IAXO – the future axion helioscope

Biljana Lakić

(Rudjer Bošković Institute, Zagreb)

for the

IAXO Collaboration

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IAXO: International AXion Observatory

Outline:

- Axions and ALPs
- Experimental searches
- The IAXO project
  - Physics
  - Magnet
  - X- ray optics
  - Low background detectors
- Sensitivity prospects
- Status of the project

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Towards a new generation axion helioscope

I.G. Irastorza,[a] F.T. Avignone,[b] S. Caspi,[c] J.M. Carmona,[a] T. Dafni,[a] M. Davenport,[d] A. Dudarev,[d] G. Fanourakis,[e] E. Ferrer-Ribas,[f] J. Galán,[a,f] J.A. García,[a] T. Geralis,[e] I. Giomataris,[f] H. Gómez,[a] D.H.H. Hoffmann,[g] F.J. Iguaz,[f] K. Jakovčić,[h] M. Krčmar,[h] B. Lakić,[h] G. Luzón,[a] M. Pivovaroff,[j] T. Papaevangelou,[f] G. Raffelt,[k] J. Redondo,[k] A. Rodríguez,[a] S. Russenschuck,[d] J. Ruz,[d] I. Shilon,[d,i] H. Ten Kate,[d] A. Tomás,[a] S. Troitsky,[l] K. van Bibber,[m] J.A. Villar,[a] J. Vogel,[j] L. Walckiers[d] and K. Zioutas[n]

IAXO project: JCAP 06 (2011) 013

IAXO magnet: I. Shilon et al, IEEE Trans. Appl. Supercond. 23

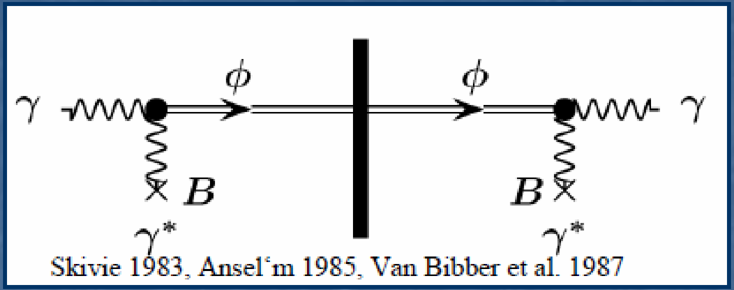
Axions and ALPs: Motivation

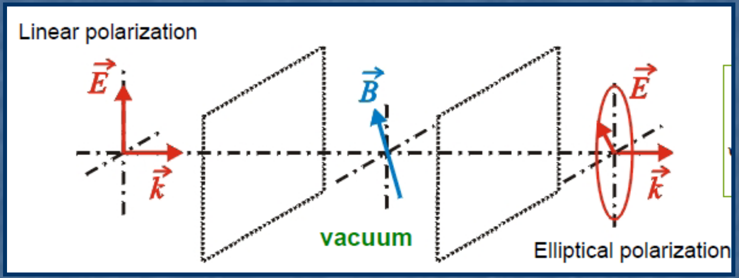
- Axions are the most elegant solution to the **Strong CP problem**: why QCD does not seem to break the CP symmetry
  - pseudoscalar particles, neutral, practically stable
- Axions are candidates for both cold and hot **dark matter**

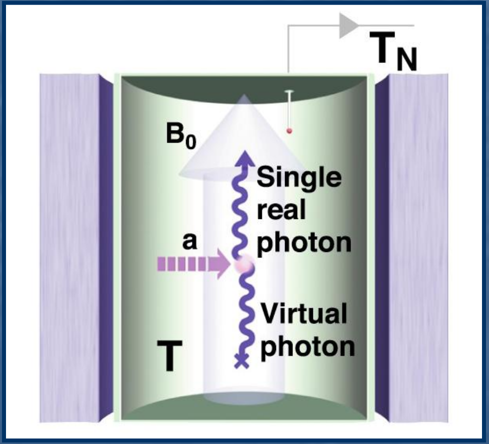
- Axion-like particles (ALPs) are predicted by many **extensions of the standard model**
- Relevant axion/ALPs parameter space at reach of current and near-future experiments
- New theory scenarios: **string theory** predicts axions/ALPs with detectable parameters
- **Astrophysical hints** for axion/ALPs?
  - transparency of the Universe to UHE gammas
  - white dwarf cooling anomaly → point to few meV axions
- ... and more ...

