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Submillimeter Spectroscopic Observations of Asteroid (21) Lutetia with MIRO Instrument on the ESA Rosetta Spacecraft

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The European Space Agency (ESA) Rosetta spacecraft flew by asteroid (21) Lutetia on July 10, 2010. The spacecraft carried a millimeter/submillimeter instrument named MIRO. MIRO made continuum measurements which are presented in a companion paper by Gulkis et al. Here we present spectroscopic measurements made near 560 GHz (0.5 mm) to search for an exosphere of Lutetia. The MIRO instrument is sensitive to four volatile species – CO, CH_3OH, NH_3, and H_2O, – including three oxygen-related isotopologues, $H_2^{16}O$, $H_2^{17}O$, and $H_2^{18}O$. While over 1000 spectra were taken throughout the encounter, only seven spectra near the closest approach can be expected to contain the targeted lines. This is because the large flyby speed and consequently large Doppler Effect shifts the lines out of MIRO's bandpass during most of the approach and departure. The seven spectra are used to estimate the upper limit of the column density of the four volatile species and their corresponding outgassing rates from Lutetia's nucleus. In order to increase the signal to noise ratio, the spectra are first individually Doppler-shift corrected, then averaged, and finally smoothed for Doppler shift broadening during the spectrum integration time of 5 seconds. The resulting spectrum did not exhibit a signal in either absorption or emission. Therefore, the standard deviation of the resulting smoothed spectrum is used to estimate the upper limit of the optical depth, which is related to the column density and the outgassing rate. The calculated upper limits are model dependent, requiring assumptions on the excitation temperature of molecules, their velocities, and their spatial distribution. If sublimation of ices is the gas-generating process, and gases are emitted in a spherically-symmetric shell with velocity 0.25 km/sec and an excitation temperature of 180 K, we estimate upper limits for the outgassing rates of H_2O, CO, CH_3OH, and NH_3 to be $\sim10^{23}$, $\sim10^{26}$, $\sim10^{24}$, and $\sim10^{23}$ molecules per second, respectively. If sputtering-based outgassing is the dominant gas production process, the molecules would be expected to have much higher excitation temperatures, perhaps 1000 K, making them easier to detect. In that case, the upper limits for each species are an order of magnitude smaller.