Istituto Nazionale di Fisica Nucleare

University of Genoa

UNIVERSITÀ DEGLI STUDI DI MILANO

BLAnCA:uno strumento innovative per la misura del coefficiente di assorbimento degli aerosol ad alta risoluzione spettrale

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TORINO PM 2024

Filter-based aerosol absorption coefficient determination

How to measure it?

Most widespread instruments are based on simple transmission measurements

Filter-based techniques: many artefacts

- Particles concentration
- Particles modification on filter
- Filter morphology upon particle deposition
- **SSA**
- **Interaction between particles and filter medium**

→ Multiple scatterings
→ Loading effect

→ Positive Artifacts

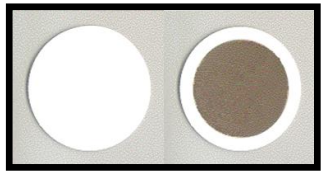
→ Negative Artifacts

→ Many correction algorithms, information on aerosol scattering properties is anyway needed

A more robust approach is the Multi-Angle Absorption Photometry: also backscattering measurements at 2 specific angles is used to obtain the absorption coefficient. MAAP is online but one wavelength only! (and discontinued)

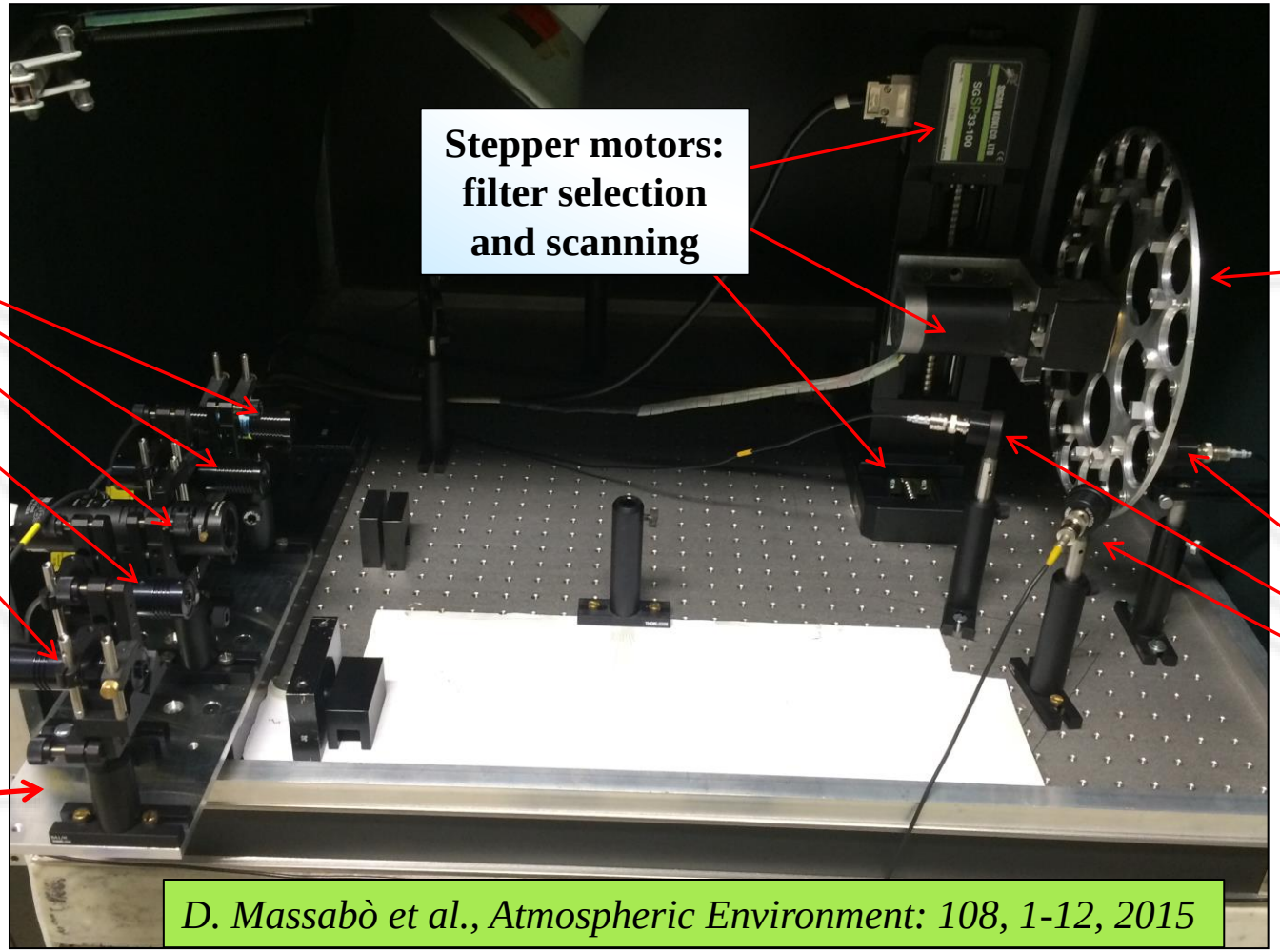
One step forward: development of custom instrumentation

