# KWISP - Hunting Chameleons with the CAST Experiment at CERN

J. Baier, G. Cantatore, S. Cetin, H. Fischer, W. Funk, A. Gardikiotis, D. Hoffmann, M. Karuza, M. Schumann, Y. Semertzidis, M. Vretenar, K. Zioutas

14th AxionWIMP conference, DESY Hamburg

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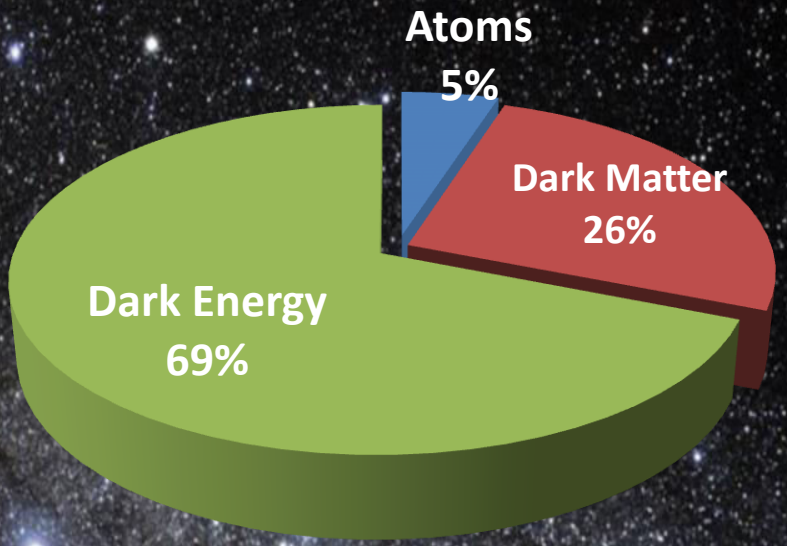
# Dark Energy – The Big Unknown

- Permeates all of space
- Accelerates expansion of the Universe
- Proposed theories:
  - Cosmological constant
  - Scalar fields
  - …




Composition of the present Universe (Planck data of 2015)

Chameleon particle:

- Proposed in 2003 by J. Khoury and A. Weltman (Phys. Rev. D 69, 044026)
- Neutral, spinless, scalar particle

(Theory still valid after detection of GW170817 and GRB 170817A, see also talk by I. Sawicki , 19 June)

# Chameleon Mechanism

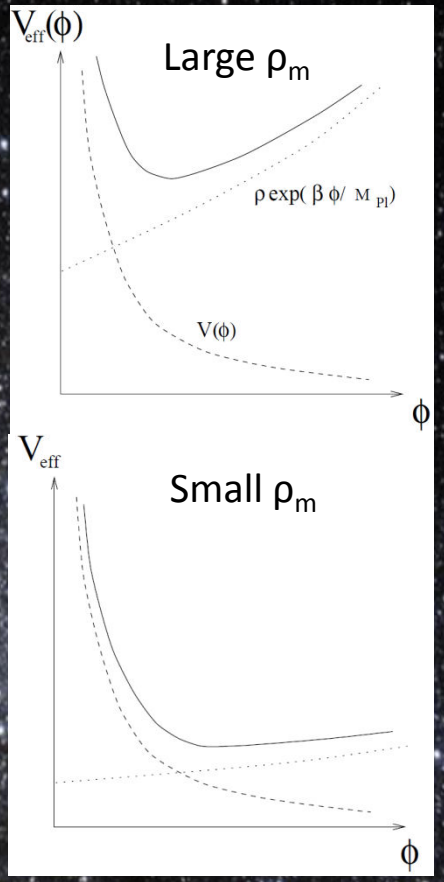
- Scalar field $\phi$ with runaway potential $V(\phi)$
- Chameleons experience effective potential $V_{eff}(\phi)$ depending on local matter density and field strength

$$V_{\mathrm{eff}}(\phi) = V(\phi) + \rho_m e^{\frac{\beta_m \phi}{M_{pl}}} + \frac{1}{4} e^{\frac{\beta_\gamma \phi}{M_{pl}}} F_{\mu\nu} F^{\mu\nu}$$

