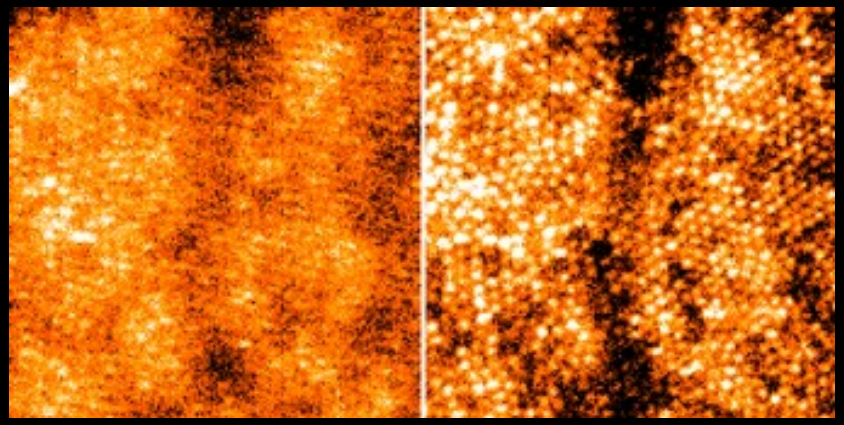
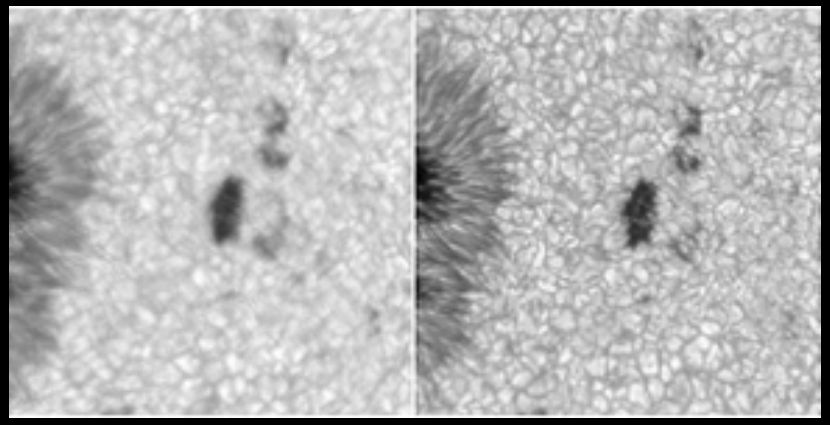
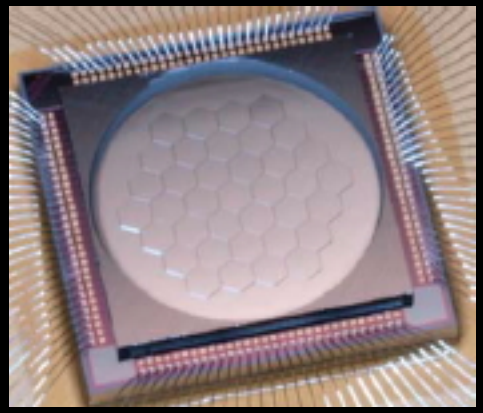


