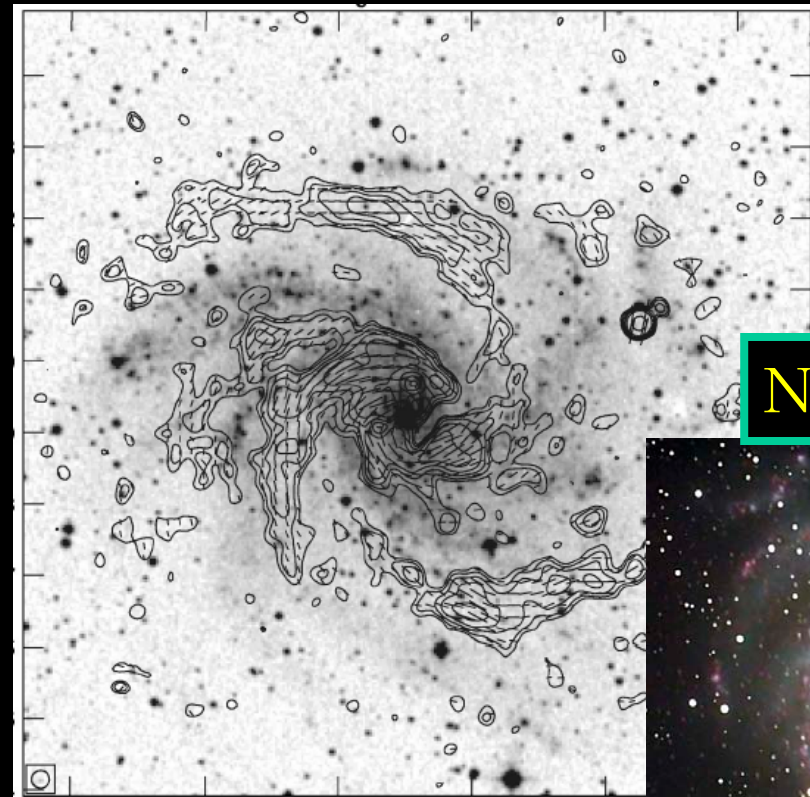
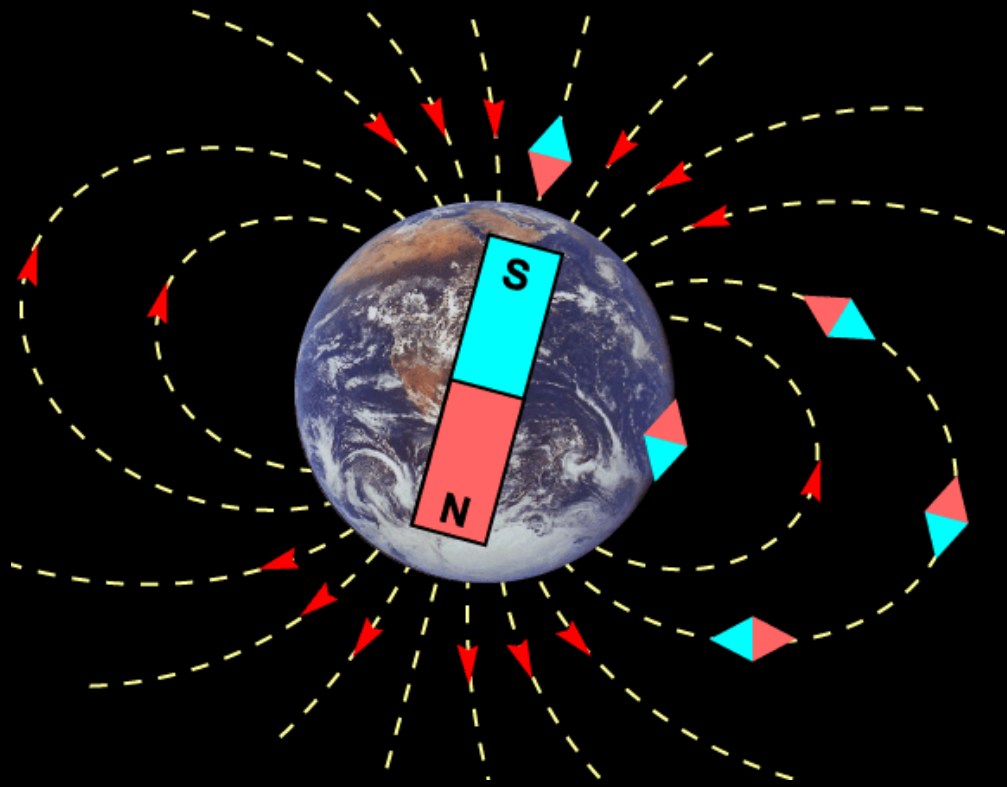


