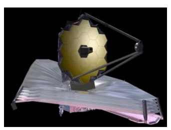
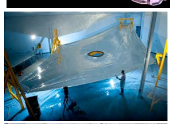
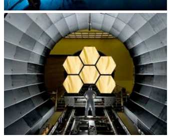
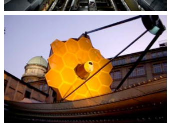
JAMES WEBB SPACE TELESCOPE

The JWST mission

P. Ferruit (ESA project scientist)

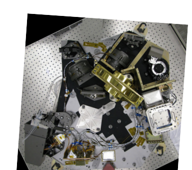





MIRI

NIRSpec

FGS/NIRISS

NIRCam



European Space Agency

Aknowledgements

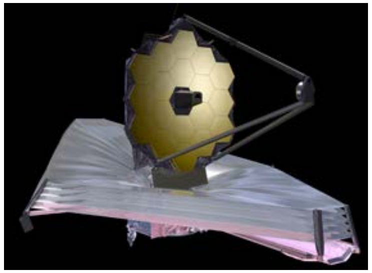
- All along this presentation you will see the results of work conducted by a large number of teams in Europe, USA and Canada.
- Many elements of this presentation are based on existing presentations prepared by other members of the JWST project, the instrument teams and STScI.

Table of contents

- **Overview of the JWST mission**
  - The JWST mission in a few slides.
  - A telescope, a sun shield, a deployment and an orbit…
- **The JWST instruments.**
  - NIRCam.
  - NIRISS.
  - MIRI.
  - NIRSpec.
- **JWST status and next steps.**
  - Status
  - What happens between now and launch?
- **Bonus track (if time permits): JWST on the web, some resources.**

The James Webb Space Telescope (JWST) mission in a nutshell

- **JWST will be one of the "great observatories" of the next decade.**
  - Often presented as the next step after the Hubble Space Telescope (HST)
- **Joint mission between NASA, ESA and CSA.**
  - High-priority endeavor for the associated astrophysical communities.
- **Setup similar to the HST one.**
  - Over the duration of the mission, > 15% of the total JWST observing time goes to ESA member states applicants.
- **To be launched at the end of 2018 for a minimum mission duration of 5 years (10-year goal).**



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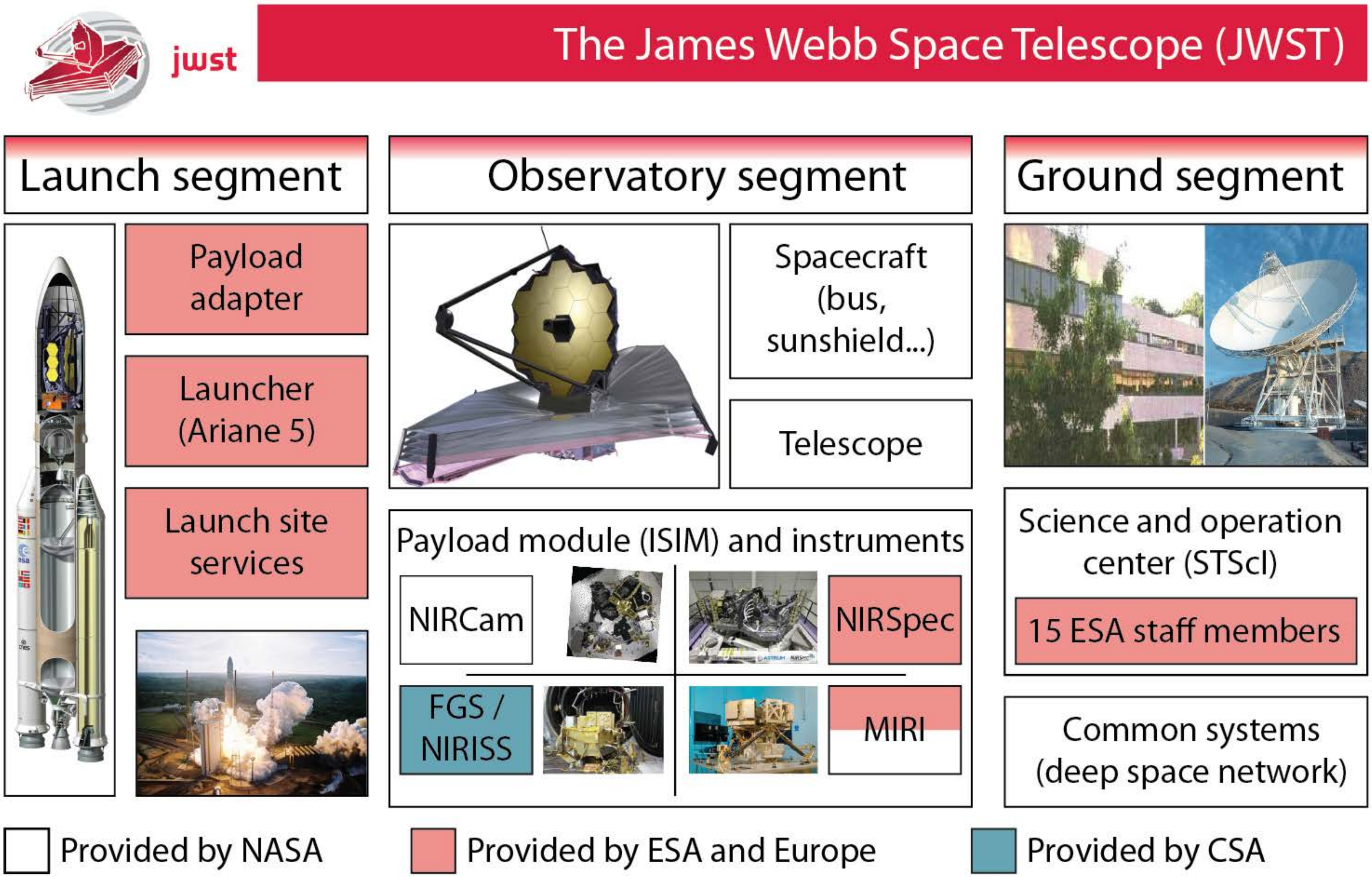
The James Webb Space Telescope (JWST) mission in a nutshell



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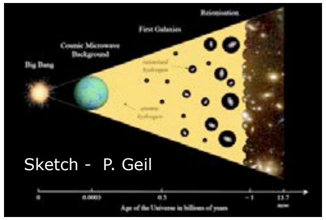
The James Webb Space Telescope (JWST) mission in a nutshell

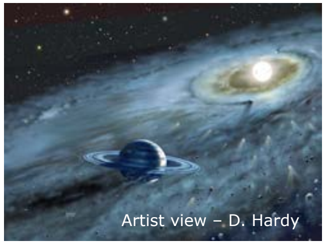
- The end of the dark ages: first light and re-ionization.


Sketch - P. Geil

- The assembly of galaxies: the formation and evolution of galaxies.


Hubble Ultra-deep Field

- The birth of stars and proto-planetary systems.


Artist view – D. Hardy

- Planetary systems (including our solar system) and the origin of life.


Artist view – R. Hurt

And a wealth of other scientific programs as JWST will be a general observatory.

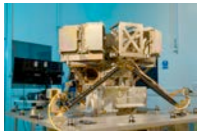
See Gardner et al., 2006, Space Science Reviews, 123, 485

JAMES WEBB SPACE TELESCOPE

What does it take to achieve these ambitious scientific goals?

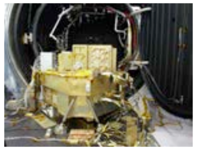
- **A wavelength coverage spanning the optical to mid-infrared spectrum (0.6-28 microns).**
    - A cryogenic space telescope in orbit around the very stable Sun-Earth L2 environment with the right instruments.
- **A high sensitivity.**
    - A 6.5-meter diameter primary mirror.
- **An angular resolution similar to the HST one but in the near infrared.**
    - A 6.5-meter diameter primary mirror diffraction limited at around 2 microns.
- **A low background level from the near-infrared to the mid-infrared.**
    - A cryogenic space telescope in orbit around
      stable Sun-Earth L2 environment.
- **Both imaging and spectroscopic capabilities.**
    - A suite of instruments.

MIRI

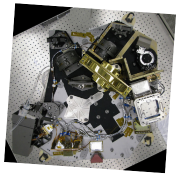


NIRSpec

FGS/NIRISS



NIRCam



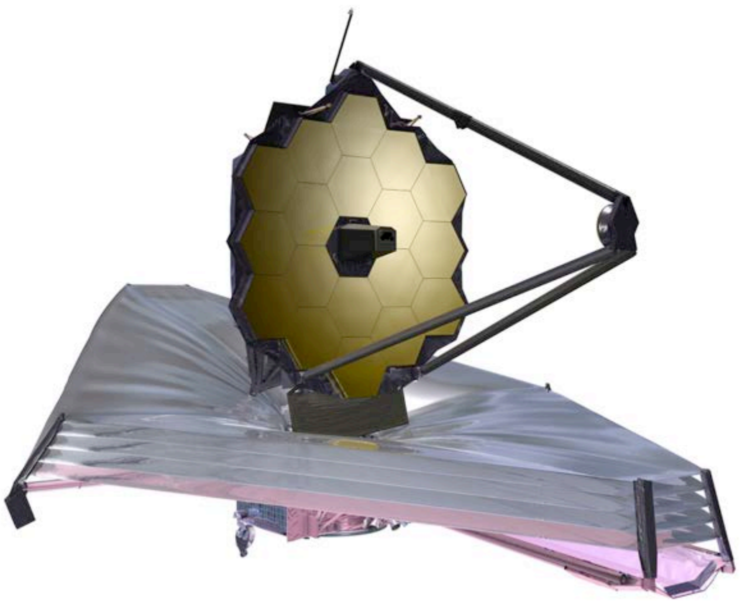
JWST

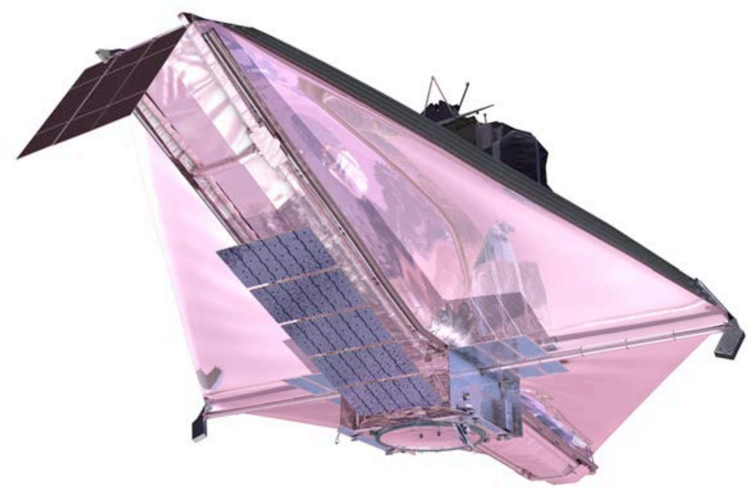
European Space Agency

The James Webb Space Telescope Implementation…

- **Several key elements that deserve a closer look…**
  - The telescope and its mirrors.
  - The sun shield.
  - A folding telescope.
  - The orbit.
  - The instruments.

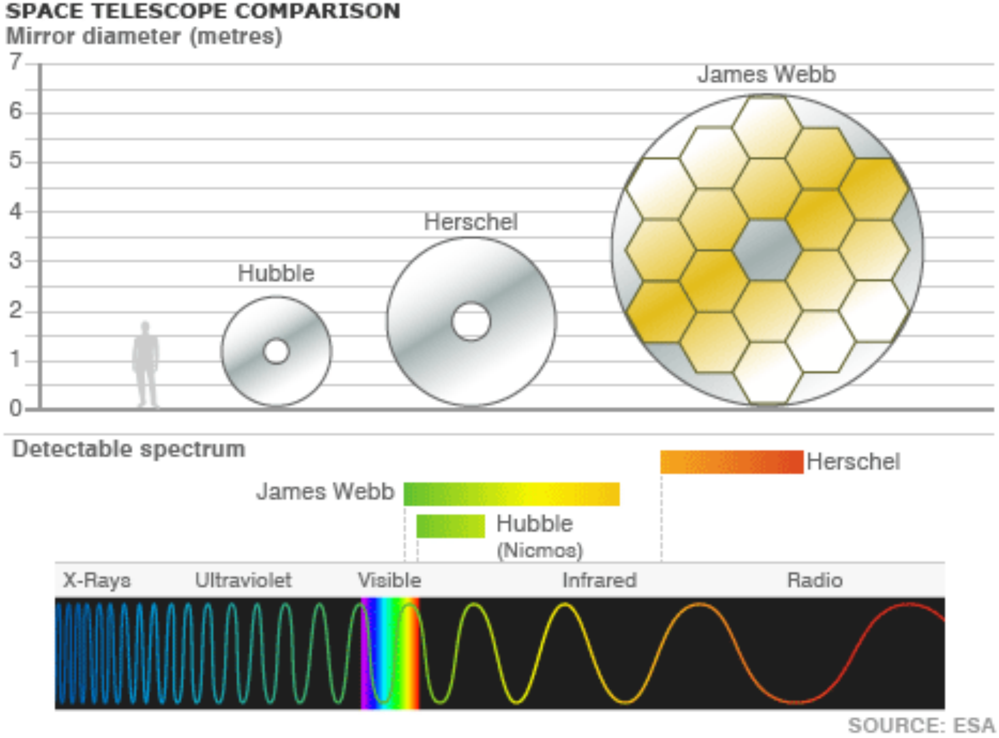
This part of the presentation is heavily based on slides from M. Greenhouse (NASA)





The James Webb Space Telescope
The telescope and its mirrors

- **A 6.5-meter gold-coated and segmented mirror.**
  - Made of 18 segments in Beryllium.

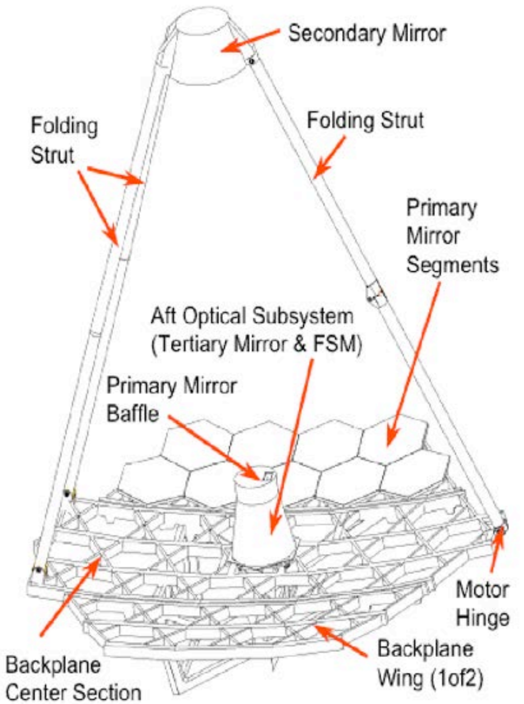


Beryllium segment mass properties
- substrate: 21.8 kg
- segment assembly: 39.4 kg
- OTE area density: ~28 kg m^{-2}
  - HST (ULE) ~ 180 kg m^{-2}
  - Keck (Zerodur) ~ 2000 kg m^{-2}

ULE = Ultra-Low Expansion

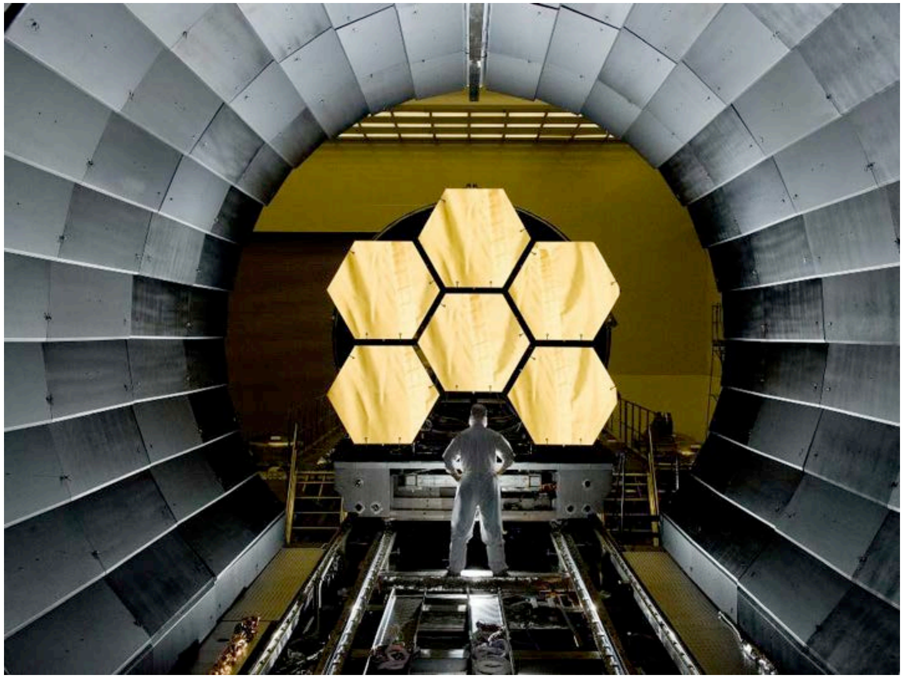
The James Webb Space Telescope
The telescope and its mirrors

- **Optical design with 4 gold-coated mirrors (including the primary mirror).**
  - Primary, secondary, tertiary and fast-steering mirror.
- **All JWST mirror have been completed and meet their optical performance requirements.**



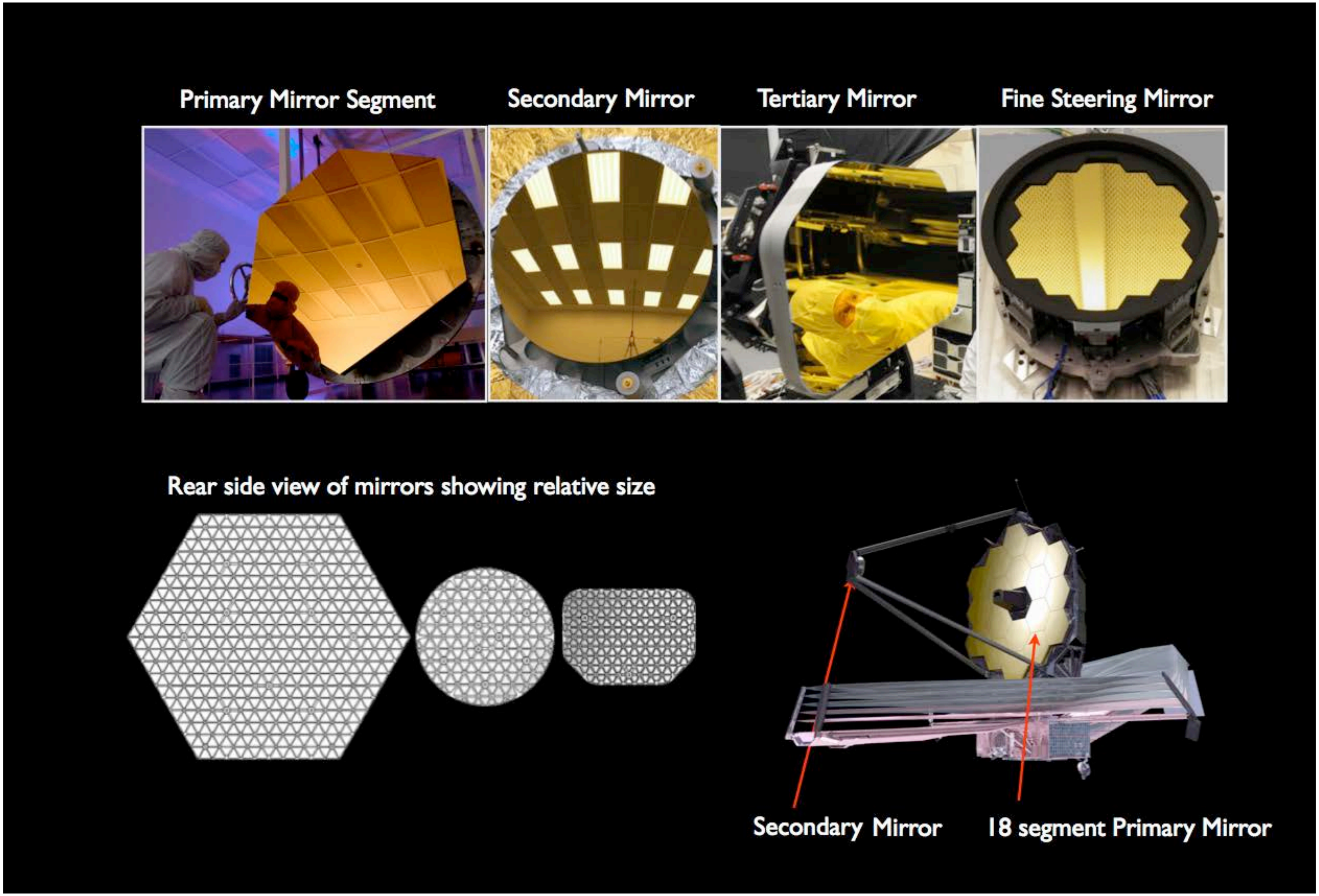
FSM = fine steering mirror

6 of the flight mirrors before cryogenic testing

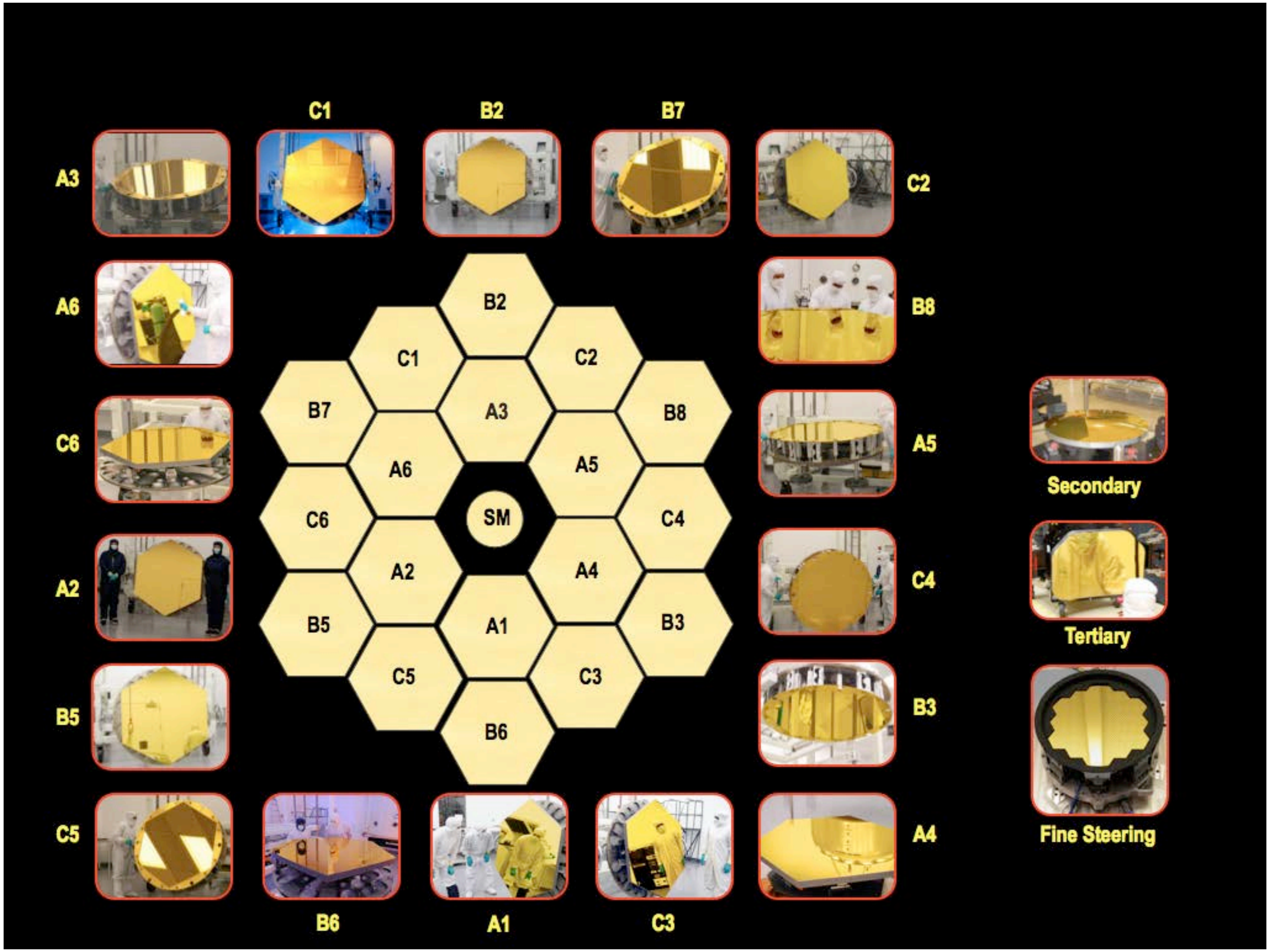


Credit: NASA/MSFC/David Higginbotham

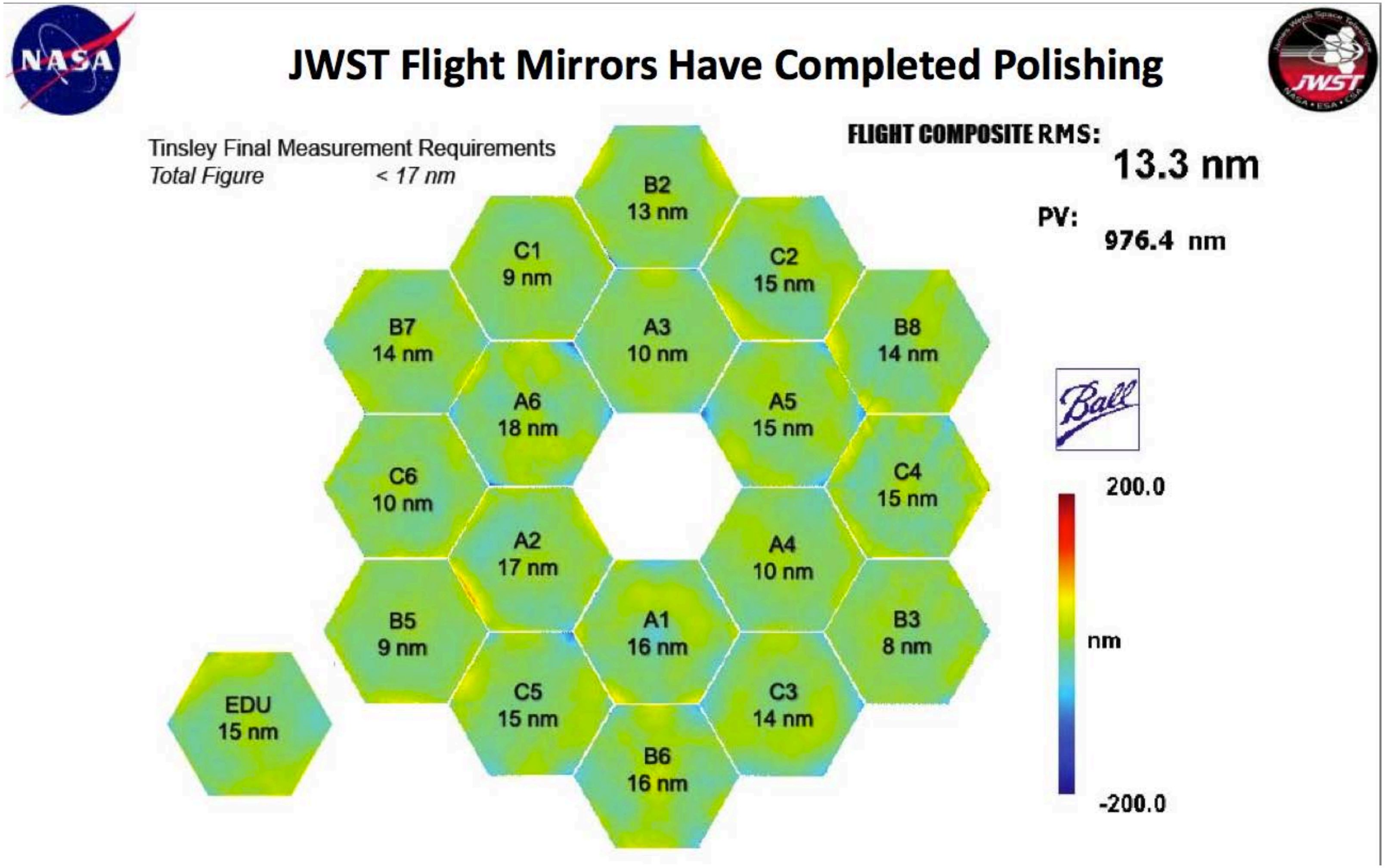
The James Webb Space Telescope
The telescope and its mirrors



The James Webb Space Telescope
The telescope and its mirrors

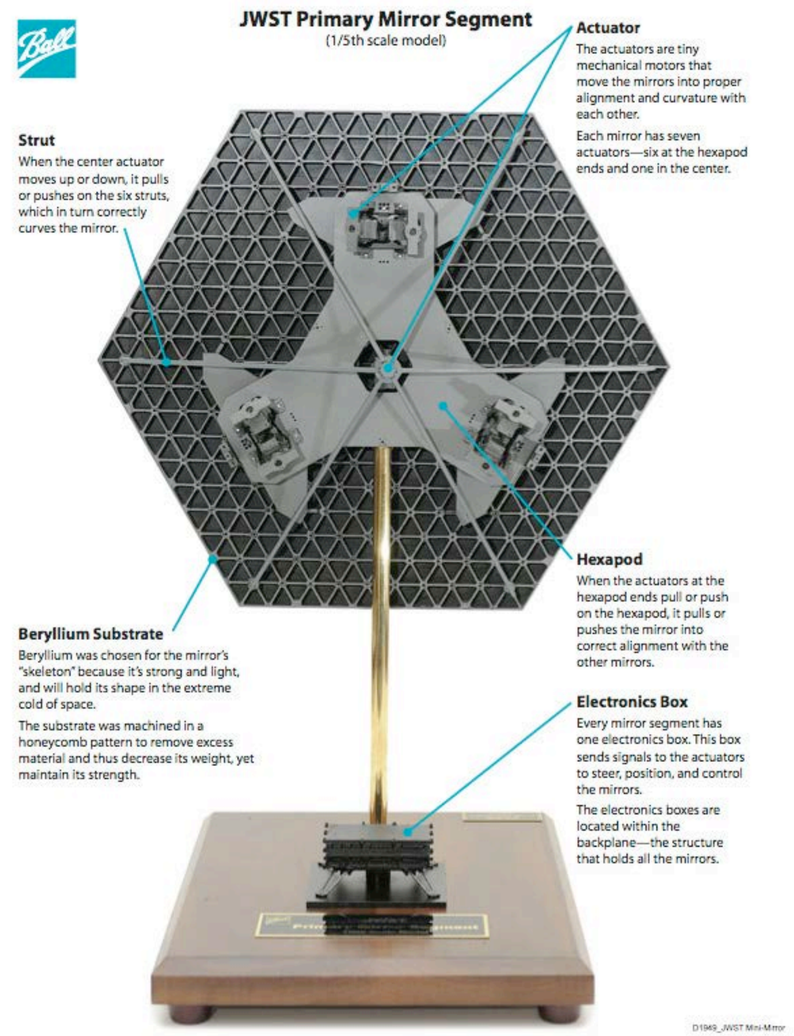


The James Webb Space Telescope
The telescope and its mirrors



The James Webb Space Telescope
The telescope and its mirrors

- **An active optic system.**
  - Actuators providing 7-degree of freedom (position, tilt and radius of curvature).



