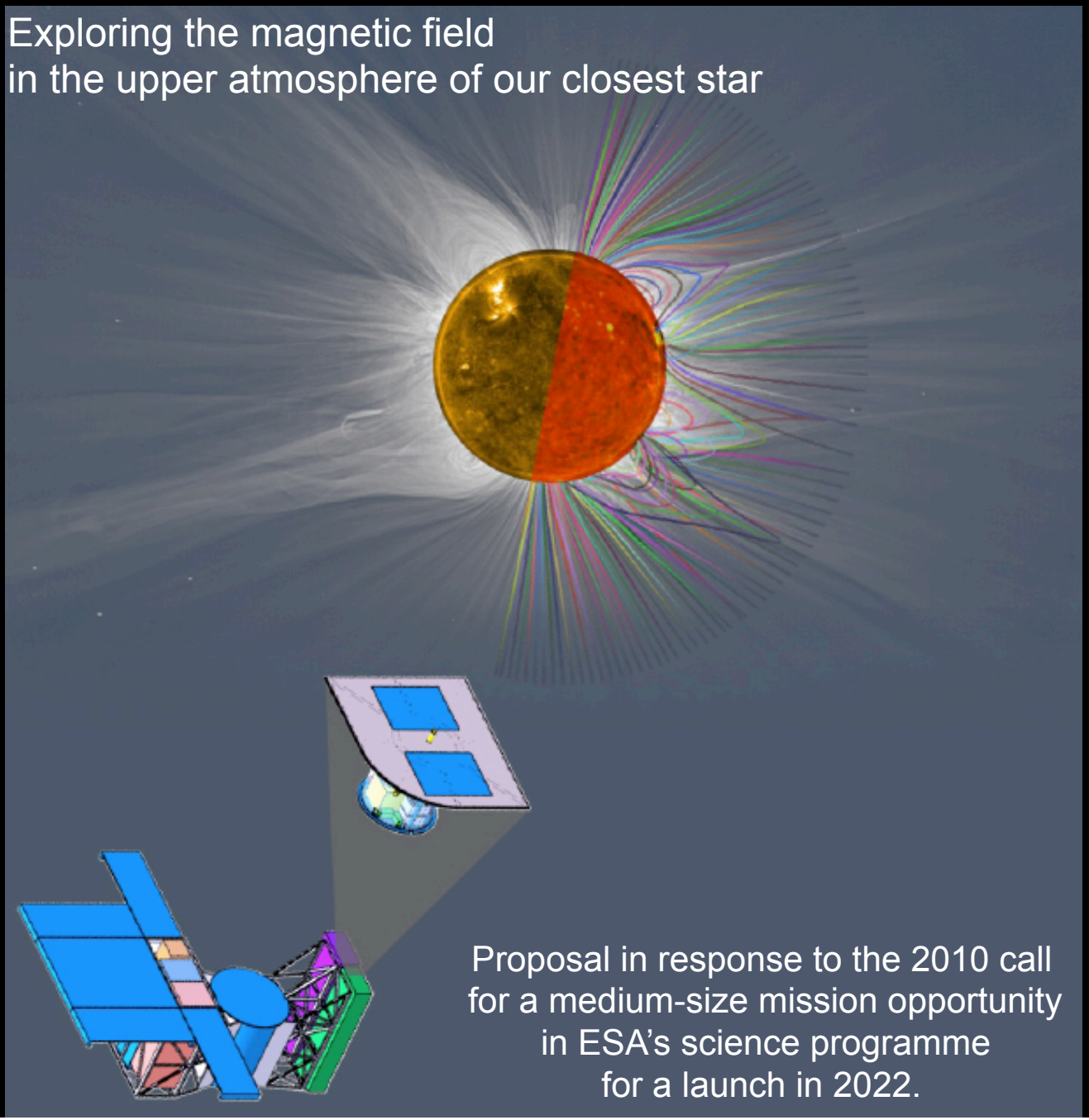
Solar magnetism eXplorer (SolmeX)

Exploring the magnetic field
in the upper atmosphere of our closest star



Proposal in response to the 2010 call
for a medium-size mission opportunity
in ESA's science programme
for a launch in 2022.

preprint at
arXiv 1108.5304
(Exp.Astron.)

or search for
"solmex" in ADS

Hardi Peter

& SolmeX team

MPS

MAX-PLANCK-GESELLSCHAFT

Solar magnetism eXplorer – SolmeX

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SolmeX consortium: *(in alphabetical order)*

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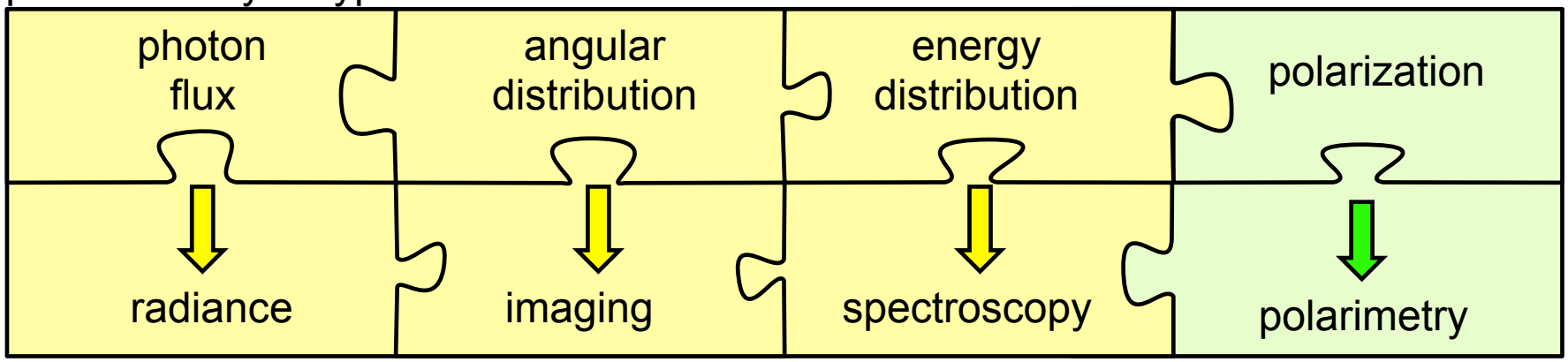
Spectro-polarimetry of the UPPER solar atmosphere

The missing piece of the puzzle

photons carry 4 types of information:



SOHO & Hinode & Solar C

[UVSP / SMM]

SDO & TRACE

IRIS

SolmeX

spatial structures and their temporal evolution

plasma diagnostics: density, temperature, etc…

diagnostics of the magnetic field

pivotal to understand interaction of plasma and magnetic field

What is SolmeX ?

very sloppily:

Remote-sensing SOHO with **increased spatial** (≈ SDO) **& temporal resolution plus full polarimetric capability**

SOHO	**+**	**polarimetry**		**SolmeX**	
UVCS	+	linear	slit	EUV	CUSP
LASCO	+	full Stokes	Fabry-Perot	IR	VIRCOR
EIT	+	linear	broad band	EUV	EIP
SUMER /CDS	+	full Stokes	slit	FUV	SUSP
MDI	+	full Stokes (Chromosphere)	Fabry-Perot	UV	ChroME

SolmeX science goals

- What is the magnetic structure of the outer solar atmosphere?
- What is the nature of the changes of the magnetic field over the solar cycle?
- What drives large-scale coronal disruptions such as flares and coronal mass ejections?
- How do magnetic processes drive the dynamics and heating of the outer solar atmosphere?
- How does the magnetic field couple the whole solar atmosphere from the photosphere to the outer corona?

Measurement objective:

provide the first comprehensive measurement of the magnetic field

in the upper atmosphere of the Sun,

i.e. in the chromosphere, transition region and corona

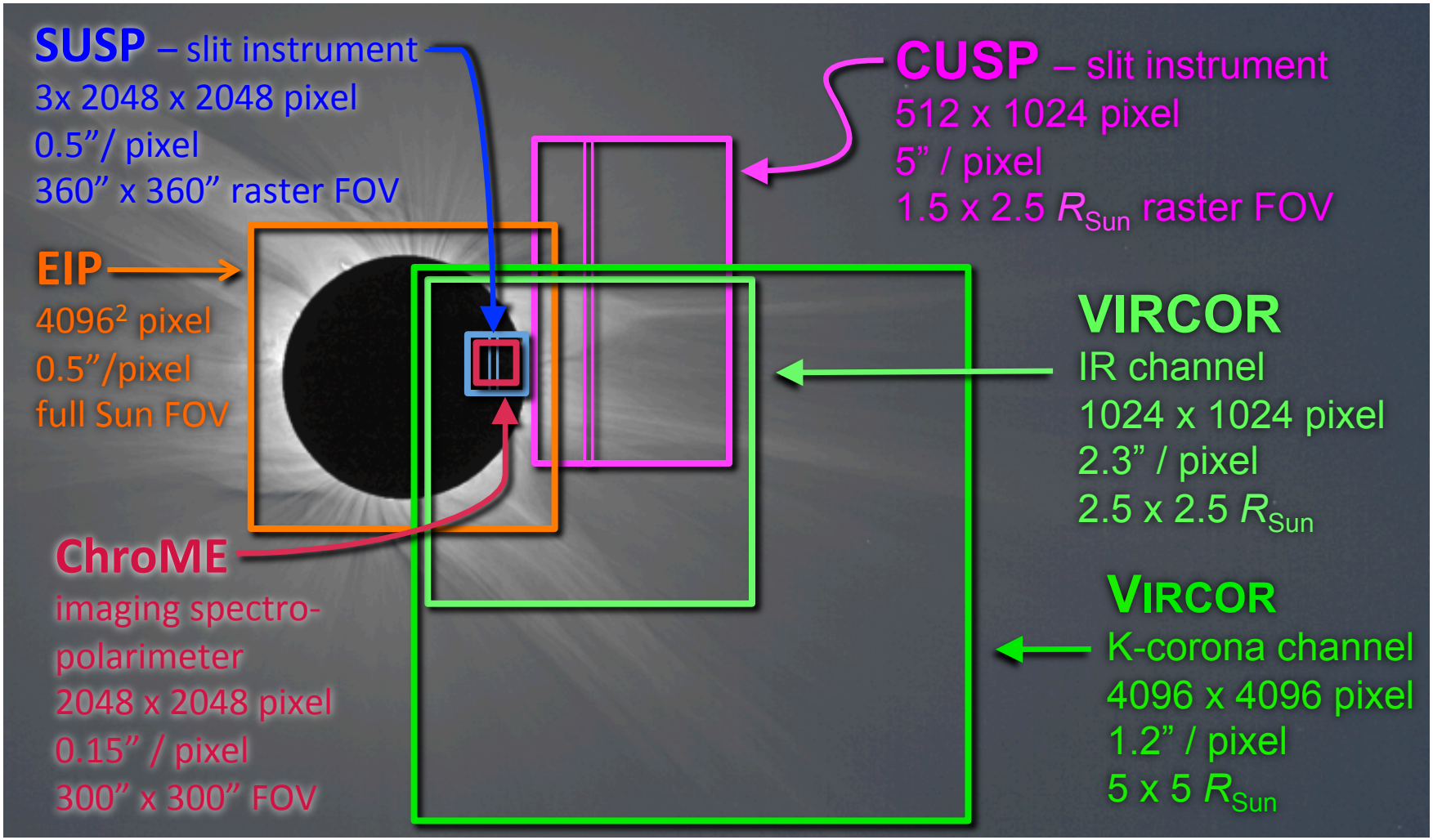
SolmeX: five instruments

on-disk:

EIP (EUV imaging polarimeter)
SUSP (Scanning UV spectro-polarimeter)
ChroME (Chromospheric magnetic explorer)

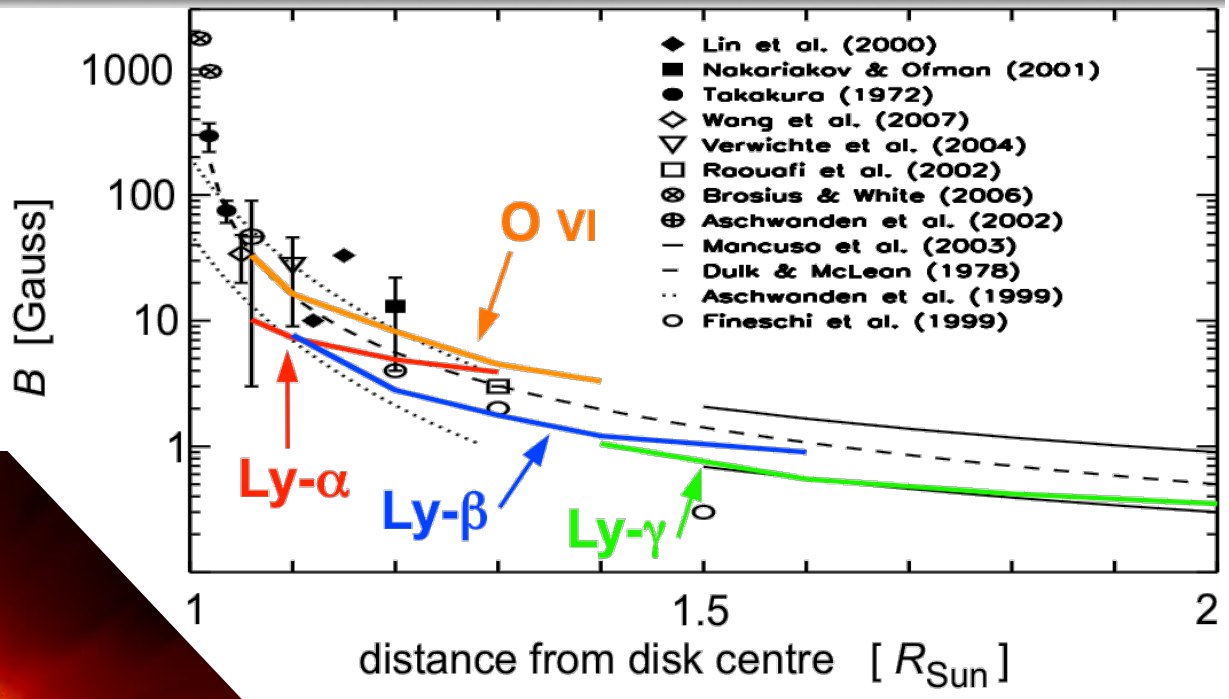
off-limb:

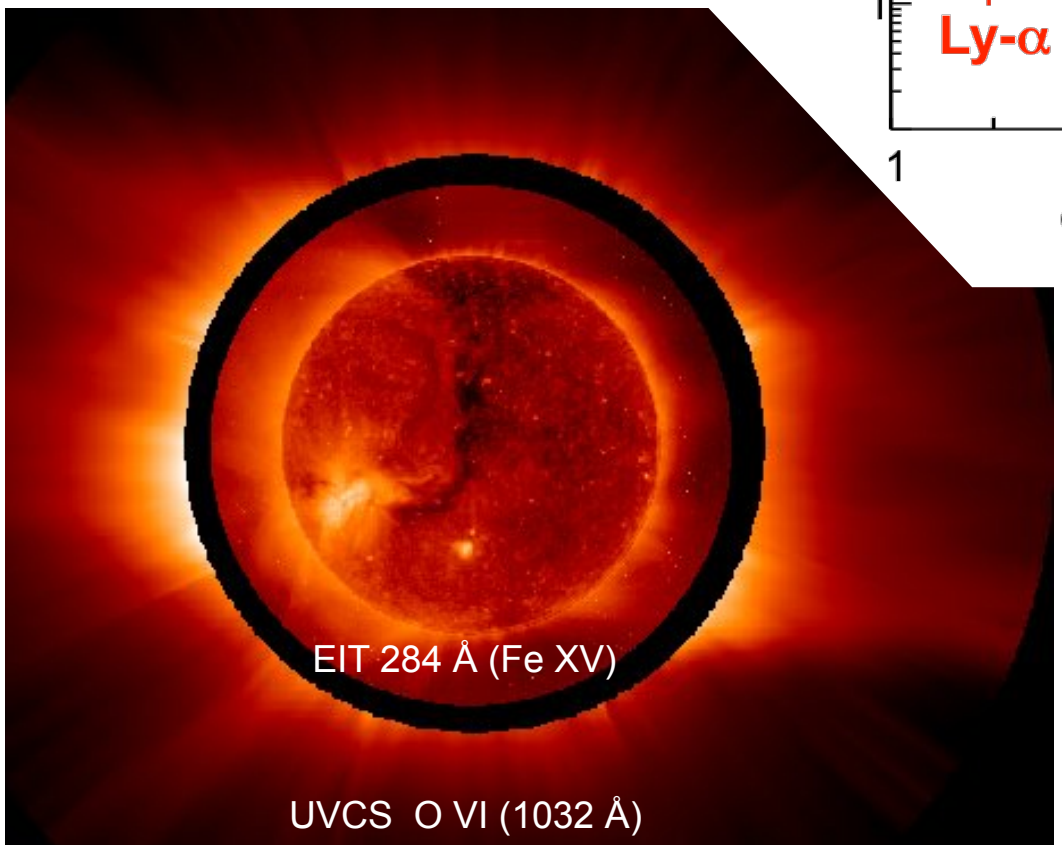
CUSP (Coronal UV spectro-polarimeter)
IRCOR (Visible light and IR coronagraph)

