CTAO Pathfinder Barcelona Raman LIDAR Cumbre Vieja volcano data

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The Barcelona Raman LIDAR (BRL) is an elastic and Raman backscatter system, officially accepted as a Cherenkov Telescope Array Observatory (CTAO) Pathfinder, in preparation to be delivered to the CTAO-North site as an in-kind-contribution. During the twilight periods from Sep. 18 to Sep. 22, 2021 the BRL took series of 2000 shots at various zenith angles from 0° to 60°. On Sep. 22 the volcano dust plume was detected. This document reports such observation.

The Barcelona Raman LIDAR (BRL)

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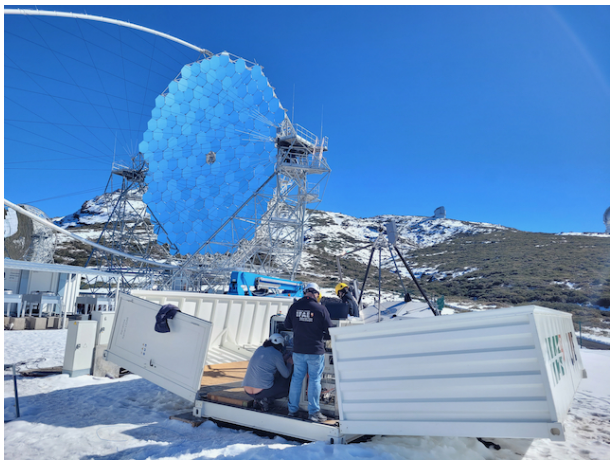
It consists of a Q-switched frequency doubled and tripled Nd:YAG laser, emitting 200 mJ and 100 mJ pulses, respectively, of 4 ns duration, at a rate of 10 Hz, and a 1.8 m diameter parabolic receiving mirror. The BRL, in its final configuration, can detect the 355 nm and 532 nm elastic lines and the 387 nm and 607 nm Raman lines from atmospheric backscattering on N_2. The spatial resolution of the BRL is of 7.5 m, reaching full overlap at less than 100 m with the help of dedicated near-range optics.



The Barcelona Raman LIDAR is a CTAO Pathfinder, deployed for commissioning at the LST-1 site in La Palma.

Currently, the BRL is located at the prototype for the CTAO's Large-Sized Telescope, LST-1[2], area (28.762°N, 17.891°W, 2200 m a.s.l.) for a one-year commissioning and test campaign. It still lacks some of its final features, such as a working second Raman line and the possibility to operate the elastic PMTs at maximum amplification, currently affected by signal saturation.

The observation of the Volcano plume

During the evening astronomical twilight periods from Sep. 18 to Sep. 22, 2021 the BRL took series of 2000 shots at different zenith angles from 0° to 60°. On the 22nd of September the volcano dust plume was detected.

[1] See instrument Project page: https://ctan-lidar-pathfinder.ung.si/
[2] Large-Sized Telescope project page: https://www.lst1.iac.es/

