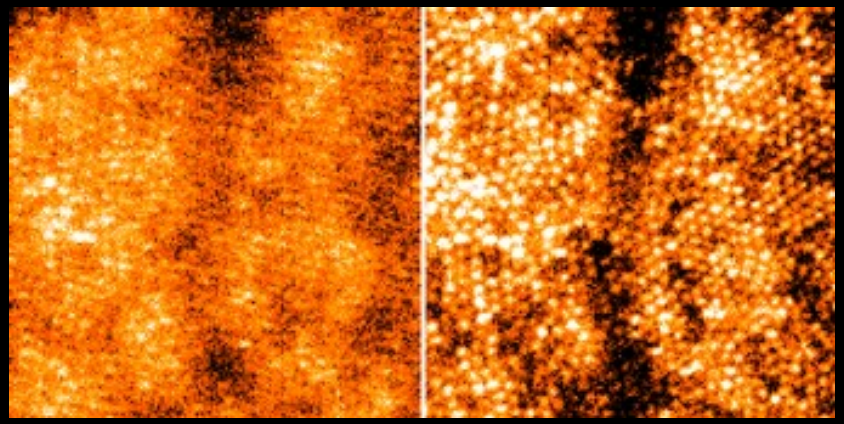
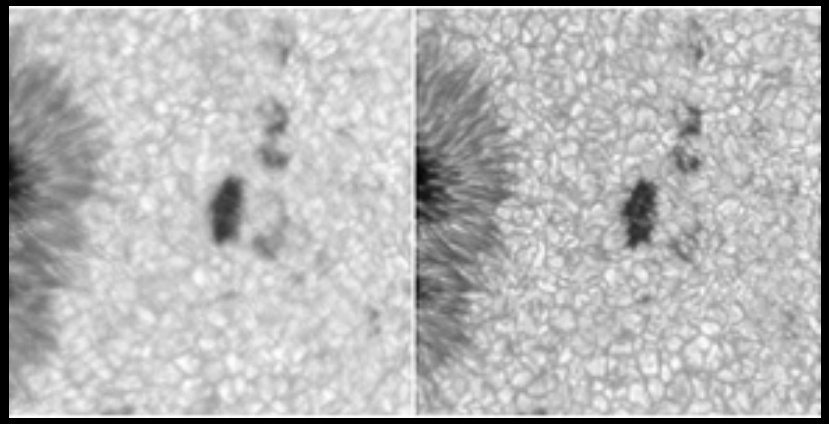
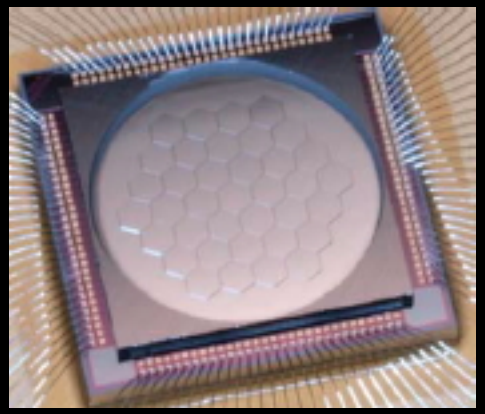


