LUNAR & PLANETARY LABORATORY

Effects of UV Radiation on Sub-Neptune Hazes Through Laboratory Experiments

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Background

Both ground and space-based observations have shown that many of the over 5500 confirmed exoplanets contain clouds and hazes[1,2,3]. The resulting atmospheric characterization becomes more difficult, creating larger than the Rayleigh limit of scattering and "flat" spectra[1,2,3]. The most common exoplanets are super-Earths and sub-Neptunes, which are likely to harbor hazes in their atmospheres[4].

What are Water Worlds?

Sub-Neptune exoplanets have a different observed mass-radius relationship (Figure 1)[5]

- Have thicker atmospheres than super-Earth exoplanets
- Higher stellar radiation creates a temperate environment[4,5]
- Could create a planet maintaining liquid water on the surface and atmosphere

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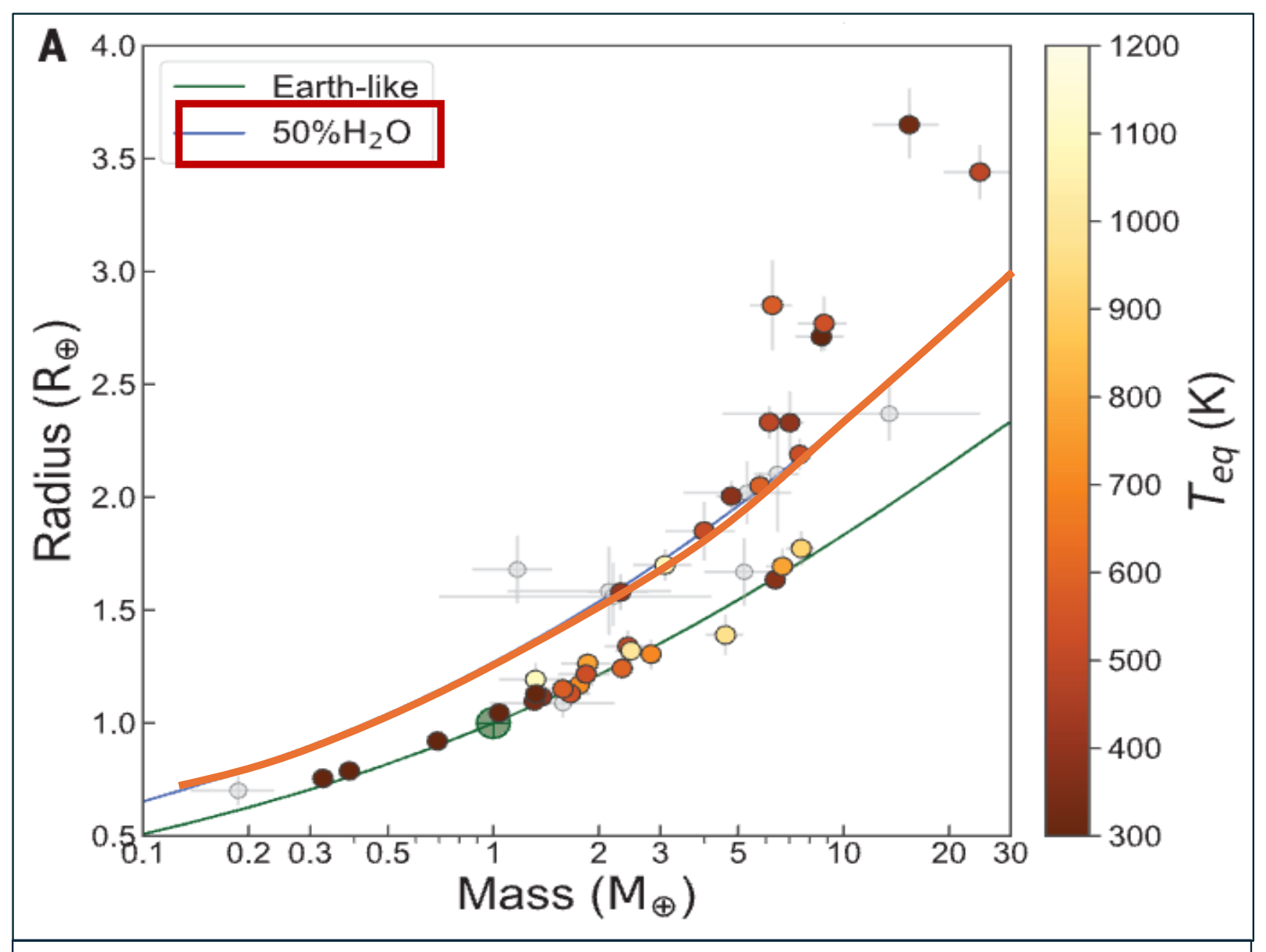


