WORK IN PROGRESS

A Thermodynamic Positivity Bound on Higher-Derivative 3-Form Couplings in de Sitter, and its Inflationary Consequences

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Superradiant Instability of Dark Photon Bound States in Rotating Stars

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The de Sitter black hole from a 3-form

01 HIGHER-DERIVATIVE ACTION

$$S = \int d^4x\sqrt{-g}\bigg(\frac{R}{2\kappa^2} - \frac{1}{48{g_3}^2}F_{\mu\nu\sigma\rho}F^{\mu\nu\sigma\rho} + c_1R^2 + c_2R_{\mu\nu}R^{\mu\nu} + c_3R_{\mu\nu\sigma\rho}R^{\mu\nu\sigma\rho}$$
$$+ c_4RF_{\mu\nu\sigma\rho}F^{\mu\nu\sigma\rho} + c_5R^{\mu\nu}F_{\mu}{}^{\sigma\rho\delta}F_{\nu\sigma\rho\delta} + c_6R^{\mu\nu\sigma\rho}F_{\mu\nu}{}^{\lambda\delta}F_{\sigma\rho\lambda\delta}$$
$$+ c_7(F_{\mu\nu\sigma\rho}F^{\mu\nu\sigma\rho})^2 + c_8\nabla_\alpha F_{\mu\nu\sigma\rho}\nabla^\alpha F^{\mu\nu\sigma\rho}\bigg),$$

02 CORRECTED BLACK-HOLE GEOMETRY

$$\begin{aligned}\widetilde{f}(r) =& f(r) + f_1(r) + f_2(r)\\ =& 1 - \frac{\kappa^2 M}{r} - \frac{r^2}{\ell^2} - \frac{24{g_3}^2}{\ell^4\kappa^2}\left(\frac{r_b^3 - r^3}{r}\right)\left(288c_7{g_3}^2 - (12c_4 + 3c_5 + 2c_6)\kappa^2\right)\\ &+ \frac{144c_6\kappa^2 M}{\ell^2 r}\ln\left(\frac{r_b}{r}\right).\end{aligned}$$

Solve perturbatively in the higher-derivative coefficients c_i around Schwarzschild-de Sitter.

Entropy positivity bounds the EFT couplings

01 WALD ENTROPY CORRECTION

$$\Delta S = S\left[\frac{8c_3\kappa^2}{\ell^2}\left(\frac{3-\eta}{1-\eta}\right) + \frac{12\kappa^2}{\ell^2}(4c_1+c_2) + \frac{48g_3^2}{\kappa^2\ell^2}\left(144c_7{g_3}^2 - (12c_4+3c_5+2c_6)\kappa^2\right) + 96c_6{g_3}^2\frac{\ln(1-\eta)}{\ell^2\eta}\right].$$

$\Delta S > 0$

THERMODYNAMIC CONSISTENCY

$$\rightarrow 2c_3\kappa^2 + \kappa^2(4c_1+c_2) + \frac{4g_3^2}{\kappa^2}\left(144c_7{g_3}^2 - (12c_4+3c_5+4c_6)\kappa^2\right) > 0.$$

Allowed combinations of higher-derivative couplings

LINK TO COSMOLOGY

3-form / scalar duality

The same c_i enter the scalar kinetic term and effective potential.

$$\hat{S} = \int d^4x\sqrt{-\hat{g}}\left[\frac{m_P}{2}\hat{R} - \frac{\hat{g}^{\mu\nu}}{2}\left(\frac{48\lambda^2 c_8}{\Omega^2} + \frac{6\mu^2\lambda^4\Phi^2}{\Omega^4 m_P^2}\right)\partial_\mu\Phi\partial_\nu\Phi + \frac{1}{\Omega^4}\left(\frac{1}{2}\frac{\lambda^2}{{g_3}^2}\Phi^2 + 576c_7\lambda^4\Phi^4\right)\right].$$