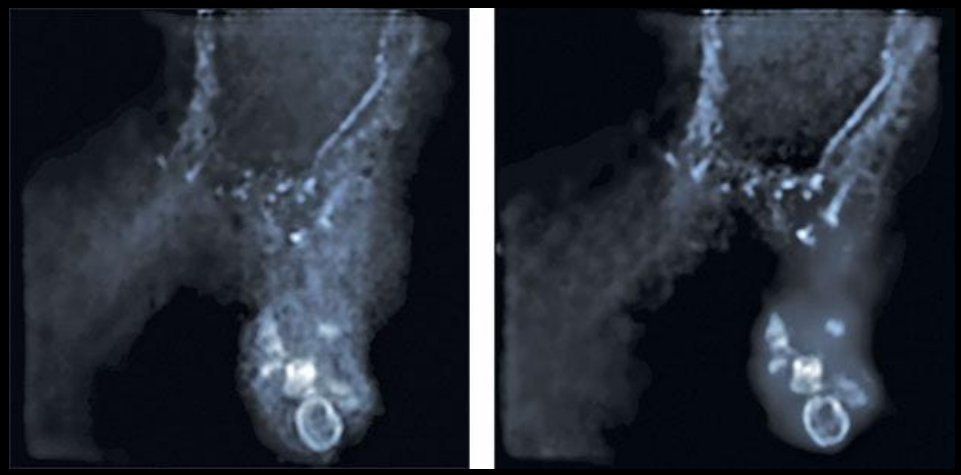


Adaptive Optics

Special Topic in Astrophysics

ASTRON 250 - Fall 2013





AO with/for high-power lasers

- J. Ballesta cannot come today
- Possibility: a visit of a high-power laser and its AO system at LBL (+ Jerome's presentation)
  - Week of 12/9-12
  - Interest? Possible day & timeslot?

Class project

- One-on-one meeting before Thanksgiving
  - Set day/time now?
- Format: 15’ presentation + 10’ Q&A
  - questions *after* presentation
- 10-page paper (not including figures)
- Your goal: teach something to all of us

