CORONAL TEMPERATURE DIAGNOSTICS DERIVED FROM MULTILAYER OBSERVATIONS WITH THE MULTI-SPECTRAL SOLAR TELESCOPE ARRAY

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ABSTRACT

In recent years, satellite-based extreme ultraviolet multilayer telescopes observing the solar corona have provided some of the most beautiful and fascinating images ever seen. However, our ability to extract quantitative information about the thermodynamic state of the solar atmosphere from these images has been limited by their broad temperature response, uncertain calibration status, and the limited number of bandpasses available. In this dissertation, I present a unique dataset and novel analysis techniques designed to provide rigorous constraints on conditions in the corona with the high spatial and temporal resolution of multilayer images. The data were obtained during the third flight of the Multi-Spectral Solar Telescope Array, a sounding rocket payload which was launched on April 30, 2002. The MSSTA imaged the solar atmosphere in seven different ultraviolet bandpasses, centered on strong emission lines at 150 Å, 171 Å, 180 Å, 195 Å, 211 Å, 1216 Å and 1550 Å. These images, along with satellite observations, can be used to constrain the differential emission measure of the corona in the temperature range of 300,000 to 3,000,000 K; however, uncertainty in the data and fundamental limitations in the emission processes impose strict limits on the range and accuracy of the results. I present spatially-resolved differential emission measure functions obtained from the MSSTA data, and discuss the potential applications of these results, along with an analysis of the limitations of the current data set and of the DEM reconstruction technique.

ACKNOWLEDGEMENTS

Much of the work described here was the collaborative effort of a number of people, and in recognition of this fact I have generally used the plural “we” to describe the activity and deliberation of the MSSTA team throughout the text. However, a number of vital contributions are not mentioned in the body of the dissertation, or were so integral to the MSSTA project or my own ability to proceed that they demand explicit recognition.

Arthur B. C. Walker conceived and created the MSSTA payload, so any work derived from that instrument owes him a tremendous debt. Even more importantly, for me, Art was a mentor and a friend. He kept me from giving up on science altogether and sparked my interest in solar physics; taught me to plan and test scientific instruments with a critical eye; and gave me the confidence to pursue my own path. His passing in April of 2001 was devastating for all who knew him. The breadth of his accomplishments, and his brilliance, kindness and courage, have been mourned by many people with more eloquence than I feel I can provide. I will always feel blessed to have known him and learned from him, and owe all the satisfaction I derive from thinking of myself as a solar physicist to him. I am also grateful to Victoria Walker for her compassion, for sharing some part of her admiration and love for Art with me.

Philip Scherrer has been my thesis advisor since 2001, and has been wonderfully supportive, patient and good to me in that time. His guidance ensured that the only obstacles I faced in continuing to work on the MSSTA mission were scientific, and enabled me to continue at Stanford. He has also helped me understand the place of my work in the larger solar physics community, and helped me to connect to other members of that community. I am grateful to the members of Phil’s research group who provided helpful suggestions on the analysis of the MSSTA data, especially Sasha Kosovichev and Rasmus Larsen.

Dennis Martínez-Galarce has managed to be a scientific colleague, an advisor, a beer-drinking comrade, and a supervisor to me, frequently playing all these roles in series within the same 24 hour period, and all without any officially-sanctioned status. He took over the direction of the

MSSTA project in 2001 and demonstrated extraordinary tenacity and ingenuity in ensuring the payload's success. I owe a great deal to his intelligence, experience, and willingness to develop an extremely productive and relaxed working relationship with me.

I'd like to think that T. J. Bay and I worked similarly well together. Certainly T. J. managed to accomplish a tremendous amount despite joining the MSSTA team as launch time approached; he made himself an expert on the payload in less than a year and made invaluable contributions to the calibration experiments, alignment, assembly and pre-flight testing of the telescopes. Ramesh Kumar and AmirAli Talasaz took over the arcane payload electronics and software, and transformed them into a sophisticated camera-control computer through long hours and divine inspiration. Naseem Hakim, Felicia Tam and Dave Robertson all helped keep the payload work moving forward and solved some of the innumerable little problems that make experimental physics interesting. Hakeem Oluseyi and Craig DeForest shared generously of their own experiences on past MSSTA flights and the wisdom they have gained since the completion of their graduate work.

The NASROC team at White Sands Missile Range, lead by Carlos Martínez and Bill Payne, probably worked harder on our payload than on any three other missions, but they never complained, and were never anything but cheerful, professional and skillful. It was difficult not to feel that they could have built and flown the whole experiment in a month if only we members of the science team would get out of their way. Their supreme competence earned my gratitude and awe.

Troy Barbee and Phil Baker were collaborators who were happy to act as teachers when it became clear that I needed more from them than just the work that the original proposal called for. Eric Gullikson and the staff at the ALS, and Hal Tompkins and the staff at SSRL, were similarly helpful and understanding. My dissertation committee – Sarah Church, Vahé Petrosian, Blas Cabrera, and Umran Inan – provided patience and useful feedback.

It goes without saying that I would have failed in a thousand ways over the past seven years without the ceaseless support of my family and friends. To all of you, thank you.

AUTHORSHIP

By its nature, a dissertation requires at least some account of how much of the described work was performed by the individual author, and to satisfy this requirement as well as to absolve the innocent of any blame for my own mistakes of commission or omission, I will attempt to make explicit the extent of my own role in the project here described.

The text of the dissertation is entirely my own writing. With the exception of Section 5.4, which is adapted from (Boerner, Martínez-Galarce et al. 2004), none of the text has been previously published elsewhere. The material in Chapter 1 is essentially a restatement of a large body of existing knowledge, which I have taken pains to cite appropriately; while this is mostly background, with little that is truly new, some of the formalism and all of the arguments presented in Chapter 1 are my own.

The experimental work described in Chapters 2 and 3 was mostly performed between 2000 and 2002. During this time, I was the senior graduate student of the MSSTA team. The planning of the experiment and the day-to-day labor in the lab were truly a team effort involving Dennis, myself, our collaborators and the other students in the group. I take full responsibility for those parts of Chapters 2 and 3 that give the impression that the MSSTA experiment was characterized by somewhat more frequent delays and errors than might be expected from an experienced scientist, and partial responsibility for the rest. I do not describe any of the experimental efforts (such as revision of the flight software) that were predominantly carried out by another member of the team.

The analysis techniques presented in Chapter 4 are my own work; I have cited the results of other authors who have performed similar analyses, but did not work directly with anyone else, outside of brief discussions, in developing these techniques.

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