Lecture 8: Observational Astrophysics at SIU

Outline

1. Solar Physics
2. Exoplanetary Systems
3. Miscellaneous

Solar Physics

What makes the Sun Unique?

- Sun is the closest star
- Only star with well-resolved atmosphere
  - electromagnetic radiation
  - particle detection
- Only star with well-observed interior
  - helioseismology
  - neutrinos
- Only star of importance for life on Earth

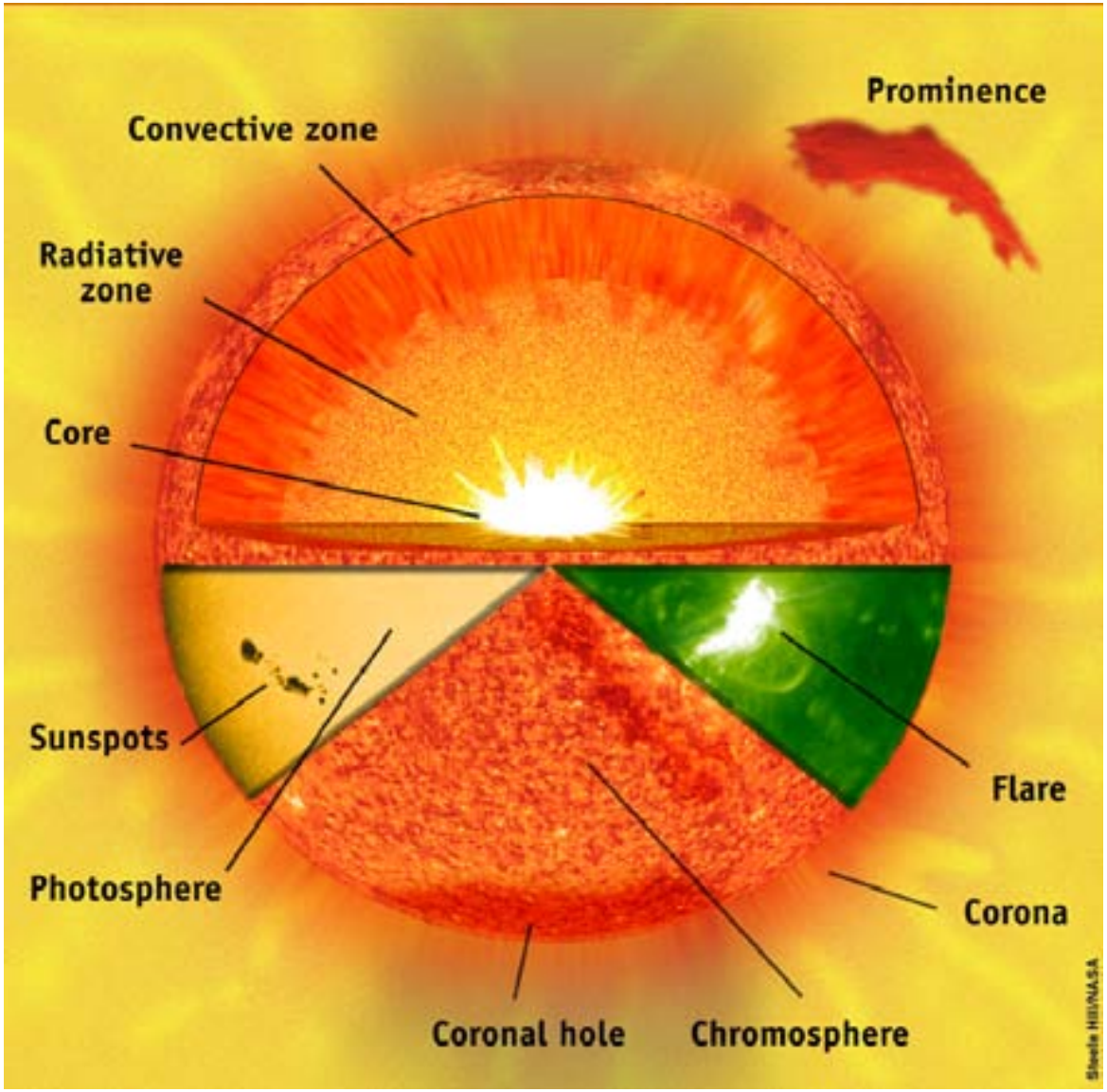
Solar Physics Research at SIU

Science Goal: Understand basic astrophysical processes that can be observed directly on the Sun by developing realistic numerical simulations, build novel instruments, obtain observations with the best telescopes and instruments and analyze them with innovative mothods to compare them to the simulations

People

- Tayeb Aiouaz, numerical simulations of upper atmosphere
- Helena Becher, scattering polarization instrumentation
- Felix Bettonvil, project manager solar telescopes, enclosures
- Catherine Fischer, solar data analysis, Stokes inversion
- Andrei Gorobets, numerical simulations of the solar atmosphere
- Rob Hammerschlag, solar telescopes, enclosures
- Aswin Jaegers, mechanical engineering
- Rob Rutten, radiative transfer in solar atmosphere
- Guus Sliepen, software engineer
- Frans Snik, instrumentation
- Nikola Vitas, radiative transfer in solar atmosphere
- Alexander Vögler, numerical radiative MHD simulations

Solar Structure and Terminology



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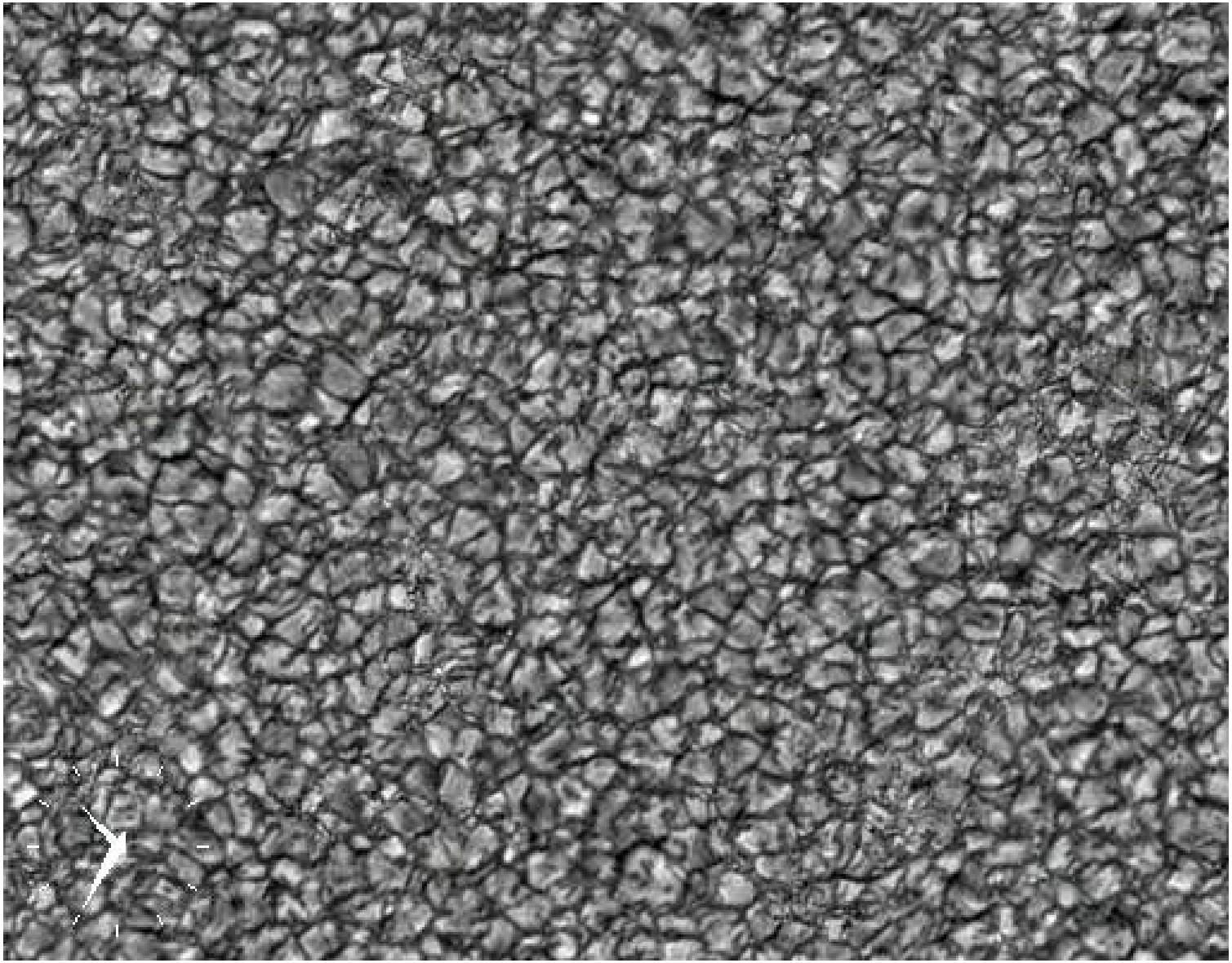
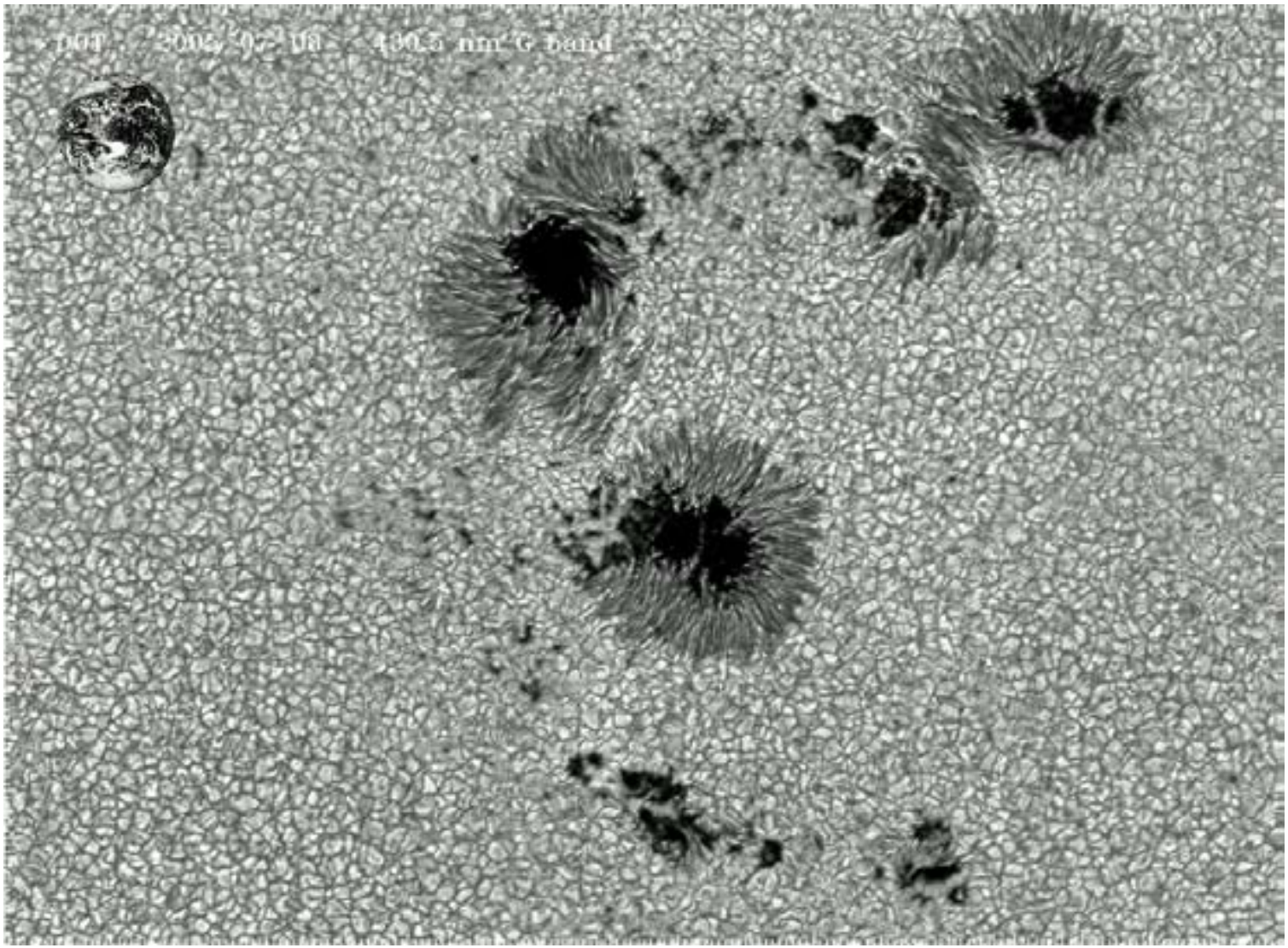
The Photosphere



