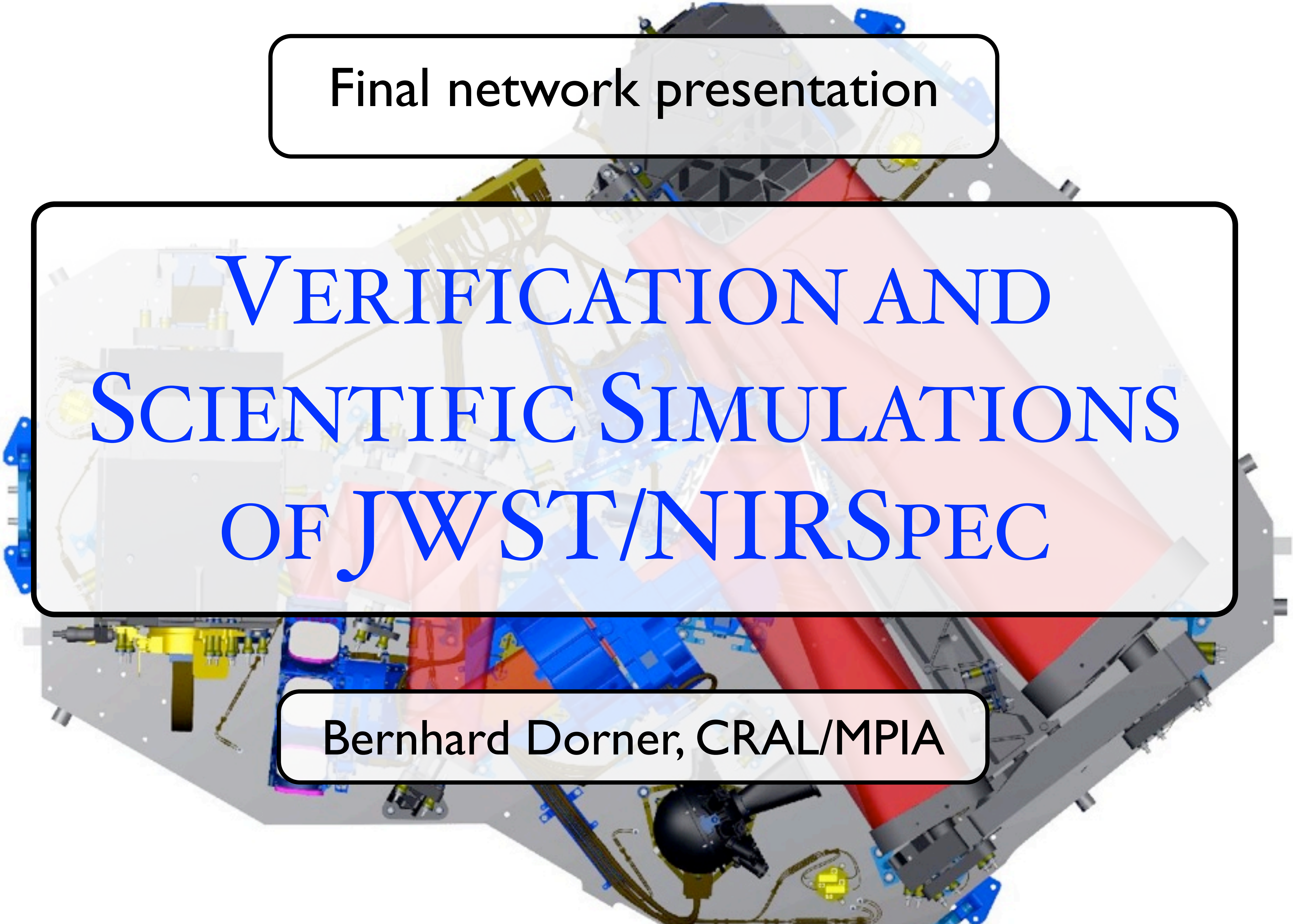

Final network presentation

Verification and Scientific Simulations of JWST/NIRSpec

Bernhard Dorner, CRAL/MPIA

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° PITN-GA-2008-214227 - ELIXIR

What's left to say?

...after all those meetings...

Kudos to:

Pierre Ferruit, Bruno Guiderdoni,
Xavier Gnata, Laure Piqueras, Emeline Legros, Pierre-Jacques Legay, Arlette Pécontal-Rousset, Aurélien Jarno, Aurélien Pons,
Jess Köhler, Jean-Francois Pittet, Werner J. Hupfer, Markus Melf, Peter Mosner, Maurice Te Plate, Peter Jakobsen, Stephan M. Birkmann, Torsten Böker, Guido de Marchi, Marco Sirianni, Giovanna Giardino,
Jeff Valenti, Tracy Beck, Camilla Pacifici, Stéphane Charlot, Enrica Bellocchi, Santiago Arribas, Hans-Walter Rix

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Outline

I. Software for NIRSpec simulations

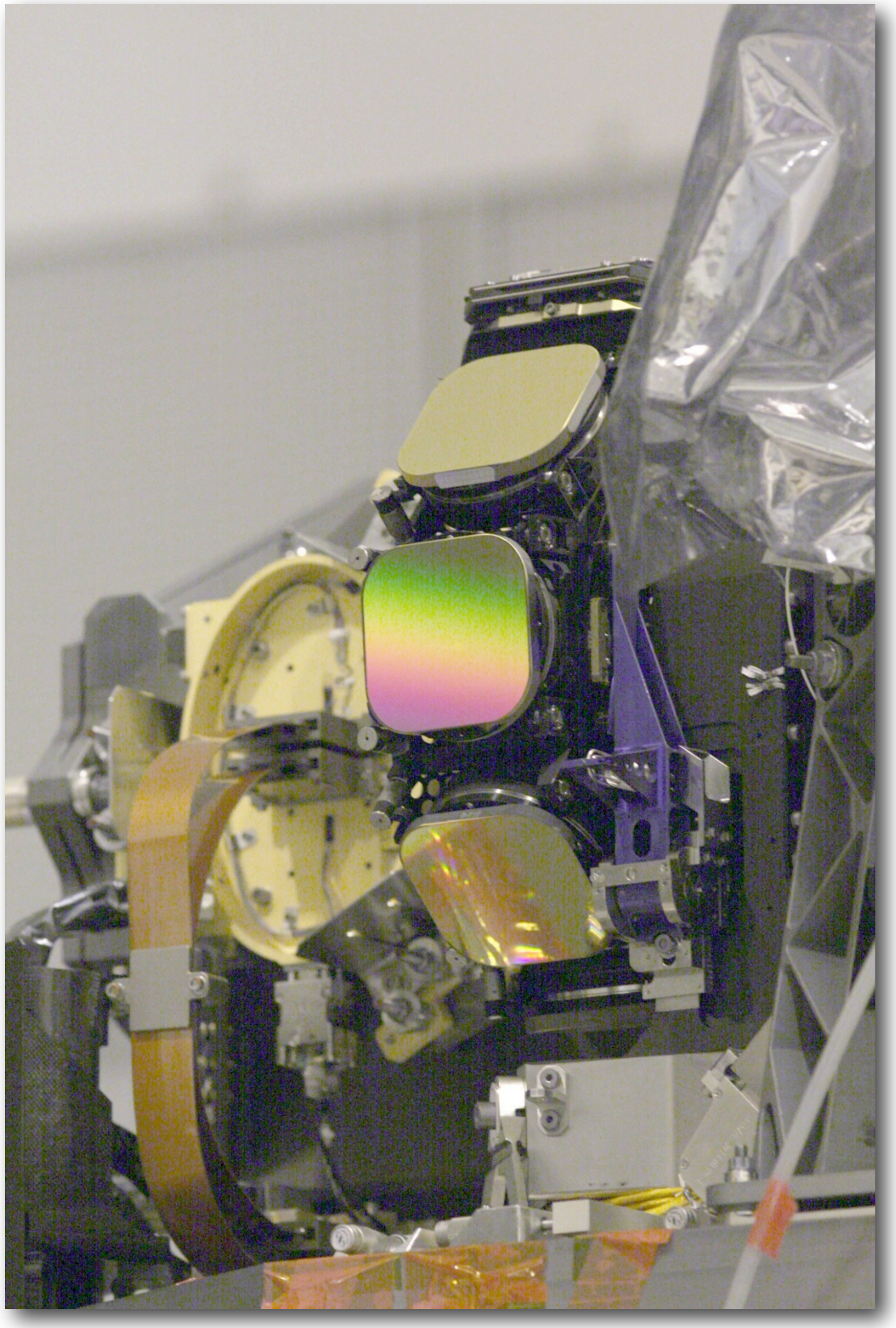
II. How to build and verify an instrument model

III. Science part 1: Spectrographic deep field

IV. Science part 2: Integral field observations

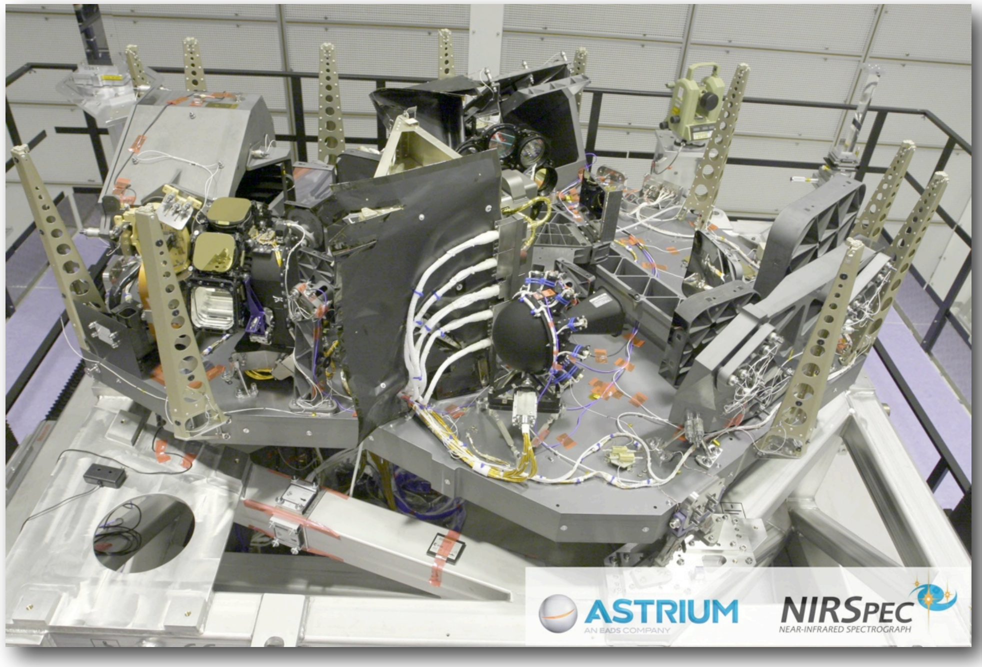
V. Science part 3: Exoplanet transits

VI. Conclusion



Once more: NIRSpec overview

- Spectral range: 0.6–5 μm
- Field of view: >9 arcmin^2
- Multi-object capability: >100 targets
- Configurable masks (MSA, 250,000 shutters, 0.2")
- Fixed slits (0.2", 0.4", 1.6")
- Integral Field Unit (IFU, 30 slices, 3x3")
- Two HgCdTe arrays (SCA), each 2048x2048 pixel
- ESA project, built by EADS/Astrium GmbH



