Future Observations of Exoplanet Atmospheres

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Does Life Exist Outside the Earth?

- Minimum requirements for life?
  1. Solid surface $\rightarrow$ terrestrial planet
  2. Liquid water $\rightarrow$ particular surface $T$, atmosphere
  3. Plate tectonics ? $\rightarrow$ particular planet mass ?

- Habitable zone for an Earth-twin
  - Roughly, just beyond Venus to Mars
  - $a_{\text{inner, outer}} = (0.7 - 1.5) \text{ AU} \times (L_{\text{star}}/L_{\text{sun}})^{1/2}$
James Webb Space Telescope

- 6.5 meter diameter mirror, 4 instruments
  - NIRCam
    - Imaging from 0.6 – 5 microns
  - NIRISS
    - Imaging & low-resolution spectroscopy from 0.6 – 3 microns
  - NIRSpec
    - Medium-resolution spectroscopy (R ~ 3000) from 1 – 5 microns
  - MIRI
    - Imaging & medium-resolution spectroscopy (R ~ 3000) from 5 – 28.3 microns
Sources: M. Clampin (GSFC), J. Valenti (STScI), T. Greene (Ames)

- Spectroscopy of hot & cold gas giants
  - In both transit & eclipse
  - High S/N and good resolution
    \((R = 100 – 3000)\)

- Transit spectroscopy of Neptunes & super-Earths around low-mass stars
  - Small stellar radii = larger transit signal
Transit Spectrum of Habitable “Ocean Planet”

- Host star
  - Mass = 0.3 solar masses
  - Radius = 0.5 solar radii

- But JWST can’t do true Earth-analogs

Simulation by J. Valenti (STScI)
ExoEarths: The Technical Challenge

- To get a direct image of a habitable planet around a nearby Sun-like star ...

0.1 arcsec (inner working angle)

$F_{\text{planet}} / F_{\text{star}} = 1.155 \times 10^{-10}$ (contrast)

Like a picture of a firefly 1 meter from a searchlight 2000 km away
Starlight Suppression

Internal Coronagraph (visible wavelengths)
aka. Terrestrial Planet Finder

Nulling Interferometer (infrared wavelengths)
aka. Darwin

External Occulter (visible wavelengths)
aka. New Worlds Observer
What Will We See?

Unresolved image = integrated light from whole illuminated area of planet

Very optimistic simulated optical image of the Solar System at 10 pc
Model Disk-Averaged Earth Spectra

- Optical spectra of Earth shows mostly reflected sunlight, then clouds and atmospheric constituents

Tinetti et al. (2006)
Simulated Spectra

- Low spectral resolution ($R \sim 100$), modest S/N
Simulated Spectra

- Low spectral resolution ($R \sim 100$), modest S/N
Simulated Spectra

- Low spectral resolution (R ~ 100), modest S/N
Issues Needing Study

- Variations from Earth model ...
  - Atmosphere composition
  - Photochemistry (different stellar input spectrum)
  - Gravity (in particular, more massive planets)
  - Orbital distance, seasonal insolation changes