



GETTING READY FOR SUNRISE III

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SUNRISE III CONSORTIUM

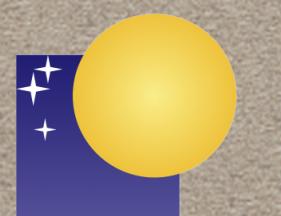


A. Lagg • Sunrise III • ESA Symposium Rocket & Balloon



JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

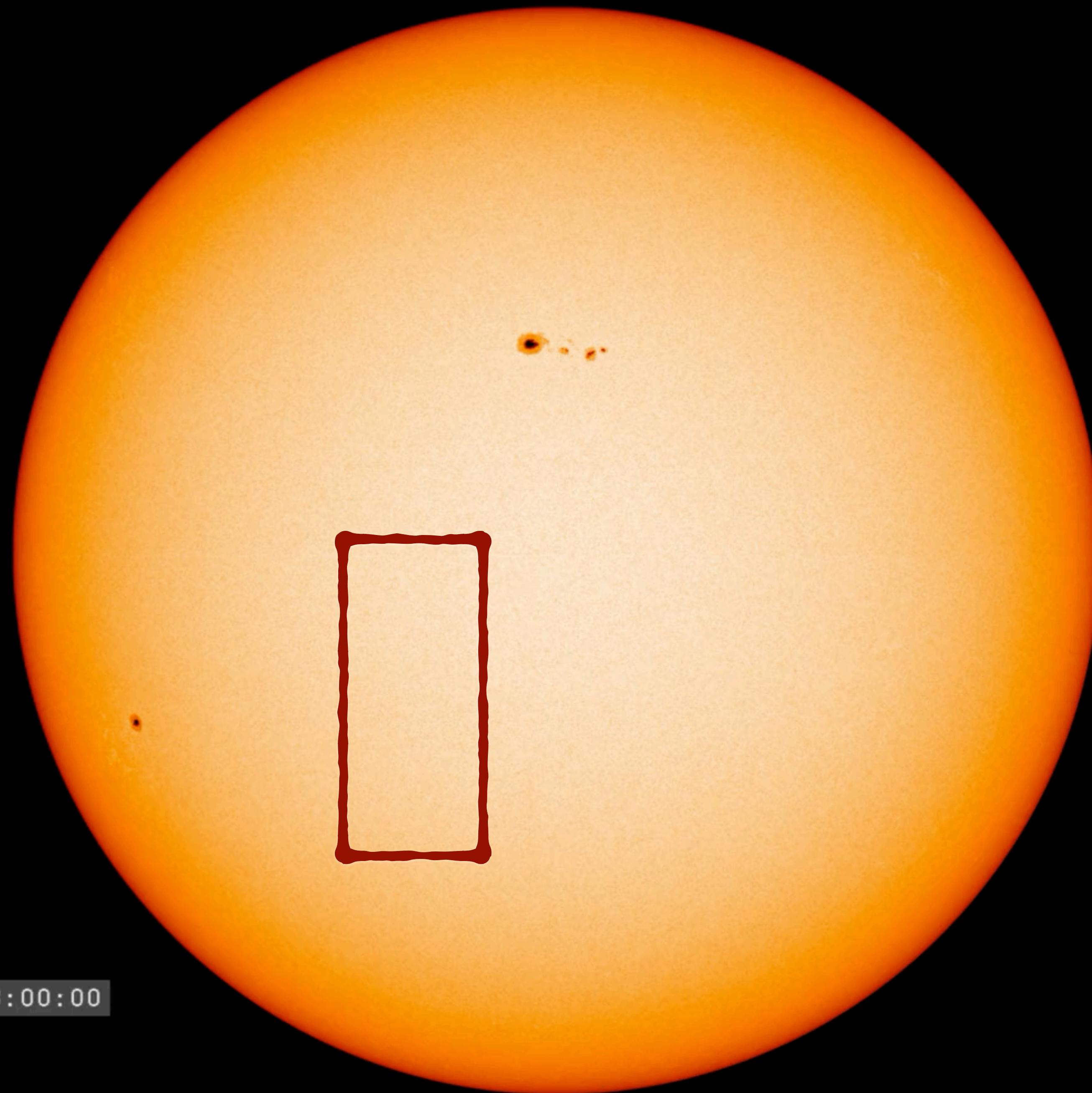
NAOJ



Leibniz-Institut für
Sonnenphysik (KIS)

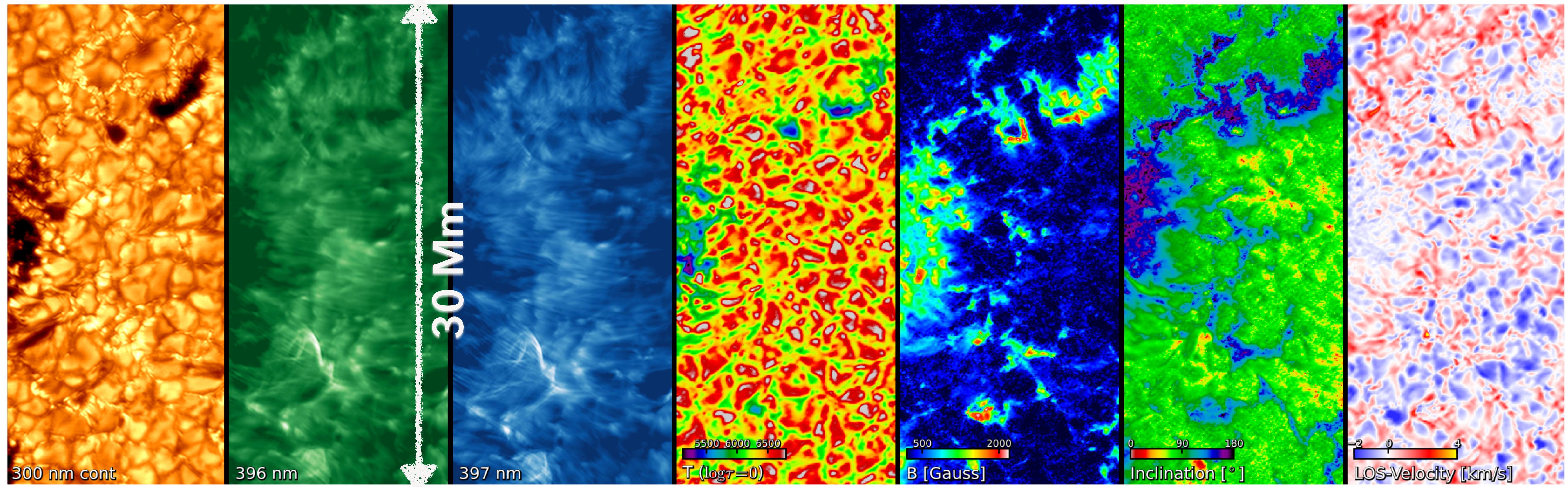


IT'S ALL ABOUT - THE SUN



2010 Mar 29 08:00:00

SDO / HMI



Intensity
image:
photosphere

Narrow-band
Ca-image:
chromosphere

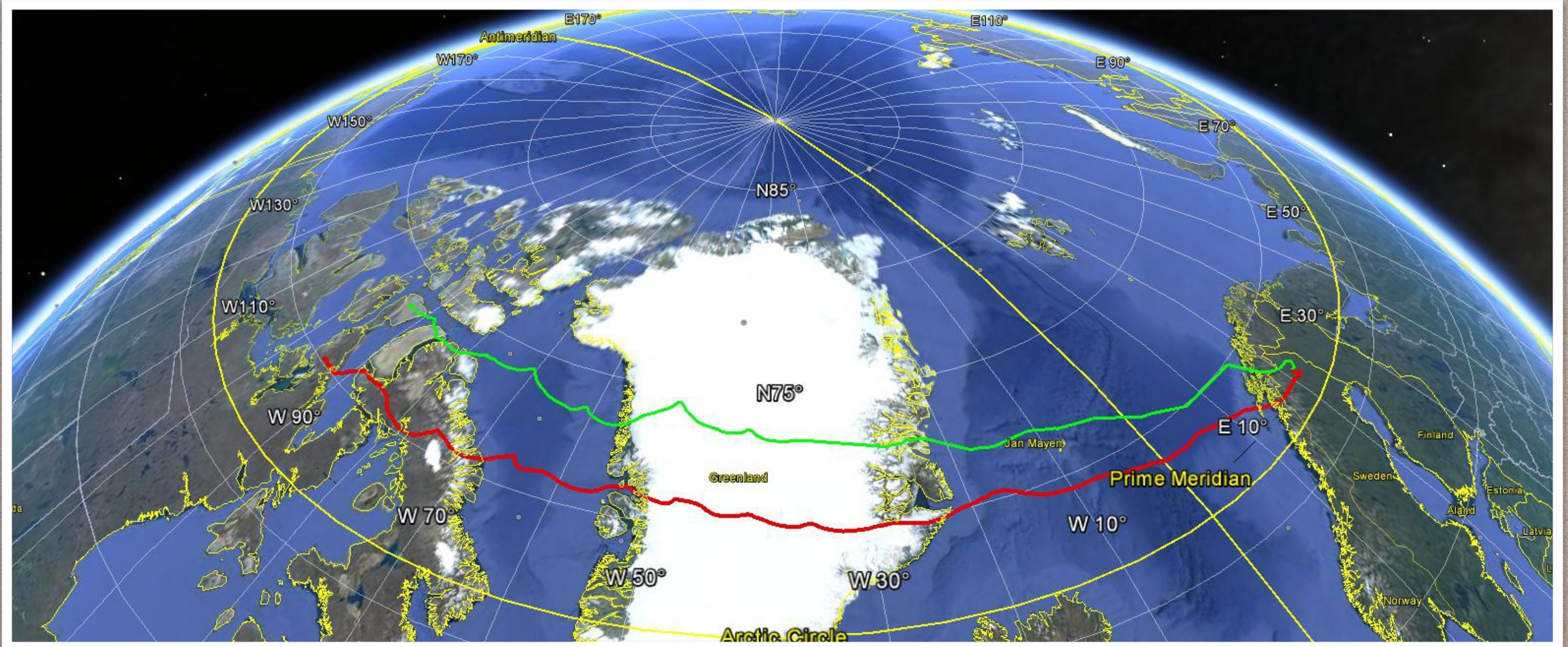
Temperature
'solar surface'

Magnetic field
strength

Magnetic field
orientation

Line-of-sight
velocity

SUNRISE I+II FLIGHT



No atmospheric seeing, UV spectral range accessible, continuous 24/7 observation of the Sun

Flight termination and instrument recovery in Canada, no overflight permission over Russia for U.S. balloon



SCIENTIFIC HIGHLIGHTS

SUNRISE I+II, 2009 & 2013

SO FAR ~100 REFEREED PUBLICATIONS

- First ever spatially resolved images of intense magnetic flux on the Sun show that semi-annual oscillations provide a reasonable model (Lagg et al. 2010).
- First ever brightness concentrations in the UV at 121 nm reveal very high values up to 5 above the mean quiet Sun (Riethmüller et al. 2010).
- First ever measurements of the contrast of granulation images up to 30%, consistent with theory. These values provide the efficiency of convective energy transportation (Hirzberger et al. 2010).
- First determination of elements directionality sampling different parts of the magnetic field contrast to investigate how they were closed. This strongly affected the results.
- Ubiquitous small-scale whirl flows are found which drag small-scale magnetic field structures into their centres (Bonet et al. 2010).
- Magnetic field extrapolations from SUNRISE/IMaX data indicate that most magnetic loops in the quiet Sun remain within the photosphere. Only a small fraction reaches the chromosphere. Discovery that 85 % of the internetwork magnetic fields stronger than 100 G are concentrated in mesogranular lanes, although there is no particular mesogranular scale (Yelles Chaouche et al. 2011).

