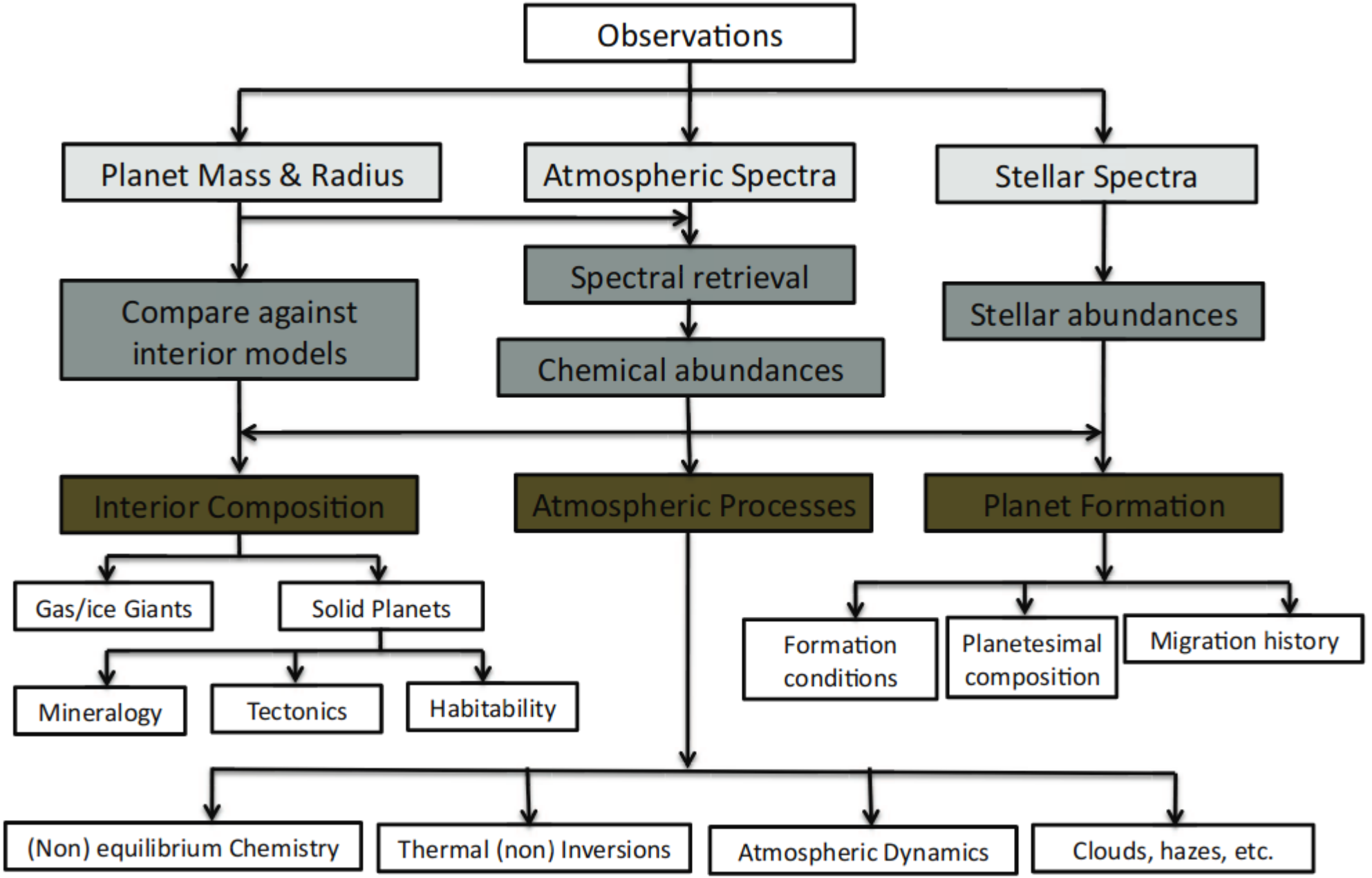
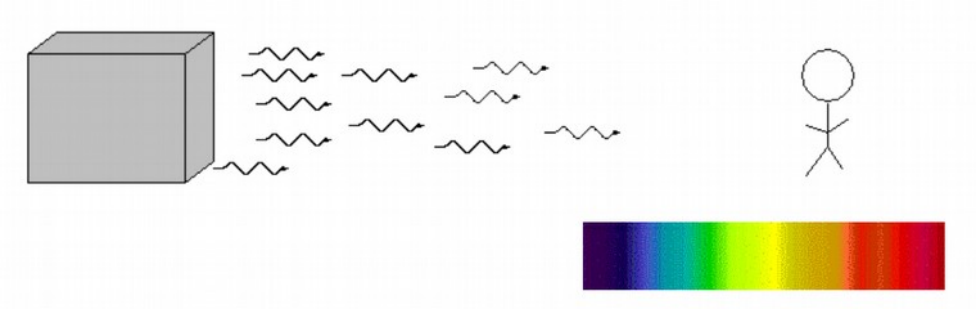
Exoplanet characterization and evolution

