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COSMO web page

CORONAL SOLAR MAGNETISM OBSERVATORY

A Facility Dedicated to the Study of Magnetic Fields and Plasma Properties in the Large-scale Solar Atmosphere and Their Role in the Generation of Space Weather

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Summary

COSMO is a proposed synoptic facility designed to measure magnetic fields and plasma properties in the large-scale solar atmosphere. Measurements of coronal and chromospheric magnetic fields are arguably the most important observables required for advancing our understanding of the processes responsible for coronal heating, coronal dynamics and the generation of space weather that affects communications, GPS systems, space flight, and power transmission. COSMO comprises a suite of three instruments chosen to enable the study of the solar atmosphere as a coupled system: (1) a coronagraph with a 1.5m aperture to measure the magnetic field, temperature, density, and dynamics of the corona; (2) an instrument for diagnostics of chromospheric, prominence and photospheric magnetic fields and plasma properties; and (3) a white light K-coronagraph to measure the density structure and dynamics of the corona and coronal mass ejections.

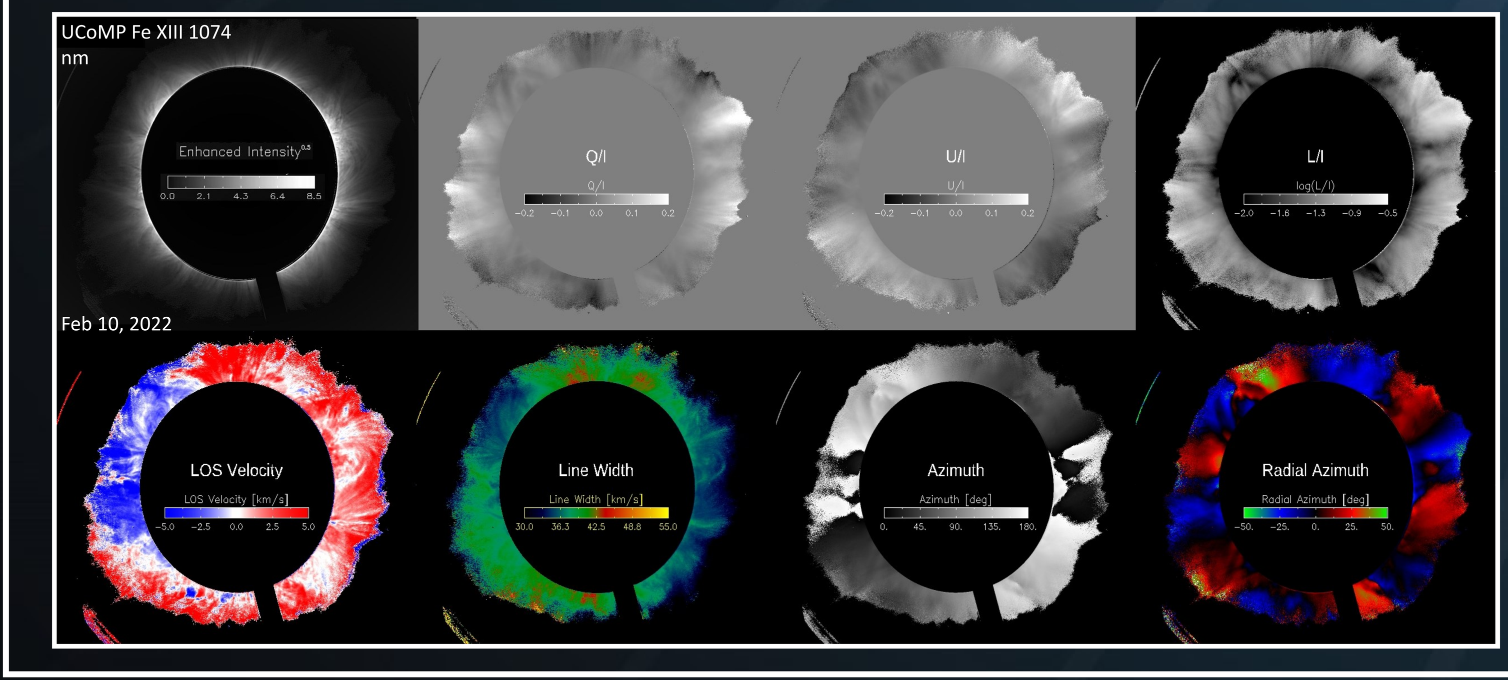
COSMO will provide a unique combination of magnetic field, density, temperature, and velocity observations in the corona and chromosphere that have the potential to transform our understanding of fundamental physical processes in the solar atmosphere and their role in the origins of solar variability and space weather. We describe the COSMO suite of instruments, COSMO mission science objectives, and the synergies of COSMO with other missions such as Daniel K. Inouye Solar Telescope (DKIST) and the Frequency Agile Solar Radio telescope (FASR). Examples of COSMO technology demonstrations and advances in interpretation tools are presented along with the latest information on the COSMO site survey and the final engineering design of the COSMO Large Coronagraph (LC).

