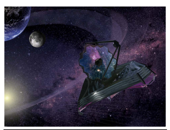
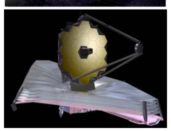
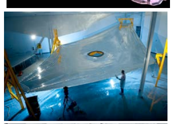
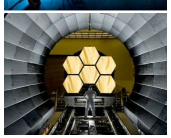
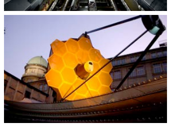
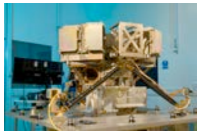
The JWST mission

P. Ferruit
(ESA JWST project scientist)

JAMES WEBB SPACE TELESCOPE

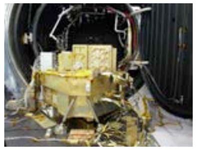






MIRI

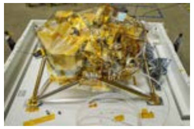


NIRSpec

FGS/NIRISS



NIRCam



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.
  - Telescope, sun shield, deployment…
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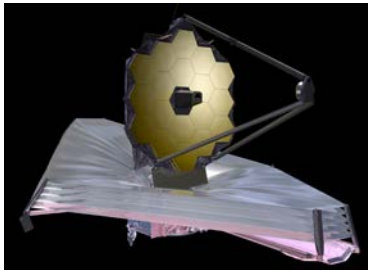
- **JWST capabilities**
  - Imaging.
  - Spectroscopy (MOS, slitless, IFU and single object).
  - Coronagraphy and aperture mask interferometry.
- **JWST status and next steps.**
  - Status and next steps till launch…
  - A few words about scientific operation and policies.
- **JSWT on the web, some resources.**
  - Bonus track - Available in the electronic version of the presentation.

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).**



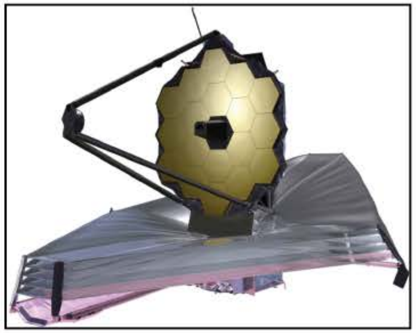
The James Webb Space Telescope (JWST) mission in a nutshell

The James Webb Space Telescope (JWST)

Launch segment

- Payload adapter
- Launcher (Ariane 5)
- Launch site services

Observatory segment

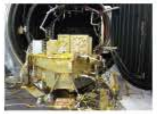


- Spacecraft (bus, sunshield...)
- Telescope

Payload module (ISIM) and instruments

- NIRCam

- NIRSpec
- FGS / NIRISS



- MIRI

Ground segment

- Science and operation center (STScI)
  - 15 ESA staff members
- Common systems (deep space network)

Provided by NASA | Provided by ESA and Europe | Provided by CSA

European Space Agency

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

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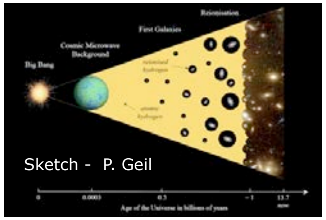
- **The end of the dark ages: first light and re-ionization.**

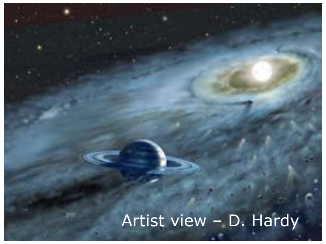


Sketch - P. Geil

- **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.

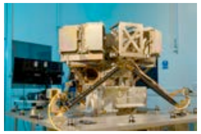
See Gardner et al., 2006, Space Science Reviews, 123, 485

European Space Agency

1/2 What does it take to achieve these ambitious scientific goals?

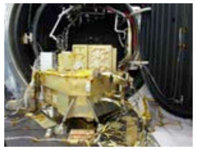
- **A wavelength coverage spanning the optical to mid-infrared spectrum (0.6-28 microns) to be able to observe distant galaxies, “cool” objects and to peer into very dusty environments.**
    - A cryogenic space telescope in orbit around the very stable Sun-Earth L2 environment with the right instruments.
- **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 and a very good pointing stability.

MIRI

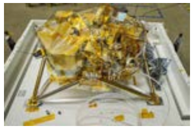


NIRSpec

FGS/NIRISS



NIRCam



JWST

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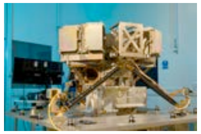
European Space Agency

2/2 What does it take to achieve these ambitious scientific goals?

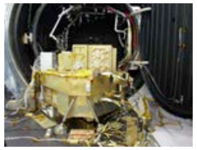
- **A low background level from the near-infrared to the mid-infrared.**
  - A cryogenic space telescope in orbit around the very stable Sun-Earth L2 environment.
- **Both imaging and spectroscopic capabilities.**
  - The right suite of instruments.
- **A moving target capability to be able to observe solar system objects.**
  - The right guiding system able to cope with objects moving as fast as 30 mas per second.

MIRI

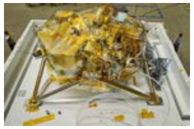


NIRSpec

FGS/NIRISS



NIRCam

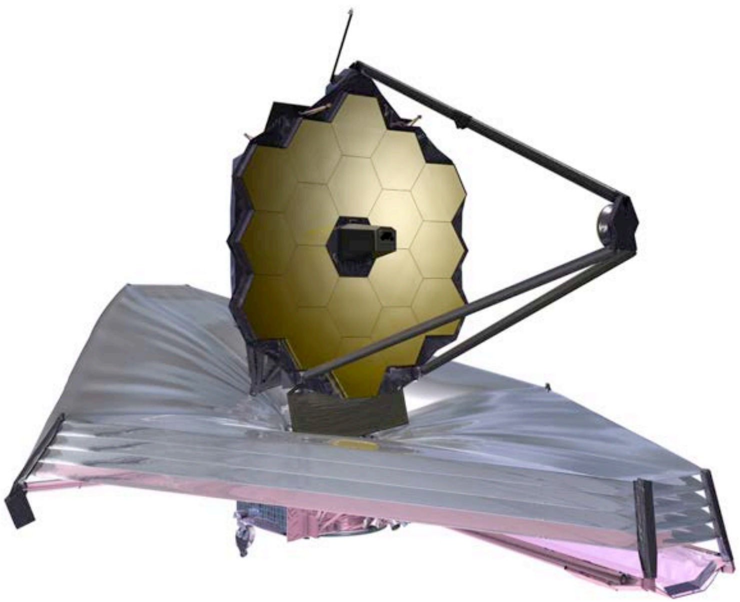


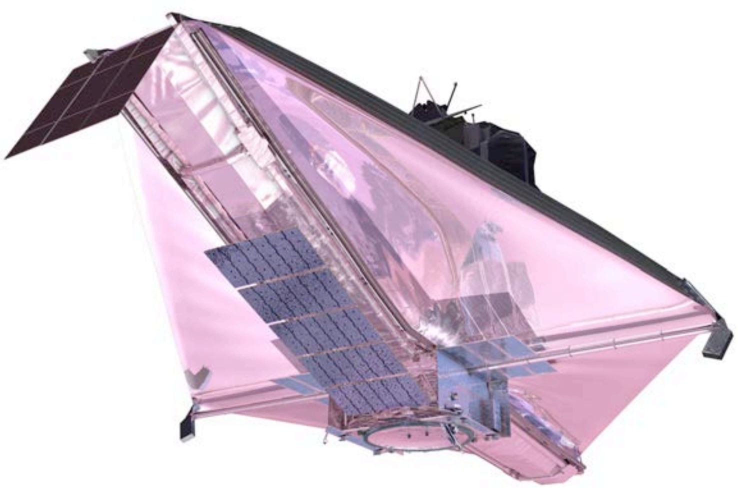
JWST

The James Webb Space Telescope Implementation…

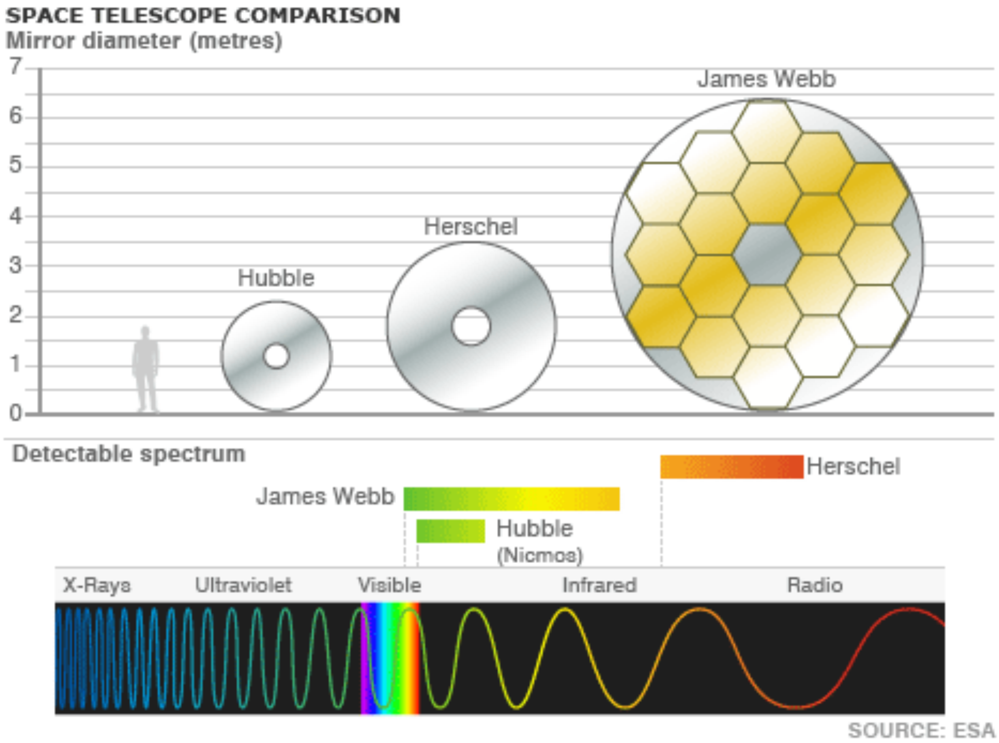
- **Several key elements that deserve a closer look…**
  - The telescope and its mirrors.
  - The sun shield.
  - A folding telescope.
  - The instruments.

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





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



Beryllium segment mass properties

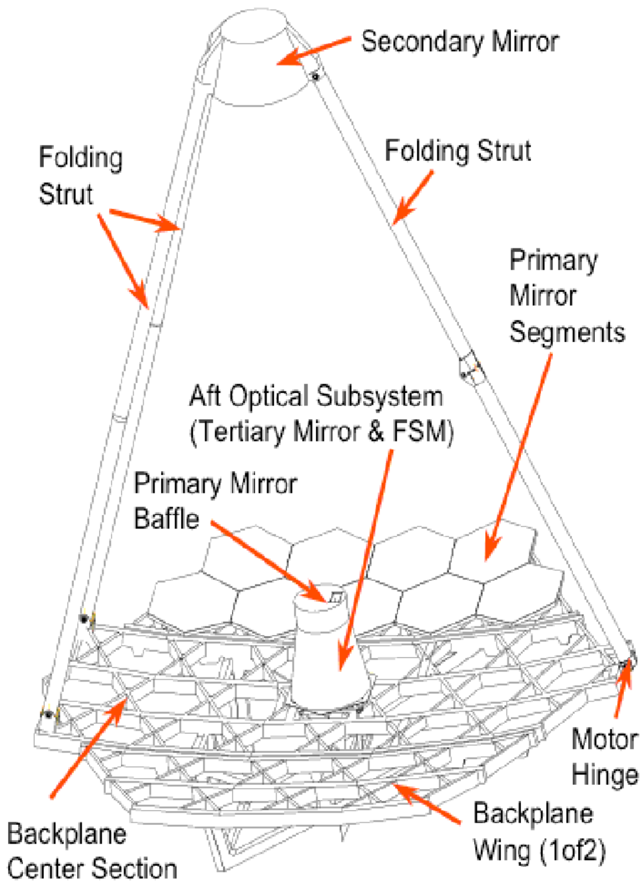
- substrate: 21.8 kg
- segment assembly: 39.4 kg
- OTE area density: ~28 kg m^{-2}
  - HST (ULE) ~ 180 kg m^{-2}
  - Keck (Zerodur) ~ 2000 kg m^{-2}

ULE = Ultra-Low Expansion

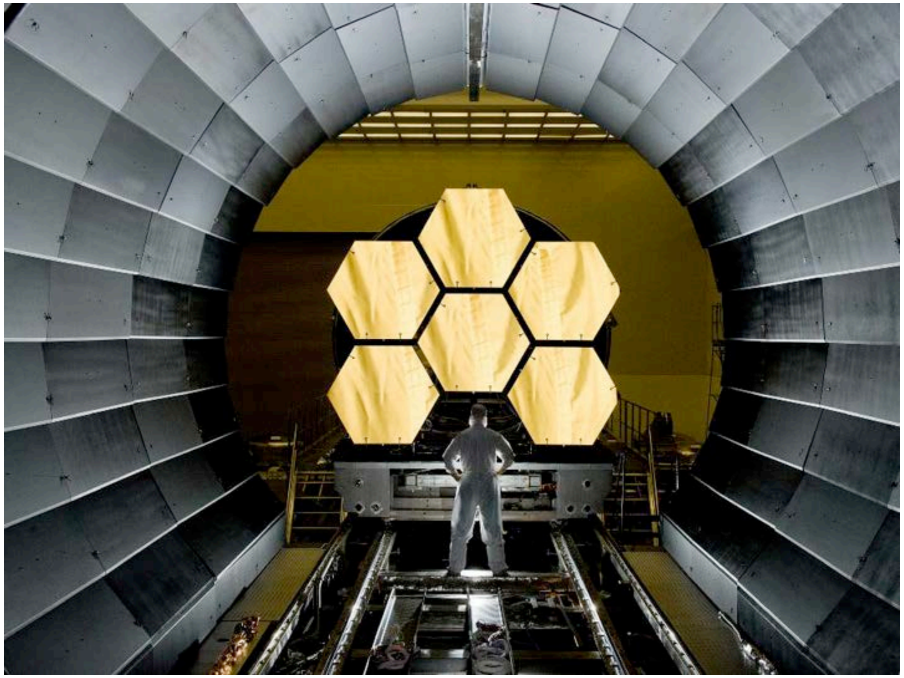
The James Webb Space Telescope
The telescope and its mirrors

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

FSM = fine steering mirror

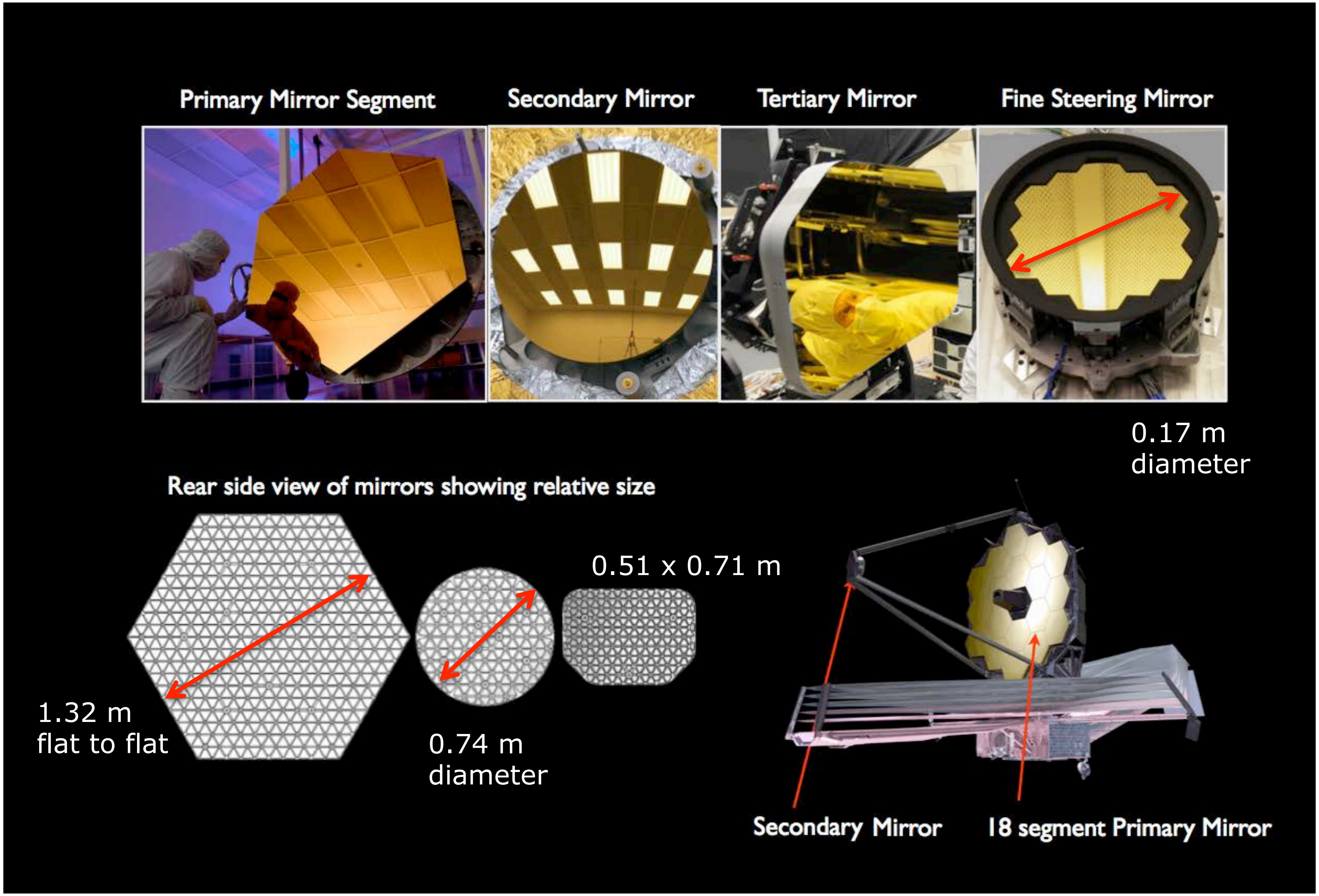


6 of the flight mirrors before cryogenic testing

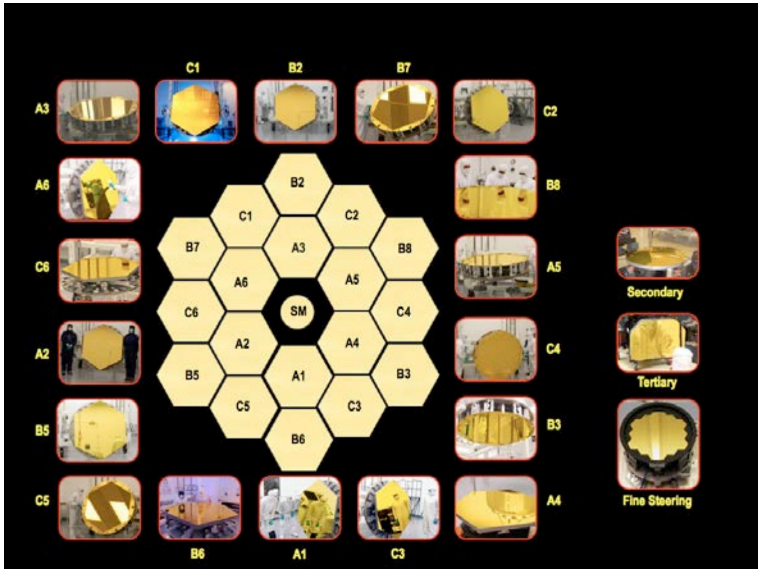


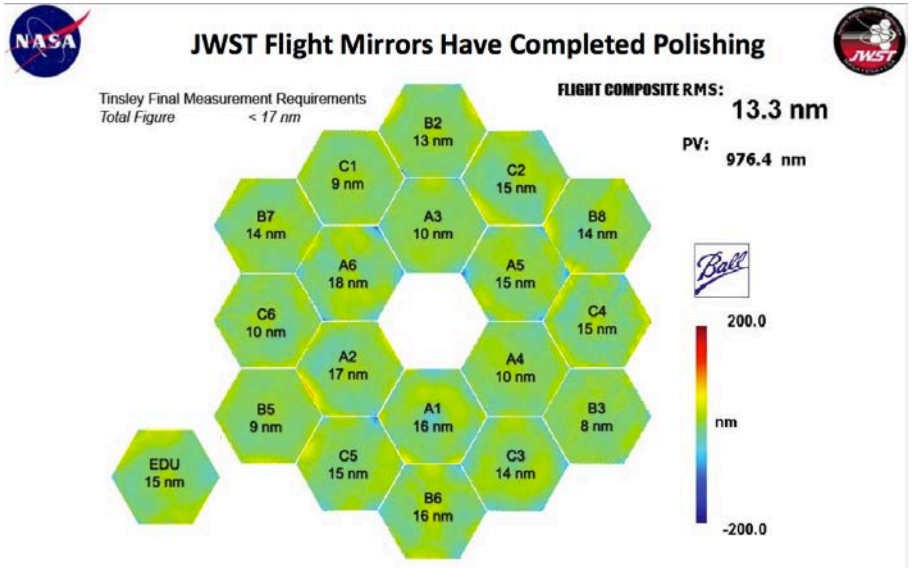
Credit: NASA/MSFC/David Higginbotham

The James Webb Space Telescope
The telescope and its mirrors



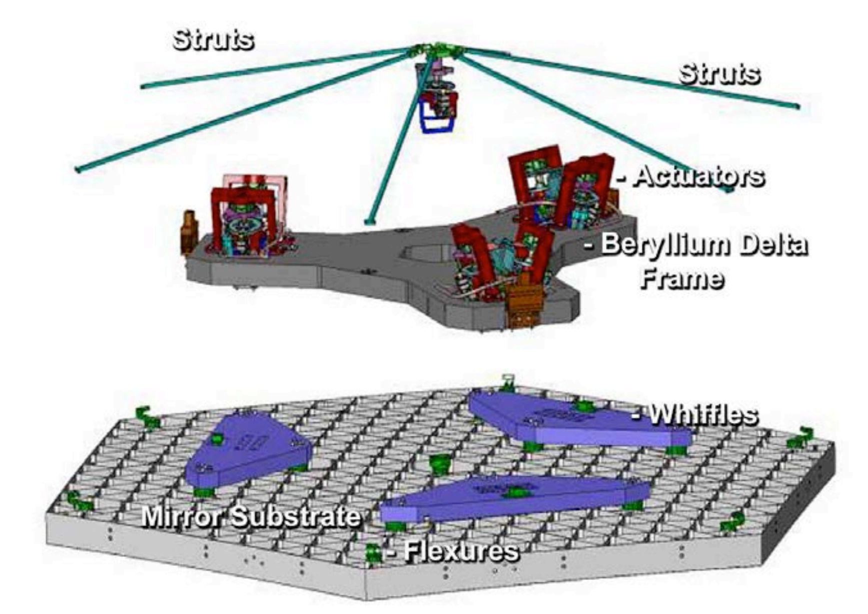
The James Webb Space Telescope
The telescope and its mirrors

