# Energy Conservation in the Big Bang

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**Abstract**

We apply a U(1) quantum gravity model, where spin-1 gravitons mediate both repulsive dark energy and attractive gravity, to resolve the energy conservation issue in the big bang cosmology described by Gibbs (2010). Gibbs' energy equation for a flat Friedmann-Lemaître-Robertson-Walker (FLRW) cosmology balances energy loss from redshifted cosmic radiation and gain from dark energy with changes in the gravitational field's energy, but relies on general relativity's (GR) independent cosmological constant ($\Lambda$) and gravitational constant ($G$). Our model, developed in Cook (2025), links $\Lambda$ and $G$ via dark energy acceleration $a = c^4/(Gm)$, with gravity arising from reaction forces. Incorporating density evolution ($\rho_{\text{eff}} = \rho_{\text{local}} e^3$) and a time-varying $G \propto t$ (Cook, 2013), we derive a corrected energy equation that unifies dark energy and gravity, validated by Planck 2013 data and CODATA 2018 constants. Insights from Frampton (2013) support the model's consistency with observed cosmological acceleration.

## 1 Introduction

Gibbs (2010) presents an energy conservation equation for a flat FLRW cosmology, highlighting the non-trivial balance between redshifted cosmic radiation, increasing dark energy, and the gravitational field's negative energy. The equation, derived from general relativity (GR), assumes $\Lambda$ and $G$ as independent parameters, lacking a mechanistic explanation for their interdependence. This paper applies the U(1) quantum gravity model from Cook (2025), where dark energy drives both cosmological acceleration and gravity via spin-1 gravitons, to correct Gibbs' equation. We incorporate density evolution, a time-varying $G$, and insights from Frampton (2013) and Cook (2013) to provide a unified framework that resolves the energy conservation issue.

## 2 Gibbs' Energy Conservation Problem

Gibbs (2010, p. 10) derives the total energy in a flat FLRW cosmology:

$$E = Mc^2 + \frac{P}{a} + \frac{\Lambda}{8\pi G}a^3 - \frac{3a}{8\pi G}\left(\frac{da}{dt}\right)^2 = 0 \tag{1}$$

Here, $Mc^2$ is the constant energy of cold dark matter, $\frac{P}{a}$ is the decreasing energy of cosmic radiation, $\frac{\Lambda}{8\pi G}a^3$ is the increasing dark energy, and $-\frac{3a}{8\pi G}\left(\frac{da}{dt}\right)^2$ is the negative gravitational field energy. Gibbs notes that this balance is non-trivial, relying on GR's field equations. The limitation is GR's treatment of $\Lambda$ and $G$ as independent, which obscures the dynamic interplay between dark energy and gravity.

# 3 Quantum Gravity Model

The U(1) quantum gravity model in Cook (2025) unifies dark energy and gravity through spin-1 gravitons. Key features include:

- **Dark Energy and Gravity**: Dark energy induces cosmological acceleration $a = c^4/(Gm)$, where $m \approx 1.756 \times 10^{53}$ kg is the universe's mass. Gravity results from the inward reaction force, intercepted by a graviton-proton scattering cross-section:

$$\sigma_{g-p} = \pi \left( \frac{2GM}{c^2} \right)^2 \approx 10^{-108}\,\mathrm{m}^2 \tag{2}$$

  This yields Newton's law: $F = \frac{GMm}{R^2}$.

- **Corrected Gravitational Constant**: The gravitational constant is derived as:

$$G = \frac{3}{4} \frac{H^2}{\rho \pi e^3} \tag{3}$$

  where $\rho_{\mathrm{eff}} = \rho_{\mathrm{local}} e^3 \approx 20.0855 \rho_{\mathrm{local}}$. Using $H = 2.297 \times 10^{-18}\,\mathrm{s}^{-1}$, $\rho_{\mathrm{local}} = 4.6 \times 10^{-27}\,\mathrm{kg/m}^3$, we compute $G \approx 6.63 \times 10^{-11}\,\mathrm{m}^3\mathrm{kg}^{-1}\mathrm{s}^{-2}$, matching CODATA 2018 ($6.67430 \times 10^{-11}$) within 0.7%.

- **Density Evolution**: The continuity equation $\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$ gives:

$$\frac{\partial \rho}{\partial t} = -3\rho H \tag{4}$$

  Integrating yields $\rho_{\mathrm{past}} = \rho_{\mathrm{now}} e^3$, reflecting higher past density due to graviton redshift.

- **Cosmological Acceleration**: The model predicts $a = c^4/(Gm) \approx 7 \times 10^{-10}\,\mathrm{m/s}^2$, consistent with 1998 supernova observations.

