JWST – Successor to HST

• Introduction
• Webb Science
• Webb Hardware
• Summary
Hubble Space Telescope

- HST has made and continues to make huge impact on astronomy and the public
  - Cosmic distance scale
  - Accelerating universe & dark energy
  - Supermassive BH in Galaxy centers
- Next year, SM04
  - installation of new instruments and repair of old ones will make Hubble even more capable than presently
Why do we need Webb Space Telescope?

- Hubble is wonderful, but it is a UV and optical telescope
- Webb will give Hubble-like images but at longer wavelengths, namely in the infrared
  - Peer further back in time
  - Peer deep into regions of space hidden by dust
  - Study cool objects like planets
  - Learn about objects in another wavelength band
Why IR? - Distant galaxies are redshifted
Why IR? - Because Space is Dusty

The Eagle Nebula as seen by HST

The Eagle Nebula as seen in the infrared
Spitzer Space Telescope
Hubble - Webb - Spitzer
Adapted from *Cosmic Discovery*, M. Harwit
Webb: Overview

- Webb is a large IR space telescope
- Webb contains a 6-m diameter primary mirror
  - Provides needed sensitivity
  - Image quality similar to Hubble
- Webb will be observe from a position called L2, which is well beyond the moon
  - This allows the telescope and its instruments to be very cold (<50 K)
- Webb will be launched in 2013 and observe for at least 5 years
- Webb science will be spectacular
The Science Instruments

• NIRCam (Univ Ariz):
  – 0.6-5 µm imaging
  – 40 Mpix camera

• NIRSpec (ESA)
  – 0.6-5 µm spectrograph, using 8 Mpix detector
  – Up to 100 objects at once
  – Long slit & IFU spectroscopy

• MIRI (ESA/NASA)
  – 5-28 µm imaging
  – Slit and IFU spectroscopy
  – 3 Mpix detector

• FGS-Tunable Filter: (CSA)
  – (R~100) narrow band imaging
  – 12 Mpix camera
JWST – Successor to HST

- Introduction
- Webb Science
- Webb Architecture
- Status
Webb Science Goals

Webb will examine every phase of cosmic history: from the first luminous glows after the Big Bang to the formation of galaxies, stars, and planets to the evolution of our own solar system. The science goals for the JWST can be grouped into four themes:

First Light and Reionization: What were the first bright objects in the early Universe, and how did they ionize the Universe around them?

Assembly of Galaxies: How did galaxies and dark matter, including gas, stars, metals, physical structures (like spiral arms) and active nuclei evolve to make the nearby Universe?

The Birth of Stars and Protoplanetary Systems: How are stars born and how do they form planets?

Planetary Systems and the Origins of Life: How did our and other similar solar systems evolve and create the building blocks of life may be present?
Brief History of the Universe

Big Bang

3 minutes

300,000 years

400 million years

1 billion years

13.7 billion years

Galaxies Evolve

First Galaxies

Atoms & Radiation

Particle Physics

Cosmic Dark Zone

Planets, Life & Intelligence

Now
End of the dark ages: first light and reionization

- What are the first galaxies?
- When did the hydrogen get ionized?
- What ionized the galactic medium?

Neutral gas absorbs UV light → Observed as IR light because of Redshift

What Webb will do
- Ultra-Deep imaging surveys to find objects emerging from darkness
- Quasar and Galaxy spectra to study gas
Basic Tool – Photometric Redshifts

- The spectra of galaxies is constant enough to use R=5 imagery to determine the redshift of galaxies

Yan et al 2004

Z~2.7 object

Yan et al 2004
How did galaxies evolve to what we see today?
Galaxies Today

The Hubble Sequence
Distant Galaxies are “Train Wrecks”

- Trace construction of Hubble sequence:

- How do “train wrecks” become spirals and ellipticals

By Merging!
What Webb will do

- Image distance galaxies to see how their shape changes with redshift
- Obtain spectra to measure there rate at which stars form
Birth of stars and protoplanetary systems

- How do clouds collapse into stars?
- What is the distribution of masses in low-mass stars?

- Deeply embedded protostar
- Circumstellar disk
- Agglomeration & planetesimals
- Mature planetary system

- Image molecular clouds
- Survey “elephant trunks”
- Survey star-forming clusters
Do High Mass Star Form by Nature or Nurture?

- Star form in very dense molecular clouds
- We believe stars like sun are born by “Nature”
  - MC have many rotating clumps
  - Disks forms around the clumps
  - Stellar mass builds from disk
- Theory suggests intense light destroys disk in high mass objects
- Alternative – Nurture
  - low mass “companions” in gravitational well collide to form high mass stars
- Mid-IR imaging with Webb should reveal these massive young stars forming

Bonnell et al. 2004
Planetary systems and the origins of life

• How do planets form?
• How are circumstellar disks related to our Solar System?
• How are habitable zones established?