# Origin of magnetic fields in the universe

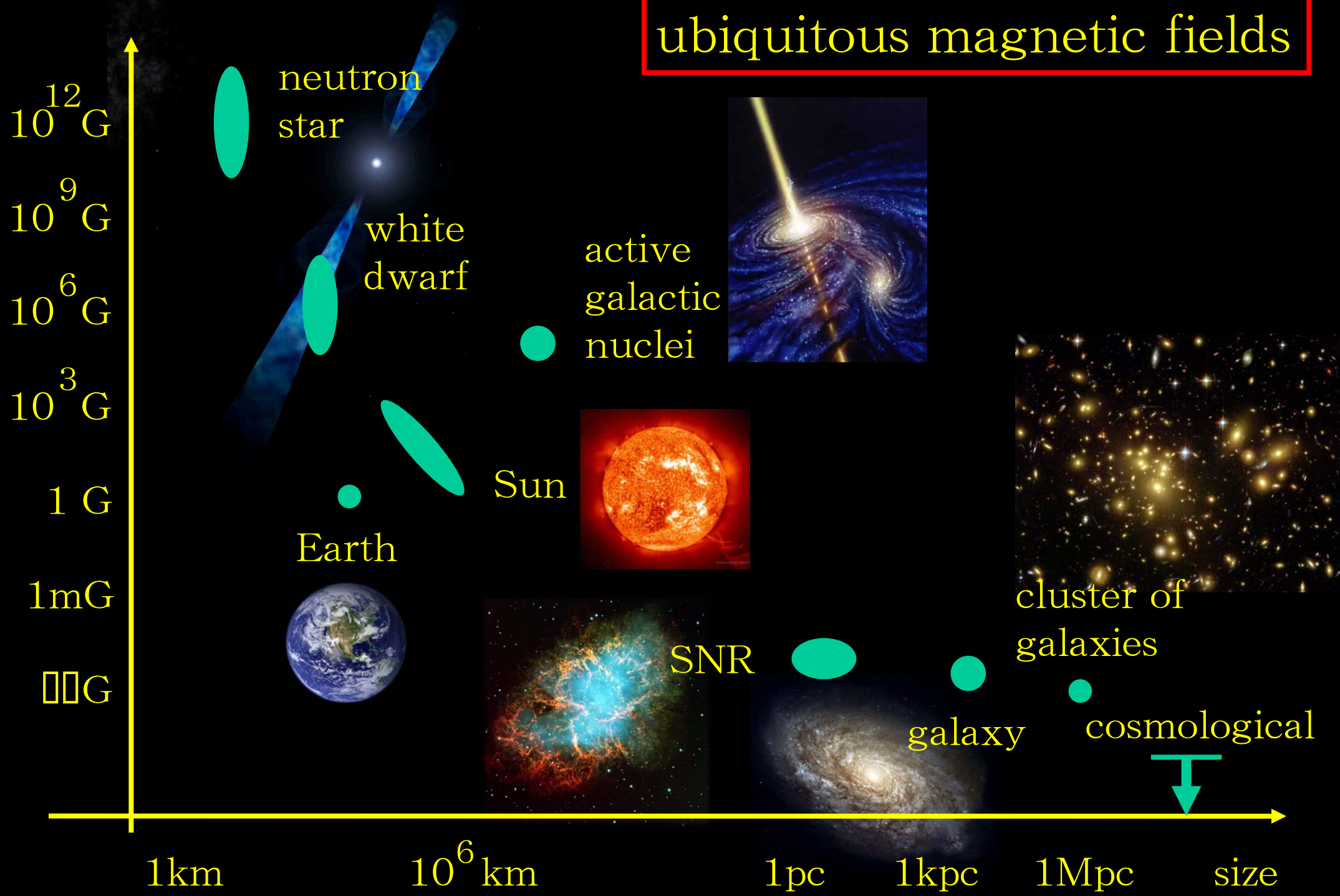


NGC6946

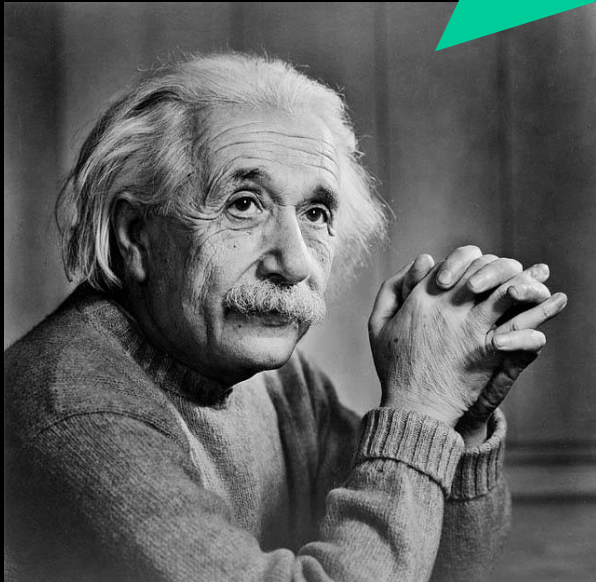


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# ubiquitous magnetic fields



Origin of magnetic fields of the earth is one of the most important problems in modern physics.



