w = -1.73 Solves the Hubble Tension But Destroys the Universe

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Background

- Present universe expansion rate H_0

  Thought to be 73 (km/sec)/Mpc

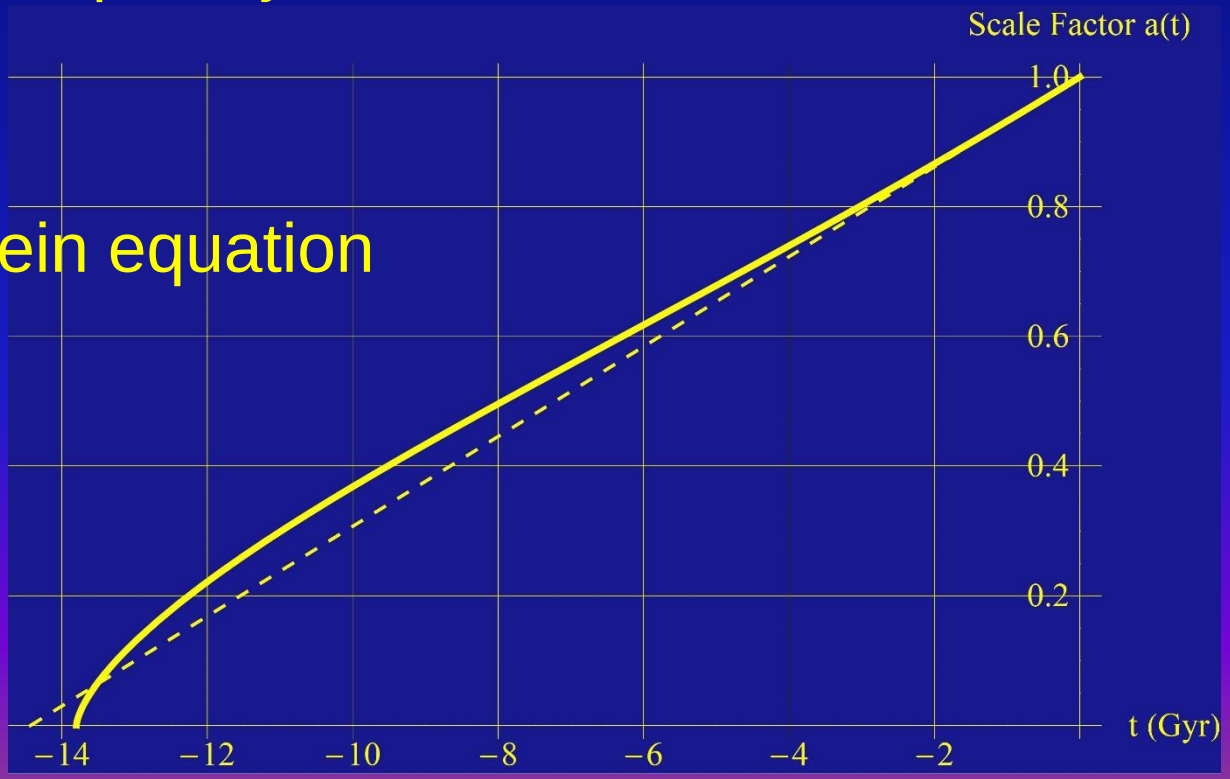
  But JWST reports 69.4
- Current theory: ΛCDM yields 68
- Serious discrepancy
- Many proposals for resolution
- $w < -1$ investigated in this presentation (wCDM)
- Units: $c = G = 1$

