COMPARING THE REFLECTIVITY OF UNGROUPED CARBONACEOUS CHONDRITES WITH THOSE OF SHORT PERIOD COMETS LIKE 2P/ENCKE. Safoura Tanbakouei[1,2], Josep M. Trigo-Rodríguez[1,2], Jürgen Blum[3], Iwan Williams[4] , and Jordi Llorca[5]. [1]Institute of Space Sciences (ICE-CSIC), Campus UAB, C/ Can Magrans s/n, 08193 Bellaterra (Barcelona), Catalonia, Spain e-mail: tanbakouei@ice.csic.es, [2]Institut d'Estudis Espacials de Catalunya (IEEC), C/ Gran Capità, 2-4, Ed. Nexus, desp. 201, 08034 Barcelona, Catalonia, Spain e-mail: trigo@ice.csic.es, [3] Institut für Geophysik und Extraterrestrische Physik, Technische Universität Braunschweig, Mendelssohnstr. 3, 38106 Braunschweig, Germany e-mail: j.blum@tu-bs.de. [4] School of Physics and Astronomy, Queen Mary, University of London, Mile End Rd. London E1 4NS, UK. [5] Institute of Energy Technologies, Department of Chemical Engineering and Barcelona Research Center in Multiscale Science and Engineering, Universitat Politècnica de Catalunya- BarcelonaTech, Catalonia, Spain e-mail: jordi.llorca@upc.edu.

Introduction: The comet 2P/Encke (hereafter Encke) is a 4.8 km-sized active comet that was discovered in 1786. It has an unusual 3.3 yr orbit, and is one of the largest known objects in the Taurid complex (hereafter TC) [1,2]. Due to gravitational interactions with the terrestrial planets, Encke's orbit is far from Jupiter's control, and this results in a very smooth orbital evolution (see e.g. [3]). The properties of Encke are quite distinct compared to other objects in the Solar System [4]. Compared to the available spectra of other cometary nuclei, Encke's spectrum is rather typical, despite its very peculiar orbit. It is also important to remark that 2P/Encke exemplifies a challenging hazardous body, because it has a very low albedo, reflecting only 4.6% of the light it receives in the visible range [5].

The reflectance spectrum of 2P/Encke exhibits a moderate red slope and is otherwise featureless [6]. To our knowledge, it has so far not been possible to find a meteorite proxy with a similar reflectance behavior. Consequently, the main goal of our work is to identify samples in our meteorite collections with reflectance characteristics similar to those of comet 2P/Encke. We consider this comet as a case study to promote studies with the aim of emphasizing the importance to achieve sample return from short-period comets and increase laboratory studies on anomalous meteorites.

Technical procedure and sample selection: We obtained reflectance spectra of the meteorites described in Table 1, using the procedure described in previous work [7]. Polished sections of the selected meteorites were measured at UPC, using a Shimadzu UV3600 ultraviolet to near-infrared (UV-Vis-NIR) spectrometer. The spectrometer diffraction-limited illumination originates from one of two lamps and passes through a variable slit; it is then filtered with a grating to select the desired wavelength, and with a chopper. Next, the beam interacts with the sample and is routed to the detector. The reference beam interacts with the material of the sample surface and then goes to the same detector [8]. Next, the beam interacts with the sample at an angle of 8° and it is later routed to the detector. The standard stage for the spectrometer is an integrating sphere with a working range in the current study of 400–900 nm, and operated under laboratory conditions. The spectrum was normalized to unity at 550 nm. It is important to remark that the Encke reflectance data was removed between 570 and 620 nm and between 720 and 780 nm, due to several issues related to the data reduction and some artefacts in the spectra.

Table 1. List of CR, CM and CK and ungrouped carbonaceous chondrites that were compared to the spectrum of comet 2P/Encke in this work.