GONZALEZ et al. 2011, REQUEREDO et al. 2011).

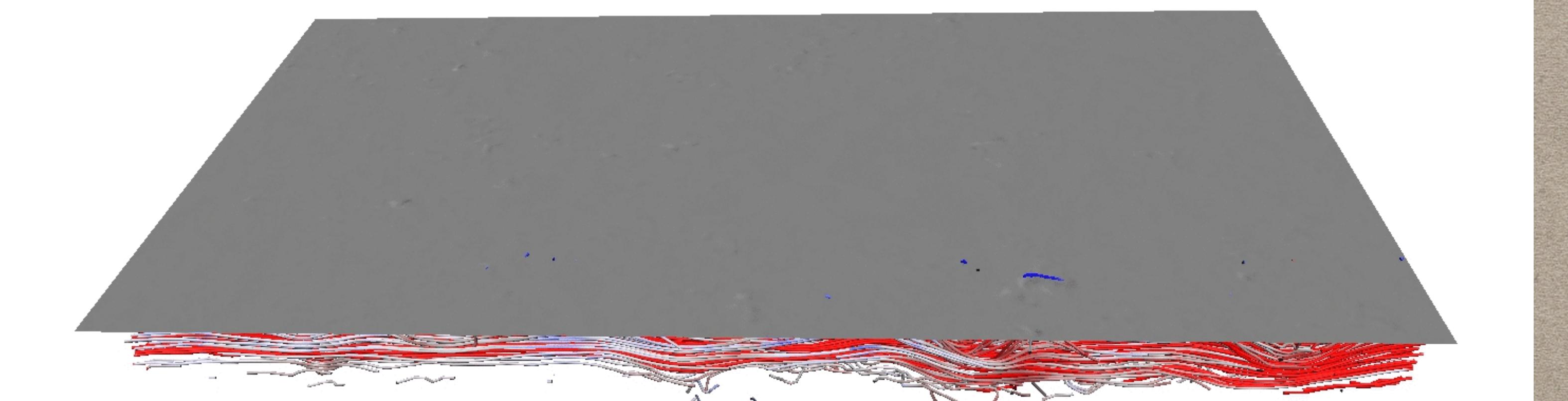
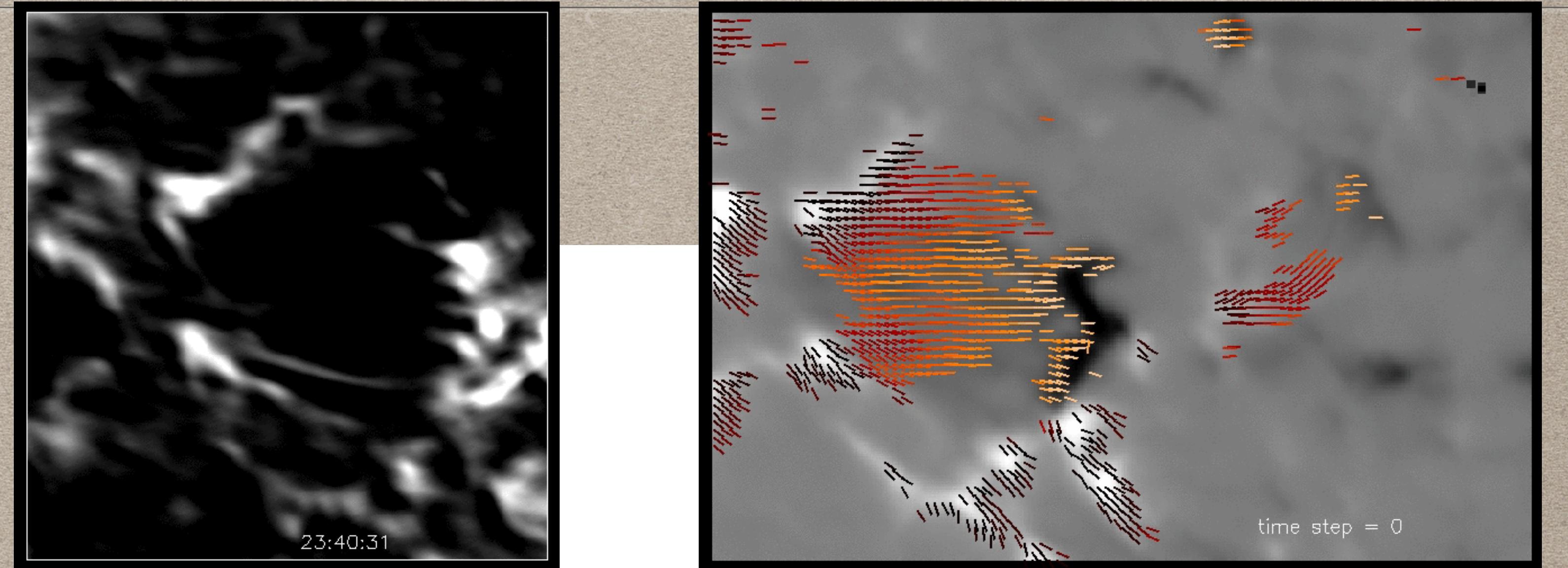
SUNRISE II SCIENCE HIGHLIGHTS (SOLANKI ET AL., 2017)

1. [Centeno et al. \(2017\)](#) analyzed emerging the interrelated dynamics of the gas and reports on two emerging flux events, d possible the interrelated dynamics of tl occurrence of magnetic reconnection du
2. The properties of a likely siphon flow connecting magnetic elements with a pc and the 3D structure of the magnetic fi determining
3. The pro of the l contrast
4. The pro and of different superdi extreme
7. The discovery of ubiquitous transverse waves travelling along these fibrils and carrying copious amounts of energy is reported by [Jafarzadeh et al. \(2017\)](#), while [Gafeira et al. \(2017a\)](#) present the discovery of compressible waves travelling along the fibrils, which they
8. [Jafarzadeh et al. \(2017\)](#) a canopy of magnetic f observations.
9. [Chitta et al. \(2017\)](#) observed that coronal loops are ro polarity fields. They provide evidence for flux cancell Y-shaped jets (signatures of magnetic reconnection) at might supply (hot) plasma to the overlying coronal lo of the traditional picture in which each loop footpoi unipolar regions on the solar surface.
10. [Danilovic et al. \(2017\)](#) compare an Ellerman bomb ob a similar, simulated event in which magnetic reconnect of emerging flux. The 3D radiation-MHD simulation re underlying physical process and the limitations of the ob SUNRISE/IMaX data cannot determine the height at wh takes place. The authors also show, however, that the ve measured at the high resolution of SUNRISE/IMaX reveal MHD simulations can be overcome.
11. [Wiegelmann et al. \(2017\)](#) have computed general linear magneto-static equilibria of the magnetic field and gas using the SUNRISE II/IMaX observations as a bounda condition. In this way they obtain the magnetic field structure in the upper atmosphere without having to assume the validity of the force-free assumption in the solar photosphere. They computed linear magneto-static equilibria for all the IMaX frames of the active region, without the problems faced when modeling the magnetic field in different atmospheric layers of the quiet Sun.
13. [Kahil et al. \(2017\)](#) probe the relationship between brightness contrast at UV and visible wavelengths and the magnetic flux in the quiet Sun, finding that the contrast keeps increasing with magnetic flux, unlike most earlier observational results, but in qualitative agreement with MHD simulations.
14. [Jafarzadeh et al. \(2017\)](#) characterize the wave modes observed at two heights in magnetic bright points, including both compressible waves seen in brightness fluc tuations and transverse waves obtained from proper motions.
15. The short travel times suggest large wave speeds. A new estimate of the flux emer gence rate in the quiet Sun is obtained by [Smitha et al. \(2017\)](#). Compared with the emergence rate deduced from Hinode/SOT data using the same technique, the emergence rate obtained from SUNRISE I data is around an order of magnitude larger.

AN ACTIVE REGION CLOSE-UP



Centeno et al. 2017;
Requerey et al. 2017;
Danilovic et al. 2017:
IMaX uncovers the
dynamics and
topology of
emerging flux
regions. The vector
magnetic field is used
to trace magnetic
field lines

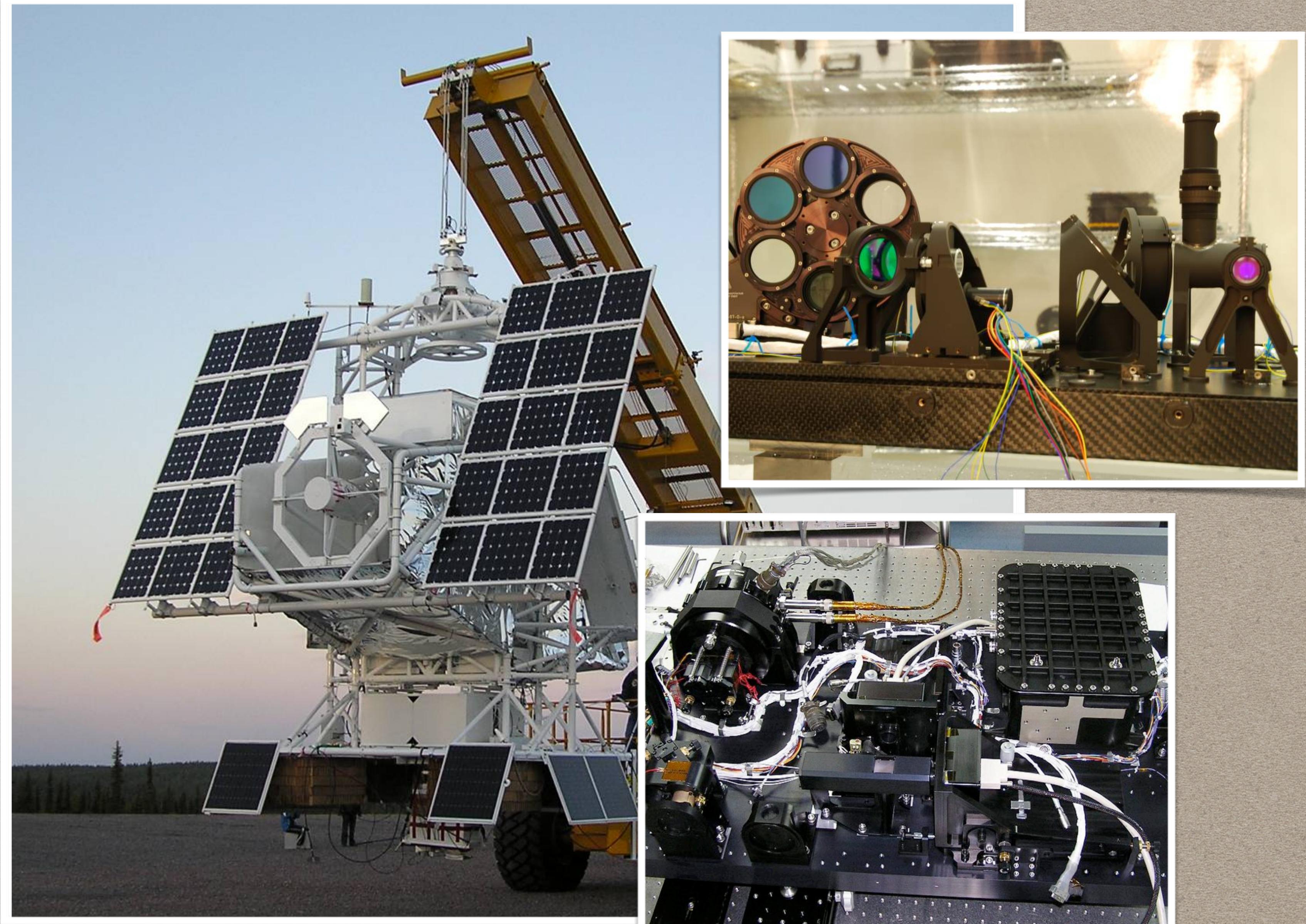


1. [Centeno et al. \(2017\)](#) analyzed emerging flux regions with a detailed description of the interrelated dynamics of the gas and the field, including the reports on two emerging flux events, describing in greater detail than previously possible the interrelated dynamics of the gas and the field, as well as the likely occurrence of magnetic reconnection during the emergence.

