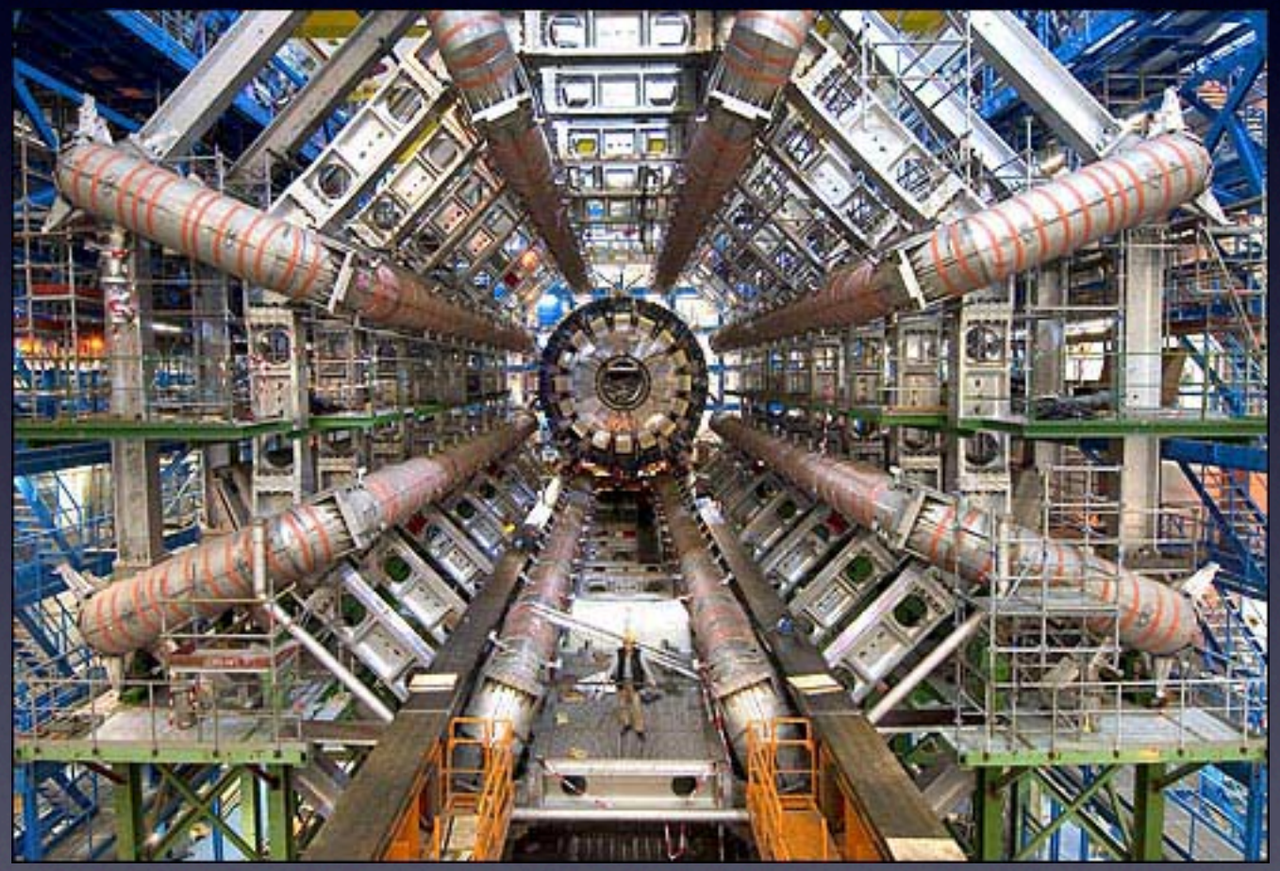
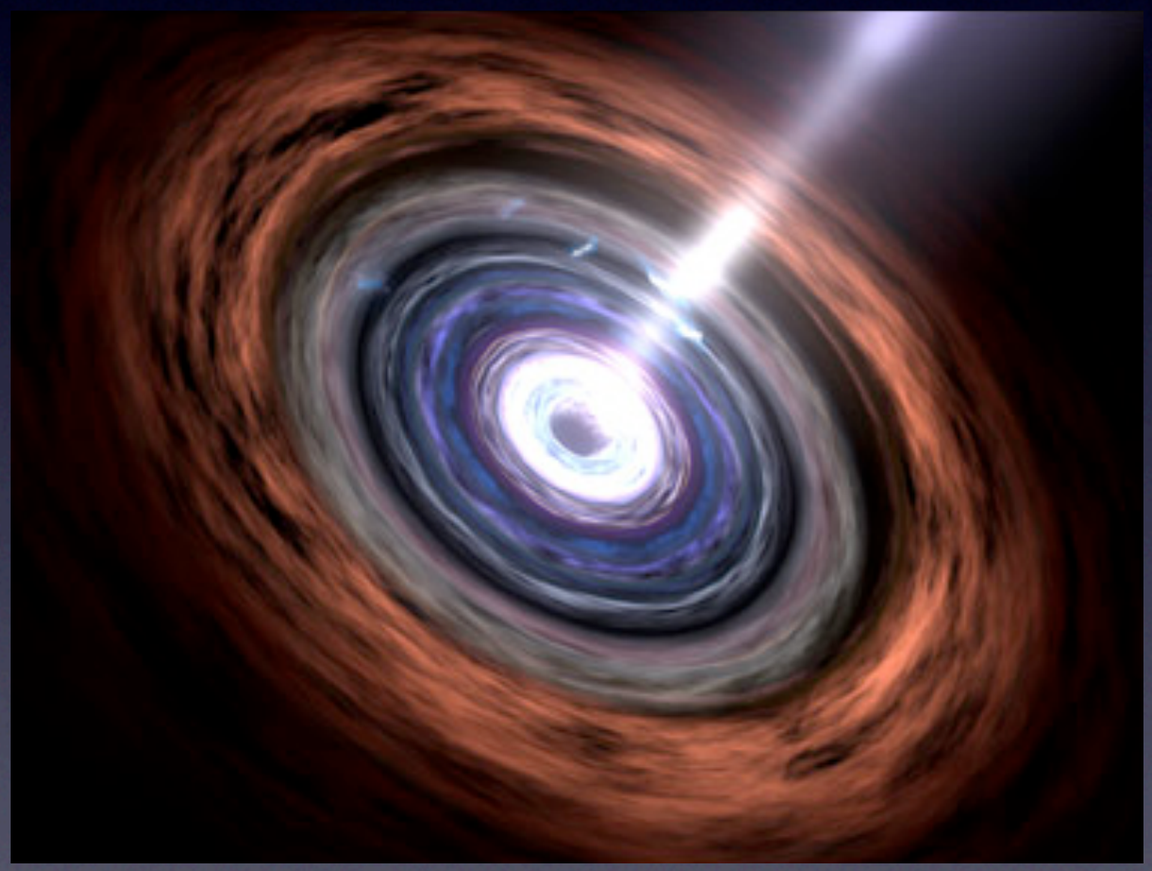
LHC Science with AGN

