Webb Science

• What if you could see the Universe create the first stars?
• What if you could study planets around other stars to look for life?

• We are building a telescope that will let you do this and more:

First Light & Reionization

Planets & Origins of Life

Birth of Stars & Planetary Systems

Assembly of Galaxies
First Light and Reionization

13.7 billion years old ($z \sim 0$)
9 billion years old ($z \sim 0.5$)

Helium Reionization:
2 billion – 2.4 billion years old ($z \sim 2.4 – 2.9$)

Hydrogen Reionization:
400 million – 1.2 billion years old ($z \sim 6 – 11$)

First Stars and Galaxies:

Cosmic Microwave Background:
380,000 years old ($z \sim 1000$)
Atmospheric transmission spectrum (4 hours) for HD209458-like Kepler source using NIRSpec ($R = 3000$). Simulation from J. Valenti.
Birth of Stars and Planetary Systems

Star formation region in visible light

Same region in infrared light
Assembly of Galaxies

Simulation of filaments of forming galaxies in the early universe

Observations of galaxies through cosmic time
Key Design Drivers

Sensitivity;
- Detection of First Galaxies

Aperture
- Collection area 25 m²
- Diffraction limited @ 2 μm

Low Backgrounds
- Cryogenic observatory
- Passive cooling

Stowable/Deployable Architecture
- Telescope stowed for launch
Webb and its Precursors

**HUBBLE**
- 2.4-meter
- $T \sim 270$ K
- $123'' \times 136''$
- $\lambda/D_{1.6\mu m} \sim 0.14''$

**WEBB**
- 6.5-meter
- $T \sim 40$ K
- $132'' \times 264''$
- $\lambda/D_{2\mu m} \sim 0.06''$

**SPITZER**
- 0.8-meter
- $T \sim 5.5$ K
- $312'' \times 312''$
- $\lambda/D_{5.6\mu m} \sim 2.22''$
- $324'' \times 324''$
- $\lambda/D_{24\mu m} \sim 6.2''$

Wavelength Coverage

- **Hubble**
  - 1 $\mu m$
  - 10 $\mu m$
  - 100 $\mu m$

- **Webb**
  - 1 $\mu m$
  - 10 $\mu m$
  - 100 $\mu m$

- **Spitzer**
  - 1 $\mu m$
  - 10 $\mu m$
  - 100 $\mu m$
The Webb space vehicle consists of three elements:

- **Optical Telescope Element (OTE)**
  Collects star light from distant objects

- **Integrated Science Instrument Module (ISIM)**
  Extracts physics information from star light

- **Spacecraft**
  Attitude control, telecom, power & other systems

Webb Full Scale Model

Webb telescope at Goddard Space Flight Center
How the Webb Telescope Works

Webb is folded and stowed for launch

Webb Orbits the 2nd Lagrange Point (L2)
384,000km

Observatory is deployed after launch

1.5 million km

Earth | Moon | L2

Cold Side: ~40K
Completed Telescope
## Webb Instrumentation

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Science Requirement</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NIRCam</strong></td>
<td>Wide field, deep imaging</td>
<td>Two 2.2’ x 2.2’ Ω (SW)</td>
</tr>
<tr>
<td>Univ. Az/LMATC</td>
<td>• 0.6 μm - 2.3 μm (SW)</td>
<td>Two 2.2’ x 2.2’ Ω (LW)</td>
</tr>
<tr>
<td></td>
<td>• 2.4 μm - 5.0 μm (LW)</td>
<td>Coronagraph</td>
</tr>
<tr>
<td><strong>NIRSpec</strong></td>
<td>Multi-object spectroscopy</td>
<td>9.7 Sq arcmin Ω + IFU + slits</td>
</tr>
<tr>
<td>ESA/Astrium</td>
<td>• 0.6 μm - 5.0 μm</td>
<td>100 selectable targets: MSA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=100, 1000, 3000</td>
</tr>
<tr>
<td><strong>MIRI</strong></td>
<td>Mid-infrared imaging</td>
<td>1.9’ x1.4’ with coronagraph</td>
</tr>
<tr>
<td>ESA/UKATC/JPL</td>
<td>• 5 μm - 27 μm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mid-infrared spectroscopy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 4.9 μm - 28.8 μm</td>
<td>3.7”x3.7” – 7.1”x7.7” IFU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=3000 - 2250</td>
</tr>
<tr>
<td><strong>FGS/NIRISS</strong></td>
<td>Fine Guidance Sensor</td>
<td>Two 2.3’ x 2.3’</td>
</tr>
<tr>
<td>CSA</td>
<td>• 0.8 μm - 5.0 μm</td>
<td>2.2’ x 2.2’</td>
</tr>
<tr>
<td></td>
<td>Near IR Imaging Slitless Spectrometer,</td>
<td>R=100 with coronagraph</td>
</tr>
<tr>
<td></td>
<td>• 1.6 μm - 4.9 μm</td>
<td></td>
</tr>
</tbody>
</table>
NIRCam provides the deepest near-infrared images ever and identifies primeval galaxy targets for NIRSpec
NIRSpec acquires spectra of up to 100 galaxies in a single exposure
MIRI will provide humanity's first high definition view of the mid-infrared universe
FGS senses pointing to 1 millionth degree precision. NIRISS images exoplanets that are too close to their star for coronagraphs.
Instruments Being Installed
Sunshield Membrane

- 5 thin membranes (each less than half the thickness of a piece of paper) protect the side in the extreme of cold space from the warm sunlit side [Equivalent Sun Protection Factor (SPF) of 1,000,000]

Mirror Support Structure

- Structures hold mirrors and science instruments super stable, behavior must be known to ~38 nanometers (~1/10,000th of a human hair!)

Segmented Beryllium Mirror

- Mirrors so smooth that if “stretched” to the size of the continental US largest deviation from perfection would be ~2 inches in height.

Advanced Near Infrared detectors

Advanced Mid-Infrared detectors

Cryogenic ASICs

Ultra-sensitive detectors on Webb could see a single candle on the Moon from 1 million km.

Microshutters

- ~100,000 computer controlled shutters, the width of a human hair enable optimal science return

Mirror phasing and control

- 18 mirror segments computer controlled to operate as one mirror in space

A cooler to chill the mid-infrared detectors to just 6 degrees above absolute zero.

5 thin membranes (each less than half the thickness of a piece of paper) protect the side in the extreme of cold space from the warm sunlit side [Equivalent Sun Protection Factor (SPF) of 1,000,000]
ISIM was tested at ~35 K in the GSFC SES chamber using a cryogenic telescope simulator (OSIM)
Spacecraft Bus at Northrop-Grumman
Engineering Model Sunshield
Webb Launch

- Launch vehicle is an Ariane 5 rocket, supplied by ESA
- Site will be the Arianespace’s ELA-3 launch complex near Kourou, French Guiana
- Date is October 2018
The End (of this presentation)

but

with the James Webb Space Telescope, we will see the beginning of everything

The first galaxies
The origins of galactic structure
The birth of stars
The creation of planets
and more …

You can follow the action: @NASAWebbTelescope #JWST

http://jwst.nasa.gov/
Deployment Sequence Overview