High Resolution Observations From the Ground

What the SST can do to enhance SOLAR-B science

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Outline

1. The Swedish 1-m Solar Telescope and its instrumentation

2. Magnetic substructure at 0''.1-0''.2

3. Concluding remarks

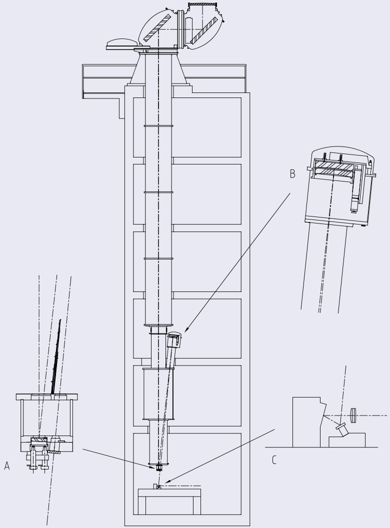
The Swedish 1-m Solar Telescope – SST

First light in May 2002

- 1 m aperture
- Integrated adaptive optics
- Small number of optical surfaces
- Very high optical quality
- Most highly resolving solar telescope ever built

$\Rightarrow$ **Solar images at $\sim$ 0.″1 resolution**

The SST – Schematic drawing



- Transmitting telescope optics made of fused silica for **stable** polarization properties.
- Field mirror can be tilted for compensation of atmospheric dispersion.

A. Field mirror and field lens
B. Schupmann corrector
C. Tip-tilt mirror, adaptive mirror, re-imaging lens

Instrumentation and techniques

- Adaptive Optics
- Phase-diversity and MOMFBD imaging and restauration
- Spectrograph (3 exit ports)
- Spectro-polarimeter (first light April 2006)
- Dual Fabry–Pérot filter system & Imaging polarimeter (end of 2006)

SST imaging polarimeter (operational early 2007)

Dual Fabry-Perot filter: High-resolution & high-reflectivity etalon combined with low-resolution & low-reflectivity etalon (Scharmer 2006).

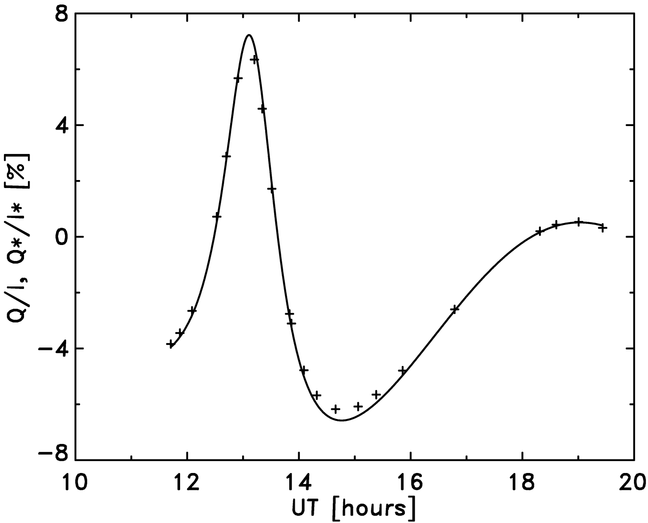
- FOV 70"x70", 0".07/pixel
- Wavelength range 520-860 nm, FWHM 60 mA at 630 nm
- High transmission (FPI > 80%, pre-filters 70-80%)
- Polarizing beam splitter with two 1kx1k CCD's
- Third CCD recording through pre-filter to allow image restauration
- Liquid crystals and filter tuned while reading out CCD's (10 ms)
- Back illuminated, low-noise CCD's operating at 30 Hz frame rate

SST polarization model (Selbing 2005)

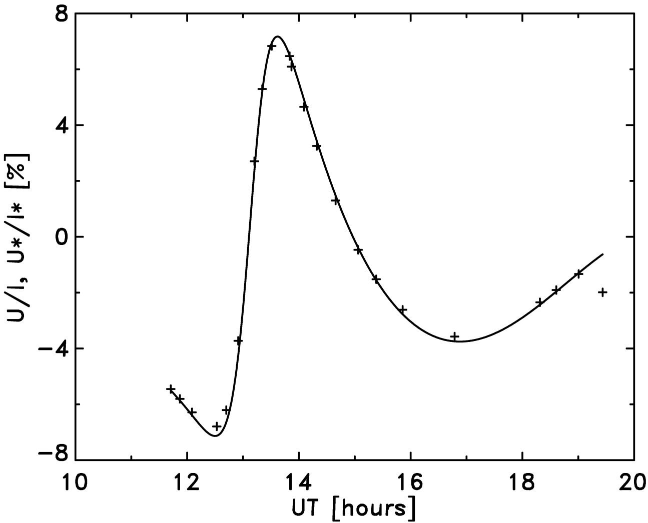
SST **strongly** polarizing, polarization measurements useless without good polarization model.