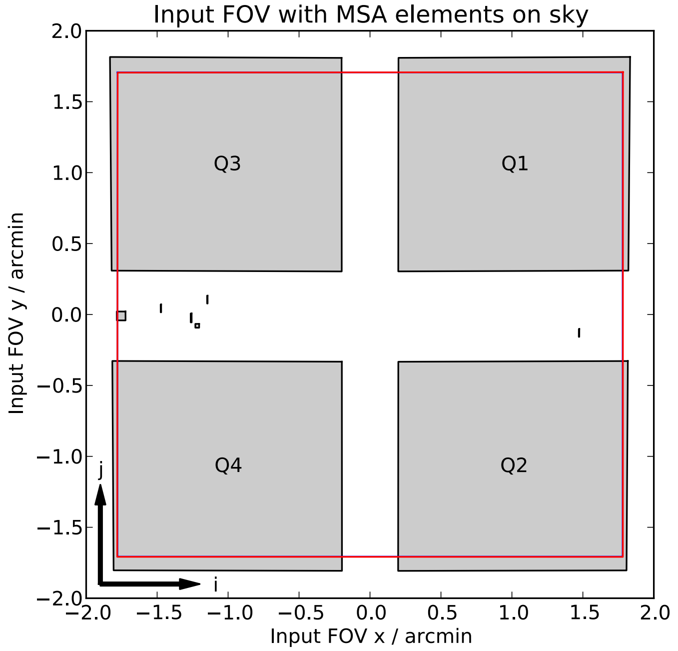
ASTRIUM
AN EADS COMPANY

see Bagnasco et al., 2007

The Instrument Performance Simulator

- Purpose:
  - Study geometrical effects
  - Verify instrument performance
  - Generate realistic output data
- Software developed by CRAL 2005–2011
  (Gnata, 2007, Piqueras et al., 2008, 2010)
- >110,000 lines of C++ code
- End-to-end simulation of NIRSpec:
  - Noiseless electron rates
  - NIRSpec raw data cube

Auxiliary software for simulations



- Science data input interface:
  - Direct object placement in slits
  - Typical input file types
- "NIRSpec IPS Pipeline Software" (NIPPLS):
  - Spectrum extraction from NIRSpec exposures
  - Uses IPS instrument model to find spectra
  - Standard "long slit" reduction, but flexible for custom tasks
  - Also used for measured data

Up next:

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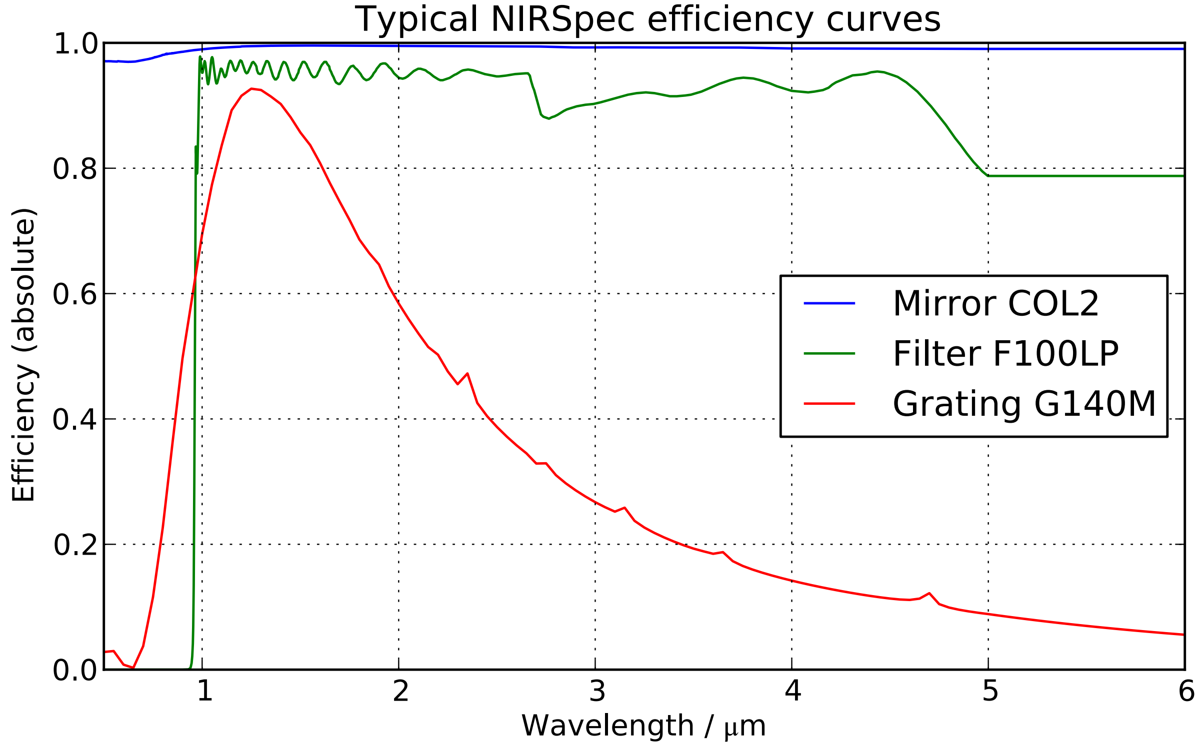
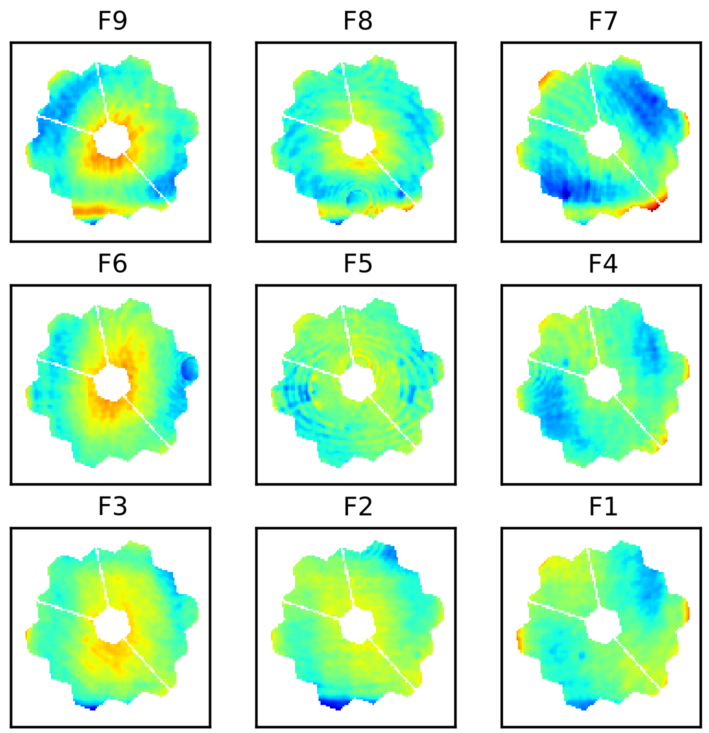
NIRSpec model data

- Collection of measurements and calculations for subsystems
- Efficiencies:
  - Mirrors, filters, detector
  - Gratings, IFU
- Geometries
  - Disperser, MSA, detector
  - Optical distortion
- Wavefront errors
  - Dispersers + IFU
  - NIRSpec optical train, Telescope (te Plate et al., 2007)





