Revitalising axion-longitudinal photon conversion

arXiv:2005.00078, arXiv:2006.10415

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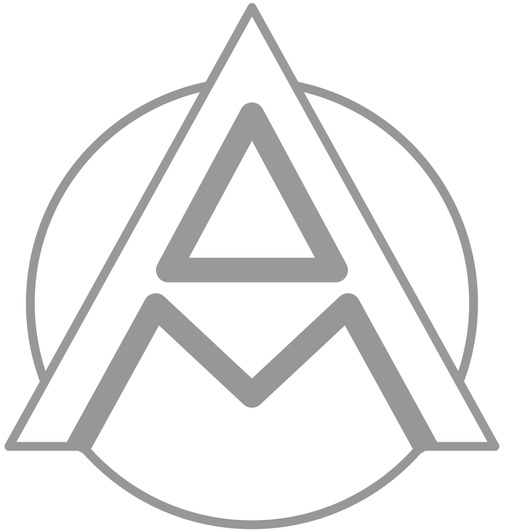

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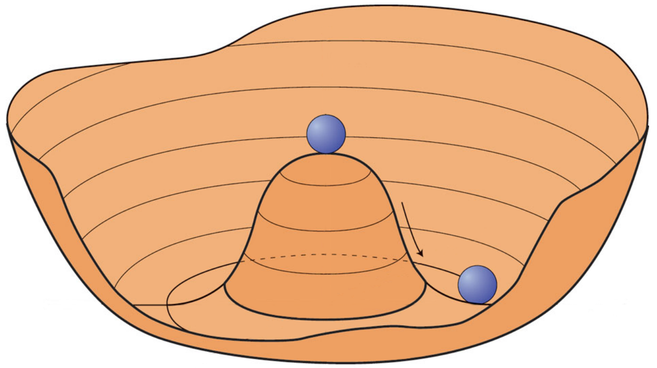
Axions

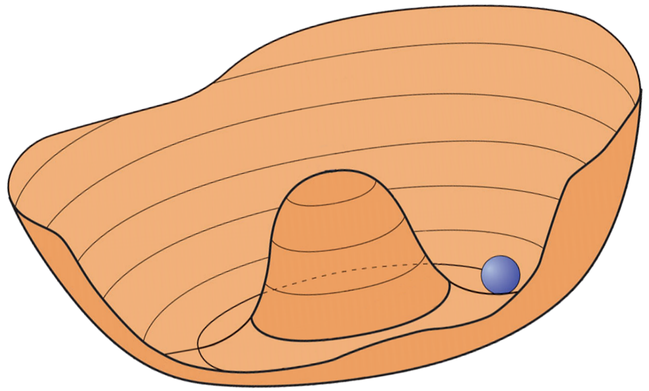
Strong CP problem: SM has a CP violating angle $\theta \frac{g^2}{32\pi^2} G\widetilde{G}$

Experimental limit: $\theta \lesssim 5 \times 10^{-9}$ °



Axion Solution:

$$\theta \to a(\mathbf{x}, t)$$



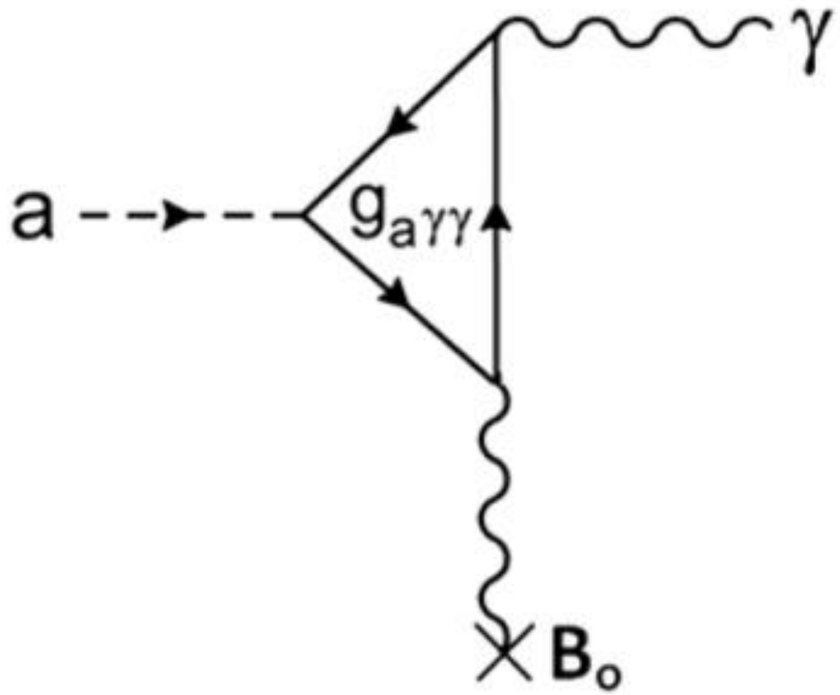
Axions

Also provides a good DM candidate

Axions and ALPs interact with photons

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - J^{\mu}A_{\mu} + \frac{1}{2}\partial_{\mu}a\partial^{\mu}a - \frac{1}{2}m_a^2a^2 - \boxed{\frac{g_{a\gamma}}{4}F_{\mu\nu}\widetilde{F}^{\mu\nu}a,}$$

Many searches use axion-transverse photon conversion in B-field



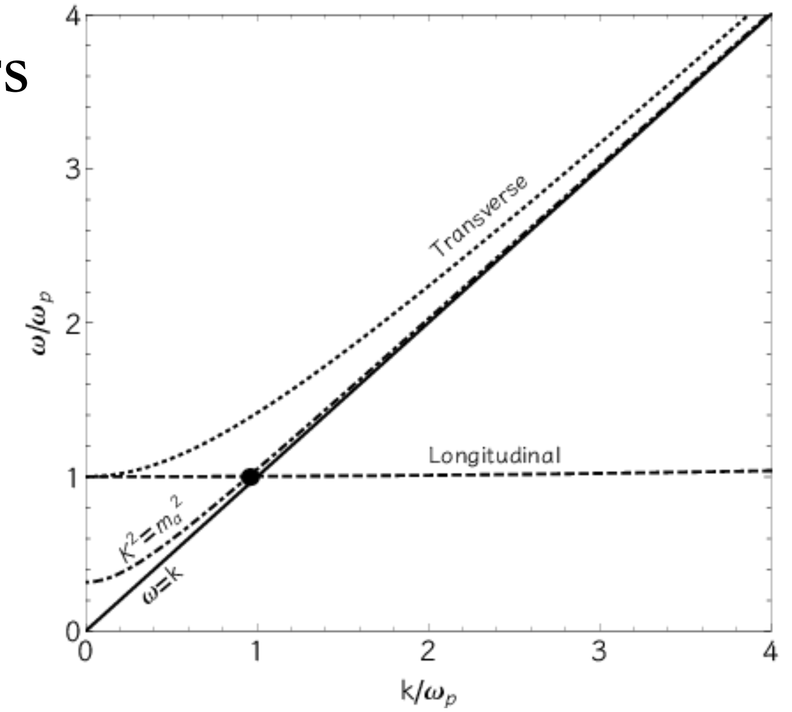
Axion-L plasmon conversion

Axions can also resonantly mix with longitudinal plasmons in a magnetic field

Not entirely new, but overlooked for many years

(9803486, 0410006, 0810.4380, 1807.06828)

Needs: a plasma and B-field



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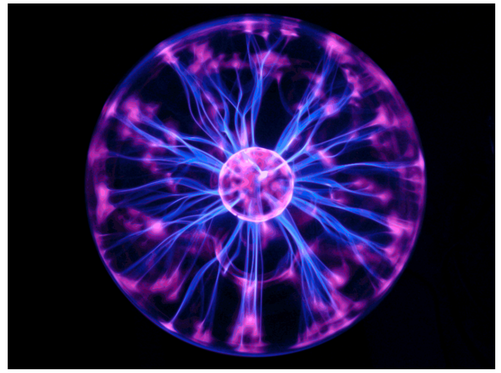
Conversion Environments

Photon → **Axion**

High T, High B

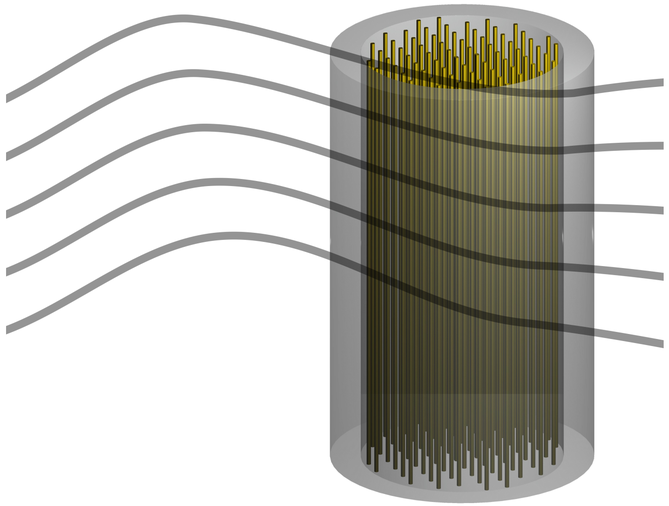
The Sun, WD, NS, plasma shining through wall (1710.01906, 1901.05910)