Thermodynamics Review

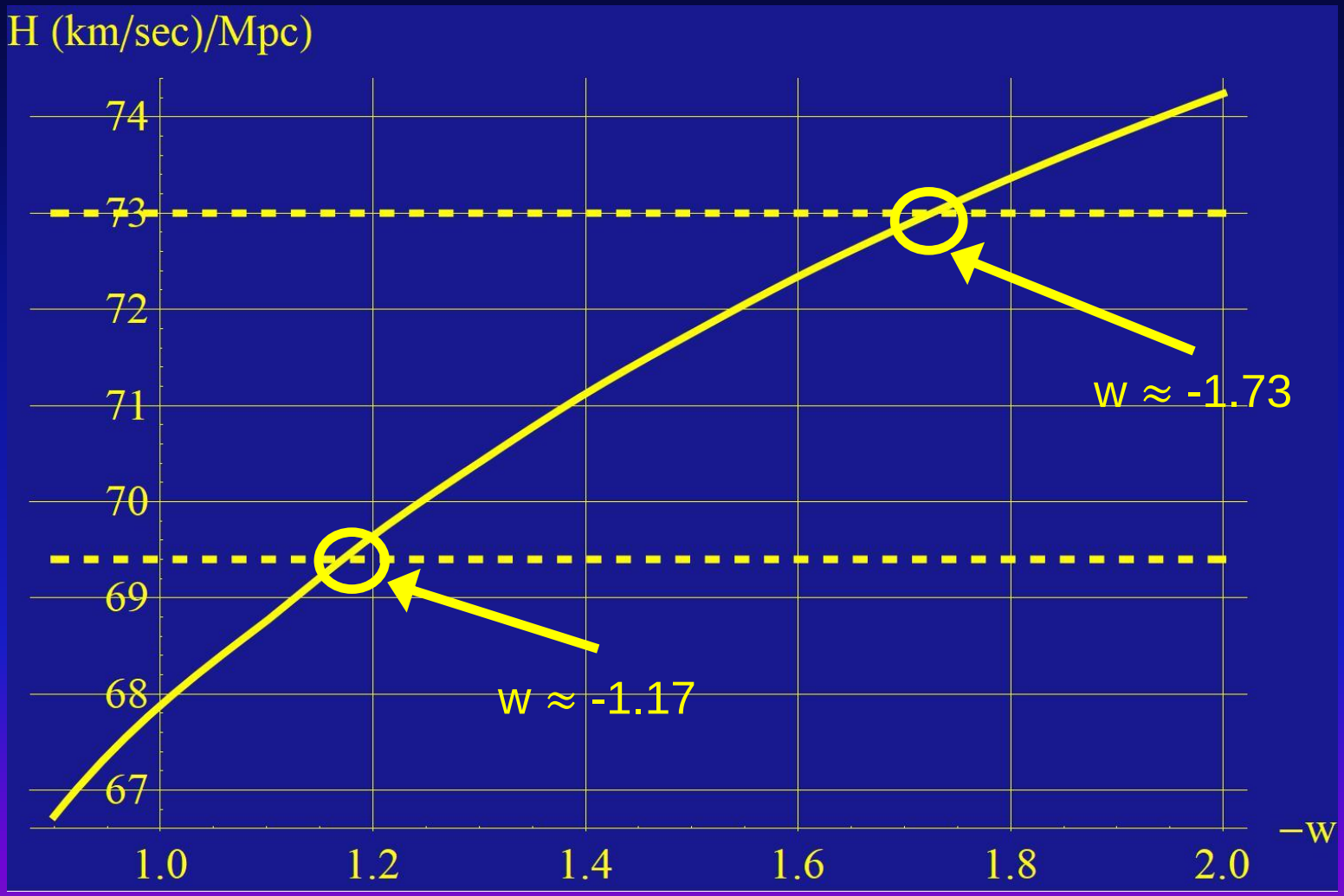
- Perfect fluid equation of state $p = w \rho_E$
- Conservation of energy yields $\rho \propto 1/V^{(w+1)}$
- Examples
  - Pure radiation: $w = \frac{1}{3}$, $\rho \propto 1/V^{4/3}$
  - Pressureless dust: $w = 0$, $\rho \propto 1/V$
  - Cosmological constant Λ: $w = -1$, $\rho = \text{const}$
  - ?: $w < -1$, ρ *grows* with V (How is this possible?)
- Perfect fluid with most negative w eventually dominates as universe expands

ΛCDM Model

- Assumptions
  - Age of the universe = 13.8 Gyr (13.8×10^9 yr)
  - Universe is spatially flat
  - $\Lambda/\rho = 2.3$
  - w = -1
- Solve Einstein equation

