

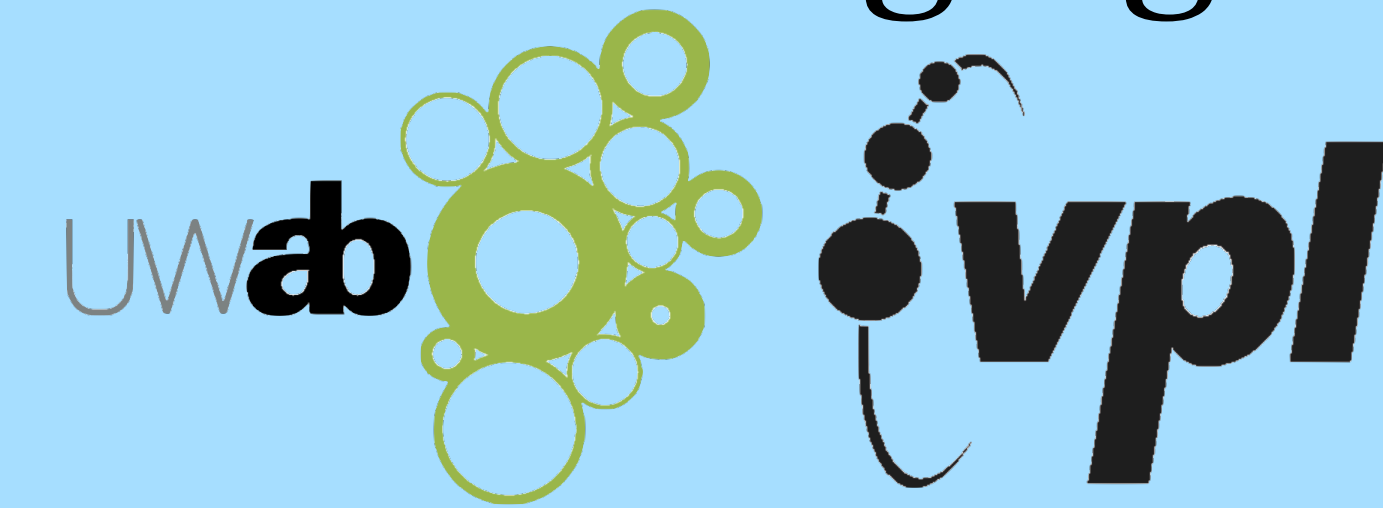
Assessing Our Ability to Interpret Biosignatures via Transmission and Direct Imaging

