

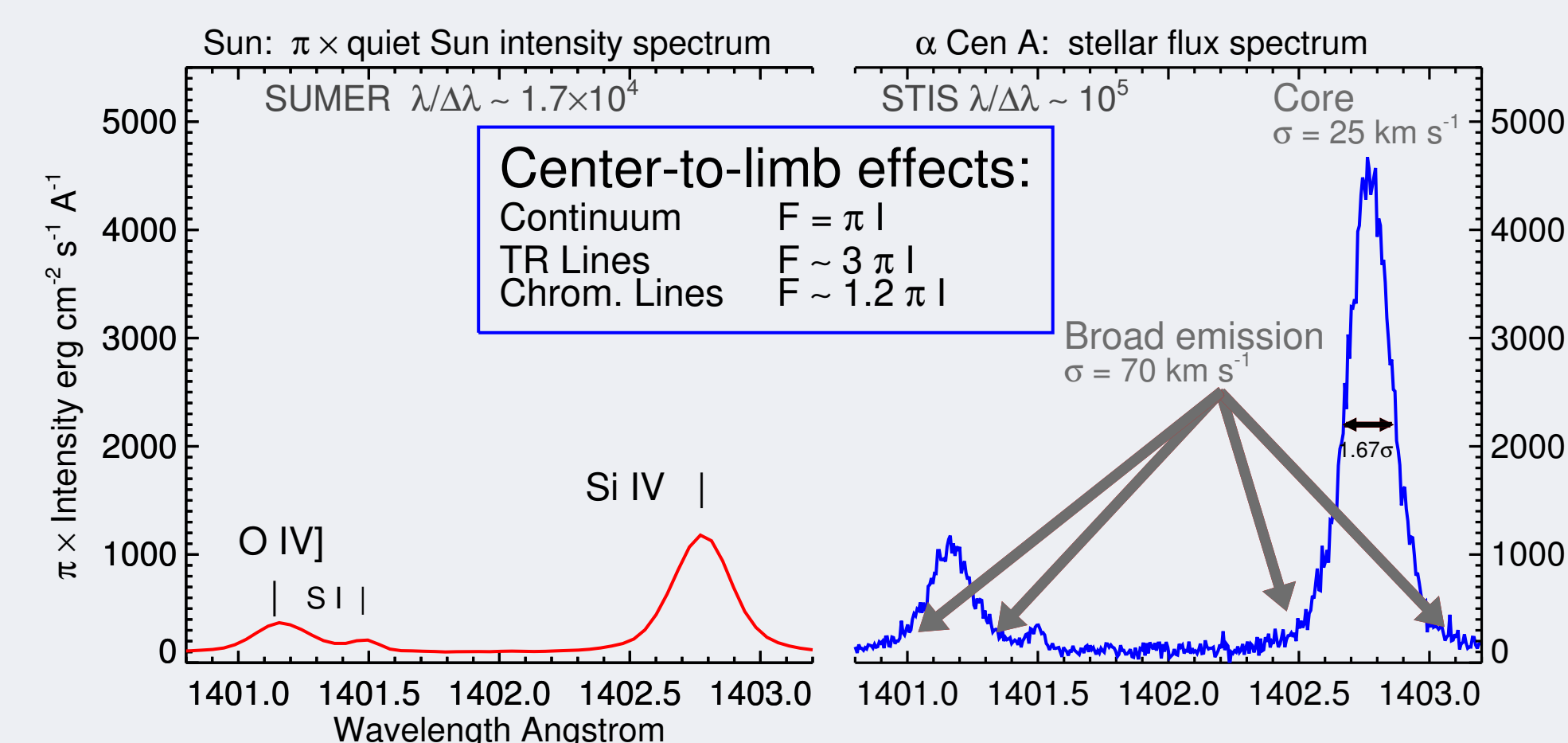
Abstract

We have proposed a sounding rocket mission to obtain the first high resolution, high quality VUV spectrum of the Sun-as-a-star. Our immediate science goal is to understand better the processes of chromospheric and coronal heating. HST data exist for a dozen or so Sun-like stars of a quality already beyond our ability to construct a comparable sun-as-a-star UV spectrum. The solar spectrum we obtain will enable us to understand the nature of magnetic energy dissipation as a Sun-like star evolves, and the dependence of magnetic activity on stellar mass and metallicity. We present the instrument design, scientific prospects, and broader impacts of the mission.

