Color Imaging of Mars with the Visible Imaging Subsytem (VIS) on the Mars Odyssey THEMIS Instrument.

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Introduction: The NASA Mars Odyssey spacecraft began its primary orbital mapping mission in February 2001. Odyssey carries an imaging instrument called THEMIS, which has both infrared and visible wavelength imaging capabilities. The THEMIS Visible Imaging Subsystem (VIS; Figure 1) is a 5-color, 1024×1024 interline transfer CCD camera that acquires high spatial resolution 425 to 860 nm multispectral images from Mars orbit. This abstract describes the data reduction and calibration methods used to process VIS data, and presents some initial results on surface color properties at high spatial resolution.

Motivation: Multispectral imaging at visible wavelengths can provide information on the composition, distribution, and physical properties of ferric (Fe^{3+}) and ferrous (Fe^{2+}) iron-bearing rocks and minerals, surface frosts and ices, and atmospheric aerosols on Mars. Previous telescopic [1-3] and spacecraft [4-6] multi-spectral observations at visible wavelengths have shown there to be distinct color units at a variety of spatial scales on Mars, and that the variability of these units is related to variations in the crystallinity of highly altered ferric minerals, ranging from regions spectrally similar to terrestrial palagonites to regions exhibiting spectral signatures consistent with more coarsely-crystalline hematite.

The five VIS filters have central bandpasses of 425, 540, 654, 749, and 860 nm, bandwidths of ~50 nm (Figure 2), and are bonded in ~1000×200 pixel strips directly onto the VIS CCD. Odyssey is in a near-polar orbit, traveling southward on the dayside of the planet, and VIS acquires multispectral images by using along-track motion to step the ground footprint through each desired filter. Nominal ground surface resolution is ~18 meters per pixel, and summing modes are available that can provide 36 m or 72 m resolution for increased surface coverage. As of early January 2003, just over 3.4% of the surface of Mars has been imaged by VIS during daytime (between about 3:00 pm to 4:30 pm local solar time), with about 40% of that coverage at 18 m/pixel and 60% of that coverage at 36 or 72 m/pixel. About half of the VIS image sequences are monochrome (654 nm) for high resolution geomorphology studies and some serve as context for higher resolution MGS/MOC images; the rest are multispectral sequences in 2 to 5 colors.

VIS data are calibrated using a combination of pre-flight radiometric calibration measurements and in-flight flatfield and bias data. We have developed a VIS calibration pipeline that performs a bias subtraction (using nightside VIS images), removes CCD frame transfer smear, and applies a flatfield correction for pixel-to-pixel nonuniformities. In addition, raw VIS data contain a substantial stray light component that is modeled and removed as part of our pipeline process using data collected in flight. VIS images corrected for these instrumental effects are then converted to PDS-format image cubes calibrated to radiance using regions observed by VIS and the Hubble Space Telescope over the same wavelengths and during the same martian season [*e.g.,* 3,7]. Dividing by the solar spectrum convolved to the VIS bandpasses results in image cubes calibrated to radiance factor (I/F; Fig. 3).

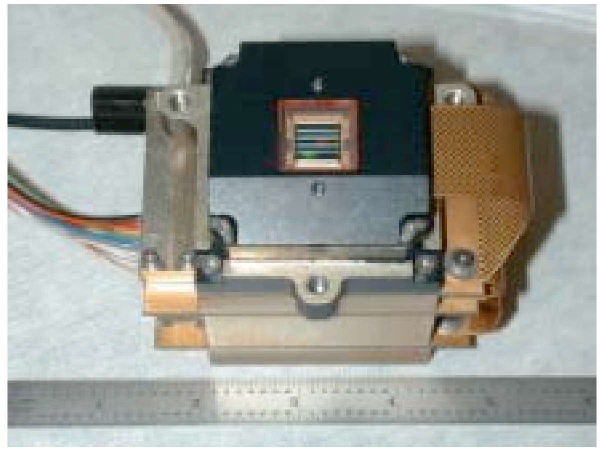

Figure 1. The Odyssey THEMIS VIS instrument. The color filters can be seen overlying the CCD at center.

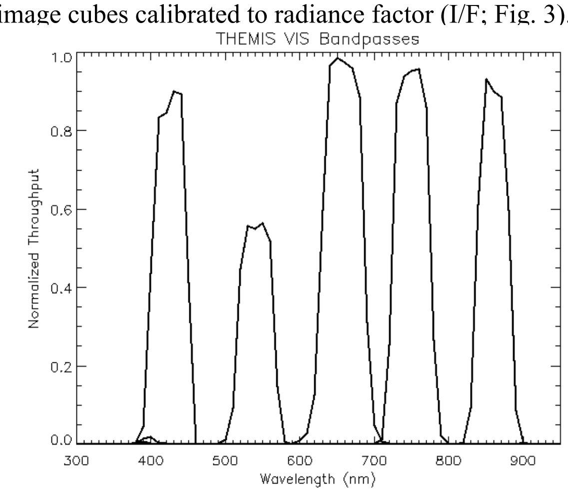

Figure 2. THEMIS/VIS Filter bandpass profiles.

