

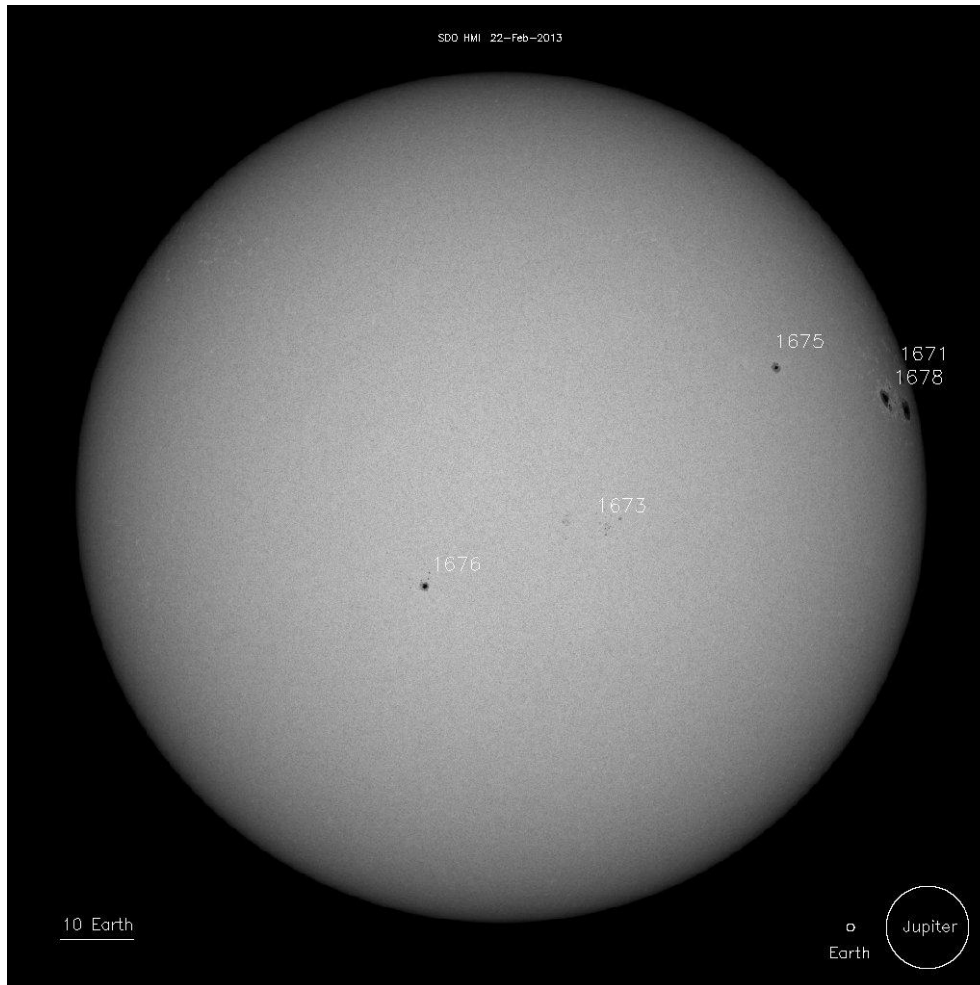
Deformable Mirrors in Solar Physics

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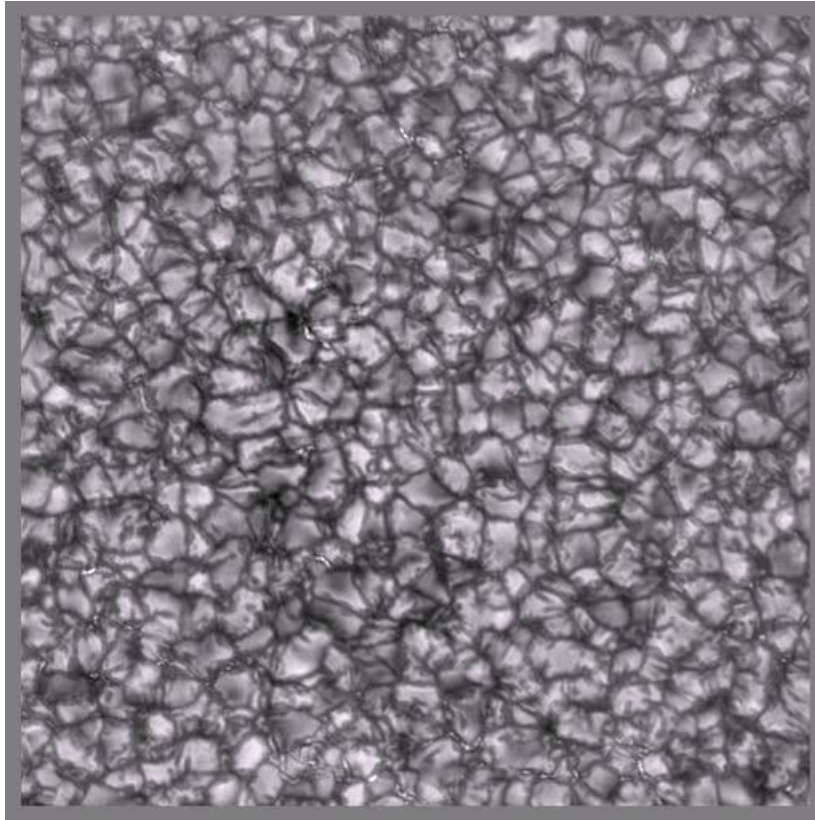
Freiburg, Germany

