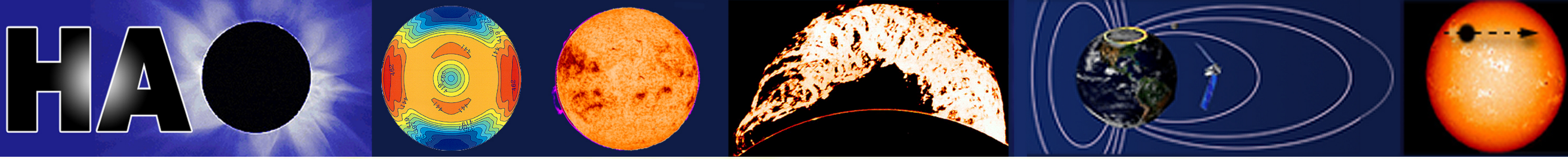


Magnetic Diagnostics of Prominences: Moving towards *ProMag*

R. Casini

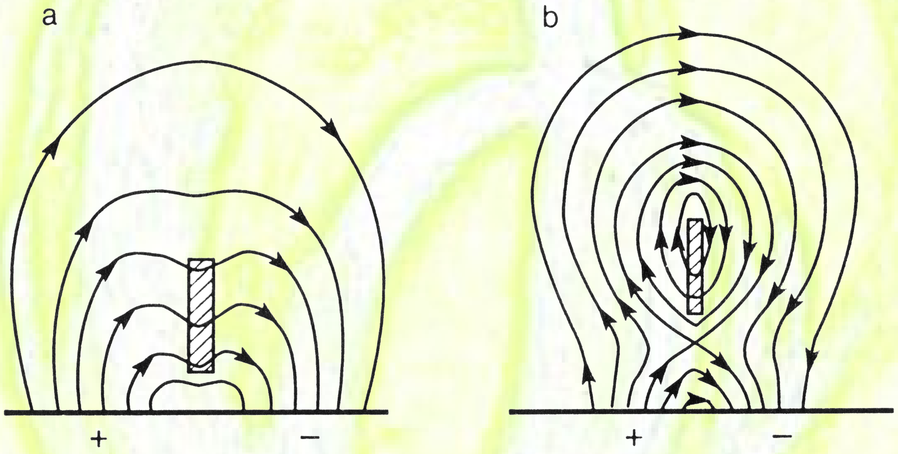
HAO-ESSL-NCAR

11 Dec. 2008

Prominence Magnetic Fields

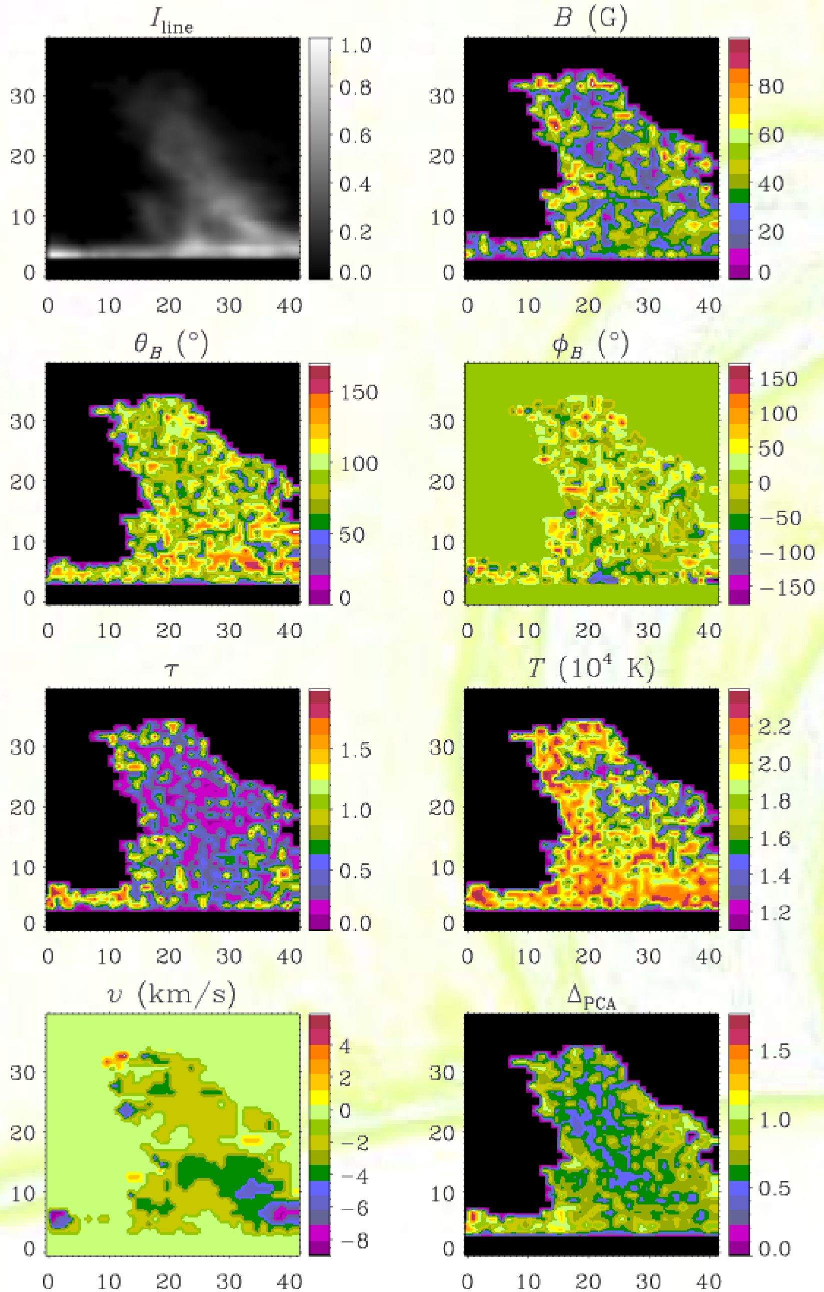
are needed to...

- understand how prominences form and evolve
- discriminate among different models of prominences (e.g., "dip" vs "flux-rope" prominences)



- understand the differences between quiet-Sun and active-region prominences and filaments
- understand the release mechanism of Coronal Mass Ejections, and forecast such events

Magnetic map of a quiescent prominence



observed May 25, 2002

He I λ587.6 nm (D_3)

