Latest results from CAST & the IAXO project

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on behalf of the CAST and IAXO Collaborations

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Outline

CAST Physics
The experiment
Latest results
IAXO: The future with the International AXion Observatory
Conclusions

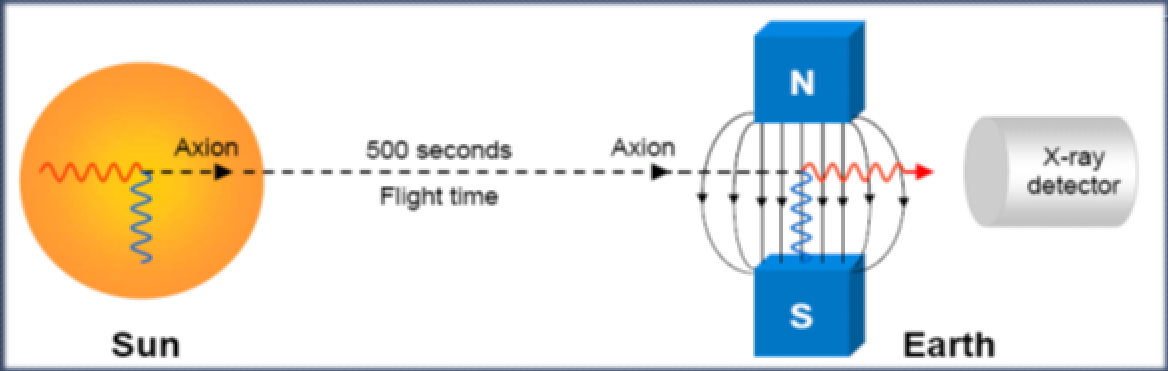
Axions

- Axions are **the most elegant solution to the Strong CP problem** (why QCD does not seem to break the CP symmetry):
  - **pseudoscalar particles, neutral, practically stable**
- Candidates for both cold and hot **dark matter**
- Axion-like particles (ALPs) are predicted by many **extensions of the standard model**
- Relevant axion/Axion-Like Particles parameter space **at reach of current and near-future experiments**

- New theory scenarios: **string theory** predicts axions/ALPs with detectable parameters
- **Astrophysical hints** for axion/ALPs?
  - transparency of the Universe to UHE gammas
  - white dwarf cooling anomaly → point to few meV axions
- ...

CERN Axion Solar Telescope:
QCD Axions or Axion Like Particles (ALPs)

CAST Physics



Signal: excess of x-rays during alignment over background

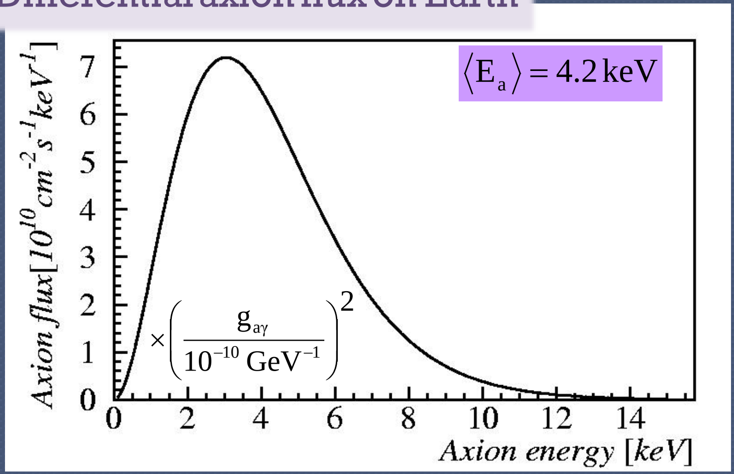
Expected number of Photons:

$$N_\gamma = \int \frac{d\Phi_a}{dE_a} \cdot P_{a\to\gamma} \cdot S \cdot t \cdot dE_a$$

Production: Primakoff effect
Thermal photons interacting with solar nuclei produce Axions.