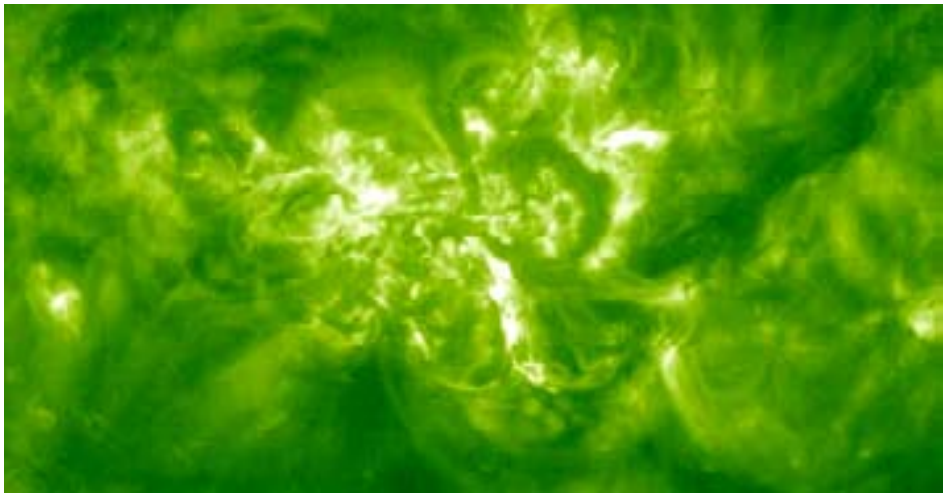
dotdb.phys.uu.nl/DOT/Data/2003_05_02

The Chromosphere



dot.astro.uu.nl/DOT_specials.html

Flares



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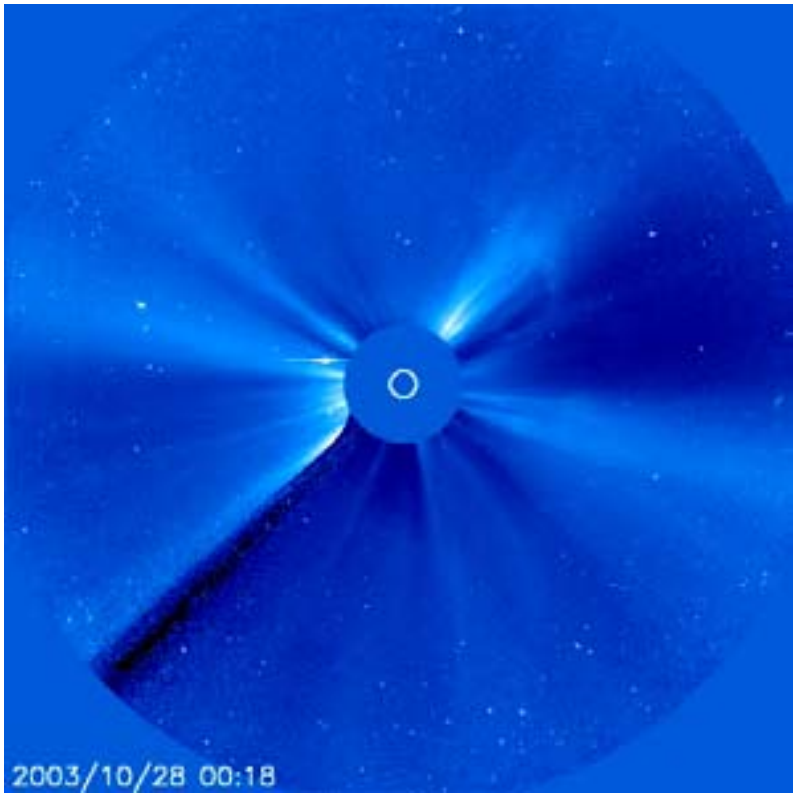
Coronal Mass Ejection



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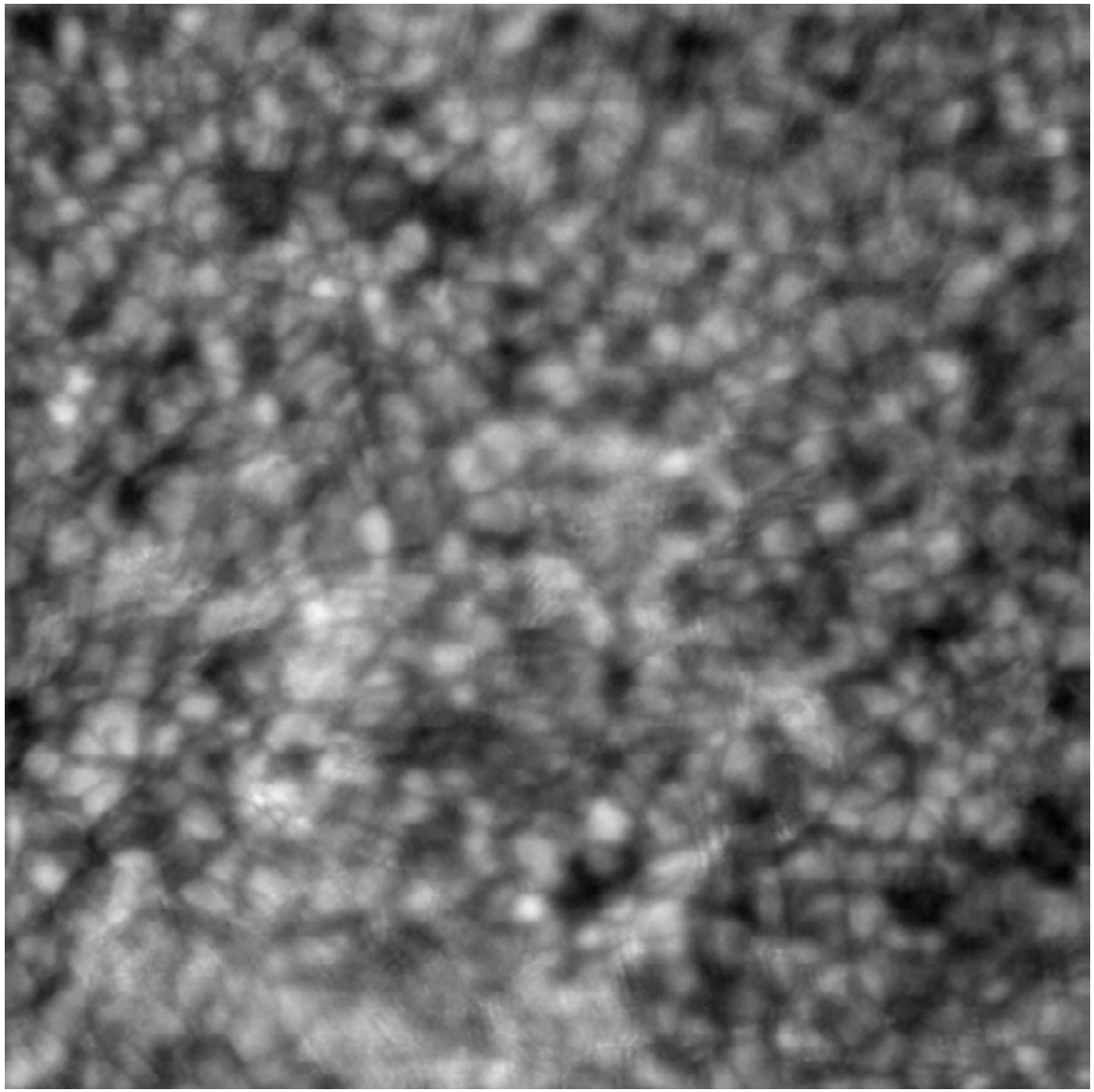
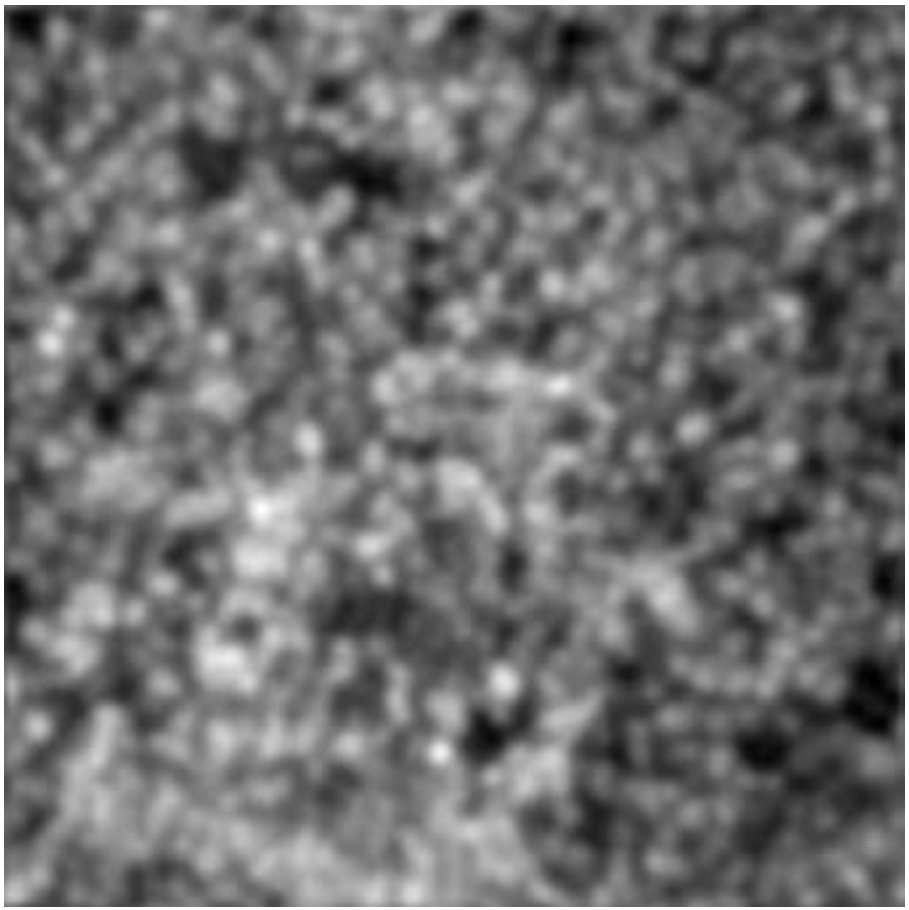
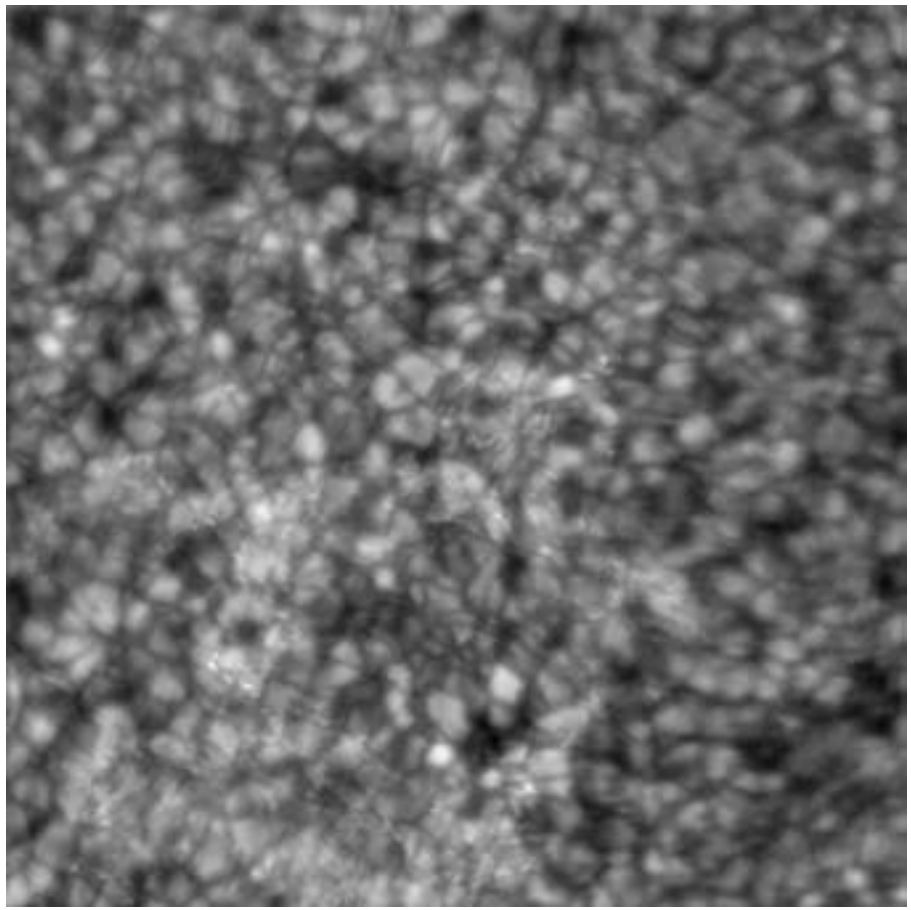
Seeing and Solar Granulation

