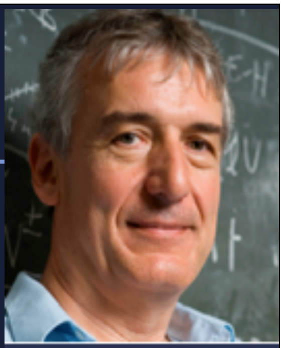
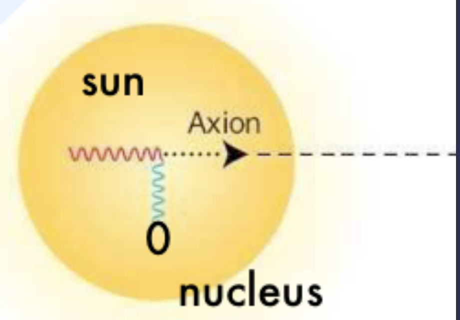
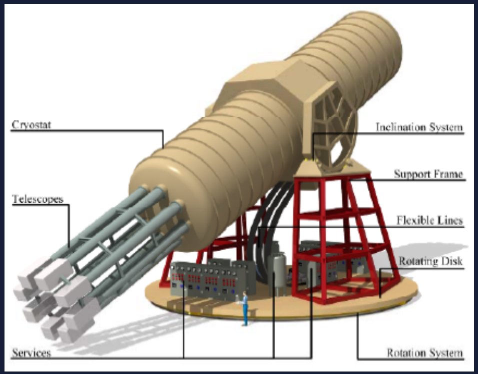
Axions and ALPs



Pierre Sikivie

Searching for Solar Axions and Axion-Like Particles with Magnetic Helioscopes: IAXO a Proposed Next Generation Search.





Frank Avignone
University of South Carolina
Columbia, South Carolina, USA

Laboratori Nazionali del Gran Sasso
April 1, 2014

The Story Starts With QCD

The Strong CP-Problem, the Neutron Electron Dipole Moment, and the PECCEI-QUINN Proposed Solution and Axions?

ALPs (Axion-Like Particles) and Their Motivation from Cosmology

The Sun as a Source of Axions and ALPS, and Detection Techniques

Searching for Solar Axions and ALPs with Helioscopes

IAXO, The Proposed Next Generation Instrument

2013 Sakurai Prize

Roberto Peccei

Helen Quinn

The U(1) Problem in QCD

In the Non-Trivial QCD Vacuum, aTerm appears in the Lagrangian That Violates “P” and “T”, but Preserves “C”.

$$\mathcal{L}_\theta = \frac{\theta}{32\pi^2} F_a^{\mu\nu} \tilde{F}_{a\mu\nu}$$

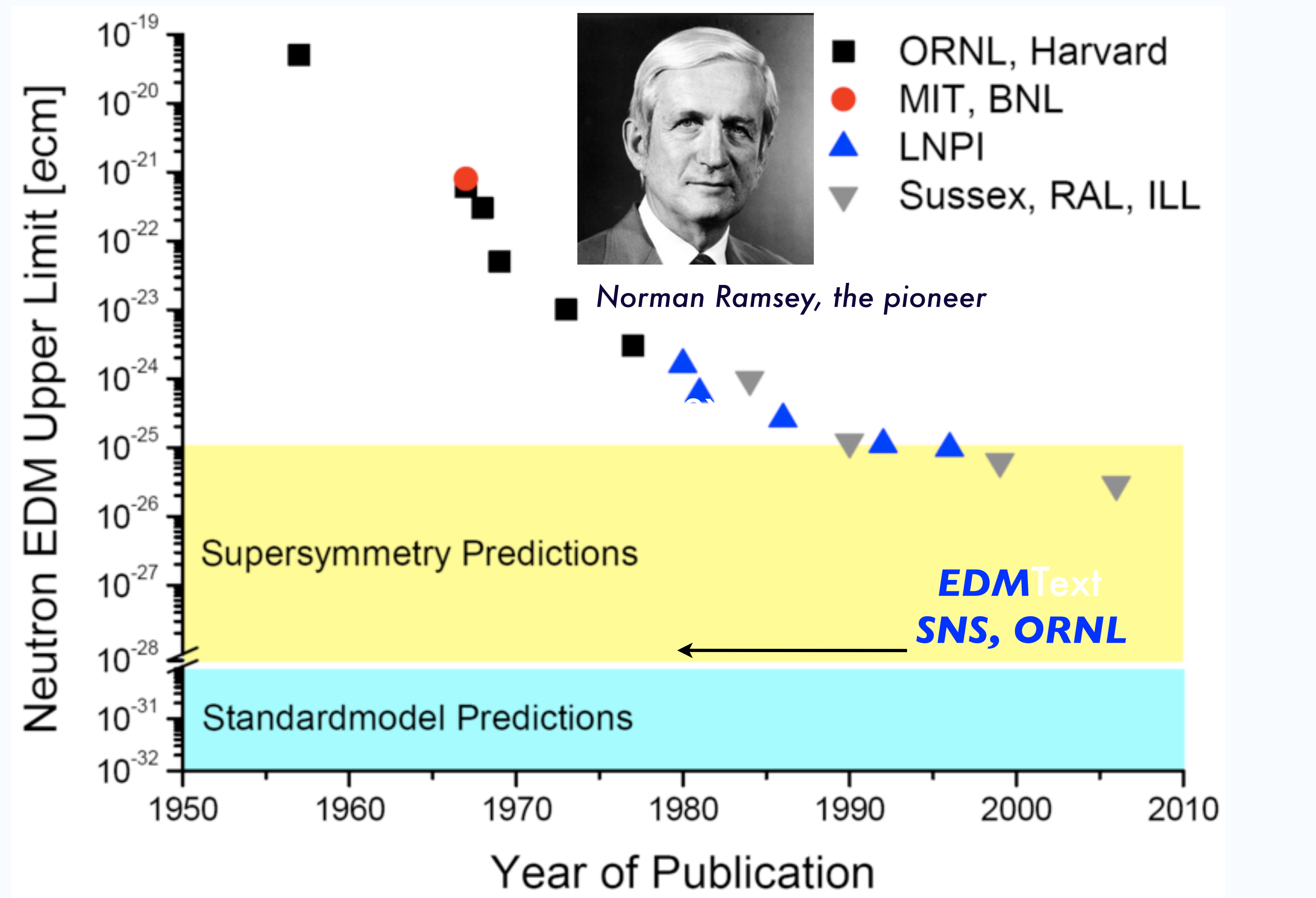
Theta is a Strong Interaction Parameter, and Unless it is of Order 10^{-10}, this Term leads to an Electric Dipole Moment of the Neutron of Order 10^{-16} e-cm.

The Experimental Upper Bound is 2.9×10^{-26} e-cm.

The Puzzle is Why a Strong Interaction Parameter is of Order 10.$^{-10}$ This is Called the Strong CP-Problem.

Neutron EDM Measurement History

How Far Can ULTRA-COLD Neutrons Take US ?



Norman Ramsey, the pioneer

The Birth of the Axion

The New Global Symmetry in QCD postulated by PECCEI and QUINN is Spontaneously Broken resulting in the cancellation of the CP-violating term. Phys. Rev. Lett. 38,1440 (1977).

Steve Weinberg

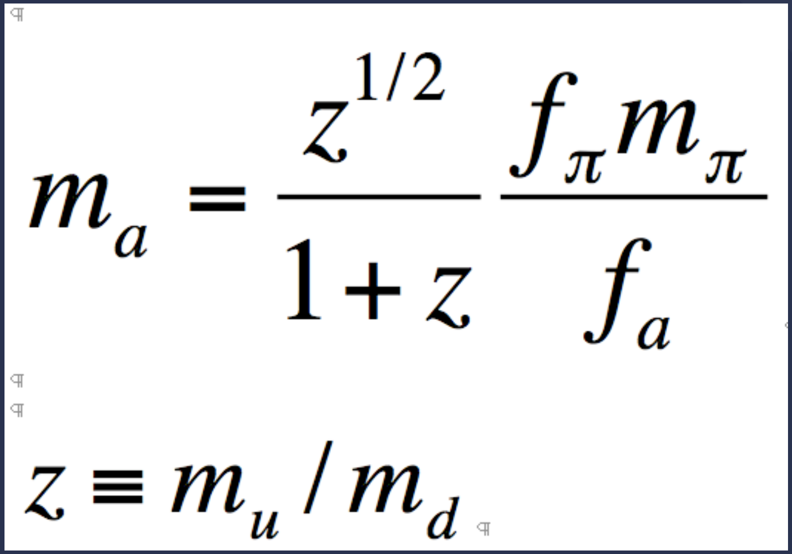
Frank Wilczek

A Goldstone Boson results from the Broken Symmetry. What are its properties ? Steven Weinberg Phys. Rev. 40, 223 (1977), and Frank Wilczek, Phys. Rev. Lett. 40, 279 (1977).

The Axion is this Goldstone Boson; It Can Interact With Photons, Electrons and Quarks!

The Properties of Axions and ALPs

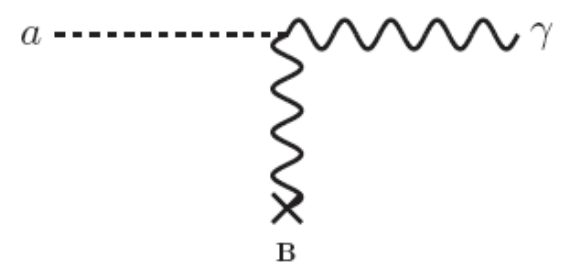
Axions are Spinless Bosons that Obey the Following Relationship Between Coupling and Mass:



$$m_a = \frac{z^{1/2}}{1+z}\frac{f_\pi m_\pi}{f_a}$$

$$z \equiv m_u / m_d$$

Peccei-Quinn Axions Obey this Relation



ALPs Couple to the Electromagnetic Field in the Same Way, but Do not obey the same constrained relationship between Mass and Coupling.

An Interesting Puzzle in Cosmology

Photons in the energy range of TeV, emitted from active galactic Nuclei (Blazers) at distances of thousands of Mpc, arrive at the Earth.

How do they survive the Extragalactic Background Radiation (EBR) ?

The Puzzle

How do TeV Photons Travel Cosmological Distances and Escape the Opacity of the Bath of Background Radiation

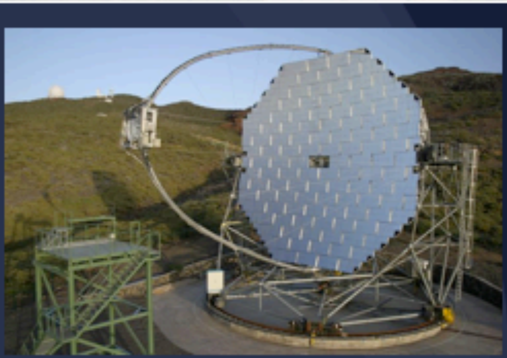
$$\sigma(\gamma_{TeV}, \gamma_{EBR}) \Rightarrow e^{+}e^{-}$$

Why are they not Severely Attenuated by the Photon-Photon interaction that Produces Electron-Positron Pairs

AXION-LIKE PARTICLES: A SOLUTION TO THE COSMOLOGICAL PHOTON-SURVIVAL PUZZLE?

H.E.S.S.

VERITAS

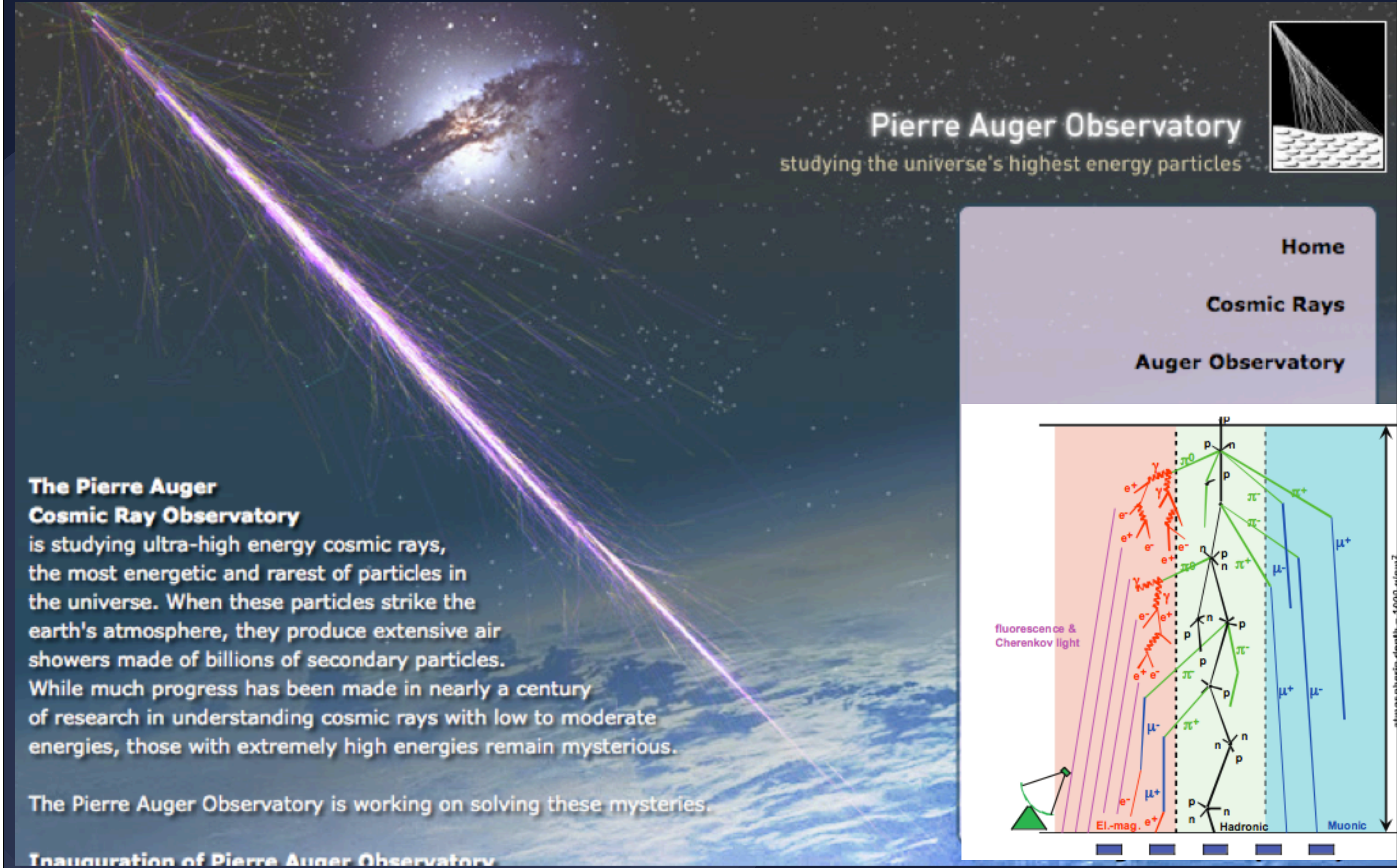


MAGIC

CANGAROO

Cerenkov Telescopes can detect ultra-high energy photons from their interaction in the atmosphere.

