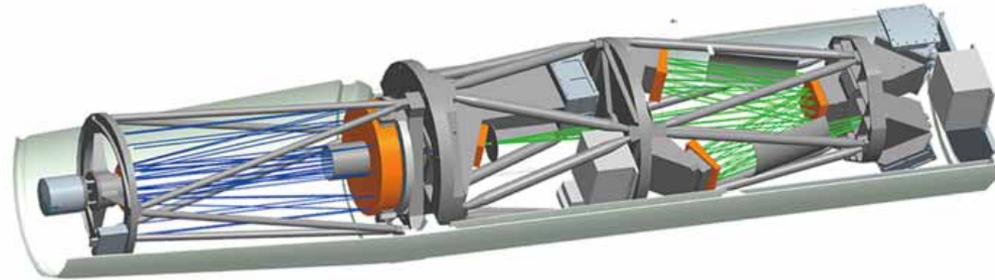# The Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP)

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M. Kubo, Y. Katsukawa, Y. Suematsu, H. Hara (NAOJ), T. Shimizu, T. Sakao (ISAS/JAXA),
K. Ichimoto (Kyoto Univ.), G. Giono (GUAS), T. Holloway, A. Winebarger,
J. Cirtain (NASA/MSFC), B. De Pontieu (LMSAL), R. Casini (HAO), F. Auchere (IAS),
J. Trujillo Bueno (IAC), R. Manso Sainz, L. Belluzzi, A. Asensio Ramos (IAC),
J. Stepan (ASCR), M. Carlsson (Univ. Oslo)
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
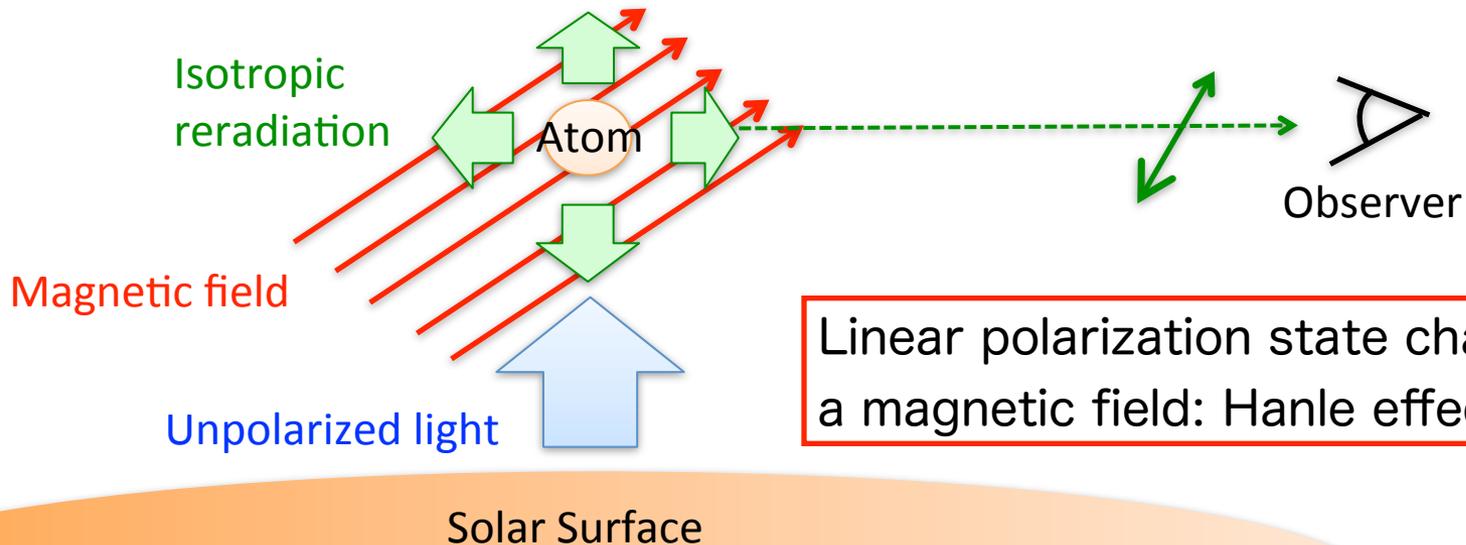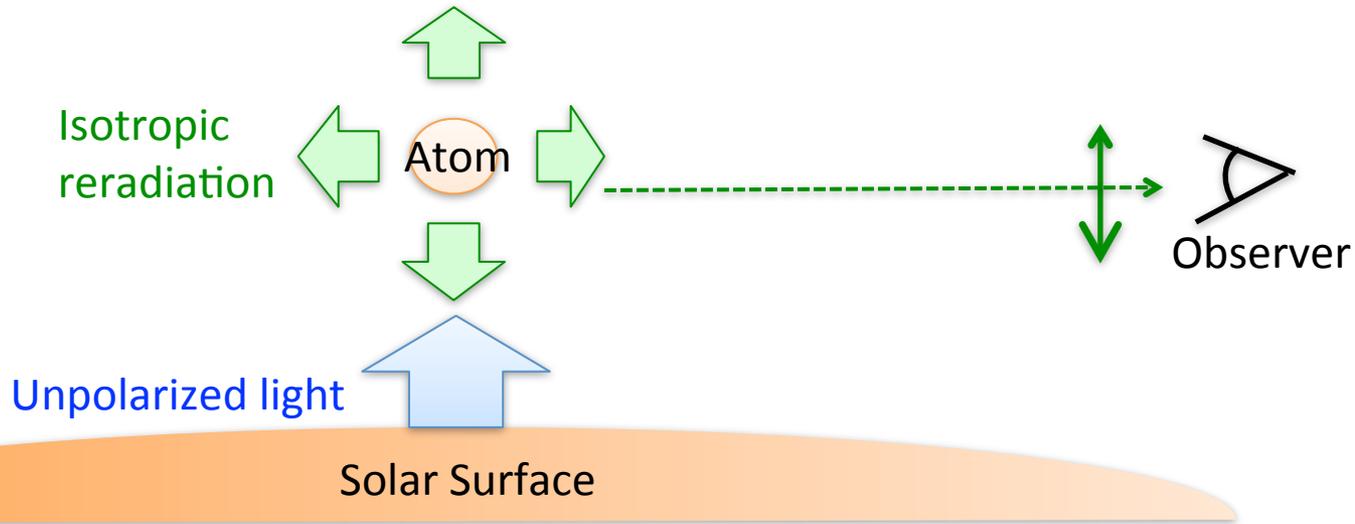the flight components are going
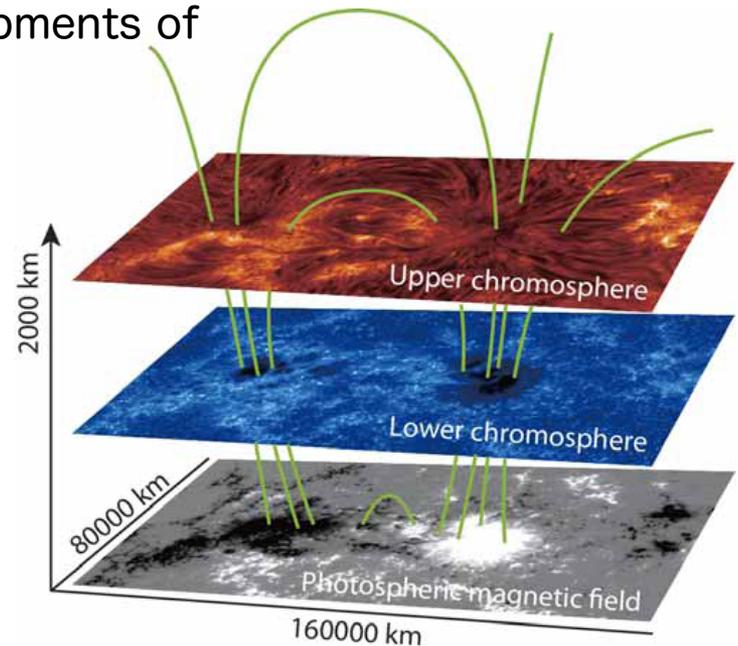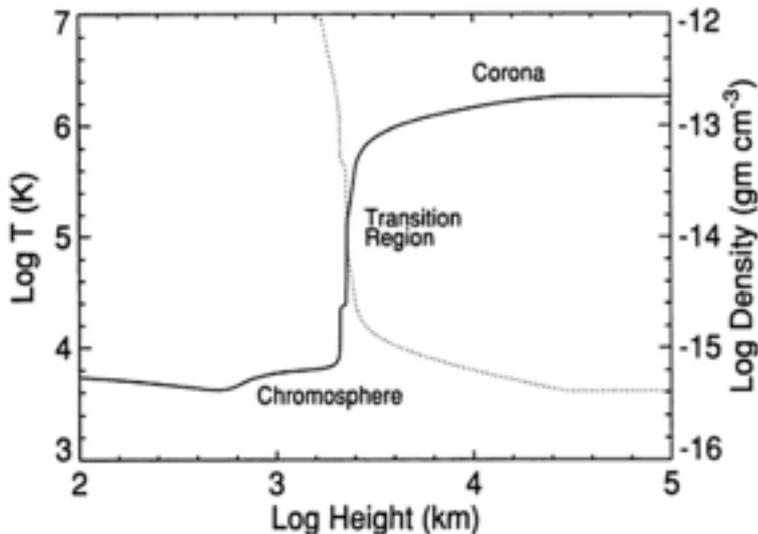
Hinode/SOT Photospheric magnetic field observation