Class wrap-up

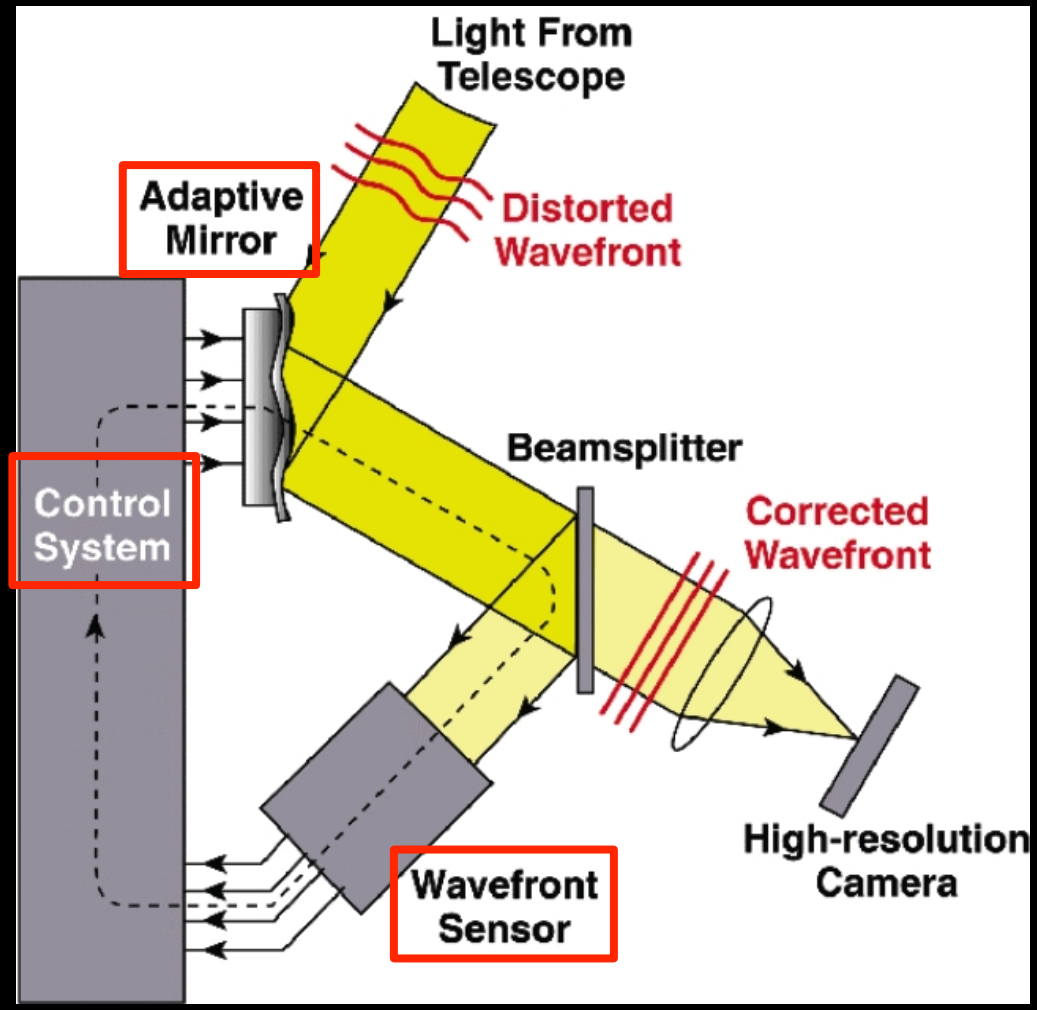
Keywords


AO
WFS
wavefront
turbulence
r0
system
frequency
aberrations
pupil
sensing
high
phase
image
images
DM
plane
correction
layer
PSF
OTF
diffraction-limited
Image
source
control
reconstruction
modes
small
simple
Shack-Hartmann
Strehl-Ratio
LGS
optics
atmosphere
function
actuators
light
many
effect
Use
sources
data
scale
tip-tilt
size
FOV
best
Quality
wind
single
relative
Pupil
science
star
astronomy
layers
focus
et
limited
slope
actuator
edge
speckles
multiple
astronomical
Need
spot
noise
vs
Fourier
τ0
time
Complex
conjugated
depends
Cn2
use
decomposition
local
errors
5/3
methods
fluctuations
commands
limit
ratio
Two
σφ2
Many
adjust
optical
loop
guide
properties
techniques
diversity
large
one
goal
quality
first
corrected
knowledge
gain
exposures
Telescope
stars
exposure
set-up
Spatial
FWHM
laser
needed
spatial
Requires
described
matrix
night-time
elements
Modal
case
imaging
correct
exp
surface
factors
telescopes
Short
domain
number
short
mirror
better
constant
path
diffraction
Single
Phase
σφ
al
different
information
possible
aberration
much
important
response
point
position

