12th Wernher von Braun Memorial Symposium
September 10 – 12, 2019

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

Donders, Nicolas[1,2]; Winebarger, Amy[3]; Kankelborg, Charles[4]; Vigil, Genevieve[3]; Kobayashi, Ken[3]; Rachmeler, Laurel[3]; Zank, Gary[1,2]

[1]Department of Space Science, University of Alabama, Huntsville, AL

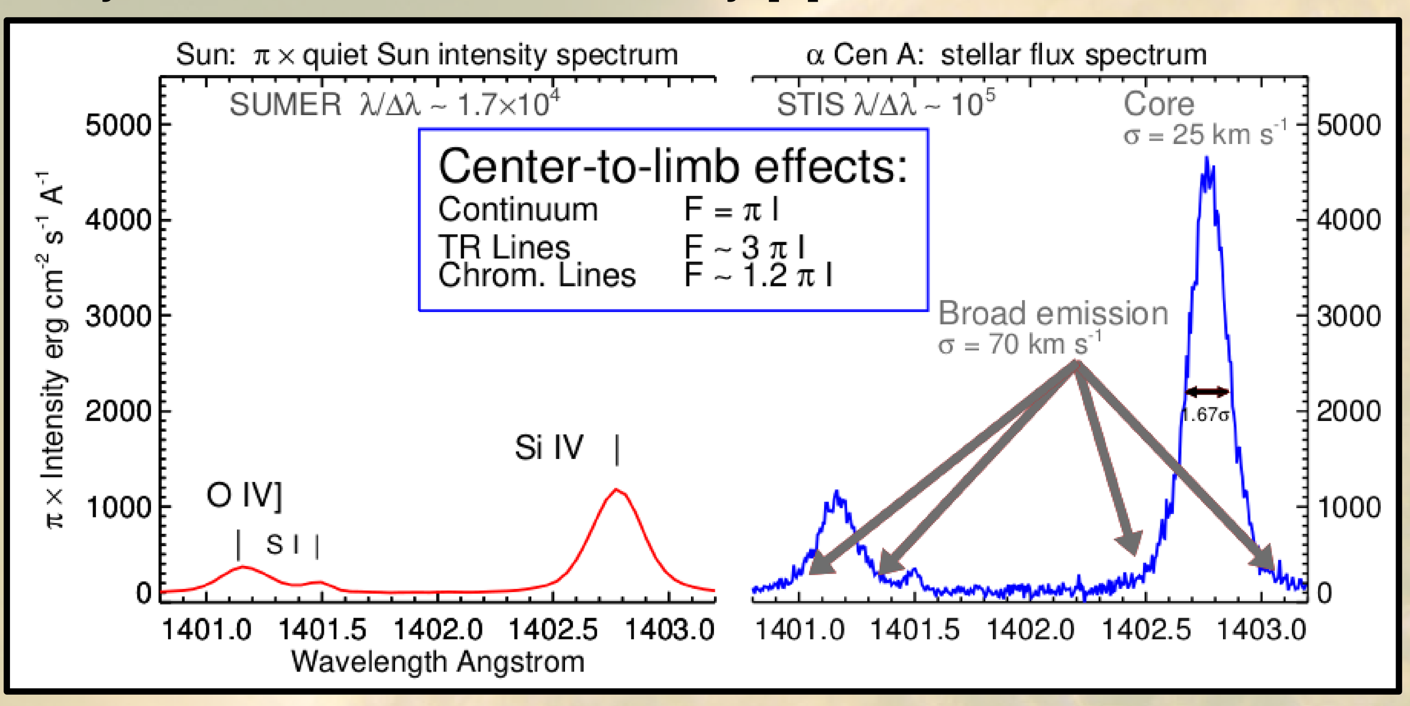
[2]Center for Space Plasma and Aeronomic Research (CSPAR), University of Alabama, Huntsville, AL

