The Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP)

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and the CLASP team
Introduction

- To understand energy release process in the Sun including solar flares, it is essentially important to measure the magnetic field of the atmosphere of the Sun.

- Magnetic field measurement of the upper layers (upper chromosphere and above) was technically difficult and not well investigated yet.

-> Upper chromosphere and transition region magnetic field measurement by Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP) sounding rocket to be launched in 2015.

The proposal is already selected and developments of the flight components are going.
Hinode/SOT Photospheric magnetic field observation

Hinode/SOT performed spectro-polarimetric observation of the optical light and vector magnetic fields are derived using the Zeeman effect

However, it is not possible to use the Zeeman effect for the magnetic field measurement of the upper layers because of weaker magnetic fields and shorter wavelengths
Magnetic field measurement of the upper layers: Hanle effect

Isotropic reradiation

Atom

Unpolarized light

Solar Surface

Observer

Isotropic reradiation

Atom

Magnetic field

Unpolarized light

Solar Surface

Linear polarization state changes by a magnetic field: Hanle effect
Lyman-alpha line as the magnetic field probe

Lyman alpha line:
Strongest upper chromosphere
/transition region line
-> high sensitivity for
  measuring vector magnetic fields
  of these layers
  using the Hanle effect

SOHO/SUMER on-disk spectrum

(Vernazza et al. 1981)
The expected deviation of the polarization degree caused by the magnetic field is only an order of 0.1%!

-> Spectropolarimetry with a precision of < 0.1% is required to measure the magnetic field.
Polarization measurement by CLASP

- Lyα light from the Sun
- Continuously rotating half waveplate
- Polarization of the incident light
- Change the polarization direction
- Extract the polarization component with a certain direction

Polarization modulation

16 measurement / rotation

D1, D2, D3, D4, ...

CCD measurement values

Time (corresponding to the waveplate angle)

Modulation amplitude
D1 - D2 - D3 + D4 ...

Polarization degree

Intensity
D1 + D2 + D3 + D4 ...

CCD Camera

Reflective polarization analyser
CLASP consists of:
- Cassegrain telescope
- Spectropolarimeter with a rotating 1/2 waveplate, spherical grating,
  reflective polarization analyzers and CCD cameras
  (taking data along the slit)
- Slitjaw optics to take images of the surrounding part of the slit
# Error budget for spurious polarization

<table>
<thead>
<tr>
<th>Cause of error</th>
<th>error (1σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon noise at Ly-a center (10” along slit and 200s obs. period)</td>
<td>0.026%</td>
</tr>
<tr>
<td>Readout noise of CCD cameras</td>
<td>0.011%</td>
</tr>
<tr>
<td>Fluctuation of exposure durations</td>
<td>5x10⁻⁵%</td>
</tr>
<tr>
<td>Time variation of source intensity</td>
<td>&lt;0.018%† (~0%)</td>
</tr>
<tr>
<td>Intensity variation from pointing jitter</td>
<td>&lt;0.018%† (~0%)</td>
</tr>
<tr>
<td>Image shift from waveplate rotation</td>
<td>~0%</td>
</tr>
<tr>
<td>Off-axis incidence with 200”</td>
<td>~10⁻⁴%</td>
</tr>
<tr>
<td>Non-uniformity of coating on primary mirror</td>
<td>10⁻³%</td>
</tr>
<tr>
<td>Error in polarization calibration</td>
<td>0.017%</td>
</tr>
<tr>
<td><strong>RSS</strong></td>
<td><strong>&lt;0.042% (~0.033%)</strong></td>
</tr>
</tbody>
</table>

†: These values are the case for the single channel demodulation, and can be reduced by dual channel modulations.
Telescope & cold mirror coating

The primary mirror will be coated to reflect the Lyα (>50%) and not to reflect the visible light (<5%)
Waveplate

Flight waveplate is made of two MgF₂ plates

The difference between the extraordinary refractive index and ordinary refractive index ($n_e - n_0$) of MgF₂ is measured precisely by our group (R. Ishikawa et al. 2013) and the flight waveplate is fabricated for the retardation to be 180-degree at Lyα

The retardation is measured to be very close to 180-degree at the Lyα wavelength.
Waveplate motor

The continuously rotating motor with the high rotation uniformity to minimize the error of the polarization degree measurement (Rotation period: 4.8s)

Error of the polarization degree measurement is estimated to be <0.01%
Reflective Polarization Analyzer

High polarization efficiency of $\sim$99% and high uniformity are achieved by multi-layer coating proposed by Bridou et al. (2011)
Operation

CLASP has an observation duration of only ~300s

Target 1: disk center (10s)
- The polarization degree is expected to be significantly smaller than at the limb:
  checking the instrument is working well

Target 2: including limb (>220s)
- Scientific observation
  Data will be integrated for the whole duration (not considering a time variation during the pointing)

To be launched in summer 2015! (White Sands, New Mexico, USA)
Summary

- CLASP is a sounding rocket experiment to observe the linear polarization profile of the Lyα line from the Sun for the magnetic field measurement in the upper chromosphere and transition region.

- CLASP estimates the magnetic field by the Hanle effect and it is necessary to measure the polarization with the precision of <0.1%.

- The developments of the flight components are well going.

- CLASP will be launched in summer 2015.