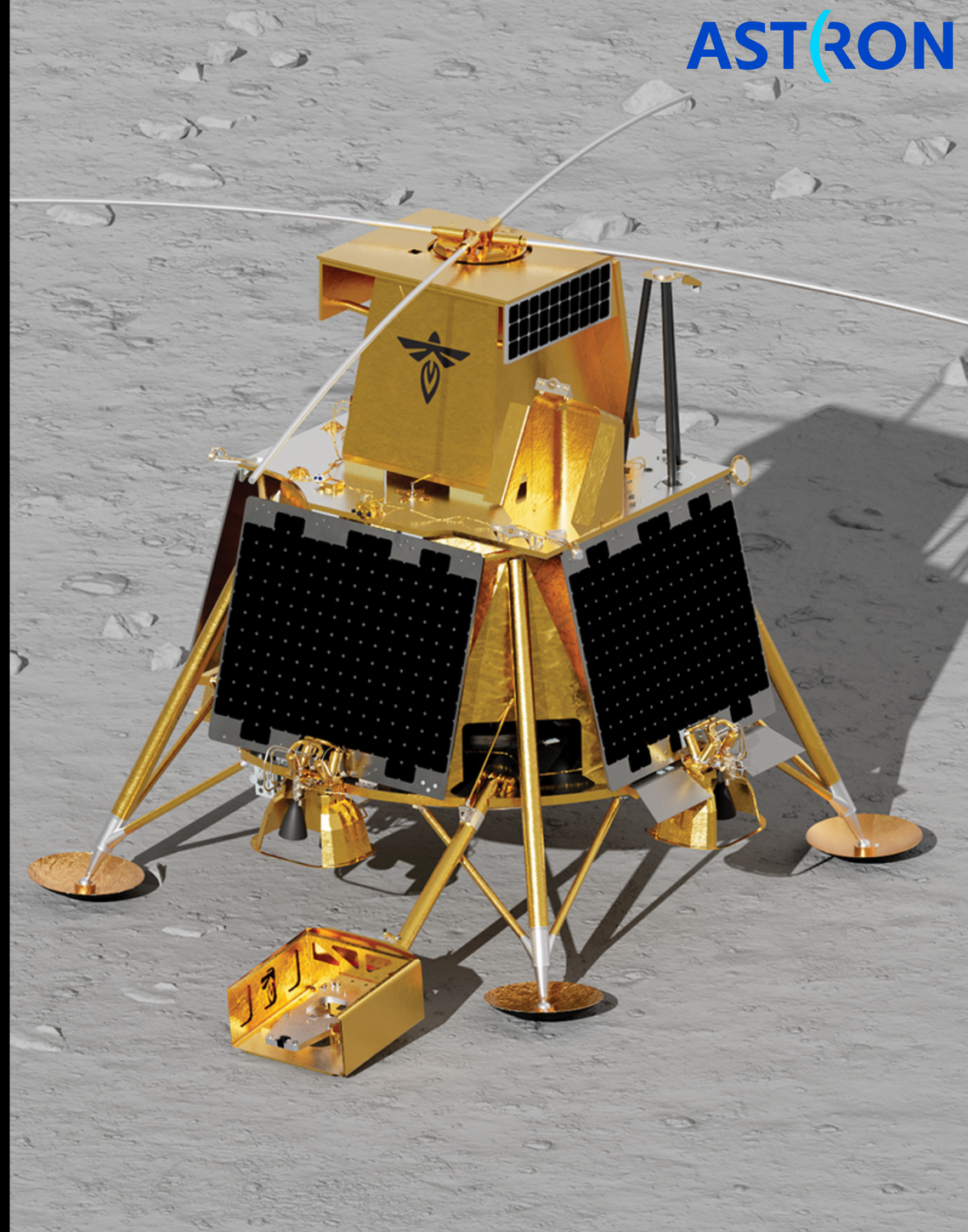
Stormchaser;
PI: Vedantham

Regolith-Related Calibration Challenges for LuSEE-Night

Cristina-Maria Cordun

Collaborators: Harish Vedantham and the LuSEE collaboration

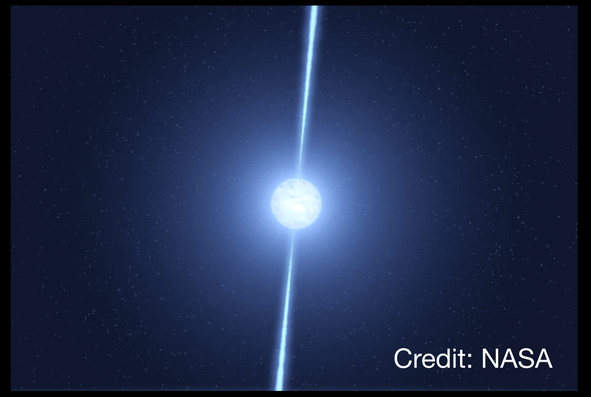


Very low frequency science

< 30 MHz

- Spectral turnover for galaxies
- Pulsars turnover

Credit: R. Timmerman



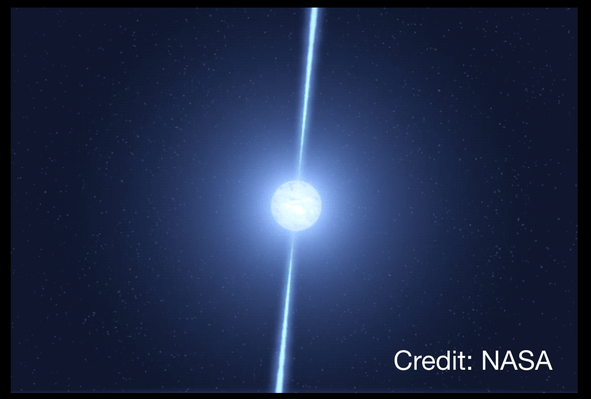
Credit: NASA

Very low frequency science

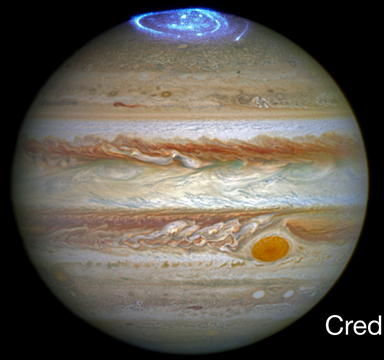
< 30 MHz

- Spectral turnover for galaxies
- Pulsars turnover
- Coherent emission from Jupiter, Saturn, Uranus, Neptune
- Coherent radio from exoplanets

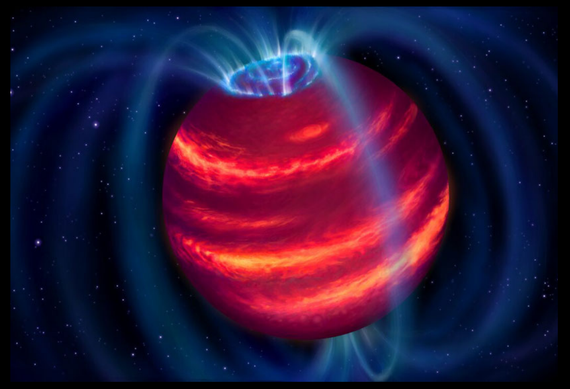
Credit: R. Timmerman



Credit: NASA



Credit: Wiki



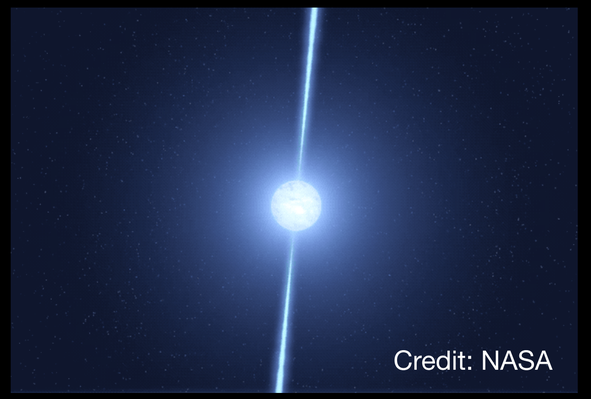
Credit: D. Futselaar

Very low frequency science

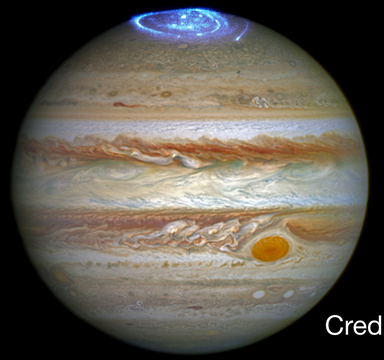
< 30 MHz

- Spectral turnover for galaxies
- Pulsars turnover
- Coherent emission from Jupiter, Saturn, Uranus, Neptune
- Coherent radio from exoplanets
- Epoch of Reionization