Figure 1: Difference in bulk density between Earth-like and 50% water planets. Super-Earths have a silicate-iron composition, whereas sub-Neptunes have ice-silicate compositions. **The change in density may be explained by the presence of water worlds**

What about Stellar Activity?

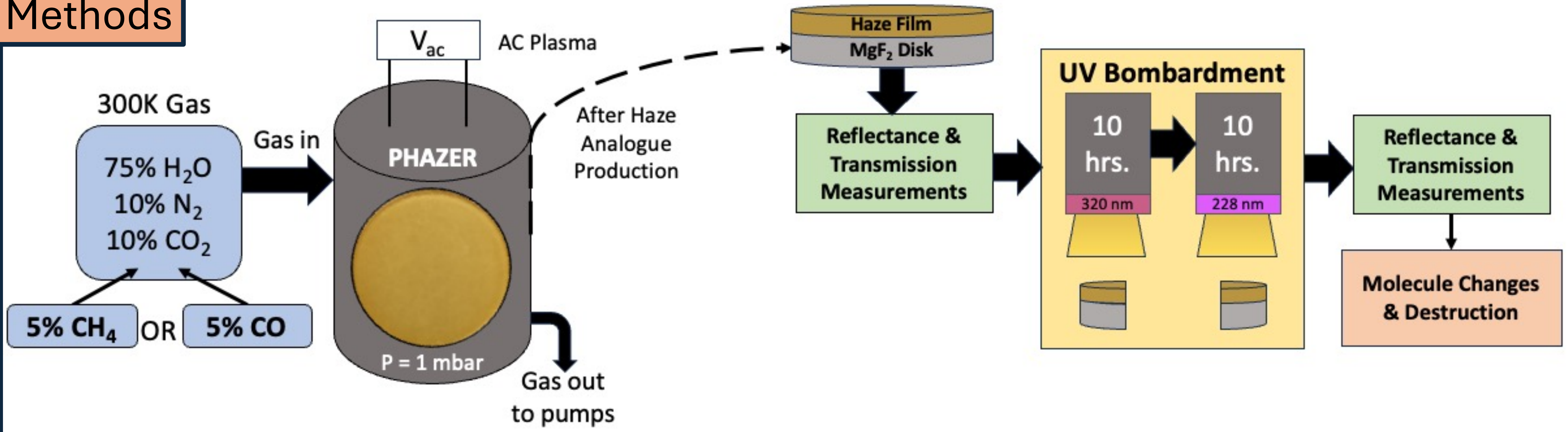
Temperate sub-Neptune water world exoplanets orbiting close to their star can be strongly affected by stellar flaring events.

- Stellar flares can affect the habitability of the surrounding planets, triggering photochemistry[6]
- Can drive water loss and atmospheric escape[7,8]

Critically, it remains unknown how stellar flaring affects exoplanet hazes. This work helps to quantify spectral changes to laboratory made exoplanet hazes across a broad wavelength range (0.2-15 µm) to:

- Improve our understanding of haze evolution and how stellar flares can impact exoplanet atmospheric compositions
- Assess if water worlds would be able to retain their atmospheres after a multitude of flaring events

