

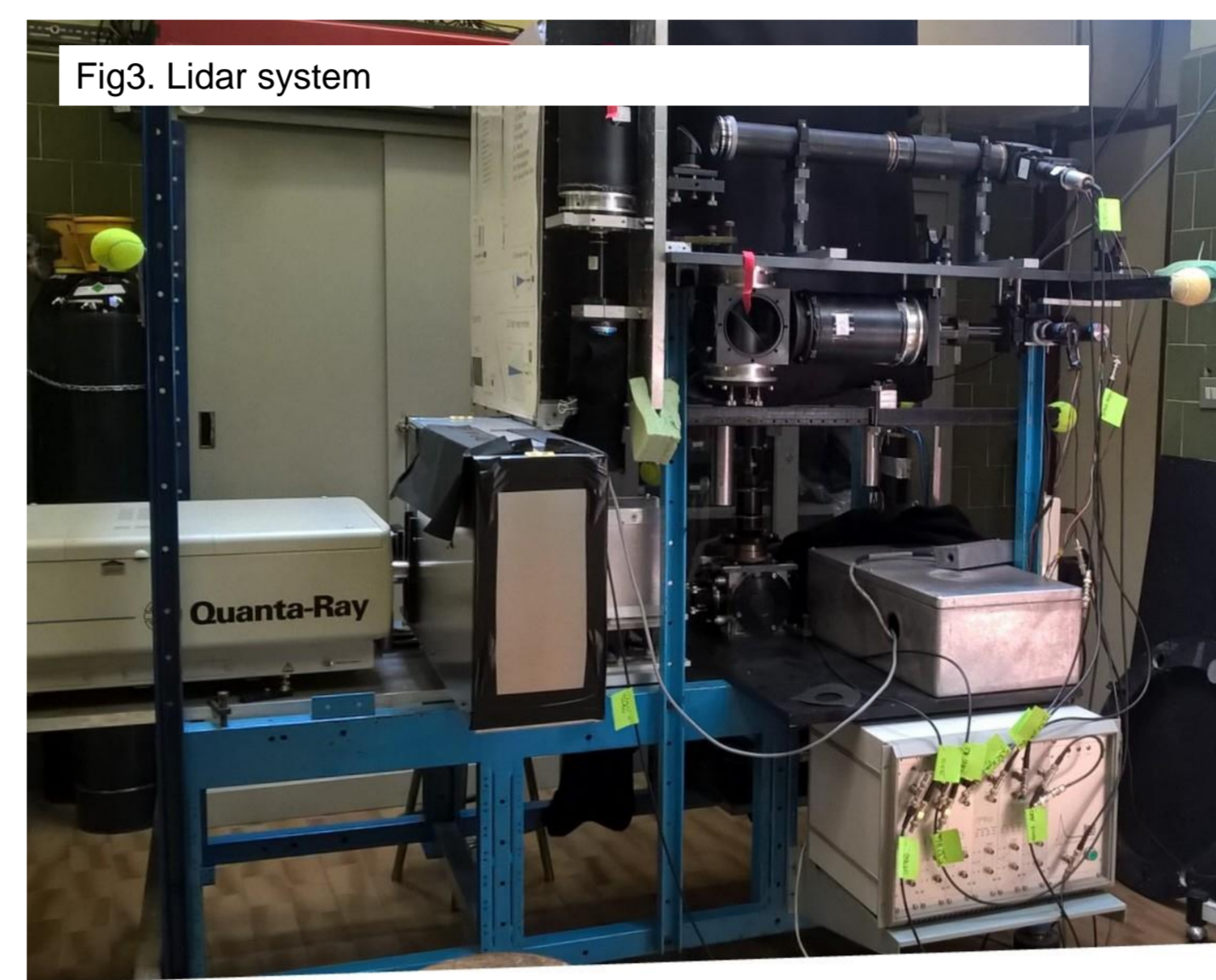
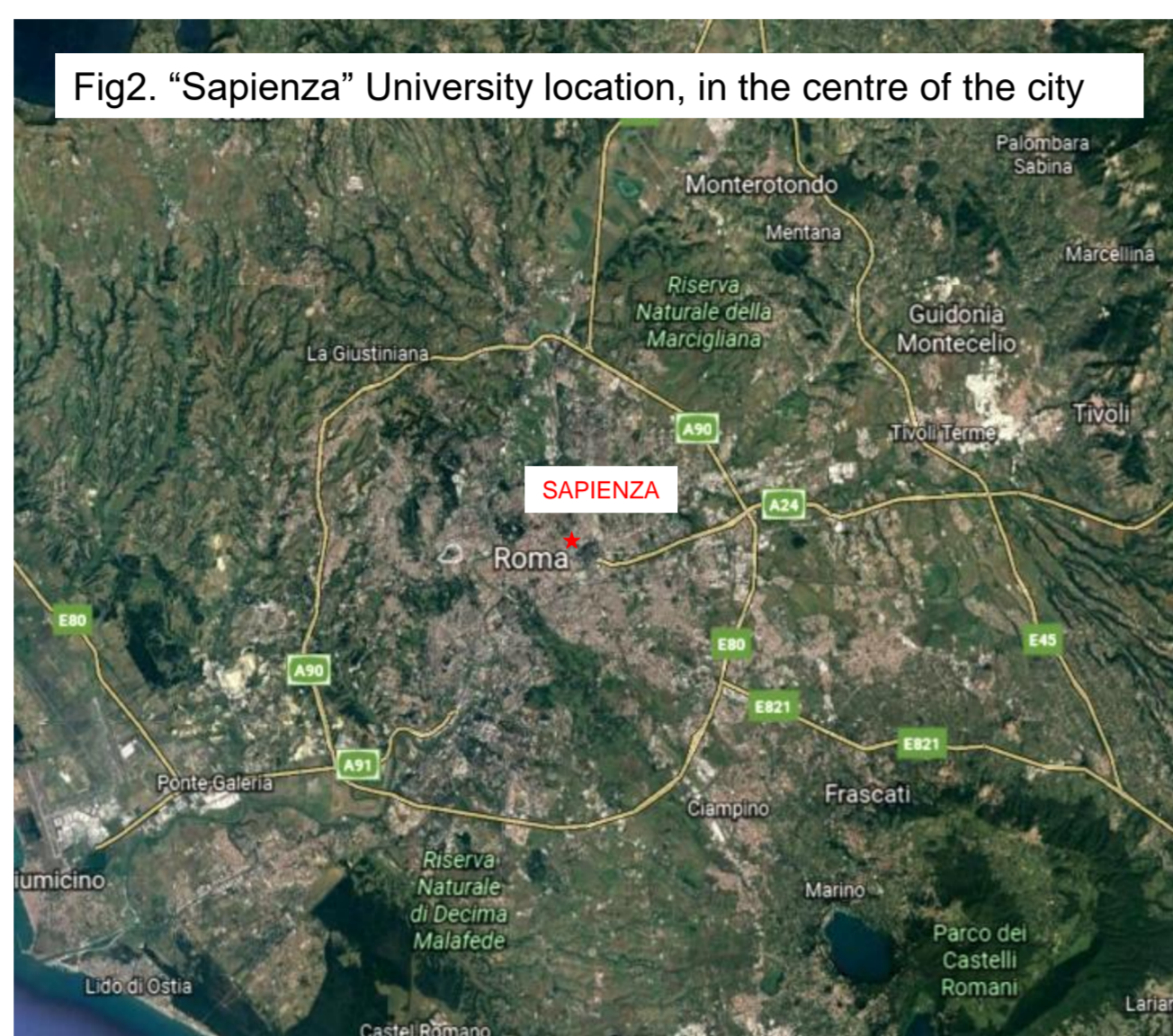
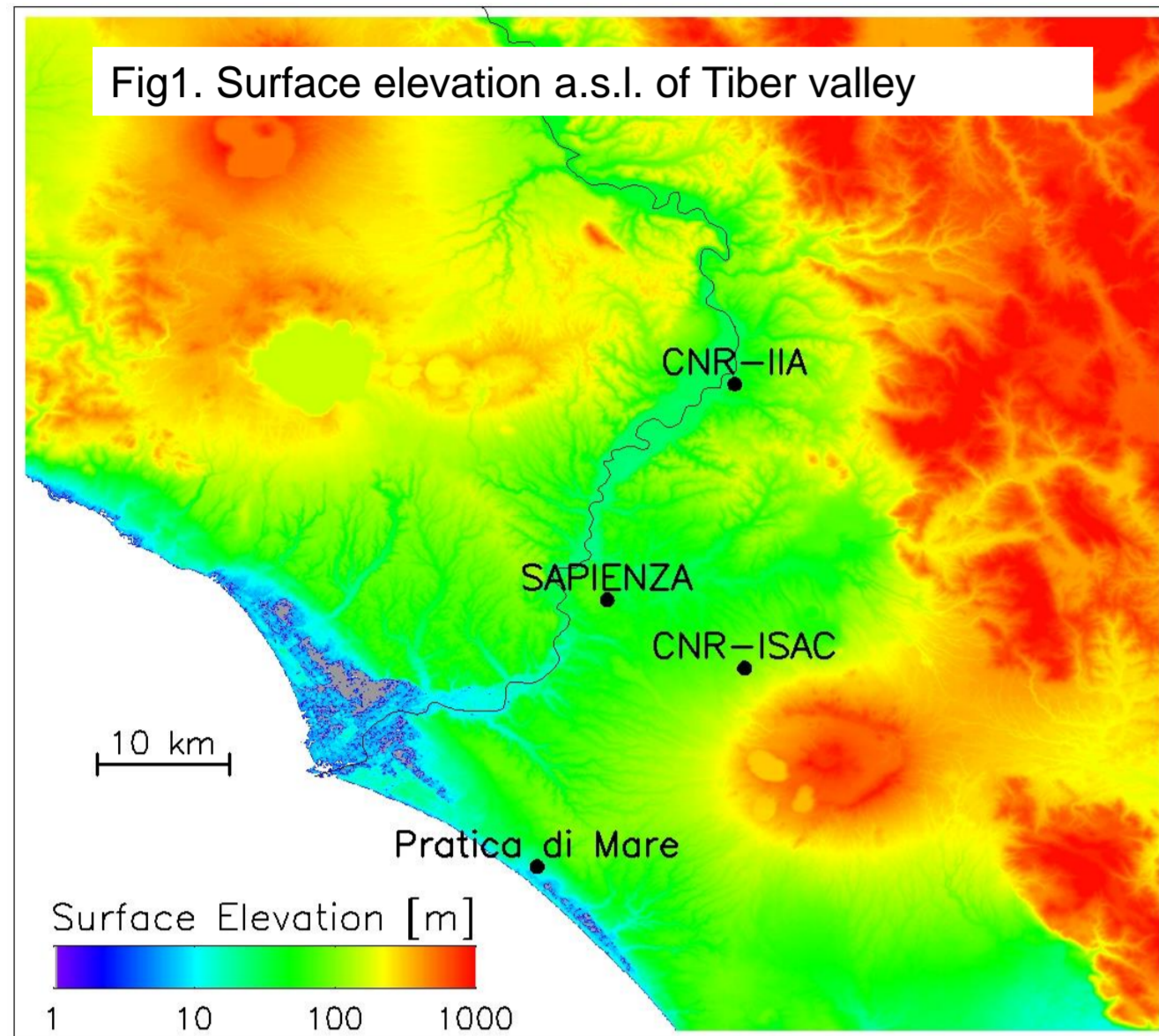
The Elastic/Raman LIDAR contribution to the Boundary-layer Air Quality Using Network of INstruments (BAQUNIN) project