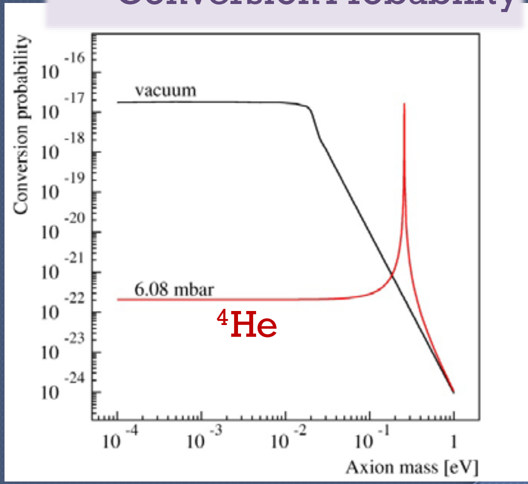
Detection (Sikivie 1983) Inverse Primakoff: axion interacting with a very strong magnetic field converts to a photon

Differential axion flux on Earth



- Conversion probability depends on medium, $(BL)^2$
- Coherence can be restored: different mass ranges can be covered in different media and densities

Conversion Probability



CAST

- Decommissioned prototype LHC dipole magnet.
- Magnetic field: **B=9 T**
- Length: **L=9.26 m**

- Rotating platform
- (Vertical: ±8°, Horizontal: ±40°)
- 2x1.5h solar tracking/day
- Sunrise: X-ray Focusing Device-CCD + 1 Micromegas
- Sunset: 2 Micromegas

CAST Physics Program

✓CAST Phase I, Vacuum

- m_a<0.02eV
- PRL94(2005)121301

JCAP04(2007)020

✓CAST Phase II, ^{4}He

- P< 13.4mbar (1.8K), 160steps
- 0.02<m_a<0.39eV

JCAP02(2009)008

✓CAST Phase II, ^{3}He

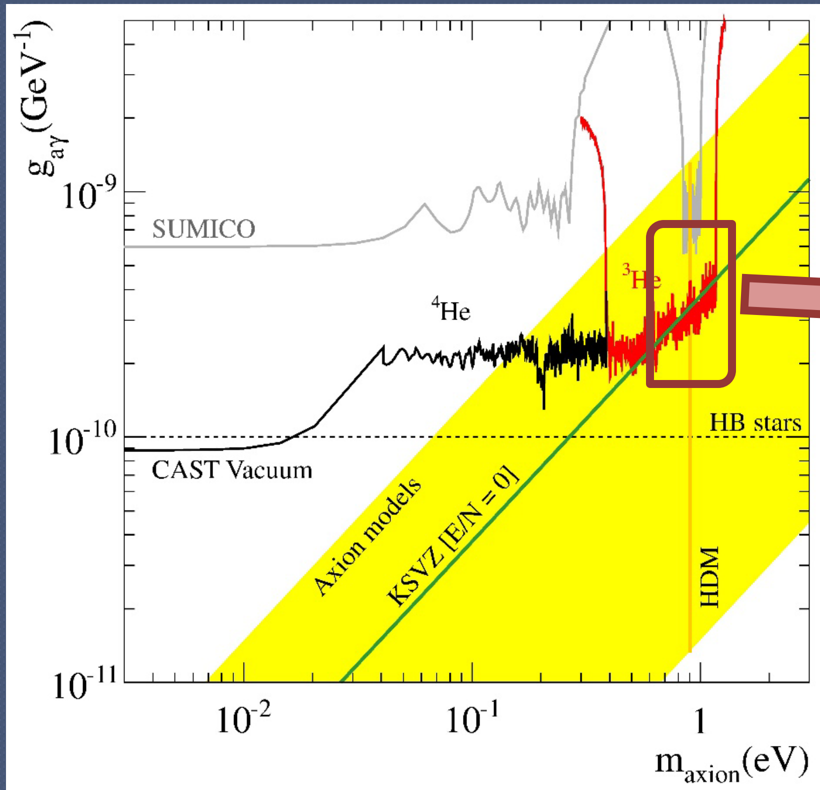
- P< 120 mbar (1.8K)
- 0.39<m_a<0.64eV

PRL 107 (2011) 261302

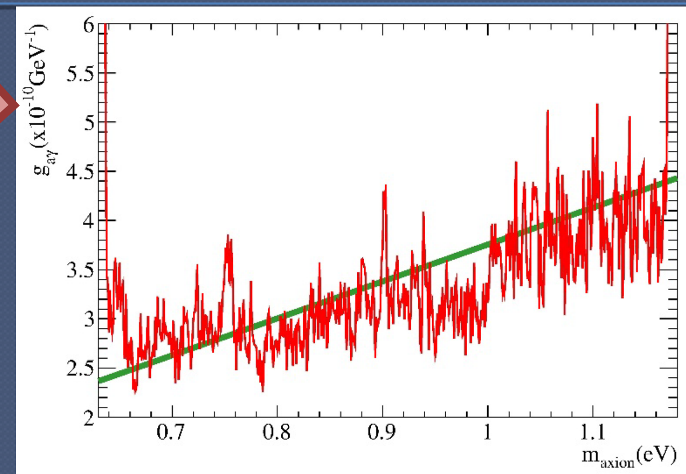
Parallel searches:

- HE axions: Data with a HE calorimeter, JCAP 1003:032,2010
- 14.4 keV axions from M1 transitions: JCAP 0912:002,2009
- LE (visible) axions: Data with a PMT/APD, arXiv:0809.4581
- Constraints on the axion-electron coupling g_{ae}: JCAP 1305 (2013) 010)
- In preparation: bounds on solar hidden photons

Latest ^{3}He results



Submitted to PRL, Preprint: 1307.1985



Results from the ^{3}He phase (only mM)

Axion mass 0.64 – 1.17 eV excluded down to

~3.3 x 10^{-10} GeV^{-1}

Working with a buffer gas:

Precise knowledge and **reproducibility** of each pressure setting is essential
Computational Fluid Dynamics (CFD) simulations are required to describe the complex gas dynamics: Predicted pressure variations are in ***satisfactory agreement*** with experimentally measured when tilting. *Publication in preparation*.

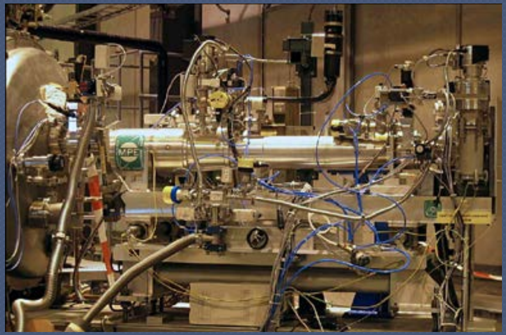
CAST detectors

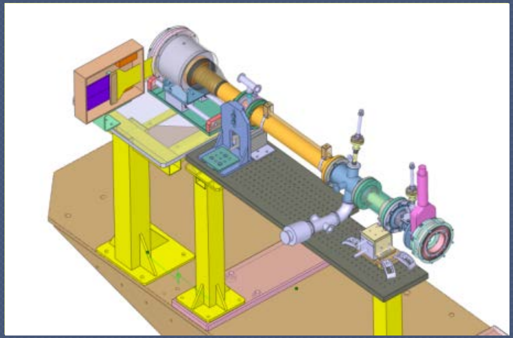
X-ray telescope +CCD

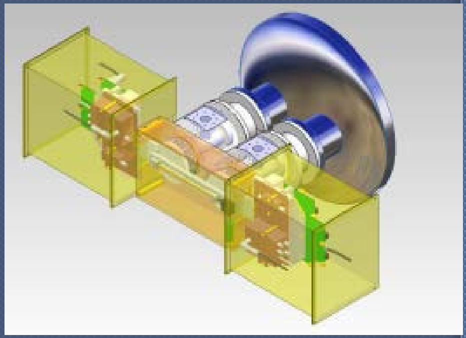
3 Microbulk Micromegas

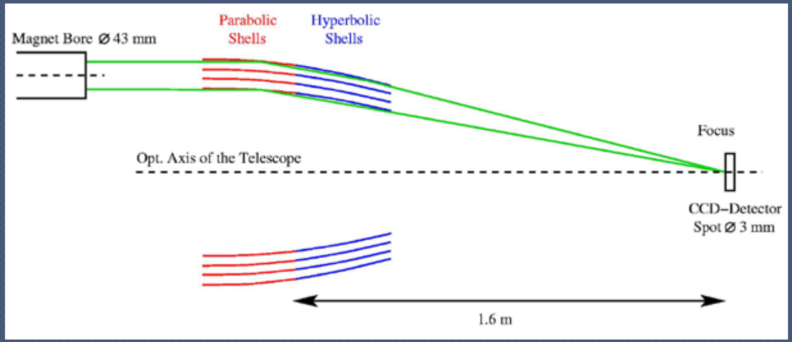
S/N improvement ~150!