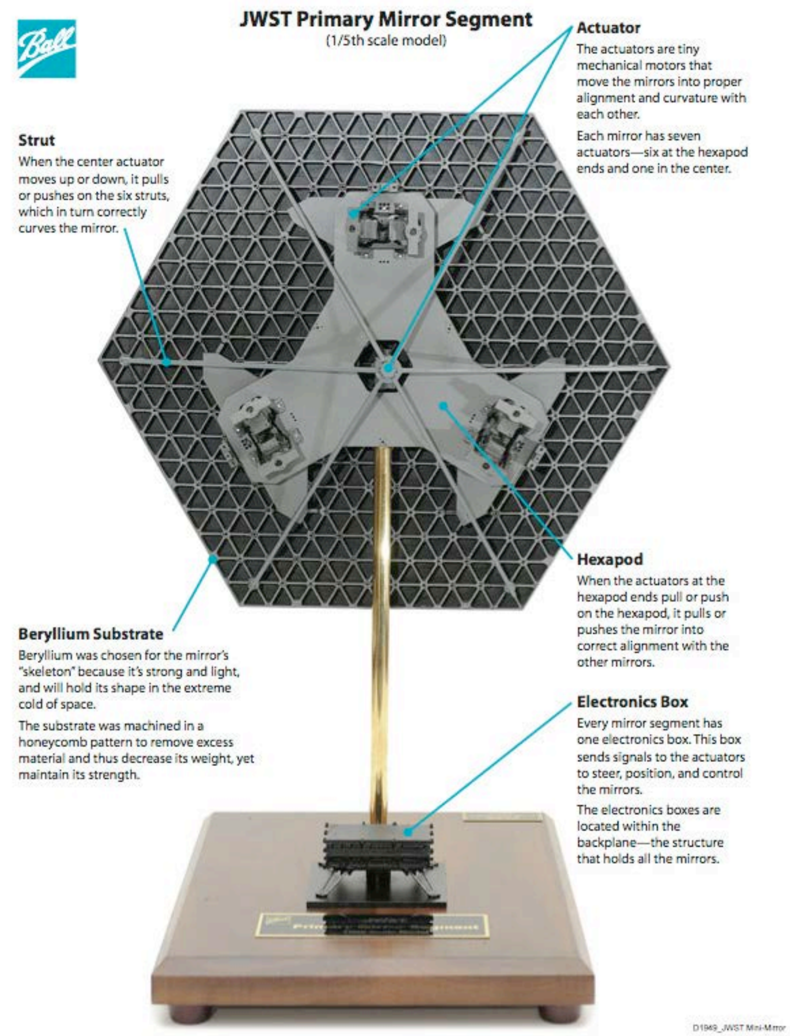




The James Webb Space Telescope
The telescope and its mirrors

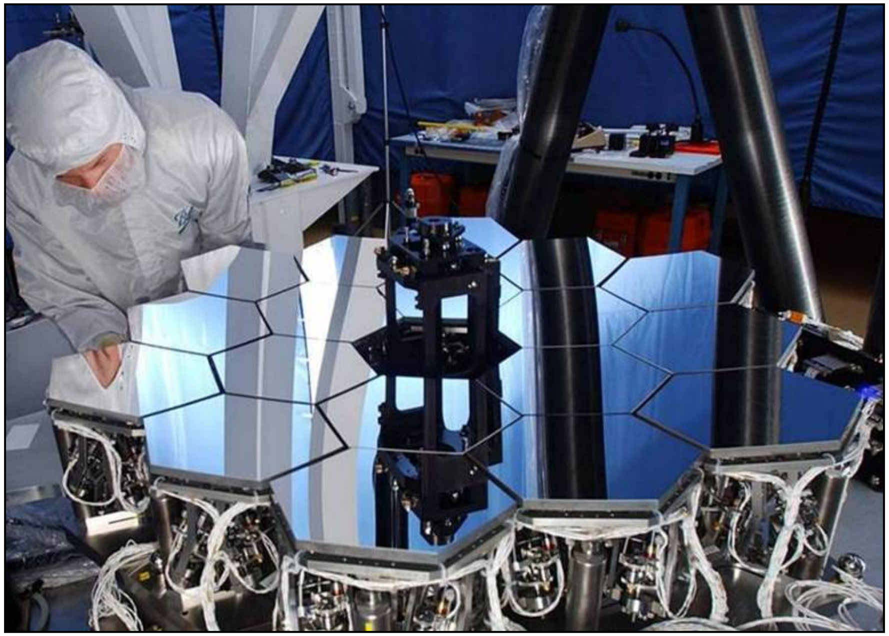
- **An active optic system.**
- Actuators providing 7-degree of freedom (position, tilt and radius of curvature).
- 10 nm minimum step size! Working at 40K.





- **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! Regular retuning.

➔ See presentation from M. Sirianni.



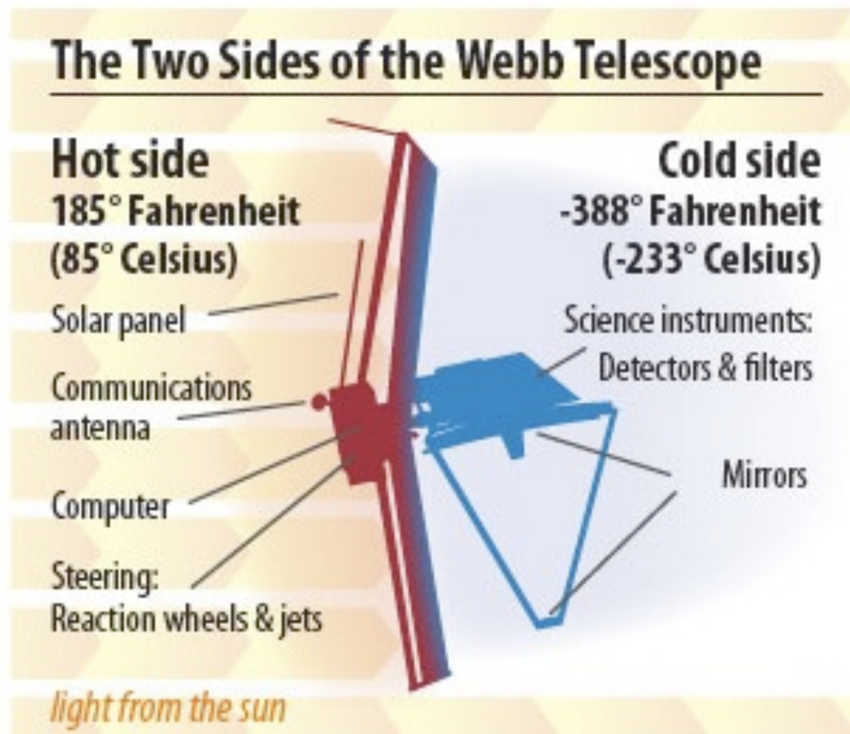
Using a 1/6th-scale engineering model to test and validate the algorithms.

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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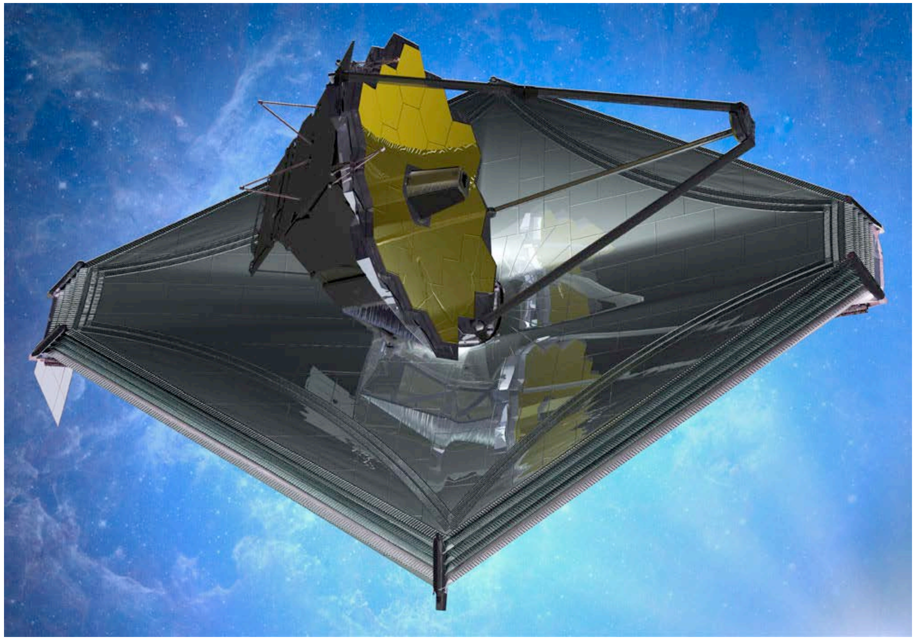
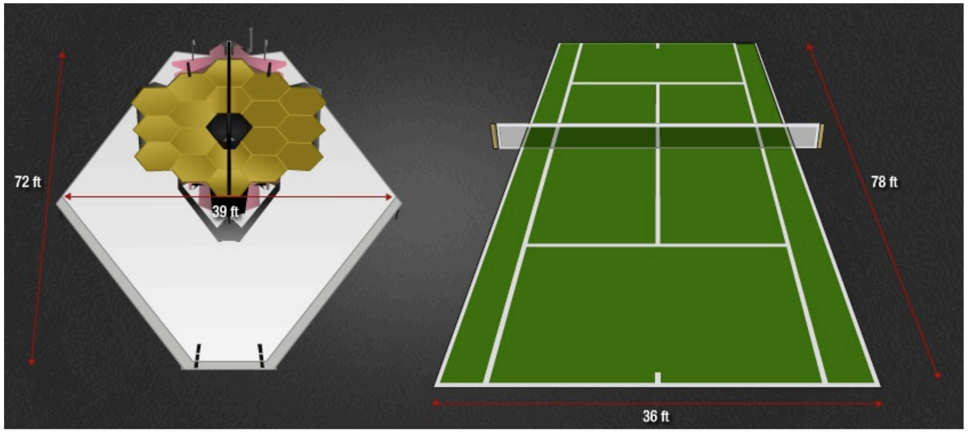
The James Webb Space Telescope
The sun shield



72 ft = 22 m



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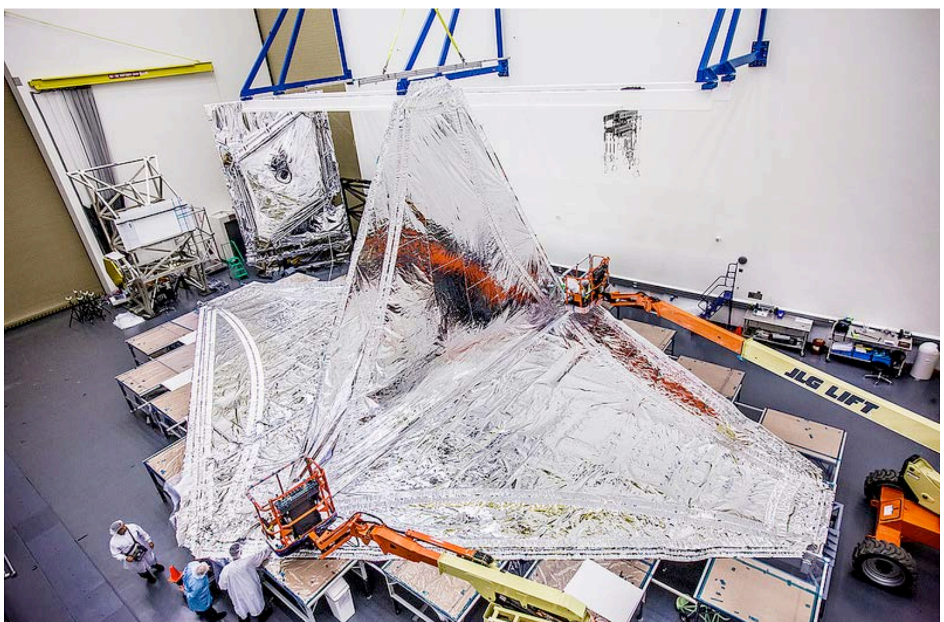
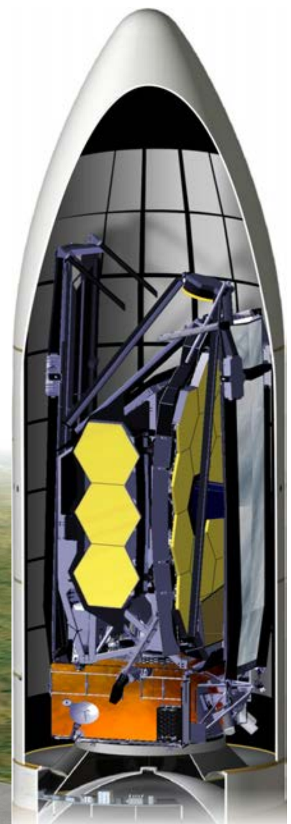
The James Webb Space Telescope
The sun shield

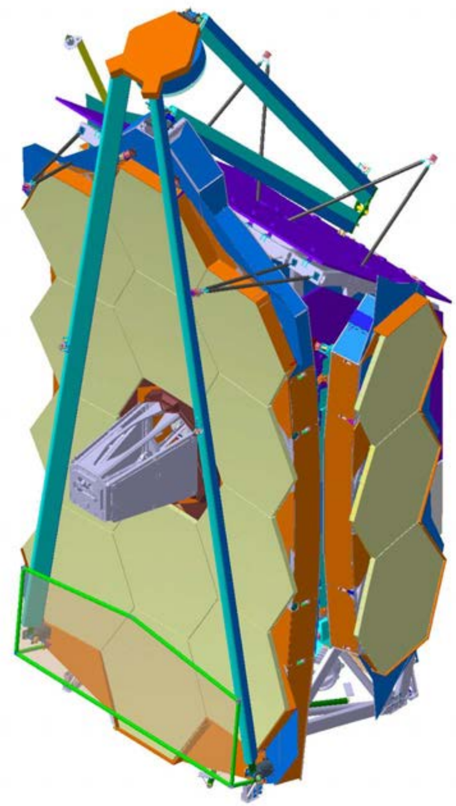
Test membranes



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.

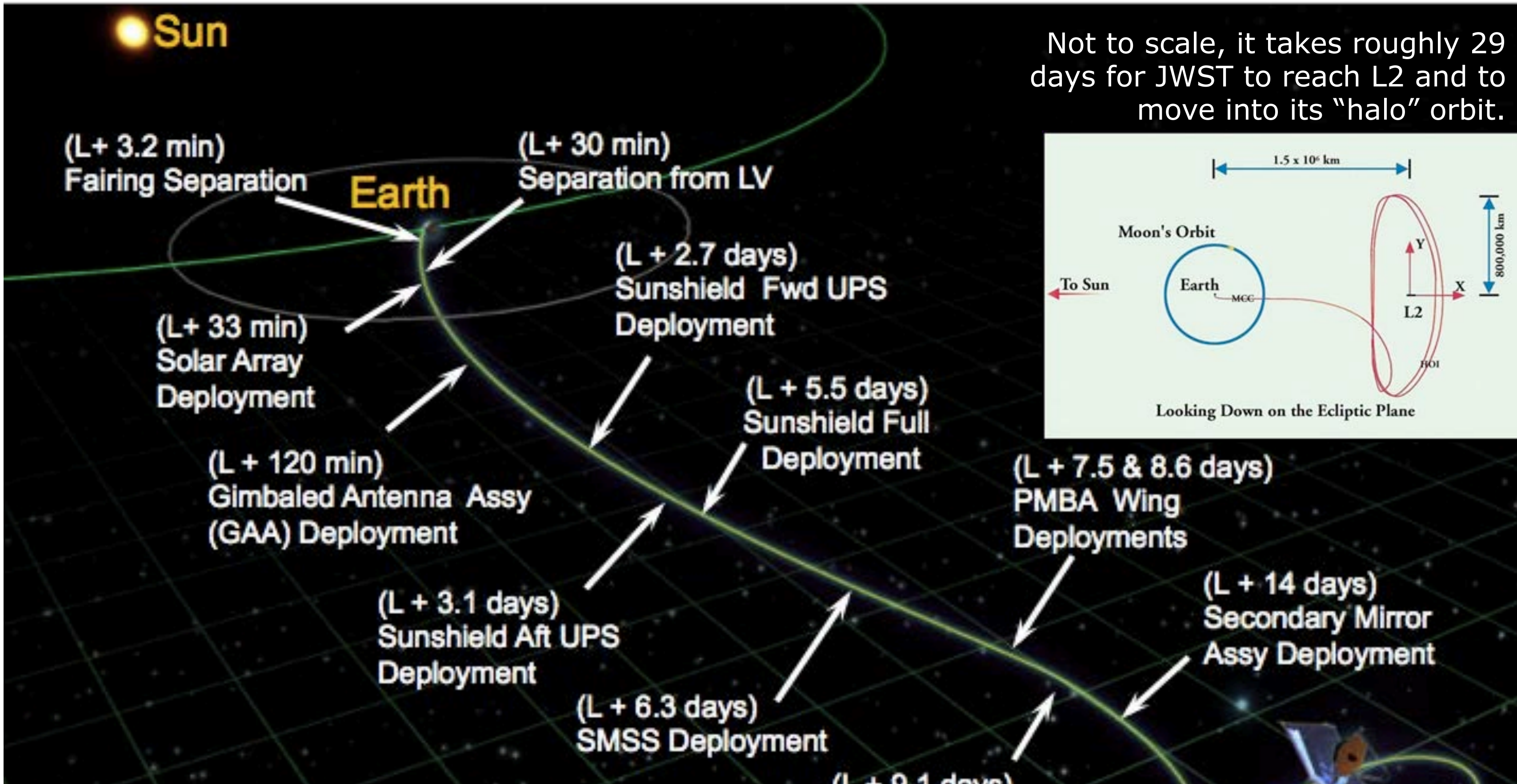




Without the sun shield

The James Webb Space Telescope
The deployment

Not to scale, it takes roughly 29 days for JWST to reach L2 and to move into its "halo" orbit.



L = launch
LV = launch vehicle
UPS = unitized pallet structure (structure supporting the sunshield)
GAA = gimbaled antenna assembly
SMSS = secondary mirror support structure
PMBA = primary mirror backplane assembly

The James Webb Space Telescope
The deployment

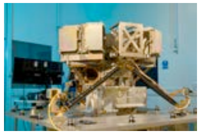
The James Webb Space Telescope
The orbit

Nice but far from correct…

The instruments…

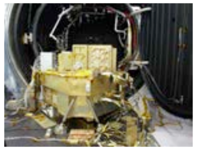
- **4 instruments installed on the "back" of the primary mirror in a structure called ISIM (integrated science instrument module).**

MIRI

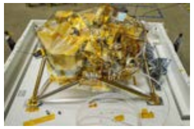


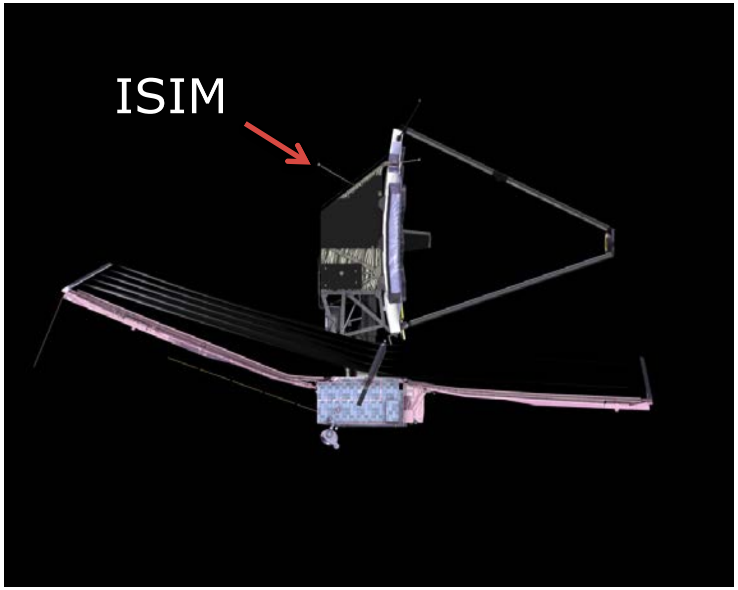
NIRSpec

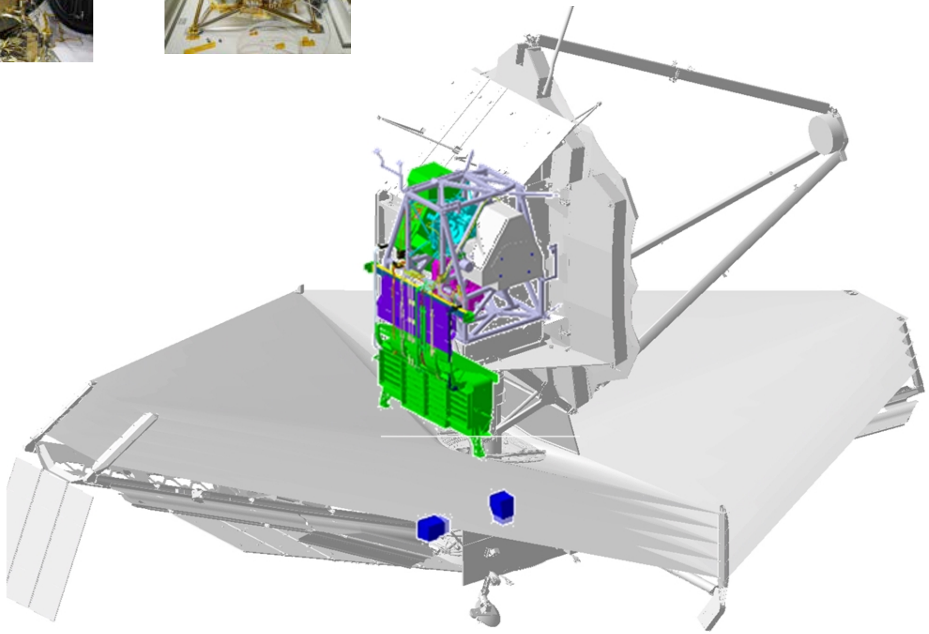
FGS/NIRISS



NIRCam

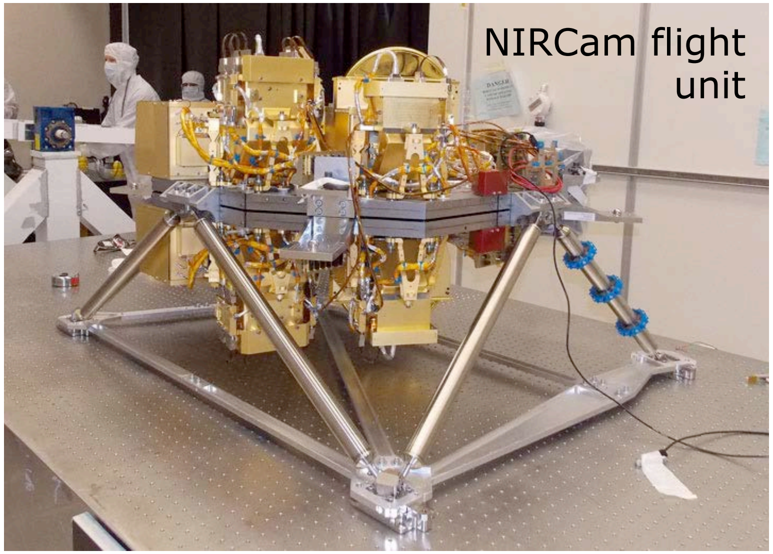






JWST/NIRCam

- **NIRCam is the main near-infrared camera (0.6-5 microns) for JWST.**
  - Also provides some coronagraphic and spectroscopic capabilities
- **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.
  - Integrated in JWST’s payload module (ISIM). Went through 1 cryogenic test campaign at ISIM level already.



