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FINAL REPORT FOR NAGW-1801

"AN INTERFEROMETRIC SPECTRAL MAPPER FOR THE CASSINI MISSION TO SATURN AND TITAN"

ABSTRACT

The research reported herein resulted in a detailed proposal for the Cassini that addressed fundamental atmospheric structure and composition questions for both Saturn and Titan. Due to the brief time available between the initiation of the research and the proposal date, it was necessary to develop the science goals in close synchronicity with the instrument design. A major goal of the program was to acquire, implement, and test SWIR and MWIR arrays suitable for use with the DIGITAL ARRAY SCANNED INTERFEROMETERS, (DASIs), for the extended goal of developing DASIs for a range of spectral mapping research in solar system exploration. These goals were all reached or exceeded in the course of this work.

Introduction

The Cassini Mission is a mission to Saturn and Titan that would have benefitted greatly from the presence on-board of a high spectral resolution capability for spectral mapping in the 3-5 μm region. There, thermal emission from molecules formed by deep chemical processing in the atmosphere of Saturn, plus H_2O, and many important atmospheric species for Titan could be readily measured, quantified, and applied to the determination of the state and evolution of the relevant atmospheres. Preparation and submission of that proposal was the first purpose of this program. Second, we acquired under this program a SWIR array detector for use in the continuation of the development of DASIs as the new instrumentality for space-borne spectral mapping, replacing grating spectrometers.

The Proposal

The technical proposal for the Atmospheric Chemical Mapper, ACM, as submitted to NASA, is included here as Appendix A. This document is the expression of months of detailed analysis of the science case and the commensurate DASI instrumental design to acquire the science measurements dictated by the science in the Saturnian and Titanian environs. This document expresses carefully and clearly the wide range of science outcomes of the proposed measurements and the means to accomplish those measurements in the vicinity of Saturn and Titan. There is a detailed development plan for the instrument with advanced designs developed expressly for Cassini. Included in the development of the proposal are the results of the efforts carried out under the PIDDP work statement.

There were fifteen items in the work statement, all of which were concluded at a sufficient level for the development of the proposal document. We were fortunate that Rockwell Science Center was able to lend us a MWIR array in time for the 5 μm measurements in the lab to support the proposal. This array allowed our studies to progress to the point that we could define the ACM's sensitivity for the proposed science measurements in the vicinity of Saturn and Titan, and resulting data signal-to-noise. Following the completion and submission for NASA's consideration of the ACM proposal, our efforts turned to continued development of the DASIs for other solar system exploration goals, and in particular, we planned to utilize the SWIR array to be acquired under this program.

The SWIR Mercury-Cadmium-Telluride (HCT) Array

Funded half in year one and half in year two of NAGW-1801, we placed an order under the auspices of the university consortium coordinated by the University of Chicago to acquire SWIR HCT arrays for application to our solar system exploration science measurement goals. This acquisition was delayed more than one year by the manufacturer, resulting in an extension of the end of the program until 10/31/91. By this time, we had received from Rockwell the required SWIR HCT arrays, the so-called "NICMOS III" devices. These arrive as detectors only and must be implemented into a camera assembly including electronics and dewars for cooing the

devices to 80 K. Much the remaining funds that we have acquired under this and the subsequent PIDDP continuing the DASI development has gone into the implementation of these camera systems, their data acquisition hardware, and the software for acquiring and analyzing the spectral mapping data. At the end of NAGW-1801, we had just finally acquired the SWIR arrays, so that the SWIR data I show here was acquired later under PIDDP auspices. Prior to that time, we had CCD arrays that could be used for many valuable measurements required for the evaluation of DASI properties for spectral mapping.

The likely applications of DASIs following the Cassini Mission were all of planetary/small body surfaces with the possible exception of studies of the atmosphere of Venus. For that reason, we emphasized the development of the simplest, most compact designs for DASIs that could attack the spectral mapping problems for those objects. In particular, we devised a birefringent DASI that was even more compact and stable than the Cassini ACM design, in keeping with the growing efforts within NASA to reduce the cost and consequently the size, mass, and complexity of its space missions. An example of such a design developed within the latter stages of this program is shown in Figure 1. This DASI has been used exclusively since that time for all our further development for solar system exploration. We have acquired extensive data sets with this instrument using the CCD (below) and now under the subsequent PIDDP, the SWIR NICMOS III array, proving the validity of the proposed capabilities of DASIs for spectral mapping missions within the solar system. Using the CCD detector, we have acquired spectral data verifying the high S/N attainable with DASIs while maintaining much smaller dimensions, weight, and power requirements compared with competing grating spectrometers. This work has continued unabated under PIDDP auspices since the conclusion of this program (with its extension to acquire the NICMOS III arrays from Rockwell) and is now yielding field data of high quality, further supporting the remarkable capabilities of these simple, lightweight instruments. The developments led, during early 1992, to further planetary exploration,proposals, and most recently, to new Discovery class missions, a mission class that did not yet exist when this effort

