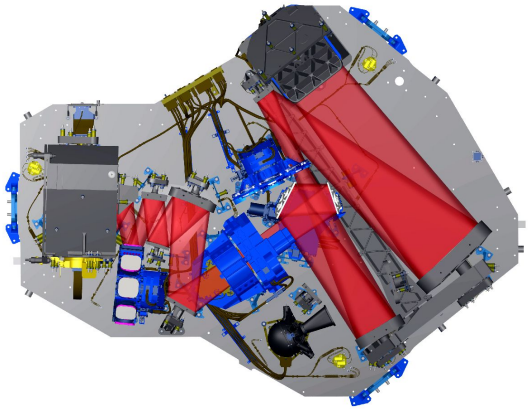
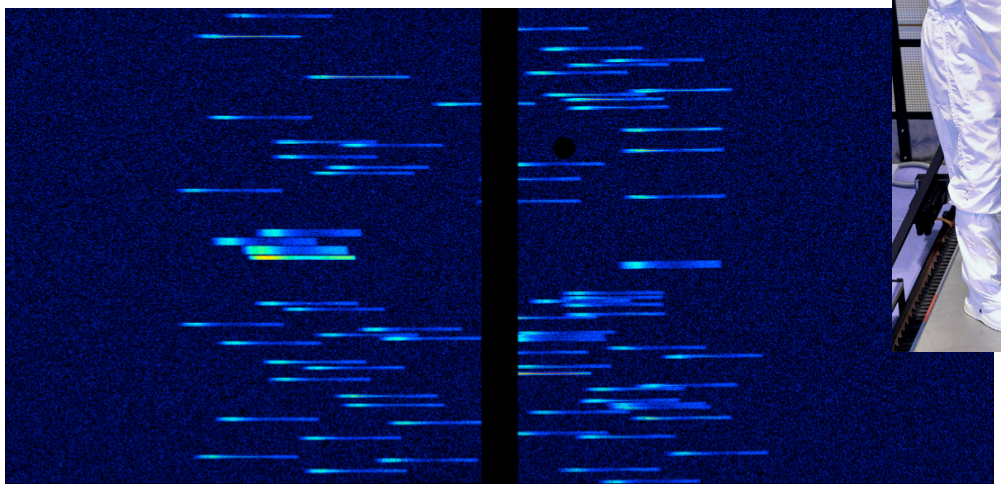
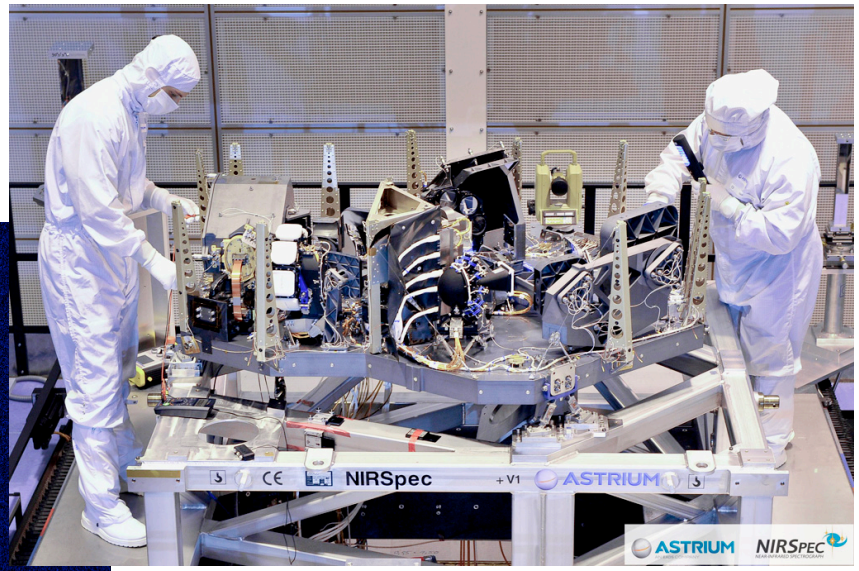
James Webb Space Telescope

The JWST near-infrared spectrograph NIRSpec

P. Ferruit (ESA JWST project scientist)







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Introduction

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- The James Webb Space Telescope will be a major observatory of the next decade (see presentation by M. Mountain)
  - Passively cooled, 6.5-meter telescope covering the 0.6-28 micron range.
  - International collaboration: NASA / ESA / CSA.
  - Suite of 4 instruments (NIRCam, NIRSpec, FGS/NIRISS and MIRI [see presentation by G. Wright]).
  - Launch in late 2018.
- NIRSpec provides JWST's main near-infrared spectroscopic capabilities in the 0.6-5 micron range.
  - Part of the ESA contribution to the JWST mission. Built by an industrial consortium led by EADS Astrium.
  - NASA-provided detectors and micro-shutter arrays.
  - Delivery to NASA scheduled for Spring 2013.

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From JWST's science goals to an instrument…

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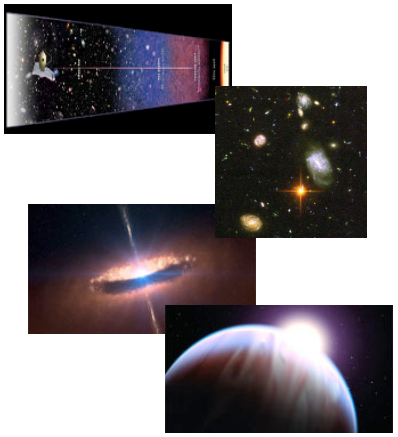
JWST main science topics



- The end of the dark ages – first light and re-ionization.
- The assembly of galaxies.
- The birth of stars and planets.
- Planets and life.

