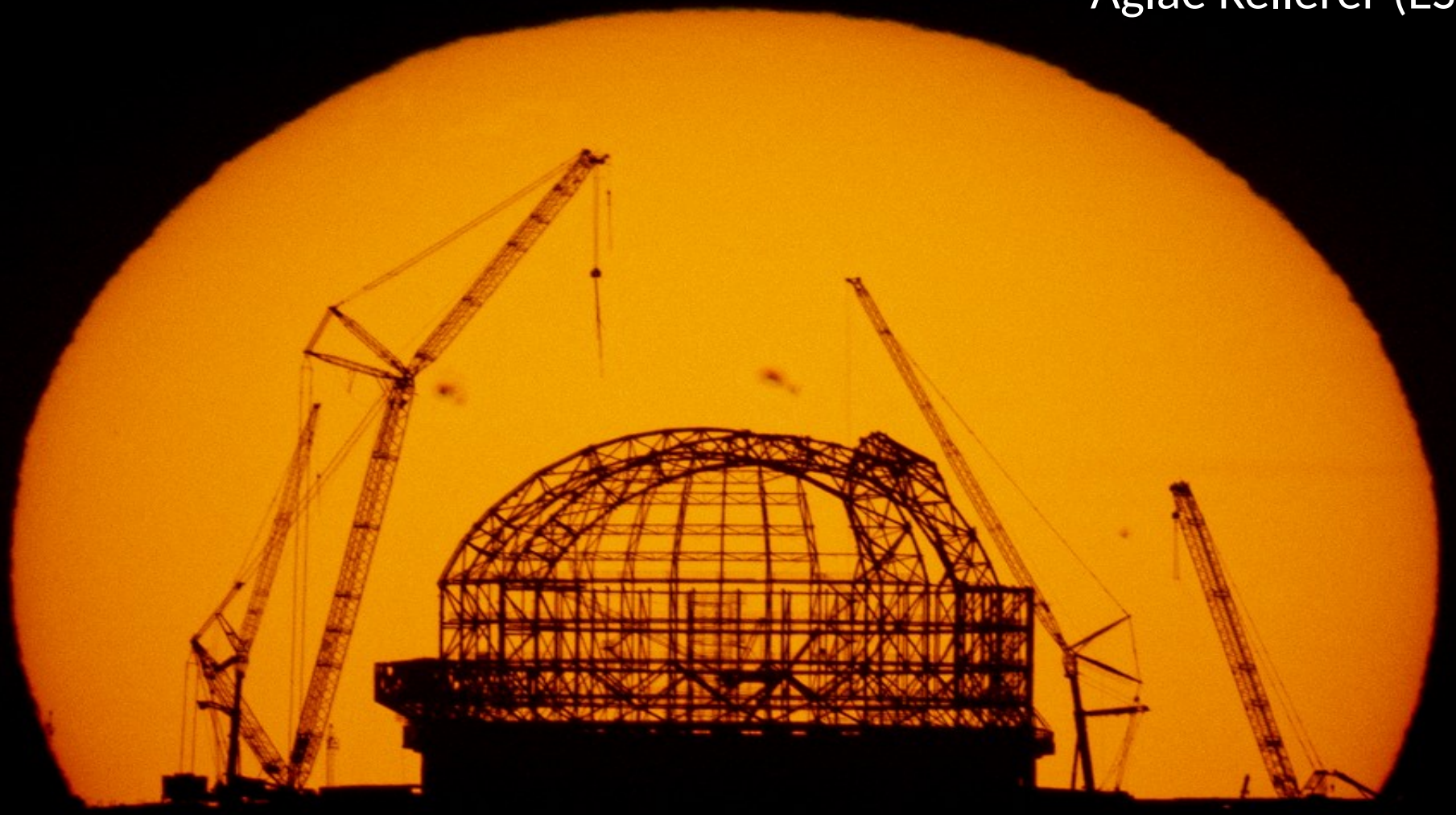
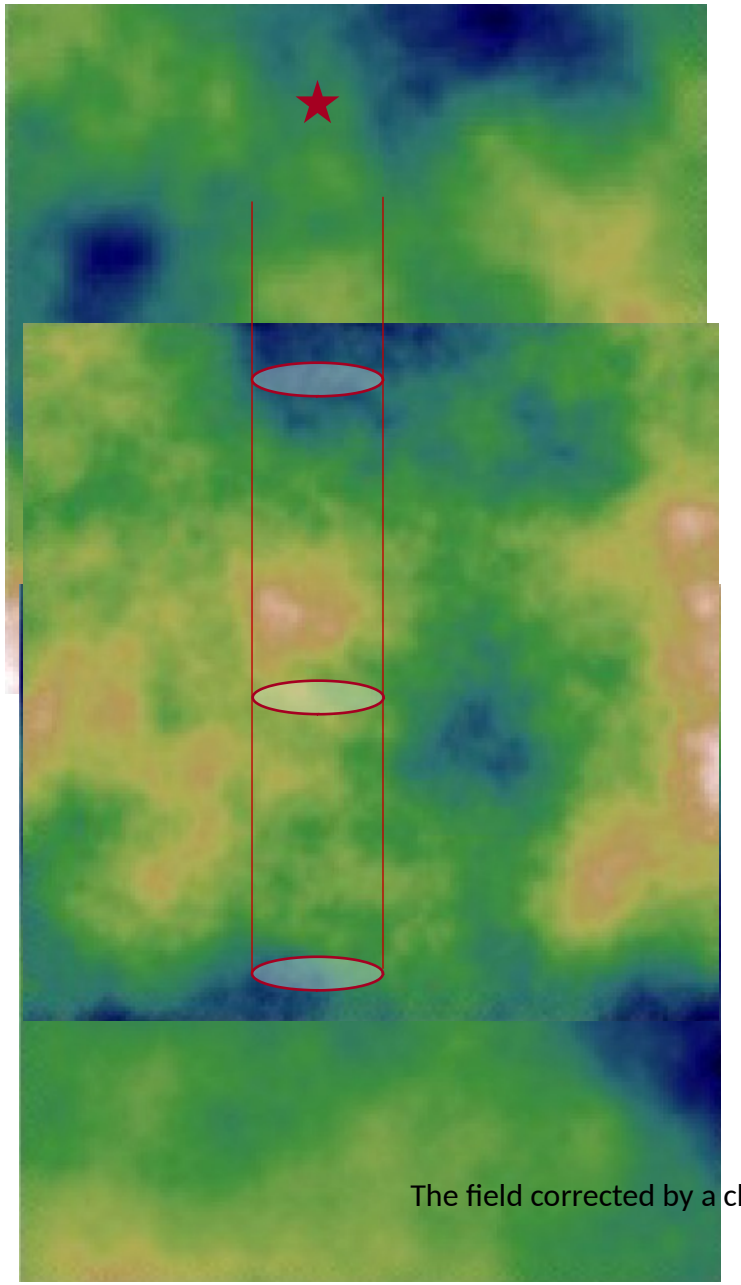
Layer oriented MCAO for solar observations

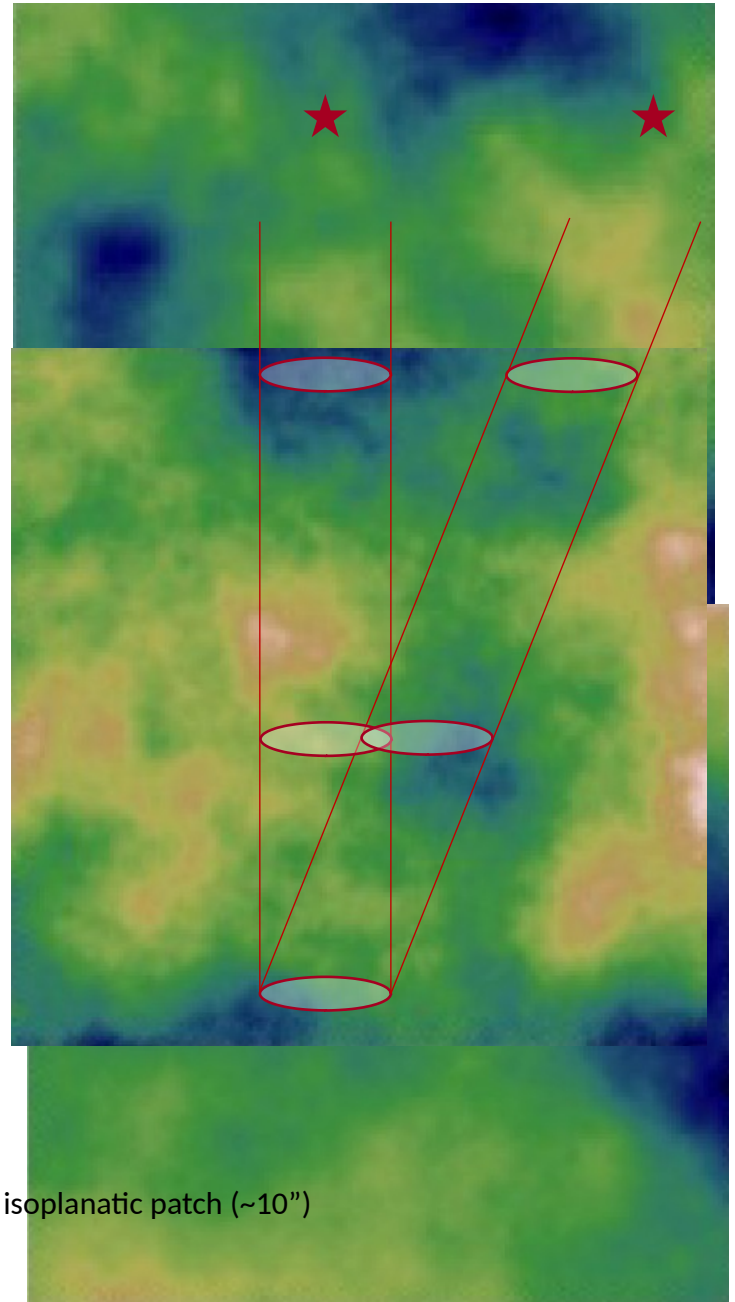
Aglae Kellerer (ESO)



