Multi-Object Adaptive Optics

Multi-object adaptive optics (MOAO, or perhaps MoAO) is a speculative adaptive optics system configuration where multiple deformable mirrors apply independent corrections for the turbulence-induced wavefront distortions in the directions of multiple small science objects distributed across a larger field-of-view. The concept is similar to multi-conjugate adaptive optics (MCAO) in that multiple guidestars and tomographic wavefront reconstruction algorithms are used to determine the wavefront corrections to be applied to compensate atmospheric turbulence. It is different in that the multiple deformable mirrors apply their corrections in parallel for separate points in the field of view, not in series for different atmospheric layers.

ESO has been studying MOAO for several years under the nickname “AO buttons” for potential application to IFU multi-object spectroscopy. They have concentrated on natural guide star (NGS) concepts for atmospheric tomography. In preparation for the Aspen conference, we have begun evaluating the performance of laser guide star (LGS) MOAO concepts, with the idea being to see what might be feasible with the proposed Gemini-South MCAO guidestar configuration or a similar constellation.

The preliminary results generated to date are summarized on the 8 attached plots. The first-order AO and observation parameters used for these calculations are as follows:

- I, J, H, and K observing bands and a 3 arc minute square field-of-view
- Performance evaluated in terms of
  - Encircled energy within a 0.1” square pixel
  - The square pixel size corresponding to 50% encircled (ensquared??) energy
- Median Cerro Pachon turbulence profile at zenith
- 5 laser guidestars, arranged in an “X” pattern on the sky with a full width of 1, 1.5, or 2 arc minutes. The 1 arc minute case matches the Gemini-South MCAO design.
- 4 tip/tilt natural guidestars, one on each side of the LGS “X.”
- Order 16 by 16 wavefront sensing for each LGS WFS
- Order 32 by 32 wavefront correction for each DM
- The effects of WFS noise, servo lag, wave optics propagation, and implementation error sources have been neglected.

In general, these best-case results show significant improvements in the encircled energy criteria compared to the seeing-limited case.

We are interested in receiving feedback on whether this concept is worth pursuing, and what the next steps to take should be if it is. Some of our assumptions to be revisited include:

- The observing scenario—spectral bands, field of view, and choice of turbulence profile (Cerro Pachon or Mauna Kea?)
• The performance criteria—is characterization in terms of encircled energy the correct metric for an IFU?

• Is performance uniformity across the full field important for this application? More uniform performance would require additional guidestars. This could raise costs significantly, both by requiring additional laser and sensors and reducing the applicability of the existing Gemini-South MCAO design.

• Are the improvements in sky coverage and performance made feasible using laser guidestars worth the additional cost and complexity?

Tools are available for more extensive and detailed modeling once these groundrules are defined. This would include parameterizing performance terms of basic first-order AO system parameters, namely (i) order of sensing and correction, (ii) WFS measurement noise, and (iii) control loop bandwidth. These parameters will determine the cost and availability of the required AO components. We are reasonably confident that these requirements will be less demanding than the values selected for MCAO, since the encircled energy criteria is probably more forgiving of low-order wavefront aberrations than the MCAO Strehl ratio requirements.

A much more critical issue for this concept is the choice of DM technology. MEMS mirrors will probably be needed, and they will need to be commanded open-loop unless additional artificial stars and IFU wavefront sensors are included in the system.