The CAST Experiment: Status Report

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The CAST (Cern Axion Solar Telescope) experiment has been looking at the Sun for more than a decade now in its quest of observing a signal coming from the conversion of the axions in the telescope's magnetic field. Such a signal has not been observed thus allowing the collaboration to set only an upper limit to the axion - photon coupling constant in the parameter space. The final results will be presented as well as a new set of detectors that are looking into the dark sector. The new detectors, currently in operation, are KWISP which is directly sensitive to the chameleon coupling to matter, INGRID which is probing the chameleon coupling to photons and CAST - CAPP that is looking for dark matter axions. Also an additional dark matter axion detector, the RADES system, will be installed this year. While the search of axions is now limited to ones that are constituents of the galactic halo, the experiment continues to look at the Sun in an effort to see a signal of solar chameleons which are created in the Sun's tachocline via Primakoff effect and are particle candidate constituents of the dark energy in the Universe.

1 Axion limits and searches

The CAST (Cern Axion Solar Telescope) experiment is using a LHC prototype dipole magnet in its effort to answer some of of still open questions in the modern physics. The unanswered questions are about the composition of the Universe and non observation of CP violation in interactions including strong force. One of the answers to both questions contemporarily is the presence of a scalar field via Peccei-Quinn [1] symmetry which is spontaneously broken. The breaking of the symmetry results in a new particle, Nambu-Goldstone boson, called the axion. One of the best places to look for them is the Sun since they can be produced there by Primakoff effect. It has been shown [2] that axions can be detected on Earth by converting them to photons in a magnetic field which is in the case of CAST provided by LHC dipole magnet capable of achieving fields of 9 T over approximately 9 m length. The magnet is mounted on a movable platform that follows the Sun for 90 minutes in the morning and in the evening. The movement is constrained by minimum/maximum angle allowed by the cryogenic operation of the magnet. The tracking accuracy is monitored by geometric surveys and twice per year by following the Sun with an optical telescope and camera which are mounted on the magnet. The optical axis of the Sun filming system is parallel to the axis of the V1 bore. It must be noted that the Sun is observed by different set of detectors in the morning and evening data taking which are placed on opposite ends of the magnet. The expected signal from an axion to photon conversion in the magnetic field is in X-rays and is peaked at about 4 keV. The latest results on axion limits were obtained with measurements taken in the period 2013-2015. The results were taken with vacuum inside the magnet bores with a new Micromegas [3] detector sitting behind a X-ray telescope built for axion searches. The result has been published in Nature Physics [4]

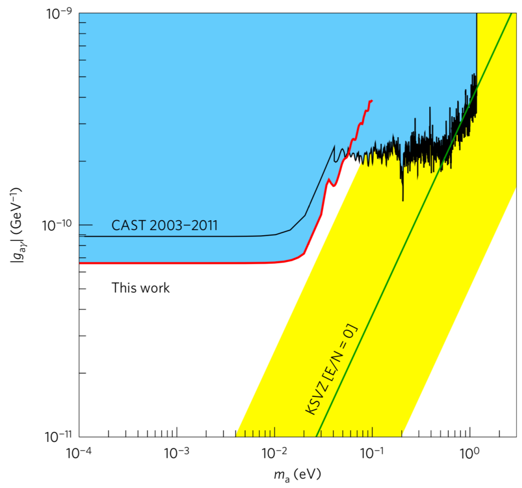

Figure 1: CAST excluded region at 95% confidence level in axion photon coupling vs axion mass plane. Plot taken from Nature Physics [4].

With this measurements the search for solar axions has been concluded since it is improbable that the limits with a current setup can be significantly improved. However a dedicated detector together with a X-ray telescope will remain on beam as a test facility for future experiments. In the meantime CAST magnet will be used also for relic axion searches. Obviously in this case the tracking capability is not needed anymore and data can be acquired continuously. Two such setups are being developed for CAST magnet, the CAST/CAPP and RADES experiment. Both experiments are based on RF cavities designed at built for the CAST magnet. The features include phase matching between cavities, tunability and fast scanning.

