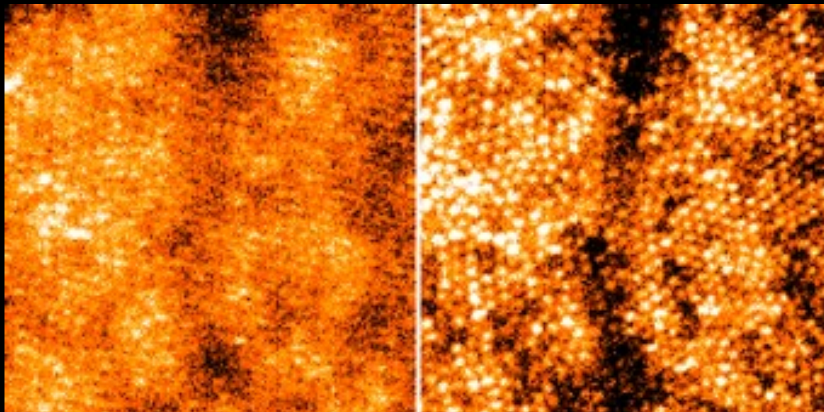
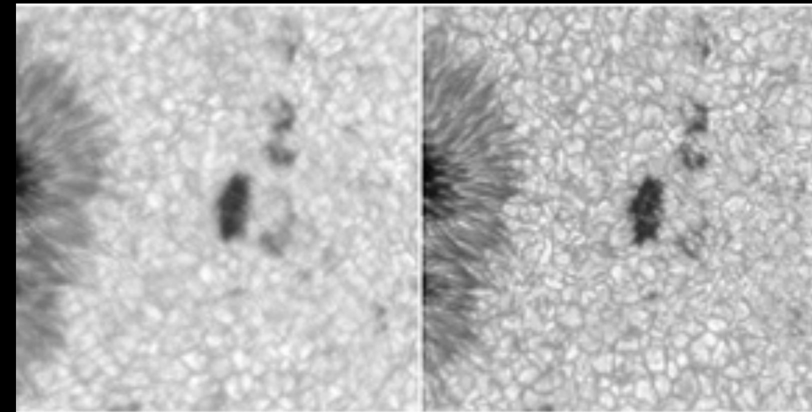
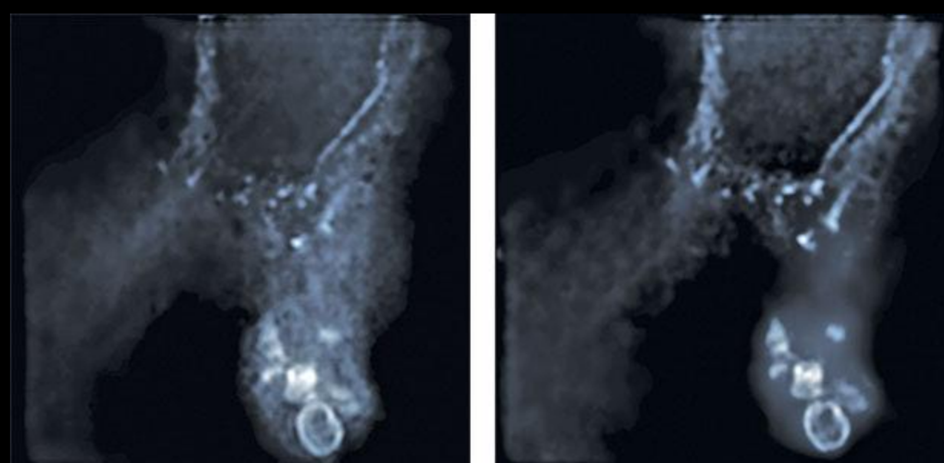




Adaptive Optics

Special Topic in Astrophysics

ASTRON 250 - Fall 2013



AO for solar astronomy: context

- Day-time *vs.* night-time
  - Poorer seeing (1.5-4'')

