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AFGL Ten Micron Mosaic Array Spectrometer - Recent Results

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Abstract

Recent measurements have been made with a novel mosaic array prism spectrometer on long period variable stars of carbon and oxygen-rich atmospheres. These stars have generally large IR excesses and show strong SiC and silicate emission features, respectively. A comparison is provided by published spectra obtained with the IRAS Low Resolution Spectrometer. Emission feature equivalent widths are independent of the absolute photometric level of the spectra and provide information on the relative variation of the feature and continuum fluxes between the epochs of the space and groundbased observations.

1. Introduction

The AFGL mosaic array spectrometer has been discussed previously (LeVan and Tandy 1987); we review the instrument briefly and report here on the more recent characterizations of its performance and on spectra of long period variable stars obtained with the instrument.

a. History The mosaic array is a 58 by 62 pixel Si:Ga detector array hybridized to a CRC-228 Direct Readout (DRO) multiplexer. It was lent to us by Santa Barbara Research Center in summer of 1984. A substantial electronics design effort was undertaken at AFGL to allow the high frame rates expected for such an array operated as a slit spectrometer in the 8 to 14 μm region at resolving powers of approximately 50. The electronics includes both the array address subsystem for operation of the array at frame rates as high as 185 Hz, and the hardware coadder circuitry that allows for real-time accumulation of digitized frames. By September of 1985, the electronics had been built and the array could undergo characterization for high speed operation in a testbed dewar. Concurrent with this, the optics, which consists of a NaCl prism slit spectrometer, was under construction by Sensor Systems Group, Waltham, MA, using our optical design. By summer of 1986, the optics and the array characterization had been completed, and the two assemblies were then integrated into an IR Laboratories Inc. dual flask dewar (an extended Model HD-8). First light was October of 1986 on the University of Wyoming 2.3 m telescope.

2. The Instrument - Electronics

a. The Mosaic Array The SBRC schematic of one of the 1798 total "unit cell" structures is shown in Figure 1. Note that the Si:Ga photoconductors have a bias voltage equal to the difference of the

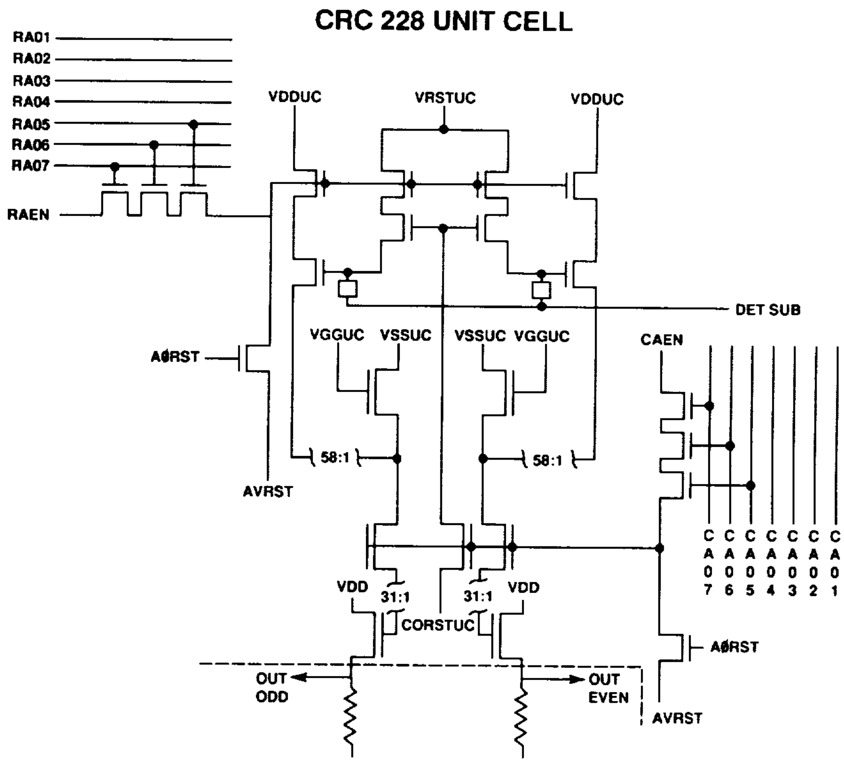

Figure 1. One of 1798 total mosaic array unit cell structures.