THE “OLD” SUNRISE

CONFIGURATION IN 2009 & 2013

- Gondola (HAO)
- Telescope (MPS)
 - 1 m aperture, 25 m focal length
 - Gregory configuration
- Image Stabilization (KIS)
- **Sunrise Filter Imager (SuFI, MPS)**
- **Imaging Magnetograph (IMaX, IAA)**

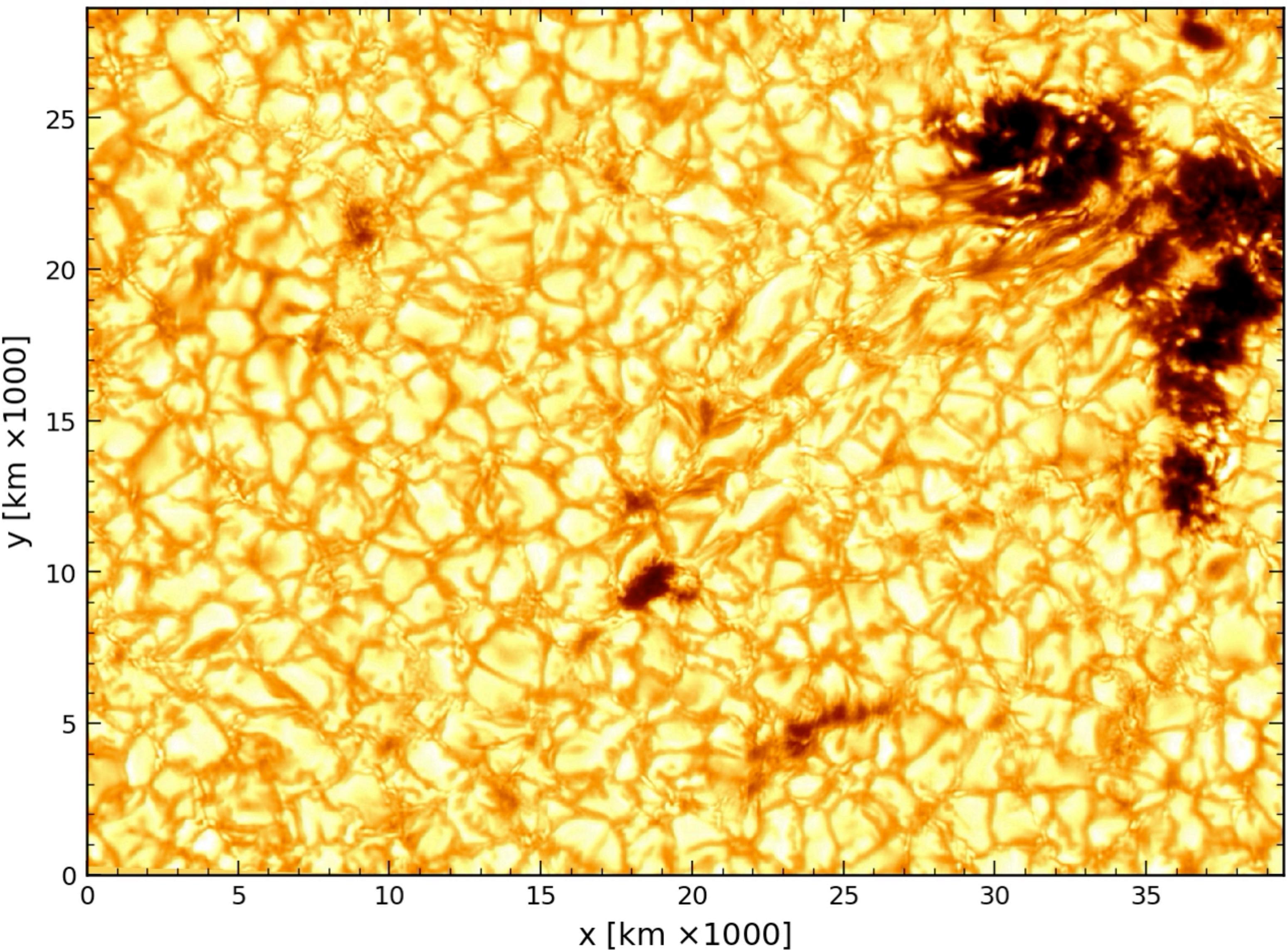


WHY SUNRISE III?

GROUND-BASED
CAUGHT UP....

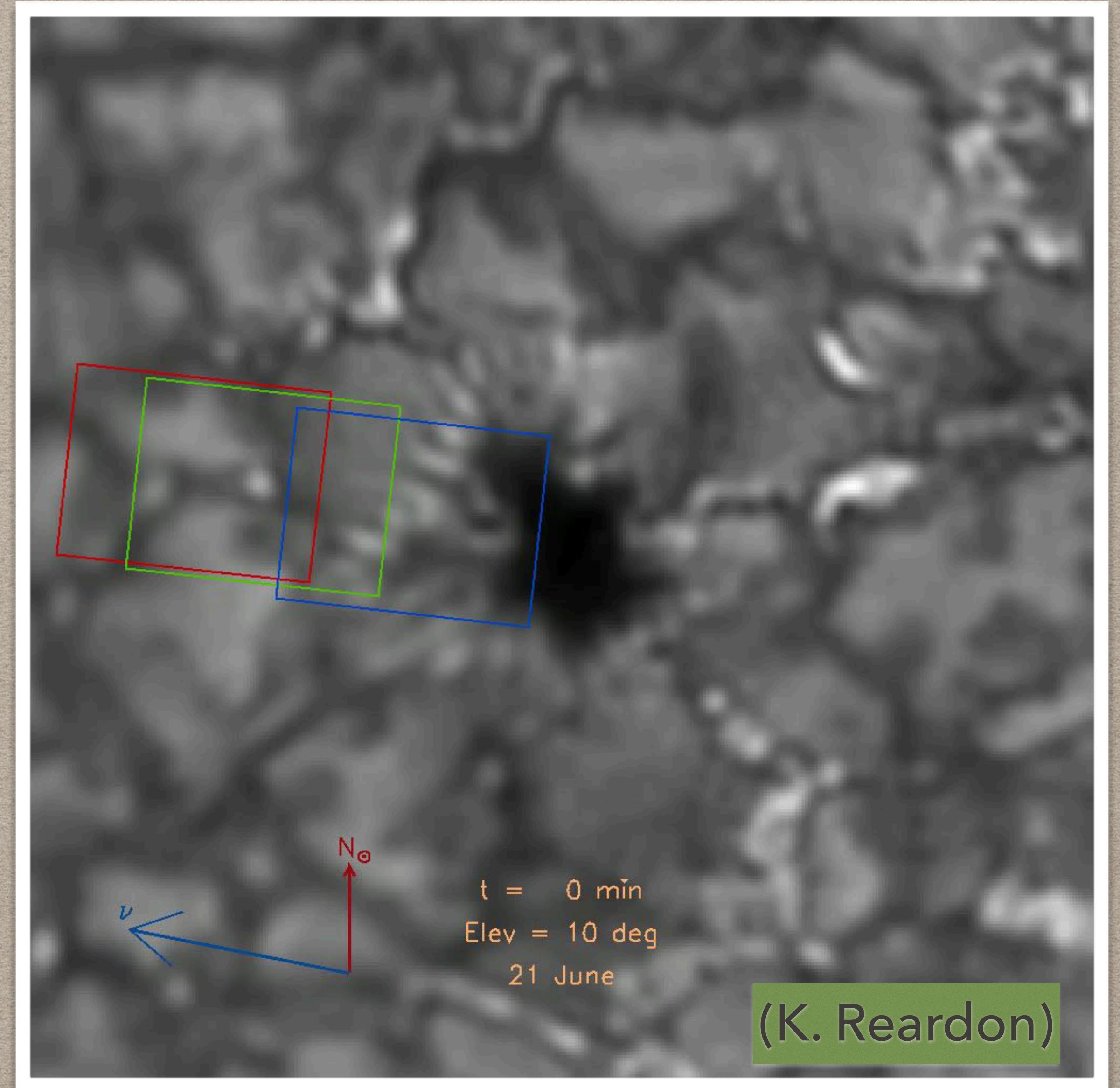
A 1-M TELESCOPE
IN THE DKIST ERA?

SST/CHROMIS - 400 nm continuum



WHY SUNRISE III?

- No Atmospheric dispersion
combine various wavelengths
 - 8542 Å
 - 10830 Å
 - 15000 Å
- long, constant-quality time series
- access to UV
- Seeing-free environment
- well-known PSF (high pol. S/N ratio, no noise increase from reconstruction)
- no telluric lines

