Simulations of NIRSpec MOS Exposures

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

Science case: Assembly of galaxies

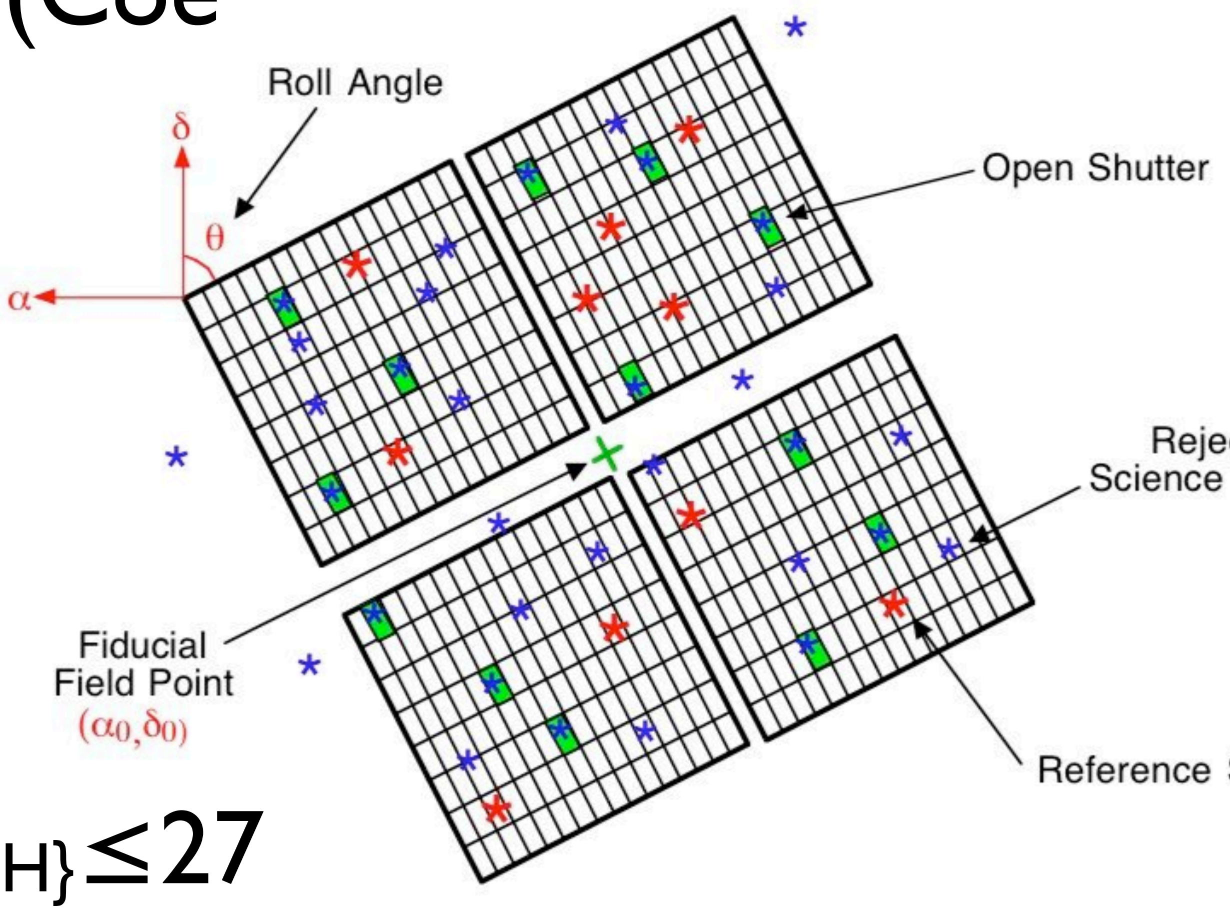
- Study evolution of galaxies, dark matter, gas, stars, metals, dust, structures from reionization until now
- Necessary: Detection (determine redshift) and characterization (spectra)
- Global understanding: Per epoch and evolutionary
- Statistical problem: Many galaxies needed

Observations and findings

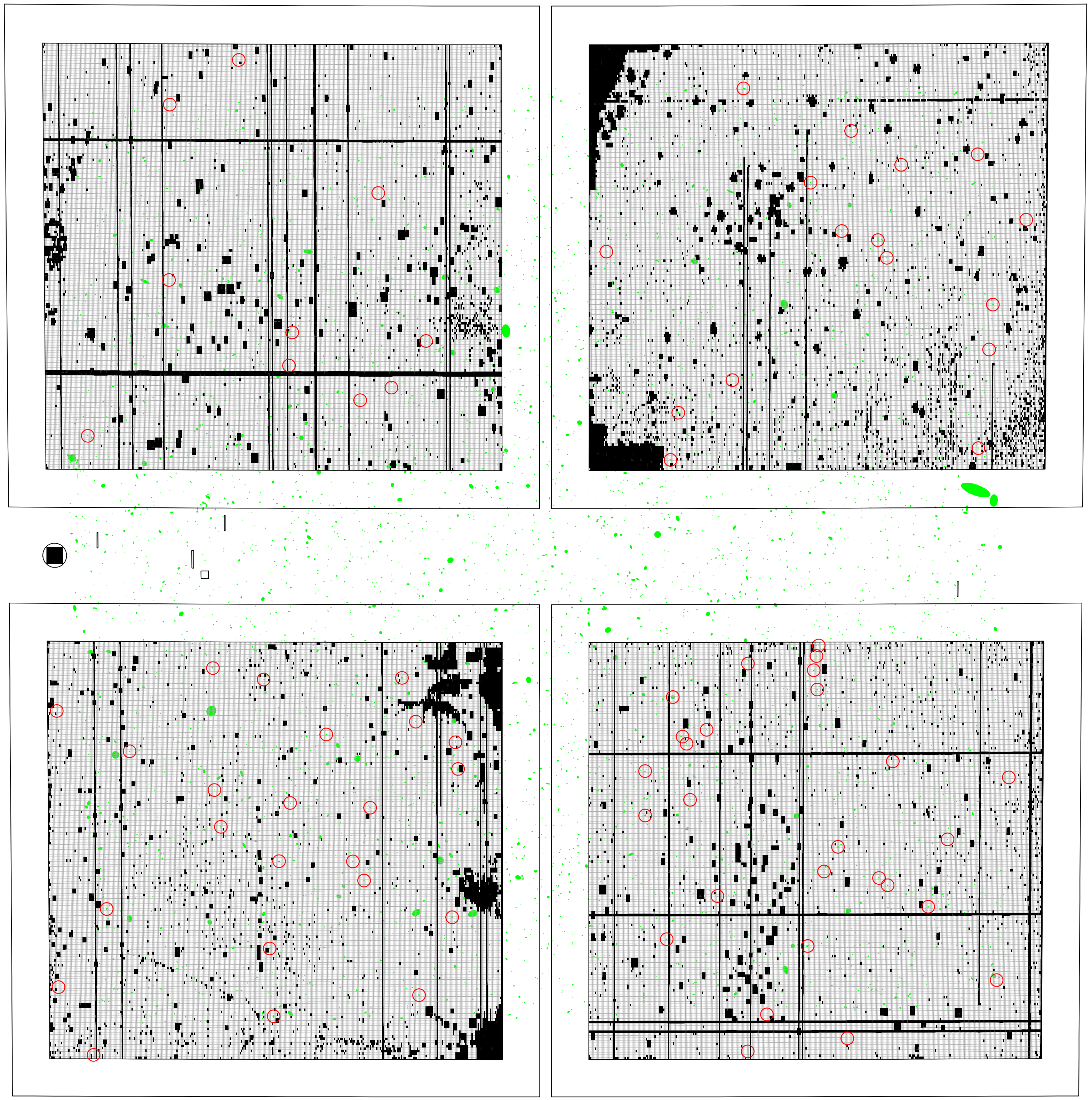
- Wanted:
  - Redshifts
  - SFR
  - Metallicities
  - Disk and merger kinematics (active/non-active)
- Planned observations:
  - Spectra R100, R1000
  - Deep field exposures (100,000 s)

Observation scene (P. Jakobsen)

- Catalog: Hubble UDF data (Coe et al, 2006)
  - Photometric redshifts
  - Half-light radii
- Set roll angle
- Select objects $z \geq 1$, $mag_{\{i,z,J,H\}} \leq 27$
- Add targets close to shutter centers with 1x3 slitlet, avoiding overlaps and failed closed



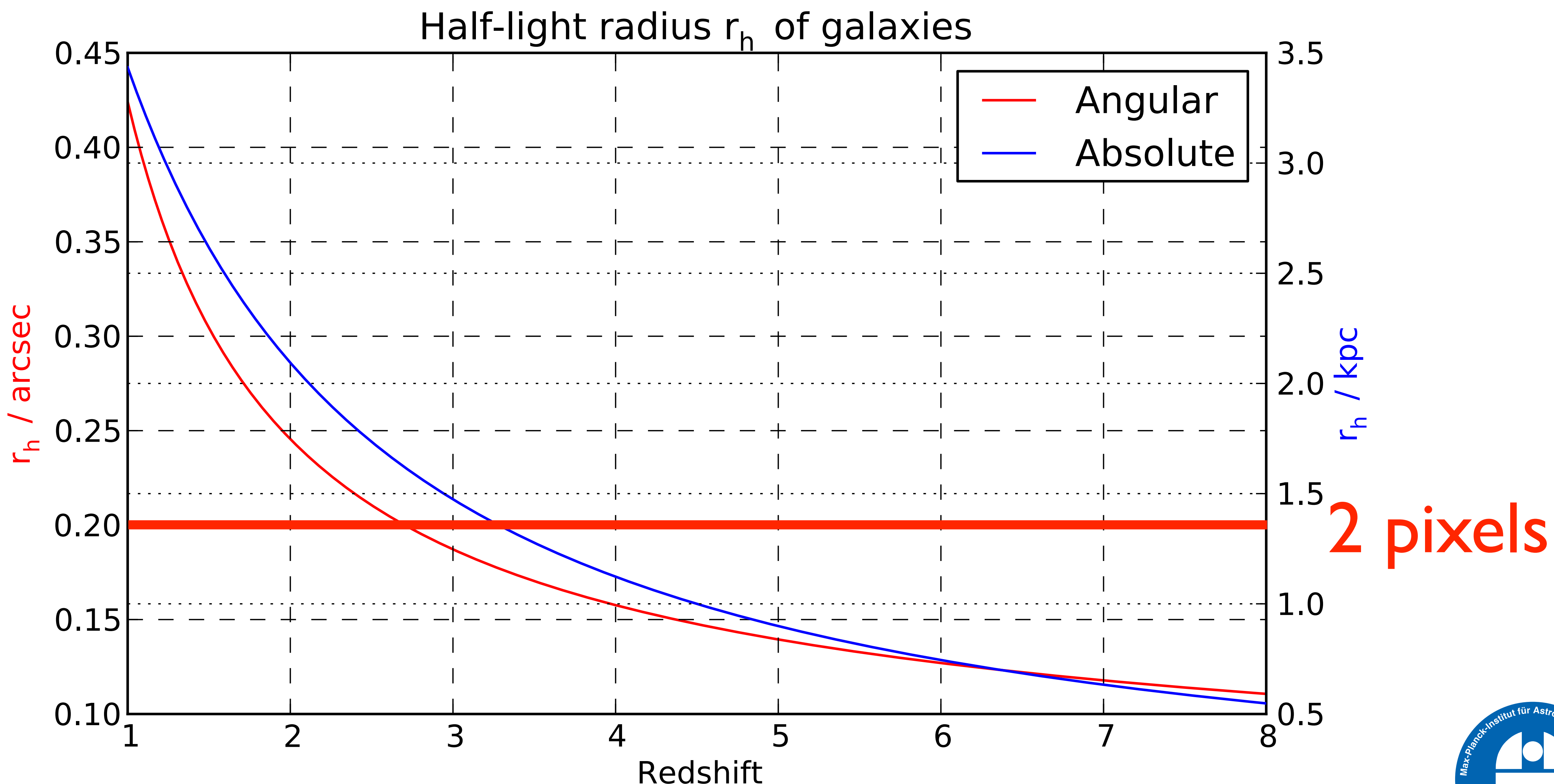
MSA overview (P. Jakobsen)



Galaxy sizes

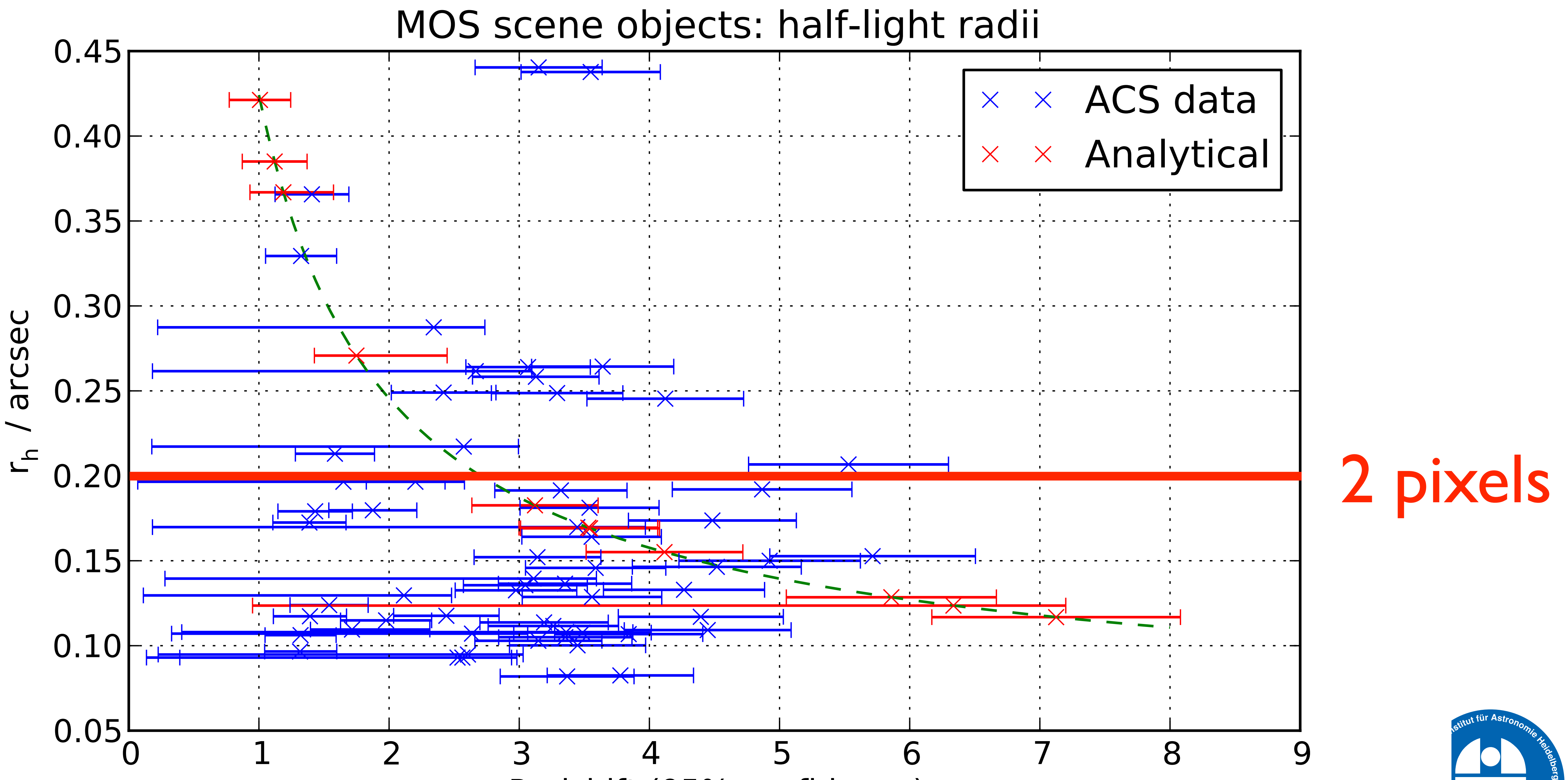
- Oesch et al. 2010: Half-light radius

$$r_h(z) = r_0(1+z)^{-m} \qquad m \approx 1.22 \quad r_0 \approx 8\,\mathrm{kpc}$$