Detection possibility via direct coupling to matter, i.e. force exerted on a surface (KWISP)

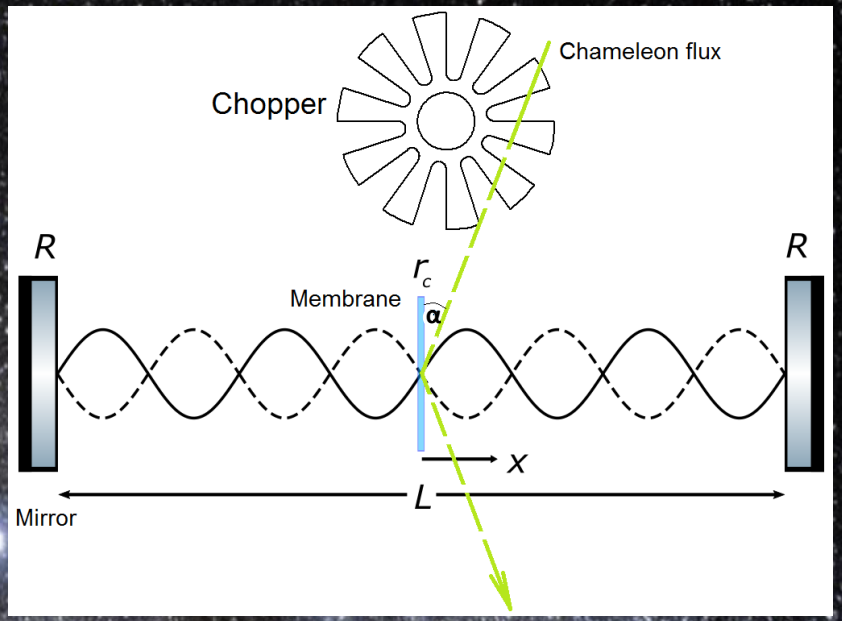
Detection possibility via inverse Primakoff effect → Helioscope

(see talk by Christoph Krieger: "*Search for solar chameleons with a GridPix detector at the CAST experiment*", Fri. 10:35)