- **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.

Overview of the NIRSpec instrument

From JWST's science goals to an instrument...

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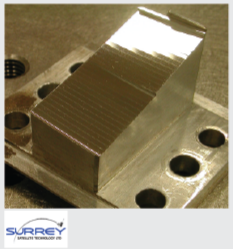
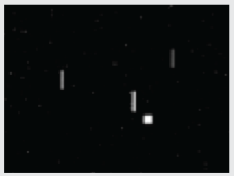
JWST/NIRSpec	MOS		- 9 square arcmin. field of view - 4 programmable arrays of 365x171 micro-shutters provided by NASA GSFC - each micro-shutter creates a small 0.2"x0.46" aperture.	- Multi-object spectroscopy with 0.2"-wide mini-slits. - Low spectral resolution (30 to 300), prism-based mode covering 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 in 4 exposures. - Higher resolution mode available but over a limited FoV.
	IFU		- 3"x3" field of view - spatial sampling of 0.1" per slice and per pixel - IFU made of 30 slices for a total of 900 "spaxels"	- IFU spectroscopy with a 0.1" sampling. - 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		- 5 slits available - 3 slits of 0.2" x 3.2" (S200A1, S200A2 and S200B1) - 1 slit of 0.4" x 3.65" (S400A1) - 1 aperture of 1.6" x 1.6" (S1600A1)	- High-contrast slit spectroscopy including with a 1.6"x1.6" square aperture for extra-solar planet transit observation. - All spectral resolution modes available. - SLIT can be used simultaneously to IFU or MOS.

Overview of the NIRSpec instrument

Main spectroscopic configurations.

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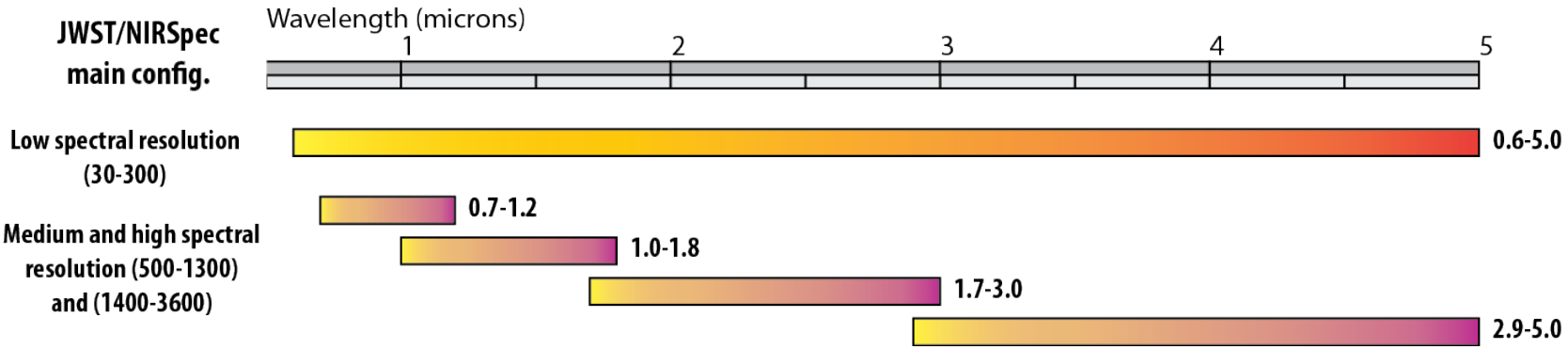
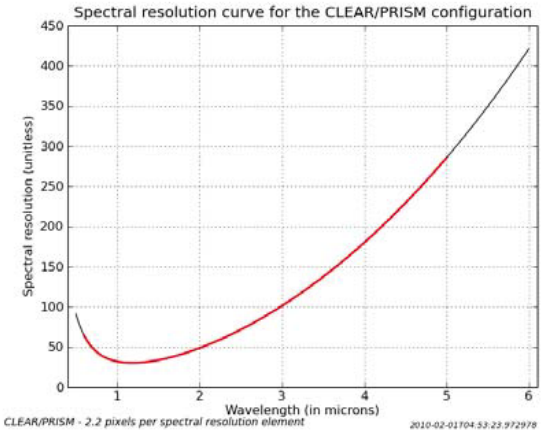
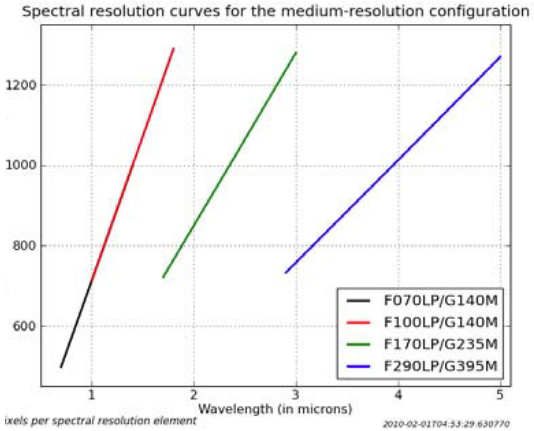
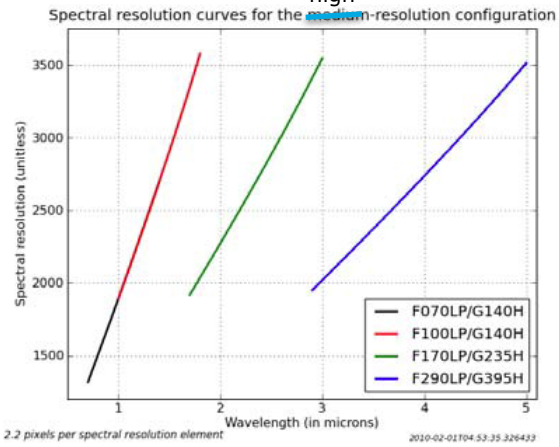






high



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Overview of the NIRSpec instrument

What does it look like on the detectors?