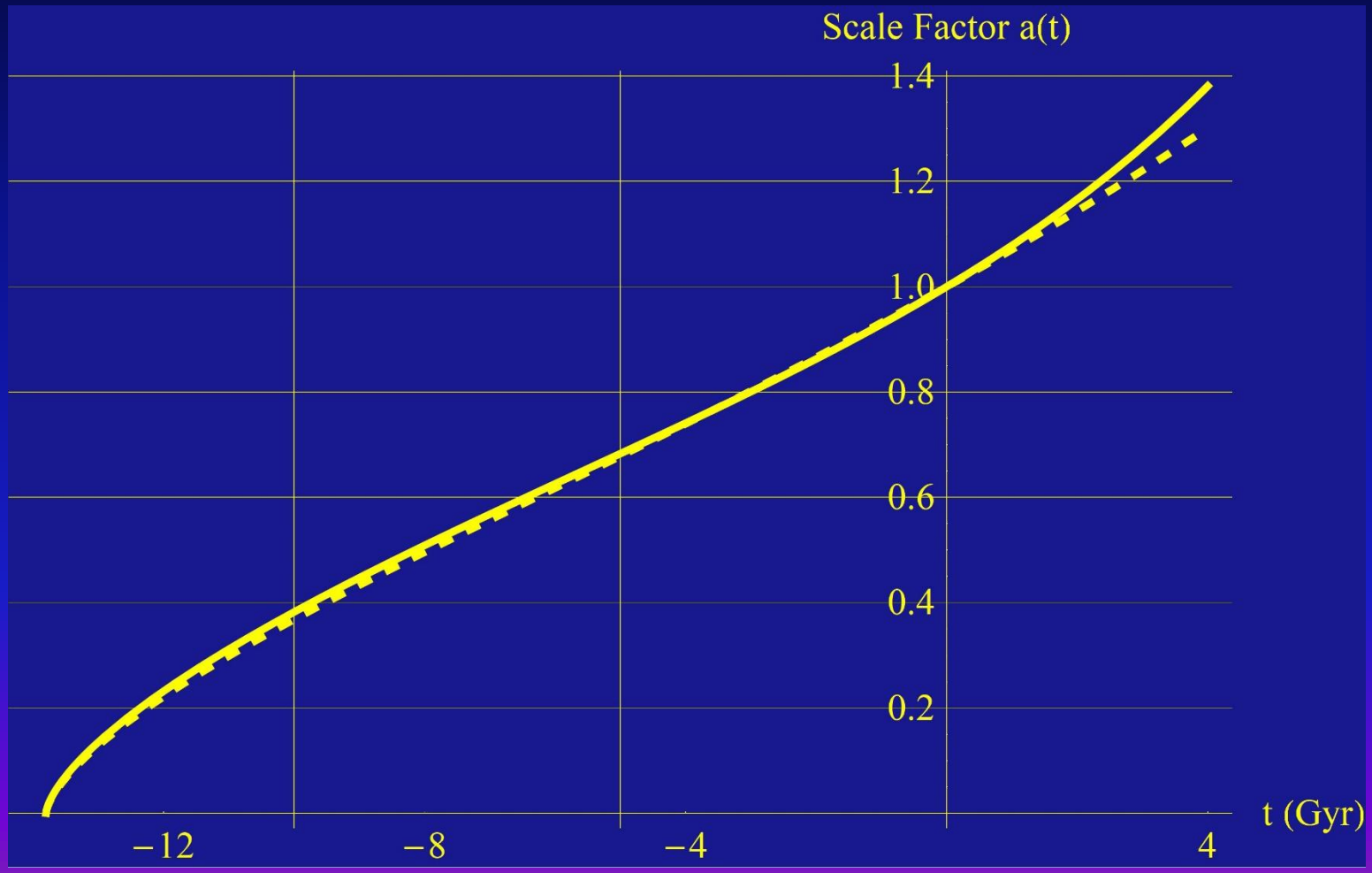


H_0 with $w \neq -1$



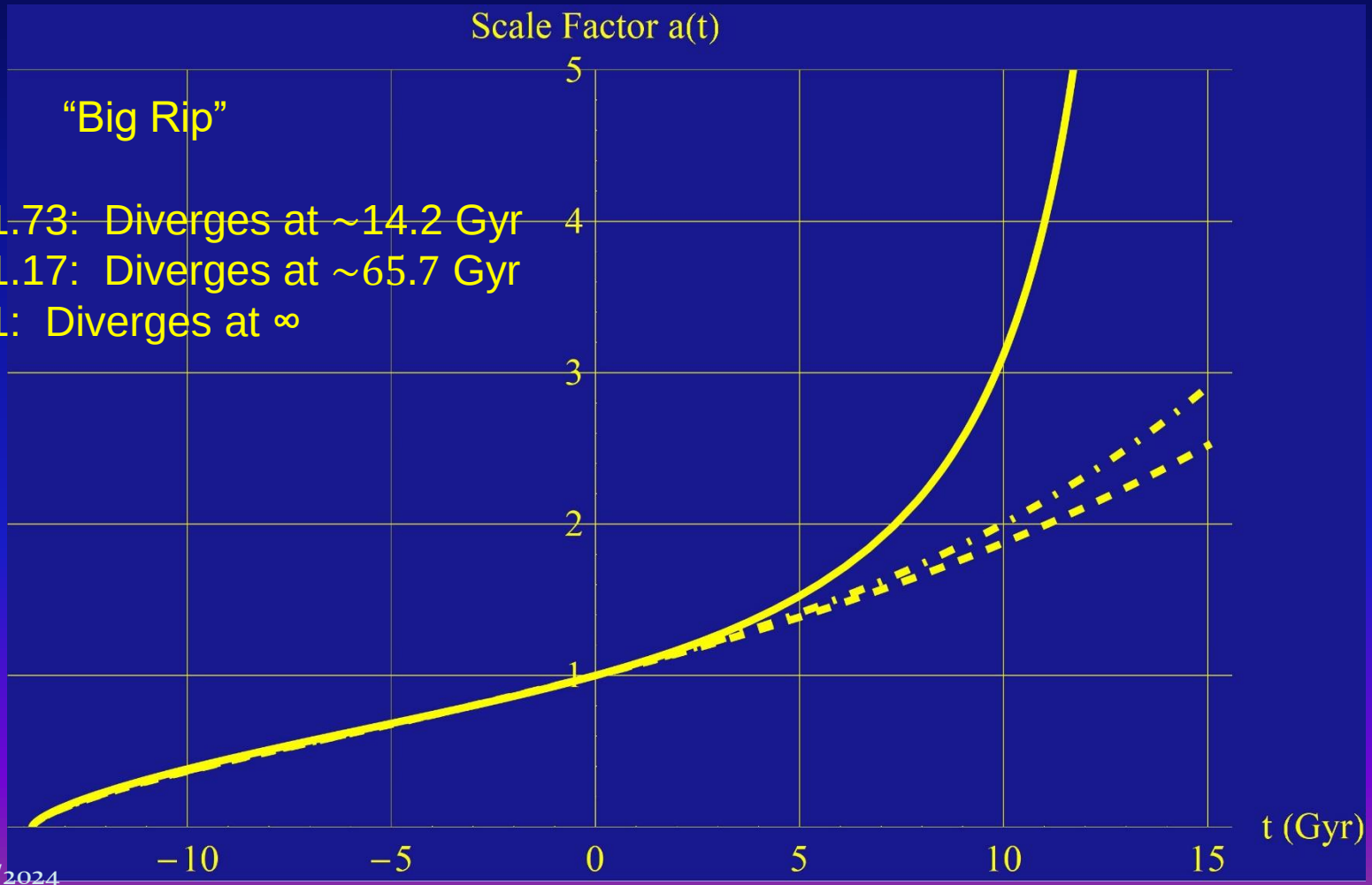
Calculated Expansion

Dotted: w = -1
Solid: w = -1.73



Future Expansion

Solid: w = -1.73
Dot-Dash: w = -1,17
Dash: w = -1



"Big Rip"

w = -1.73: Diverges at ~14.2 Gyr
w = -1.17: Diverges at ~65.7 Gyr
w = -1: Diverges at ∞

Late Universe
Expanding Single Perfect Fluid Models

- Most negative w fluid dominates
- $a(t) \propto t^{2/3(w+1)}$
  - $w > -1/3$: Expansion decelerates
  - $w = -1/3$: Expansion linear in t
  - $w < -1/3$: Expansion accelerates
- $w = -1$: Expansion exponential in t
- $w < -1$: Expansion diverges at finite $t = t_{RIP}$
  - $a(t) \propto (t_{RIP} - t)^{2/3(w+1)}$
  - $w = -1-x$, $x>0$: $a(t) \propto 1/(t_{RIP} - t)^{2/3x}$
  -

Just Before the End

w = -1.73

Event	Time to Big Rip
Unbind Clouds of Magellan	180 million yrs
Tear solar system from galaxy	12 million yrs
Tear earth out of orbit	6 days