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Instrument site. The LIDAR is installed inside the Atmospheric Physics Laboratory of University of Rome "Sapienza" (APL-Sapienza), at the last floor of the Department of Physics Fermi Building (CU033, Fig2). The building is inside the University Campus, located downtown Rome and surrounded by civil, commercial and administration buildings. On the roof of the same building other instruments for atmospheric observation are operative, most of them included in the BAQUNIN supersite equipment. The LIDAR operates vertically through a hatch in the roof. Transmitter and receivers are installed on a metallic frame sitting on the floor of the LIDAR room. The LIDAR control station is located in the LIDAR room and connected via LAN to the web.

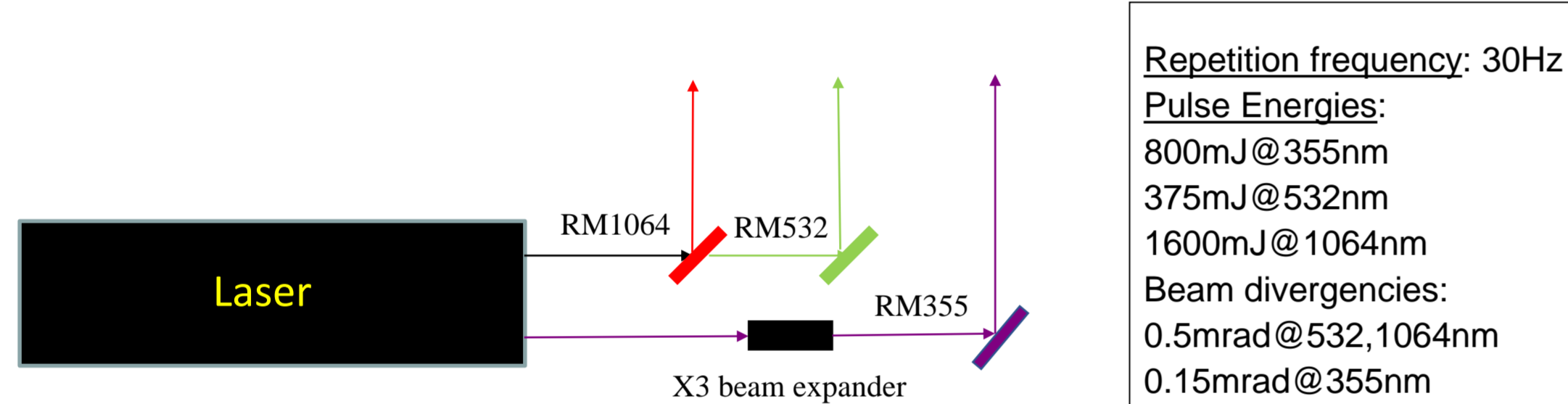
LIDAR overview. This LIDAR has been designed and assembled using both custom-made and commercial equipments (Fig3). Laser source, sensors, electronics and optics are commercial items, while frames and optomechanics were designed and built in the mechanical workshop of the Physics Department. The controlling software has been developed by the laboratory personel. This modular approach allows a regular upgrading of each component and gives the possibility to add to the basic instrument new acquisition channels, in order to improve the system performance. Presently the system includes a large power pulsed laser, emitting 3 wavelengths, 4 receivers and 12 acquisition channels. LIDAR can be operative in no-rain day and night conditions.



Position (lat., lon., alt.)	41.90°N, 12.52°E, 75 mASL
Max Vertical Resolution	7.5 m
Max Time Resolution	10 s
Max Vertical Range	30000 mASL
Min Overlap Height (Elastic)	150 mASL
Min Overlap Height (Raman)	1000 mASL
Emitted wavelengths	355, 532, 1064 nm
Received wavelengths	
Elastic backscattering	355±1.5 nm
	532±0.18 nm
	1064±1.07 nm
N2 Raman Backscattering	386±0.31 nm
H2O Raman Backscattering	407±0.25 nm

Transmitter.

A Quanta Ray Pro-290-30 laser produces pulses at three wavelengths, 1064, 532 and 355 nm, all emitted along the same beam path. The 355nm-beam is separated from the others by a Harmonic Separator (HS) beam splitter before leaving the laser. 1064nm and 532nm beams are then separated by another HS outside the head. The three beams are directed to the vertical direction by adjustable mirrors and prisms. For safety reason and to prevent that laser light leakages could be picked up by the receivers, the beams travel inside black enclosures throughout the path from the laser head to the hatch in the roof.