Experimental searches (a – γ coupling)

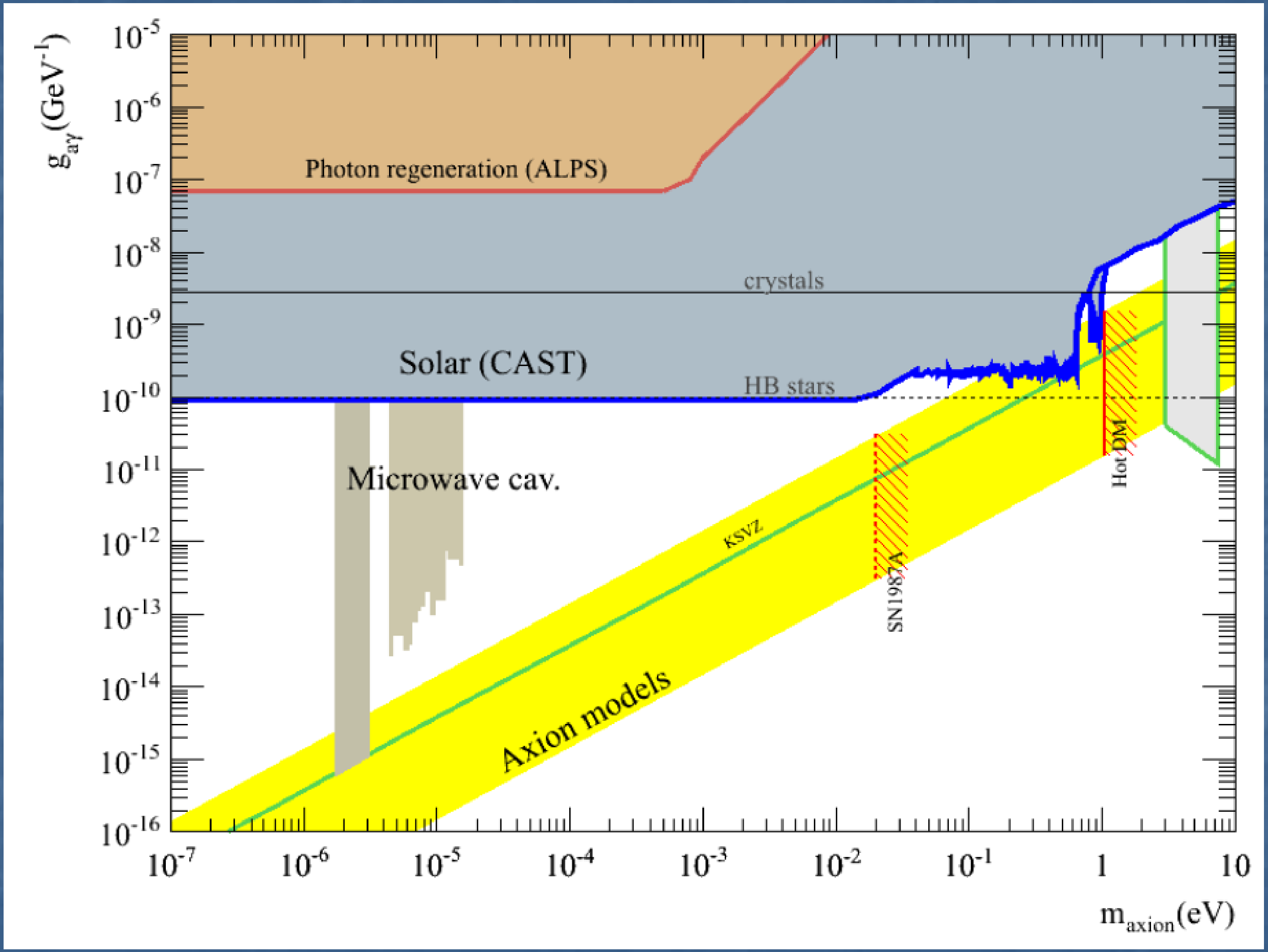
- Laser experiments:
  - Photon regeneration ("invisible light shining through wall")
  - Polarization experiments (PVLAS)
- Search for dark matter axions:
  - Microwave cavity experiments (ADMX)
- Search for solar axions:
  - Crystal detectors
  - Helioscopes (SUMICO, **CAST**)



