EPSC Abstracts
Vol. 8, EPSC2013-245, 2013
European Planetary Science Congress 2013
© Author(s) 2013

Infrared spectroscopy of transiting exoplanets

T. Encrenaz (1), G. Tinetti (2) and A. Coustenis (1)
(1) LESIA, Paris Observatory, France, (2) University College London, UK (therese.encrenaz@obspm.fr)

Abstract

The development of infrared spectroscopy of transiting exoplanets offers a new opportunity for characterizing exoplanetary atmospheres. In this paper, we review the properties of primary and secondary transit observations, and we discuss the expected nature of infrared spectra. Then we select a few objects that appear to be well suited for near-infrared observations.

1. Introduction

The spectroscopic characterization of transiting exoplanets is an exploding field in astronomy. Thanks, in particular, to the highly successful Kepler mission, we now know more than 300 transiting objects [1, 2]. Most of them, however, are too weak for spectroscopic characterization; only less than a dozen have been used for transit spectroscopy. Still, we can anticipate a rapid development of this research field in the coming couple of decades, thanks to expected advances in ground-based instrumentation, to be followed by the launch of JWST and, hopefully, dedicated space missions.

2. Primary and secondary transits

When an exoplanet passes in front of its host star, the event is called a primary transit; when it passes behind the star, it is called a secondary transit. In both cases, the information on the exoplanet's atmosphere is retrieved from the flux difference of the (star + planet) system before and/or after the transit, and during the transit. Most of the results have been obtained on HD209458b and HD189733b, using HST and Spitzer space data [3,4].

2.1 Primary transits

In the case of a primary transit, the area of planetary atmosphere observed in transmission is an annulus around the planet with a radial height of about 5 x H, where H is the scale height [5]. The amplitude of the atmospheric absorption can be estimated as follows:

$A = 1.4\ 10^{-6} \times R_P \times H/R^{*2}$ (1)

where R_P is the planetary radius and R* the stellar radius [6]. In the case of hot Jupiters, the total absorption due to the whole planet is about a percent. The additional absorption A due to the planet's atmosphere is in the range of a few 10^{-4}. A is especially strong for hot, inflated Jupiters. Primary transit observations probe the exoplanet at terminator. They give information upon the column densities of planetary species, which are always observed through absorption spectroscopic features.

2.2 Secondary transits

Secondary transits allow us to measure a direct emission spectrum of the dayside of the exoplanet. Its detectability is a function of the [Planet/Star] flux ratio. Over a broad visible/NIR range, it can be approximated using Stefan's law:

$\rho = [R_P^2/R^{*2}] * [T_e^4/T^{*4}]$ (2)

T* is the effective temperature of the star. Te is the equilibrium temperature of the planet which can be calculated by the following equation, assuming a slow-rotation, tidally locked planet [6]:

$T_e = (1 - a)^{0.25} \times 331.0\ [T^*/5770.0] \times (R^*)^{0.5} / D^{0.5}$(3)

An assumption has to be made on the albedo a. we assume a = 0.03 (Rayleigh or Mie scattering) in the case of hot giant exoplanets, and a=0.3 for temperate exoplanets (clouds/ surface).

In contrast with primary transits, molecular signatures of secondary transit spectra can appear in emission or in absorption, depending upon the gradient of the temperature profile. Their interpretation is thus more complex, as it requires the simultaneous retrieval of the temperature vertical distribution.

2. The infrared spectrum of an exoplanet

In order to analyse an exoplanet's infrared spectrum, it is essential to know which regime dominates, the stellar reflected light (which peaks in the visible range) or the thermal emission (which dominates at longer wavelengths). Figure 1 shows the two expected components in the case of a warm small exoplanet, GJ 1214b, assuming two possible values of the albedo, a = 0.3 and a = 0.03. It can be seen that the crossover between the two components lies between 2 and 4 μm, depending on the albedo.

