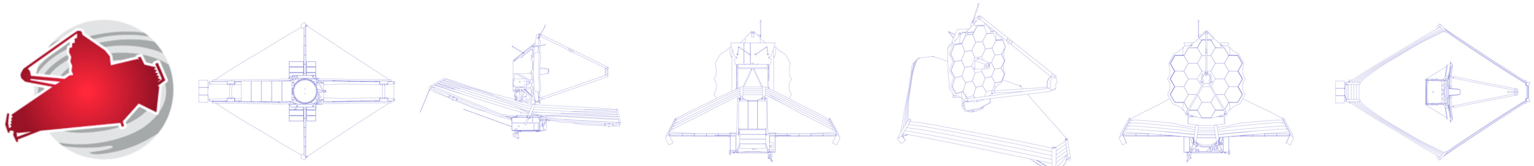
Observing (whomever) with NIRspec/JWST

Catarina Alves de Oliveira, European Space Agency

From super-Earths to brown dwarfs: Who's Who?, IAP, July 2015



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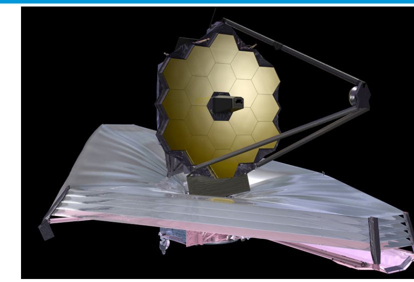
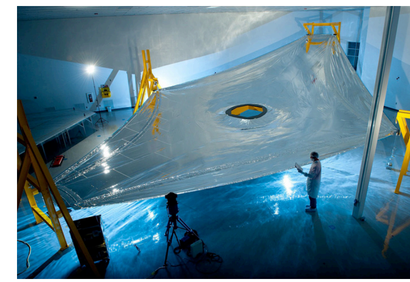
European Space Agency

The James Webb Space Telescope

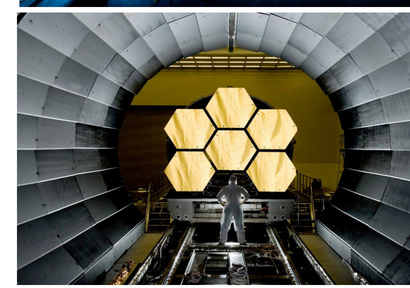
International collaboration NASA, ESA, and CSA

NASA   esa European Space Agency   CSA ASC

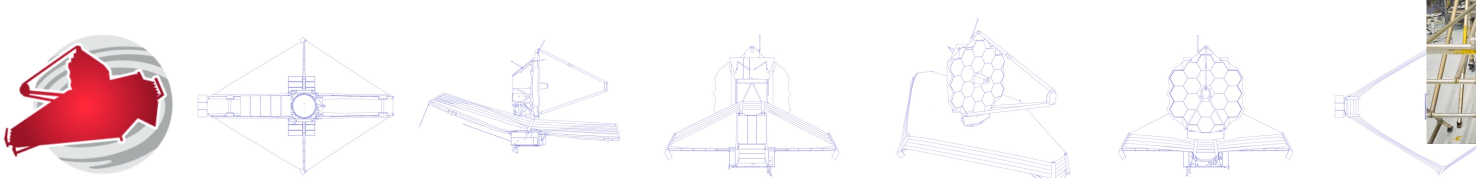




Next major astrophysical space observatory, largely seen as 'the successor to *Hubble* Space Telescope'



To be launched at the end of 2018, for a minimum mission duration of 5 years (10-year goal)



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The mission in a nutshell

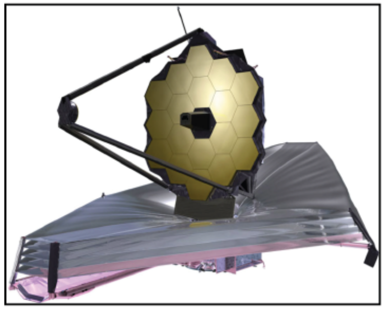
jwst

The James Webb Space Telescope (JWST)

Launch segment

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

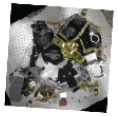
Observatory segment



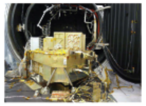
- Spacecraft (bus, sunshield...)
- Telescope

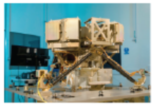
Payload module (ISIM) and instruments

- NIRCam



- NIRSpec
- FGS / NIRISS



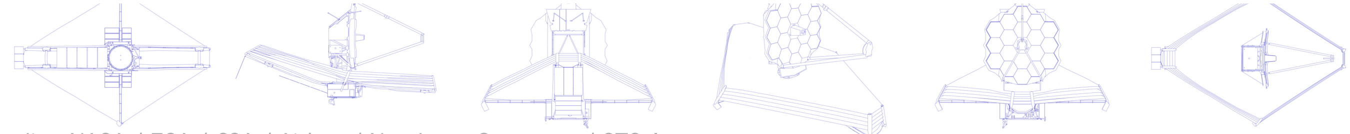


- MIRI

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



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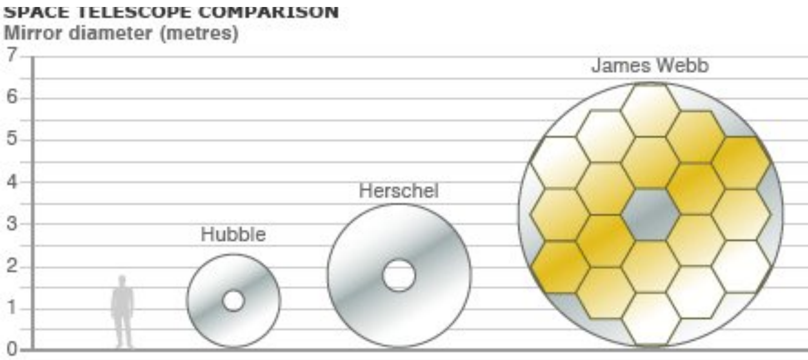
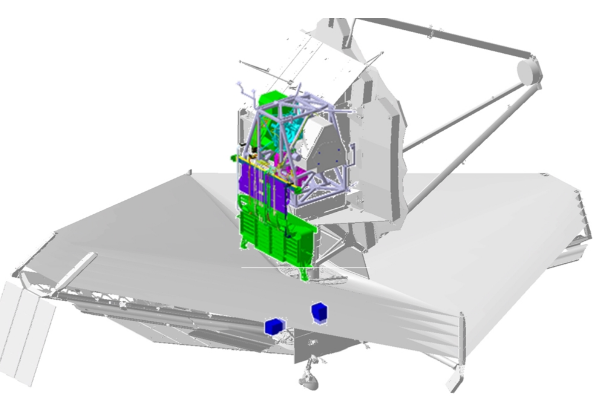
lementation

The telescope: 6.5m segmented primary mirror – 18 segments

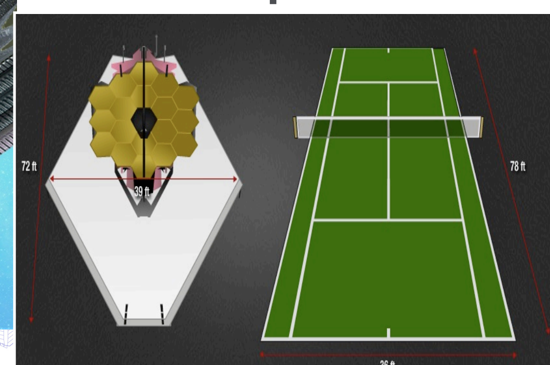


Northrop Grumman / STScI

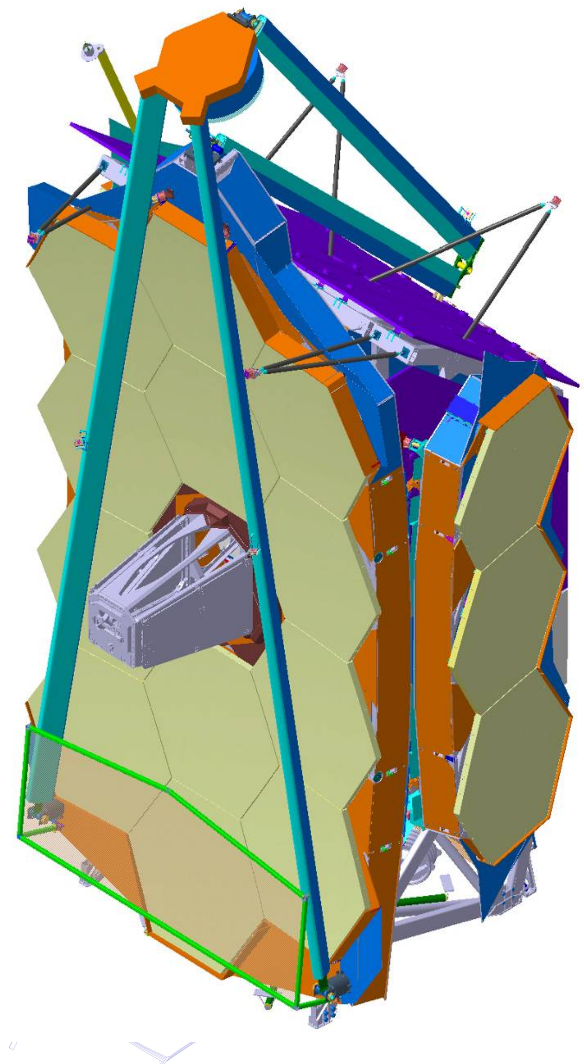
Payload module: 4 instruments



The sunshield: 5 membranes of Kapton foil allow passive cooling of the telescope and instruments