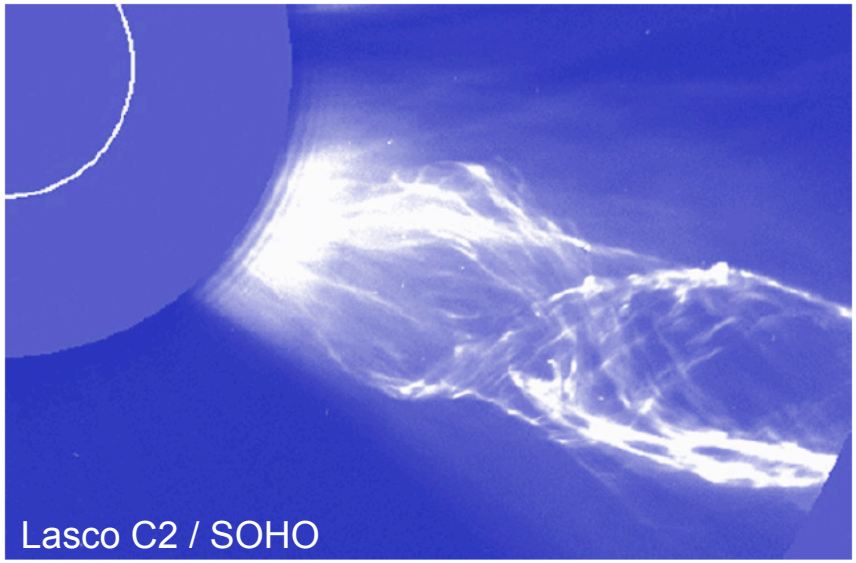


Large-scale corona above the limb

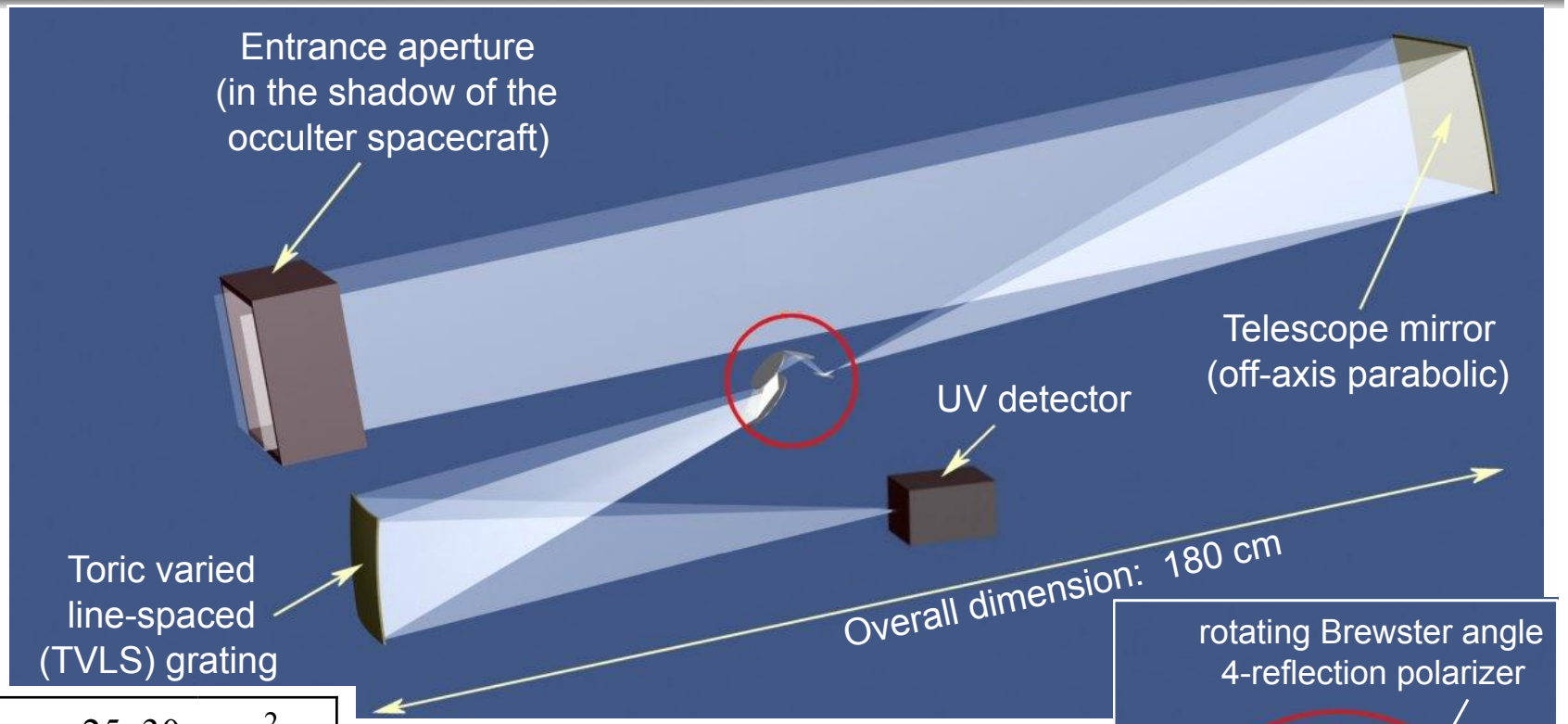
- linear polarization off-limb due to anisotropic illumination from the disk
- **Hanle-effect** modifies this polarization



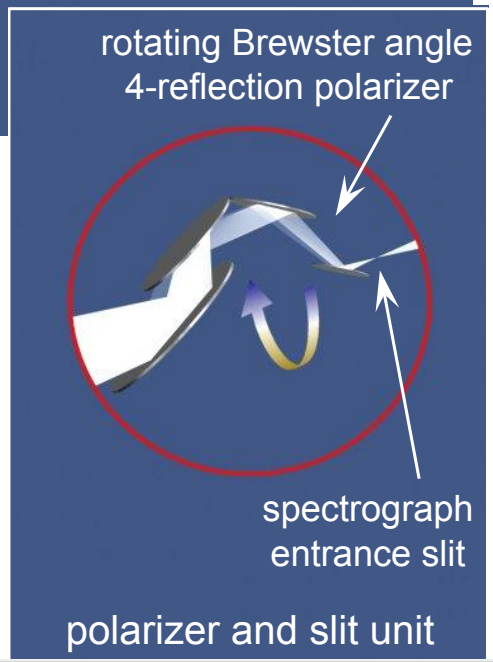




Coronal UV spectro-polarimeter – CUSP



aperture	25x30	cm^2
envelope	180x60x30	cm^3
mass	70	kg
power	30	W
detector	512 x 1024	
sampling	5 9	arcsec pm
data rate	150	kbit/s

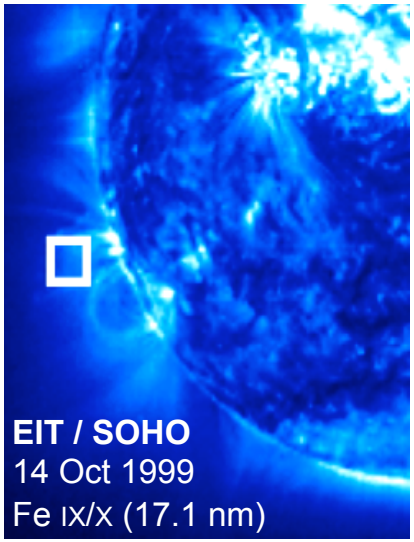


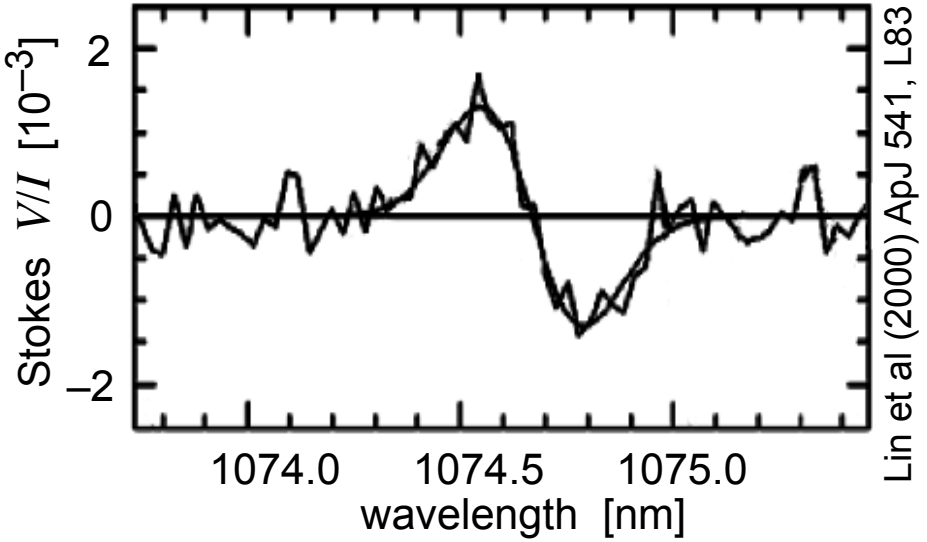
Off-limb corona above active regions

- IR line emission
  L-corona (Fe XIII):

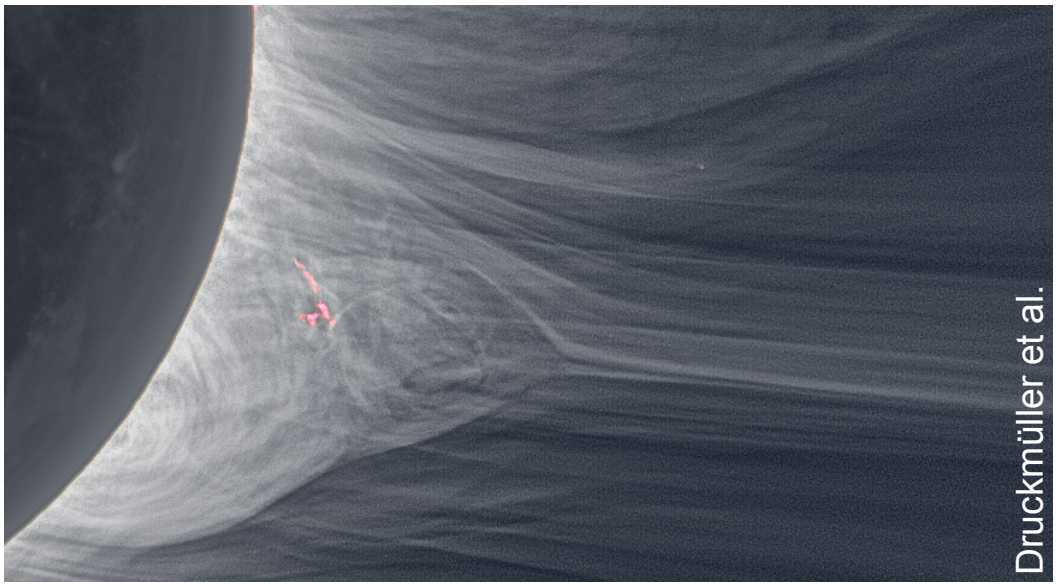
  circular and linear polarization:

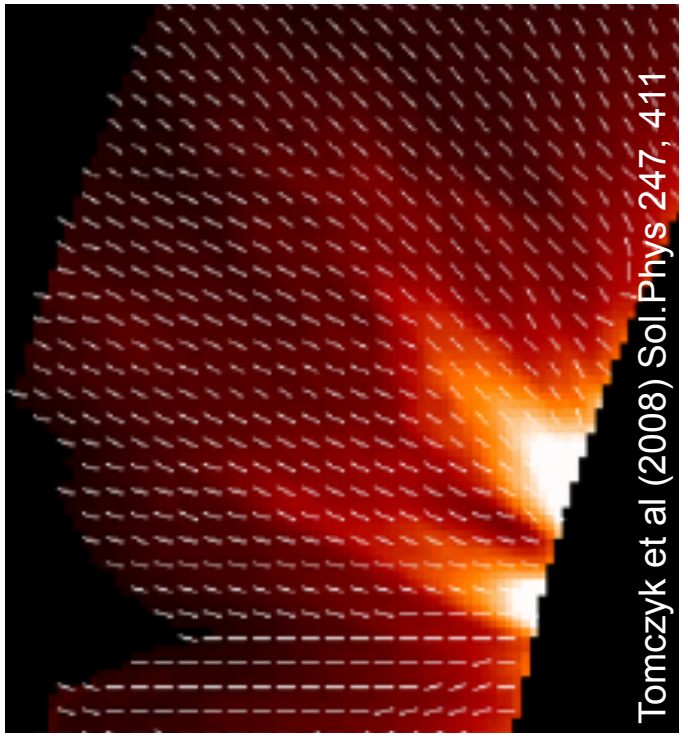
  Zeeman effect
  plus
  Hanle signature



