Spatial Scans with the STIS CCD

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Abstract

Spatial scanning with the STIS CCD is a recently enabled, *available-but-unsupported* mode for obtaining high S/N ratio spectra of relatively bright targets by trailing the target in the cross-dispersion direction within one of the long STIS apertures. Expected scientific applications include the reliable detection of weak stellar and interstellar absorption features (particularly in the red and near-IR, where ground-based observations can be severely compromised by strong telluric absorption) and accurate time-series monitoring of bright sources (e.g., for characterizing brown dwarfs and transiting exoplanets). In this contribution, we discuss possible/recommended uses for this relatively new observing mode and provide information on how to design the observations.

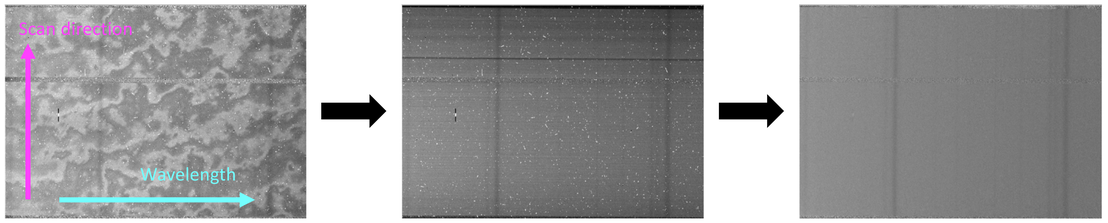
1. Spatial Scans

How do spatial scans work?

- Trail the target in cross-dispersion (spatial) direction within long slit.

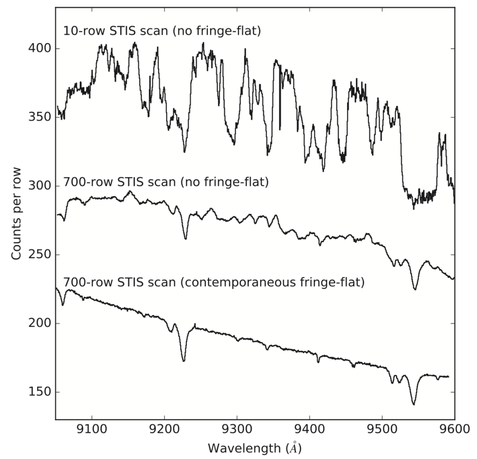
Advantages of spatial scans with STIS

- Many more photons can be collected before reaching saturation.
  → Improved S/N
- Light spread over larger fraction of the detector area.
  → Improved flat fielding
- Trailing along slits result in IR fringing patterns closer to the contemporaneous lamp flats.
  → Improved near-IR fringe removal
- A wider variety of bad-pixel rejection algorithms can be used.
  → Improved removal of hot pixels and cosmic rays



Raw STIS spatial scan image | Flat field + fringe removal | Scan rate correction + CR removal

2. High S/N Spectroscopy in the Near-IR (Cordiner et al. 2017)

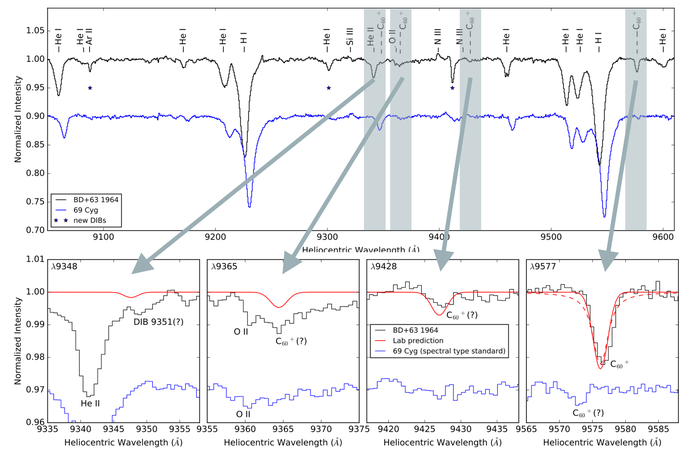


HST STIS spectra of B0 giant BD+63 1964

[Top] standard STIS spectrum extracted over 10 rows showing severe fringing.

[Middle] STIS scanning (700 rows) results in substantial reduction in fringing even w/o correction.

[Bottom] Result spectrum after flat fielding using a contemporaneous fringe flat.