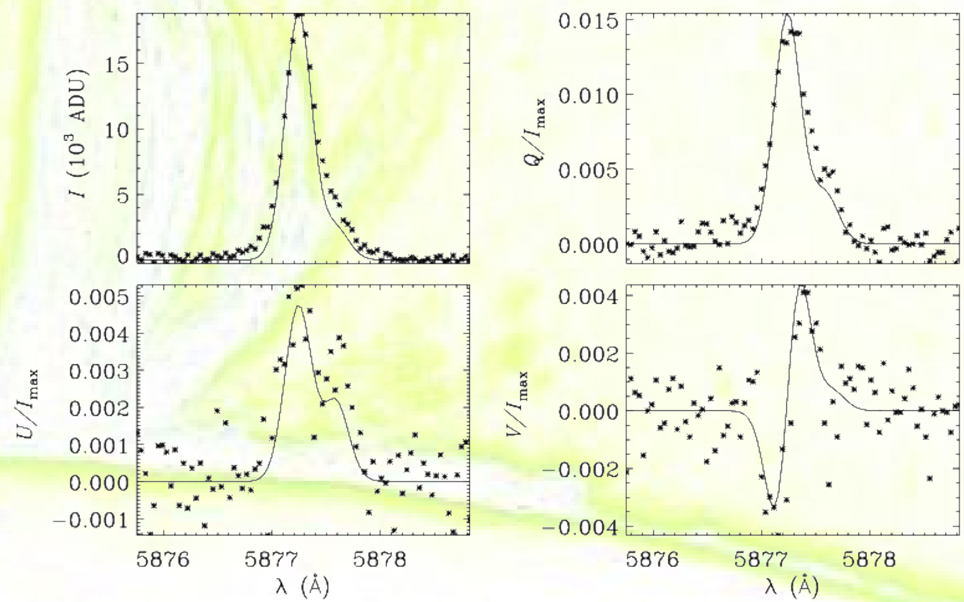
at

NSO Dunn Solar Telescope

with

HAO Advanced Stokes Polarimeter

(Casini et al. 2003)



observed July 5, 2005

He I λ1083.0 nm

at

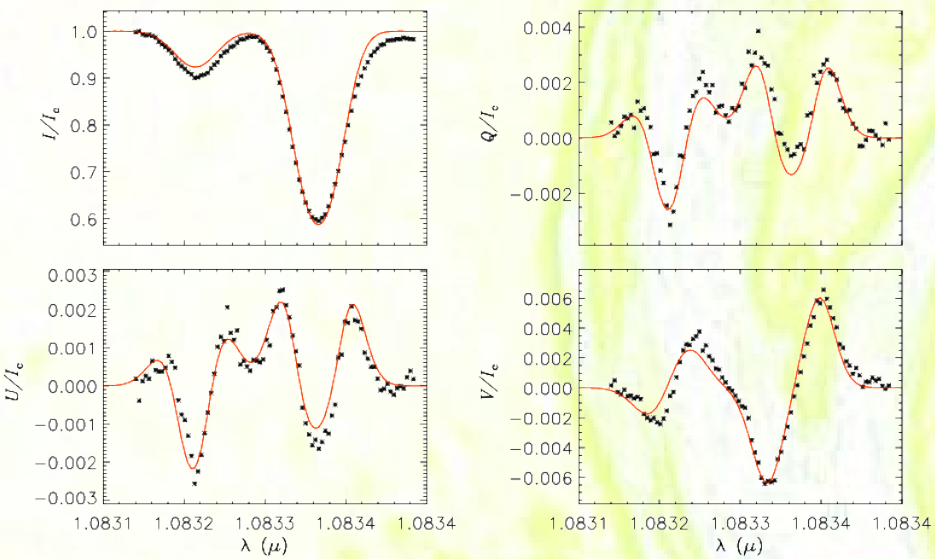
Vacuum Tower Telescope

with

IAC Tenerife Infrared Polarimeter II

(Martínez Pillet et al., in preparation)