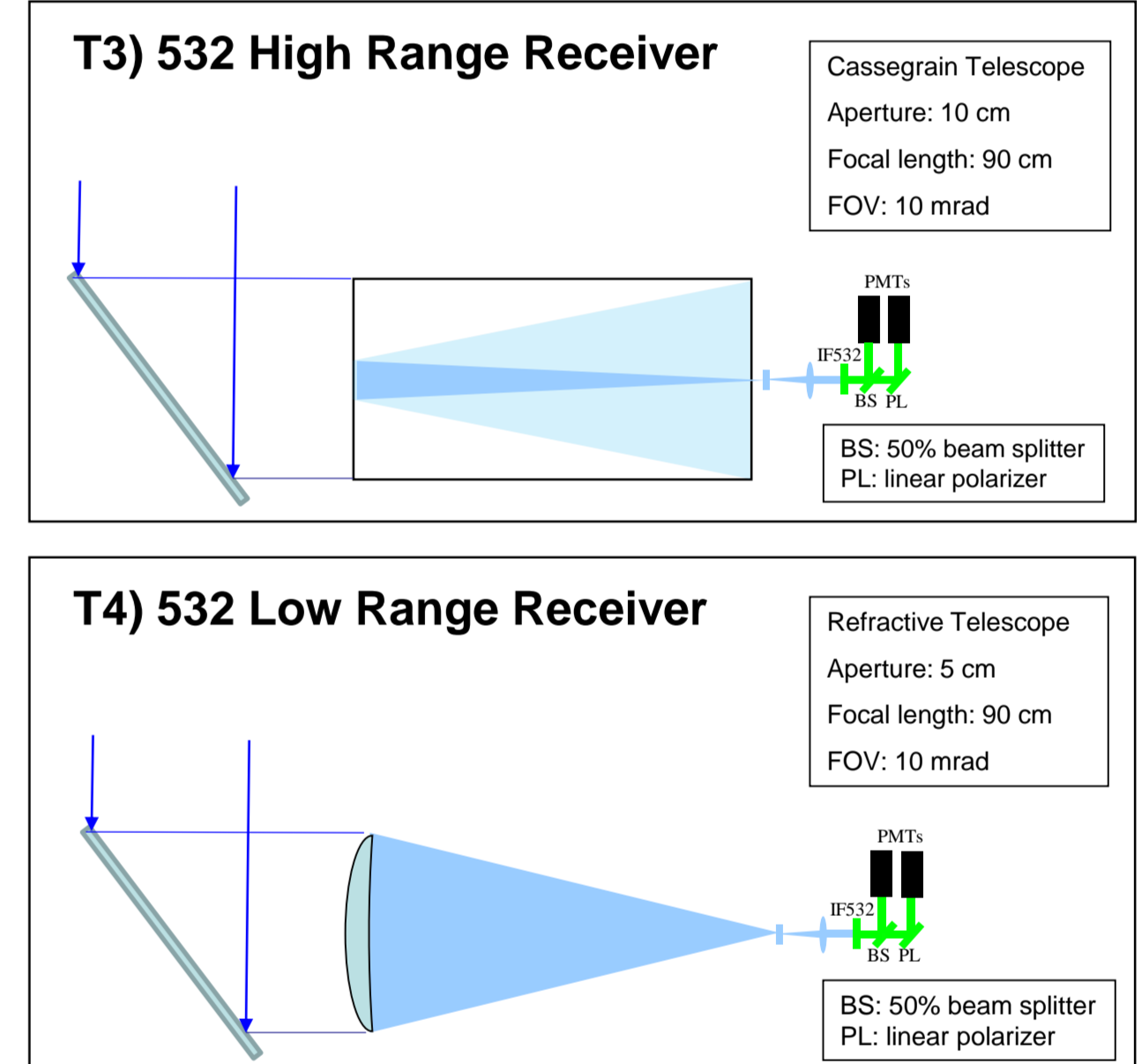
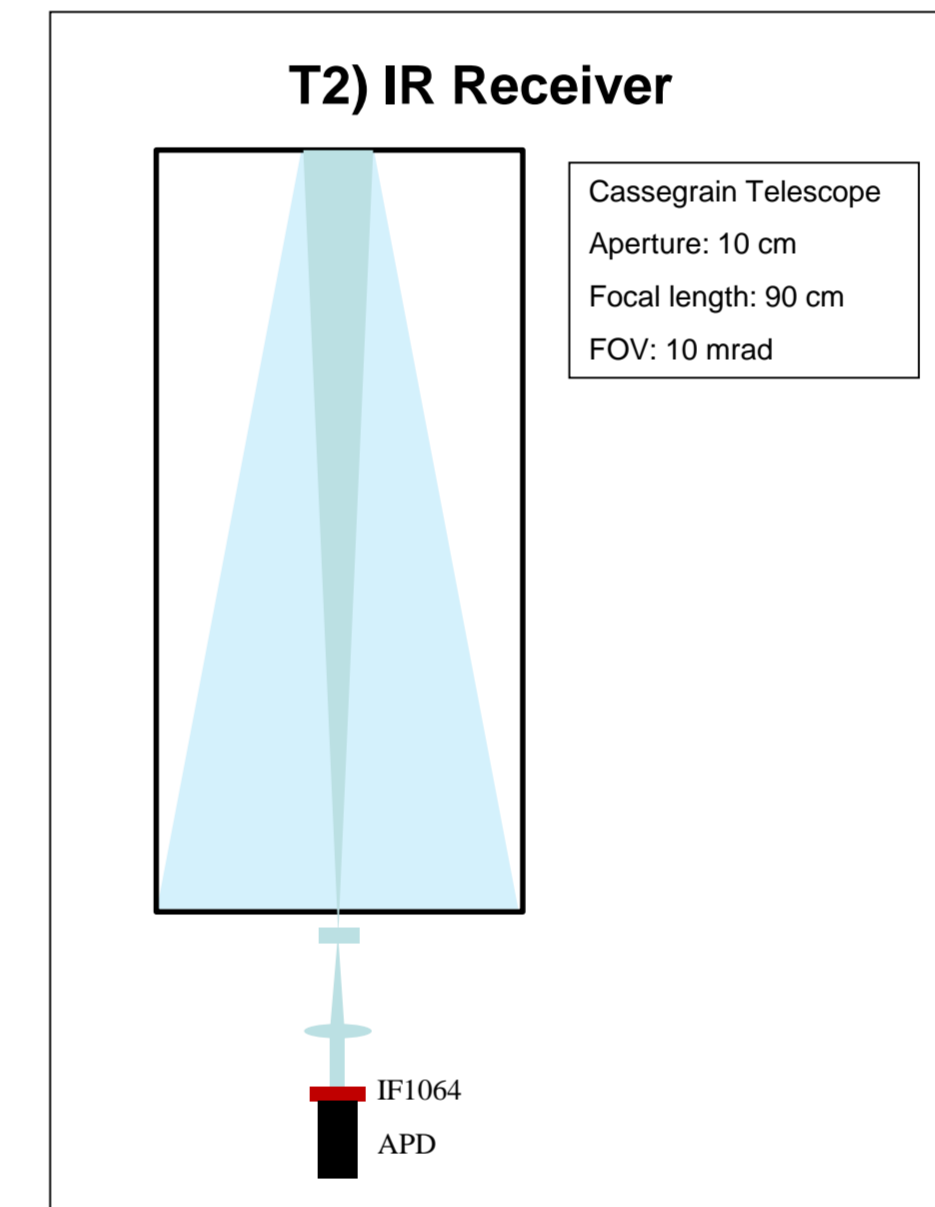
