The Coronal Solar Magnetism Observatory (COSMO)

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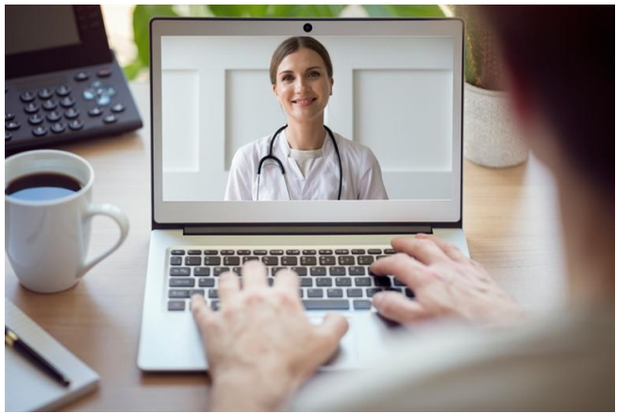
National Center for Atmospheric Research
High Altitude Observatory

Actionable Earth System Science: Space Weather

Our technological society has become increasingly vulnerable to Solar Activity

Power Grids



Tele-Work/
Tele-Medicine

Humans in Space

Communication Systems

Navigation Systems

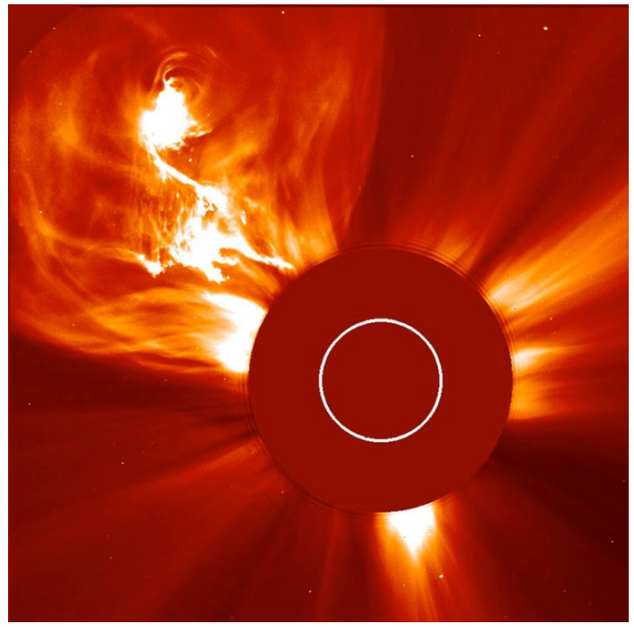
COSMO Motivation

The solar corona is highly ionized and dominated by magnetic forces

The storage and release of magnetic energy in the solar corona is responsible for Space Weather

To understand and predict Space Weather, we need **Daily** measurements of the **Large-Scale Coronal Magnetic Field**

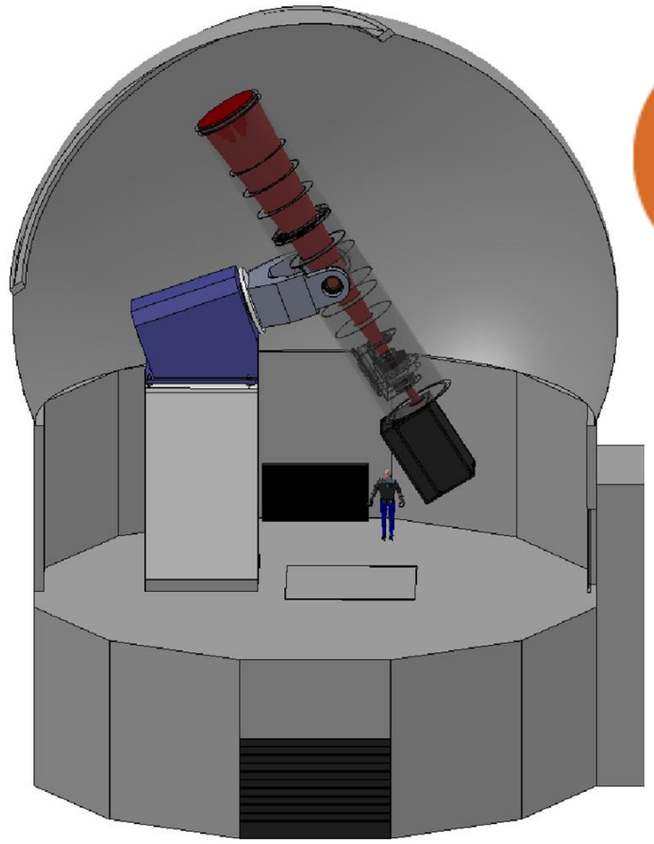
This capability does not currently exist