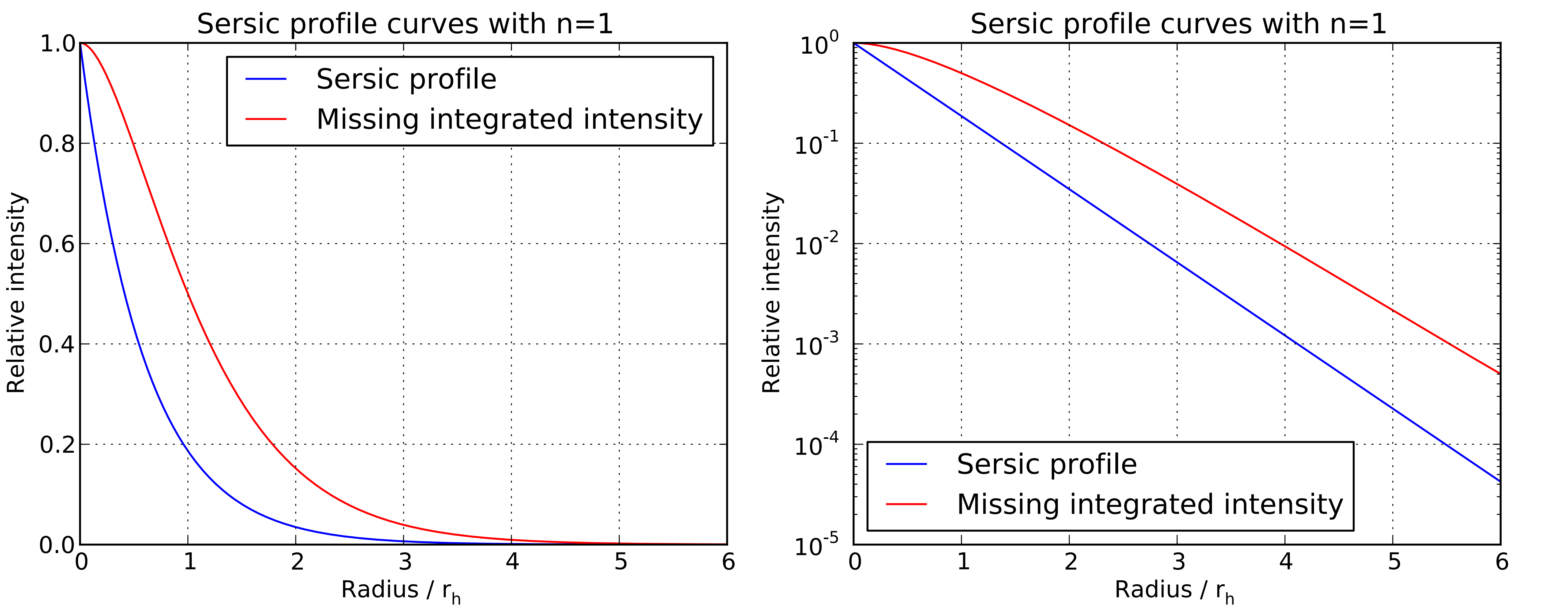
Galaxy sizes

- UDF ACS data (Coe et al. 2010, Beckwith et al. 2006)



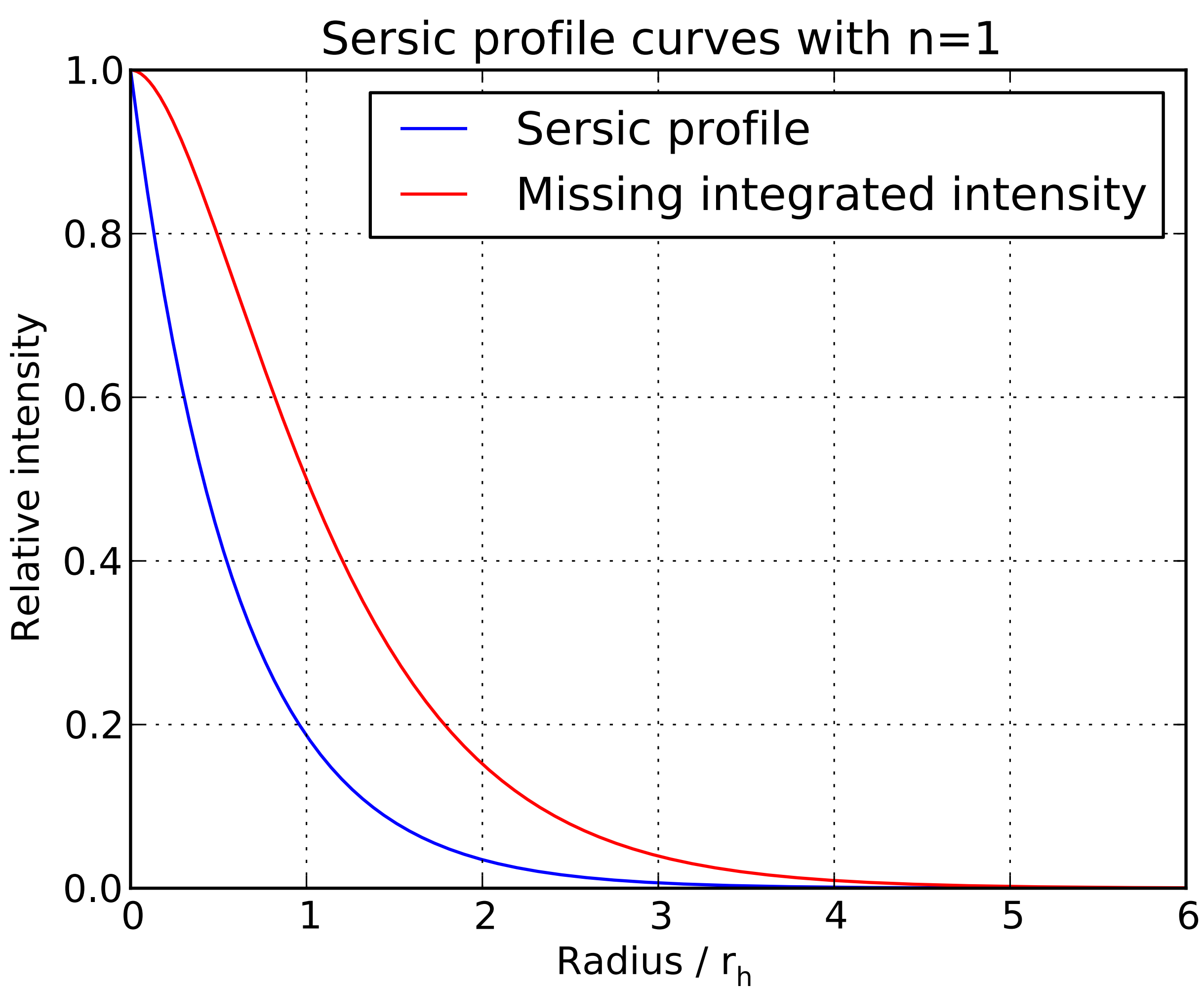
Galaxy shapes

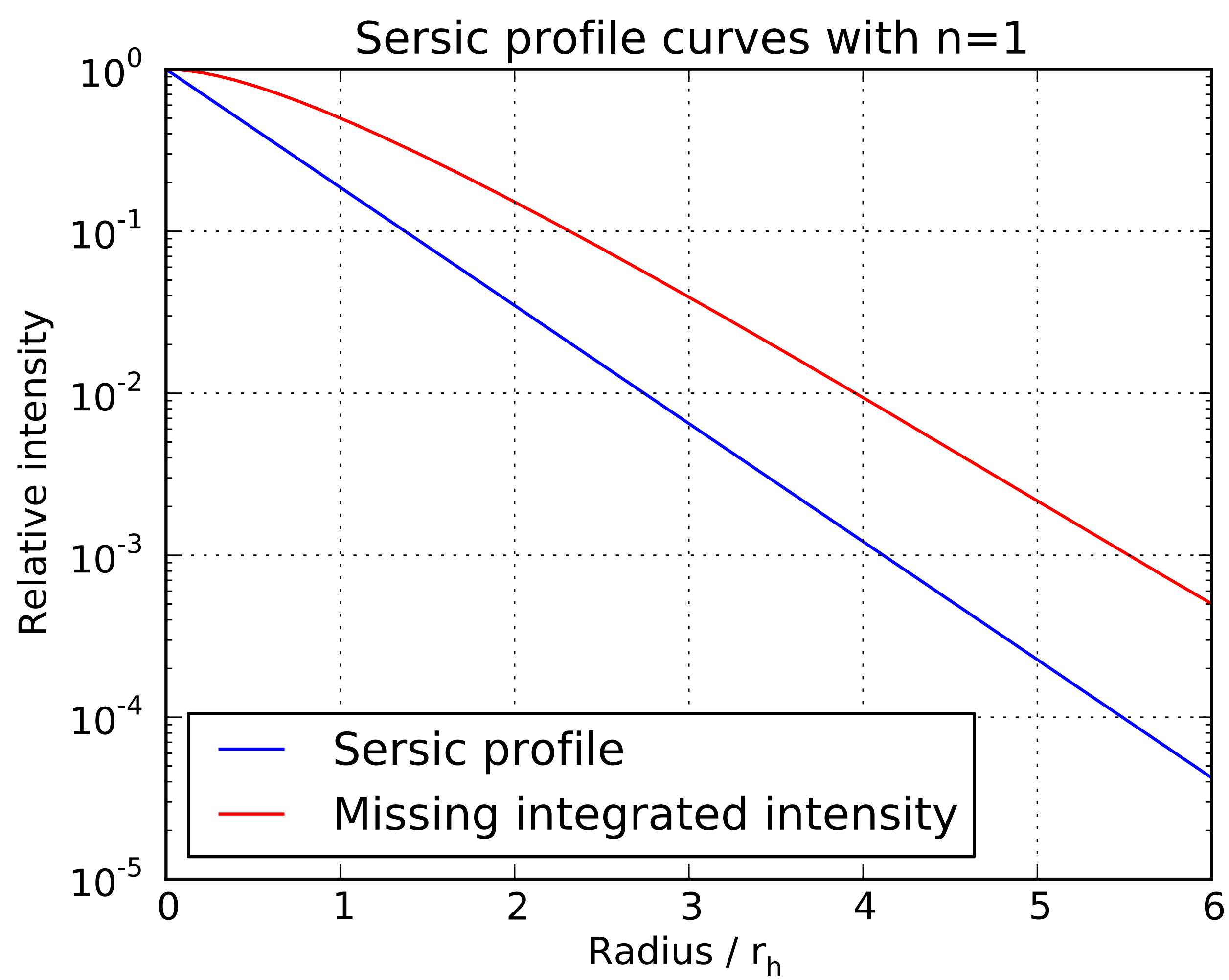
- Sérsic profile $I(r) = I_0 \exp(-kr^{1/n})$
- Spiral and dwarf ellipticals: $n = 1$
- Normalization: $I(r) = I_0 \exp\left(-1.67835 \frac{r}{r_h}\right)$



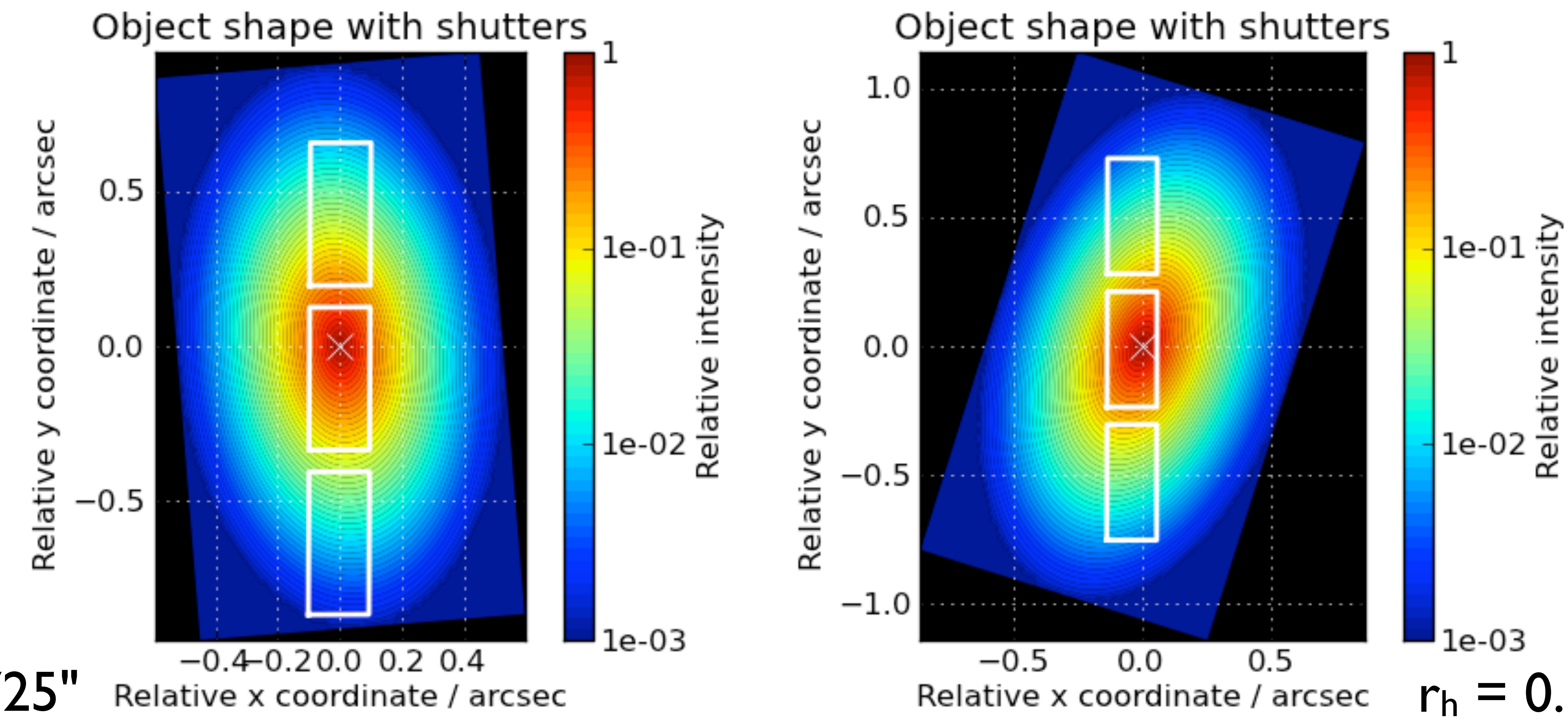
Galaxy shapes

- Create target out to $r_h = 4$
- Deform images to elliptical shape





Galaxies in shutters



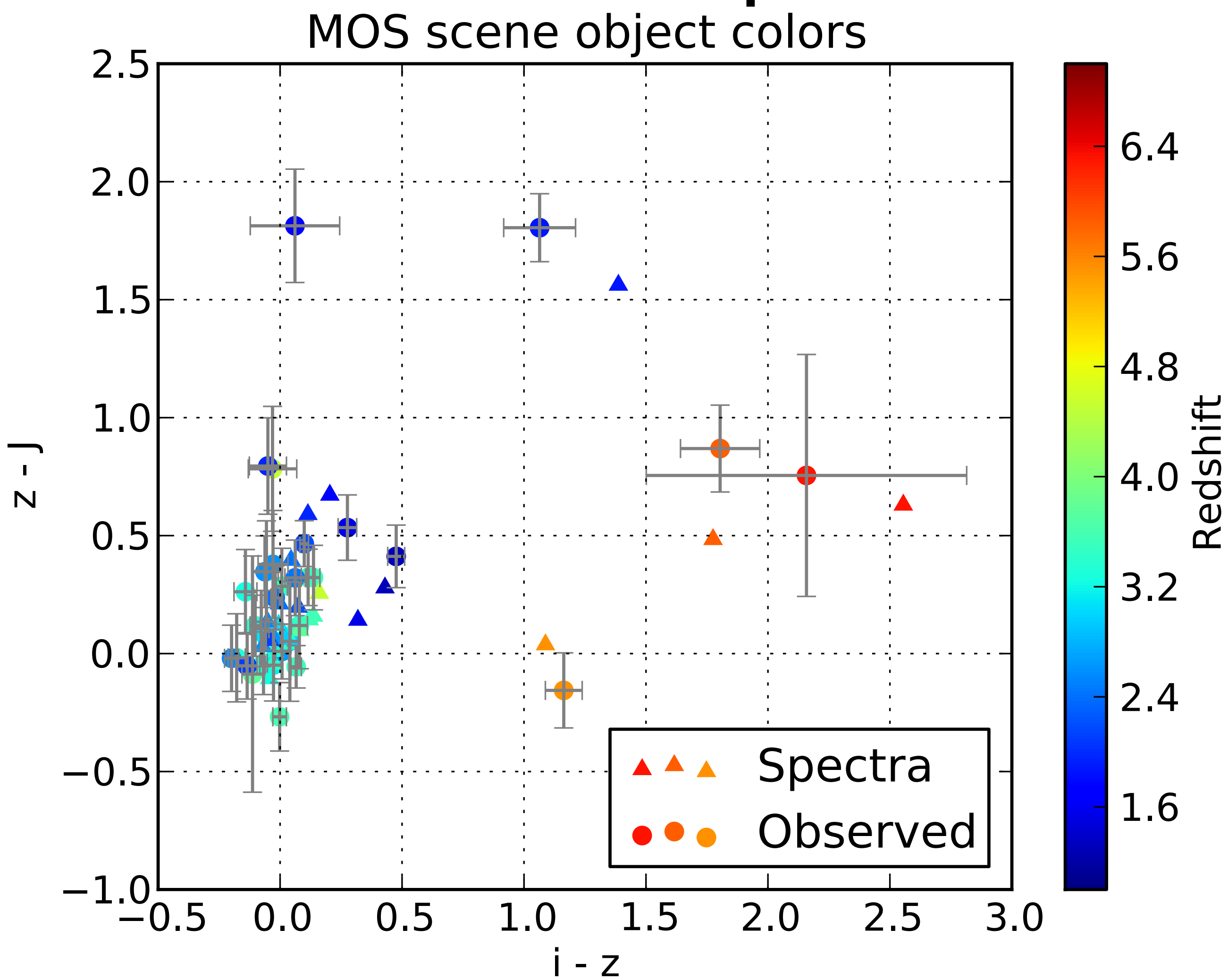
r_h = 0.1725"