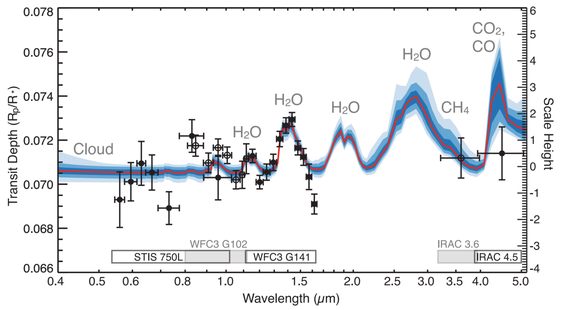
STIS spectra for BD+63 1964 (black) and comparison star 69 Cyg (blue)

- For both stars, STIS spatial scans allow S/N ~ 600-800 w/o saturation.
- Ground-based spectra in similar wavelength range show significant contamination by telluric lines, but STIS spectra are free of them.
- Weak diffuse interstellar bands (DIBs) detected in BD+63 1964 (c.f. 69 Cyg) thanks to the unprecedented S/N achieved via spatial scans.
- Confirmation of matching wavelength and profile for interstellar and laboratory bands of C_{60}^+ at 9577Å.

3. Other Applications of STIS Spatial Scans

Characterizing Exoplanet Atmospheres

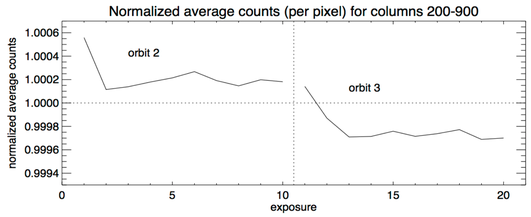
- Both WFC3 G102 and STIS G750L cover the 0.97 μm H_2O band (see Figure from Wakeford et al. 2017 →).
- STIS data were obtained via pointed, saturated observations Note the larger STIS error bars (closed dots) vs. WFC3 (open) at 0.8~1.0 μm, due to imperfect fringe correction.
- Spatial scans should allow better de-fringing which may yield uncertainties comparable to those of WFC3 G102.
- STIS G750L covers Na I and K I lines at shorter wavelengths. More importantly, broader coverage will yield better spectral slopes (e.g., for study of hazes).



Transmission spectrum of HAT-P-26b from Wakeford et al. (2017). Red line (with blue shades) shows the model. Observed data points with error bars are from various instruments as indicated by the labeled bars at the bottom.

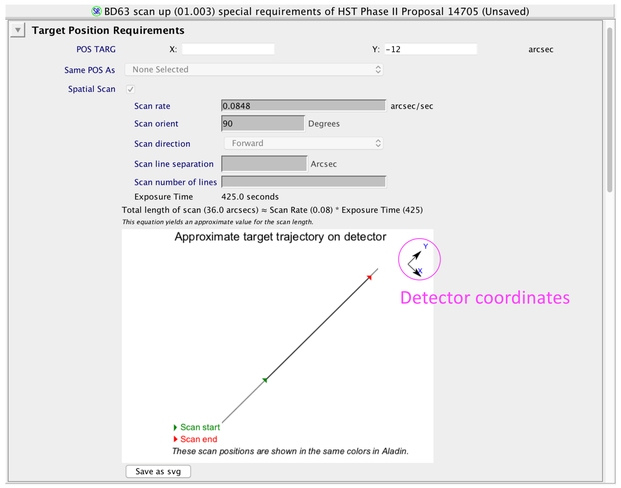
Optimizing STIS Spatial Scans

- Calibration program 15383 obtained data for testing the alignment and flux reproducibility of STIS spatial scans.
- For two sets of 10 short (12”) spatial scans of 55 Cnc with G750L, the total fluxes in the raw images agree within 0.005% for the last 7-8 scans of each set.
- Full analysis of these data (including proper de-fringing, cosmic-ray removal, etc) is in progress.



Average counts for 20 scans of 55 Cnc obtained during orbits 2 and 3 of the second visit of program 15383, normalized by the overall average for those 20 scans.

4. How to Construct a STIS Spatial Scan Observing Plan



In APT, “Spatial Scan” mode can be turned on by entering the Target Position Requirements level under individual exposures. Image above shows an example spatial scan exposure for program 14705 (Cordiner et al. 2017). Users must input the scan parameters (which are grayed out in this image) manually, and verify the target trajectory image generated by the APT.

Required Parameters

- POS TARG: starting location in arcsec, relative to the aperture fiducial point.
- Scan rate in arcsec/s.
- Scan orientation (nominally 90 deg).
- Scan direction (only forward recommended)
- Exposure time

Designing STIS Spatial Scan Observations

- Current ETC does not have STIS scan mode, so use STIS spectroscopic ETC (CCD) to calculate expected peak flux levels.
- Calculate the scan rate for a given scan length (52” or less) and exposure time that will not saturate the star.
- Add fringe flats by setting TARGET = NONE + special requirement LAMP=TUNGSTEN with exposure time that gives comparable signal to the targets.
- See STIS IHB Section 12.12.3 for details.