Magnetic map of an A-R filament



τ = 0.958 ± 0.035

T = 13534.70 ± 521.18 K

δ = 0.736

θ = 27.04 ± 0.76

h = 0.0338 ± 0.0038 R

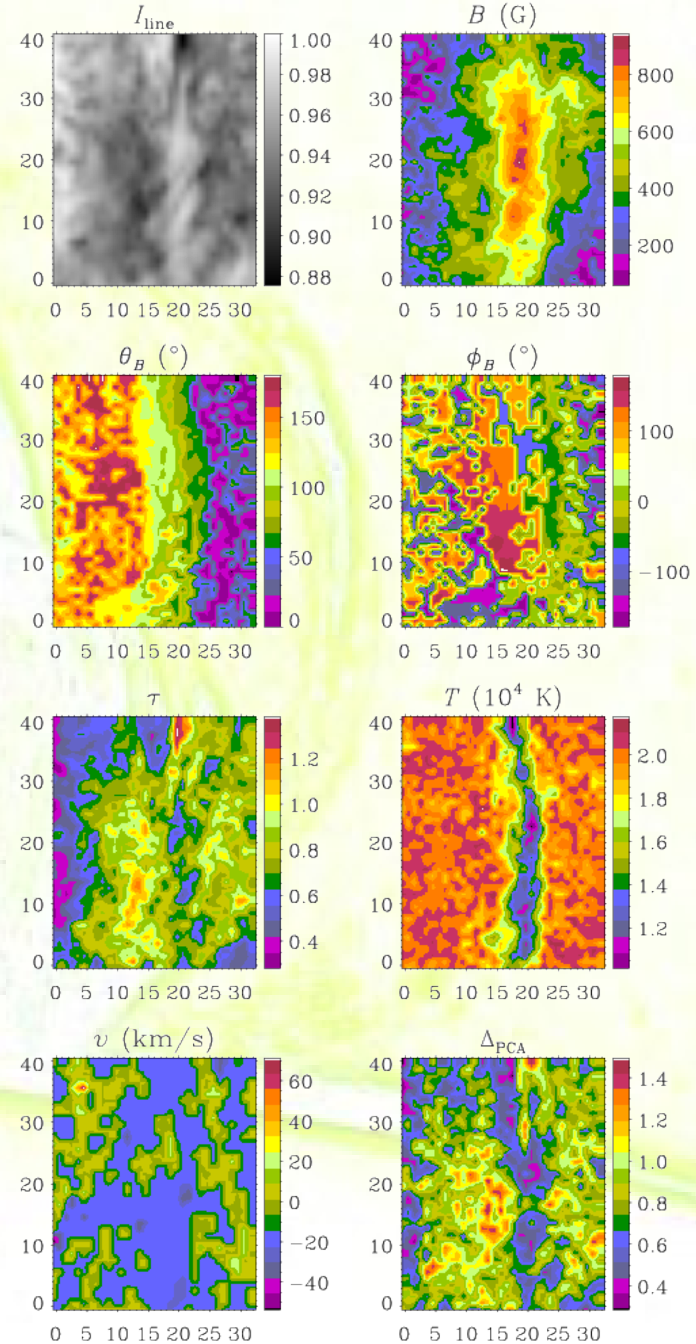
B = 733.05 ± 22.96 G

θ_B = 104.89 ± 0.99

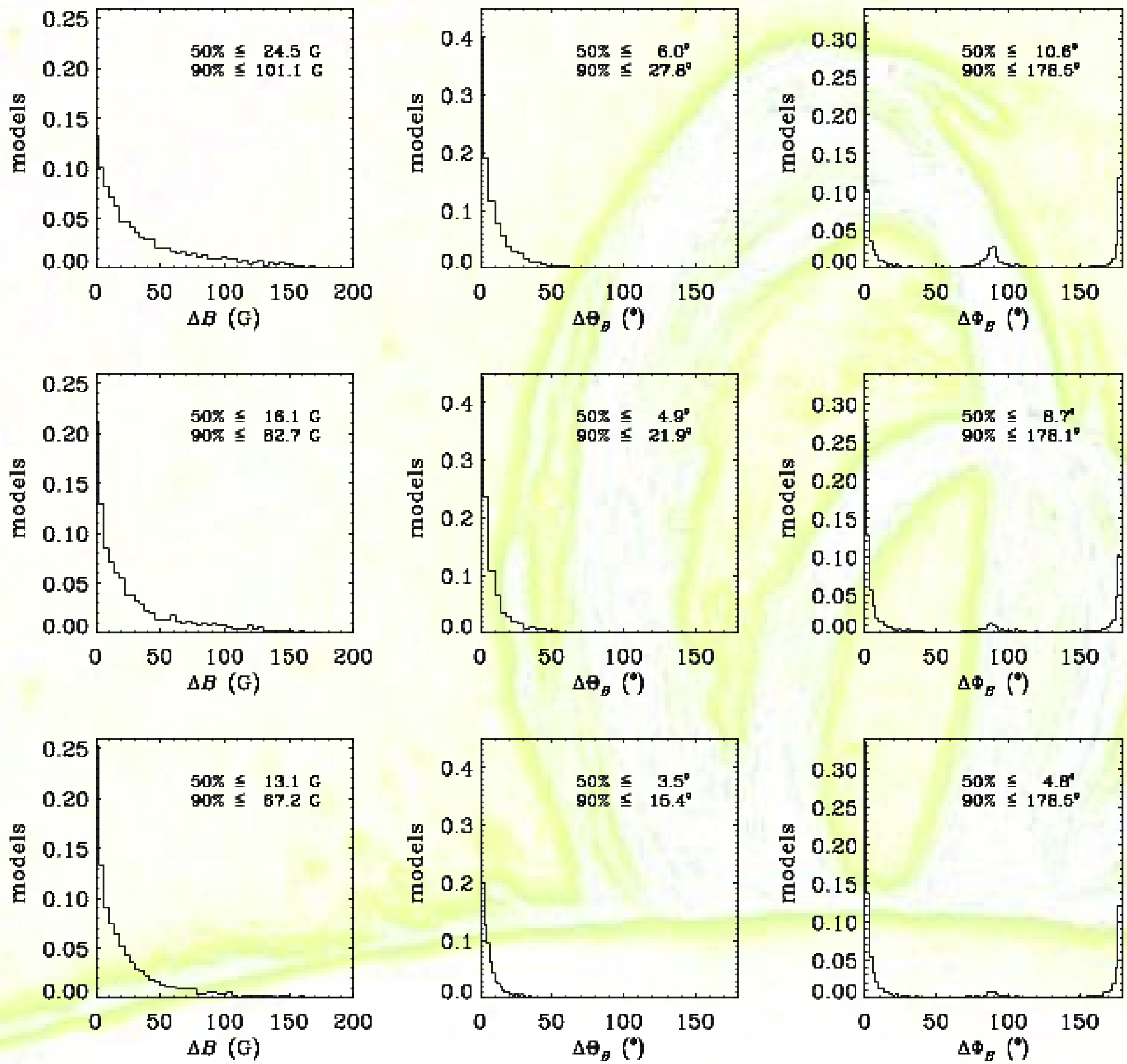
ϕ_B = −74.92 ± 0.99

Θ_B = 96.58 ± 0.49

Φ_B = −69.93 ± 23.87



Multi-Line Inversion



He I 1083

He I D_3

He I 1083
+
He I D_3

Prominence Case

$B < 200$ G

$0° < \vartheta_B < 180°$

$-180° < \varphi_B < 180°$

$S/N \sim 10^3$

Some Instruments with Multi-Line Capability

- NSO/DST with HAO/SPINOR
  (e.g., He I D_3, λ1083 nm, Ca II λ854.2 nm)
- NSO/DST with Arcetri/IBIS
  (e.g., Na I D_1, Ca II λ854.2 nm)
- THEMIS
  (e.g., He I D_3, λ1083 nm, Hα)

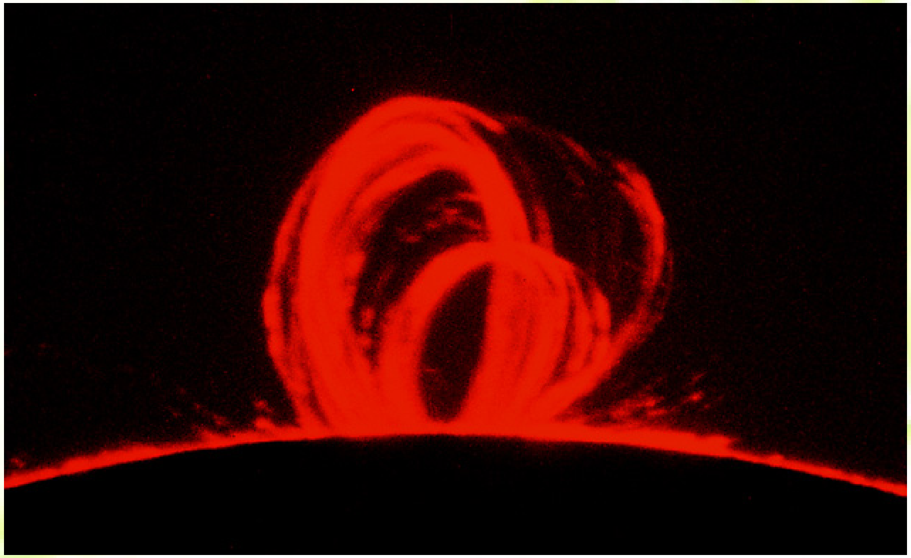
- large aperture, but not optimized for low instrumental scattered light

⟶ good for on-disk observations (e.g., filaments), and for the brightest, low-lying prominences, but not for fainter, higher prominences

- highly subscribed

⟶ inadequate for monitoring studies of prominences and filaments

HAO Prominence Magnetometer



NSO / Evans Solar Facility

- 40-cm, f/20 coronagraph

Magnetometer

- dual-beam achromatic polarimeter 2 Pancharatnam plates (6 FeLCs)
- λ-operation range: 550 nm-1200 nm
- dual-camera spectrograph (placed on the E-bench)

First funding: October 2004

Deployed: March 2008

First light: ?????

HAO Prominence Magnetometer

Instrument specifications

(Elmore et al., SPIE Proc. 2008)

Table 1. Instrument requirements derived from observational requirements

Spectral lines:	587.6 nm and 1083.0 nm, simultaneously and co-spatially 656.3 nm and 1083.0 nm, simultaneously and co-spatially Other lines one at a time between 587.6 nm and 1350 nm (goal)
Field: Spatial resolution:	Span a prominence > 100 arcsec 2 to 3 arcsec
Spectral resolution:	5 pm @ 587.6 nm
Polarimetry:	I, Q, U, V: noise $< 10^{-3}\, I_c$ (goal: $< 5 \times 10^{-4}\, I_c$), dual-beam

Table 2. Constraints on the ProMag design.

