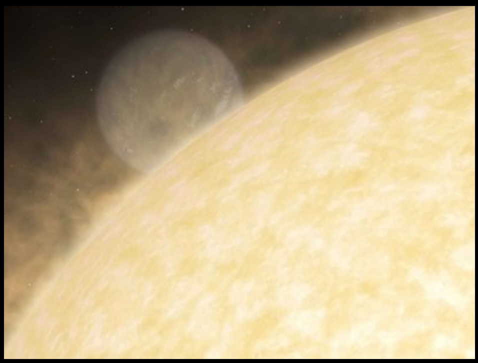
Atmospheres of stars and exoplanets



SUMMARY.
The largest information content from astrophysical objects comes from their spectra. Particularly, stellar and exoplanet spectra allow us to measure stellar and exoplanet atmospheres' thermal, chemical and dynamical properties. We will first learn the fundamental physical processes that shape stellar and planetary atmospheres' temperature and chemical structure. Then we will learn how to extract physical and chemical information about the atmospheres of stars and exoplanets based on ground and space-based observations of their spectra.

OBJECTIVES

- Learn the physical principles determining the thermal and chemical properties of stellar and planetary atmospheres.
- Learn what physical ingredients determine the atmospheric spectra of stars and exoplanet atmospheres and how to retrieve them from observations.
- Learn how to use numerical codes to calculate the thermal structure and spectra of stellar and planetary atmospheres and how to compare them to space-based (JWST) and ground-based telescope observations.

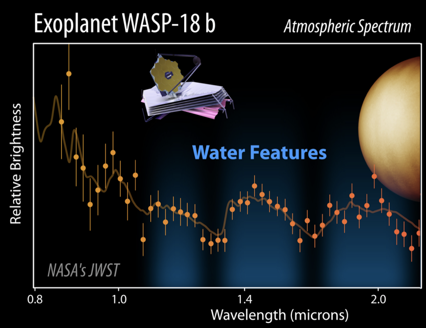
PREREQUISITES

Stellar Physics course (S2)

THEORY

by PARMENTIER & CHIAVASSA

- Radiative/convective equilibrium
- Equilibrium and disequilibrium chemistry
- Opacity
- Formation of emission and transmission spectra for exoplanets and stars
- Confounding factors (stellar contamination, 3D effects, instrumental effects)



APPLICATIONS

by PARMENTIER & CHIAVASSA

The students will learn how to use two different codes:

- scCHIMERA is a 1D radiative transfer code that calculates the radiative/convective/chemical equilibrium solution for an irradiated exoplanet together with its emission and transmission spectra as observable by the James Webb Space Telescope.
- OPTIM3D is a 3D radiative transfer code that calculates the high spectral resolution spectra of stellar convection simulations taken from the 3D stellar atmospheric grid STAGGER-grid.

Then the students will pick a project with a focus on exoplanet or stellar spectra:

- ◇ *The JWST emission spectra of WASP-18b.* The students will study the ultra-hot Jupiter WASP-18b. They will obtain the JWST emission spectrum of the planet from the literature and model it with the scCHIMERA code. The students will explore the possible parameters that can reproduce the observations such as metallicity, carbon-to-oxygen ratio, and presence of an optical absorber and determine which values of these parameters best explain the spectrum.
- ◇ *The JWST transmission spectra of WASP-39b.* The students will study the hot-Saturn WASP-39b. They will obtain the JWST transmission spectrum of the planet from the literature and model it with the scCHIMERA code. The students will vary the temperature, molecular abundances, and cloud coverage of the atmosphere to find the best match for the spectra.
- ◇ *Stellar atmospheres in 3D.* The students will study the 3D structure of stellar atmospheres as a function of different stellar parameters (effective temperature, gravity, and metallicity). The students will make use of OPTIM3D

to calculate the spectra from the 3D stellar model Stagger-code to explore the impact on spectral line formation (shape, position, width) at different resolving powers as a function of temporal variation due to convective-related movements and it's influence on the interpretation of transiting exoplanet spectra.

MAIN PROGRESSION STEPS

- First half of the period: theoretical courses.
- Second half of the period: numerical project.
- Last week: preparation of the final oral presentation.

EVALUATION

- Written exam based on the theoretical lectures (30%), typically in the 3rd or 4th week.
- Mark from the supervisors (30%), based on our interactions during the METEOR. The gradewill be related to the rigorous attitude, active participation and autonomy of the student.
- Final presentation of the individual projects (40%)

BIBLIOGRAPHY & RESSOURCES

WASP-39b JWST observation
WASP-18b JWST observation
Exemple of OPTIM3D code.
The STAGGER-grid

CONTACT

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