Dynamics of High Redshift Galaxies

M. Stiavelli, STScI Baltimore

Lecture plan:

1. **Introduction. Galaxy kinematics at high redshift.**
2. **Dynamics of elliptical galaxies at high redshift and evolution of the Fundamental Plane.**
3. **Evolution of the black hole mass vs galaxy mass relation. Dynamics without kinematics.**
4. **Future developments in the study of the dynamics of high redshift galaxies.**

Things we would like to do…

- Measure resolved kinematics of spirals at z>2.4

  JWST, 30m

- Measure velocity dispersion of ellipticals at z>1.2

  JWST

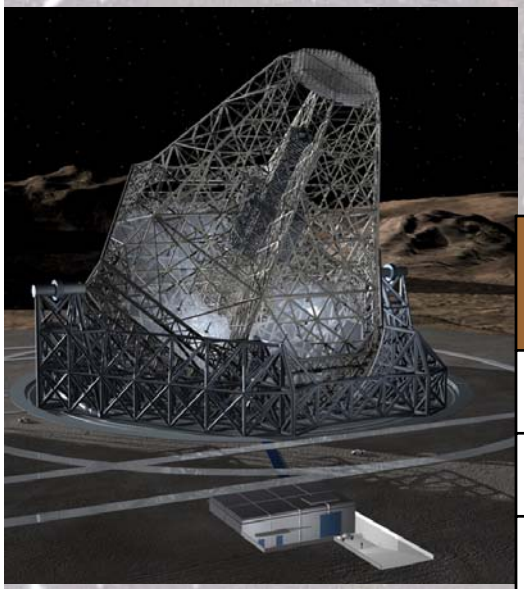
- High sensitivity IFU spectroscopy at < 0.1 arcsec resolution

  30m, JWST

- Multi-object spectroscopy in the near-IR over large FOV

  30m, JWST

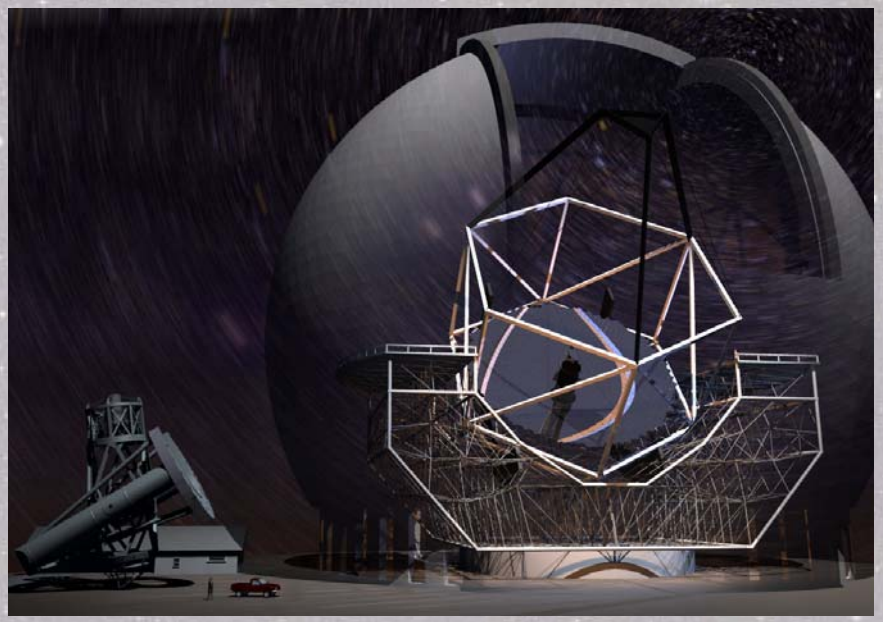
30m ground based telescopes



ESO is developing an extremely large telescope concept with size in the range 30m-50m

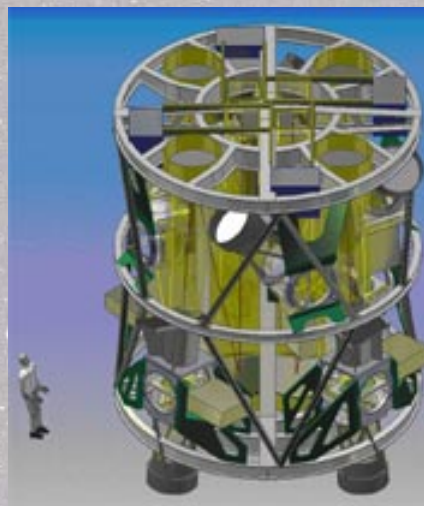
Instrument	Wave range (μm)	Capability	Primary Science Goals	Institutes
CODEX	0.4-0.7	High velocity accuracy, visual spectrograph	To measure the dynamics of the Universe	ESO, INAF-Ts, Geneve Obs, IoA Cambridge
T-OWL	2.5-20	Thermal, Mid Infrared Imager and possibly Spectrograph	Search, study of planets, high redshift Hα galaxies	MPIfA, Heidelberg, Leiden, ASTRON ,ESO
QUANTEYE	0.4-0.8	Study will review /explore aspects of quantum astrophysics with OWL	Astrophysical phenomena varying at sub-second time scale, others tbd	Padova Univ., Lund University
SCOWL	250-450-850 tbc	Imaging at sub-millimeter wavelengths	Surveys of dusty regions, of extr. fields for star-forming galaxies	ATC
MOMFIS	0.8-2.5	Near IR spectroscopy using many deployable IFUs	Masses of high z galaxies, regions of star formation, GC stars	CRAL, LAM, OPM
ONIRICA	0.8-2.5	NIR Imaging Camera on a field of 1x1 / 2x2 arcmin	Faint stellar and galaxy population	INAF- Arcetri Heidelberg MPIfA
EPICS	0.5- 1.9	Camera-Spectrograph at diffraction limit	Imaging and spectroscopy of earth-like planets	ESO + ext. consultants
Hyper-telescope Camera	1-2.5 tbc	Speckle interferometry with a partially filled OWL aperture	Planetary disks, exo-planets	LISE lab at OHP

30m ground based telescopes



The Thirty Meter Telescope is a joint concept developed by AURA (GSMT), Caltech (CELT), Univ. of California and Canadian partners