Credit: Eduardo Garces and Nicolas Dubost

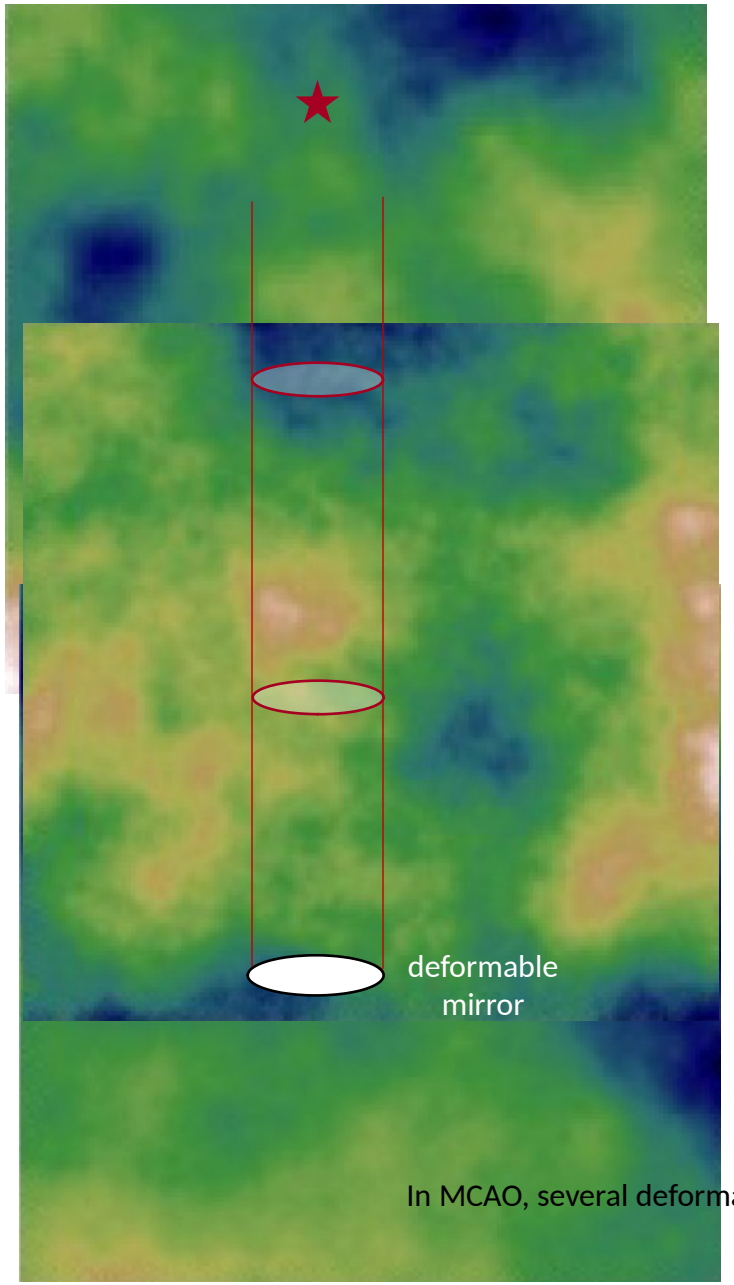
limited correction field of classic Adaptive Optics



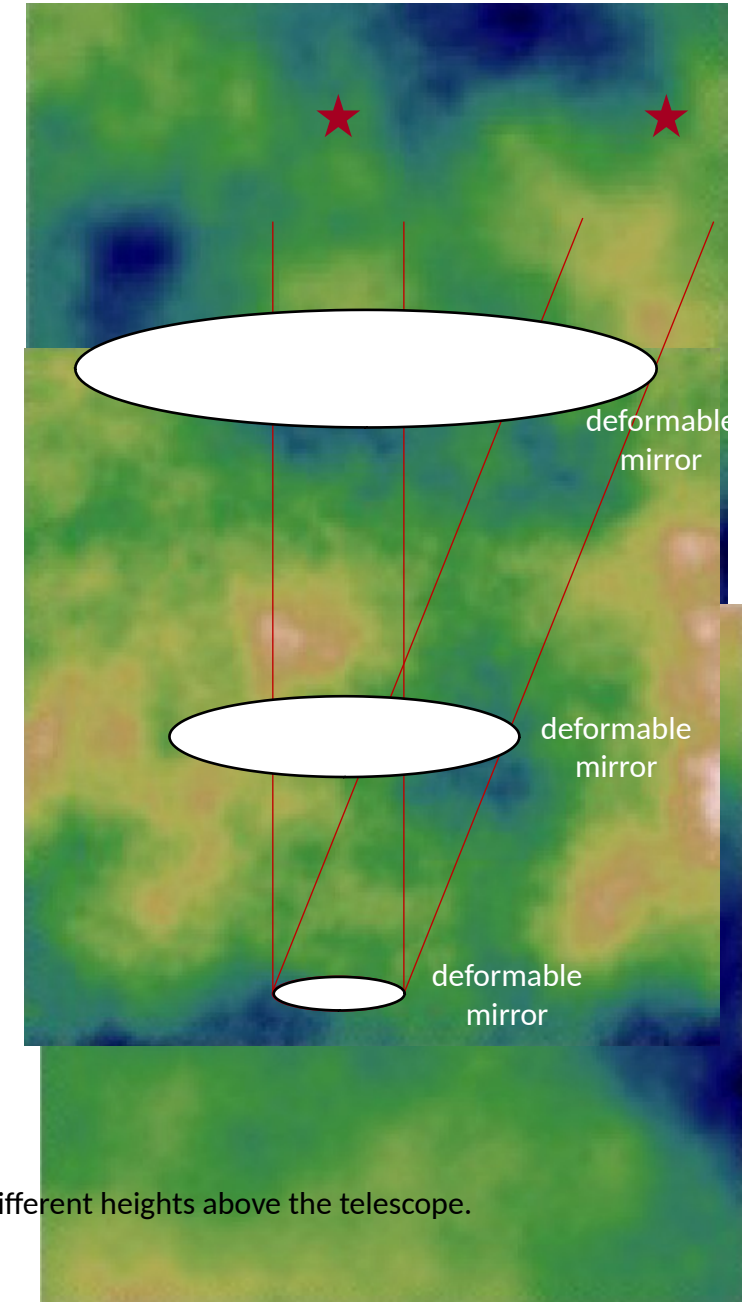


The field corrected by a classic AO system is limited to the isoplanatic patch (~10”)

