VIRUS Low Surface Brightness Observations Guide

Gary Hill. Maximilian Fabricius, Greg Zeimann

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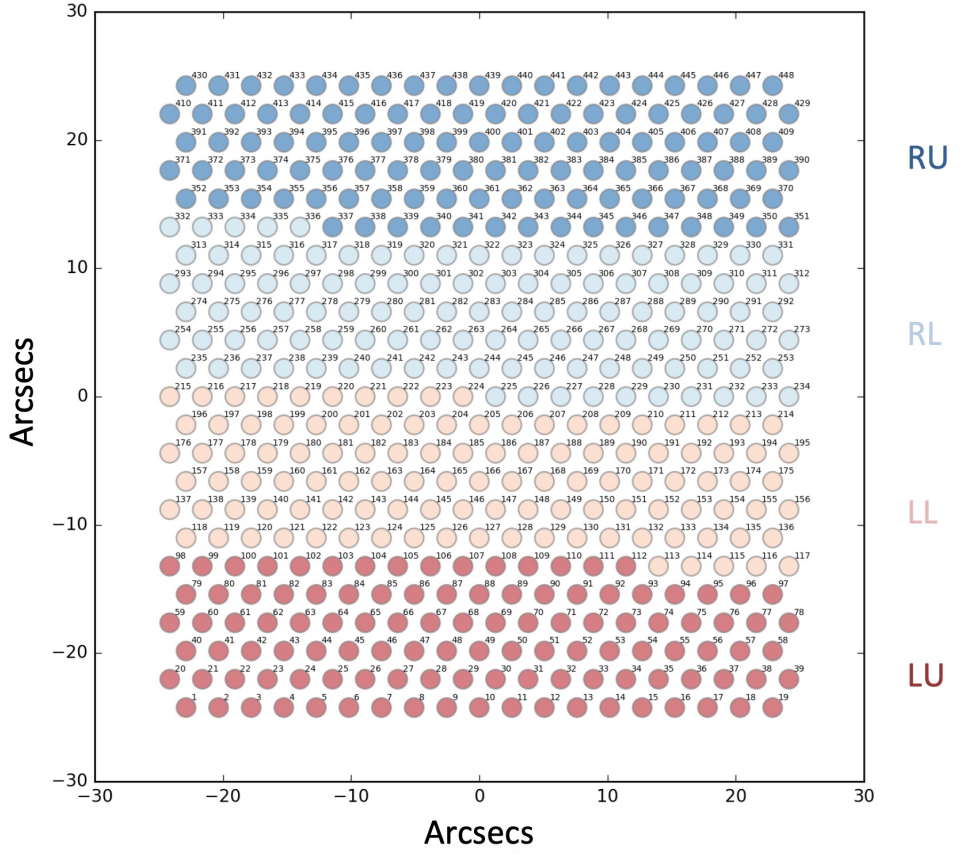
- VIRUS has large fibers (1.5” diameter) on a large telescope, so has superb sensitivity to low surface brightness emission
- So long as systematics in sky subtraction do not dominate as exposures are increased
- This note addresses this by answering two questions
  - What is the systematic error floor to such observations?
  - Can large areas be coadded to increase S/N ratio?
- The conclusions are
  - No systematic error floor is encountered for exposures of 6 hours per fiber
  - Coadding/averaging data in apertures up to 20 arcsec diameter scales the noise as expected by $(\text{area})^{-1/2}$.

