CPU2AL

Sounding Rocket Spectral Calibration

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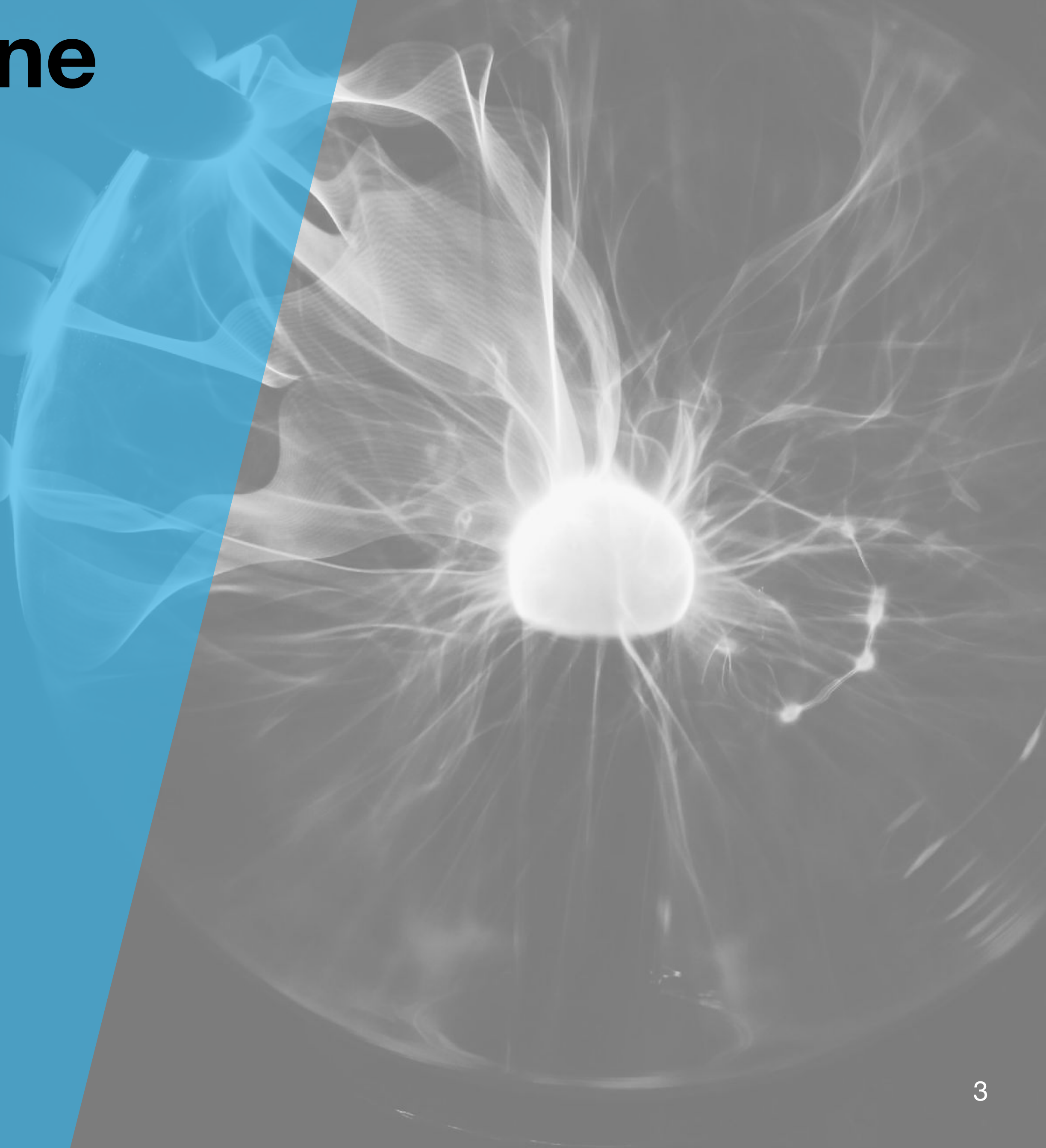
Presentation Outline

- Overview
- Scientific Motivation
- Pre-/Post-flight Spectral Calibration
- In-Situ Spectral Calibration



OVERVIEW

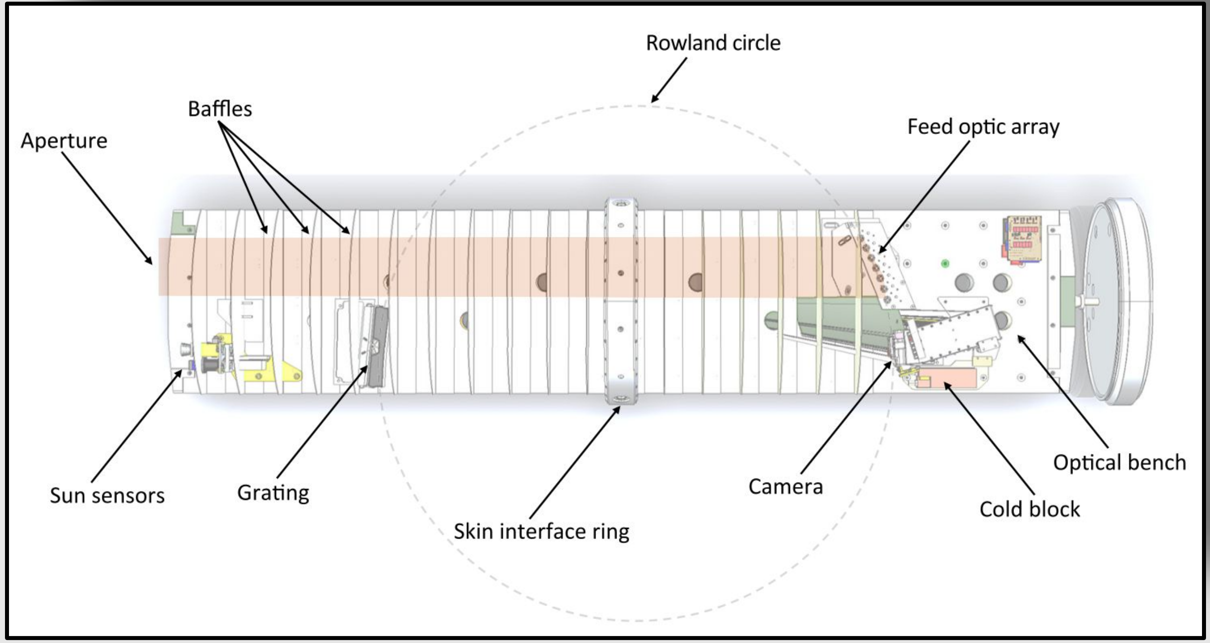
of sounding rockets and FURST

What are Sounding Rockets?