Classic Adaptive Optics

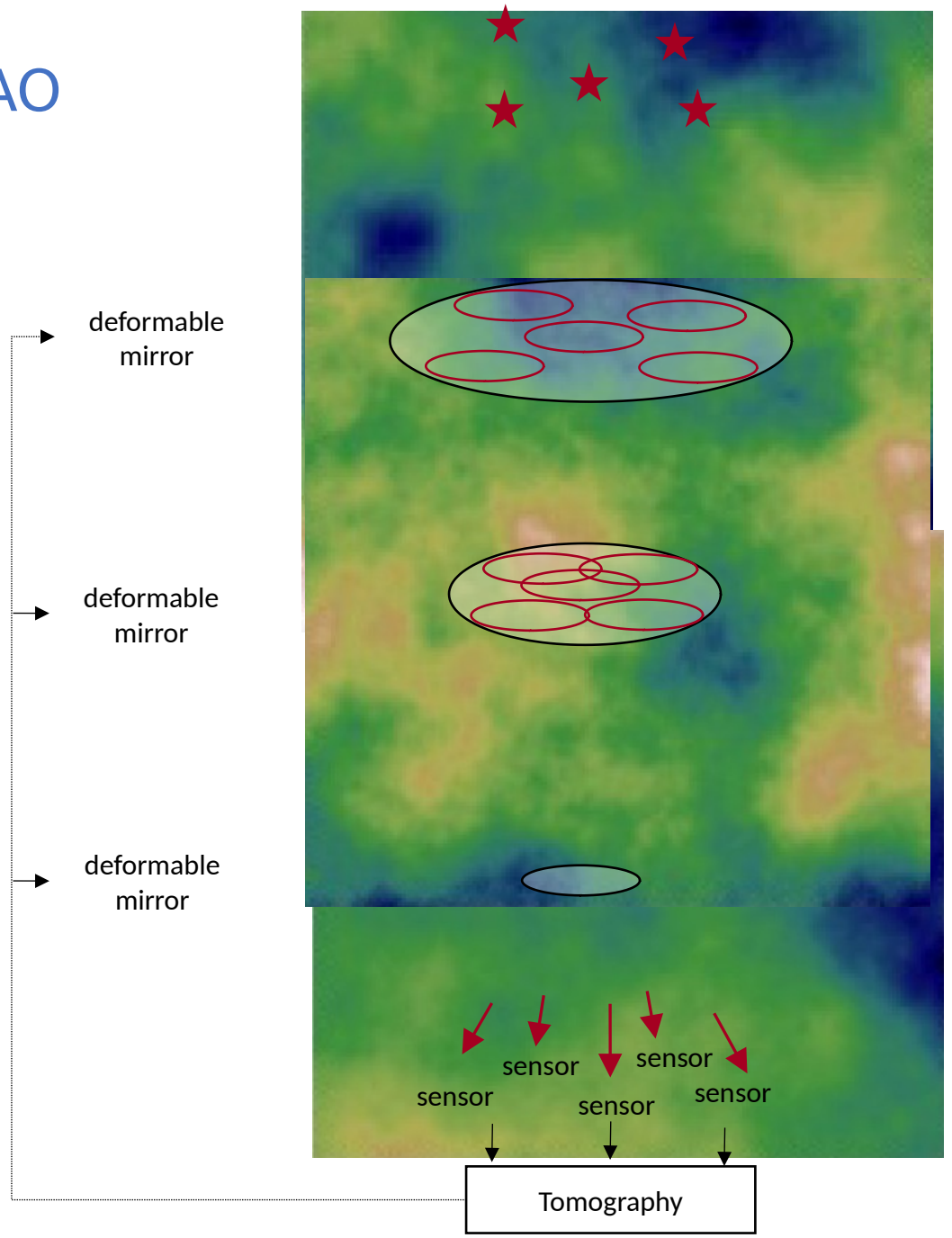


Multi-conjugate Adaptive Optics (MCAO)



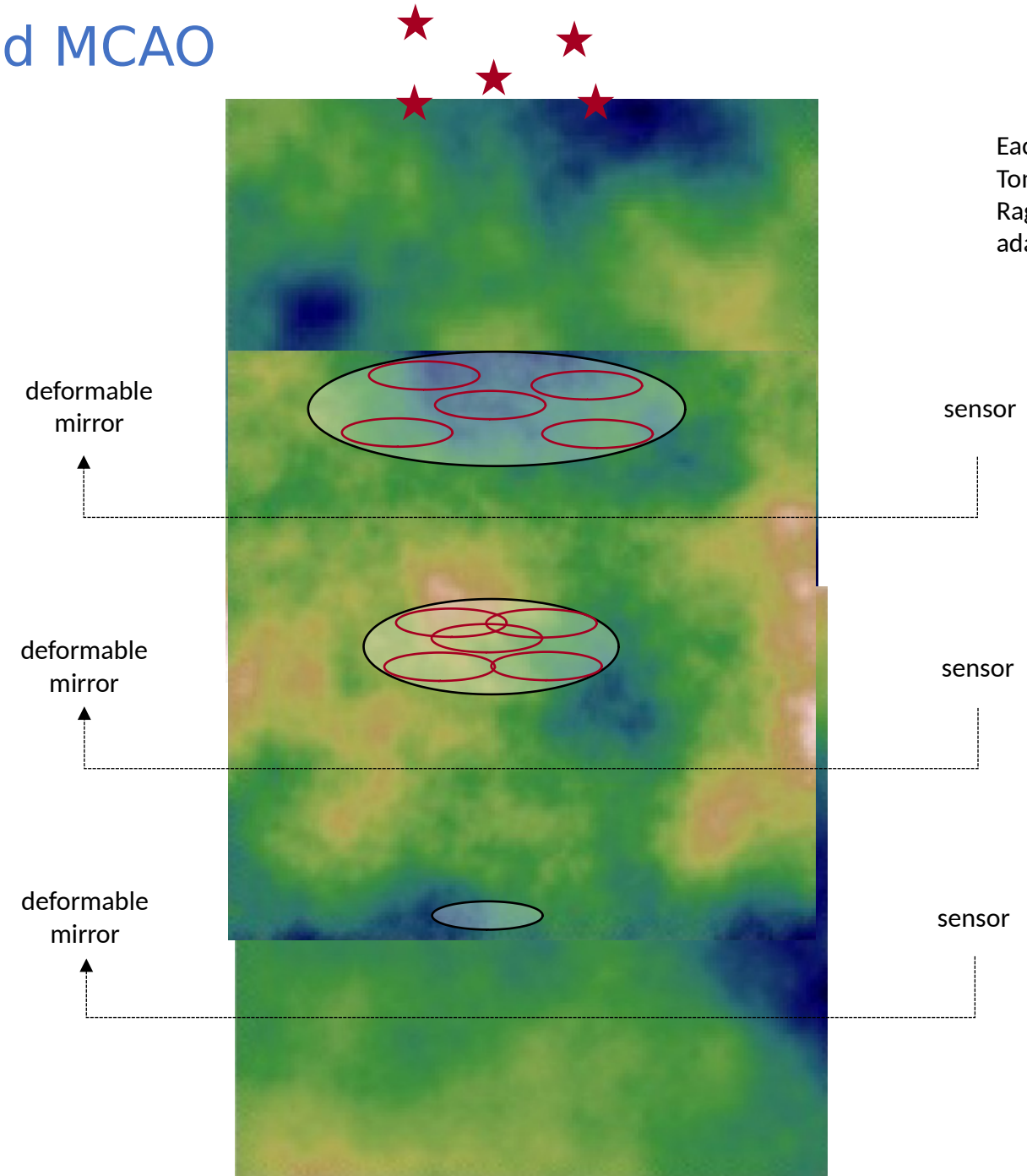
In MCAO, several deformable mirrors are conjugated to different heights above the telescope.

