STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

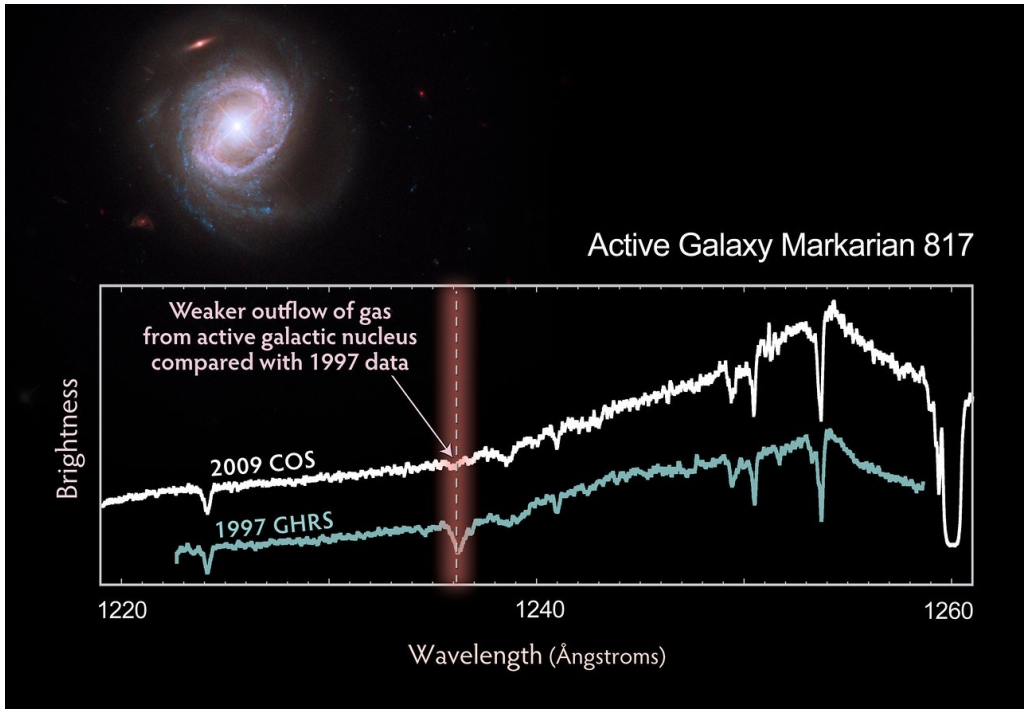
The Hubble Advanced Spectral Products: Enhancing the Legacy of HST Spectral Data

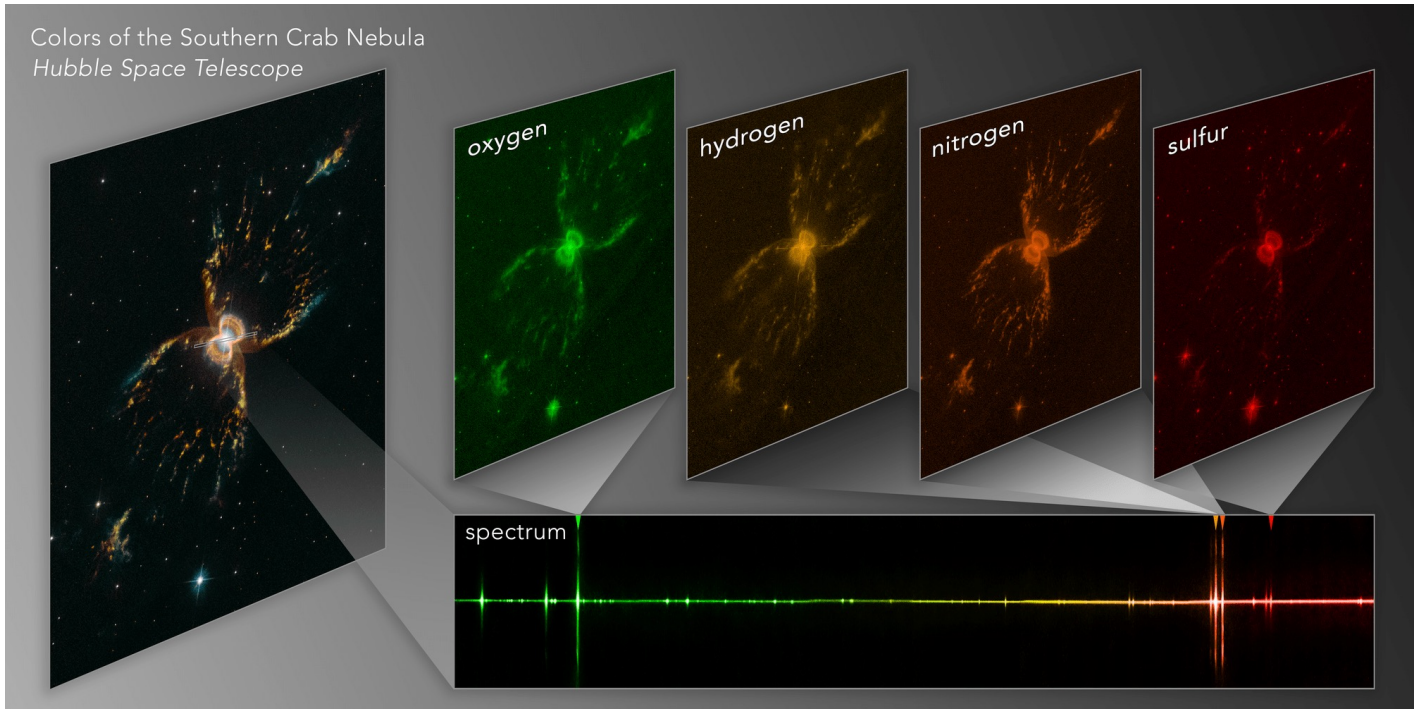
The HASP Team

11/30/2023

The Spectroscopic Legacy of HST

- COS and STIS have observed ~10,000 unique objects spectroscopically
- Over 64,000 datasets from 3200+ programs (and increasing each Cycle)
- How can we extend and improve on the legacy of these spectra?

