A Sunphotometer for Mars Atmosphere Studies

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MOTIVATION

- Dust is a ubiquitous component of the Mars atmosphere (Martin and Zurek, 1993) and *strongly absorbs solar radiation controling the heating profile and therefore affecting synoptic scale circulations* (Haberle et al., 1993). This leads to dust storms that vary in size from dust devils to planetary scale storms, which affect the atmospheres thermal and dynamic structure (Murphy et al., 1993; Santee and Crisp, 1993).
- *In addition to affecting the thermal properties of the Mars atmosphere, dust also creates problems for remote sensing efforts.* The presence of Mars dust affects these retrievals by absorption, scattering and emission in these wavelength regions (Smith et al., 2000).
- Sunphotometery has been used on all previous Mars landers to determine the properties of dust, however, instruments not specifically designed for sunphotometry have been used to make the measurements. For example, Lemmon et al. [2004] used the MER Pancam [Bell et al., 2003] system to estimate optical depths.
- A dedicated instrument is required to study Mars' atmosphere and climate.
- The Advanced Sunphotometer is ideal for this application. It has no moving parts, is small, light weight, and consumes little electrical power.

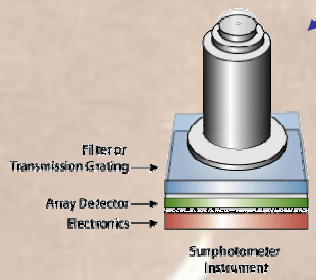
OUTREACH

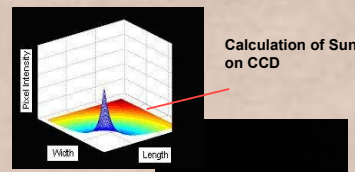
Graduate and undergraduate students from San Jose State University have been involved in this project from its inception. Ten students have helped in the modeling of the instrument and conducted test with the prototypes. This project will serve as a Master's Thesis project for 2 students.

Mars Sunphotometer Concept

The Advanced Sunphotometer is an innovative concept that uses a combination of unique optics and a detector array (typically a charged-coupled device (CCD), complementary metal-oxide semiconductor (CMOS) or charge induction device (CID)) to eliminate the moving parts inherent in a tracking sunphotometer. This makes the Advanced Sunphotometer smaller, compact, reliable, and suitable for planetary missions. A simplified diagram of the components of the instrument is shown at left. The first component of the system is a mirror optic that collimates light from a 2π steradian hemisphere through a filter or transmission grating and onto a detector array. The electronics element performs basic imaging processing functions to produce the required data.

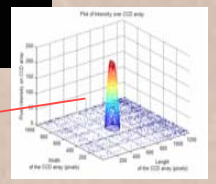
Patent Protection is being sought.





Calculation of Sun's intensity on CCD

Image of collimated light source in the lab



Data from the image above
Note that the CCD had only 8 bits - we only got the top of the intensity curve

Potential Data Products

Direct-to-Total Flux ratio – important in climate modeling

Optical Depth of Dust Throughout the Day

Size Distribution, Shape, Refractive Index of Dust from Phase Function (see text at right)

Column Density of Trace Gases, e.g., methane; validation of remote sensing

Cloud Cover Statistics

Dust Devil Statistics

In-Field Calibration

Two prototypes of the Advanced Sunphotometer have been assembled. The reflecting optic is a cone that is 25 mm high with entrance and exit apertures of 1 mm and 12.5 mm respectively. The first prototype (see Figure at right) used a Vitana PixeLink PL A653 array with 8 bit resolution.

A computer model of the instrument has been constructed to provide a theoretical mapping from position on the CCD to a position in the sky. A plot showing the theoretical prediction of the array image when the source is directly overhead is shown in the Figure at top left. An actual image of this geometry taken in our lab is shown in the center Figure at left and a contour plot showing the intensity on the array is shown in the Figure at bottom left. Note that with the limited well depth of our detector only the top of the direct beam peak is measured.

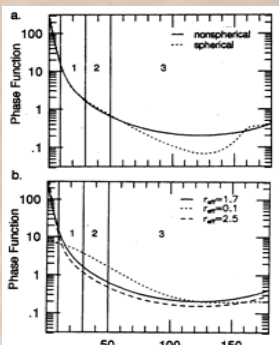
We have just obtained a cooled Santa Barbara Instrument Group (SBIG) CCD array with 16 bit resolution and filter wheel with 9 filters at 320, 394, 420, 455, 520, 610, 630, 855, and 940 nm. A picture of this prototype is shown at right. Because of the added distance between the array and the cone, telescoping optics need to be constructed in order to obtain usable images.

Other Applications

This instrument would have applicability to the Discovery and Mars Exploration class Missions.

Detection of trace gases (Methane)

Applicable for any planet or moon with an atmosphere, for



The figure at right demonstrates the affect of particle shape and size on the phase function. The Mars Sunphotometer will be able to measure the direct solar beam and the diffuse scattered phase function simultaneously.

The figure at right is a comparison of five single-scattering phase functions, demonstrating the effect of particle (a) shape and (b) size on scattering behavior. The numbers denote the specific areas that were chosen by Pollack et al. for optimizing the phase function parameters: zone 1, particle size distribution; zone 2, imaginary refractive index; zone 3, particle