Axion → **Photon**

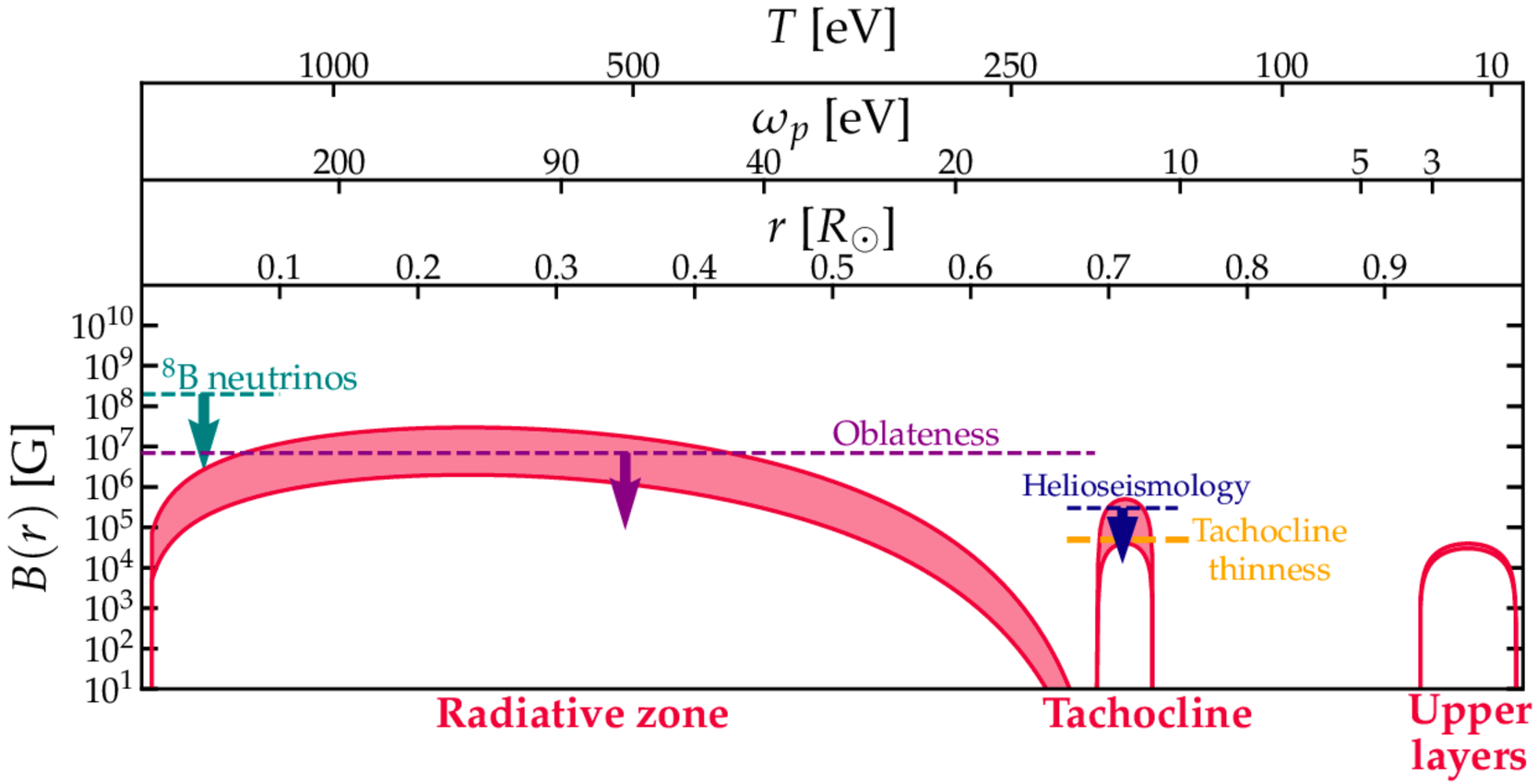
Low T, High B, Lowish ω_p

NS, plasma haloscopes (1904.11872, 2006.06836)...