"detector substrate" and reset (VRSTUC) voltages immediately after reset; this voltage difference decreases as signal charge is integrated onto the capacitance formed at the detector array and multiplexer interface. The bias and clock voltages may be controlled externally; these were chosen for high speed operation as discussed in **b**, below. Finally, the pair of source followers that comprises the last stage of the multiplexer has associated load resistors that are external (shown below dashed line in Figure 1) and therefore selectable.

b. Operating Bias Voltage and Load Resistor Values The values of bias and clock voltage are in general those determined by NASA/GSFC during testing of a similar mosaic array under low background conditions (Lamb et al. 1986). Several deviations from these values were found by us to permit high speed operation of the array: 1) The source follower gate voltage (VGGUC in Figure 1) was increased from 0.7 to 0.85 volts, and 2) the load resistance was decreased from 100 KΩ to 10 KΩ. These settings resulted in a decrease of the reset time for a one volt source follower signal from approximately 10 to 1 μsec. The reset speed is set by the charging rate of the dewar wire capacitance, which is increased for the higher source follower drain currents. The higher currents are made possible with larger values of VGGUC and smaller load resistances. (For extreme values of either, the gain of this stage suffers).

MODE	ALU	RAM	DATA SELECT
COADD	F = A+B	R/W	ADC
OUTPUT	F = A-B	R	BUS

Figure 2. Hardware Coadder schematic. The inserted table shows component states for data acquisition (= coadd) and data output.

c. Hardware Coadder A schematic of the co-addition electronics shown in Figure 2 illustrates its function for data acquistion (= coadd) and data output. A key component is the Arithmetic Logic Unit (ALU), the mode of which changes from sum to difference between coadd and output modes. In coadd mode, the B input to the ALU is the digitized signal from a mosaic array pixel, the A input is the accumulation of previous signals for the same pixel fetched from RAM in read mode, and the output is the sum of these. This output is latched and rewritten to RAM at the same pixel address. In output mode, the A and B inputs are the accumulation of previous signals for a given pixel in separate telescope secondary mirror chopping positions, and the output of the ALU is the difference of these. The difference is transferred to the data acquisition computer. The table shown in Figure 2 summarizes several of the state changes between data acquistion and data output modes.

d. Electronics Overall Timing An attempt to summarize the timing of the more important clock controls may be helpful: The pixel clock rate of 333 KHz corresponds to 3 μsec pixel "windows" during which we clamp the signal, reset the signal charge, and sample and convert the difference between the clamped and reset levels (= Correlated Double Sampling). The frame rate is 185 Hz and the pixel integration time is 5.4 msec as a consequence of the continuous (as opposed to burst mode) frame reads. After every 32 frames, we command the telescope secondary mirror to chop. Although the array continues to be scanned after the chop command, coaddition is suppressed during a selectable number of frames to allow for the settling of the secondary mirror. After 5 full chop cycles, the coadded frames of the plus and minus telescope beams are differenced and transferred to the computer. This transfer takes place at a rate of about 25 μsec per pixel, keeping the duty cycle high (96% , or 48% if one considers only the source frames).

3. The Instrument - Optics Characterization

The optical ray trace and assembled optics bench are illustrated in a prior publication (LeVan and Tandy 1987). Here, we discuss spectra of polystyrene film acquired to assess the wavelength calibration of the instrument. Spectral features of polystyrene near 9.35, 9.73, 11.0, 11.9, and 13.3 μm are clearly visible for three spectral rows of a single exposure with the mosaic array spectrometer (See Figure 3). These features are seen to be broadened by the instrumental response over the reference spectrum also shown in Figure 3. By using the Image Reduction and Analysis Facility (IRAF) Onedspec package, a wavelength solution was obtained that is in excellent agreement with published values of dn/dλ for NaCl. IRAF was subsequently used to interpolate program object spectra onto an equally spaced wavelength grid.

4. Observing Setup

The dewar is mounted on a down-looking interface to the telescope cassegrain focus. All analog electronics and the analog to digital converters are enclosed in a metal box mounted to the dewar. Four commercial pulse generators (Berkeley Nucleonics Corp. Model 8010) are mounted to the telescope backplane, as is the hardware coaddition electronics. The power supplies reside on the floor of the dome, and the data acquistion computer in the control room at a distance of roughly 20 meters.