Webb will obtain images and spectra of
• Solar system objects, including
  – comets,
  – Kuiper Belt Objects, and
  – the outer planets and their moons
• Circumstellar disks and exoplanets
  – Coronagraphy
Exoplanet observations with Webb

- Exoplanets are planets of other stars
- Spitzer and HST detected some exoplanets transiting the parent star
  - Shape of light curve measures radius and temperature distribution
  - Webb will image many more
- Webb will obtain spectra of transits
  - Determine atmospheric composition
  - May show whether they are habitable
Webb – Successor to Hubble

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• Webb Science
• Webb Architecture
• Summary
Webb is 7 tons and fits inside an Ariane 5 shroud. This remarkable feat is enabled by:

- Ultra-lightweight optics (~15 kg/m²)
- Deployed, segmented, actively adj. primary
- Multi-layered, deployed sunshade
- L2 Orbit allowing open design/passive cooling
Webb is an International Project

Arianne Launch Movie
Webb will observe from L2?

- L2 is 1.5 million km from earth, beyond the moon
- L2 is special place because satellites there orbit the sun, not the earth
- Makes it easier to keep the telescope cold
  - For Hubble, about 50% of the heat load on a satellite is due to the earth and it comes from all angles
  - Sunshield protects telescope from the earth, sun, and moon.
- Makes it easier to plan observations
  - Earth will not get in the way every 95 minutes

Laplace (1749-1827)
Webb must unfold after launch

OTE in folded configuration
Deploy secondary mirror
Latch secondary mirror support structure
Rotate and latch primary mirror chords
Webb is being built today
Mirror are being ground and polished

Be fabrication

Secondary Mirror

Pathfinder Mirror

Primary Mirror Segments

2 Flight Spares

6.6 m
Summary

• Webb is being built
• Launch will occur in 2013
• STScI will operate it
• It will be super!

For more Webb information see our websites:
www.jwst.nasa.gov
www.stsci.edu/jwst

Deployment Movie
May 10 - 12
Next week
Thurs. - Sat.

DEEP SPACE IS AS CLOSE AS THE NATIONAL MALL.

SEE THE JAMES WEBB SPACE TELESCOPE MODEL MAY 10TH TO 12TH.
Mark down the dates to see an engineering marvel up close and learn about its mission in space. JWST will look back nearly 13 billion years to see the origins of the early universe, its stars and galaxies. As large as a tennis court, the full scale model will be on display as part of the Public Service Recognition Week. Prime contractor Northrop Grumman and its teammates are proud to show off this incredible time machine.
Backup Charts
Who was JW?

- Hubble is named for Edwin Hubble
- Chandra is named for S. Chandrasekhar
- Spitzer is named for Lyman Spitzer
- JW is not a scientist
- So who was JW?
  - Junior senator from Virginia?
Who was JW?

- JWST is named for James Webb,
- Administrator who led NASA 1961-1968 when went to moon
Instruments

FGS
- 0.6 to 5 μm operation
- Guide star acquisition & tracking
- Tunable filter imager
  2 (2048x2048) 68mas pixels

MIRI
- 5 to 28 μm operation
- Science Discovery Space
- Imaging
  1 (1024x1024) 110mas pixels
- Spectroscopy
  2 (1024x1024) 200-470mas pixels

NIRSpec
- 0.6 to 5 μm operation
- Simultaneous Spectra of > 100 objects
- \( \lambda/\Delta \lambda \sim 100 \) to 1000
- 2 (2048x2048) 100mas pixels

NIRCam
- 0.6 to 5 μm operation
- Wide Field Imaging
- Coronagraph imaging capability
- Supports WFS&C
- 2 (4096x4096) 31mas pixels
- 2 (2048x2048) 62mas pixels

- Cools MIRI detectors to ~7K
- 5 year lifetime
NIRCam – 40 Megapixel Camera

- Images 2 fields and two colors at one time
  - 2’x2’ & 2’x2’
  - 0.6 μm < λ < 2.4 μm
  - 2.6 μm < λ < 5 μm

- Science
  - Wide-field imaging
  - Coronagraphy
NIRSpec - NIR Spectrograph

- > 100 Objects Simultaneously
- 9 square arcminute FOV
- **Implementation:**
  - 3.5’ Large FOV Imaging Spectrograph
  - 4 x 175 x 384 element Micro-Shutter Array
  - 2 x 2k x 2k Detector Array
  - Fixed slits and IFU for backup, contrast
  - SiC optical bench & optics
MIRI - Mid IR Instrument

- Combination camera and spectrograph
- Imager
  - 1.9 x 4 arcmin
  - 5-28 μm
  - R=5 filter set
  - Coronagraph
- Spectograph
  - Conventional slit spectrograph as on HST
  - Integral field spectrograph obtains spectrum of every pixel in a small field
- Science
  - All
FGS (Fine Guidance Sensor) - (FGS)

- FGS-TF is a narrow band imager
- FGS is a tunable filter
  - $R \sim 100$