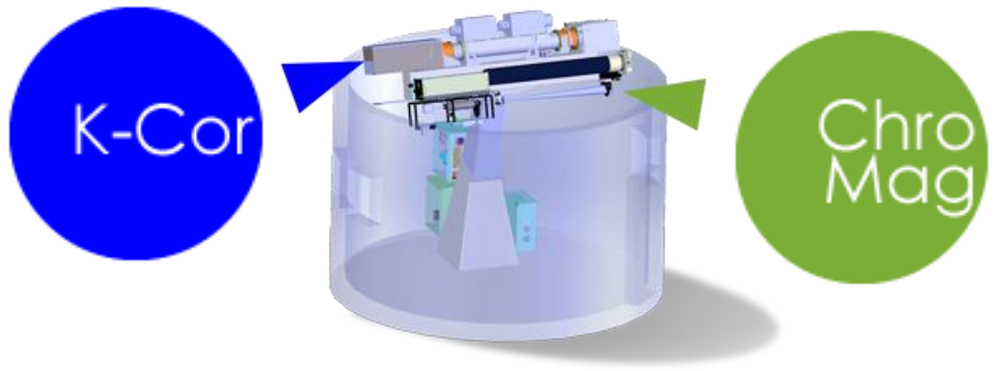
LASCO/SDO

Coronal Solar Magnetism Observatory (COSMO)

COSMO is a proposed synoptic facility to measure magnetic fields and plasma properties in the large-scale solar atmosphere



Large Coronagraph

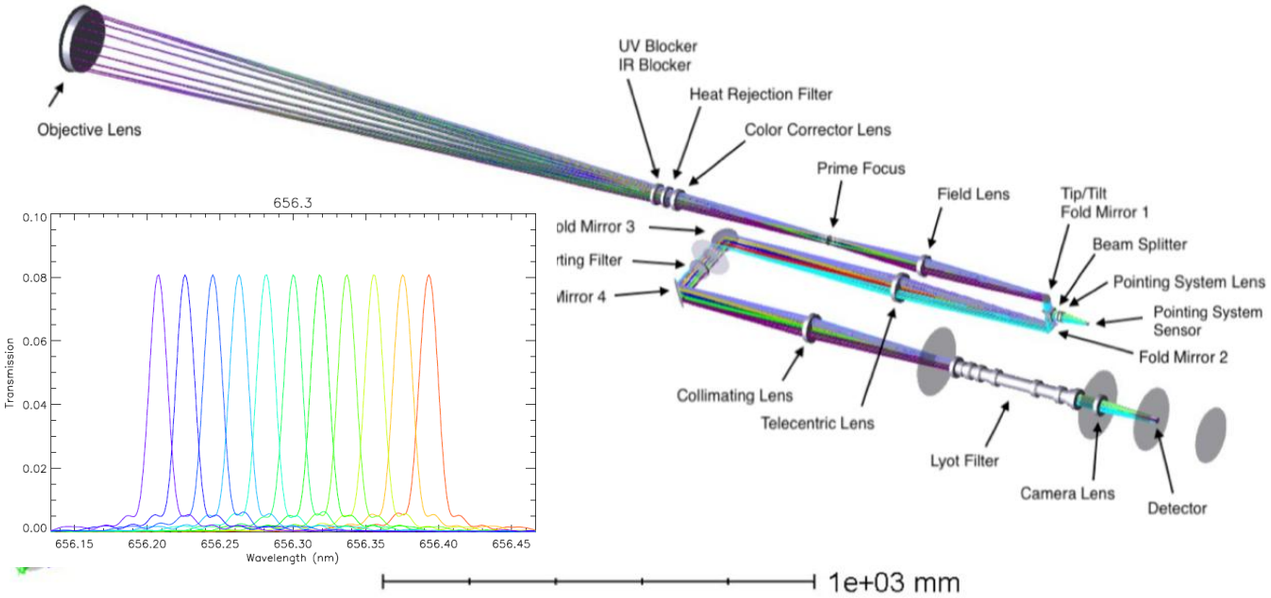


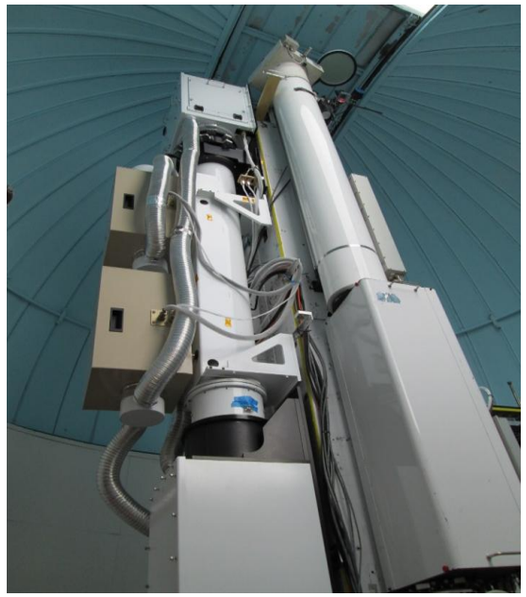
Spar Facility with
K-Coronagraph and
Chromospheric Imager