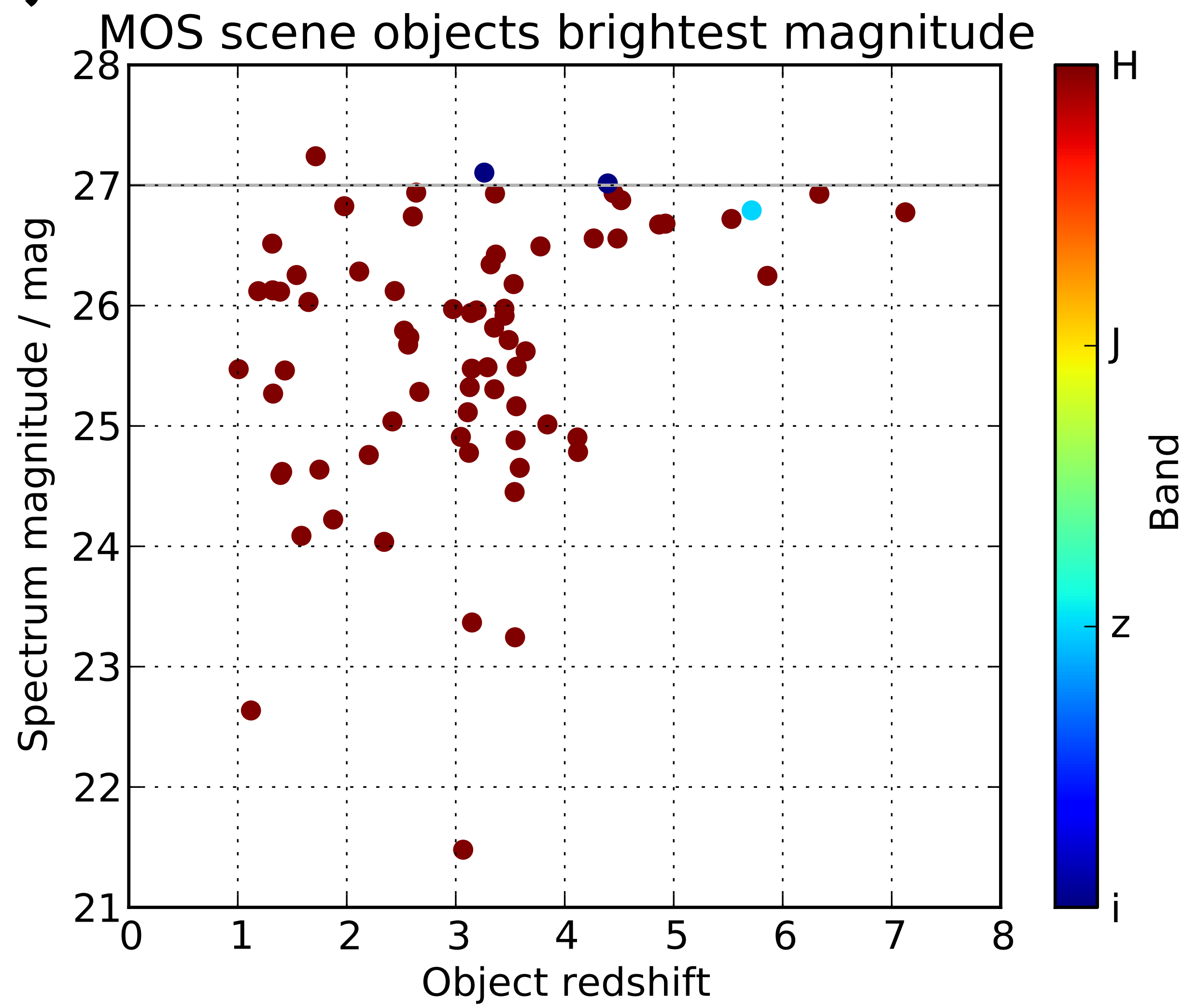
r_h = 0.1920"

- Larger slitlets required for background subtraction
- Use sizes in scene preparation
- Simulations only with point sources: no problem here

Galaxy spectra

- Catalog of simulated spectra out to z=8 (Camilla, Stéphane)
- Match band magnitudes with data from Coe+ 2010
- Pick best-fit spectrum for object

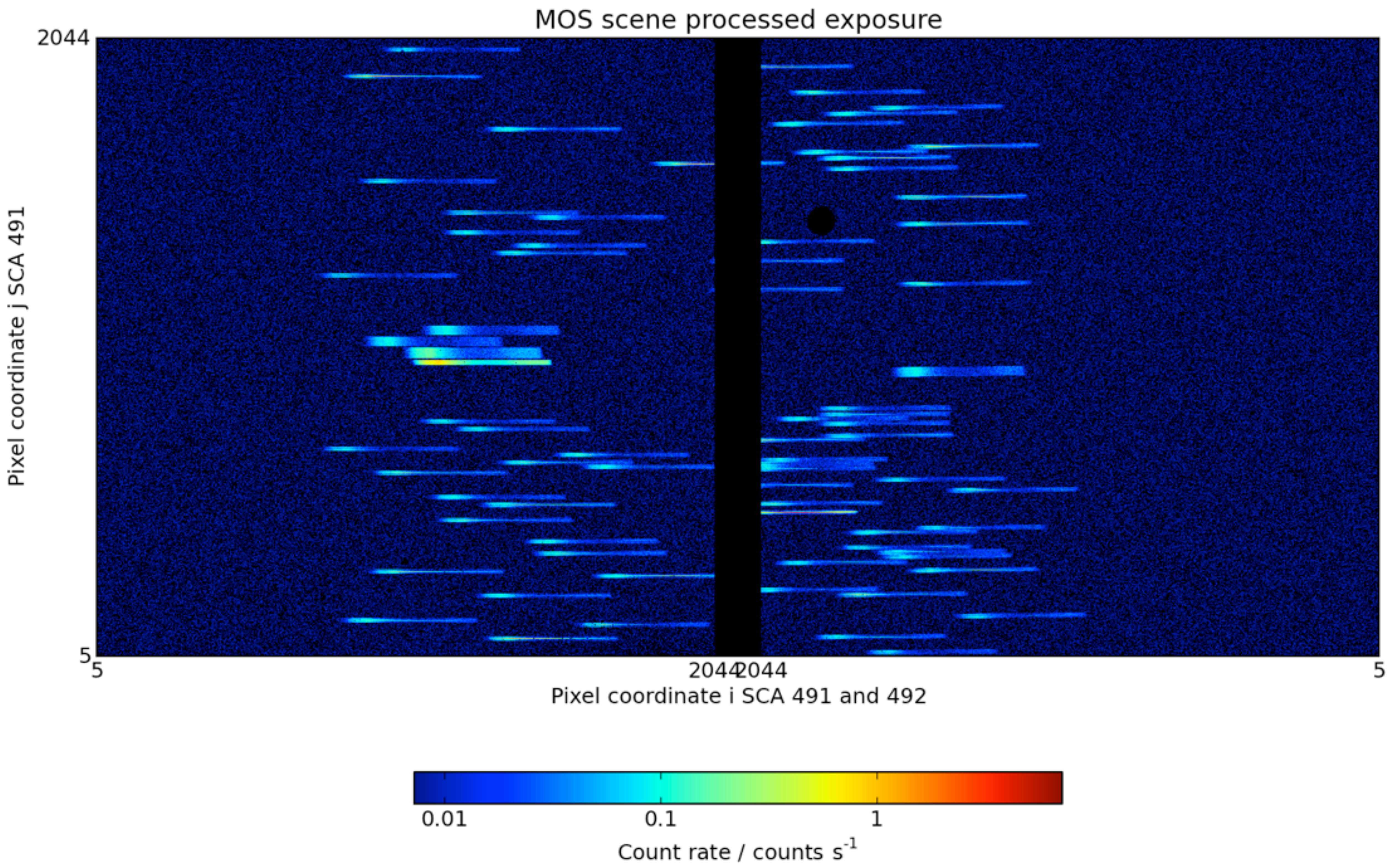




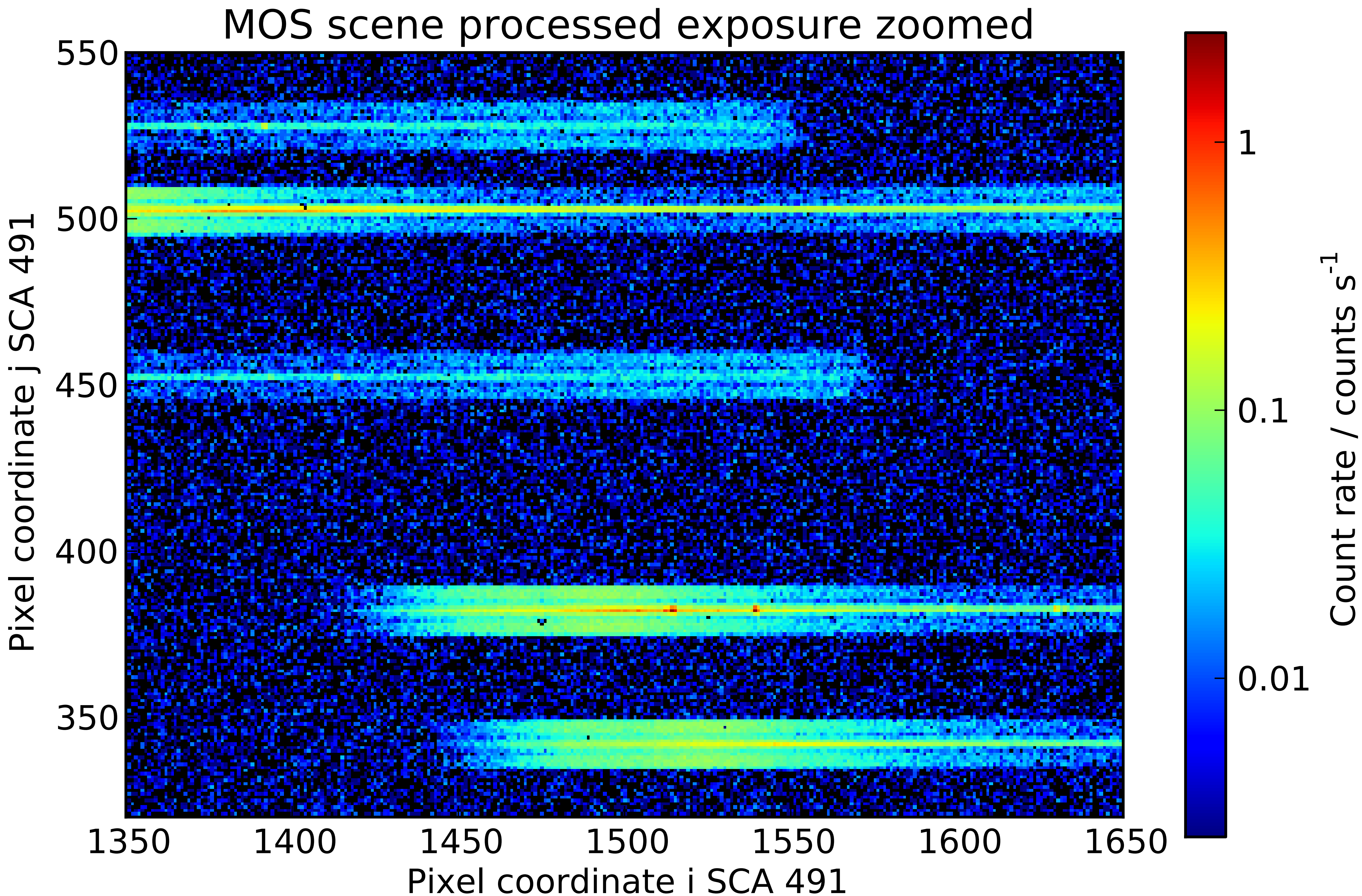
Exposure simulation: PRISM

- Added Zodiacal light
- PRISM (R100)
- CLEAR filter (0.6–5 μm)
- Typical "22x4" exposure (effective time: 945 s)
- Noise: analytical with readout and Poisson (optimistic)
- No cosmic rays
- Additional exposures: Internal flatfields and fake reference stars (SNR optimized)

