Airborne Instrumentation for Solar Coronal Studies

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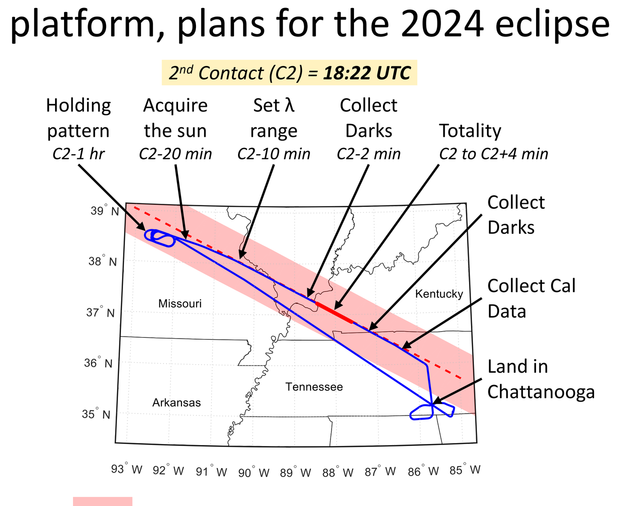
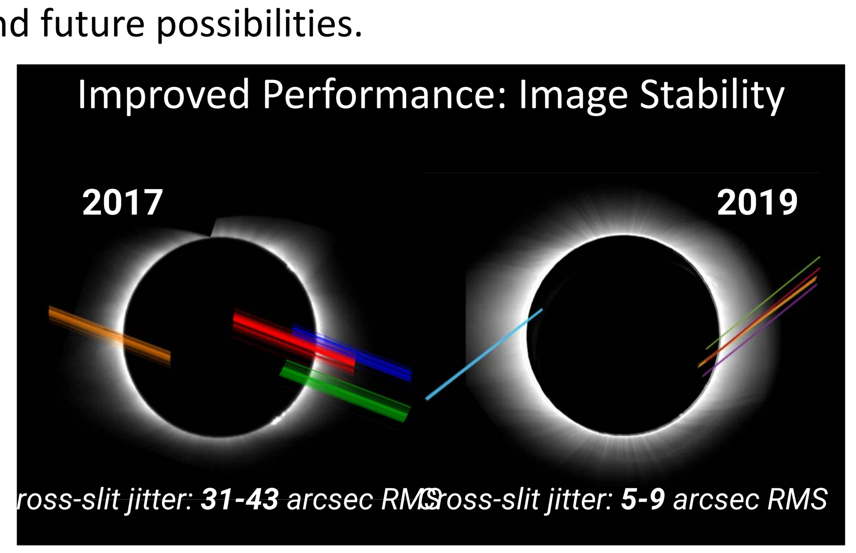
Airborne instrumentation has been used to explore the mid-infrared corona through solar eclipse observations [1], [2]. Existing platforms, the NSF/NCAR Gulfstream V (GV) and NASA's WB-57F, provide infrastructure that future instrumentation can utilize. We give an overview of recent science from airborne eclipse observations. We then describe the Airborne Stabilized Platform for InfraRed Experimentation (ASPIRE) for the GV and the potential for new instrumentation on the WB-57s using the existing Airborne Imaging and Recording System (AIRS) pointing platform and possible future options.

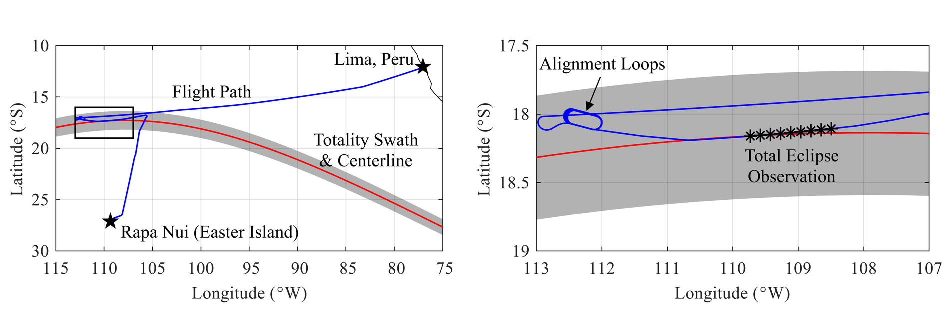
SAO & NCAR AIR-Spec Team, US embassy staff and Peruvian academic and government scientists.

