THE SLOWING DOWN OF STARDUST COMETARY GRAINS IN AEROGEL : THE FE-XANES INFORMATION. F. Grossemy[1] , J. Borg[1], A. Simionovici[2], Z. Djouadi[1], L. Lemelle[3], T. Ferroir[3], P. Bleuet[4], J. Susini[4], and P. Gillet[3], [1]Institut d'Astrophysique Spatiale, CNRS, Univ. Paris-Sud, UMR8617, Orsay Cedex, France, faustine.grossemy@ias.u-psud.fr, [2]Laboratoire de Géophysique Interne et Tectonophysique, UMR5559, Univ. J. Fourier, 38041 Grenoble, FRANCE, [3]Laboratoire des Sciences de la Terre, UMR CNRS 5570, ENS Lyon, 46 allée d'Italie, 69364 Lyon, France, [3]ESRF, beamlines ID21 and ID22, BP220, 38043 Grenoble Cedex, France.

Introduction: On January 15, 2006, the Stardust mission of the NASA brought back to Earth aerogel collectors in which grains of the comet 81P/Wild 2 as well as interstellar grains have been trapped [1]. The cometary samples were collected when the Stardust spacecraft flew through the coma of comet Wild 2 at a relative velocity of ~6.1 km/sec. After a detailed documentation of the collector, aerogel tiles and aluminium foils were removed and distributed to members of the Preliminary Examination Teams (PET) around the world [2]. In the framework of the Bulk Composition PET, we carried out a XANES study on five keystones, extracted pieces of aerogel containing both the incident grain and its penetration track. XANES spectra at the iron K-edge were performed on these samples using X-ray Microscopy at the European Synchrotron Radiation Facility (ESRF), Grenoble (France) in order to study the slowing down of Wild 2 cometary grains in aerogel.

Experiment description: Our experiment was performed at the ESRF on beamlines ID22 and ID21 which provide fluxes up to 10^{11} and 10^{9} ph/sec at the edge of iron respectively. The beam can be focused to generate a probe as small as 2 µm on ID22, 1 µm on ID21. Fluorescence mappings of the keystones were performed as a first step using an incident energy of 13 keV on ID22, 7.2 keV on ID21, to select Fe-hotspots where to acquire spatially resolved XANES spectra at the Fe K-edge. An incident energy ranging from 7.1 to 7.2 keV in steps down to 0.25 eV was used to cover the K-edge of iron (7112 eV). A high-purity iron reference foil (Fe^{0}) and a San Carlos olivine (Fe^{2+}) were used to calibrate the energy of the monochromator. Each spectrum was processed following [3] and [4]. The energy of the absorption edge and the centroid energy of the pre-edge were then determined, giving information on the Fe redox states of the hotspots, mainly the terminal particles and, for two samples, grains located along the penetration track.

Results: Figure 1 summarizes the results we obtained. Both the pre-edge and edge energies indicate that the iron of the terminal particule and of the grains inside the track is in the Fe^{2+} state. This is true for all the samples except C027 which is rather a mixture of Fe^{2+} and Fe^{3+} and C2009_29mar06 which is dominated by metallic iron. Its XANES spectrum displays no pre-edge feature and an absorption edge at 7111.62 eV, as it is the case for the iron reference foil (metal).