Star oriented MCAO



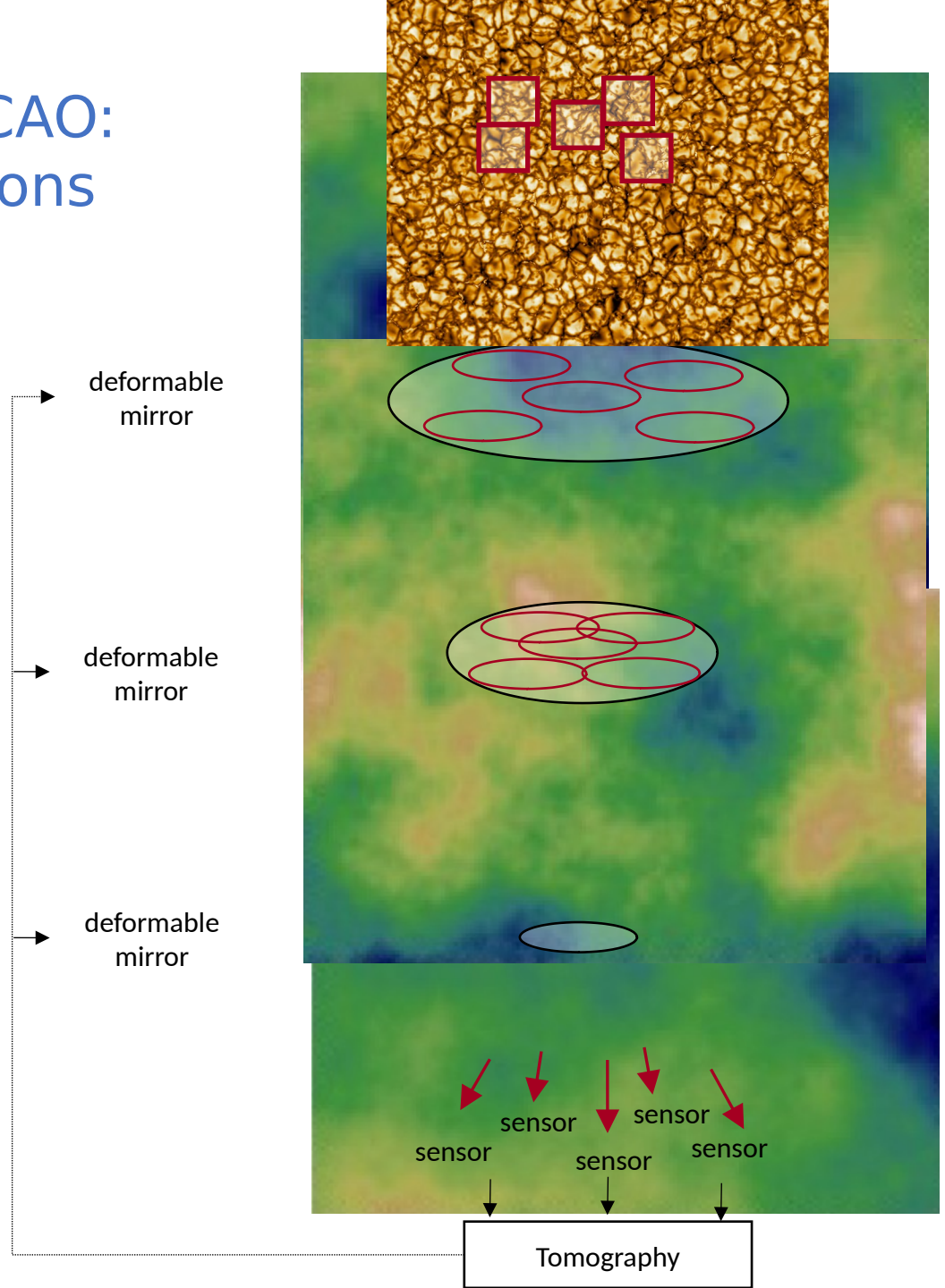
Several classic AO sensors work in parallel.
Tomographic reconstruction done numerically.

Layer oriented MCAO

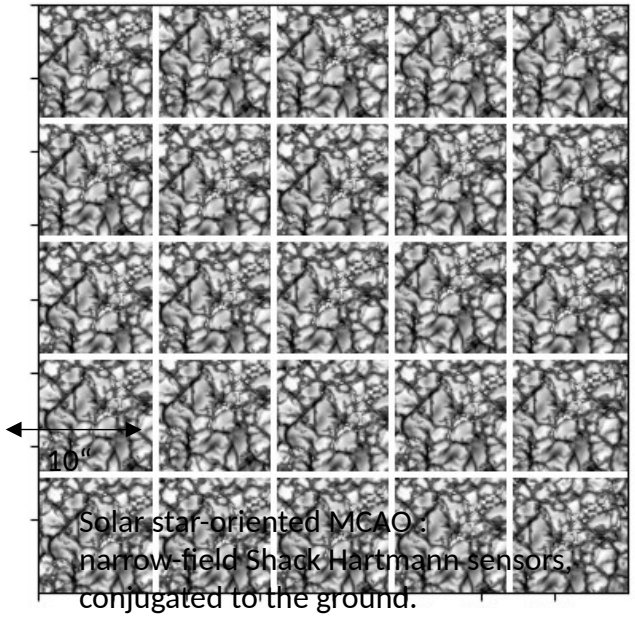


Each sensor tuned to one layer in the atmosphere.
Tomographic reconstruction is done optically.
Ragazzoni et al. “Multiple field of view layer-oriented adaptive optics” A&A 2002