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

(preflare)

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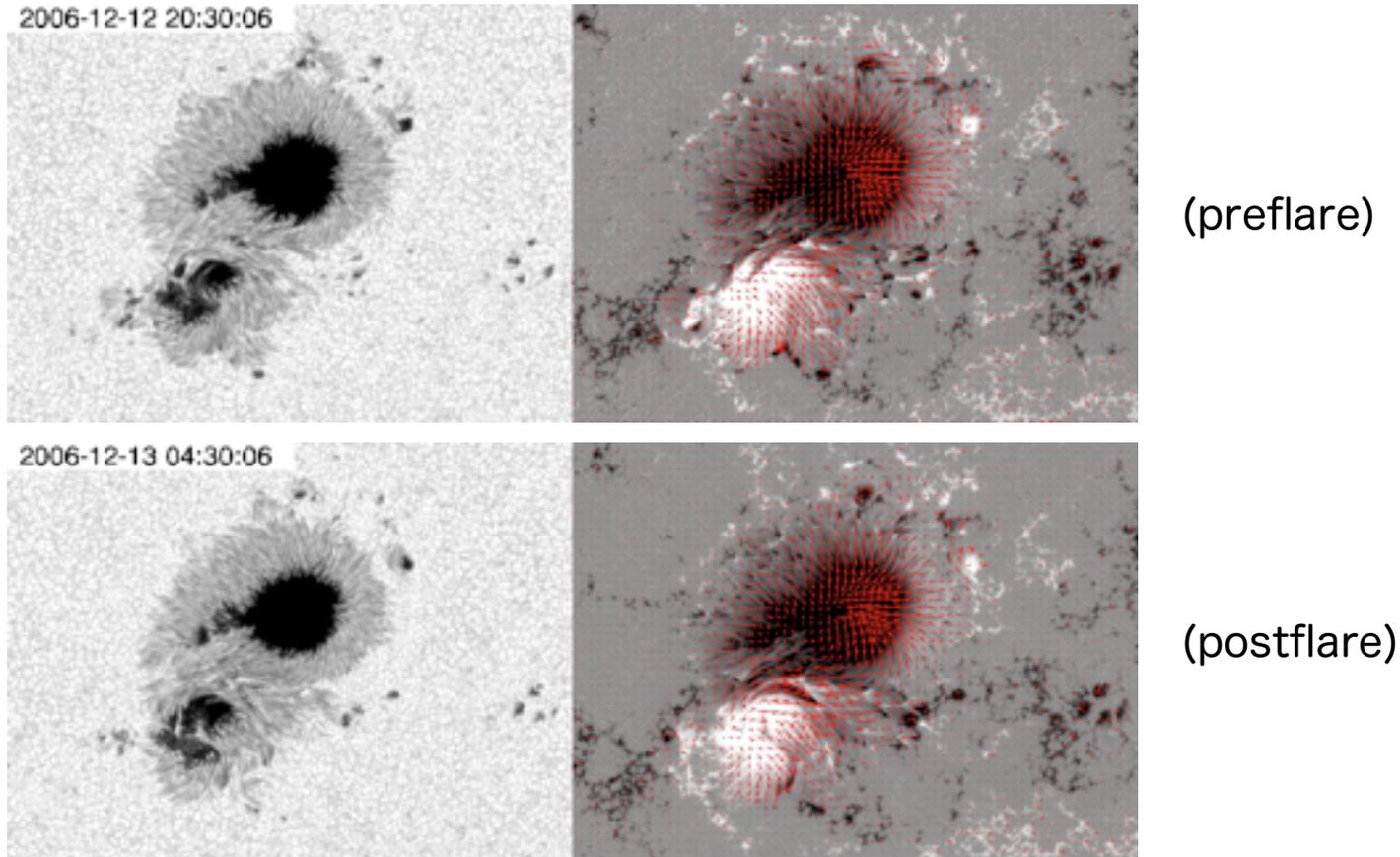
However, it is not possible to use the Zeeman effect for the magnetic field measurement of the upper layers because of weaker magnetic fields and shorter wavelengths

