Science and Evolution of Gemini Observatory

"Under the Hood" Talk:
Distant Galaxy Cluster Imaging and Spectroscopy with Gemini

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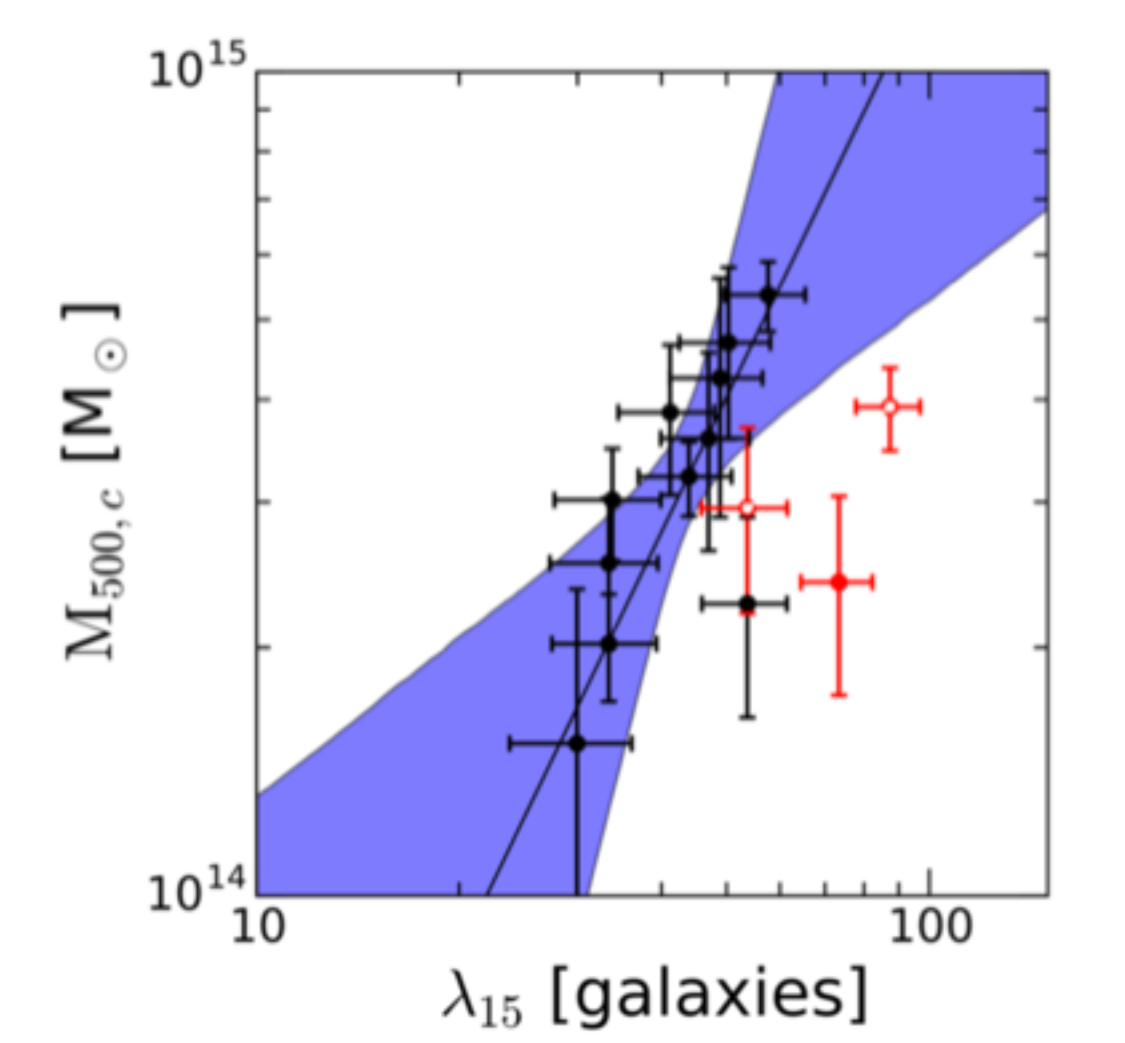
presented by Mark Brodwin (UMKC)

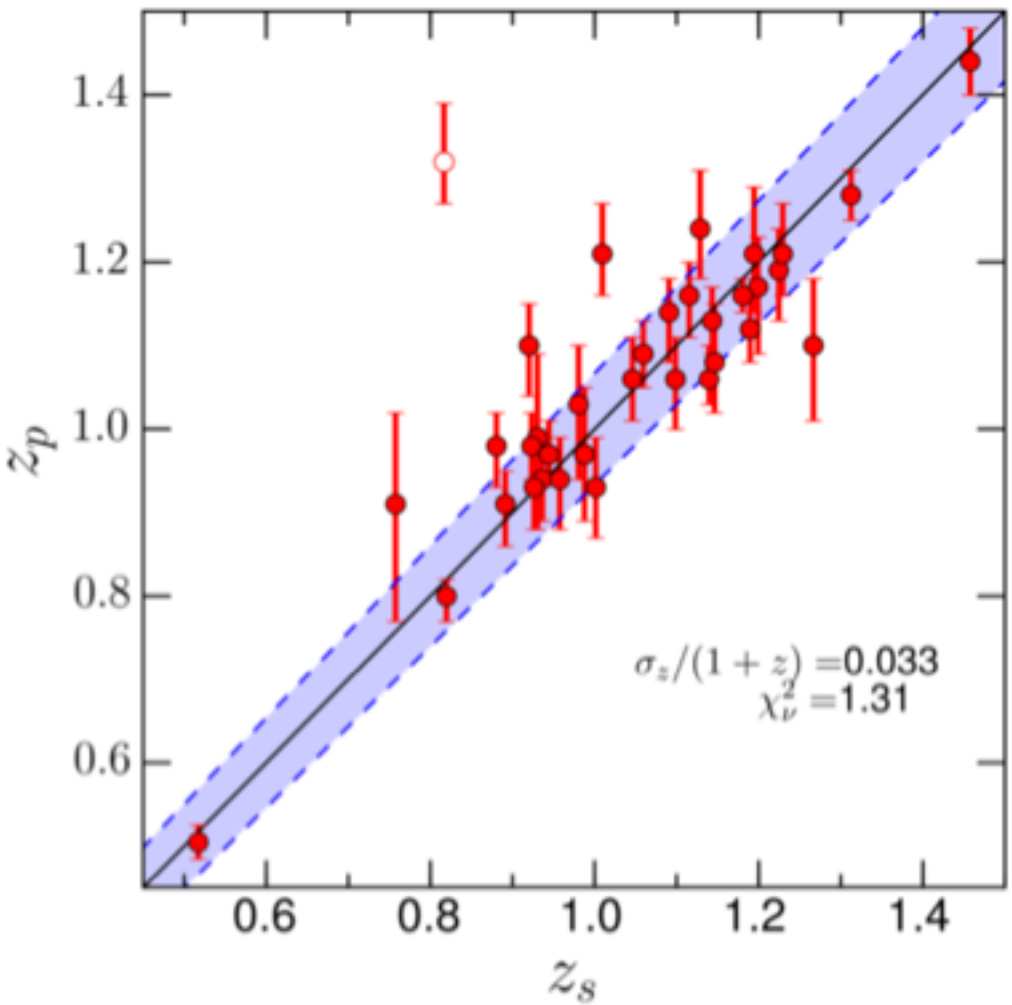
MaDCoWS: Optical Imaging and Spectroscopy with GMOS

