ORBIT, METEOROID SIZE AND COSMIC HISTORY OF THE OSCEOLA (L6) METEORITE

Matthias M. M. Meier[1,2], Maria Gritsevich[3,4,5], Kees C. Welten[6], Esko Lyytinen[4], Amy A. Plant[2], Colin Maden[2], and Henner Busemann[2]

Main mass of Osceola (Photo: Larry Atkins)

Go to HTML abstract | Go to PDF

[1]Naturmuseum St.Gallen, St.Gallen, Switzerland. [2]ETH Zurich, Institute of Geochemistry and Petrology, Zurich, Switzerland. [3]Finnish Geospatial Research Institute, Masala, Finland. [4]Finnish Fireball Network, Helsinki, Finland. [5]Institute of Physics and Technology, Ural Federal University, Ekaterinburg, Russia. [6]Space Science Laboratory, University of California, Berkeley CA, United States of America

INTRODUCTION & BACKGROUND

Meteorites with orbits

- Today, ca. 64'000 meteorites are catalogued in the Meteoritical Bulletin Database[1].
- For only 34 of them, the orbit of the meteoroid is known[2], usually based on fireball observations followed by triangulation.
- For each orbit, a probability distribution of the most likely source regions in the asteroid belt can be derived for the meteorite[3].
- Cosmic-ray exposure ages (i.e., meteoroid travel times in free space) can provide additional constraints on source regions[4].

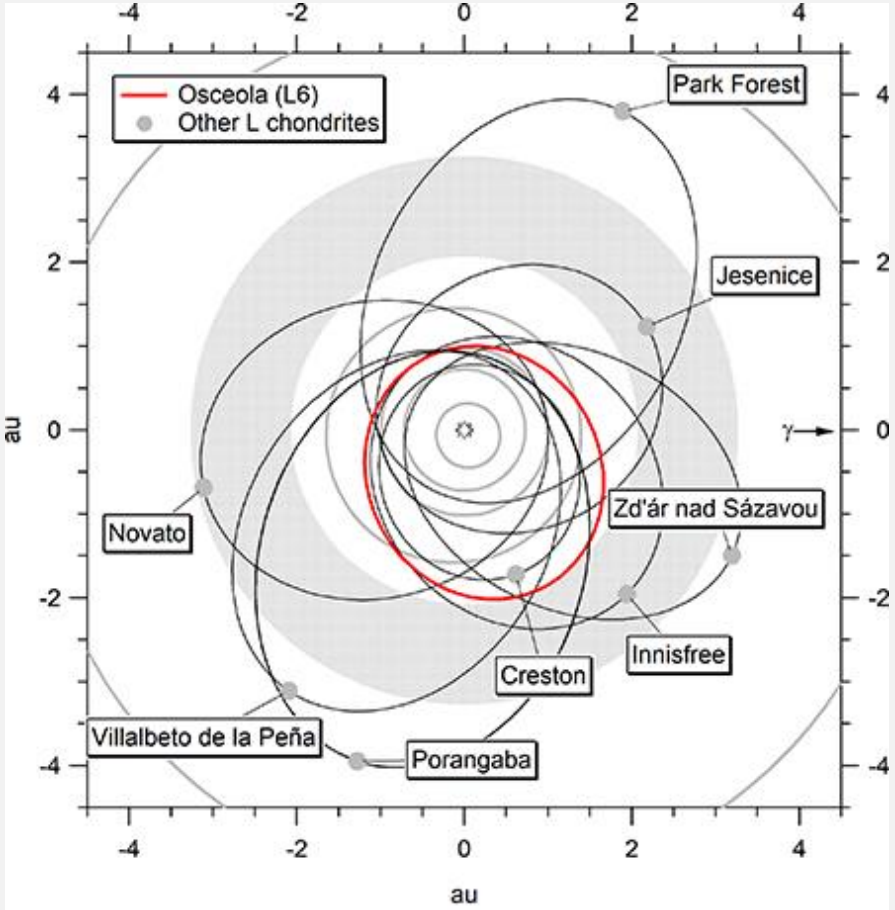


Figure 1: Orbit of Osceola in comparison with the eight other L chondrites with known orbits [2].

