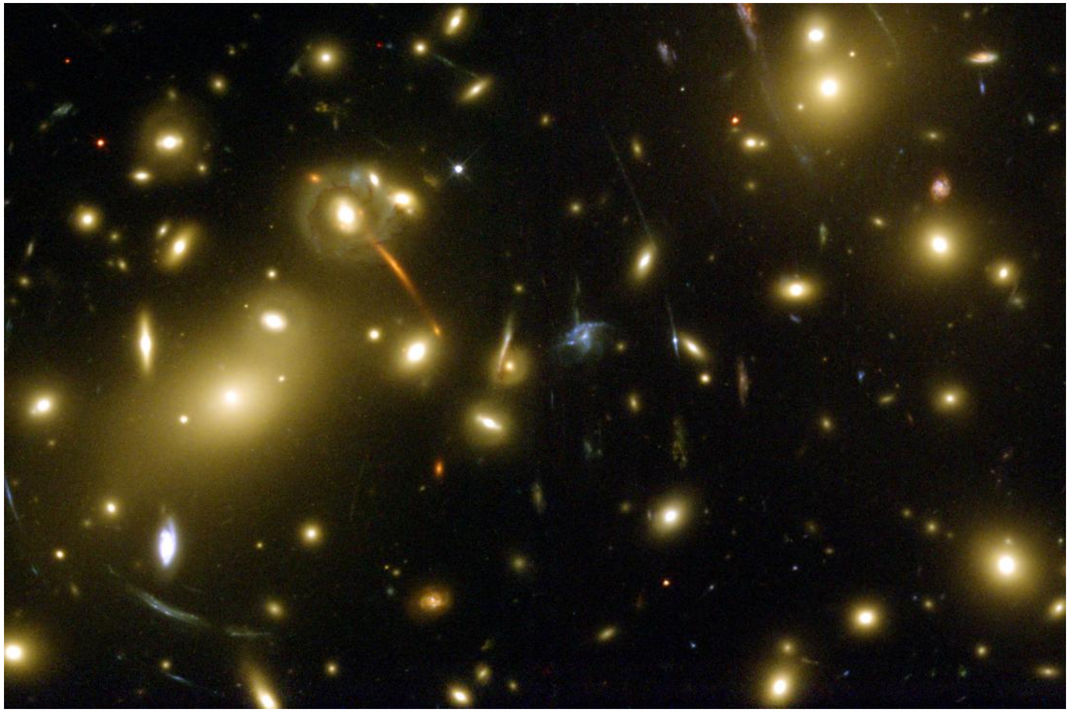
The Role of Dark Matter in the Large-Scale Structures of the Universe



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Astrophysical Dynamics
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Agenda

- Introduction
- Types of matter
- Dark matter
  - Types of Dark Matter
  - Hot Dark Matter
  - Cold Dark Matter
  - Cold vs Hot Dark Matter
  - Cold and Hot Dark Matter
  - Cold Dark Matter and Dark Energy
- More models and theories
- Conlusions

Introduction

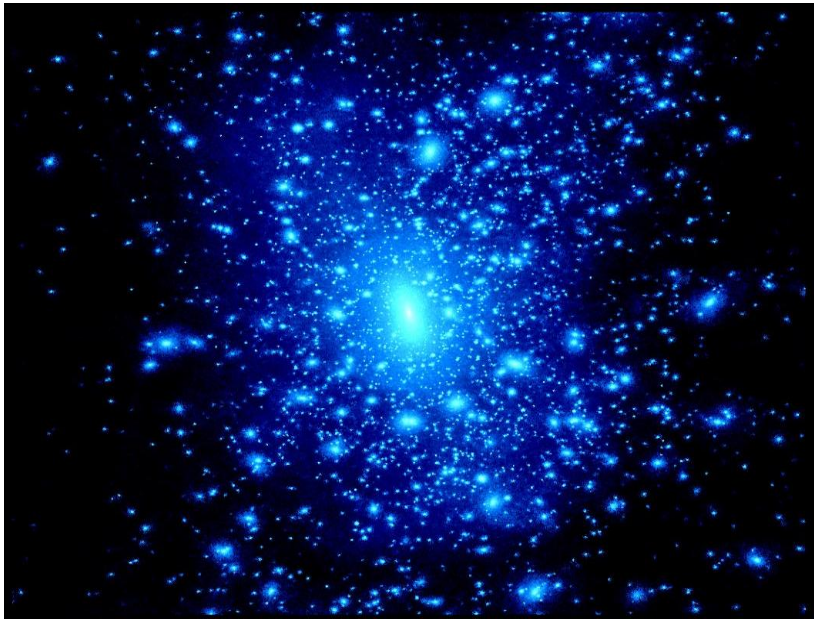
- Evidences of missing matter. Can Dark Matter be the answer?
- Concept introduced in the 30´s but accepted until 70-80´s
- Studied from Cosmological point of view
- Gap between cosmology and galaxy studies