- Sub-orbital flight path
- Instruments include
  - Imagers
  - Spectrographs
  - Polarimeters, etc.
- Testbed for novel concepts
- Quick project turnaround time
- Much cheaper than satellites

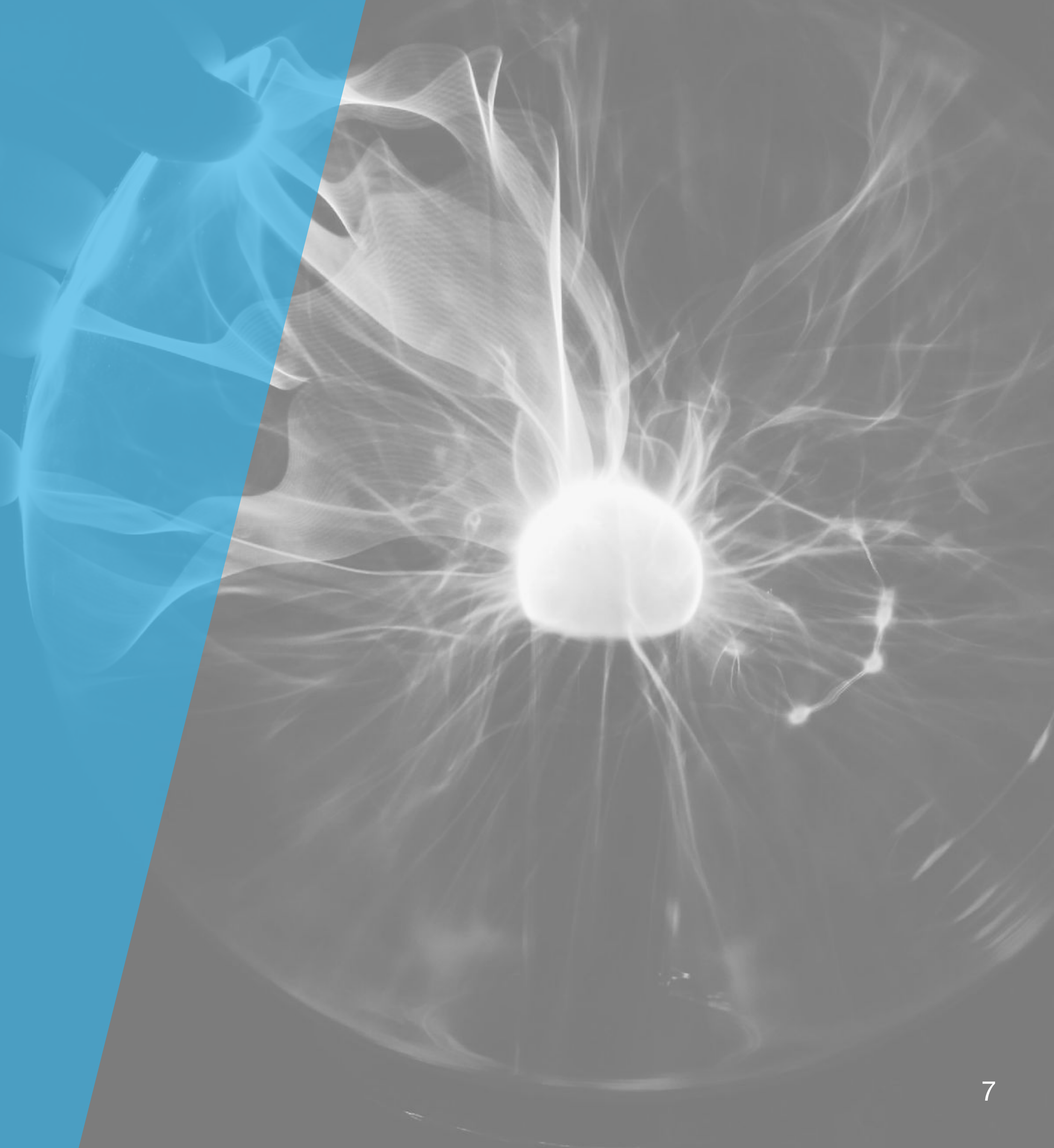
Full-sun Ultraviolet Rocket SpecTrograph (FURST)

- Virtual slit covers full sun
- Range: 120-181 nm
- Resolution: $R > 2x10^4$, $\Delta V < 15$ km/s
- Altitude: 109-255 km
- Launch Date: Summer 2022
- Launch Location: WSMR, NM



