Ground conjugated AO Simulations

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Ground Conjugated AO:

- GCAO/AO/MCAO relative merits
- Basic limitations and principles
- Performance (Monte-Carlo & Analytical)
Idea very similar to MCAO, but using a single ground conjugated deformable mirror instead.

The ground layer is the strongest.

The FWHM gains are modest, but the field of view much larger than AO/MCAO tailored to different applications.

Performance independent of telescope D

Borderline to use NGS, but LGS available
SNR gain ≈ \frac{\text{#photons obj comp.}}{\text{#photons obj uncomp.}} \times \frac{\text{FWHM obj uncomp.}}{\text{FWHM obj comp.}}

≈ \text{Strehl}_{\text{comp}} \times 0.7 \times \frac{D}{r_0}

Metrics (arbitrary?):

1 → SNR gain \times \frac{\text{FoV}}{\text{FoV(AO)}}

2 → SNR gain \times \frac{[\text{FoV}/\text{FoV(AO)}]}{\text{cost}}
## GCAO/AO/MCAO relative merit

<table>
<thead>
<tr>
<th></th>
<th>AO</th>
<th>MCAO</th>
<th>GCAO</th>
<th>Seeing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SNR gain</strong></td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>FoV</strong></td>
<td>20”</td>
<td>80”</td>
<td>10’</td>
<td>∞</td>
</tr>
<tr>
<td><strong>Cost (AU)</strong></td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Metric1</strong></td>
<td>5</td>
<td>56</td>
<td>1800</td>
<td>∞</td>
</tr>
<tr>
<td><strong>Metric2</strong></td>
<td>5</td>
<td>19</td>
<td>900</td>
<td>∞</td>
</tr>
</tbody>
</table>
Geometry of the Problem
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The effective thickness of the compensated layer depends on:

- seeing
- wavelength (via \( d \))
- Field of view

\[ h_{\text{eff}} \approx 2 \frac{r_0}{\theta} \]

For good seeing:

- \( h_{\text{eff}}(K) = 1600 \text{m} \)
- \( h_{\text{eff}}(V) = 275 \text{m} \)
Actuator Density
(Analytical approach)

- Average FWHM at V band versus the diameter of the field of view for actuator densities of:
  - 25cm (lower solid)
  - 50cm (dot)
  - 100cm (dash)
  - Pachon $C_n^2$ profile & $r_0$
Wavelength dependency
(Analytical approach)

Natural (straight upper lines) and Compensated (lower curves) FWHM averaged across field of view:

- Bands:
  - V (solid)
  - J (dot)
  - K (dash)

- Cerro Pachon Cn² profile
- Actuator density = 1m.
Developed a new AO simulation code (Yorick based)
Handles any number of DMs (PZT/bimorph) at any altitude, any number of WFSs (SH/Curvature) at arbitrary location in the field. Cone effect included. Only simple least square implemented (upgrade).
Include most of AO effects (fitting, aliasing, servo-lag, anisoplanatism, noise)
Goal here is to validate the analytical results and investigate:
- dependence upon telescope diameter
- dependence upon number of guide stars
- dependence upon compensated field of view
- dependence upon the wavelength, Cn2 profile, etc...
- Uniformity and shape of the PSF across the field
Performance vs Field of View
(Monte-Carlo Simulations)

- **Average FWHM (mas) vs FoV**
- **rms FWHM (mas) across FoV**

### Conditions:
- $\lambda = 1.25\, \mu m$
- Seeing(500nm)=0.5”
- Pachon profile (64% @ ground level)
- 8-m telescope
- 50cm pitch
- 10 WFSs
- GS placed on a circle
- No AO results: FWHM = (400± 14) mas
- Checked telescope diameter has little impact
Performance vs Field of View
(Monte-Carlo Simulations)

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