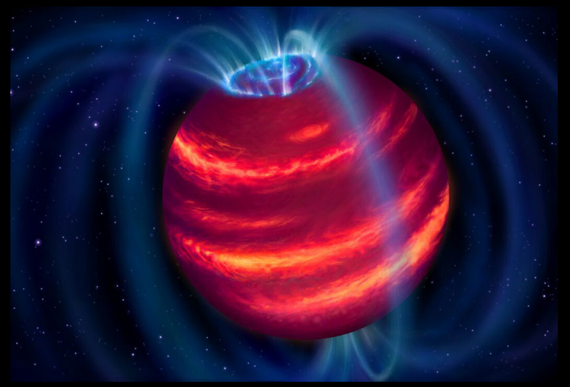
Credit: R. Timmerman



Credit: NASA

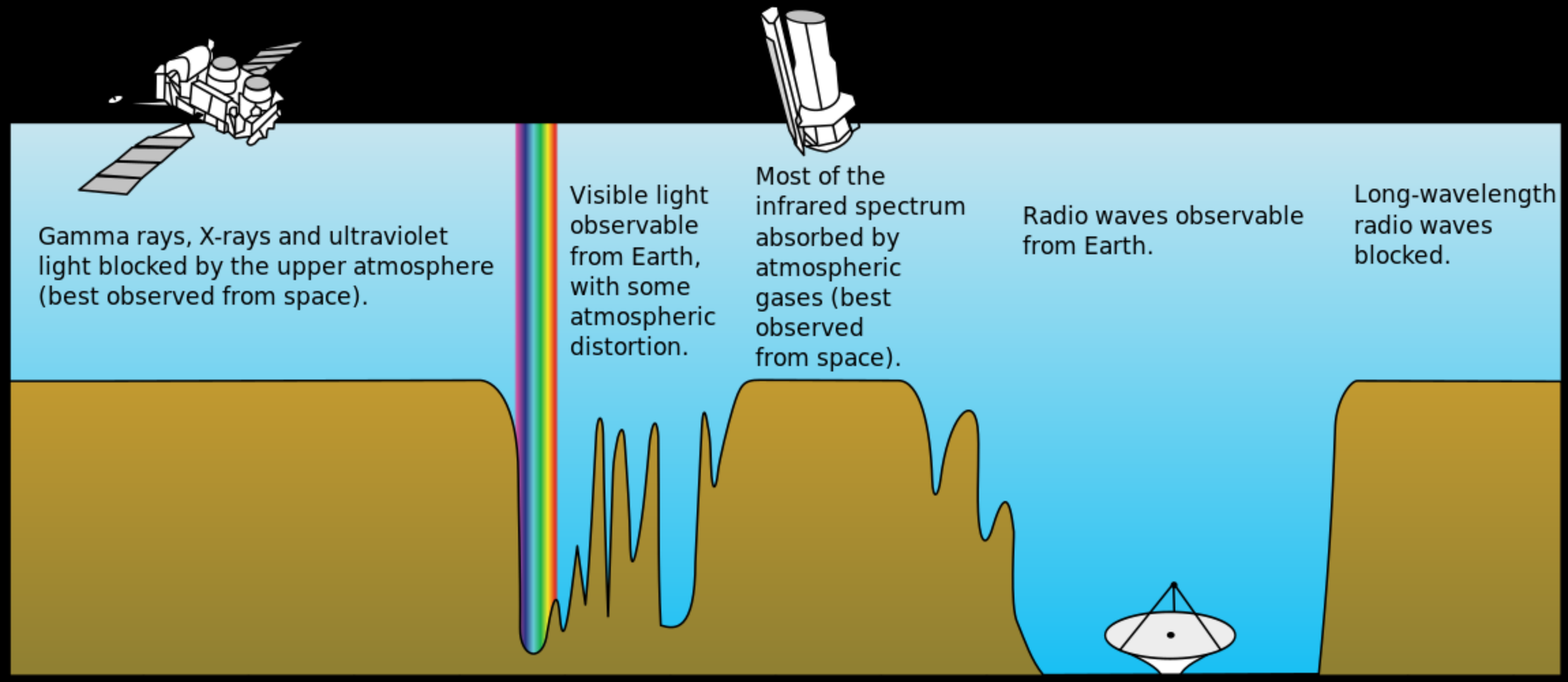


Credit: Wiki

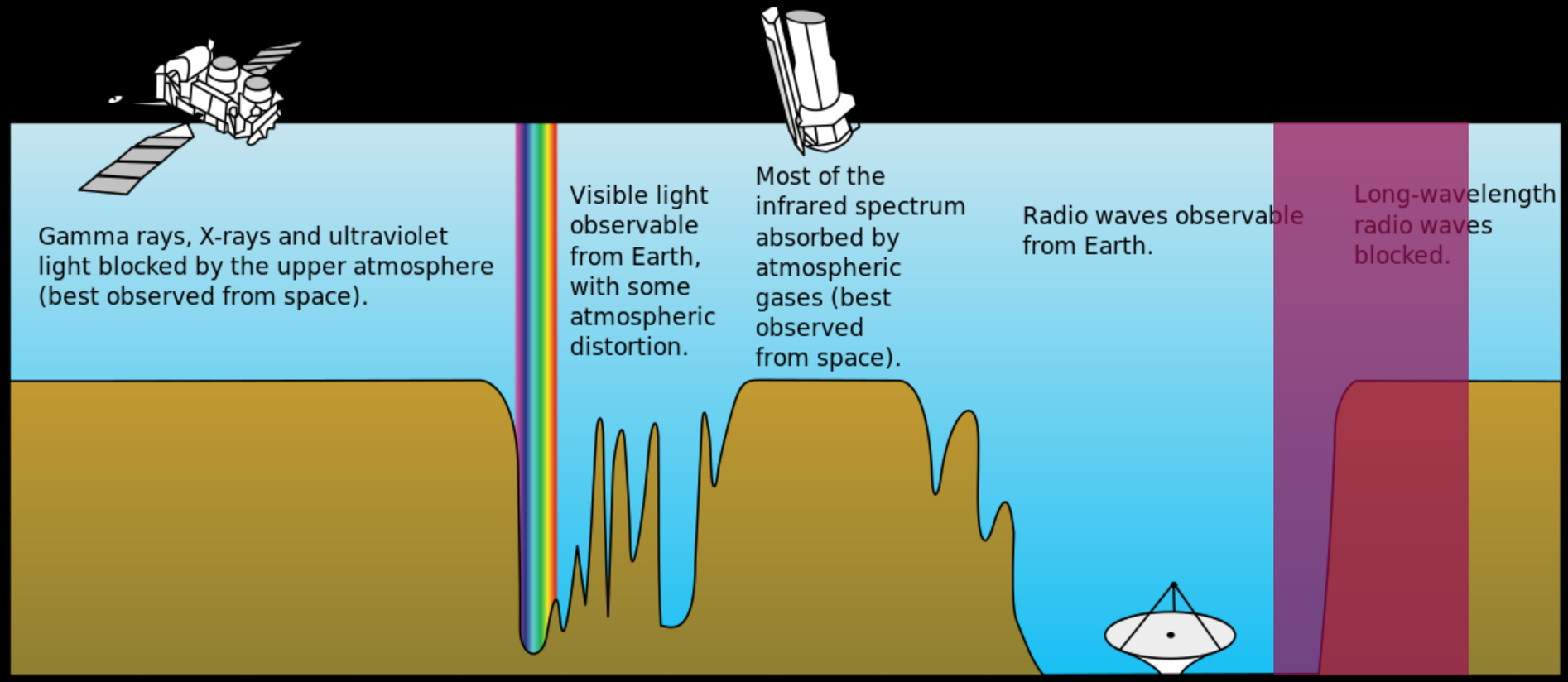


Credit: D. Futselaar

Why leave Earth?



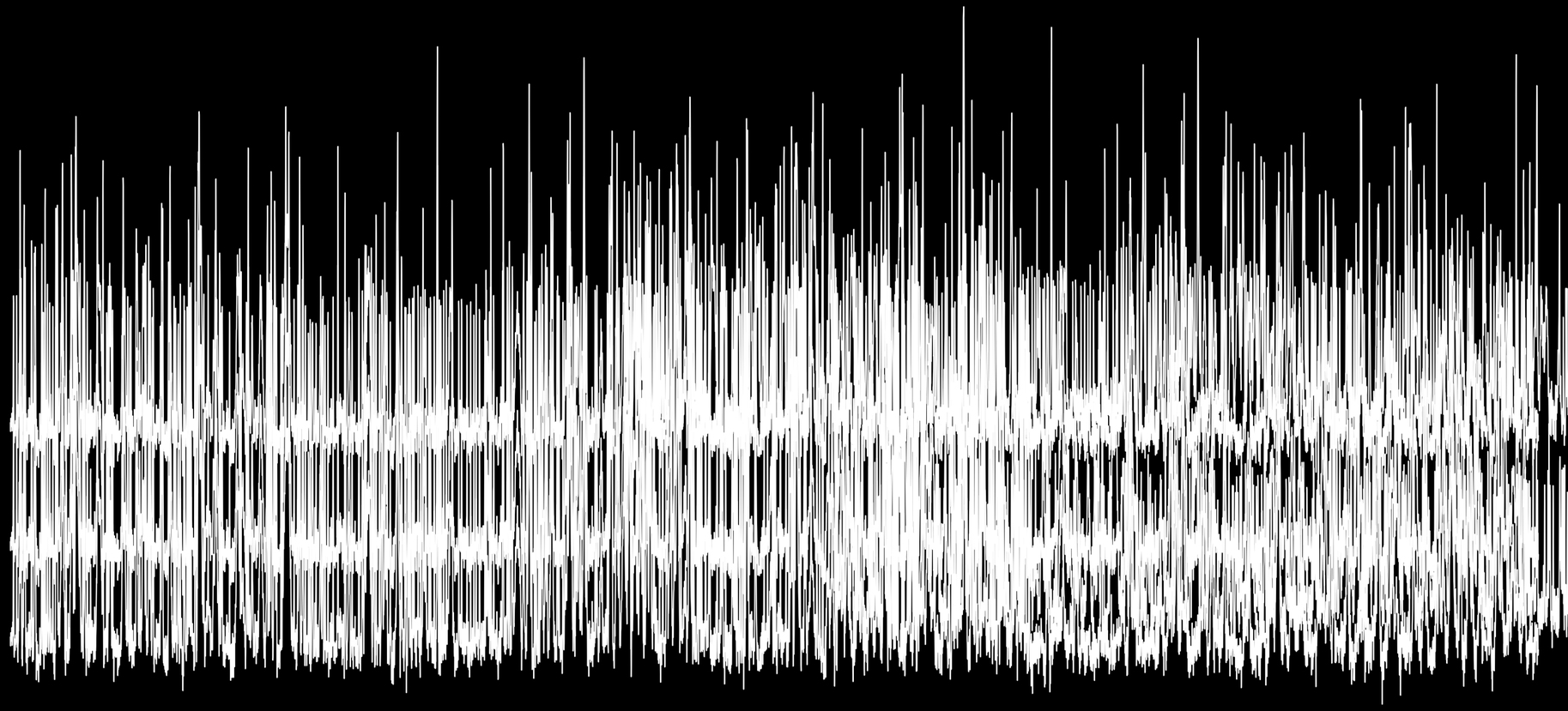
Why leave Earth?



Why leave Earth?