Keywords

Removed: AO, WFS, DM, wavefront

AO: the basic concept



Basic goal: correct for optical aberrations

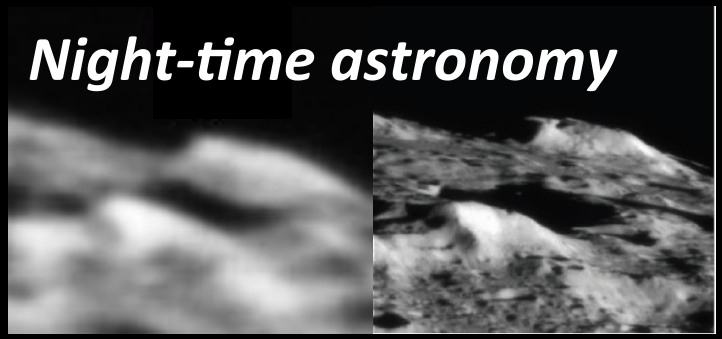
High-resolution imaging

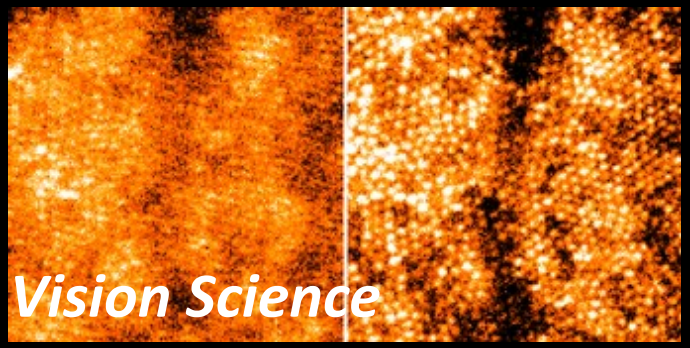
Image quality boosting

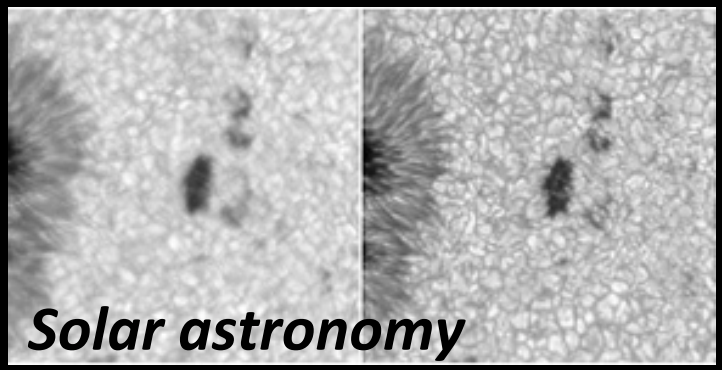
Beam control/quality

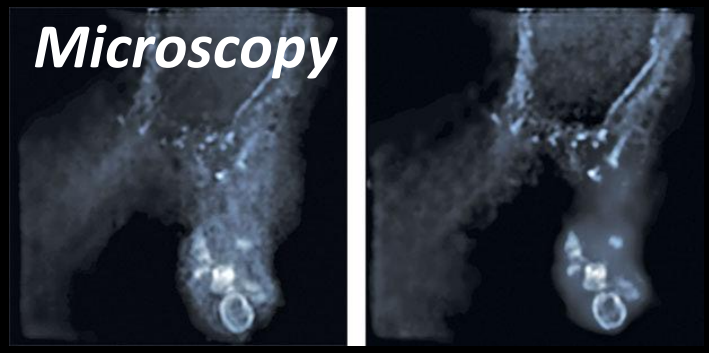
Fiber coupling with adaptive optics for free-space optical communication

AO in a variety of fields









Low-noise adaptive optics for gravitational wave interferometers

Adaptive Optics for High-Peak-Power Lasers – An Optical Adaptive Closed-Loop Used for High-Energy Short-Pulse Laser Facilities: Laser Wave-Front Correction and Focal-Spot Shaping

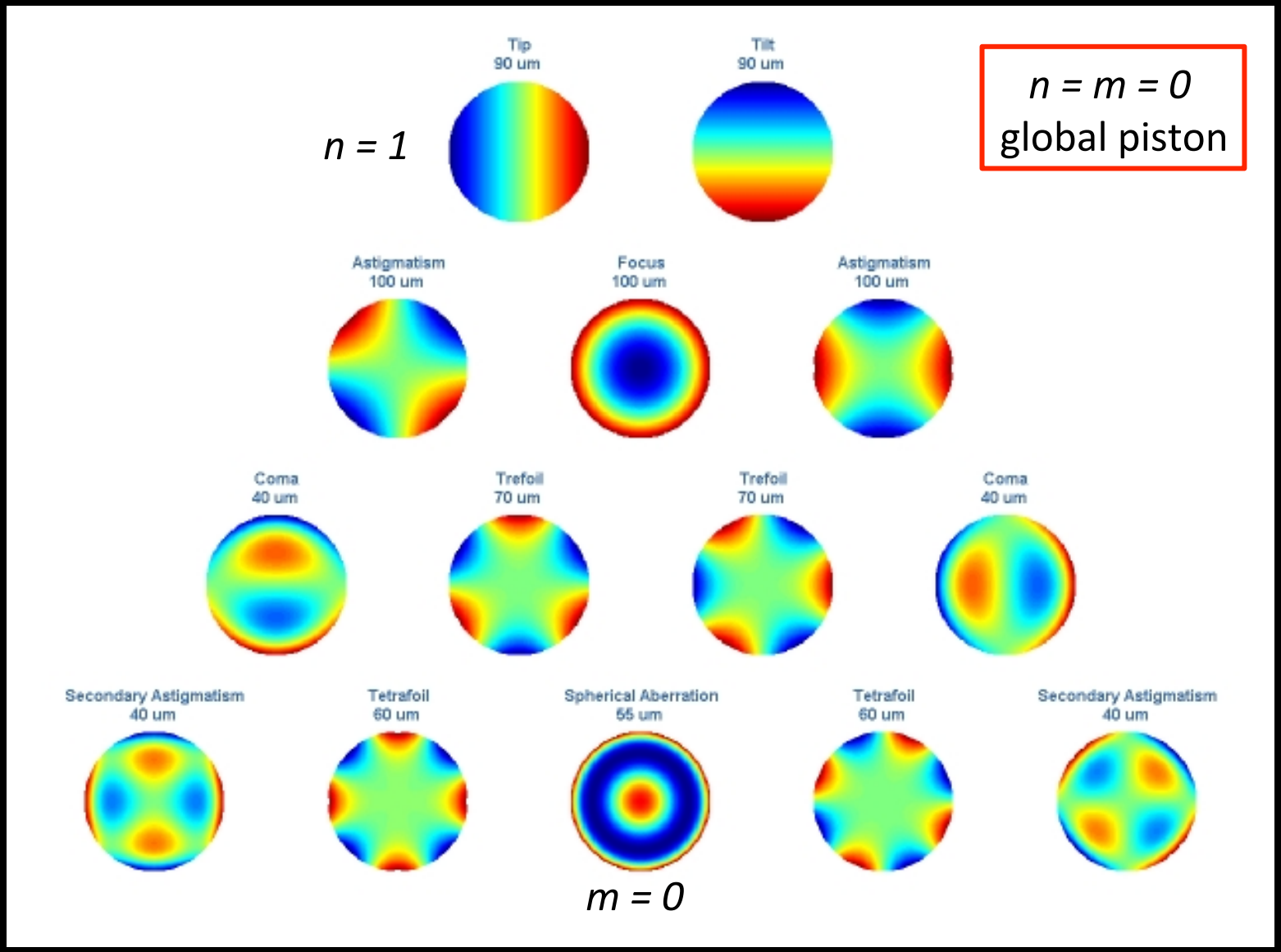
Microelectronics and Microsystems
Optical Military Systems