- Fused silica in all transmitting telescope optics $\Rightarrow$ **stable** polarization properties
- The same polarization model used for polarimetry based on narrow-band filters and on the spectrograph
- Uses 5-component **general** Müller matrix for 1-meter lens
- Model **based** on data with 1-meter rotating linear polarizer
- Model **verified** with unpolarized input light

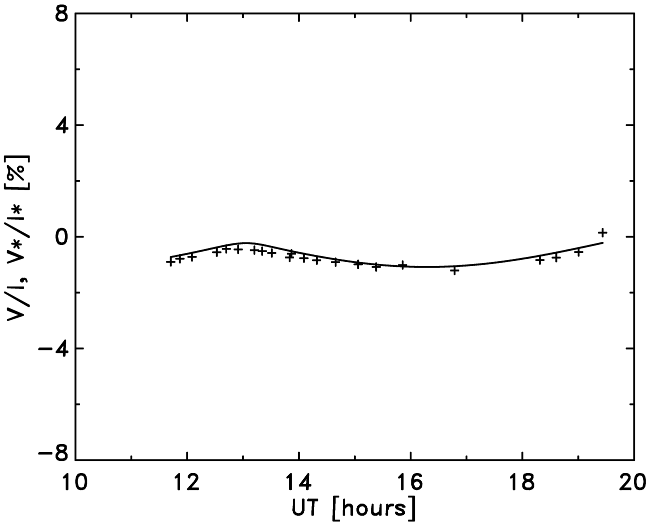
Polarization model verification, I ⇒ Q cross-talk



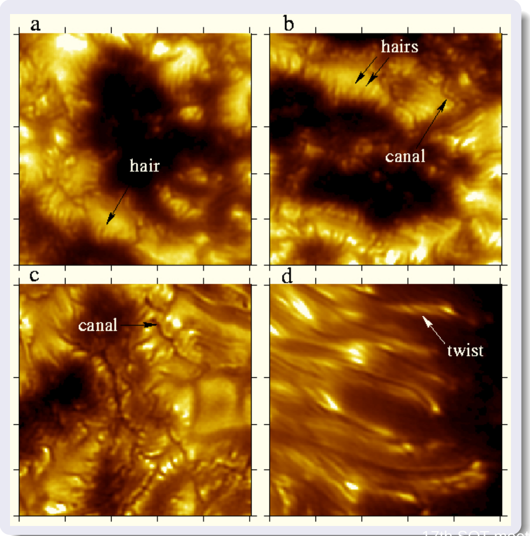
Polarization model verification, I ⇒ U cross-talk



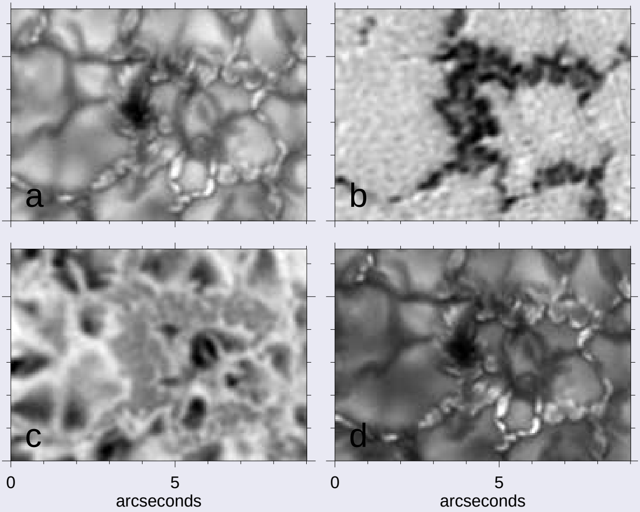
Polarization model verification, I $\Rightarrow$ V cross-talk



