Exoplanets Group Study 2025/26: Resources List & Useful Notes

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List of external resources and papers

Sub-Neptune exoplanets and trends in their atmospheres

Review paper on sub-Neptune exoplanets:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020JE006639

Observed cloud/haze trends in (sub-)Neptune exoplanet atmospheres:
https://iopscience.iop.org/article/10.3847/2041-8213/ad1b5c/pdf

Metric to determine best targets for JWST observations:
https://iopscience.iop.org/article/10.1088/1538-3873/aadf6f/pdf

Sample selection in exoplanet atmosphere population studies:
https://iopscience.iop.org/article/10.3847/1538-3881/ac9f45/pdf

Modelling exoplanet transmission spectra

Modelling exoplanet atmosphere transmission spectra (see Sections 2.1.2-2.1.4):
https://arxiv.org/pdf/1808.10017

DACE online opacity tool: https://dace.unige.ch/opacity/

Textbook on exoplanet atmospheres (available from the main library):
https://birmingham.primo.exlibrisgroup.com/permalink/44BIR_INST/jmfpgg/alma990028742260204871

Simulating JWST data

PandExo tool for simulating JWST data (paper):
https://iopscience.iop.org/article/10.1088/1538-3873/aa65b0/pdf

Online PandExo tool: https://exoctk.stsci.edu/pandexo/

JWST Pocket Guide:
https://www.stsci.edu/files/live/sites/www/files/home/jwst/instrumentation/_documents/jwst-pocket-guide.pdf

<u>Notes on JWST</u>

JWST has four instruments:

- NIRISS (Near-Infrared Imager and Slitless Spectrograph)
- NIRSpec (Near-Infrared Spectrograph)
- NIRCam (Near-Infrared Camera)
- MIRI (Mid-Infrared Instrument)

Each instrument has different modes, which can have different wavelength ranges and spectral resolutions.

Spectral resolution is often described by the 'R' number, where R = $\lambda/\Delta\lambda$. For this project, you won't need particularly high resolution. However, higher-resolution modes can be useful when observing bright stars as they can avoid saturation (light from the star is spread out more). Saturation makes the observations unusable and can also damage the detector.

For this project, NIRISS, NIRSpec and/or NIRCam will be most appropriate given their wavelength ranges. The following modes are used for exoplanet atmospheres:

- NIRISS: Single Object Slitless Spectroscopy (SOSS) mode, 0.6-2.8 microns
- NIRSpec: Bright Object Time Series (BOTS) mode. There are different grism/filter combinations available, and the most used for exoplanets are G235M/H (1.66 – 3.17 microns) and G395M/H (2.87 – 5.27 microns). M vs H refers to medium (R=1000) vs high (R=2700) spectral resolution.
- NIRCam: Grism Time Series. The most commonly-used filters used are F322W2 (2.7 – 4 microns) and F444W (4 – 5 microns).

See the JWST Pocket Guidebook and the PandExo online tool (linked above) for more information.

Notes on calculating equilibrium temperature

Step 1: Start with the Energy Balance

The planet absorbs energy from its star and emits thermal radiation. At equilibrium:

Energy absorbed = Energy emitted

Step 2: Energy Absorbed

The stellar flux at the planet's orbit is:

$$F_s = L_s/(4\pi a^2)$$

where:

- $L_s = 4\pi R_s^2 \sigma T_s^4$ is the star's luminosity, R_s is its radius and T_s is its temperature
- a is the semi-major axis (distance from the star)
- σ is the Stefan–Boltzmann constant

The planet intercepts a cross-sectional area πR_p^2 and reflects some light depending on its Bond albedo, A. For reference, Earth's Bond albedo is 0.3.

Absorbed power = $(1 - A) \times \pi R_p^2 \times F_s$

Step 3: Energy Emitted

The planet radiates as a blackbody over its entire surface area $4\pi R_p^2$:

Emitted power = $4\pi R_p^2 \sigma T_{\mathrm{eq}}^4$

Step 4: Combine and Solve

Set absorbed = emitted:

$$\frac{(1 - A) 4\pi R_s^2 \sigma T_s^4}{4\pi a^2} = 4\sigma T_{\mathrm{eq}}^4$$

Simplify:

$$T_{eq} = (1 - A)^{1/4} \times \sqrt{\frac{R_s}{2a}} \times T_s$$