

## **STAND OFF OPTICAL SYSTEMS FOR CHEMICAL DETECTION AND IDENTIFICATION AS TOOL TO IMPROVE PUBLIC SECURITY**



**Andrea Malizia, PhD**

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3. International Master Courses in Protection Against CBRNe events, Department of Industrial Engineering & School of Medicine and Surgery, University of Rome Tor Vergata ([www.mastercbrn.com](http://www.mastercbrn.com))

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## LASER MONITORING

- SAI - LIDAR system (smoke/pollutants at long distance)
- TELEMACO (particle analysis with laser in air at long distance)
- SNIFF – LIDAR & DIAL systems (environmental pollutants source and diffusion control)

## MATERIAL SCIENCE

- Material characterization (SEM, XRD, X-ray and Optical Spectroscopy)
- New structure growth and possible applications (new detectors, specific material properties, etc...)

## DIDACTICAL ACTIVITIES

- Undergraduate Courses in Physics, Laser Systems, Fusion Energy
- Post Graduate Courses in:
  - CBRNe Protection : [www.mastercbrn.com](http://www.mastercbrn.com) ([info@mastercbrn.com](mailto:info@mastercbrn.com))
  - Nuclear fusion : ([segreteriafusione@gmail.com](mailto:segreteriafusione@gmail.com))





## **NUCLEAR FUSION – Magnetic Confinement**

- Energy production
- Material studies (Fast particle production and radioprotection)
- Safety studies (Loss of Vacuum Accidents) with STARDUST-U facility
- Development of a genetic code to process database to find connection and physics law (computational work)

## **NUCLEAR FUSION – Inertial Confinement**

- Controlled nuclear explosions for energy production
- Equation state in Warm Dense Matter (Stars, giant Planets core)
- Material studies (Fast particle production and radioprotection)
- Development in diagnostic and detectors (operation in extreme regime)
- Hydrodynamic simulations



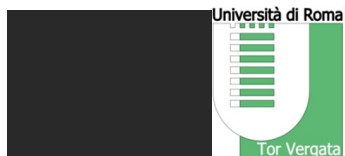
# AGENDA

- 1. Overview**
- 2. LIDAR as Detection technology**
  - **LIDAR based equation**
  - **LIDAR Systems developed & applications**
- 3. DIAL as Identification technology**
  - **DIAL based equation**
  - **DIAL Systems developed & applications**
- 4. Integration of both methodologies and Future development**

# 1. OVERVIEW



Chemical events



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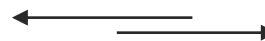
# 1. OVERVIEW

The intentional or accidental diffusion of chemical contaminants in air (both in open and closed environments) presents a dramatic risk for the health of the public worldwide.

## Chemical events:

**Natural or incident event**

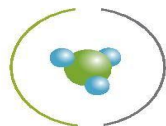
**War**



**Terrorism**



**Viareggio (2009)**



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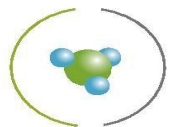
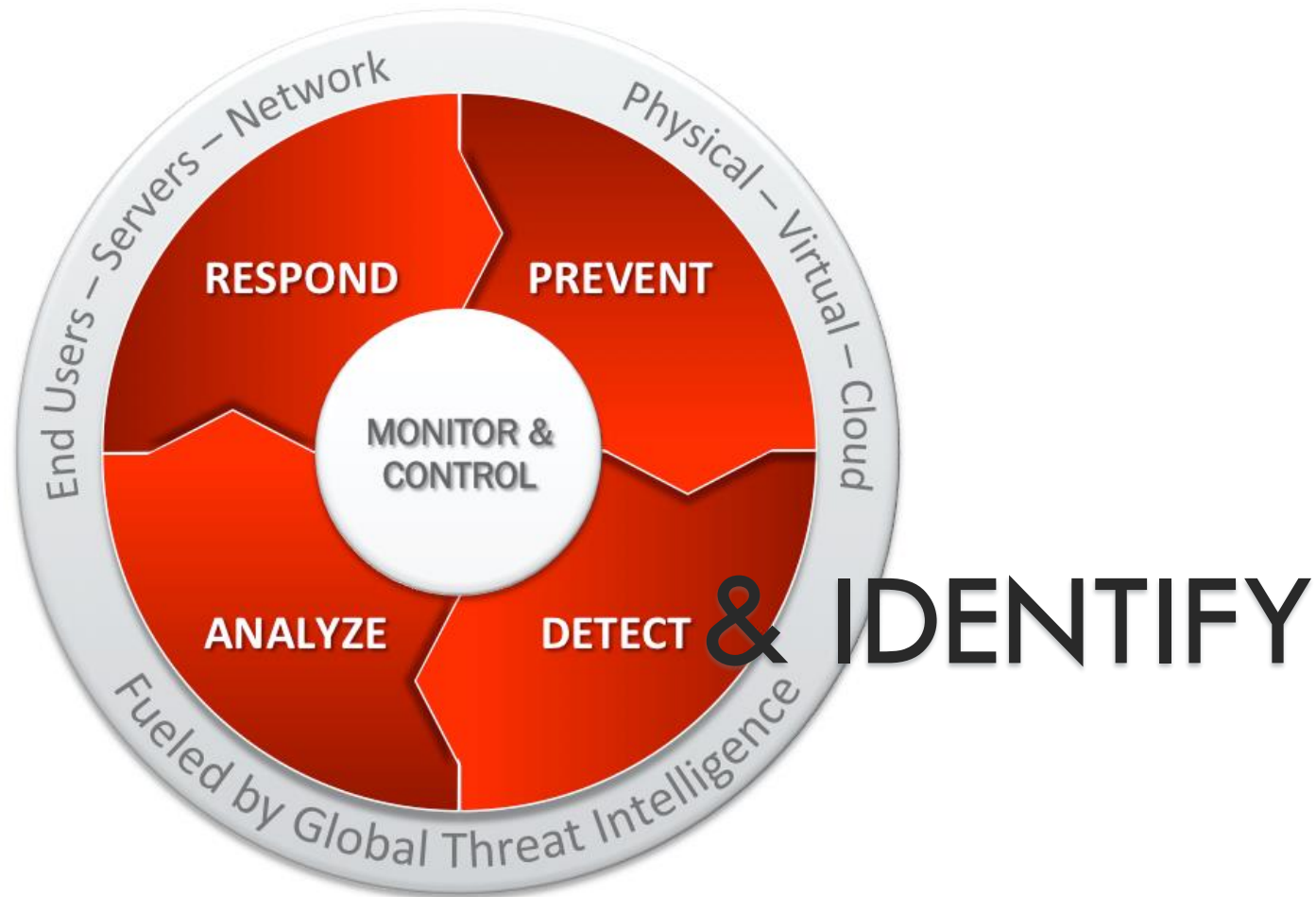


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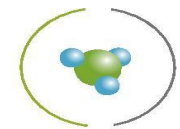


# 1. OVERVIEW



## 2. LIDAR AS DETECTION TECH.

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# DETECT ANOMALIES

# SOMETHING is SOMEWHERE

# = ALARM!





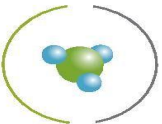
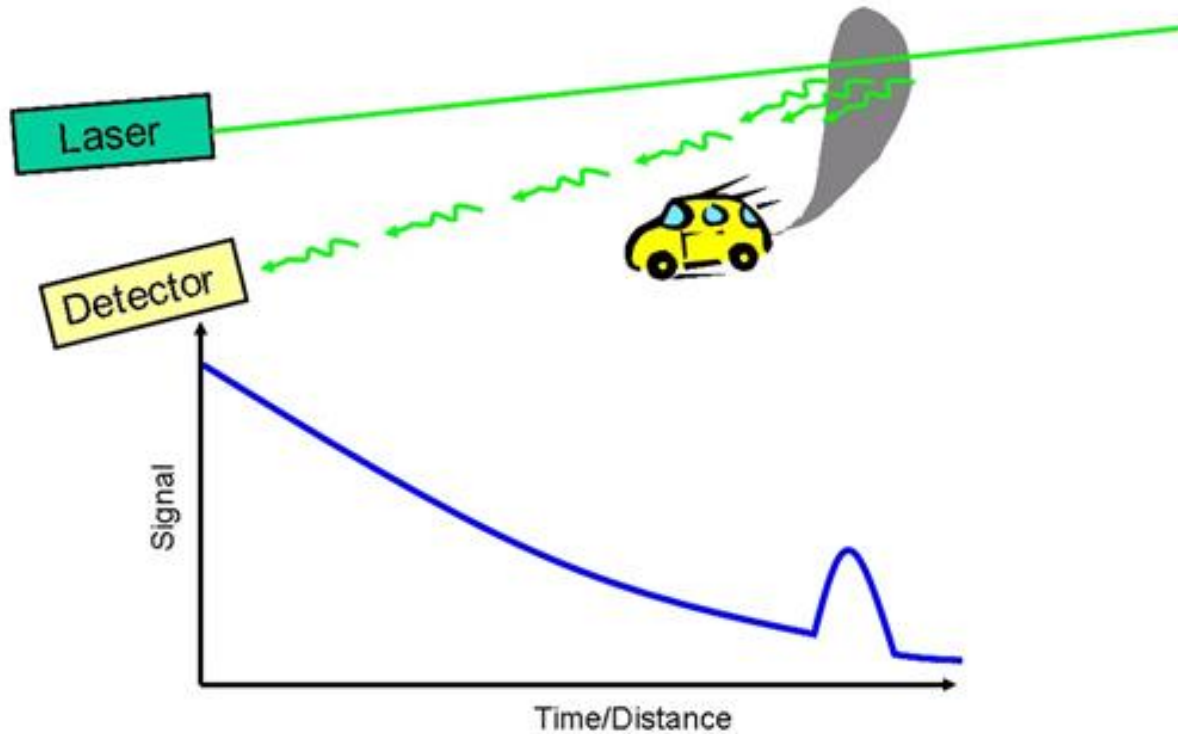
# 2. LIDAR AS DETECTION TECH.

## Remote sensing laser based technologies

- Detection methodologies (LIDAR)
  - Particulate measurements for:
    - Forest fire detection
    - Pollutants source detection
      - Industrial activity
      - Urban activity
  - Atmospheric measurements for evaluate PBL height

# 2.1 LIDAR BASED EQUATION

$$P_{\lambda_0}(z) = P_0 \frac{O(z)}{z^2} [\beta_{\lambda_0}^{aer} + \beta_{\lambda_0}^{mol}] \times \exp \left\{ -2 \int_0^z [\alpha_{\lambda_0}^{aer}(\zeta) + \alpha_{\lambda_0}^{mol}(\zeta)] d\zeta \right\}$$



Some applications based on particulate detection:

- Fire detection
- Vertical Particulate concentration and measurements
- Pollutants source detection
- Detection of anomalies in monitored area for first alert in case of accidental releases



# 2.2 LIDAR SYSTEMS DEVELOPED & APPLICATIONS

## Forest Fire detection

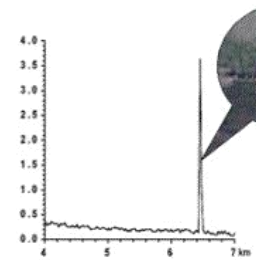
# SAI system



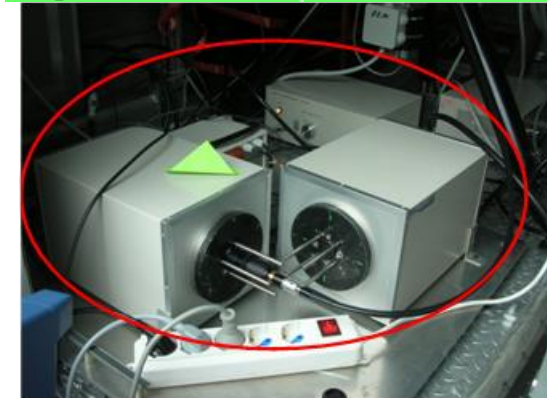
TRANSMITTER	
Laser	Q-switch Nd:Yag
Energy pulse at 1064 nm	360 mJ
Pulse time width	5 ns
Divergence angle	0,5 mrad
Pulse Frequency	10 Hz



1064 nm - 532 nm - 355 nm



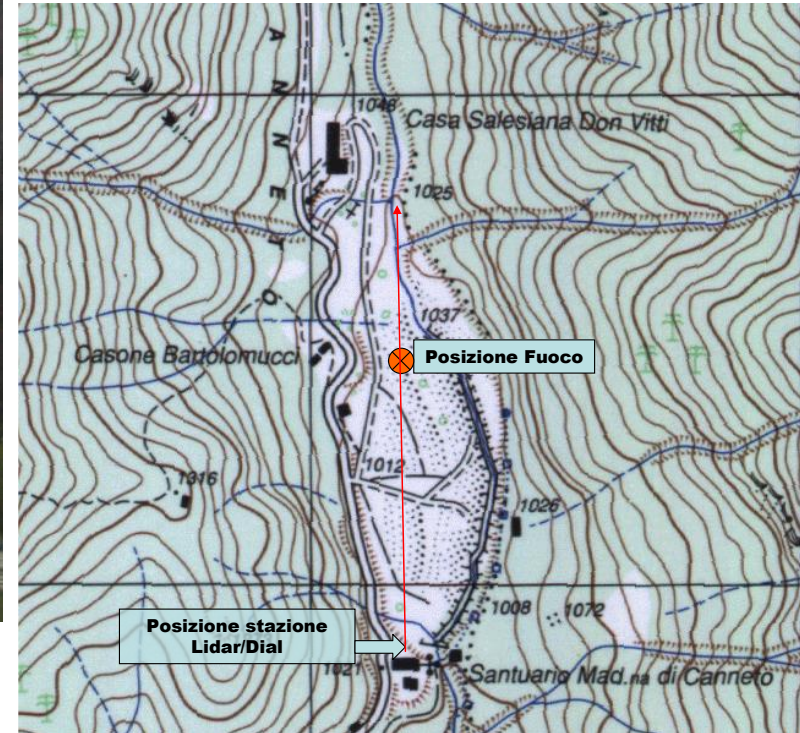
RECEIVER	
Telescope type	Newtonian
Nominal focal length	1030 mm
Primary mirror diameter	210 mm
Detector	Photomultiplier (PMT)
Photocathode sensibility	0.256 mA/W
Response time	28 ns