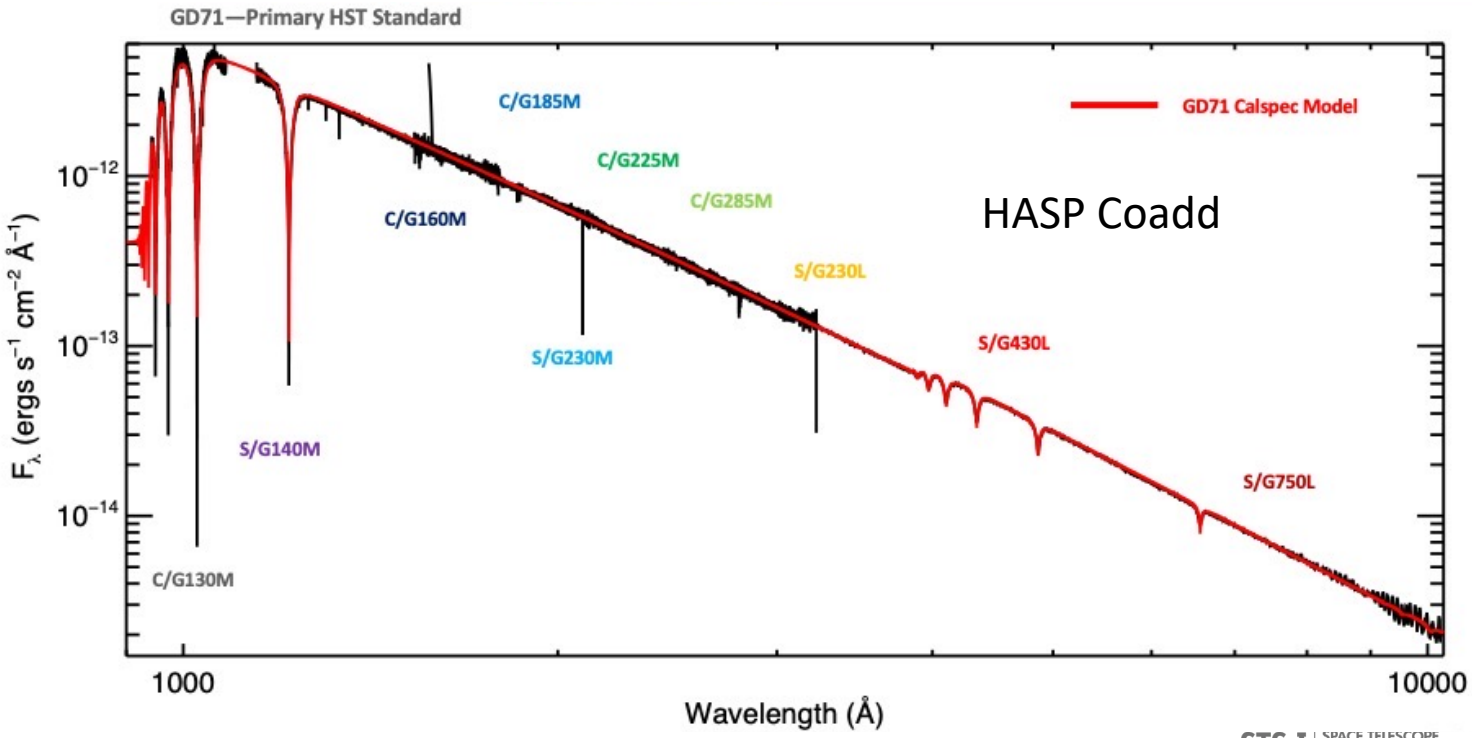




Hubble Advanced Spectral Products (HASP)

- HASP includes automated visit-level and program-level coadds of 1-D spectra as FITS binary tables for public and proprietary COS and STIS spectra
- Individual coadds for gratings and instruments
- Combined coadds of all modes into a single “quicklook” high quality spectrum

- Different modes are abutted according to a prioritization list for the various COS and STIS modes—flexible for the given set of input data
- Provenance table that records which input spectra were included
- Coaddition procedure built upon heritage ULLYSES **coadd** code infrastructure and original HSLA (Peeples+17)



The HASP Team is a collaboration of INS and DMD

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**primary coadd code developer

HASP requirements

- Requirements are for non-variable isolated and compact sources with successful 1-D extractions (i.e. x1d or sx1 products)
  - Compact source: r_{source} ~<0.3”
- >75% of coadds should have flux and wavelength accuracy within 5% of the input x1d spectra
- Absolute flux and wavelength accuracy should meet the requirements of individual modes when tested against known flux standards
- HASP will pre-filter failed observations to meet the above requirements

Pre-filtering potentially problematic datasets

Observing issues:

- Guide star acquisition failures, observatory or detector failure events
    - EXPFLAG (exposure data quality flag) anything other than 'NORMAL', EXPTIME (exposure time) is zero seconds or shorter than expected, take data flag down, FGSLOCK (fine guidance system lock) is not 'FINE

