James Webb Space Telescope Observations of the End Stages of Stellar Evolution

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The James Webb Space Telescope (JWST) is an infrared-optimized astrophysics observatory to be launched in 2018. The JWST instruments will enable spectroscopic studies of Planetary Nebulae (PNe) and Supernova Remnants (SNRs) in the Milky Way and in galaxies at least to a distance of 30 Mpc. This capability means that the end stages of stellar evolution can be examined in environments with metallicities and star formation histories that are different than the Milky Way and the Magellanic Clouds.

JWST Observatory

JWST is a large aperture (6.5m), cryogenic, infrared-optimized space observatory under construction by NASA, ESA, and CSA for launch in 2018. The JWST observatory will be placed in an Earth-Sun L2 orbit by an Ariane 5 launch vehicle provided by ESA. The observatory is designed for a 5-year prime science mission, with propellant for 10 years of science operations.

The first call for proposals for JWST observations will be released in Fall 2017. The JWST science center will be located at STScI in Baltimore, Maryland.

Construction of the JWST observatory is nearing completion. The instruments, telescope optics, telescope structure, and spacecraft structure are finished (see photos at right). Cryogenic testing of the full optical system is underway.

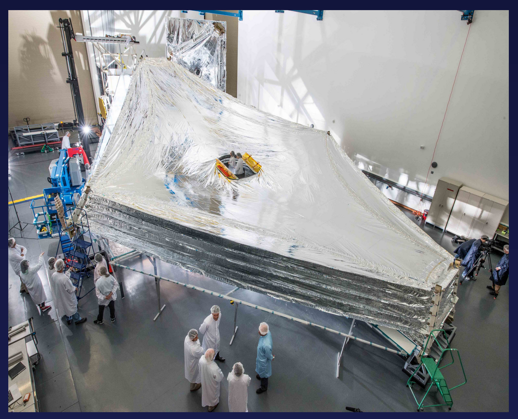
The JWST observing modes and expected sensitivity are shown in the tables and figures to the right.

JWST Hardware Nearing Completion

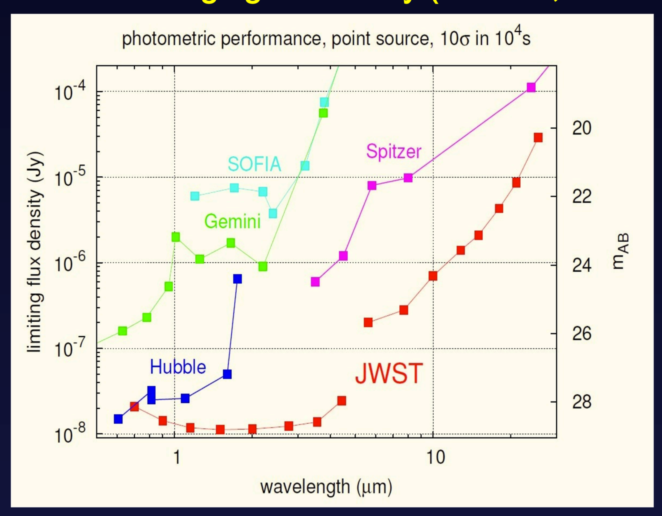

Science instruments done


Telescope structure done

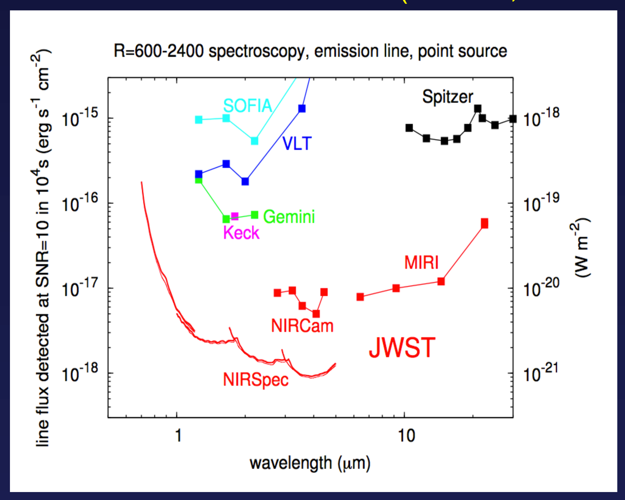

Telescope mirrors done


Sunshield under construction

Point Source Imaging Sensitivity (10 ksec, S/N=10)



Medium-Resolution Spectroscopic Sensitivity Unresolved Emission Lines (10 ksec, S/N=10)