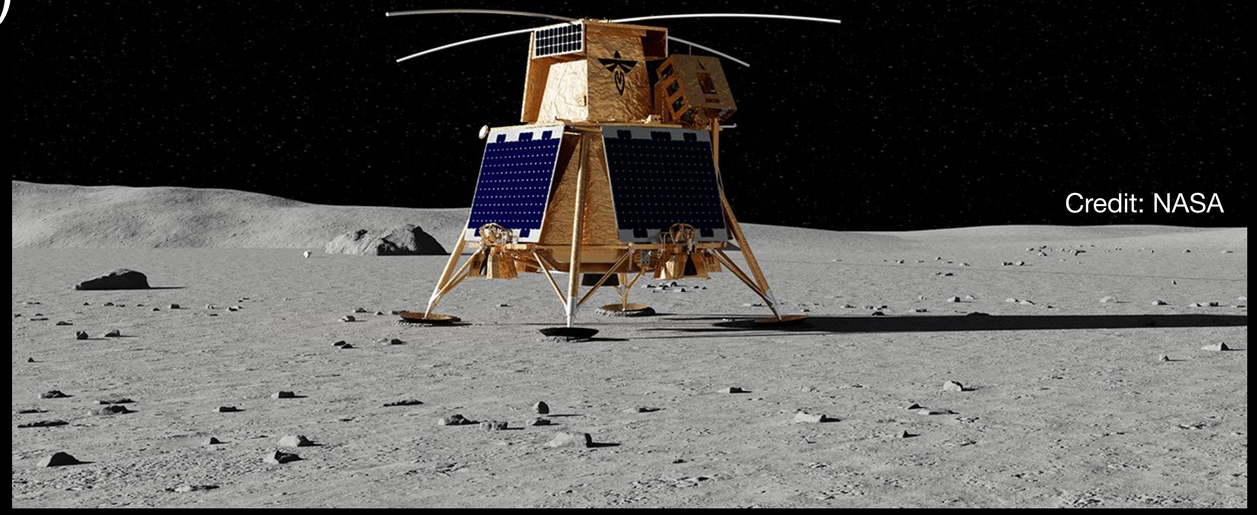
Credit: Wiki


Credit: New Scientist

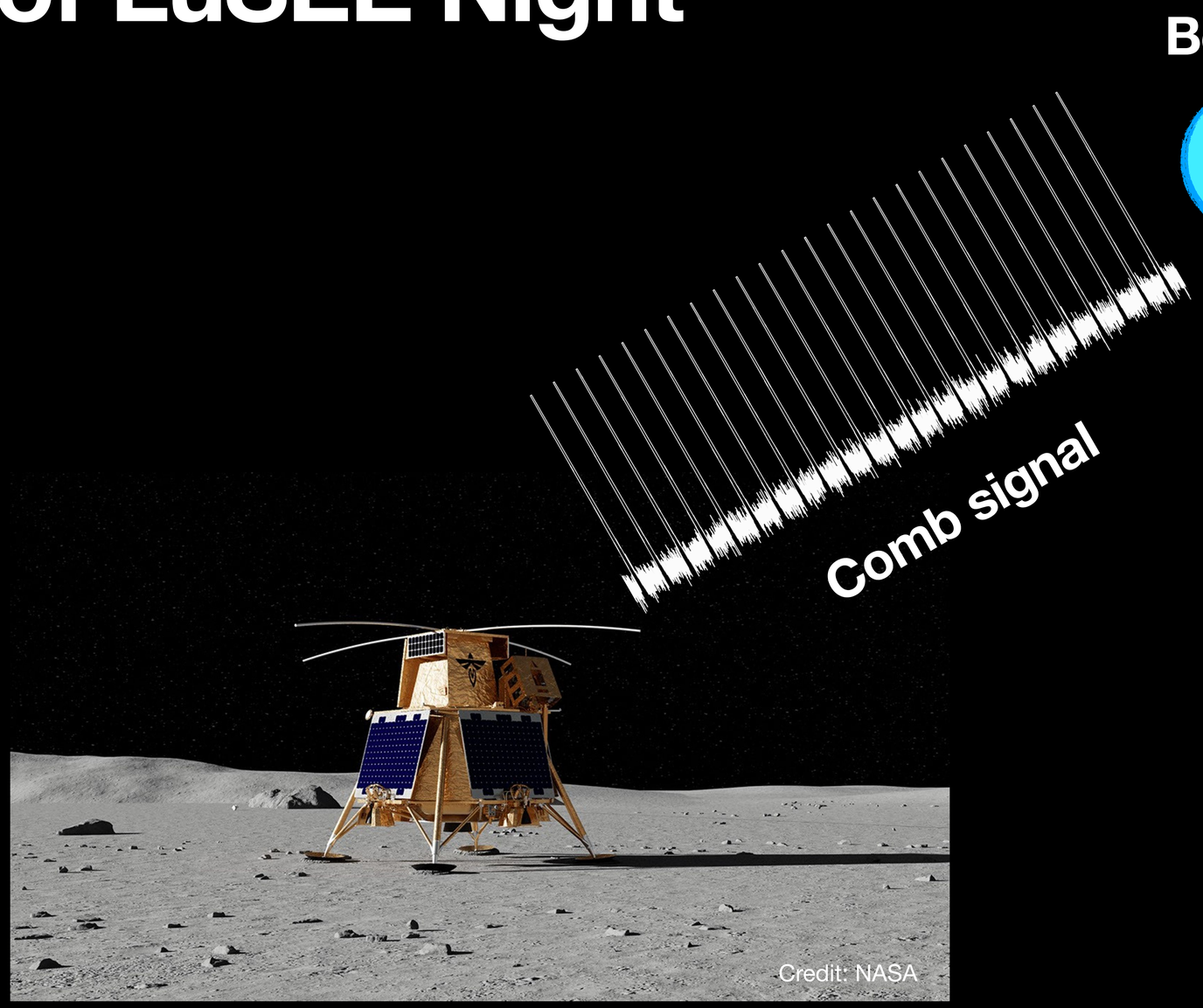


LuSEE Night

- LuSEE Night = Lunar Surface Electromagnetics Experiment at Night
- Launch is early 2027
- 0.1 - 50 MHz (Saliwanchik et. al, 2024)
- 4 monopoles
- Calibration beacon