Cherenkov Light from UHE Gamma-Rays



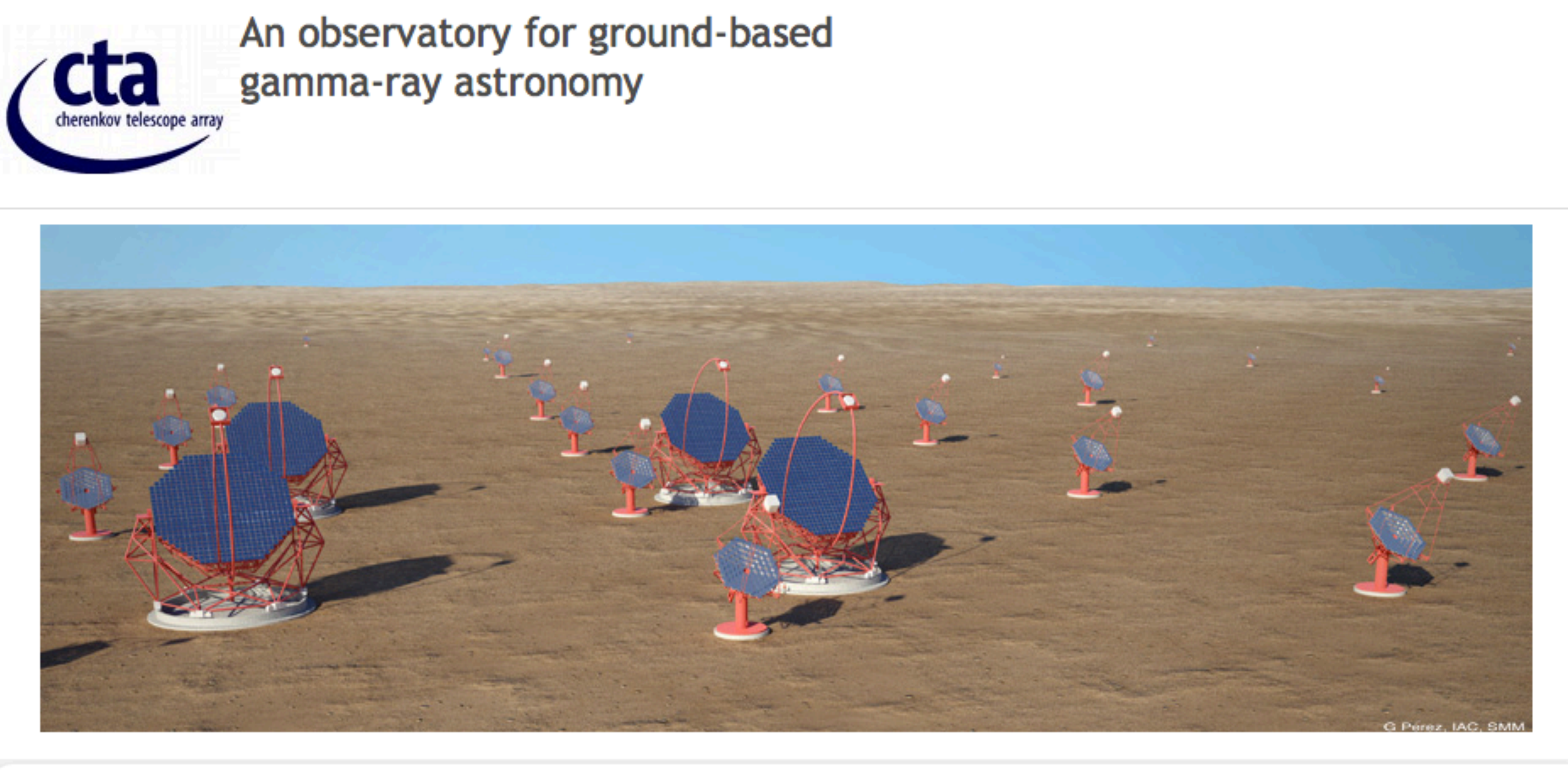
Pierre Auger Observatory
studying the universe's highest energy particles

The Pierre Auger Cosmic Ray Observatory is studying ultra-high energy cosmic rays, the most energetic and rarest of particles in the universe. When these particles strike the earth's atmosphere, they produce extensive air showers made of billions of secondary particles. While much progress has been made in nearly a century of research in understanding cosmic rays with low to moderate energies, those with extremely high energies remain mysterious.

The Pierre Auger Observatory is working on solving these mysteries.

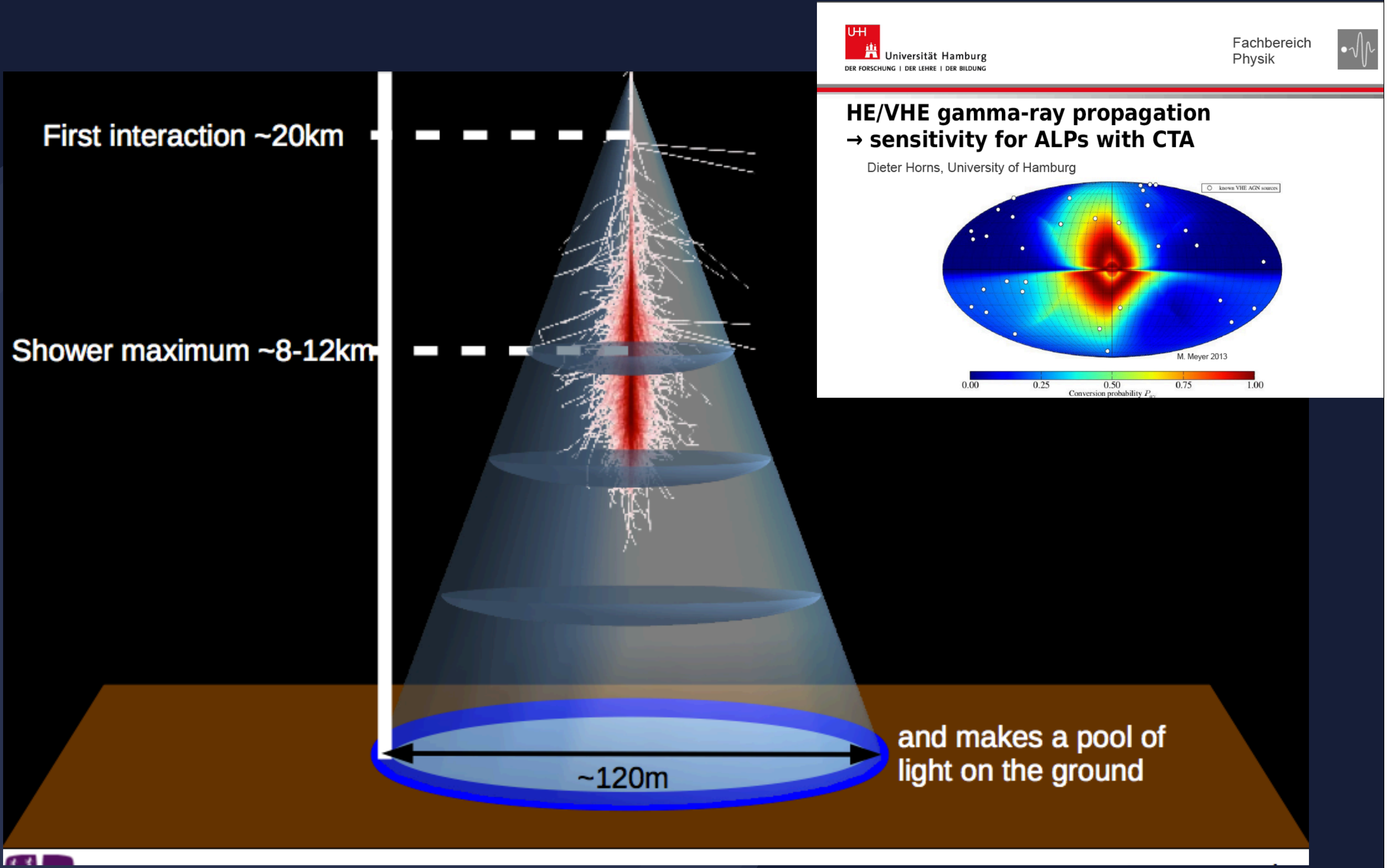
Inauguration of Pierre Auger Observatory

The Magic Cherenkov Telescope Array



An observatory for ground-based gamma-ray astronomy

UHE Gamma-Rays Produce Cherenkov Light



First interaction ~20km

Shower maximum ~8-12km

~120m

and makes a pool of light on the ground

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

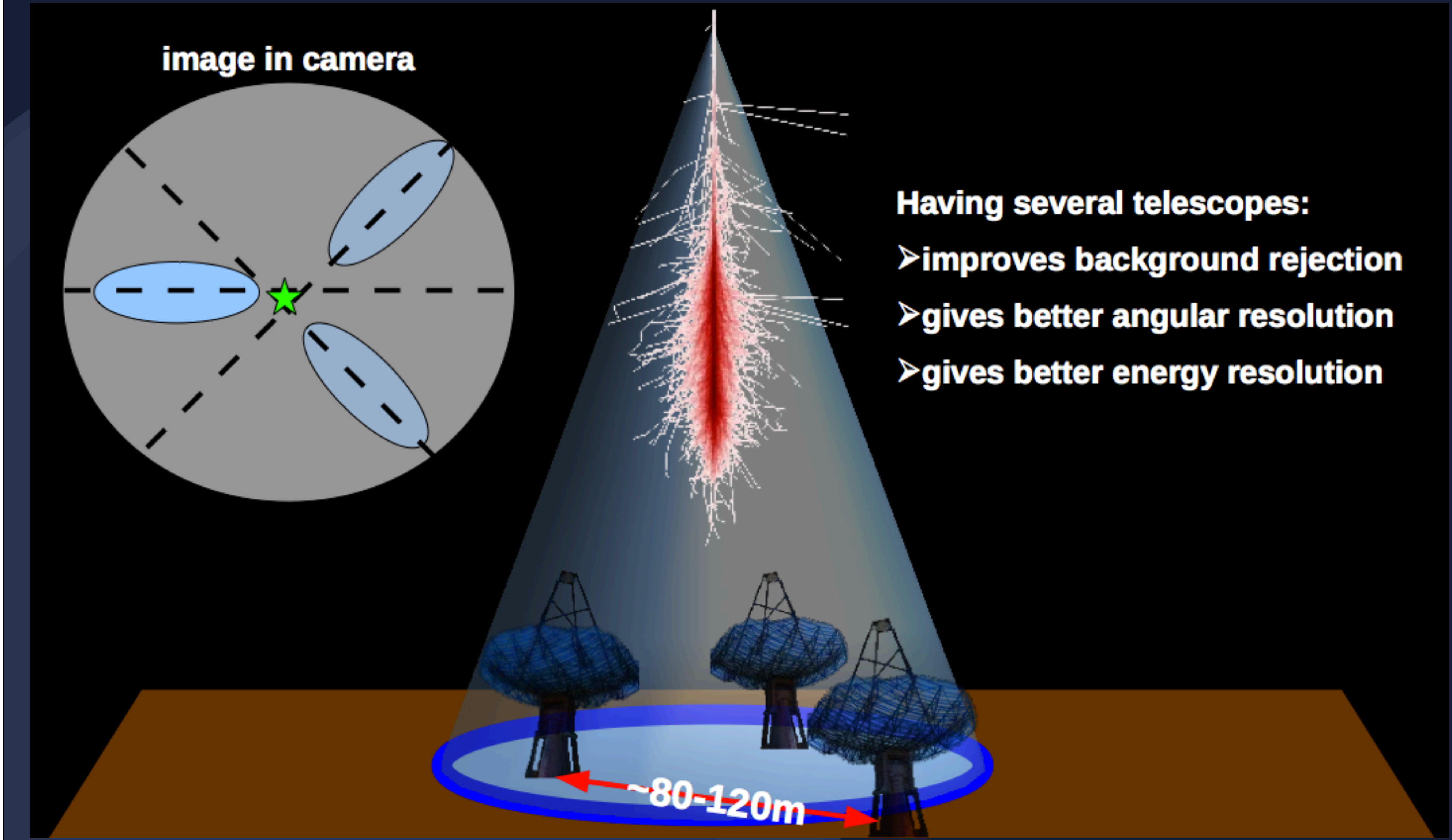
Fachbereich
Physik

HE/VHE gamma-ray propagation
→ sensitivity for ALPs with CTA

Dieter Horns, University of Hamburg

From a talk by Dieter Horns- Univ. Heidelberg

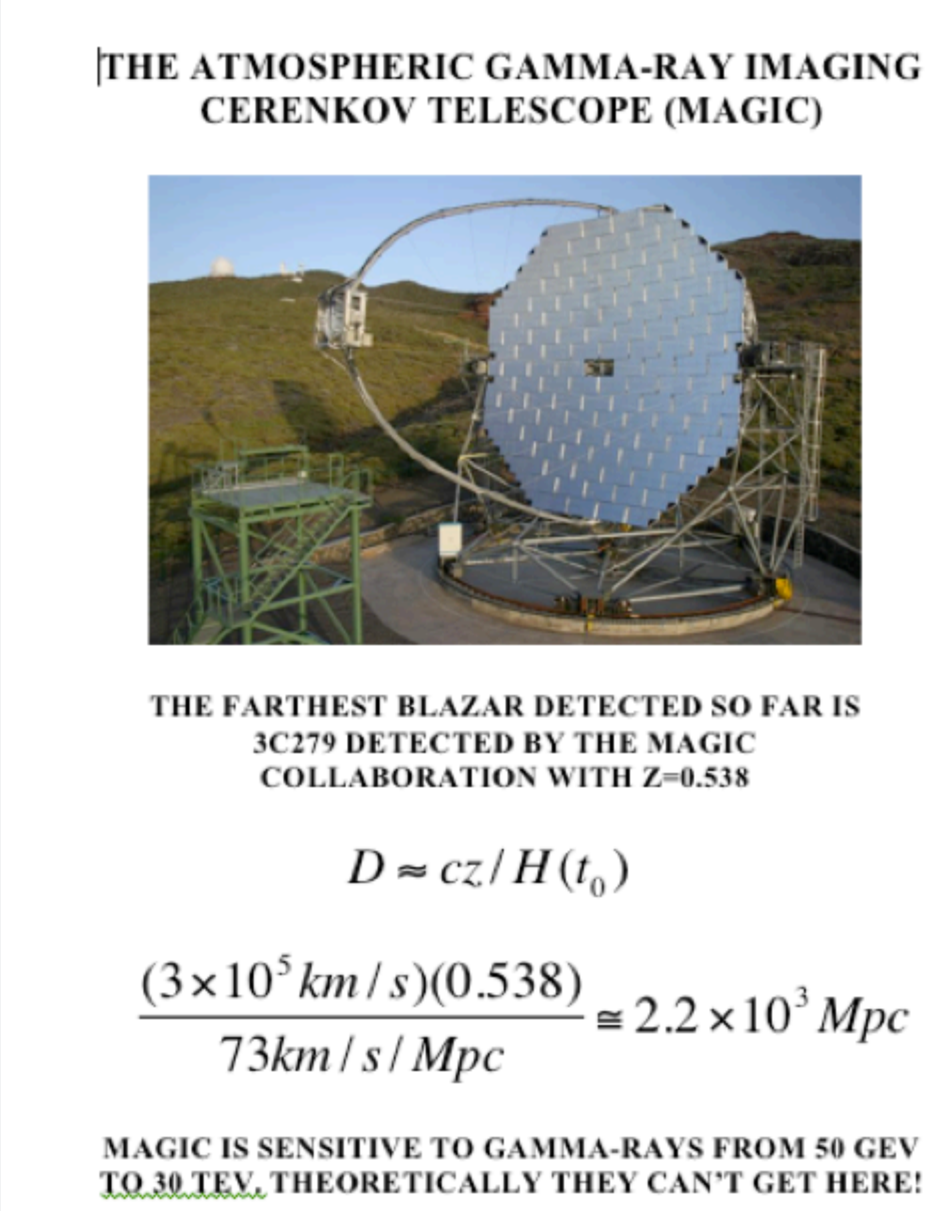
Location of the Source



Having several telescopes:

- improves background rejection
- gives better angular resolution
- gives better energy resolution

MAGIC



THE ATMOSPHERIC GAMMA-RAY IMAGING CERENKOV TELESCOPE (MAGIC)

THE FARTHEST BLAZAR DETECTED SO FAR IS 3C279 DETECTED BY THE MAGIC COLLABORATION WITH Z=0.538

$$D \approx cz / H(t_0)$$

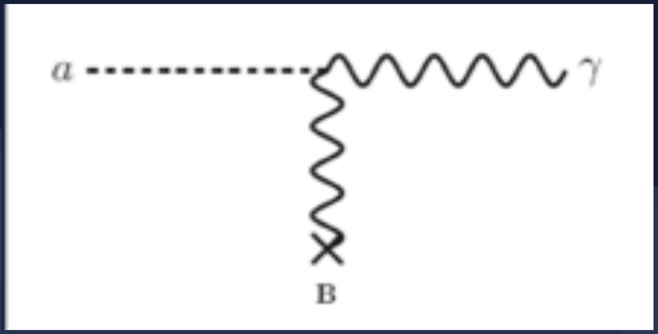
$$\frac{(3\times10^5 \, km/s)(0.538)}{73 km/s/Mpc} \cong 2.2\times10^3 \, Mpc$$

MAGIC IS SENSITIVE TO GAMMA-RAYS FROM 50 GEV TO 30 TEV, THEORETICALLY THEY CAN'T GET HERE!

The discovery of 3C279 at Z=0.538

This distance is about 5 billion light years. The approximate density of extra-galactic background radiation, and the known cross section for photon-photon interactions lead one to conclude that these photons should have been absorbed by the pair-production process!

The Hypothesized ALP Explanation



Marco Roncadelli

A solution to the problem was introduced by De Angelis, Roncadelli and Mansutti: Phys. Rev. D 76,121301 (2007).

The photons are converted to ALPs in the inter galactic magnetic fields, converting to photons in the Milky way.

This was modified by Simit, Cooper and Serpico, Phys. Rev. D 77, 063001 (2008).

In this scenario, the gamma ray is converted to an ALP in the strong magnetic field of the AGN, traverses the EBR, and converts back to a photon in the magnetic field of the Milky Way.

What are the ranges of the parameters of ALPs that could be candidates ?

What is the range of mass ?

What is the range of coupling ?

Could P-Q axions fulfill the requirements ?