[3]NASA Marshall Space Flight Center (MSFC), Huntsville, AL

[4]Solar Group, Department of Physics, Montana State University, Bozeman, MT

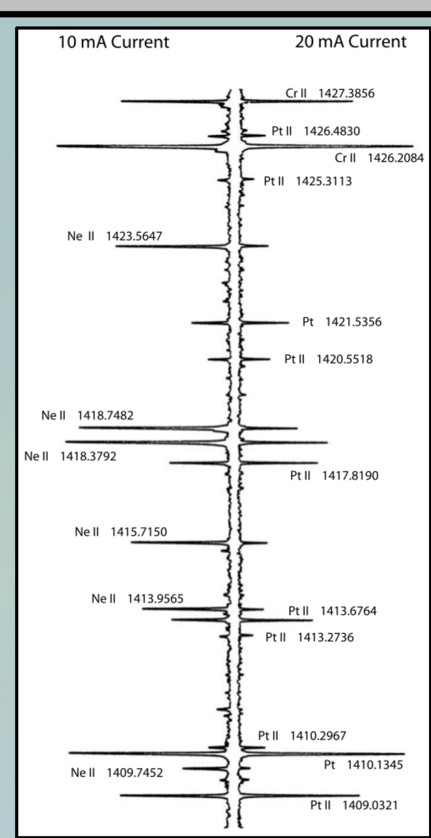
The Motivation

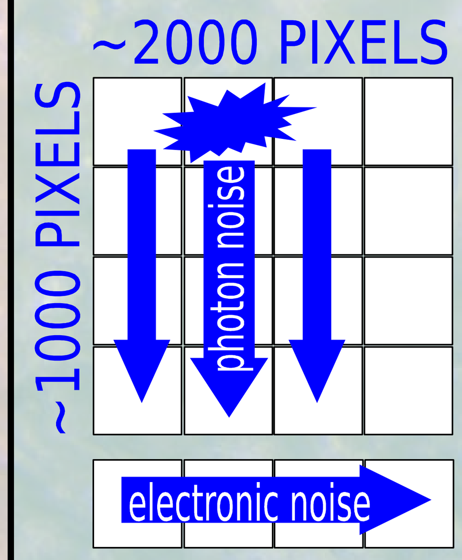
- Sounding Rockets are test-beds for new technology
  - CLASP [1], MaGIXS (2020), **MOSES-II**, **ESIS**, etc [2-7]
- FURST will launch in August 2021
  - Aim: Highest resolution **full-disk** FUV spectra to-date (**comparable with Hubble data**)
- Very limited data exists currently [8]:

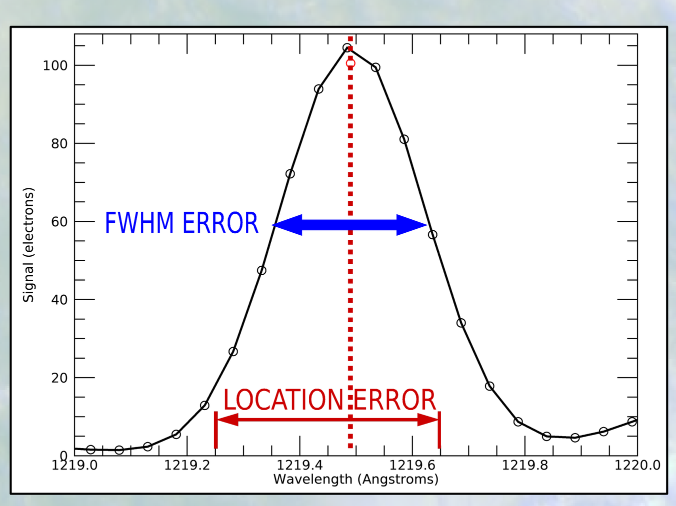


The Simulation

- Diagnostic signal from a **Pt/Cr-Ne hollow cathode lamp** [9]
  - The same type on HST
  - Used 10 mA current signal (left)
- We simulate an incident signal with approximations for:
  - photon noise (**Poisson error**)
  - CCD electronic **readout noise** (DNs)
  - Statistical error (**Monte-Carlo** method)