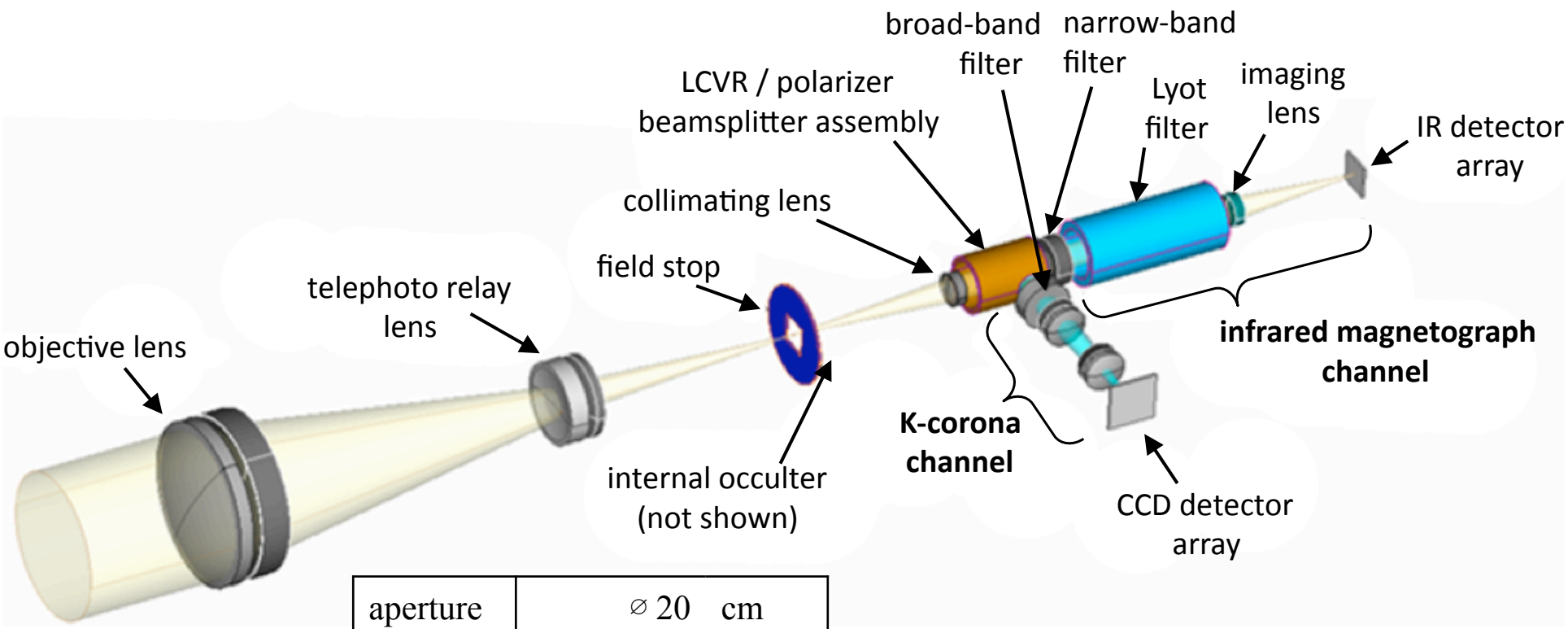


K-corona → high-resolution imaging
→ temperature & density diagnostics





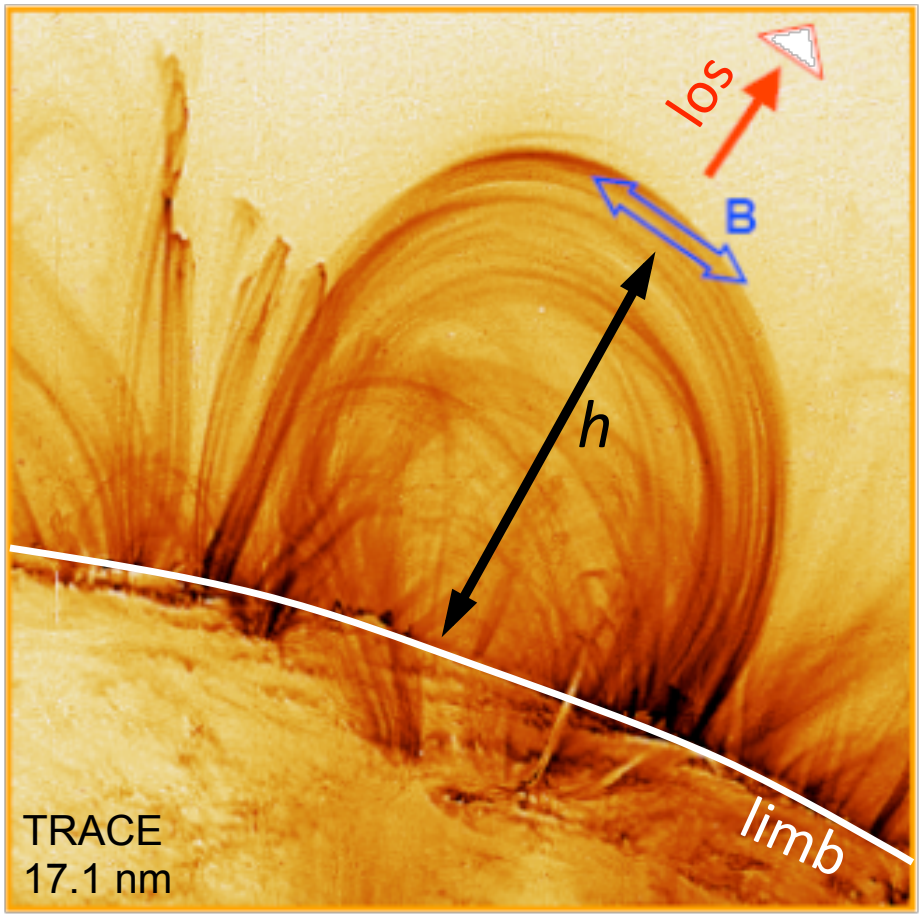
Visible and infrared coronagraph – VIRCOR

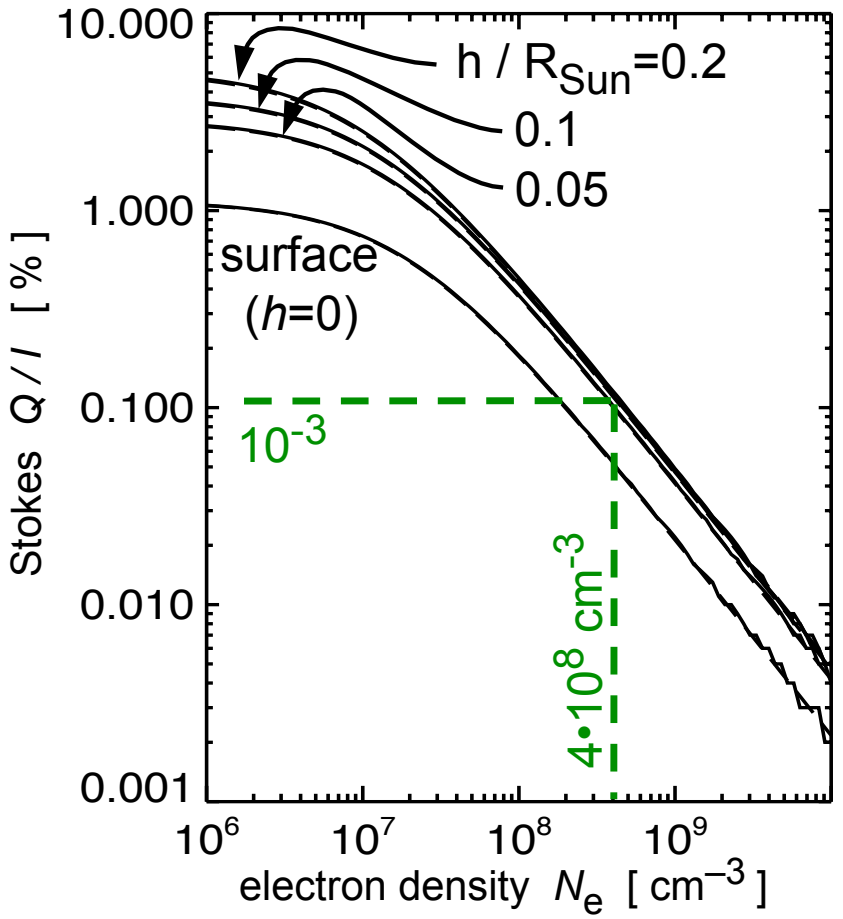


aperture	⌀ 20	cm
envelope	180x50x25	cm^3
mass	60	kg
power	50	W
detector	1 k / 4 k	
sampling	2 / 1 0.2	arcsec nm
data rate	300	kbit/s

Magnetic field direction in coronal loops

- Upward collisional transfer of optically-pumped ground-level polarization
  → *linear polarization*
- Hanle effect (in ground-level saturation regime) sensitive to the magnetic field orientation
  → *modifies linear polarization*

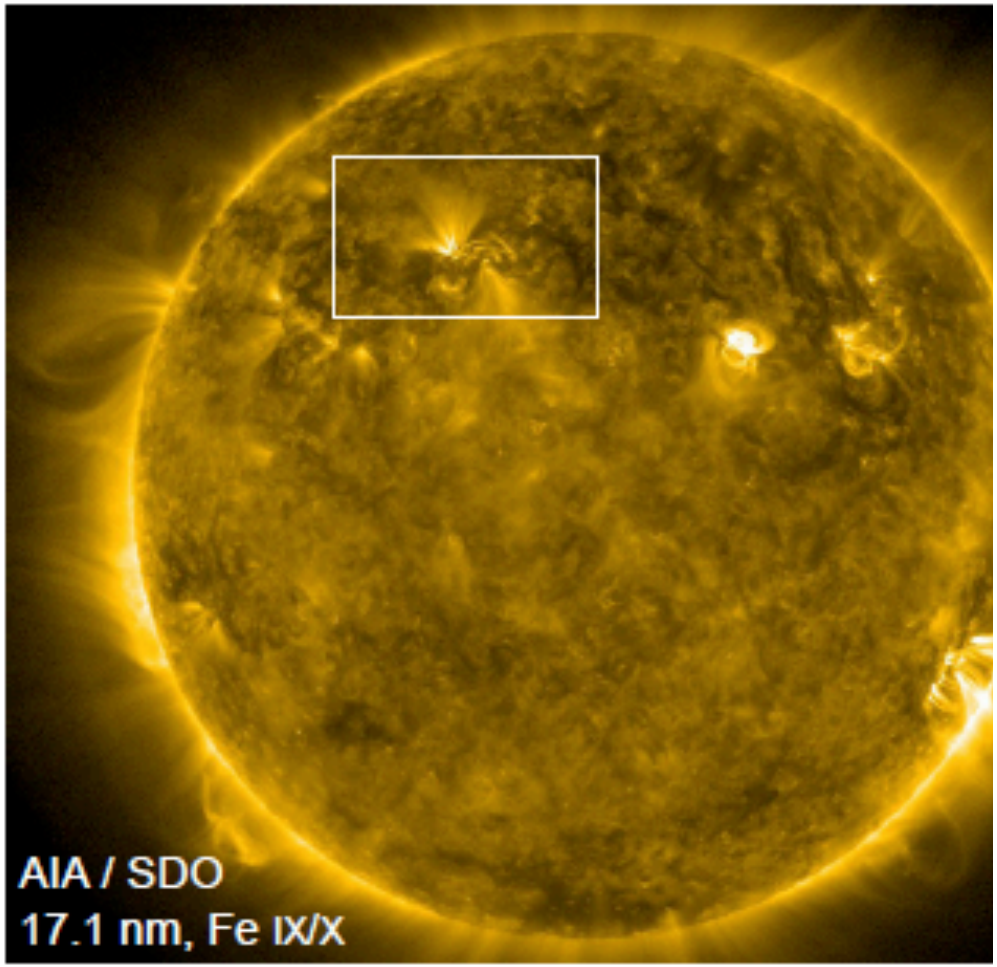


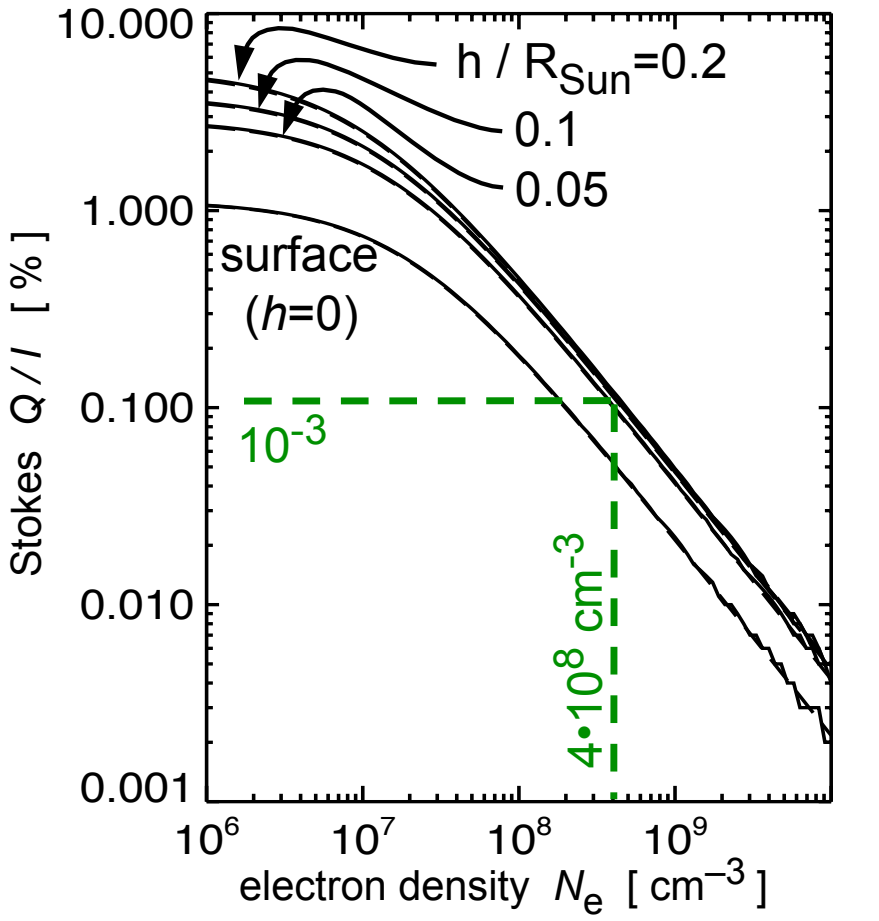


Manso Sainz & Trujillo Bueno (2009)

Magnetic field direction in coronal loops

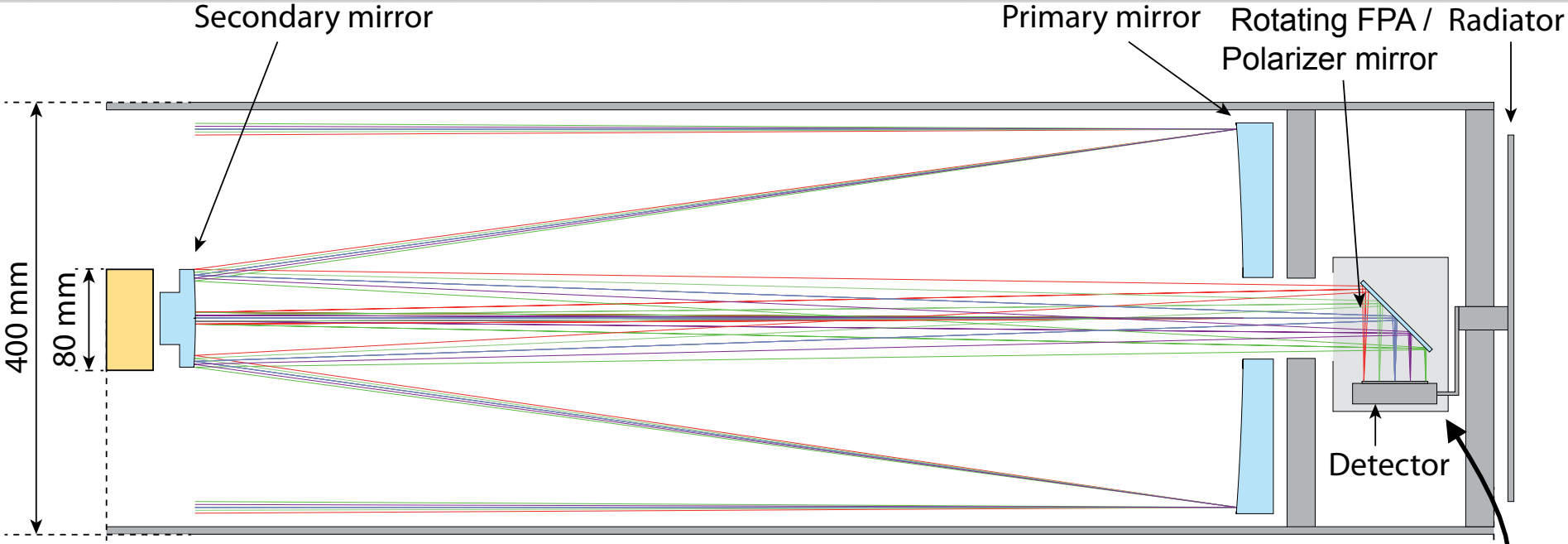
- Upward collisional transfer of optically-pumped ground-level polarization
  → *linear polarization*
- Hanle effect (in ground-level saturation regime) sensitive to the magnetic field orientation
  → *modifies linear polarization*
- works also on disk !