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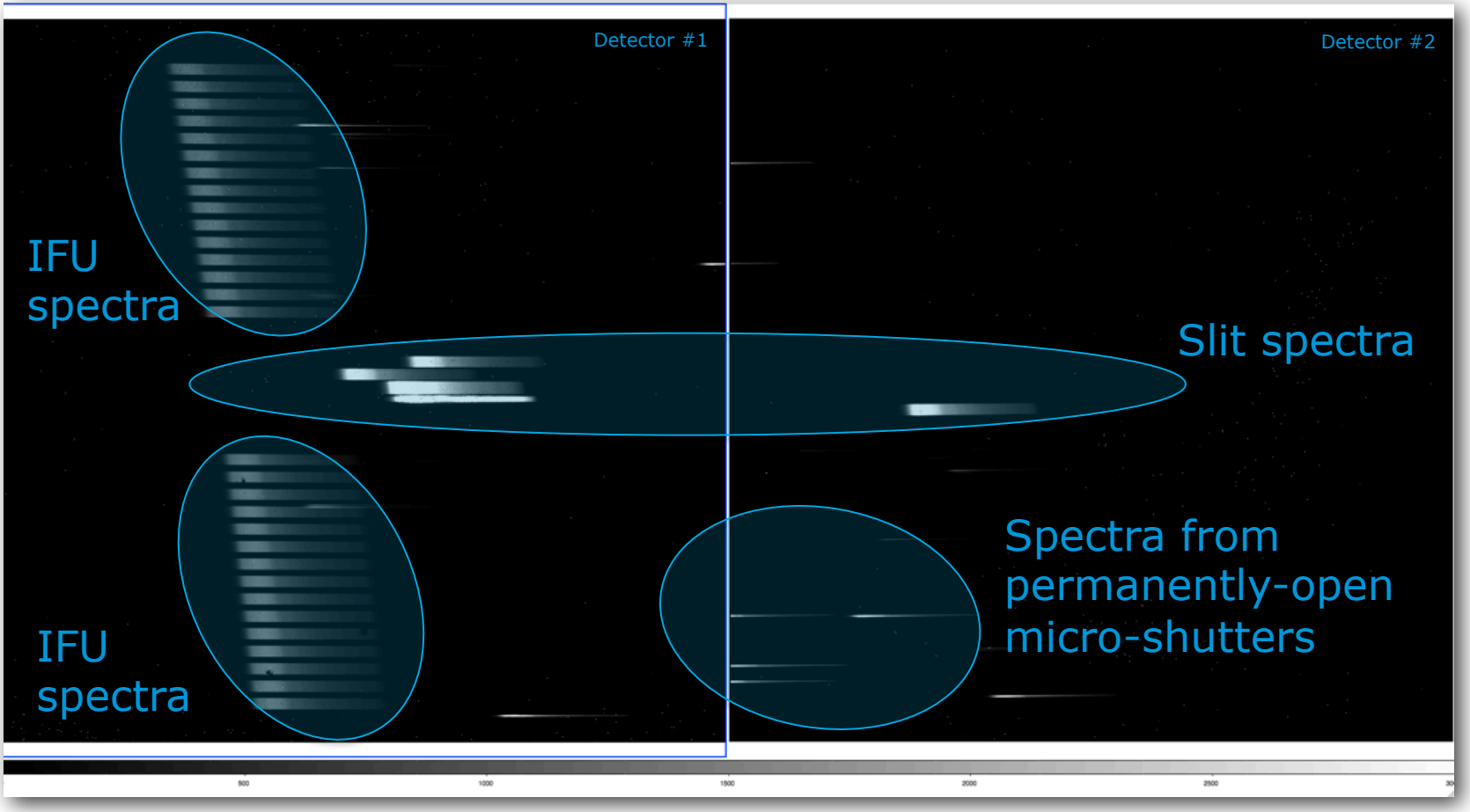

Short continuum spectra obtained with the prism during cryogenic testing in 2011. Only IFU and SLIT modes were available.

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Overview of the NIRSpec instrument

What does it look like on the detectors?