or

Warm Converters



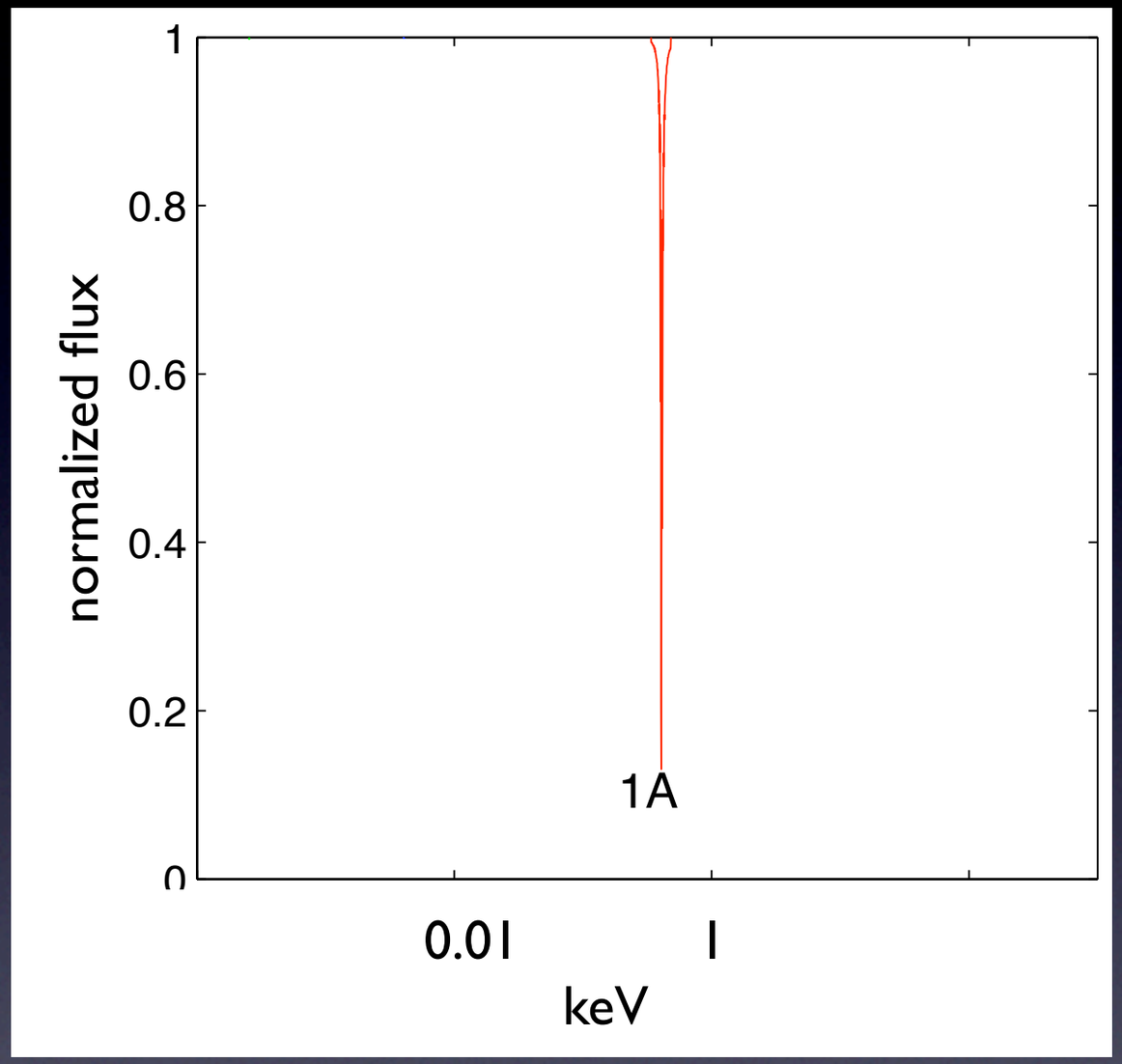


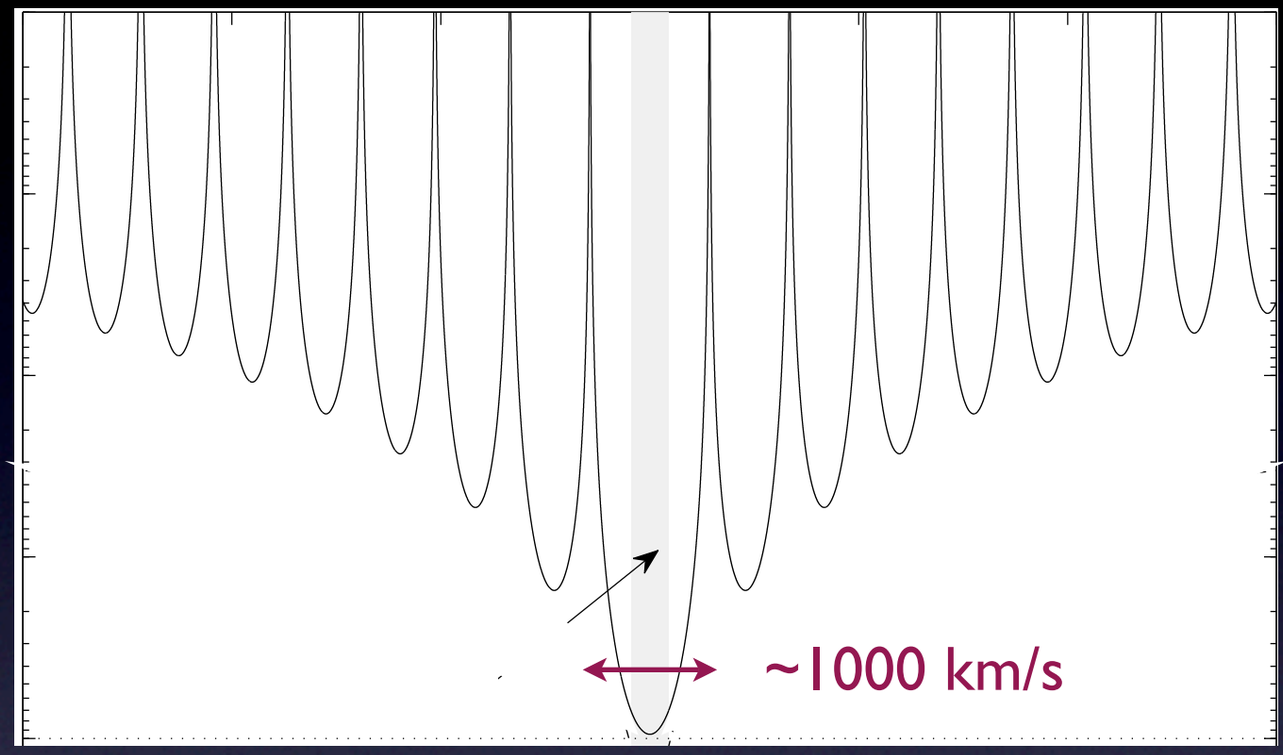
CITA ICAT Canadian Institute for Theoretical Astrophysics / L'institut canadien d'astrophysique theorique

Doron Chelouche

(Canadian Institute for Theoretical Astrophysics)

Have you seen this?





an absorption-like feature:
***not* a line**
***not* an edge**

If so then...

