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Photometric variability of the disk-integrated thermal emission of terrestrial planets

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Abstract

Our interest is focused on the characterization of earth-like planets with very low spectral resolution observations. We present an analysis of the globally-integrated mid-infrared (4–50 μm) photometric time series model of earth-like planets, with 3 hr time resolution, constructed from emission maps (longitude, latitude, time) of the top-of-the-atmosphere. Our model calculates the planetary disk exposed to a remote observer and computes the integrated flux to simulate the point-like signal detected. We have studied the annual, seasonal, rotational and diurnal variability to determine which planetary and atmospheric properties can be inferred from this signal. The model implements the case of an Earth-Moon system. We find that correlated phases of a Moon-like satellite can cause the misinterpretation of the signal in the absence of spectral information. We will discuss the relevance of several effects on the signal: atmospheric thickness, density, clouds, the distribution of surface features and the instrumental requirements.

1 Model

In order to construct the time series of the emitted infrared flux, we have used top-of-the-atmosphere all-sky upward longwave flux data from the NASA/GEWEX SRB program in the case of the Earth and 3D Global Circulation Model flux data developed by the Laboratoire de Météorologie Dynamique de Paris in the case of earth-like planets (collaboration with François Forget, Robin Wordsworth and Francis Codron). To simulate the infrared observations of the planet seen from any given direction, we have used a geometric model taking into account any possible planetary viewing geometries and integrating the disk emitted flux towards the remote observer.

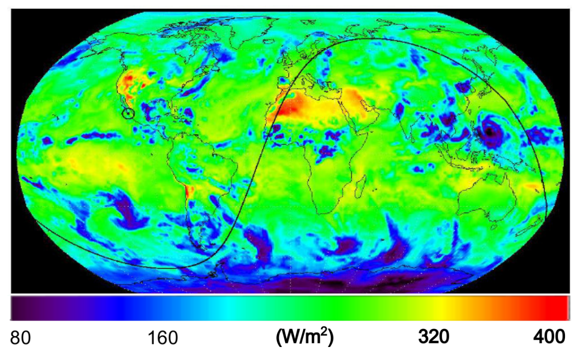

Figure 1: Maps of Earth's outgoing mid-infrared radiation. Average over the period 18:00–21:00 UT of 2001 July 1.

The atmosphere of the Earth is optically thin enough in some windows of the thermal infrared to observe the influence of surface features. We have performed the periodicity analysis of the signal in order to determine the rotational period. In order to study the intrinsic parameters of the planet, it is useful to construct time folding light curves. The diurnal light curves allows us to minimize the smoothing effect of the clouds over the signal.

2. Summary and Conclusions

We have constructed a 3 hr resolution model of the integrated mid-infrared emission of the Earth and ten earth-like planets in the direction of a remote observer randomly located. The Earth does not exhibit phases but the signal is dominated by the seasonal variability due to the inhomogeneous distribution of land masses (Gómez-Leal et al. 2012). The rotational variability is detectable because of the uneven distribution of continents and/or atmospheric patterns with planetary longitude. In the Earth's case, the daily maximum of the

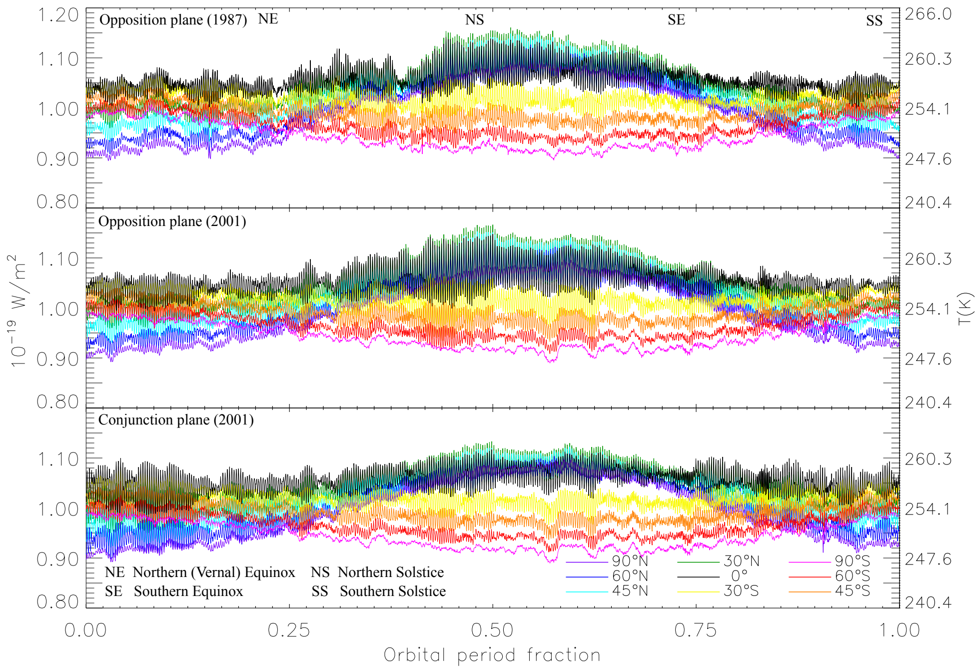

Figure 2: Time series of the mid-infrared emission flux for the two years of 1987 (top) and 2001 (middle and bottom) for several the sub-observer's point latitudes and the direction planes of opposition (O) (top and middle) and conjunction (C) (bottom) at the initial time (January 1, 0:00 UT) .

mid-infrared flux is shown when dry large masses of land, such as the Sahara desert, are in the observer's field of view and the daily minimum appears when cloudy humid regions such as the Indonesian area is visible. It is important to remark the strong influence of the weather patterns, humidity and clouds are sometimes able to mask the rotation period of the signal for several days at a time, this effect can be solved by time folding. A satellite of the size of the Moon would introduce a strong phase variability that would completely dominate over the planet's signal. This effect adds high complexity to its interpretation by photometry. If the planet is not completely covered by clouds, as Venus is, the presence of strong surface inhomogeneities (continents) can be extracted from the daily variations. The time series can also give estimates of the planet effective temperature, the variability in the obliquity of its orbit, and the distribution of land at larger scale. At the light of these results, it seems that future infrared photometric observations of terrestrial planets can be useful in order to characterize their atmospheric and surface features. A further study on narrow spectral bands is on going.

Acknowledgements

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