The Sun as a target



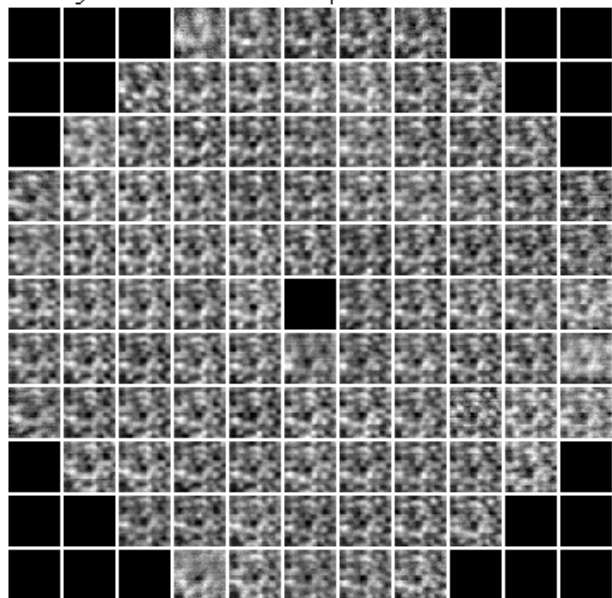
- There is granulation:
 - Typical structure size = 2"
 - intrinsic contrast > 10%
 - contrast in focus < 5%
- There are pores and sunspots
 - sizes 5" – 100"
 - contrasts > 50%