Exposure image: PRISM

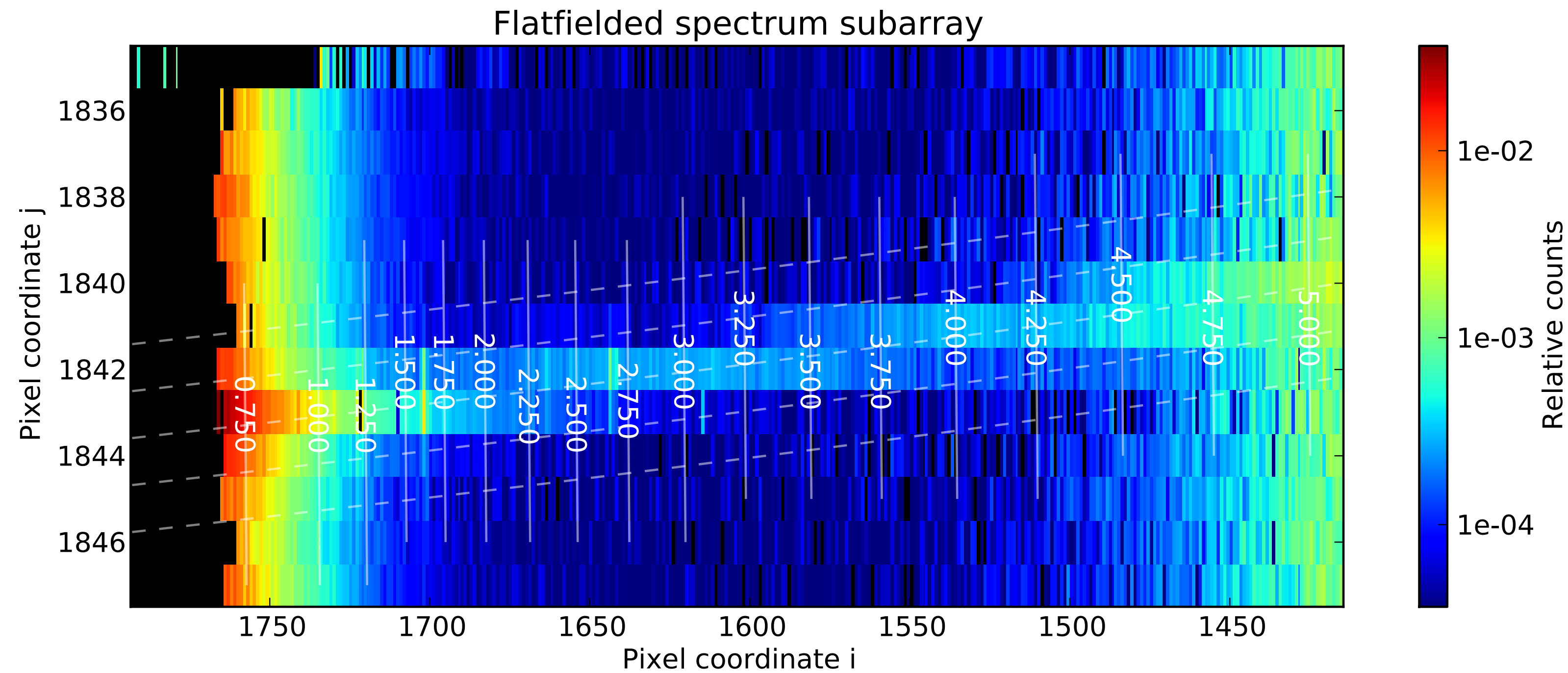


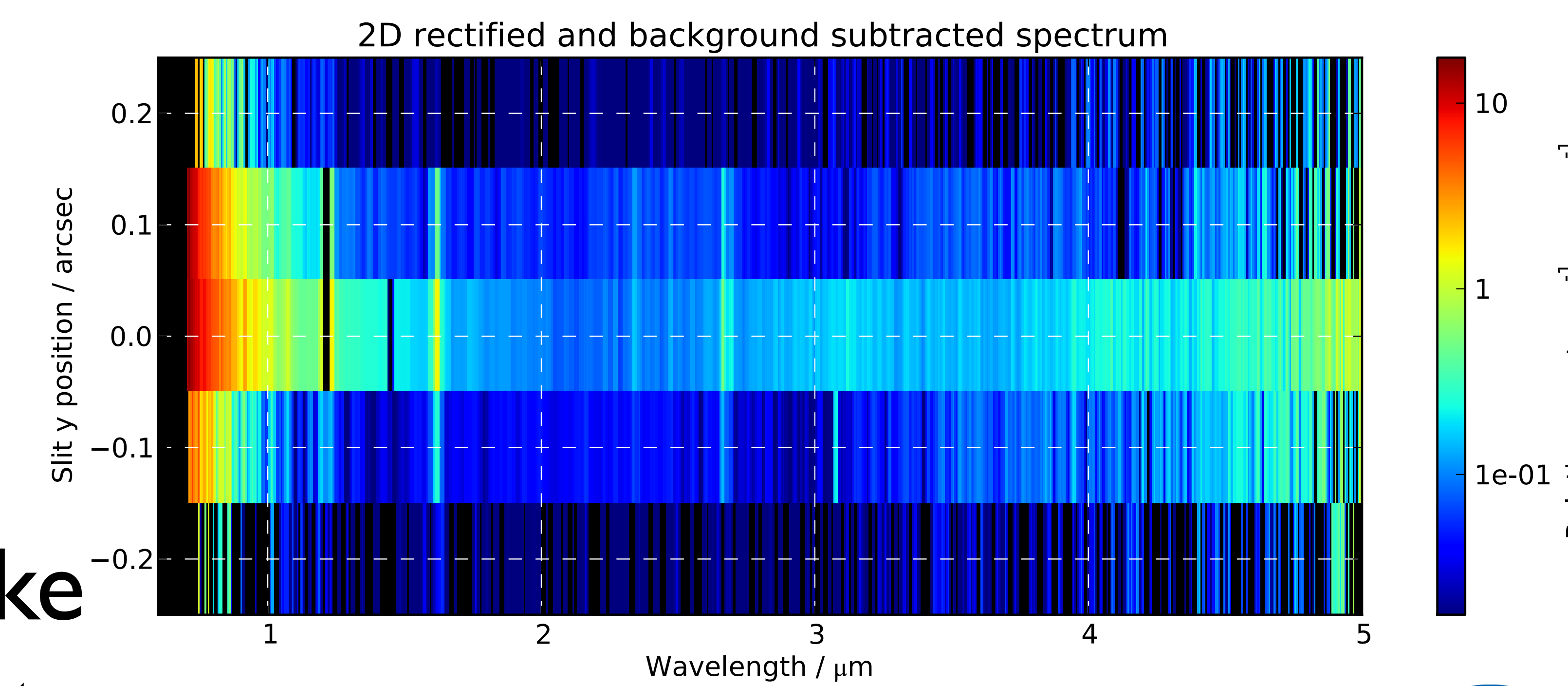
Exposure image: PRISM



Spectrum extraction

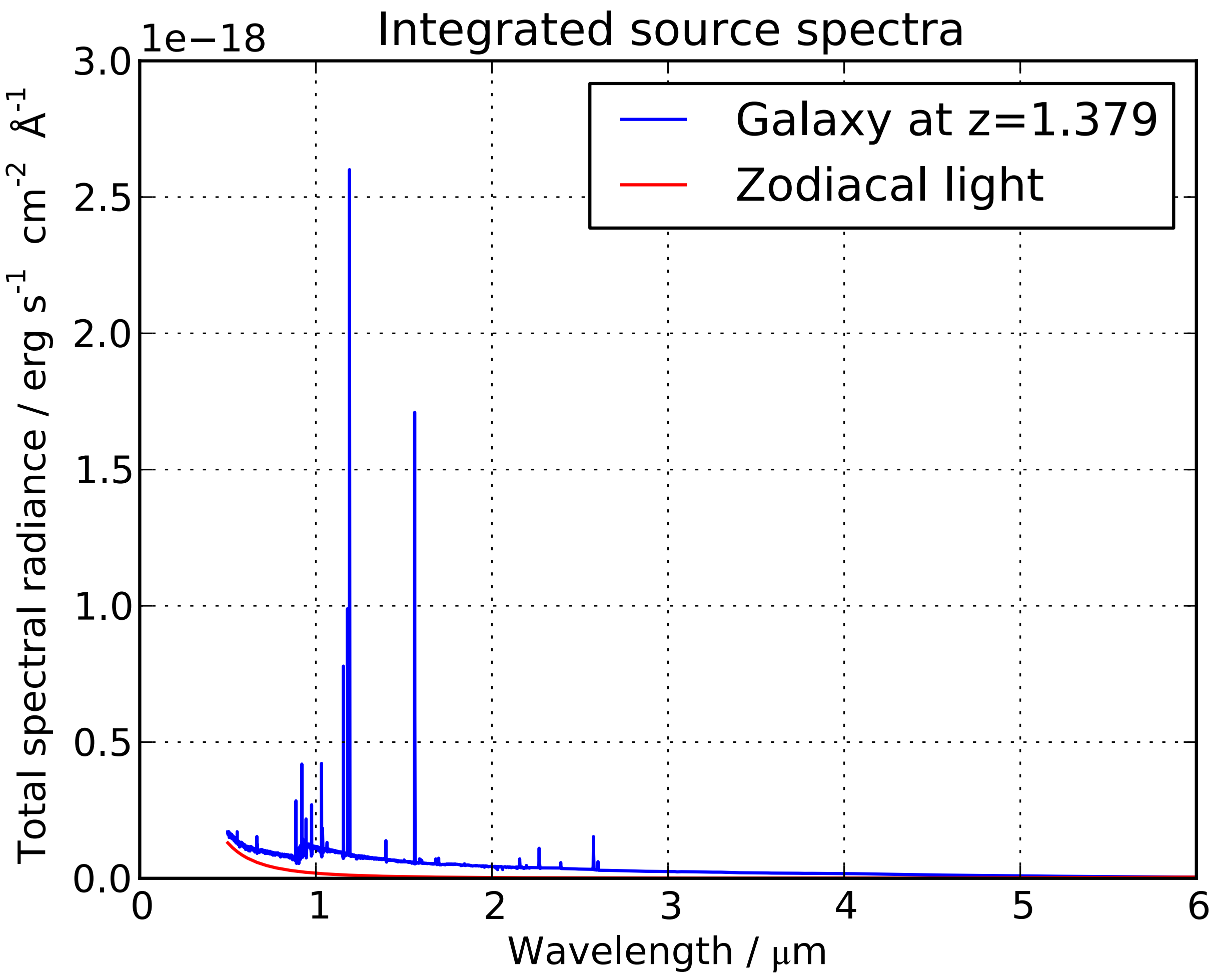
- Flatfielding
- Trace extraction
- Rectification
- Background subtraction
- Collapse over 5 central pixels
- Calibrate with fake reference star data