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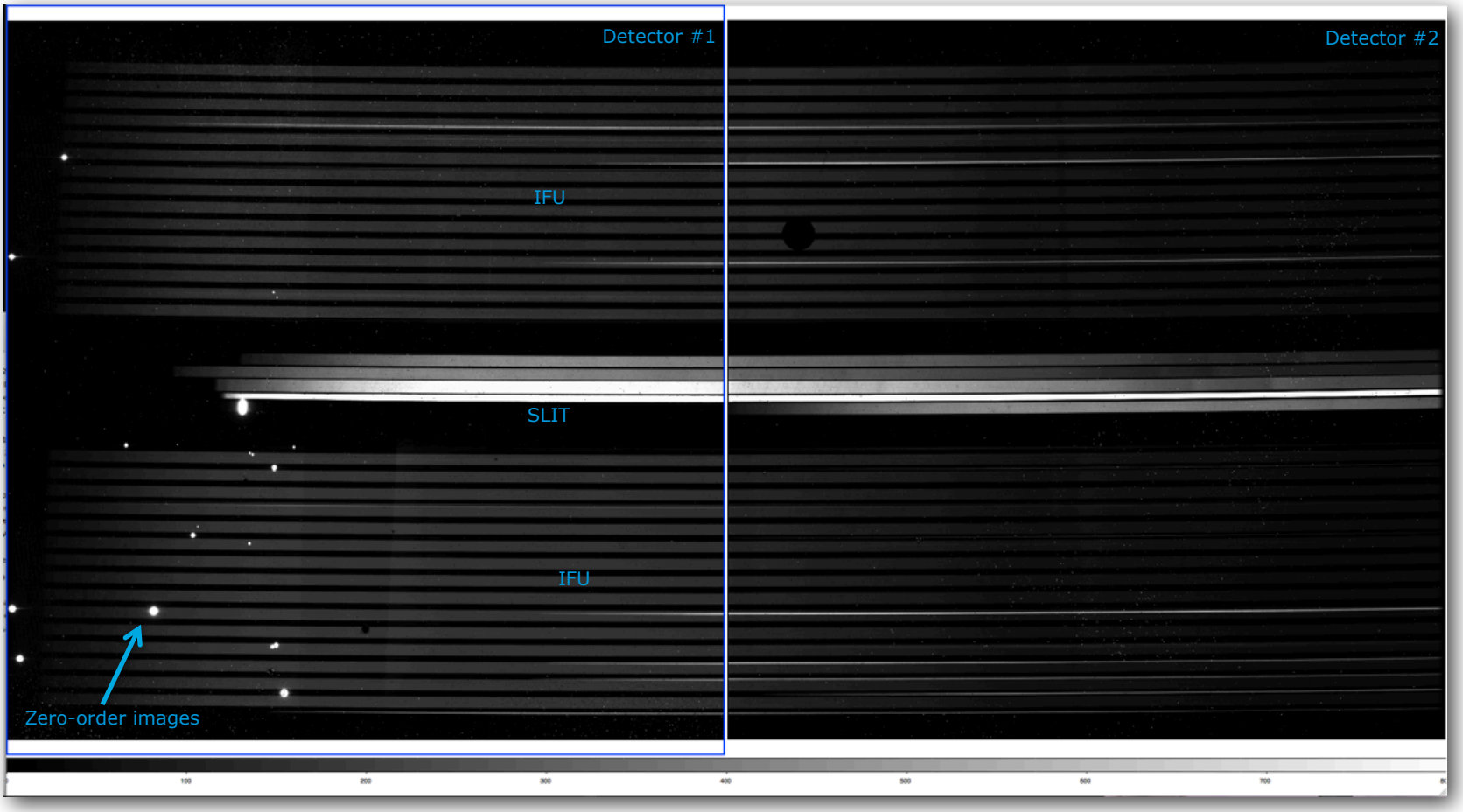

Medium (R=700-1300) continuum spectra obtained with the IFU during cryogenic testing in 2011. Only IFU and SLIT modes were available.

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Overview of the NIRSpec instrument

What does it look like on the detectors?

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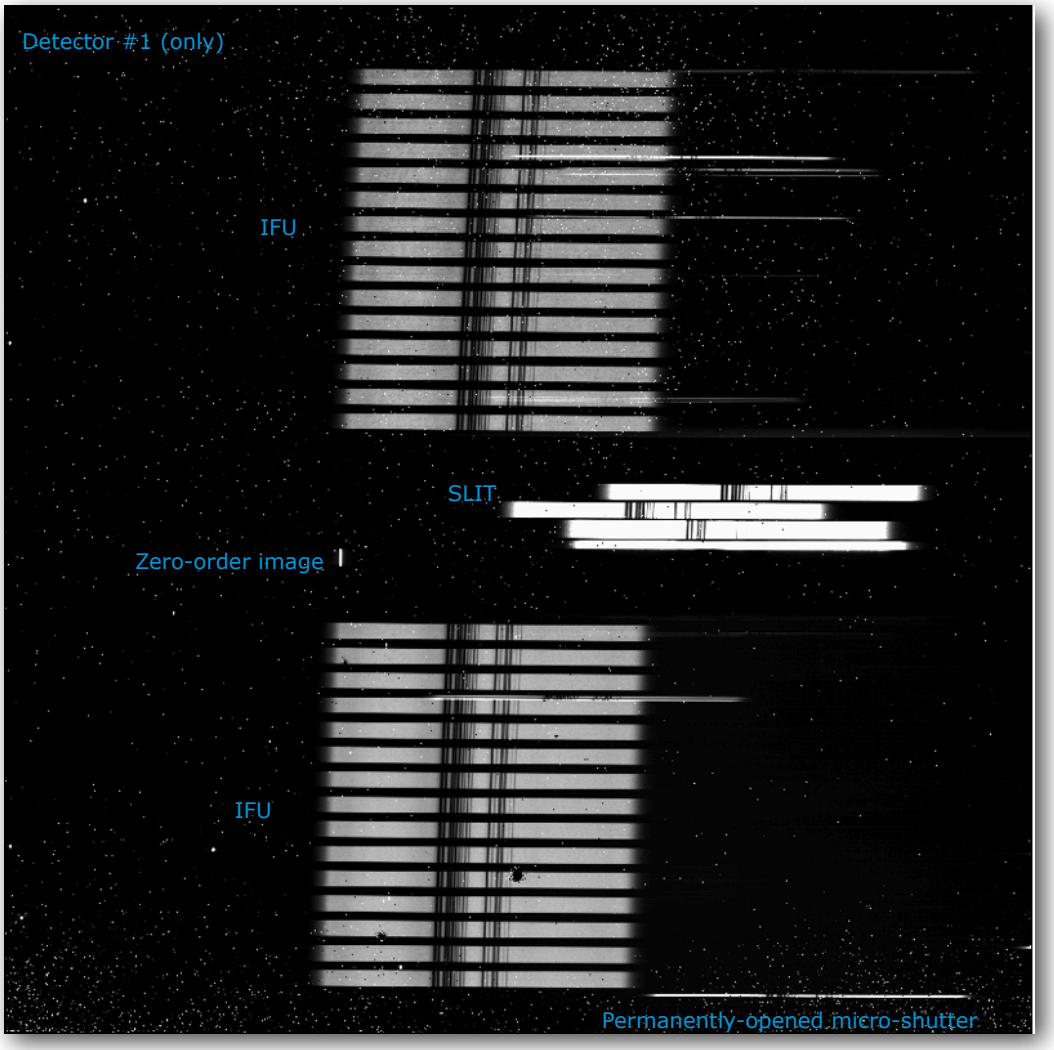
Medium resolution (R=700-1300) spectra of a continuum source with absorption features obtained with the IFU during cryogenic testing in 2011.



