Astro 500

Techniques of Modern Observational Astrophysics

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Lecture Outline

Spectroscopy from a 3D Perspective

- ✓ Basics of spectroscopy and spectrographs
- ✓ Fundamental challenges of sampling the data cube
- Approaches and example of available instruments
  - I: Grating-dispersed spectrographs ← a lot of material
  - II: Fabry-Perot interferometry
  - III: Spatial heterodyne spectroscopy

Approaches
Examples of available instruments

- ✓ Grating-dispersed spectrographs
  - ✓ basic spectrograph design
  - ✓ dispersive elements
  - ➢ Long-slit spectrographs
    - o General Observing Considerations
  - ➢ Double spectrographs
  - ➢ Multi-objects spectrographs: slitlets vs fibers
  - ➢ Echelle spectrographs
  - ➢ 3D spectroscopy: coupling formats and methods
    - o Fiber
    - o Fiber+lenslet
    - o Slicer
    - o Lenslet
    - o Filtered multi-slit
  - ➢ summary of considerations
  - ➢ sky subtraction

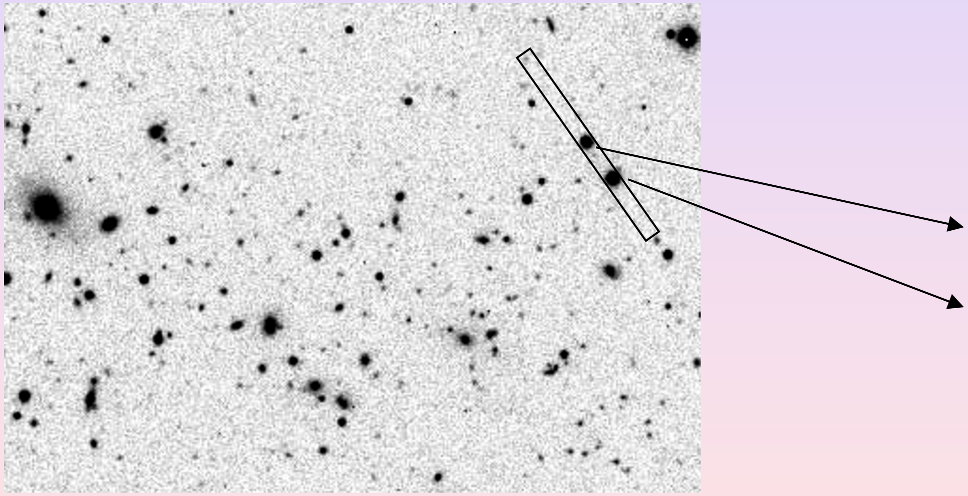
Multiobject Spectroscopy

- Very popular option for the last 30 years.
  - Multislit – truly 2D slit placement
  - Fiber-fed – basically long-slit spectrographs

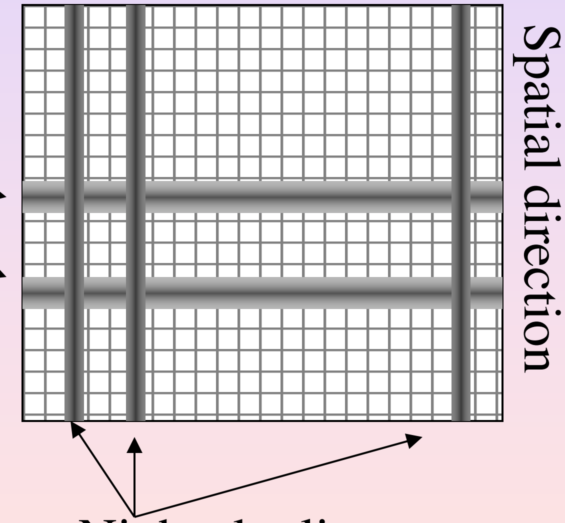
  - Pro's and con's to these approaches

Multislit spectroscopy

- Remember the simple case: carefully rotated long slit. Note: better have an ADC.