- Primary goal is spectroscopic confirmation of 15-20 massive z~1 galaxy clusters
- Confirmation is defined as at least 5 redshifts within r~1 Mpc and +/- 3000 km/s
- Three step process:
  - Targets selected by IRAC-richness, and to have photometric redshifts at $0.9 < z < 1.3$
  - Pre-imaging with two bands (*r, z*)
  - Spectroscopy consists of one mask per cluster for maximum time efficiency: we have ~90 hours mostly in Band 2 to observe 15-20 clusters

Target Selection: IRAC richness



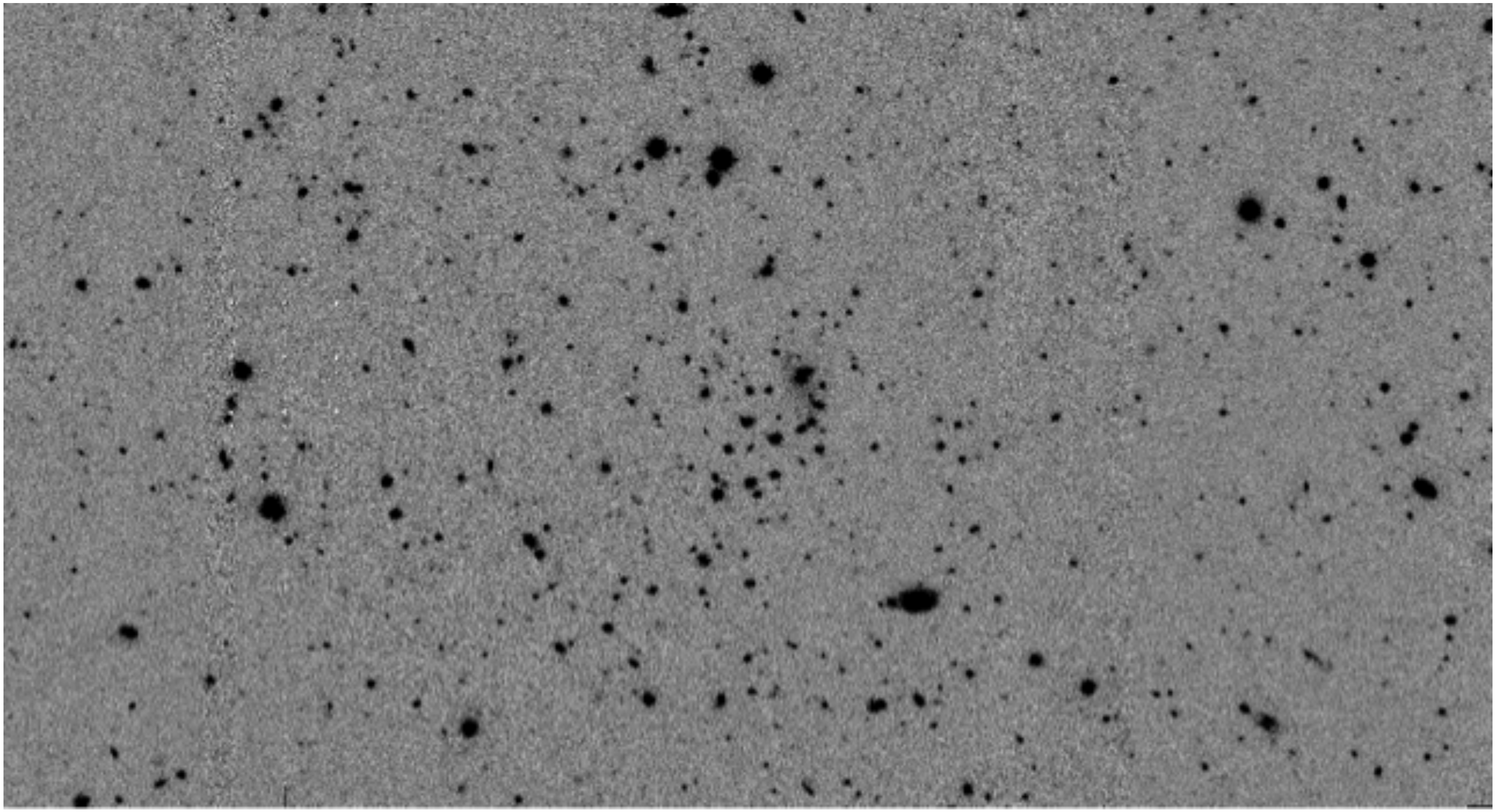
Target Selection: photo-z



Pre-imaging: observations

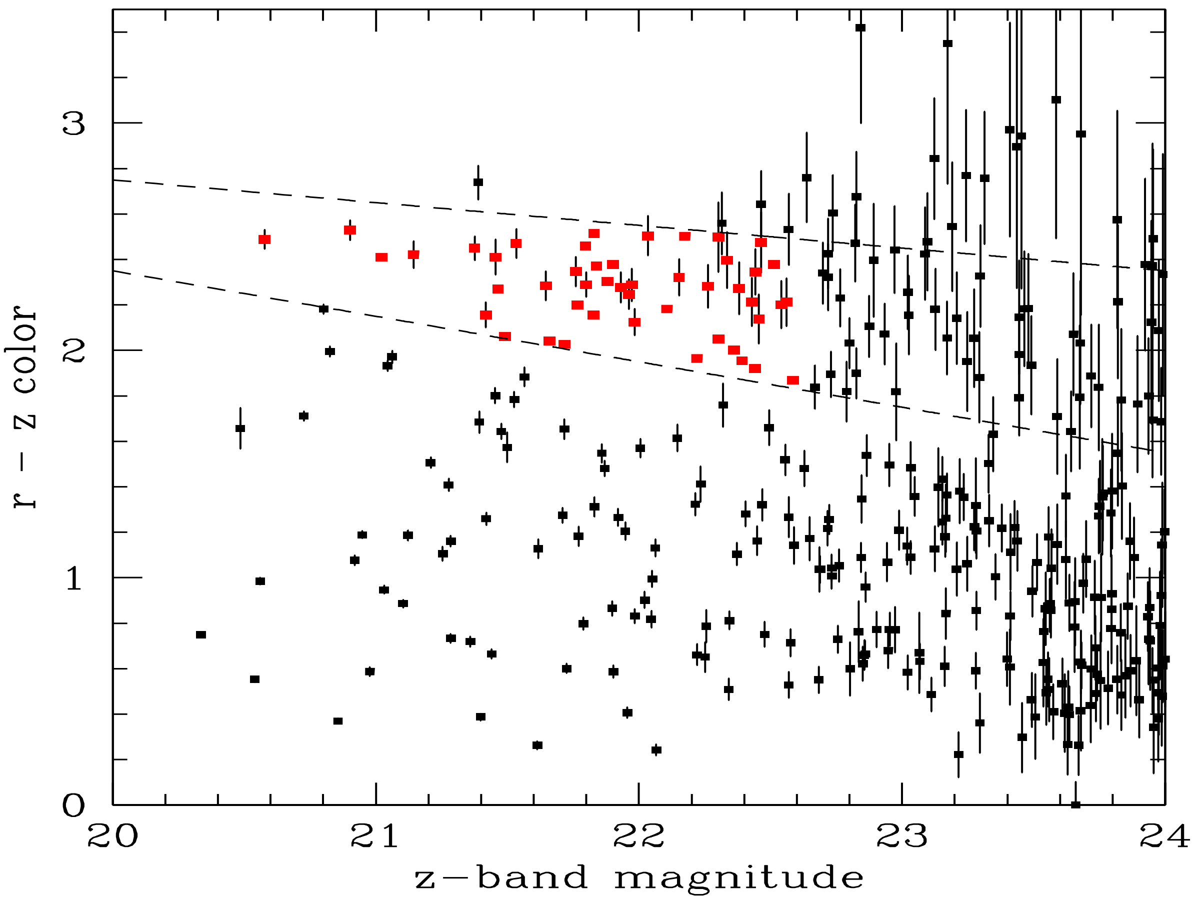
- GMOS imaging in the *r*, *z*-bands down to m* + 0.5; typically 1080s/360 s respectively
- Image quality requirement relaxed to IQ=85 (from 70) for Band 2 observations in order to increase chances of getting data
- Standard image reductions performed by our team