New generation, high-radiopurity, very low background





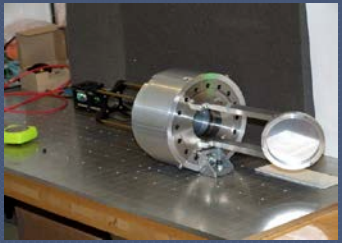




	Typical Rates
MM (2-10 keV)	~0.5 cts/h
CCD (1-7 keV)	~0.2 cts/h

BarBe

Parasitic line for Low Energy axions in the visible, with a PMT



Microbulk Micromegas

Low intrinsic radioactivity

Light mass, Radiopure materials

Signal topology, offline analysis

2D readout pattern, Time information

Shielding

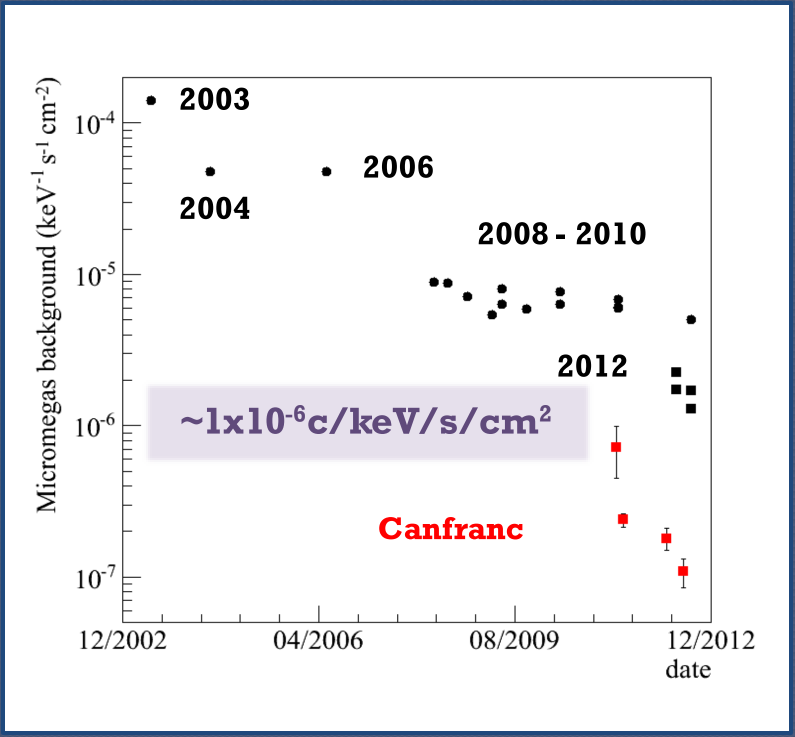
archeological lead, inner Cu, N_2 flushing.

Reduction of ~100x since the beginning!

Active R&D program

- Experimental tests with current detectors at CERN, Zaragoza, Saclay
- Underground setup at Canfranc
- Simulation works to build a background model

Background Level evolution at CAST



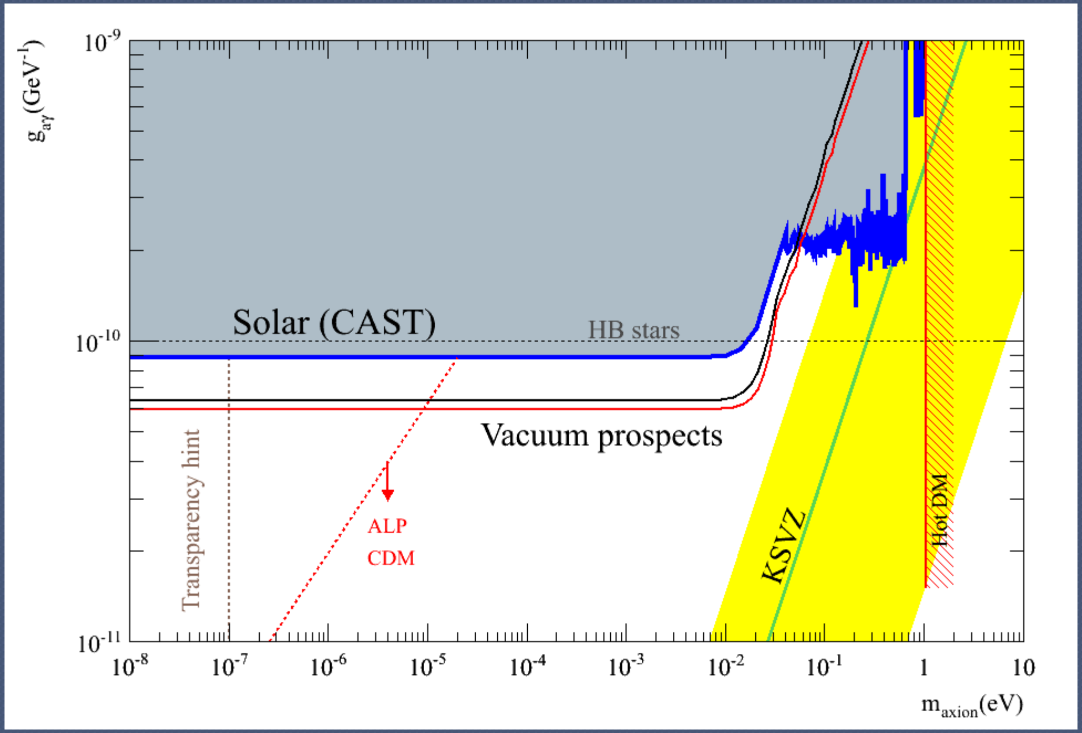
Goal: $<10^{-7}$ c/keV/cm^2/s (down to 10^{-8} if possible)

