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Adaptive Optics with a Laser Guide Star - The ALFA system

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Abstract. All 8-metre class telescopes will be equipped with adaptive optics systems in order to reach their highest angular resolutions. With the additional requirement for maximal sky coverage comes the mandatory use of a laser guide star. ALFA is an adaptive optics system using a sodium laser guide star, which is installed on the 3.5-m telescope at Calar Alto observatory. It has shown that it is possible to reach Strehl ratios better than 20% in the K-band. In this contribution we describe the design of the system, the observational trade-off necessary to use a laser guide star, and the performance that might be expected.

1. ALFA - An Overview

ALFA is an adaptive optics system with sodium laser guide star for the 3.5m telescope on Calar Alto, Spain. ALFA is developed jointly by the Max-Planck-Institute for Astronomy and MPE. Performance goal is diffraction-limited imaging at any point in the sky in the near-infrared under average seeing conditions. All core components were installed at the telescope in the course of 1996; the system is currently undergoing integration and testing. ALFA is equipped with a 97 actuator continuous face-sheet deformable mirror. The wavefront sensor of the Shack-Hartmann type, with a maximum of 30 subapertures, is equipped with a low-noise CCD (read noise $<$ 4 electrons), capable of frame-rates up to 1250 Hz. Wavefront sensing is possible on natural guide stars and on artificial guide stars created by focusing the light from a 6 W continuous-wave dye laser on a layer of sodium which occurs naturally at 90 km height. The narrowband laser is tuned to the sodium D_2 line and the induced fluorescence light from the excited sodium atoms is used as the artificial guide star. ALFA is used with OMEGA, an infrared camera with a 1024^2 pixel detector, and 3D, an infrared integral field spectrometer.

2. Adaptive Optics and Laser Guide-Stars

The progress in adaptive optics techniques during the last few years promises to revolutionize ground based astronomy in the optical and infrared by removing the wavefront aberration caused by the atmospheric turbulence, thus providing images and spectroscopy with unprecedented resolution. With adaptive optics the distorted wavefront is sensed and restored in real time before its detection by

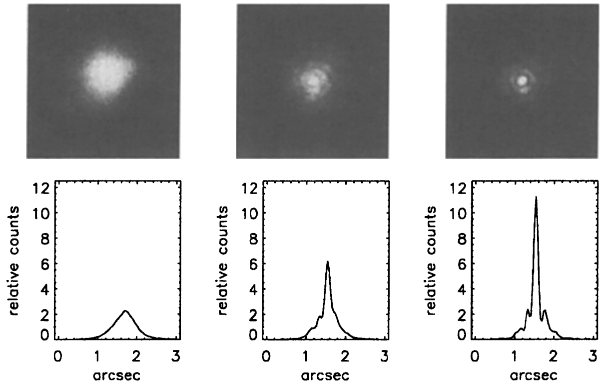

Figure 1. The superb performance displayed by these images of a star achieved shows the exciting future potential of adaptive optics with laser guide stars. On the left is the openloop PSF, in the middle the 13% Strehl achieved in a 200 sec integration when using the LGS, and on the right is the best 10 sec in which the diffraction limit and a Strehl of 23% were reached.

the science camera. To do this, a reference source is needed, which, in the case of a Shack-Hartman sensor, is preferably pointlike, bright ($m_V < 14.5$ for the ALFA wavefront sensor) and close (< 10 arcsec) to the object of interest (e.g., a faint distant galaxy). Unfortunately, there are only very few such galaxies that have a bright reference star nearby. A solution to this problem is the creation of artificial guide stars in the Earth's atmosphere by projecting high power lasers into the mesosphere. The fact that the laser guide star light which is returned by the scattering layer traverses the atmosphere twice prevents the artificial star from being used for wavefront tip/tilt (i.e., image motion) compensation. Therefore laser guide star adaptive optics systems still need a natural star for tip/tilt correction, but this star can be much fainter than the star needed for correction of the higher-order wavefront aberrations (since the entire telescope aperture can be used for tip/tilt sensing) and hence the sky coverage is increased considerably.

References

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