COSMO
Science Rationale and Use Cases

Enrico Landi
University of Michigan
Overview

I  -  Science goals
II -  COSMO LC observations
III -  Why a ground-based coronagraph
IV  –  Plasma diagnostics with COSMO LC
V  –  Use cases
I – Science goals

The solar atmosphere is ruled by the magnetic field

• Structures the plasmas along magnetic field lines
• Heats the plasma to multimillion degree temperatures
  
  Emits the Sun's UV, EUV, X-ray radiation

• Likely accelerates the solar wind

  Shapes the Heliosphere
  Affects CME arrival time

• Creates the necessary conditions for solar activity events

  Flares
  Coronal Mass Ejections

These events have direct consequences on Earth, human technology
Problem:

We can't measure the magnetic field as needed

We need an instrument that measures

1 - Magnetic fields
2 - Plasma parameters at the same time
3 - Does (1) and (2) over the entire corona

**COSMO main goal**

COSMO will provide the necessary observations to obtain:

1 - Magnetic field LOS, POS measurements
2 - Spectroscopic diagnostics of plasma properties
COSMO has four focused science goals

I  - Determine the configurations that lead to CME onset
II - Study the role of prominences in CMEs
III - Monitor magnetic field properties during multiple solar cycles
IV - Understand coronal heating and solar wind acceleration

These goals will be pursued by measuring

I  - The magnetic field in the solar atmosphere
II - The dynamics and thermodynamic properties of solar atmospheric plasmas
III - Covering the whole corona $1.05-2.0 \, R_{\text{sun}}$
II - COSMO LC observations

COSMO’s Large Coronagraph (LC) will host a narrow band tunable filter

- Quasi-monochromatic images
- Scan wavelengths over line profiles

It will observe

- Line of sight magnetic field
- Circular polarization (Stokes U,Q)

- Plane of the sky magnetic field
- Linear polarization (Stokes V)

- Spectral line profiles
- Line intensity
- Line centroid
- Line width
Science requirements

Lifetime: Multiple solar cycles

Field of view: 1 degree (centered on the Sun)
Offset mode

Spatial resolution: 2 arcsec

Observables:
- Coronal magnetic field: 1G in 15 minutes
- Plasma composition: Low, High FIP elements
- Density structure: At multiple temperatures
- Temperature structure: Chromosphere to corona, CME conditions
- Velocity fields: At multiple T, 30 m/s in 30s
## Line list

<table>
<thead>
<tr>
<th></th>
<th>CME core</th>
<th>CME hot</th>
<th>Corona</th>
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<tbody>
<tr>
<td><strong>Priority 1 lines</strong></td>
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<tr>
<td>CME core</td>
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<tr>
<td>H I 656.3 nm</td>
<td>Fe X 637.5 nm</td>
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<td>He I 587.6, 1083.0 nm</td>
<td>Fe XI 789.2 nm</td>
<td>Fe XI 789.2 nm</td>
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<tr>
<td>Ca II 854.2 nm</td>
<td>Fe XIV 530.3 nm</td>
<td>Fe XIII 1074.7, 1079.8 nm</td>
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<tr>
<td>Fe VI 520.0 nm</td>
<td>Fe XV 706.2 nm</td>
<td>Fe XIV 530.3 nm</td>
<td>Ar X 552.2 nm</td>
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<td>S XII 761.1 nm</td>
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<td>Ar XIII 830.0, 1014.3 nm</td>
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<td>Ca XV 544.5, 569.4 nm</td>
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<td><strong>Priority 2 lines</strong></td>
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<tr>
<td>CME core</td>
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<tr>
<td>Ne III 386.9 nm</td>
<td>S VIII 991.3 nm</td>
<td>Ni XV 670.2, 802.4 nm</td>
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<tr>
<td>C III 464.8 nm</td>
<td>S XIII 1030.0 nm</td>
<td>Si X 1430.4 nm</td>
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<tr>
<td>O III 500.8 nm</td>
<td>Ar XIV 441.4 nm</td>
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<tr>
<td>Fe V 384.0 nm</td>
<td>Ca XII 332.8 nm</td>
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<tr>
<td>Ne IV 471.5 nm</td>
<td>Ni XVI 360.2 nm</td>
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<tr>
<td>Ne V 342.7 nm</td>
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<tr>
<td>Ca II 393.4 nm</td>
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III – Why a ground based coronograph

I – Operations

Instrument
Longer lifetime
Easier to repair/upgrade
Cheaper

Observations
Depend on sky condition
Night/Day cycle
Atmospheric Pollution

II – Spectroscopic performances

A - Coronal magnetic field
B - Same temperature purity as EUV lines
C - Similar temperature coverage Of EUV lines
C - Continuum emission
III – Field of view

IV - Simultaneous imaging and spectroscopy

Intensity

Doppler shifts

Line width

11 July 2010 eclipse

Eclipse: ~1 min

EIS raster: ~ 68 min
IV – Diagnostic capabilities

1 - Continuum spectrum
2 - Line emission spectrum

Eclipse 2006 – Lybia. Courtesy of Sarah Jaeggli, Univ. Hawaii
Spectrum formation mechanisms