earth  $\rightarrow$  astronomical objects  
cosmological fields?



galactic magnetic fields  $\sim 1 \mu\text{G}$



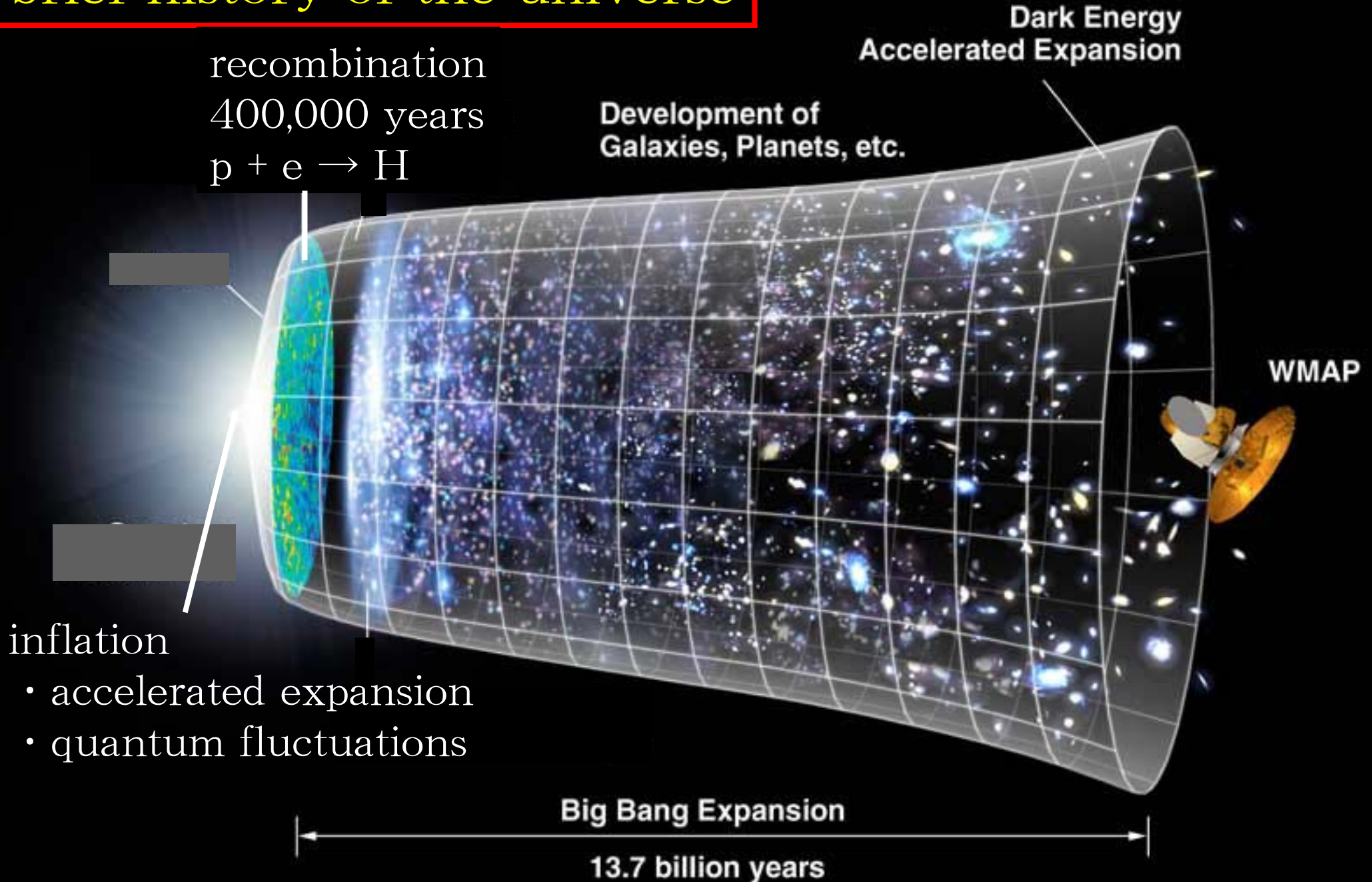
galactic dynamo



tiny seed magnetic fields

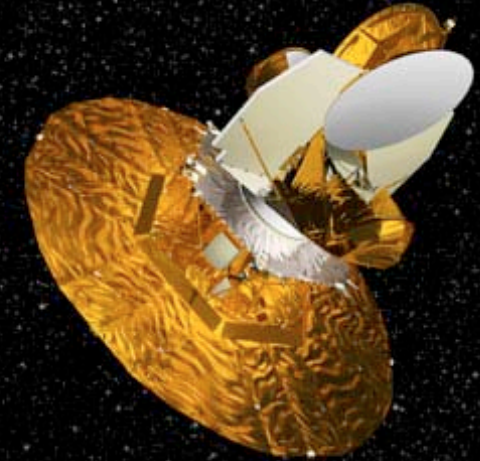
magnetogenesis  
in the early universe

