COSMOdern: an HST/COS Monitoring System for the Contemporary

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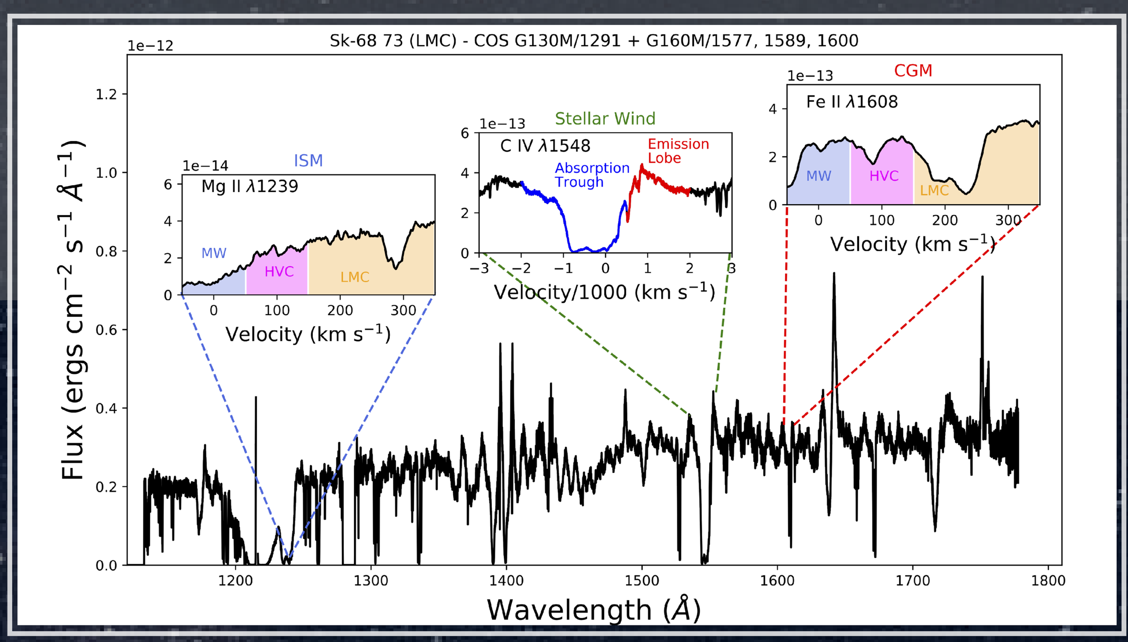
The Hubble Space Telescope and the Cosmic Origins Spectrograph

The **Cosmic Origins Spectrograph** (COS) was installed on the **Hubble Space Telescope** (HST) in May 2009. COS performs high-sensitivity, medium- and low-resolution spectroscopy of astronomical objects in the 815-3200 Å wavelength range. COS significantly enhances the spectroscopic capabilities of HST at ultraviolet wavelengths, providing observers across astronomy with unparalleled opportunities for observing faint sources of ultraviolet light.

The primary science objectives of the instrument are the study of the origins of large scale structure in the universe, the formation and evolution of galaxies, the origin of stellar and planetary systems, and the interstellar and intergalactic mediums.

Below. A COS spectrum of Wolf-Rayet star Sk-68 73 in the Large Magellanic Cloud.