Types of matter

- Baryonic
  - Matter that forms atoms
  - Can contribute to the missing matter: black holes, neutron stars, white dwarfs, …
- Non-baryonic
  - No emits, absorbs, scatter radiation
  - Gravitational interaction with normal matter

Dark matter

- What's Dark Matter?
  - Nobody really knows
  - No emits, absorbs or scatter radiation
  - About 95% matter of the universe

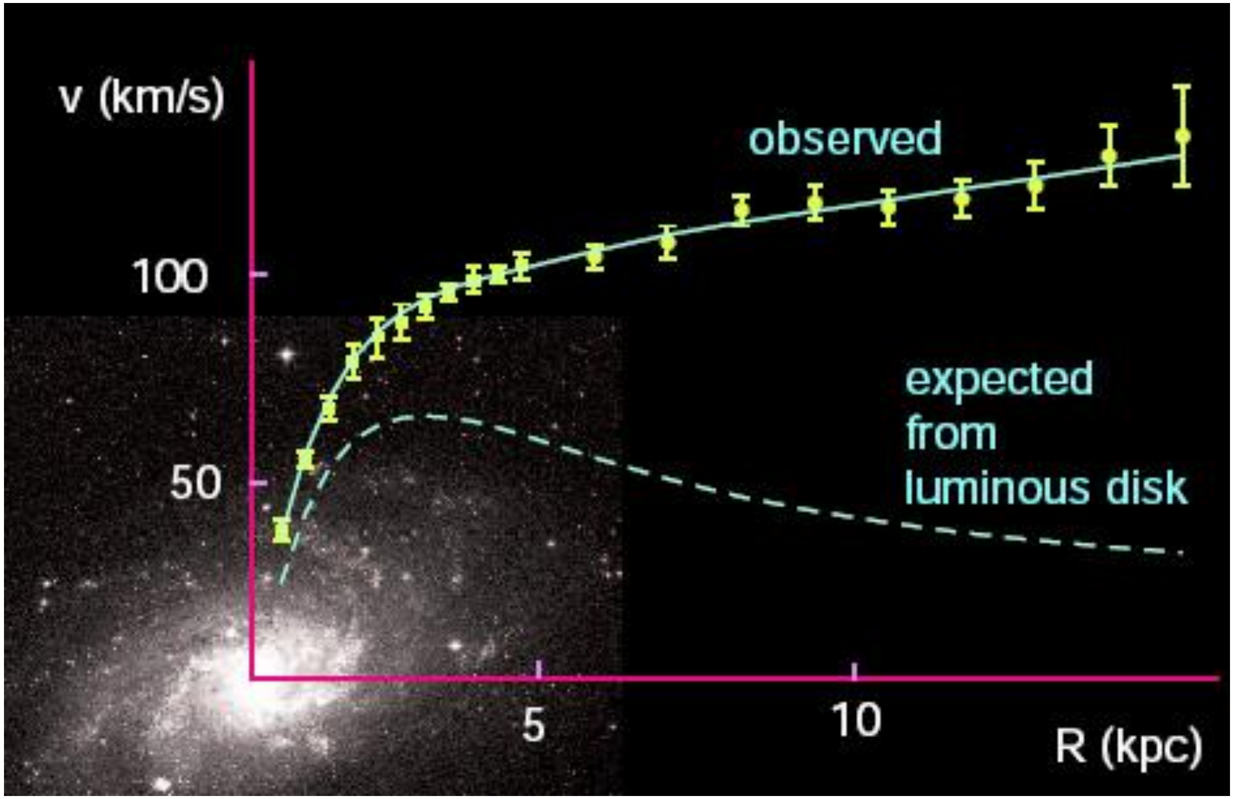


Dark Matter

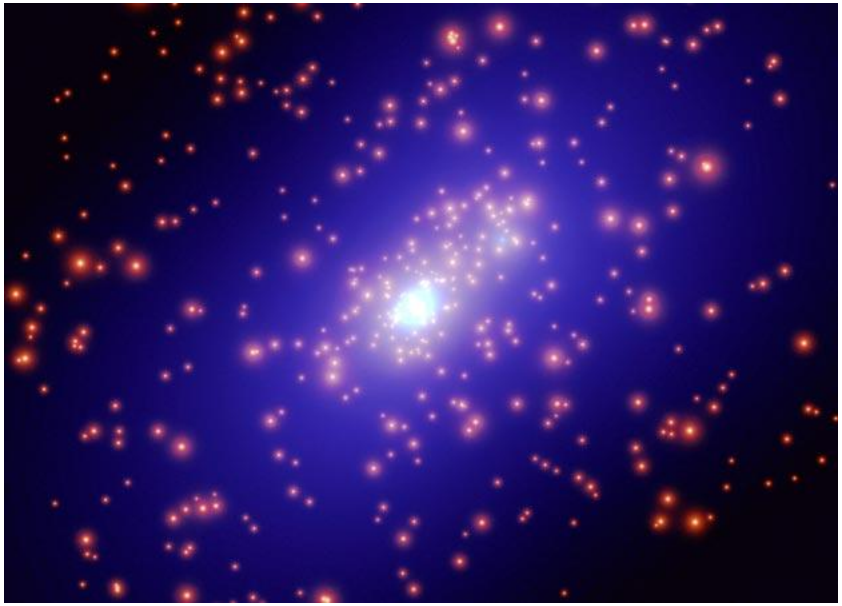
- Idea proposed in the 30's by Fritz Zwicky. Why?
  - Speed of Galaxies in large cluster too large
