Progress by the JWST Science Working Group

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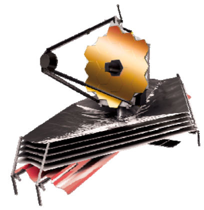
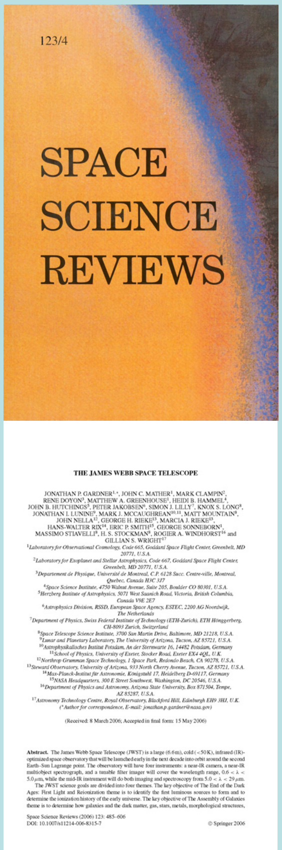


The JWST Science Working Group recently published a comprehensive, top-level review of JWST science in the journal Space Science Reviews (Gardner et al. 2006, SSR, 123/4, 485). That review paper gives details of the 4 JWST science themes, and describes the design of the observatory and ground system. Since publication, the SWG, working with members of the astronomical community, has continued to develop the science case for JWST, giving more details in a series of white papers. The white paper topics include astrobiology, first light, exoplanets, stellar populations, galaxy surveys, AGN, bright targets, supernovae and moving targets. The white papers are in various stages of completion. In this poster, I review recent progress.

Gardner et al. 2006, Space Science Reviews, 123/4, 485, "The James Webb Space Telescope."



123/4

SPACE SCIENCE REVIEWS

THE JAMES WEBB SPACE TELESCOPE

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Abstract. The James Webb Space Telescope (JWST) is a large (6.6 m), cold (<50 K), infrared (IR)-optimized space observatory that will be launched early in the next decade into orbit around the second Earth–Sun Lagrange point. The observatory will have four instruments: a near-IR camera, a near-IR multiobject spectrograph, and a tunable filter imager will cover the wavelength range, 0.6 < λ < 5.0 μm, while the mid-IR instrument will do both imaging and spectroscopy from 5.0 < λ < 29 μm. The JWST science goals are divided into four themes. The key objective of The End of the Dark Ages: First Light and Reionization theme is to identify the first luminous sources to form and to determine the ionization history of the early universe. The key objective of The Assembly of Galaxies theme is to determine how galaxies and the dark matter, gas, stars, metals, morphological structures,

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The End of the Dark Ages: First Light and Reionization

What are the first galaxies?
When and how did reionization occur?
What sources caused reionization?

JWST will conduct ultra-deep near-infrared surveys with spectroscopic and mid-infrared follow-up to find and identify the first galaxies to form in the early universe. It will determine the processes that caused reionization through studies of the Lyman-alpha forest and the properties of galaxies during that epoch.

Observations

Observation	Depth and Mode	Target	Comments
Ultra-deep survey (UDS)	1.4 nJy at 2 micron	10 arcmin^2	Find high-z drop-outs.
In-depth study	23 nJy, R~100	Galaxies in UDS	Follow-up spectroscopy.
	23 nJy at 5.6 micron		Age estimates.
Lyman alpha forest	2×10^{-19} erg cm^{-2} s^{-1}	Bright z>7 quasar	Look for Gunn-Peterson trough
Lyman alpha emitters	2×10^{-19} erg cm^{-2} s^{-1}	4 arcmin^2	Lyman alpha sources near known high-z object
Lyman alpha/Balmer lines	2×10^{-19} erg cm^{-2} s^{-1}	UDS	Spectral lines before and after reionization
Measure ionizing continuum	2×10^{-19} erg cm^{-2} s^{-1}	UDS	Measure hardness of ionizing continuum
Ionization source nature	2×10^{-19} erg cm^{-2} s^{-1}	UDS	Line widths separate AGN and star formation
	23 nJy at 5.6 micron	UDS	Mid-IR photometry separates AGN and star formation
LF of dwarf galaxies	1.4 nJy at 2 micron	UDS	Properties of dwarf galaxies change with reionization

Hubble Ultra-deep Field

The Assembly of Galaxies

How and how did the Hubble Sequence form?
How did the heavy elements form?
What physical processes determine galaxy properties?
What are the roles of starbursts and black holes in galaxy formation?