# 2.2 LIDAR SYSTEMS DEVELOPED & APPLICATIONS

## Automatic fire detection: a case study

## Italian National Park of Abruzzo, Lazio and Molise

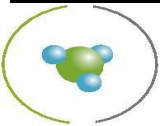
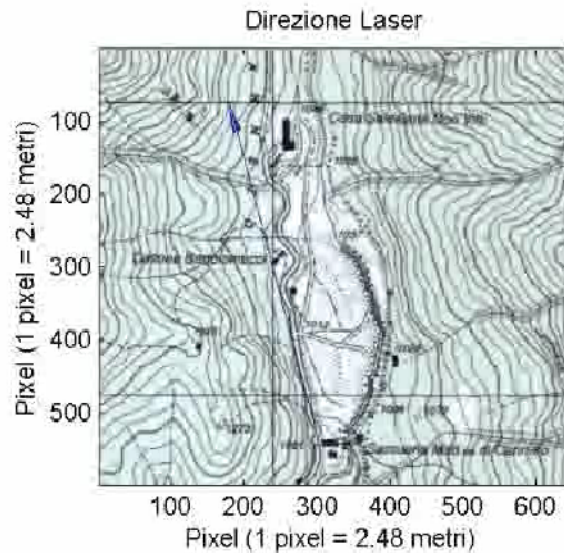




## Automatic fire detection

SAI: Elev. 1009 m 41° 40' 44.9" N

13° 54' 30.3" E





# COLI system

## Mini LIDAR system

**Mini-Lidar unit** (operating at 1064 nm).

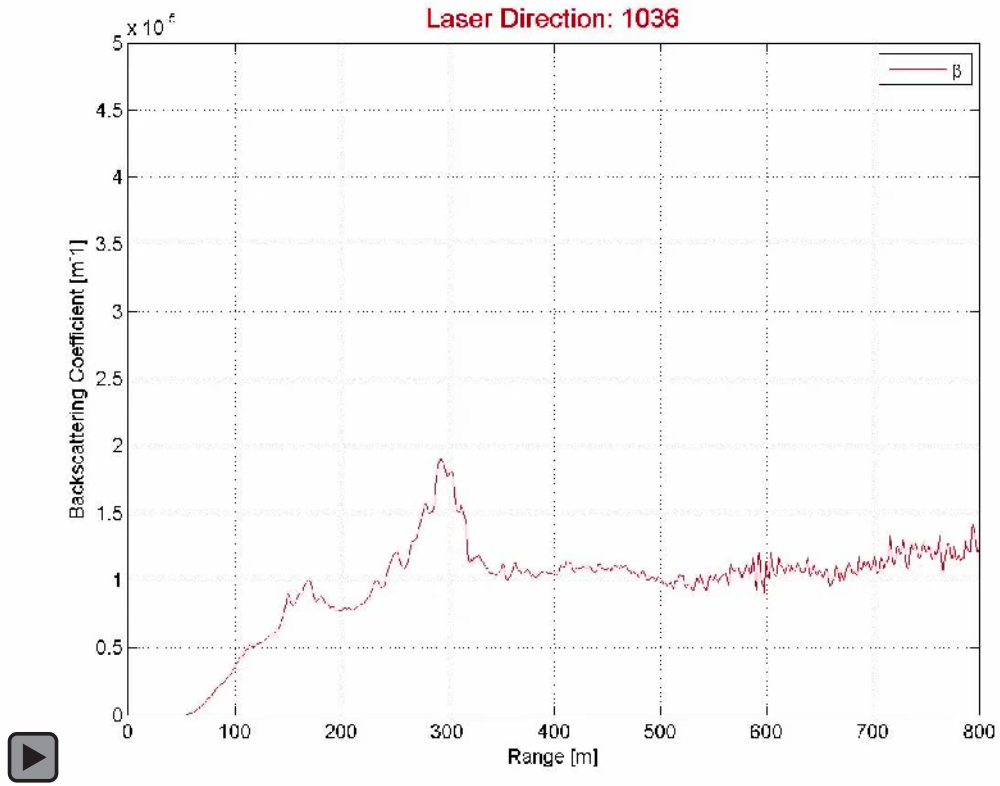
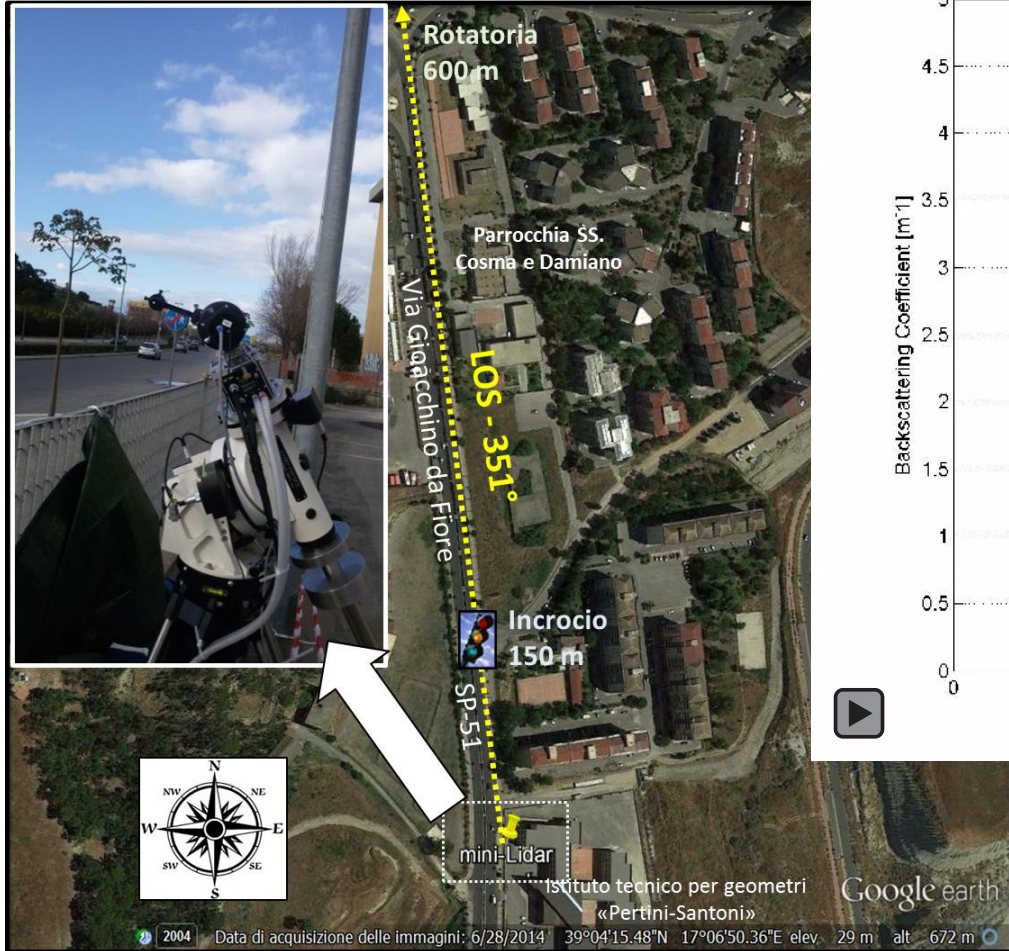
Assembling and easily transportable compact lidar system. Configuration is monostatic and biaxial. The whole apparatus is mounted on altazimuthal system.

The transmitter is constituted by a Nd:YAG laser, the receiver system is based on a Cassegrain telescope and a Si-APD module.



# 2.2 LIDAR SYSTEMS DEVELOPED & APPLICATIONS

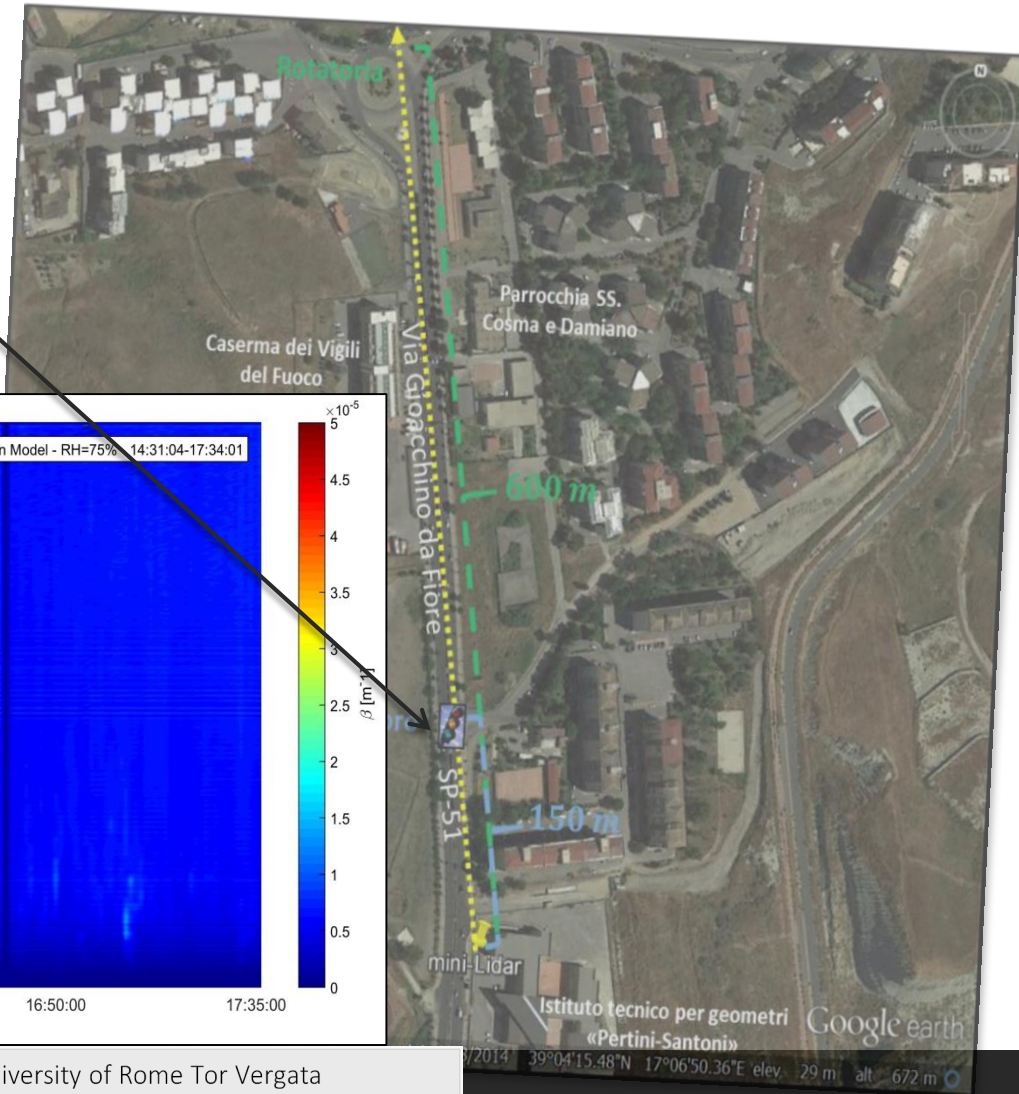
## Particulate detection in urban area





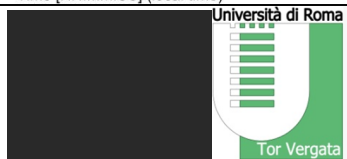
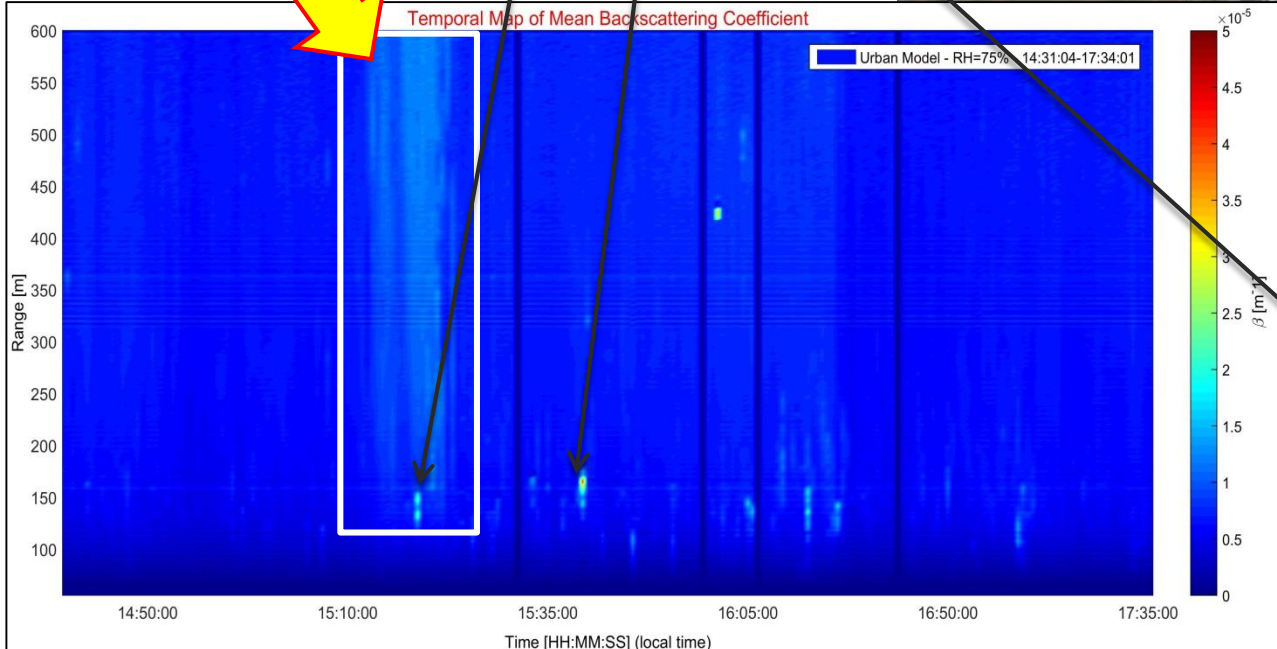
# 2.2 LIDAR SYSTEMS DEVELOPED & APPLICATIONS

