LambdaCDM model summary

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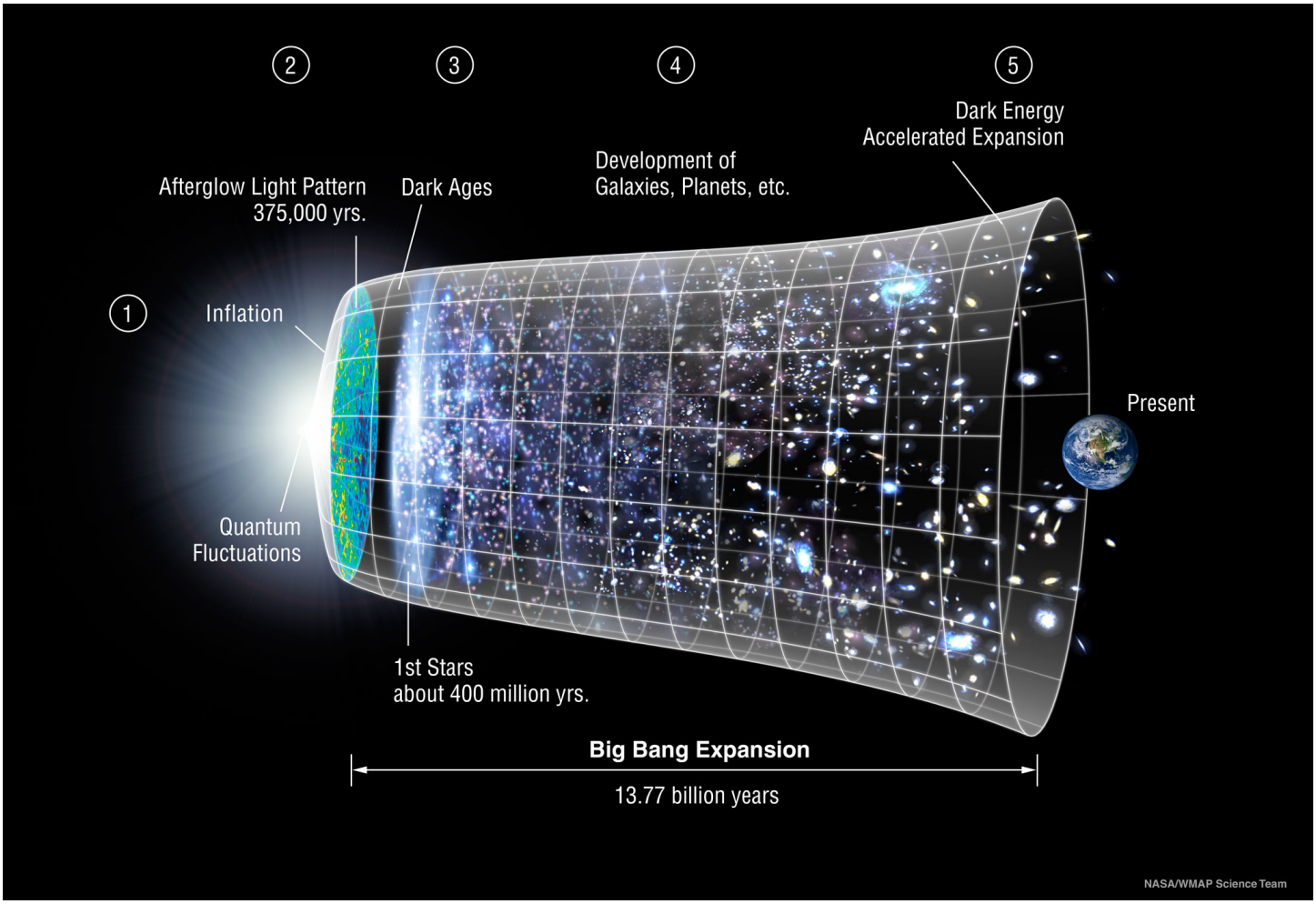

Figure 1: LCDM

We illustrate a brief and simplified picture of theorized stages in the evolution of the universe, to provide a context for discussing ΛCDM parameters.

In this picture, the infant universe is an extremely hot, dense, nearly homogeneous mixture of photons and matter, tightly coupled together as a plasma. An approximate graphical timeline of its theoretical evolution is shown in the figure above, with numbers keyed to the explanatory text below.

1. The initial conditions of this early plasma are currently thought to be established during a period of rapid expansion known as inflation. Density fluctuations in the primordial plasma are seeded by quantum fluctuations in the field driving inflation. The amplitude of the primordial gravitational potential fluctuations is nearly the same on all spatial scales (see e.g. reviews by Tsujikawa 2003 and Baumann 2009). The small perturbations propagate through the plasma collisionally as a sound wave, producing under- and overdensities in the plasma with simultaneous changes in density of matter and radiation. CDM doesn't share in these pressure-induced oscillations, but does act gravitationally, either enhancing or negating the acoustic pattern for the photons and baryons (Hu & White 2004).

2. Eventually physical conditions in the expanding, cooling plasma reach the point where electrons and baryons are able to stably recombine, forming atoms, mostly in the form of neutral hydrogen. The

photons decouple from the baryons as the plasma becomes neutral, and perturbations no longer propagate as acoustic waves: the existing density pattern becomes "frozen". This snapshot of the density fluctuations is preserved in the CMB anisotropies and the imprint of baryon acoustic oscillations (BAO) observable today in large scale structure (Eisenstein & Hu 1998).

3. Recombination produces a largely neutral universe which is unobservable throughout most of the electromagnetic spectrum, an era sometimes referred to as the "Dark Ages". During this era, CDM begins gravitational collapse in overdense regions. Baryonic matter gravitationally collapses into these CDM halos, and "Cosmic Dawn" begins with the formation of the first radiation sources such as stars. Radiation from these objects reionizes the intergalactic medium.

4. Structure continues to grow and merge under the influence of gravity, forming a vast cosmic web of dark matter density. The abundance of luminous galaxies traces the statistics of the underlying matter density. Clusters of galaxies are the largest bound objects. Despite this reorganization, galaxies retain the BAO correlation length that was established in the era of the CMB.

5. As the universe continues to expand over time, the negative pressure associated with the cosmological constant (the form of dark energy in ΛCDM) increasingly dominates over opposing gravitational forces, and the expansion of the universe accelerates.