Observation parameters:

- Pointing offsets not in dispersion direction, mosaics
- OPT_ELEM (grating) = PRISM (STIS only)
- APERTURE = BOA (Bright Object Aperture) (COS only)

Target parameters (a coadd may be produced):

- Moving targets (only visit-level coadds with the same target name)
- Variable targets, extended targets (not rejected by default, but some exposures may be removed by the code's flux checking routine)

Flux Checking

- Some problematic datasets might slip through the above filtering—the goal is consistency at the requirements of absolute flux calibration level
- As a final check, we assume that a problem input spectrum will likely have less overall flux than a nominal one for a non-variable source
- The `coadd` code does a flux check for anomalous datasets and rejects any dataset where:

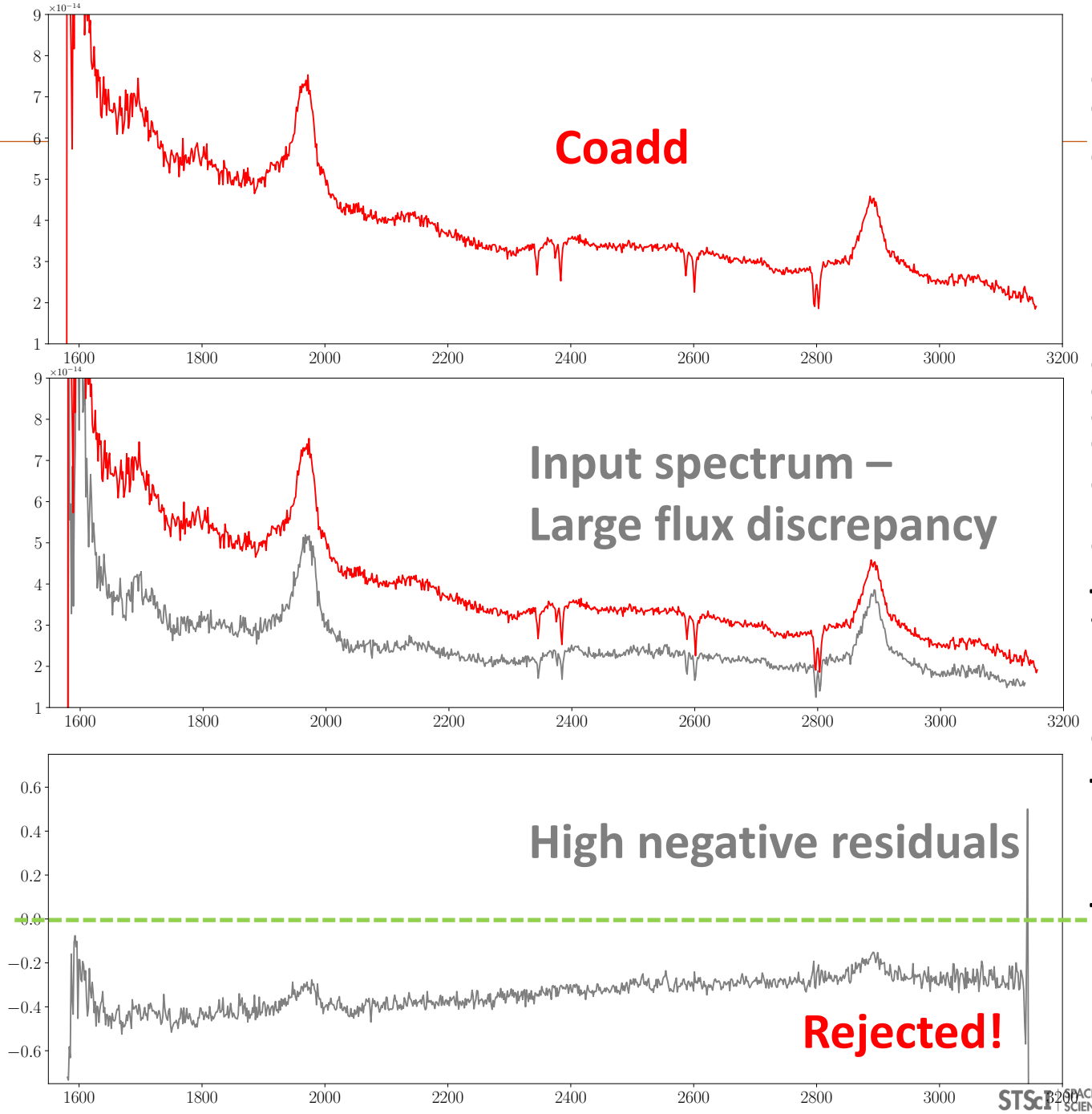
$$\left\langle \frac{F(i)_{x1d} - F(i)_{coadd}}{\sigma(i)_{x1d}} \right\rangle < \frac{-50}{\sqrt{(N_{pix})}}$$

$$\sigma(i)_{x1d} \sim F(i)_{x1d} / \min(SNR, 20)$$

Note: STIS (CCD, MAMA) COS(MAMA) N_{pix}=1024
COS (FUV) N_{pix}~ 14000

Flux Checking

- An initial coadded spectrum is made (**red**) incorporating all input spectra
- Each input spectrum's flux is compared against the coadd (residuals illustrated by green dashed line)
- Those that fail the check criterion are rejected (gray)
- A new coadded spectrum is subsequently generated from the retained input spectra (blue)
- Flux checking and algorithm repeats iteratively until no additional input spectra are rejected from coadd