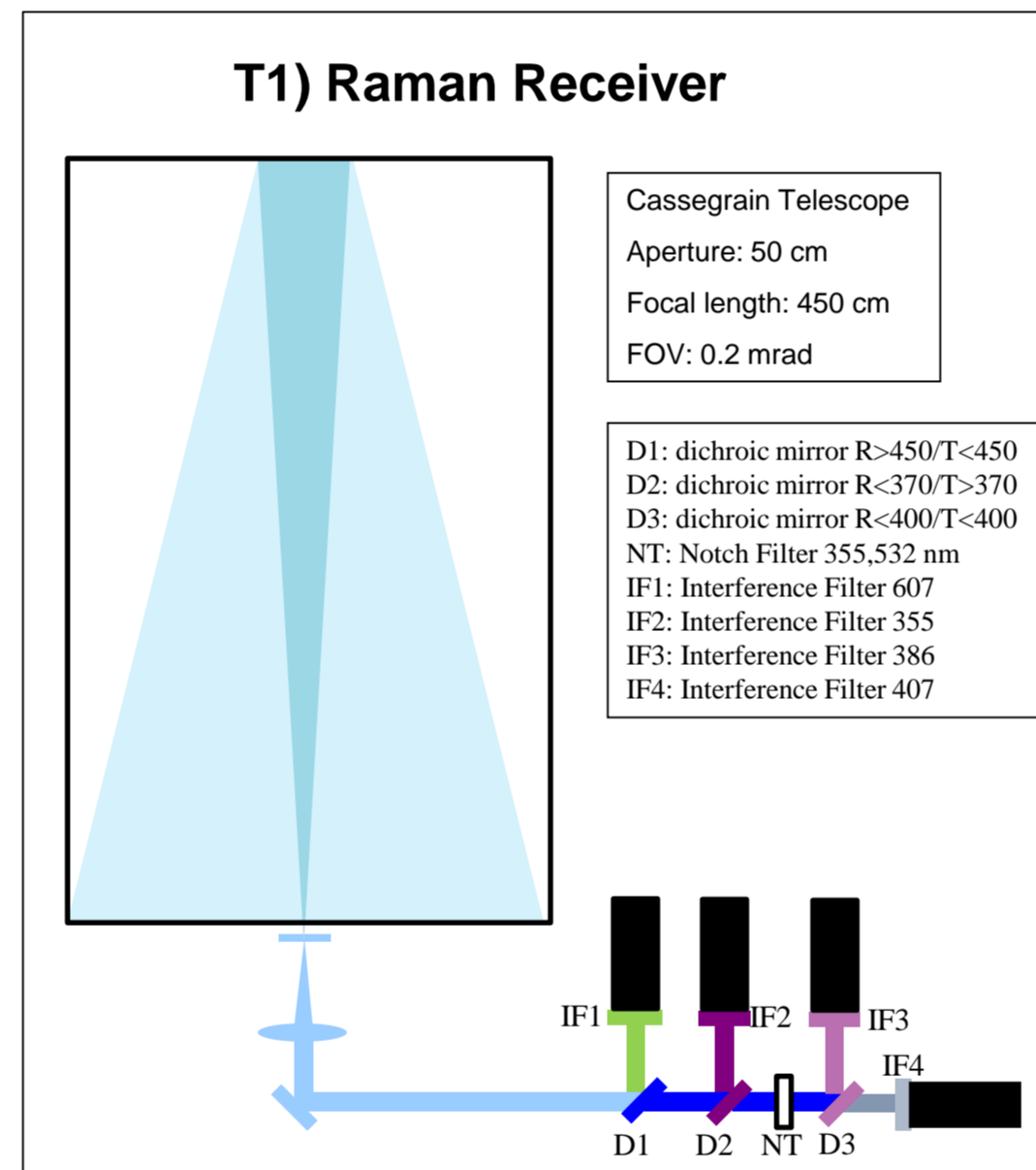