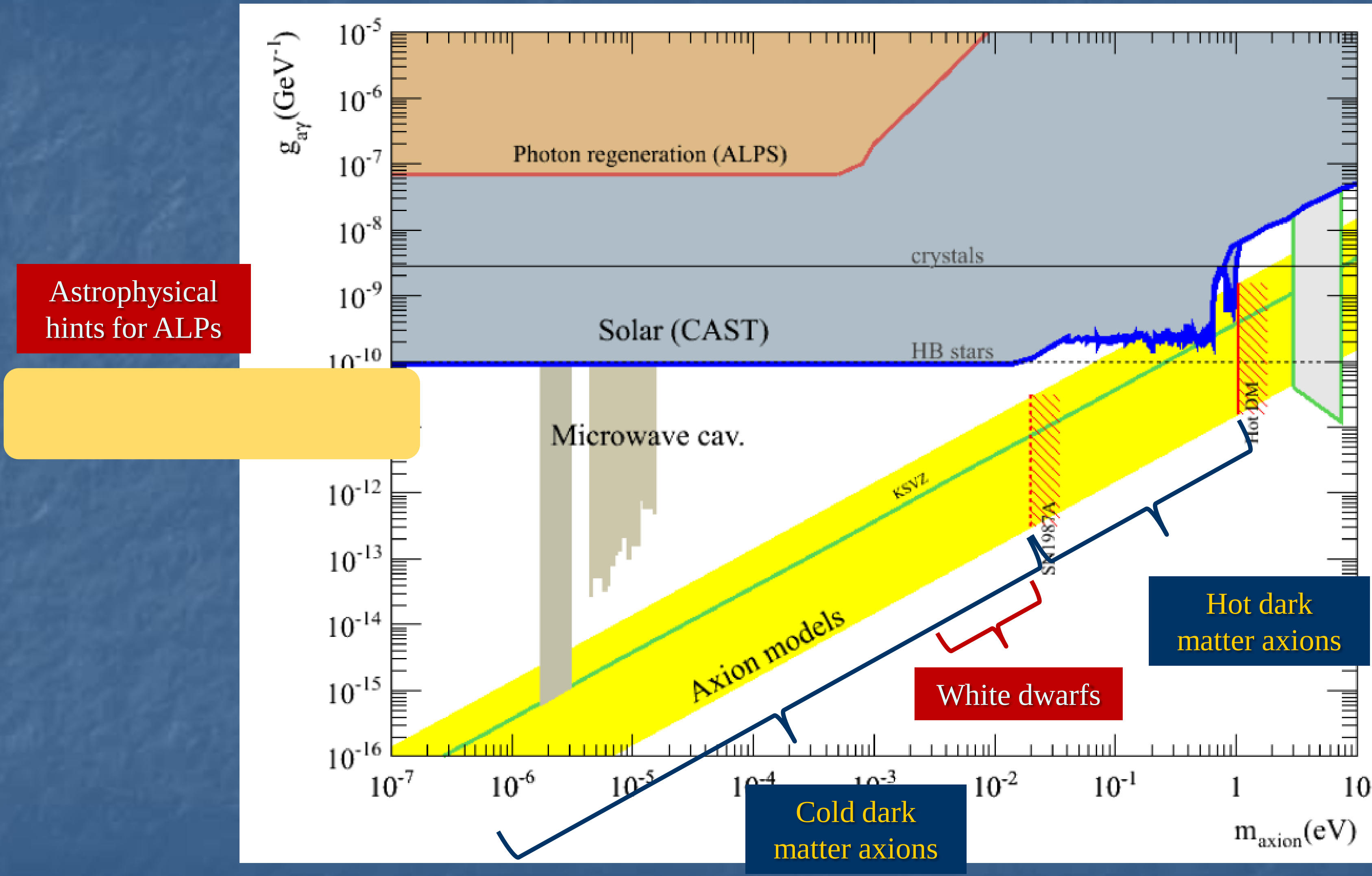




Axion/ALP parameter space

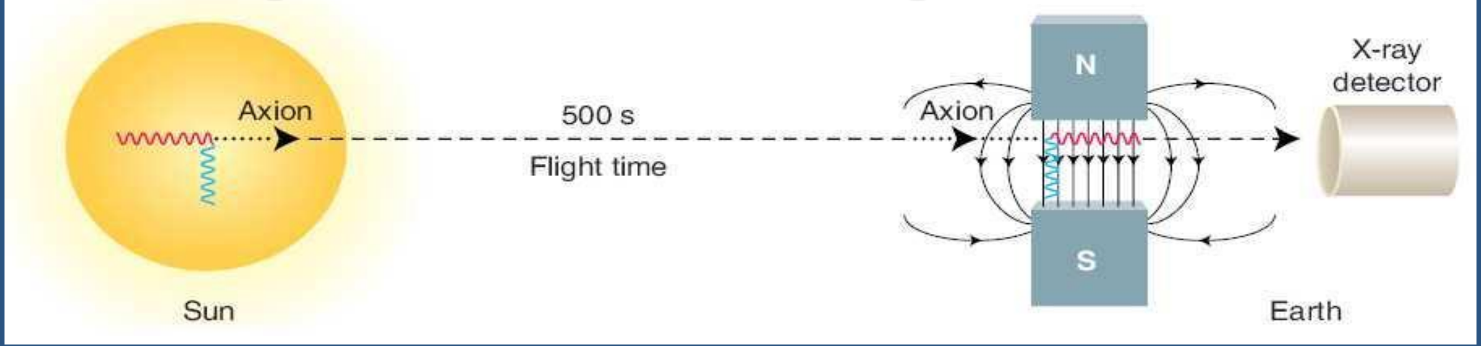


Axion/ALP parameter space



IAXO: Physics

Principle of the Axion helioscope Sikivie, Phys. Rev. Lett 51 (1983)