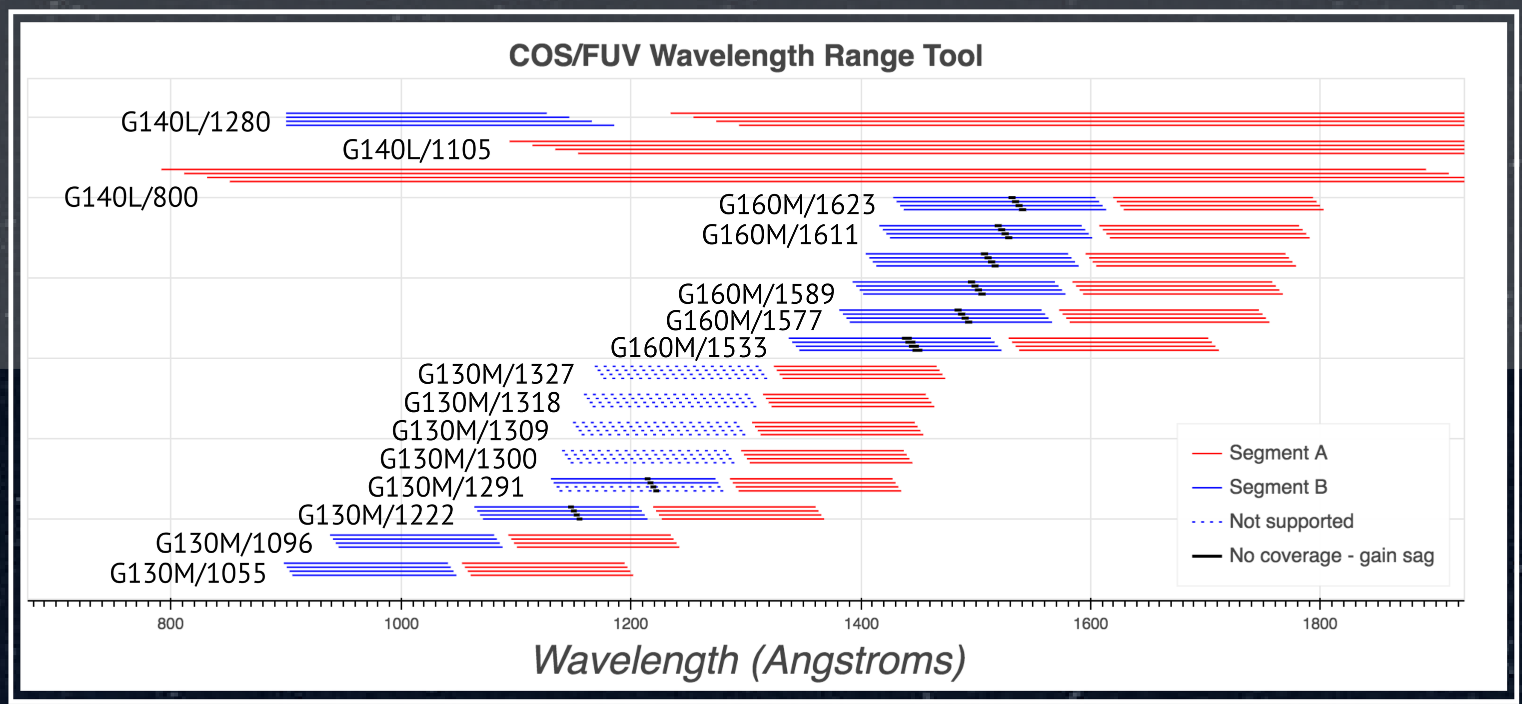


COS Monitoring and the COS 2025 Initiative

As HST and COS hold importance for the astronomical community, and with no planned future servicing missions to the telescope, the COS 2025 Initiative represents the interests of retaining the scientific capabilities of the instrument until 2025 and ideally beyond. The Far Ultraviolet (FUV) microchannel plate detectors of the instrument are vulnerable to a decrease in gain over time with continued usage and therefore regions of the detector become unusable--resulting in restrictions placed on what modes are available for use.

In addition to these restrictions and lifetime position changes (reconfiguring the optical paths for data to fall on pristine regions of the detector), **COS Mo**nitoring (COSMO) efforts have been paramount in extending the best scientific lifetime of the instrument. As the instrument ages and the landscape of software systems in astronomy evolves, it is both imperative and possible to build better and better systems that are more efficient and more targeted at answering the questions we need to ask. It is with these ideas in mind and the availibility of new tools that we set out to build an updated system.

Right. The COS/FUV Wavelength Range Tool is an interactive tool for the community to visualize all available modes and restrictions.



The Next Iteration: Updates for Robustness, Efficiency, and Uniformity

Starting with a simple API

All of the important elements that require routine monitoring on COS come from various data file types. This means that a standardized system for monitoring these elements is extremely important for keeping the system future proof and robust. Our new system emphasizes this by creating a simple set of rules for all monitors that is subdivided into Monitors and DataModels, set by a separate `monitor-framework` package.

Data Model
Represents the monitor's interface with the data necessary for that monitor; defines how new data is acquired and then stored in the database.

Monitor
Must be defined with an associated model; uses the database to access the data, perform computations & analysis, and produce output.