Particulate detection in urban areas



**Traffic Jam**  
15:10-15:25

Traffic light

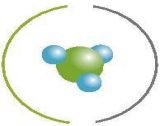
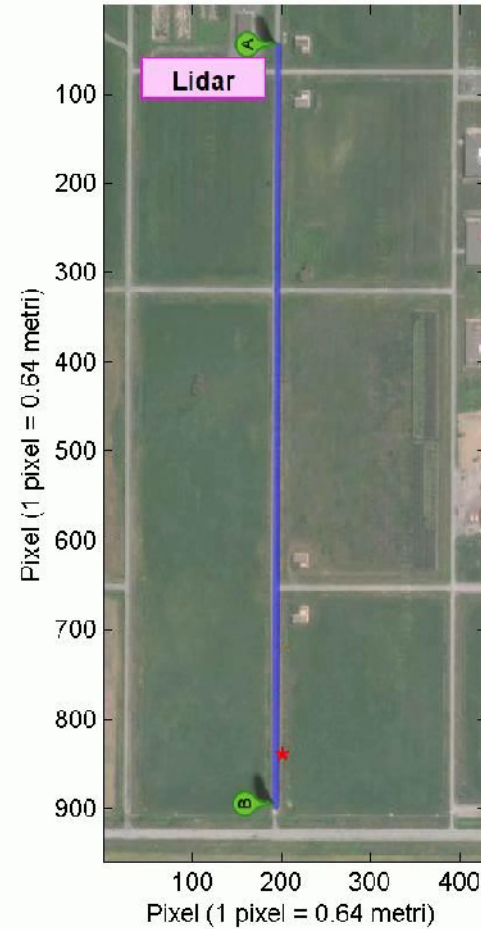
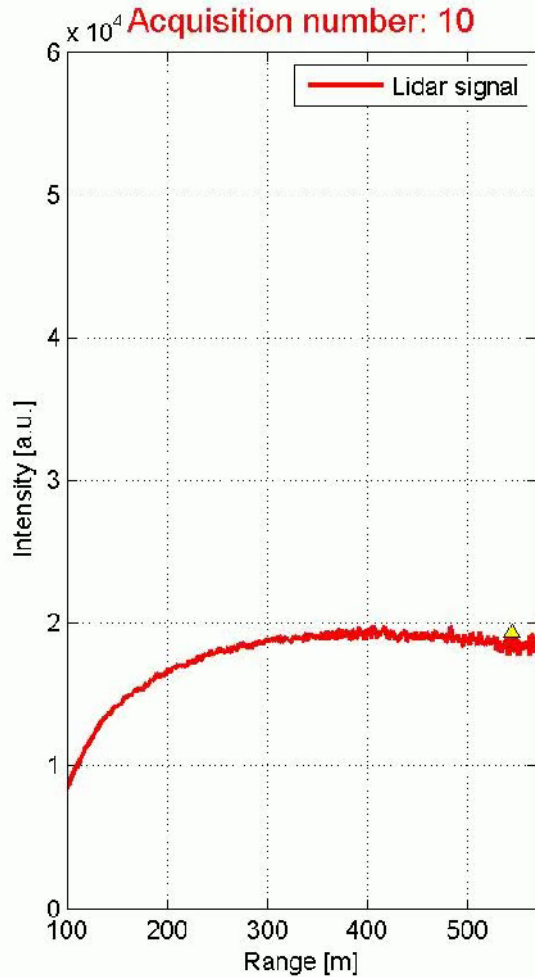


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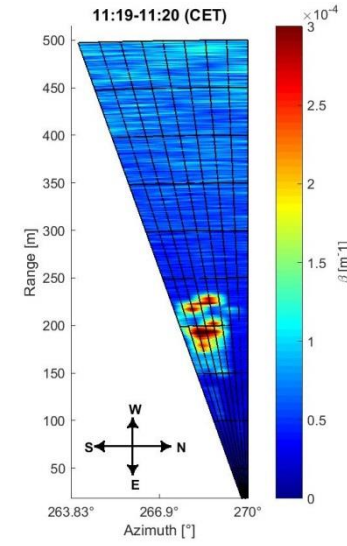
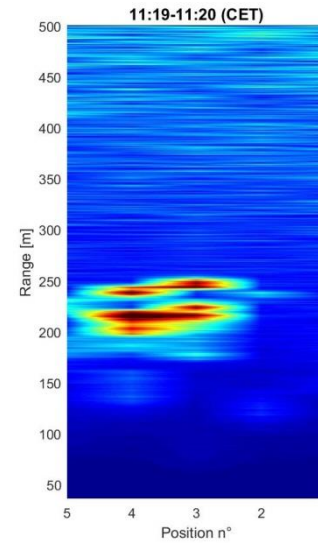
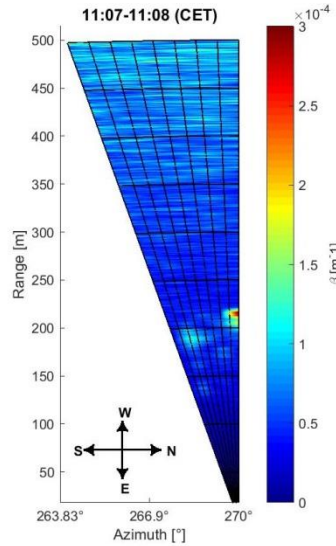
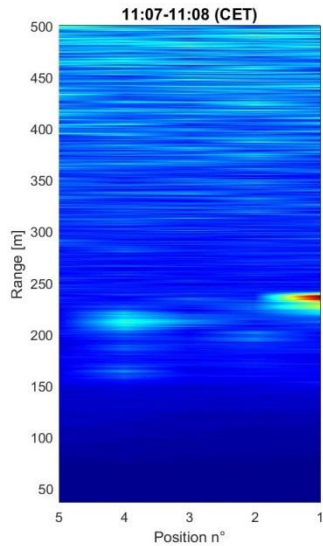
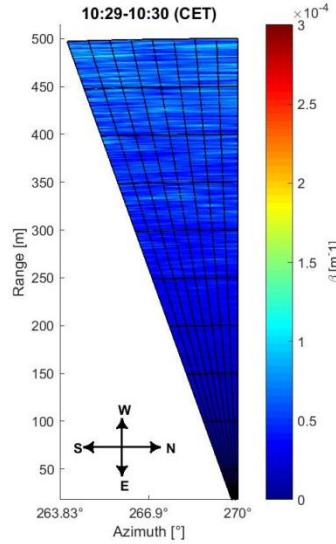
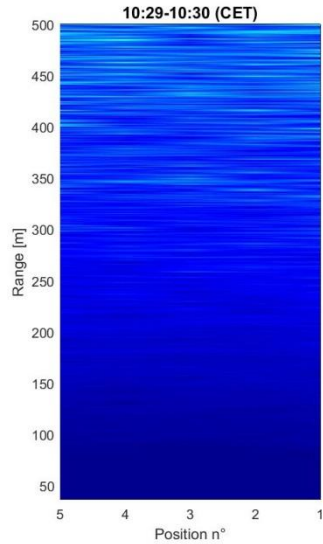
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# 2.2 LIDAR SYSTEMS DEVELOPED & APPLICATIONS

## Automatic detection of pollutant source in real time

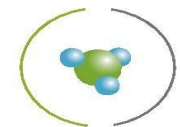
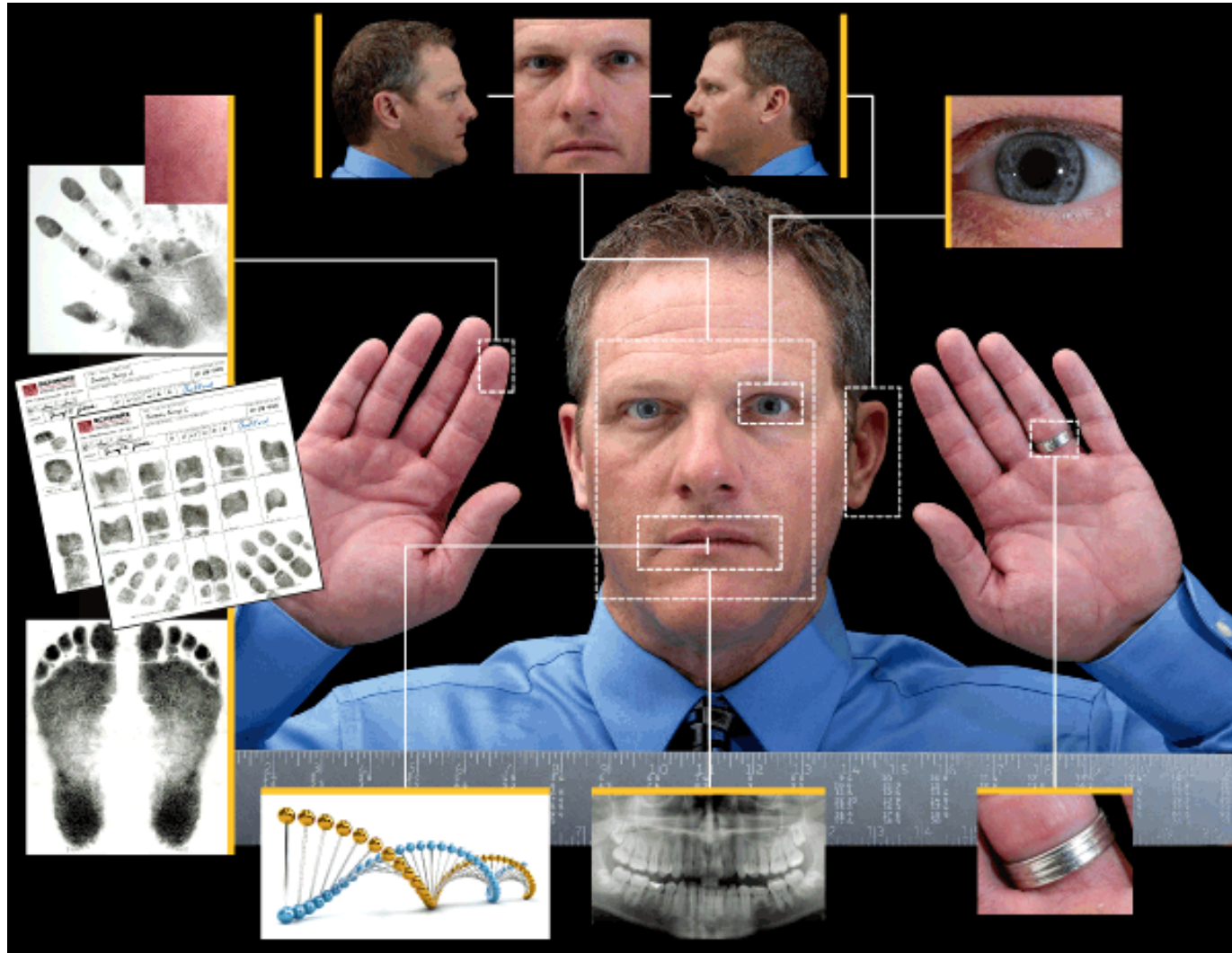


## Automatic detection of pollutant sources: a temporal map





# 3. DIAL AS IDENTIFICATION TECH.



# 3. DIAL AS IDENTIFICATION TECH.

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# IDENTIFY CHEMICALS



# SUBSTANCES FINGERPRINTS= EMERGENCY!

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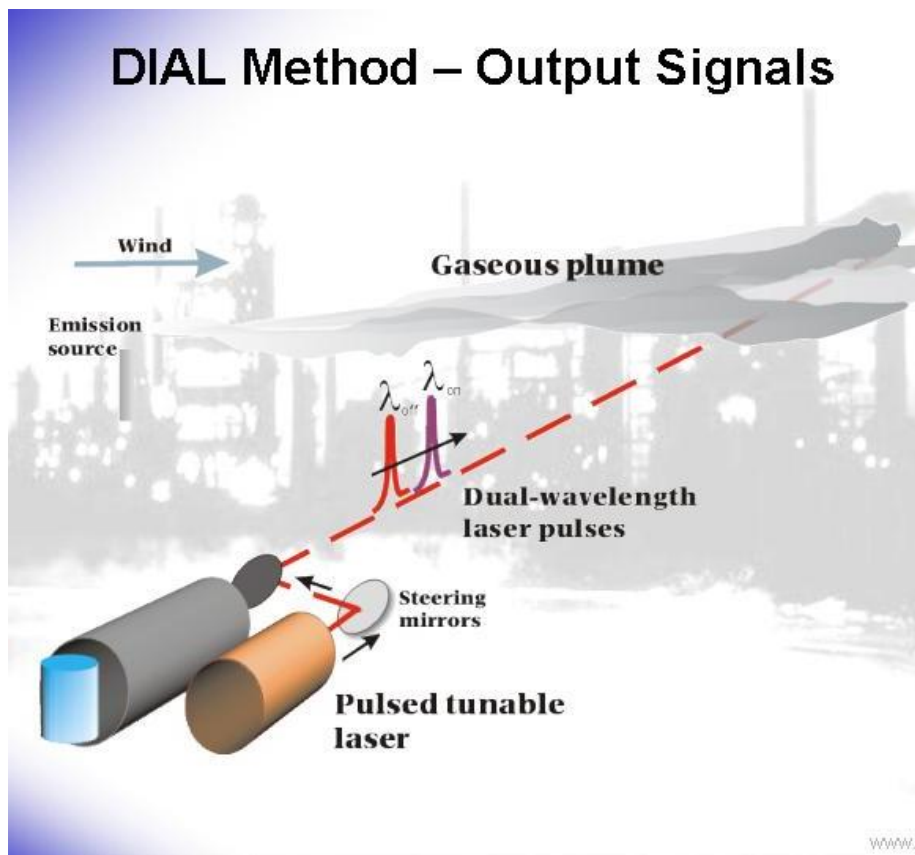
# 3. DIAL AS IDENTIFICATION TECH.

