Journal of Physics: Conference Series **595** (2015) 012031 doi:10.1088/1742-6596/595/1/012031

New generation LOLAS: Redesign of an Optical Turbulence Profiler with High Altitude-Resolution

L J Sánchez[1], **R Avila**[2], **C A Zúñiga**[2], **I. Cruz-González**[1], **J J Tapia-Rodríguez**[3], **J L Avilés**[4]

[1] Instituto de Astronomía, UNAM, México D.F., México
[2] Centro de Física Aplicada y Tecnología Avanzada, UNAM Campus Juriquilla, Qro., México
[3] Instituto Tecnológico de Morelia, Mich., México
[4] Instituto Nacional de Astrofísica, Óptica y Electrónica, Pue., México

E-mail: leonardo@astro.unam.mx

Abstract. We present the instrument and first results of a Low Layer SCIDAR (Scintillation Detection and Ranging), called new generation LOLAS (LOLAS 2), which consists of the optical coupling of a Ritchey-Chrétien telescope and an EMCCD camera, and allows the measurements of optical turbulence profiles in the atmosphere from ground level with high altitude-resolution. The system is designed for widely separated double star targets, which enables a high altitude resolution of $5 \leq \Delta h \leq 35$ meters above the first kilometer, measured from ground level. The first results were obtained in June and November 2013, and May 2014 at the Observatorio Astronómico Nacional de San Pedro Mártir (OAN-SPM), México.

1. Introduction

This second generation instrument design Low Layer SCIDAR 2 (LOLAS 2), which includes several improvements (Zúñiga et al. 2015) yielding an optimized performance from our prototype LOLAS (Avila et al. 2008; Chun et al. 2009; Avilés et al. 2012), allows the measurements of optical turbulence profiles in the atmosphere from ground level with high altitude-resolution.

The LOLAS concept consists of putting into practice a Generalized SCIDAR (G-SCIDAR) on a dedicated portable telescope, using widely separated double stars as light sources. Wider star separations yield better altitude resolution but shortens the maximum detection altitude.

LOLAS are designed to use a small telescope, an Electron Multiplied Charge Coupled Device (EMCCD) to improve sensitivity and a real-time computation of the scintillation autocovariance.

2. G-SCIDAR method description

The LOLAS instrument is based on the G-SCIDAR method to obtain the optical turbulence profiles $C_n^2(h)$ at an altitude h. This parameter quantifies the intensity of the turbulence fluctuations of the atmosphere refractive index n.

The G-SCIDAR is based on the detection of stellar scintillation, the variance σ_2 of which is proportional to $h^{5/6}$.

In order for the instrument to be sensitive for turbulence at $h = 0$, the detection plane is placed instead at a distance h_{gs} below the telescope conjugated pupil, which then implies that σ_2 is proportional to $|h - h_{gs}|^{5/6}$.

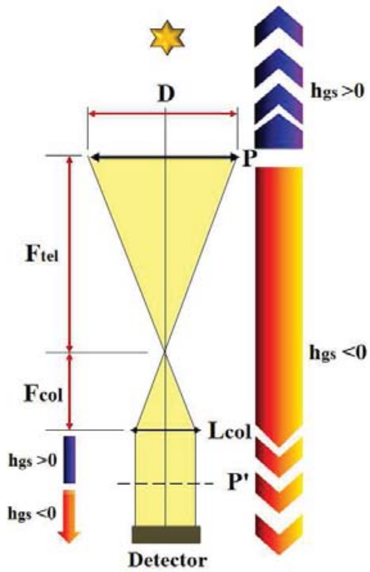

Figure 1. Optical scheme for the G-SCIDAR method.

Figure 1 shows a schematic G-SCIDAR description of the method. D and L_{col} are the telescope and the collimator diameters, and F_{tel} and F_{col} their focal distances. P' marks the telescope conjugated pupil plane. The CCD detector is located below this plane.

Figure 2. The instrument LOLAS second generation working at the Observatorio Astronómico Nacional at San Pedro Mártir, Baja California in México.

3. LOLAS prototype instrument and LOLAS 2

The components of the LOLAS prototype instrument were: a Schmidt–Cassegrain telescope 40.6 cm in diameter, an EMCCD camera, optics (two achromatic doublets), and real time data processing software (GUI).

The new generation LOLAS makes use of an RC Optical 40.6 cm $f/9$ Ritchey-Chrétien open telescope, a robust Astro-Physics German equatorial mount, an EMCCD Andor iXon camera, an SBIG guiding camera and an improved real-time data processing software (GUI).

The LOLAS 2 instrument improved software, focus stability and guiding allows to achieve an optimized performance.

4. LOLAS 2 first results

The instrument was tested at the Observatorio Astronómico Nacional at San Pedro Mártir, Baja California in México (OAN-SPM) during three observing runs June and November 2013, and May 2014. Figure 2 shows the instrument working at the OAN-SPM.