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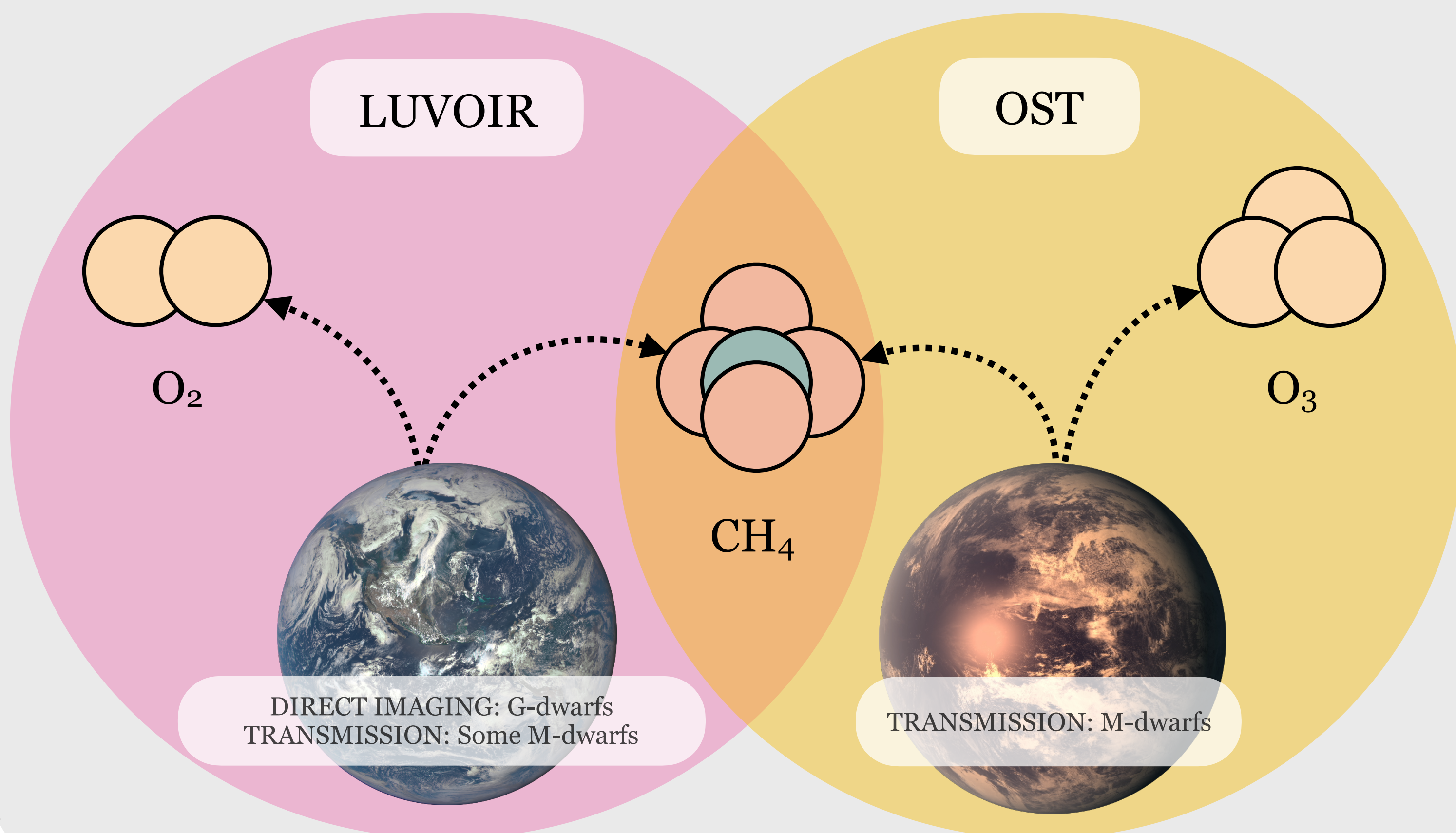
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How well can we interpret signs of life using different observing techniques?



- The rate at which molecules are created at the surface can give us clues as to whether there is a biological or abiotic source.
- Surface fluxes are an important tool for discriminating between such sources.
- We need surface fluxes to identify something as a biosignature.