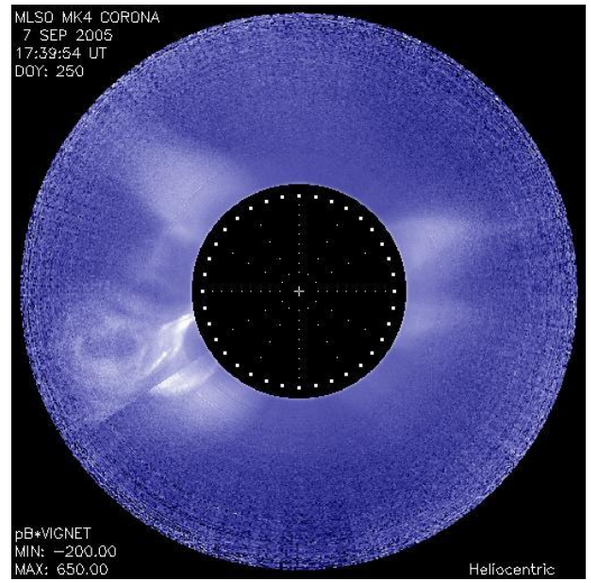
Collaboration between HAO and CU, UH, UM, GMU, SAO, NSO
Under development for 15 years. Endorsed in last Helio Decadal Survey

COSMO Instruments

The COSMO suite of instruments will study the solar atmosphere as a coupled system, with magnetic and plasma observations spanning the photosphere, chromosphere and corona



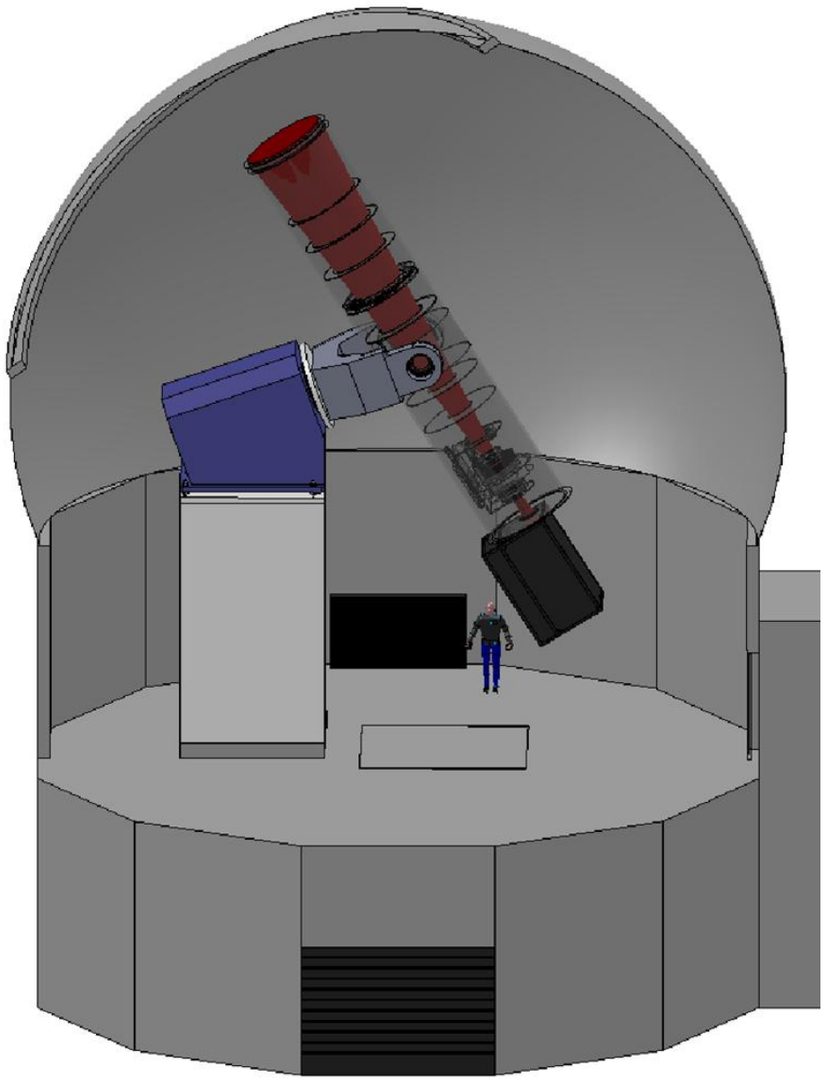




- ChroMag, Alfred deWijn (PI)
- 14-cm Imaging Spectropolarimeter
- Magnetic field measurement in Photosphere and Chromosphere
- High cadence, multi-line observations provide height dependence
- ChroMag is under construction