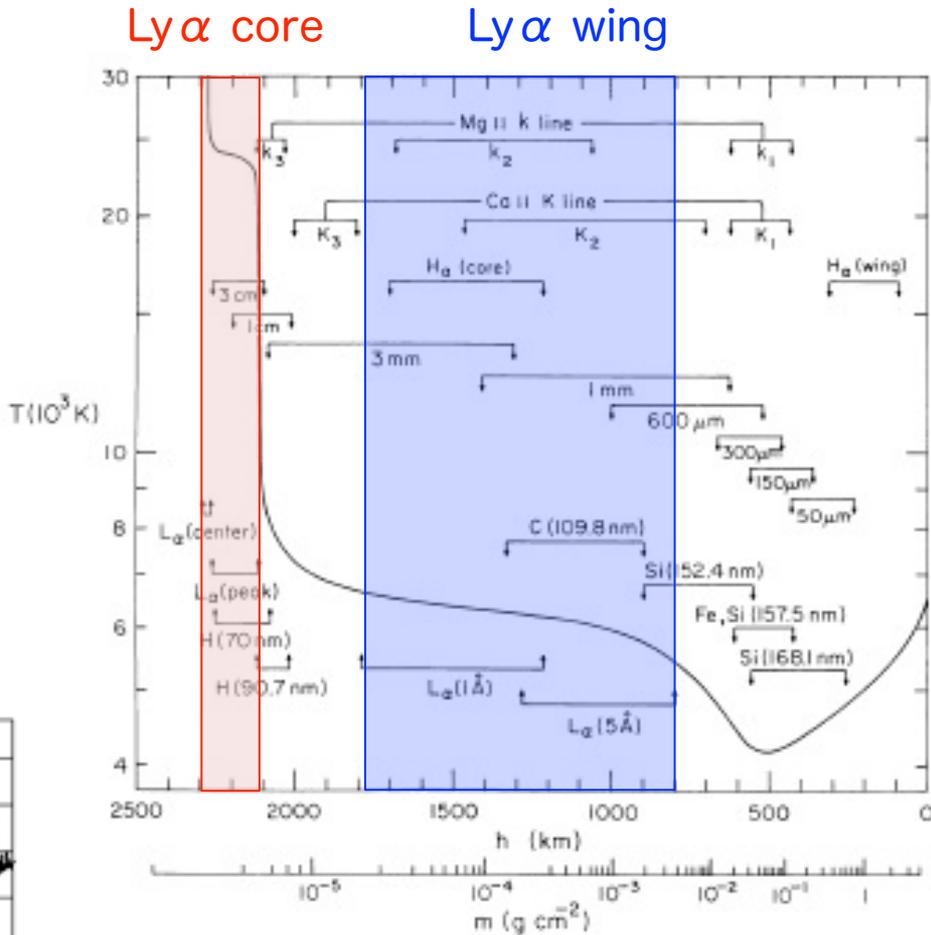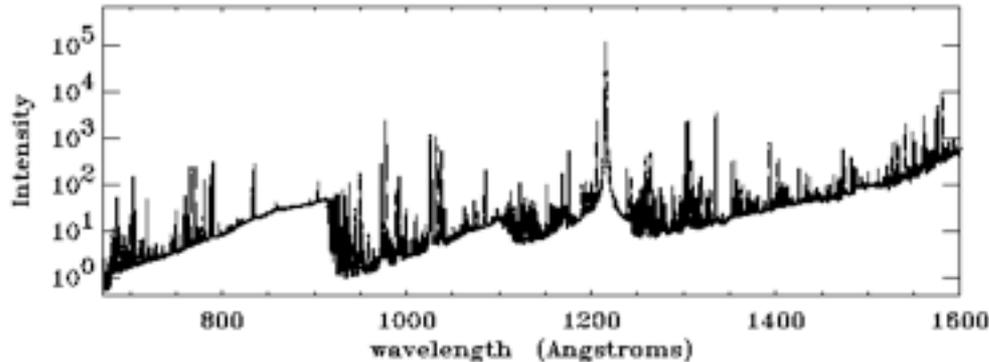# Magnetic field measurement of the upper layers: Hanle effect

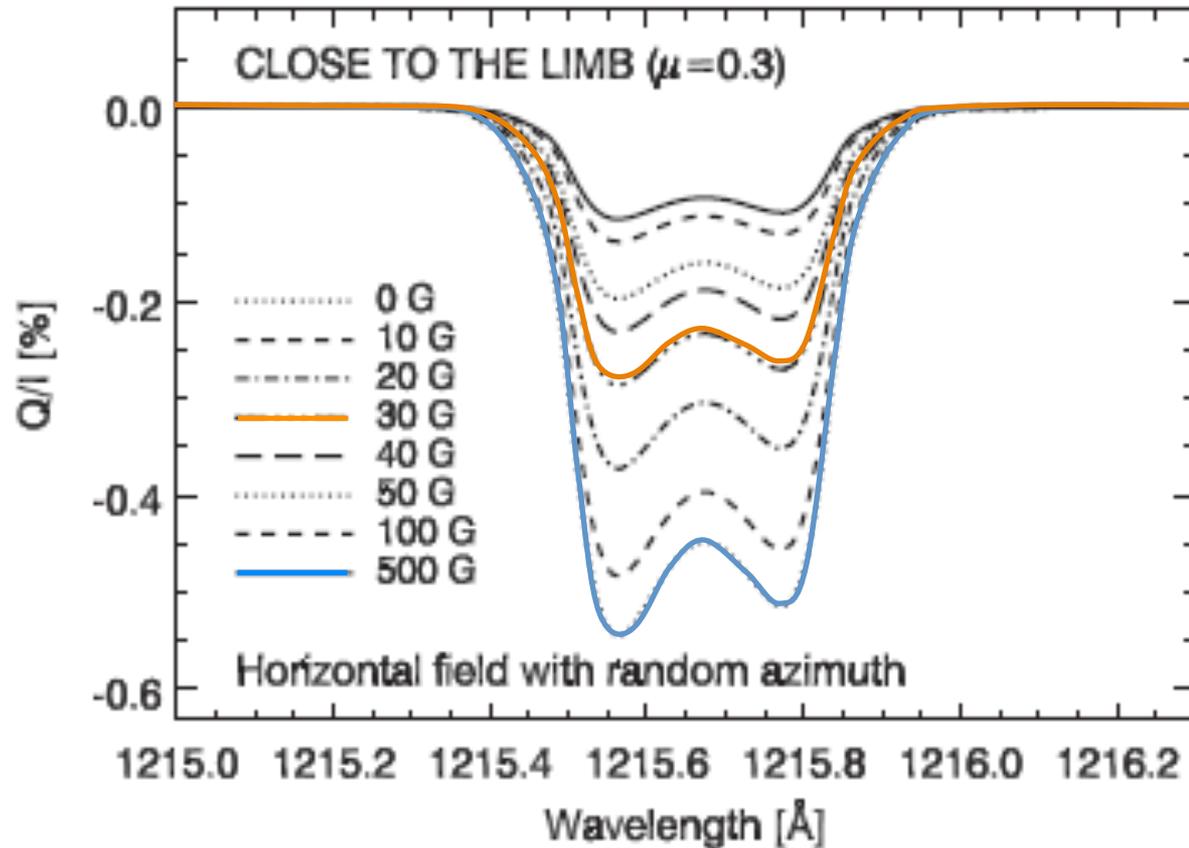# Lyman-alpha line as the magnetic field probe