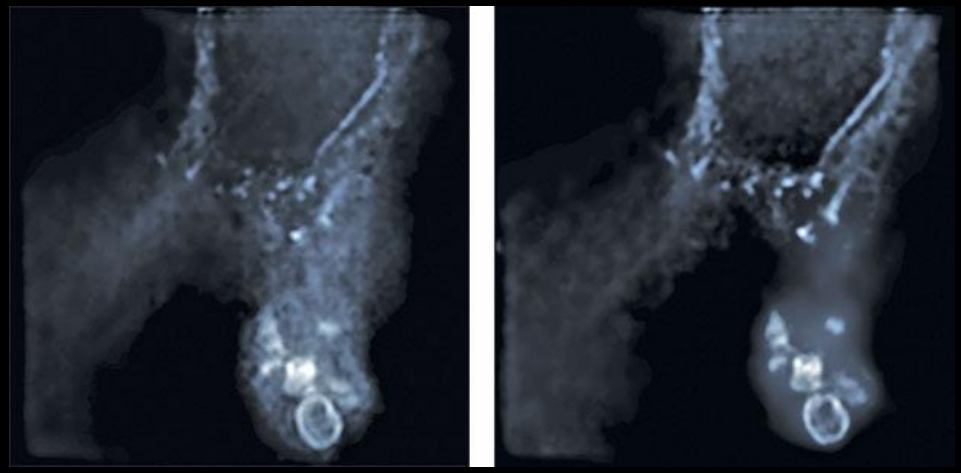


Adaptive Optics

Special Topic in Astrophysics

ASTRON 250 - Fall 2013

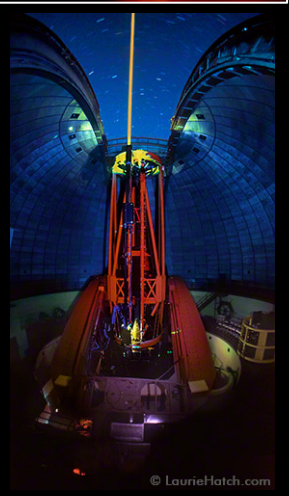




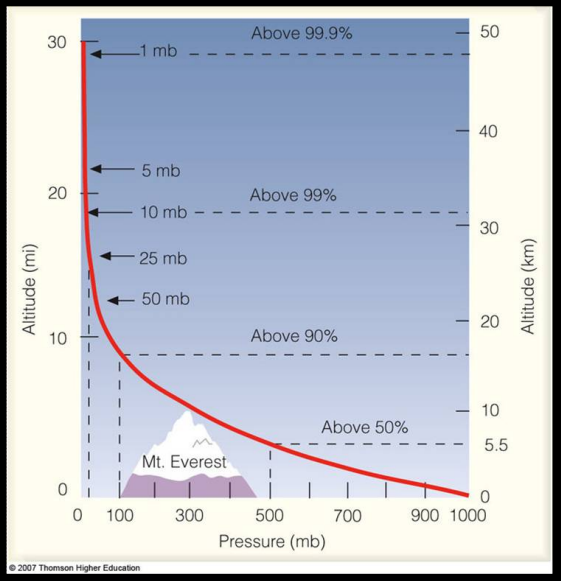
Laser Guide Star AO

- Regular (Natural Guide Star) AO requires a bright reference star
  - Very limited sky coverage (anisoplanatism)
  - Many science cases "closed off"
- Using a laser to project an artificial guide star is the next step
  - Initially a military project
  - Secret until 1991
  - Now widespread

LGS flavors (I)

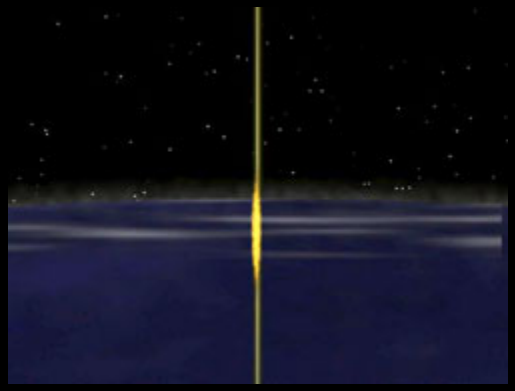


- Use Rayleigh scattering off molecules in the atmosphere to produce a spot as high as possible ($z \approx 20$ km)
- Use pulsed lasers and gating to select only photons from a specific layer
  - Removes signal from lower atmos.
- Works best at short λ (e.g., UV)
  - Higher scattering cross-section

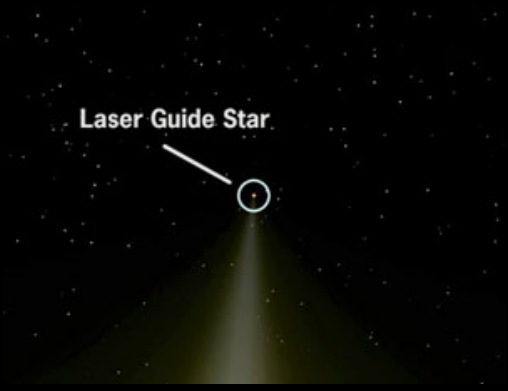


LGS flavors (II)

