EXPERIMENT'S NAME: **The CERN Axion Solar Telescope (CAST)**

New Physics with natural and man-made magnetic telescopes like CAST (present - future).

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1. What is the broad physics goal of your experiment? How does it compare to other experiments?

CAST is searching for solar axions, paraphotons, chameleons and has the potential to become an antenna for axions and axion-like relics. CAST is a 3rd generation axion helioscope. It is the only magnetic helioscope with an X-ray optics.

2. Experimental setup

CAST is the strongest ever built axion helioscope. It uses for the first time state of the art detectors and for the first time an X-ray telescope which improves considerably the signal-to-noise ratio, and at the same time it is best suited for PID purposes, since it measures noise and signal simultaneously. It is scheduled to install in CAST at least one more new XRTelescope in 2013.

3. Accelerator or Lab Facility

CAST is a running CERN experiment. It needs no beam.

4. Physics Reach

CAST has provided so far the best limits for the coupling constant ($g_{a\gamma\gamma}$) for solar axions. Its data have been used and provided new limits for solar paraphotons by other groups. The most recent preliminary results from CAST are shown in the figures below. The same applies also for solar chameleons, with the re-evaluation being at present in progress. CAST is then also for solar chameleons the best performing magnetic helioscope, with the potential of an essential improvement, once low energy threshold detectors are available. (~100eV – few keV).

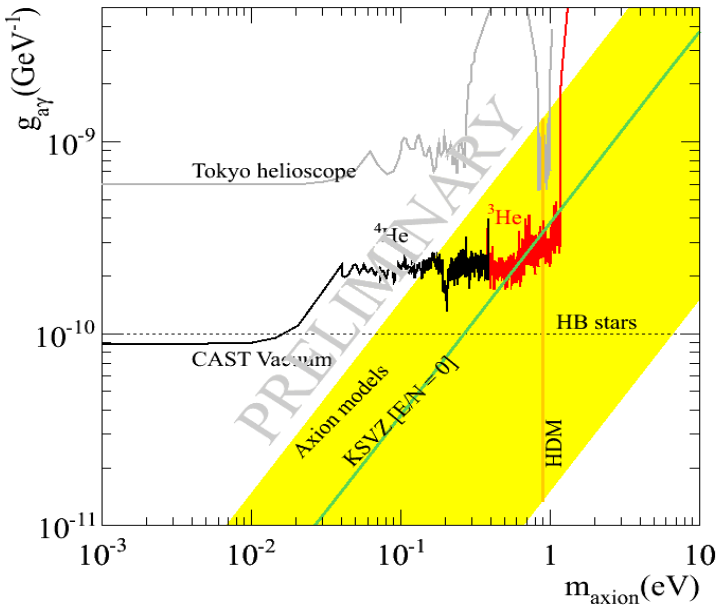

Figure 1. Exclusion regions in the $m_{axion} - g_{a\gamma\gamma}$ plane achieved by CAST with vacuum, ^{4}He and ^{3}He phase in the magnetic pipes, where the conversion axion-to-photon is supposed to take place. It is also shown the constraints from the Tokyo helioscope, horizontal branch (HB) stars, and the hot dark matter (HDM) bound. The yellow band represents typical but relaxed theoretical models. Above 0.65eV/c^2 are given preliminary analysis, while published data are given below 0.65eV, with the most recent one being accepted by PRL (2011) (http://xxx.lanl.gov/PS_cache/arxiv/pdf/1106/1106.3919v1.pdf).