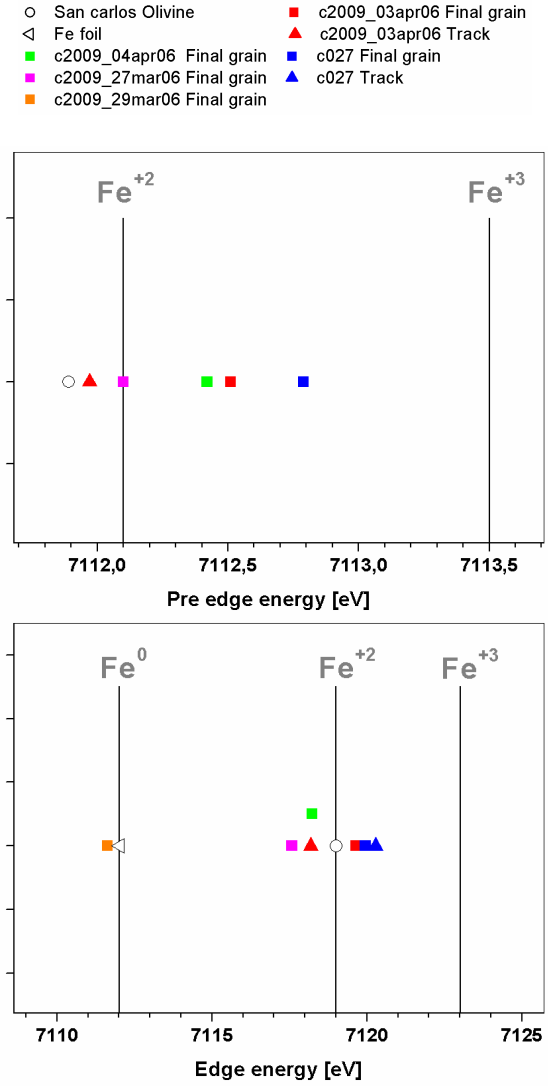

Figure 1: Pre-edge and edge absorption energies of each Fe-XANES spectrum acquired on terminal particles (squares) and on grains inside the track (triangles). The vertical lines indicate the average pre-edge and edge absorption energies for Fe^{0}, Fe^{2+} and Fe^{3+} compounds.

Discussion:

Previous study : A Fe-XANES study previously done on Stardust samples analogs (Orbital Debris Collection Experiment samples and an Allende grain shot into « Stardust » aerogel using a light gas gun) shows that the iron of the terminal particle is found in the same oxidation state as that of the incident grain [5]. In this study the edge and the pre-edge centroid indicated an evolution from a Fe^{3+} form at the track entrance to a more reduced form along the track and in the terminal particle. Several mechanisms were inferred to account for the Fe redox state observed. Based on the results for an Allende grain known to be Fe^{2+} rich [6,7], the most probable scenario is the following. Incident grains of 2+ oxidation state undergo rapid oxidation to 3+ at the entrance of the track, due to high temperature slowing down from the initial velocity of a few $km.s^{-1}$ in the presence of the aerogel oxygen. The shell of oxidized iron is then lost at the track entrance by the grain that remains in the 2+ oxidation state at the end of the track.

Study of Wild 2 samples : As shown in Figure 1, iron in terminal particles of Wild 2 samples is in ferrous form, which is in agreement with the proposed scenario. Evidence of Fe^0 was found in sample C2009_29mar06. The presence of metallic iron could be due to smelting, reduction of the iron of the incident particule by the carbon of the aerogel. But as suggested by [5], the incident particle could already be in Fe^0 form and its oxidation state be preserved during the slowing down into the aerogel. Thus in future work on additional keystones it is important to confirm this hypothesis by analysing Fe-hotspots at various positions along the track, from the track entrance to the terminal particle.

Conclusion : If such a scenario for the slowing down of cometary grains in the Stardust aerogel is confirmed, it means that the main information concerning the redox state of the incident particle is found in the terminal grain. Whereas both the track and the terminal particle have to be analyzed to measure the elemental composition of Wild 2 samples [8], this Fe-XANES study indicates that a mineralogical identification of the incident particle is possible provided we only consider the terminal grain.

References: [1] Tsou P. et al. (2006) *LPS XXXVII,* Abstract #2189. [2] Brownlee D. E. et al. (2006) *Science, 314,* 1711-1716. [3] Wilke M. et al. (2001) *Am. Mineral., 86,* 714-730. [4] Berry A.J. et al. (2003) *Am. Mineral., 88,* 967-977. [5] Grossemy F. et al. (2006) *accepted for publication in Planet. and Space Sci*. [6] Olivier F.W. et al. (1984) *Meteoritics & Planet. Sci., 19,* 1, 25-27. [7] Hoffman E. et al. (2000) *Meteoritics & Planet. Sci., 35,* 2, 431-434. [8] Flynn et al. (2006) *Science, 314,* 1731-1735.

Acknowledgements: This work was supported by the French Space Agency CNES and by the ESRF in the framework of beamtime allocation EC47. The authors would like to acknowledge the NASA Stardust Project for providing them with the samples.