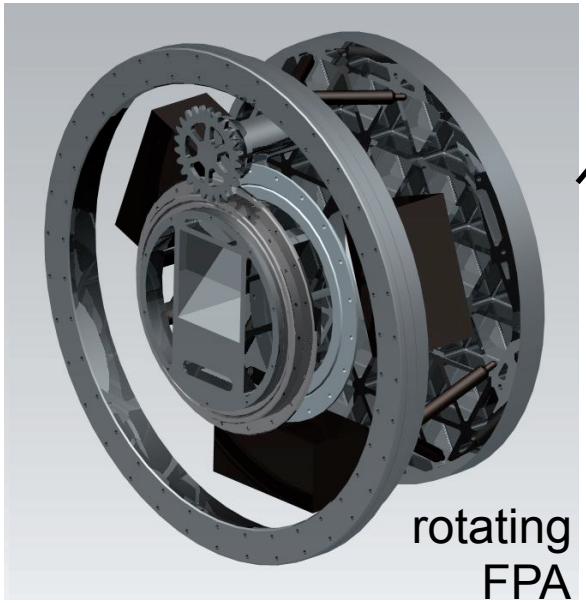


Manso Sainz & Trujillo Bueno (2009)

EUV imaging polarimeter – EIP



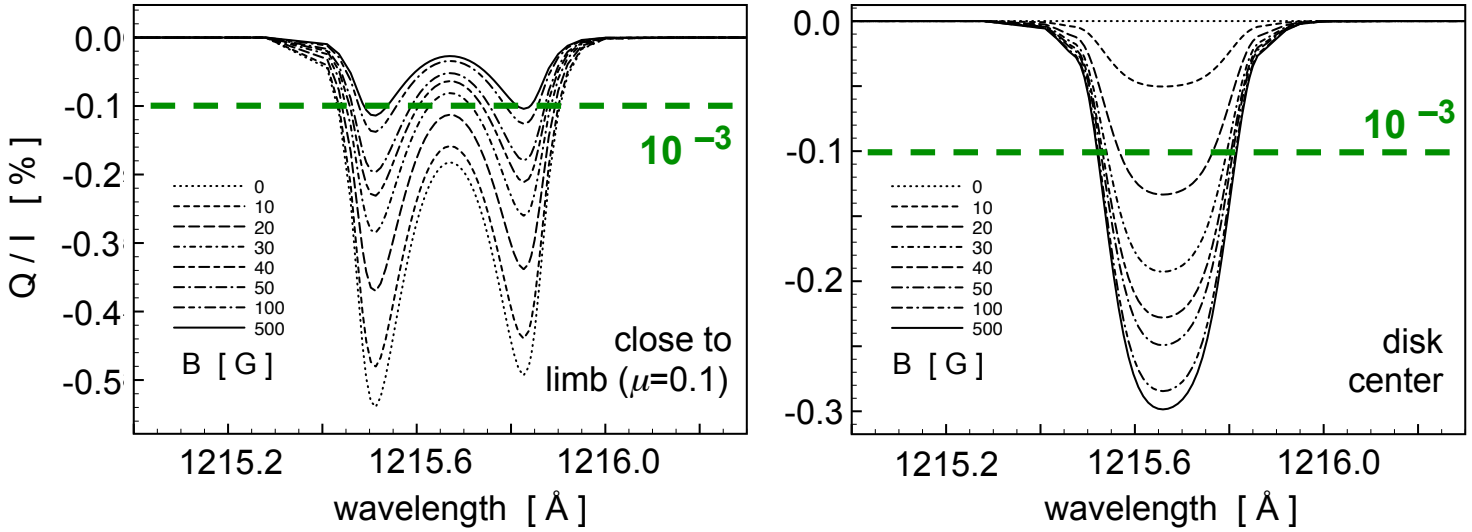
aperture	⌀ 28	cm
envelope	100x40x40	cm^3
mass	40	kg
power	50	W
detector	4096 x 4096	
sampling	0.5 FWHM 0.35	arcsec nm
data rate	550	kbit/s



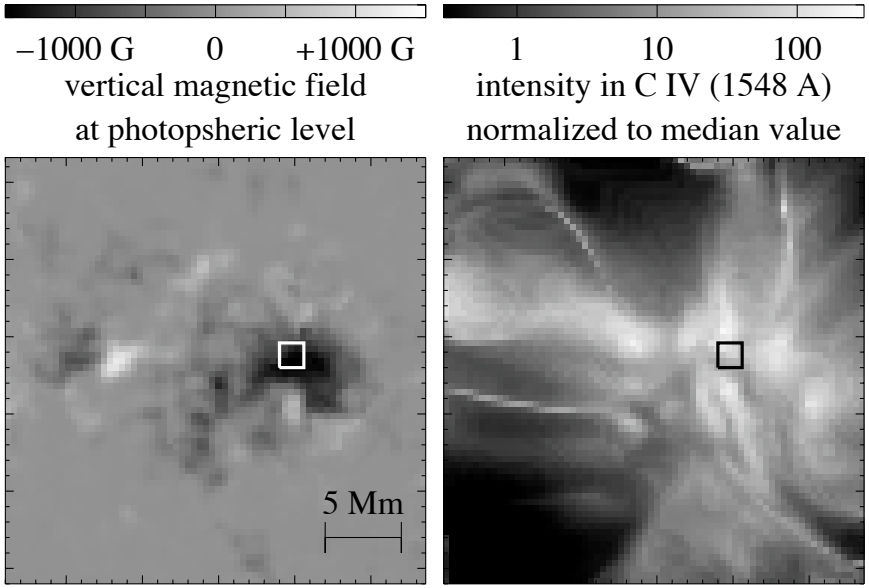
Magnetic field in the transition region

Ly-α:
Hanle effect
in 90° scattering and forward scattering

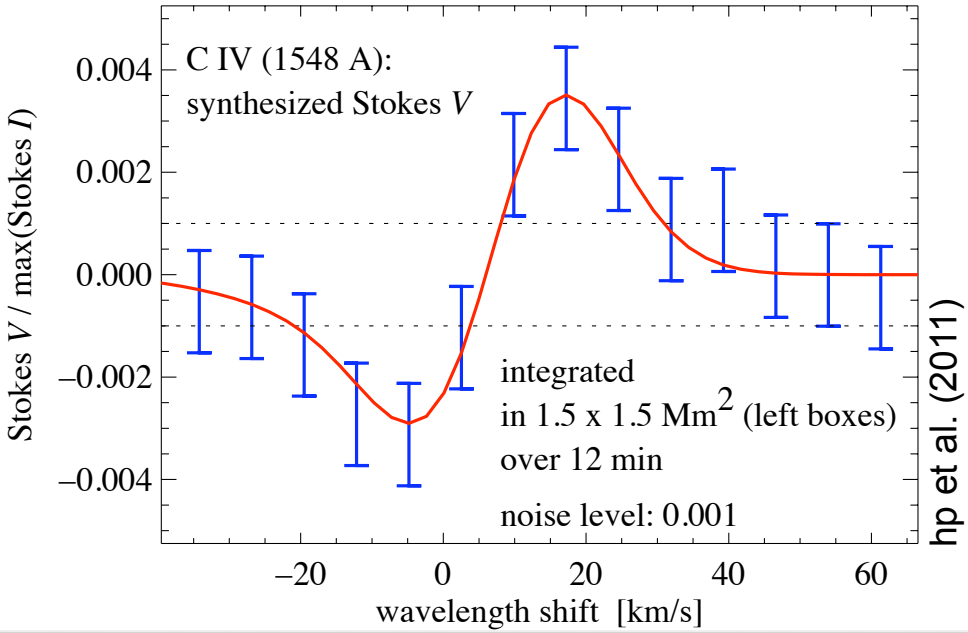
(Trujillo Bueno et al. 2011, ApJ 738, L11)



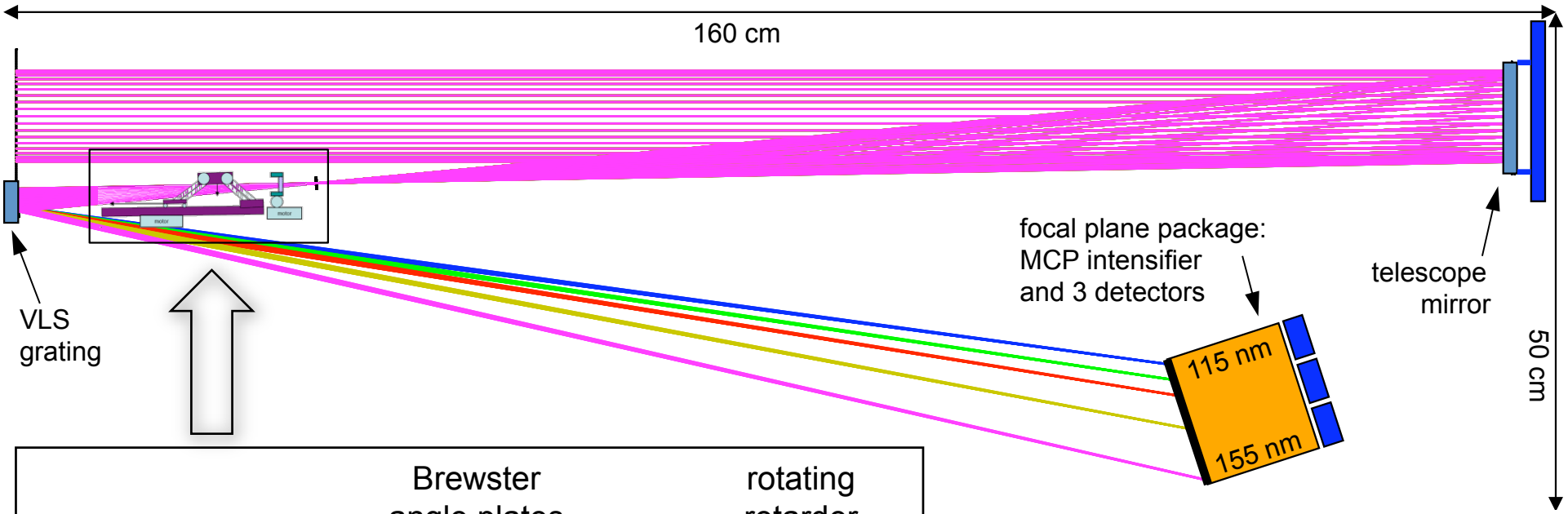
C IV (1548): Zeeman-effect

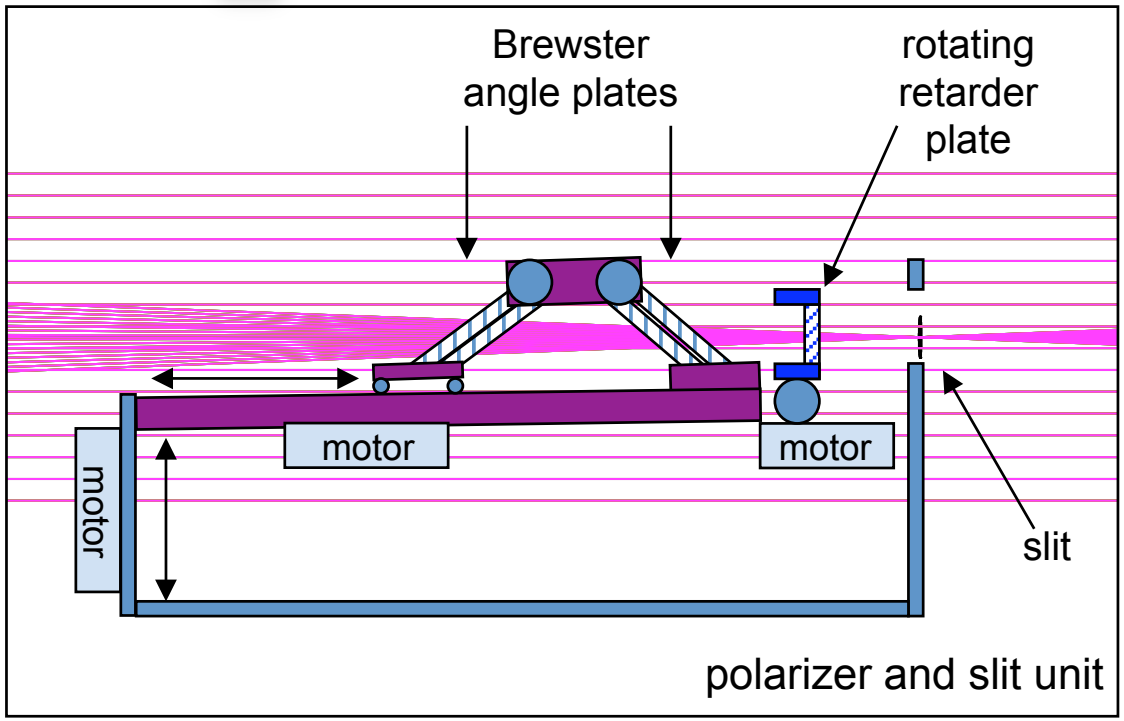


top view of part of 3D MHD simulation: 28 Mm x 28 Mm



Scanning UV spectro-polarimeter – SUSP

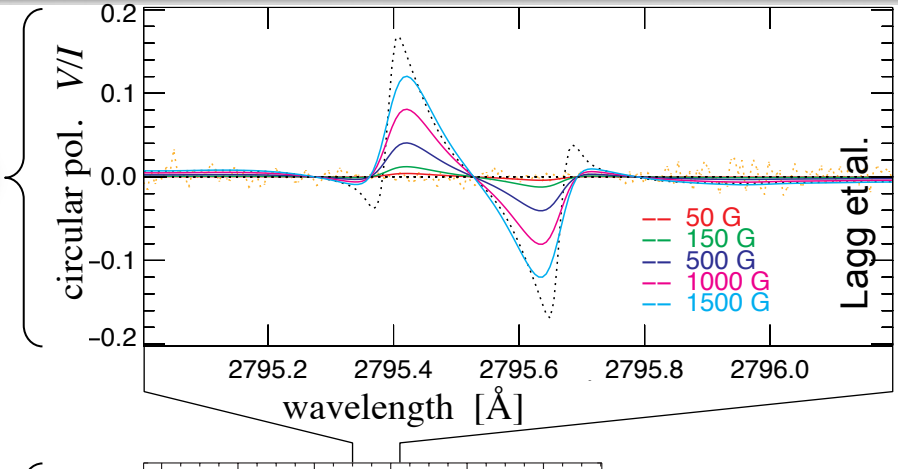




aperture	15 x 10	cm^2
envelope	160x50x40	cm^3
mass	68	kg
power	25	W
detector	3x 2048 x2048	
sampling	0.5 6	arcsec pm
data rate	300	kbit/s

