Wavelength Calibration of the Full-Sun Ultraviolet Rocket SpecTrometer (FURST)

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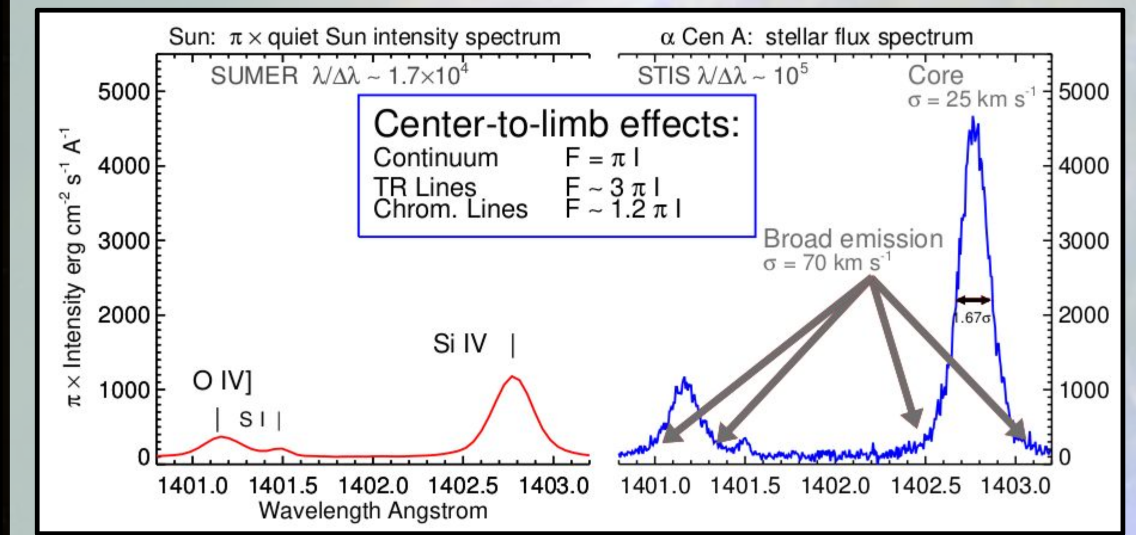
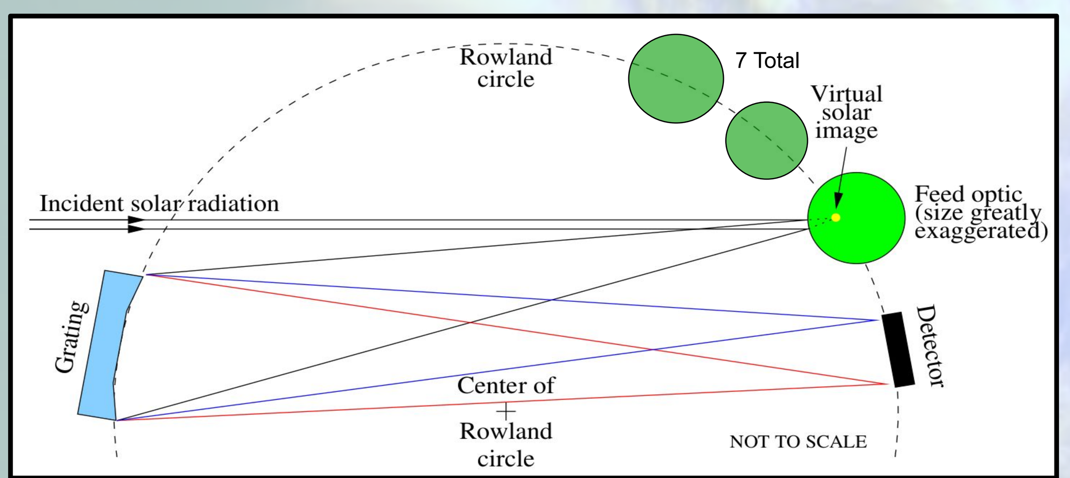
The Motivation

- Sounding Rockets are test-beds for new technology
  - CLASP [1], MaGIXS (2020), **MOSES-II**, **ESIS**, etc [2-7]
- FURST will launch in August 2021
  - Aim: Highest resolution **full-disk** FUV spectra to-date (**comparable with Hubble data**)
- Very limited data exists currently [8]:



The Instrument

- Treat the "Sun-as-a-Star" by using 10 optical cylinders [10]
- Cameras adapted from the existing ESIS detectors



