5-MINUTE FLASH TALK

Dark Fluids & Black Holes

A Curvature-Dependent Equation of State in Strong-Field Regimes

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Why Curvature-Dependent Dark Energy?
(Or is it the other way round-Dark Energy influences Curvature ?)

Cosmological Paradox

Standard **ΛCDM** presumes dark energy is perfectly static everywhere in the Universe. Normal EOS P= w Rho. $w = -1$

However, assuming identical DE behavior across both vast voids and extreme gravitational wells near black holes is physically restrictive.

General Covariance

Setting a naive coordinate dependence violates General Relativity principles. $w(r)$

To preserve covariance while capturing strong-field response, the Equation of State must depend on **scalar curvature invariants**.

The Curvature Model & Dual Regimes

Choice of Scalar: Kretschmann Scalar K

$$R = 0$$

Outside Schwarzschild black holes, the simplest scalar - Ricci scalar vanishes. .We adopt the second simple scalar - The **Kretschmann scalar**:

$$K = R_{\mu\nu\rho\sigma} R^{\mu\nu\rho\sigma} = \frac{48M^2}{r^6}$$

Non-zero in vacuum, non-singular at event horizon $r = 2M$, and diverges only at physical singularity $r = 0$

PROPOSED EQUATION OF STATE

$$w(K) = w_0 + w_1 \frac{K}{K + K^*}$$

- **Weak Curvature:** (Cosmological ΛCDM recovered)

$$w \to w_0 \approx -1 \qquad K \ll K^*$$

- **Strong Curvature:** (Dynamical DE shift near BH)

$$w \to w_0 + w_1 \qquad K \gg K^*$$

Accretion Dynamics & Flow

Relativistic Fluid Flow

Relativistic accretion rate scales as . $\dot{M} \propto \rho + P = \rho (1 + w)$

- **Standard ΛCDM:** . Zero dark energy accretion onto black hole.
  $w = -1 \Rightarrow \rho + P = 0$
- **Modified Curvature Flow:** In strong gravity, if , then , allowing active DE inflow. As M dot > 0 now.

  $w = -1 + \epsilon \qquad \rho + P > 0$

- **Sonic Point Shift:** Michel accretion critical radius shifts as local sound speed varies continuously. The sonic point changes its location

  $c_s^2 = w (K)$

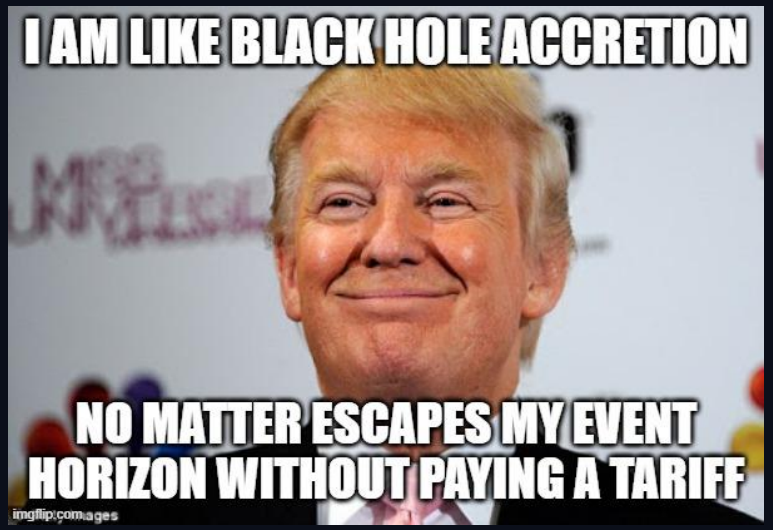
  .

