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The spectro-photometric variability of the globally-integrated infrared emission of terrestrial planets

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Abstract

The detection of the infrared emission of earth-like planets seems closer day by day, particularly it will become possible with JWST for hot super-earths around K stars and for cooler planets around M stars. Our interest is focused on the characterization of these types of planets with very low spectral resolution observations. We present an analysis of the globally-integrated far-infrared flux using emission maps (longitude, latitude, time) either from satellite observations in the case of the Earth and from 3D atmospherical models in the case of solar system planets or exoplanets. Our model calculates at any time the fraction of the planetary disk exposed to a remote observer and computes the integrated flux to simulate the pointilke signal detected by the observer. We have studied the annual, seasonal and diurnal variability to determine which planetary and atmospheric properties (rotation, temperature, radius, climate, atmospheric composition, ...) can be inferred according to the instrument used (JWST, ELT, Darwin/TPF) and the quality of the signal (time resolution, signal to noise ratio,...).

1 Methods

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 solar system planets and exoplanets (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 of the reflected/emitted radiation of the Earth (Pallé et al, 2003, 2008) and a similar geometric model for exoplanets, taking into account any possible planetary viewing geometries and integrating the disk emitted flux towards the remote observer.

In order to study the intrinsic parameters of the planet, it is useful to construct time folded light curves. In the case of the Earth, because of the large day-to-day variability in the longwave flux, it is useful to make the rotation light curves. This diurnal light curves allows us to minimize the smoothing effect of the clouds over the signal. We have performed the periodicity analysis of the signal in order to determine the rotational period. The duration of the statistically significant peaks in the autocorrelation time series can give us an estimation of the lifetime of the cloud structures, typically of around one week for Earth clouds (Pallé et al, 2008).

2 Figures

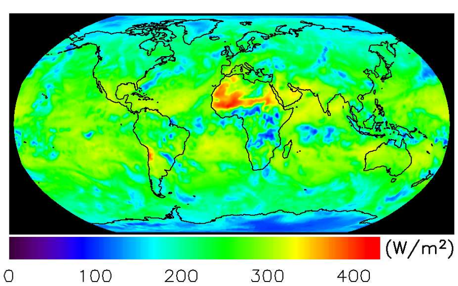

Figure 1: Map of the Earth's outgoing longwave radiation for the 1st of April 2001, averaged over the period 15:00-18:00 hours UT.

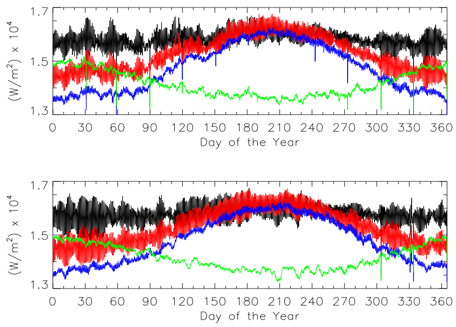

Figure 2: Time series of the emitted longwave flux. From top to bottom, the years of 1987, 2001 for 0, 45, 90 and -90 degrees inclination angles (black, red, blue and green lines respectively).

3 Summary and Conclusions

In the case of the Earth, we have found that the daily variations in longwave emitted radiation have an amplitude of several percent, which is comparable to that of the seasonal variations. It is important to remark, however, the strong influence of the weather patterns in the diurnal variability of the emitted flux, which are sometimes able to completely obscure the 24-hour rotation periodicity signal for several days at a time. We find that the analysis of the time series and light curves allows us to determine the 24-hour rotation period of the planet. The influence of solar illumination does not play a key role on the infrared emission, except for introducing a seasonal variability in the Earth's case due to the inhomogeneous distribution of land masses (Gómez-Leal and Pallé, in prep.).

The study of the combined signal of the Earth/ Moon system, the limb darkening effect and the signal to noise ratio is in progress. The comparison with the 3D Global Circulation Model results will be presented during the congress.We will discuss the relevance of several effects on the signal: atmospheric thickness, density, clouds, the spectral band range of the observations, the distribution of surface features and the instrumental requirements.

References

[1] Pallé, E., et al. 2003. J. Geophys. Res., 108(D22), 4710

[2] Pallé, E., et al. 2008, ApJ, 676, 1319-1329

[3] Gómez-Leal, I., and Pallé, E., The infrared photometric variability of the globally-integrated light emitted from Earth as a planet (in prep.).