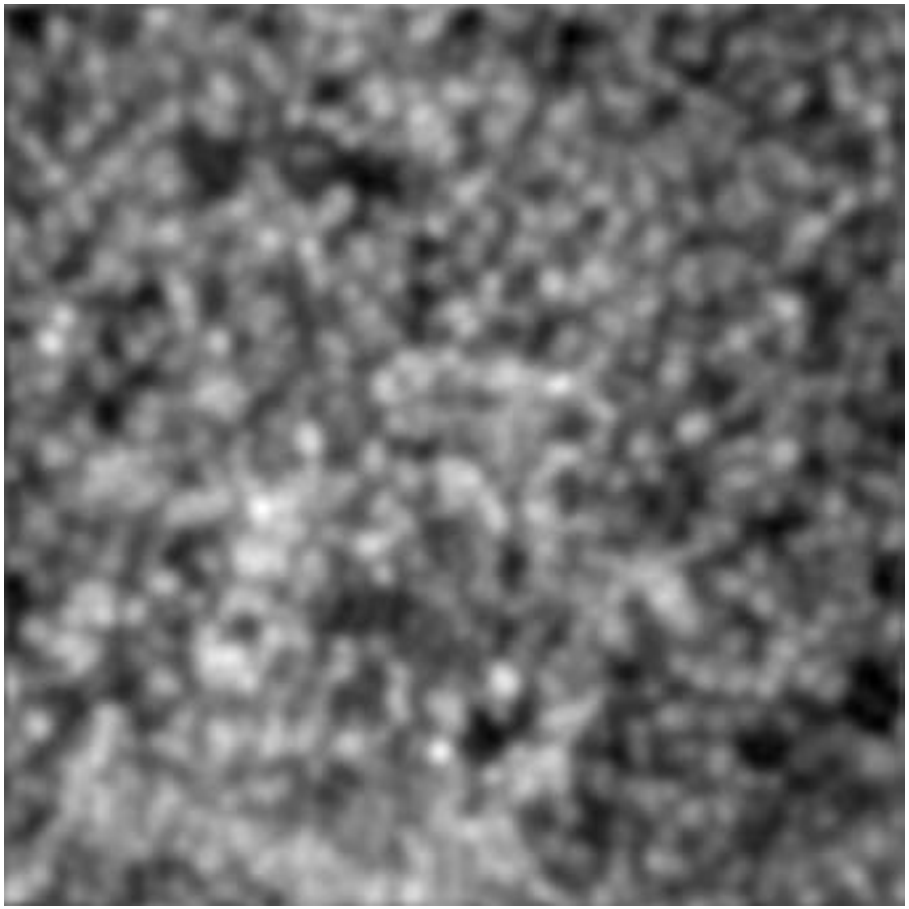


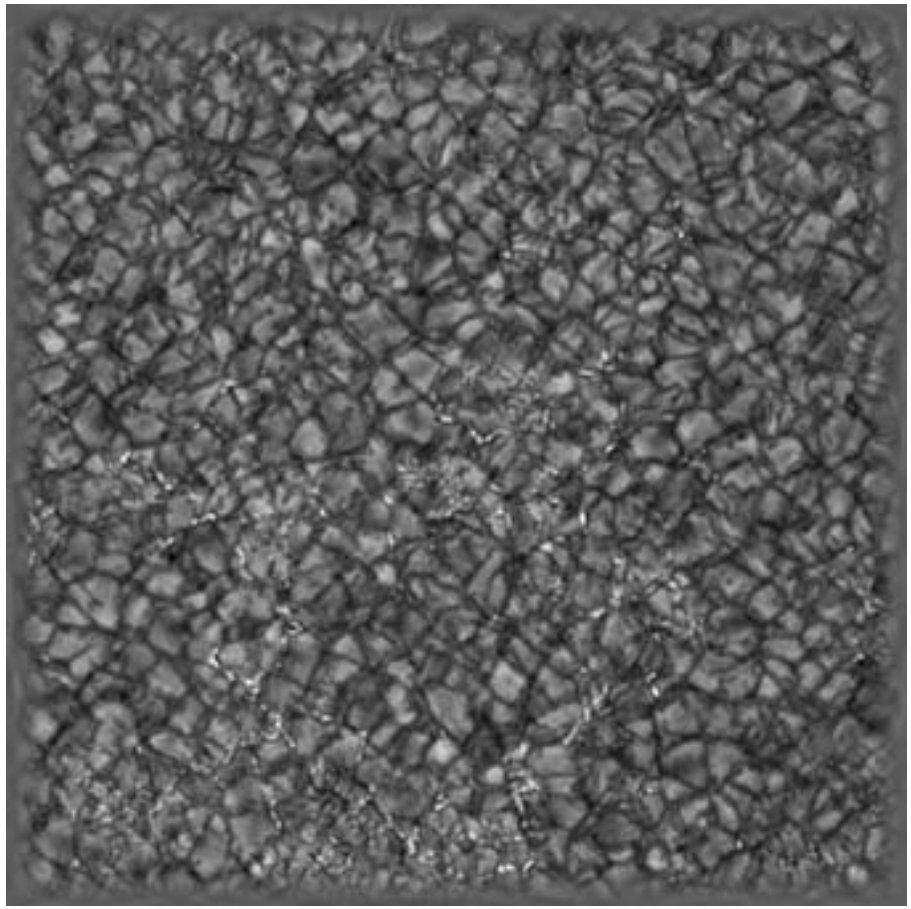
Average and Best Frame of Image Series





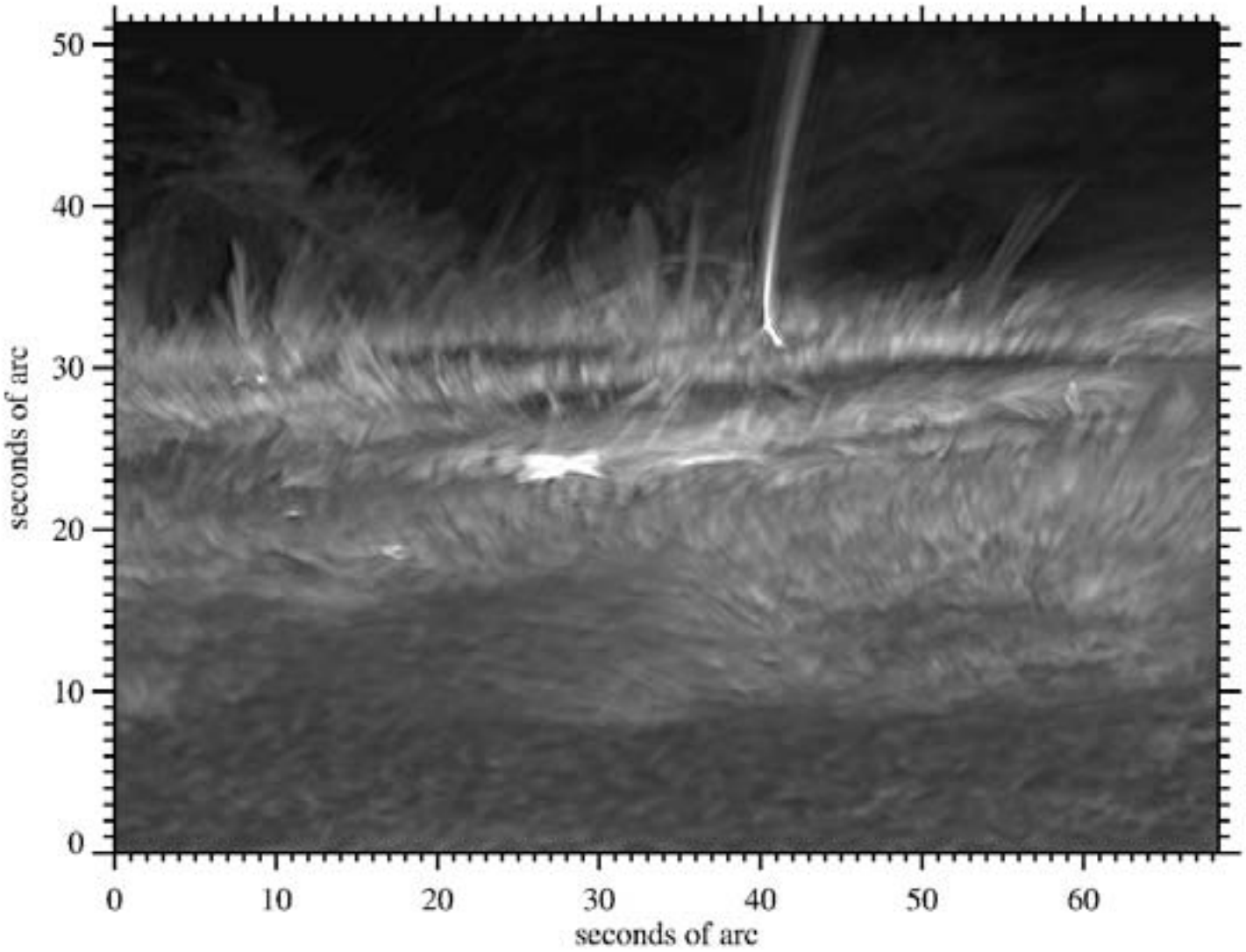
Average and Knox-Thompson Reconstruction