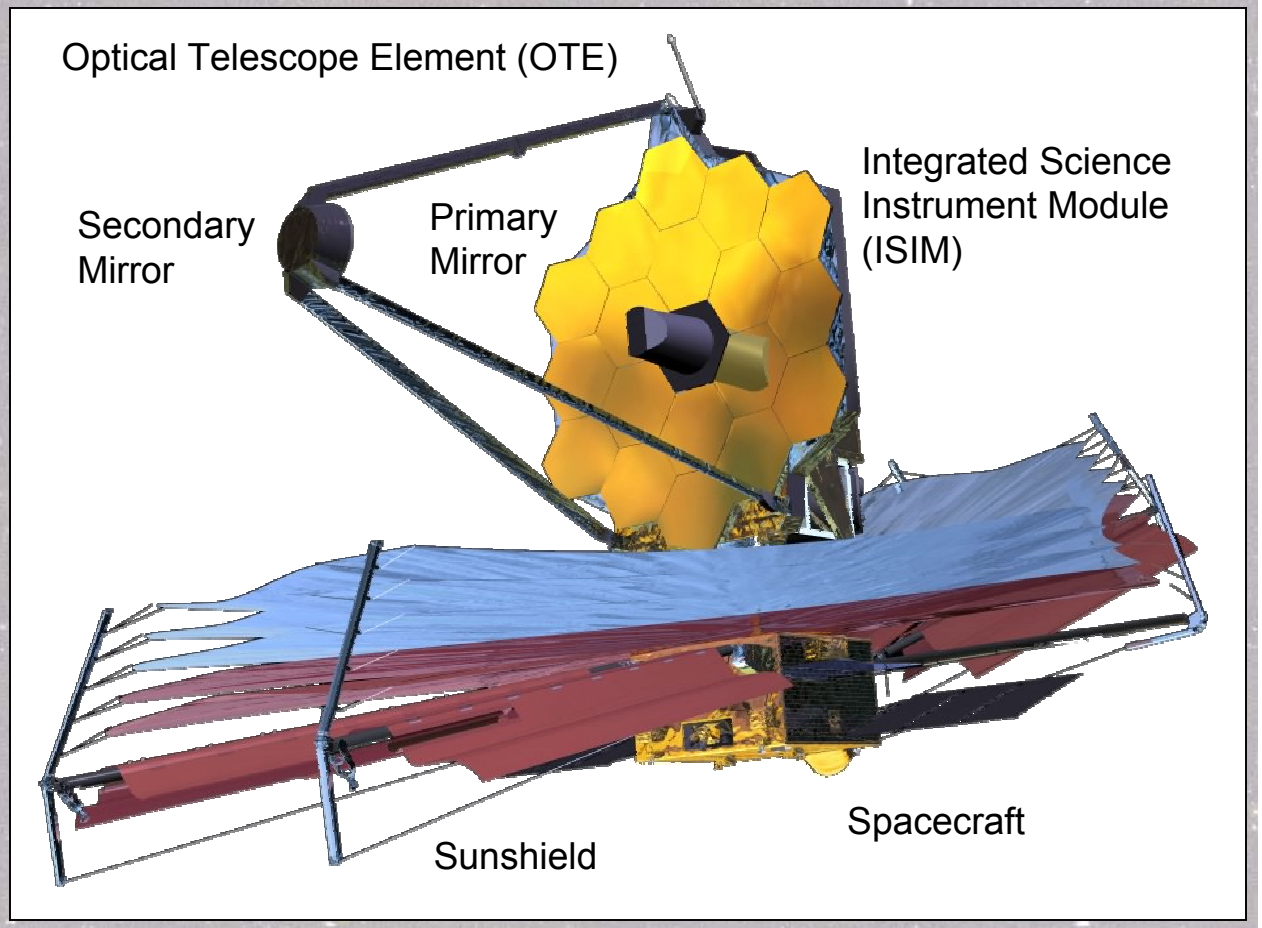
- Infrared imaging spectrometer
- Wide-field optical spectrometer
- Infrared multi-object spectrometer
- Mid-IR high-resolution echelle spectrometer
- Planet formation instrument
- High-resolution optical spectrometer
- Narrow field infrared adaptive optics system



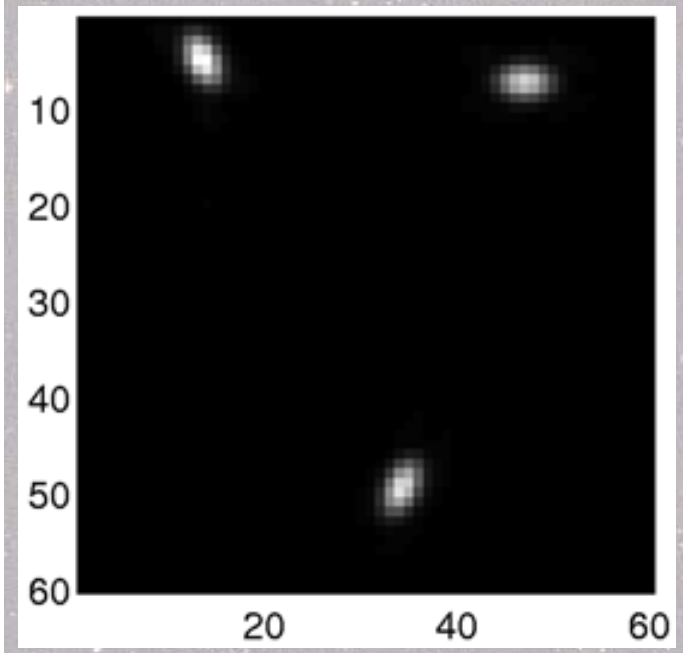
The Wide Field Optical Spectrograph (WFOS).

James Webb Space Telescope

- 6.6m Telescope
- Launch in 2013 to L2.
- Successor to Hubble & Spitzer.
- Demonstrator of deployed optics.
- Passively cooled to 50K.
- Named for 2nd NASA Administrator
- NASA + ESA + CSA
- Lead: Goddard Space Flight Center
- Prime: Northrop Grumman Space Technology