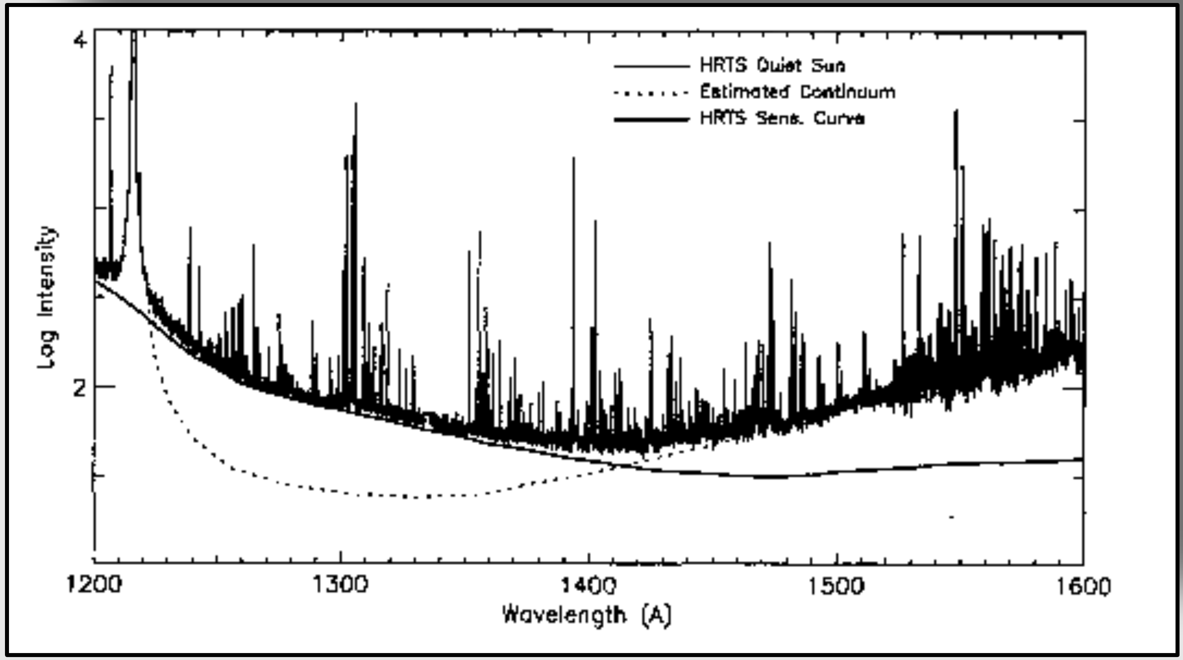
SCIENTIFIC MOTIVATION

for FURST



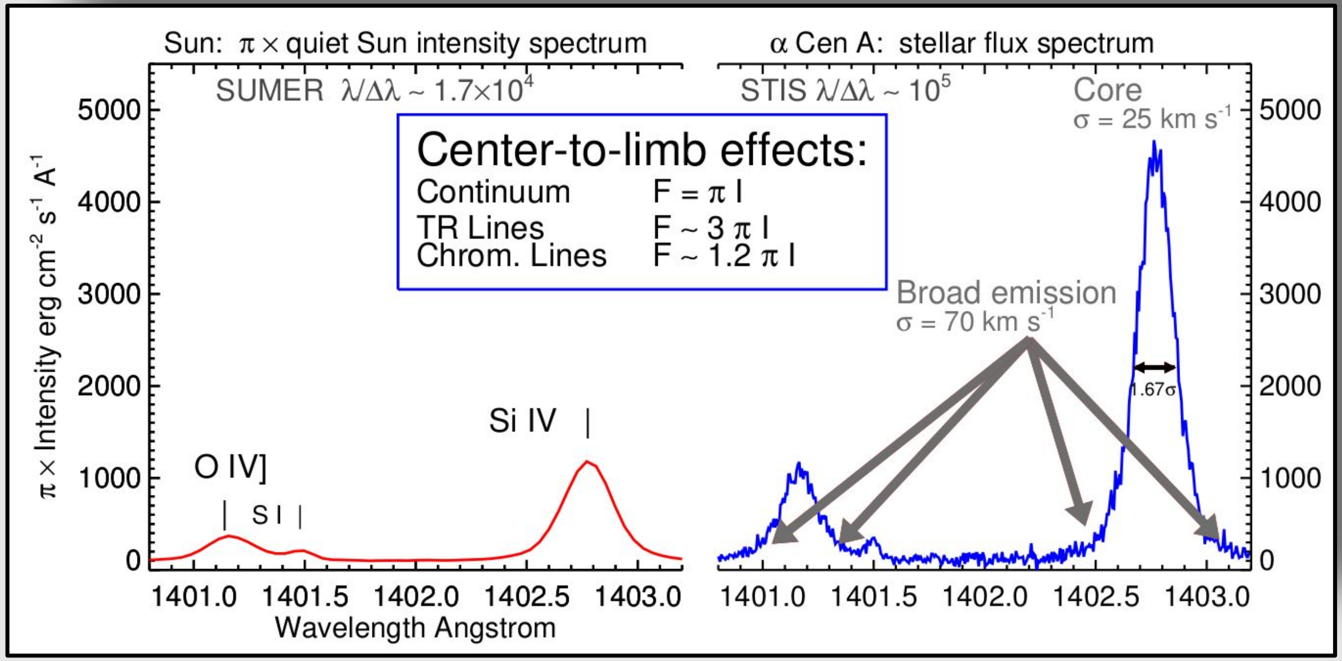
Motivation for FURST

- To obtain high-resolution full-disk UV spectra
  - HRTS has a **higher noise** curve and **small field of view**
  - SUMER has good SNR, but a small field of view
  - (See also Curdt+ 2001)
- To close the large data gap
  - Typical full-disk spectrographs have a limited wavelength range
  - (See also Peter+ 1999a, 1999b)



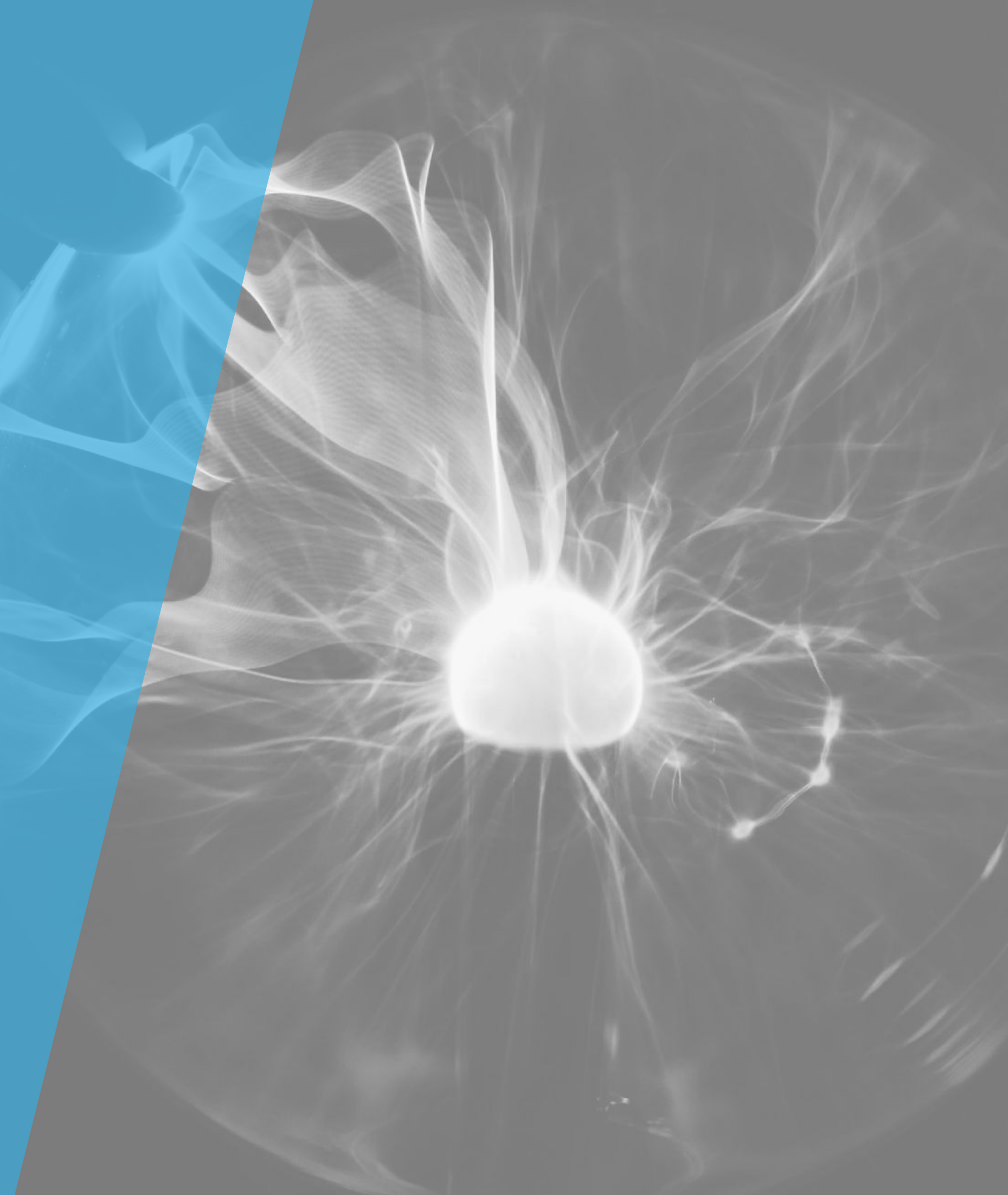
Motivation for FURST

- To directly compare with HST & JWST (See Judge+ 2017)
- To extend the technology to other applications (i.e. planetary atmospheres)
- To show the value of FURST as a satellite



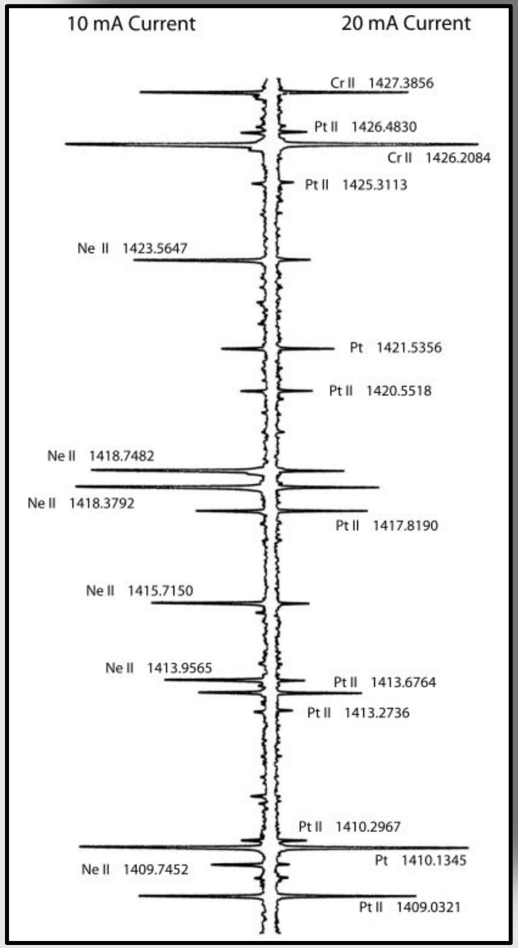
PRE-/POST-FLIGHT

spectral calibration



Spectral Calibration with a Diagnostic Lamp

- The main topic of my research
  - (Donders+ 2019, 2020a, 2020b)
- Calibration code which can:
  - Read-in diagnostic images based on the **NIST calibrated lamp**
  - Perform 2D Lorentz cross-correlation
  - Obtain (non)linear **spectral plate scales**
  - Estimate associated error
- This code will aid our team in:
  - laboratory spectral and radiometric calibration
  - tracing science goals and achieving them