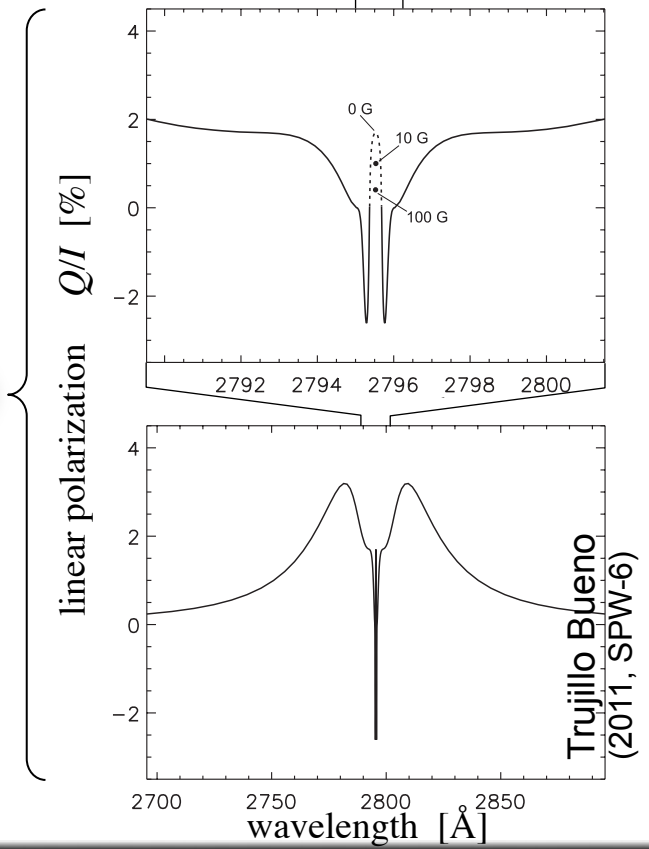
Magnetic fields in the chromosphere

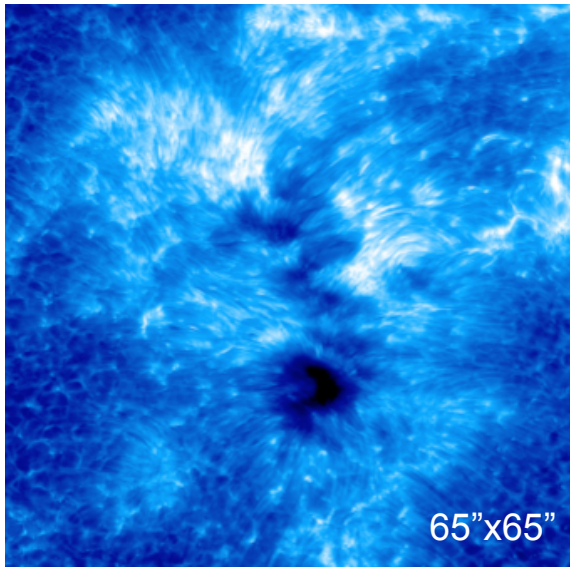
Zeeman effect



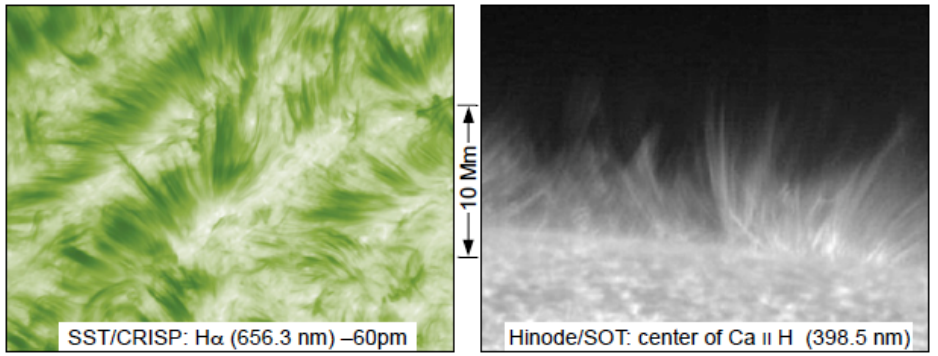
Mg II k @ 2795 Å

Hanle effect





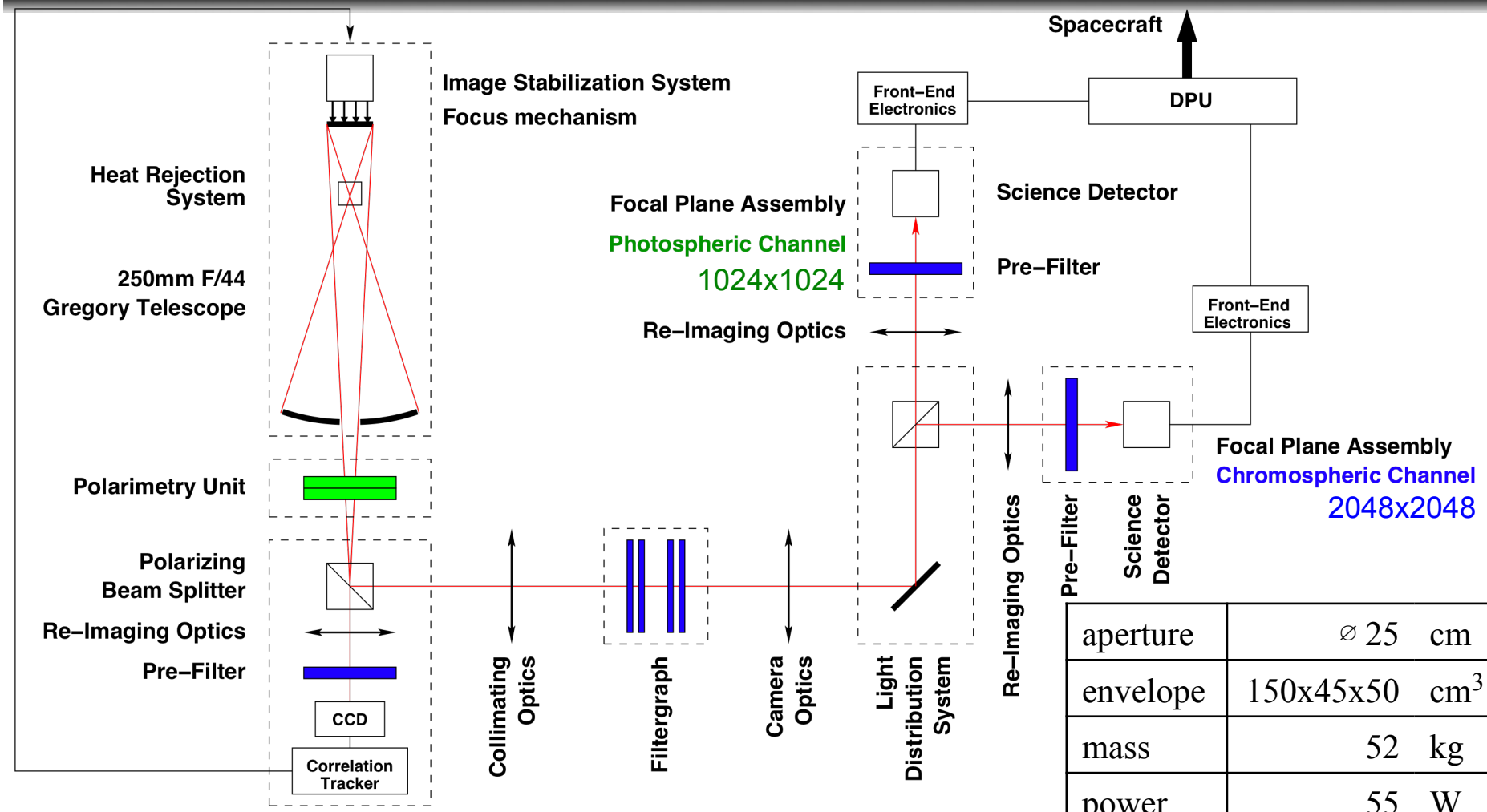
What is the magnetic field structure in the chromosphere ?
And how is it rooted to the photosphere ?



Anna Pietarila

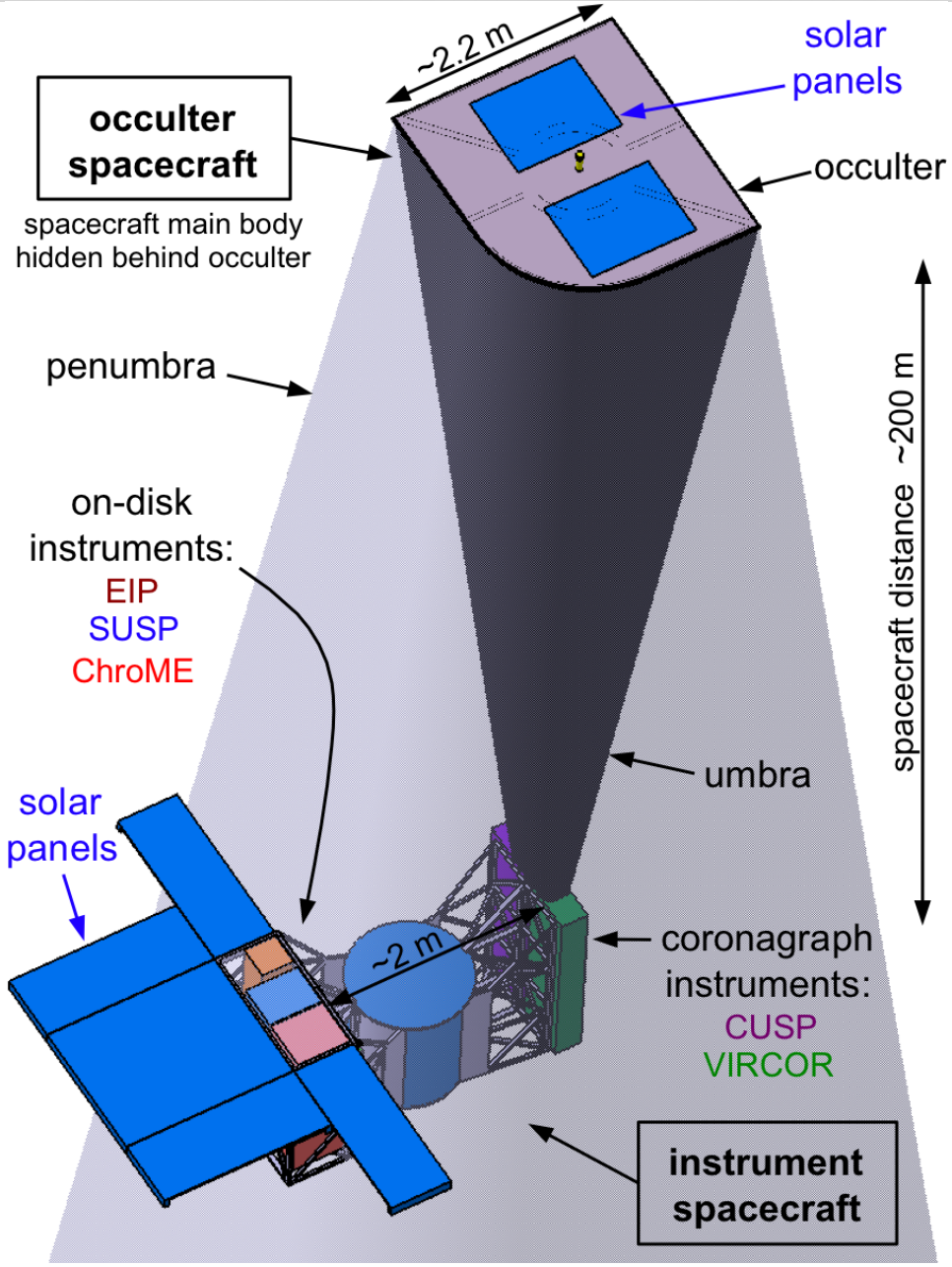
Judge & Carlsson (2010) ApJ 719, 469

Chromospheric magnetic explorer – ChroME



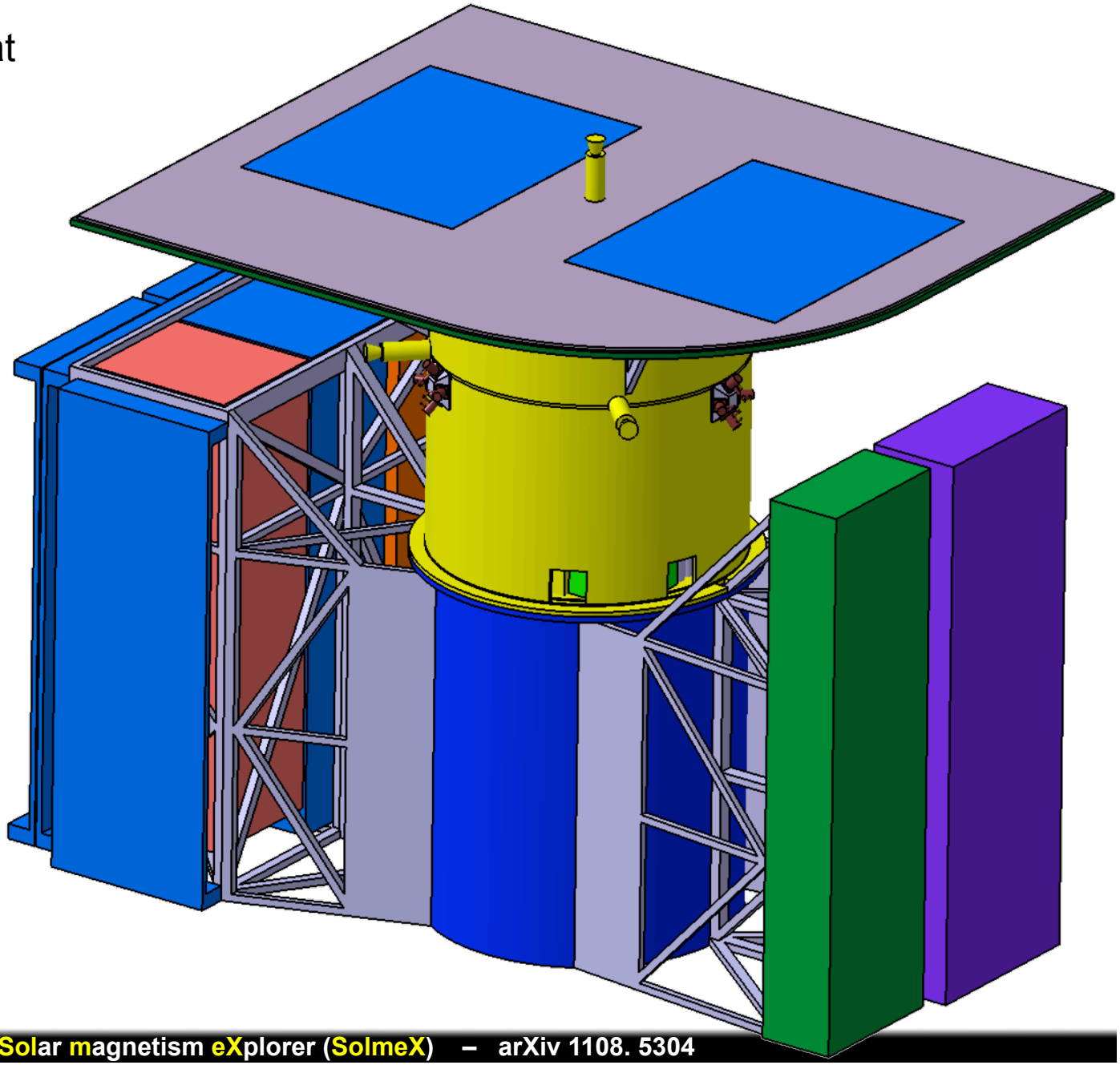
aperture	⌀ 25	cm
envelope	150x45x50	cm^3
mass	52	kg
power	55	W
detector	2k / 1k	
sampling	0.15 / 0.3 5	arcsec pm
data rate	700	kbit/s

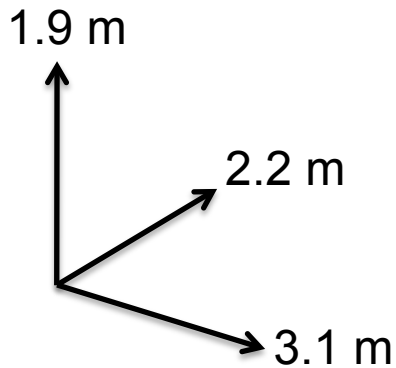
Spacecraft science configuration



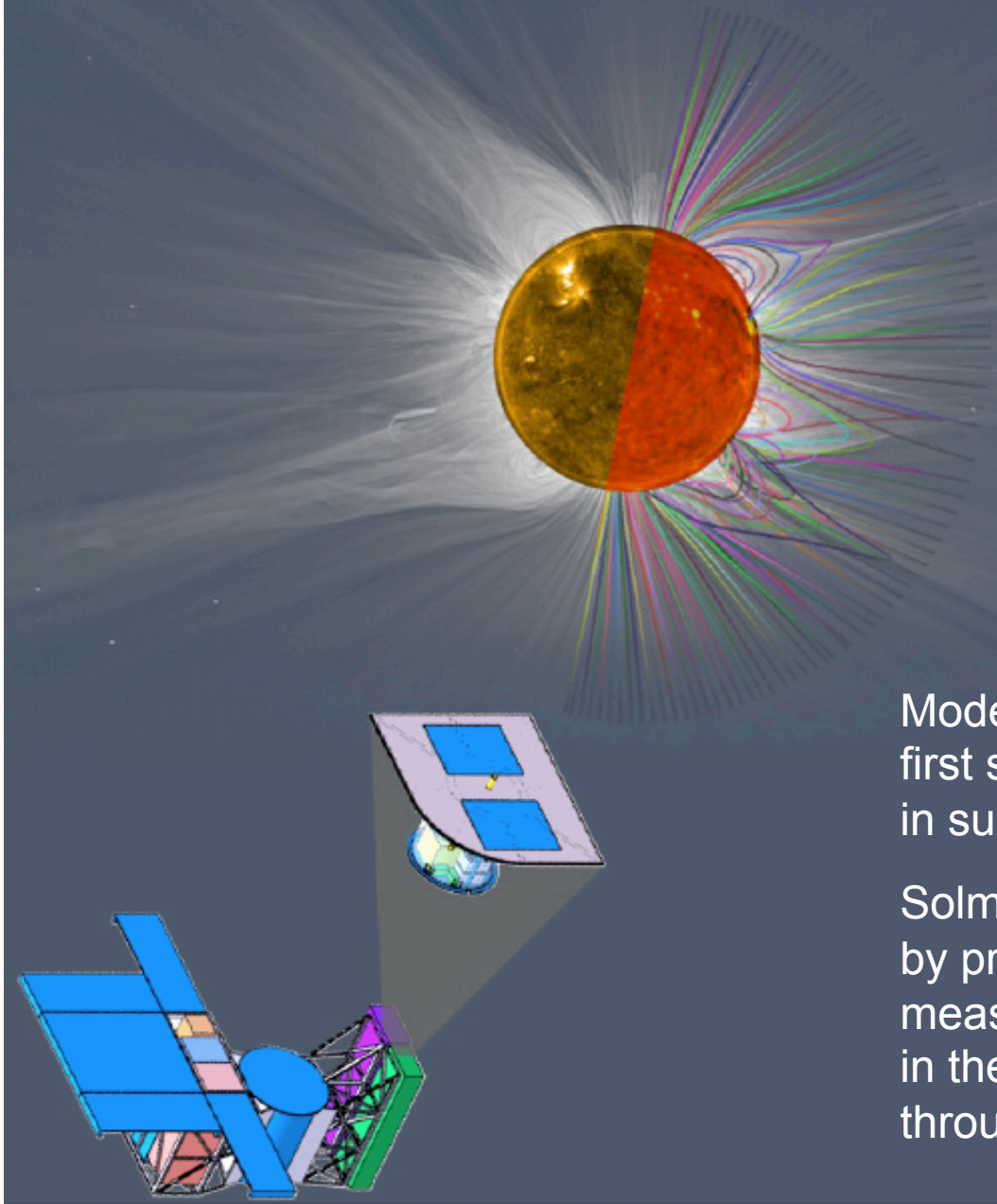
Launch configuration

- fits into Soyuz-Fregat
- central s/c tube fits on launch adapter ring
- total mass: 2075 kg





Solar magnetism eXplorer (SolmeX)



Measure **magnetic field**
and plasma properties
from the surface into the corona

All instruments have
spectro-polarimetric capabilities !