Quantum Coherence in Magnetic Fields

The Axion Enters the B-Field; It Becomes Coherent With the Photon

$$\Psi_a(\vec{r},t) \Rightarrow \left\{c_a\Psi_a(\vec{r},t) + c_\gamma\Psi_\gamma(\vec{r},t)\right\}$$

This Limits the Effective Length of the Magnet to a Coherence Length

$$(c - v_a)t \equiv \lambda/2 = (1-\beta_a)ct$$

$$ct \equiv L_{coh}$$

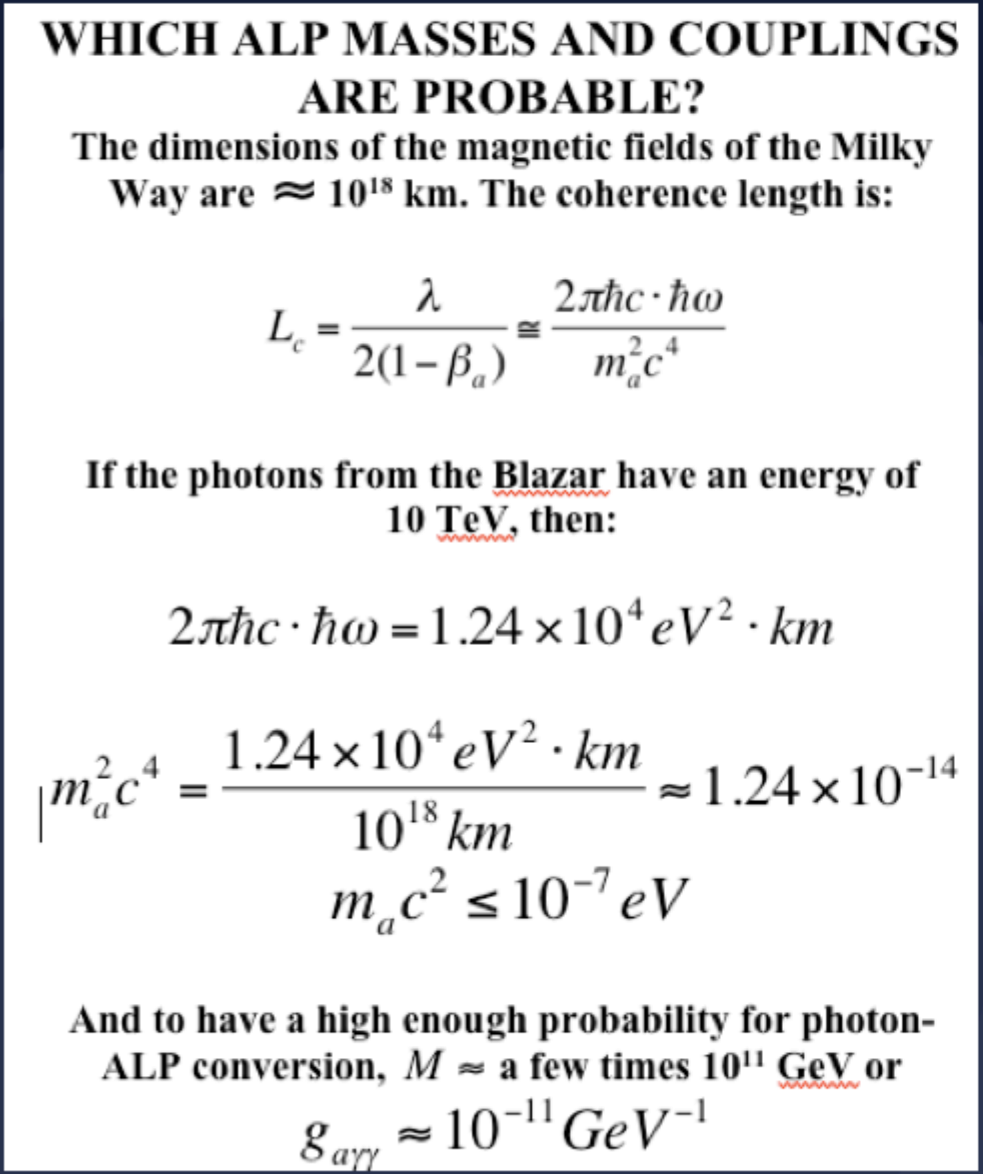
$$L_{coh} = \frac{\lambda}{2(1-\beta_a)}$$

$$\gamma_{rel} \cong \frac{h\omega}{m_a c^2}$$

$$1-\beta_a \cong \frac{m_a^2 c^4}{2\hbar^2\omega^2}$$

$$L_c = \frac{\lambda}{2(1-\beta_a)} \cong \frac{2\pi\hbar c\cdot\hbar\omega}{m_a^2 c^4}$$

What Would Be the Parameters of the ALPs



WHICH ALP MASSES AND COUPLINGS ARE PROBABLE?

The dimensions of the magnetic fields of the Milky Way are ≈ 10^{18} km. The coherence length is:

$$L_c = \frac{\lambda}{2(1-\beta_a)} \cong \frac{2\pi\hbar c \cdot \hbar\omega}{m_a^2 c^4}$$

If the photons from the Blazar have an energy of 10 TeV, then:

$$2\pi\hbar c \cdot \hbar\omega = 1.24\times10^4\, eV^2 \cdot km$$

$$m_a^2 c^4 = \frac{1.24\times10^4\, eV^2 \cdot km}{10^{18}\, km} \approx 1.24\times10^{-14}$$

$$m_a c^2 \le 10^{-7}\, eV$$

And to have a high enough probability for photon-ALP conversion, M ≈ a few times 10^{11} GeV or

$$g_{a\gamma\gamma} \approx 10^{-11}\, GeV^{-1}$$

There are several scenarios suggested by Burrage et al., Phys. Rev. Lett. 102, 201101 (2009). They use larger distances for the magnetic fields:

$$M \approx 1-3\times10^{11}\, GeV$$

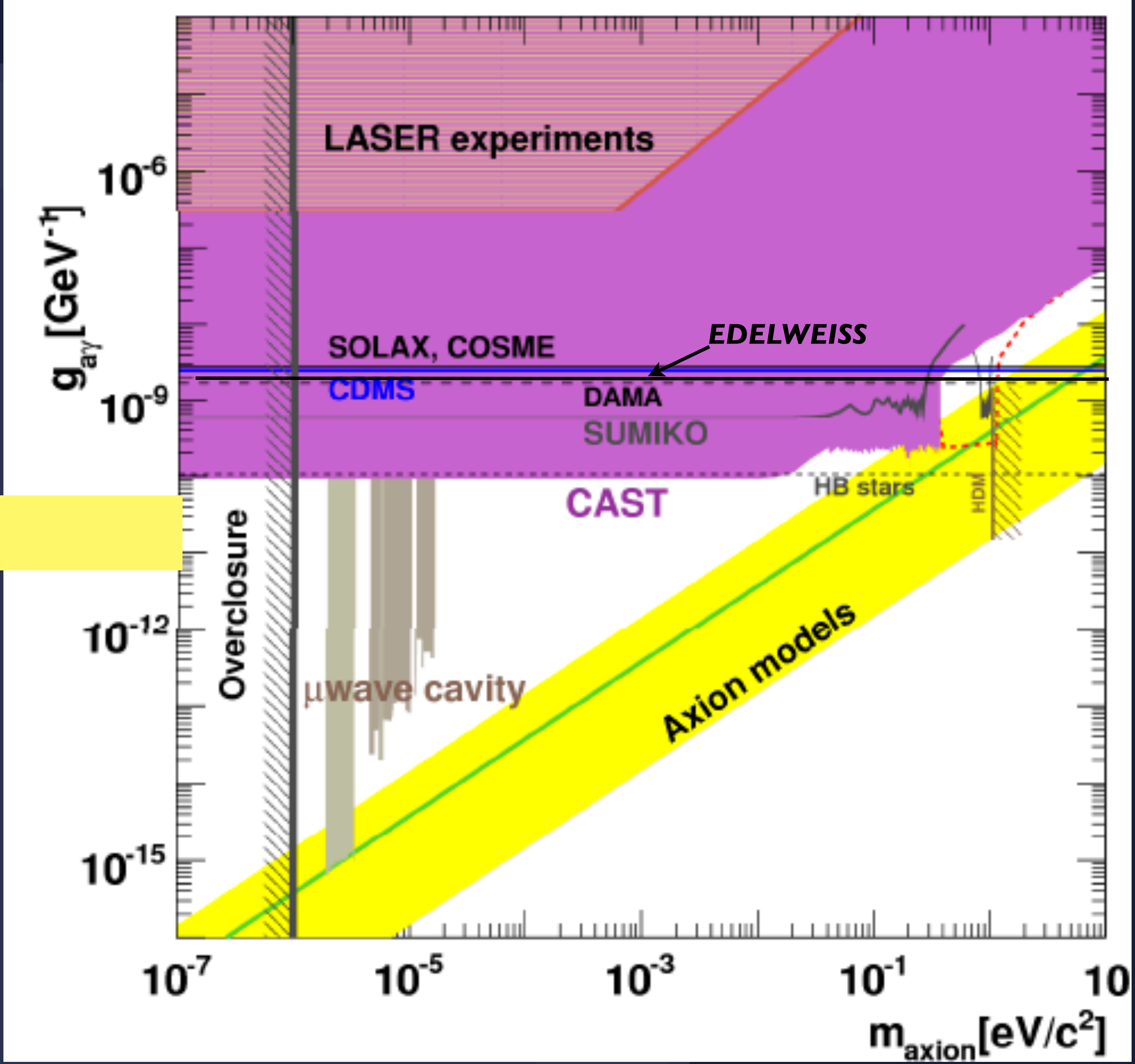
$$and\_m_a c^2 \le 10^{-12}\, eV$$

and one very close to the present CAST bounds

$$M \approx 10^{10}\, GeV$$

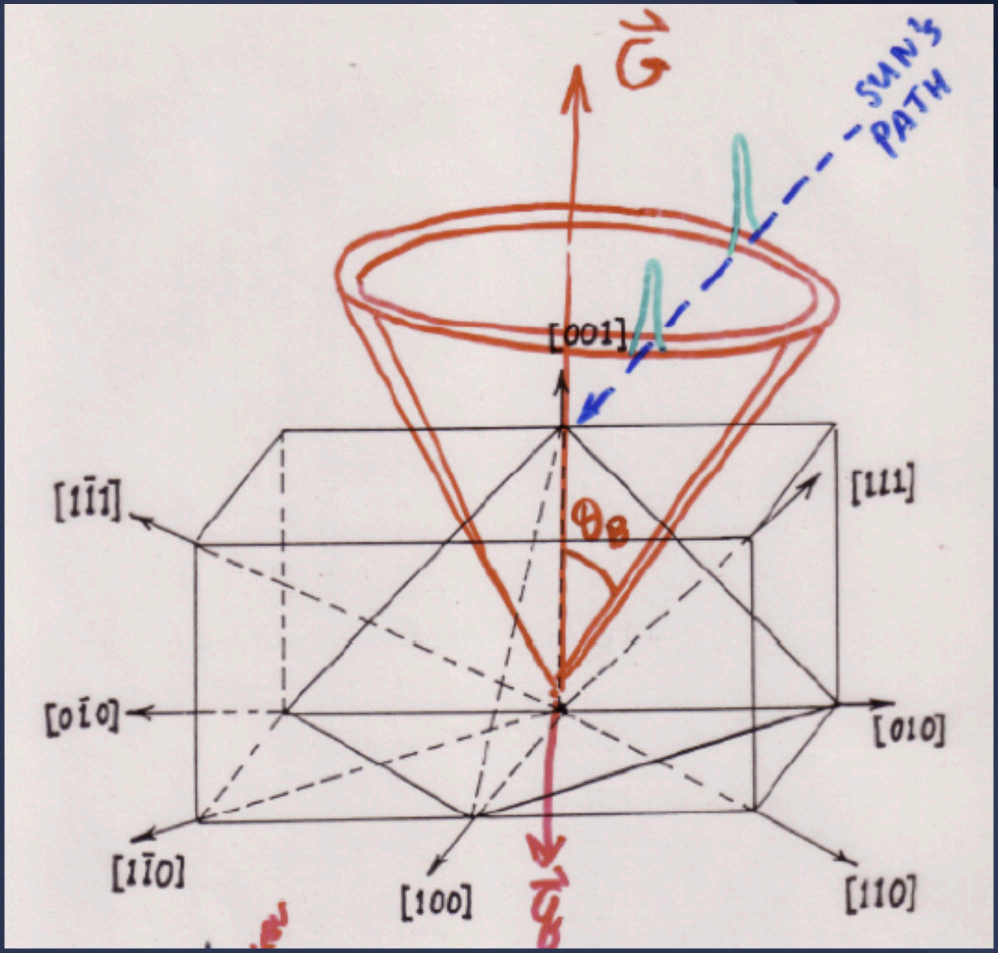
$$and\_m_a c^2 << 10^{-7}\, eV$$

An Example of an Exclusion Plot



ALPs

Bragg-Coherent Primakoff axion-aphoton Conversion



TeO$_2$ Has a Known Crystal Structure and the Bolometer Crystals are Grown Along Known Axes.

When the Line of Sight to the Sun Satisfies a Bragg-Coherence Condition, Conversion of an Axion in the Electric Field of the Nucleus of an Atom is Enhanced Resulting in a Predictable Modulation of the Signal.

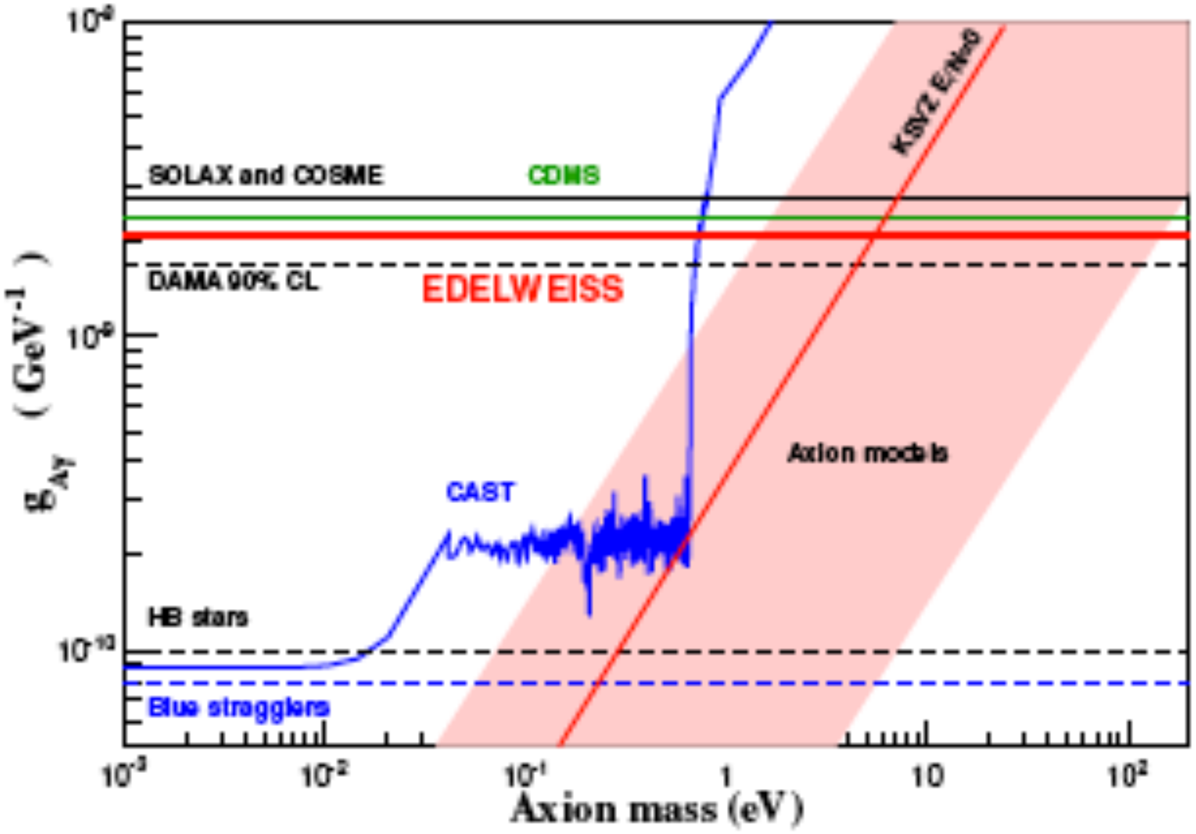
R.J. CRESWICK et al., Phys. Lett. B 427 (1998) 235.