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

Ly α core   Ly α wing

(Vernazza et al. 1981)

Expected polarization observation

CLOSE TO THE LIMB (μ=0.3)

Legend:
- 0 G
- 10 G
- 20 G
- 30 G
- 40 G
- 50 G
- 100 G
- 500 G

Horizontal field with random azimuth

Q/I [%]

Wavelength [Å]
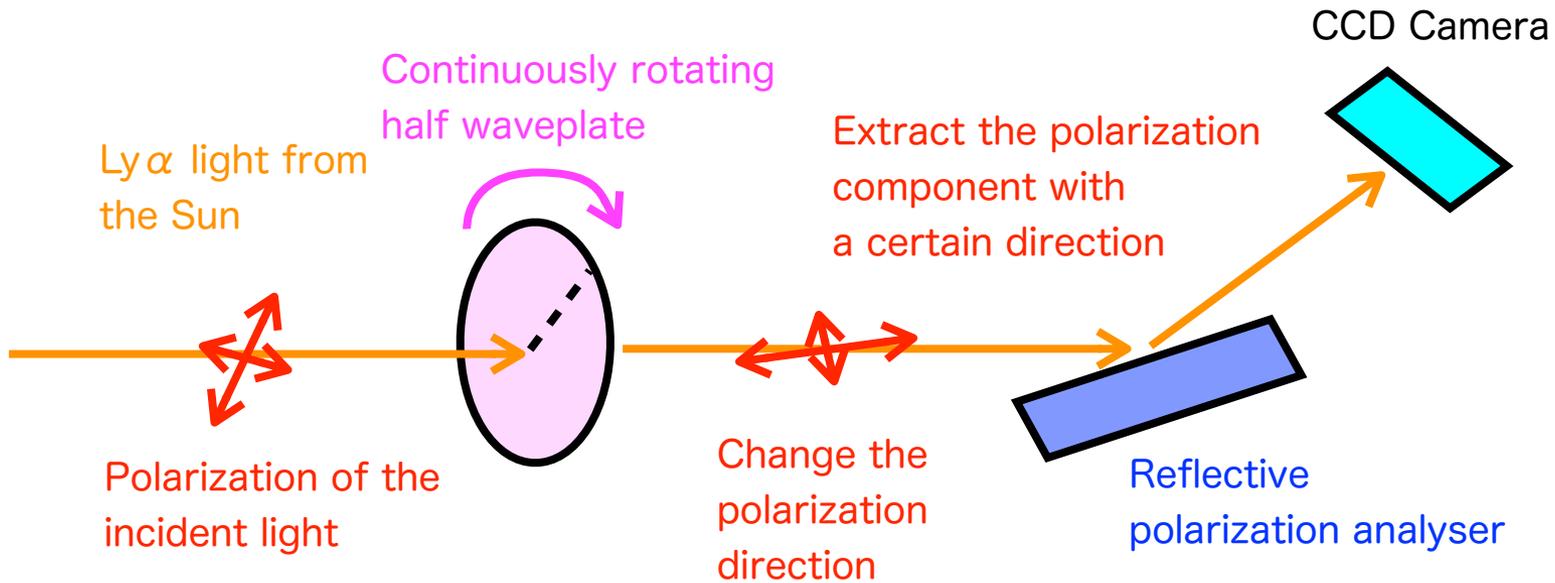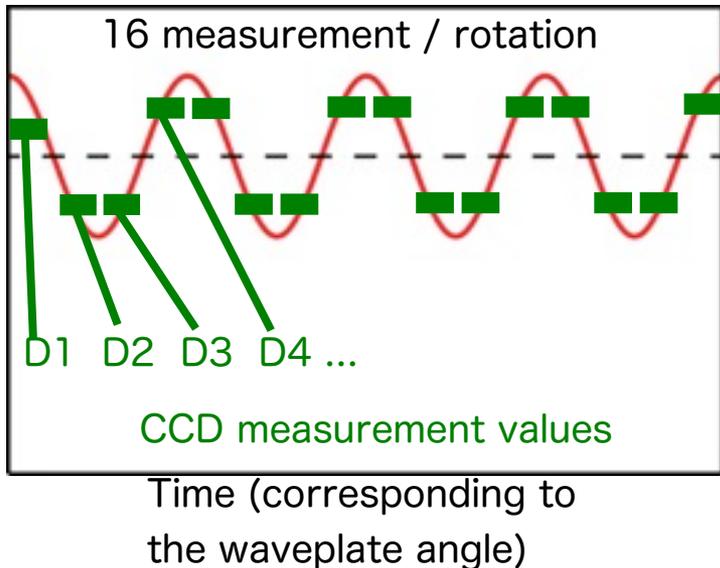
The expected deviation of the polarization degree caused by the magnetic field is only an order of 0.1% !

-> Spectropolarimetry with a precision of < 0.1% is required
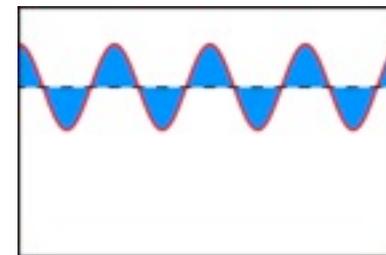   to measure the magnetic field

Polarization measurement by CLASP

Lyα light from the Sun

Continuously rotating half waveplate

Extract the polarization component with a certain direction

CCD Camera

Polarization of the incident light

Change the polarization direction

Reflective polarization analyser

Polarization modulation

16 measurement / rotation

D1 D2 D3 D4 ...