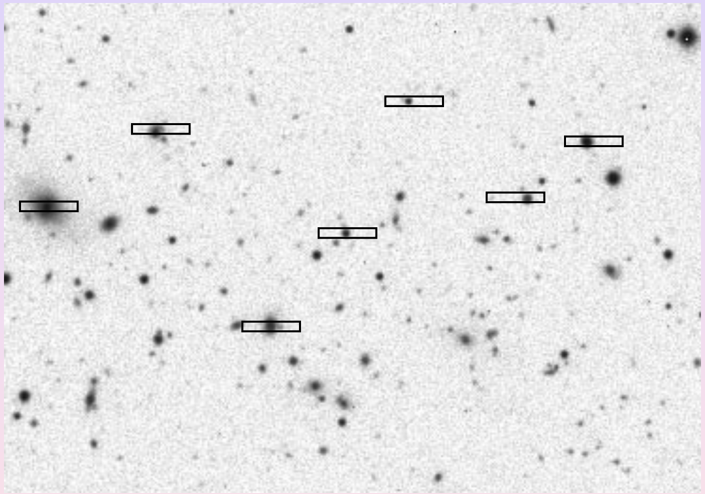


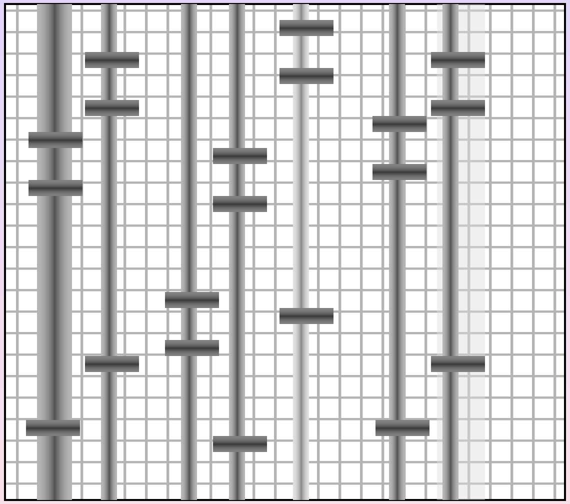
Telescope focal plane

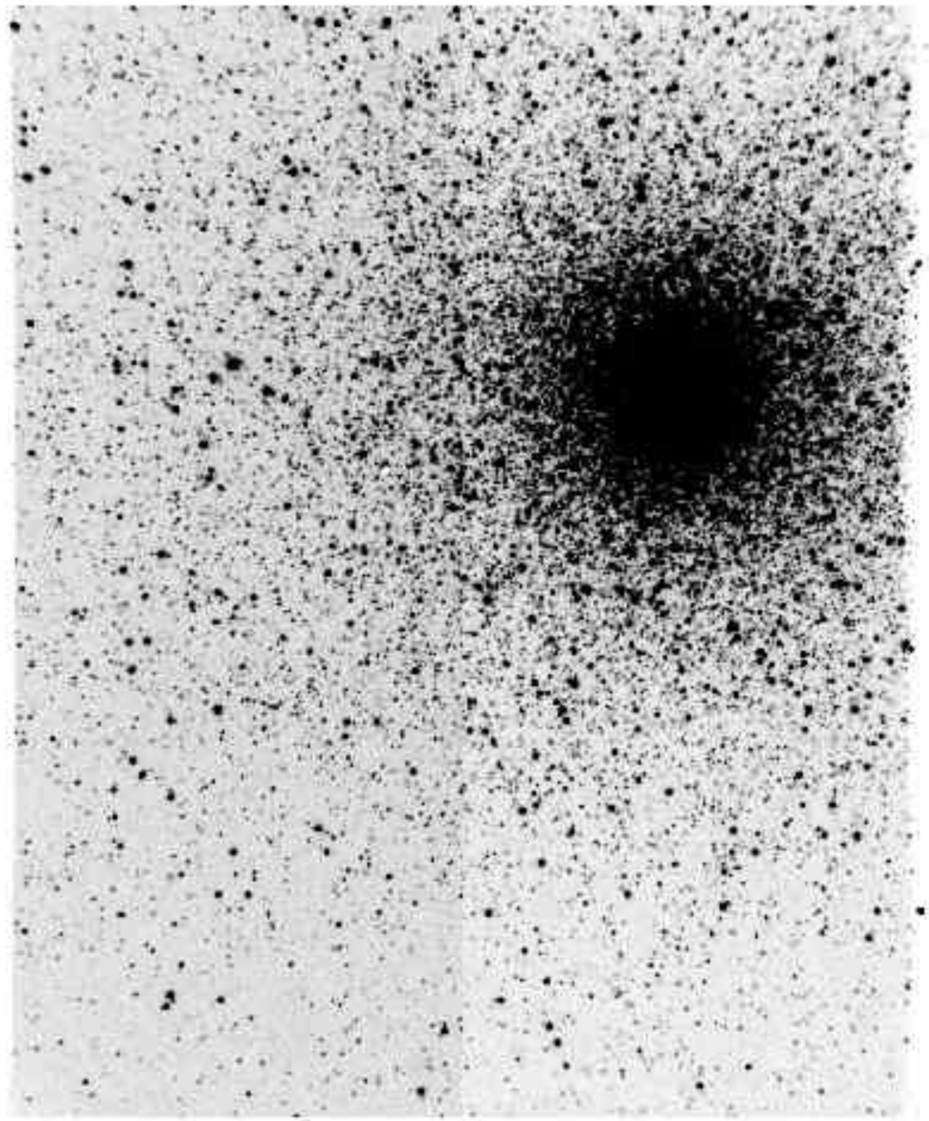


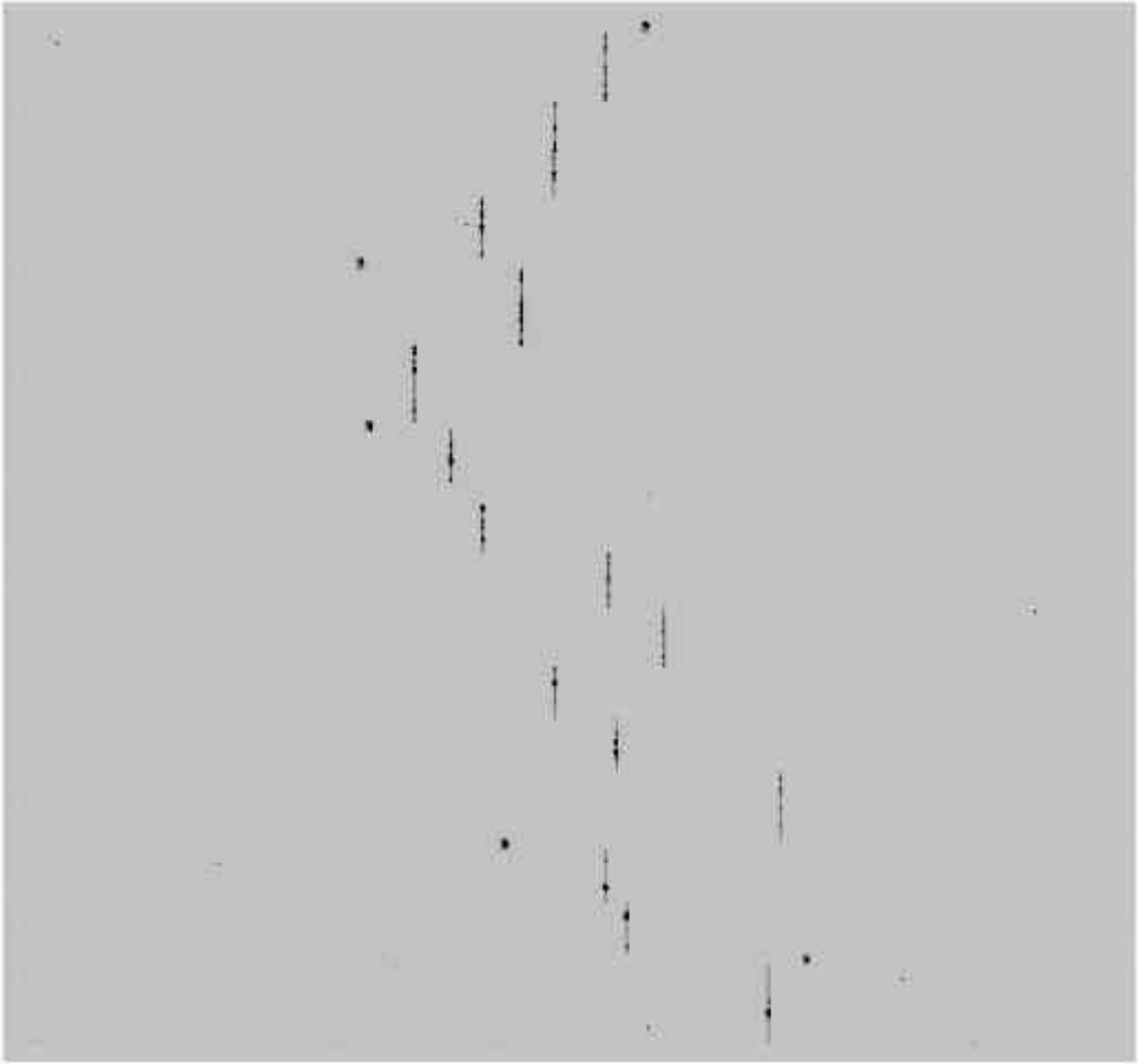
Spectrometer camera focal plane

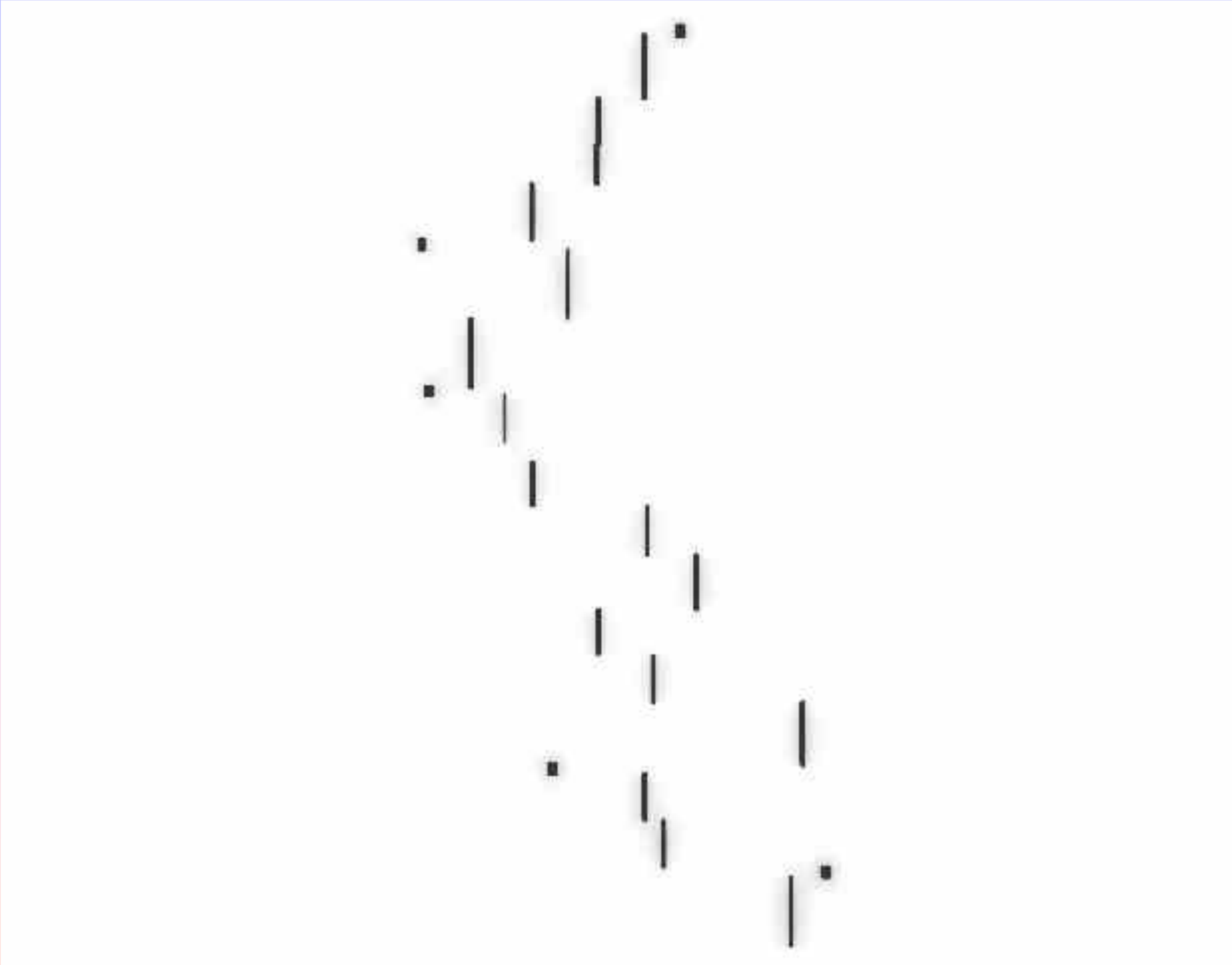
