The Barcelona Raman LIDAR for the CTAO-North

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Abstract: The Barcelona Raman LIDAR (BRL) project is developing a LIDAR for online aerosol characterization of the northern site of the Cherenkov Telescope Array Observatory (CTAO-N). Such telescopes observe Cherenkov light emitted throughout the lower stratosphere and the troposphere, the aerosol and cloud profiles of which must be continuously monitored. Requirements include the ability to take aerosol extinction profiles to distances of more than 30 km and time scales of less than a minute after pointing to any target in the sky down to 25° altitude. The BRL consists of a 1.8 m parabolic mirror and a pulsed Nd-YAG laser. A liquid light guide collects the light at the focal plane and transports it to an in-house built polychromator unit. A prototype of the device was brought to the site and tested, the experience of which has resulted in a few improvements to the system.

1. Introduction

The Cherenkov Telescope Array Observatory (CTAO) [1] will observe cosmic very-high-energy γ-rays with greatly improved sensitivity, angular and energy resolution over current experiments [2]. Such improvements must come along with a significant reduction of systematic uncertainties in energy and flux reconstruction of the secondary air shower produced by the γ-ray, which itself emits the observed Cherenkov light. Because of the indirect way of detection, uncertainties are dominated by atmospheric effects [3]. The local troposphere and lower stratosphere must hence be monitored given the typical altitudes of extended air showers (ranging from 5 to 18 km a.s.l.). The CTAO has opted for a combination of two complementary instruments to achieve this goal: A wide-field telescope optimized for stellar photometry across a field-of-view as large as that of CTAO telescopes [4], and a powerful Raman LIDAR capable of measuring vertical aerosol optical depths from 15 km a.s.l. to the ground with an accuracy better than 0.03 rms and height resolution of at least 300 m on time scales of a minute.

The Institut de Física d'Altes Energies (Spain), the Universitat Autònoma de Barcelona (Spain), the University of Nova Gorica (Slovenia) and the Istituto Nazionale di Fisica Nucleare sez. di Padova (Italy) have joined the *Barcelona Raman LIDAR (BRL) project*, to develop a Raman LIDAR tailored to the requirements of the CTAO: precise characterization of the aerosol extinction over a large dynamic range on short time scales using two wavelengths characteristic for the measured Cherenkov light, and their corresponding vibrational Stokes lines from Raman scattering on atmospheric nitrogen. Detailed link-budget simulations have predicted the basic functioning of the chosen solutions, and the construction of a working prototype has shown that the system meets its performance requirements, particularly after a few upgrades envisaged. The main difficulties resolved so far relate to the large optics required and the corresponding dimensions of the polychromator.

2. The Barcelona Raman LIDAR

The BRL consists of a Q-switched Nd:YAG laser, with frequency-doubled and -tripled exit wavelengths of 532 nm and 355 nm, respectively. It incorporates a 1.8 m diameter parabolic receiving mirror purchased from the dismantled CLUE experiment [5]. At the focal point of the telescope, an 8 mm wide liquid light guide (LLG) of Lumatec Series 300 transports the light to a polychromator unit, mounted at the rear of the telescope structure. The polychromator was specifically designed and built in-house to separate the four wavelengths [6], and capture the light on photomultipliers (PMTs). Currently, the system is equipped with four PMTs of type Hamamatsu R11920, but an upgrade with specific PMTs optimized for each channel is ongoing. That upgraded system will also incorporate dynode gating for the two elastic lines and the new condenser lens developed by Hamamatsu compared to the prototype [7,8]. The PMT signals are processed by a commercial data acquisition system from LICEL. The laser, a Brilliant model from Quantel, is positioned on an XY-table with stepping motors adjacent to the telescope structure, recently upgraded to a new model from the company Litron with a higher repetition rate. Its beam exits along the optical axis of the main mirror in a coaxial configuration thanks to two 5” dichroic guiding mirrors designed and provided by Optoprim Italia. These mirrors also serve as absorbers for the 1064 nm wavelength [9], which cannot be blocked at the laser and could potentially produce damage to the liquid light guide. Recently, also an additional near-range system for distances from 100 m to about 1.5 km has been incorporated, for the moment with only one elastic line read out. Further specifications of the system are detailed in Table 1.