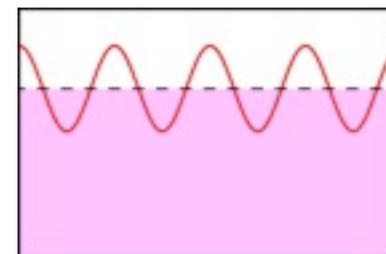CCD measurement values

Time (corresponding to the waveplate angle)
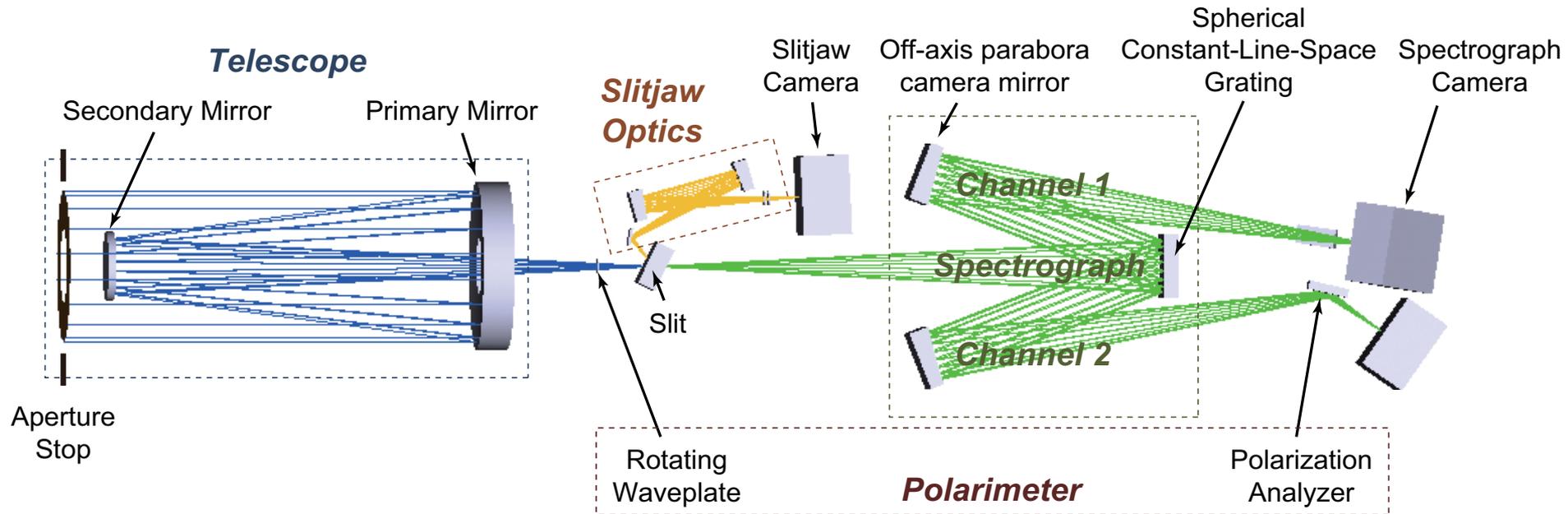
Polarization degree $\propto$

Modulation amplitude

D1 - D2 - D3 + D4 ...

Intensity

D1 + D2 + D3 + D4 ...

CLASP instrumentation

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
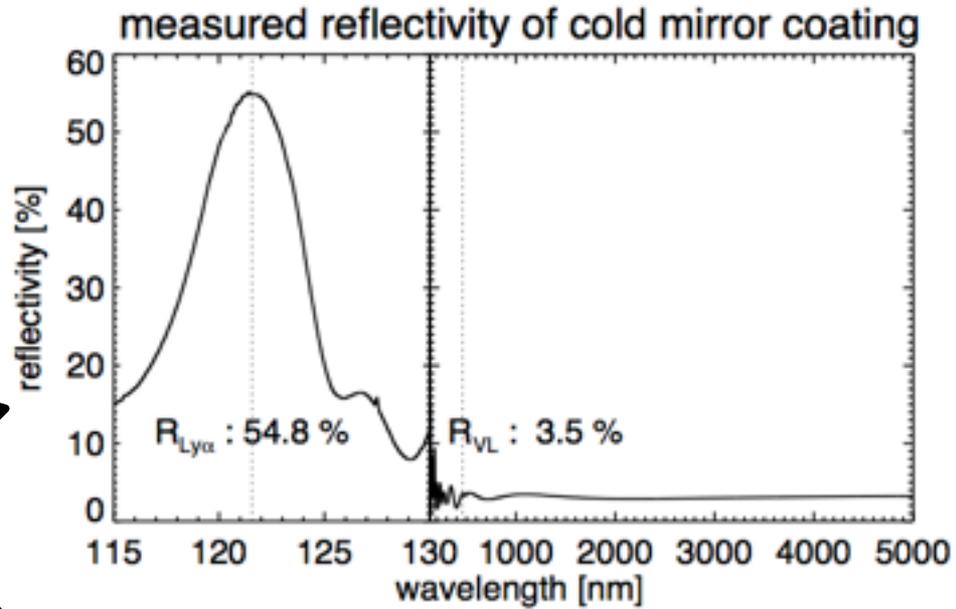
Error budget for spurious polarization

Cause of error	error (1σ)	
Photon noise at Ly-a center (*10"* along slit and *200s* obs. period)	*0.026%*	Random noise
Readout noise of CCD cameras	0.011%	
Fluctuation of exposure durations	5×10^{-5}%	
Time variation of source intensity	<0.018%† (~0%)	*dI/dt*
Intensity variation from pointing jitter	<0.018%† (~0%)	
Image shift from waveplate rotation	~0%	
Off-axis incidence with 200"	~10^{-4}%	Induced by telescope
Non-uniformity of coating on primary mirror	10^{-3}%	
Error in polarization calibration	0.017%	
RSS	***<0.042% (~0.033%)***	