JWST/FGS and NIRISS

- **NIRISS = Near-infrared imager and slit-less spectrograph and FGS = Fine Guidance Sensor**
    - Provided by the Canadian Space Agency (PIs: René Doyon).
    - Delivered to NASA (in July 2012).
    - Integrated in JWST's payload module (ISIM). Went through 2 cryogenic test campaigns at ISIM level already.
- **NIRISS will provide both imaging and spectroscopic capabilities**
    - Complementary to NIRCam.
    - Also aperture mask interferometry.
- **FGS is the guider for JWST.**



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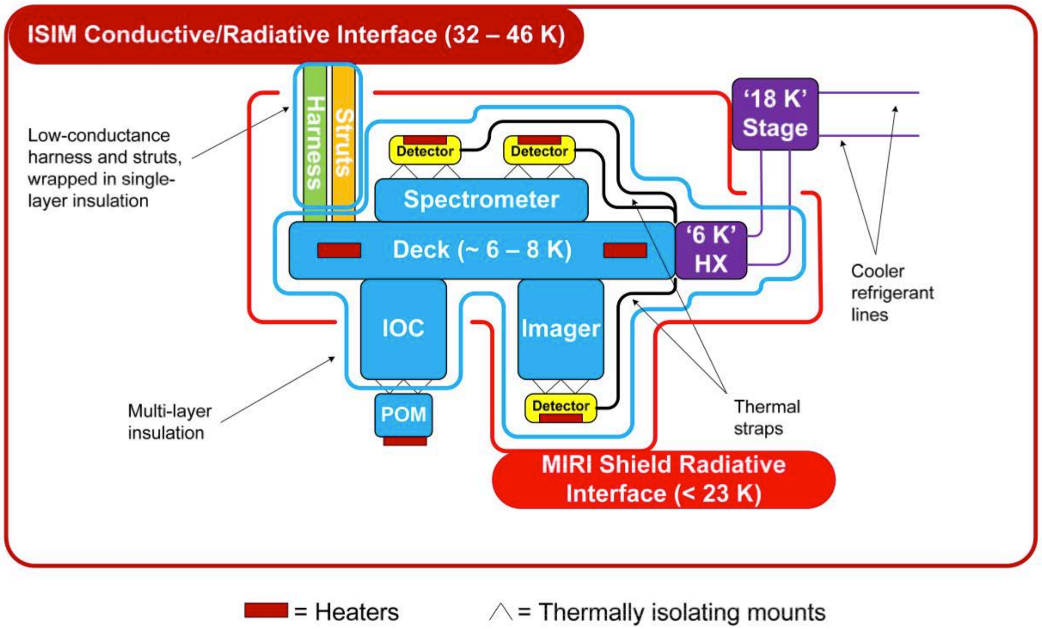
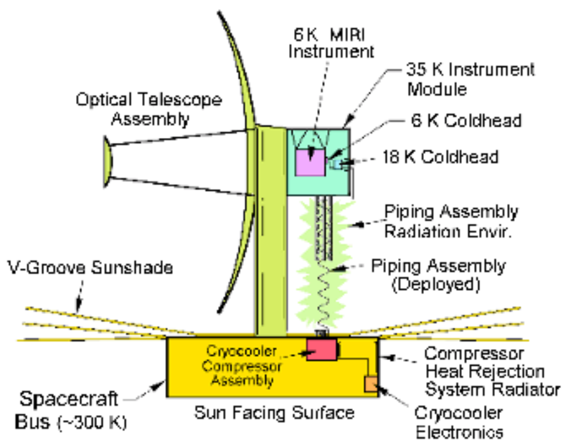
JWST/MIRI

- **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).
    - Integrated in JWST’s payload module (ISIM). Went through 2 cryogenic test campaigns at ISIM level already.
- **Will provide imaging, spectroscopic and coronagraphic capabilities from 5 to 27-28 microns.**
    - Unique capabilities within the JWST instrument suite.

JWST/MIRI

- **MIRI instrument consists 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.

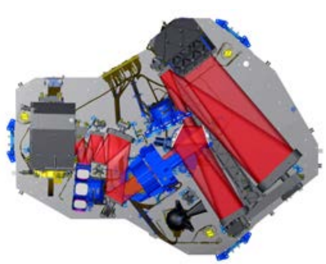


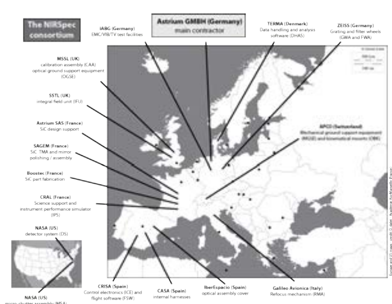


JWST/NIRSpec

- **NIRSpec = Near-InfraRed Spectrograph**
  - Part of the ESA contribution to the JWST mission.
  - Built for ESA by a European industrial consortium led by EADS Astrium GMBH.
  - NASA-provided detectors and micro-shutter arrays.
  - Integrated in JWST's payload module (ISIM). Went through 1 cryogenic test campaign at ISIM level already.

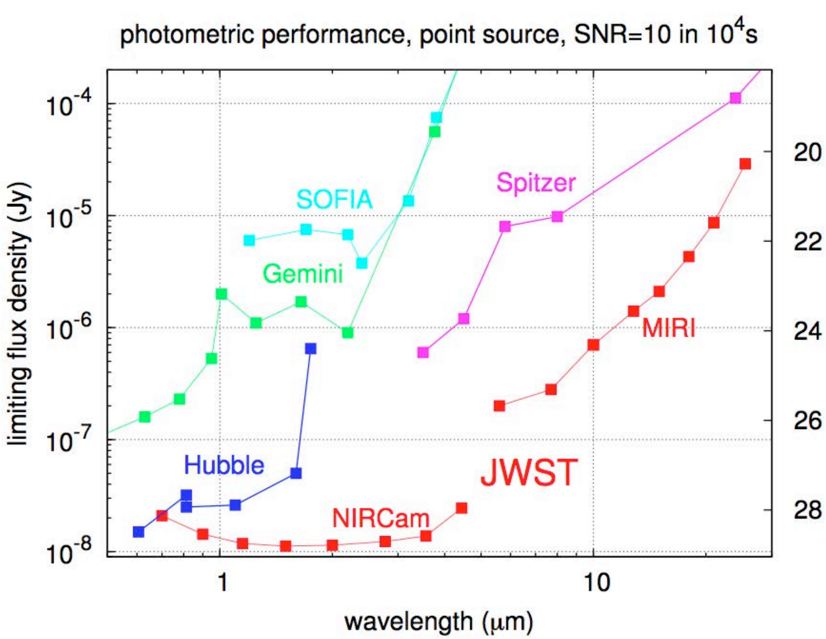
- **NIRSpec provides spectroscopic capabilities in the 0.6-5.0 micron range.**

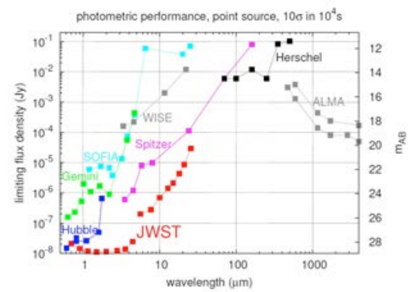




JWST imaging capabilities

Instrument	Wavelength (in microns)	Pixel scale (in mas/pixel)	Field of view (arcmin x arcmin)
NIRCam	0.6-2.3	32	2.2′ x 4.4′
NIRCam	2.4-5.0	65	2.2′ x 4.4′
NIRISS	0.9-5.0	65	2.2′ x 2.2′
MIRI	5.0-28	110	1.3′ x 1.7′



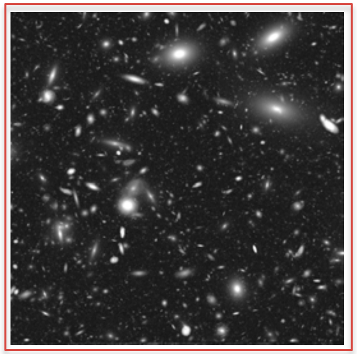


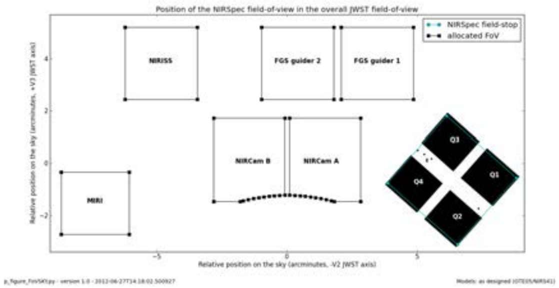
NIRCam: Simultaneous imaging of the same field of view in the 'blue' and 'red' channels.

- **More than one order of magnitude sensitivity improvement in some bands.**
- Extremely powerful observatory, a lot of discovery space.

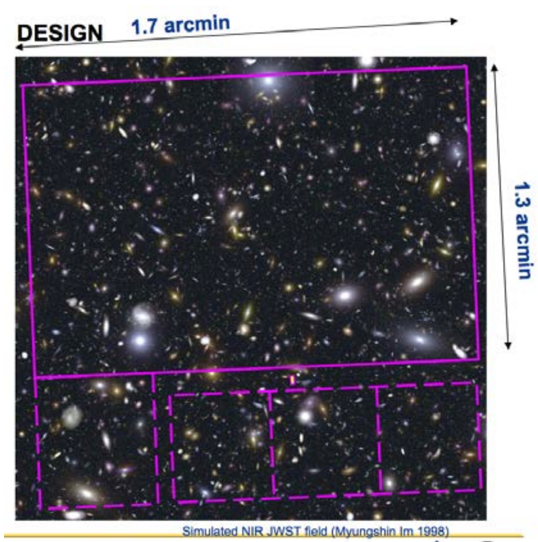
JWST imaging capabilities

NIRISS (2.2′ x 2.2′)

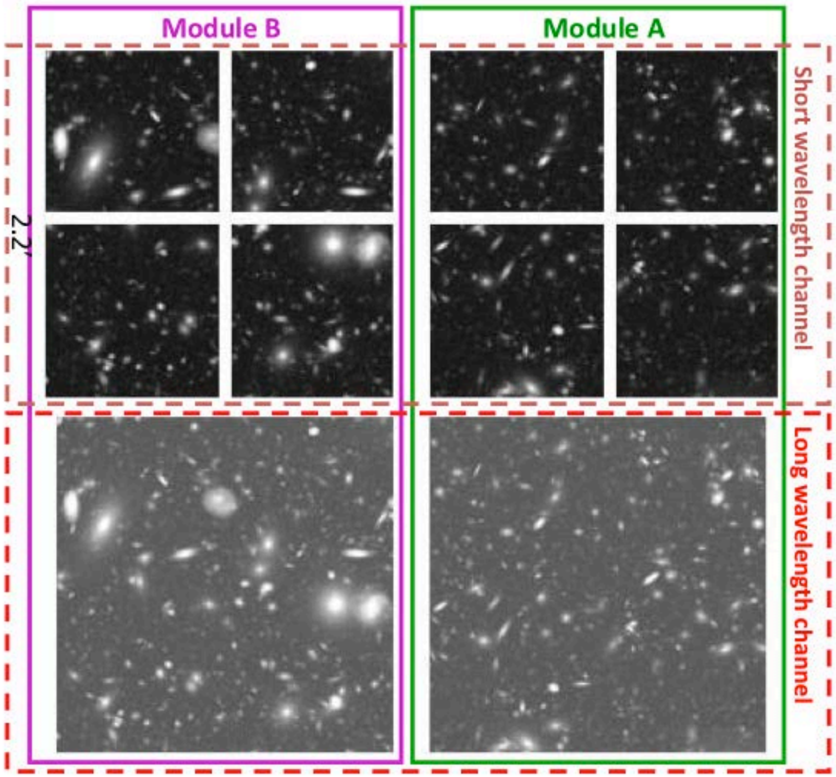




MIRI (1.7′ x 1.3′)



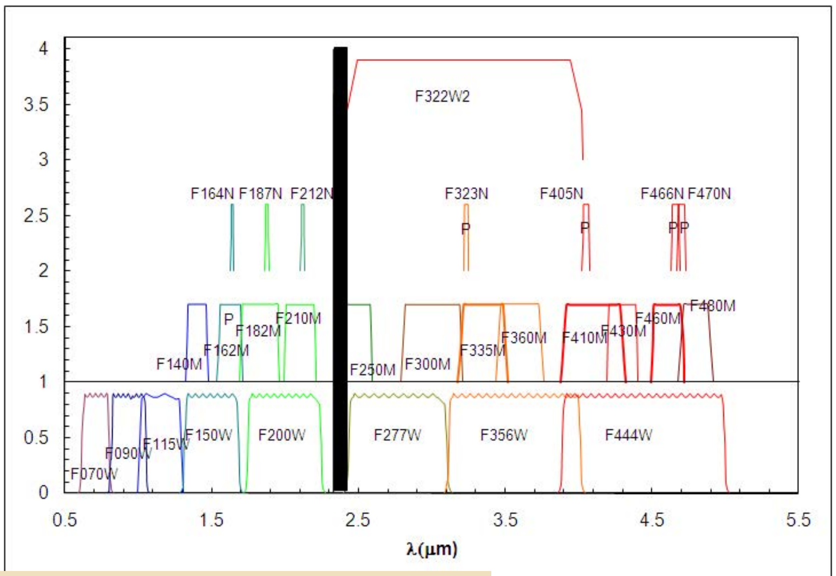
NIRCam (4.4′ x 2.2′)

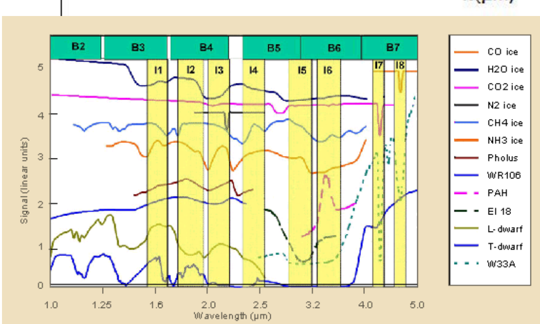


Not to scale.

JWST imaging capabilities

- **NIRCam and MIRI: a wide choice of filters.**
  - NIRCam wide filters are also available in NIRISS.
- **Band passes selected to cover interesting spectral features / bands both in the galactic and extra-galactic domains.**





NIRCam

MIRI

Filter name (and wavelength)	Pass band Δλ (μm)
F560W	1.2
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

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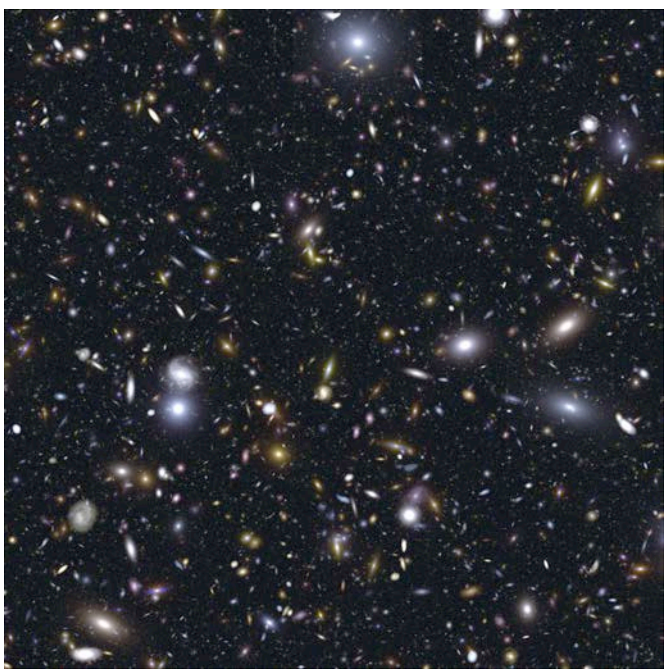
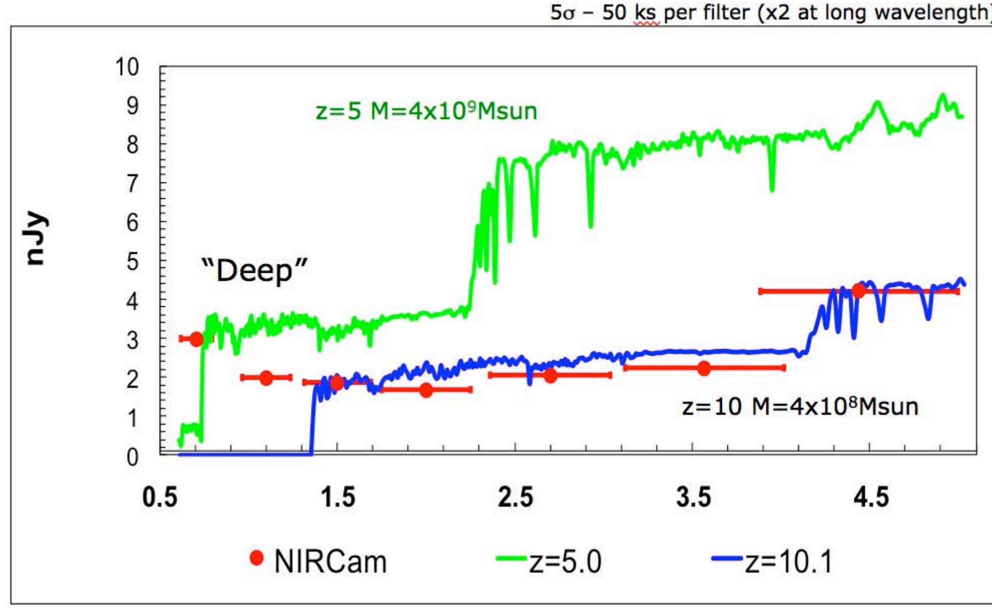
European Space Agency

JWST imaging capabilities
Deep-field science case

- **Emblematic science case in the context of the study of the formation of the first stars and galaxies.**
  - Looking for "not-so-massive" objects in the z>10 Universe.
  - Going far beyond the limits reached by the HST in projects like the HUDF (z between 5 and 10; struggling).
- **Very deep multi-band imaging with exposure times that can go up to 50-100ks per field and per band.**



5σ – 50 ks per filter (x2 at long wavelength)



Milky Way = 5-6 x 10^{11} M_{sun}

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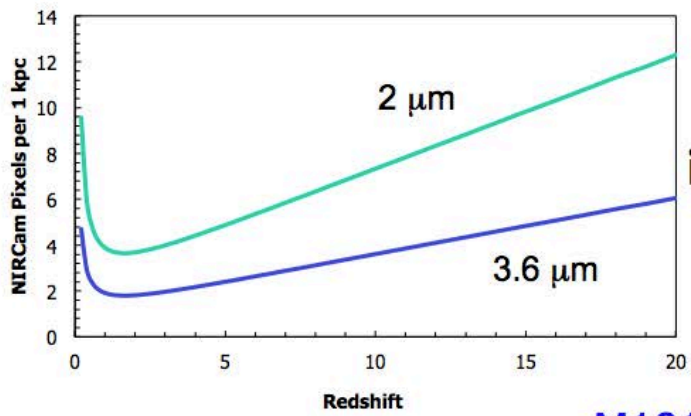
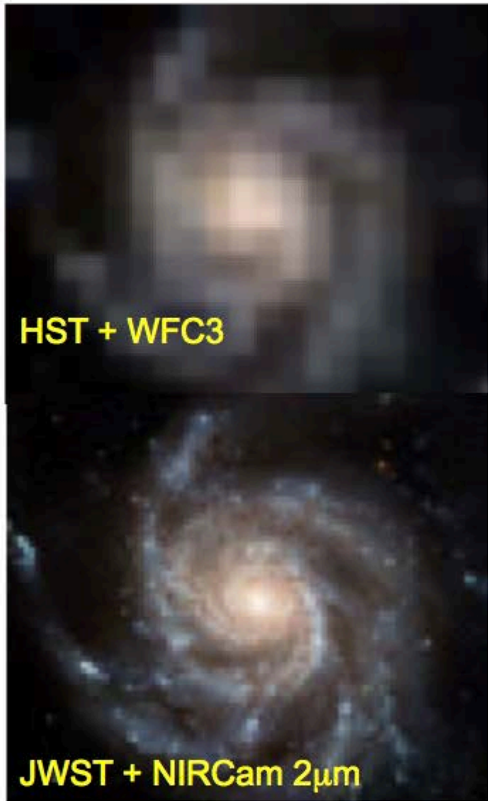
European Space Agency

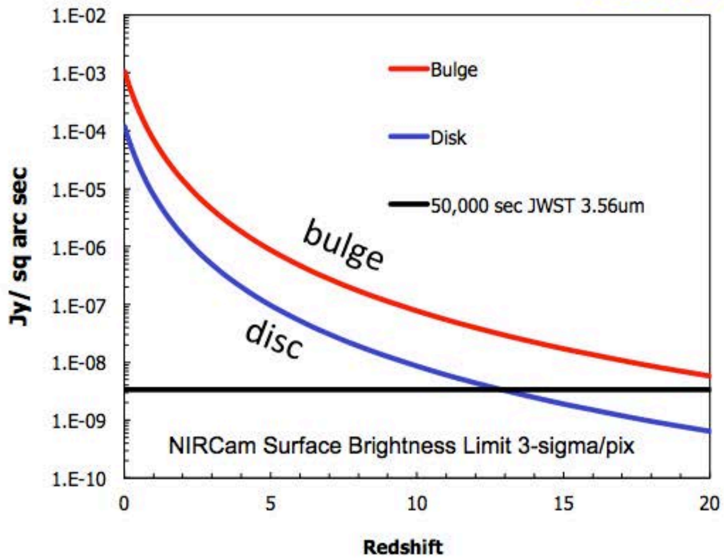
JWST imaging capabilities
Deep-field science case

Not just photometry: resolving the evolution of individual galaxy components



M101 at z=5





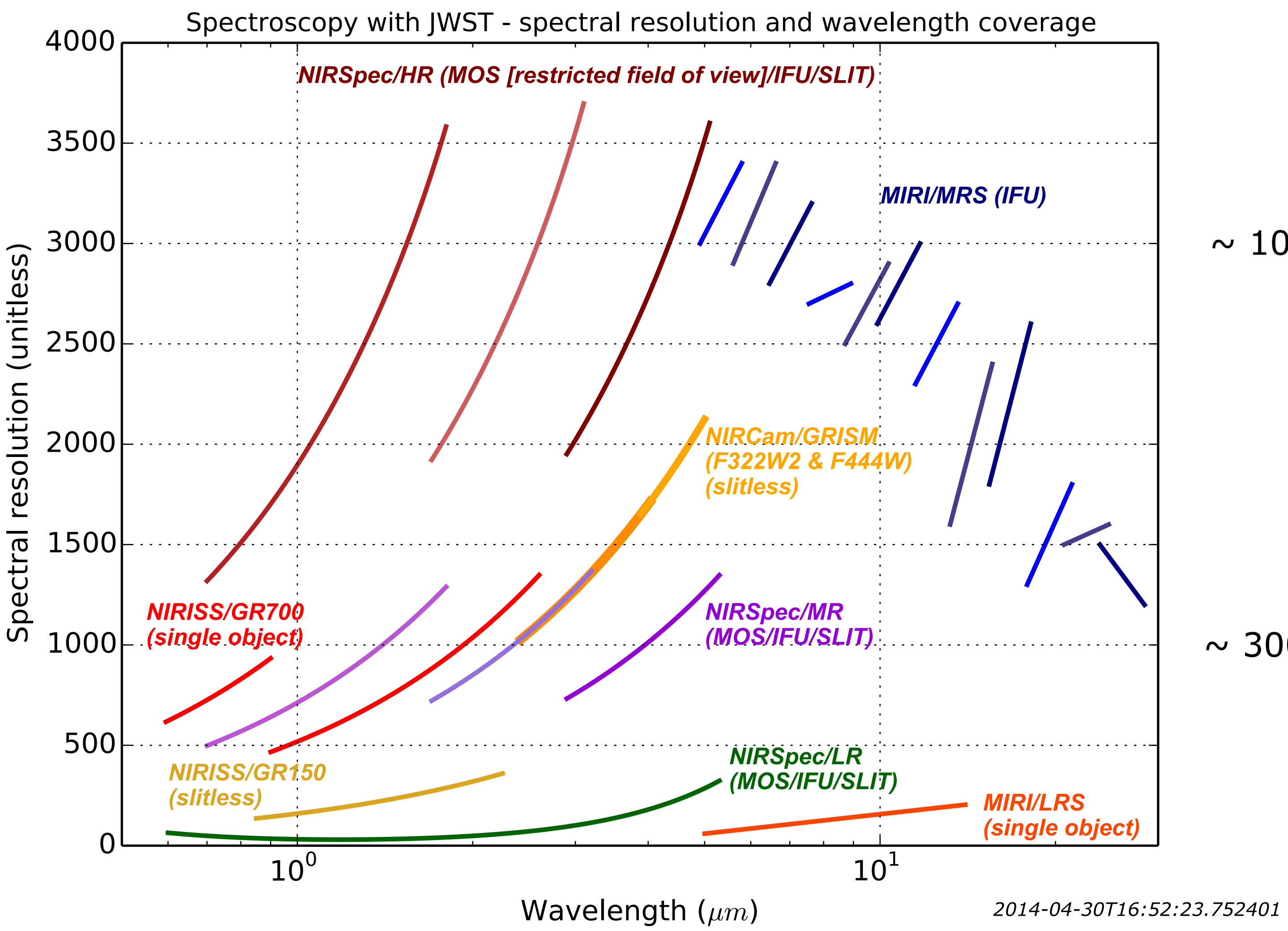
From Maiolino 2014, presentation at the HST conference IV in Rome

JWST spectroscopic capabilities

- **Take-home message: in JWST, spectroscopy comes in many different flavors…**
  - Can address many different scientific needs.