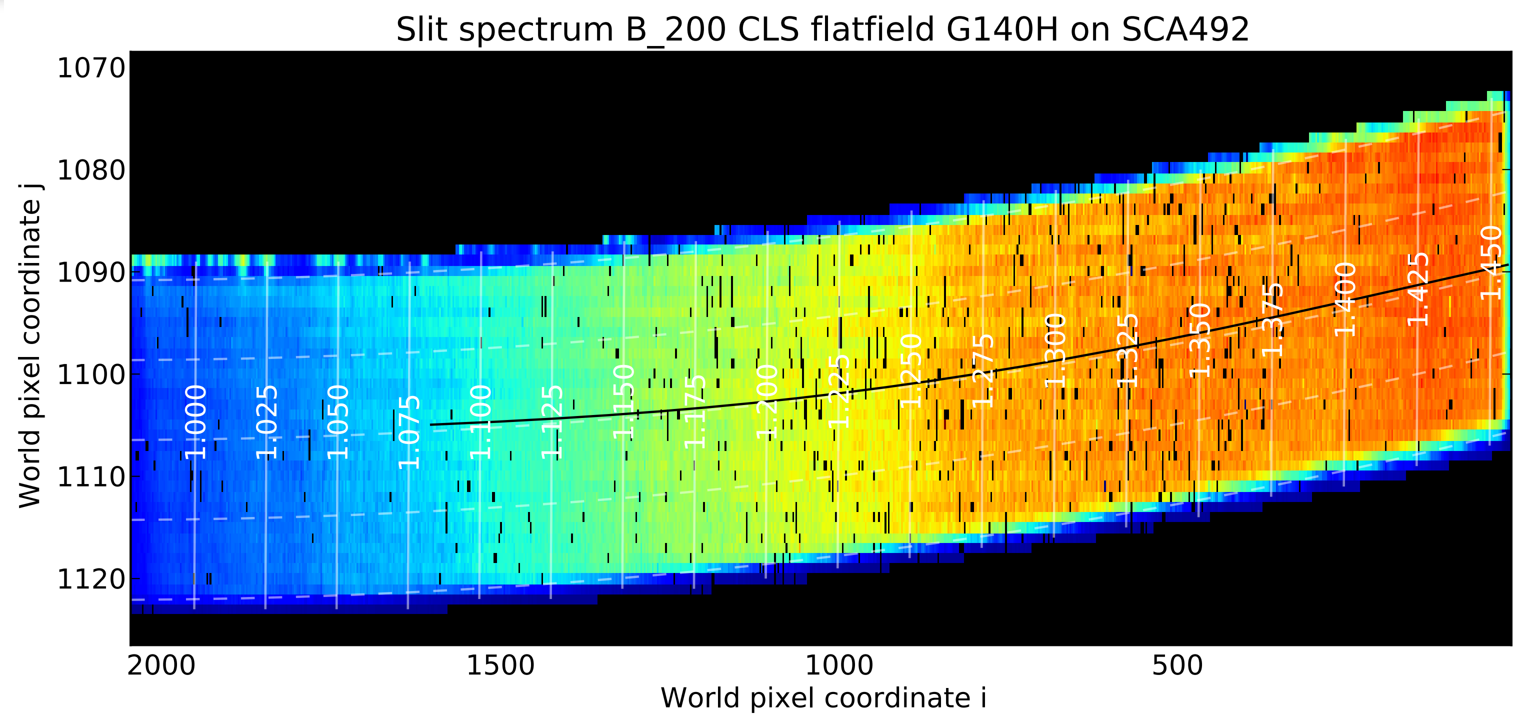
FORE WFE in telescope pupil

Model verification

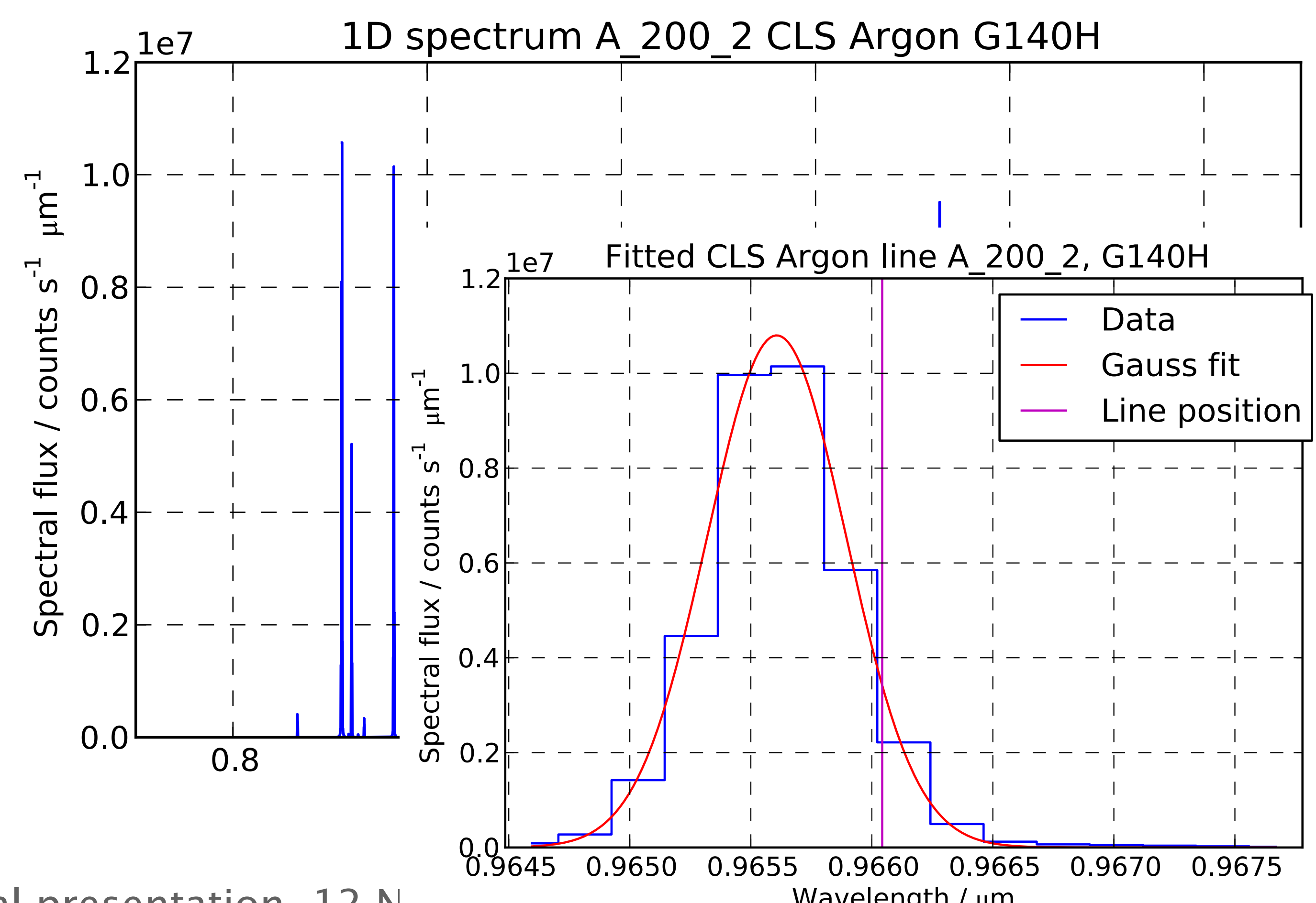
- Why?
  - Verification of model as a whole: remove uncertainties, check data interplay
  - Provide input for data processing and simulations
- How?
  - Compare model prediction with calibration measurements (fixed slits and IFU, February 2011)
  - Analysis done in NIPPLS
- What?
  - Instrument geometry and efficiency

Geometry: reference data

Spatial: Trace polynomials



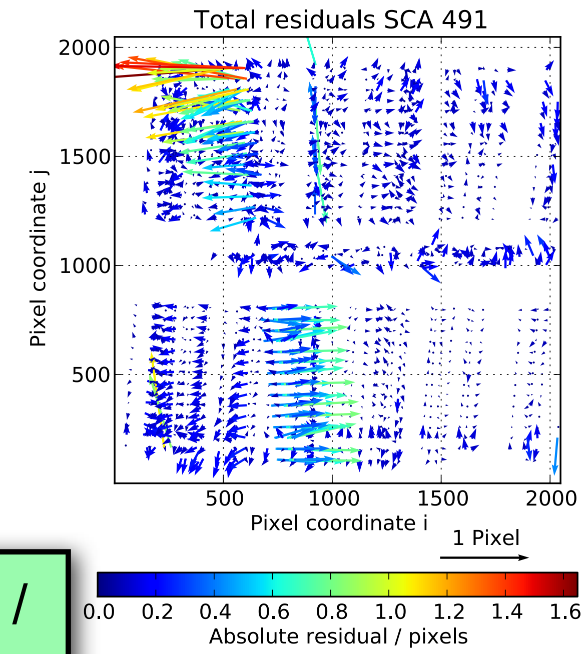
Spectral: Argon emission lines

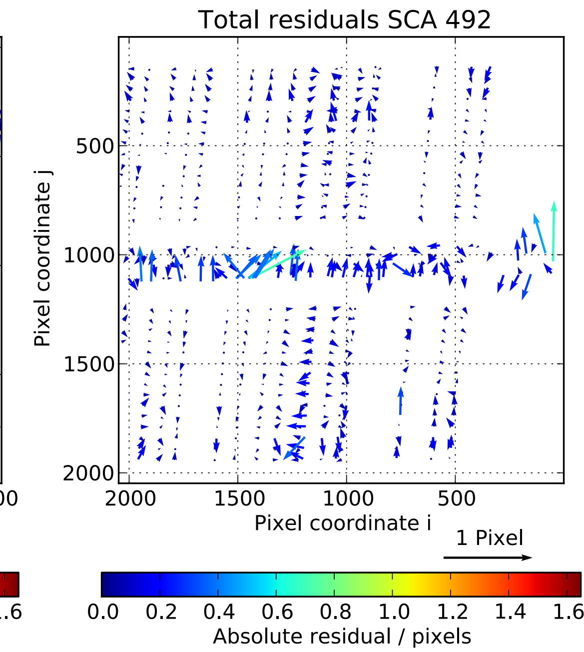


Reference data tuples

$$(Pixel_i, Pixel_j, \lambda_{ref})$$

Optimization: Forward





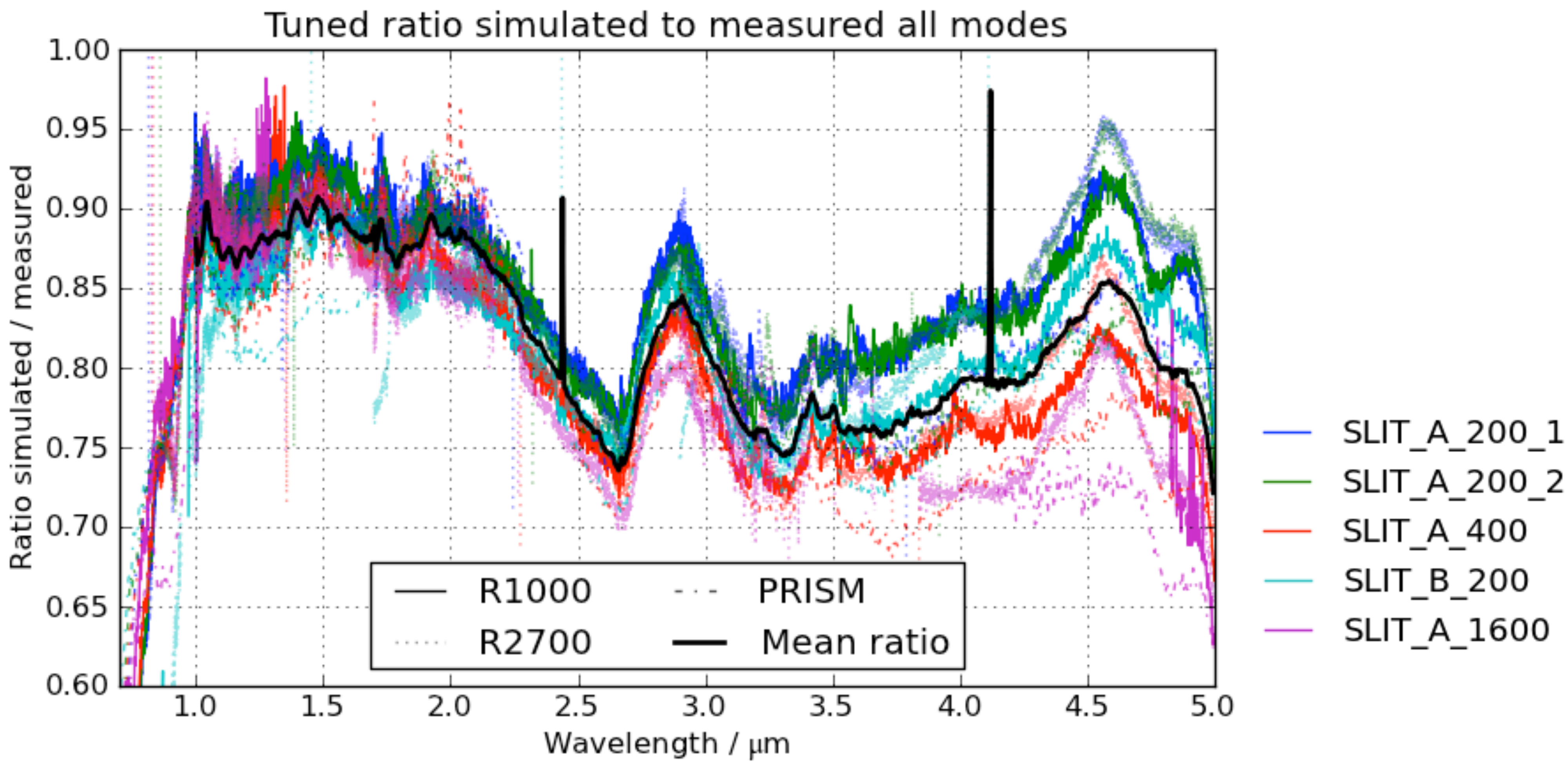
- Total forward residuals:

Dispersers	Reference points	Median residual / pixel fraction
Gratings	2233	1/15
PRISM	219	1/4
MIRROR	35	1/5.6
Total	2487	1/14

- Instrument requirement (spectral): 1/4th pixel
- Modeling approach works

Total instrument throughput

- Ratio simulated to measured, all dispersers



- Consistent across bands
- Divergence of slits
- Some residual features
- Mean: 0.82±0.05 (Calibration source?)
- Final accuracy: 0-10% absolute, 5% relative