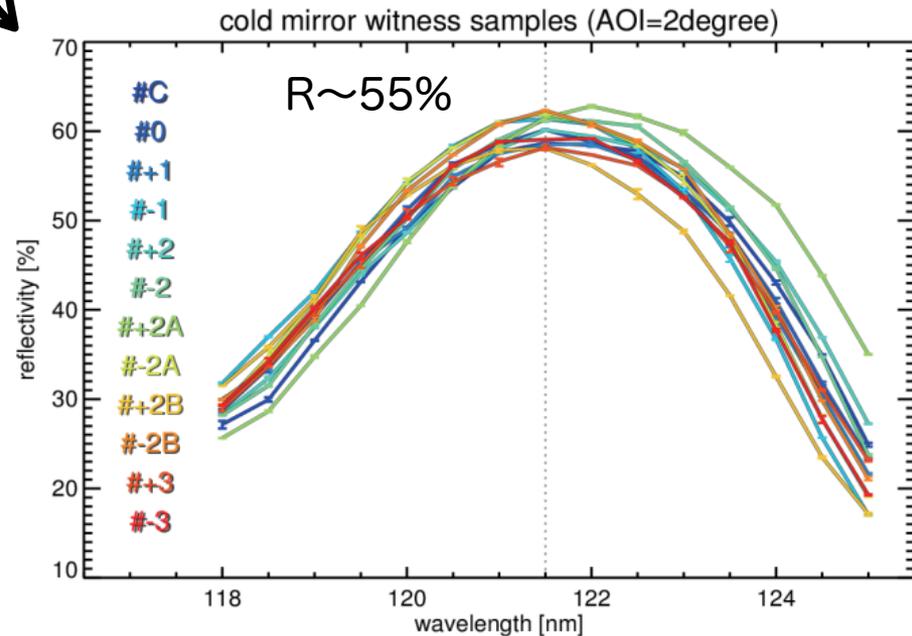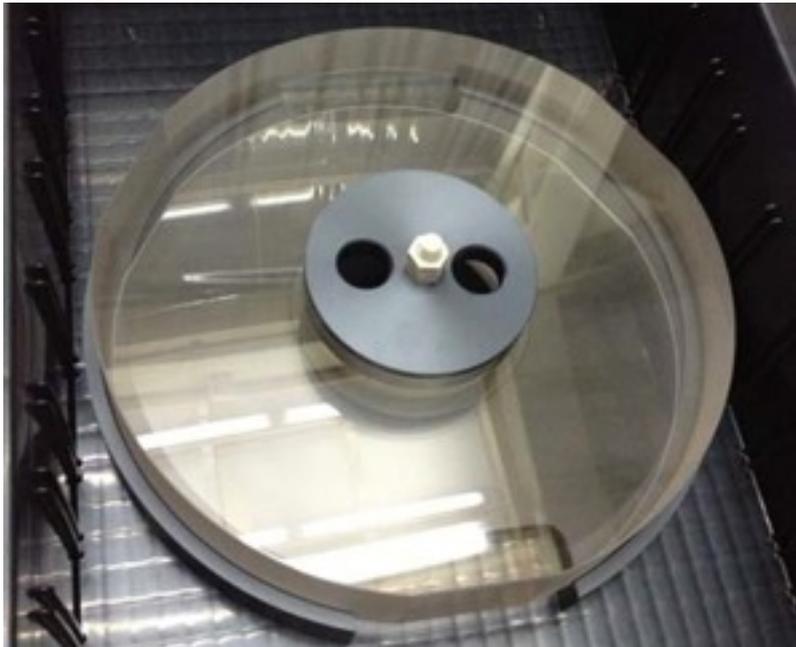†: These values are the case for the single channel demodulation, and can be reduced by dual channel modulations.

Telescope & cold mirror coating

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

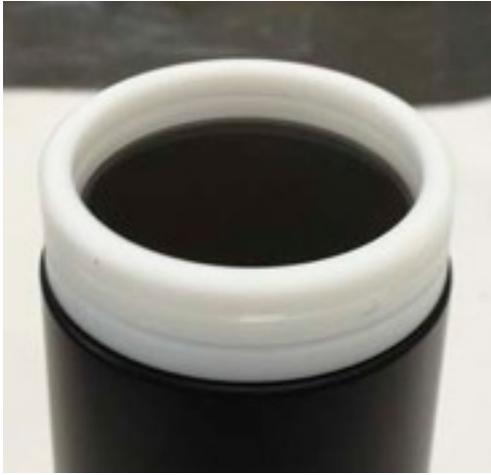Test piece results

Flight primary mirror (not coated yet)

measured reflectivity of cold mirror coating

$R_{Ly\alpha}$: 54.8 %

R_{VL} : 3.5 %

cold mirror witness samples (AOI=2degree)

R~55%

#C
#0
#+1
#-1
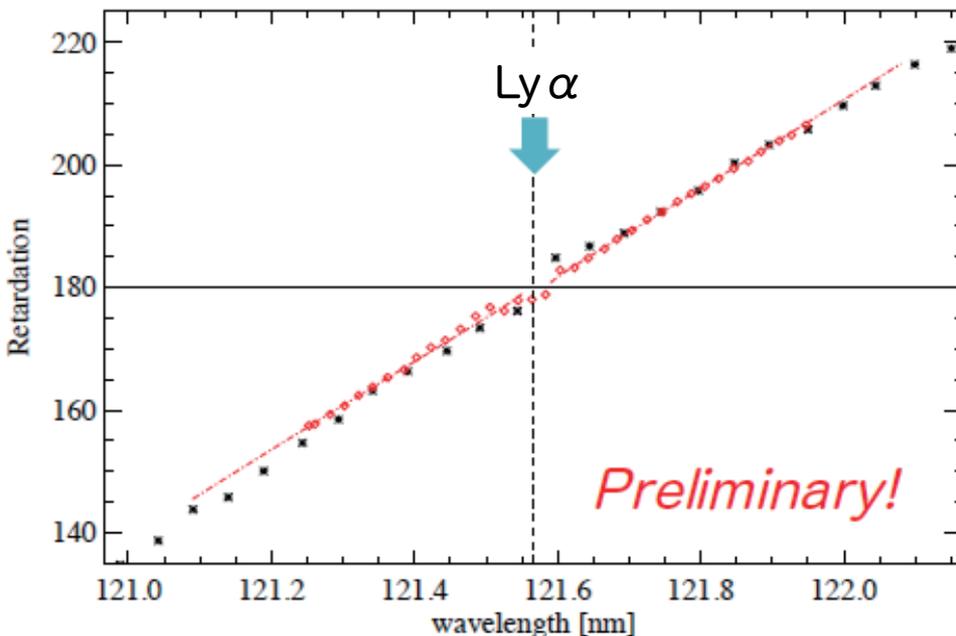#+2
#-2
#+2A
#-2A
#+2B
#-2B
#+3
#-3