Instrument	Type	Wavelength (microns)	Spectral resolution	Field of view
NIRISS	slitless	1.0-2.5	~150	2.2′ x 2.2′
NIRCam	slitless	2.4-5.0	~2000	2.2′ x 2.2′ (TBC)
NIRSpec	MOS	0.6-5.0	100/1000/2700	9 square arcmin.
NIRSpec	IFU	0.6-5.0	100/1000/2700	3″ x 3″
MIRI	IFU	5.0-28.8	2000-3500	>3″ x >3.9″
NIRSpec	SLIT	0.6-5.0	100/1000/2700	Single object
MIRI	SLIT	5.0-10.0	60-140	Single object
NIRISS	Aperture	0.6-5.0	100/1000/2700	Single object
NIRSpec	Aperture	0.6-2.5	700	Single object

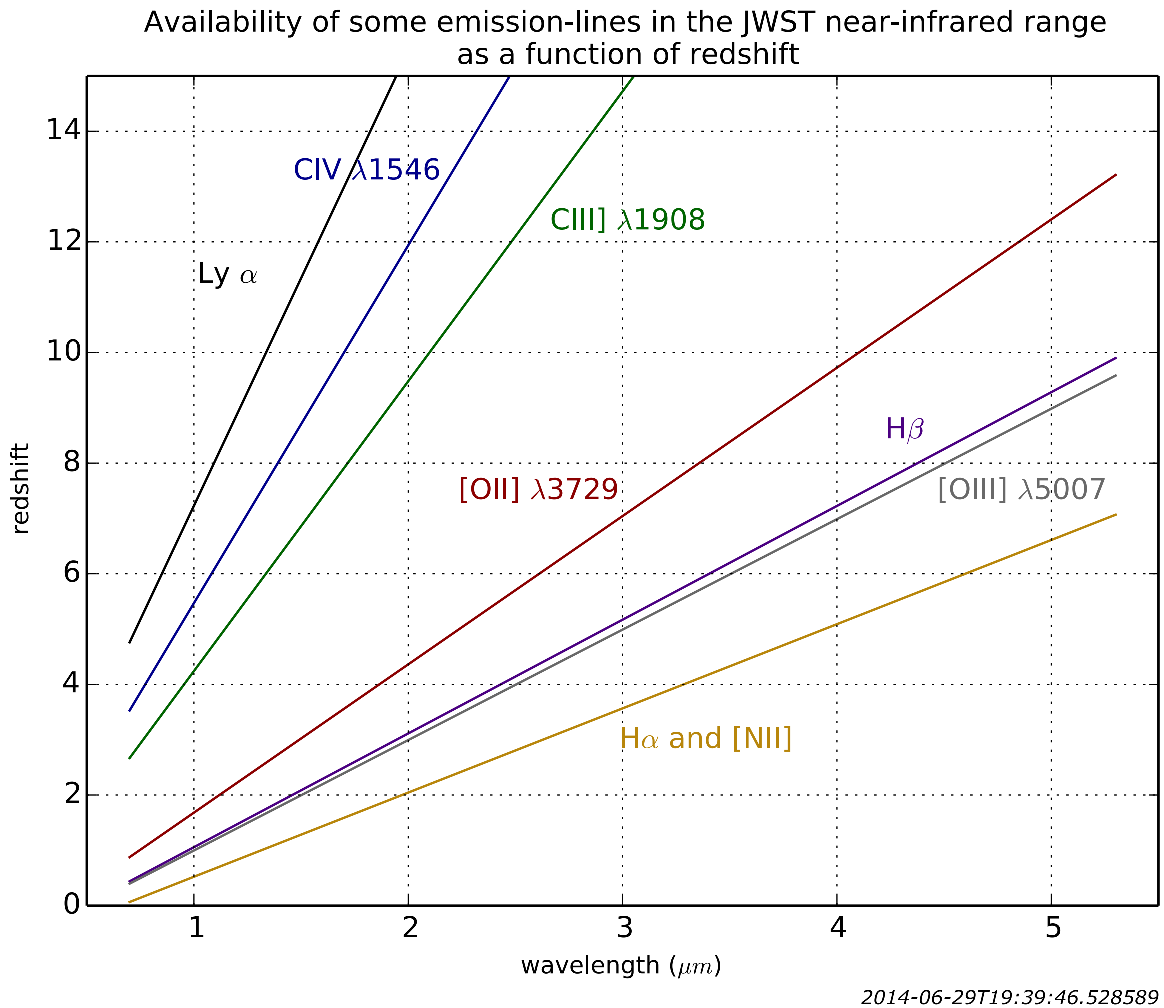
JWST spectroscopic capabilities
Spectral resolution



~ 100 km/s

~ 300 km/s

JWST spectroscopic capabilities
“Classical” emission-lines versus redshift

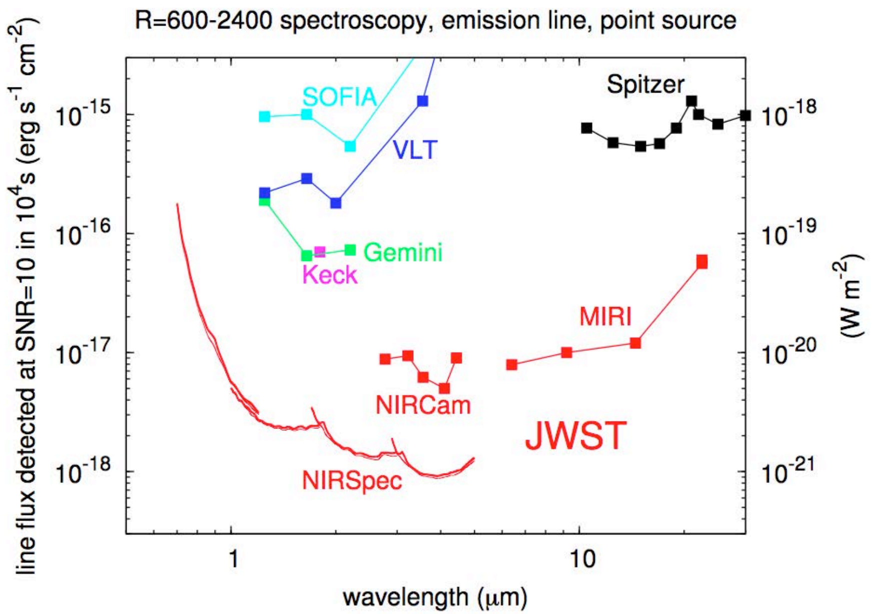


Classical lines moving into the mid-infrared domain

Classical diagnostics available in the near-infrared instruments

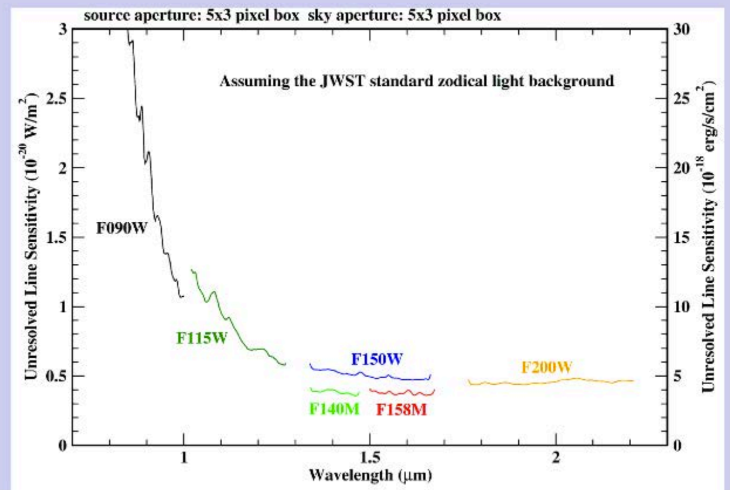
JWST spectroscopic capabilities

- **Huge sensitivity improvement compared to existing or passed facilities.**
    - Extremely powerful observatory, a lot of discovery space.
- **And what about the ELTs?**
    - Different strengths and weaknesses. ➔ strong complementarity.

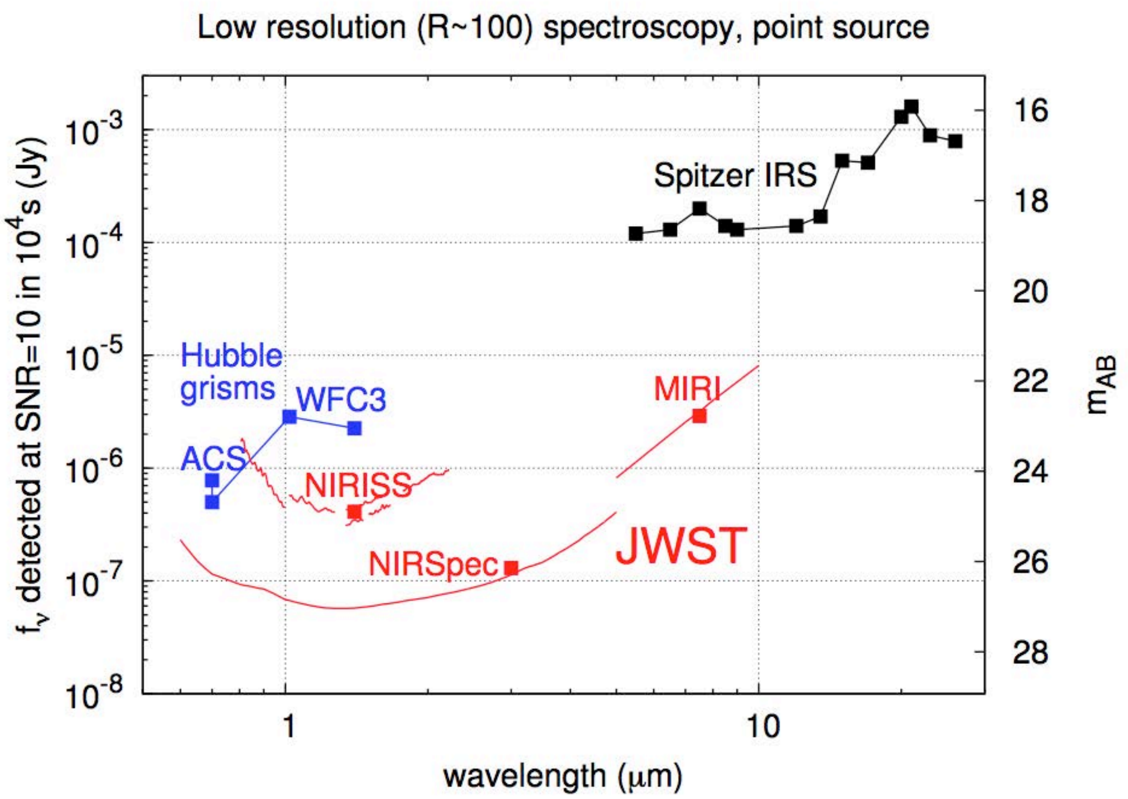


NIRISS/slitless spectrally unresolved line

5×10^{-18} erg/s/cm^2 with S/N=10 in 10 ks

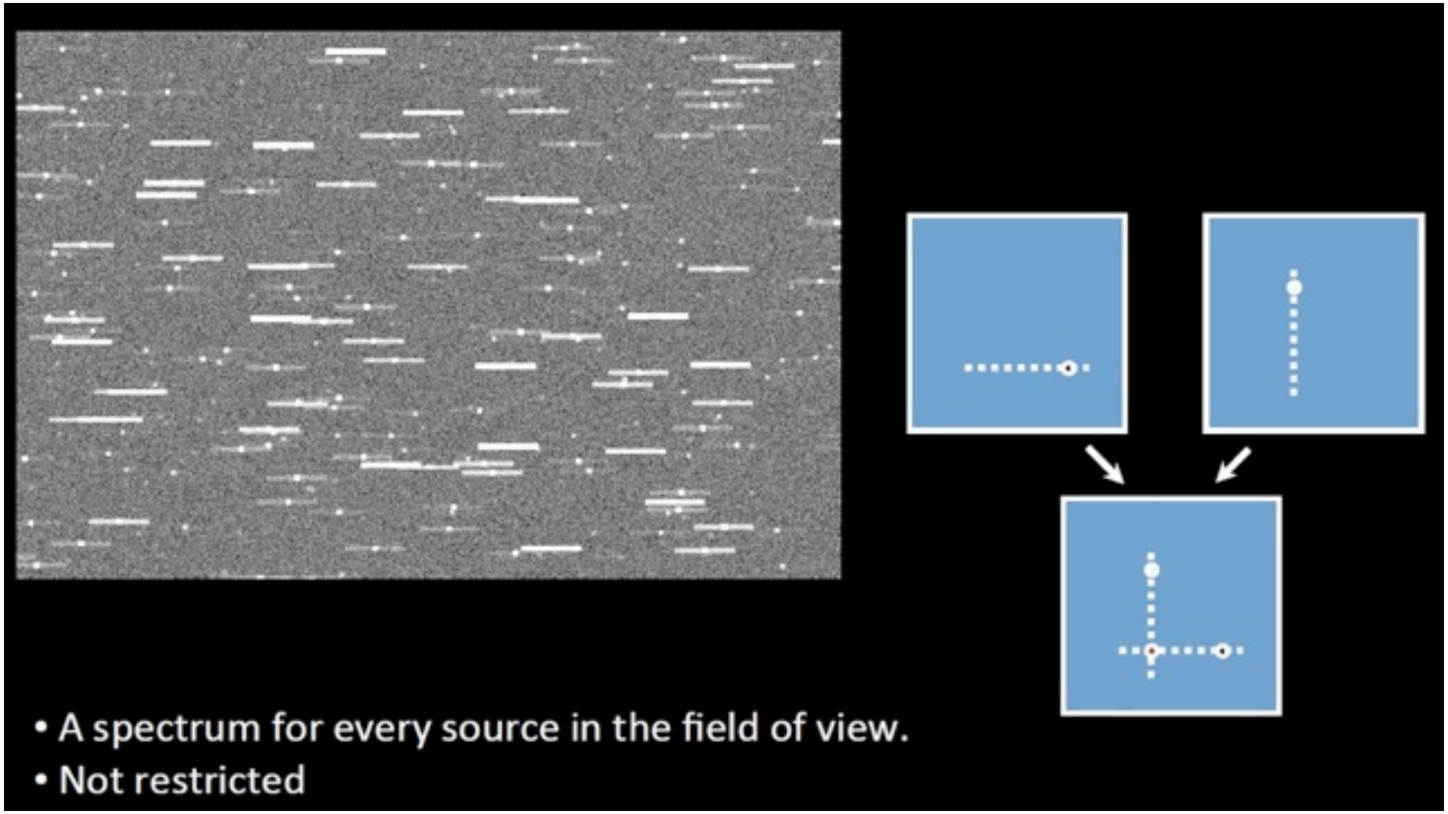


JWST spectroscopic capabilities



JWST spectroscopic capabilities
Slitless spectroscopy

- **Mode proposed by NIRISS (0.6-2.5 microns) and NIRCam (2.5-5.0 microns)**
  - Optimized configurations with 2 different dispersion directions readily available.



Credit: C. Willot

JWST spectroscopic capabilities
Slitless spectroscopy

Wide-Field Slitless Spectroscopy with NIRISS: Simulations of MACS J0647+7015

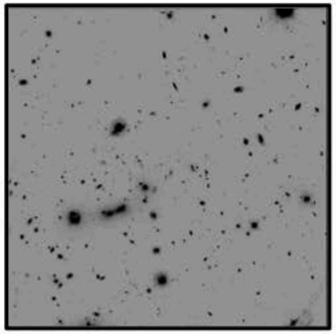
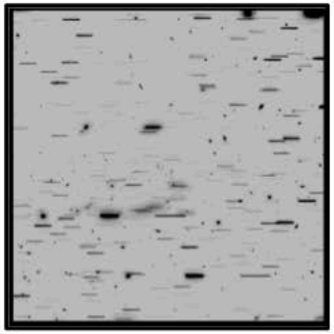
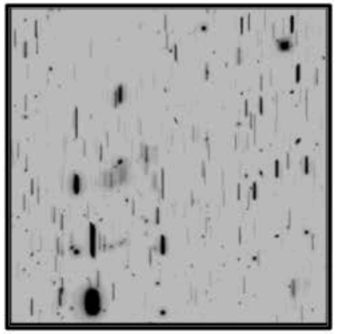


Image: F200W

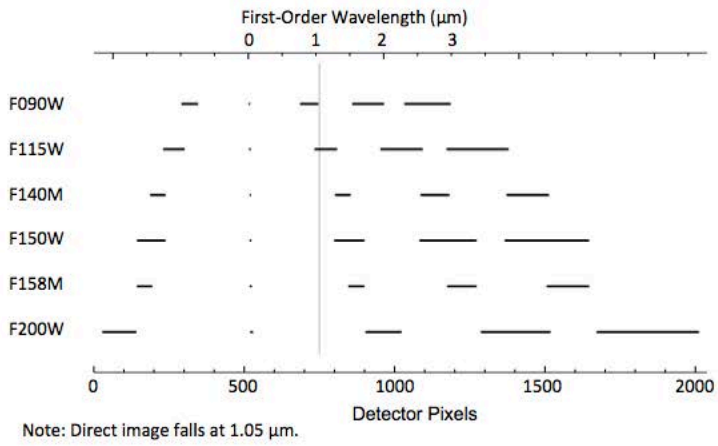


Spectra: GR150R, F200W

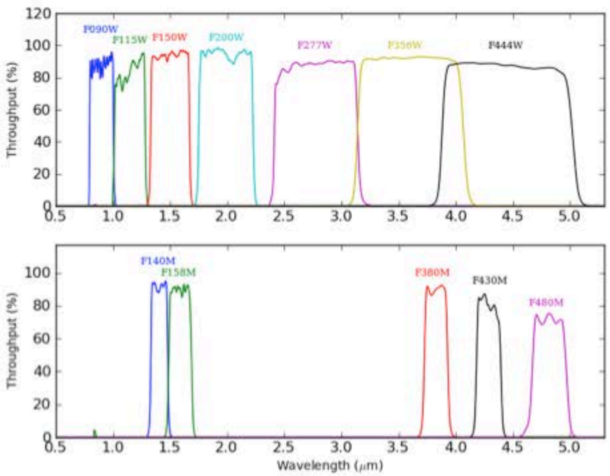


Spectra: GR150C, F200W

Layout of Spectral Orders



Filter Transmission Profiles

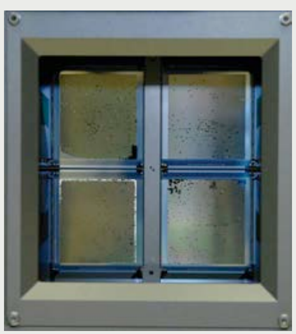


Credit: C. Willot

JWST spectroscopic capabilities
MOS spectroscopy

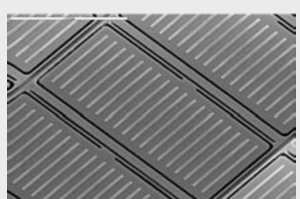
- **MOS = Multi-Object Spectroscopy**
  - Getting spectra of 60-100 objects per exposure while masking the light from the rest of the field of view.
- **Masking the rest of the field of view is where the challenge is.**
  - Implemented in NIRSpec using **arrays of micro-shutters** that can be individually controlled (open or closed).

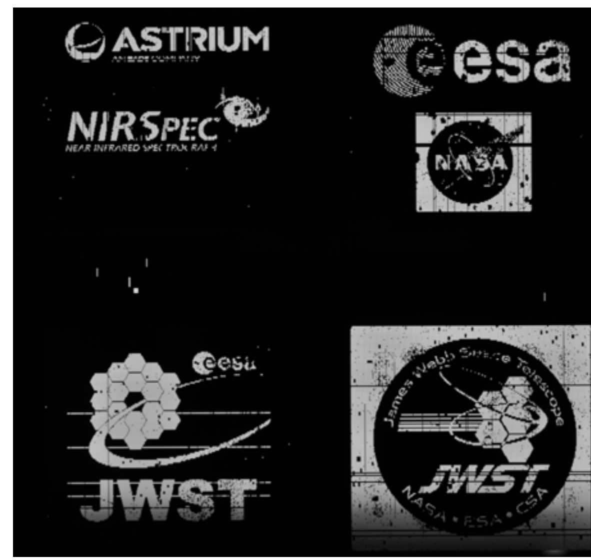
Using 4 arrays of 365x171 micro-shutters each, provided by NASA GSFC.