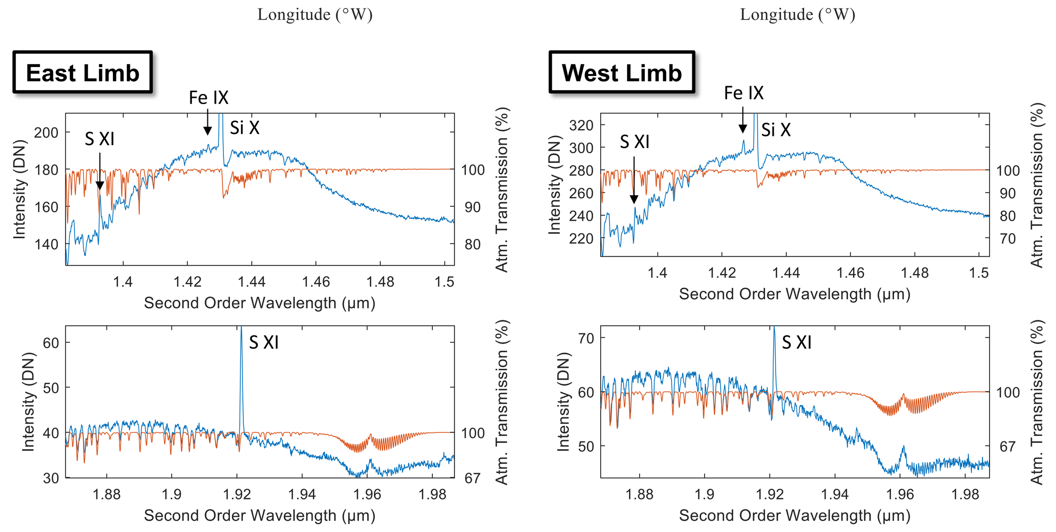
AIR-Spec on-board the GV for the 2019 Eclipse

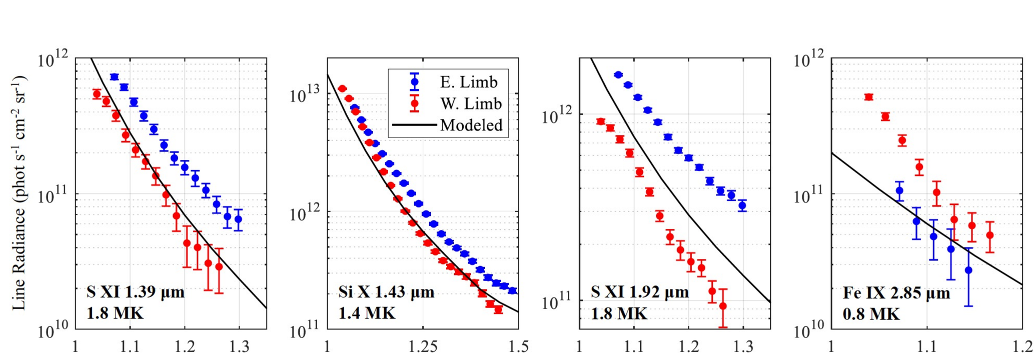
The NSF funded AIR-Spec, ASPIRE and ACES programs use the NCAR Gulfstream V High-performance Instrumented Airborne Platform for Environmental Research (HIAPER) aircraft. This platform allows for deployment across the globe as the jet has no restrictions for its deployment. The AIR-Spec program had successful flights during the 2017 and 2019 total solar eclipses. These two flights demonstrated the flexibility of the observing system as sun was on the south side of the aircraft during 2017 and on the north side during 2019. Eclipse flights in the Antarctic in 2020 and 2021 were planned and only canceled due to international travel restrictions caused by the pandemic. We describe the results from the the successful eclipse observations, the capabilities available to the community with the new ASPIRE platform, plans for the 2024 eclipse and future possibilities.











