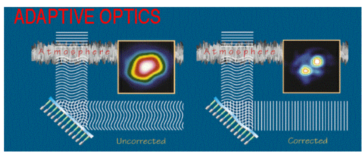
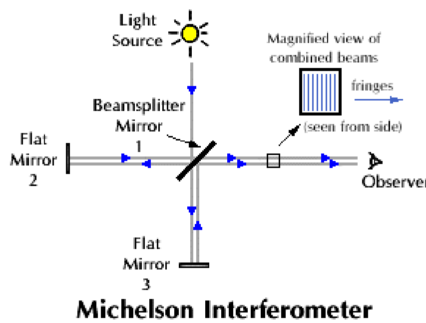
# Modern Techniques in Astronomical Observations

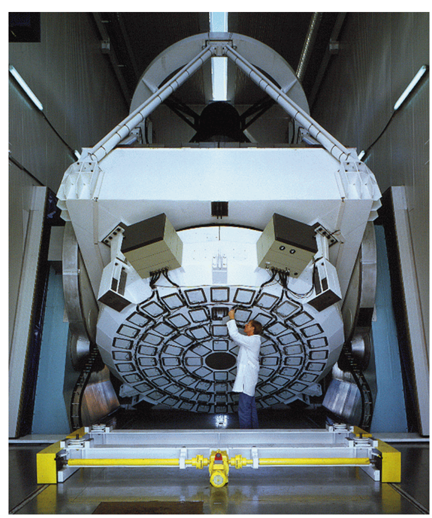
- Adaptive Optics
- Interferometry



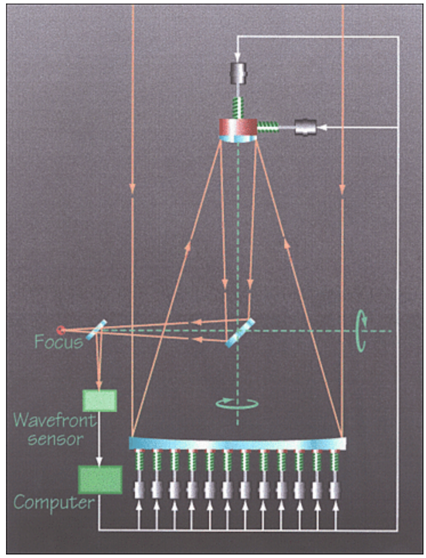




# Active Optics

Low temporal frequency ≤ 0.05 Hz adjustments of corrective optical elements to compensate for, e.g., thermal and mechanical distortions

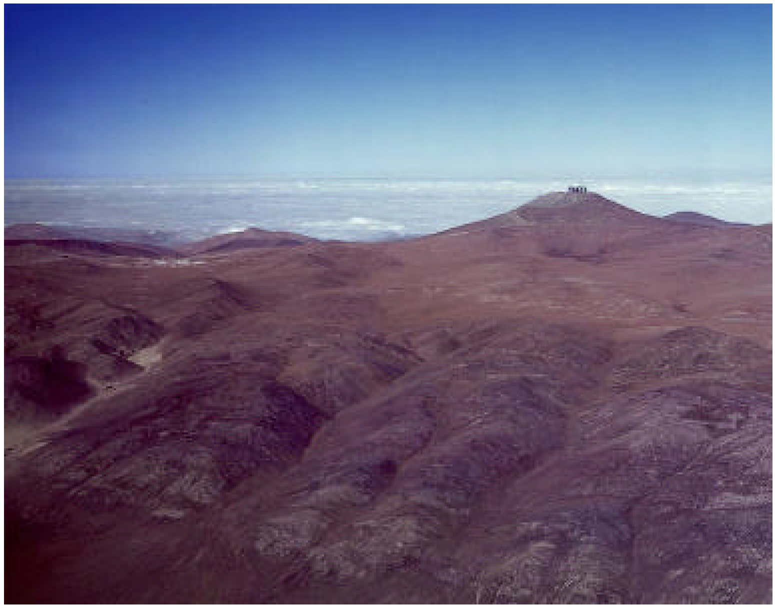


Active optics support of the main mirror (3.5 m) of the ESO New Technology Telescope (NTT)



