Deformable Mirrors in Solar Physics

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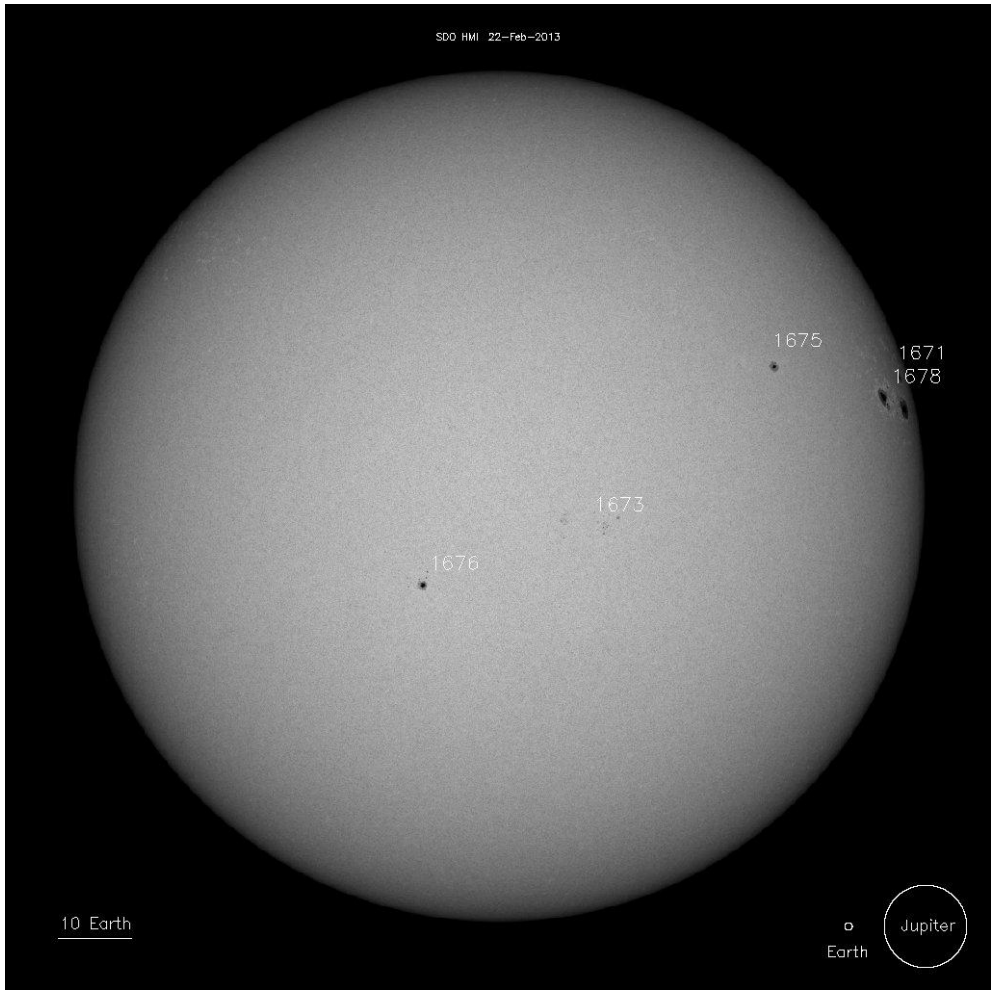
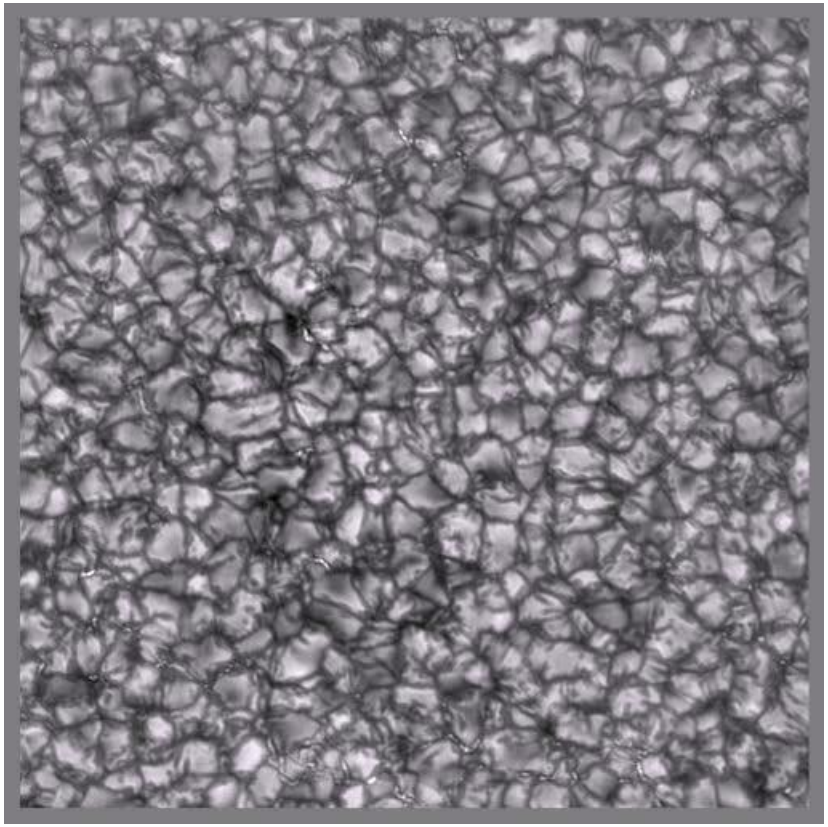
The Sun as a target