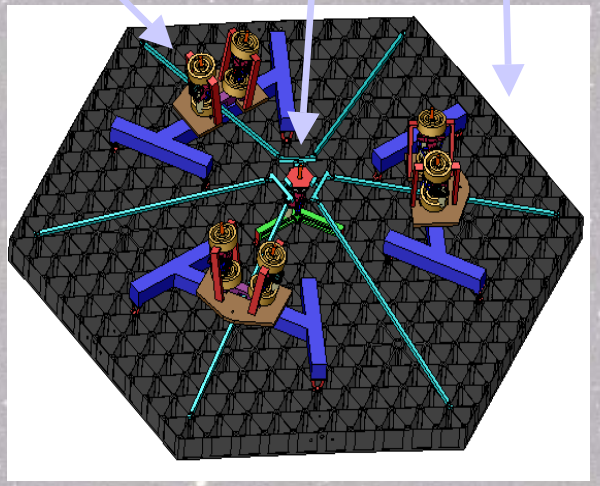


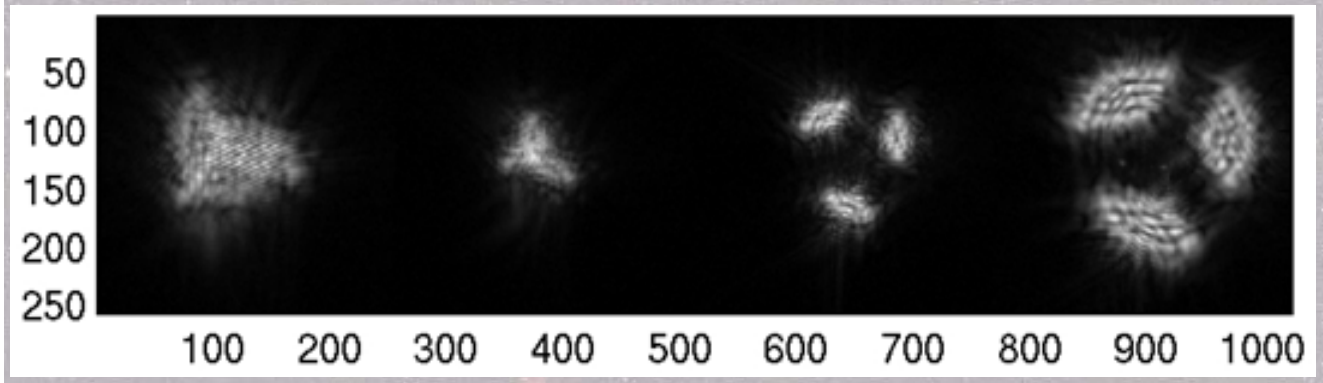
Mirror Segment Control



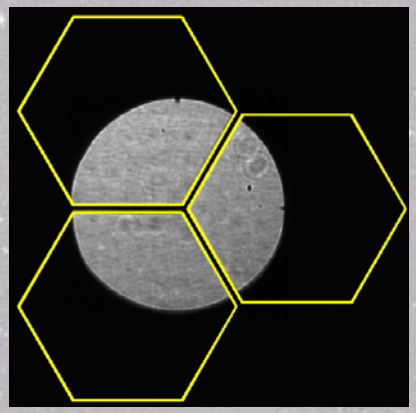
Focused Image

Testbed Mirror with 3 Segments

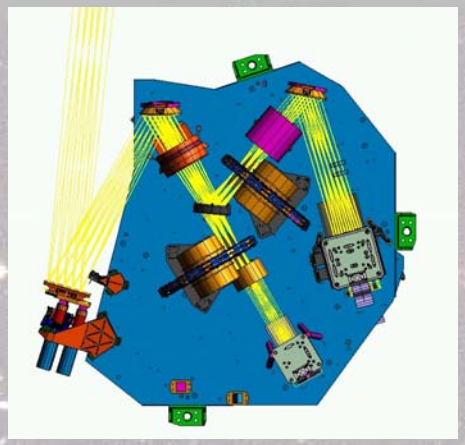




Unfocused Images



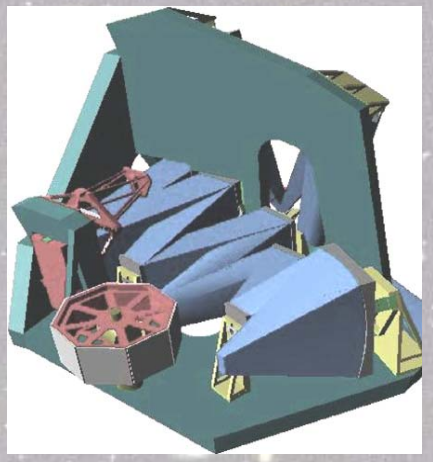
Instrumentation



Arizona: Marcia Rieke PI

Lockheed-Martin & Rockwell

- NIRCam, 0.6 to 5.0 micron:
  - 2.3 x 4.5 arcmin FOV
  - Broad & narrow-band imaging
- NIRSpec, 0.6 to 5.0 micron
  - 3.4 x 3.4 arcmin FOV
  - Micro-shutter, IFU, slits
  - R~100, 1000, 3000
- TFI, 1.6 to 4.8 micron
  - 2.2 x 2.2 arcmin FOV
  - R~100 narrow-band imaging
- MIRI, 5.0 to 27.0 micron
  - 1.4 x 1.9 arcmin FOV imaging
  - 3 arcsec IFU at R~3000
- Coronagraphy
  - NIRCam, TFI & MIRI

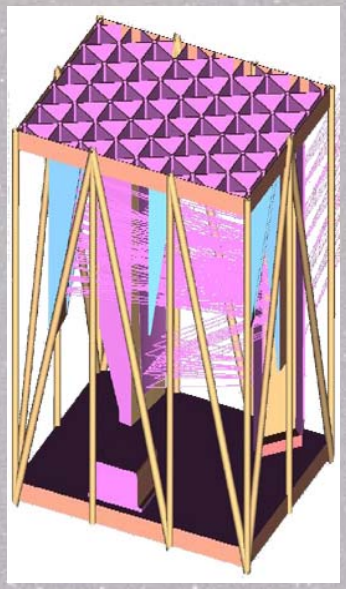


ESA: Peter Jakobsen

EADS Astrium & GSFC

George Rieke & Gillian Wright

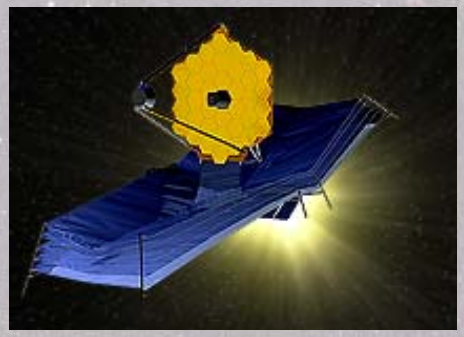
JPL and European Consortium



CSA: Rene Doyon

COM DEV

Operations



JWST at L2

Ka S

DSN

THE ASTROPHYSICAL JOURNAL

Astronomer

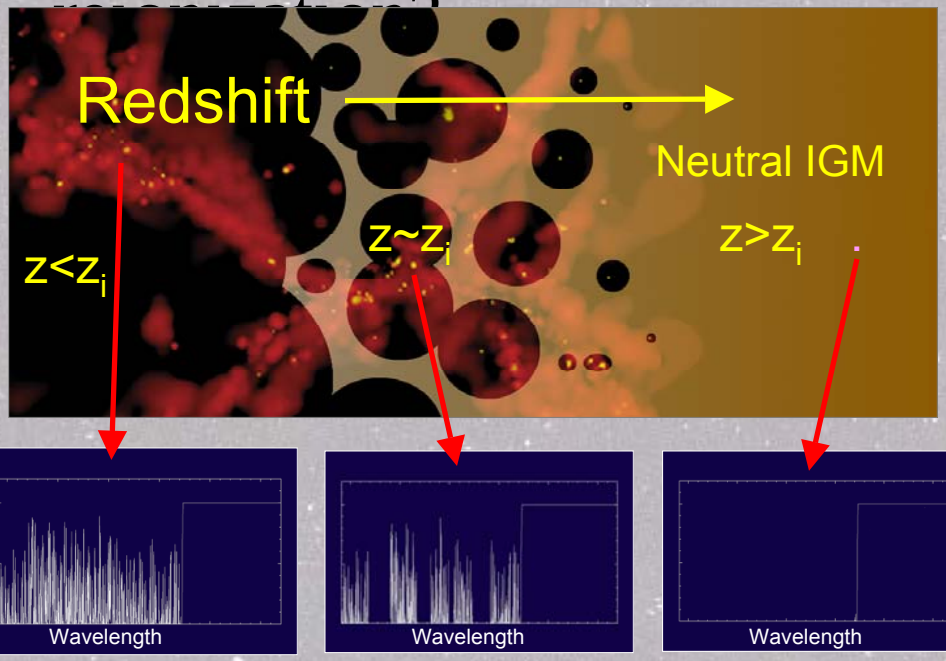
- STScI has been designated as Science Operations Center
- GO, Legacy/Treasury and GTO programs similar to HST