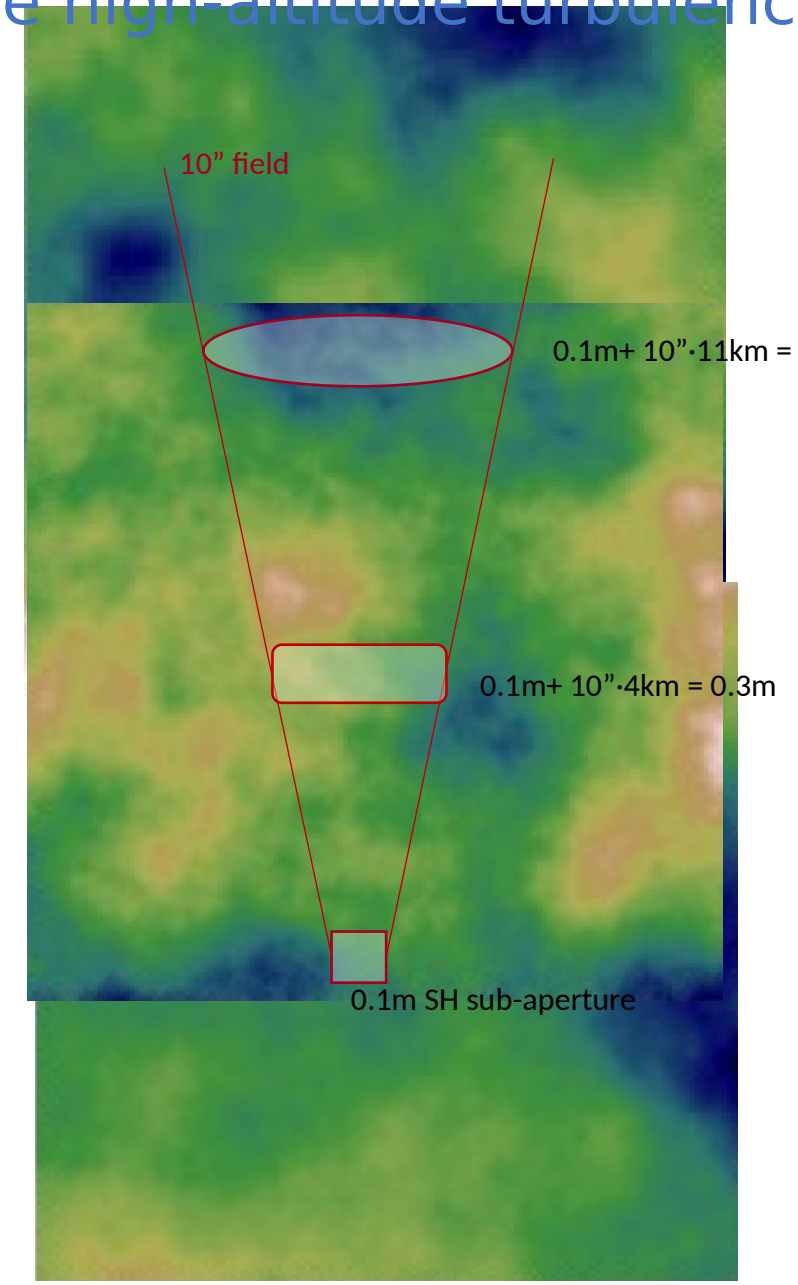
Star oriented MCAO: solar observations



oriented MCAO: difficult to sample high-altitude turbulence

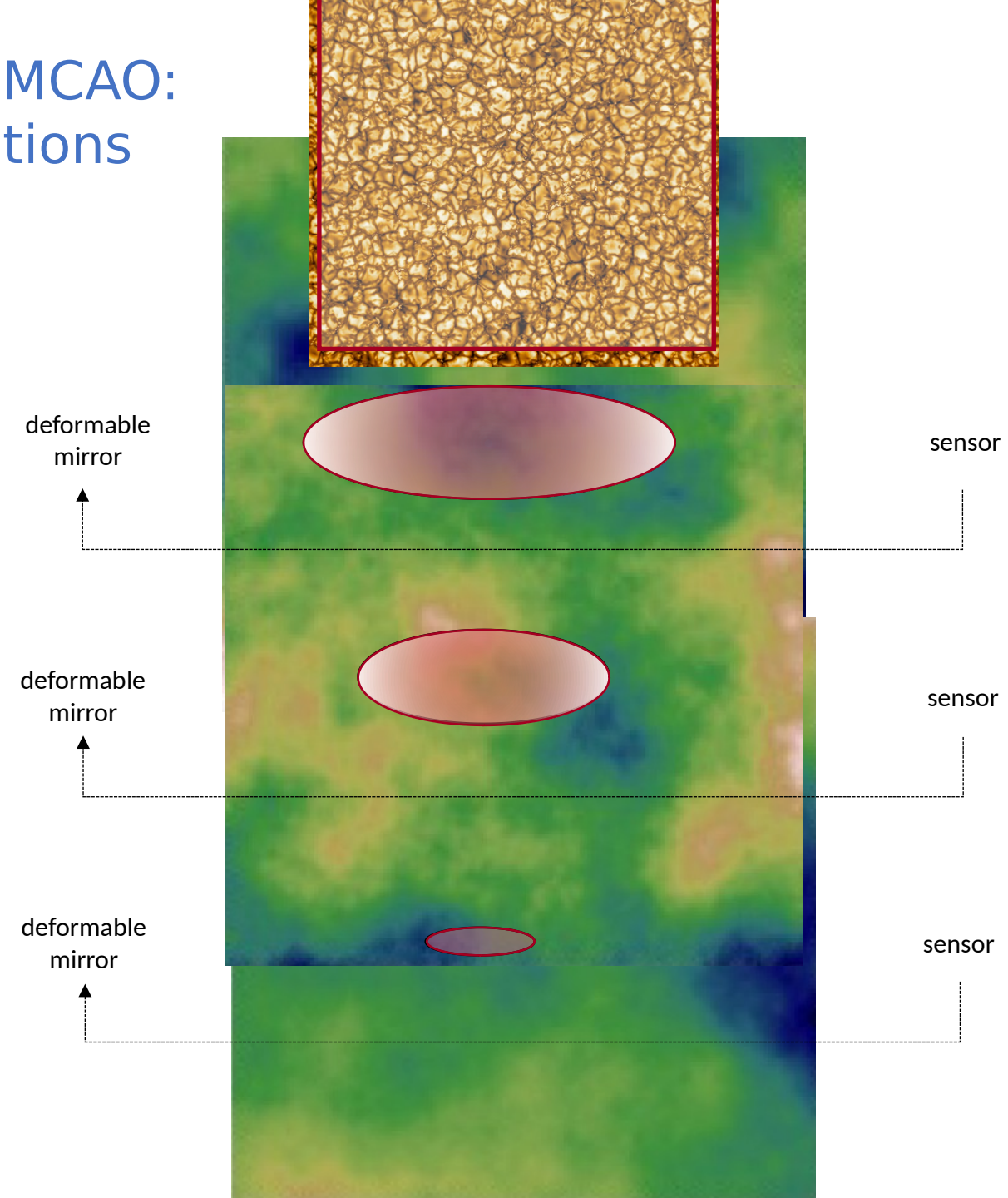


Solar star-oriented MCAO:
narrow-field Shack Hartmann sensors,
conjugated to the ground.

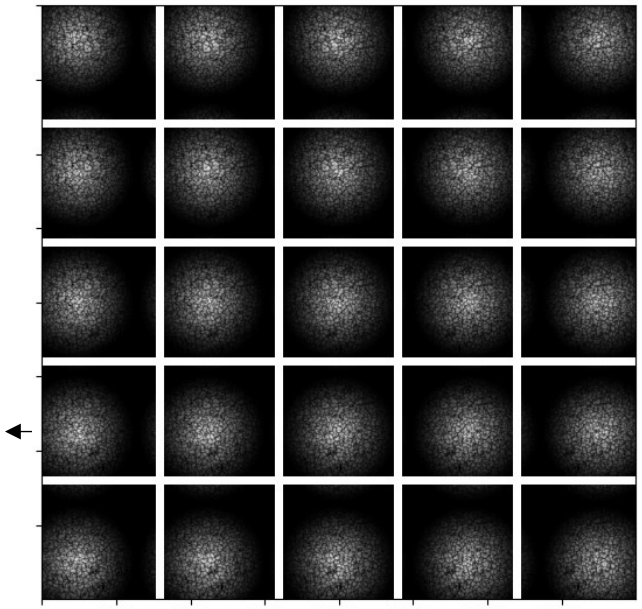


Due to the 10" field, the metapupil increases in size with altitude.
The spatial sampling of high- altitude turbulence is therefore reduced.

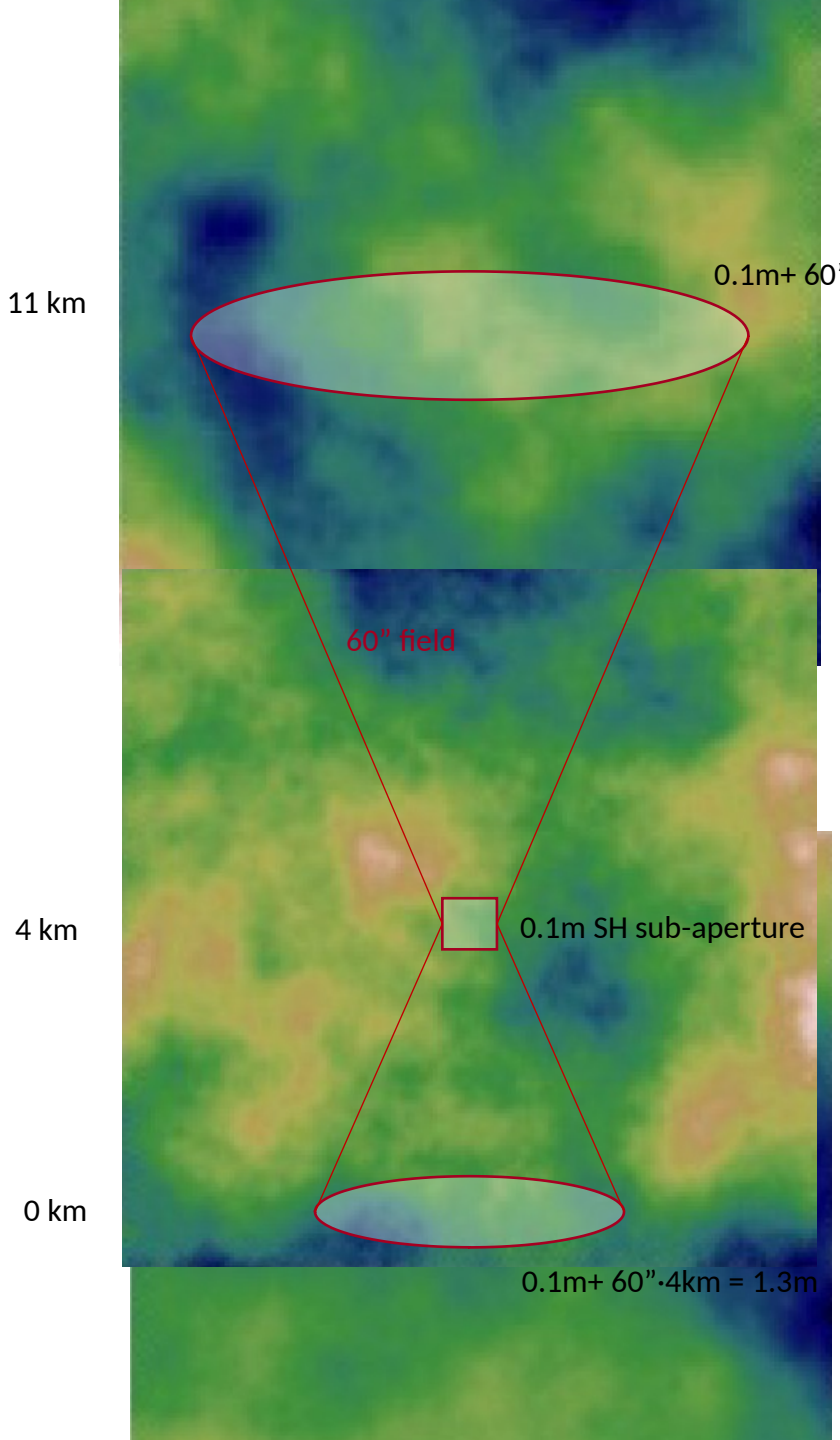
Layer oriented MCAO: solar observations



Layer oriented MCAO

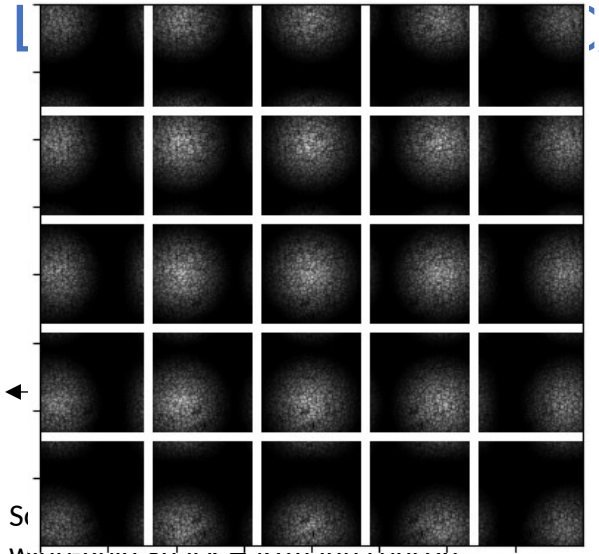


conjugated to the turbulent layers.