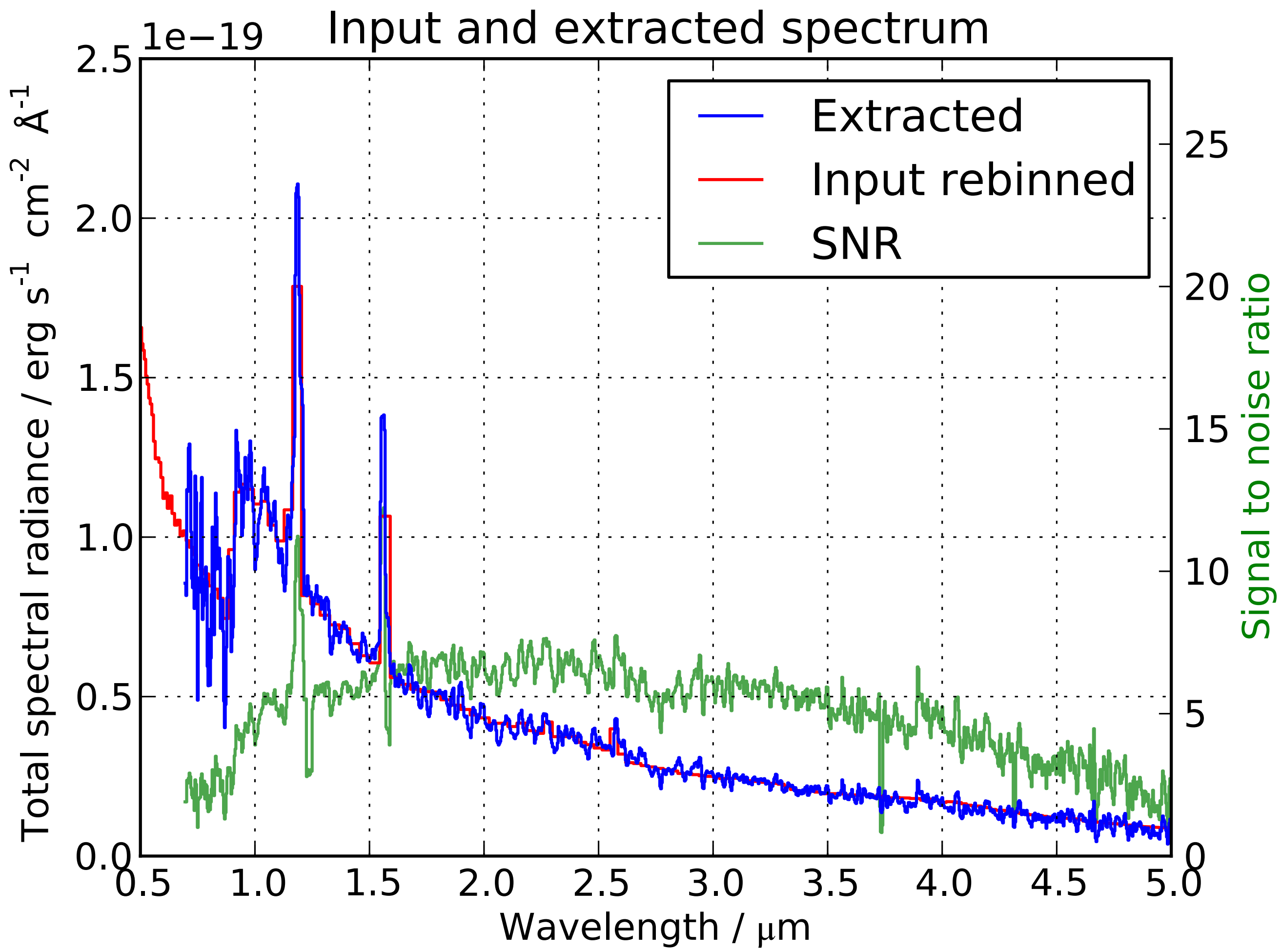




Results: single exposure

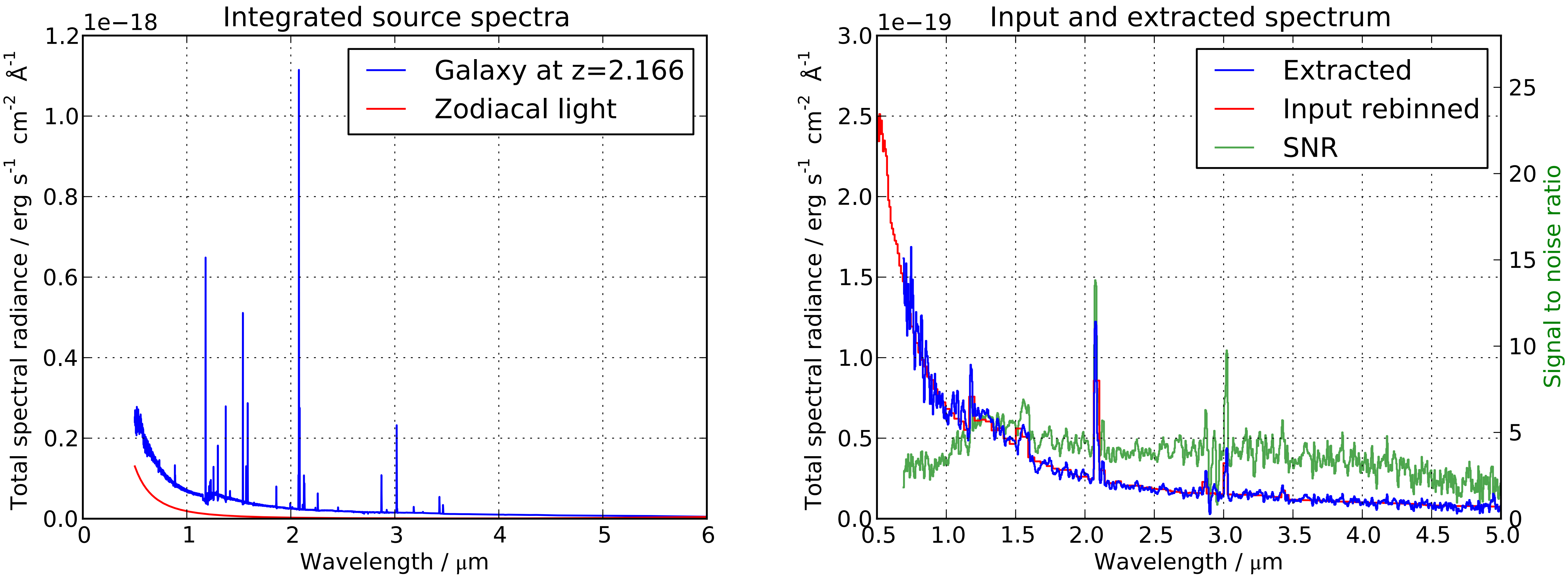
z=1.379, mag_H=24.6





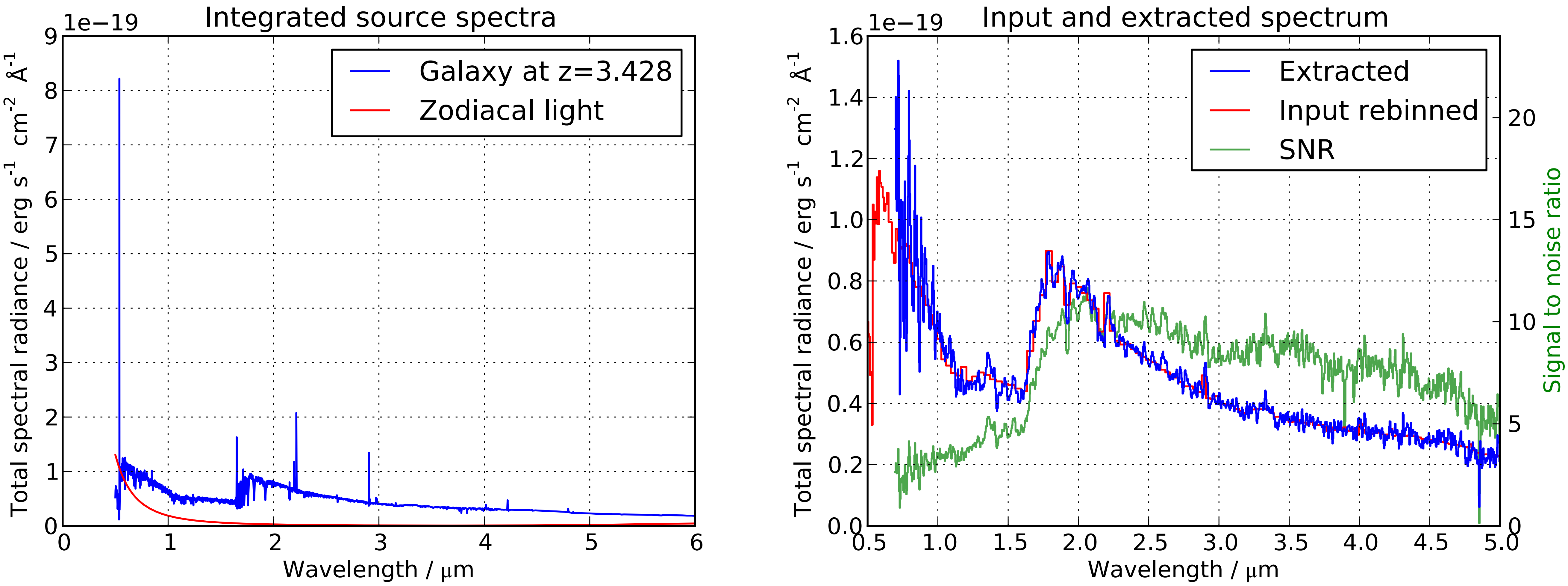
Results: single exposure

z=2.166, mag_H=25.0



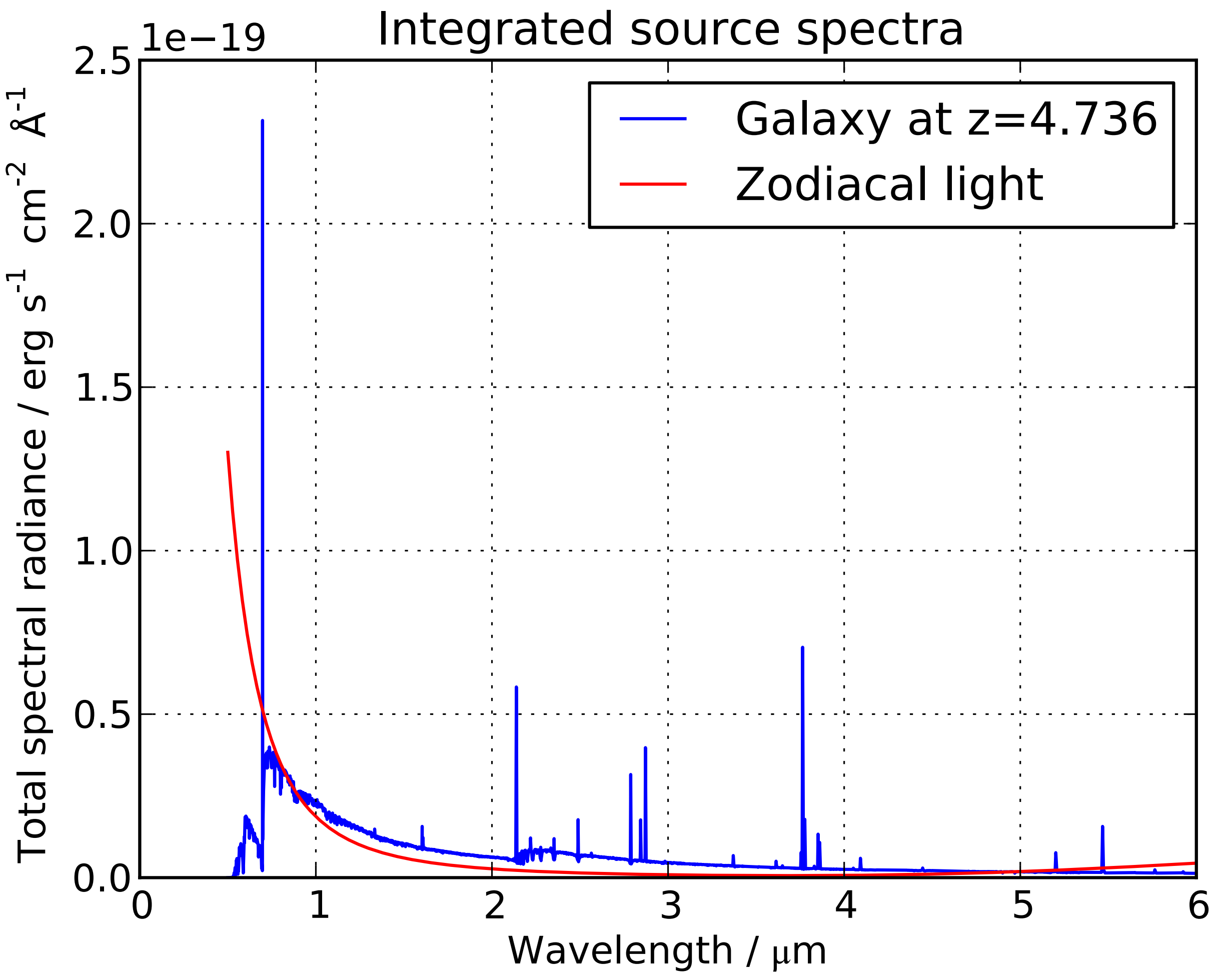
Results: single exposure

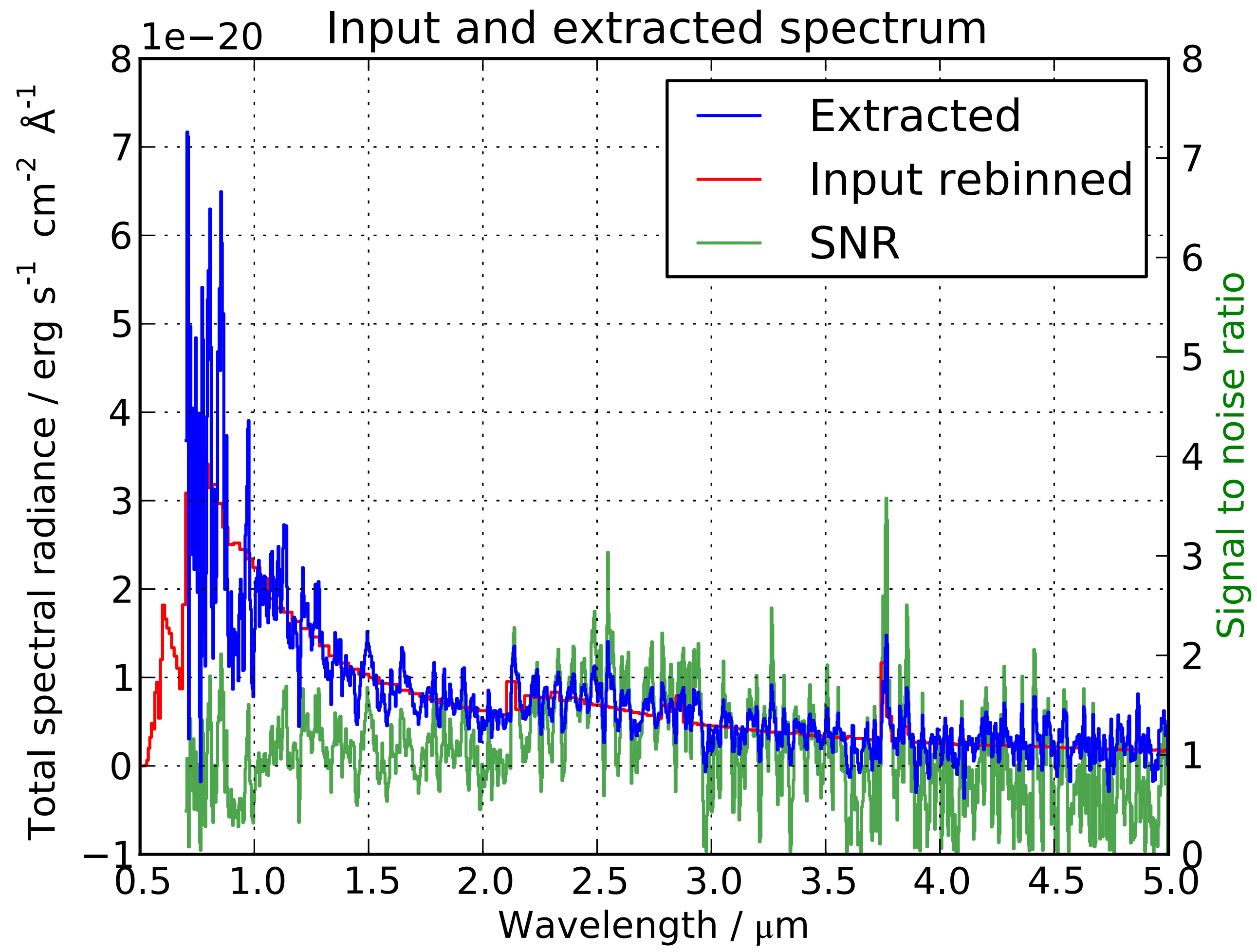
z=3.428, mag_H=24.7



Results: single exposure

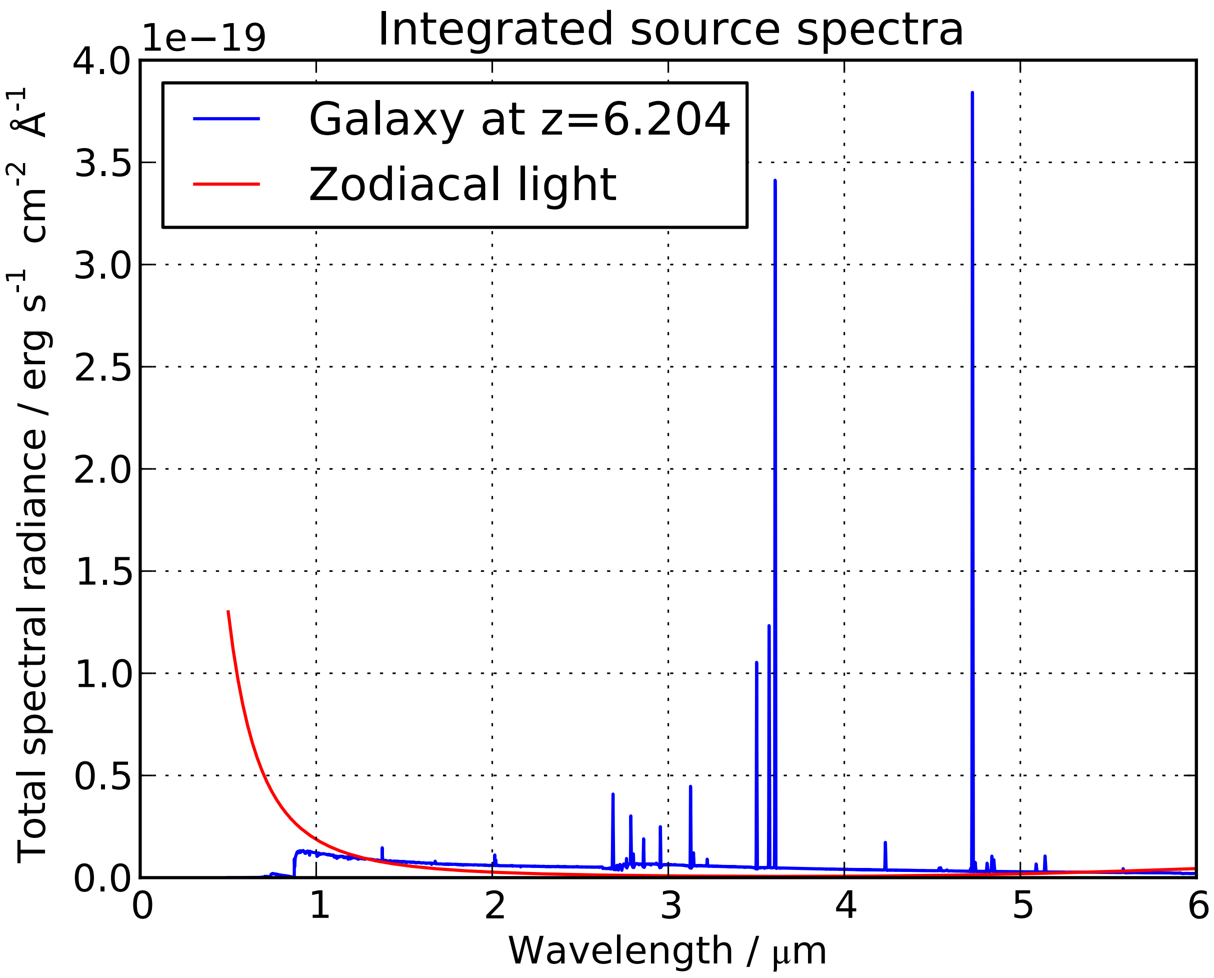