…nearly 14 billion years ago, expansion started…

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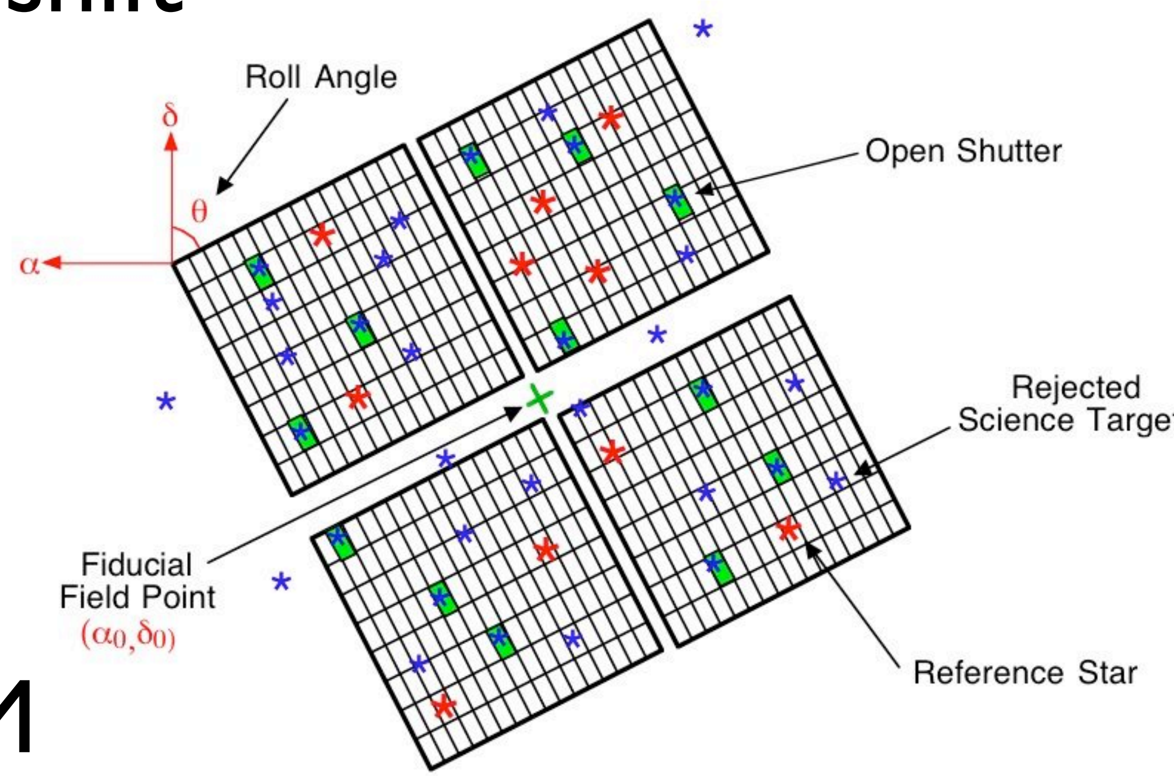
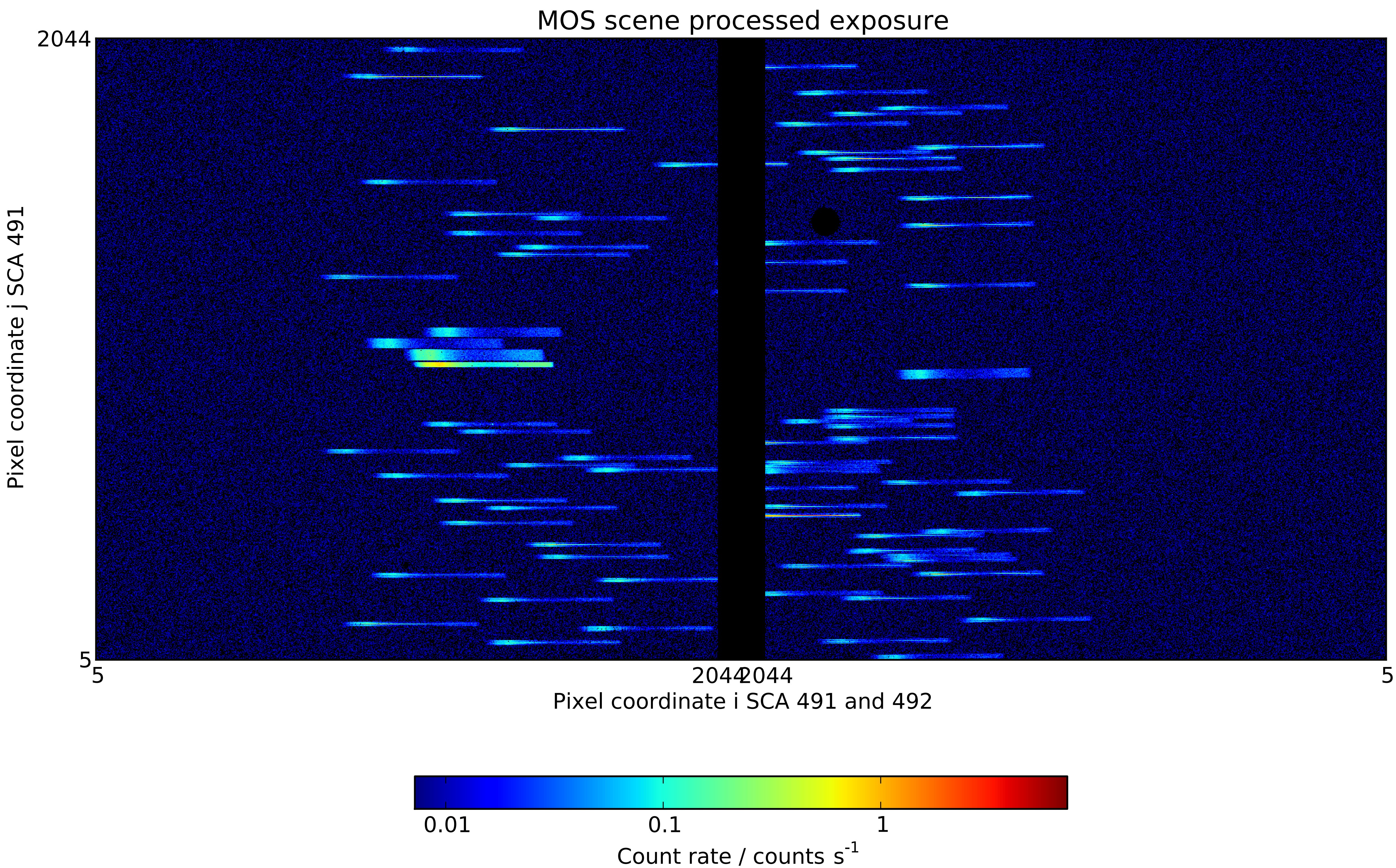
Deep field spectroscopy simulation

- Sky scene from
  - Hubble UDF: Objects with band photometry and derived redshift (Coe et al., 2006)
  - Model galaxy spectra from simulations (Pacifici et al., 2012)
- Simulation with
  - Point sources, CLEAR, PRISM
  - Noise for 945s exposure
- Extraction with NIPPLS