Multislit spectroscopy

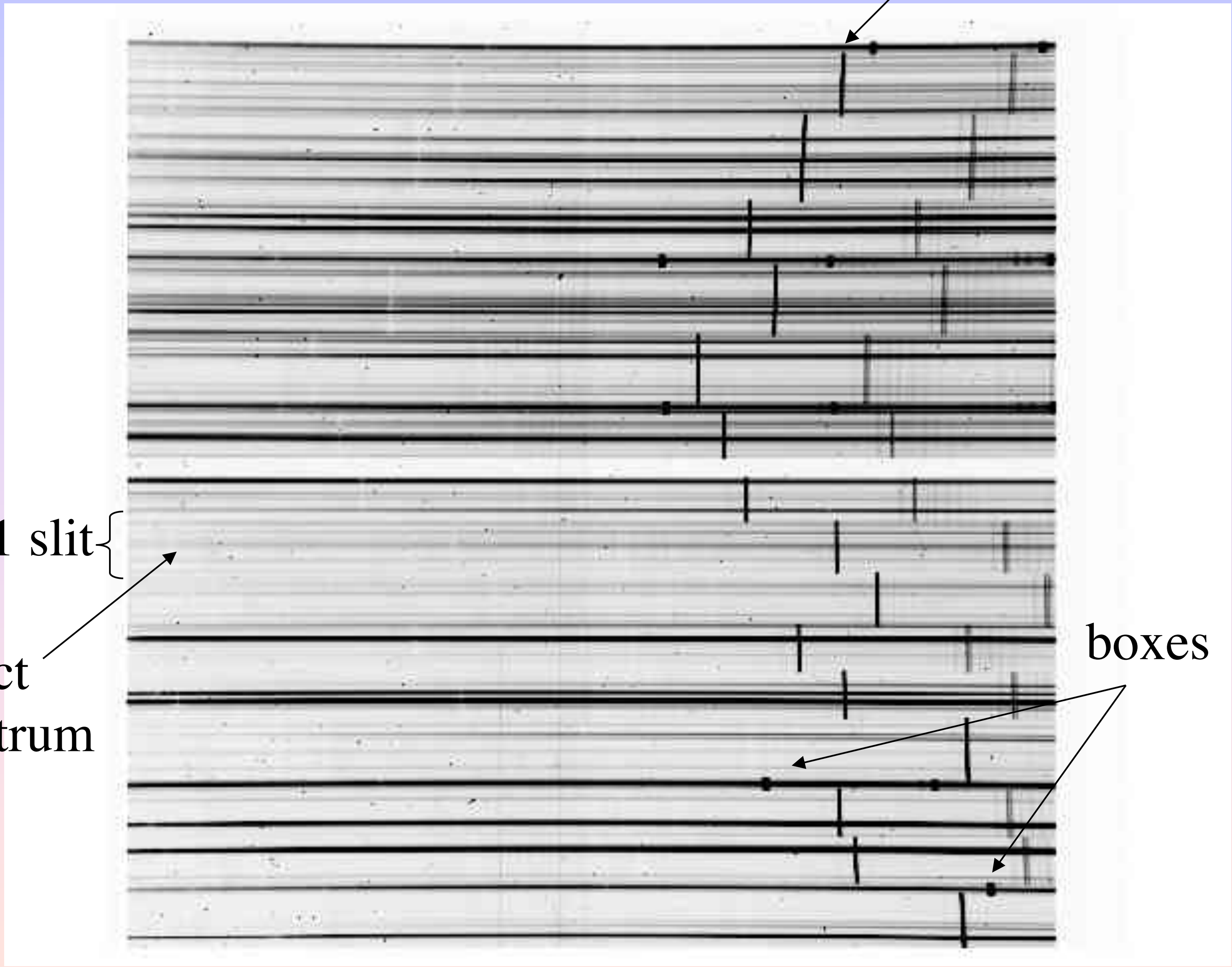


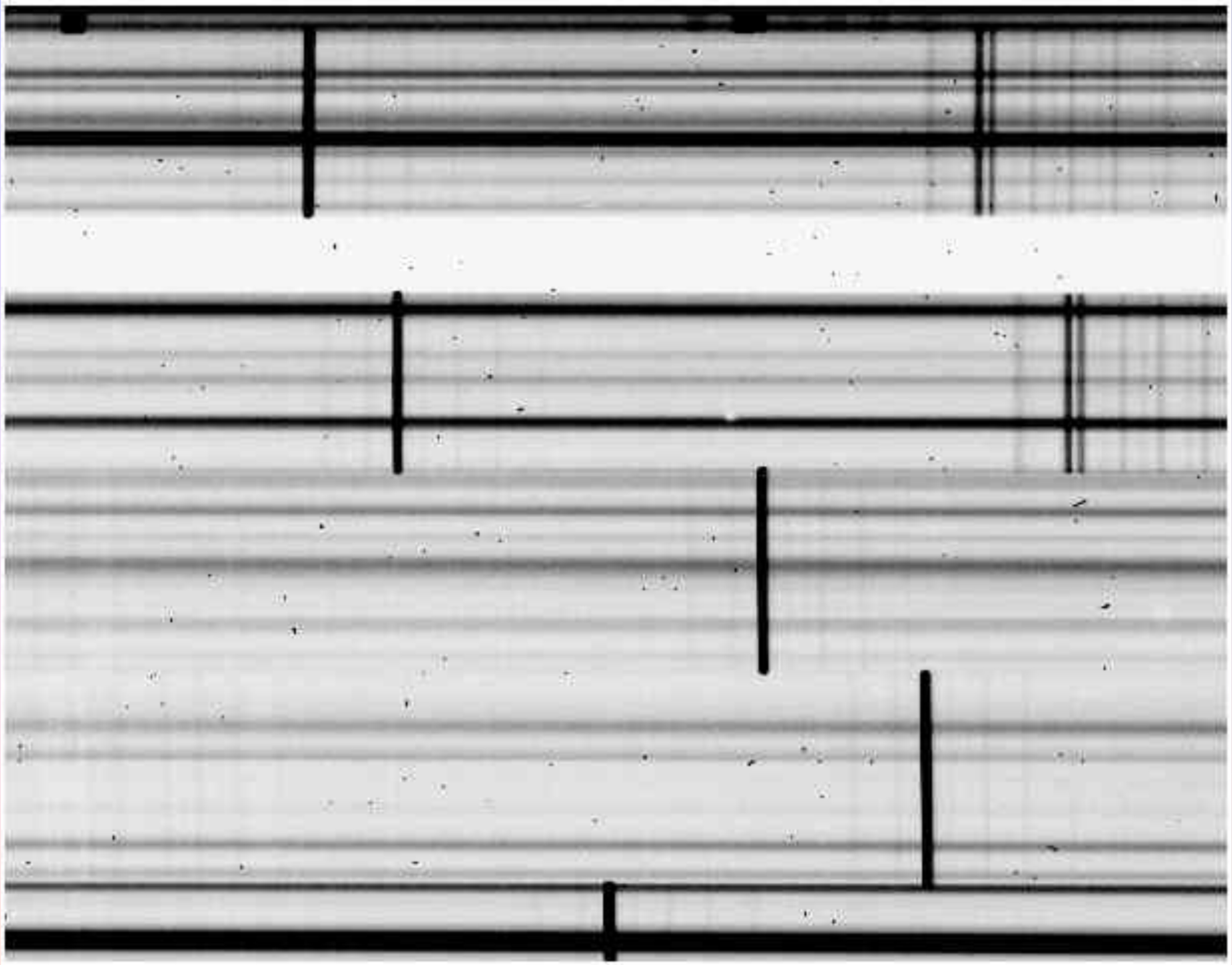








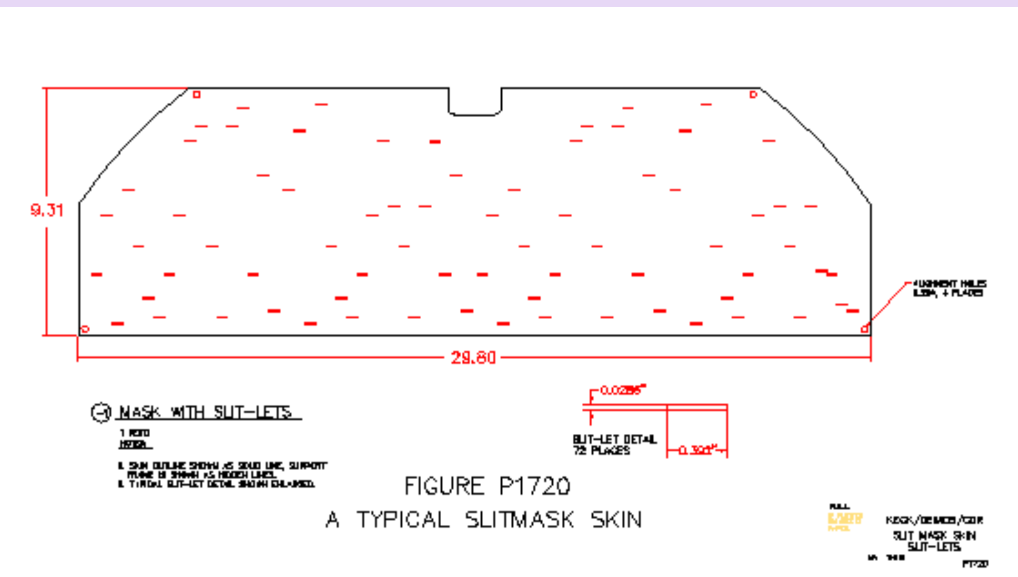

Night sky line
1 slit
object
spectrum
boxes

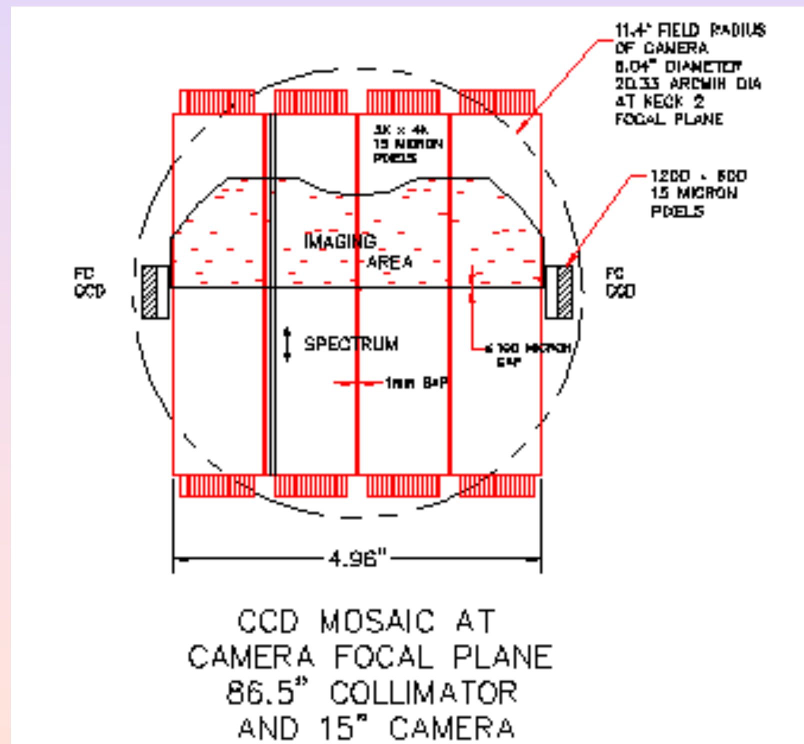