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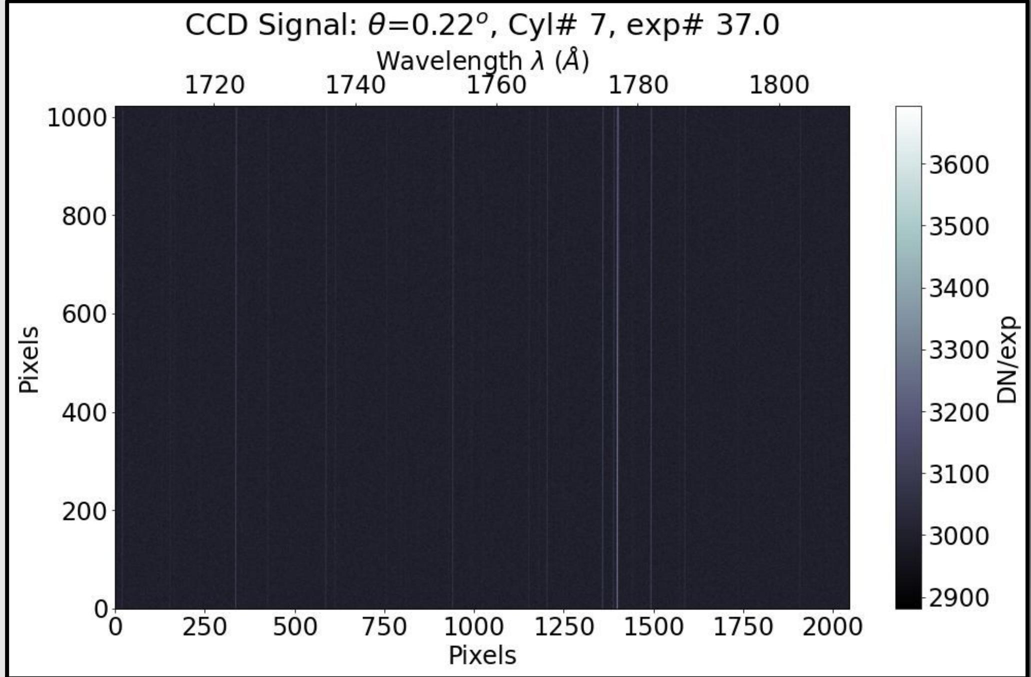

$$\lambda = (\lambda_0 + \Delta\lambda_0) + (A + \Delta A)\cdot x + (B + \Delta B)\cdot x^2 + (C + \Delta C)\cdot y + (D + \Delta D)\cdot y + (E + \Delta E)\cdot x \cdot y$$

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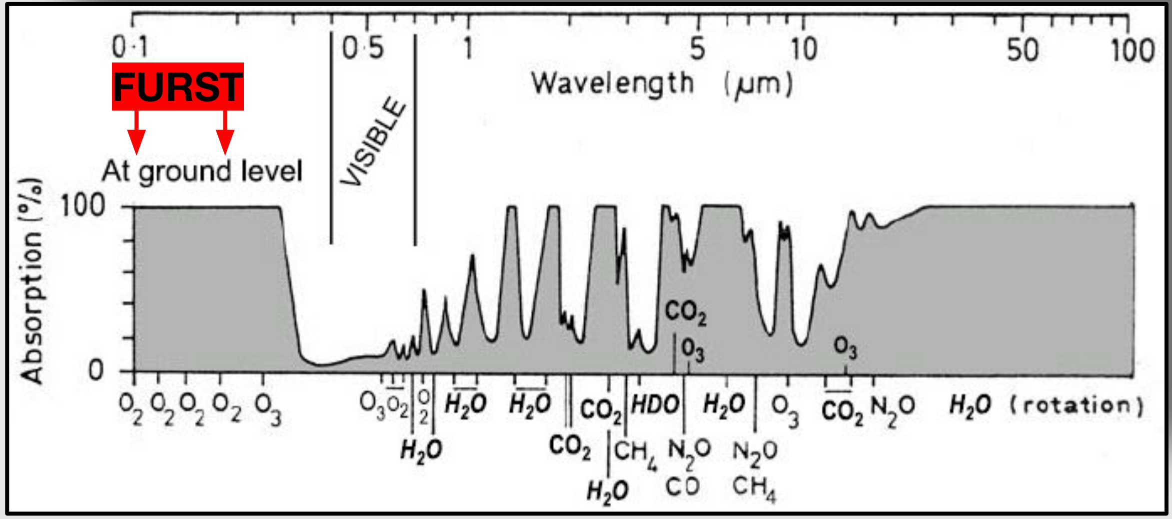
IN-FLIGHT

spectral calibration

Spectral Calibration with Atmospheric Absorption

- Primary motivation:
  - Ensure high SNR
  - Help us understand effect of varying launch time/day/location
  - (See also He+ 2019; Sun+ 2018, 2022)
- Secondary motivation:
  - Might improve/confirm calibration
  - Might find atmospheric properties hidden in data!

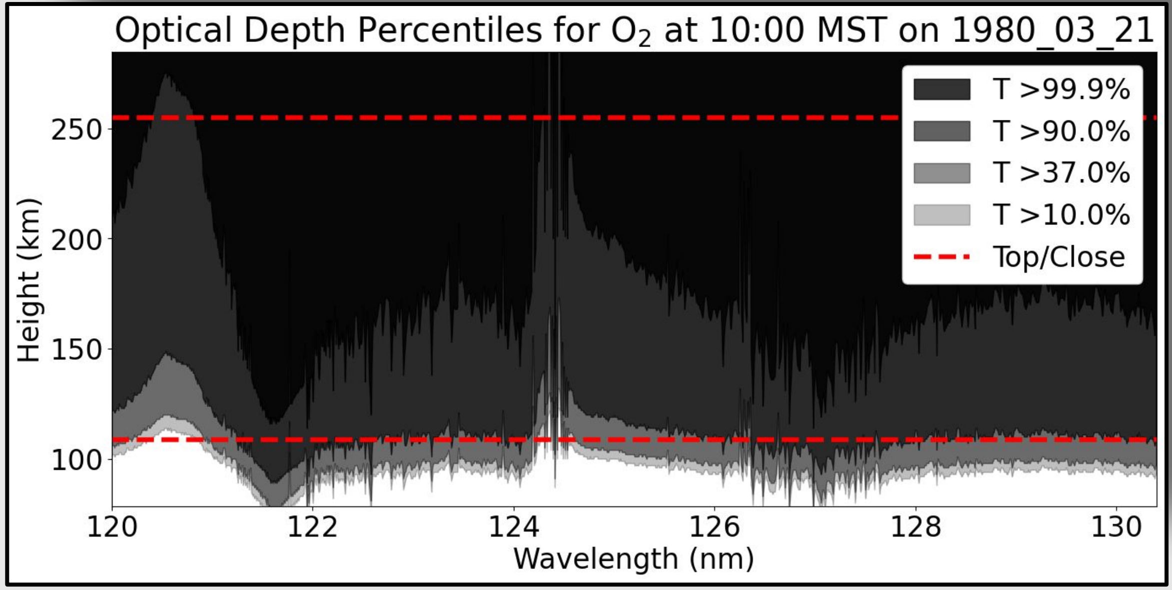


Atmospheric Absorption Model: The set-up

- Beer-Lambert's Law estimates Transmission:

$$T = e^{-\tau},\ \tau_{i,j} = \sum_{i'=i}^{\infty} \sigma_{i',j}\eta_{i'}\Delta L_{i'}$$