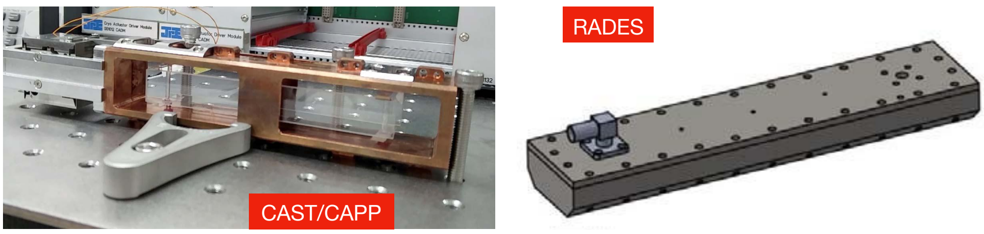

Figure 2: CAST/CAPP cavity tuning mechanism in its assembly frame on the left and RADES design on the right.

The last feature becomes important if the axion dark matter density is not uniform as is suggested by some distribution models. In particular, axion streaming and or clustering is of high probability [8] because of solar or planetary gravitational focusing of relic axions. Those fluctuations can boost the axion density up to several orders of magnitude raising the axion detectability provided the axion antenna is sensitive to axion bursts.

2 Dark energy searches

Beyond for the searches for solar and relic axions as candidate particles for dark matter, the CAST collaboration has started also a search for dark energy candidate. Notably, the so called chameleons. To be able to account for the accelerated expansion of the Universe, and at the same time not contradicting the observation a screening mechanism is added to the chameleon potential. With this mechanism the mass of the chameleons depends on the surrounding matter density. The assumed chameleon potential depends on the coupling of the field both to matter and photons. CAST is a unique experiment which can independently measure both coupling constants. First measurements of the coupling to photons was done with an SDD detector [5], and currently the measurements with an InGrid detector [6] are in progress. The other coupling constant can be measured by measuring the recoil of a thin membrane due to chameleon flux which has not enough energy to penetrate it. This normally happens at a grazing incidence to a material surface which also enables focussing of this hypothetical flux by an X-ray telescope. Furthermore the chameleon flux can be periodically interrupted by an surface that is oscillating in and out of the flux thus making it time dependent. It is obvious that the readout of the membrane position which is proportional to the pressure applied has to be extremely sensitive in order to fill still available gaps in the chameleon properties' parameter space. Two readout schemes have been proposed. One is so called KWISP 1.5 a Michelson interferometer with homodyne readout, an intermediate version on the way to Fabry - Perot based enhanced sensitivity detector [7]. The sensing element and the interferometer are placed in a vacuum chamber in order to minimise the the background noise in a part of the setup where beams propagate on different paths. Outside the vacuum chamber are only the light source and the readout electronics. The membrane and the chopper wheel have similar densities thus reflecting chameleons in the same energy range at the same angle with respect to the chameleon beam. KWISP 1.5 has performed a first measurement in December 2016. The occasion was related to

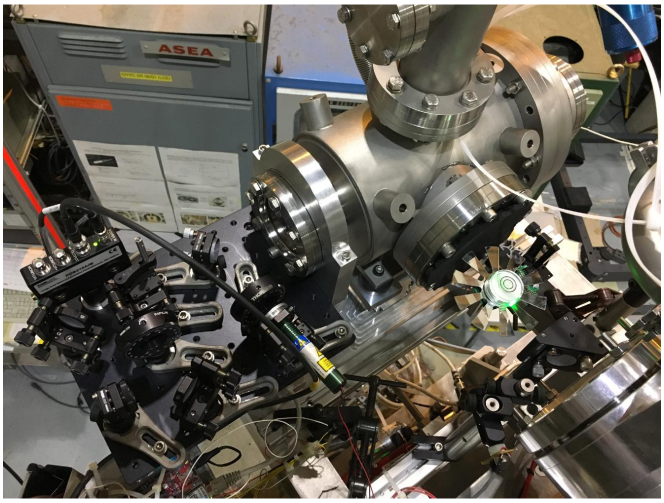

Figure 3: Photo of the KWISP 1.5 setup on beam. A breadboard with optical elements attached to the vacuum chamber can be seen on the left, while a chopper is in the middle between X-ray telescope and the vaccum chamber hosting the sensing element.

the alignment of Sun with the galactic center when an enhanced flux of chameleons due to the gravitational lensing could be expected. Data taking campaigns during which the setup was tested and improved followed during February and April.

3 Conclusion

Although the solar axion measurements are basically concluded, the CAST experiment has evolved and is becoming a Dark detector. It will search for Dark Matter with CAST/CAPP and RADES detectors, while also searching for signs of Dark Energy in form of chameleons through their coupling to matter and photons which makes it unique among Dark Energy detectors.

4 Acknowledgments

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