Physics 2020

http://nobelprize.org/nobel_prizes/physics/laureates/ 2020 /index.html

nobel prize

Google Maps | Reddening-g...ions: QSOs | oh my dog! | Reddening-g...ions: QSOs | CosCalc | האארץ | census | webmail (IAS) | arXiv | ADS

Nobelprize.org

Physics

The Nobel Prize in Physics 2020

"for the discovery of pseudo-scalars and for solving of the strong-CP problem of QCD and the dark matter problem of cosmology"

Jelle Kaastra

1/3 of the prize

Helen Quinn

1/3 of the prize

Roberto Peccei

1/3 of the prize

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The 2008

The strong-CP problem

C 

× weak (1956/7)

CP 

× weak (1964)

CPT 

P 

× weak (1956/7)

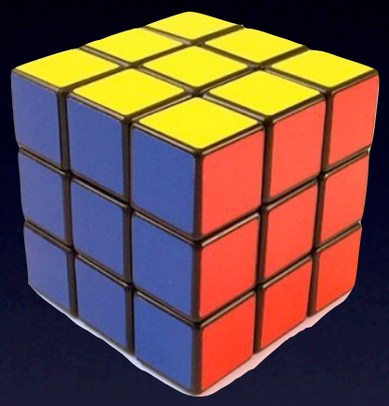
Landau

T 

× weak ✓ strong

The QCD Lagrangian

building blocks:



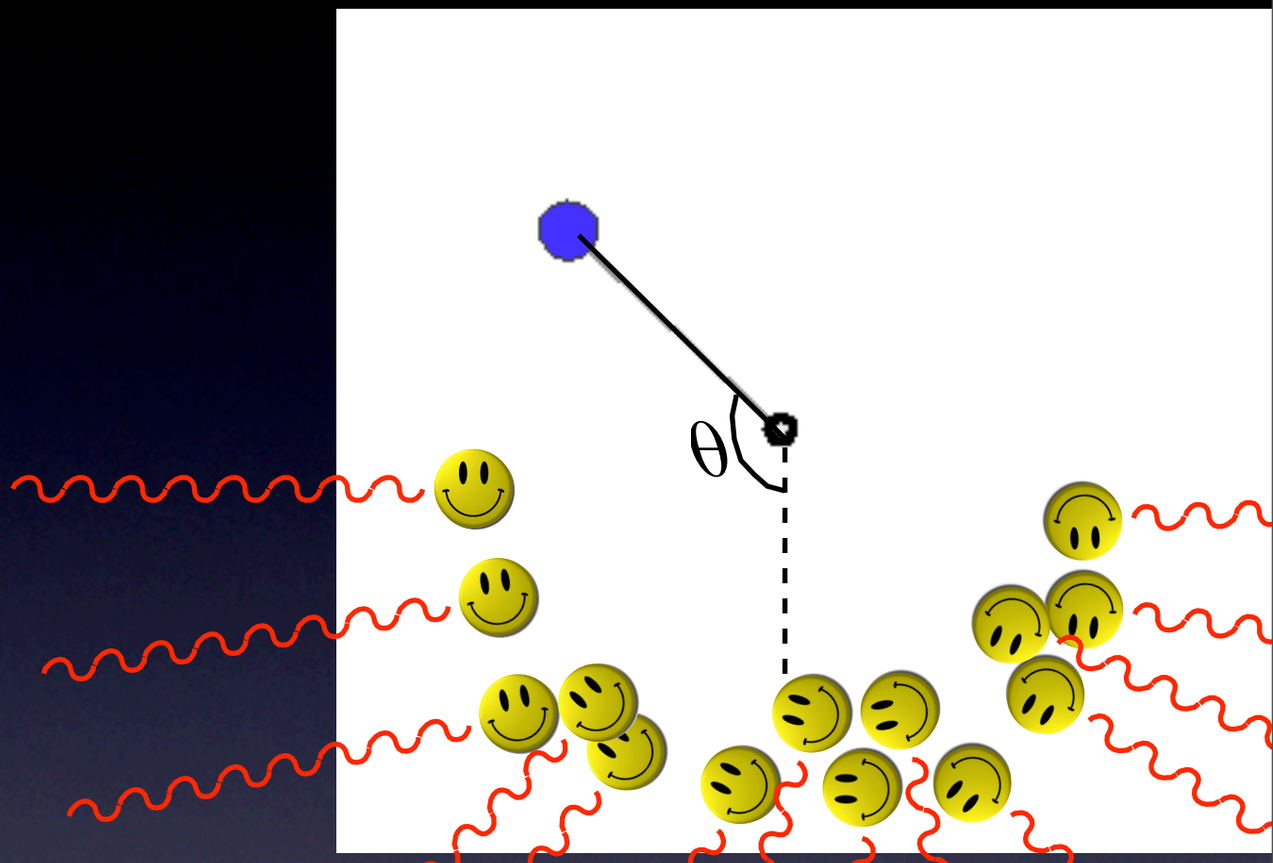
symmetries:

$$\mathfrak{L} = -\frac{1}{4}\mathrm{tr}F_{\mu\nu}F^{\mu\nu} - \boxed{\theta\frac{n_f g^2}{32\pi}\mathrm{tr}F_{\mu\nu}\tilde{F}^{\mu\nu}} + \bar{\psi}\left(i\gamma^\mu D_\mu - me^{i\theta'\gamma_5}\right)\psi$$

strong obeys CP $\qquad \theta \ll 10^{-10}$

Fine tuning!!!

