

INCOMPATIBLE SOLAR ALTITUDE ANGLE DURING THE APOLLO 11 EVA FROM ECLIPTIC CALCULATIONS.

ALEXIS ZAGANIDIS

ABSTRACT. From ecliptic calculations, we found a solar altitude angle of 07.75° (not more than 09.75° with respect to the ground of the Tranquility base) instead of a minimal solar altitude angle of 19.00° at the official lunar landing site (Tranquility base) during the Apollo 11 EVA (extravehicular activity). Since the rotation speed of the moon is particularly slow, during the period were both astronauts were outside the lunar module of the Apollo 11 mission, the solar angle variation in the lunar sky was only 0.888° .

The official ending time of the Apollo 11 EVA (extravehicular activity) was $t_{A11} = 1969 - 07 - 21 \ 05 : 11 : 00 \ UTC$. We have chosen that precise time for all the ecliptic coordinates involved in the present article since the sun was rising at that time and at the Apollo 11 lunar landing site (Tranquility base). Both astronauts of the Apollo 11 mission were outside the lunar module during 1.62 consecutive hours at the lunar landing site. Since the rotation speed of the moon is particularly slow, during the period were both astronauts were outside the lunar module of the Apollo 11 mission, the solar angle variation in the lunar sky was only 0.888° .

The ecliptic coordinates ($J2000.0$) of the moon at t_{A11} is (Stellarium 0.18.0):

$$(1) \quad (l, b) = (193^\circ 07', -01^\circ 37')$$

The Cartesian unit vector of the moon position at t_{A11} is:

$$(2) \quad e_r = (Cos(b) Cos(l), Cos(b) Sin(l), Sin(b))$$

$$(3) \quad = (-0.973522, -0.226844, -0.0282124)$$

The ecliptic coordinates ($J2000.0$) of the lunar north pole at t_{A11} is the following, with the approximation of a major standstill (29th March 1969) and with an opposite tilt of the moon's orbital plane of 5.145° :

$$(4) \quad (l, b) = (-90^\circ 00', 90^\circ 00' - 05.145^\circ)$$

The Cartesian unit vector of the lunar rotation axis at t_{A11} is the following, with the approximation of a major standstill (29th March 1969):

$$(5) \quad e_\theta = (Cos(b) Cos(l), Cos(b) Sin(l), Sin(b))$$

$$(6) \quad = (0.00, -0.0896766, 0.995971)$$

The ecliptic coordinates ($J2000.0$) of the lunar north pole at t_{A11} is the following, with the major standstill (29th March 1969) with an opposite tilt of the moon's

orbital plane of 5.145° and with the constraint $e_r \cdot e_\theta = 0$ is:

$$(7) \quad (l, b) = (-95^\circ 00', 90^\circ 00' - 05.145^\circ)$$

The Cartesian unit vector of the lunar rotation axis at t_{A11} is the following, with the major standstill (29th March 1969) and the constraint $e_r \cdot e_\theta = 0$:

$$(8) \quad e_\theta = (Cos(b) Cos(l), Cos(b) Sin(l), Sin(b))$$

$$(9) \quad = (-0.00781583, -0.0893353, 0.995971)$$

The Cartesian unit vector e_ϕ at t_{A11} is:

$$(10) \quad e_\phi = e_r \times e_\theta = (-0.228451, 0.96982, 0.0851969)$$

The ecliptic coordinates ($J2000.0$) of the sun at t_{A11} is (Stellarium 0.18.0):

$$(11) \quad (l, b) = (118^\circ 41' 30'', 00^\circ)$$

The Cartesian unit vector of the sun position at t_{A11} is :

$$(12) \quad e_{sun} = (Cos(b) Cos(l), Cos(b) Sin(l), Cos(l))$$

$$(13) \quad = (-0.480096, 0.877216, 0.00)$$

The lunar selenographic coordinates at the Apollo 11 lunar landing site (Tranquility base) is:

$$(14) \quad (\lambda_{A11}^{moon}, \beta_{A11}^{moon}) = (23^\circ 26', 00^\circ 41')$$

The Cartesian unit vector in the referential (e_r, e_θ, e_ϕ) pointing perpendicularly downward to the lunar surface of the the Apollo 11 lunar landing site (Tranquility base) is:

$$(15)$$

$$e_{A11}^{moon} = (Cos(-\beta_{A11}^{moon}) Cos(-\lambda_{A11}^{moon}), Sin(-\beta_{A11}^{moon}), Cos(-\beta_{A11}^{moon}) Sin(-\lambda_{A11}^{moon}))$$

$$(16)$$

$$= (0.917458, -0.0119261, -0.397653)$$

Remarks: the unit vector e_θ is upward and play the role of e'_z , the unit vector e_r is forward and play the role of e'_x , and the unit vector $-e_\phi$ is leftward and play the role of e'_y .