Current activities: 2013-2014

Revisiting the vacuum phase :

Three high performance microbulk detectors, increase sensitivity

preparation of an x-ray optics for the sunrise one, boost discovery potential.



But also other exotica:
chameleons, paraphotons, low energy axions (visible)

which require:
low background
low threshold

To test also:
InGrid micromegas,
Silicon Drift Detector (SDD)

The International AXion Observatory

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Towards a new generation axion helioscope

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JCAP 06 (2011) 013

The International AXion Observatory

New Generation axion Helioscope

- >4 orders of magnitude improvement in S/N wrt CAST (>1 order of magnitude in $g_{a\gamma}$)
- Improving all possible points:
  - New, dedicated magnet
  - Extensive use of X-ray optics
  - Low-background detectors

$$g_{a\gamma} \propto (B\,L)^{-1/2}\ A^{-1/4}\ (b^{1/8} / t^{1/8})$$

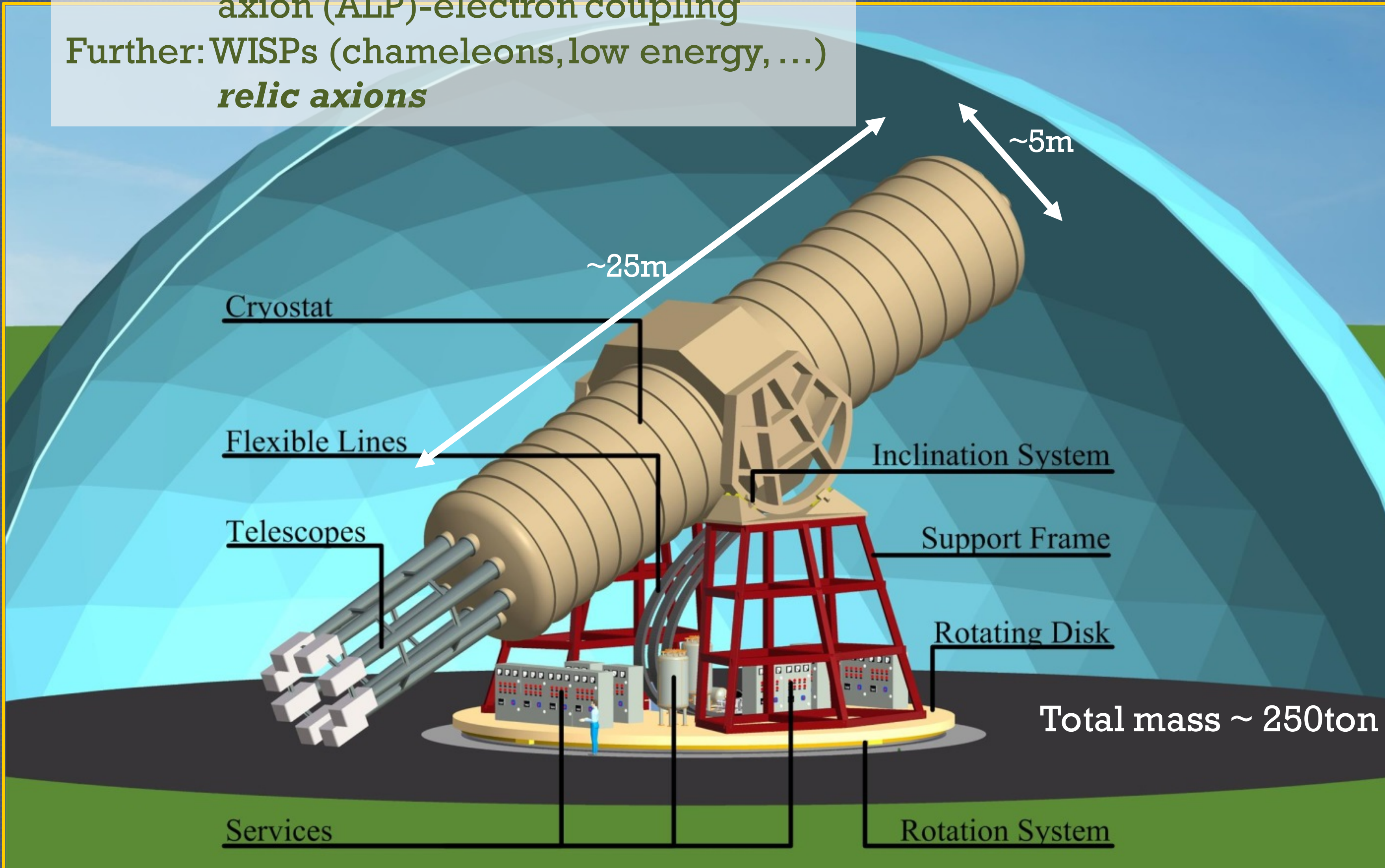
Detectors
Very low bkg and/or x-ray focusing optics