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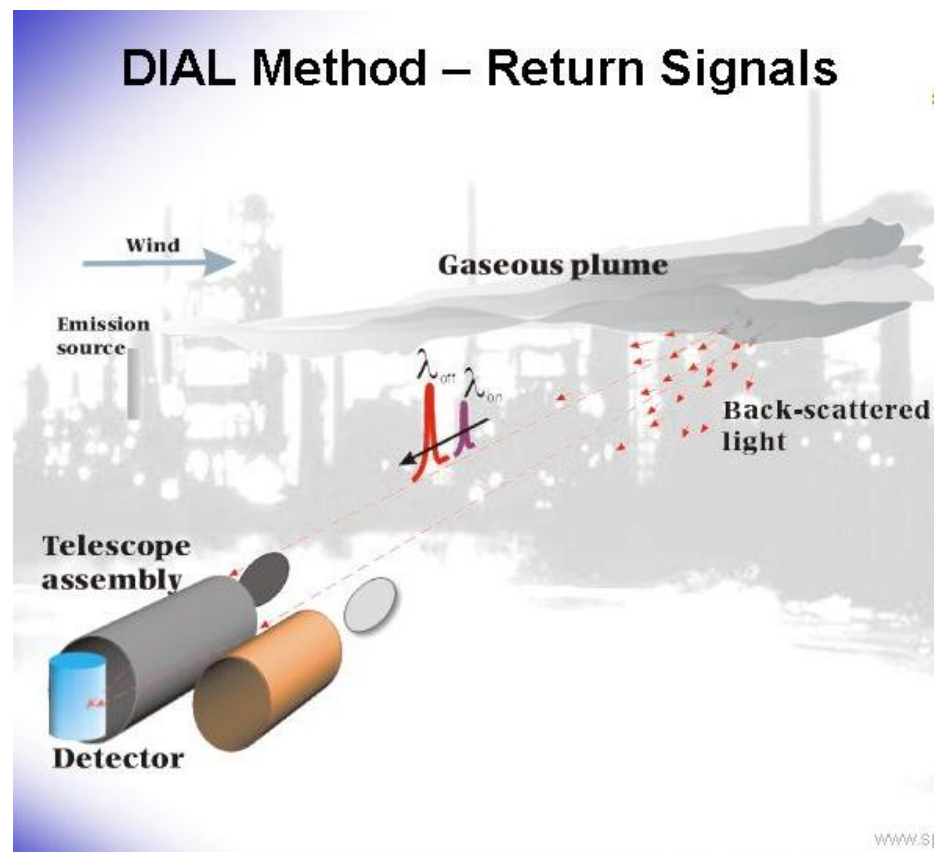
- Identification methodologies (Differential Absorption Lidar - DIAL)
  - ▣ Chemical identification
  - ▣ Dispersion of chemical gas by industrial area
  - ▣ Water vapour measurements
  - ▣ Pollutant dispersion study

# 3. DIAL AS IDENTIFICATION TECH.

## DIAL Method – Output Signals



## DIAL Method – Return Signals

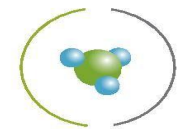
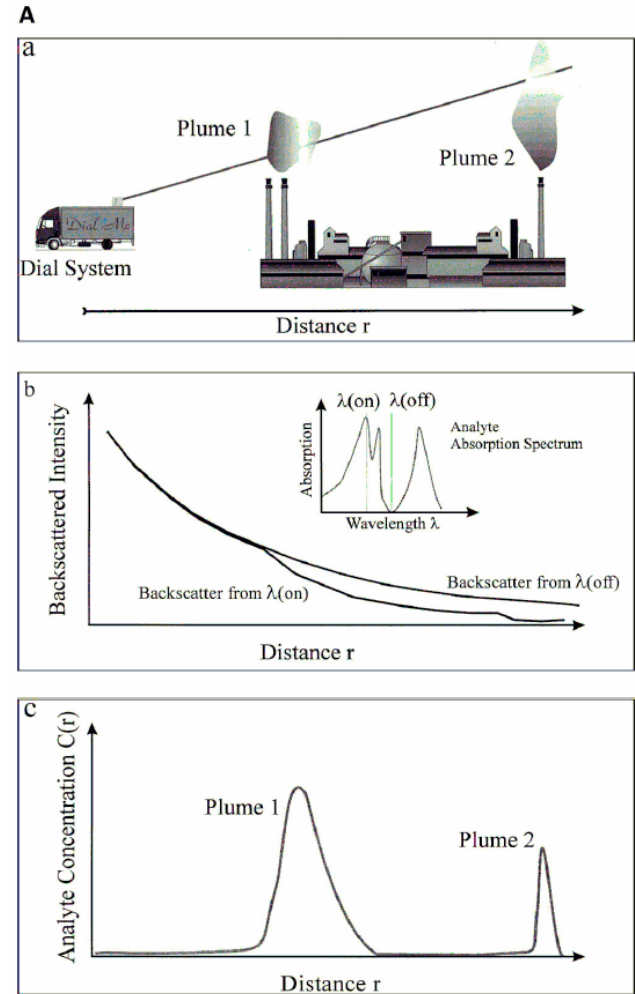


# 3.1 DIAL BASED EQUATION

$$\frac{P_{\lambda_{off}}(z)}{P_{\lambda_{on}}(z)} \cong \frac{\exp\left\{-2 \int_0^z \left[\alpha_{\lambda_{off}}^{aer}(\zeta) + \alpha_{\lambda_{off}}^{mol}(\zeta)\right] d\zeta\right\}}{\exp\left\{-2 \int_0^z \left[\alpha_{\lambda_{on}}^{aer}(\zeta) + \alpha_{\lambda_{on}}^{mol}(\zeta)\right] d\zeta\right\}}$$

$$N(R) = \frac{1}{2\Delta\alpha(\lambda_{on}, \lambda_{off})} \times \frac{d}{dR} \ln\left(\frac{P_{\lambda_{on}}(z)}{P_{\lambda_{off}}(z)}\right)$$

$$\Delta\alpha(\lambda_{on}, \lambda_{off}) = \alpha_{on}(\lambda_{on}) - \alpha_{off}(\lambda_{off})$$

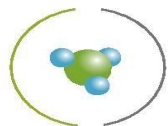
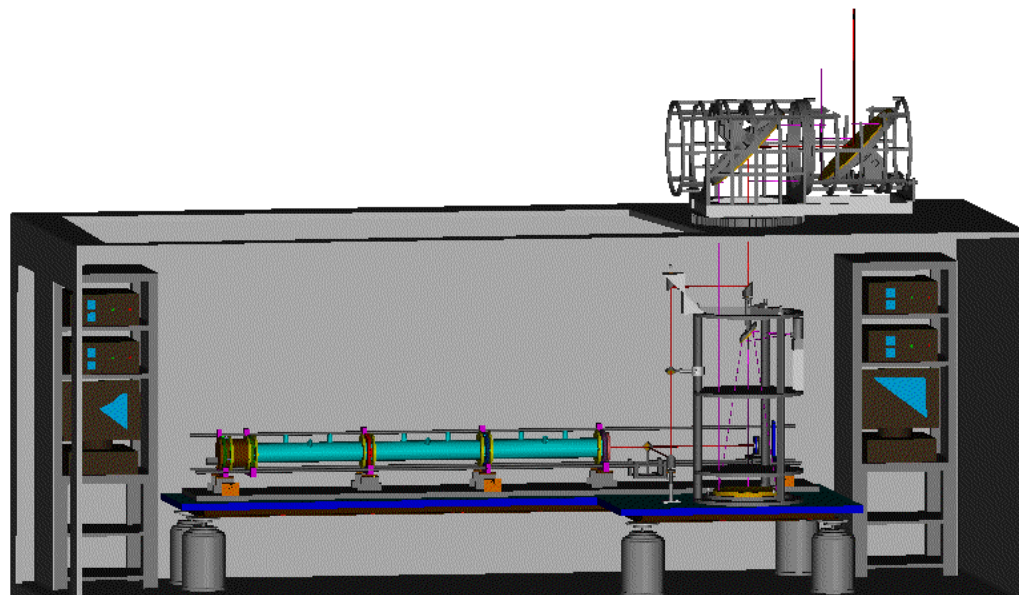




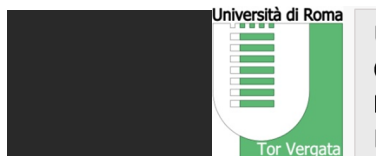


## TAEMS system

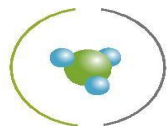
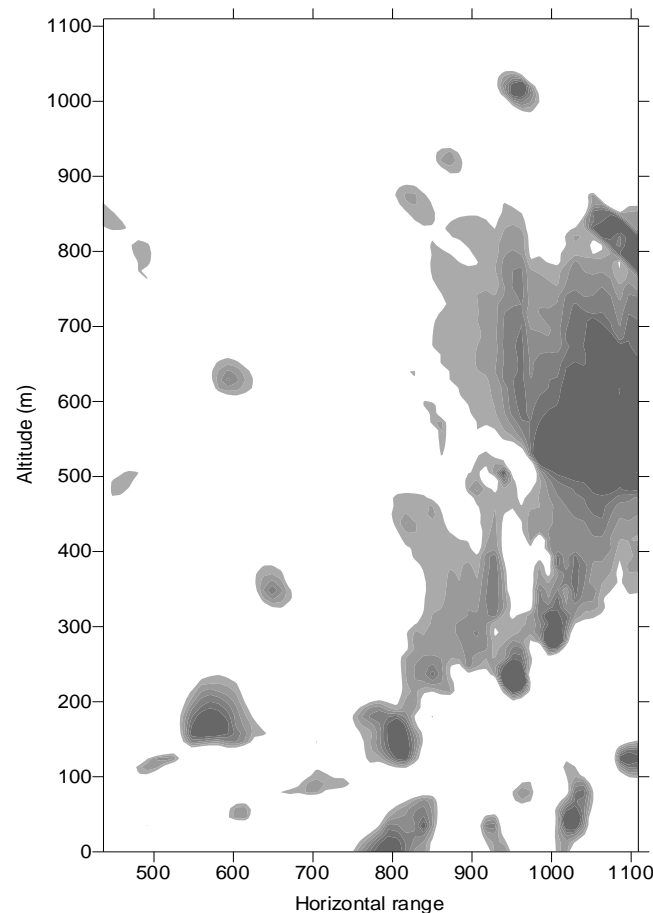
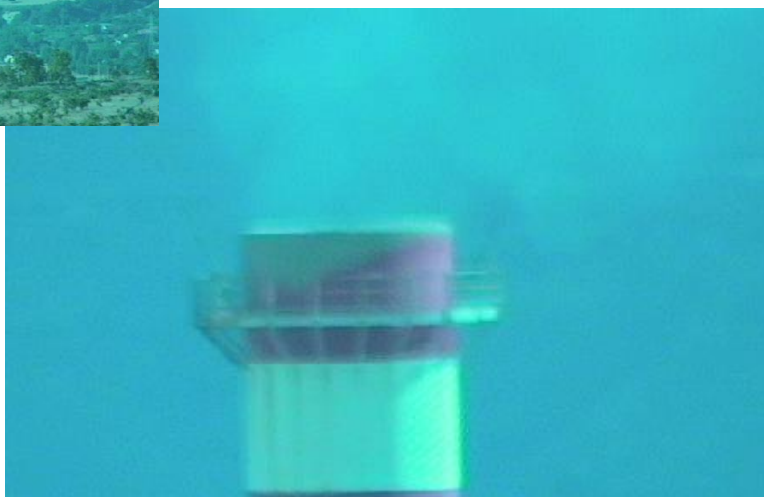
TEA CO <sub>2</sub> laser (tunable about 60 lines)	
Output Energy	500 mJ
Pulse width	100 ns
Beam divergence	0.77 mrad
Spectral range	9 ÷ 11 μm