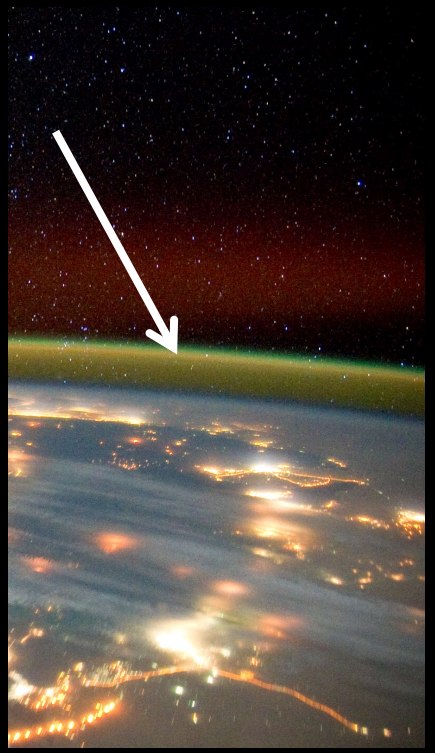
- Use resonant scattering off sodium atoms in thin layer above the mesosphere
  - $z \approx 90$ km (± 15 km)
  - Extremely high cross-section
  - Strong requirement on laser λ (589nm)



Lateral view



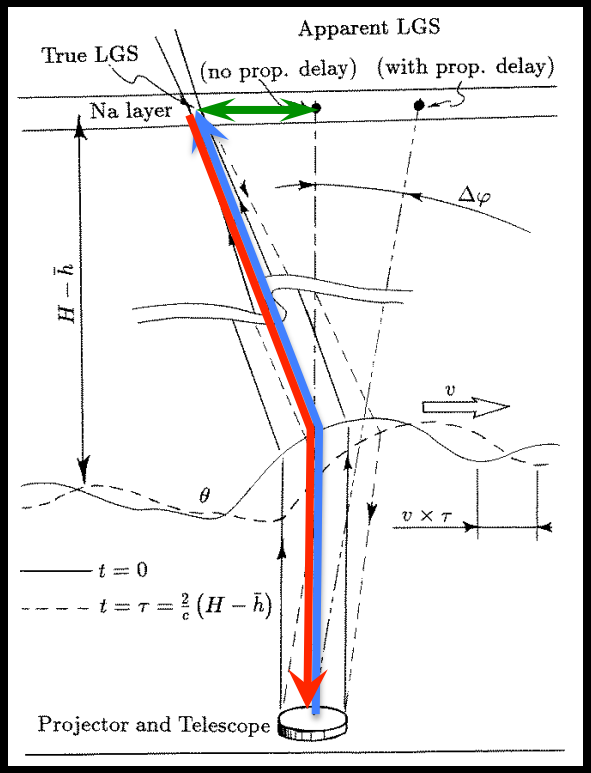
View from ground



© Gemini

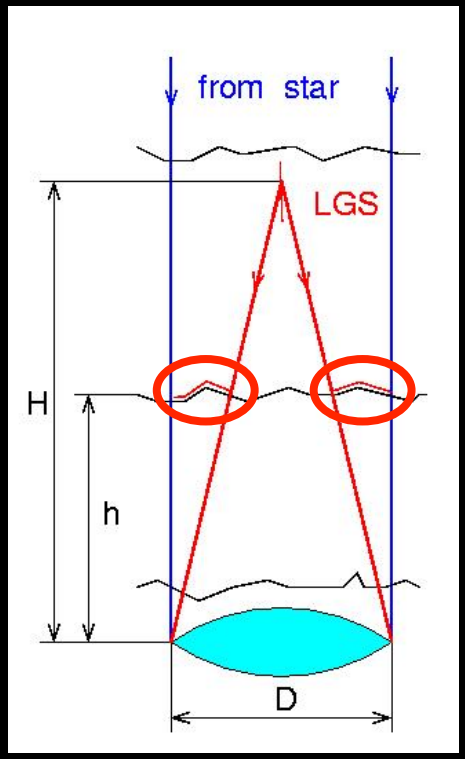
LGS challenges (I)

- Upward laser propagation follows the exact same path as LGS light downward
  - Received laser star has imprint of turbulence
  - Laser “star” is speckled
  - Global tip-tilt is un-sensed!
- Separate tip-tilt star needed
  - On- or off-axis (within θ_0)
  - Can be much fainter
- Sky coverage < 100%



LGS challenges (II)

