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# Summary of the “Axions Beyond Discovery” session

Pierre Sikivie

31 January 2024



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Sebastian Hoof 🚗

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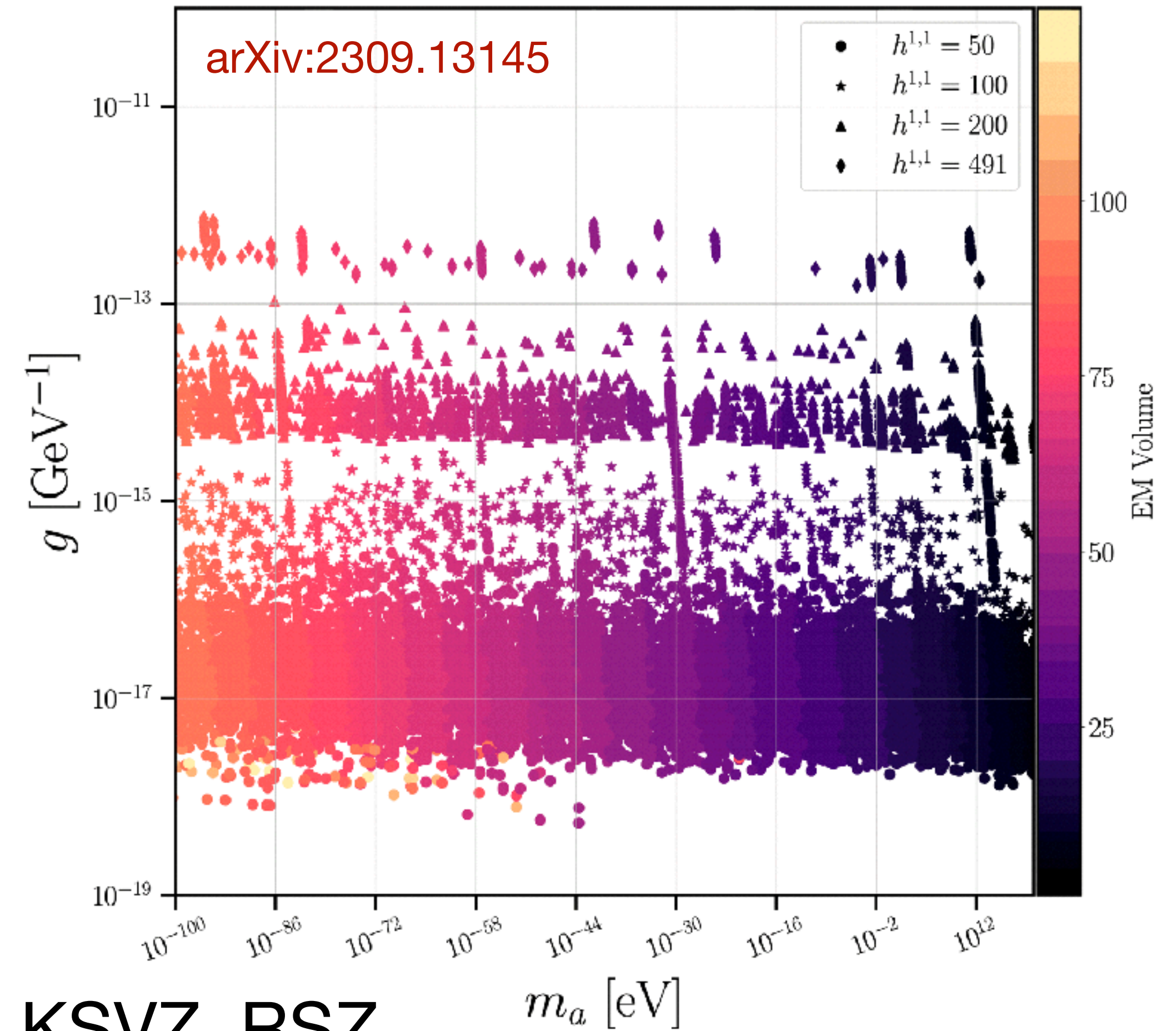