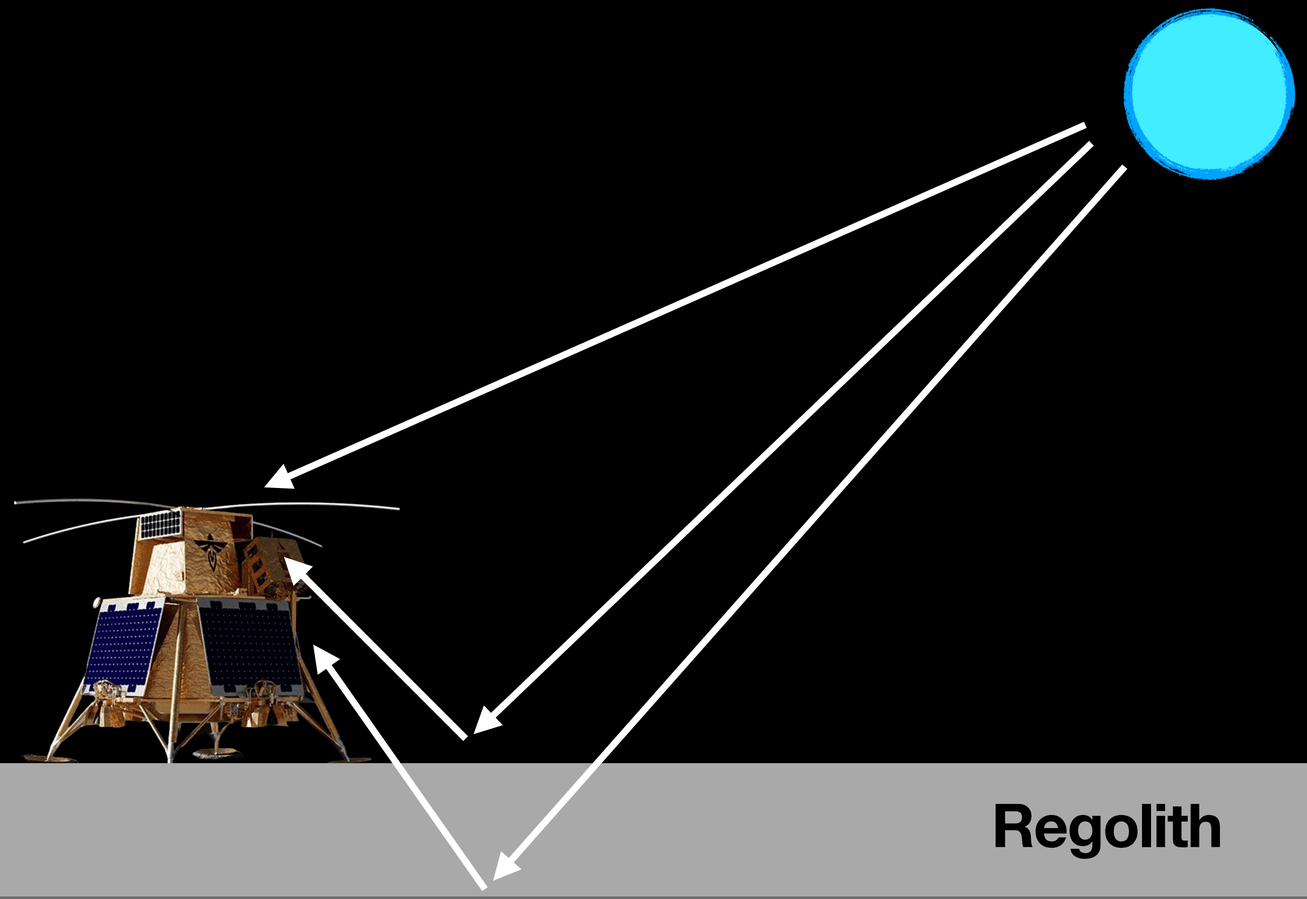

Credit: NASA

Calibration of LuSEE Night



NAC 2026 cordun@astron.nl

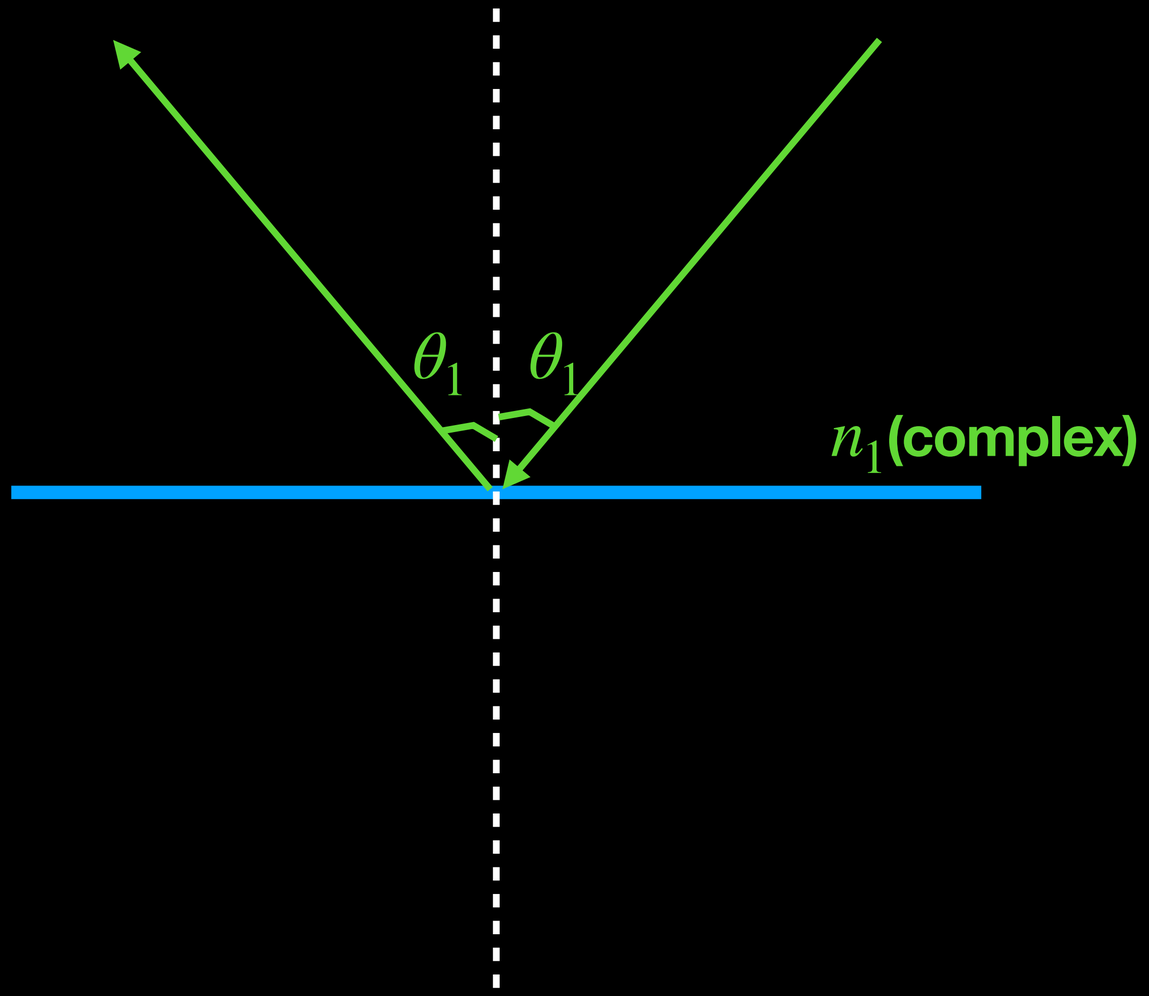
Main issue



Work framework

Fresnel coefficients:

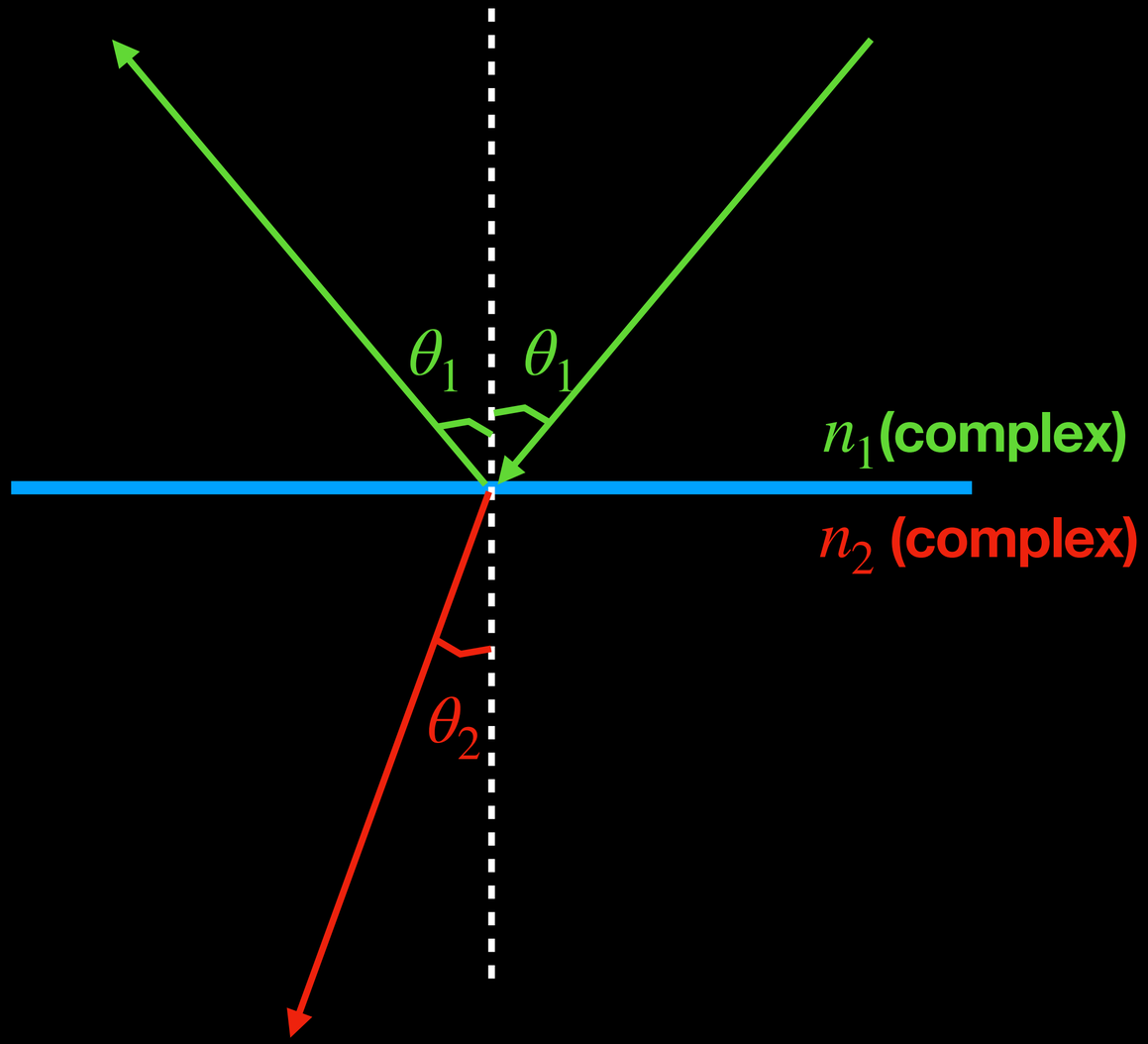
- $r_{12}^{(s,p)}(n_1, n_2, \theta_1, \theta_2)$ - reflection



Work framework

Fresnel coefficients:

- $r_{12}^{(s,p)}(n_1, n_2, \theta_1, \theta_2)$ - reflection
- $t_{12}^{(s,p)}(n_1, n_2, \theta_1, \theta_2)$ - transmission



