

Astro 289C, Winter 2008

Computer Simulation Exercise: Error Budget Spreadsheet

Assignment dated February 19

Due February 26th

Background:

There are three main types of computer simulation tools used for AO system design and performance estimates:

a) Spreadsheet-level models. These calculate error budgets for AO systems, based on the type of analytical expressions we have been deriving in class. Typically each source of wavefront error is considered as an independent quantity, so that correlations between them are ignored. Spreadsheets are an excellent way to understand system tradeoffs and to get a handle on optimization issues. Typically the design of an AO system starts with a spreadsheet model, and then progresses to the more complex simulations described below.

b) Codes based on linear systems models in the spatial frequency (Fourier) domain. These utilize the second-order statistics of the atmosphere and AO system (e.g. the covariance matrix) to calculate the joint effect of multiple sources of wavefront error at once. They make some idealized assumptions in order to do this. Examples include CIBOLA (<http://cfao.ucolick.org/software/cibola.php>), PAOLA, and OPTICA. At present these codes do not do multiple laser guide star tomography.

c) Monte Carlo simulation codes. These codes propagate light through randomly chosen turbulent "phase screens" with a full model of the atmospheric turbulence profile and AO system. This is the most sophisticated and computer-intensive type of model. Examples are CAOS (<http://www-luan.unice.fr/caos/>), LAOS for the Thirty Meter Telescope Project, and ARROYO, a C++ library (<http://cfao.ucolick.org/software/arroyo.php>). In the past these codes have typically not been used until the first two types of codes above have done the exploratory work. However until the codes described in b) above implement good models for multiple laser guide star tomography, Monte Carlo codes are the main choice for multi-conjugate and multi-object AO.

Assignment:

I'd like you to use a spreadsheet model (download Don Gavel's model from the class website) to explore issues in AO system design and optimization. Start out by understanding what the spreadsheet model has in it, and how the various quantities are calculated. Be sure to note which quantities are "inputs" and which are "derived". Note that you can choose to use either a sodium or a Rayleigh laser guide star.

Then I'd like to you take a couple of hours to explore questions which interest you, using this spreadsheet model. I have in mind the kind of free-form investigation that you would do if you were beginning to design an AO system for yourself. You are exploring parameter space to get a feel for how your new AO system might perform. Make graphs of performance vs. specific

design parameters, trade off different variables, and generally get a “gut feel” for the behavior of the spreadsheet model. You can choose your own questions, or use some of the ones below.

Please write me a brief (one page maximum) description of the questions that you investigated; include key graphs or other quantitative conclusions. Due February 26th.

Here is a sample of the type of question which you could explore:

- 1) If someone gave you a 2 Watt CW laser at 589 nm and you could build any AO system to go with this laser, what AO system would you build? On what size telescope? For what observing wavelengths? Why? What if the laser was 20 Watts instead of just 2 Watts?
- 2) For a given telescope size, atmospheric turbulence profile, observing wavelength, wind speed, and laser (you choose the above parameters for yourself), how would you trade off closed-loop AO system bandwidth and subaperture size to get the best Strehl ratio?
- 3) Choose a set of telescope and AO system parameters. Compare sky coverage for the Mauna Kea and Cerro Pachon atmospheric turbulence profiles. (These are built into the spreadsheet – choose them in cell E20).
- 4) For several different size telescopes (you choose the sizes), compare the wavefront error due to focal anisoplanatism obtained with the Mauna Kea and with the Cerro Pachon atmospheric turbulence profiles.
- 5) For several different size telescopes, trade off the height of Rayleigh guide star against photon return and cone effect errors. (The higher the Rayleigh guide star, the smaller the cone effect but also the fewer the photons returned.) How would you decide on the optimum Rayleigh guide star altitude?