Example: Mrk 817 with STIS G230L – PID 16196

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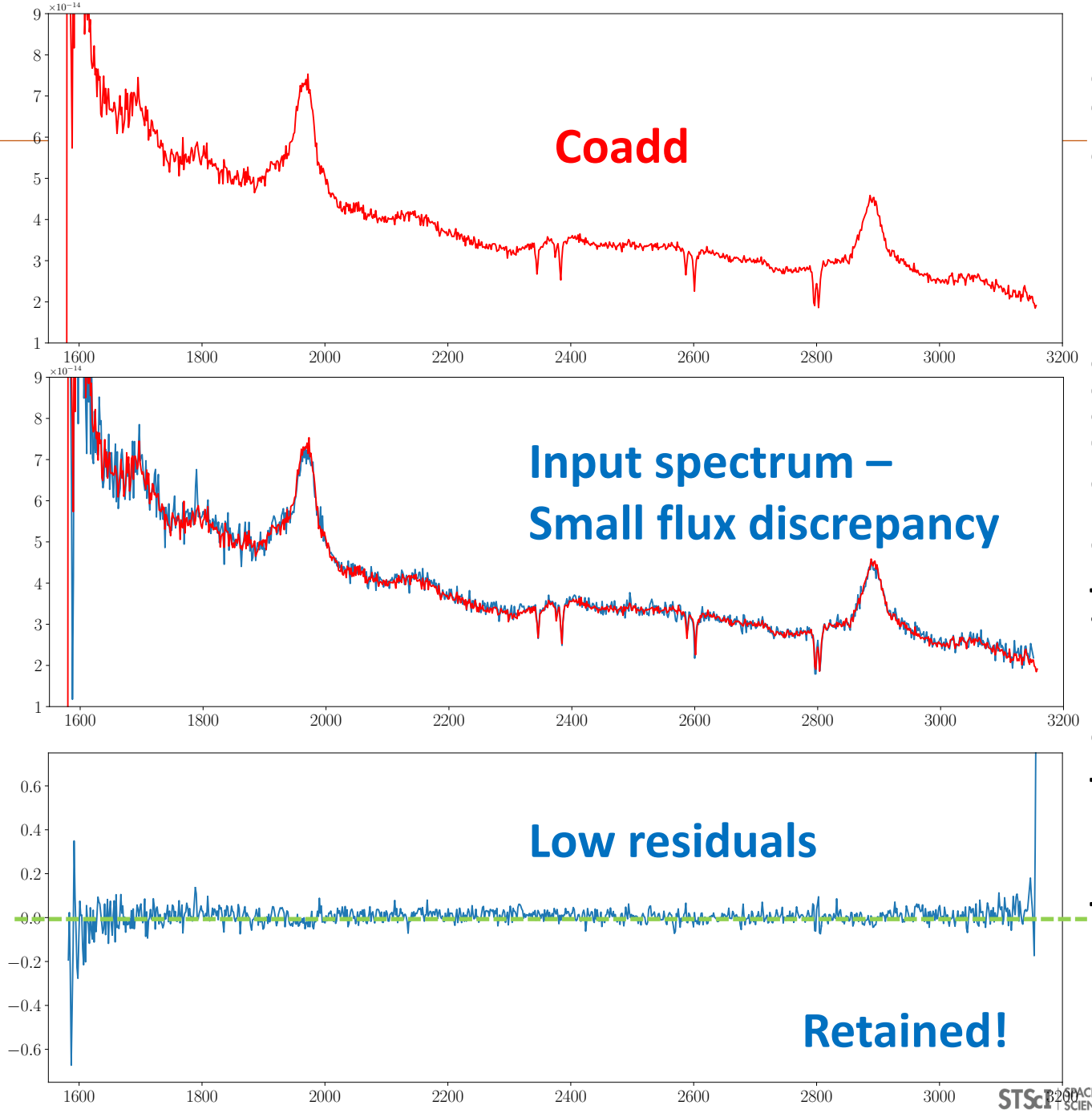