- 20-cm K-Coronagraph, Joan Burkpile (PI)
- Measures coronal structure and evolution
- Observes coronal mass ejections in real-time
- Observes shocks that produce energetic particles
- K-Cor became operational in Sept 2013

COSMO Large Coronagraph



- 1.5 m refractive coronagraph
- 1º field-of-view
- Synoptic operation
- Low scattered light, 5 ppm
- Will obtain measurements of coronal B-field with 1 Gauss precision in 12 minutes, 2 arcsecond spatial resolution

Focal plane instrument is an imaging spectrometer observing emission lines in the Visible and IR

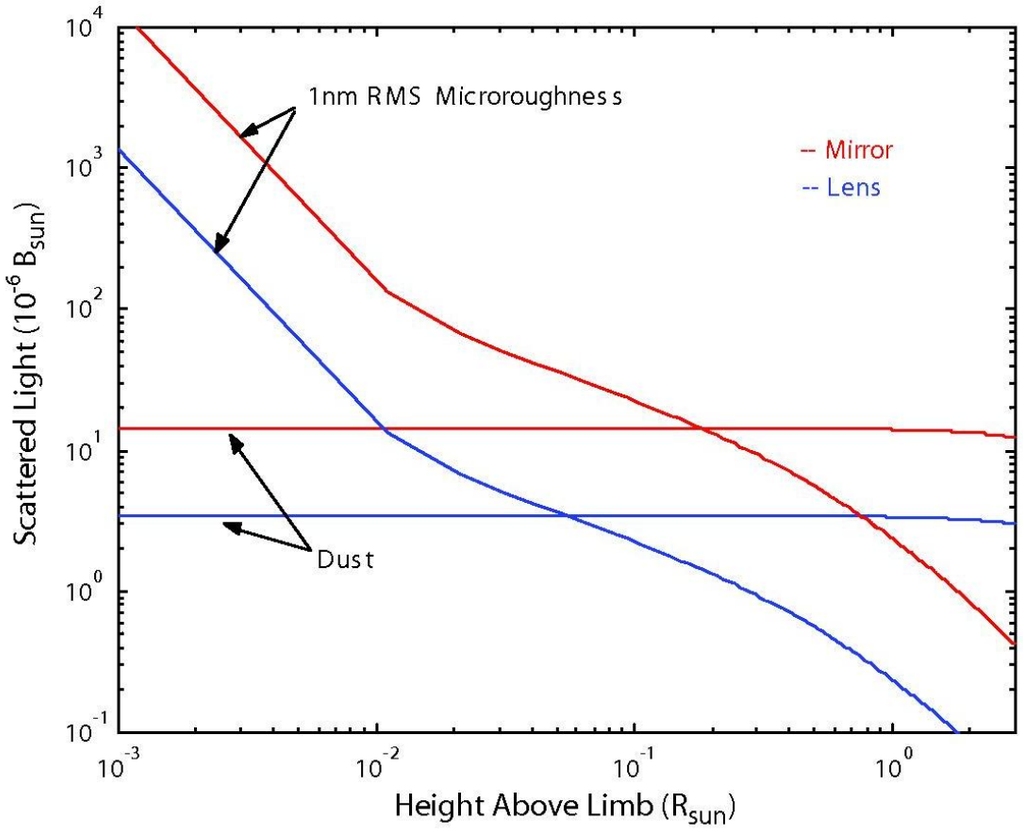
Imaging Spectroscopy of Visible/IR Coronal Emission Lines

Information on the plasma temperature, density and magnetic field is derived from the intensity and polarization of coronal emission lines

- **Plasma Temperature and Density** derived from line Intensity Ratios
- **Line-of-Sight field strength** derived from Longitudinal Zeeman effect in Circular Polarization (V/I 10^{-4} / G)
- **Plane-of-Sky field direction** derived from Resonance Scattering effect in Linear Polarization (Q/I, U/I 5-20%)
- **Line-of-Sight velocity** derived from Doppler effect in Intensity
- **Plane-of-Sky magnetic field strength** from the phase speed of Alfvén waves through Coronal Seismology

Why a 1.5 m Aperture Refractive Coronagraph?