Modern solar physics started with the first surface magnetic field measurement in sunspots by Hale in 1908.

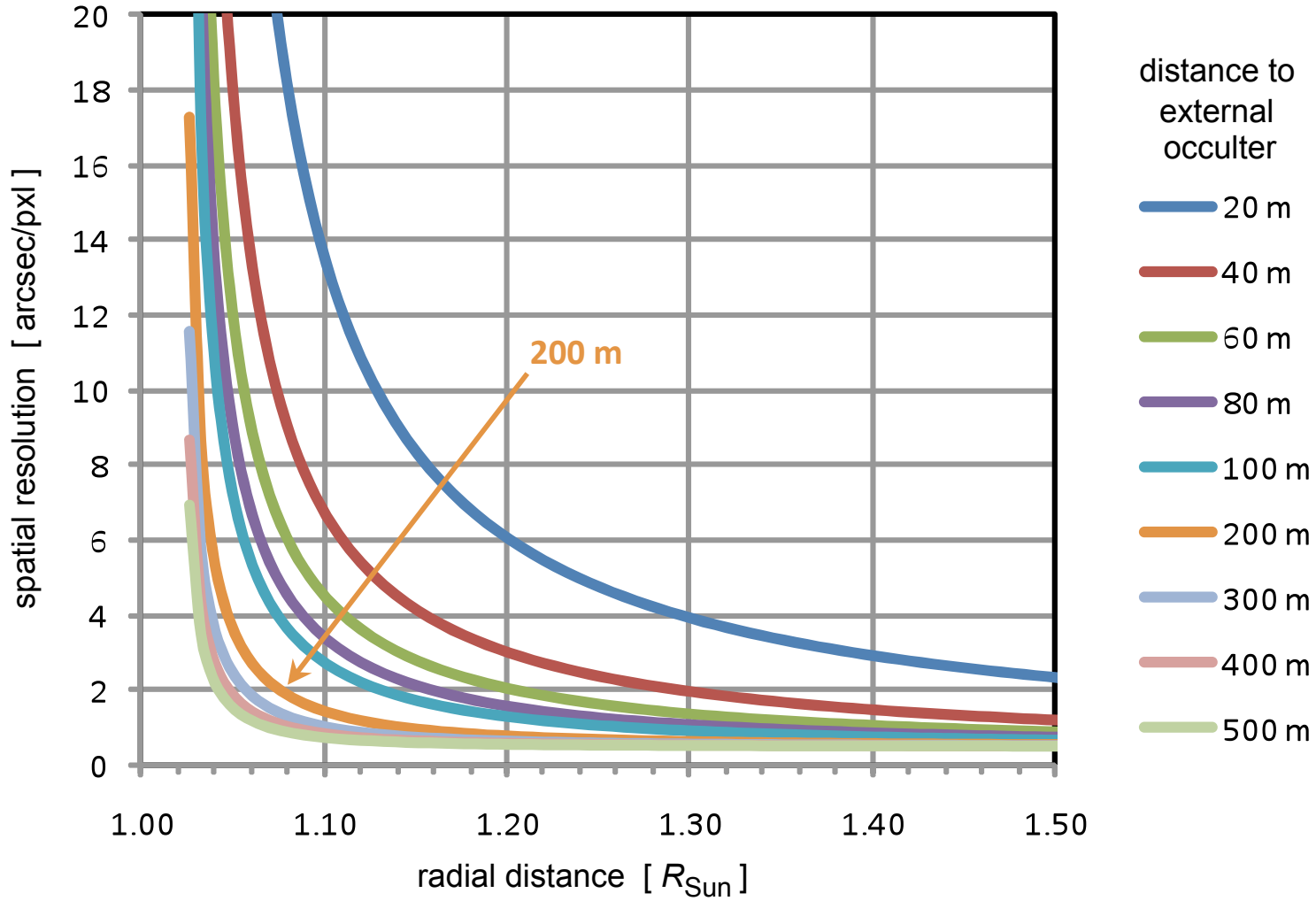
SolmeX could complete these achievements by providing the first comprehensive measurements of the magnetic field in the outer atmosphere of our Sun through spectro-polarimetry.

spare slides

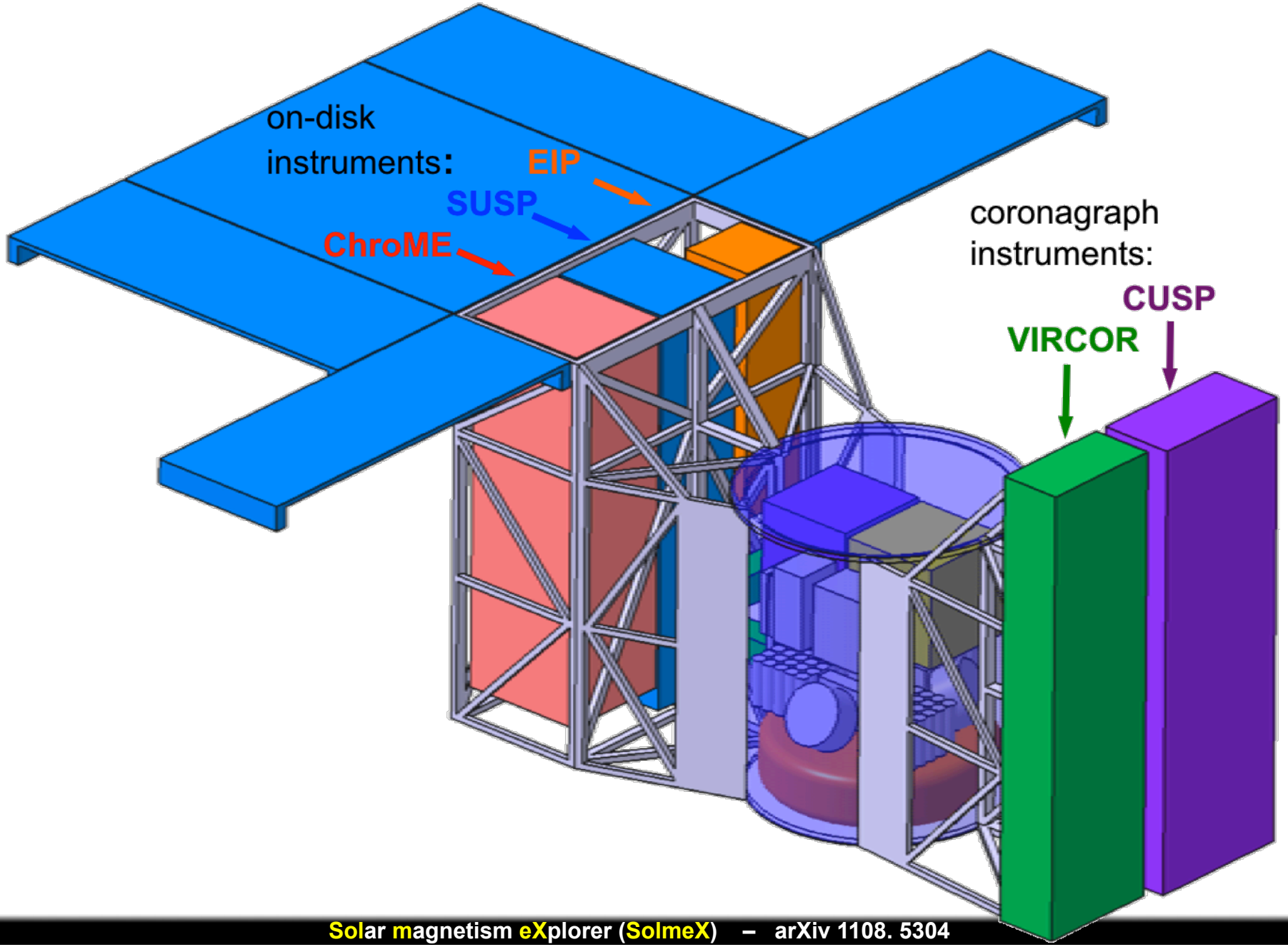
Spatial resolution and occulter distance

SOHO/LASCO C1: 5.6” / pxl
STEREO COR1: 7.5” / pxl [2pxl binning; 3.75” / pxl possible but basically not used]

SolmeX/VIRCOR: 1.2” / pxl [in visible / K-corona channel]

