Alternative Models for Accelerating Universe

Different model types to quickly navigate the landscape of alternatives to a pure cosmological constant Λ.

⭐ 1. Emergent / "Effective" Dark Energy (No Fundamental DE Field)

These models try to *generate* acceleration from structure, particle-creation effects, or non-standard effective pressures—often without an explicit scalar-field or Λ term.

1.1 Emergent dark energy from new physics

- **Ben-Dayan & Kumar (2023)** — *Emergent Unparticles Dark Energy*, JCAP 12 (2023) 047
  - Unparticle sector produces an effective late-time DE that can fit H_0 & S_8 tensions better than ΛCDM.

1.2 Phenomenological Emergent Dark Energy (PEDE)

- **Hernández-Almada et al. (2024)** — *Phenomenological emergent dark energy in the light of DESI DR1*, PDU 46 (2024)
  - Uses DESI BAO to re-evaluate PEDE vs ΛCDM.

1.3 Emergent DE from structure formation

- **Lapi et al., Part II (2025)** — *Emergent dark energy from structure formation*, JCAP 04 (2025)
  - Structures produce backreaction-like effects that mimic DE, reducing tensions.

1.4 Particle-creation–driven acceleration

- **Lima et al. (2025)** — *Accelerating cosmology without dark energy*, EPJC 85 (2025)
  - Acceleration arises from gravitational particle creation + RRG model; no DE fluid.

⭐ 2. Dynamical Dark Energy ($w(z) \neq -1$)

These explicitly assume DE is a field or fluid with time-varying equation of state—CPL, phantom crossing, etc.

2.1 DESI DR1 → preference for w(z) evolution

- **Giarè et al. (2024)** — *Robust preference for Dynamical Dark Energy*, JCAP 2024
  - Finds ~3σ evidence for evolving w after marginalizing systematics.

2.2 DESI 2024 / DESI + Planck + SNe analysis

- **Roy (2025)** — *Dynamical dark energy in the light of DESI 2024*, PDU 48 (2025)
  - Uses w(a) parameterization showing phantom crossing; reduces H_0 tension.

2.3 DESI DR2 flagship Nature Astronomy paper

- **Gu et al. (2025)** — *Dynamical dark energy in light of DESI DR2*, Nature Astronomy (2025)
  - Shows moderate Bayesian preference for w(z) evolution; strongest mainstream claim against Λ = const.

2.4 Physics-motivated DE families with DESI constraints

- **Lodha et al. (DESI Collaboration, 2025)** — *Physics-focused aspects of dark energy*, PRD 111 (2025)
  - Analyzes thawing, freezing, mirage, and other scalar-field families vs DESI BAO.

⭐ 3. Modified Gravity / Alternative Gravity Theories

These keep some form of DE optional or remove it entirely by modifying the gravitational sector.

3.1 Broad MG approaches to cosmic tensions

- **Di Valentino et al. (eds.) (2024)** — *Special Issue on Modified Gravity*, Universe 10 (2024)
  - Includes f(R), f(Q), scalar–tensor, Galileon, etc., many mimicking accelerations without Λ.

⭐ 4. Challenges / Re-examinations of the Evidence (Systematics-focused)

These do **not** propose new models but question whether the *data* prefers evolving DE or whether systematics mimic it.

4.1 Supernovae systematics may mimic w(z)

- **Efstathiou (2025)** — *Evolving dark energy or supernovae systematics?*, MNRAS 538 (2025)
  - Finds that evolving-DE evidence depends strongly on SN sample.

4.2 Internal consistency of DESI's BAO analysis

- **Wang (2024)** — *Self-consistency of DESI analysis*, arXiv:2404.13833
  - Argues dynamical-DE claims may be sensitive to modeling choices.

⭐ 5. Meta-Analyses / Reviews (Context, not new models)

5.1 Review of w(z) constraints (2023–2024)

- **Escamilla et al. (2024)** — *State of the dark energy equation of state*, JCAP 05 (2024)
  - Summarizes emergent, interacting, scalar-field, and MG models vs current data.

5.2 PDG Dark Energy review

- **Turner & Huterer (2023)** — *Dark Energy*, PDG Review
  - Good baseline: reviews why acceleration is robust but microphysics is open.

🎯 What this organization tells you

1. The "alternative explanation" side:

- Emergent DE papers (Ben-Dayan; Lapi; Lima) aim to remove the need for a cosmological constant.
- Modified-gravity papers (Universe 2024 issue) change Einstein's equations instead of adding DE.

2. The "Λ works but w varies" side:

- DESI DR1/DR2 papers (Giarè, Roy, Gu) provide the strongest statistical hints that $w(z) \neq -1$.

3. The "Check your systematics!" side:

- Efstathiou and Wang caution that some of the evolving-DE signature may be from SN calibration or BAO analysis subtleties.

4. The field is very active:

This is one of the hottest areas in cosmology—2023–2025 saw the strongest challenges to ΛCDM in over a decade.