Cosmology and the origin of structure

Rocky I: The universe observed

Rocky II: The growth of cosmological structure

Rocky III: Inflation and the origin of perturbations

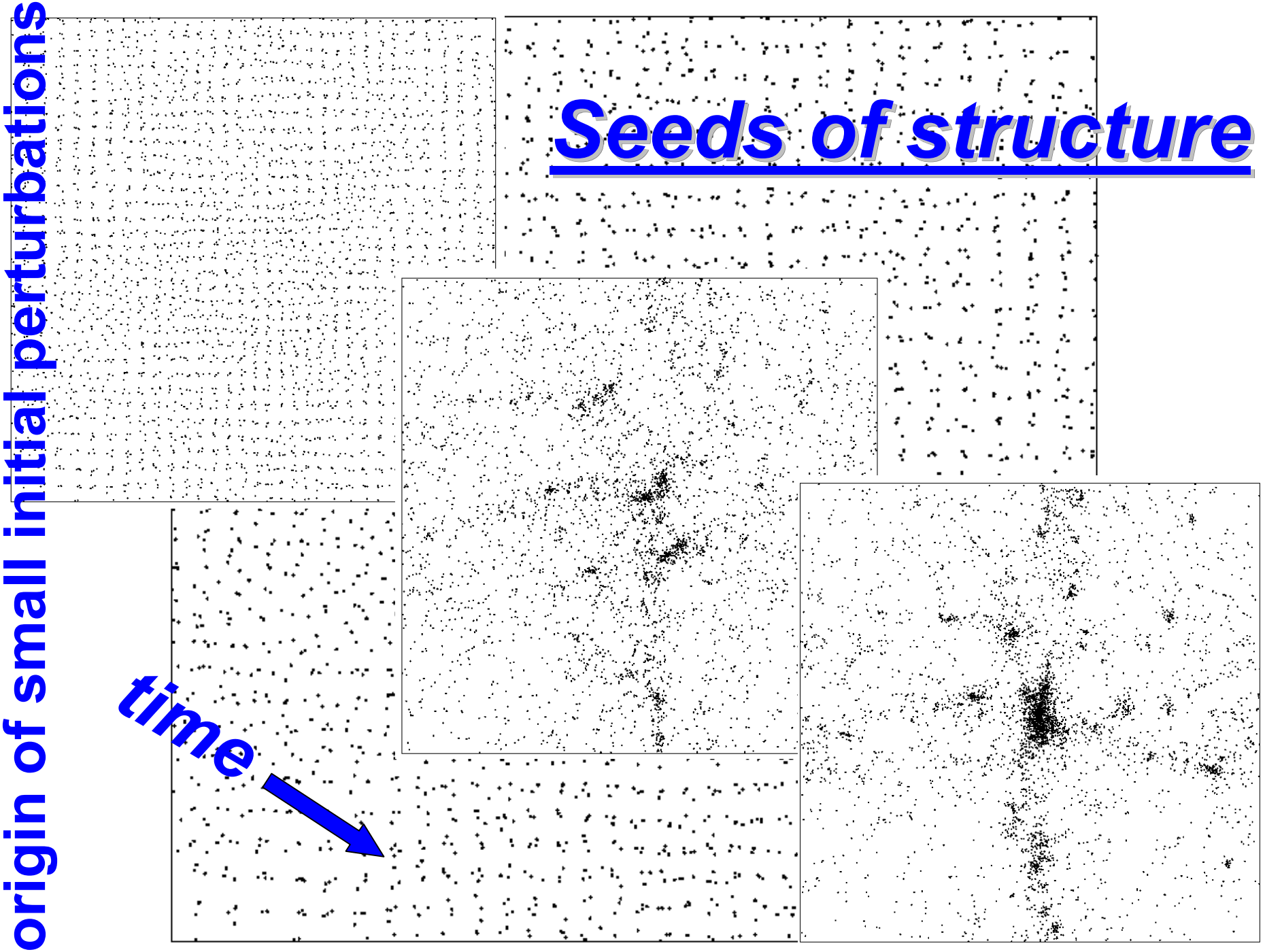
Rocky IV: Dark matter and dark energy

Academic Training Lectures

Rocky Kolb

Fermilab, University of Chicago, & CERN

Seeds of structure

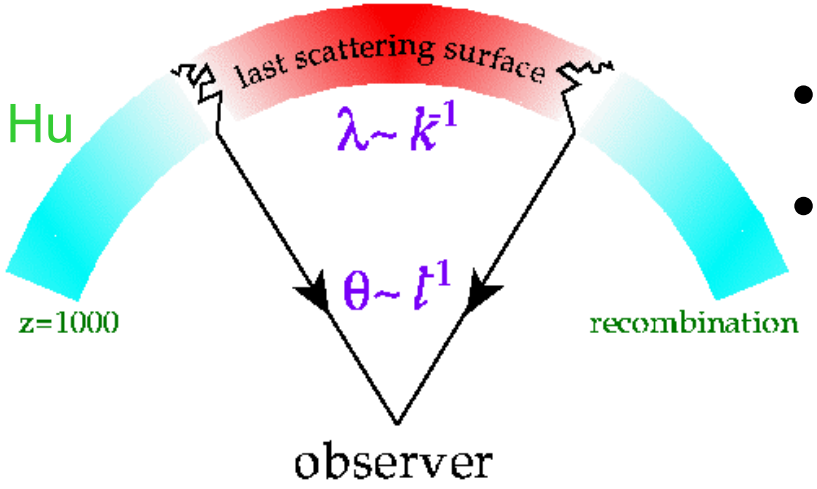


Rocky III: Inflation

