# CERN Axion Solar Telescope

➔ axions, axions, …


K. Ζιούτας

Πανεπιστήμιο Πατρών & CERN

+ ΕΜΠ Ε. Γαζής

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CERN, 27th June 2008

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# The CAST Collaboration

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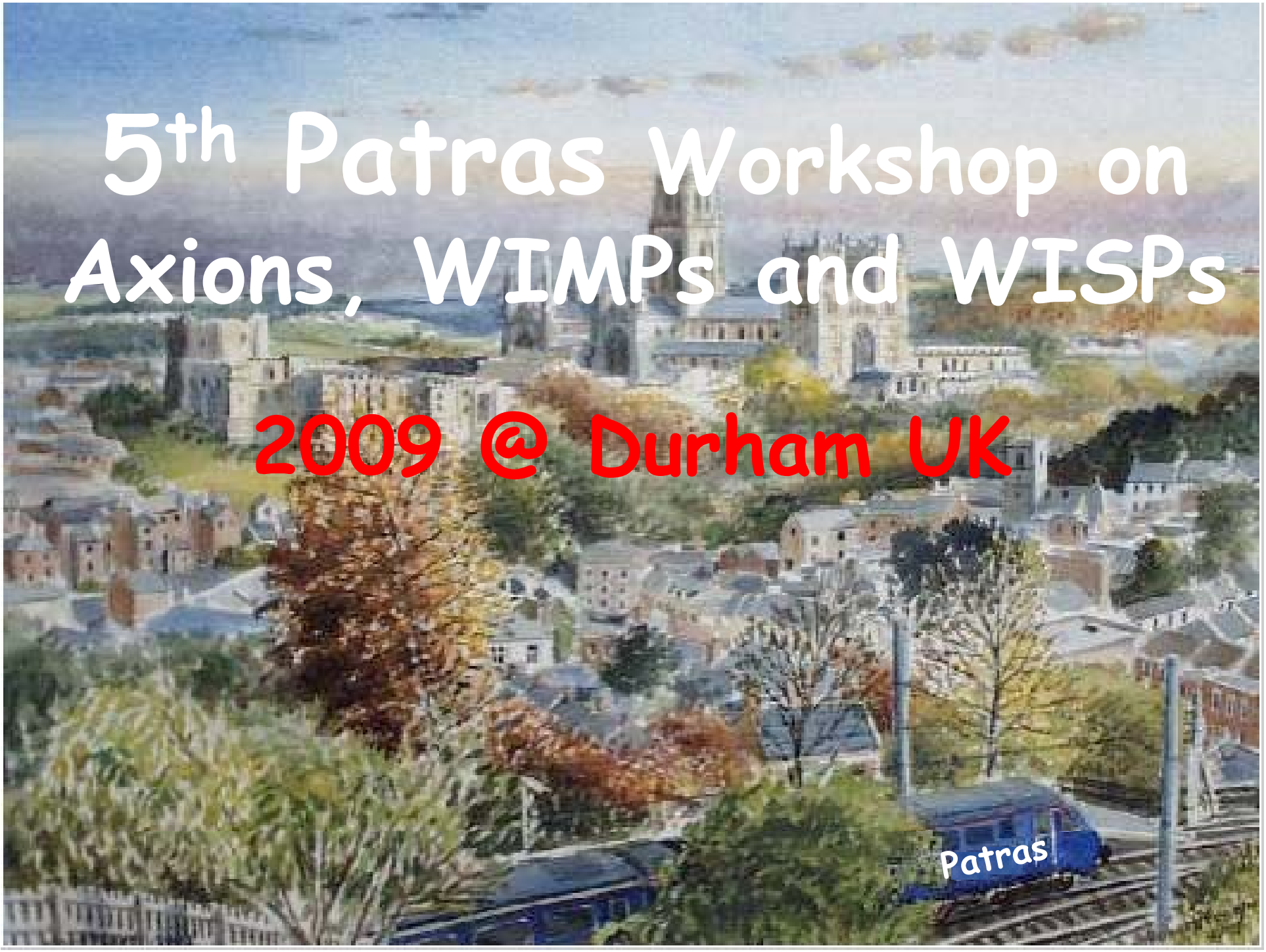
20. Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Germany
21. National Technical University of Athens, Athens, Greece

+

Giomataris

Papaevangelou

# Axions in the spotlight!


5th Patras Workshop on
Axions, WIMPs and WISPs
2009 @ Durham UK
Patras

# 4th Patras Workshop on Axions, WIMPs and WISPs

**Physics of Axions, Weakly Interacting Massive Particles and Weakly Interacting Sub-eV Particles in Universe and Laboratory**

## DESY, Hamburg Site/Germany

## 18-21 June 2008

### Programme:

- The physics case for WIMPs, Axions, WISPs
- Review of collider experiments
- Signals from astrophysical sources
- Direct searches for Dark Matter
- Indirect laboratory searches for Axions, WISPs
- Direct laboratory searches for Axions, WISPs
- New theoretical developments


**Organizing committee:**

Laura Baudis (Zürich University)
Josef Jochum (Universität Tübingen)
Axel Lindner (DESY)
Javier Redondo (DESY)
Andreas Ringwald (DESY)
Konstantin Zioutas (CERN/University of Patras)


**http://axion-wimp.desy.de**

# 3rd Joint ILIAS-CERN-DESY Axion-WIMPs Training Workshop

**University of Patras* / Greece**
**19-25 June 2007**

AXIONS

## Let there be axions

**Konstantin Zioutas** reports on the first Joint ILIAS–CAST workshops, which covered a wide range of studies, from e reactors to investigations of the roles of axions in solar ph

One of the biggest mysteries of science is the nature of dark matter, which first became apparent as astronomer Fritz Zwicky's "dunkle Materie" in 1933. The two leading particle candidates for this "missing matter" are weakly interacting massive particles (WIMPs) and axions – hypothesized uncharged particles that have a very small but unknown mass, which barely interact with other particles. To bring together the widespread axion community, the Integrated


*Axions bridge the gap between theory and observation of the strong interaction, and have also inspired the artist Evdoxia Kyrmanidou.*

of experiments started by Nobel laureates Norman Ramsey and Edward Purcell in the 1950s, which continues today with the ambitious goal of reaching $10^{-28}$ e cm by the end of the decade. Other proposed neutron EDM experiments include those at the Paul Scherrer Institut and at the Spallation Neutron Source in Oak Ridge with goals of $10^{-27}$ e cm and $10^{-28}$ e cm, respectively. A new technique with the deuteron

NEW PARTICL

## Axions create excitement and doubt at Princeton

A workshop at the Institute for Advanced Study paid much attention to a small-scale experiment that might have found the first direct indication of a new particle.

*Workshop participants pose in the sunshine outside of the Institute for Advanced Study at Princeton in October 2006.*

WORKSHOP

## Fundamental physics re-explored in Patras

*Participants gather at the 3rd Joint ILIAS–CERN–DESY Axion–WIMPs training workshop.*

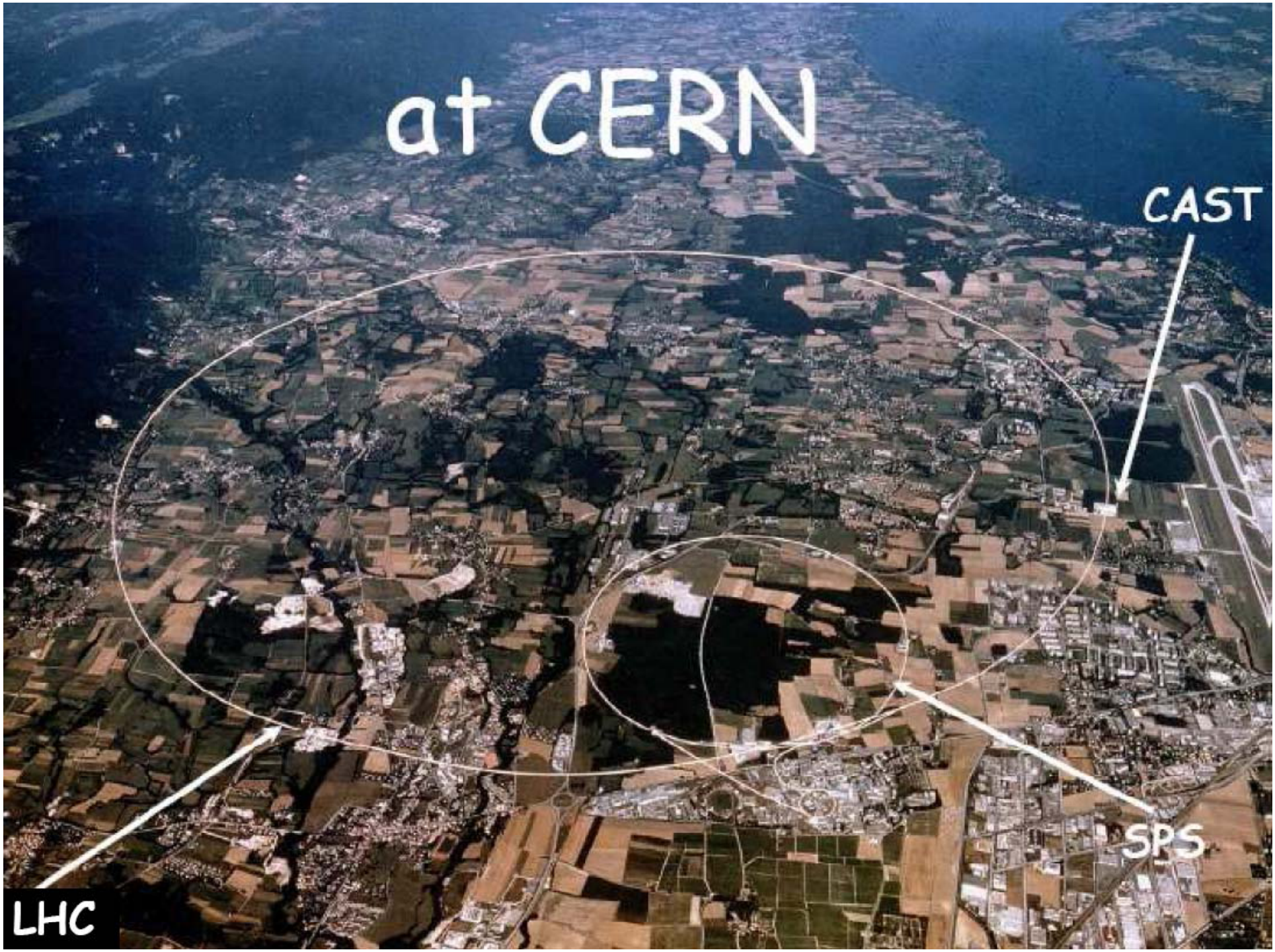
sruhe), N. Elias (CERN), E. Gazis (NTU & CERN), I. Giomataris (Saclay), m U), J. Jochum (U.Tübingen), M. Karuza (Trieste), S. Katsanevas (U.Paris Kuster (Darmstadt), B. Lakic (RBI, Zagreb), A. Lindner (DESY), G. Lutz (MPI), D. Nanopoulos (Texas A&M U., Houston HARC & Athens, Academy), P. Pugnat (CERN), J. Redondo (U. Barcelona), S. Riemer-Sorensen (DARK Copenhagen), A. Ringwald (DESY), C.Robilliard (Toulouse), Y. Semertzidis (BNL), A. Siemko (CERN), S. Solanki (MPS Lindau), J. Steffen (Fermi LAB), J. Vigen (CERN), K. Zioutas (U. Patras)