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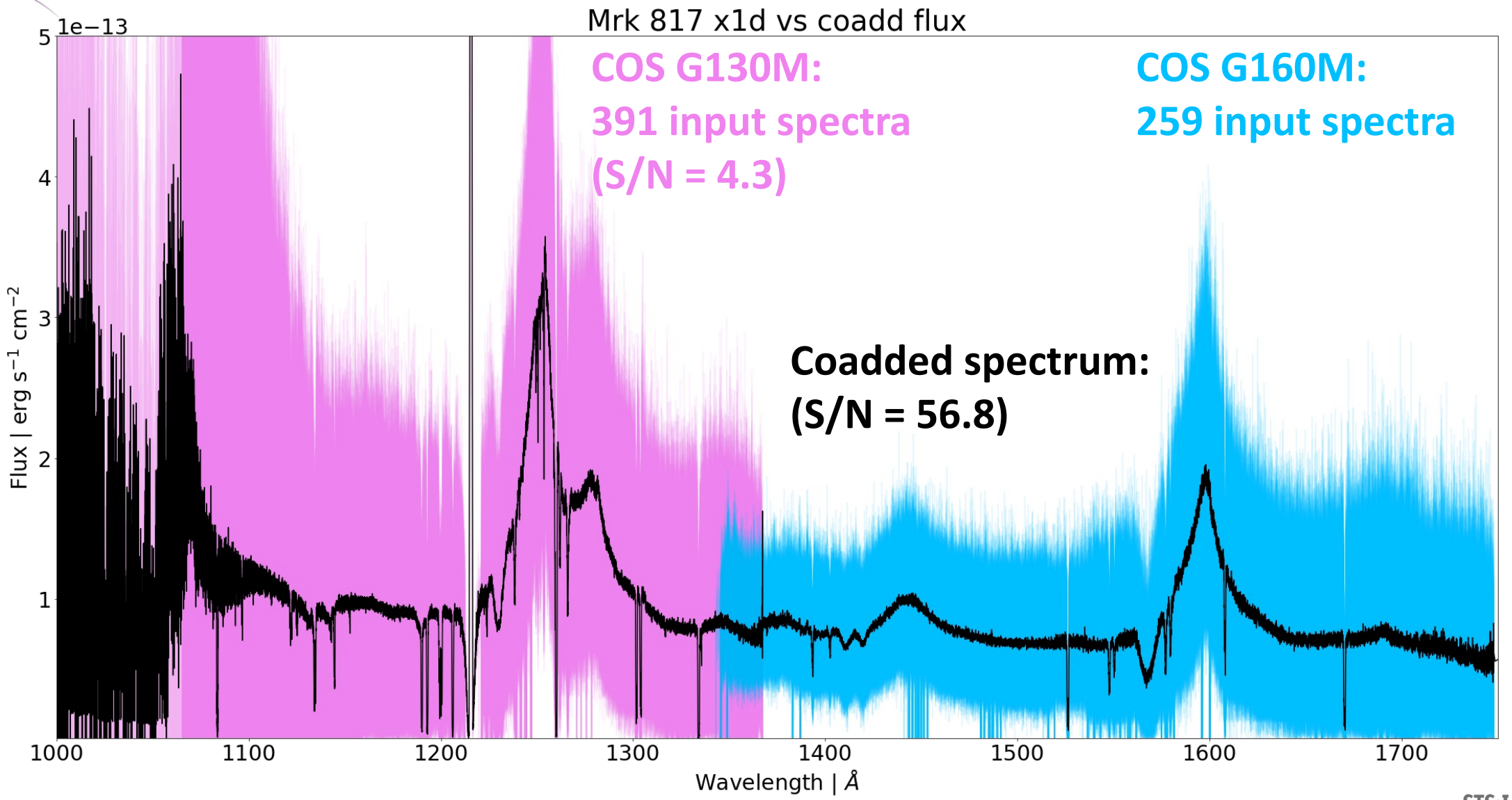
Example Coadditions