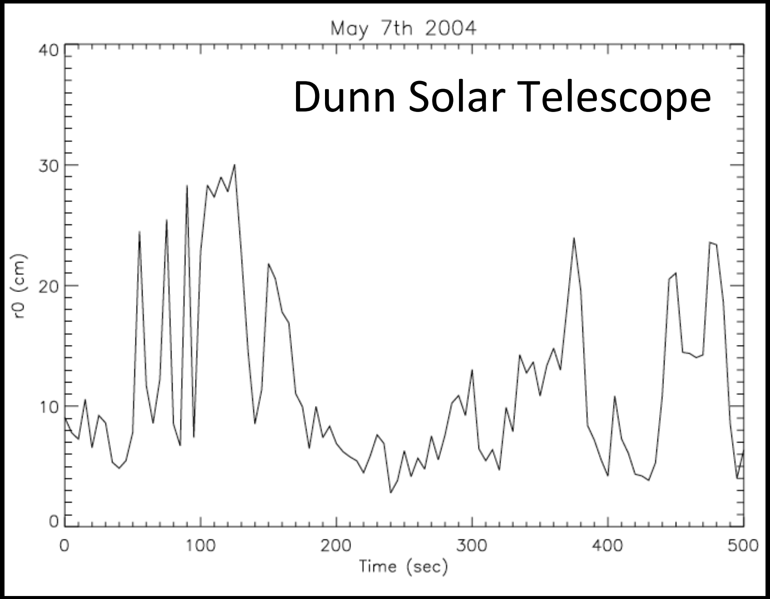
Night time conditions:
r_0 = 10-25 cm

Period/Site	EAM	LAM	EPM	LPM	All Days
Apr.–Jun.					
Big Bear	6.57	6.64	5.85	4.45	6.21
Haleakala	5.04	2.79	2.42	3.57	3.03
La Palma	5.49	3.48	3.17	3.42	3.65
Panguitch Lake	4.08	3.87	3.51	3.14	3.77
Sacramento Peak	4.86	2.65	1.93	2.13	2.40
San Pedro Martir	4.37	2.99	2.54	3.09	3.00
TUG	5.55	4.28	4.63	–	4.89
Jul. – Sep.					
Big Bear	6.34	7.13	6.50	4.93	6.45
Haleakala	5.40	3.12	2.71	3.53	3.33
La Palma	5.47	3.55	3.22	3.72	3.73
Panguitch Lake	4.15	3.63	2.92	3.53	3.59
Sacramento Peak	5.16	2.65	2.05	2.19	3.13
San Pedro Martir	3.91	2.66	2.19	2.42	2.73
TUG	5.36	3.16	2.65	2.83	3.56
Oct. – Dec.					
Big Bear	5.28	6.61	5.71	5.44	5.93
Haleakala	5.86	3.58	2.74	3.38	3.57
La Palma	4.08	2.90	2.66	3.20	2.96
Panguitch Lake	2.48	2.88	2.79	2.75	2.77
Sacramento Peak	4.90	2.96	2.20	2.58	2.72
San Pedro Martir	–	–	–	–	–
TUG	6.95	6.40	5.15	4.73	6.12

Ozisik et al. (2004)

