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Lutetia's Surface as a Dust Laboratory

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Abstract

Here we present some initial estimates of Lutetia's electrostatic charging environment given its dusty debris layer: solar wind parameters, photoelectron sheath parameters, and global surface potential and electric field.

1. Introduction

Asteroid 21 Lutetia was selected as a flyby target for the Rosetta spacecraft because of its large size and its puzzling composition [2]. At dimensions of $\sim$126$\times$ $\sim$103$\times$ $\sim$95 km, it is the largest asteroid visited by a spacecraft. Pre-encounter Lutetia data that presented particular polarimetric properties characterized by large inversion angles and a narrow 10 micron emission feature [1], indicated that Lutetia's surface should be covered by fine regolith with a grain size $\leq$50 microns [7] or $\leq$20 microns [4]. The team of the Rosetta-OSIRIS camera during its encounter with the asteroid July 10, 2010, gave further estimates of Lutetia's regolith layer by examining the sharper edges of the impact craters in many of the images; in order to claim that the asteroid is covered by a 600 m deep blanket [9, 3].

These first estimates of Lutetia's regolith characteristics draw tantalizing comparisons with the Moon's dusty surface, where a collisionally-evolved regolith, which acquires a charge from solar radiation and solar wind, exhibits unusual electrostatic behavior including levitation and transport [6]. The most comprehensive studies of asteroid dust levitation, so far, were performed by [10] for asteroids, generally, and by [5, 8], for Eros, in particular.

What makes Lutetia an attractive dust laboratory, which is different from the previous Eros studies is that: 1) it was found to have a thick blanket of dust/debris, 2) it has a long 292-day season with a hemisphere in sunlight, so that photoemission processes will be acute, leading to the possiblility of dust levitation and supercharging, 3) it is large and massive, which means that local gravity will have a competing effect with electrodynamic effects on the smaller dust particles, 4) it may have a metallic core with remnant magnetism such as that expected from an internal core dynamo [14].

Some useful parameters about Lutetia's electrostatic environment are Lutetia's (global) surface potential Φ_s and charge potentials of dust particles. The first is plotted as a function of solar elevation angle (degrees) in Fig. 1, with a maximum at 4.135 V at local noon. Thus the surface potential Φ_s is positive over the sunlit hemisphere. In the photoelectron sheath above this surface, the solar wind will not short-circuit the electric field anywhere. On the dark hemisphere, the potential may reach strongly negative values of order -1000 V [12], where the significant Debye length is $\lambda_{\rm sw}$. Because both $\lambda_{\rm sw}$ and λ_{pe} have lengths significantly smaller than the asteroid, one does not need to be concerned with noncollective effects on either the sunlit or shadowed hemispheres.

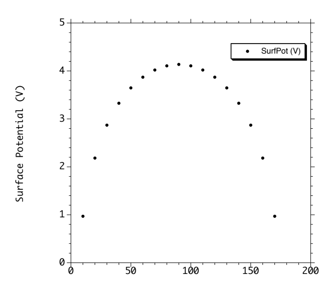

Figure 1: Lutetia's diurnal variation of the surface potential determined by the balance of photoemission from the surface and collection of solar wind electrons.

The following table gives initial plasma parameters for Lutetia's charging environment, then it gives estimates: photoelectron sheath parameters, surface charge density, electric field.

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Table 1: Lutetia Surface Charging Parameters

Solar wind[a]	
plasma density (cm^{-3}) $n_{\rm sw}$	0.844
electron temperature (K) T_e	8.288x10^4
ion temperature (K) T_i	5.525x10^4
Debye length (m) $\lambda_{\rm sw}$	22.0
Photoelectron sheath	
current[b] (electrons-cm^{-2}-s^{-1}) $I_{\rm ph0}$	4.722x10^8
average temperature[c] (eV) $k_B T_{\rm pe}$	2.2
electron density at local noon[d] (electrons-cm^{-3}) $n_{pe,0}$	10.731
Debye length[e] (m) $\lambda_{\rm pe}$	3.4
Surface charge density[f] (electrons-cm^{-2}) σ	3.6 x 10^3
Electric field over sunlit surface (V-m^{-1}) E	3.5 [g]

[a] from Eqns. 15,16 of [12], at Lutetia's distance

[b] $I_{\rm ph0}$ from [15] at Lutetia's distance

[c] Discussion of Maxwellian validity in [5], velocity from $\sqrt{\frac{2k_BT}{m_e}}$

[d] $n_{\rm pe,0} = \frac{2I_{\rm ph0}\sin(i_s)}{v_{\rm pe}}$ from [5]

[e] $\lambda_{pe} = \sqrt{k_B T_{pe}/4\pi n_{pe,0} q e^2}$ from [12, 5] at Lutetia's distance

[f] $\sigma = n_{\rm pe,0}\lambda_{pe}$

[g] $E = 2\sqrt{2}\Phi_s/\lambda_{pe}$ from [12, 11, 13]