

Searches for Axions and other (very)  
Weakly Interacting sub-eV particles

# Input documents

- The International Axion Observatory IAXO case status and plans. (27)
- Input from the Spanish Particle Physics Community (31)
- Physics Beyond Collider study (42)
- PBC technology subgroup report (60)
- Statement by the German Astroparticle Physics Community as input to the European Strategy for Particle Physics (69)
- A European Strategy Towards Finding Axions and Other WISPs (112)
- Vacuum Magnetic Birefringence Axion search using pulsed magnetic fields (113)
- MAGIS-1K A 1000m Atom Interferometer Device for Searches in Dark Matter and Gravity Waves (161)

# Axions

- Excellent motivation from strong CP problem
- Additional motivation from string embedding
- Interesting astrophysical hints
- Natural dark matter candidate → favored parameter region
- Experiments are entering the favored region  
→ Race for discovery has begun

Experiments with discovery potential in next 5-10 years!

# WISP/Dark Matter/Dark Sector

- Other candidates are theoretically interesting
  - Axion-like particles
  - Dark/Hidden photons
  - ...
- Most experiments can search for them  
“in parallel”
  - ➔ Focus on Axions and ALPs for simplicity

# Mature Key Techniques

- Haloscopes
- Helioscopes
- Light-shining-through-walls

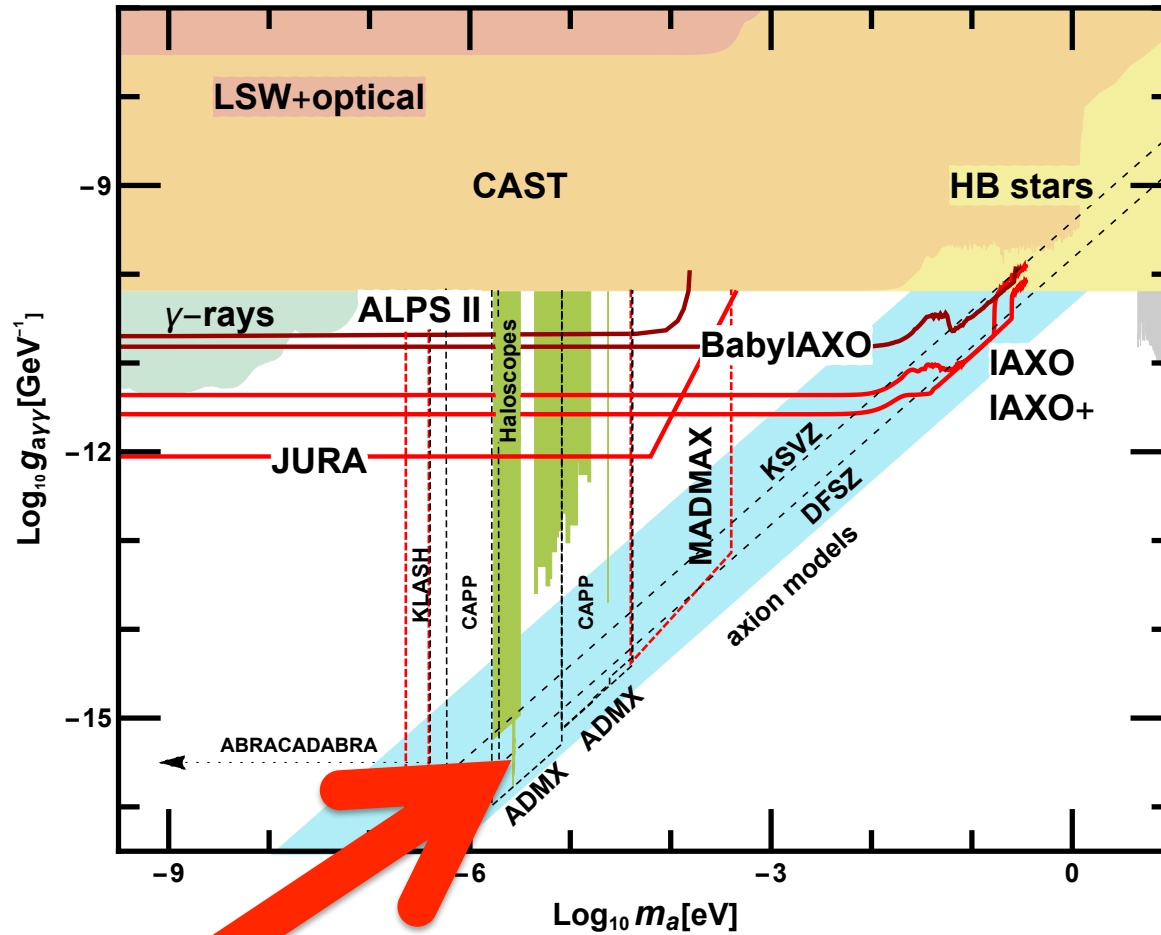
# Haloscopes

## Searches for Axion/WISP Dark Matter

- Resonant cavity haloscopes → **ADMX**
  - Running; probing relevant axion parameter space
  - New geometries/technologies are being tested in development setups
  - **Developments in Europe: QUAX- $\alpha\gamma$ , RADES, KLASH, BRASS, CNRS/LNCMI-Grenoble...**
- Semi-resonant dielectric Mirrors → **MadMax**
  - Probes complementary high mass parameter range
  - In development
  - Should move into construction phase
  - **Collaboration between DESY and MPP; siting at DESY would help**
- Novel searches via gluon and other couplings.
  - Significant European effort → Casper, QUAX, HeXenia, aKWISP ...**
  - Rapid development; mostly still relatively small scale
    - Place to watch for the next 5 years.
  - **Support and exchange with other experiments crucial**