Repetition frequency: 30Hz
Pulse Energies:
800mJ@355nm
375mJ@532nm
1600mJ@1064nm
Beam divergencies:
0.5mrad@532,1064nm
0.15mrad@355nm

Receivers.

The lidar signals are collected by four receivers:

- T1) a large telescope for collecting the signals in the UV range (elastic backscattering at 355 nm and 355-nm exited Raman backscattering from atmospheric N2 and H2O);
- T2) a medium size telescope for collecting the elastic backscattering at 1064 nm;
- T3) a medium size telescope for collecting the elastic backscattering at 532 nm from the medium altitude range;
- T4) a small size telescope for collecting elastic backscattering at 532 from closer altitude range.



Acquisition System

The acquisition system is based on 6 Transient Recorders TR20@LICEL. Each TR20 is equipped with an ADC as well as a Photon counter. Altogether 12 channels are available for the signals acquisition. The analogic channels are dedicated to the acquisition of the stronger elastic backscatter signals, while the photon counting is the method to digitalize the weak Raman backscattering from atmospheric water vapour and molecular nitrogen.

Inversion method

Backscattering coefficient β and absorption coefficient α profiles are the two main quantities that can be obtained inverting the LIDAR data. The LIDAR equation describes the signal intensity S received as function of the altitude (Kovalev and Eichinger, 2004):

$$(1) \quad S(z) = C(\beta_m(z) + \beta_m(z)) \exp\left(-2 \int_{z_0}^z (\alpha_m(z') + \alpha_m(z')) dz'\right),$$

Where C is a constant depending on both atmosphere and observing system, z_0 is the LIDAR overlapping altitude and α_m and β_m are the absorption and backscattering coefficient due to air molecules.

Aerosol

In order to calculate α and β from the Equation 1, we employ the Rayleigh scattering theory using radio-soundings pressure and temperature profiles. We also impose a linear relation between absorption and backscattering: $\alpha = LR \beta$, where LR is defined LIDAR Ratio. This quantity depends on the nature of particulate (desert dust, urban aerosol, cloud droplets, etc.)

Even with this auxiliary information the problem is mathematically ill-posed; the solution is computed using the Kaul-Klett method (Klett, 1981).

The measured profile is analyzed computing the LIDAR factor,

$$f = S / \left(\beta_m(z_m) \exp\left[-2 \int_{z_0}^{z_m} \alpha_m(z') dz'\right] \right)$$

where z_m is a region in which no aerosol or clouds are present. Using the definition of f the Eq. 1 can be rewritten as

$$\frac{\beta(z) + \beta_m(z)}{\beta_m(z)} = \frac{S(z)}{f \beta_m(z) \exp\left[-2 \int_{z_0}^z \alpha_m(z') dz'\right]} \exp\left[-2 \int_z^{z_m} LR \beta(z') dz'\right]$$

This equation can be solved using a recursive algorithm in order to retrieve β and α .

Water vapor

Water Vapor Mixing Ratio is proportional to the ratio of Raman signals of water vapor and nitrogen. System calibration constant is obtained by the comparison with the values measured in the free atmosphere by closest-in-time and -distance radiosounding. A result obtained with this procedure is shown in fig.5.