The Sun as a target

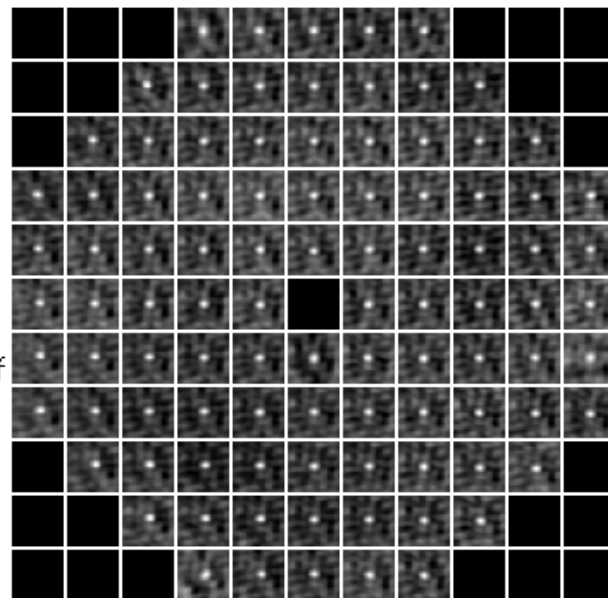


Lifetime of granulation: Typical 8 min
→ frequent update of reference image

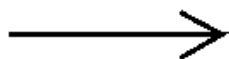
Array of subaperture images



2-d Crosscorrelations

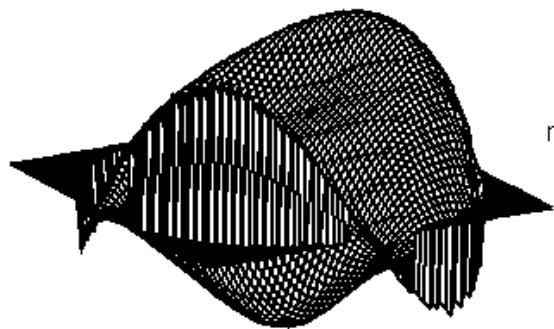


compute cross-correlations



using off-the-shelf DSP processors

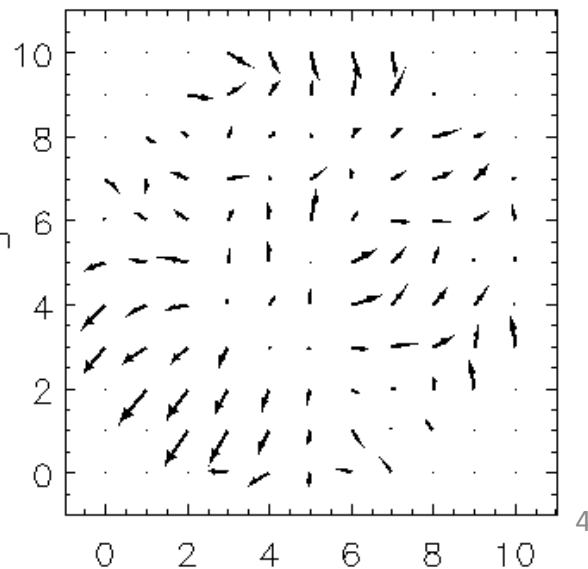
Wavefront



modal reconstruction

24 modes

Slope Vectors



to XINETICS

97 actuator DM

taken from ATST archive

21.02.2013

D. Soltan (KIS), Delft Workshop

21./22.02.13

GREGOR AO GUI

KAOS

Main Menu

Run AO

M11 correction...

Take Flats...

mark subapertures...

Run AO...

quit

Calibrate System

Take Flats...

Take Darks...

Check Pupil Alignment...

Calibrate Mirrors...

Take WFS Reference...

Misc

Move Mirrors / Actuators...

Move Motors...

Camera / Loop Settings...

Intensity Control

100% 10%

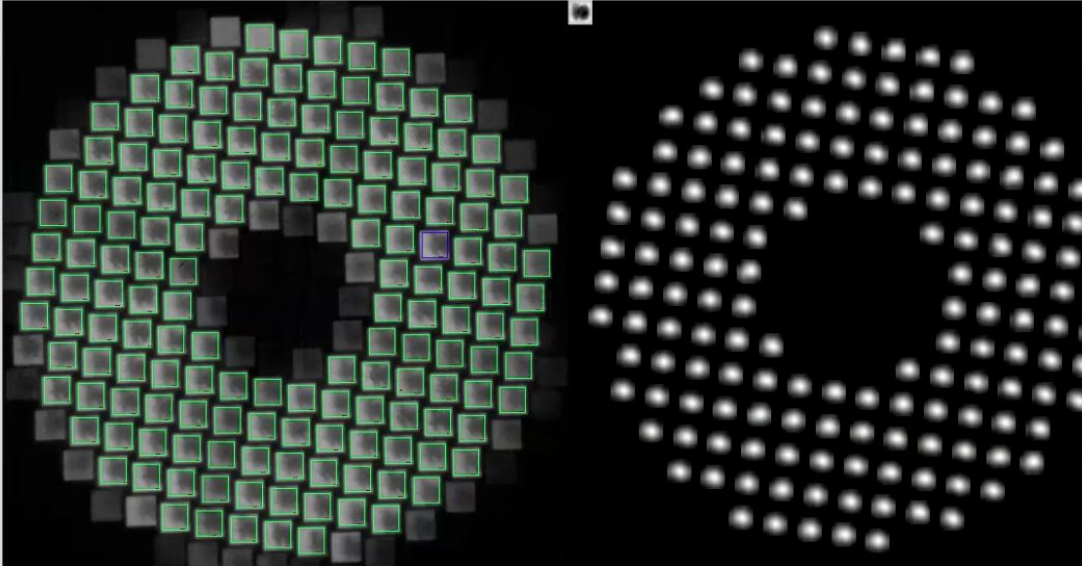
Subaperture Positions

show no positions

reference dots

reference squares

nullvolt squares



Run AO

run AO

no correction 90 max. #corrected modes

tip/tilt correction

ao correction M11 pupil correction

misc

reference update now

mode offsets...

servo params...

record data

Status: AO correction

#corrected modes: 90

Fried Param r0 [cm]: 8

Strehl [%]: 0

RMS contrast [%]: 26.9

subapnr	shiftx	shifty	intens	contrast [%]
0	-0.45	0.44	73129.9	5.6
1	0.27	0.55	74265.9	11.2
2	-0.22	0.46	65293.9	21.6
3	1.29	-0.23	56450.9	15.2
4	-0.44	0.20	52295.6	17.5
5	0.82	-0.04	74592.7	11.0
6	0.14	0.21	62410.8	26.2
7	-0.18	0.72	57371.6	25.7
8	-0.17	0.50	58177.2	27.4
9	-0.17	0.40	60500.4	28.8
10	-0.60	0.23	50643.0	17.4
11	-0.24	0.11	56672.9	27.3