# brief history of the universe

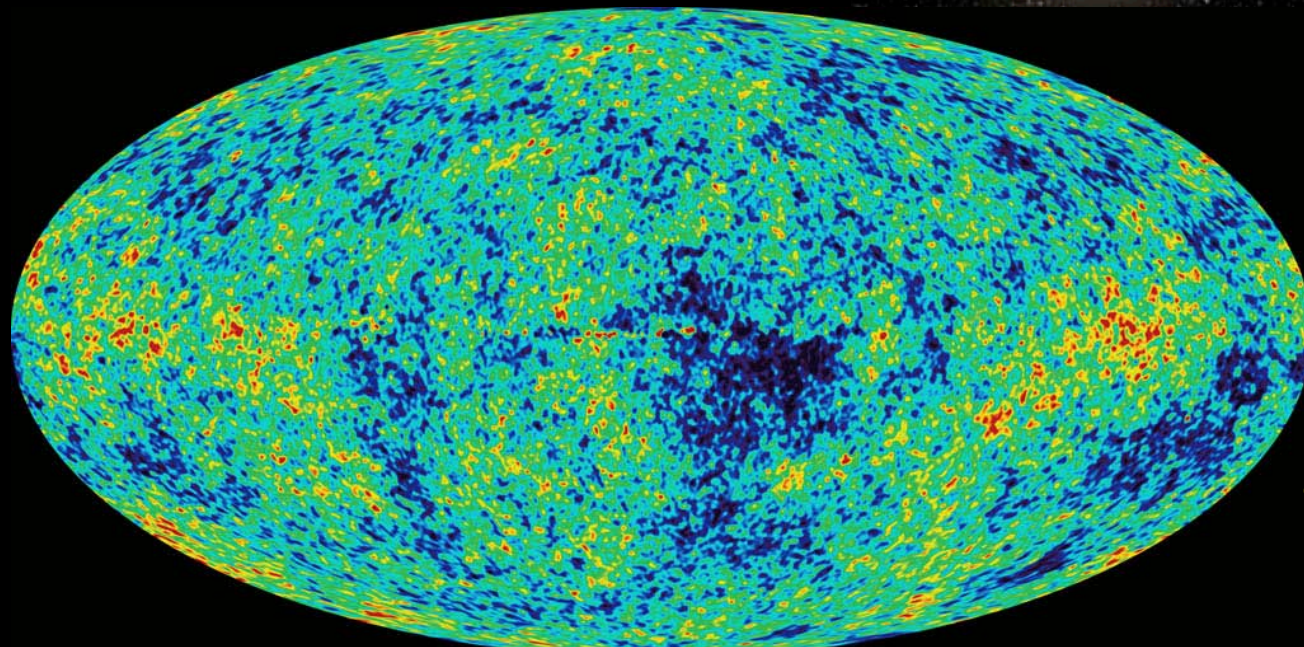


# cosmic microwave background

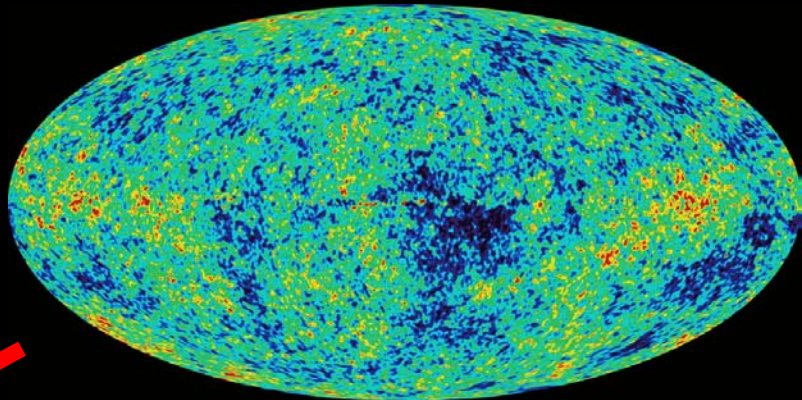
fluctuations  $\rightarrow$  anisotropy in CMB  
average temperature  $\sim 3\text{K}$   
anisotropy  $\sim 10^{-5}$



