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LUNAR HORIZON GLOW AND THE CLEMENTINE MISSION

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Introduction. The Clementine spacecraft is to be launched into Earth orbit in late January for subsequent insertion into lunar orbit in late February, 1994 [1]. There, its primary mission is to produce--over a period of about two months--a new photographic map of the entire surface of the Moon; this will be done, in a variety of wavelengths and spatial resolutions, in a manner greatly superior to that previously accomplished for the whole Moon. It will then go on to fly by, and photograph, the asteroid Geographos. A secondary goal that has been accepted for this mission is to take a series of photographs designed to capture images of, and determine the brightness and extent of, the Lunar Horizon Glow (LHG). One form of LHG is caused by the solar stimulation of emission from Na and K atoms in the lunar exosphere [2]. The scale height of this exosphere is of the order of 100 km. There are also brighter LHG components, with much smaller scale heights, that appear to be caused by sunlight scattered off of an exospheric lunar dust cloud [3,4,5].

Background. The Surveyor V, VI, and VII spacecraft, that were landed on the Moon before the manned missions began, photographed a narrow band of light that glowed along the lunar horizon, and that lasted up to 2 hours after local sunset [3]. The brightness of this LHG ranged up to about $10^{-6}B_o$, where B_o is the mean brightness of the Sun (For comparison, $10^{-6}B_o$ is also about the mean brightness of the full Moon). The source of this LHG was deduced [e.g. 4] to be sunlight scattered by a lunar exospheric cloud of dust with a scale height of 10 to 20 cm. It was further deduced that meteoroid impact ejection of lunar soil grains could not account for the very high spatial density of the exospheric dust cloud that was inferred from the LHG observations; therefore electrostatic ejection of lunar grains from an electrically charged lunar surface was postulated to give rise to this dust cloud [4].

During the Apollo 17 mission, in Dec., 1972, the Lunar Ejecta and Meteorites (LEAM) experiment was placed on the Moon [5]. Over the next 22 months after activation, a remarkable phenomenon was observed: a very pronounced increase in the dust grain impact rate occurred around the sunrise and sunset terminator crossings. This could not be understood as due to impacts by interplanetary meteoroids. Nor was it due to sunrise/sunset thermal noise; the impact rate started increasing as early as 150 hours before sunrise while the Sun was over 70 degrees below the horizon. Berg and co-authors [5] could find no other explanation for these data than that lunar dust grains were being electrostatically transported over the lunar surface; and further that this transport was somehow connected with terminator crossings.

Also, after return from the lunar surface but while still in orbit around the Moon, the three Apollo 17 astronauts sketched various dim light features that they observed when the Sun was occulted from the spacecraft by the Moon. One of the features that they sketched was a glow above the lunar horizon that may have extended as much as 80 degrees along the horizon. This "new" LHG was quite dim and was not recorded with any of the hand-held photography. This glow was later analyzed by Zook and McCoy [6] and found to correspond to a brightness of about $2*10^{-12}B_o$, and to be due, most probably, to an exospheric dust cloud with a scale height of about 10 km (plus-or-minus a factor of 2). Similarly to the previous authors, they also estimated that the dust cloud arises from electrostatic ejection of grains from the lunar surface--as meteoroid impact ejection of lunar soil was deemed an insufficient source.

In short, three lines of evidence indicate the existence of a surprisingly high spatial density of dust grains above the lunar surface. Estimates of the LHG brightness derived from astronaut sketches are quite uncertain in accuracy, however, and new quantitative data for the high altitude dust are greatly needed.

Capability of the Clementine cameras to sense LHG. The CCD cameras on the Clementine spacecraft are primarily designed to photograph the sunlit lunar surface. Because the Moon is quite bright, long exposures were not necessary; nor was it necessary to actively cool the CCD's. For these, and other, reasons, the longest exposure that can be made with either the f/1.96 UV/Vis camera or the f/1.25 star-tracker camera is 0.77 seconds. Because the backplanes to which the CCD's are thermally coupled are not actively cooled, the CCD temperatures are expected to float between about -20 ^oC and +10 ^oC; the corresponding number of electrons expected to be thermally excited to the conduction band per pixel is estimated to range between 1000 and 4000 electrons per 0.77 sec exposure [7]. Along with CCD "read noise", the poisson fluctuation in the number of thermal electrons also creates a background noise. The two sources of noise, coupled together, are expected to range between 50 and 100 electrons per pixel per 0.77 sec exposure. The camera designers, partly with this in mind, digitized the output of the cameras so that one digital unit corresponds to 150 electrons for the UV/Vis camera and to 75 electrons for the star-tracker camera.

Taking all camera characteristics into account, we would expect that a 0.77 sec exposure of a $2*10^{-12}B_o$ bright LHG would result in about 1300 electrons per pixel in either the UV/Vis (through the clear filter) or the star-tracker camera, assuming a solar spectrum. This corresponds to about 8 digital units above background for the UV/Vis camera and about 17 digital units above background for the star-tracker camera. The above exposure duration for the UV/Vis camera through the 340 nm filter would only result in a signal of about 18 electrons; this signal level could not be seen against the noise background (and the same is true of the other narrow band filters). If, however, the LHG is caused by sunlight scattered by particles smaller than about 0.1 μm in radius, then the scattered sunlight will be strongly blue-weighted by the factor $(\lambda o/\lambda)^4$, where λo is the weighted wavelength for the dark-adapted eyes of the astronauts (approximately, λo=500 nm). For this case we could expect about 90 electrons through the UV/Vis 340 mm filter, and this might be detectable--especially if we have underestimated the LHG absolute brightness. Thus LHG should show up as a glow above the lunar horizon with both cameras. The 28deg*43deg field-of-view (fov) of the star-tracker camera will give a good panoramic view of the glow, while the UV/Vis camera (fov=4.2deg*5.6deg) will detail the vertical extent with a sensitivity of about 400 meters per pixel. The LIDAR camera (fov=0.3deg*0.4deg) may also be able to measure the LHG with about 10 times the spatial resolution of the UV/Vis camera. The Na and K LHG, with its much greater scale height, is expected to be significantly above the threshold for detection only in the star-tracker camera; thus, it too may be recorded.

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