Observed continuum (Thomson scattering):
\[ I_{\text{cont}} \propto J n_e \]

Observed intensity of a visible coronal line:
\[ I_{\text{obs}} = I_{\text{coll}} + I_{\text{rad}} \]

Collisional excitation
\[ I_{\text{coll}} \propto F(X^{+m}) A_x n_e^2 \]
Depends on \( n_e^2 \)

Radiative excitation
\[ I_{\text{rad}} \propto F(X^{+m}) A_x J n_e \]
Depends on \( n_e \)

Ion fraction  \quad \text{Incident radiation}
Element abundance
1 - Line to continuum ratio:

\[ R \sim [a \times n_e + b] \ F(X^{+m}) \ A_x \]

A - Change of line excitation regime

B – Measurement of charge state evolution

In the radiative excitation regime:

\[ R \sim b \ F(X^{+m}) A_x \]

- Determine charge state evolution
- Determine final, frozen-in charge state distribution
- Compare with models, in-situ data

Direct, quantitative connection with in-situ charge state measurements

Habbal et al. 2011

Landi et al. 2012
2 – Temperature-resolved morphology of the upper corona

Eclipse observations show narrow T distribution

- Large scale, simultaneous 2D temperature maps
- Large scale thermal structure maps
- Temporal evolution of coronal temperature over long periods of time

First 2D, temperature resolved imaging of the extended corona
3 – Tomographic reconstruction of the solar corona

Tomographic reconstructions of visible coronal line intensities will open the door to a whole new level of coronal science

A – Determine 3D structure of the solar corona during the solar cycle
   - Evolution of T-resolved individual structures

B – Reconstruct line and continuum 3D distribution
   - Apply all diagnostics in 3D
   Elimination of line of sight integration issues

C - Combine with global magnetic field models
   - Follow charge state evolution along individual field lines
   - Apply wind diagnostic techniques to the same parcel of plasma
   Directly connect low corona diagnostics with in-situ measurements

Courtesy of CSEM/Univ. Michigan
4 – Dynamics of the extended corona

A – Doppler velocities

3D reconstruction of CME trajectory

Absolute acceleration measurements
Interaction with nearby magnetic structures

B – Line width measurements

Solar wind heating

Ion-cyclotron waves
Individual ion heating
Wave propagation and damping
- Determine height of wave dissipation
- Estimate energy release
- Study minor ion heating in solar wind

Shock line broadening
- Determine location of shocks
- Measure effects on local plasma
- Study SEP sources
V – Use cases

The COSMO steering committee developed use cases

Here a few of them are summarized based on such input

1 - Long term synoptic observations of the solar corona

2 - Coronal Mass Ejections

3 - Cavity studies
Long term synoptic observations of the solar corona

Objective: Study solar cycle evolution of the solar corona

Significance:

Changes in irradiance
Changes in plasma composition
Changes in plasma properties
Changes in the magnetic configuration
**COSMO products:**
- Magnetic field
- Plasma temperature and density distributions
- Plasma elemental composition
- Plasma ion abundances
- 3D tomographic reconstruction of the whole corona

**COSMO strategy:**
- Daily synoptic observations in core lines
  - Density diagnostics
  - Temperature coverage
  - Low-, high-FIP elements
  - Magnetic field sensitivity

**COSMO uniqueness**
- First time such measurements will be provided continuously
- Extends to 2 solar radii
- Combines the capabilities of EUV imagers and spectrometers
Coronal Mass Ejections

Objective:
- Measure plasma properties of CMEs during eruptions
- Determine 3D trajectory
- Determine magnetic configuration of CME plasmas

Significance:
- CMEs critical for Space Weather
- Determine energy budget
  - Kinetic energy
  - Thermal energy
- Follow CMEs up to 4 solar radii
- Study all CME components
  - Core
  - Front
  - Cavity
  - Current sheet
COSMO products:

- Kinetic to Thermal energy ratio
- 3D velocity determination
- Plasma diagnostics in all CME components
- Magnetic configuration

COSMO strategy:

- Target of Opportunity observations
- Observations:
  - Sun-centered - up to 2 $R_{\text{sun}}$
  - Offset - up to 4 $R_{\text{sun}}$

COSMO uniqueness

- First measurements of CME plasma properties
- Determination of CME evolution during onset
- Identification of magnetic structure
- Measurements up to 4 solar radii
Flux rope-cavity evolution

Objective:
Study formation, evolution
Measure their properties
Understand when they are destabilized

Significance:
They can originate CME
Current work mostly uses
Morphology
Statistical studies
Photospheric magnetic field extrapolations
COSMO will provide the first complete measurements
COSMO products:
- Coronal magnetic field measurements
- Velocity fields
- Density, temperature, abundance measurements

COSMO strategy:
- Target of Opportunity observations
- Prolonged observations to capture 3D structure

COSMO uniqueness:
- First measurements of coronal properties
- Provide constraints to models
- Monitor the structure for long periods to identify CME precursors