DEIMOS: *The Beast*

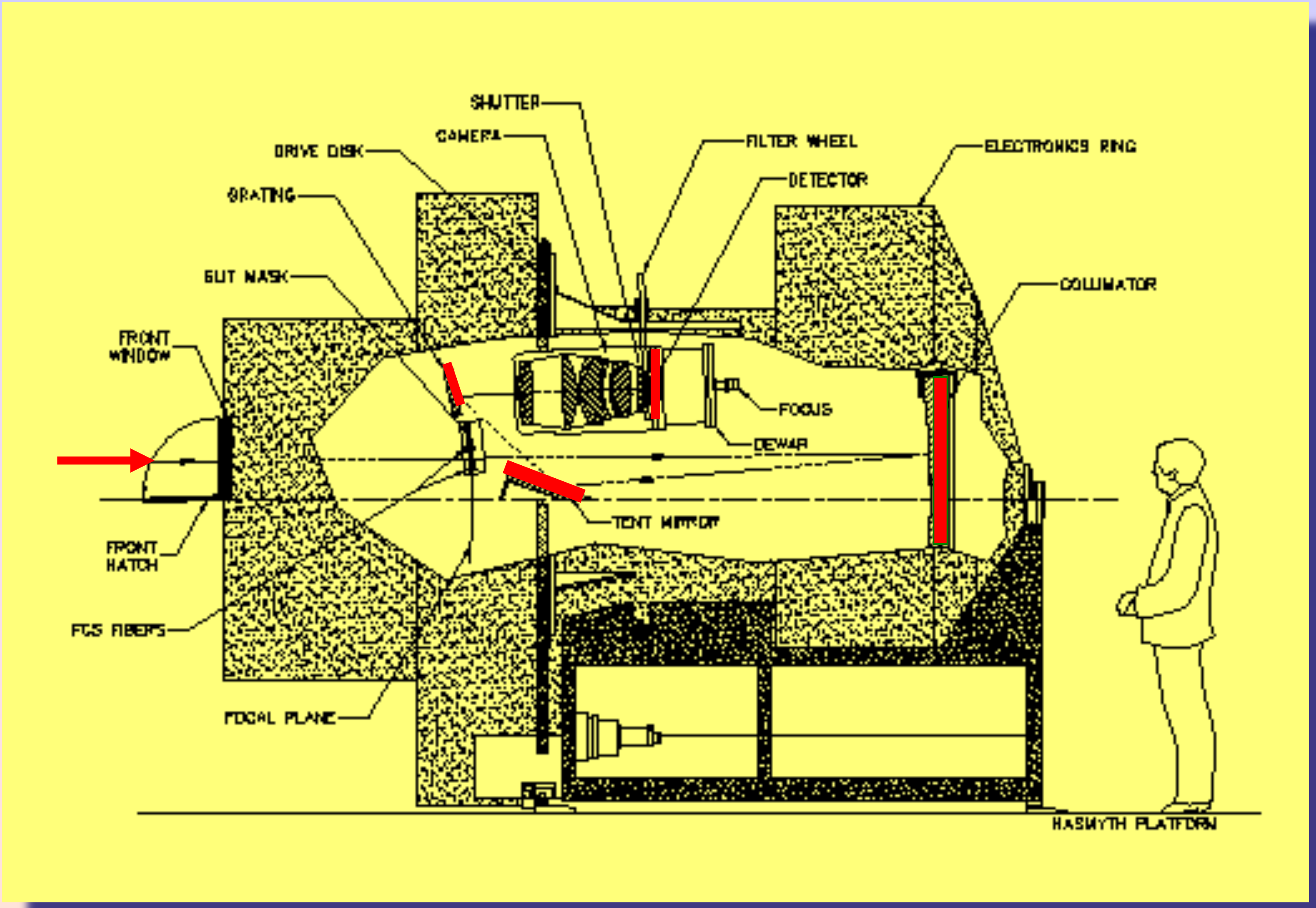
- Slit masks are curved to match the focal plane and imaged onto an array of 2k × 4k CCDs

- Readout time for full array (150 MB!) is 50 seconds (8 amplifier mode)