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Water vapour emission map from the chimney



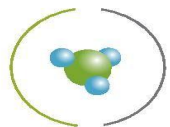
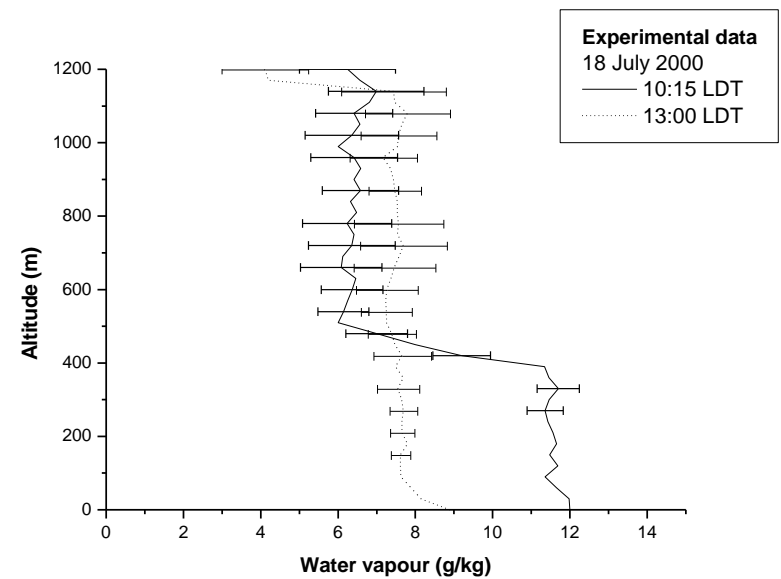
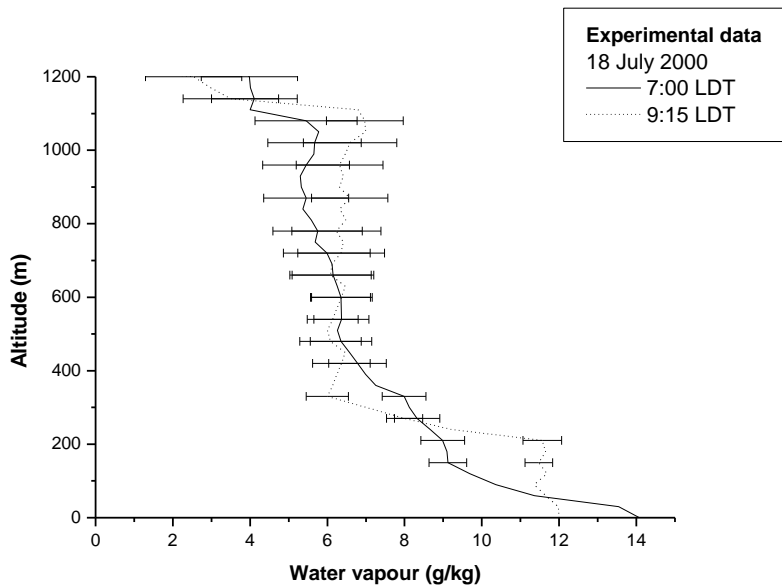
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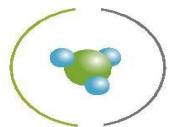
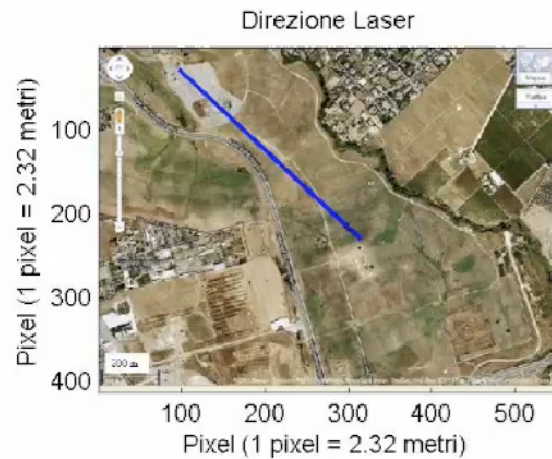


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## Vertical profile of Water Vapour: PBL height

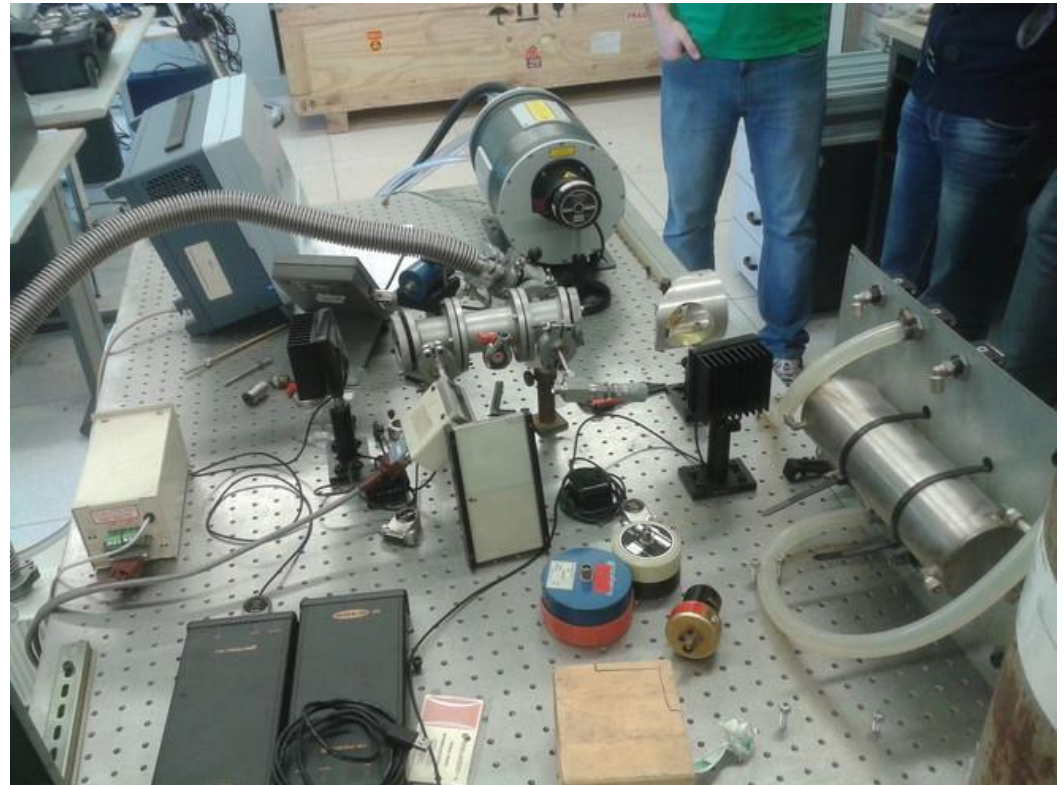




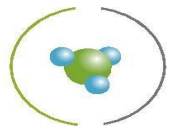




Work in progress .....



The **mini-CO<sub>2</sub>** system, based on DIAL technique, was born within a research project in collaboration with the Italian Army in order to obtain a remote, stand-off identification of CWAs, TIMs and TICs.



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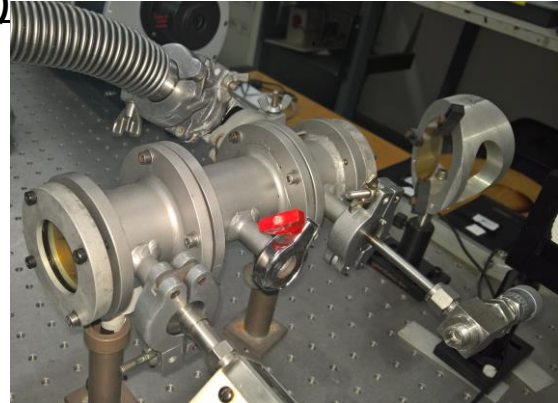
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### LASER TEA MTL-5 (Transversely Excited-Atmospheric)



### CELL AND VACUUM PUMP



### MOTOR CONTROLLER DC MERCURY C-862



### SENSOR GENTEC

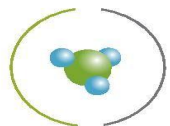
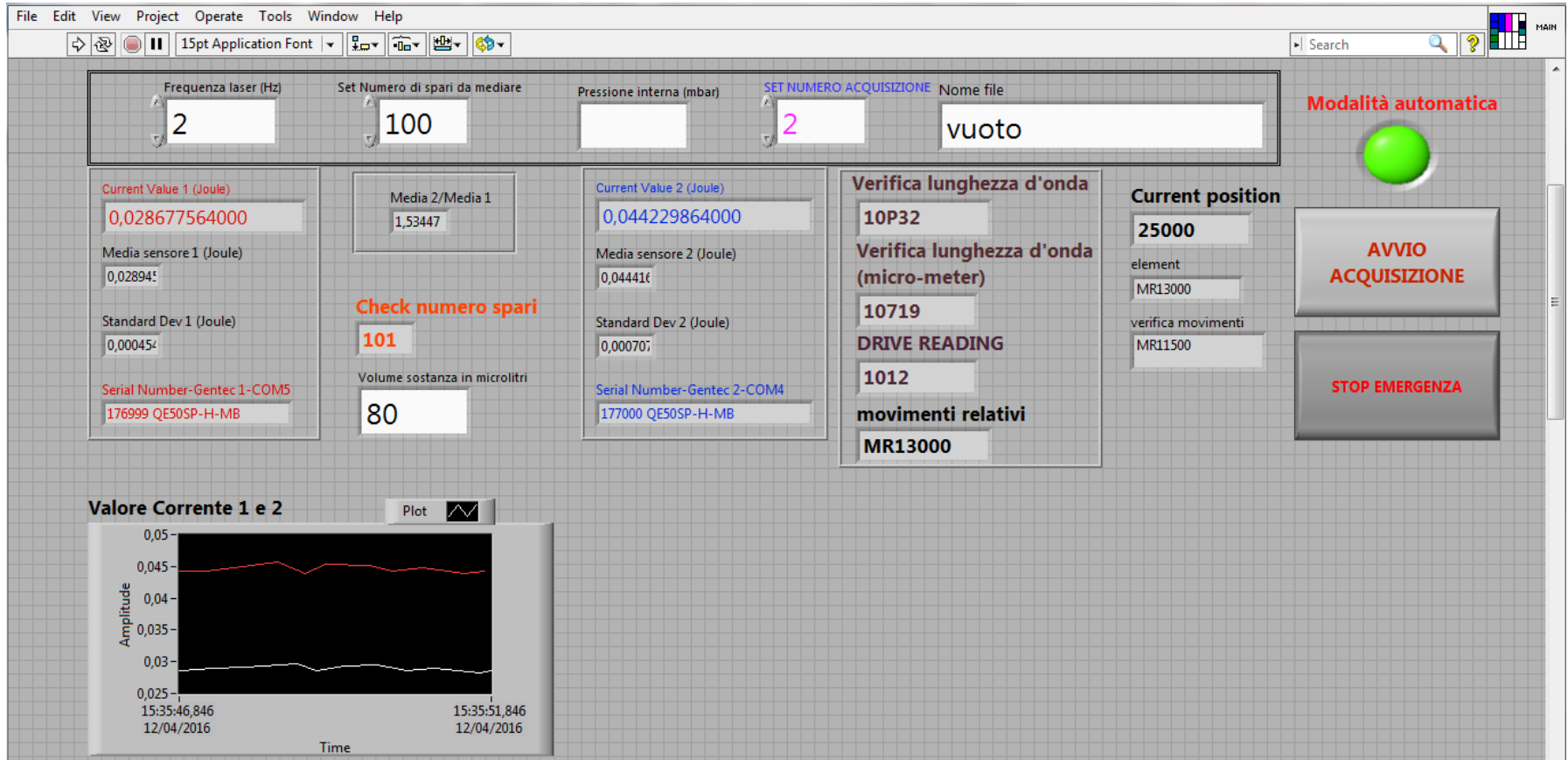