A lens scatters much less light than a mirror from both microroughness and dust



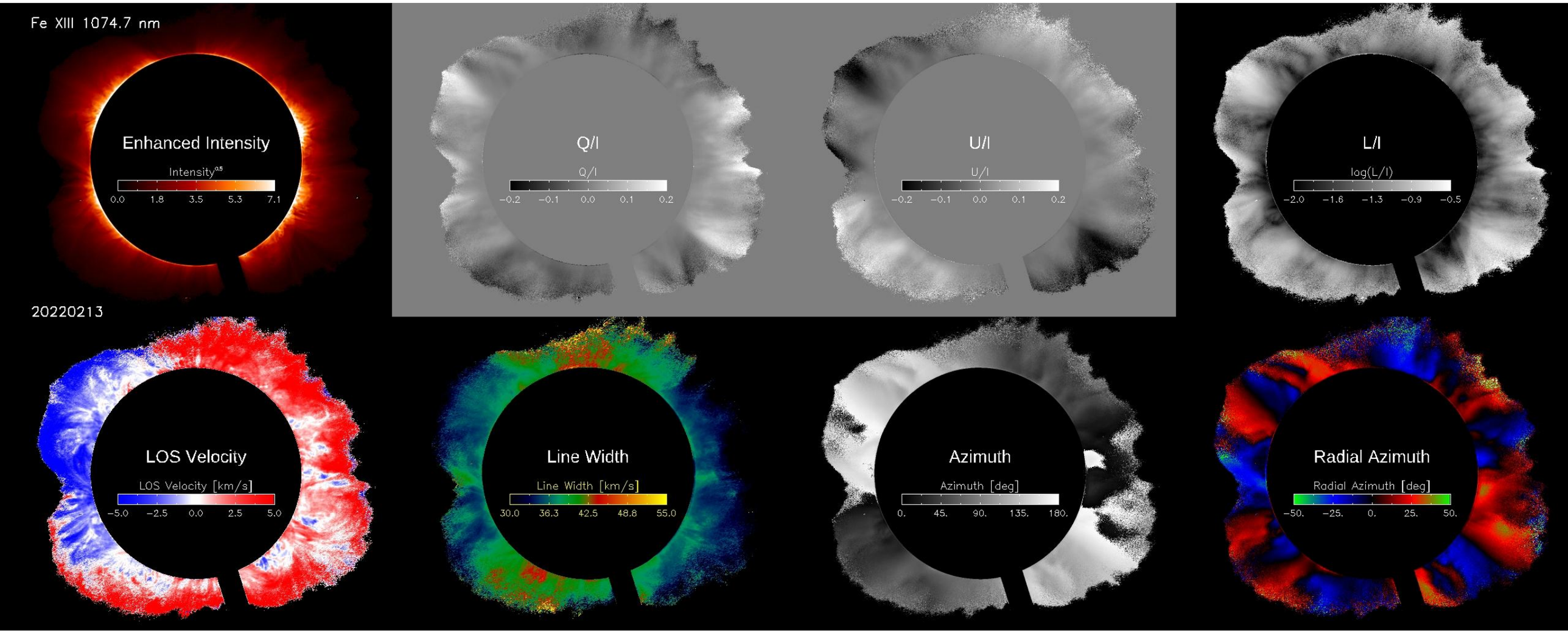
- 10x less from microroughness
- 4x less from dust

Lyot achieved 5 x 10^{-6} scattered light with a lens-based coronagraph in 1938

A 1.5 m aperture is required to collect sufficient photons to achieve needed SNR for circular polarization measurements

Prototype Coronal Polarimeter

The Updated Coronal Multichannel Polarimeter (UCoMP) is a 20-cm aperture coronagraph and imaging spectropolarimeter observing coronal forbidden emission lines in the Visible and IR at Mauna Loa Solar Observatory