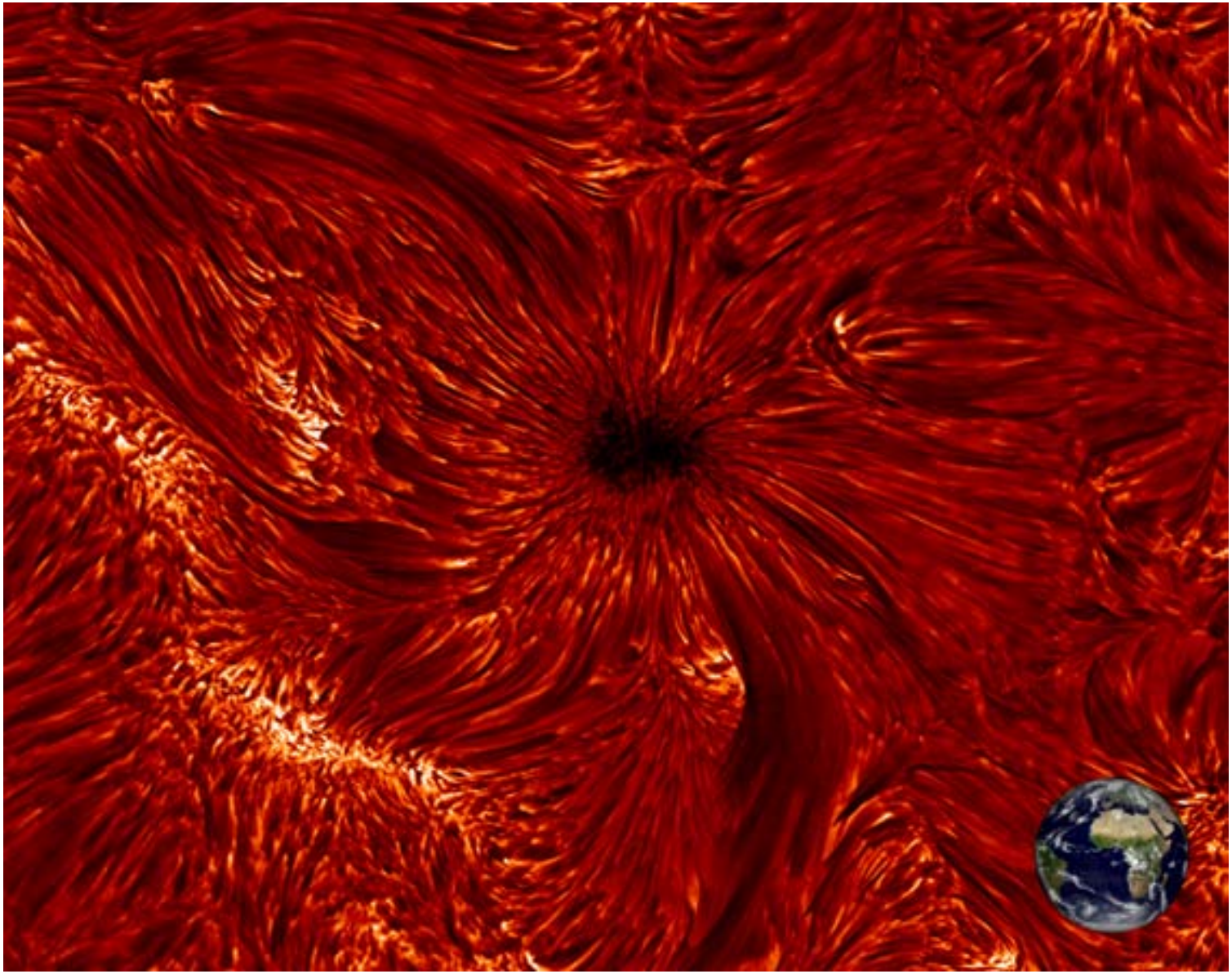


Dutch Open Telescope (DOT) at La Palma, Canary Islands

DOT CaII K Close to the Limb



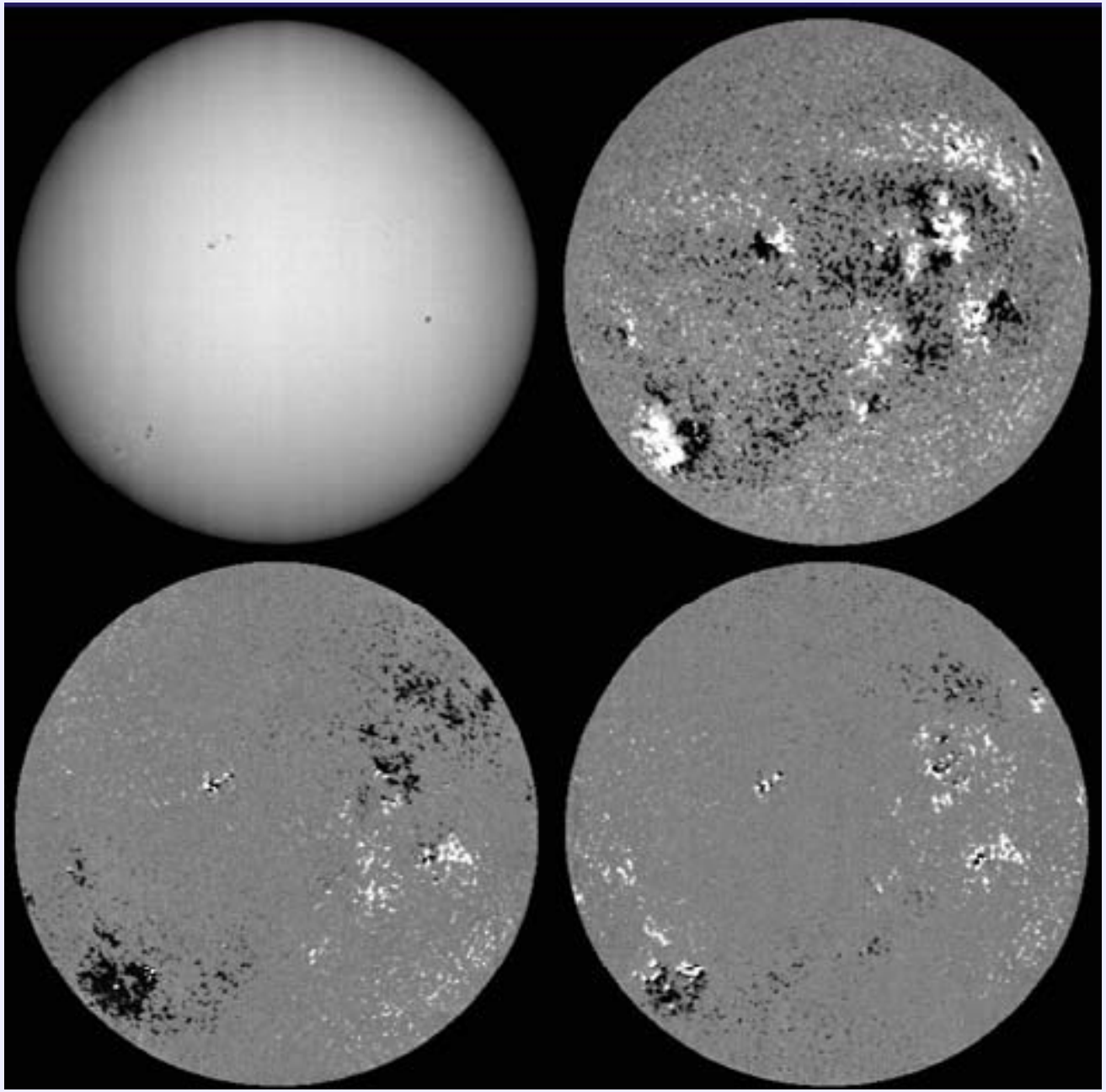
DOT Hα Image

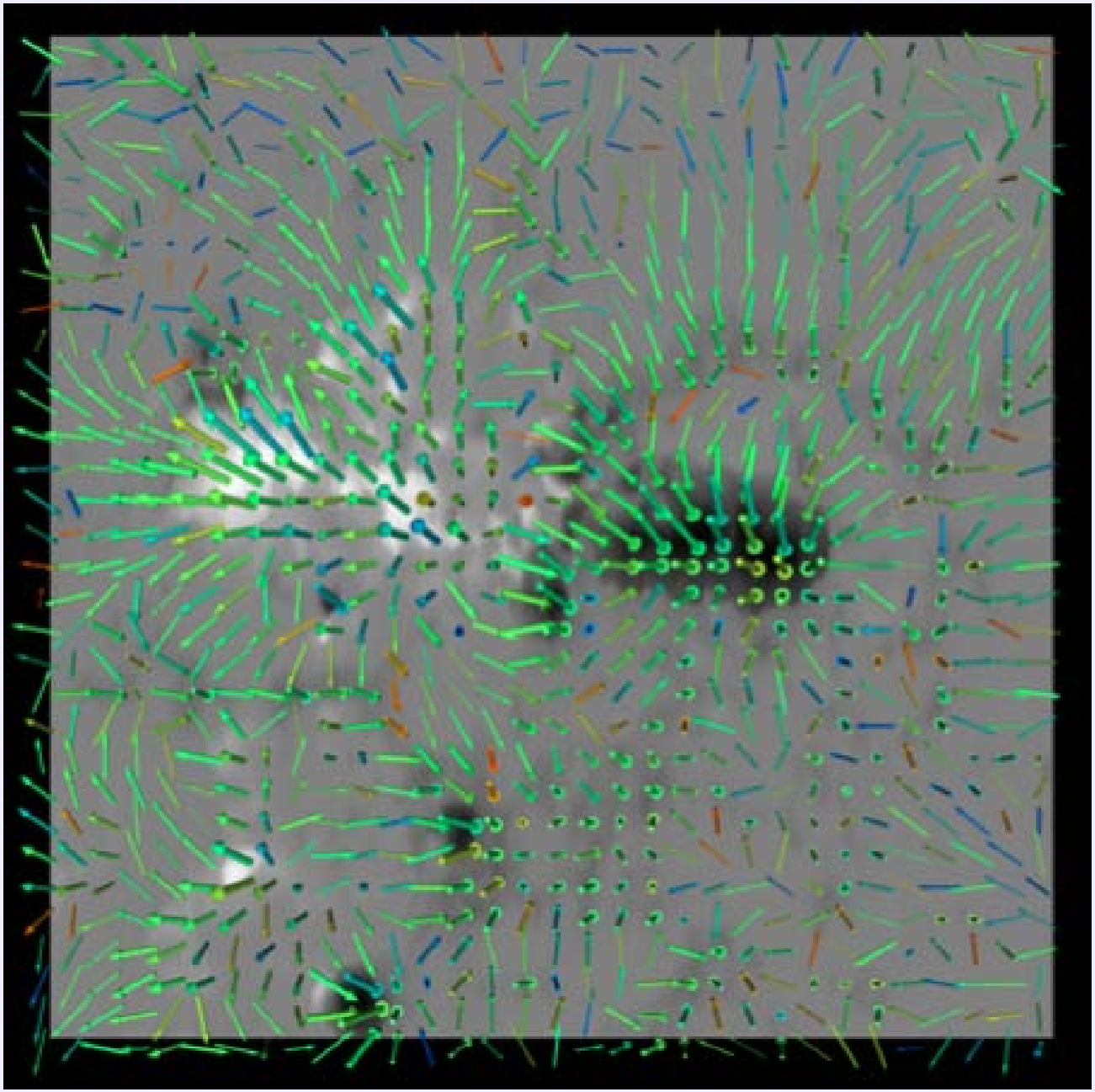


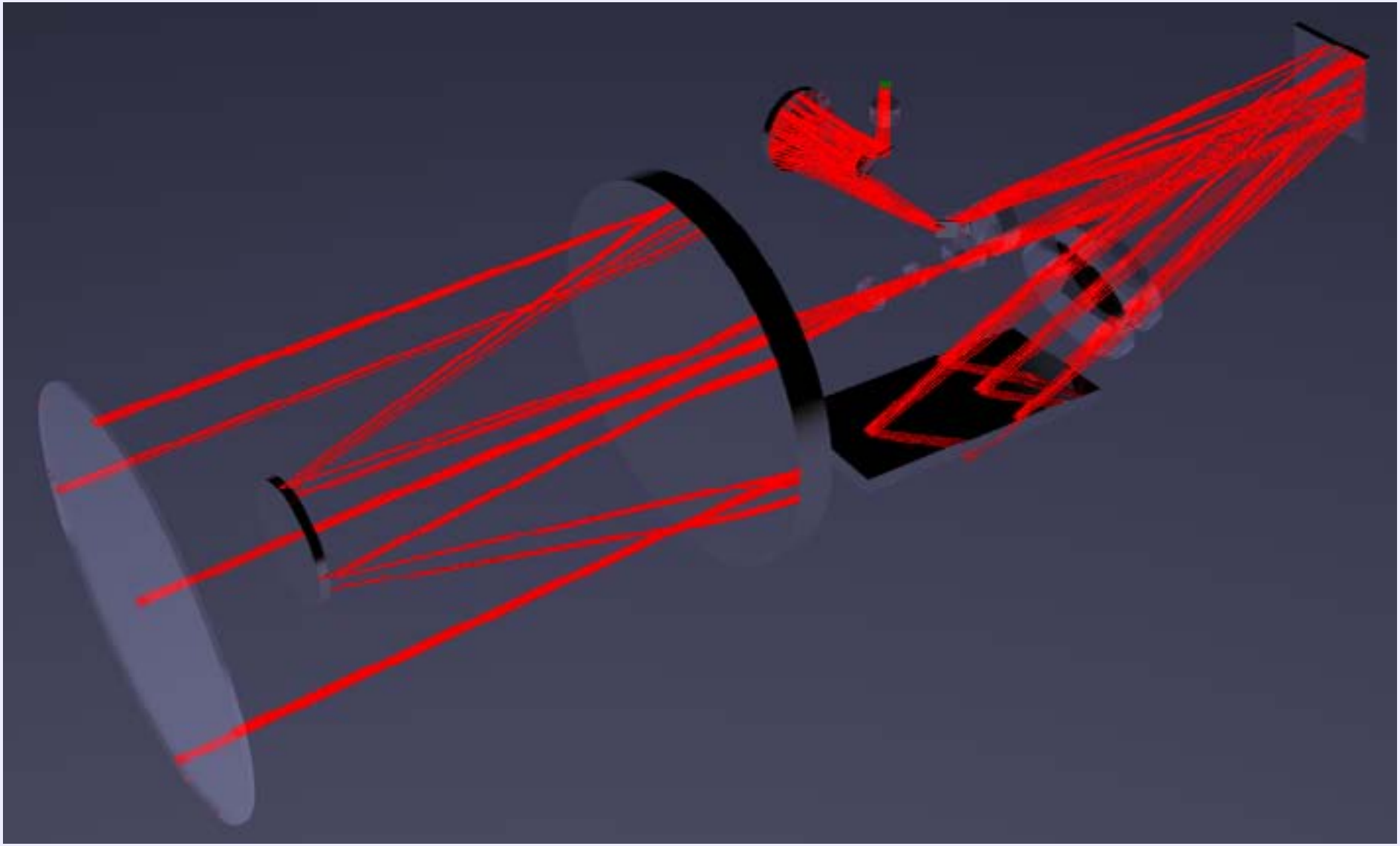
SOLIS Vector-SpectroMagnetograph (VSM)

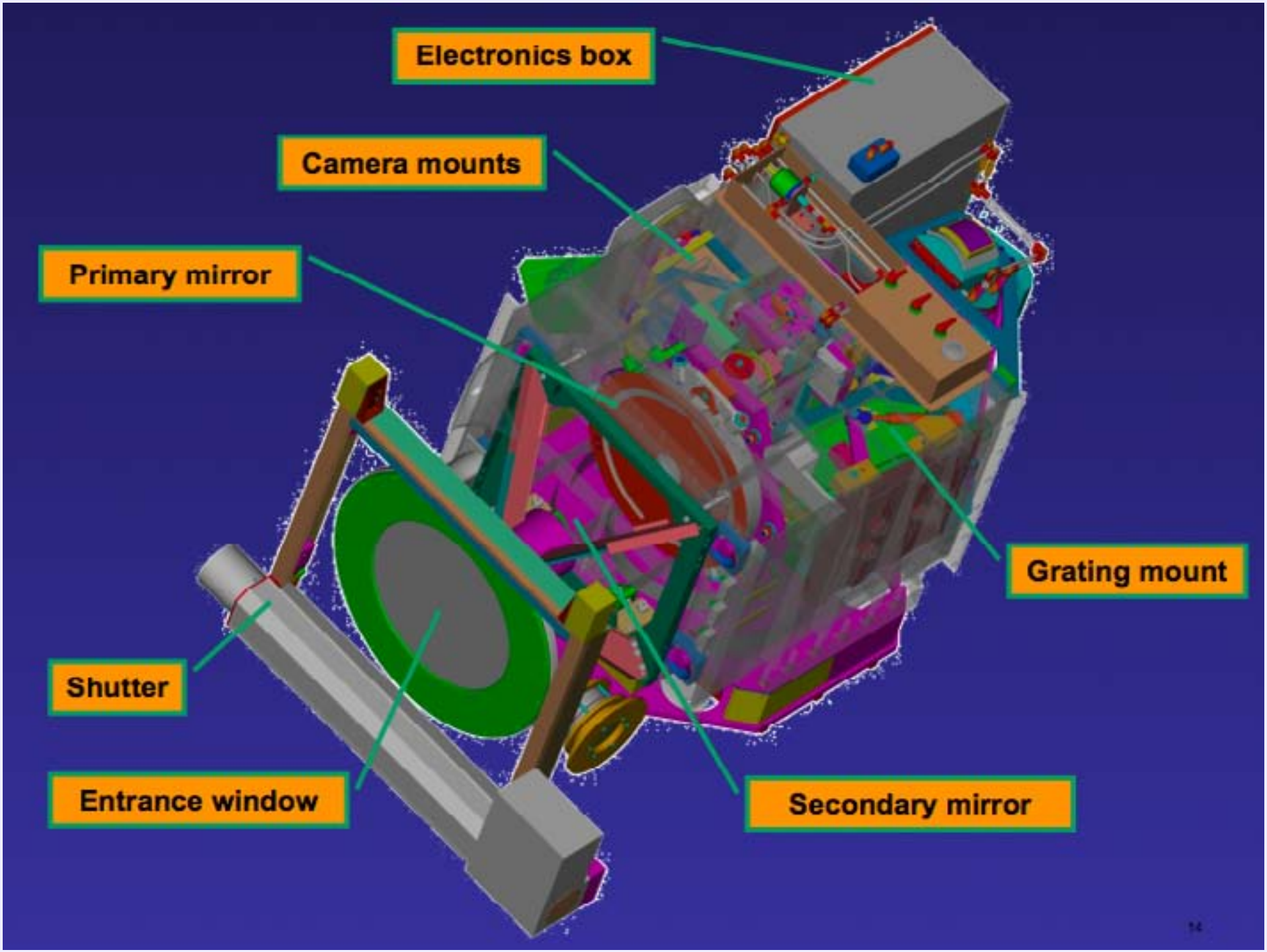
SOLIS VSM Capabilities

- located on Kitt Peak, Arizona, USA
- scanning full-disk, long-slit spectrograph
- ferro-electric liquid crystal polarization modulator
- high-speed CMOS Hybrid cameras running at 92 frames/s
- 4 different observing modes at 3 wavelengths:
  1. photospheric full-disk longitudinal magnetograms in FeI 630.15 and 630.25 nm
  2. photospheric full-disk vector-magnetograms in FeI 630.15 and FeI 630.25 nm
  3. chromospheric full-disk magnetograms in CaII 854.2 nm
  4. full-disk HeI 1083.0 nm line characteristics



