THE NEAR-INFRARED SPECTROSCOPY OF TWO M-CLASS MAIN BELT ASTEROIDS, 77 FRIGGA AND 325 HEIDELBERGA. D. Takir[1], P.S. Hardersen[1, 2], M.J. Gaffey[1,2]. [1]University of North Dakota, Department of Space Studies, 4149 University Avenue Stop 9008, Grand Forks, ND 58202. driss.takir@und.nodak.edu, hardersen@space.edu, gaffey@space.edu. [2]Visiting Astronomer at the Infrared Telescope Facility under contract from the National Aeronautics and Space Administration, which is operated by the University of Hawai'i, Mauna Kea, HI 96720.

Introduction: This study is a part of a NASA Planetary Astronomy Program grant, which is a continuing near-infrared (NIR: ~0.7- to 2.5-µm) spectral survey of the M-asteroid population, which is attempting to constrain the surface mineralogies, potential meteorite analogs, and geologic histories of these asteroids. The Tholen taxonomy [1] classified M-asteroids as a group of asteroids with moderate albedo (~0.07 to 0.30) and featureless spectra based on different spectral and non-compositional parameters. However, [2, 3, 4, 5, 6, 7] have discovered that M-asteroids are not all spectrally featureless and found that many of these objects exhibit weak absorption features that reveal the presence of minerals such as olivine and pyroxenes. Thus far in the program, ~80% of the M-asteroid data that has been reduced shows evidence for weak pyroxene, olivine, and spinel absorption features. In this study, we analyzed the NIR spectra of two M-asteroids, 77 Frigga and 325 Heidelberga, to constrain their surface mineralogies, search for meteorite analogs, and better understand their geologic histories.

Observations and Data Reduction: 77 Frigga was discovered November 12, 1862, by C.H.F Peters [8]. The diameter of this asteroid is 69.25 ± 2.1 km with an IRAS albedo of 0.1440 ± 0.009 [9]. 325 Heidelberga was discovered March 4, 1892, by M.F. Wolf [8]. The diameter of this asteroid is 75.72 ± 1.7 km with an IRAS albedo of 0.1068 ± 0.005 [9]. Tholen classified both asteroids as a member of the M taxonomic class [1].

The observing run of 77 Frigga and 325 Heidelberga took place at the NASA Infrared Telescope Facility (IRTF), on Mauna Kea, Hawai'i, on the night of January 23, 2007 (UT). NIR spectra were obtained with the SpeX spectrograph in the low-resolution mode (R ~95) from ~0.8 to 2.5µm [10]. A total of 32 spectra of 77 Frigga and 34 spectra of 325 Heidelberga were obtained. In addition to the asteroids' spectra, the local standard stars, HD 9986 and HD 121867, and the solar analog star, SAO 120107, spectra were also obtained. Asteroid and standard star observations were interspersed within the same air mass range to obtain optimal modeling of atmospheric extinction. The data were reduced by using a combination of IRAF and SpecPR [11, 12]. IRAF was used to extract each spectrum into 1-D array of fluxes and to conduct the wavelength calibration. The data files processed by IRAF were converted to (.txt) files using a Windows-based program, Transpex, and then imported to SpecPR. Primary SpecPR reductions included deriving empirical atmospheric extinction coefficients (i.e., starpacks) to remove the telluric water vapor absorption features (1.4- and 1.9-µm), channel shifting spectra to eliminate offsets, and averaging spectra to increase the signal-to-noise ratio (SNR). Finally, the quantitative mineralogical analysis method [13] was used to constrain asteroid surface mineralogy of non-featureless asteroids through isolation of absorption features and determination of absorption band centers and areas, when appropriate.

Results and Interpretations: The average spectra of 77 Frigga and 325 Heidelberga are presented in Figure 1 and Figure 2 below:

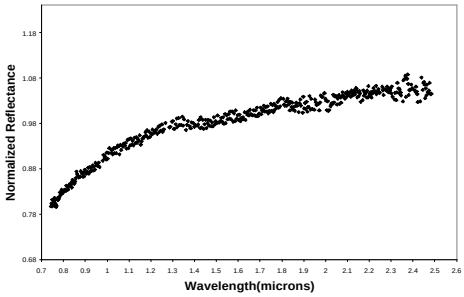

Figure 1. 77 Frigga. Average of 32 spectra.