The Peccei-Quinn solution

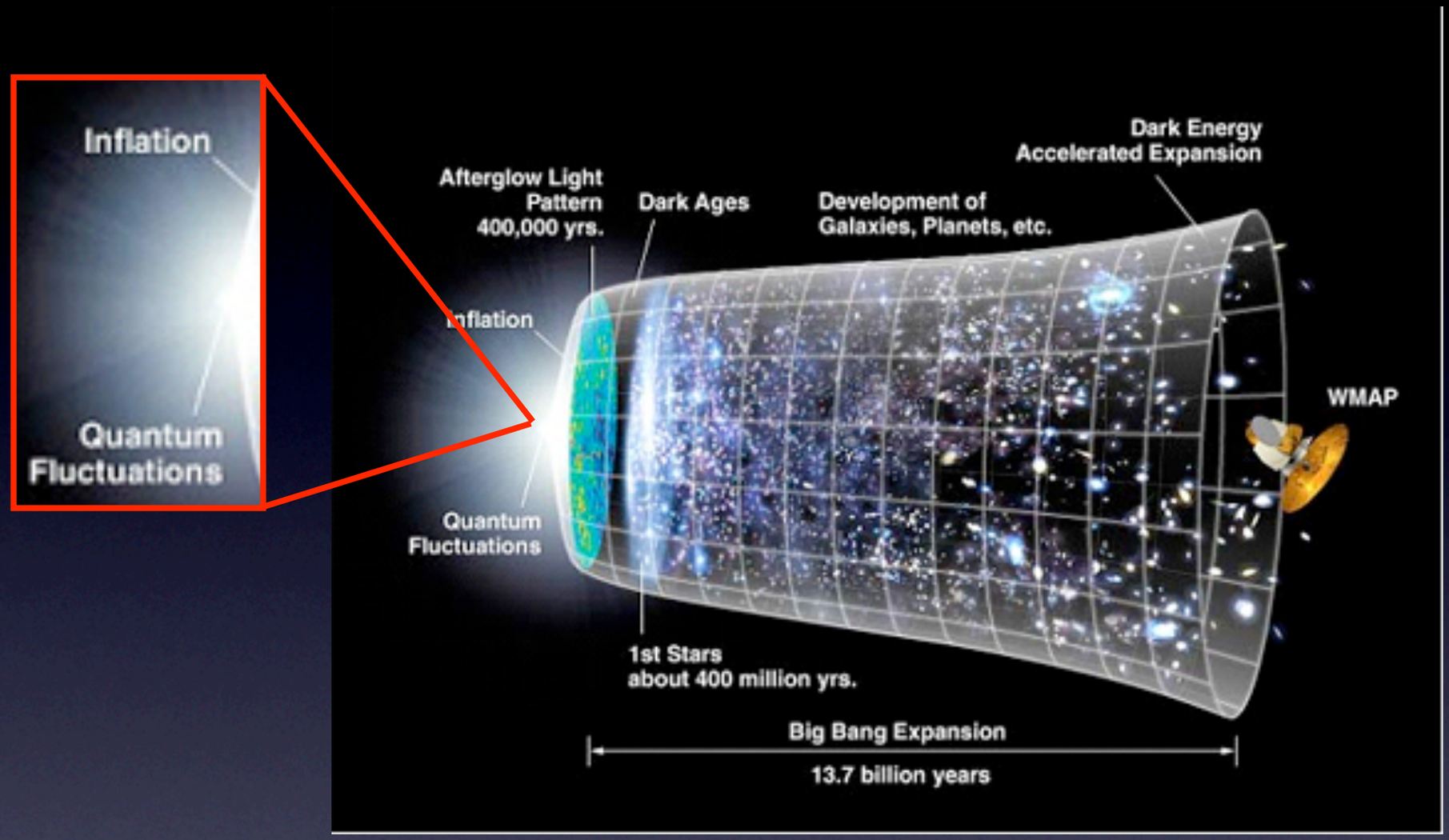


θ naturally relaxed to zero!!!

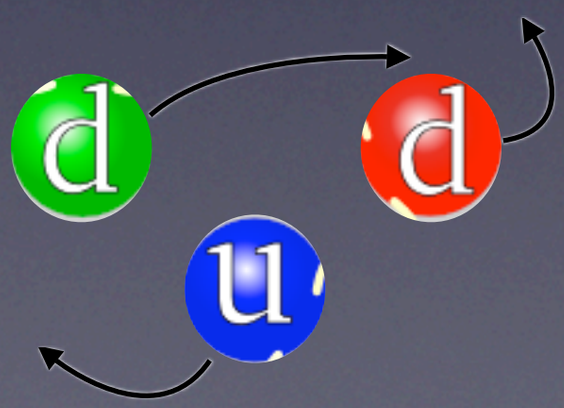
pseudo-scalar
(spin-0, boson)

Wilczek: "... for cleaning the strong CP problem..."