Solar magnetic fields

- Very hard to access the inner regions of the Sun: weak bounds



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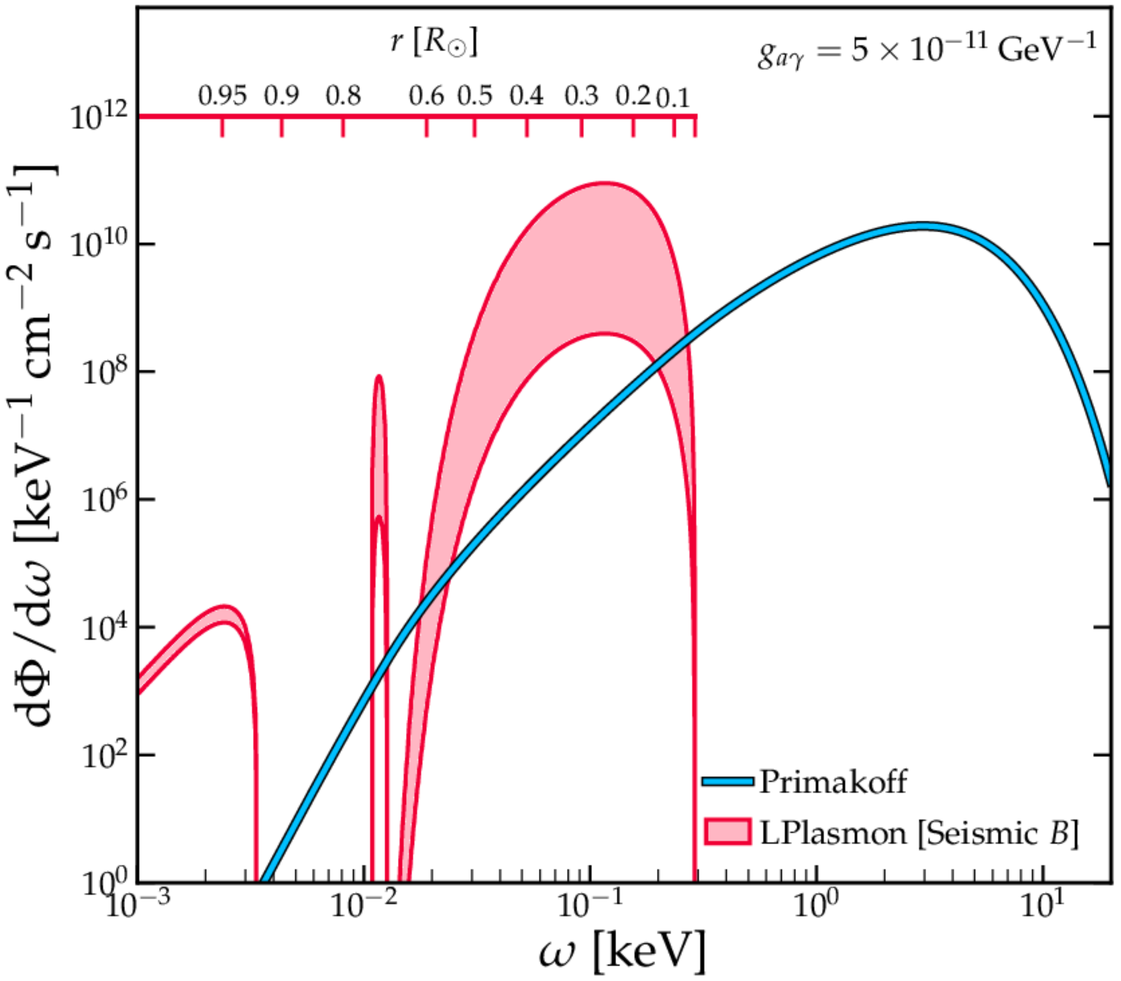
Axion-L plasmon conversion in the sun

- Axions are produced at the plasma frequency at a given solar radius
- Flux proportional to the square of the B-field
- Ideal for magnetometry (requires at least one axion...)