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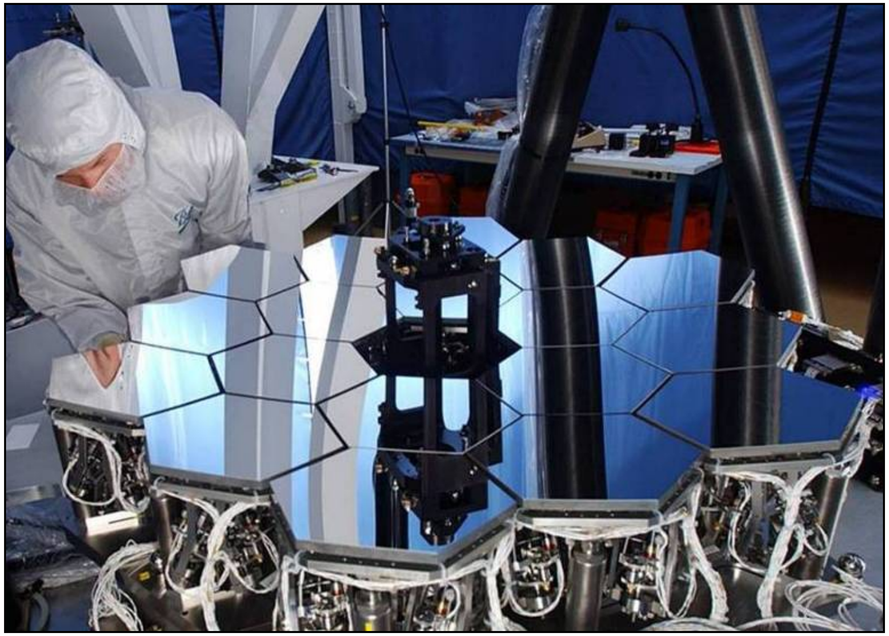
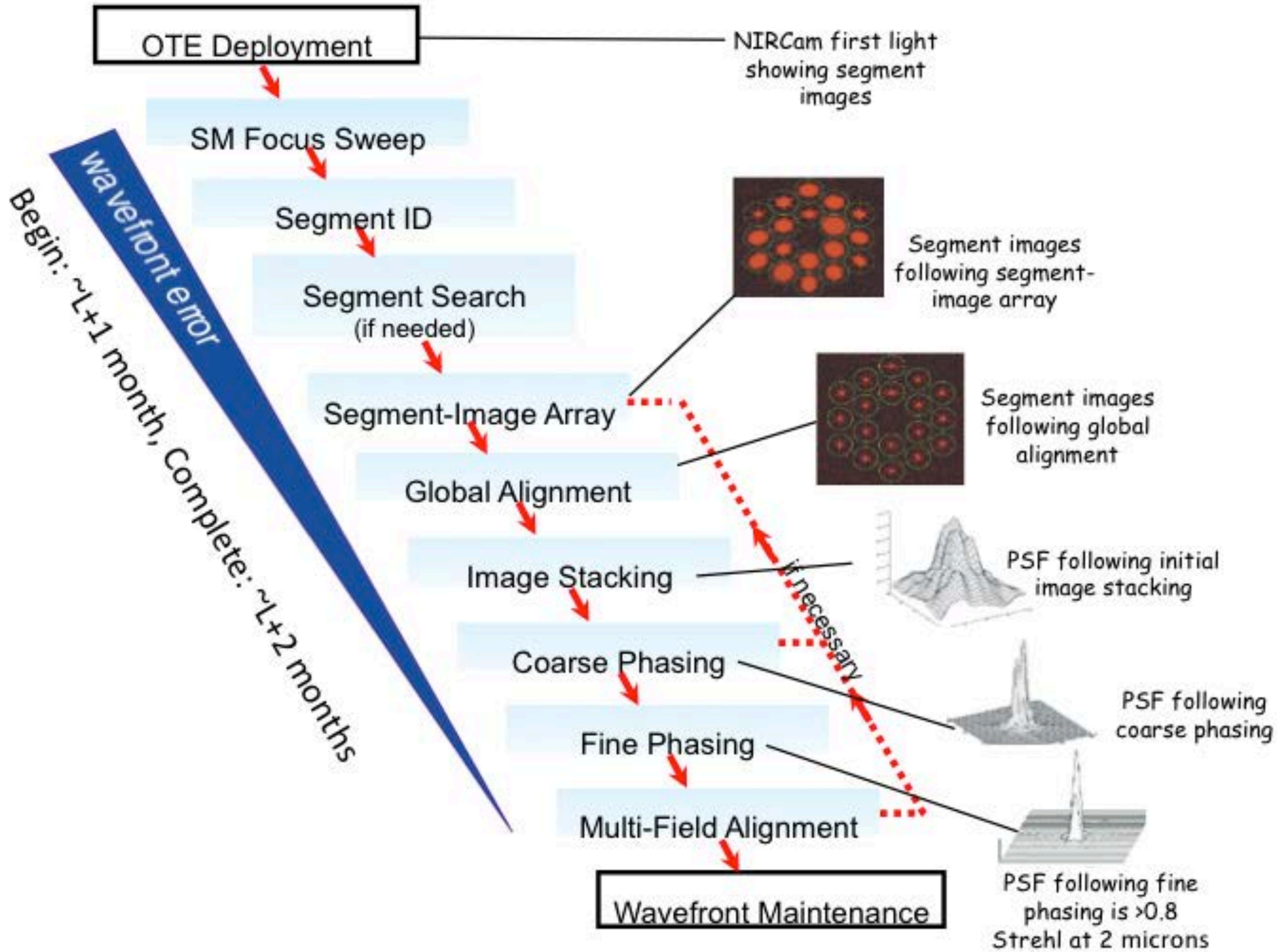
The James Webb Space Telescope
The telescope and its mirrors

- **Having 18-segments to act like a single mirror**
  - Phasing using one of the instruments (NIRCam) as wave front sensor.
  - Initial phasing is a complicated one!



Using a 1/6th-scale engineering model to test and validate the algorithms.

The James Webb Space Telescope
The telescope and its mirrors

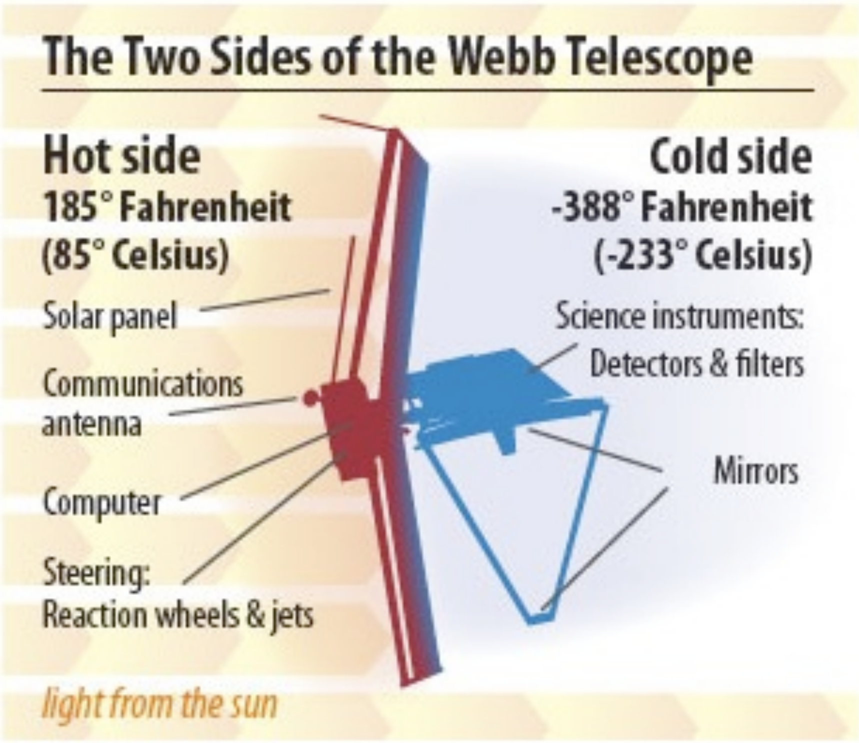


The James Webb Space Telescope
The sun shield

- **With the exception of the MIRI instrument, JWST is a passively cooled observatory.**
- **Using a 5-layer sunshield to protect the telescope and its instruments from the heat of the Sun.**

SUNSHIELD FACTS

- Measures 73 x 40 feet and has 5 layers
- Made of heat-resistant Kapton coated with silicon on sun side and aluminum on other surfaces.
- Sun side reaches 358 K (85º C), dark side stays at 40 K (-233º C)
- Each of the 5 layers consist of 50 pieces to form shape.
- Seaming involves 180-m of thermal welds.
- Seam-to-seam accuracy ~ 2 mm with the shape of the tennis court size layers accurate to a fraction of a cm.



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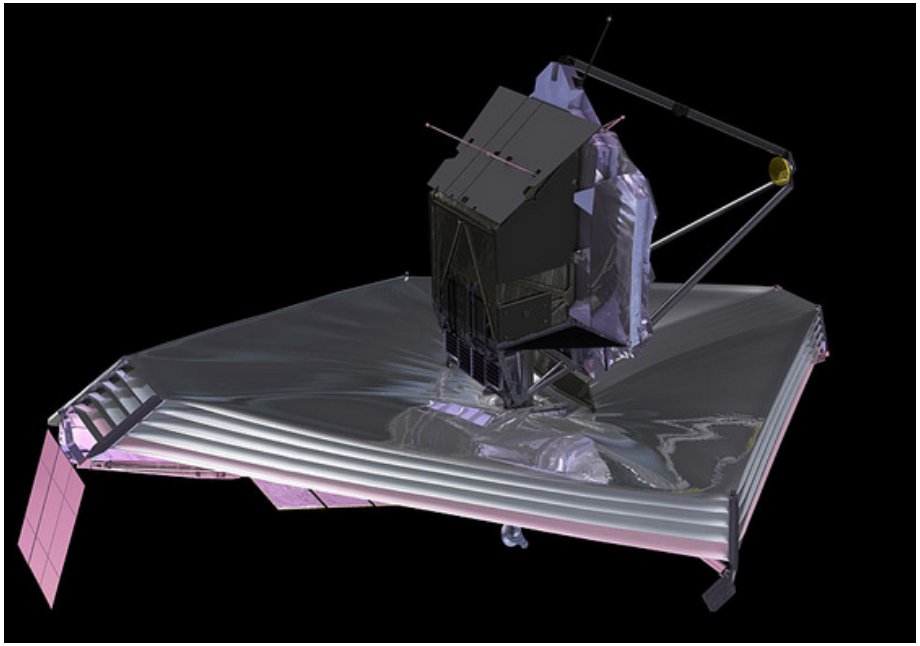
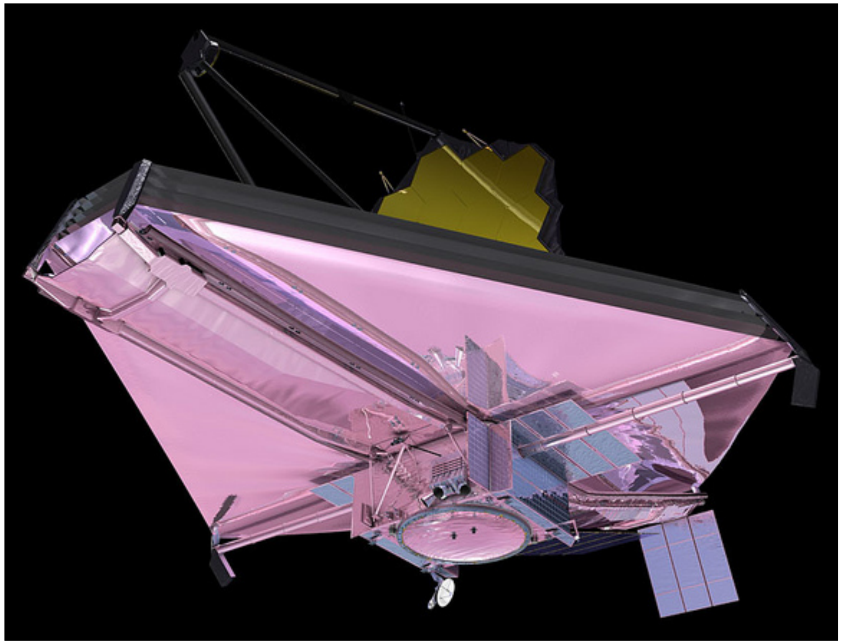
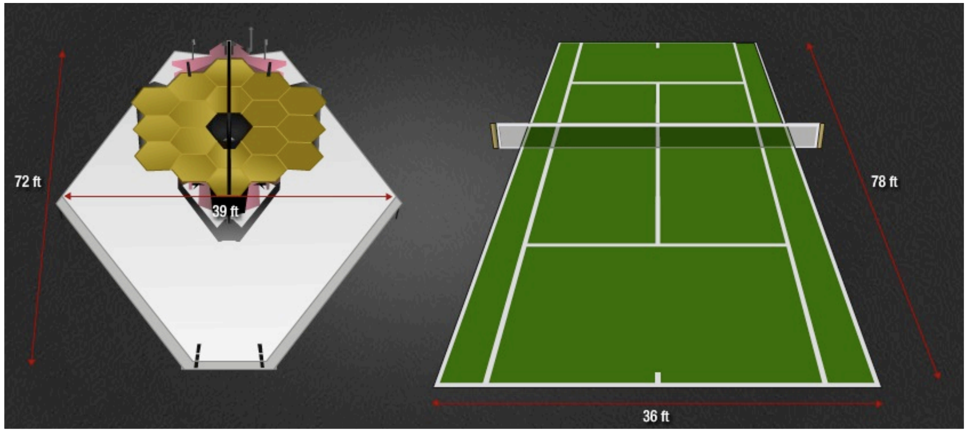
The James Webb Space Telescope
The sun shield

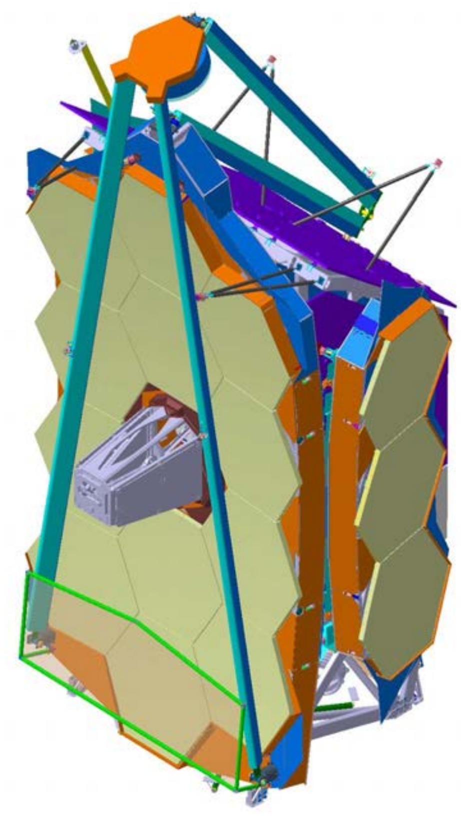




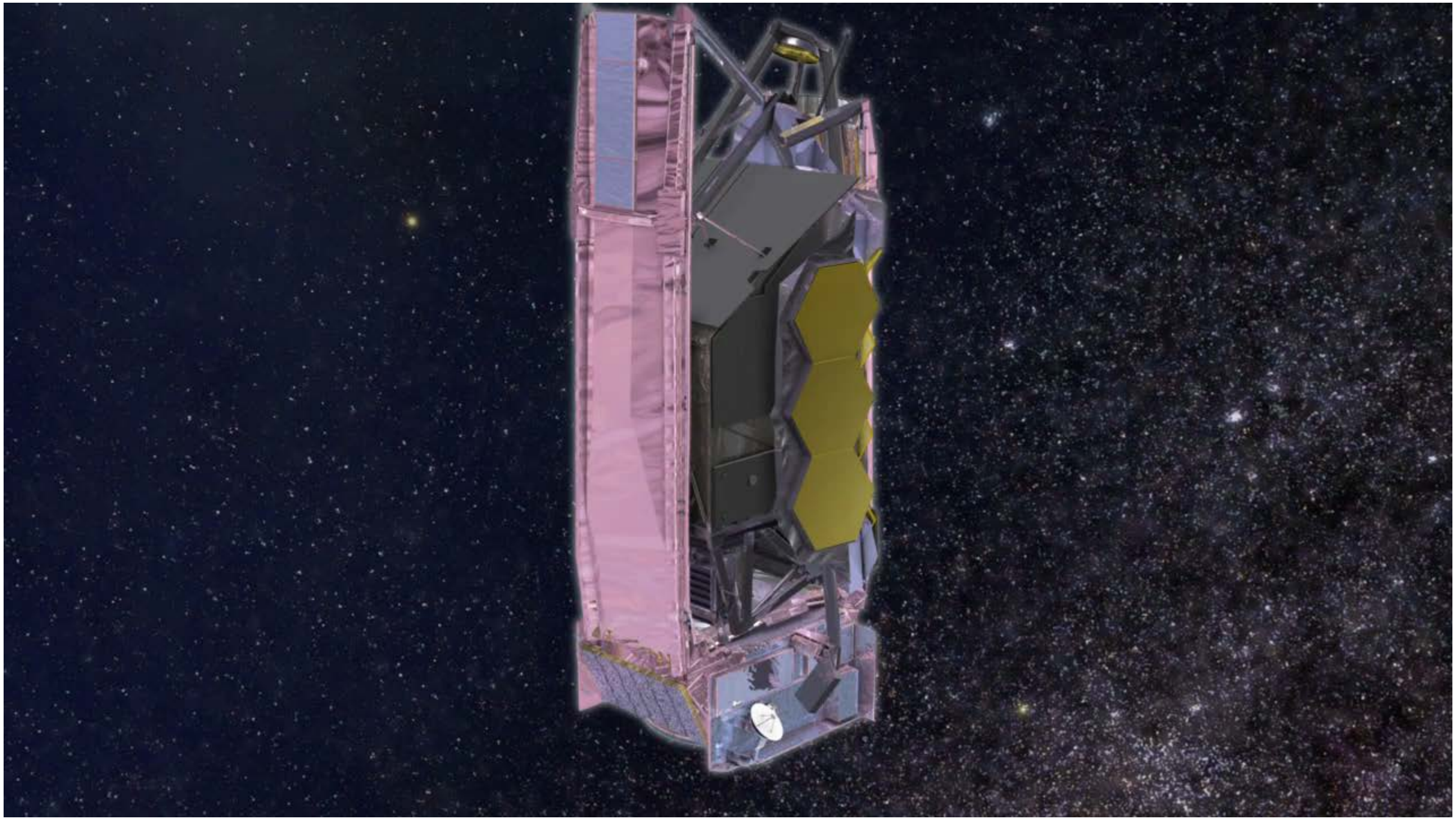


The James Webb Space Telescope
The deployment

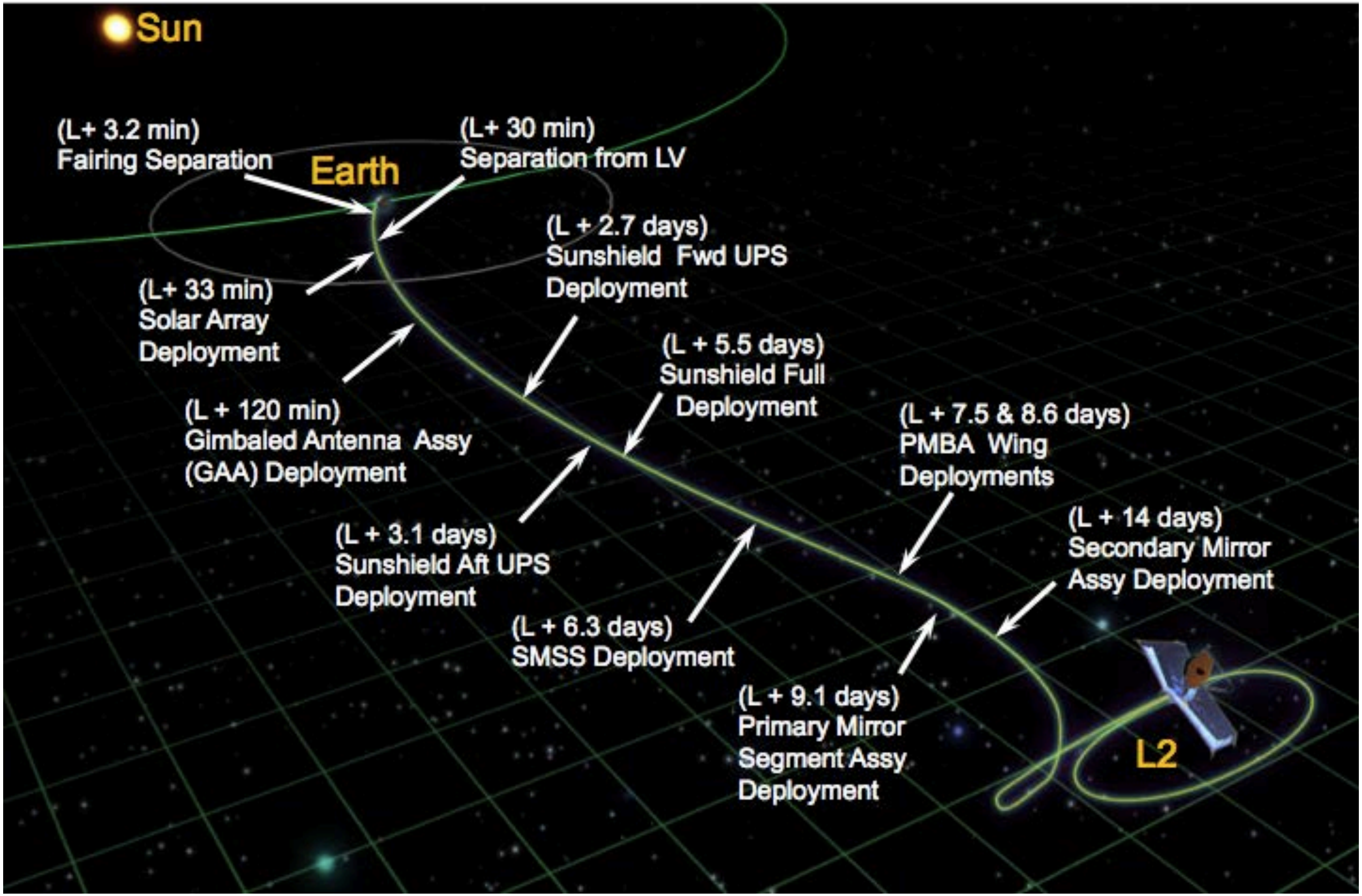
- **JWST will be launched by an Ariane 5 rocket with a 5-meter diameter fairing.**
    - JWST will be folded to fit in the Ariane 5 fairing and will deploy on in-orbit.



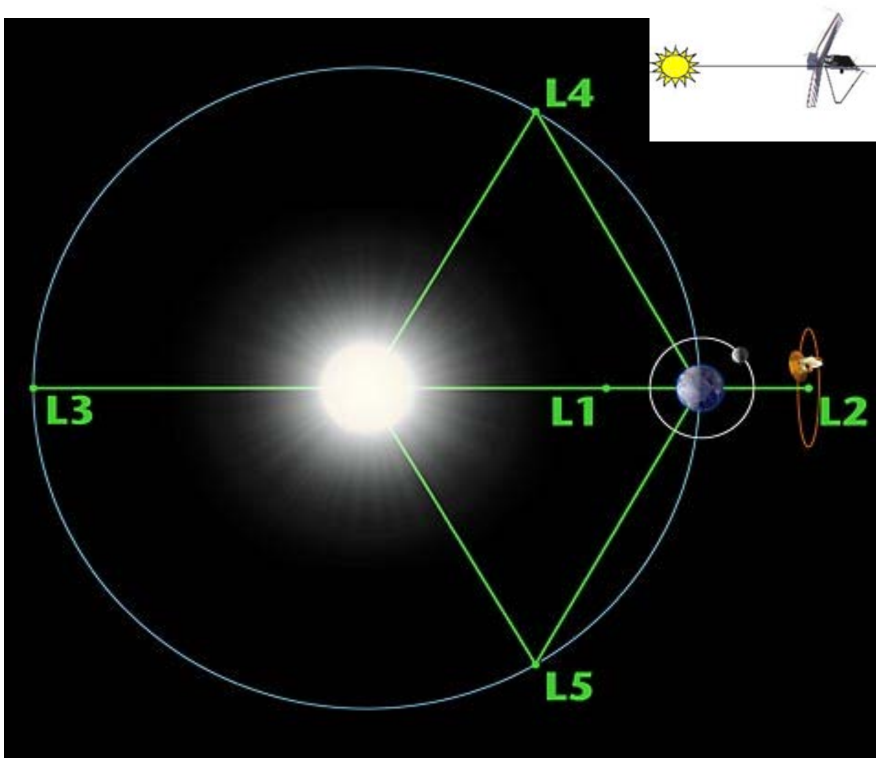
The James Webb Space Telescope
The deployment

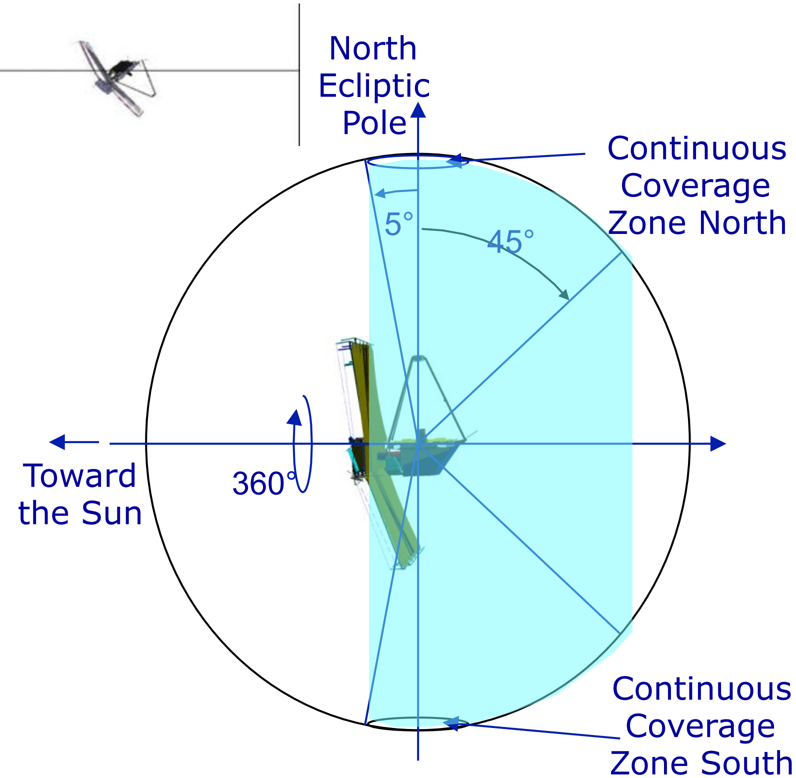


The James Webb Space Telescope
The deployment



The James Webb Space Telescope
The orbit





- The JWST can observe the whole sky while remaining continuously in the shadow of its sunshield
    - The field of Regard is an annulus covering 35% of the sky
    - The whole sky is covered each year with small continuous viewing zones at the Ecliptic poles

The James Webb Space Telescope
The orbit

Nice but far from correct…

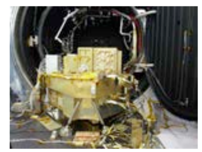
The instruments…

- **4 instruments installed on the "back" of the primary mirror in a structure called ISIM (integrated science instrument module).**