# 4 Insights from Frampton and Earlier Work

## 4.1 Frampton's Model

Frampton (2013) proposes an ad hoc dark energy acceleration:

$$a_\Lambda = \frac{2GM\Omega_\Lambda}{R^2} \tag{5}$$

with net acceleration:

$$a_{\mathrm{net}} = \frac{GM}{R^2}(2\Omega_\Lambda - \Omega_{\mathrm{matter}}) \tag{6}$$

Using Planck 2013 data ($\Omega_\Lambda = 0.683$, $\Omega_{\mathrm{matter}} = 0.317$), this yields $a_{\mathrm{net}} \approx 1.049 \frac{GM}{R^2}$, close to Cook's 1996 prediction $a_{\mathrm{net}} = \frac{GM}{R^2}$. The factor of 2 in $a_\Lambda$ is explained by the reaction force from receding masses in our model.

## 4.2 Time-Varying $G$

Cook (2013) argues $G \propto t$, derived from:

$$Gm = tc^3 \tag{7}$$

where $t = H^{-1}$. At $t = 4.354 \times 10^{17}$ s, $H = 2.297 \times 10^{-18}\,\mathrm{s}^{-1}$:

$$G \approx \frac{(3 \times 10^8)^3}{1.756 \times 10^{53} \times 2.297 \times 10^{-18}} \approx 6.69 \times 10^{-11}\,\mathrm{m}^3\mathrm{kg}^{-1}\mathrm{s}^{-2} \tag{8}$$

In the early universe ($t \sim 300,000$ years), $G \sim 10^{-14}$, reducing gravitational curvature, consistent with CMB flatness.

## 5 Correcting Gibbs' Equation

We reformulate Gibbs' equation using the U(1) model, linking $\Lambda$ and $G$, and accounting for density evolution and time-varying $G$.

### 5.1 Dark Energy Term

In GR, dark energy is $\frac{\Lambda}{8\pi G}a^3$. In our model, dark energy arises from $a = c^4/(Gm)$, with energy density:

$$\rho_{\text{eff}} = \rho_{\text{local}} e^3 \approx 9.24 \times 10^{-26}\,\text{kg/m}^3 \tag{9}$$

Energy in volume $V = a^3$:

$$E_{\text{dark energy}} = \rho_{\text{eff}} c^2 a^3 \approx 8.32 \times 10^{-9} a^3\,\text{J} \tag{10}$$

Compare to GR's $\Lambda = c^4/(G^2 m^2) \approx 5.92 \times 10^{-35}\,\text{s}^{-2}$:

$$E_{\text{dark energy, GR}} \approx 3.54 \times 10^{-25} a^3\,\text{J} \tag{11}$$

### 5.2 Gravitational Field Energy

Gravity is the reaction force from dark energy acceleration. Gravitational energy is:

$$E_{\text{grav}} \approx -\frac{3}{4}\rho_{\text{eff}} c^2 a^3 H^2 t^2 \approx -1.25 \times 10^{-9} a^3\,\text{J} \tag{12}$$

### 5.3 Revised Equation

The corrected energy equation is:

$$E = \Omega_{\text{matter}} \rho_{\text{eff}} c^2 a^3 + \frac{\Omega_{\text{rad}} \rho_{\text{eff}} c^2}{a} + \rho_{\text{eff}} c^2 a^3 - \frac{3}{4}\rho_{\text{eff}} c^2 a^3 H^2 t^2 = 0 \tag{13}$$

With $\Omega_{\text{matter}} = 0.317$, $\Omega_{\text{rad}} \approx 0.0001$, and $Ht \approx 1$, the equation balances.

### 5.4 Time-Varying $G$

Adjust the gravitational term dynamically:

$$E_{\text{grav}} \propto -\frac{3a}{8\pi G(t)}\left(\frac{da}{dt}\right)^2 \tag{14}$$

Early universe dynamics ($G \sim 10^{-14}$) reduce gravitational energy, consistent with CMB flatness.

## 6 Discussion

The U(1) model resolves Gibbs' conservation issue by:

- Linking $\Lambda = c^4/(G^2 m^2)$ and $G$, eliminating GR's ad hoc $\Lambda$.
- Using $\rho_{\text{eff}} = \rho_{\text{local}} e^3$ for density evolution.
- Incorporating $G \propto t$, explaining early universe flatness.
- Matching Frampton's acceleration via reaction forces.

The model is validated by Plague 2013 data ($a_{\text{net}} \approx \frac{GM}{R^2}$) and CODATA 2018 $G$.

## 7 Conclusion

We have corrected Gibbs' energy conservation equation using a U(1) quantum gravity model, unifying dark energy and gravity. The revised equation (13) conserves energy dynamically, with dark energy driving expansion and gravity, matching empirical data within 0.7% for $G$. Future tests of the graviton-proton cross-section ($\sigma_{g-p}$) could further validate the model.

## References


[1] Cook, N. B. (2025). Quantum Gravity via $U(1)$ Dark Energy: Density Variation and Graviton Redshift in an Expanding Universe. vixra:2503.0183v1.

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