IDENTIFICATION OF SPECTRAL ENDMEMBERS IN CRISM DATA USING FACTOR ANALYSIS AND TARGET TRANSFORMATION. N. H. Thomas and J. L. Bandfield, Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310; nancyth@u.washington.edu.

Introduction: Spectral datasets contain large volumes of data with variable mixtures of individual spectral endmembers. It is often difficult to identify and isolate these spectral endmembers from the data since they are not often separated from other components. Factor analysis and target transformation is a methodology that addresses this problem and can be used to both identify the number of individual components and test for the presence of and isolate individual endmembers using a set of mixed spectra [1].

This methodology has been applied to laboratory and spacecraft thermal infrared (TIR) spectral data [2-5]. Here, we have adapted and applied these techniques to near-infrared (NIR) spectral data collected by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board the Mars Reconnaissance Orbiter [6].

Methodology: Factor analysis uses a set of mixed spectra to derive a set of orthogonal eigenvectors and associated eigenvalues. Although physically meaningless, the eigenvectors and eigenvalues can then be used to estimate the number of components present in a mixed system. Assuming linear mixtures, the data can be described in just n dimensions where n is the number of independent components present. This greatly reduces the complexity of the dataset and all spectra in the system can be reconstructed using n eigenvectors. Eigenvectors with order greater than n will only contain noise and can be discarded. This, of course, is more ideal than real - systems are not perfectly linear and systematic errors are often present. However, these techniques have been successfully applied to spectral datasets despite the presence of systematic errors and non-linear components [2].

Target transformation can also be used to reconstruct endmember spectra using a linear combination of the set of eigenvectors, even if those pure endmembers do not exist in the original data. In practice, the target transformation test is simply a least squares fit of the significant eigenvectors to laboratory spectra. If a laboratory spectrum can be closely matched, then it is a possible endmember present in the system. The least squares fit typically produces a spectrum that reflects specific details about the endmember present in the mixed spectra. The best fits can be used to narrow down fine spectral distinctions such as those due to variable cation content.

This methodology can also be used to remove noise and significantly improve the quality of CRISM data. We use the first 10 eigenvectors to reconstruct the original CRISM data. This assumes that all higher order eigenvectors represent only noise, which is discarded. Since the reconstructed CRISM data only contains information from significant eigenvector components, the noise can be greatly reduced.

Results and Discussion: *Factor Analysis.* Our application of factor analysis to CRISM data indicates that the first 10 eigenvectors derived typically contain all the spectral variation present in the data. All higher order eigenvectors contain only noise rather than useful spectral information. For this work, we applied factor analysis to a spectral range of 120 spectral bands from 1.8 – 2.6 μm. This spectral region contains significant spectral features present in a variety of phases and is sufficient to accurately identify their presence.

Target Transformation. We tested our methodology on CRISM data containing evidence for the presence of carbonates [7-9]. Target transformation was applied to all carbonate identifications in CRISM stamps identified near Nili Fossae by *Ehlmann et al.* [7]. The target transformation clearly confirms the presence of Mg-rich carbonates (Fig. 1). In addition to confirming the detection of magnesite, the target transformation returned endmember spectra with reduced noise and increased the clarity of the characteristic carbonate 2.3 and 2.5 μm absorptions.

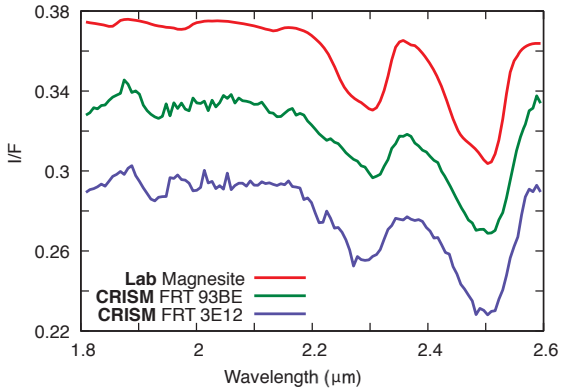

Figure 1: CRISM spectra of carbonates in Nili Fossae recovered using a laboratory spectrum of magnesite as the test vector. Spectra are offset for clarity.

Factor analysis and target transformation also confirmed the presence of siderite in Leighton crater (CRISM image ID FRT0000A546) [8]. In this case, there is less certainty than the detection of magnesite near Nili Fossae because of greater noise and a less well-defined 2.5 μm absorption. This is probably due to weaker and subtler features in the CRISM data.

In our third example, target transformation analysis of carbonates identified by *Wray et al.* [9] on the Huygens rim crest showed that there was no clear match to any carbonate in the spectral library (Fig. 2). This indicates that the set of carbonate spectral features are not present as an independent spectral endmember.

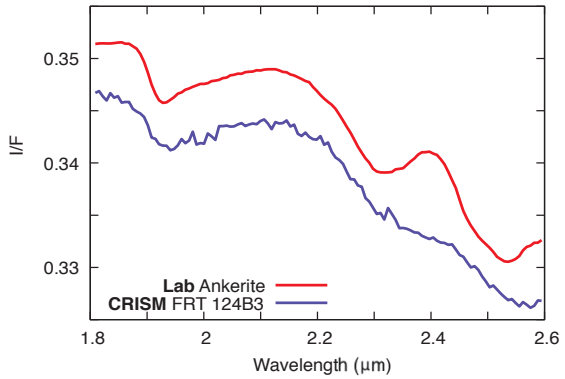

Figure 2: Best fit CRISM spectrum in FRT000124B3 to a laboratory spectrum of ankerite. Spectra are offset for clarity.