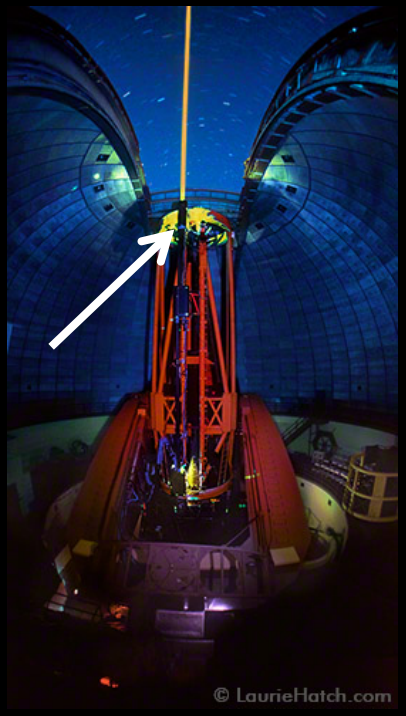
- Light from the laser spot does not sample turbulence in the same way as starlight
  - "missing" the edges of the beam
- This "cone effect" is important for
  - Low LGS spots (Rayleigh)
  - High turbulent layers (tropopause)
  - Large telescopes
  - $\sigma^2_{cone} \approx (D/d_0)^{5/3}$ [$d_0 \approx 1$ m]

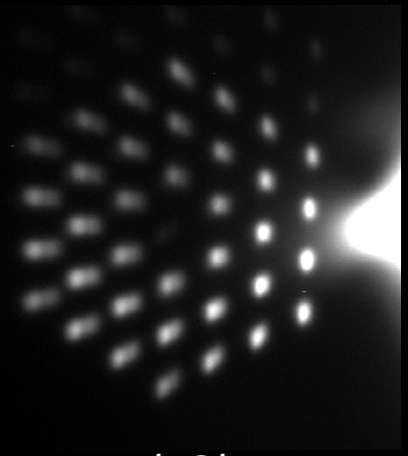


A. Tokovinin

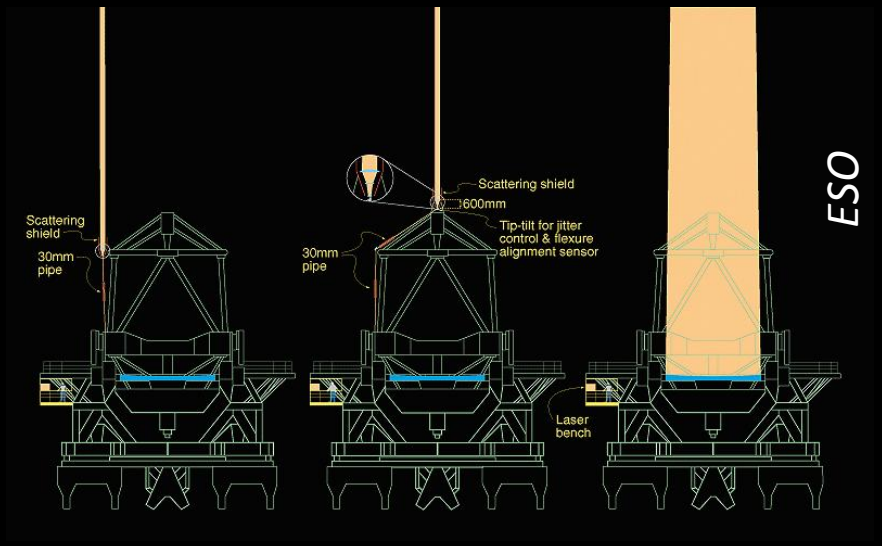
LGS challenges (III)

- Launching telescope and spot elongation
  - Mechanical/optical complexity
  - Spot elongation = reduced precision for S-H WFS





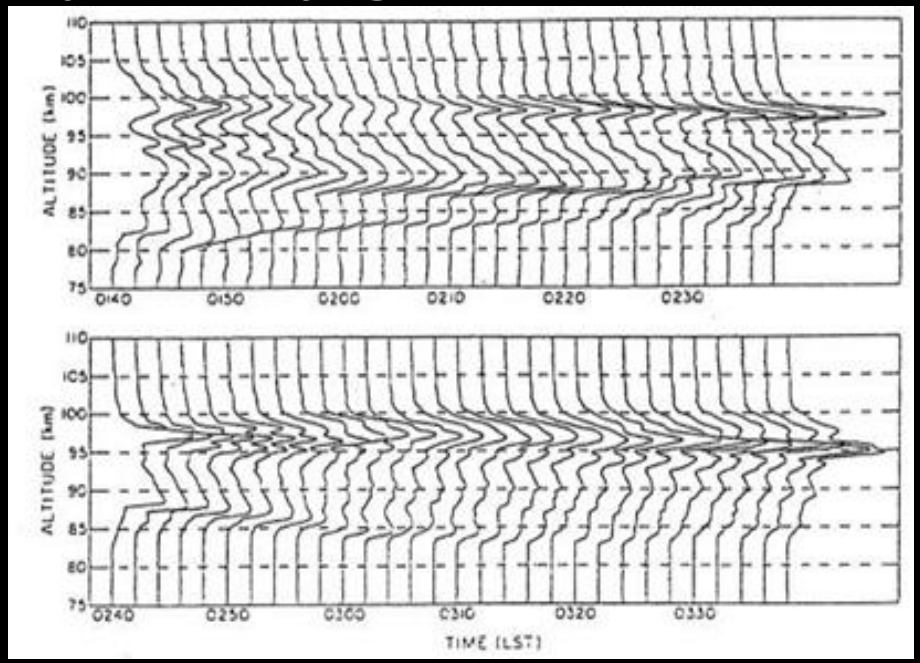
Keck Obs.