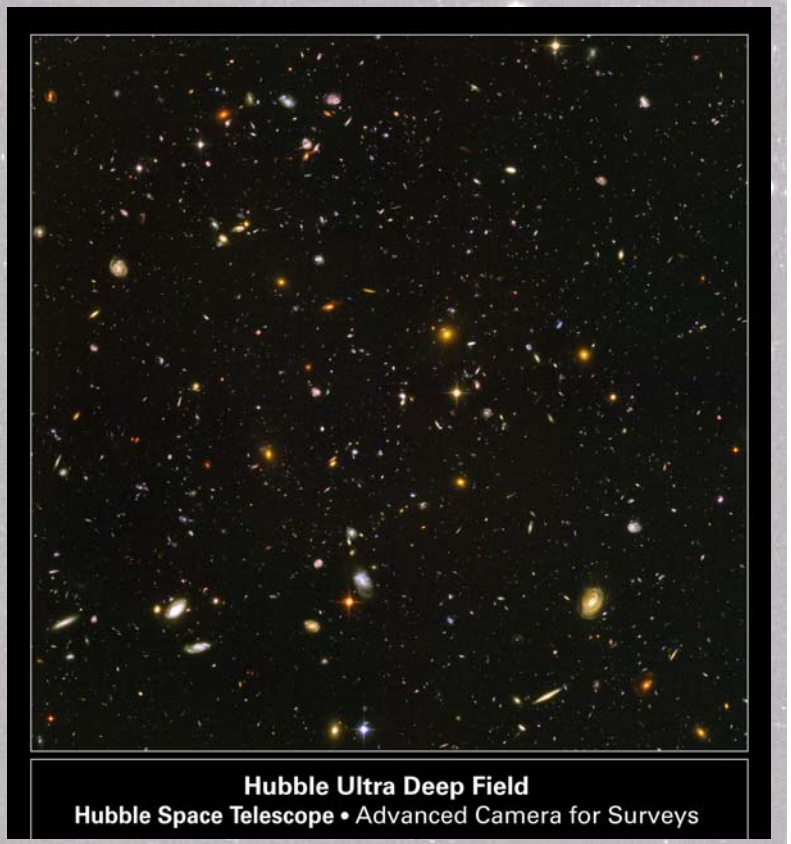
STScI

TAC

End of the dark ages: first light and reionization

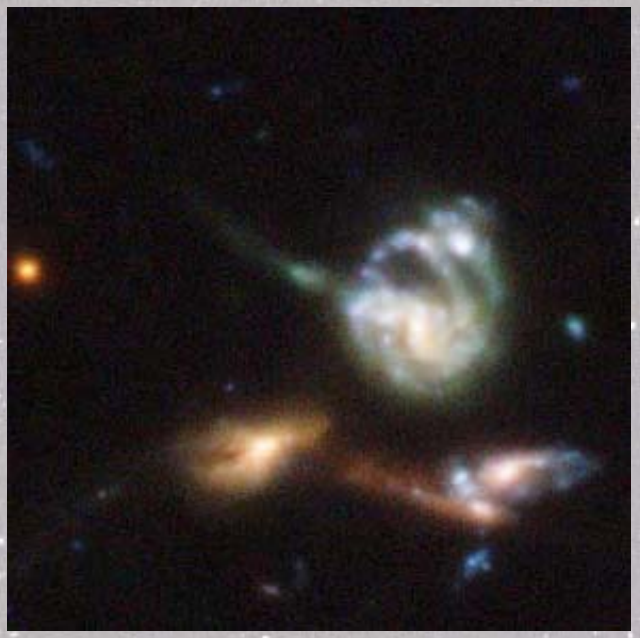
- What are the first galaxies?
- When did reionization occur?
  - Once or twice?
- What sources caused reionization?





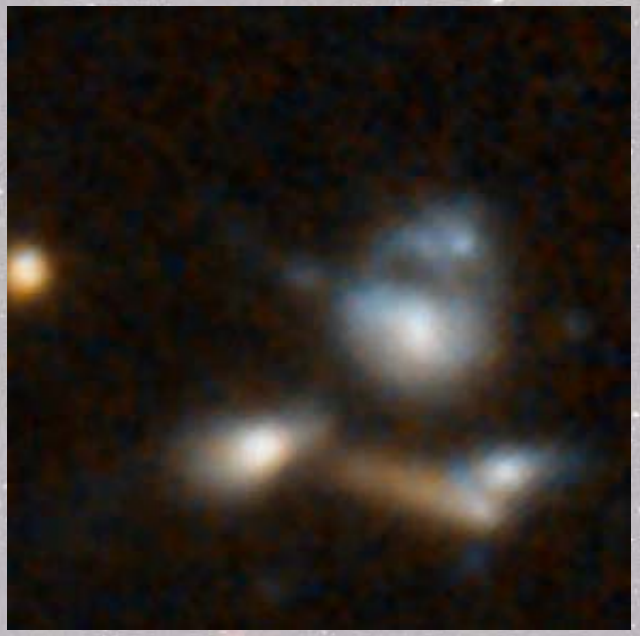
- Ultra-Deep NIR survey (1.4 nJy), spectroscopic & Mid-IR confirmation.
- QSO spectra: Ly-α forest
- Galaxy spectra: Balmer lines (2×10^{-19} ergs/cm^2/sec)

