-12}\ \text{rad/pass}$$

E. Zavattini et al.
PRL (2005)

Particle interpretation of PVLAS results

photons decay into light ALPs ϕ

Scale: $1\ 10^5 < M < 6\ 10^5$ GeV $\quad M = g_{\phi\gamma\gamma}^{-1}$

Mass: $0.7 < m < 2$ meV $\quad m = m_\phi$

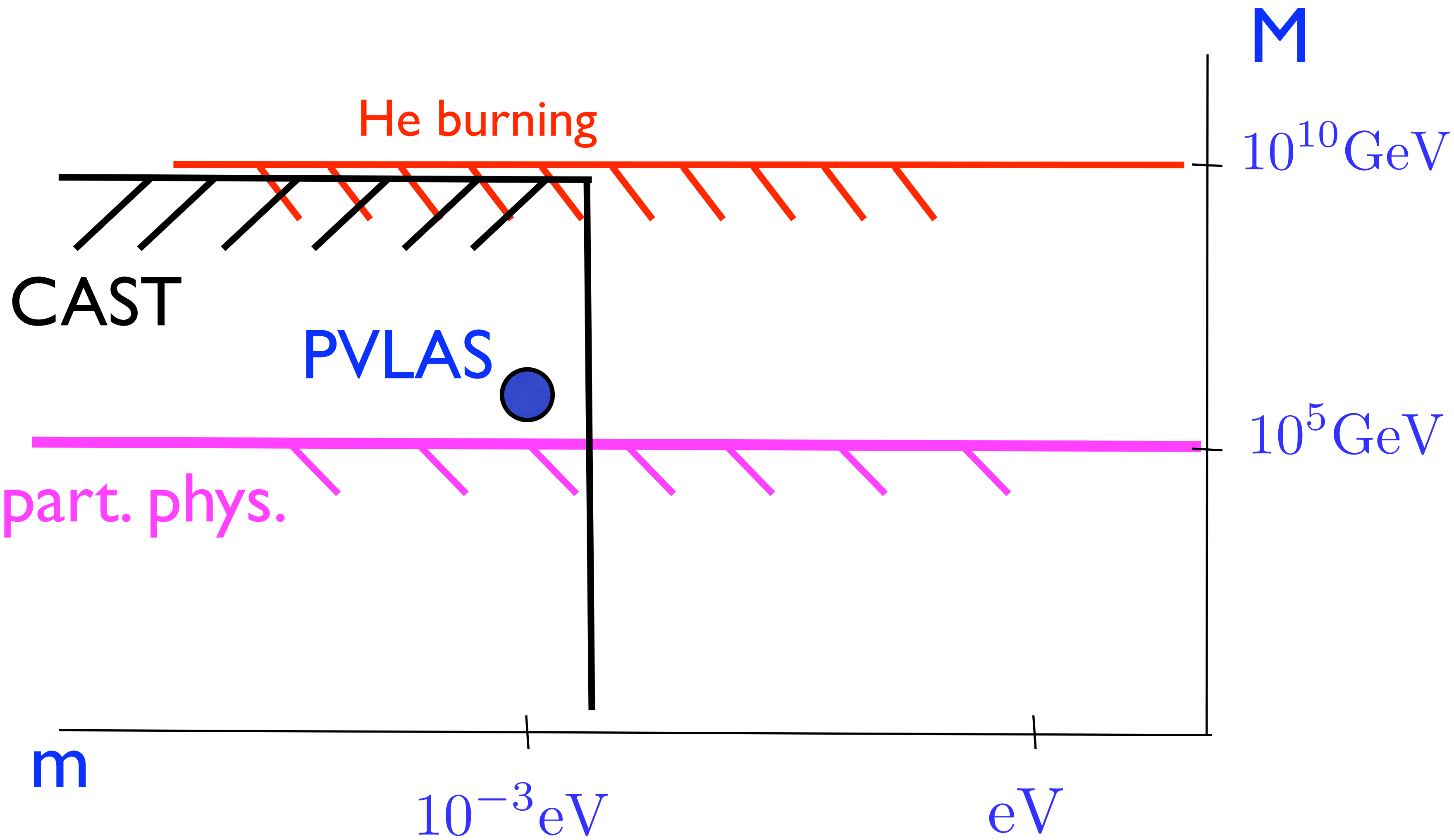
ϕ is NOT be the standard axion

$\sqrt{M\,m} \sim 1\,\mathrm{MeV}$ vs. $\sqrt{M_a\,m_a} \sim 1\,\mathrm{GeV}$

(this is whay I call it ALP)

PVLAS, CAST & the STARS

Obvious and dramatic conflict !



PVLAS strength of interaction leads to $\mathcal{L}_{exotic} \sim 10^6\ \mathcal{L}_\odot$

PVLAS, CAST & the STARS

EM, Redondo

A way out of the puzzle is to have a model where
the Sun emits much less ALPs
than expected

⇨ There would be less energy loss
and thus stellar limit are avoided

⇨ CAST limit not valid because
it assumes "solar- standard" ϕ - flux

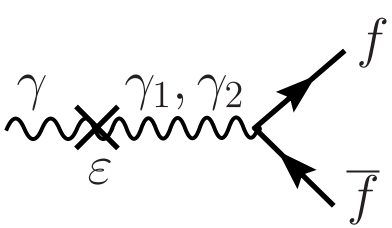
Two-Paraphoton model

EM, Redondo

Charge suppression at keV energies ?

May be obtained within a
two-paraphoton model with partial cancellation

Introduce γ_1, γ_2



$\varepsilon_1 = \varepsilon_2$ high-energy structure

$e'_1 = -e'_2$ (para)charge assignments

$\mu_1 \neq \mu_2$ scalar sector

$$q(T) \simeq \frac{\mu^2}{T^2}\, q(0)$$

$\mu \ll T$

To simplify

$e_1 = e, e_2 = -e$

$\mu_2 = 0, \ \mu_1 \equiv \mu \neq 0$

Beyond the Standard Model of Particle Physics

Assume ALP interpretation of PVLAS result

- Existence of ϕ is physics BSM
- Compatibility of ϕ with "stars" and CAST requires even more physics BSM
- I have presented one example (paraphotons). Are there other models ?
- The model I have presented can be obtained in string theory

Abel, Jaeckel, Khoze, Ringwald

Message

Evasion of astrophysical bounds
difficult = possible in sophisticated models

If PVLAS confirmed
not many new-physics models
do the job