Imaging Modes

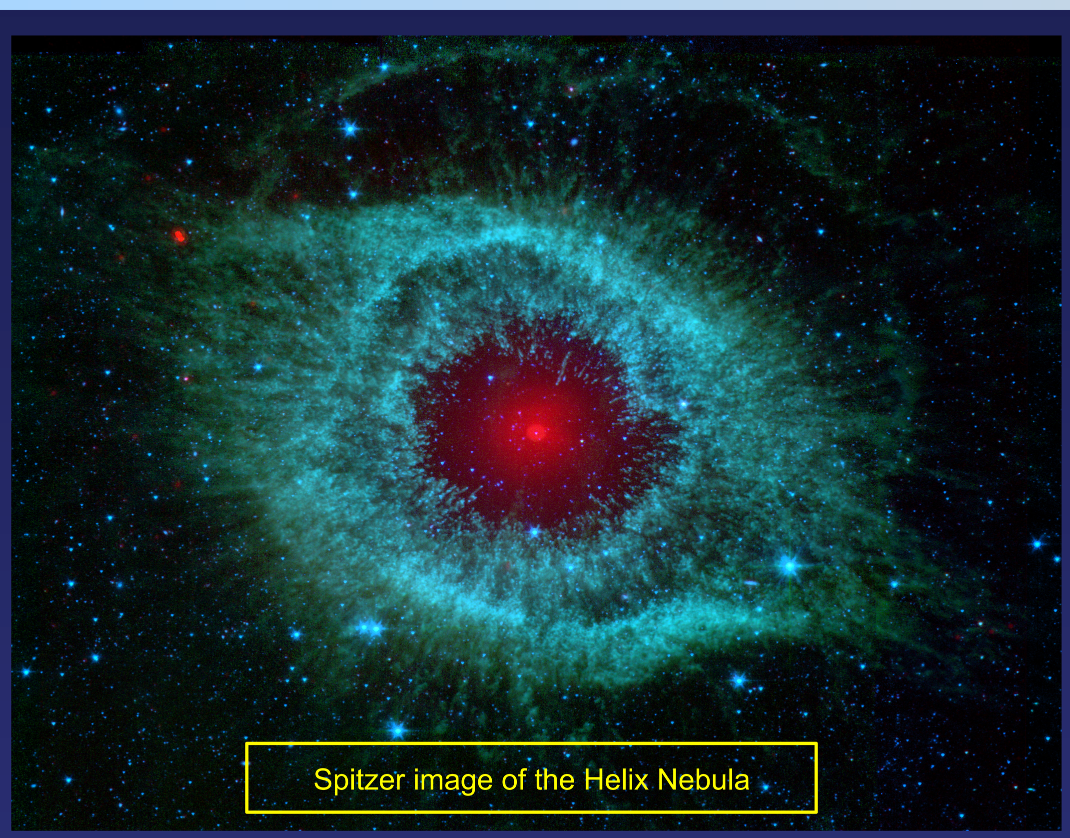
Mode	Instrument	Wavelength (μm)	Pixel Scale (")	Full-Array Field of View
Imaging (wide, medium, narrow filters)	NIRCam*	0.6 – 2.3	0.032	2.2 x 2.2′
	NIRCam*	2.4 – 5.0	0.065	2.2 x 2.2′
	NIRISS	0.9 – 5.0	0.065	2.2 x 2.2′
	MIRI*	5.0 – 28.8	0.11	1.23 x 1.88′
Aperture Mask Interferometry	NIRISS	3.8 – 4.8	0.065	------
Coronagraphy	NIRCam	0.6 – 2.3	0.032	20 x 20″
	NIRCam	2.4 – 5.0	0.065	20 x 20″
	MIRI	10.65	0.11	24 x 24″
	MIRI	11.4	0.11	24 x 24″
	MIRI	15.5	0.11	24 x 24″
	MIRI	23	0.11	30 x 30″