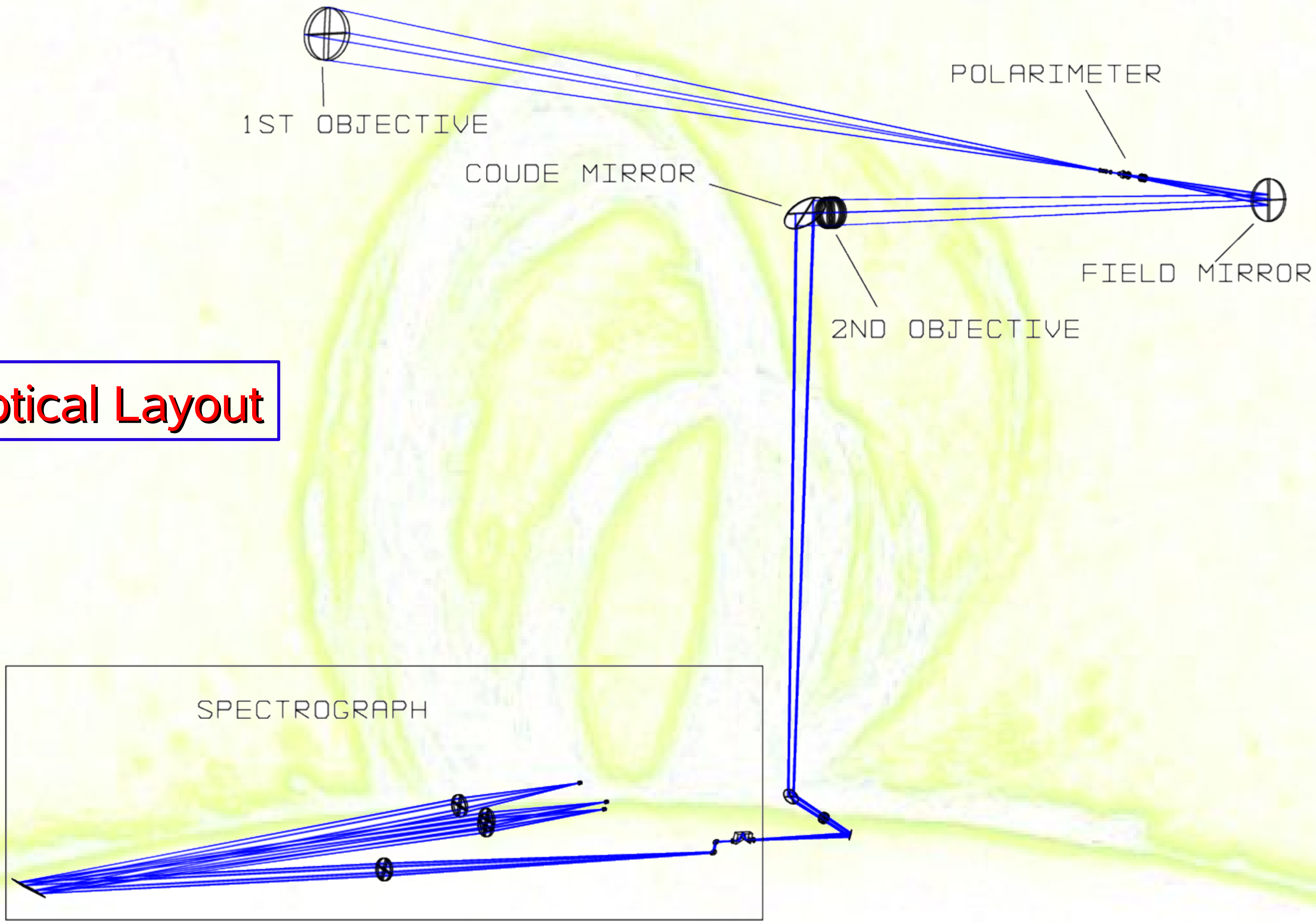
Cameras:	PixelVision Pluto, 652×488, 12 μm pixels FLIR Alpha InGaAs 320×256, 30 μm pixels
Telescope:	Evans Solar Facility, 40-cm coronagraph, East bench, and ESF control.

Table 5. Spectral resolutions calculated from the spectrograph geometry, spectral slit width, spectral pixel width, and grating resolution.

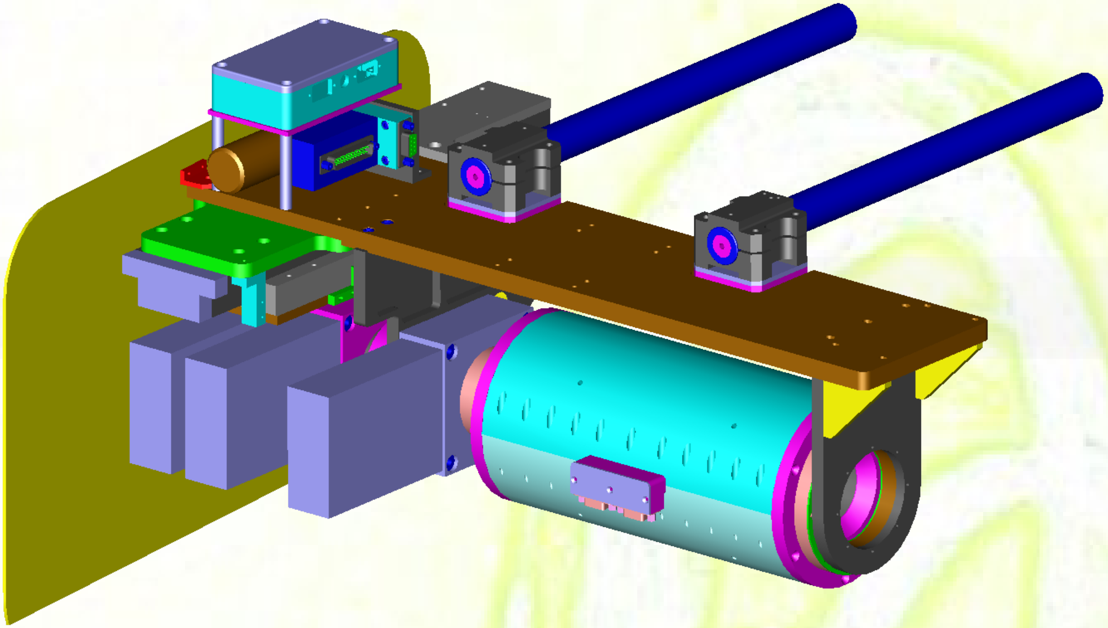
Wavelength (nm)	Pixel sample (pm)	Slit sample (pm)	RSS Resolution (pm)	Length (nm)	Efficiency
587.6	1.78	3.05	3.64	0.87	0.66
1083.0	5.45	5.68	8.43	5.58	0.97
656.3	2.04	3.41	4.12	0.99	0.87
854.2	2.88	4.49	5.66	1.41	0.93
1435.0	8.60	7.75	12.80	8.81	0.37