EDELWEISS-II, JCAPII (2013) 067

Journal of Cosmology and Astroparticle Physics

An IOP and SISSA journal

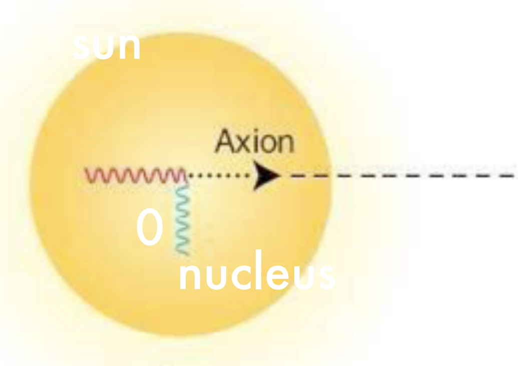
Axion searches with the EDELWEISS-II experiment



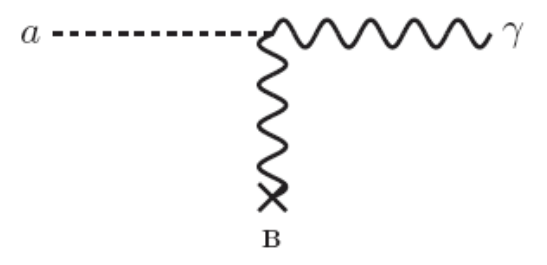
Helioscope Searches For Solar Axions ?

Axions Can Be Converted Into Photons in Transverse Magnetic Fields!

They Could be Created in the Sun by Photons Interacting with Nuclear Coulomb Fields !

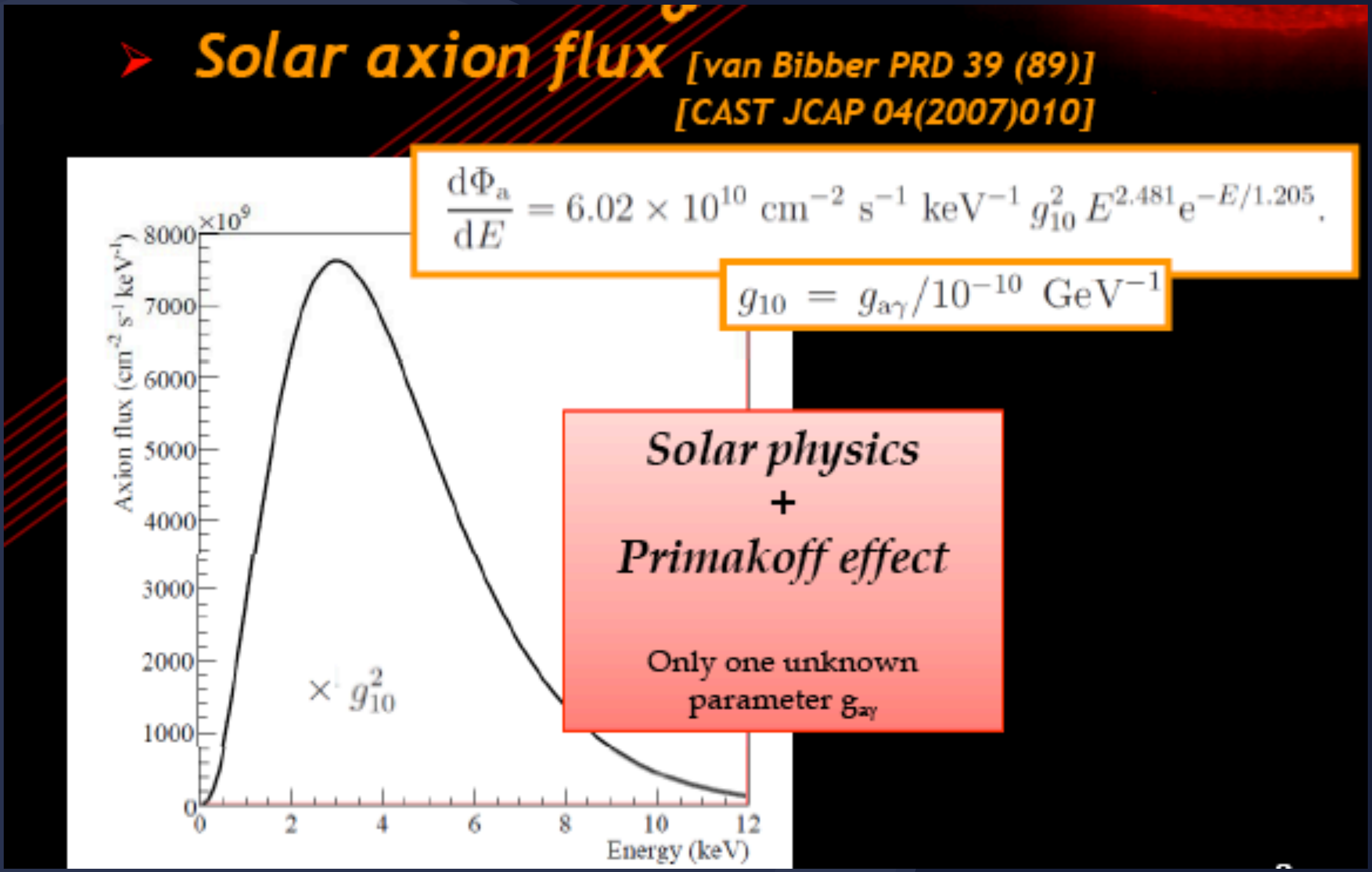


$$\frac{d\sigma}{d\Omega} = \frac{g_{a\gamma\gamma}^{2}}{32\pi^{2}} F_{a}^{2}(2\theta)\sin^{2}(2\theta)$$



The Conversion Probability in a Magnetic Field

$$P_{a\gamma} = 2.6 \times 10^{-17}\left(\frac{B}{10T}\right)^{2}\left(\frac{L}{10M}\right)^{2} \times \left(g_{a\gamma} \times 10^{10}GeV\right)^{2}$$



Solar axion flux [van Bibber PRD 39 (89)] [CAST JCAP 04(2007)010]

$$\frac{\mathrm{d}\Phi_a}{\mathrm{d}E} = 6.02\times10^{10}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{keV}^{-1}\ g_{10}^2\ E^{2.481}\mathrm{e}^{-E/1.205},$$

$$g_{10} = g_{a\gamma}/10^{-10}\ \mathrm{GeV}^{-1}$$

Solar physics

+

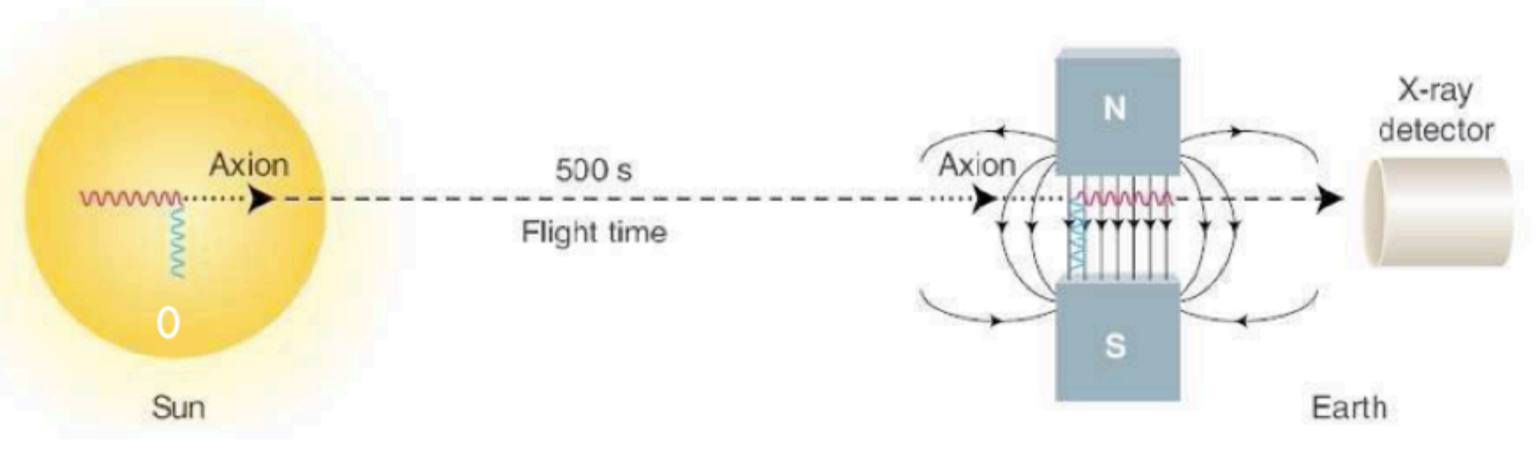
Primakoff effect

Only one unknown parameter $g_{a\gamma}$

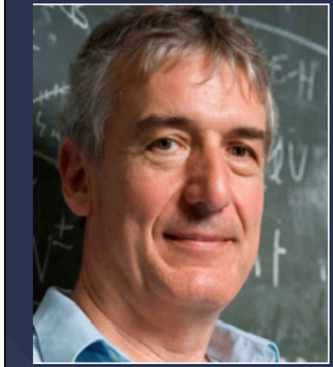
Searching for Solar Axions and ALPs with Magnetic Helioscopes

The Axion Helioscope Principle

Konstantin Zioutas led a team in building CAST the CERN Axion Solar Telescope

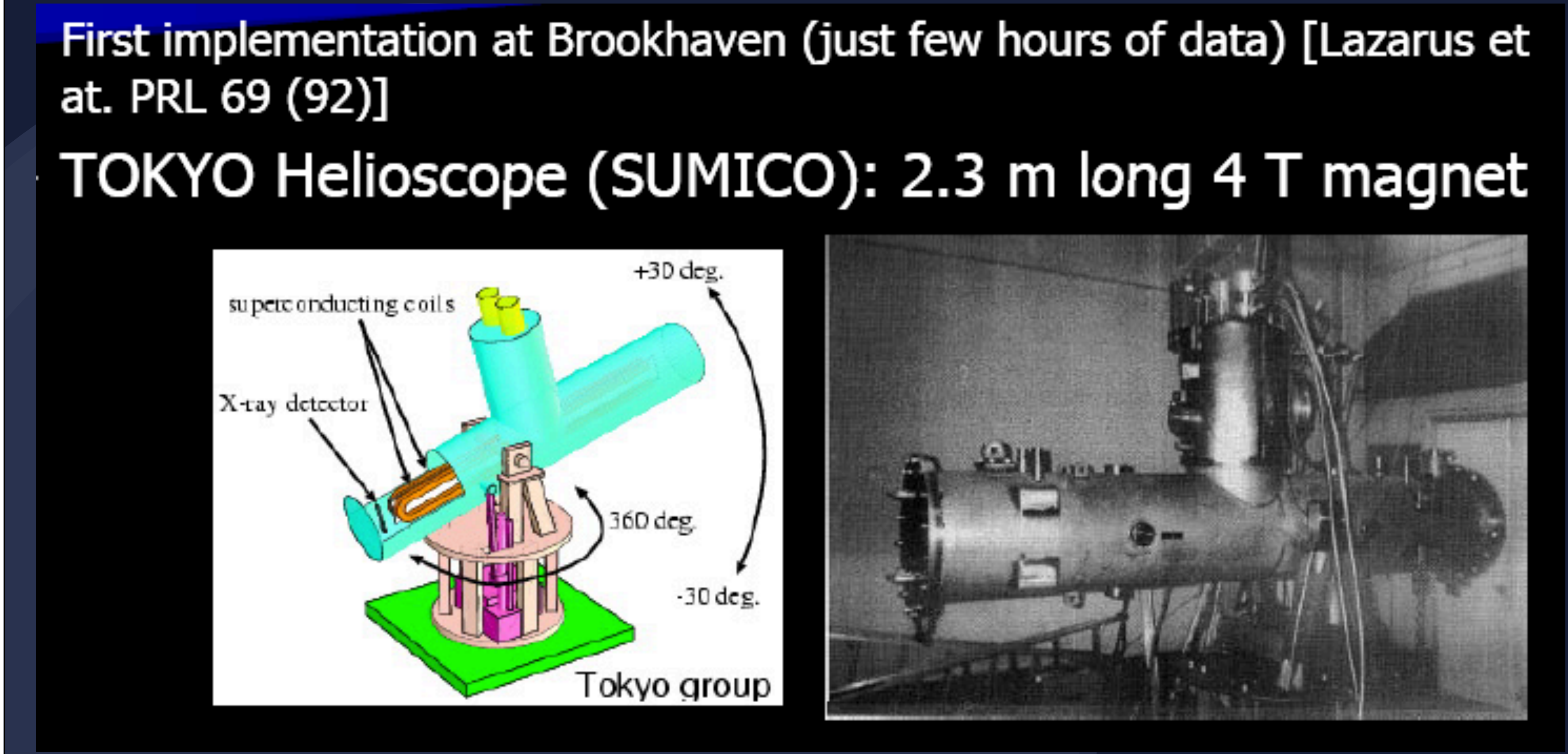


Principle of the Axion Helioscope P. Sikivie, Phys. Rev. Lett. 51 (1983)



Pierre Sikivie conceived of the axion helioscope in 1983

Earlier Helioscope Experiments



First implementation at Brookhaven (just few hours of data) [Lazarus et at. PRL 69 (92)]

TOKYO Helioscope (SUMICO): 2.3 m long 4 T magnet

The CERN Axion Solar Telescope

10-Meter Long LHC Test Magnet With a 9-Tesla Magnetic Field

Konstantin Zioutas, University of Patras, Spokesman

Why Can't We Just Increase The Length?

The CERN Axion Solar Telescope

CAST Has Produced the Most Sensitive Solar Axion Search DataTo Date. The Magnet Tracks the Sun 1.05 hr During Sunrise and Again During Sunset (+/-) 8 Degrees.

Quantum Coherence in the Magnet

The Axion Enters the B-Field; It Becomes Coherent With the Photon

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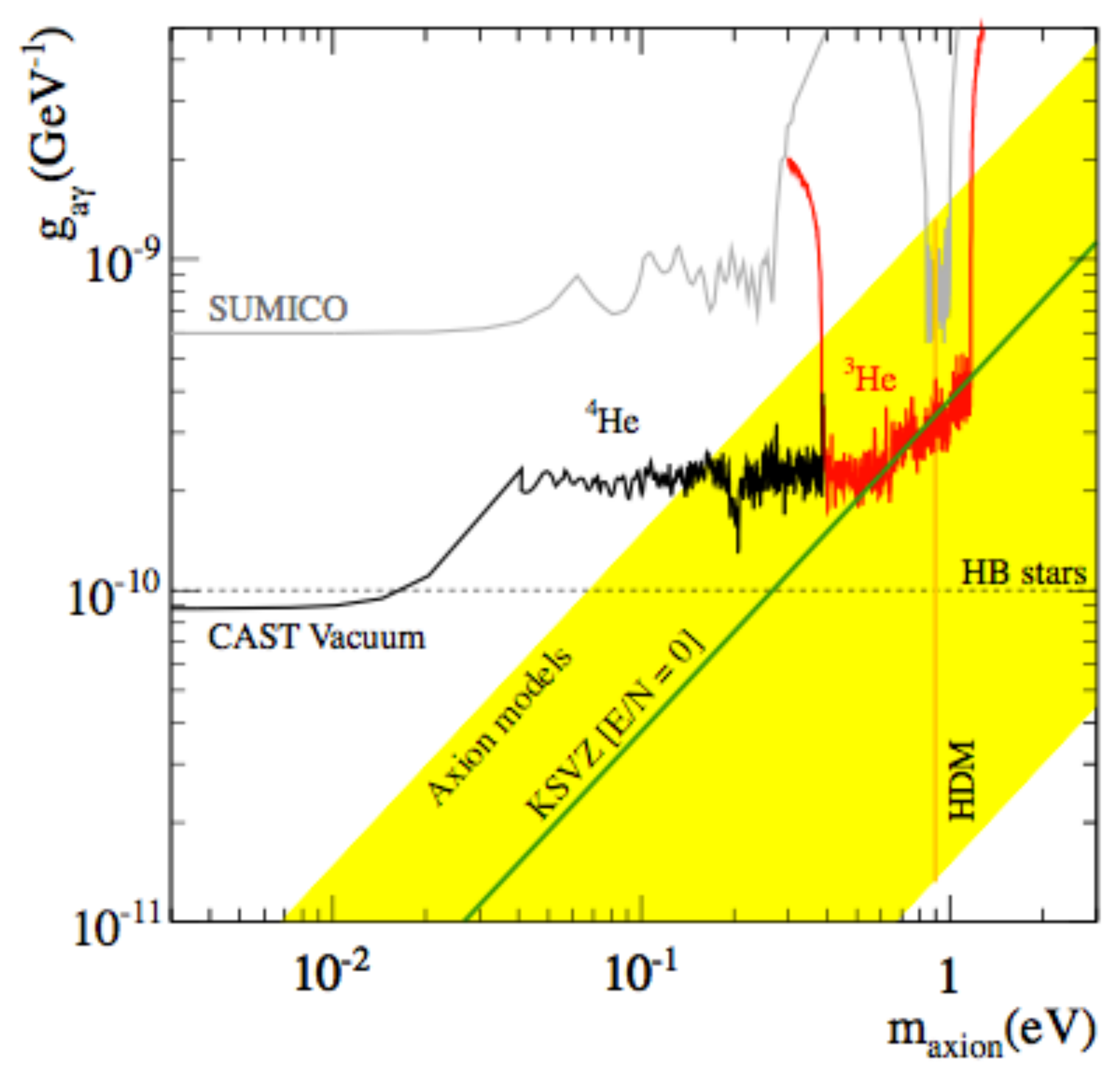
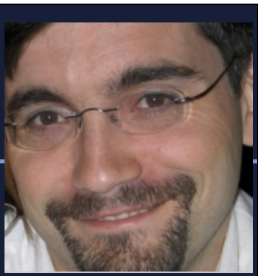
$$L_c = \frac{\lambda}{2(1-\beta_a)} \cong \frac{2\pi\hbar c\cdot\hbar\omega}{m_a^2 c^4}$$

Coherence Effects on the CAST Results



The CAST sensitivity has arrived at its best value. Where do we go from here ?