simple → complex

LGS challenges (IV)

- The sodium layer is not static, with varying height and flux return over tens of minutes
  - Need to adjust focus of launch telescope
  - Need to adjust conjugation of WFS

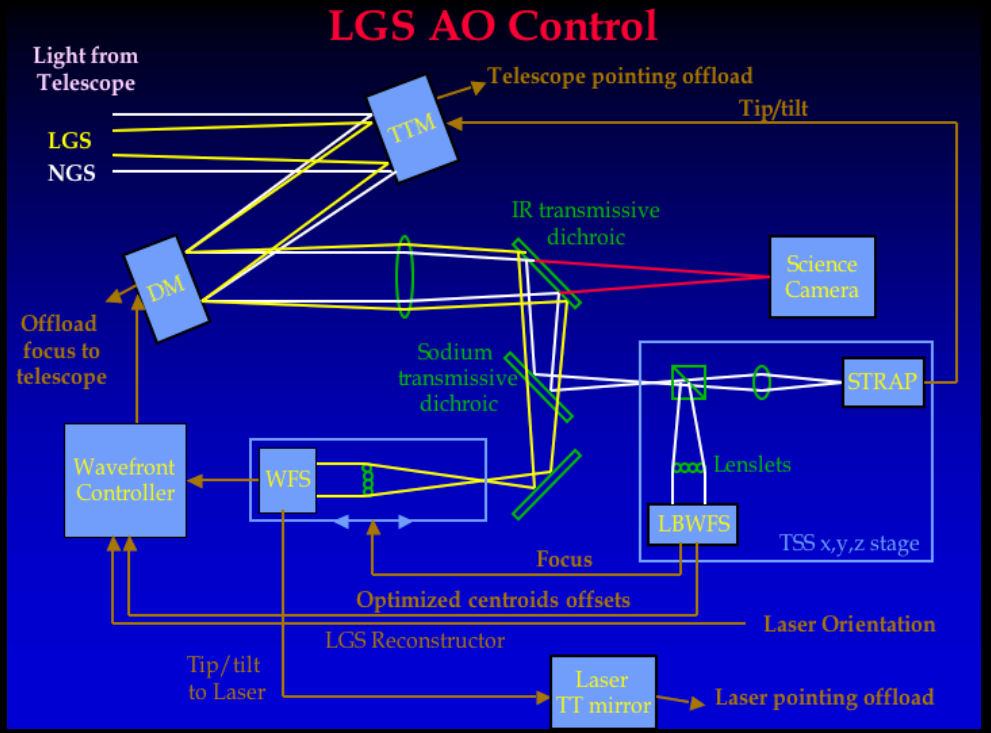


LGS challenges (V)

- Brightness of laser point source is limited to less than the brightest stars
  - Sometimes insufficient for poor conditions
- Excitation can be saturated
  - Natural linewidth is much broader than laser bandwidth: only a small fraction of atoms are available for excitation
  - Pumping up laser power does not help!

LGS challenges (VI)

- Complex control with many active elements and feedback mechanisms compared to normal AO
- More optical/mechanical elements
- Operations issues:
  - Laser safety
  - "spotters"
  - Space Command



Keck

Next week readings

- Advanced adaptive optics systems
  - Multi-Conjugate AO (MCAO)
  - Ground-Layer AO (GLAO)
  - Multi-Object AO (MOAO)
  - Extreme AO (xAO)
  - Hubin et al. (2006)
- AO for laser propagation (J. Ballesta's presentation)