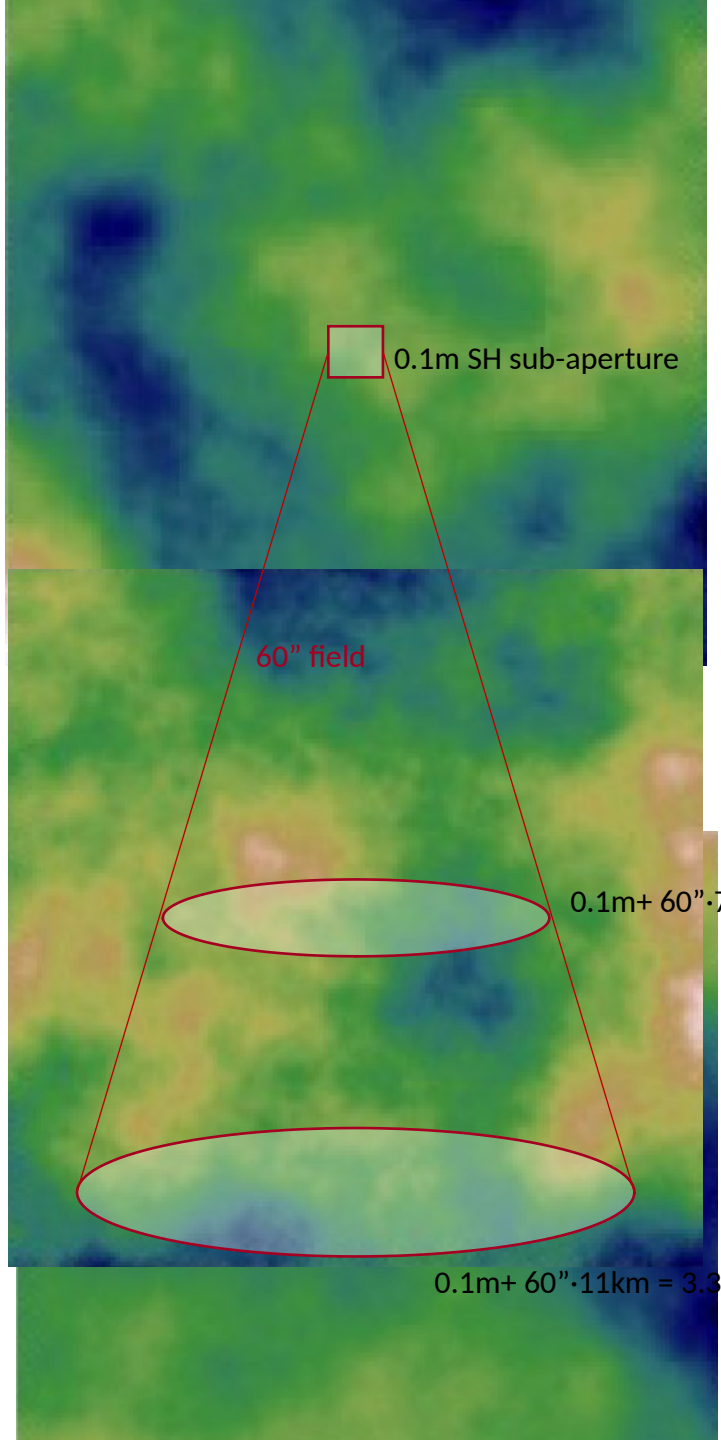


Sensor is conjugated to 4km. Metapupil increases with the distance to this 4km conjugation height

L CAO



S
wide-field Shack Hartmann sensors,
conjugated to the turbulent layers.

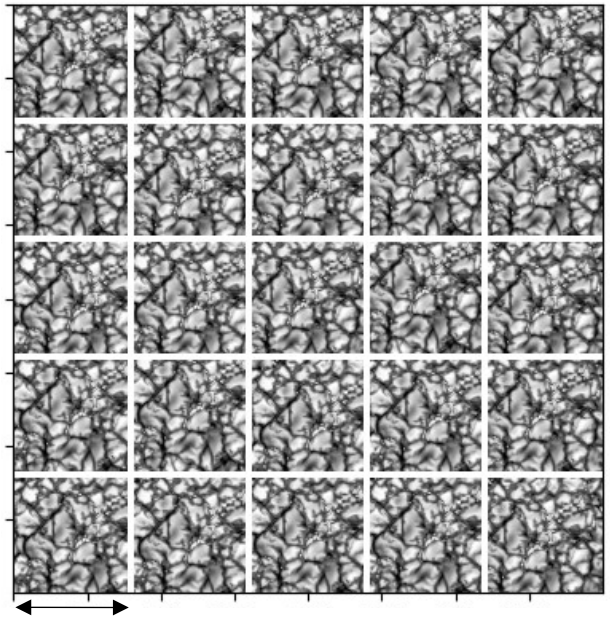


Sensor is conjugated to 11km. Metapupil increases with the distance to this 11km conjugation height