Adaptive Optical Systems

Know your enemy!

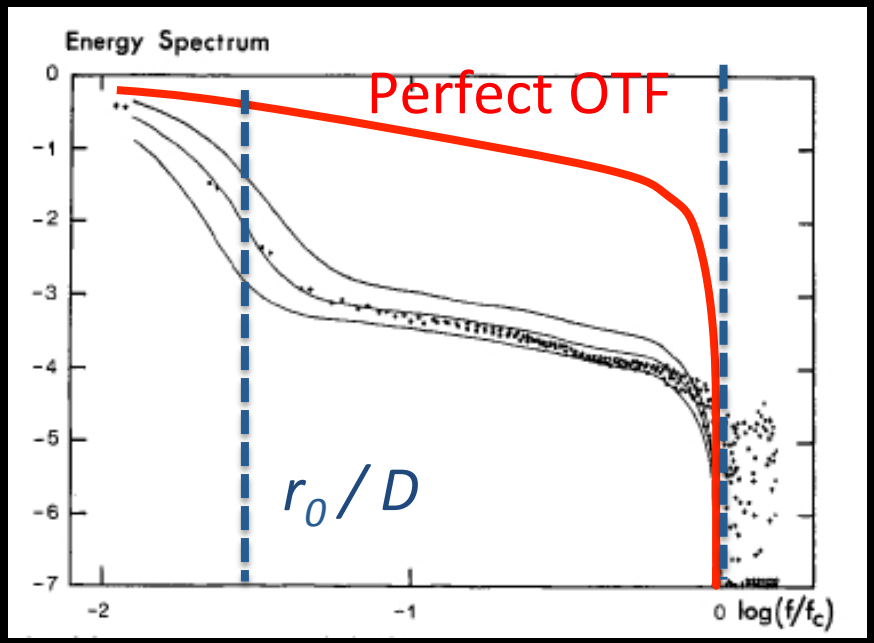
- One needs to understand (and measure) the properties of aberrations to correct for them, or anticipate their effects on the image
  - Ideally precisely (for static aberrations)
  - If they are randomly variable, key statistical properties and power spectrum can be enough
- Situations are drastically different in the many applications of AO

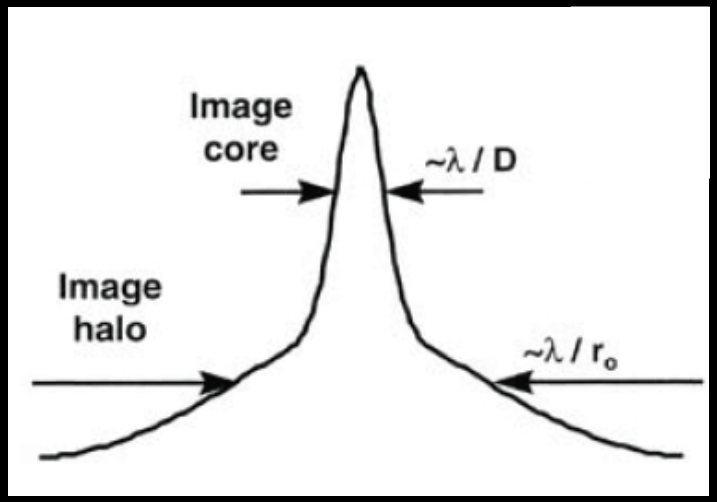
A natural basis to describe aberrations



Optical conjugation

- Pupil and image planes are conjugated
  - E/B fields in the pupil and image planes are connected via a Fourier transform
  - Similarly, PSF = FT[OTF]