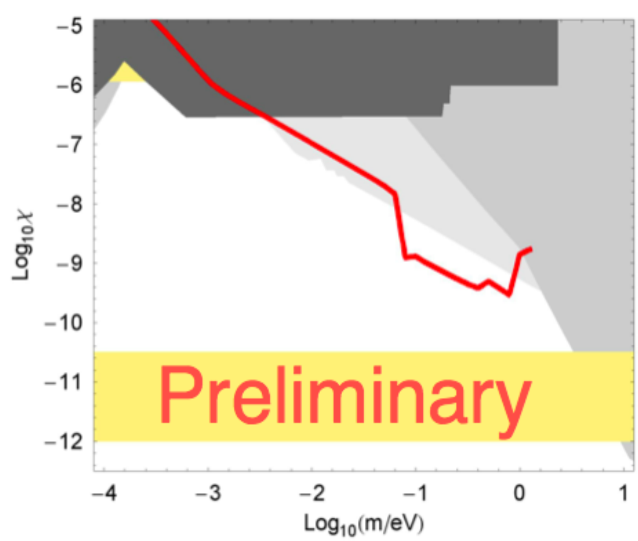

Figure 2. The preliminary exclusion plot (thick red line) shows the kinetic mixing parameter χ as a function of the solar paraphoton rest mass.

5. Status and Schedule

CAST exists since 13/4/2000. The basic program has been completed July 2011, while the evaluation of the data taken is in progress. After the very recent approval by the CERN SPSCommittee, we will continue in 2012 re-measuring some parameter phase space with ^{4}He gas inside the conversion pipes. We are preparing and exploring the feasibility of novel state-of-the-art measurements beyond 2012 for solar paraphotons, chameleons and also relic axions or other exotica with similar properties. It seems to be a rich, challenging and promising research program.

6. CAST future Plans

a. To run CAST in 2012 with ^{4}He (instead of ^{3}He) inside the magnetic pipes, a wide maintenance is under way. Scheduled start of data taking: June 2012. Thus:
   2012: Run with enhanced sensitivity in the axion rest mass region of ~0.4 eV
b. In parallel, an R&D work is ongoing, in order to have all the equipment needed to search in the sub-keV range from 2013 onwards. This implies the following work :
   - Develop thin transparent windows to search in parallel for other WISPs (chameleons and hidden sector paraphotons), with :
     - Nanotubes based on Al_2O_3 . Fraction of incident photons can be transmitted directly or channeled through pores. Test of such windows at DESY in progress.
     - Feasability studies for Kapton based thin foils using Microbulk techniques (honeycomb).
c. A next-generation framestore pn-CCD detector is being tested with ~90% quantum efficiency in the energy range from 0.3 keV to 11 keV, which fits very well the needs for the search for solar chameleons.
d. Finalise new design of Micromegas detectors, in order to reach background levels approaching 2×10^{-7}counts keV^{-1} s^{-1} cm^{-2} , combined eventually with lower energy threshold :
   - Improve radiopurity of construction materials
   - Inclusion of new electronics providing 3D information
   - More compact and full coverage shielding
   - Study different gas mixtures to increase the gain

e. Develop new optics to be coupled to Sunrise Micromegas, which will allow to improve CAST' sensitivity for solar axions below ~0.02eV rest mass.

f. TES based detector tests on the BaRBE line of CAST, which provided already new results on solar paraphotons (see Figure 2).

Thus :
2013 - : CAST vacuum phase with lower background and lower threshold detectors and a 2nd new X-ray optics. Parallel to the solar axion search below ~0.02eV axion restmass, CAST will be sensitive to solar exotica like chameleons and paraphotons.

g. Following a recent proposal, CAST seems to have the potential to be transformed to a wide band sensitive new type of relic axion antenna (see proposal to CERN / SPSC in April 2011).

7. Collaborating Institutions and Collaborators

Namelist and Institutes participating in CAST can be found in the most recent publication accepted by PRL: (http://inspirehep.net/record/914185?ln=en#).
New collaborators from Danmark, Germany and USA have entered CAST recently as it will be documented in the next ADDENDUM MoU to start 1/1/2012.