The Cartesian unit vector pointing perpendicularly downward to the lunar surface at the Apollo 11 lunar landing site (Tranquility base) is the following, at the time t_{A11} :

$$(17) \quad e_{A11} = e_{A11,1}^{moon} e_r + e_{A11,2}^{moon} e_\theta + e_{A11,3}^{moon} e_\phi$$

$$(18) \quad = (-0.802229, -0.592707, -0.0716407)$$

The angle between the Cartesian unit vector pointing perpendicularly downward

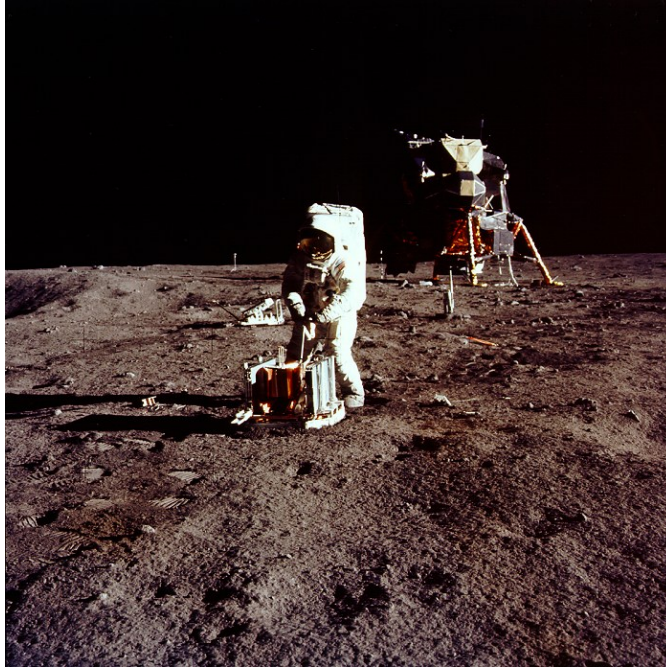


Figure 01 -

to the lunar surface of the the Apollo 11 lunar landing site (Tranquility base) and between the unit vector pointing toward the sun position is the following, at the time t_{A11} :

$$(19) \quad \theta_Z = \text{ArcSin} (||e_{sun} \times e_{A11}||) = 97.75^\circ$$

The solar altitude angle is the following, at the Apollo 11 lunar landing site (Tranquility base) and at the time t_{A11} :

$$(20) \quad \alpha_Z = 90 - \text{ArcSin} (||e_{sun} \times e_{A11}||)$$

$$(21) \quad = 07.75^\circ$$

$$(22) \quad \text{Cot}(\alpha_Z) = 7.35$$

On the following NASA archive picture of the Apollo 11 mission, we can measure relatively precisely the cotangent of the solar altitude angle at the Apollo 11 lunar landing site (Tranquility base) and at the time t_{A11} :

$$(23) \quad \text{Cot}(\alpha_Z^{max}) = \text{Cot}(\alpha_Z + 2^\circ) = 5.82$$

$$(24) \quad \alpha_Z^{max} = \alpha_Z + 2^\circ = 09.75^\circ$$

$$(25) \quad \text{Cot}(\alpha_Z^{NASA-Fig-01}) \cong 8.5/2.5 = 3.4$$

$$(26) \quad \alpha_Z^{NASA-Fig-01} \cong \text{ArcCot}(8.5/2.5) = \text{ArcCot}(3.4) \cong 16.4^\circ$$

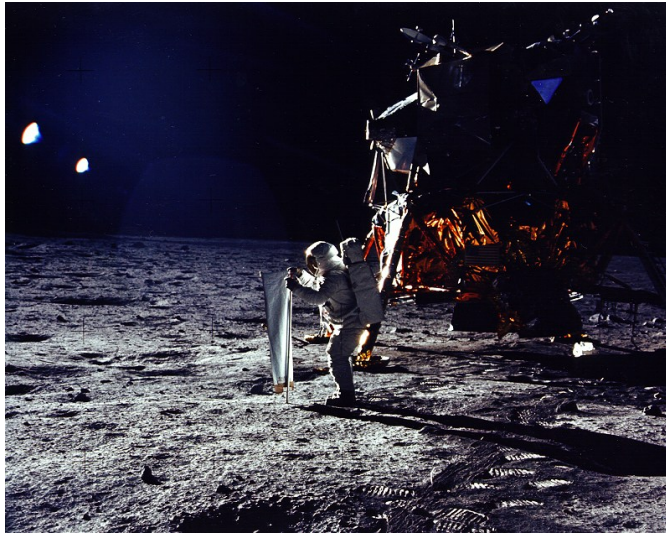


Figure 02 -



Figure 03 -

$$(27) \quad \text{Cot} \left(\alpha_Z^{NASA-Fig-02} \right) \cong 15.0/5.3 = 2.8$$