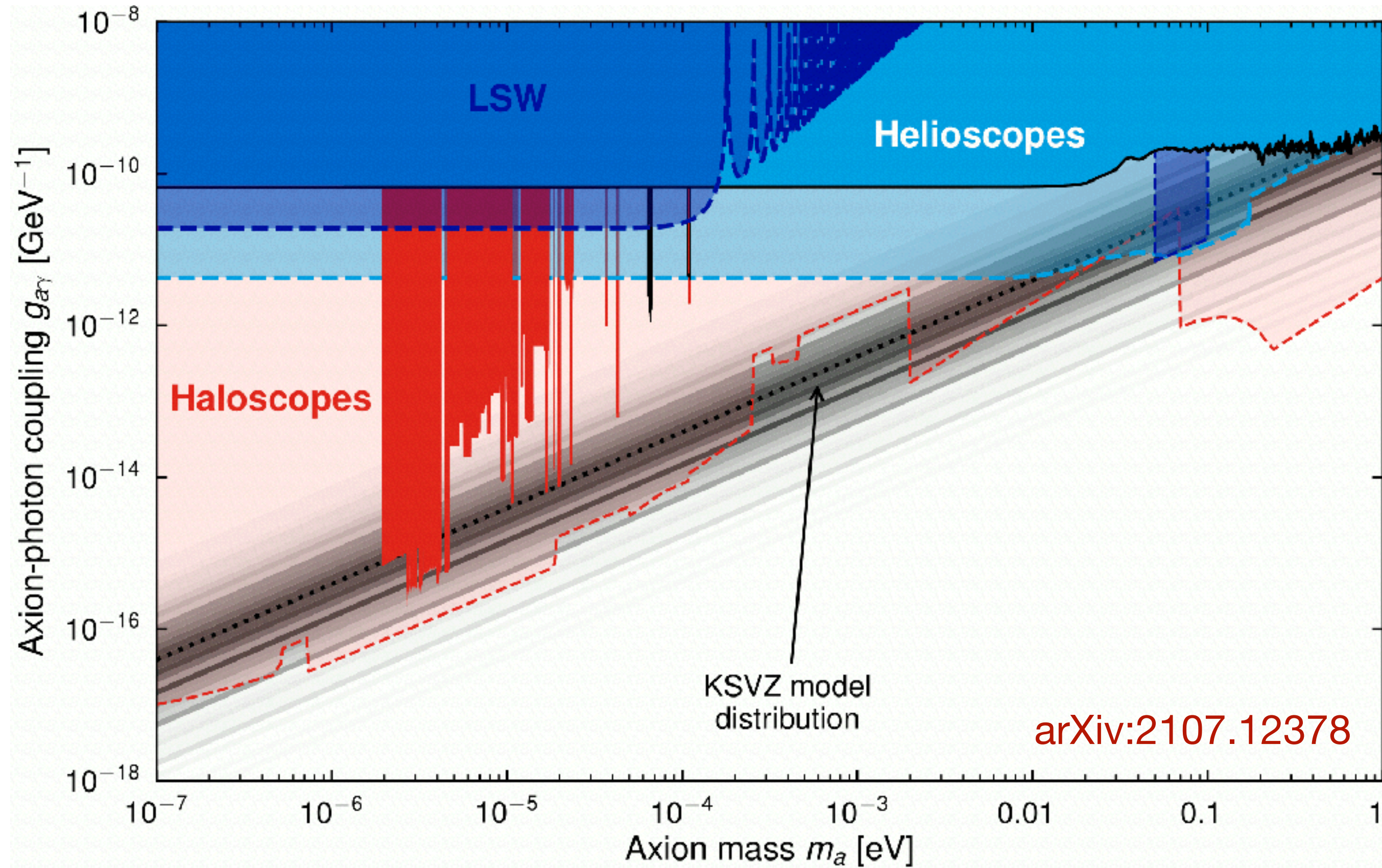
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🚗 I actually impersonated Pierre before when I accidentally took his Uber at the Patras Workshop. The driver still thinks I'm Pierre.

