DTU Space

and the search for axions

The X-ray optics for babyIAXO

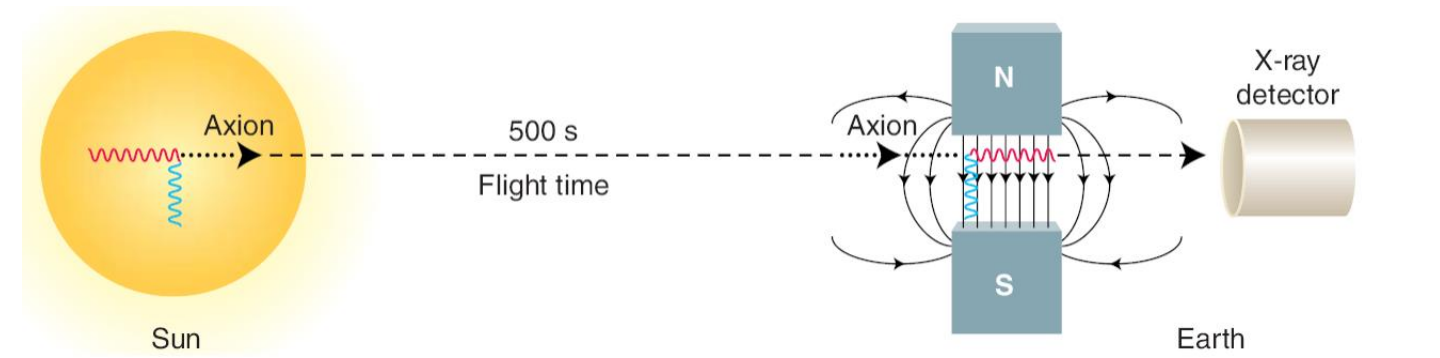
Desiree Della Monica Ferreira
desiree@space.dtu.dk

Solar Axion Detection

- First axion helioscope proposed by P. Sikivie

Sikivie *PRL* 51:1415 (1983)

  - Blackbody photons (keV) in solar core can be converted into axions in the presence of strong electromagentic fields in the plasma
  - Reconversions of axions into x-ray photons possible in strong laboratory magnetic field



- Idea refined by K. van Bibber by using buffer gas to restore coherence over long magnetic field

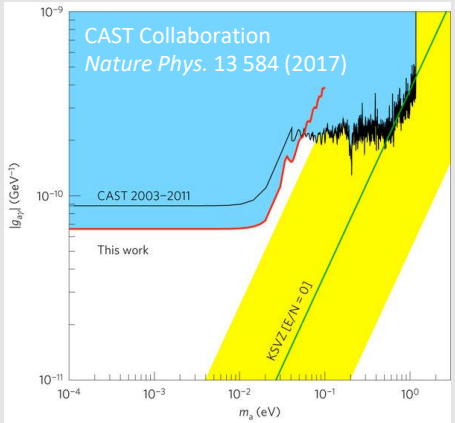
Van Bibber et al. *Phys.Rev. D* 39:2089 (1989)

Slides/image credit: IAXO collaboration

Solar Axion Detection

- **1st generation helioscope: Brookhaven**
  - Just a few hours of data
  - Lazarus et at. PRL 69 (92)
- **2nd generation: Tokyo Helioscope (SUMICO)**
  - 2.3 m long, 4 T magnet
- **3rd generation: CERN Axion Solar Telescope (CAST)**
  - Most sensitive axion helioscope to date (10 m, 9 T)
  - No axions detected yet
  - Best experimental limit on axion-photon coupling over broad axion mass range

    $g_{a\gamma} < 0.66 \times 10^{-10}$ GeV^{-1} (95% C.L.)
  - Latest results enabled by IAXO-pathfinder: NuSTAR-like X-ray optic coupled with low-background Micromegas