nr	Mode name	reserr	rms	toterr	tms
0	x-tilt (TT)	-0.58	1.65	33.19	16.50
1	y-tilt (TT)	0.47	0.86	-20.99	12.17
2	x-tilt (DM)	0.00	0.00	0.00	0.00
3	y-tilt (DM)	0.00	0.00	0.00	0.00
4	focus	0.29	0.18	1.75	1.44
5	astigmatism	0.22	0.25	1.13	1.87
6	astigmatism	-0.15	0.27	-3.14	2.43
7	cma	0.04	0.16	1.83	1.08
8	cma	0.13	0.14	0.38	1.17
9	trifoil	0.43	0.19	-3.13	1.32
10	trifoil	0.08	0.18	1.10	1.17
11	spherical ab.	-0.16	0.08	0.06	0.48

WFS: Shack-Hartmann

- WFS has to see granulation with contrast $> 2\%$
- \rightarrow Subaperture size has to be > 8 cm
- \rightarrow There is an upper limit for the number of actuators

$$N \leq \left(\frac{D \text{ [m]}}{8} \right)^2$$

$D_{\text{Tel/cm}}$	N
150	350
200	600
400	2500

Mirror size

- Depends on actuator pitch p
- Heat load : some 100 W

$$D_{DM} [m] = \frac{D_{Tel} [m]}{8} p [m]$$

$$f_{Koll} = 40 D_{DM}$$

D_{DM}	D_{Tel}	p	f_{Koll}
5.6 cm	150 cm	0.3 cm	220 cm
9.4 cm	150 cm	0.5 cm	376 cm
7.5 cm	200 cm	0.3 cm	300 cm
12.5 cm	200 cm	0.5 cm	500 cm
15 cm	400 cm	0.3 cm	600 cm
25 cm	400 cm	0.5 cm	1000 cm

Mirror stroke

- $> 4\mu\text{m}$

DMs in Solar Physics.

On sky 7, breadboard 3, ordered soon 1, planned 6

Telescope	DTel / mm	pupil (beam) / mm	Type	# act./electr.	Stroke / μm	Vendor	Geometry	pitch	Remark
Yunnan	260	15	membrane	37		Flexible Optics	hex		on sky
VTT	700	50	bimorph	35	10 m rc	Laplacian	Keystone		on sky
VTT		50	bimorph	35	10 m rc	Laplacian	Keystone		spare
KIS MCAO 0 km			bimorph	68	20 m rc	Night	Keystone		Breadboard
KIS MCAO breadboard 25 km		43	Piezo (transvers effect)	69		Flexible Optics	Cartesian	4.75 mm	Breadboard
KIS MCAO breadboard 8 km		43	Piezo (transvers effect)	69		Flexible Optics	Cartesian	4.75 mm	Breadboard
NSO/DST	760	100	PMN (dielectric ceramics)	97	?	Xinetics	Cartesian	7 mm	on sky
SST	970	37	bimorph	37	?	AOPTIX Technologies	Keystone		on sky
McMath-Pierce	1500	37	membrane	37		Flexible Optics	hex		on sky
BBSO/NST	1600	100	PMN	357	?	Xinetics	Cartesian	5 mm	on sky
GREGOR	1440	50	Piezo-Stack (longitudinal effect)	256	8 μm	CILAS	Cartesian	3.2 mm	on sky
GREGOR	1440	55	bimorph	80	10 m rc	Night	Keystone		spare
ATST	4000	207		1500 - 1600	?	?	Cartesian	3.9 mm(?)	under construction
NLST	2000	180	stacked piezo	appr. 500	8um	?	Cartesian	7.2 mm	proposed
EST 0 km	4000	260	stacked piezo	appr. 2000	10 μm	?	Cartesian	5.2 mm	Study
EST 30 km	4000	150	?	?	?	?	?	?	Study
EST 15 km	4000	150	?	?	?	?	?	?	Study
EST 9 km	4000	150	?	?	?	?	?	?	Study
EST 5 km	4000	150	?	?	?	?	?	?	Study

Future Demands

- NLST (India)
 - $D = 180$ mm, angle of incidence 22.5° , pitch = 7.2 mm, Stroke $> 6 \mu\text{m}$
- EST
 - Ground layer DM $D = 260$ mm , angle of incidence = 45° , pitch = (5.2 mm, 3.6 mm)
 - MCAO mirrors, $D = 150$ mm, angle of incidence 45° , pitch not yet defined
- Other projects
 - China?
 - Russia?

Summary

- Development for solar AO is limited by subaperture size
- In the near future (5 years) some mirrors with 500 to 2500 actuators may be needed
- If MCAO is successful may be more
- Currently no large telescope ($> 4\text{m}$) is planned before 2025)
- smaller mirrors may be interesting for upgrading small telescopes