**Searching for Decaying Axionlike Dark Matter from Clusters of Galaxies**

➔ **new τ** ← **KK-axions**

**Riemer-Sørensen, Zioutas, Hansen, Pedersen, Dahle, Liolios**

PRL99 (2007) 131301


at CERN
CAST
SPS
LHC

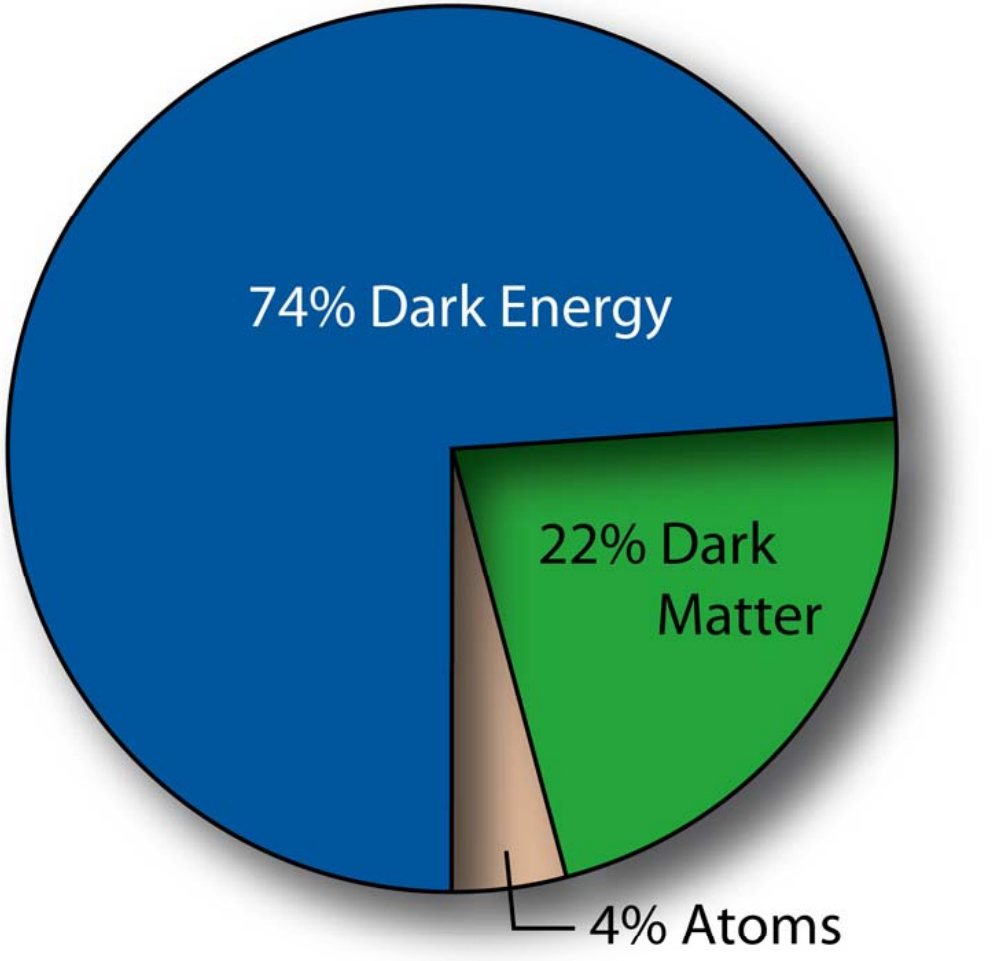

3sat

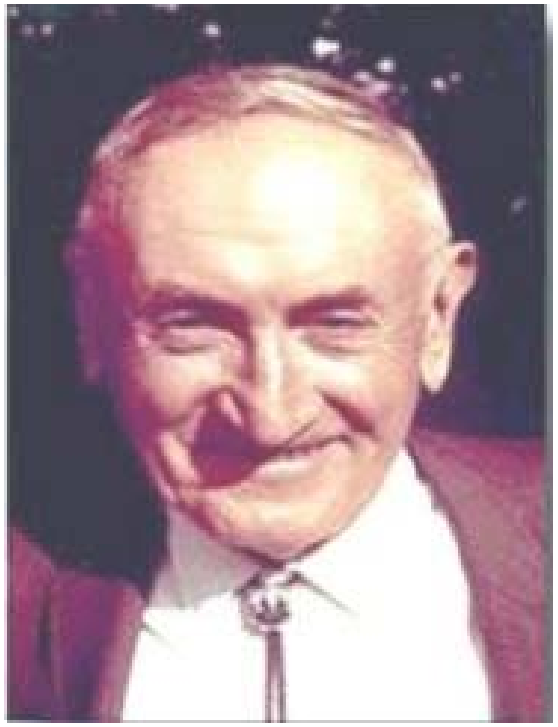
# The CAST Experiment


- Decommissioned superconducting prototype LHC dipole magnet.
- **T=1.8 K  B=9T  L=9.26m.**
- Rotating platform (Vertical: ±8°, Horizontal: ±40° )
- ~90 min solar tracking @ sunrise/sunset
- 3 X-ray detectors + **X-ray Focusing/Imaging Telescope**