z=4.736, mag_H=26.7

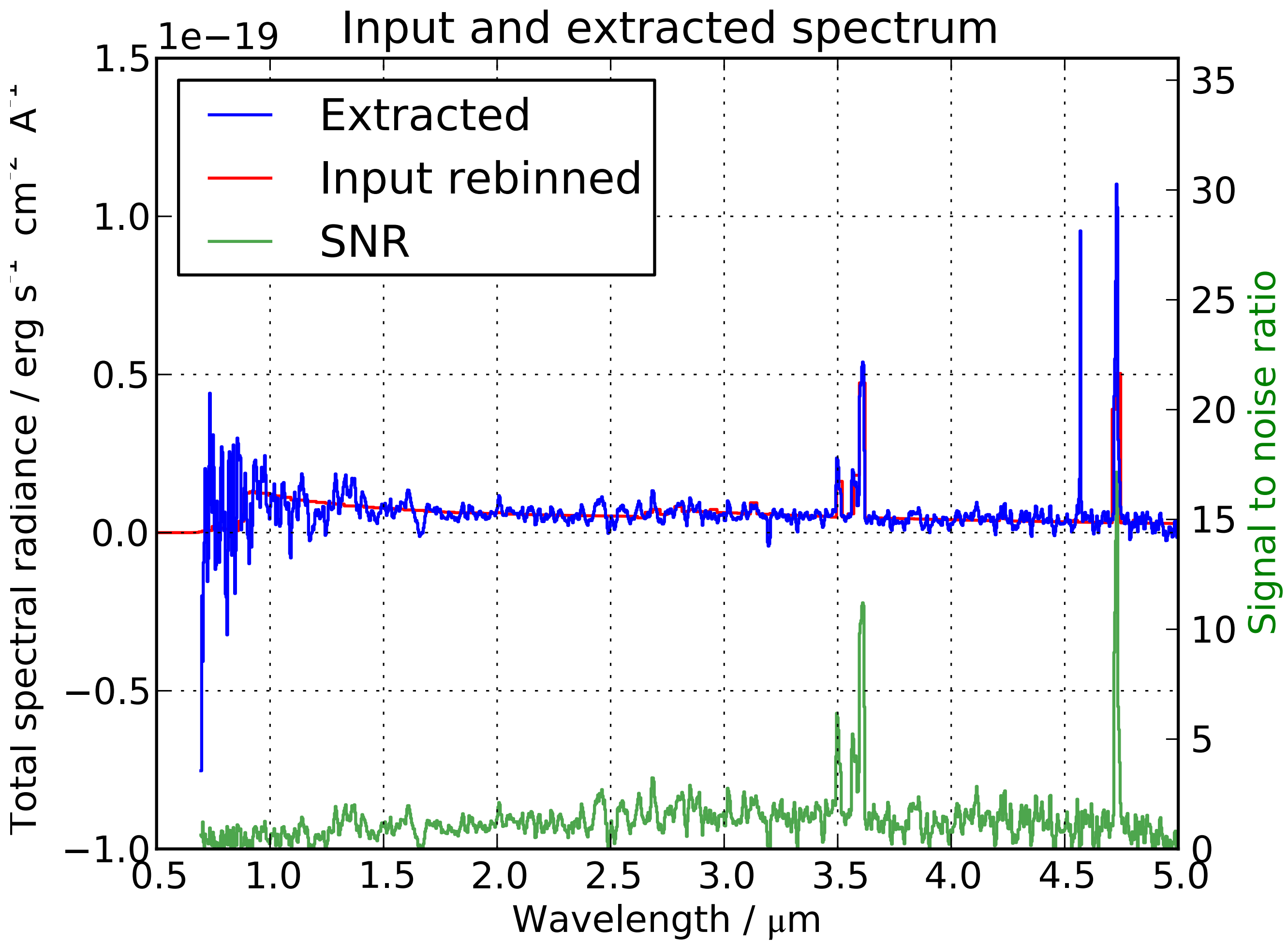




Results: single exposure

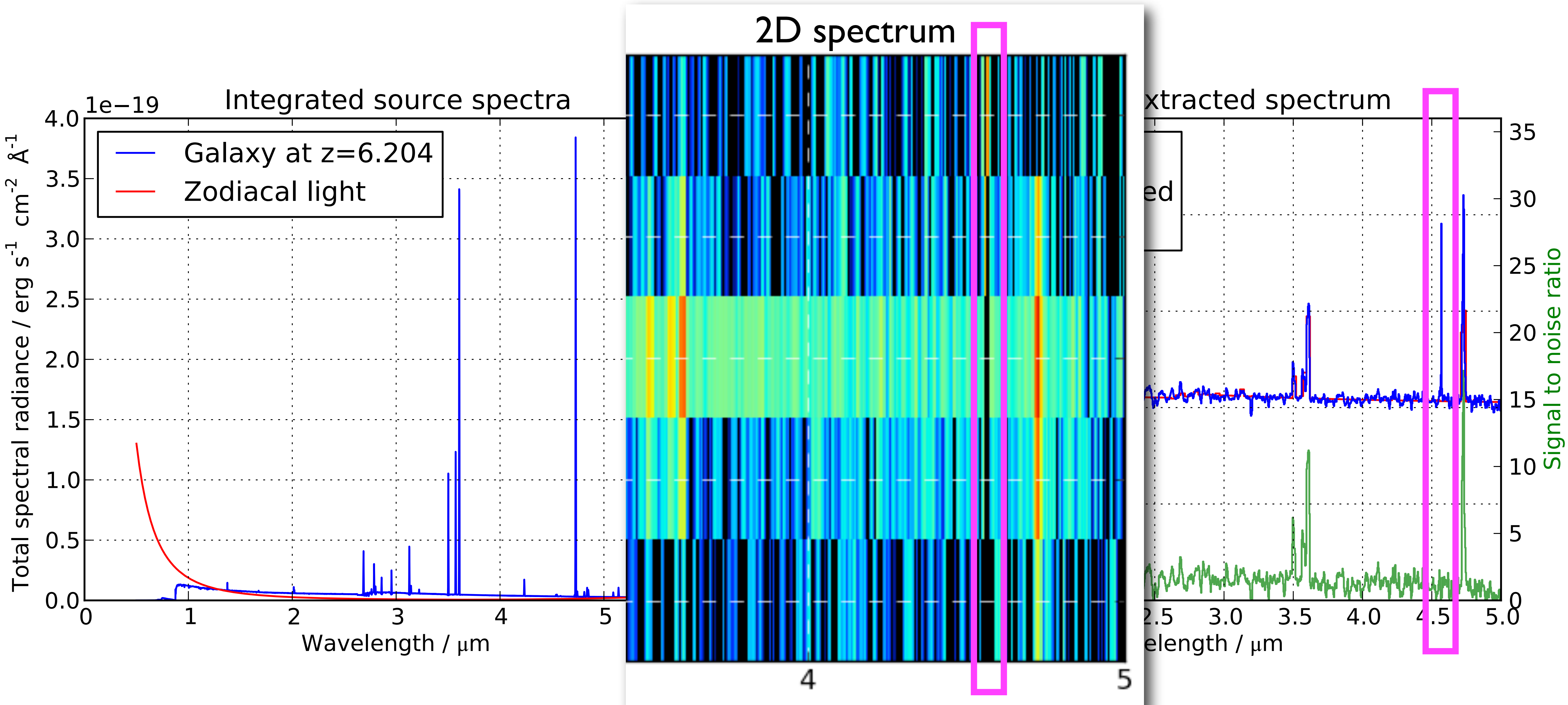
$z=6.204$, $mag_H=26.9$





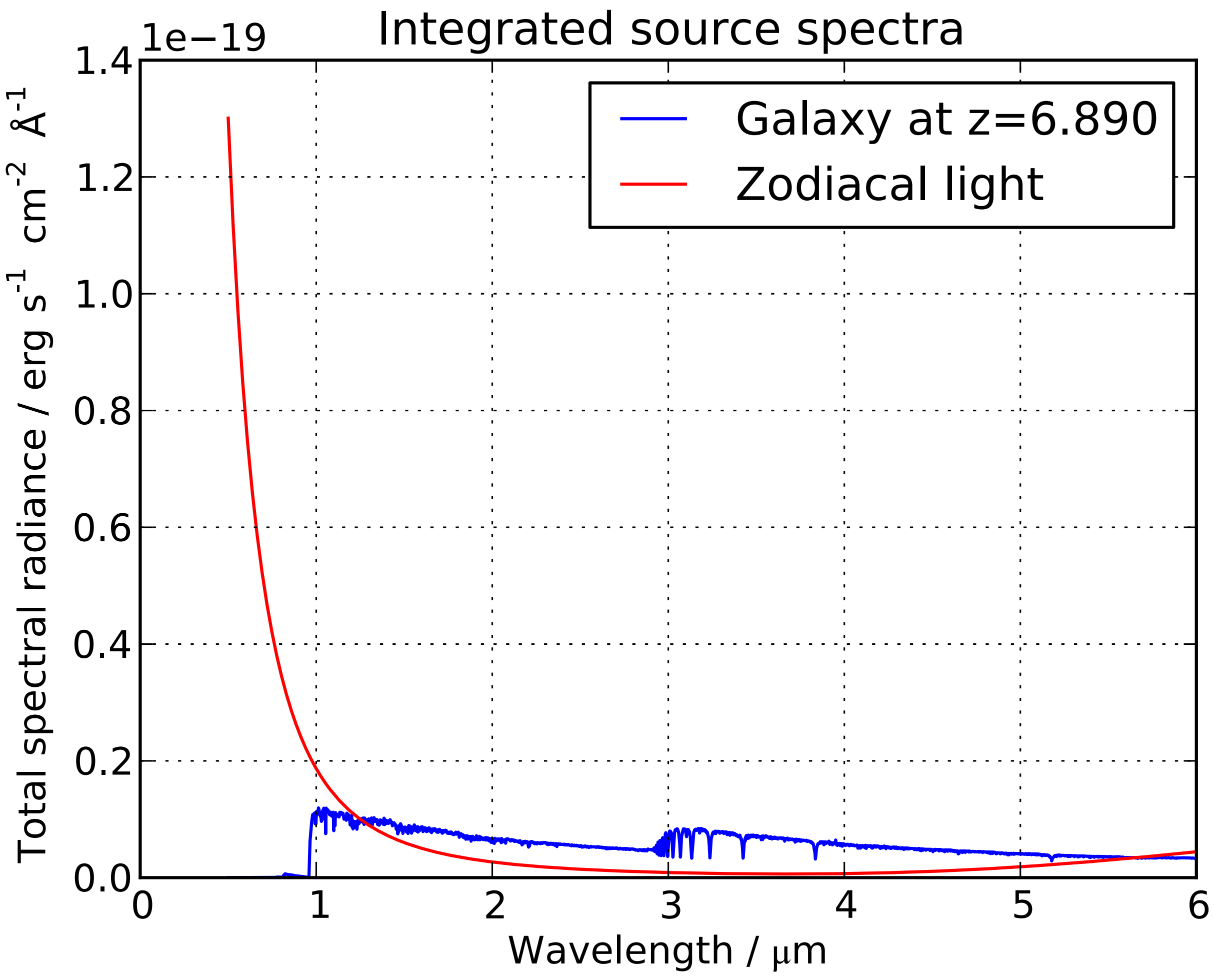
Results: single exposure

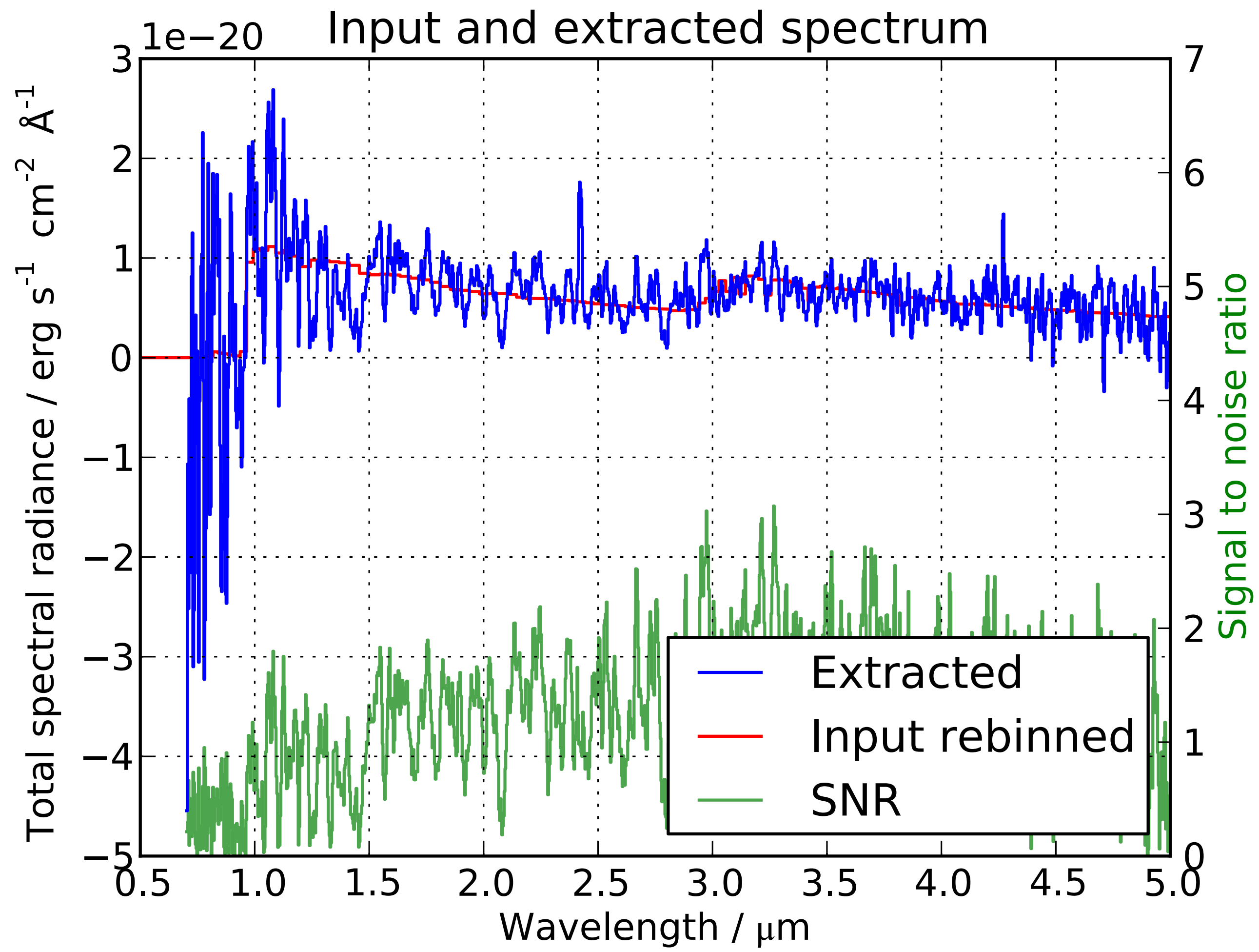
z=6.204, mag_H=26.9



Results: single exposure

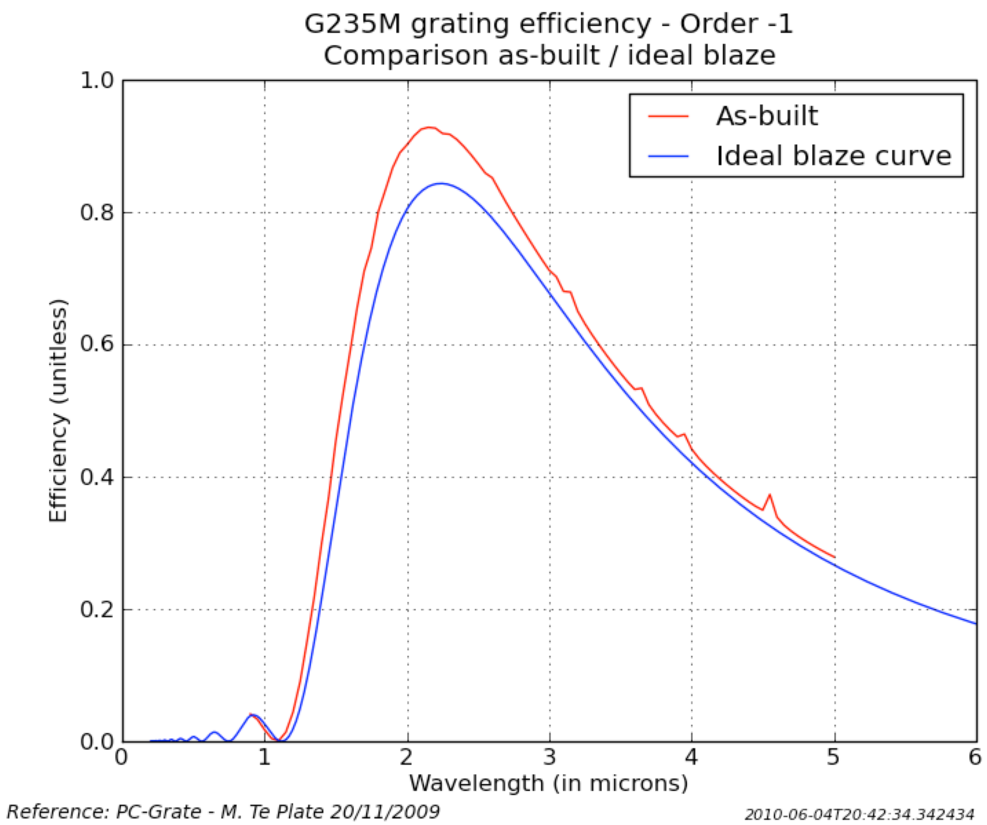
z=6.890, mag_H=26.8

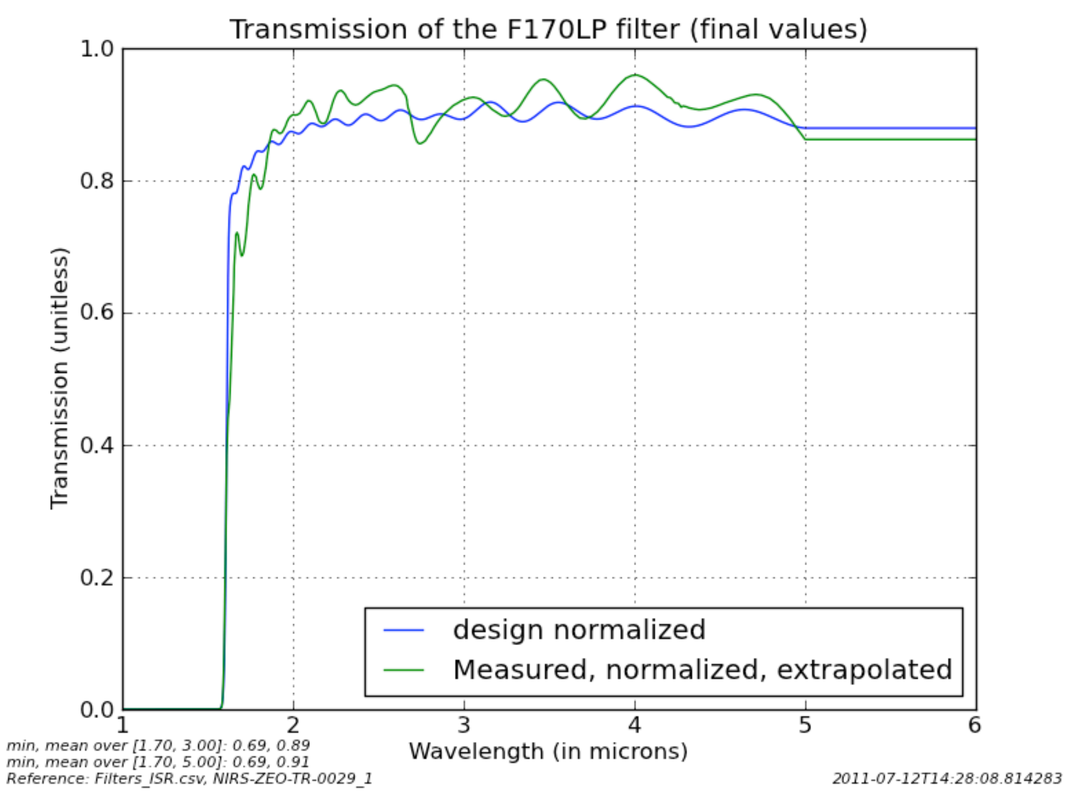