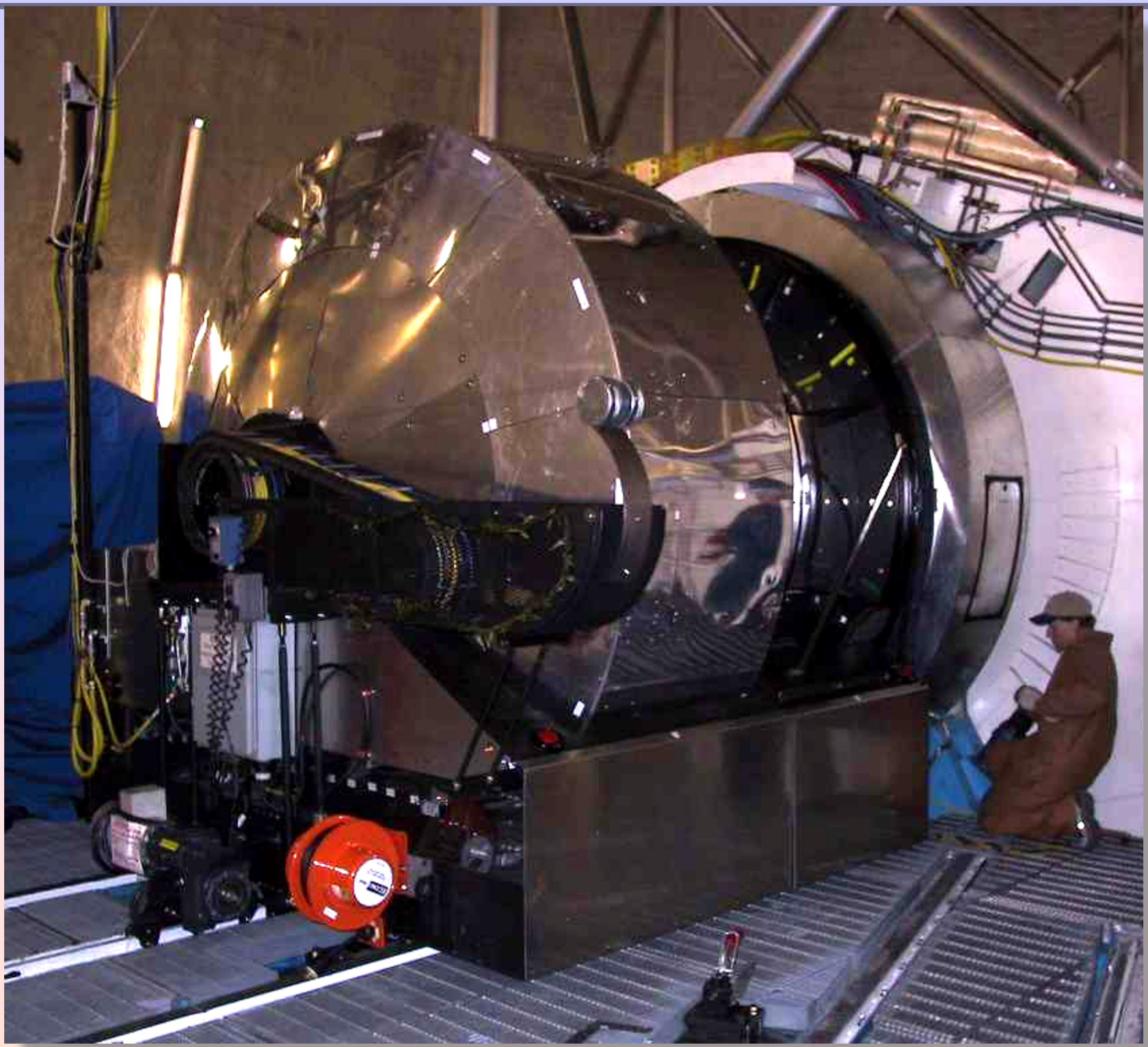




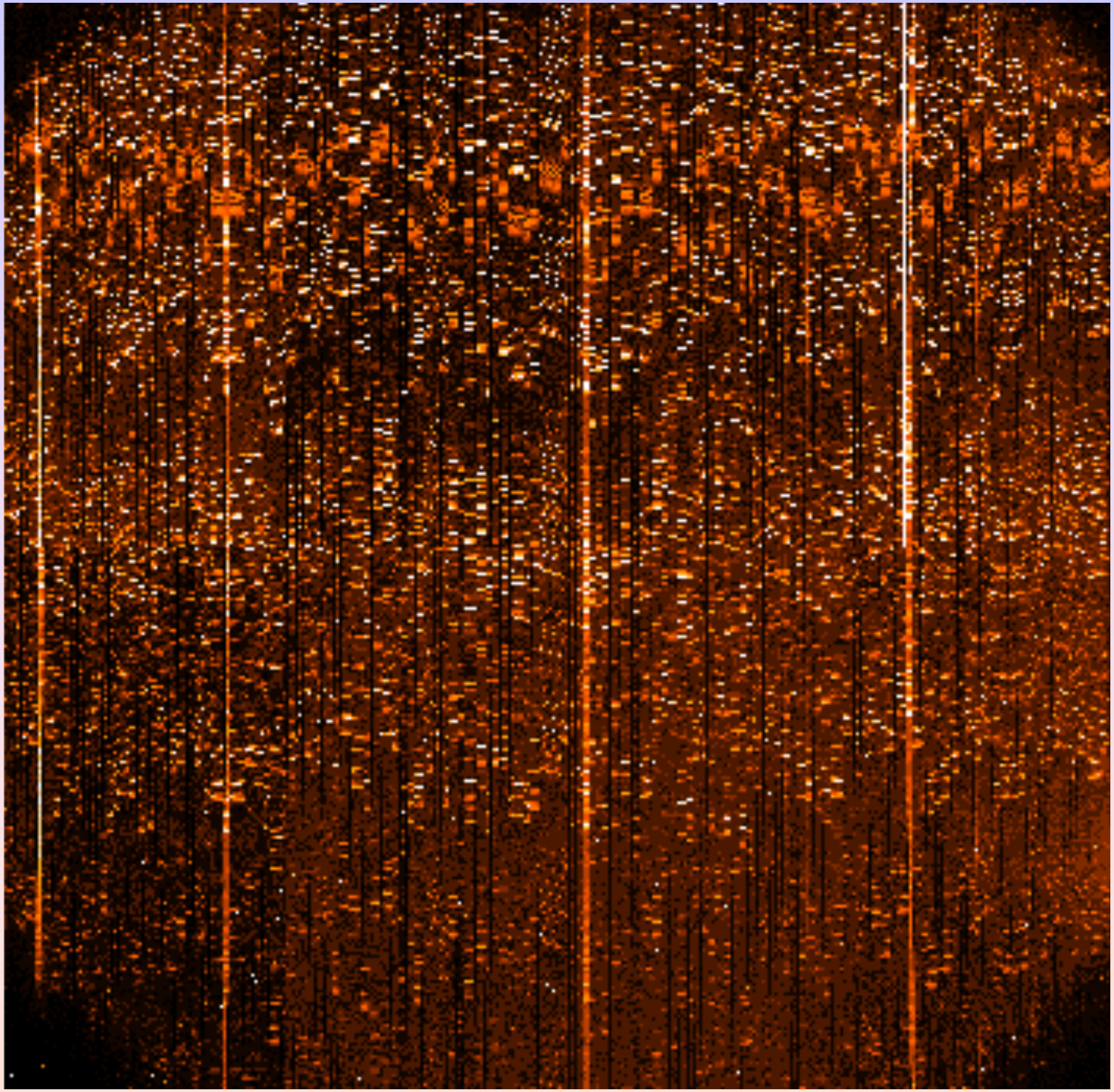
Structural Overview



At the Nasmyth Focus at Keck II

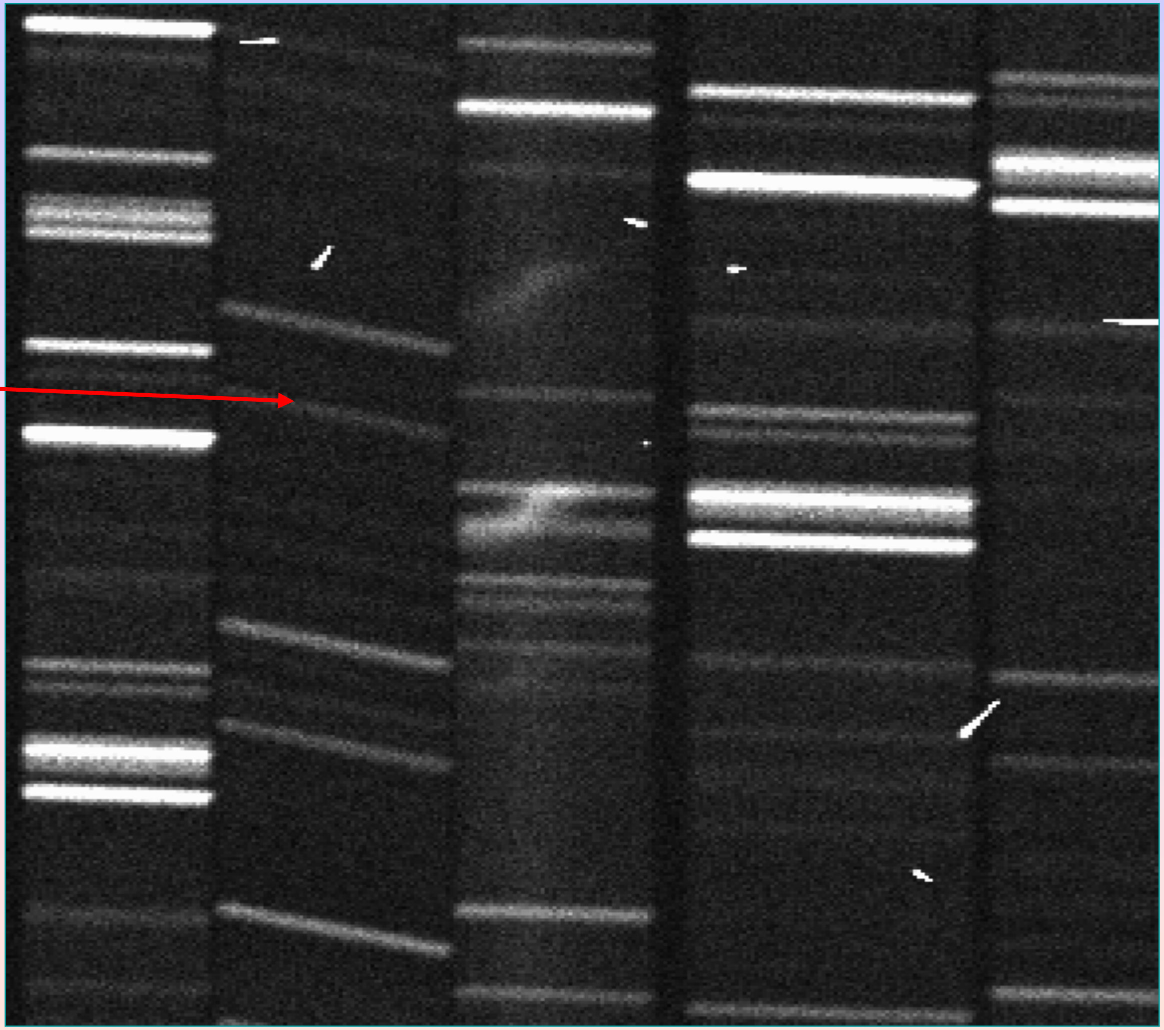


First-light Spectrum

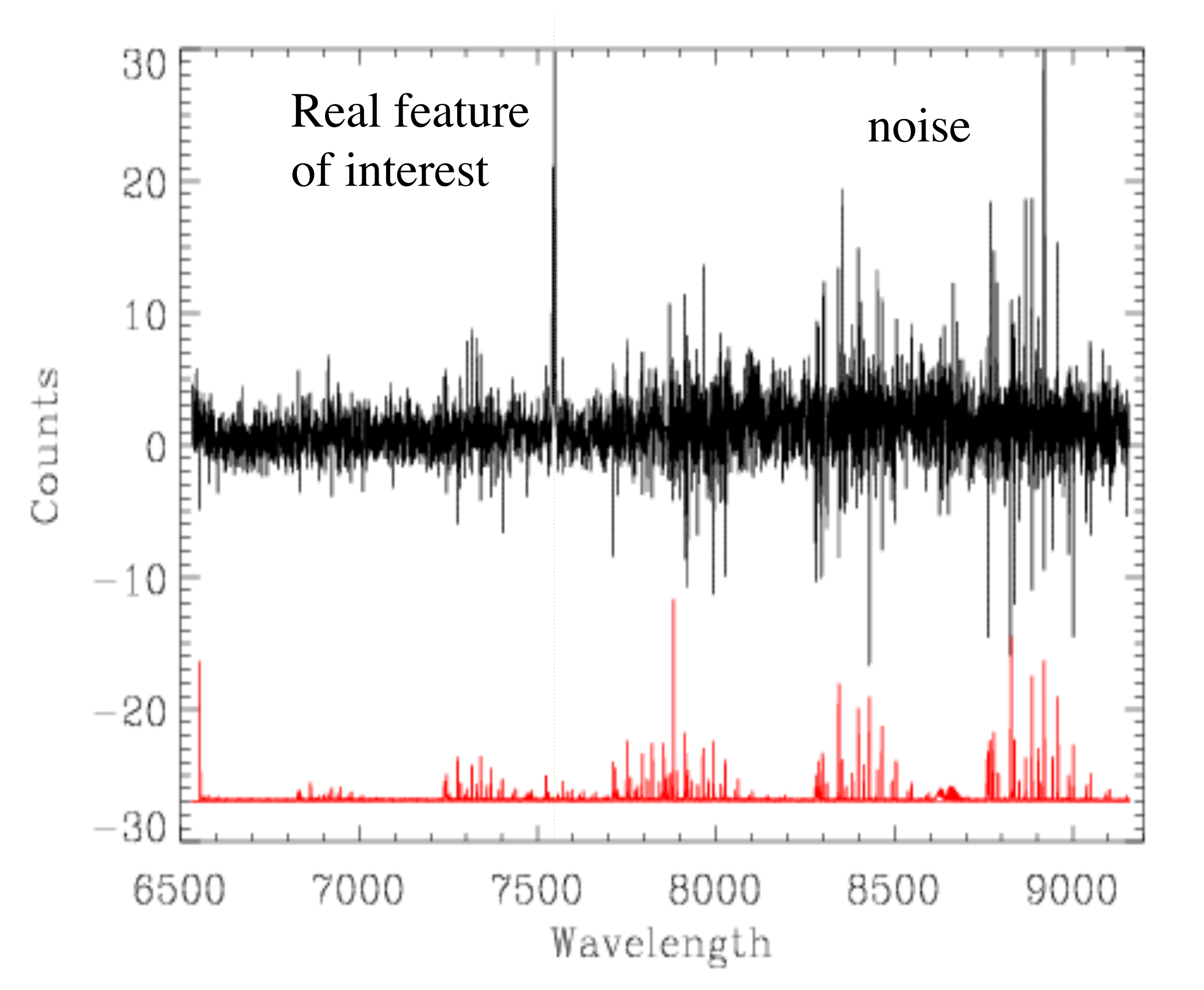


Sky Subtraction is Key

What's going on here?