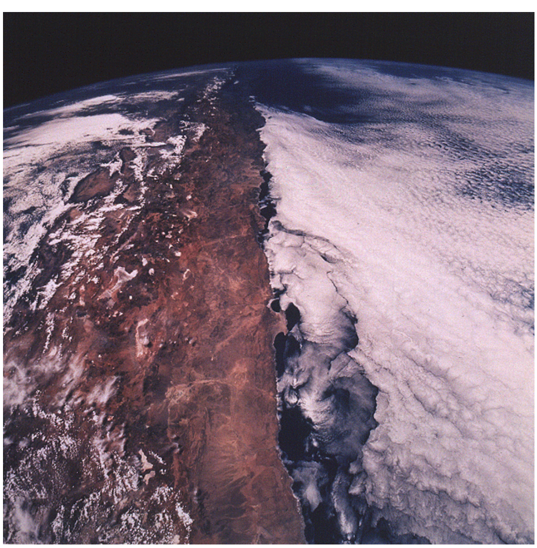

http://www.hq.eso.org/projects/vlt/unit-tel/actopt.html

La Silla, Chile



Cerro Paranal --- 2635m mountain, in northern Chile

Very Large Telescope (VLT) ---
Four 8-m telescopes in Cerro Paranal

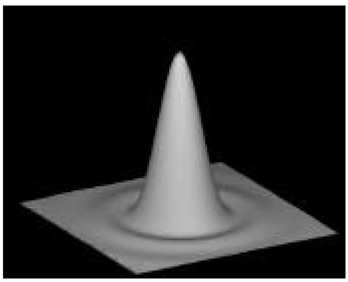
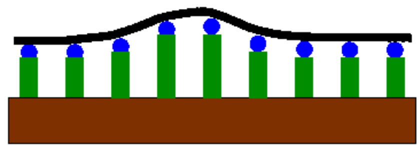


Space shuttle view of the Atacama Desert

http://www.eso.org/outreach/info-events/ut1fl/whitebook/

## Adaptive Optics

- optical systems which **adapt** to compensate for optical effects introduced by the medium between the object and its image.

http://www.ctio.noao.edu/~atokovin/tutorial/intro.html

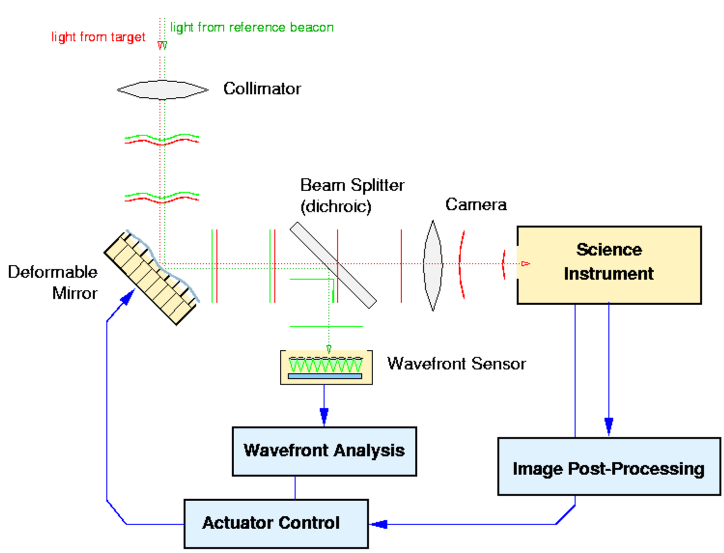
## Atmospheric Blurring on images

- $\alpha = 1.22\ \lambda/D$ [radian]
- So, an human eye can resolve, in theory, objects as close as $\alpha \sim 0.3'$ in visible light
- Keck Telescope (D=10 m), $\alpha \sim 0.013$ arcsec
- In practice, $\alpha \sim 1'$ for an eye, and 0.5-1" at the best sites