# The three phases of an axion discovery

- Pre-discovery phase
- Discovery phase
- Post-discovery phase

# Pre-discovery phase



- Vast QCD axion model landscape: DFSZ, KSVZ, RSZ, ...
- Ongoing studies to compute string theory ALP properties
- Many other ALP models “to the left of the band” with discovery potential

# Pre-discovery phase

- Pre-SN monitoring with neutrinos (post-discovery also with axions) to anticipate and study the SN axion burst
- Discussions about living in a local over- or under-density: e.g. saturation of detectors, post-discovery ideas for axion miniclusters
- Homework: are there any cheap, simple upgrades to current axion searches that could boost their science potential?

# Discovery Phase

- Discovery: is it a QCD axion? It's an ALP until we verify its gluon coupling
- However, we can strengthen the case for QCD axions by measuring as many couplings as possible, combining data in “global fits” to disentangle signal dependences, e.g.

$$\text{LSW: } \Phi \propto g_{a\gamma}^4 \quad | \quad \text{Helioscope: } \Phi \propto \left( 1 + C \frac{g_{ae}^2}{g_{a\gamma}^2} \right) g_{a\gamma}^4 \quad | \quad \text{Haloscope: } P \propto \rho_{\text{DM,loc}} g_{a\gamma}^2$$

- N.B. Astro opportunities for  $g_{aN}$ ; weak (strong) dependence on axion model (environment); running of  $g_{aN}$  relevant, perhaps even useful for understanding the UV model?
- Axions = low-energy physics telling us about HEP; QCD axions come with additional Higgs doublets, heavy fermions, ...: learning about the axion's UV model = learning about the SM (N.B. not strictly required for post-discovery applications)