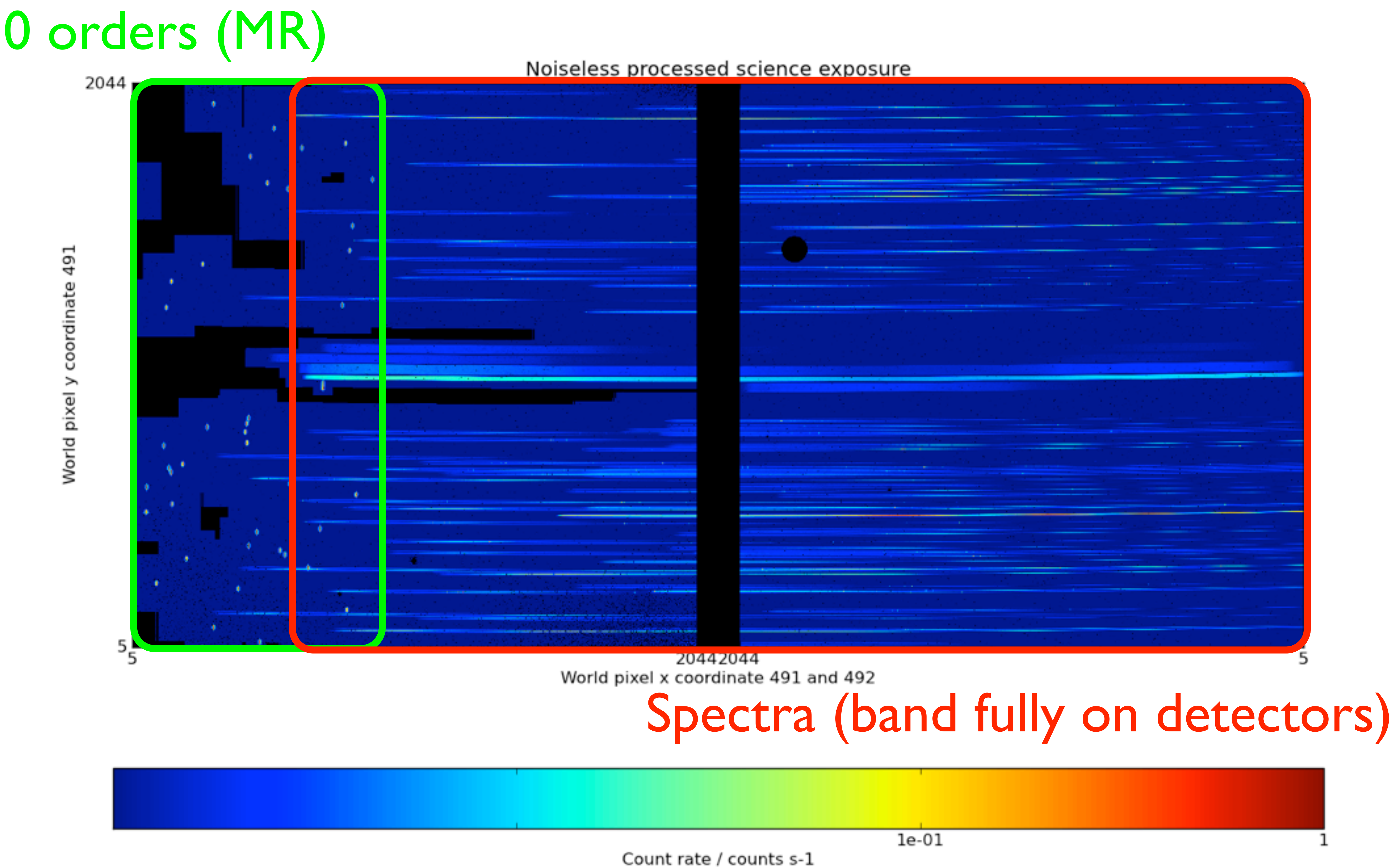
Exposure scene: Gratings

- Added Zodiacal light
- G235M (R1000 band II)
- F170LP filter (1.7–3 μm)
- Noiseless exposure (demonstration)
- No cosmic rays



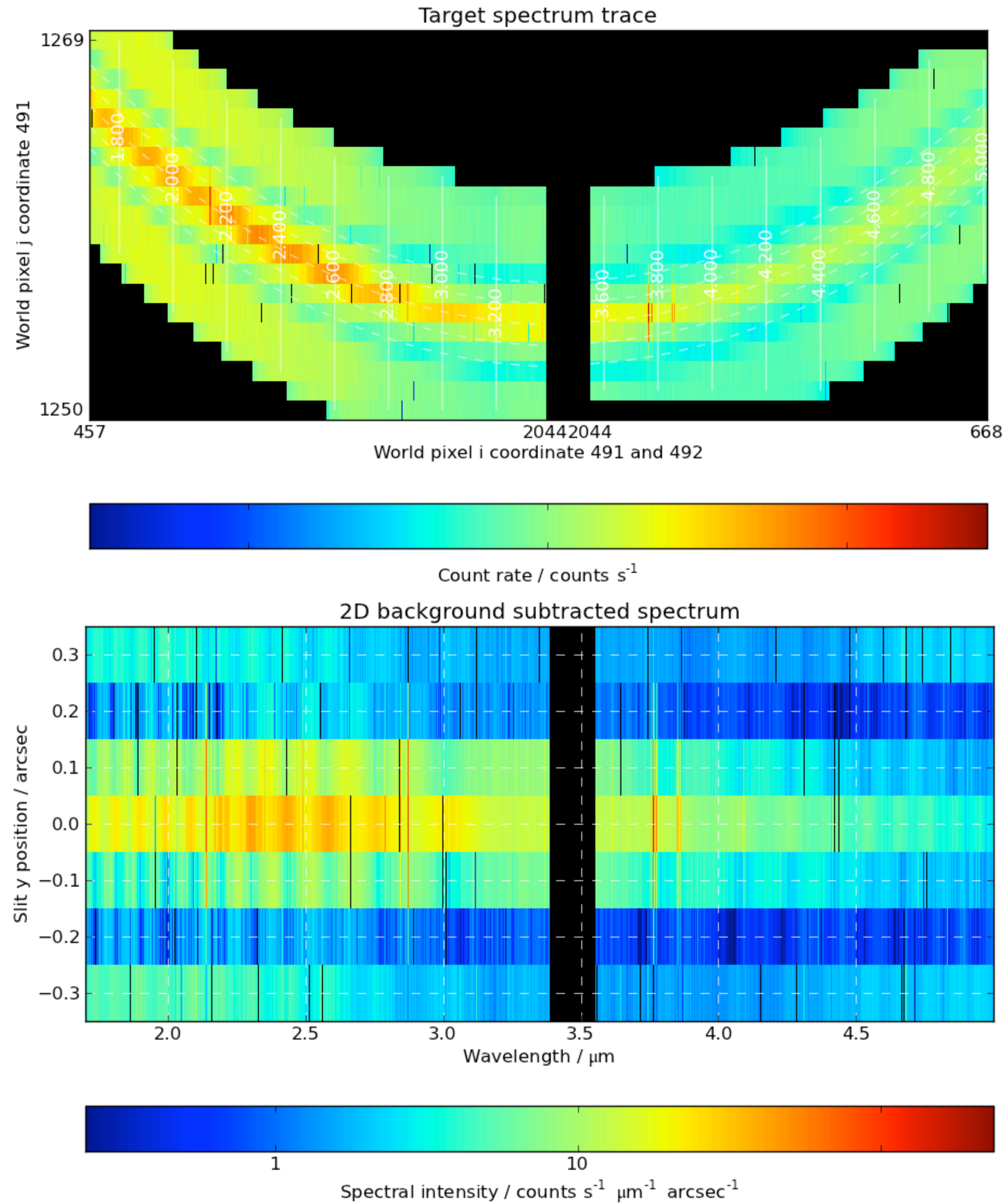


Exposure image: G235M



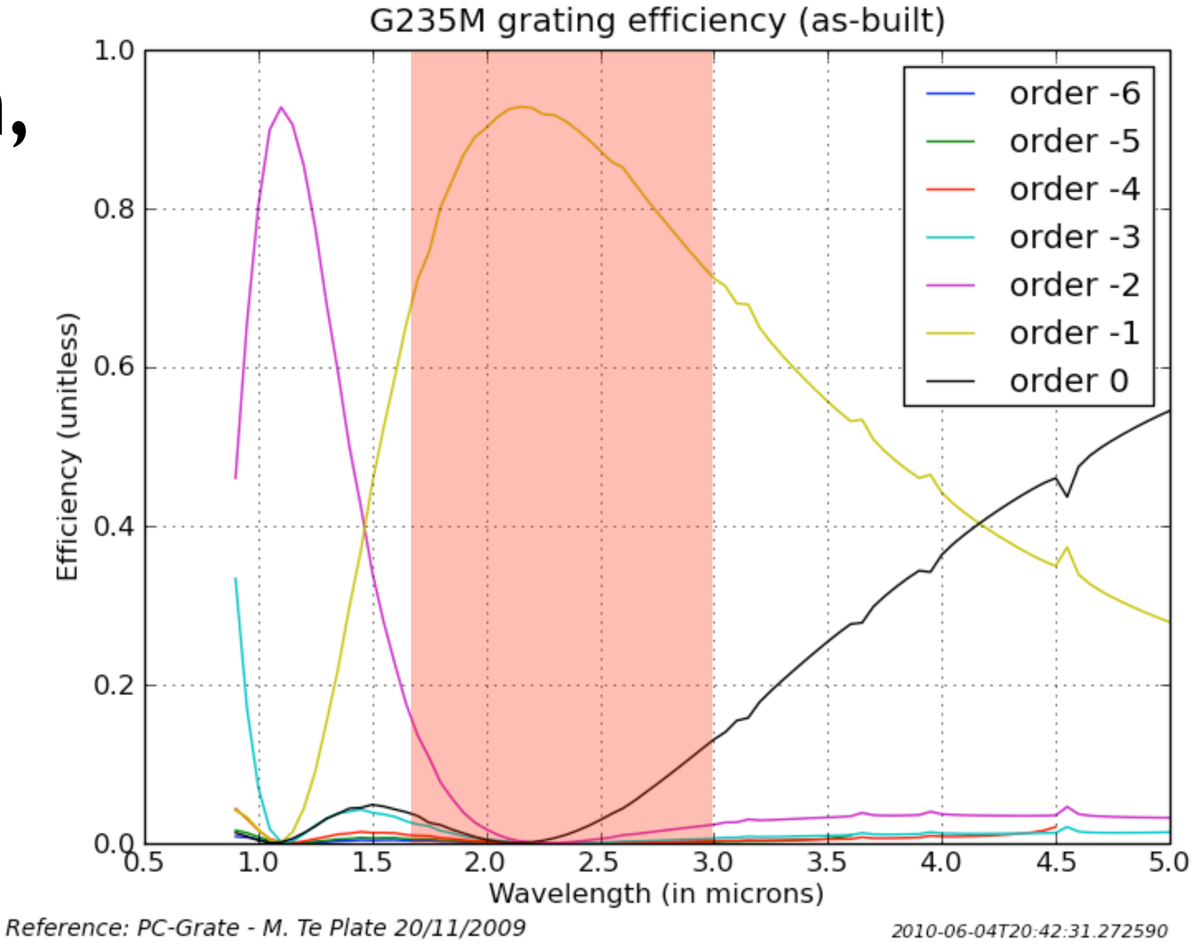
Spectrum extraction

- Use range 1.7–5.0 µm
- Trace extraction
- Rectification
- Background subtraction
- Collapse over 5 central pixels