Spatial systematics investigation at low surface brightness

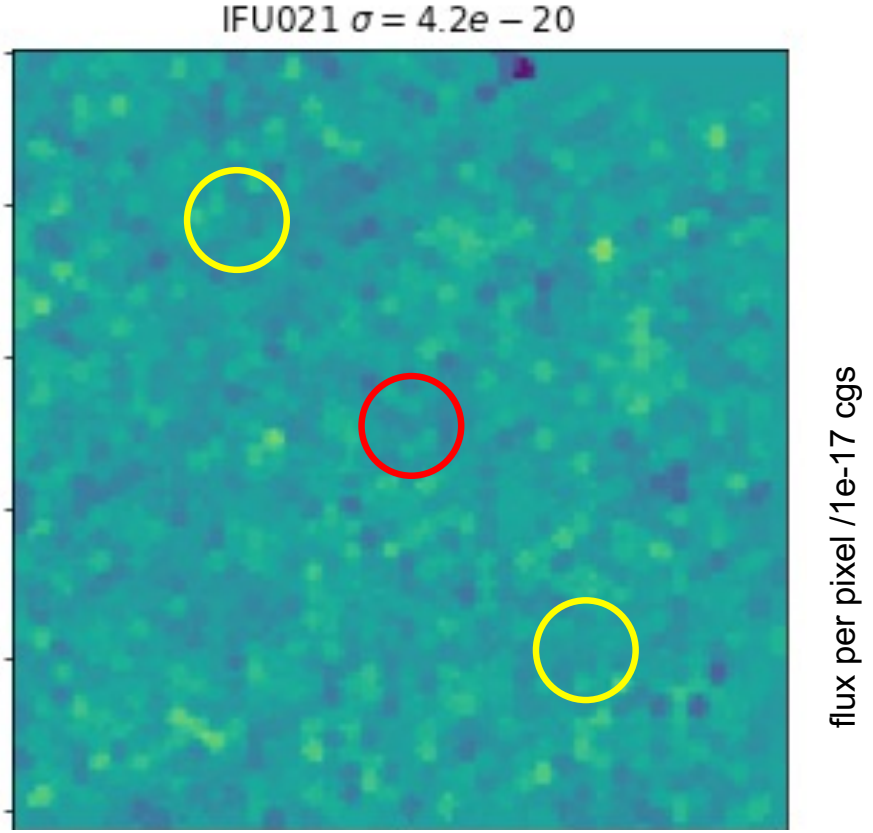
- VIRUS consists of 156 independent spectrograph channels, each with a CCD read out through two amplifiers
- The 312 individual amplifiers are considered independently during the data reduction
  - IFU fibers map to 4 CCD amplifiers in 2 spectrograph channels
- Reductions show subtle residuals correlated with position on fiber “slit” that are removed by referring to flat sky
- Do any of these transitions show residuals in very deep data?
  - There is concern that there may be systematic structures associated with the way the fibers map to the spectrograph channels and CCD amplifiers



Fiber map for a VIRUS IFU with the fibers color-coded by spectrograph channel (R/L) and CCD amplifier (U/L); parallactic angle is to the right in this view