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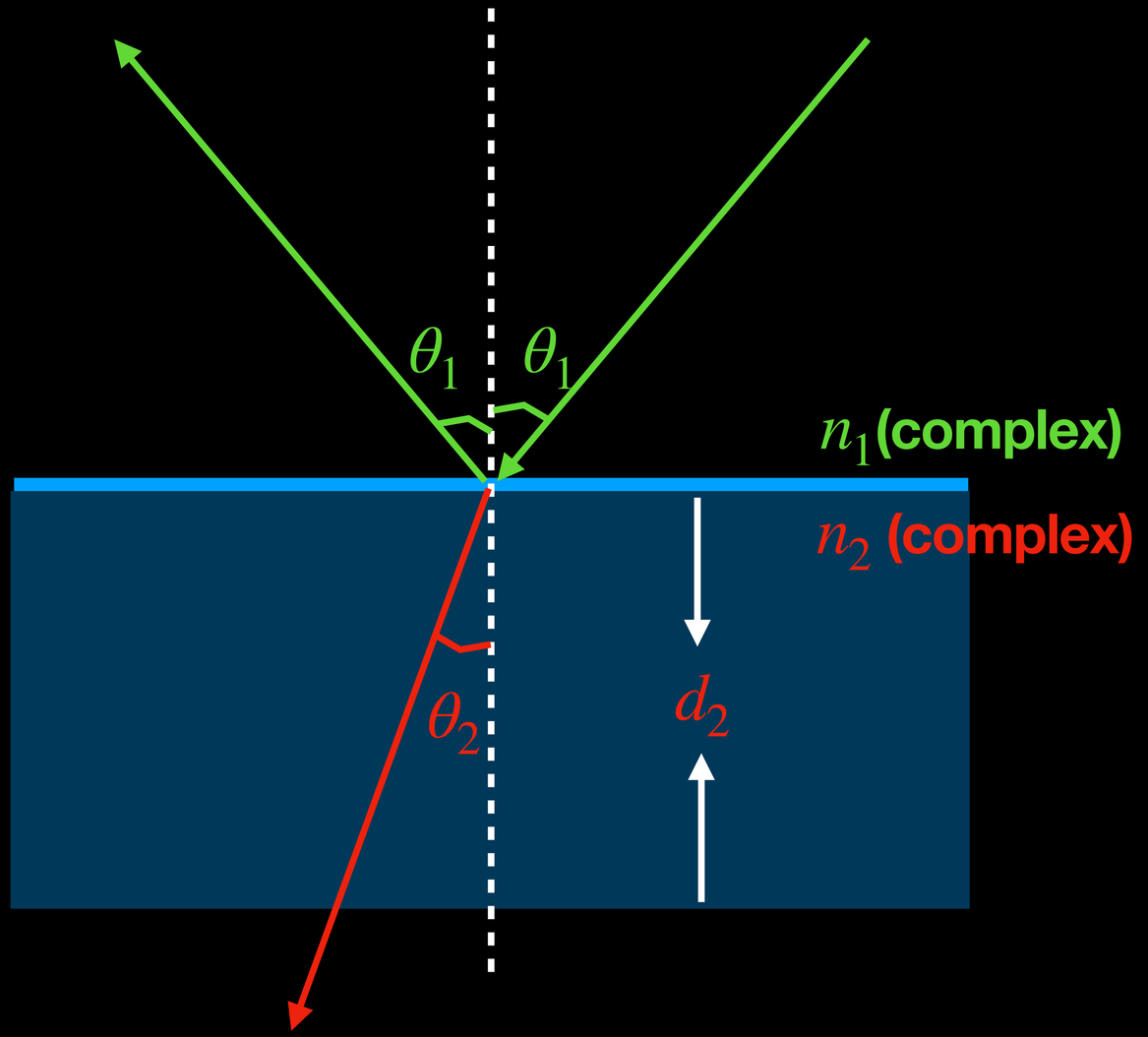
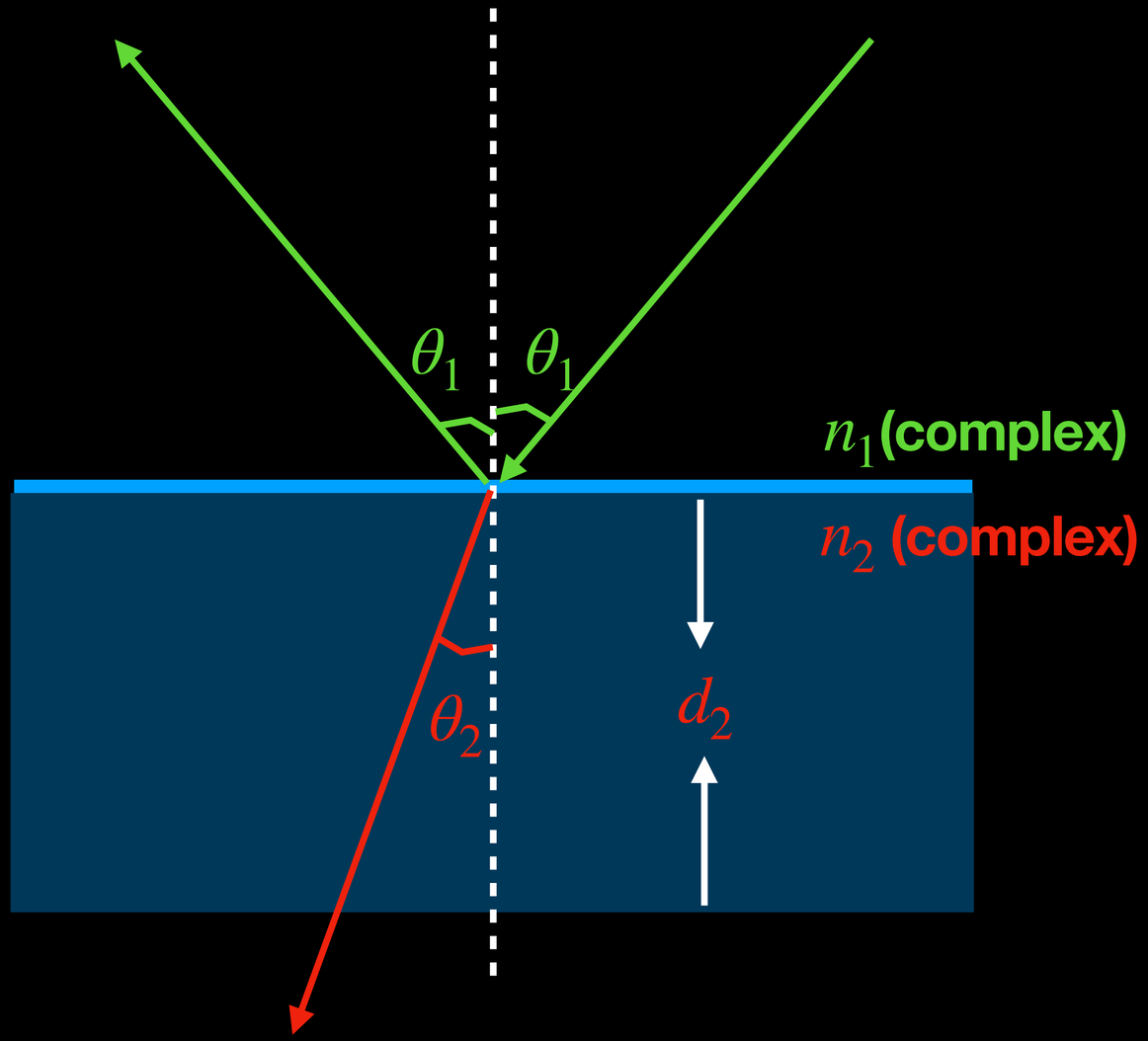
- $A(\nu, n_2, d_2, \theta_2)$ - attenuation



Work framework

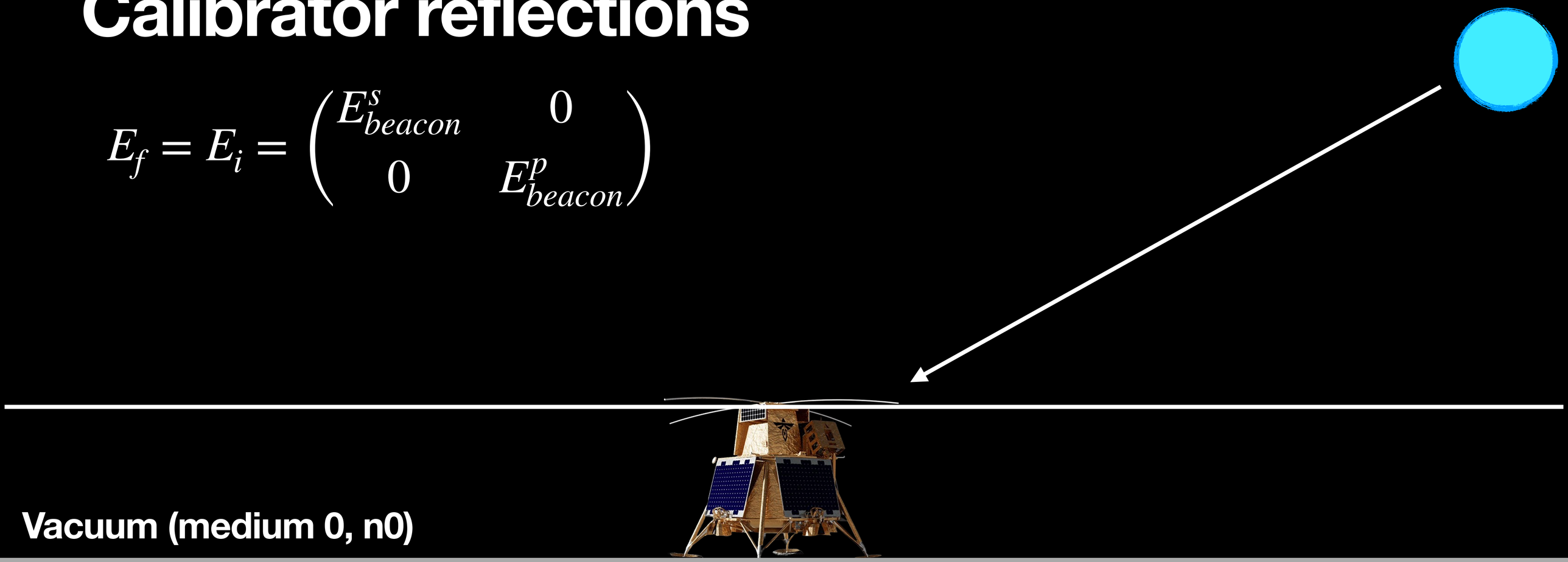
Fresnel coefficients:

- $r_{12}^{(s,p)}(n_1, n_2, \theta_1, \theta_2)$ - reflection
- $t_{12}^{(s,p)}(n_1, n_2, \theta_1, \theta_2)$ - transmission
- $A(\nu, n_2, d_2, \theta_2)$ - attenuation
- $R_{12}(n_1, n_2, \theta_1, \theta_2) = \begin{pmatrix} r_{12}^s & 0 \\ 0 & r_{12}^p \end{pmatrix}$
- $T_{12}(n_1, n_2, \theta_1, \theta_2) = \begin{pmatrix} t_{12}^s & 0 \\ 0 & t_{12}^p \end{pmatrix}$
- $A_2(\nu\,. n_2, d_2, \theta_2) = \begin{pmatrix} A & 0 \\ 0 & A \end{pmatrix}$



Calibrator reflections

$$E_f = E_i = \begin{pmatrix} E^s_{beacon} & 0 \\ 0 & E^p_{beacon} \end{pmatrix}$$



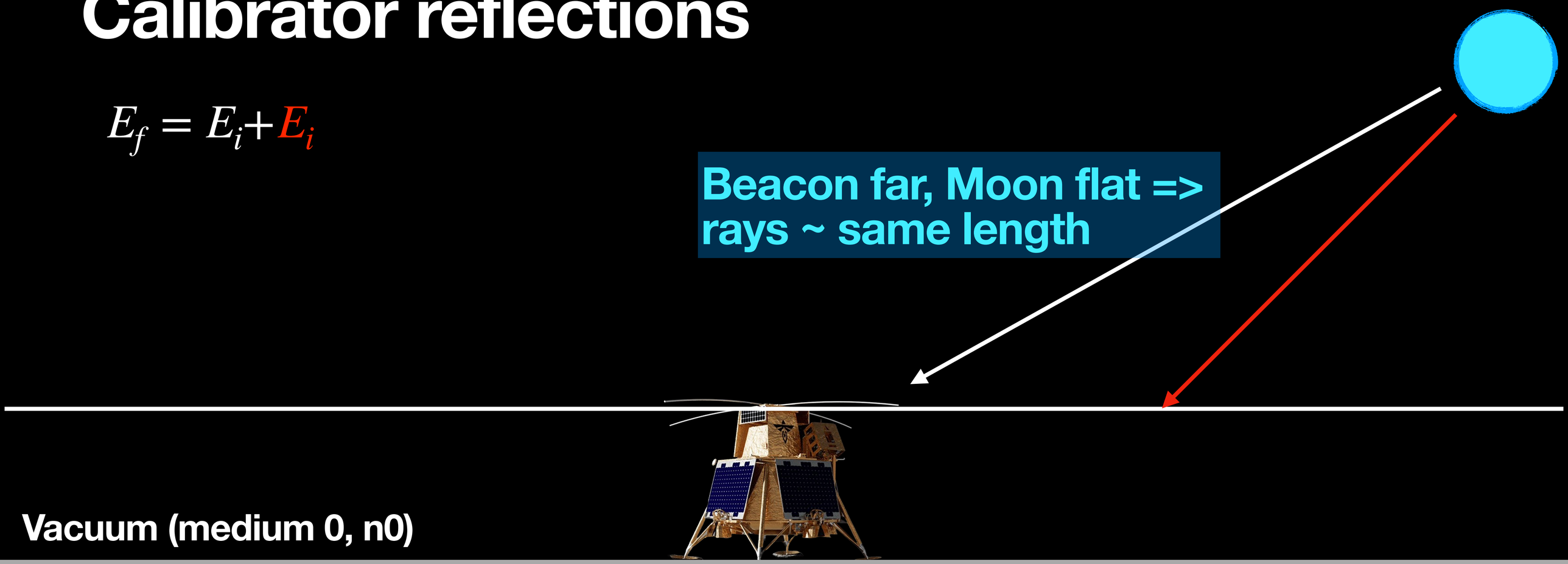
Vacuum (medium 0, n0)