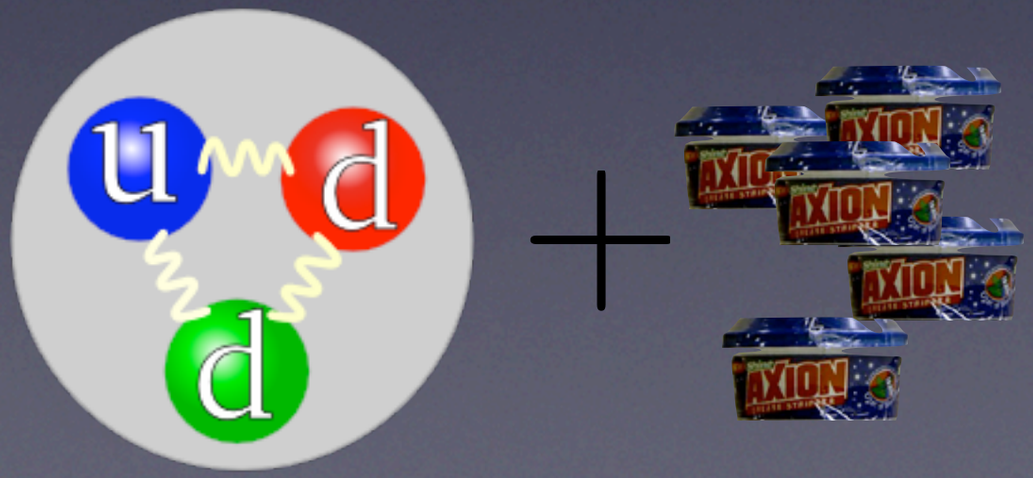
Axions as DM particles



(very) early universe

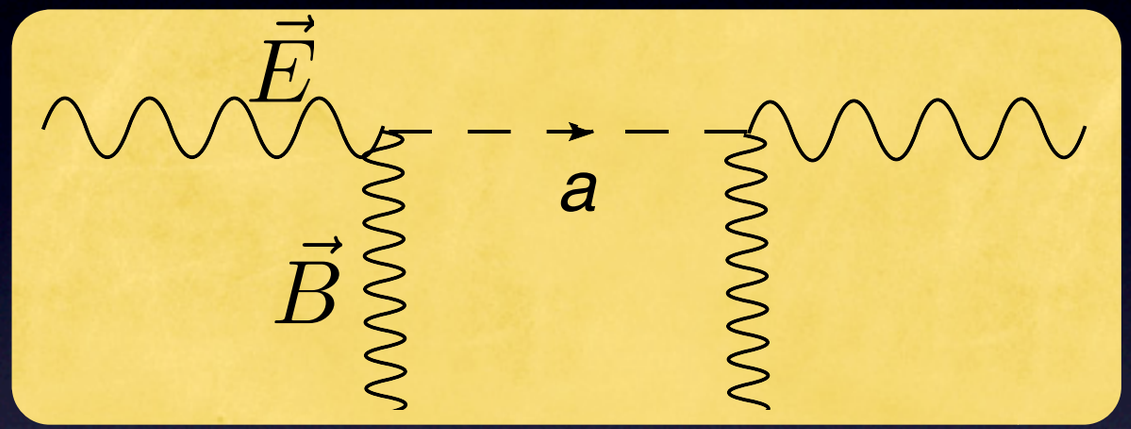


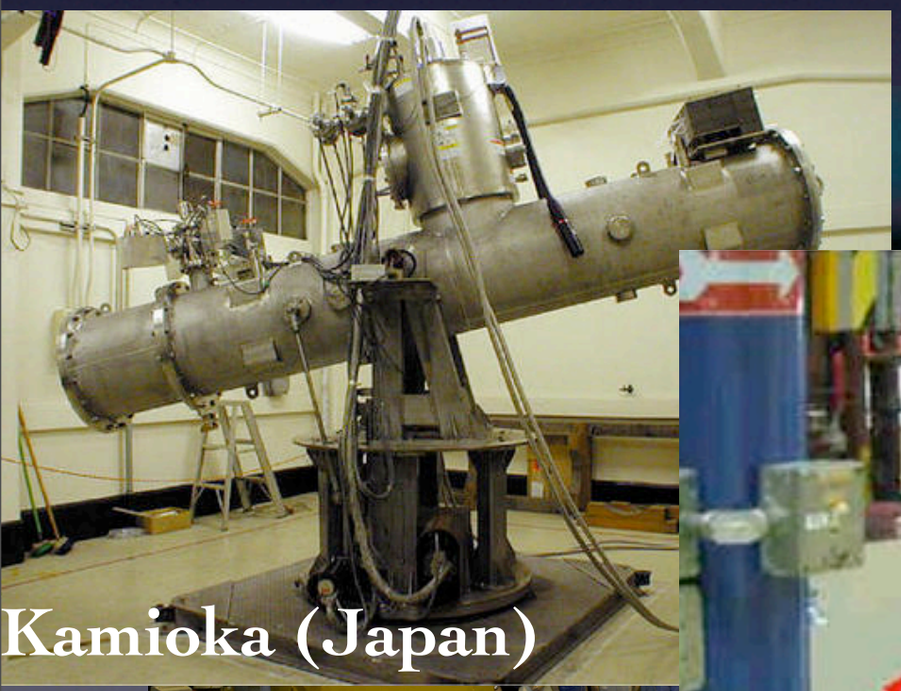
QCD phase transition



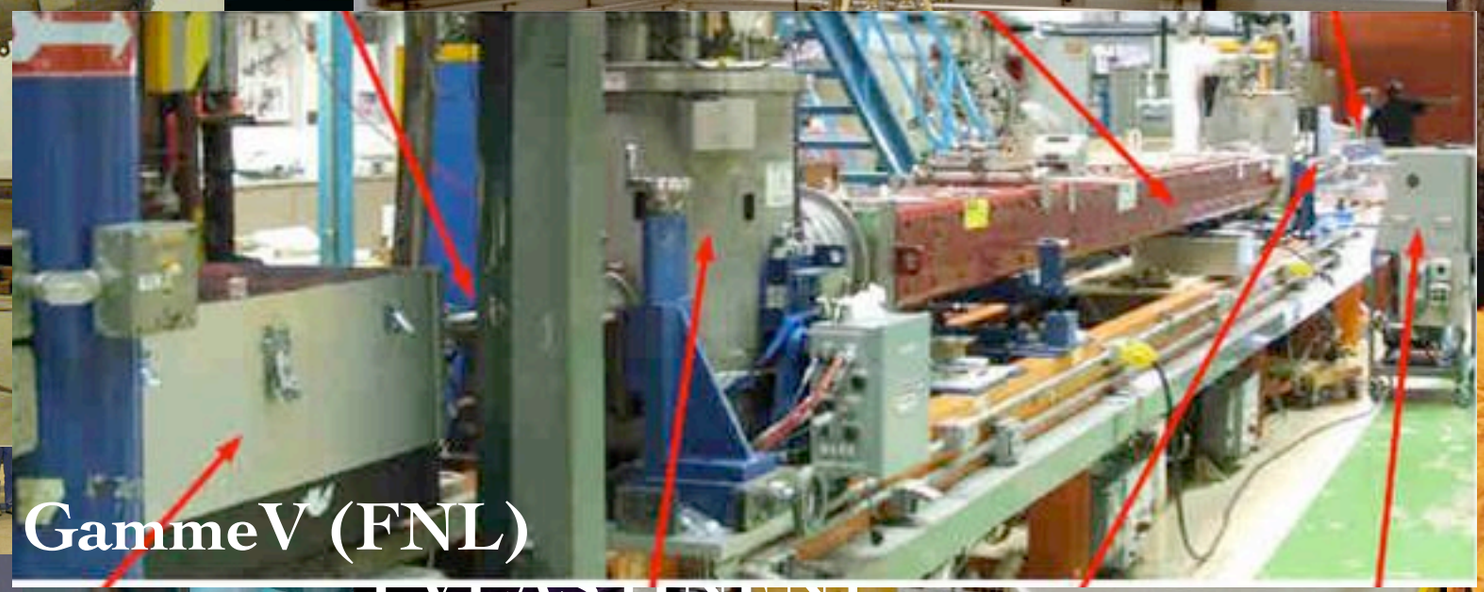
The EM+axion Lagrangian

$$\mathfrak{L}_{\mathrm{EM}} = \mathfrak{L}_{\mathrm{EM}}^{free} + g\vec{B}\vec{E}a$$




Kamioka (Japan)