Spatial systematics investigation at low surface brightness

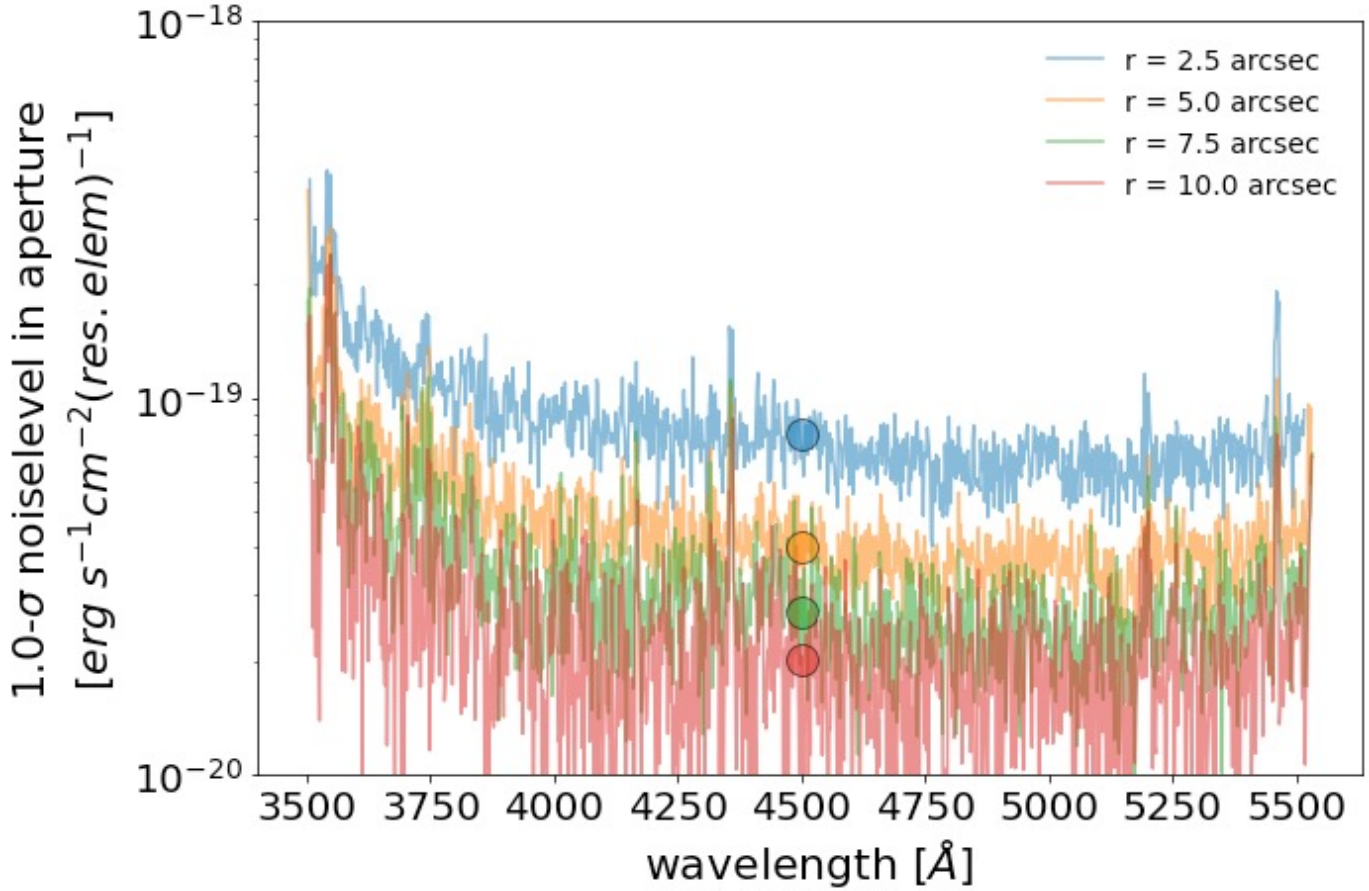
- "Super-stacks" of data have been created utilizing a deep field dataset with 4 sky positions (a map) and 15 observations each, of standard HETDEX exposure (3x360s)
- Medians of the data are created on a per-IFU basis, after masking objects
  - Equivalent to 4x15=60 exposures or 6 hours per sky position
- There is no sign of systematics associated with IFU edges or CCD amplifier layout in the reduced data
- IFU to IFU results are very consistent except where there are known amplifier readout issues



Very deep "super-stack" of 60 x 360 second exposures on VIRUS IFU021 with the position of the transition between spectrograph channels indicated by the red circle and the between the CCD amplifier pairs by the yellow circles. The noise is shown as 1-σ in a 10 arcsec. diameter aperture.

Low surface brightness sensitivity in apertures

- Often we wish to smooth or average data in larger regions than individual fibers in order to enhance sensitivity to low surface brightness features
- Does such averaging over area result in an improvement in S/N ratio as sqrt(area), as expected?
- This can also be tested with the “Super-stack” coadded data
- Plot demonstrates that the noise scales as expected up to 20 arcsec diameter
- No systematics at 1000 x below the sky level



Sensitivity of very deep “super-stack” of 60 x 360 second exposures with wavelength in different sized aperture diameters from 5 to 20 arcsec. The measured 1-s noise in each aperture (traces against wavelength) is compared with the noise extrapolated as sqrt(area) from that in the 5 arcsec diameter aperture at 4600A wavelength (blue circle), to each of the larger apertures