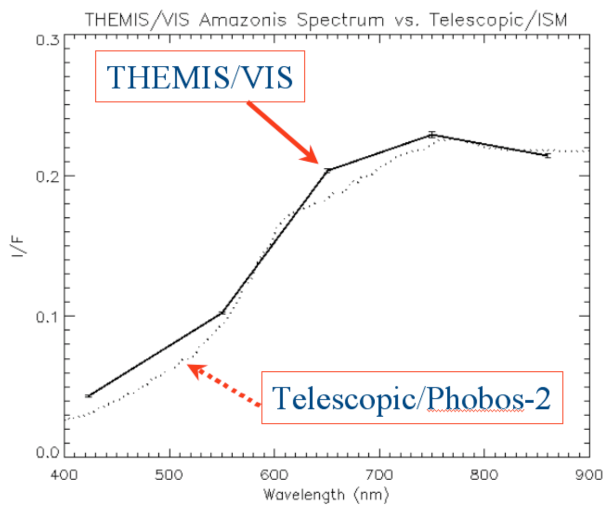

Figure 3. THEMIS/VIS calibrated I/F spectrum of the Amazonis bright region (solid line) compared to composite Phobos-2 ISM/telescopic spectroscopic observations of the same region ([8], dotted line), photometrically corrected to the VIS viewing geometry using a simple Minnaert model.

The contribution of the martian atmosphere to the observed VIS radiance is a function of the amount of aerosol particles (dust, ice) suspended in the atmosphere and on their microphysical properties (*e.g.,* size, shape, and composition). The situation is complicated by the limited viewing geometry of the VIS imaging sequences and the general lack of aerosol absorption features in the VIS bandpasses. We are modeling the VIS radiances and thermal IR radiances from the THEMIS IRS subsystem [9] and using other existing knowledge/assumptions about the properties of martian aerosols in order to characterize the aerosol radiance contribution and separate it from that of the surface.

THEMIS/VIS images in the 654, 540, and 425 nm filters can be converted to approximate "true color" views of Mars (Figure 4) by transforming the data to a standard color space and convolving over the bandpasses corresponding to typical human RGB color receptors [*e.g.*, 10]. While our process is not yet fully refined, and calibration continues to improve, our initial results indicate that while albedo contrasts are strong in many places, color variations detected so far by VIS are subtle and often occur only at scales comparable to the VIS resolution. This is perhaps not surprising given similar previous telescopic, ISM, and Viking results at coarser scales [*e.g.,* 3,5,11], and points out the need for continued refinement of the VIS calibration accuracy in order to better detect, quantify, and interpret the subtle color variations that do exist in the VIS data.

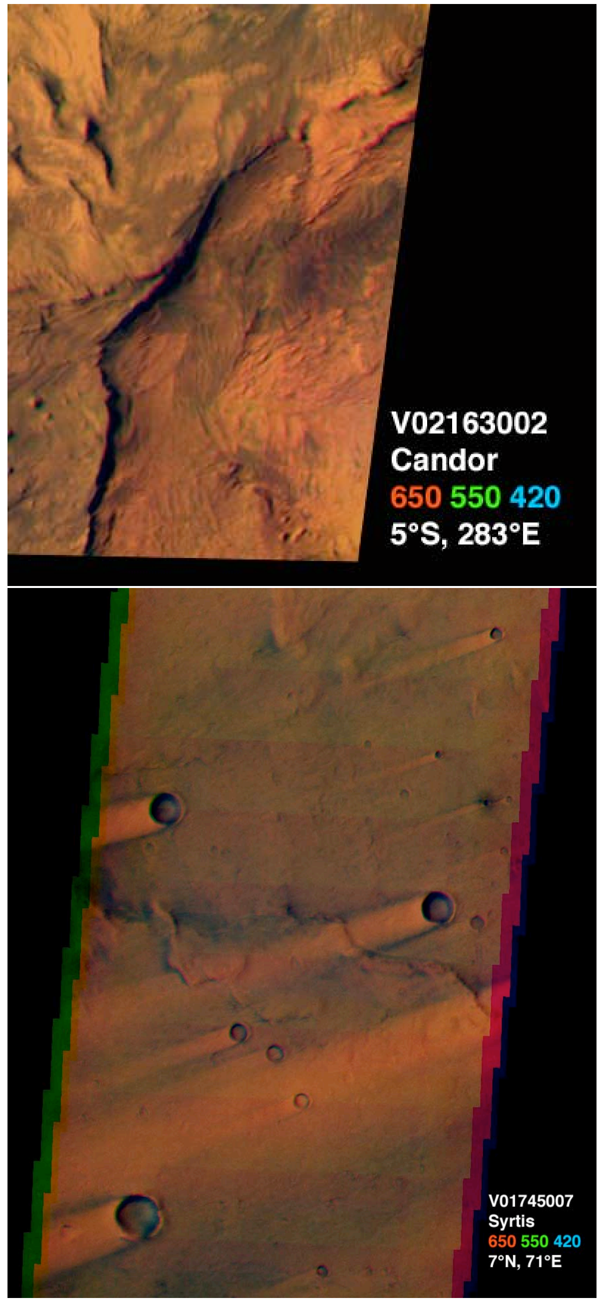

Figure 4. RGB composite VIS images of Candor Chasma (top) and wind streaks in Syrtis Major (bottom). Both images acquired at 36 m/pixel. North is up.

References: [1] Singer, R.B. *et al.* (1979) *JGR, 84,* 8415. [2] Bell, J.F. *et al.* (1990) *JGR, 95,* 14447. [3] Bell, J.F. *et al.* (1997) *JGR, 102,* 9109. [4] Soderblom, L.A. *et al.,* (1978) *Icarus, 34,* 446. [5] McCord, T.B. *et al.* (1982) *JGR, 87,* 10129. [6] Morris, R.V. *et al.* (2000) *JGR, 105,* 1757. [7] Bell, J.F. *et al.* (1999) *Icarus, 138,* 25. [8] Mustard, J.F. and J.F. Bell III (1994) *GRL, 21*, 353. [9] Christensen, P.R. *et al.* (2003) submitted to *Science.* [10] Maki, J.N. *et al.* (1999) *JGR, 104,* 8781. [11] Murchie *et al.* (2000) *Icarus, 147,* 444.