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Overview of the NIRSpec instrument

A short look at the design / hardware…

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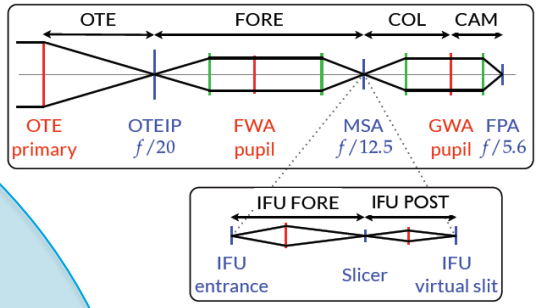
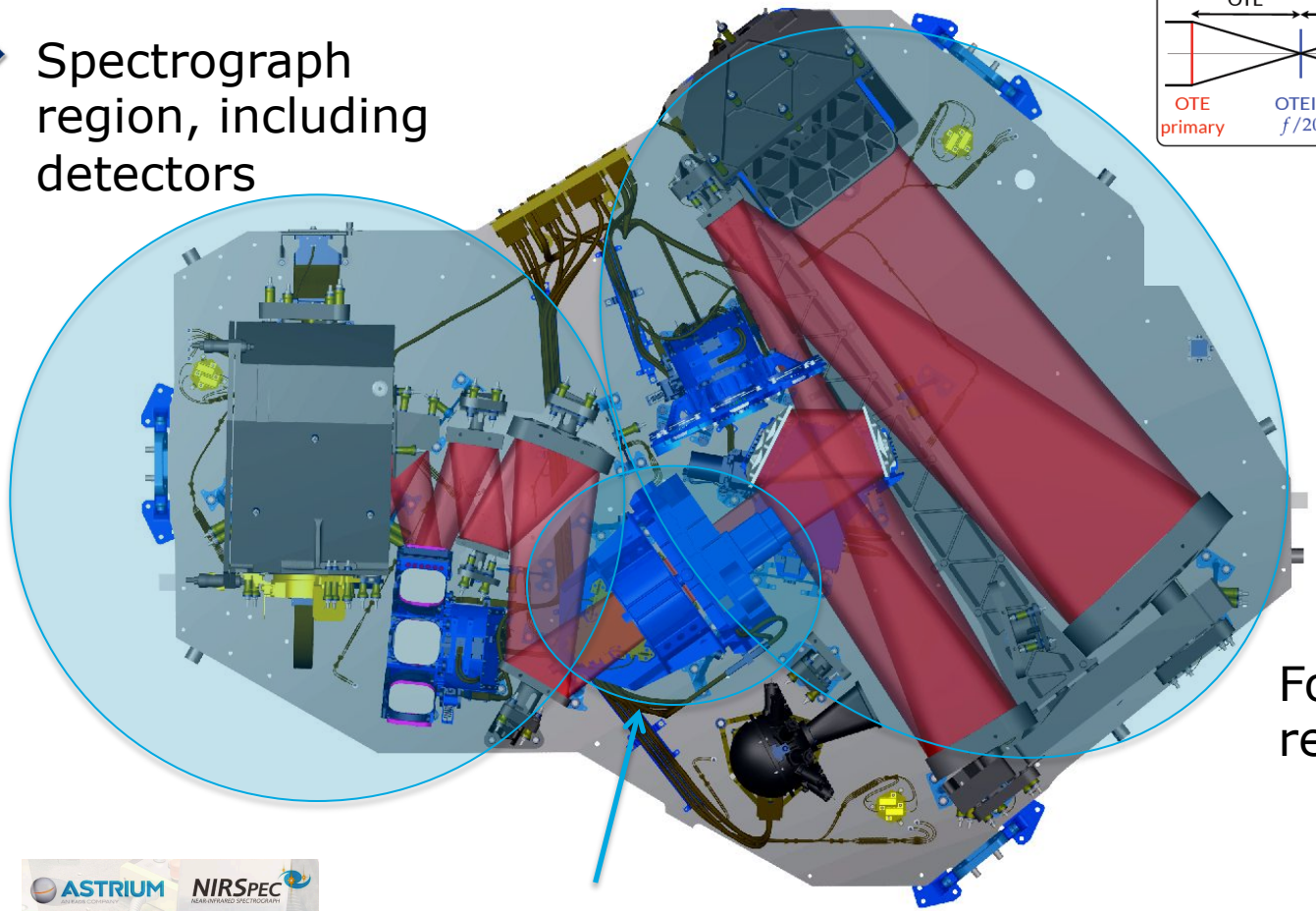
Figure credit: B. Dorner, PhD, 2012



Spectrograph region, including detectors



Fore-optics region

ASTRIUM NIRSPEC

MSA, IFU and slits

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

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Overview of the NIRSpec instrument

A short look at the design / hardware…

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NIRSpec flight model #1 in early 2011 at the end of its integration at EADS Astrium.

