VISIBLE TO NEAR-IR IMAGING SPECTROSCOPY OF MARS USING HST. J.F. Bell III1 and M.J. Wolff4, 1Cornell University, Department of Astronomy, Ithaca NY, 2Space Science Institute, Boulder CO.

Summary: We used the Space Telescope Imaging Spectrograph (STIS) instrument on the Hubble Space Telescope (HST) to obtain high spatial and spectral resolution long-slit visible to near-IR spectra of Mars during the 1999 opposition. Each slit image consists of hundreds of spectra along a north-south chord across the planet at approximately 20x80 km spatial resolution, covering the 530 to 1030 nm wavelength region at 0.48 nm resolution. Observations were timed so that multiple observations were obtained while slewing the slit across the planet, thus generating a 3-D spatial x spectral image cube. Image cubes were generated during four different observing periods, each separated by ~90° in Martian longitude, resulting in coverage of all longitudes north of 63°S with one to three STIS spectra. We have performed a photometric calibration of the data to within 5-10% absolute accuracy. Here we show some initial results that validate the calibration and attest to the potential of the dataset.

Background: Models of the formation, alteration, and weathering of secondary iron oxide minerals on Mars [1-3] provide a way to relate present, observed mineral abundances and distributions to previous, inferred climatic regimes. Specifically, does the observed surface mineralogy support extended "warm and wet" epochs on Mars, invoked by some to explain the appearance of extensive fluvial networks and possible shoreline morphologies [4,5], or is the mineralogic inventory more consistent with short-lived episodic outbursts of volatile species [6,7] that might not reflect true "climate change"? In particular, a definitive search for specific hydroxyl-bearing minerals, thermodynamically unstable under current climatic conditions, would provide strong evidence to support or refute claims of a warmer, wetter early Martian climate. Such a study would form one important contribution to the current NASA focus on the question of whether the environment of early Mars could have been conducive to life.

Current knowledge of the mineralogy and physical state of the Martian surface is limited because: (1) Ground-based observations can only achieve spatial resolutions of many hundreds of km near opposition; (2) Ground-based data exhibit calibration uncertainties from variations in seeing and telluric O3 and H2O in diagnostic spectral regions; and (3) Spacecraft investigations have either not provided the spectral sampling and resolution required (Viking), have provided only limited spatial coverage (Mariners 6,7; Phobos-2), or have been thwarted by global dust storms or mission catastrophes (Mariner 9, Mars Observer.

Laboratory studies have shown that well-crystalline iron oxides and oxyhydroxides have distinctive spectral slopes and absorption bands in the visible to near-IR [8-10]. Of relevance to Mars surface observations are: (a) the position of the near-UV O2→Fe3+ charge transfer absorption edge that gives the iron oxides (and Mars) their distinctive red to yellow colors; (b) the amount of spectral structure of the long-wavelength wing of the near-UV charge transfer edge from about 400 to 700 nm, caused by a series of Fe2+→Fe3+ electronic pair transitions that indicate the degree of crystallinity; and (c) the strengths and positions of two Fe3+ ligand field transitions in the red to near-IR: one (A1→T2,G) near 650 nm that exhibits minor variations with mineralogy, and the second (A1→T1,G) near 860 to 900 nm that shows diagnostic changes as a function of mineralogy [8-10]. The general absence of spectral structure in previous ground-based Mars 400 to 700 nm spectra has led to the interpretation that most of the surface Fe3+ exists as amorphous or nanophase ferric oxide [11-17]. Detection of an 860 nm band and a 650 nm inflection have provided the initial evidence for well-crystalline but extremely fine-grained hematite (α-Fe2O3) on Mars at the ~5% abundance level [12-18]. Recent results from the MGS/TES instrument appear to confirm and extend this finding to coarser hematite grain sizes [19]. Subtle shifts in the position of the (A1→T2,G) ferric transition towards longer wavelengths (890 to 920 nm) also provide tentative evidence for the presence of ferric oxyhydroxide phases like goethite (α-FeOOH) on Mars (e.g., [20,21]).

Ground-based and spacecraft reflectance studies show that, where exposed in low albedo regions, the bedrock ferrous (Fe2+) mineralogy is dominated by high-Ca pyroxene [22-24]. These dark rocks and soils exhibit 5-15% deep Fe2+ absorption bands near 950 to 1000 nm, characteristic of relatively unweathered pyroxenes. Laboratory studies have shown that accurate data on pyroxene chemistry (Fe, Ca, Mg ratios) can be obtained by analyzing subtle shifts in the position of this "1 µm" feature [22,25]. Comparisons of the available spectra with spectra and petrology of the SNC meteorites [26] indicates that the ferrous mineralogy of the dark regions may be a mixture of high-Ca and low-Ca pyroxenes with similarities to some terrestrial komatiitic basalts [27]. More recent TES observations of dark regions suggest only a single pyroxene composition, however [19,28], making this still a topic of considerable debate and uncertainty.

Observations: Observations were made on April 27, May 1, May 6, and May 7, 1999 (Ls ~ 132°) using STIS configured with a 52" x 0.2" slit. On each date, the slit was pushbroom-scanned through ~70 adjacent positions to cover ~14° of the 16" diameter Martian disk. Figure 1 shows maps at 726 nm of the corresponding slit positions for each of the observing dates. Each map is a simple cylindrical projection centered on 0°W, 0°N. Figure 2 shows a composite 726 nm global map generated from all the merged slit positions. This
map is a Mollweide projection centered on 0°W, 0°N. The data have been reduced using the standard STIS data reduction pipeline, augmented by additional procedures that we have developed and refined for removing fringe artifacts, generating image cubes, and calibrating the spectra to radiance factor.

Initial Results: Figure 3 shows three example spectra from the May 1 observations. The spectra have been smoothed to 2 nm spectral resolution. Error bars represent regional variance within ~80x80 km spots (every tenth error bar is plotted). The spectra are consistent with previous measurements of the broadly classified "bright", "dark", and "ice" units on Mars, and show additional spectral detail that may be related to surface or atmospheric variations. We plan to model and evaluate the influence of aerosols in these spectra using WFPC2 UV to near-IR multispectral images of Mars obtained contemporaneously [29].

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