Exoplanet characterization

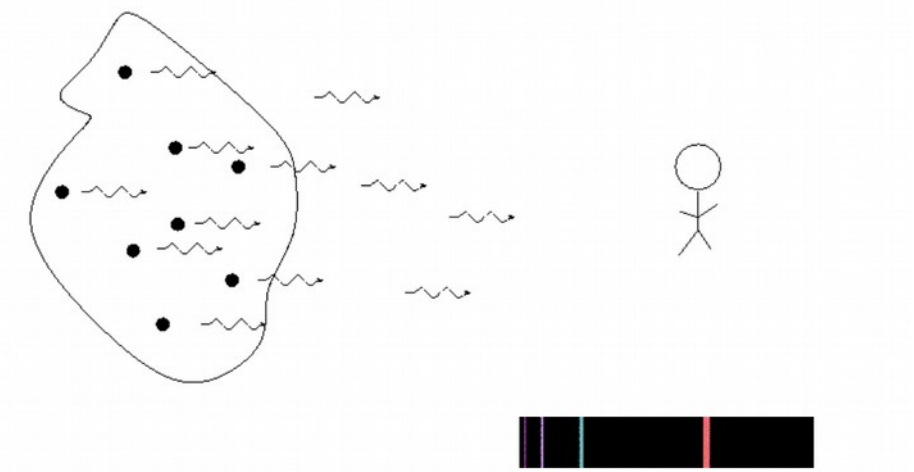


Madhusudan et al. 2013

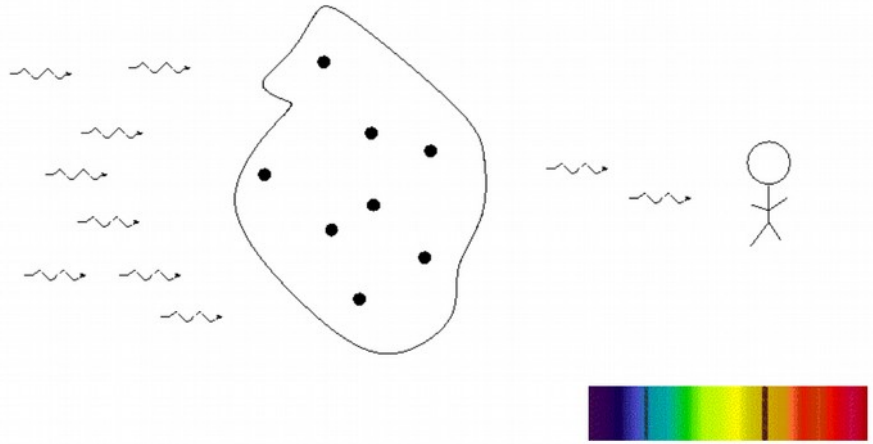
Reminder: types of spectra



dense:
blackbody



thin, warm/hot:
emission lines



thin, in front of light source:
absorption lines

M. Richmond, RIT

Atmospheres: transmission spectroscopy

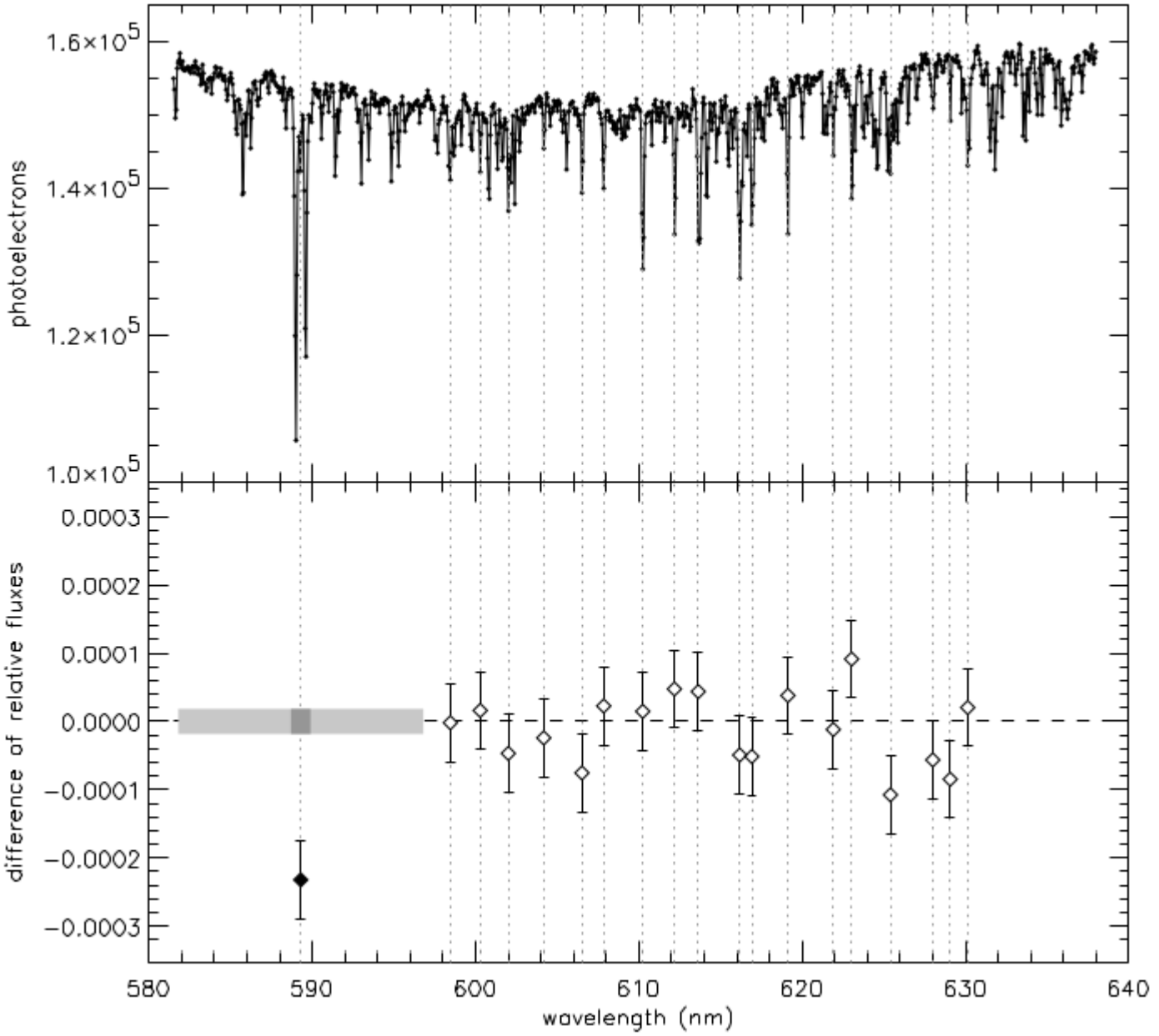
Observe:

Spectrum during transit, spectrum out of transit

Subtract or divide spectra by each other.

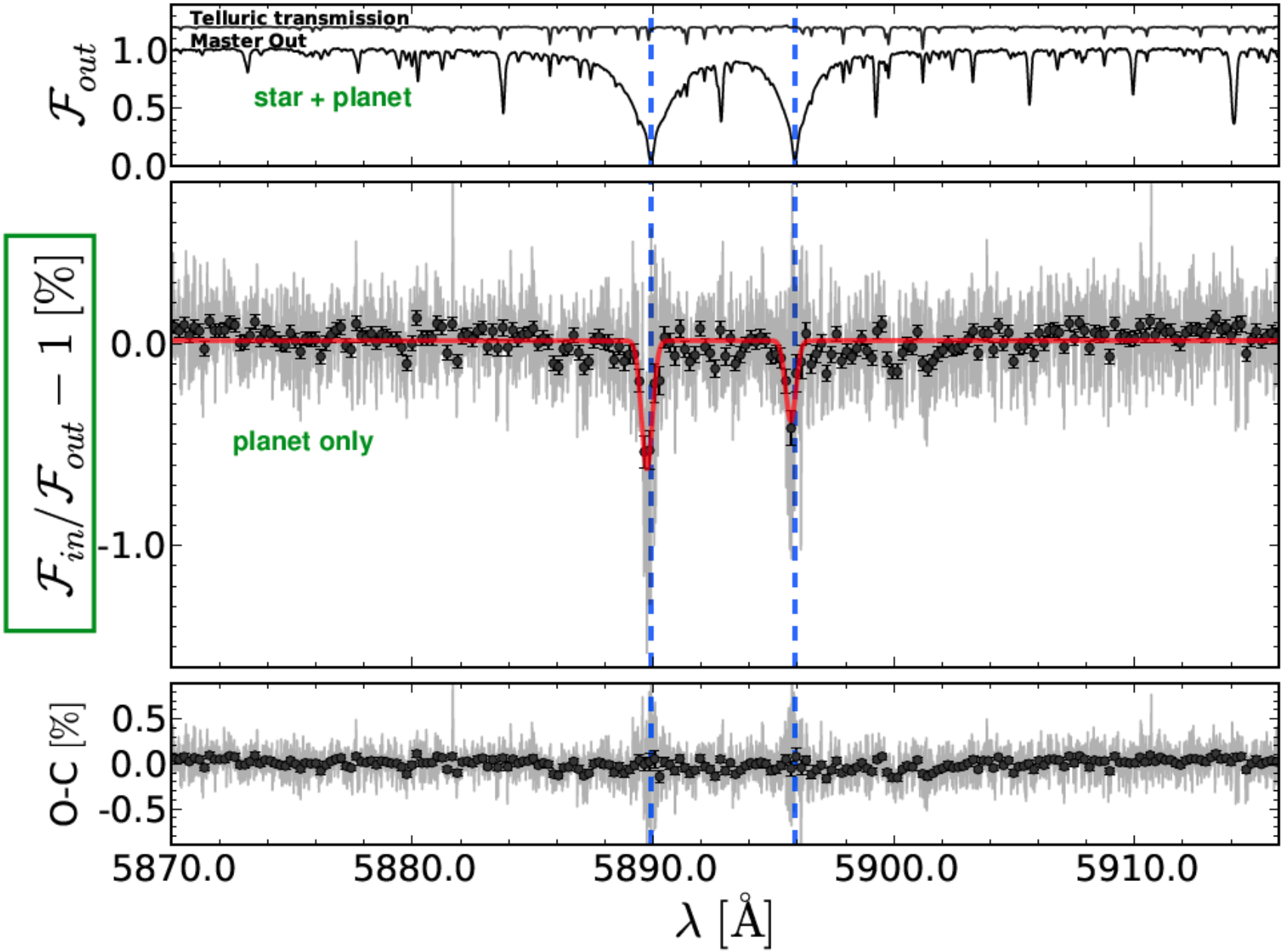
Relative measurement, no absolute flux measurement. But spectral lines corresponding to absorbers in the planet's atmosphere will be deeper.