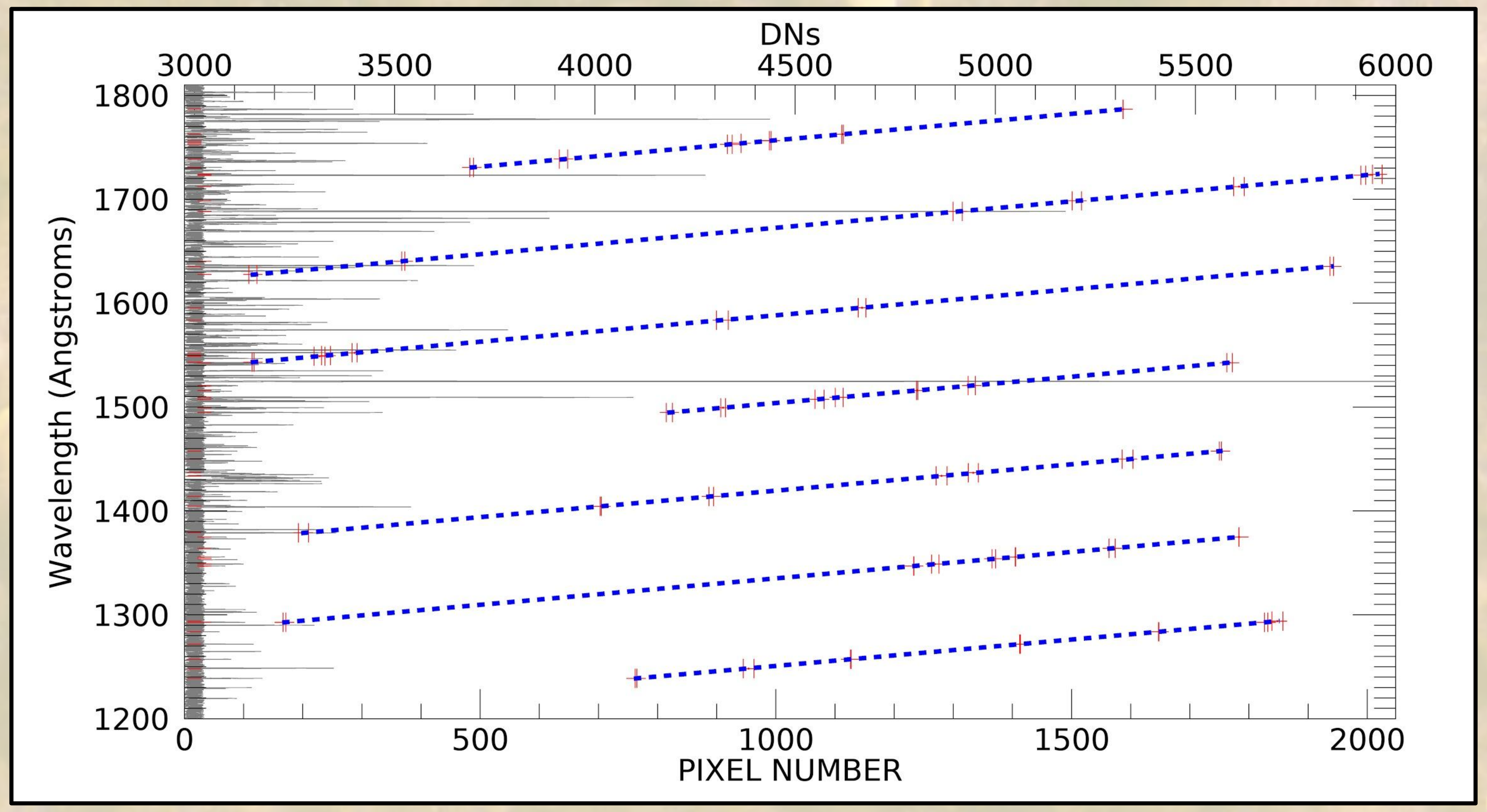
- Resolution goals:
  - ***R* = λ/Δλ > 10,000**
  - **SDO EVE has a maximum R = 1,000 [11]**
  - Range: 120 - 181 nm
- Solves many problems in solar spectroscopy:
  - Reduces solid angle and extreme intensity of the Sun
  - **Most detectors saturate at Lyα 121.5 nm**

The Collimator

- Used for **calibration and alignment**
  - Essentially a Newtonian telescope
  - **Calibration at MSFC and NIST**
- Our current Collimator needs upgrading
  - Higher **radiometric requirements**
  - Larger rocket-skin (22" from 17")

The Results

- The spectroscopic signal is **mapped as a function of pixel number**
- Diagnostic lines are chosen and shown
  - **error-bars in red**
- **Nonlinear Orthogonal Distance Regression** gives parameters of the mapping