Regolith (medium 1, n1, d1)

Hard rock bed (medium 2, n2)

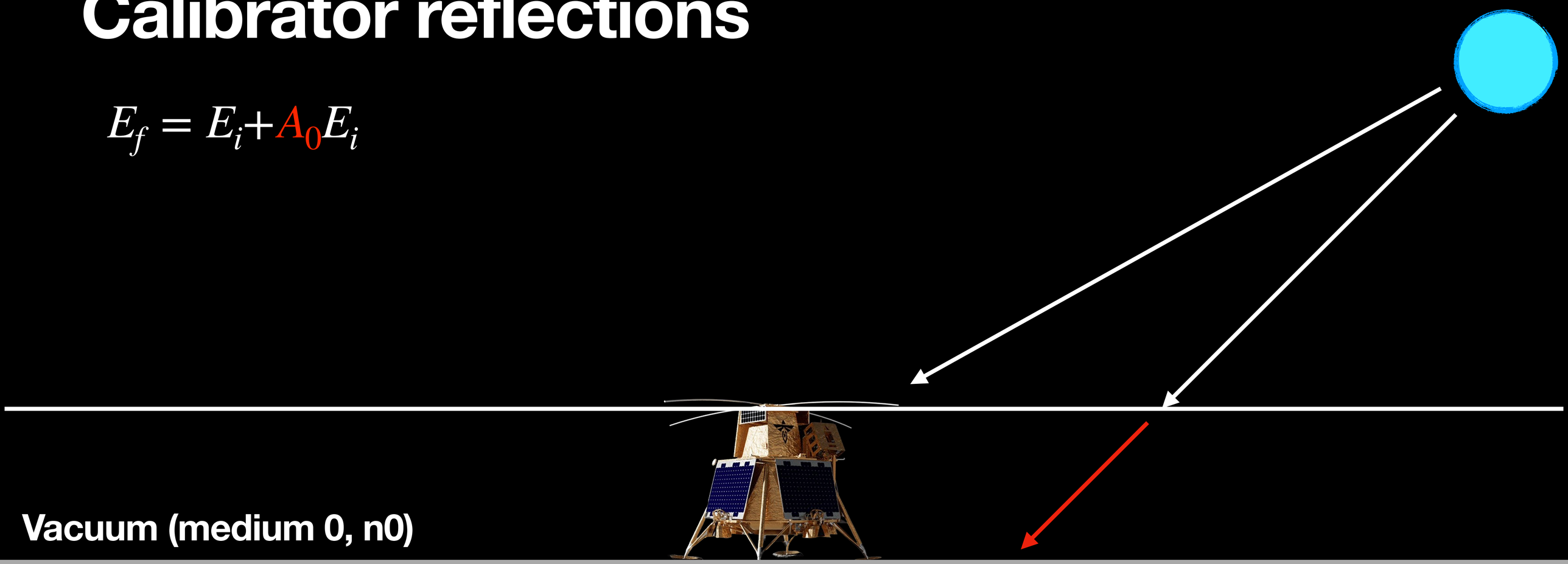
Calibrator reflections

$$E_f = E_i + E_i$$



Calibrator reflections

$$E_f = E_i + A_0 E_i$$



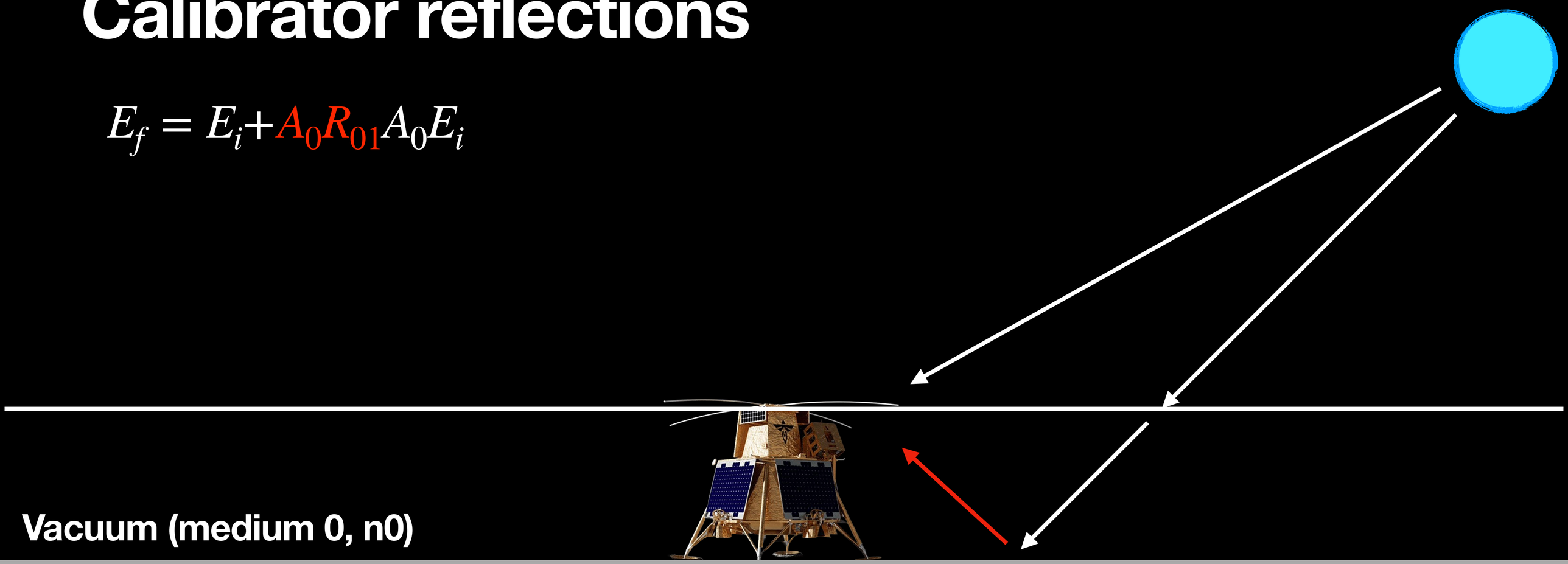
Vacuum (medium 0, n0)

Regolith (medium 1, n1, d1)

Hard rock bed (medium 2, n2)

Calibrator reflections

$$E_f = E_i + A_0 R_{01} A_0 E_i$$



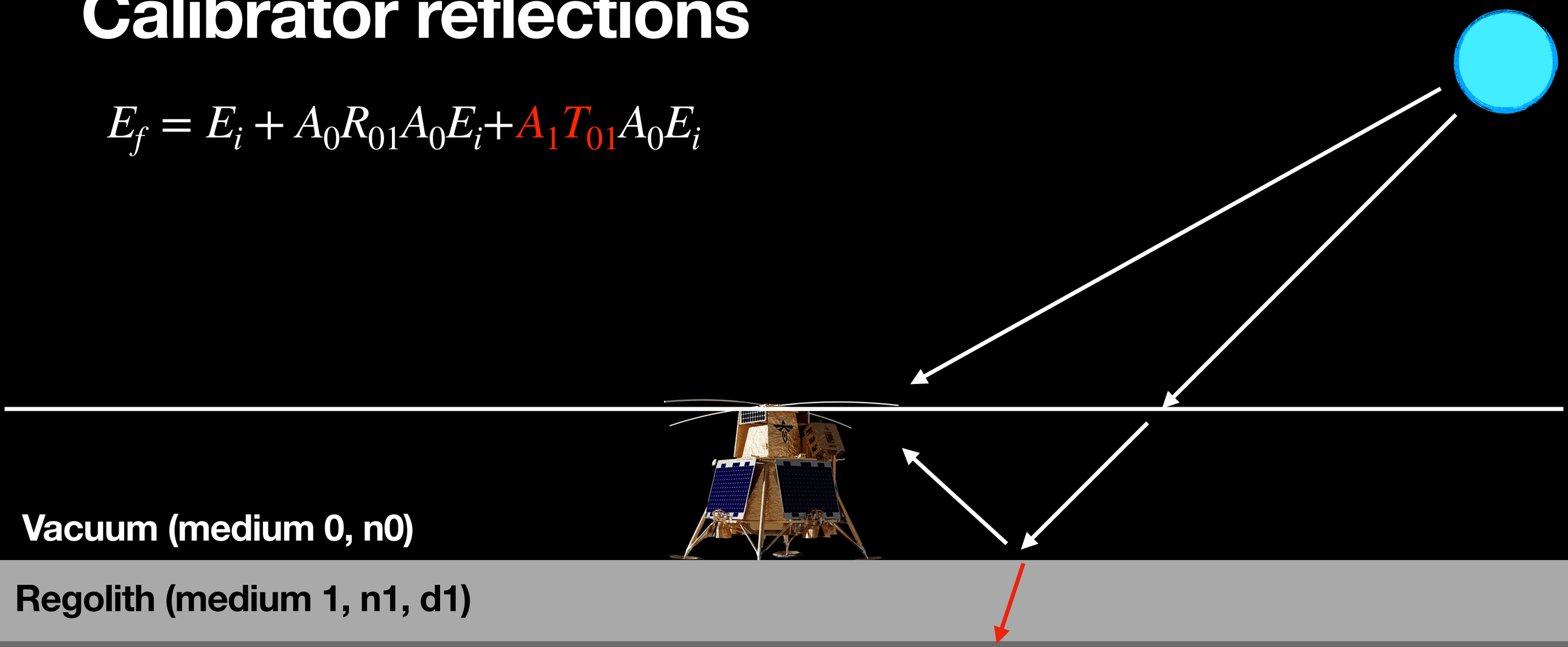
Vacuum (medium 0, n0)