Atmospheres: transmission spectroscopy



Charbonneau et al. 2002

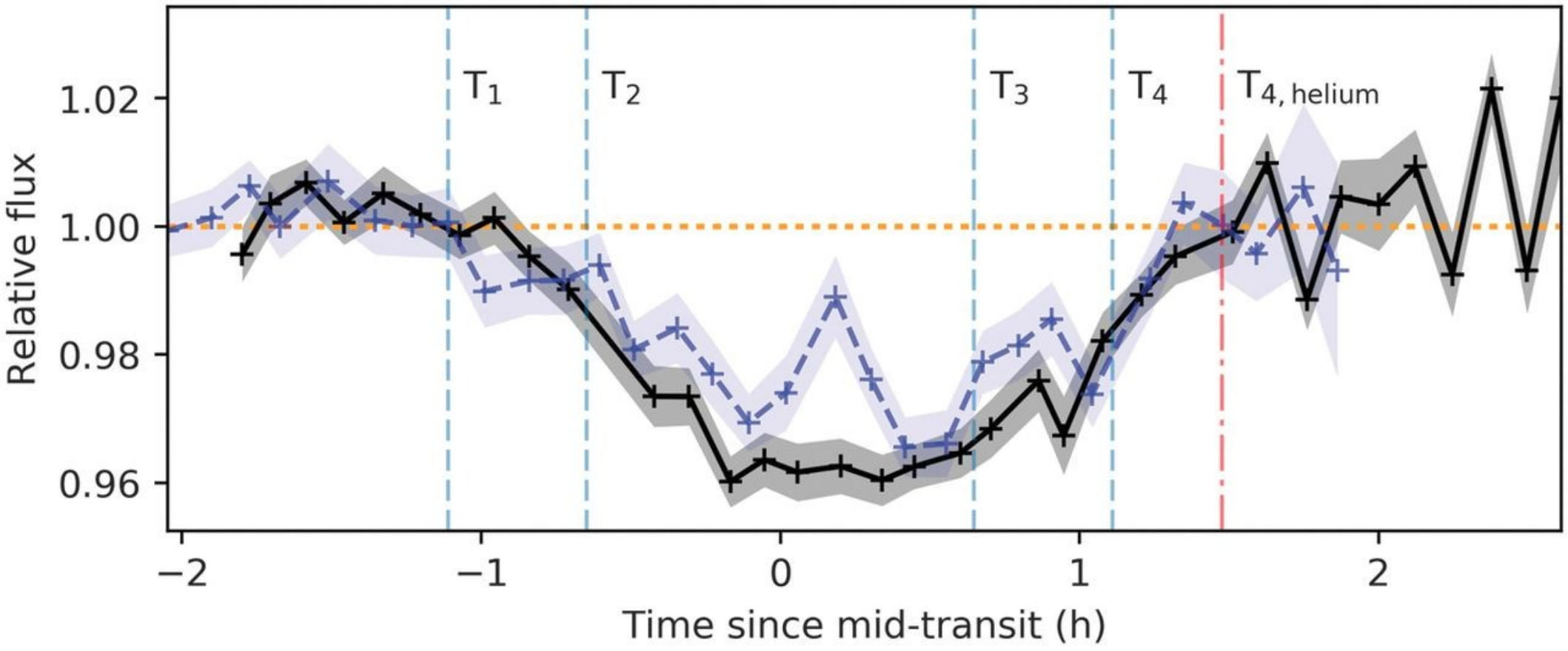
Atmospheres: transmission spectroscopy



Wyttenbach et al. 2015

Atmospheres: transmission spectroscopy

Measures **excess absorption** compared to a spectrally flat (“grey”) transit that reduces the flux by the same fraction everywhere in the spectrum.



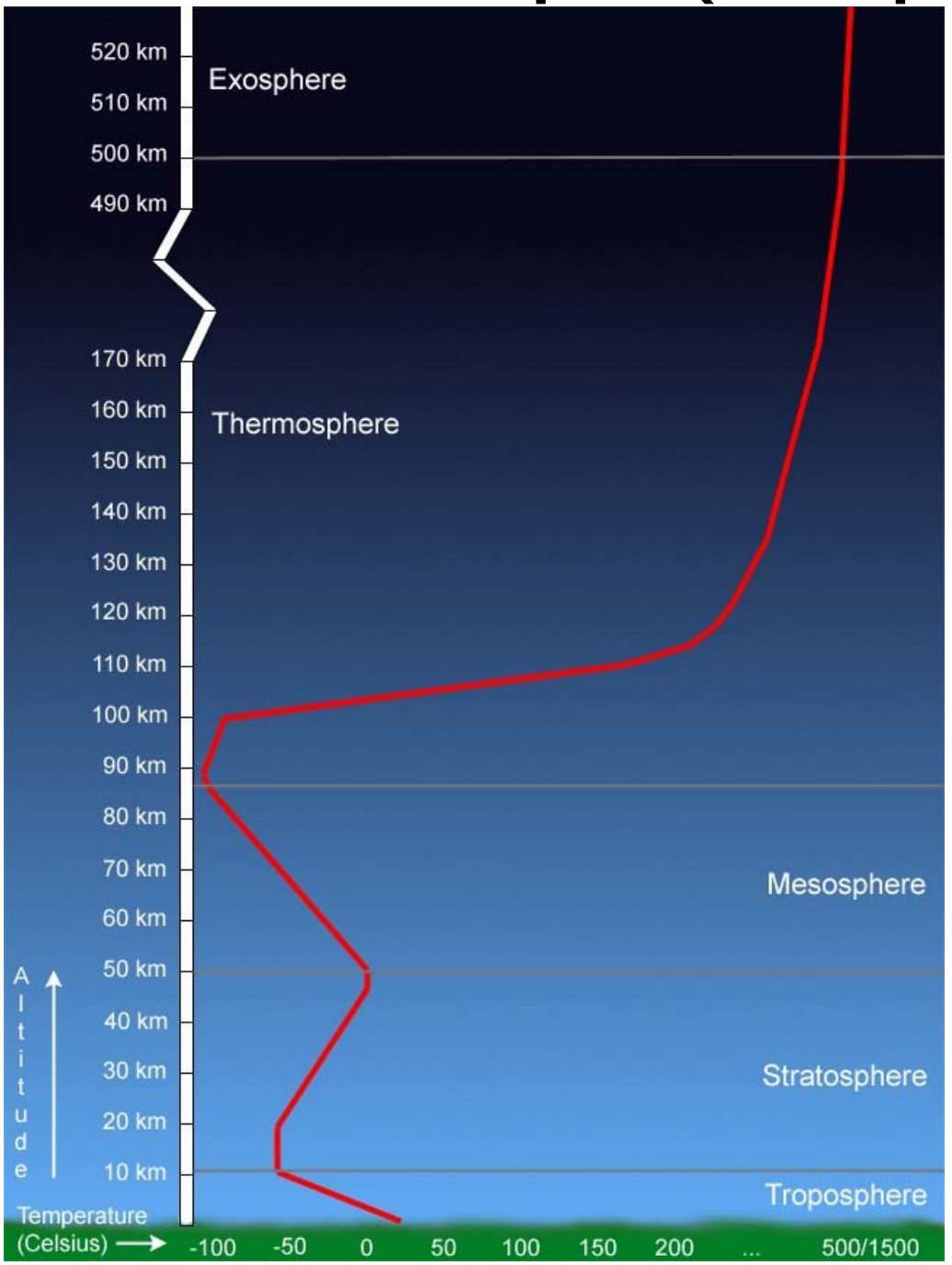
Nortmann et al. 2018

Atmospheric escape (evaporation)