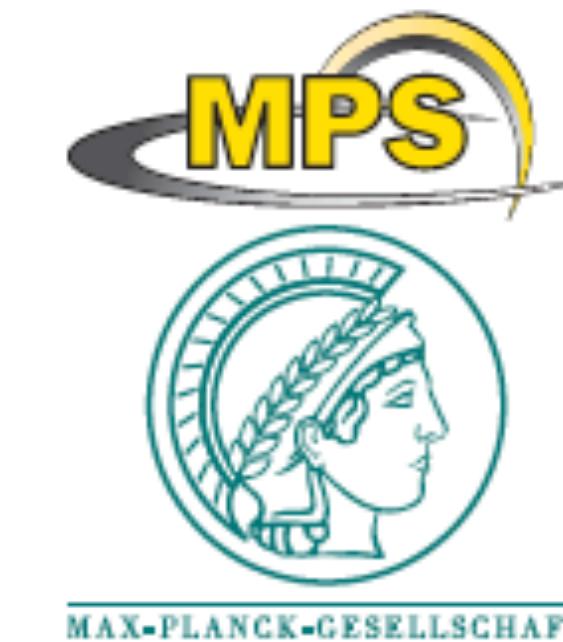


THE NEW SUNRISE

EXPLOITING THE 3RD DIMENSION



SUNRISE Re-Flight 2020:
Seeing the Sun with new Eyes

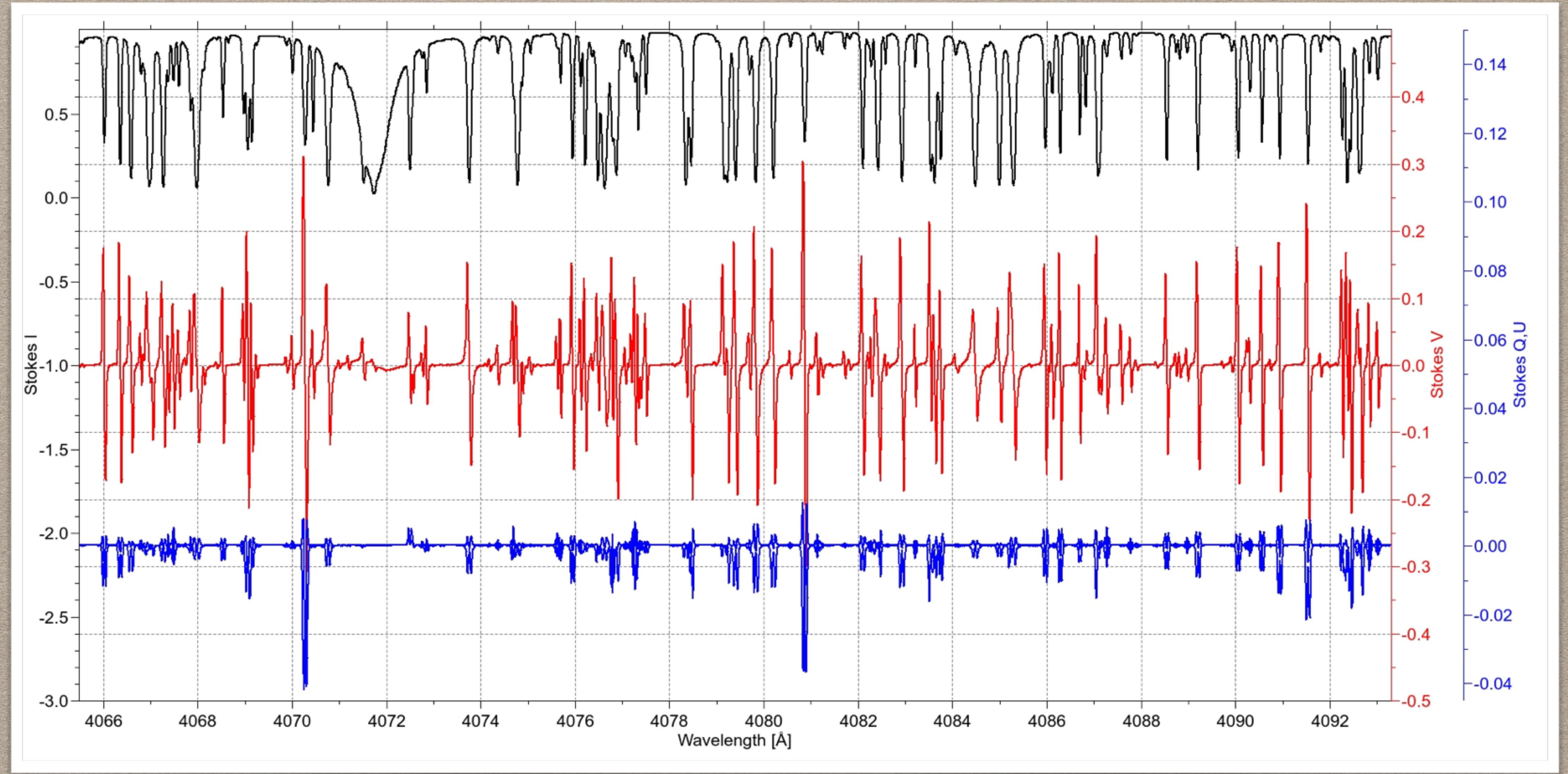


Sami K. Solanki and the SUNRISE team

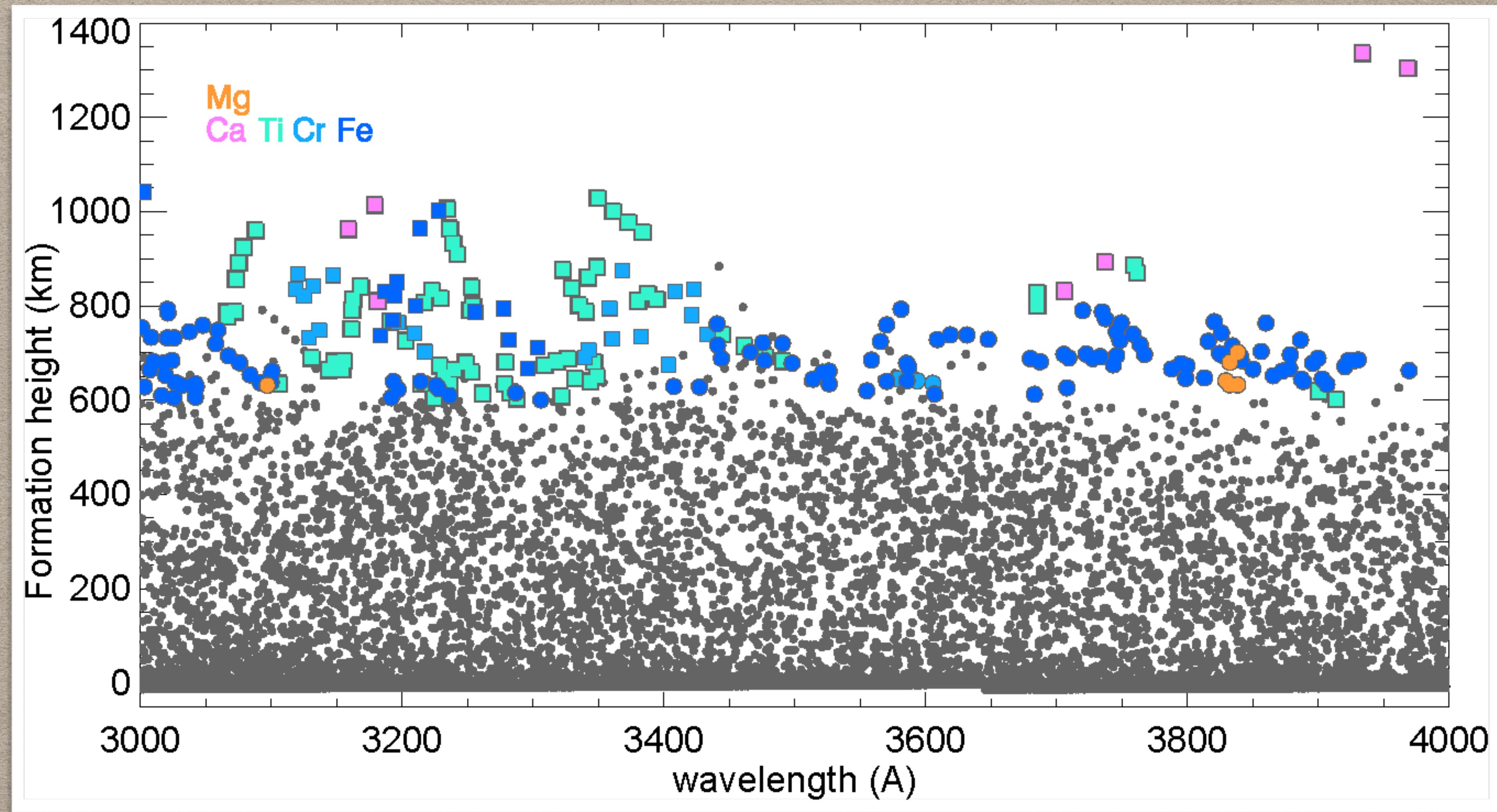
Max-Planck-Institut für
Sonnen systemforschung
Justus-von-Liebig-Weg 3
37077 Göttingen