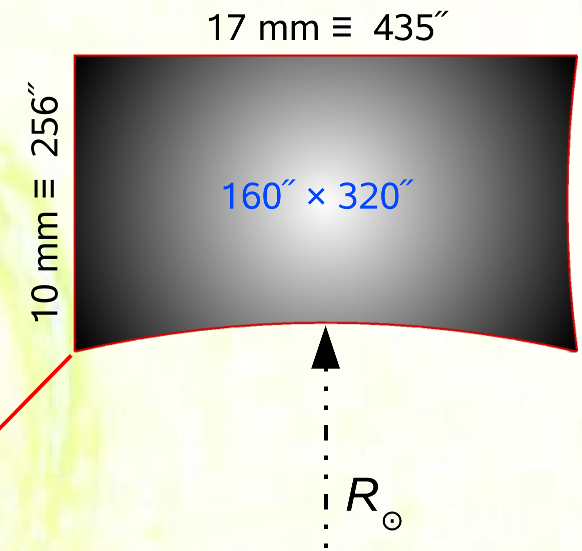
HAO Prominence Magnetometer

Optical Layout

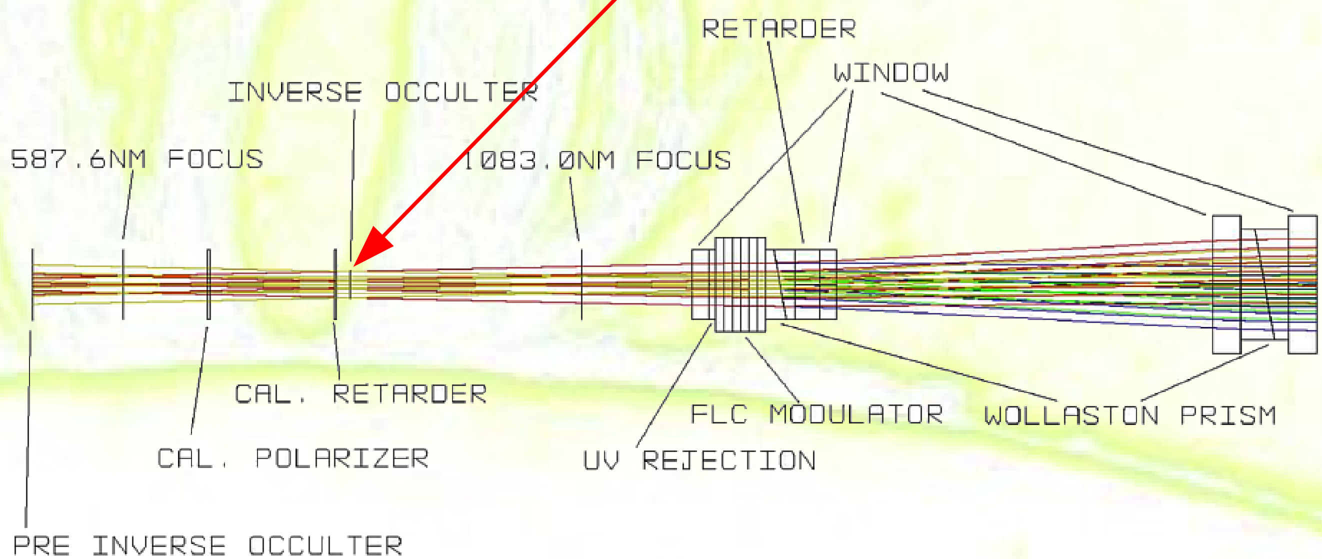


HAO Prominence Magnetometer

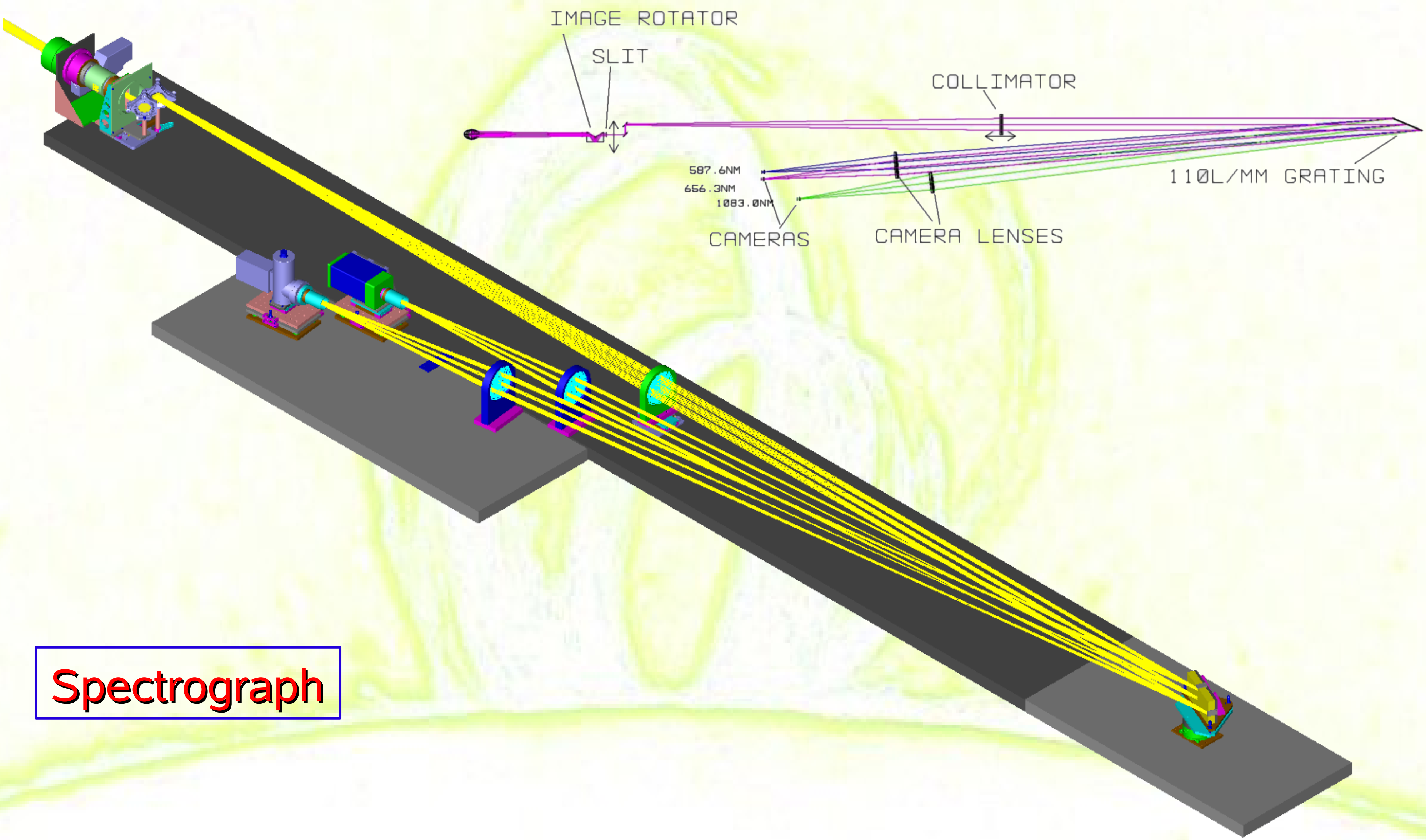




Polarimeter

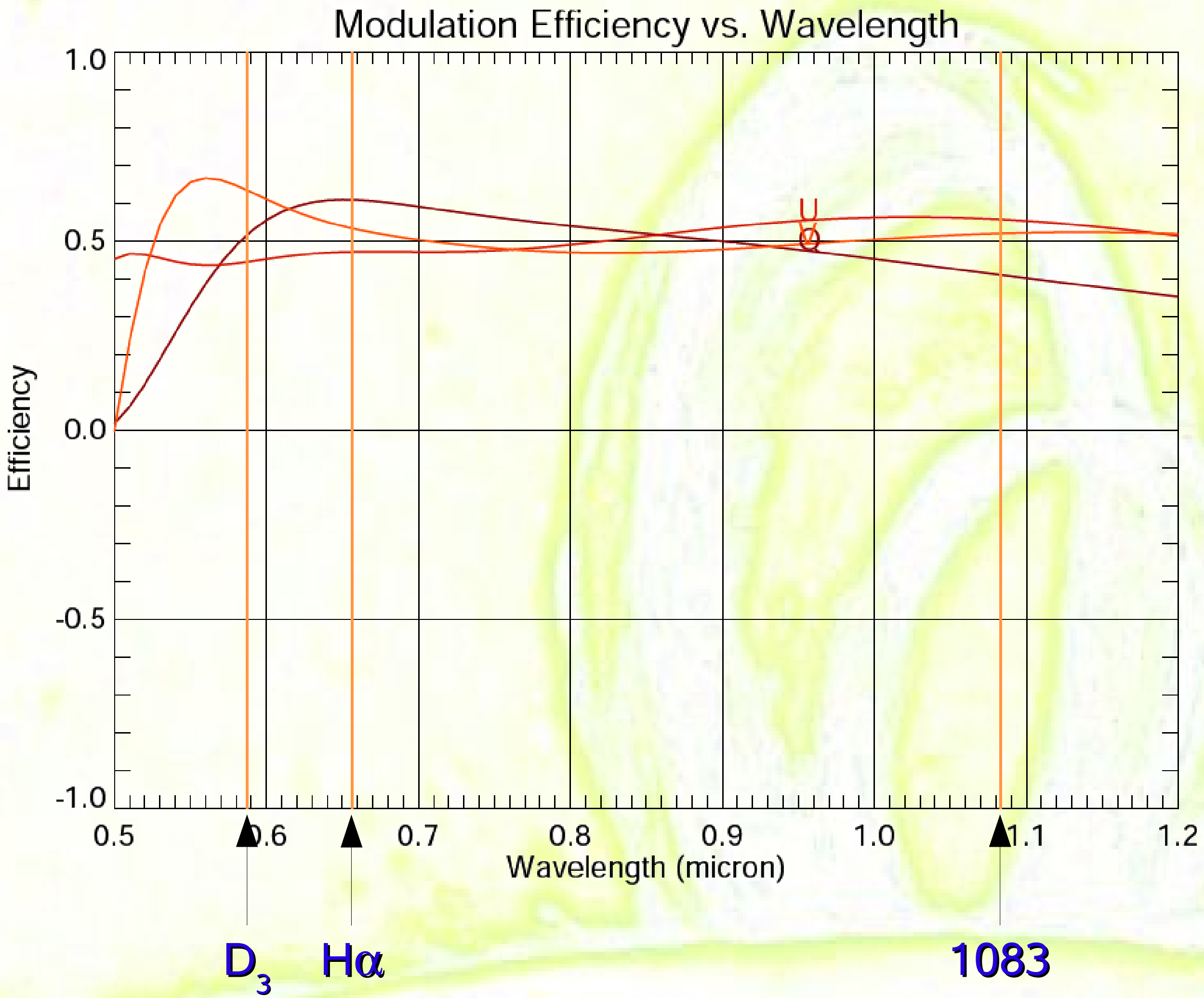


HAO Prominence Magnetometer



Spectrograph

HAO Prominence Magnetometer



$$\mathbf{T}(\mathrm{D}_3) \equiv \begin{pmatrix} 1 & -0.413 & -0.242 & -0.878 \\ 1 & 0.286 & 0.349 & -0.892 \\ 1 & 0.654 & -0.712 & 0.255 \\ 1 & -0.700 & 0.485 & 0.525 \end{pmatrix}$$

$$\mathbf{E}(\mathrm{D}_3) \equiv (1, 0.513, 0.447, 0.637)$$

$$\mathbf{T}(\mathrm{H}\alpha) \equiv \begin{pmatrix} 1 & -0.445 & -0.498 & -0.744 \\ 1 & 0.319 & 0.601 & -0.733 \\ 1 & 0.839 & -0.523 & 0.150 \\ 1 & -0.814 & 0.277 & 0.511 \end{pmatrix}$$

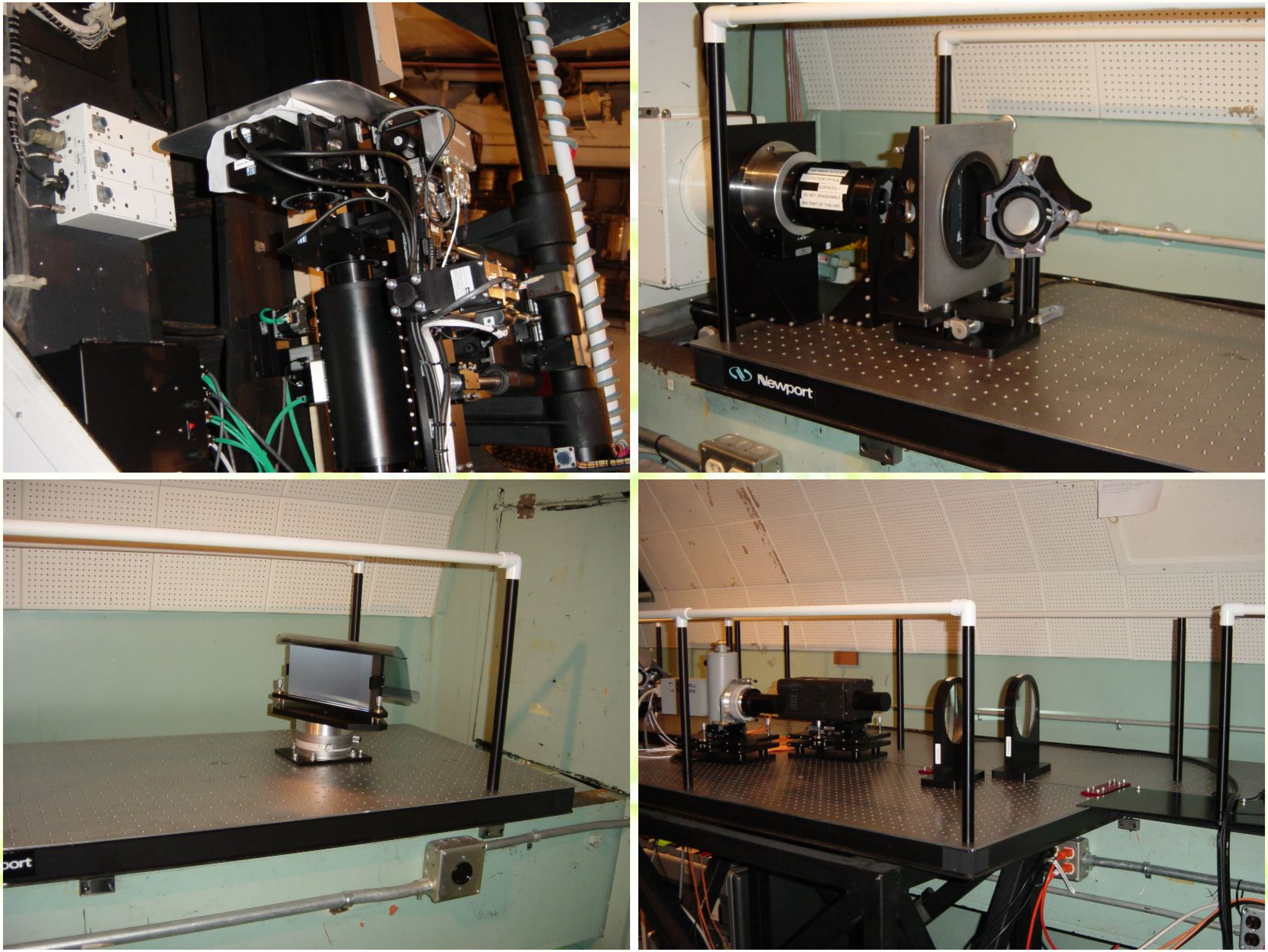
$$\mathbf{E}(\mathrm{H}\alpha) \equiv (1, 0.604, 0.475, 0.534)$$