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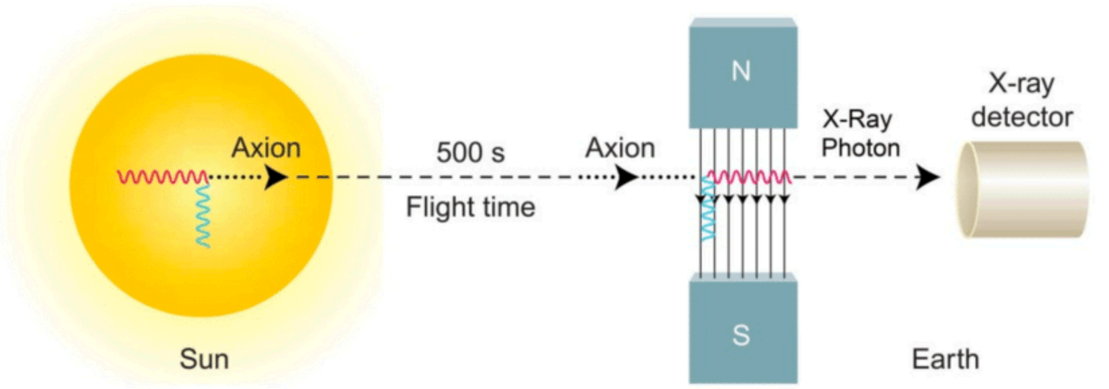
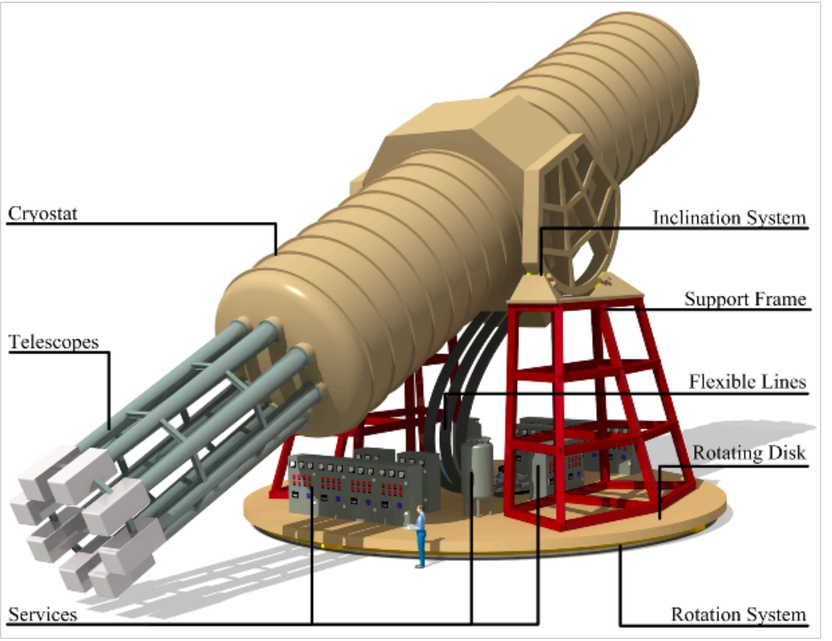
Iaxo: next generation helioscope