Multi-object processed exposure



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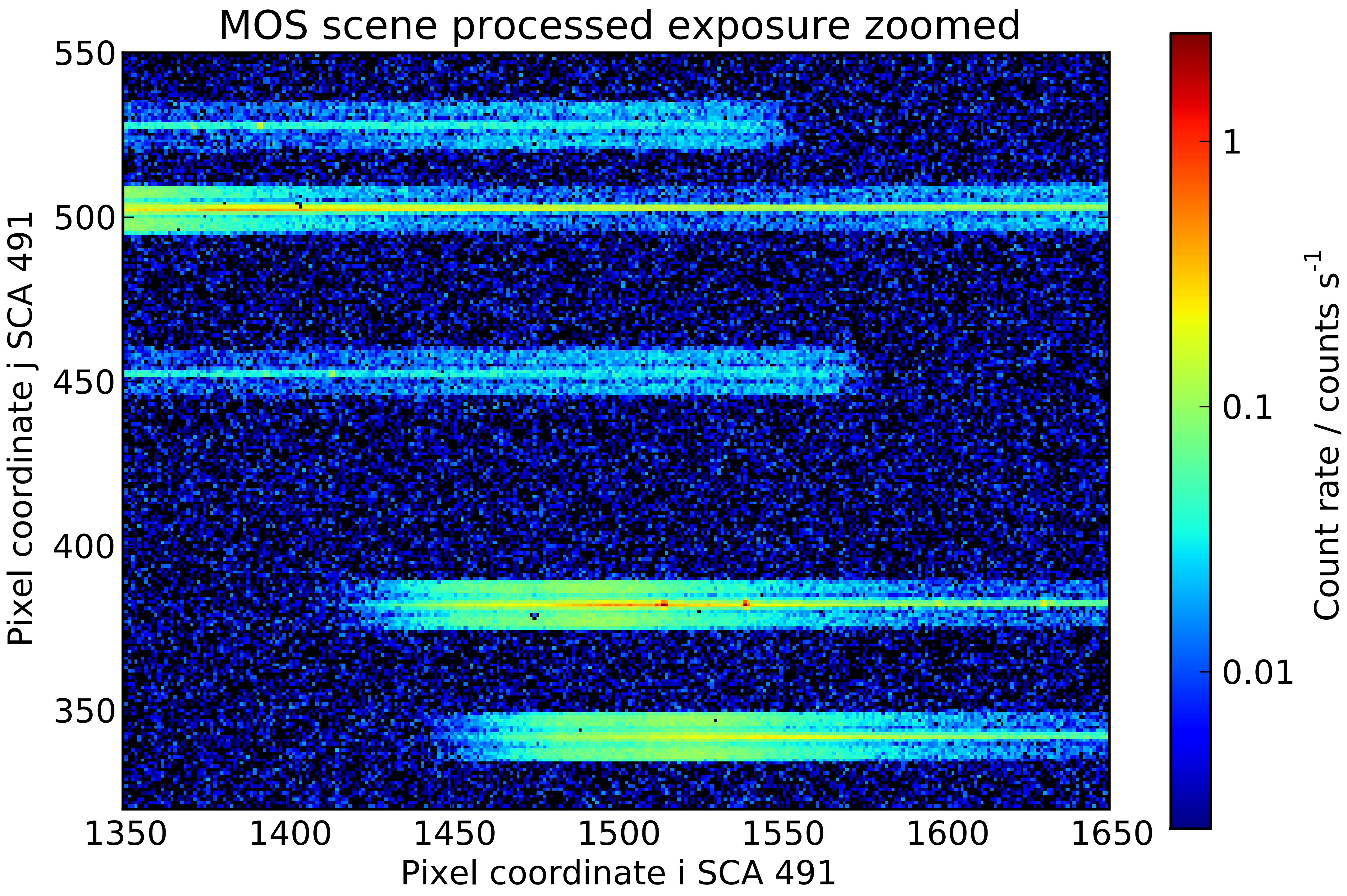
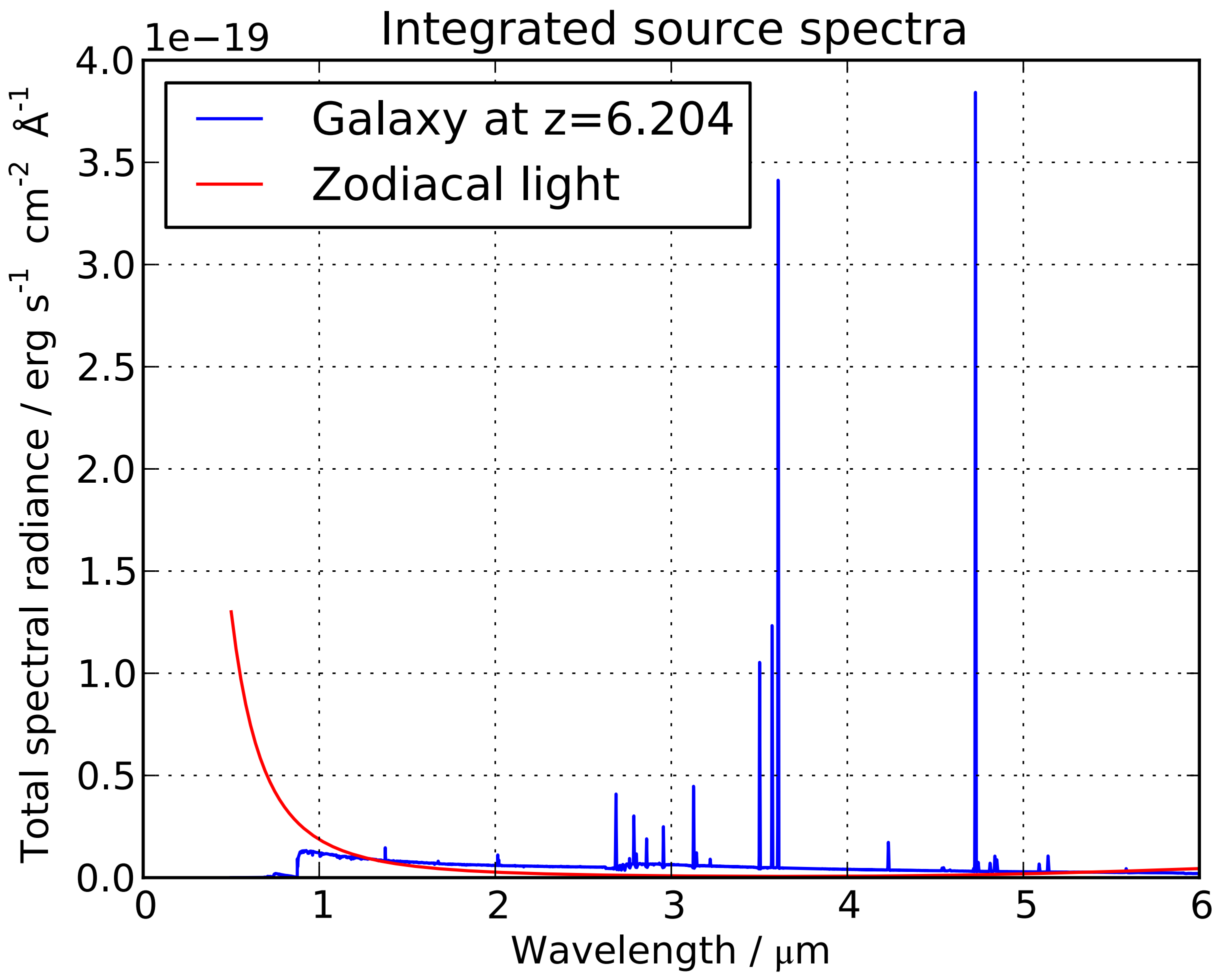
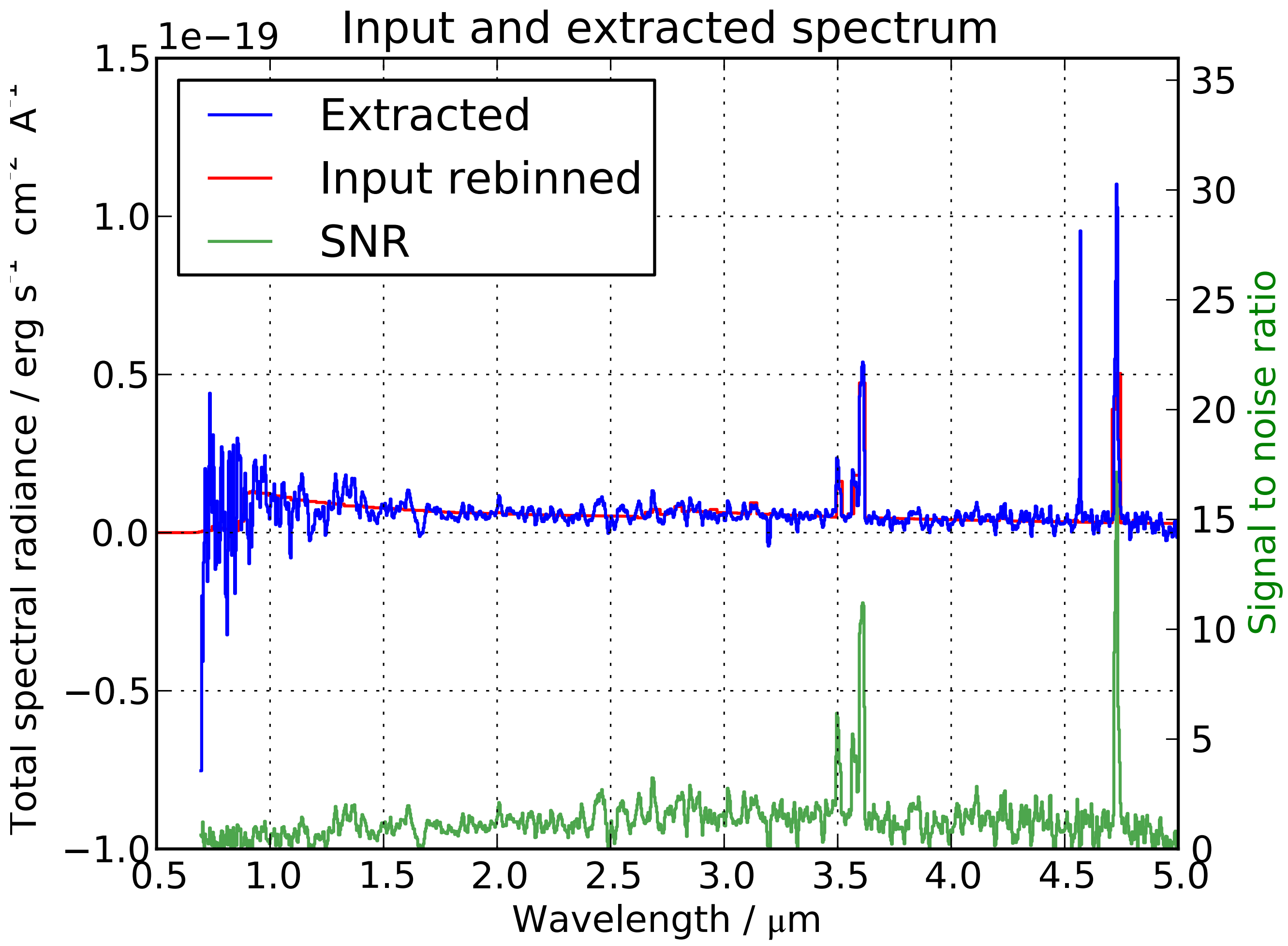


Galaxy spectrum example

z=6.204, mag_H=26.9





NIRSpec cubism

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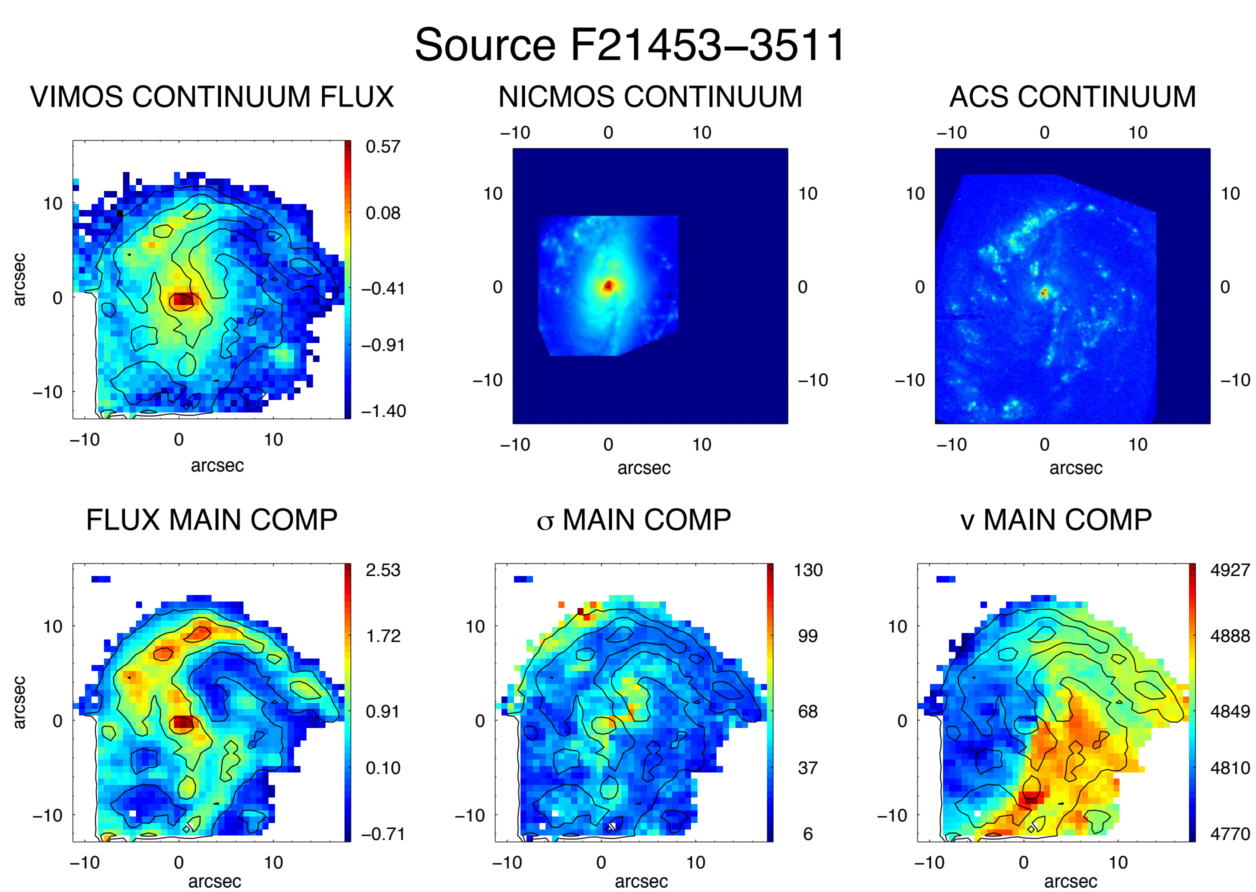
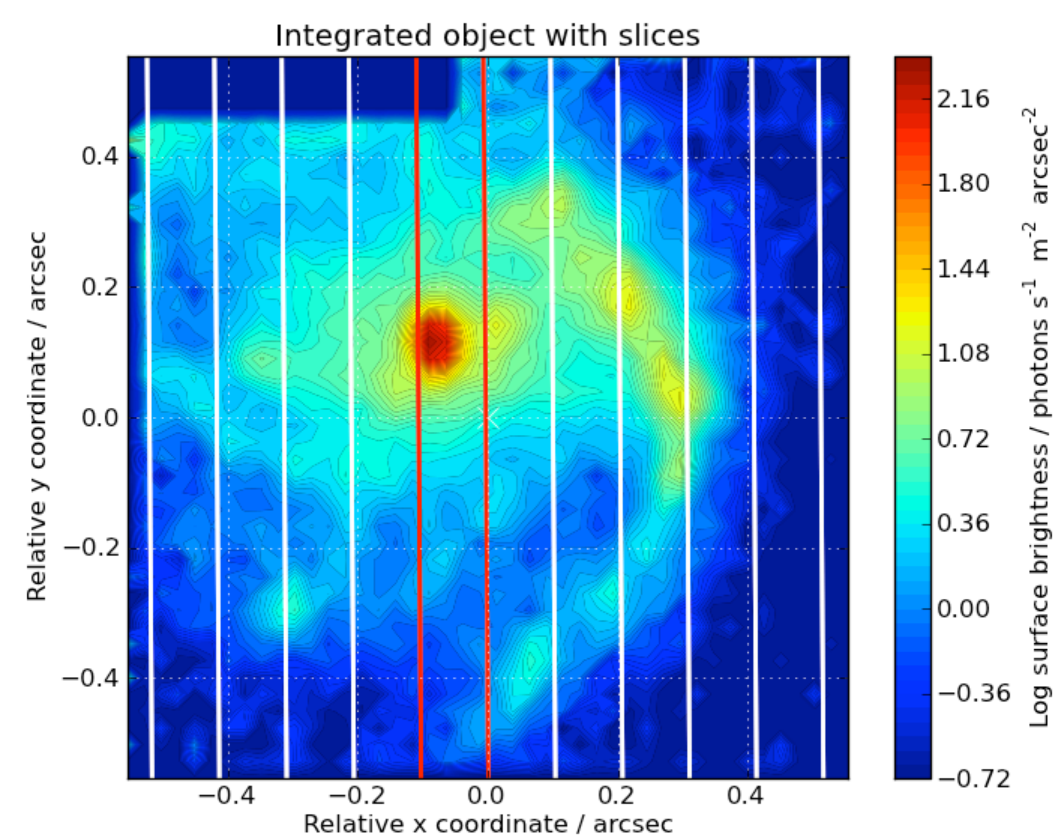
An ULIRG in the NIRSpec IFU