# Detection Principle

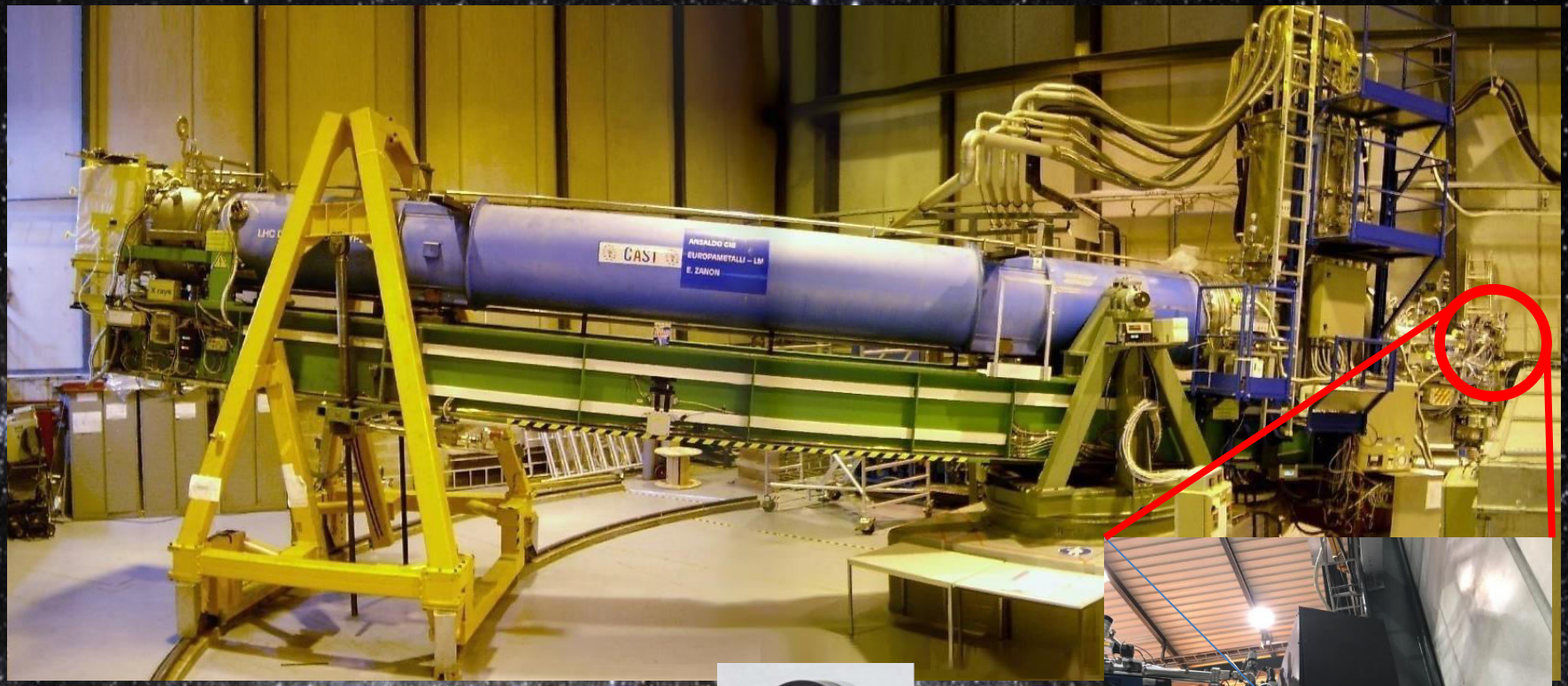
- Thin membrane ($Si_3N_4$, 5*5 $mm^2$, 100 nm thick) inside cavity
- $V_{eff}$ leads to effective mass of chameleon inside membrane
- If $E_{cham} < m_{eff} / \sin\alpha$ → Reflection
- Membrane gets displaced




→ Change of cavity frequency: $\omega_{cav}(x) = \frac{c}{L} cos^{-1}\left(|r_c| \cos\left(\frac{4\pi x}{\lambda}\right)\right)$

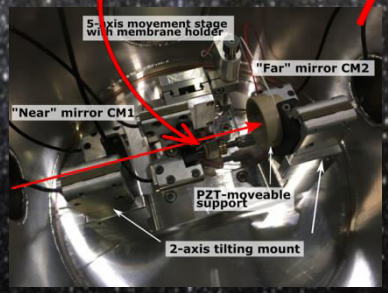
- Intensity changes of transmitted / reflected light related to membrane position

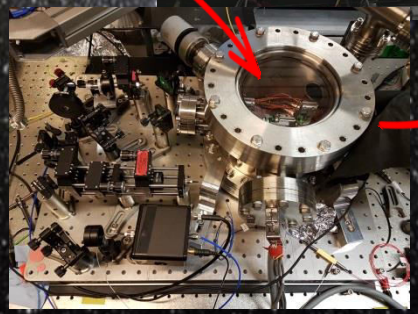
# KWISP at CAST




Detector sensitivity:

- In the lab: $10^{-15}$ m/√Hz
- On beam: t.b.a.



# KWISP - Hunting Chameleons with the CAST Experiment at CERN

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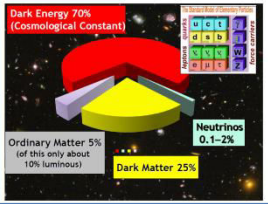
The CERN Axion Solar Telescope (CAST) is an experiment to search for hypothetical particles called "axions" and "chameleons". These have been proposed to explain the invisible dark matter and dark energy. The experiment is searching for these particles with a telescope designed to detect them from the Sun. To this end it utilizes equipment from particle physics, laser physics and astronomy. Among the different detectors of CAST the KWISP detector aims for direct detection of solar chameleons.