The Impact of Dynamic Visualization

The conclusions we are able to draw from our monitoring rely heavily on visualizing our results in an impactful and efficient manner--efficient in that we can clearly see what is occuring. This is most obviously seen in updates made to our FUV dark monitor. Both the legacy monitoring system (*below*, top) and the active system (*below*, bottom) plot the dark rate computed on the detector over time, with the solar radio flux in a subplot. The dark rate has long been established to vary with the solar cycle (*as seen by the tall spikes*), but it was difficult to assess where the unusual variation was coming from (*red circles*) until we separated the monitor into subplots corresponding to different regions of the detector. From this analysis, we were able to determine the edges of the detector exhibited abnormal dark behavior, while the remaining majority of the detector followed trends as expected. This led us to redefine background regions for spectral extraction and improve on the methodology used in **calcos**, the COS calibration pipeline.

An Organized and Open-Source System

A modern system means modern practices. For pythonic software systems that means build tests, code coverage, documentation, version control, and open source software. Find us continuing to build on GitHub!

github.com/spacetelescope/monitor-framework/
github.com/spacetelescope/cosmo/

```
cosmo/
├─cosmo/
│  ├─monitors/
│  │    data_models
│  │    monitors
│  ├─retrieval/
│  │    *legacy system for collecting all COS data*
│  ├─sms/
│  │    *database building for internal HST
│  │     scheduling files*
│  └─helper modules
├─docs/
├─tests/
└─coverage, build, setup files
```

