The Optical Lunar Opposition Effect
An Invitation to Radio and Radar Studies

Talk to the Fifth International Congress of the European Radio Astronomy Club

Elmar Schmidt
SRH Univ. of Applied Sciences, Heidelberg

and

Yasmin A. Walter
ERAC, Mannheim
Let’s talk about the Moon!
And a little bit about its foremost illuminant source, the Sun.
Fortunately, the (extraterrestrial) solar constant varies by only
±0.08% (1.1 Wm⁻²)
with the sunspot cycle
What about the Radio Sun?

The view at 17 GHz (1.8 cm) is not so much different from VIS.

It is very variable, though.
If the Moon were a giant painted disk
then its projected area specific brightness (luminance) would be the same from any angle

much in the same way, that a sheet of paper or a projection screen shows us the same whiteness from any angle

If the Moon were a giant painted ball
then it can be shown by integrating Lambert‘s cosine law, that the Full Moon would be $\pi$ times brighter than the Half Moon

→ actually it is about a dozen times brighter
Gossen Mavospot 2 - Data from 2008 by Yasmin A. Walter

[Lunar luminance in cd/m²]

|Phase angle| in degrees

- Full Moon
- Half Moon

5th ERAC Congress 2009 – Schmidt&Walter – The Optical Lunar Opposition Effect
It is even a bit more complicated, because*

*Lunar Brightness Magnitude vs. Phase Angle (signed!)

*the waning Moon shows more of the dark maria
It’s not easy to tell the Full Moon’s brightness

- Published luminance data are varying between 2500 und 3700 cd/m² (factor 1.5)
- Illuminance data are even varying more between 0.15 und 0.27 lx (factor 1.8)
  in „grey“ literature even more so: 0.1 … 3 lx

As we have seen, this span of brightnesses is not artificial, because it represents measured data which have been corrected for atmospheric transmission.
Influences on

the Full Moon’s luminance

(1) Solar distance via the sun’s illuminance ± 3.3%
(2) Lunar opposition effect in albedo (reflectivity) +30% !
   *is independent from the Moon’s distance to Earth!*

and additionally on

the Earth’s illuminance from the Full Moon

(3) Lunar elliptical orbit -11% // +16%

→ *Total brightness variation* -14% // +56%  *factor 1.8 !!!*
Opposition Surge:

near the Full Moon

its luminance almost
doubles(!), although
the illuminated area
increases by less
than 5%
Near the Full Moon the lunar optical albedo (reflectivity) increases from 10.5% to 13.5%.

Data from ROLO (RObotic Lunar Observatory), Flagstaff, Arizona
The Lunar Opposition Surge at close-up
The opposition effect is for Earthlings too

Photos by Eva Seidenfaden, Trier
http://www.paraselene.de
Now, what is the opposition effect?

Most of it is shadow-hiding on granular or rough surfaces at bidirectionally near-normal incidence.

It can be enhanced by retroreflection (coherent backscattering), e.g. from glassy spherules in the lunar regolith soil.
Five LRRRs (corner cube reflectors) on the Moon need powerful lasers like in LIDAR to be noticeable; the Moon lacks open bodies of water or ice and has not been positively glinting sunlight.
Actually ...

I am in this business because of an early interest in the photometry of lunar eclipses,

and it has been a long way from rough visual estimates …

... to precision photometry

Nina Hernitschek with photometer

photographed with 20 inch Cassegrain telescope

Lunar Eclipse, March 4th, 2007, 2 a.m.

www.techfreaq.de

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Of course

• the remaining light in the Earth’s shadow contains information on aerosol in the high atmosphere

• **there can’t be a Full Moon of zero phase angle from Earth, because it is eclipsed starting at**

  \[ \varphi = 1.45^\circ \]
However …

… the lunar opposition surge is stronger than even a 42% penumbral eclipse, giving us the **Fullest Moon possible**
Let’s go to Hawaii…

… to an altitude of 3400 m
... and do the Total Lunar Eclipse on August 27th/28th, 2007
The linearly scaled light curve
(thus details in the minimum are suppressed)
This has been the *optical* lunar opposition effect, so what about *radio waves*?

**Questions and challenges:**

- Can solar radio waves be detected after reflection by the moon?
  
  *I guess so, as it is used to monitor the sun at night*

- Has anyone determined the phase angle function?

- Is there an opposition surge at radio wavelengths?
  
  *Probably not, because of the penetration depth*

- Are there lunar radio eclipses?
  
  *They should be happening, and worth a look*
At some radio wavelengths, the solar corona strongly emits. This will change the corresponding incidence angles and flatten lunar radio eclipses.
Here is the related active Ham Radio project „Moon Bounce“

On July 17, 1960, Eimac (San Carlos) radio station (W6AY) made the first-ever amateur two-way 'moon-bounce' contact with the Rhododendron Swamp Radio Club (W1BU) in Massachusetts.
Raw data Delay Doppler RADAR lobe (with diffraction rings) from the 300 m Radio Telescope in Arecibo, Puerto Rico on the lunar crater Aristarchus, as seen by the NRAO 100 m dish in Green Bank, W.Va.

Is this monostatic or bistatic RADAR?

In any case, I guess, not quite an amateur project

so I close in saying:

Thank you for the kind attention!