

Supermassive Black Holes as Detectors for Ultra-light Bosons

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8 August 2022,
17th Patras Workshop on Axions WIMPs and WISPs, Mainz



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Axion Cloud and Birefringence

- ▶ Axion: strong motivation in high energy physics!
Strong CP problem, extra dimension/string theory, dark matter.

- ▶ **Gravitational atom** accumulates from **superradiance**:  $r_g m_a \approx \mathcal{O}(1)$

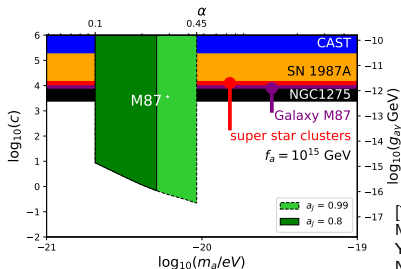
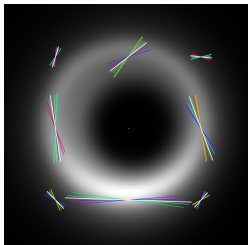
$$a^{\text{GA}}(x^\mu) \simeq R_{11}(\mathbf{x}) \cos(\omega t - \phi) \sin \theta; \quad a_{\text{max}}^{\text{GA}} \simeq \mathcal{O}(1) f_a; \quad \omega \simeq m_a.$$

- ▶ $g_{a\gamma} a F_{\mu\nu} \tilde{F}^{\mu\nu} \rightarrow$ rotate linear polarization orientation $\chi \equiv \arg(Q + i U)/2$.

- ▶ **Stringent constraints** for $c \equiv 2\pi g_{a\gamma} f_a$ using EHT data [EHT 21']:

Shift for each photon:

$$\Delta\chi \approx g_{a\gamma} \times a^{\text{GA}}(x_{\text{emit}}^\mu)$$

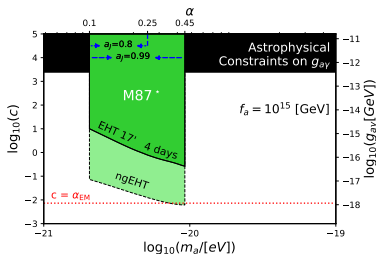
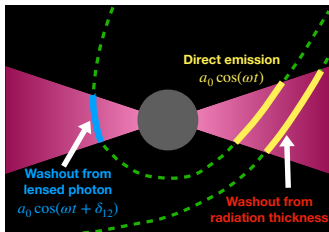


[YC, Liu, Lu, Mizuno, Shu, Xue, Yuan, Zhao, Nature Astronomy]

Prospect for next-generation EHT

- ▶ Correlation between $\Delta\chi$ at **different radius** and **frequency**.

At 86 GHz, lensed photon is **suppressed** due to **higher optical thickness**.



- ▶ **Longer and sequential** observations.
- ▶ Better **understanding of intrinsic variations** accretion flow and jet.
- ▶ **Horizon scale SMBH landscape** with ngEHT (**space, L2**):
Broader range of axion mass: 10^{-22} eV to 10^{-17} eV.