$$(28) \quad \alpha_Z^{NASA-Fig-02} \cong \text{ArcCot} (15.0/5.3) = \text{ArcCot} (2.84) \cong 19.4^\circ$$

$$(29) \quad \text{Cot} \left(\alpha_Z^{NASA-Fig-03} \right) \cong 7.75/2.8 = 2.7$$

$$(30) \quad \alpha_Z^{NASA-Fig-03} \cong \text{ArcCot} (7.75/2.8) = \text{ArcCot} (2.77) \cong 19.8^\circ$$

$$(31) \quad \text{Cot} \left(\alpha_Z^{NASA-Fig-04} \right) \cong 2.72$$

$$(32) \quad \alpha_Z^{NASA-Fig-04} \cong \text{ArcCot} (2.72) \cong 20.2^\circ$$

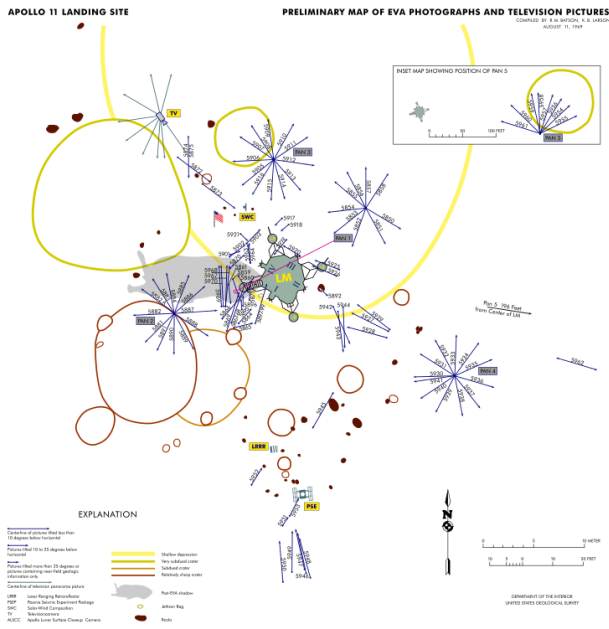


Figure 04 -

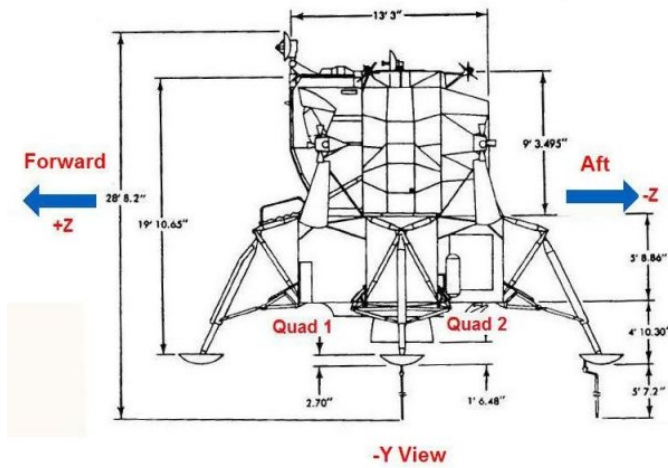


Figure 04 -

Remarks: α_Z^{max} is the solar altitude angle with respect to ground with a maximal slope of 2° .

The single consecutive period is the following, when both astronauts of the Apollo 11 missions are outside the lunar module at the lunar landing site (Tranquility base):

$$(33) \quad \Delta_T = 111 + 39/60 - 109 - 42/60 - 20/60 = 1.62 \text{ hr}$$

The solar angle variation in the lunar sky is the following, when both astronauts of the Apollo 11 missions are outside the lunar module at the lunar landing site (Tranquility base):

$$(34) \quad \Delta_{sun} = \Delta_T / T_{moon}^{sidereal} \times 360^\circ = 1.61667 / 27.322 / 24 \times 360 = 0.888^\circ$$

The official ending time of the Apollo 11 EVA is:

$$(35) \quad t_{A11} = 1969 - 07 - 16 \ 13 : 32 : 00 \text{ UTC} + 111 \text{ hr} + 39 \text{ min}$$

$$(36) \quad = 1969 - 07 - 21 \ 05 : 11 : 00 \text{ UTC}$$

The official starting time of the Apollo 11 EVA is:

$$(37) \quad t_{A11} = 1969 - 07 - 16 \ 13 : 32 : 00 \text{ UTC} + 109 \text{ hr} + 42 \text{ min}$$

$$(38) \quad = 1969 - 07 - 21 \ 03 : 14 : 00 \text{ UTC}$$

In conclusion, the Apollo 11 cheaters have probably been reckless about the exact position of the sun in the lunar sky at the lunar landing site (Tranquility base) during the Apollo 11 EVA. Indeed, that precision for the sun position would be much less meaningful on Earth with a usual ground much less flat and a sun rotating much faster in the Earth sky.

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