JWST will conduct deep-wide imaging and spectroscopic surveys of thousands of galaxies to study morphology, composition and the effects of environment. It will conduct detailed studies of starbursts and AGN to investigate what powers these energetic sources.

Observations

Observation	Depth and Mode	Target	Comments
Deep-wide survey (DWS)	3 nJy at 3.5 micron	100 arcmin	Faint galaxy identification and morphology
Metallicity determination	2×10^{-19} erg cm^{-2} s^{-1}	Galaxies in DWS	Multi-object spectroscopy of 1000s of galaxies
Scaling relations	11 micro-Jy at 9micron, R~3000	z~3 galaxies	Velocity dispersions of CO bandheads
	3 nJy at 3.5 micron	DWS	Weak lensing to measure halo masses
Obscured galaxies	23 nJy at 5.6 micron	ULIRGs	Imaging ULIRGs in mid-IR penetrates dust
	5×10^{-19} erg cm^{-2} s^{-1}	ULIRGs & AGN	Redshift identification of sub-mm galaxies
	1.4×10^{-16} erg cm^{-2} s^{-1} at 24 micron, R~2000	ULIRGs & AGN	Determine energy sources

M81 by Spitzer

The Birth of Stars and Protoplanetary Systems

How do proto-stellar clouds collapse?
How does the environment affect star formation?
What is the sub-stellar IMF?
How do proto-planetary systems form?
What are the life cycles of gas and dust?

JWST will observe protostars at all phases of their evolution, penetrating the dust to determine the physical processes that produce stars, planets and debris disks.

Observations

Observation	Depth and Mode	Target	Comments
Cloud collapse	9 nJy at 2 micron	e.g. Barnard 68	Measure extinction to background stars
	1 micro-Jy at 7 micron		Mid-IR imaging reveals densest cores
Protostar evolution	1 micro-Jy at 15 micron	e.g. Taurus-Auriga	Density and structure of "Class 0" protostars
	7×10^{-19} erg cm^{-2} s^{-1} at 15 micron		Diagnose extinction windows, shock tracers and PAHs.
Massive stars	2 micro-Jy at 3.8 micron	e.g. Eagle Nebula	Crowded star-forming regions
	55 nJy at 3.5 micron		Deep imaging of elephant trunks
	Fixed slits, IFU	Sources in Eagle Nebula	Masses, age and evolutionary state
	34 micro-Jy at 20 micron		Mid-IR sees through deepest dust columns
IMF	2.9 nJy at 2.2 micron	e.g. Orion Nebula, 30 Dor	Low-mass end of IMF
	290 nJy at 2.2 micron		Follow-up of low-mass objects
Protoplanetary systems	1×10^{-13} erg cm^{-2} s^{-1} as^{-2} at 1.87 micron	e.g. Orion Nebula	Resolve dust disks against brighter background
Astrochemistry	2.6×10^{-17} erg cm^{-2} s^{-1} as^{-2} at 17 micron	Protostars and debris disks	Spectroscopy of organic molecules

David Hardy

Planetary Systems and the Origins of Life

How do planets form?
How are circumstellar disks like our solar system?
How are habitable zones established?

JWST will use coronagraphy to investigate exosolar planets and debris disks, and will compare these observations to objects within our own Solar System.

Observations

Observation	Depth and Mode	Target	Comments
Isolated giant planets	4 nJy at 2 micron	Star-forming regions	Continuation of low-mass IMF
Bound planets	200 micro-Jy at 4 micron	Nearby stars	Coronagraphy at 10^{-4} at 0.5 arcsec
In-depth study	60 nJy, R~100	Nearby stars	Follow-up studies
Transiting planets	R~1000	Kepler discoveries	Differential light curves
Circumstellar disks	1 micro-Jy at 15 micron	Debris disks	Spectra reveals ices and silicates
Comets	1 micro-Jy at 2 micron, R~3000, 1 micro-Jy R~3000 at 15 micron	10/year	Organic molecules, HDO, mineralogy
KBOs	4 nJy at 2 micron; 1 micro-Jy R~3000 at 2 micron; 1 micro-Jy at 15 micron	10 arcmin2	Population dynamics and sub-classes
Satellites	1 micro-Jy R~3000 at 2 micron; 1 micro-Jy at 15 micron	Titan	Titan 10 years after Cassini

Robert Hurt

White Papers by the JWST Science Working Group and the community

Seager & Lunine, 2004, white paper: "Astrobiology and JWST"

JWST will study:
- Circumstellar disks.
- Ices, mineral and PAH features.
- CO, H_2, H_2O
- Water and prebiotic organics in Comets
- Exoplanets: coronagraphy & transits

Organic molecules in circumstellar disks …

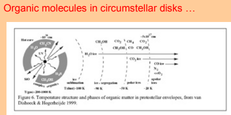


Figure 6. Temperature structure and phases of organic matter in protostellar envelopes, from van Dishoeck & Hogerheijde 1999.

