**EVIDENCE FOR THERMAL METAMORPHISM OR PARTIAL DIFFERENTIATION OF ASTEROID 21 LUTETIA FROM ROSETTA.** B. P. Weiss[1], L. T. Elkins-Tanton[1], M. A.. Barucci[2], H. Sierks[3], M. Pätzhold[4], C. Snodgrass[3], S. Marchi[5], I. Richter[6], P. R. Weissman[7], M. Fulchignoni[2], and R. P. Binzel[1]. [1]Dept. of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA (bpweiss@mit.edu), [2]Observatoire de Paris LESIA, France, [3]Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany, [4]Rheinisches Institut für Umweltforschung, Abt. Planetenforschung, Germany, [5]Université de Nice-Sophia Antipolis, Observatoire de la Côte d'Azur, France, [6]TU-Braunschweig, Institute for Geophysics and Extraterrestrial Physics, Braunschweig, Germany, [7]Jet Propulsion Laboratory, Pasadena, CA, USA.

**Introduction:** Achondrites are thought to have formed as a result of heating by short-lived radionuclides on bodies >~20 km in radius that accreted <~3 Ma after the formation of calcium aluminium inclusions [1]. By comparison, chondrites are traditionally thought to have formed on smaller and/or later-formed bodies that never melted [2]. However, thermal modelling of planetesimals [3] and paleomagnetic studies of CV carbonaceous chondrites [4] suggest that partially differentiated asteroids, with melted interiors overlain by relic, chondritic crusts, could also have formed in the early solar system. This would indicate that some chondrites and achondrites could originate from a common parent body.

**Rosetta at Asteroid Lutetia:** Asteroid 21 Lutetia was selected as a flyby target for the Rosetta spacecraft because of its large size (allowing a precise measurement of its mass) and its puzzling composition [5]. With a mean diameter of ~100 km [6], it is the first asteroid visited by a spacecraft that is unambiguously in the size regime capable of large-scale melting. The July 2010 Rosetta flyby therefore also provided an unprecedented opportunity to study planetesimal thermal evolution and differentiation.

**Surface of Lutetia:** Lutetia's surface composition is now constrained by a diversity of observations. Visible-near-infrared reflectance spectra from groundbased and Rosetta VIRTIS observations are flat and nearly featureless [5, 7, 8], compatible with some carbonaceous chondrites [4, 9] and enstatite chondrites [10] but distinct from all other meteorite groups. Lutetia's polarization properties are similar to that of CV and CO chondrites and different from other meteorite groups [9]. Lutetia's visible geometric albedo measured by the Rosetta OSIRIS camera [11] is similar to enstatite chondrites [10] and CO, CK, and possibly CV carbonaceous chondrites [12]. The Spitzer Space Telescope far-infrared emissivity spectrum of Lutetia resembles that of CO and CV carbonaceous chondrites [5] and differs from that of enstatite and ordinary chondrites and stony achondrites. Finally, Lutetia's radar albedo of 0.19-0.24 [13, 14] implies regolith densities consistent with grain densities of a variety of carbonaceous (other than CM and CI), ordinary, and enstatite chondrites, as well as basaltic, primitive, and stony iron achondrites, and is inconsistent with that of iron meteorites [15]. Overall these constraints favor a surface like that of CV, CO, CK, CR, or CH carbonaceous chondrites, although an enstatite chondrite composition cannot be ruled out.

**Interior of Lutetia:** Rosetta has preliminarily determined that Lutetia has a bulk density of ~3200-3700 kg $m^{-3}$ [6, 16], among the highest known for any small body and within error of that of the differentiated asteroid 4 Vesta [17]. Lutetia's bulk density equals or exceeds that of all known chondrite and achondrite groups with the exception of iron and stony iron meteorites. A pure composition of either of the latter two metallic lithologies is not supported by the radar and visible-infrared spectral properties, respectively.

If Lutetia has macroporosity similar to that of most other asteroids in its size range (>5-10% and ranging up to 80%), then the implied bulk densities of its constituents materials would likely exceed that of all known stony meteorites. In fact, there is indirect evidence that Lutetia may have substantial macroporosity: the minimum diameters of hypervelocity impactors that would catastrophically shatter and destroy Lutetia are ~2-4 km and ~22 km, respectively (following [18]). Using scaling laws for hard rock [19], we estimate that the largest crater visible on Lutetia was formed by an impactor of diameter ~4-6 km. Therefore, Lutetia is likely thoroughly shattered, resembling other asteroids visited by spacecraft and that are inferred to have porosities of ~20-40% [14].

**Evidence for Sintering or Differentiation:** The surfaces of chondrite parent bodies are thought to have initially had porosities like that of aggregates of fine dust (~26-50% [1]). However, nearly all chondrites other than CI and most CM chondrites have lower porosities [15], consistent with sintering from thermal metamorphism to ≥~330˚C following accretion [1]. Therefore, Lutetia's high density is evidence that the asteroid was heated to at least these temperatures.

Differentiation into a layered structure with metallic core and silicate mantle could also have produced the high bulk density of Lutetia in two ways. Density measurements of achondrite and chondrite groups indicate that melting usually leads to a further reduction of porosity beyond that from sintering [15]. Furthermore, hypervelocity impacts would be expected to preferentially remove the less dense silicate exterior.

**Conclusions:** The high density of Lutetia provides evidence for the action of postulated planetary heat sources in the early solar system. If Lutetia even has modest macroporosity (>~1-14%, depending on the bulk density range discussed above), its density would be inconsistent with that of common chondrite groups and likely would indicate a metallic core. Lutetia's apparently chondritic surface would therefore imply that it is a partially differentiated asteroid.

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