

Novel Proposal of the Cosmological Constant: Dark Energy, Dark Matter, and the Accelerated Expansion of the Universe

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ABSTRACT: Recent observations from the James Webb Space Telescope (JWST) have intensified the long-standing tension in measurements of the Hubble constant and have raised questions about the completeness of the standard cosmological-constant description of dark energy. The Λ CDM model successfully accounts for a wide range of large-scale observations by combining ordinary matter, radiation, cold dark matter, and a cosmological constant Λ . Nevertheless, the physical origin of Λ remains unsettled: the observed magnitude of the vacuum energy density is many orders of magnitude smaller than naïve quantum-field estimates. This paper examines the conceptual relationships among cosmological distance, recession velocity, dark matter, dark energy, and the cosmological constant. We emphasize that dark matter and dark energy play distinct dynamical roles—dark matter contributes gravitationally to structure formation and early deceleration, while dark energy drives the late-time acceleration of cosmic expansion. We introduce a phenomenological density-ratio parameter $L \equiv \rho_{DE} / \rho_{DM}$ as a flexible diagnostic of the relative importance of the two dark components. Building on this ratio, we propose a revised expansion relation that recovers the conventional low-redshift Hubble law while allowing a density-dependent modification at larger distances. Any such alternative must ultimately be tested against the established observational constraints provided by Type I supernovae, baryon acoustic oscillations, the cosmic microwave background, and large-scale structure surveys.

KEYWORDS: cosmological constant; dark energy; dark matter; cosmic expansion; Hubble parameter; cosmological distance; vacuum energy; James Webb Space Telescope

1. INTRODUCTION

The discovery that the expansion of the Universe is accelerating constitutes one of the most significant developments in modern cosmology. Within the standard Λ CDM framework this acceleration is attributed to dark energy, most commonly represented by a cosmological constant Λ . Although the model furnishes an effective description of a broad suite of observations, the fundamental nature of dark energy remains unknown.

The conceptual difficulty is not merely observational. It also concerns the relationship between geometry, dynamics, and energy content in general relativity. Cosmological distance is not simply the product of a fixed length scale and a velocity. The measured distance between two objects depends on the chosen distance measure (luminosity distance, angular-diameter distance, etc.), on the entire expansion history of the Universe, and on the spacetime geometry through which light propagates. Likewise, the recession velocity of a distant galaxy is not an ordinary Newtonian velocity; it is an apparent velocity induced by the expansion of space itself.

Recent high-redshift observations by the James Webb Space Telescope have sharpened existing tensions, particularly the discrepancy between early-universe and late-universe determinations of the Hubble constant H_0 . These tensions suggest that the simplest constant- Λ description may be incomplete and that a more flexible parametrization of the dark sector could be required. The purpose of the present paper is to clarify the physical meaning of several related quantities and to develop a phenomenological relationship among cosmological distance, expansion velocity, dark matter, and dark energy. We do not treat dark matter and dark energy as interchangeable; rather, we emphasize their distinct dynamical roles and explore whether a density-based ratio can serve as a useful parameter in a revised expansion law.

2. DISCUSSION: MOTIVATIONS FROM OBSERVATIONAL TENSIONS

Although the Hubble constant has been a cornerstone of observational cosmology for more than a century, the persistent “Hubble tension” and the new high-redshift data delivered by JWST have reopened questions about the adequacy of a strictly constant Λ . In the standard picture the cosmic expansion rate evolves because the relative densities of the various energy components change with time. Matter density scales as $\rho_m \propto a^{-3}$ (where a is the scale factor), while a pure cosmological constant maintains a constant energy density. Consequently the ratio of dark-energy density to matter density grows as the Universe expands, eventually allowing dark energy to dominate the late-time dynamics.

In general relativity the cosmological constant Λ has dimensions of inverse length squared, whereas the density parameters Ω_i that appear in the Friedmann equation are dimensionless. Any phenomenological ratio constructed from energy densities must therefore be handled with care if it is to be inserted into an expansion law that also involves distance and velocity. The novel conceptual strength of the framework proposed here is that

it explicitly links the onset of cosmic acceleration to the evolving density balance between matter (including dark matter) and dark energy.

3. A NOVEL DENSITY-RATIO FORMULATION

3.1 The density-ratio parameter L

We introduce a dimensionless dominance parameter that measures the relative importance of dark energy and dark matter:

$$L \equiv \rho_{DE} / \rho_{DM}.$$

In a flat Λ CDM universe this ratio is simply related to the conventional density parameters:

$$L(a) = (\Omega_{\Lambda} / \Omega_m) a^3,$$

where Ω_{Λ} and Ω_m are the present-day density parameters of dark energy and total matter, respectively. The parameter has a transparent interpretation:

- $L < 1$: matter density exceeds dark-energy density;
- $L = 1$: matter and dark energy contribute equally;
- $L > 1$: dark energy dominates.

