USING *Bayesian Analysis for Remote Biosignature Identification on exoEarths* IN CORONAGRAPHY OBSERVATION SIMULATIONS FOR CO2

BARBIE

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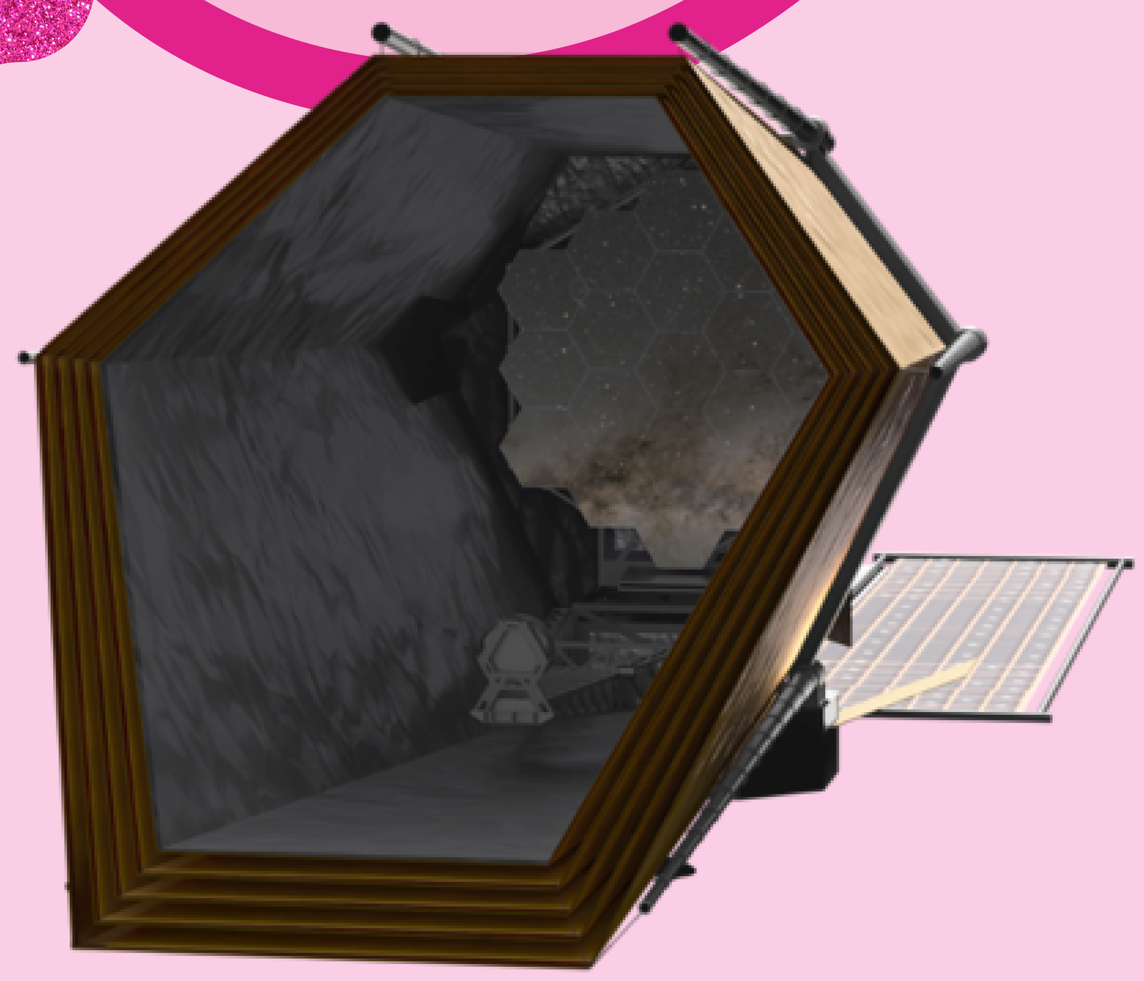

Figure 1: This image shows a design concept for HWO.

INTRODUCTION

The Habitable Worlds Observatory (HWO) will be looking at Earth-like worlds around Sun-like stars. In these worlds, we are interested in analyzing their atmospheres to understand whether there is a possibility for life by studying the molecular composition. Our main molecules of interest are H2O (water), CH4 (methane), O2 (oxygen), O3 (ozone), CO2 (carbon dioxide), and CO (carbon monoxide). These are molecules that tell us whether life can exist and does exist. The detectability of these molecules vary based on the abundance, signal-to-noise ratio (SNR), and wavelength. Thus, we need to know what the wavelength range should be so that will be able to detect all of these molecules' spectral features while also being realistic about the budget and engineering of HWO.

