Stringent axion constraints with Event Horizon Telescope polarimetric measurements of M87⋆

1. Probing axions with event horizon telescope polarimetric measurements

   Physical Review Letters, *124*(6), 061102. 1905.02213

2. Stringent axion constraints with Event Horizon Telescope polarimetric measurements of M87⋆

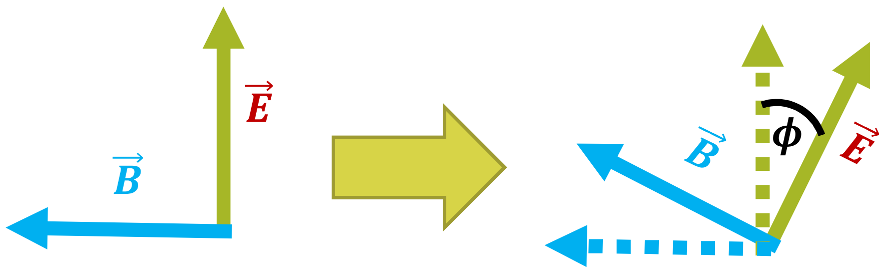
   Nature Astronomy (2022), *1-7*. 2105.04572

Xiao Xue | University of Hamburg / DESY (Quantum Universe) | EuCAPT 24th May 2022

1/3 Axion induced birefringence signal

- Axion-Photon Interaction:

$$\mathcal{L}_{\rm in} \supset -\frac{1}{2} g_{a\gamma}\, a\, F^{\mu\nu}\tilde{F}_{\mu\nu} = 2\, a\, g_{a\gamma}\, \vec{E}\cdot\vec{B}$$



- Dispersion relation of photon traveling in axion background (Circular Polarization Basis)

$$\omega^{\pm}(\boldsymbol{k}) \simeq |\boldsymbol{k}| \pm g_{a\gamma}(\hat{\boldsymbol{k}}\cdot\boldsymbol{\nabla}a + \dot{a})$$

McDonald, Jamie I., and Luís B. Ventura. "Optical properties of dynamical axion backgrounds." Physical Review D 101.12 (2020): 123503. 1911.10221

Free field:

$a = a_0 \cos(\mu\, t - \boldsymbol{p}\cdot\boldsymbol{x} + \alpha)$

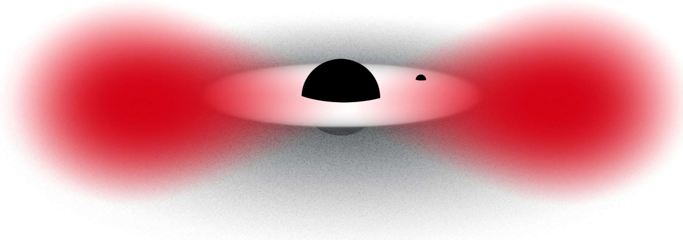
$\Delta\phi \propto g_{a\gamma} a_0$

- Polarization angle (Linear Polarization Basis)

$$\Delta\phi \equiv \frac{1}{2}\int d\lambda(\omega^{+} - \omega^{-}) = g_{a\gamma}\left(a_f - a_i\right)$$

2/3 Superradiant axion cloud around Kerr black holes

- Black hole superradiance



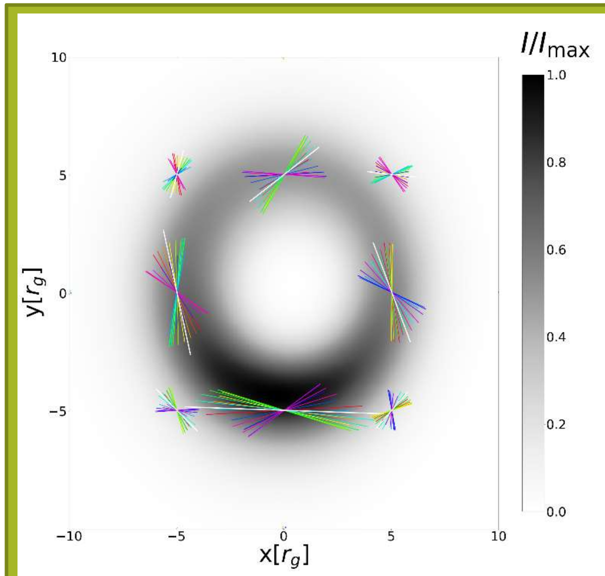
R. Brito, V. Cardoso & P. Pani, "Superradiance", Lect. Notes in Physics 971 (2020)

- Factors for the **fastest growth**
  High spin ($a_J = 0.99$)
  $\alpha \equiv GM_{BH}\mu \simeq 0.4$
  $l = 1, m = 1$

- Factors for **the densest** axion field
  $V(a) = f_a^2 \mu^2 \left[1 - \cos\left(\frac{a}{f_a}\right)\right]$
  $a_{max} \leq f_a$
  Define $c \equiv 2\pi f_a g_{a\gamma}$