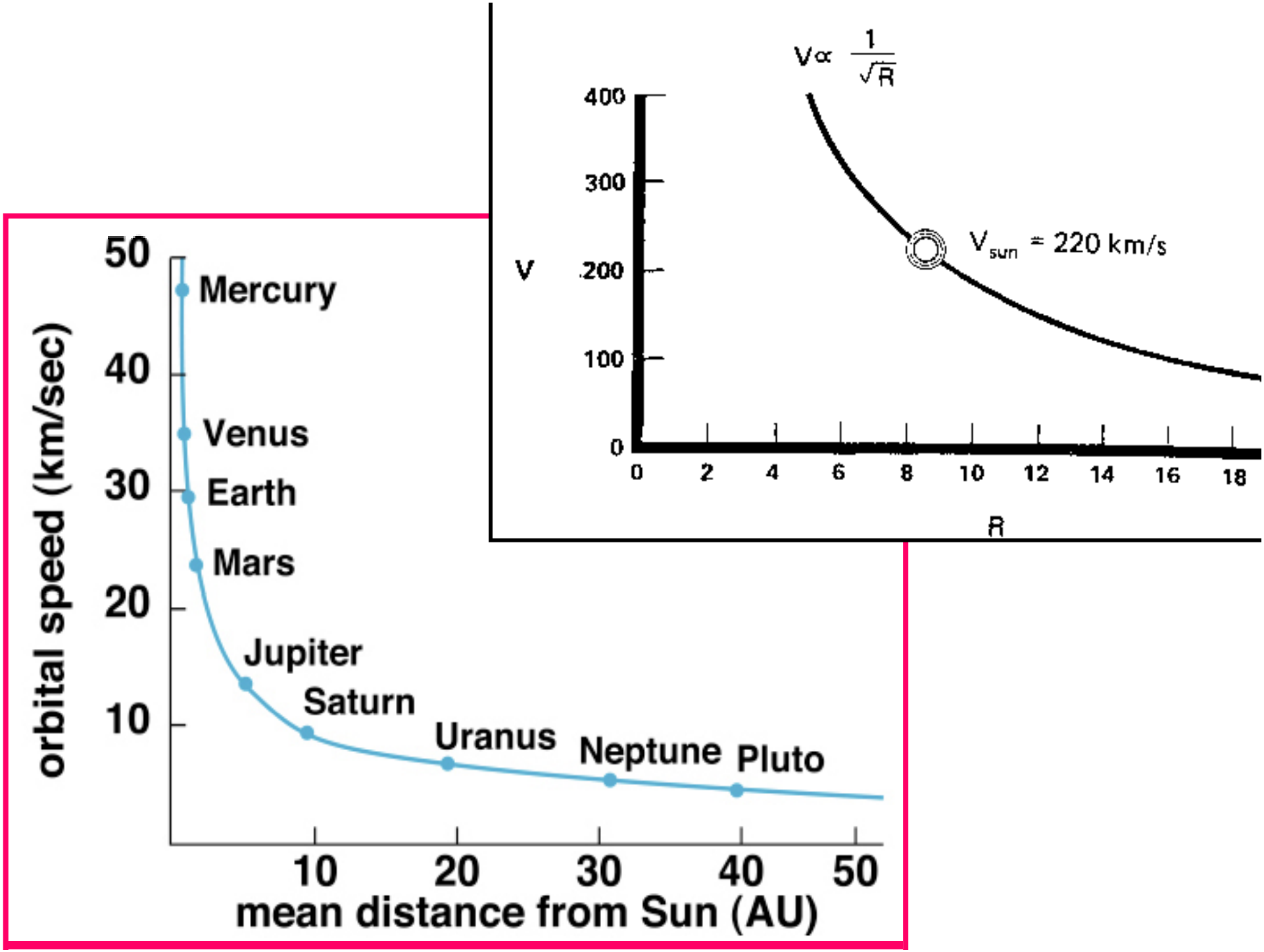
**→ a CAST "first"**

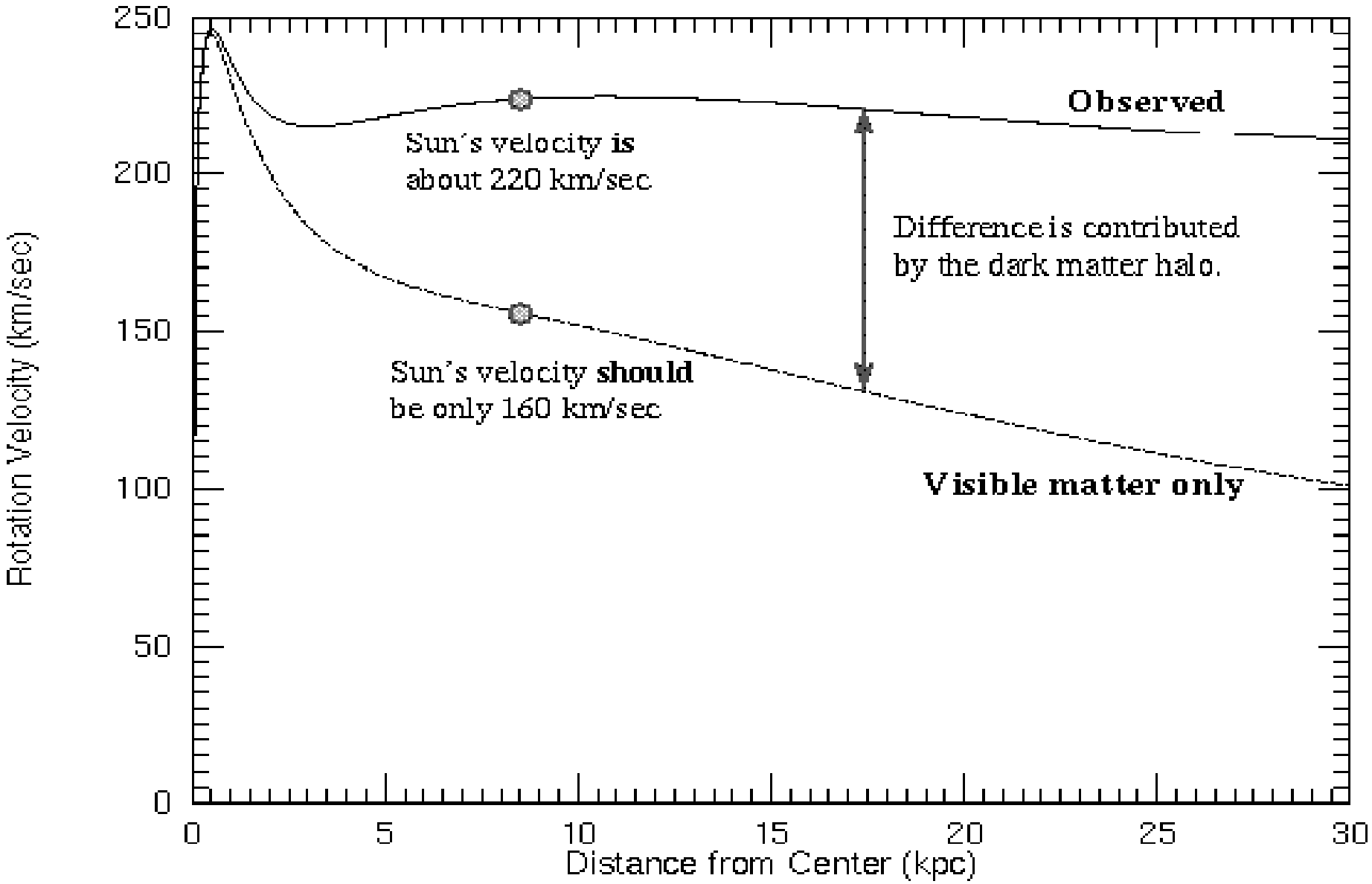
Why?



**Fritz Zwicky**
**1898 – 1974**


Vα 1/√R
400
300
V
200
100
0
0
2
4
6
8
10
12
14
16
18
R
V_sun = 220 km/s
orbital speed (km/sec)
50
40
30
20
10
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto
10
20
30
40
50
mean distance from Sun (AU)




The gravity of the visible matter in the Galaxy is not enough to explain the high orbital speeds of stars in the Galaxy. For example, the Sun is moving about 60 km/sec too fast. The part of the rotation curve contributed by the visible matter only is the bottom curve. The discrepancy between the two curves is evidence for a **dark matter halo.**

# Why axions?

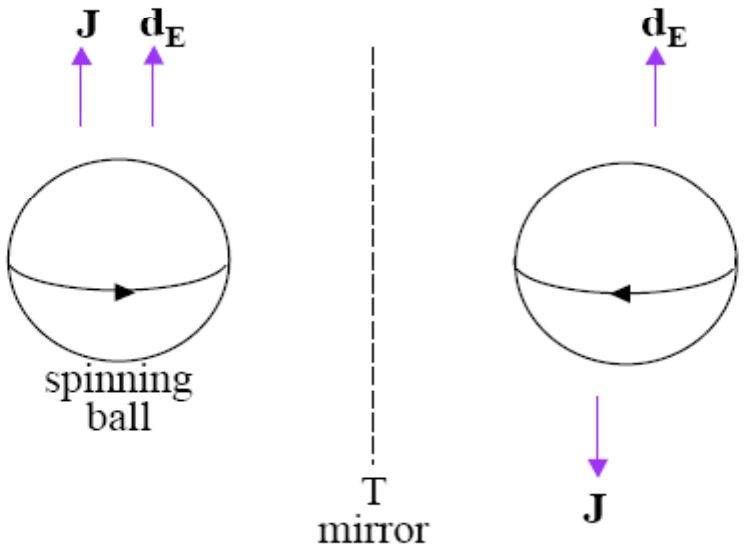
# nEDM → dEDM

The discrete symmetry "mirrors"

T ≡ time reversal

C ≡ changing particles to antiparticles

P ≡ space inversion



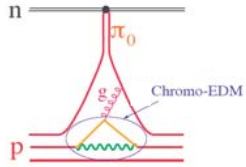

If you see an EDM: ~~T~~ + CPT = ~~CP~~

# Probing the Deuteron Nucleus EDM in a Storage Ring

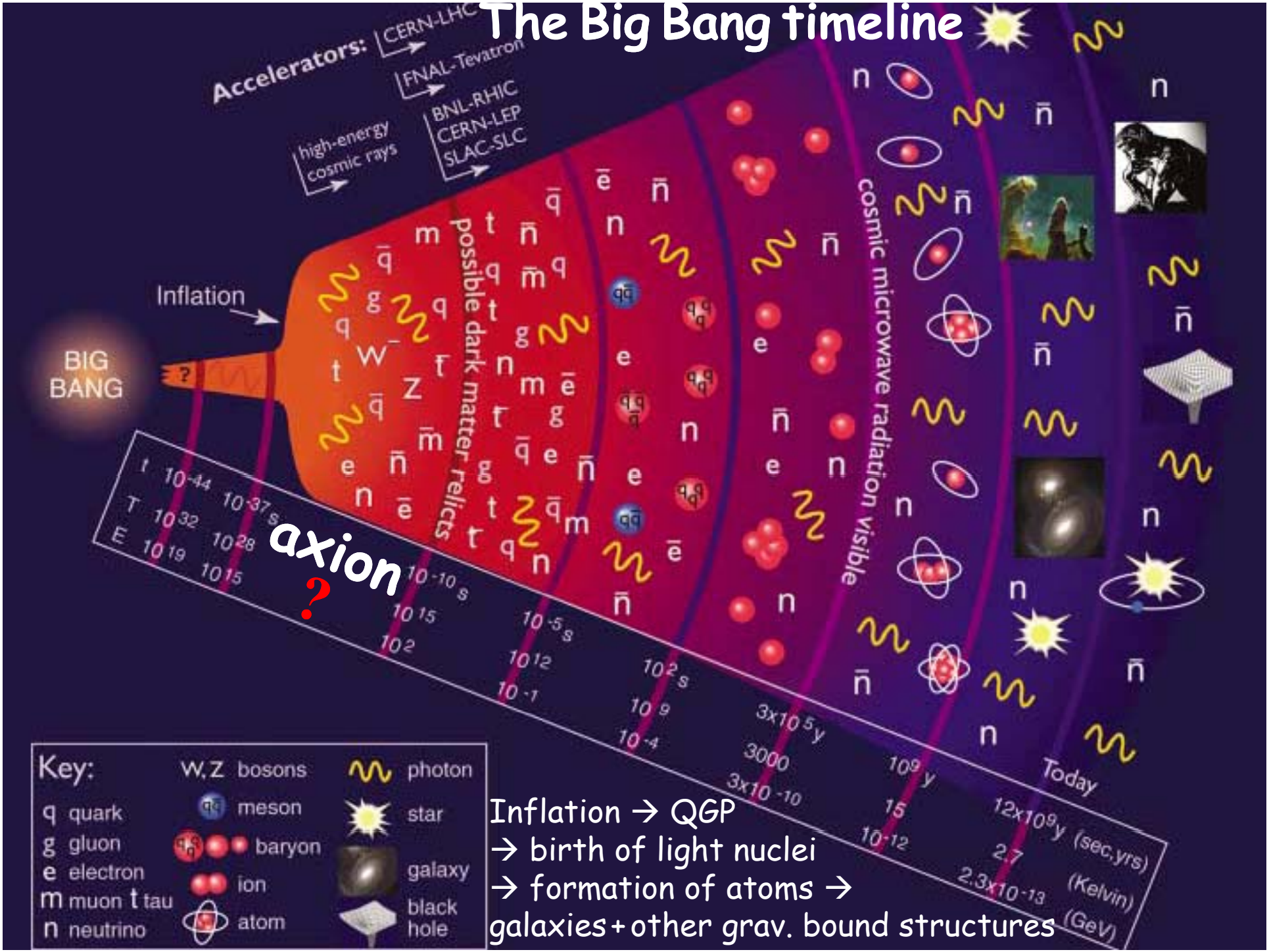
- Utilizing the large E-field in the deuteron rest frame
- High intensity polarized deuterons available
- High analyzing power