  - Other evidences:
    - Rotation curves
    - Structure of galaxy groups and clusters
    - Etc.

Dark Matter

Example of rotation curve discrepancy



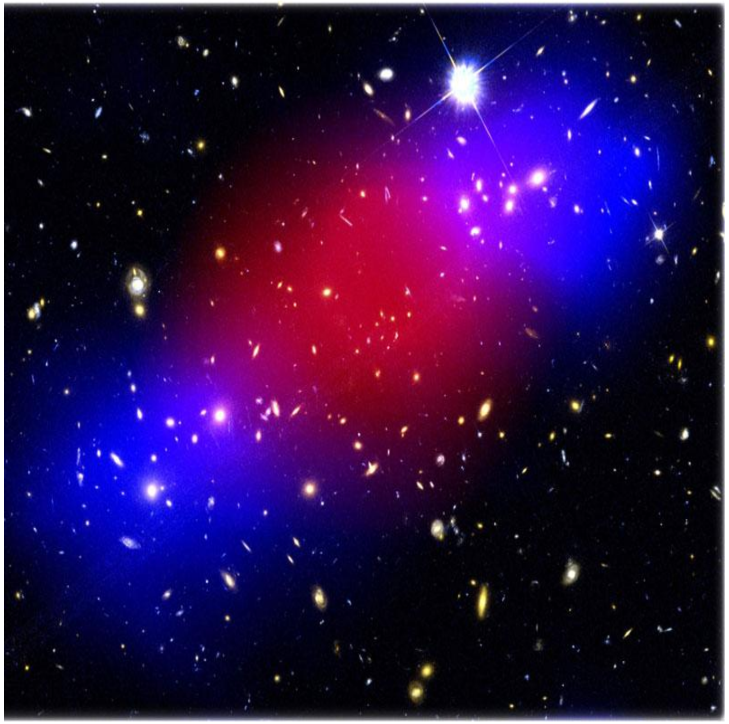
Dark Matter: Types of Dark Matter



- Two main types
  - Hot Dark Matter (HDM)
  - Cold Dark Matter (CDM)

Dark Matter: Hot Dark Matter

- Light neutrinos that decoupled when they had relativistic velocities
- Free streaming: Eliminate fluctuations in density smaller than superclusters $\sim 10^{15} M_\odot$
- Top-down process: Fragmentation