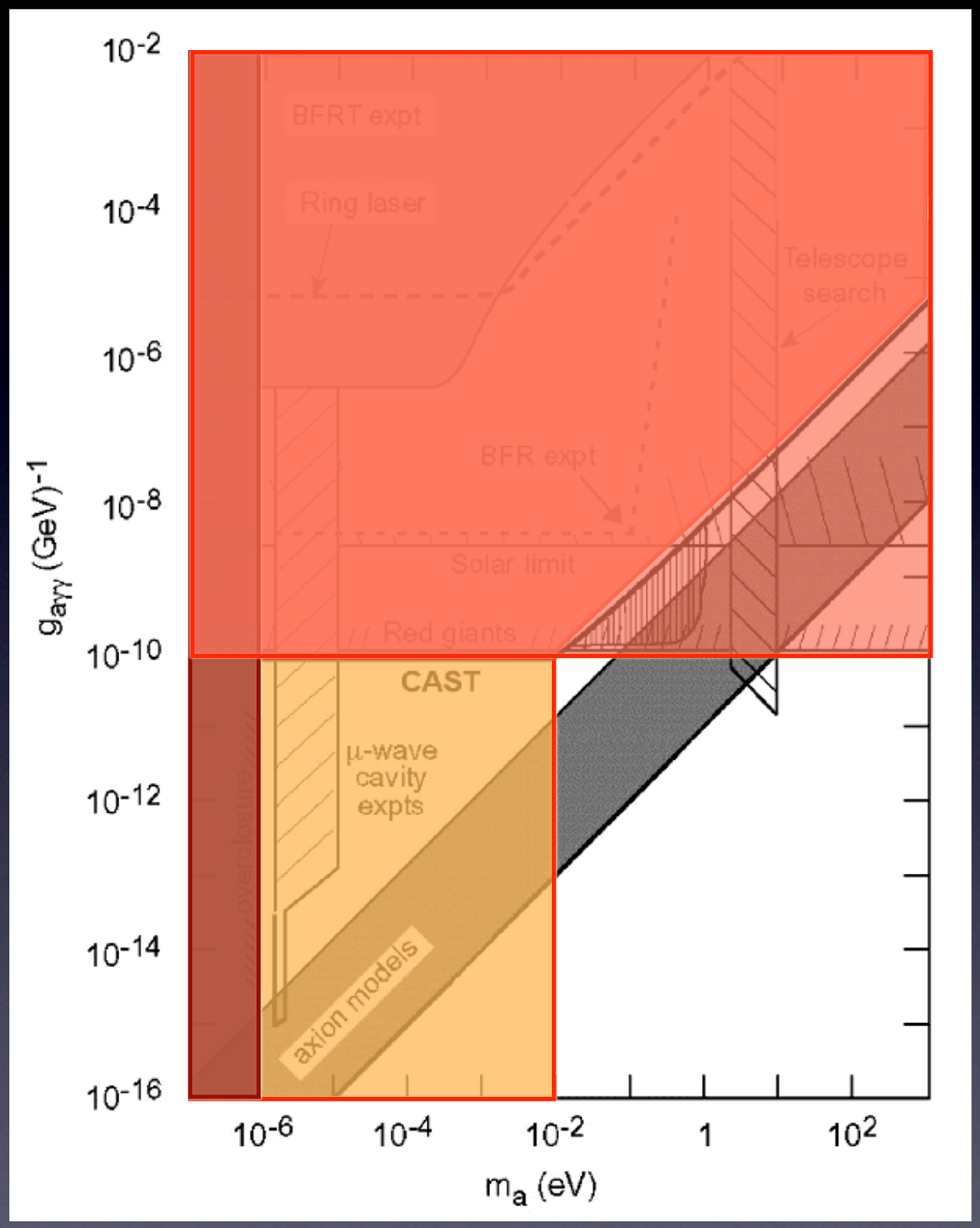

CAST (CERN)


GammeV (FNL)

ADMX (LLNL)

TEXAS (INFN)

Current limits



$$m_a > 10^{-6}\,\mathrm{eV}$$

$$g < 10^{-10}\,\mathrm{GeV}^{-1}$$

main limitation:

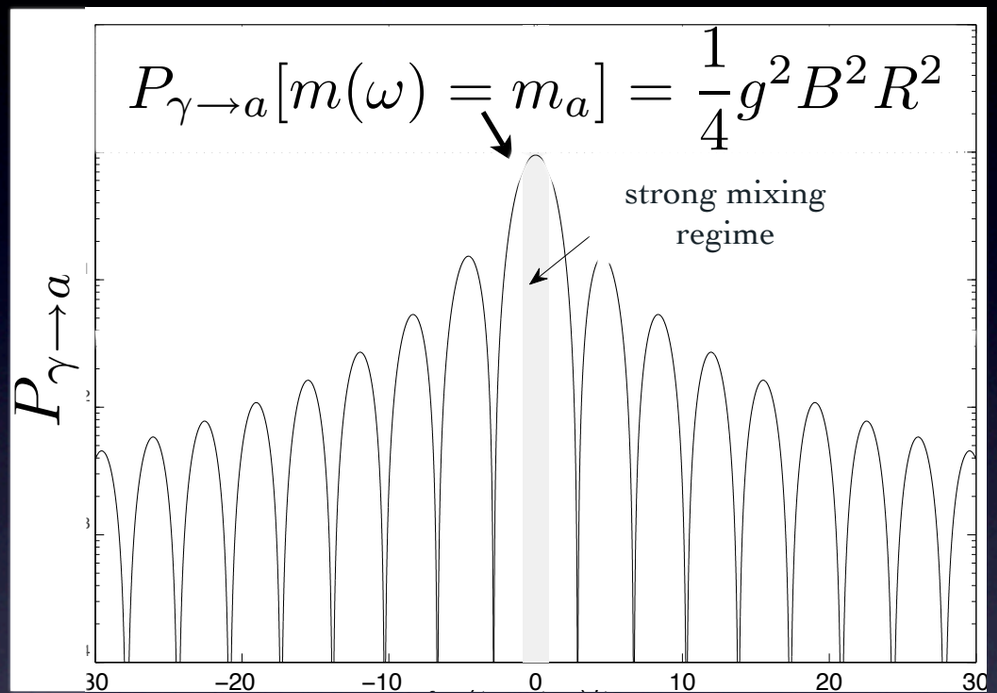
$$P_{a\to\gamma} \sim g^2 B^2 R^2$$

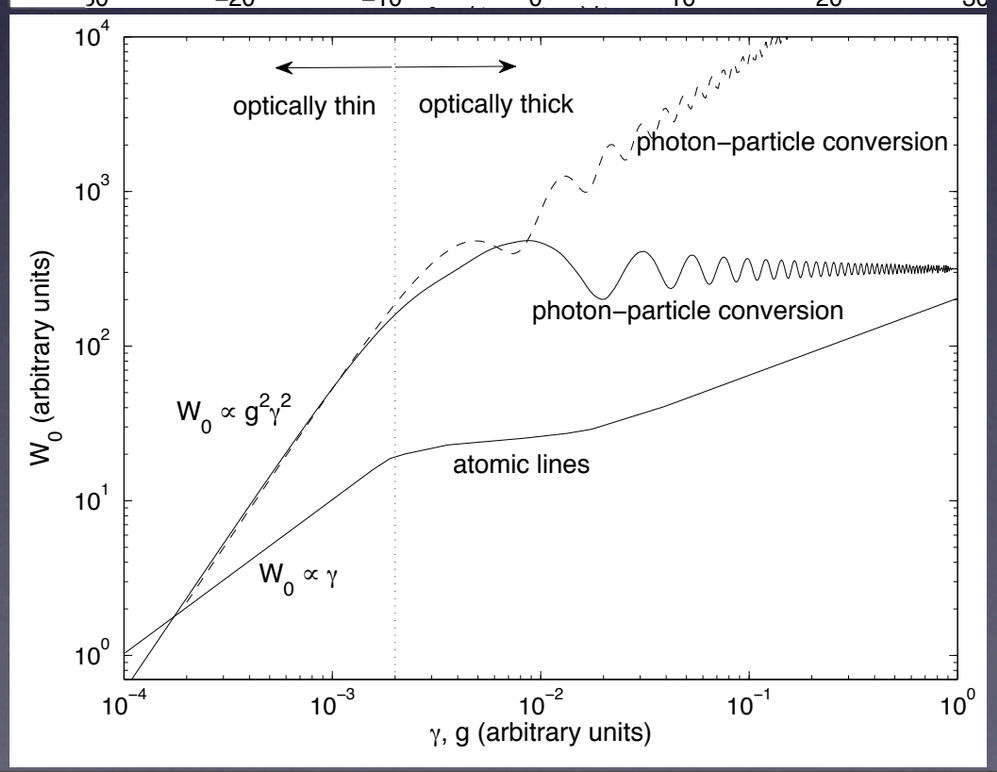
$$\left[\frac{B_{\rm quasar}}{B_{\rm CAST}}\frac{R_{\rm quasar}}{R_{\rm CAST}}\right]^2 \sim 10^{20}$$

One could do better w/AGN

photon-axion conversion

$$\begin{bmatrix} \mathbf{k}^2 - \omega^2 + m_\gamma^2 & -g B_\parallel \omega \\ -g B_\parallel \omega & m_a^2 \end{bmatrix} \begin{pmatrix} \gamma \\ a \end{pmatrix} = 0$$





Resonance energy: $m_\gamma(\omega) \simeq m_a$

dependence on plasma density and temperature, and magnetic field value.

(NO DEPENDENCE ON ATOMIC DATA)

"Feature" depth:

non-linear dependence on the magnetic field and the system's size

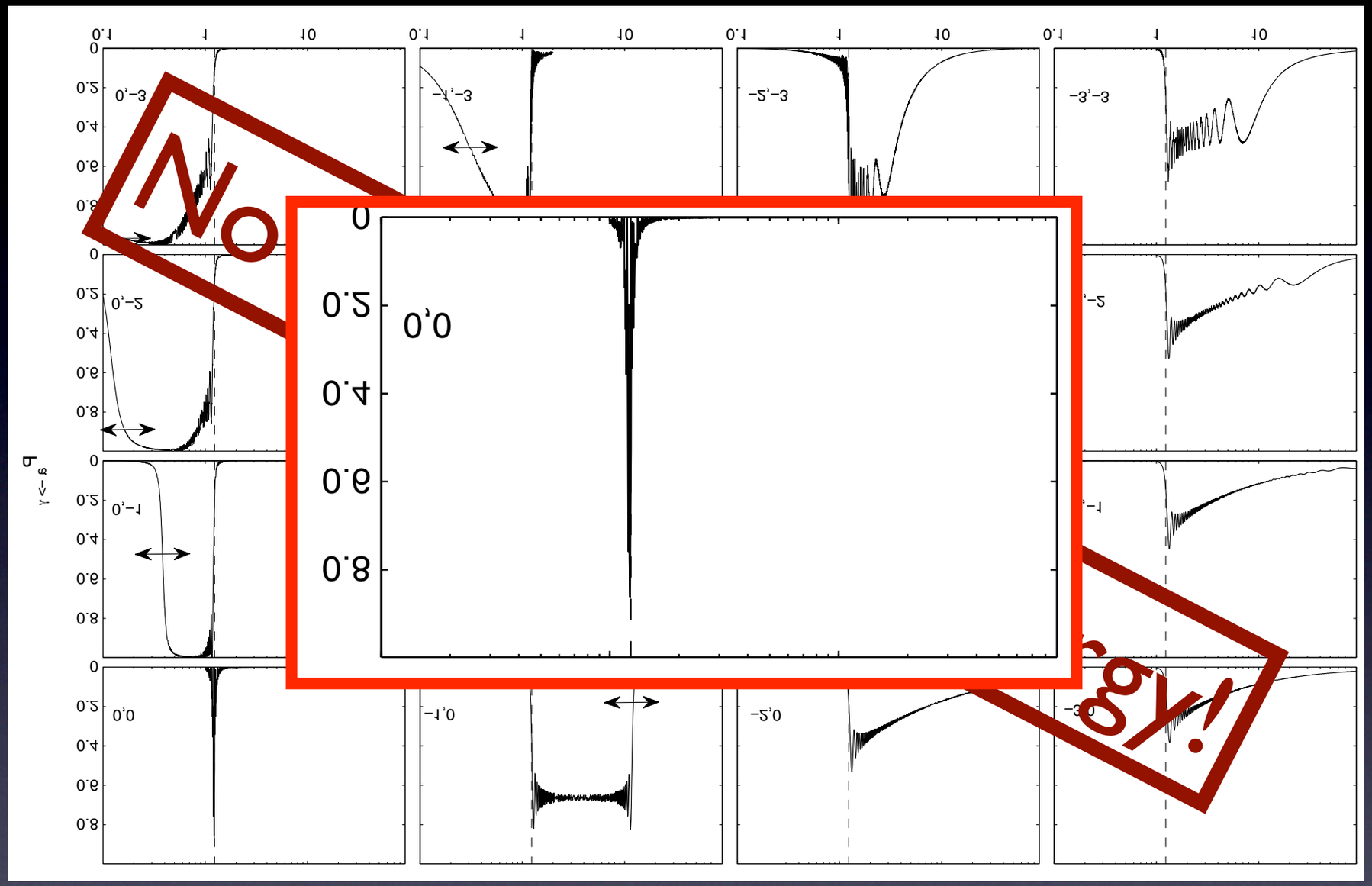
(VERY DIFFERENT CURVE OF GROWTH)

"Feature" width:

depends primarily on the stratification of the magnetic field and density, and, to a lesser extent, on the system size.