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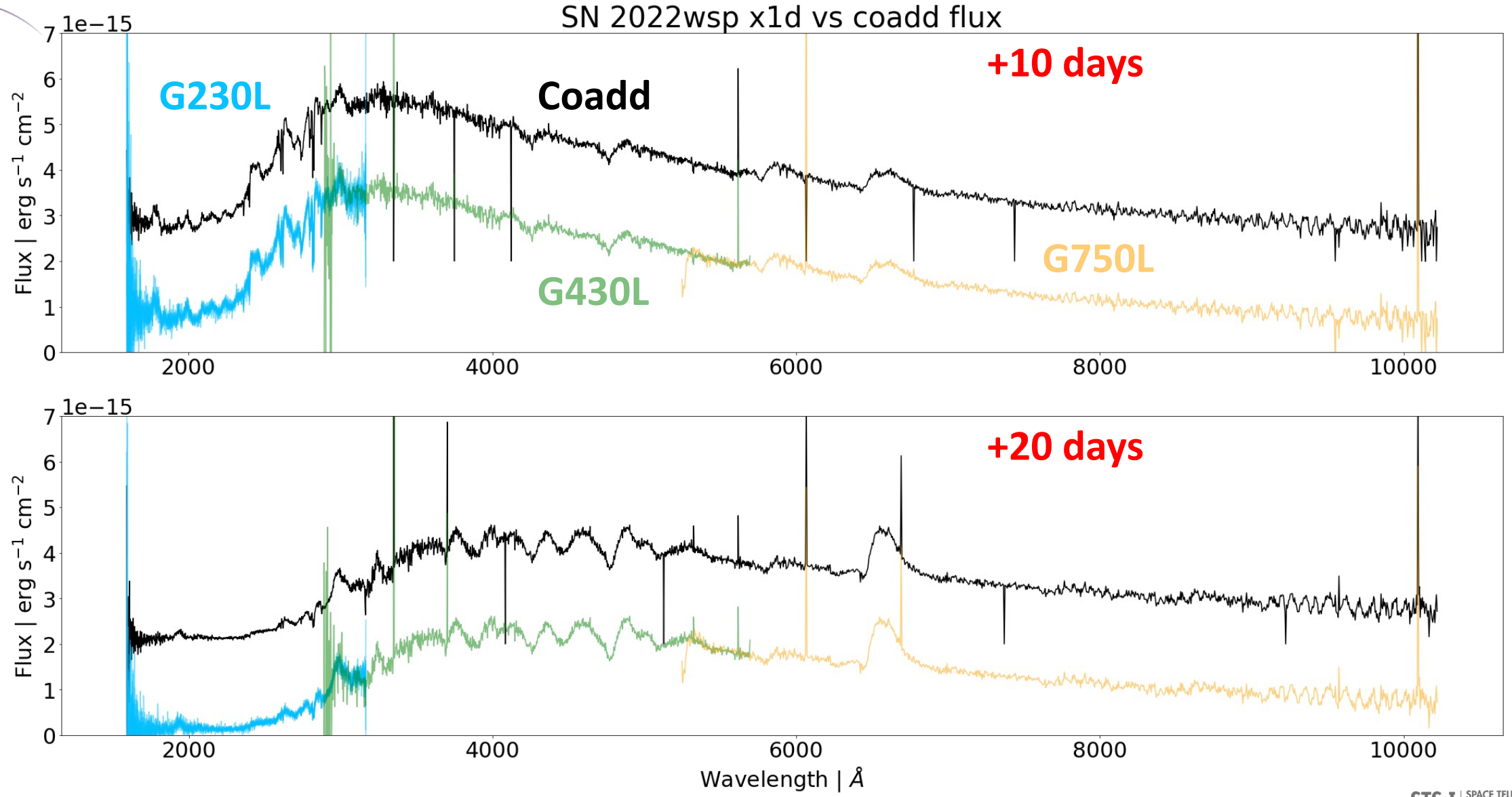
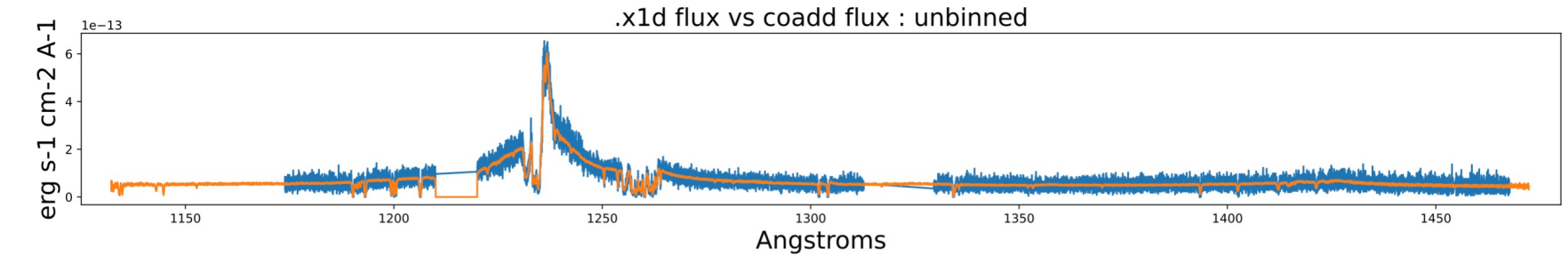
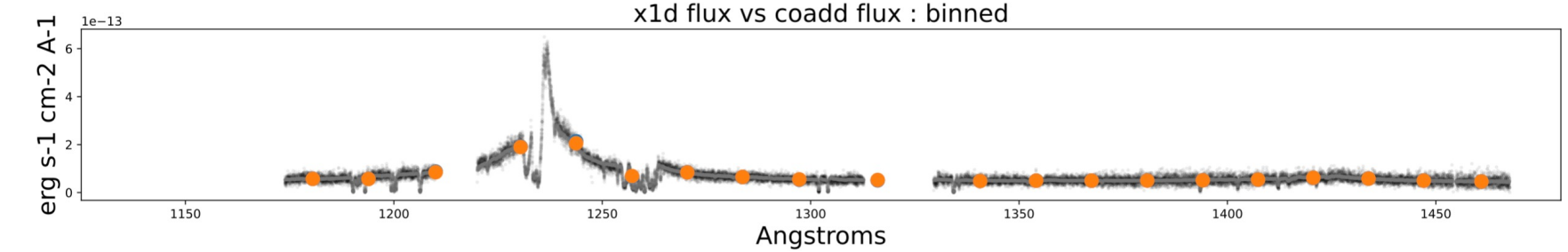
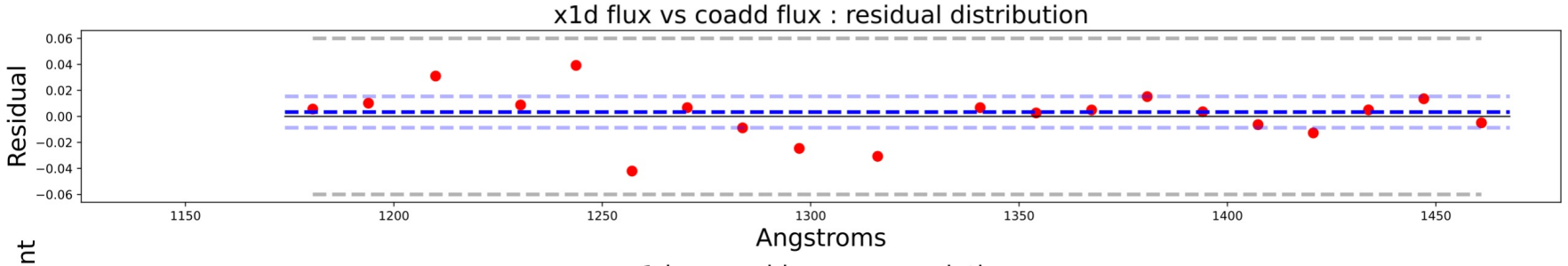
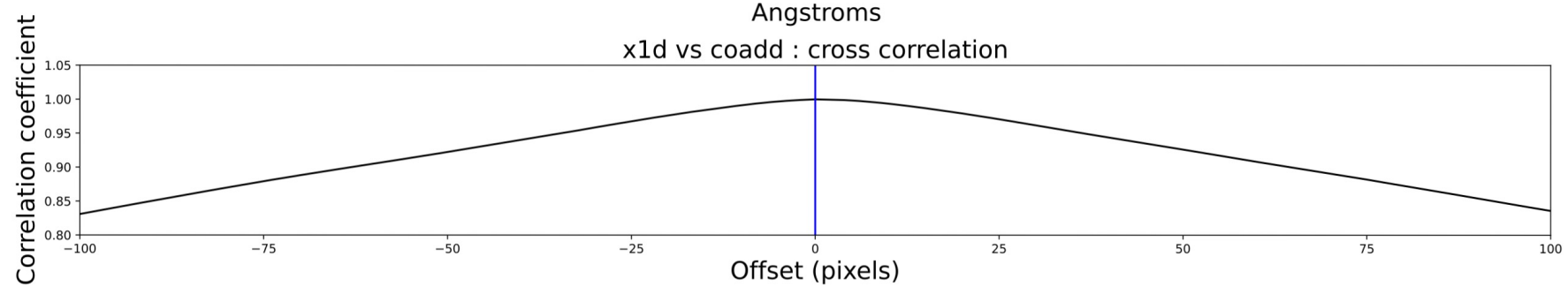