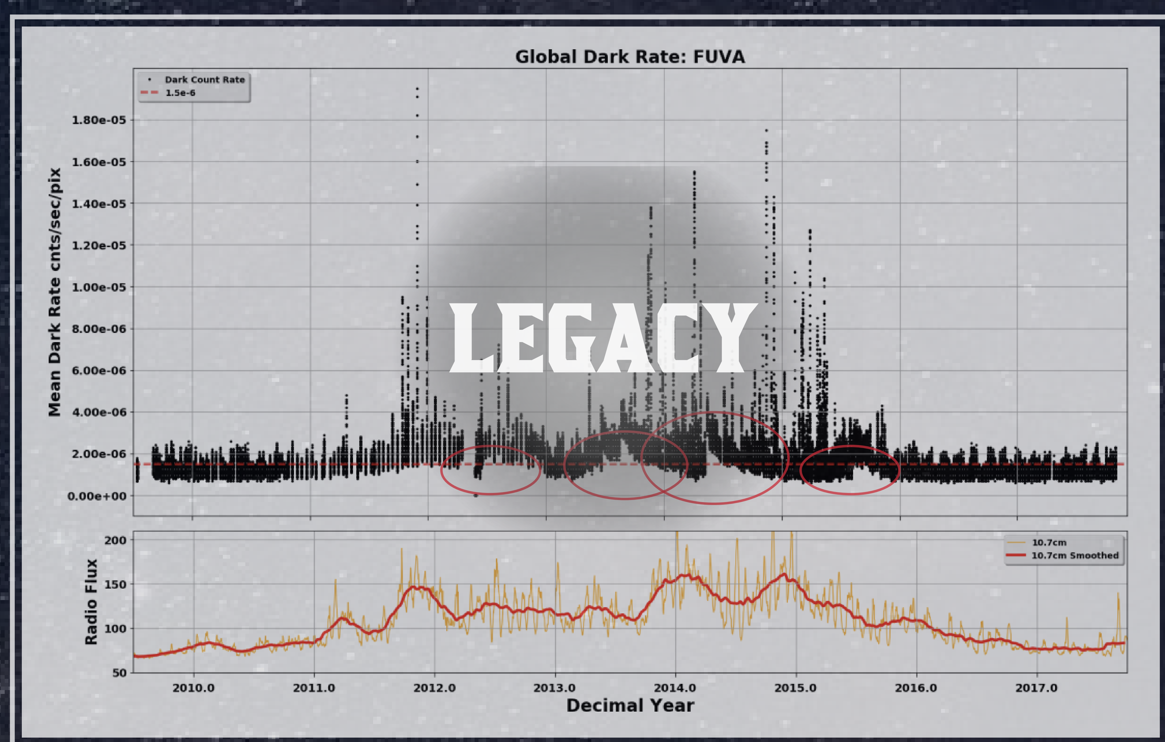
State-of-the-art building blocks

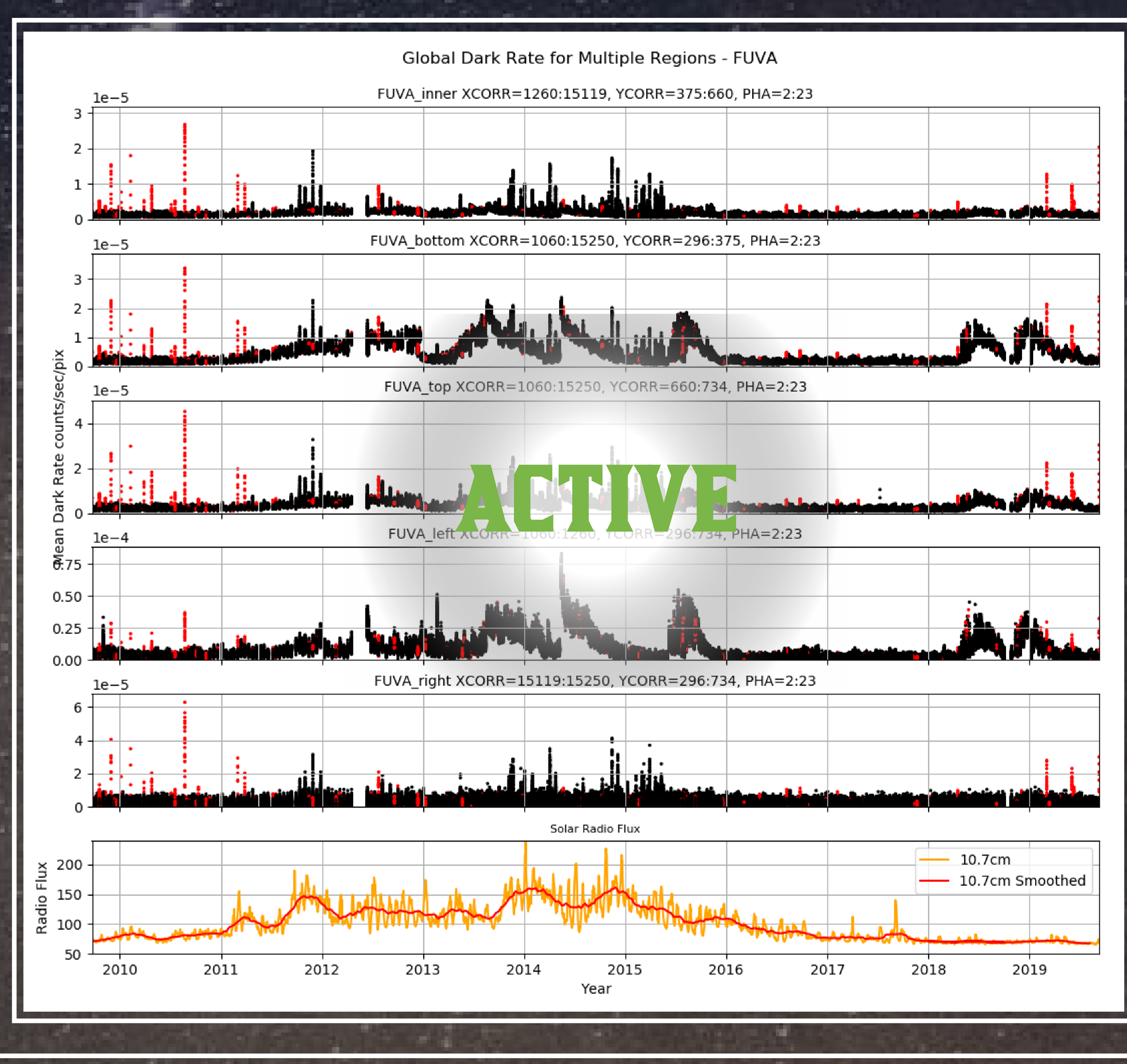
These aren't your kid's legos. As the python software empire booms, state-of-the-art, well-established packages have become available to us for use in updating our system.

dask is an advanced library for parallel computing in python; easily used and important for processing large amounts of data

plotly is a visualization tool for interactive and dynamic plots, allowing us to capture a lot of information at once-check out the demo!

peewee is a lightweight manager for SQL that makes working with databases a lot easier and provides the foundation for data models





References

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