HST/ACS
Viz



JWST/NIRCam
Viz

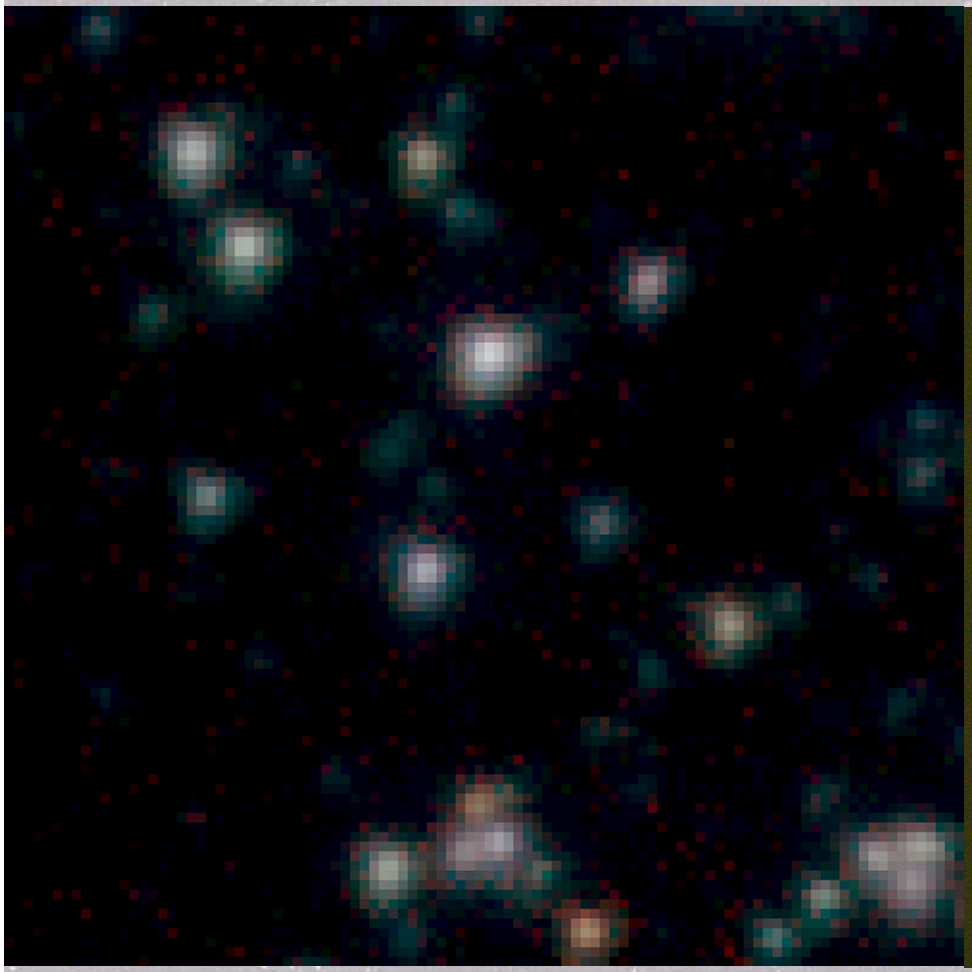
HST/NICMOS
J H



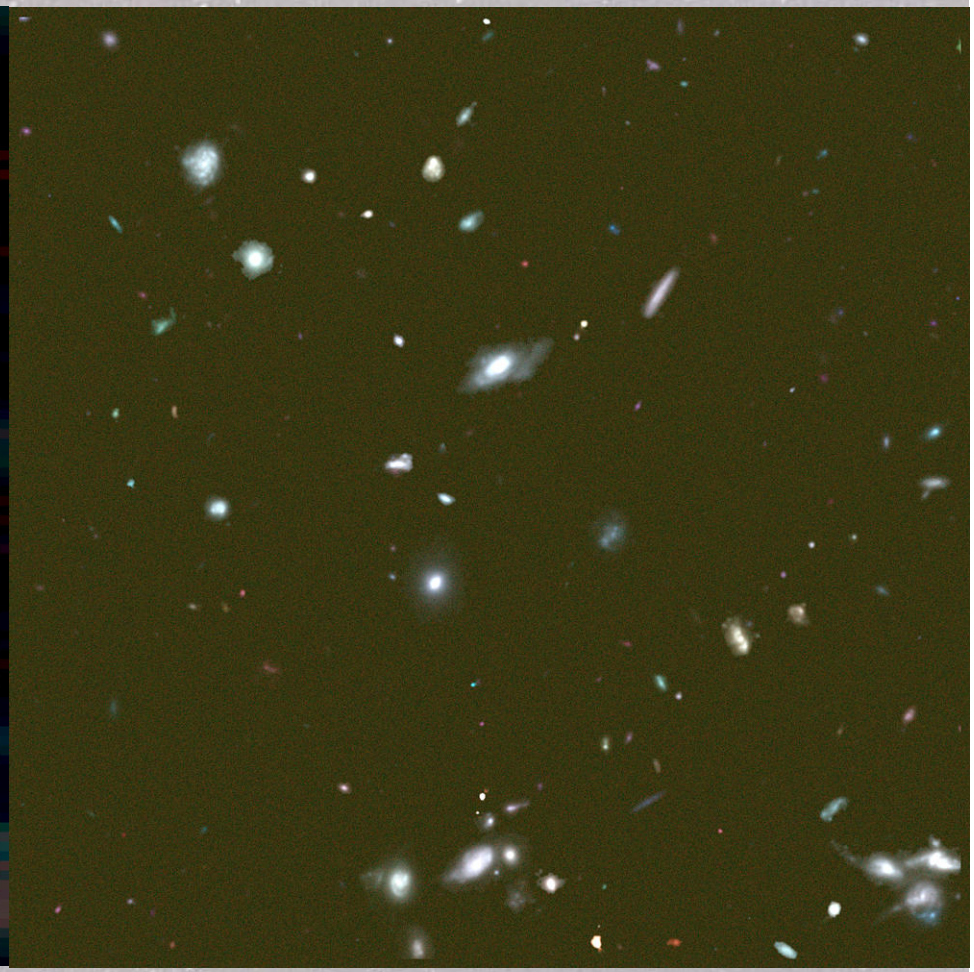
JWST/NIRCam
J H

JWST-Spitzer image comparison

1'x1' region in the UDF – 3.5 to 5.8 μm



Spitzer, 25 hour per band (GOODS collaboration)

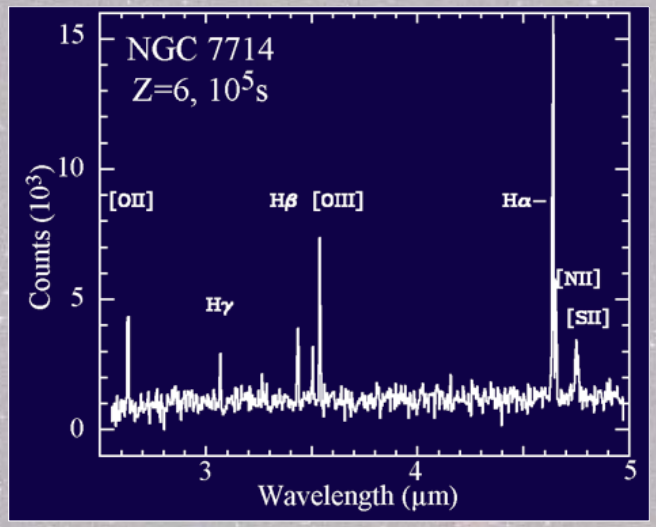


JWST, 1000s per band (simulated)

The assembly of galaxies

- Where and when did the Hubble Sequence form?
- How did the heavy elements form?
- Can we test hierarchical formation and global scaling relations?
- What about ULIRGs and AGN?

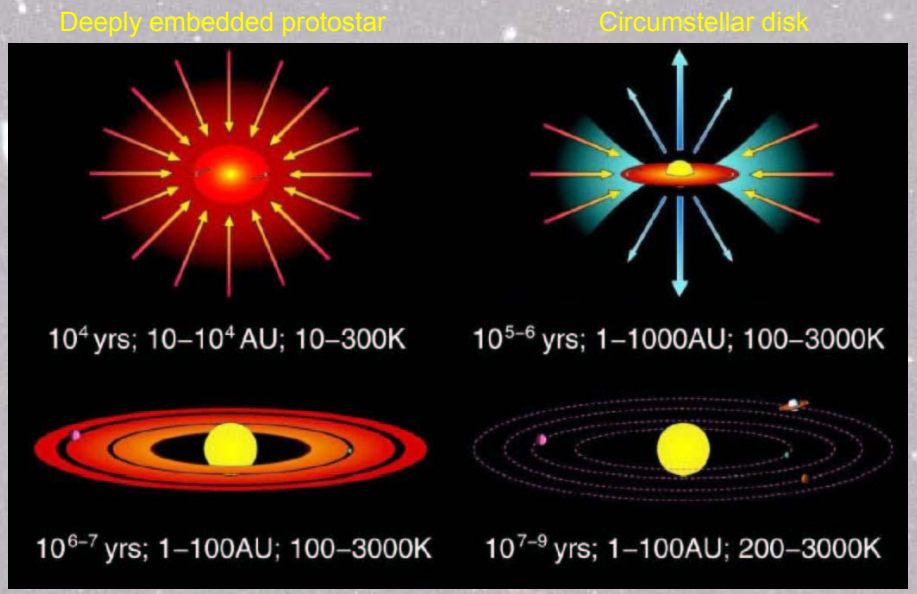
Galaxies in GOODS Field



- Wide-area imaging survey
- R=1000 spectra of 1000s of galaxies at $1 < z < 6$
- Targeted observations of ULIRGs and AGN

Birth of stars and protoplanetary systems

- How do clouds collapse?
- How does environment affect star-formation?
  - Vice-versa?
- What is the low-mass IMF?

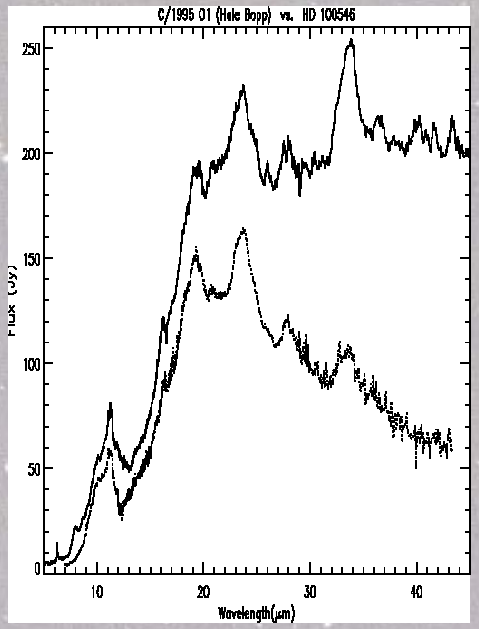


The Eagle Nebula
as seen in the infrared

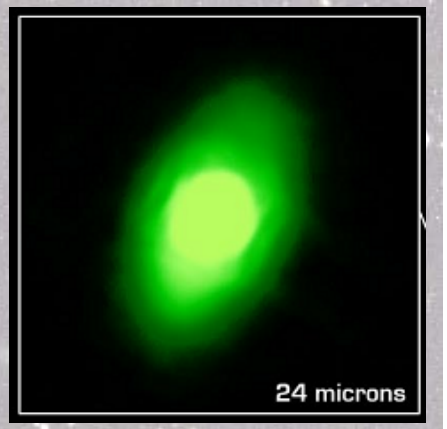
- Imaging of molecular clouds
- Survey “elephant trunks”
- Survey star-forming clusters

Planetary systems and the origins of life

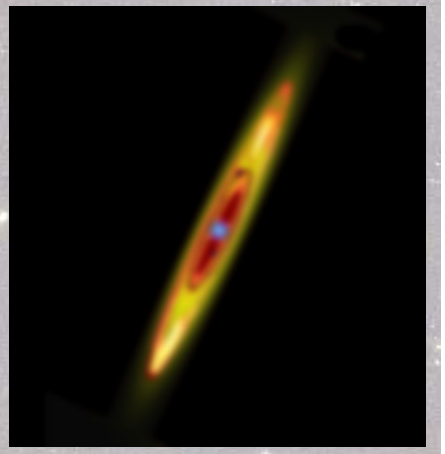
- How do planets form?
- How are circumstellar disks like our Solar System?
- How are habitable zones established?