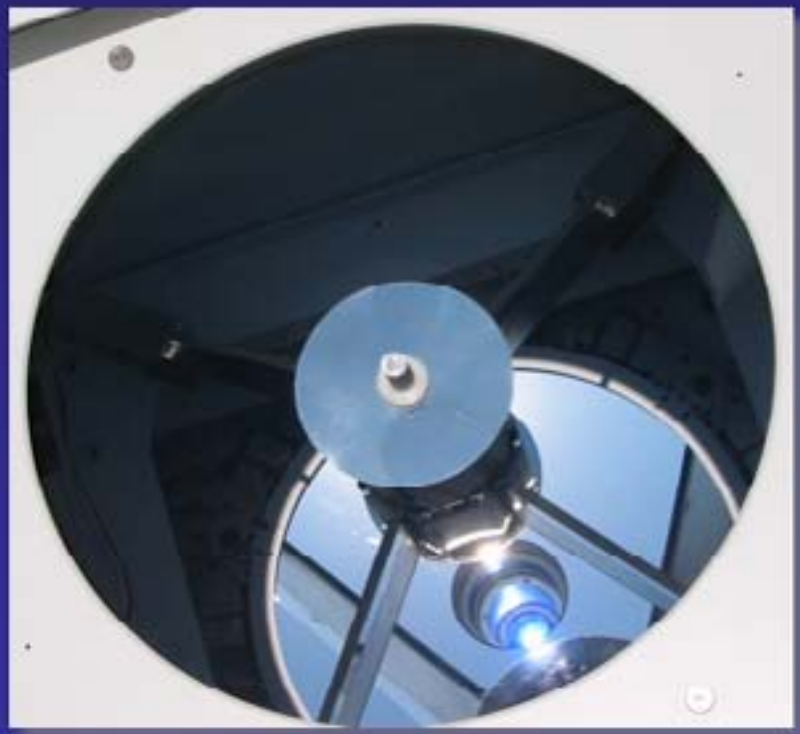





Electronics box
Camera mounts
Primary mirror
Grating mount
Shutter
Entrance window
Secondary mirror

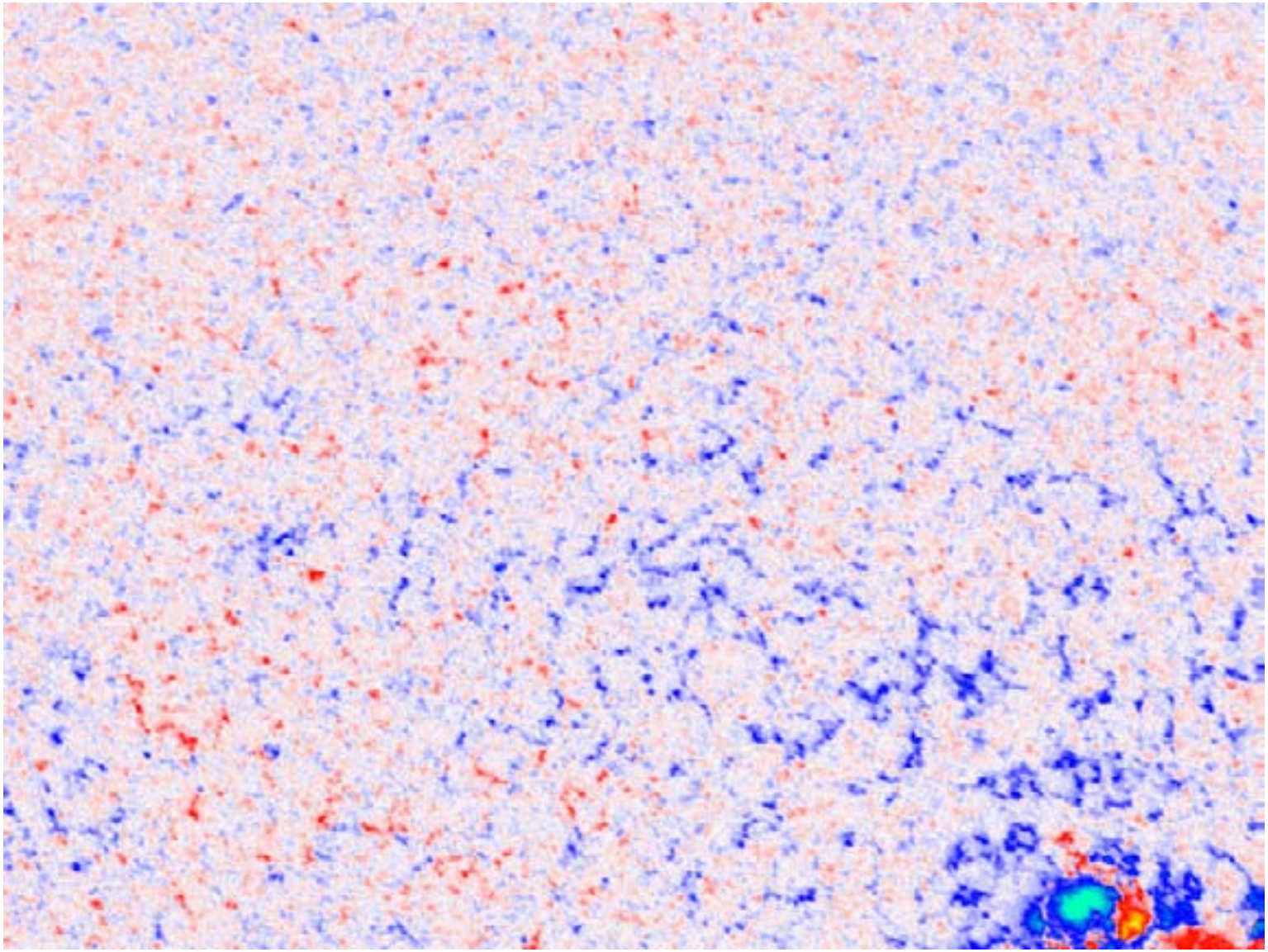
Telescope

- Helium-filled f/6.6 Ritchey-Chrétien with field corrector lenses
- Entrance window provides environmental protection
  - 6-mm thick oversized, fused silica to minimize edge effects
  - 'Floats' in RTV to minimize stress birefringence

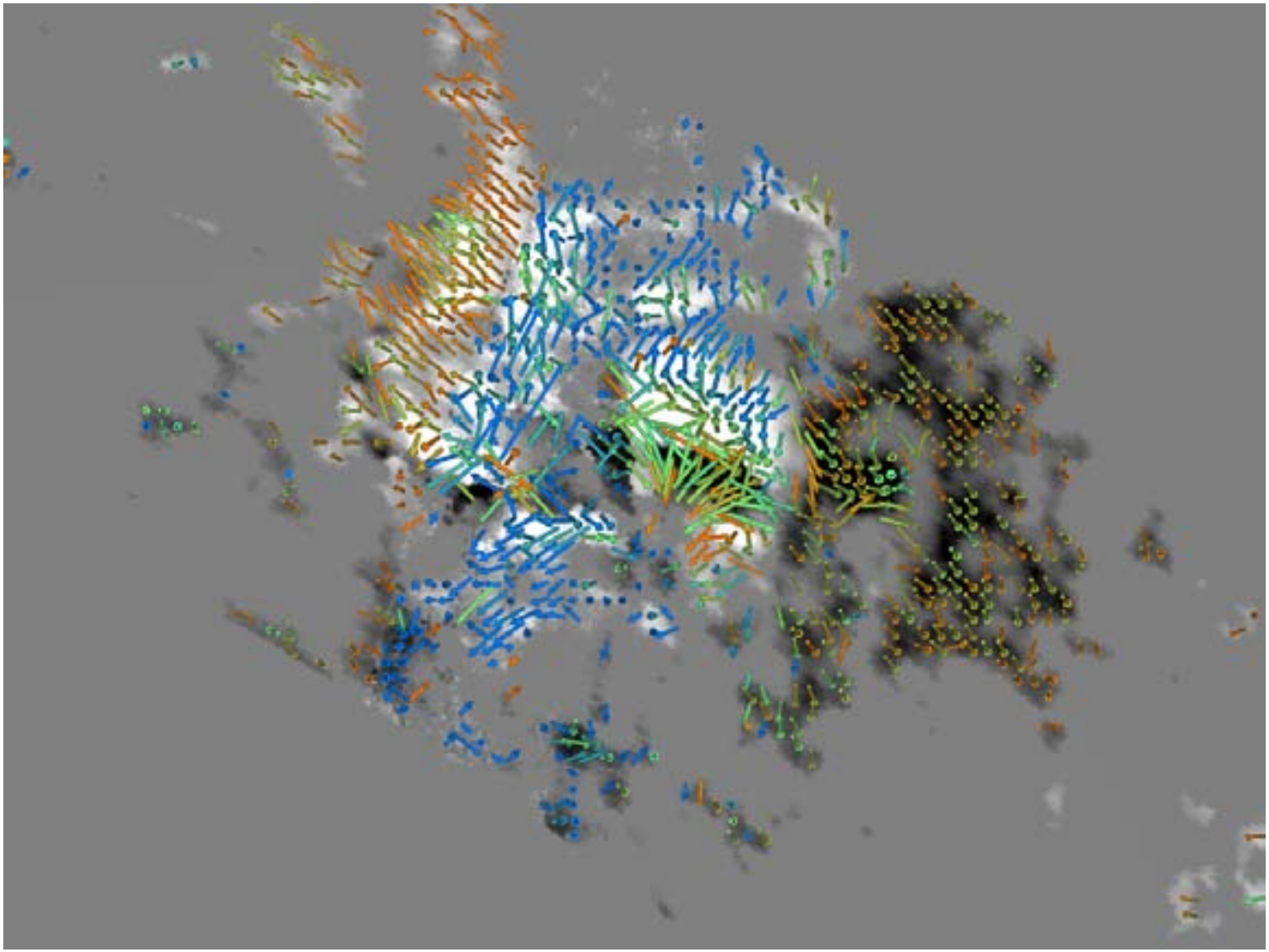


- 575-mm f/1.4 ULE primary mirror
- Single crystal silicon secondary
  - 40 Hz tip/tilt closed-loop bandwidth piezo platform
  - Slow closed-loop focus control
  - Cooled by helium flow

Magnetic Field Maps from Zeeman Effect Polarization



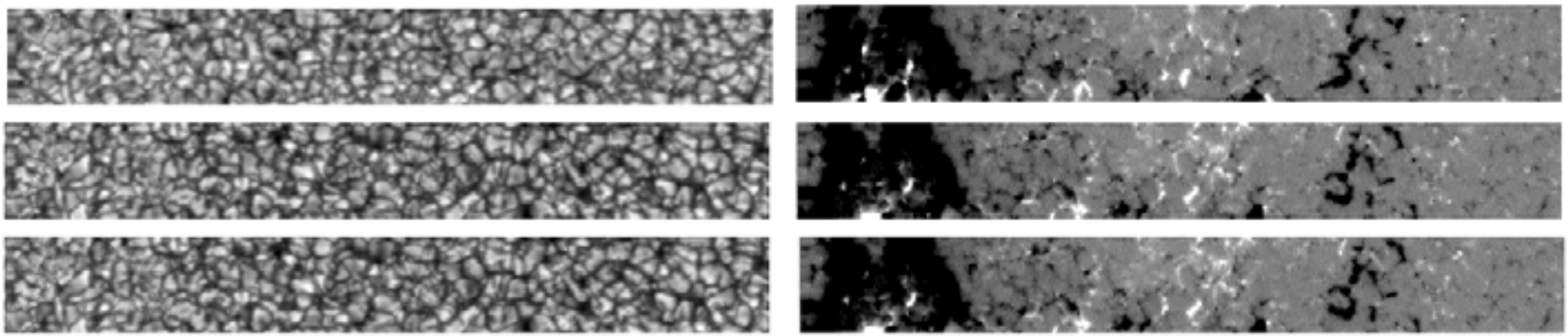
SOLIS VSM X-class Flare



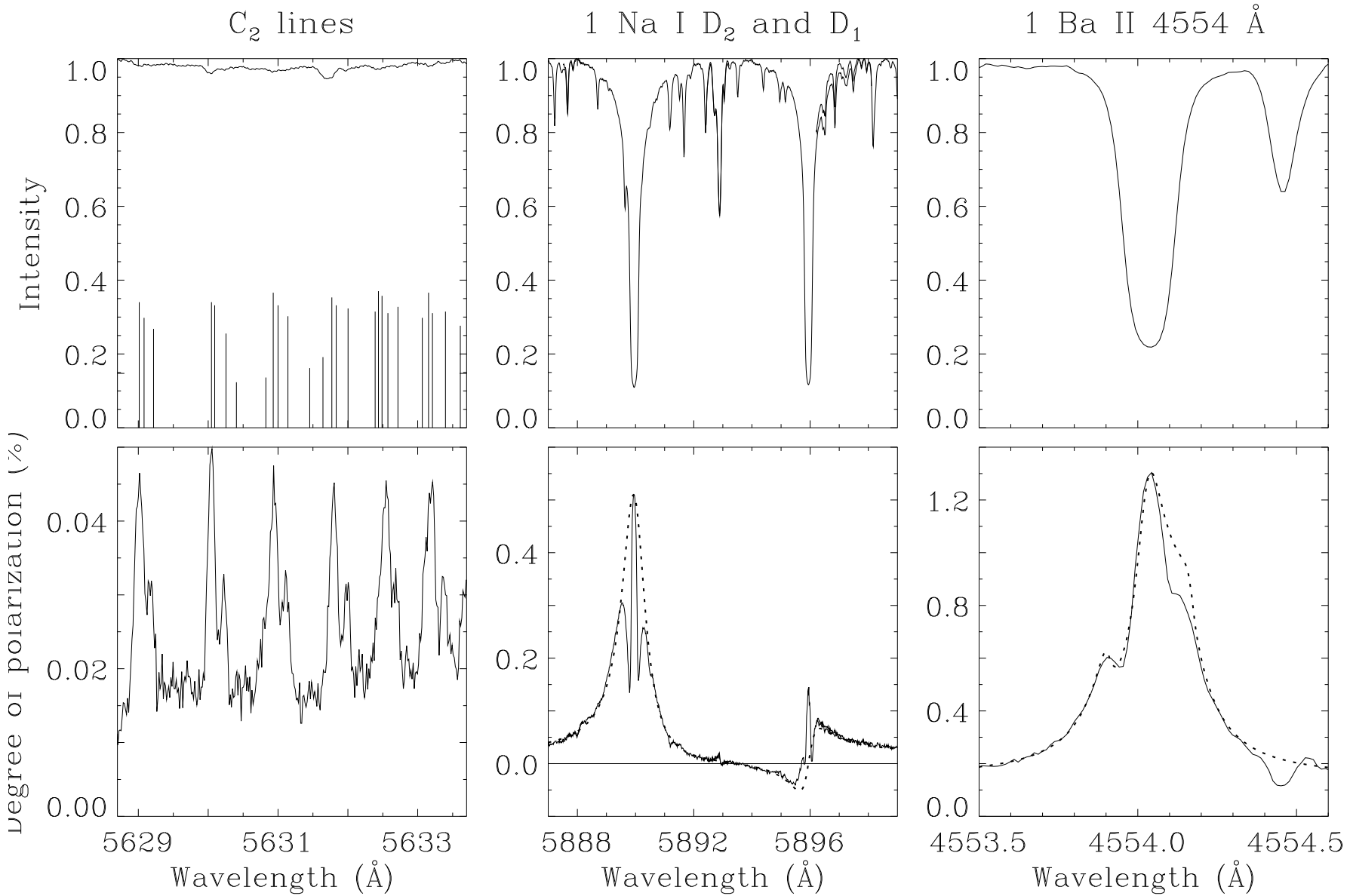
Temporal Evolution of Solar Magnetic Fields (C.Fischer)