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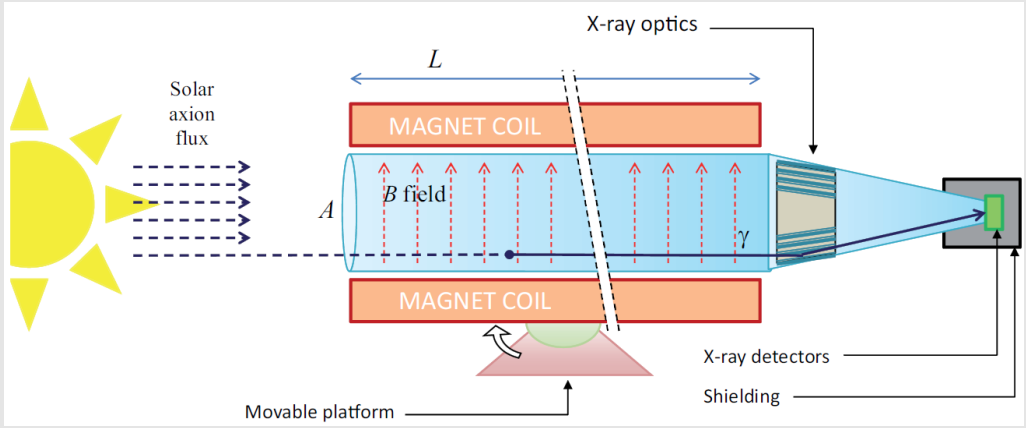
4th Generation: An Enhanced Axion HelioScope

Enhanced axion helioscope: JCAP 1106, 013 (2011)



Measure of sensitivity to axion-photon interaction:

The smaller $g_{a\gamma}$ the better!

$$g_{a\gamma}^4 \propto \underbrace{(BL)^{-2}A^{-1}}_{\textbf{magnet}} \times \underbrace{t^{-1/2}}_{\textbf{exposure}} \times \underbrace{s^{1/2}\varepsilon_0^{-1}}_{\textbf{optics}} \times \underbrace{b^{1/2}\varepsilon^{-1}}_{\textbf{detectors}}$$

magnet
- B = magnetic field
- L = magnet length
- A = cross-sectional area

exposure
- t = time

optics
- s = spot size
- ε_0 = efficiency

detectors
- b = background
- ε = efficiency

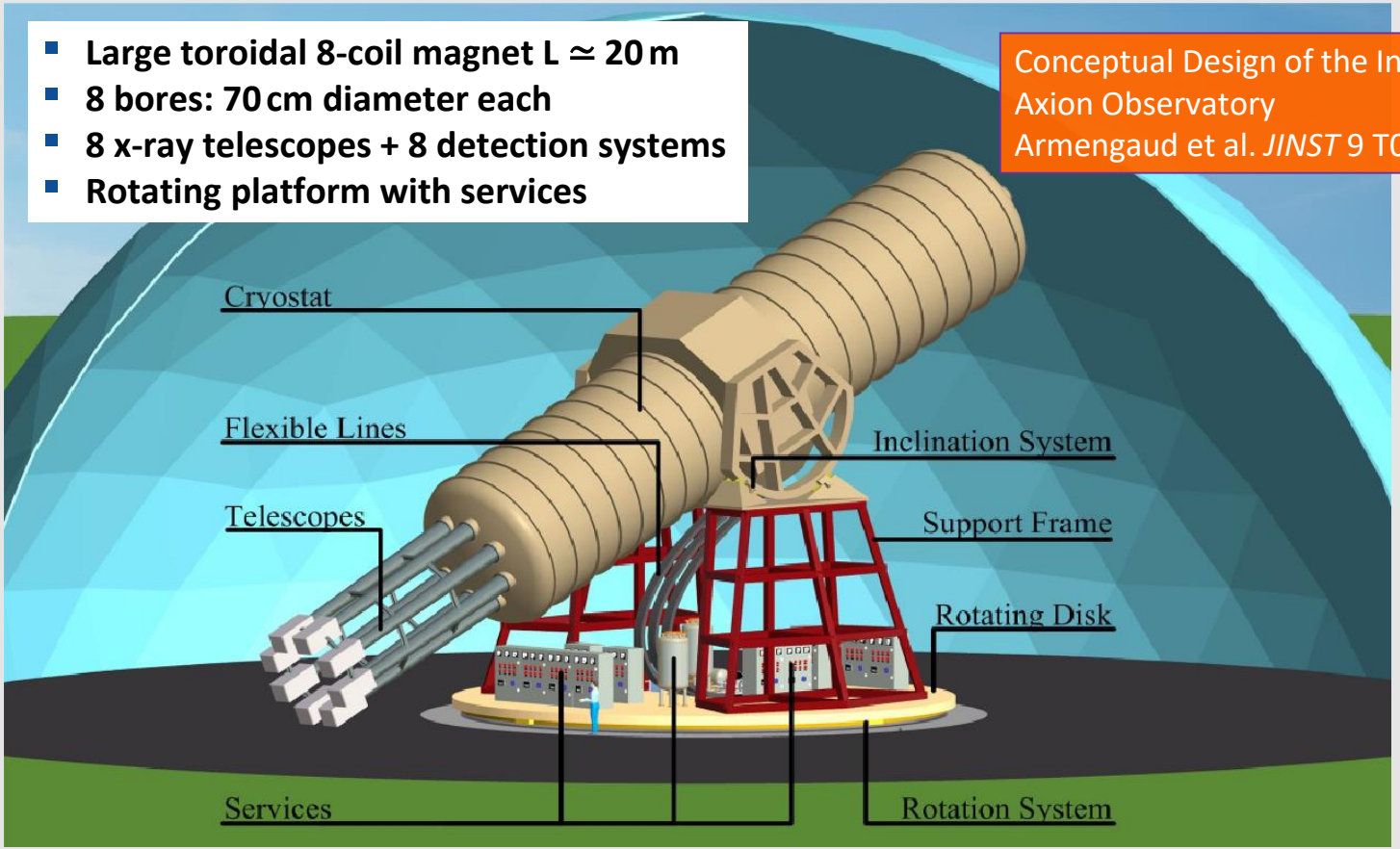
Expected improvement over CAST with IAXO:
1–1.5 orders of magnitude in sensitivity to $g_{a\gamma}$ (factor of 10000-20000 in S/N)