Wavefront sensing

Image plane	Sharpening	Conceptually simple	“blind”, slow
	Phase diversity	Single detector/opt. path	Difficult inversion problem, esp. if object is resolved
Pupil plane: Modal		Direct measurement of most important modes (T/T, focus)	Limited to low-order
Pupil plane: Zonal	Shearing Interferom.	No reference source needed	Requires narrow-band filtering
	S.-H.	Conceptually simple Sensitivity to larger aberrations	Fixed discretization Complicated optics
	Pyramid	Higher resolution than S.-H. Variable gain built-in	Continuous control required
	Curvature	Simplicity for low-order	Scaling to high-order difficult

Deformable mirrors

Continuous	Segmented
Smooth WF surface No loss of light (gaps) Modal correction	**Easier control** Larger strokes Scalable to many actuators Microchip-sized option
Cross-actuator influence “Dead” actuators problem Smaller strokes Hysteresis Larger physical size	**Discretization of WF** **Edge discontinuities** Loss of light in gaps Diffraction off edges

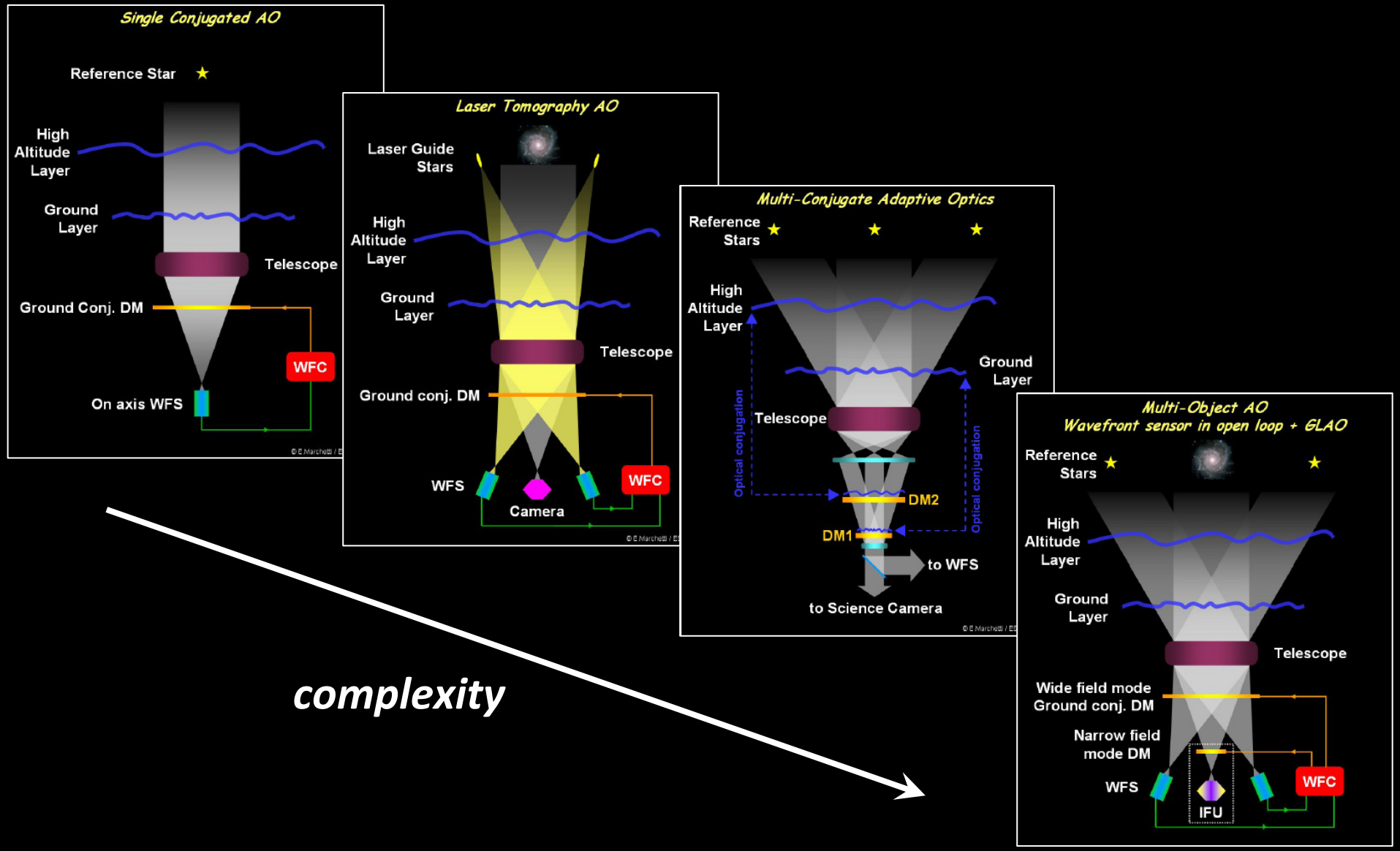
Another approach: Spatial Light Modulator

