Project 2-. Cosmology

Daniel Rodrigo Garduño Roa 143974

Universidad de Guanajuato. División de Ciencias e Ingenierías

***Abstract*—**

In this project we explore how the CMB and matter power spectrum varies as function of the cosmological parameters, and what is the observational data available to compare with and qualitatively determine the best cosmological model... Modify and expand this abstract as you prefer

I. Introduction

The field of cosmic microwave background (CMB) anisotropies has dramatically advanced over the last decade, especially on its observational front. The observations have turned some of our boldest speculations about our Universe into a working cosmological model: namely, that the Universe is spatially flat, consists mainly of dark matter and dark energy, with the small amount of ordinary matter necessary to explain the light element abundances, and all the rich structure in it formed through gravitational instability from quantum mechanical fluctuations when the Universe was a fraction of a second old. Observations over the coming decade should pin down certain key cosmological parameters with unprecedented accuracy . These determinations will have profound implications for astrophysics, as well as other disciplines.

The most important observables of the CMB are the power spectra of the temperature and polarization maps. Theory predicts, and now observations confirm, that the temperature power spectrum has a series of peaks and troughs. Although they are the most prominent features in the spectrum, and are the focus of the current generation of experiments, future observations will turn to even finer details, potentially revealing the physics at the two opposite ends of time. Finally, the past few years have witnessed important new advances, from a growing body of CMB data analysts on how best to extract the information contained in CMB data. Some of the fruits of this labor have already spread to other fields of astronomy.

The expansion of the Universe is described by the scale factor a(t), set to unity today, and by the current expansion rate, the Hubble constant $H_0 = 100 h km/s/Mpc$ with h 0.7 . The Universe is flat (no spatial curvature) if the total density is equal to the critical density, $\rho_c = 1.88 h2x10^{-29} g/cm^3$; it is open (negative curvature) if the density is less than this and closed (positive curvature) if greater. The mean densities of different components of the Universe control a(t) and are typically expressed today in units of the critical density Ω_i, with an evolution with a(t) specified by equations of state $\omega_i = p_i/\rho_i$, where p_i is the pressure of the ith component. Density fluctuations are determined by these parameters through the gravitational instability of an initial spectrum of fluctuations.

The working cosmological model contains photons , neutrinos , baryons , cold dark matter , and dark energy with densities proscribed within a relatively tight range. For the radiation, $\Omega_r = 4.17x10 - 5h^{-2} (\omega_r = 1/3)$. The photon contribution to the radiation is determined to high precision by the measured CMB temperature, $T = 2.728 \pm 0.004K$. The neutrino contribution follows from the assumption of 3 neutrino species, a standard thermal history, and a negligible mass $\omega_\nu << 1ev$. Massive neutrinos have an equation of state wnu=1/3→0 as the particles become non-relativistic. For mnu 1eV this occurs at a 10^{-3} and can leave a small but potentially measurable effect on the CMB anisotropies [Ma Bertschinger, 1995,Dodelson et al, 1996].

For the ordinary matter or baryons, Ω_b $0.02h^{-2}(\omega_b$ $0)$ with statistical uncertainties at about the ten percent level determined through studies of the light element abundances. This value is in strikingly good agreement with that implied by the CMB anisotropies themselves as we shall see. There is very strong evidence that there is also substantial non-baryonic dark matter. This dark matter must be close to cold $(\omega_b = 0)$ for the gravitational instability paradigm to work and when added to the baryons gives a total in non-relativistic matter ofΩ_m 1/3. Since the Universe appears to be flat, the total Ω_{tot} must be equal to one. Thus, there is a missing component to the inventory, dubbed dark energy, with Ω_Λ 2/3. The cosmological constant $(\Omega_\Lambda = -1)$ is only one of several possible candidates but we will generally assume this form unless otherwise specified. Measurements of an accelerated expansion from distant supernovae provide entirely independent evidence for dark energy in this amount.

there are three satellites designed to measure ancient light leftover from the big bang that created our universe 13.8 billion years ago. Called the cosmic microwave background, this light reveals secrets of the universe's origins, fate, ingredients and more.The first spacecraft, launched in 1989, is NASA's Cosmic Background Explorer, or COBE (left panel). Two of COBE's principal scientists earned the Nobel Prize in Physics in 2006 for the mission's evidence supporting the big bang theory, and for its demonstration that tiny variations in the ancient light reveal information about the state of the universe. These variations, called anisotropies, came into sharper focus with NASA's next-generation spacecraft, the Wilkinson Microwave Anisotropy Probe, or WMAP (middle panel). This mission, launched in 2001, found strong evidence for inflation, the very early epoch in our universe when it expanded dramatically in size, and measured basic traits of our universe better than ever before. The most advanced satellite yet of this type is Planck, a European Space Agency mission with significant NASA contributions. Planck, launched in 2009, images the sky with more than 2.5 times greater resolution than WMAP, revealing patterns in the ancient cosmic light as small as one-twelfth of a degree on the sky. Planck has created the sharpest all-sky map ever made of the universe's cosmic microwave background, precisely fine-tuning what we know about the universe.

Planck is a European Space Agency mission, with significant participation from NASA. NASA's Planck Project Office is based at NASA's Jet Propulsion Laboratory, Pasadena, Calif. JPL contributed mission-enabling technology for both of Planck's science instruments. European, Canadian and U.S. Planck scientists work together to analyze the Planck data.