Waveplate

Flight waveplate

Flight waveplate is made of two MgF_2 plates

The difference between the extraordinary refractive index and ordinary refractive index $(n_e - n_o)$ of MgF_2 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 $Ly\alpha$
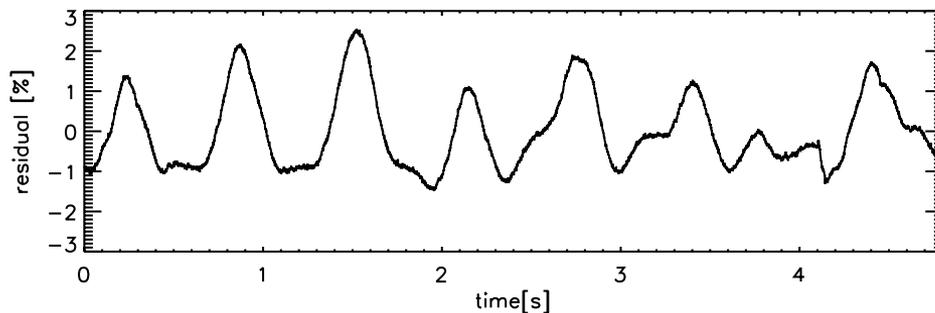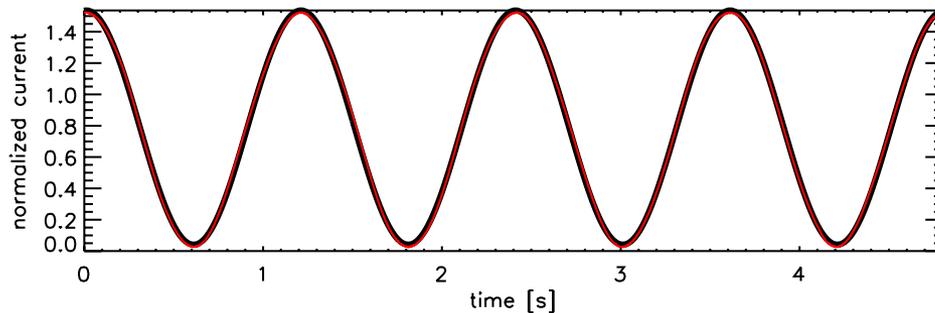
The retardation is measured to be very close to 180-degree at the $Ly\alpha$ wavelength
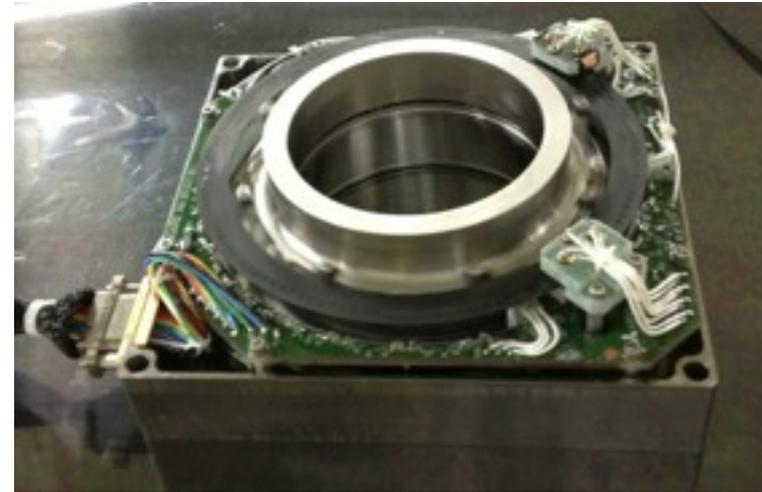
Waveplate motor

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

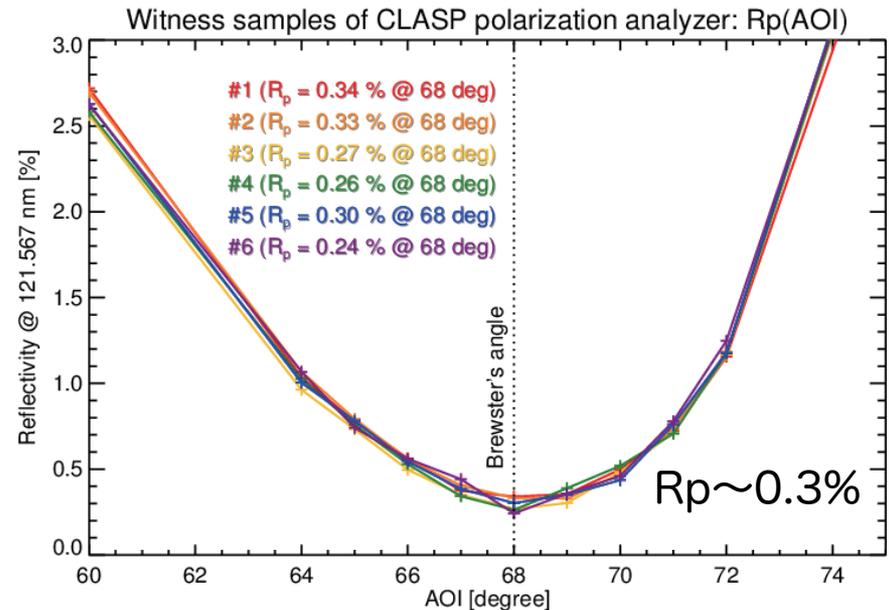Error of the polarization degree measurement
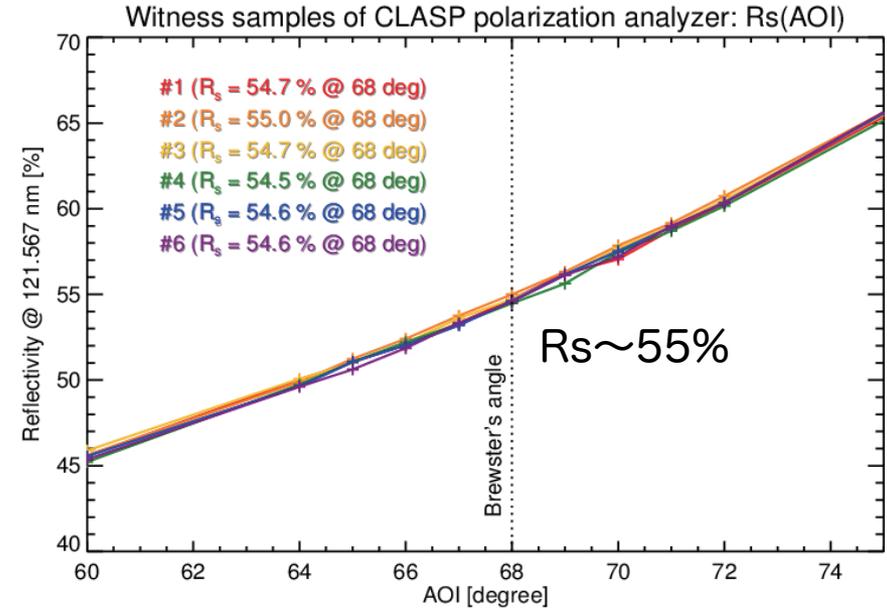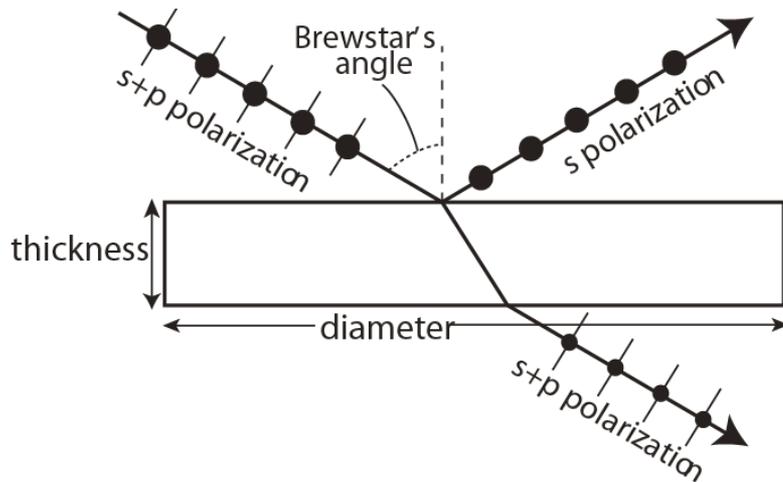is estimated to be <0.01%