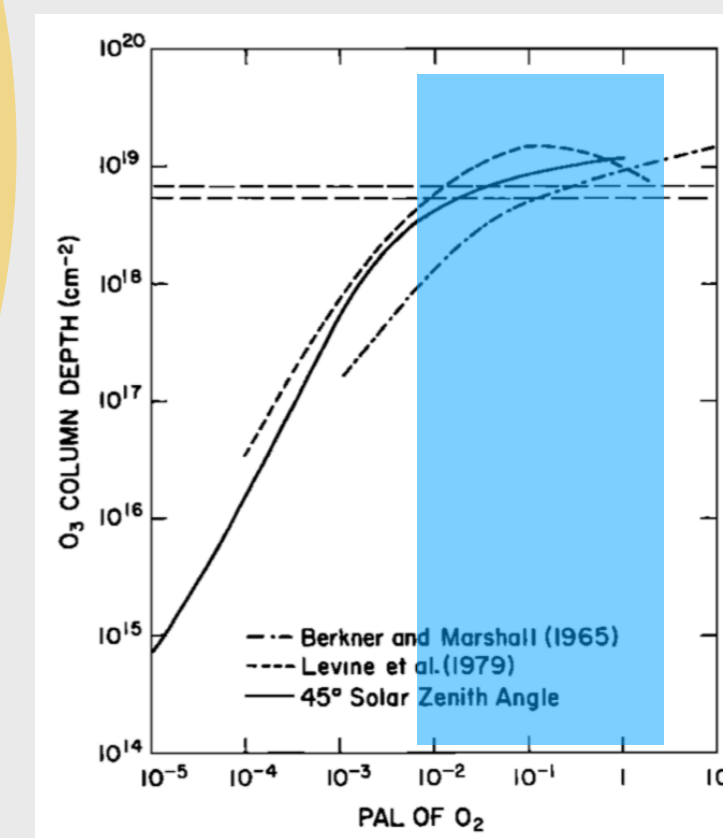
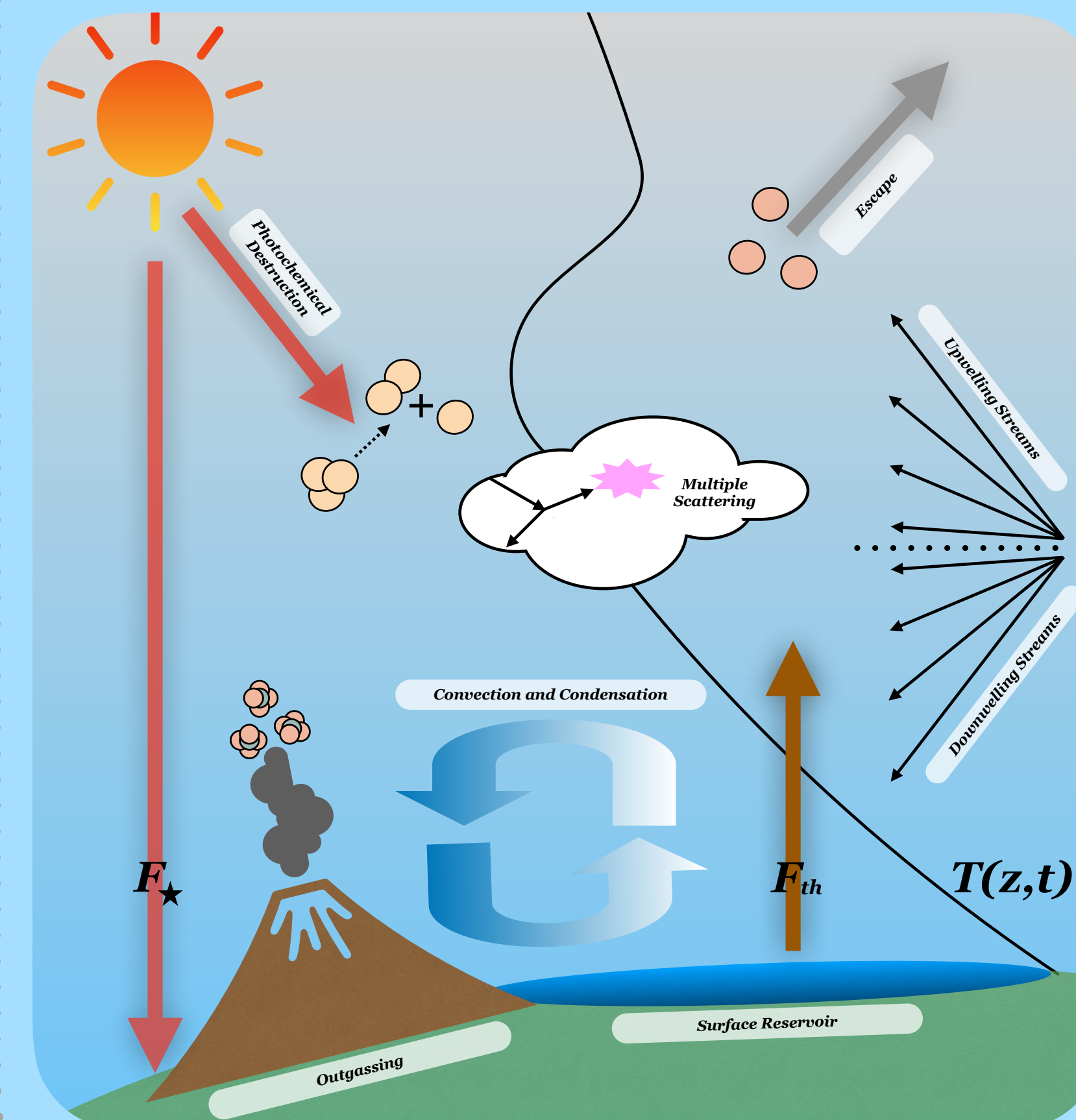


Figure credit: J. Kasting (1980)

- ### Challenges
- Surface flux must be inferred from chemical abundance.
 - O₃ must be used as an O₂ proxy in the mid-IR.
 - Photochemical destruction rate depends on stellar type/activity.
 - Transmission does not sample the near-surface atmosphere.