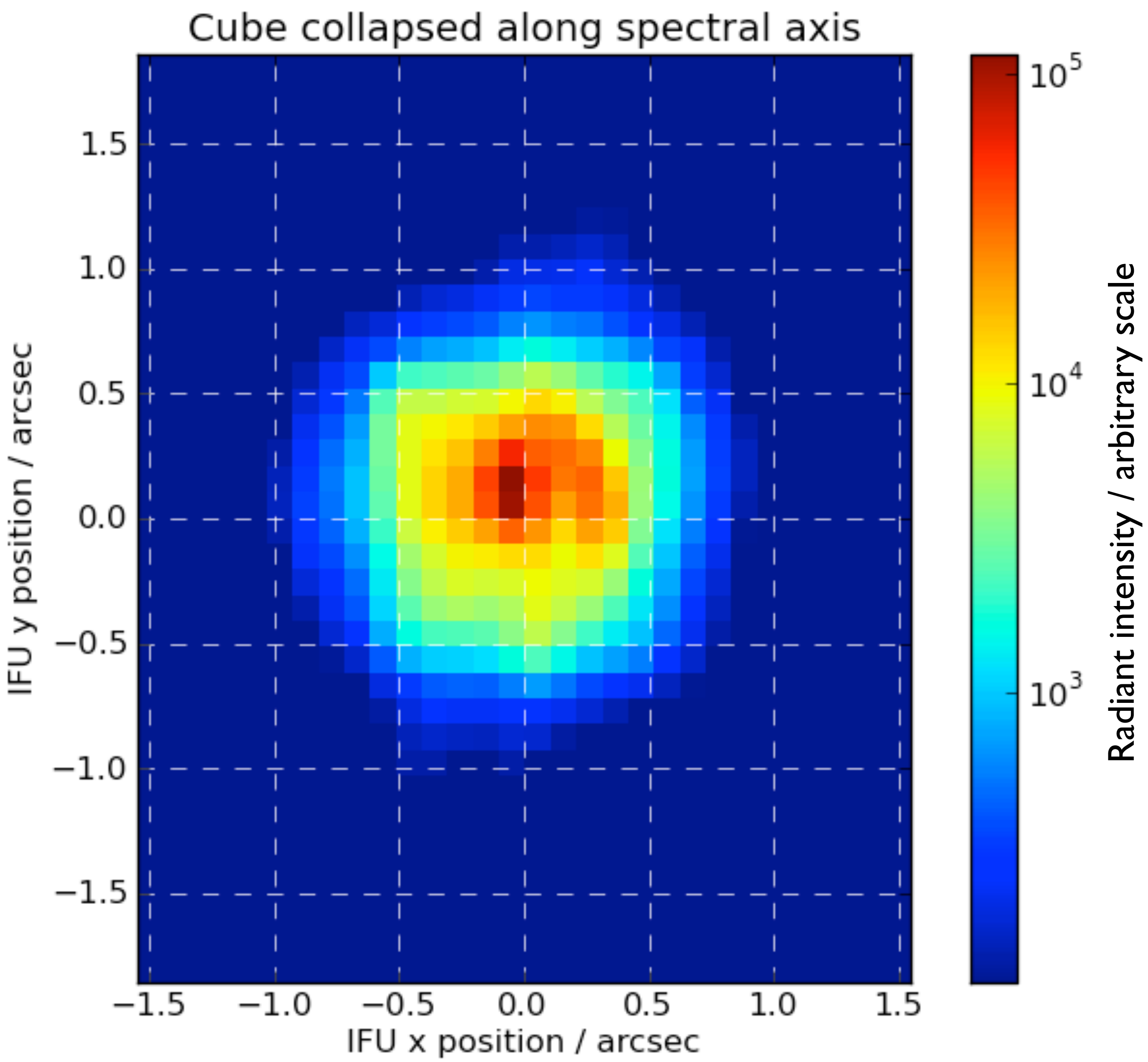
- Single Ultra-luminous infrared galaxy with velocity field in integral field mode
- Data: VLT/VIMOS observation of Hα + [NII] (from Bellocchi et al. 2012)
- For NIRSpec: Scale to redshift z=1

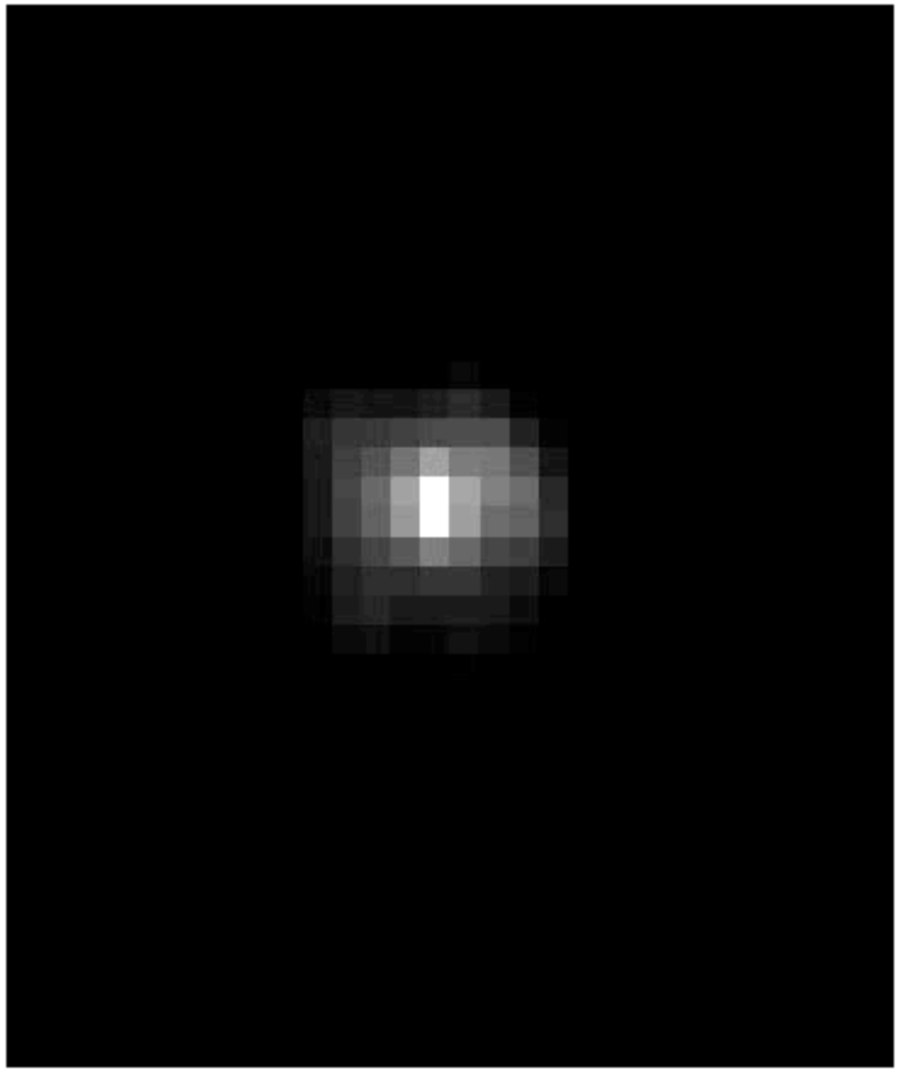




NIRSpec IFU example

- Observation with G140H (band 1, R2700)
- Only electron rates (no calibration)