Probing gluon and other couplings necessary to establish QCD axion nature and reveal information on underlying model

# Haloscopes



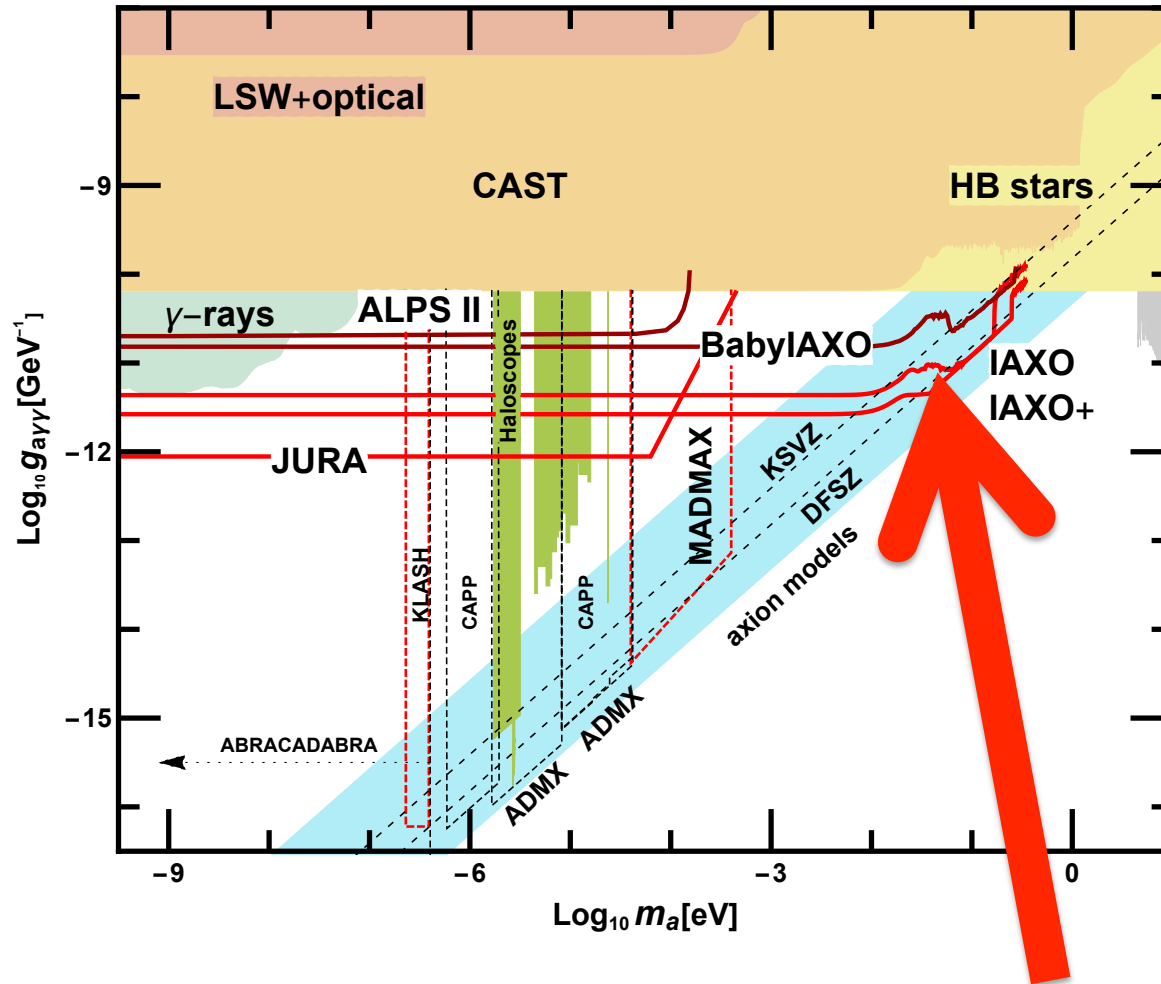
# Helioscopes

Searches for Axions/WISPs produced inside the sun

- Probes „high mass“ meV-eV axions  
→ complementary
- **Clear International Project → IAXO**
  - Medium scale ( $\sim 50$  MEURO)
  - Mature design  $\leq 5$  years needed
  - „Ready to build“ test version BabyIAXO with interesting physics potential
  - Possible siting at DESY
  - Can yield additional information → mass, photon vs electron coupling...  
identify axion model