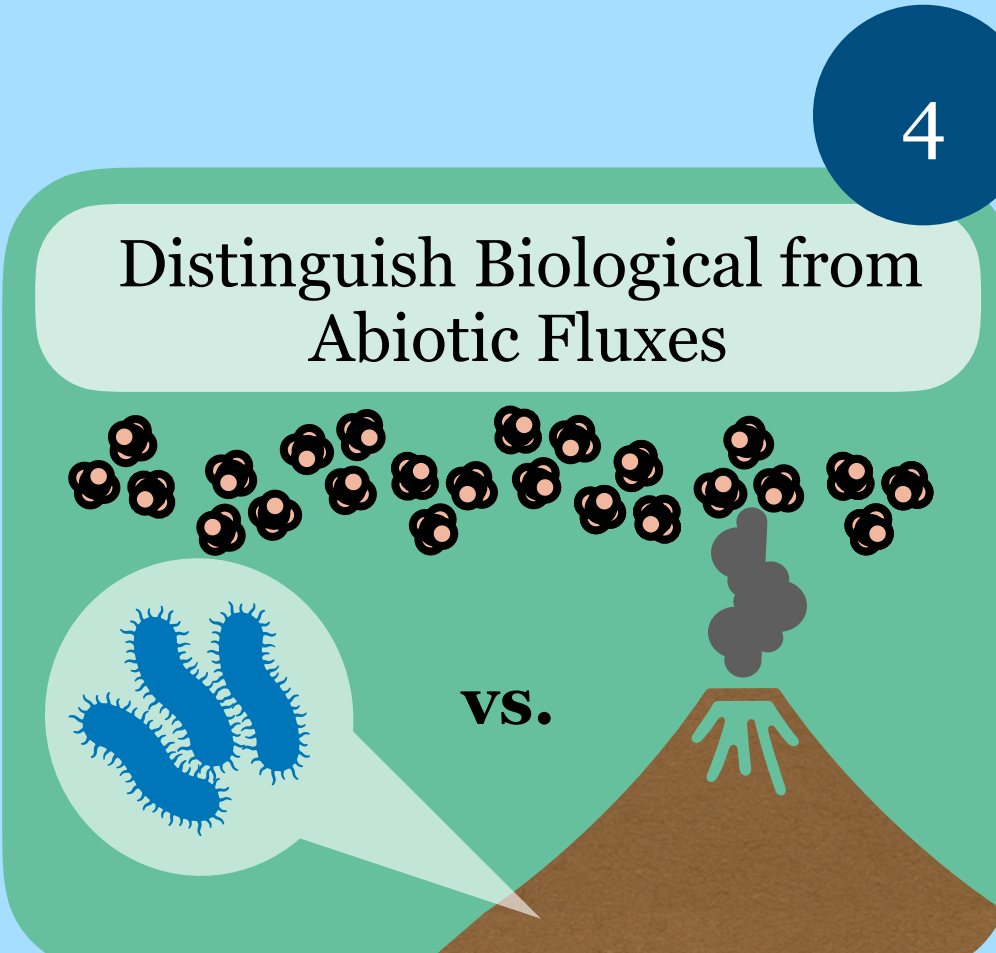
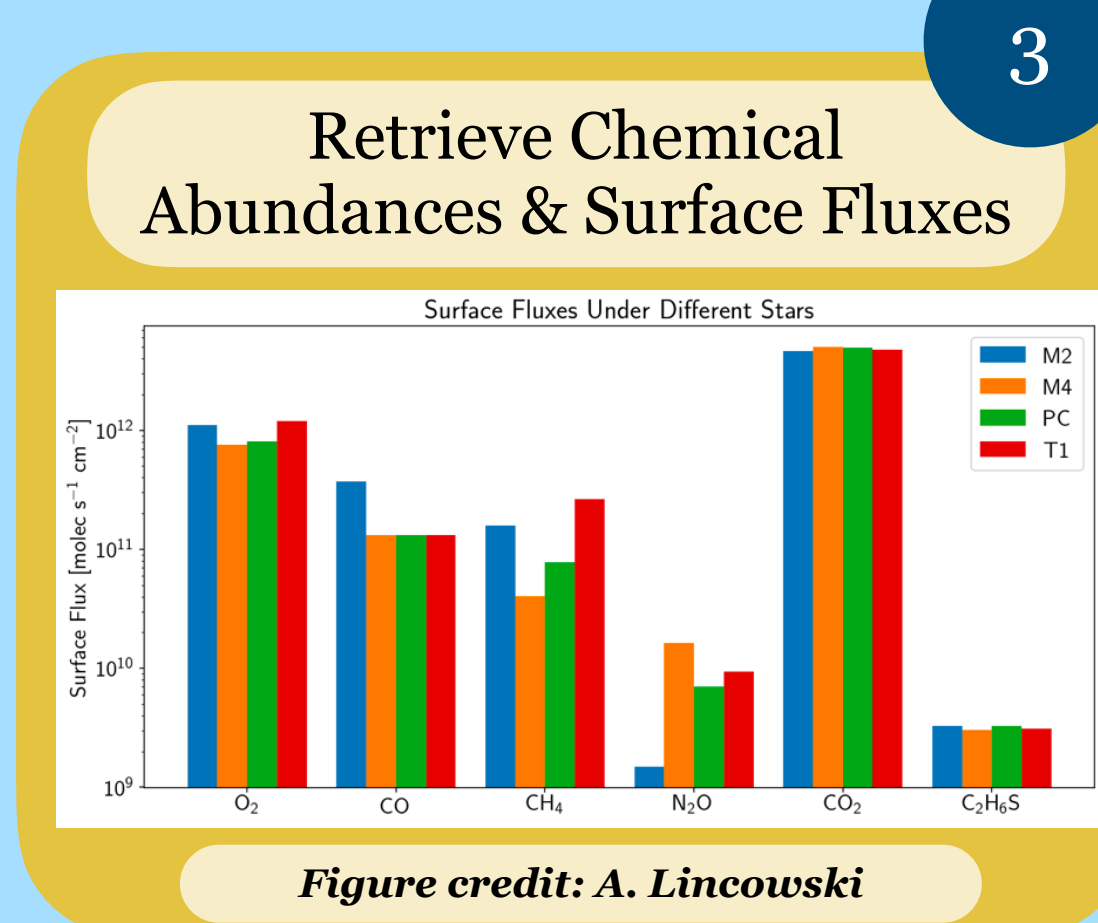