Proposed Suite of Instruments

A Large Coronagraph devoted to obtaining daily, synoptic observations of magnetic fields and plasma properties of the large-scale solar corona. The science requirements call for a 1.5 meter coronagraph with a large field of view (1 degree), and 2 arcsecond spatial resolution. The post-focus instrument will be a filter-based imaging spectropolarimeter capable of observing coronal emission lines at visible and IR wavelengths formed over a wide range of temperatures.

A Chromosphere and Prominence Magnetometer (ChroMag) devoted to polarimetric measurements on the disk and above the limb. Vector magnetic field observations will be made using the chromospheric lines of He 587nm, H 656nm, Ca 854nm and He 1083nm, as well as the photospheric line of Fe 617nm. ChroMag has a spatial resolution of 2 arcseconds and a +/- 1.25 Rsun field of view. It is currently under construction and will be completed in 2022.

A K-Coronagraph (K-Cor) to observe the column density of electrons in the corona. This instrument was constructed and put into operation at Mauna Loa in Sept 2013. K-Cor high temporal cadence (15 sec) and field-of-vew from 1.05 to 3 Rsun can track CMEs from their onset through the middle corona. K-Cor data is available at: https://www2.hao.ucar.edu/mlso/mlso-home-page



Science Objectives

- Understand the storage and release of magnetic energy by characterizing the physical processes leading up to eruptions
- Understand CME dynamics and consequences for shocks by characterizing local and global interactions
- Determine the role of waves in solar atmospheric heating and solar wind acceleration by characterizing spatial and temporal wave properties
- Understand how the coronal magnetic field relates to the Sun's dynamo and evolving global heliosphere by characterizing variations on solar cycle time scales
- Constrain and improve space-weather forecast models by incorporating coronal and chromospheric magnetothermal observations

Figure 1. Below Right: Rendering of 1.5 m aperture f/5 refractive Large Coronagraph (LC). The dome is positively pressurized with HEPA filtered air to maintain cleanliness of the objective lens. The dome is ~13 meters in diameter. Below Left: Smaller dome (5.5 m diameter) with solar pointed community spar carrying the K-Cor and ChroMag instruments. Space is available on the spar for community developed instruments.

Technology Demonstration

Fig. 2: Measurements (Lin, et al. 2004) of circular polarization of FeXIII coronal emission line at 1074.7 nm. Observations were made with the Optical Fiberbundle Imaging Spectro-polarimeter (OFIS) behind the 46-cm aperture Solar-C coronagraph. The fibers subtend 20 arcsec. The measurement required 70 min integration time. This success is due in large part to the use of IR emission that has high sensitivity to the Zeeman splitting.

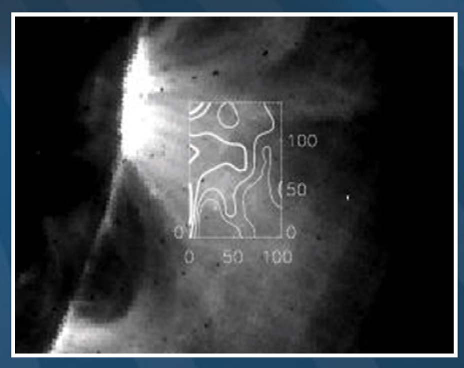
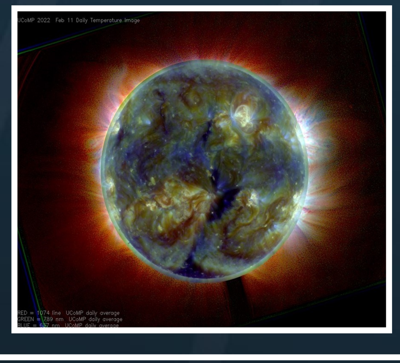


Fig. 2. Coronal LOS magnetogram obtained by OFIS overlaid on EIT FeXVI 284 A image. Contours are 5G, 3G, and 1G.