Solar Activity in a Stellar Context

The *Full-sun Ultraviolet Rocket SpecTrometer (FURST)* will obtain the first high resolution VUV spectrum of the Sun-as-a-star.

- HST data of Sun-like stars like α Cen A are of higher quality than existing full-disk solar data.
- Profiles of stellar UV lines reflect magnetic heating processes in chromospheres and coronae, unsolved problems with a 70+ year history. Broad components accompany shifted line cores (Wood et al., 1997).



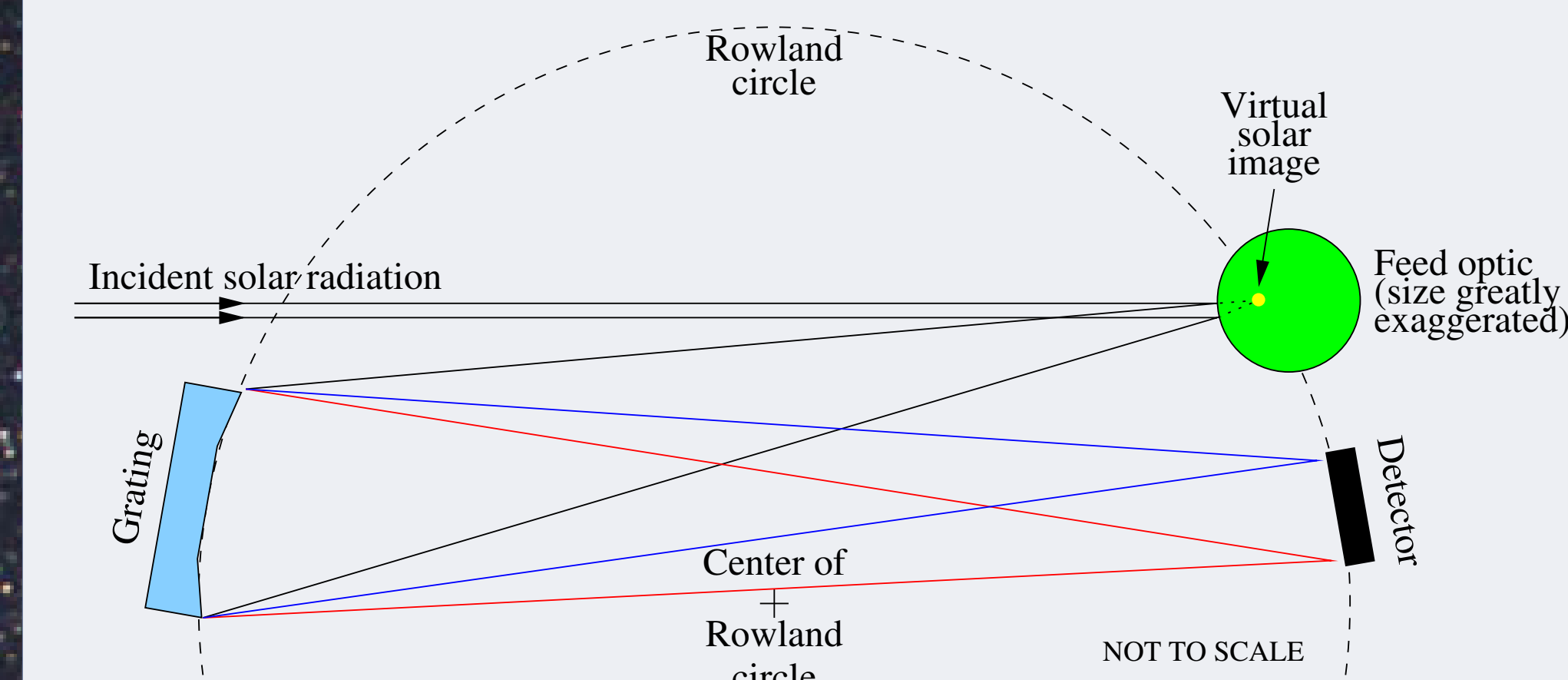
Above, a quiet Sun spectrum (Curdt et al., 2001) is compared to α Cen A (HST/STIS). The continuum spectra are very similar because the center-to-limb behavior is flat. But in the lines, the solar disk center spectrum greatly underestimates the solar flux spectrum which is in fact far closer to the α Cen A spectrum (Judge et al., 2017).

