syntos: A theoretical model of star and exoplanet emission spectra

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This project has been founded by Novo Nordisk Foundation Interdisciplinary Synergy Programme, grant no. NNF19OC0057374

The input model

A 1D, plane-parallel, atmospheric model from **MARCS** is used in this preliminary study:

- ▷ Local Thermodynamic Equilibrium (LTE)
- ▷ Radiative Equilibrium
- ▷ Mixing Length Theory for convection
- ▷ Equilibrium chemistry (calculations provided by the software **GGChem** (2))

Opacity sources

Continuum opacity sources: H_I, H^-, H_2^-, H^+_2, He_I, He^-, C_I, C_{II}, C^-, N_I, N_{II}, N^-, O_I, O_{II}, O^-, Mg_I, Mg_{II}, Al_I, Al_{II}, Si_I, Si_{II}, Ca_I, Ca_{II}, Fe_I, Fe_{II}, CH, OH, CO^-, H_2O^-. For more details see Tab.1 in (1).

Line opacity sources: AlCl, AlF, AlH, AlO, BeH, C_2, CaF, CaH, CH, CH_4, CN, CO, CO_2, CP, CrH, CS, FeH, H_2CO, H_2O, HCN, KCl, KF, LiCl, LiF, LiH, MgH, NaCl, NaF, NaH, NH, NH_3, NO, SN, OH, PH_3, PN, PO, PS, SiH, SiO, SiS, HS, SO_2, TiH, TiO, VO

Clouds

The cloud distribution and opacity contribution in this preliminary study is provided the **Static Weather** software (mineral clouds, homogeneous nucleation, growth and evaporation of heterogeneous dust grains, element conservation) (3).

What is syntos?

syntos is a theoretical model of star and exoplanet emission spectra, based on the Model Atmospheres in Radiative and Convective Scheme (**MARCS**) framework (1). **Syntos** takes as input a **MARCS** atmospheric model; it solves the radiative transfer equation (RTE) for the given atmospheric structure and opacity sources and outputs a high resolution synthetic spectrum (up to $R = \lambda/\Delta\lambda = 20000$) in any desired wavelength range between $0.125\mu m - 25\mu m$.
syntos allows for the simultaneous calculation of up to 15 synthetic spectra and it can show the specific contribution to the spectrum of a single chemical species, or a subset of chemical species present in the input model atmosphere.

How does it work?

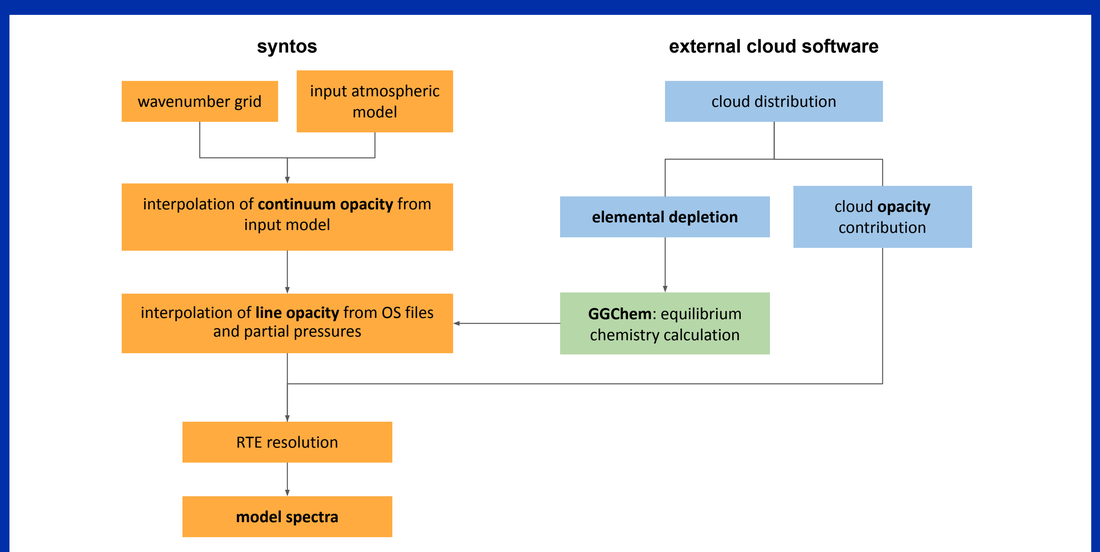

Figure: Scheme of **syntos** workflow. The main steps of the spectrum calculation are shown.

Preliminary Results

In this preliminary study I present the synthetic spectrum of a L-dwarf-like object at 1500K in the bandbass of JWST-NIRISS ($0.8 - 5.0\mu m$), at a resolution $R = \lambda/\Delta\lambda = 15000$). The black spectrum is given by all molecular contributions together, the colored lines are the specific contributions of single relevant molecules to the spectrum: H_2O, CH_4, CO, TiO, CO_2, HCN.

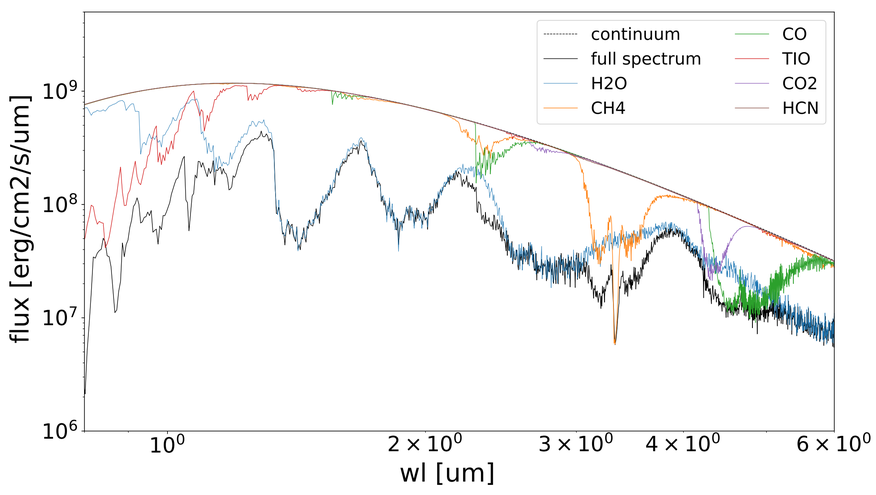

Figure: Synthetic spectrum of a brown-dwarf at 1500K in the bandbass of JWST-NIRISS. The full spectrum is in black, the colored lines are the specific contributions of single relevant molecules to the spectrum.

State of the art

At the moment, the implementation of the RTE in **syntos** is lacking any external irradiation or the presence of a planetary surface. Therefore **syntos** can only model objects without a surface and that receive a negligible amount of irradiation, such as isolated brown dwarfs and free floating planets.

Future implementation

The ultimate goal of my project is to model Earth-like atmospheres. The following inclusions to **syntos** are needed:

- ▷ External irradiation and presence of a surface in the RTE calculation
- ▷ Non-mineral clouds, that form under physical conditions compatible with an Earth-like atmosphere

References

(1) Gustafsson, B. et al. 2008, A&A, 486, 951
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