8. Written Materials

a. CAST Physics Publications:

PRL 94 (2005) 121301; JCAP 0704 (2007) 010; JCAP 0902 (2009) 008; JCAP 0912:002,2009, arXiv:0809.4581; JCAP 1003:032,2010;
PRL (2011) *in print*, preprint in the archives: 1106.39119.
See also proposals to CERN SPSC from April and October 2011, respectively, which describe in detail the CAST schedule for the near future, including the participating additional external collaborators:
http://cdsweb.cern.ch/record/1340994
http://cdsweb.cern.ch/record/1390488

b. Two recent CAST related publications on solar chameleons and relics:

1/ P. Brax, A. Lindner, K. Zioutas,
*Chameleon fore*CAST,
submitted to PRD (2011), preprint: astro-ph / 1110.2583
(http://xxx.lanl.gov/abs/1110.2583)

2/ O.K. Baker, M. Betz, F. Caspers, J. Jaeckel, A. Lindner, A. Ringwald, Y. Semertzidis, P. Sikivie, K.Zioutas,
Prospects for Searching Axion-like Particle Dark Matter with Dipole, Toroidal and Wiggler Magnets,
submitted to PRD (2011), preprint: astro-ph / 1110.2180
(http://xxx.lanl.gov/abs/1110.2180)

9. Any other info?

Natural axion or axion-like telescopes and astrophysical signatures.

CAST' working principle is based on the oscillation (inside its magnetic field) between particle exotica like the celebrated solar axion and the photon. This is inspiring, if one takes into account the ubiquitous solar magnetic field and a dynamical varying plasma density in all places, along with the plethora of conventionally unexplained (solar) observations which occur preferentially near magnetized solar regions. This is an exciting correlation, which we have followed in parallel since CAST' conceptual design. Therefore, I will present / stress in my talk mainly:
the potential of deciphering solar signatures of axions (dark matter candidates) and chameleons (dark energy candidates) in the energy range from hard solar X-rays to EUV, and eventually to much lower energies. Various orbiting telescopes can operate as detectors of solar exotica such as axions, paraphotons and chameleons. It is even more exciting, to decipher signatures of such particles being hidden in every day's solar observations or in archived data.
In summary, while the working principle inside the huge magnetized solar atmosphere / interior can be almost identical to that of earth bound helioscopes like CAST, still the "naturally" fine tuned dynamical (solar) configurations might have essential built-in advantages compared to ongoing or scheduled terrestrial searches for axions and WISPs. Therefore, the potential following this astrophysical quasi cost free approach, in outer space, of a natural helioscope like CAST might be also proven to be beyond reach by any man made magnetic helioscope. In other words, the orbiting detectors / telescopes of all kind and the intervening magnetic fields to the putative "radioactive" source of exotica inside/outside the Sun, can operate as the wide-band axion or axion-like magnetic telescope of unprecedented sensitivity. Therefore, this avenue should be followed even more than so far, while gaining more and more solar and other astro-physicists, for a genuine interdisciplinary approach.
Thus, beyond the mysterious 11-years solar cycle, as a first and the most striking solar paradox (1939 -) might be the solar coronal heating problem. In summary, the question is: how can be the solar atmosphere ~100-1000 hotter than the upper photosphere only some 100 km underneath? The measured analog spectrum for the quiet non-flaring Sun is given in Figure 3. Interestingly, the sun emits unexpectedly X-rays, originating preferentially from magnetized places, with the X-ray intensity being proportional to ~$\mathbf{B}^2$, being suggestive for axions and chameleons or other WISPs, including the gravitationally self-trapped massive axions of the Kaluza-Klein type.
In short, there is a large but so far little explored potential for new physics in outer space; after all, mysteries reflect unknown physical phenomena, and some of the solar mysteries exist since several decades to few centuries. For comparison, the solar neutrino "problem" lasted ~3 decades "only".