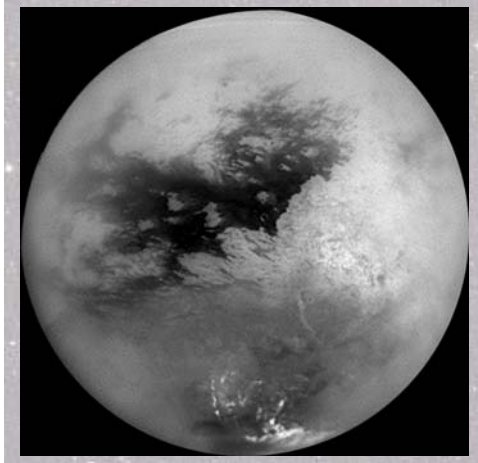
Malfait et al 1998



Spitzer image



Simulated JWST image
Fomalhaut at 24 microns



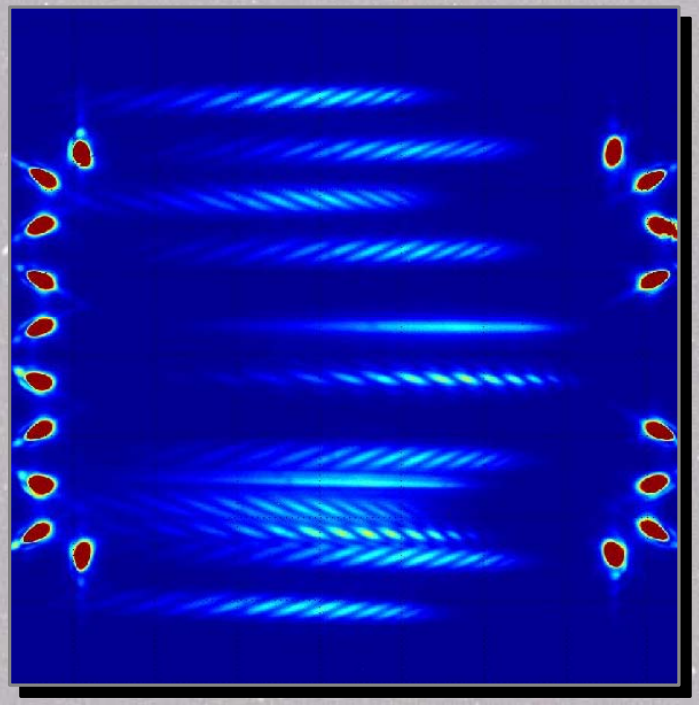
Titan

- Extra-solar giant planets
  - Coronagraphy
- Spectra of circumstellar disks, comets and KBOs
- Spectra of icy bodies in outer Solar System

Shroud Installation at MSFC X-Ray Calibration Facility (XRCF)

JWST Segment Test
NASA/MSFC - XRCF

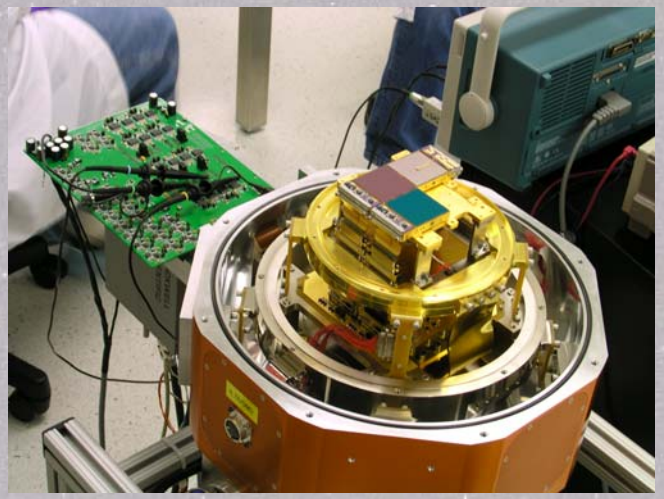
WFSC achieves Two Milestones



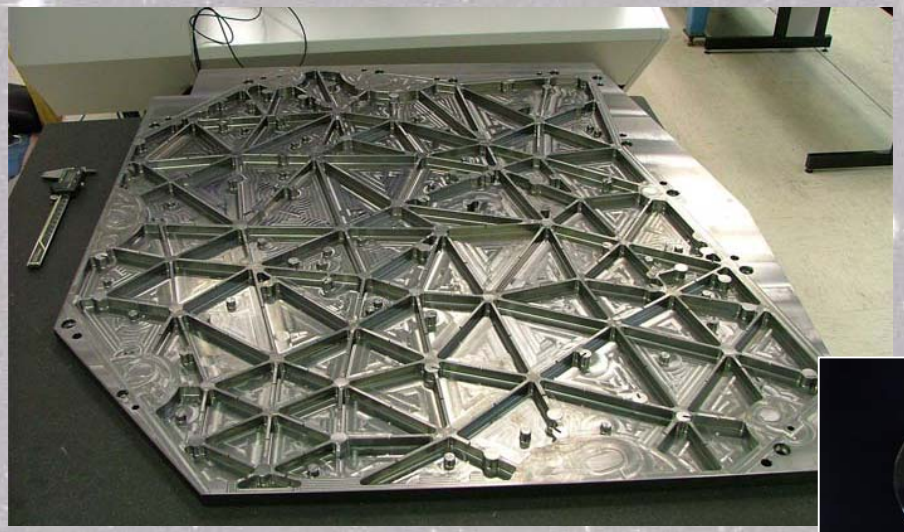
Dispersed Hartmann Sensor demonstrated on Keck telescope