JWST hardware implementation



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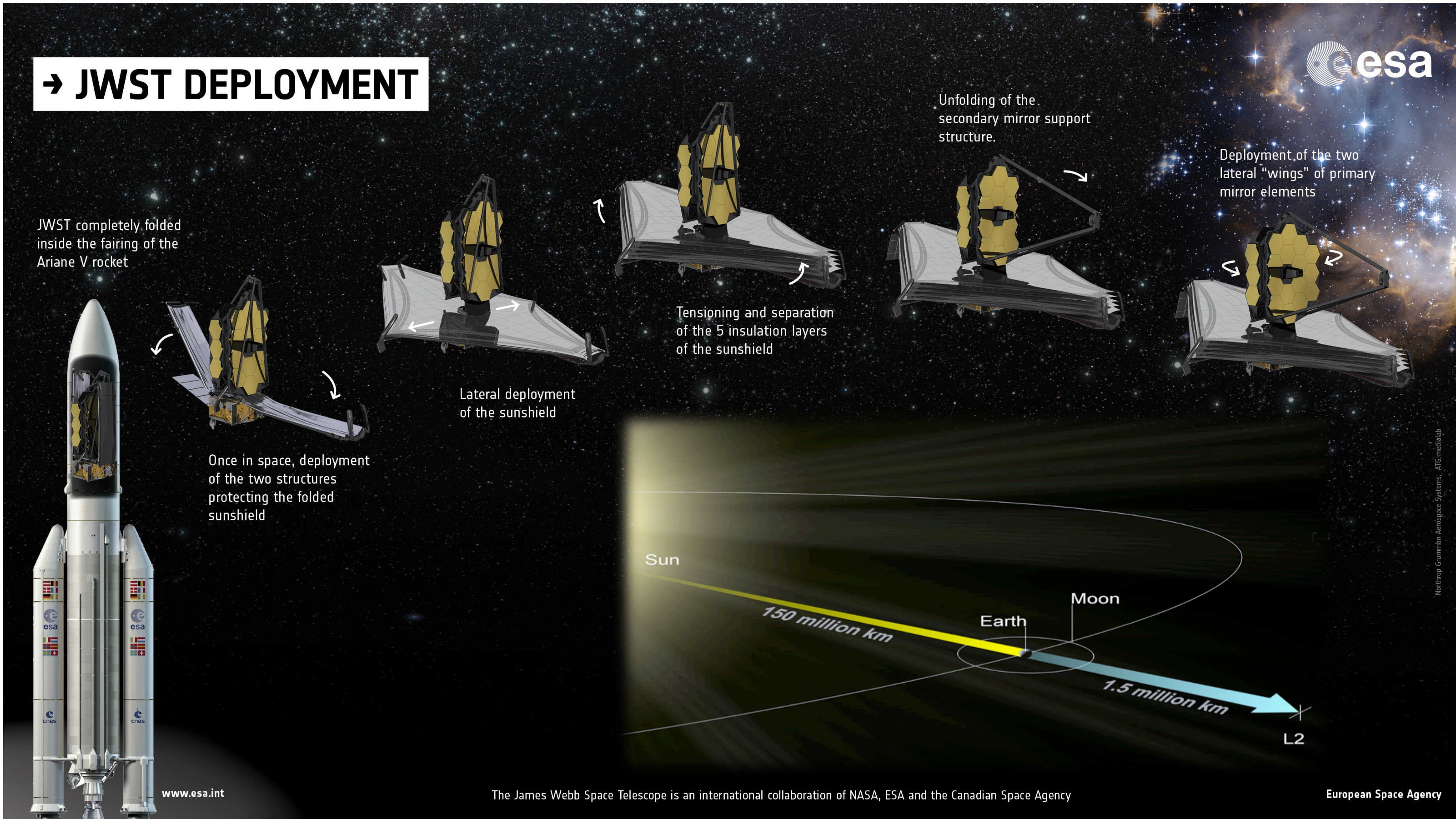
JWST deployment sequence



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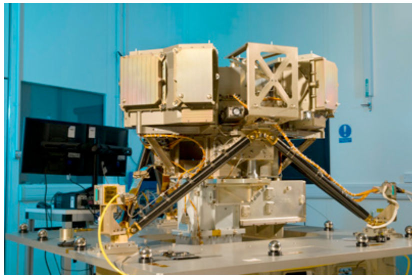
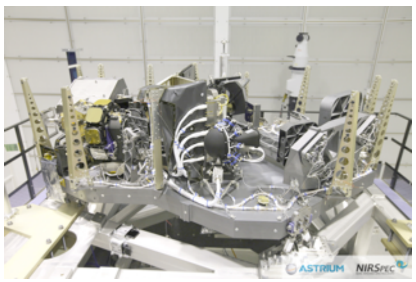
JWST instruments



MIRI = Mid-InfraRed Instrument

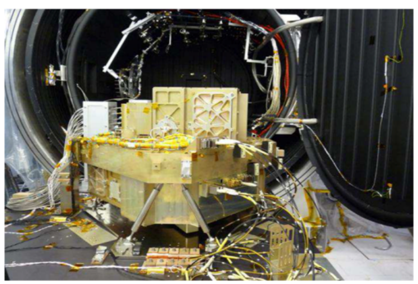
50/50 partnership between a nationally funded consortium of European institutes (MIRI EC) under the auspices of ESA and NASA/JPL

PIs: G. Wright and G. Rieke



NIRSpec = Near-infrared Spectrograph

Provided by the European Space Agency, built by an industrial consortium led by Airbus Defence and Space



NIRISS = Near-infrared Imager and Slitless Spectrograph

FGS = Fine Guidance Sensor

Provided by the Canadian Space Agency

PIs: R. Doyon & C. Willott

NIRCam = Near-InfraRed Camera

Developed under the responsibility of the University of Arizona

PI: M. Rieke

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NIRSpec/JWST: 3 instruments in 1

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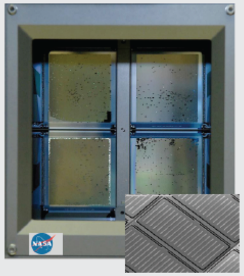
JWST/NIRSpec

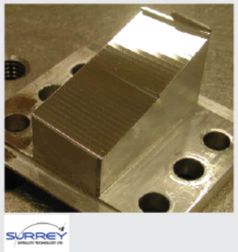
MOS



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")

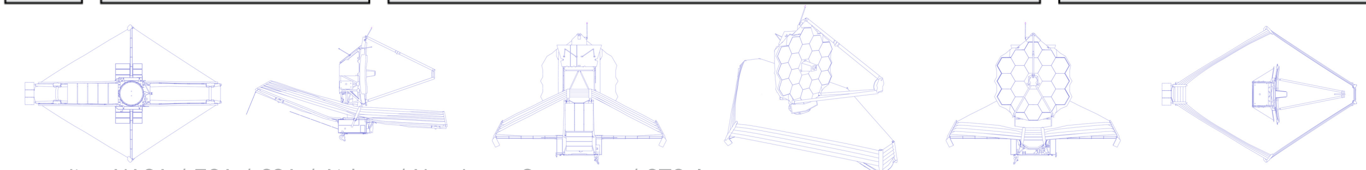
- 3"x3" field of view
- Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.
- Medium (500 to 1300) and high (1400-3600) spectral resolution modes, covering the 0.7-5.0 range in 4 exposures.
- IFU and MOS cannot be used at the same time.

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.