MANY-LINE ANALYSIS WITH SUNRISE III

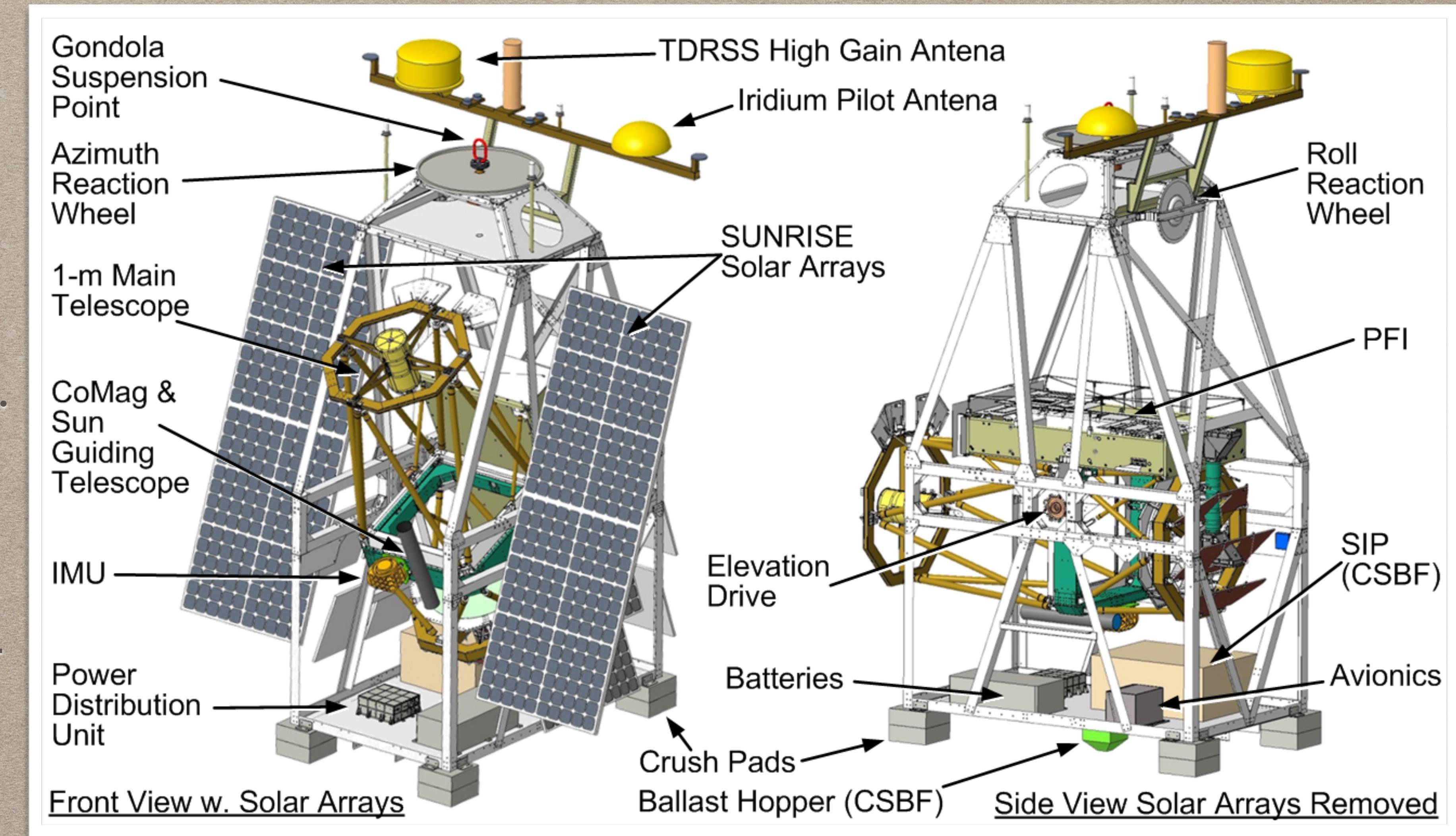


MANY-LINE ANALYSIS WITH SUNRISE III



THE "NEW" SUNRISE

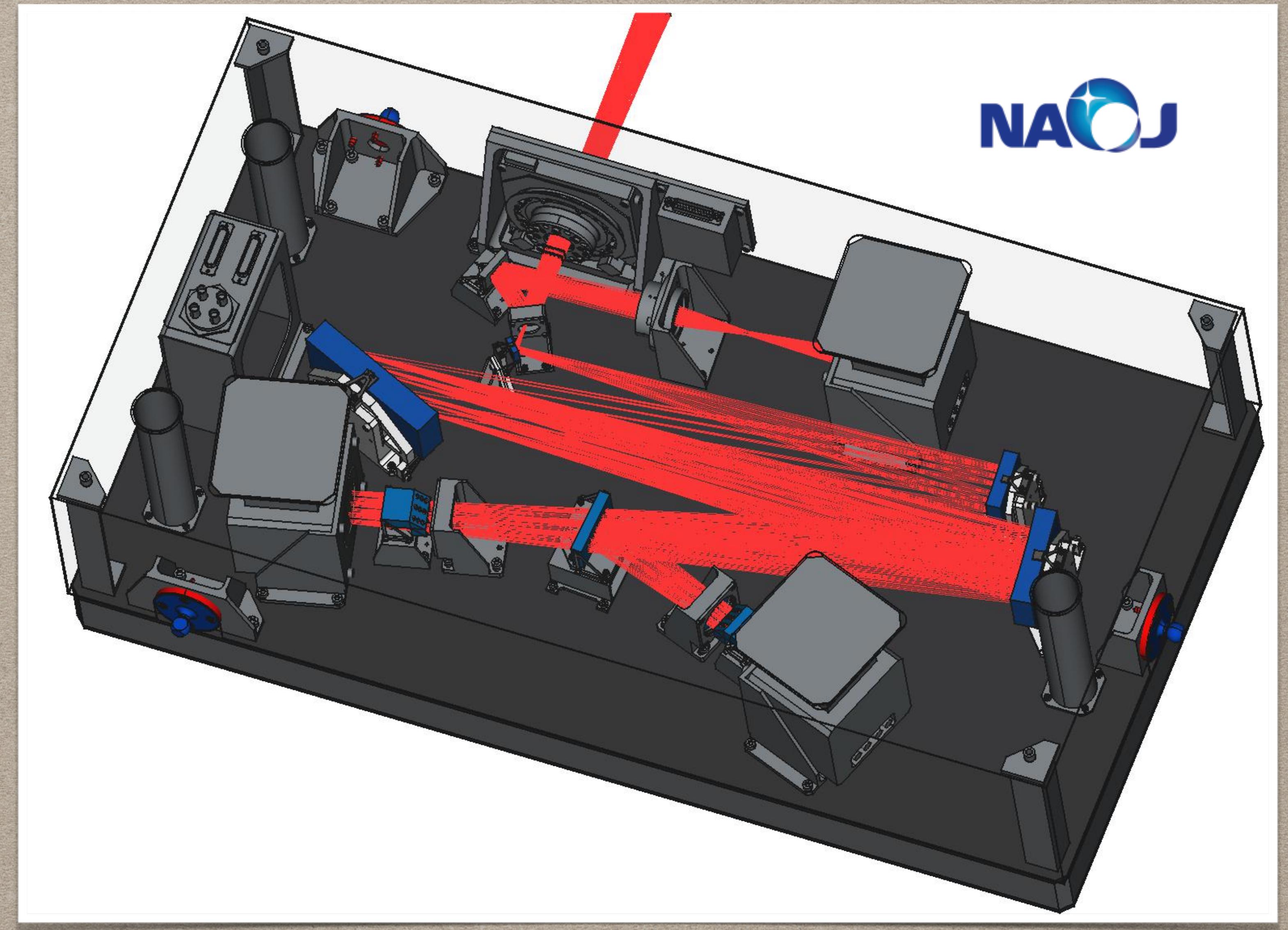
- new gondola (APL): now with roll damping
- new instruments:
 - Chromospheric Infrared Spectropol. (SCIP)
 - UV Spectropol. & Images (SUSI)
- refurbished IMaX+
- 160 TByte onboard SSD storage



SUNRISE CHROMOSPHERIC INFRARED SPECTRPOL (SCIP)



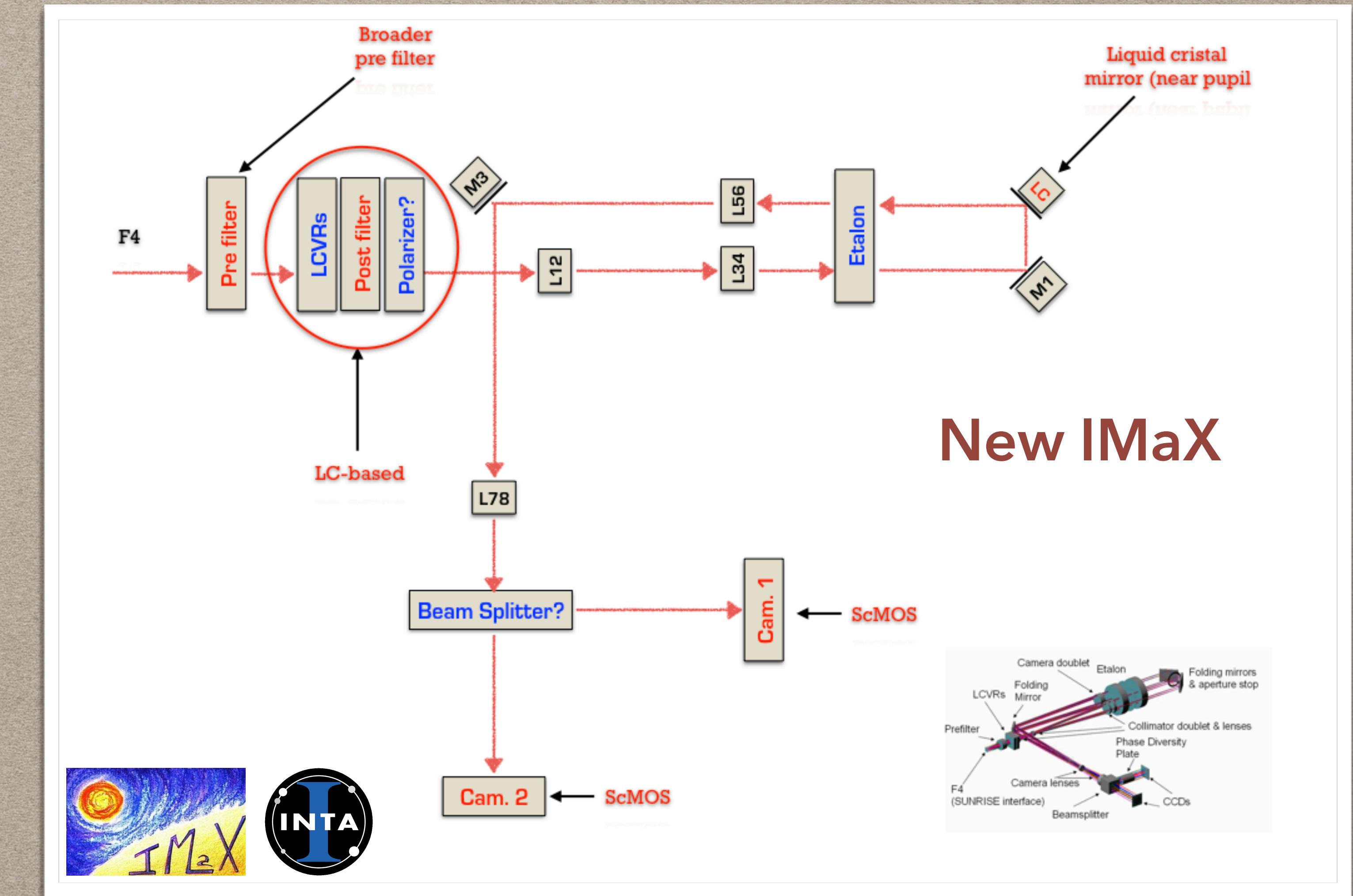
Spectral range	765 - 855 nm
Optical scheme	dual-beam spectrograph, slit scan unit (in ISLiD) and slit-jaw imager
Scientific target, wavelength bands	Photosphere: Fe I 846.8 nm, Fe I 851.4 nm Upper photosphere: K I 766.5 nm, K I 769.9 nm Chromosphere: Ca II 849.8 nm, Ca II 854.2 nm
FOV	58" x (61 - 83) Å
sampling	0.094" x (39 - 42) mÅ/px
Cadence	1 - 10 s
Max. pol. accuracy	3×10^{-4}



IMAGING MAGNETOGRAPH EXPERIMENT (IMAX+)