Spectroscopic Modes

Mode	Instrument	Wavelength (μm)	Resolving Power (λ/Δλ)	Field of View/ Slit size (″)
Slitless Spectroscopy	NIRISS	1.0 – 2.5	150	132″ x 132″
	NIRISS	0.6 – 2.5	700	single object
	NIRCam	2.4 – 5.0	2000	132″ x 132″
Multi-Object Spectroscopy	NIRSpec	0.6 – 5.0	100, 1000, 2700	204″ x 204″ with 250,000 0.20 x 0.46″ apertures
Single Slit Spectroscopy	NIRSpec	0.6 – 5.0	100, 1000, 2700	0.4″x3.8″, 0.2″x3.3″,1.6′′x1.6″
	MIRI	5.0 – ~14.0	~100 at 7.5 microns	0.6″ x 5.5″
Integral Field Spectroscopy	NIRSpec	0.6 – 5.0	100, 1000, 2700	3.0″ x 3.0″ x 0.10″
	MIRI	5.0 – 7.7	3500	3.0″ x 3.9″ x 0.18″
	MIRI	7.7 – 11.9	2800	3.5″ x 4.4″ x 0.28″
	MIRI	11.9 – 18.3	2700	5.2″ x 6.2″ x 0.39″
	MIRI	18.3 – 28.8	2200	6.7″ x 7.7″ x 0.65″

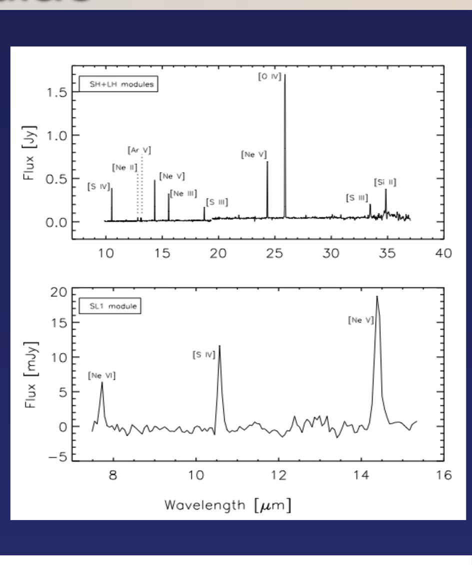
See www.stsci.edu/jwst/science/sensitivity for performance details

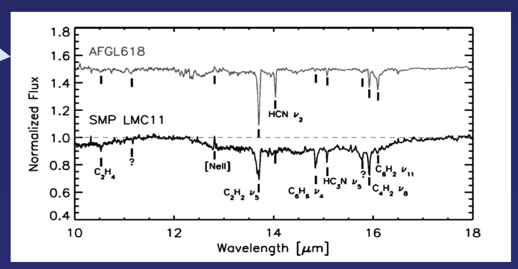
Planetary Nebulae


Spitzer image of the Helix Nebula

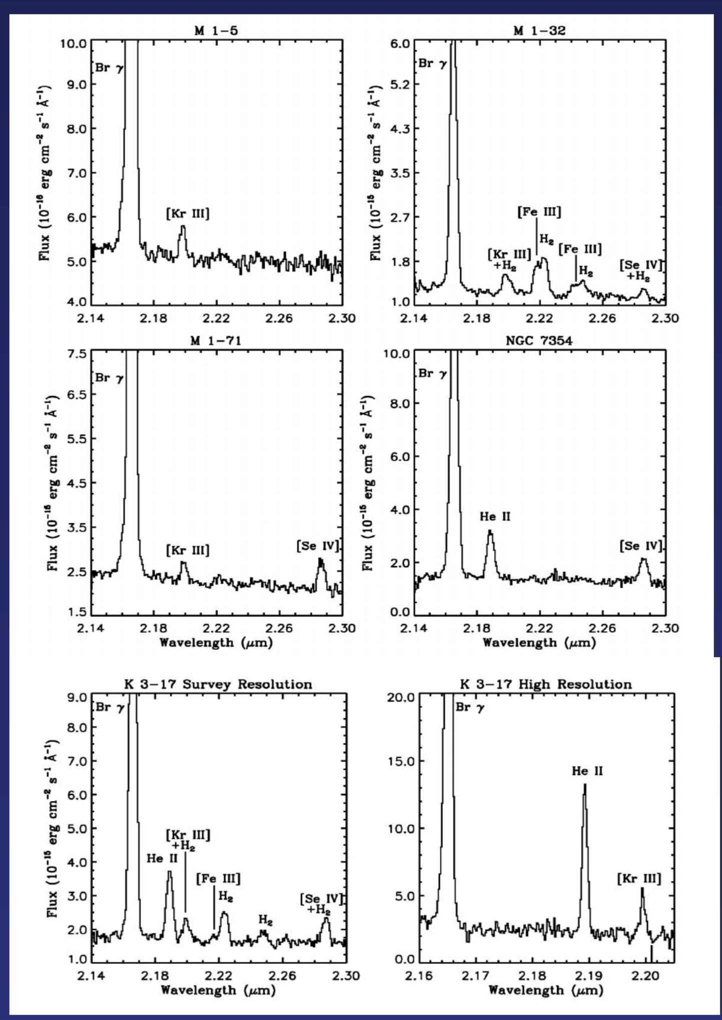
- JWST will expand the infrared study of planetary nebulae pioneered by IRAS, ISO, and Spitzer.
- JWST's high angular resolution and sensitivity are expected to reveal new details in PN structures and physics, including optically obscured regions; dust, small grain, and PAH properties; emission from neutral material, especially H_2; and a wide range of ionization conditions.