The Airborne Coronal Emission Surveyor (ACES) is an imaging Fourier transform spectrometer to observe the solar corona from the NSF Gulfstream V during the 2024 total solar eclipse across North America. ACES will observe the 1–4um wavelength region to look for lines that may be viable candidates for measuring the coronal magnetic field and plasma diagnostics at large solar radii. ACES is a new focal plane instrument enabled by the Airborne Stabilized Platform for InfraRed Experiments (ASPIRE). It builds on the success of ASPIRE and AIR-Spec to expand the infrared window for plasma and magnetic field studies of the sun's outer atmosphere.

λ (nm)	Ion	LogT (K)	FIP (eV)	Fit Error (%) QS	Fit Error (%) AR
1014.3	Ar XIII*	6.45	15.76		5.1
1030.1	S XIII*	6.40	10.36		16.9
1074.9	Fe XIII	6.25	7.90	0.7	0.3
1080.1	Fe XIII	6.25	7.90	0.8	0.5
1083.3	He I	4.50	24.59	4.9	6.3
1252.4	S IX	6.05	10.36		12.7
1392.8	S XI	6.25	10.36	22.5	4.0
1430.5	Si X	6.15	8.15	1.1	0.8
1920.1	S XI	6.25	10.36	11.7	3.2
1935.0	Si XI*	6.20	8.15	20.8	10.0
1963.0	Si VI*	5.60	8.15	6.7	
2206.3	Fe XII*	6.20	7.90	6.9	8.3
2218.3	Fe IX*	5.90	7.90	9.5	17.2
2265.0	Ca XIII*	6.50	6.11		14.2
2482.6	Si VII*	5.80	8.15	3.2	15.0
2584.6	Si IX*	6.05	8.15	5.3	5.9
2856.3	Fe IX	5.90	7.90	7.9	17.3
3028.5	Mg VIII	5.90	7.65	3.2	12.8
3927.7	Si IX	6.05	8.15	5.3	12.1

Table 1. Strong lines in the 1–4 μm range. Density sensitive line pairs and high-FIP elements are highlighted. Asterisks indicate lines that have not been observed [4]. The last two columns give the uncertainty (due to photon noise) in the measured line intensity at 1.1 R⊙ in the quiet sun (QS) and an active region (AR).

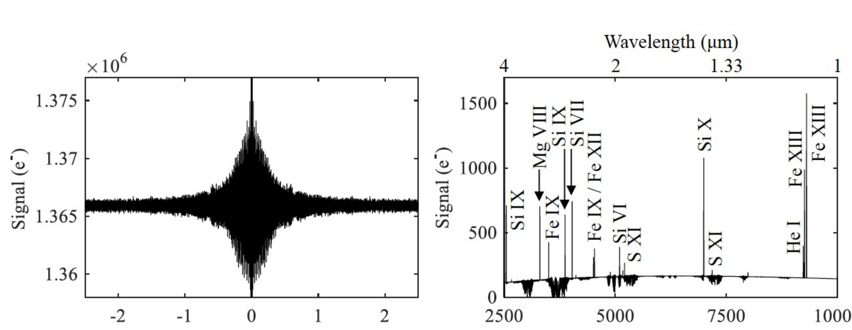


Figure 9. Modeled ACES interferogram (left) and spectrum (right).