Sunspot fine structure close to the resolution limit (Scharmer et al. 2002)

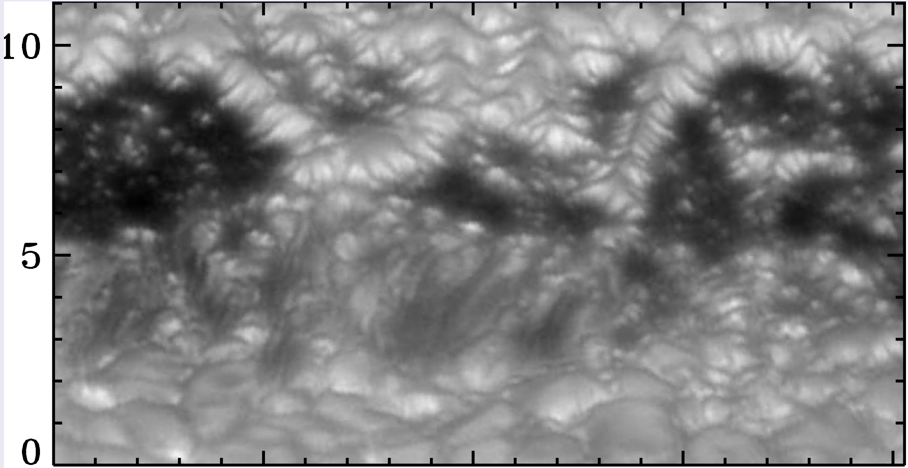


Magnetic substructure close to the resolution limit (Berger et al. 2005)



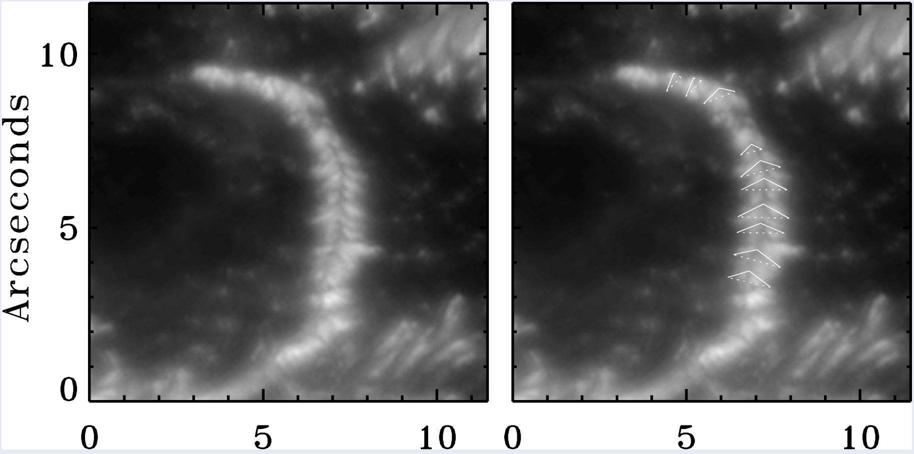
a: Wideband
b: Magnetogram
c: Doppler
d: G-band

3D structures in sunspots and pores (Lites et al. 2004)



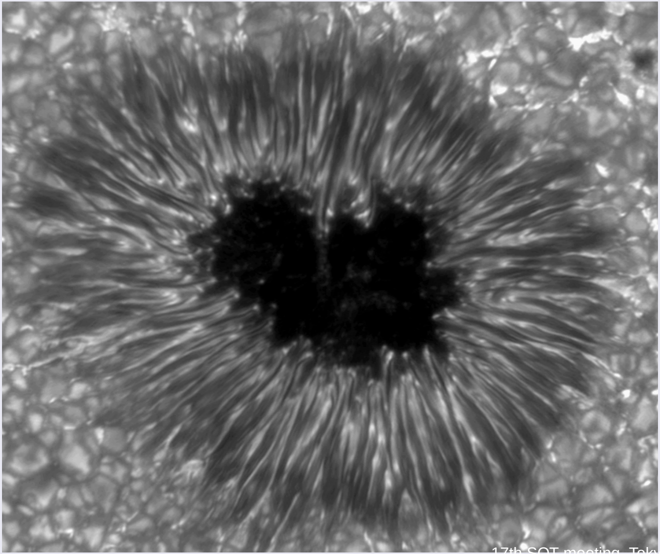
25 July 2002

3D light bridge structure (Lites et al. 2004)