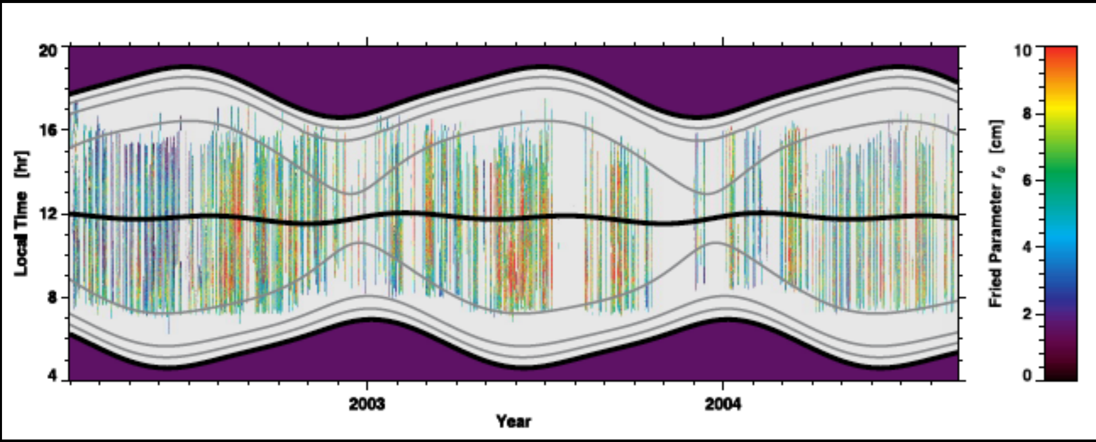
AO for solar astronomy: context

- Day-time *vs.* night-time: atmosphere
  - Poorer seeing
  - Strong, rapid fluctuations



Marino et al. (2004)

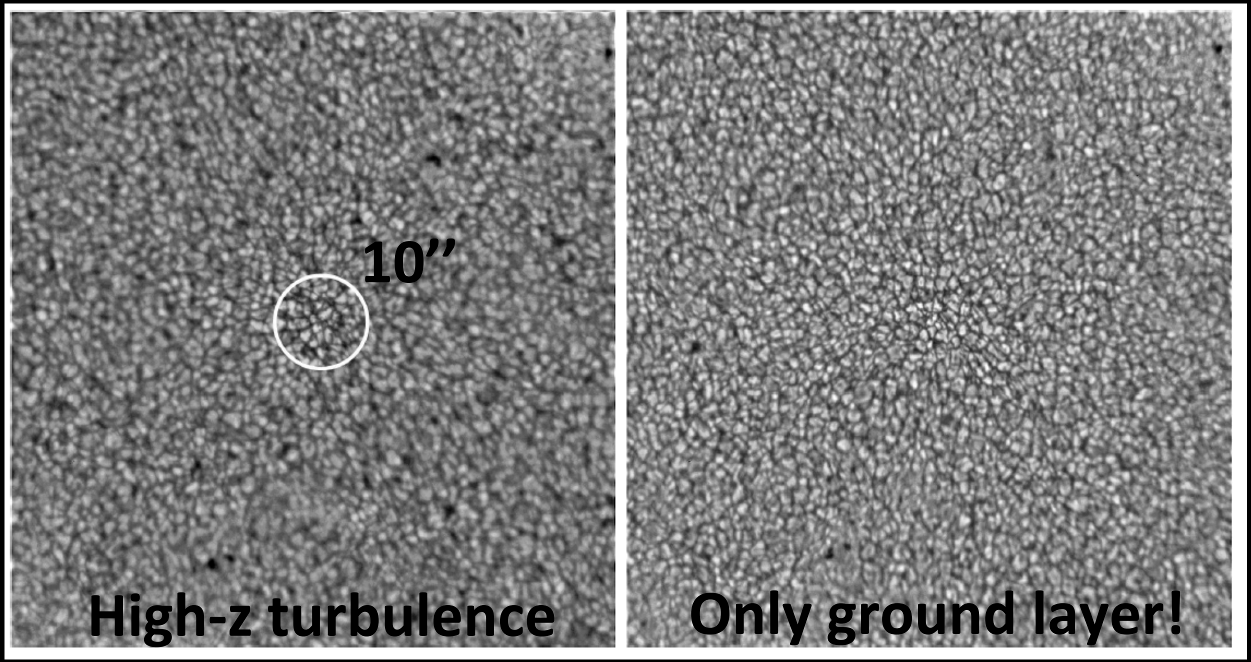
Big Bear Solar Observatory



Verdoni et al. (2007)

AO for solar astronomy: context

- Day-time *vs.* night-time: atmosphere
  - Poorer seeing
  - Strong, rapid fluctuations
  - Chromatic anisoplanatism



Rimmele & Marino (2011)

AO for solar astronomy: context

- Day-time *vs.* night-time: atmosphere
  - Poorer seeing
  - Strong, rapid fluctuations
  - Chromatic anisoplanatism
- Importance of surface layer
  - Elevate telescopes!
  - Potentially large θ_0

Swedish 1m Telescope (La Palma)