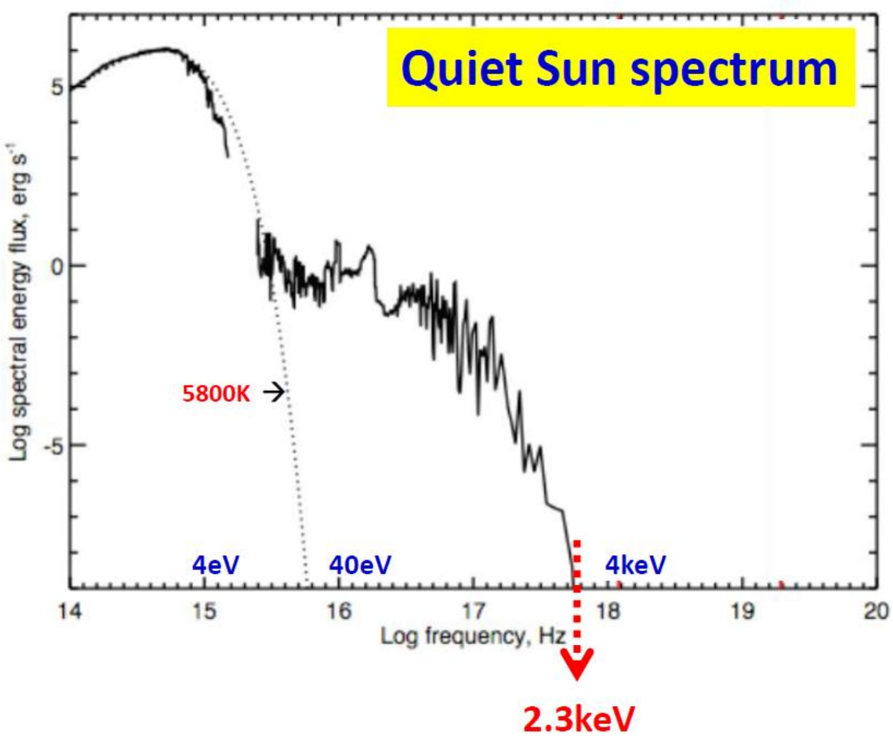

Figure 3. The solar analog photon spectrum for quiet sun conditions [Hugh Hudson, private communication (November 2011)]. Note, the huge photon excess above that expected from a black body at 5800K (the temperature of the photosphere underneath the corona), in the energy range above ~40eV, reflects the solar corona mystery (see ref's [1-3]).

Finally, in my presentation at the workshop, for comparison reasons, a few examples will be given for WIMP searches in space, which demonstrate how far advanced is already their astrophysical and cosmological approach. And this, for as yet unexplained observations, which should point actually to axions and/or WISPs as being the next candidates to provide an alternative interpretation.

In conclusion, if such exotica like axions could not have been detected before by earth bound experiments, e.g., due to missing detection sensitivity or chosen parameter values, they may well leave their fingerprints in celestial observations dubbed as mysterious, anomalous, unexpected, etc., requiring new astroparticle physics.

References:

[1] See a recent presentation, and the references given therein, at the 7th Patras workshop on axions, WMPs and WISPs, held in Mykonos / Greece, June/July 2011:
http://axion-wimp.desy.de/e102694/e102699/e118317/Zioutas-K.pdf

[2] K. Zioutas, M. Tsagri, Y. Semertzidis, T. Papaevangelou, T. Dafni, V. Anastassopoulos, *Axion Searches with Helioscopes and astrophysical signatures for axion(-like) particles*, New J. Phys. 11 (2009) 105020 **"BEST OF 2009"**
(http://iopscience.iop.org/1367-2630/11/10/105020)
(preprint http://xxx.lanl.gov/abs/0903.1807)

[3] P. Brax, A. Lindner, K. Zioutas, *Chameleon fore*CAST, *submitted* to PRD (2011), preprint: astro-ph / 1110.2583, and ref's therein.
(http://xxx.lanl.gov/abs/1110.2583)