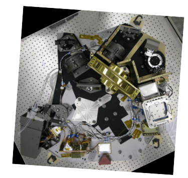
MIRI

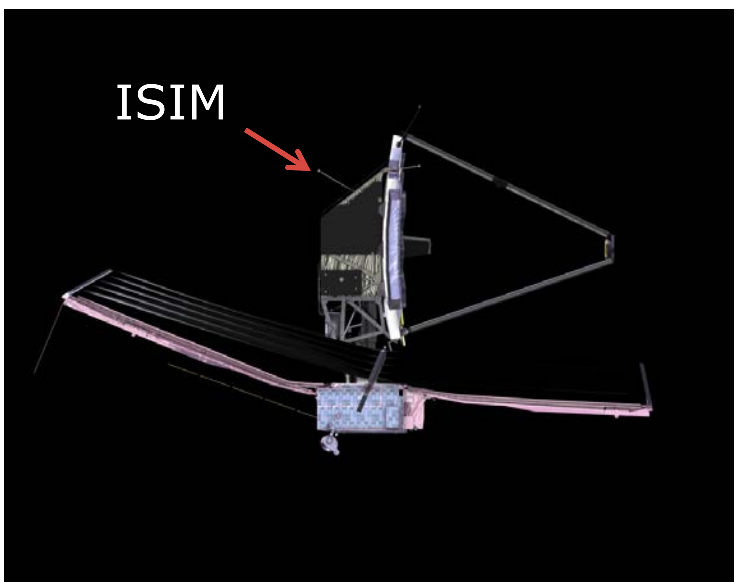
NIRSpec

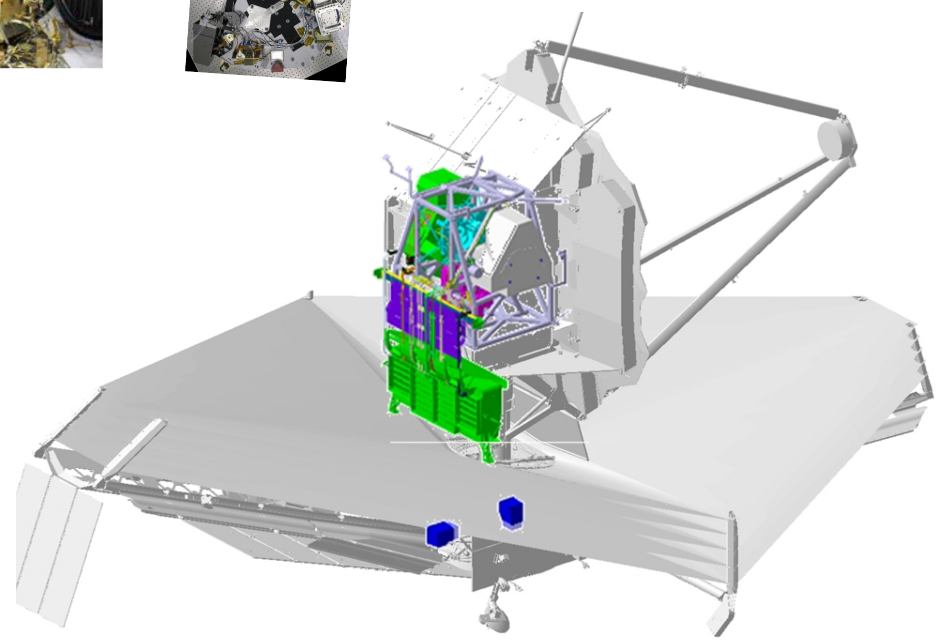
FGS/NIRISS



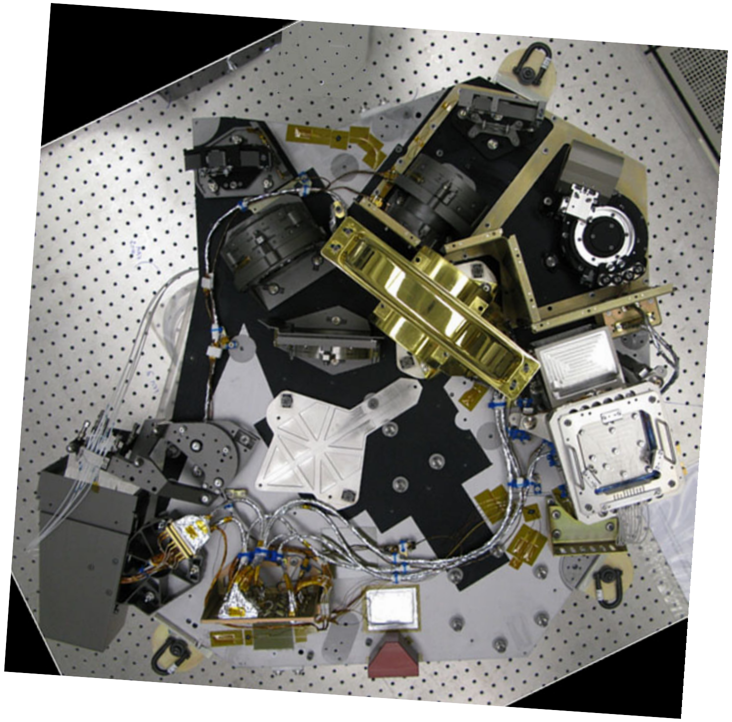
NIRCam



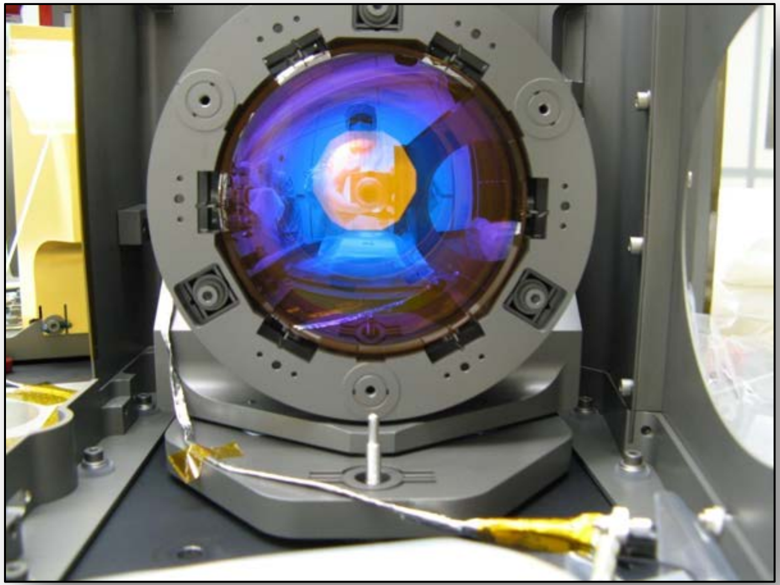




JWST/NIRCam

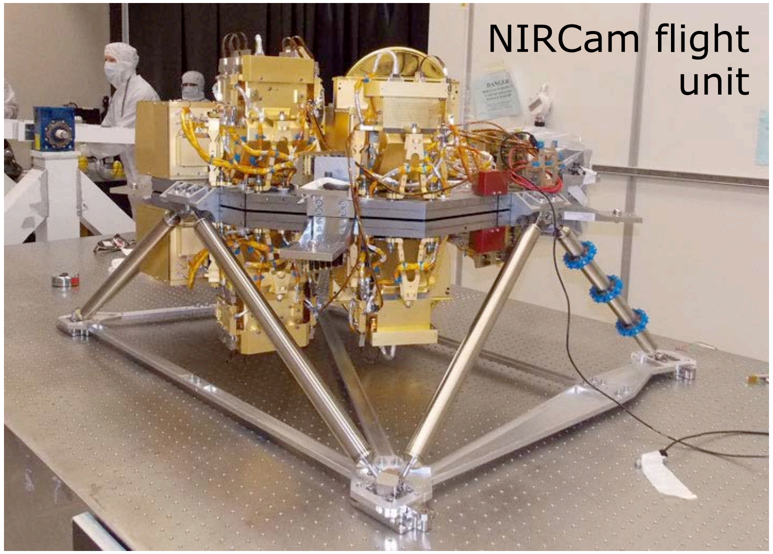


This part of the presentation is heavily based on slides from M. Rieke (NIRCam PI)



JWST/NIRCam – Introduction

- **NIRCam is the main near-infrared camera (0.6-5 microns) for JWST.**
- **It is developed under the responsibility of the University of Arizona (PI: M. Rieke)**
    - Has arrived at NASA Goddard Space Flight Center in July 2013.
    - Finishing environmental testing. Getting ready for integration on ISIM.

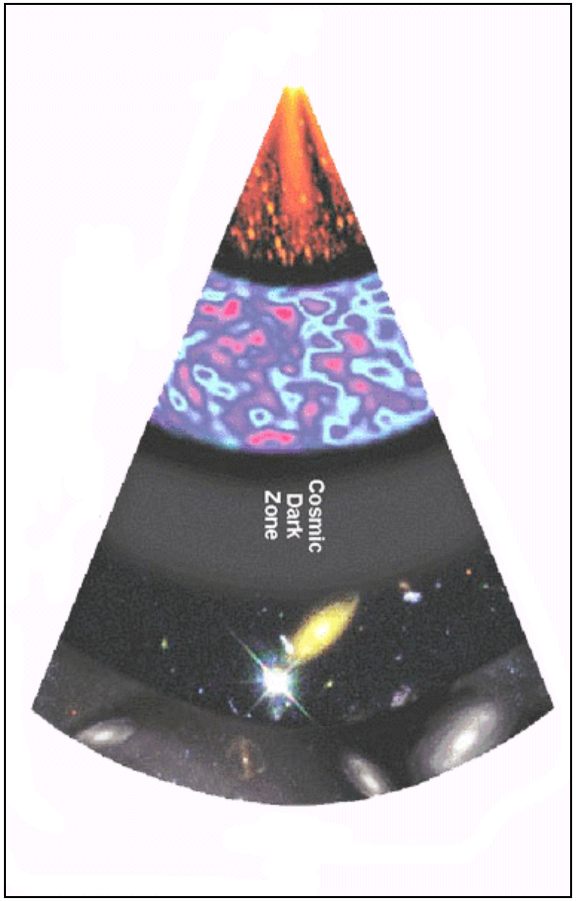


NIRCam flight unit

JWST/NIRCam – Introduction

- **NIRCam has a primary imaging capability.**
  - Dichroic used to split range into short (0.6-2.3microns) and long (2.4-5 microns) sections
  - Nyquist sampling of the PSF at 2 and 4 microns (32 and 65 mas/pixel)
  - 2.2 arc min x 4.4 arc min total field of view seen in two colors (40 MPixels)
- **NIRCam has a coronagraphic capability for both short and long wavelengths**
  - Not presented here.
- **NIRCam has a long-wavelength slitless grism capability.**
  - Link to the wavefront sensing capability but can also be used for science (e.g. transit spectroscopy). Not presented here.
- **NIRCam is also the wavefront sensor for JWST!**
  - **Must be fully redundant (2 identical modules).**
  - Not presented here.

JWST/NIRCam – Introduction
Its role in JWST's science themes

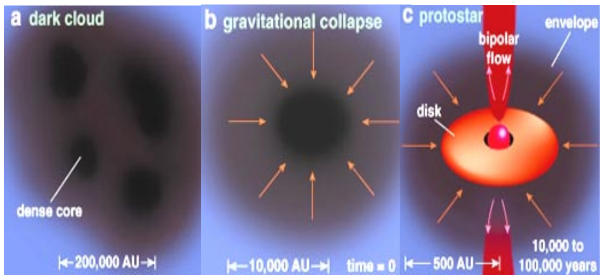


- **The First Light in the Universe:**
  - Discovering the first galaxies, reionization.

  ➔ NIRCam executes deep surveys to find and categorize objects.
- **Period of Galaxy Assembly:**
  - Establishing the Hubble sequence, Growth of galaxy clusters

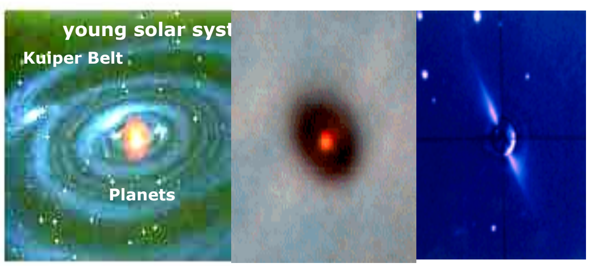
  ➔ NIRCam provides details on shapes and colors of galaxies, identifies young clusters

JWST/NIRCam – Introduction
Its role in JWST's science themes



- **Stars and Stellar Systems:**
  - Physics of the IMF, Structure of pre-stellar cores,
  - Emerging from the dust cocoon

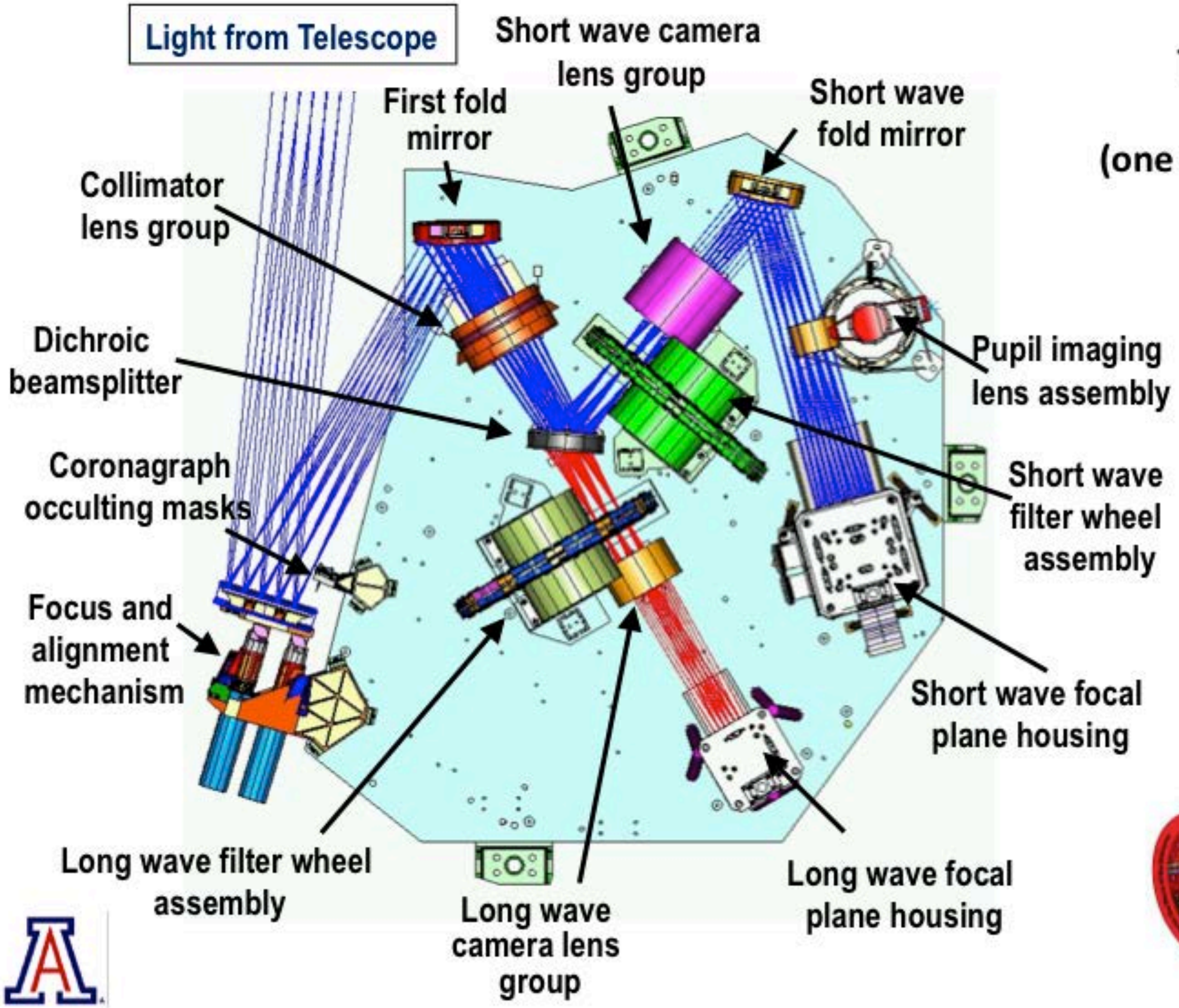
  ➔ NIRCam measures colors and numbers of stars in clusters, measure extinction profiles in dense clouds.



- **Planetary Systems and the Conditions for Life:**
  - Disks from birth to maturity, Survey of KBOs, Planets around nearby stars

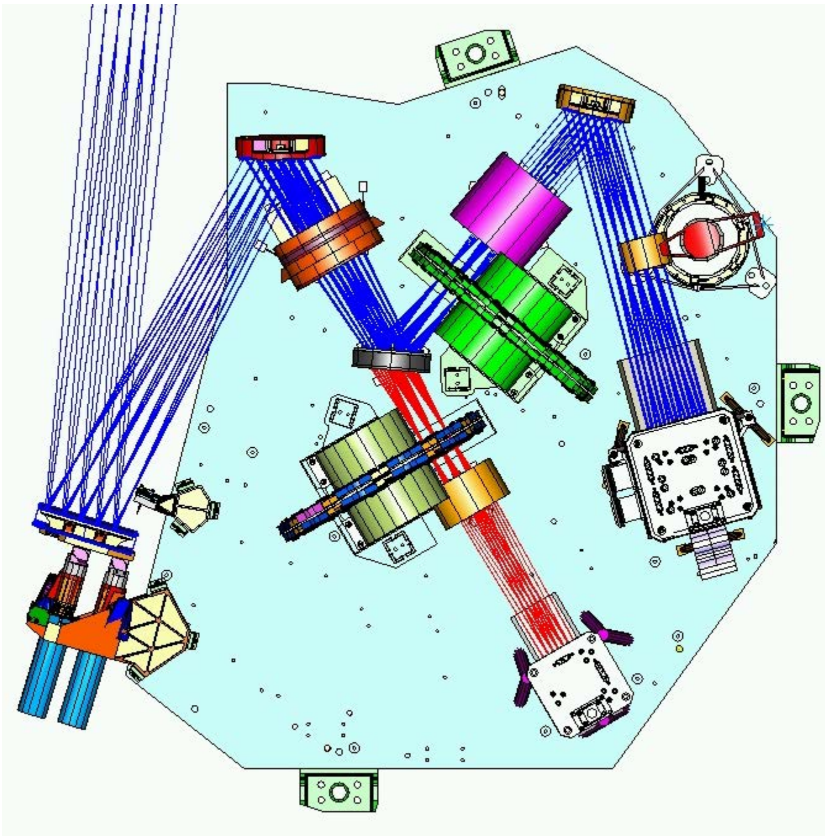
  ➔ NIRCam and its coronagraph image and characterize disks and planets, classifies surface properties of KBOs

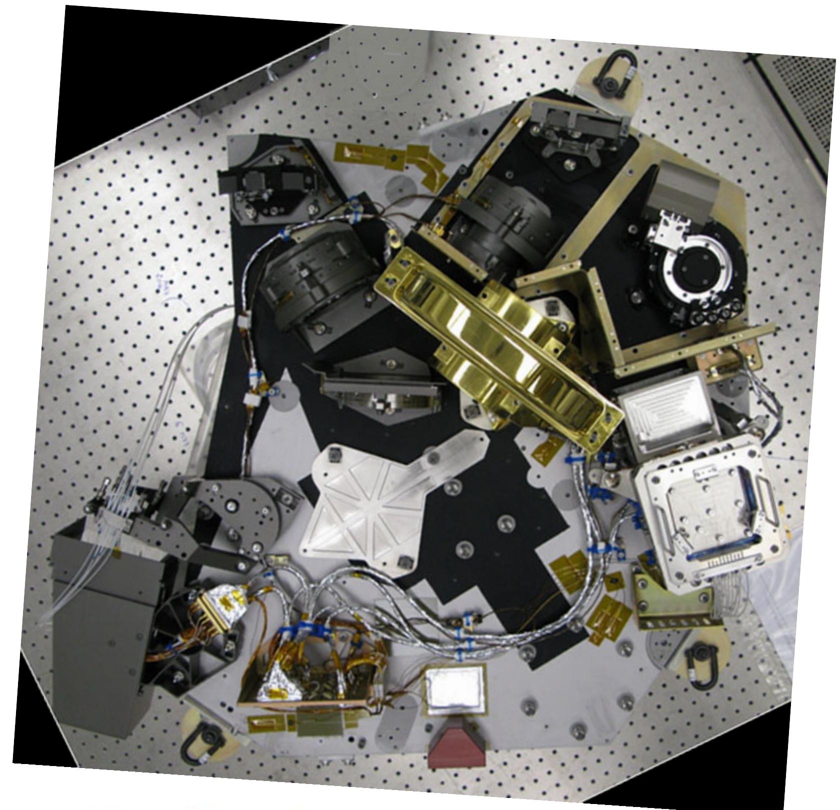
JWST/NIRCam – Design



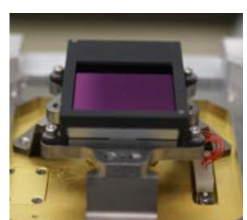
Two redundant modules (one on each side of the bench)

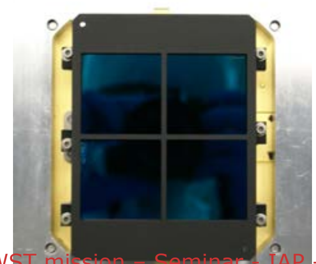
JWST/NIRCam – Design





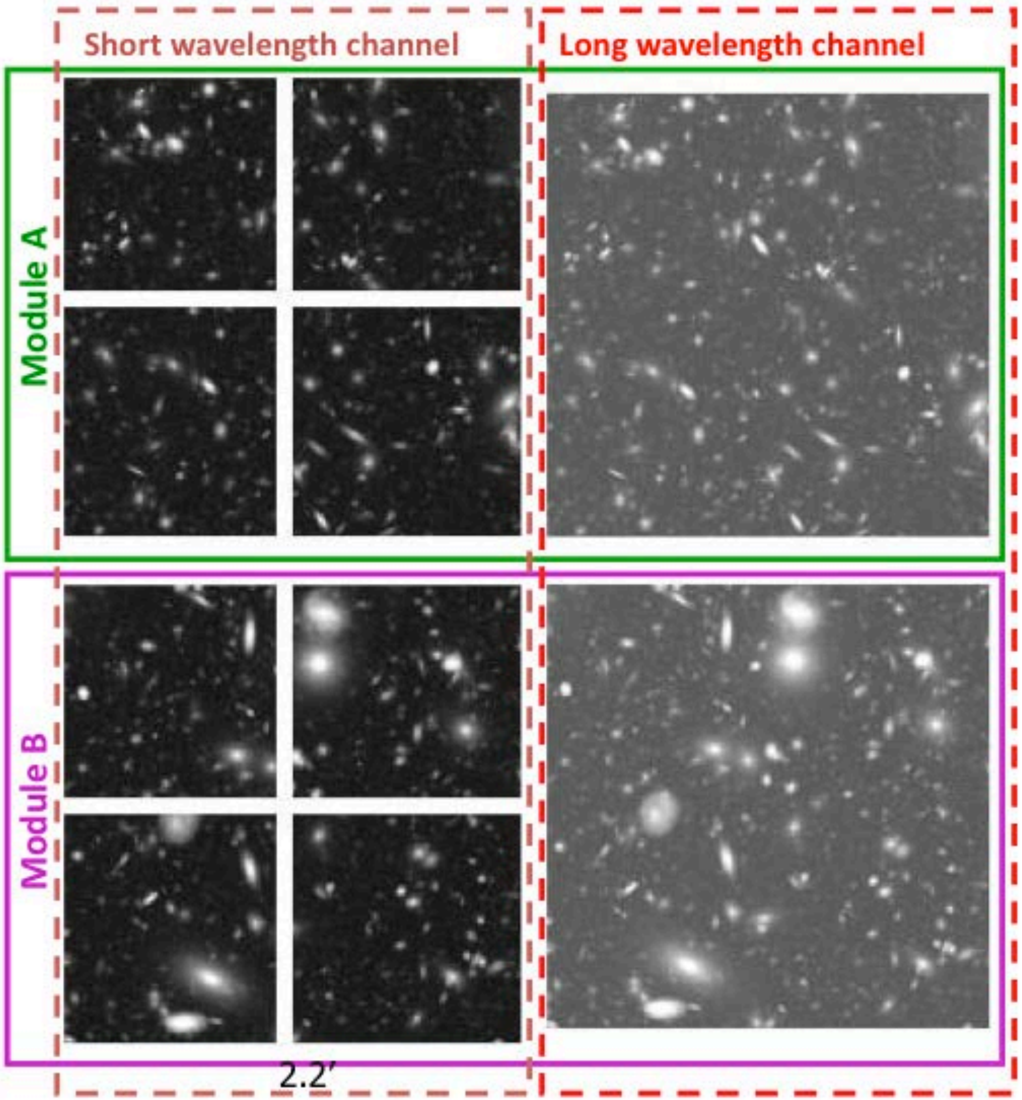
1 long wavelength detector





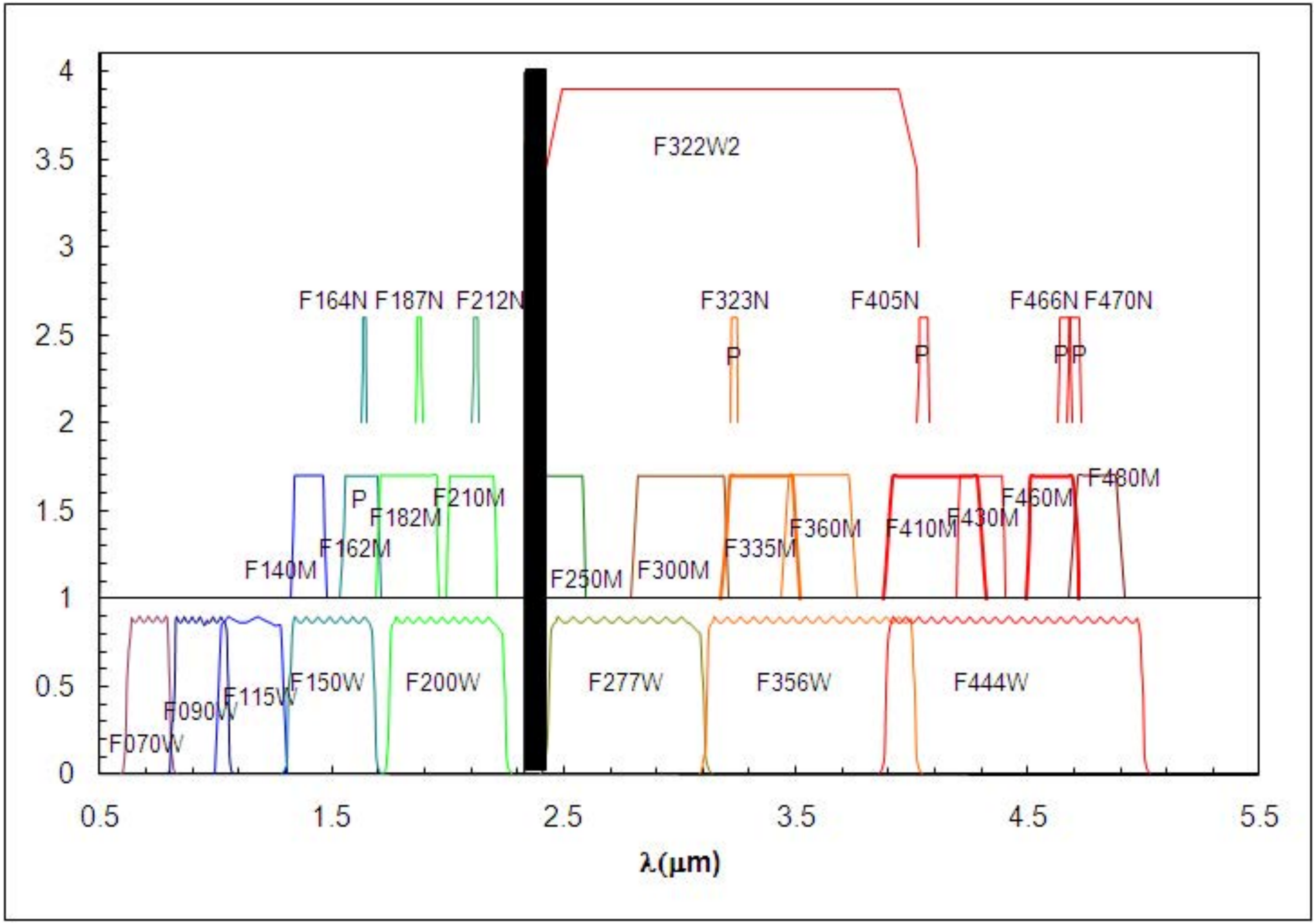
4 short wavelength detectors

JWST/NIRCam – Field of view

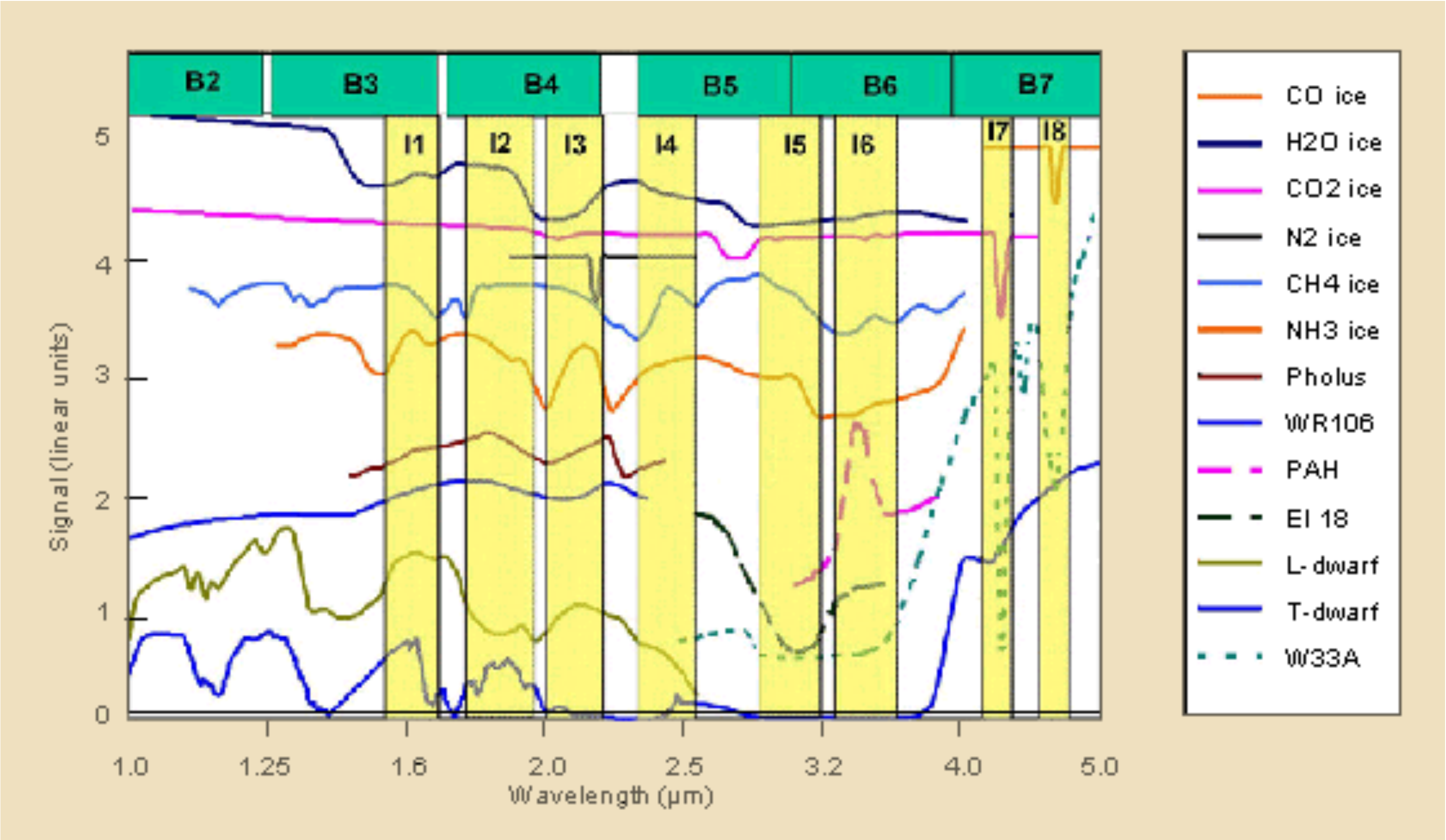


- Each module has two bands (0.6 microns to 2.3 microns and 2.4 microns to 5 microns)
  - ➢ Survey efficiency is increased by observing the same field at long and short wavelength simultaneously
- Short wavelength pixel scale is 0.032″/pix.
- Long wavelength pixel scale is 0.065″/pix.