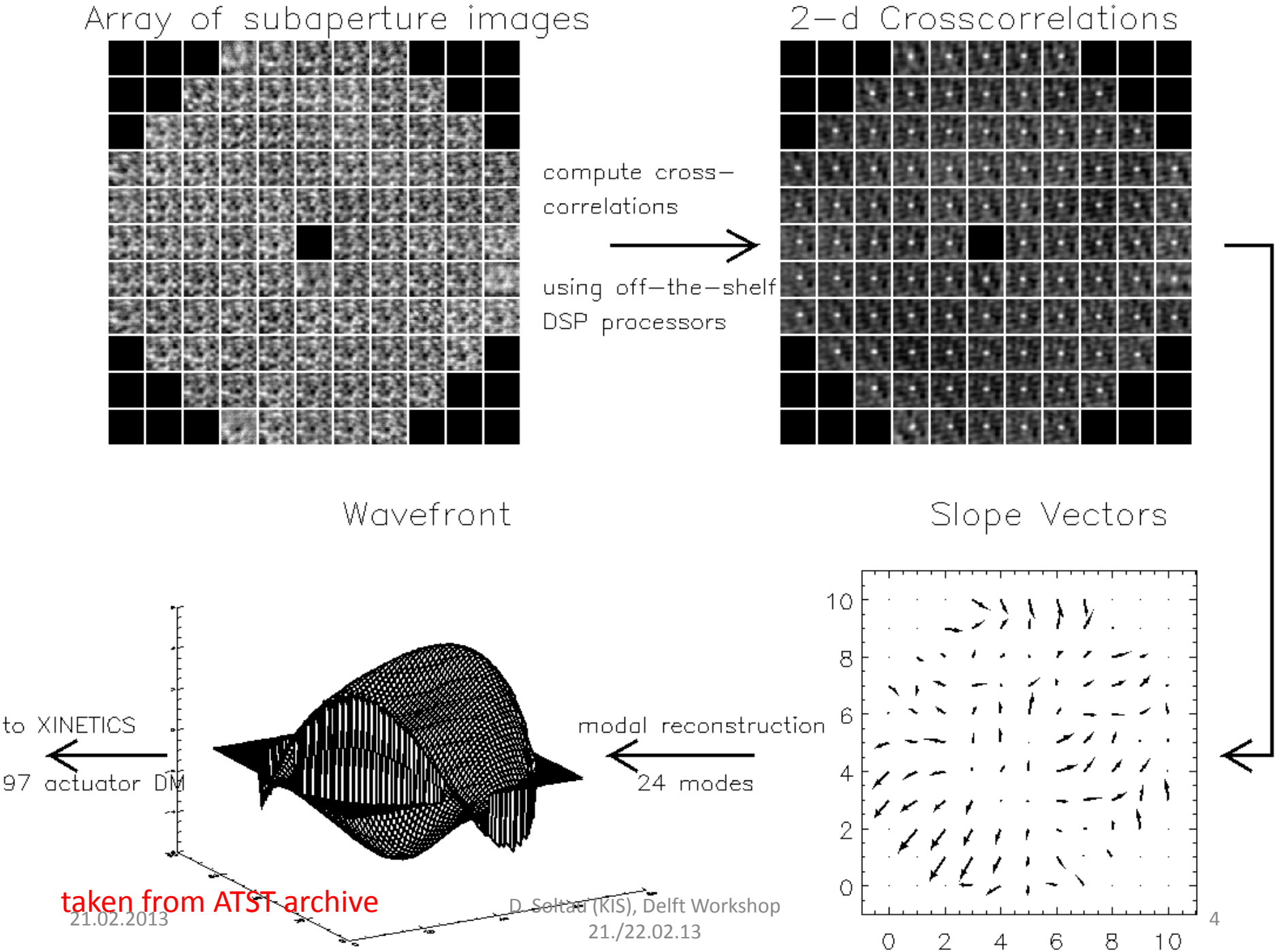


- There is granulation:
  - Typical structure size = 2“
  - intrinsic contrast > 10%
  - contrast in focus < 5%
- There are pores and sunspots
  - sizes 5“ – 100“
  - contrasts > 50%