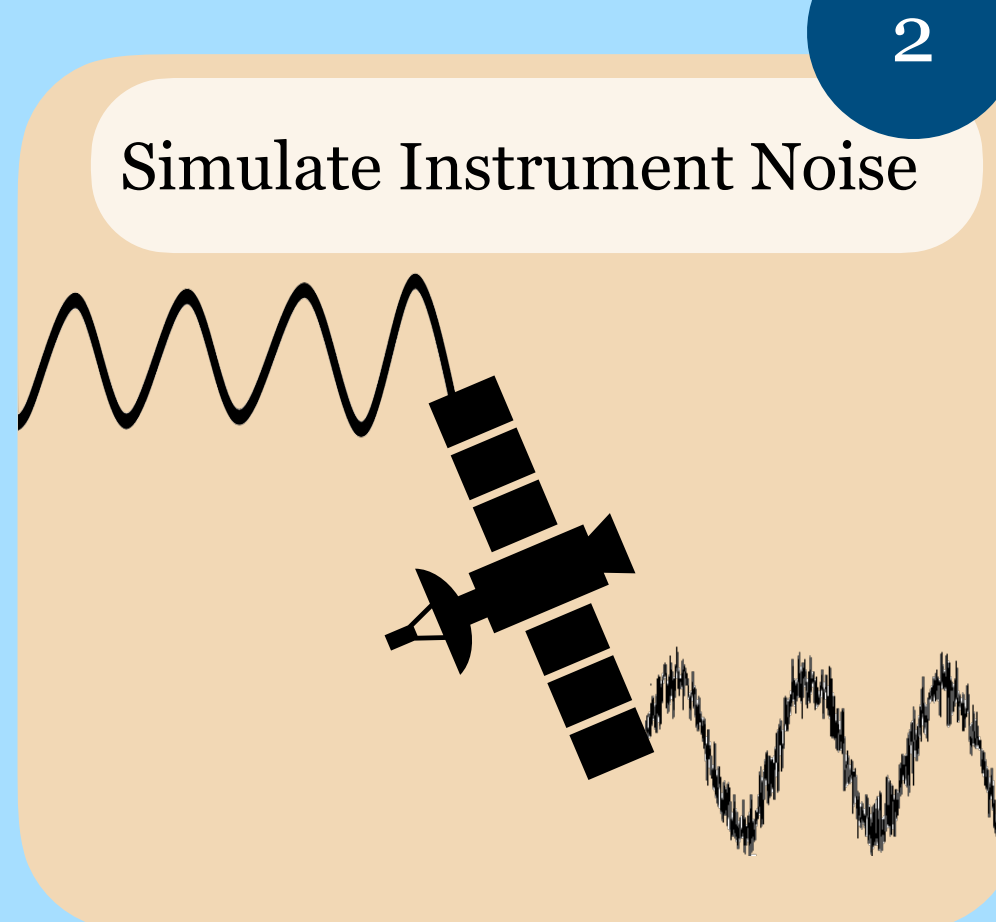