AO for solar astronomy: context

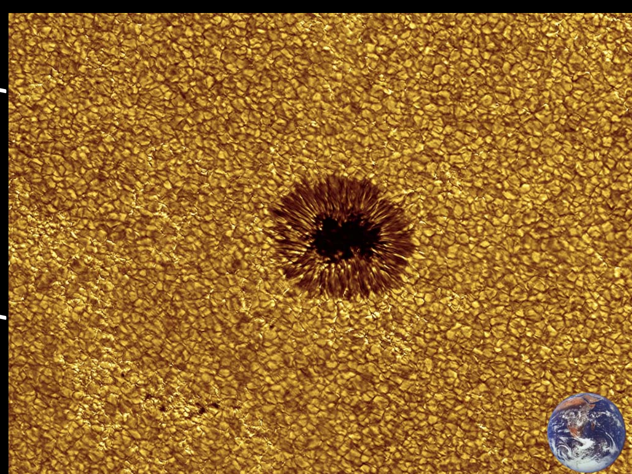
- Day-time *vs.* night-time: atmosphere
  - Poorer seeing
  - Strong, rapid fluctuations
  - Chromatic anisoplanatism
- Importance of surface layer
  - Elevate telescopes!
  - Potentially large θ_0
- Observations conducted in the visible
  - All turbulence factors are (much) worse!

AO for solar astronomy: context

- Good night-time sites are good day-time sites
  - e.g., Haleakala site selected for upcoming ATST
- Solar telescopes are "small" (currently: D ≈ 1m; ATST: D ≈ 4m)
  - Not light-starved!
  - Compensates for small r_0 and short λ
  - Still, high number of actuators needed for good correction: $N_{act} \approx (D/r_0)^2 \approx 100s$ even for D = 1m

AO for solar astronomy

- Day-time *vs.* night-time: guide star
  - The Sun is an extended source (~32’)
  - Sunspots (~15’’), not everywhere on the surface
  - Low contrast, fast-changing surface granulation (~1’’)

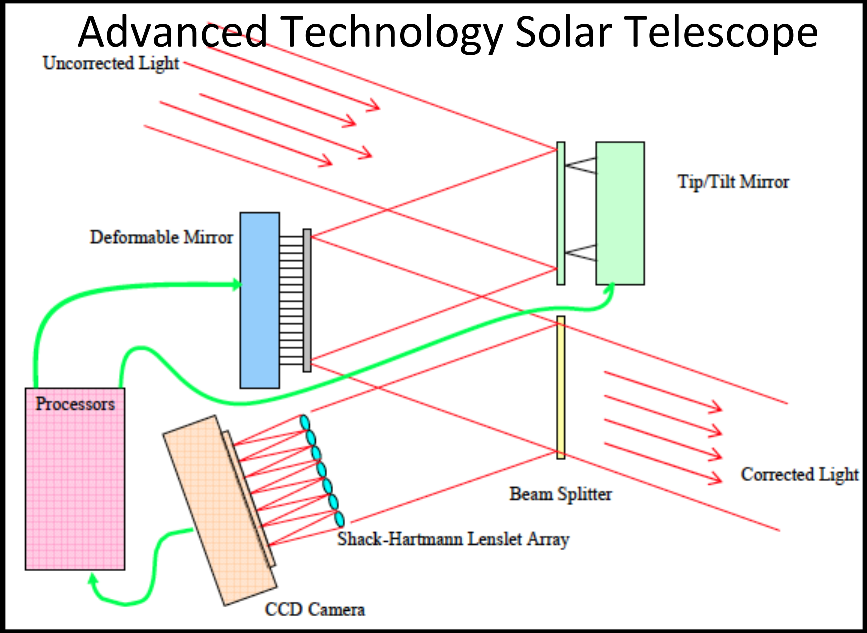


Dutch Open Telescope

© NASA

Basics of a solar AO system

- Basic AO set-up is very similar to night-time AO
  - Shack-Hartmann sensor
  - Matrix reconstruction
  - Piezoelectric, continuous facesheet DM
  - Woofer-tweeter setup
- Other setups exist