- Proposal to BNL (2008) available at http://www.bnl.gov/edm/

from **Yannis Semertzidis** / BNL

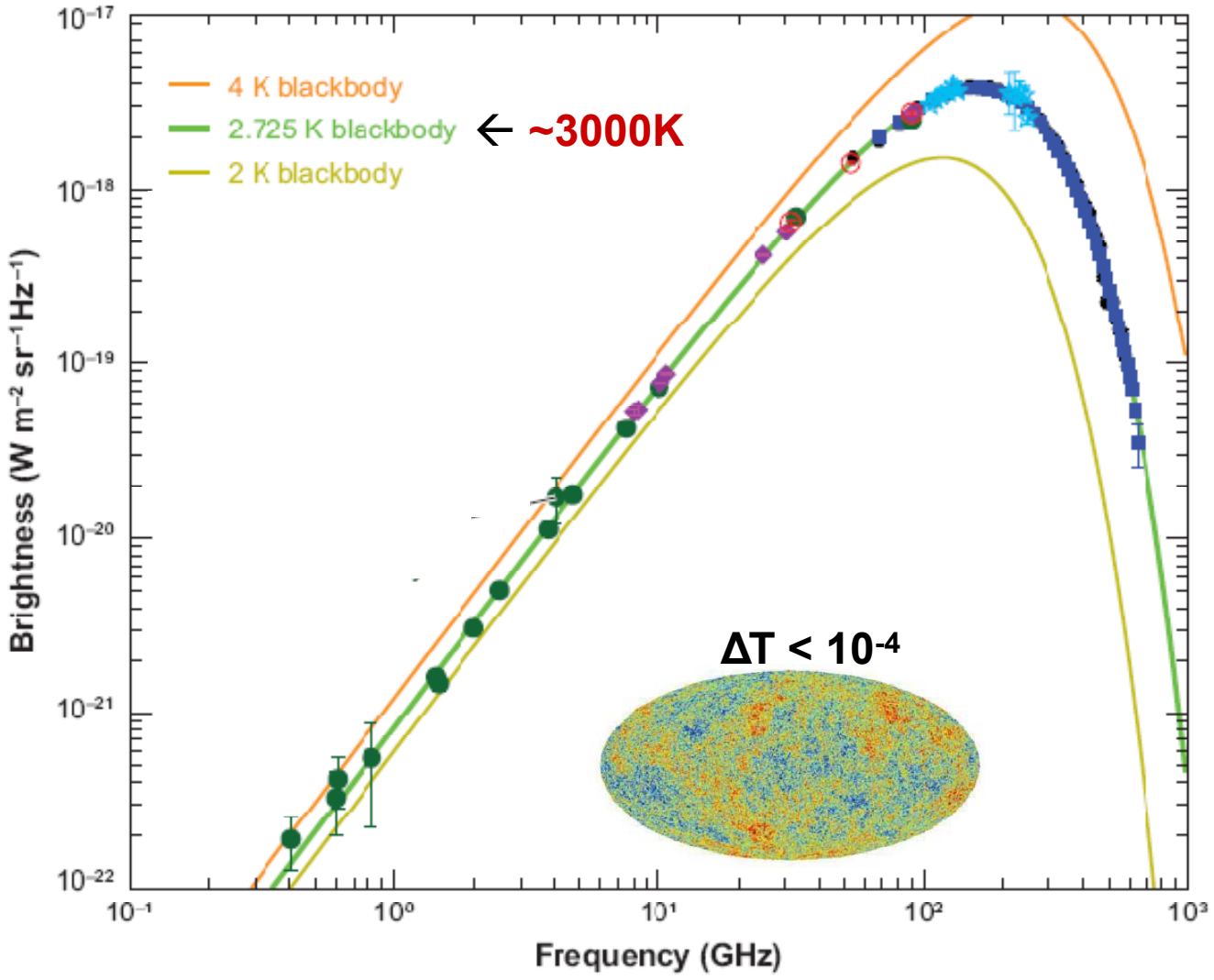


# The Big Bang timeline

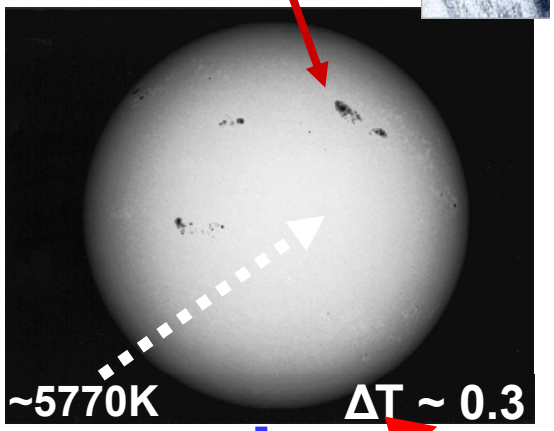



Inflation → QGP
→ birth of light nuclei
→ formation of atoms →
galaxies + other grav. bound structures

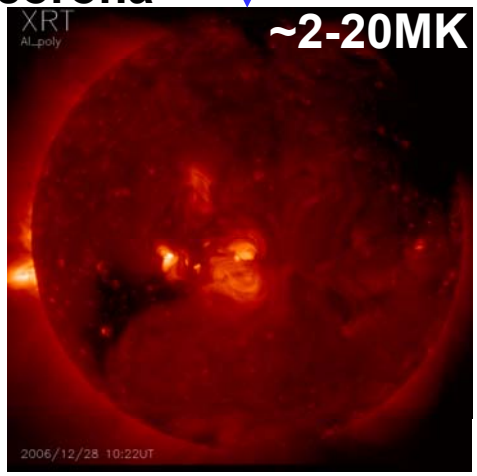
# The Cosmic Microwave Background




~4000K




corona




D. Samtleben, S. Staggs, B. Winstein, ARNPS 57 (2007) 245

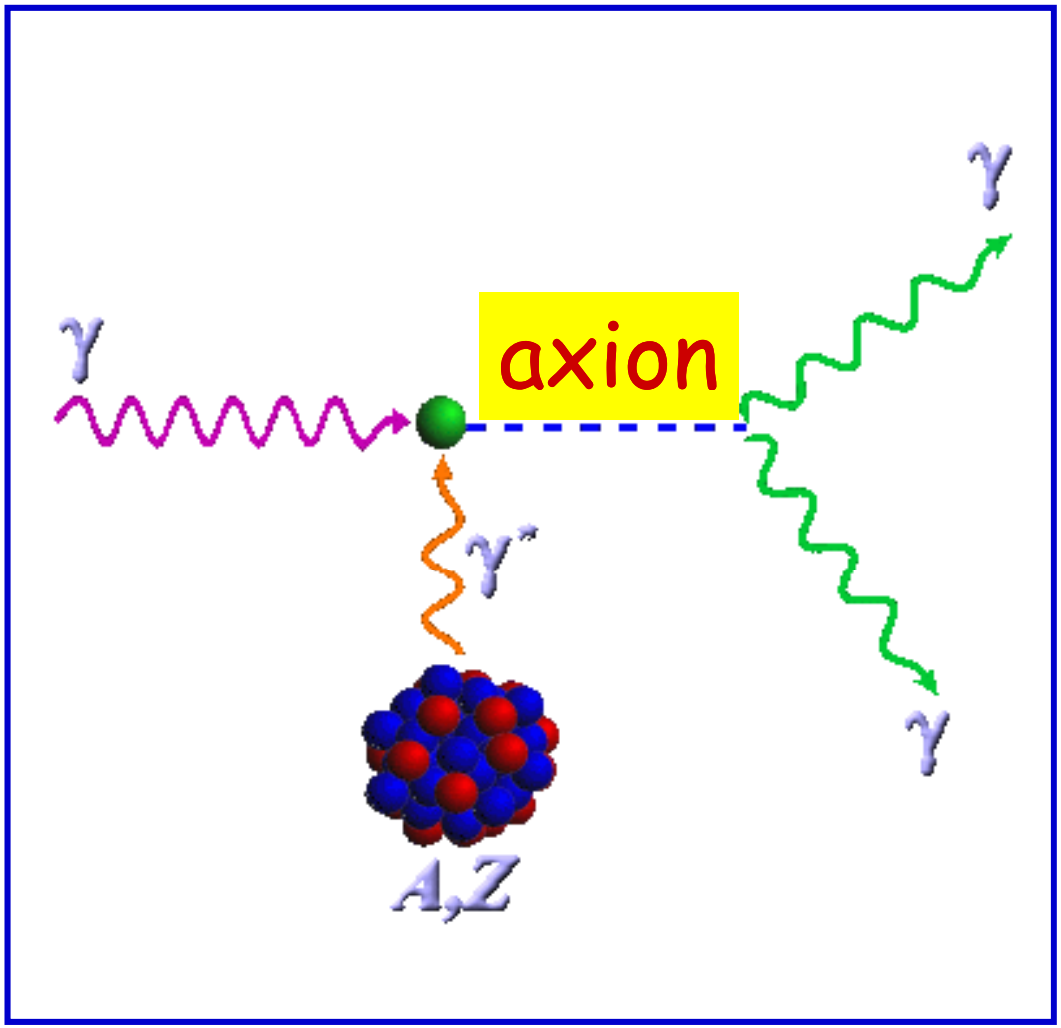
# SUN:

➔ 5 Mtons / s of energy is released

~100 'ktons' ~axions / s …

… overlooked?