### MICROMETERS M-231



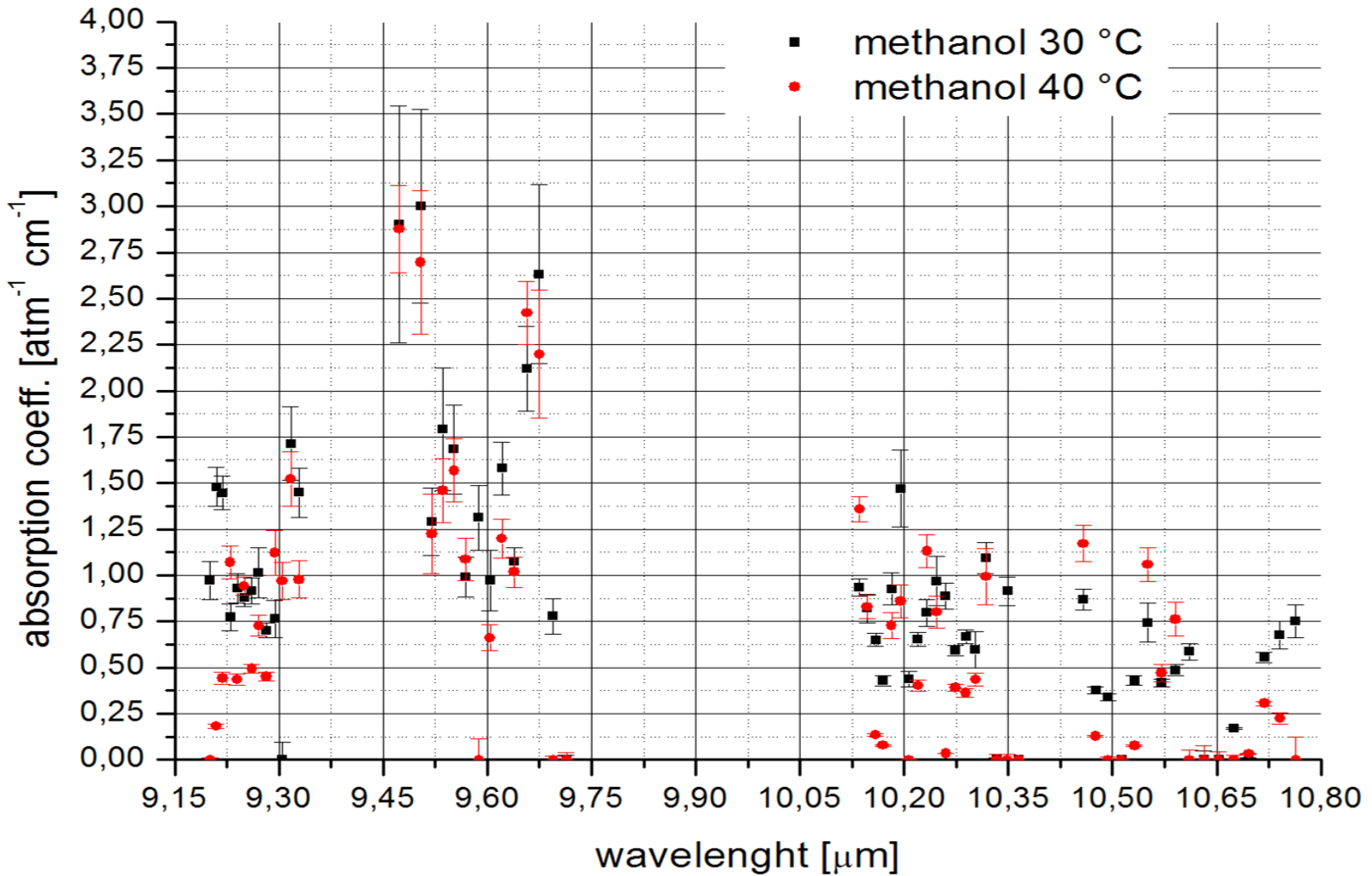
### CARRIER GAS





# 3.2 DIAL SYSTEMS DEVELOPED & APPLICATIONS

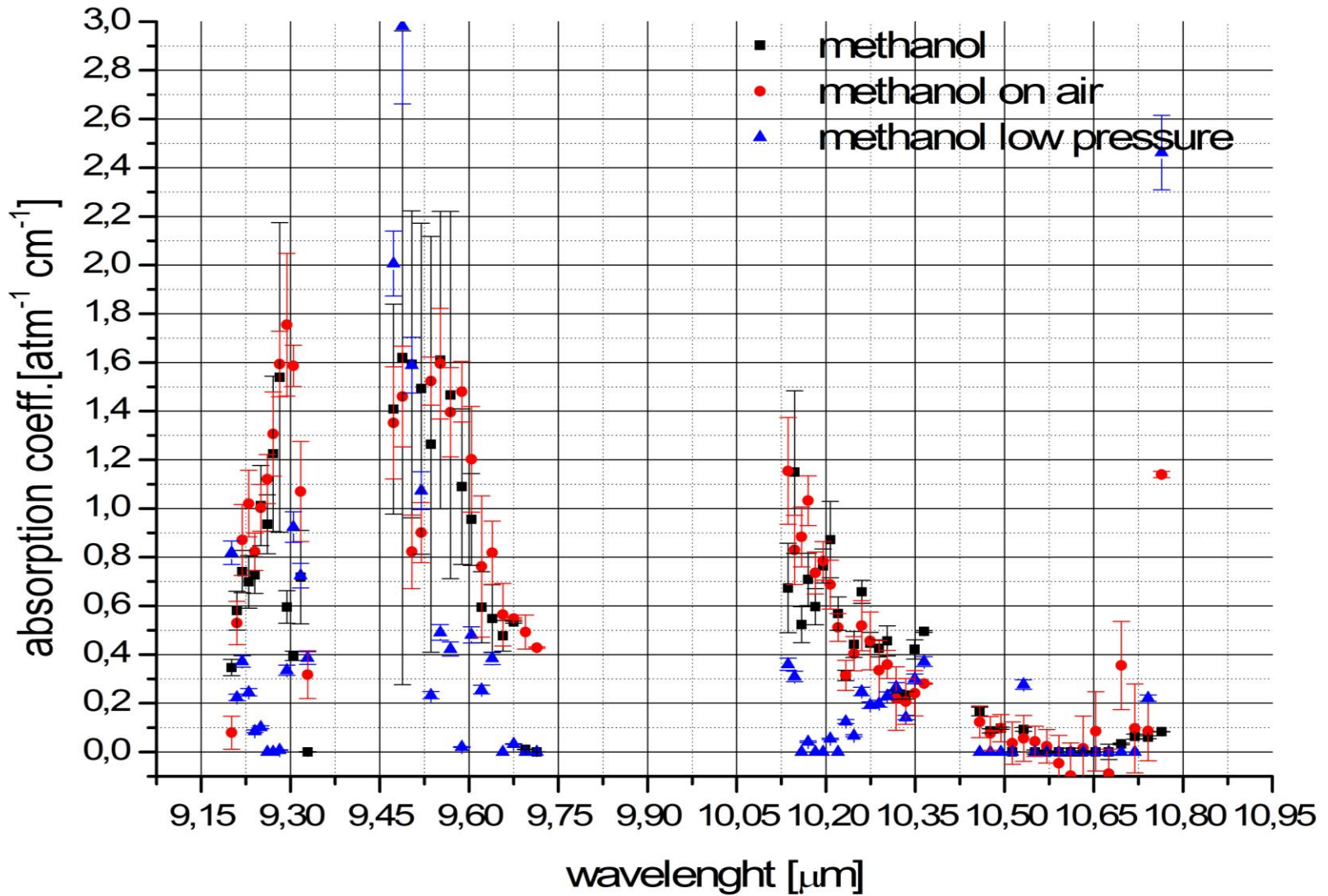
Absorption coefficient of methanol - different conditions



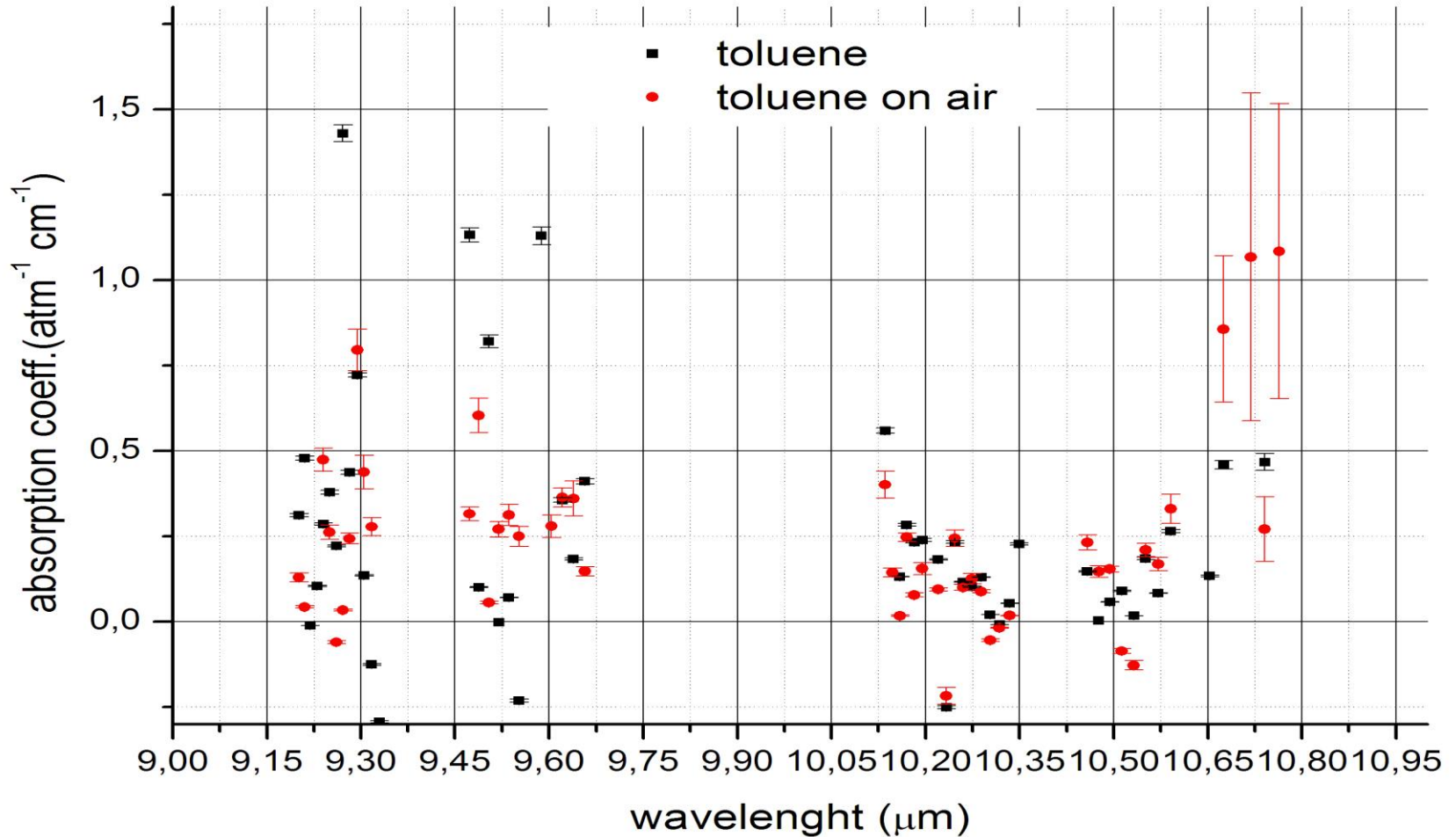


# 3.2 DIAL SYSTEMS DEVELOPED & APPLICATIONS

Absorption coefficient of methanol - different conditions

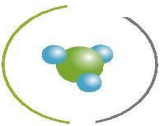
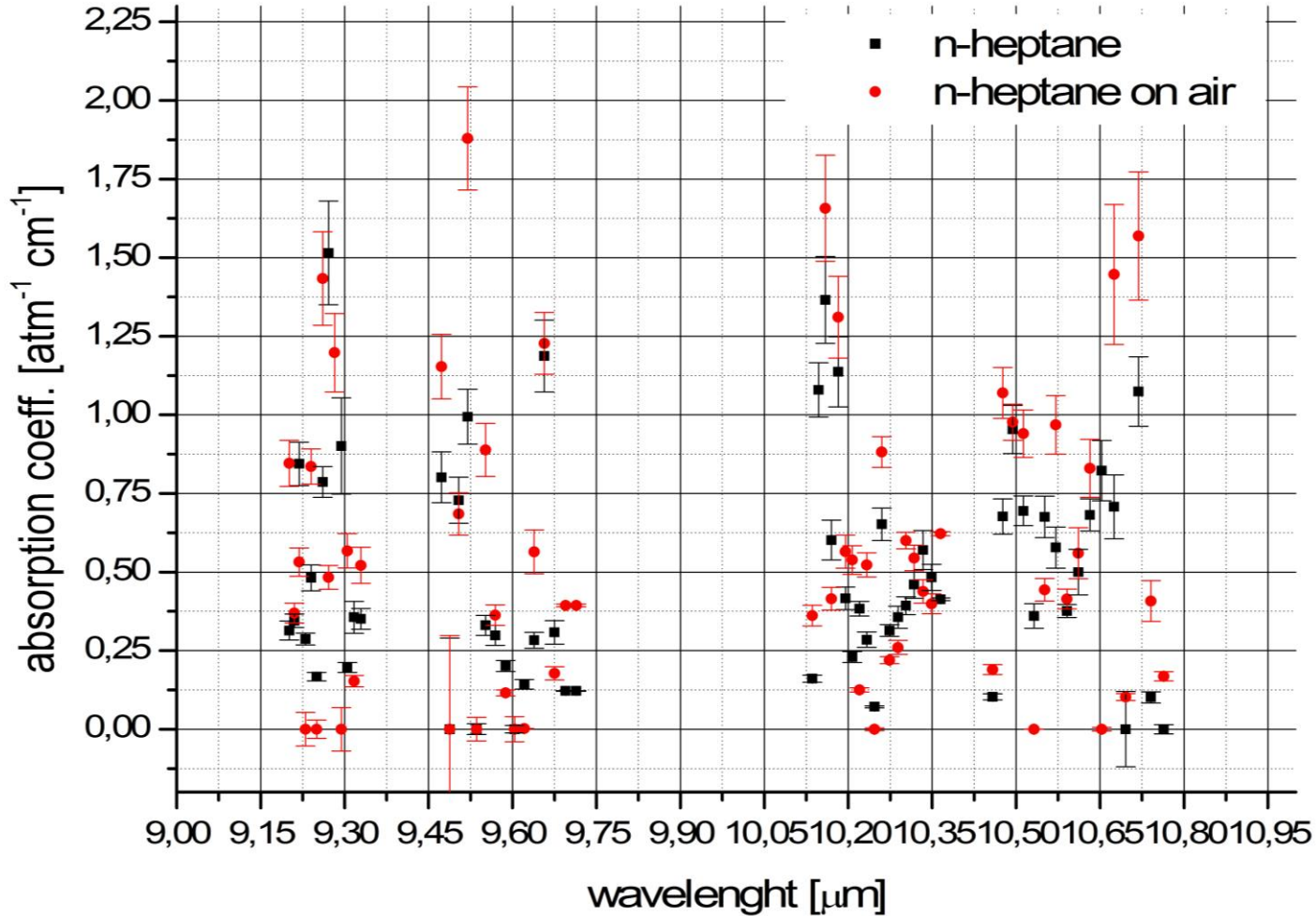