- **Offline measurements of PM sampled on filter media**
- **High sensitivity**
- **Multi-lambda**



Previous work: ***The Multi-Wavelength Absorbance Analyzer (MWAA)***

Multi-λ determination of b_{abs} of aerosol collected on filter media



D. Massabò et al., Atmospheric Environment: 108, 1-12, 2015

MWAA follows the approach reported by [Petzold e Schönlinner, 2004] and implemented in the **Multi-Angle Absorption Photometer** (**MAAP**).

Towards a new prototype instrument for offline measurements of optical properties of atmospheric aerosols

The absorption coefficient of atmospheric aerosol is obtained by applying the radiative transfer model developed by Hanel (1987,1994) in which the effects of ***multiple scattering*** are considered.

Forward emisphere, particle-loaded filter

Forward emisphere, blank filter

Backward emisphere, particle-loaded filter

Backward emisphere, blank filter

$$\frac{P_F}{P_F^{(0)}} = \frac{T_L + F_L}{1 - B_L^* B_M},$$

$$\frac{B_F}{B_F^{(0)}} = P_L^* \frac{T_L + F_L}{1 - B_L^* B_M} + \frac{B_L}{B_M}$$

Hanel, 1994

At first member: optical properties related to quantities directly measurable by the optical system.

At second member: the quantities are not directly measurable, but functions of the **optical thickness τ**, the **single scattering albedo ω** and the phase particle functions.

The numerically resolution of the model provides the two parameters necessary to calculate the absorbance ABS:

Optical thickness → $\tau = b_{ext} \cdot x$

Single Scattering Albedo → $\omega = \frac{b_{scat}}{b_{ext}}$

$$ABS = \tau \cdot (1 - \omega)$$

Absorption coefficient → $b_{ABS} = ABS \cdot \frac{A}{V}$

Active filter surface area

Volume of sampled air

A new prototype instrument for offline measurements of optical properties of atmospheric aerosols

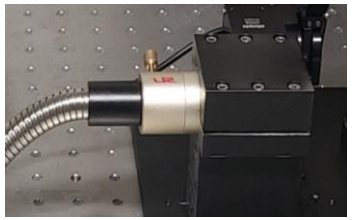
BLAnCA: Broadband Light Analyzer of Complex Aerosol

Major advances in respect to the MWAA to be achieved:

- High angular resolution measurements instead of 3 fixed angles (to measure the light phase function instead of reconstructing it) → **polar measurements**
- Extended measurement range (**350-900 nm** instead of 375-850 nm)
- Higher spectral resolution → **broad spectrum source** instead of a set of lasers

