

# MODELS OF THE UNIVERSE II

## 1. From Static to Expanding Universes

- ✓ • 1917: Einstein and a finite static model  
de Sitter and an empty expanding model
- ✓ • 1922: Friedmann and a dynamic universe
- ✓ • 1929: Hubble and the Expansion
- 1931: Lemaître and the Primeval Atom

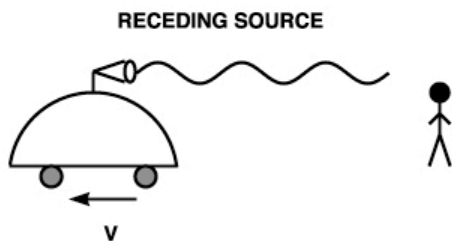
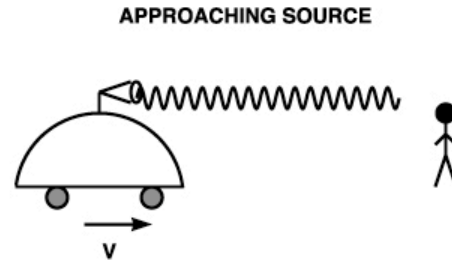
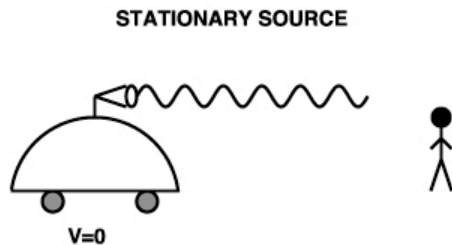
## 2. The Big Bang Model

- 1948: Steady-State universe
- 1948: The BB model
- 1965: Confirmation of BB model
- Limitations of the BB model

- 1929: Hubble discovers expansion

finally some data to guide theory!!

Hubble's expansion law:  $V(t) = H D(t)$ ,  $H$  is Hubble's const.



Far away galaxies are receding with velocity proportional to distance!!

\* but problems with age...

\* Assumes a constant expansion rate

\* Galaxies as standard candles OK?

- 1931: Lemaître proposes the “Primeval Atom” model

## 2. The Big Bang Model

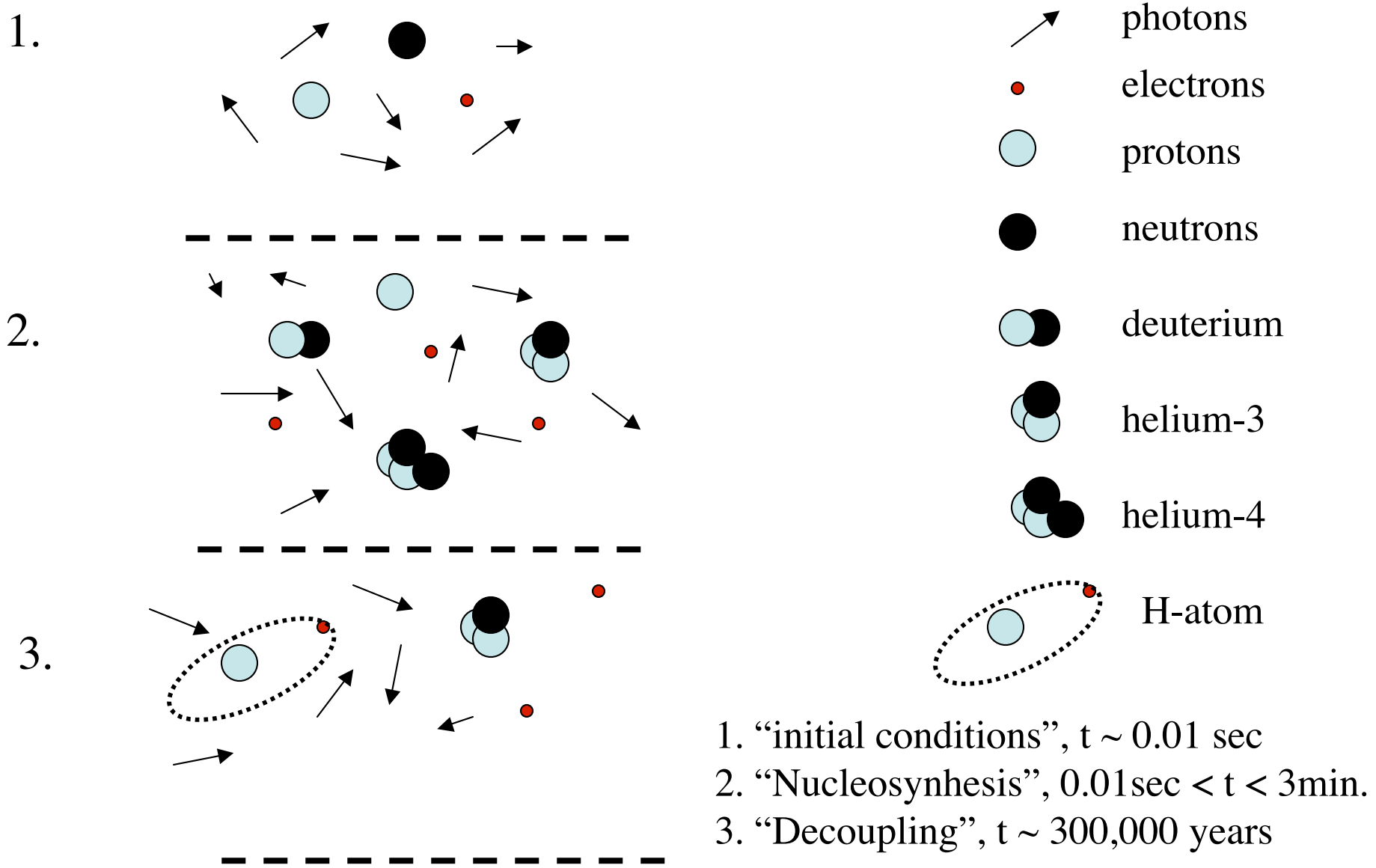
- 1948: Steady-state model: Hoyle, Bondi and Gold  
uncomfortable with “origin” problem  
➔ “perfect cosmological principle”: universe always same  
(but...violation of energy conservation!)

- 1948: George Gamow: Universe was hot and dense in the  
“beginning”, filled with PRIMORDIAL SOUP  
Primordial soup = photons, protons, neutrons, electrons, neutrinos

### PREDICTIONS:

- 1) existence of “cosmic microwave background radiation”
- 2) abundances of light nuclei (H, D, He, Li)

➔ **Universe starts simple!! And then structures emerge as it expands and cools**



What about before  $t \sim 0.01$  sec ? Invoke particle physics...