5. Recent Results - Long Period Variable Star Spectra

a. Motivation

We now discuss recent results of an ongoing measurement program on the University of Wyoming 2.3 m telescope using the mosaic array spectrometer. Eight sources have been measured during two observing runs reported here. These stars, with the exception of the calibration standard, are long period variables with generally large IR excesses. Three stars have carbon rich atmospheres, and an accompanying SiC emission feature near 11.3 μm. Three others have oxygen rich atmospheres and show pronounced silicate feature emission. We seek to address the possiblity of variation of the feature flux as the continuum varies. An additional observational epoch is provided by the IRAS Low Resolution Spectrometer (LRS) whose published spectra are contained in the Atlas of Low Resolution Spectra (Olnon and Raimond 1986). Since neither the LRS or AFGL instrument is strictly photometric, we may compare equivalent widths of the emission features for the purpose of determining relative variability of feature and continuum fluxes.

b. Spectrometer Exposures The observations consist of 4 exposures per star that individually result from telescope beamswitching over an approximate two minute interval. For such an exposure, the instrument obtains spectra of signal to noise greater than 10 for a -2.5 mag point source. Whereas the quoted sensitivity compares unfavorably with single pixel and mosaic array cameras operated with narrow bandpass filters, the spectral multiplex advantage nevertheless allows for observing efficiencies vastly improved over that of CVF systems.

c. Spectra We show representative spectra for each class of star and for each instrument in Figure 4. Blackbody continuum fits are shown that match best the continua on each side of the feature. Note the short wavelength cut-on of the AFGL instrument is approximately 9 μm and does not encompass the continuum point on the blue side of the strong silicate feature - a correction for this is made by setting the continuum such that its ratio to the feature at 9 μm is approximately that of the LRS spectrum. Also shown in Figure 4 is the feature profile that results upon subtraction of the continuum fit. Of the two stars shown, the V Cygni equivalent widths are in good agreement between the two observational epochs. On the other hand, IRC +10420 appears to exhibit a change in equivalent width between the earlier and later epochs. Further details, including the results of comparison for all six long period variable stars with LRS spectra, are contained in a forthcoming publication (LeVan and Sloan 1989, submitted to PASP).

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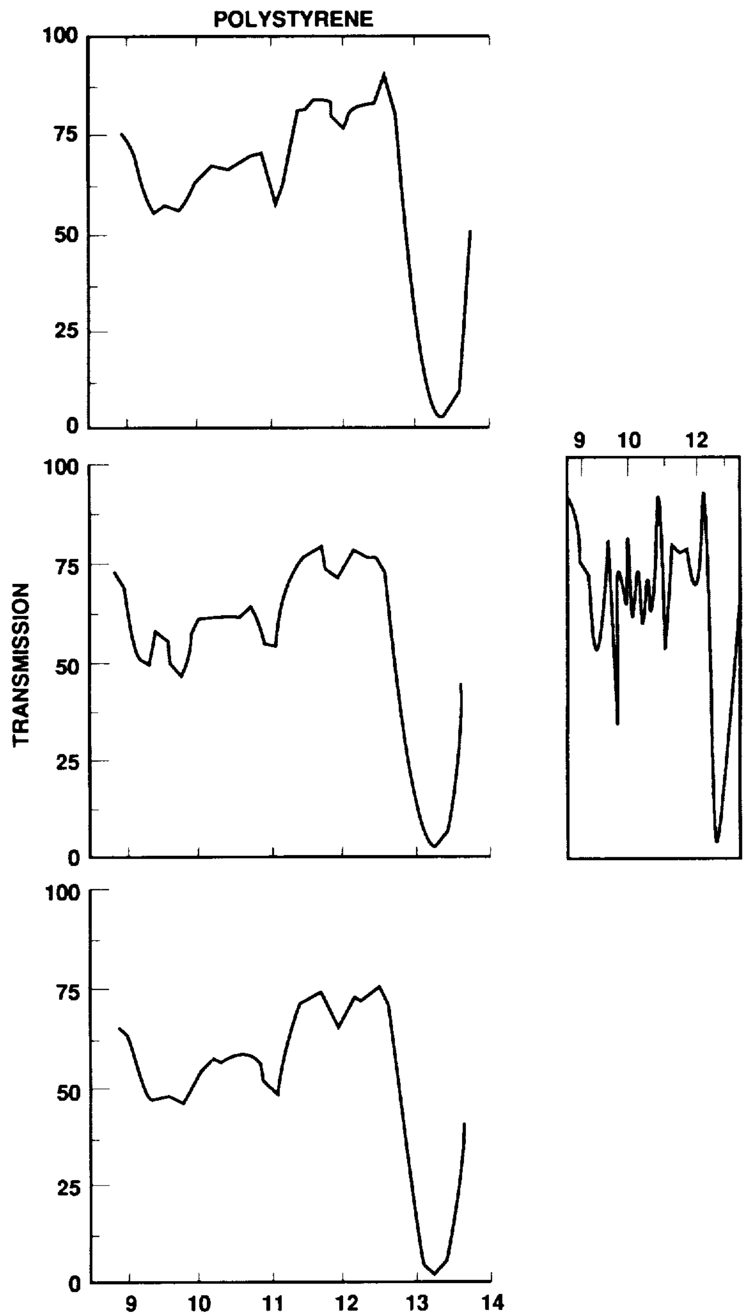

Figure 3. Spectra of polystyrene film. Shown are three spectra from a single mosaic array exposure along with the reference spectrum.