Pre-imaging: observations



MOO J0132+0329, z-band image

Pre-imaging: color-mag diagram



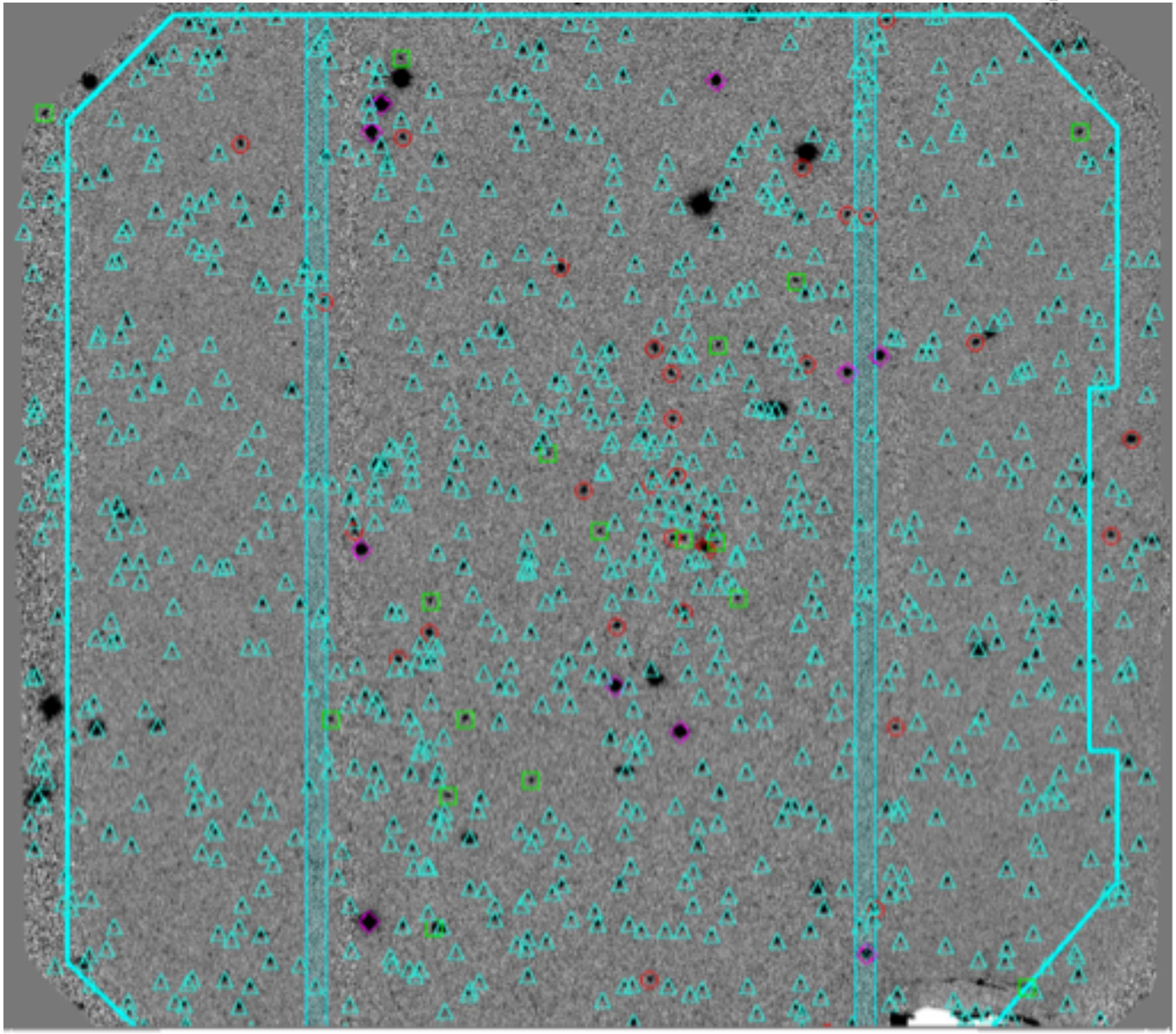
Objects in the red sequence selected as primary targets for mask design, usually down to m* + 0.5

