Extraterrestrial Life: Lecture #22

Habitable extrasolar planets may be common - **if** we define habitable as meaning Earth mass planets at around 1 AU from Solar-type stars

Some other requirements for habitability (geological activity, magnetic field…) are hard to determine from afar

Can we detect the signs of atmospheric modification that on Earth are due to life?

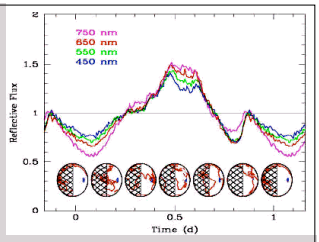
Characterizing extrasolar planets

In the near-future, extrasolar planets will be *unresolved* - a single pixel only (no maps, direct detection of continents).

Brightness of the planet will change as the planet rotates, depending upon the:

- rotation rate
- variety of surface terrain (oceans, continents, ice covered areas)
- extent of cloud cover

Depending upon the wavelength of the observations, changes can be large - factor of two



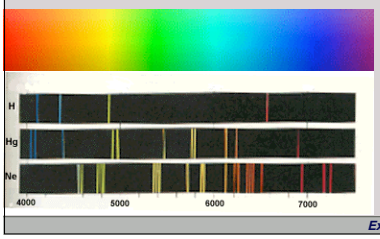
Permits *at least*:

- determination of the rotation rate of the planet (length of the `day')
- crude idea of what fraction of the surface is covered by land and ocean

Spectroscopy

Break up light into constituent colors form a **spectrum:** plot of the flux as a function of the wavelength.

Spectra contain *lines* (narrow regions where the flux is either larger or smaller than nearby in the spectrum), whose wavelengths / energies correspond to characteristic energies in atoms or molecules.



Wavelengths of spectral lines are diagnostic of composition of the atmosphere

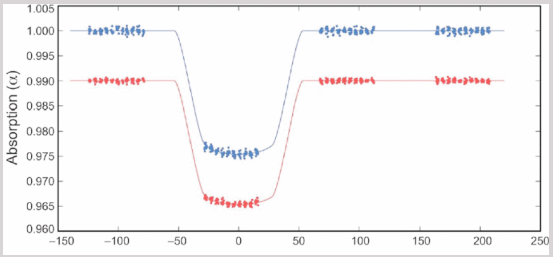
Atoms: energies of spectral lines reflect the differences between energy of electrons in different energy levels

Molecules: changes in the vibration and / or rotation state of the molecules lead to emission of absorption of radiation in spectral lines

Easiest molecules to observe in optical and infrared are O_2, O_3, CO_2 and H_2O. CH_4 also possible.

potential biosignatures!

Molecules have already been detected in **giant** planet atmospheres in *transmitted starlight* during transits:



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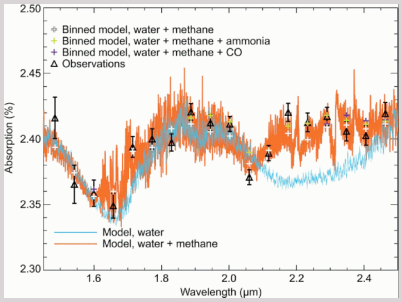
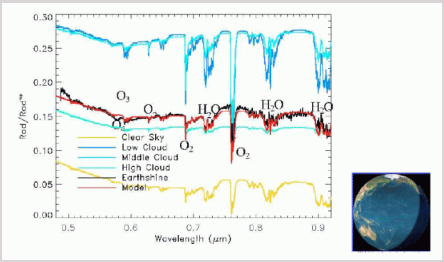


Methane in a giant planet atmosphere

Swane et al. (2008)

For terrestrial planets, hope to detect molecular signatures either in reflected light (in the optical) or in thermal emission in the infrared:



Optical spectrum

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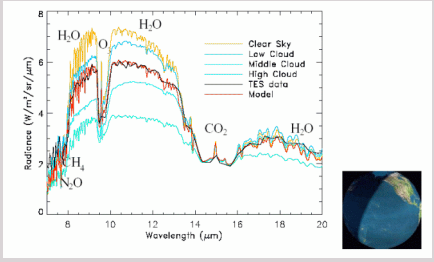
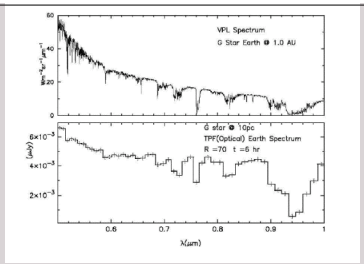
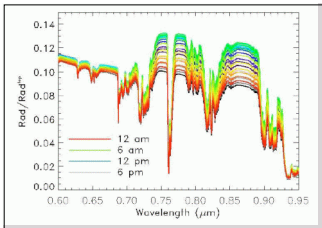


Infrared spectrum



With feasible instruments the spectrum will be of quite low resolution - but ought to be able to see O_2, O_3 and water quite easily.



The `red edge'

More definitive signatures of life exist, but are less certain…

e.g. chloroplasts in cells involved in photosynthesis lead to a signature of vegetation - reflect in green and absorb in the blue and the red…

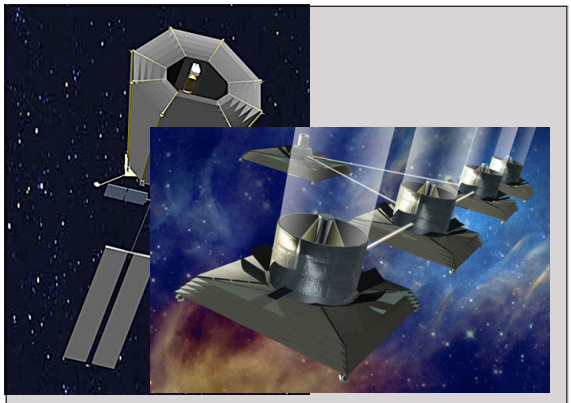
Unfortunately, this signature seems to be hard to see on a realistic planet that has clouds.

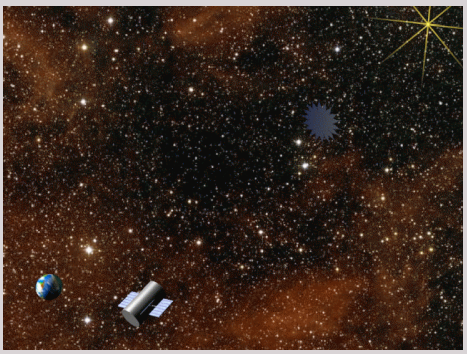
The Terrestrial Planet Finder

Possible future NASA mission to image habitable planets and measure the spectrum of their atmospheres:

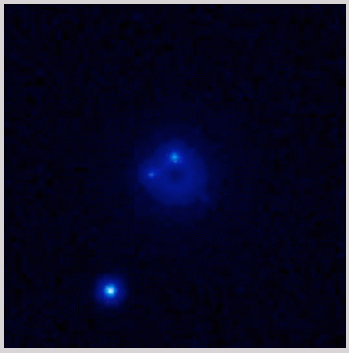
- TFP coronograph: single telescope with a device to block out the starlight allowing planet imaging
- TPF interferometer: 4 or more telescopes flying in formation whose light would be combined to cancel out the starlight

New Worlds Observer: Colorado concept to block the starlight with an external occulting disk.





Simulated NWO image



Outlook

Technically, appears feasible to search for signs of atmospheric modification by life on extrasolar planets within the next decade

Any TPF mission will be complex and thus expensive… competes with other NASA priorities

Q: will detection of oxygen or ozone convince people that life is really present?