COORDINATED LABORATORY STUDIES OF METEORITES SUPPORTING ROSETTA MISSION'S ASTEROID FLYBY TARGET: 2867 STEINS. L.A. McFadden[1] , E. Ammonito[2], E.A. Cloutis[3], A. Coradini[2], M.C. deSanctis[2],M. Fulchignoni[4], E. Hadamcik[5], T. Hiroi[6] , L. Kolokolova[1], A.C. Levasseur-Regourd[5] ,V. Psarev[7], J.-B. Renard[5]. [1]U. Maryland (Department of Astronomy, College Park, MD 20742-2421 mcfadden@astro.umd.edu), [2]IFSI-INAF Rome, [3]U. Winnipeg (Department of Geography, Winnipeg, MB, Canada R3B 2E9, [4] University of Paris/Observatoire de Paris-Meudon, [5]UPMC Univ. Paris 06, UMR 7620, 91371 Verrières, France, [6]Brown University, Providence, RI, [7]Kharkiv Astronomical Observatory, Kharkiv, Ukraine.

Introduction: A coordinated study of meteoritic material has been planned to support interpretation of the Rosetta flybys of asteroids 2867 Steins and 21 Lutetia. Candidate meteorites are identified, requested and prepared so that the same sample is geochemically characterized and measured by remote sensing laboratory techniques that simulate measurements acquired during the spacecraft flybys. We report the data aquired to date using the aubrite meteorite ALHA78113,82 which may contribute to interpretation of the Steins flyby that took place Sept. 5, 2008.

2867 Steins is an E-type asteroid that may be related to aubrite meteorites because of its high albedo of 0.45 [1], absence of 1 and 2 micron bands of iron-bearing pyroxene in its reflectance spectrum [2] (Fig. 1), and an IR spectrum with restrahlen bands with band position consistent with enstatite [3]. The absorption band at 500 nm in the spectrum of Steins needs to be understood and is one focus of this study.

In-Situ Measurements of Steins. Images of Steins from Rosetta's camera, OSIRIS, included the range of phase angles from 40° to 0° on approach and to 140° upon receding from the asteroid. Data were also acquired from the visual and infrared spectrometer (VIRTIS), the UV spectrometer (ALICE), and the Microwave Radiometer (MIRO). VIRTIS returned spectral imaging from 0.3-5.0 μm, ALICE measured a spectrum from 700-2050 Angstroms, and MIRO acquired signal as well.

There are two separate questions related to both aubrites and Steins. First, what is the nature of the absorption band first measured in the sample of ALH78113,101 at 430 nm? And quite separately, what is the spectroscopically active feature in the ground-based spectrum of Steins at 500 nm?

Laboratory Measurements: Coordinated measurements on the aubrite ALH78113,82 are under way. A 5-gram sample comprised mostly of nearly iron-free enstatite, olivine and diopside, small amounts of Ni-Fe, and sulfides with some iron oxide halos, was provided by the Antarctic Meteorite Working group.

Reflectance Spectra and Spectral Imaging. Spectral reflectance of whole rock and powdered samples of ALH78113,82 were measured at the NASA-Keck RELAB facility at Brown University. The spectra have a UV absorption band shortward of 600 nm and no 1-μm nor 2-μm bands indicating the absence of Fe^{2+} in the mafic silicates that dominate this meteorite. There is no absorption at 430 nm as was measured in a different sample of this same meteorite (Fig. 2). The sample measured in 1985 at RELAB has a different sample number, 101, than the new data presented here, 82. Use of a derived product of the spectrum from sample 101, that was misunderstood to be that of the meteorite has lead to an incorrect association of the 500 nm band in Steins to the spectrum of this meteorite. However a spectrum of CaS, oldhamite, a component of aubrites, does have an absorption near 500 nm [4].

Spectral images between 450-900 nm were made at the INAF facility in Rome of the pieces of this meteorite at a spatial resolution of 0.25 mm. The different components of the meteorite have different spectra. None of these spectra show an absorption at 500 nm.

In order to constrain possible causes of the 500 nm absorption feature in the spectrum of Steins, we have measured reflectance spectra of alabandite (MnS), which is present in aubrites and is related to the more abundant oldhamite (CaS). The spectrum of a terrestrial alabandite sample (<45 μm powder, containing 0.67 wt. % Fe) does not display a 500 nm absorption feature as is seen in reflectance spectra of oldhamite.

We are also investigating the possibility that the 500 nm absorption feature arises from radiation induced color centers in plagioclase feldspar, another common constituent of aubrites. We have found a terrestrial plagioclase sample which exhibits an absorption feature at 500 nm (Figure 3) and are investigating its cause.

