Clearing Our View of the Universe with Adaptive Optics

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It is blurry from down here.

“For the Air through we look upon the Stars, is in perpetual Tremor …cause the Star to appear broader than it is…”

Sir Isaac Newton

Christiaan Huygens
So what’s going on with the atmosphere?

• The sun heats the ground.
• Hot air rises and mixes with cold air.
• The index of refraction of air changes with temperature.
• Light from stars is passing through a dynamic lens.
Newton and Huygens were on to something!
Solutions proposed in the 1950s

Horace Babcock (U.S.A.)


V. P. Linnik (U.S.S.R.)

Independent proposal for adaptive optics systems and their limitations.
Modern Adaptive Optics

Astrophysical objects

Atmospheric turbulence

Distorted light waves

Telescope

Deformable mirror

Science camera
Astrophysical objects

Laser guide star

Atmospheric turbulence

Distorted light waves

Telescope

Laser

Wavefront sensor

Lenslet array

Computer

Science camera
Adaptive Optics  OFF
Adaptive Optics  ON
Adaptive Optics  OFF
Adaptive Optics  ON
Adaptive Optics  OFF
Adaptive Optics ON
Jupiter’s Moon Ganymede

2.4-m Hubble Space Telescope

Adaptive Optics on 5.1-m Hale Telescope
4 gas giant planets around HR8977, ~10,000 times fainter.
Adaptive Optics Components

- Astrophysical objects
- Laser guide star
- Atmospheric turbulence
- Distorted light waves
- Telescope
- Laser
- Wavefront sensor
- Lenslet array
- Deformable mirror
- Computer
- Science camera
Laser

Commercial 12 W Ultraviolet Laser
Laser drilling and scribing

(Nilsson et al., 2004)
Laser beam projector
Adaptive Optics Components

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Measuring the shape of light

Shack-Hartmann wavefront sensor

Flat → Lenslet array → Images on detector

Light wave

Non-planar
High-order Wavefront Sensor
Deformable mirrors affect light waves

B E F O R E

A F T E R

Incoming Wave with Aberration  Deformable Mirror  Corrected Wavefront

Credit: Claire Max
Deformable mirrors affect light waves
Deformable mirrors

Electrostatically actuated diaphragm

Attachment post

Membrane mirror
Silicon deformable mirror
The entire system
Robo-AO on the Palomar 60” telescope

Robotic Software

Adaptive Optics System + Vis/NIR Science Instruments

Laser guide star

Robotic Telescope (P60)
Maunakea is an excellent site, best for adaptive optics

HST-like resolution

On-sky in ~2 years

Testing of cutting-edge technologies

Graduate and local undergraduate student research!
Adaptive optics is great for high-tech student education.
Mahalo!

http://robo-ao.org