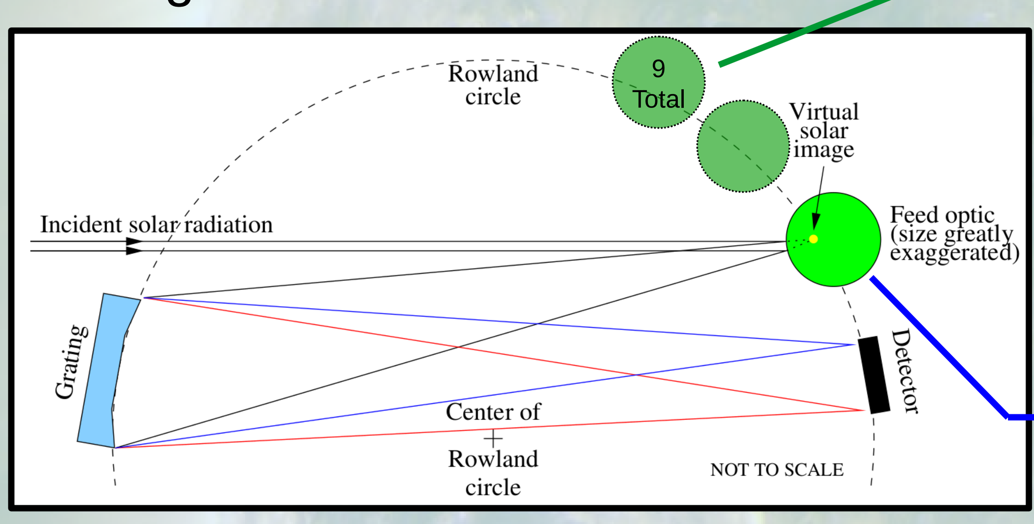




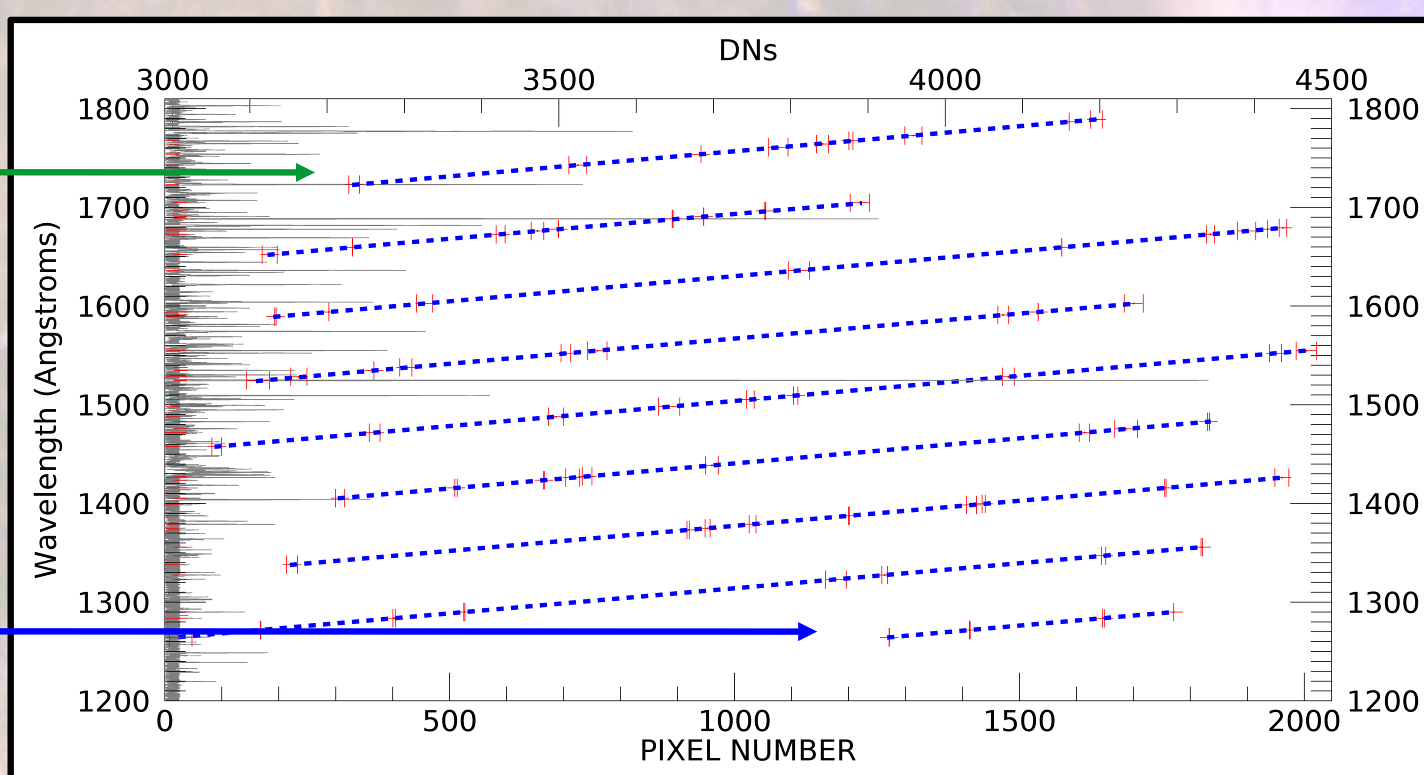
- Used to determine the error budget
- Allows us to resolve the relative motion of **Low Temperature Plasma**

The Instrument

- Treating the "Sun-as-a-Star



- Uses an optical cylinder [10]
- Adapted from the ESIS detector
- Resolution goals:
  - ***R* = λ/Δλ > 10,000**
  - Range: 1120- 2000 Å
  - SDO EVE has a maximum ***R* = 1,000** [11]
- Solves many problems in solar spectroscopy:
  - Large solid angle and extreme intensity
  - **Most detectors saturate at Lyα**
    - **121 nm**



The Results

- Signal and error are mapped as a function of pixel number
- Diagnostic lines with error-bars are highlighted in red

$$\lambda = \lambda_0 + A \cdot x + B \cdot x^2$$

- Nonlinear **Orthogonal Distance Regression** (ODR) employed using an **IDL/Python** bridge
- Assuming linearity, parameter A gives:

Resolution (per pixel) $R = \lambda/\Delta\lambda = c/\Delta v$ → Δλ (Å) $10^{-3} \pm 10^{-7}$ → Δv (km/s) $10^{-1} \pm 10^{-5}$ → ~3 km/s resolution goal is possible!

The Collimator

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

The Future

Simulation Results → Calibration Requirements

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

Add more sources
Nonlinear model

- Absolute Radiometric
- Absolute Wavelength
- Relative Wavelength

Acknowledgments

References: [1] Ishikawa et al., 2017; [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) for the opportunity to study this exciting mixture of experimental and theoretical research, as well as Dr. Kankelborg and the MSU partnership that makes this possible. 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.