Radiance sampling in synthetic lunar images

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1 Dansk Abstract

Ved planlæggning af billedoptagelser af Månens overflade fra en satellitt i kredsløb, skal man kende til de forventede lysforhold. Med kendskab til Måneoverfladens radians samt udformningen af kamera-udstyret kan dette beregnes.

Denne rapport udforsker den forventede monokromatiske radians som funktion af Månefase og Jordens albedo.

2 English Abstract

In planning imaging of the lunar surface from lunar orbit it is necessary to know the expected lighting conditions. The conditions to be expected are a function of the radiance of the lunar surface and the properties of the camera equipment.

This report explores the expected monochromatic radiance of the lunar surface as a function of position on the Moon, the viewing direction, the lunar phase and the terrestrial albedo.

3 Introduction

The lunar surface radiance is a function that depends on angle, position and epoch - that is, what the lunar phase is because the surface is illuminated by the Sun and also by the reflected sunshine from the Earth.

For use in planning lunar orbiter missions we can use the DMI synthetic lunar image model to produce insight into how radiance depends on the above factors.

The DMI synthetic lunar image model has previously been discussed in (Gleisner and Thejll, 2008; Thejll et al., 2014, 2015). The model produces synthetic images of the Moon, as seen from a chosen position, in terms of radiance but specifically for the angles determined by where the Sun is (i.e. the lunar phase) and where the observer is, as well as assumptions about the albedo of the Earth and choices about the type of theoretical BRDF (Bidirectional Reflectance Distribution Function) for the lunar and terrestrial surfaces.

A good standard reference for the concepts of the BRDF is (Hapke, 2012). Our synthetic lunar image model was inspired by (Jensen et al., 2001).

4 Method

Using the synthetic model, we generated images of the Moon for random dates inside a whole month (thus sampling lunar phase), as well as for a range of realistic terrestrial albedos, and at positions on the lunar surface that are randomly selected, thus sampling darker low-land (Mare) areas, as well as brighter high-land areas.

We have assumed that Earth scatters uniformly (i.e. a Lambertian reflectance function), has uniform albedo, and that the lunar albedo is determined from the Clementine (Hillier et al., 1999) monochromatic surface map, observed at 750nm, scaled in the mean to the mean of the Johnson V-filter (Wildey, 1977) photometric determination of lunar albedo. We do not take lunar altitude into account, thus all surfaces are horizontal. All rays are propagated as parallel rays.

We use the (Hapke, 1963) BRDF for the lunar surface, with parameter $g = 0.6$. g relates to the type of lunar surface under consideration, but is kept fixed here.

In principle, the Lunar Reconnaissance Orbiter albedo map of the Moon, which may contain colour-information could replace the Clementine map.

5 Results

Some 200,000+ samples of the surface radiance were generated, and are available as a digital file on Zenodo (Gleisner and Thejll, 2024). The columns of the *.rds*-type dataframe (generated in *R*, and readable by *python*) are shown in table 1, and a sample of 10 lines from the table is given here:

radiance	lonSEL	latSEL	Sunangle	Outangle	IllumFract	Albedo
2.647978e+01	-7.526625	6.1952686	1.16367078	0.000000000	0.6962	0.2441346
2.054777e-02	4.102366	3.3177564	2.86433792	0.006575787	0.0165	0.3180915
2.277393e+02	3.735726	-4.5396991	0.16795231	0.006728336	0.9916	0.3051012
2.826029e+02	3.062871	-4.0069513	0.05421677	0.006834510	0.9992	0.2840768
1.285558e-02	4.073373	0.7946485	1.79155350	0.006834562	0.3988	0.4394225
7.388551e-03	-5.077054	7.1625233	2.85555530	0.006856654	0.0201	0.1934836
1.088909e+02	5.919915	-2.4245887	0.74411923	0.006862414	0.8710	0.2141335
2.664801e+02	2.999870	-4.3381610	0.05942690	0.006890232	0.9990	0.2905535
3.031980e-02	3.617777	-3.2864215	2.85428739	0.006934198	0.0195	0.5030967
3.172411e-02	2.825143	-3.3587570	2.84042335	0.006934198	0.0195	0.5030967

In Figure 1 we plot various properties of the samples.

In the upper left panel we see a histogram of the many possible radiances of the bright side (BS) of the Moon - i.e. the brightly sunlit areas.

Upper right shows the same for the dark side (DS) that is only lit by Earthlight.

Middle left panel shows DS radiance as a function of terrestrial albedo - it depends very much on the terrestrial albedo, but considerable scatter is also seen due to the various viewing angles possible.