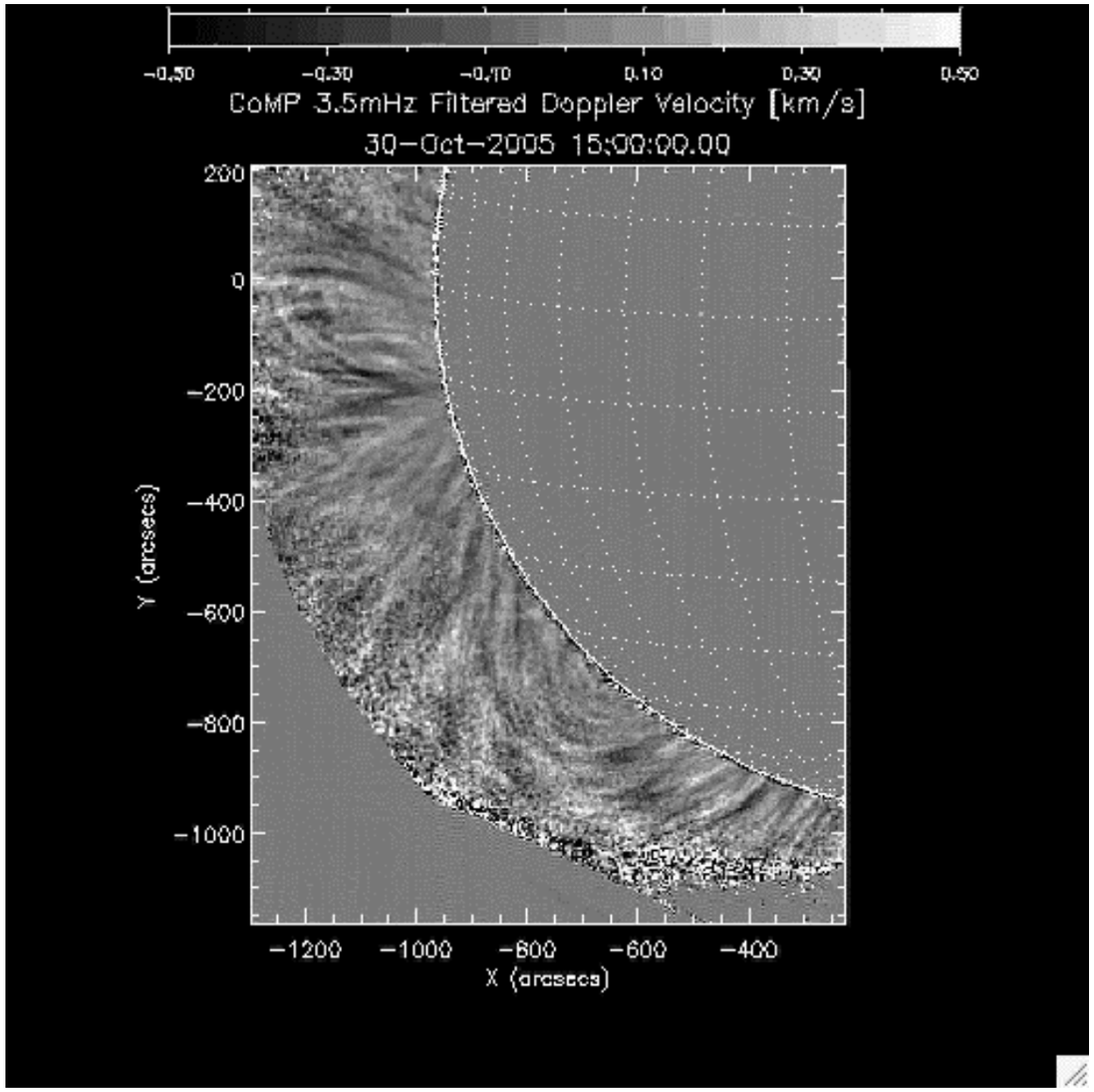
Coronal parameters from UCoMP observations of FeXIII 1074.7 nm on 13 Feb 2022. Top row from left: unsharp masked intensity, Stokes Q/I, Stokes U/I, the fraction of total linear polarization. Bottom row: LOS velocity, line width, the direction of the magnetic field wrt horizontal, the direction of the magnetic field wrt the local radial direction.

The limited aperture of UCoMP is insufficient to constrain the LOS component of the coronal magnetic field; **a 1.5 m aperture is needed**

Alfvénic Waves

- Contribute to coronal heating
- Accelerate the solar wind
- Alfven wave phase speed can be used to measure the plane of sky component of the coronal field