Sun: a thermal photon converts into an axion via Primakoff process in the solar plasma

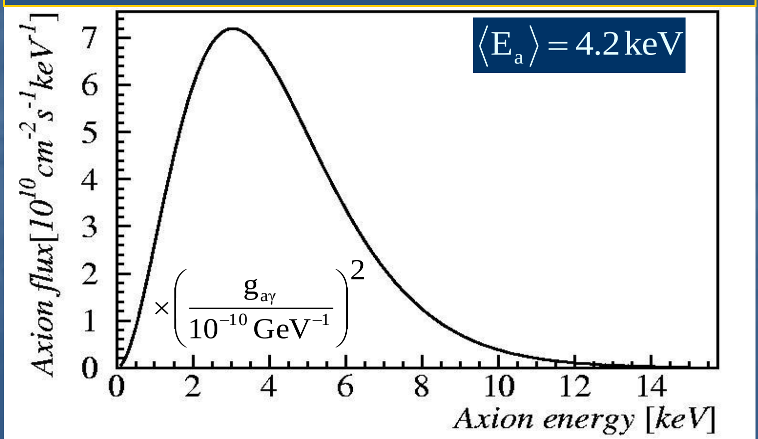
Earth: an axion converts into a photon in a strong transverse magnetic field

- expected number of photons

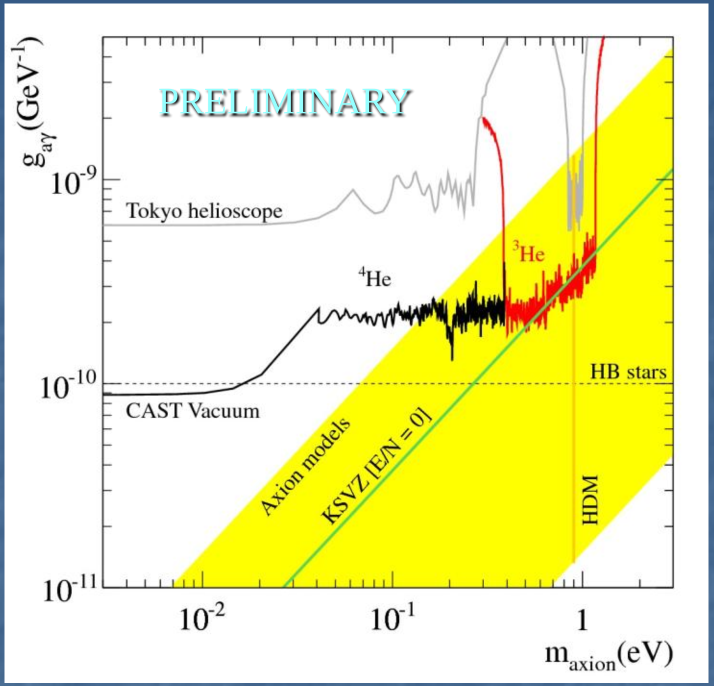
$$N_\gamma = \int \frac{d\Phi_a}{dE_a} P_{a\to\gamma} S\, t\, dE_a \quad \propto \quad g_{a\gamma}^4$$

$$P_{a\to\gamma} = \left(\frac{g_{a\gamma} B}{q}\right)^2 \sin^2\left(\frac{qL}{2}\right) \qquad q = \frac{m_a^2}{2E}$$

- differential axion flux at the Earth:



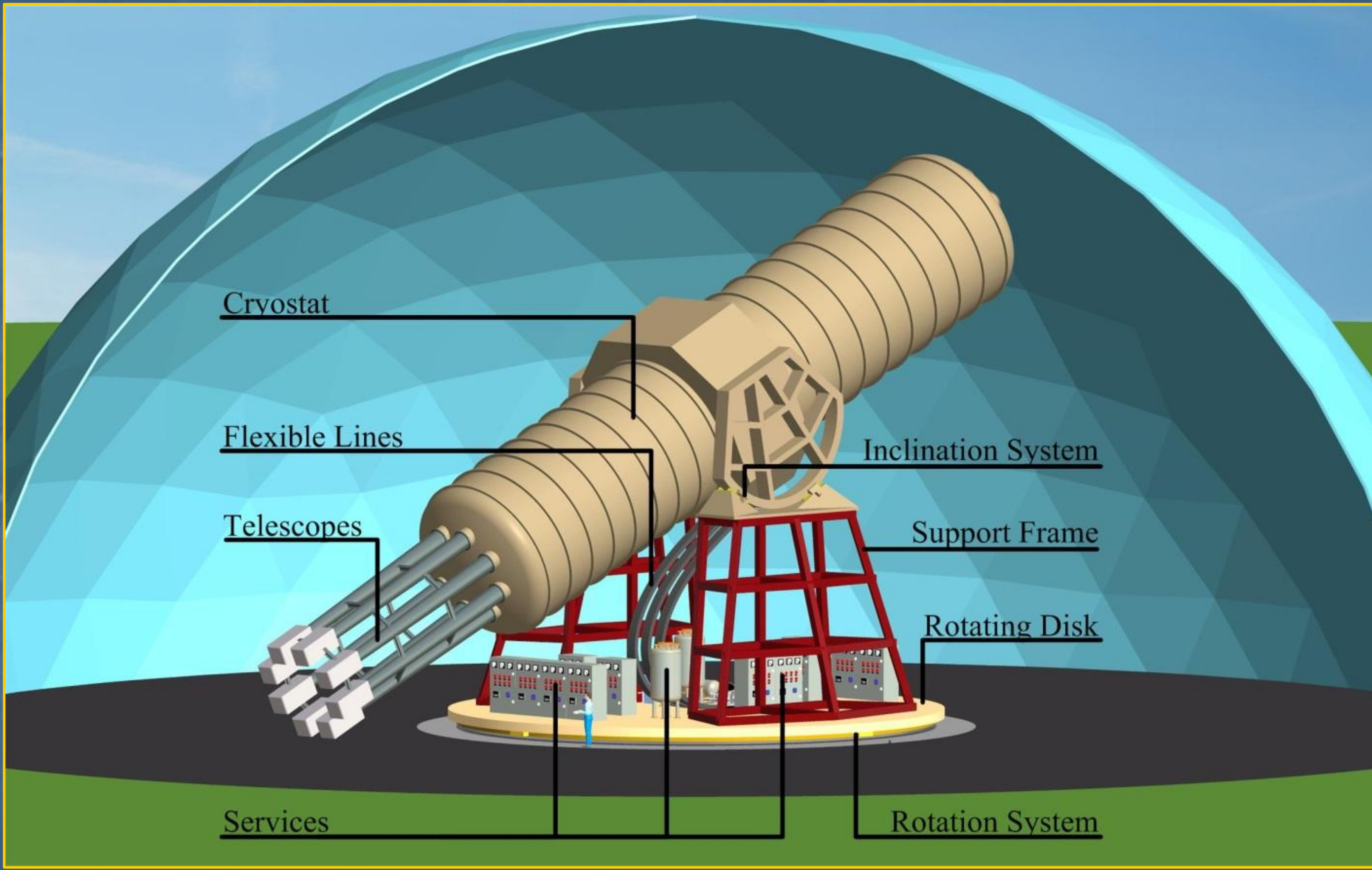
IAXO: Physics



- **CAST** (CERN Axion Solar Telescope) is currently the most sensitive axion helioscope
- No signal over background observed so far
- The best experimental limit on $g_{a\gamma}$ over a broad range of axion masses
- The collaboration gained a lot of experience in axion helioscope searches

- **IAXO** (International AXion Observatory) is a new generation axion helioscope
- Goal: more than 4 orders of magnitude in signal-to-noise ratio with respect to CAST (more than 1 order of magnitude in sensitivity to $g_{a\gamma}$)
- Challenges:
  - New dedicated superconducting magnet
  - Extensive use of X-ray optics
  - Low background detectors

IAXO: Design

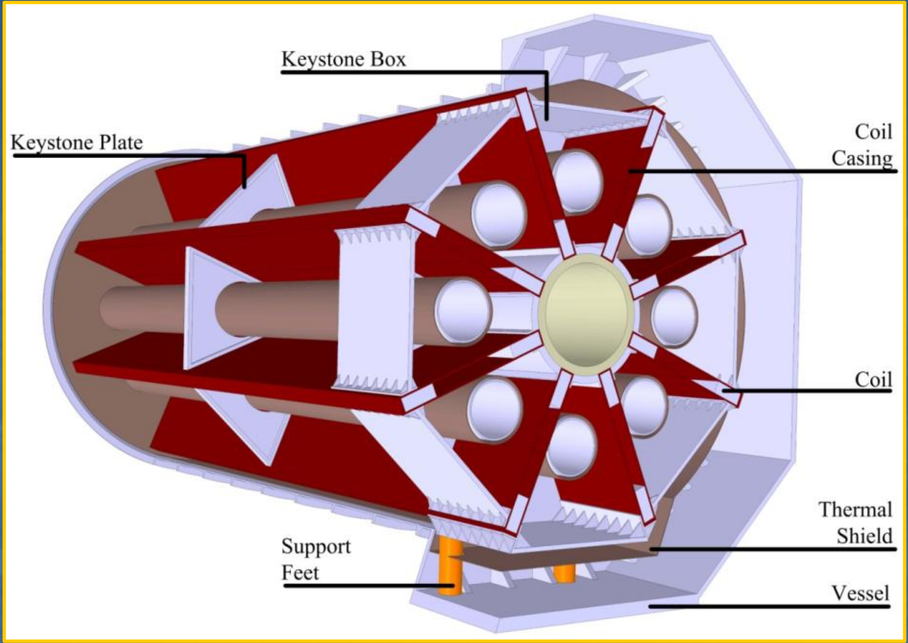


Cryostat
Flexible Lines
Telescopes
Inclination System
Support Frame
Rotating Disk
Services
Rotation System