Typical Extracted 1-d Spectrum

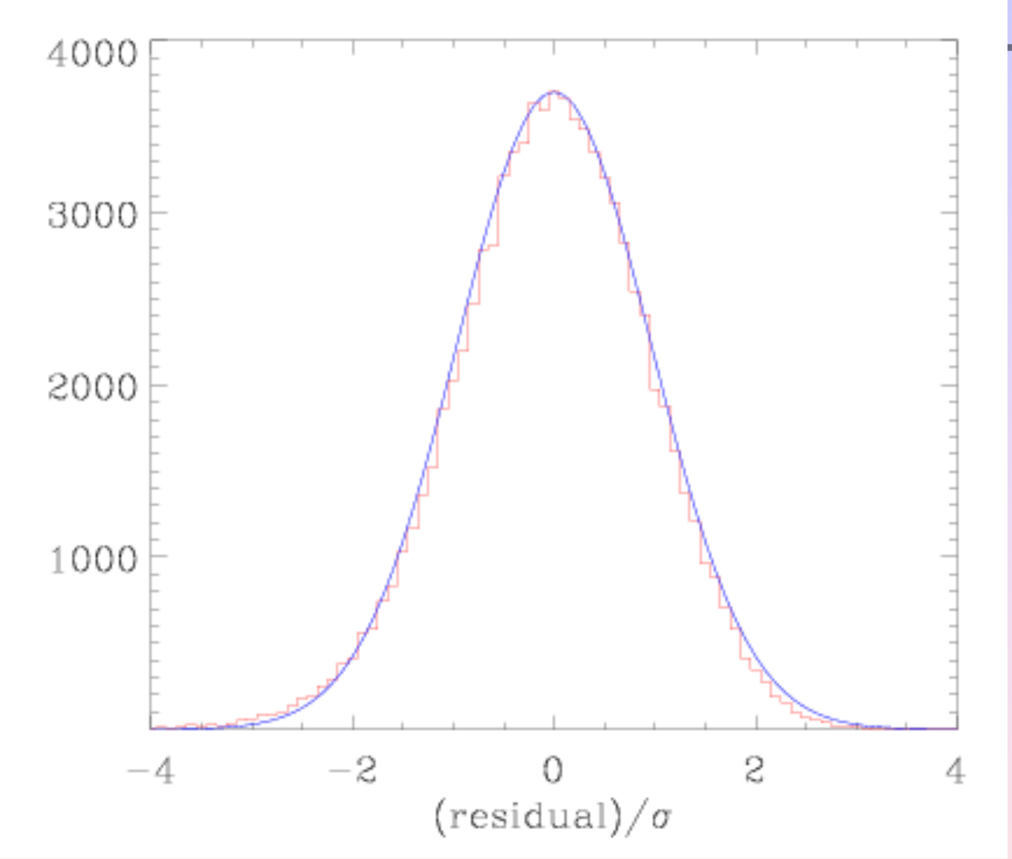


Unsmoothed 1-d spectrum with background sky (red) offset and rescaled.

Poisson-Limited Sky Subtraction

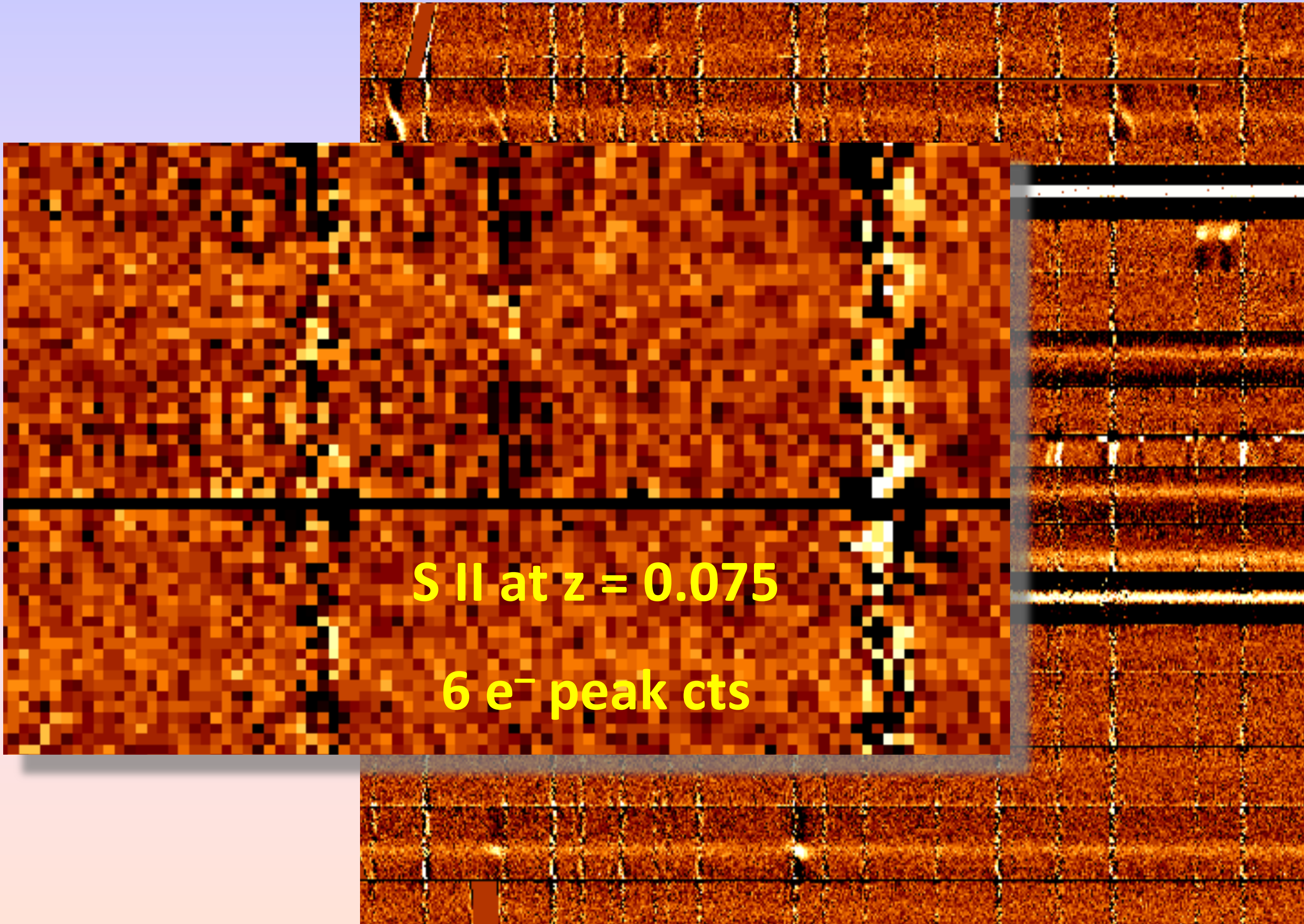
Plot shows residual of flux from b-spline sky model in region of sky emission lines, in units of local RMS.

Smooth curve is gaussian, width 1.



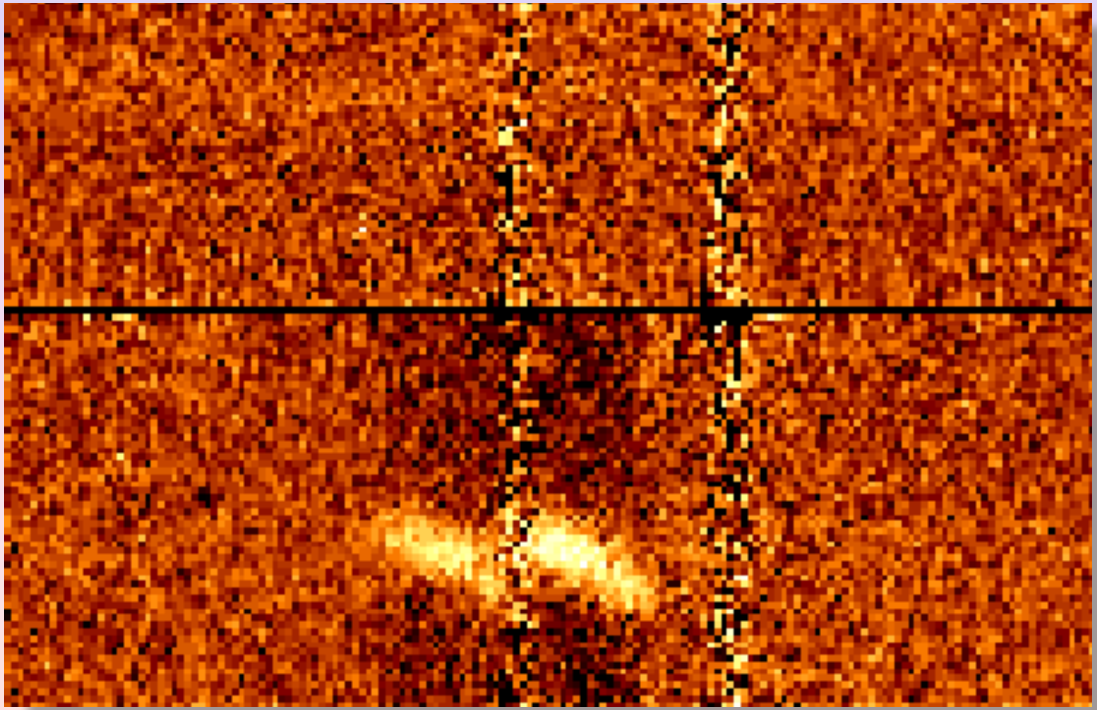
Work in progress to do non-local sky subtraction using narrower, sky-only slitlets, for the shortest slitlets where local sky subtraction is impossible.

