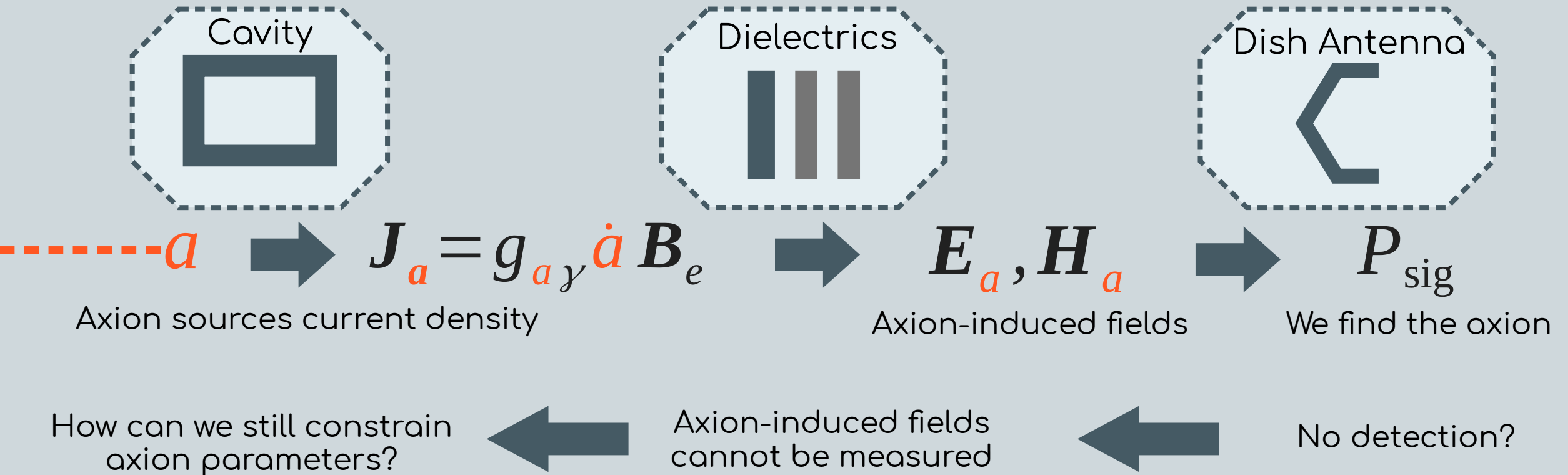


Axion Haloscope Calibration from Reciprocity



$$J_R \rightarrow E_R, H_R$$

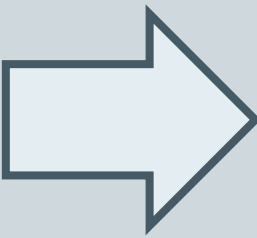
Excite haloscope from the outside
(reflection/transmission measurement)

However, generally

$$E_R \neq E_a$$

$$H_R \neq H_a$$

Reciprocity Theorem



Signal Power

- measurable fields
- simple and elegant

Poster #57

Axion Haloscope Calibration from Reciprocity

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Introduction

- Axion haloscopes convert axions from the galactic dark matter halo to photons
- To constrain axion parameters, we need to estimate the expected signal power
- The signal power depends on axion-induced electromagnetic fields that are unknowable without detection
- Can we predict the signal power from measurable quantities alone?

Setup properties

- Open or closed optical system with arbitrary geometry
- Linear materials (ϵ, μ, d)
- Matched to receiver chain via single mode waveguide
- Axion field gradient negligible

Signal power to receiver

$$P_{in} = \text{Re} \int_{\text{Vol}} dA n \cdot (E \times H)$$

Without detection, axion-induced fields are not measurable

How to predict signal power?

Perform reflectivity measurement

Axion Reciprocity

Reciprocity theorem relates fields

$$\int dV E_1 \cdot J_2 - E_2 \cdot J_1 = \oint dA n \cdot (E_1 \times H_2 - E_2 \times H_1)$$

Signal power from reciprocity

$$P_{in} = \frac{1}{16\pi} \int dV E \cdot J$$

Conclusion

- Signal power now depends on measurable reflectivity-induced fields, external magnetic field and axion parameters
- Simple expression applicable to cavities, dish antennas, dielectric haloscopes

Example: Dielectric Haloscope

Simulation

- Axisymmetric FEM (Comsol)
- Open dielectric haloscope

Axion approach

- Simulate axion-induced fields
- Calculate power coupled to gaussian beam

Reciprocity approach

- Illuminate with gaussian beam
- Integrate reflectivity-induced fields over conversion volume

Graph: Signal Power vs Frequency (GHz). Shows a resonance peak at approximately 18 GHz. Labels include 'Main resonance', 'Axion approach', and 'Reciprocity approach'.