Here, we present BARBIE and our CO2 detectability results with varying CO2, H2O & CH4 abundances.

CO2 DETECTABILITY WITH MODERN H2O & CH4

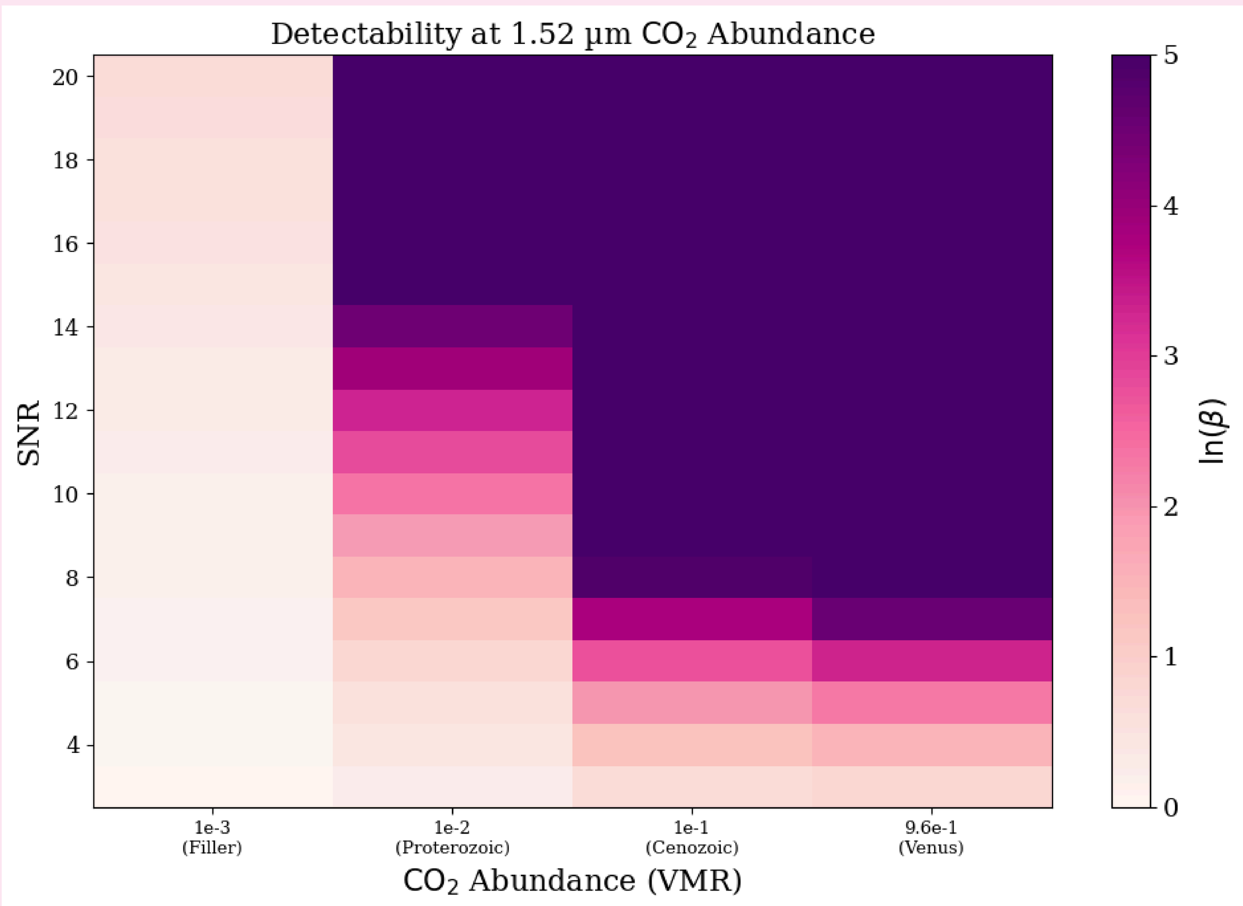

Figure 2: Shows the requirements of CO2 abundance (x-axis) and SNR (y-axis) for a strong CO2 detection at 1.52μm. The darker the purple, the stronger detection there is as shown by the sidebar on the right. This is with modern levels of H2O & CH4.