Dark Matter: Hot Dark Matter

- Good points
  - Structure of filaments is formed

- Bad points
  - Structures form to late
  - More inhomogeneous distribution than observed

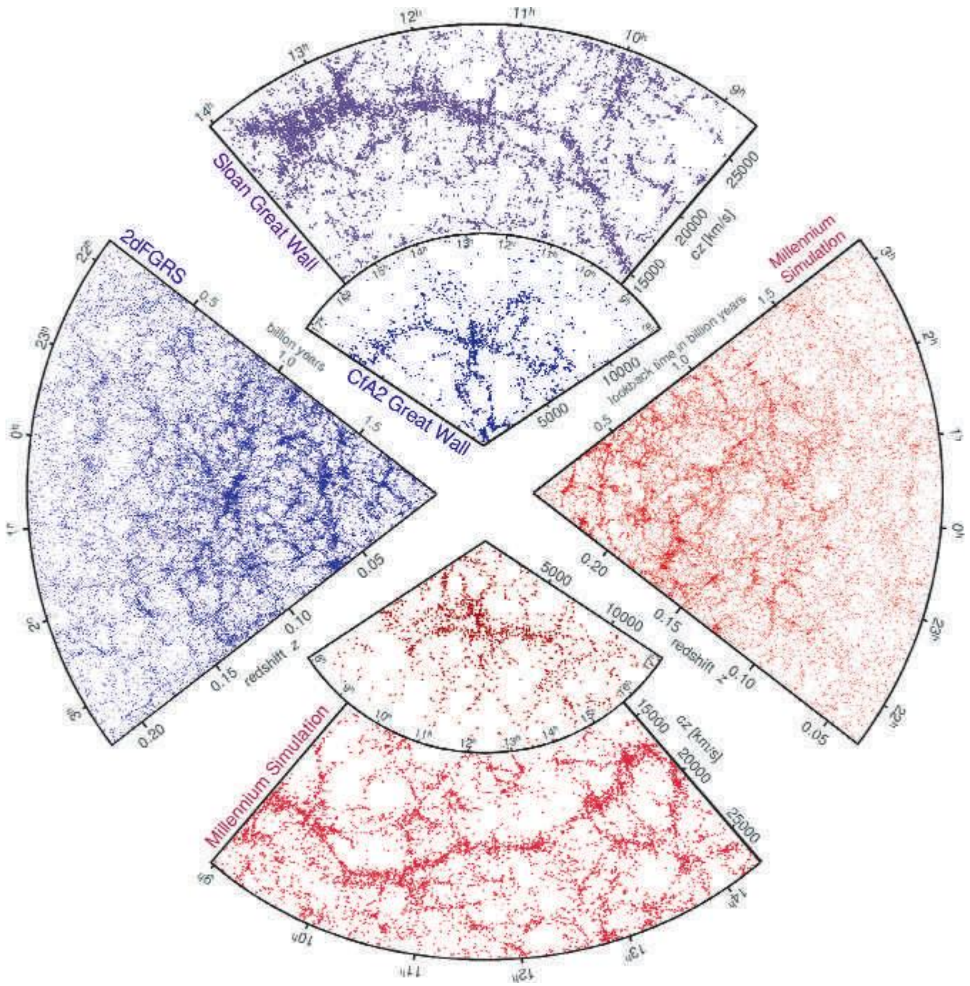
Dark Matter: Cold Dark Matter

- Particles with Non-relativistic speed
- Possible candidates:
  - WMIP
  - Axions
- Perturbations at all scales survived, even small ones
- Bottom-up process: Hierarchical clustering