IAXO: Magnet

Toroidal magnet:

- Much bigger aperture than CAST: ~ 0.6 m ∅ each bore (× 8 bores)
- Bores at room temperature
- Decoupled from the optical detection system
- Relies on known engineering solutions (developed for ATLAS)



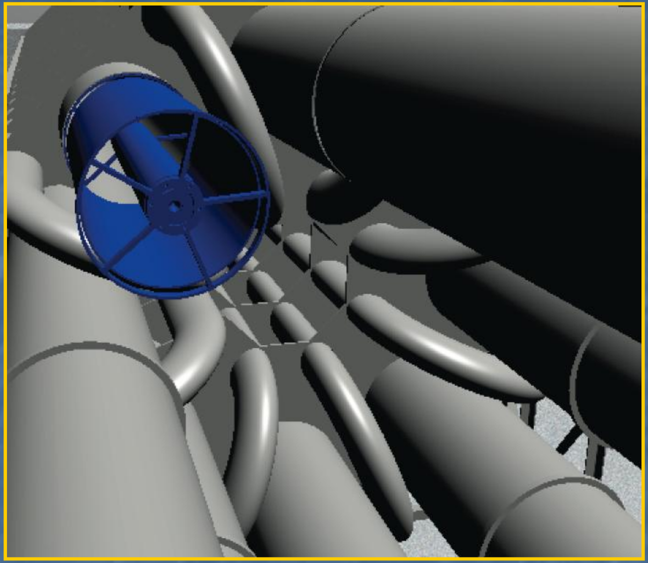
	Property	Value	Unit
Cryostat dimensions:	Overall length	25	m
	Outer diameter	5.2	m
	Cryostat volume	~ 530	m^3
Toroid size:	Inner radius, R_{in}	1.05	m
	Outer radius, R_{out}	2.05	m
	Total axial length	21	m
Mass:	Conductor	65	tons
	Cold Mass	130	tons
	Cryostat	35	tons
	Total assembly	~ 250	tons

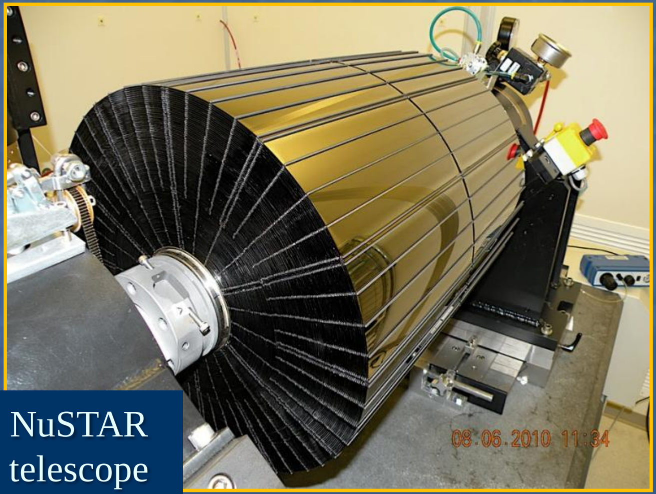
IAXO: X-ray optics

CAST X-ray optics: high technology, expensive, exquisite imaging properties (required in X-ray astronomy)

IAXO X-ray optics:

- Exquisite imaging not required
- Large area to be covered
- Pursued solution: thermally-formed glass substrates
  - Successfully used by NASA for NuSTAR telescope
  - Cost effective solution
- Some properties:
  - 8 telescopes, 5 m focal length
  - Good throughput (0.3 – 0.5)
  - Small focal point (~ 1 cm^2)