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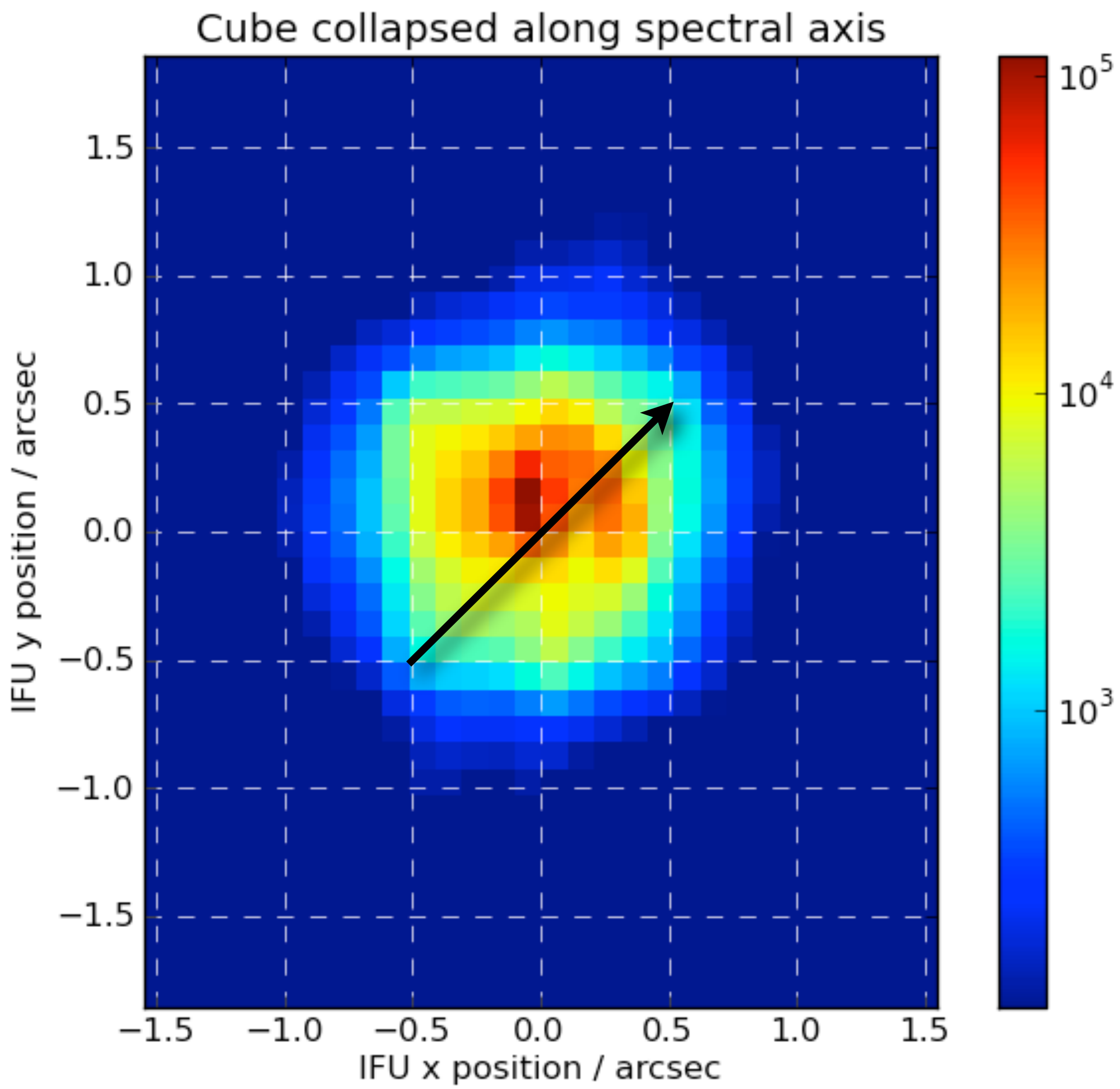

