LIMITS ON THE MAFIC MINERALOGY OF MARS THROUGH MGM ANALYSIS OF ISM SPECTRA. J. F. Mustard[1] and J. M. Sunshine[2], [1]Department of Geological Sciences, Box 1846, Brown University, Providence RI 02912, [2]SETS Technology Inc., 300 Kahelu Ave., Miliani HI 96789.

Introduction: From analysis of the ISM imaging spectrometer data, numerous areas on the surface of Mars have been identified as containing well exposed, weakly altered volcanic materials. In addition, distinct units are recognized on the basis of the position, strength, and shape of mafic mineral absorptions. The presence of pyroxenes is readily documented by their unique1 and 2 μm absorption features. Other mineral components have been inferred from qualitative comparisons of remote observations with laboratory reference spectra. However, qualitative analysis applied to subtle inflections or distortions of the "normal" pyroxene band shape to determine mineralogy is highly subjective. In this analysis we use the Modified Gaussian Model (MGM) to deconvolve the ISM reflectance spectra into constituent absorptions. The results are compared with previous MGM modeling of natural pyroxenes and pyroxene mixtures to place general limits on the composition of weakly altered martian crust.

Spectral Data: The ISM data consist of 64-channel reflectance spectra from 0.77 to 3.14 μm for each high spatial resolution pixel (22 km) in the 9 images acquired (1,2). The data windows are ≈300 km wide and 2000 km long and sample a wide variety of terrain and surface morphologies. Details of data reduction, calibration, and previous analyses are presented elsewhere (2,3). ISM spectra from surfaces that exhibit the least alteration are dominated by mafic mineral absorptions near 1 and 2 μm and are qualitatively interpreted to be volcanic materials containing augitic pyroxene of intermediate iron content (3). On the basis of these previous analyses, ISM spectra from two regions that exhibit distinct and well defined mafic mineral absorptions, Nili Patera on Syrtis Major and Eos Chasma on the floor of Valles Marineris, have been selected for detailed mineralogic modelling with the MGM.

Approach: Under the MGM, reflectance spectra are modelled as a sum of absorption bands superimposed on a baseline or continuum. The model has been used successfully to deconvolve superimposed and overlapping absorptions in mafic mineral mixtures, solid solution series, and natural lithologic samples (4,5,6,7). The parameters defining the absorption bands (center, strength, width) are quantitatively associated with mineral abundance in mixture series and composition in solid solution series. Thus, it should be possible to determine mineral abundance and composition from spectra of mafic rocks as was done for spectra of the EETA 79001 shergotite (7). The ISM data of the weakly altered terrains are dominated by pyroxene absorptions for which excellent observational (8) and modelling (4,7) bases exists. However, the strengths of mafic mineral absorptions in the ISM data are weak (5-15%) which makes derivation of unique solutions with the MGM difficult. Nevertheless, results can be critically analyzed in the context of existing data bases and experience from which we can then determine the limits on the surface compositions allowed by this approach.

Our approach to this problem was to first establish a reasonable continuum that is consistent for all model runs. Based on some initial analyses, it is determined that a negative continuum that is linear in energy provides the best approximation to the negative continuum observed for Martian dark regions. We begin with models that make the fewest assumption about consituents and proceed to more complex models. The initial model parameters for absorption band centers for the trials used in this analysis are shown in Table 1. In all trials the modified stocastic inversion was used (9,4) and model parameters were minimally constrained.

Results:

Trial 1: This model presumes that all absorptions are the result of a single pyroxene imposed on a continuum. The resulting band centers of the 1 and 2 μm bands are not consistent with laboratory studies (8), the width of the 1 μm band is atypical of known pyroxenes (4), and there is a systematic error as a function of wavelength ($E(\lambda)$) near 0.85 μm and longwards of 1.9 μm. These results indicate that addition components are required.

Trial 2: This is the same as Trial 1, but with the addition of an absorption centered near 0.85 μm to accomodate absorptions due to ferric components expected to be on Mars. The band centers

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and widths are more consistent with known samples, but there is still an E(λ) longwards of 1.9 μm indicating an additional pyroxene component.
Trial 3: In this model, we assume that there are two pyroxenes present, one with absorptions typical of low calcium and one typical of high calcium pyroxene. Although there is a good fit in the 2.0 μm region, consistent with known parameters for pyroxene, the fit in the 1 μm region is inconsistent with known pyroxenes. Furthermore, it violates the coupling between 1 and 2 μm band centers and relative strength established in laboratory analyses (4,8).
Trial 4: Inclusion of a band near 0.85 to model ferric contributions provides results that are entirely consistent with known parameters for pyroxenes and for pyroxene mixtures. However, the model parameters are under-determined and specific results are highly dependent on the starting model.

Discussion It is clear from solutions using either one or two pyroxenes that a band near 0.85 μm is required. Models that do not include this band have a characteristic E(λ) between 0.77 and 1.0 μm, typical of a missing absorption. In addition, the results of some trials have band centers and widths atypical of known pyroxenes. It is not unreasonable to expect there to be a ferric component in these surfaces since ferric components are so prevelant on Mars. However the specific origins for this feature are unclear (alteration products spatially associated or ferric phases in mineral constituents (e.g. ferric pyroxenes)) and few observational and modeling bases exist for analyzing ferric absorptions (10). A negative continuum that is linear in energy adequately approximates the blue continuum for dark regions on Mars. The continuum is an important property of the MGM and can affect model parameters. The continuum used is considered at this stage to be entirely empirical and a useful approximation, but more work is needed to understand this important property of Martian surfaces. The solutions for the Trial 2 runs were extremely robust. It was possible to vary the starting conditions considerably and arrive at the same minimun solution every time. However, these solutions, assuming a single pyroxene composition, were not entirely consistent with observational data bases. Analysis of the 2.0 μm regions was together with the 1 μm region provided essential evidence for evaluating the entire fit. The solutions for the Trial 4 runs could provide band centers, widths, and strengths for both the 1 and 2 μm bands that were consistent with known low and high calcium pyroxene endmembers and pyroxene mixtures. However, these solutions were underdetermined and the specific conditions of the input model parameters strongly controlled the derived model parameters.

Conclusions: MGM analysis of ISM spectra show that the mafic mineralogy of Mars is complex. We clearly demonstrate that a ferric component and two ferrous pyroxenes are required. In addition, there is no compelling evidence for olivine within the limitations of these data. These conclusions were critically dependent on simultaneous analysis of the 1 and 2 μm regions which allowed us to examine the consistency of results with known coupling of pyroxene absorption positions and relative strengths. This argues for extended and complete wavelength coverage of any future missions that are designed to measure martian mineralogy. Further refinement of compositional estimates using visible-near infrared reflectance spectra hinges on our ability to understand and quantify ferric absorptions and the continuum of Mars.

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Table 1: Initial Band Centers for MGM Trials

Trial	0.85	0.91	1.02	1.15	1.93	2.29
1		x		x		x
2	x	x		x		x
3		x	x	x	x	x
4	x	x	x	x	x	x

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