Proposal for a
GDR of the Intensity Frontiers

all names

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There are a large variety of future experiments at the intensity frontier planned in the coming years. In most cases they are very cheap, and often can parasitise older experiments. Here we focus on searches for weakly nteracting new light particles, commonly called WISPs, of which the two canonical candidates are hidden photons and axion-like particles.

The best motivated WISP is the QCD axion itself, which is expected to solve the strong CP problem but is associated with new physics above 10^9 GeV. Its mass may lie anywhere in the sub-eV range, and it is a very well-motivated dark matter candidate.

Axion-like particles (ALPs) are (pseudo)-scalars, perhaps cousins of the QCD axion but which do not obtain their masses from QCD. They are characterised by their coupling to photons in a Lagrangian term $\mathcal{L} \supset -\frac{1}{4} g_{a\gamma\gamma} a F_{\mu\nu} \tilde{F}^{\mu\nu}$. These are highly motivated from top-down constructions as generically arising when symmetries are broken at high scales, and also make attractive dark matter candidates. On the other hand, and perhaps most importantly, there have recently been several studies indicating possible discoveries of such particles in various astronomical observations: either as an explanation for excessive white dwarf cooling or anomalous transparency of the universe to gamma rays, and most excitingly as an explanation for the soft excess of X-rays from the coma cluster (at 200 eV) and/or the oscillatory modulation of X-rays from the Perseus cluster (and even, perhaps, an explanation for an observed 3.55 keV X-ray line). These hints all point to a very light ALP ($< 10^{-12}$ eV) with a coupling $g_{a\gamma\gamma} \sim \mathcal{O}(10^{-11} \div 10^{-12})\mathrm{GeV}^{-1}$. However, while this is a very interesting region to probe, such a particle could have a wide range of masses and couplings.

Hidden photons are new (massive) gauge bosons which mix kinetically with the visible photon via a dimensionless kinetic-mixing parameter χ. While one motivation of these is as a possible explanation for the 3σ discrepancy between the measured and calculated value of the muon dipole moment – this would require a hidden photon in the $\mathcal{O}(100)$ MeV range with $\chi \sim \mathcal{O}(10^{-3})$ – they also appear generically in top-down constructions of beyond-the-Standard Model physics. They have been proposed as perhaps the most natural force carriers for light dark matter particles, or could even make up the dark matter themselves.

Intensity frontier experiments searching for these either search for the particles as dark matter or attempt to directly produce them. In the dark matter case, the assumption that there is a large abundance of particles all around us greatly enhances the reach; on the other hand, for the very light ALPs this is unlikely to be the case. The dark matter searches consist of resonant cavities, helioscopes, and now many more exotic suggestions. Direct searches are broadly photon regeneration experiments (light shining through a wall), electron colliders or beam dumps.

Important upcoming experiments include:

- Axion haloscopes (magnetic resonant cavity experiments) ADMX-HF, YMCE and WISPDMX at the University of Washington, Yale and Hamburg respectively are all expected to report results soon, probing axion masses in the μeV range.
- The FUNK experiment in Karlsruhe uses a dish antenna to search for dark matter hidden photons.
- The helioscope SHIPS at Hamburg searches for hidden photons produced in the sun.
- The REAPR and ALPS-II photon regeneration experiments at Fermilab and DESY respectively will attempt to directly produce ALPs or hidden photons in the lab.
- The IAXO helioscope at CERN uses a magnetic field to search for ALPs produced in the sun. It is expected to operate over the next decade and there are significant synergies with the French community.
- The SHIP beam dump experiment using the SPS proton beam at CERN has a substantial input from French theorists and experimentalists. It has the potential to search for particles in the GeV range, which included heavier ALPs, as well as other candidates such as right-handed neutrinos. Its development will encompass much of the lifetime of the proposed GDR.
- There will be electron beam-dump experiments HPS, DarkLight and MESA at SLAC, JLab and Mainz respectively, with the latter running in about 2020. These will provide high intensity competition to hidden-photon searches in the $10 - 1000$ MeV range.
- The BMV experiment at Toulouse received ANR funding in 2014 to build phase two and complement its 2007 results. It can perform photon regeneration searches; it also included an X-ray regeneration experiment.
- There is also a proposal to use the Tore Supra tokamak at Cadarache to search for ALPs. This would be particularly interesting to unite with the plasma physics community.

8 Conclusion