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A very turbulent year 2011…

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- In early 2011, the NIRSpec flight model (#1) was fully assembled and test at operating temperature (~40 K).
  - MSA could not be operated at the time but IFU and SLIT spectra were obtained.
  - Very successful test campaign.
- However, at the end of 2011, cracks were discovered in the NIRSpec bench.
  - Decision was taken to replace this bench by the spare one.
  - Removal of all the elements from the damaged FM1 bench and final preparation of the FM2 bench for "re-integration" of NIRSpec.
  - Extensive set of analyses / testing / update of integration procedures to make sure the problem does not occur again.

Integration and testing of the NIRSpec FM2

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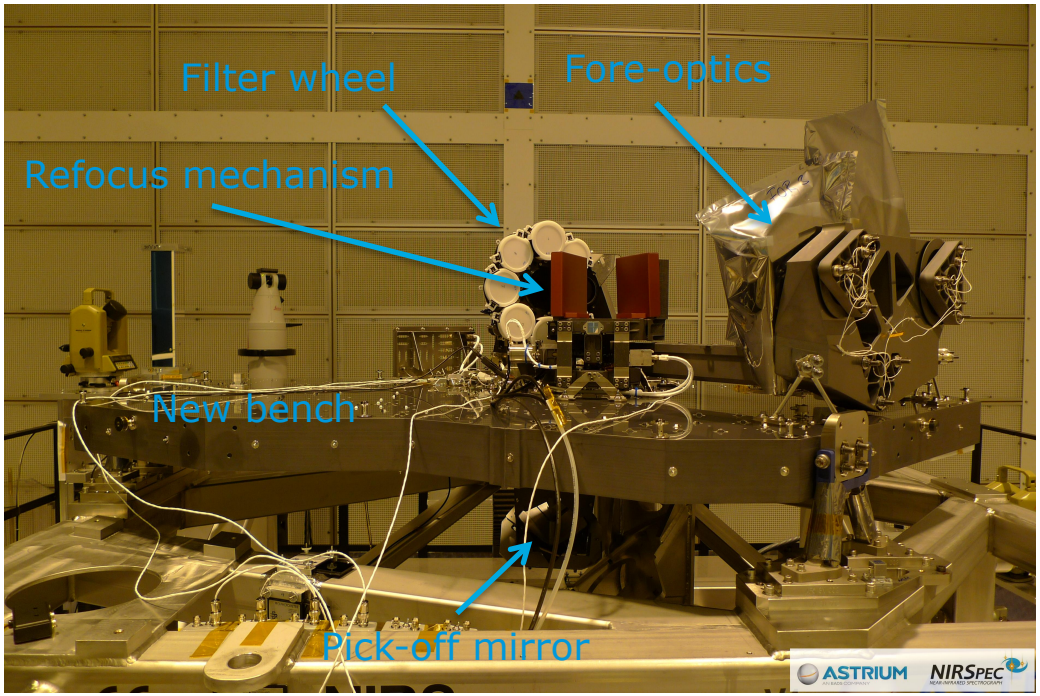
- The integration of the NIRSpec flight-model #2 (FM2) is on-going at EADS Astrium

NIRSpec FM2 – end of May 2012



- Next milestones:

Aug. 2012: completion of integration.

Soon…

Sep.-Oct. 2012: cryogenic cycle.

Nov.-Dec. 2012: vibration + acoustic testing.

Early 2013: main cryogenic test campaign.

- **Delivery to NASA scheduled for Spring 2013**

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Expected performances. Simulated observations

Sensitivity status.

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- Waiting for the main cryogenic campaign of early 2013 to get "as-built" sensitivity estimates.
  - But so-far, the 2011 test campaign showed that NIRSpec performances and efficiency were in line with the predictions.

NIRSpec is on track to meet its sensitivity requirements.

