STIS Calibration Enhancement: Implementation of Model Based Techniques for *Wavelength Calibration* and *Charge Transfer Inefficiency*

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[Website Link: www.stecf.org/poa]
Empirical Wavelength Calibration - Quick Review

- Polynomial dispersion solution:
  - Deep “wavecal” observations of on-board lamp
  - Line list for on-board lamp
  - Fine tuning with contemporaneous short wavecal
    - Finds zeropoint offsets due to monthly offsets, MSM uncertainty & central wavelength
Short and Long Wavecal
Short and long wavecal, detail
Echelle model

- Matrix based model of STIS optical components
  - ~35 parameters
  - Inversion is *not* possible
STIS Spectrograph Model

- Optimization with deep wavecals establishes exact configuration of fixed optical components
- Change in central wavelength for different MSM positions turns out to be a linear function of just one of the physical model parameters.
- 35 parameters ⇒ 2
- Compare to the ~7 parameters of the empirical model
Simulated Wavecals

- Config determined with optimisation can be plugged back into the model to produce simulated wavecals.
- Given a model SED, astronomical sources can also be simulated in this way - *advanced ETC*
Other visualisation products
Optimisation of Contemporaneous Wavecal

- Find strongest features
- Optimise just X-disperser angle
- **NO NEED FOR ANY FURTHER SHIFTS**
  - cf A1CENTER & A2CENTER (nominal location), MOFFSET1 & 2 (MAMA commanded) and SHIFTA1 & 2 (wavecals) Shifts used by calstis
Science case

- Thermal Pressures in ISM from CI Fine-Structure Excitation
- E140H, 1180Å-1280Å
- O5LH01010-1040, O5LH02020-2040, O5LH08010-8030
- Authors noted that features in order overlaps had discrepant wavelengths
Order Overlap
Order Overlap
Model Based CTI Correction
How CTI effects x-section

- Large charge packets fill available traps
- Subsequent smaller packets receive the charge emitted by the traps
- Relative positions of sources can be important

Remember:
- All other “CTI effects” are manifestations of the effects upon x-section.
- Flux loss
- CTI tails
- Profile in figure could be vertical x-section of stellar image or stellar spectra

Red is observed  
Readout direction
Empirical Solution

- Estimate **flux loss** from *point sources* as a function of:
  - Position on chip
  - Size of charge packet (flux)
  - Background
  - Time on orbit

- Only applies to photometry, not astrometry, structure etc.
- Only applies to the type of objects it was calibrated for (usually point sources or spectra of point sources)
- Requires extensive calibration observations
- Cannot account for image complexity
Readout model: Motivation

- A physical solution, CTI effects understood in terms of the CCD operation and environment
- A correction that applies to the entire 2D array:
  - Equally valid for imaging and spectroscopy
  - Also applicable to extended objects
- Portable to other space based detectors (WFPC2, ACS, WFC3?, Kepler instruments etc.)
- Extendable to model further aspects of CCD readout
Readout Model: Concept

- **Forward Simulation:**
  - Start with
    - 2D Charge distribution on chip
    - Distribution of bulk traps
  - Shift the charge under each electrode as during readout
  - Calculate capture and emission of charge in each shift

- **Take into Account:**
  - Status of bulk traps
  - Dark current
  - Trap capture and emission timescales
  - Chip clocking frequency, architecture, gain etc.
Restoring data with simulation results

- CTI effect is grossly exaggerated in figure!
- --- Original profile
- --- Raw (observed) profile, after CTI readout
- --- Raw profile + sim CTI
- --- Raw profile - sim CTI (red-[blue-red])
- Further iterations will converge on original profile
Correction:

- Raw data >> SIMULATION

Readout direction

Further iterations (usually not necessary):

- Corrected image >> SIMULATION
Quantitative Validation

- Matches photometric and spectroscopic empirical corrections (Goudfrooij & Kimble 2002, Bohlin & Goudfrooij 2003) well with physically realistic parameters
- Charge restored reliably to central isophotes of point sources => whole image array is corrected reliably.
- 2 CE-STIS ISRs describing these results
- Large parameter space explored in order to find the optimum model configuration => physical properties of STIS CCD
Comparison to Empirical Corrections for Imaging Data

- Empirical calibration used as a test of physical model
  - On average we should expect agreement
  - This comparison can also help to calibrate the physical model
- Good general agreement (especially for objects to which the empirical calibration applies)
Special Cases: Images
Science Case: *Proper motions of local dwarf galaxies*

- Slawomir Piatek, Carlton Pryor, Edward Olzewski et al.


- Highly accurate astrometry of stars in local Dwarfs (Carina, Sculptor, Fornax) and background QSO (as reference)

- Repeat observations with STIS and WFPC2 taken several years apart.
Proper motions - CTI effects

- CTI during readout will shift the centroids
  - Row dependent shift
  - Luminosity dependent shift
  - *Epoch* dependent shift
    - later observations suffer significantly more CTI
Proper motion data with and without CTI correction

March 2000

March 2003
Proper motions - Full Analysis

- See poster from Piatek et al
- Piatek et al. AJ, 130, pp95 (Ursa Minor)
- Piatek et al. AJ, in press (Sculptor)
- Data processed for further Carina study
Summary - STIS Pixel based CTI Correction Status

- Pipeline version delivered to STScI Feb’ 04
- Testing delayed (STIS safe mode in mid 2004)
- Imaging results not bad:
  - Point sources, sparse field - As good as empirical
  - Point sources, crowded field or in presence of artefacts - Better than empirical
  - extended sources - Only approach available
  - Proper motions science case
- Application to spectra not as good
- Slow:
  - Could be more efficiently coded…
  - Any pixel based solution will necessarily be computationally expensive