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

MEMS device – 105x206 micron shutters

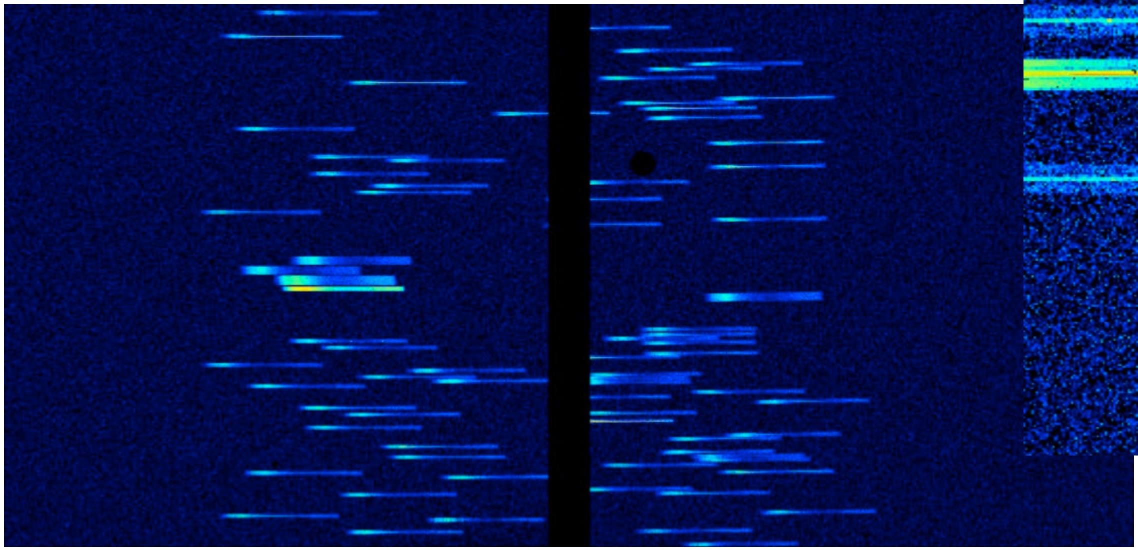


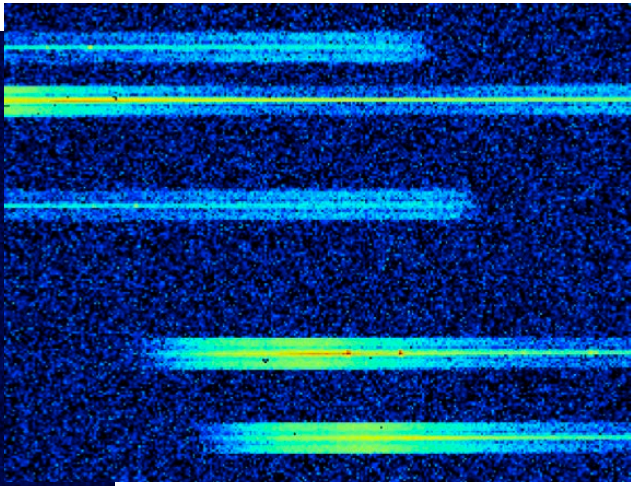


The operability of the shutters is a key performance parameter (~85-90%).

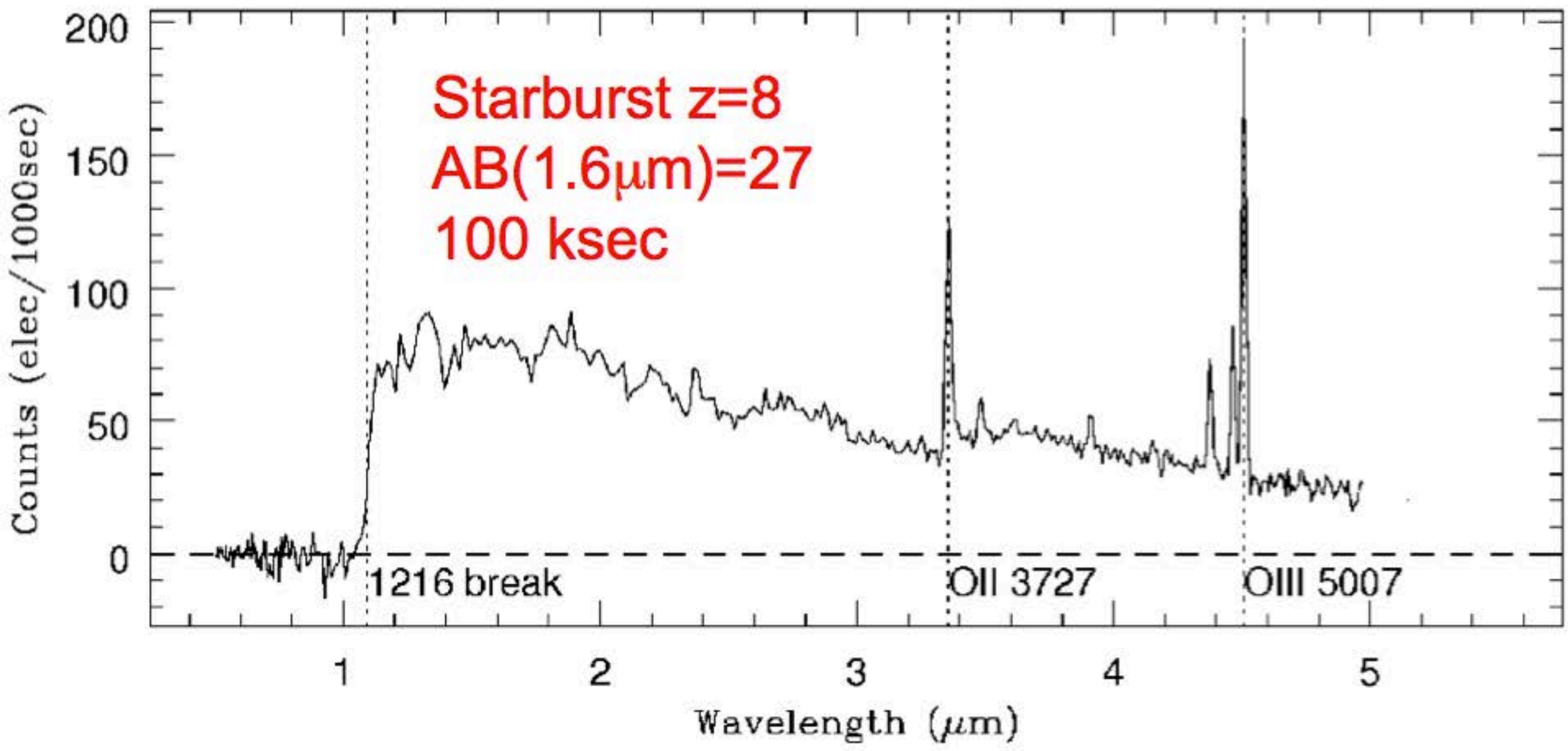
JWST spectroscopic capabilities
MOS spectroscopy

- **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.





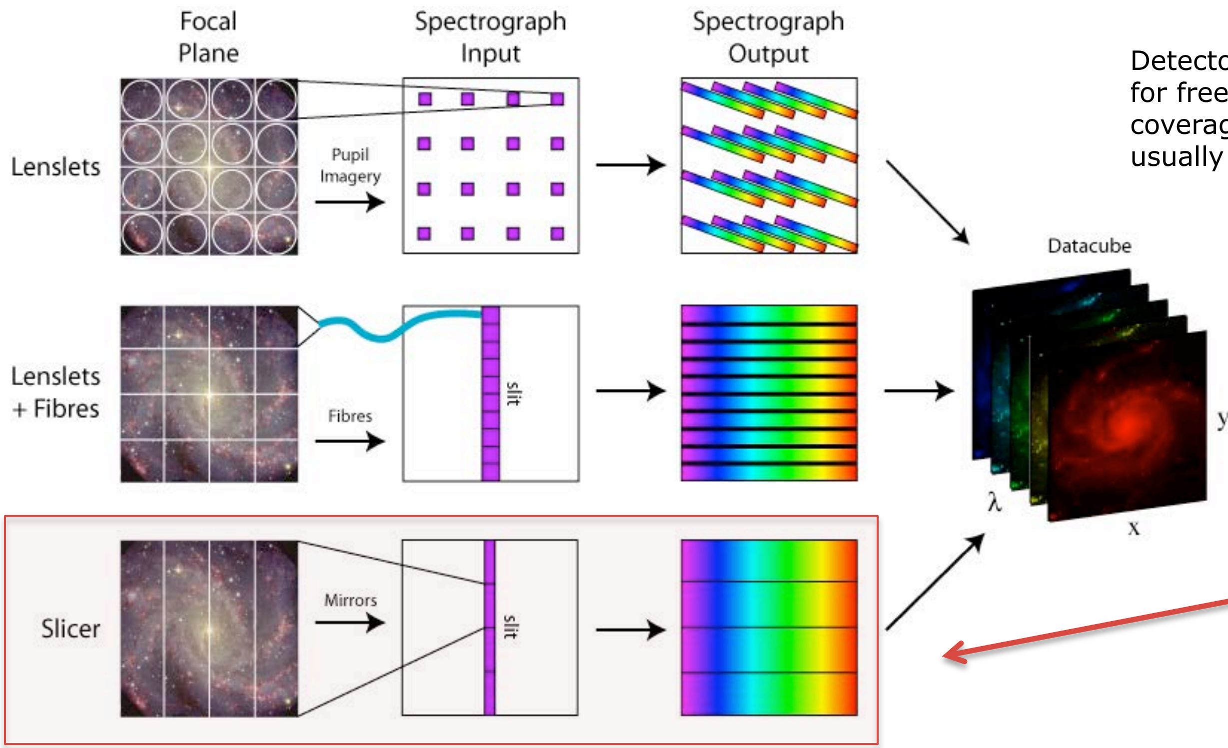
JWST spectroscopic capabilities
MOS spectroscopy



From Maiolino 2014, presentation at the HST conference IV in Rome

JWST spectroscopic capabilities IFU spectroscopy

- **IFU = integral-field unit**
  - Implemented in NIRSpec and MIRI.
- **Packing 3 dimensions on a 2D detectors…**
  - Rearranging the view to be able to disperse the light without ending up with overlapping spectra.

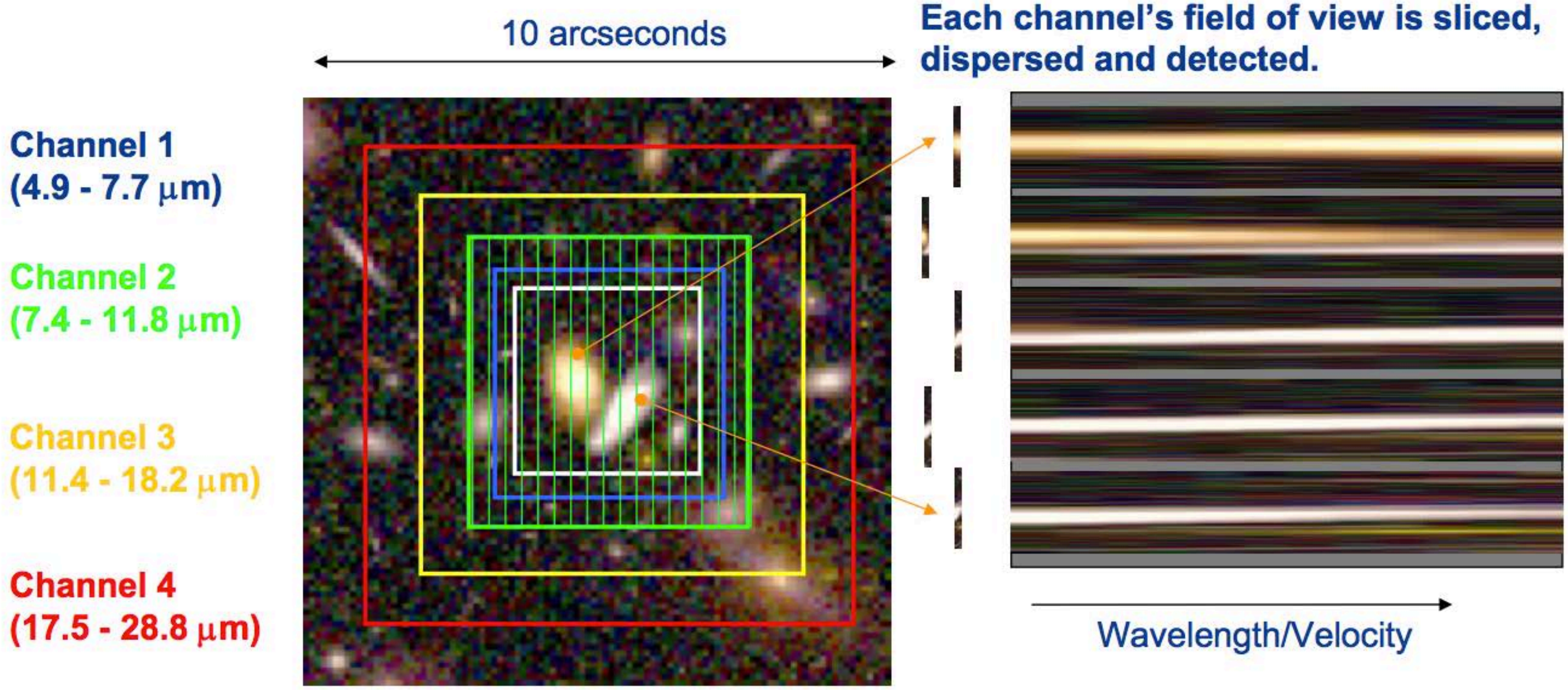


Detector real-estate does not come for free. The price for 2D spatial coverage is that IFU modes have usually small fields of views.

Solution used in JWST

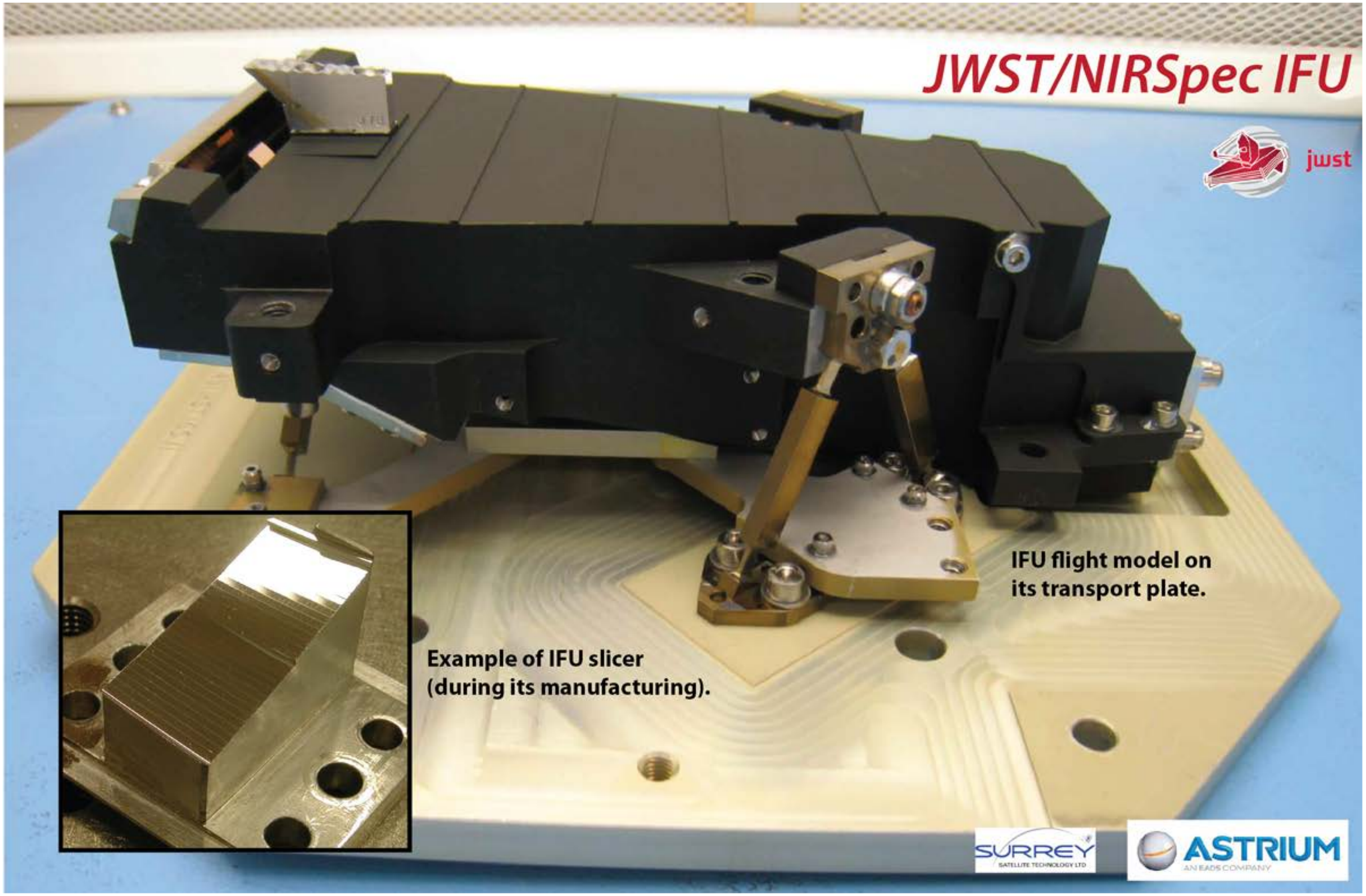
Credit: M. Westmoquette, adapted from Allington-Smith et al. 1998

- **MIRI IFU**
  - Covering the 4.9-28.8 micron range continuously in 3 exposures!
  - Mapping spectrally your objects over a field of view larger than 3” x 3.9”.



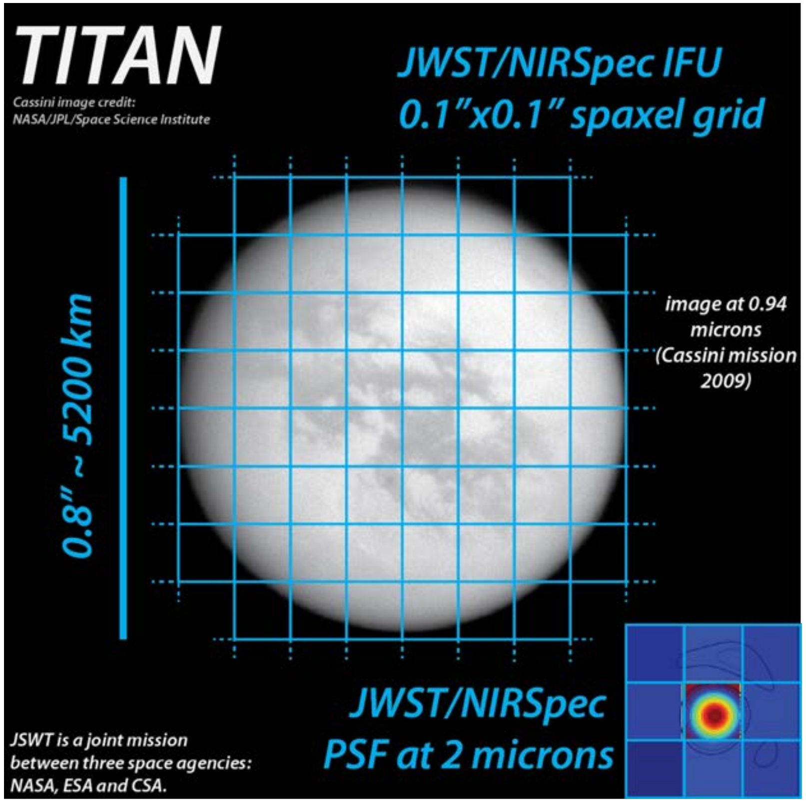
Credit: M. Westmoquette, adapted from Allington-Smith et al. 1998

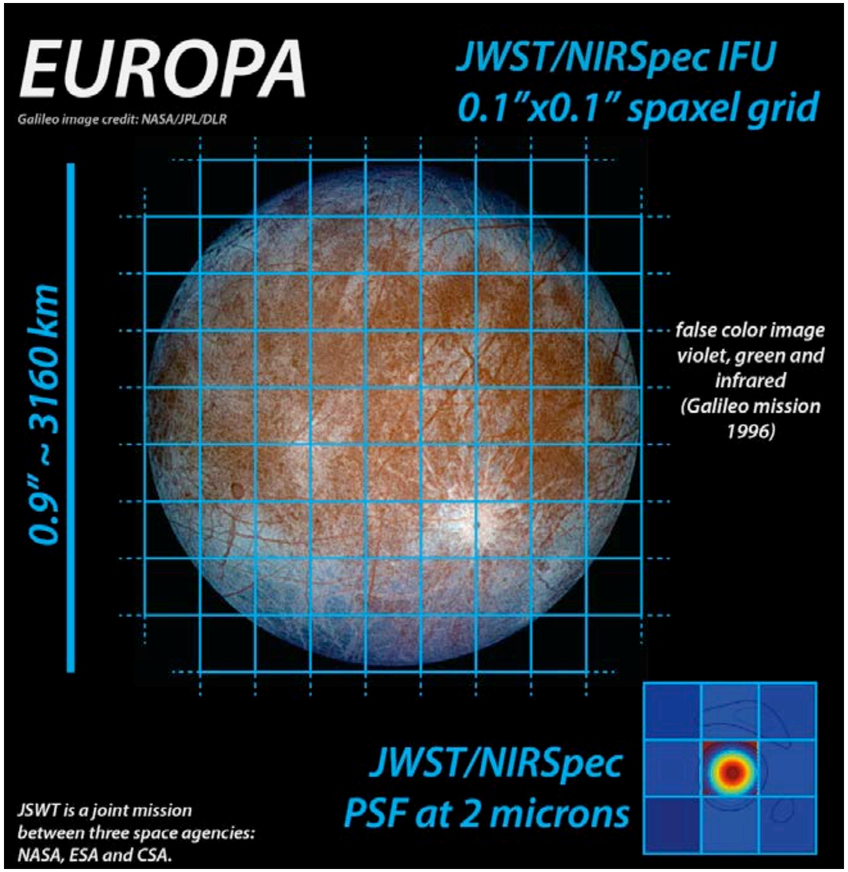
JWST spectroscopic capabilities
IFU spectroscopy



Note: the complete IFU has the size of a shoe box.