Science Requirements

Science	Driver	Measurement Requirement
Sun-as-a-star, heliospheric and solar system physics	Solar VUV spectral irradiance	Full solar disk observation with VUV spectrometer
Detailed comparisons of solar and HST spectra	HST UV radiometry $\pm 5\%$ STIS [§] /COS $\mathcal{R} = \lambda/\Delta\lambda \approx 2.5 \times 10^4$ UV wavelengths $> 115 \text{ nm}$	Radiometry $\pm 5\%$ $\mathcal{R} \geq 2 \times 10^4$ $\lambda_{\text{min}} = 115 \text{ nm}$
Detect small-scale magnetic reconnection and dissipation (explosive events, microflares)	Distinguish broad components of strong lines from continuum	SNR > 20 in 150 nm continuum
Resolve non-Gaussian line core profiles	TR core turbulent FWHM $\sim 40 \text{ km/s}$ Strong self-reversed lines H I, O I	$\mathcal{R} \approx 2 \times 10^4$
Resonant absorption in atmospheres of solar system bodies	orbital speeds (e.g. Europa) $\pm 13 \text{ km/s}$; sensitive to shifts < 0.1 linewidth [†]	absolute wavelength calibration $\pm 3 \text{ km/s}$
Quantify $\text{Ly}\alpha$ /solar system plasma interactions	H Ly α flux $\approx 100\times$ others	$\lambda 121.6 \text{ nm}$ unsaturated
Plasma diagnostic lines, strong lines	e.g. O I 115.2, C III 117.5, Si III 120.6, La 121.6, N V 123.8, C II 133.5, O IV 140.1, Si IV 139.3, C IV 154.8, He II 164.0, O III 166.0, Al II 167.0, Si II 180.7	cover wavelengths $115 < \lambda < 181 \text{ nm}$

