Automated Data Pipeline for the MLSO/UCoMP Polarimeter

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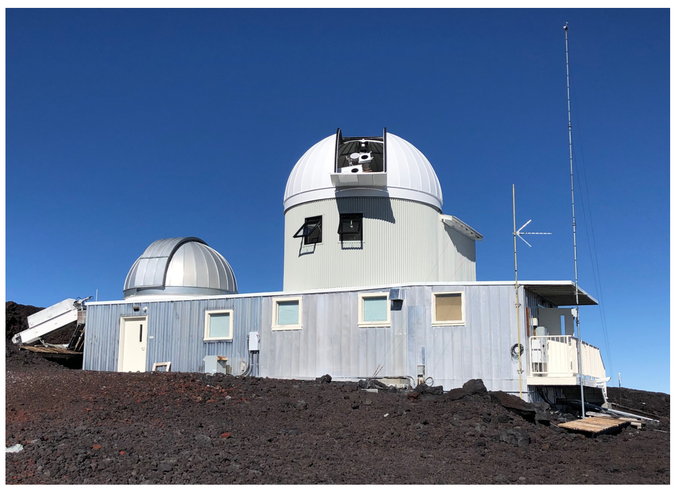
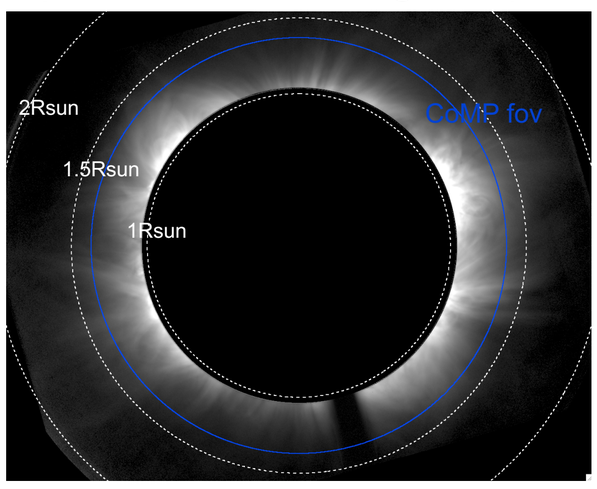


The Mauna Loa Solar Observatory (MLSO) is located in the Big Island of Hawaii on the flank of the Mauna Loa Mountain at 3394m above sea level. It is an ideal site for coronal observations because of the dark sky and dry atmosphere. MLSO is currently closed because of a volcanic eruption and is expected to reopen in Spring 2025. UCoMP is a 20cm coronagraph at MLSO.

UCoMP

The Upgraded Coronal Multi-channel Polarimeter, UCoMP, is an imaging polarimeter to measure the Stokes I, Q, U, and V. It uses a tunable Lithium Niobate Lyot filter to observe emission lines from the visible to near IR in the solar corona and chromosphere off-limb. It is an upgrade of its predecessor CoMP: it has a broader wavelength range, 530-1083nm, a larger fov up to 2 Rsun, and higher spatial resolution of ~3 arcsec/pixel.



Wavelength (nm)	UCoMP Line	Temperature (MK)	
530.3	FeXIV	1.90	removed Nov 2022
637.4	FeX	1.10	whole mission
656.3	HI	0.02	removed Nov 2022
670.2	NiXV	2.50	added Nov 2022
691.8	ArXI	1.90	removed Nov 2022
706.2	FeXV	2.20	whole mission
761.2	SXII	2.20	added Nov 2022
789.4	FeXI	1.30	whole mission
802.4	NiXV	2.50	added Nov 2022
991.3	SVIII	0.80	added Nov 2022
1074.7	FeXIII	1.80	whole mission
1079.8	FeXIII	1.80	whole mission
1083.0	HeI	0.02	removed Nov 2022

UCoMP is a dual beam polarimeter: it consists of two identical visible-IR cameras and a beam-splitter to image the emission line and nearby continuum simultaneously. The continuum is subtracted during calibration to extract the line and remove seeing effects. The measure is repeated with the cameras that observe the continuum and the emission line swapped to reduce systematic effects.

Automatic Data Pipeline

The raw data and metadata are saved as FITS at MLSO and transferred at the end of the observing day to the High Altitude Observatory in Boulder, Colorado, where they are validated and processed overnight by the automatic calibration pipeline. Calibrated science FITS files, quick-look images, and movies are made publicly available on the MLSO website, typically within12h from acquisition, and permanently archived at the NCAR.