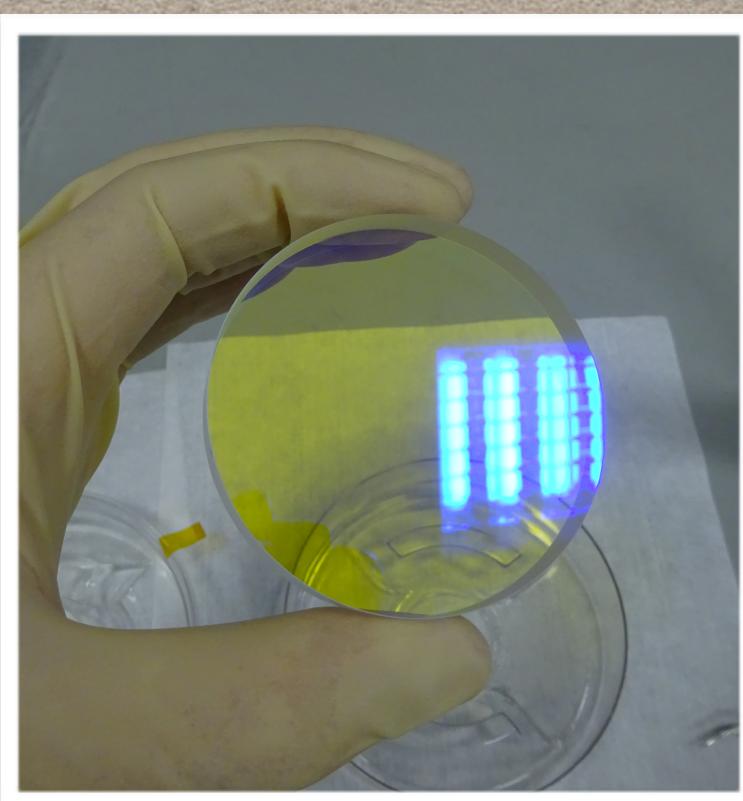
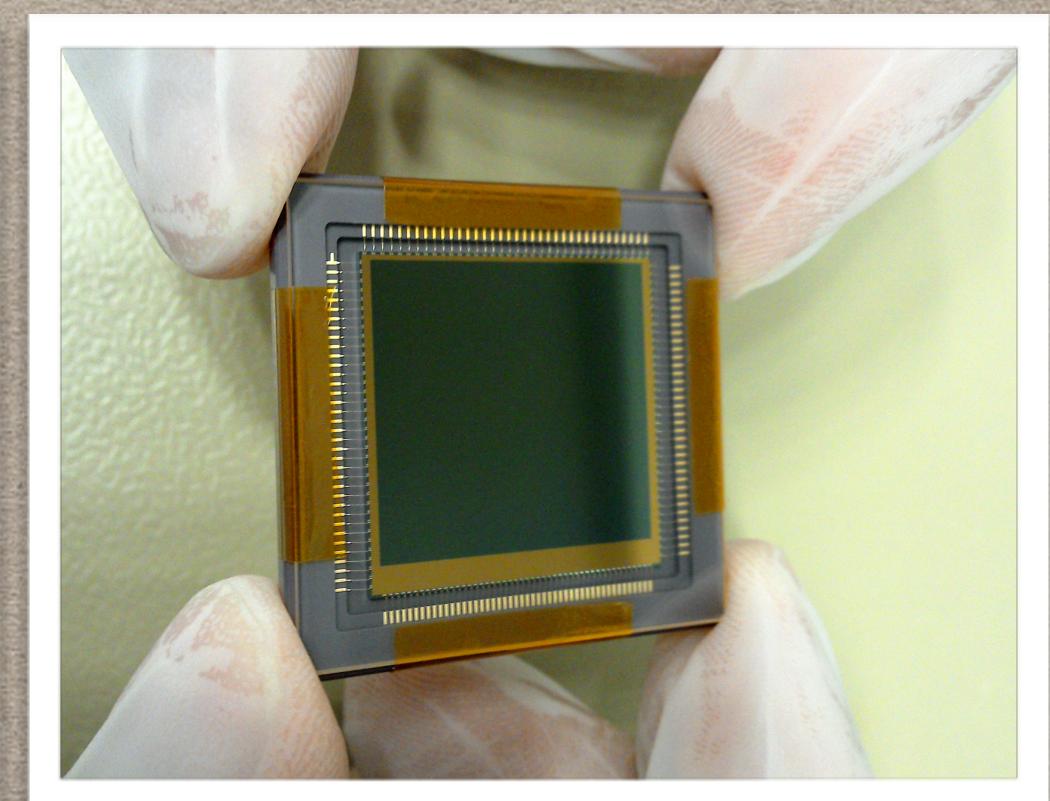
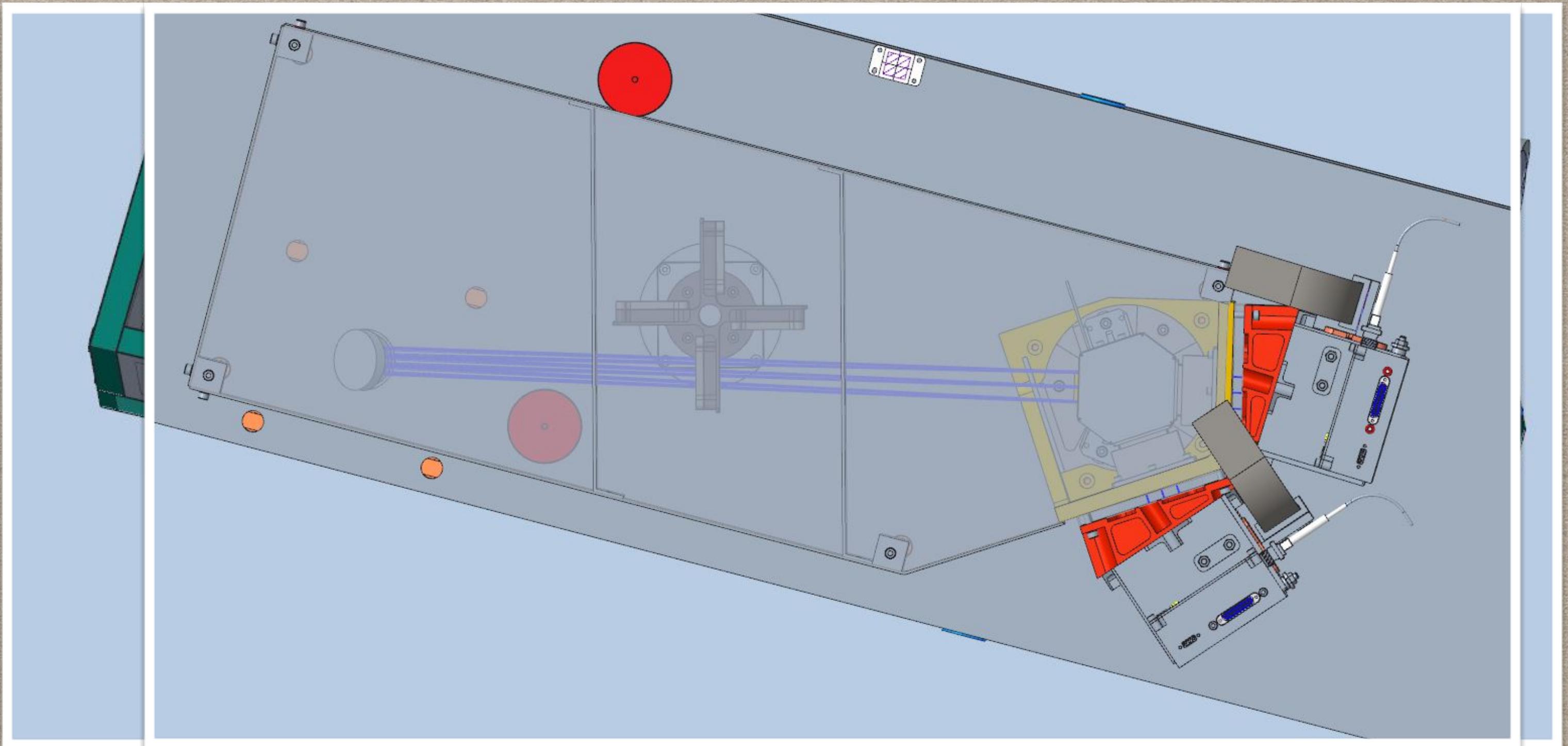
Spectral range	517 - 525 nm
Optical scheme	Collimated double-pass Fabry-Pérot filtergraph
Scientific target, wavelength bands	Photosphere: Fe I 525.06 nm Fe I 525.02 nm Temperature minimum: Mg I 517.3 nm
FOV	56" x 56"
Spatial & spectral sampling	0.055"/px 65 mÅ FWHM
Cadence	8 - 33 s
Max. polarimetric accuracy	< 1×10^{-3}



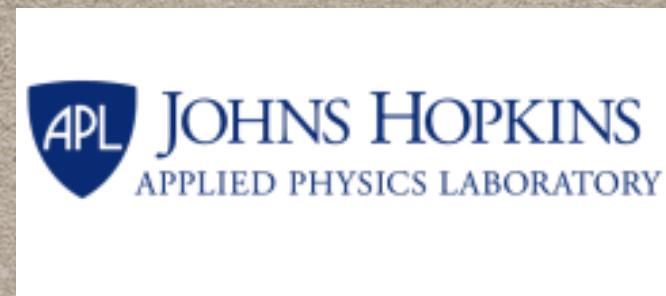
SUNRISE UV SPECTROPOL. AND IMAGER (SUSI, MPS)



Spectral range	300 - 430 nm
Optical scheme	dual beam spectrograph, tunable grating, slit scan unit and slit-jaw imager
Scientific target, wavelength bands	314 nm (Zeeman++) 323 nm (Scatter++) 359 nm (Scatter++) 393 nm Ca II K 397 nm Ca II H 408 nm (Zeeman++)
FOV	61" x (14.3 - 20.5) Å
sampling	0.03" x (7 - 10) mÅ/px
Cadence	5 - 20 s
Max. pol. accuracy	5×10^{-4}



	DKIST / Ground based	Sunrise III
spatial resolution	+++	+
height resolution	++	+++
magnetic sensitivity	+++	+++
instrumentation	+++	+
long-term stability	+	+++
atmospheric straylight	-	+++
near-UV exploration	-	+++



S.K. Solanki + MPS Team

Max Planck Institute for Solar System Research, Germany

PM, Telescope, PFI infrastructure, ISLiD, ICS, SUSI

P. Bernasconi + APL Team

Applied Physics Laboratory, Johns Hopkins University, USA

Gondola, Interface to CSBF

J.C. del Toro-Iniesta + IMaX Team

Instituto de Astrofisica de Andalucia, Spain and the IMaX consortium

IMaX+

Y. Katsukawa + NAOJ Team

National Astronomical Observatory of Japan

SCIP

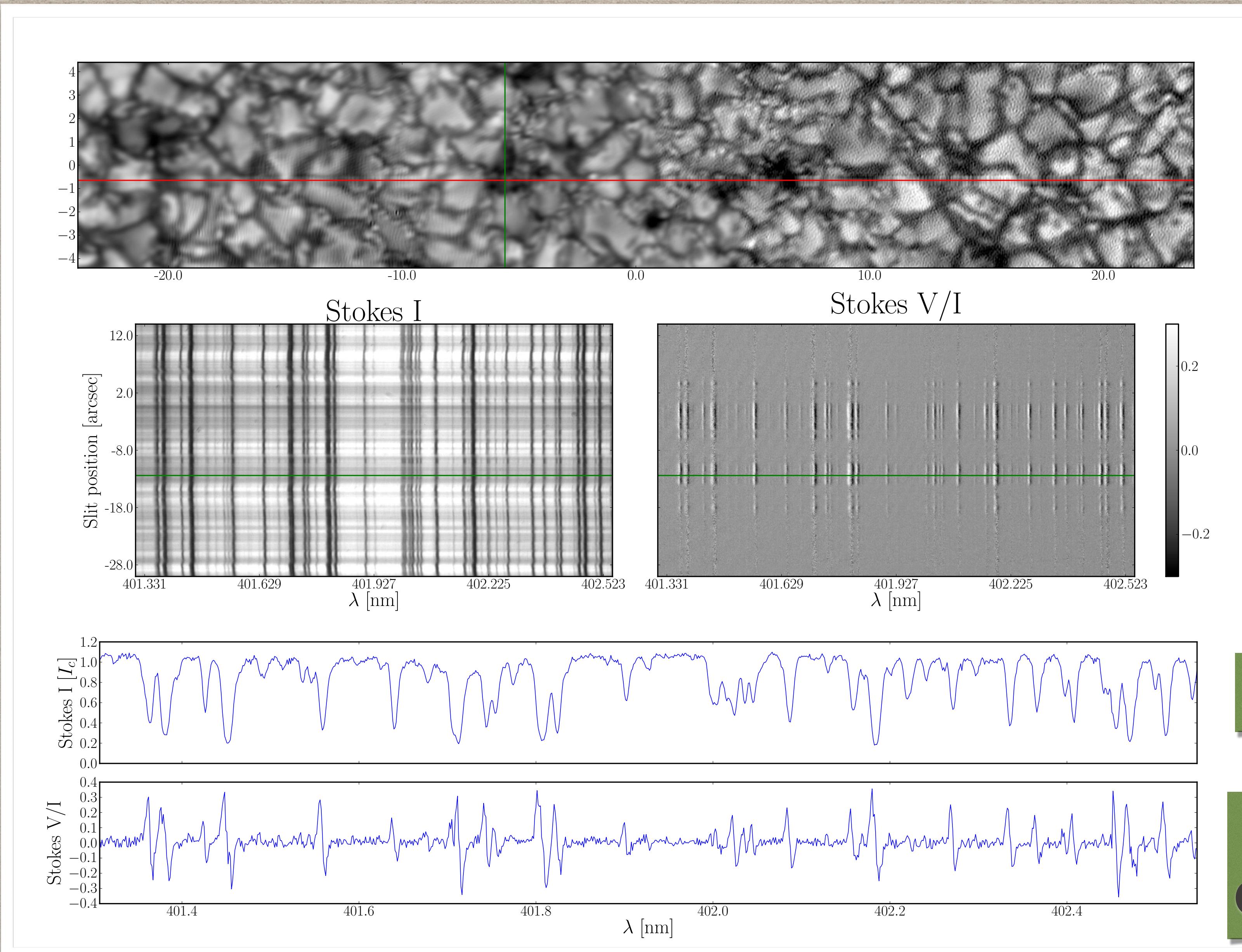
T. Berkefeld + KIS Team

Leibniz Institut für Sonnenphysik, Germany

CWS

LAUNCH DATE: JUNE 2021

MANY-LINE TEST OBSERVATIONS (SST/TRIPPEL, 2016)



