

## Diffraction Limited Imaging of High Redshift Galaxies with Adaptive Optics

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**Abstract.** The major cornerstone of future ground-based astronomy is imaging and spectroscopy at the diffraction limit using adaptive optics. To exploit the potential of current AO systems, we have begun a survey around bright stars to study intermediate redshift galaxies at high resolution. Using ALFA to reach the diffraction limit of the 3.5-m telescope at Calar Alto allows us to study the structure of distant galaxies in the near-infrared at scales of 100–150 pc for  $z=0.05$  and at scales 1.0–1.5 kpc at  $z=1$ . In this contribution we present the initial results of this project, which hint at the exciting prospects possible with the resolution and sensitivity available using an AO camera on the 8-m class VLT.

Resolution and sensitivity are crucial for studies at high redshift of galaxy dynamics and demographics, quasar hosts, etc. The immense potential of modern telescopes for such work is largely wasted unless adaptive optics (AO) can be used to correct for the seeing induced by atmospheric turbulence. Since it is likely to be several years before laser guide stars begin to be used as a standard tool, we must observe in the vicinity of natural guide stars. But all current deep surveys deliberately avoid stars of any sort, leaving the AO without a reference. Instead we can invert the problem and look for target objects near the best reference stars, a technique that we and Larkin & Glassman (1999) have shown to be successful.

For AO to make an impact on astrophysics, a Strehl ratio of 20% can be considered a realistic minimum correction for the K-band. But, because any target object is likely to be 20–30'' from a reference star, to achieve this we require 40–50% Strehl on the star (Le Louarn et al. 1999). The star must therefore be bright,  $V < 12$  (depending on the wavefront sensor). To reduce scattered light in the infrared bands we can choose to search near only early type stars – the scattered K-band light from a 12 mag A-star is nearly the same as that from a randomly chosen 14 mag star because most of these are G-type or later. Lastly, selecting stars away from the Galactic plane minimises both the number of background stars and the extinction.

We have made a 1 hr exposure in the  $K'$ -band at the 3.5-m telescope at Calar Alto (Spain), with the 80'' field centered on the  $V = 9.08$  A0 star SAO 81538. The MPIA/MPE adaptive optics system ALFA (Kasper et al. 2000) provided a Strehl ratio of 32% in seeing of 0.87''. The high Strehl makes the data particularly sensitive to point sources – i.e., stars, or galaxies with bright compact nuclei such as AGN or starbursts. On the other hand, the small pixel scale means that

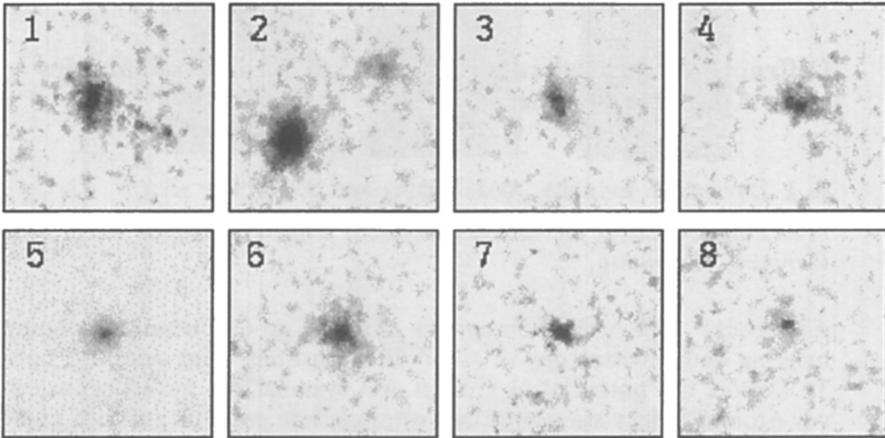


Figure 1.  $6.5'' \times 6.5''$  cutouts of objects within  $30''$  of the guide star, smoothed with a median filter of radius  $0.16''$ . Upper row: interacting and multiple-nuclei galaxies. Lower row: galaxies with single nuclei.

faint extended objects might be missed. The caveat is that the population of objects seen in such an image is almost certainly different from, and a subset of, those generally investigated in seeing-limited data.

The cutouts in Fig. 1 show that we have detected at least 8 galaxies, 4 of which are interacting or have multiple nuclei. All the objects in the figure have magnitudes  $K \sim 19$ – $20$ , for which we estimate a mean redshift of 0.7 (Cowie et al. 1996). The structure of the 4 faintest objects (not shown), which have  $K = 20.5$ – $20.7$ , cannot be determined from these data alone.

The graph in Fig. 2 shows the radial profiles for the on-axis reference star and 3 objects similar distances from it: another star which defines the PSF, and 2 single nuclei galaxies (objects 5 & 6 above). The core of the galaxy which is object 6 is resolved even though it has an intrinsic  $\text{FWHM} < 0.2''$ .

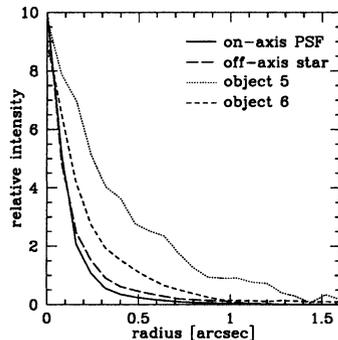


Figure 2. Azimuthally averaged profiles for the on-axis reference star and 3 objects all similar distances from it.

## References

- Cowie, L., Songaila, A., Hu, E., & Cohen J. 1996, *AJ*, 112, 839  
 Kasper, M., Looze, D., Hippler S., Herbst, T., Glindemann, A., Ott, T., & Wirth, A., 2000, *Experimental Astronomy*, 10, 49  
 Larkin, J., & Glassman, T. 1999, *PASP*, 111, 1410  
 Le Louarn, M., Foy, R., Hubin, N., & Tallon, M. 1998, *MNRAS*, 295, 756