Right centre shows same for the BS, and here terrestrial albedo is not an important factor - the BS is simply so bright that the faint earthlight does not contribute much.

Lower left panel shows DS radiance against lunar illumination fraction - i.e. lunar phase. The DS is illuminated by Earth and Earth's phase is complementary to the Moon's, so at New Moon the Earth is almost Full and thus casts a lot of light onto the Moon and the effect is very clearly seen for the DS.

Finally, lower right panel shows the same but for the BS and here only a smaller dependence on lunar phase is seen - more pixels are seen under more overhead lighting conditions and due to the phase-dependence of the BRDF we see an effect.

Figure 2 show an atlas of the near-side lunar surface, for use in selecting dark and bright areas on the lunar surface. Figure 3 shows the far side which has fewer dark Mare.

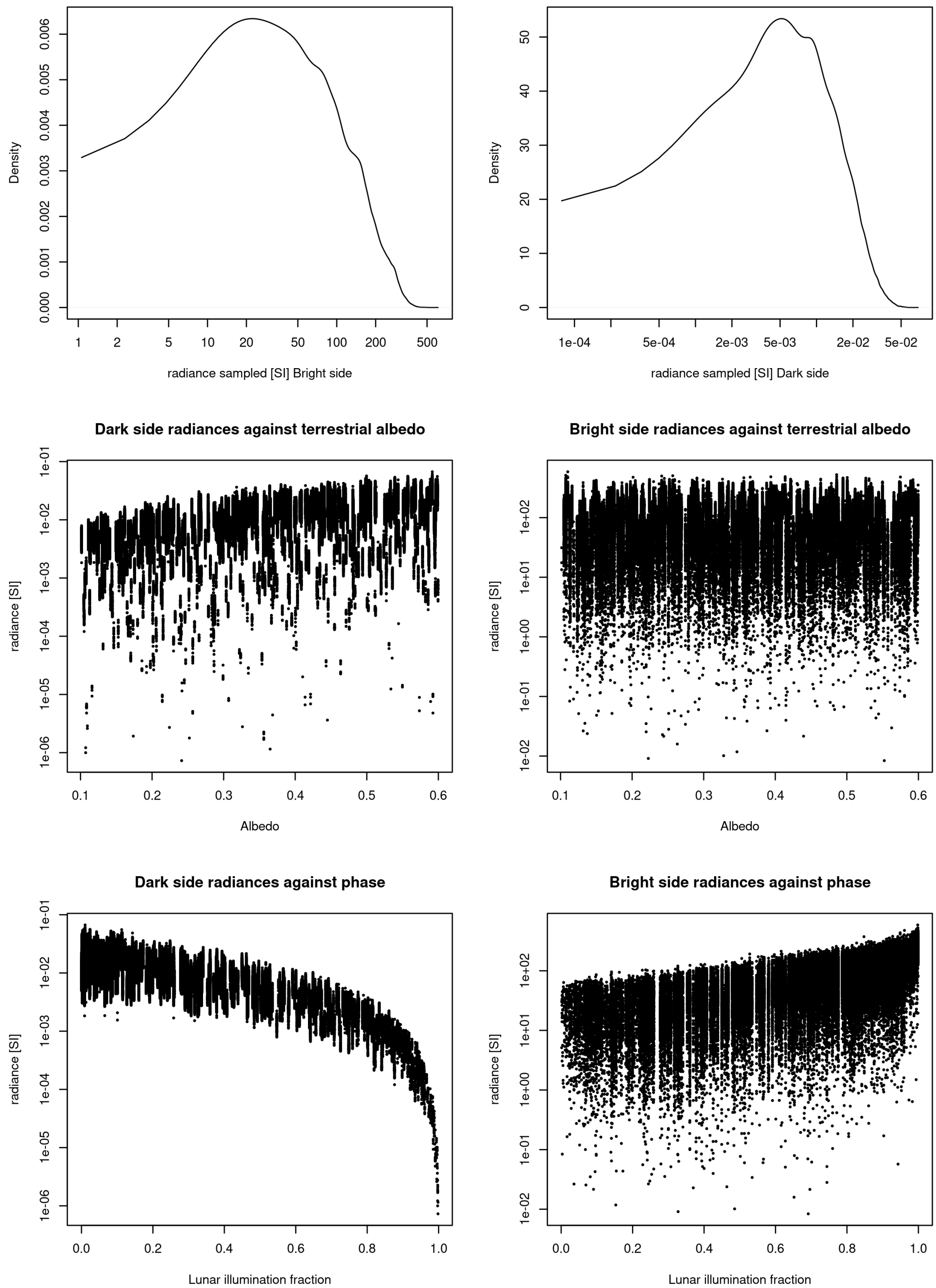

Figure 1: Various properties of the sampled synthetic lunar images.