JWST/NIRCam – A wide choice of filters

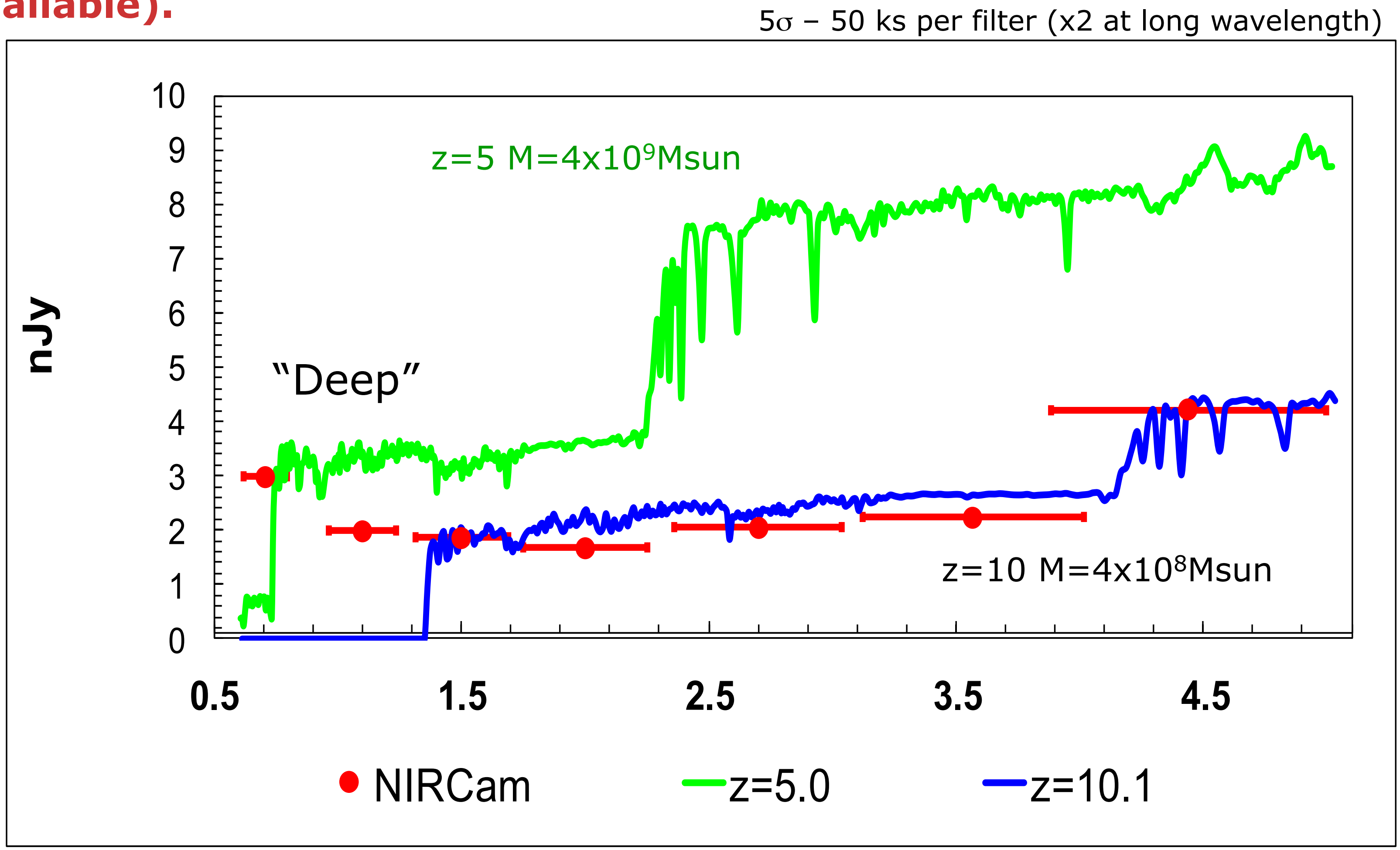


JWST/NIRCam – A wide and wise choice of filters



JWST/NIRCam – Sensitivity

NIRCam will have the high sensitivity necessary to study "first-light" objects (factor 10 to 100 better that what is currently available).



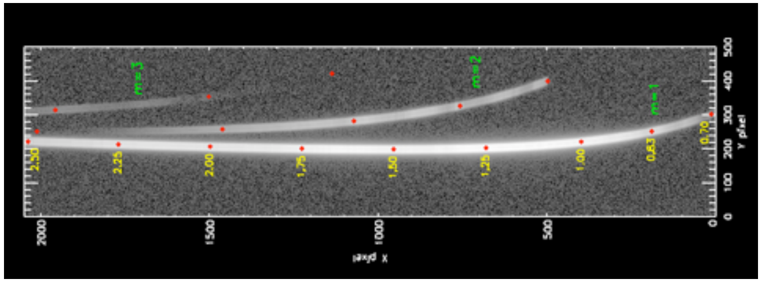
NIRCam has been designed to take advantage of JWST's large and cold primary mirror…

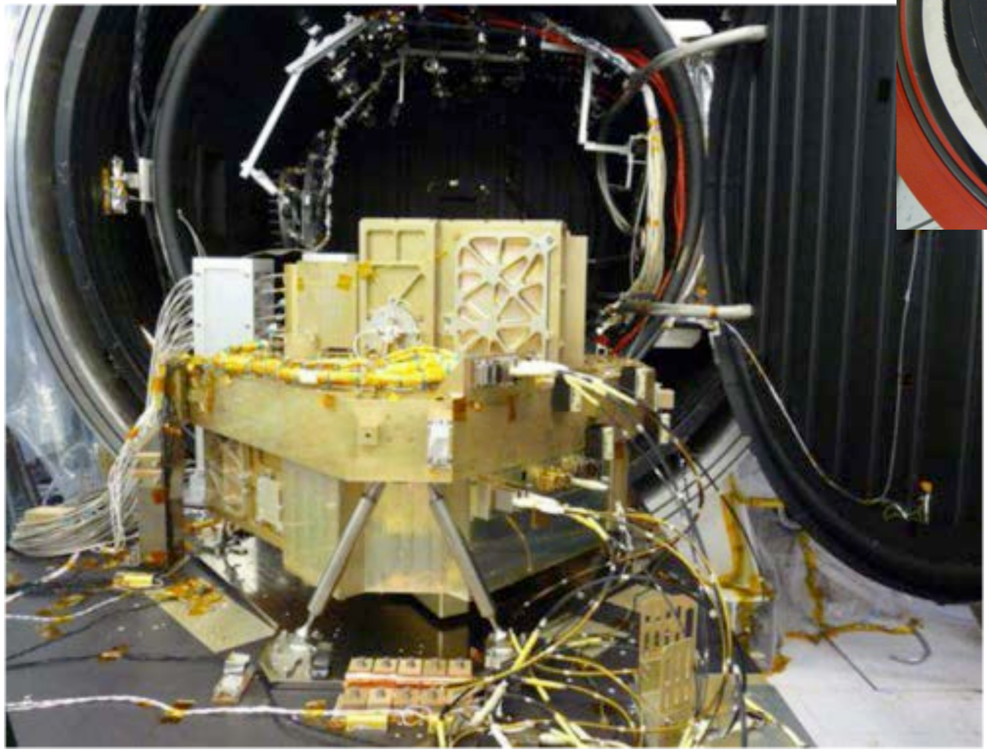
I just scratched the surface of NIRCam capabilities, more information on NIRCam is available at:

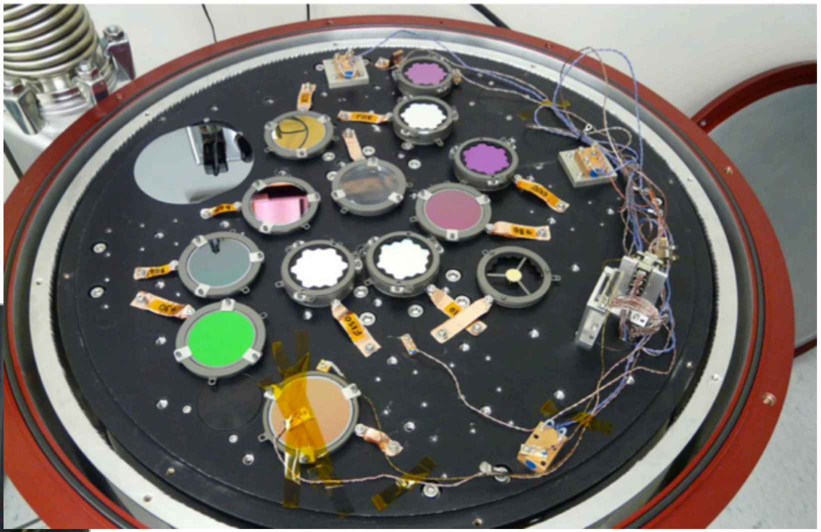
http://ircamera.as.arizona.edu/nircam/

http://www.stsci.edu/jwst/instruments/nircam/

JWST/NIRISS







This part of the presentation is heavily based on slides from C. Willot

JWST/NIRISS - Introduction

- **NIRISS = Near-infrared imager and slit-less spectrograph.**
  - Provided by the Canadian Space Agency (PI: René Doyon).
  - **Delivered to NASA (in July 2012).**
  - **Already installed in ISIM and recently been tested at cryogenic temperature!**
- **Will provide both imaging and spectroscopic capabilities**
  - Some unique capabilities complementary from those provided by NIRCam and NIRSpec.
  - In addition, provide some redundancy for some capabilities of NIRCam and NIRSpec.



JWST/NIRISS – Modes of observation

Observation Modes

Optical elements in the Pupil and Filter Wheel of NIRISS support 4 modes of observation:

Wide-Field Slitless Spectroscopy (WFSS), R~150; 1.0 – 2.5 microns; enabled by a matched pair of orthogonal grisms (G150H and G150V) in the Filter Wheel and a selection of blocking filters in the Pupil Wheel (F115W, F140M, F150W, F158M, F200W).

Single-Object Slitless Spectroscopy (SOSS), R~700; 0.6 – 2.5 microns; enabled by the grism G700XD, which generates 3 orders of cross-dispersed (XD) spectra for a target placed at a reference point in the FOV.

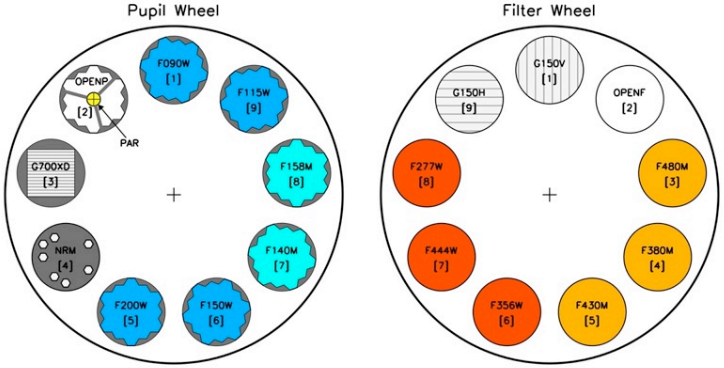
Aperture Mask Interferometry (AMI), 3.8 – 4.8 microns; enabled by the non-redundant mask (NRM) in the Pupil Wheel and medium-band filters (F380M, F430M, F480M) in the Filter Wheel. The mask consists of 7 "holes" (apertures), which produce an interferogram that samples 21 unique ("non-redundant") baselines.

Imaging, 0.9 – 5.0 microns; enabled by wide-band filters F090W, F115W, F150W, F200W in the Pupil Wheel and F277W, F356W, F444W in the Filter Wheel.

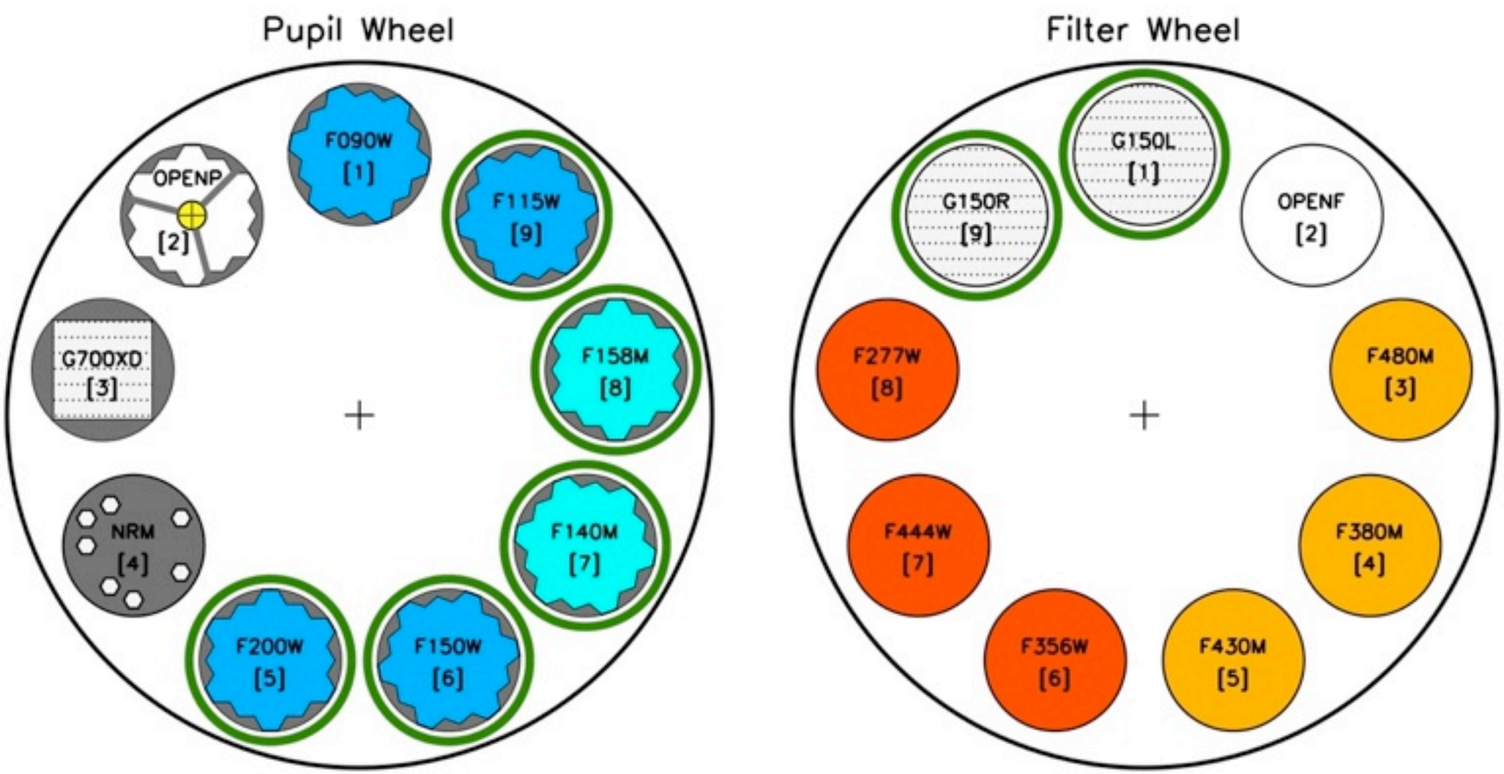
- **NIRISS can also be used as a backup for the FGS (fine guidance sensor).**
    - Note that the FGS and NIRISS are part of the same structure.

JWST/NIRISS - Design

- **Imaging / slit-less spectroscopy system with a single detector array.**
    - Wavelength coverage of 0.6 to 5 microns ("long wavelength" HgCdTe detector).
    - Sampling of approximately 0.065 arcsec per pixel (equivalent to the NIRCam sampling in its long wavelength channel).
    - Nyquist sampling at 4 microns. 2.2 arcmin field of view.
- **A dual-wheel is at the heart of NIRISS design.**
    - Pupil wheel carrying the various optical elements that can be combined to provide its imaging and slit-less spectroscopy capabilities.



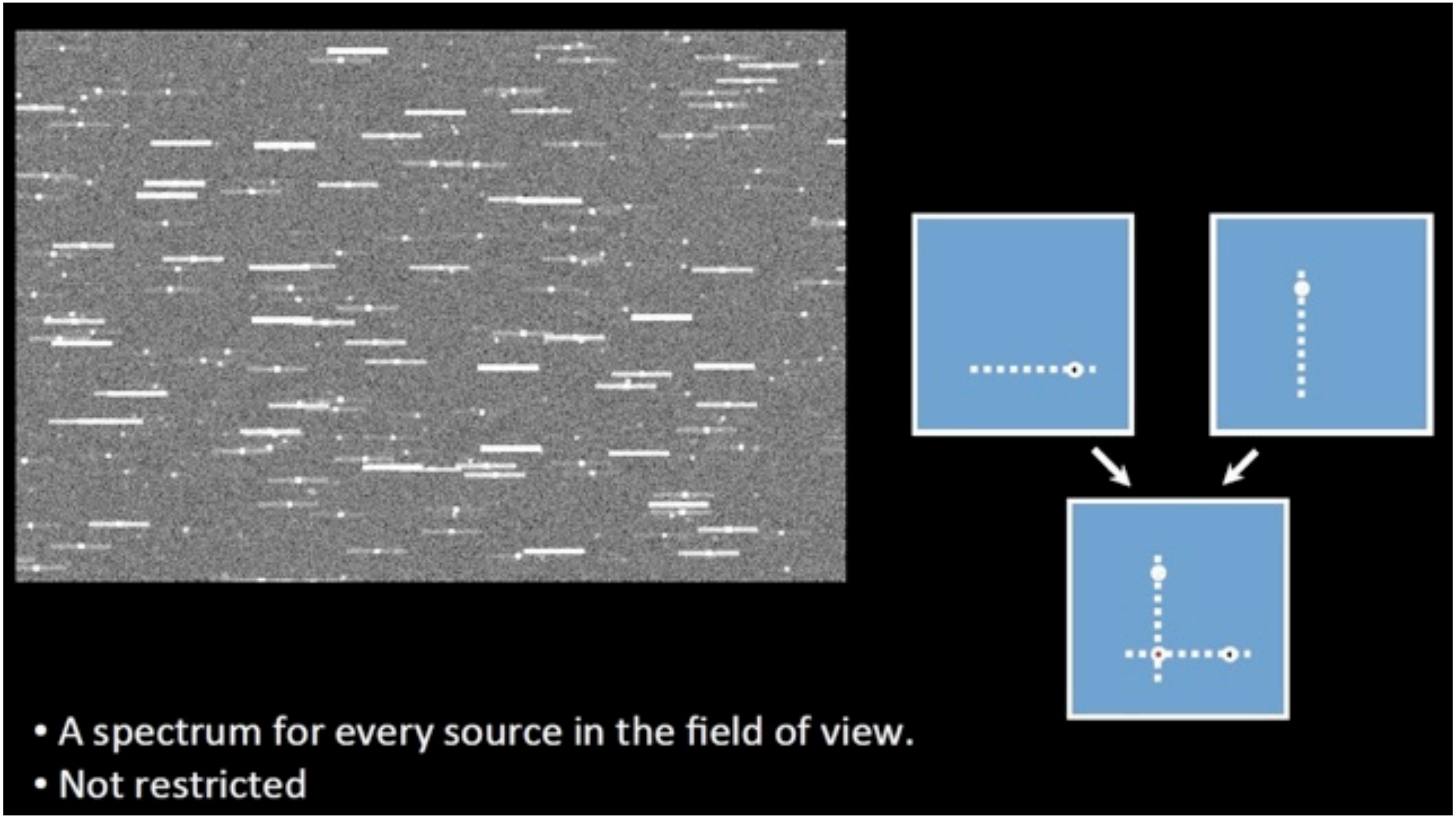
JWST/NIRISS – Wide-field slit-less spectroscopy



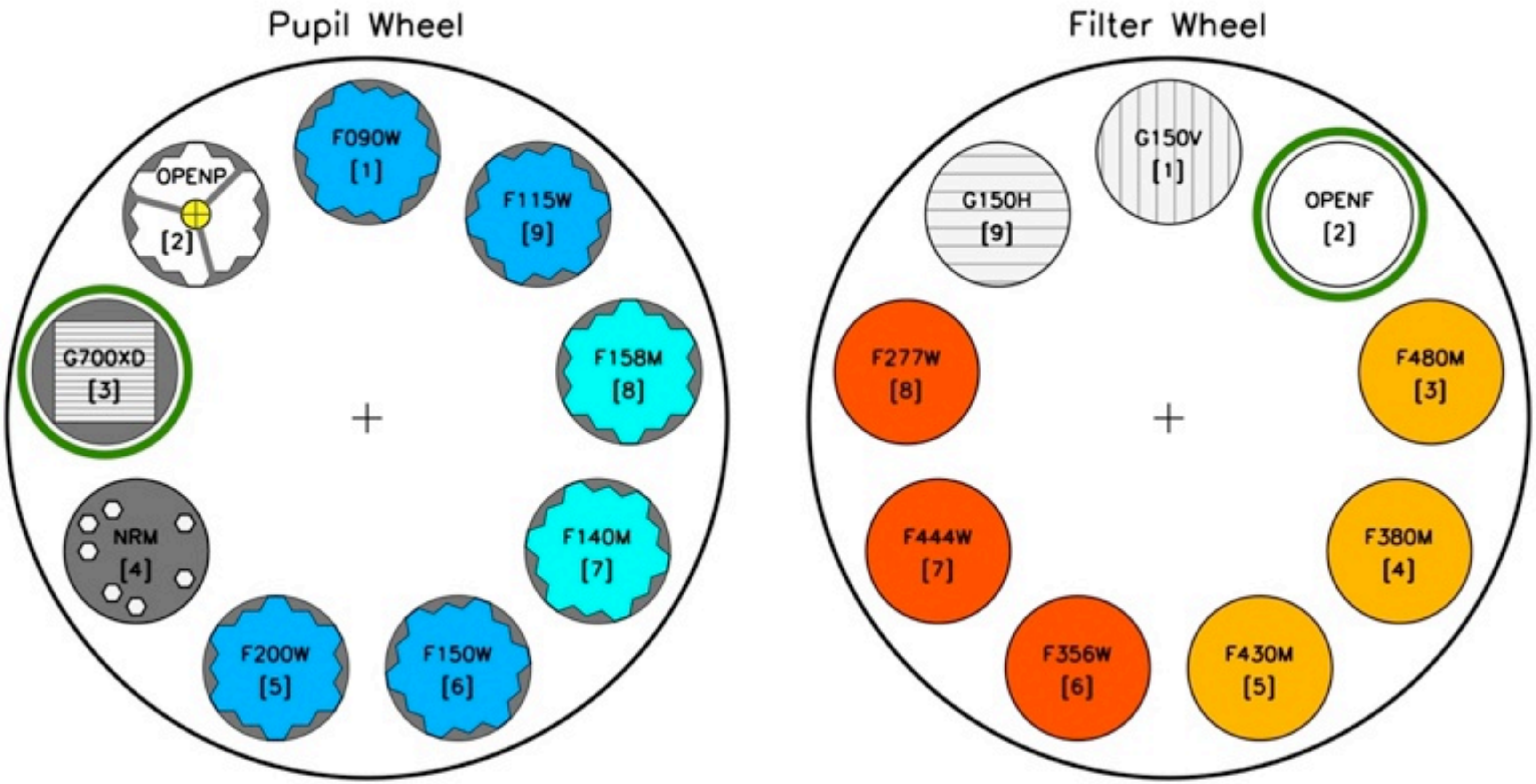
- **Two R~150 grisms mounted orthogonally and a set of filters.**
  - Short wavelength coverage.

JWST/NIRISS – Wide-field slit-less spectroscopy

- **Some similarities with the very popular HST WFC3 IR slit-less mode (but behind JWST and going further in wavelength…)**



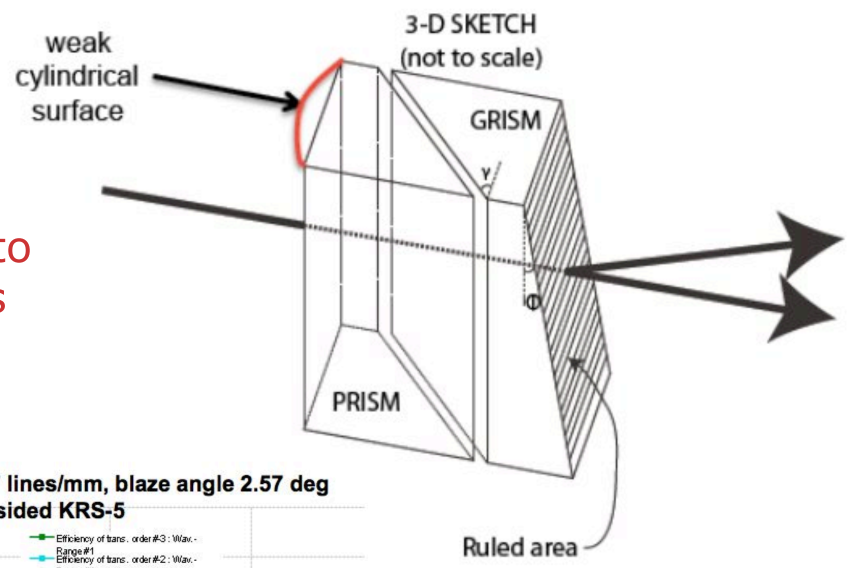
JWST/NIRISS – Single-object slit-less spectroscopy

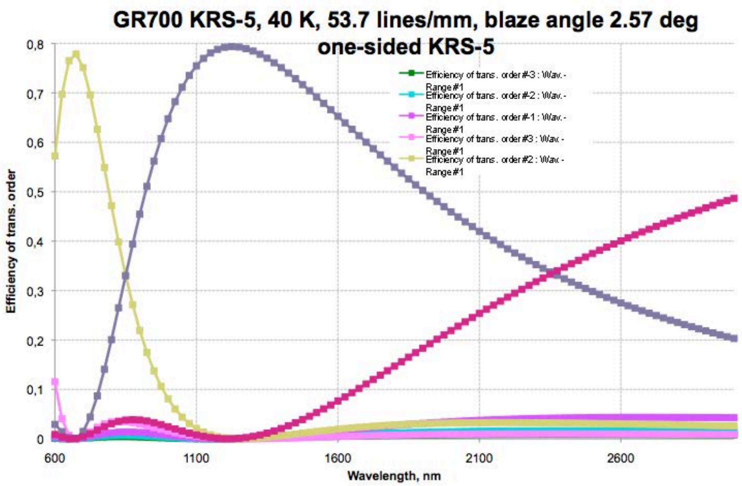


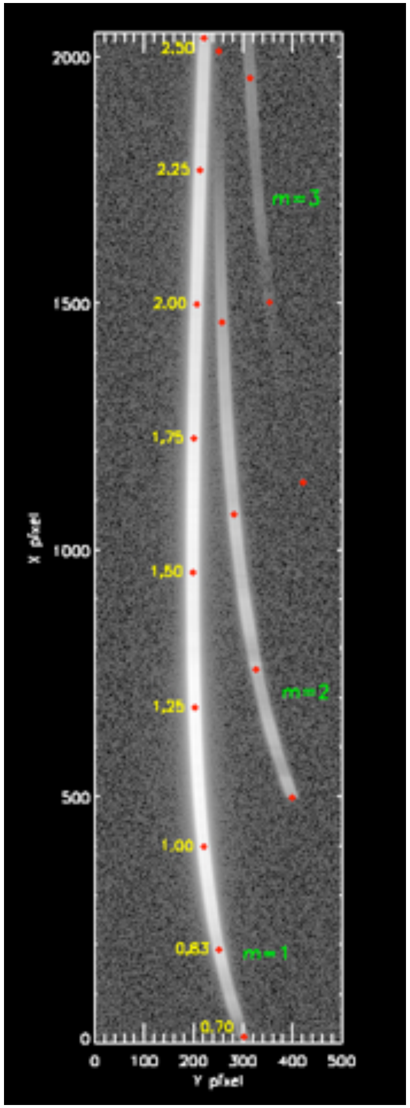
- **Higher-dispersion grism without any filter in front providing a 1-2.5 micron coverage at resolutions of ~700.**

JWST/NIRISS – Single-object slit-less spectroscopy

Weak lens defocuses along spatial direction to allow more pixels to sample spectrum