With Zeeman measurements can provide vector B

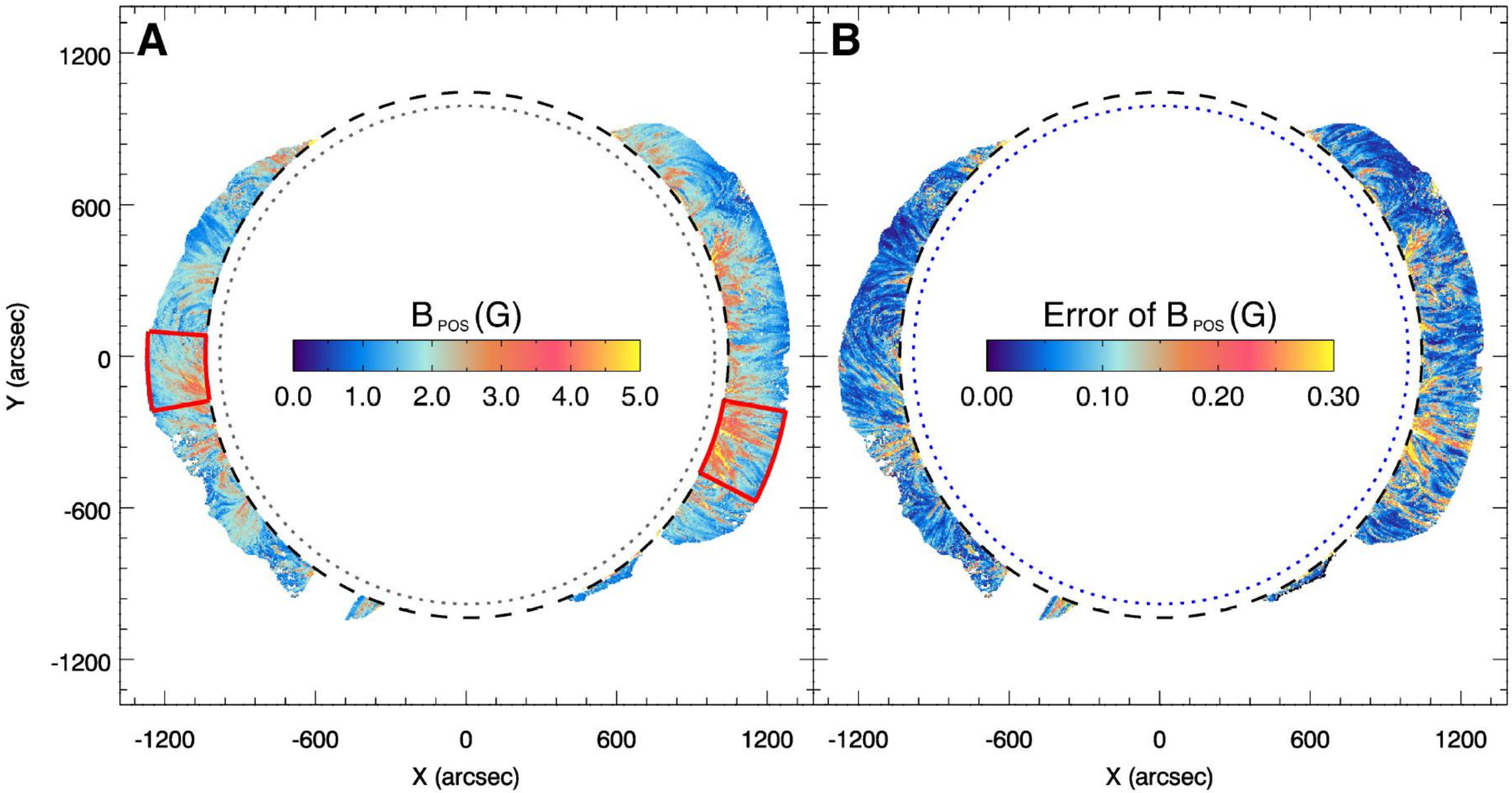


CoMP Doppler Data, 30 Oct 2005

$$v_A = \frac{B}{\sqrt{4\pi\rho}} = 1210\left(\frac{B}{20\,\mathrm{G}}\right)\left(\frac{n_e}{10^9\,\mathrm{cm}^{-3}}\right)^{-1/2}\ (\mathrm{km/s})$$ (Aschwanden, 2004)

Coronal Transverse Field Strength from Waves

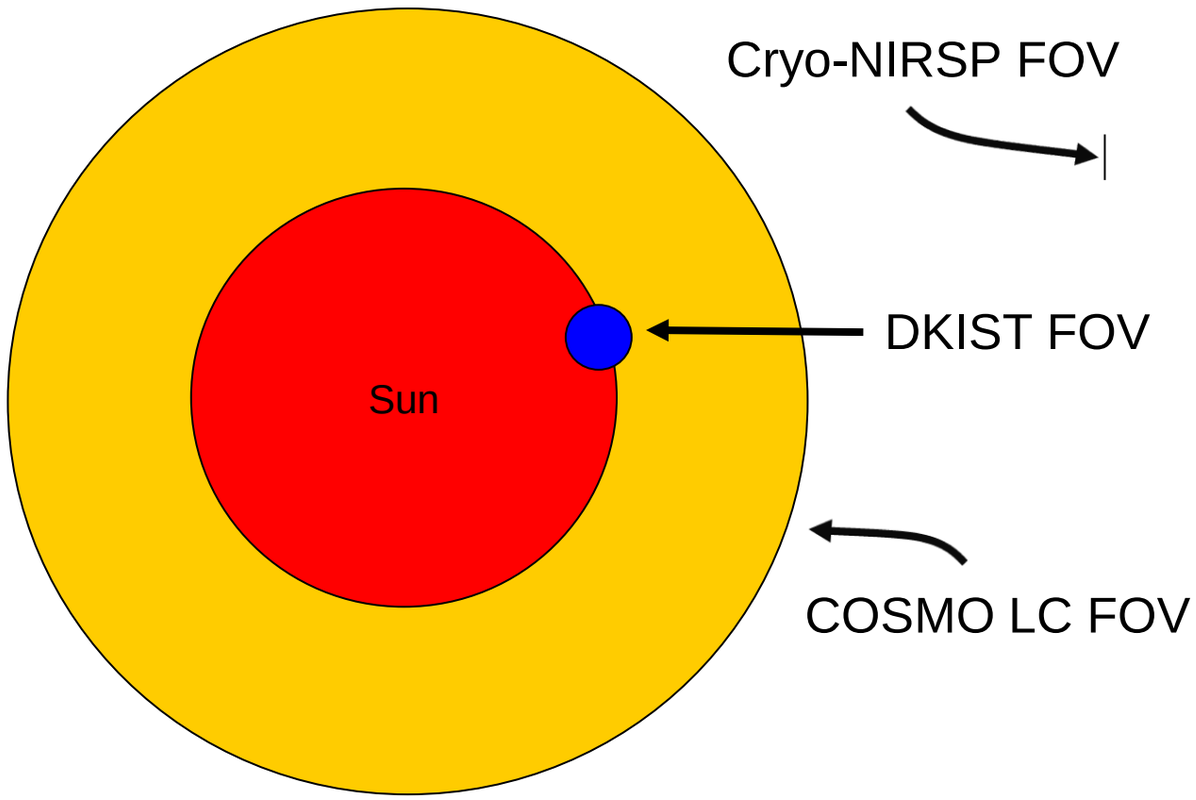
Oct 14, 2016 using LOS Doppler data from the Coronal Multi-channel Polarimeter