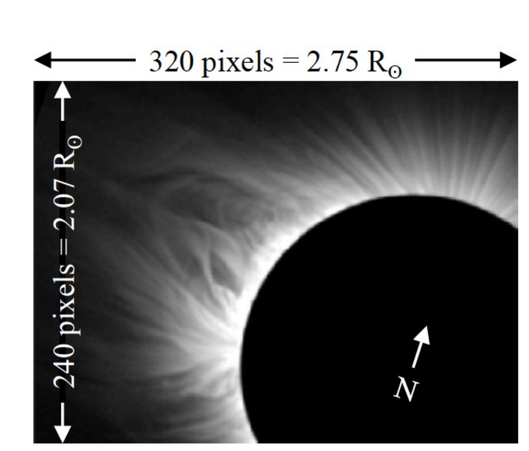
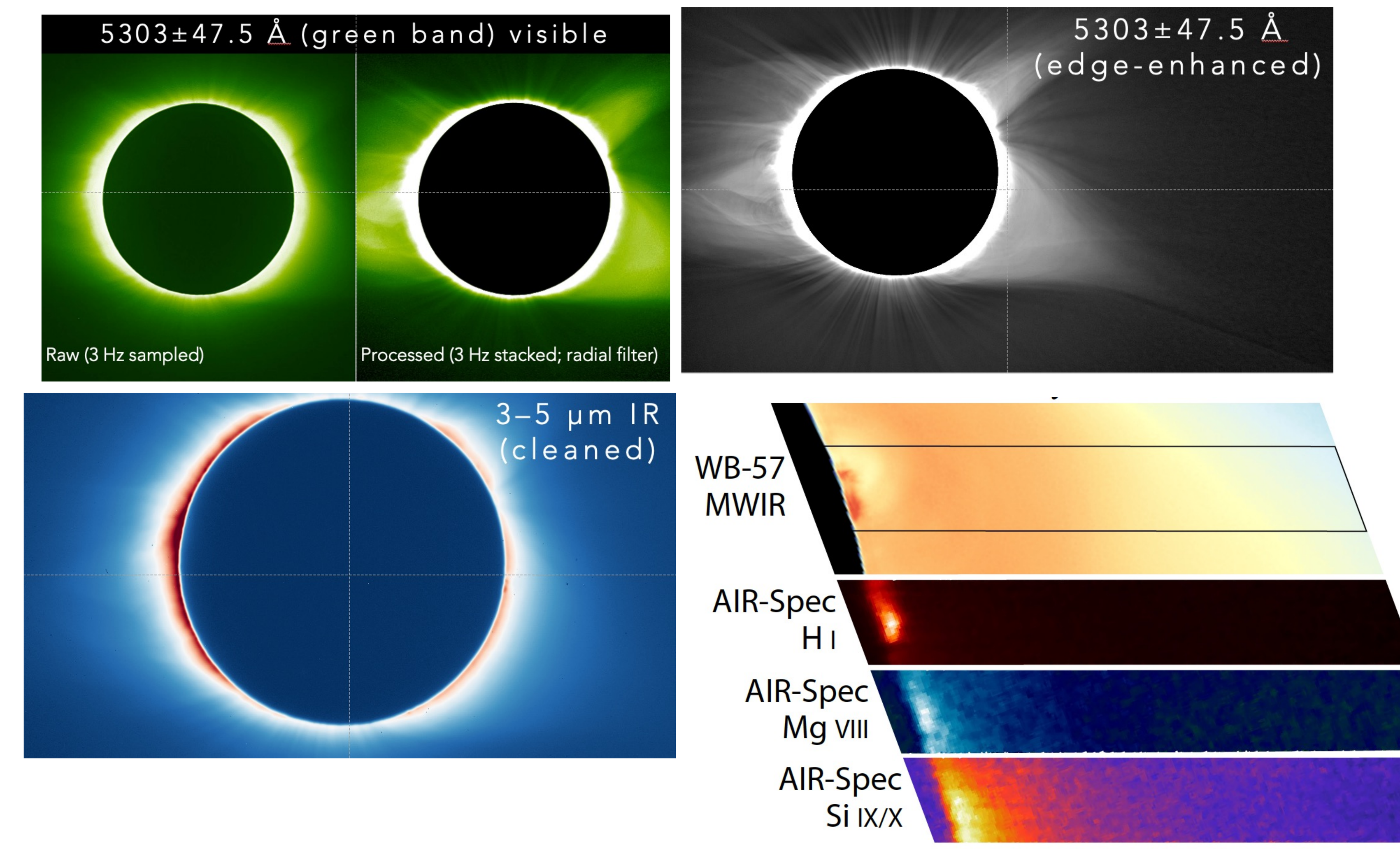


Figure 11. Example image at ZPD, showing the FOV and spatial resolution.

The Day/Night Airborne Motion Imager for Terrestrial Environments (DyNAMITE)

A dual-telescope suite comprising two independent co-aligned camera+lens systems that collect full-color HD VIS and 3–5 μm MWIR image sequences. Exposure time, frame rate, zoom levels, focus, etc. are adjustable in real-time.