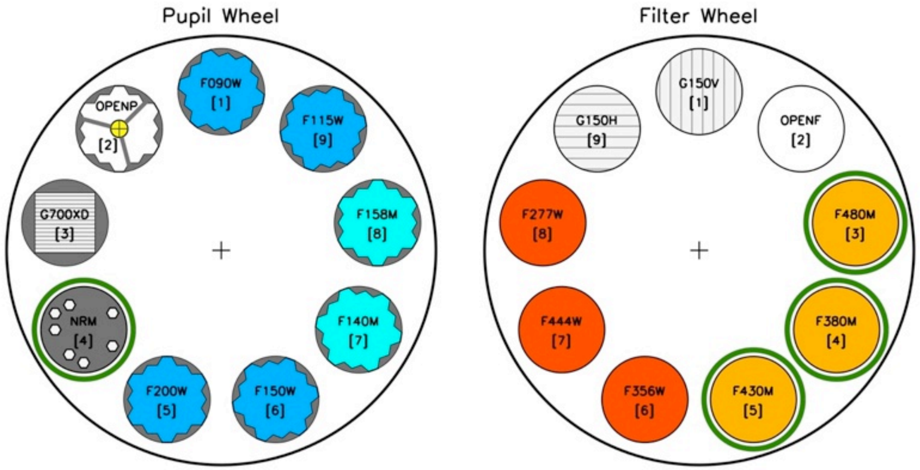


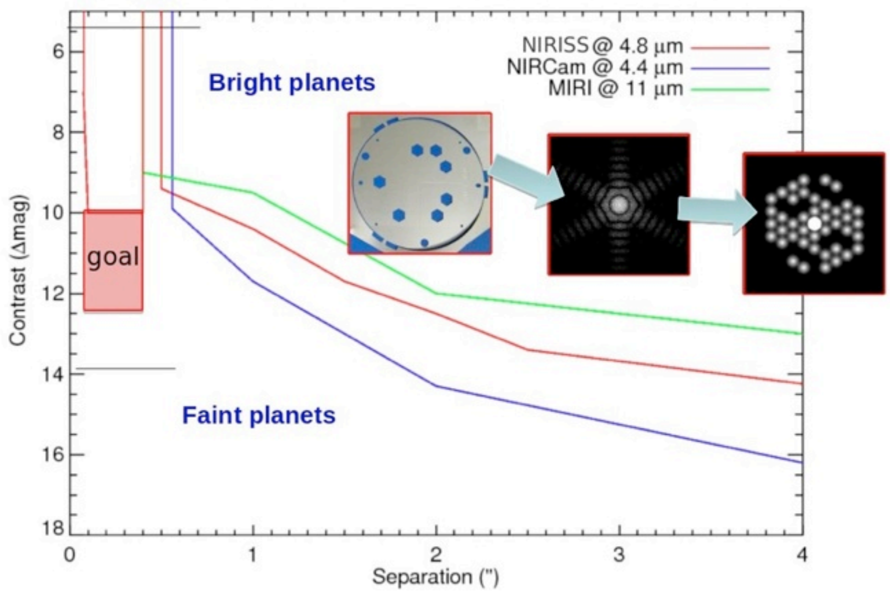




- **Specially designed for exoplanet transit spectroscopy.**

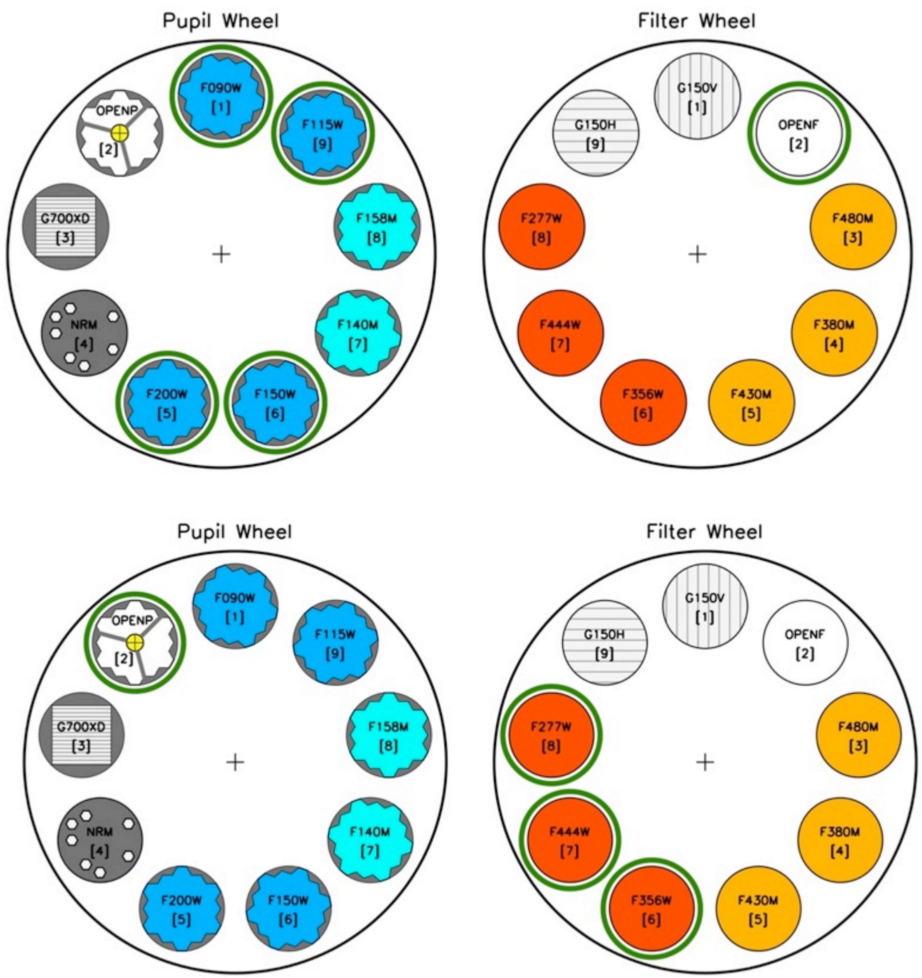
JWST/NIRISS – Aperture mask interferometry





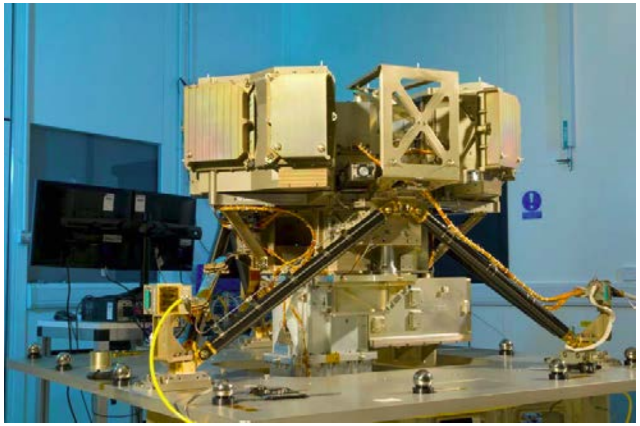
- **Specially designed for high-contrast observations around bright sources.**

JWST/NIRISS – and, of course, broad-band imaging



- **Short and long wavelength broad-band imaging over a 2.2 arcmin x 2.2 arcmin field of view.**
- **Same "wide" filters than NIRCam.**

JWST/MIRI



This part of the presentation is heavily based on slides prepared by the MIRI team for the MIRI acceptance review.

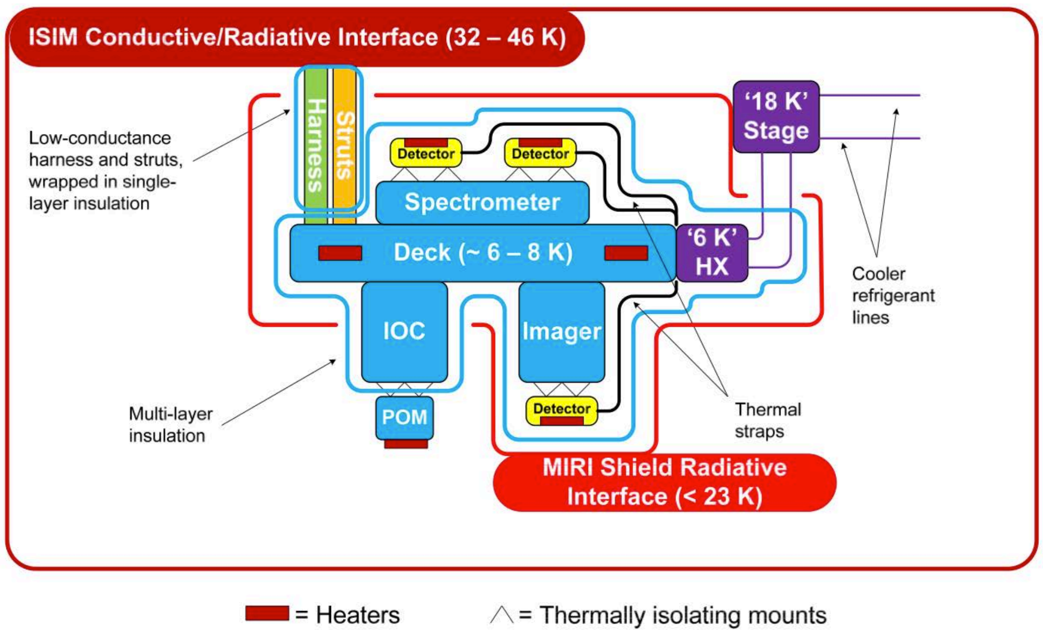
JWST/MIRI - Introduction

- **MIRI = Mid-InfraRed Instrument**
  - 50/50 partnership between a nationally funded consortium of European institutes (known as MIRI EC) under the auspices of ESA and NASA/JPL.
  - PIs: G. Wright and G. Rieke
  - **Delivered to NASA (in May 2012).**
  - **Already installed in ISIM!**
- **Will provide imaging, spectroscopic and coronagraphic capabilities from 5 to 27-28 microns.**
  - Unique capabilities within the JWST instrument suite.



JWST/MIRI – Overview – Main elements

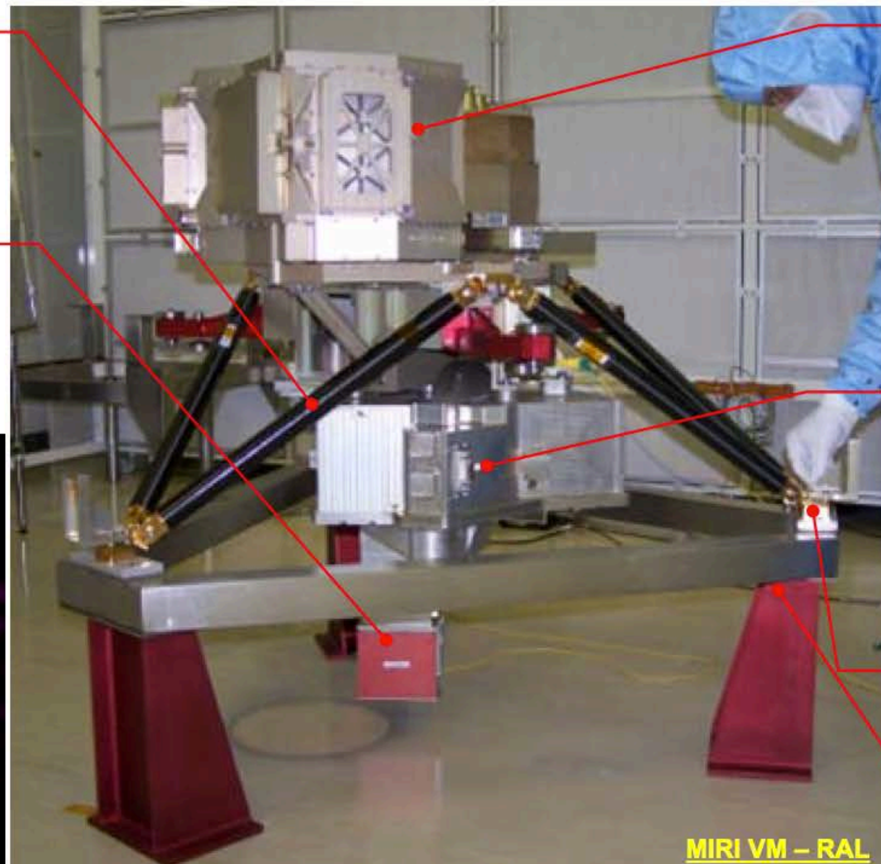
- **MIRI instrument consists in of two main elements**
    - The MIRI optical system delivered by the MIRI EC including the detector systems provided by JPL.
    - The MIRI cryo-cooler system to be delivered by JPL.
- **MIRI is actively cooled down to 7K.**
    - In the passively cooled 40K JWST environment.



JWST/MIRI – Overview – Optical system

A carbon fibre truss isolates 7 K MIRI optics from the 40 K telescope

Light enters from the JWST telescope

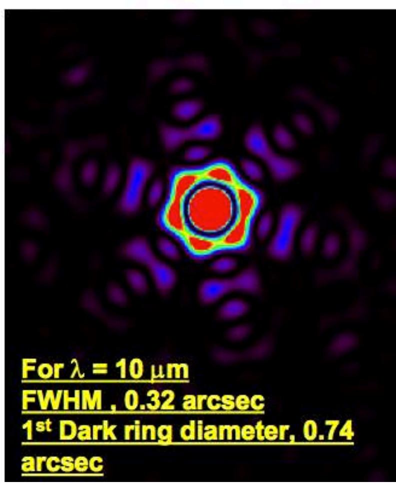


A 10 x 10 arcsec field passes through the deck into the R ~ 3000,
4 channel integral field spectrometer
2 detectors
2 channels per detector

A 115 x 115 arcsec region of the focal plane is directed into the imager
10 bandpass filters
4 coronagraphs
R ~ 100

Interface to ISIM

GSE



JWST/MIRI – Overview – Examples of links to the JWST's main science themes

- **The mass assembly of galaxies**
    - Detection of bright high redshift sources (lensed or not-lensed, QSOs…)

    ➔ Imaging deep fields.

    - Mass and morphology of the older stellar population.

    ➔ Deep images in the 6-8 micron domain provide direct measurement of the rest-frame red/near-IR light of z=6-10 galaxies.

    - Role of starbursts and AGNs in galaxy evolution.

    ➔ Deep, near-IR rest frame integral field spectroscopy of intermediate redshift galaxies.

JWST/MIRI – Overview – Examples of links to the JWST's main science themes

- **Exo-planet characterisation**
  - Study of the spectrum of exo-planets in the mid-infrared domain.

  ➔ Transit spectroscopy (not planet hunting).

  - Direct imaging (e.g. beta-Pictoris)

  ➔ Coronagraphy

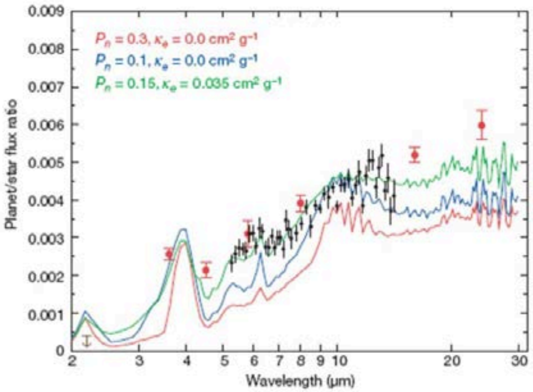
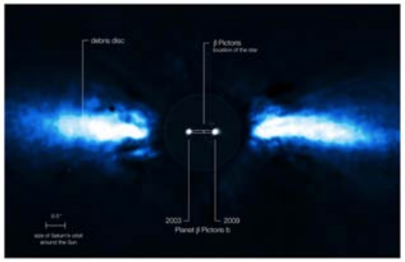


Figure 3 **Comparison of spectral observations with broadband photometry and theoretical models of the dayside atmosphere of HD 189733b.** The black points show the mean planet/star flux ratios for six second-order spectra (5–8 μm) and four first-order spectra (7.5–14 μm). The data have been binned by a factor of four after light-curve fitting (corresponding to two IRS resolution elements), and the plotted uncertainties reflect the standard error in the mean in each wavelength bin. The filled red circles show broadband measurements from ref. 5 at 3.6, 4.5, 5.8, 8.0, 16 and 24 μm (error bars on this data, s.e.). The upper limit at 2.2 μm is derived from Keck spectroscopy[16]. The red, blue and green traces are atmospheric model predictions for three values of a dayside–nightside heat redistribution parameter, P_n, and two values of the extra upper-atmosphere opacity, κ_e. The model predictions have not been scaled in any way.

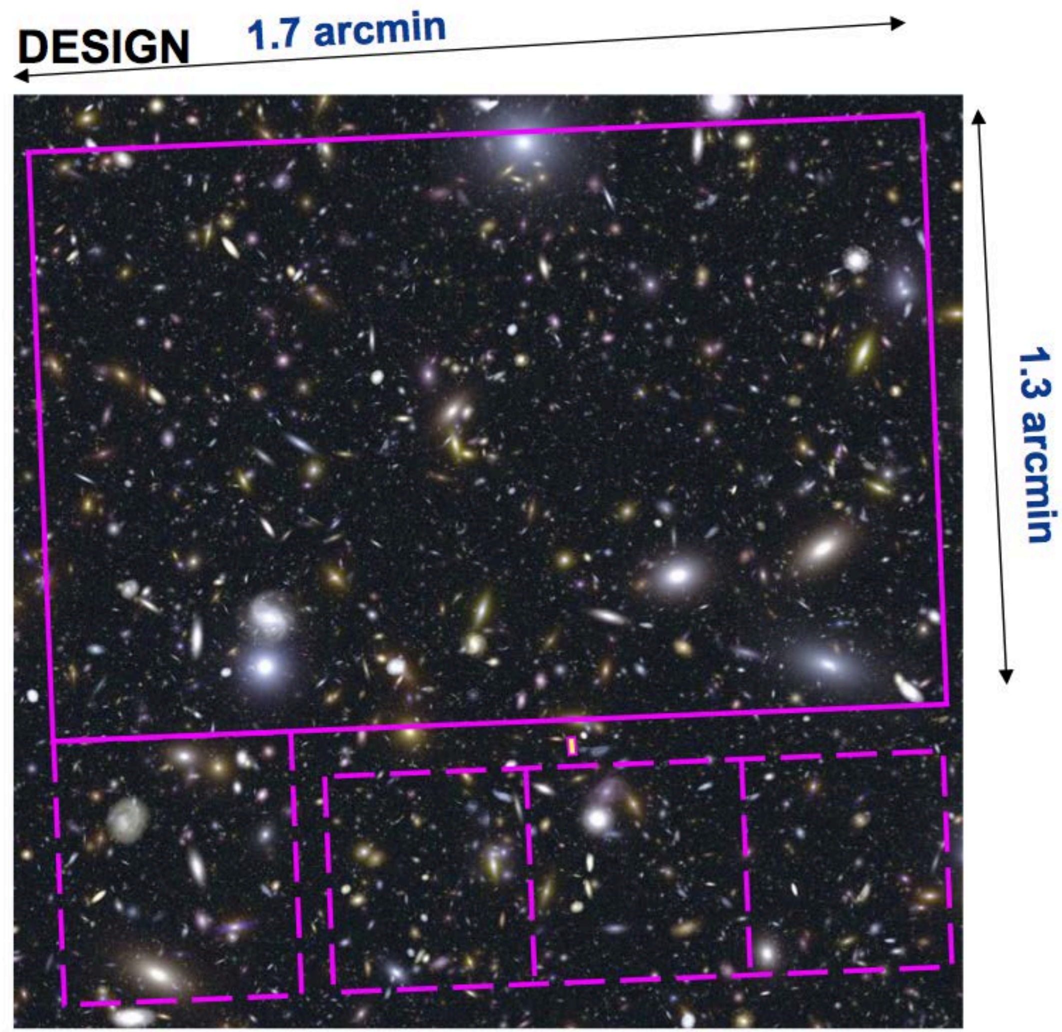
From Grillmair et al., Nature 2008.



Combination of two images taken in 2003 and 2009 with the NACO (ESO-VLT) coronagraph, showing the movement of an exoplanet around the β-Pic star (Lagrange et al. 2010).

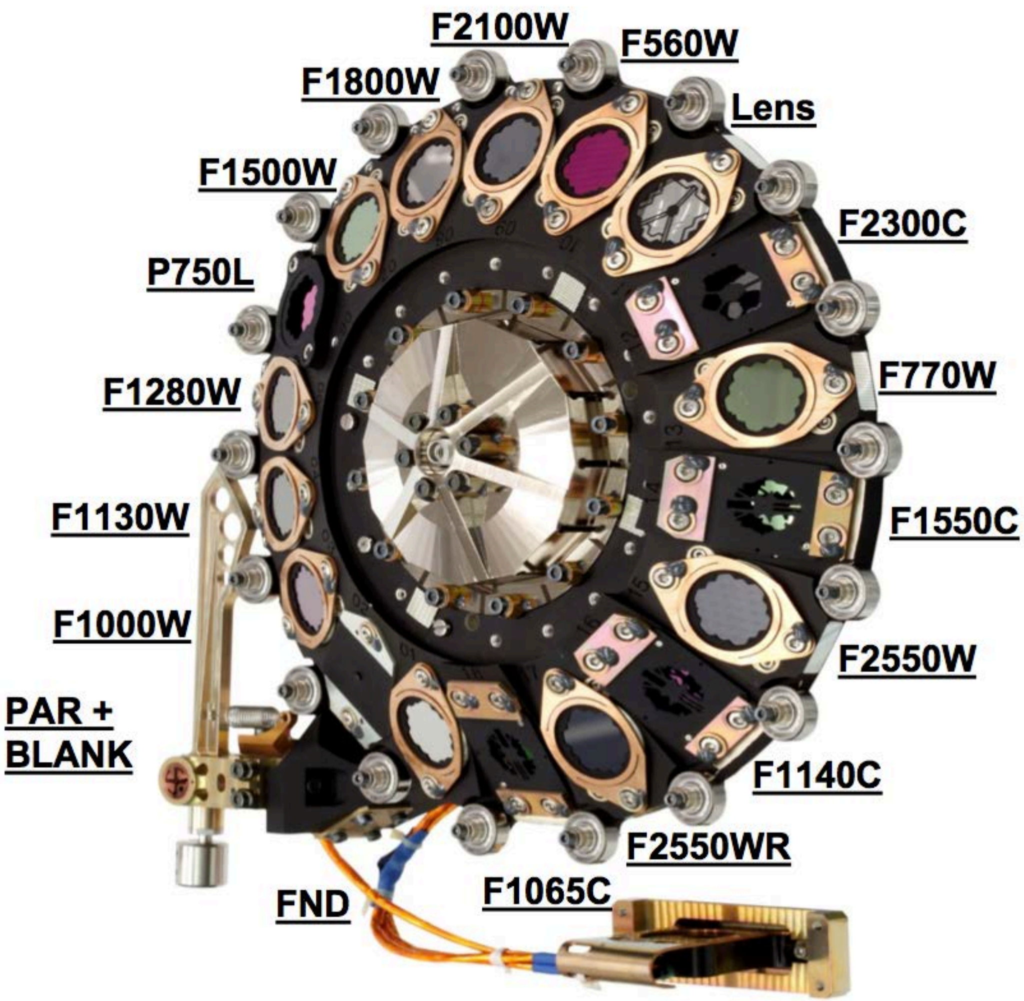
JWST/MIRI – Capabilities - Imager

- **Sampling of 0.11 arcsec per pixel.**
- **Diffraction limited long ward of 5.6 microns.**
- **Additional capabilities:**
  - Coronagraphy
  - Single object R=100 spectroscopy.



Simulated NIR JWST field (Myungshin Im 1998)

JWST/MIRI – Capabilities – Imager



Filter name (and wavelength)	Pass band $\Delta\lambda$ (μm)	Function
F560W	1.2	Imaging
F770W	2.2	
F1000W	2.0	
F1130W	0.7	
F1280W	2.4	
F1500W	3.0	
F1800W	3.0	
F2100W	5.0	
F2550W	4.0	
F2550WR	4.0	
P750L	5	R ~ 100 Spectroscopy
F1065C	0.53	Coronagraphy
F1140C	0.57	
F1550C	0.78	
F2300C	4.6	
FND	10	Target Acquisition
FLENS	N/A	Alignment
PAR+BLANK	N/A	Calibration

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JWST/MIRI – Capabilities – IFU spectroscopy

- **Medium resolution IFU spectroscopy**

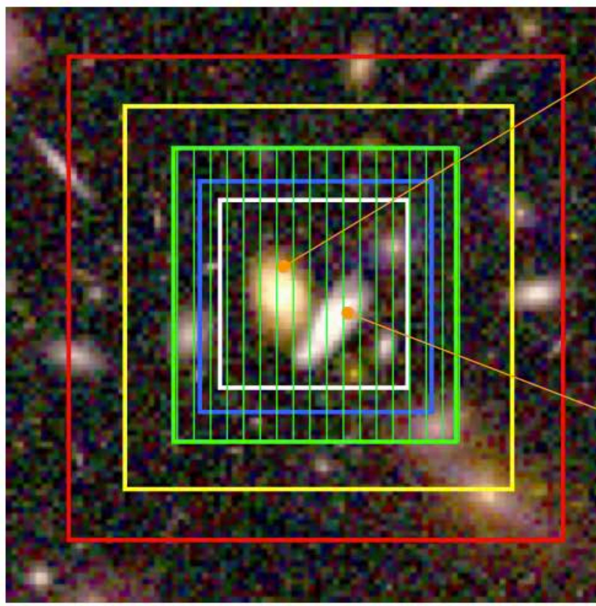
Channel 1
(4.9 - 7.7 µm)

Channel 2
(7.4 - 11.8 µm)

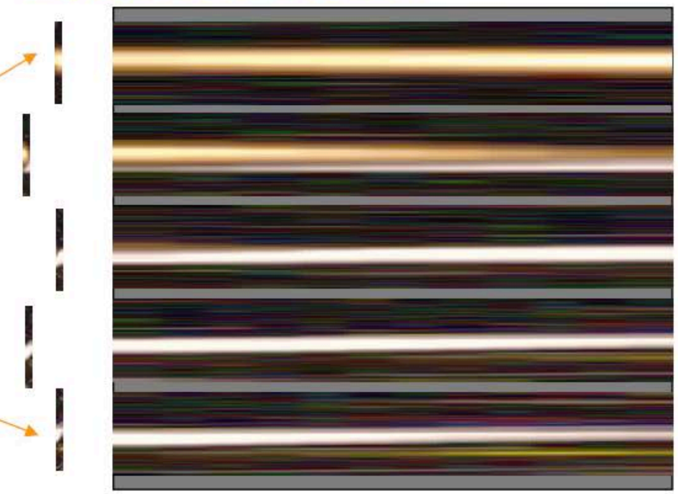
Channel 3
(11.4 - 18.2 µm)

Channel 4
(17.5 - 28.8 µm)

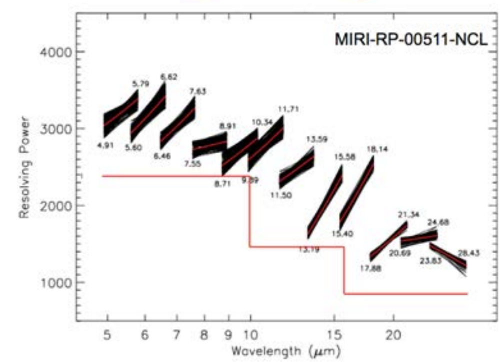
10 arcseconds



Each channel's field of view is sliced, dispersed and detected.