IAXO, The Future



IAXO International AXion Observatory

Letter of Intent to CERN SPSC

Igor G Irastorza

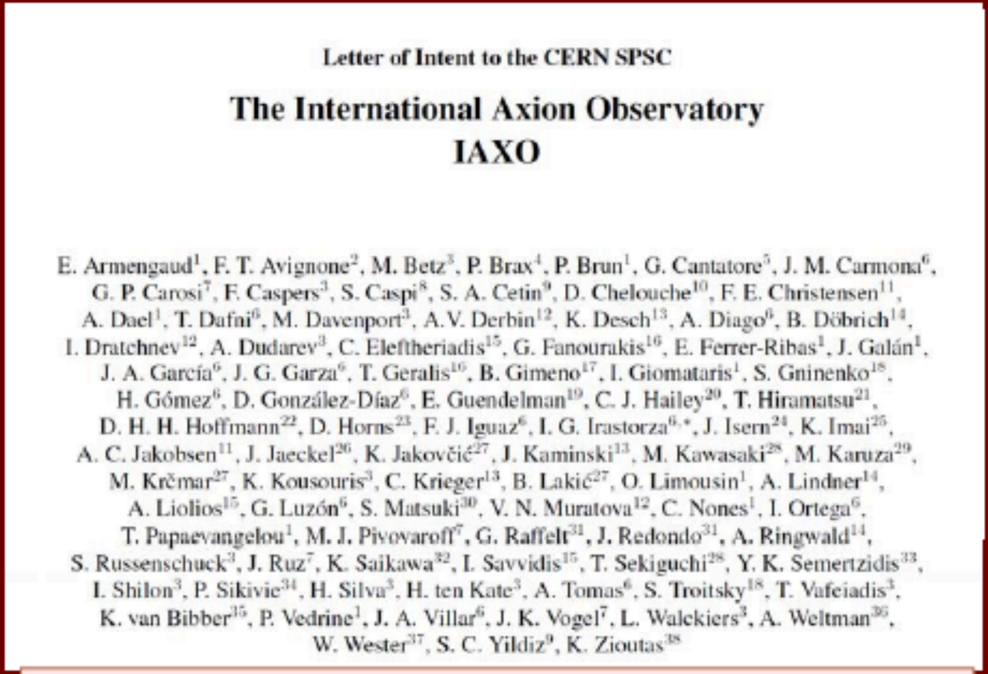
Universidad de Zaragoza

On behalf of the IAXO collaboration

Open session of the SPS Committee – October 22nd 2013 – CERN

Letter of Intent presented to CERN SPSC

- Axion motivation:
  - Strong CP problem
  - Axions as CDM
  - Solar axions
- Previous helioscopes & CAST
- IAXO Conceptual Design
  - Magnet
  - Optics
  - Detectors
- IAXO physics potential
- Timescale & costs
- Status of project. Requests to CERN

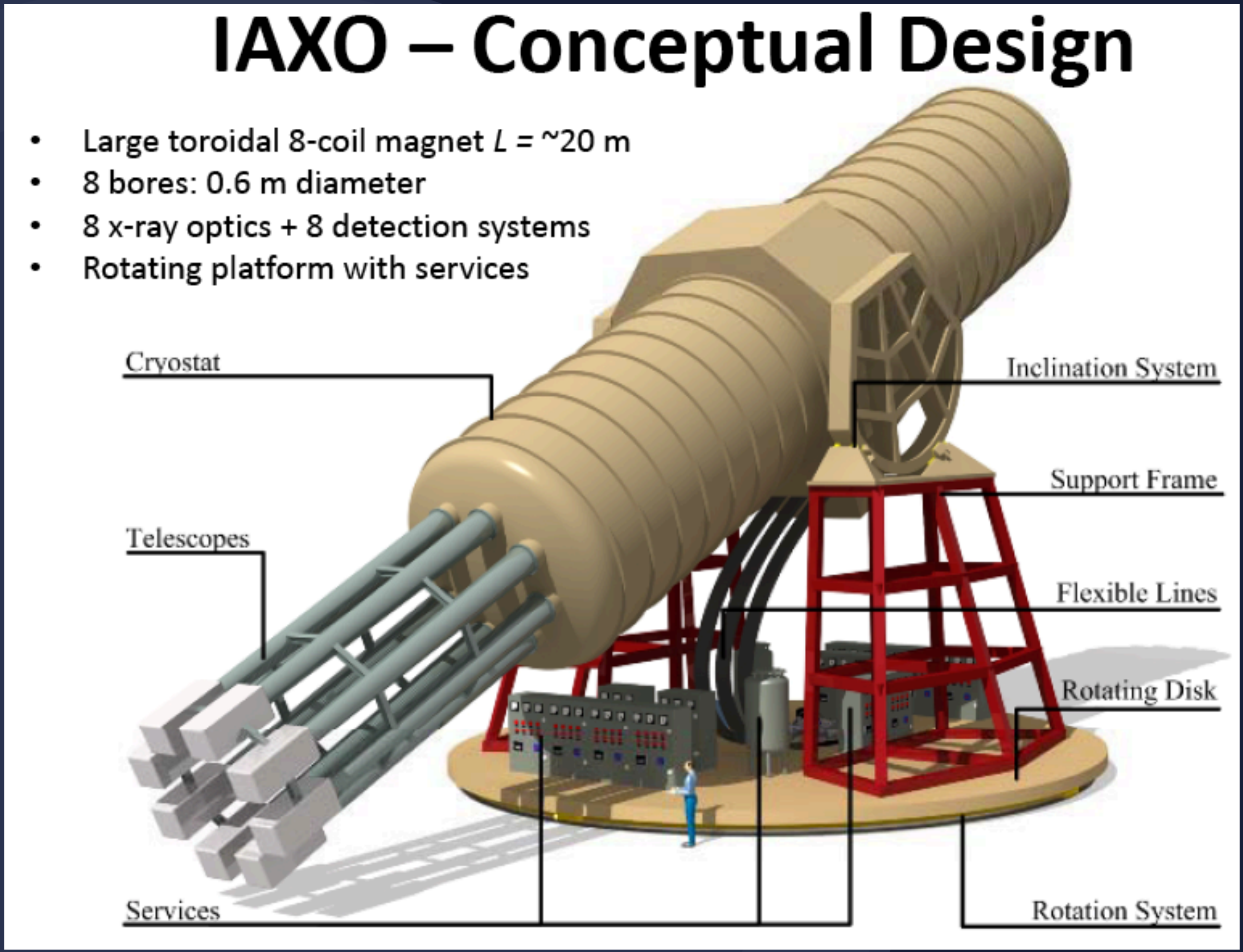


Letter of Intent to the CERN SPSC

The International Axion Observatory
IAXO

E. Armengaud[1], F. T. Avignone[2], M. Betz[3], P. Brax[4], P. Brun[1], G. Cantatore[5], J. M. Carmona[6], G. P. Carosi[7], F. Caspers[3], S. Caspi[8], S. A. Cetin[9], D. Chelouche[10], F. E. Christensen[11], A. Dael[1], T. Dafni[6], M. Davenport[3], A.V. Derbin[12], K. Desch[13], A. Diago[6], B. Döbrich[14], I. Dratchnev[12], A. Dudarev[3], C. Eleftheriadis[15], G. Fanourakis[16], E. Ferrer-Ribas[1], J. Galán[1], J. A. García[6], J. G. Garza[6], T. Geralis[16], B. Gimeno[17], I. Giomataris[1], S. Gninenko[18], H. Gómez[6], D. González-Díaz[6], E. Guendelman[19], C. J. Hailey[20], T. Hiramatsu[21], D. H. H. Hoffmann[22], D. Horns[23], F. J. Iguaz[6], I. G. Irastorza[6,*], J. Isern[24], K. Imai[25], A. C. Jakobsen[11], J. Jaeckel[26], K. Jakovčić[27], J. Kaminski[13], M. Kawasaki[28], M. Karuza[29], M. Krčmar[27], K. Kousouris[3], C. Krieger[13], B. Lakić[27], O. Limousin[1], A. Lindner[14], A. Liolios[15], G. Luzón[6], S. Matsuki[30], V. N. Muratova[12], C. Nones[1], I. Ortega[6], T. Papaevangelou[1], M. J. Pivovaroff[7], G. Raffelt[31], J. Redondo[31], A. Ringwald[14], S. Russenschuck[3], J. Ruz[7], K. Saikawa[32], I. Savvidis[15], T. Sekiguchi[28], Y. K. Semertzidis[33], I. Shilon[3], P. Sikivie[34], H. Silva[3], H. ten Kate[3], A. Tomas[6], S. Troitsky[18], T. Vafeiadis[3], K. van Bibber[35], P. Vedrine[1], J. A. Villar[6], J. K. Vogel[7], L. Walckiers[3], A. Weltman[36], W. Wester[37], S. C. Yildiz[9], K. Zioutas[38]

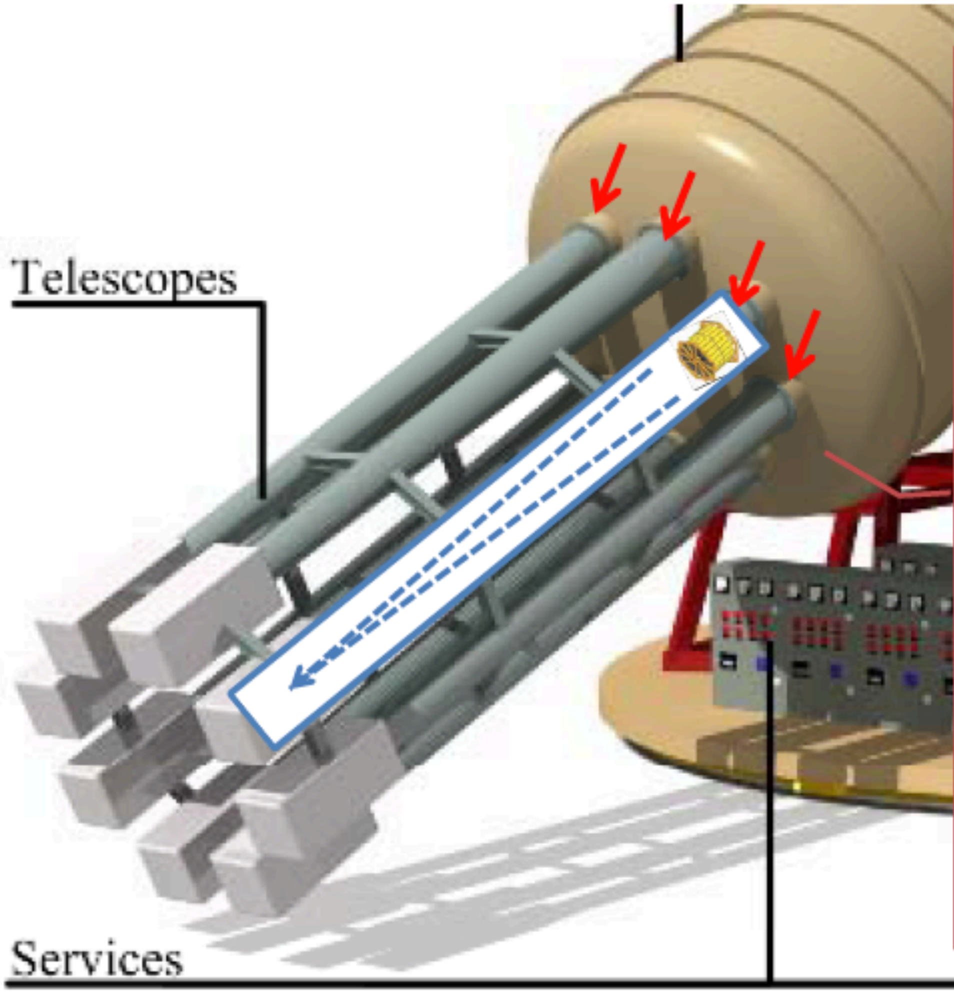
IAXO Letter of Intent: CERN-SPSC-2013-022
90 signatures / 38 institutions



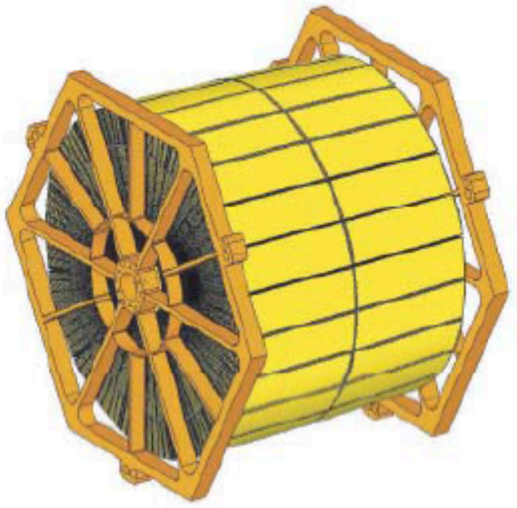
IAXO – Conceptual Design

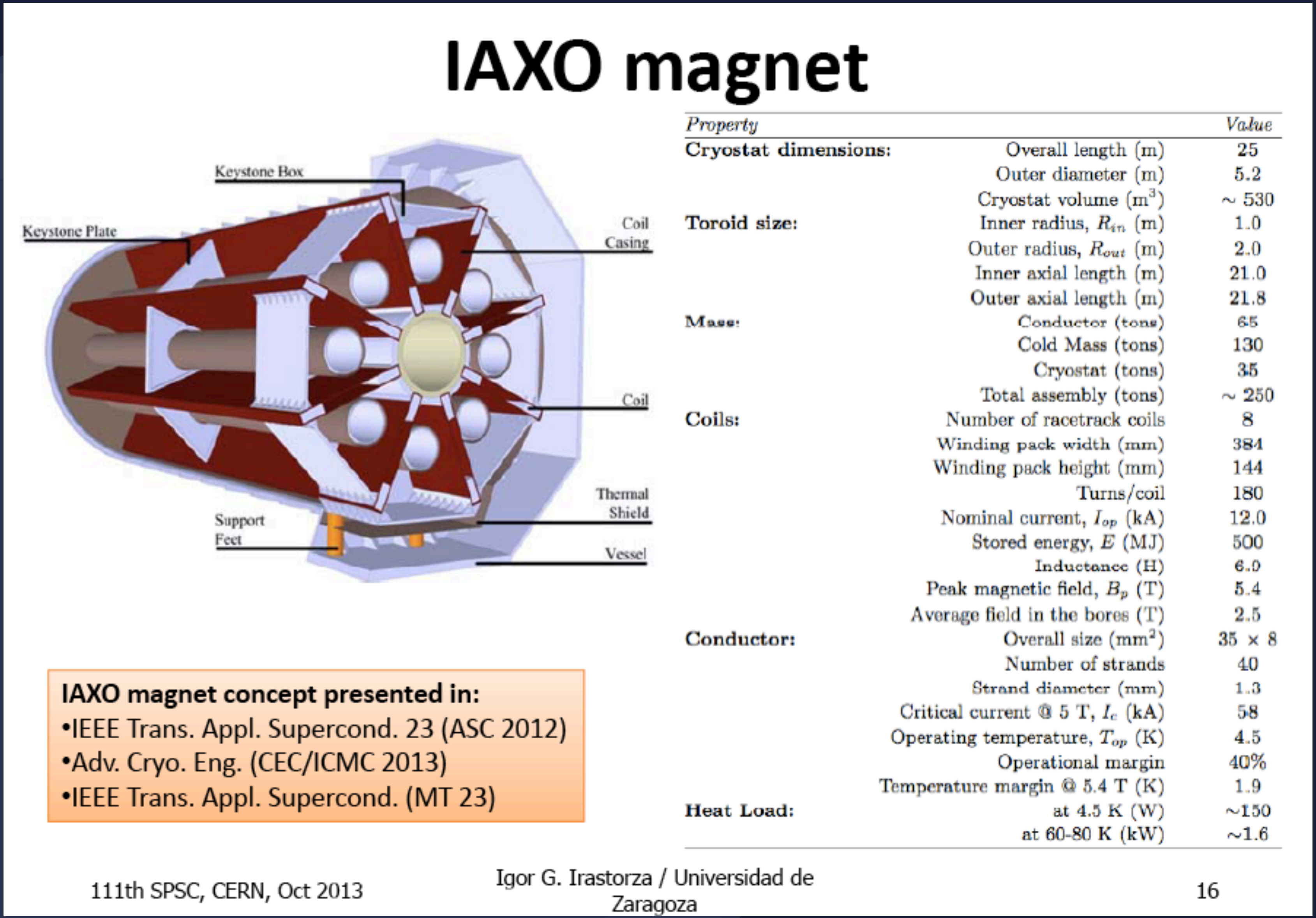
- Large toroidal 8-coil magnet *L* = ~20 m
- 8 bores: 0.6 m diameter
- 8 x-ray optics + 8 detection systems
- Rotating platform with services

IAXO x-ray optics



- Each bore equipped with an x-ray optics
- Exquisite imaging not required
- **BUT** need cost-effective way to build 8 (+1 spare) optics of 600 cm diameter each.