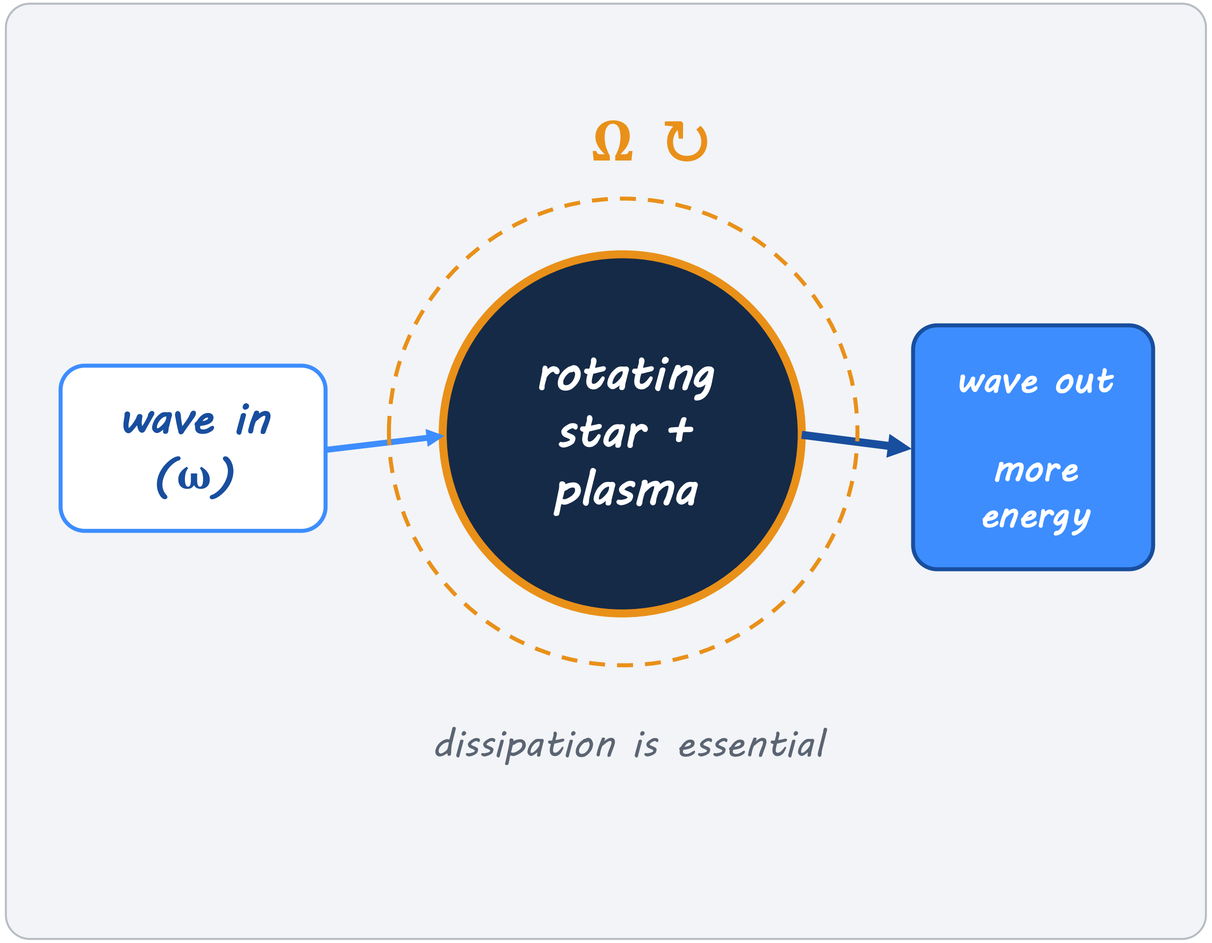
Superradiance extracts rotational energy

A rotating, dissipative system can amplify a co-rotating mode.

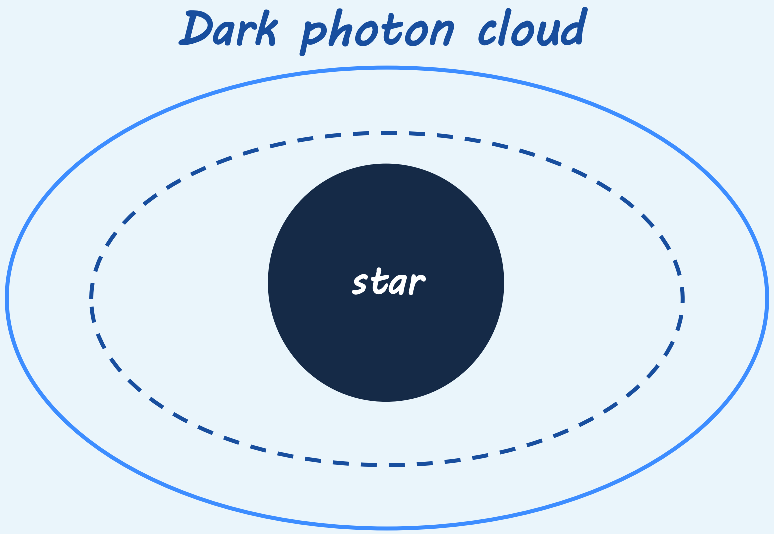
$$\omega < m\Omega$$

To the rotating medium, the mode has frequency $\omega < m\Omega$. Dissipation then allows the outgoing wave to carry away more energy.

The extra energy comes from rotation



Why use a dark-photon bound state?



Dark photon mass → gravitational bound state

long interaction time near the star

WHY THIS SYSTEM?

01 A massive vector can be gravitationally trapped

02 A long-lived cloud remains close to the rotating star

03 Small mixing ϵ lets the cloud communicate with ordinary plasma

Can the star feed this bound state and give us some signal of dark photon?