Methods



300K Gas

75% H_2O
10% N_2
10% CO_2

5% CH_4 OR 5% CO

Gas in

V_{ac}

AC Plasma

PHAZER

P = 1 mbar

Gas out to pumps

After Haze Analogue Production

Haze Film
MgF_2 Disk

Reflectance & Transmission Measurements

UV Bombardment

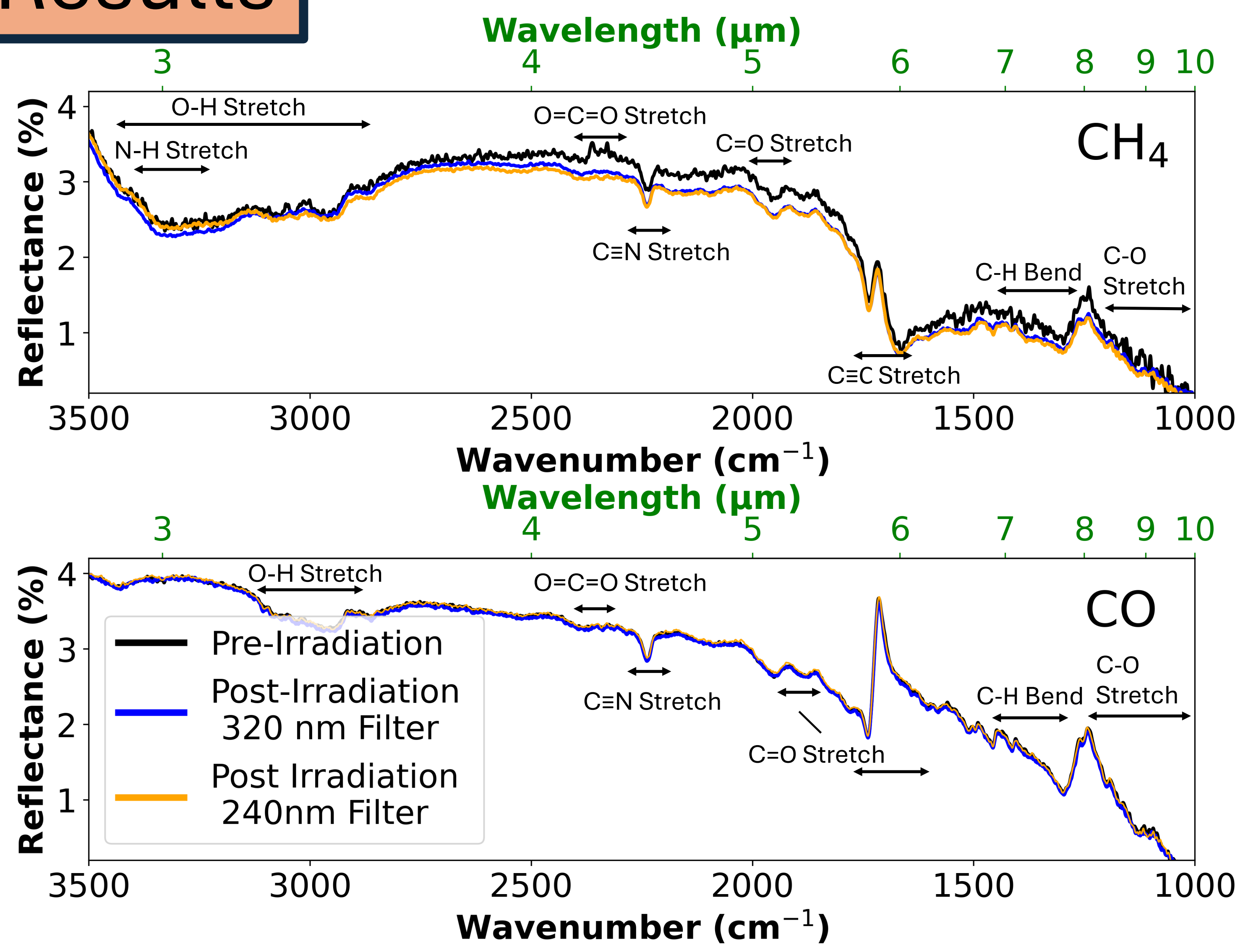
10 hrs.
320 nm

10 hrs.
228 nm

Reflectance & Transmission Measurements

Molecule Changes & Destruction

Results



The 5% CH_4 sample degraded more during the irradiation process compared to the 5% CO sample.