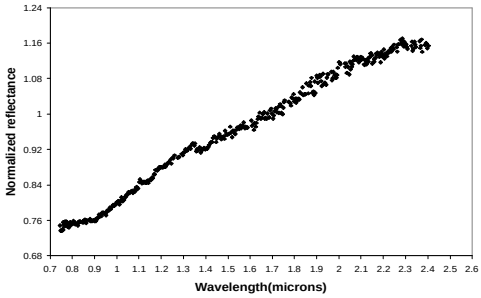

Figure 2. 325 Heidelberga. Average of 20 spectra.

77 Frigga. The average NIR spectrum in Figure 1 is generally reddish and featureless with no spectral absorption features. The spectrum increases in reflectance until ~1.35 μm and then rolls over to become an almost horizontal spectrum at longer wavelengths. The featureless nature of this spectrum can be explained by the lack of Fe-bearing minerals that would produce the typical absorption features. For dark asteroids, features can be weakened or eliminated due to the presence of opaque phases such as magnetite or carbon-bearing phases [14, 15]. However, 77 Frigga has a moderate albedo (~0.1440) [9] and feature suppression by opaque phases is not likely. Enstatite chondrites and nickel-iron meteorites are potential meteorite analogs because they produce featureless and reddish spectra similar to the spectrum of 77 Frigga [14].

325 Heidelberga. [5] observed 325 Heidelberga and only obtained four spectra of this asteroid on April 29, 2001, using IRTF/SpeX. [5] reported that Heidelberga's spectrum increases almost linearly with no apparent absorption features within the noise of the data. [5] also suggested that it is possible that a 1-2% ~0.9-μm feature may exist and could be seen in a higher SNR spectrum. 325 Heidelberga was also observed by [16] using IRTF/SpeX, but different techniques, the chi square and MGM, were used to reduce and analyze the data. [16] reported that 325 Heidelberga is featureless and similar with the spectra of metallic meteorites. This finding can be a consequence of how data were reduced and analyzed, along with the cutting off of the data shortwards of 0.80-μm. Our new results on the other hand, show that this asteroid exhibits a weak feature with a band I center at 0.90-μm that is ~1-2% deep. This feature suggests the presence of low-Fe pyroxene, as seen in the spectra of six M-asteroids in [5]. [5] suggested that both enstatite chondrites and nickel-iron meteorites are viable candidates for Heidelberga's spectrum. However, the discovery of the new feature at 0.9-μm eliminates the enstatite chondrites option for 325 Heidelberga.

Conclusion and Future Work: Based on our analysis we conclude that 77 Frigga is featureless and 325 Heidelberga exhibits a weak feature indicating the presence of low-Fe orthopyroxene. These results continue to reveal the diversity in the M-class asteroids studied thus far. Further data analysis of 77 Frigga and 325 Heidelberga are necessary to determine any variations in spectral absorption features that are present.

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References: [1] Tholen D.J. (1984) *Ph.D. thesis*, U. Arizona, Tucson, 150pp. [2] Rivkin A.S. et al. (2000) *Icarus* 145, 351-368. [3] Rivkin A. S. et al. (2002) *Asteroids III*, 235-253. [4] Clark B.E. et al (2004) *AJ* 128, 307-308. [5] Hardersen P.S. et al. (2005) *Icarus* 175, 141-158. [6] Hardersen P.S. et al (2006) *LPS XXXVII*, Abstract #1106. [7] Hardersen P.S. et al (2007) LPS XXXVIII, Abstract#1956. [8] Schmadel L.D. (1999) *Dictionary of Minor Planet Names*, Springer, 1319pp. [9] Tedesco E.F. et al. (2002) *AJ* 123, 1056-1085. [10] Rayner J.T. et al. (2003) *PASP*, 115, 362-382. [11] Clark R.N. (1980) *PASP*, 92, 221-224. [12] Gaffey M.J. (2005) *LPS XXXVI*, Abstract #1916. [13] Gaffey M.J. et al. (2002) *Asteroids III*, 183-204. [14] Gaffey M.J. (1976) *J.Geophys. Res.* 81, 905-920. [15] Cloutis et al (1990) *Icarus* 84, 315-333. [16] Birlan M. et al (2007) *A&A* 475, 747-754.