Scintillation images are captured on an active zone of 256 × 80 pixels of the CCD detector. Frames are binned 2 by 2, with a resultant pixel size of 32 μm.

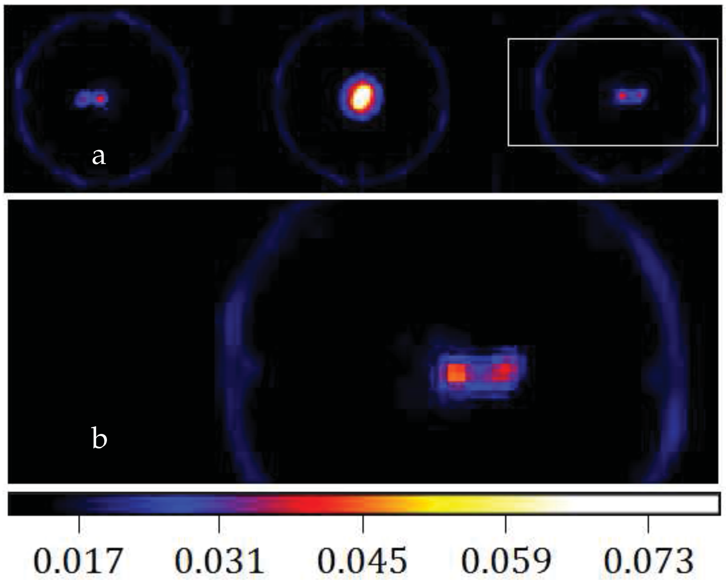

Figure 3. (a) Example of a LOLAS 2 measured autocovariance map. (b) Enlarged view showing the signature of two layers, one at the ground and one near the ground.

The autocovariance of this stochastic illumination is obtained by computing the spatial normalized autocorrelation of each image and averaging those autocorrelations over thousands of statistically independent image samples. Each layer of optical turbulence contributes to the resulting scintillation autocovariance with three covariance peaks.

The exposure time was set to 2 ms. The number of images to calculate one autocovariance was set to 30000. An example of one autocovariance map obtained with LOLAS 2 is shown in Figure 3.

The $C_n^2(h)$ profile shown in Figure 4 was obtained analyzing the autocovariance using a modified CLEAN algorithm. The source was a double star (12 Cam) with 181 arcsec separation, $h_{gs} = -1212$ m and $\lambda = 0.5\,\mu$m. For these parameters we obtained an altitude resolution of 14 m.

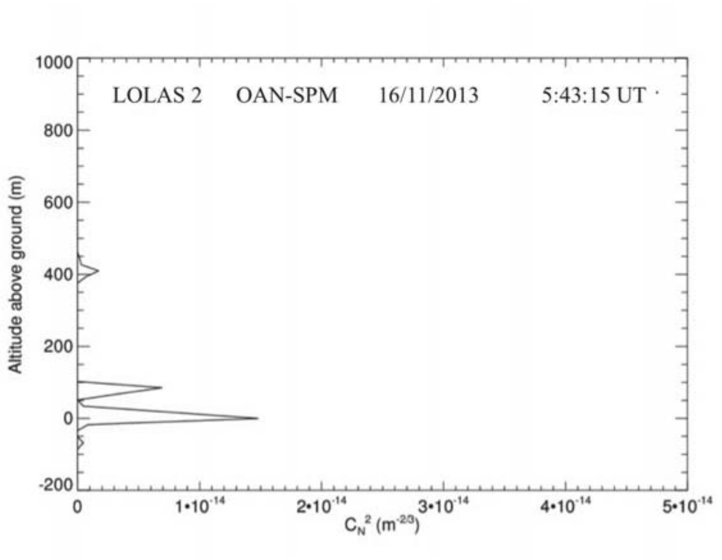

Figure 4. LOLAS 2 $C_n^2(h)$ profile corresponding to the autocovariance in Figure 3.

5. Conclusions

We designed and build a new generation LOLAS instrument with improved focus stability, guiding and software. The optimized performance of the instrument allows better measurements of optical turbulence profiles with high altitude-resolution above the first kilometer, measured from ground level.

Acknowledgments

We acknowledge the technical and administrative staff of the OAN-SPM for their support. Partial founding was provided by DGAPA (Universidad Nacional Autónoma de México) PAPIIT grants IN103913 and IN115013.

References

Avila R, Avilés J L, Wilson R W, Chun M, Butterley T and Carrasco E 2008 *MNRAS* **387-4** 1511

Avilés J L, Avila R, Butterley T, Wilson R, Chun M, Carrasco E, Farah A and Cuevas S 2012 *MNRAS* **423-1** 900

Chun M, Wilson R, Avila R, Butterley T, Avilés J L, Wier D and Begnini S 2009 *MNRAS* **394-3** 1121

Zúñiga C A, Avila R, Tapia-Rodríguez J J, Sánchez L J, Cruz-González I, Avilés J L, Valdés-Hernández O and Carrasco E 2015 *PASP* submitted