Figure 2: Enlarged spectrum between 3500 - 1000 cm^{-1} of the 5% CH_4 (top) and 5% CO (bottom) sample haze as a function of wavelength. Between pre- and post-bombardment, there are larger changes in the 5% CH_4 spectrum compared to the 5% CO sample.

Higher energy flares (240nm filter) cause more degradation to the haze spectra than lower energy flares (320nm filter)

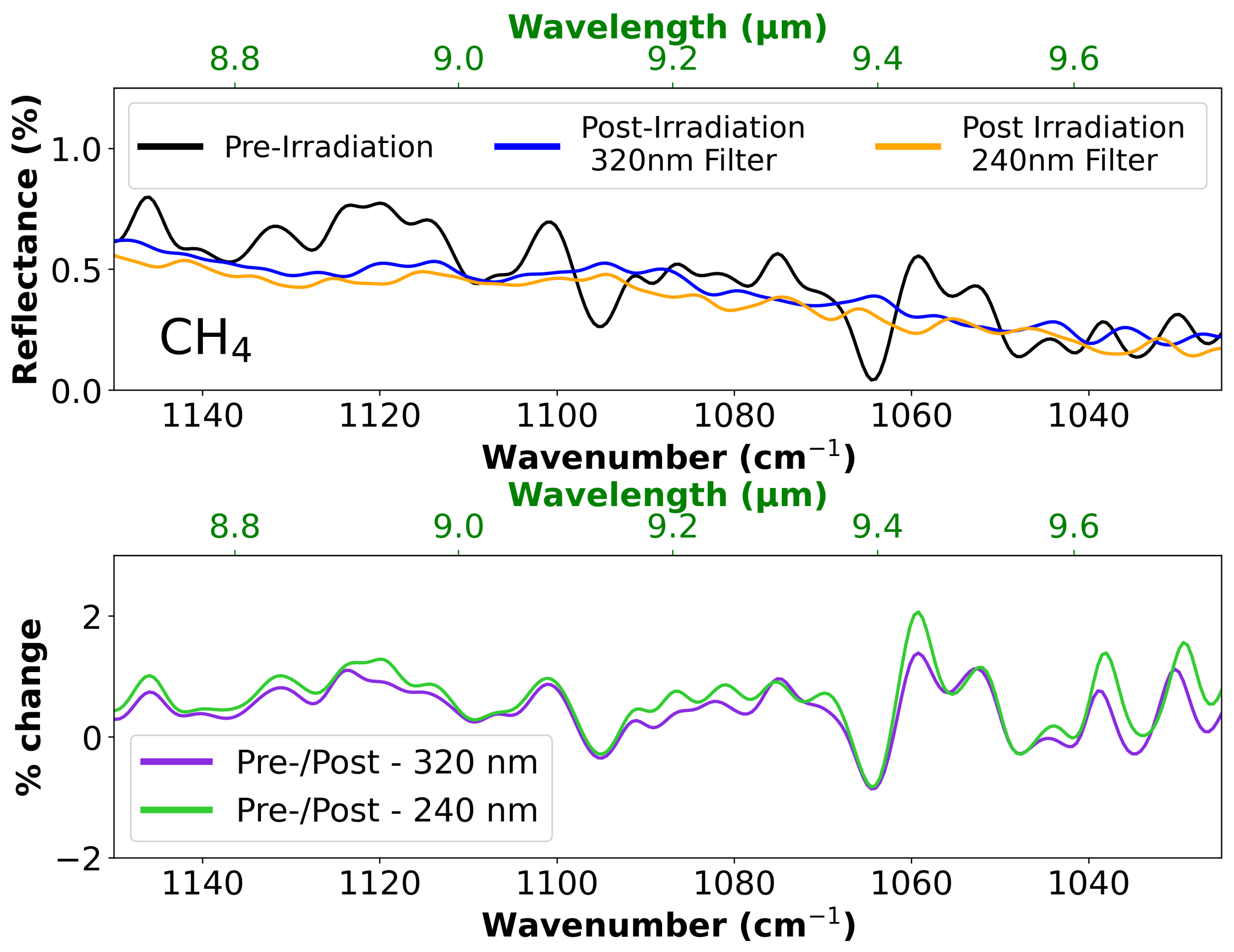


Figure 3: C-O stretching features of the 5% CH_4 sample seen pre- and post-irradiation in reflectance (top) with percent change (bottom) between the pre-irradiation filter and each irradiation filter, respectively. The irradiation process degraded the spectral features by large percentages.