AO overcomes the blurring ➔ sees clearer,
➔ better contrast

# How An Adaptive Optic works

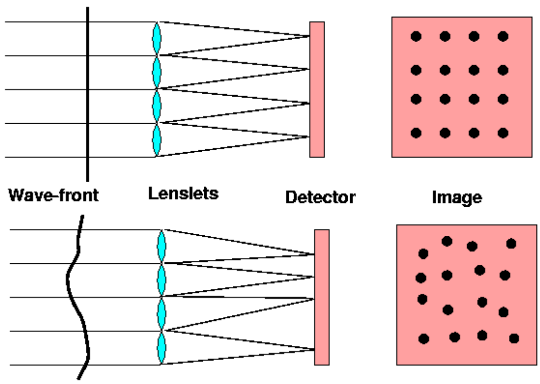
- The most basic systems use a point source of light as a **reference beacon** (e.g., a bright star), whose light is used to probe the shape of the wavefronts. Light from this reference source is analyzed by a **wave-front sensor**, and then commands are sent to actuators (pistons) which change the surface of a deformable mirror to provide the necessary compensations. For the system to work well, it must respond to wave-front changes while they are still small; for the earth's atmosphere, this means updating the mirror's shape ***several hundred times a second***!




http://cfao.ucolick.org/images/aoscheme.gif

Speckle Movie

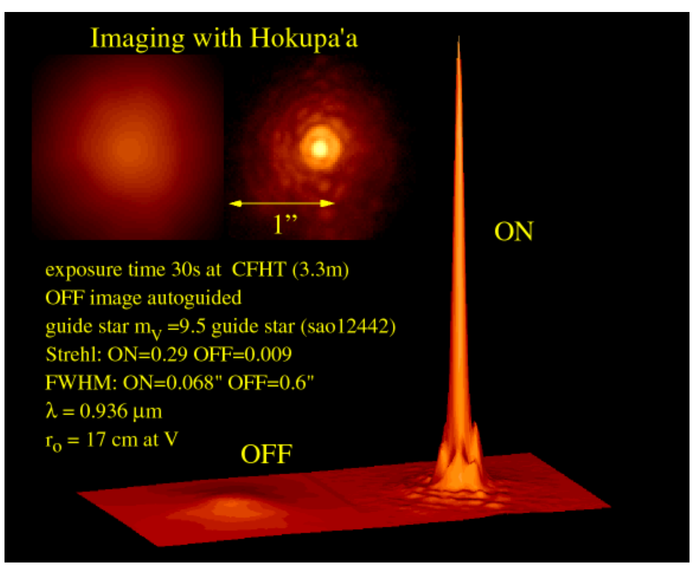
# Wave-front Sensor




If wave-front is plane → images are located in a regular grid

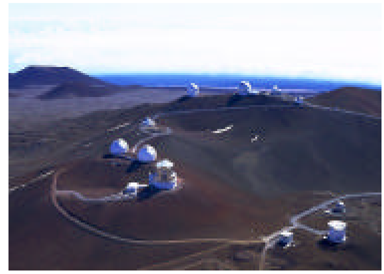
If wave-front is distorted → images become displaced from their nominal positions

**Hartmann test**



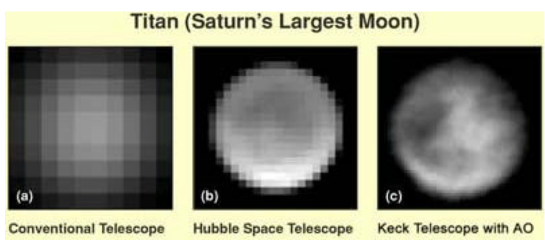

http://www.ctio.noao.edu/~atokovin/tutorial/part2/dm.html

Hubble Space Telescope (HST): aperture 2.4 m;in space

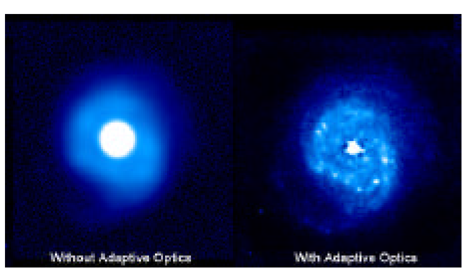


Keck Telescope: aperture 10 m, in Mauna Kea
→ light-gathering power ~ 20 X of that of HST
→ angular resolution ~ 4-5 X of that of HST