L chondrite histories

- Osceola is an L chondrite which fell to Earth on January 24th, 2016 in Florida, USA[5].
- L chondrites are the most abundant type of meteorite falling to Earth today (ca. 30%)[6].
- Many have a shock age of ca. 470 Ma[7]. Based on this and other evidence, the L chondrite parent asteroid (LCPB; >100 km diameter) was likely disrupted at the time[8].
- L chondrites with shock ages ca. 470 Ma thus allow us to better understand asteroid disruptions

METHODOLOGY & RESULTS

Analytical techniques used, and their aims

- Four chips with a total mass of ca. 120 mg were analysed at ETH Zurich for all stable isotopes of He, Ne, Ar and for ^{84}Kr, ^{129,132}Xe, in order to determine the meteoroid size, cosmic-ray exposure (CRE) and radiogenic gas retention (RGR) ages. Methods, see 4.
- Cosmogenic radionuclides (^{10}Be, ^{26}Al) are still being analysed at the Space Science Laboratory, UC Berkeley. Once analysis is completed, they will provide additional constraints on the meteoroid size, and a more robust ^{26}Al/^{21}Ne-based CRE age.

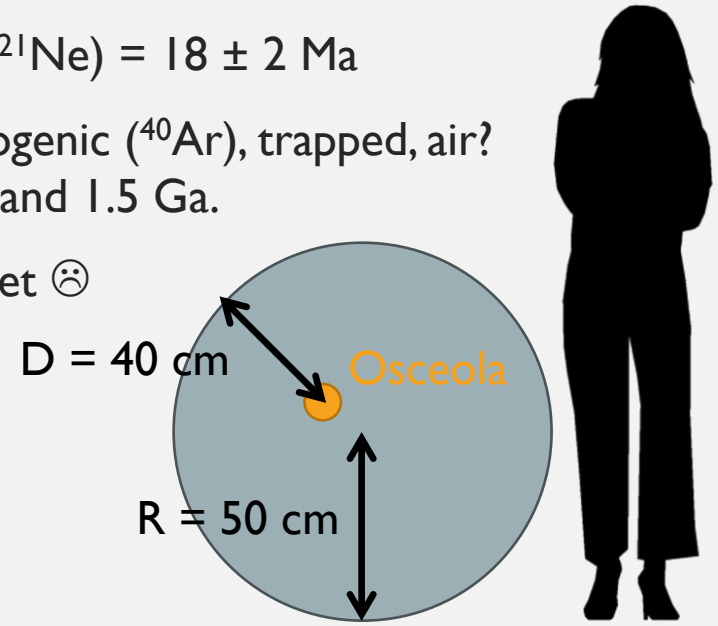
Table 1: He, Ne, Ar in Osceola

Chip (mg)	$^{3}He=^{3}He_{cos}$	^{4}He	^{20}Ne	^{21}Ne	^{22}Ne	^{36}Ar	^{38}Ar	$^{40}Ar = ^{40}Ar_{rad}$	$^{4}He_{rad}$	$^{21}Ne_{cos}$	$^{38}Ar_{cos}$
Os-3 (21.5)	34.9	342	7.20	7.58	8.21	4.39	2.04	714	133	7.58	1.38
Os-4 (15.8)	35.9	337	7.00	8.18	8.73	3.55	2.11	498	122	8.18	1.64

All concentrations given in units of 10^{-8} cm^3STP/g (uncertainty in amounts <3%).

Results

- He, Ne: cosmogenic and radiogenic (^{4}He). No loss of He vs. Ne. U,Th-He RGR age = 420 and 460 Ma (Os-3, -4).
- ^{22}Ne/^{21}Ne = 1.07 suggests relatively high shielding: R >= 50 cm, shielding depth D = ca. 40 cm (models[9,10])
- CRE age (^{22}Ne/^{21}Ne-^{21}Ne) = 18 ± 2 Ma
- Ar: cosmogenic, radiogenic (^{40}Ar), trapped, air? K-Ar RGR age = 1.1 and 1.5 Ga.
- ^{10}Be, ^{26}Al: not done yet ☹



DISCUSSION & CONCLUSIONS

Orbit

- The orbit of Osceola is dynamically evolved, i.e., only marginally touches the inner edge of the asteroid belt (see Fig. 1), indicating that the meteoroid likely had at least one close encounter with a terrestrial planet in the past. The only other L chondrite with a dynamically evolved orbit is Creston[11].