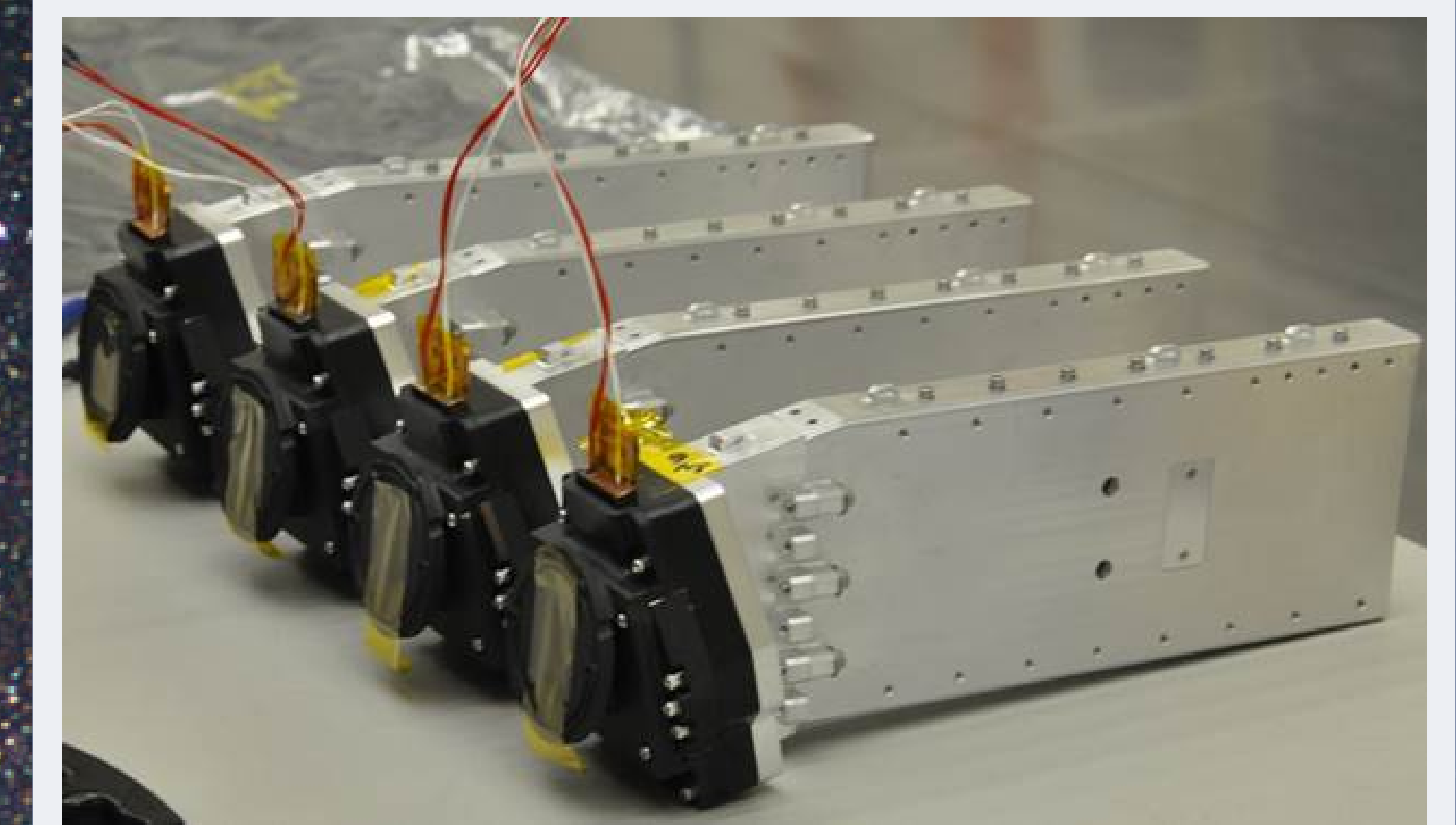
^{*}Pagano et al. (2004); [†](Ghavamian et al., 2009); [§]STIS data handbook, <http://www.stsci.edu/>