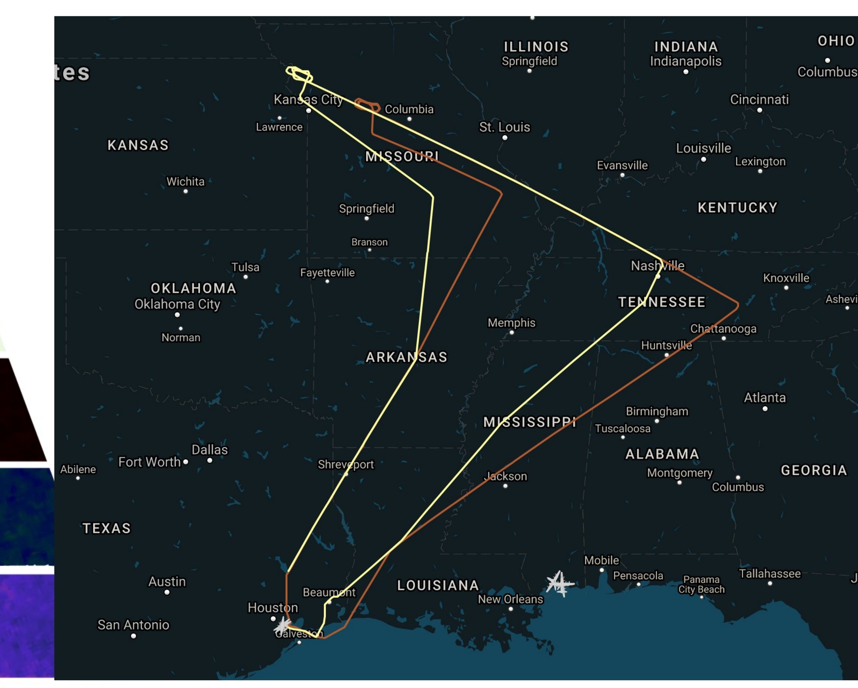


Fig. 3: Cutout of 2017 DyNAMITE MWIR image of a prominence, cavity, & streamer, & corresponding spectral line images using AIR-Spec. Multispectral data provide insight into the nature of coronal IR emission (Williams et al. 2020).

SCIFLI Airborne Multispectral Imager (SAMI)

SAMI carries a complement of high frame-rate scientific cameras sensitive to multiple passbands to allow us to characterize the complete spectral profile of coronal structures from visible to MWIR wavelengths. The four high-resolution cameras (with fixed FOVs) are all fed by a single 203-mm telescope and operate simultaneously.

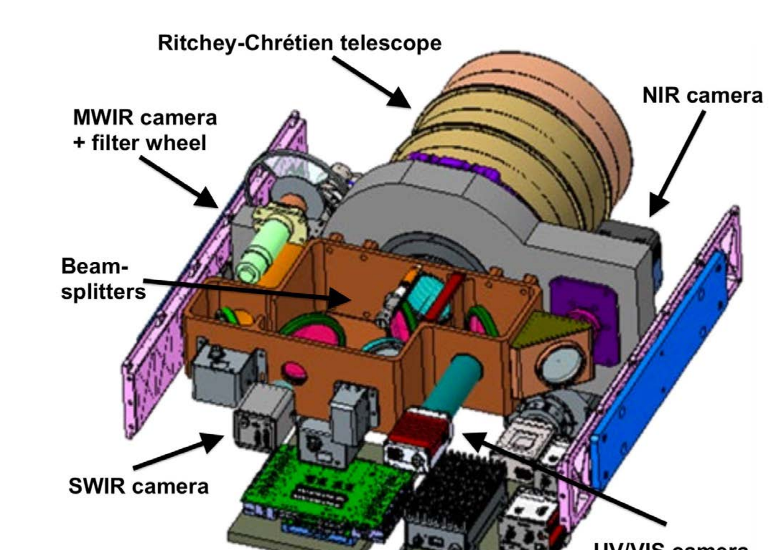


Table 2: Noise budget shows adequate SNR at all altitudes with only moderate binning in space and time. High-altitude flight suppresses residual sky brightness, which is negligible here.