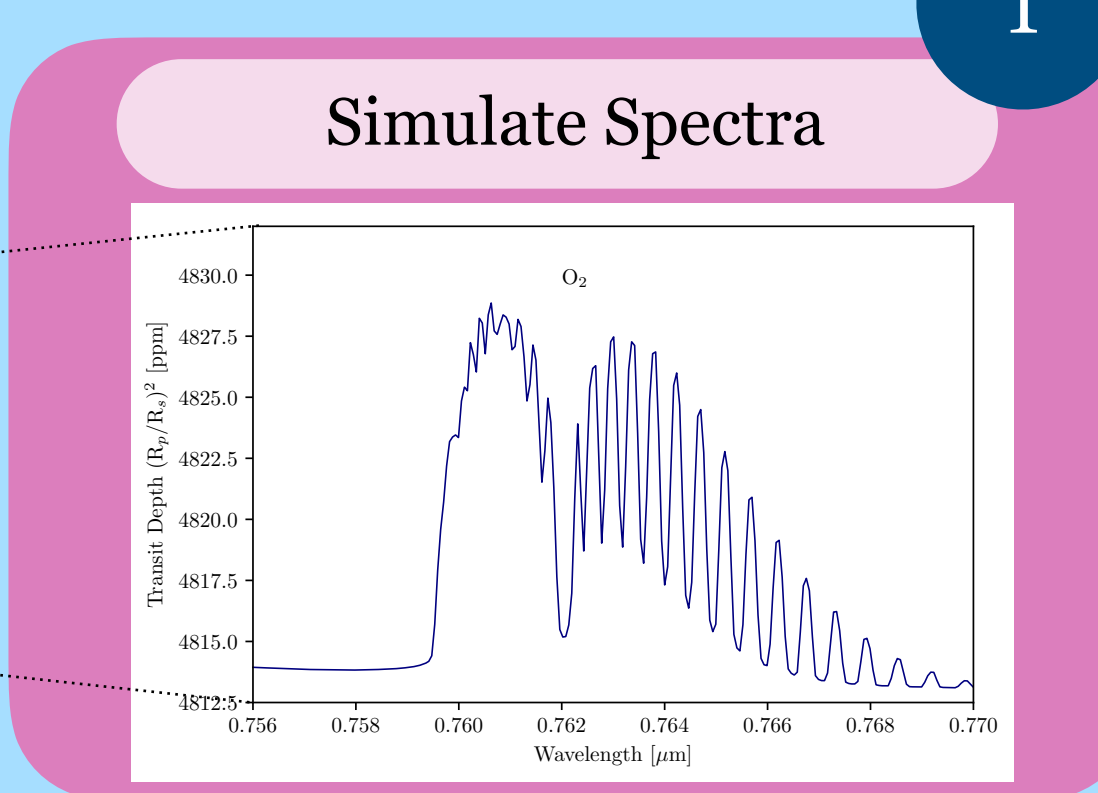
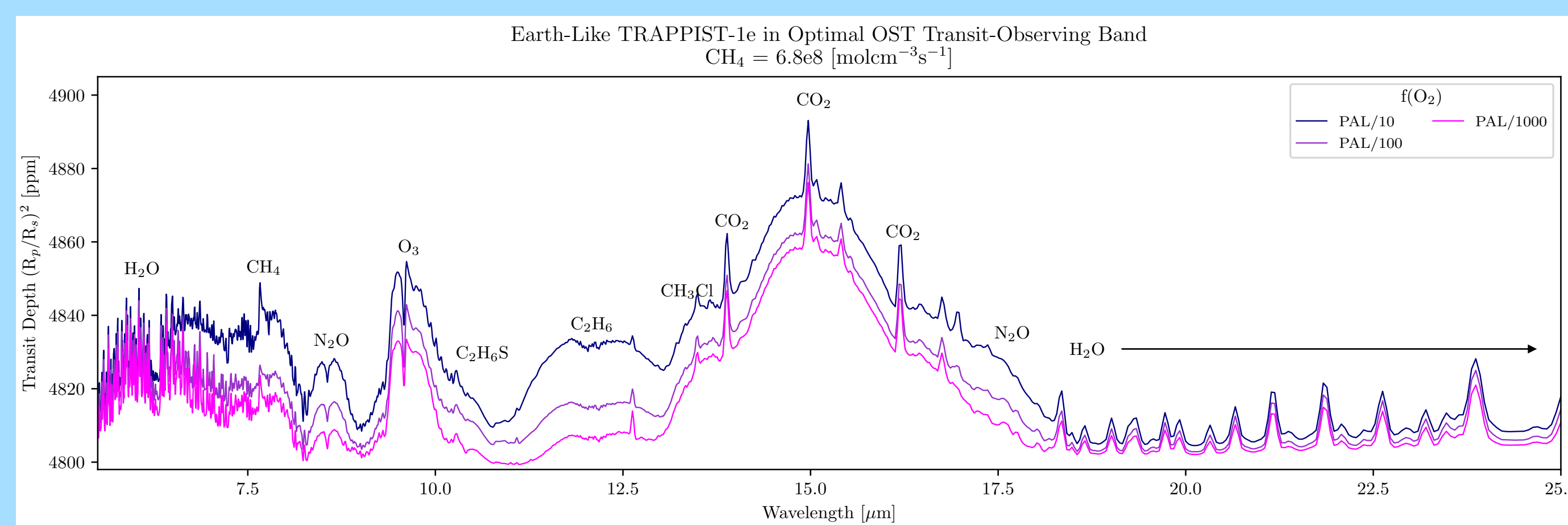
