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The variation of biomarkers in the spectrum of Earthshine

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Abstract. We present preliminary results from a study of the variations of the optical spectrum of the Earthshine over a period of a year. Our goal is to follow, on several timescales, the spectral changes of the signature of various biomarkers that are potential indicators of habitability and/or biological activity, and of the Vegetation Red Edge, a feature around 700 nm due to photosynthetic organisms.

Keywords. Earth, planetary systems

1. Introduction

The idea of studying the Earth, the only inhabited planet known, as a proxy for habitable exoplanets emerged from the *Galileo* mission in the early 1990s (Sagan *et al.* 1993). Since then, numerous signs of habitability and life were identified in spectroscopic data gathered by spacecrafts. While useful to study the Earth from afar, spacecrafts are so costly that they are generally unsuitable to follow the variations of the Earth's spectrum over a long period. An alternative way to do so is to observe the Earthshine (ES), the weak glow produced by sunlight reflected from the surface of our planet on the otherwise dark side of the lunar disk. This method, already proposed a hundred years ago as a tool to study the Earth, was revived in the last 10 years as exoplanet science bloomed. The ES spectrum, composed of the spectra of the Sun, the Earth and the Moon, can be divided by the Moonshine (MS) spectrum, which only contains contributions from the Moon and the Sun, to isolate the Earth's spectrum. The portion of the Earth reflecting light towards the Moon depends on the lunar phase and on the longitude of the observer. In this contribution, we present the first results of a study of the variations of the ES spectrum over timescales ranging from a fraction of an hour to months.

2. Observations and Data Reduction

The 1.6 m telescope at the Observatoire du Mont-Mégantic (45°27′N, 71°09′W) was used with an optical spectrograph equipped with a 300 l mm^{-1} grating that allowed coverage of the $\sim$ 350-950 nm region. The longitude of the site is such that a few days before new moon, the portion of the Earth contributing to the ES is Africa, Europe and the Atlantic ocean, while a few days after it, it is the Pacific ocean and the Americas. Between 2008 July 28 and 2009 November 23, in the limited periods when the Moon displayed the right illumination, we secured data on 10 different nights, 4 before new moon (phase angle: $-105°$ to $-125°$) and 6 after (phase angle: 90° to 140°). The quality of the data varies appreciably, as it depends on the cloud cover on site and on the illumination of the Moon (10-40 %). On each of these 10 dates, typically 5-10 spectra with

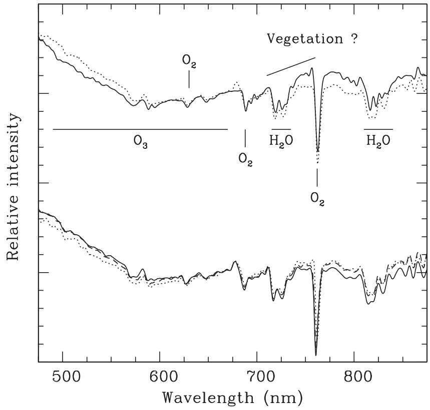

Figure 1. Top panel: The Earth's spectrum on 2008 July 28 (07:50 UT; solid line) and 2009 March 1 (00:00 UT; dotted line); Bottom panel : Changes observed in the Earth's spectrum during the night of 2009 February 28-March 1. The spectra secured at 23:40 (solid line), 00:00 (dotted line) and 00:25 (dashed line) UT are displayed.

the spectrograph slit positioned on the ES and its adjacent sky were taken. MS spectra were taken before and after each ES. Our data reduction procedure closely followed that of Hamdani *et al.* (2006).

3. Preliminary Results

Many atmospheric biomarkers that suggest the presence of life can be seen in our low resolution ($R \sim 1000$) optical spectra, examples of which are shown in Fig. 1: water (720, 820 nm), oxygen (630, 690, and 760 nm) and ozone (around 600 nm) are readily seen. Another feature of interest is the Vegetation Red Edge (VRE), an abrupt rise in the spectrum around 700 nm associated with photosynthetic organisms. This feature is difficult to detect in the disk-averaged spectrum of the Earth because of the restricted area typically covered by vegetation and of the frequent presence of cloud cover. Previous efforts (Arnold 2008) suggest that the VRE should be observed as a few percent increase in reflectivity around 700 nm. Our preliminary analysis suggests that *i)* the VRE is detectable in our data and *ii)* on some nights, we observe a variation of the VRE as vegetation-covered landmasses (esp. Amazonia) appear into view. Further analysis of the VRE and its variation is in progress.

Our data also display time variations of the ES spectrum on different scales. The top panel of Fig. 1 displays sample results secured on nights roughly seven months apart. In this specific case, the Earth phase differed drastically. The bottom panel, in contrast, displays spectra secured within a fraction of an hour of each other. In this case, the Earth phase did not change substantially, but the cloud pattern had time to evolve. Both types of variations could be observed in the spectra of terrestrial exoplanets.

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