Validating HASP — flux and wavelength









Validating HASP — flux and wavelength

Total Datasets: 89161 | COS 53177 STIS 35934

Flux Testing - Residual median and standard deviation < 5%

% with 4+ high SNR bins: 79%| COS 71% STIS 88%

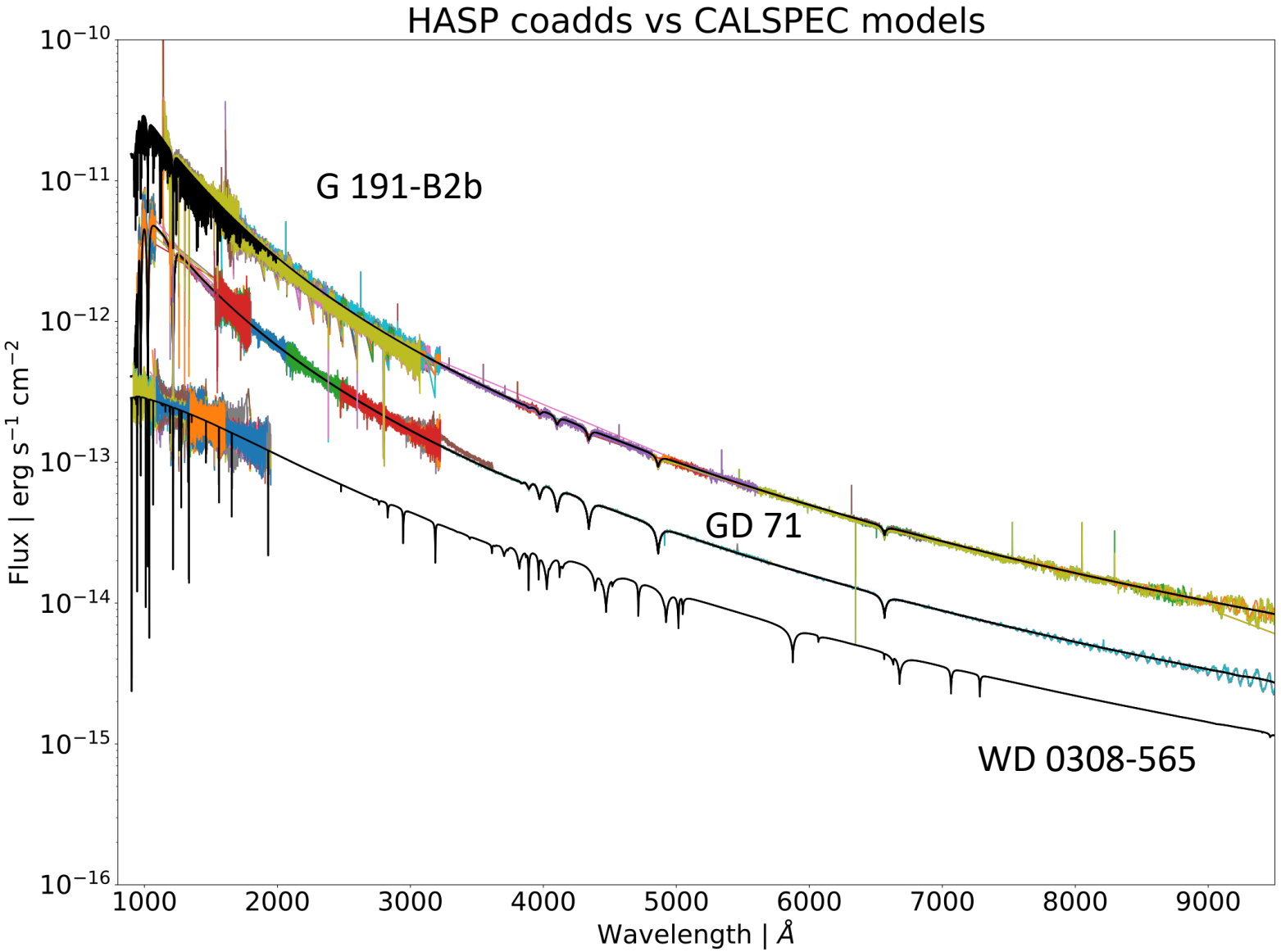
Success Rate: **91%**| COS 94% STIS 89%

Wavelength Testing - Wavelength offset < 2 pixels

Success Rate: **97%**| COS 99% STIS 95%

Exceeds target requirement success rates of >75%

Validating HASP — comparison to flux standards



Custom Coaddition-An integral part to HASP

Motivation

- Some good quality datasets are rejected by default due to the prefiltering that the `coadd` wrapper performs
- Some data require additional custom processing that cannot be automated
- Some users will want to coadd differently to make specialized products

Goals

- Demonstrate how to install and use the codes
- Show examples of custom data processing and coadd creation
- Make these publicly available and easy to use!