Below Left: Fig. 3. coronal parameters from UCoMP FeXIII 1074.7 nm on 10 Feb 2022. Top row from left: unsharp masked intensity; Stokes Q/Intensity; Stokes U/Intensity; and fraction of total linear polarization. Bottom row: LOS Doppler; line width; direction of the magnetic field wrt horizontal; direction of the magnetic field wrt the local radial direction.

Below: UCoMP temperature image from UCoMP Fe XIII, Fe XI, Fe X. Solar disk from NASA AIA Fe XI, FeXII and Fe XIV



Another prototype demonstration, illustrated in Fig. 3, shows coronal properties measured by the HAO/NCAR Upgraded Coronal Multi-channel Polarimeter (UCoMP) instrument observing in Fe XIII emission line at 1074.7 nm on 10 Feb 2022. UCoMP is an imaging spectropolarimeter employing a tunable birefringent filter based on lithium niobate crystals that demonstrates a key technology of the COSMO LC filtergraph. These data have a spatial sampling of 3 arcseconds per pixel and required 1 hour of integration time. Neither of these demonstrations have the spatial or temporal resolution required to meet COSMO scientific objectives due to the small coronagraph apertures.

See Ben Berkey's poster: 'An introduction to the UCoMP hardware and data products'

1.5 m Coronagraph Feasibility

Engineering studies show that a lens scatters significantly less light than a mirror. A 1.5 meter lens does not suffer in any significant way from deformation under gravity (Fig. 4). For list and other information see the Technical Notes section of the COSMO web site (http://www.cosmo.ucar.edu)

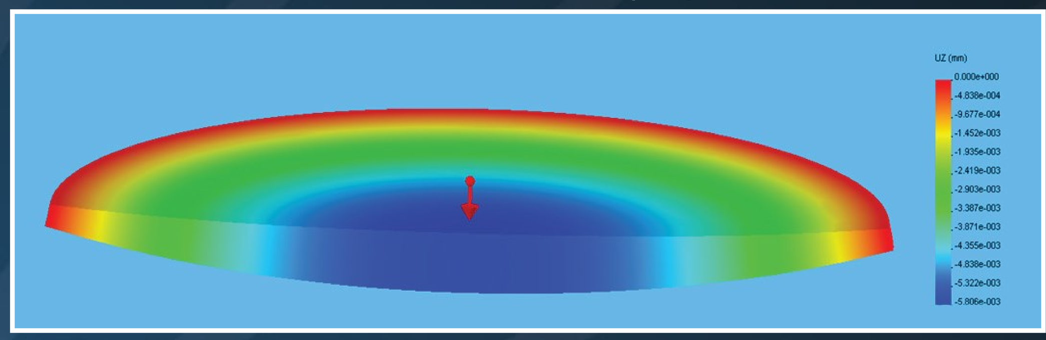
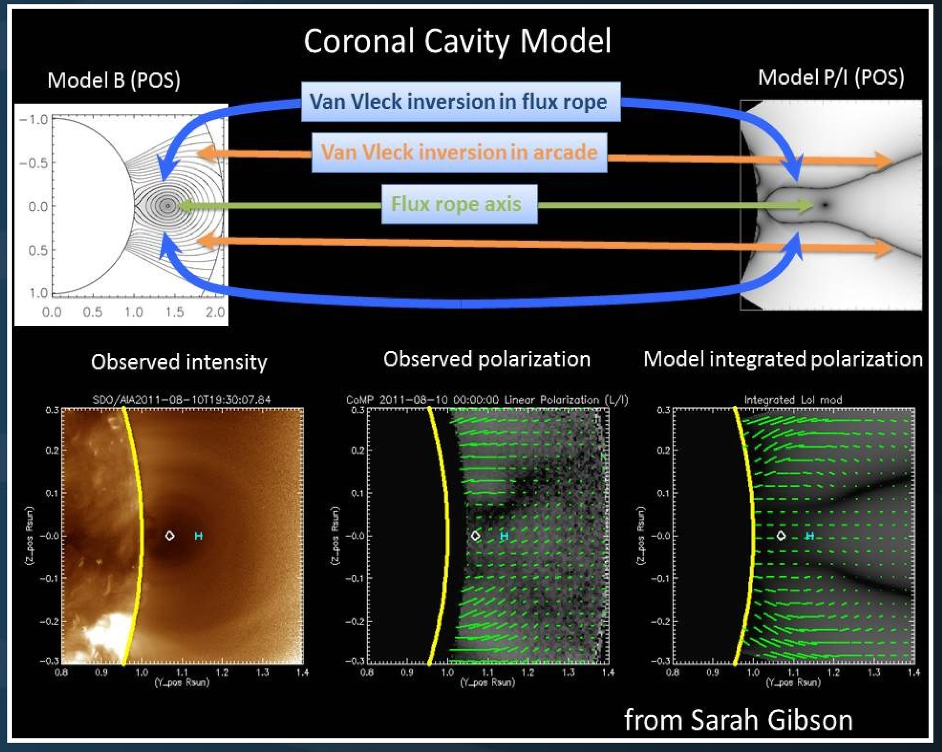