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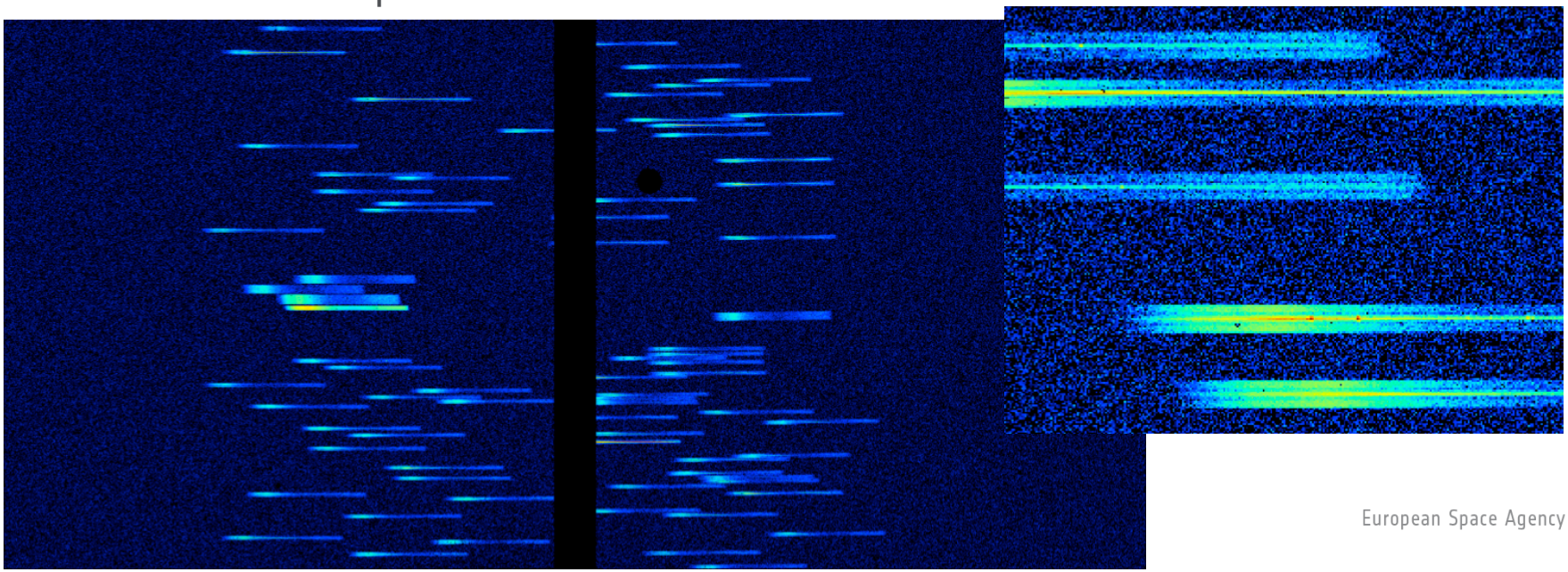
Simulated observation – MOS scene

- 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.



Simulated observation – MOS scene

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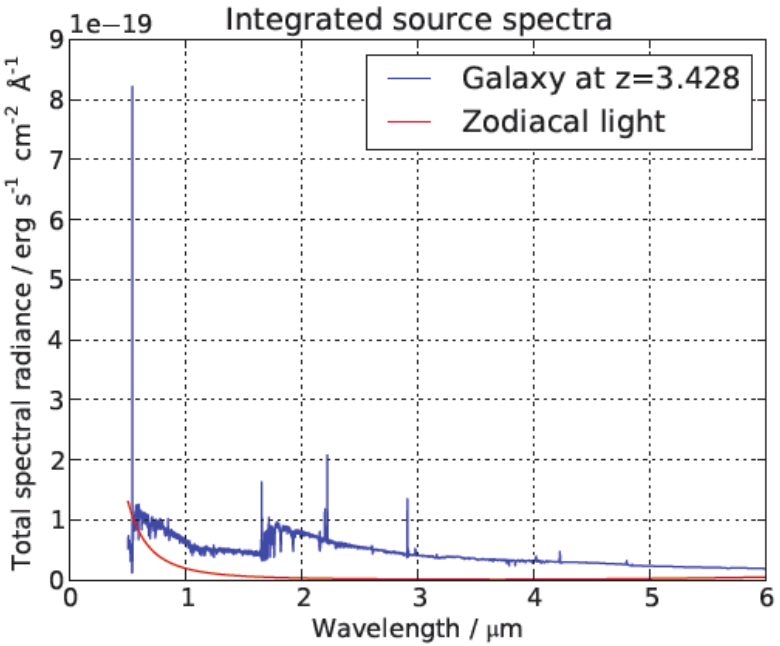
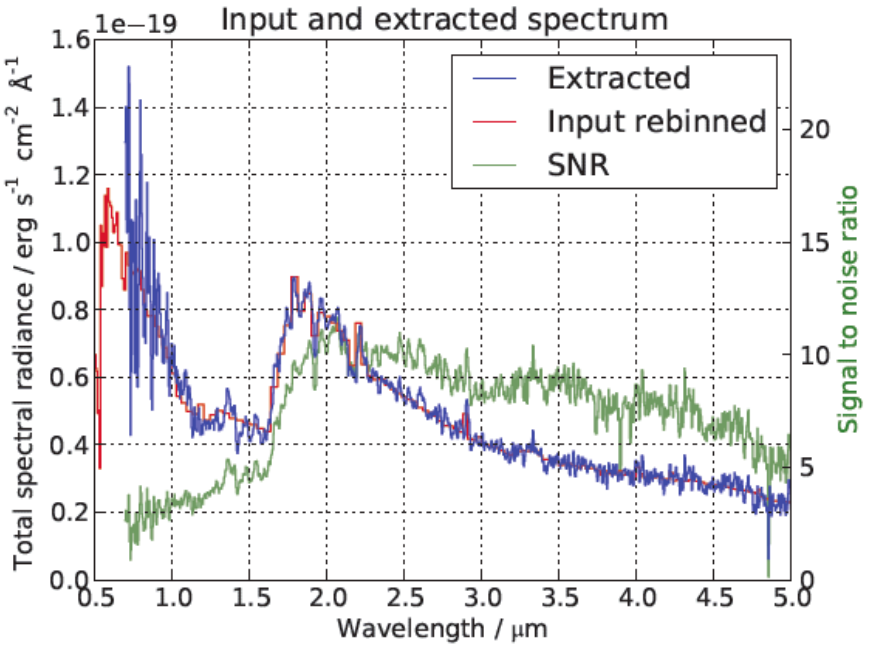
- Some examples of spectra extracted from the simulated low spectral resolution 945-s exposure.