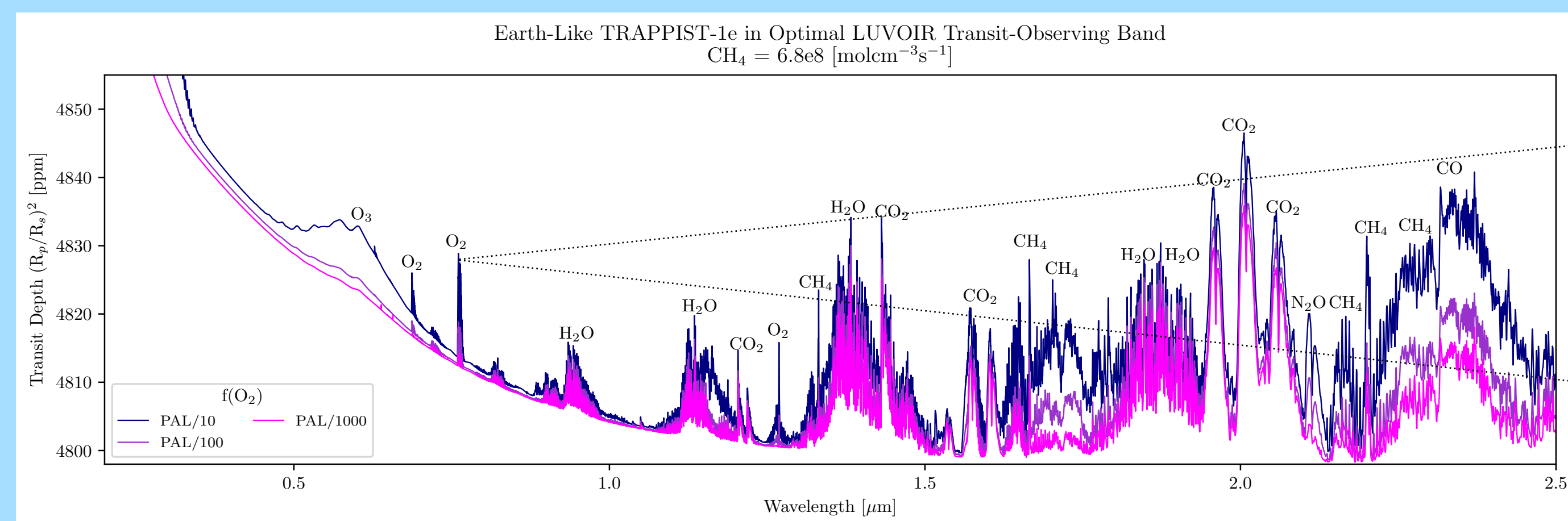
Methods