Main Pipeline Steps:

- quality check on L0 FITS
- average camera frames to increase S/N
- apply dark and flat (use darks/flats before and after interpolated at the time of the science image)
- polarimetric calibration to extract Stokes I,Q,U,V
- correct for camera distortion and find occulter center
- subtract nearby continuum
- de-banding
- rotate images North up
- combine cameras
- write Level 1 FITS, .gif, and movies
- quality check on L1 data
- fit line profile and compute linear polarization and azimuth from Stokes Q and U
- Write Level 2 FITS, .png and movies

UCoMP Pipeline Advantages:

- automatic and robust to run without human supervision
- fast to handle large datasets (minimize I/O, optimize algorithms, parallelization)
- automatically identify and remove bad images
- minimize interpolations to preserve image integrity

Current Challenges:

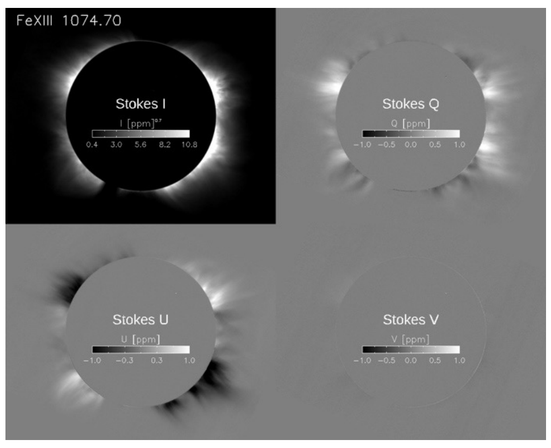
- co-align images to account for atmospheric effects and pointing uncertainty is difficult for occulted images (no adaptive optics for coronal images, FFT standard approach does not work)
- make calibrated images available in real-time
- use ML/AI to identify and remove bad images
- improve stray light removal

UCoMP Data Products

Level 0

The L0 data are raw data produced by the UCoMP instrument and consist of science and calibration files. For a long observing day, they amount to ~100GB.

Level 1



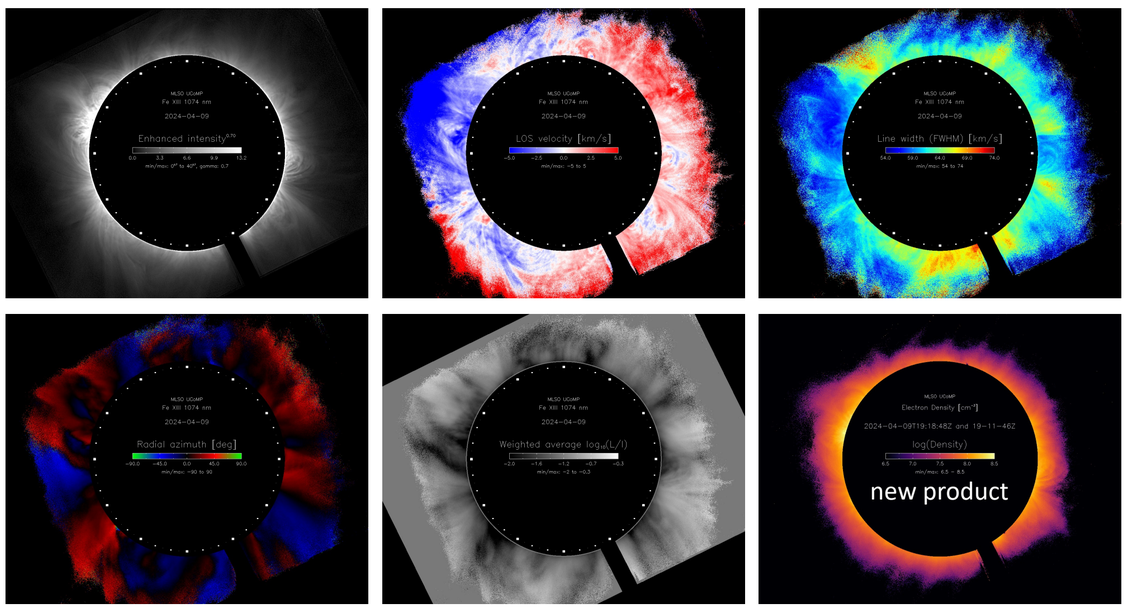
The L1 FITS consist of calibrated images in heliographic coordinates in units of B/Bsun for each emission line. Each FITS extension is a 1280x1024x4 array that contains I,Q,U, and V at a given wavelength.

Level2

The L2 FITS are derived from L1 data by fitting the line profile with an analytical gaussian function to estimate the line-of-sight velocity and FWHM. For the FeXIII lines linear polarization and azimuth are computed from Q and U.

Higher level products

Electron densities, coronal Alfven waves, and plane-of-sky coronal magnetic fields can be derived by UCoMP L2 data.



Sample UCoMP images. Top: unsharp-masked intensity, line-of-sight velocity, FWHM. Bottom: radial azimuth, linear polarization, and electron density from the FeXIII 1074nm/1079nm line ratio.

https://github.com/NCAR/ucomp-pipeline

https://www2.hao.ucar.edu/mlso