Control loop

- Direct WFS-DM link (Babcok's idea)
- Matrix-vector multiplication
  - Pseudo-inverse / least square approach
  - Singular value decomposition
  - Sparse matrix techniques
- Fourier Transform reconstructor

- Fixed / Adjustable control scheme

Many possible AO architectures



Error budget

Fitting errors

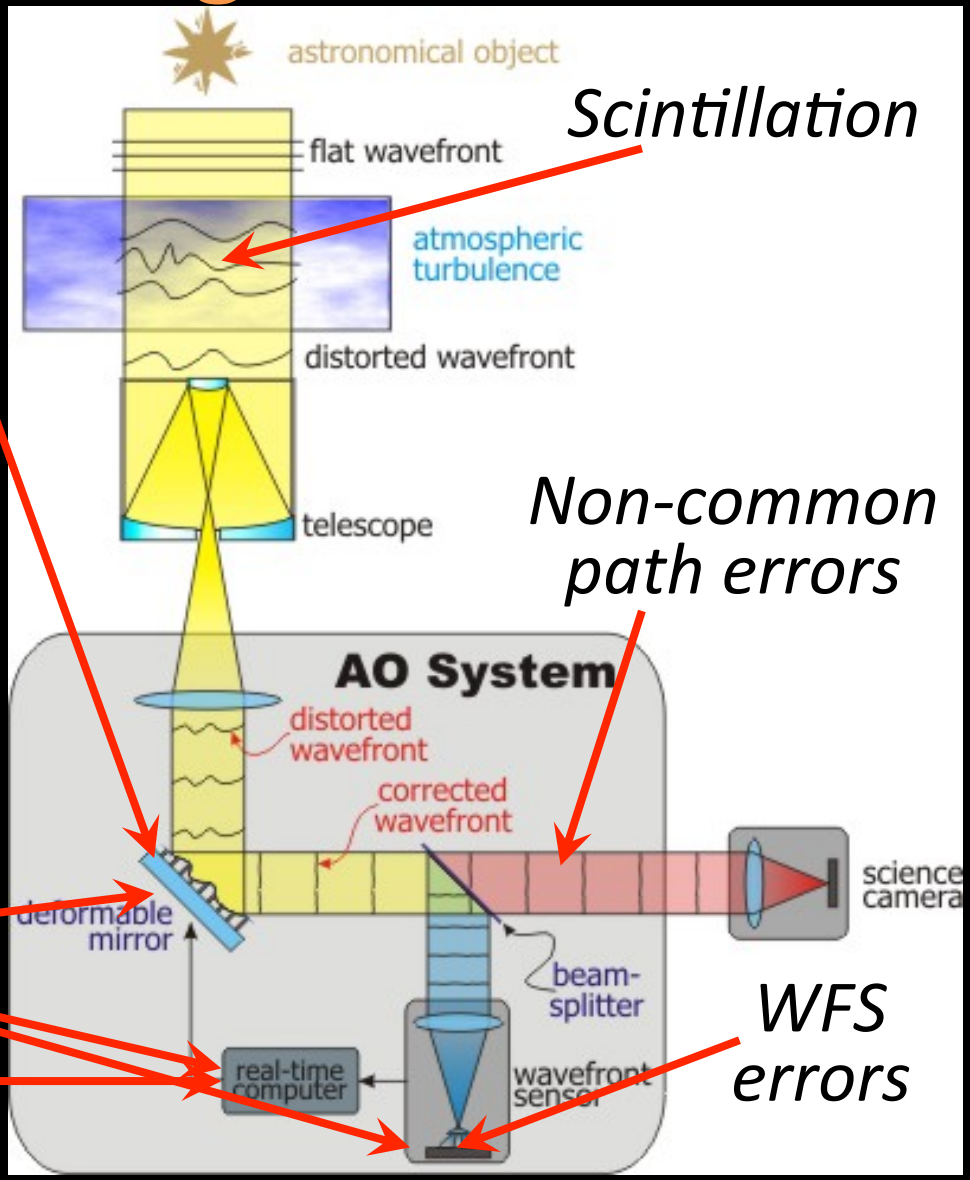
- Anisoplanatism
- Averaging within subapertures