Adapted from Lincowski et. al, 2018

- ### VPL Modeling Suite
- Radiative Transfer (**Meadows & Crisp, 1996**):
 - Line-by-line, multi-stream, multi-scattering
 - Vertically-resolved atmospheric layers
 - Computes accurate layer-by-layer heat fluxes
 - Convection:
 - Mixing length theory: stability determines convection
 - Condensation, evaporation
 - Exchange of latent heat
 - Assumes full rain-out
 - Input Parameters:
 - UV bands, CIA, vis-IR line lists (HITRAN, Ames)
 - High-resolution stellar SED
 - Wavelength-dependent surface albedo
 - Thermodynamic properties (SVP, enthalpy of formation)
 - Aerosol properties (absorption, scattering, optical depth)
 - Coupling to Photochemistry:
 - T(z,t) input to photochemistry
 - Photochemistry uses T(z,t) to recalculate abundances
 - Abundances input to climate

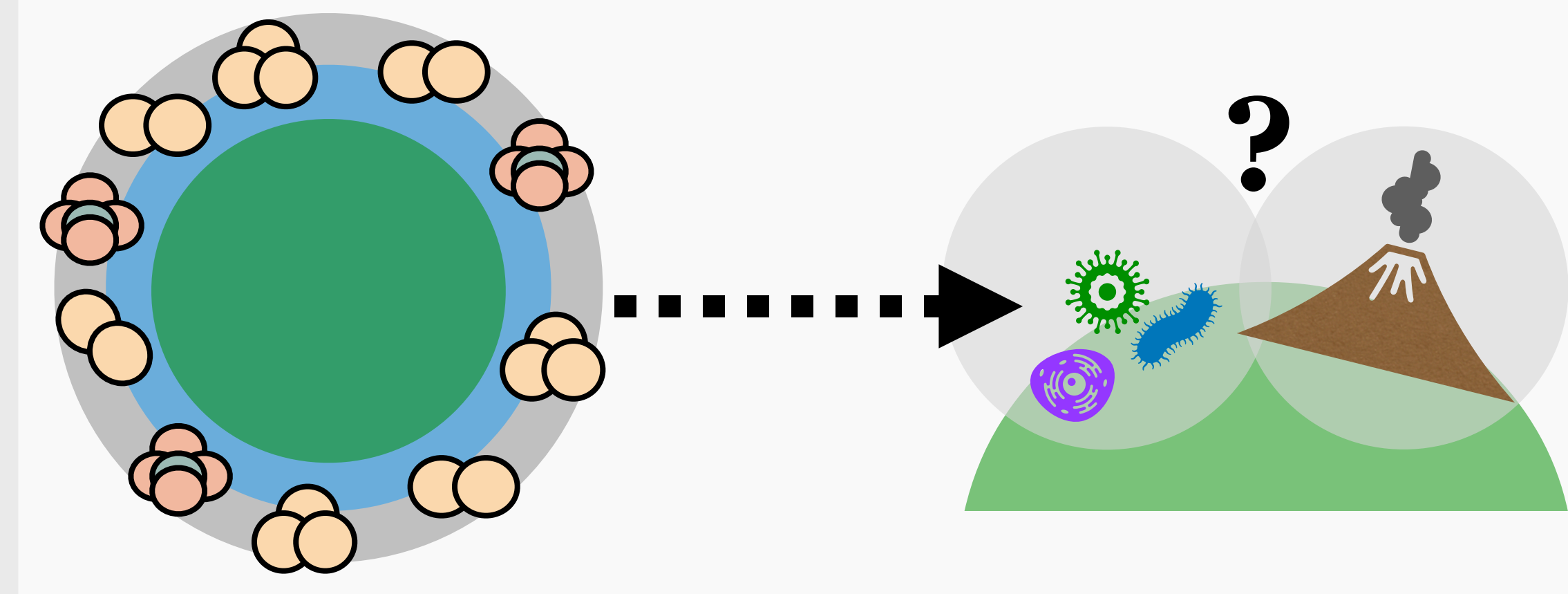
Results & Next Steps



- ### Work in Progress
- We have started generating different potential environments with biological and abiotic sources.
 - We will run these environments through instrument simulators for HabEx, LUVUOIR, OST, and JWST.
 - We will then assess how well we can quantify the abundance of biosignature gases and infer their surface fluxes.
 - We will then determine if we can distinguish biological surface fluxes from abiotic surface fluxes.

Questions to Address

- Are some observing techniques more robust than others in detecting biosignatures?
- How confident will we be in detecting life using these techniques?
- How do we use surface fluxes to accurately interpret a disequilibrium?



How do we *prove* life is present?

Acknowledgments

This work by the Virtual Planetary Laboratory team was supported by the NASA Astrobiology Program Grant Number 80NSSC18K0829 and is part of the NASA Nexus for Exoplanet Systems Science research coordination network.