Ground-based Mineralogical Characterization of low Δv ASTEX Mission Targets. A. Nathues[1], V. Reddy[2,1], S. Schaeff[3], A. Wiegand[3], R. Michelsen[4], J.A. Sanchez[1] and H. Boehnhardt[1], [1]Max-Planck-Institute for Solar System Research, Max-Planck-Straße 2, 37191 Katlenburg-Lindau, Germany, e-mail: nathues@mps.mpg.de; [2]Department of Space Studies, University of North Dakota, Grand Forks, USA; [3]Astos Solutions, 78089 Unterkirnach, Germany; [4]Astronomical Society of Denmark, 2100 Copenhagen, Denmark

Introduction: ASTEX is a feasibility study of an in-situ exploration mission to two near-Earth asteroids (NEAs) which was funded by the German Space Agency DLR [1]. The mission objectives call for targets with different mineralogical compositions: one asteroid should be of "primitive" nature, the other one should be a fragment of a differentiated asteroid. The goals of the mission are to explore the physical, geological and mineralogical nature of the asteroids and to provide information and constraints on the formation and evolution history of our planetary system. In addition, the detailed knowledge of the properties of NEAs will allow for the selection of potential mitigation systems when required. The mission scenario consists of an orbiting and landing phase at each target.

Scientific aims: Primitive and differentiated asteroids represent two main formation stages of the building blocks (planetesimals) of the terrestrial planets, which are important for our understanding of the origin and evolution of the solar system. Two scientific aspects play an important role, i.e. the search for, and study of the origin and evolution of primordial material that may have played a role in the formation of life in the solar system, and the understanding of the processes that have led to differentiated planetary embryos in the asteroid belt. Beside these, the following immediate mission aims have been defined:

1) Determination of the inner structure of the bodies.
2) Search for material relevant to the formation of life.
3) Determination of the basic physical parameters of the targets (e.g. size, shape, mass, etc.).
4) Determination of thermal conductivity, roughness, material strength and surface physical properties.
5) Visible and near-IR mapping of the surfaces to determine the morphology, the chemistry, the mineralogy and the geology of the targets.
6) Investigation of the correlation between meteorite classes and asteroid types.
7) Exact determination of an asteroid orbit around the Sun using radio tracking.
8) Provision of essential information for mitigation strategies against hazardous NEAs.

Target Characterization: From the huge number of possible NEA combinations 1210 have been preselected and the respective transfers computed within the period 2015 to 2040. In an effort to characterize a subset of these targets, we launched a ground-based spectroscopic campaign in 2009 to determine their composition. Here we present some preliminary science results from ground-based studies.

Observation/Data Reduction: Observations of ASTEX targets were done remotely using the SpeX instrument of NASA's IRTF on Mauna Kea, Hawai'i. Of the four awarded observing runs, two were lost due to poor weather conditions. Near-Earth asteroid (207945) 1991 JW was observed on May 19, 2009, and (136617) 1994 CC was observed on October 19, 2009. The data were reduced by using SpecPR [2] and, as an independent check, using Spextool [3], leading to essentially the same result. Spectral band parameters (band centers and band area ratio/BAR) were calculated using SpecPR.

Mineralogical Analysis: Figure 1 shows an average of 18 spectra of 1991 JW when the asteroid was of V magnitude 15.1. The spectrum shows two absorption features typical of the mafic minerals olivine and pyroxene. The Band I center is located at 1.00 ±0.01 µm and the Band II center is at 2.00 ±0.01 µm with a BAR of 0.48. The weak inflection at 1.3 µm and the location of the Band I center confirms the presence of olivine as the dominant mineral phase on the surface. Pyroxene is a minor phase and can be inferred by the presence of the Band II absorption feature.

Using BAR vs. pyroxene abundance relationship from Cloutis et al. [4] and Burbine et al. [5], the pyroxene abundance ranges between 25-35% confirming the dominance of olivine in the surface assemblage. The Band I center of 1.00±0.01 µm is shortward of even the most Mg-rich (Fo_{100}) olivine which typically have Band I centers ~1.04±0.01 µm [6]. Pyroxenes typically have Band I centers between 0.900-0.935 µm for low-Ca pyroxenes, 0.91-1.07 µm for Type B high-Ca pyroxenes and Band II centers between 1.78-1.97 µm for low-Ca pyroxenes and ~1.97-2.36 µm for Type B high-Ca pyroxenes [7]. The presence of pyroxene on 1991 JW likely causes the Band I center to move to shorter wavelength. Thus the olivine chemistry can't be estimated using the Band I center.

Plotting the asteroid on the Band-Band plot from Adams [8], 1991 JW plots close to LL-chondrites (Figure 2). The lower end of the pyroxene abundance (25%) estimated for 1991 JW is also within the pyroxene abundance range for LL-chondrites (~27%) [9]. Based on this, the most plausible meteorite analogs are LL-chondrites.