CAST EXPERIMENT

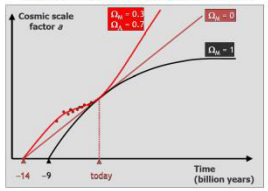
## Setting the Scene

### Composition of the Universe

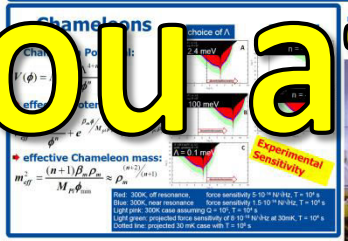



| Dark Matter | Dark Energy |
|---|---|
| Acts gravitationally like ordinary matter (attractive force) | Provides "negative pressure" "Anti-gravitation" |
| Probably new form of weakly interacting particles | Cosmological constant? Vacuum energy of quantum field? Quintessence, new scalar field? |
| Dominates dynamics of galaxies, clusters, larger structures | Plays no role on small scales Homogeneous, does not cluster |
| Decelerates cosmic expansion | Accelerates cosmic expansion |

### Expansion in Different Cosmological Models



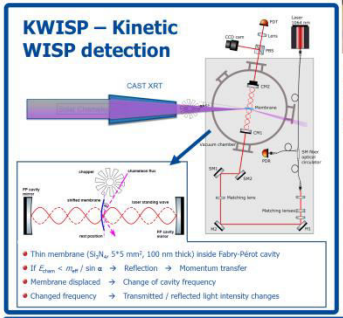

## Chameleons




- effective Chameleon mass:

$$m_{eff}^2 = \frac{(n+1)\beta_n \rho_m}{M_{Pl}\phi_{min}^{(n+2)/(n+1)}} \approx \rho_m$$

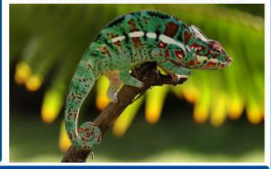
## KWISP – Kinetic WISP detection



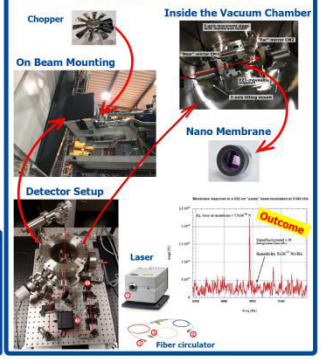

- Thin membrane ($Si_3N_4$, 5*5 mm², 100 nm thick) inside Fabry-Pérot cavity
- If $E_{cham} < n_{lat}$ / sin α → Reflection → Momentum transfer
- Membrane displaced → Change of cavity frequency
- Changed frequency → Transmitted / reflected light intensity changes

## The CAST Experiment at CERN

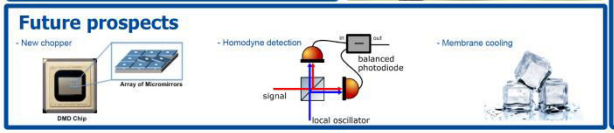
- Decommissioned superconducting prototype LHC dipole magnet.
- **T=1.8 K B=9T L=9.26m.**
- Rotating platform (Vertical: ±8°, Horizontal: ±40° )
- ~90 min solar tracking @ sunrise/sunset
- 2 bores with **X-ray Focusing/Imaging Telescopes** behind
  - simultaneous operation of 2 detectors (KWISP, InGrid)



## Experimental Setup




## Future prospects




## Contact

cast.web.cern.ch/CAST/

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## References

- M. Karuza *et al.*, *KWISP: An ultra-sensitive force sensor for the Dark Energy sector*, Physics of the Dark Universe, **12**, 100-104 (2016), DOI: 10.1016/j.dark.2016.02.004
- S. Baum *et al.*, *Detecting solar chameleons through radiation pressure*, Physics Letters B, **739**, 167-173 (2014), DOI: 10.1016/j.physletb.2014.10.055

See you at the poster!