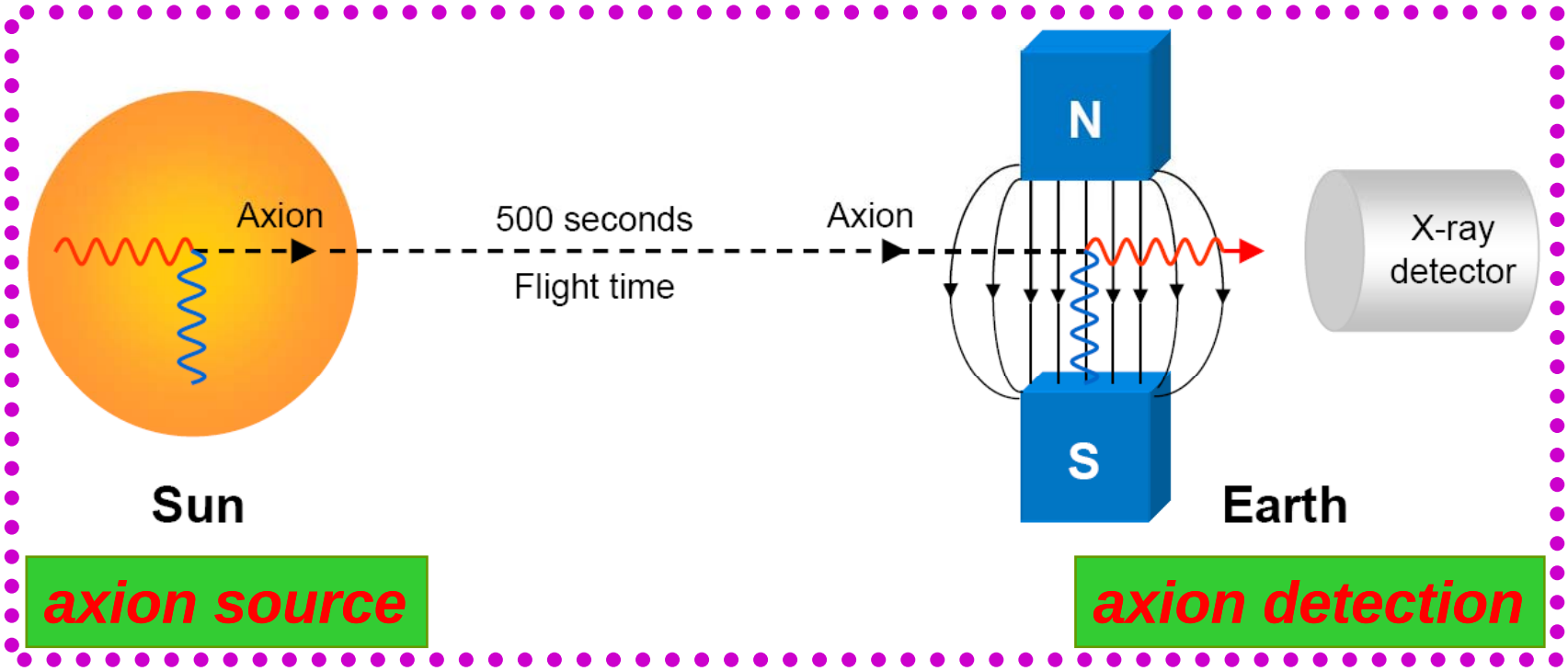
# The Primakoff Effect 1951

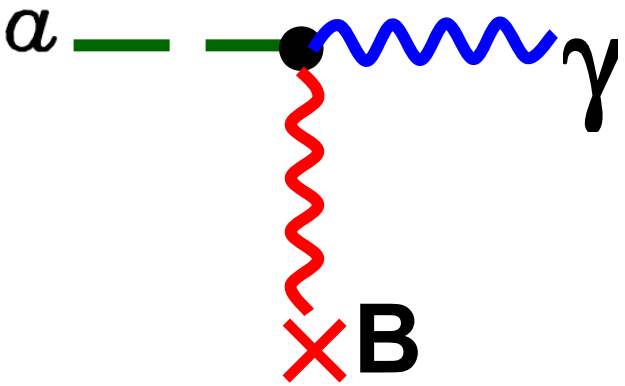




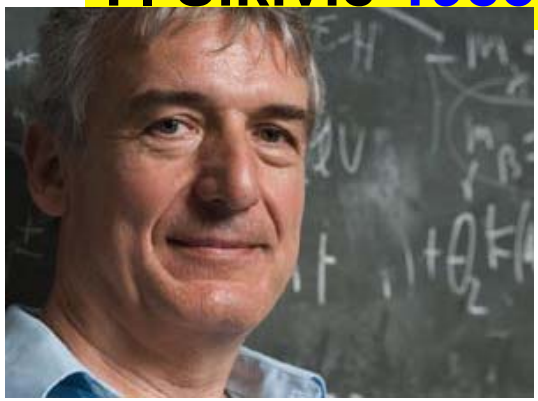
Behind <u>all</u> present axion work! → solar axions

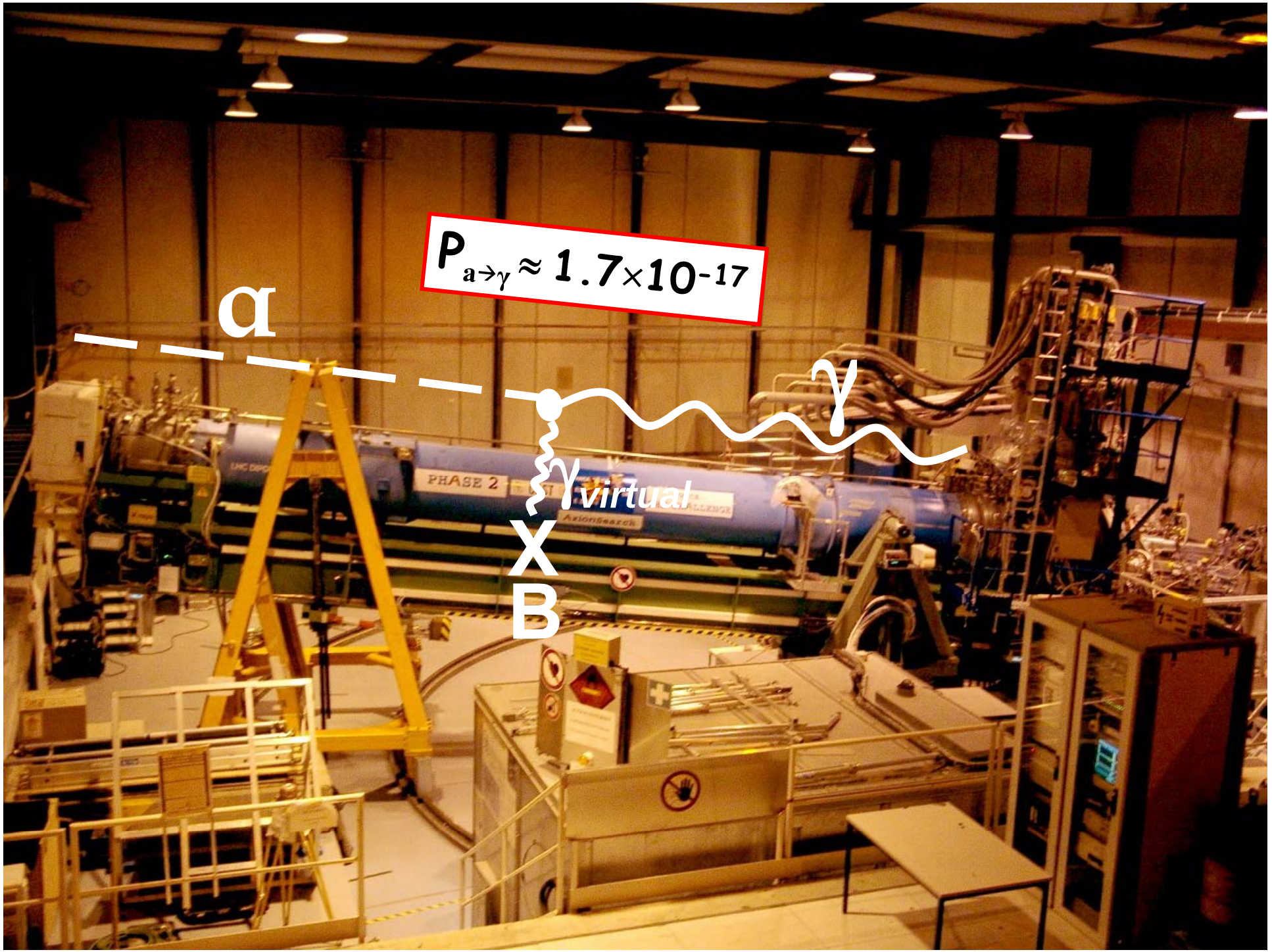
# CAST



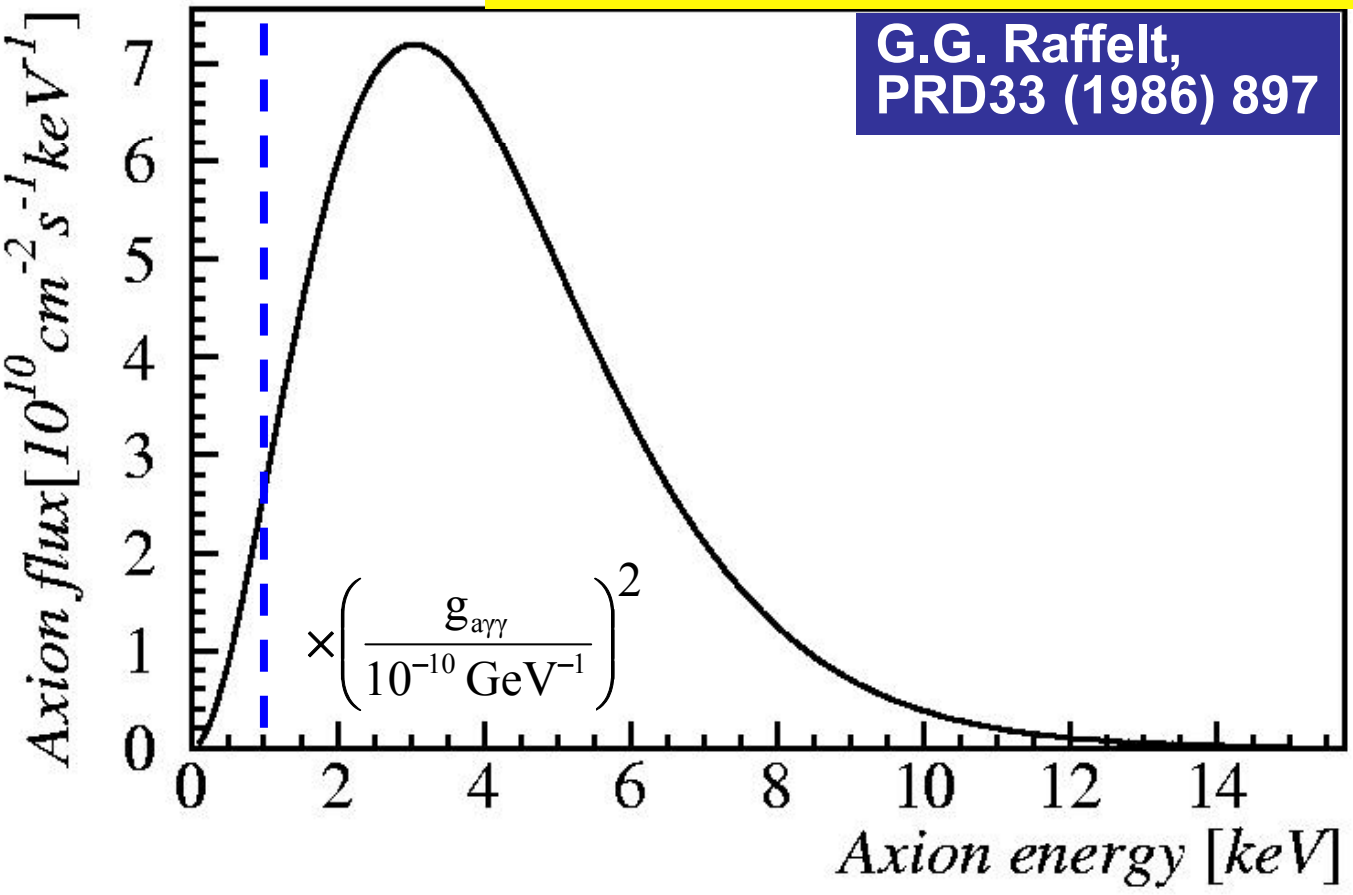

P. Sikivie 1983




$P_{a\to\gamma} \approx 1.7\times10^{-17}$
α
γ
$\gamma_{virtual}$
X
B
PHASE 2
ADMX
ADMX
AxionSearch

# Solar axion spectrum

screening effects → 25x suppression, or?