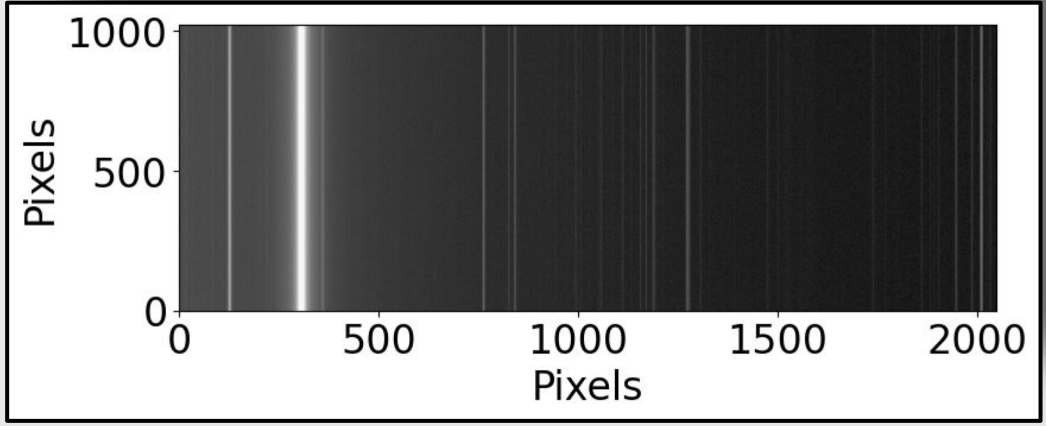
- Basic Physics:
  - Trig relations, Snell's Law, Density, absorption cross-section
  - See also:
    - **NRL MSISE atm. model**
    - **MPI-Mainz UV-VIS database**
    - **NOAA Solar Position Calculator**
    - (See Phillips 1920; Liu+ 2008; Keller-Rudek+ 2013, 2014; Sander+ 2014; Hitran 2016; Gordon+ 2017; Cornwall+ 2022; ESRL 2022)



- Ensure results match **Meier (1991)**

Atmospheric Absorption Model: The results

- Used data from High Resolution Telescope and Spectrograph (HRTS)
  - Quiet Sun (QS) data is folded into FURST optics to **simulate an image** (Brekke 1993)
  - FURST noise floor will be significantly lower than HRTS was.
- Between 120-130.4nm, we calibrate using absorption lines
  - Pick 2 pairs of pixels/wavelengths.
  - **Find the plate scale to within ~0.5%.**



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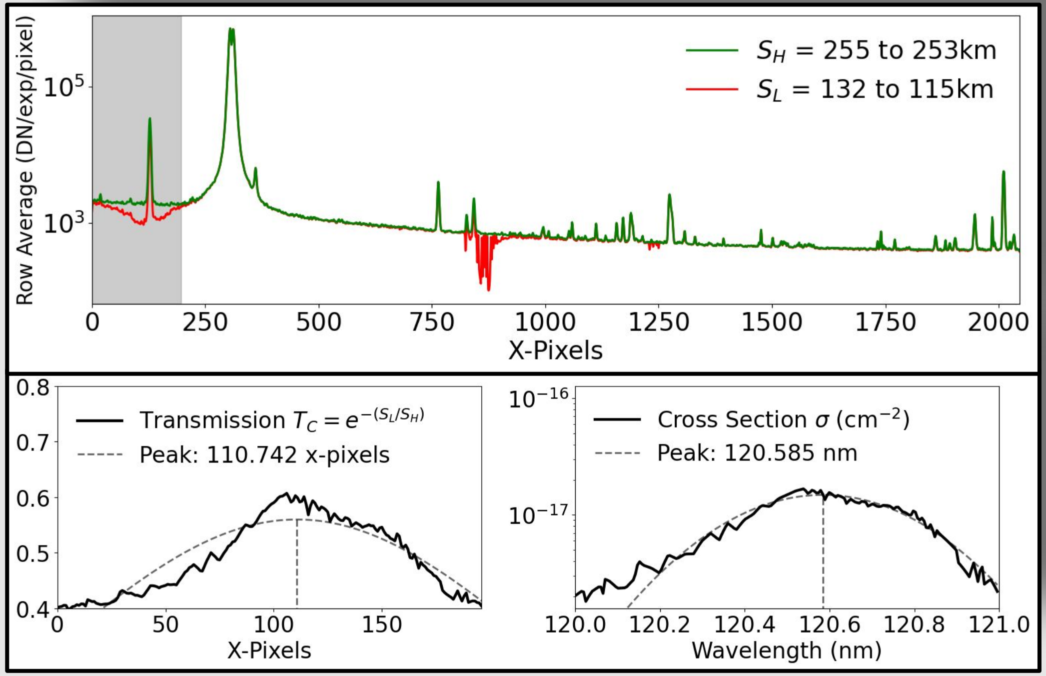
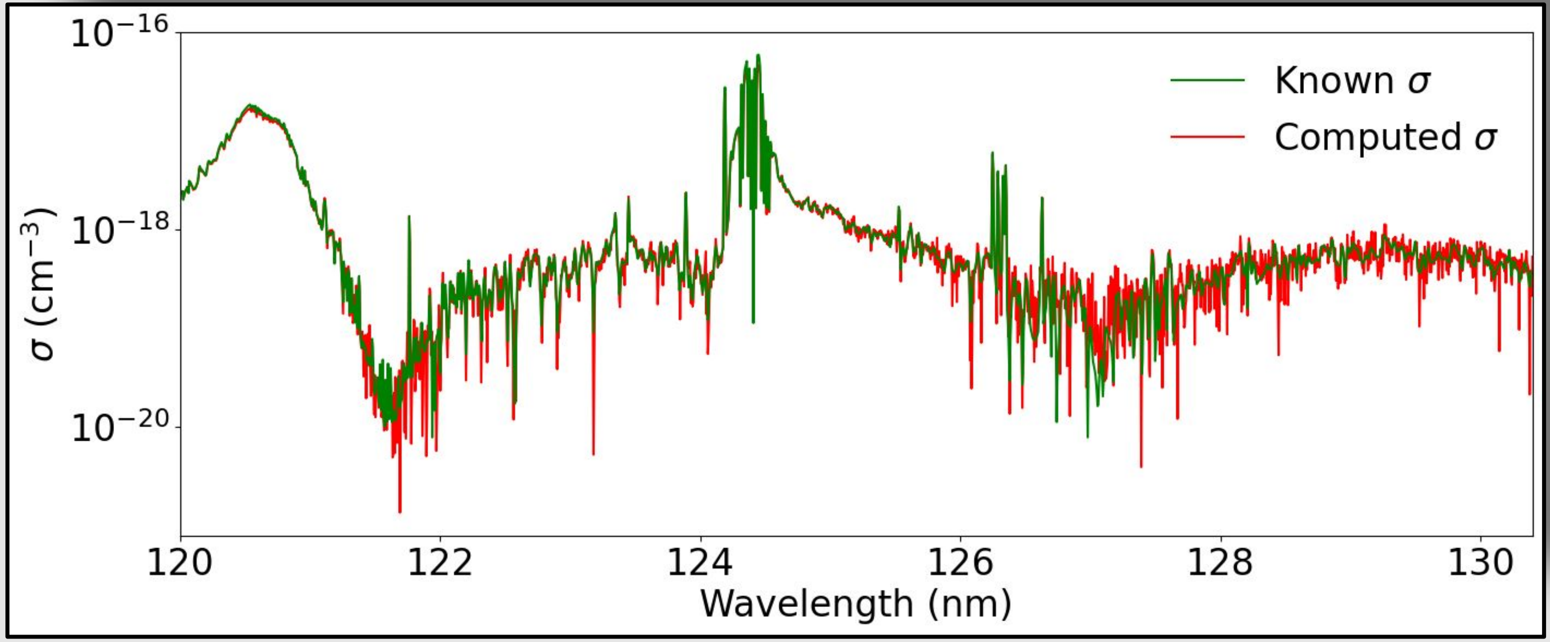


