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Rocket and Laboratory Studies in Astronomy

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Status Report for the Period
September 1, 1992 - August 31, 1993

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I. INTRODUCTION

This report covers the period from September 1, 1992 to August 31, 1993. During the reporting period we launched the Faint Object Telescope to measure absolute fluxes of two hot dwarf stars in the spectral range below 1200 Å. Although all systems worked normally, a higher than anticipated pressure in the detector led to ion-feedback that masked the useable data from the source. We have identified the source of the problem and are preparing for a reflight in the Fall of 1993. Our laboratory program for the evaluation of the ultraviolet performance of charge-coupled-detector (CCD) arrays continued with the aim of including a UV-sensitive CCD in a payload to be flown in 1994 and we have begun the assembly of this payload. Work has continued on the analysis of data from previous rocket experiments and from the UVX experiment which flew on STS-61C in January 1986.

II. ROCKET EXPERIMENTS

Terrier-Black Brant V 36.085 UG was launched on December 14, 1992 from the White Sands Missile Range. The science objective was to measure the absolute flux between 912 to 1350 Å (the FUV) of a primary science target, the hot white dwarf star G191-B2B, and a secondary target, the hot sub-dwarf BD+28 4211. The payload consists of an aft section housing a Cassegrain telescope with silicon carbide coated mirrors, and a fore instrument section housing a vacuum spectrograph and associated electronics. In flight a vacuum door covering the slit-jaw of the spectrograph is opened, allowing FUV light to disperse from a SiC coated grating and form a stellar spectrum on a microchannel plate (MCP) detector. The spectrograph is evacuated because it is destructive to operate the detector at pressures above $\sim 10^{-4}$ Torr.

During flight, all systems (TM, ACS, S19, ORSA, the command uplink system (CUS), toilet seat, experiment spectrograph door, electronics, etc.) functioned correctly with the exception of the spectrograph detector. At T+120, the spectrograph door opened and within 6 seconds the pressure measured by the spectrograph's ion pump rose to $> 6 \times 10^{-5}$ Torr. At T+135 seconds the ion pump was turned off and at T+145 seconds the detector was turned on. The immediate response was an anomalously high count rate that remained high throughout the duration of the flight. The detector GSE displayed an anomalous diagonal line at a low count rate and no stellar spectrum appeared when the star was positioned in the slit at \approx T+245 seconds. Normally, the detector has only a few dark counts ($\sim 1 - 10$ per second), which are distributed uniformly on the display when FUV light is not present. The immediate suspicion was that the detector had been swamped by a higher than anticipated pressure from an unknown source. Apparently, the high pressure produced a potentially destructive MCP detector condition known as ion feedback that caused the detector pulse location algorithm to become confused, creating the diagonal line on the detector display.

Following the flight, we conducted vacuum simulations that were used to determine the following. The source of the high pressure, which caused the detector anomaly, was outgassing from the experiment instrument section interior. The detector anomaly, ion feedback, is a non-linear process that occurs suddenly when the pressure

inside of the spectrograph rises above $>8 \times 10^{-5}$ Torr. It is possible to stimulate the ion feedback at a pressure below the threshold (7×10^{-5} Torr) by introducing ionizing radiation (UV light) into the spectrograph. In the stimulated mode at the lower pressure, the feedback can be quenched if both the ionizing radiation and the detector high voltage are turned off. These pressures are just slightly higher than the $>6 \times 10^{-5}$ Torr measured in the spectrograph during flight.

The results of the vacuum simulations indicate that the experiment was right on the borderline of success. The laboratory observation of stimulated ion feedback suggests that acquisition of the target in the spectrograph slit at $\approx T+245$ seconds only exacerbated the problem. Around this time the count rate increased from $2700 \text{ count s}^{-1}$ to $4500 \text{ count s}^{-1}$, falling slightly after the experimenter made a move off slit near $T+400$ seconds. We speculate that this rise in count rate is an indication that the mirror coatings worked and that the CUS was used successfully to acquire the target. In hindsight, if we had requested a command uplink control of the ion-pump and detector HV we might have been able to quench the feedback and lowered the pressure enough to achieve stable detector operation. If the ion feedback could have been quenched, we believe the minimum success criteria would have been met.

We have reconfigured the payload to allow evacuation of the telescope prior to launch and are scheduled for a reflight (36.109 UG) later this year. In passing, we note that this was the first use of the new command uplink system developed at WSMR and that we were very pleased with its performance during the mission. The work on the absolute stellar calibration flight is being carried out by Dr. Feldman, Dr. McCandliss, Mr. Martinez, Mr. Morrissey and Mr. Pelton.