Sky-subtracted Sub-regions



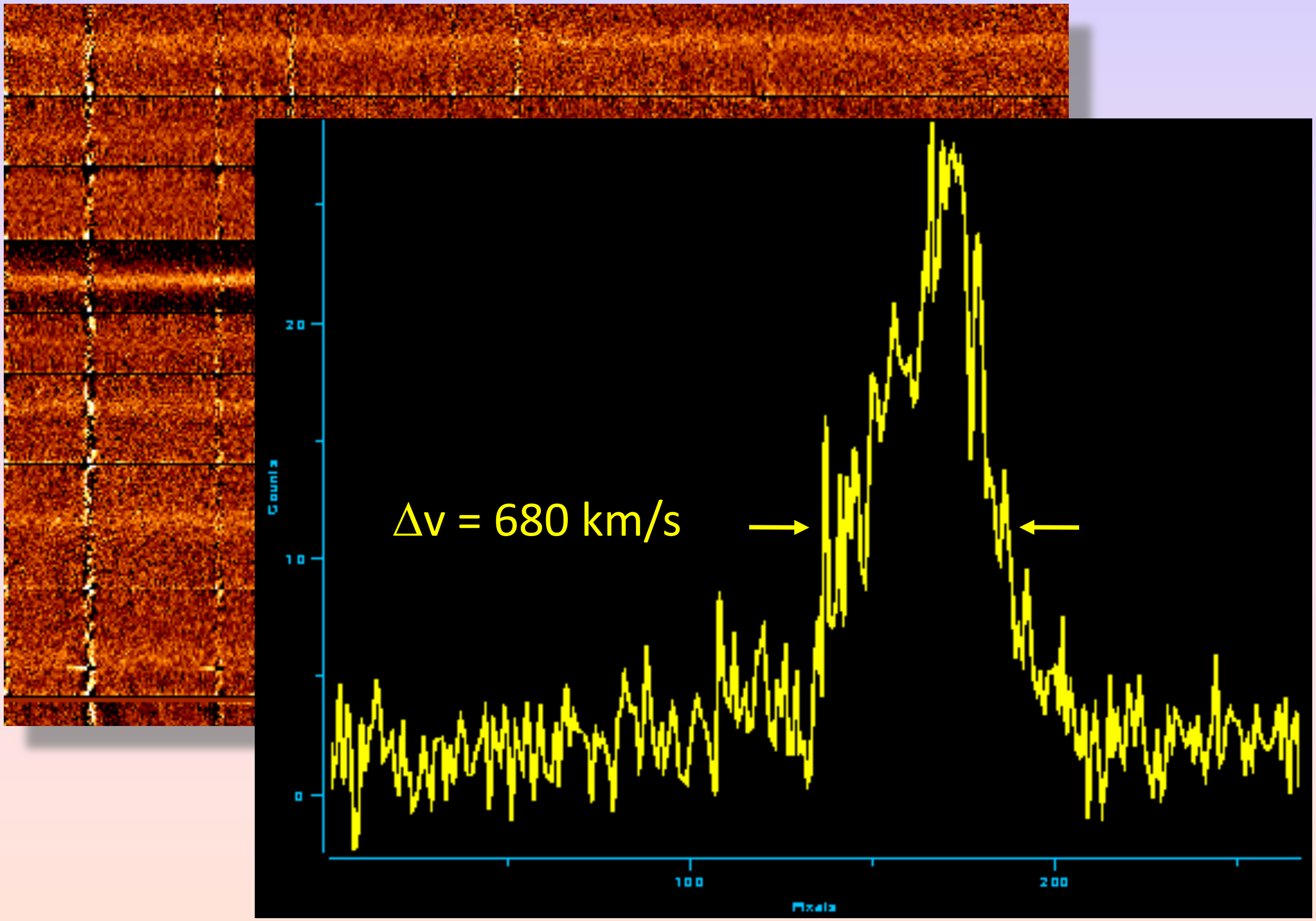
Kinematic Information

O II at z = 1.29 v_{rot} ~ 100 km/s



Kinematic Information

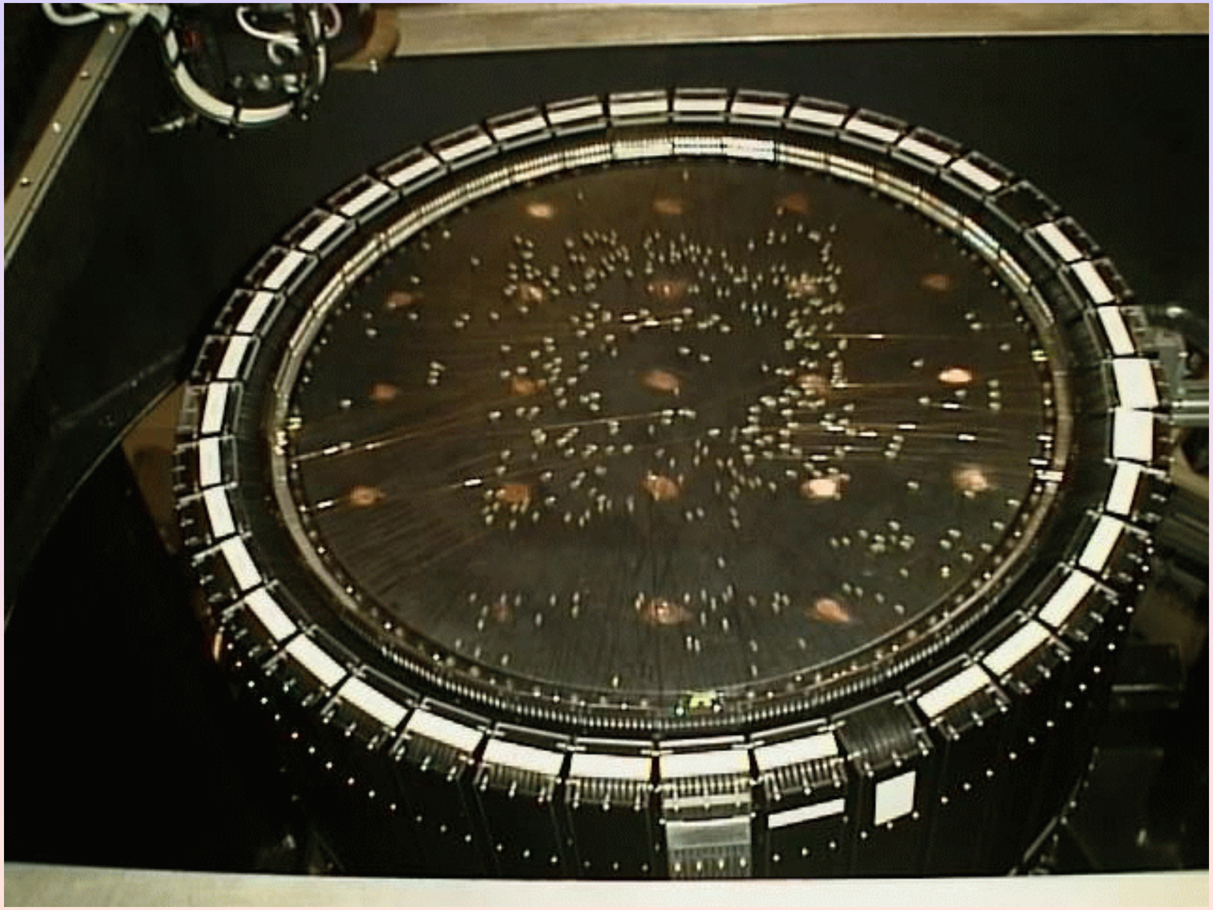
O III 5007/4959 at z = 0.62



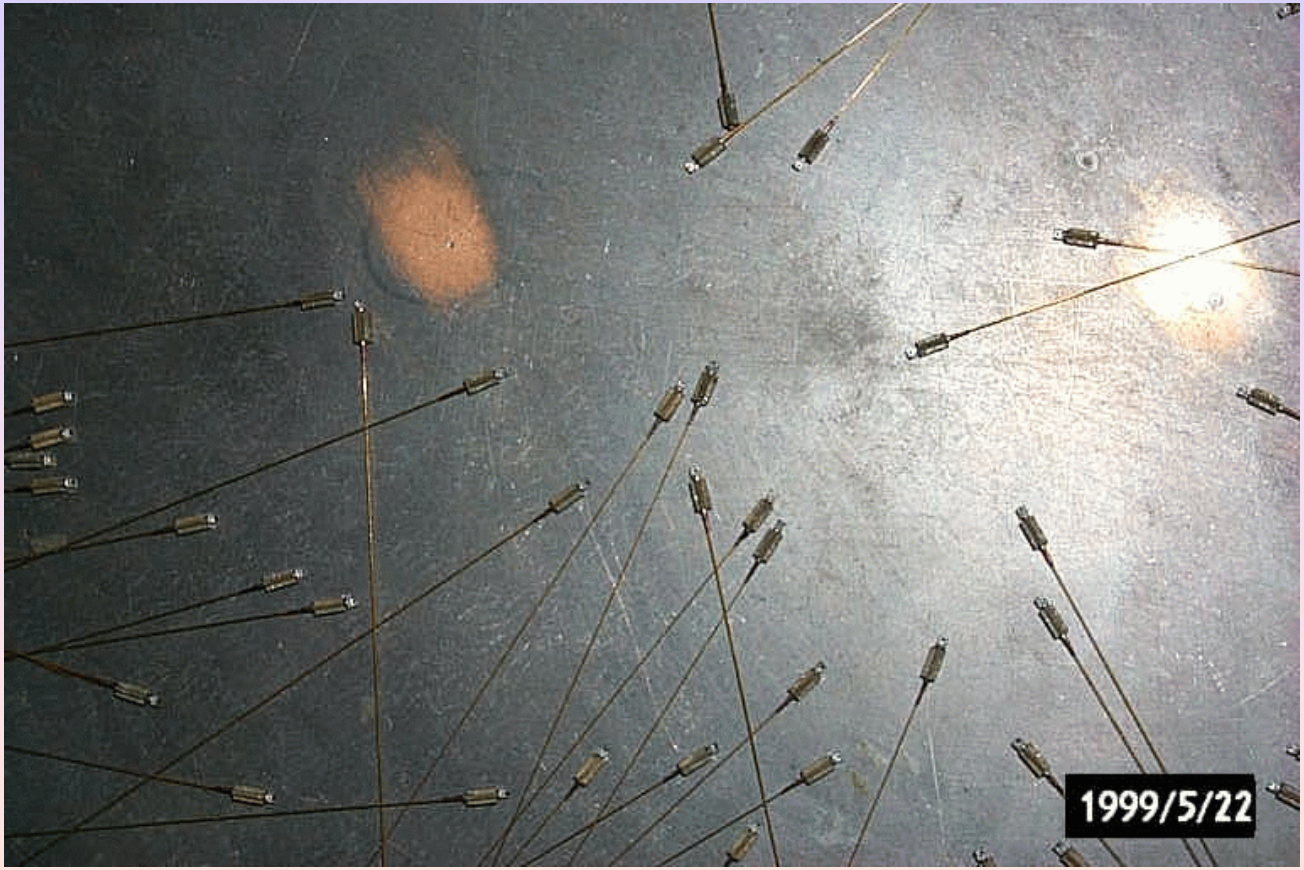
Fiber-fed MOS

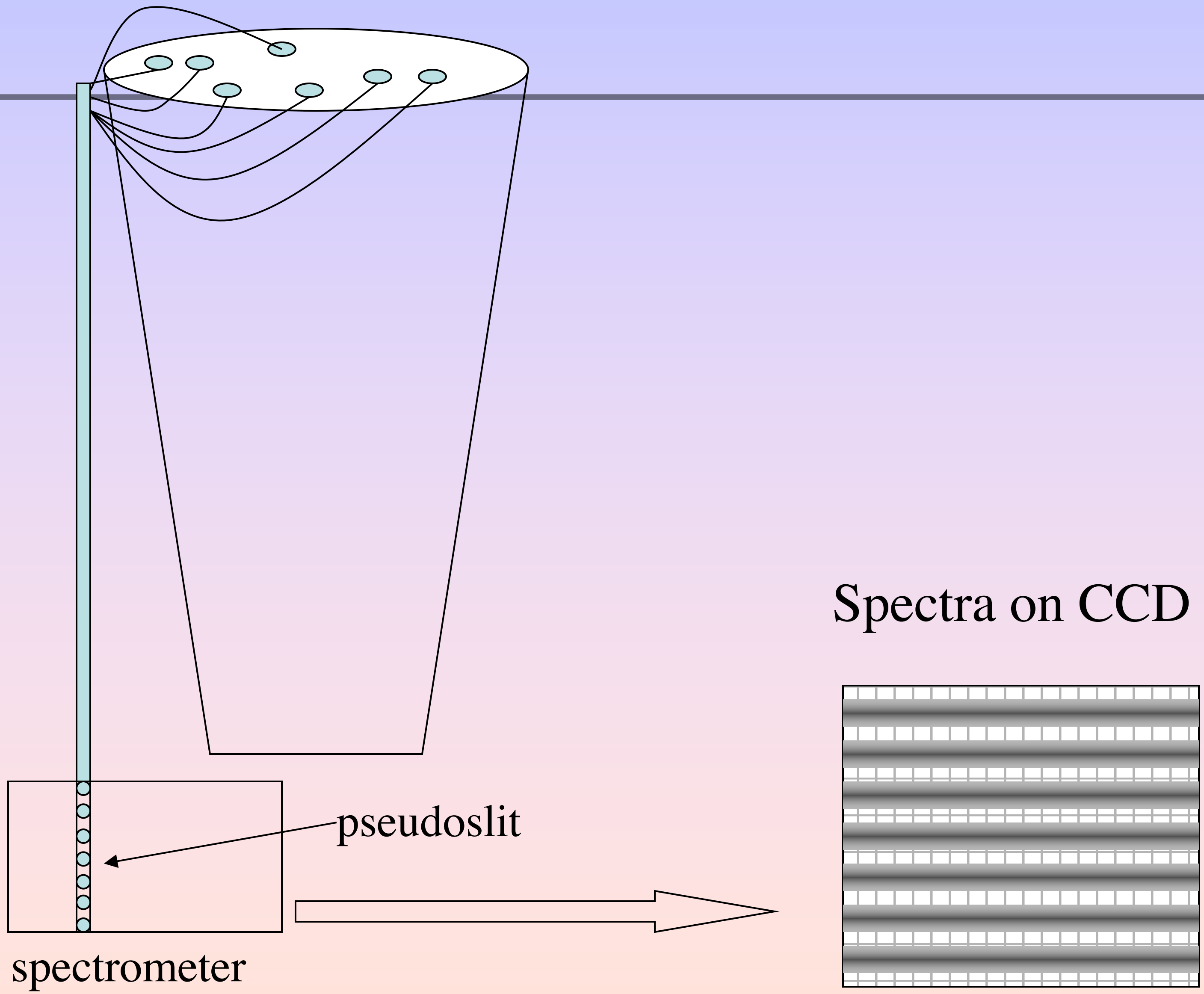
- ASP Conf Series #37, 1997
- Examples:
  - Lick 3m MOS (80 fibers/1° field)
  - HYDRA@ WIYN (100- fibers/1° field)
  - 2DF@ AAT (400 fibers/2° field)

2DF focal plane



2DF buttons+fibers

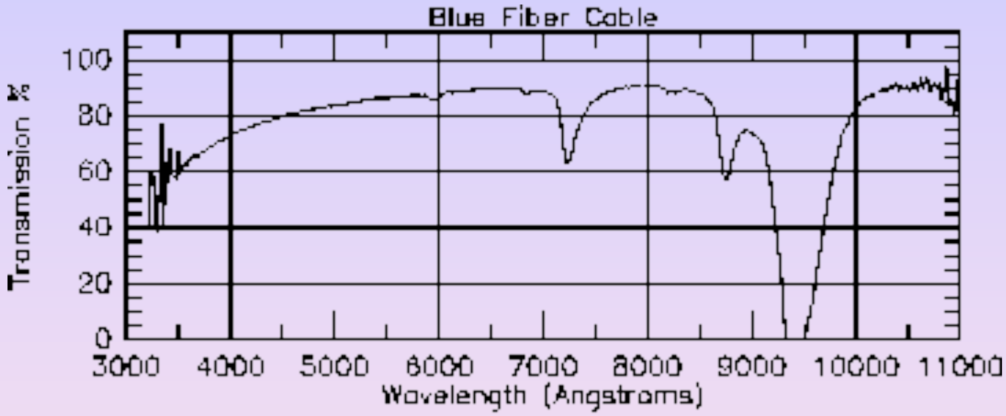


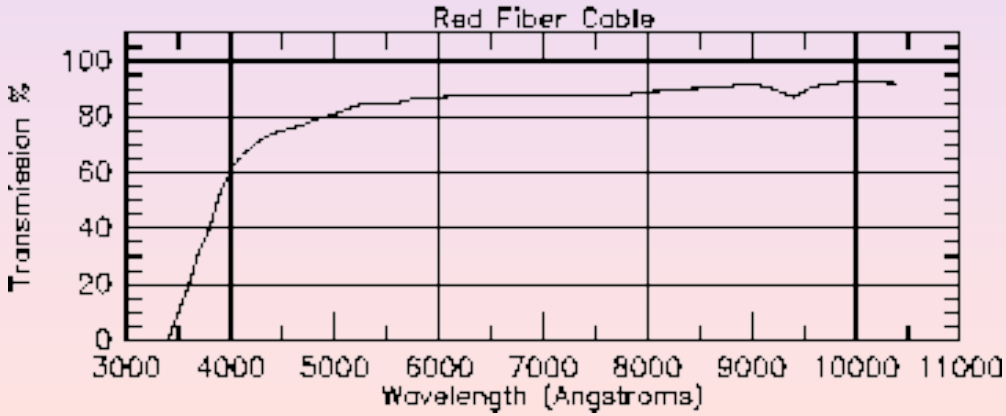

Spectra on CCD
pseudoslit
spectrometer

Fibers vs Slits: Pro's &Con's

- Advantages of multislits:
  - High throughput
  - Can choose slit width and length
  - Good sky subtraction
  - Can place slits close together in telescope focal plane
- Disadvantages of multislits:
  - wavelength coverage varies with the slit position
  - do not always use the detector area efficiently.

- Advantages of multi-fiber systems
  - Large fields
  - Uniform wavelength coverage
  - Efficient use of detector area
- Disadvantages
  - Minimum separation is between a few and 10+ arcseconds
  - Fiber losses are significant and grow with time (fiber are delicate)
  - Sky subtraction difficulties
  - Setup times can be long





Add in `button' losses and focal-ratio degradation.

Fiber loss is per unit length

Spectral Resolution

- $R=\lambda/\Delta\lambda$
- For slit spectra, depends on slit width and grating choice.

What is the effective slit-width of a circular fiber?

What is the effective slit-width of a tilted slit?