According to our model near a Black Hole:

$M \propto \rho [1+w0+w1]$

According to our model at cosmology scale:

$M \propto \rho [1+ w0]$



Physics, Bounds & Extensions

Energy Conditions

Null, Weak, Dominant, and Strong Energy Conditions tightly constrain the parameter space, ruling out phantom instabilities & superluminal speeds. (w_0, w_1)

Scalar Field Origin

Can be Derived dynamically from effective field theory with scalar non-minimal coupling to curvature:

$$\alpha K \phi^2$$

Kerr BH Extension Ψ_2

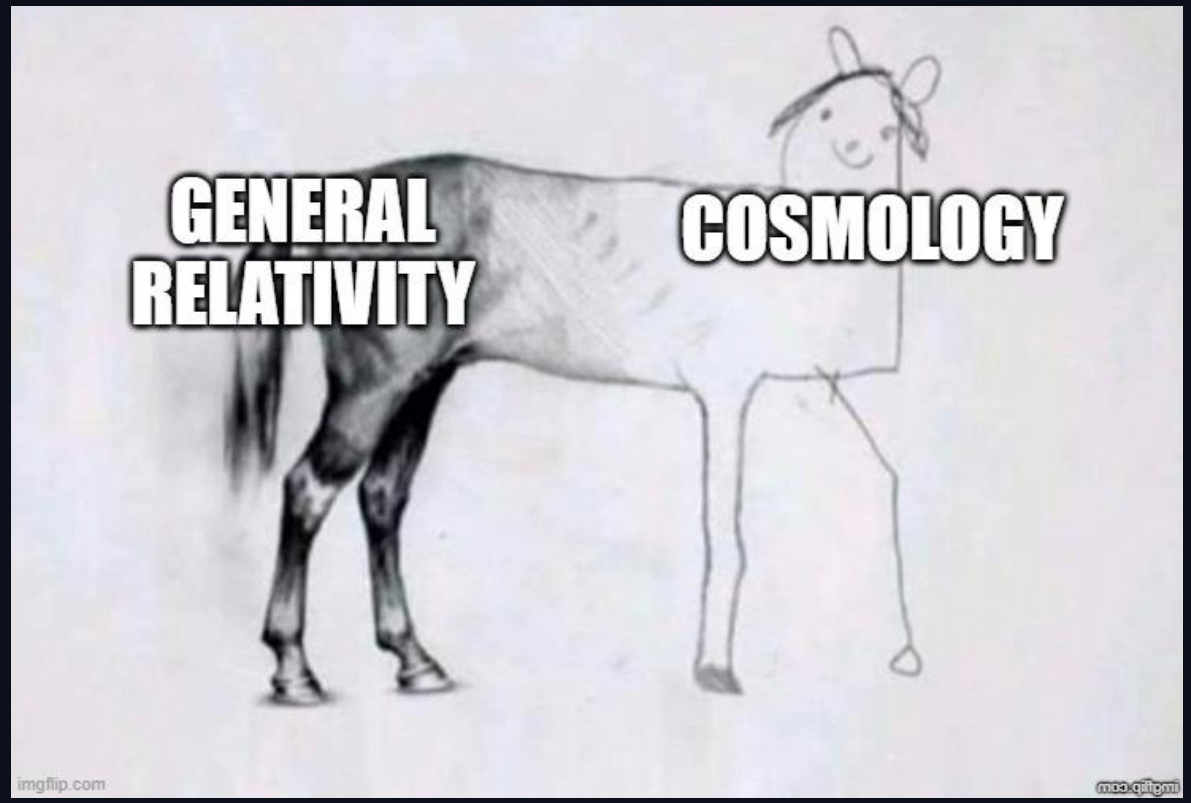
Using Newman-Penrose Weyl scalar , rotation introduces angular asymmetry , distorting the DE profile at the equator. $w(r, \theta)$

Motivation, Model , Summary , all in 1 Picture:

FLASH TALK SUMMARY

Core Results

Our Model EoS smoothly connects cosmological constants with strong-field modified dark energy near black hole horizons.



Observational Signature

Provides an analytical mechanism for DE accretion, opening pathways to test BH mass growth & gravitational wave ringdown shifts.

A fully covariant framework bridging cosmology and local strong gravity physics

Thank you for listening! Questions & Discussion welcome.