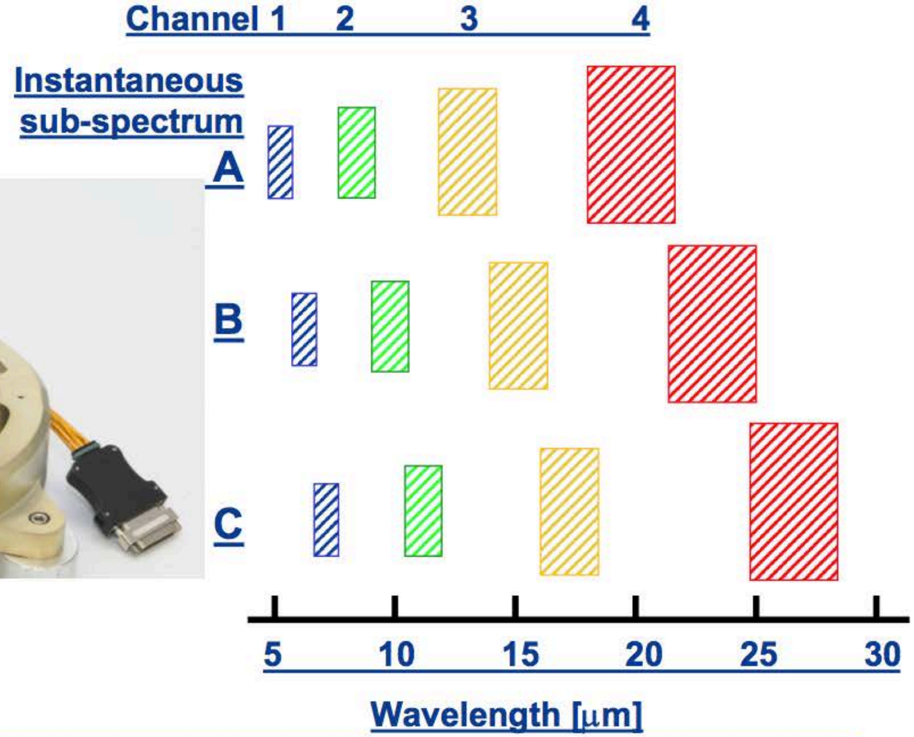


Wavelength/Velocity



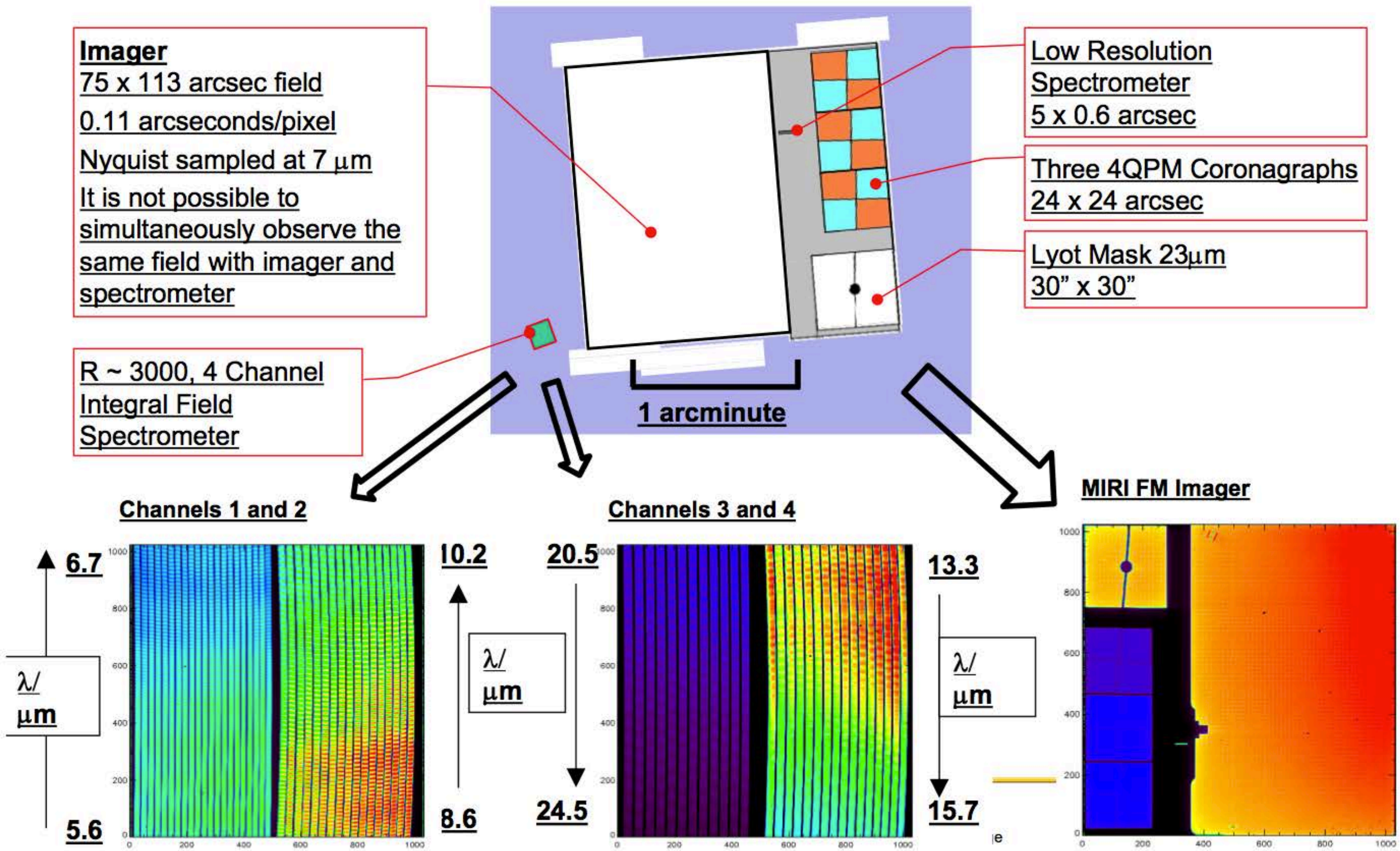
JWST/MIRI – Capabilities – IFU spectroscopy

- 3 mechanism selected sub-spectra per channel with dedicated dichroic and gratings

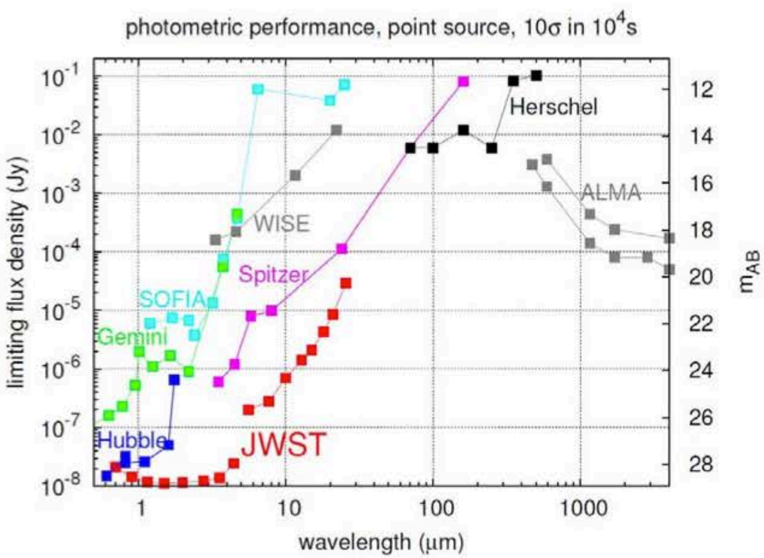


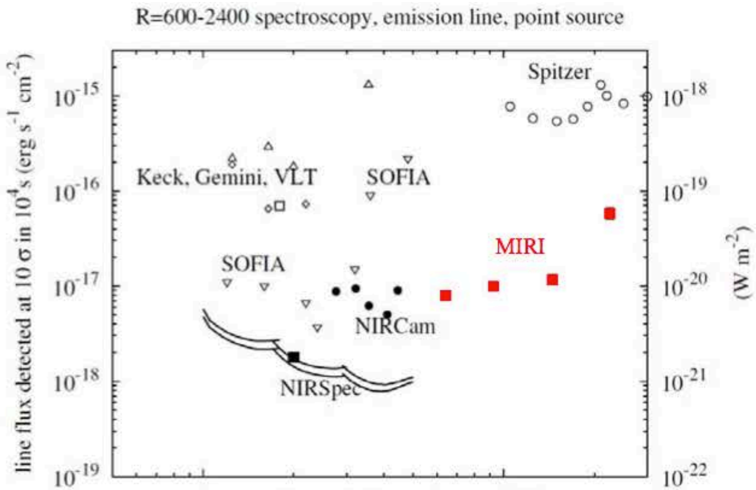
JWST/MIRI – An optimal use of the detector real estate…

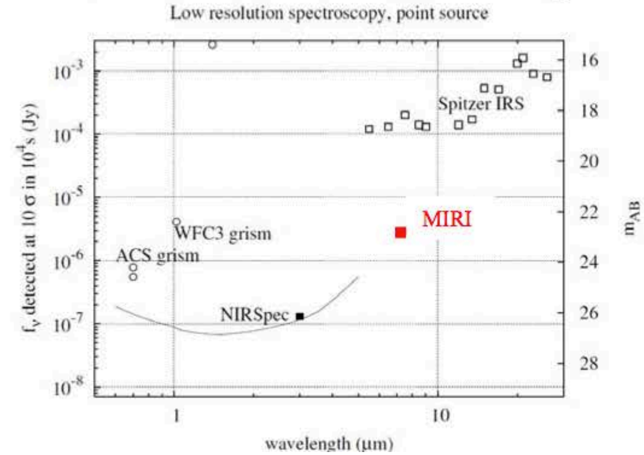
- **Three 1kx1k Si:As detectors (with Spitzer heritage) provided by JPL.**



JWST/MIRI – Sensitivity requirements







- **MIRI provides a huge increase in observational capabilities compared to current and future facilities**
  - Orders of magnitude in sensitivity & resolution
  - many of the most important results likely to be unexpected discoveries."

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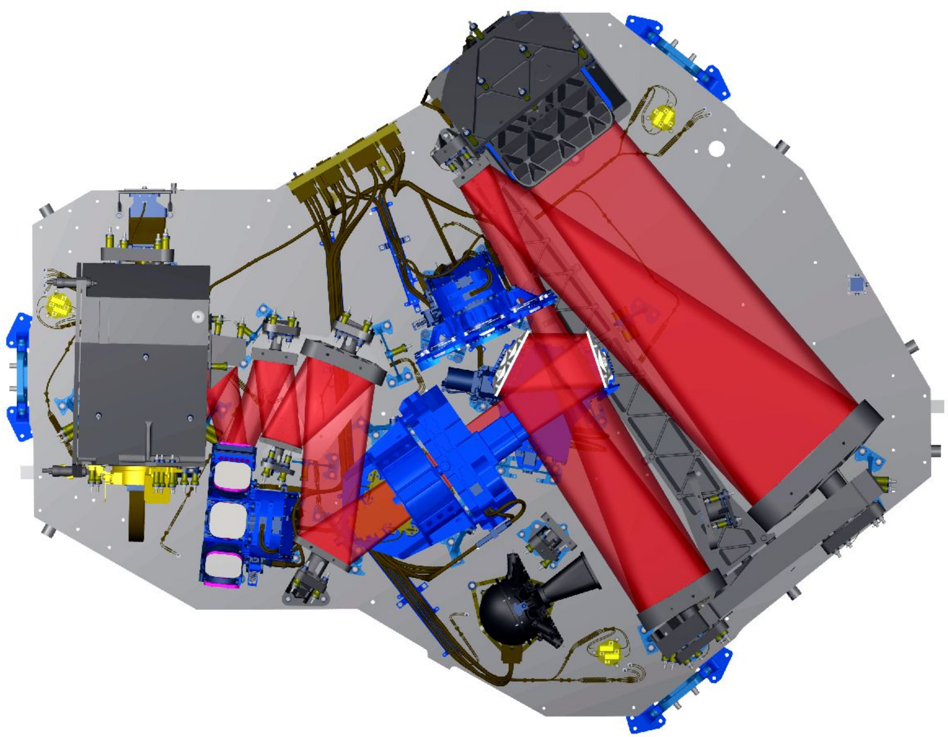
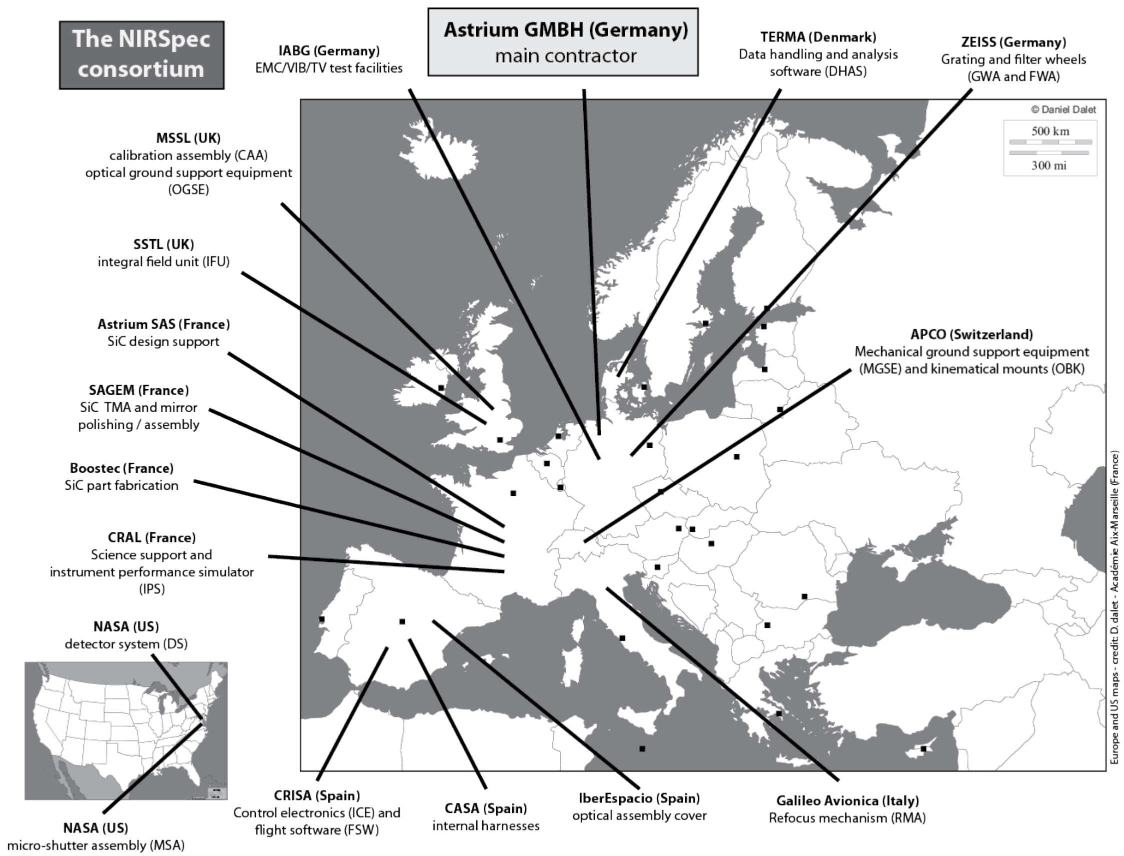
JWST/NIRSpec - Introduction

- **NIRSpec provides some of the JWST's main near-infrared spectroscopic capabilities in the 0.6-5 micron range.**
  - Part of the ESA contribution to the JWST mission.
- **Delivered! Arrived at NASA last week!**



JWST/NIRSpec - Introduction

- **Built for ESA by an industrial consortium led by EADS Astrium GMBH.**
- **NASA-provided detectors and micro-shutter arrays.**

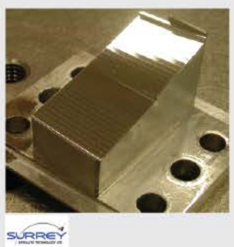
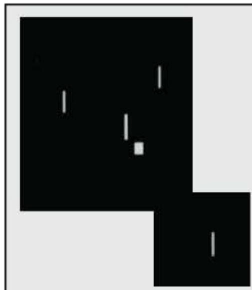


JWST/NIRSpec – Overview
From JWST's science goals to an instrument…

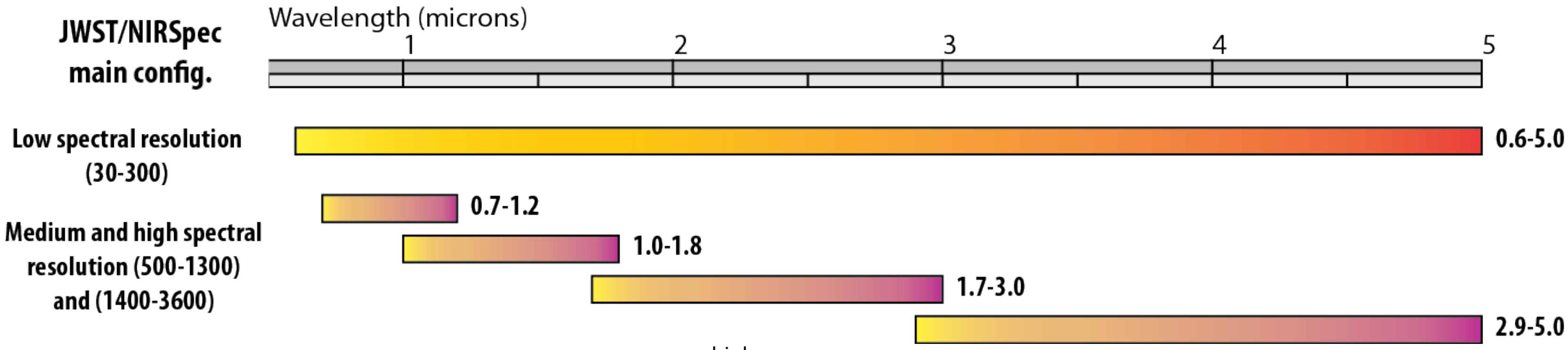
- **To achieve JWST science goals a near-infrared spectrograph was needed in the instrument suite. It should be capable of:**
  - **Deep multi-object spectroscopy** at low, medium (around 1000) resolution over a "wide" field of view.
  - **Spatially-resolved, single-object spectroscopy** at "high" (a few thousands) spectral resolution over a "small" (a few arc seconds) field of view.
  - **High-contrast slit spectroscopy** at various spectral resolutions, including an aperture for extra-solar planet transit observations.

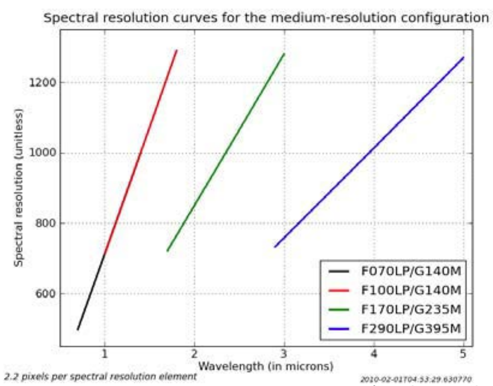
JWST/NIRSpec – Overview
From JWST's science goals to an instrument…

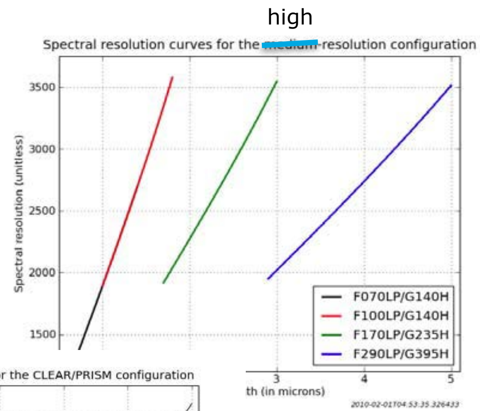
JWST/NIRSpec

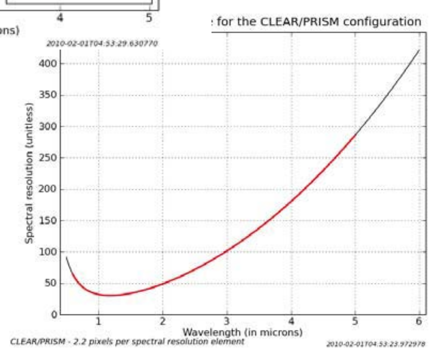
MOS		**Multi-object spectroscopy with 0.2"-wide mini-slits.**	- 9 square arcmin. field of view - Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure. - Medium spectral resolution (500 to 1300), grating-based mode covering the 0.7-5.0 range
IFU		**IFU spectroscopy with a 0.1" sampling.** (IFU made of 30 slices for a total of 900 "spaxels")	- 3"x3" field of view - Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure. - Medium (500 to 1300) and high (1400-3600) spectral resolution modes, covering the 0.7-5.0 range in 4 exposures. - IFU and MOS cannot be used at the same time.
SLIT		**High-contrast slit spectroscopy.** (including with a 1.6"x1.6" square aperture for extra-solar planet transit observation)	- 5 slits available All spectral resolution modes available. - SLIT can be used simultaneously to IFU or MOS.

JWST/NIRSpec – Overview
Main spectroscopic configurations

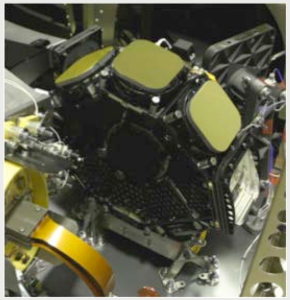








Configurations that can be obtained thanks to a combination of filters and dispersers installed on two wheels (FWA and GWA)



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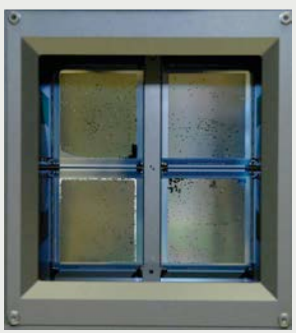
JWST/NIRSpec - Multi-object spectroscopy

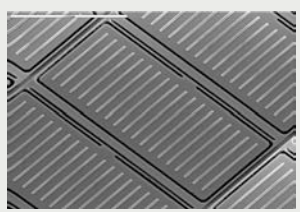
- **The challenge of multi-object spectroscopy**
  - Letting the light from selected objects (> 100) go through while blocking the light from all the other objects.
  - A configurable mask was needed.

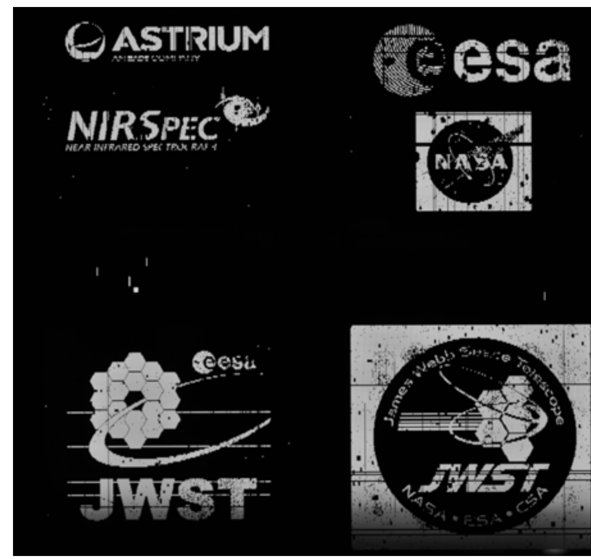
Using 4 arrays of 365x171 micro-shutters each, provided by NASA GSFC.

This gives us a total of almost **250 000** small apertures that can be individually opened/ closed



MEMS device – 105x206 micron shutters





> 90 % of the shutters are operable.

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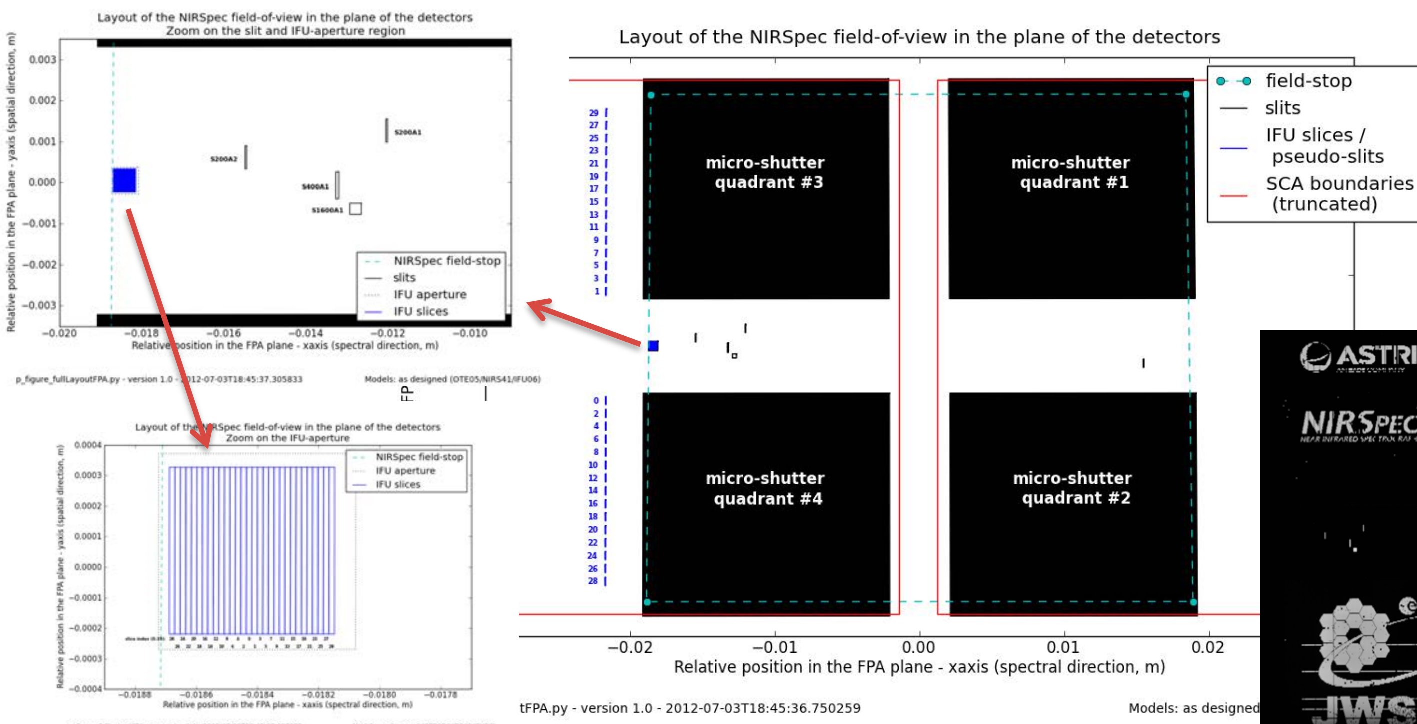
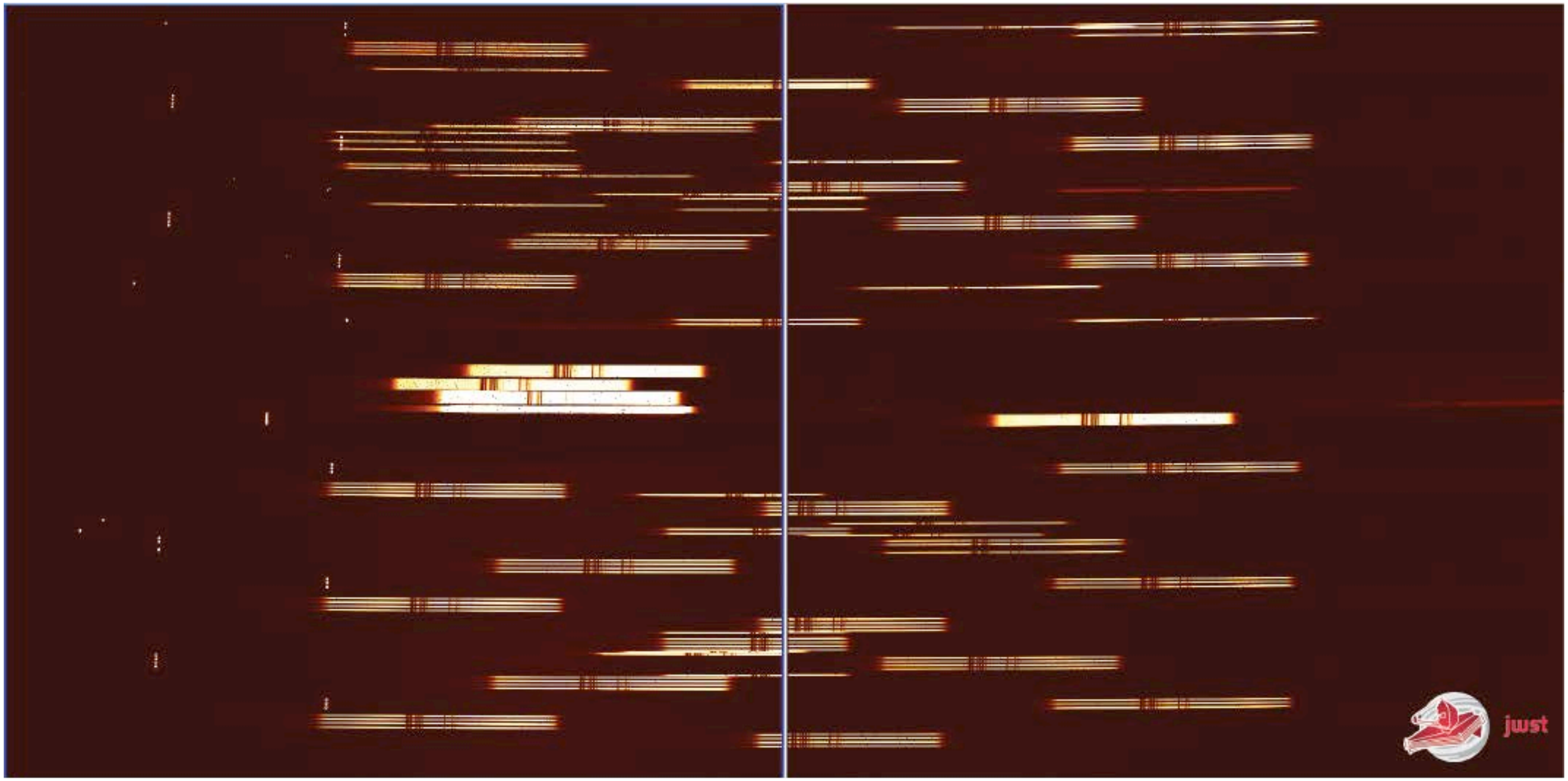
- **A complex field-of view layout**
  - Using the magnet arm of the micro-shutter array to block/ unblock the entrance of the IFU and select between the MOS and IFU modes.
  - A specific area is dedicated to the SLIT mode.

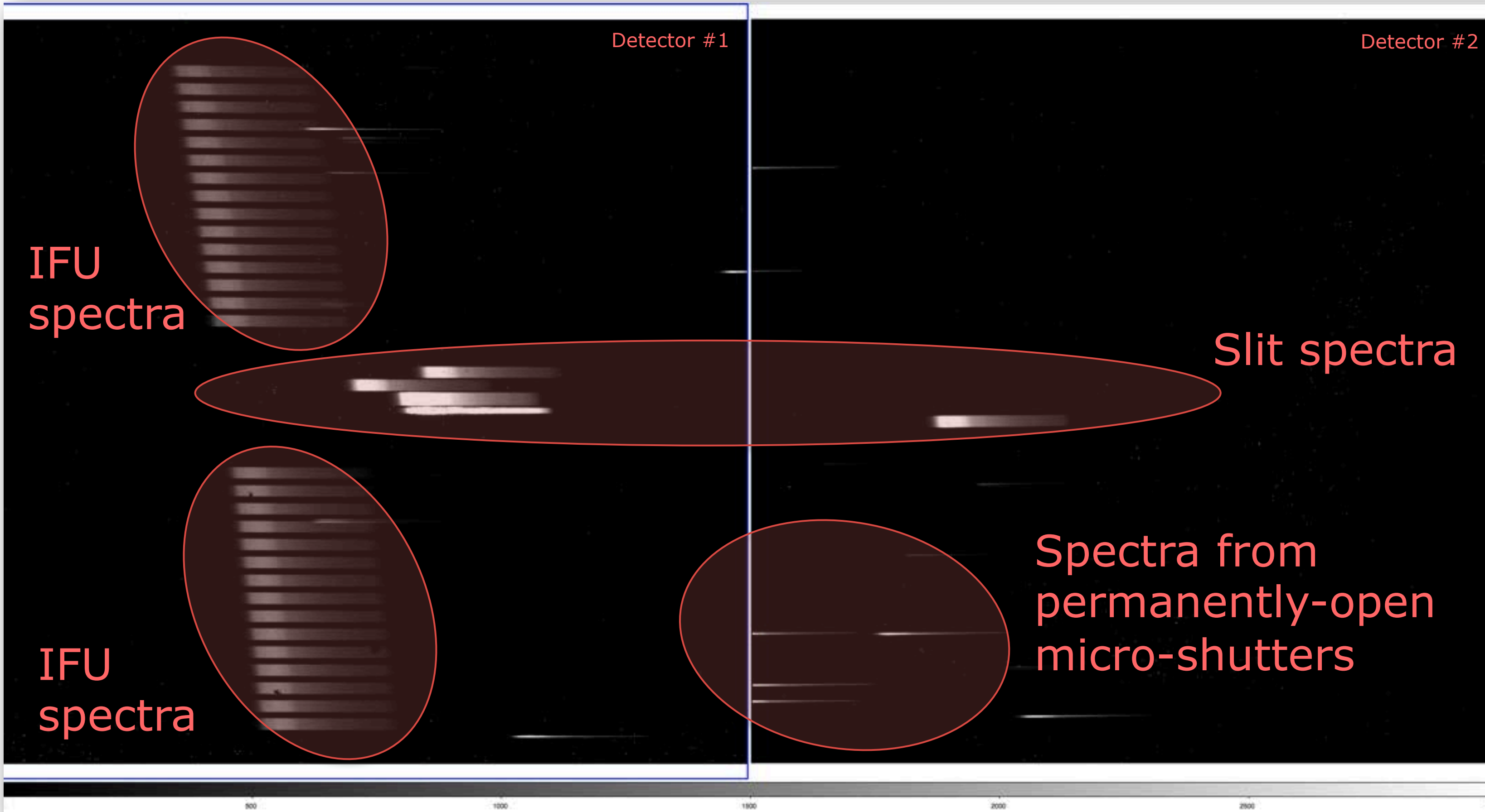


JWST/NIRSpec – What does it look like on the detectors?