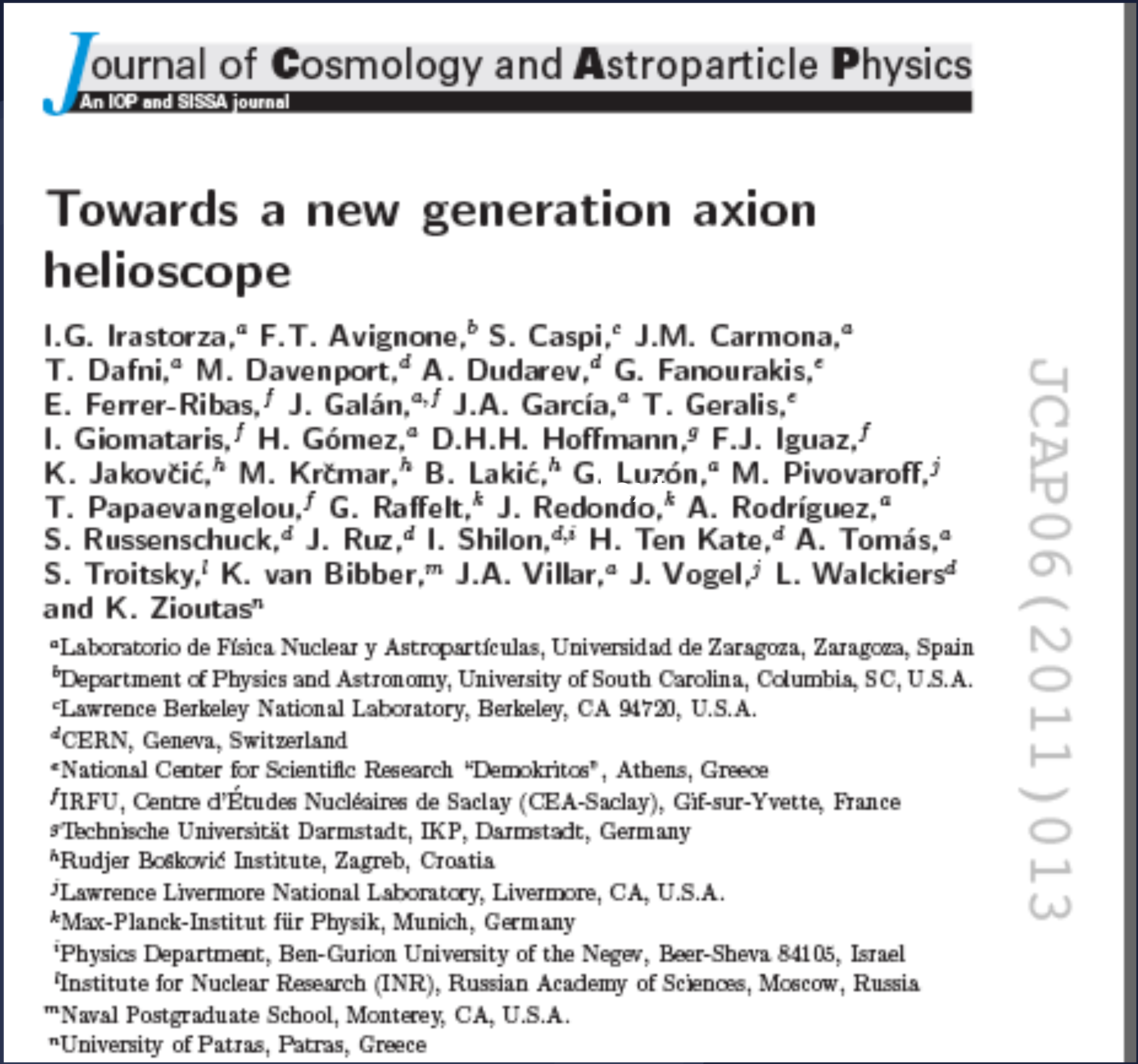


IAXO magnet

Property		*Value*
Cryostat dimensions:	Overall length (m)	25
	Outer diameter (m)	5.2
	Cryostat volume (m^3)	~ 530
Toroid size:	Inner radius, R_{in} (m)	1.0
	Outer radius, R_{out} (m)	2.0
	Inner axial length (m)	21.0
	Outer axial length (m)	21.8
Mass:	Conductor (tons)	65
	Cold Mass (tons)	130
	Cryostat (tons)	35
	Total assembly (tons)	~ 250
Coils:	Number of racetrack coils	8
	Winding pack width (mm)	384
	Winding pack height (mm)	144
	Turns/coil	180
	Nominal current, I_{op} (kA)	12.0
	Stored energy, E (MJ)	500
	Inductance (H)	6.9
	Peak magnetic field, B_p (T)	5.4
	Average field in the bores (T)	2.5
Conductor:	Overall size (mm^2)	35 × 8
	Number of strands	40
	Strand diameter (mm)	1.3
	Critical current @ 5 T, I_c (kA)	58
	Operating temperature, T_{op} (K)	4.5
	Operational margin	40%
	Temperature margin @ 5.4 T (K)	1.9
Heat Load:	at 4.5 K (W)	~150
	at 60-80 K (kW)	~1.6

IAXO magnet concept presented in:
- IEEE Trans. Appl. Supercond. 23 (ASC 2012)
- Adv. Cryo. Eng. (CEC/ICMC 2013)
- IEEE Trans. Appl. Supercond. (MT 23)

I.G. Irastorza et al., JCAP06(2011)013



Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Towards a new generation axion helioscope

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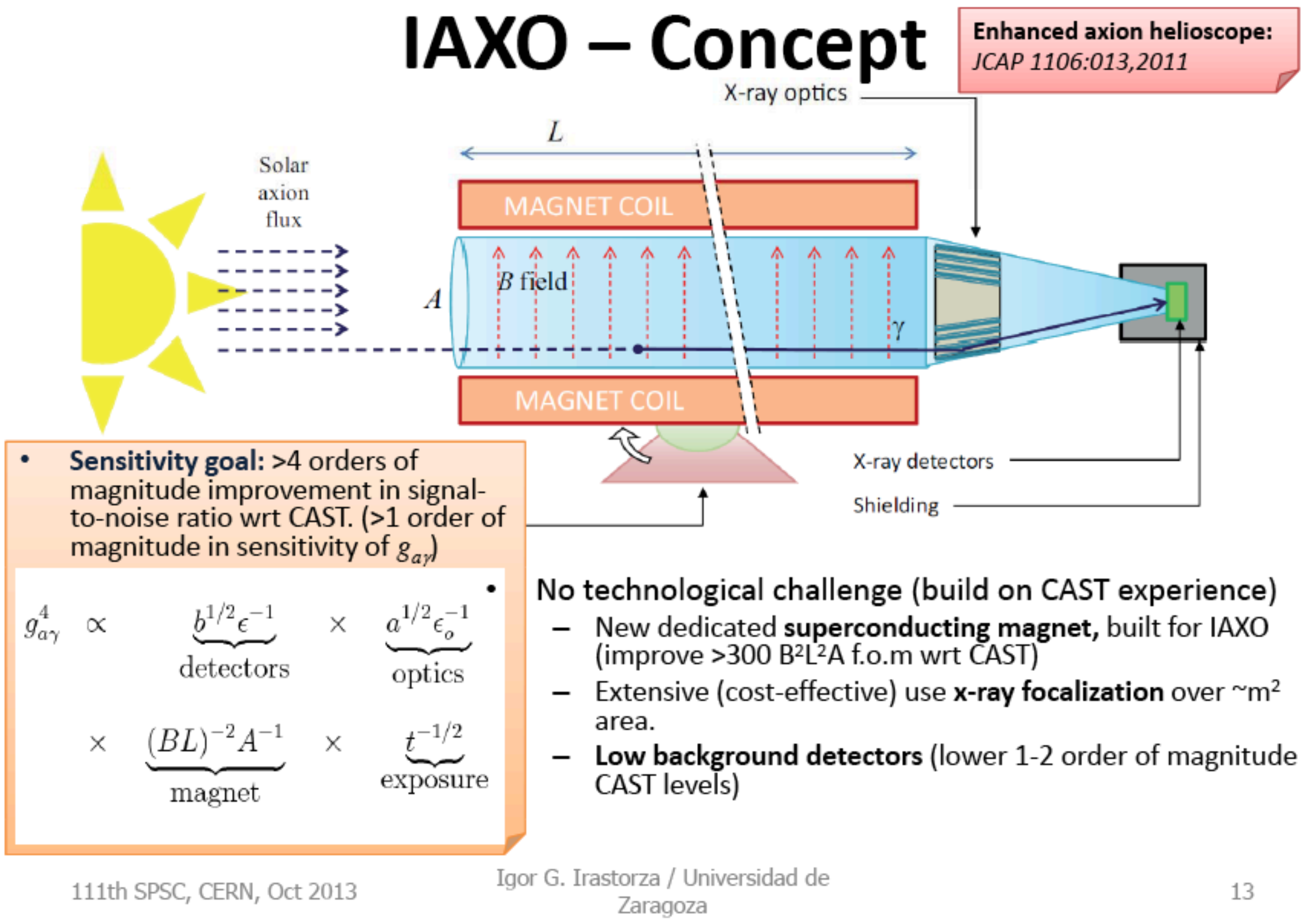


IAXO – Concept

Enhanced axion helioscope:
JCAP 1106:013,2011

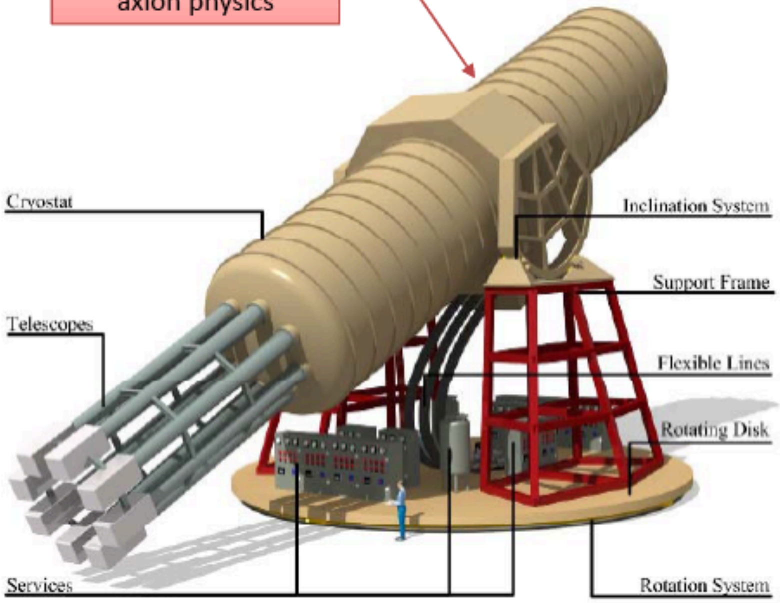
- **Sensitivity goal:** >4 orders of magnitude improvement in signal-to-noise ratio wrt CAST. (>1 order of magnitude in sensitivity of $g_{a\gamma}$)

$$g_{a\gamma}^4 \propto \underbrace{b^{1/2}\epsilon^{-1}}_{\text{detectors}} \times \underbrace{a^{1/2}\epsilon_o^{-1}}_{\text{optics}} \times \underbrace{(BL)^{-2}A^{-1}}_{\text{magnet}} \times \underbrace{t^{-1/2}}_{\text{exposure}}$$

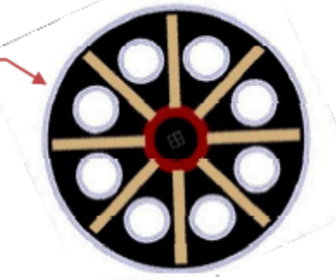
- No technological challenge (build on CAST experience)
  - New dedicated **superconducting magnet,** built for IAXO (improve >300 B^2L^2A f.o.m wrt CAST)
  - Extensive (cost-effective) use **x-ray focalization** over ~m² area.
  - **Low background detectors** (lower 1-2 order of magnitude CAST levels)

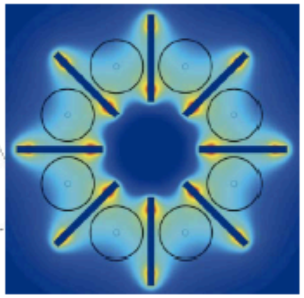
IAXO magnet

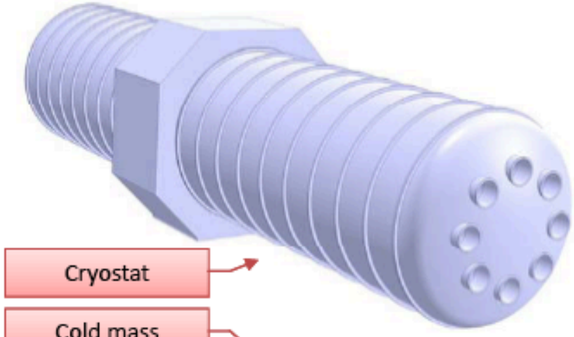
TOROIDAL CONFIGURATION specifically built for axion physics



