Chlorophyll and ozone in the Earthshine

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When the space missions will be able to detect planets similar to the Earth, it will be important to know which are the indices of the presence of life on these planets, in particular some biosignatures like atmospheric components and the vegetation chlorophyll, etc. In order to determine how the Earth appears from far away, a team of scientists, among whom several researchers of the Paris Observatory, carried out observations with the NTT (telescope of 3.5 m at ESO), of the earthshine on the Moon, which corresponds to the reflexion on the surface of the Moon of the light coming from the Earth. It appears that the Earth "blue dot" can be almost white, and the vegetation biosignature on a

When a terrestrial extrasolar planet could be observed, it will appear as a dot, and could be observed only as a whole, without separating its different parts. Life on other planets will probably present unusual and unknown forms. However as nothing is known about these forms of life, it is necesary to search how to detect on a very distant planet the signature of a life similar to the one we know on Earth. For this it is required to search how to detect life on Earth seen as a very distant planet.

Figure 1 : Diagram of the path of the light during Earthshine observations : the light of the Sun arrives on Earth, is reflected by Earth, arrives on the Moon, is reflected by the Moon and comes back on Earth. Each place of the Moon reflects Earth as a whole.   Click on the image to enlarge it

It would be possible to use a space mission as distant as to see Earth as a whole. An alternative method is to use the Moon as a giant mirror and to study Earthshine. Earthshine can be seen on the dark part of the Moon, between the horns of the narrow bright crescent, during the first or the last days of the lunar cycle, and we know for a long time (Galileo or even more Leonardo da Vinci) that this very faint lighting of the Moon corresponds to the Earthshine, that is to say the Sun light reflected by Earth to the Moon, and reflected again by the Moon to the Earth. So thanks to its roughness, every place on Moon reflects the totality of the lightened Earth, which corresponds to the case of an terrestrial exoplanet observed from Earth. The pattern of the path of the light when Earthshine is observed on the Moon is shown on figure 1.   It is known that the spectrum of Earth vegetation presents a sharp increase in albedo of almost one order of magnitude, around 700 nm. Vegetation has developed this strong reflectance as a refreshing mechanism to avoid an over-warming, which would imply a chlorophyl deterioration. Although the sand albedo increases near infrared, this sharp edge, typical signature of vegetation, known as the "Vegetation Red Edge" (VRE) is steeper and can be detected on the Earth seen as a whole.

Figure 2 : Earth seen from the Moon during observations, whereas continents, Africa and Europe, are facing the Moon.

Figure 3 : Earth seen from the Moon during observations, whereas Pacific Ocean is facing the Moon

An observation program at the NTT (3.5 m telescope at European Southern Observatory) was established, corresponding to the reflection on the Moon sometimes of the Pacific Ocean (in the evening, during the first days of the lunar cycle), and sometimes of the African and European continents (in the morning, during the last days of the lunar cycle). So it is possible to search and study the vegetation signature corresponding to different landscapes. Integrated Earth reflectance spectra were obtained from near UV (320 nm) to near IR (1020 nm), for different Earth phases (continents or oceans seen from the Moon). Near UV spectra, which are the first near-UV integrated earth spectra obtained from Earthshine observations, reveals a dark Earth below 350 nm due to the strong O_3 absorption (ozone Huggins absorption bands). The value of the Vegetation Red Edge obtained is smaller than what was obtained during a preliminary former study, but nevertheless shows different values depending whether ocean or salient land are facing the Moon, as it is 4.0 % when Europe and Africa forests are seen from the Moon and only 1.3% when the Pacific Ocean is reflected by the Moon. Figures 2 and 3 present the Earth seen from the Moon during observations (cloudless model). Also significant variations of the Rayleigh scattering were obtained depending of the cloud cover : so the so-called Earth "blue dot" can be almost white.   As a conclusion, the detection of vegetation on a extra-solar planet will be difficult to carry out. Actually, it will be necessary to devise a special instrumentation that these results will help to define. A spectro-photometric accuracy better than 1% will be required and instruments will be all equipped with an optimized coronagraph allowing starlight rejection better than 105 to be able to provide the image of the planet itself. Let us recall that the light of a terrestrial planet is 1010, that is to say 10 thousand million, fainter than the light of its star. A survey over at least one year with monthly observations would allow to follow the vegetation spectrum seasonal variations and undoubtedly improve our knowledge of the behavior of this biomarker.

Reference

- Biomarkers in disk-averaged near-UV to near-IR Earth spectra using Earthshine observations   S. Hamdani (1), L. Arnold (1), C. Foellmi (2), J. Berthier (3), M. Billeres (2), D. Briot (3), P. François (3), P. Riaud (3), and J. Schneider (3) 2006, A&A, http://arxiv.org/abs/astro-ph/0609195   (1) OHP, Observatoire de Haute Provence   (2) LAOG, Observatoire de Grenoble   (3) Observatoire de Paris

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