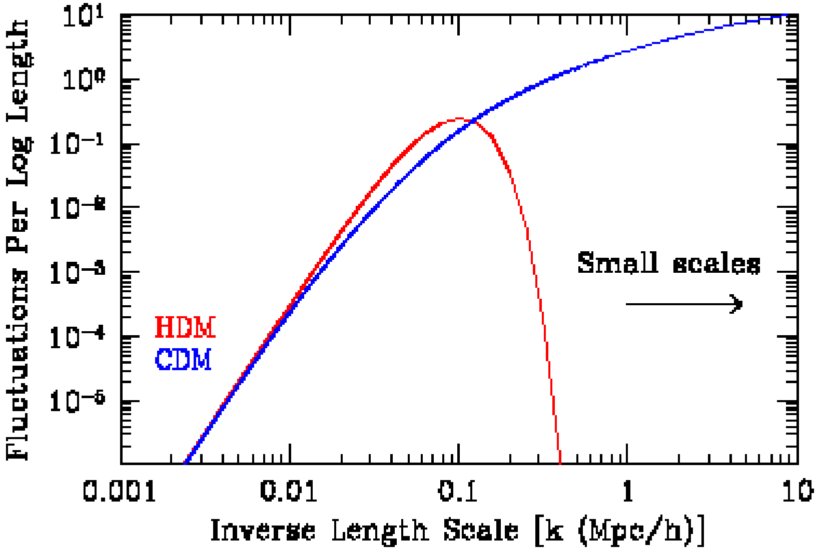
Dark Matter: Cold Dark Matter

- Good points
  - Predicted distribution of galaxies agrees better with observations
- Bad Points
  - Missing satellite galaxies
  - Cuspy halo problem

