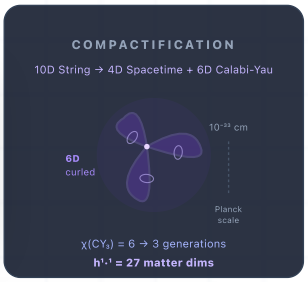
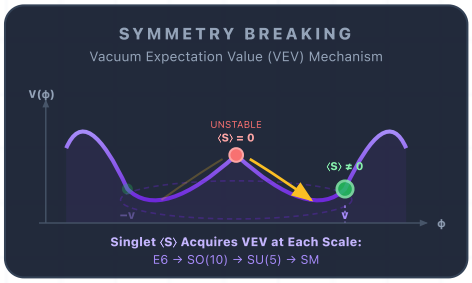
ENERGY / TEMPERATURE OF THE UNIVERSE

10^19 GeV
PLANCK SCALE

E8 × E8
HETEROTIC STRING THEORY
10 Dimensions • 496 Symmetries
Compactifies on Calabi-Yau Manifold → 4D Spacetime
Anomaly-Free in 10D (unique with SO(32))





HIDDEN SECTOR
MIRROR UNIVERSE
E8 • 248 Dimensions
Communicates Only via Gravity

VISIBLE SECTOR
OUR UNIVERSE BLUEPRINT
248 DIMS = 170 (Matter/Gravity) + 78 (Forces)

SPACETIME & MATTER

170 LEFTOVERS
GRAVITY & MATTER DIMS
- 162 Matter Dimensions
- 8 encode curvature of 6 extra dimensions

10^16 GeV
GUT SCALE

E6 GUT
78 FORCE DIMENSIONS
- Contains all Unified Gauge Bosons
- Acts on the 162 Matter Dimensions
- SUSY enables gauge coupling unification here

GEOMETRIC TRIALITY

3 GENERATIONS
✓ OBS.
SO(8) TRIALITY SYMMETRY
- 27 Dims × 3 Families = 81 Dims
- (+ 81 Anti-Matter) = 162 Matter Total
- Calabi-Yau χ/2 = 3 (geometric origin)

COSMIC INFLATION
~10¹⁶ GeV — Both Sectors Inflate Space Simultaneously

Inflaton Candidates in E8×E8:
- Kähler/CY Moduli (extra-dimension shape fields)
- Singlet S flat direction (same field that breaks GUTs)
- Right-handed sneutrino ν̃_R (SUSY partner)

12 MISSING PER GEN

UNOBSERVED MATTER
PRED.
THE 12 EXOTIC SLOTS (27 – 15 SM = 12)
- 1 Right-Handed Neutrino (Seesaw → light ν)
- 6 Heavy Exotic Quarks (D, D^c)
- 4 Exotic Leptons (Yields the Higgs)
- 1 Singlet (S) Field = 12 Total

SO(10) → SU(5) → SM
THE FORCE SPLINTERING
E6(78) → SO10(45) → SU5(24) → SM(12)
(66 forces decouple as universe cools)
Breaking: 27→16-plet (SO10) → S singlet (SU5)
CP-violating decays → Baryogenesis (matter/antimatter asymmetry)

TRIGGERS BREAKING

THE SINGLET (S)
THE MASTER SWITCH
- Breaks GUT Symmetries
- Generates effective μ-term (NMSSM)
- Axion solves Strong CP problem

DARK MATTER: Axions (Unobserved)

DECOUPLED / HEAVY

66 EXOTIC FORCES
PRED.
78 (E6) – 12 (SM) = 66 GAUGE BOSONS
- 33 from E6: Z'/W' & Leptoquarks
- 21 from SO(10): X', Y' & Z' Bosons
- 12 from SU(5): X, Y (Proton Decay)

GAUGINO CONDENSATION
Breaks Supersymmetry

~1 TeV
SUSY BREAKING SCALE

R-PARITY (Z2) — DISCRETE REMNANT
STABILIZES THE UNIVERSE
- Forbids Proton Decay • Makes LSP Dark Matter Stable
- Dim-5,6 decay allowed: $\tau_p \sim 10^{34-36}$ yr (testable at Hyper-K)

SOFT SUSY MASSES

SUPERSYMMETRY
PRED.
SOFT MASSES AT ~1 TeV
- Every SM particle gets a superpartner
- Stabilizes Higgs mass (hierarchy problem)
- Required for gauge coupling unification

DARK MATTER: Lightest SUSY Particle (LSP)

Gravity-Mediated, M_Planck-Suppressed (Gravitinos)
GRAVITATIONAL CROSS-TALK

BREAKS EW SYMMETRY

HIGGS MECHANISM
✓ PARTIAL
ELECTROWEAK BREAKING
- Scalar superpartners of Exotic Leptons
- Contains the observed 125 GeV Higgs
- Breaks SU(2) × U(1) → U(1)_EM
- Gives Mass to W/Z Bosons & Fermions

100 GeV
ELECTROWEAK SCALE

SHADOW MATTER
PRED.
THE MIRROR UNIVERSE
- ~5x Mass of Visible Matter
- Interacts ONLY via Gravity

PRIMARY DARK MATTER COMPONENT

STANDARD MODEL
✓ CONF.
OUR LOW-ENERGY UNIVERSE
12 FORCE DIMS: Gluons(8), $W^{\pm}/Z(3)$, γ(1)
15 MATTER DIMS: Per Gen (15 × 3 = 45)



Visualized by Prof. Andy Haas, NYU Physics, 2026