Spectroscopy: mask design

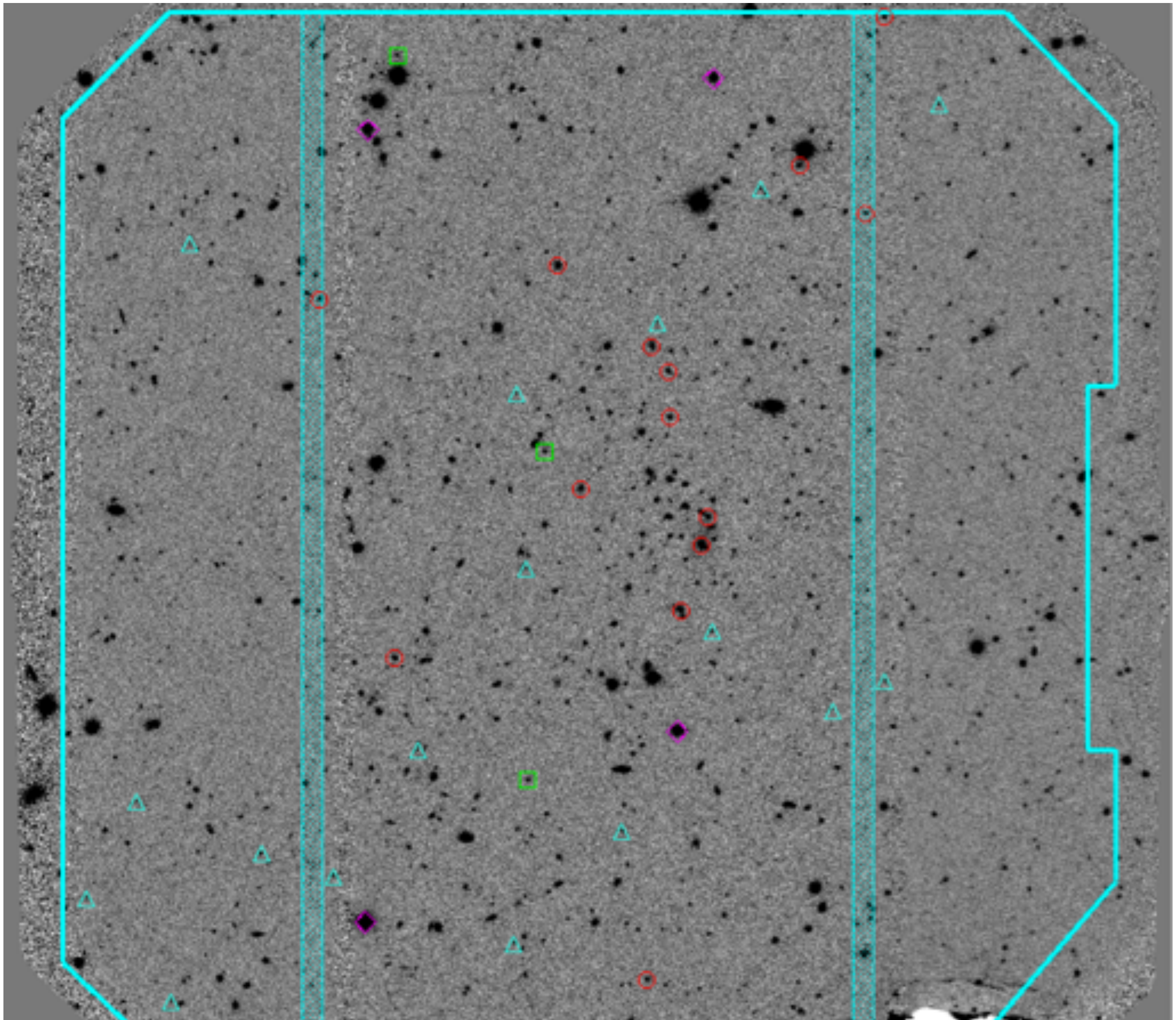
- Primary objects defined by red sequence in the CMD above a chosen mag limit; secondary filler objects selected from both bluewards of and fainter than the red sequence region
- AGN candidates identified from available IRAC, VLA, and Chandra data are targeted; in practice only a few exist per cluster on average, so usually include only one in a mask
- Spatial distribution of primary objects (from the red sequence in the CMD) determines the choice of micro shuffle vs. band shuffle
- Slitlets are 1.0 arcsec wide and minimum of 3 arcsec in length
- Fixed GMOS PA restricts design effectiveness

MOO J0132+0329
z-band image

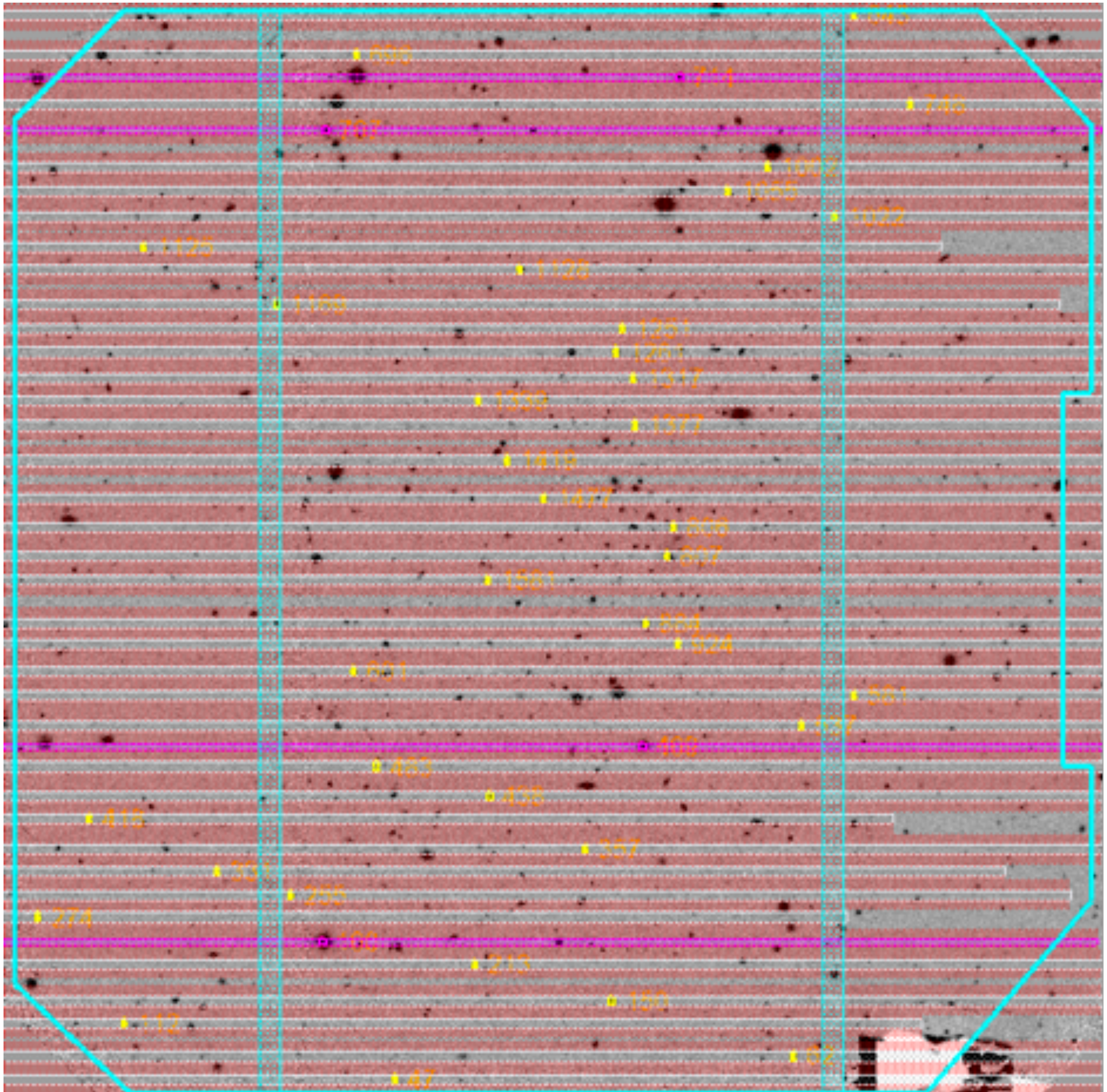
Red circles = primary
Green squares = secondary
Triangles = filler
Purple diamonds = alignment



