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NATURE *VS.* NURTURE DEBATE ON TNO CARBONS: CONSTRAINTS FROM RAMAN SPECTROSCOPY

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Abstract. We compare spectroscopic data of irradiated laboratory analogs with those of an interplanetary dust particle of cometary origin. We investigate if this comparison can help constraining the origin of carbonaceous materials on small icy bodies in the outer Solar System (TNOs, Centaurs, etc.). We suggest that Raman spectroscopy can help in interpreting the observed heterogeneity of the extraterrestrial carbonaceous component and in constraining the irradiation dose accumulated in space.

1 Introduction

Complex organic materials on small outer Solar System icy bodies probably include a primary native component accreted during the formation of planetesimals ("nature"), and a secondary component that is a by-product of (cosmic and/or solar wind) ion and photon irradiation of simpler C-bearing volatile ices ("nurture"). The debate of nature *vs.* nurture has been recently summarized by Dalle Ore *et al.* (2011). An example of an object which shows the presence on its surface of a red carbonaceous component (nature?) and of a black component (nurture?) has been discussed by Guilbert *et al.* (2009). Experimental studies can simulate some of these processes and provide interesting inputs to this debate on the origin of the carbonaceous component of trans-Neptunian Objects (TNOs) and Centaurs.

2 Micro-Raman spectra of a cometary IDP

Chondritic porous (CP) IDPs probably originated from comets, or P–type or D–type asteroids. They are good analogs of the refractories (carbons, silicates) possibly present on small outer Solar System icy bodies. A CP–IDP of cometary origin (IR spectra match the small silicate grains emission of comet Hale–Bopp)

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provided by NASA was analyzed with IR, Raman, and FESEM–EDX, in the framework of the analysis of cometary materials performed by the "Astrochimie et Origines" team in Orsay, in collaboration with SMIS-SOLEIL and Università di Napoli "Parthenope".

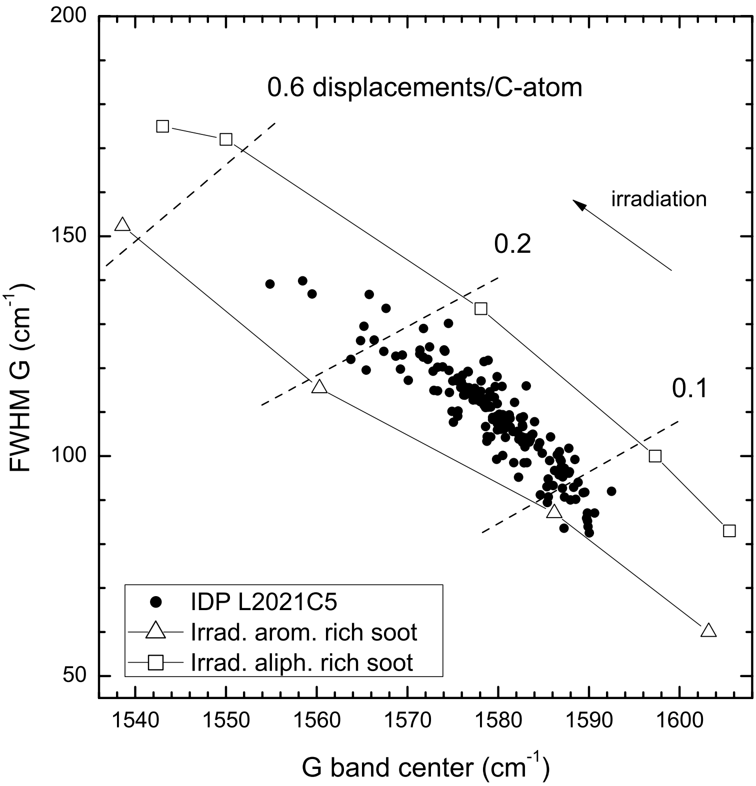

Fig. 1. G band full width at half maximum (FWHM) as a function of G band peak position, for IDP L2021C5 (Brunetto *et al.* 2011) and irradiated aliphatic-rich and aromatic-rich soot (Brunetto *et al.* 2009). An arrow marks the evolutionary path due to ion irradiation.

Raman spectra have evidenced strong heterogeneity of the carbonaceous structures with different degrees of order (Brunetto *et al.* 2011). The combination of the three techniques indicates that the particle experienced only mild flash heating on atmospheric entry. Raman spectroscopy is sensitive to the carbon structure and to its degree of order. It has been used to characterize the organic matter of meteorites and IDPs (*e.g.* Wopenka 1988; Matrajt *et al.* 2004; Quirico *et al.* 2005; Busemann *et al.* 2007), and organics captured from comet 81P/Wild 2 (*e.g.* Rotundi *et al.* 2008; Muñoz–Caro *et al.* 2008).

3 Comparison with irradiated laboratory analogs

In Figure 1 we compare spectroscopic data of irradiated soot (laboratory analogs of cosmic dust, Brunetto *et al.* 2009) with those of IDP L2021C5. This preliminary comparison can help constraining the origin of TNO carbonaceous materials. Baratta *et al.* (2004) found an upper limit to the highest dose accumulated by IDPs due to ion irradiation in the interplanetary medium: about 0.5 displacements per C atom, compatible with the exposure time of these particles.

We find that about 80% of carbons in IDP L2021C5 have upper limit dose between 0.1–0.2 displacements per C-atom. Only about 10% of carbons can be compatible with high irradiation dose. Further investigation is needed to determine whether the observed heterogeneity of the extraterrestrial carbonaceous component is primordial or an effect of irradiation during residence in interplanetary medium. In any case, we confirm that Raman spectroscopy of relevant extraterrestrial carbons gives interesting and complementary (to other techniques) information that can help in interpreting the observed heterogeneity of the extraterrestrial component and in constraining the dose accumulated in space.

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