Wavefront Sensing and control (WFSC) testbed completed

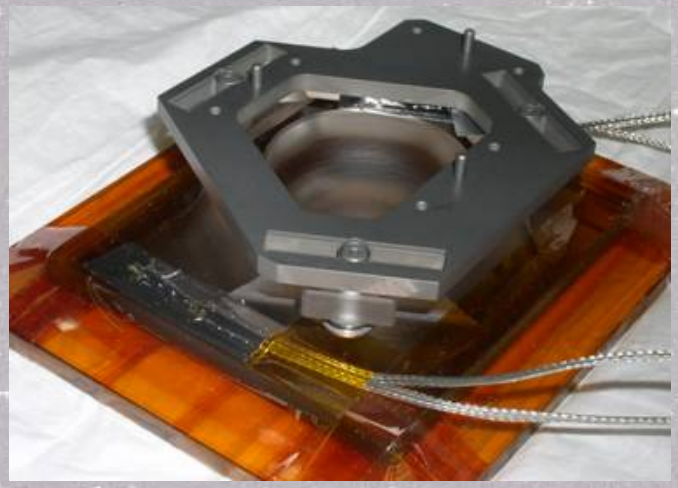
NIRCam Hardware



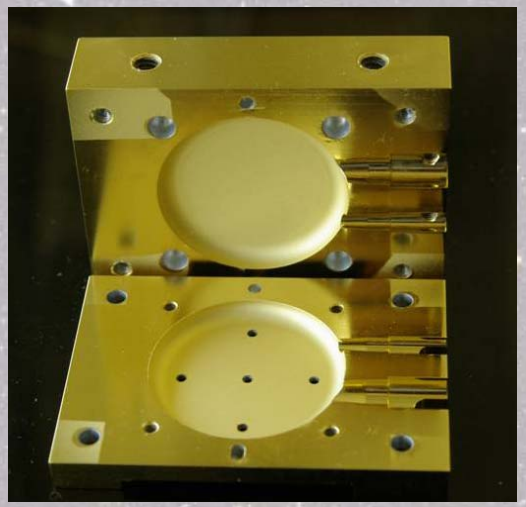
Eng Model 2Kx2K HgCdTe Detectors



ETU Optical Bench



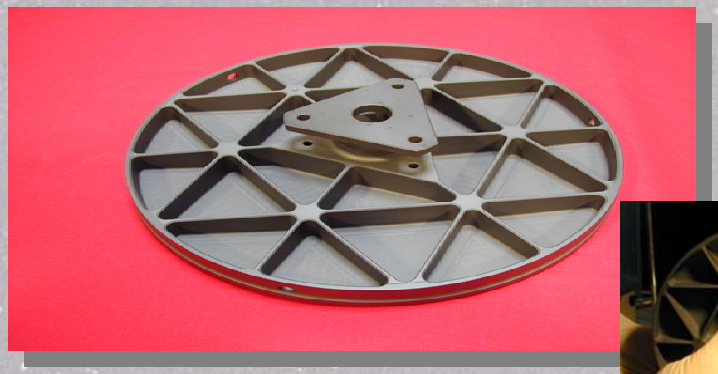
Prototype Pickoff Mirror

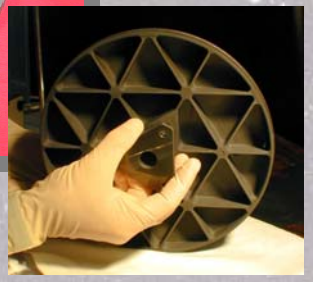


Prototype Calibration Cavity

Prototype Lens Triplet

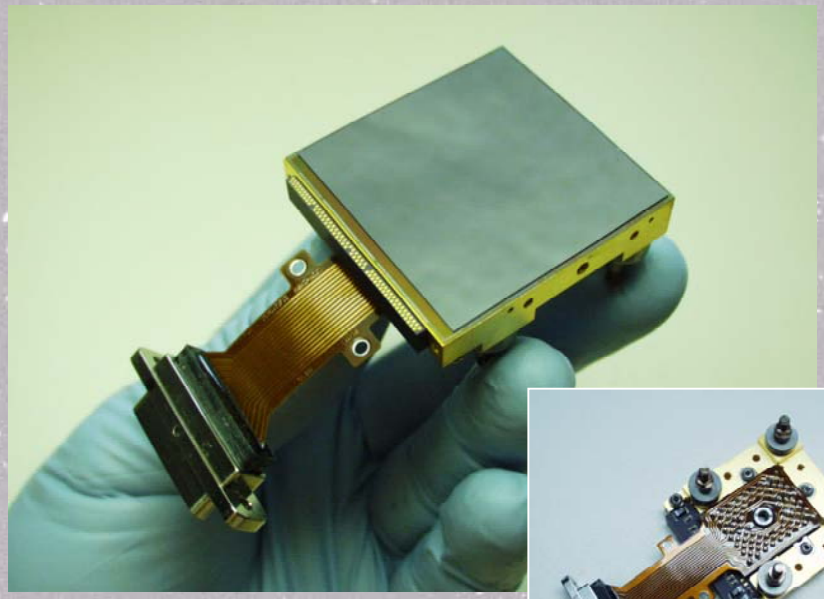
NIRSpec Hardware

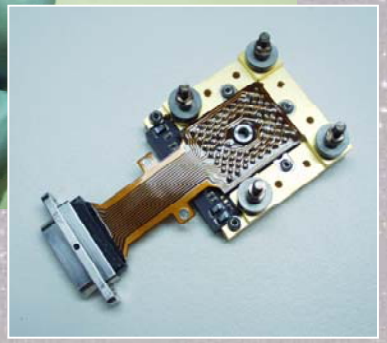




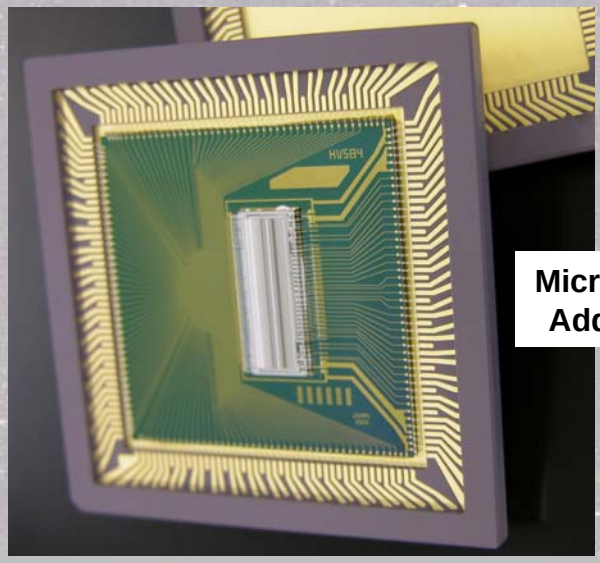
Prototype SiC Mirror

First Microshutter Array Flight Candidate





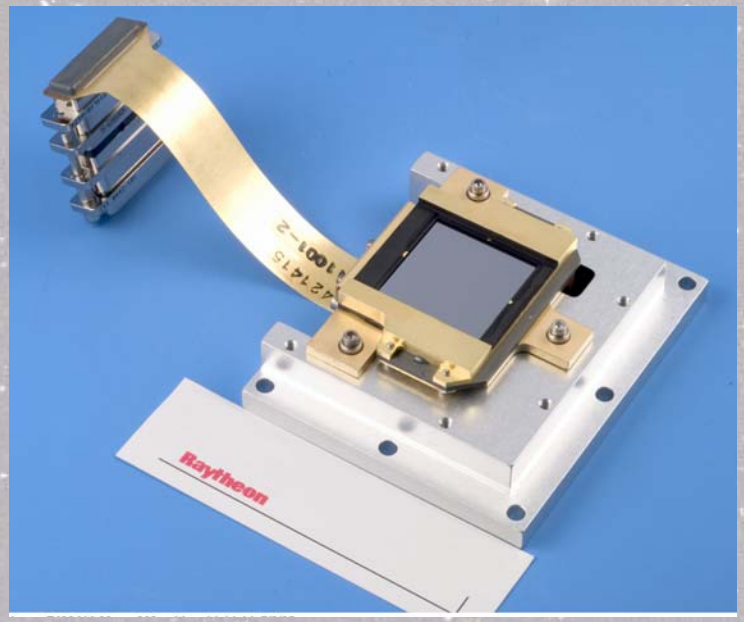
2Kx 2K HgCdTe
Sensor Chip Assembly



Microshutter Cryo
Addressing Chip

MIRI Hardware

Optical Assembly Structural/Thermal Model



1Kx1K SiAs Detector Assembly

Dichroic Filter Wheel Qual Unit

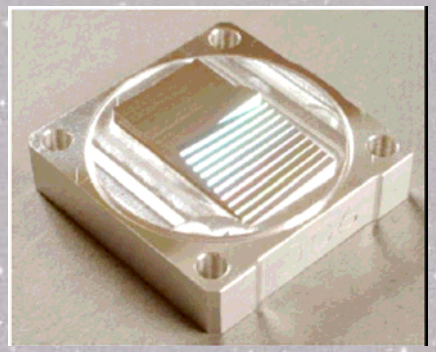
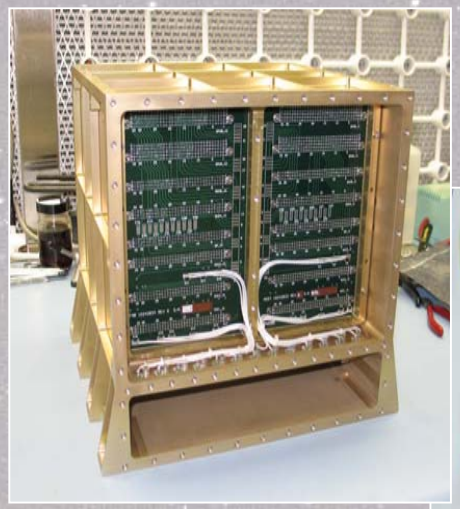
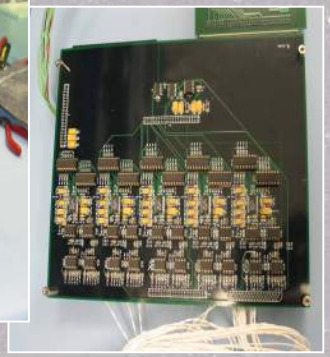