(c) $z = 3.428$, $mag_H = 24.7$

Dorner, 2012 (PhD)

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Expected performances. Simulated observations

Simulated observation – MOS scene

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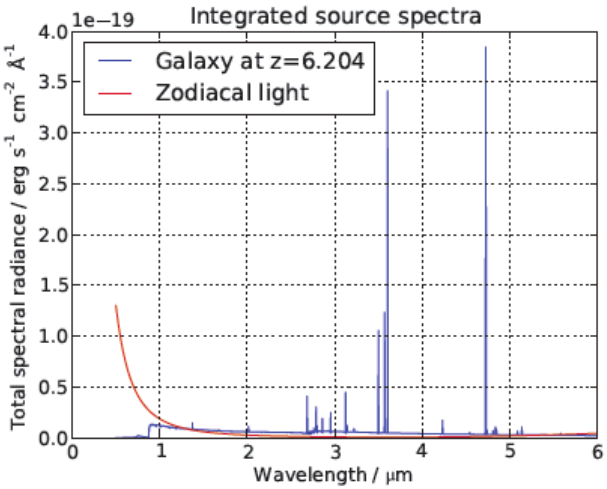
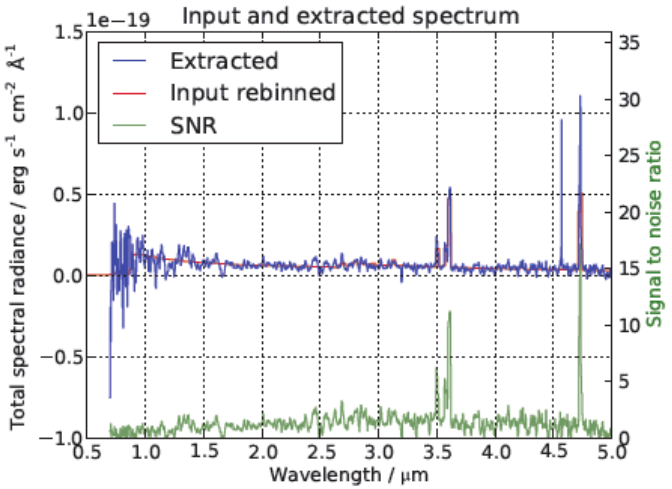
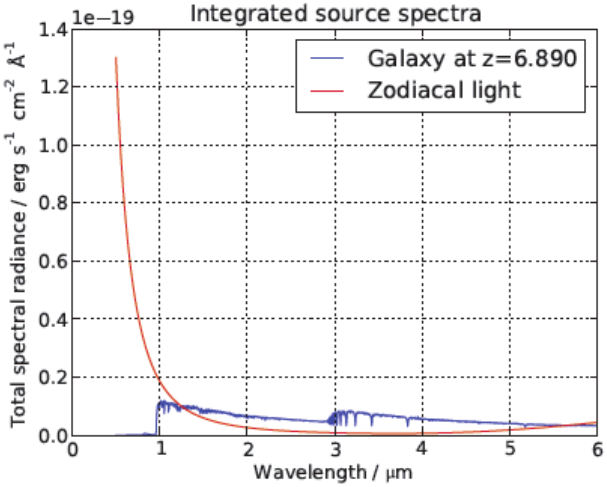
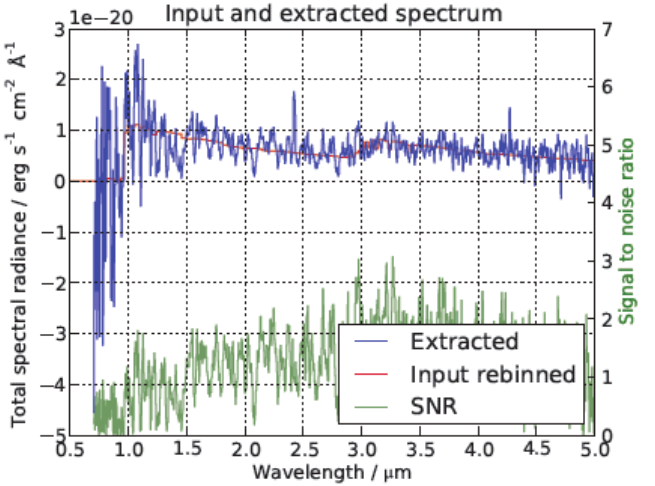
For the faintest objects, 10 to 100 of these 945s exposures will be obtained when conducting a spectrographic deep-field.





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





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

Dorner, 2012 (PhD)

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Technology development program

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- The question of the technology developments is quite generic.
- For all ESA scientific missions / projects, the maturity of the technologies that are needed is evaluated in the early phases.
  - Big emphasis on the re-use of existing / mature technologies ("heritage").
  - Requirement to achieve a certain level of maturity before we freeze the design and/or start manufacturing flight parts.
- ESA has a strong "technology development program"
  - Bringing critical technologies to a sufficient level of maturity.
  - Mission enabling activities; strong risk reduction (cost, schedule…).

Technology developments for NIRSpec

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- Actually for NIRSpec the two critical technology developments were on NASA side.
  - ASIC: the proximity electronics for the detectors
  - MSA: the micro-shutter arrays
- Dedicated development programs were put in place by NASA for these two items.
  - Demonstrated sufficient maturity at the mission CDR (critical design review).
- CAUTION: this does not mean everything else is "easy" as the instruments usually require to achieve state-of-the-art performance levels…

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Conclusion

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- NIRSpec will be a fantastic instrument on-board a fantastic observatory.
- After a turbulent year 2011, the instrument is back on track and will be delivered to NASA in Spring 2013.

Thanks for your attention!

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