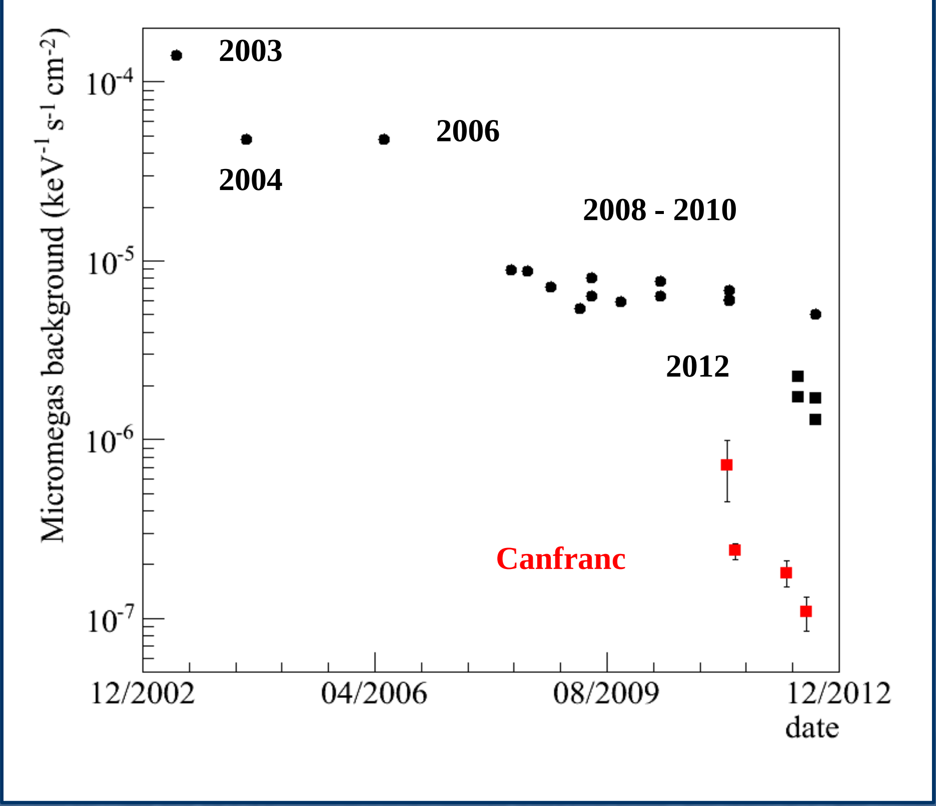
NuSTAR telescope

IAXO: Detectors

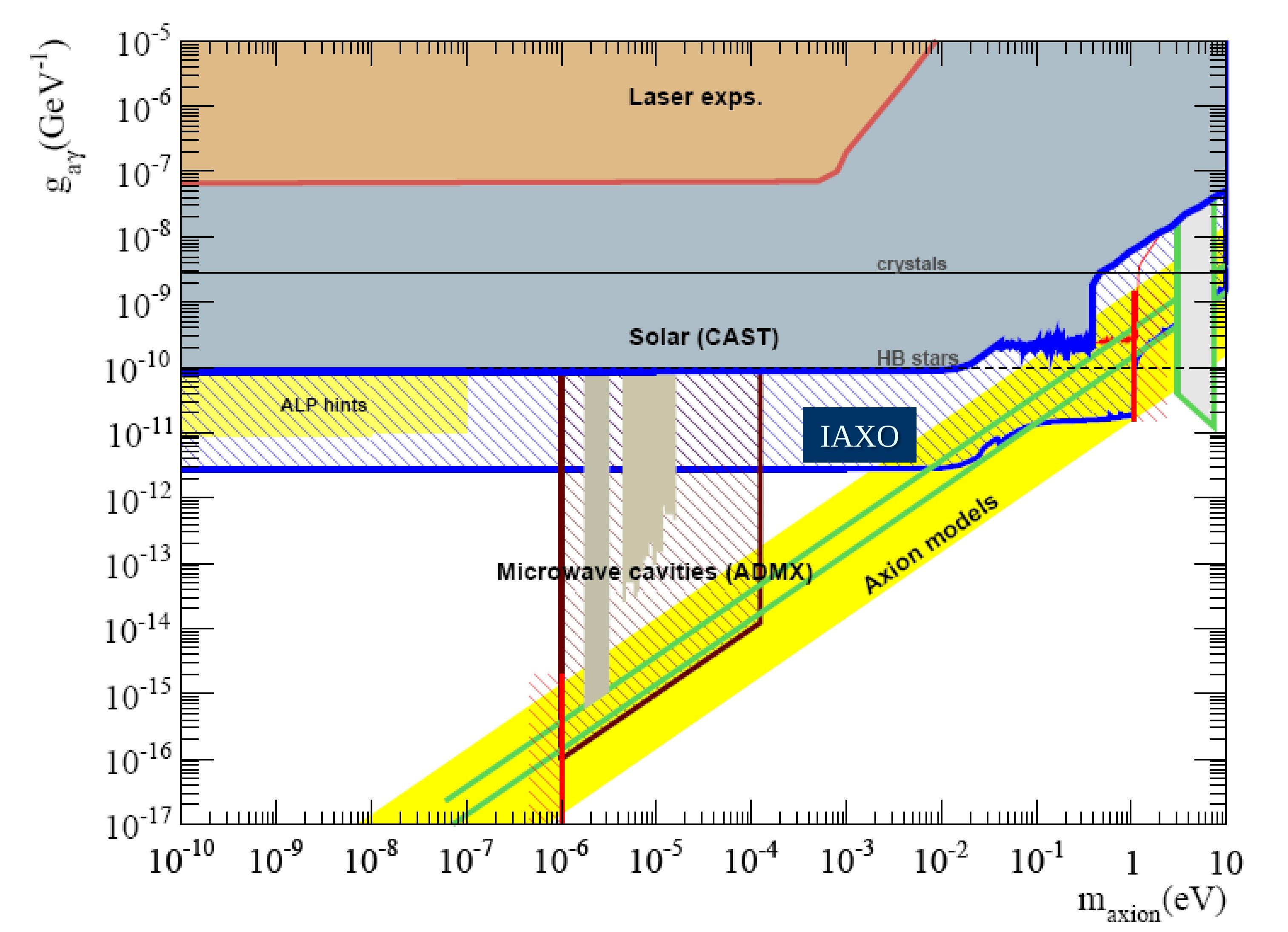
Low background detectors for IAXO:
Micromegas detectors (used in CAST)