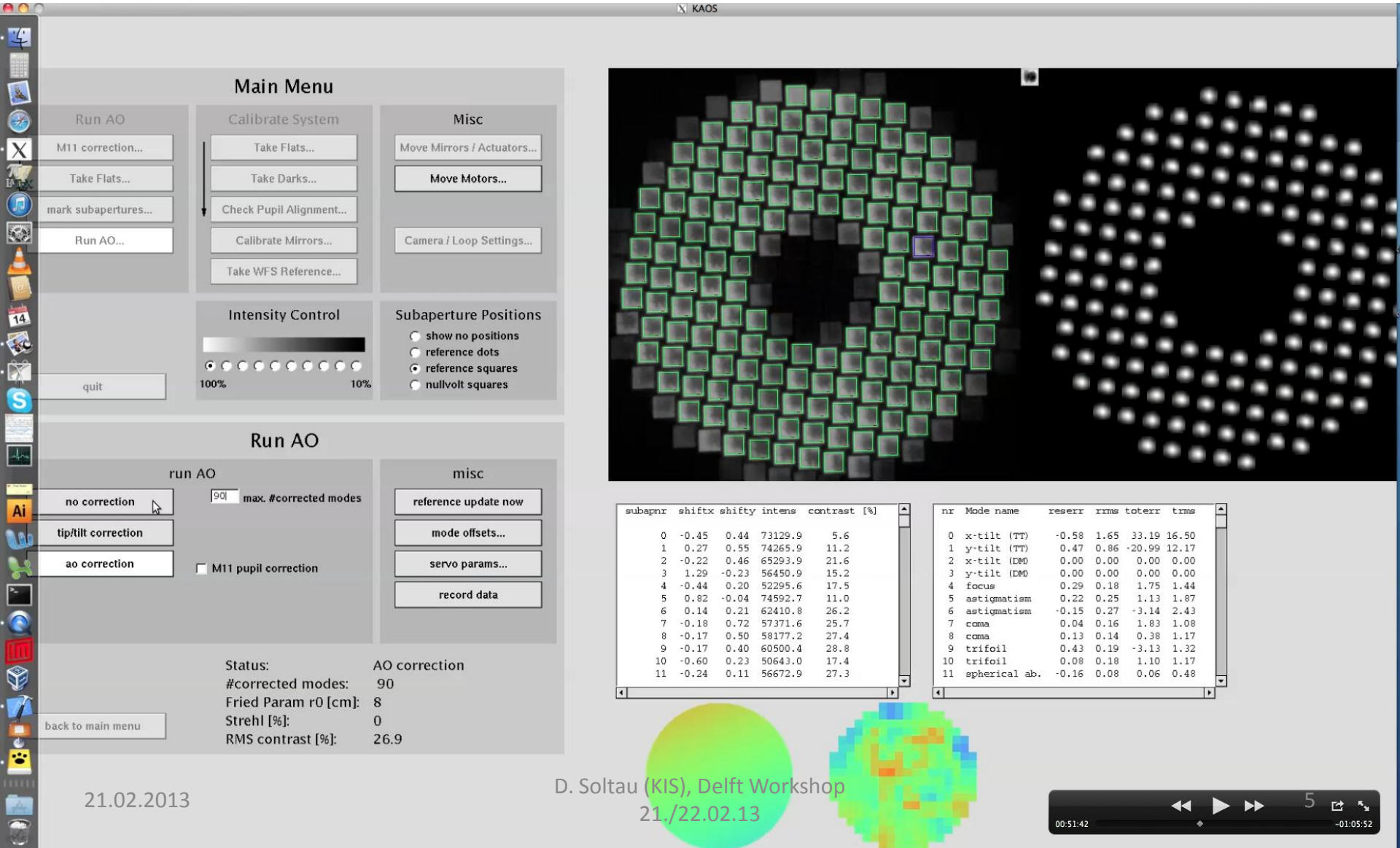
The Sun as a target



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


Array of subaperture images
compute cross-correlations
using off-the-shelf DSP processors
2-d Crosscorrelations
Slope Vectors
modal reconstruction
24 modes
Wavefront
to XINETICS
97 actuator DM
taken from ATST archive

GREGOR AO GUI



WFS: Shack-Hartmann

- WFS has to see granulation with contrast > 2%
- ➔ Subaperture size has to be > 8 cm

- ➔ There is an upper limit for the number of actuators

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

D_{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

- > 4μm

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 µm
- 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 (> 4m) is planned before 2025)
- smaller mirrors may be interesting for upgrading small telescopes