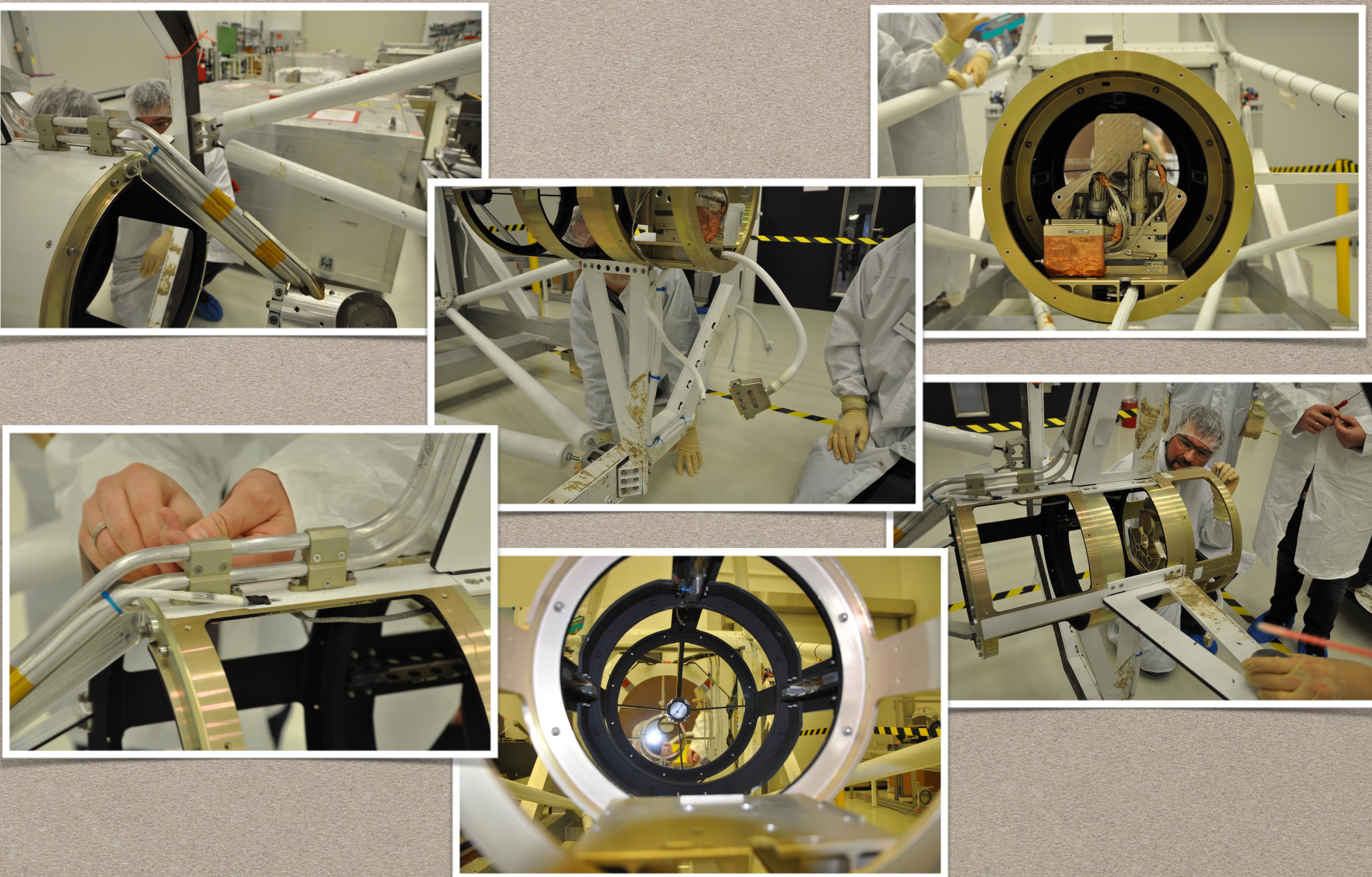
Intensity image

Spectrum: Intensity

Spectrum:
Circular Polarization

TELESCOPE

- Unmounted in January 2019
- All parts inspected
- M1 & M2 at SAGEM (France) for inspection
- Some parts / mechanisms need to be replaced; procurement in progress



SUNRISE 3 - POST FOCUS INSTRUMENTATION

Science instruments

- SUSI = SUNRISE UV Spectropolarimeter and Imager,
 $\lambda = 300 - 408$ nm
MPS + NAOJ
- SCIP = SUNRISE Chromospheric Infrared Spectro-
Polarimeter, $\lambda = 770$ nm, 850 nm
NAOJ + JAXA + Kyoto Univ. + IAA + MPS
- IMaX+ = upgraded Imaging Magnetograph
eXperiment
 $\lambda = 517, 525$ nm
INTA + IAA

Service units:

- ISLiD = Image Stabilization and Light Distribution
system
MPS
- CWS = Correlation tracker and Wavefront Sensor
KIS

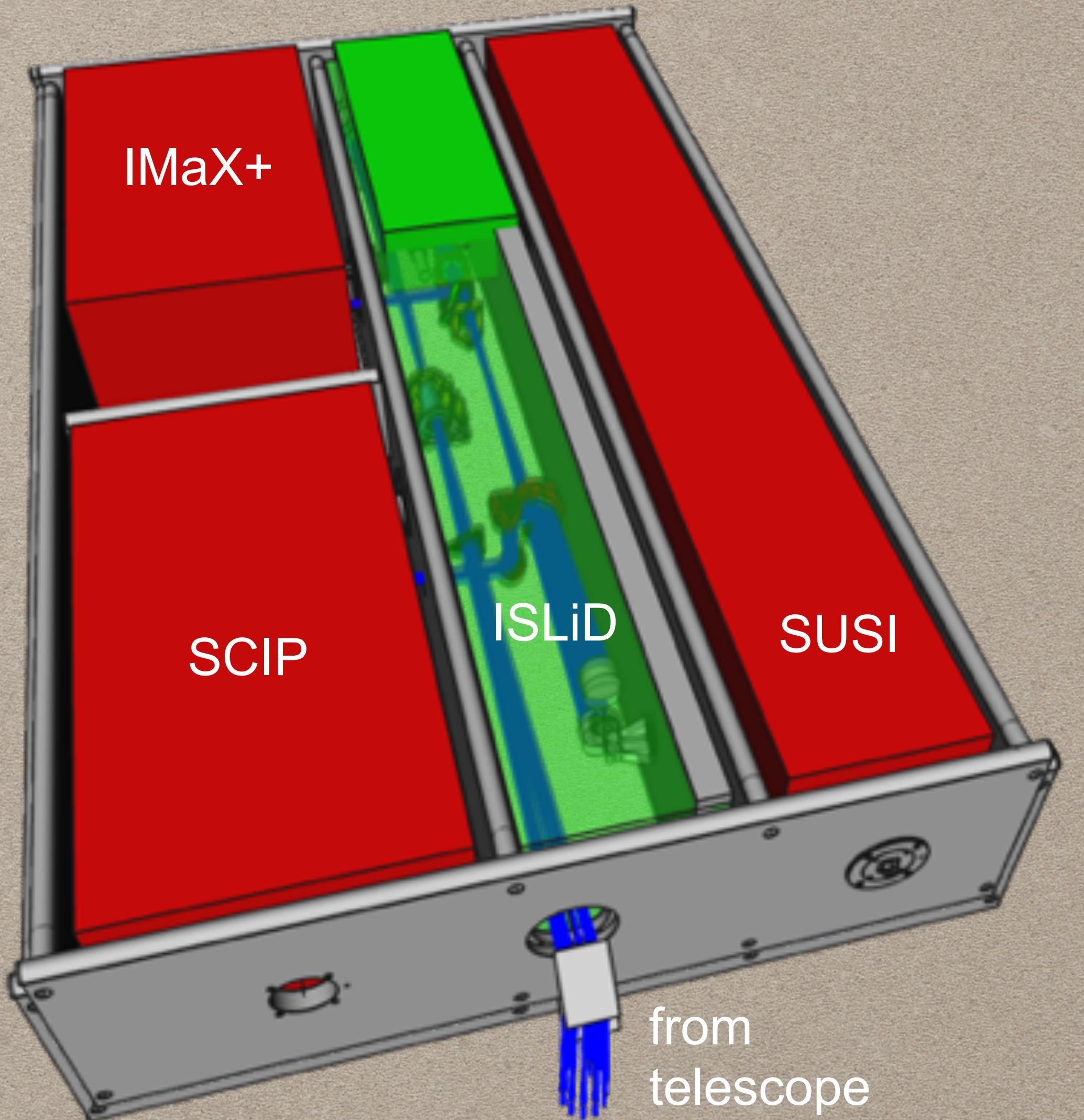
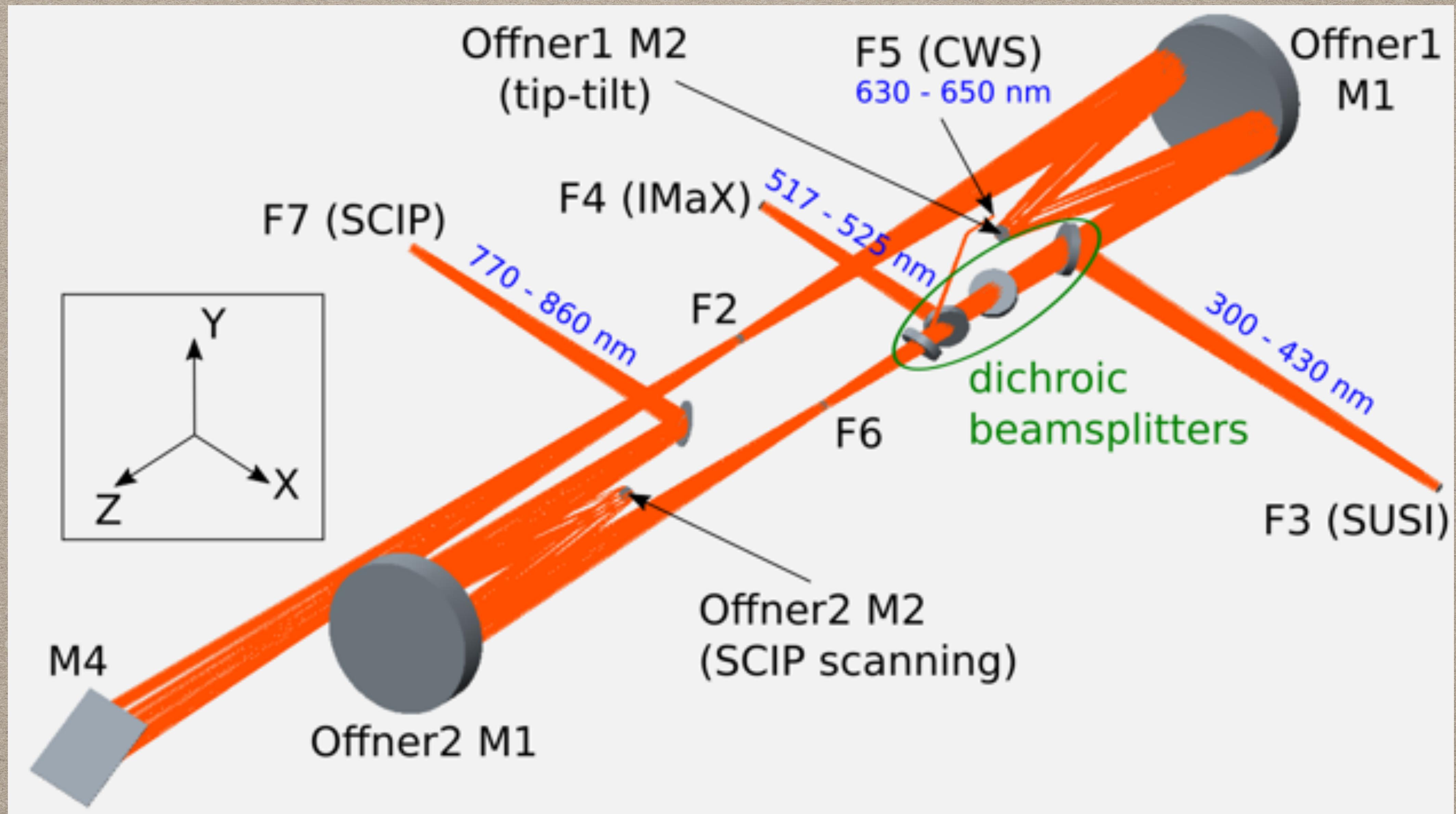