- **Mapping spatially extended objects…**





Credit: M. Westmoquette, adapted from Allington-Smith et al. 1998

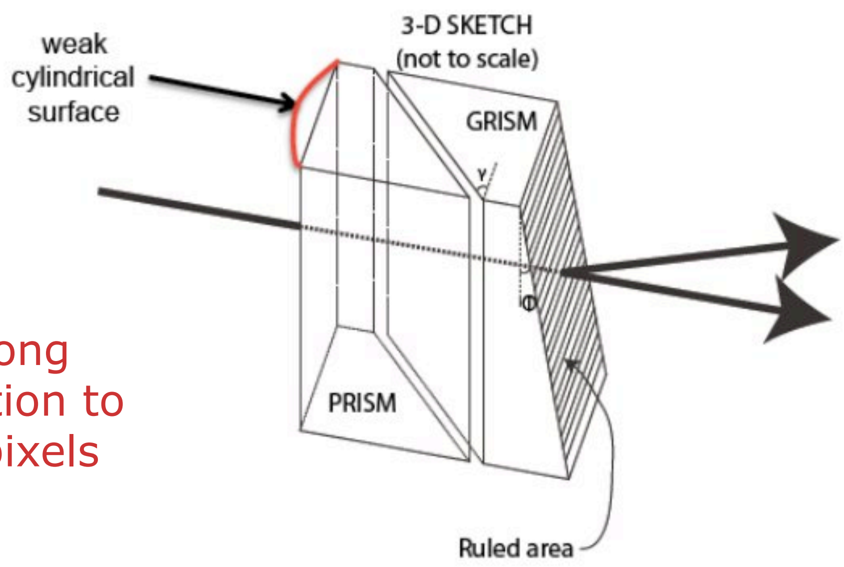
JWST spectroscopic capabilities Slit and aperture spectroscopy

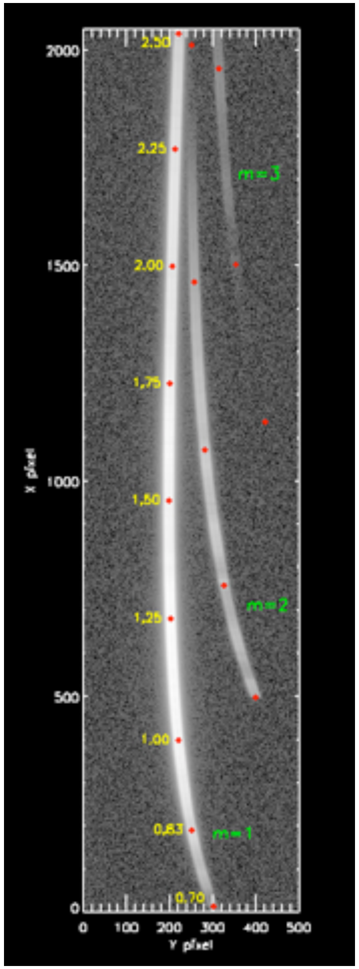
- **A variety of slit and aperture spectroscopy modes have been implemented in NIRISS, NIRSpec and MIRI.**
- **Dwelling a little bit more on the case of exo-planet transit spectroscopy.**
  - This topic has gained more and more momentum as JWST was developed.
  - Specific modes have been implemented.
- **The observation conditions for transit spectroscopy are very different from those encountered when doing faint-object spectroscopy.**
  - Detecting faint variations of a very strong signal.
  - JWST is typically aiming at detecting variations **in spectra** of several tens to a few hundreds parts per million.

- **CAUTION: JWST will not be a "survey" mission aiming at detecting transits (photometry) but will be very powerful for the follow-up.**

Credit: M. Westmoquette, adapted from Allington-Smith et al. 1998

- **NIRISS has implemented a single object mode dedicated to transit spectroscopy and providing a 1-2.5 micron coverage at a resolution of ~700.**
  - Optimized to minimize systematics.



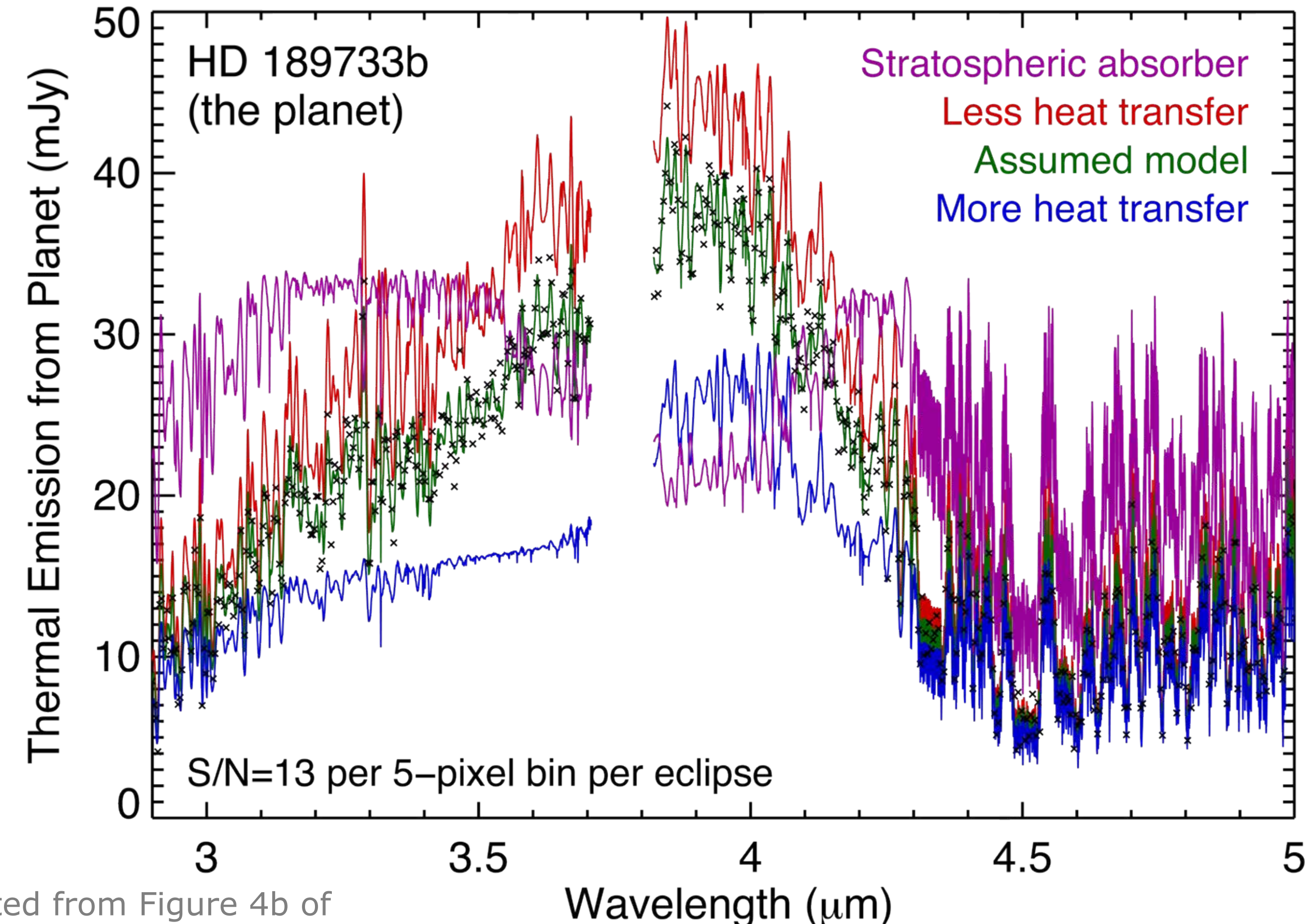


Weak lens defocuses along spatial direction to allow more pixels to sample spectrum

This allows the observation of very bright parent stars and minimizing the impact of pixel-level signatures in the signal.

JWST spectroscopic capabilities
Transit spectroscopy – Example with NIRSpec

- **Thermal emission from a hot Jupiter (secondary eclipse)**
  - Credit for the slide: J. Valenti (STScI).



Adapted from Figure 4b of
Burrows, Budaj, & Hubeny (2008)

JWST coronagraphic and aperture masking interferometry capabilities

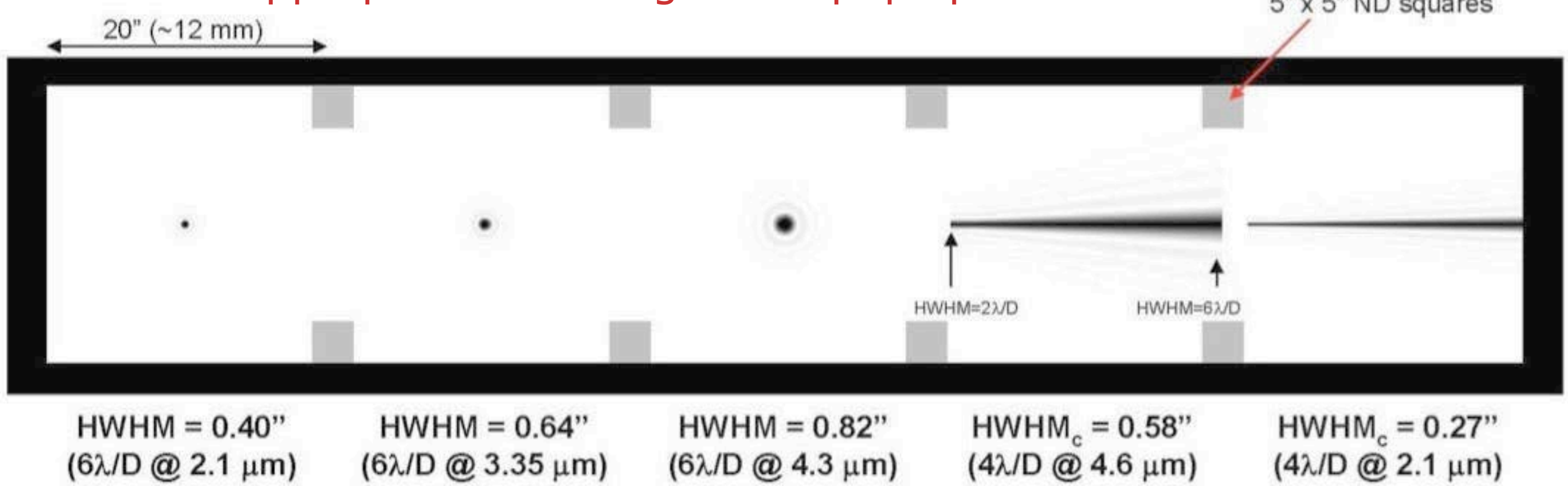
- **Example science cases: study of proto-planetary and debris disks, search for planetary companions.**

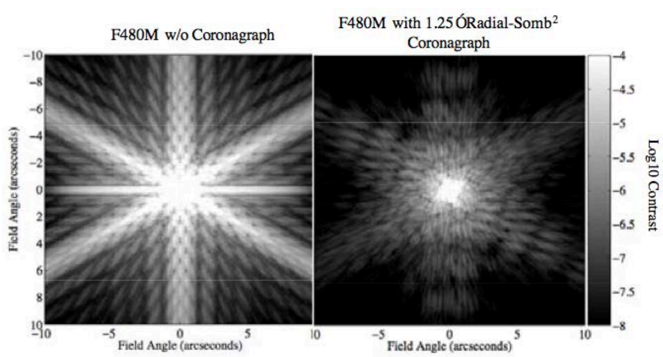
Instrument	Wavelength (in microns)	Pixel scale (in mas/pixel)	Field of view	Type
NIRCam	0.6-2.3	32	20″ x 20″	Lyot
NIRCam	2.4-5.0	65	20″ x 20″	Lyot
NIRISS	3.8-4.8	65	0.1-0.5″	Aperture masking interferometry
MIRI	10.65	110	24″ x 24″	4QPM
MIRI	11.4	110	24″ x 24″	4QPM
MIRI	15.5	110	24″ x 24″	4QPM
MIRI	23	110	30″ x 30″	Lyot

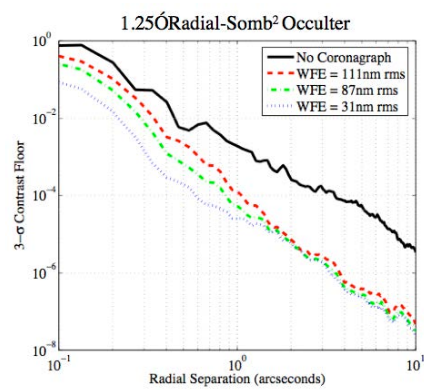
- **QPM = four-quadrant phase masks**

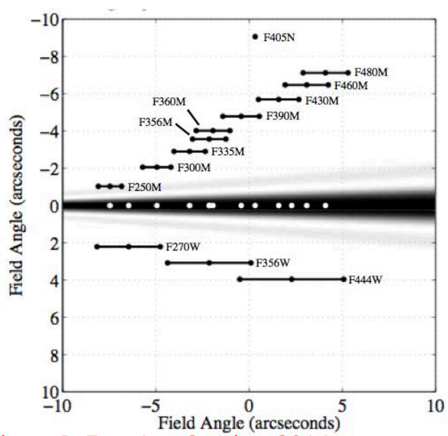
JWST coronagraphic and aperture masking interferometry capabilities

- **Lyot-stops**
  - Dedicated masks in the image plane associated to the appropriate masking in the pupil plane.









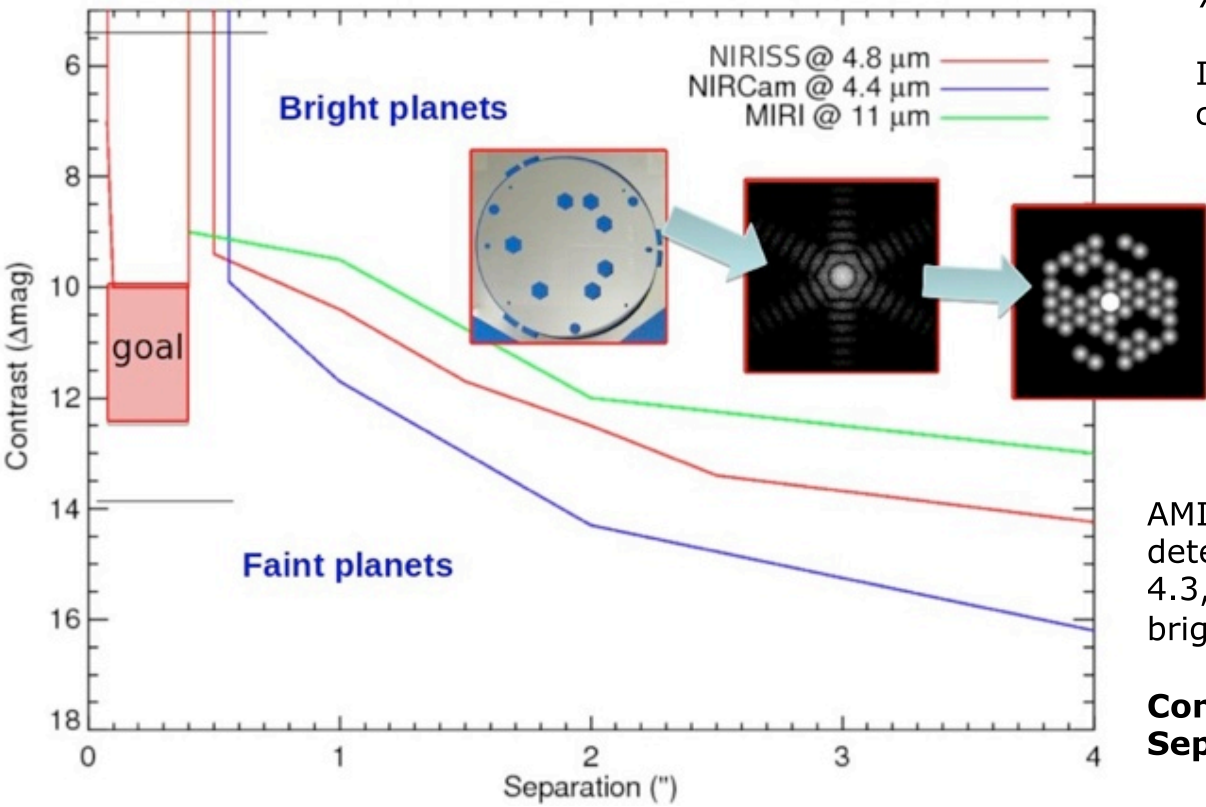
From Green at al., SPIE, 2005. Simulations

JWST/NIRISS – Aperture masking interferometry

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

PSF with a concentrated core corresponding to a resolution of 75 mas at 4.6 microns.

I need to go through the corresponding computation!!!

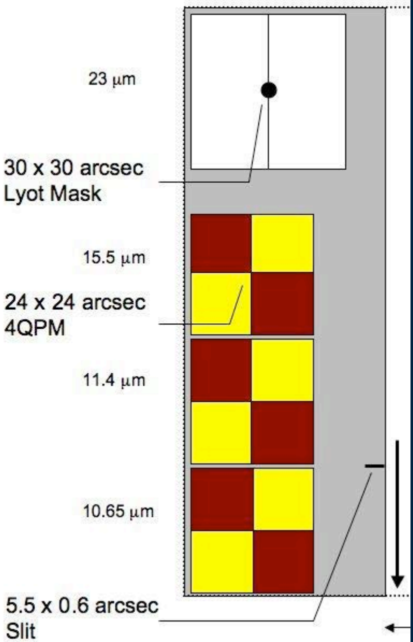


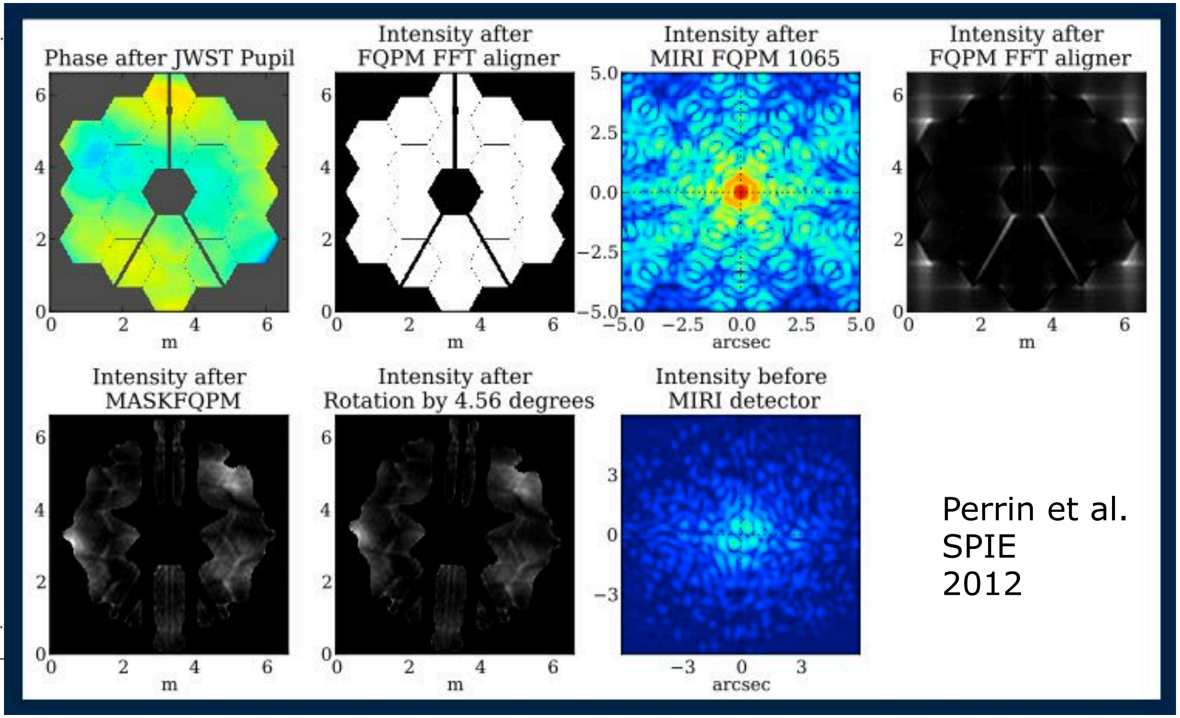
AMI with NIRISS enables the detection of exoplanets at 3.8, 4.3, and 4.8 μm around stars as bright as **M' ~ 5** with:

Contrast: ~2×10-5 (S/N~5)
Separations: 70 – 400 mas

JWST/MIRI – Coronagraphy

- **4 coronagraphic modes on the side of the imaging field of view.**





Perrin et al.
SPIE
2012

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

JWST – Status - Programmatic

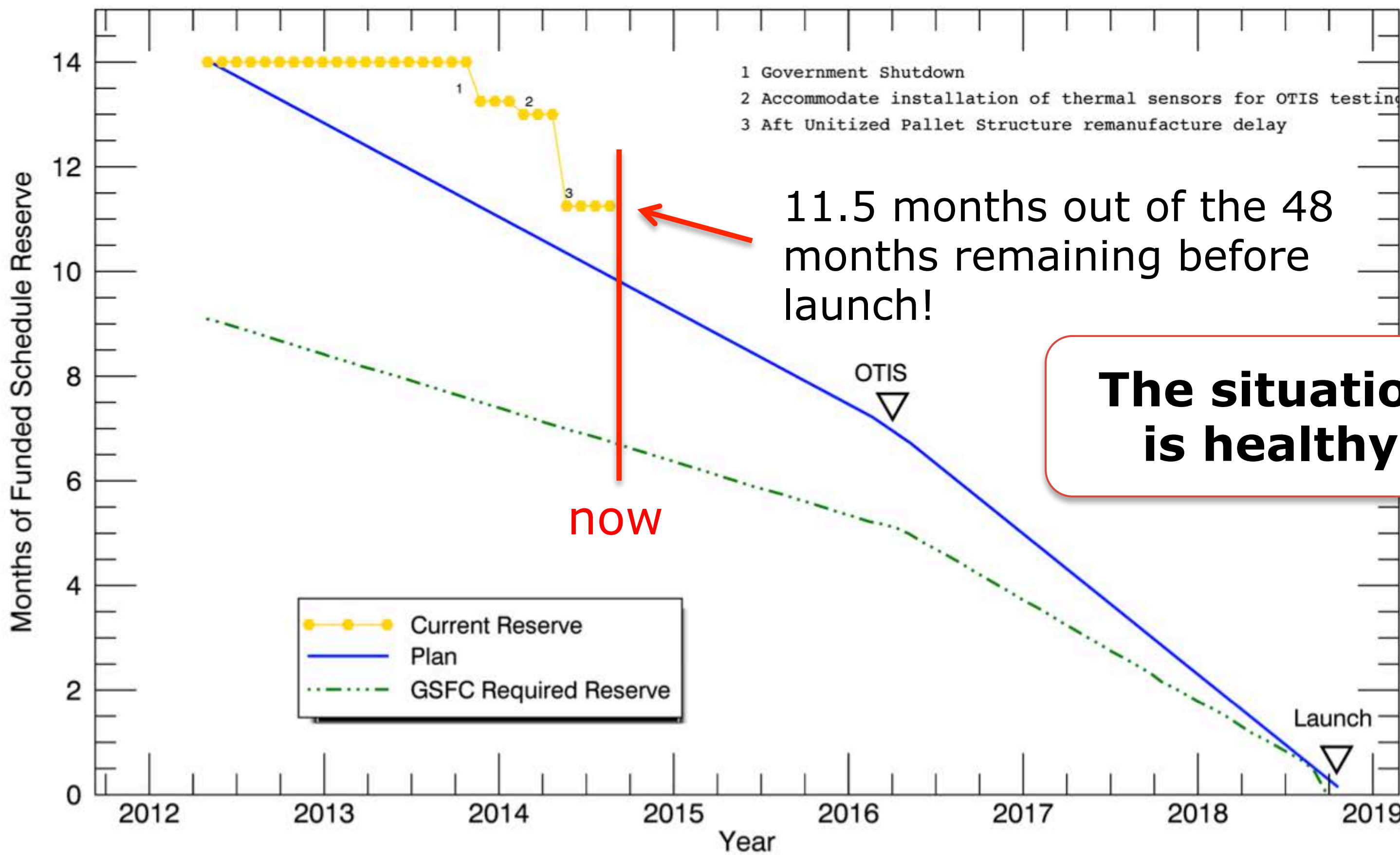
- **Overall things are going well!**
  - After several very turbulent years where the mission was threatened of being cancelled, things are back on track.