- Motivation for “acausal” perturbations
- Inflation in the cosmic symphony
- The alarming phenomenon of particle creation
- Inflation phenomenology

Acoustic peaks

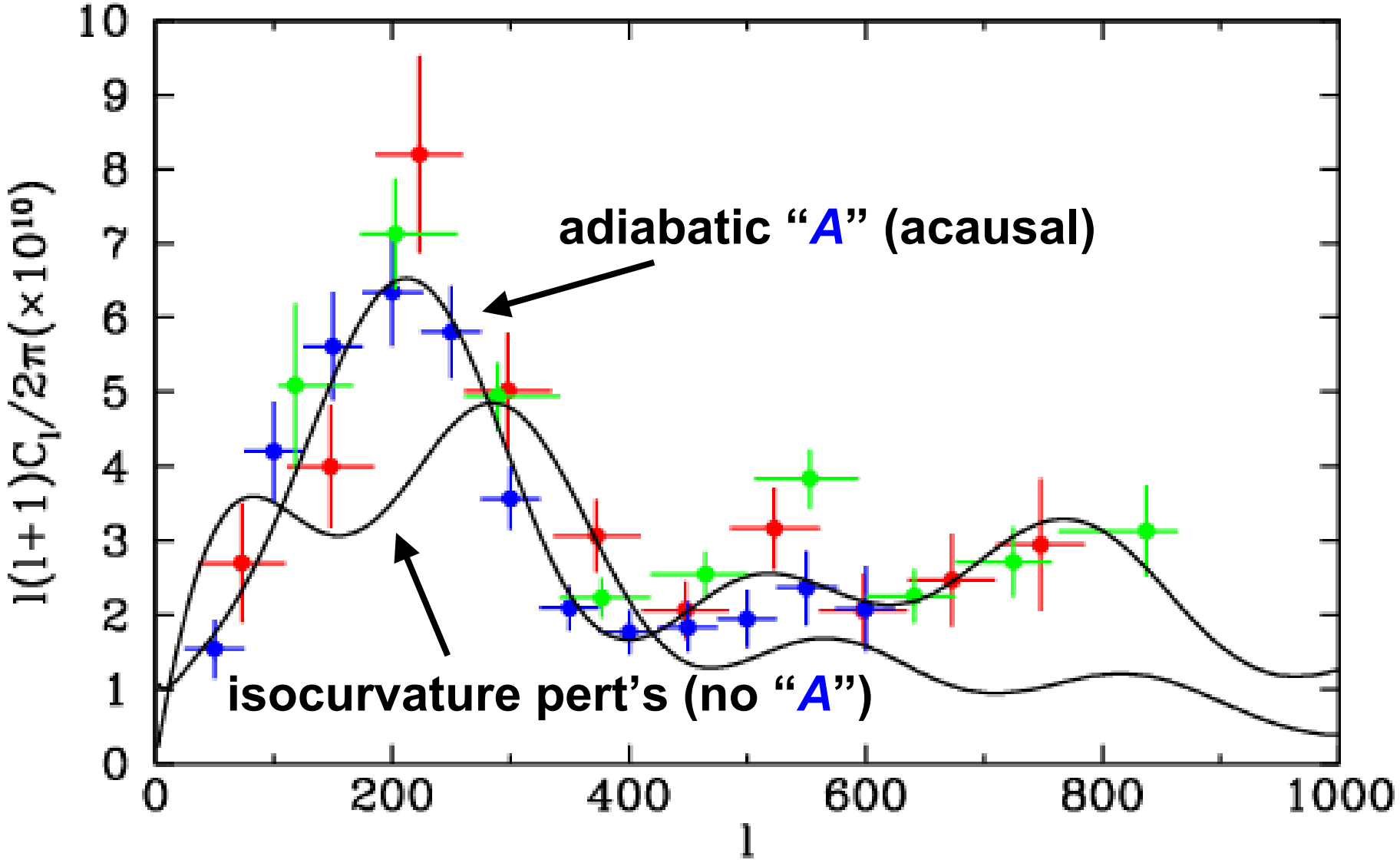
- At recombination, baryon–photon fluid undergoes "acoustic oscillations" $A\cos kt + B\sin kt$
- Compressions and rarefactions change T_γ
- Peaks in ΔT_γ correspond to extrema of compressions and rarefactions