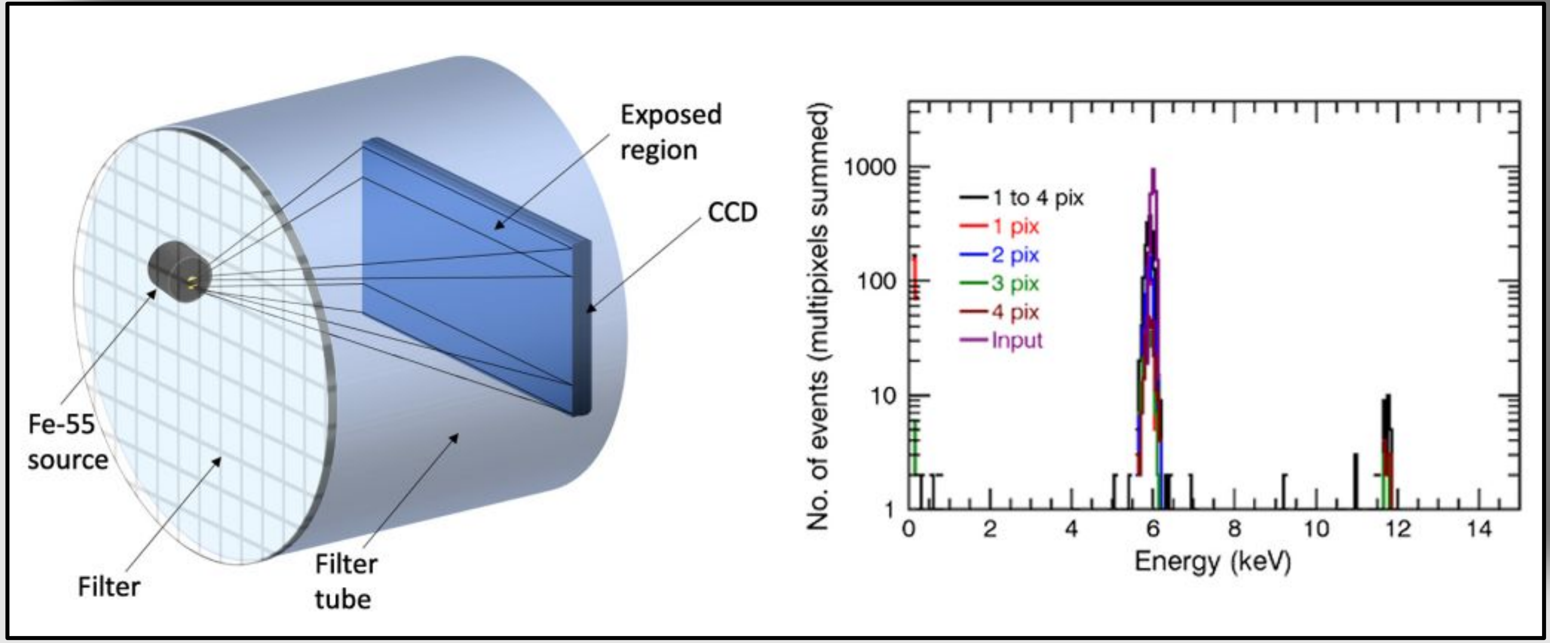
Atmospheric Absorption Model:
The results

- Assuming temperature variations are small during exposures:
  - Use 2 images to factor out absorption.
  - **Find the values with an error of ~27%.**
- The next step: try it on real data!



Radiometric Calibration with a Radioactive Source

- Gain fluctuation is an unknown
- An on-board Fe-55 source will provide in-situ calibration (Vigil 2021)
- This is another novel concept!



Future Work

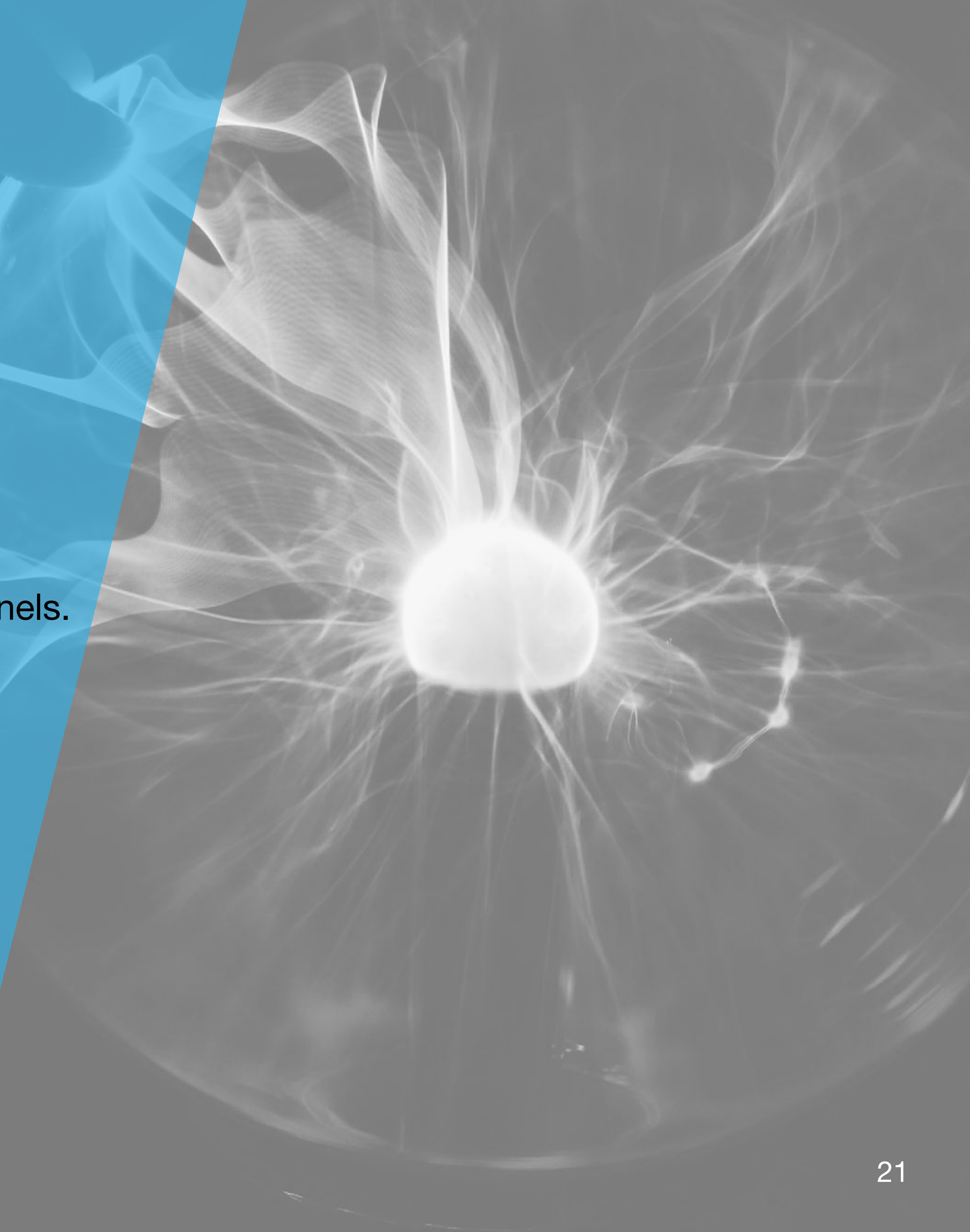
For Spectral Calibration:

- Improve signal estimation
- Explore “Gaussian process regression”
- Perform laboratory calibration before/after launch

For Atmospheric Absorption:

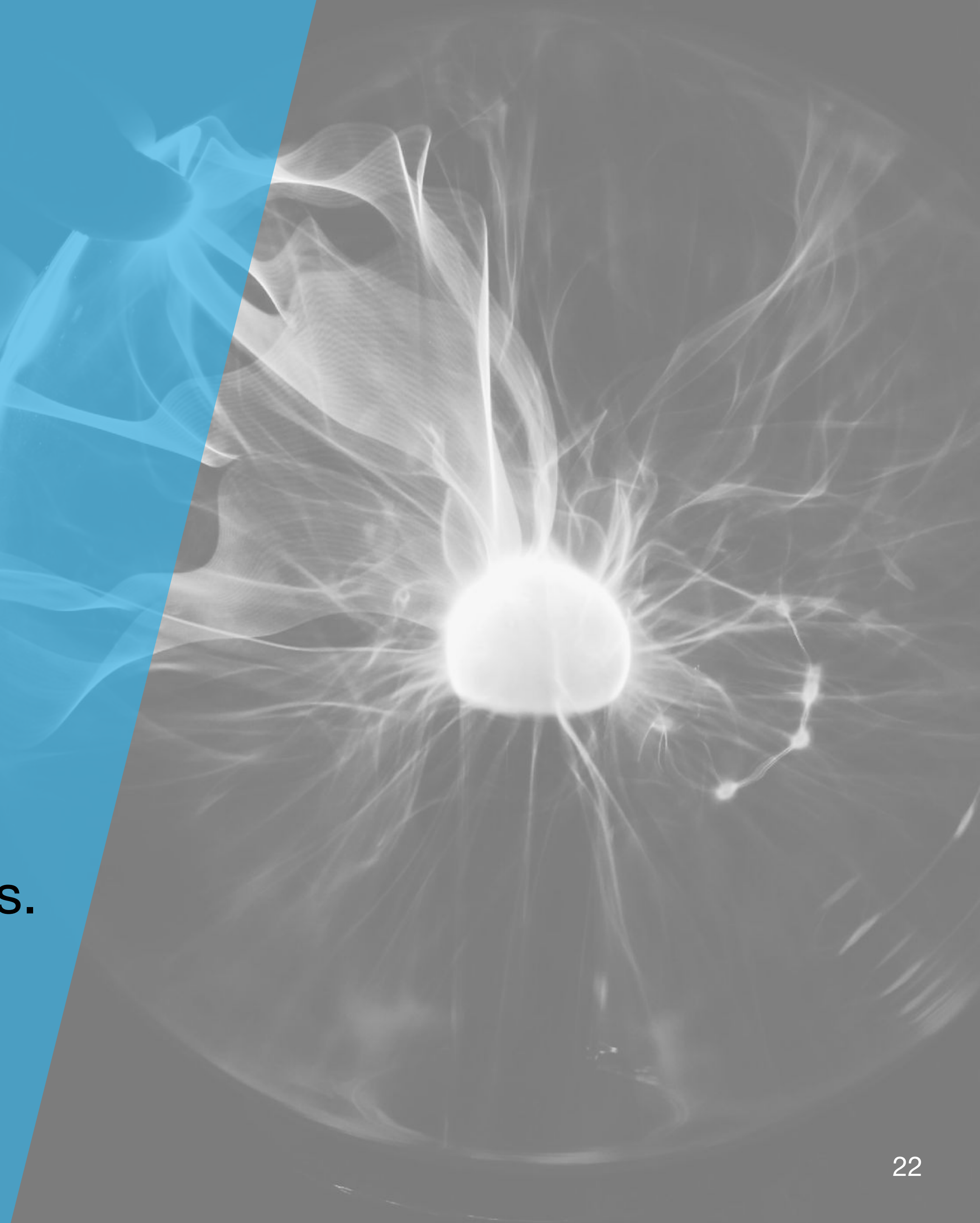
- Test SNR by varying exposures and coupling wavelength channels.
- Calculate H & O self-absorption (Degenstein 2000).
- Determine cross-section temperature-dependency.
- Apply these methods to existing SR raw data such as HRTS.

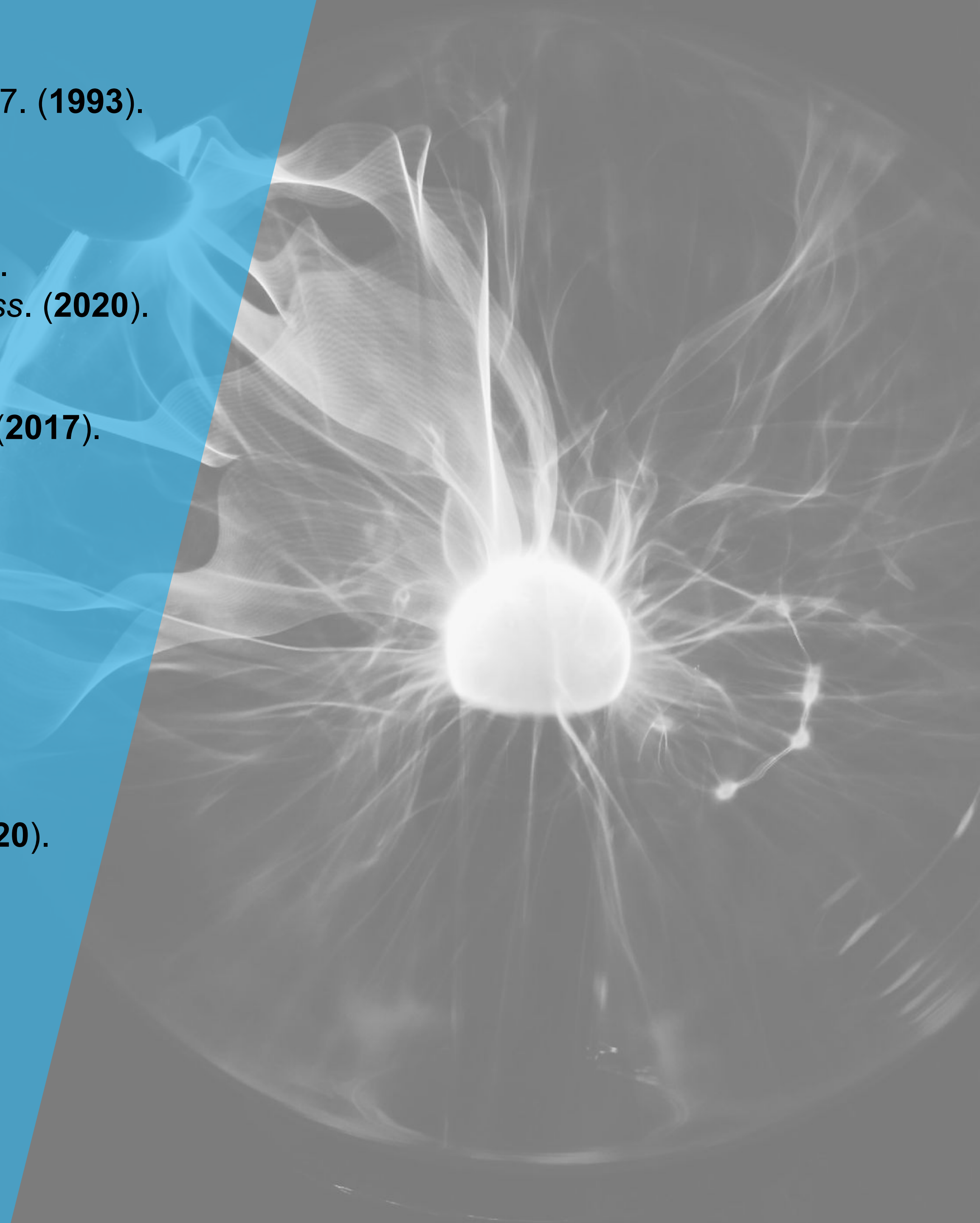
Thesis/Dissertation and Defense



Conclusions

- I am focused on building and testing instruments both on the computer and in the lab.
- FURST is the primary driver, but the applications go beyond.
- I am connecting Heliophysics research to their observational sources.