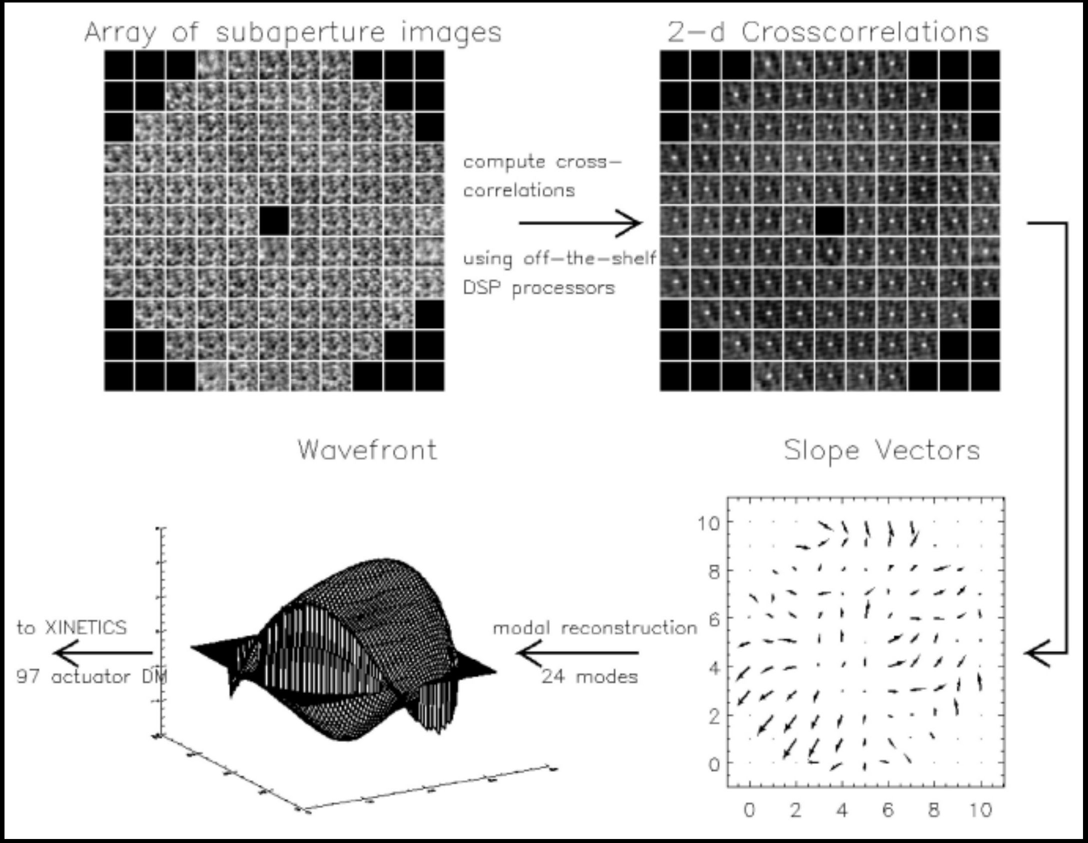
Richards & Rimmele (2008)

Wavefront sensing

- S-H WFS normally relies on a reference target that is bright and small
  - Works with well-contrasted sunspots and pores
  - Severe limitation in "Sun coverage"
- More useful is the granulation, but it is low contrast (~2% at best) and short-lived (≈1 min)
- "Derivative focal mask" is a generalization of Foucault's knife-edge for extended source

Wavefront sensing

- The most advanced WFS technique uses a correlating S-H sensor (more CPU demanding!)



Rimmele & Marino (2011)

Wavefront sensing

- The most advanced WFS technique uses a correlating S-H sensor (more CPU demanding!)
  – Potentially useful in many other settings: better noise properties and deals with extended source
- Solar AO has a significant potential gain in using phase diversity WFS
  – Complex, extended illuminating source
  – Turbulence varies much faster than object itself
  – Severe requirements for real-time processing

For more on the topic

- Great review of science drivers, history, technical implementation and future of the solar AO field:
  - *Rimmele & Marino (2011)*

Next week readings

- Laser guide stars in astronomy
  - Foy & Labeyrie (1985)
  - Happer et al. (1994)
  - Tyson's book (§3.3)
- AO for biological microscopy (J. Kubby's remote presentation)