1994 CC is a triplet NEA that was observed on October 19, 2009, when the asteroid was of V magnitude 17.4. Figure 3 shows an average spectrum of 1994 CC with a prominent Band I absorption feature with center at 1.045±0.01 µm. No deep Band II feature is within the limits of the spectrum seen. Using the Band I center we estimated the olivine chemistry of 1994 CC to be >Fo_{90} (Figure 4). The dominance of Mg-rich olivine has been detected on several main belt A-type asteroids [9] and these are believed to have formed via igneous processes like partial melting.

Conclusion: Based on our mission science requirement, 1991 JW would not be an ideal target candidate as it is not a primitive carbonaceous asteroid. While 1994 CC's mineralogy strongly supports a body that has experienced igneous temperatures, the dynamical environment in a triplet system would be an engineering challenge to safely operate the spacecraft and perform surface experiments with the lander.

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References: [1] Nathues et al. 2009, ASR, in press [2] Clark R.N. (1980) *Publ. ASP*, 92, 221-224. [3] Cushing M. C. et al. (2004) *Publ. ASP*, 116, 362-376. [4] Cloutis et al. (1986) *JGR.* 91(B11), 11641-11653. [5] Burbine T. J. et al. (2003) *Ant. Met. Research, 16, 185.* [6] King T.V.V. and Ridley W.I. (1987) *J. Geophys. Res.* 92, 11457-11469. [7] Cloutis E.A. & Gaffey M.J., (1991) *JGR.* 96(E5), pp. 22809–22826. [8] Cloutis et al. (1986) JGR. 91(B11), 11641-11653. [9] Hutchison, R. (2004), Meteorites: A Petrologic, Chemical and Isotopic Synthesis. [9] Sunshine et al. (2007) *MAPS 42, # 2, 155-170*.

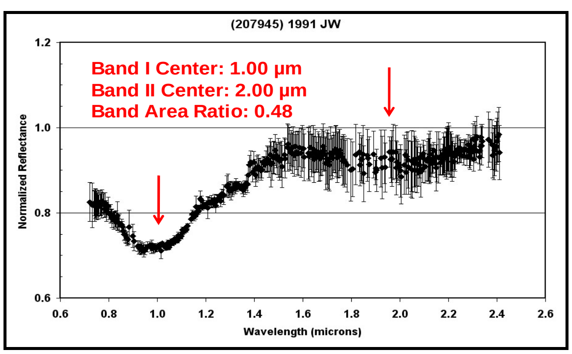

Fig 1. Near-IR Spectrum of 1991 JW.

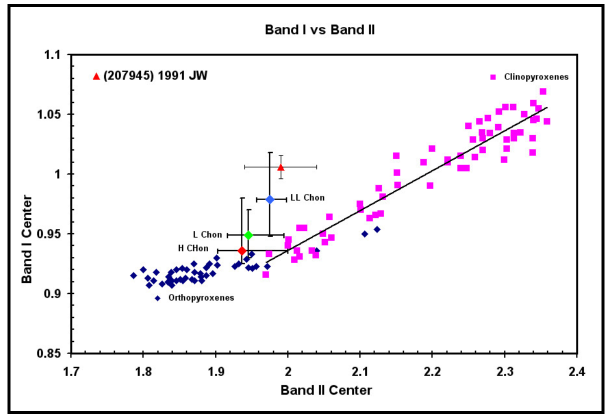

Fig.2. Band I vs. Band II center plot showing 1991 JW.

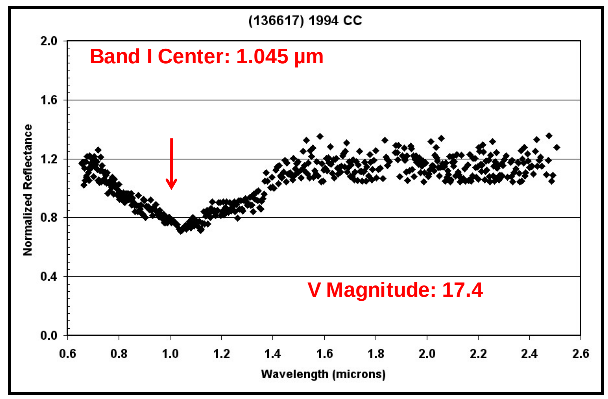

Fig.3. Near-IR reflectance spectrum of NEA 1994 CC.

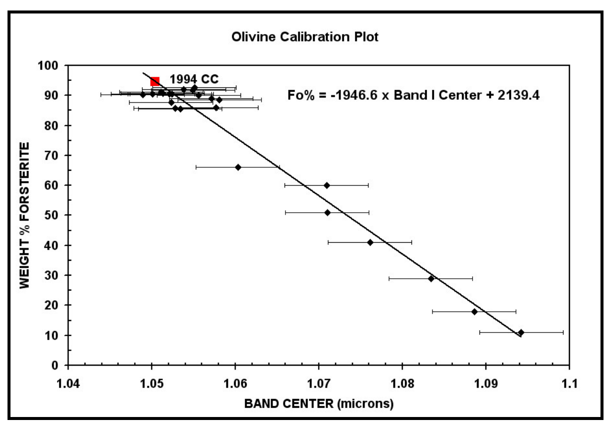

Fig.4. Band I center vs. forsterite content. 1994 CC plots on the trend line >Fo_{90}.