# Helioscopes (IAXO)

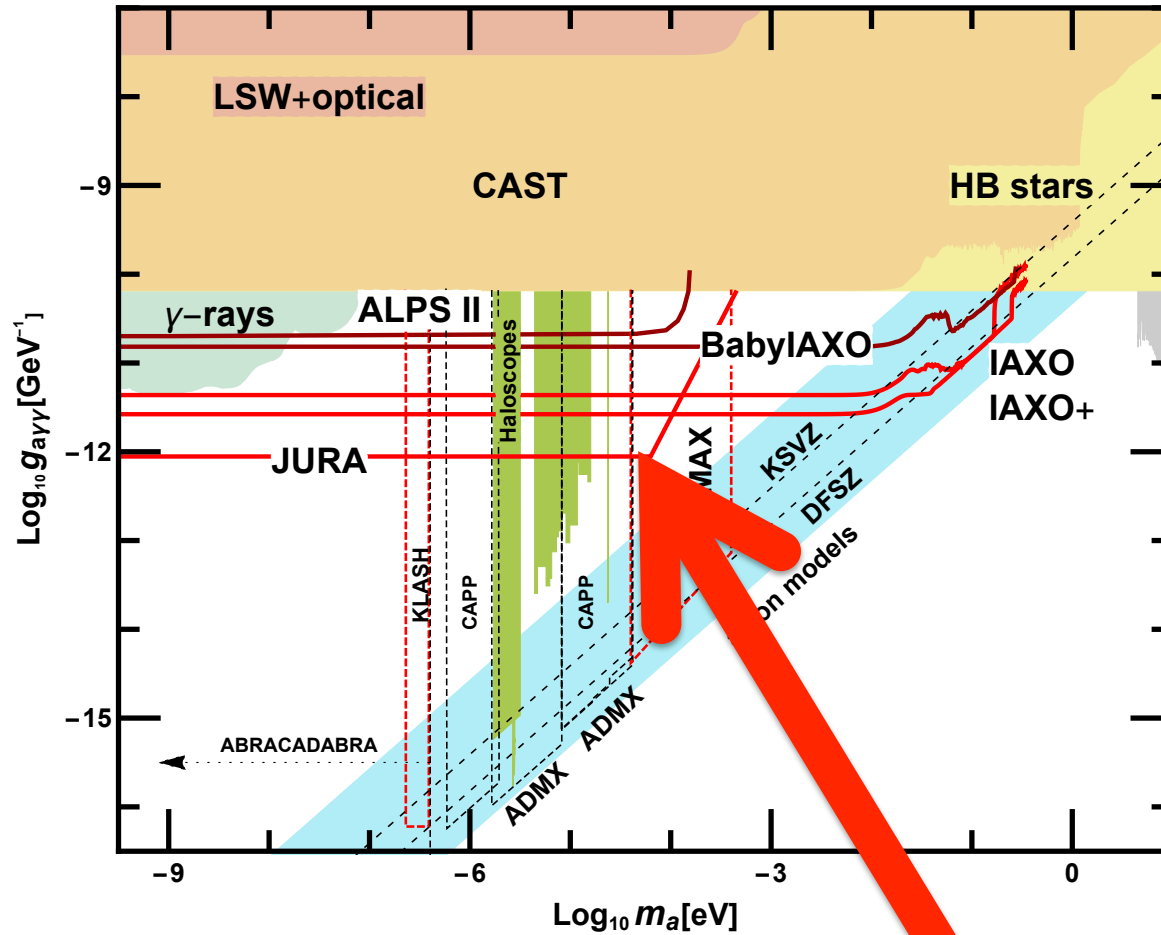


# Light-Shining-Through-Walls

Purely laboratory test of Axions/WISPs

- Fully controlled setup
- Experiments in construction/running → **ALPS II**
  - Enter untested parameter space in near future
- Proposed with new technologies (RF): **STAX**
- Long term project **JURA**

# Light-shining-through-walls



# Key Technologies

- Large volume-high field magnets
- Optics
- Radiofrequency cavities techniques
- Cryogenics
- Vacuum
  
- Quantum Sensing

# Collaboration

Technology exchange beyond communities:

Particle physics with

- gravitational waves (ALPS, MAGIS, AION)
- X-ray astronomy (IAXO)
- Radio astronomy (MadMax, RADES...)
- NMR (Casper)
- Condensed Matter (QUAX)
- Atom interferometry (MAGIS, AION)
- Quantum Sensing (All)
  
- Experiments/Theory on all levels (conceptual to simulation)  
(All)

# New Developments

- Atom interferometry (MAGIS and AION proposals) and similar techniques can search for ultralight scalar DM  $\leftrightarrow$  gravitational wave detection
- Solid state/low temperature „absorption“ detectors
- Oscillating EDM at EDM ring (prototype)
- Electron signals in large scale DM detectors like DARWIN become relevant

# Challenges

- Many experiments small scale
- But transition to medium/large scale experiments (IAXO, MadMax, JURA)
- Need to take steps now