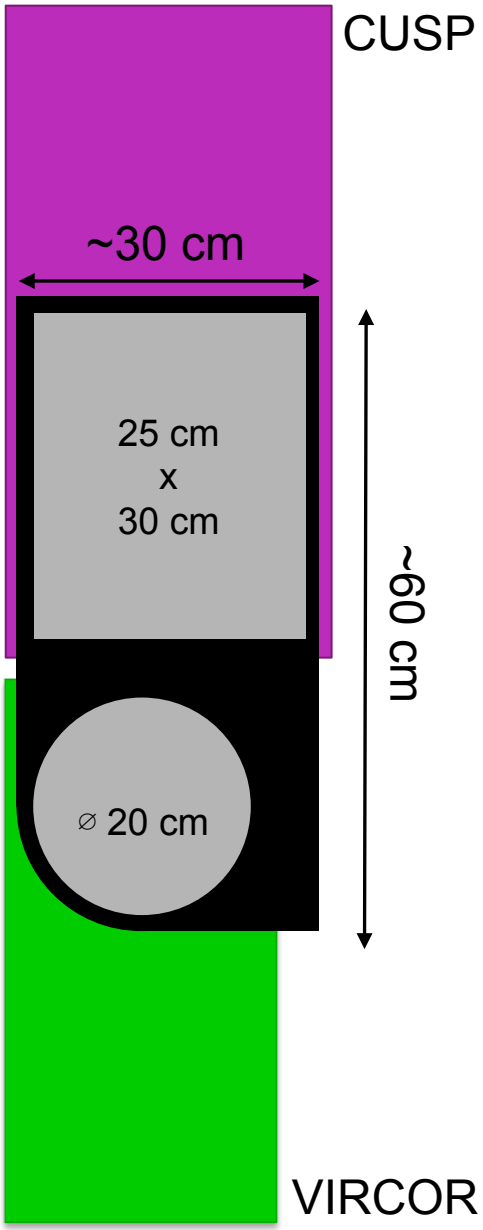


Instrument spacecraft

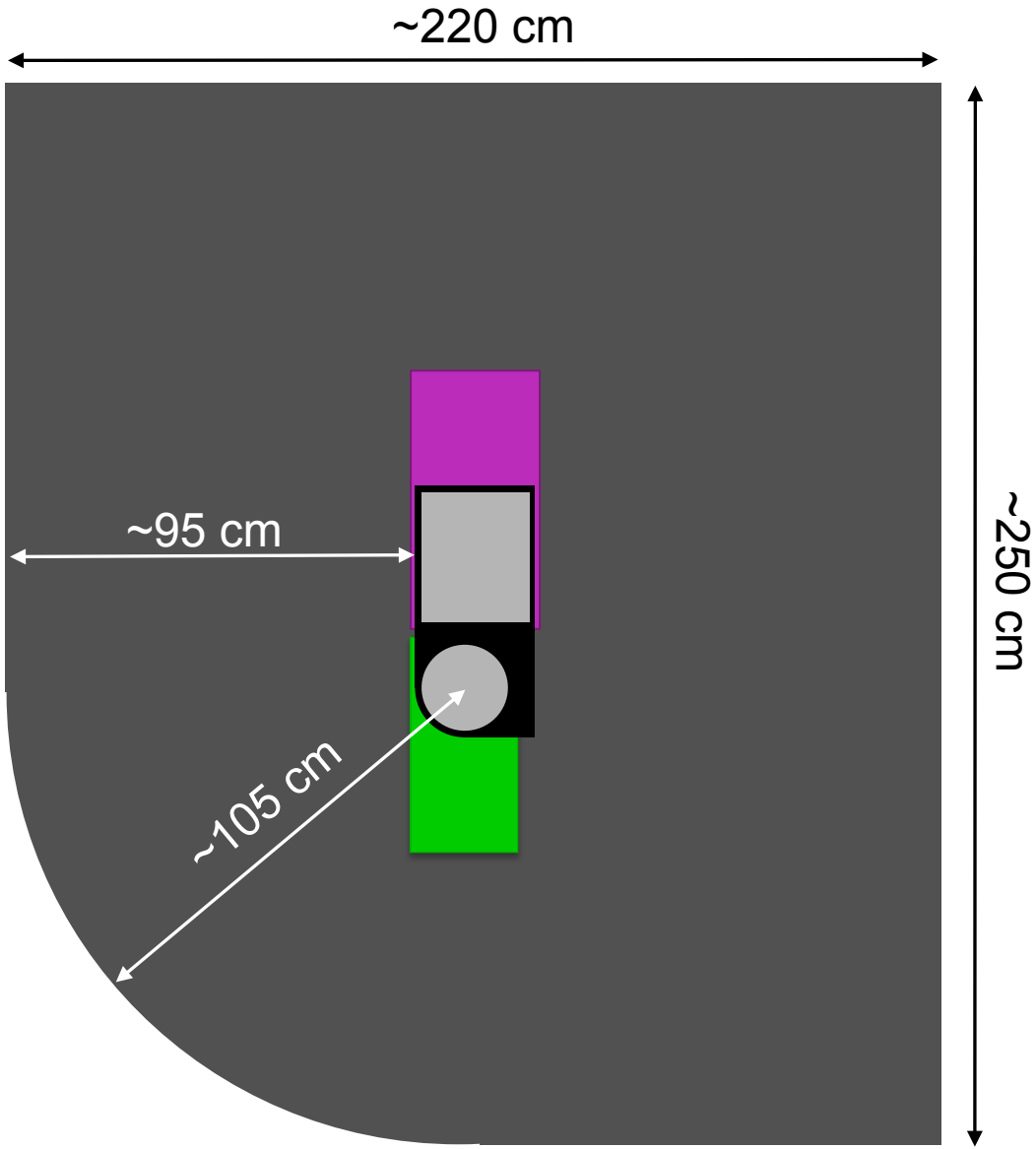


Occulter disk and umbra

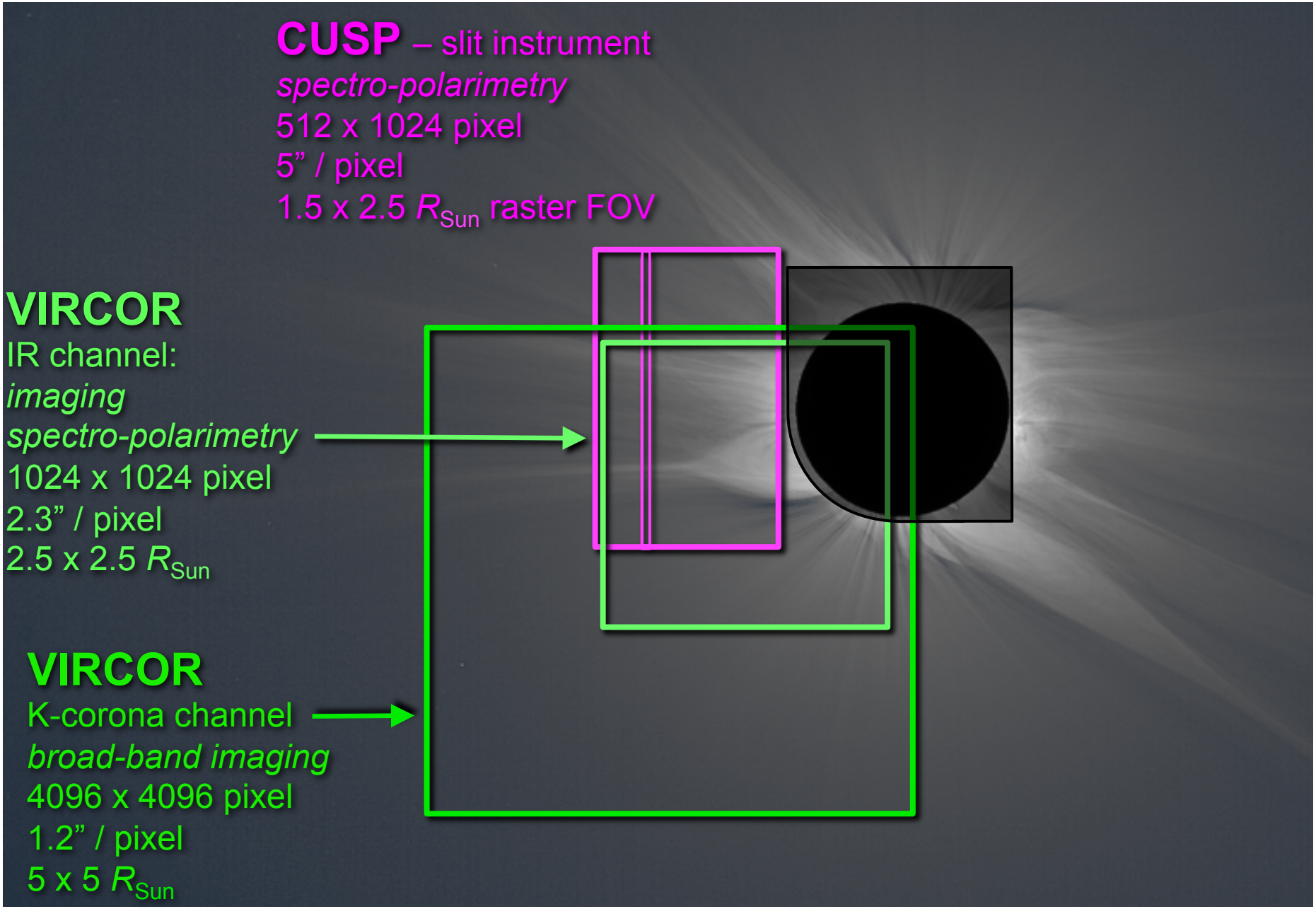
umbra on coronagraphs



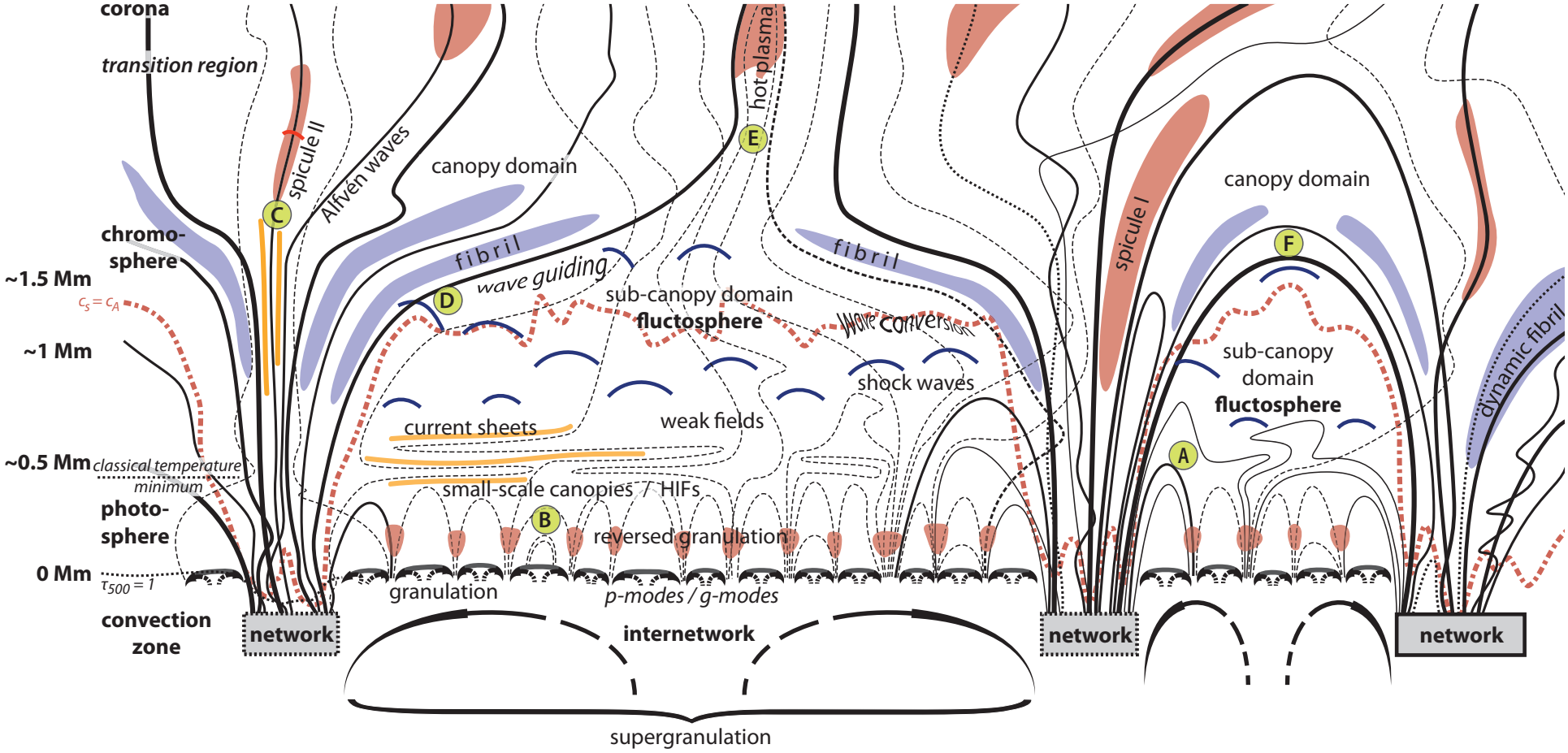
shape of occulting disk (200 m distance)



Occulted area and FOV of coronagraphs

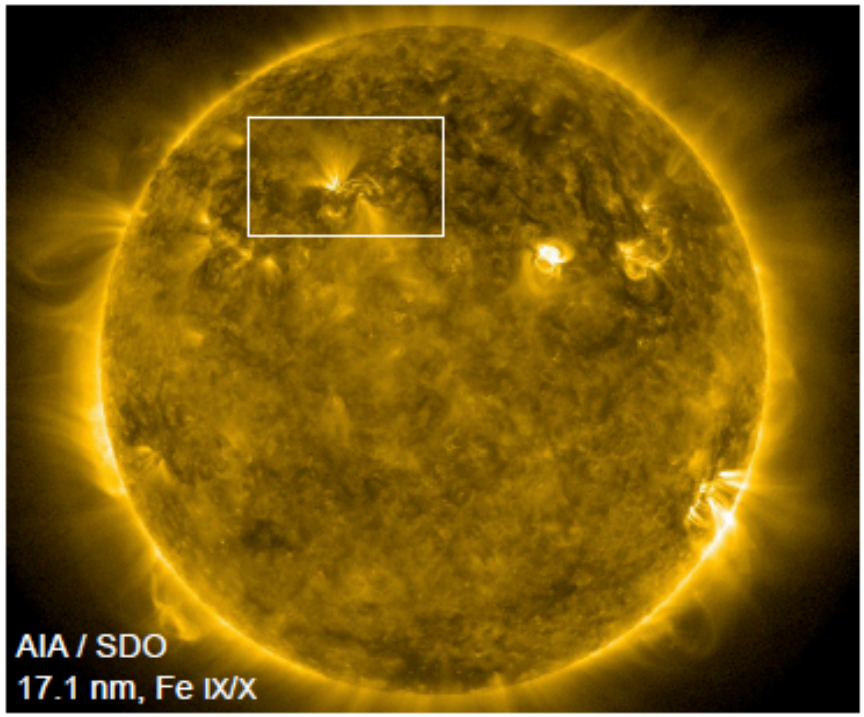


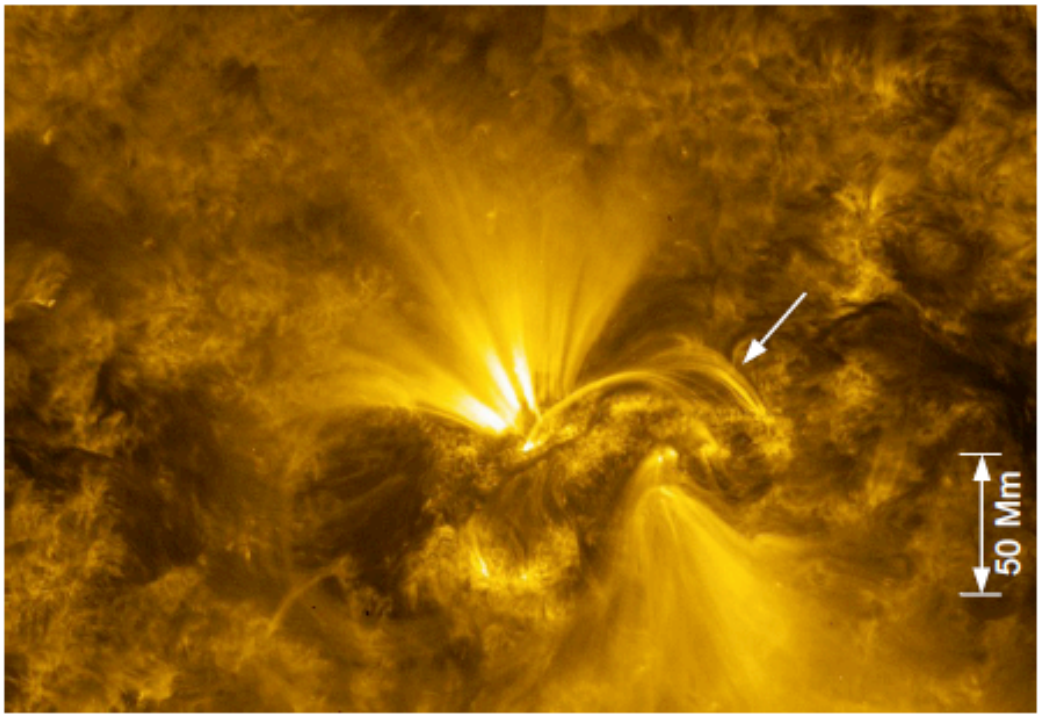
Magnetic coupling through the atmosphere



Wedemeyer-Bohm et al. (2009) SSR 144, 317

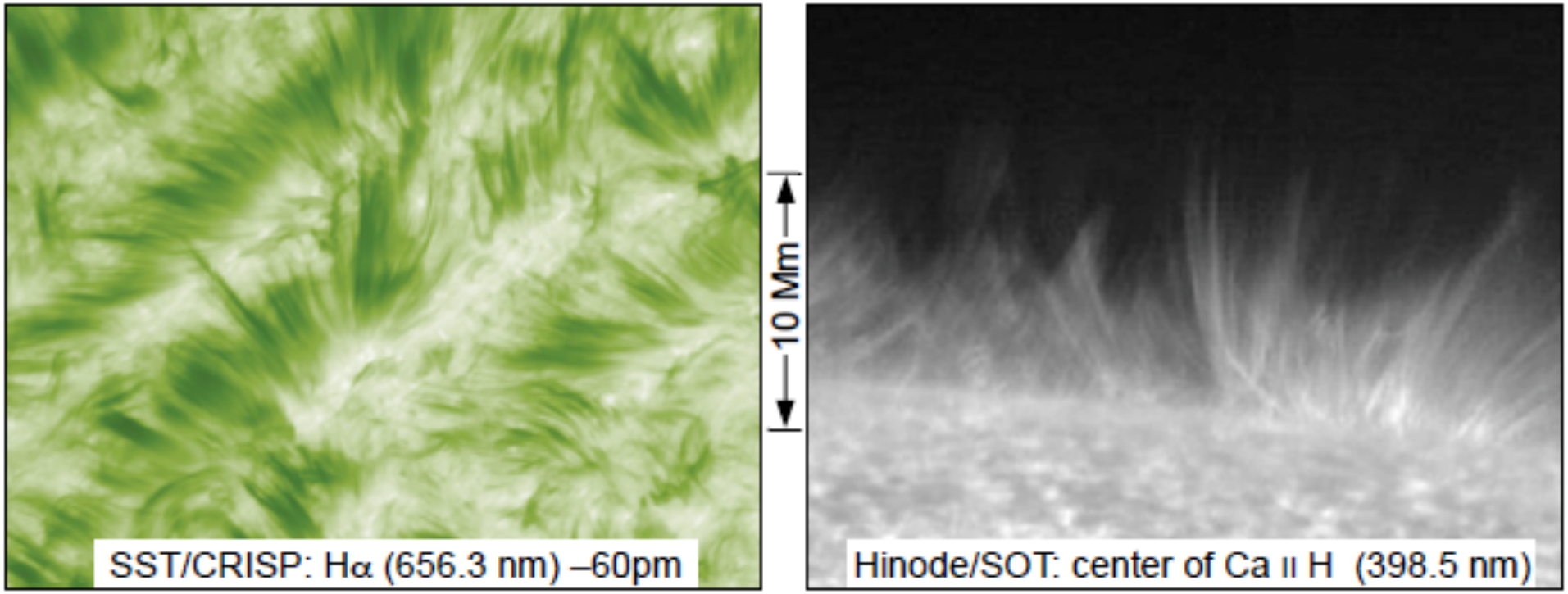
Magnetic structure of active regions ?





AIA 171 Å / SDO

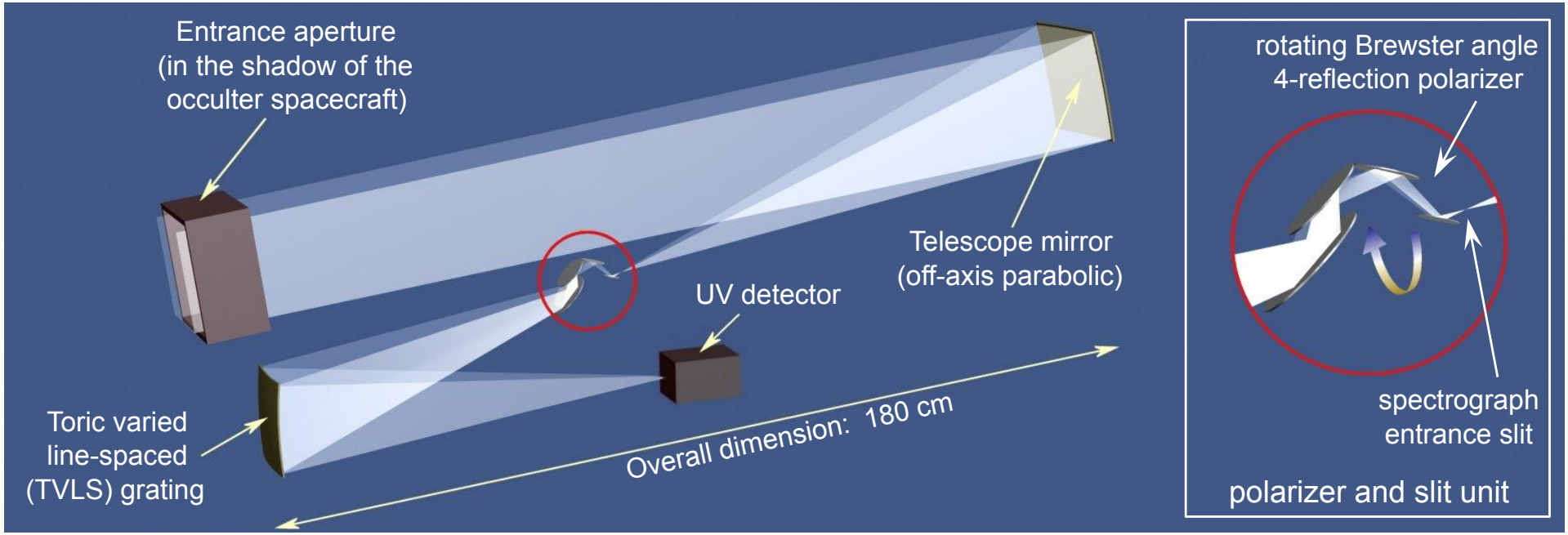
Magnetic driving of small-scale structures