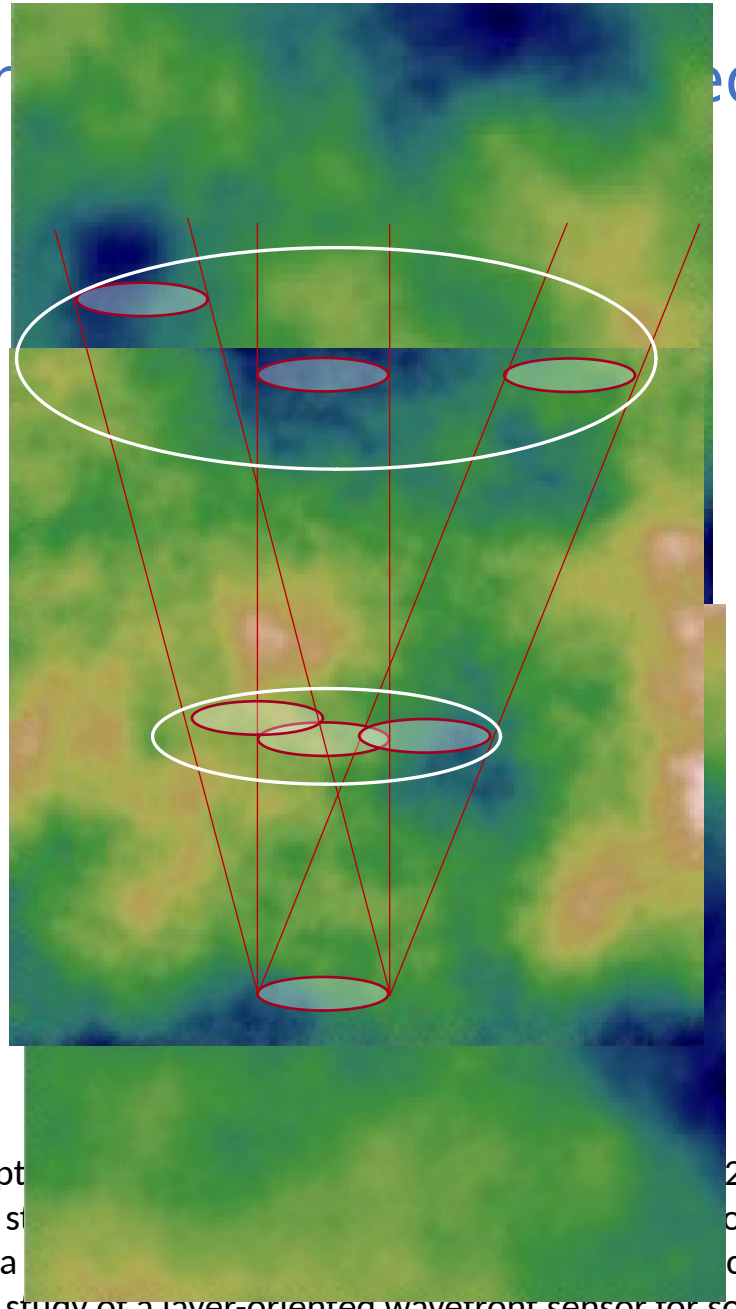
Vigr ed MCAO

Star oriented

Shack Hartmann sensor:
small field, no vignetting

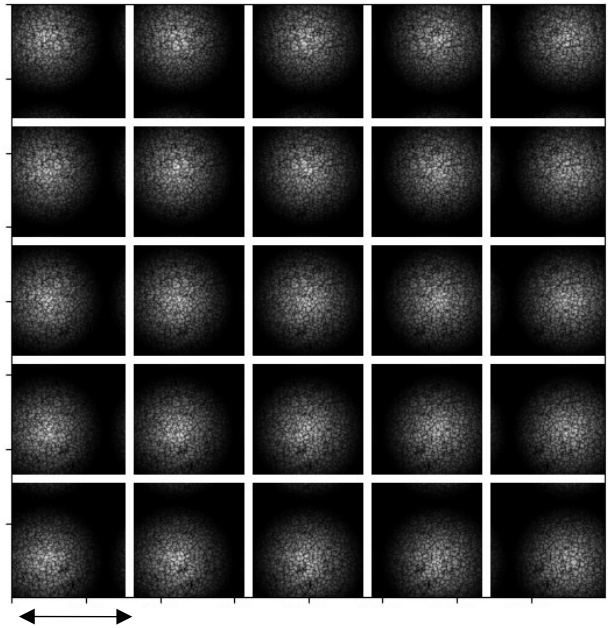


10“



Layer oriented

Shack Hartmann sensor conjugated to high altitude:
wide-field, vignetting



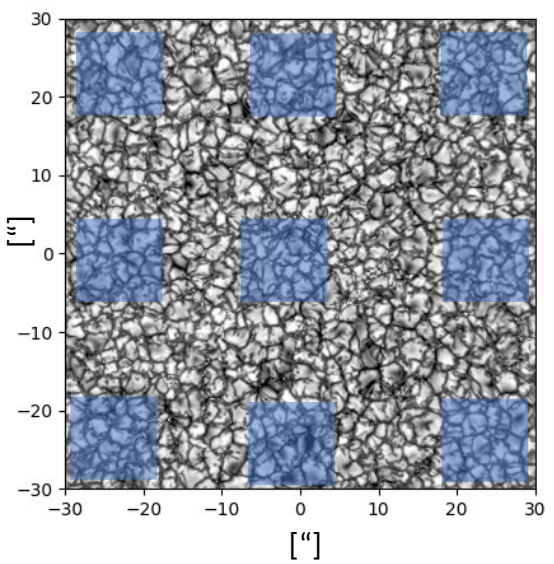
60“

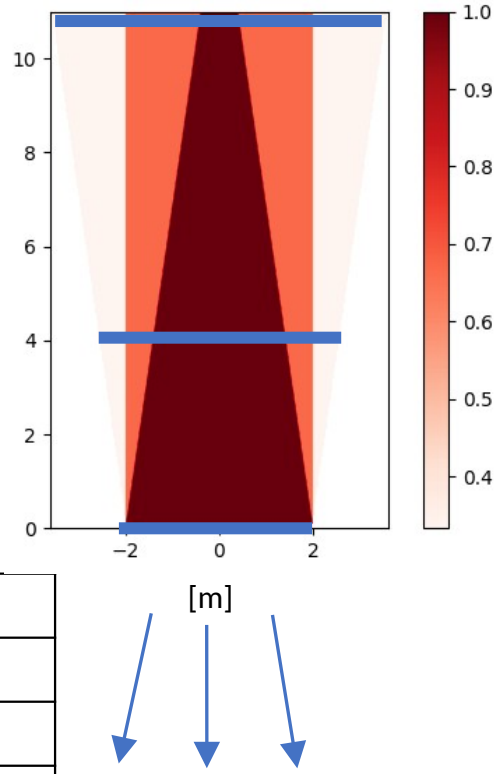
Kellerer “Layer-oriented adapt 2012
Marino & Wöger “Feasibility s olar telescopes” Applied Optics 2014
Kellerer “Feasibility study of a copes: comment” Applied Optics 2014
Marino & Wöger “Feasibility study of a layer-oriented wavefront sensor for solar telescopes: reply” Applied Optics 2014
Kellerer “Wide-field solar adaptive optics in a layer-oriented approach” J. Phys. Conf Ser. 2015

Design example

Telescope diameter	4m
Size of corrected field	60”
Height of deformable mirrors	0, 4 and 11km

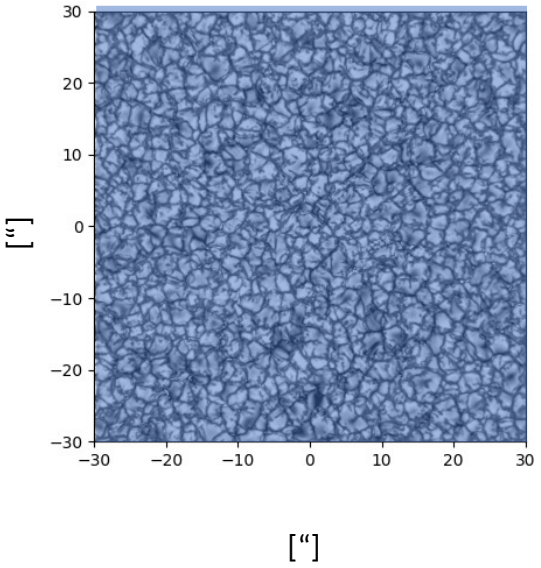
Star oriented

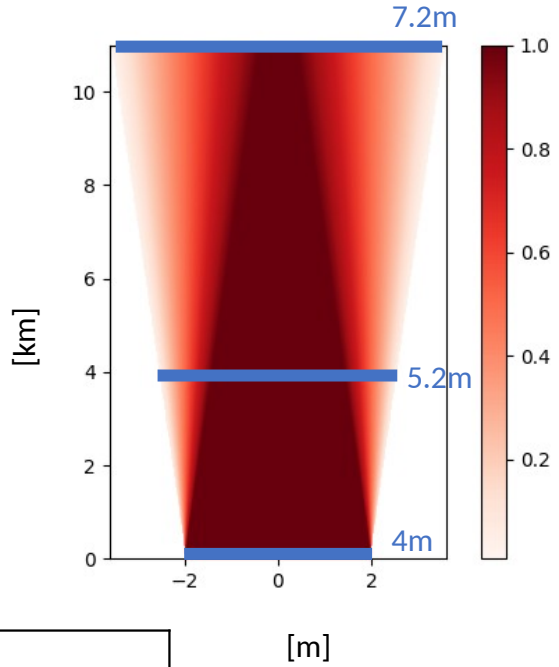




Number of sensors	9
Field of each sensor	11”
Spatial sampling	0.09m
Correction frequency	2 kHz
Angular sampling	0.5”
Detector size	980^2

Layer oriented





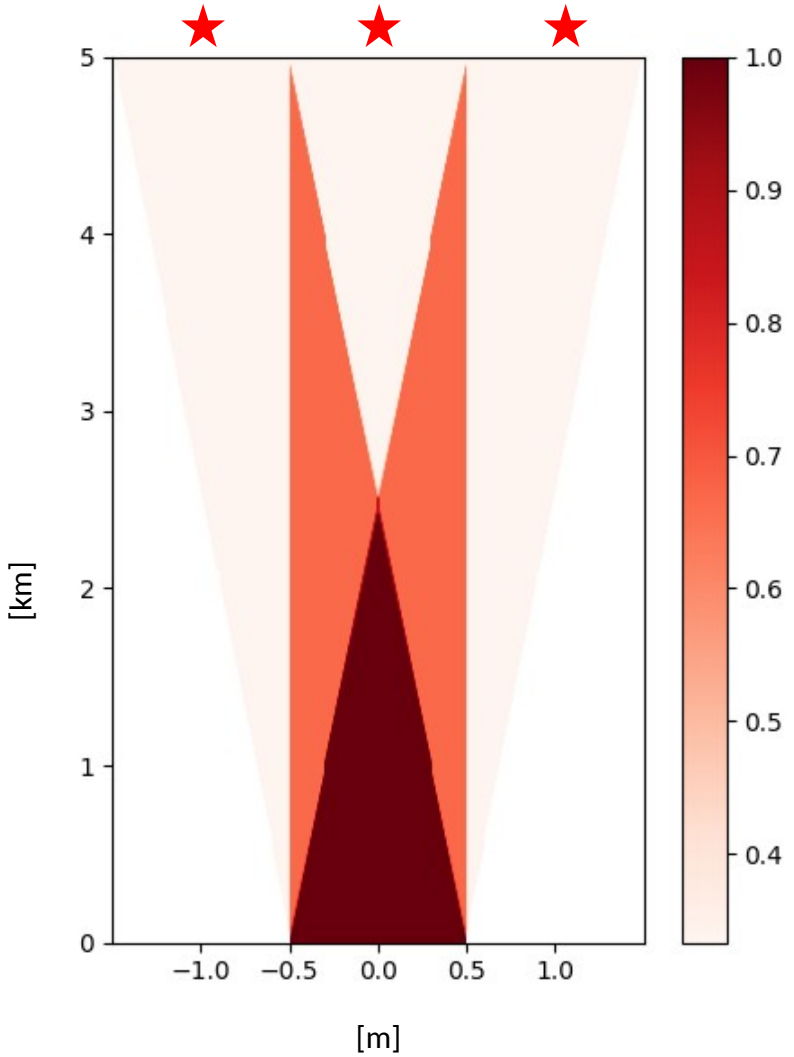
Number of sensors	3
Field of each sensor	60”
Spatial sampling	0.2m – 0.3m – 0.5m
Correction frequency	2 kHz – 1kHz – 1kHz
Angular sampling	0.5”
Detector size	2400^2 - 2080^2 - 1730^2