Custom Coaddition notebooks – ready to go!

Setup:

- Shows how to setup a conda environment, install the HASP `coadd` package, and run the scripts
- Explains the data product filename conventions

Introduction to `coadd`:

- Demonstrates using Astroquery to download data
- Shows how to create your own coadded data products
- Shows how to change the threshold of the flux checker

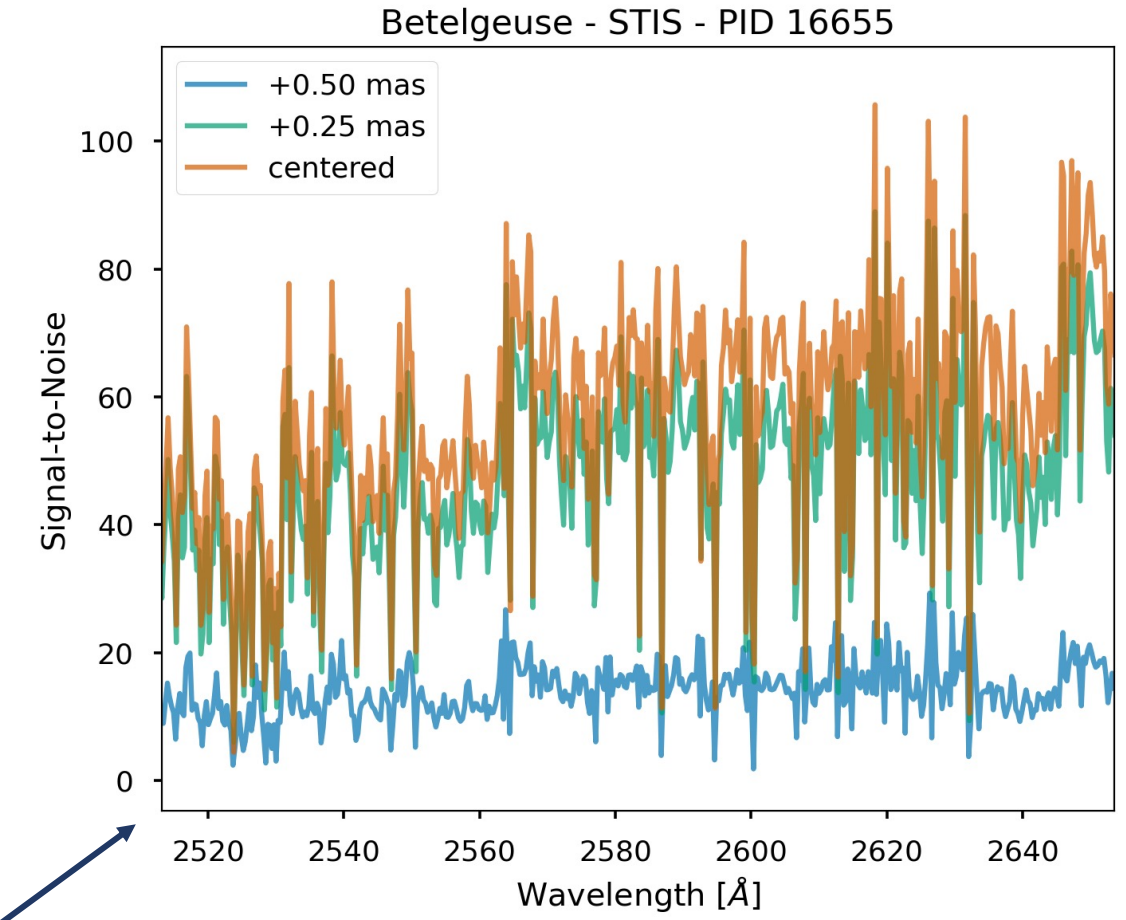
Custom Coaddition Notebooks – ready to go!

Data diagnostics

- Shows how to read output logs from **coadd** to determine which datasets were rejected and why
- How to run **coadd** with the default rejection criteria turned off to create custom data products

Examples include:

- Assessing the quality of a dataset observed partially in gyro guiding and adding it into a coadd
- Turning off the flux filtering to allow all datasets to be included in the coaddition to detect weak spectral features
- Coadding datasets of a star observed at different POSTARG offsets across visits



Custom Coaddition Notebooks – ready to go!

Flux scaling

- Shows how to scale input spectra to the same median flux, and then use **coadd** to create custom data products
- Designed for users whose science does not depend on the accuracy of a dataset's absolute flux, and/or who would like coadditions of datasets that may be rejected by the flux checker

Releasing HASP and next steps

HASP will be announced at the winter AAS to the community

- Data products available through Astroquery and the MAST portal
- HASP dedicated website live
- HASP ISR published
- HASP custom coaddition notebooks available
- The Mission Search Form will deliver HASP (this will be advertised via newsletter)

Future Work:

- Automated cross-program coadds

➢ HASP sets the foundation for a new, revitalized, and automated HSLA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Unsupported targets or modes

- COS BOA aperture observations
- STIS PRISM observations
- STIS Occulted Spectroscopy modes
- COS NUV G230L Stripe C observations, due to lower sensitivity and contamination from second-order light.
- Moving targets (only visit-level coadds with the same target name)**
- Extended targets with r>0.3”**
- Variable targets**
- Observations with certain PATTERN1 (e.g., 90) and P1_FRAME (e.g., 'POS-TARG') values, or purposes like mosaicking
- Observations with calibration special commanding
- Statically archived data

**A coadd may be produced