BLAnCA: technical features

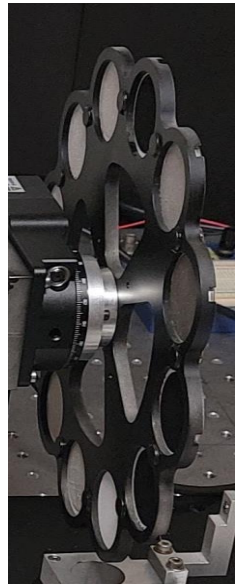
Light source
300nm – 1100nm

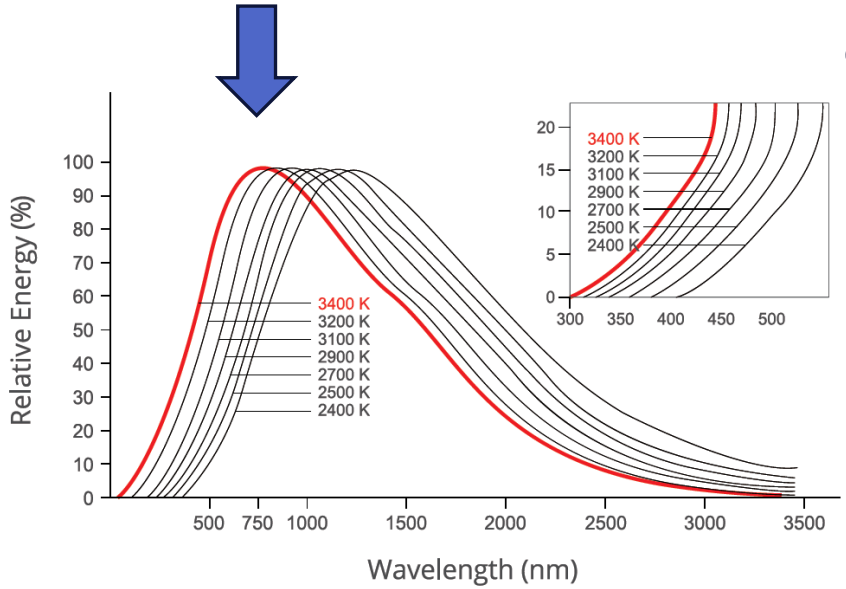


Light guide

Collimator

Sample holder wheel





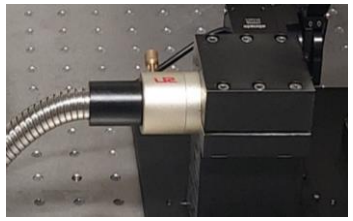
Particle-loaded filter

Broad continuous spectrum

Collimated white light source (*SLI – Mighty Light Plus*)