Table 1. BRL specifications

Laser wavelengths	355 nm, 532 nm
Raman wavelengths	387 nm, 607 nm
Energy per pulse	100 mJ, 200 mJ (30 mJ, 40 mJ)
Repetition rate	10 Hz (300 Hz)
Pulse duration	4 ns
Beam divergence	≈1 mrad
Mirror area	2.5 m^2
Focal length	1.8 m
f/D	1.0
Point spread diameter	3.3 mrad
Point spread on focal plane	6 mm
Receiver Field of View	4.4 mrad
Field of View on focal plane	8 mm
Channels	4

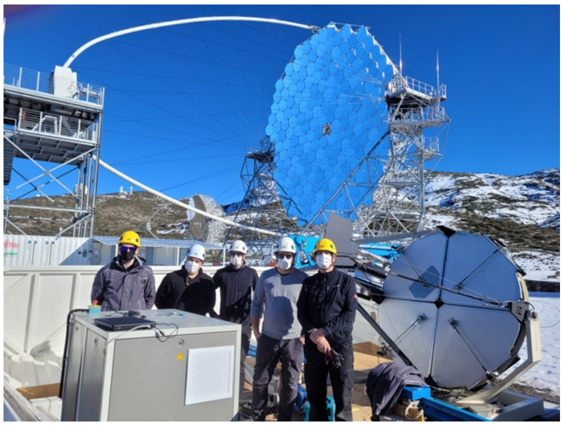

Figure 1. The Barcelona Raman LIDAR at the CTAO-N site.

3. Commissioning data

A prototype of the BRL was brought to the CTAO-N site for a one-year testing as an official CTAO pathfinder [10]. Luckily, this test phase overlapped with the Cumbre Vieja volcano eruption on La Palma. Although the prevailing wind normally blew the dust plume away from the LIDAR site, on a few occasions the dust plume could be detected by the BRL (see Figure 2).

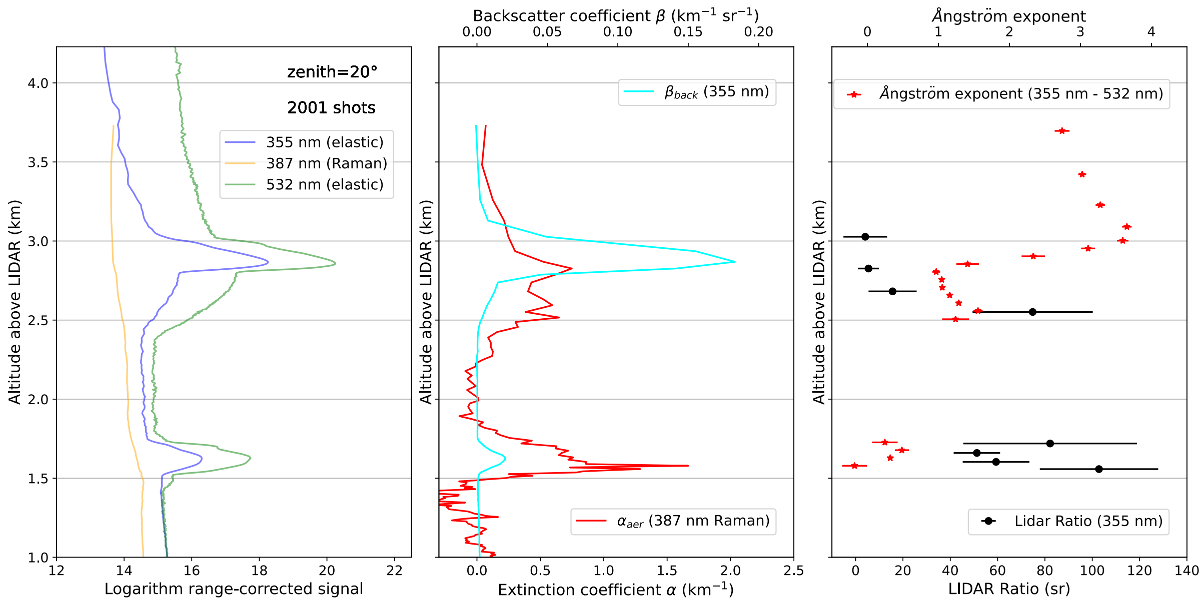

Figure 2. LIDAR returns for data taken from the Cumbre Vieja dust plume over La Palma during the commissioning phase of the BRL prototype. Note that the PMTs were operated with reduced high-voltage for the elastic lines to avoid saturation and signal ringing within the readout because a gating system was not yet incorporated.

4. Conclusions

The BRL prototype is now back in Barcelona for a general overhaul and upgrade to the final system. That comprises the new laser from Litron, operating at a 300 Hz repetition rate, which has been successfully tested in our laboratories. New PMTs incorporating the new condenser lens from Hamamatsu and a dynode gating system are being tested to be incorporated into the polychromator. The new upgraded system is envisaged to be ready soon, and the first test data might be ready for this conference.

5. References

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