Figure 4. (left) Deformation of a large refractive objective under gravity (~5 waves at 1074 nm) increases the power slightly on the lower surface and decreases the power on the top surface. This self-correcting property of refractive optics results in insensitivity of image quality to deformation.

Advances in Interpretation Tools

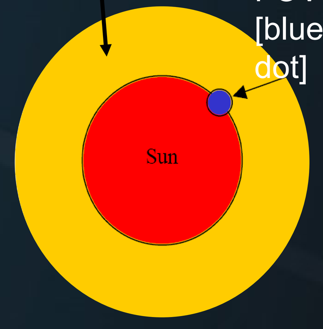
Sarah Gibson and colleagues have been developing tools for comparing forward models of coronal magnetic fields with observations from COSMO, UCoMP, CoMP, and other instruments. Figure 5 shows a simulation of a coronal cavity compared to CoMP. The forward modeling tools are available at: https://www2.hao.ucar.edu/mlso/forward-model

Figure 5. Comparison of the line-of-sight integrated polarization signals from a coronal cavity model based on a flux rope with observations from the CoMP instrument taken in the FeXIII 1074.7 nm coronal forbidden emission line. Nulls in the degree of linear polarization due to the vanVleck effect are clearly seen in the model and observations.



COSMO Complementarity to DKIST and FASR

The full coronal field-of-view (FOV) of COSMO, shown by the yellow annulus at right, complements the very high resolution, small field-of-view (FOV) of DKIST, shown by the small blue circle. The recent Decadal Survey, Pathways to Discovery in Astronomy and Astrophysics for the 2020s cited the need for global synoptic measurements of the coronal magnetic field to supplement the restricted FOV of DKIST. The COSMO FOV captures large scale structures such as Coronal Mass Ejections (CMEs) that cannot be fully observed by DKIST.



COSMO also complements observations from the Frequency Agile Solar Radio telescope (FASR). FASR will acquire observations of the coronal magnetic field on the solar disk, which COSMO cannot observe. COSMO can detect both strong and weak (quiet Sun) coronal magnetic fields, while FASR is only sensitive to stronger magnetic fields, such as in and around active regions.

COSMO Status

- COSMO was endorsed in the last Helio Decadal Survey
- Large Coronagraph PDR passed Nov 2015
- K-Cor is in operation at Mauna Loa Solar Observatory. Chromospheric Imager (ChroMag) is under construction and will be completed in 2022
- We are currently funded by NSF to perform:

1) COSMO Site survey (ongoing). See NEWS on COSMO webpage

2) Final design for the 1.5-m Large Coronagraph (contracted to European Industrial Engineering)

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