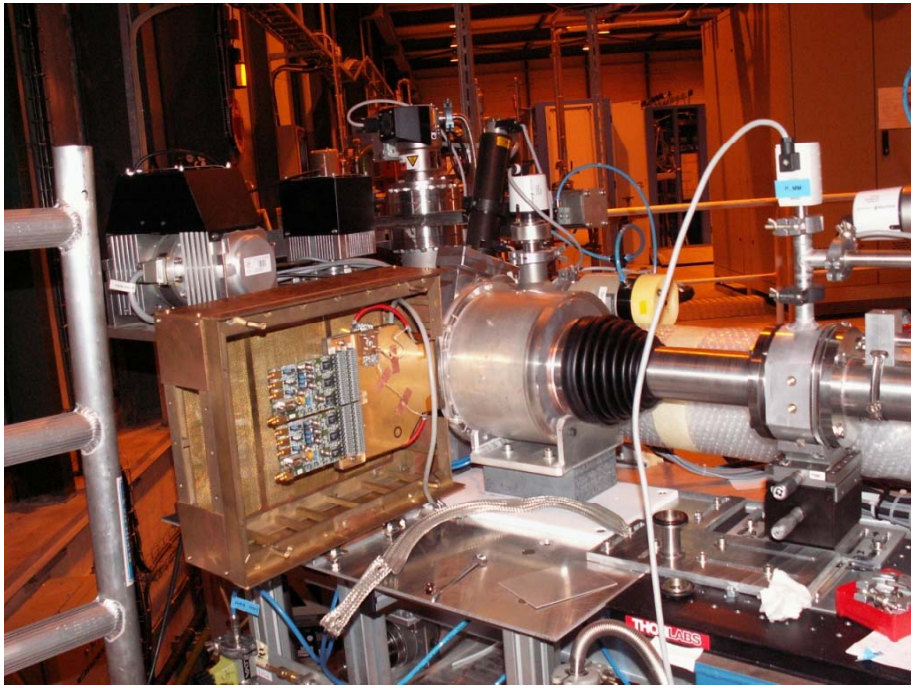


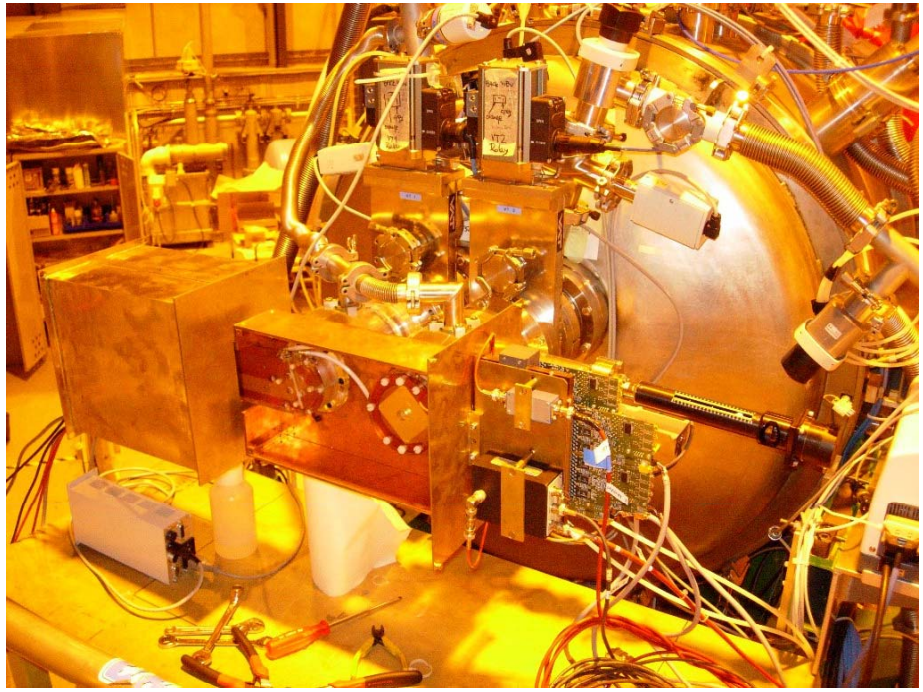

∀ Theoretically + experimentally → new territory!