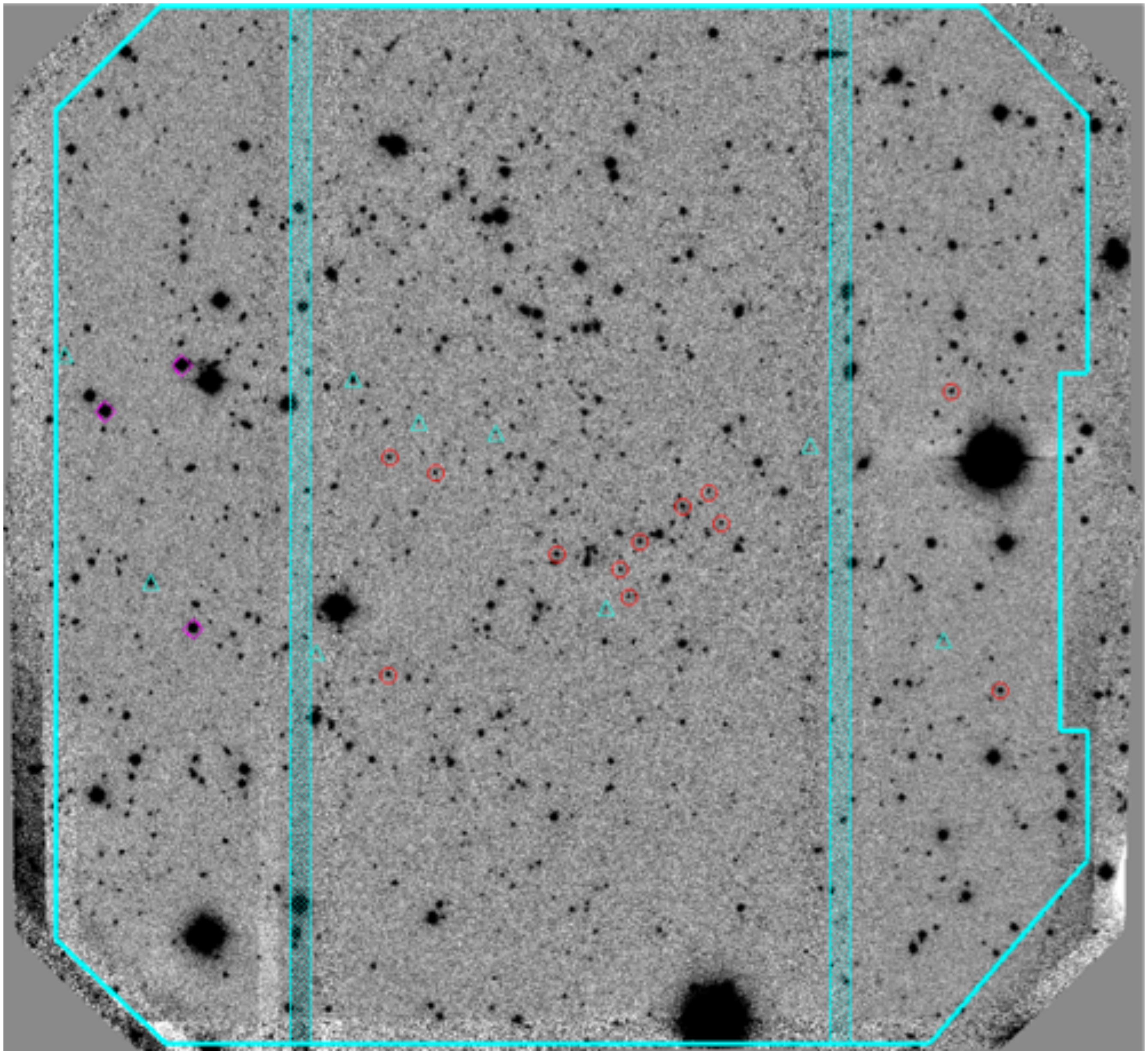
Micro-shuffle mask



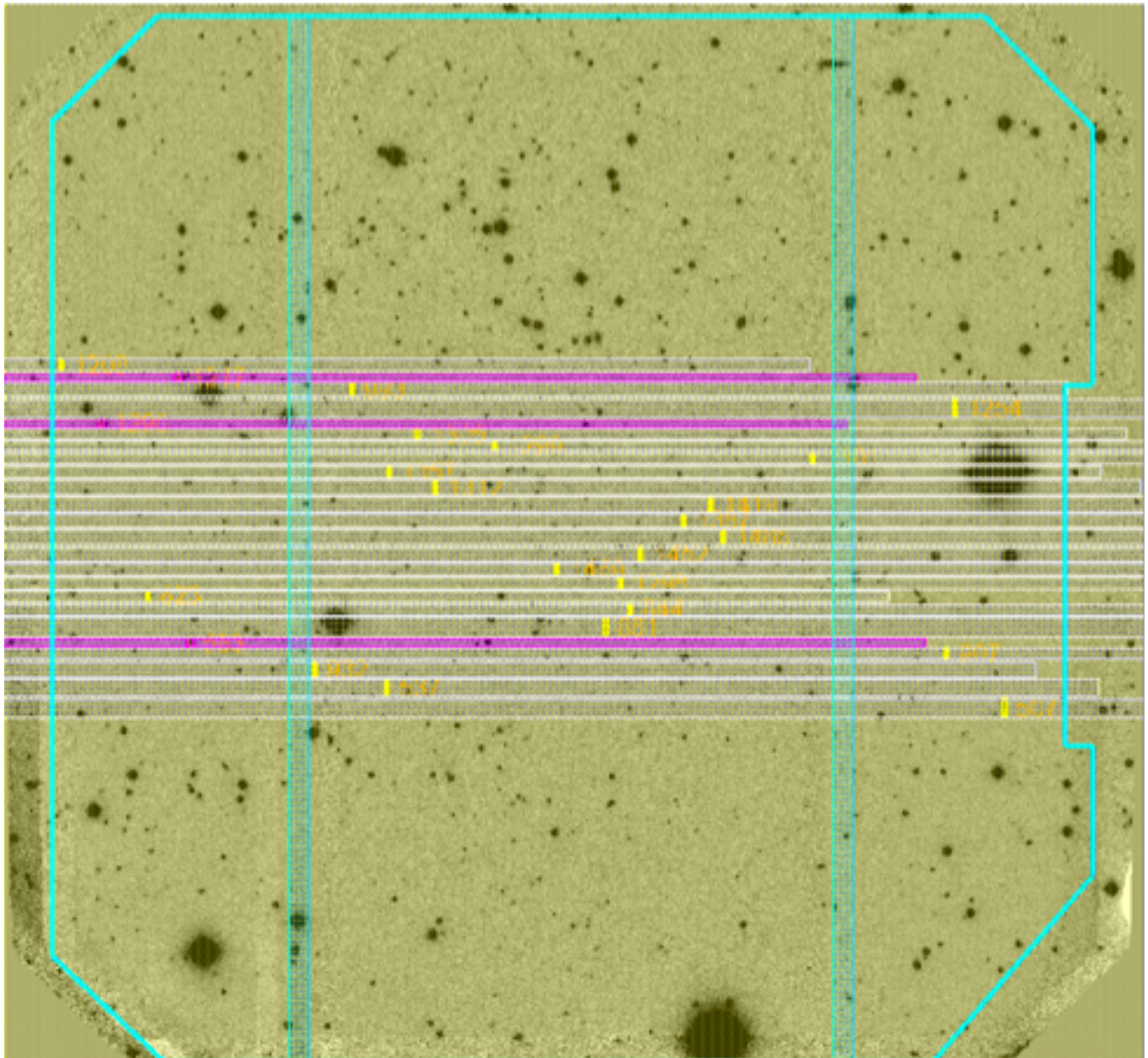
Micro-shuffle mask



Band-shuffle example: MOO J1751+4307



Band-shuffle example: MOO J1751+4307



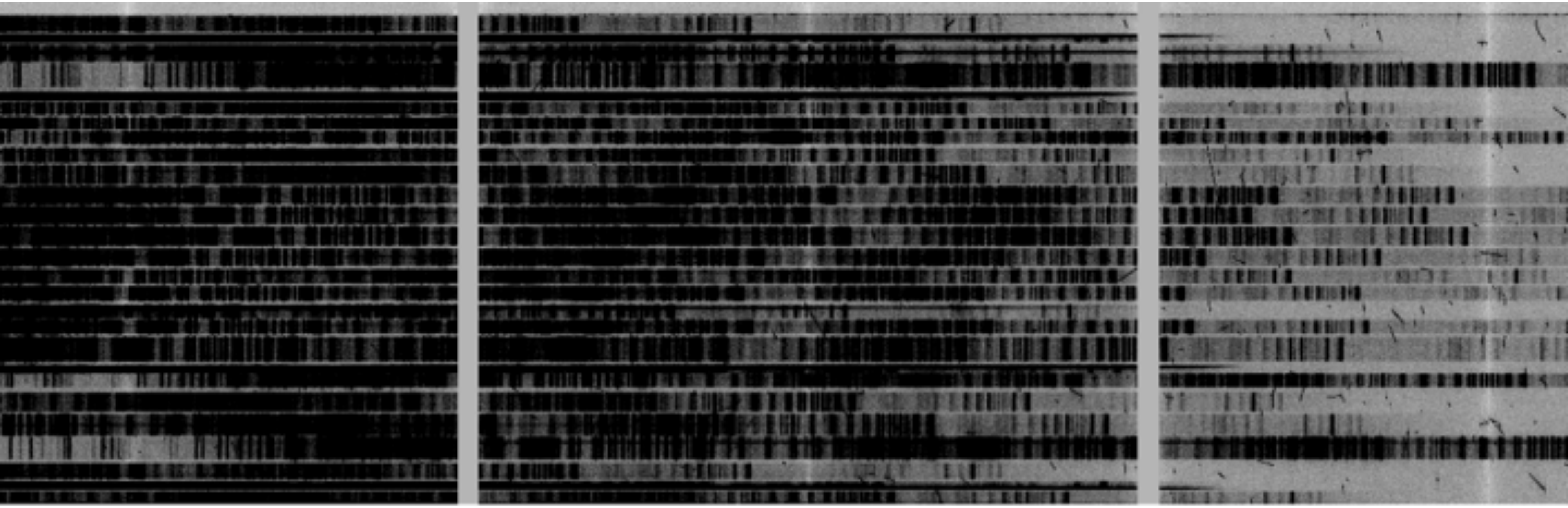
Spectroscopy: observations

- R400 grating and the RG610 filter; primary wavelengths of interest are ~7000 to ~9300 Angstroms
- Nod/shuffle mode with offsets of +/- 0.75 arcsec
- Exposure consists of 8-9 cycles of 60s
- Two wavelength settings centered at 800 and 810 nm, to fill in chip gaps in the final stack
- Typical sequence in each wavelength setting of flats, then 2-3 exposures, then flats, etc
- Total exposure time per mask usually ~2 hours