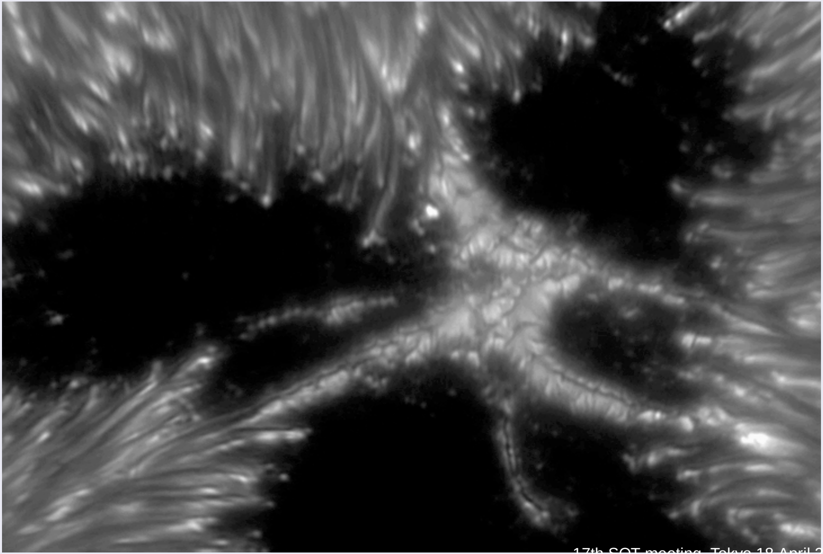


25 July 2002

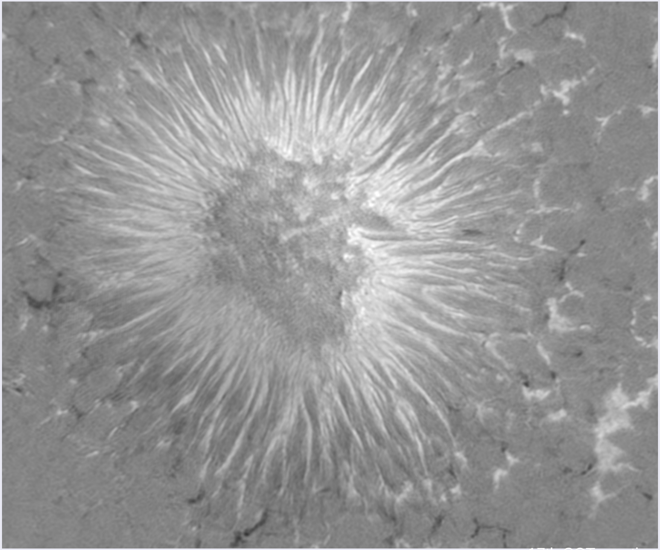
Dark-cored penumbra filaments (Spruit & Scharmer 2006)



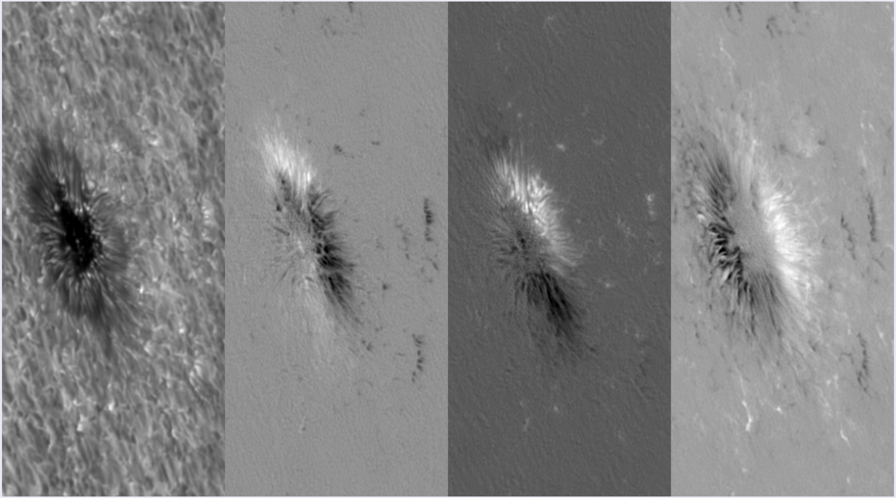
Connection light bridges - dark cored filaments (Löfdahl et al. in prep.)



