M^3 spectrum. The error brackets (and the associated composite error bracket) do not evaluate the effect of each potential source of error (e.g., reduced spectral resolution, increased noise, etc.) explicitly, but do evaluate them in the sense that all sources of error contribute to the observed ranges. Future work on this subject will likely focus on deconvolutions of laboratory spectra with reduced spectral sampling and various levels of random noise introduced in order to quantify these effects more explicitly. Even in the ideal case of MGM deconvolutions of laboratory olivine reflectance spectra, compositional predictions with this approach can be accurate only to within ~5–10% (5–10 Fo # units) [*Sunshine and Pieters*, 1998; *Isaacson and Pieters*, 2010]. The range predicted for the "composite error" is on the order of 20 Fo # units (on a 0–100 scale in molar Mg/Mg +Fe *100). Thus, our reported compositions should be viewed and interpreted as approximate solutions, even in a relative sense.

[31] The relative olivine compositions predicted from the M^3 spectra can be used to draw some geological interpretations. The Moscoviense olivines appear to be diverse but Mg-rich relative to the other olivines evaluated here. The most Mg-rich compositions found at Moscoviense appear consistent with the evaluation suite results, which in absolute terms are similar to some of the most Mg-rich olivines found in Mg suite rocks with compositions near ~Fo$_{90}$ [e.g., *Papike et al.*, 1998]. While there are reasons to be cautious in interpreting this similarity, it is suggestive that the olivines found to be the most Mg-rich in the region may be quite Mg-rich in absolute terms as well. This may suggest that these olivines are derived from a relatively primitive plutonic source, which would be consistent with the plutonism hypothesized to have produce the unusual mafic lithologies observed elsewhere in the Moscoviense region [*Pieters et al.*, 2011]. Our results do not allow us to evaluate a possible genetic relationship to the olivines studied at Moscoviense and those identified in association with unusual exposures of olivine, orthopyroxene, and spinel (OOS) by *Pieters et al.* [2011], largely because the olivines identified by Pieters *et al.* do not exhibit sufficient spectral contrast or purity to evaluate with our current approach. However, such a comparison would be a logical avenue for future work if the spectral contrast and purity issues can be overcome. The diversity of the olivine compositions observed at Moscoviense may indicate a long-lived geologic process capable of producing a trend in olivine compositions toward more Fe-rich compositions as the olivine's source material evolved. The observed diversity is distributed across a relatively small spatial region (less than 100 km^2), and a wide variation in olivine composition across a small area is difficult to explain petrologically. However, the large error bars in these analyses may help explain some of the widespread variation (the actual compositional diversity may be magnified by errors). Additionally, it is of course possible that random noise may contribute to the observed heterogeneity. However, the real spectral differences apparent in Figure 9 suggest that real compositional variability is largely responsible for the spread in predicted compositions. Regardless, the diverse compositions observed for the Moscoviense olivines suggest a different process than that responsible for the olivines at Copernicus, which are spectrally (and thus compositionally) more homogenous.

[32] The olivines at Copernicus are found to be relatively Mg-rich, comparable to the most Mg-rich of the compositions predicted at Moscoviense. Additionally, they are more spectrally and thus compositionally homogeneous than those observed at Moscoviense. Their predicted compositions are also similar to those of the evaluation suite spectra. The consistency between all spectra analyzed for the Copernicus central peak indicates that the olivine is fairly homogenous in composition, which is consistent with a single magmatic or mantle source, rather than a process in which a source region evolved over time producing a trend of increasing olivine Fe contents. The relatively Mg-rich compositions argue against a volcanic origin and in favor of a plutonic origin, as olivines in mare basalt largely (but not always) tend to be somewhat more Fe-rich [e.g., *Papike et al.*, 1976]. As the Aristarchus and Marius spectra exhibit clear contributions from absorptions not due to olivine, we elect not to model them with the MGM, as the results would be biased by the other absorptions in the general 1000 nm region where the principal olivine absorptions are found. We merely point out their clear spectral differences from the Moscoviense and Copernicus spectra, which alone are sufficient to demonstrate the different lithological associations of the Aristarchus and Marius olivines relative to those at Moscoviense and Copernicus.

5.2.3. Mixtures

[33] Currently, our approach is likely to produce meaningful results only for spectra in which olivine is the dominant phase (i.e., no other ferrous absorptions in the 1000 nm region). This rules out compositional analyses of pyroxene-olivine mixtures. Olivine-plagioclase mixtures can be analyzed, especially if the plagioclase is in its shocked form (maskelynite) and lacks its typical feature near 1300 nm [e.g., *Bell and Mao*, 1973; *Adams and Goullaud*, 1978; *Pieters*, 1996]. Crystalline, Fe-bearing plagioclase does exhibit absorptions near 1300 nm, and if such absorption features were detectible in the olivine-plagioclase mixture spectrum, that spectrum could not be analyzed with our present approach. However, the plagioclase absorption feature does tend to get masked by other mafic absorptions such as those of olivine and pyroxene [e.g., *Isaacson et al.*, 2011], meaning that olivine-plagioclase mixtures generally can be analyzed with our approach except in rare cases where the plagioclase absorption feature persists.

[34] In principle, our approach could be applied to spectra of mixtures such as olivine-pyroxene. The potential problems associated with extending the approach to mixture spectra lie in determining the properties of the olivine absorptions in the presence of additional absorptions near 1000 nm, as discussed above in the context of the Marius olivine spectra. The MGM seeks a mathematically optimized solution, without regard for whether or not the fit is physically reasonable (consistent with the mineralogy of the material represented by the input spectrum). Each Gaussian is based on three model parameters (position, strength, and width), so the presence of additional absorption features substantially increases the number of free parameters in the model, and reduces the likelihood of obtaining a unique and physically reasonable fit. *McFadden and Cline* [2005] used the MGM to model laboratory reflectance spectra of Martian meteorites, including several containing mixtures of olivine and pyroxene. While they were able to produce reasonable