absorption coefficients of toluene - different conditions



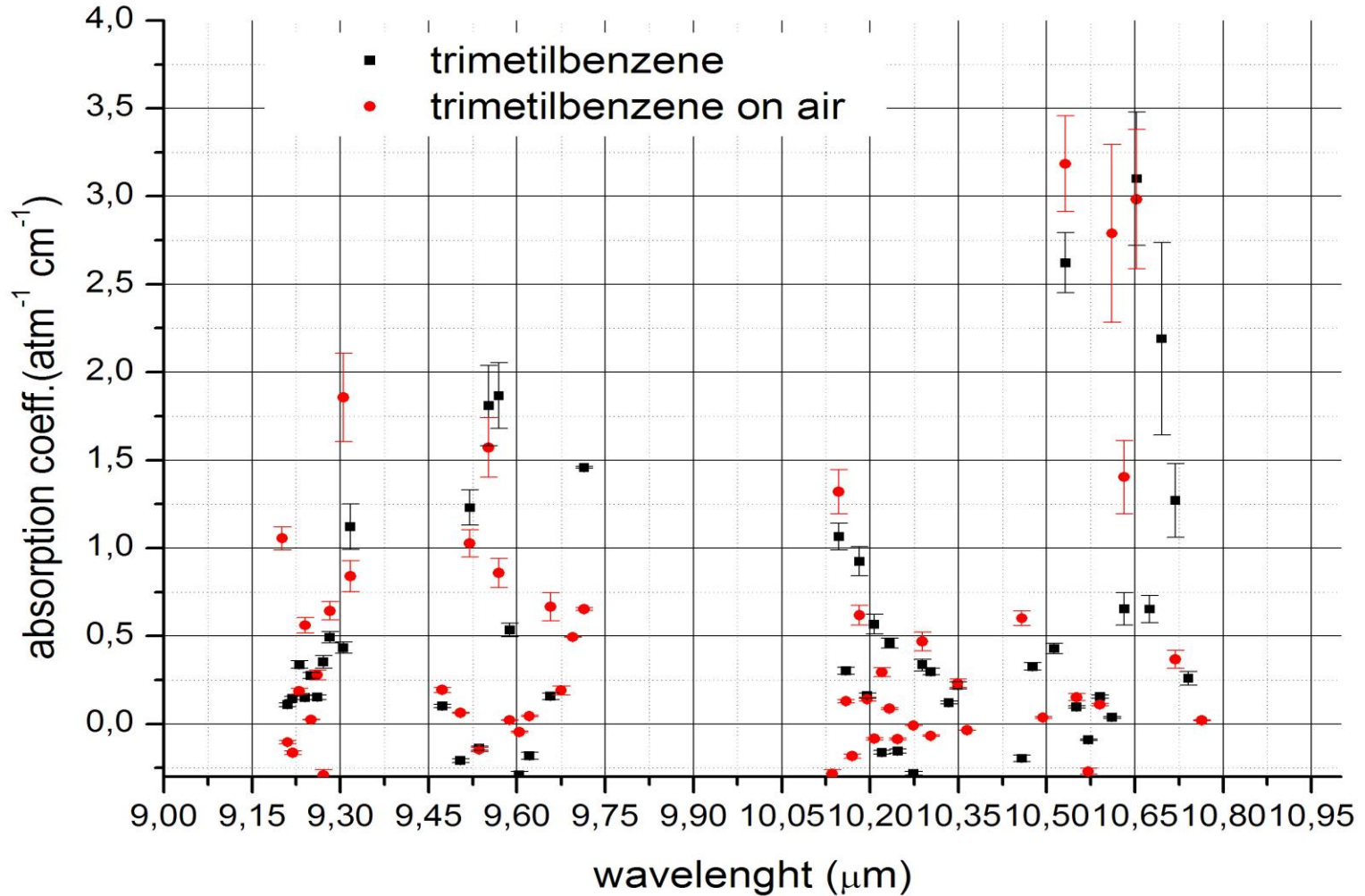
# 3.2 DIAL SYSTEMS DEVELOPED & APPLICATIONS

absorption coefficients of n-heptane - different conditions



# 3.2 DIAL SYSTEMS DEVELOPED & APPLICATIONS

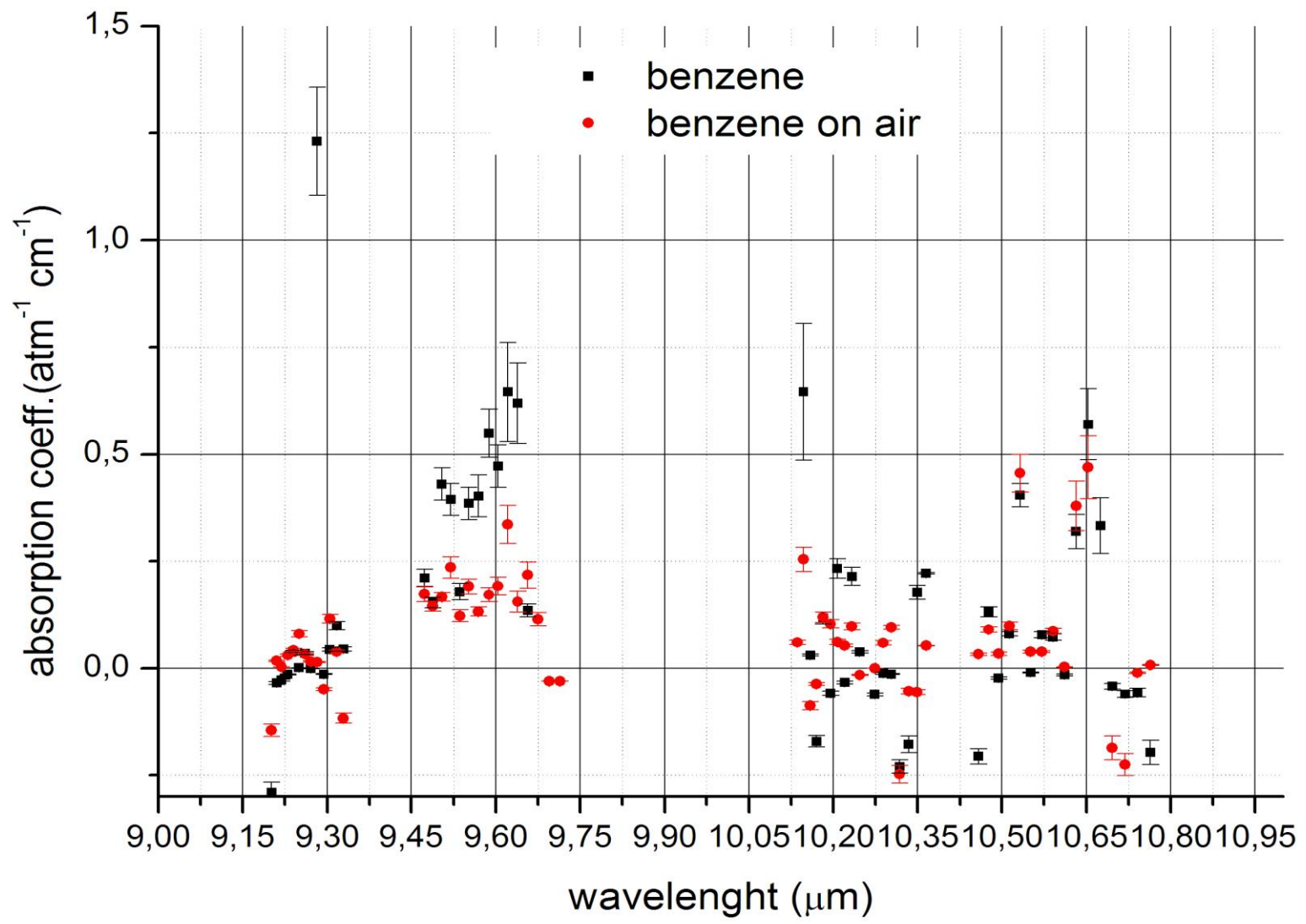
absorption coefficients of trimetilbenzene - different conditions





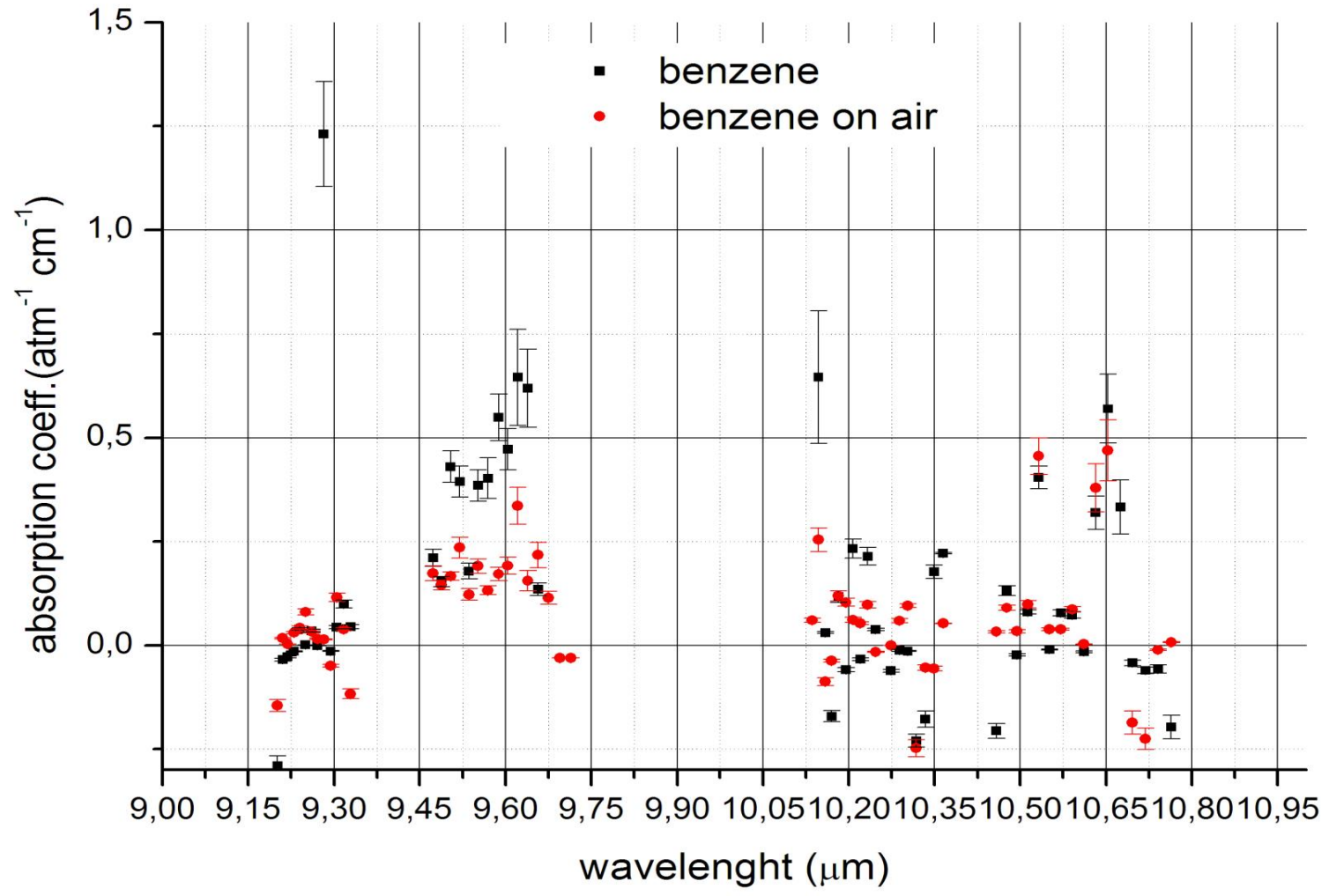
# 3 OPTICAL SYSTEMS DEVELOPED & APPLICATIONS

absorption coefficients of benzene - different conditions



3.