Magnet
Stronger field, bigger area

Movement
Extension of observation time

IAXO

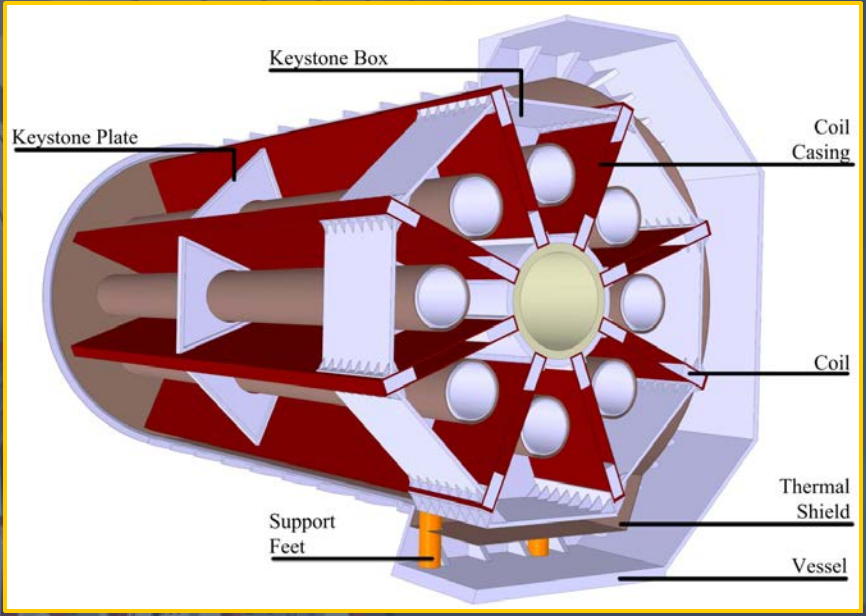
For (almost) all kinds of searches:
Basic: axion (ALP)-photon coupling
axion (ALP)-electron coupling
Further: WISPs (chameleons, low energy, …)
relic axions