$$\mathbf{T}(1083) \equiv \begin{pmatrix} 1 & -0.376 & -0.369 & -0.850 \\ 1 & 0.391 & 0.129 & -0.911 \\ 1 & 0.368 & -0.900 & 0.235 \\ 1 & -0.546 & 0.832 & 0.101 \end{pmatrix}$$

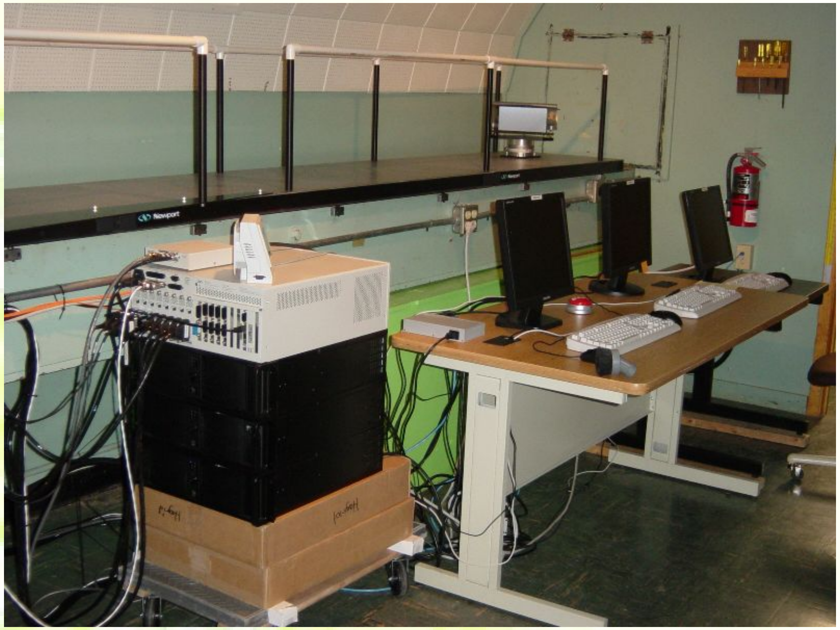
$$\mathbf{E}(1083) \equiv (1, 0.420, 0.557, 0.524)$$

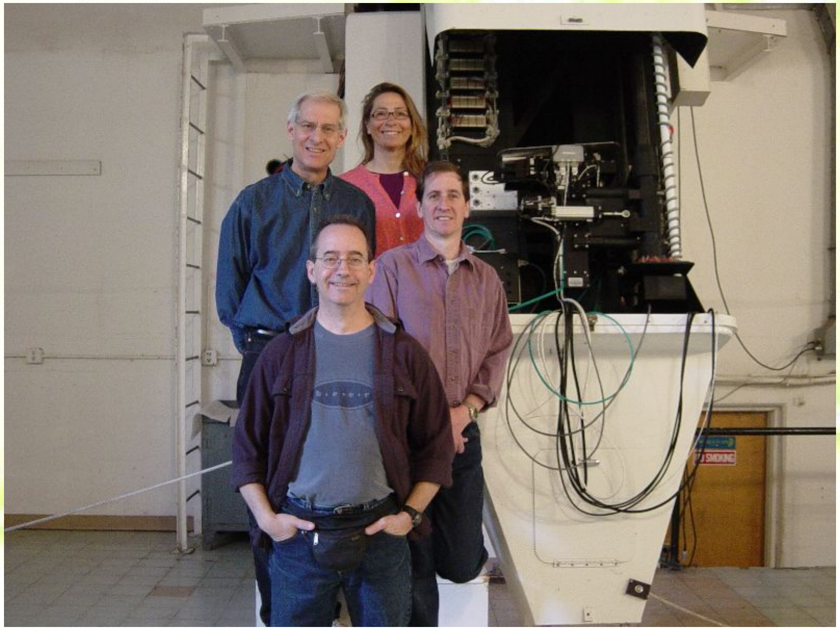
Demodulation scheme $\longrightarrow$ $\mathbf{M} \equiv \begin{pmatrix} + & - & - & - \\ + & + & + & - \\ + & + & - & + \\ + & - & + & + \end{pmatrix}$

HAO Prominence Magnetometer



HAO Prominence Magnetometer





clockwise from the top:
A. Lecinsky, G. Card, R. Lull, D. Elmore

What's Next?

Dec. 2008: re-characterization of the FeLC modulator
Sometimes 2009: ProMag's first light

- test polarimeter's thermal stability
- test polarimeter's orientability
- test telescope-image rotator synchronization
- test calibration procedure on solar data
- acquire first science data (hopefully!)