- **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 October 2018***.

- **The mission is now receiving adequate funding after years of under-funding that lead to the initial launch delays and to most 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 - Programmatic

Funded schedule reserve for the mission (as of 10/2014)

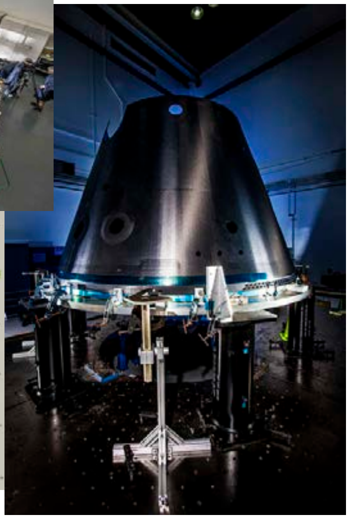
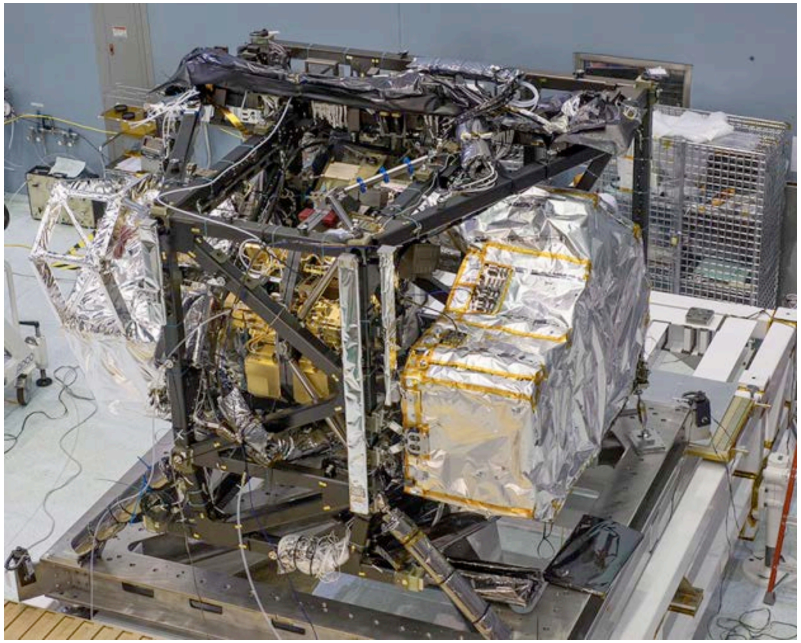


The situation is healthy

JWST – Status - Hardware

- All JWST mirrors have been manufactured.
- All 4 instruments have been delivered and have been integrated in the payload module.
- The first two cryogenic test campaigns of the payload module have been successfully completed.
- A lot of on-going work on the spacecraft / the sunshield / the telescope itself.



JWST – What happens next?

JAMES WEBB SPACE TELESCOPE

European Space Agency

JWST – What happens next?

2012	2013	2014	2015	2016	2017	2018	2019	2020 and beyond

NORMAL OPERATION

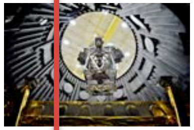
COMMISSIONING

LAUNCH !

FINAL STEPS OF THE INTEGRATION AND TESTING OF THE SPACECRAFT

TESTING OF THE TELESCOPE AND INSTRUMENTS TOGETHER

ISIM INTEGRATION AND TESTING



DELIVERY !

: TESTING

INTEGRATION

Only the path of the instruments is shown, in reality plenty of things are running in parallel!

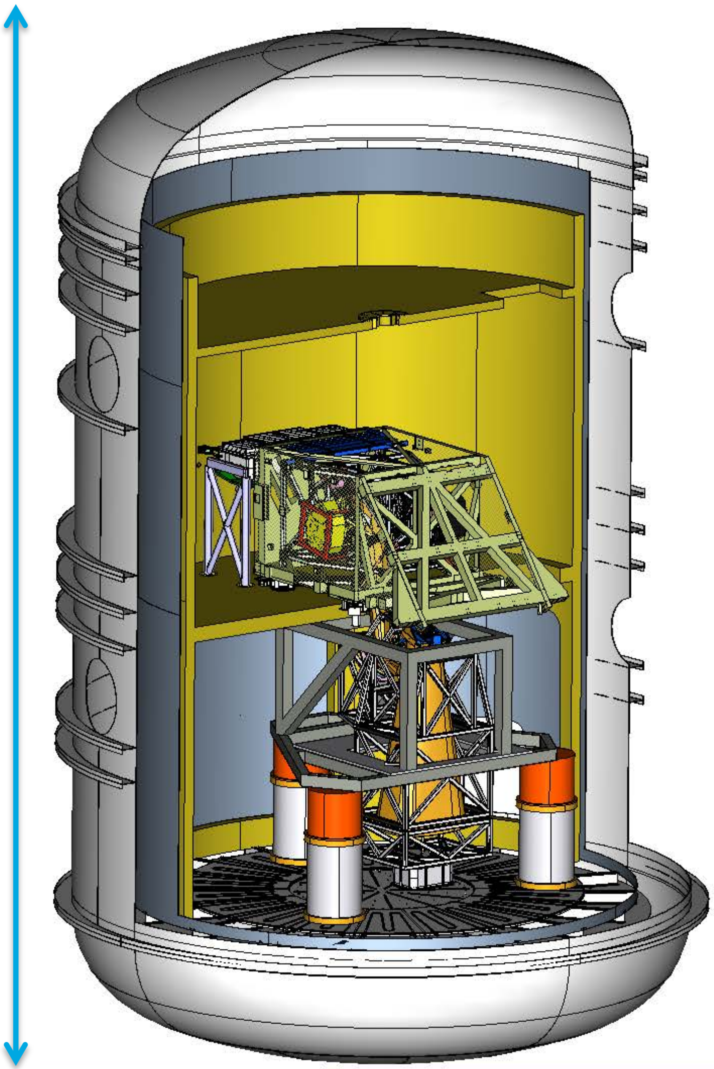
Instrument-level activities

10/2014

Progressive integration of JWST…

JWST – What happens next?

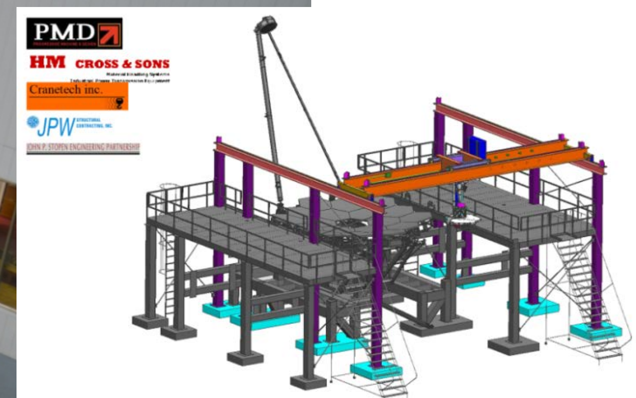
18-meter high

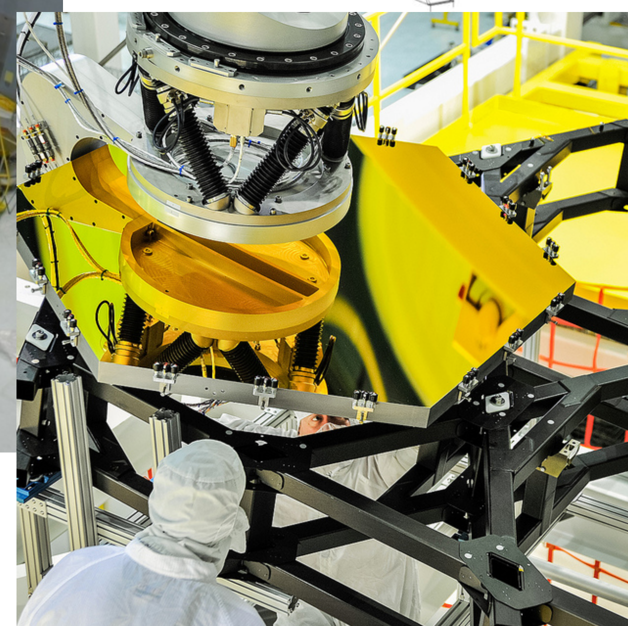


2015 - Instruments in their final flight configuration and final payload module testing.

JWST – What happens next?

Throughout 2015, take a look at the webcam image of the cleanroom: www.jwst.nasa.gov





2015- Assembling the telescope (including the installation of the primary mirror segments on the backplane).

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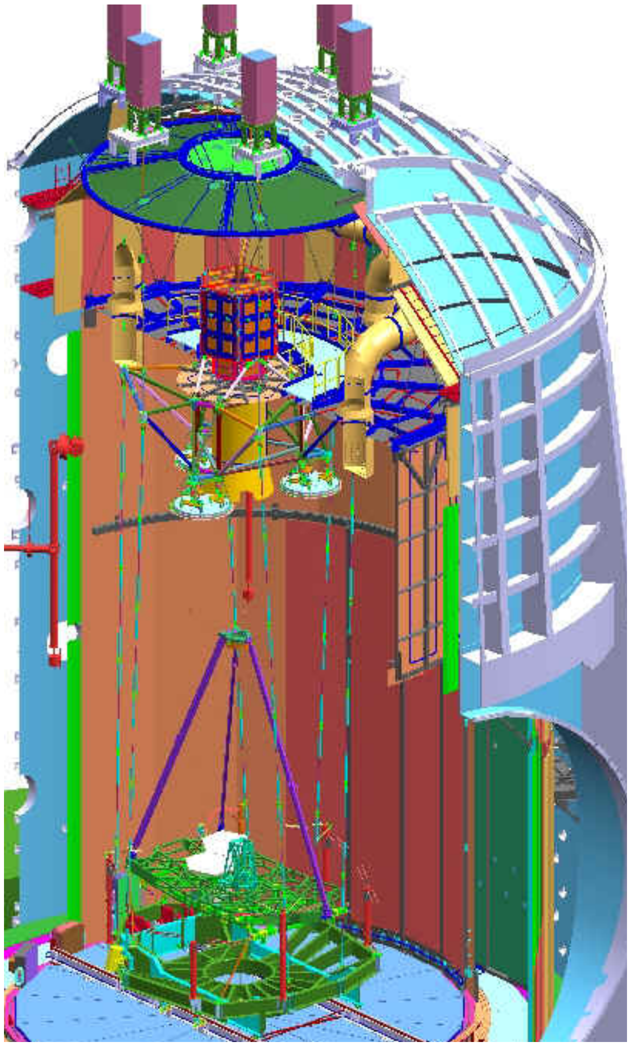
JWST – What happens next?

Almost 35-meter high!



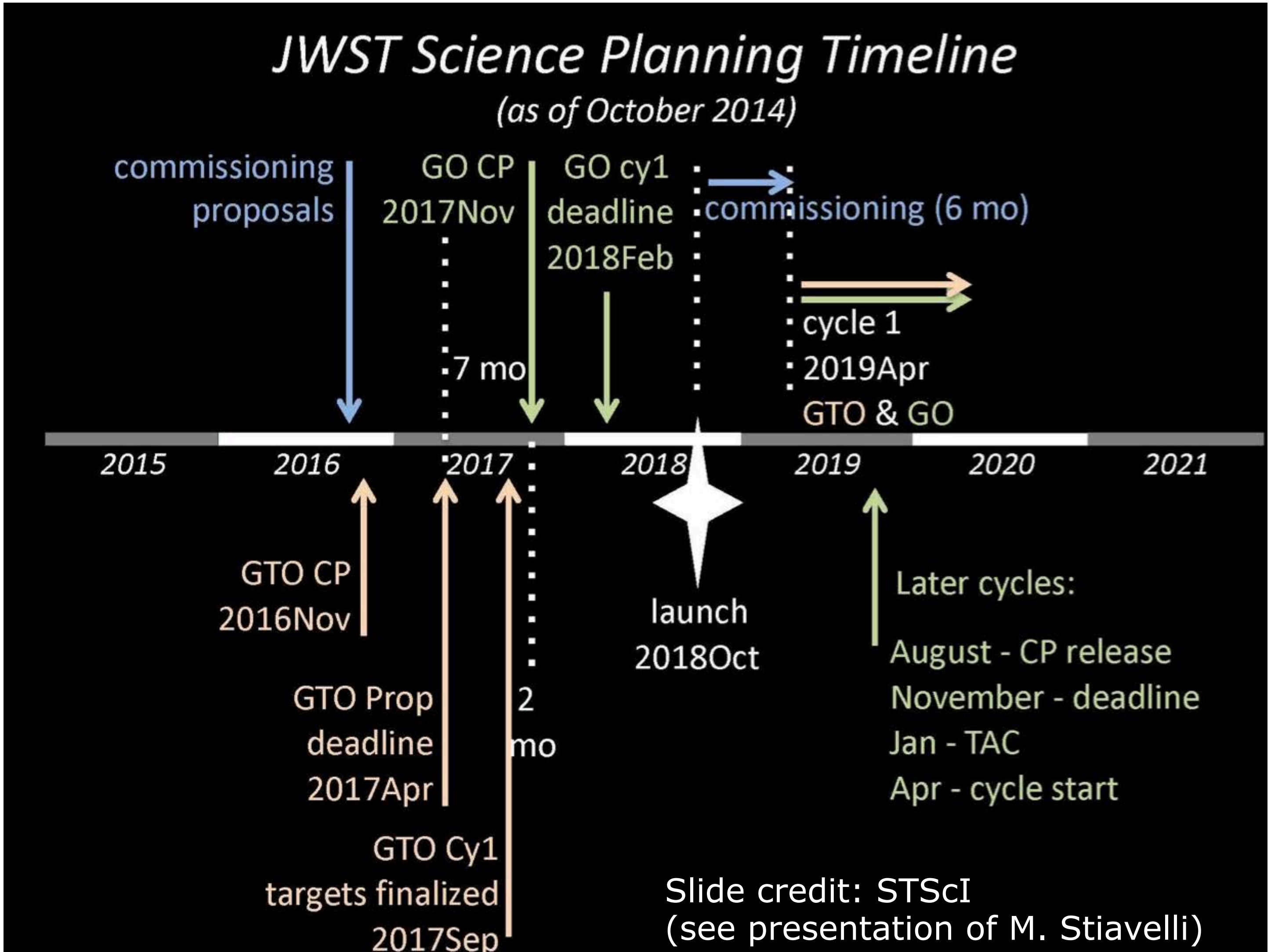
2016-2017 – Putting the telescope and the instruments together and testing them. In parallel, assemble the spacecraft.

JWST – What happens next?

2017-2018: final integration and testing of the spacecraft and…

… LAUNCH!

JWST – Scientific operation
Initial timeline



JWST – Scientific operation Miscellaneous policy elements…

- **The European share of JWST's observing time.**
    - >15% of JWST's observing time for applicants from ESA's member states.
- **How much time will be available for GOs during the first cycles?**
    - The GTOs have a total of 3960 hours to distribute within the first 3 cycles (with some constraints on how to spend them).
    - Director discretionary time: (up to) 10% of each cycle.
    - Numbers including direct and indirect overheads (policy under discussion).
    - Requirement on overheads < 30%; in reality large variations from program to program; question of indirect overheads to be addressed. ➔ work in progress.

Cycle	Total number of hours	Director discretionary time		Available for GOs and GTOs	GTO allocation use boundaries per cycle				Corresponding time available for GOs			
					Minimum		Maximum		Minimum		Maximum	
Cycle 1 (2019-2020)	8766 hours	≤ 10%	≤ 876 hours	7890 hours	25%	≥ 1972 hours	49%	≤ 3866 hours	51%	≥ 4024 hours	75%	≤ 5918 hours
Cycle 2 (2020-2021)	8766 hours	≤ 10%	≤ 876 hours	7890 hours			33%	≤ 2603 hours	51%	≥ 5286 hours	100%	≤ 7890 hours
Cycle 3 (2021-2022)	8766 hours	≤ 10%	≤ 876 hours	7890 hours			10%	≤ 789 hours	90%	≥ 7101 hours	100%	≤ 7890 hours
Cycle >3 (>2022)	8766 hours	≤ 10%	≤ 876 hours	7890 hours							100%	≤ 7890 hours
					Total GTO allocation:			**3960 hours**				

Important note: direct and indirect overheads are included in the allocations (policy under discussion).

JWST – Scientific operation
Miscellaneous policy elements…

- **Many of the observing policies for JWST are not yet frozen.**
  - Work on the preparation of the scientific operation of JWST is ramping up and so are the policy discussions.
  - The JSTAC (committee advising the director of STScI in particular on policy implementation issues) is a key player.
  - Some of the major discussions involve also the different partners (NASA, ESA and CSA).

- **Some key policy elements that are currently being discussed:**
  - Duration of the GO proprietary duration (request from the STScI director to decrease it from 1 year to 6 months). Will be discussed by the different partners.
  - Definition of observing programs categories (small / medium / large / legacy…).
  - Implementation of parallel observing (pure parallels, coordinated parallels…).

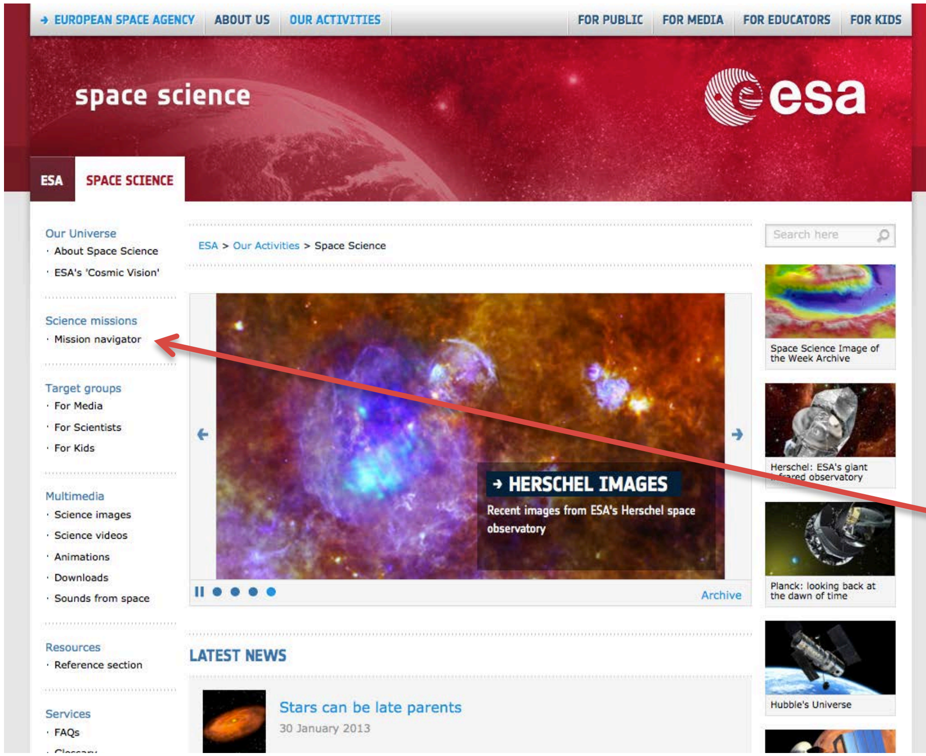
JWST is on track for a launch in October 2018 and for a start of scientific operation in the first half of 2019!

Dates you may want to put in your calendars:

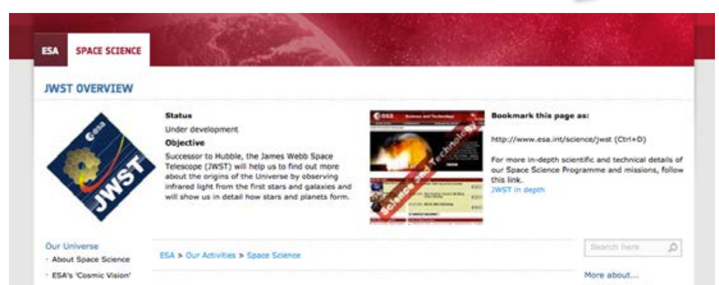
- October 12-16, 2015: conference “Exploring the Universe with JSWT” at ESA/ESTEC (The Netherlands).
- *November 2017 – First call for proposals!*
- Spring 2019 – Start of scientific operation!

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

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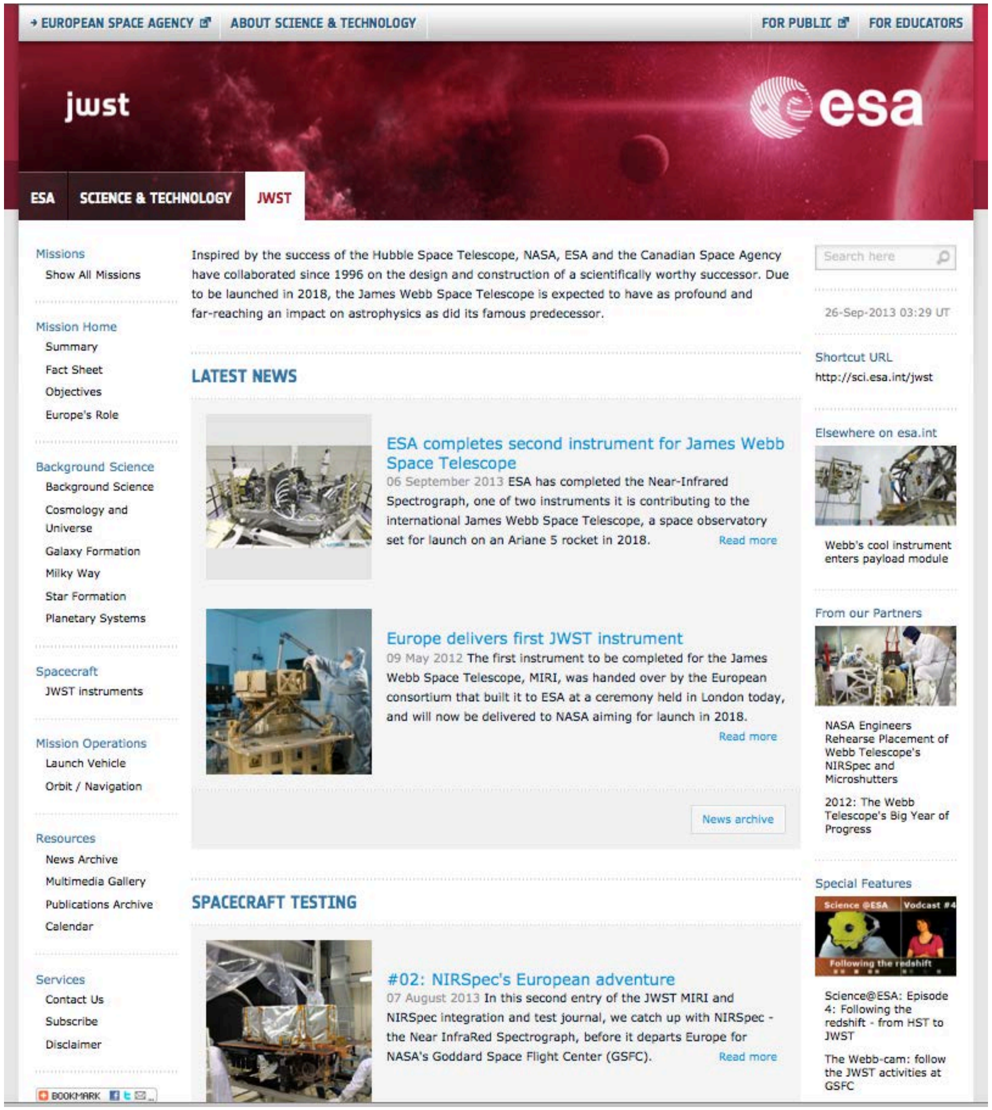

- "Science and technology" section dedicated to JWST
- http://sci.esa.int/jwst/
- Latest news with the press releases for major milestones.
- Spacecraft testing section with a "journal" following what happens to MIRI and NIRSpec.