Slides/image credit: IAXO collaboration

IAXO Conceptual Design

- **Large toroidal 8-coil magnet L ≃ 20 m**
- **8 bores: 70 cm diameter each**
- **8 x-ray telescopes + 8 detection systems**
- **Rotating platform with services**

Conceptual Design of the International Axion Observatory
Armengaud et al. *JINST* 9 T05002 (2014)



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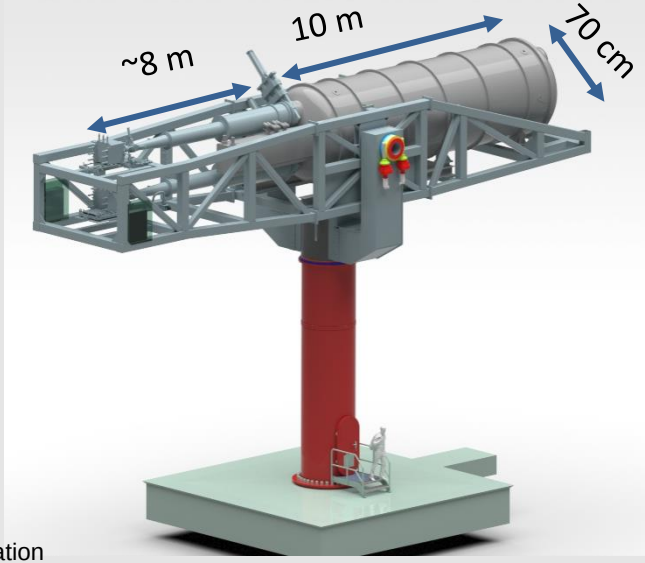
BabyIAXO

BabyIAXO = Intermediate experimental stage before IAXO

- Performance verification for IAXO and significant science return at the same time
- Conceptual design finished and successfully reviewed by DESY 2019
- Magnet will be upscalable version for IAXO
- Two bores of dimensions similar to final IAXO bores



Free bore [m]	2 x 0.7
Magnetic length [m]	10
Field in bore [T]	~2-3
Stored energy [MJ]	40-50
Peak field [T]	4.1
~10x CAST B^2L^2A	

Slides/image credit: IAXO collaboration

BabyIAXO X-ray Optics

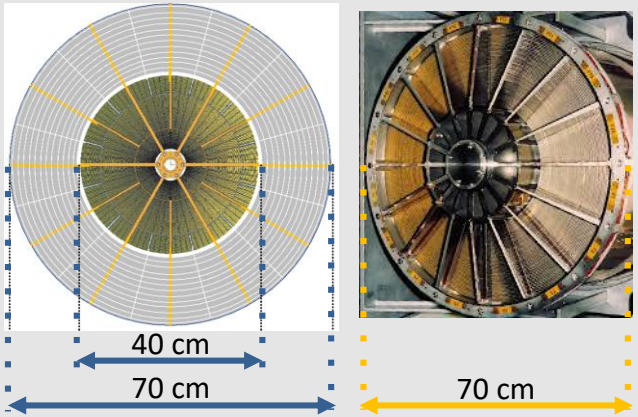
Baseline option: One custom IAXO optic (multilayer-coated, segmented-glass or Al-foil Wolter-I) and flight spare XMM telescope

