Hubble Science Briefing

Looking Forward to our Deepest View of the Universe:
Science with the Near-Infrared Camera on the James Webb Space Telescope

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The James Webb Space Telescope (JWST)
Who is James E. Webb?

- 1906 - 1992
- NASA’s Second Administrator
- Led the Apollo effort
- Implemented the space science program within NASA
- Began proposal efforts for large space based telescopes
Bigger is Better!

JWST’s mirror is almost 3 times larger than Hubble’s.
Where to find JWST
A gold plated telescope!
A gold plated telescope!
What is Infrared Light?
Infrared Light

• Infrared light can see through some materials that visible light can’t.

• With an infrared camera, we can see the heat from the man’s arm and hand and “see” through the black bag.

• Infrared light can also see through thick smoke and fog.

• We need infrared light to see the stars in the most distant galaxies.
Infrared Light

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The Universe is Expanding

Image Credit: Science Blogs, Ethan Siegel
http://scienceblogs.com/startswithabang/2008/02/07/the-cosmic-microwave-background-not-always/

Image Credit: GSFC HEASARC “Imagine the Universe”
http://imagine.gsfc.nasa.gov/features/yba/M31-velocity/hubble-more.html
Redshifts and Blueshifts

Scale factor \((1+z)\) tells us how much the wavelengths have been stretched.

Image Credit: Wikipedia/Aleš Tošovský
Formation of the First Galaxies

Visible light for these galaxies is redshifted to infrared wavelengths.

Image Credit: *Evolution*, a Scientific American Reader 2006, University of Chicago Press
Four Science Instruments

NIRCam

MIRI

NIRISS

NIRSpec
Fields of View of JWST Instruments

Horizontal Field Position (arcmin)

Vertical Field Position (arcmin)

NIRISS

FGS

NIRCam

MIRI

NIRSpec
NIRCam has Two Imagers in Two Modules

Two adjacent fields of view (2.2 arcminute)$^2$
Both fields in SW and LW bands

Two back-to-back modules
View of NIRCam’s Optics
NIRCam with Enclosures
NIRCam Filter Wheel
Assembled Modules
NIRCam: The Near Infrared Camera

- 2 functionally identical (mirror image) modules
- 2 channels in each module:

<table>
<thead>
<tr>
<th>Short Wavelength (0.6-2.3 μm)</th>
<th>Long Wavelength (2.4-5.0 μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HgCdTe FPA Format (2x2) x (2040 x 2040)</td>
<td>HgCdTe FPA Format 1 x (2040 x 2040)</td>
</tr>
<tr>
<td>0.032 arcsec/pixel</td>
<td>0.065 arcsec/pixel</td>
</tr>
<tr>
<td>FOV= 2.21x2.21 arcmin^2</td>
<td>FOV= 2.21x2.21 arcmin^2</td>
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- 5” gap between SW SCAs
- 40” gap between A & B

- Filters provide (W ⇒ R=4; M ⇒ R=10; N ⇒ R=100)
- LW Grisms provide R~3000
- Sensitivity (S/N=10, R=4, in 10^4 s):
  - 1.1 μm: 10.4 nJy
  - 2.0 μm: 12.1 nJy
  - 4.4 μm: 24.5 nJy

- Coronographic masks:
NIRCam Sensitivity Comparison

Galaxy models:
- Ground (Keck/VLT)
- Space (HST or SPITZER)
- NIRCam

- 5-sigma, 50,000 secs

Wavelength (Microns)

- HST
- SST
- NIRCam
- JWST NIRCam
JWST has Four Science Goals

- End of the dark ages: first light and reionization
- The assembly of galaxies
- Birth of stars and protoplanetary systems
- Planetary systems and the origins of life
Galaxies Form as Gas Clouds Collapse in the Early Universe

- After the Big Bang, gas in the universe is smoothly distributed, with slight irregularities that we can see in the Cosmic Background Radiation.

- Gravity causes the densest filaments and points to collapse.

- These dense knots form the first stars and galaxies.

Image Credit: NASA / WMAP: http://map.gsfc.nasa.gov/media/080997/index.html

Image Credit: Volker Springel, et al. 2004
End of the dark ages: first light and reionization

- What are the first galaxies?
- What objects reionized the gas between the galaxies?

Key JWST Observations:

- Ultra-Deep Near InfraRed survey (NIRCam, NIRISS)
- Spectroscopic Near-IR & Mid-IR confirmation.
  (NIRCam & NIRISS Grisms, NIRSpec, MIRI)

- The red circles show the locations of faint, red distant galaxies.
The assembly of galaxies

- Where and when did the Hubble Sequence form?
- How did galaxies like the Milky Way take shape?
Birth of stars and protoplanetary systems

- How do interstellar clouds collapse to form stars?
- How do gaseous disks form around stars?
- How do planets condense out of the gaseous disks?

- Imaging of molecular clouds
- Survey “elephant trunks”
- Survey star-forming clusters
Birth of stars and protoplanetary systems

- How do interstellar clouds collapse to form stars?
- How do gaseous disks form around stars?
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Deeply embedded protostar  Circumstellar disk

- Imaging of molecular clouds
- Survey “elephant trunks”
- Survey star-forming clusters
Planetary systems and the origins of life

- How do planets form?
- How are circumstellar disks like our Solar System?
- How are habitable zones established?

• NIRCam will use coronagraphy to image protoplanetary disks and extra-solar giant planets

• NIRCam will obtain images and spectra of circumstellar disks, comets, moons, and Kuiper Belt Objects in the outer Solar System
NIRCam’s Wavefront Sensing Role

- NIRCam provides the imaging data needed for wavefront sensing.

- Dispersed Hartmann Sensors at 0° and 60° orientations permit phasing of adjacent mirror elements.

First Light

After segment capture

Fine phasing

After coarse phasing

Fully aligned

Coarse phasing w/DHS

DHS at pupil

Spectra recorded by NIRCam
On-line Resources

- STScI JWST Home Page
  http://www.stsci.edu/jwst/

- JWST Primer
  http://www.stsci.edu/jwst/doc-archive/handbooks

- STScI NIRCam Page
  http://www.stsci.edu/jwst/instruments/nircam

- University of Arizona NIRCam Page
  http://ircamera.as.arizona.edu/nircam/

- University of Arizona NIRCam Girl Scouts Page
  http://zeus.as.arizona.edu/~dmccarthy/GSUSA/index.htm

- NASA NIRCam Page
  http://www.jwst.nasa.gov/nircam.html