Noble Gases, CRE age, size

- He, Ne and Ar in Osceola are dominated by cosmogenic and radiogenic nuclides – typical for equilibrated ordinary chondrites.
- The CRE age of 18 ± 2 Ma is in the normal range observed in L chondrites, (~1-100 Ma) but does not fall on a particular peak in the CRE age histogram[12] (see Fig. 2).
- The CRE age and the radius of >50 cm are compatible in the sense that a R = 50 cm body should have an average collisional life-time of ca. 14 Ma inside the asteroid belt (more for larger objects)[13].

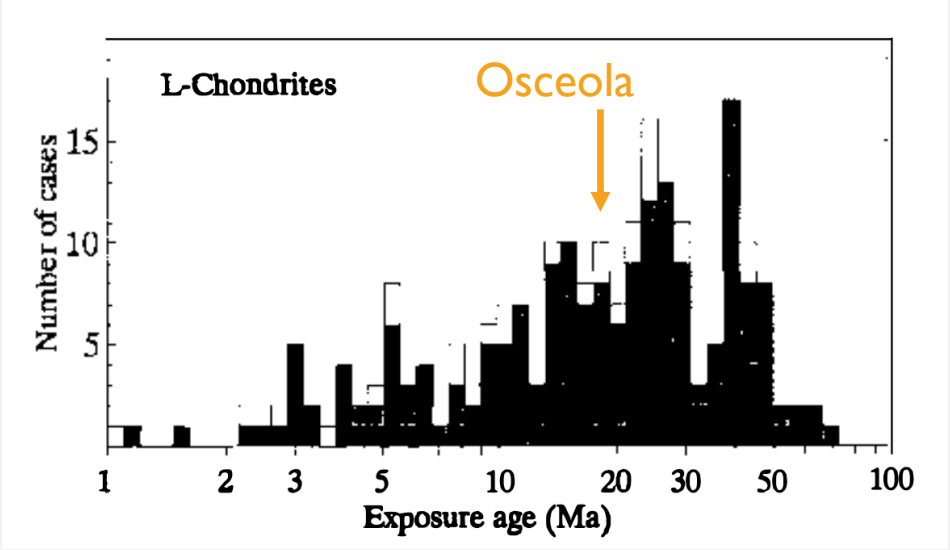


Fig 2: CRE histogram of the L chondrites[12]

RGR ages, shock

- The U,Th-He age of Osceola (420-460 Ma) is compatible, within characteristic uncertainties, with the age of the disruption of the LCPB at 470 Ma[7,8].
- The K-Ar age is higher (1.1-1.5 Ga), perhaps due to only a partial reset 470 Ma ago, as is often observed for meteorites with shock stage S4, like Osceola[14].

Title
Refs.

REFERENCES & ACKNOWLEDGEMENTS

References

1. https://www.lpi.usra.edu/meteor/metbull.php
2. https://www.meteoriteorbits.info
3. Granvik & Brown 2018, Icarus 311:271-287
4. Meier et al. 2017, Meteoritics & Planetary Science 52:1561-1576
5. Gritsevich et al. 2017, Ann. Meeting of the Met. Soc., 6188
6. Burbine et al. 2002, in: Asteroids III, Univ. of Arizona Press
7. Bogard 1995, Meteoritics 30:244-268
8. Schmitz et al. 2001, Earth & Planetary Science Letters 194:1-15
9. Leya & Masarik 2009, Meteoritics & Planetary Science 44:1061-1086
10. Dalcher et al. 2013, Meteoritics & Planetary Science 48:1841-1862
11. Jenniskens et al. 2019, Meteoritics & Planetary Science 54:699-720
12. Marti & Graf 1992, Ann. Rev. Earth & Planetary Science 20:221-243
13. Farinella et al. 1998, Icarus 132:378-387
14. Stöffler et al. 1991, Geochimica et Cosmochimica Acta 55:3845

Acknowledgements

- MMMM and AAP were supported by an Ambizione grant from the Swiss National Science Foundation (SNSF)
- HB was supported by the NCCR PlanetS, funded by the SNSF
- MG acknowledges the Academy of Finland project No. 325806 (PlanetS) and the Russian Foundation for Basic Research, project Nos. 18-08-00074 & 19-05-00028.