Biosignature Detectability in Rocky Exoplanet with ELT-HARMONI and ELT-METIS in Different Coronagraph Contrast Levels

Huihao Zhang, Ji Wang, Michael Plummer

The Ohio State University
Department of Astronomy

GFORSE
Group for Studies of Exoplanets

Introduction

Biosignatures

- Signs of life
- Composed of special gas combinations
- Causes chemical disequilibrium in terrestrial planet atmospheres

Key Question: Are biosignatures detectable directly through METIS and HARMONI?

- Mid-infrared ELT Imager and Spectrograph (ELT/METIS)
- High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph (ELT/HARMONI)

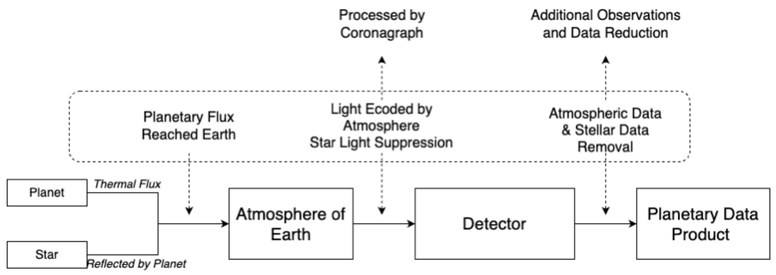
We explored the detectability (resolution element SNR) of METIS and HARMONI direct imaging modes for GJ 887 b

- Wavelength: 0.5-2.45 μm for ELT/HARMONI, 3-5.6 μm for ELT/METIS
- Exposure time: one hour with medium spatial resolution (~1000)
- Four cases with coronagraph contrast ranging from 10^{-3} to 10^{-6}
- A modern Earth atmosphere with biosignatures of CH_4, O_2, H_2O, and CO_2 is assumed for GJ 887 b
- Based on the noise and difference (signal) in the spectrum of modern Earth's atmosphere and biosignature-free atmosphere in the feature wavelengths of biosignatures

Methodology

We perform an end-to-end calculation for the photon count at an ELT instrument.

Simulation Flowchart



Description

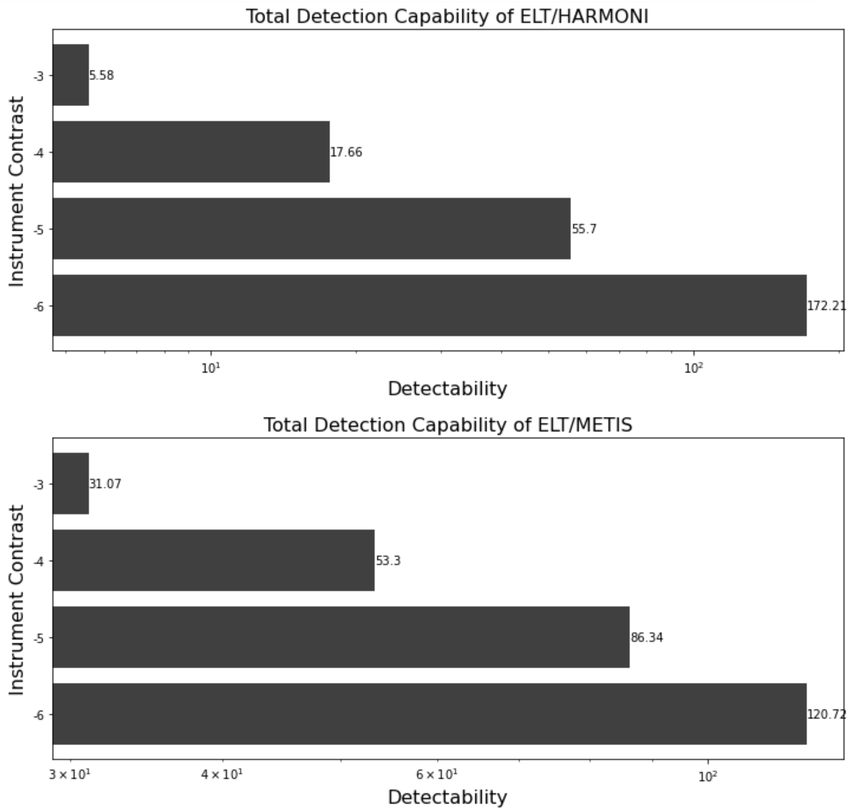
Reflected light from GJ 887 b:

- Originates from the host star,
- Reflected by the GJ 887 b,
- Encoded by the GJ 887 b's atmosphere
- Passes through Earth's atmosphere, ELT, and a high-contrast instrument
- Being recorded on a detector.