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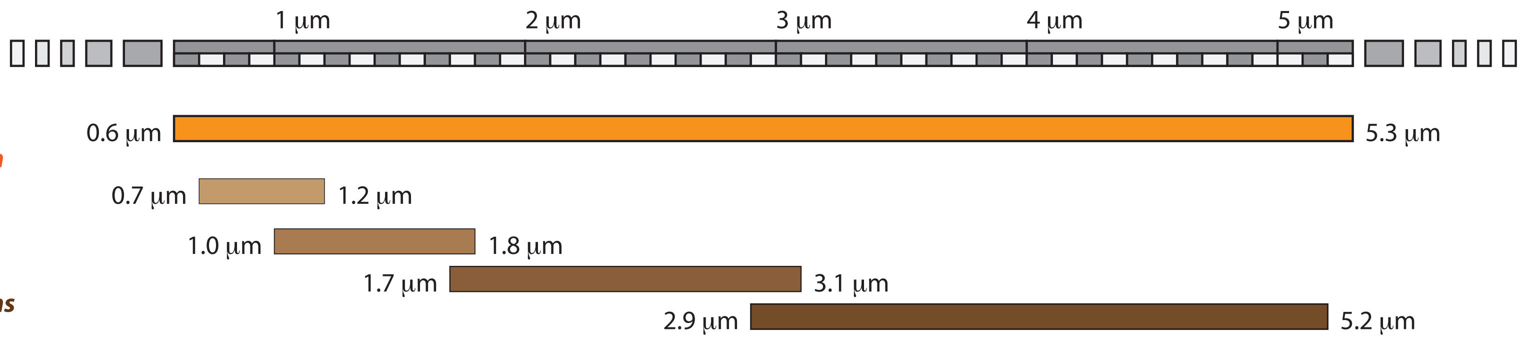
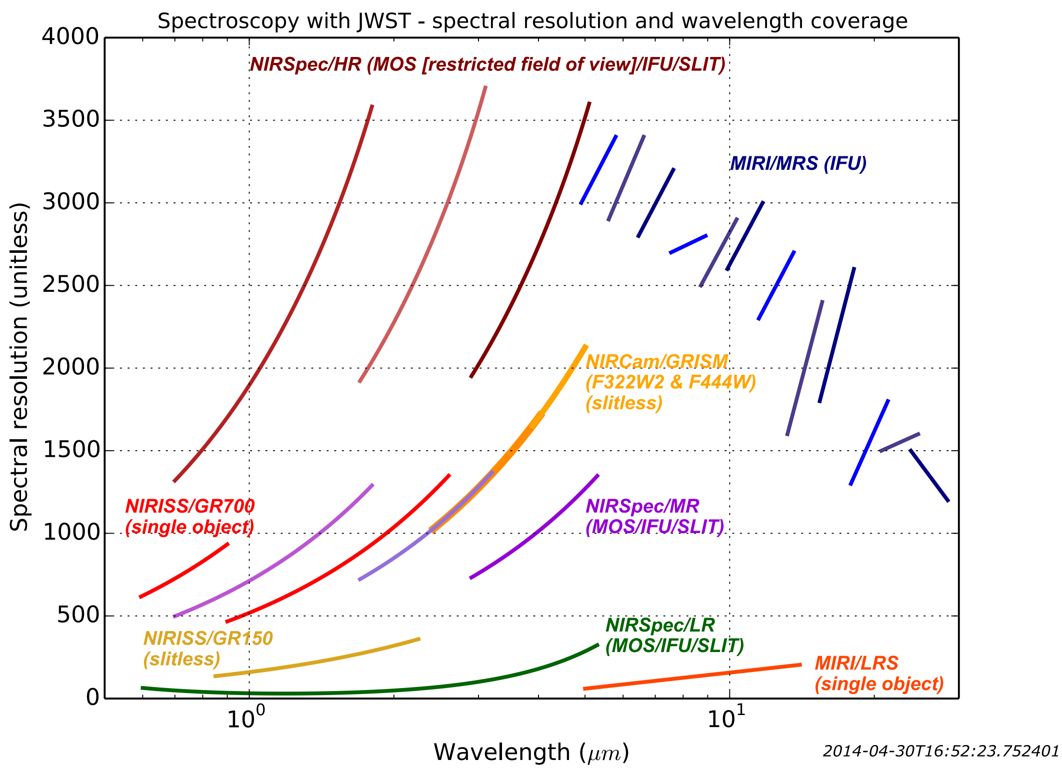
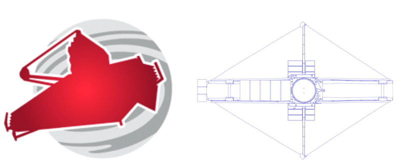
JWST/NIRSpec spectroscopic capabilities

Low spectral resolution configuration

Medium and high spectral resolution configurations







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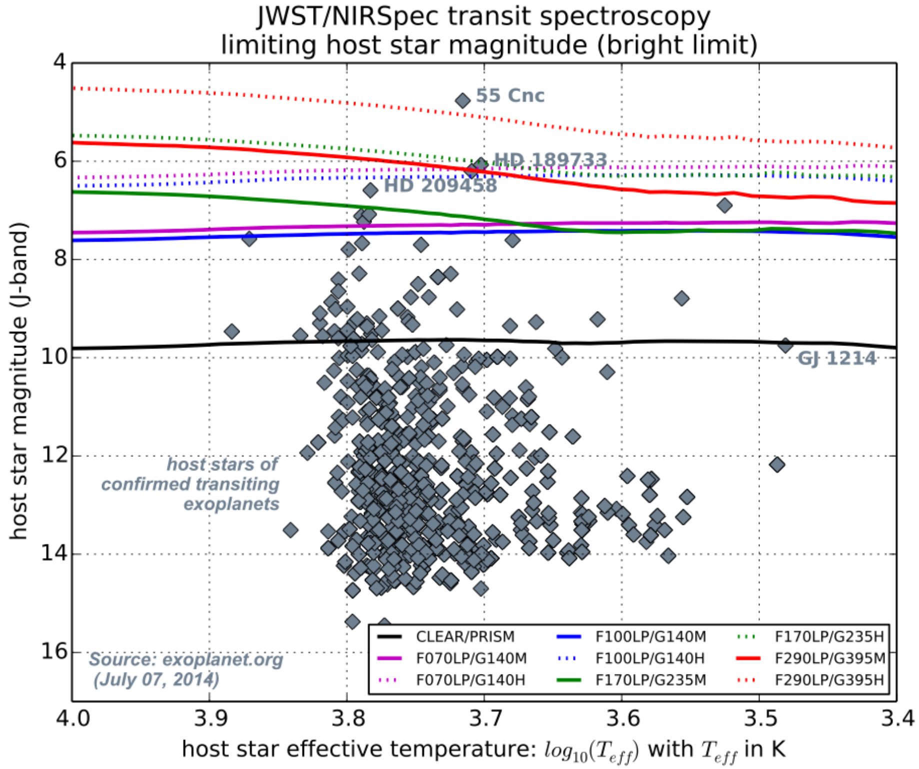
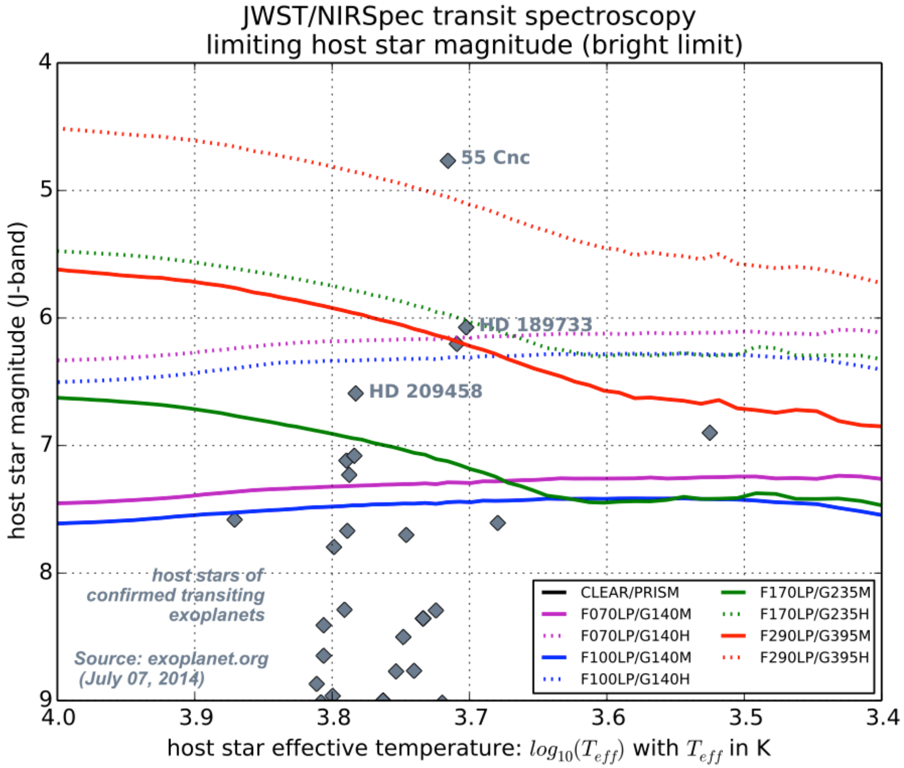
Exoplanet observations with NIRSpec: bright source limits

- NIRSpec features a dedicated large aperture (1.6” x 1.6”) for exoplanet transit spectroscopy
- **Estimated J-band magnitude as a function of stellar T_{eff} for different NIRSpec modes** (*Ferruit et al. 2014, SPIE, 9143*, typical uncertainties of ~0.2 mag)