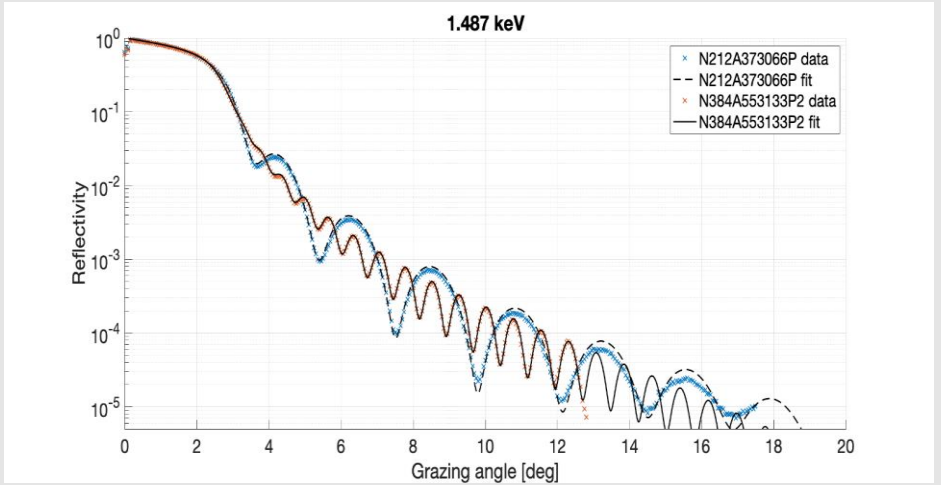
Minimal risk to the project

- Risk reduction for final IAXO segmented-glass optics
- XMM optics specs very close to IAXO optics design
- First coating test (10 & 30 nm Ir) on Nustar flight spare glass and Willow glass, great match of data and model

Custom optics
Hot and cold slumped glass

XMM Flight spare
Replicated optics





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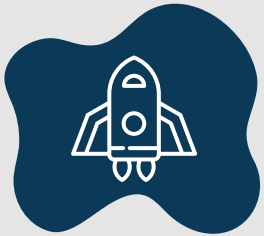
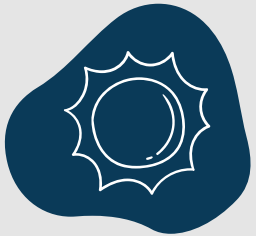
Why DTU Space?

Who are we?



What do we do?



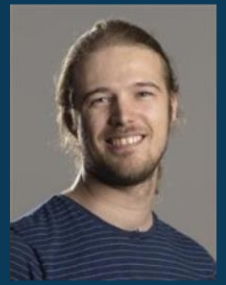
How can we help?

Research in High Energy Instrumentation for Astrophysics Group at DTU Space

Desiree D. M. Ferreira
Senior Researcher, Astrophysicist.
Astrophyics, Data analysis,Telescope design.

Sonny Massahi
Postdoc, Engineer.
Nanofabrication, Programming, Material Science.

Sara Svendsen
Postdoc, Physicist.
Nanofabrication, Data analysis, Ray-tracing.



Arne 'S Jegers
PhD Student, Engineer.
Programming, Ray-tracing, High-energy optics geometry.

Nis C. Gellert
PhD Student, Engineer.
Nanofabrication, High-energy optics, Data analysis.

Finn E. Christensen
Senior Researcher Emeritus, Physicist.
Material science, Reflectometry, Telescope design.

Niels Jørgen Westergaard
Senior Adviser Emeritus, Physicist.
Ray-tracing, Astrophysics, Telescope design.

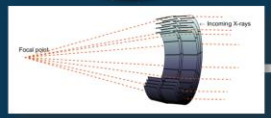
What do we do:

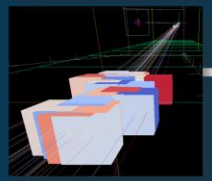
High Energy Astrophysics

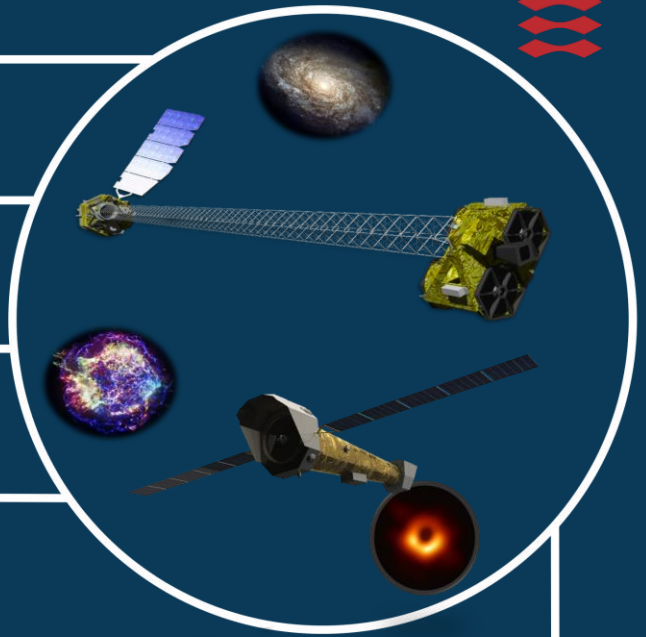
X-ray Telescope Design

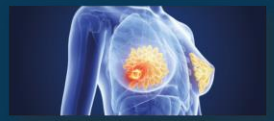
Experimental X-ray Physics

Simulation of Performance



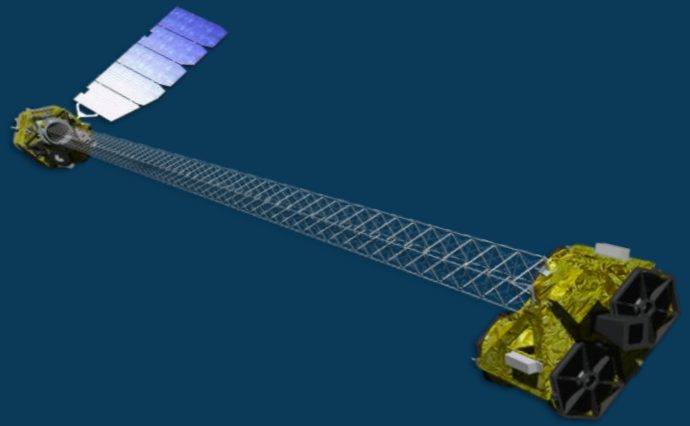


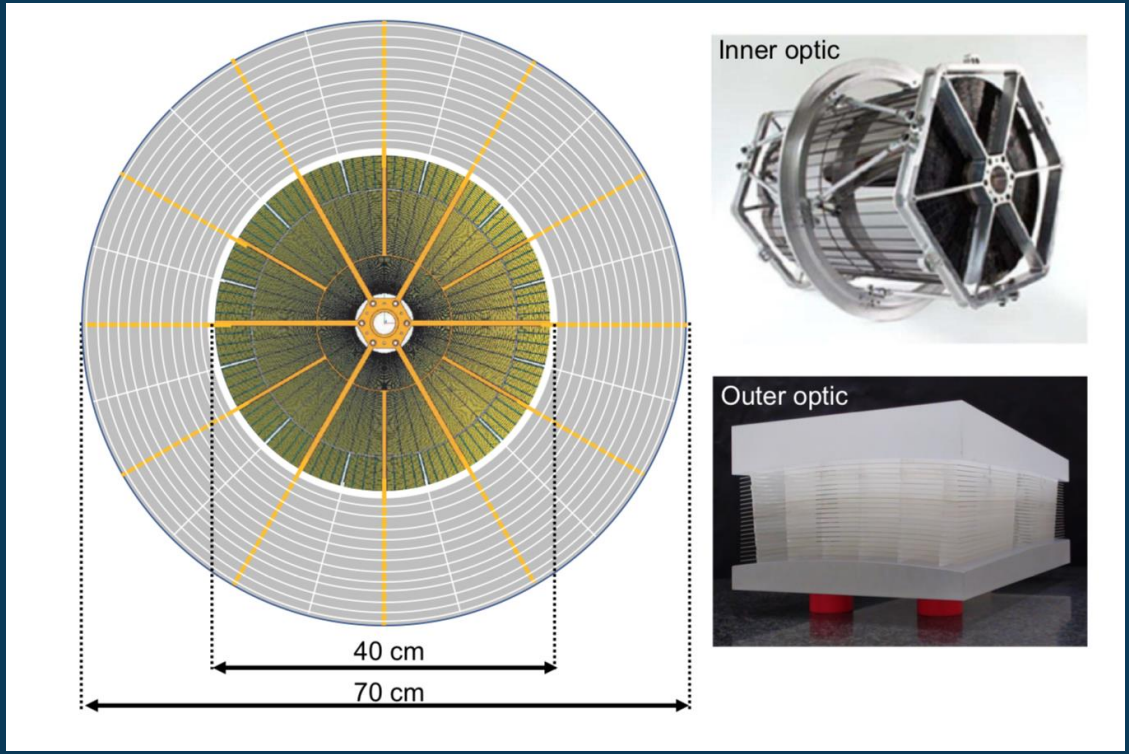




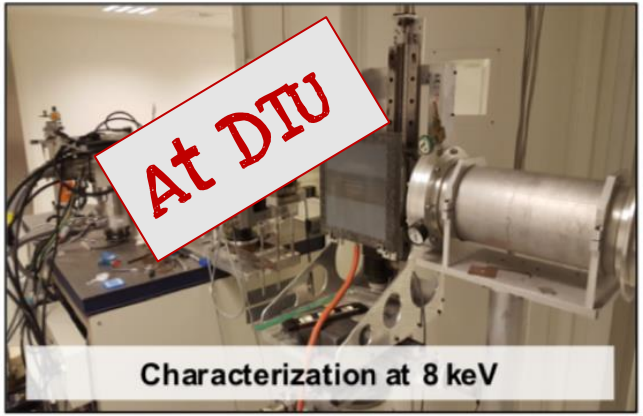
How can we help?

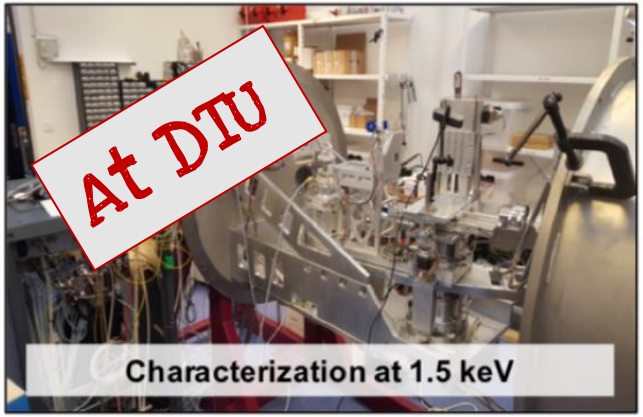
- **NuSTAR like telescope**
  - X-ray reflective mirror coatings successfully developed and manufactored at DTU Space.
  - Sent to space in 2012 still operational
  - In-house hardware and know-how

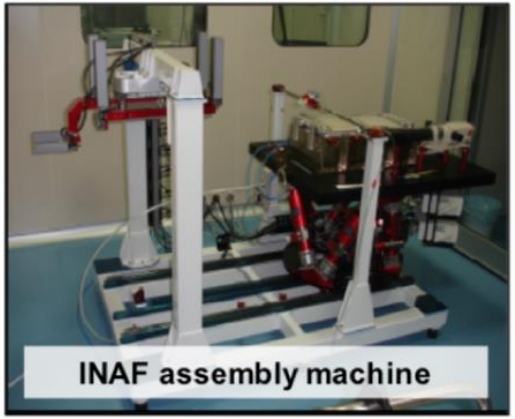




How can we help?







From 2022

Building BabyIAXO
Expect 1 year for X-ray optics coating
and qualification at DTU Space

~2027

BabyIAXO operational

2030s

IAXO operational

What now?

Space needs you!

$$$

1 Scientific Staff

2 Technical Staff

3 Materials

Iridium coated X-ray mirrors

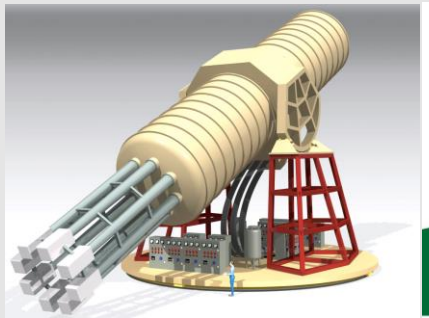
4 Lab use and maintenance

Expected coats for our activity at DTU Space

500.000 Euros

Summary

- Axions and ALPs could solve the dark matter problem.
- Helioscopes can search for axions and ALPs from the Sun over wide mass range.
- BabyIAXO envisioned to reach a few 10^{-11} GeV^{-1} in coupling of axion-to photons as a scalable prototype of the IAXO experiment.
- Denmark has the capacity to participate in this exciting experiment providing a critical, science enabling technology, fundamental for the helioscope.
- We need funding.



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