BLAnCA: technical features

Light source
300nm – 1100nm



Light guide

Sample holder wheel

Collimator

θ = 165°

Motorized rotating arm

Fiber optic cable

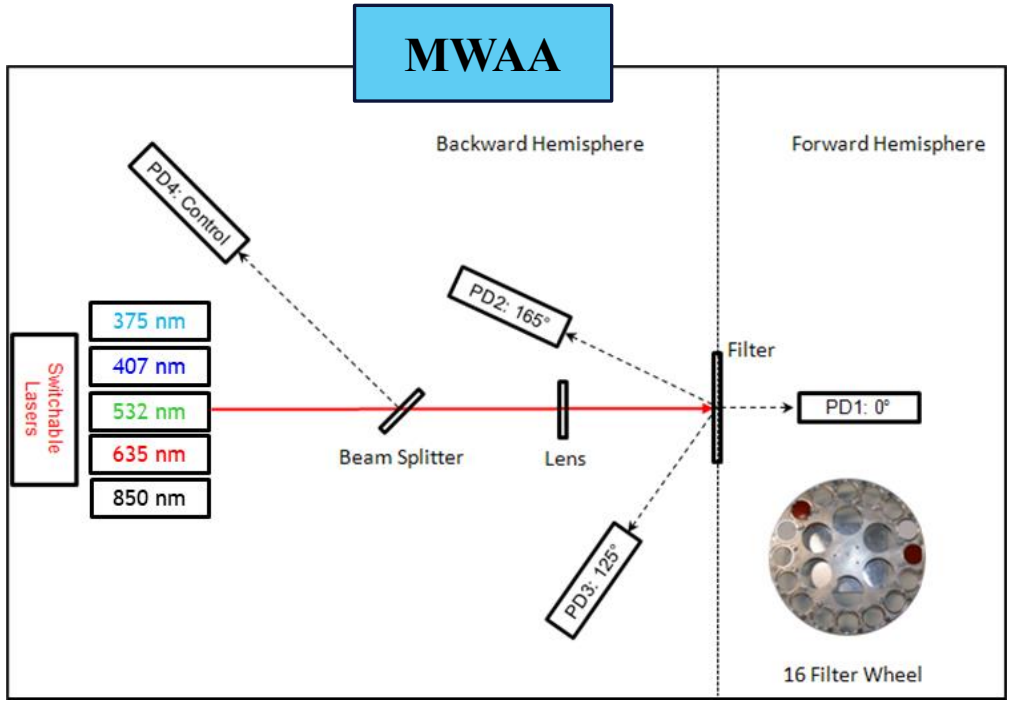
Detector for measurement of scattering profile: optical fiber mounted on a rotating arm, capable of sweeping a semi-plane between 0° and 165°

➡ Angular resolution down to 0.1°

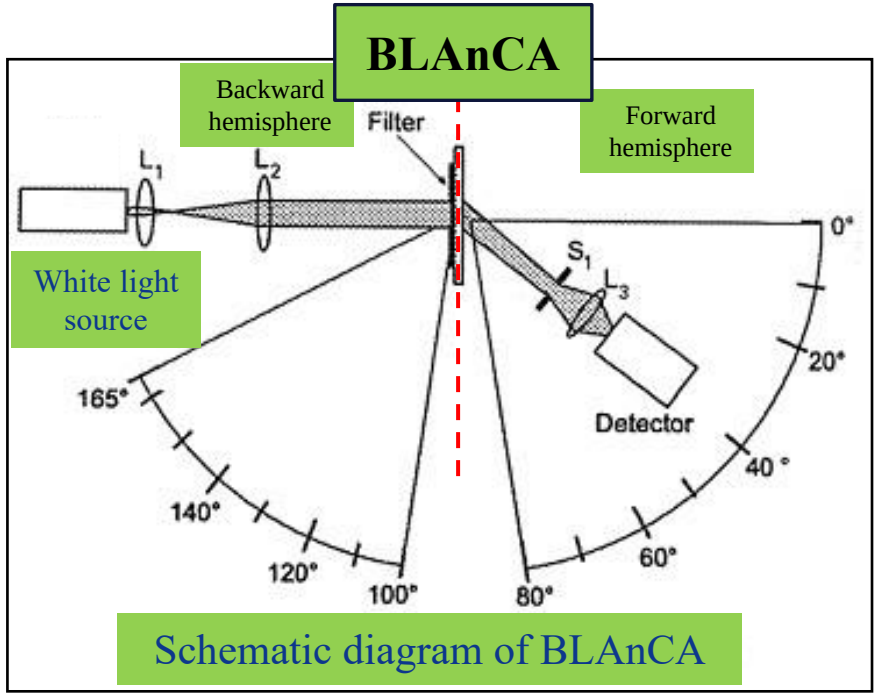
BLAnCA: technical features

B_{abs} values measured by BLAnCA are obtained by following the same minimization algorithm as MWAA, but:

1) **Light distribution directly measured** instead of reconstructed thanks to analytical functions