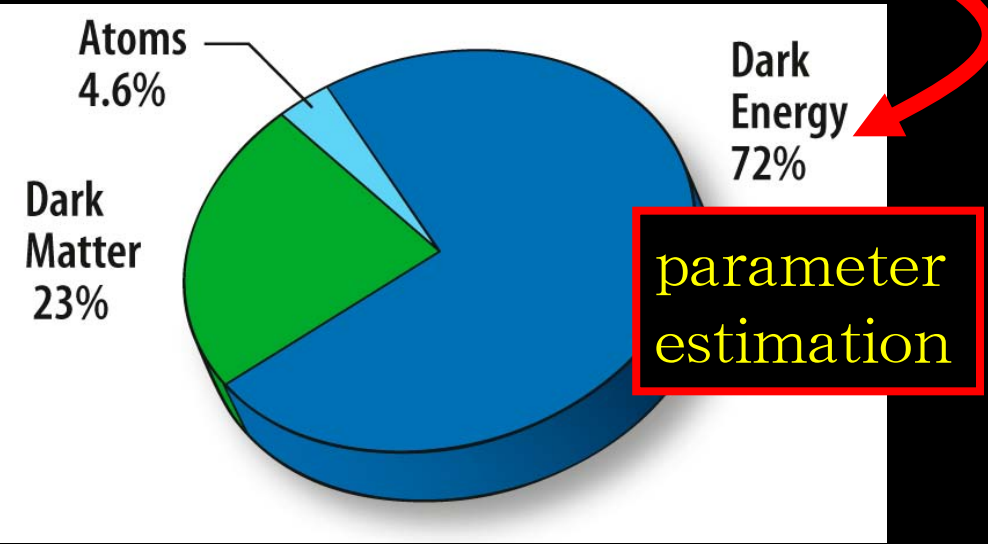
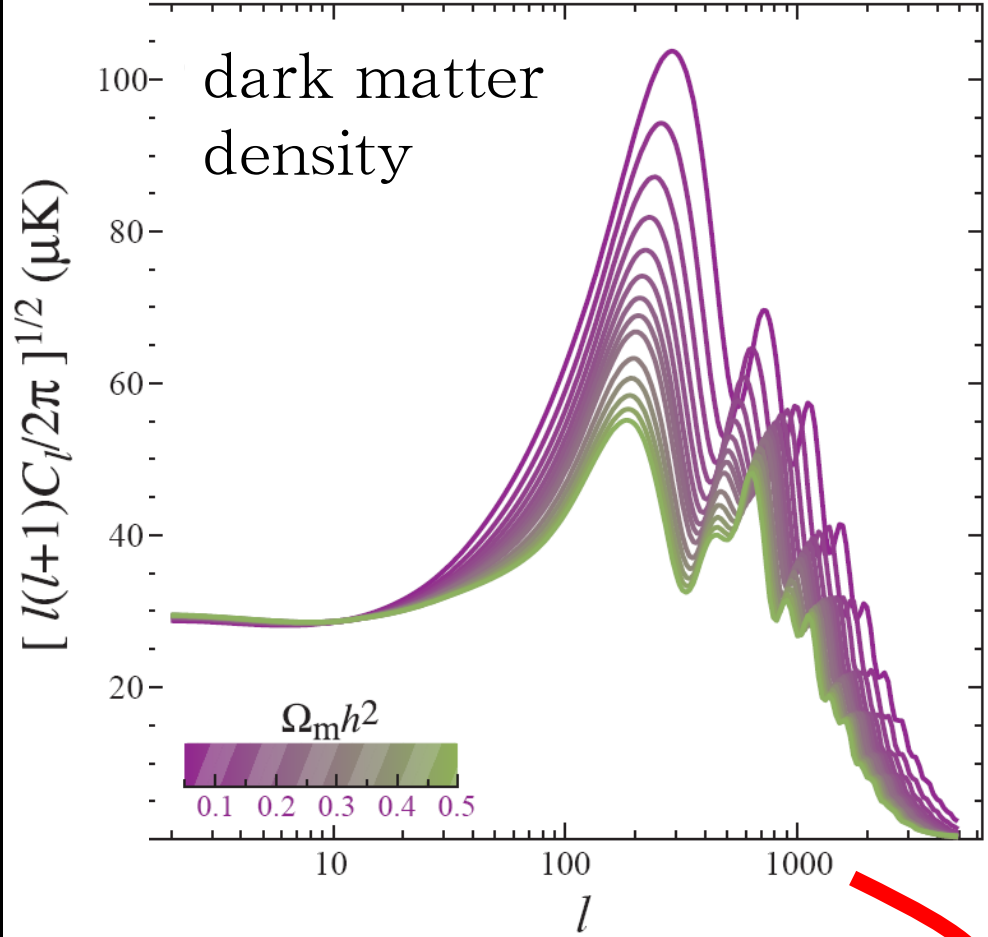
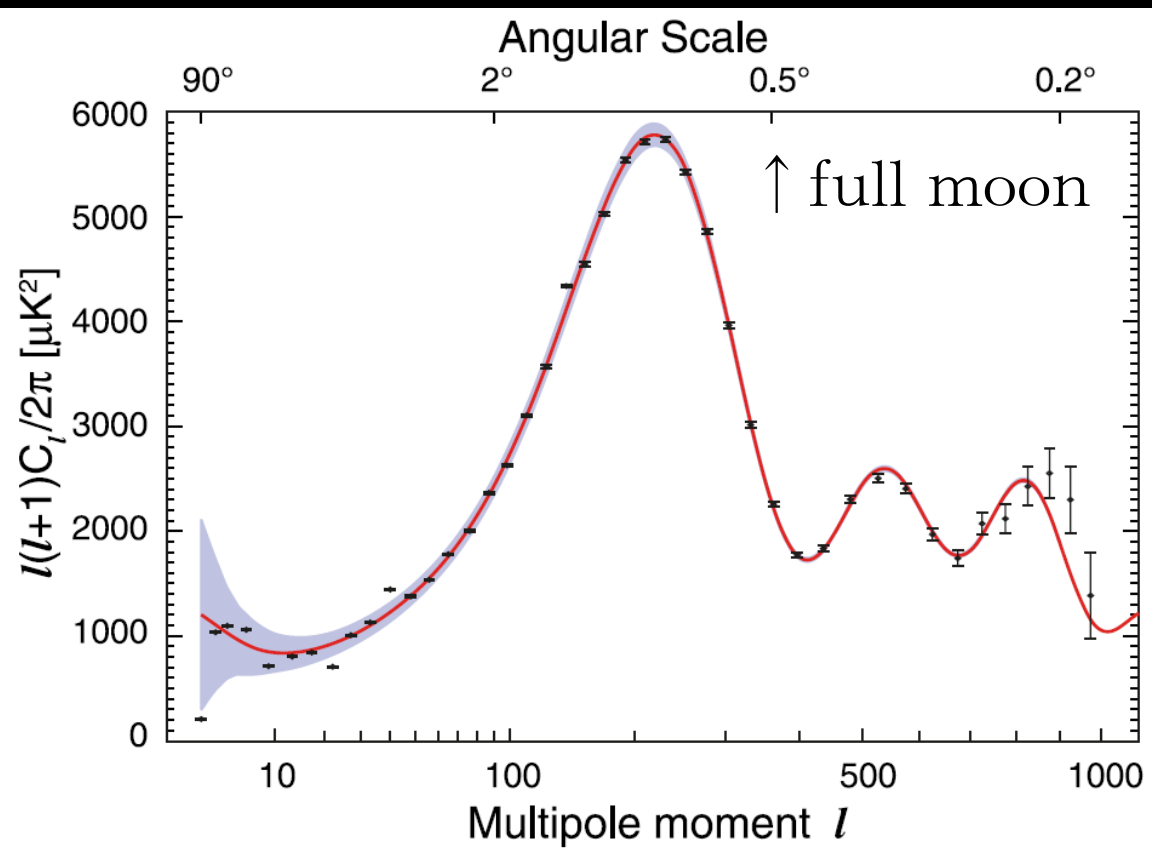
WMAP