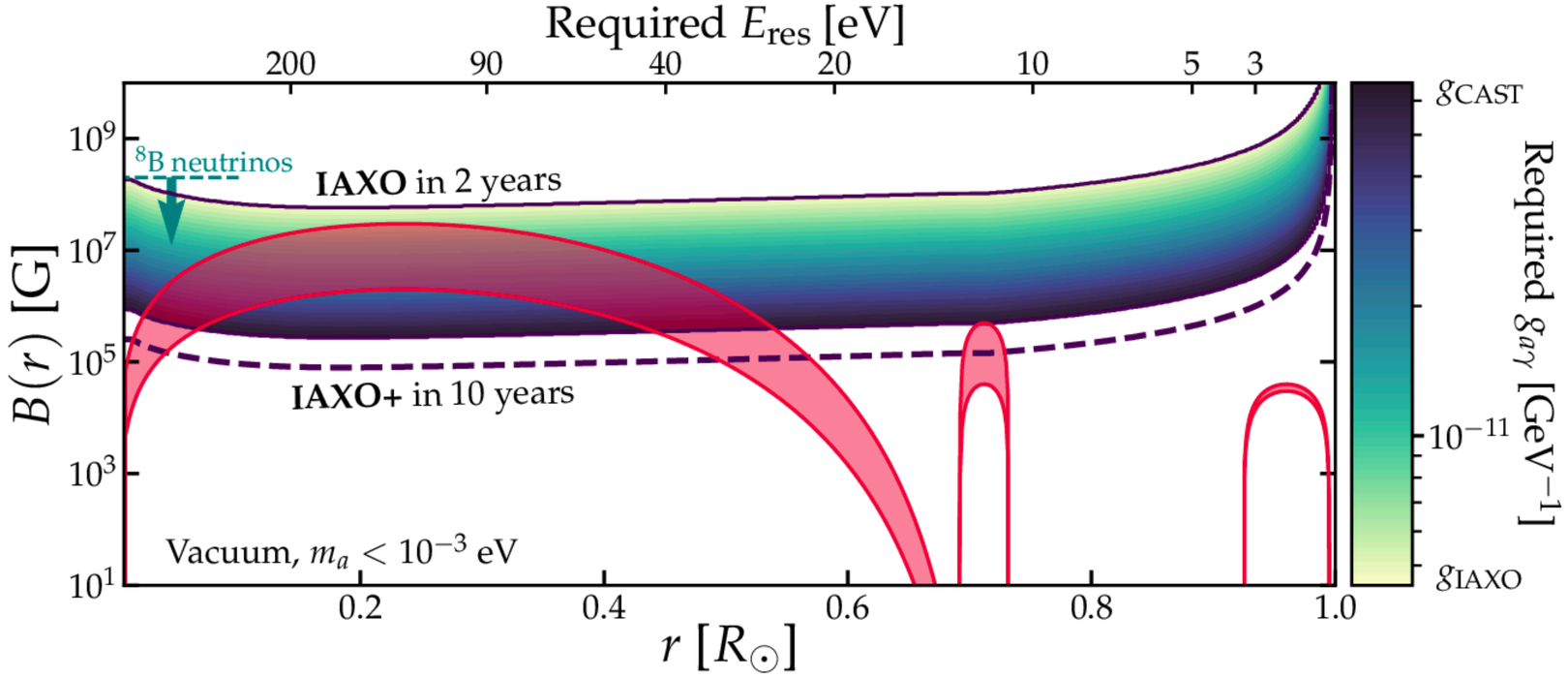
- Converts axions into photons with a B-field
- Previous experiment used an old LHC magnet
- IAXO a proposed (much, much bigger) axion observatory
- Could you use it to map the solar B-field?





Iaxo as a magnetometer

- LP flux is in the low energy end of the spectrum, with less total energy
- IAXO's sensitivity depends on the energy resolution, which is not yet determined, but between 200 and 2 eV are being considered



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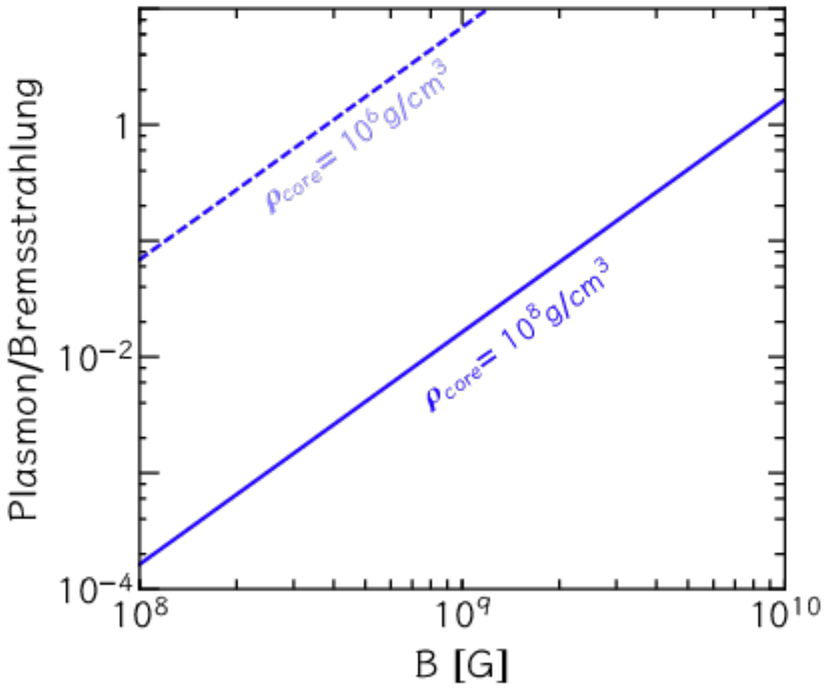
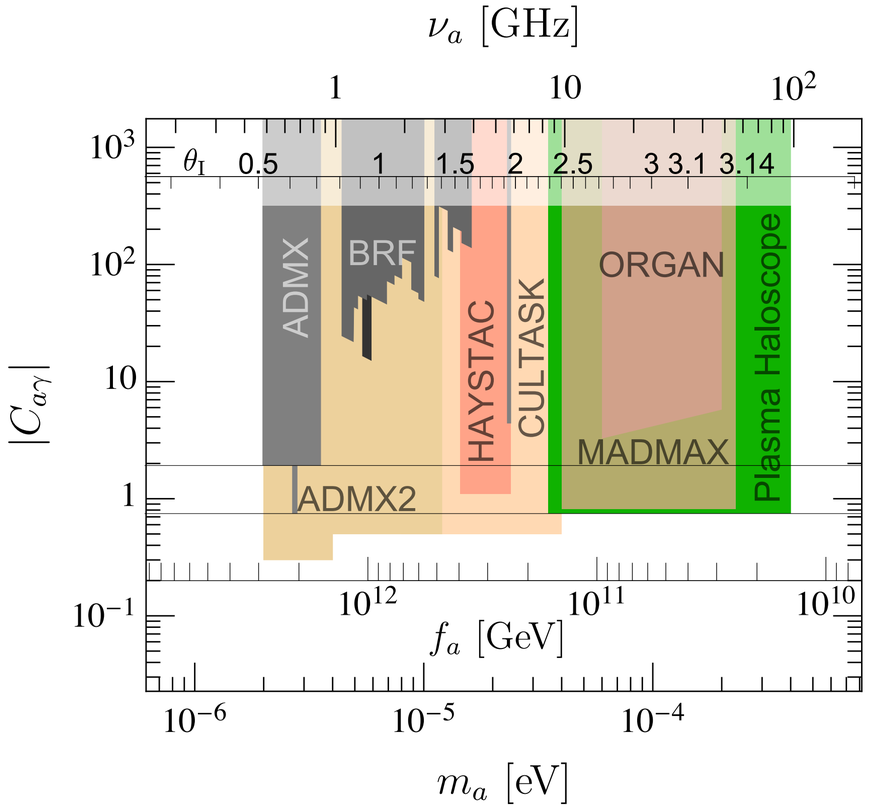
Other environments

