Combining
ALPS and BabyIAXO+DM

Exploration Beyond Discovery

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Special Thanks to

Lennert Thormaehlen[1] and Sebastian Hoof[2]

+ Everybody I forgot...

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WARNING!!!

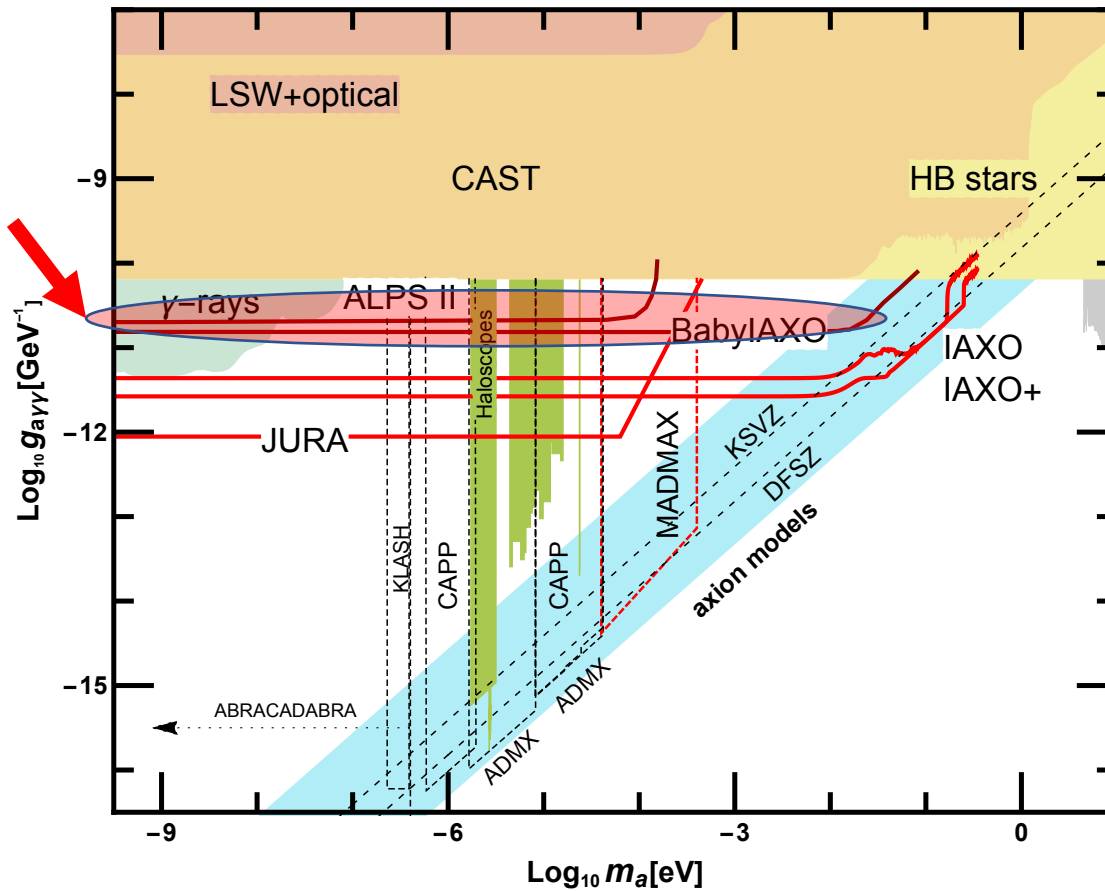All that follows is super-optimistic and purely qualitative!!!

A proper quantitative treatment probably yields that one must improve quite a bit more
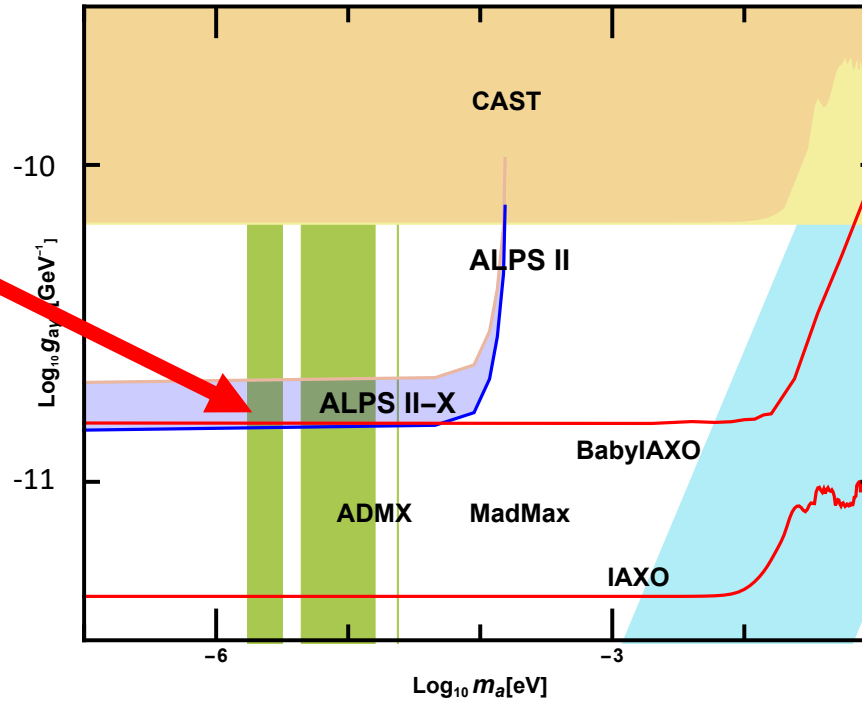(~1000 *events required)!

