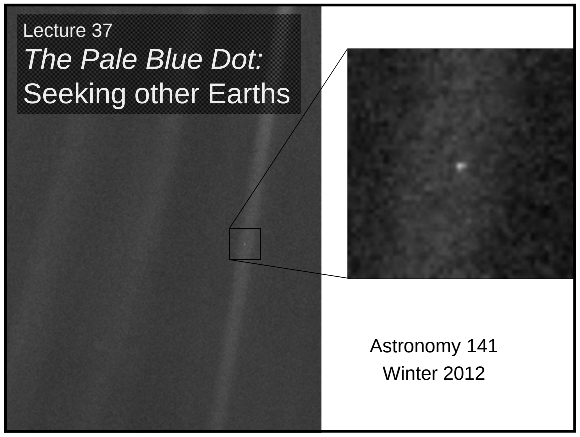


Lecture 37

The Pale Blue Dot:
Seeking other Earths

Astronomy 141
Winter 2012

This lecture discusses exoEarths – Earth-like planets around other stars

Direct detection of exoEarths is hard because of their small size and extreme faintness relative to their parent stars.

The spectrum of the Earth has two humps: reflected sunlight and thermal emission.

Spectral properties can measure the size and surface temperatures of exoEarths.

Spectral biomarkers can indicate the presence of life on an exoEarth.

Time-variability of their reflectance spectrum would tell us about oceans, continents, and weather.

To date, we have not yet found any Earth-mass planets around other stars, but the hunt is on…

The ultimate goal is to find Earth-like planets in the Habitable Zones of their parent stars.

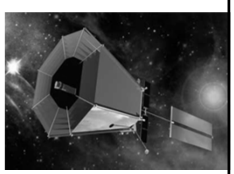
The RV method is currently insensitive to Earth-mass planets.

Transit methods are most sensitive to large planets, but the Kepler mission launched in 2008 is changing that.

Microlensing can find Earths, but not around nearby stars. Good for a global census, but not likely to be good for follow-up studies.

The Kepler mission was launched in 2008 and is searching FGKM stars for transiting Earths.

Darwin and TPF Missions



Proposed ESA & NASA Missions to search nearby stars for planets using direct imaging and follow-up with spectroscopy.

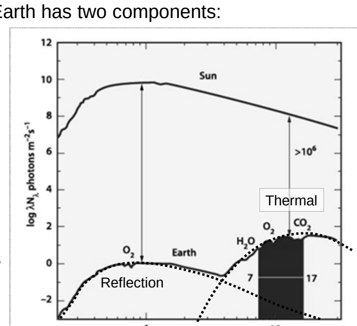
Goals:

- Direct images of Earths in the Habitable Zones of nearby stars
- Spectroscopic searches for atmospheric biomarkers

The big challenge: Earths are extremely faint compared to the light of their parent stars.

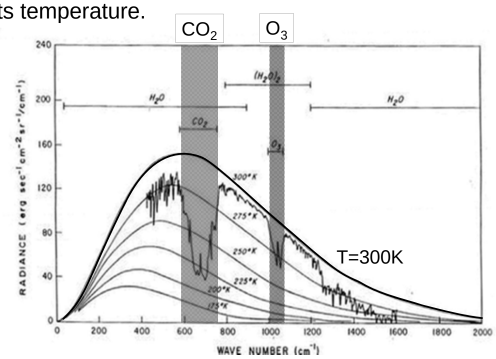
The spectrum of the Earth has two components:

- Reflected Sunlight
- Thermal Infrared Emission

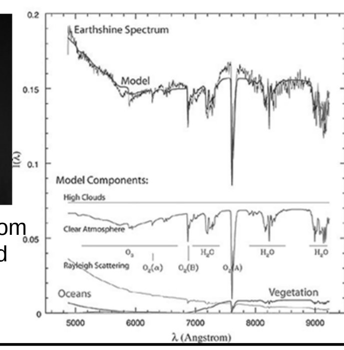


Combined, the Earth is about 2 billion times fainter than the Sun.

A planet's thermal infrared spectrum tells you its temperature.



Earth's spectrum can be measured from spacecraft or by reflection off the Moon (Earthshine)



Absorption lines from different atoms and molecules in the atmosphere.

Woolf et al. 2002, ApJ, 574, 430

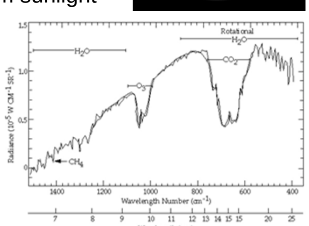
Spectral Biomarkers are spectrum features indicative of life chemistry

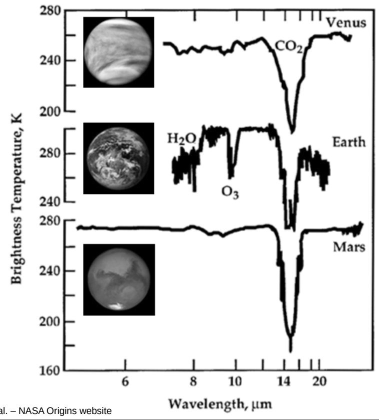
O_2 – good but easily confused with other features (false positives)

O_3 (ozone) – results from sunlight shining on O_2.

H_2O – necessary but not sufficient for life

CH_4 – byproduct of anaerobic life



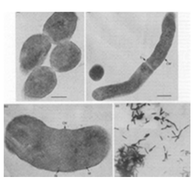


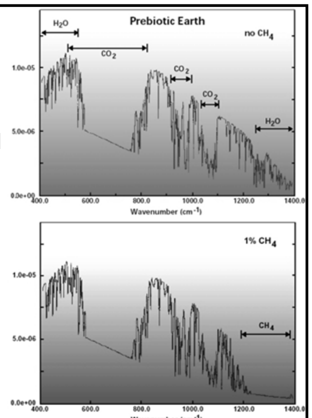
from Beichmann et al. – NASA Origins website

Methane (CH_4) is a strong biomarker

Produces strong IR absorption even in small concentrations.

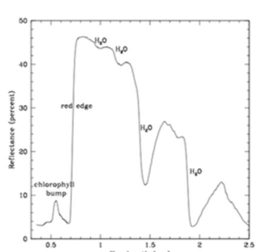
It was stronger in the early Earth than now.





Earth plants reflect infrared light, giving their spectrum a distinctive “Red Edge”

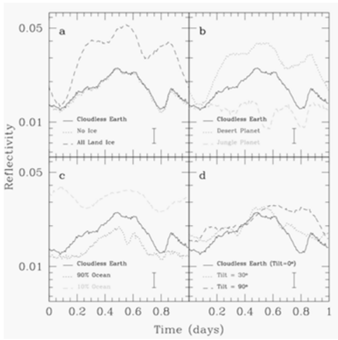
This is how plants keep cool in full sunlight.



Variability in the brightness of an exoEarth would reveal surface and weather features.

See oceans and continents as they rotate into and out of view.

Could even infer gross climate like deserts, snowballs, and jungle worlds.



The technology exists to find Earth-mass planets around other stars today.

A positive detection of an Earth-like planet it its parent star’s habitable zone is likely in a few years.

Many efforts are in progress from the ground and from space.

Direct imaging of exoEarths and spectroscopy to detect spectral biomarkers is for the future (next 20-30 years).