JWST/NIRSpec - FM2 cyrogenic test campaign 01/2013

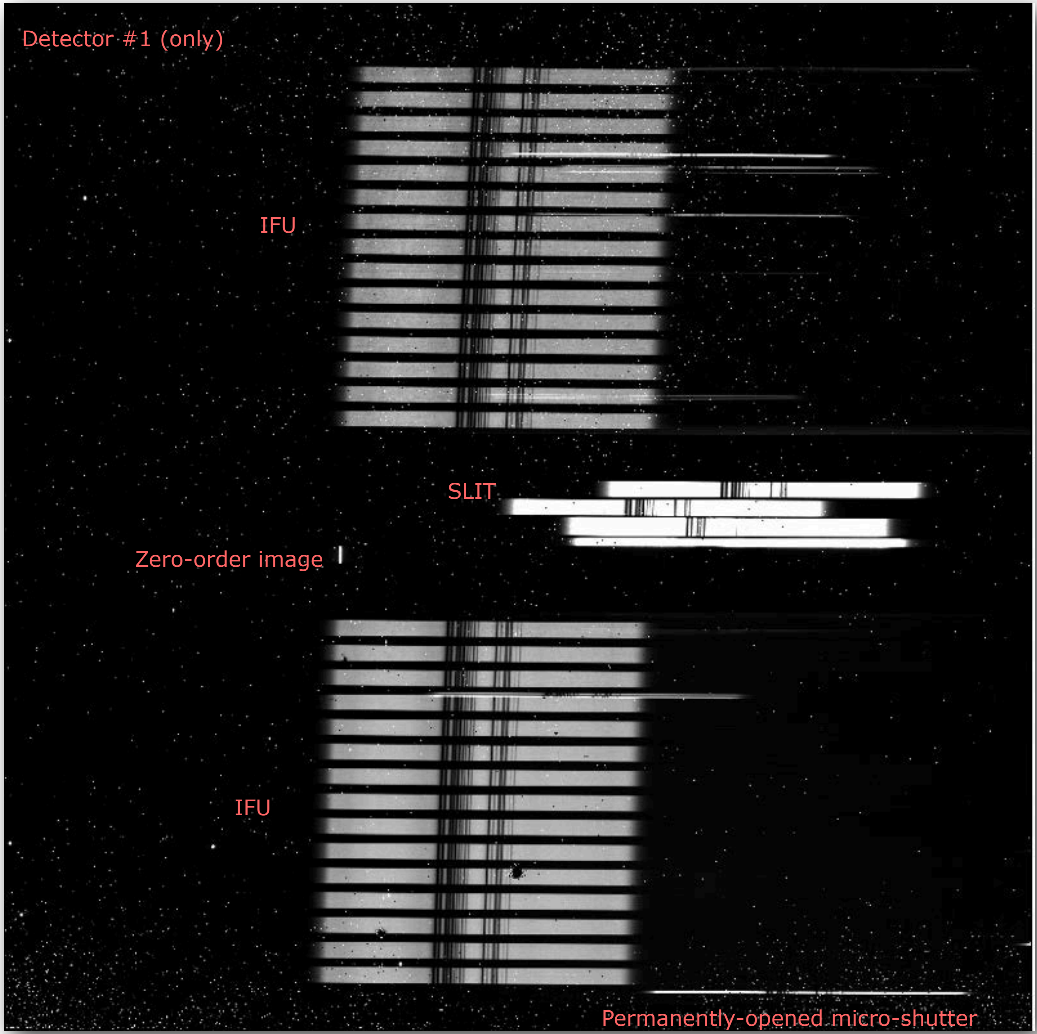
JWST/NIRSpec – What does it look like on the detectors?



Short continuum spectra obtained with the prism during cryogenic testing in 2011. IFU and SLIT modes.

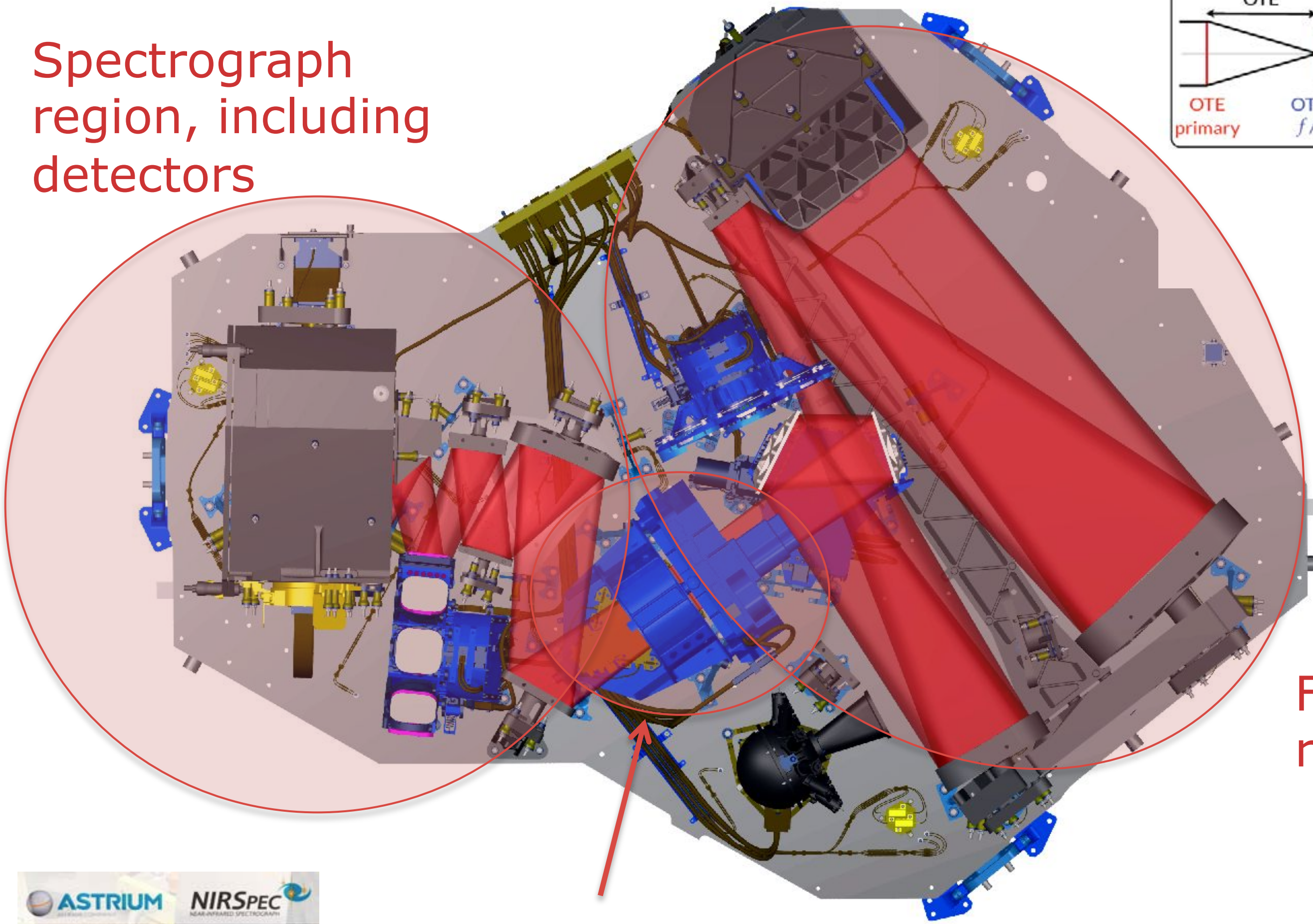
JWST/NIRSpec – What does it look like on the detectors?

Medium resolution (R=700-1300) spectra of a continuum source with absorption features obtained with the IFU during cryogenic testing in 2011.



JWST/NIRSpec – A short look at the design / hardware

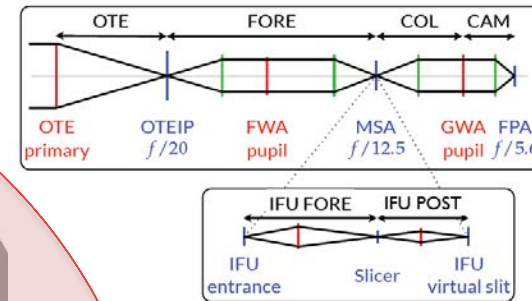
Spectrograph region, including detectors



Fore-optics region

MSA, IFU and slits

Figure credit: B. Dorner, PhD, 2012



Size: ~ 1.9 m x 1.3 m x 0.7 m
Mass: < 220 kg

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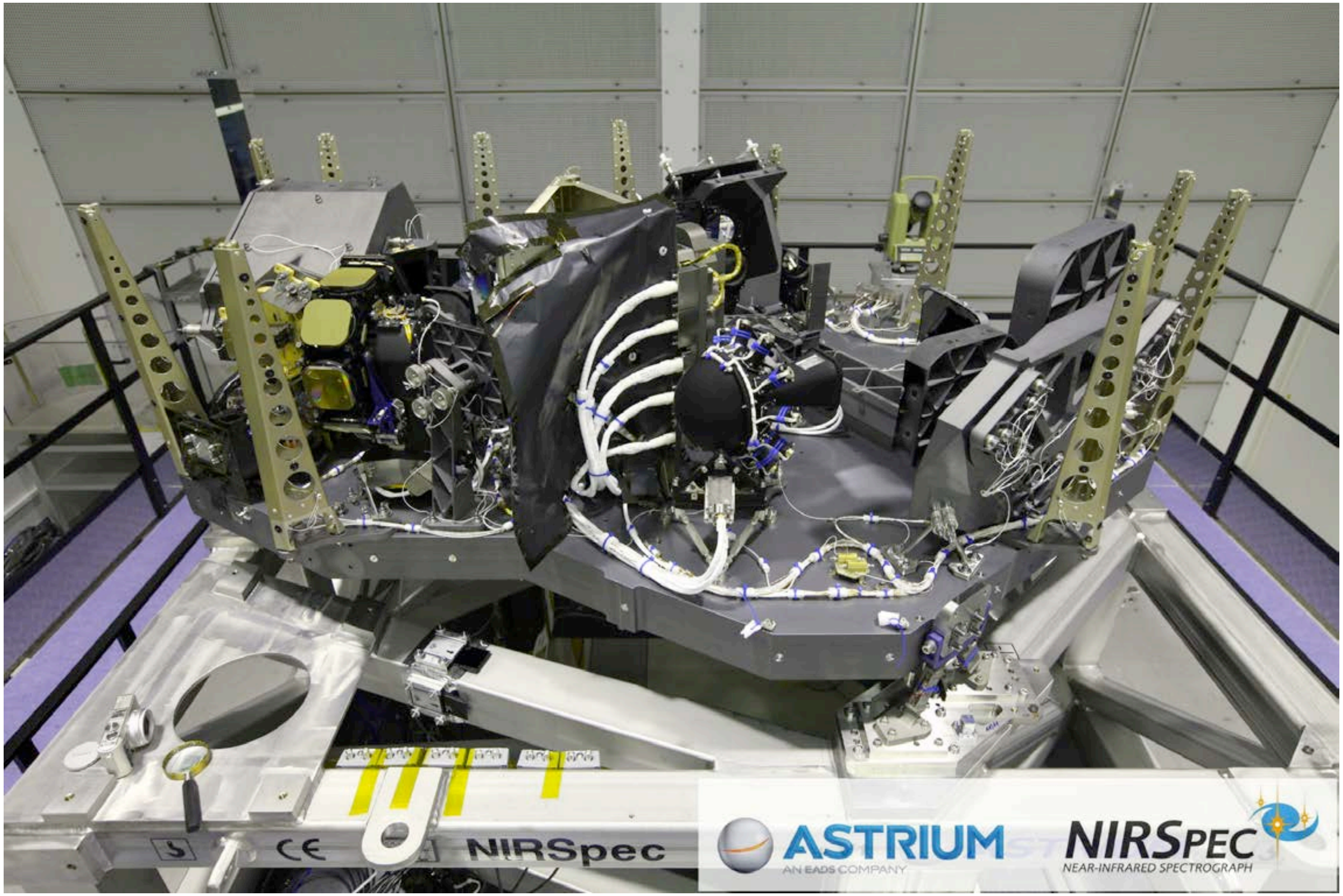
European Space Agency

JWST/NIRSpec – The flight hardware

- **NIRSpec flight model #2 in November 2012 at the end of its integration at EADS Astrium.**



JWST/NIRSpec – The flight hardware

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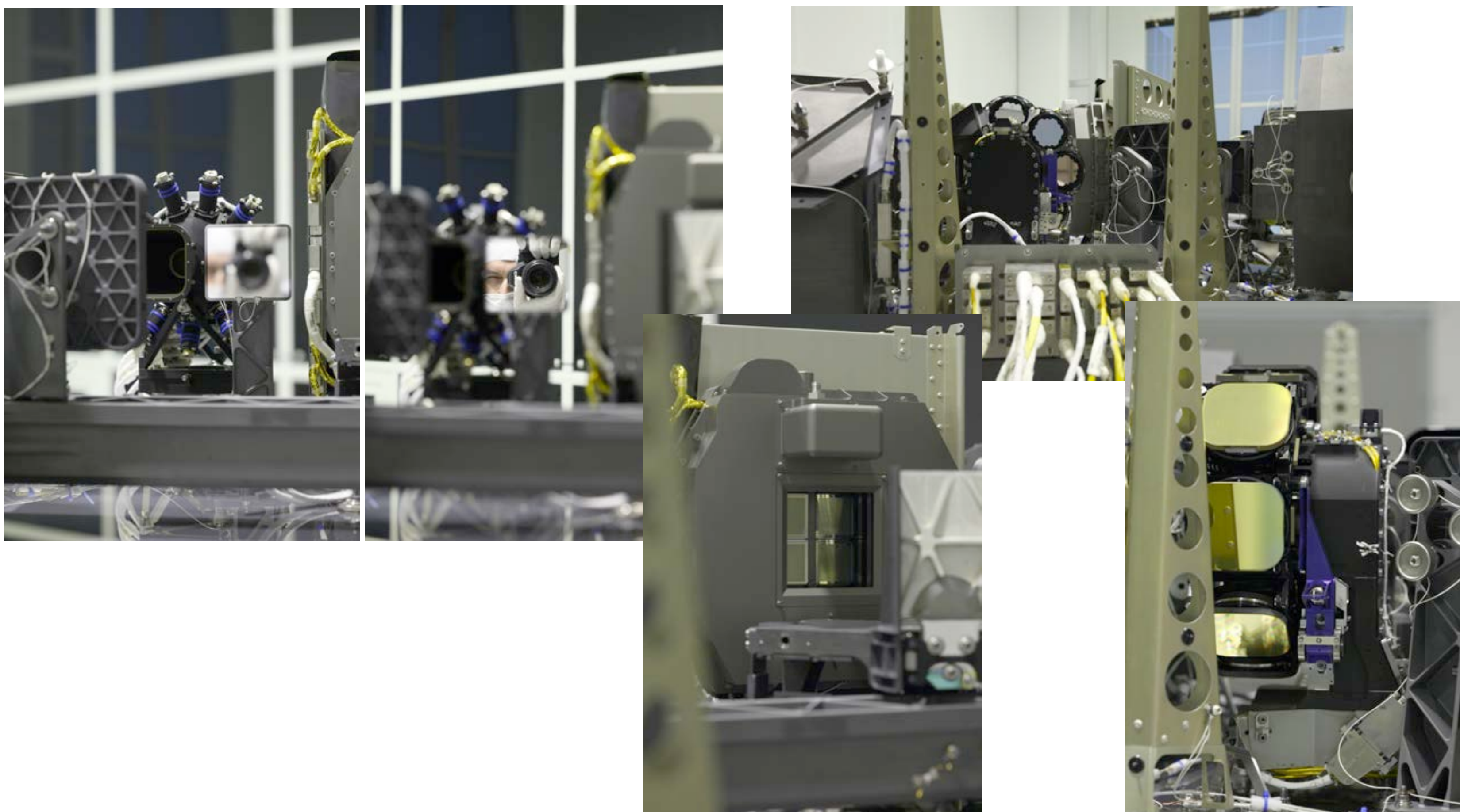
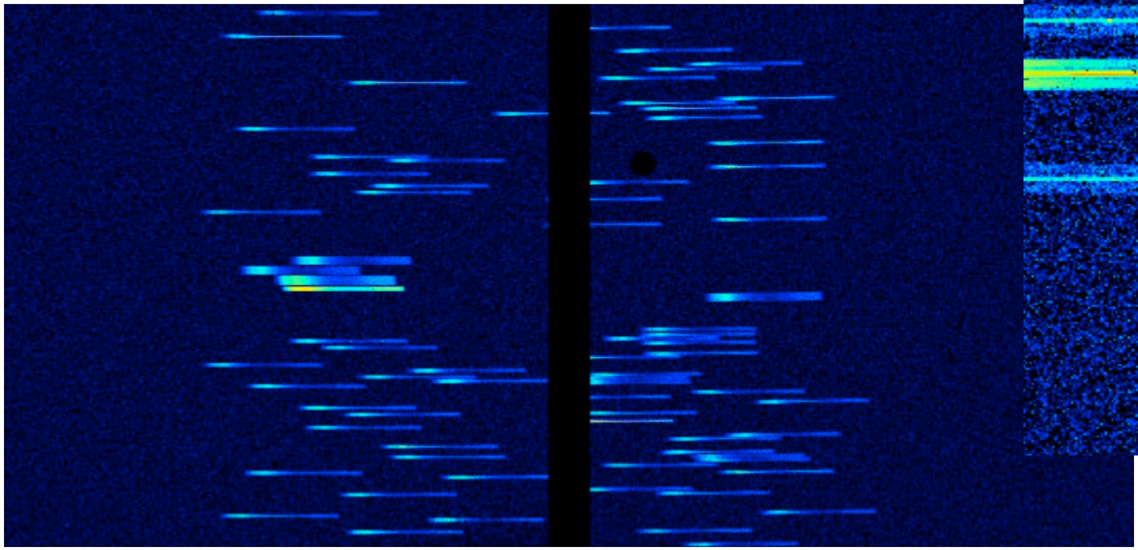
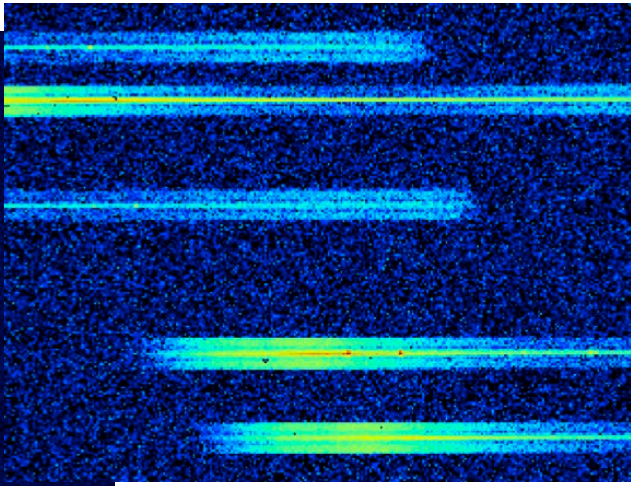


JWST/NIRSpec – Simulated observations - MOS scene

- **Simulation of an individual spectrographic deep-field exposure in MOS mode from Dorner 2012 (PhD)**
  - Collection of HUDF-type galaxy distribution with (synthetic) spectra from Pacifici et al. (2012).
  - Point-source + zodiacal background. 3x1 “mini-slits”.
  - Single 945-s exposure over the 0.6-5.0 micron domain at low spectral resolution.





JWST/NIRSpec – Simulated observations - MOS scene

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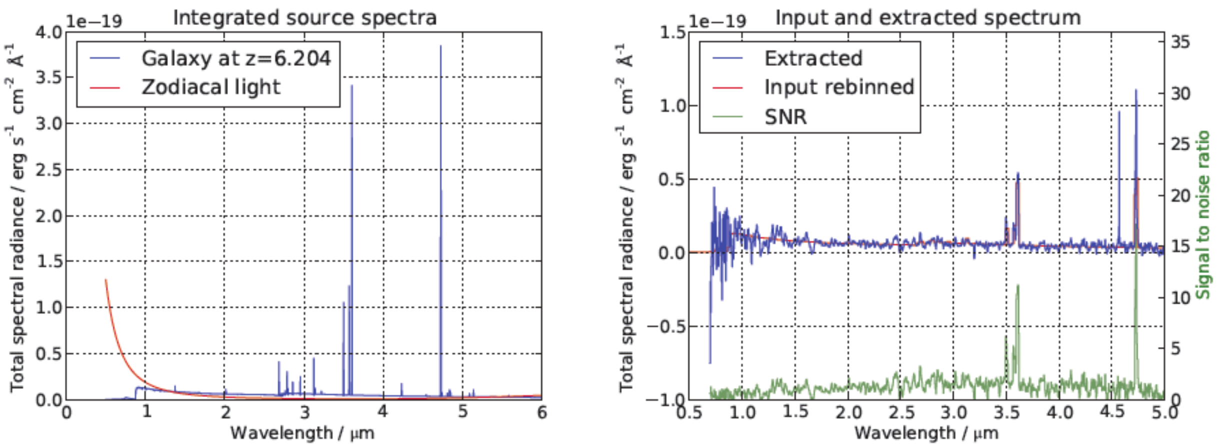
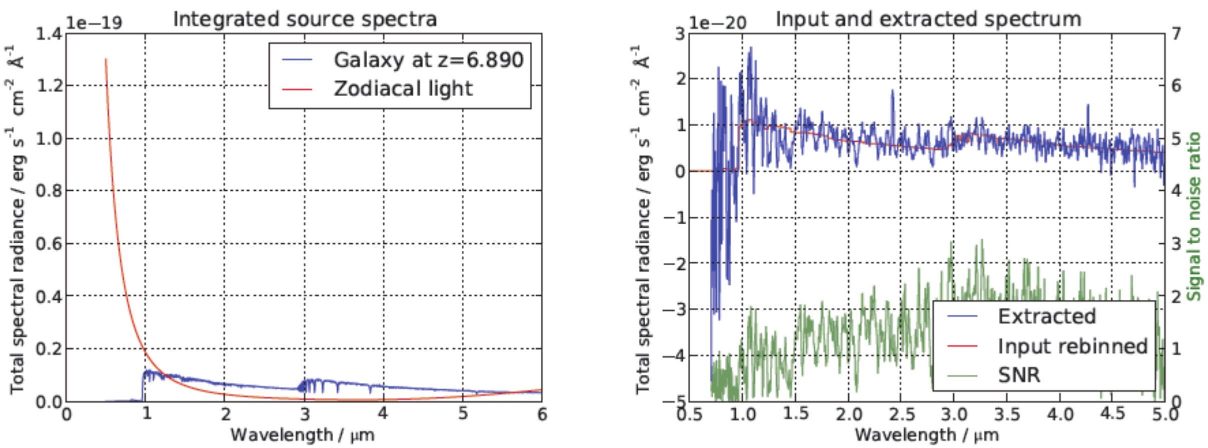
For the faintest objects, **10 to 100** of these 945s exposures will be obtained when conducting a **spectrographic deep-field**.



(e) $z = 6.204$, $mag_H = 26.9$



(f) $z = 6.890$, $mag_H = 26.8$

European Space Agency

You got the "tour" of JWST and of its instruments, but now, what is the actual status of the mission? What are the next steps in its development?

JWST - Status

- **Overall things are going well!**
  - After several very turbulent years where the mission was threatened of being cancelled, things are back on track.
- **Since the "replan" that took place on the US side around 2010-2011, the development of the JWST mission has been progressing steadily.**
  - Within cost and within schedule for a launch in 2018.
- **The mission is now receiving adequate funding after years of under-funding that lead to the initial launch delay and to some part of the 2010 cost increase.**
  - Things are back on track and this reflects immediately in the good record of milestone achievements during the last 2-3 years.

JWST - Status

- **All JWST mirrors have been manufactured.**
- **All 4 instruments have been delivered.**
- **2 instruments are already installed in the payload module (ISIM)**
    - MIRI and FGS/NIRISS
- **The first cryogenic testing of the payload module has been successfully completed.**
- **A lot of on-going work on the spacecraft (CDR at in Januaray 2014).**

- **Replacing the current near-infrared detectors by new ones (toward the end of 2014).**
- **And, now more and more testing, testing...**

(if you ever wondered what we would do between the instrument deliveries and launch...)

JWST – What happens to the instruments after delivery?

JWST – What happens to the instruments after delivery?

2012	2013	2014	2015	2016	2017	2018	2019	2020 and beyond

NORMAL OPERATION

COMMISSIONING

LAUNCH !

FINAL STEPS OF THE INTEGRATION AND TESTING OF THE SPACECRAFT

TESTING OF THE TELESCOPE AND INSTRUMENTS TOGETHER

ISIM INTEGRATION AND TESTING

NIRSpec DELIVERY !

NIRSpec TESTING

NIRSpec INTEGRATION

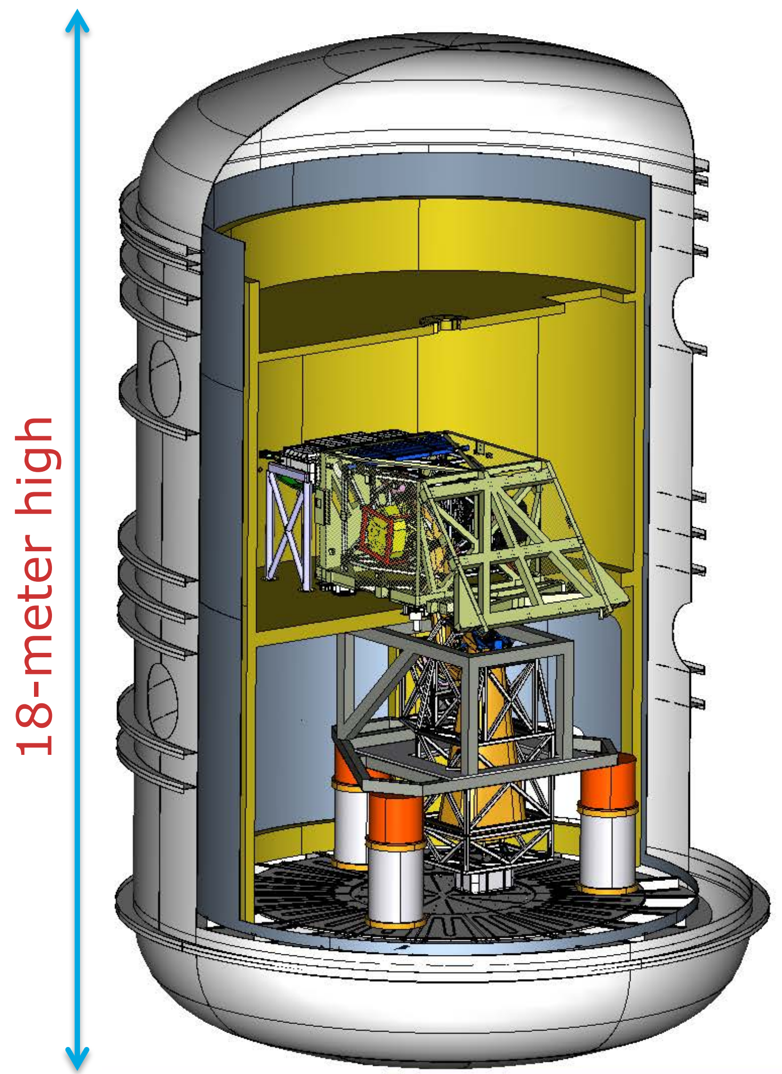
Only the path of NIRSpec is shown. Plenty of activities are actually running in parallel!

Instrument-level activities

Progressive integration of JWST…

No real wait time! However, schedule margins are included.

JWST – What happens to the instruments after delivery?



This is becoming cosy…

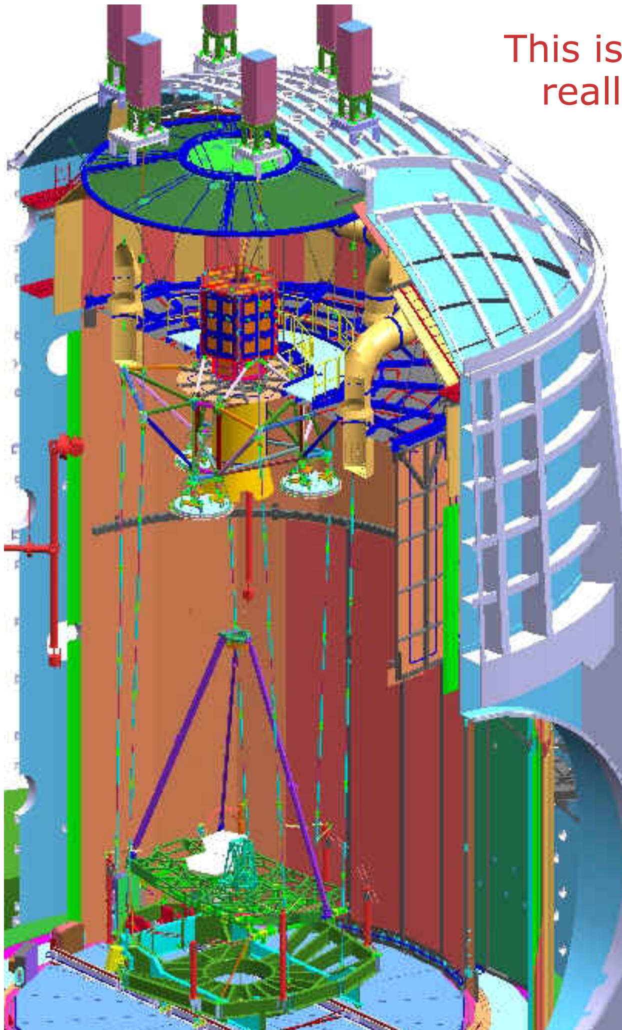
ISIM-level testing…

JWST – What happens to the instruments after delivery?