- PNe have a wide range of ionization states of fine-structure lines in the IR spectrum. See spectrum of SMP 83 in the SMC at right (from Bernard-Salas et al. 2004).
- The PN LMC 11 (right, bottom) actually appears more like a pre-planetary object like AFGL 618. LMC 11 has strong features of C_4H_2, C_6H_2, and C_6H_6. These molecules are the building blocks from which more complex hydrocarbons are produced (Bernard-Salas et al 2006).
- Spitzer/MIPS observations of the Helix Nebula (Left) found an unresolved central source with excess thermal continuum at 24 and 70 um, as well as in the IRAC 8um band (Su et al 2007). The central emission is most likely from a dust disk that JWST should be able to image and resolve.





- Neutron-capture elements (Z>30) can provide key insight into nucleosynthesis histories of stellar populations, mixing processes, and the internal structure of AGB stars.
- Trans-iron abundances in PNe are of particular interest because these nuclei can be produced via slow n-capture (s-process) in PN progenitor stars.
- The s-process can occur in the intershell region between the H- and He-burning shells during the thermally-pulsing AGB stage, and later be ejected into the nebula.
- Ground-based NIR spectroscopy found [Kr III] 2.119 μm and [Se IV] 2.287 μm nebular emission in many Galactic PNe.
- JWST will be able to extend this study to PNe in nearby galaxies.

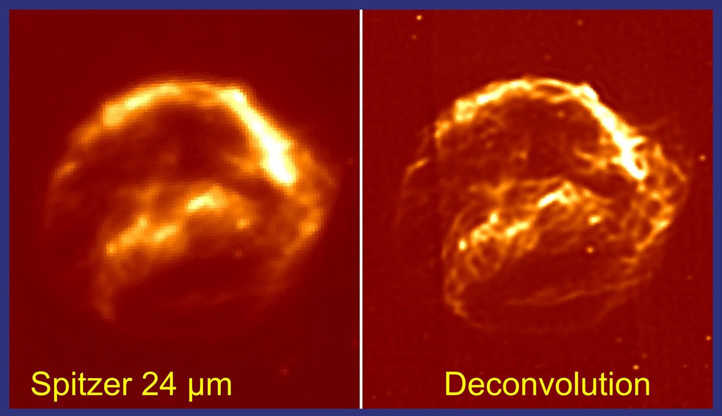


Figures from Sterling et al. (2008)

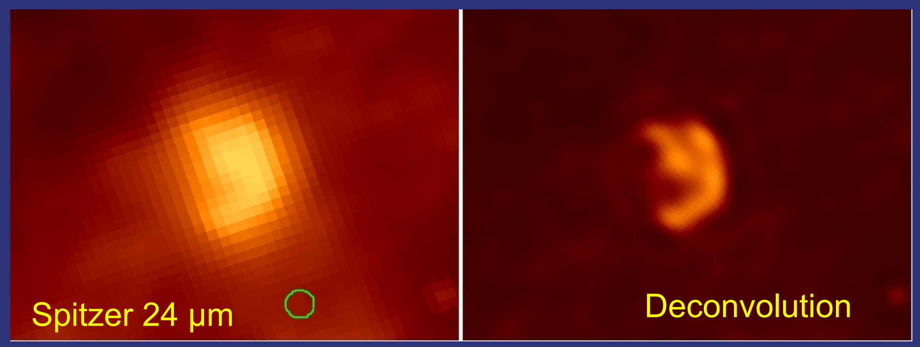
Supernova Remnants

JWST's 6.5-meter telescope will provide sub-arcsecond imaging in the mid-IR.

