A Literature Review of Research on the Cosmic Microwave Background

Hayden M. Webb

Southwestern Oklahoma State University

Like any other explosion, the Big Bang had a shock wave. This remnant of the creation of the universe is known as the CMB (cosmic microwave background). The CMB can be measured all across the observable universe and thus can be used as a tool to measure the universe. This paper investigates the state of research being done on the CMB and how it is being applied. It is hypothesized that a research has created a foundation for understanding and using the CMB, but is open to expansion. The following four literature reviews are used to establish an understanding of current and past works on the cosmic microwave background in order to support the hypothesize.

First, Schlegel et al. created the fundamental paper used at the beginning of CMB research (1997). The group wanted to refine the work of prior experiments to create a map of galactic dust for the study of the CMB. Their project combined data from the DIRBE (Diffuse Infrared Background Experiment) and IRAS (Infrared Astronomy Satellite) missions to construct a full-sky map. Schlegel et al. improved upon the previous missions by removing potential light contamination and cosmic infrared background. Their map is able to show the density of galactic dust based on its infrared emission. At the time the map was intended to test and estimate the potential extinction of the universe. The map served as a standard for work at the time and as a foundation for future projects. By identifying the location of galactic dust, researchers were able to study the CMB in regions of sky that were less polluted. As of the creation of this paper, Schlegel et al. is the most cited work in the field of CMB research. This paper appears to have paved the way for future groups to continue the understanding of the CMB.

Second, the Wilkinson Microwave Anisotropy Probe (WMAP) research team is a collaboration between Princeton University and NASA. The group’s first year paper set out to use more precise data than previous projects to test cosmological models. The WMAP enabled the group to more finely test measurement. The paper presented microwave maps in five separate frequency bands. These maps were used to confirm readings gather by COBE (Cosmic Background Explorer). The first-year paper tended to focus on refining and confirming information rather than exploring new avenues. The main take away from the first-year paper is a base line for future research. The group also showed that they can separate the CMB from other cosmological readings to produce a refined single. The more precise data was then used to determine the age, temperature, and size of the universe. In the words of the WMAP team “We have demonstrated the ability to separate the CMB anisotropy from Galactic and extragalactic foregrounds. We provide masks for this purpose. In addition, we have produced CMB maps in which the Galactic signal is minimized” (Hinshaw G. et al. 2003). The WMAP team’s first paper began the first steps to understanding the CMB and using it as a tool. The WMAP continued to refine their work and published a paper roughly every year.

Third, the fifth-year WMAP shows the progress the team had made toward refining their work. The fifth-year paper specifically addressed cosmological constraints. A concept they addressed during the three-year WMAP paper, but not to the same degree. The WMAP team also focused on significantly improving data on cosmic temperature and polarization. The group worked to increase the accuracy of their measurements and test the six-parameter ACDM model. The paper addresses this fact in stating:

In this paper, we have explored our ability to limit deviations from the simplest picture, namely non-Gaussianity, nonadiabatic fluctuations, nonzero gravitational waves, nonpower-law spectrum, nonzero curvature, dynamical dark energy, parityviolating interactions, nonzero neutrino mass, and nonstandard number of neutrino species. Detection of any of these items will immediately lead us to the new era in cosmology and a better understanding of the physics of our universe. (Hinshaw G. et al. 2008)

Without the detection of the afore mentioned deviations WMAP can show their data fits with the ACDM model. This being the case, the group was able to measure optical depth. The fifth-year WMAP constructed its constraints through data collected by WMAP alone. The group’s model also fits small scale CMB data and other data sources used to measure the expansion rate of matter in the universe. The WMAP team shows that they had expanded upon their work and planned to continue to do so. However, the group still considered their analysis as a prototype and encourage outside research.

Finally, a more recent example of CMB research is found in Yacine Ali-Haïmoud and Marc Kamionkowski (2017). Their paper seeks to discuss the relationship between the CMB and primordial black holes (PBHs). The paper was founded on that current theory that PBHs might comprise some or all of the universes dark matter. The paper looks at the effects of PBHs on the CMB temperature and polarization power spectra. Yacine and Marc attempt to accomplish this by computing the luminosity of PBHs while accounting for the drag and cooling caused by CMB photons. They also estimate the Schwarzchild radius and velocity of the primordial black holes by the surrounding gas. Yacine and Marc revised existing CMB limits to include the abundance of PHBs and noted that “We showed that CMB-anisotropy measurements by the Planck satellite exclude PBHs as the dominant component of dark matter…”. Primordial black holes are a rather recent develop in study of the CMB and will require more research as the field continues.

In conclusion, finds in the literature reviews support the hypothesis. Research being done on the cosmic microwave background is diverse and expanding. A common theme among earlier works appears to be compounding information and verifying others works. While more recent CMB research appears to have become more specialized. Later papers are more likely to repeat each other rather than working in connection to affirm and expand on each other. There also appears to be a lack of a base standard for mapping that has been produced as of late. More research is warrant in this field in order to reestablish a common standard. WMAP serves as an example as to how research should be cared out when starting in the field of CMB. One must first begin testing and confirming others’ works before specializing in different aspects of the CMB. The CMB is definitely a growing field, but modern foundation for research to be based on is required.

Work Cited

Ali-Haïmoud, Yacine, and Marc Kamionkowski. “Cosmic microwave background limits on accreting primordial black holes.” Physical Review D, vol. 95, no. 4, 2017, doi:10.1103/physrevd.95.043534.

Dunkley, J. et al. “FIVE-YEAR WILKINSON MICROWAVE ANISOTROPY PROBE \* OBSERVATIONS: LIKELIHOODS AND PARAMETERS FROM THE WMAP DATA.” *The Astrophysical Journal,* vol. 180, no. 2, 2008, pp. 330-376, doi: 10.1088/0067-0049/180/2/306.

Schlegel, David J., et al. “Maps of Dust Infrared Emission for Use in Estimation of Reddening and Cosmic Microwave Background Radiation Foregrounds.” The Astrophysical Journal, vol. 500, no. 2, 1998, pp. 525–553., doi:10.1086/305772.

Verde, L. et al. “First-Year *Wilkinson Microwave Anisotropy Probe*(*WMAP*)\* Observations: Determination of Cosmological Parameters.” *The Astrophysical Journal,* vol. 148, no. 1, 2003, pp. 1-27, doi: 10.1086/377226.