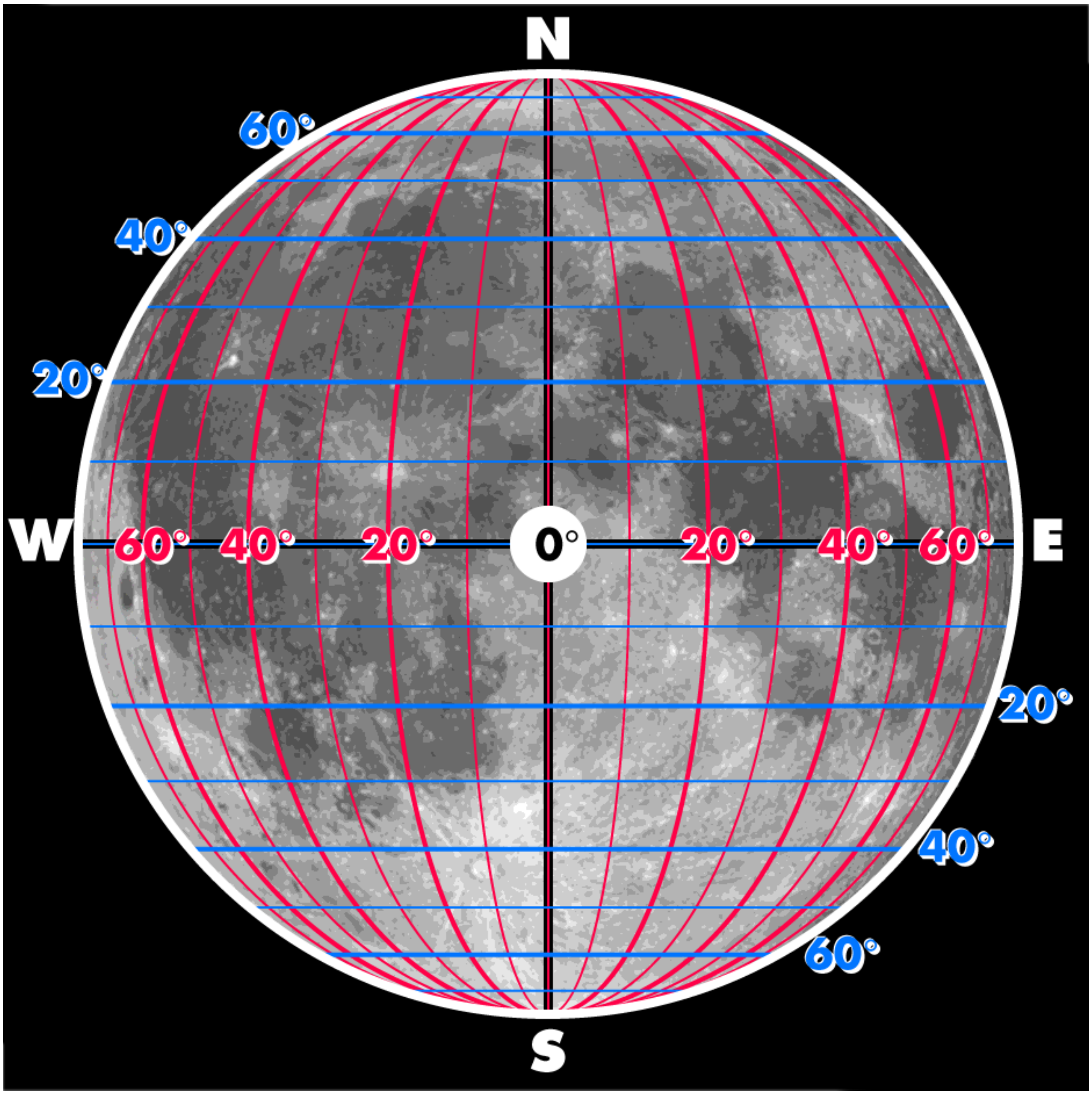

Figure 2: Lunar near-side atlas by John Reid at the English-language Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4116855

