Influence of Magnetic Structure Size on Solar Irradiance Variations

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The following is an excerpt from a longer piece. For the full text, please visit https://scholar.colorado.edu/concern/undergraduate_honors_theses/td96k423g or scan the QR code.

Abstract

This thesis examines the interrelationship of the size of the magnetic structures on the Sun, particularly faculae, and the solar irradiance variations which are of significance for the understanding of the solar dynamics and the climate of the Earth. Using the high-resolution data coming from the Sunrise I Balloon-Borne Solar Observatory and the broader observations of the Precision Solar Photometric Telescope (PSPT), this study investigates the magnetic activity of the Sun and its nature, the implications, and the physics behind it. Through an analysis encompassing observational data and sophisticated MURaM simulations, the research delineates the nuanced interplay between magnetic field strength, structure size, and solar irradiance. Key findings highlight a significant correlation between the size of solar magnetic structures and their magnetic potency, offering new insights into the complex mechanisms driving solar luminosity variations. The study also deals with the methodological difficulties in comparing high-resolution observations with synthetic spectra and stresses the need to replicate the instrumental and atmospheric effects in simulations. The combination of observational and simulated data not only deepens our knowledge of solar magnetic fields but also highlights the possible effects of solar irradiance fluctuations on space weather and terrestrial climate systems. This thesis brings a considerable contribution to the field of solar physics by providing a holistic study of solar magnetic structures which in turn helps us to understand the Sun's role in the solar-terrestrial environment and the prospects for future research on solar dynamics and climate impact.

Lay Summary

Our Sun, while often regarded as a stable beacon in our sky, undergoes small yet important variations in brightness over time. In this research, we investigate one source of these variations: magnetic structures on the Sun's surface. The Sun's magnetic fields, created by powerful flows of hot plasma inside the star, can form dark spots (sunspots) and bright patches (faculae) on its surface. While dark sunspots slightly reduce the Sun's brightness, the bright faculae can compensate and even exceed that effect, causing an overall increase in the solar energy reaching Earth at certain times. By combining data from the Sunrise Balloon-Borne Solar Observatory, which flies high above most of Earth's atmosphere for crisp, detailed views, and the Precision Solar Photometric Telescope in Hawaii, which captures broader, full-disk images, we measured and compared these features in unprecedented detail. We also used computer simulations (the MURaM code) to model how these magnetic structures should look if our understanding is correct. Our analysis focused on two main questions: how does the size of these magnetic features relate to their magnetic field strength, and do these stronger, often larger features produce more brightness? We found a noticeable pattern: bigger structures tend to have stronger magnetic fields. These structures appear visually brighter than their surroundings, although more work is needed to pin down a precise, quantitative link between their strength and actual radiative output. These findings help us better understand how the Sun's complex magnetism affects its brightness—and, by extension, conditions here on Earth.