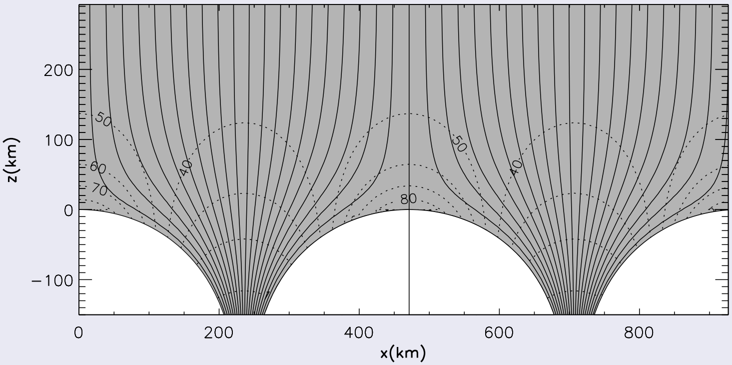
Magnetogram (suggests spine structure rather than embedded flux tubes)



First Stokes images from SST (individually scaled)

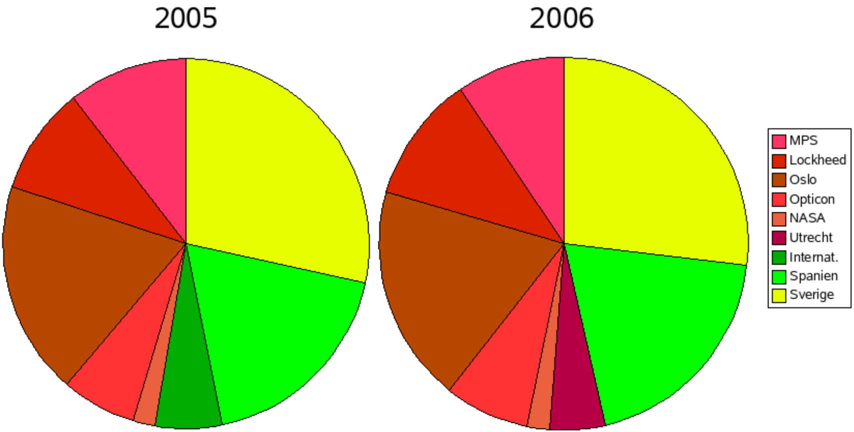


Proposed penumbra magnetic field (Spruit & Scharmer 2006)



Note: Any two-component representation would need **gradients** in **both** components!

SST observing time 2005-2006



SST data of potential importance to SOLAR-B

For up to $\approx 1-2$ hours on $\approx 10\%$ of the days, SST can provide data **strongly enhanced** by image restauration and short exposures:

- Highly resolved ($\approx 0''.1$) images and movies in Ca H wing and at blue wavelengths
- Highly resolved ($\approx 0''.2$) multi-wavelength Stokes images using dual FPI system (operational early 2007). Low residual seeing induced cross-talk.

Spectropolarimetric data will be available but **unlikely** to be comparable with SOLAR-B data as regards spatial resolution due to long integration times needed.

Operational constraints

- SST used by several partners (Oslo and Utrecht Universities, IAC, Max-Planck Institut für Sonnensystemforschung, LMSAL) and programs (Opticon, IAC ITP). **Collaborations require contacts with individual institutes**
- IAC International Time Program (ITP) program provides direct means of obtaining SST observing time
- Swedish financial support for operating SST is declining

Comments on interpretation

Data at 0''.1 spatial resolution suggest that:

- $\tau = 1$ surface strongly warped by magnetic field, needs sophistication of diagnostics and inversion techniques
- No evidence for embedded flux tubes in outer penumbra. Connection dark-cored penumbral filaments and light bridge dark lanes suggest field-free gaps in penumbra (Spruit & Scharmer 2006).
- Inversion techniques unlikely to resolve multiple components with complex magnetic field topologies. Supplementary measurements at high spatial resolution desirable in order to help resolving ambiguities in interpretation.