(NO DEPENDENCE ON TEMPERATURE)

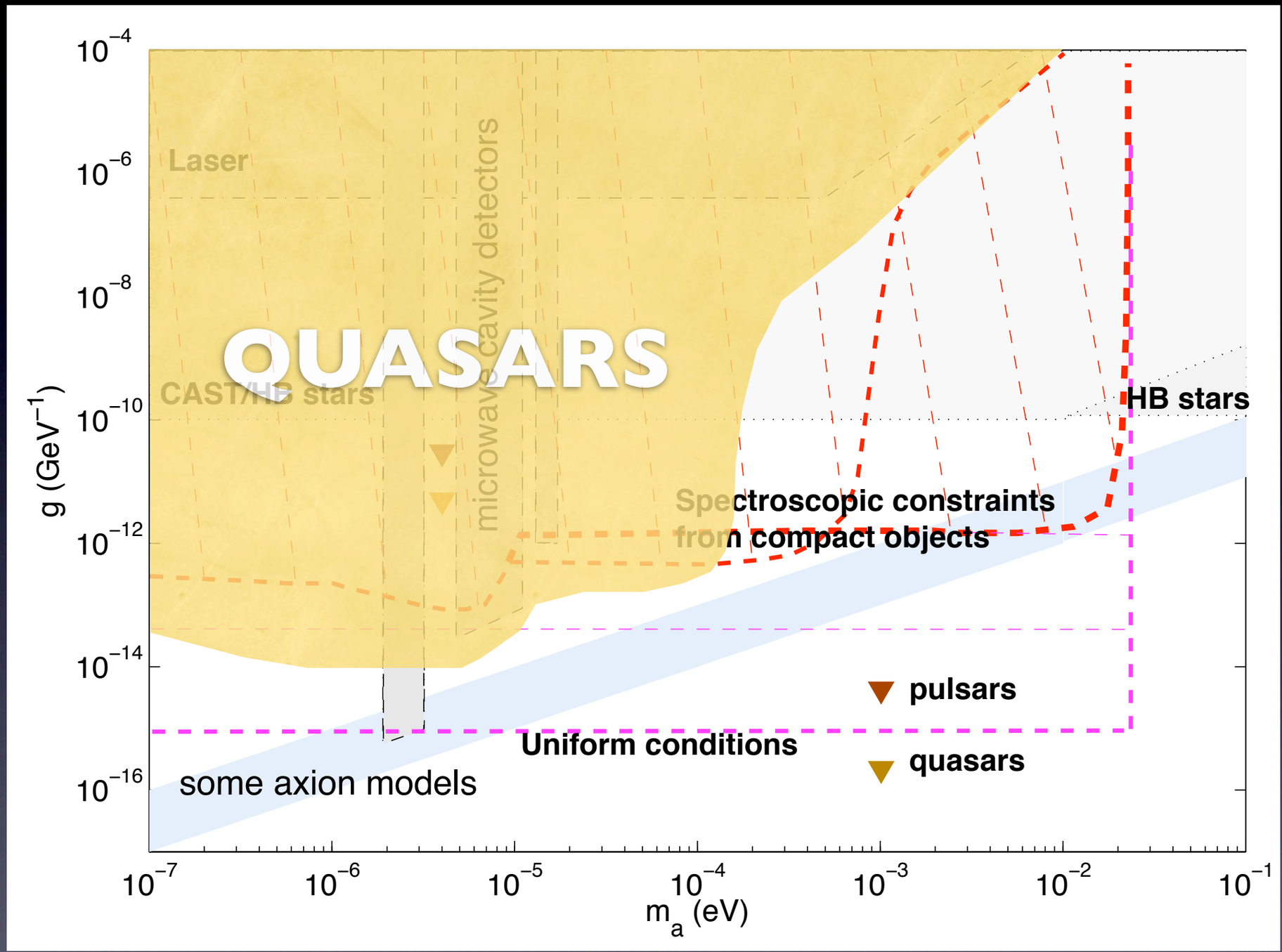
Gallery



$$10^{-3} < W_{\gamma\to a} < 10\,\text{Å}$$

$$0.1\,\text{keV} < E_{\gamma\to a} < 100\,\text{keV}$$

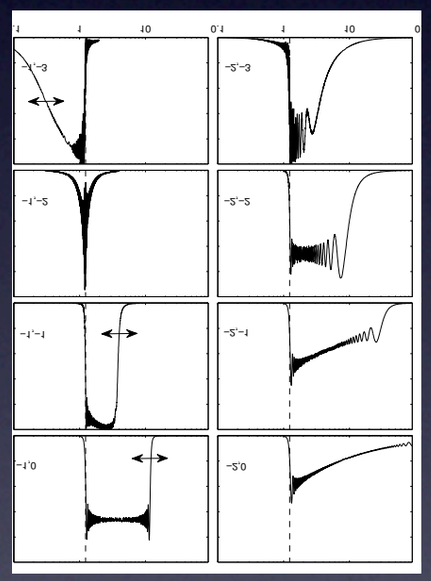
Astrophysical Objects



We can do much better!!!

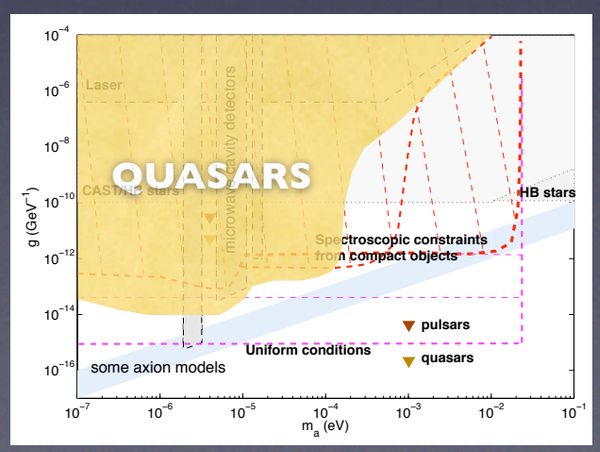
Summary

•Axions provide a solution to the strong-CP problem and dark matter problems. Their detection may also help to establish string theory and could shed light on quintessence fields (cosmological constant).



•Detailed spectral predictions of photon-axion oscillations were calculated

•Features are expected to show up in the soft to hard X-ray band and require high-res grating spectra to be securely detected



•Observations of AGN (and also magnetars and pulsars in the IR band) are several orders of magnitude more sensitive to axions compared to current terrestrial experiments.