Meteorites	Group	Mass (g)
QUE 99355	CM2	32.4
Murchison	CM2	~100.000
EET 92159	CR2	67.6
LAP 02342	CR2	42.4
Renazzo	CR2	~1000
PCA 82500	CK4-5	90.9
LAR 12265 thin	CK5	14.3
ALH 85002	CK5	438
MET 01017	CV3-an	238.0
GRO 95551	C-ung	213.3

Results and discussion: In order to gain insight into the nature of evolved comets, we compared the reflectance spectra of CCs with the reflectance spectrum obtained for comet Encke [5]. The reflectance spectrum of Encke covers the full visible range from 400 to 900 nm on the detector. Concerning the comparison with other CC groups, the specimens belonging to most carbonaceous chondrite groups exhibited very different reflectance spectra. After many attempts among the meteorites studied, we found a likely reflectance similarity in one meteorite, named Meteorite Hills 01017 (MET 01017). This meteorite is classified as an as a CV3-an chondrite (MetBull: 88, 2001). Another sample with a spectral behavior similar

to that of 2P/Encke is Grosvenor Mountains 95551 (GRO 95551). This meteorite is an ungrouped CC, an unusual metal-rich breccia formed by two main types of clasts: chondritic and achondritic. As we can see in Fig. 1, at first sight the spectral slope of the two studied meteorites is compatible with that of 2P/Encke. The spectrum of the comet shows a shallower slope above 800 nm.

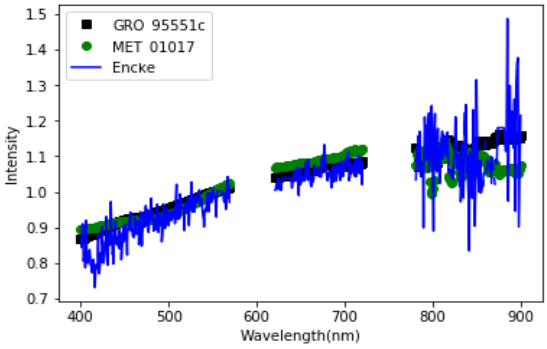

Figure 1. Reflectance spectra from 400 to 900 nm of the two ungrouped carbonaceous chondrites compared with the spectrum of the comet 2P/Encke (blue line).

That being said, 2P/Encke's reflectance spectrum is similar to that of primitive asteroids [5], so even when scarce it should be present in meteorite collections. Figure 1 shows that both ungrouped CC samples and comet Encke exhibit a common absorption feature at 500 nm (Table 2). From the spectral similarities, a tentative link between Encke, MET 01017, and GRO 95551 can be made. It is interesting that ungrouped carbonaceous chondrites have highly variable spectral properties and that the surface of comet Encke was subjected to significant changes due to solar heating [5]. Obviously, to rule out other possibilities, we compared 2P/Encke spectrum with specimens from other potentially "cometary" chondrite groups like e.g. CK, CR, and CM [9]. Such a spectral match is not obvious for other CC groups. A comparison with CM, CR, and CK chondrites exhibits no evidence of compositional similarities with comet Encke probably because short period comets have experienced significant collisional processing, ending in highly brecciated surfaces, even at mm-scale.

Conclusion: We find that the most common and well established aqueously altered CC groups do not match the spectrum of the comet 2P/Encke, but two anomalous carbonaceous chondrites might be good candidates to be associated with this type of evolved comets. Despite being almost featureless spectra, some spectral similarities between our two ungrouped CC and the spectrum of Encke were found. Olivine, phyllosilicates, and Fe oxides bands are present, and together with a similar spectral slope, they reasonably match the VIS-NIR reflectance spectrum characteristics of this short-period comet. In any case, we recognize that additional work is needed to establish a more precise link. The study of fresh anomalous carbonaceous chondrites unaffected by terrestrial weathering might be relevant [10], but certainly future sample-returned materials from short period comets could provide final clues in this regard.

Table 2. Main absorption bands in the two ungrouped CC meteorites and their mineral assignments [9].

Meteorites	Absorption band (nm)	Mineral
MET 01017	495	Olivine
	665	Magnetite/maghemite
	700–720	Phyllosilicates
	850	Olivine
	875	Orthopyroxene
GRO 95551	470	Olivine
	665	Magnetite/maghemite
	710	Phyllosilicates
	850	Olivine

Acknowledgments: J.M.T.R. and S.T. acknowledge financial support from the Spanish Ministry (PGC2018-097374-B-I00, PI: JMTR). J.L. is grateful to ICREA Academia program and funding from Generalitat de Catalunya (2017 SGR 128). US Antarctic meteorite samples are recovered by the Antarctic Search for Meteorites (ANSMET) program. J.B. thanks the DLR and the DFG.

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