On the Detection of CO as an Anti-biosignature in Exoplanetary Atmospheres

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The detection of molecules that are associated with life (biosignature gases) is a feasible next step in the search for life on other planets. Oxygen is the most commonly suggested molecule for which to search, but the authors (Wang et al.) argue that, at least around M Dwarfs, it should not be. The unique UV spectra of M Dwarfs induces photochemistry that produces an Earth-like abundance of oxygen even in abiotic planets. Interestingly, the same photochemistry would produce a similar abundance of carbon monoxide (CO).

However, CO can act as an energy source for microbes, and thus it is more difficult for CO to accumulate in the atmosphere of an inhabited planet. The same is not true for oxygen. Therefore, the ability to detect CO is important, since its presence is able to distinguish between a rocky, Earth-like planet with life and one without life. The presence of CO would indicate a planet is abiotic; it is an anti-biosignature.

Given the plausible relevance of CO to inferring life on other planets, the authors examine the feasibility of detecting it. They use a radiative transfer model (the LT model) to calculate the emission, reflection, and transmission spectra of exoplanets. Values congruous with an Earth-like climate around an M dwarf are input, and then the model is run twice: once with the relevant species (CO or oxygen), and once without. They focus on the main absorption bands of each in the near infrared and then determine the difference in reflectivity when the molecule is included. A larger difference indicates a feature that is easier to detect.

The reflectivity difference is used to estimate the maximum noise that would still allow for detection. The authors then use this noise, along with many assumptions, to determine the observing time needed in order to detect each molecular feature with JWST. Their optimistic estimates show observation times as short as 0.024 hours for CO (4.67 microns) and 4.3 hours for oxygen (0.76 microns). The results show that not only can JWST feasibly detect CO absorption features on Earth-like planets around M dwarfs, but also that it can be detected concurrently with oxygen. However, they make many assumptions that could be considered too idealistic.

I will expand on their analysis by (1) rederiving the expression for observation time given their assumptions and (2) derive the same expression with a real M dwarf spectrum instead of assuming a blackbody. Rederiving this term will allow me to fully understand how important each of their assumptions is. I focus on the blackbody assumption because the stellar spectra of cooler M dwarfs have absorption features. If these line up with the CO or oxygen bands, then the flux at the wavelength of the feature will decrease. This means the feature will be more difficult to detect and so the observing time needed will be longer. The magnitude of this effect is not known, and so I believe it is worth exploring.

Reference:

Wang, Y., Tian, F., Li, T., & Hu, Y. 2015, Icar, 266, 15