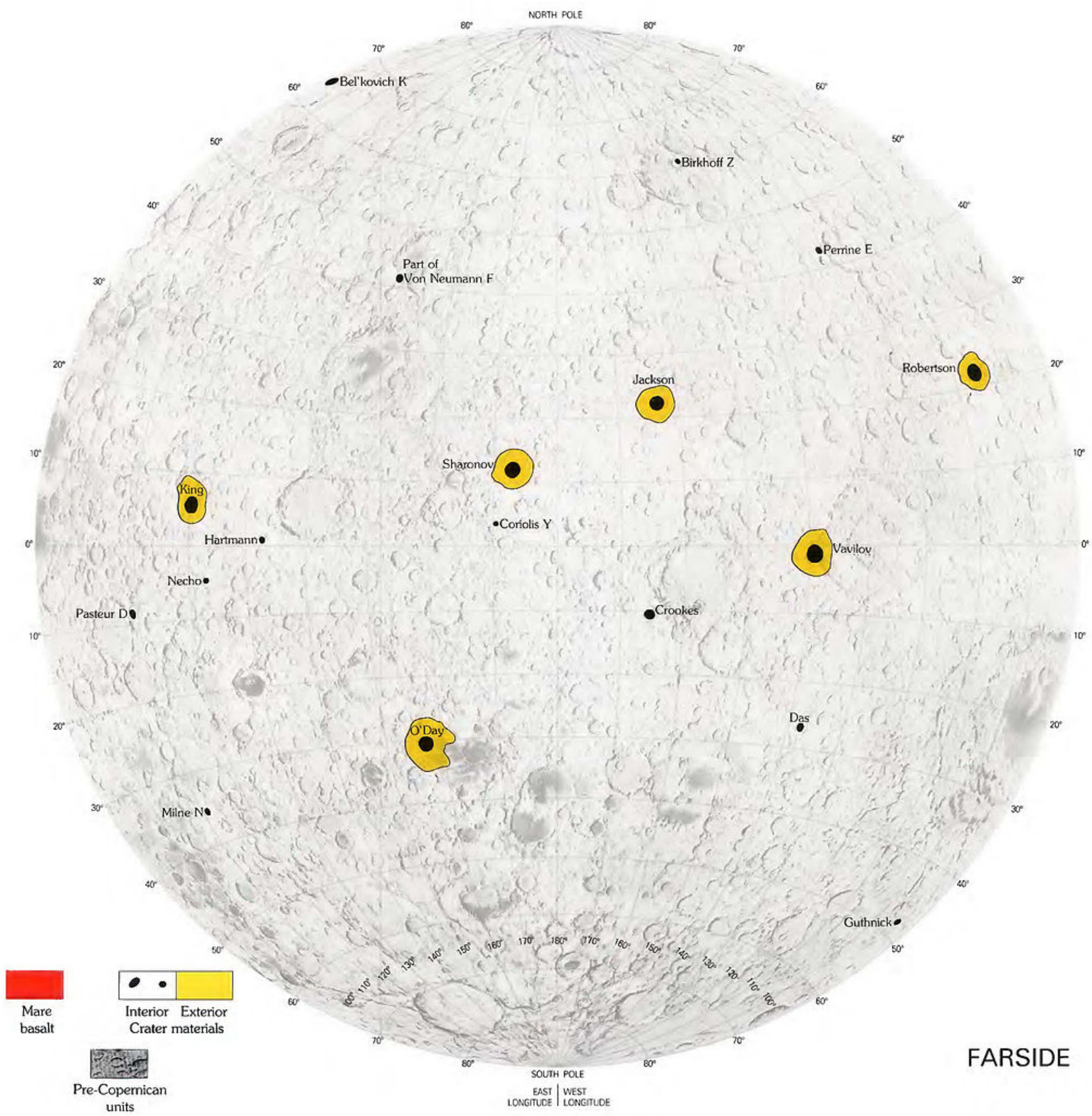

Figure 3: Lunar far side atlas by Donald Wilhelms (published in USGS Professional Paper) - The geologic history of the Moon by Wilhelms, Don E.; with sections by McCauley, John F.; Trask, Newell J. USGS Professional Paper: 1348 (1987).The original image is in the public domain because it is a work of the U.S. Government (USGS).Immediate source: plate 11B, Public Domain, https://commons.wikimedia.org/w/index.php?curid=38088994

variable name	Notes
radiance	The surface radiance in SI units ($W/m^2/sr$) for the particular pixel, with angles given by other columns in the same table line
lonSEL	selenographic longitude
latSEL	selenographic latitude
Sunangle	The angle between the surface normal and the direction to the Sun
Outangle	Angle between the surface normal and the direction to the observer
IllumFract	The illumination fraction of the Moon (0=New Moon, 1= Full Moon)
Albedo	The uniform single-scattering albedo assumed for the Earth.

Table 1: Variables samples from the synthetic lunar models.

6 Conclusion

The DMI synthetic lunar image model may be useful for determining lighting conditions when planning lunar imaging projects, such as new radiometric lunar orbiters.

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