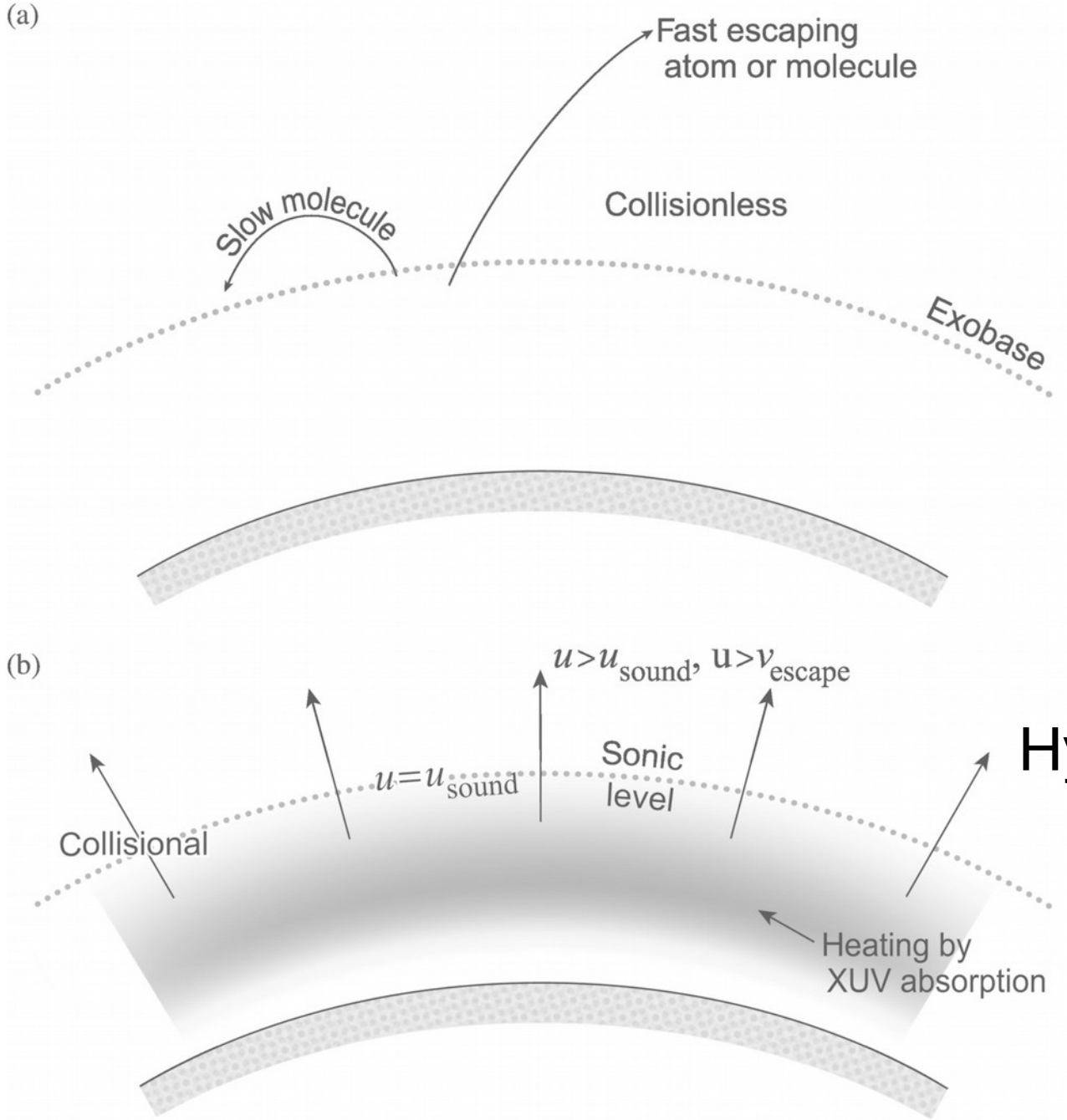
Hot planets with gaseous atmospheres: can they evaporate?

Calculation example: Jeans escape.

Atmospheric escape (evaporation)



Atmospheric escape (evaporation)

