If you are interested in atmospheres, transiting exoplanets are the best kind of exoplanet, as they are the only ones for which the physical parameters are determined robustly.

Doppler Method
Determine Planet Mass

Transit Method
Determine Planet Diameter

Calculate Planet Density and Infer Composition:
Gas giant (Jupiter), Ice giant (Neptune), or Rocky planet (Earth)
In the past decade, our knowledge of exoplanets has *exploded* . . .

<table>
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<tr>
<th>Year</th>
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<td>2011</td>
<td>150 <em>(but really 1300)</em></td>
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Very Recent Progress

*The first habitable-zone sub-Neptune?*

*The first Earth-sized exoplanets?*

*The first Earth-sized, habitable-zone planet?*
Very Recent Progress

*The first habitable-zone sub-Neptune?*  
Announced December 5th 2011

*The first Earth-sized exoplanets?*  
Announced December 20th 2011

*The first Earth-sized, habitable-zone planet?*  
?
Very Recent Progress

The first habitable-zone sub-Neptune? Announced December 5th 2011
The first Earth-sized exoplanets? Announced December 20th 2011
The first Earth-sized, habitable-zone planet? ?

JWST will see first light perhaps 5 years after the discovery of the first exo-Earths.
Transits Allows Studies of the Atmospheres That Are Not Possible for Non-Transiting Planets

- Detection of:
  - Atoms & Molecules
  - Stratospheres
  - Clouds
  - Winds
Transits Allows Studies of the Atmospheres That Are Not Possible for Non-Transiting Planets
JWST Transit Science: The Best of Spitzer and Hubble

- My wish list for exoplanet spectroscopy platform:
  - Orbit that assures thermal stability and low background
  - Orbit that assures long dwell times
  - A stable PSF and excellent pointing
  - Infrared sensitivity (planetary temperatures; molecules)
  - Aperture sufficient to permit mod resolution spectroscopy
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- These are obtained with a large aperture, cryogenic telescope placed at L2, with a detailed error budget and careful instrument characterization prior to launch

- JWST is an excellent platform for Exoplanet Spectroscopy
JWST Transit Capabilities

- JWST offers a broad range of capabilities for transit observations

<table>
<thead>
<tr>
<th>Instrument Mode</th>
<th>λ (µm)</th>
<th>R (δ/δλ)</th>
<th>FOV</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIRCcam</td>
<td>0.6 - 2.3, 2.4 - 5.0</td>
<td>4, 10, 100, 4, 10, 100</td>
<td>2 x (2.2' x 2.2'), 2 x (2.2' x 2.2')</td>
<td>Transit light curves of primary and secondary eclipses</td>
</tr>
<tr>
<td>NIRCcam (Defocused)</td>
<td>0.6 - 2.3</td>
<td>4, 10, 100</td>
<td>Defocused images: 1) radius = 0.74'', 2) radius = 1.42'', 3) radius = 2.11''</td>
<td>High precision transit light curves of primary eclipses - defocusing of bright targets to avoid saturation</td>
</tr>
<tr>
<td>MIRI</td>
<td>5.0 - 28.0</td>
<td>4 - 6</td>
<td>1.9' x 1.4'</td>
<td>Transit light curves of secondary eclipses</td>
</tr>
<tr>
<td>NIRISS</td>
<td>0.6 - 5.0</td>
<td>4, 10</td>
<td>2.2' x 2.2'</td>
<td>Transit light curves of primary and secondary eclipses</td>
</tr>
<tr>
<td>Spectroscopy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIRCcam</td>
<td>2.4 - 5.0</td>
<td>1700</td>
<td>2 x (2.2' x 2.2')</td>
<td>Transmission and emission spectroscopy of transiting planets</td>
</tr>
<tr>
<td>NIRSpec</td>
<td>1.0 - 5.0</td>
<td>100, 1000, 2700</td>
<td>1.6'' x 1.6''</td>
<td>Transmission and emission spectroscopy of transiting planets</td>
</tr>
<tr>
<td>NIRISS</td>
<td>0.6 - 2.5</td>
<td>700</td>
<td>2.2' x 2.2'</td>
<td>Transmission spectroscopy of transiting planets - spatially defocused images to avoid saturation of bright targets</td>
</tr>
<tr>
<td>MIRI-LRS</td>
<td>5 - 11</td>
<td>100</td>
<td>1.9' x 1.4' Slitless</td>
<td>Emission spectroscopy</td>
</tr>
<tr>
<td>MIRI-HRS</td>
<td>5.9 - 7.7, 7.4 - 11.8, 11.4 - 18.2, 17.5 - 28.8</td>
<td>3000, 3000, 3000, 3000</td>
<td>3.7'' x 3.7'', 4.7'' x 4.5'', 6.2'' x 6.1'', 7.1'' x 7.1''</td>
<td>Emission spectroscopy of transiting planets</td>
</tr>
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</table>
Thermal Emission from a Hot Jupiter

HD 189733b (the planet)

Stratospheric absorber
Less heat transfer
Assumed model
More heat transfer

S/N=13 per 5–pixel bin per eclipse

J. Valenti (STScI)
Hydrogen Rich Super-Earth (1.4 $R_{\text{Earth}}$, 5 $M_{\text{Earth}}$)

NIRSpec: 20 transits

- NIRSpec- 20 transits
- Binned to R~300

M. Clampin
Model by E. Kempton
Transit Spectrum of Habitable-Zone Earth-size Ocean Planet (1 $R_{\text{Earth}}$, 0.5 $M_{\text{Earth}}$)
So, how will we identify the optimal targets to enable this JWST science?
MIT-led Mission: NASA, Orbital Sciences, Harvard-SAO

Discover Transiting Earths and SuperEarths around Bright, Nearby Stars

- Rocky planets
- Water worlds
- Habitable zone planets

Discover 1000+ Exoplanets

All Sky Survey of Bright Stars

- ~40000 deg² (~400 x Kepler)
- F, G, K dwarf stars: 4.5 to 12 magnitude
- M stars known within 50 pc (= 150 l-yr)
- 500,000 stars in two years
Predicted Science Yield from TESS Mission

TESS Will Discover ~300 Earths + SuperEarths
Probability of a Transiting Habitable-Zone Planet as a Function of Distance (in pc)

See Deming et al. (2009) for details
JWST will be an excellent platform for sniffing alien atmospheres.
Simulated MIRI Observations of HD 189733b

HD 189733b, 1 eclipse per MRS setting

J. Valenti (STScI)