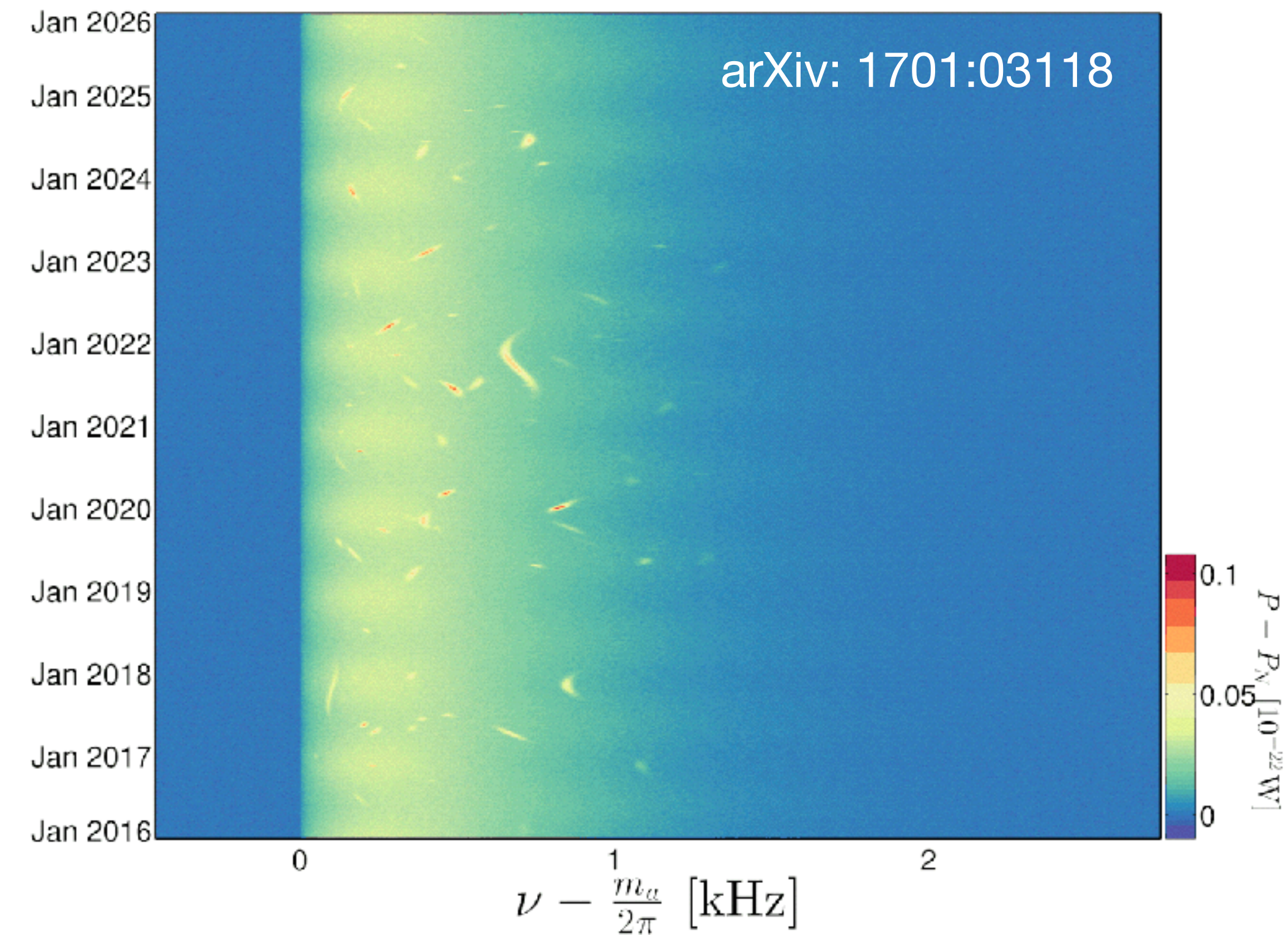
# Discovery Phase

- Need to revisit cosmological history: e.g. KSVZ can have built-in early epoch of matter domination
- If axions  $\neq$  (all of) DM, are haloscopes still useful? Yes, they can be used for other science goals; e.g. searching for the axiverse, GWs
- Lively discussion on how to strengthen the QCD axion case; potentially unfeasible but stimulating, further investigation needed:  $m_a(T)$  vs Fe collisions? Higher-order effect in 5<sup>th</sup> force experiments? Finite density of effects on  $g_{aN}$ ? Plasma effects on  $g_{a\gamma}$ ? High-mass new particles in ultra-high-energy air showers?

# Post-discovery phase

Growing number of examples for applications of axions as messengers:

- Solar metallicity, B-field or T profiles, ...
- Local DM halo: velocity distribution and its tail, substructures and streams, axion miniclusters, gravitational potential, ...
- Existing “hints” (TeV transparency, stellar cooling, ...) explained by ALPs or point to new astro effects





# Post-discovery phase

- More uses of “axion tomography”? B-field tomography from GRBs?
- Axion telescopes via interferometry: we could quickly transition from axion facilities into axion telescopes; homework: how could interferometry already be used to improve the experimental sensitivity?
- A discovery would justify higher budgets: upgrade current experiments to post-discovery mode, e.g. ALPS with alternating magnets?
- Post-discovery ideas for axions may not win navy grants, but that shouldn't deter us from thinking about them!

# Concluding remarks

- Axion physics still fascinating: lots of ideas, great discovery prospects at DESY and around the world!
- Physics aside: let's push for more interactions within and across communities, focus on applying good practices, conserve data, reproducibility, and transparency when communicating results — it's easier than ever!
- Contact Joerg about the questionnaire regarding issues with ALP/FIP papers and community interactions!

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- A big **Thank You** to Axel & Co. for this wonderful discussion workshop!