Not enough stars in the sky?

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June 2001 issue of the CTIO Newsletter

Nowadays, most of large ground-based telescopes are equipped with Adaptive Optics systems to compensate for the turbulence and to achieve better angular resolution. Those systems need guide stars to measure the perturbed wave fronts in real time. They must be bright enough and close enough to the scientific target, which is not generally the case. This is why astronomers want to implement artificial *Laser Guide Stars* (LGSs). Using several LGSs, it will even be possible to do tomographic reconstruction of the instantaneous turbulent volume and to compensate it in 3 dimensions, as is actually planned for the 8 m Gemini South telescope at Cerro Pachon.

Figure 1: The yellow cone of laser light scattered in the lower atmosphere is seen in this picture taken with a fixed camera by M. Boccas. The 4 m dome and Milky way are in the background.

LGSs must simulate natural stars, hence be far enough. The best choice is to use the glow of sodium atoms in the mesosphere, excited by a powerful laser beam. The mesospheric sodium layer has a typical altitude of 90 km, a typical thickness of 10 km. It is known to be highly variable on time scales from minutes to months. Sometimes strong "sporadic" layers with increased concentration

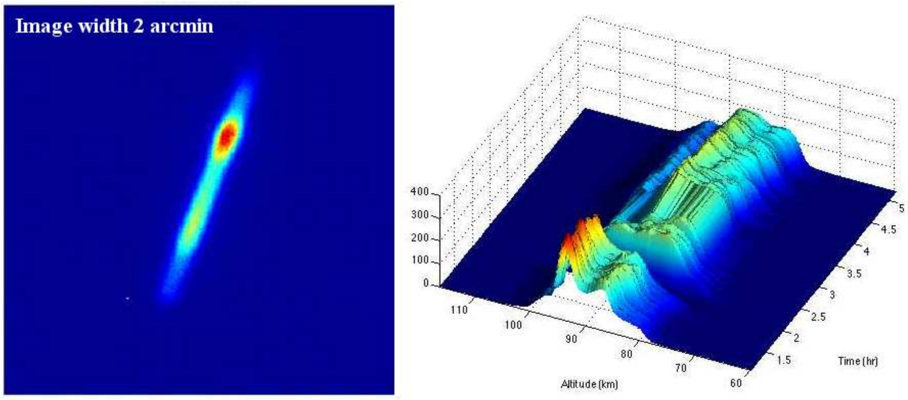

Figure 2: The image of the sodium stripe (left, artificial colors) and the temporal evolution of the sodium profile during one night (right).

of Na appear and then slowly degrade. The properties of the Na layer (total number of atoms, vertical profile) need to be known for a proper design of an AO system. Unfortunately, the available information is not sufficient, especially for the southern hemisphere where most of the sodium LGSs are being planned.

The Gemini team took an initiative to organize a systematic campaign of the sodium layer measurements in southern Chile. This is a collaborative project involving ESO and CTIO; the partners provide a part of financial support and will benefit from the results. The team is chaired by Celine d'Orgeville (PI) from Gemini and consists of Gelys Trancho (Gemini), a group from CTIO (Brooke Gregory, Maxime Boccas, Andrei Tokovinin) and researchers from the Imperial College of London (Chris Dainty, John Quartel, Nick Wooder, Laurent Michaille) who contribute their experience with previous sodium measuring campaigns.

The sodium experiment at CTIO is actually a small-scale simulation of the future LGS. The beam of a dye laser tuned to the Na D2 line is launched vertically into the atmosphere. Some light is scattered in the lower layers (0–30 km), making the beam visible even to a naked eye when standing close to a 50-cm launch telescope (see Figure 1). This so-called "Rayleigh cone" is not useful for AO, but its intensity is very sensitive to a presence of any additional scattering, e.g. to cirrus clouds. The sodium star has a magnitude of about 13 for the laser power of 0.4 mW used in this experiment (in future systems with laser optical power of several W, the LGSs of $10^m - 11^m$ will be lit in the sky).

The lasers (the dye laser and its 7W argon-ion pump laser) are located in a utility building below the Blanco telescope, the beam is launched through a circular hole in the roof. The sodium star is observed at the 0.9 m telescope with its standard CCD, through an interference filter for a better contrast against the sky. In this way, we see the mesospheric column of excited atoms "from the side" and can measure the altitude distribution of Na from the brightness profile of the observed stripe. The telescope is fixed, stellar images in the field leave trails during the 10-30 s exposures. To measure the absolute height of the layer, simultaneous exposures are taken at the Curtis Schmidt telescope; the displacement of the Na stripe relative to star trails permits to do something like a triangulation.

The first run of this campaign took place on February 12-20, 2001. Data were taken successfully and are now being processed. Four more runs are planned until February 2002 to sample the Na layer in different seasons (it is known already that there is an important seasonal variability).

The sodium experiment is a combination of excitement (after all, it's something unusual) and routine (monotonous data taking when everything goes smoothly). Well, it does not run smoothly all the time: the laser is very complex, sometimes it looses the lock on the sodium line, sometimes additional experiments are conducted. Overall, it is a rather complicated endeavor involving 3 distinct locations on the mountain, many people from different organizations, and, of course, specific data processing. We hope that the result will be worth the effort, paving the way to LGS-assisted astronomical adaptive optics. Special thanks go to all CTIO staff who made this experiment possible (optical table installation, drilling the hole in the roof, bringing water and power supply for the laser, etc.)