Notes on Second Meeting of NGAO Extragalactic Subgroup, February 3, 2006 Claire Max, subgroup chair

Attendees: Aaron Barth (UCI), Claire Max (UCSC), Tommaso Treu (UCSB).

Members who could not attend: David Koo (UCSC), James Larkin (UCLA), Richard Dekany, Richard Ellis, Chuck Steidel (Caltech)

The group refined the "short list" of four key extragalactic science-case topics, and assigned subgroup members to lead the work on each area.

It was decided that we would circulate zeroth drafts for each topic on or before FEBRUARY 27th, and that we would schedule the next telecon for sometime between FEBRUARY 28th and MARCH 3rd.

General considerations: Stability of PSF in both space and time is key issue. For a narrow- field high-Strehl AO system, may be able to live with PSF that falls off with distance from axis *IF* it is very stable in time. See attached file (Ellerbroek.Variability.TMT.jpg) showing simulation results for stability of wavefront aberration (and hence Strehl ratio) for TMT, as a function of off-axis distance in several MCAO systems. We may want to construct similar graphs for the various Keck NGAO systems under consideration.

Below is a summary of the discussion for each area.

1) Stellar populations in nearby galaxies. Claire Max, topic leader

For this application it is not clear whether KPAO or MCAO would be superior, so want to investigate both. Also want to investigate relative benefits of going into the visible down to various wavelengths (may be important for extracting information from color-color and/or color-magnitude diagrams). MOAO less useful because of huge crowding, and because photometry rather than spectroscopy is the main tool.

Three types of simulation inputs would be useful. All would involve us giving an initial star-field to the modelers, which they would propagate downwards thru the atmosphere and AO systems (KPAO and MCAO). We would then use our spiffiest data-analysis tools to extract photometry from these star-fields and to determine photometric errors and their effects on the physical quantities we want to measure. Potential inputs for simulations:

a) A narrow "cross" (+) in color-magnitude space. The spread in the cross after data analysis is a measure of the photometric and magnitude uncertainties.

b) A narrow line in color-magnitude and color-color space representing a cluster of a specific age, metallicity, dust content, and crowding/confusion. The data analysis would show how well we could reconstruct the stellar population for KPAO vs. MCAO.

c) Repeat b) for different amounts of crowding, or scale using Knut Olsen's scaling laws (Olsen, Blum, Rigaut, AJ 126, 452, 2003). Talk with Mike Liu and/or John Tonry re crowding issues (surface brightness fluctuations).

Look closely at methods used in Gemini MCAO and GSMT Book chapters. Check out Esslinger and Edmunds (A&AS 129, 617, 1998) for photometric accuracy with AO. Consider bringing in someone who does resolved stellar populations for a living; for example perhaps, Mike Rich, Tammy Smecker-Hanes, Taft Armandroff, or Judy Cohen.

2) AGNs and supermassive black holes. Aaron Barnes, topic leader.

For both nearby and distant AGNs, the innermost arc sec or two are of most interest. AGNs are distant from each other on the sky. So narrow-field AO system is desirable. Need to investigate benefits/costs of going down into the visible (and how far into the visible would pay off). Need to explore relative costs/benefits of 50% vs. 90% Strehl ratios (or whatever other target numbers are appropriate at each wavelength for each AO system).

M-sigma relation is key area. Topics discussed included:

a) Kinematics of stars or gas to improve M-sigma relation (increased accuracy, larger span of distances). Questions to think about: What spatial and spectral resolutions are best for AGNs at various redshifts/distances? What is the minimum detectable black hole mass as a function of redshift/distance? Relative advantages of using Ca triplet, H_alpha, or rest-frame near-IR lines (such as H_2) at various redshifts.

b) Calibrate reverberation-mapping black hole masses by deriving stellar-dynamical black hole masses for the same galaxies. What lines are optimal to use? (Ca triplet, H_alpha, rest-frame near-IR lines). Was tried using HST but need better spatial resolution. Hicks and Mountain are trying with OSIRIS; suspect that Ca triplet might be better because it buys you a factor of 2 in spatial resolution (at the diffraction limit).

c) Imaging and bulge velocity dispersions in QSO host galaxies (more distant ones than can be done today with OSIRIS). High Strehl and high contrast are important if bulge is compact. Need to coordinate with folks in the Galactic Astronomy subgroup who are considering high-contrast targets for direct imaging of extrasolar planets: Bruce Macintosh is point-person. What redshifts are possible with each AO system? Can we reach z=7? Look for Ly_alpha halos around high-z quasars.

3) Field galaxies: imaging and kinematics. We nominated David Koo as leader (since he wasn't on the phone this time).

This is the main extragalactic application where we need to analyze all three potential AO systems: KPAO, MCAO, MOAO as a function of observing wavelength and redshift. See attached file
(Density.on.Sky.jpg) which shows that most
high-z objects of interest have a sky density of 5 - 10 per square arc minute, so a modest amount of multiplexing (e.g. with 5 to 10 deployable IFUs) over a few-square-arc minute field of regard would pay off nicely.

Objectives: galaxy morphology using GalFit or similar tools; stellar populations of disk, spheroid, other components; rotation curves and kinematics.

Some specific questions to address:

a) Morphology. What is accuracy of GalFit or similar tools in determining morphological features such as bulge radius, disk-to-bulge ratio, stellar populations of individual components of the galaxies. To what accuracy can you distinguish between exponential disk and r^(-1/4) disk?
Host galaxies of distant
AGNs/QSOs: how much does high Strehl buy you
in terms of distinguishing between elliptical and disk galaxies? Each of the above needs to be asked as a function of redshift, observing wavelength, and AO system characteristics.

b) Kinematics and redshift. What is rotation curve in emission lines? What is Vmax in outer parts of galaxy? Metallicity gradients? Disordered motions of clumps w/in the galaxy? Other quantities that survey such as DEEP are measuring? What spectral resolution is needed? A key question is what does the added spatial resolution of a next-generation AO system gain you for a) clumpy disks, or b) smooth disks. For individual knots, can you measure resolved ISM properties?

c) High-z galaxies: topics such as Lyman Break galaxies, various kinds of drop-outs, ... (We didn't discuss these at our second telecon - needs input from Steidel, Ellis, Koo, ...)

4) Gravitational lensing. Tommaso Treu, topic leader.

Goals: redshifts, kinematics, populations, metallicity of lensed high-z galaxies.

Note on attached file (Density.on.Sky.jpg) that within a gravitationally lensed system, the density on the sky of lens arcs is said to be as high as 10 per square arc minute. Treu will do an independent assessment of this number. Each individual lens arc has a scale of ~ an arc second, and on theoretical grounds the Einstein radii of a lensing system is roughly half an arc minute. So this application looks best for an MOAO or MCAO AO system with deployable IFUs but could also be done with a narrow-field system by repeating measurements for each different lens arc. Need to evaluate the efficiency gain of wider-field AO systems (MCAO, MOAO) with deployable IFUs.

Issues to work on:

a) what is the required pixel scale/spatial resolution?
b) what is optimum field of view for narrow-field and wide-field AO systems?
c) what is required spectral resolution? (e.g. is 30-50 km/sec OK?)
d) what photometric bands are going to be useful, given the expected range of redshifts?

Tools: Want to do simulation of a gravitationally lensed galaxy (+ cluster) with input specified by extragalactic subgroup.
Treu has a student who would create a model for a lensed galaxy (starting with galaxy-sized lens, moving up to cluster- sized lens). This model image (which would include wavelength information) would then be propagated downward through the atmosphere and the various AO systems, and the extragalactic subgroup would use its data analysis tools to assess items a) through d) above.