Kepler's SNR

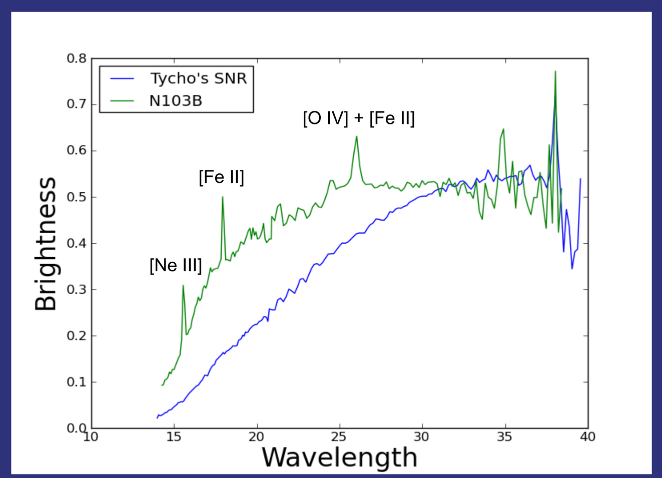


SNR N103B in the LMC



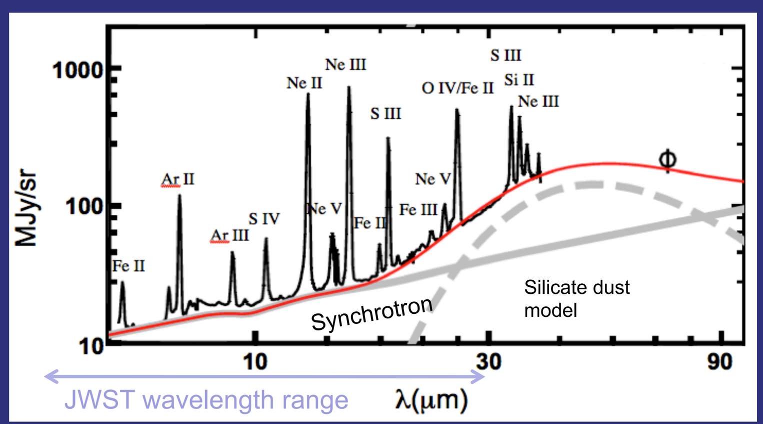
Spitzer 24 μm images of Kepler's SNR in our Galaxy (left, above) and N103B in the LMC (right, above). These two SNRs are thought to be very similar except for age (N103B is older) and distance (4 vs. 50 kpc). The 24 μm emission comes from shock-heated circumstellar dust. Each object is shown at standard Spitzer resolution (left panel of each figure) and after deconvolution with the "Image Co-addition with Optional Resolution Enhancement (ICORE) software written by Frank Masci. Even with this factor of 3 improvement, JWST will improve resolution by at least another factor of 3. Such observations, especially in conjunction with X-ray observations, provide powerful constraints on the densities and dust masses in these objects. See Williams et al 2012, 2013, and 2014 for details on Kelper, Tycho, and N103B, respectively.

Two SN Type Ia Remnants



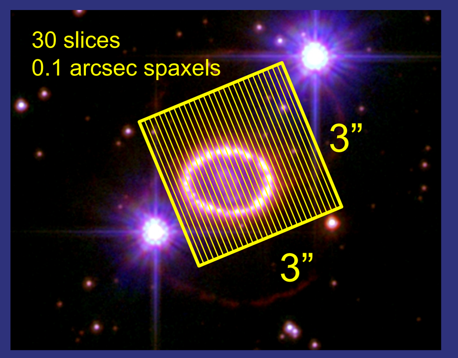
Spitzer IRS low spectra of N103B and Tycho's SNR, two remnants of Type Ia events. Fine structure lines in the mid-IR provide unique and powerful diagnostics of abundances, kinematics, and physical conditions in supernova remnants. The strong lines of [Ne III], [Fe II], and [O IV] are identified. JWST will be able to resolve the [O IV] and [Fe II] lines at 26 μm. The continuum shape changes in the JWST spectral range provides diagnostics of the dust temperature and composition.

Crab Nebula Filament



Spitzer IRS low spectrum of a bright filament in the Crab Nebula, showing a rich spectrum of fine-structure emission from Ar, Ne, Fe, S, and O. The continuum is a combination of synchrotron emission from the pulsar wind nebula and thermal emission from dust in the filament. The dust can be modeled as silicates with T~55K (Temim et al 2012). This dust temperature is probably close to the lower limit of what can be measured with JWST, given the long wavelength cutoff (28.5 μm) and thermal emission from the JWST primary mirrors (T~50K) that will contribute to the observed background.

SNR 1987A



The JWST spectrographs each have integral-field spectrographs with image slicers. The slice widths are closely matched to the telescope PSF as a function of wavelength. The IFU fields of view are 3"x3" to 7"x7" (see table above). Image mosaics with the IFUs can provide 3D data cubes of larger objects or regions.