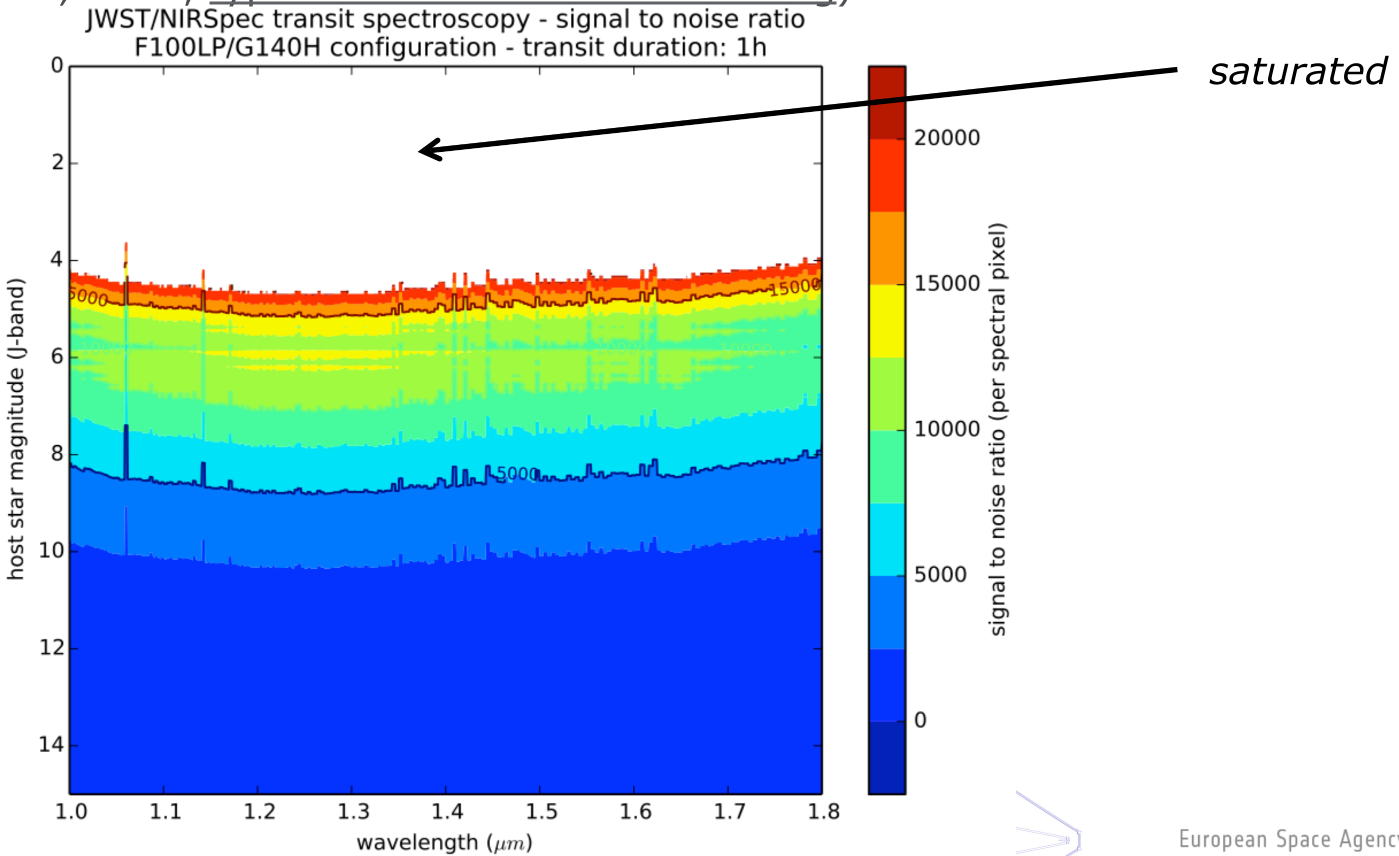


Exoplanet observations with NIRSpec: benchmark noise floor

Noise floor = benchmark lowest noise level that would be achieved if we had only two noise components: detector noise + shot noise from the host star

F100LP/G140H
1.0-1.8 microns in one shot R~2700

(*Ferruit et al. 2014, SPIE, 9143*, typical uncertainties of ~0.2 mag)



Observing Y dwarfs with NIRSpec

Y dwarf:

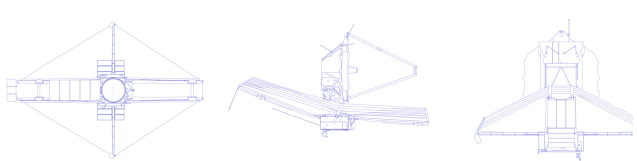
T_{eff}=450K

log(g)=4.0

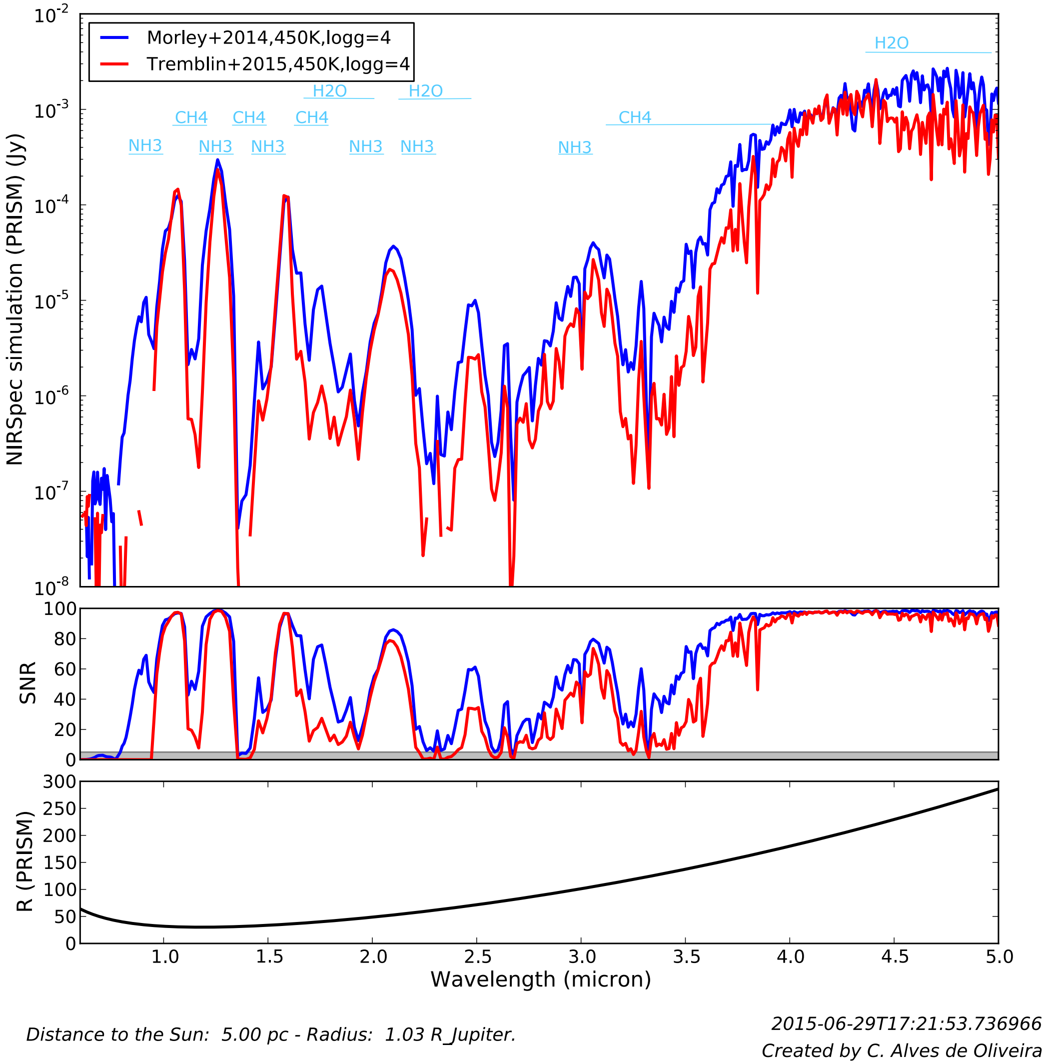
distance=5pc

NIRSpec simulations of Y dwarfs:

- PCE for telescope+instrument
- slit-losses
- detector noise
- background contribution
- accuracy of flatfield correction



CLEAR/PRISM: 1 exposure (754s on source)
0.6-5.3 microns in one shot / R~30-300

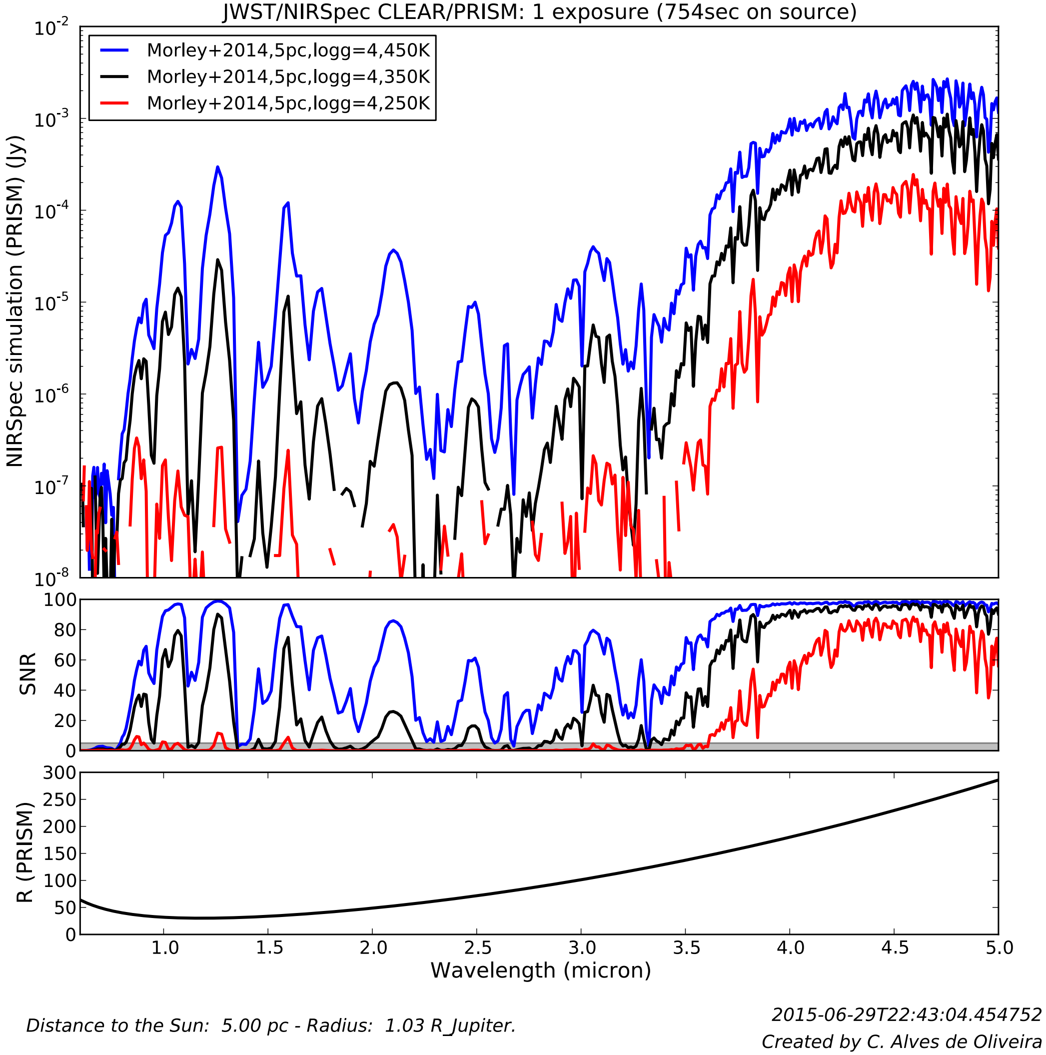


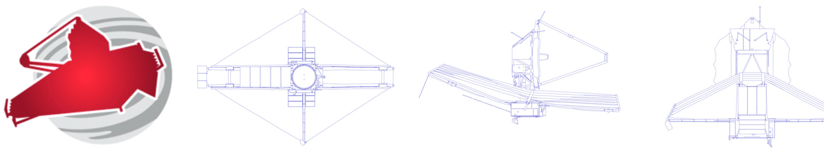
Observing Y dwarfs with NIRSpec

Y dwarf:

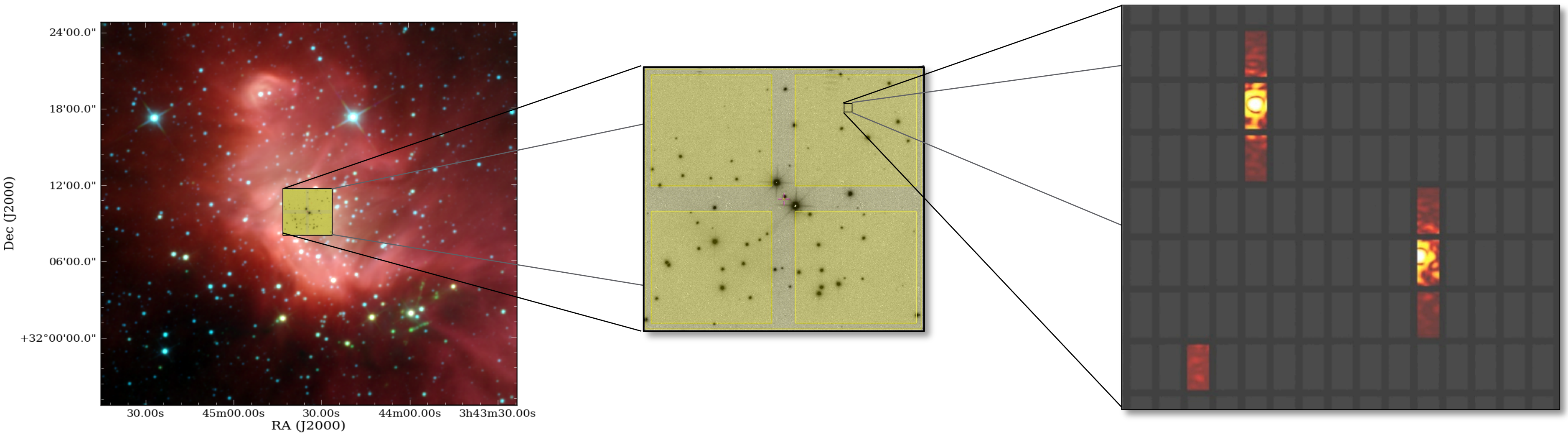
- T_{eff}=450K, 350K, 250K
- log(g)=4.0
- distance=5pc

CLEAR/PRISM: 1 exposure (754s on source)
0.6-5.3 microns in one shot / R~30-300

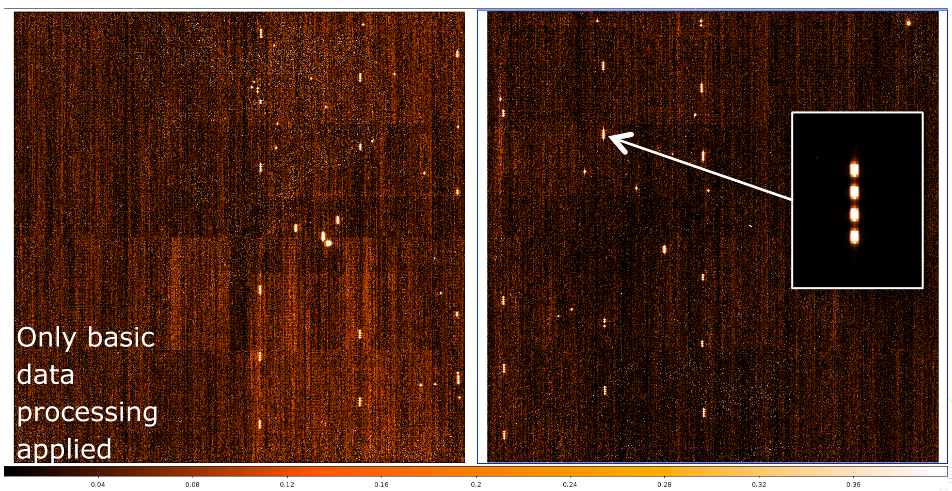


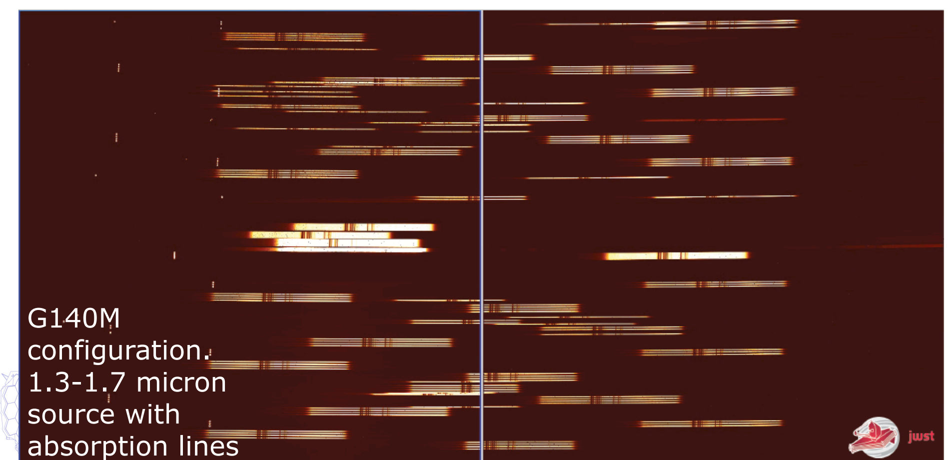


Observing brown dwarfs in clusters



Opening a collection of "dashed-slits"… → and getting spectra.