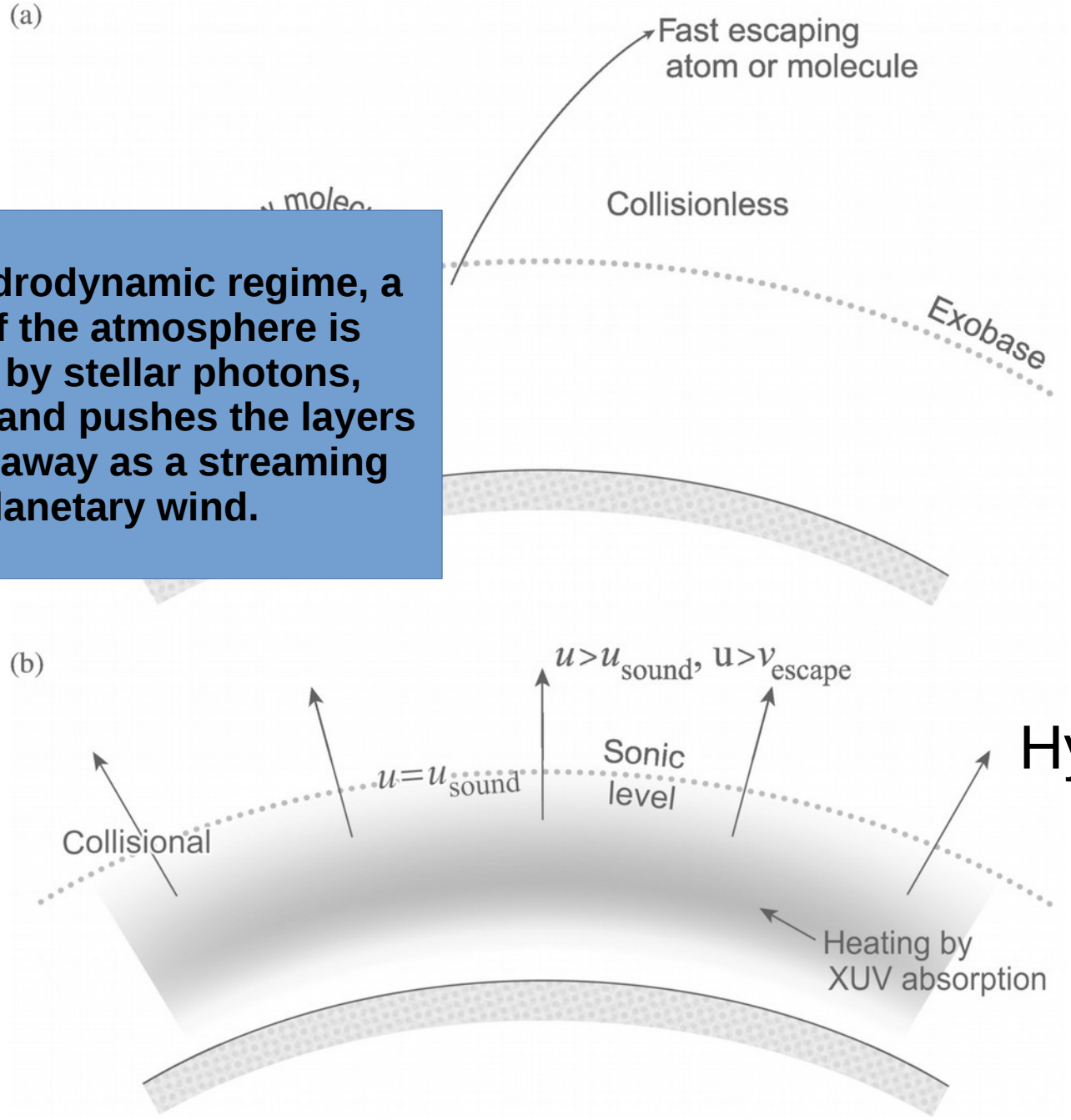


Jeans

Hydrodynamic

Catling & Kasting 2017

Atmospheric escape (evaporation)



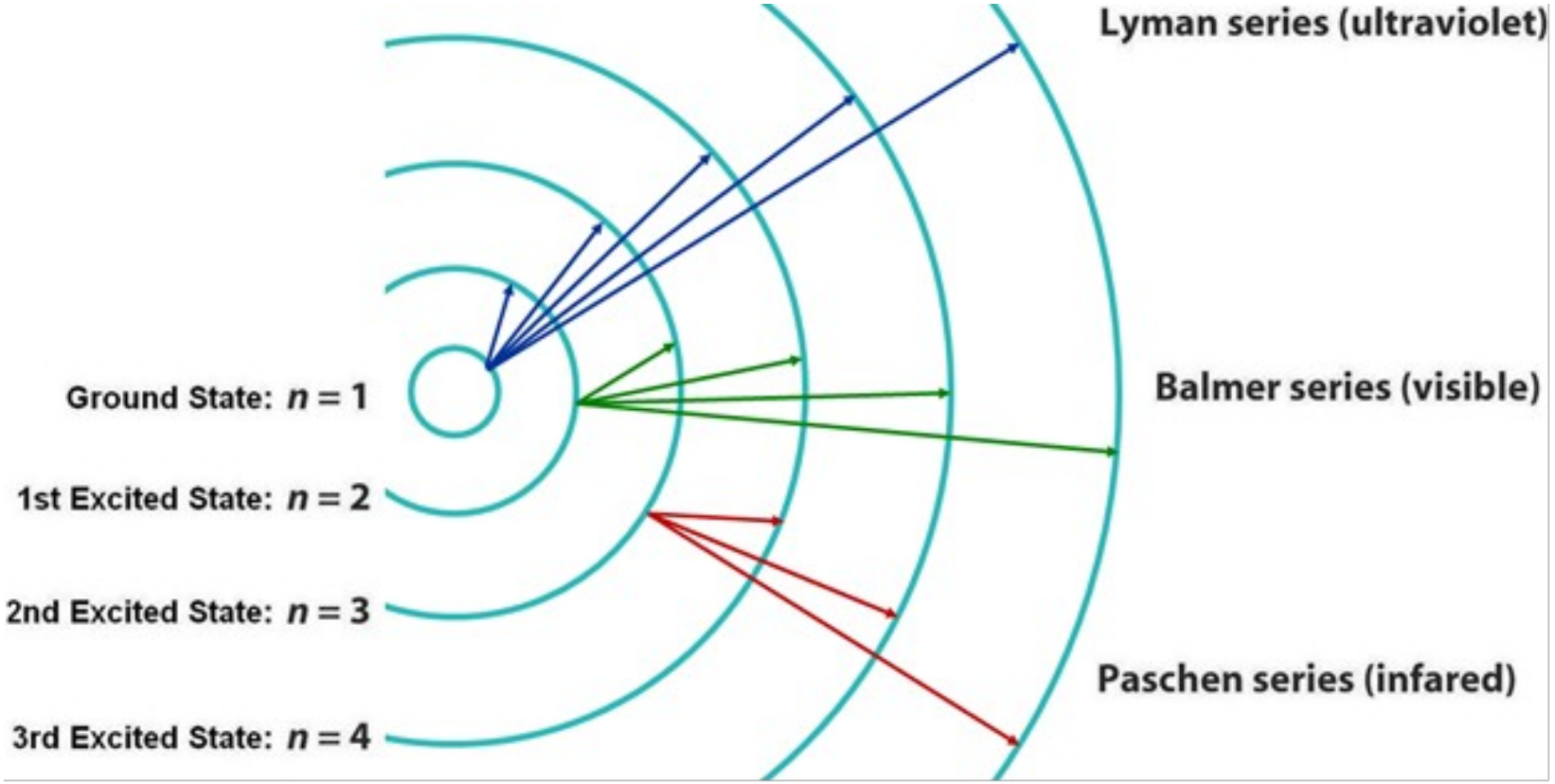
Jeans

Hydrodynamic

In the hydrodynamic regime, a layer of the atmosphere is heated by stellar photons, expands, and pushes the layers above it away as a streaming planetary wind.