absorption coefficients of benzene - different conditions



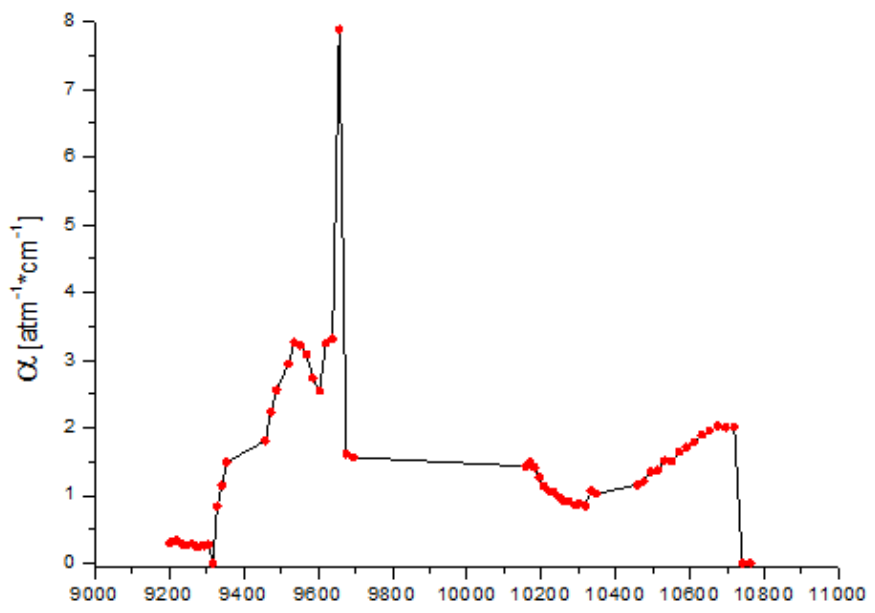
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Alcol allilico 24/03/16

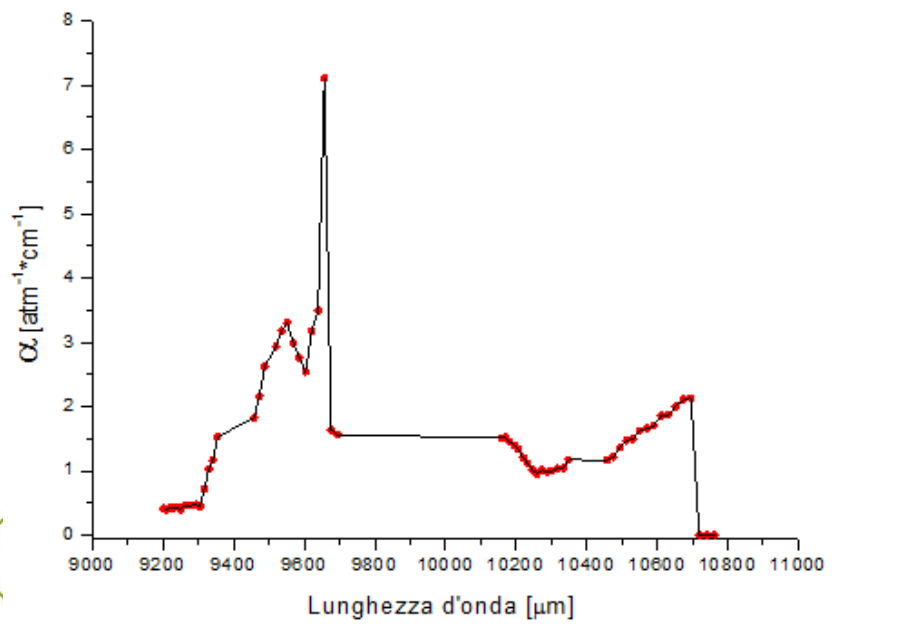


**ITERATE MEASUREMENTS**



**CREATE A DATABASE  
(Principal Component  
Analysis)**

Alcol allilico 04/04/16



**IDENTIFY A CHEMICAL  
AGENTS IN AIR BY A  
DIAL SYSTEM**

Present problem:

1. Develop mini LIDAR system able to detect anomalies in atmosphere very compact and low cost.
2. Develop an DIAL system able to discriminate several chemical compound in atmosphere

## TECHNIQUES INTEGRATION

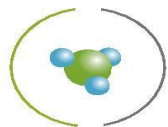


**Used to detect accidental or intentional releases at long distances (up to 2-3 Km)**

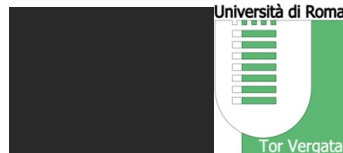
**Useful for a first alarm**



**Used to identify extraneous/unknown/foreign substances at shorter distances (up to 1 Km)**



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## Present Research

Development of methodologies of a multi-wavelength analysis in order to identify in atmosphere CWA and Toxic agents.

### PROBLEM

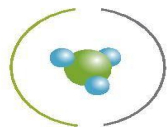
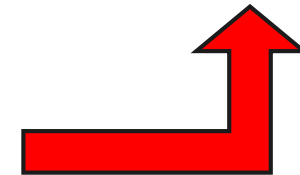
THE IDENTIFICATION OF TOXIC CHEMICAL AGENTS IN ATMOSPHERE



No, it is not possible because of interfering substances with similar functional set



Is it possible to identify a particular gas in atmosphere using only two wavelengths (DIAL method)?



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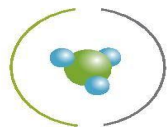
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**Each molecule can be identified if its absorption spectrum is known**



**INCREASING THE WAVELENGTHS USED IN DIAL METHOD COULD ALLOW TO IDENTIFY CHEMICAL WA COMPOUNDS IN ATMOSPHERE**



# VISION

## Need

**CBRNe First Responders**

**CBRNe Advisors for Decision Makers**

**IDEA : 2 POST GRADUATE COURSES IN CBRNe**

PROJECT  
SINERGY BETWEEN ENTITIES

PRODUCTS  
**2 MASTER COURSES IN "PROTECTION AGAINST CBRNe EVENTS"**  
BEGINNING MARCH 2016

### 1st Level Course

- 120 ECTS → 2 Academic Years
- Practical Preparation
- Training activities:
  - ✓ JCBRNE COE NATO (Vyskov)
  - ✓ NBC School of Rieti (Italy)
  - ✓ VVU (Czech Rep.)
  - ✓ Seiesdoorf Laboratories (Austria)
  - ✓ Chernobyl Center (Ukraine)

### 2nd Level Course

- 60 ECTS → 1 Academic Year
- Theoretical Preparation - Management
- Training activities:
  - ✓ NATO SCHOOL (Oberammergau)

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Both Master Courses have been granted with the **NATO SELECTED** status by the **NATO HQ SACT** (Supreme Allied Commander Transformation – Norfolk, Virginia, USA).

The University of Rome Tor Vergata has signed a **Cooperation Agreement** with the **OPCW** (Organization for the prohibition of Chemical Weapons), which support the **Master Courses**.

As it is stated in the **OPCW Press Release**,

**“It is the first such agreement the OPCW has made with a university in this field”**

([https://www.opcw.org/index.php?id=242&tx\\_ttnews%5Btt\\_news%5D=1719&cHash=a51e455b9203696a4d17771ae5282b11](https://www.opcw.org/index.php?id=242&tx_ttnews%5Btt_news%5D=1719&cHash=a51e455b9203696a4d17771ae5282b11))





# MASTER CBRNe



Chemical, Biological, Radiological, Nuclear and explosive  
Department of Industrial Engineering and School of Medicine and Surgery

## Advanced Search

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COURSE TITLE  CONTAINS

Area

Section

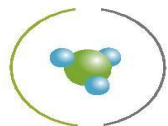
Delivery Method

NATO Course Accreditation

Training Audience

Training Institution

Country



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# Requirements

**Requirements:** Bachelor Degree or Equivalent title in Engineering, Science, Medicine, Biology, Chemistry, Physics, Law, Politic Science, Strategic Science, Journalism or similar (contact: [info@mastercbrn.it](mailto:info@mastercbrn.it))

**Requirements:** Master Degree or Equivalent title in Engineering, Science, Medicine, Biology, Chemistry, Physics, Law, Politic Science, Strategic Science, Journalism or similar (contact: [info@mastercbrn.it](mailto:info@mastercbrn.it))

## 1<sup>st</sup> Level Course

**120 ECTS – 2 YEARS**

**(European Credit Transfer System)**

## 2<sup>nd</sup> Level Course

**60 ECTS – 1 YEAR**

**(European Credit Transfer System)**

**OFFICIAL ACADEMIC TITLE**

**RECOGNIZED BY**

**“BOLOGNA PROCESS”**

**ALLOW ACCES to 2<sup>nd</sup> Level Course**

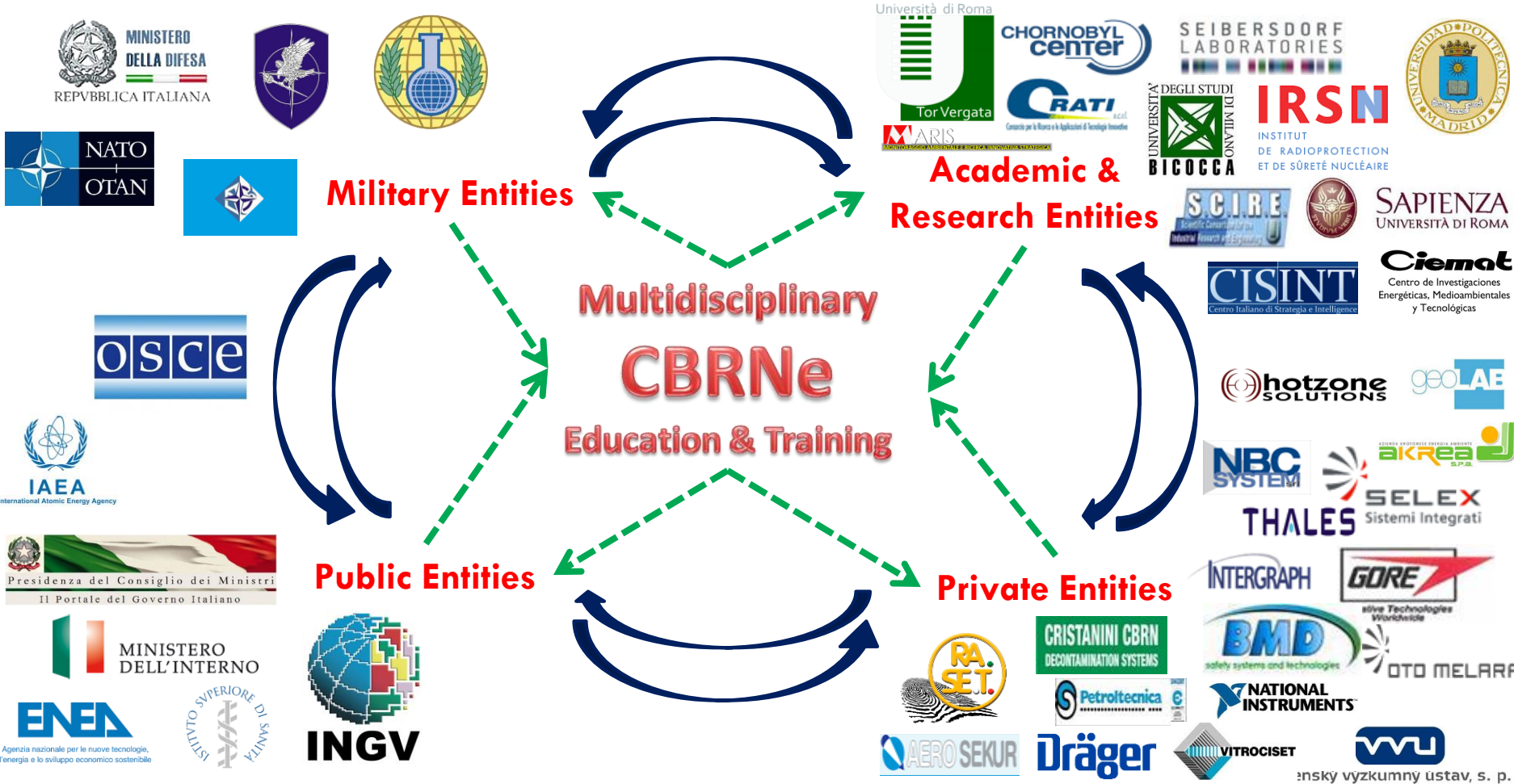
**ALLOW ACCES to PhD Programs in  
Safety & Security**





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mský vyzkumny ustav, s. p.





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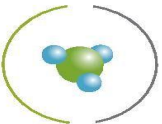
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Andrea Malizia, PhD

# SICC 2017

Scientific International Conference  
on CBRNe

Rome, 2017 April 11-13



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Andrea Malizia, PhD

# Welcome to the first Scientific International Conference on CBRNe!

The mission of the Conference is to create and promote the vision of CBRNe as a scientific discipline, boosting the role of the Academia and its interplay with, Stakeholders, Industries, End-Users, State-actors and private entities.

The SICCC is an arena to present what science is doing to improve safety and security in the field of unconventional events, as well as to discuss ideas and collect needs from professionals working in this framework.

The conference will be held yearly in Rome to discuss the latest trends and topics, with a specific focus each year. For its first edition, SICCC will discuss about the integration of strategies and new solutions to improve preparedness and response in the following sessions:

- **Emergency Systems and Solutions**
- **Emergency Communication**
- **Medical Management, First Aid and Psychology**
- **Decision Support Systems**
- **International Legal Framework**  
(including case studies on National legal frameworks)
- **Economical aspects of CBRNe events**
- **Diffusion & Dispersion of CBRNe Agents**
- **Detection & Identification**
- **CBRNe Forensics**
- **Protection & Decontamination**
- **Cyber Security**
- **Education and Training**

A selection of the works presented during the SICCC will be published on peer reviewed, indexed journals and special issues of the Conference

The three days conference includes an industrial exhibition a poster session and a conclusive on-field integrated demonstration by CBRNe experts.

Plenary Session

Oral Sessions

Poster Session

Practical Activities

Industrial Exhibition



SICCC is the place where Academia and the CBRNe community meet



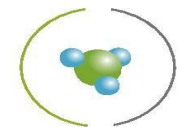
**Andrea Malizia, PhD**

**malizia@ing.uniroma2.it**

**+39 0672597202**

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