WDs can give X-ray signals



Tuneable plasmas can search for DM



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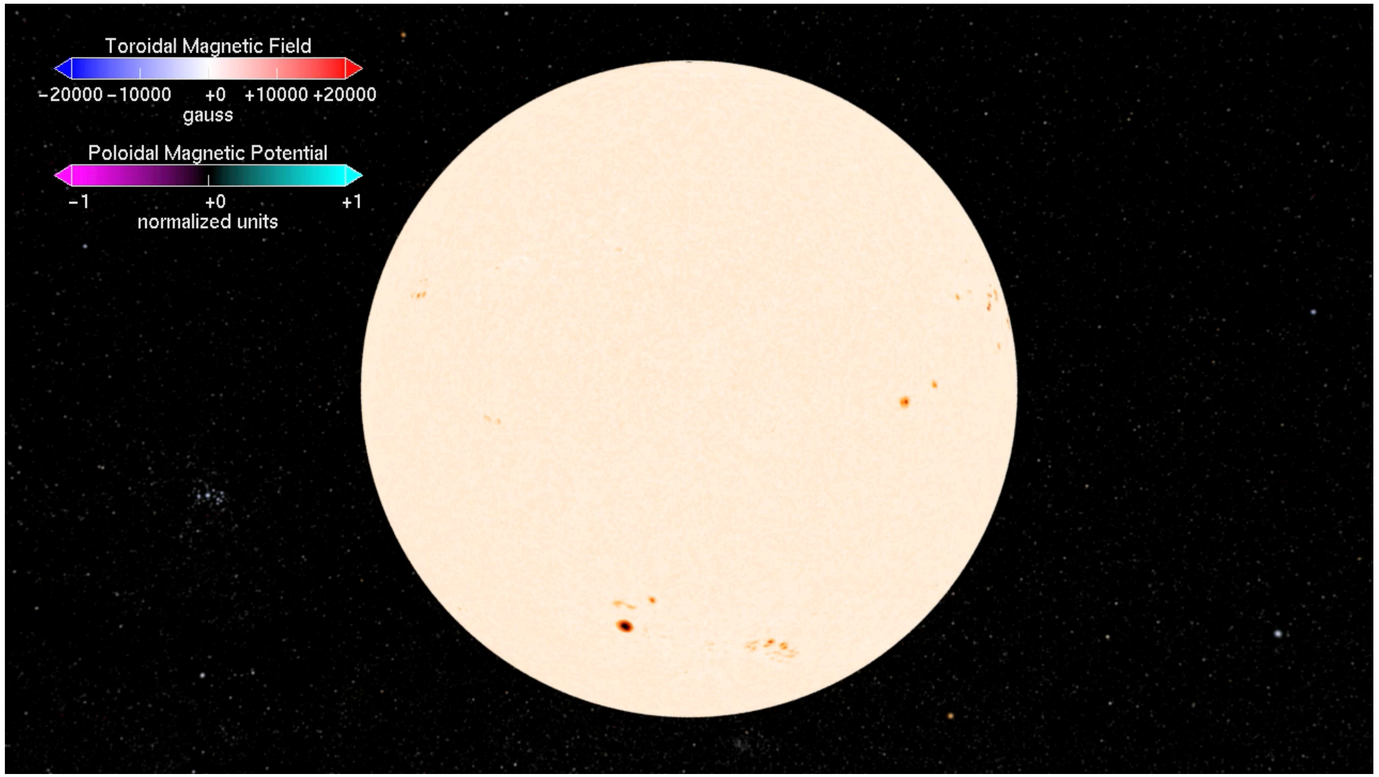
Conclusions