During this period we have also begun to assemble a new telescope payload for the objective of ultraviolet imagery of Jupiter as described in our three-year proposal submitted in August 1992. A Project Initiation Conference for rocket 36.115UG was held at Wallops Flight Facility in June 1993 with a launch anticipated for May 1994. However, the recent discovery of a comet (Shoemaker-Levy 9) that was broken into multiple pieces during a close encounter with Jupiter in July 1992 and which is expected to impact Jupiter in July 1994, may alter our launch strategy. The telescope and secondary mirror image motion compensation system have been completed by Research Support Instruments and the focal plane camera design has been completed by Mr. Morrissey. The camera will utilize the ultraviolet-sensitive CCD detectors that we have been studying in the laboratory (see below), and we have begun the design and procurement of the detector electronics and cooler. We expect to begin integration at Wallops during the Spring of 1994.

During this period Dr. Feldman and Mr. Pelton supported the pre- and post-launch calibration efforts for the payload of Dr. John Clarke (University of Michigan), 36.101 UL, that was launched at White Sands Missile Range on June 15, 1993.

III. DETECTOR DEVELOPMENT

During the past few years we had developed the two-dimensional intensified array detector as a convenient, low-cost photon-counting detector suitable for applications in

space ultraviolet astronomy. The use of a Reticon diode array as a readout device grew out of our original application of a 1024 element linear array for the focal plane of the HUT spectrograph. For an imaging spectrograph, where a two-dimensional readout is required, we adopted the same basic design, but used a 100 x 100 element Reticon array in place of the 1 x 1024 array. To determine the centroid of each photon event, one dimension is first analyzed in a hardware arithmetic logic unit, followed by a software algorithm in the flight processor. The electronic stability of this process has been demonstrated to 1/8 of a diode (each Reticon diode is 60 μm x 60 μm square), while the optical resolution on the bench has been established at 1/4 of a diode, or 15 μm . A paper describing the detector has been accepted for publication in the *Review of Scientific Instruments*. The main disadvantage of this detector is the limit on maximum count rate, which makes it difficult to use in general applications. For our rocket experiments on faint extended astronomical sources this is not a problem, but it does limit the potential use of this detector with general purpose or facility-type instruments and has led to our investigation of the possible use of an ultraviolet-sensitive CCD in our rocket experiments.

Recent advances in CCD technology have allowed the use of these detectors at short wavelengths. We have investigated the suitability of a new-technology CCD for use in ultraviolet rocket astronomy and acquired a 1024 x 1024 *CRAF-Cassini* CCD manufactured by Loral (formerly Ford Aerospace) from test lot 3. This CCD has 12 μm square pixels and a coating of phosphorescent lumigen on the surface. Our primary efforts have been in determining the quantum efficiency (QE) of the chip as a function of wavelength. In the range 2000-4000 \AA , the QE is about 16% and is constant to within a few percent. The QE rises rapidly at longer wavelengths, reaching 34% QE at 5200 \AA , which is at a slightly longer wavelength than that of the peak lumigen output. In the ultraviolet, half of the light is lost to re-radiation away from the detector as a result of scattering from the lumigen. We have measured the QE down to Lyman- α in the CTE, and found it to decrease slightly from its value at 2000 \AA . A paper describing these results has been accepted for publication in *Applied Optics*. One advantage of the lumigen coating is its stable sensitivity in the ultraviolet; a thinned backside-charged CCD must be sensitized with a UV flood that requires keeping the CCD cold in order to achieve stable ultraviolet response. However, in recent months, advances in thinning technology combined with the much higher ultraviolet QE attainable has caused us to turn our attention away from the lumigen coated devices and accept the relatively minor problem of UV sensitization that can be easily accommodated in the rocket environment.

The goal of these studies has been the evaluation and subsequent procurement of a device suitable for flight use in the experiment to image the Jovian aurora that we have planned for 1994. This work is being done by Dr. McCandliss and Mr. Morrissey.

IV. DATA ANALYSIS

Mr. Martinez has continued his analysis of the long-slit ultraviolet spectrum of the Io plasma torus obtained from rocket flight 36.057 UG that flew in January 1991. Dr. Feldman, together with Dr. Scott A. Budzien, now at the Naval Research Laboratory, have continued analysis of the data from the UVLIM experiment, a collaborative project with Dr. R.R. Conway of NRL, that flew on space shuttle flight STS-39 in April 1991. Dr. Henry

and collaborators have re-examined some of the results from the UVX experiment (STS-61C, January 1986) in view of recent observations of the diffuse ultraviolet background made by the *Voyager* UVS and the UIT experiment on Astro-1.

Also, during the reporting period, Dr. Henry gave an invited review on the topic of observations of the diffuse ultraviolet background at the May 1993 symposium at the Space Telescope Science Institute, which this year was in honor of Riccardo Giacconi and was on the topic "Extragalactic Background Radiation." There appears to be a very real possibility that there is a genuinely diffuse extragalactic background, originating directly in the baryonic dark matter (ionized intergalactic medium) and implying the necessity of a specific form for the non-baryonic dark matter (neutrinos decaying with the emission of ionizing photons, needed to maintain the ionization).

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