CO2 DETECTABILITY WITH VARYING H2O

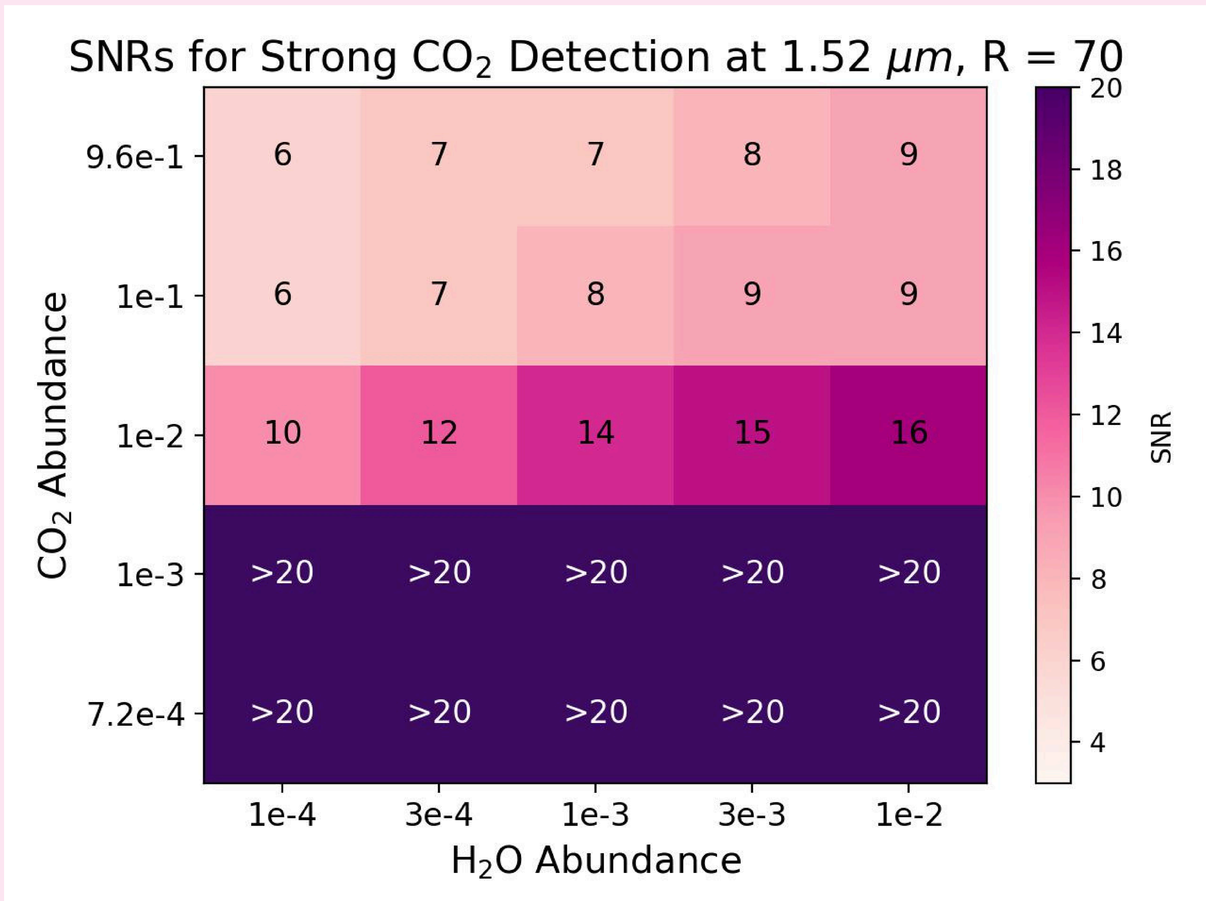

Figure 3: Shows the SNR required for a strong CO2 detection based on varying H2O abundances (x-axis) and CO2 abundances (y-axis) at 1.52μm. The minimum SNR required is plotted in each cross section; the darker the purple, the higher the SNR, and the lighter the pink, the lower the SNR.