Flight motor & driver

Reflective Polarization Analyzer

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

Witness samples of CLASP polarization analyzer: Rs(AOI)

#1 (R$_s$ = 54.7 % @ 68 deg)
#2 (R$_s$ = 55.0 % @ 68 deg)
#3 (R$_s$ = 54.7 % @ 68 deg)
#4 (R$_s$ = 54.5 % @ 68 deg)
#5 (R$_e$ = 54.6 % @ 68 deg)
#6 (R$_s$ = 54.6 % @ 68 deg)

Rs∼55%

Witness samples of CLASP polarization analyzer: Rp(AOI)

#1 (R$_p$ = 0.34 % @ 68 deg)
#2 (R$_p$ = 0.33 % @ 68 deg)
#3 (R$_p$ = 0.27 % @ 68 deg)
#4 (R$_p$ = 0.26 % @ 68 deg)
#5 (R$_p$ = 0.30 % @ 68 deg)
#6 (R$_p$ = 0.24 % @ 68 deg)

Rp∼0.3%

Operation

CLASP has an observation duration of only ~300s
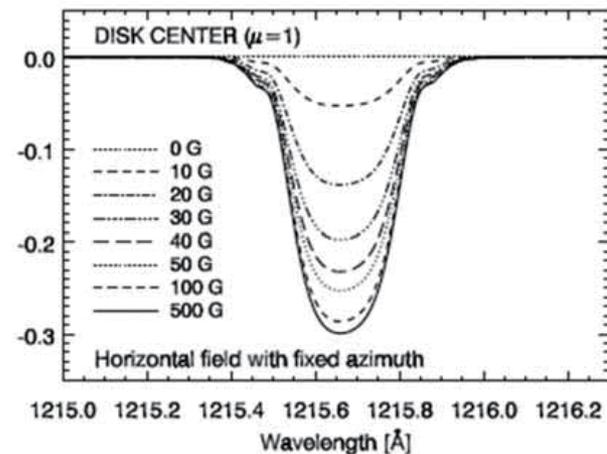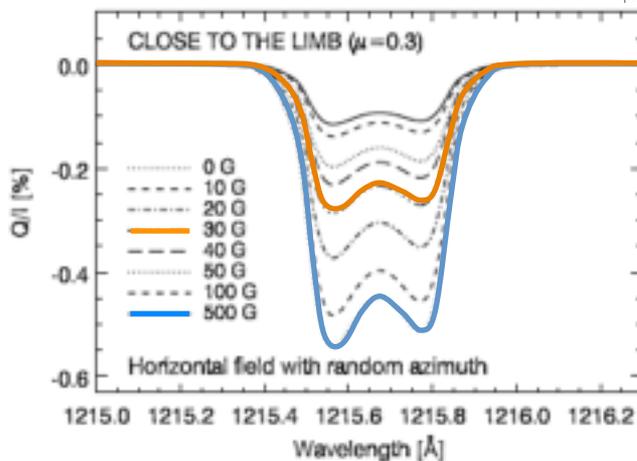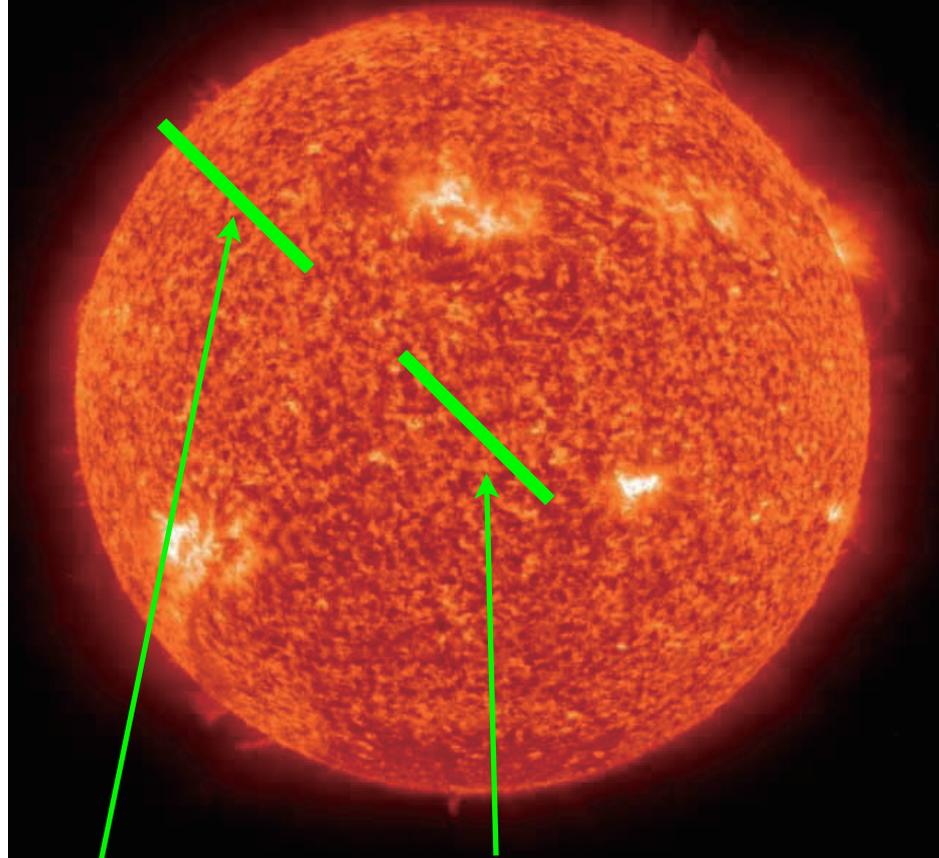
Target 1: disk center (10s)
 - The polarization degree is expected
   to be significantly smaller than
   at the limb:
   checking the instrument is working well

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)

Slit width: 400''

CLOSE TO THE LIMB (μ=0.3)

0 G
10 G
20 G
30 G
40 G
50 G
100 G
500 G

Horizontal field with random azimuth

Q/I [%]

DISK CENTER (μ=1)

0 G
10 G
20 G
30 G
40 G
50 G
100 G
500 G

Horizontal field with fixed azimuth

Wavelength [Å]

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