Optical Concept



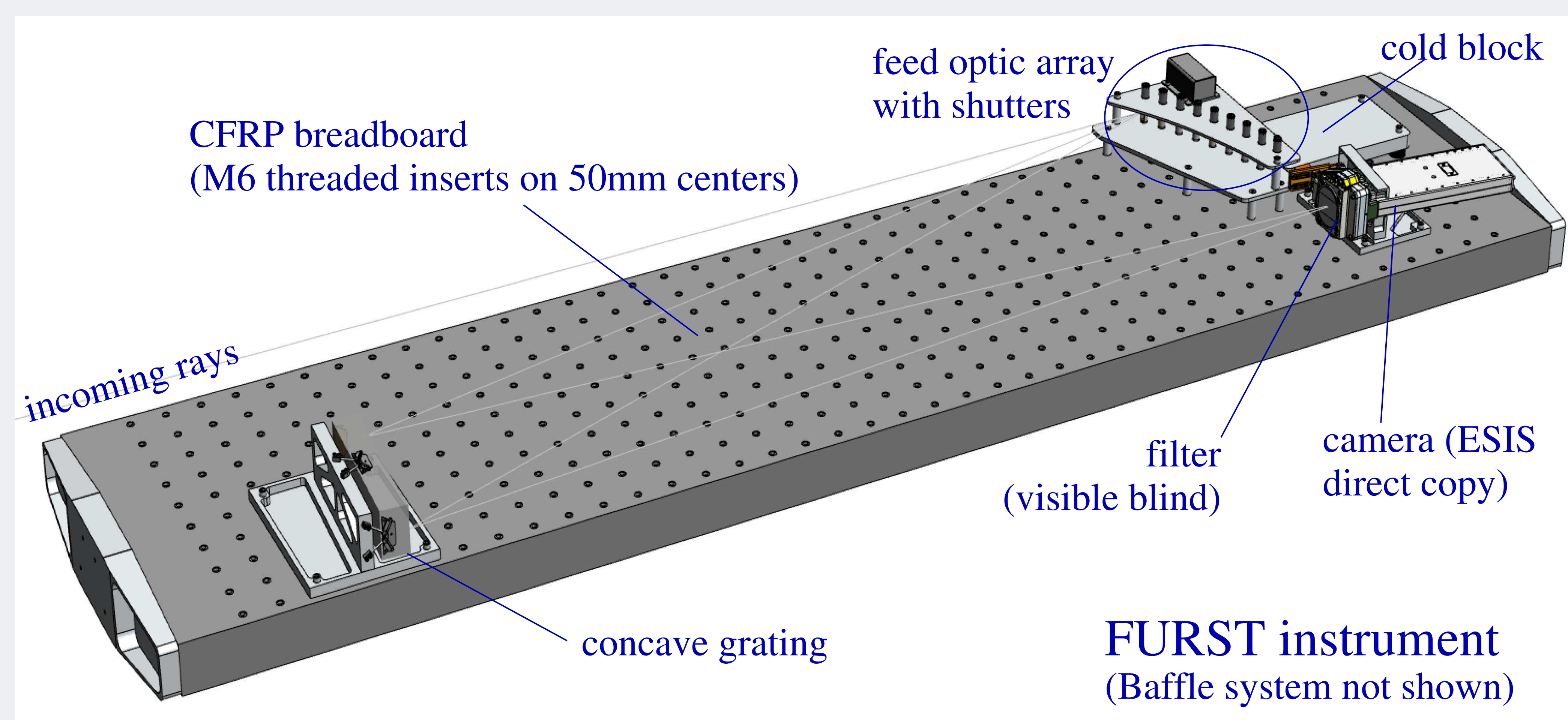
Spectrometer optics, not to scale. A cylindrical feed optic produces a virtual image of the Sun, which is re-imaged by the grating onto the detector. The position of the virtual image along the Rowland circle sets the wavelength range falling on the detector.

Camera System



MSFC will build the FURST camera. It is a direct copy of the ESIS design, derived from Hi-C2. ESIS (EUV Snapshot Imaging Spectrograph) is a NASA Sounding Rocket scheduled for flight in fall, 2018. The picture shows four completed, tested ESIS cameras that are being delivered *this week*.

Full-disk Ultraviolet Rocket SpecTrometer (FURST)



FURST has 9 feed optics, each a 3 mm radius glass cylinder with a broadband UV coating. The feed optic positions correspond to wavelength channels of the instrument. Each feed optic is enclosed in a cylindrical shutter with a slot that rotates to face the Sun when that channel is operated.

Full wavelength range	112-200	nm
Single exposure wavelength range	10.4	nm
Spectral sampling interval	5.06	pm
Effective resolving power, \mathcal{R}	$> 2 \times 10^4$	$\lambda/\Delta\lambda$
Exposure duty cycle (shutter limited)	> 99	%
Signal-to-noise (150 nm continuum)	> 200	CBE

Solar System Science

Strong solar UV line emission is absorbed and scattered in gas and plasma of solar system objects. *FURST* will provide the first full-disk spectra with sufficient resolution to investigate how radiative interactions with solar system bodies are modified by orbital Doppler shift. For Europa and Enceladus, the solar spectrum is Doppler shifted by $\pm 13 \text{ km/s}$ during the orbit; in comets it can approach several hundred km/s.

References

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