Each conversion bore (between coils) 0.6 m diameter

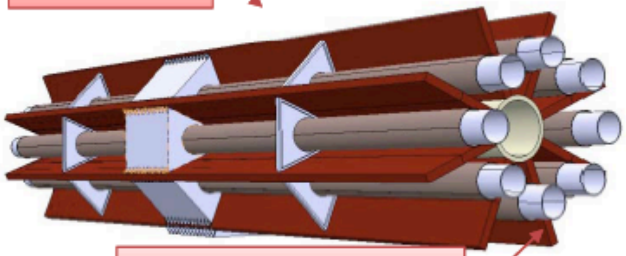






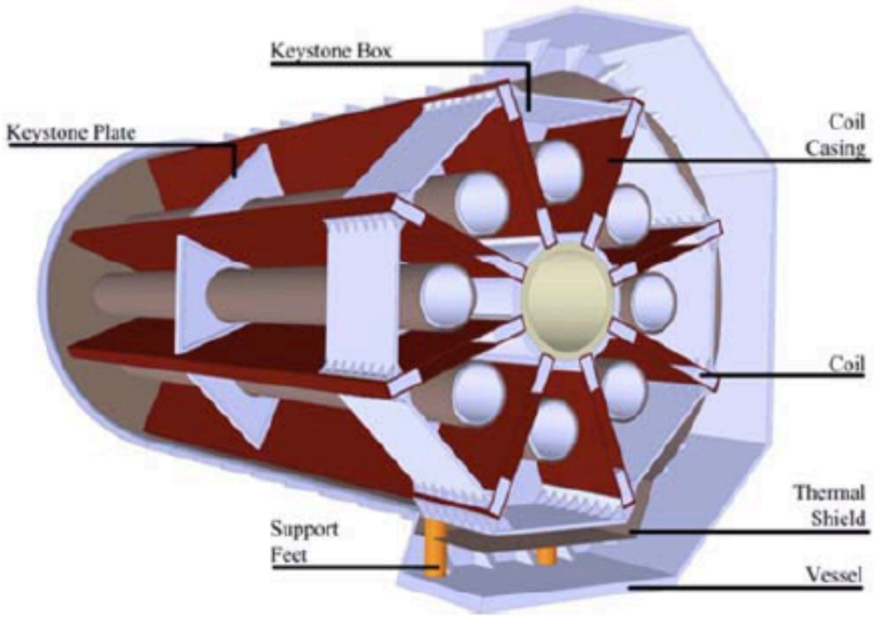
Cryostat

Cold mass



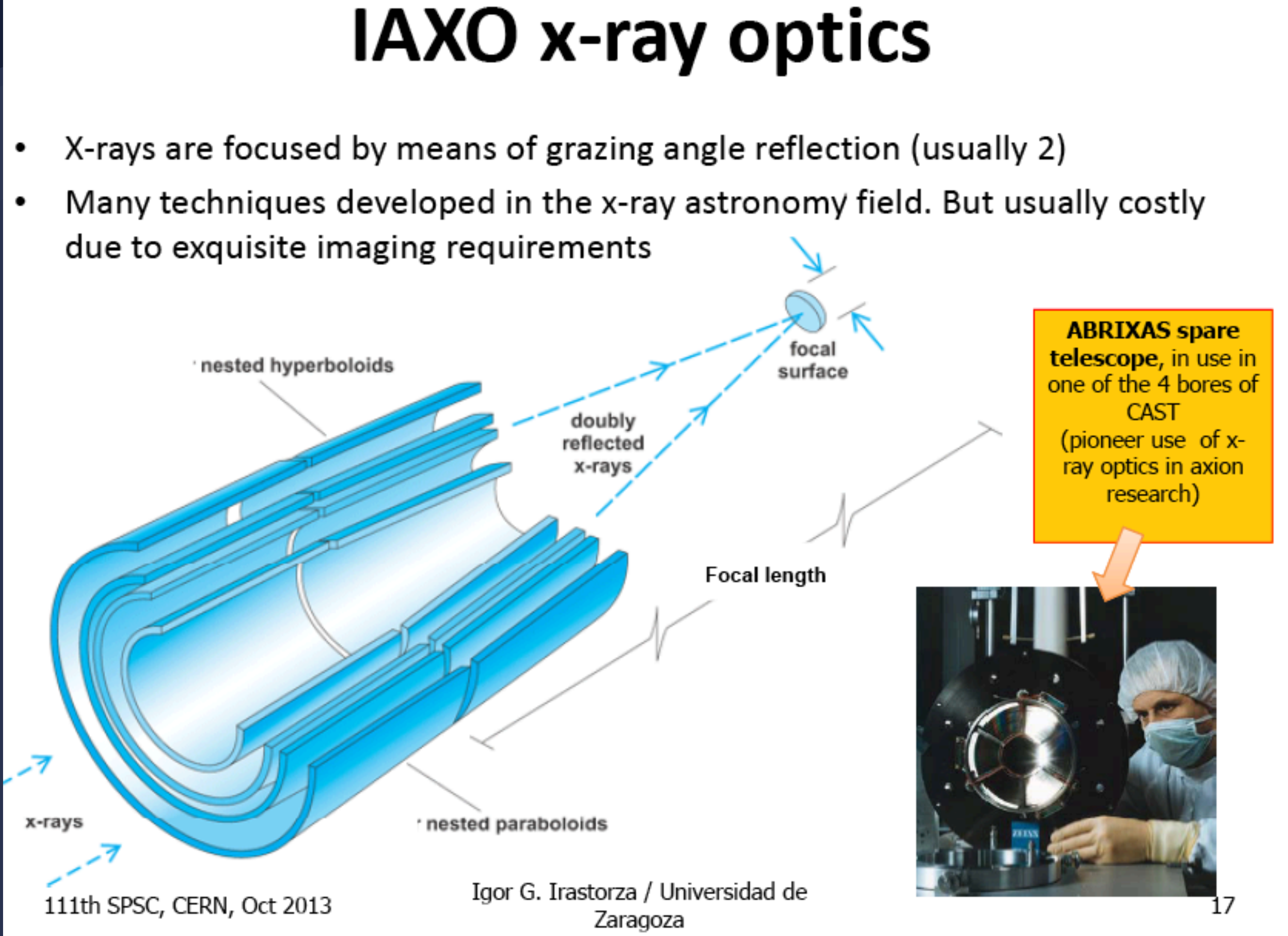
Bores go through cryostat

Magntic length 20 m Total cryostat length 25 m



IAXO magnet concept presented in:

- IEEE Trans. Appl. Supercond. 23 (ASC 2012)
- Adv. Cryo. Eng. (CEC/ICMC 2013)
- IEEE Trans. Appl. Supercond. (MT 23)

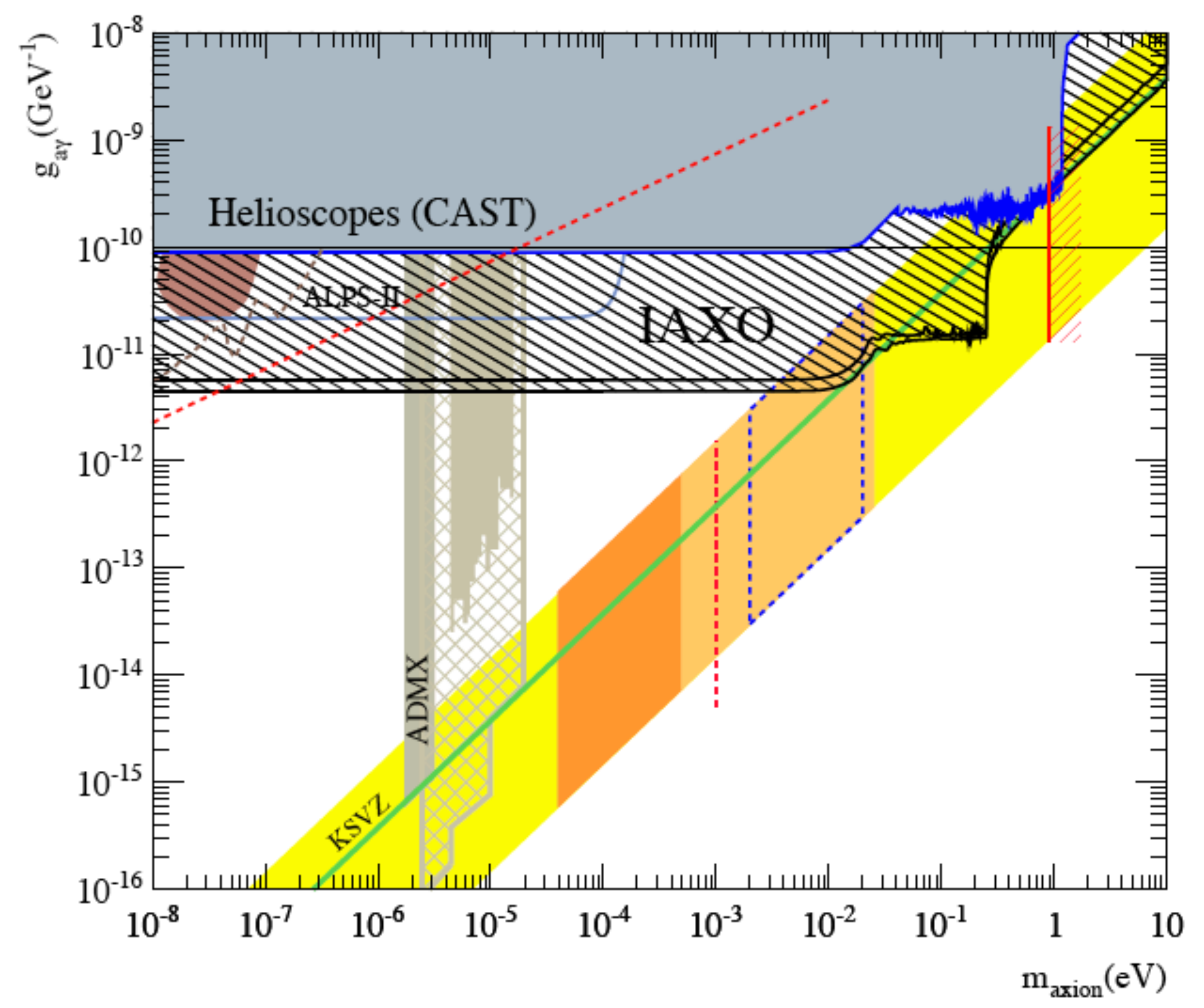


IAXO x-ray optics

- X-rays are focused by means of grazing angle reflection (usually 2)
- Many techniques developed in the x-ray astronomy field. But usually costly due to exquisite imaging requirements

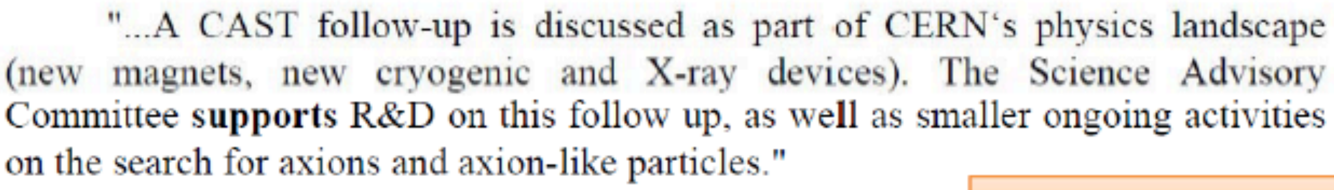
ABRIXAS spare telescope, in use in one of the 4 bores of CAST
(pioneer use of x-ray optics in axion research)

The Predicted IAXO Sensitivity



IAXO in astroparticle roadmaps

- **ASPERA/APPEC Roadmap** acknowledges axion physics, CAST, and **recommends** progress towards IAXO.



> "...A CAST follow-up is discussed as part of CERN's physics landscape (new magnets, new cryogenic and X-ray devices). The Science Advisory Committee **supports** R&D on this follow up, as well as smaller ongoing activities on the search for axions and axion-like particles."

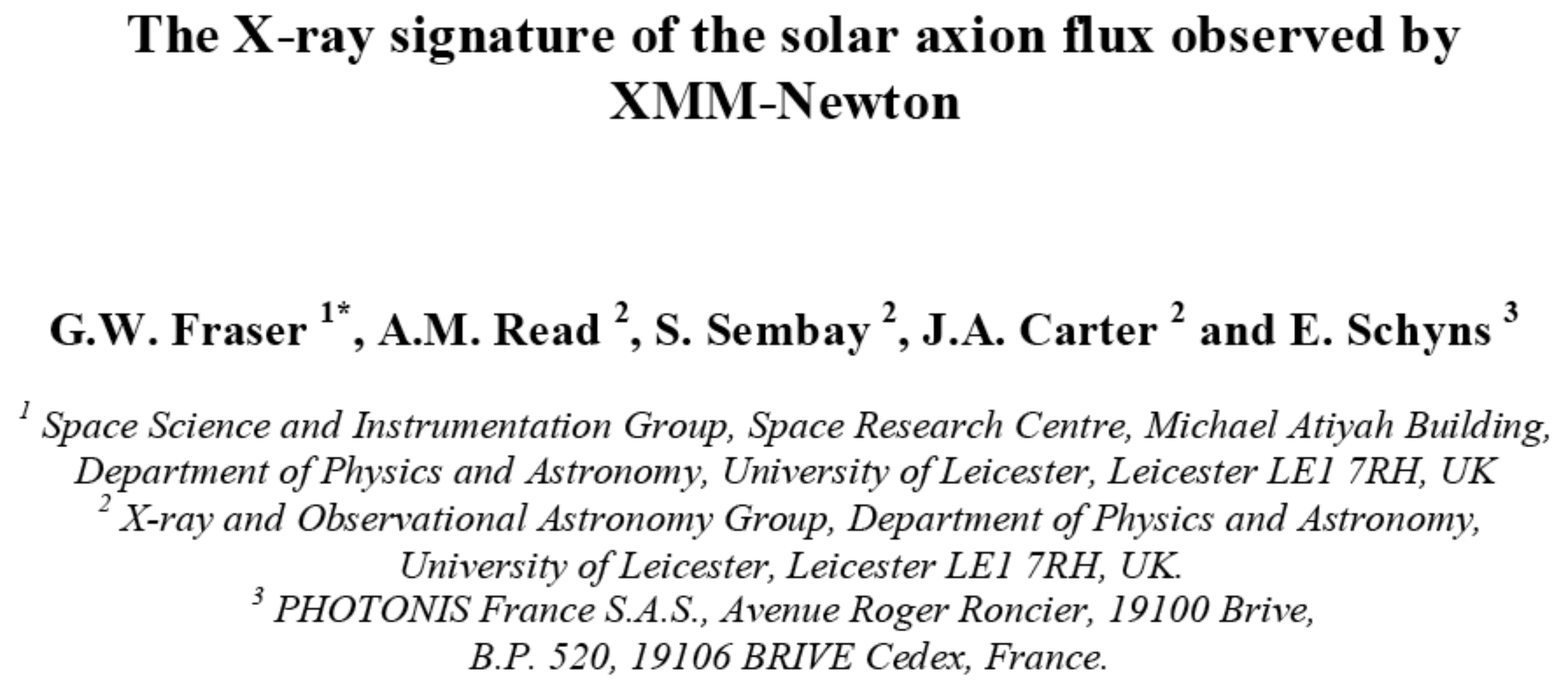
C. Spiering, ESPP Krakow

- Important community input in the **European Strategy for Particle Physics**
- Presence in the Briefing Book of the ESPP, which reflects also APPEC roadmap recommendations.
- **ESPP recomends CERN to follow APPEC recomendatons.**

ALPs, to be, or not to be !

We Finish With a Few Tantalizing Data Interpretations from the Observational Community !

arXiv:1403.2436 March 2014



The X-ray signature of the solar axion flux observed by XMM-Newton

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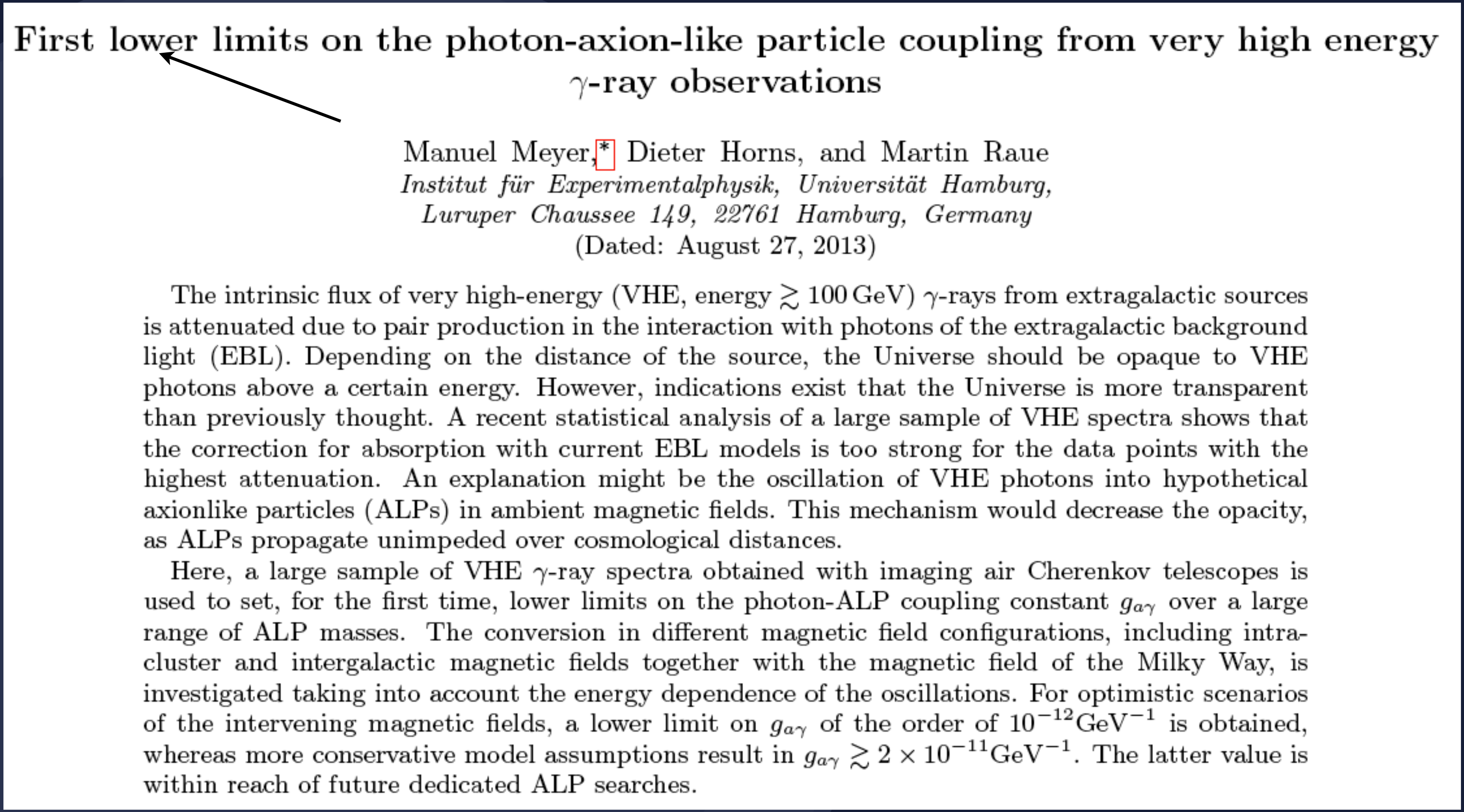
B.P. 520, 19106 BRIVE Cedex, France.