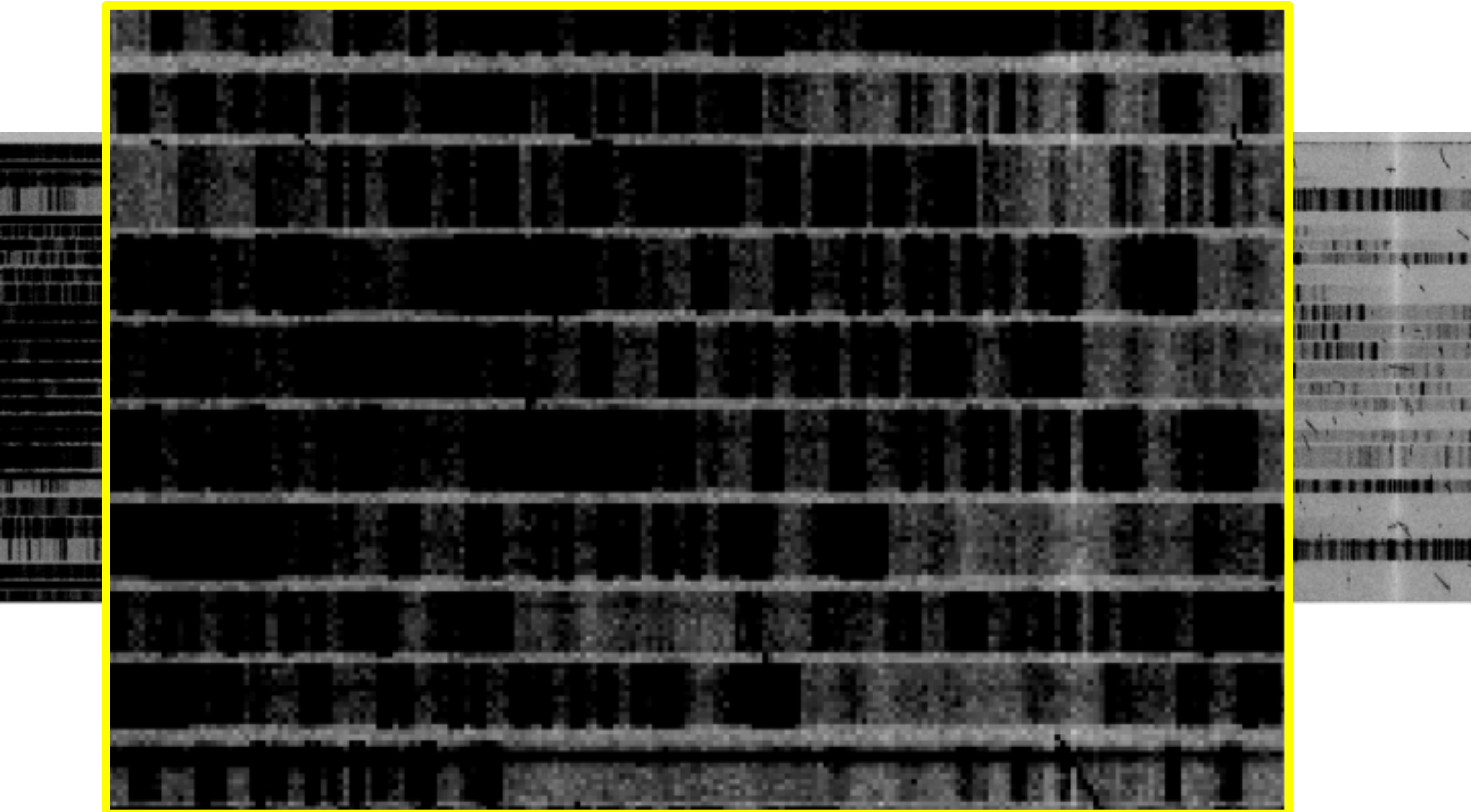
Spectroscopy: reductions

- Make wavelength-specific flats (i.e. at each λ setting)
- Trim, bias correct, flat field object exposures
- Cosmic ray removal using *laplace* routine
- Sky-subtraction using special IRAF routine *gnsskysub*
- Convert "negative" spectra from nod position to positive spectra
- Shift and coadd positive and negative two-d spectra
- Slice the two-d stacks into individual slitlets
- Determine wavelength calibration from arc exposures
- Apply two-d wavelength transformation to object stack
- Extract 1-d spectra

Single frame – bias subtracted, flattened

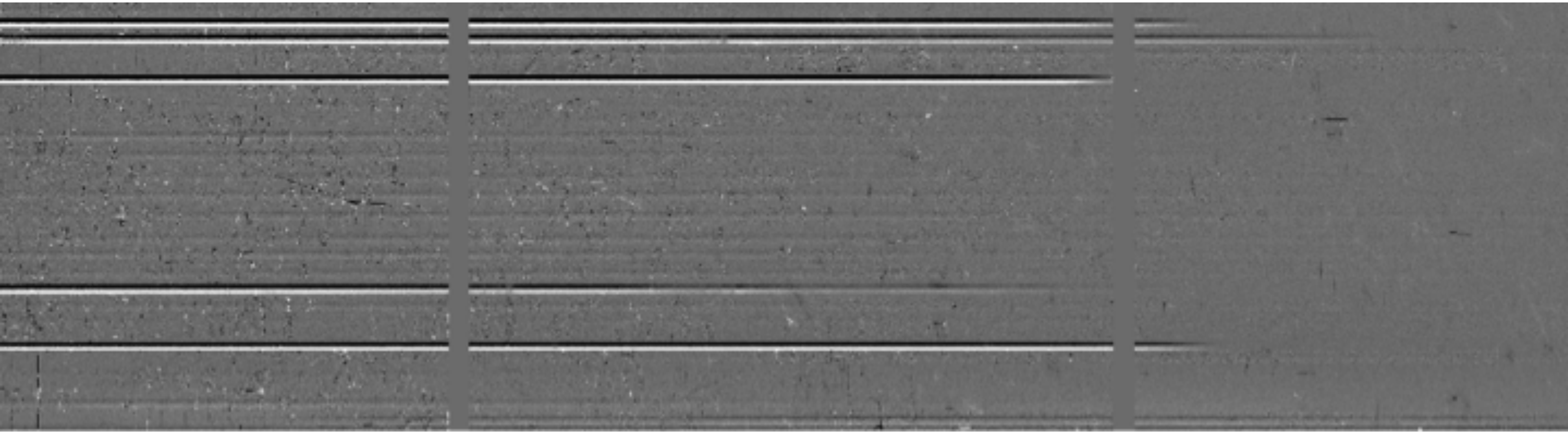


Single frame – bias subtracted, flattened

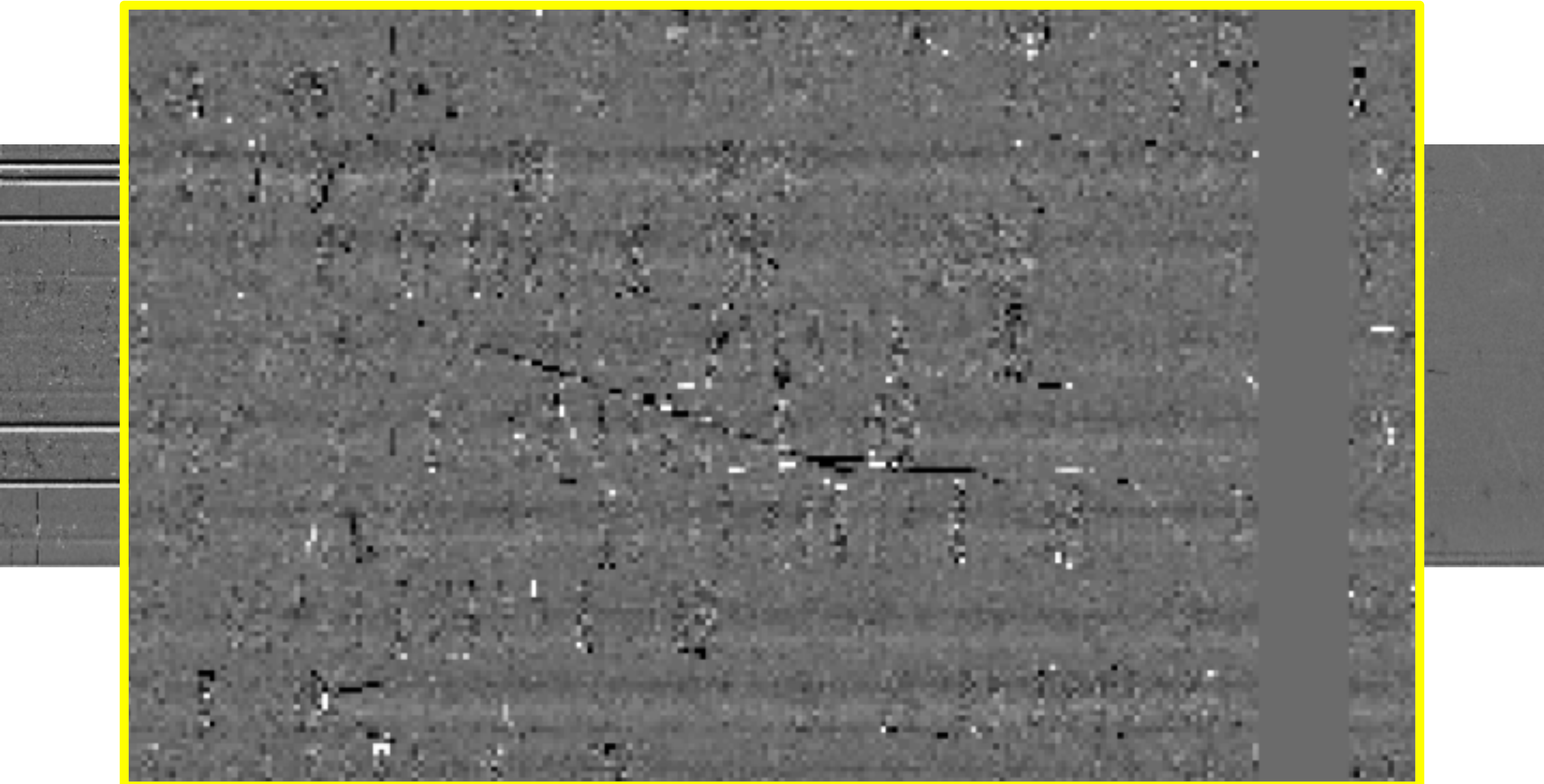


Lots of sky!