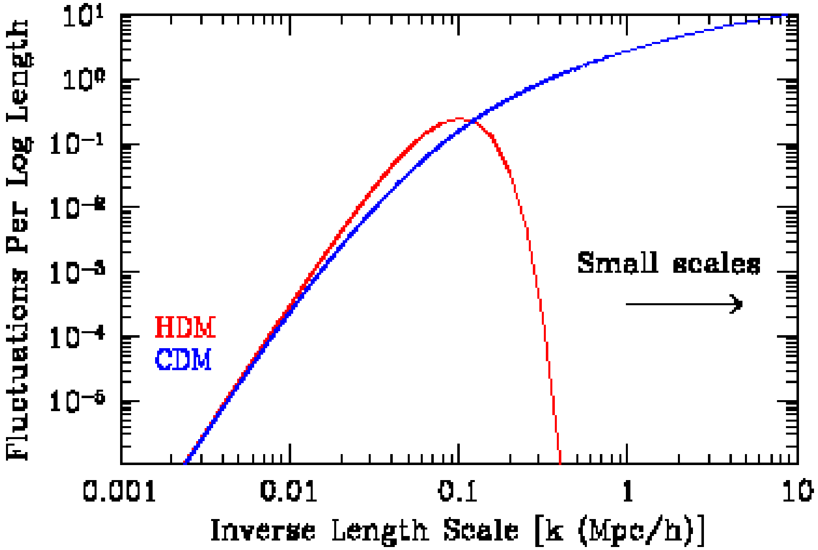
Dark Matter: Cold Dark Matter

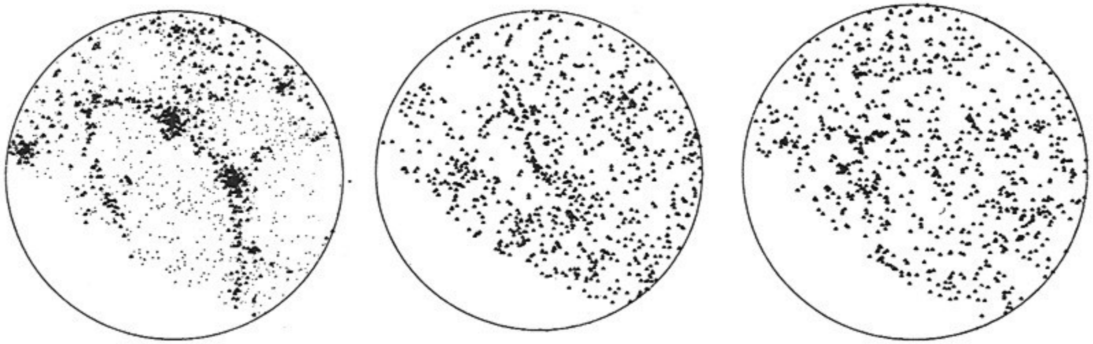


Cold vs Hot Dark Matter



Cold vs Hot Dark Matter





HDM   Observed Galaxy Distribution   CDM

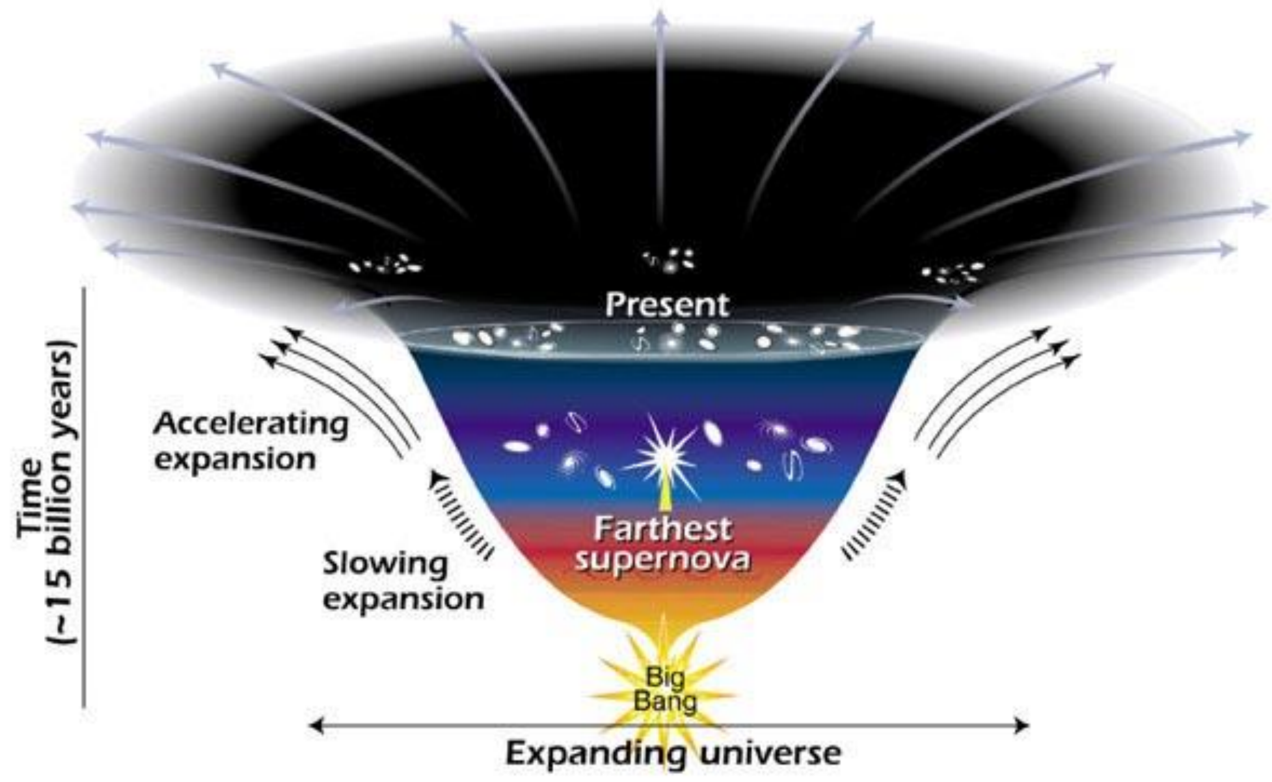
Dark Matter: Cold Hot Dark Matter

- Enough neutrino mass to take into account
- Small fluctuations can survive, just their grow rates are decreased
- About 20-30% of total matter is HDM
- Large matter density $\Omega_m=1$

Dark Matter: Cold Dark Matter and Dark Energy (ΛCDM)

- Inclusion of Dark Energy
- What is Dark Energy?
  - Some kind of negative pressure. Increase expansion rate of the universe
  - Evidences from Supernova Ia observations
- $\Omega_m \sim 1/3 \quad \Omega_\Lambda \sim 2/3 \quad \Omega_m + \Omega_\Lambda = 1$
- Observational data gives evidences favouring ΛCDM

Dark Matter: Cold Dark Matter and Dark Energy (ΛCDM)



More models and theories

- ΛCHDM
  - Include neutrino mass (HDM) into the ΛCDM
- Modified Newtonian Dynamics (MOND)
  - Gravity depends on the scale of study

Conclusions

- ΛCDM is the most accepted model
- ΛCHDM seems very promising
- Gap between Cosmological and smaller scale studies. Need to study this field

Thank you!!

Questions? :)