Tear apart earth	18 minutes
Dark Pressure = -1 atmosphere	16 minutes
Dark energy = density of water	47 msec
Rips apart neutron star	50 μsec

Thank you!

- Dark energy Λ with w at $t = 0$

- $a(t)$ is scale factor

Metric, order is (t, r, θ, ϕ):

$$g_{\mu\nu} = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & a(t)^2 & 0 & 0 \\ 0 & 0 & r^2 a(t)^2 & 0 \\ 0 & 0 & 0 & r^2 a(t)^2 \sin^2(\theta) \end{pmatrix}$$

Einstein equation:

$$\begin{pmatrix} \frac{3a'(t)^2}{a(t)^3} & 0 & 0 & 0 \\ 0 & -\frac{2a(t)a''(t)+a'(t)^2}{a(t)^4} & 0 & 0 \\ 0 & 0 & -\frac{2a(t)a''(t)+a'(t)^2}{r^2 a(t)^4} & 0 \\ 0 & 0 & 0 & -\frac{\csc^2(\theta)\left(2a(t)a''(t)+a'(t)^2\right)}{r^2 a(t)^4} \end{pmatrix} =$$

$$= 8\pi \begin{pmatrix} \frac{\Lambda a(t)^{-3w}+\rho}{a(t)^3} & 0 & 0 & 0 \\ 0 & \Lambda w a(t)^{-3w-5} & 0 & 0 \\ 0 & 0 & \frac{\Lambda w a(t)^{-3w-5}}{r^2} & 0 \\ 0 & 0 & 0 & \frac{\Lambda w \csc^2(\theta) a(t)^{-3w-5}}{r^2} \end{pmatrix}$$