Discussion

There are distinct changes in the spectra pre- and post-irradiation.

- Energy outputs for 10-400nm photons:
  - Quiescent M-Dwarf ~ 3.5 W/m^2 (He et al. 2023)
  - Deuterium Lamp ~ 1.1 W/m^2

Significant changes seen in the spectra during our 10 hours of irradiation at energies much less than quiescent energy observed on M-dwarfs.

We conclude that, neglecting haze production rates in the atmosphere, stellar flares can potentially strip away hazes in the atmospheres of water world exoplanets orbiting M-dwarf stars.

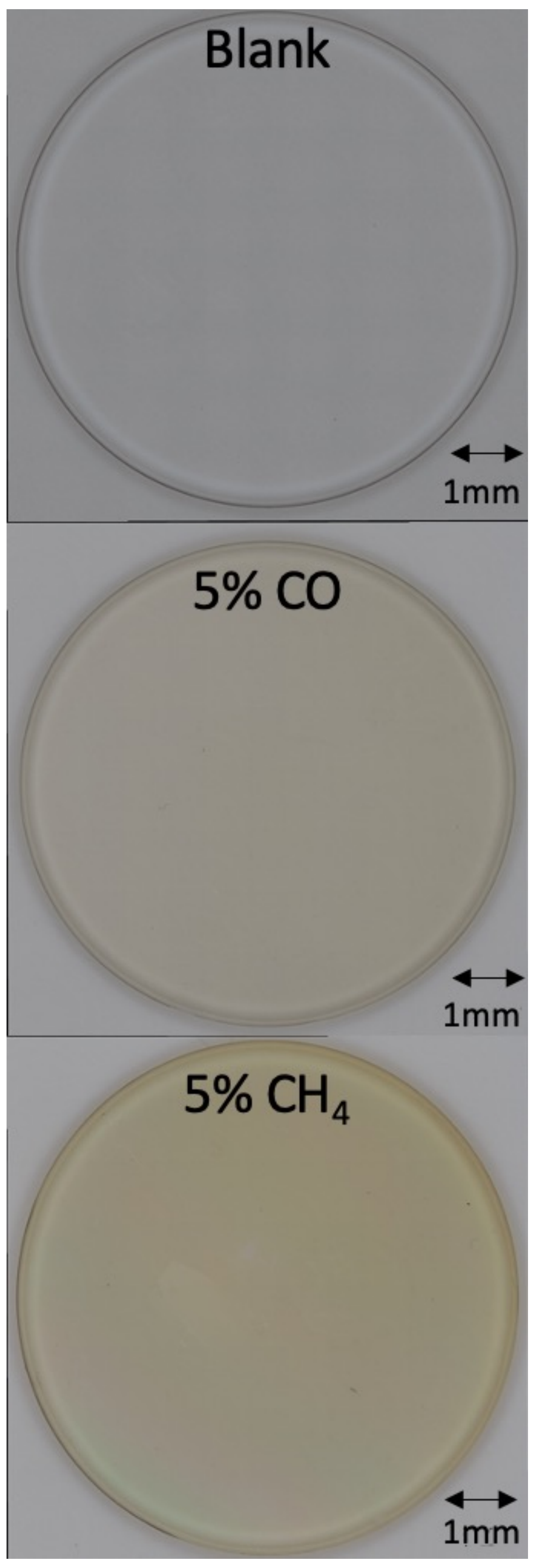


Figure 4: 50x magnification images of the post-irradiation haze analogues in addition to a blank (top) MgF_2 substrate disk. The 5% CH_4 sample (bottom) is more yellow than the 5% CO sample(middle). This is largely due to more haze particles being produced in the 5% CH_4 sample.

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