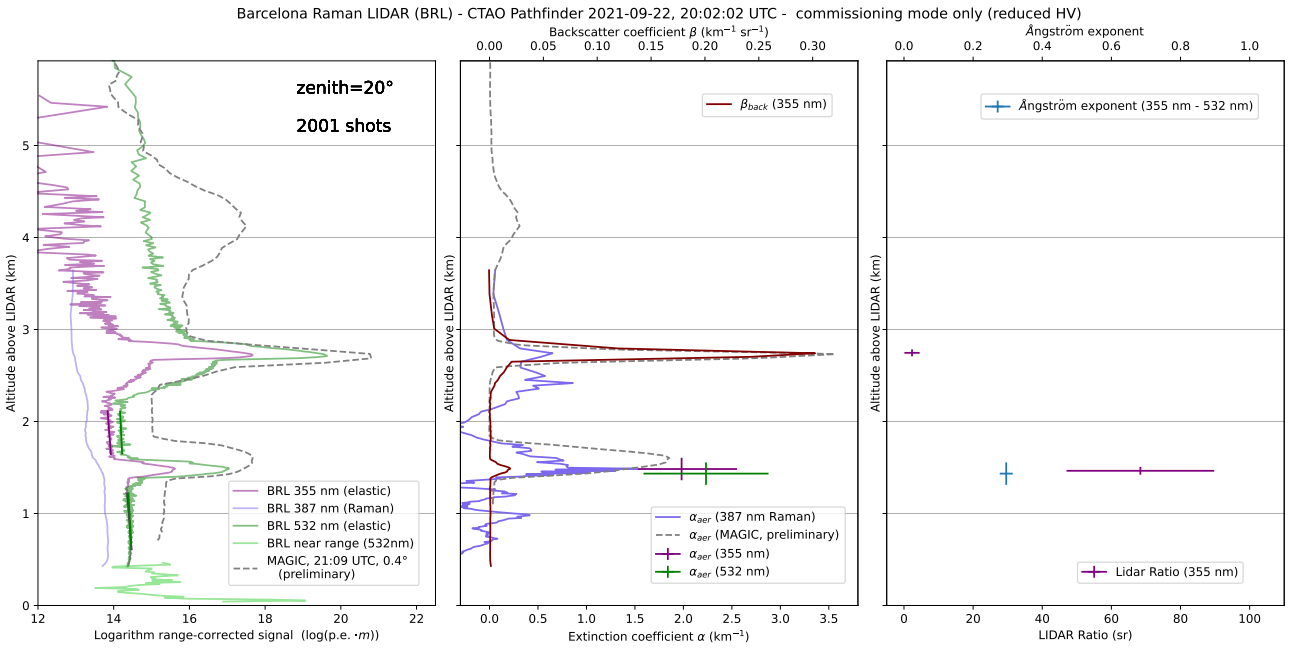


Fig. 1 BRL analysis of data from Sep. 22, 2021, 20:02 UTC. Left: altitude above ground vs. logarithm of range-corrected signals. For comparison, almost synchronous data from the MAGIC elastic backscatter LIDAR is shown. Center: extinction and backscatter coefficients for the BRL and MAGIC LIDAR. Right: retrieved LIDAR ratios and the Ångström coefficient. All error bars show statistical uncertainties only. The MAGIC data are preliminary and have been made available as a courtesy of the MAGIC collaboration.

Figure 1 displays a preliminary data reconstruction: on the left side, the logarithm of the **range-corrected signals** for three different wavelengths and the near range are shown. The BRL green elastic line was re-scaled to the ratio of detection efficiencies of the system between 355 nm and 532 nm. All signals, except for the near-range, were mildly smoothed using a Savitzky-Golay filter. For comparison, the data from the MAGIC 532 nm elastic LIDAR are also shown. These were taken about one hour later, and the device was pointing into a similar direction as the BRL. Two aerosol layers can be clearly distinguished from 1.2 km to 1.6 km above the ground (3.4 km to 3.8 km a.s.l.) and above 2.2 km (4.4 km a.s.l.). As will be shown later, the lower layer can be interpreted as a dust plume from the Cumbre Vieja volcano, and the upper layer as a cloud, with typical characteristics for La Palma at these altitudes.

The **inversion products** of the 387 nm Raman signal are shown in the central plot, together with two estimates based on the elastic lines only. The latter have been obtained by fitting a pure molecular profile expectation to the logarithm of range-corrected signals at the altitude ranges from 0.6 km to 1.2 km and from 1.6 km to 2.1 km and calculating the resulting aerosol optical depths of the volcano dust plume.

From the extinction and backscatter coefficients, an **average LIDAR ratio** could be calculated for the volcano dust plume and the cloud above, as shown in Figure 1, right. The extinction Ångström coefficient, obtained from the aerosol optical depths is also presented. We obtain a LIDAR ratio of (70 ± 20) sr and an Ångström coefficient of 0.30 ± 0.02 for the volcano dust plume, indicative of particles with large diameters and very typical for these events, whereas the LIDAR ratio for the cloud is considerably smaller and comparable with almost point-like scatterers.

Follow-ups: Please refer further readings to the instrument project page `https://ctan-lidar-pathfinder.ung.si/` and questions regarding to the CTAO Pathfinder Barcelona Raman Lidar to: Manel Martinez (Co-PI): martinez@ifae.es and Markus Gaug (Co-PI): markus.gaug@uab.cat.

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