Starting point ~2025

- BabyIAXO has discovered a new particle ☺.

➔ Can we learn more by combining with ALPS-IIx?

Prospects

**Area of interest
today**

Zoom on BabyIAXO/ALPS area

**Assume
factor 4
Improvement in
Figure of Merit**

➔ Considerable Parameter space could be explored
   by both Baby-IAXO and ALPS II-X

➔ Question: What new things can we learn
   from a combination of ALPS and BabyIAXO?

Determine $g_{a\gamma\gamma}$ and g_{aee}

- BabyIAXO sees a combination of

$$observed\ flux \sim |g_{a\gamma\gamma}|^2(C|g_{a\gamma\gamma}|^2 + D|g_{aee}|^2)$$

- ALPS

$$observed\ flux \sim |g_{a\gamma\gamma}|^4$$

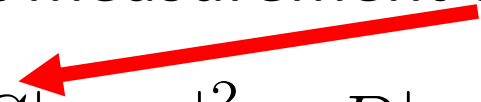➜ Combined measurement allows to determine both couplings independently

https://arxiv.org/pdf/1811.09278.pdf

(Baby)IAXO may also resolve both couplings independently,
but this requires a spectral measurement and probably more events...
but this needs to be quantified...

Measure Solar Physics
(Thanks to L. Thormaehlen!)

- If $``g_{a\gamma\gamma}"$ can be measured to $\lesssim (2-3)\%$

  we can turn around and call it measurement of

$$observed\ flux \sim |g_{a\gamma\gamma}|^2(C|g_{a\gamma\gamma}|^2 + D|g_{aee}|^2)$$

- $\lesssim (2-3)\%$ measurement of C

  ➔ We can tell difference

  between low- and high-metallicity solar models

https://arxiv.org/pdf/2101.08789.pdf

Mass measurement $m \sim 10^{-4}\,\mathrm{eV}$

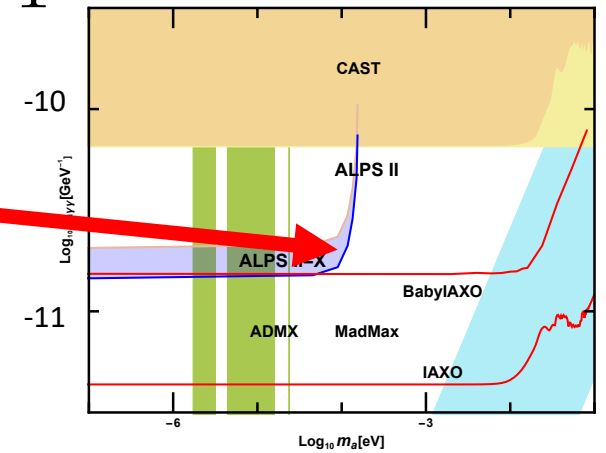- (Baby)IAXO can measure masses $m \gtrsim \mathrm{few} \times 10^{-3}\,\mathrm{eV}$

- Changing distances between magnets (not easy) (moves interferences)

- Maybe insert gas or similar $n \neq 1$

→ ALPS could measure masses

$$m \sim 10^{-4}\,\mathrm{eV}$$

Talk by Dieter Trines

Determine CP properties of ALP

$$\mathcal{L} \supset -g_{a\gamma\gamma}\frac{a}{4}\left[F\tilde{F} + \epsilon F^2\right] \sim -g_{a\gamma\gamma}a\mathbf{B}_{mag}\left[\mathbf{E}_{Las} + \epsilon\mathbf{B}_{Las}\right]$$