- What are coefficients A & B ?
- A nonzero ⟶ perturbations in limit $kt_{\text{last-scattering}} \ll 1$

$$kt_{\text{last-scattering}} \ll 1 \Rightarrow \frac{t_{\text{last-scattering}}}{\lambda} \ll 1 \Rightarrow t_{\text{last-scattering}} \ll \lambda$$

Angular power spectrum



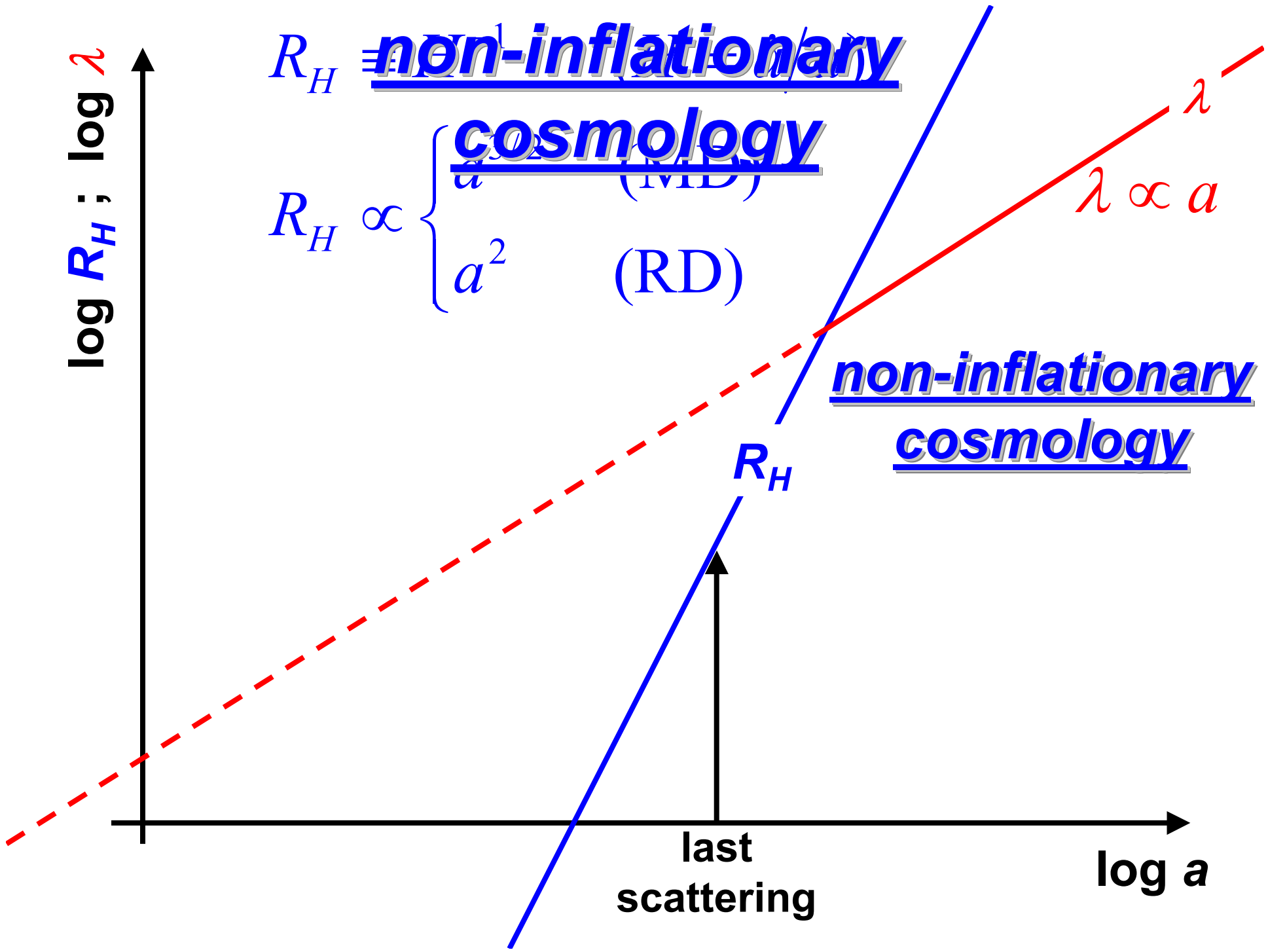
Input from the early universe

1. Spectrum of perturbations (power spectrum)

   CMB correlations on scales greater than Hubble radius ($R_H \sim ct$) ⟶ INFLATION

2. Matter content

   baryons, dark matter (cold, warm, hot), vacuum energy, ……


non-inflationary cosmology
$R_H \propto \begin{cases} a^2 & (\mathrm{MD}) \\ a^2 & (\mathrm{RD}) \end{cases}$
λ
$\lambda \propto a$
non-inflationary cosmology
R_H
log R_H ; log λ
last scattering
log a

log