TOPOGRAPHIC AND ATMOSPHERIC PRESSURE MAPPING OF MARS. S. Chamberlain[1] , J. Bailey[1], D. Crisp[2] and M. Walter[1], [1]Australian Centre for Astrobiology, Macquarie University. [2]NASA Jet Propulsion Laboratory/Caltech.

Introduction: The topography of Mars remained unknown until the first orbiting spacecraft, since early ground-based observations of Mars displayed only variations due to albedo which correspond to changes in surface composition and texture rather than changes in surface altitude. However a technique was being developed in the late 1960s and early 1970s to determine the Martian topography by measuring the spatial variation in the strength of the atmospheric CO_2 absorption bands [1, 2, 3] and was later improved for use over limited Martian equatorial regions with the ISM instrument on board the Russian spacecraft Phobos 2 [4]. The observations presented here use near-infrared ground-based observations to produce relatively detailed topographic maps of Mars that correlate well with topographic maps produced by the Mars Orbiting Laser Altimeter (MOLA) on board the Mars Global Surveyor (MGS).

Observations: Near Infrared narrow band images and hyperspectral scans were obtained using the United Kingdom InfraRed Telescope (UKIRT) and the UKIRT Imaging Spectrometer (UIST) [5] on Mauna Kea, Hawaii. The seeing was as good as 0.3arcsecs during our observing run. The observations were made during mid-August and early September, either side of the 2003 opposition in order to optimize the spatial resolution of the observations, and to allow Mars to rotate with respect to Earth to obtain observations covering most of the Martian globe.

Narrow band images were obtained as a series of short exposures, the images with above average seeing were stacked together resulting in what could be the highest resolution image of Mars ever taken from a ground-based telescope (Fig. 1). An image scale of 16km per pixel was achieved.

Hyperspectral scans were obtained by positioning the spectrometer slit in the Martian north-south orientation and incrementally stepping the slit across the disk in the east-west direction. A spectrum was obtained at each location. A resolving power of 950 was obtained for a spectral range of 1.4 – 2.5µm. The data were stored in a three dimensional cube with two spatial axes (x and y) and a spectral axis (z). This is a versatile storage system since spectra can be obtained from any location on the Martian disk and images of Mars can be obtained at any observed wavelength. Images extracted from the data cube have minimum spatial resolution of 97km.

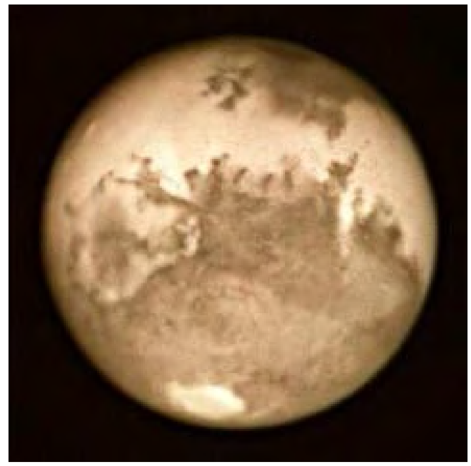

Figure 1: Narrow band image of Mars obtained on Sept. 4th 2003. The image depicts the Martian albedo at 1.64 µm and is possibly the highest resolution image of Mars ever obtained from a ground-based telescope.

Topographic Images. The Martian atmosphere is composed primarily (95.3%) of CO_2, which is present in near-infrared spectra as a number of weak absorption features. Variations in the strengths of these absorption features are mainly due to the atmospheric path length which is influenced by the underlying topography. A colour index can be made by ratioing an image obtained from the wavelengths of the deepest part of an absorption feature, with an image obtained from wavelengths corresponding to the nearby continuum. The 2µm absorption band was used since it has the best signal to noise ratio.

The CO_2 image produced from our data has a very good correlation to the map produced by the Mars Orbiting Laser Altimeter on board the Mars Global Surveyor which is topographically accurate to 2m vertically and 160m horizontally [6]. It can be seen that the CO_2 index image produced from our data displays all the sufficiently large topographic features and, on comparison, smaller scale features can be identified.