II. Methods

The Code use in this project is CLASS (the the Cosmic Linear Anisotropy Solving System) and the main purpose of using that code is because is the easiest way to measure the power mass spectrum with varying some cosmological parameters. Also CLASS is a dedicated library to do this calculations of the CMB data.

III. Results and Discussion

In the code we obtain the follow results:

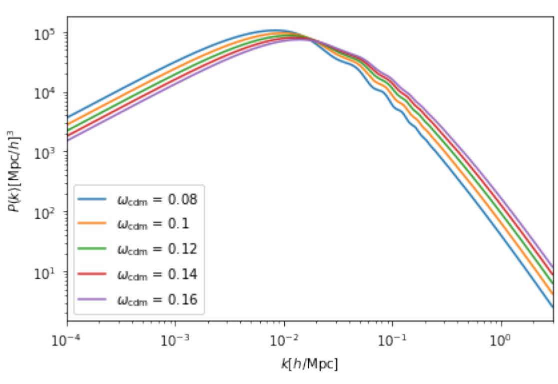

Fig. 1: mass power spectrum varying ω_{cdm}

IV. conclusions

V. References

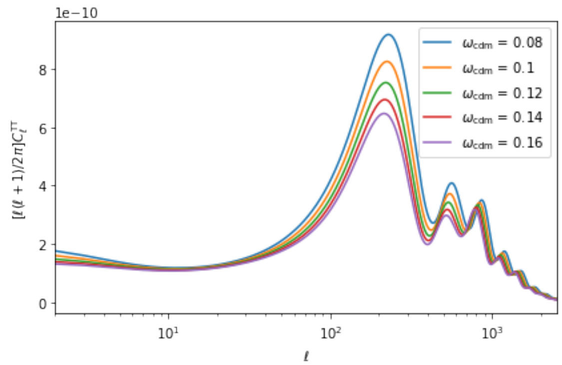

Fig. 2: angular power spectrum varying ω_{cdm}

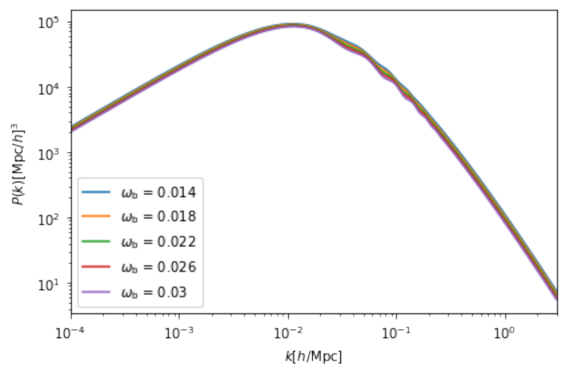

Fig. 3: mass power spectrum varying ω_b

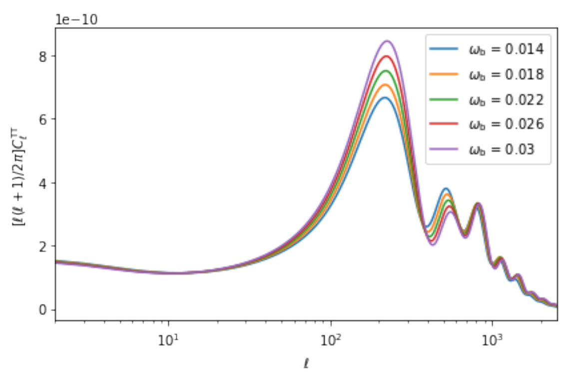

Fig. 4: Angular power spectrum varying ω_b

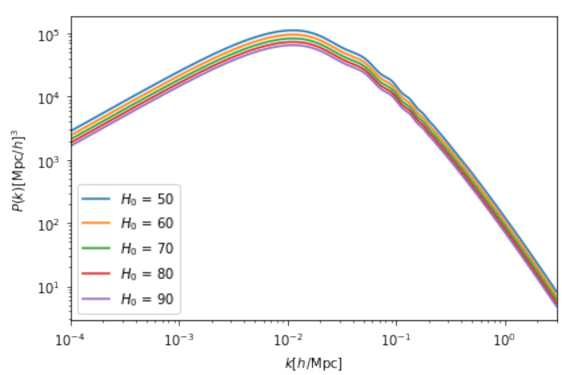

Fig. 5: Mass power spectrum vayring H_0

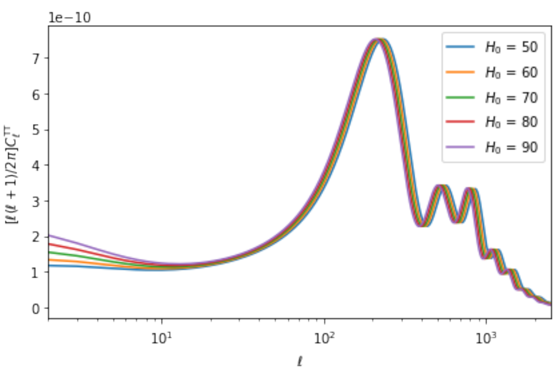

Fig. 6: Angular power spectrum varying H_0