Regolith (medium 1, n1, d1)

Hard rock bed (medium 2, n2)

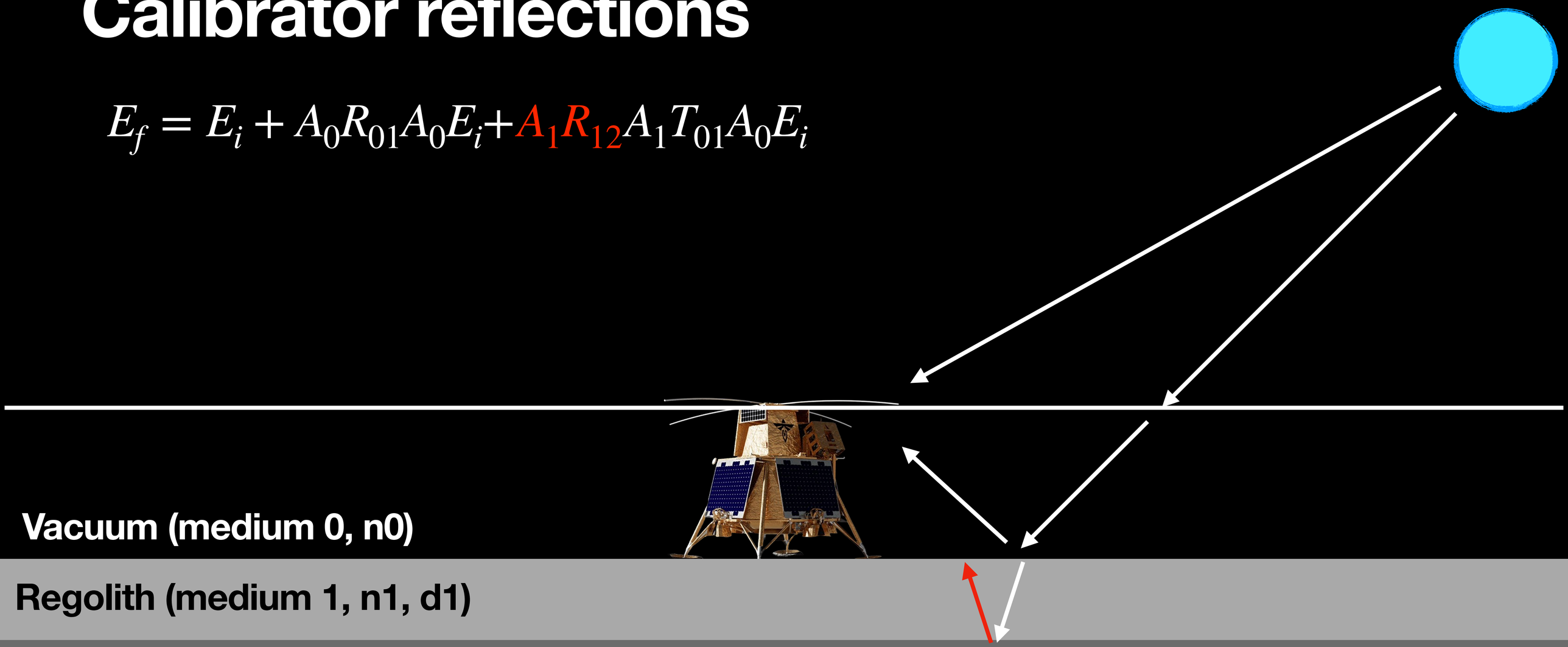
Calibrator reflections

$$E_f = E_i + A_0 R_{01} A_0 E_i + A_1 T_{01} A_0 E_i$$



Calibrator reflections

$$E_f = E_i + A_0 R_{01} A_0 E_i + A_1 R_{12} A_1 T_{01} A_0 E_i$$



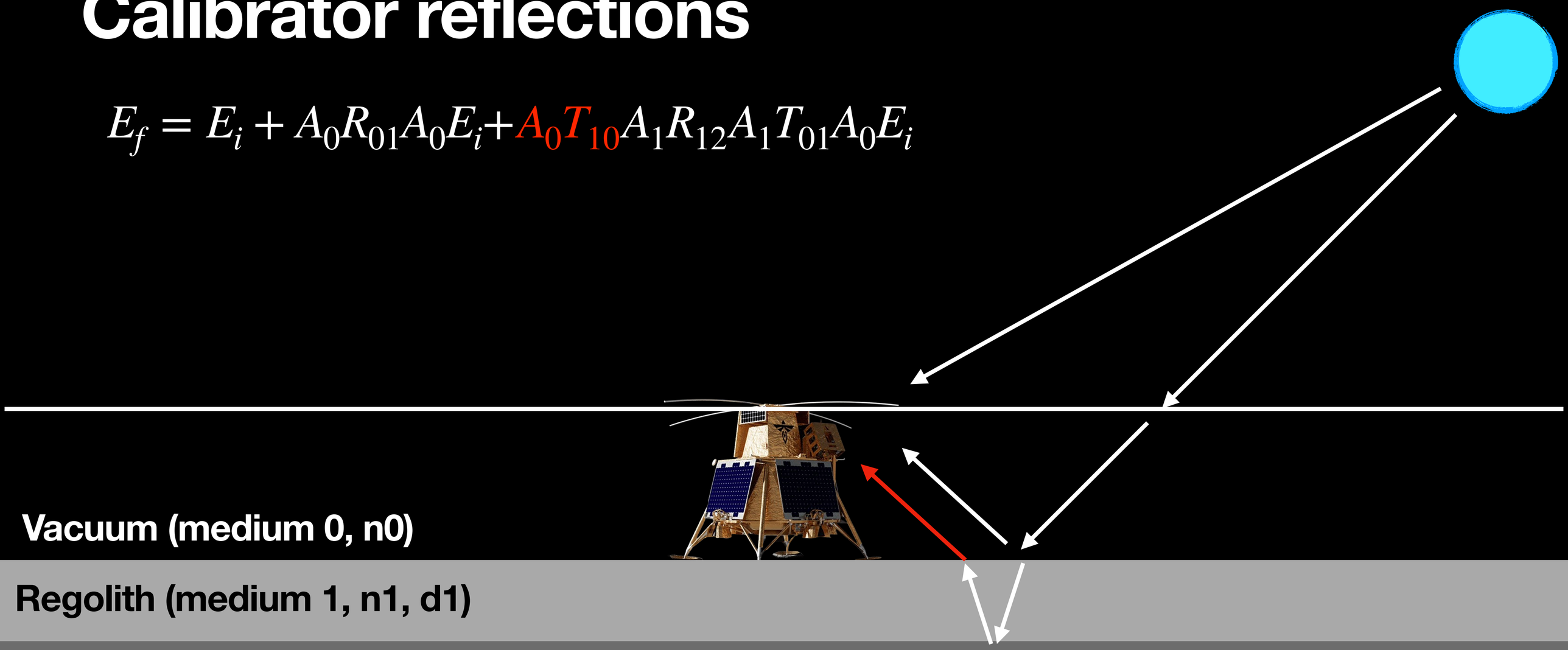
Vacuum (medium 0, n0)

Regolith (medium 1, n1, d1)

Hard rock bed (medium 2, n2)