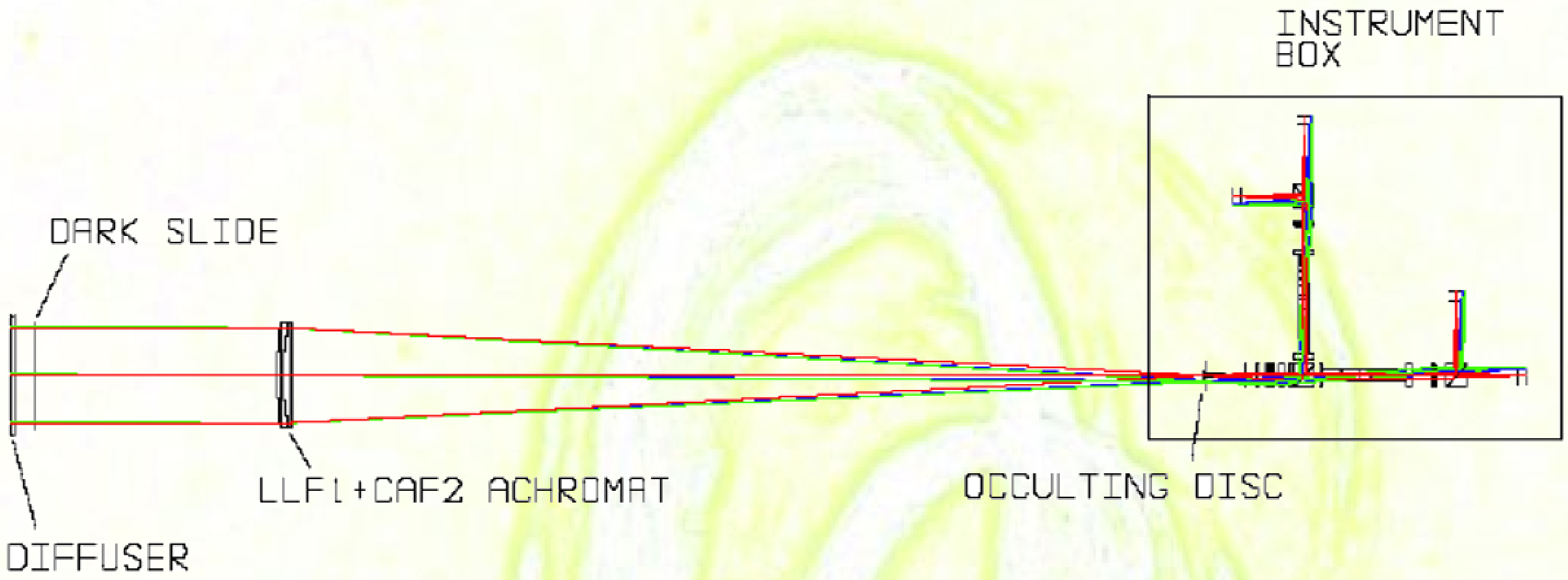
After: 2 wks/quarter ESF time to ProMag (as per MOU)

NSO and AFRL participation to support and observation: Elmore (~30%), Balasubramanian (~10%), others?

Eventually: establish a monitoring program of magnetic fields in the chromosphere and corona

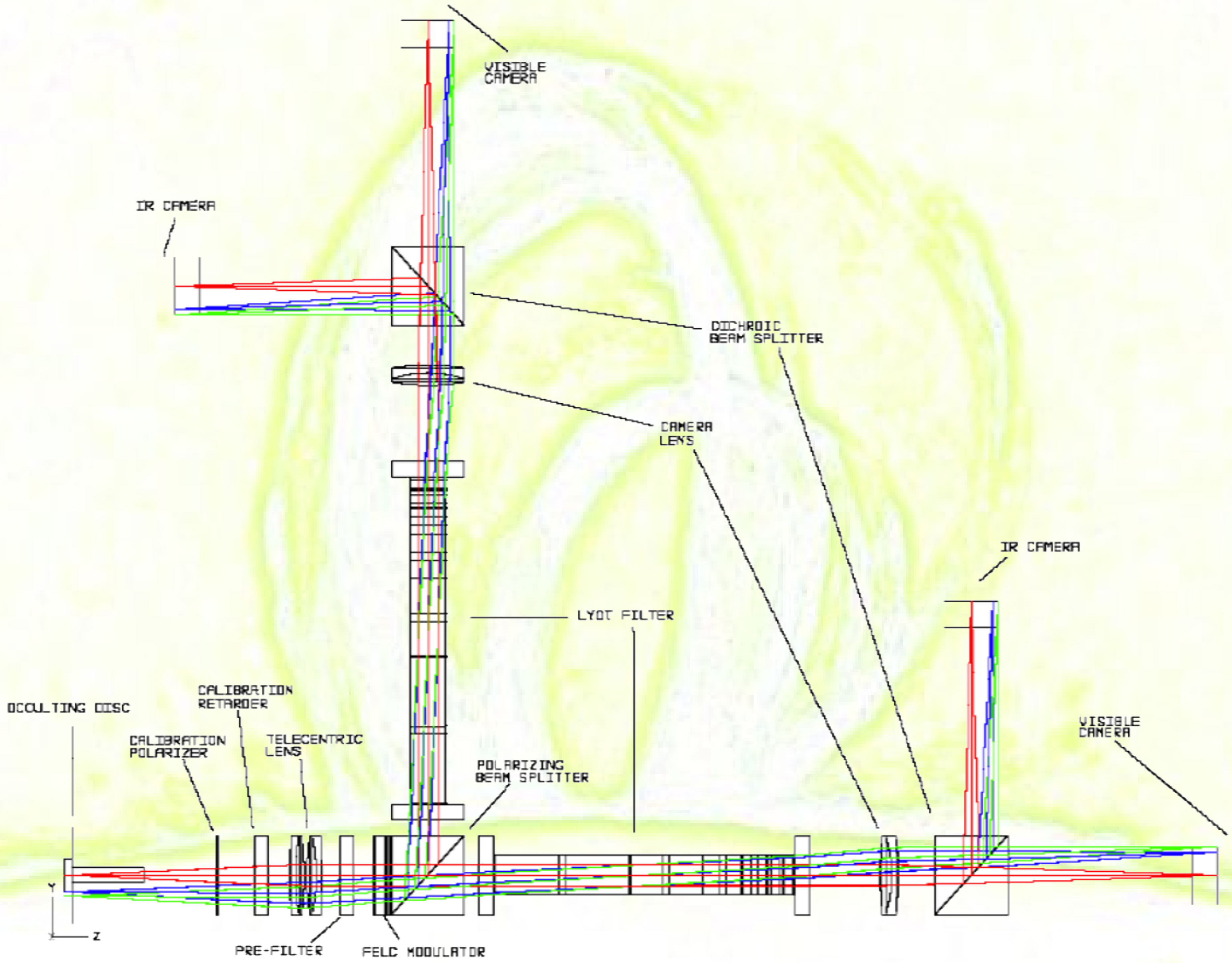
... looking forward to ChroMag / COSMO

ChroMag



Diam. = 200 mm
FOV = 2.5 $R_\odot$
2K x 2K cameras
Spatial res. = 2.3”
Tunable, narrow-band, Lyot filters
(220mA at 588nm, 460mA at 1083nm)
12 sampling wavel. → 15 sec/scan

ChroMag


VISIBLE CAMERA
IR CAMERA
DICHROIC BEAM SPLITTER
CAMERA LENS
IR CAMERA
LYOT FILTER
OCCULTING DISC
CALIBRATION RETARDER
CALIBRATION POLARIZER
TELECENTRIC LENS
POLARIZING BEAM SPLITTER
VISIBLE CAMERA
Y
Z
PRE-FILTER
FELC MODULATOR

Conclusions

Multi-line capability (almost) a necessity:

- **He I 588 nm**: highest diagnostic content; optically thin (only usable off limb); good handle on $B \gtrsim 10$ G
- **He I 1083 nm**: only option on the disk; helps constraining field geometry; good handle on $B \lesssim 10$ G

Large FOV instrument preferred (e.g., 20 cm achromat)

Filter-based polarimetry (need smart scan strategy)