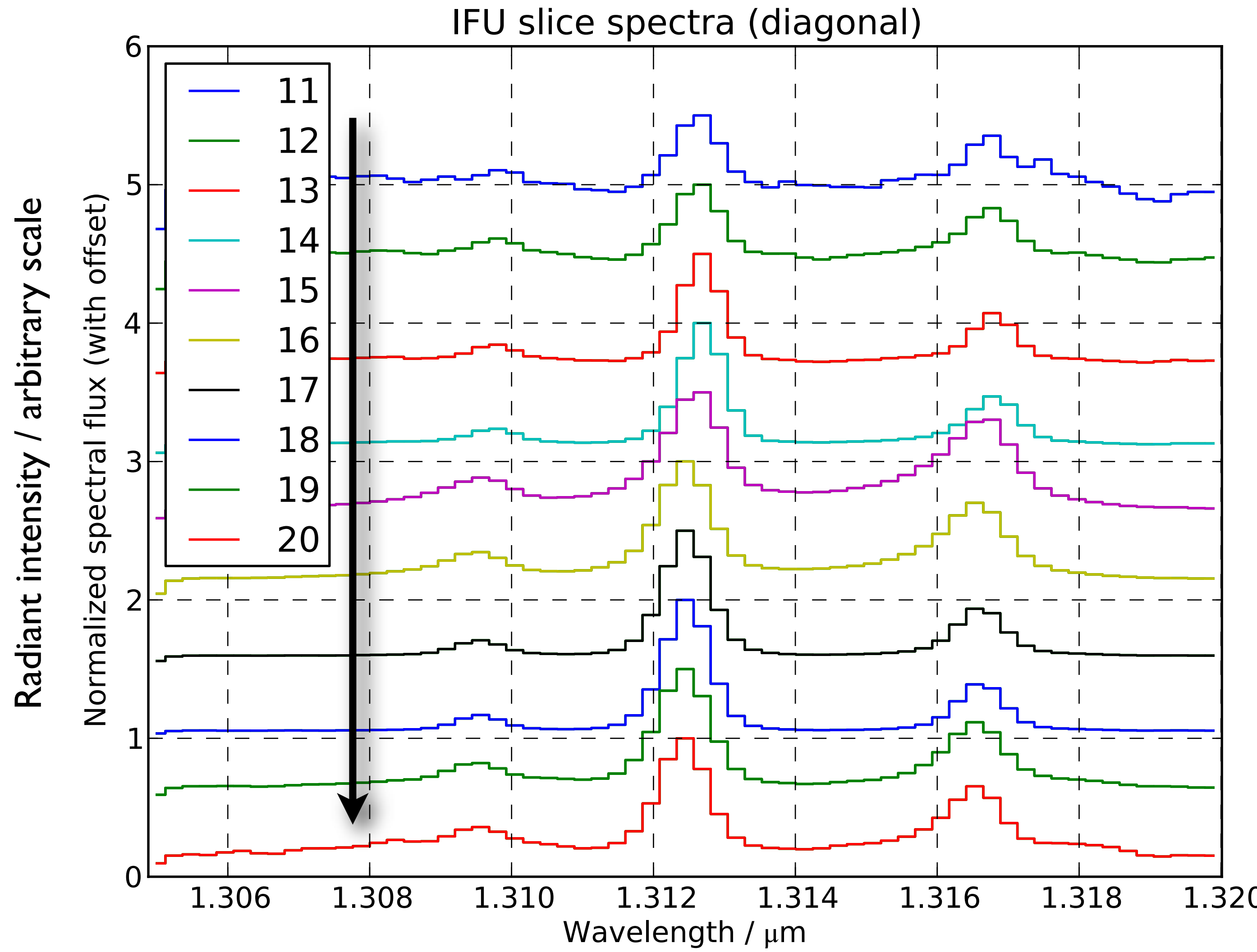

Seeing the bright light

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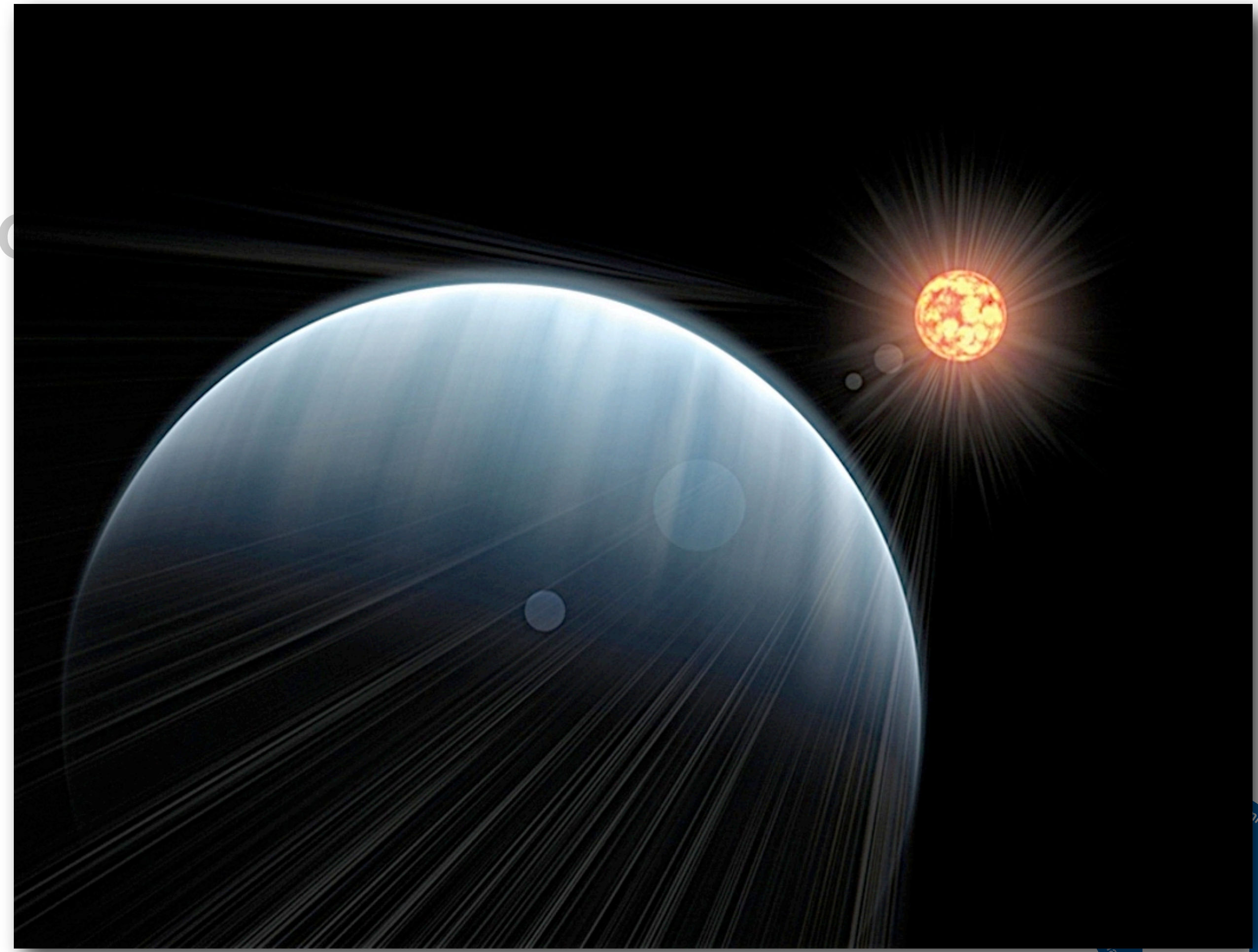
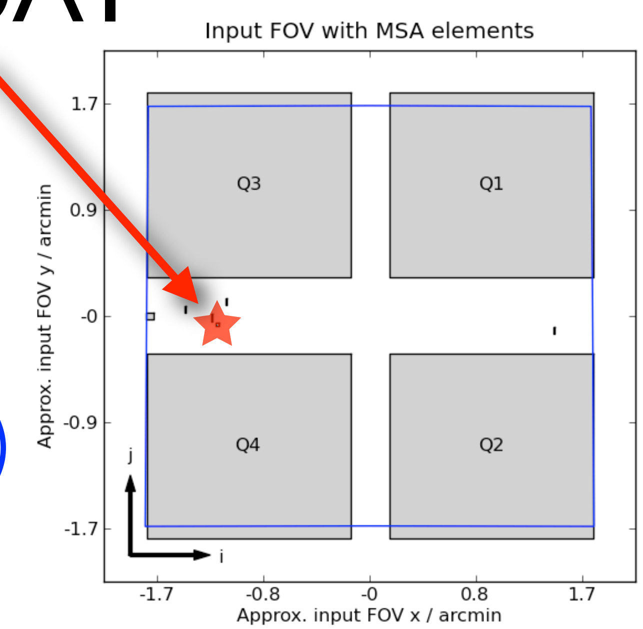
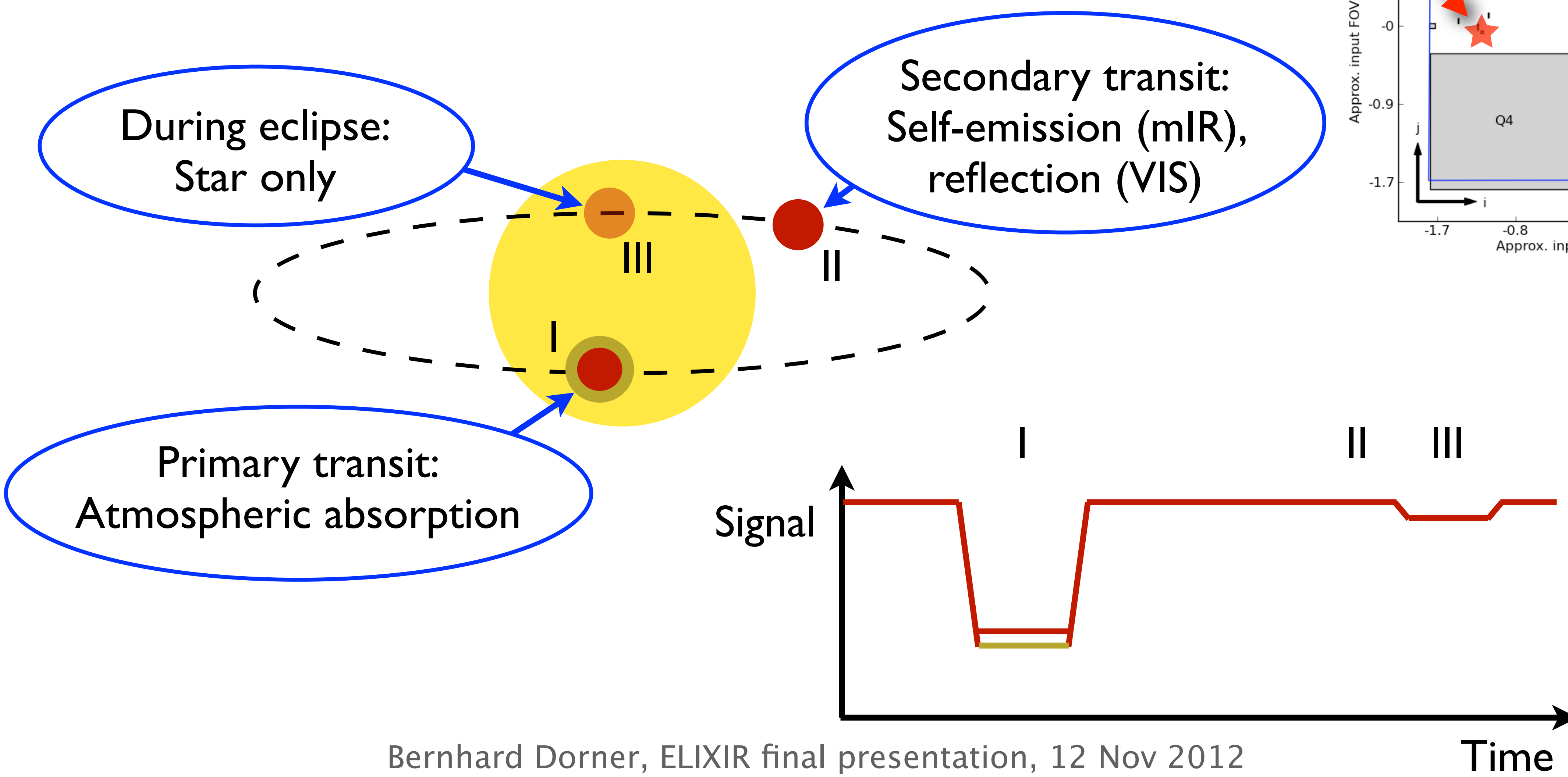


Observation setup

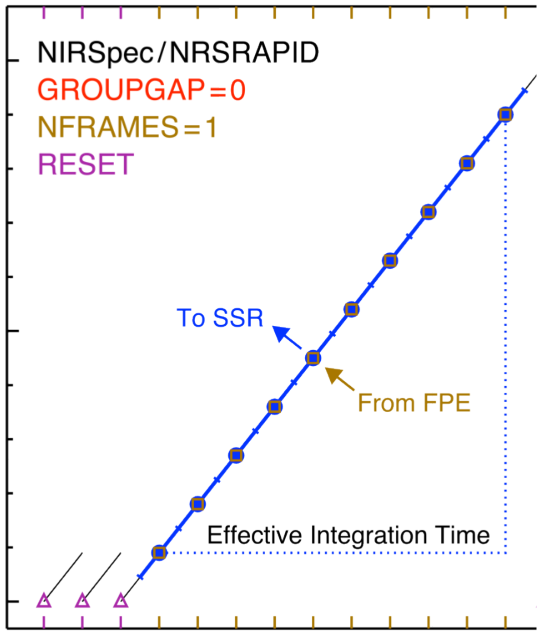
- Observation of total system brightness
- NIRSpec: special square aperture S1600A1
- Subarray readout (2048x32 pixels)



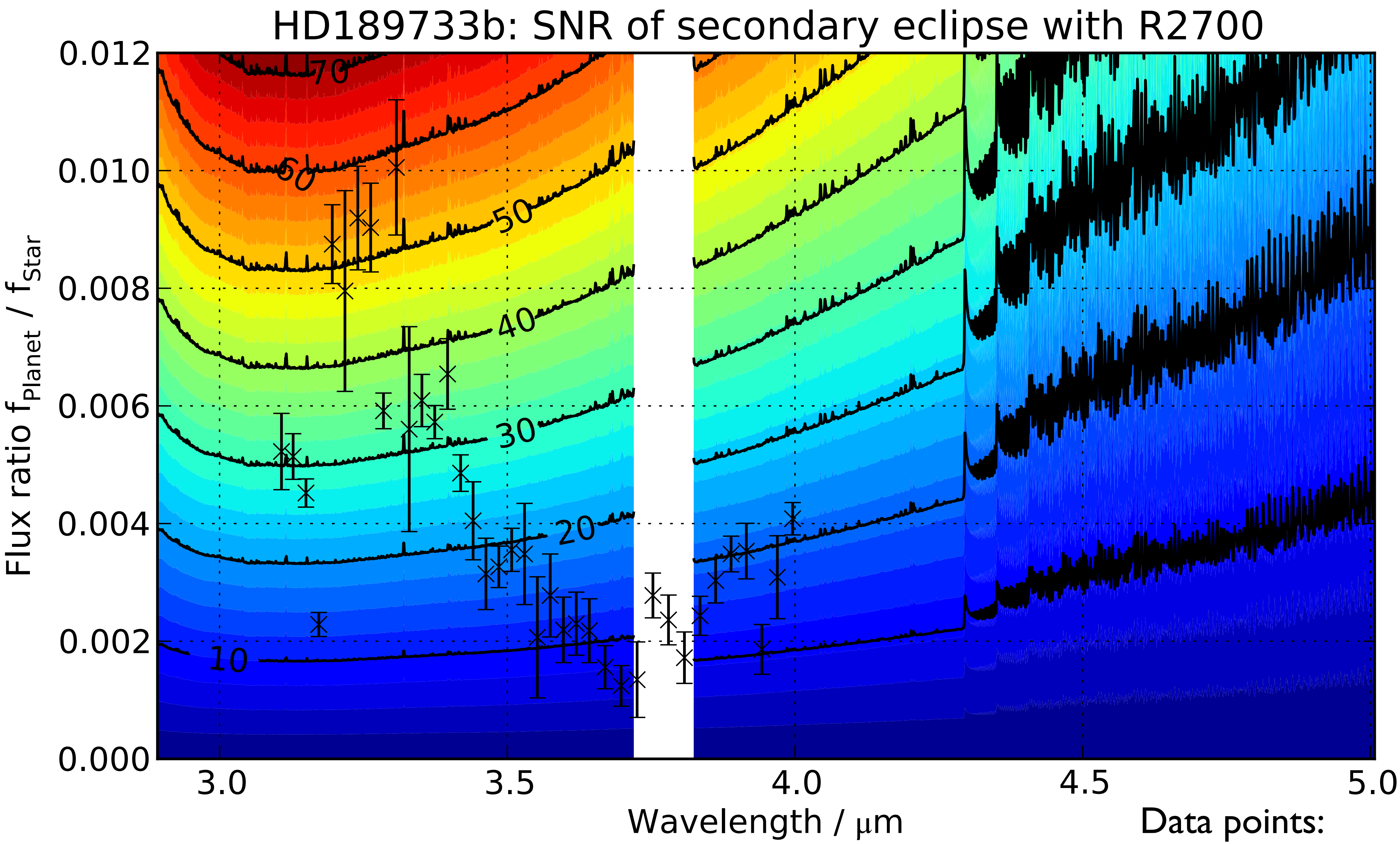


Instrumental effects

- High sensitivity: Maximum stellar brightness limits (gratings: $mag_K \approx 6–7$)
- Readout overheads: Reduction of effective exposure time during transit (up to $^2/_3$)
- Thorough noise discussion:
  - Limited by photon and readout noise
  - Other instrumental noise sources negligible



HD189733b eclipse



$\Delta\lambda = 0.67\,\mathrm{nm}$

Data points:
Waldmann et al., 2012
(4 transits, R=175)

The bottom line

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Conclusion

- IPS + NIPPLS: useful tools for verifying and simulating NIRSpec data
- Assembly and verification of as-built model: Successful with FM1 data
- First science simulations of high-z galaxies and exoplanets: Confirm exceptional capabilities of NIRSpec

Conclusion: Network

- ELIXIR: Over, but not dead
- Very beneficial for simulation activities:
  - Spectra for deep-field scenes (Camilla)
  - IFU sources (Enrica)
- Hopefully continuation and further exploitation (still some work on the software)

What's next?

- New old job at MPIA: NIRSpec calibration and verification (next campaign in 2013)
- Instrument model: Verify with FM2 data
  - MSA operable
  - Higher orders in optics
  - Throughput
- Continue science preparation with simulations