Conclusions

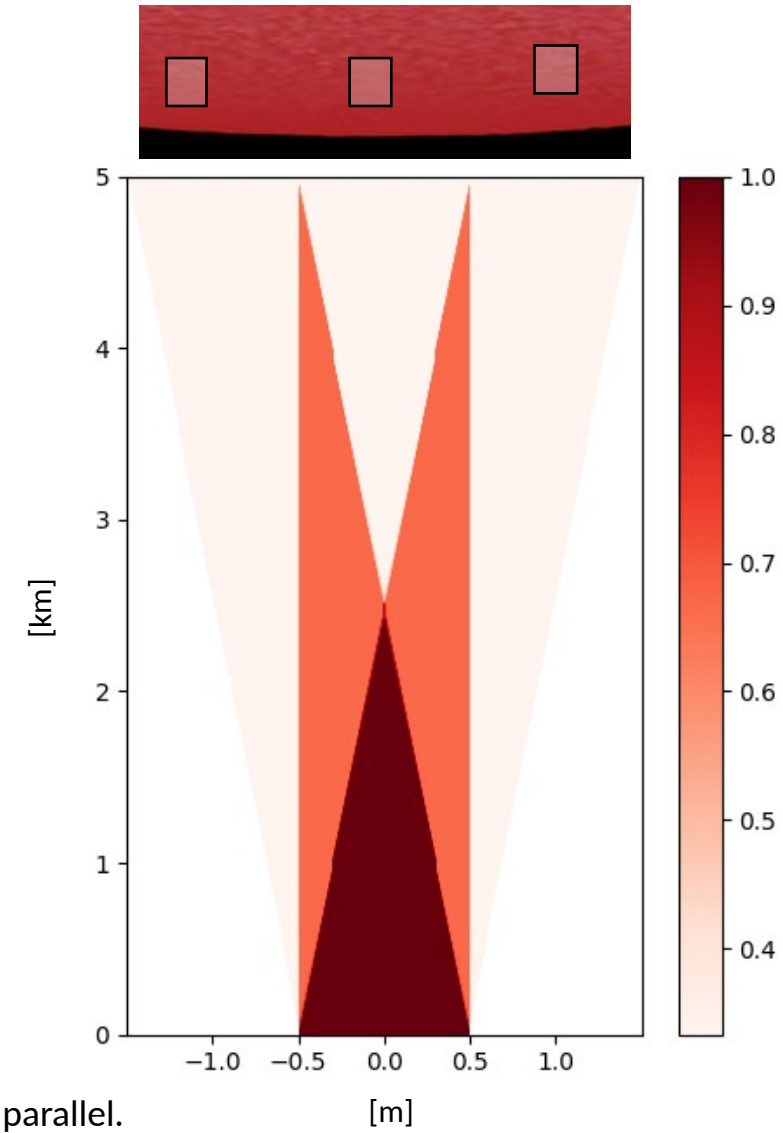
- The Sun, as an extended object, is ideally suited for layer oriented MCAO:
  - Tomographic reconstruction is optimal.
- No computational effort required for tomographic reconstruction. Done optically.
- Images recorded by the wavefront sensor are vignetted.
  - This is inherent to the layer-oriented approach.
  - Requires to modify data analysis procedures.
- Requires large detectors
  - Each SH subaperture should image the entire field. Technological challenge on detectors.
- Requires less wavefront sensors than typical star-oriented MCAO:
  - One sensor per deformable mirror.
- Each sensor - mirror pair works in an independent loop:
  - Each sensor tuned to its layer in terms of temporal and spatial sampling.

Star oriented MCAO

Night-time astronomy



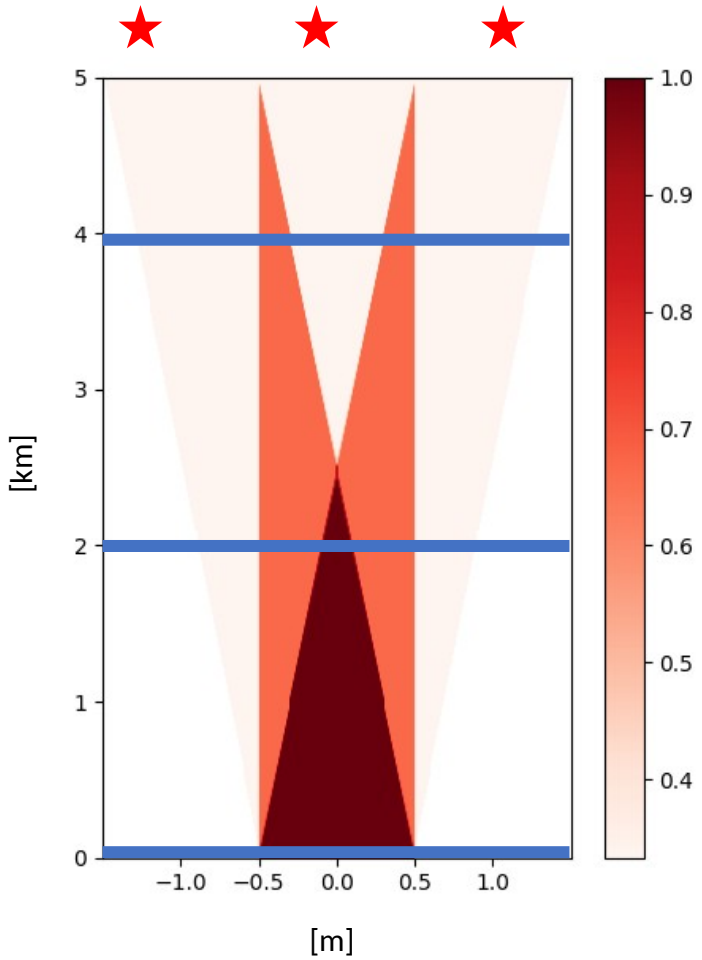
Solar astronomy



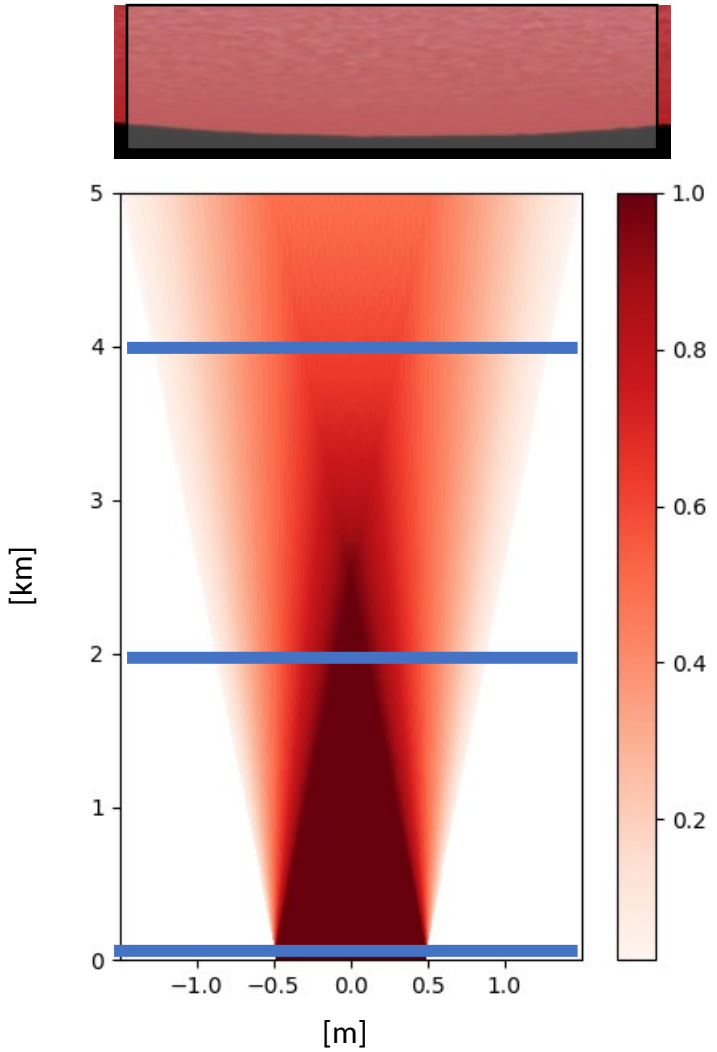
Star oriented MCAO is equivalent to having several, classic AO sensors working in parallel.
On the Sun, each sensor is pointed onto a small field.
Tomographic reconstruction is done numerically.

Layer oriented MCAO

Night-time astronomy



Solar astronomy



The main advantage of layer oriented MCAO is its field averaging property.
This property is best used on an extended object (light everywhere within the field).
Solar astronomy is therefore ideal for layer oriented MCAO.