- evolution of solar magnetic field leads to *Space Weather* with significant influence on life on Earth and in Earth-orbit
- existing instruments on the ground and in space measure Zeeman polarization in spectral lines
- radiative transfer modeling deduces magnetic field vector
- time variation of field vector to understand instabilities
- comparison with numerical realistic MHD simulations by A.Vögler

Hinode satellite High-Resolution Observations



Second Solar Spectrum from Scattering Polarization



Current Problems in Solar Physics

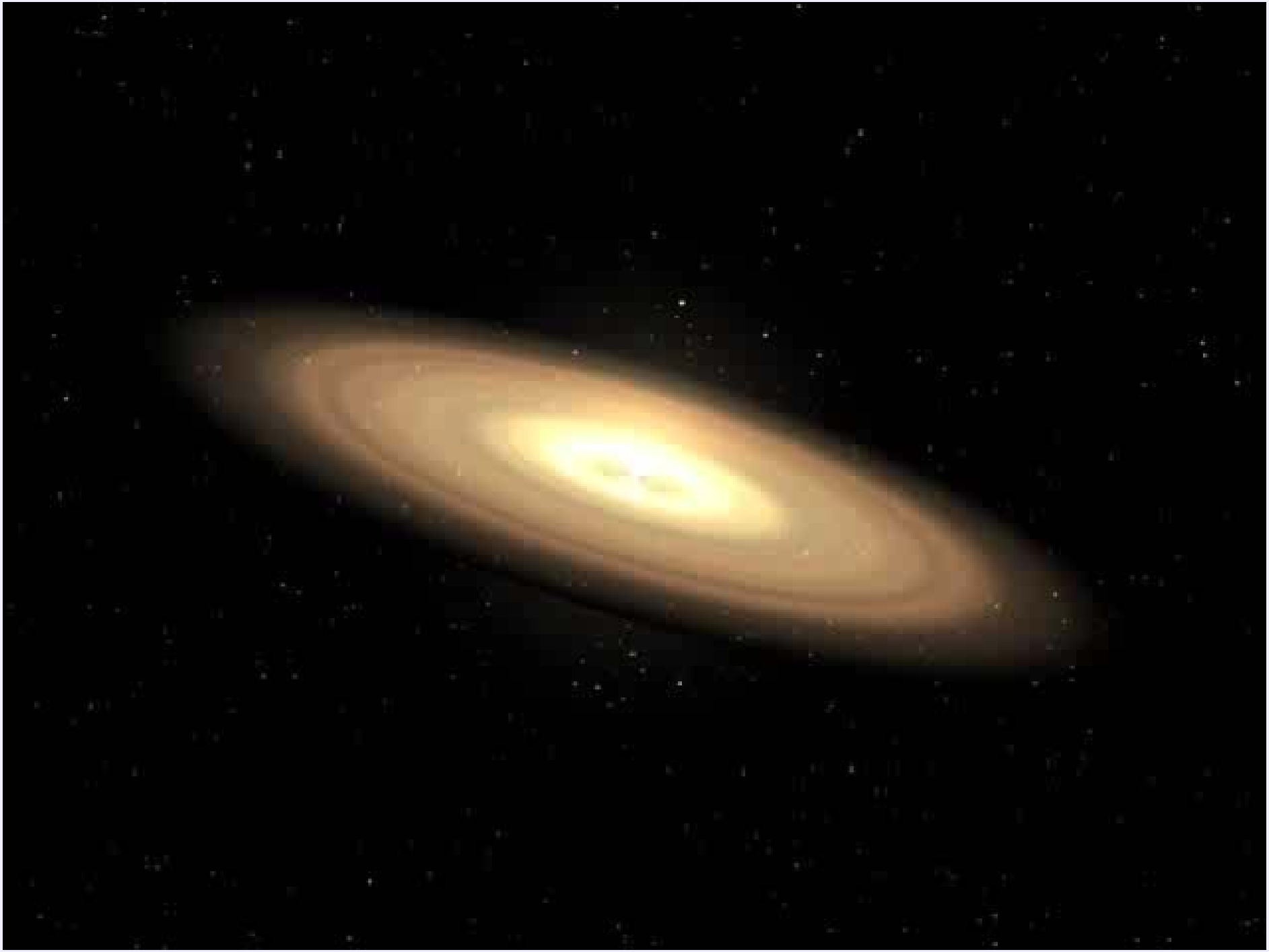
- **oxygen abundance**: numerical simulations imply metal abundances that are in disagreement with helioseismic frequencies
- **FIP-effect**: photospheric and solar wind abundances are not the same
- **origin of supergranulation**: physical mechanism
- **coronal heating process**: energy source, transport, dissipation mechanisms
- **solar wind accelleration**: physical mechanism
- **nature of flares**: source of magnetic energy, instability, forecasting
- **origin of solar cycle**: physics of the (large-scale) dynamo
- **origin of small-scale fields**: leftovers from sunspot cycle or small-scale dynamo in surface layers

Exoplanetary Systems Research at SIU

- Science Goal: Characterization of exoplanetary systems
- Development of imaging polarimeters:
  - ExPo for the William Herschel Telescope (La Palma)
  - SPHERE for the VLT (Chile)
  - EPICS for the E-ELT
- Development of innovative data reduction methods
- Development of numerical models to explain observations

People

- Sandra Jeffers, observations
- Michiel Rodenhuis, instrumentation
- Hector Canovas Cabrera, data analysis
- Frans Snik, polarimetry

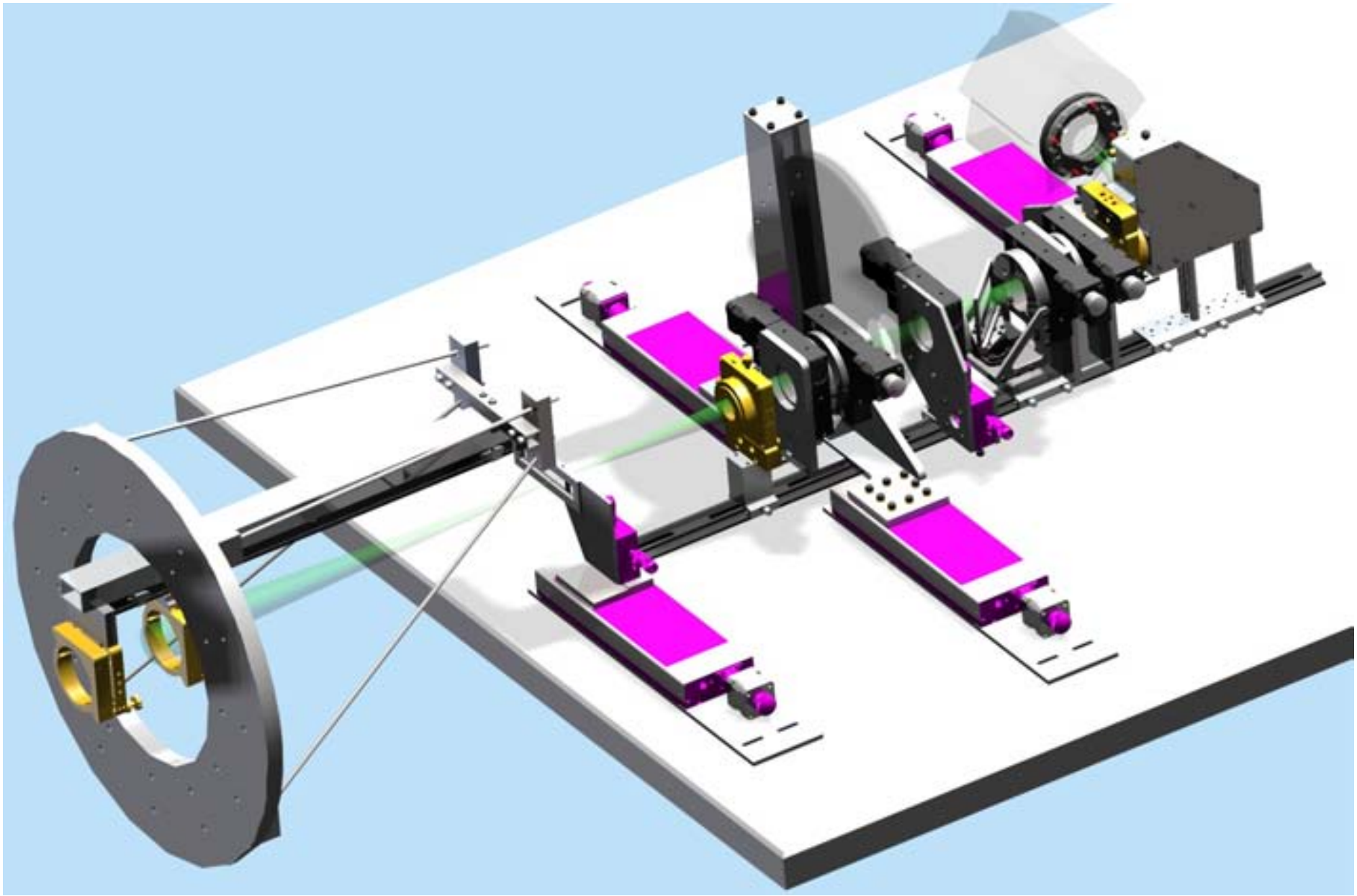


ExPo – the Extreme Polarimeter

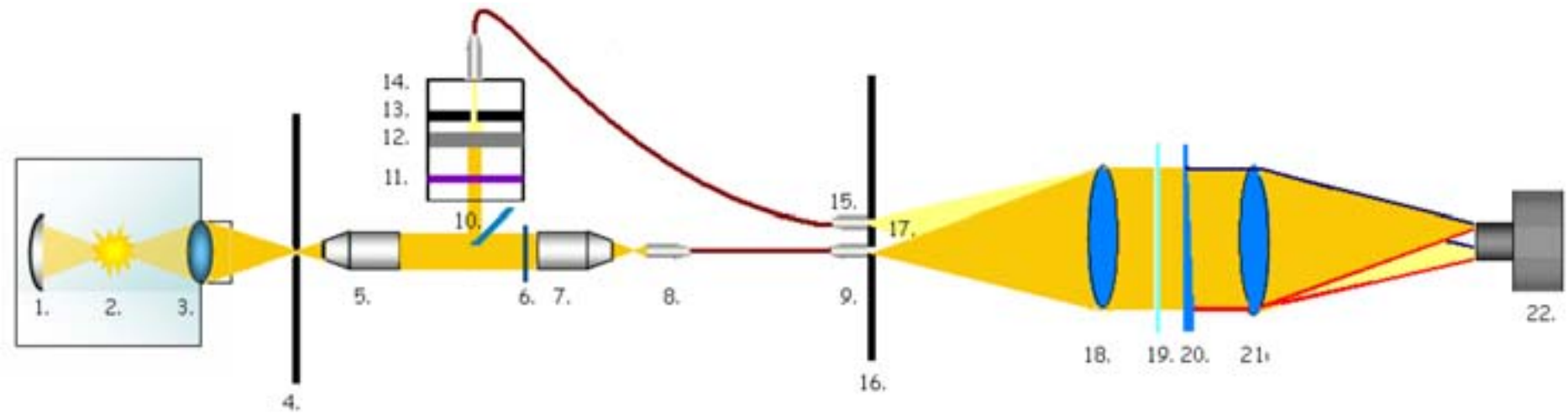
- Combination of 4 techniques
  - Polarimetry with 10^{-5} sensitivity
  - Optimum signal extraction
  - Coronagraph
  - Adaptive Optics
- Experimental imaging polarimeter
- Supported by NWO VICI grant
- Initially at 4.2-m William Herschel Telescope in La Palma
- Major new science results on circumstellar disks
- Potential to image exo-Jupiter
- Polarimetry pathfinder for VLT and ELT instruments