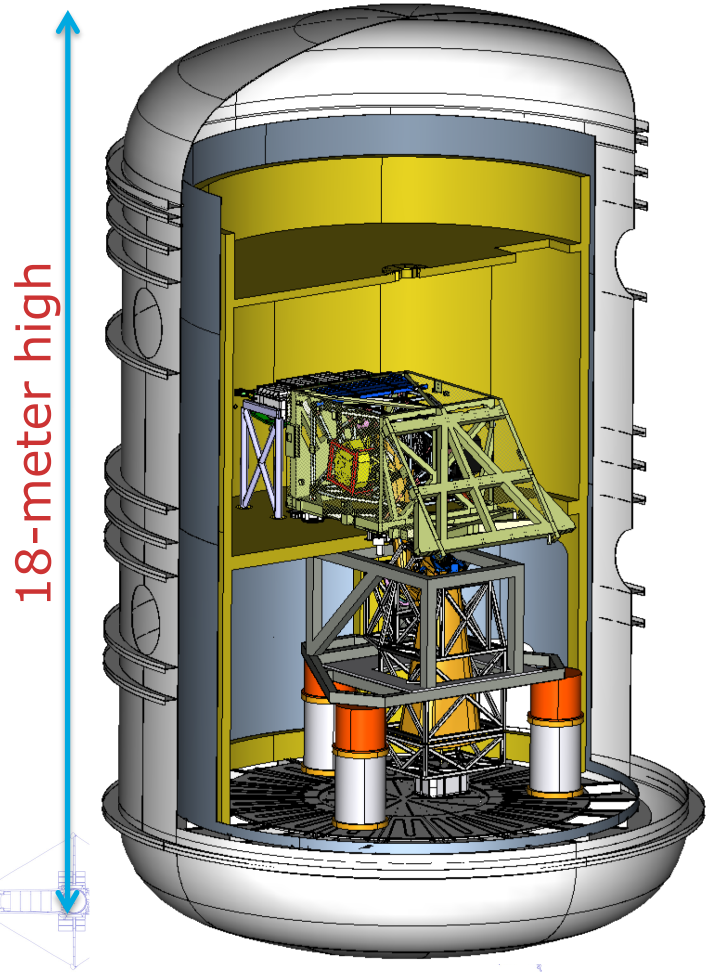


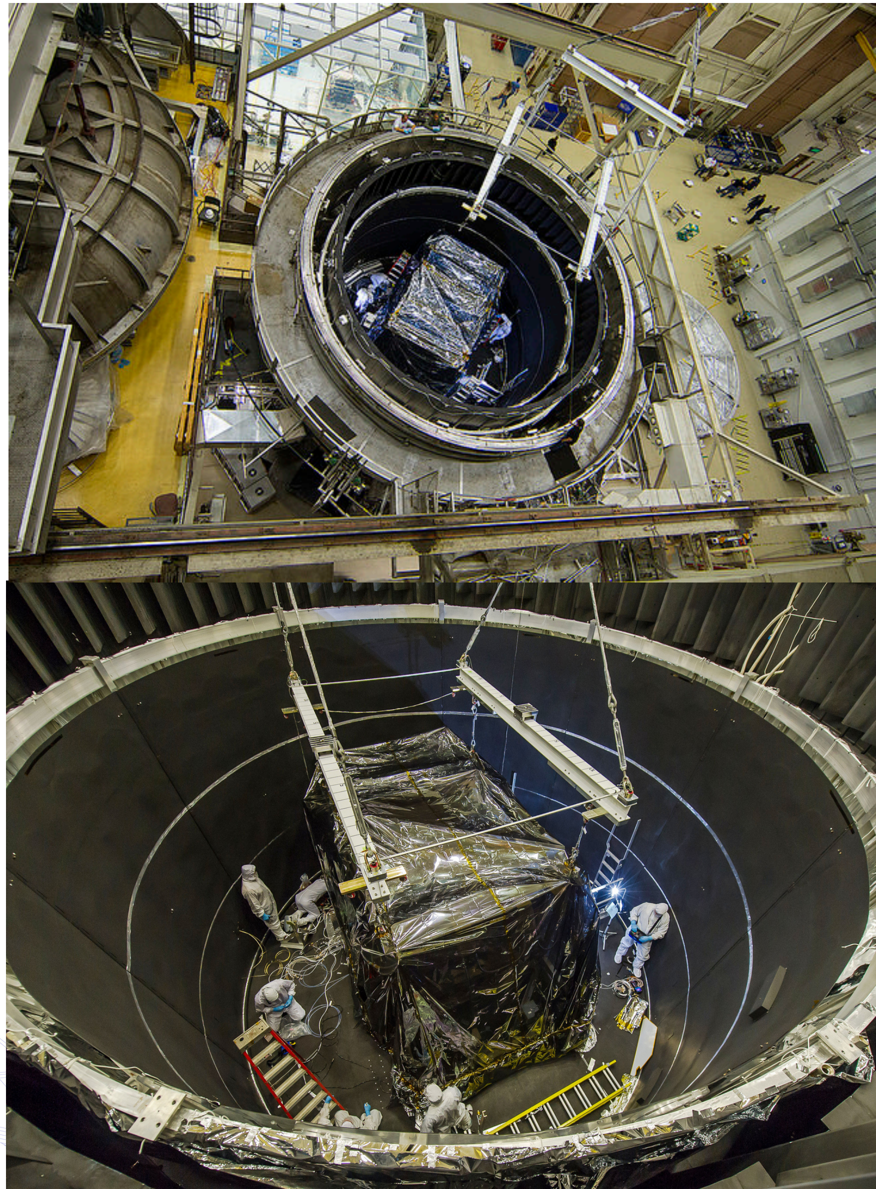


JWST/NIRSpec - FM2 cyrogenic test campaign 01/2013

From now to launch...

2015 - Instruments in their final flight configuration for final payload module testing





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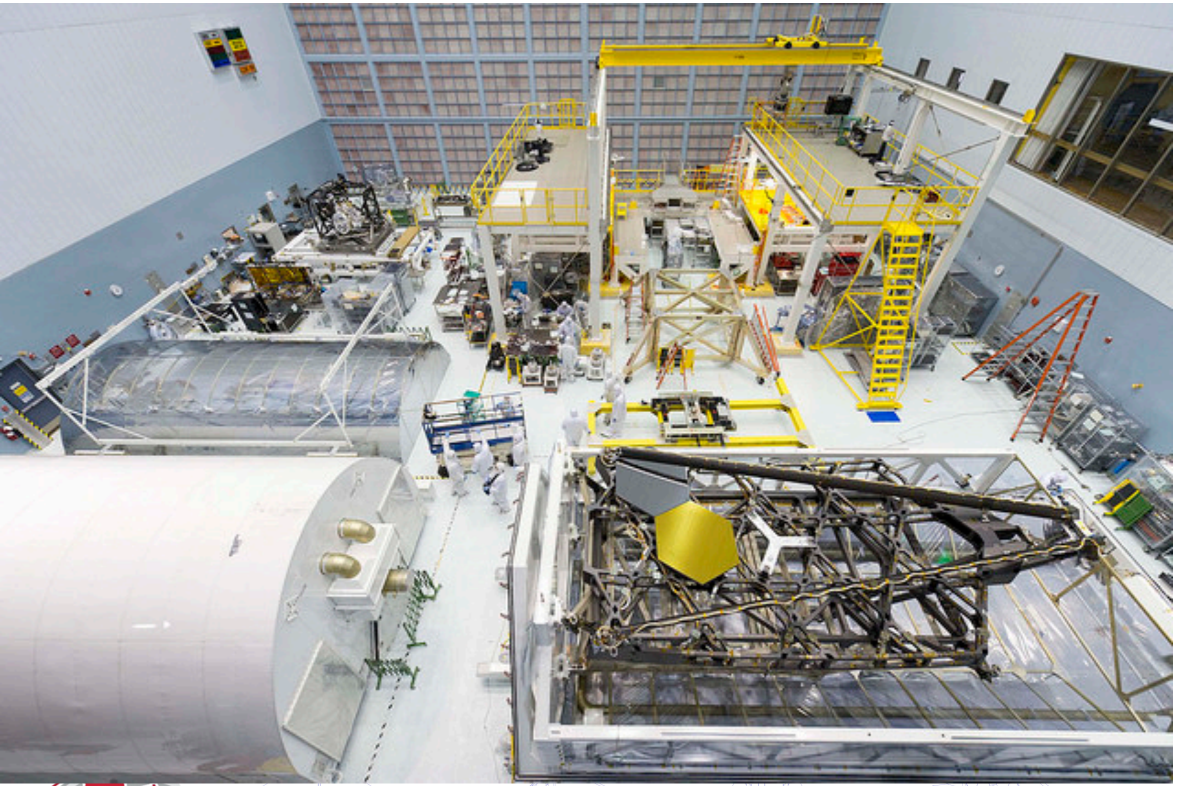
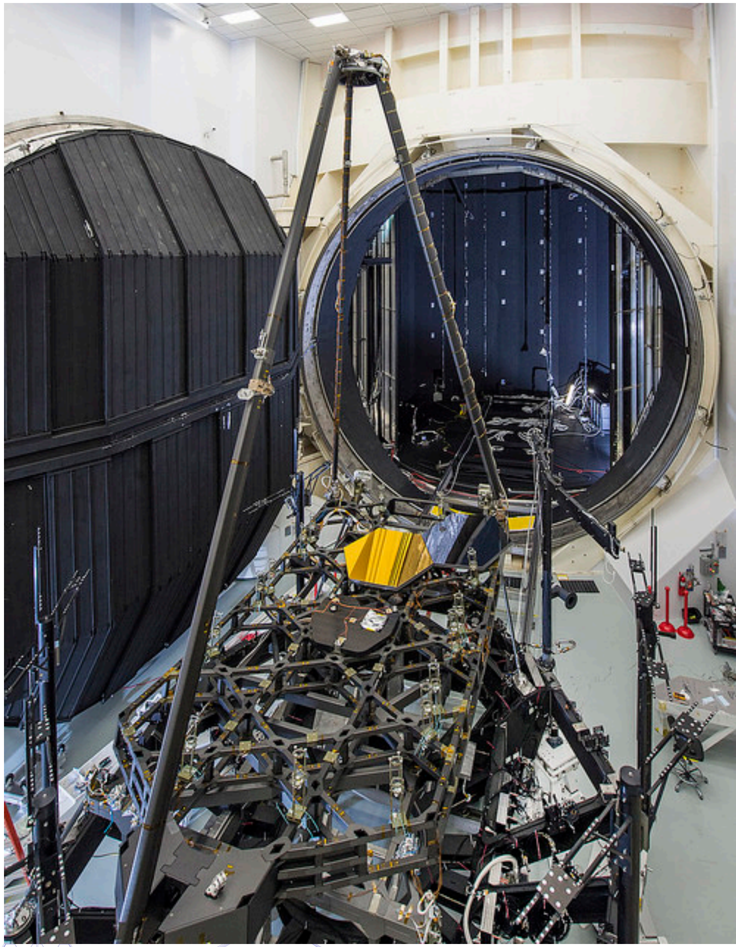
From now to launch...