IAXO

Using known technologies and existing tools

NuSTAR telescope

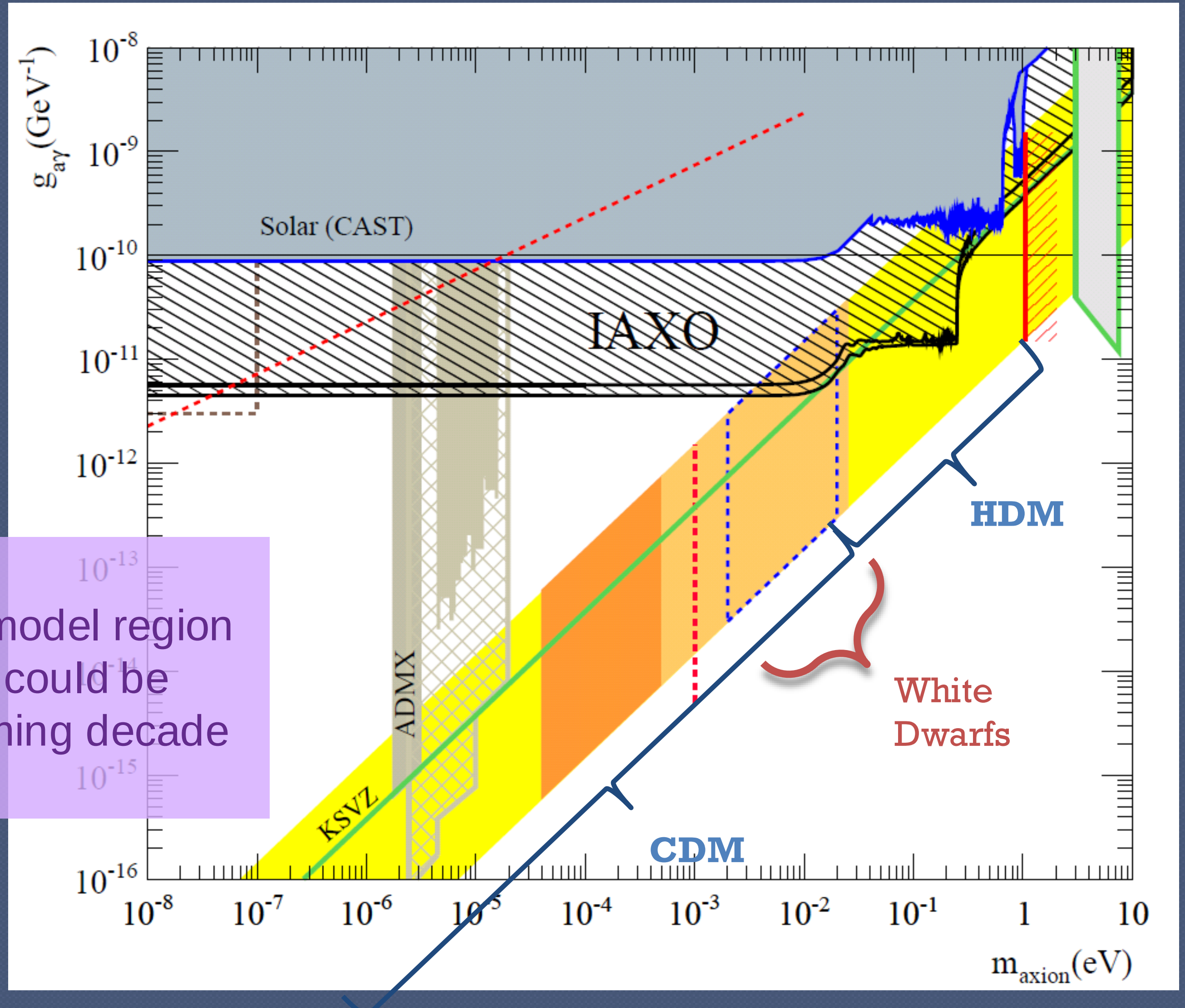


New Micromegas

More info:
I.G. Irastorza et al. , JCAP 06 (2011) 013
I. Shilon et al, IEEE Trans. Appl. Supercond. 23

IAXO

LoI to be submitted to CERN by the end of this month



Large parts of the model region for QCD axions could be explored in the coming decade

Summary

CAST, in these 11 years:

- is established as a reference in axion physics, has put the strictest limit on axion searches for a wide m_a range and has gained much experience on Helioscope Axion Searches
- is close to its final result, the latest one being (submitted to PRL):

$$g_{a\gamma} \leq 3,3 \times 10^{-10}\ GeV^{-1}\ (95\%\ C.L)\ \ for\ 0.64 < m_a < 1.17\ eV$$

at present is looking to:

- improve the vacuum results of the experiment with detectors that will increase the sensitivity and explore the possibilities to study other exotica: solar chameleons, paraphotons, improve the LE setup

The future is the International Axion Observatory (IAXO)

- Will improve the results of CAST by >1 order of magnitude
- Based on: low background detectors
  large area X-ray optics
  a new, specifically designed magnet

LoI to be submitted to CERN this month, new groups are welcome.

end

Thank you for your attention