WHT

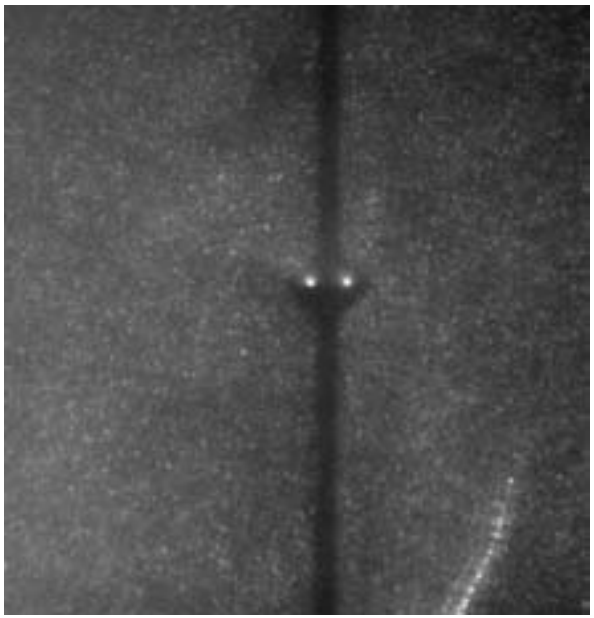
ExPo CAD Drawing



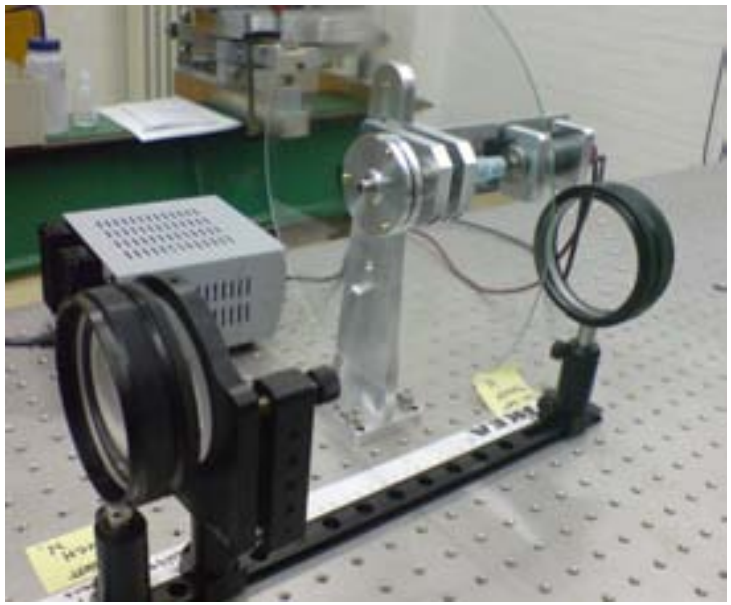
Laboratory Simulator Schematic



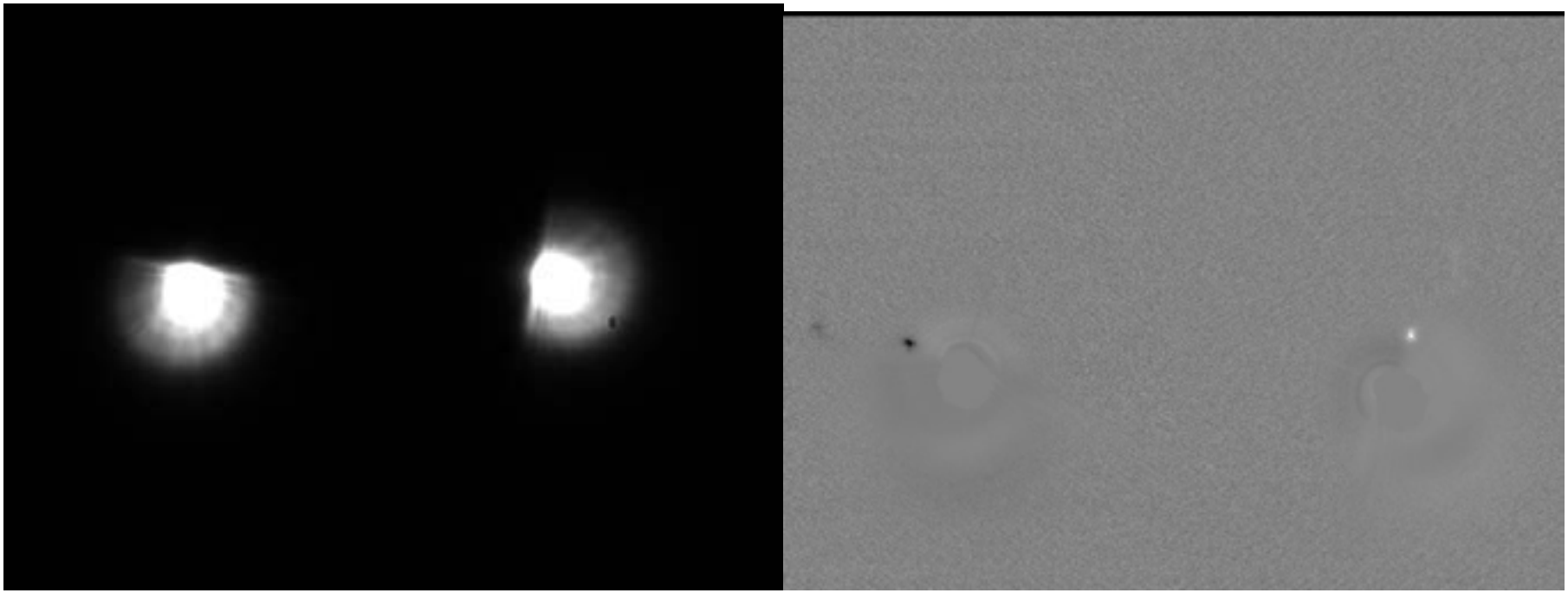
Fiber Head



Telescope Simulator



First Laboratory Results



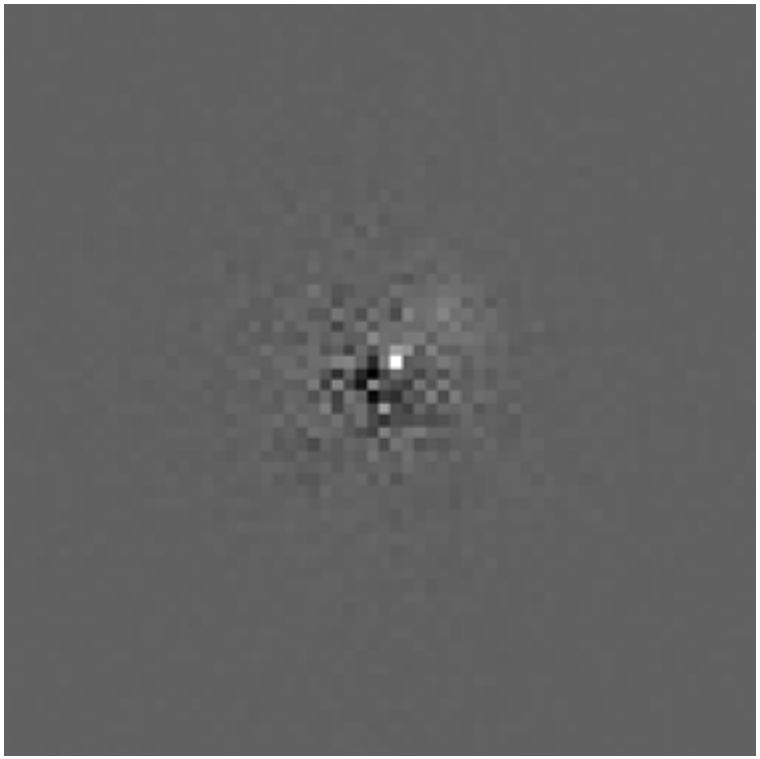
ExPo Status

- built laboratory simulator
- first results from prototype setup in 2007
- first observing run at WHT 6-17 October 2008

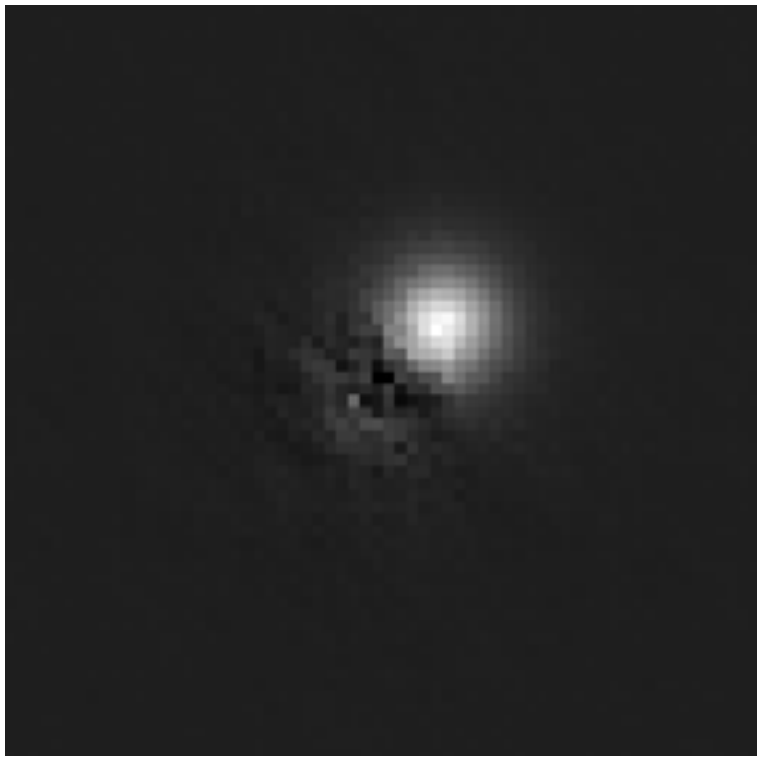
Average Cross-correlation of Intensity and Polarization

- determines position, strength of polarization in optimum way
- polarization signal-to-noise ratio is amplified by square root of signal-to-noise ratio in intensity

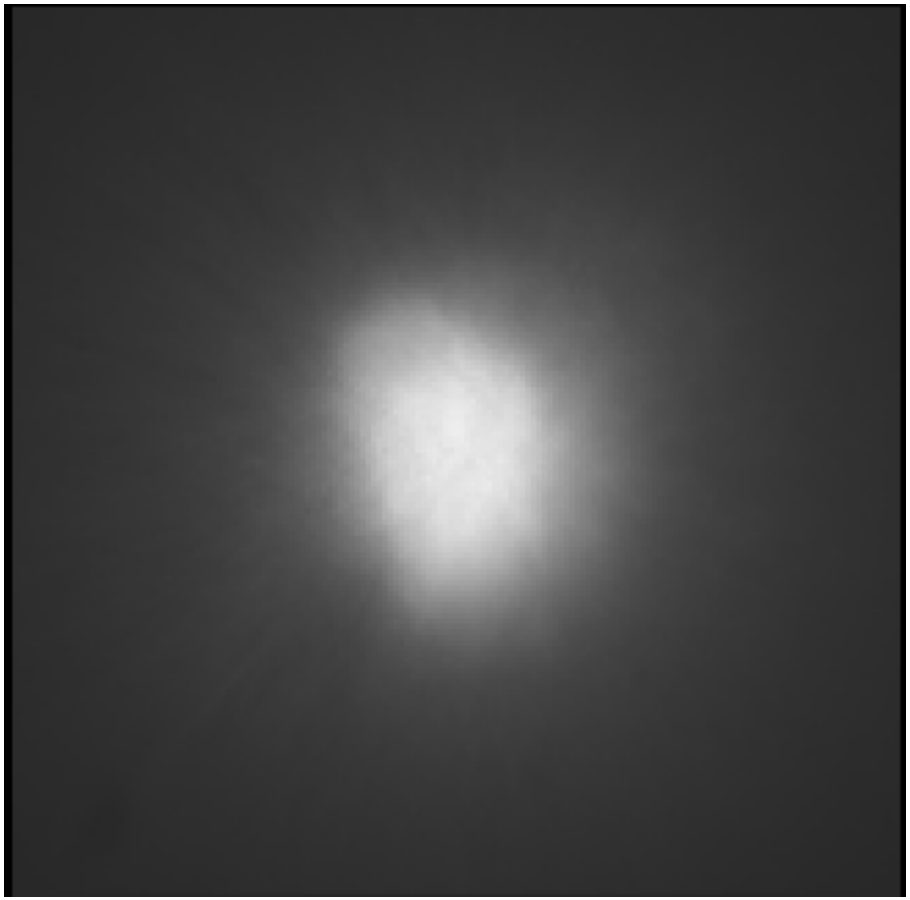
polarization



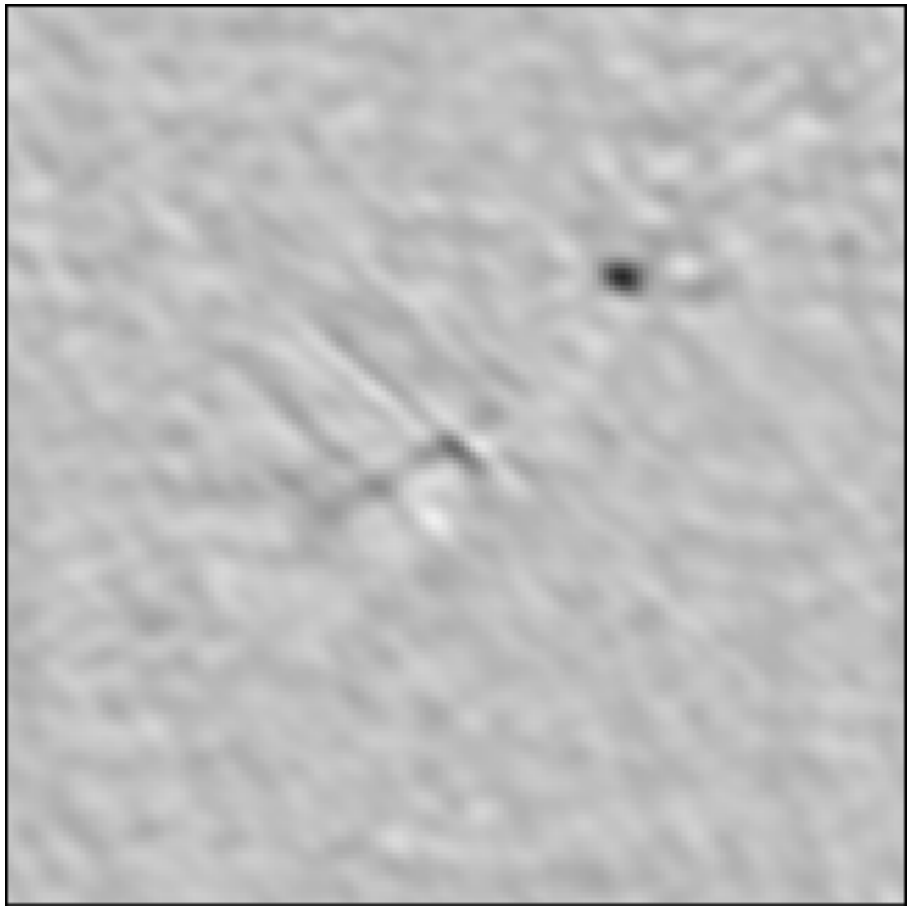
CC(polarization,intensity)