Signal = tracking - background

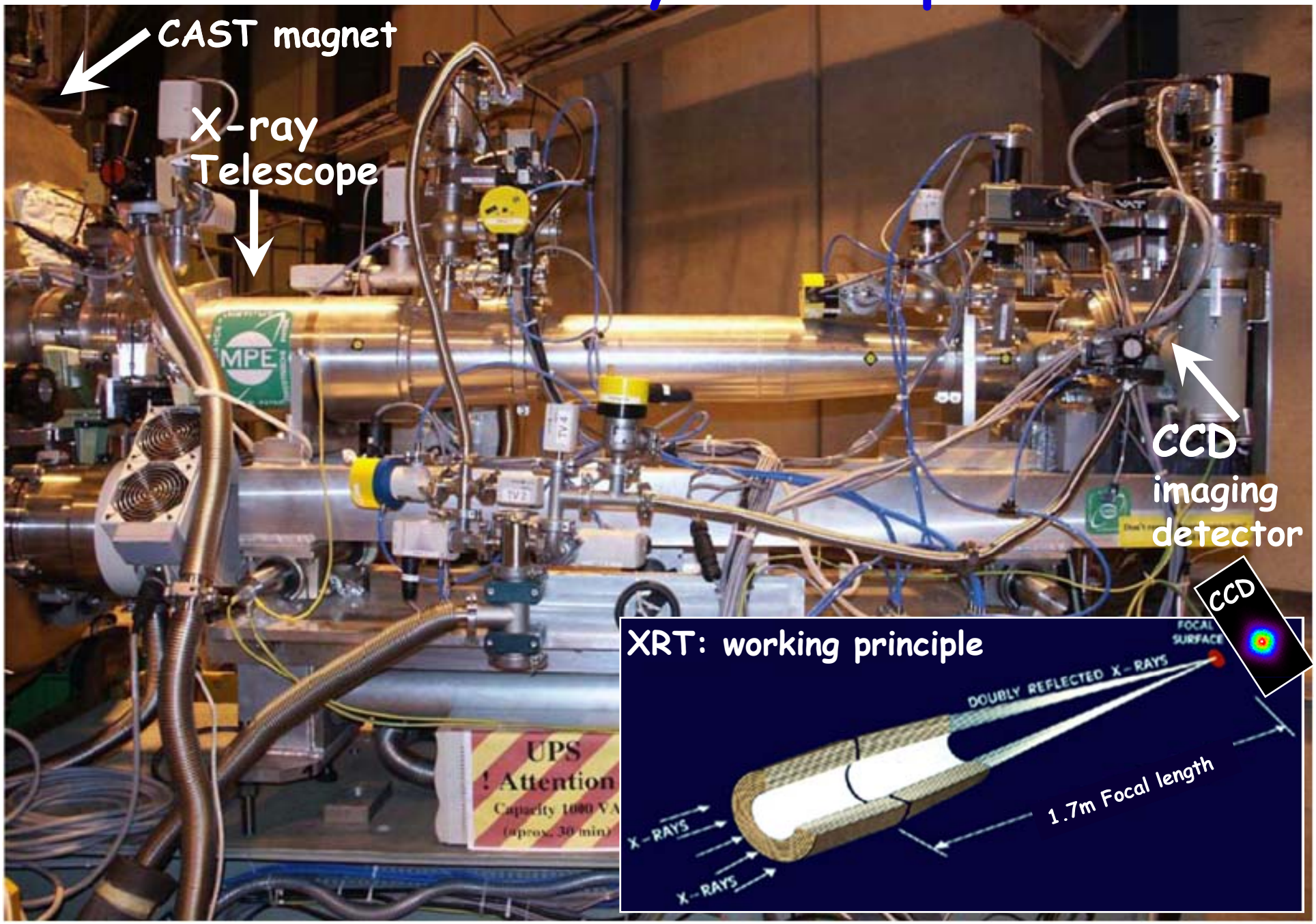
# Micromegas detectors

Sunrise I. GIOMATARIS Sunset

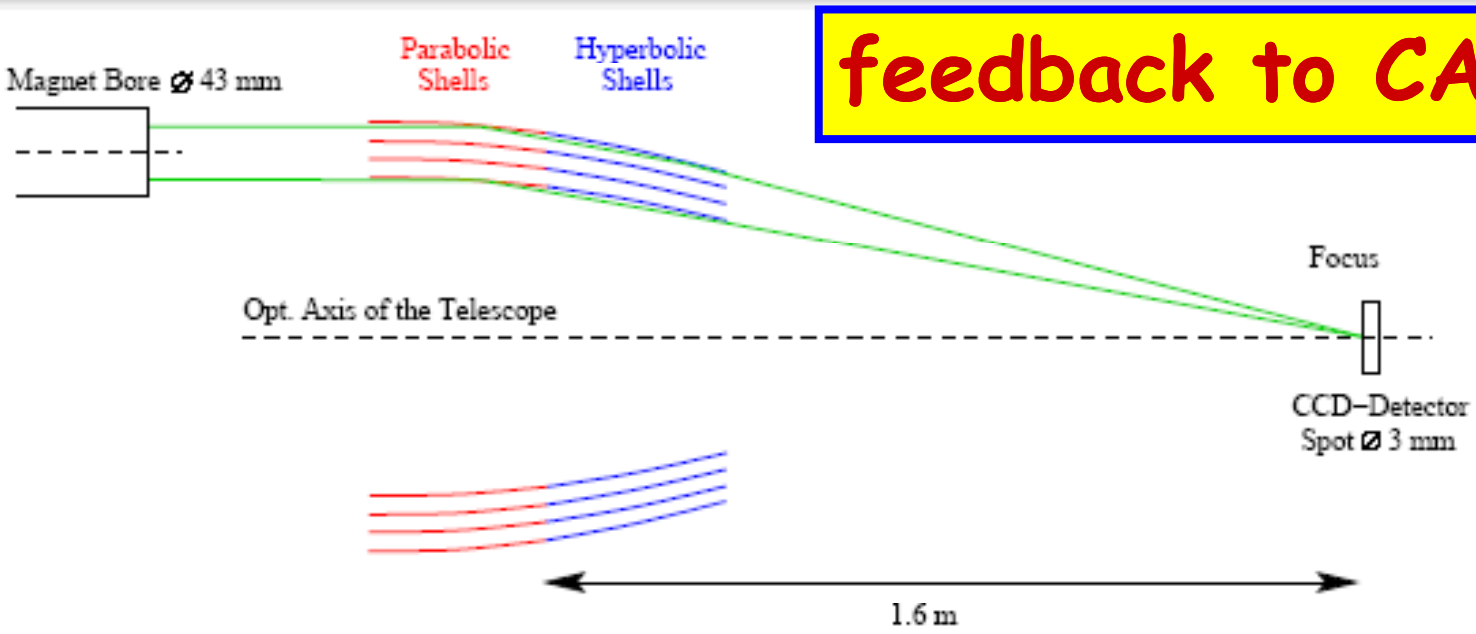




# CAST X-ray Telescope



# The X-ray Telescope of CAST




**feedback to CAST**

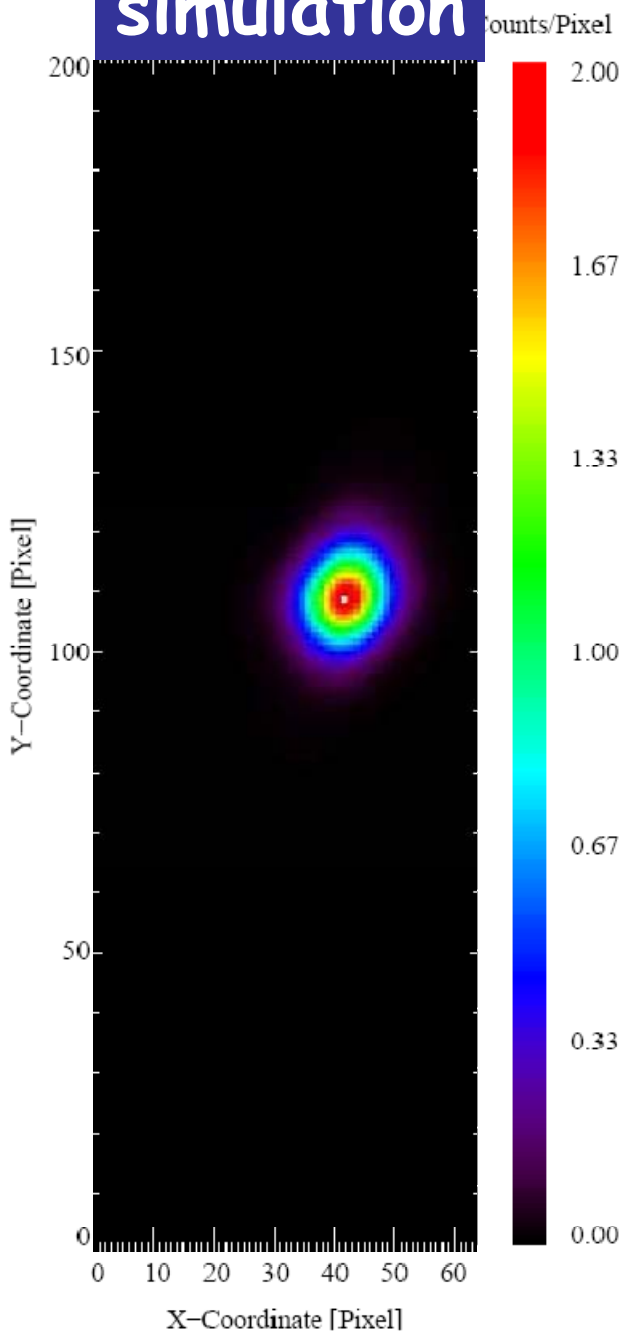
Wolter I type grazing incident optics (Prototype for *ABRIXAS* space mission):

- 27 nested gold coated nickel shells, on-axis resolution $\approx$ 43 arcsec
- Telescope aperture 16 cm, used for CAST 43 mm
- Only one sector of the full aperture is used for CAST

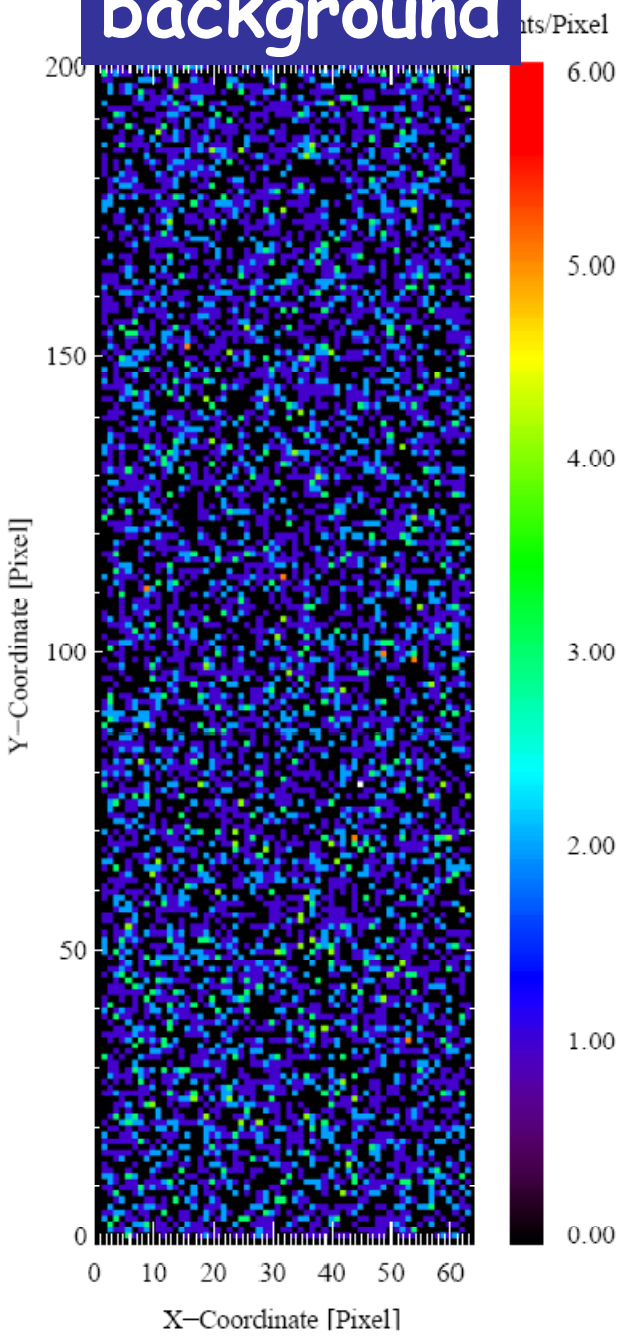
$\varnothing$43 mm (LHC Magnet aperture) $\Longrightarrow$ $\varnothing$3 mm (spot of the sun)
Significantly improves the signal to background ratio !

CAST

simulation




background

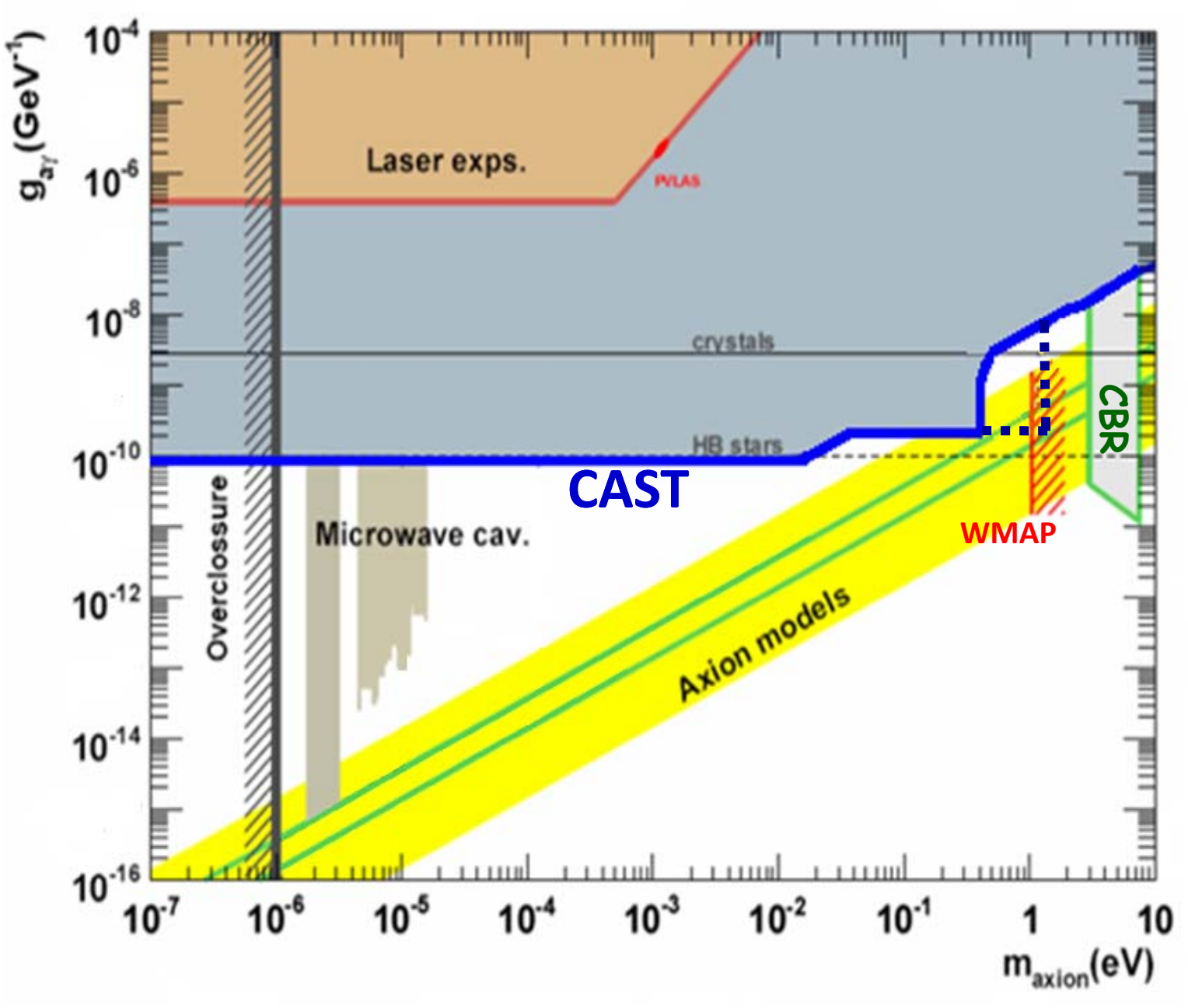



XRT/CCD

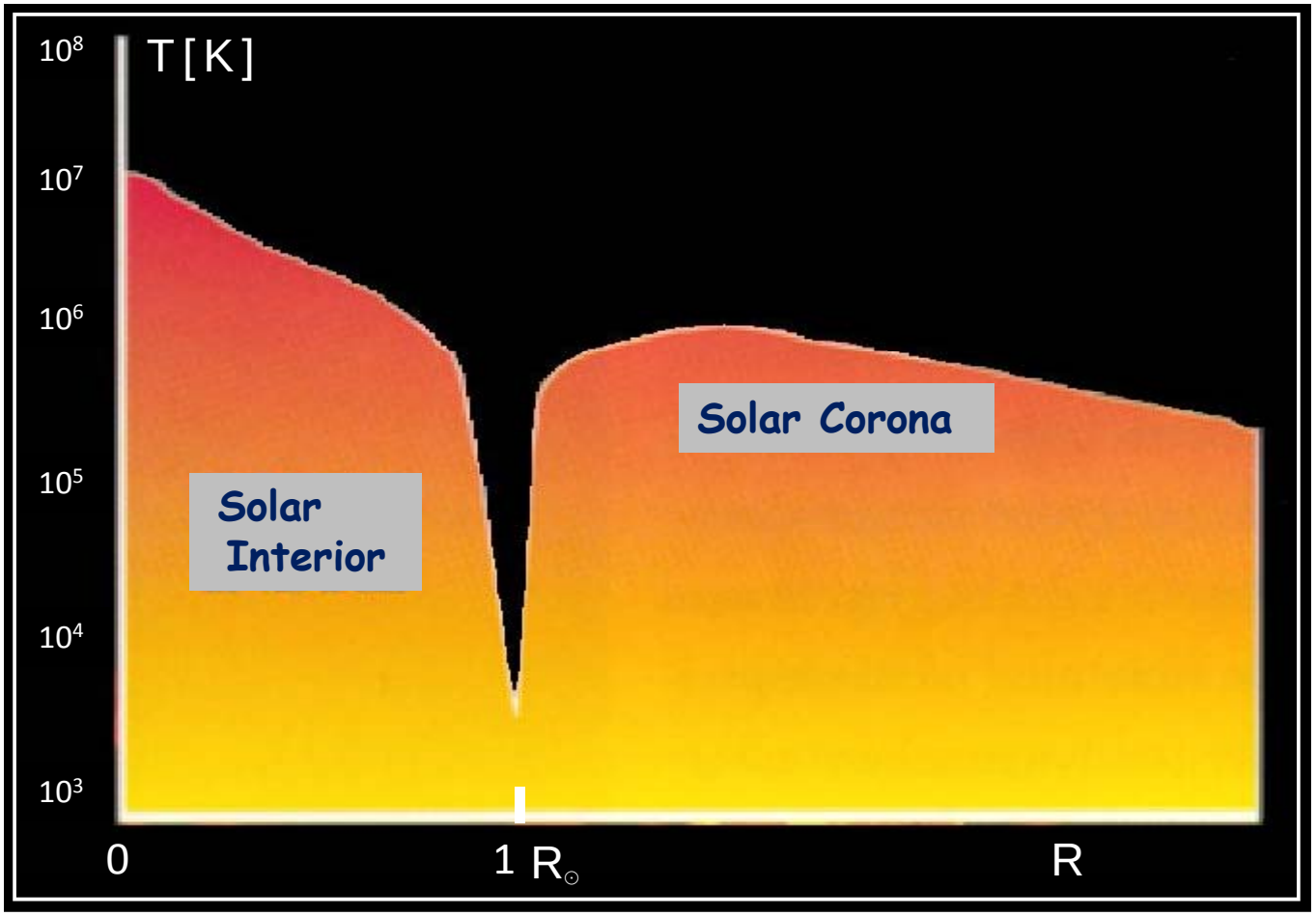
$g_{a\gamma}(95\%) < 0.9 \times 10^{-10}\ \mathrm{GeV}^{-1}$