Light Scattering Properties at Zero G. Remote observations of the linear polarization of solar light scattered by asteroids provide a clue to the properties of the dust on the surface [5]. The polarization dependence upon the phase angle gives access to the albedo [6], while its dependence upon the wavelength (for phase angles above about 25°) shows a negative gradient for bright S-types and a positive gradient for dark C-types [7]. The $PROGRA^2$-surf and $PROGRA^2$-vis experiments measured the linear polarization on a large range of phase angles and for two wavelengths (543.5 nm and 632.8 nm), on layers (-surf) in the laboratory,

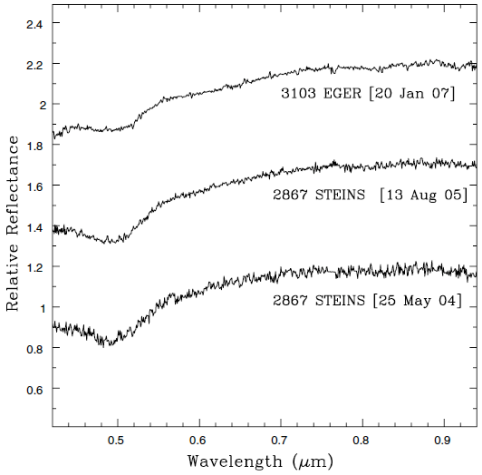
and on levitating dust particles (-vis) during parabolic flight campaigns on board the Centre National d'Etudes Spatiales' dedicated aircraft [8, 9]. Laboratory measurements have been performed during the last trimester of 2008, with two samples of powders of ALH78113,82 aubrite, corresponding to size distributions <125 μ and in the 125-250 μ range. They indicate that the polarimetric spectral gradient is indeed very small and negative consistent with the brighter asteroids.

Photometry at Very Small Phase Angles. The laboratory photometer/polarimeter of Kharkiv Astronomical Observatory has been used to measure the brightness as a function of phase angle at two wavelengths (472 and 670 nm). To simulate Stein's flyby, an enstatite mineral, not from the meteorite but of the same albedo and grain size consistent with aubrites, has been measured showing 25% increase in brightness between 0.0076-1 degree. This is similar to the first reported results of Steins from OSIRIS.

Plans for Future Measurements: The chemistry and mineralogy of the components of this meteorite will be characterized independently from these remote sensing experiments. A UV spectrometer laboratory facility is under development at SWRI Boulder. There are plans to measure the UV spectrum in the region of the ALICE instrument. Bombardment by Ar ions will also be made and the reflectance spectrum will be measured before and after to look for effects simulating space weathering. Goniometric measurements are planned to provide constraints on grain size and scattering properties. We are investigating methods to measure the dielectric constant of the sample to relate the results of MIRO to this type of meteorite.

References: [1] Fornasier, S., et al. (2006) Astron. Astrophys. 449, L9-L12. [2] Fornasier, S., et al. (2007) *Astron. Astrophys. 474, L29-L32.* [3] Barucci, M.A. (2007) *Astron.Astrophys. 477, 665-670.*
[4] Burbine, T. H. et al. (2002) *Meteoritics & Plan. Sci.* 37, 1233-1244. [5] Levasseur-Regourd, A.C. and Hadamcik, E. (2003) *J. Quant. Spectros. Radiat. Transfer*, 79, 903-910. [6] Cellino, A., et al. (2006) *Advances in Geosciences*, 7, 21-32. [7] Belskaya, I. et al. (2008) *Icarus*, 199, 97-105. [8] Renard, J.-B., et al. (2002) *Appl. Opt.*, 41, 609-618. [9] Hadamcik, E., et al. (2008) *Experimental optics of light scattering media*, Praxis, in press.

Acknowledgments: This work is supported by NASA NNG05GC65G (LMcF). EAC's research for this project is supported with grants from NSERC, the Canadian Space Agency, and the U of Winnipeg.



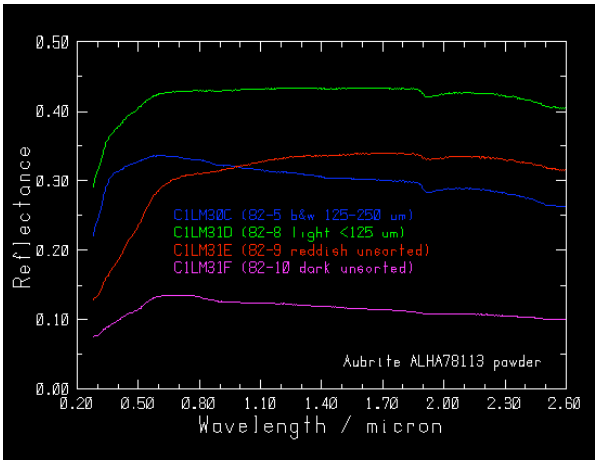


Figure 2 Spectral Reflectance of 4 powders of ALH78113,82. Two separated by grain size with red (terrestrially weathered) material removed. Two are dark material and red material and have not been sieved. See legend for details.

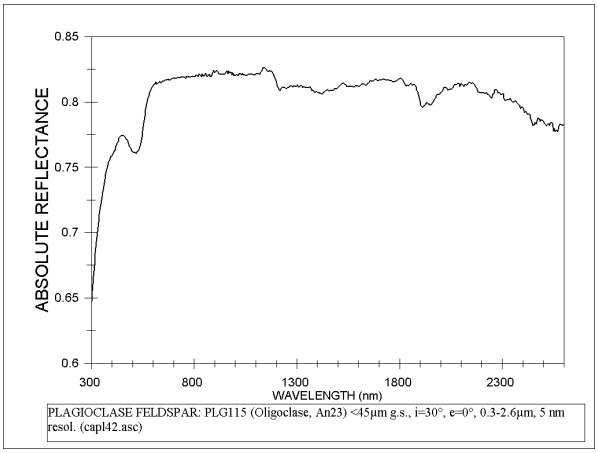


Figure 3 A terrestrial plagioclase with an absorption band at 500 nm. Its cause is under investigation.