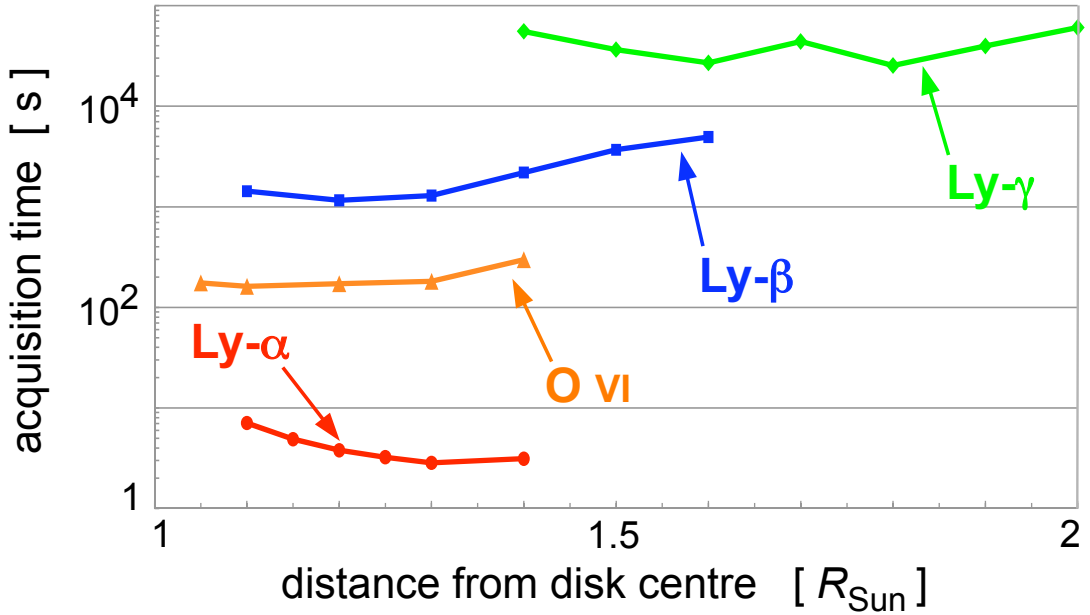
Anna Pietarila

Judge & Carlsson (2010) ApJ 719, 469

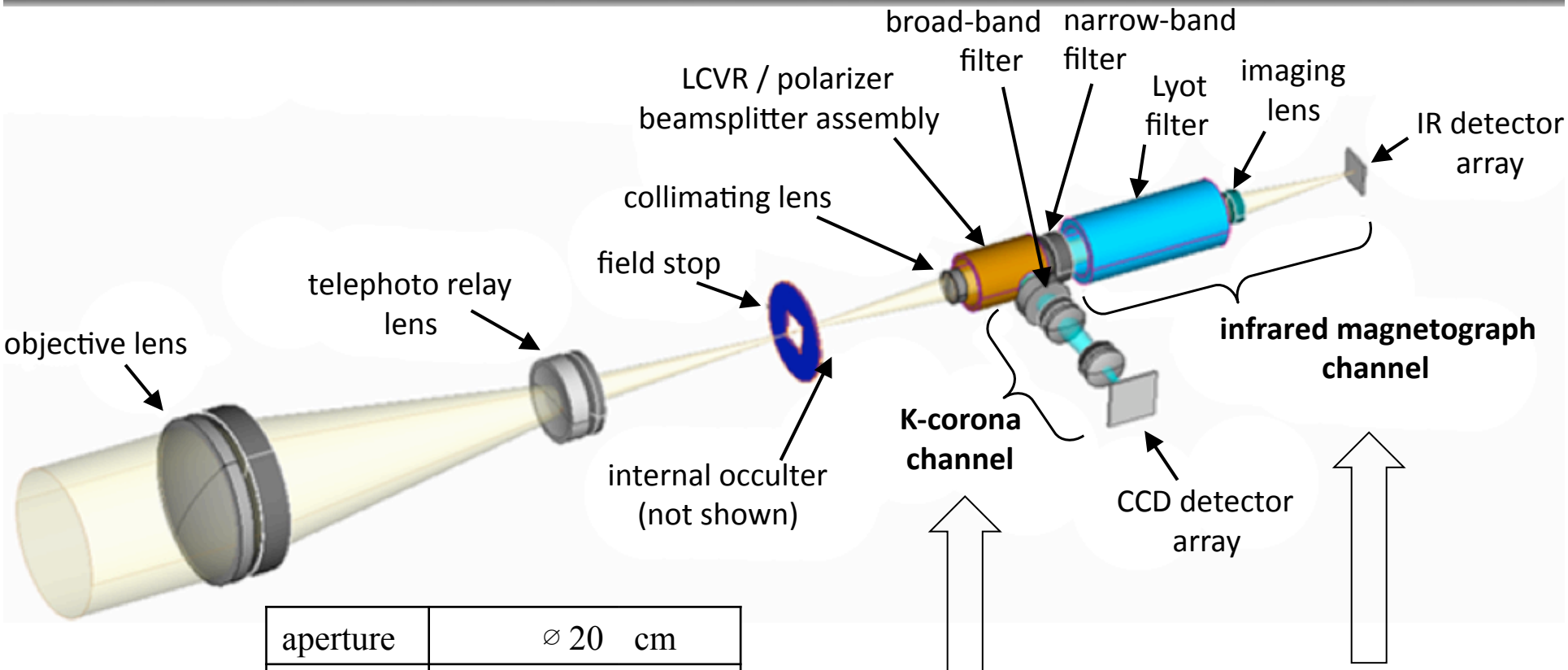
Coronal UV spectro-polarimeter – CUSP



aperture	25x30	cm^2
envelope	180x60x30	cm^3
mass	70	kg
power	30	W
detector	512 x 1024	
sampling	5 9	arcsec pm
data rate	150	kbit/s



Visible and infrared coronagraph – VIRCOR



aperture	⌀ 20 cm
envelope	180x50x25 cm^3
mass	60 kg
power	50 W
detector	1 k / 4 k
sampling	2 / 1 arcsec 0.2 nm
data rate	300 kbit/s

continuum
~400 nm

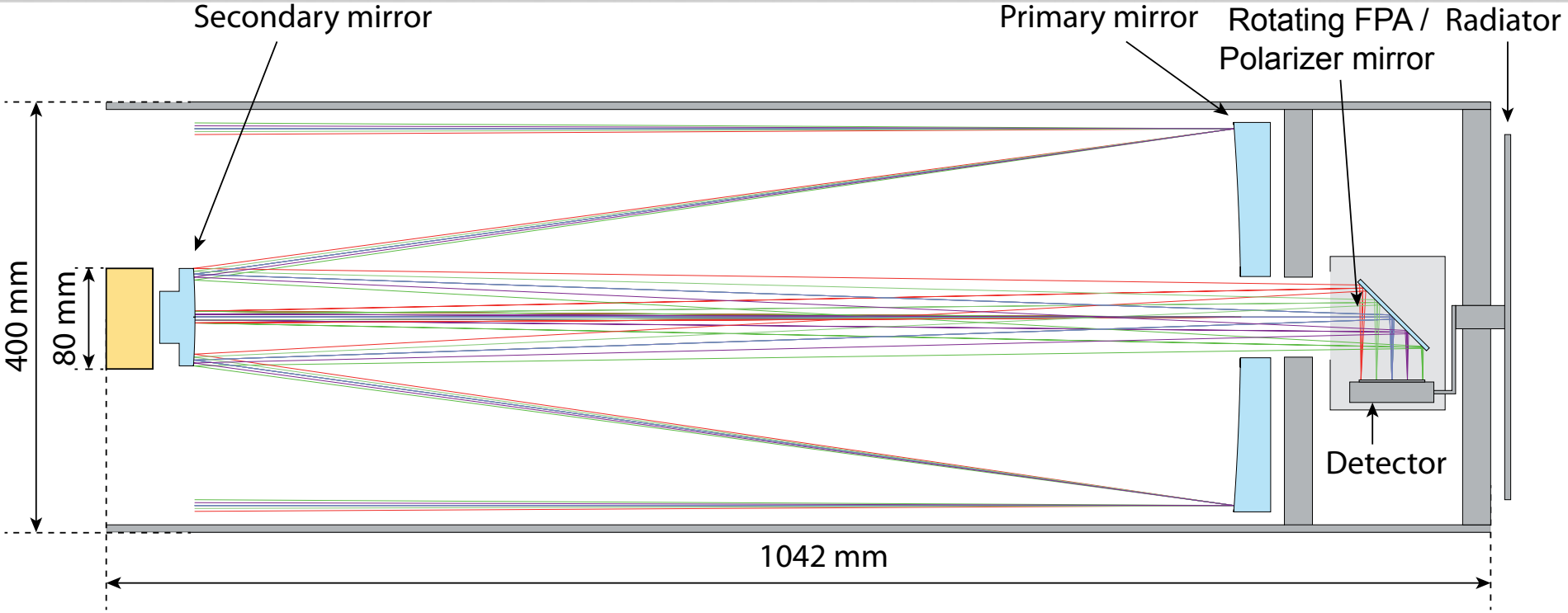
4096 x 4096 pxl

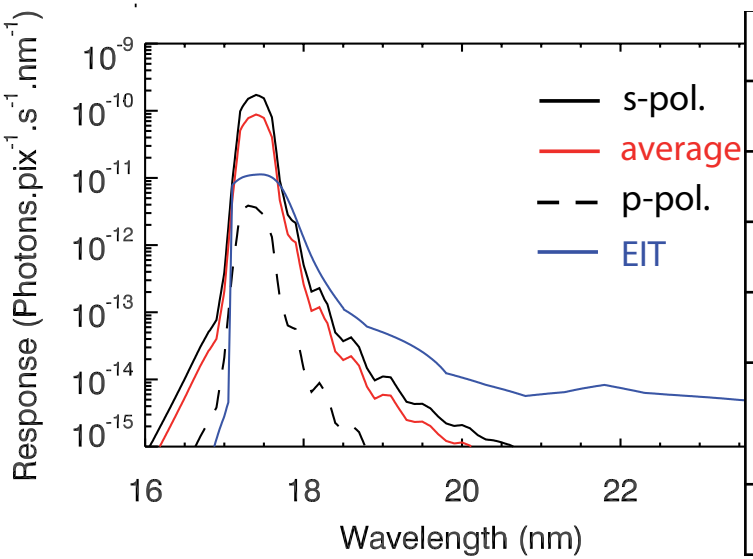
Fe XIII 1074.7 nm
Fe XIII 1079.8 nm

He I 1083 nm

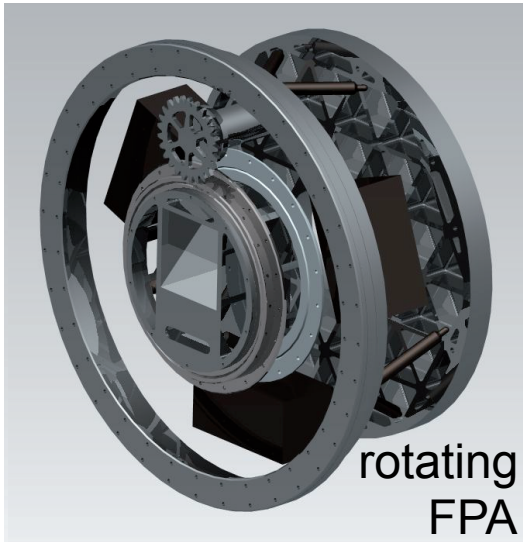
1024 x 1024 pxl

EUV imaging polarimeter – EIP

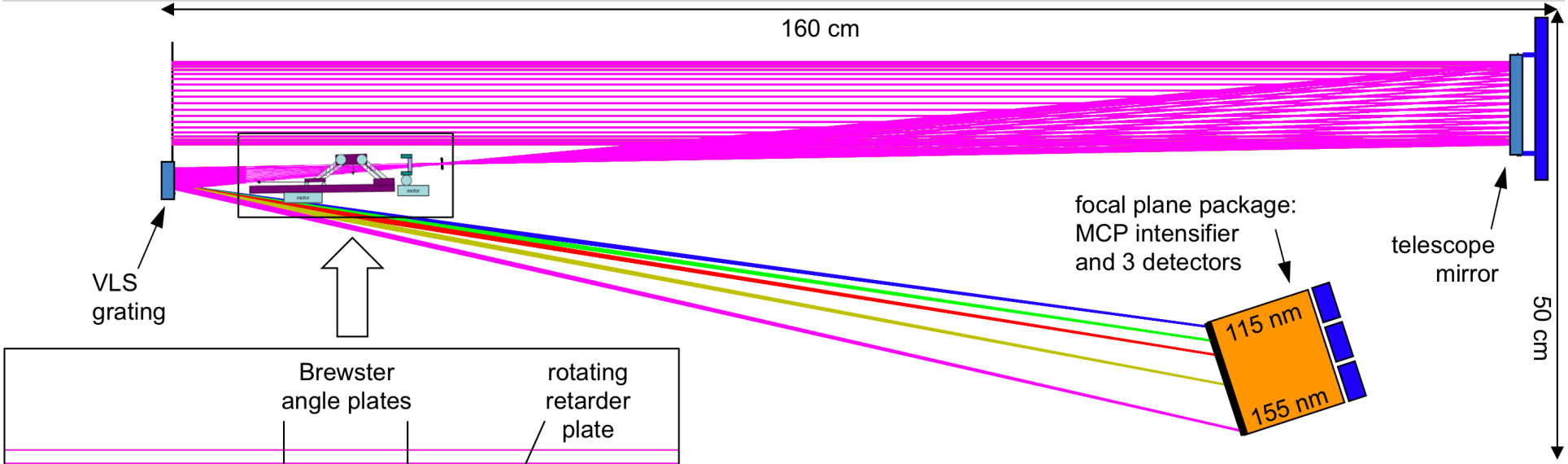


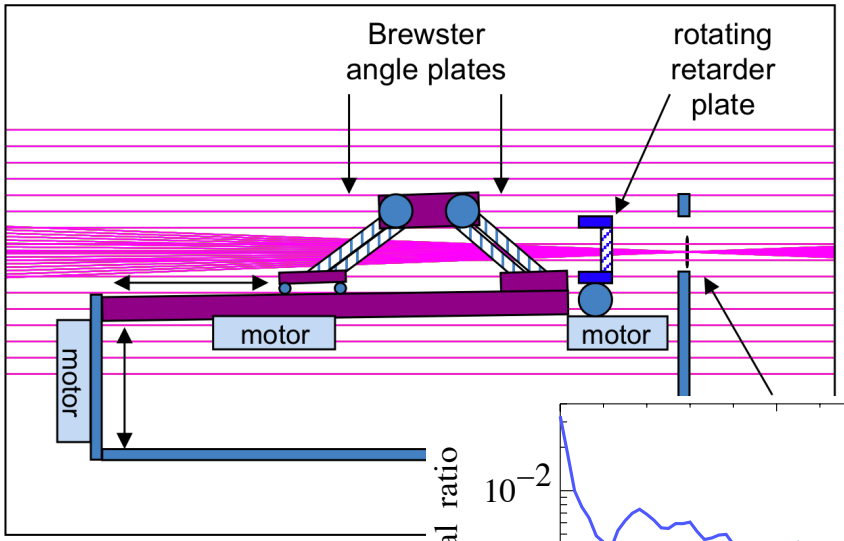


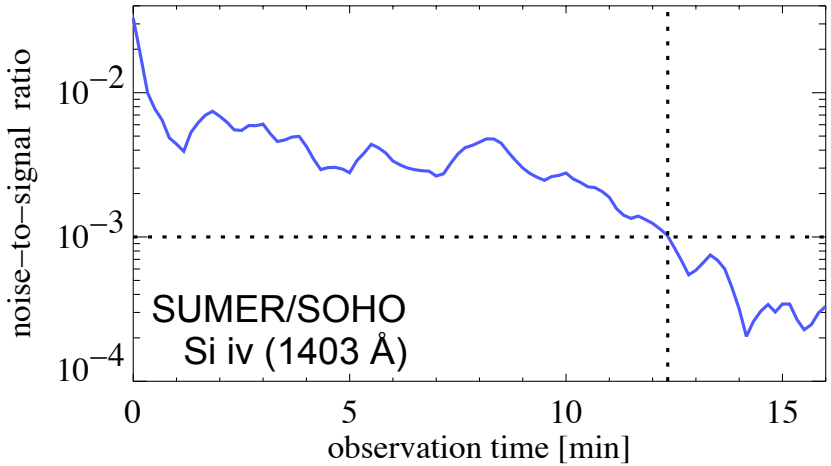
aperture	⌀ 28	cm
envelope	100x40x40	cm^3
mass	40	kg
power	50	W
detector	4096 x 4096	
sampling	0.5 FWHM 0.35	arcsec nm
data rate	550	kbit/s



Scanning UV spectro-polarimeter – SUSP







aperture	15 x 10	cm^2
envelope	160x50x40	cm^3
mass	68	kg
power	25	W
detector	3x 2048 x2048	
sampling	0.5 6	arcsec pm
data rate	300	kbit/s