SMBH	M	a_J	μ range	μ for $\alpha = 0.4$
M87*	$6.5 \times 10^9 M_\odot$	0.99	$2.1 \times (10^{-21} \sim 10^{-20})$ eV	8.2×10^{-21} eV
Sgr A*	$4.3 \times 10^6 M_\odot$	$\cdots$	$3.1 \times (10^{-18} \sim 10^{-17})$ eV	1.2×10^{-17} eV

Y. Chen, J. Shu, X. Xue, Q. Yuan and Y. Zhao, "Probing Axions with Event Horizon Telescope Polarimetric Measurements" PhysRevLett.124.061102 (2020)



SIMULATION OF THE BLACK HOLE IMAGE:

IPOLE Moscibrodzka, M. & Gammie, C. F. "ipole – semi-analytic scheme for relativistic polarized radiative transport.", MNRAS, 475, 43-54 (2018)

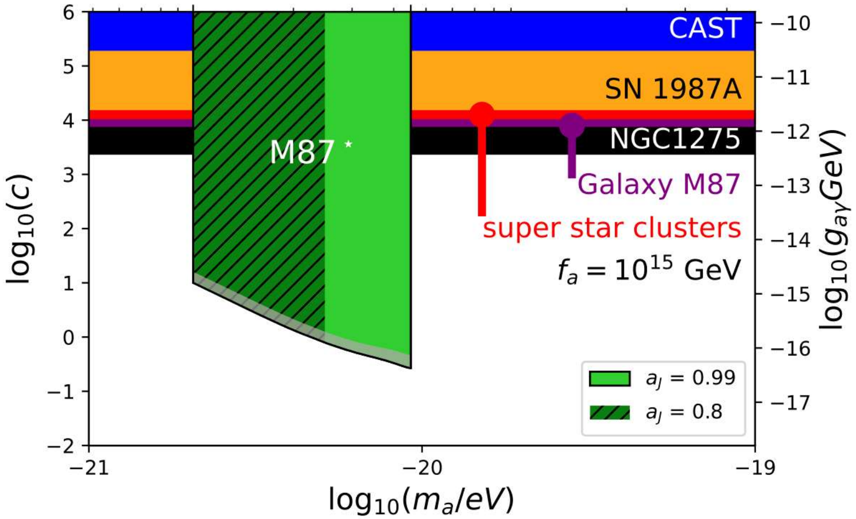
RIAF accretion flow Pu, H.-Y. & Broderick, A. E. "Probing the innermost accretion flow geometry of Sgr A* with Event Horizon Telescope. Astrophys. J.", 863, 148 (2018)

a_J=0.99, 17° inclination angle EHT et al. "First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole.", APJL, 875, L1 (2019).

Y. Chen, Y. Liu, R. Lu, Y. Mizuno, J. Shu, X. Xue, Q. Yuan, and Y. Zhao. "Stringent axion constraints with Event Horizon Telescope polarimetric measurements of M87." Nature Astronomy (2022): 1-7.*

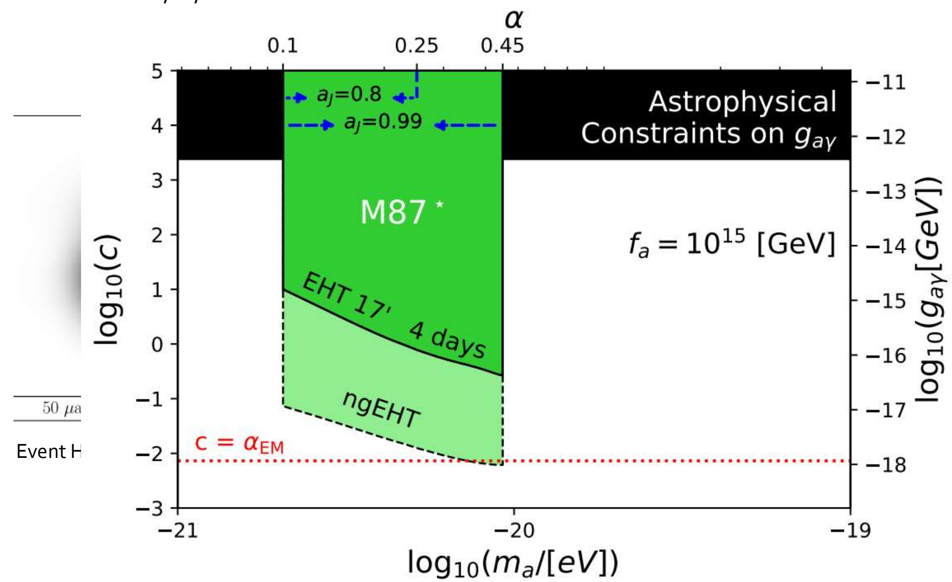
3/3 Axion Constraints with EHT polarimetric measurements of M87*

- EHT 2017
  - *Y. Chen, J. Shu, X. Xue, Q. Yuan and Y. Zhao, "Probing Axions with Event Horizon Telescope Polarimetric Measurements" PhysRevLett.124.061102 (2020)*



$c \equiv 2\pi f_a g_{a\gamma}$

- Next generation EHT
  - *In preparation*



THANK YOU!