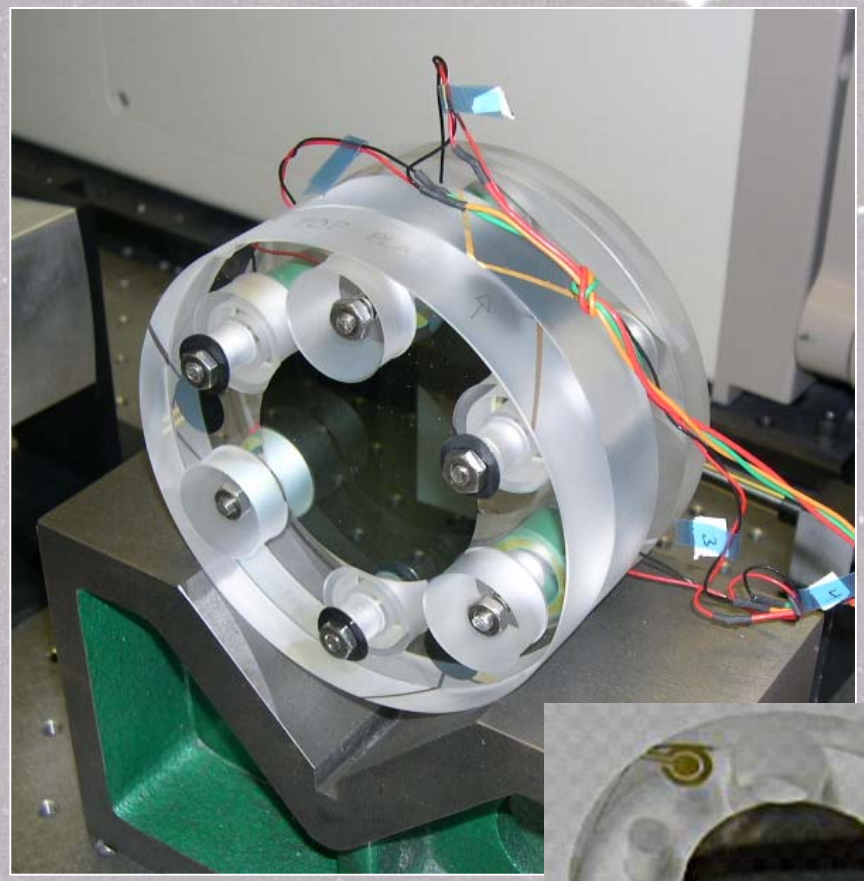
Image Slicing Mirror Prototype



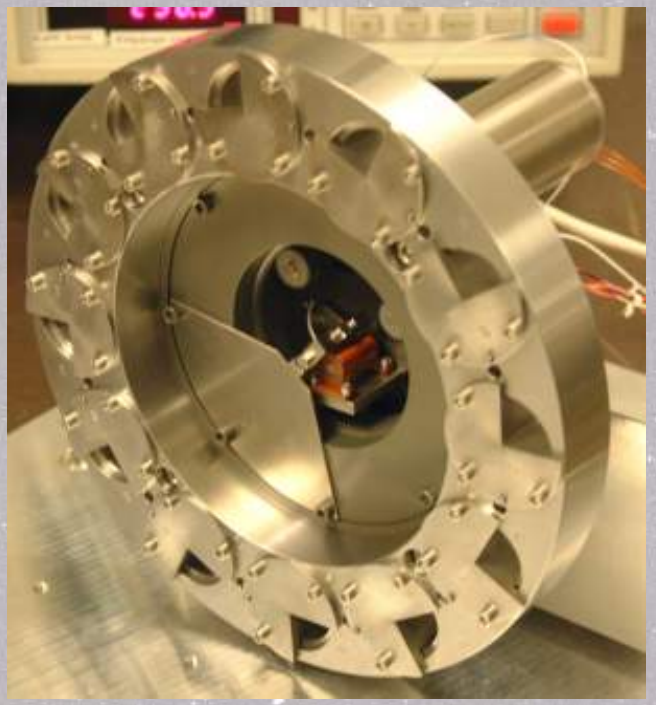


Focal Plane Electronics Breadboard

FGS Hardware

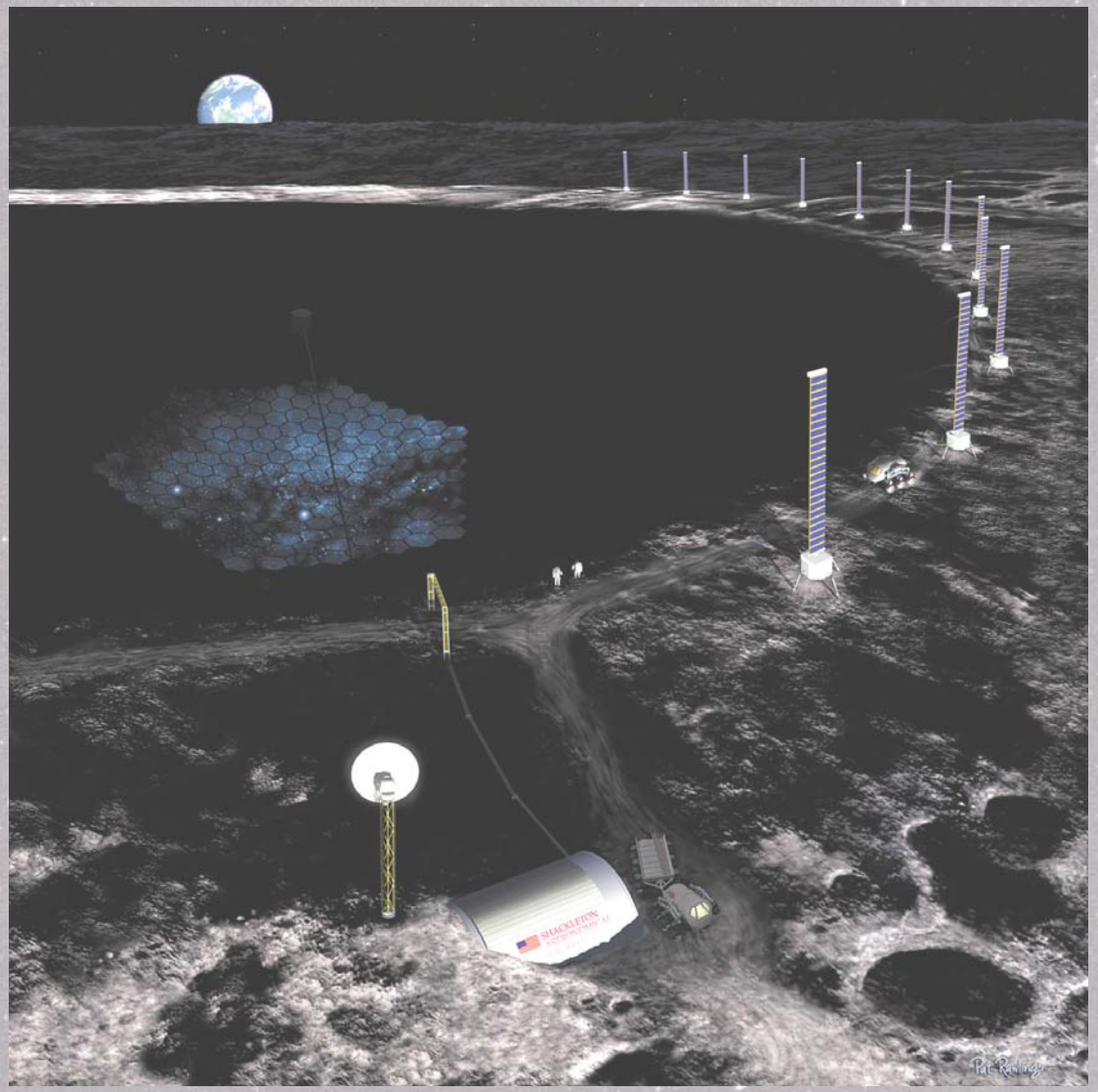


Shortwave Tunable
Filter Etalon Prototype



Filter Wheel

All Primary Mirror Segments Completed


SHACKLETON