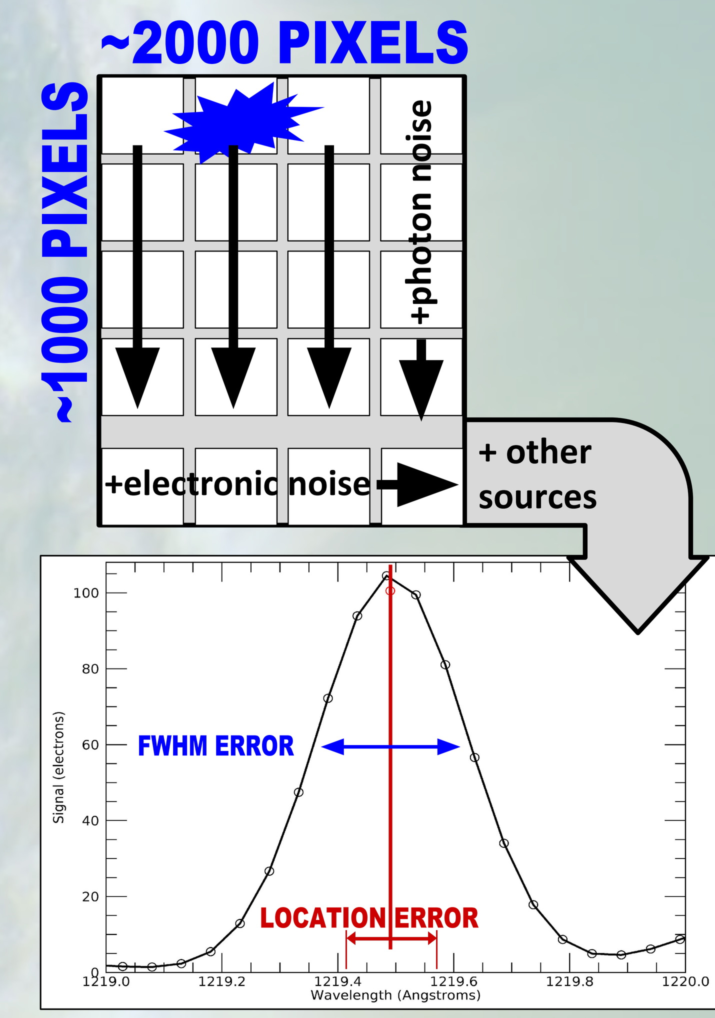
$$\lambda = (\lambda_0 + \Delta\lambda_0) + (A + \Delta A) \cdot P + (B + \Delta B) \cdot P^2$$

Resolution (per pixel) $R = \lambda/\Delta\lambda = c/\Delta v$ → $R_{\Delta\lambda 0}$ ~ 5K, $R_{\Delta A}$ **~ 3M** → Δv **~0.1** (km/s) → 3 km/s goal is possible

The FURST instrument should be able to resolve small scale spectral features of the Sun, such as spectral line profiles and sub-pixel doppler shifts.

The Simulation

- Diagnostic signal from **Pt/Cr-Ne hollow cathode lamp** (the same type on HST) [9]
- Simulate a sun-source, with approximations for:
  - photon noise (**Poisson error**)
  - CCD electronic **readout noise** (DNs)
  - Statistical error (**Monte-Carlo** method)
- Used to **determine the error budget** required to **resolve the relative motion of Low Temperature Plasma**.



The Future

Improve accuracy of
- **photon noise**
- **electronic error**
- **Diagnostic lines (NIST)**

Add more sources
Nonlinear model

→ Simulation Results

Absolute Radiometric
Absolute Wavelength
Relative Wavelength

→ Calibration Requirements

Acknowledgments [1] S. Ishikawa et al., 2017 (CLASP); [2] Kobayashi et al., 2013; [3] Kobayashi et al., 2014; [4] Kano et al., 2012; [5] Shimizu et al., 2008; [6] Tsuneta et al., 2008; [7] Kosugi et al., 2007; [8] Peter, 1999; [9] Sansonetti et al., 2004; [10] Kankelborg et al., 2017; [11] Woods et al., 2010. Thank you to my advisers (Dr. Winebarger and Dr. Zank) as well as Dr. Kankelborg and the MSU partnership, in addition to the Alabama NSF EPSCoR funding that allows for this exciting mixture of experimental and theoretical research. As always, thank you to God, my Wife, and Family for their continual support. *This material is based upon work supported by the NSF EPSCoR RII-Track-1 Cooperative Agreement OIA-1655280. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*