Budget type:	Small-Scale Features		Wave Motion	
Observation altitude:	1.5 R⊙	2.0 R⊙	1.5 R⊙	2.0 R⊙
Total K+F photon flux:	1.1×10^5 ph/s/pix	2.4×10^4 ph/s/pix	1.1×10^5 ph/s/pix	2.4×10^4 ph/s/pix
K photon flux:	7.9×10^4 ph/s/pix	1.1×10^4 ph/s/pix	7.9×10^4 ph/s/pix	1.1×10^4 ph/s/pix
Resolution element:	2×2 pix	2×2 pix	2×1 pix	2×1 pix
Observation time:	1 s	1 s	0.2 s	0.2 s
SNR:	**340**	**100**	**107**	**32**

The NSF supported GV aircraft enables future solar coronal instrument development using the ASPIRE platform via the NSF MRI program. The NASA WB57 aircraft have new instruments in place that are well suited for high cadence, high resolution coronal eclipse observations. The ability of the community to use the WB57 aircraft is limited as NASA does not operate this as a community facility.

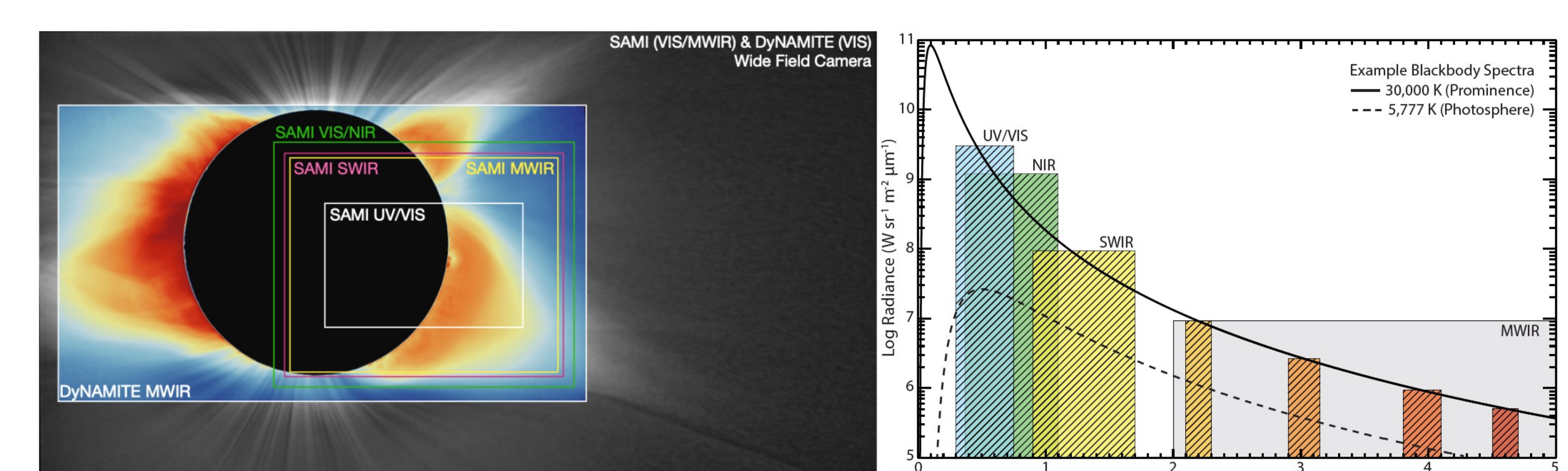


Fig. 2: (Left) Images from 2017 campaign (color: MWIR; mono: VIS) with SAMI FOVs for scale; actual FOVs are co-boresighted. Pointing will be determined during pre-event planning based on predicted solar activity. (Right) Schematic of SAMI spectral bands; comparison of fluxes between bands discriminates between emission mechanisms, e.g., direct vs. scattered blackbody emission.

References

[1] Samra. et al. (2018) ApJL., 856, L29.

[2] Caspi A. et al. (2020) ApJ, 895, 131