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Astronomical Methods and the Terrestrial Climate: An Estimation of the Earth's Albedo Based on Self-obtained Data

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The significance of the albedo for the terrestrial climate
The albedo is defined as the ratio of reflected to incident light on a body in the case of diffuse reflection. For celestial bodies—such as the planets, asteroids or comets—the albedo is an essential quantity, because on the one hand it determines their visibility and on the other hand it allows statements about their surface properties. Already the comparison of different planets and moons yields astonishing results: The albedo of the earth is about three times higher than that of the moon, which appears very bright and white. In general, the albedo of planets with an atmosphere is significantly higher than that of planets or moons an atmosphere and with a rocky surface. An exception is again the very fresh ice surface of Saturn's moon Enceladus. Here there is a clear difference to the likewise icy, but very dark cometary surfaces, whose albedo is comparable to fresh asphalt. [1]
For the Earth's climate the albedo of the planet is of very high importance. In educational contexts, the mean surface temperature of the Earth is often calculated based on the balance of incident solar energy $E_in = G_SC\ \pi R_E^2$ to the emitted energy $E_{out} = 4\pi R_E^2\ \sigma_{SB}\ T^4$ across the Earth's surface. [2, 3] Here G_{SC} is the solar constant, R_E is the Earth's radius, and σ_{SB} is the Stefan-Boltzmann constant. However, in order to obtain an approximately correct result, the irradiated energy must be reduced by a certain factor, which results just from the Earth's albedo A. It causes a considerable part of the solar radiation to be reflected before it becomes effective in the climate system. This modification for the albedo results in the effective irradiated energy: $E_{eff} = G_{SC}\ \pi\ R_E^2\ \ (1 - A)$.
The numerical value for the albedo is usually given at this point and used as a global mean value of $A = 0.3$. However, due to its importance, it seems desirable to also teach the method behind the determination of this value and to enable students at an undergraduate level to collect and evaluate their own data on the Earth's albedo.

Estimation of the albedo on the basis of self-performed measurements
The method for the determination of the Earth's albedo requires for its practical realization, besides some basic astronomical data, hardly more than the knowledge of the phase function of the moon (which is assumed to be known here) and intensity measurements for the illuminated (I_{bright}) and the non-illuminated side (I_{dark}) of the moon. The brightness of the unlit part of the lunar surface is never zero, because at any time light from the Earth (both from the atmosphere and from the surface) is scattered towards the Moon. From geometrical considerations the albedo of the earth can then be concluded from the ratio of the intensities [3]: $A \propto\ \ I_{dark}/I_{bright}$.

This contribution will focus on the handling of the obtained data, the factors influencing their quality, possible improvements in data collection as well as the general limitations and further potentials of the method. For example, the influence of scattered light is a major challenge, which can, however, be countered by means of suitable procedures if the observation conditions are good. However, this requires that there is no excessive contribution from external light sources, especially if these cause reflections within the telescope optics. The exact procedures for data acquisition, i.e., the selected patches on the lunar surface, also represent a potential source of measurement uncertainties, where a balance must be found between the effort required to analyze the data and the desired accuracy.

Conclusion
The Earth's albedo, as an essential factor for modeling the terrestrial climate, can be derived with sufficient accuracy for educational purposes from data which is obtained with simple instruments. For the evaluation, the handling of external influences on the measured intensities and the conditions of the measurement play a role above all. A discussion of the individual factors, as well as strategies for dealing with them, can provide valuable insights into the acquisition and processing of observational data.

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