➔ JCAP (2007), hep-ex/0702006

# CAST performance



# CAST @ the Sun?




**Inverted Temperature:**

the coronal heating problem / paradox

→ Grotrian (**1939**)

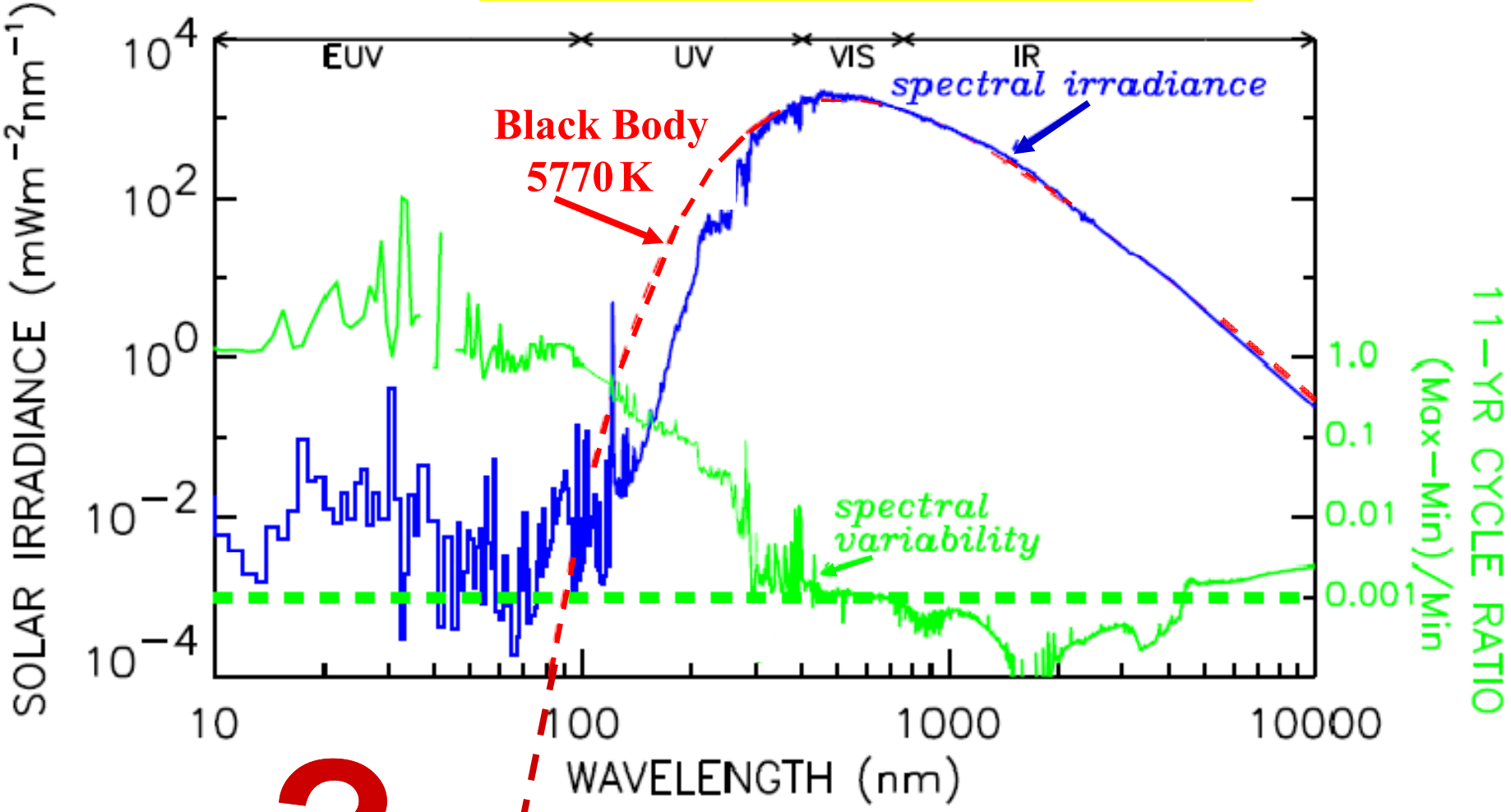
**The enigma of coronal heating**

**one of the outstanding puzzles of stellar astronomy +**

**one of the most challenging problems in astrophysics.**


Aschwanden, Adv. Space Res. 39 (2007) 1867
Jefferies, McIntosh, Armstrong, Bogdan, Cacciani, Fleck, ApJL. 648 (2006) 151
Priest, Longcope, Heyvaerts, ApJ. 624 (2005) 1057

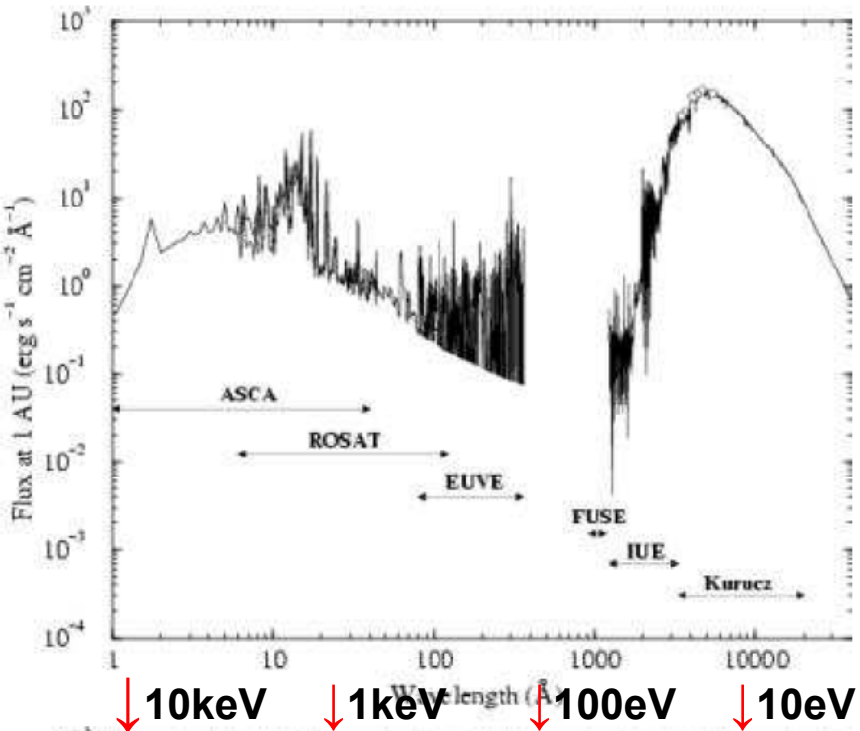
# Solar spectral irradiance

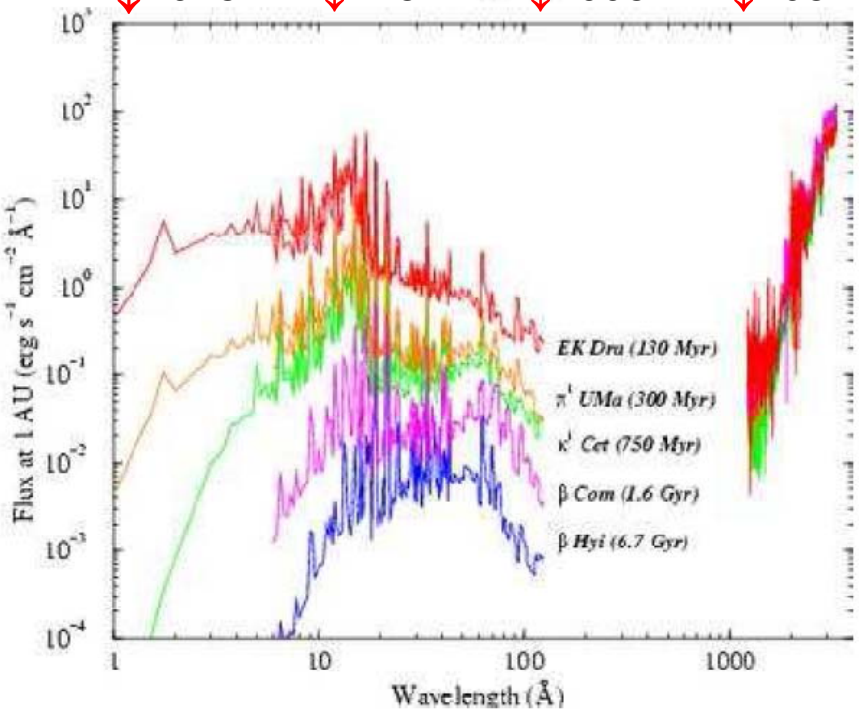



?

**Solar corona problem → 1939-**

→ one of the most challenging problems in astrophysics.




← Spectral irradiance of EK Dra for a distance of 1AU.

→ $L_x$ saturates < $L_{\sim axion}$!

← Irradiances at 1AU from solar analogs with different ages.

# CAST + more @ the Sun!

… αναμείνατε!