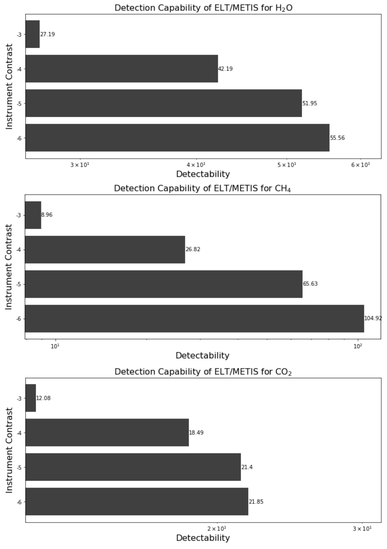
Thermal Emission from GJ 887 b:

- Originates from the GJ 887 b,
- Encoded by the GJ 887b 's atmosphere
- Passes through Earth's atmosphere, ELT, and a high-contrast instrument
- Being recorded on a detector.

Results

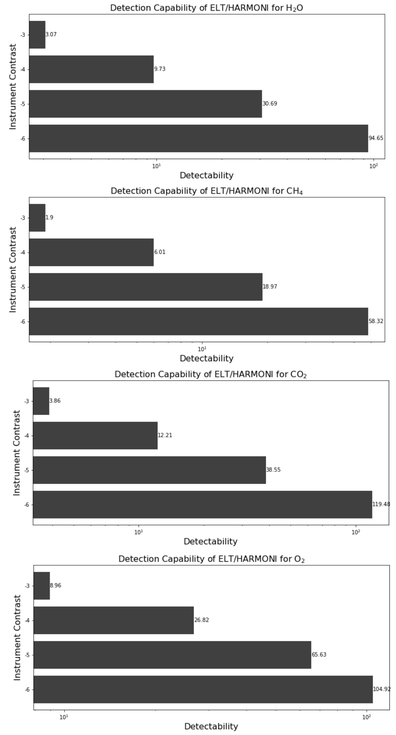


ELT/METIS



Within 3-5.6 μm, the absorption feature of oxygen for photon is very low

ELT/HARMONI



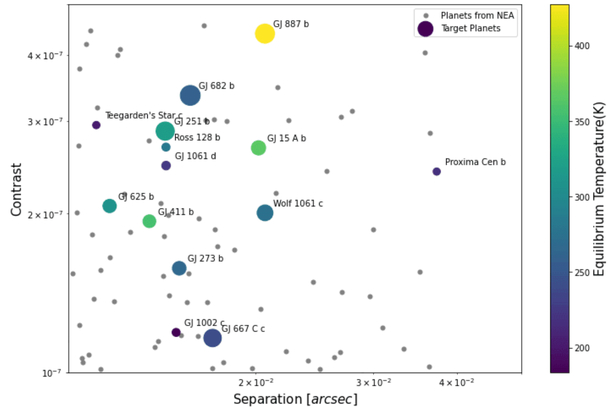
THESELECTION OF PLANETS AND INSTRUMENTS

Selection of Planets

We employ NASA Exoplanet Archive (NEA) and the following selection:

- Angular separation larger than 10.5 mas;
- Contrast above 10^{-7};
- Planets with radii between 1.0 $R_\oplus$ and 2 $R_\oplus$;
- Equilibrium temperature below or around 450 K

We have identified 14 rocky exoplanets as below:



Based on magnitudes, we selected **GJ 887 b** from them as the target.

Selection of Instruments

- Both ELT/METIS and ELT/HARMONI are equipped with coronagraph
- Both ELT/METIS and ELT/HARMONI are possess the capability for medium-resolution imaging
- The spatial bands covered by ELT/METIS (3-13 μm)and ELT/HARMONI (0.47-2.45 μm) coincide with our desired range of interest (0.5-5.6 μm).

Conclusion

1.The direct imaging mode in 3-5.6 μm of ELT/METIS has the capability to detect CH_4, CO_2, and H_2O in the atmosphere of GJ 887 b over the coronagraph contrast range from 10^{-3} to 10^{-6}.

2.In contrast of 10^{-4}, the direct imaging of ELT/HARMONI has the ability to detect CH_4, CO_2, O_2, and H_2O, but it requires a significant amount of exposure time, especially for O_2.

3.Once the instrument contrast exceeds 10^{-5}, improvement in the coronagraph contrast is less helpful for the detection capability of ELT/METIS.

4.From contrast =10^{-3} to 10^{-6}, the improvement in performance of the coronagraph greatly aids in the detection capability of ELT/HARMONI.