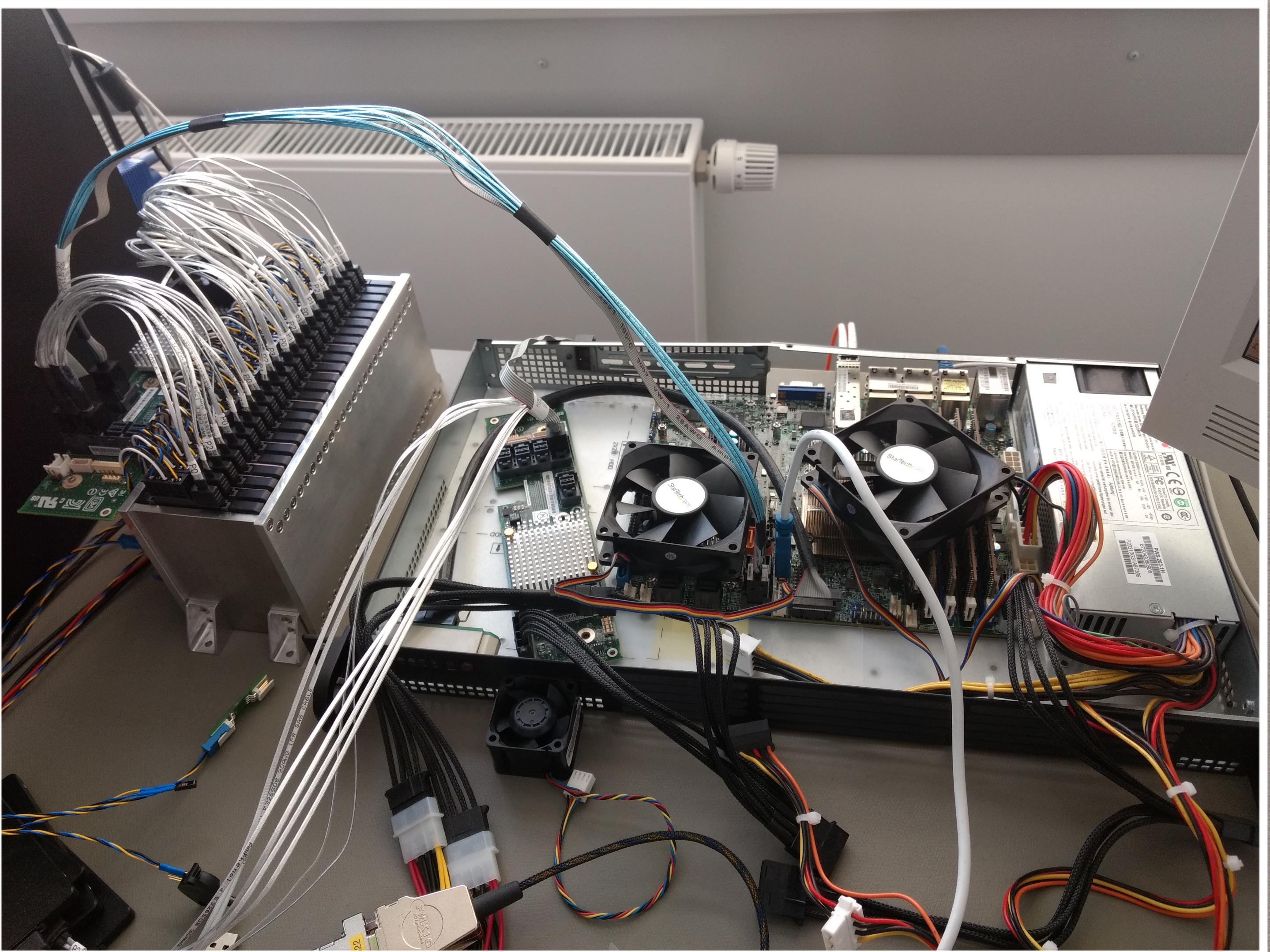
IMAGE STABILIZATION AND LIGHT DISTRIBUTION SYSTEM (ISLiD)



SUNRISE ICS (ICU + DSS)



Data Rate	700 MByte/s
Capacity	122 TByte
Power	171 W (including frame grabber, full load)
Mass	"keine Ahnung" (TR)



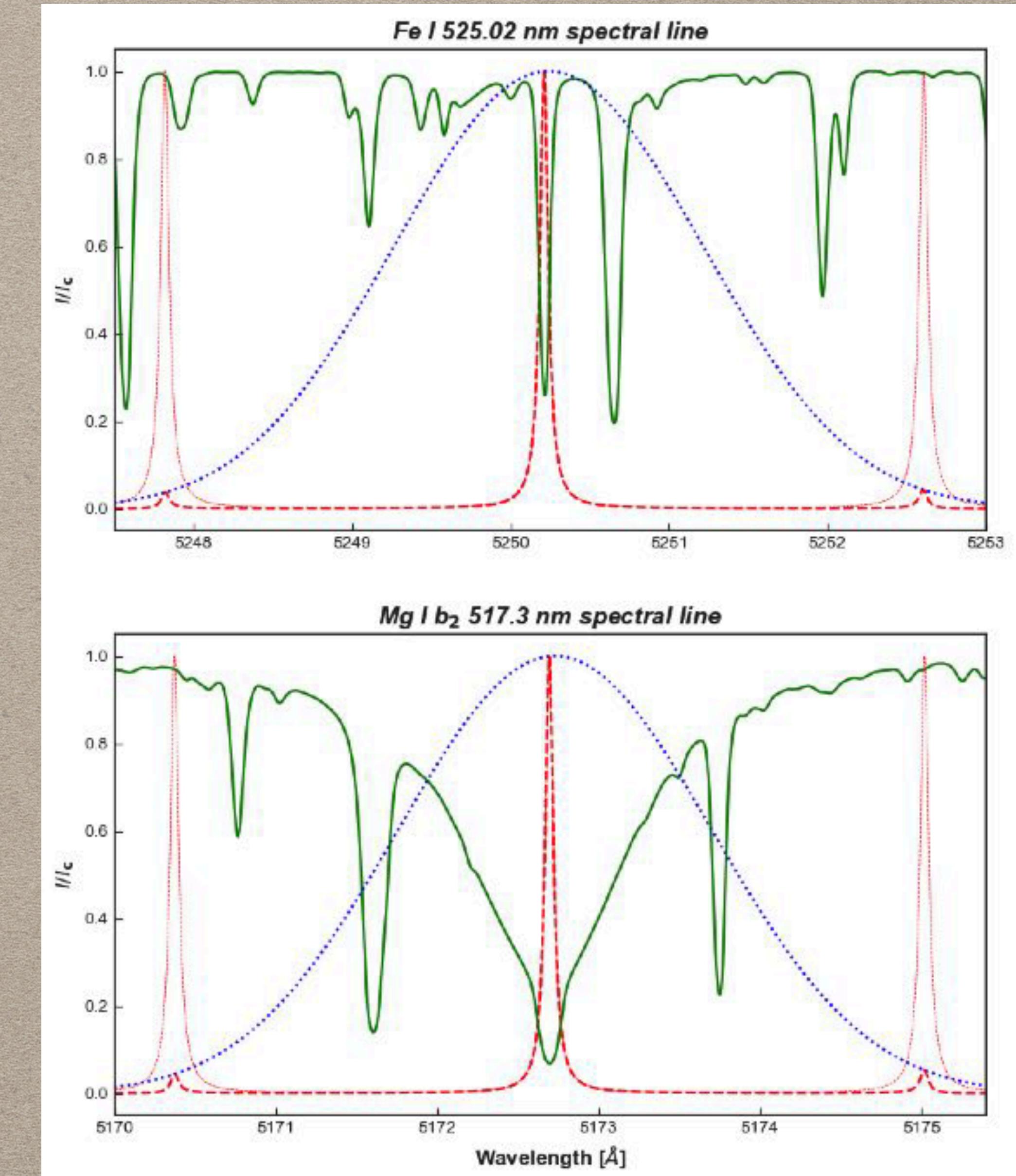
Bread board setup (office Tino)

Main scientific improvement:

- Tuning at several wavelengths
 - Prefilter wheel
 - LiNbO₃ Narrow-band prefilter
 - Liquid Crystal Variable Retarders

Technical improvements:

- Supression of image shifts
- Improve the mechanical design to obtain a stronger stiffness
- Astigmatism suppression
- Cameras change



SUNRISE-3 SCIENCE INSTRUMENTS: OVERVIEW

	SUSI	SCIP	IMaX+
Optical layout	<ul style="list-style-type: none"> • Grating spectrograph with slit-scan unit and slit-jaw imager • Dual-beam polarization modulation based on rotating waveplate 	Tunable grating	Fixed grating
Spectral windows	300 – 320 nm 340 – 408 nm	764.5 nm – 772.5 nm Lower photosphere Fe I, Si I	525.02 nm Photosphere Fe I
Some key spectral lines	Many-line diagnostics (>100 lines) within 2 nm spectral windows	Lower chromosphere K I	517.3 nm Temp. min. height (500 km) Mg I
Atmospheric height ranges	Photosphere Chromosphere (≤ 1300 km)	846.5 nm – 855 nm Photosphere Fe I Chromosphere (≤ 1500 km) Ca II	
Field of view	61" x (20 – 24) Å	58" x (61 – 83) Å	56" x 56"
Spatial / spectral sampling	0.03" x (9.9 – 11.9) mÅ	0.094" x (39 – 42) mÅ	0.055", 65 mÅ filter bandwith
Polarimetric accuracy	0.1%	0.03%	0.1%
Data rate	560 MB/s		
Data volume	160 TB (5 days, 50% duty cycle, incl. RAID overhead)		

MANY-LINE ANALYSIS WITH SUNRISE III

- MHD experiments with many-line inversions show:
 - MHD cube (QS - pores)
 - Strong polarization
 - Signals available through height strat. → perfect solution
 - Gain of information by possible
 - the use of many spectral lines
 - Synthesize spectrum
- Spectral range contains telescopic spectral resolution
- Highest & accuracy of T and v_LOS measurements in

Log(τ)	σ_{314_248} [G]	σ_{408_204} [G]	σ_{630_63} [G]	σ_{630_2} [G]
-2.5	240	65	65	130
-1.5	130	84	84	120
-0.8	89	42	49	110
0	130	95	106	1000

CHROMOSPHERIC 3D OBSERVATIONS WITH SCIP