CP violating scalar coupling

➔ Measure polarization dependence ($\theta = \measuredangle\mathbf{B}_{mag}, \mathbf{E}_{Las}$)
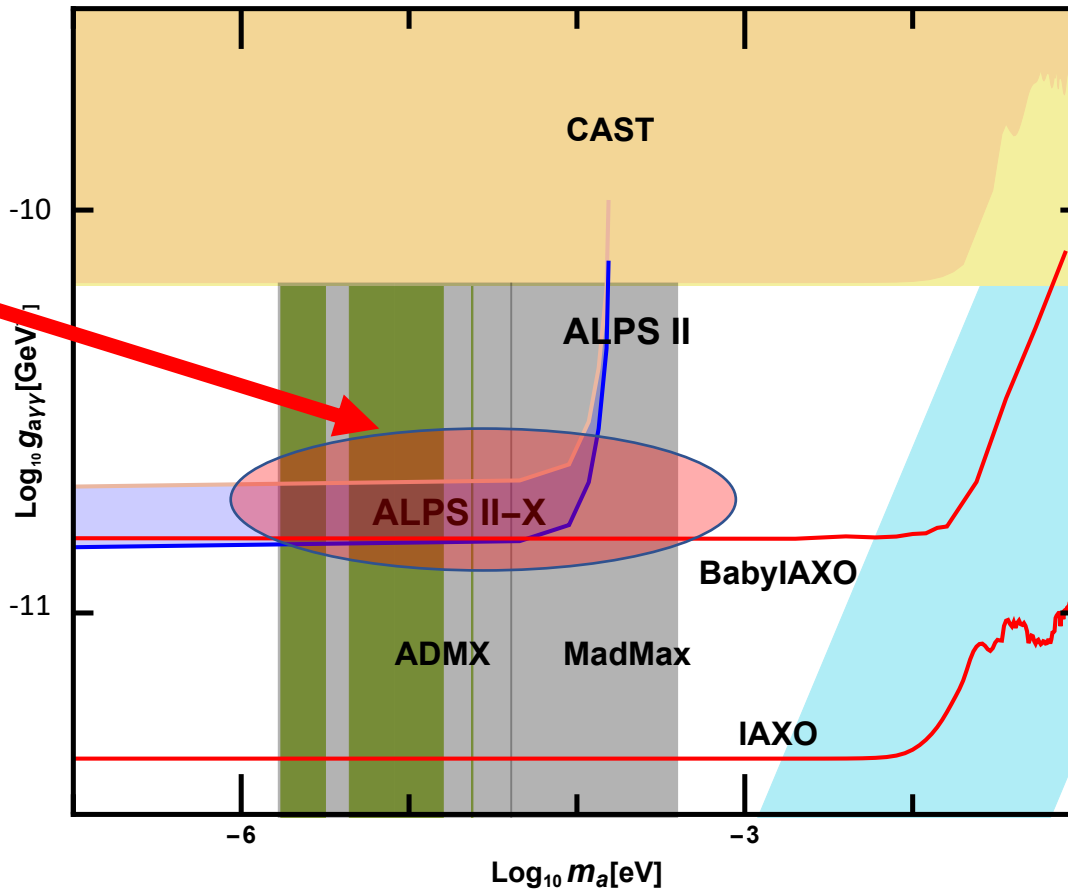
$$observed\ flux \sim \cos^4(\theta - \epsilon)$$

Caveat: Fifth-Force measurements constrain

$$\epsilon \lesssim 10^{-7}\left(\frac{10^{-10}\ \text{GeV}}{g_{a\gamma\gamma}}\right)$$

$$\text{for } m \sim 10^{-4}\ \text{eV}$$

Combining with Dark Matter Experiments

Check for Dark Matter

- DM experiments (e.g. ADMX, MadMax) could perform a DM search of the target area

- Due to the large coupling in the target area this should be doable quickly

➜ Good mass measurement by ALPS in region $m \sim 10^{-4}\,\mathrm{eV}$

　➜ can decide whether ADMX or MadMax better

　➜ scanning significantly easier (especially for MadMax)

Dark Matter is Discovered ☺

- BabyIAXO and ALPS measure $g_{a\gamma\gamma}$

- DM experiment (MadMax or ADMX)

$$observed\ flux \sim |g_{a\gamma\gamma}|^2 \rho_{\mathrm{CDM}}^{\mathrm{local}}$$

➡ Measure $\rho_{\mathrm{CDM}}^{\mathrm{local}}$

➡ Confirm this is **dominant form of DM**

➡ DM really discovered!

Conclusions (Pipe dreams of discovery)

If we are lucky...

Combined measurements (ALPS, BabyIAXO, ADMX, MadMax...) can tell us a lot:

- Determine $g_{a\gamma\gamma}$ and g_{aee}
- Measure mass   ➔information on underlying model
- Measure CP properties

- Resolve solar metallicity problem

- Facilitate DM search
- Measure $\rho_{\mathrm{CDM}}^{\mathrm{local}}$ and discover dominant DM

CAVEAT: All this needs to be quantified!