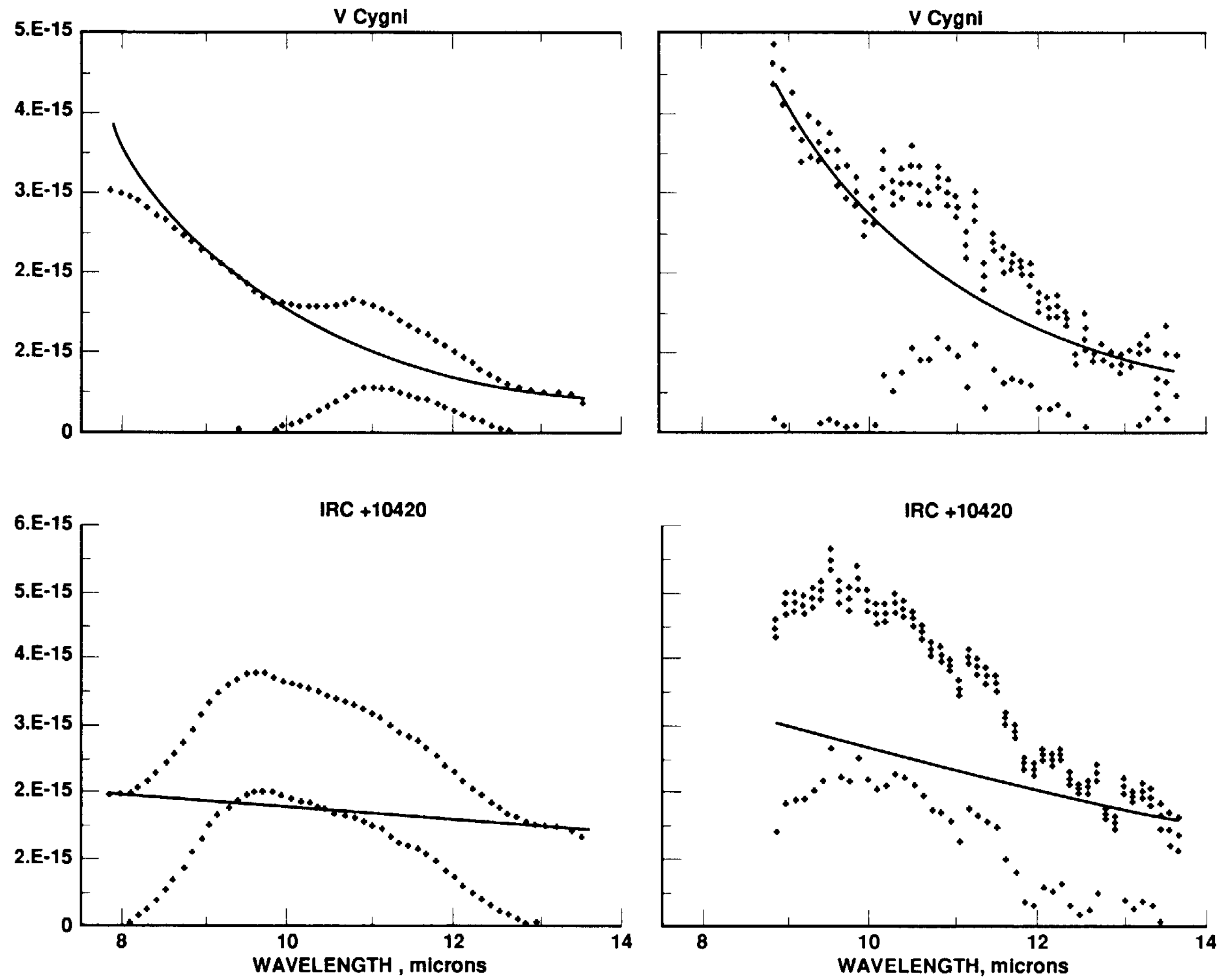

Figure 4. Spectra from the LRS (Left) and AFGL (Right) instruments, before and after subtracting an (approximate) blackbody continuum fit. The units of the vertical axis are W /cm² /µm.