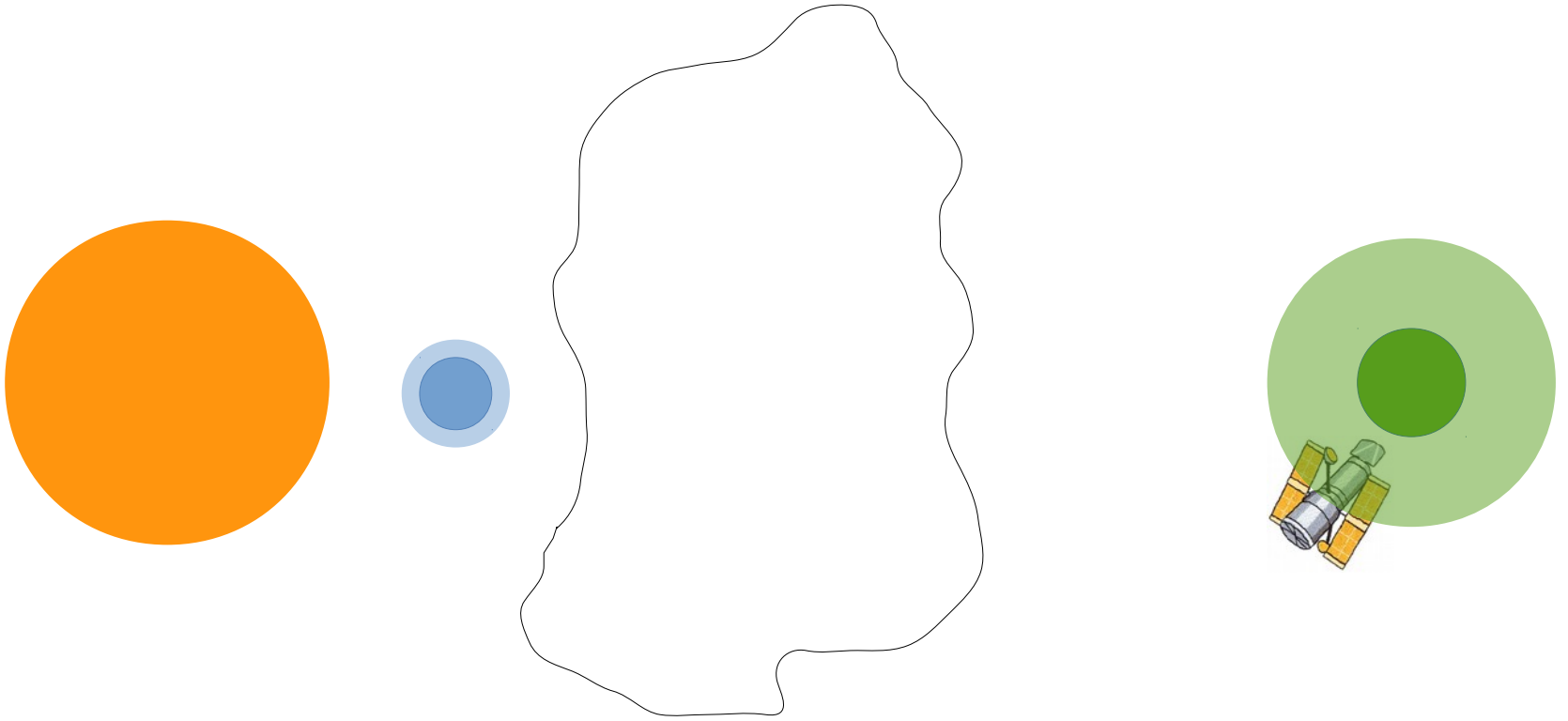
Catling & Kasting 2017

Atmospheric escape (evaporation)



Hydrogen Lyman-alpha line:
1216 Angstrom (121.6 nm), UV

Atmospheric escape (evaporation)



star planet interstellar medium (not to scale:) geocorona, space telescope

Atmospheric escape (evaporation)

Apollo UV image of earth: geocorona
Hubble orbit (height ca. 500 km) within geocorona

Atmospheric escape (evaporation)

What should a hydrogen Ly-alpha transit of a planet look like?

- stellar line profile

- absorption by planet

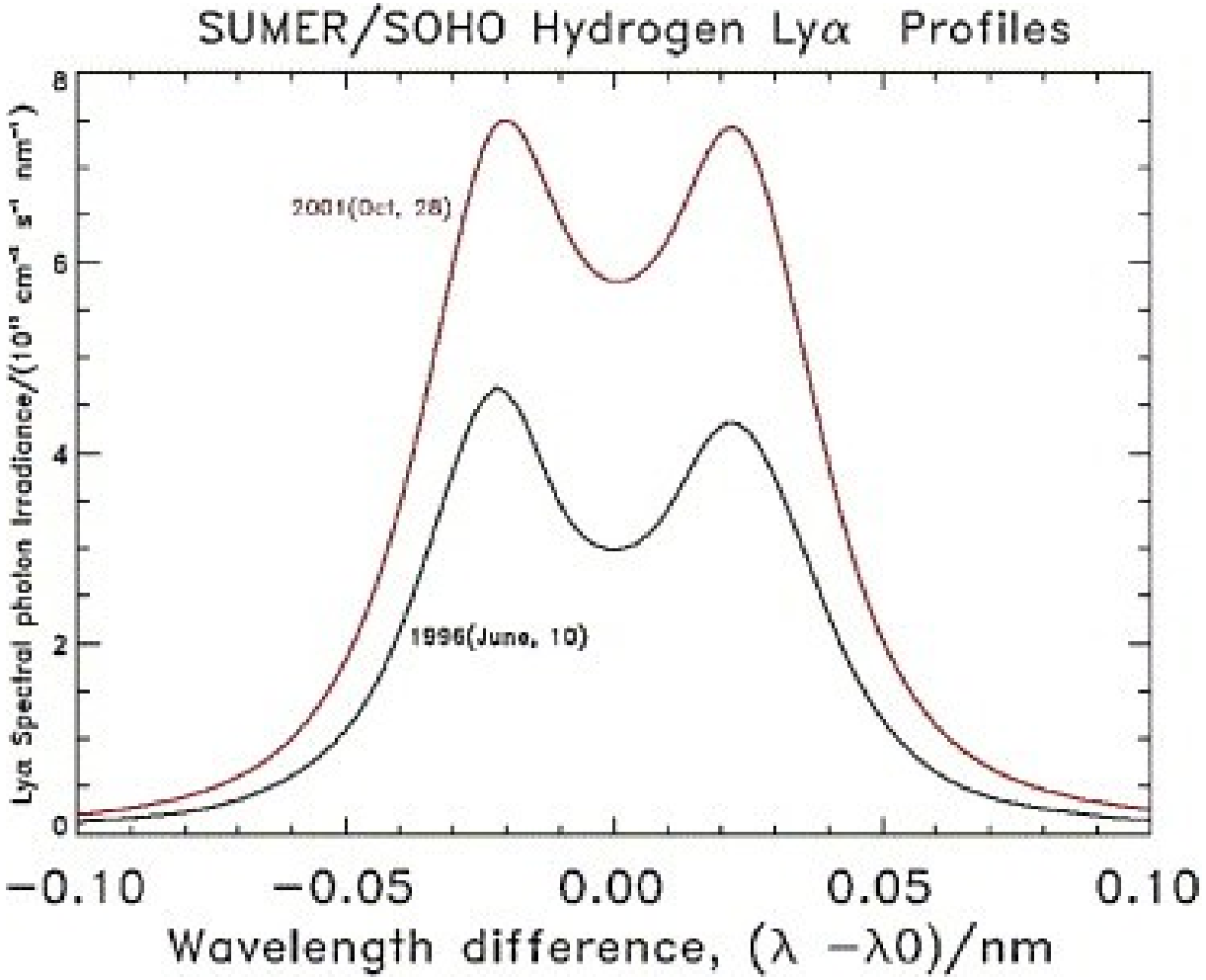
- absorption by ISM (hydrogen and deuterium)

- emission of geocorona

- instrumental profile of telescope

Atmospheric escape (evaporation)

