Earth-like Planets Around M Dwarfs

Biosignatures of the first detectable Earths

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Aims

Rocky planets in the Habitable Zone of M dwarfs will be the first detectable – potentially habitable – Earth-like planets. Several potentially rocky planets in the habitable zone (HZ) have already been detected (by NASA's Kepler mission as well as ground-based searches). The type of the host star will influence our ability to detect atmospheric features and biosignatures with future telescopes. Particularly the smallest most numerous stars – cool M dwarfs – show a wide range of activity and UV flux that changes the photochemistry and observable spectra of such planets. We model how much harder/easier it will be to detect biosignatures (O_3/O_2) in combination with a reducing gas like CH_4, or N_2O or CH_3Cl with a habitability markers such as H_2O and CO_2) for M dwarfs.

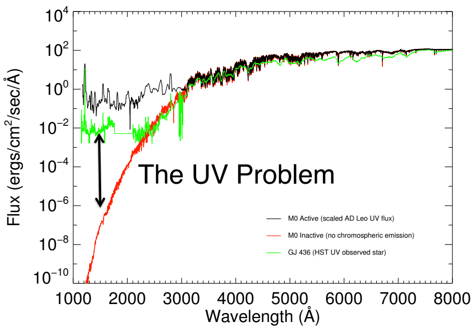

Figure 1: Active M dwarfs (black) and even quiescent M stars (green) have ~10^{10} higher UV flux than stellar models (red) which neglect chromospheric activity.

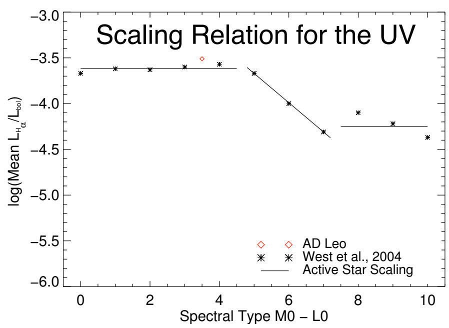

Figure 2: We use a scaling to H-alpha observations for the average active M dwarf (from West et al., 2004) for our models.

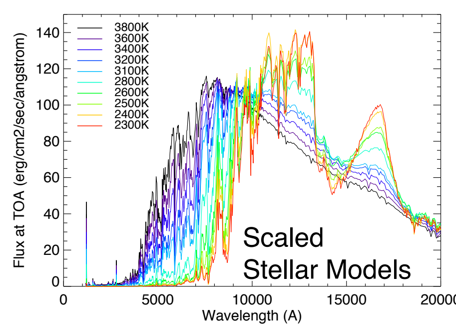

Figure 3: Models for active M dwarfs (red dwarf stars) from M0V to M9V.

Stellar Models, UV & Photochemistry

Stellar models do not include UV fluxes (Fig. 1) that are driven by magnetic field activity in the chromosphere of a star. UV photons drive photochemistry and ultimately the detectability of biomarkers in the atmospheres of Earth-like planets. We use close-by and therefore observed M dwarfs to scale the UV flux for M stars (Fig. 2) and create a catalogue of varying UV activity level input stellar models for the full M dwarf spectral class (Fig. 3).

Earth-Like Planet Atmospheres

We examine how atmospheric species, including biosignatures, change with stellar flux for active and inactive M dwarfs ranging from 3800K (M0V) to 2300K (M9V) and for 6 nearby HST observed M dwarfs (not shown). Due to lower UV activity levels around late and/or inactive M dwarfs, O_3 levels drop off for inactive stars while species such as CH_4, CH_3Cl and N_2O build up in the atmosphere. Thus it is easier to detect biosignatures (O_3+CH_4) for less active M dwarfs (Fig. 5). Cooler M dwarfs have low flux at O_2 making it increasingly difficult to detect (Fig. 6).

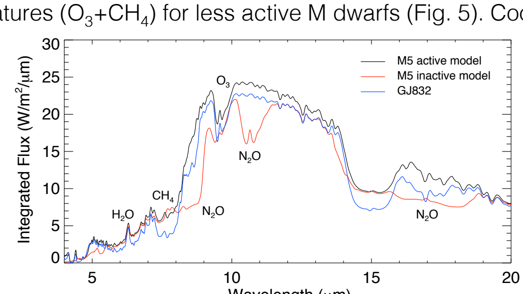

Figure 5: Detectable spectra and biosignature strength of an Earth-twin in the Infrared for an active versus inactive cool M star Model (UV vs no UV) and observed quiet UV.

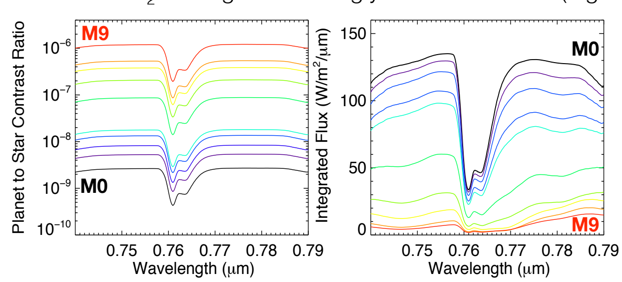

Figure 6: Observable Oxygen feature assuming 21% abundance in a relative absorption / contrast ratio (left) and in absolute detectable flux (right) for M star grid.

Conclusions

- Rocky planets in the Habitable Zone of M dwarfs will be the first detectable – potentially habitable – exoEarths.
- Atmospheric species, including biosignatures, are strongly affected by the level of UV output of its host star.
- O_2 may be difficult to detect for coolest M dwarfs since absolute flux is low.
- It will be easier to detect biosignatures for inactive M dwarfs.
- Few UV observations of M dwarfs exist. More are needed to explore their effect on habitable planets and detectable spectra.

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References

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