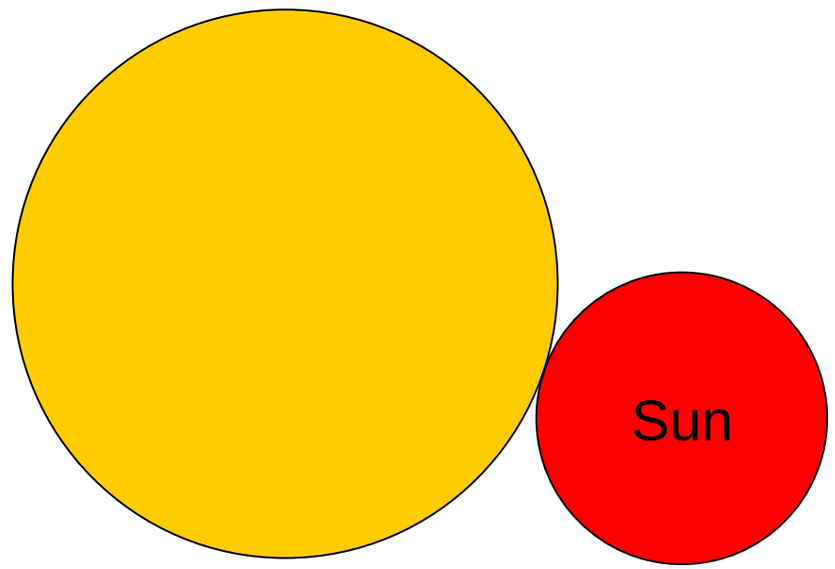
Zihao Yang et al., Science, 2020

COSMO LC is Very Complementary to DKIST

The large field-of-view and dedicated mission of the COSMO Large Coronagraph make it highly complementary to the high spatial resolution, small FOV and general-purpose DKIST



The COSMO LC FOV is 8.3x10^4 larger than DKIST/Cryo-NIRSP. The COSMO LC will have a light gathering power that far exceeds that of the DKIST



COSMO LC Offset Mode

COSMO LC is a synoptic survey telescope for the solar corona - It is more like Rubin than DKIST

COSMO Progress

- COSMO was endorsed in the last Helio Decadal Survey
- K-Coronagraph (K-Cor) became operational Sept 2013
- Large Coronagraph PDR passed Nov 2015
- Chromospheric Imager (ChroMag) is under construction and will be completed in 2022
- We are currently funded by NSF to perform:

  1) Site survey for COSMO location (ongoing)

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

Summary

- COSMO will provide unique data that will advance our understanding of the sources of Space Weather, move the community towards a predictive capability and has clear societal benefits
- COSMO is very complementary to existing and planned ground- and space-based assets
- The COSMO methodologies have been demonstrated with prototype instruments
- The COSMO components are either operational (K-Cor), under construction (ChroMag) or approaching final design (Large Coronagraph)

Thank You

More information can be found at:

COSMO: https://www2.hao.ucar.edu/cosmo

UCoMP: https://www2.hao.ucar.edu/mlso/instruments/upgraded-coronal-multi-channel-polarimeter-ucomp