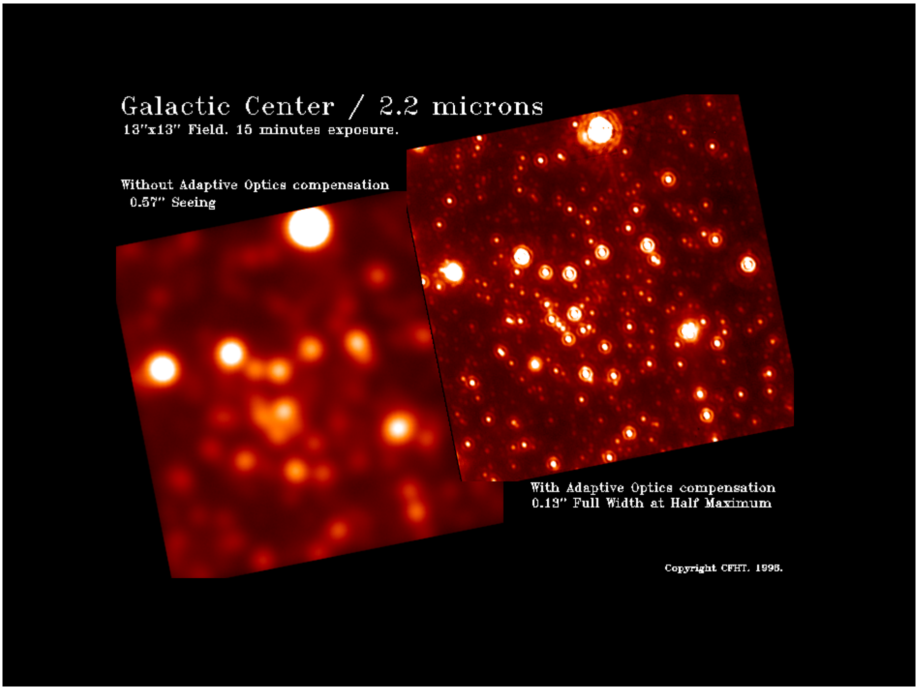
But HST costs ~ 20 X that of Keck!




http://cfao.ucolick.org/ao/



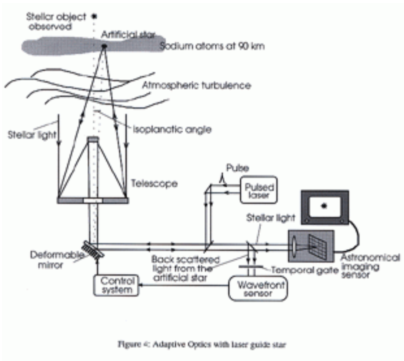

The nuclear region of the nearby galaxy NGC 7469, with and without AO (from CFHT)




# Limitations of AO

- Isoplanatic patch for the atmosphere small → only a tiny fraction of the sky will be near suitably bright stars that can serve as reference beacons. The most promising way to overcome this limitation is the use of **powerful lasers** to excite sodium atoms high in the atmosphere, producing an **artificial star** that can be placed near any target of interest.

# Use of Artificial Guide Stars




Sodium-Layer Laser Guide Star Feasibility Experiments (1992, Lawrence Livermore National Laboratory)

A very faint beam from the Keck sodium laser appears in this 20-minute exposure http://www2.keck.hawaii.edu:3636/news/laser0.html

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http://caao.as.arizona.edu/