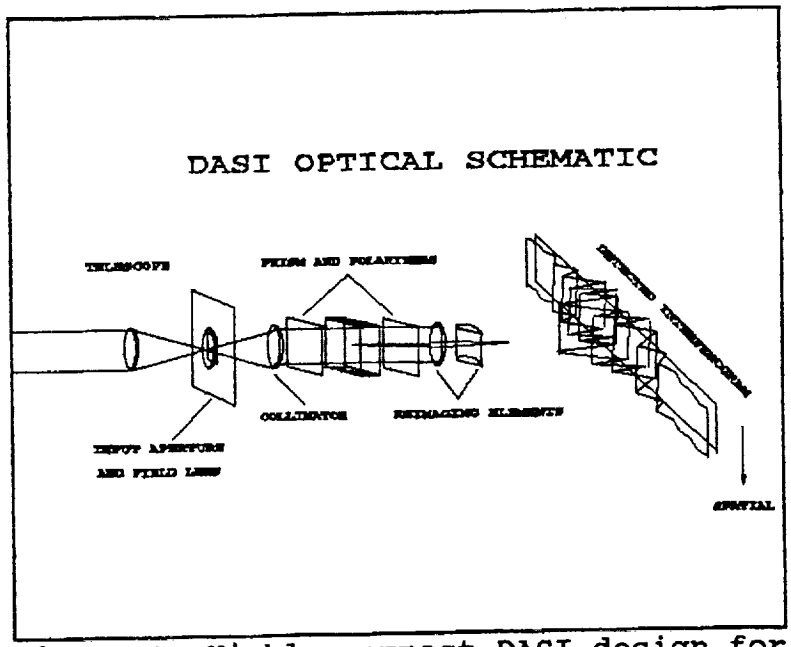

Figure 1. Highly compact DASI design for SWIR spectral mapping

was begun.

Verification of the properties of the DASI has included spectral observations of standard samples to confirm that spectral measurements were quantitatively reliable. Figure 2. shows the DASI spectrum for didymium glass, a well known spectral standard, that is identical in every aspect with published calibration spectra of this glass. Similarly, in Figure 3. we plot a reflectance spectrum for hematite that again agrees with published hematite spectra for the CCD spectral region. In conjunction with these data, we have verified many of the advantages for high spectral fidelity available to the DASI method.

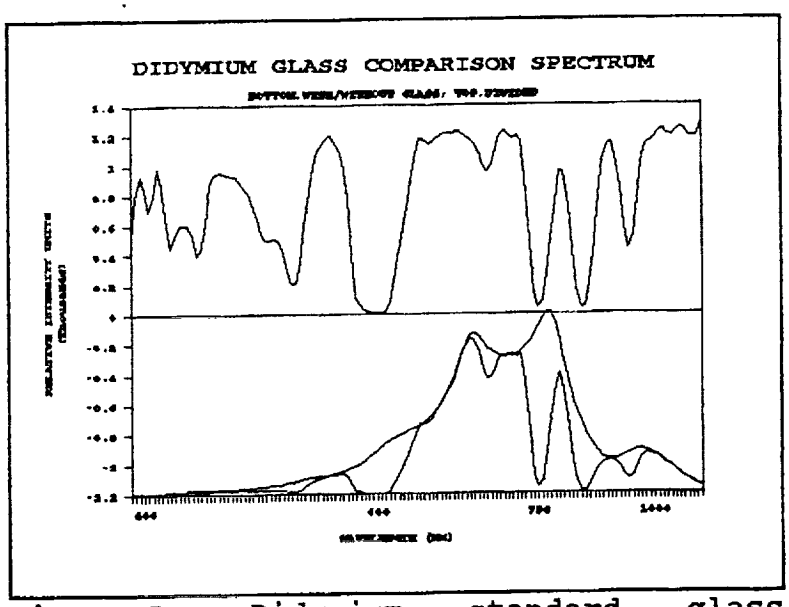

Figure 2. Didymium standard glass spectrum, obtained with DASI in the CCD spectral region.

Publications.

Publications on these and other extensive observations are in press or in preparation. Our major publication during this PIDDP was, however, the enclosed technical document for Cassini which represents an extraordinary level of effort by all the members of the team named therein. I would like to express here my appreciation for the enthusiasm and intellectual input of the Co-Is and the Ball team during this intense period of activity leading up to the submission of the ACM proposal. The proposal was not selected for inclusion in the Cassini Mission, but that does not detract from the fact that we identified and developed and extended the science goals of the 3-5 μm spectral region in the context of the deep chemistry and composition of the atmospheres of both Saturn and Titan and identified clear methods of retrieving those science goals with the proposed

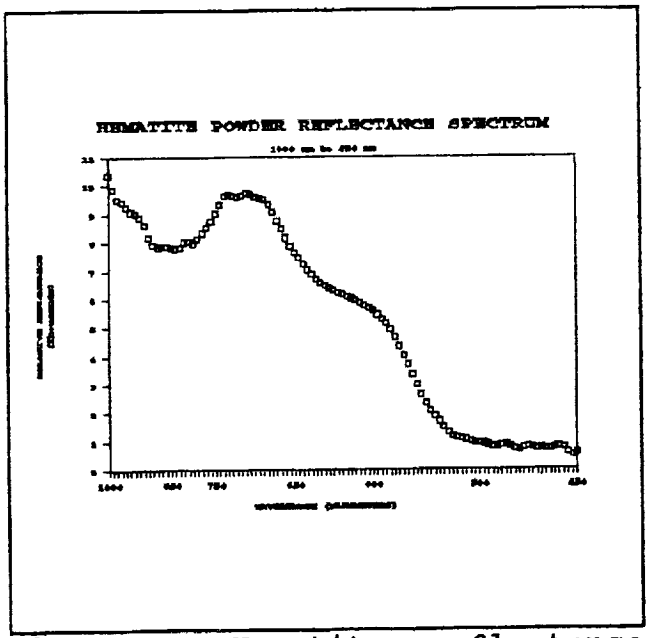

Figure 3. Hematite reflectance spectrum obtained with a DASI in the CCD spectral region.

instrument. This is the best unfunded proposal it has ever been my pleasure to write. In addition, our inception article on DASIs appeared in the referred literature during the period of NAGW-1801.

Reference

Digital Array Scanned Interferometers, (with W. V. Schempp), Experimental Astronomy, 1, 389-405, 1991.