Calibrator reflections

$$E_f = E_i + A_0 R_{01} A_0 E_i + A_0 T_{10} A_1 R_{12} A_1 T_{01} A_0 E_i$$



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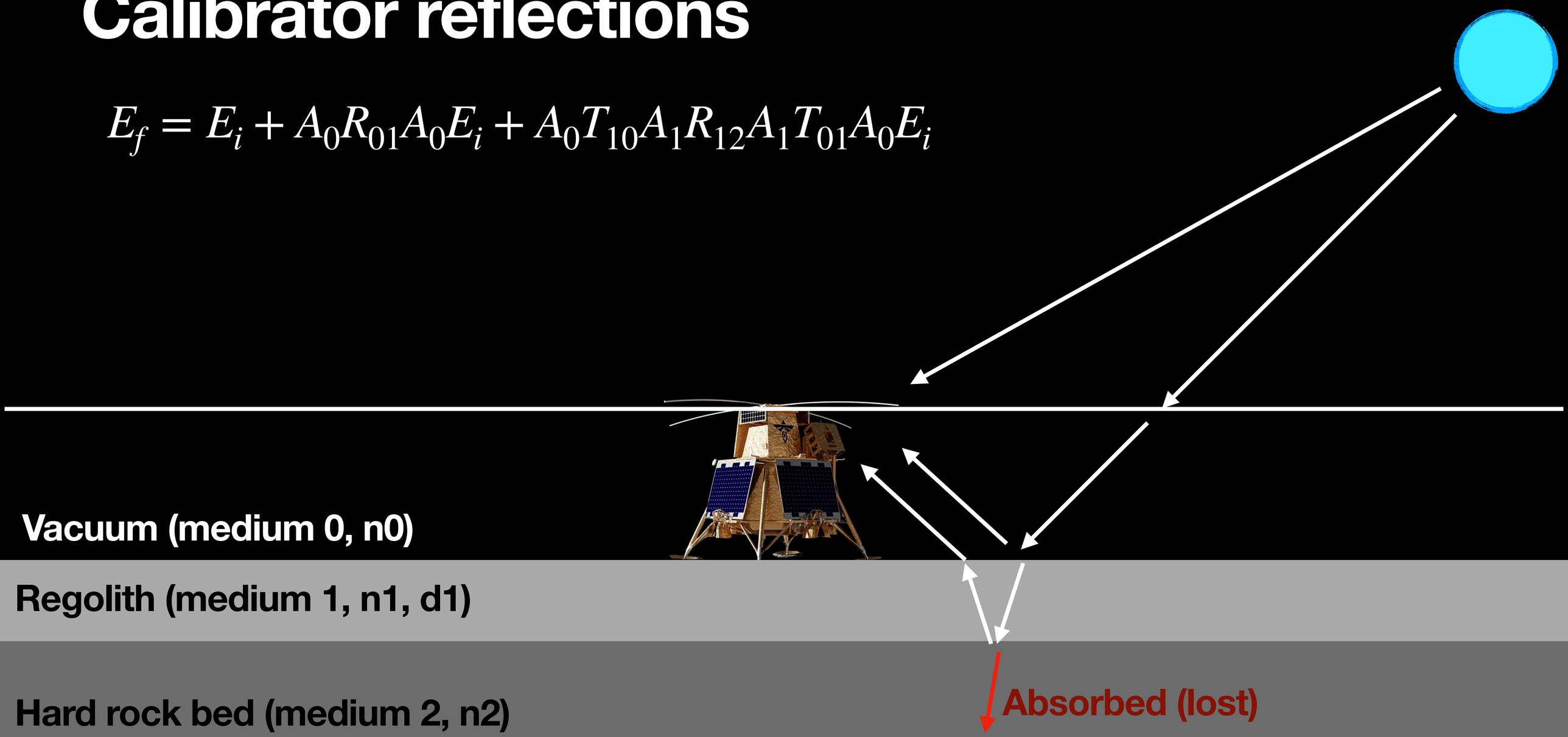
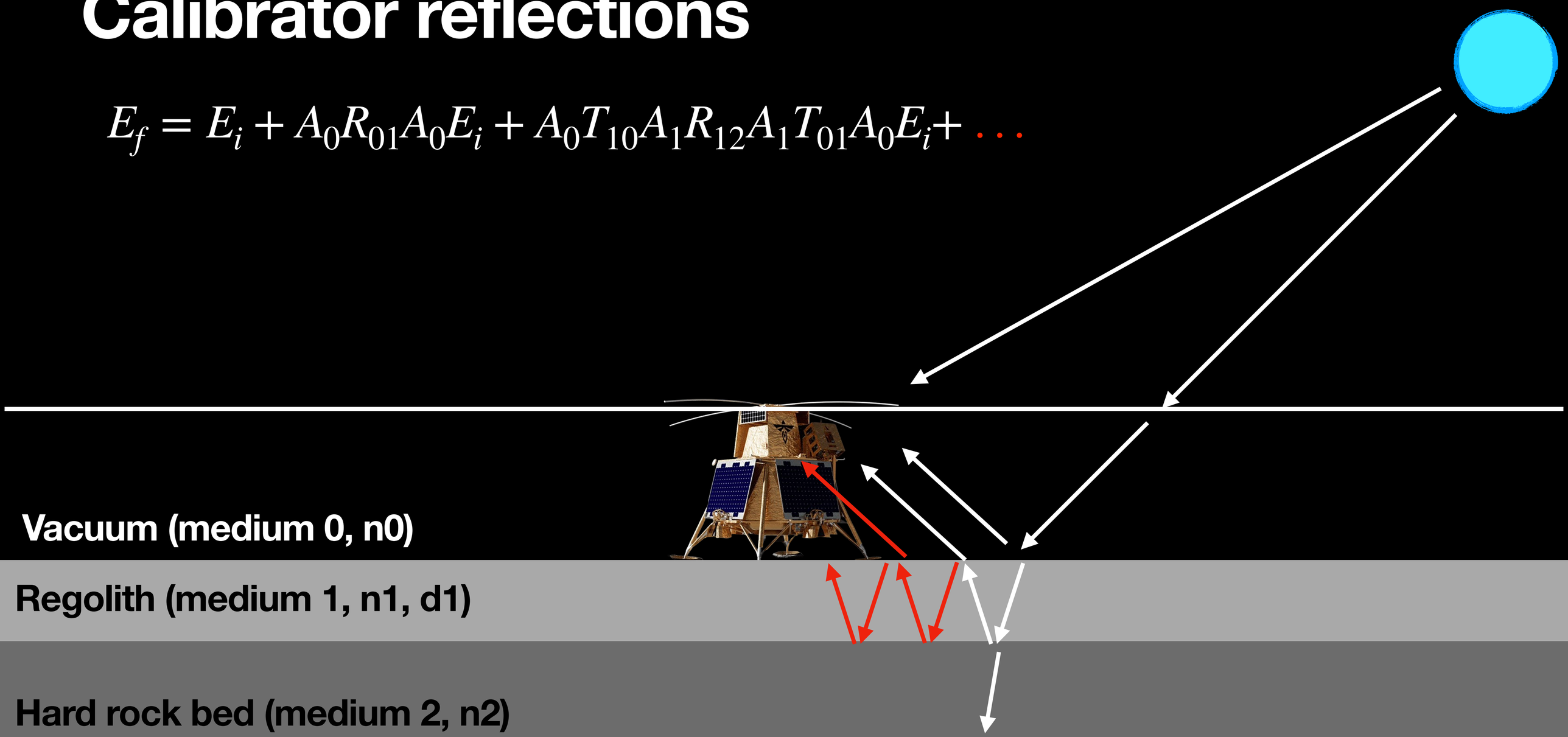
Calibrator reflections

$$E_f = E_i + A_0 R_{01} A_0 E_i + A_0 T_{10} A_1 R_{12} A_1 T_{01} A_0 E_i$$



Calibrator reflections

$$E_f = E_i + A_0 R_{01} A_0 E_i + A_0 T_{10} A_1 R_{12} A_1 T_{01} A_0 E_i + \ldots$$



Calibrator reflections

$$E_f = \left[I + A_0 R_{01} A_0\right] E_i + A_0 T_{10} \left[I - A_1 R_{12} A_1 R_{10}\right]^{-1} A_1 R_{12} A_1 T_{01} A_0 E_i$$

all angles, Ei, n0, d0 - known n1, d1, n2 - unknown

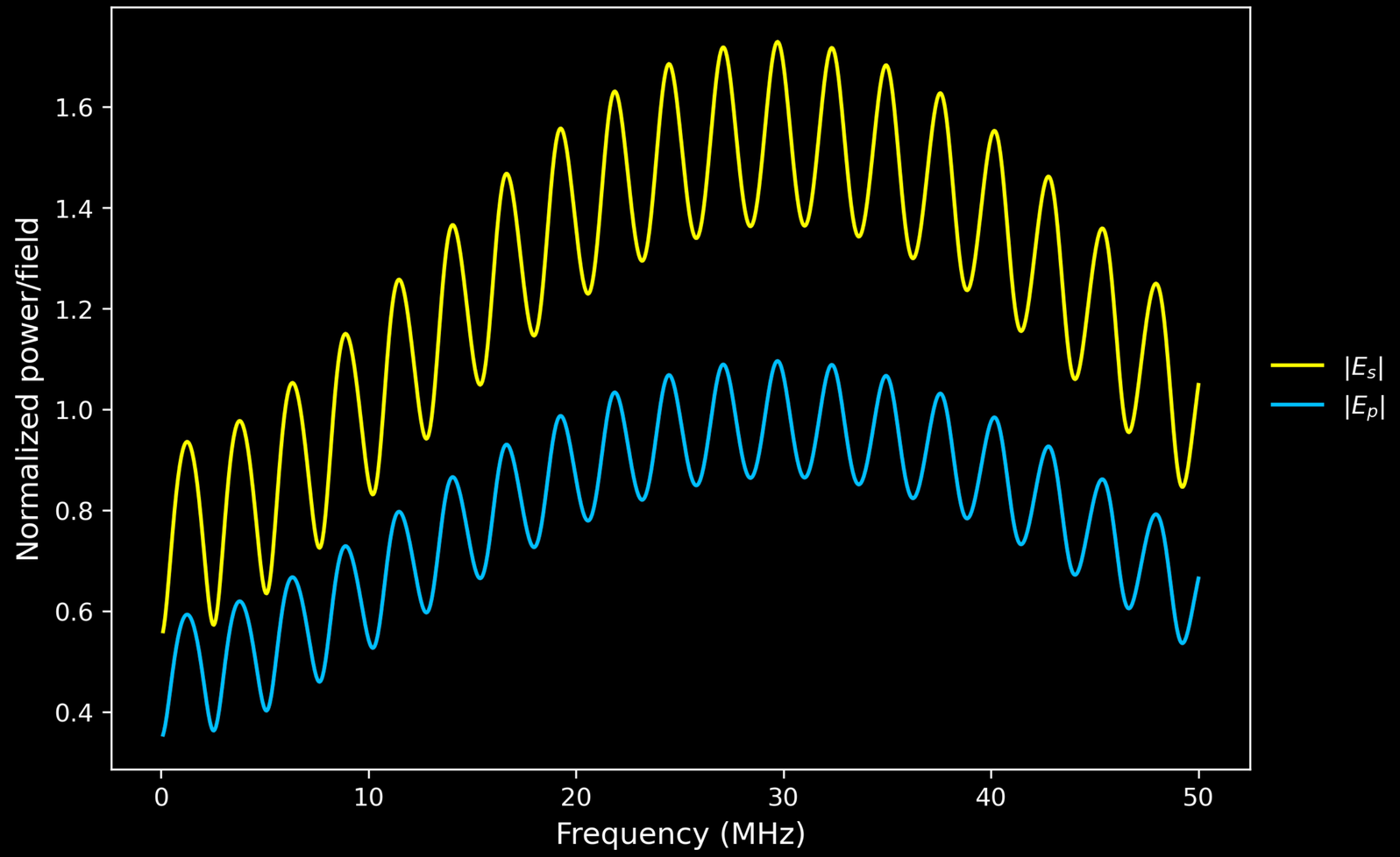
Vacuum (medium 0, n0)

Regolith (medium 1, n1, d1)

Hard rock bed (medium 2, n2)

Simple example

At a specific regolith depth and refraction insides



We are missing something important

Antenna can be added with:

- Green's function (with regolith effects)
- Pocklington's equation

$$Z_{mn}^{\text{Moon}} = \frac{\Delta^2}{j\omega\epsilon_0}\left[D_s^2 g_{\text{Moon}}(\mathbf{r}_m, \mathbf{r}_n) + k^2 g_{\text{Moon}}(\mathbf{r}_m, \mathbf{r}_n)\right]$$

Next steps

- Implement full antenna configuration
- Use with simulated data (https://github.com/lusee-night/luseepy/)

Credit: NASA

Conclusion

LuSEE night will launch soon, but

we need to understand the lunar environment to be able to do science