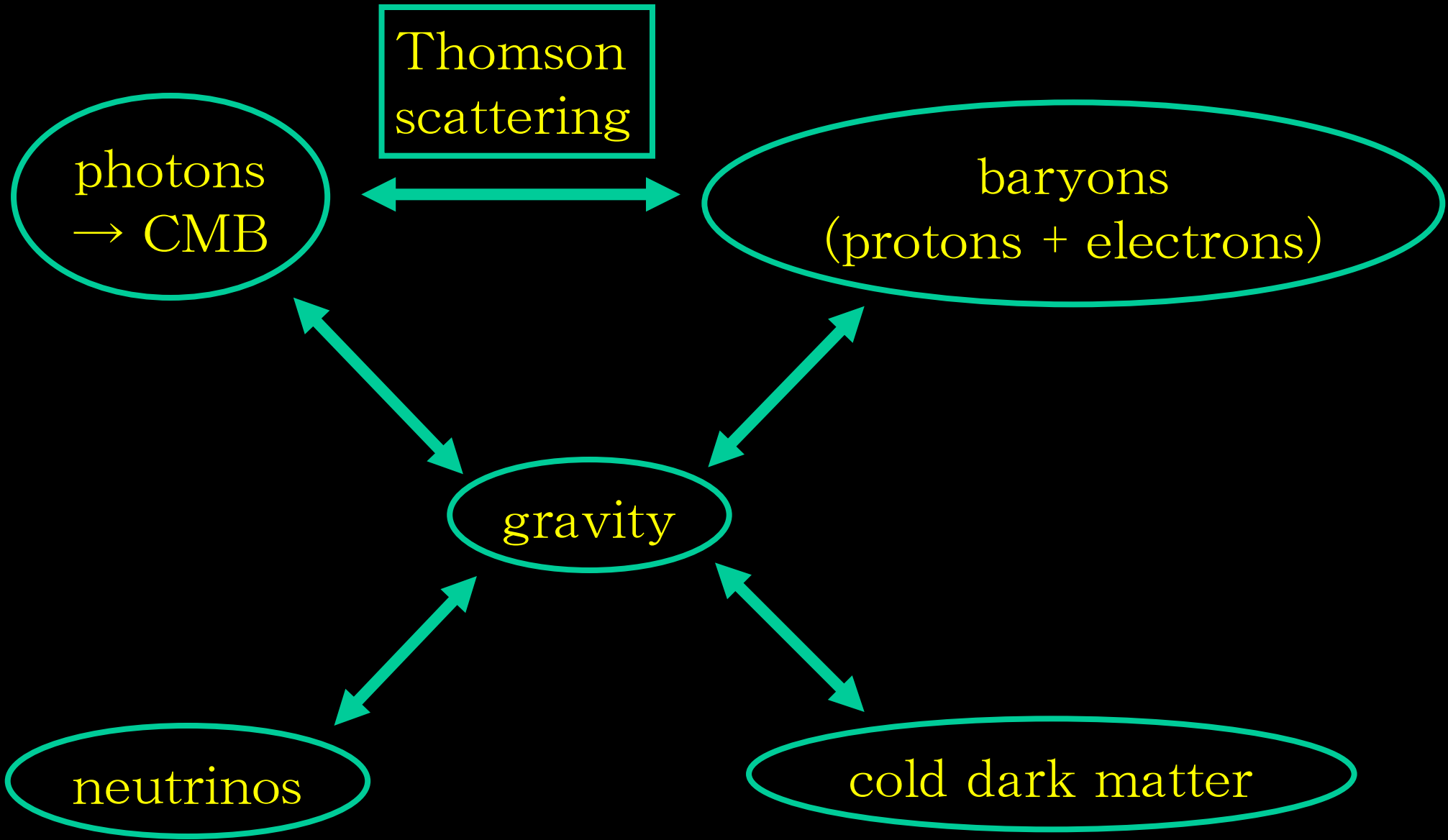
CMB observation  
 $\downarrow$   
cosmological parameters  
(age, matter density,  
spatial curvature)