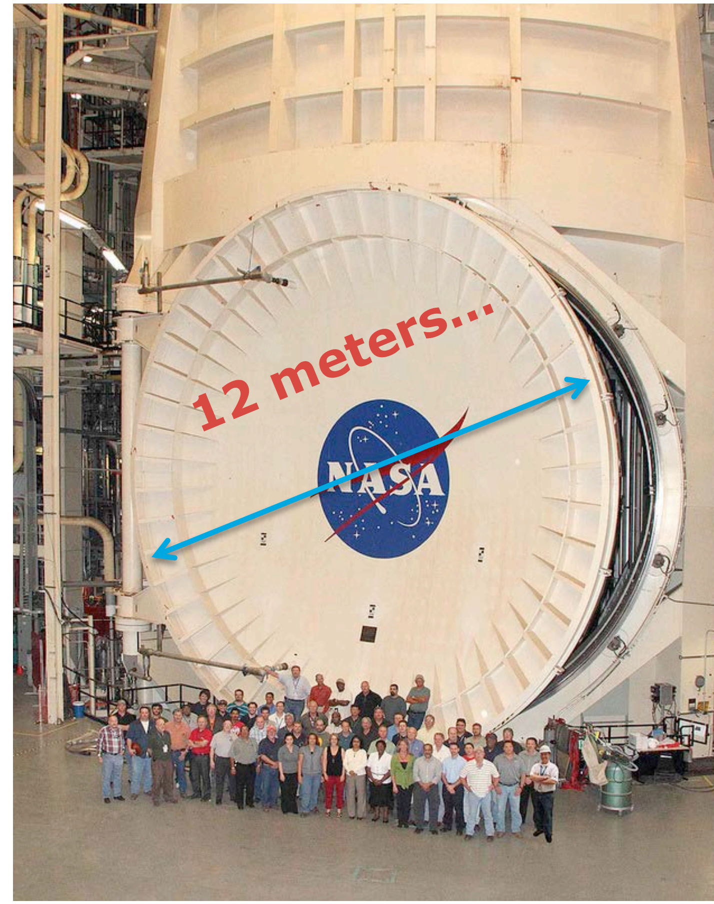
Assembling the primary mirrors on their structure.

JWST – What happens to the instruments after delivery?

Almost 35-meter high!



This is becoming really huge…

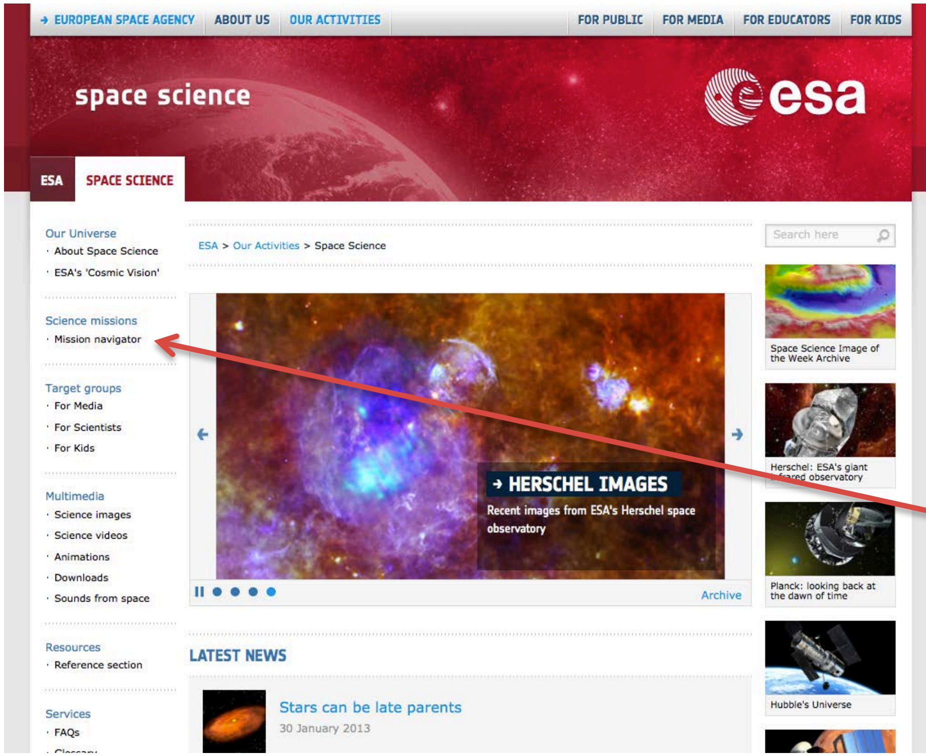


OTIS-level testing…

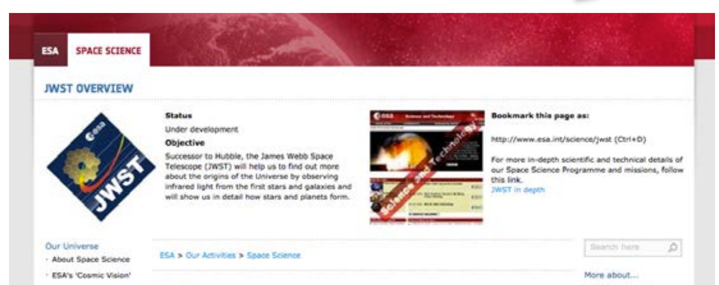
And, finally in 2018!

Thank you for your attention…

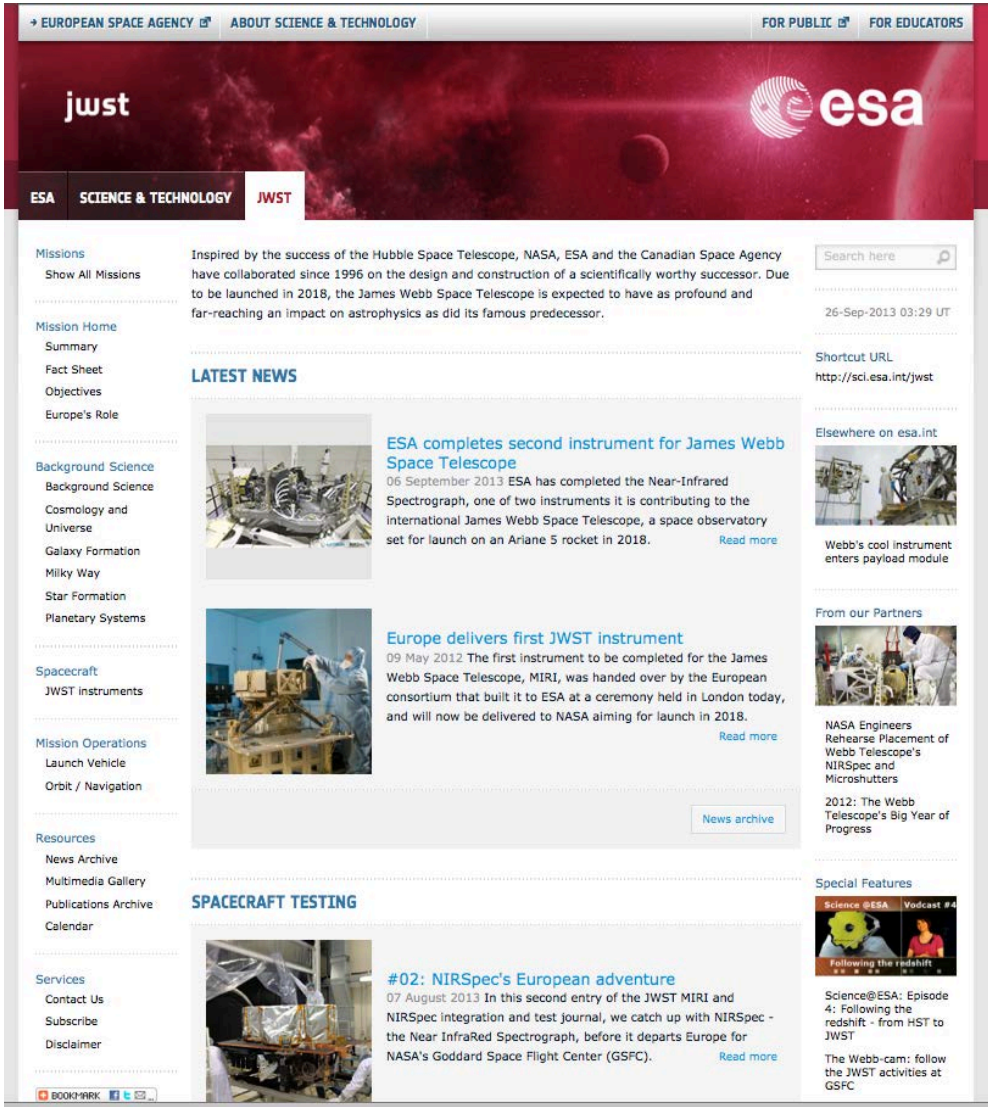
JWST on the web – Resources – ESA web sites



- **Overall ESA science missions web site**
- **www.esa.int/Our_Activities/Space_Science/**
- **JWST overview page available through the "Mission navigator" page.**



JWST on the web – Resources – ESA web sites



- **"Science and technology" section dedicated to JWST**
- **http://sci.esa.int/jwst/**
- **Latest news with the press releases for major milestones.**
- **Spacecraft testing section with a "journal" following what happens to MIRI and NIRSpec.**

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JWST on the web – Resources – ESA web sites

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- Internal

ESA AND THE JAMES WEBB SPACE TELESCOPE

The James Webb Space Telescope (JWST) is a collaborative project between NASA, ESA, and the Canadian Space Agency (CSA). Although radically different in design, and emphasizing the infrared part of the electromagnetic spectrum, JWST is widely seen as the successor to the Hubble Space Telescope (HST).

The JWST observatory will consist of a deployable 6.6 meter passively cooled telescope optimized for infrared wavelengths, and will be operated in deep space at the anti-Sun Earth-Sun Lagrangian point (L2). It will carry four scientific instruments: a near-infrared camera (NIRCam), a near-infrared multi-object spectrograph (NIRSpec) covering the 0.6 - 5 μm spectral region, a near-infrared slit-less spectrograph (NIRISS), and a combined mid-infrared camera/spectrograph (MIRI) covering 5 - 28 μm. The JWST focal plane (see image to the right) contains apertures for the science instruments and the Fine Guidance Sensor (FGS).

The focal plane of the JWST telescope with the assigned field of views for the instruments.

The scientific goals of the JWST mission can be sorted into four broad themes:

- The end of the dark ages: first light and re-ionization
- The assembly of galaxies
- The birth of stars and proto-planetary systems
- Planetary systems and the origins of life

Although the first two of these themes are extragalactic in nature and concerned with exploring the formation of stars and galaxies in the remote Universe at the earliest times, they are intimately linked to the latter two mainly galactic themes, which aim at understanding the detailed process of star and planet formation in our own galaxy.

The European Space Agency is responsible for providing NIRSpec from ESA funds, and approximately half of MIRI through special contributions from the member states via a consortium of European science institutions (EC). As its non-instrument contribution, ESA will provide the Ariane 5 launcher that will place the JWST observatory in its orbit around L2. Furthermore, a number of ESA staff will be posted at the Space Telescope Science Institute (STScI) in Baltimore in support of the European payload components as ESA's contribution to JWST operations.

The purpose of this web-site is to provide information specific to the NIRSpec instrument, its performances and calibration. Designed as a multi-object spectrograph (MOS), NIRSpec will be able to observe more than 100 astronomical objects simultaneously. It has a large field of view (≈ 3' × 3') and is highly sensitive over its wavelength range (0.6 to 5 μm). The purpose of NIRSpec is to provide low (R~100), medium (R~1000), and high-resolution (R~2700) spectroscopic observations in support of the four main science themes of JWST. NIRSpec is developed by ESA with EADS Astrium Germany GmbH as the prime contractor.

If you are looking for more general information on

- **JWST and NIRSpec web site maintained by the science and operation team at ESA.**
- http://www.rssd.esa.int/JWST/
- **The main focus is the NIRSpec instrument.**
- **Work in progress…**
- **More information will be added as time goes on.**

JWST on the web – Resources – NASA JWST web site

- **NASA JWST site**
- **www.jwst.nasa.gov**

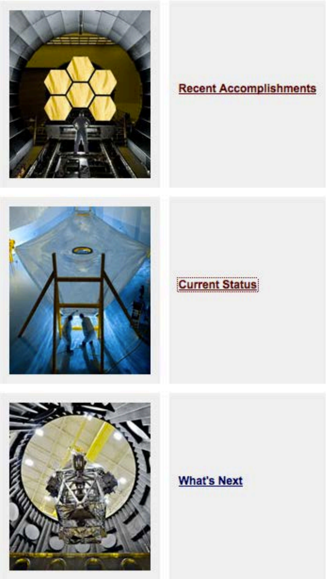
- **A lot of information.**
- **In the "FOR SCIENTISTS" section, you can register to receive the JWST newsletter, "The Webb update".**

JAMES WEBB SPACE TELESCOPE

European Space Agency

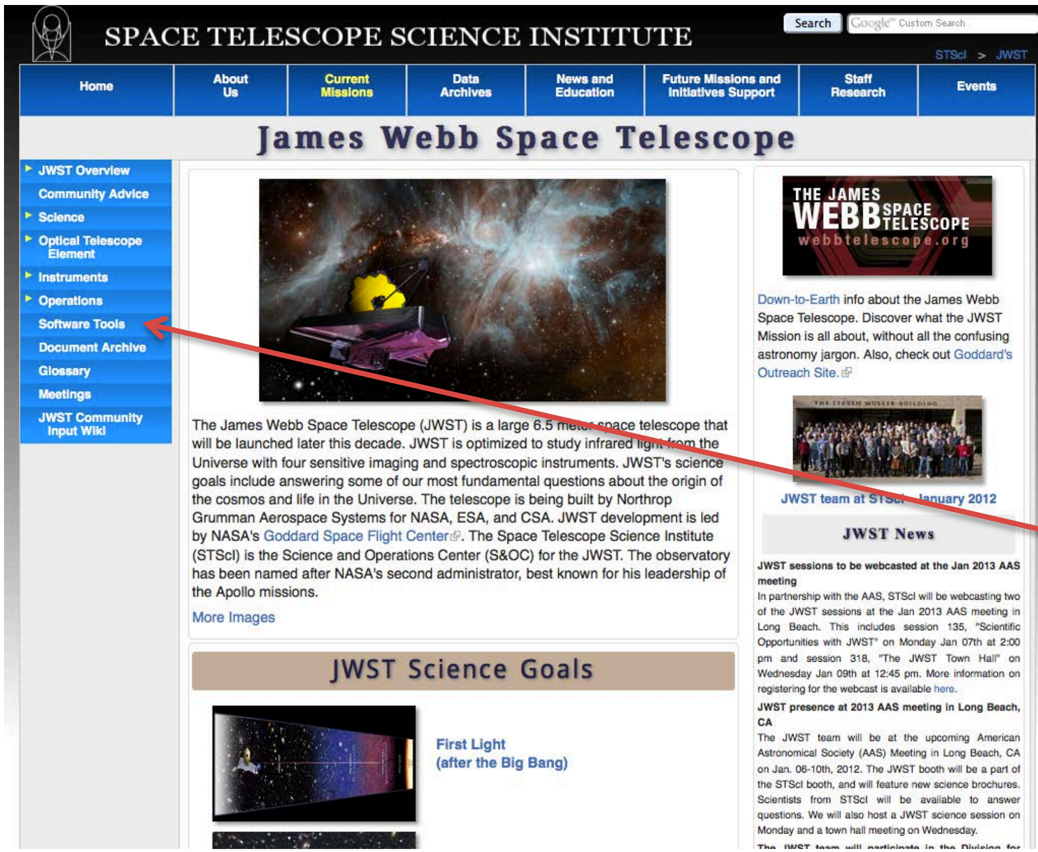
JWST on the web – Resources – NASA JWST web site

- In the "STATUS" section, you can have a look at the progress of the project (achievements, milestones, next steps…)



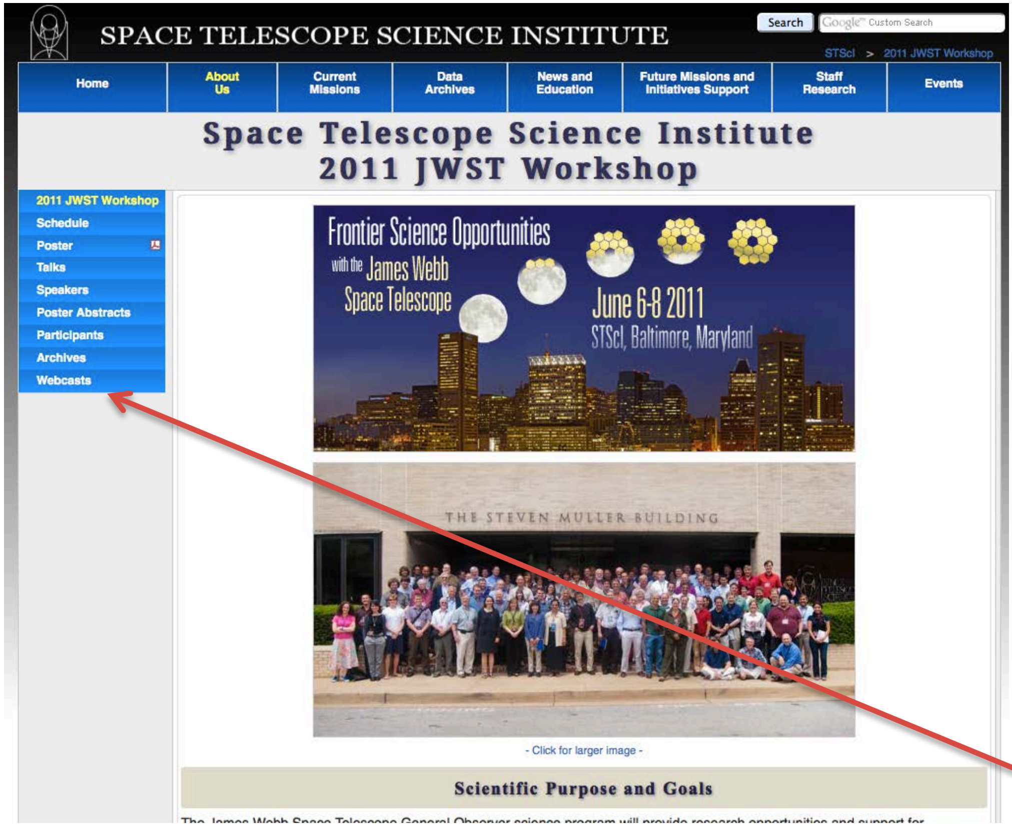
This is also a gold mine for images and videos

JWST on the web – Resources – STScI JWST web site



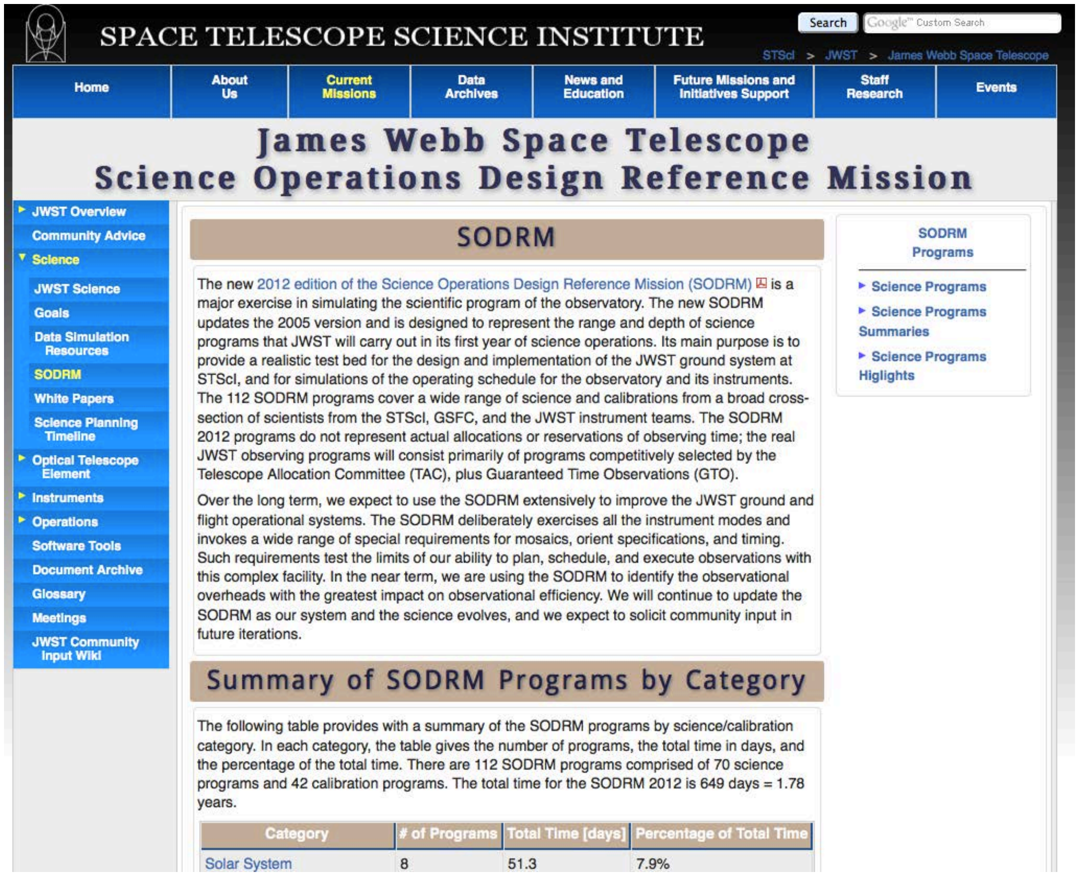
- JWST web site at STScI.
- http://www.stsci.edu/jwst/
- A lot of information.
- Prototype ETCs can be found in the "Software Tools" section.
- Note also the presence of development versions of the JWST APTs (astronomer's proposal tools)

JWST on the web – Resources – STScI JWST web site



- Web site of the 2011 STScI workshop on "Frontier Science Opportunities with JWST"
- http://www.stsci.edu/institute/conference/jwst2011/
- Look at the STScI webcast archive to view the various talks.

JWST on the web – Resources – STScI JWST web site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James Webb Space Telescope Science Operations Design Reference Mission

- JWST Overview
- Community Advice
- Science
  - JWST Science
  - Goals
  - Data Simulation Resources
  - SODRM
  - White Papers
  - Science Planning Timeline
- Optical Telescope Element
- Instruments
- Operations
- Software Tools
- Document Archive
- Glossary
- Meetings
- JWST Community Input Wiki

SODRM

The new 2012 edition of the Science Operations Design Reference Mission (SODRM) is a major exercise in simulating the scientific program of the observatory. The new SODRM updates the 2005 version and is designed to represent the range and depth of science programs that JWST will carry out in its first year of science operations. Its main purpose is to provide a realistic test bed for the design and implementation of the JWST ground system at STScI, and for simulations of the operating schedule for the observatory and its instruments. The 112 SODRM programs cover a wide range of science and calibrations from a broad cross-section of scientists from the STScI, GSFC, and the JWST instrument teams. The SODRM 2012 programs do not represent actual allocations or reservations of observing time; the real JWST observing programs will consist primarily of programs competitively selected by the Telescope Allocation Committee (TAC), plus Guaranteed Time Observations (GTO).

Over the long term, we expect to use the SODRM extensively to improve the JWST ground and flight operational systems. The SODRM deliberately exercises all the instrument modes and invokes a wide range of special requirements for mosaics, orient specifications, and timing. Such requirements test the limits of our ability to plan, schedule, and execute observations with this complex facility. In the near term, we are using the SODRM to identify the observational overheads with the greatest impact on observational efficiency. We will continue to update the SODRM as our system and the science evolves, and we expect to solicit community input in future iterations.

SODRM Programs
- Science Programs
- Science Programs Summaries
- Science Programs Higlights

Summary of SODRM Programs by Category

The following table provides with a summary of the SODRM programs by science/calibration category. In each category, the table gives the number of programs, the total time in days, and the percentage of the total time. There are 112 SODRM programs comprised of 70 science programs and 42 calibration programs. The total time for the SODRM 2012 is 649 days = 1.78 years.

Category	# of Programs	Total Time [days]	Percentage of Total Time
Solar System	8	51.3	7.9%

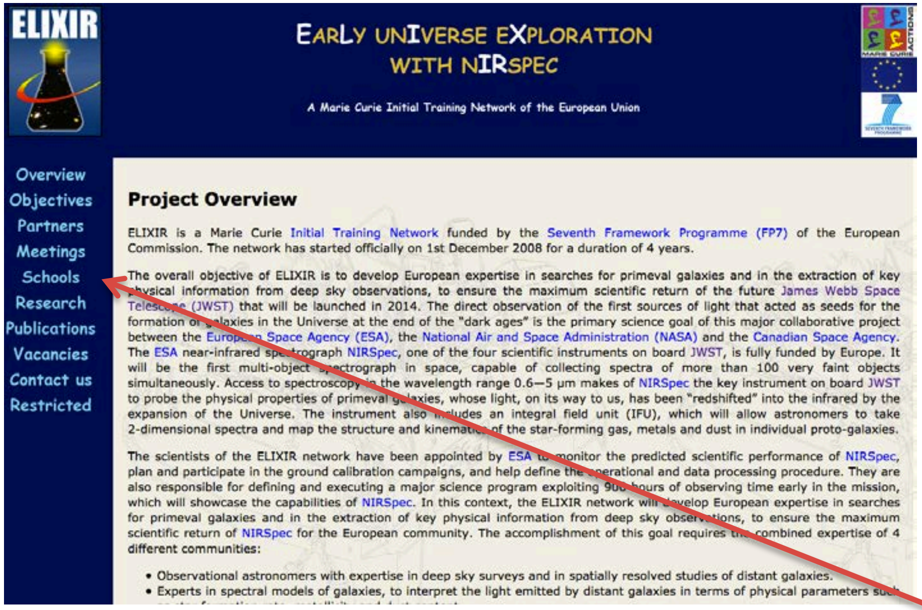
- The so-called SODRM
- http://www.stsci.edu/jwst/science/sodrm/

- Exercise aiming at simulating what could be one year of JWST observations.

JWST on the web – Resources – "Behind the Webb"

- **Series of short videos showing various moments in the development of JWST**
- **http://webbtelescope.org/webb_telescope/behind_the_webb/**
- **Oriented toward a fairly wide audience.**

JWST on the web – Resources – The ELIXIR network web site



ELIXIR

EARLY UNIVERSE EXPLORATION WITH NIRSPEC

A Marie Curie Initial Training Network of the European Union

Overview
Objectives
Partners
Meetings
Schools
Research
Publications
Vacancies
Contact us
Restricted

Project Overview

ELIXIR is a Marie Curie Initial Training Network funded by the Seventh Framework Programme (FP7) of the European Commission. The network has started officially on 1st December 2008 for a duration of 4 years.

The overall objective of ELIXIR is to develop European expertise in searches for primeval galaxies and in the extraction of key physical information from deep sky observations, to ensure the maximum scientific return of the future James Webb Space Telescope (JWST) that will be launched in 2014. The direct observation of the first sources of light that acted as seeds for the formation of galaxies in the Universe at the end of the "dark ages" is the primary science goal of this major collaborative project between the European Space Agency (ESA), the National Air and Space Administration (NASA) and the Canadian Space Agency. The ESA near-infrared spectrograph NIRSpec, one of the four scientific instruments on board JWST, is fully funded by Europe. It will be the first multi-object spectrograph in space, capable of collecting spectra of more than 100 very faint objects simultaneously. Access to spectroscopy in the wavelength range 0.6—5 μm makes of NIRSpec the key instrument on board JWST to probe the physical properties of primeval galaxies, whose light, on its way to us, has been "redshifted" into the infrared by the expansion of the Universe. The instrument also includes an integral field unit (IFU), which will allow astronomers to take 2-dimensional spectra and map the structure and kinematics of the star-forming gas, metals and dust in individual proto-galaxies.

The scientists of the ELIXIR network have been appointed by ESA to monitor the predicted scientific performance of NIRSpec, plan and participate in the ground calibration campaigns, and help define the operational and data processing procedure. They are also responsible for defining and executing a major science program exploiting 900 hours of observing time early in the mission, which will showcase the capabilities of NIRSpec. In this context, the ELIXIR network will develop European expertise in searches for primeval galaxies and in the extraction of key physical information from deep sky observations, to ensure the maximum scientific return of NIRSpec for the European community. The accomplishment of this goal requires the combined expertise of 4 different communities:

- Observational astronomers with expertise in deep sky surveys and in spatially resolved studies of distant galaxies.
- Experts in spectral models of galaxies, to interpret the light emitted by distant galaxies in terms of physical parameters such

Schools

The ELIXIR network will organize 3 "technology-oriented" schools on the NIRSpec project.

First ELIXIR School: ***"The JWST/NIRSpec Project" (31 May-2 June 2010)***

Location: EADS/Astrium GmbH (Ottobrunn, Germany)

Second ELIXIR School: ***"How Does a Space Project Work?" (19-20 May 2011)***

Location: ESA/ESTEC (Noordwijk, The Netherlands)

Third ELIXIR School: ***"What Will it Look Like to Observe with NIRSpec?" (26-27 September 2012)***

Location: ESA/ESTEC (Noordwijk, The Netherlands)

- **Web site of the ELIXIR network (PI: S. Charlot, NIRSpec related)**
- **http://www.iap.fr/elixir/index.html/**
- **A lot of interesting material in the "Schools" section (presentations made during the 3 network schools).**

JWST on the web – Resources – Miscellaneous

- **MIRI at RAL, ROE and JPL**
  - http://www.stfc.ac.uk/RALSpace/18419.aspx/
  - http://jwst-miri.roe.ac.uk/
  - http://www.jpl.nasa.gov/missions/details.php?id=5921

- **NIRCam at the University of Arizona**
  - **http://ircamera.as.arizona.edu/nircam/**

- **FGS/NIRISS at CSA**

  http://www.asc-csa.gc.ca/eng/satellites/jwst/facts.asp