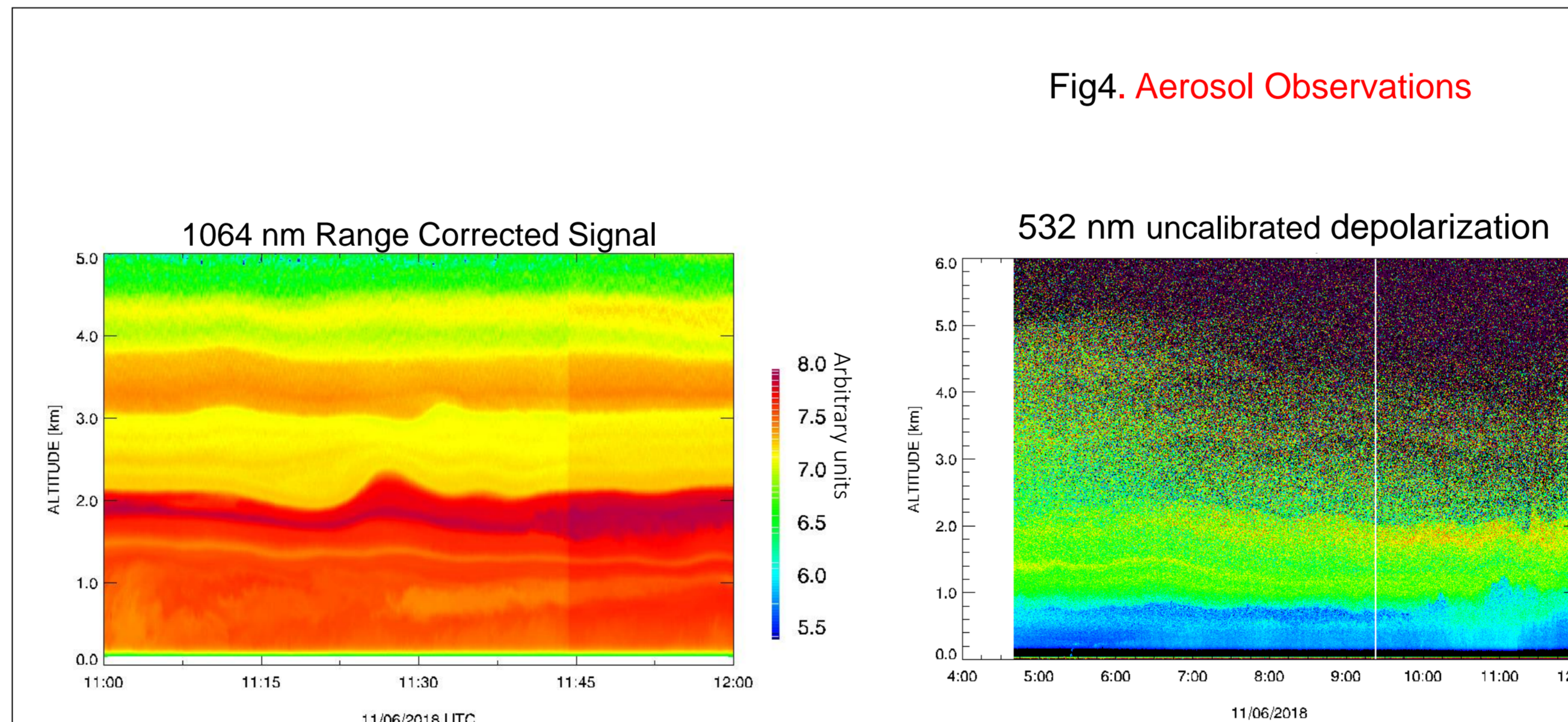


Fig4. Aerosol Observations

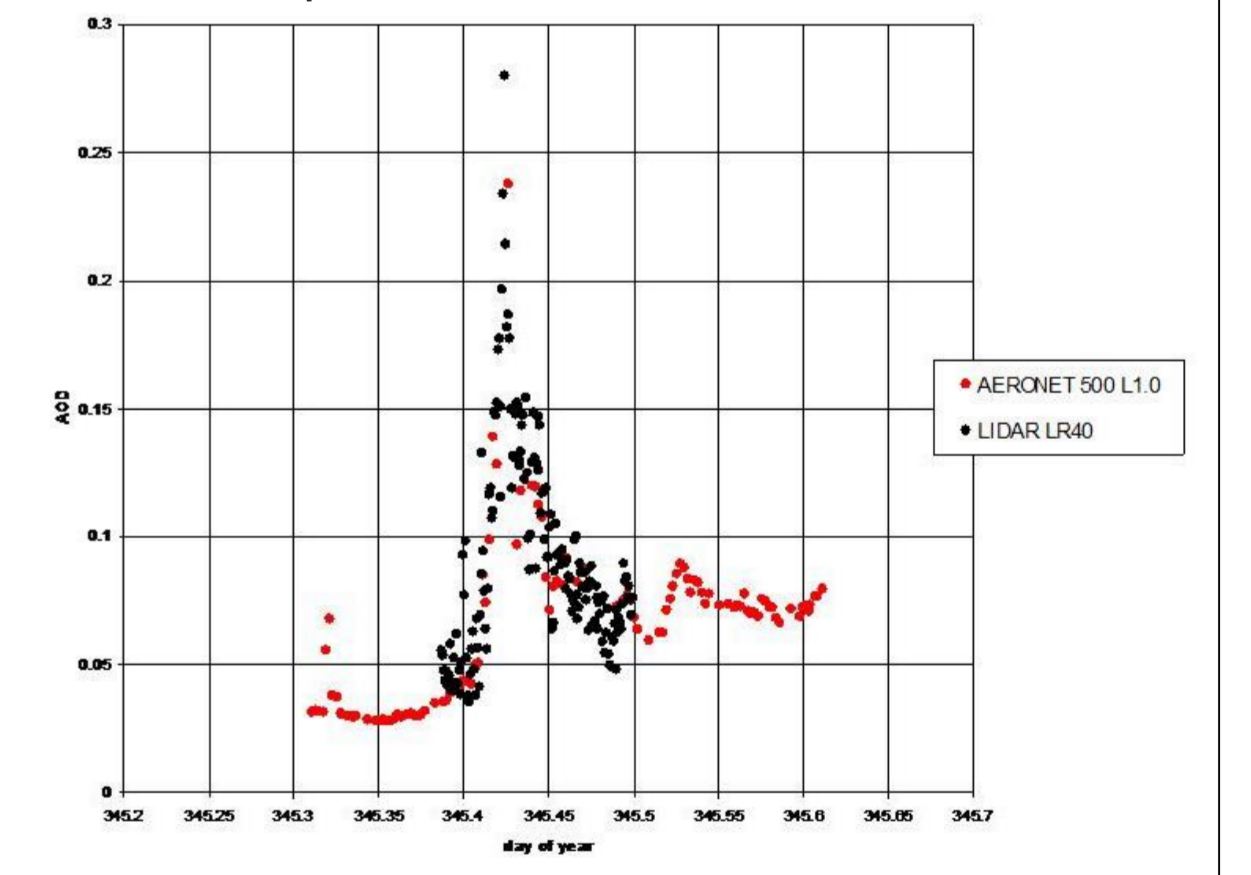
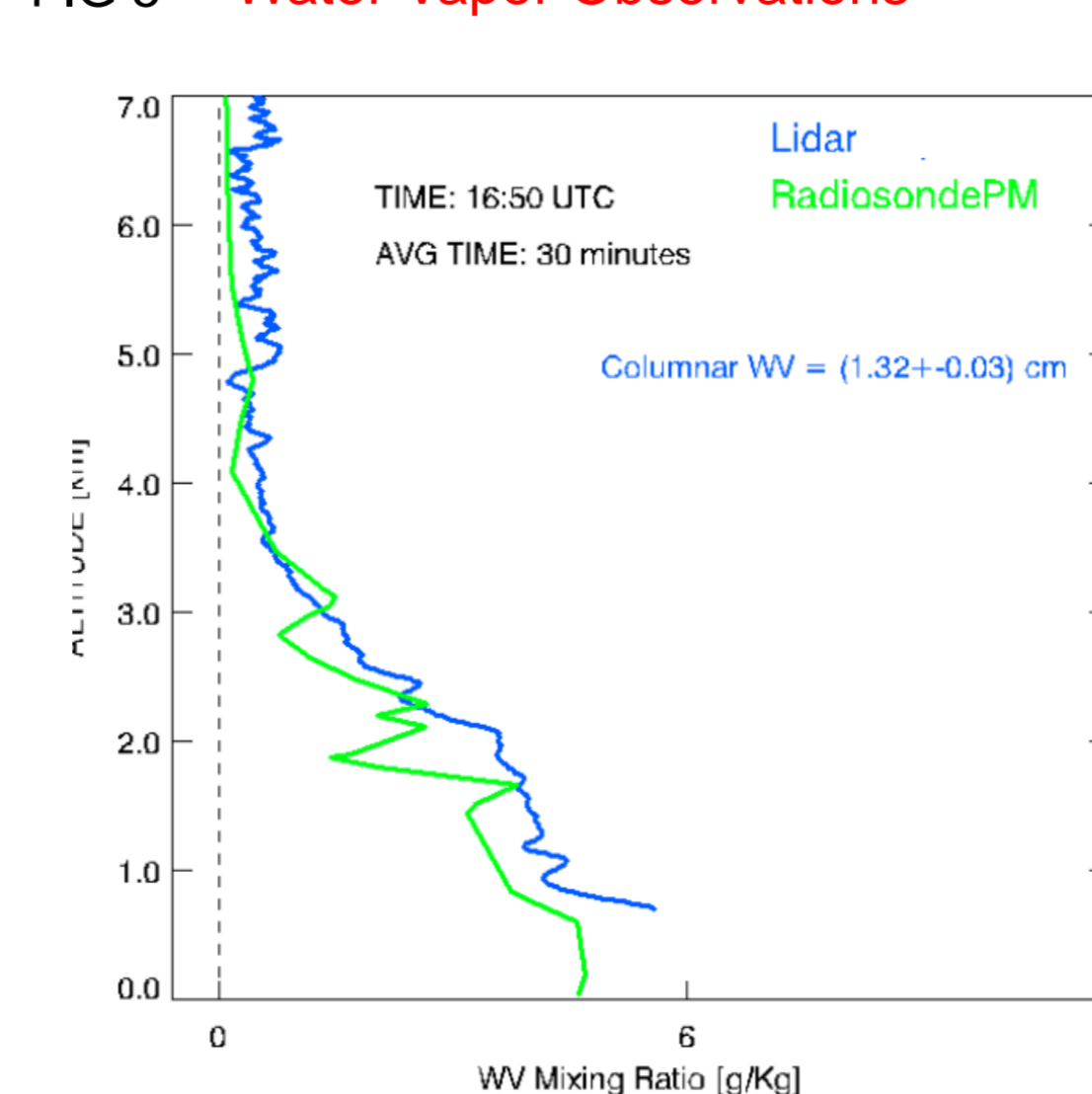


FIG 5 Water Vapor Observations



Quality Assurance

Quality assurance procedures adopted to characterize LIDAR performances and errors follow the indications for the EARLINET LIDARs (Freudenthaler et al., Atmos. Meas. Tech. Discuss., 2018) :

- 1) The time delay between pulse emission and the zero-range of signals has been measured using the peak delay generated from stray-light from the laboratory walls.
- 2) The correct alignment of the telescope in the near range has been obtained using the telecover method.
- 3) The analysis of polarization calibration is in progress.

Conclusions

Presently the Baqunin LIDAR system, in synergy to the other Baqunin equipment, is involved in the CAL/VAL SENTINEL 5P activity and in the DIVA project. The instrument is also used for the study of Urban Boundary Layer (UBL), in particular to retrieve the evolution of aerosol loading and humidity, the height of Mixing Layer as well as the interaction between UBL and Free Atmosphere.

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