The equality epoch therefore occurs when $L = 1$, i.e., at the scale factor

$$a_{eq} = (\Omega_m / \Omega_{\Lambda})^{1/3}.$$

The corresponding redshift is

$$z_{eq} = (\Omega_{\Lambda} / \Omega_m)^{1/3} - 1.$$

Cosmic acceleration begins when the total effective equation-of-state combination $(\rho + 3p)$ becomes negative. For a matter-plus- Λ universe the transition occurs somewhat earlier than the equality epoch, at roughly $\Omega_m a^{-3} \approx 2 \Omega_{\Lambda}$.

3.2 Revised relation between distance and recession velocity

At low redshift the standard Hubble law reads

$$v \approx H_0 d,$$

or equivalently $d \approx v / H_0$, where H_0 has dimensions of inverse time. The inverse quantity $t_H = 1/H_0$ is the Hubble time—a characteristic timescale of cosmic expansion, though not identical to the age of the Universe.

Motivated by the desire to incorporate the evolving density balance, we propose a phenomenological generalization in which the effective conversion factor between distance and velocity depends on the density ratio L :

$$d = (c / H_{eff}) \cdot f(L) \cdot (v/c),$$

where c is the speed of light, H_{eff} is an effective expansion rate that reduces to H_0 at low redshift, and $f(L)$ is a dimensionless function of the density ratio that approaches unity when $L \ll 1$ (matter-dominated regime) and grows when $L \gtrsim 1$ (dark-energy-dominated regime). In the simplest linear ansatz one may write

$$H_{eff}(L) = H_0 / (1 + \alpha L),$$

with α a dimensionless coupling constant of order unity to be constrained by data. This form recovers the conventional Hubble law at small L while permitting a density-dependent modification at the redshifts where dark energy becomes important. The construction is deliberately phenomenological; a fully relativistic derivation from a modified stress-energy tensor or from a dynamical dark-energy field remains a task for future work.

3.3 Consistency with the onset of acceleration

Because L scales as a^3 , the proposed H_{eff} decreases relative to a pure matter-dominated Hubble rate once dark energy begins to dominate. This reduction in the effective expansion rate is precisely the behaviour required to produce late-time acceleration when the second derivative of the scale factor is examined. Thus the same density ratio that diagnoses the relative abundance of the two dark components also supplies a natural mechanism for the transition from deceleration to acceleration, without invoking an independent ad-hoc time dependence for Λ itself.

4. REQUIRED OBSERVATION

Any alternative to the constant- Λ paradigm must confront the same precision data that currently support Λ CDM. In particular, the proposed density-ratio formulation should be confronted with:

- the magnitude–redshift relation of Type Ia supernovae;
- the angular scale of the baryon acoustic oscillation feature measured by large-scale structure surveys;
- the temperature and polarization power spectra of the cosmic microwave background;
- the growth rate of cosmic structure as probed by redshift-space distortions and weak gravitational lensing.

Only after such future observation can one decide whether our novel density-dependent effective parameter improves the global fit relative to standard Λ CDM, or whether the residual tensions are better addressed by other extensions (early dark energy, modified gravity, interacting dark sectors, etc.).

5. CONCLUSION

We have reformulated the conceptual relationship among cosmological constant in ratio scale presentation with recession velocity, dark matter, and dark energy by introducing our novel density ratio constant $L = \rho_{DE} / \rho_{DM}$ as a phenomenological diagnostic. Because matter density dilutes as a^{-3} while a cosmological-constant density remains, as a result L grows with expansion and naturally explains the late-time dominance of dark energy. By allowing the effective conversion between distance and velocity to depend on L , one obtains a flexible generalization of the Hubble law that recovers the standard low-redshift limit while accommodating a density-dependent modification at higher redshift. We emphasize that our novel construction of new LCDM can be sustained by future observation by James Webb. Nevertheless, the density-ratio perspective offers

a compact and unifying language for describing the dynamical distinction between dark matter and dark energy. It clarifies how the relative evolution of their energy densities governs the transition from matter-dominated deceleration to dark-energy-dominated acceleration: as the Universe expands, the matter density decreases relative to the dark-energy density, eventually allowing dark energy to dominate the cosmic energy budget and drive accelerated expansion.

It is hoped that the present discussion will stimulate further theoretical development and observational confrontation of density-ratio formulations of the dark sector.

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