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JWST on the web – Resources – ESA web sites


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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.

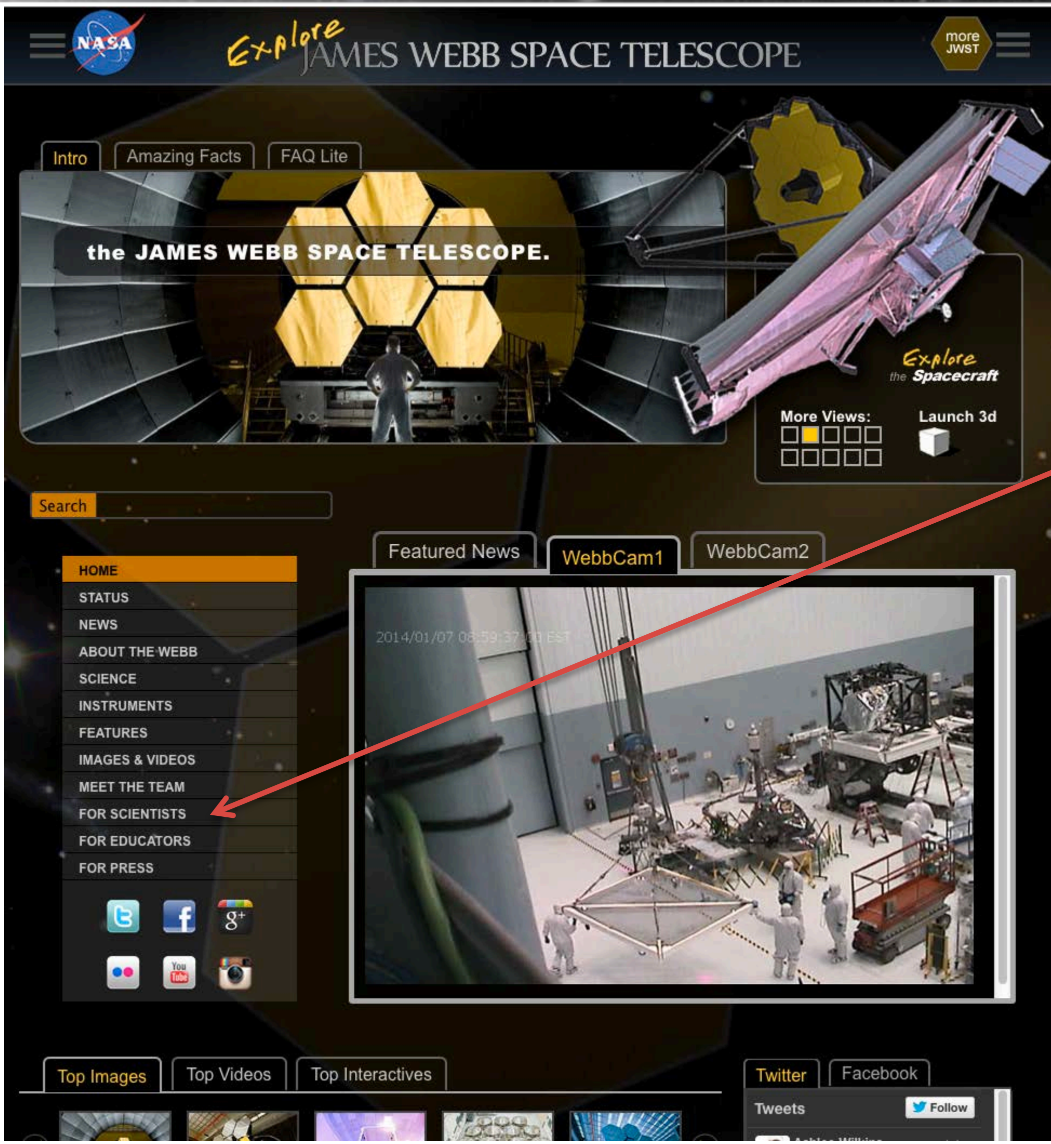
The purpose of this web-site is to provide information specific to the NIRSpec instrument, its performances and calibration. Designed as a multi-object spectrograph (MOS), NIRSpec will be able to observe more than 100 astronomical objects simultaneously. It has a large field of view (≈ 3' × 3') and is 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/

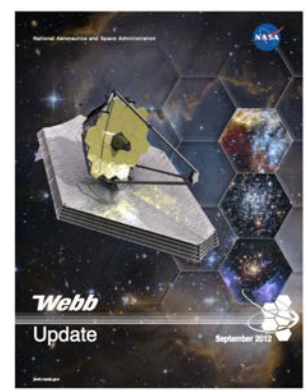
- **The main focus is the NIRSpec instrument.**
- **Work in progress…**
- **More information will be added as time goes on.**

JWST on the web – Resources – NASA JWST web site

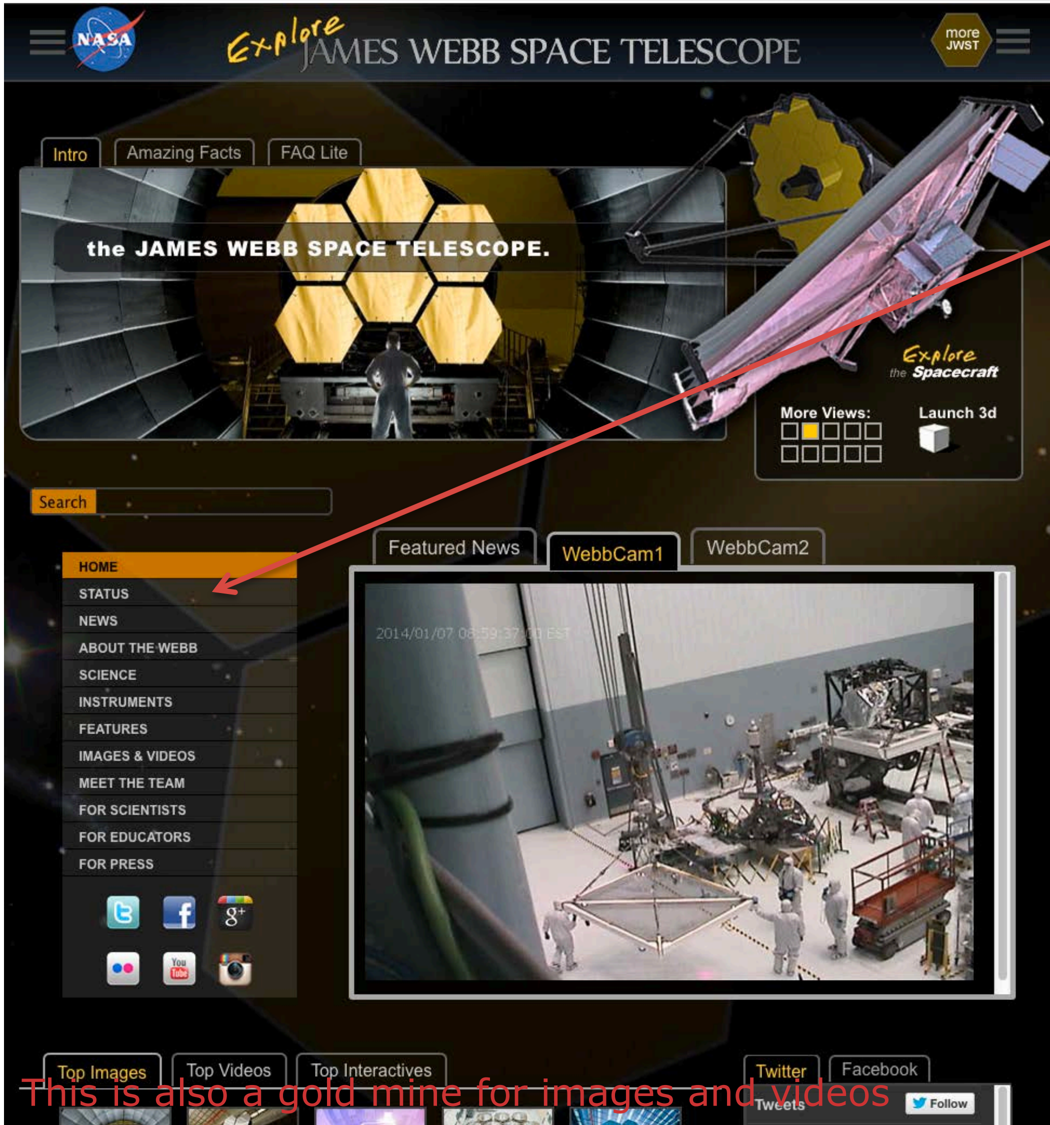


- **NASA JWST site**
- **jwst.nasa.gov**

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

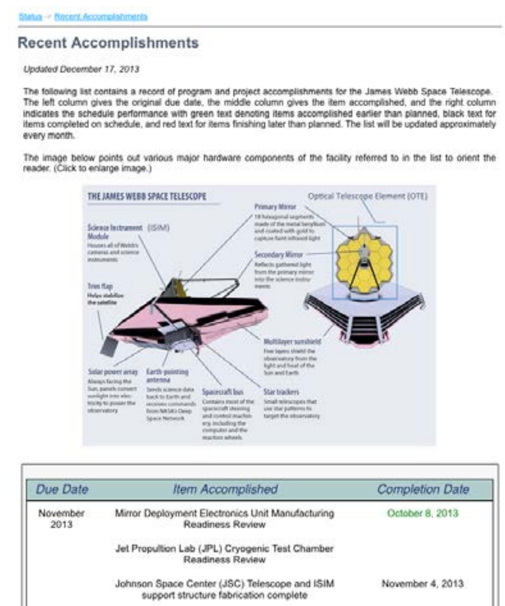


JWST on the web – Resources – NASA JWST web site



This is also a gold mine for images and videos

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



Status → Recent Accomplishments

Recent Accomplishments

Updated December 17, 2013

The following list contains a record of program and project accomplishments for the James Webb Space Telescope. The left column gives the original due date, the middle column gives the item accomplished, and the right column indicates the schedule performance with green text denoting items accomplished earlier than planned, black text for items completed on schedule, and red text for items finishing later than planned. The list will be updated approximately every month.

The image below points out various major hardware components of the facility referred to in the list to orient the reader. (Click to enlarge image.)

Due Date	Item Accomplished	Completion Date
November 2013	Mirror Deployment Electronics Unit Manufacturing Readiness Review	October 8, 2013
	Jet Propultion Lab (JPL) Cryogenic Test Chamber Readiness Review	
	Johnson Space Center (JSC) Telescope and ISIM support structure fabrication complete	November 4, 2013

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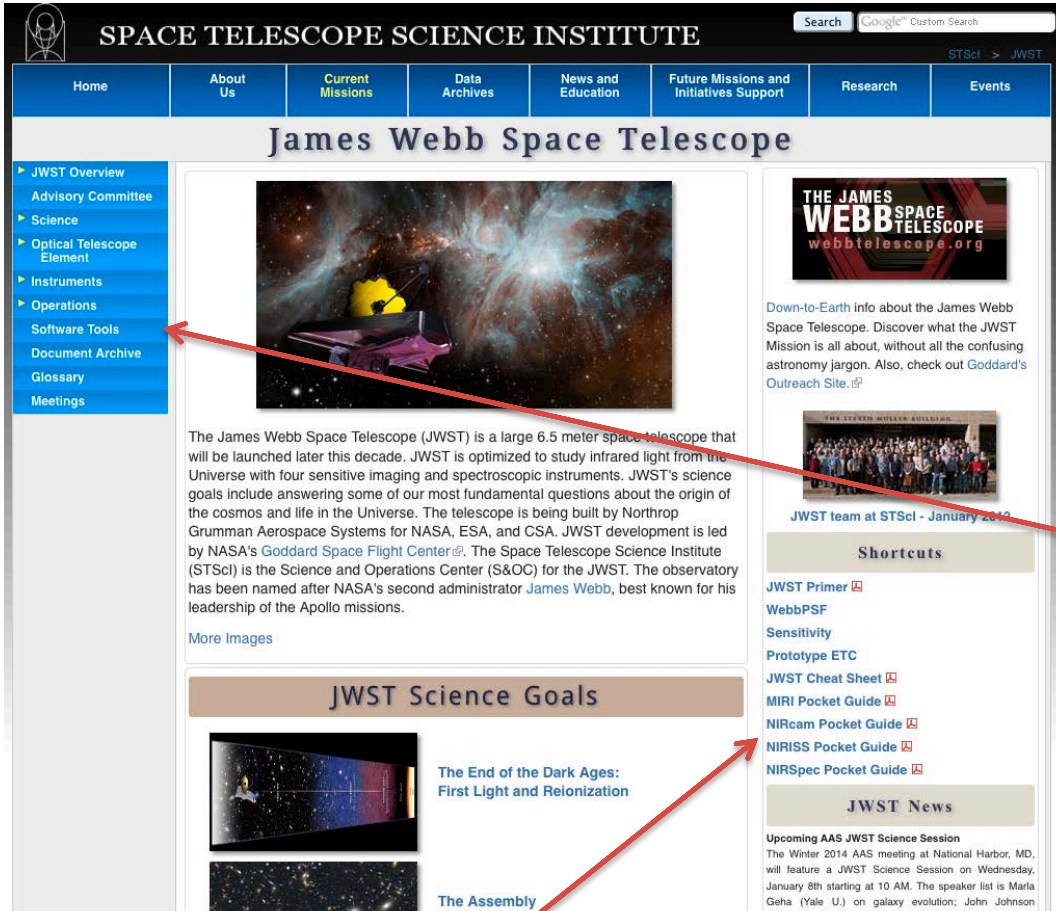
JWST on the web – Resources – STScI
JWST web site



- **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)**
- **Pocket guides**

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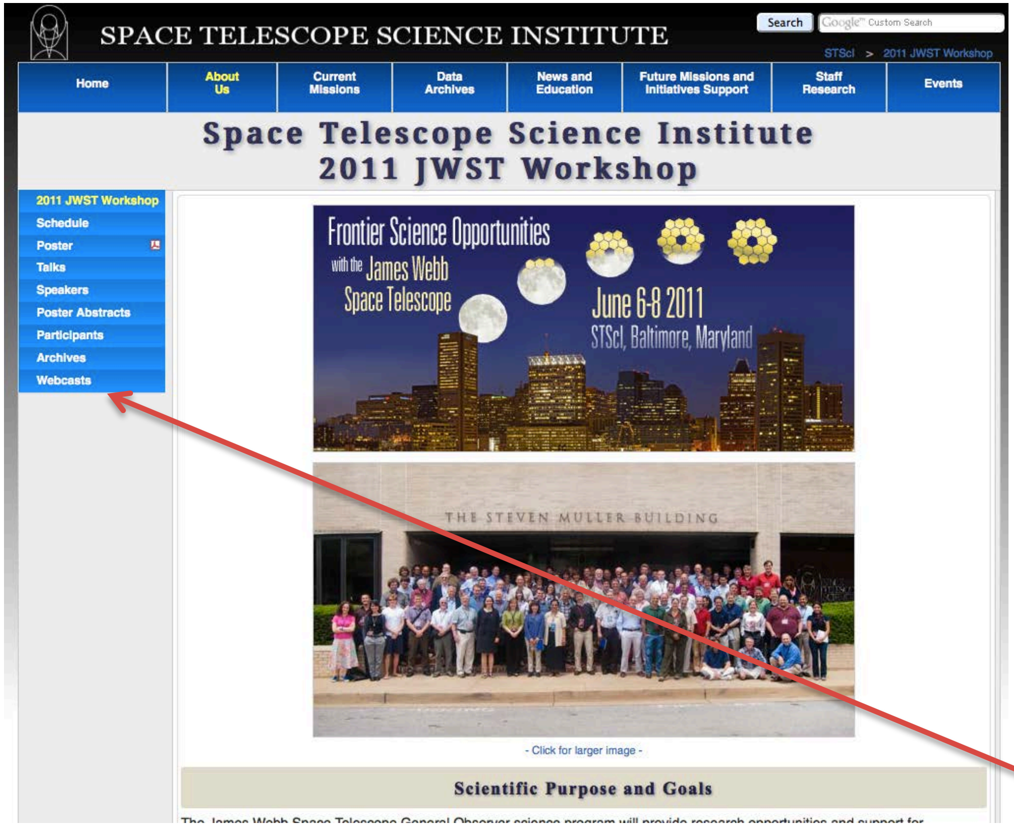
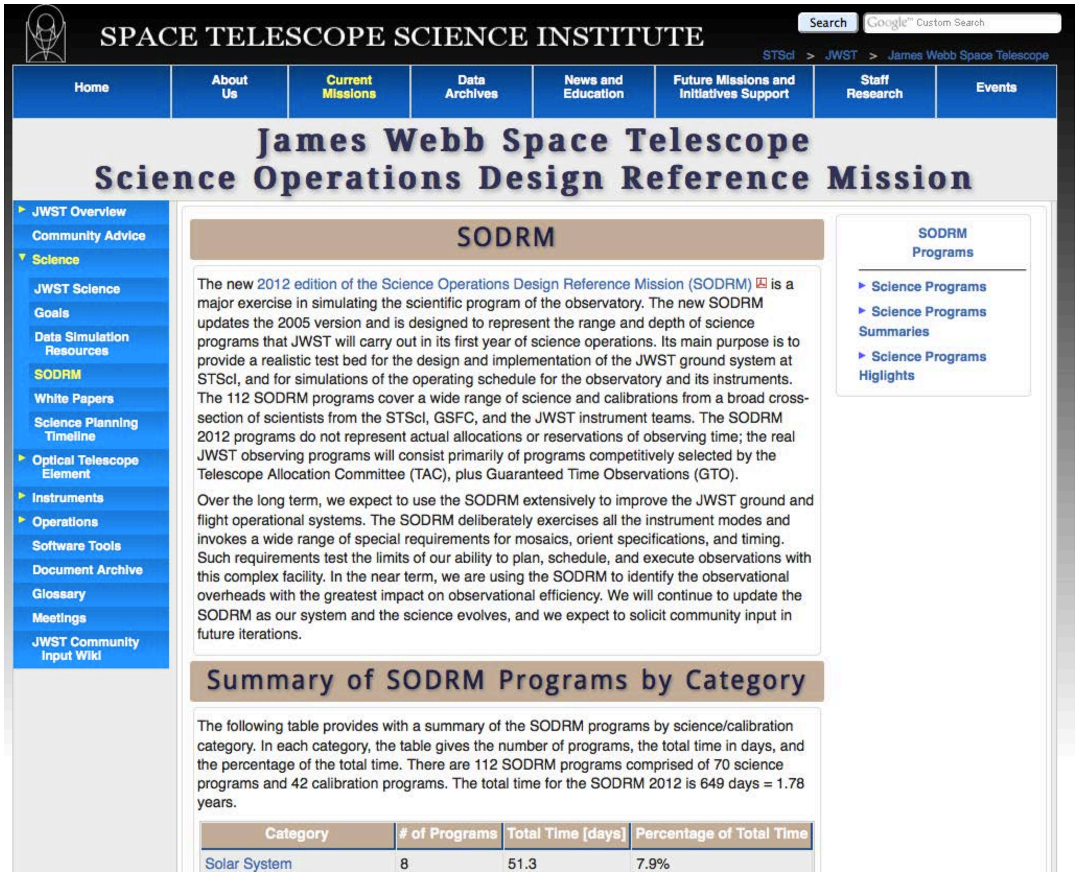
JWST on the web – Resources – STScI JWST web site



- 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.

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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.**

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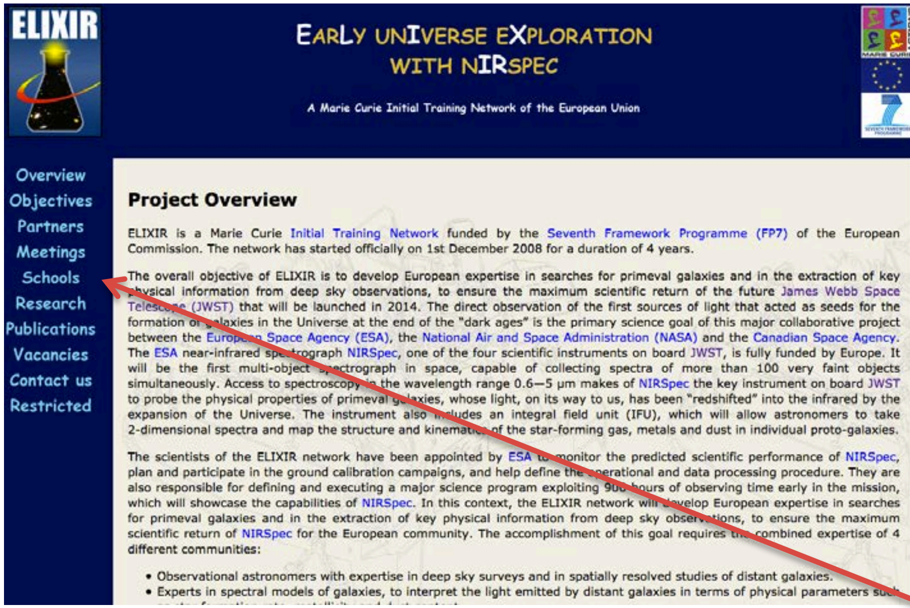
JWST on the web – Resources – The ELIXIR network web site


ELIXIR

EARLY UNIVERSE EXPLORATION WITH NIRSPEC

A Marie Curie Initial Training Network of the European Union

Overview
Objectives
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Meetings
Schools
Research
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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