Phys. Rev. D 87, 035027 (2013)



First lower limits on the photon-axion-like particle coupling from very high energy γ-ray observations

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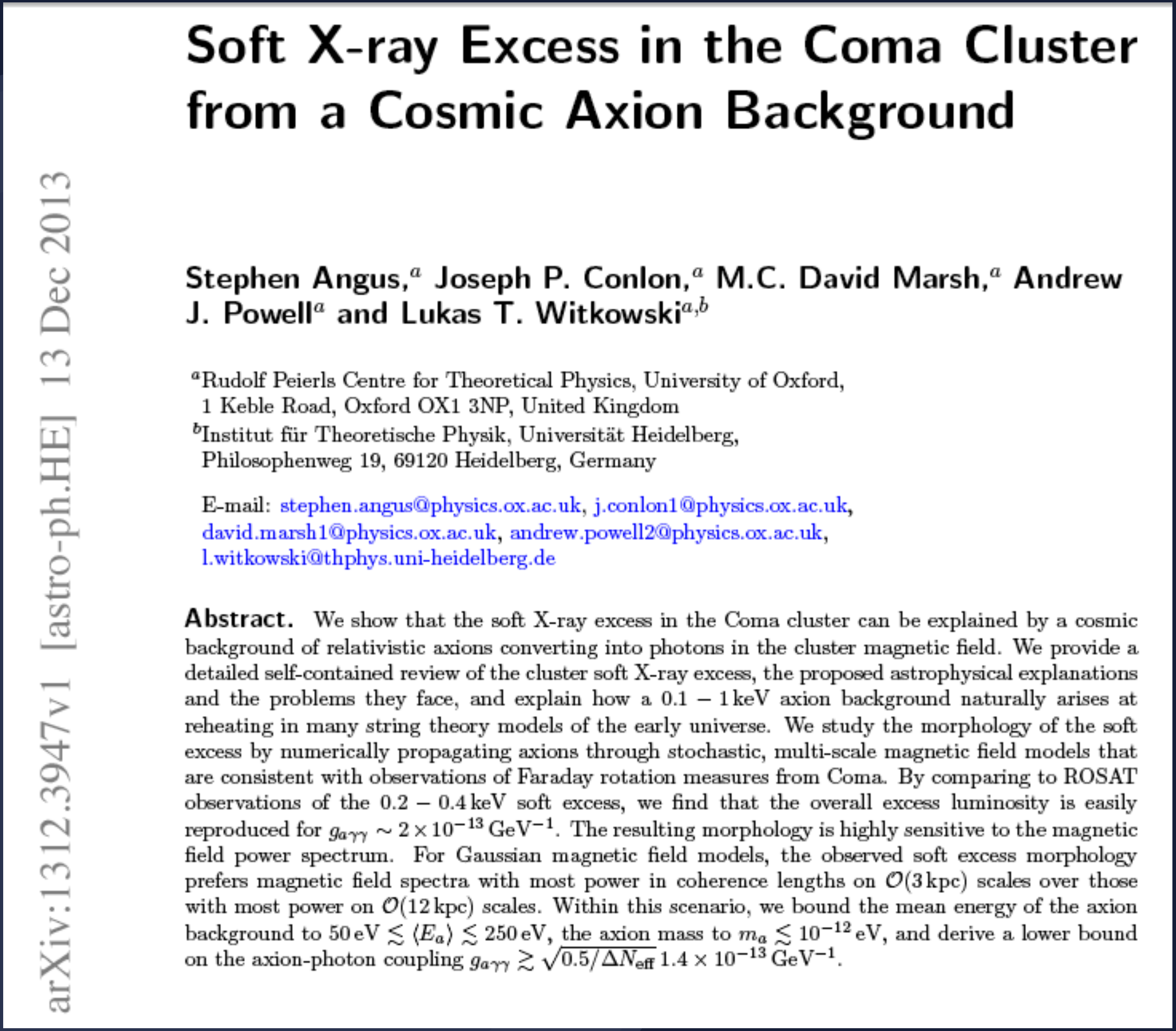
Luruper Chaussee 149, 22761 Hamburg, Germany

(Dated: August 27, 2013)

The intrinsic flux of very high-energy (VHE, energy $\gtrsim 100\,\mathrm{GeV}$) γ-rays from extragalactic sources is attenuated due to pair production in the interaction with photons of the extragalactic background light (EBL). Depending on the distance of the source, the Universe should be opaque to VHE photons above a certain energy. However, indications exist that the Universe is more transparent than previously thought. A recent statistical analysis of a large sample of VHE spectra shows that the correction for absorption with current EBL models is too strong for the data points with the highest attenuation. An explanation might be the oscillation of VHE photons into hypothetical axionlike particles (ALPs) in ambient magnetic fields. This mechanism would decrease the opacity, as ALPs propagate unimpeded over cosmological distances.

Here, a large sample of VHE γ-ray spectra obtained with imaging air Cherenkov telescopes is used to set, for the first time, lower limits on the photon-ALP coupling constant $g_{a\gamma}$ over a large range of ALP masses. The conversion in different magnetic field configurations, including intra-cluster and intergalactic magnetic fields together with the magnetic field of the Milky Way, is investigated taking into account the energy dependence of the oscillations. For optimistic scenarios of the intervening magnetic fields, a lower limit on $g_{a\gamma}$ of the order of $10^{-12}\mathrm{GeV}^{-1}$ is obtained, whereas more conservative model assumptions result in $g_{a\gamma} \gtrsim 2 \times 10^{-11}\mathrm{GeV}^{-1}$. The latter value is within reach of future dedicated ALP searches.

arXiv:1312.3947 Dec. 2013



Soft X-ray Excess in the Coma Cluster from a Cosmic Axion Background

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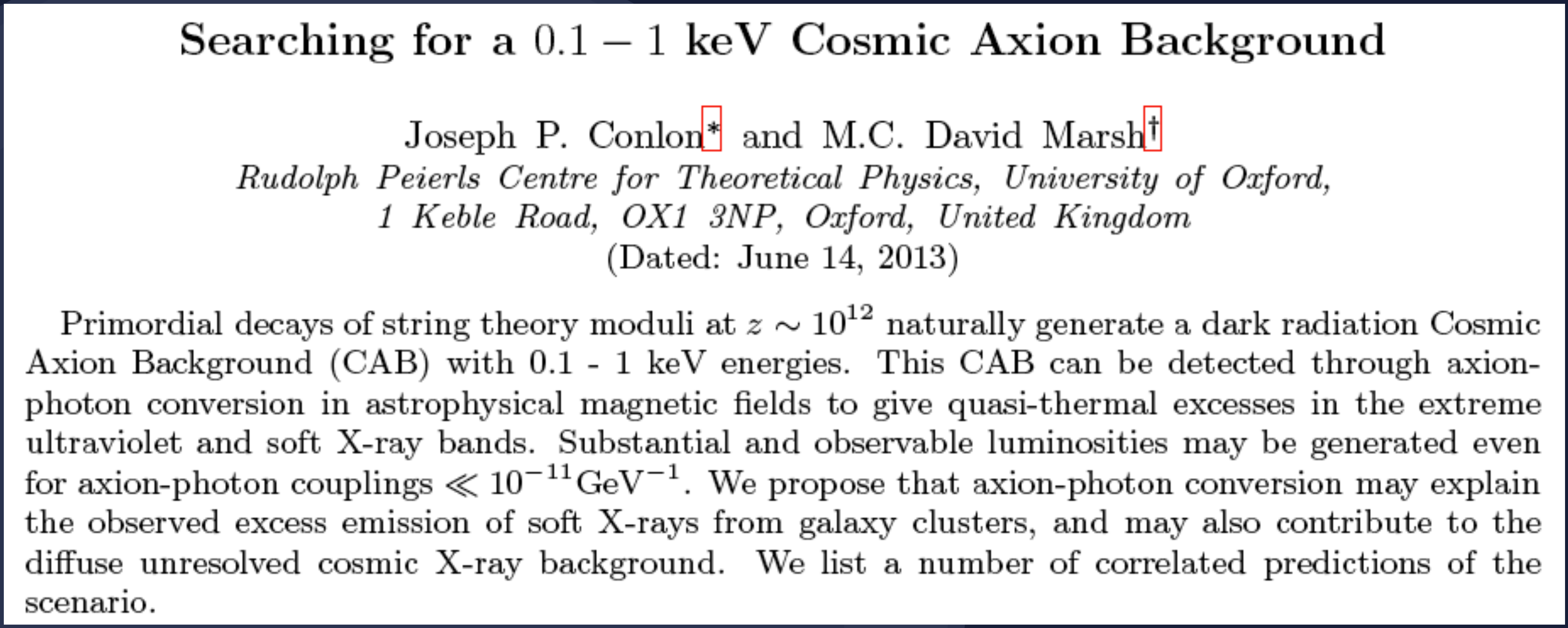
Abstract. We show that the soft X-ray excess in the Coma cluster can be explained by a cosmic background of relativistic axions converting into photons in the cluster magnetic field. We provide a detailed self-contained review of the cluster soft X-ray excess, the proposed astrophysical explanations and the problems they face, and explain how a $0.1-1\,\text{keV}$ axion background naturally arises at reheating in many string theory models of the early universe. We study the morphology of the soft excess by numerically propagating axions through stochastic, multi-scale magnetic field models that are consistent with observations of Faraday rotation measures from Coma. By comparing to ROSAT observations of the $0.2-0.4\,\text{keV}$ soft excess, we find that the overall excess luminosity is easily reproduced for $g_{a\gamma\gamma} \sim 2\times10^{-13}\,\text{GeV}^{-1}$. The resulting morphology is highly sensitive to the magnetic field power spectrum. For Gaussian magnetic field models, the observed soft excess morphology prefers magnetic field spectra with most power in coherence lengths on $\mathcal{O}(3\,\text{kpc})$ scales over those with most power on $\mathcal{O}(12\,\text{kpc})$ scales. Within this scenario, we bound the mean energy of the axion background to $50\,\text{eV} \lesssim \langle E_a \rangle \lesssim 250\,\text{eV}$, the axion mass to $m_a \lesssim 10^{-12}\,\text{eV}$, and derive a lower bound on the axion-photon coupling $g_{a\gamma\gamma} \gtrsim \sqrt{0.5/\Delta N_{\text{eff}}}\,1.4\times10^{-13}\,\text{GeV}^{-1}$.

arXiv:1305.3603 June 2013



Searching for a $0.1 - 1$ keV Cosmic Axion Background

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(Dated: June 14, 2013)

Primordial decays of string theory moduli at $z \sim 10^{12}$ naturally generate a dark radiation Cosmic Axion Background (CAB) with 0.1 - 1 keV energies. This CAB can be detected through axion-photon conversion in astrophysical magnetic fields to give quasi-thermal excesses in the extreme ultraviolet and soft X-ray bands. Substantial and observable luminosities may be generated even for axion-photon couplings $\ll 10^{-11}\text{GeV}^{-1}$. We propose that axion-photon conversion may explain the observed excess emission of soft X-rays from galaxy clusters, and may also contribute to the diffuse unresolved cosmic X-ray background. We list a number of correlated predictions of the scenario.

Conclusions

The discovery of axions would give important needed confirmation of the elegant Peccei-Quinn solution of the Strong CP-Problem.

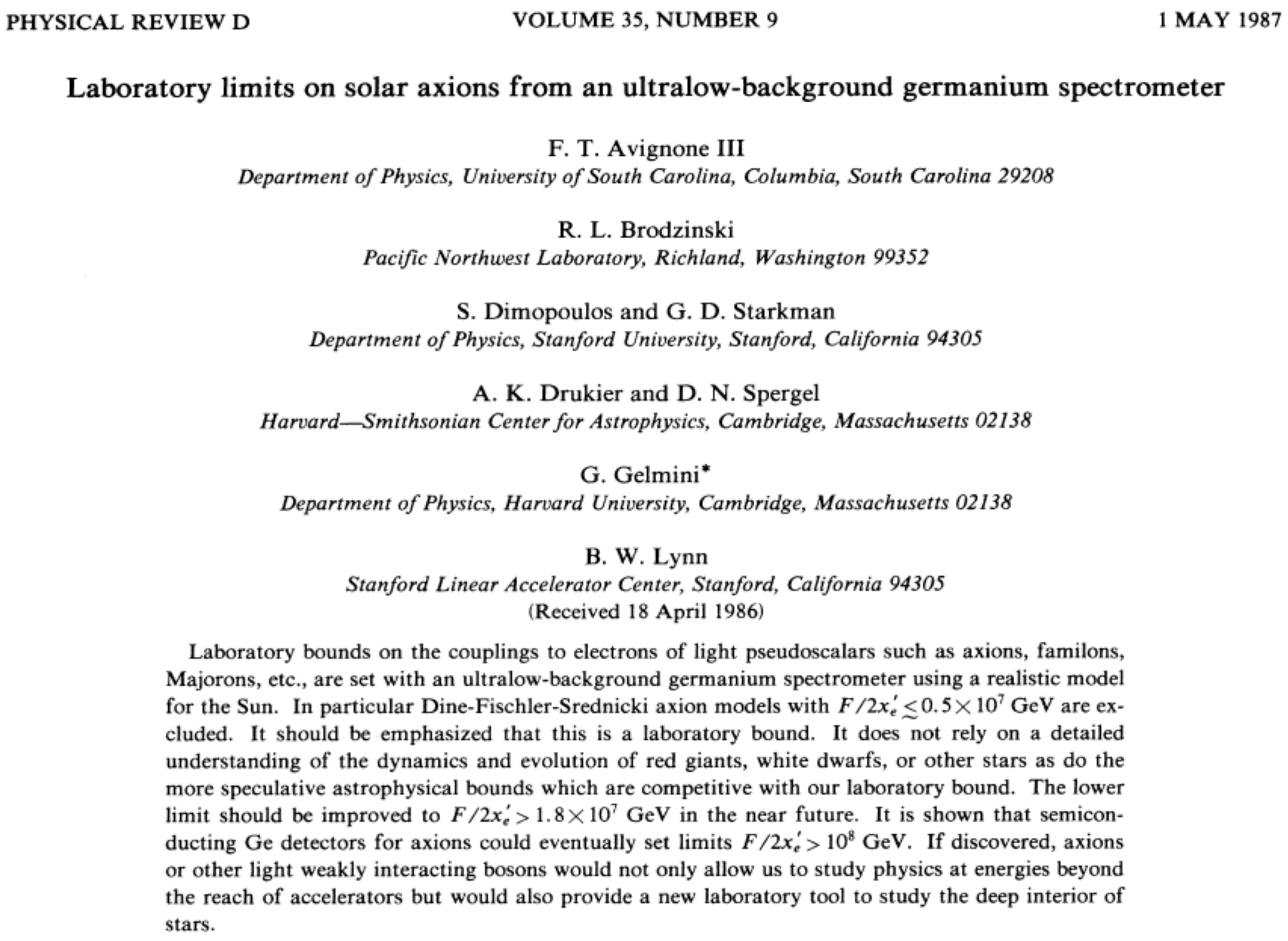
The CAST experiment is the most sensitive Broad Mass Search; However, loss of coherence prevents it from probing important regions of the axion-model space.

The proposed ALP explanation of the observation of extra-galactic TeV gamma rays is another motivation for increasing the physics reach of axion helioscopes.

The proposed International Axion Observatory (IAXO) is the next step in extending the sensitivity of Solar Axion/ALP searches.

There is great interest in axions/ALPs being generated in the astrophysics and cosmology communities to explain a number of interesting phenomena.

Is This the First Published Search for Solar Axions ?



PHYSICAL REVIEW D VOLUME 35, NUMBER 9 1 MAY 1987

Laboratory limits on solar axions from an ultralow-background germanium spectrometer

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(Received 18 April 1986)

Laboratory bounds on the couplings to electrons of light pseudoscalars such as axions, familons, Majorons, etc., are set with an ultralow-background germanium spectrometer using a realistic model for the Sun. In particular Dine-Fischler-Srednicki axion models with $F/2x'_e \lesssim 0.5\times10^7$ GeV are excluded. It should be emphasized that this is a laboratory bound. It does not rely on a detailed understanding of the dynamics and evolution of red giants, white dwarfs, or other stars as do the more speculative astrophysical bounds which are competitive with our laboratory bound. The lower limit should be improved to $F/2x'_e > 1.8\times10^7$ GeV in the near future. It is shown that semiconducting Ge detectors for axions could eventually set limits $F/2x'_e > 10^8$ GeV. If discovered, axions or other light weakly interacting bosons would not only allow us to study physics at energies beyond the reach of accelerators but would also provide a new laboratory tool to study the deep interior of stars.


IL LAVORO MI PERSEGUITA, MA IO SONO PIU' VELOCE!