CHEMICAL AND MINERALOGICAL ANALYSES OF PARTICLES FROM THE STRATOSPHERIC COLLECTIONS COINCIDING WITH THE 2002 LEONID STORM AND THE 2003 COMET GRIGG-SKJELLERUP TRAIL PASSAGE. G. J. Flynn[1], A. Lanzirotti[2], and S. R. Sutton[2,3], [1]Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh NY 12901 (george.flynn@plattsburgh.edu), [2]CARS and [3]Dept of Geophysical Sciences, University of Chicago, Chicago IL 60637.

Introduction: NASA collected particles from the stratosphere at times coinciding with the 2002 Leonid Shower, associated with comet Tempel-Tuttle, and with Earth's crossing of the dust steam from comet Grigg-Skjellerup in 2003, using the same techniques employed for collection of interplanetary dust particles (IDPs). We compared these putative cometary particles with previously examined IDPs, the majority of which are believed to be from asteroids [1].

Samples and Techniques: We performed X-Ray Microprobe (XRM) chemical and X-Ray Diffraction (XRD) mineralogical analyses at Beamline X26A of the National Synchrotron Light Source. We analyzed one spherical particle from the L2018 collector, which flew during the Leonid Shower, and eight irregularly shaped particles from the L2055 collector, which flew during the Earth's passage through the dust from Grigg-Skjellerup. Five L2055 particles were collected intact, while three were cluster fragments.

Unlike most IDPs we have previously analyzed, whose major element chemistry was determined by SEM-EDX prior to allocation by the Cosmic Dust Curatorial Facility, the L2018 and L2055 particles were selected and allocated to us simply based on their morphology and color. Thus, although the IDPs analyzed previously were known to have approximately chondritic major element contents, compositional information was unavailable for these L2018 and L2055 particles prior to our analyses.

XRM Analyses: Several L2055 particles exhibited extremely low fluorescence count rates, a order-of-magnitude or more lower than we see for typical chondritic particles of their size (~10 microns). Either these particles have extremely low densities or they are composed mostly of elements lighter than S.

In a chondritic particle analyzed under these conditions, the highest fluorescence peak is from Fe. Fe was not the largest peak in the fluorescence spectrum (which covered S through Sr) of L2055D1, L2055D5, and L2055E1 (from cluster #1). In addition, the count rates for L2055D1 and L2055D5 were unusually low for their size. In L2055D1 the dominant element was Cr (Cr/Fe = 17.8), while Ti and Cr made the major contributions to the spectrum of L2055D5 (Cr/Fe = 19.1, Ti/Fe = 8.6), and Cu and Zn gave the highest peaks in L2055E1 (Cu/Fe = 3.6, Zn/Fe = 2.2). L2055D1, L2055D5 and L2055E1 are not chondritic in composition. L2055D3 had a low count rate, consistent with background, and no elements were identified.

In our analysis of over 200 IDPs collected from the stratosphere we found, in almost all cases, the Ni/Fe ratio is within a factor of two of CI. Four of the L2055 particles exhibited Ni/Fe ratios within a factor of two of CI. L2055D2 and L2055D4, were collected intact while L2055E2 (from cluster #7) and L2055E5 (from cluster #5) are fragments from cluster particles. L2055D4 gave a low count rate, but its fluorescence spectrum was consistent with a chondritic composition. The other three particles – L2055D2, L2055E2, and L2055E5 gave chondritic fluorescence spectra and exhibited normal count rates for their sizes. The CI and Fe normalized element abundances for the four particles having chondritic Ni/Fe are shown in Fig. 1.

A high variability in Ca is normally seen in IDPs, and Schramm et al. [2] noted that anhydrous IDPs generally have a higher Ca content than the hydrated IDPs. If the L2055 particles follow that trend, then the low Ca/Fe ratio suggests L2055E5 might be hydrated.

All four of the chondritic particles have Zn contents substantially below the CI value, with the two cluster fragments, L2055E2 and L2055E5, showing extremely low Zn contents. In IDPs collected intact, low Zn/Fe correlates with both the presence of well-developed magnetite rims [3] and low concentrations of solar wind He [4], showing that low Zn content is an indicator of substantial heating during atmospheric entry. Thus, it appears that L2055D2 and L2055D4 experienced moderate heating on atmospheric entry, resulting in the loss of Zn. In the case of the cluster

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Table 1: Properties of L2055 Particles

No.	Type*	XRF Chemical Results Ni/Fe	Major Peaks	Zn	XRD Results Mineral[@]	Mag[#]
D1	I	high	Cr			
D2	I	~CI	Fe	low	saponite	N
D3	I	only background				
D4	I	~CI	Fe	low	pyroxene	Y
D5	I	high	Cr, Ti			
E1	C	low	Cu, Zn			
E2	C	~CI	Fe	very low		
E5	C	~CI	Fe	very low		N

* Type: I = collected intact, C = cluster fragment
[@]tentative ID by comparing the d-spacings to olivine, pyroxene, layer-silicates Fe-sulfide, and magnetite.
[#]Mag.: Y = magnetite ring(s), N = no magnetite ring(s)

fragments, such as L2055E2 and L2055E5, the low Zn content may simply indicate that the fragmentation resulted in separation of the Zn-bearing sulfides from the material we analyzed. Analysis of additional fragments from these clusters is required to determine the degree of entry heating based on their Zn contents.