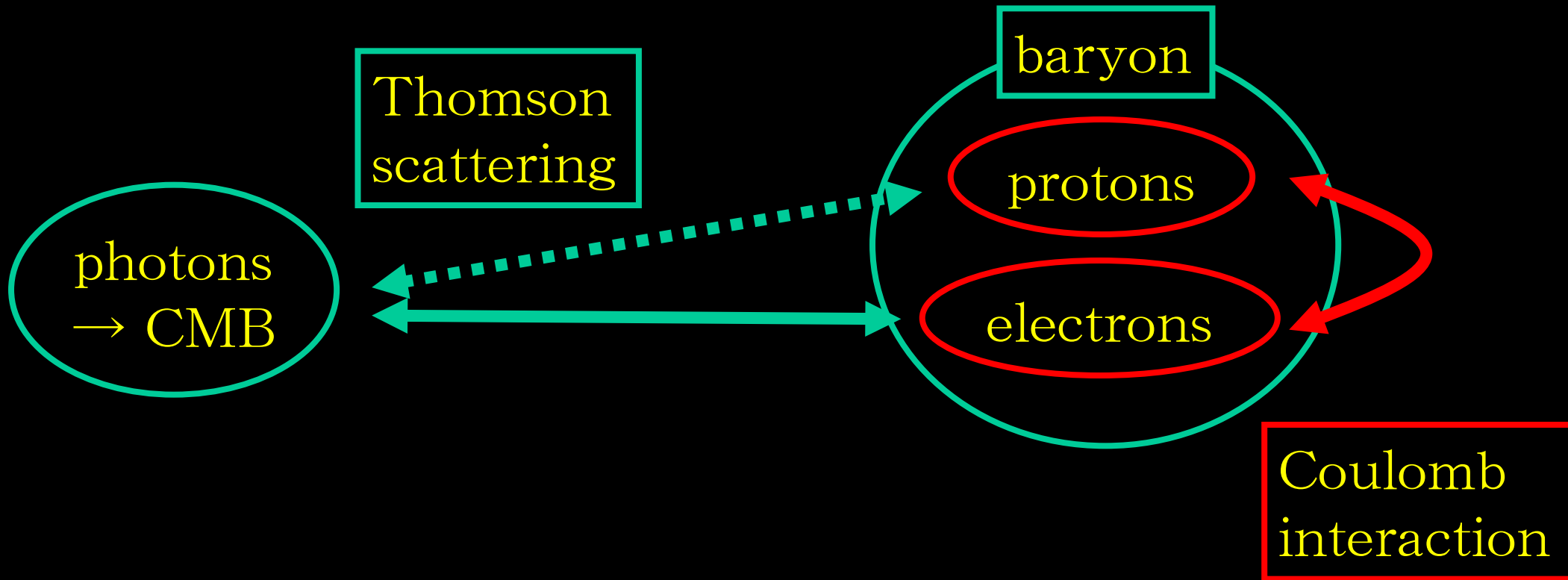
multipole expansion



# components of the universe



# magnetogenesis



Thomson scattering

→ deviation in motion due to mass difference

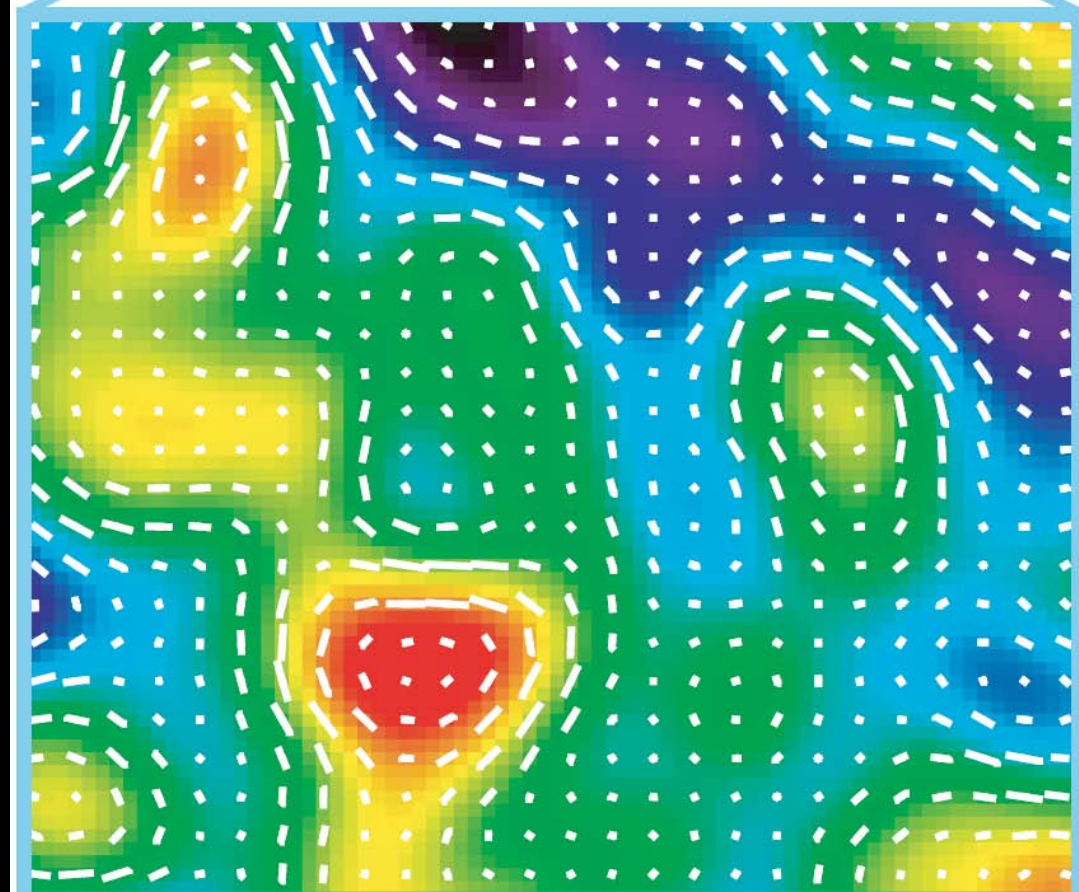
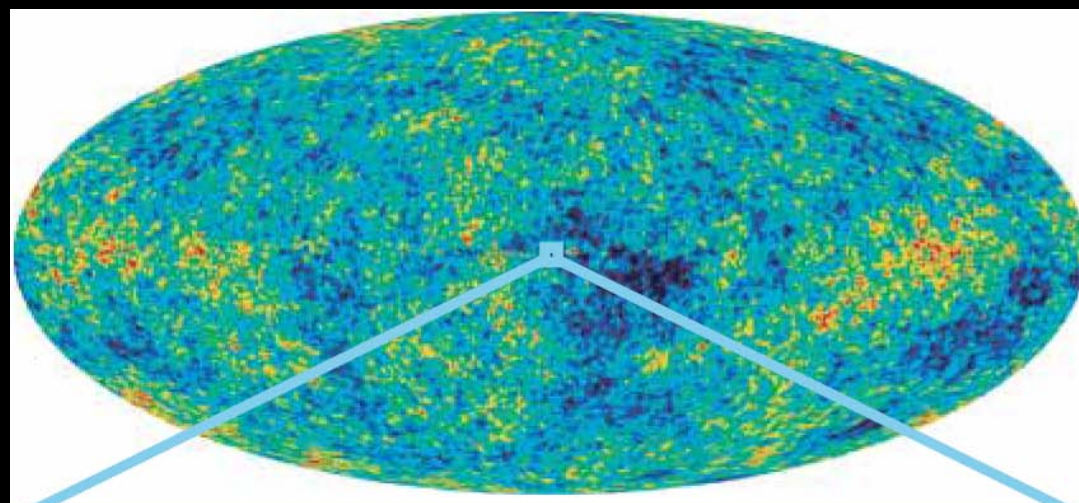
→ generation of net electric charge density and current

→ generation of magnetic fields



# magnetogenesis

- deviation between protons and electrons due to Thomson scattering (separate treatment)
  - fluid vorticity (nonlinear effect)
- • magnetogenesis from density fluctuations (correlation with CMB)
- $\sim 10^{-20}$  Gauss
- • cosmological fields
- seed fields



KT et al., Science 311 (2006)827