… are detectable in the Mid-IR by JWST.

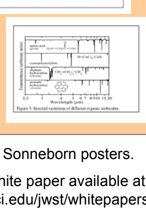


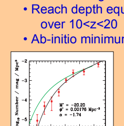
Figure 3. Spectral variations of different organic molecules.

See Rieke & Sonneborn posters.

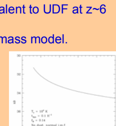
Astrobiology white paper available at:
http://www.stsci.edu/jwst/whitepapers

Stiavelli et al, 2006, white paper: "First Light Study"

How faint are the first galaxies?
Compare 3 models:
- Non-evolving z~6 LF
- Reach depth equivalent to UDF at z~6 over 10<z<20
- Ab-initio minimum mass model.



z~6 luminosity function from GOODS & UDF, showing evolution to z~3 (green line). Bouwens et al. 2006.



Minimum mass at 100X over-density, Tvir=10^4K, normal IMF.

Method	F200W depth (nJy)
Non-evolving LF from z=6	10 for z=17
UDF relative depth	1.63 for z=15
Ab-initio	0.2 for z=10

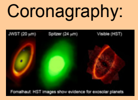
We are using 1.6 nJy at 2 μm as a guide for JWST Ultra-Deep Survey plans. ~100 hours/filter.

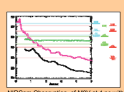
See Stiavelli & Windhorst posters.

First Light Study available at:
http://www.stsci.edu/jwst/whitepapers

Clampin et al, 2007, Exoplanet white papers.

Coronagraphy:



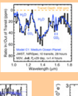


NIRCam Observation of M0V at 4 pc with 2 MJup planet @ 7 AU(Krist et al. 2006)

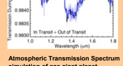
JWST Coronagraphy

Instrument	Channel/Mode	λ (μm)	R (λ/δλ)	Comments
NIRCam	Short λ Lyot Coronagraph	0.6 - 2.3	4, 10, 100	High Contrast Imaging
NIRCam	Long λ Lyot Corongagraph	2.4 - 5.0	4, 10, 100	High Contrast Imaging
TFI	Multi-l coronagraph	1.6 - 2.5	100	High contrast imaging with speckle deconvolution
TFI	Multi-l coronagraph	3.2 - 4.9	100	High contrast imaging with speckle deconvolution
MIRI	Quadrant Phase Coronagraph	10.65	20	High Contrast Imaging
MIRI	Quadrant Phase Coronagraph	11.4	20	High Contrast Imaging
MIRI	Quadrant Phase Coronagraph	15.5	20	High Contrast Imaging
MIRI	Lyot Coronagraph	23	5	High Contrast Imaging

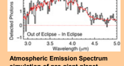
Transits:



Simulated JWST measurement of H_2O and CO_2 in the atmosphere of a habitable, Earth-sized, ocean planet. (Valenti et al. 2007)



Atmospheric Transmission Spectrum simulation of gas giant planet

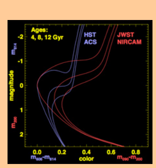


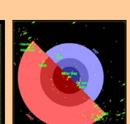
Atmospheric Emission Spectrum simulation of gas giant planet

See Clampin posters.

Exoplanet white papers available at:
http://www.stsci.edu/jwst/whitepapers

Stiavelli et al, 2007, white paper: "Stellar Populations"





Theme	Distance	Main Wavelength
Star formation histories	4 Mpc	Visible-near IR
Study of the bright red stars	40 Mpc	Infrared
WD cooling sequence	5.3 kpc	Visible

See Stiavelli poster.

Stellar populations white paper in progress.

White papers in progress.

Galaxy Surveys:
- How many surveys are needed?
  - Depth? Area? Number of targets?
- How will we use all 4 instruments together?
- Roles of MOS & IFU spectroscopy?

QSOs & AGN:
- Black hole – galaxy evolutionary relationship.
- QSOs as targets for reionization studies.
- Energetics of accretion.
- Relation to star formation.

Observing Bright Targets:
- Bright sources as JWST target:
  - Coronagraphy acquisition.
- Bright sources as source of stray light
  - Low-mass stars in Orion near 4th mag star
- Detector issues.

Supernovae:
- Target of opportunity requirements.

Moving Targets:
- Observing objects in our Solar System.

See Sonneborn poster on Solar System Science.

These white papers are in progress.