All four particles are enriched in Br compared to CI, but three, L2055D2, L2055D4 and L2055E2, have Br enrichments far smaller than the mean Br enrichment of ~50 times CI reported in IDPs [5].

The Leonid meteors enter the Earth's atmosphere with a velocity of ~ 70 km/sec. Even ~10 micron particles entering at this speed are expected to be so severely heated that most would melt or vaporize [1]. L2018C1 is an ~10 micron diameter spherical particle. Surprisingly, L2018C1 shows enrichments in all the moderately volatile elements we measured compared to the Fe and CI normalized values (see Figure 2).

L2005J11 is a typical ~10 micron spherical IDP from the stratosphere. Both L2018C1 and L2005J11 show relatively flat abundance patterns for the refractory elements, but L2018C1 is enriched in all of the moderately volatile elements detected (Mn, Ge, Rb, Se, Zn, S, and Br) compared to CI, while L2005J11 is depleted, as expected, in each of these elements.

XRD Analyses: We obtained XRD patterns from three of the four chondritic particles from the L2055 collector, L2055D2, L2055D5, L2055E5, and from L2018C1. The XRD pattern of L2055D2 is consistent with the saponite group, inconsistent with pyroxene or olivine, and shows no evidence of magnetite. L2055D4 has a few strong reflections, consistent with a coarsely crystalline phase. These are difficult to interpret, because the relative intensities of the spots depend on crystal orientation. Considering only the common minerals in IDPs (olivine, pyroxene, layer-silicates, and Fe-sulfides), the best match is to clinoenstatite. L2055D4 shows one clear ring, indicating the presence of a finely crystalline phase, consistent with magnetite. L2055E5 produced very few reflections, but we see no evidence of magnetite. The major spots in the XRD pattern of L2018C1 are consistent with pyrrhotite, which may explain the excess chalcophile elements in L2018C1.

Conclusions: Although we detected magnetite ring patterns in every stratospheric IDP previously examined [6], magnetite was not detected in three of the four particles analyzed by XRD from these timed collections. The absence of magnetite in the cluster fragment, L2055E5, may simply indicate that this fragment came from the interior of the original particle. However, the absence of magnetite in the particles collected intact, L2055D2 and L2018C1, is puzzling. If they are extraterrestrial, as indicated by their chondritic Ni/Fe, then the absence of magnetite suggests they did not react as much with the atmosphere during entry as most other IDPs. This may indicate that they entered the atmosphere in the interior of larger objects that fragmented or exploded at low altitude, after they had decelerated.

If the short-period comet Grigg-Skjellerup is the source of these L2055 particles, then our results indicate this comet exhibits considerable mineralogical and chemical diversity at the ~10 micron scale, including the presence of both anhydrous and hydrated silicates, low-Z material, and a range of mineral grains. That would suggest the ~10 micron grains collected by the NASA Stardust spacecraft from the short-period comet Wild-2 might show similar diversity.

References: [1] Flynn, G. J. (1989) *Icarus,* **77**, 287-310. [2] Schramm, L. S. et al. (1989) *Meteoritics*, **24,** 99-112 [3] Thomas, K. L. et al. (1992) *Lunar & Planet. Sci XXIII*, 1427-1428. [4] Kehm, K. *Meteoritics & Planet. Sci*., **37**, 1323-1335. [5] Flynn, G. J. et al. (1996) in *Physics; chemistry; and dynamics of interplanetary dust,* ASP Conf. Series 310, 291-297. [6] Flynn, G. J. et al. (2000) *Lunar & Planet. Sci. XXXI*, Abs # 1772.

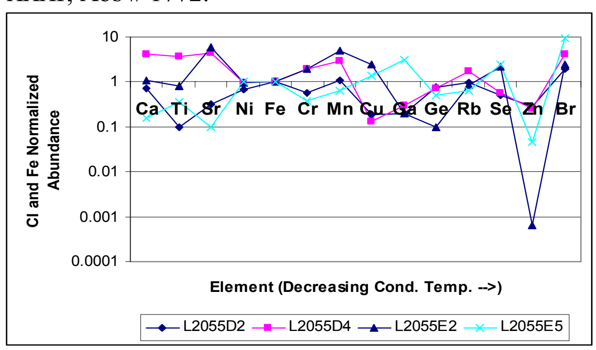

Figure 1: CI and Fe normalized element abundances in four chondritic particles from the L2055 collector, flown during the Grigg-Skjellerup encounter. (Ga, Ge, and Rb are upper limits in E2).

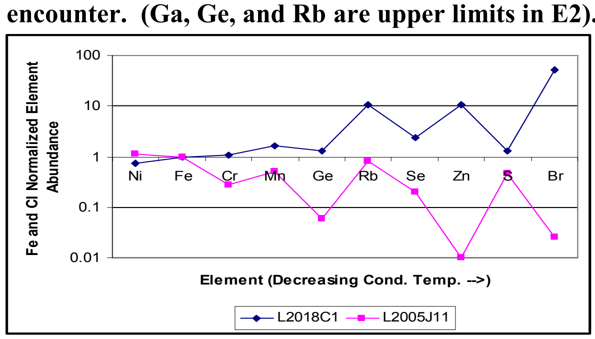

Figure 2: CI and Fe normalized element abundances in L2018C18 and in an ~10 micron spherical particle from the L2005 collector, flown during the Leonid shower. (Ge, Rb and Zn are upper limits in L2005J11).