Highlights of Astronomy, Volume 15
XXVIIth IAU General Assembly, August 2009
Ian F. Corbett, ed.

doi:10.1017/S1743921310011038

Earthshine observations and the detection of vegetation on extrasolar planets

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Abstract. To prepare future observations of terrestrial planets and the detection of life, we search for life on the planet Earth seen as a point source. Observations of Earthshine is a convenient way to see Earth as a remote planet. The vegetation reflectance spectrum presents a sharp edge in the near infrared: the Vegetation Red Edge. Observational programs in progress are described, particularly our observations at the Concordia station in Antarctica.

1. Introduction

Earthshine (or Ashen Light) is the light from the Moon which is reflecting the illuminated part of the Earth that is facing it. The first known publication of the correct explanation of the origin of Ashen Light is in the "Sidereus Nuncius" published by Galileo Galilei in 1610. While Kepler attributed the correct interpretation to his master Maestlin (1550-1631), the oldest unpublished one is found in manuscripts of Leonardo da Vinci dated 1506–1509. Another unpublished explanation predating the "Siderius Nuncius" can be found in "Pensieri", a collection of notes written between 1578 and 1597 by Fra Paolo Sarpi, a friend of Galileo.

As early as 1912, Arcichovsky (1912) suggested looking for a signature of chlorophyll in Earthshine to calibrate for chlorophyll in the spectra of other planets. However, this approach was not technically feasible at the time and was soon forgotten, even though such observations allowed Tikhoff (1914) to deduce the blue colour of our planet due to Rayleigh scattering (more about Tikhoff can be found in Tejfel 2009, or Briot *et al.* 2004). Nearly nine decades later, it was rediscovered independently when the detection of extrasolar planets kindled new interest in the search for life. Indeed, due to the roughness of the lunar surface, any lightray in Earthshine corresponds to a reflection of the entire disk of the Earth, a situation that simulates the case of an exoplanet seen as a point source.

One can reasonably think that extrasolar terrestrial planets, or Super Exo-Earths, will be detected and extensively studied in the forthcoming decades. Therefore, we need to plan for the detection of life. Vegetation, which covers approximately 60% of the surface of the continents, plays an important role in the Earth albedo. Chlorophyll is the fundamental pigment of photosynthesis. The spectrum of chlorophyll presents a small hump in the green wavelength range, so we see grass and plants as green, but it also exhibits a much more important sharp rise in the near infrared ($\approx 700\,nm$), the so-called Vegetation Red Edge (VRE), which can hardly be confused with another spectral feature.

2. Past results and present observations

The first detections of the VRE in the Earth spectrum were obtained by Arnold *et al.* (2002) and by Woolf *et al.* (2002). The red side of the spectrum shows the presence of O_2 and H_2O absorption bands and of the VRE of chlorophyll, while the blue side clearly shows the Huggins and Chappuis ozone (O_3) absorption bands (see for example Hamdani *et al.* 2006). Atmospheric molecules like oxygen and ozone are possible biomarkers.

Values of the VRE collected from the literature are given in Arnold (2008). Its magnitude is only a few percent, and Arnold *et al.* (2002), and Hamdani *et al.* (2006), have shown that it is lower when an ocean is facing the Moon (1.3% for the Pacific Ocean), than when forested lands are visible (4% for Africa and Europe). At low or mid-latitudes, Earthshine can only be observed during morning or evening twilight, and only two distinct portions of the Earth surface can be facing the Moon for a given telescope. If observations are carried out at very high latitudes, Earthshine can be observed during a large fraction of the day during about 8 periods in the year, and because of Earth rotation, different terrestrial "landscapes" are facing the Moon. For this reason, we use the Concordia station, a French-Italian base for scientific research, including astronomical observations, located at the Dome C in Antarctica (lat = 75°S, lon = 123°E, altitude = 3220 m) where the polar night lasts 3 months, the mean air temperature is −50.8°C, and the lowest air temperature is −84.4°C. A dedicated instrument called LUCAS was built (Briot *et al.* 2009). After technical setbacks during the 2008 winterover campaign, successful observations were carried out during the three usable lunar cycles since the June 2009 solstice. Observation runs lasted up to 8 hours, which is an impossible feat at mid-latitudes.

3. Conclusions

Observations of Earthshine represent a good example of a scientific topic which was first carefully investigated, then abandoned, and finally becomes very interesting again. Some geophysical applications also exist, according to the recommandations made by the NASA Navigator Program: "continued observations of Earthshine are needed to discern diurnal, seasonal, and interannual variations". As such, LUCAS is also a test for the design and improvement of small instrumentation, data collecting and management of observations in a extremely cold environment as in the Concordia station.

Acknowledgements

Many thanks are due to all the members of the LUCAS team: J. Schneider, S. Jacquemoud, L. Arnold, J. Berthier, and P. Rocher, and specials thanks to the valiant winterover observers: K. Agabi, E. Aristidi, E. Bondoux, Z. Challita, D. Petermann, and C. Pouzenc.

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https://doi.org/10.1017/S1743921310011038 Published online by Cambridge University Press