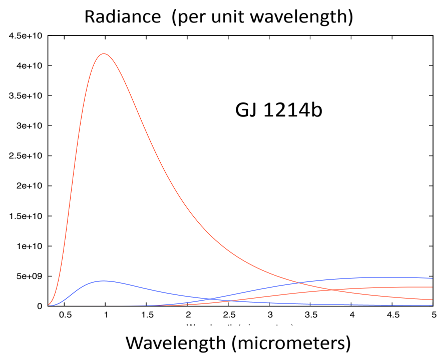

Figure 1: The reflected and thermal components of GJ 1214b, assuming two values of the albedo: a = 0.03 (T_e = 651 K, blue) and a = 0.3 (T_e = 600 K, red). The figure is taken from [6]

3. Which targets for ground-based near infrared spectroscopy?

Table 1 shows a list of exoplanets, listed as a function of increasing V magnitude of their host star, for which the A and ρ values calculated by Equations (1) and (2) are especially high. The V magnitude ranking is chosen because objects around bright host stars are expected to give the best signal to noise data. Values of A and ρ are highlighted in red for the most favourable targets. Wasp-33b is a very hot and massive object, well suited for secondary transits. HAT-P1b, Wasp-34b and Wasp-13b are hot, inflated objects, best suited for primary transits. Wasp-48b, Wasp-17b and Wasp-12b are good targets for both kinds of transits. HD149026b is kept in the list of favourable hot Jupiters, although its A and ρ values are not especially high, because its host star is relatively bright. HAT-P26b is a hot Neptune well suited for primary transits. The small exoplanet GJ 1214b (Figure 1) is an interesting case, with high expected values of A and ρ, mostly due to the very small size of its host star, a M-dwarf. However, its faintness (V >14) will make its observation difficult. In the case of the small exoplanet CoRoT-7b, very close to its star, a stable atmosphere is not expected, except possibly silicate haze or noble gases.

Exoplanet	V	M_P (jovian mass)	R_P (jovian radius)	T_e (K)	R* (solar radius)	T* (K)	A (10^{-4})	ρ1 (10^{-4})
Hot Jupiters								
HD209458b	7.65	0.714	1.380	1702	1.146	6075	9.2	3.2
HD189733b	7.67	1.138	1.178	1422	0.788	4980	6.4	5.2
HD149026b	8.15	0.356	0.718	2071	1.497	6147	1.8	0.87
Wasp-33b	8.30	4.590	1.438	3170	1.444	7400	1.9	7.7
HAT-P1b	10.40	0.524	1.217	1529	1.115	5975	8.2	2.0
Wasp-34b	10.40	0.590	1.220	1369	0.930	5700	9.4	2.4
Wasp-13b	10.42	0.460	1.210	1447	1.000	5826	11.0	1.8
Wasp-48b	11.06	0.980	1.670	1921	1.090	6570	15.0	7.7
Wasp-17	11.60	0.486	1.991	1963	1.380	6650	32.0	5.4
Hot/warm Neptunes								
HAT-P11b	9.59	0.081	0.452	1025	0.750	4780	1.3	0.35
GJ 436b	10.68	0.074	0.365	842	0.464	3864	5.0	0.62
HAT-P26b	11.74	0.059	0.565	1174	0.788	5090	11.0	0.47
Small Exos								
55CnCe	5.95	0.027	0.190	2122	0.943	5196	1.2	0.27
HD97658b	6.27	0.020	0.262	814	0.730	5170	2.6	0.05
CoRoT-7b	11.70	0.015	0.150	1971	0.870	5275	11.0	0.15
GJ 1214b	14.70	0.020	0.245	600	0.210	2949	19.0	1.2

Table 1: Favourable targets for transit observations[6]

References

[1] Batalha, N. M., et al.. *Astrophys. J. Supp.* **204**, id.24, 21 pp., 2013

[2] Schneider, J., Deldieu, C., Le Sidaner, P., Savalle, R., Zolotukhin, Z. The exoplanet.eu database. *Astron. Astrophys*. 532, A79, doi: 10.1051/0004-63361/201116713, 2012

[3] Perryman, M. *The Exoplanet Handbook*. Cambridge University Press, 2011.

[4] Tinetti, G., Encrenaz, T., Coustenis, A. *Astron. Astrophys. Rev*, in press, 2013.

[5] Seager, S., Deming, D., Valenti, J. A. in *Astrophysics of the New Decade: JWST and concurrent facilities*. Astrophysics and Space Science Library, Springer Netherlands, p. 123-145, 2009.

[6] Encrenaz T, *Phil.Trans. Royal Soc. A*, in press, 2013.