Single frame – nod/shuffle sky subtracted

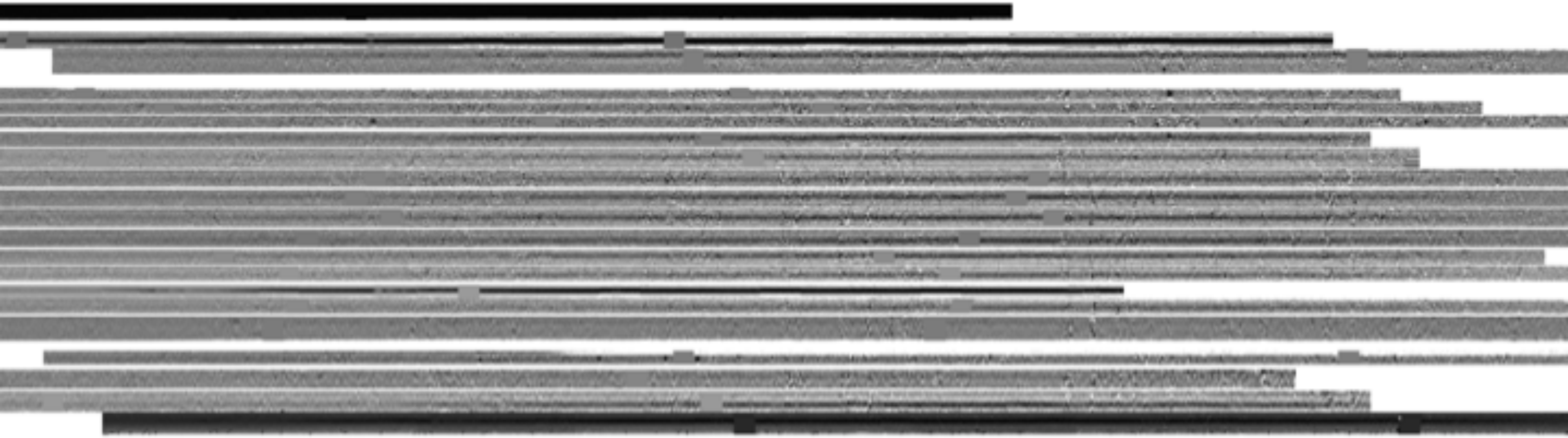


Single frame – nod/shuffle sky subtracted

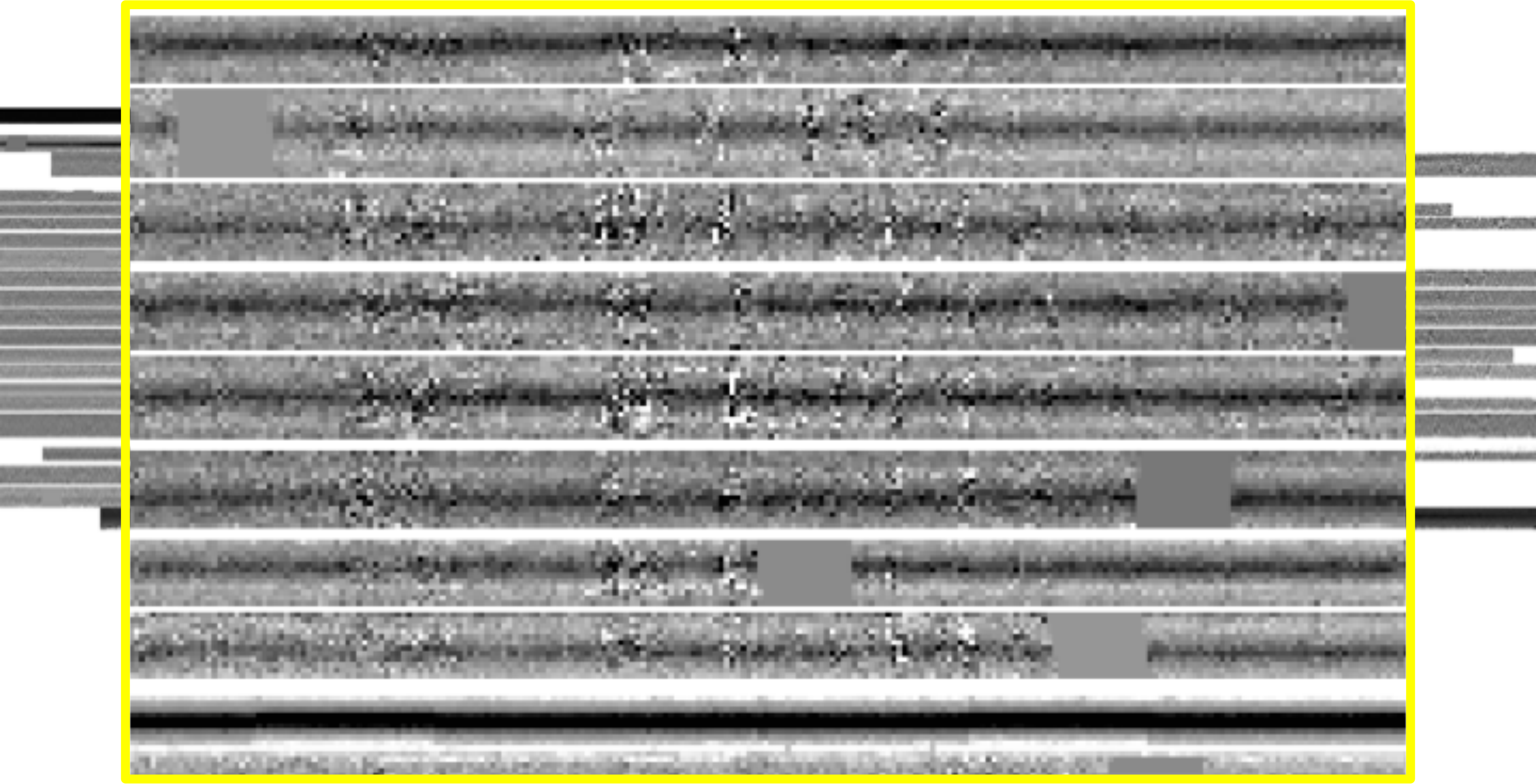


Sky cleanly removed

Stack – completely reduced



Stack – completely reduced



Extracted Spectrum, z = 1.0058