Discussion: Measurements of the Martian atmospheric pressure systems are of great interest for testing and constraining general circulation models of the Martian atmosphere [7]. We have shown that good topographic data can be obtained using modern ground-based telescopes, however the CO_2 index is also influenced by atmospheric pressure systems (i.e. weather). Therefore by removing the topographic information, it is possible to produce a map of the Martian pressure systems. Past pressure measurements of the Martian atmosphere show diurnal and pressure system variations with amplitudes as high as 50Pa, in a total pressure of 800Pa [8, 9]. A rough sensitivity of 4 -5 Pa was calculated for our observed CO_2 index images.

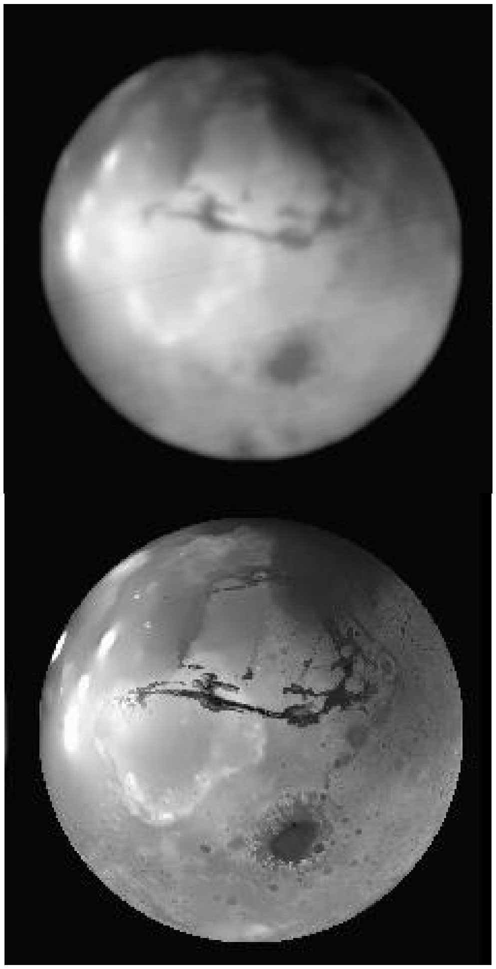

Figure 2: Comparison of the CO_2 index image obtained on September 4th 2003 (Fig. 2a - top) with the corresponding MOLA/MGS topographic map (Fig. 2b-bottom).

These data are not obtainable from currently orbiting spacecraft at the spectral resolutions required. An advantage of ground based measurements is that pressure systems can be monitored almost simultaneously across the whole earth-facing disk of Mars.

Quantitative data requires a precise calibration between the CO_2 index and surface pressure which is difficult to achieve as the relationship depends on the local atmospheric temperature profile which are not well sampled across Mars. Errors are also produced in the observed atmospheric pressure systems due to the problematic removal of the terrestrial atmospheric CO_2 absorptions. This is normally addressed by dividing the observed spectrum by the spectrum of a relatively featureless standard star observed under similar atmospheric conditions and thereby removing the common spectral components (absorption by the terrestrial atmosphere). This method cannot be used, because CO_2 absorption is present in both the Mars and Earth atmospheres at similar strengths and is composed of many unresolved saturated narrow lines. Once a line is saturated it ceases to behave linearly. The terrestrial absorption therefore produces a greater absorption in the spectra of the standard star, due to the initial lack of features, than in the Martian spectra which already have strong absorptions at these wavelengths. This effect is maximized at opposition due to the lack of relative velocity along the line of sight between the two planets, and would result in removing more than just the terrestrial component of the CO_2 absorption. The high resolution Spectral Mapping Radiative Transfer (SMART) model developed by Dr David Crisp (NASA, JPL) [10] can be used to reduce this problem. Simulated spectra are being produced using different pressures, temperatures and dust optical densities of the Martian atmosphere (taken from the European Mars Climate Database [11]) to investigate their effects on the CO_2 index used to create the topographic images. The results of this will help to determine the relative sensitivity of this method for producing weather maps of Mars.

References:

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