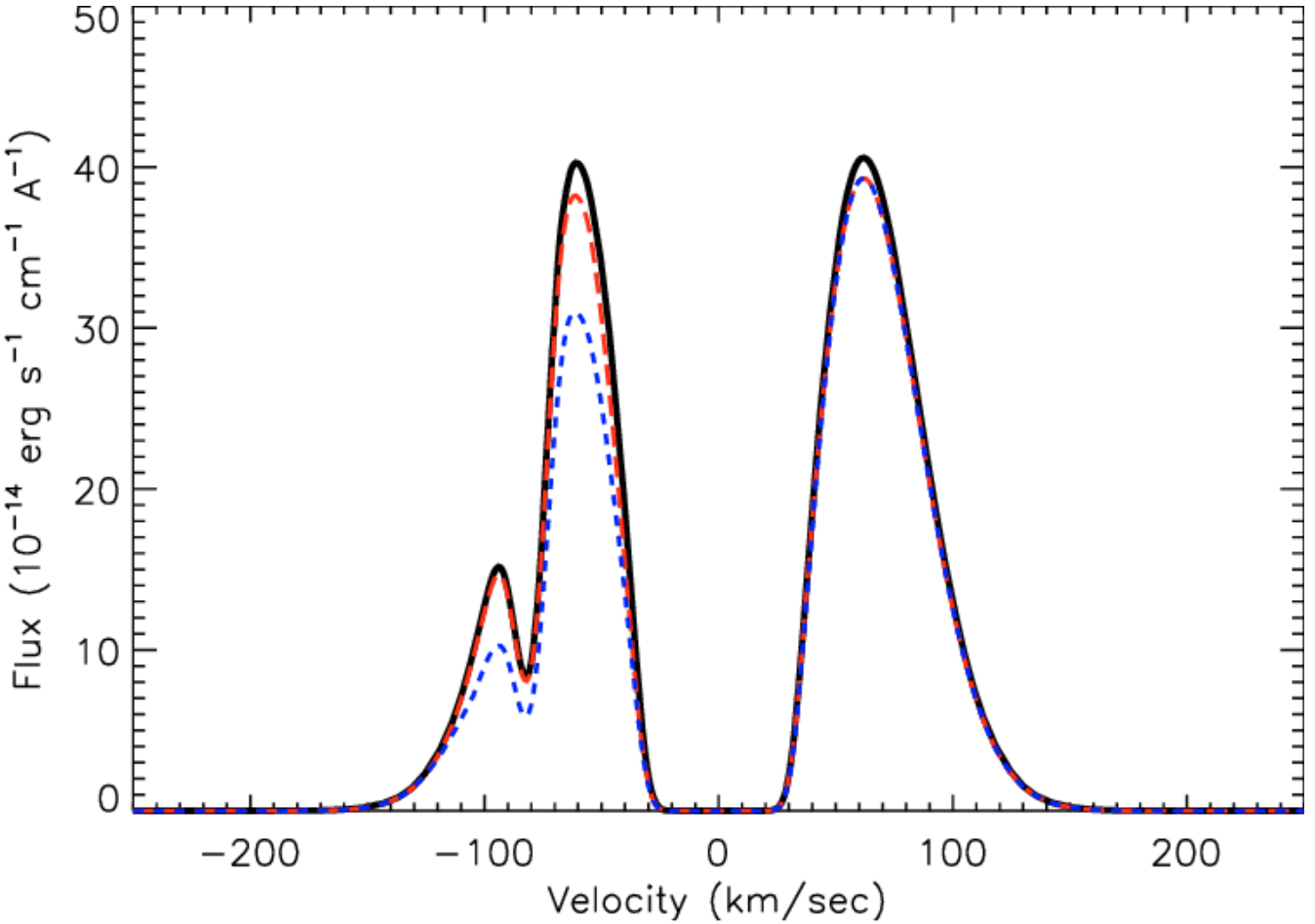
Stellar line (take Sun as example):



Emerich et al. 2005

Atmospheric escape (evaporation)

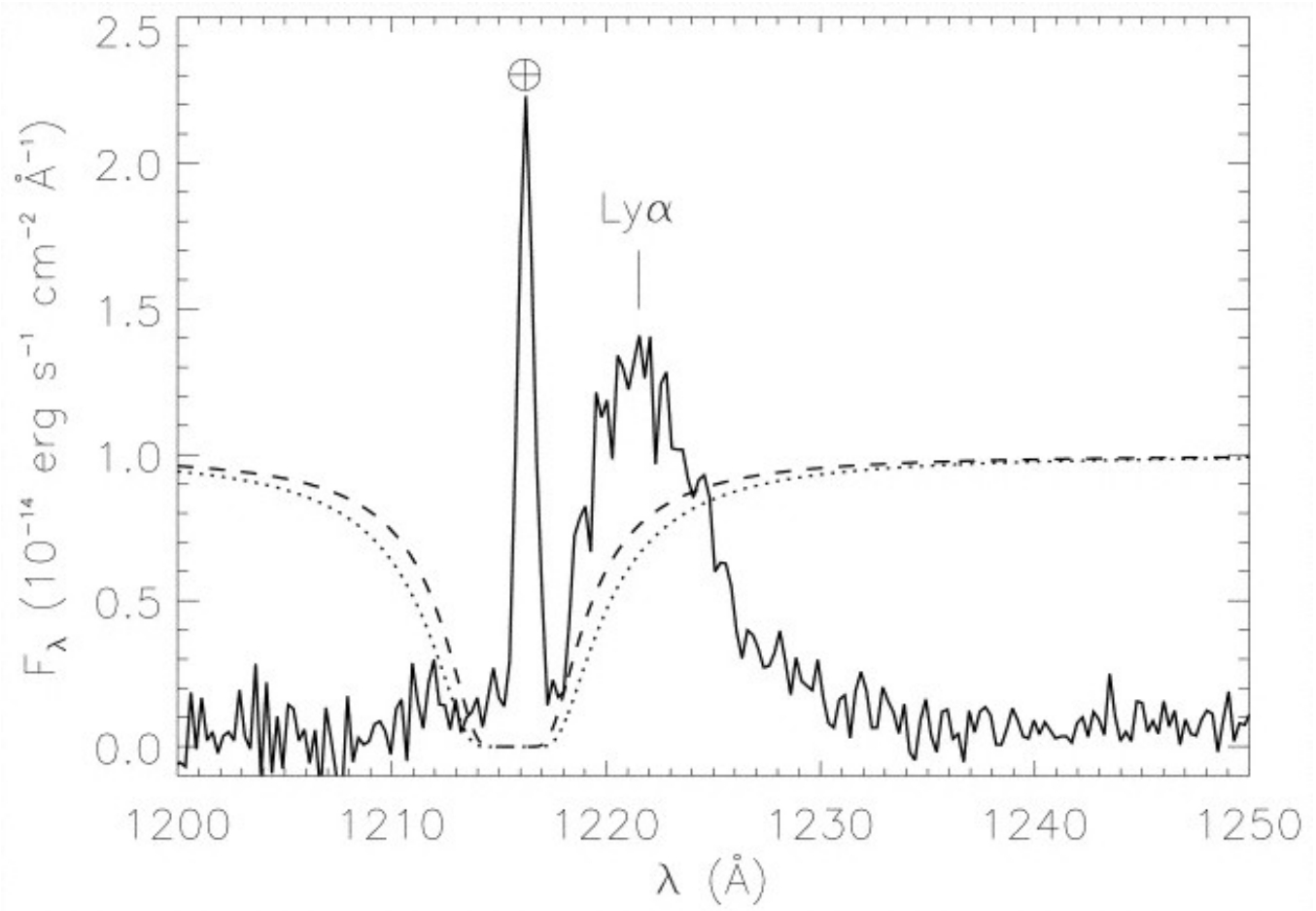
ISM absorption:



Lecavelier des Etangs et al. 2010

Atmospheric escape (evaporation)