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





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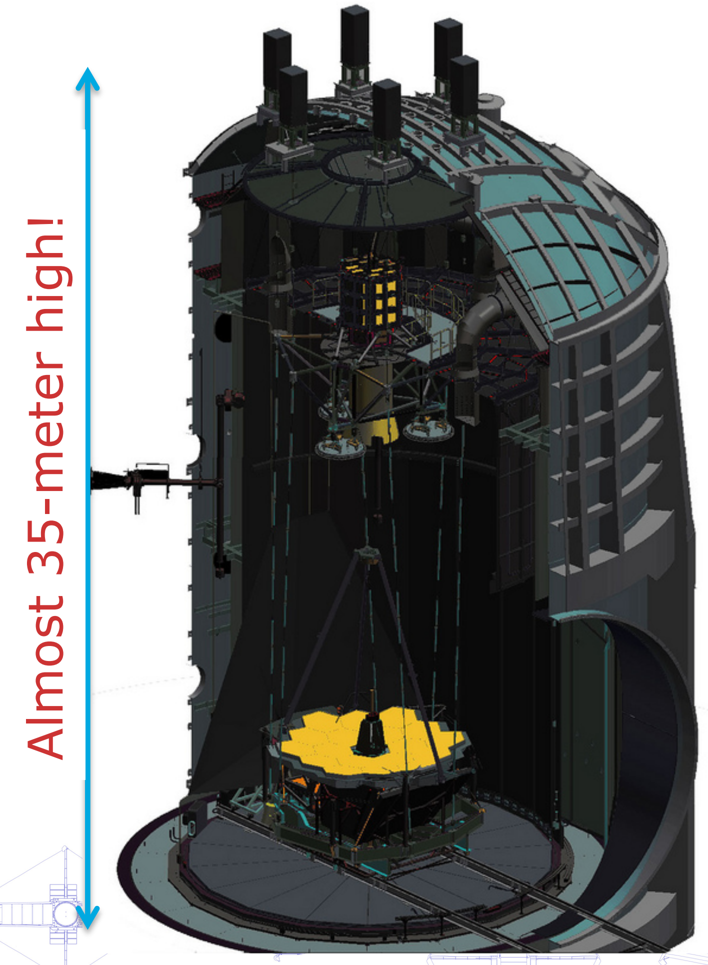
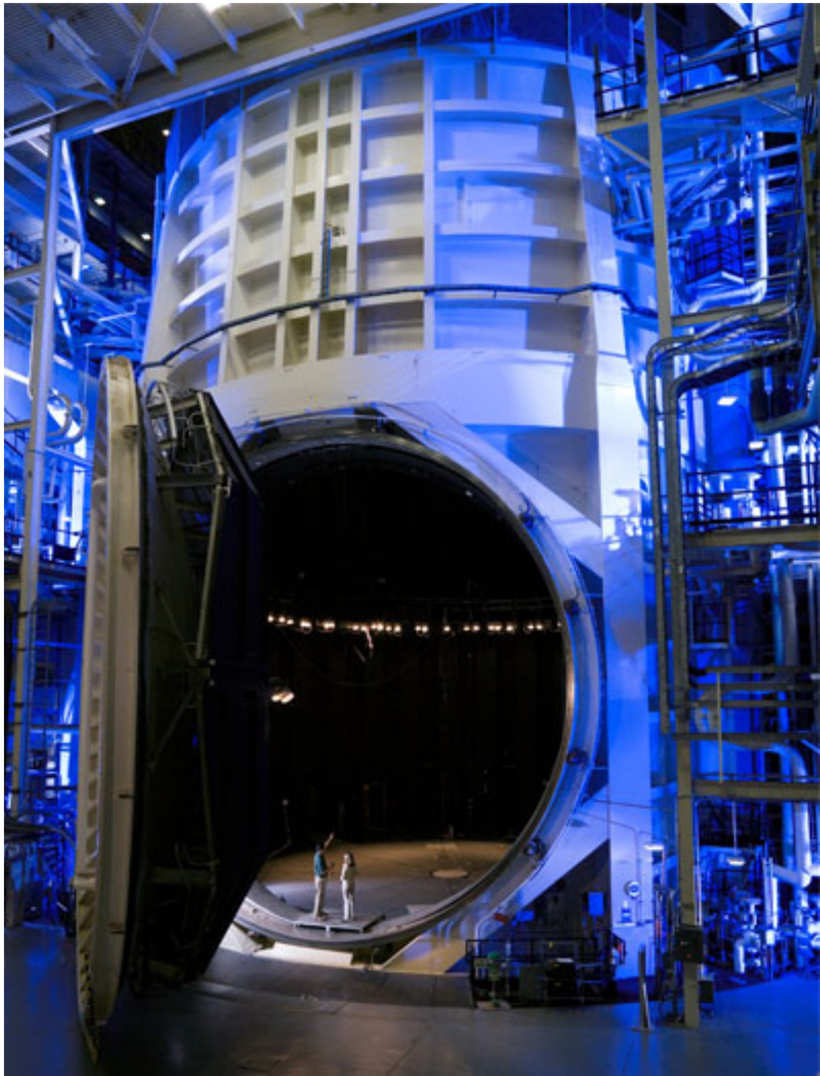
From now to launch...

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





Images/Diagrams credits: NASA / ESA / CSA / Airbus / Northrop Grumman / STScI

From now to launch...

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

… LAUNCH!

But this will only be the beginning of the story for the scientific life of JWST!

Agency

Images/Diagrams credits: NASA / ESA / CSA / Airbus / Northrop Grumman / STScI

Conclusions

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- **JWST/NIRSpec**
- versatile near-IR spectrograph with an unprecedented combination of sensitivity and spatial resolution
- wavelength coverage and range of possible spectral resolutions ideal to study cool atmospheres of brown dwarfs and exoplanets

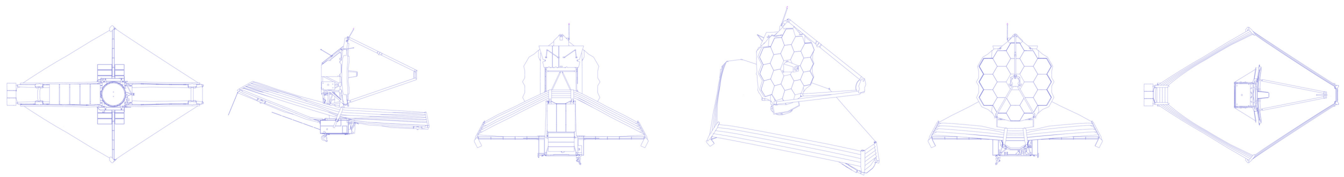
- **Transiting Exoplanets**
- High sensitivity enables noise floor levels of ~100 ppm for a 1 hour transit duration. Expecting observations to routinely reach down to noise floor levels of a few tens of ppm.
- Handle on systematics will be key to the final S/N ratio that can be achieved. Success of studies conducted on HST and Spitzer data give us hope that we will be able to approach the photon noise limit with NIRSpec.

- **Brown dwarfs**
- NIRSpec will provide an invaluable tool to study ultracool atmospheres
- Multi-object spectroscopy capability will enable the statistical study of planetary-mass objects in nearby clusters

Conclusions

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

- **Some dates of relevance:**
  - Preparatory workshops will be organized both in Europe and the USA in the coming years (keep an eye-out for those)
  - ***November 2017 – First call for proposals***
  - Spring 2019 – Start of scientific operations



ESA	http://sci.esa.int/jwst/
	http://www.rssd.esa.int/JWST/
NASA	jwst.nasa.gov
STScI	http://www.stsci.edu/jwst/

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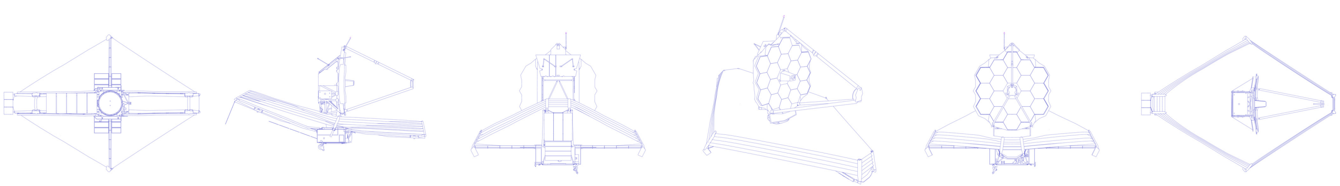
From super-Earths to brown dwarfs: Who's Who?, IAP, July 2015



Additionally slides

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From super-Earths to brown dwarfs: Who's Who?, IAP, July 2015

Exoplanet observations: expected systematics

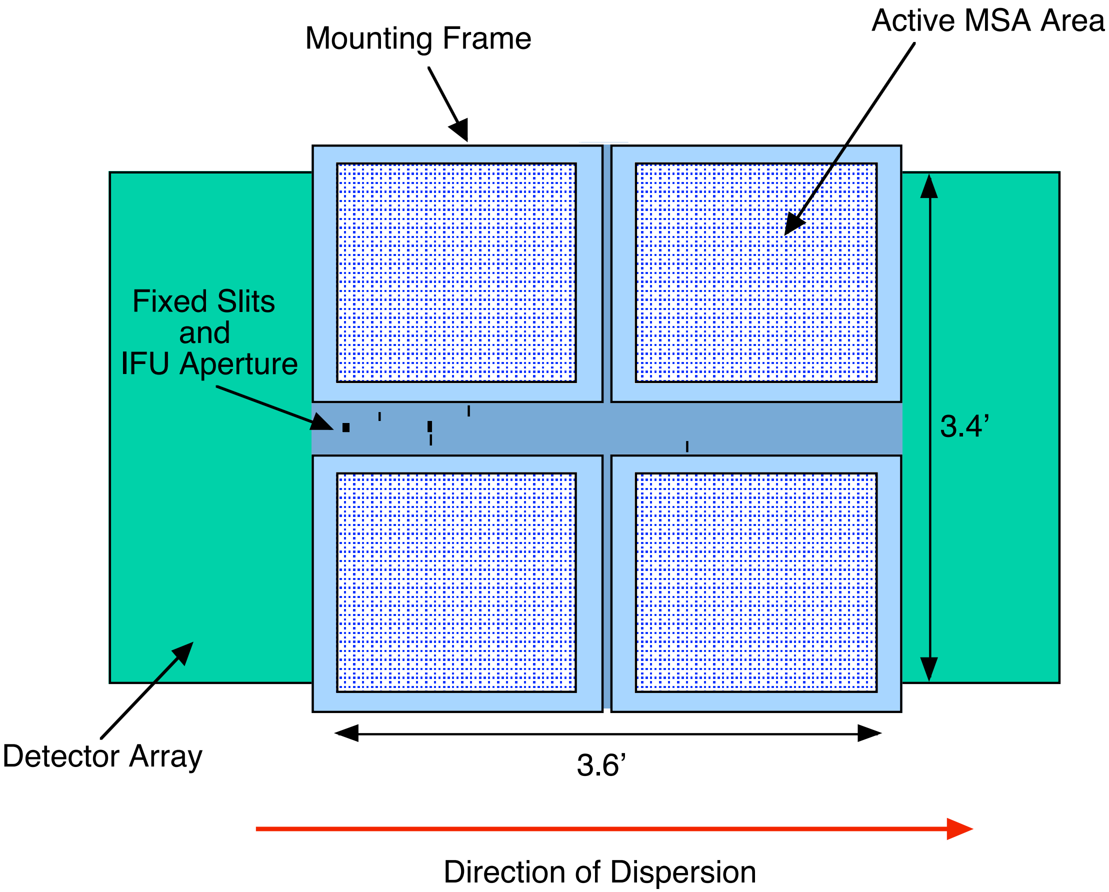
- NIRSpec features a dedicated large aperture (1.6" x 1.6") for exoplanet transit spectroscopy