- 20× background reduction during the CAST operation:
  - High radio-purity materials
  - Shielding
  - New technique (Microbulk)
- Active program to further reduce background
  - Experimental tests with current detectors at CERN, Zaragoza, Saclay
  - Underground setup at Canfranc
  - Simulation works to build up a background model
- Goal: at least **10^{-7} c/keV/cm^2/s** (down to 10^{-8} c/keV/cm^2/s if possible)

History of background evolution of Micromegas detectors in CAST

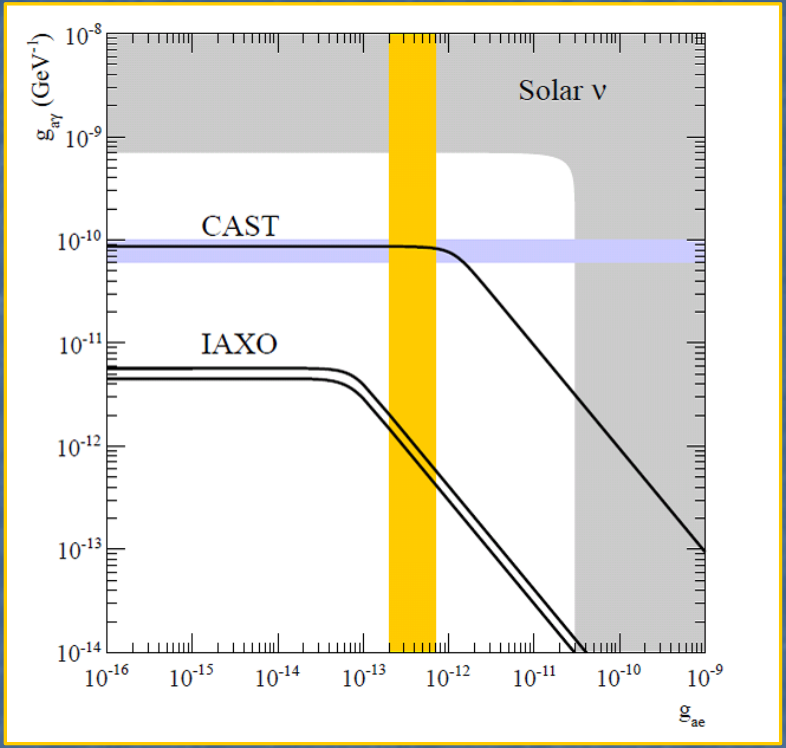


IAXO: Sensitivity prospects



IAXO: Sensitivity prospects

IAXO basic program: axion(ALP) – photon coupling , axion(ALP) – electron coupling



Further physics cases:

- search for WISPs: paraphotons, chameleons, ...
- relic axions: if equipped with microwave cavities, cold dark matter halo axions could be searched for → under study

IAXO: Status of the project

- IAXO collaboration:
  - Most CAST groups
  - New groups & extended expertises (magnet, optics)
  - Open for new interested groups
- CAST 2013 – 2014 plan includes tests of techniques and know-how for IAXO
  - Small X-ray optics (~5 cm aperture) fabricated using thermally formed glass substrates
  - Micromegas low background detector
- Conceptual Design Report in preparation
- Letter of Intent is practically finished and will be submitted to CERN soon

Conclusions

- CAST is currently the most sensitive axion helioscope. The collaboration has gained a lot of experience in axion helioscope searches (magnet, optics, low background detectors).
- IAXO is a new generation axion helioscope aiming to improve CAST sensitivity to axion-photon coupling constant by 1 – 1.5 orders of magnitude.
- Potential for additional physics cases: axion-electron coupling, relic axions, WISPs
- Future helioscope experiments and Microwave cavity searches (ADMX) could cover a big part of QCD axion model region in the next decade.