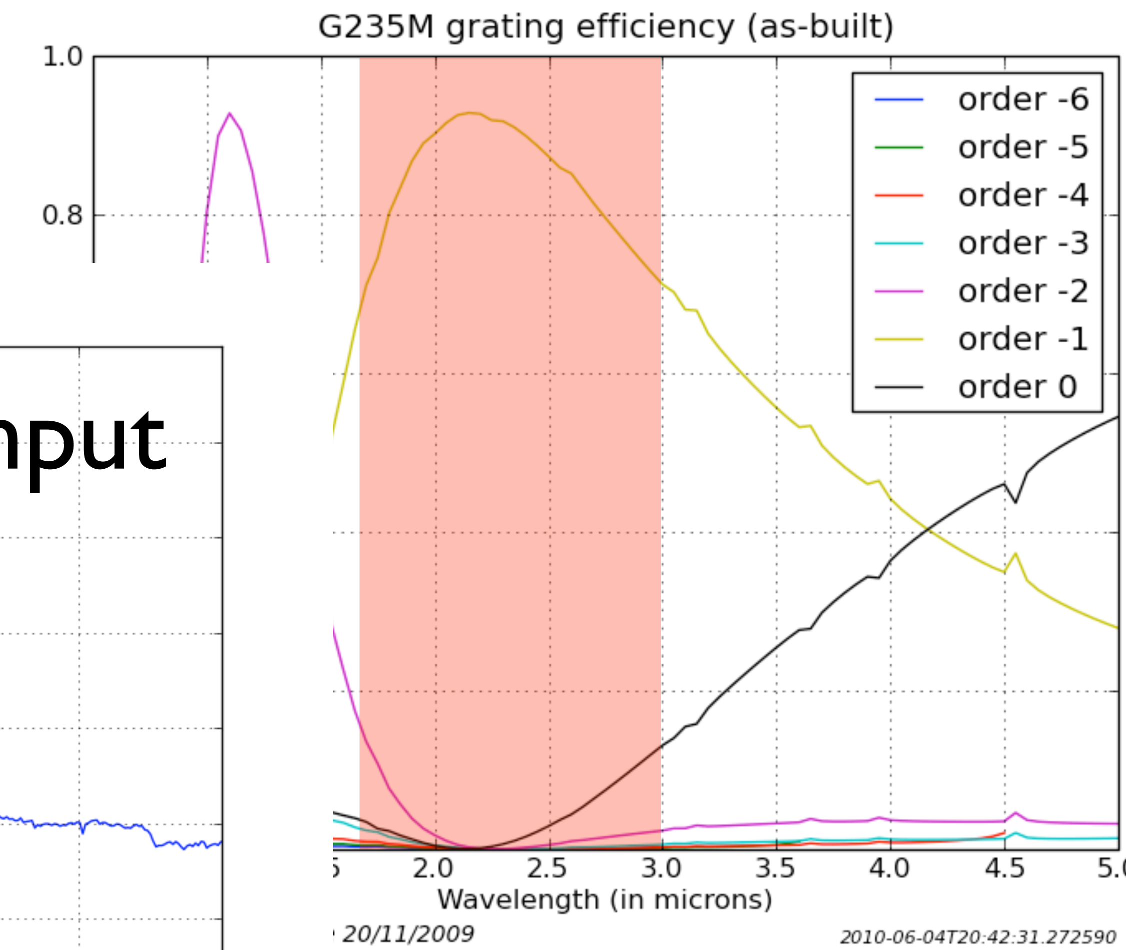
Results: Grating orders

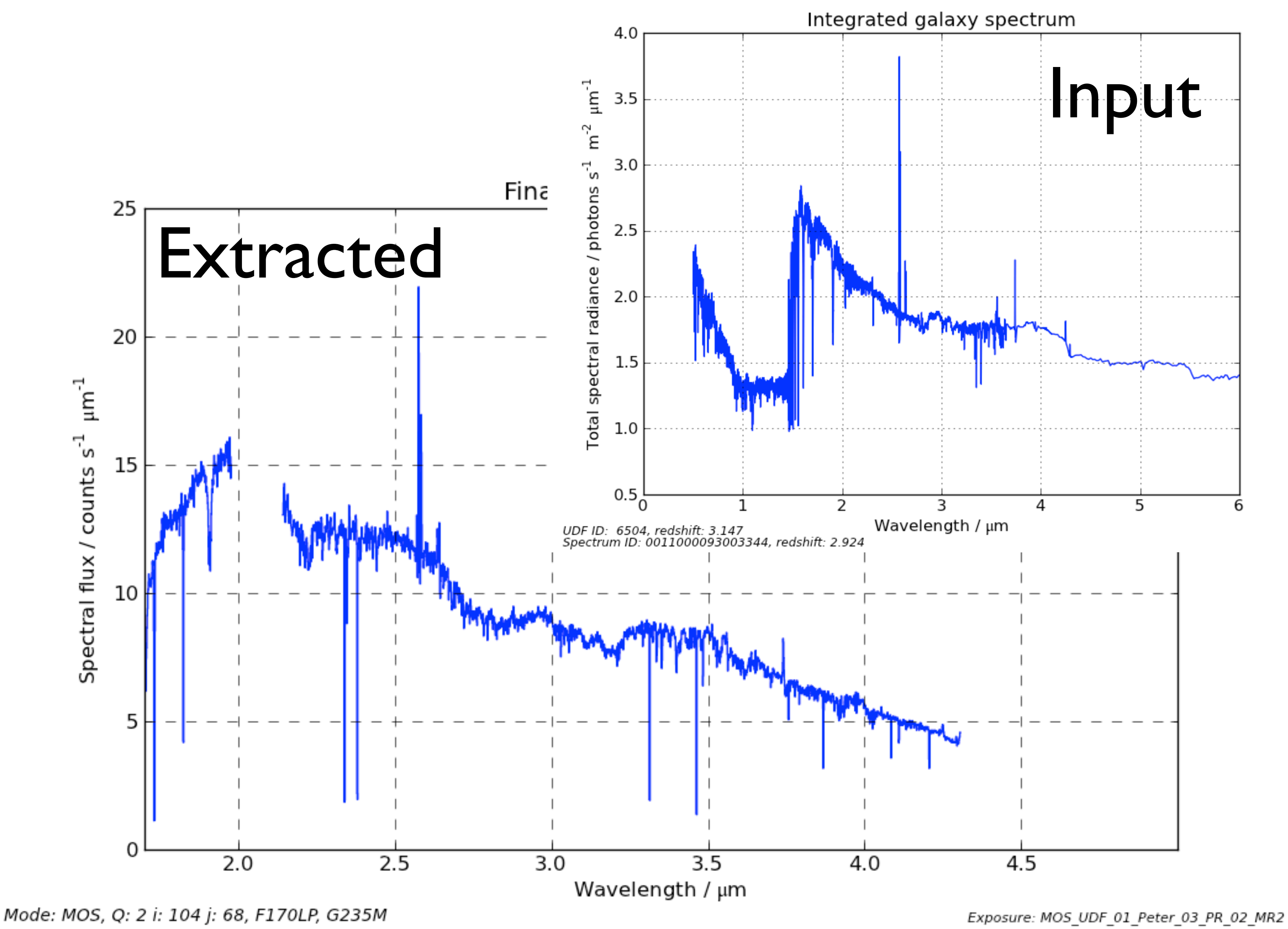
- Order overlap after 3.2 μm, but low efficiency



Results: Grating orders

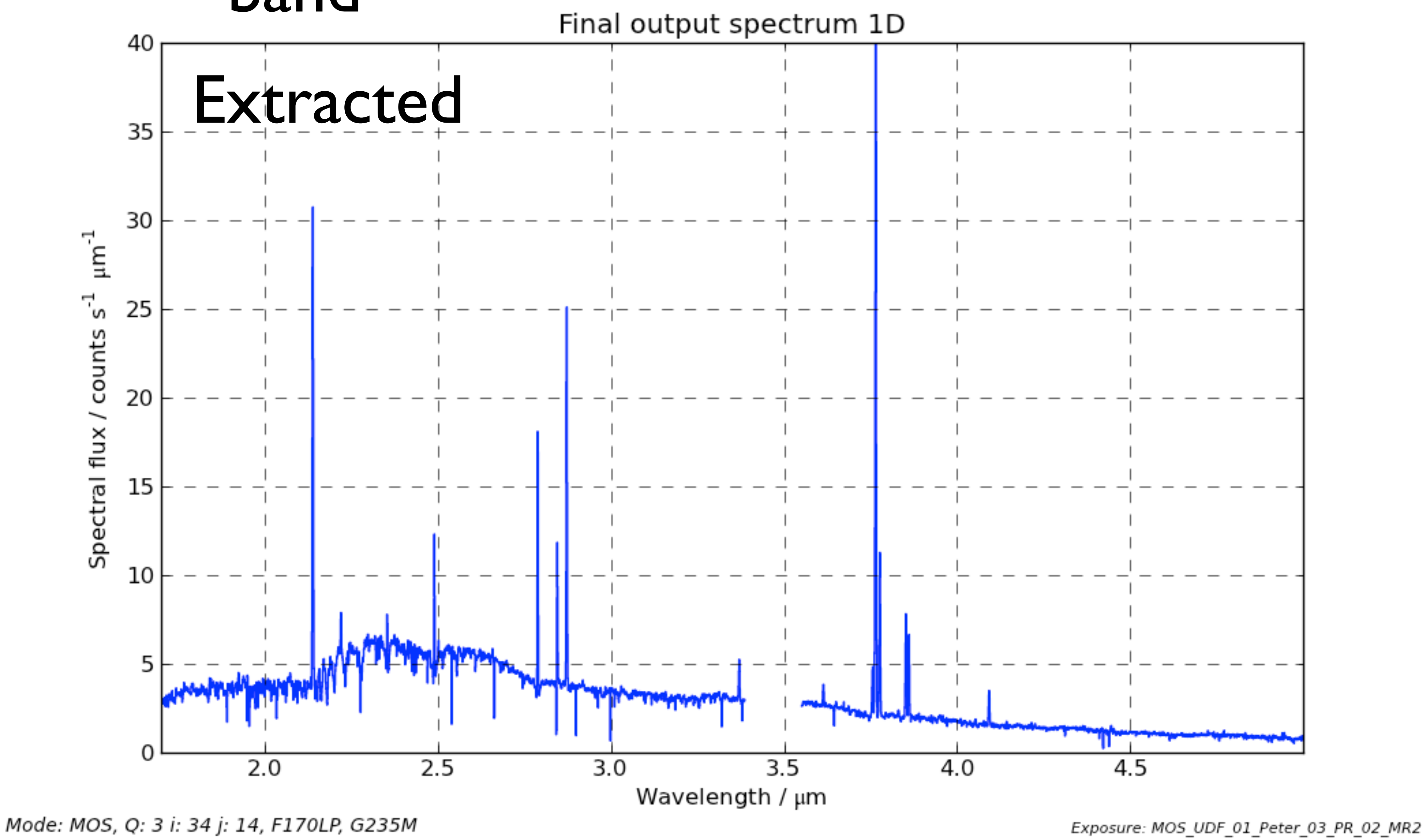
- Order overlap after 3.2 µm, but low efficiency





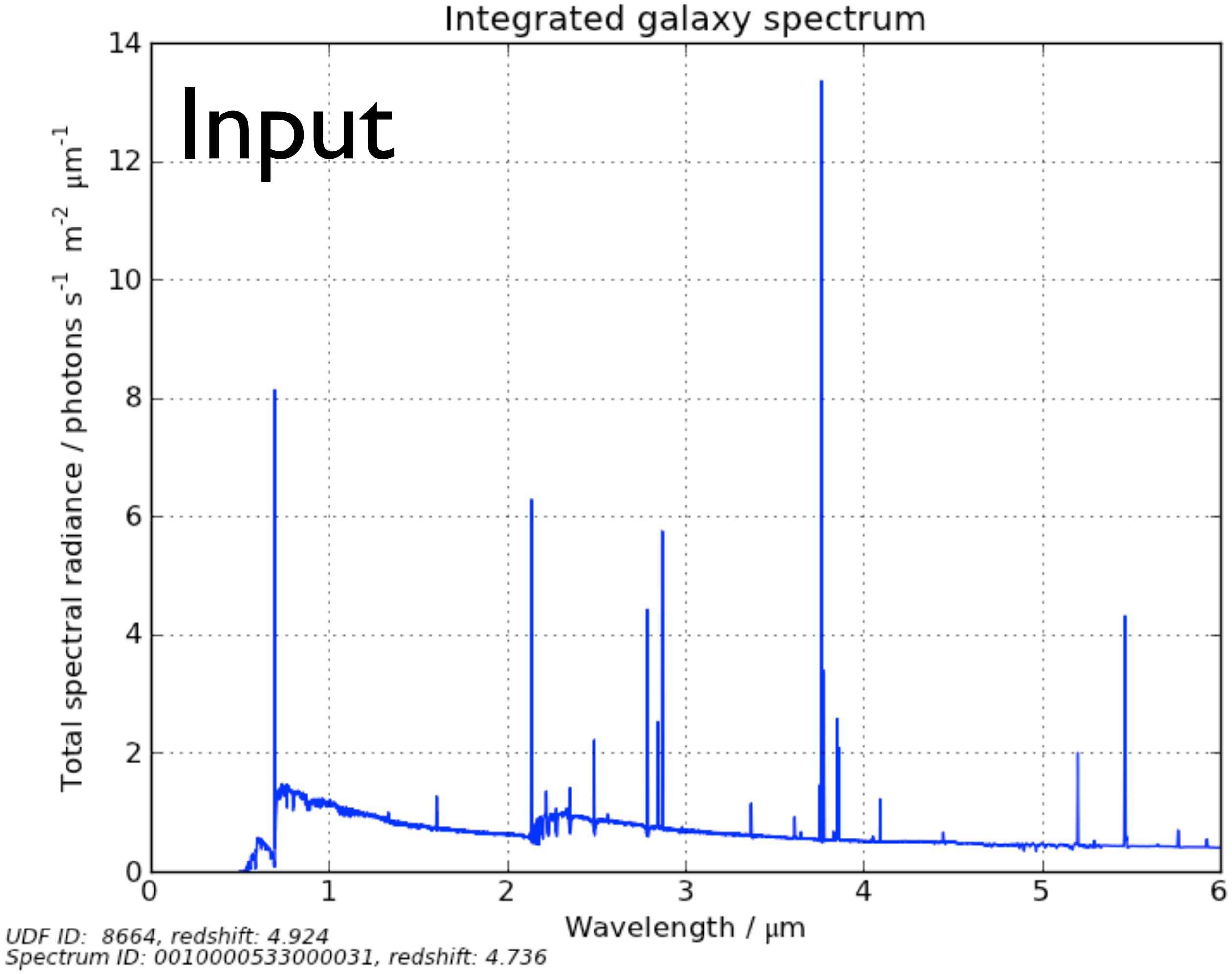
Results: Grating spectrum

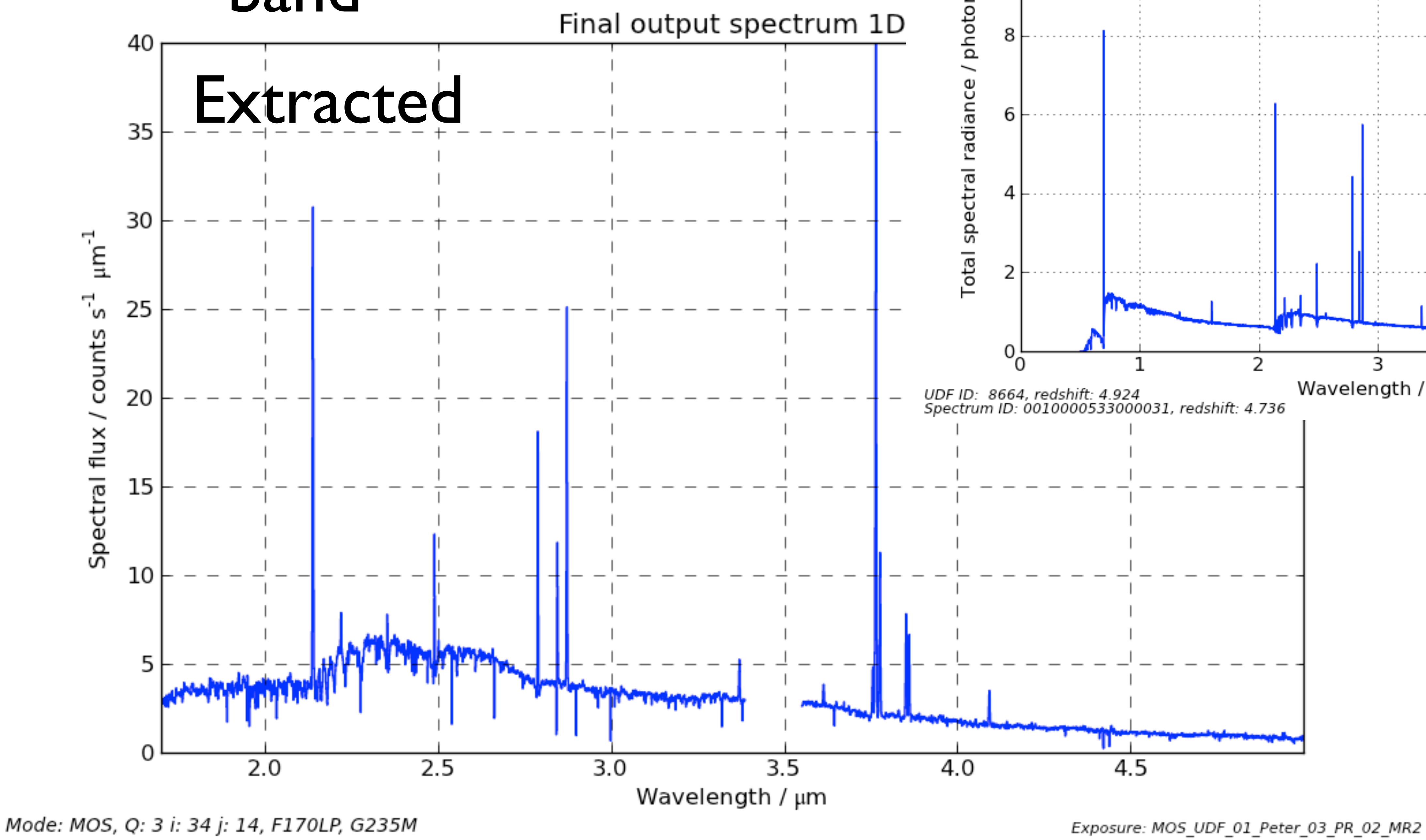
- Emission lines stand out over continuum beyond band



Results: Grating spectrum

- Emission lines stand out over continuum beyond band





Conclusions: MOS preparation

- Target selection and placement tricky
- Object sizes have to be taken into account
- Exclusion based on Hubble magnitudes may be misleading (use NIRCam survey instead)
- Gratings need single shutter row

Conclusions: MOS simulations

- Simulations not quite there (extended objects)
- NIRSpec performance with single exposure very promising (planned: 100,000 s total, 106x longer)
- Grating orders overlap
- Keep track of errors and flags in processing
- IPS and NIPPLS powerful combination to analyze planned observations