Compact Objects and Large-Scale Structure in the Universe

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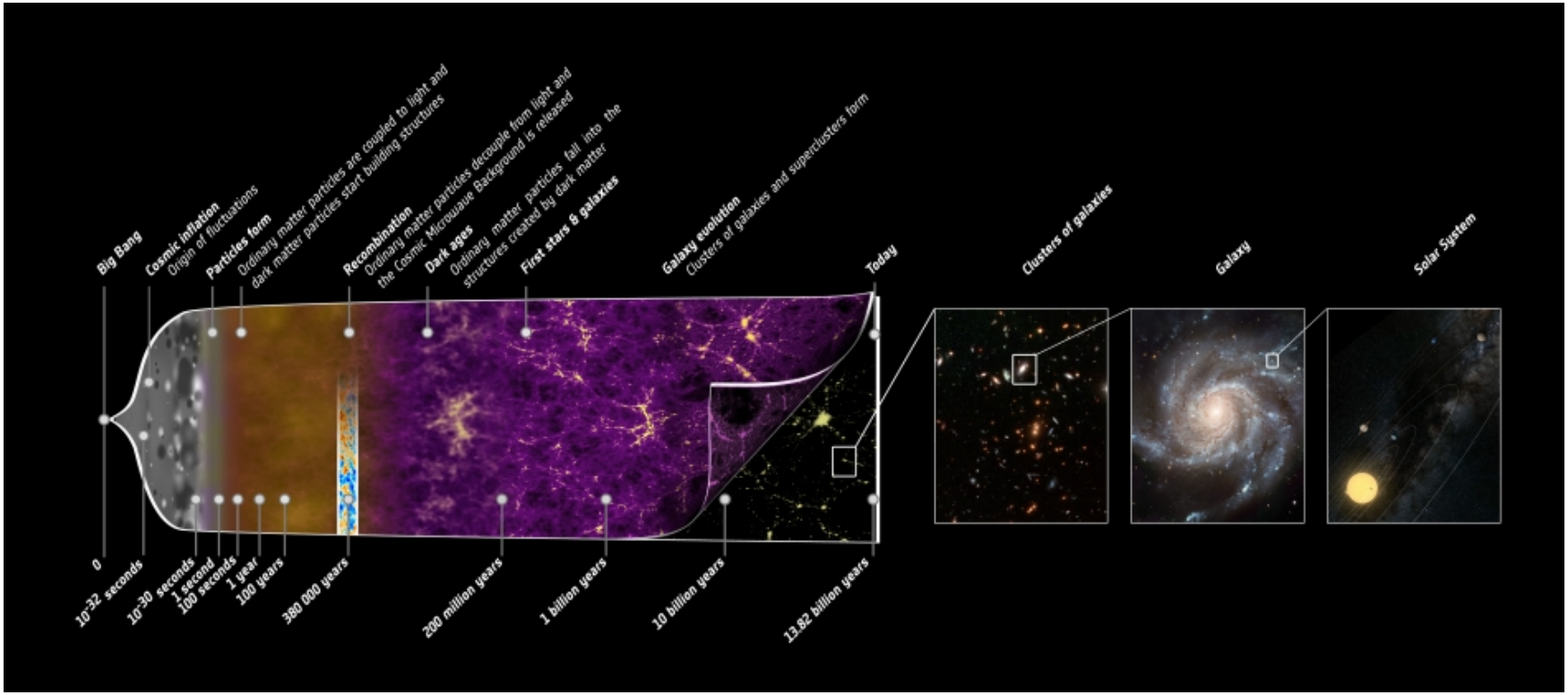
General Highlights

- Structure formation at the stellar and the cosmological scales:
  1. Gravity: Einstein vs. Modified Gravity
  2. Equation of State: Radiation vs. Matter
  3. Gravitational Collapse: formation of compact objects

- Observational Constraints:
  1. CMB Temperature and Polarization, Weak Lensing, Galaxy Clustering
  2. Masses, Radii, Tidal Deformabilities of NS
  3. Gravitational waves: mergers and cosmological background

Timeline



Courtesy of NASA website

Goal: studying the cosmological impact of PBHs

- PBHs are formed when the Universe is still radiation dominated
- PBHs spans an enormous range of masses, from mini black holes (Hawking radiation) to supermassive black holes (center of Galaxies)
- PBHs are interesting candidates for dark matter component ($M_{\rm sun}$ formed during the QCD phase transition)
- The formation of PBHs is a highly non linear phenomenon

$$\Downarrow$$

Relativistic numerical simulations

Goal: determine the content, structure and dynamics of the universe

- structure and dynamics depend on the laws of gravity
- gravity can be degenerate with the content of the universe

- cosmological parameters (densities, expansion) can be biased
- do we really want to blindly extrapolate gravity over 15 orders of magnitude in length?

Goal: Use multi-messenger astronomy to constrain and refine the EOS

- The EOS of hot and dense matter is essential for the description of phenomena such as core-collapse supernovae (CCSN), neutron stars (NS), and their mergers (NSM).
- Its theoretical determination has become evermore pressing in light of the discoveries of 2 $M_\odot$ NS, efforts to measure radii of NS through newly-launched satellites, and the detection of gravitational waves and photons from NSM.

- Perform a complete calculation of the EOS addressing all relevant degrees of freedom (nuclei, nucleons, other hadrons, quarks, etc.) and taking into account phase transitions and collective effects.
- Explore the macroscopic consequences of the EOS in general-relativistic hydrodynamic simulations of CCSN and NSM.