

Comments on Science, Instrumentation, AO and ELT's

Dunk Island
11 April 2008
Jerry Nelson

Telescope Projects

- ◆ TMT
 - Pragmatic, balanced emphasis on seeing limited and high quality AO
- ◆ EELT
 - Idealistic, emphasis on AO usage, strong K band support, less clear about shorter wavelength AO
 - 6 warm reflections to a science instrument? ADDED thermal background, loss of signal (turns EELT into TMT)
- ◆ GMT
 - Pragmatic, strong emphasis on seeing limited usage, GLAO, take what they can get in conventional AO
- ◆ Real Observatories
 - Working hard to make AO work in its many modes and find out what works and what doesn't

- ◆ AO technology is hard
 - DM's
 - ◆ Current usage is ~ 200 actuators/DM
 - ◆ ELT requirements are ~4000 actuators. This is a big step
 - ◆ AO system size is driven by DM size
 - ◆ MEMS DM's
 - Slow in coming
 - Not as inexpensive as promised
 - Small, good for enabling compact AO systems
 - Too small for ELT's, cant provide large solid angle coverage
 - VERY promising for open-loop capability
 - Ideal for MOAO applications - small fields, tweeter applications
 - Single vendor a risk for long term availability

AO experience-2

- Astronomy needs large sky coverage, hence laser beacons
- For ELT's Na beacons are only option for high quality correction
- Na laser technology is HARD
 - ◆ Very small market, so hard to get vendors interested
 - ◆ Technology is esoteric, so not easy for astronomers to do themselves
 - ◆ Achieving desired characteristics a problem
 - Desired pulse shape unavailable (spot elongation mitigation)
 - Coupling efficiency to Na layer widely variable among lasers
 - Beam transfer optics complex, \$
 - Fibers not readily available with high power transmission
 - Lasers \$\$
 - Long term vendor availability?
 - High power needed, so even more esoteric
 - Needed power varies as $\lambda^{-18/5}$ so short wavelength AO is very hard and sky coverage will be limited too

- ◆ Today's AO systems took much longer than expected to become useful
- ◆ Today's AO systems do not work as well as predicted
- ◆ Performance degrades VERY rapidly with poor seeing conditions
- ◆ How will the next generation of AO perform?
 - Gemini MCAO
 - Keck NGAO (but ~5 years away)
- ◆ How confident are we that the ELT AO systems will work as designed?
 - Experiments very important (MAD, CANARY, VILLAGES, etc)

Usage of AO

- ◆ ELT's assume their future revolves around AO
 - Productivity of AO in poor conditions important uncertainty
 - ◆ Poor seeing
 - ◆ Short t_0
 - ◆ Clouds
 - Reliability of components (lasers)
 - Very complex systems
 - We need the overhead for operating/setup to come down
 - Sky coverage an issue
 - ◆ TMT believes one needs to correct the natural TT stars to get decent sky coverage (need low noise, fast IR detectors)
 - Are there as yet unknown problems? (Claire's concern)

◆ What is impact of GLAO?

- Negligible experience, so a lot to learn about when this system will work and what kind of science it can aid
- Do its drawbacks in complexity, throughput negate the image size improvements?

◆ Since GLAO changes shape of PSF we need to be careful in predicting the science impact.

- Suggest we use equivalent noise area (ENA) as a metric for this

$$\text{ENA} = \frac{1}{\int \text{PSF}^2 d\Omega} \text{ (units of arcsec}^2\text{)}$$

AO at short wavelengths

- ◆ Point source sensitivity $\sim S^2$
- ◆ Designers should be using language of rms wavefront error (in nm), not Strehl

$$S = e^{-\left(\frac{2\pi\sigma}{\lambda}\right)^2}$$

- ◆ $\sigma=133\text{nm}$ gives
 - $S=0.84$ at $2\mu\text{m}$
 - $S=0.50$ at $1\mu\text{m}$,
 - $S=0.34$ at $0.8\mu\text{m}$ ($S=0.5$ when $\sigma=106\text{ nm}$)
 - $S=0.06$ at $0.5\mu\text{m}$ ($S=0.5$ when $\sigma=66\text{nm}$)

- ◆ We need more experience!
 - How do we do 2% photometry
 - What limits astrometry
 - How frequently can/should we use AO on ELT's
 - ◆ This is both a technical and a science question
 - Tomography
 - Optimal use of natural guide stars
 - MOAO sounds great but many challenges and \$\$
- ◆ We need to pursue innovation, but AO is very expensive which tends to emphasize conservative paths
- ◆ How well can we extract PSF's with tomography, etc
 - Important for photometry and astrometry
 - Both theoretical and practical studies needed

- ◆ MCAO
 - MAD system working
 - will be evaluated at Gemini
- ◆ IR work limited by OH in general, so OH suppression work has great potential with or without AO
- ◆ Modeling for ELT's is very detailed
- ◆ MEMS DM's

conclusions

- ◆ AO on ELT's has enormous scientific promise
- ◆ New techniques in AO will greatly enhance science
 - MCAO
 - MOAO
 - GLAO?
 - Laser Tomography