CO2 DETECTABILITY WITH VARYING CH4

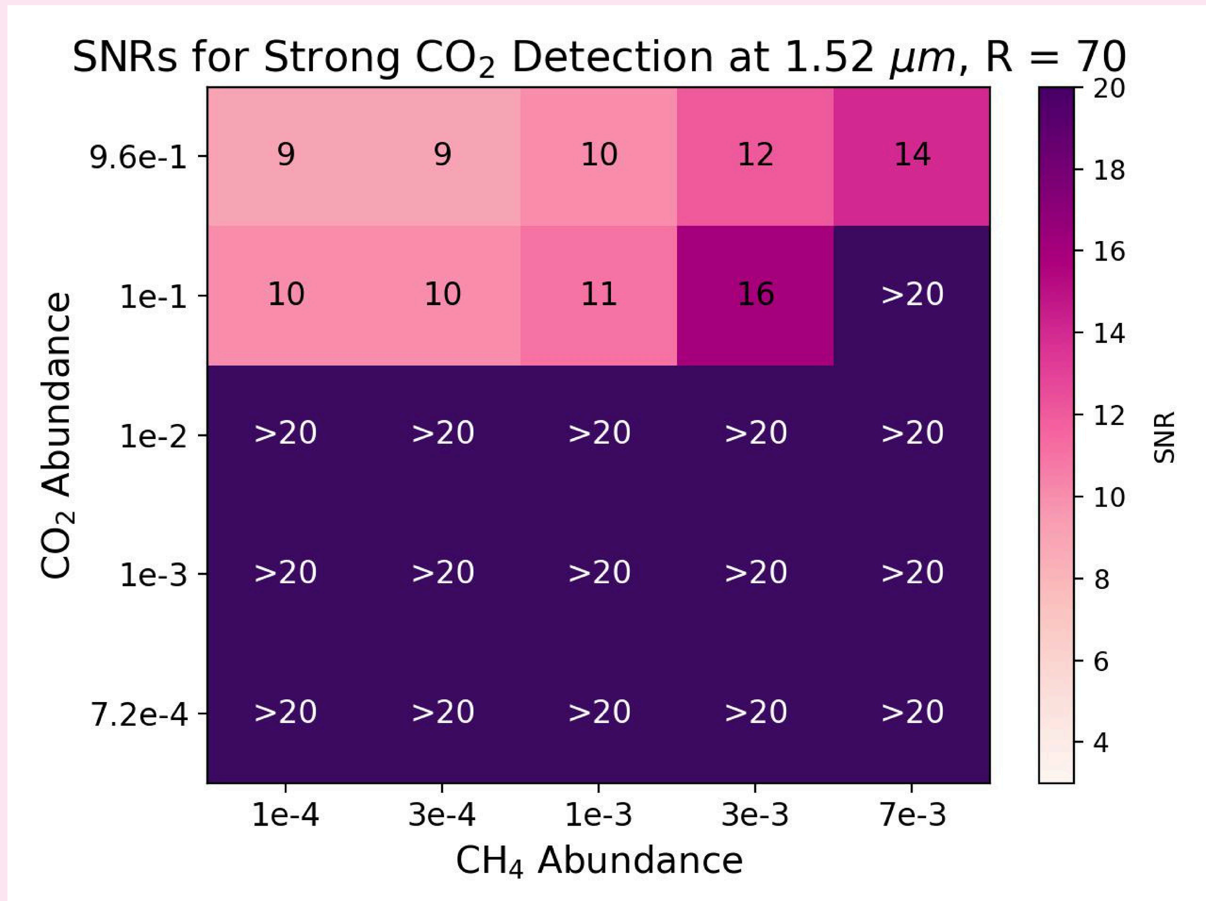

Figure 4: Shows the SNR required for a strong CO2 detection based on varying CH4 abundances (x-axis) and CO2 abundances (y-axis) at 1.52μm. The minimum SNR required is plotted in each cross seciton; the darker the purple, the higher the SNR, and the lighter the pink, the lower the SNR.

HOW DOES BARBIE WORK?

1. **Define** molecule, abundances, resolving power, bandpass width, wavelength & grids
   - 25 evenly-spaced 20% bandpasses
   - 0.8 - 2μm for CO2 & CO
   - Simulate tests that vary CO2 & H2O and CO2 & CH4 abundances
2. Use a grid-based retrieval routine - **KEN grids** - that allows for repeated Bayesian retrievals
   - Cover a grid of wavelength and SNR values
3. Run **retrievals** in a distributed computing framework on our Discover cluster
4. For each retrieval, Bayes-factor statistics calculates a **detectability assessment** for specific atmospheric species (Benneke and Seager et al.)
   a. **Unconstrained:** lnB < 2.5
   b. **Weak:** 5 > lnB > 2.5
   c. **Strong:** lnB >5
      - lnB is calculated by subtracting the Bayes Factor for a retrieval WITHOUT the molecule from the Bayes Factor for a retrieval WITH the molecule.
      - lnB directly compares fits by examining if an improved fit occurs with the molecule included, and addresses the likelihood of the presence of the molecular species and its detectability.
5. **Analyze** plots and data to determine the detectibility of molecules

CONCLUSIONS

- At modern abundances of CH4 & H2O, only Venus-like, Archean-like & Proterozoic-like CO2 abundances achieve strong detections
- CO is not detectable anywhere with any abundance of CO2
- Both H2O and CH4 impact the detectability of CO2
  - Increased H2O & CH4 abundances make it harder to strongly detect CO2
  - Decreased H2O & CH4 abundances make it easier to strongly detect CO2

REFERENCES & ACKNOWLEDGEMENTS

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