- Axion-L plasmon conversion very relevant for astrophysical and lab environments
- Axions could provide the best probe yet of the solar magnetic field, particularly in the inner regions
- Relevant also to the new plasma haloscope proposal (arXiv:1904.11872)
- Part of the new AxionDM research environment at SU

Solar magnetic fields

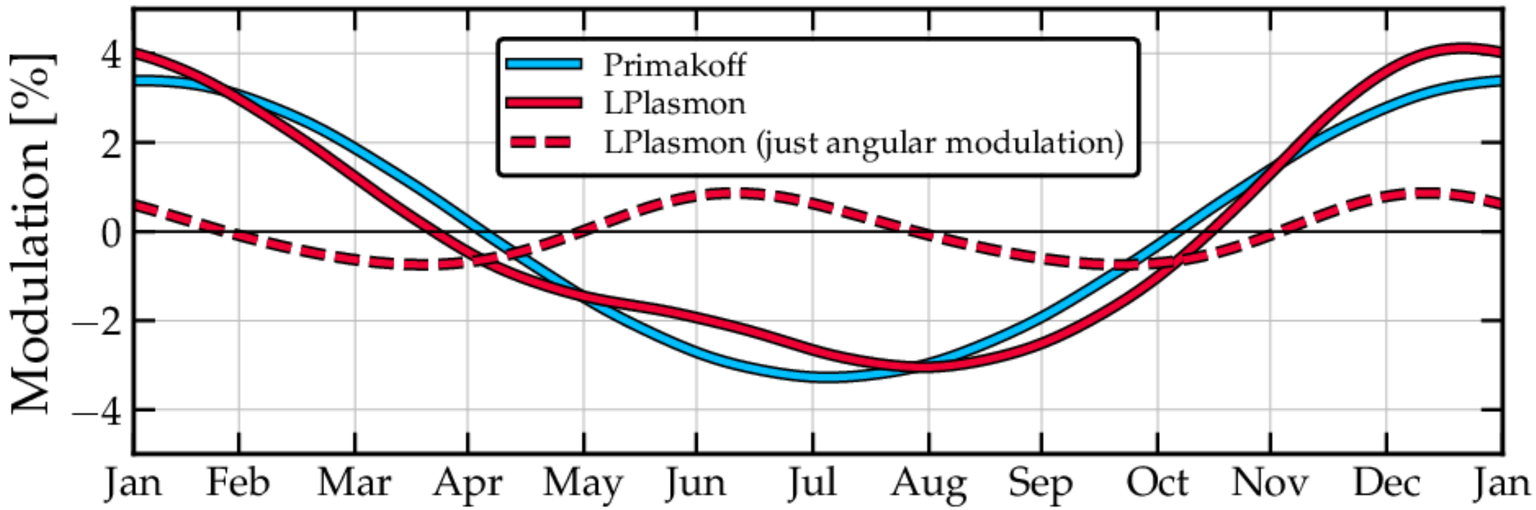
The solar B-field is mostly toroidal:

Axions preferentially emitted in the equatorial plane of the sun (luckily, where the Earth sits)



Modulation

- Annual and biannual modulations of the signal may allow the orientation of the B-field to be determined
- Annual modulation: Earth-Sun distance varies
- Biannunal modulation: Earth moves in and out of the equatorial plane



Iaxo as a magnetometer