The factor analysis and target transformation techniques are a robust test for the presence or absence of carbonates and can also be used to identify other phases of interest. For example, we also applied our methodology to test for the presence phyllosilicates in each of the three regions discussed above using the same set of eigenvectors (Fig. 3).

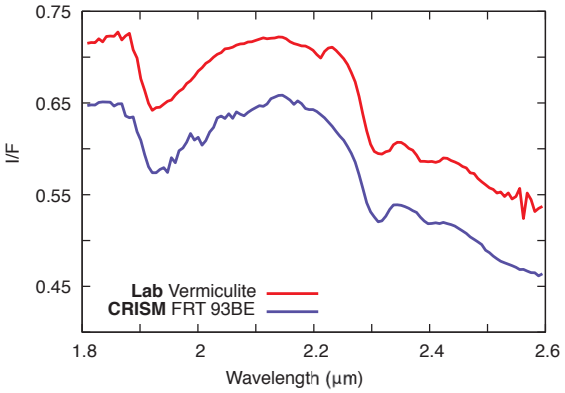

Figure 3: CRISM spectra of an example phyllosilicate recovered using a laboratory spectrum of vermiculite. Spectra are offset for clarity.

Dataset Noise Removal. Reconstruction of the original CRISM data using only the first significant eigenvectors (in this case 10) showed significant reductions of noise in the spectral data. This noise reduction is reflected in CRISM absorption index images [e.g., 10]. For example, the noise removal technique described here more clearly identifies regions containing carbonate absorptions while lowering the noise typically present in index maps (Fig. 4). This application complements our target transformation spectral results by more clearly showing the geographic locations where additional analysis should be applied to refine our detections.

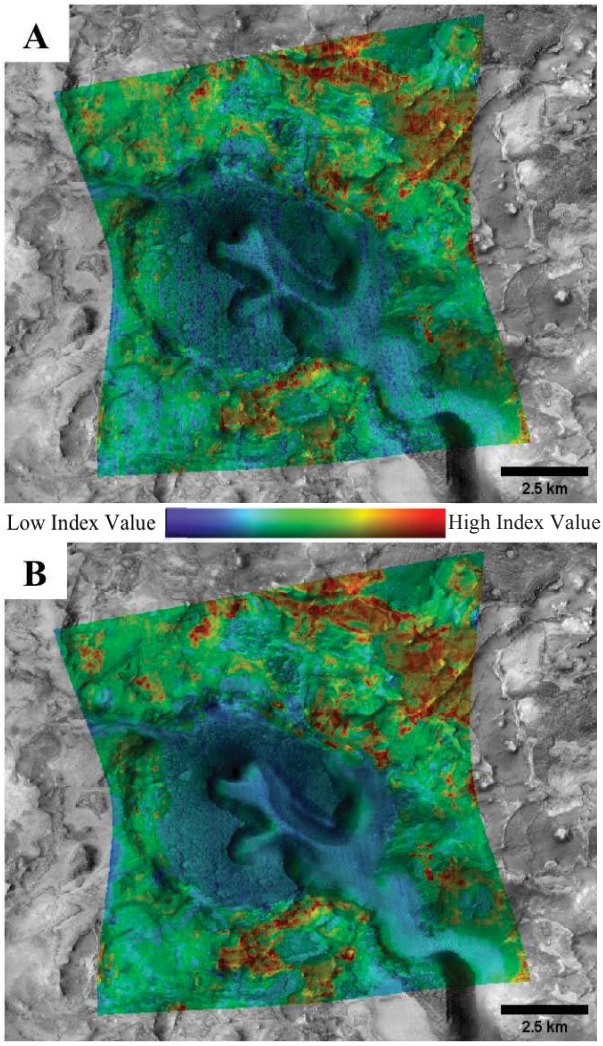

Figure 4: Noise removal for FRT00003E12 carbonate index. **B** is the cleaned index map.

References: [1] Malinowski E. R. (1991) *Factor Analysis in Chemistry*, 2nd ed., John Wiley & Sons, New York. [2] Bandfield J. L. et al. (2000) *JGR*, 105, 9573-9587. [3] Bandfield et al. (2002) *JGR-Planets*, 107, 5092. [4] Glotch T. D. and Bandfield (2006), *JGR*, 111, E12S06. [5] Hamilton V. E. and Ruff S. W. (2012) *Icarus*, 218, 917-949. [6] Murchie S. L. et al. (2007) *JGR*, 112, E05S03. [7] Ehlmann B. L. et al. (2008) *Science*, 322, 1828-1832. [8] Michalski J. R. and Niles P. B. (2010) *Nat. Geosci.*, 3, 751-755. [9] Wray J. J. et al. (2011) *LPS XLII,* Abstract #2635. [10] Pelkey S. M. et al. (2007) *JGR*, 112, E08S14.