- DM influence function
- Interactions between DMs
- WFS sampling errors

- Electronic noises
- Dynamic calibration errors
- Extraneous modes (vibrations)

Bandwidth errors

Reconstruction errors



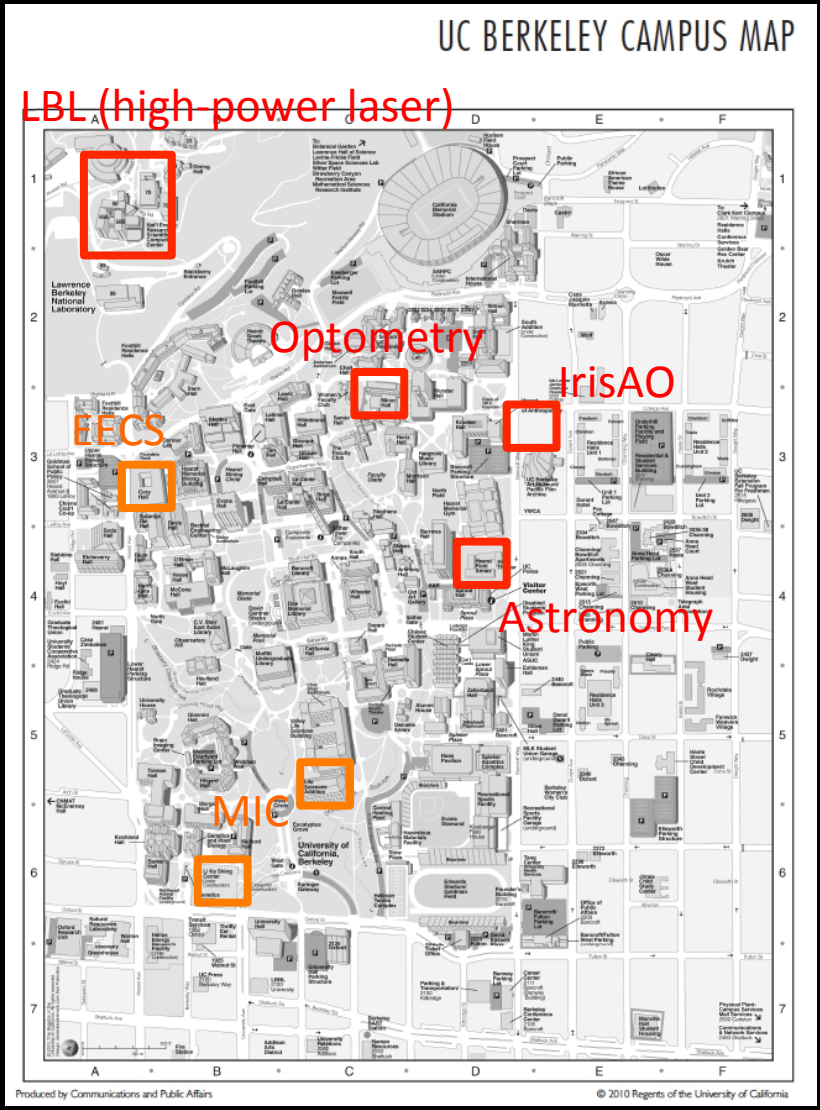
Scintillation

Non-common path errors

WFS errors

Ask an unanswered question!

World-wide topic, local expertise



External resources

- Key readings
  - *Principles of AO*, R. Tyson [Eng.]
  - *AO in astronomy*, F. Roddier ed. [Phy./Ast.]
  - *AO for astronomical telescopes*, J. Hardy [Phy./Ast.]
  - *AO for biological imaging*, J. Kubby ed. [e-book]
  - Many research articles (back to the source!)
- Websites
  - UC *Center for AO* (CfAO) cfao.ucolick.org
  - Many more…

Keywords

Removed: AO, WFS, DM, wavefront