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Thank you!
Any Questions?

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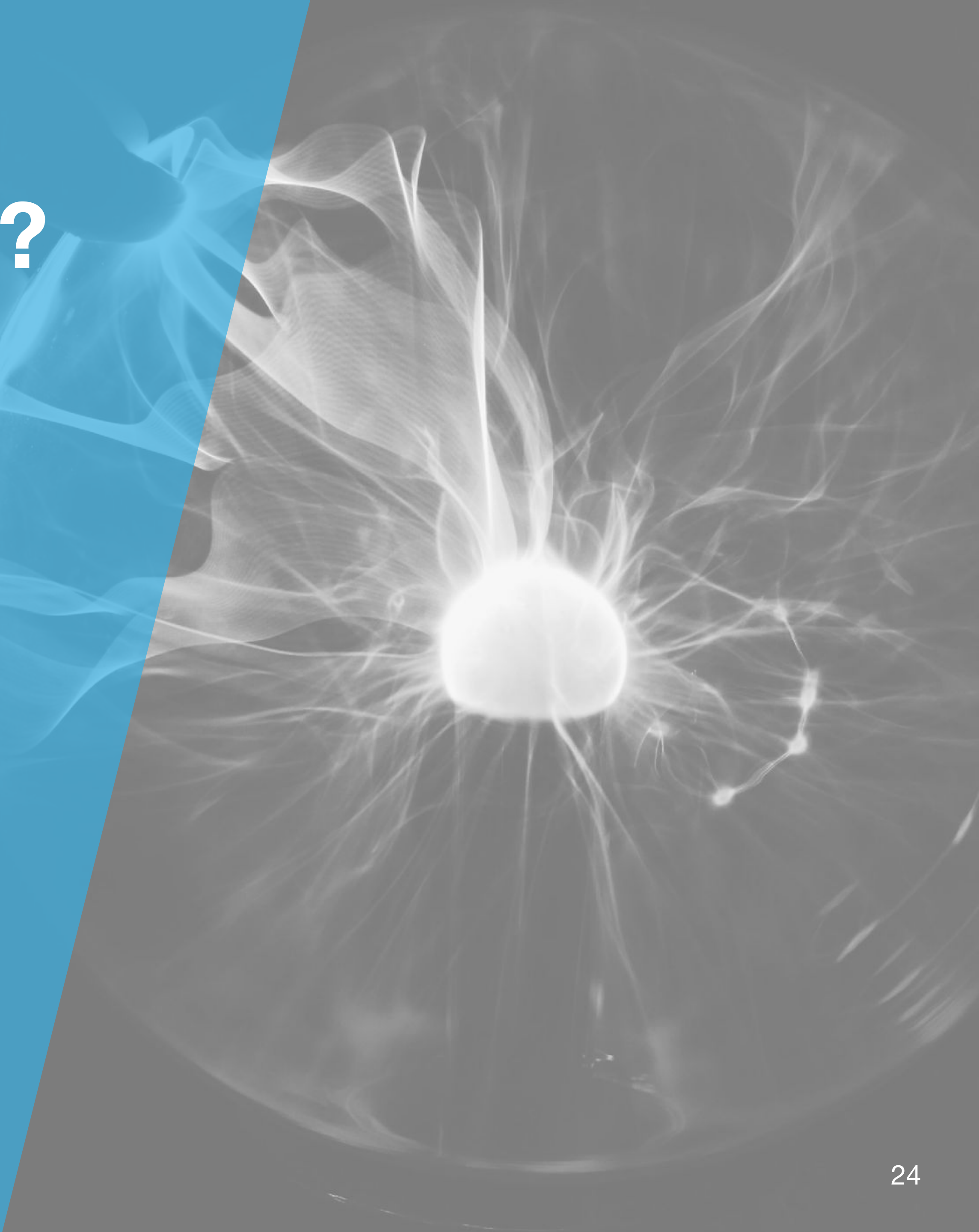

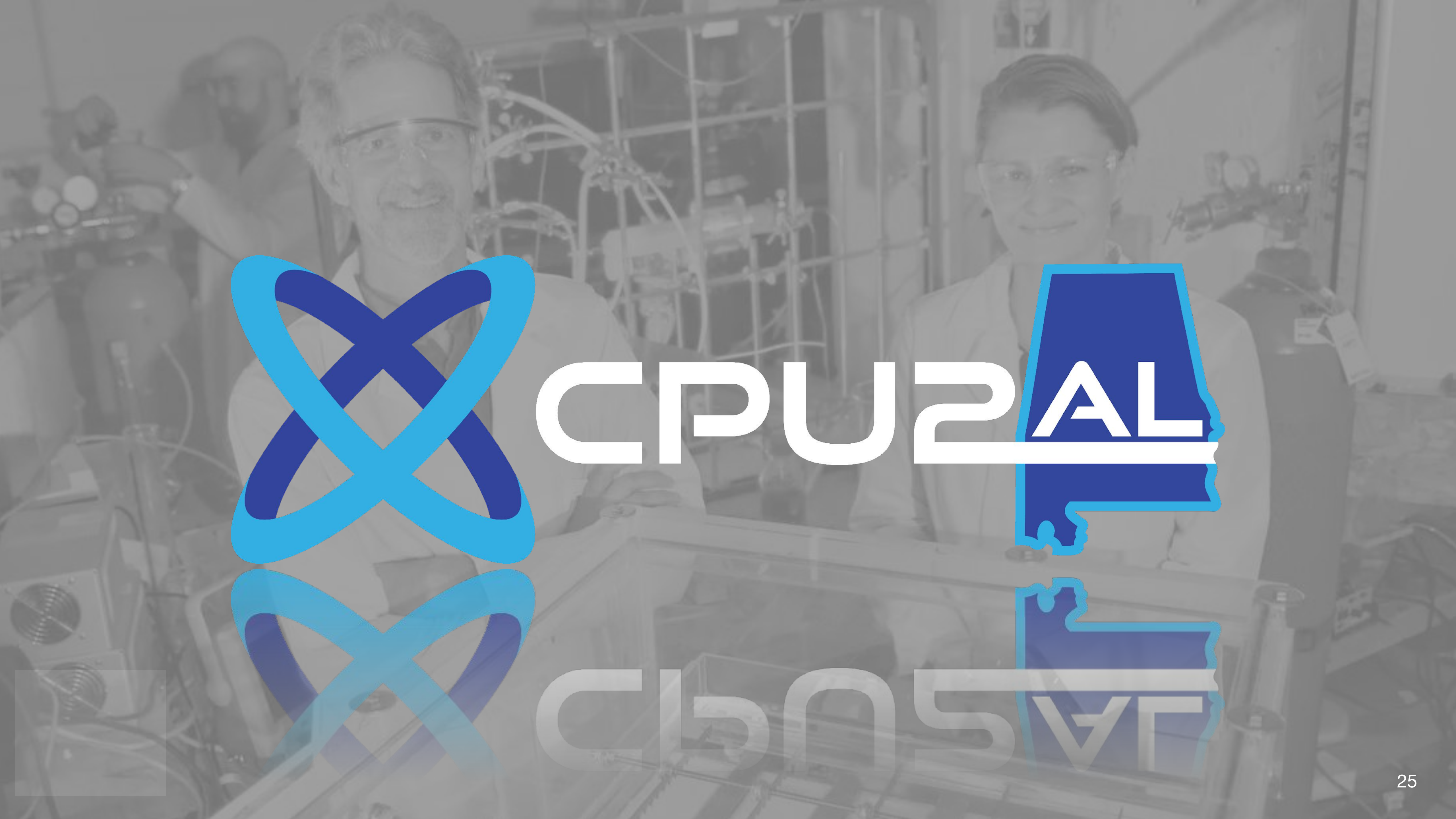
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