INTRODUCTORY SUMMER SCHOOL IN ASTRONOMY AND ASTROPHYSICS

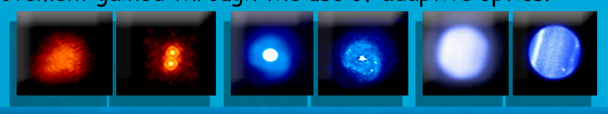
ADAPTIVE OPTICS

MAY 7 – JUNE 8, 2012

"The twinkling stars always mesmerized me as a child
but as an astronomer i wish that they (the stars) never twinkled" -Anonymous

WHAT IS ADAPTIVE OPTICS?

Adaptive optics is a technique employed that allow ground-based telescopes to adjust for the blurring effects of the Earth's atmosphere.The image below shows the dramatic improvement gained through the use of adaptive optics.



ATMOSPHERIC TURBULENCE LIMITED IMAGING

When light from a star or another astronomical object enters the Earth's atmosphere, the turbulence caused by variation of temperatures (and thus the refractive index) distorts the wavefront. So, even with a very large aperture the image quality obainted is limited by the atmospheric seeing condition for large telescopes. Until the advances in adaptive optics the only solution was to put a telescpe in space, which is indeed very expensive...

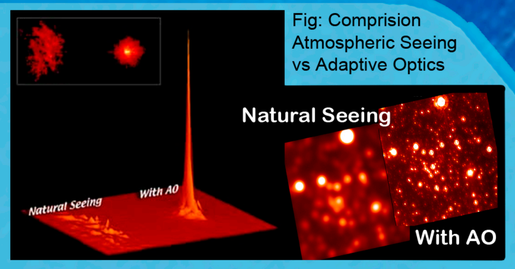
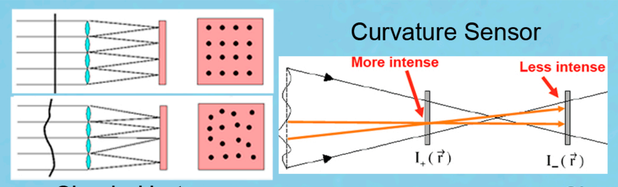


Fig: Comprision Atmospheric Seeing vs Adaptive Optics

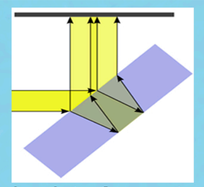
WAVE FRONT SENSORS

A wavefront sensor is a device for measuring the aberrations of an optical wavefront. Various commonly used types are:

1. Shack- Hartman
2. Curvature Sensor
3. Shearing Interferometer



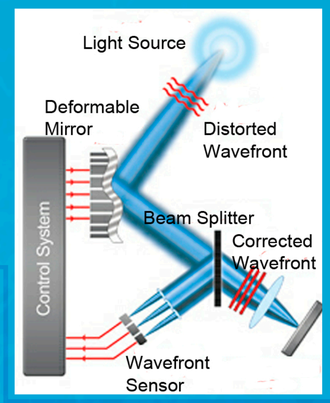
Shack- Hartman



Shearing Interferometer

ADAPTIVE OPTICS SYSTEM

The light coming from the star is first collected and focused by the telescope, part of the light is collimated into an adaptive optics system where it get reflected off a deformable mirror.
After reflecting off the deformable mirror, the light passes through a beam splitter where a part of the beam enters the wave-front sensor which takes a snapshot of the distortions on the wave-front and sends the information via a computer back to the deformable mirror to adjust the wave-front and keep the wavefront flat. Finally the light is focused and imaged on the detector.



NATURAL AND LASER GUIDE STARS

Adaptive optics systems require a wavefront reference source in order to correct atmospheric distortion of light. Sufficiently bright stars are not available in all parts of the sky, which greatly limits usefulness of natural guide based AO. Laser guide stars are a form of artificial star created as an reference for imaging by shining a laser into the atmosphere. This star can be positioned anywhere the telescope desires to point, opening up much greater amounts of the sky to adaptive optics.

Types of Laser Guide Stars
- Rayleigh : 10-20 Kms
- Sodium : 90 Kms

ROBO AO

Robo-AO is an autonomous laser guide star adaptive optics (AO) system, delivering diffraction-limited resolution observing in the visible and near-infrared (0.1"-0.25") for up to hundreds of targets per night on modest sized telescopes. Robo-AO enables the exploration of science parameter spaces such as large targeted AO surveys, rapid AO imaging of transient events and long-term AO monitoring not feasible on large diameter telescopes.

THE THIRTY METER TELESCOPE

The proposed 30-meter telescope, operating in wavelengths ranging from the ultraviolet to the mid-infrared, will use adaptive optics to operate at diffraction limit and provide high-sensitivity spatial resolution more than 12 times sharper than what is achieved by the Hubble Space Telescope.

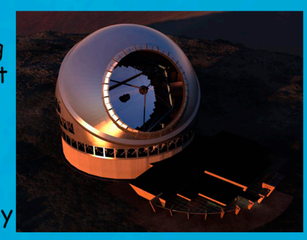
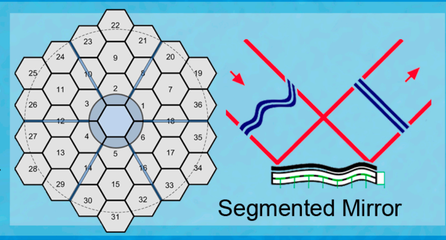


Fig: The Thirty meter Telescope

ADAPTIVE OPTICS SYSTEM
- TELESCOPE
- WAVEFRONT SENSOR
- DEFORMABLE MIRROR
- COMPUTER SERVO CONTROL

DEFORMABLE MIRROR

Deformable Mirrors(DM) are mirrors whose sureface can be deformed, in order to achive wavefront control and correction of optical abberations. Deformable mirrors are used in combination with wavefront sensors and real-time control systems in adaptice optics.



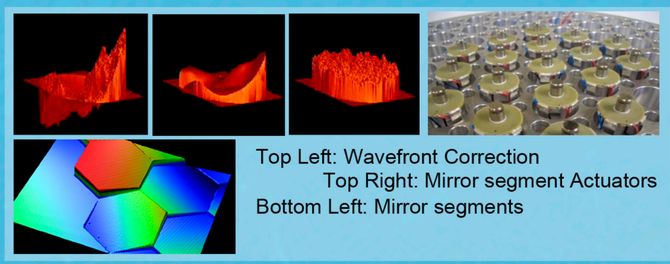
Segmented Mirror

Various types of Deformable Mirrors are:

1. Segmented Mirror
   - MEMS Deformable Mirror
2. Continuous faceplate Mirror
   - Bimorph Deformable Mirror
3. Edge actuated Mirror

COMPUTER SERVO CONTROL

Adaptive optics works in closed loop: the WFS measures any remaining deviations of the wave-front from ideal and sends the corresponding commands to the DM. The System controlling the deformable mirrors (say Servos) are controlled by a computer that calcuates the corrections and adjusts the various mirrors according the the feedback.



Top Left: Wavefront Correction
Top Right: Mirror segment Actuators
Bottom Left: Mirror segments

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REFRENCES

- Introduction to Adpative optics, Tyson
- MIT, Lincoln Lab Web, www.ll.mit.edu
- Wikipedia- www.wikipedia.org/Adaptiveoptics
- Adaptive Optics for Astronomical Telescopes, Hardy

KEYWORDS

Adaptive Optics, Imaging through turbulence, Wavefront correction, Very Large telescopes, IGO, TMT

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