Observed Intensity



Reconstructed Polarization



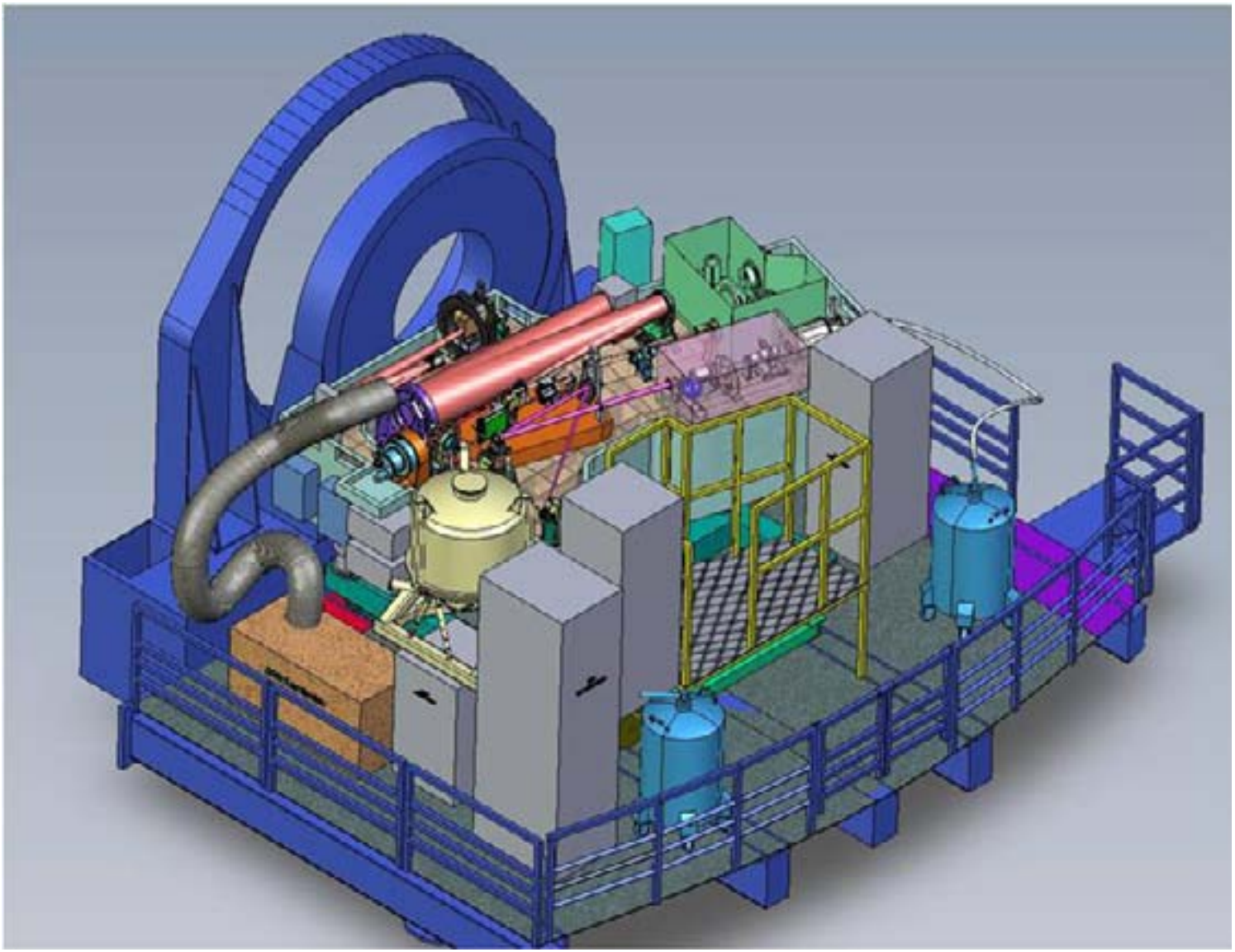
SPHERE for the 8.2-m Very Large Telescope

- second-generation VLT instrument
- the VLT planetfinder instrument
- French-Italian-Swiss-Dutch-German consortium
- extreme AO with three instruments:
  - IFS - Ontegral Field Spectrograph
  - IRDIS - Dual Imager and Spectrograph
  - ZIMPOL - Zurich Imaging Polarimeter

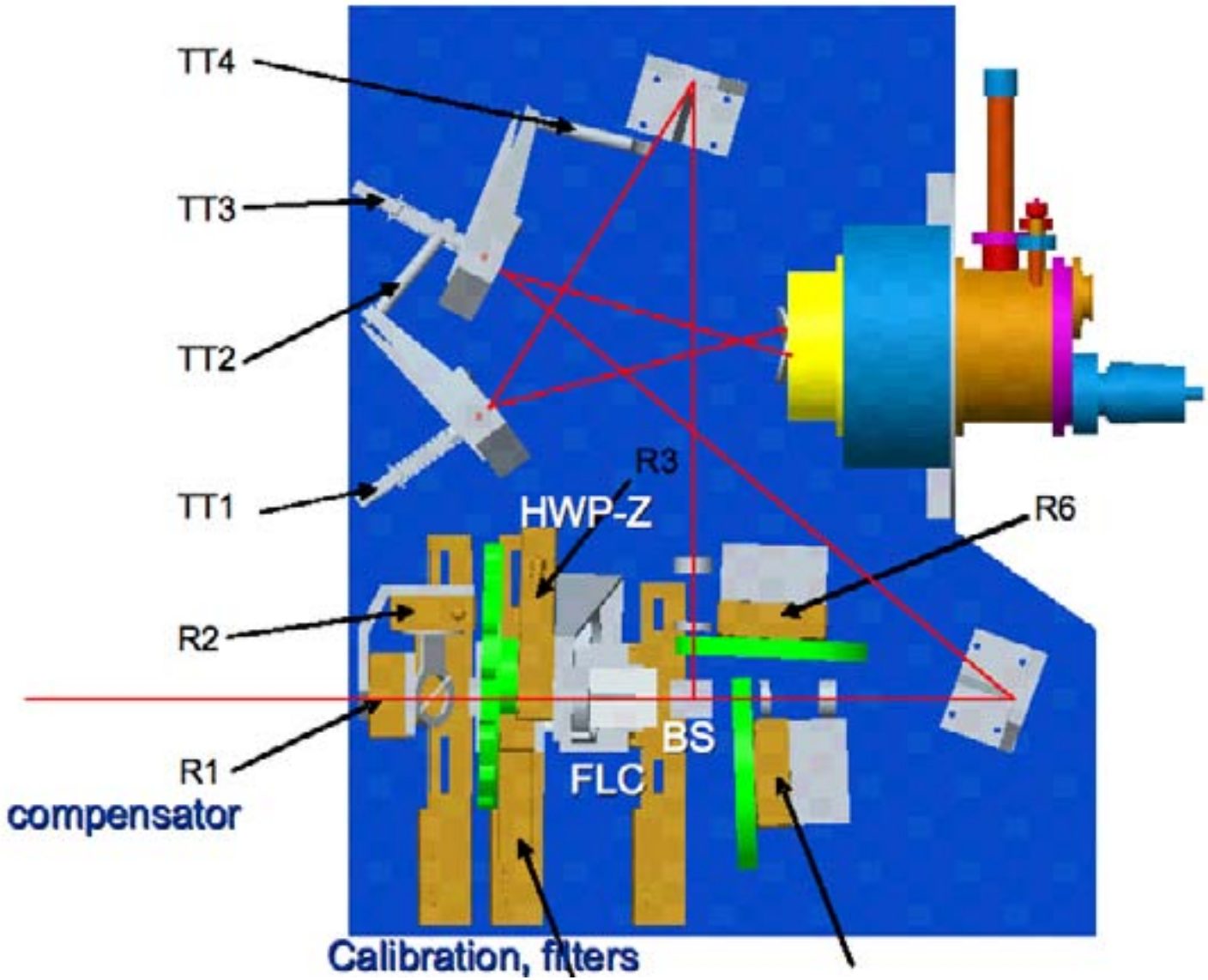
ZIMPOL - A Highly Sensitive Polarimeter

- UvA - ASTRON - UU in NL, ETH in Switzerland
- spectral range 600-900 nm
- sampling: $\lambda/2D$ at 600 nm
- FOV: 3 by 3 arcsec, 8 arcsec squared by mosaicing
- variety of filters
- special CCD array detector

SPHERE CAD Drawing



ZIMPOL CAD Drawing



Integral Field Spectrograph

- spectral range: 950-1350 nm
- R$\sim$30
- contrast 10^{-6} to 10^{-8}
- FOV: 1.35 arcsec squared, 3 arcsec squared

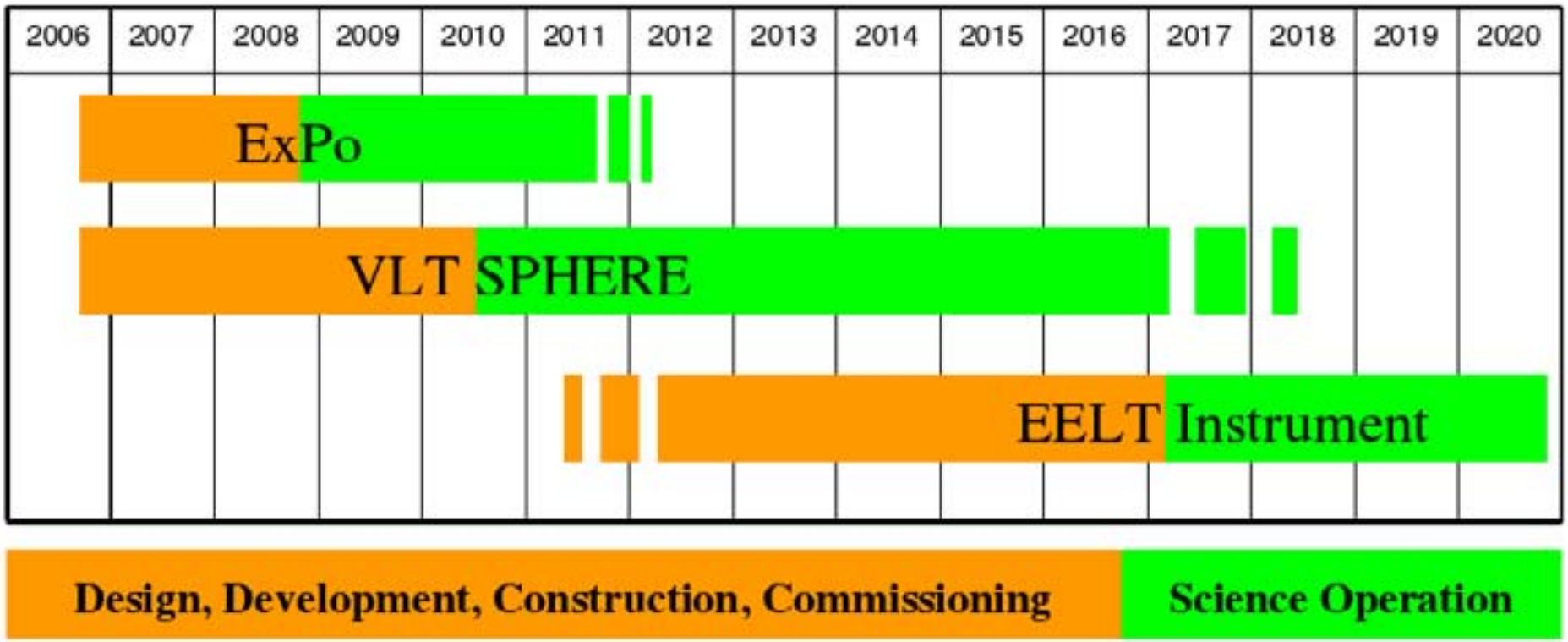
IRDIS

- spectral range: 950-2320 nm, Y to Ks Bands
- image sampling: 12.25 mas ($\lambda/2D$ at 950 nm)
- FOV: 11 by 12.5 arcsec
- dual band differential imaging (2 bands, 2 polarizations
- long slit spectroscopy, R 50, Y to Ks simultaneously, Medium resolution: R$\sim$500, Y to H simultaneously

EPICS for the EELT

- EPICS = Exo-Planet Imaging Camera and Spectropgraph
- Ueber-SPHERE for the 42-meter European Extremely Large Telescope (E-ELT)
- emphasis on characterization of exoplanets

Timeline



Other Observational Astrophysics at SIU

Comparison of Simulations and Observation

- chromosphere and corona (T.Aiouaz, A.Gorobets)
- sunspots (N.Vitas, A.Vögler)
- quiet sun (C.Fischer, R.Rutten)

Scattering polarization, S5T (F.Snik, H. Becher)

- Synoptic measurement of solar scattering polarization

Stellar Magnetic Fields (S.Jeffers)

- Zeeman Doppler imaging
- HARPSipol for ESO 3.6-m telescope at La Silla, Chile (F.Snik), upgrade for HARPS, most successful planet-hunting instrument

Solar System Polarimetry (F.Snik)

- aerosol, dust polarimetry in Earth, Mars, Titan atmospheres

Bachelor and Master Research Topics

- SOLIS VSM quiet sun dynamics
- transient events and statistical behaviors in the solar atmosphere
- solar abundance of manganese
- stray light correction in an atlas of sunspot umbral spectra
- wavefront measurement of Hinode Solar Optical Telescope
- measurement of polarized fringes
- polarization of a spectrograph slit
- analysis of Hinode solar satellite data
- laboratory equivalent of space mission with adaptive optics
- low-resolution multi-slit spectrograph
- simulation of EPICS for E-ELT performance analysis

www.astro.uu.nl/ãstrowik/astrowiki/index.php/BS_and_MS_Thesis_Projects