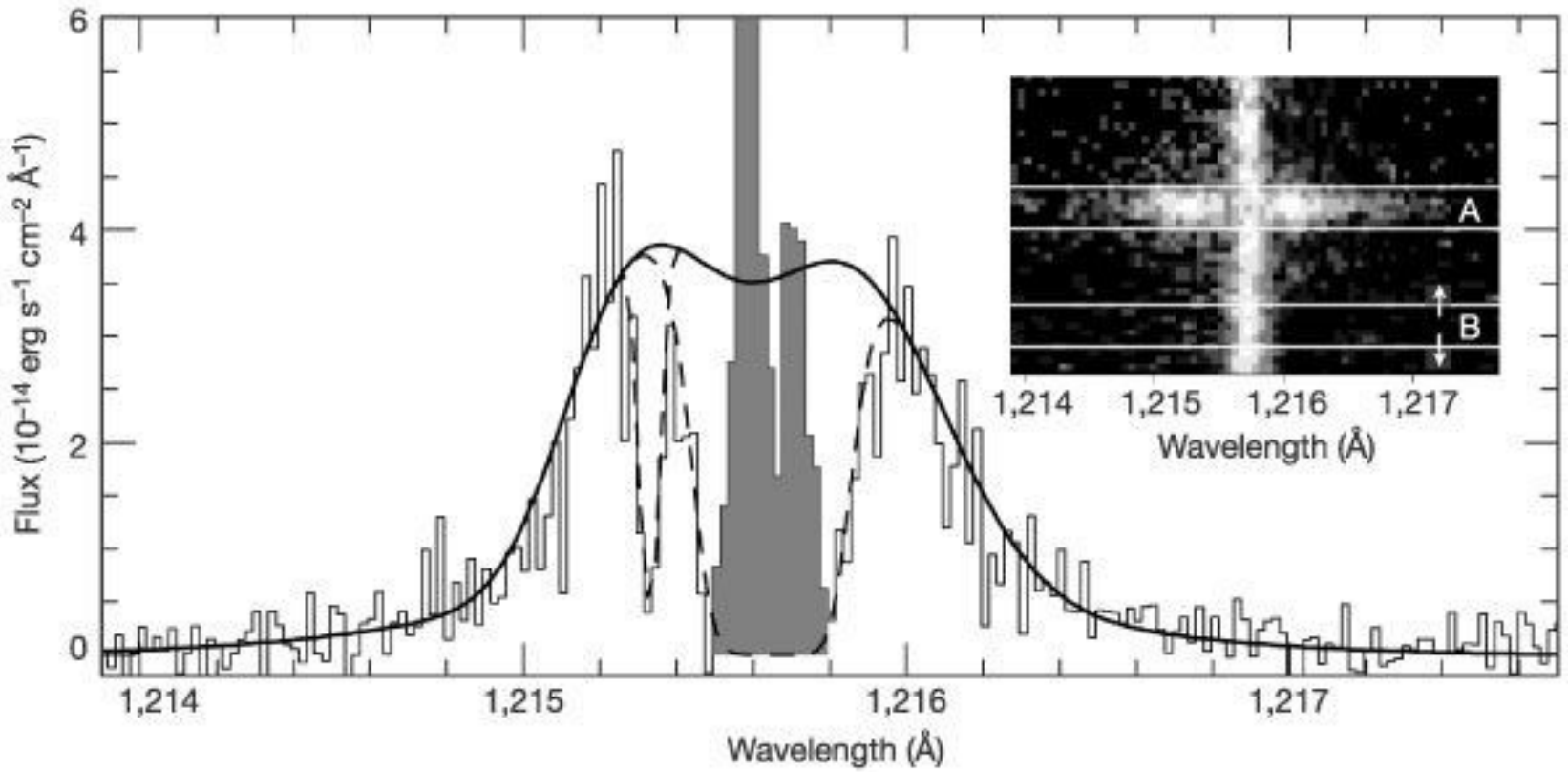
geocoronal Ly-alpha line (narrow):



Sankrit et al. 1999

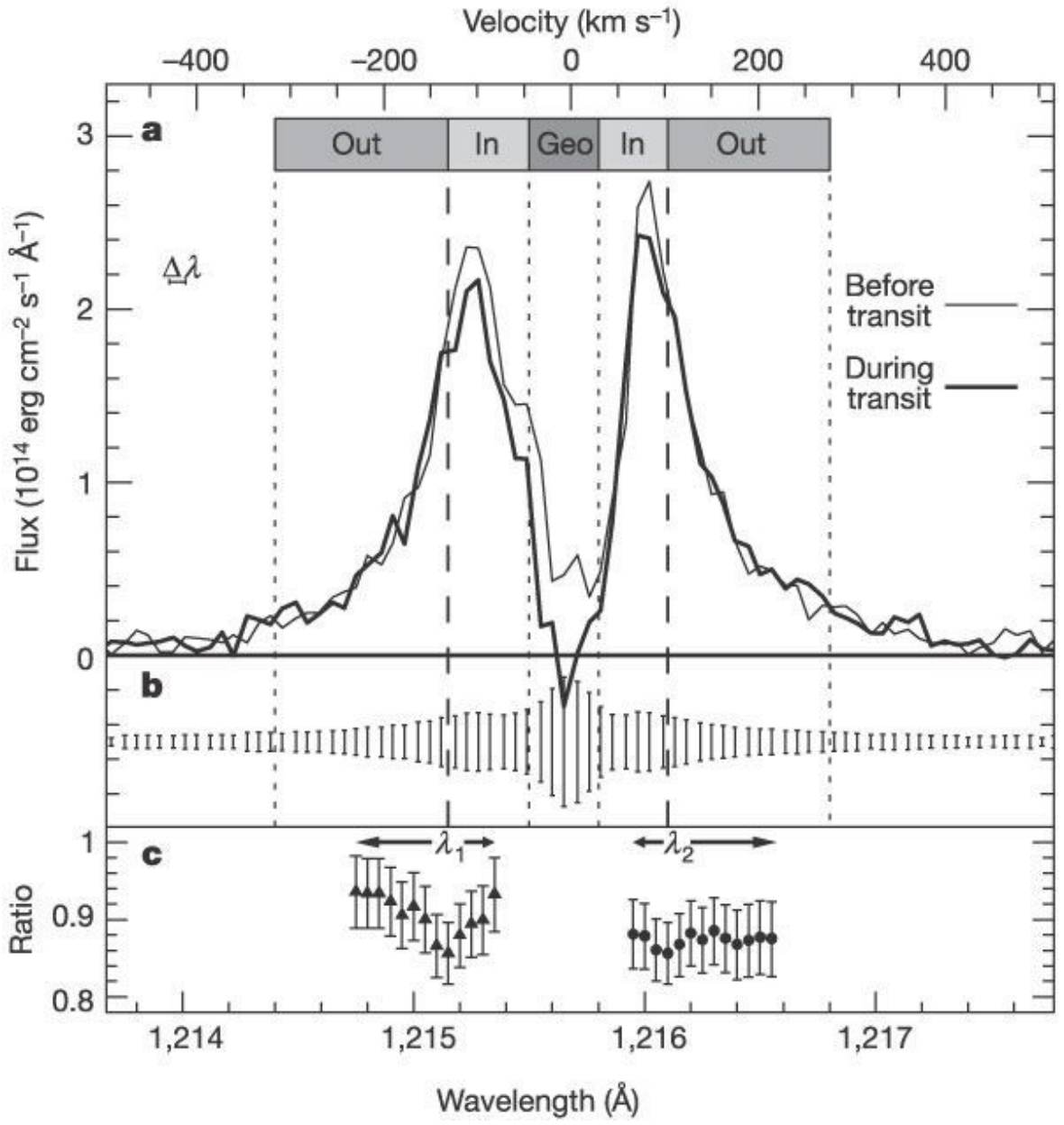
Atmospheric escape (evaporation)

Hydrogen Ly-alpha transit of Hot Jupiter HD 209458 (Vidal-Madjar et al. 2003):



Atmospheric escape (evaporation)

Hydrogen Ly-alpha transit of Hot Jupiter HD 209458 (Vidal-Madjar et al. 2003):



Atmospheric escape (evaporation)

Can also collect light curves only in relevant parts of line and plot that versus time:

Warm Neptune
GJ 436 b,
Kulow et al. 2014,
Ehrenreich et al. 2015