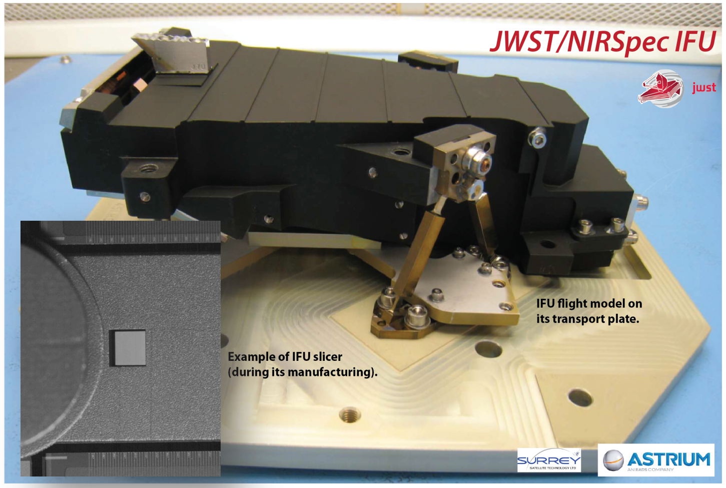
- **Expected systematics for NIRSpec/JWST exoplanet observations**

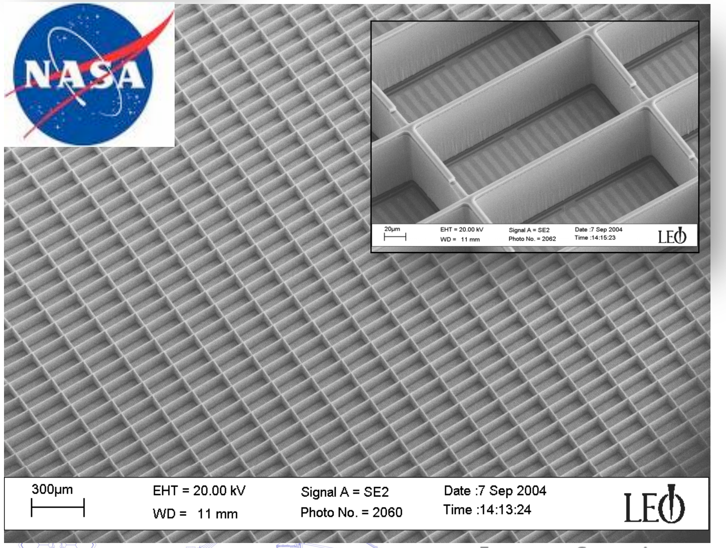
(*Ferruit et al. 2014, SPIE, 9143*)

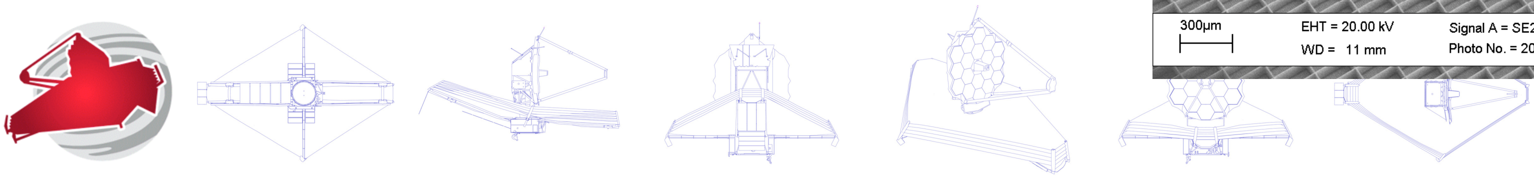
Noise contribution	Description	Impact if not corrected/ calibrated
Detector read noise and shot noise	White noise floor	Included in noise floor benchmark
Variable aperture losses	The level of aperture losses can change when the source drifts during an observation	**[RAW]** Up to 40 ppm
Intra-pixel-sensitivity (IPS) changes	The pixel response can change when the source drifts during an observation	**[RAW]** Up to 400 ppm
Accuracy of the flat-field correction	Associated with residual flat-field errors and source drifts over pixel boundaries during an observation	not fully assessed, probably in the 10 ppm range
PSF variations	The signal will change as the footprint of the PSF on the detectors changes	not fully assessed, smaller than IPS effects due to drifts
Detector persistence	Detector response changes with illumination history	Observed e.g. in HST/WFC3 data

NIRSpec field-of-view: 3 instruments in 1









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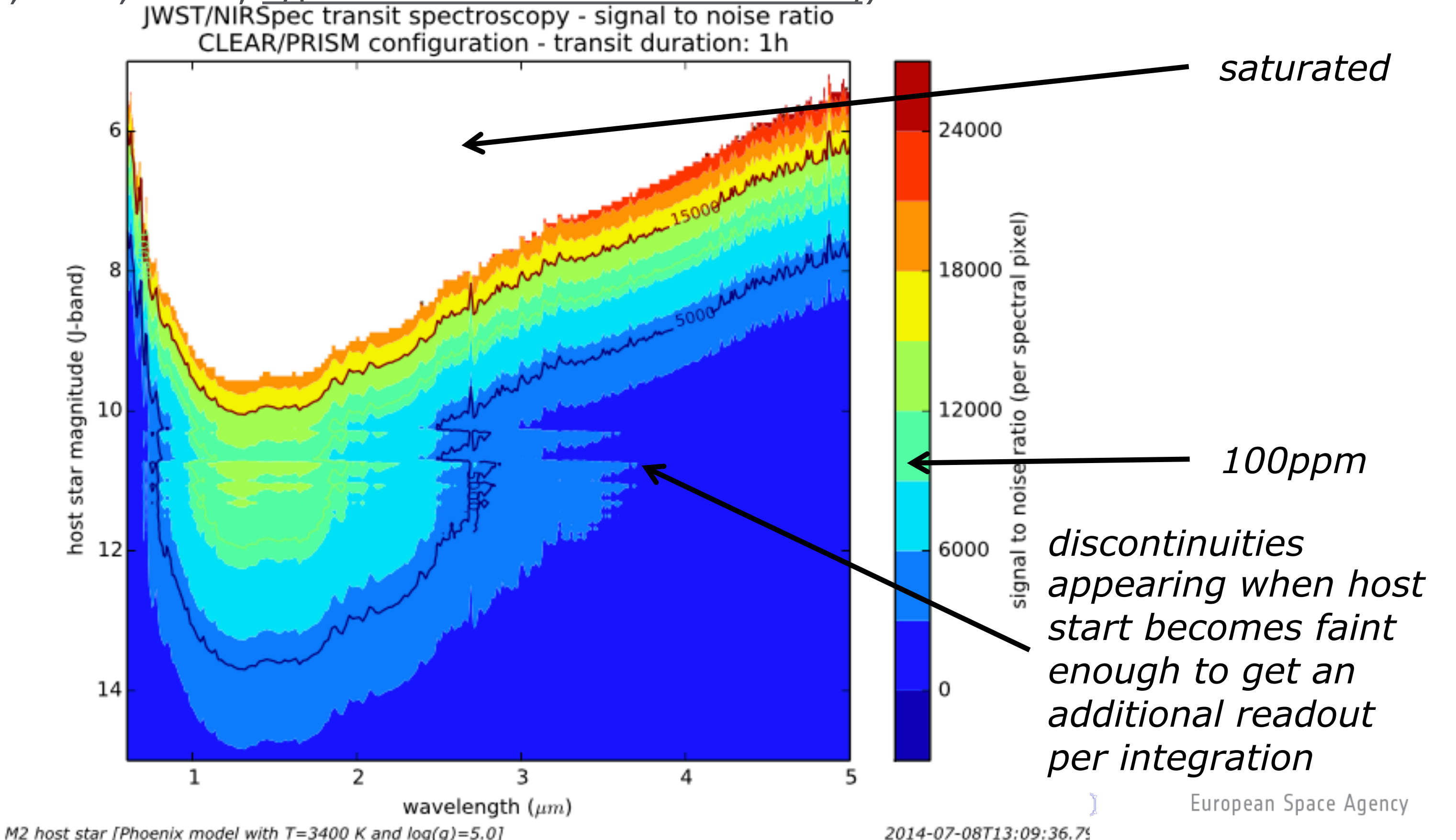
Exoplanet observations with NIRSpec: benchmark noise floor

Noise floor = benchmark lowest noise level that would be achieved if we had only two noise components: detector noise + shot noise from the host star

CLEAR/PRISM
0.6-5.3 microns in one shot / R~30-300
(*Ferruit et al. 2014, SPIE, 9143*, typical uncertainties of ~0.2 mag)



Simulation of a NIRSpec MOS observation

Simulation of an individual spectrographic deep-field exposure (galaxies!, but point-like) in MOS mode using the Instrument Performance Simulator

(B. Dorner 2012, PhD)