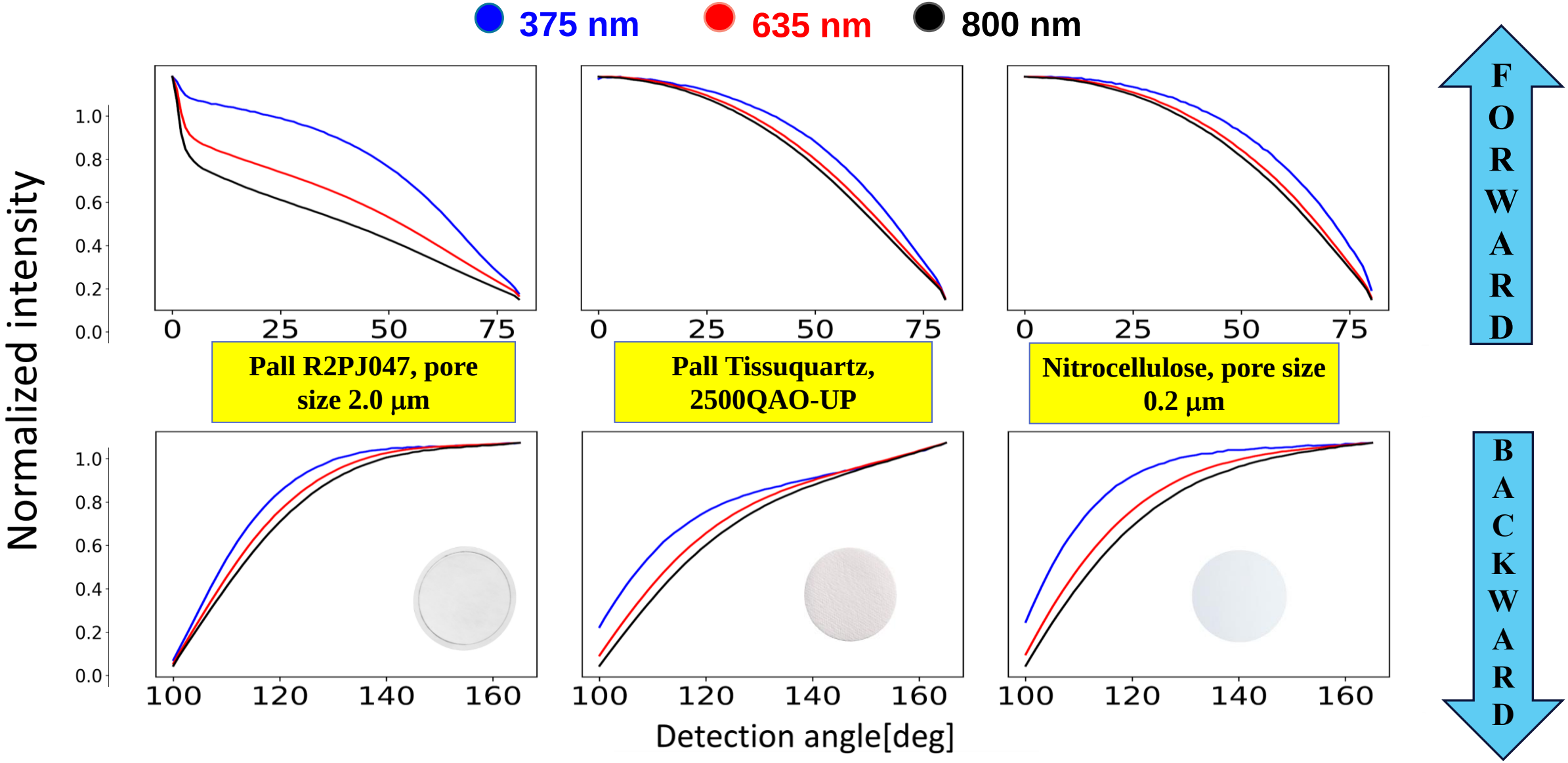
The angular distribution of the radiation scattered in both hemispheres is reconstructed starting from measurements at 3 angles only



Schematic diagram of BLAnCA

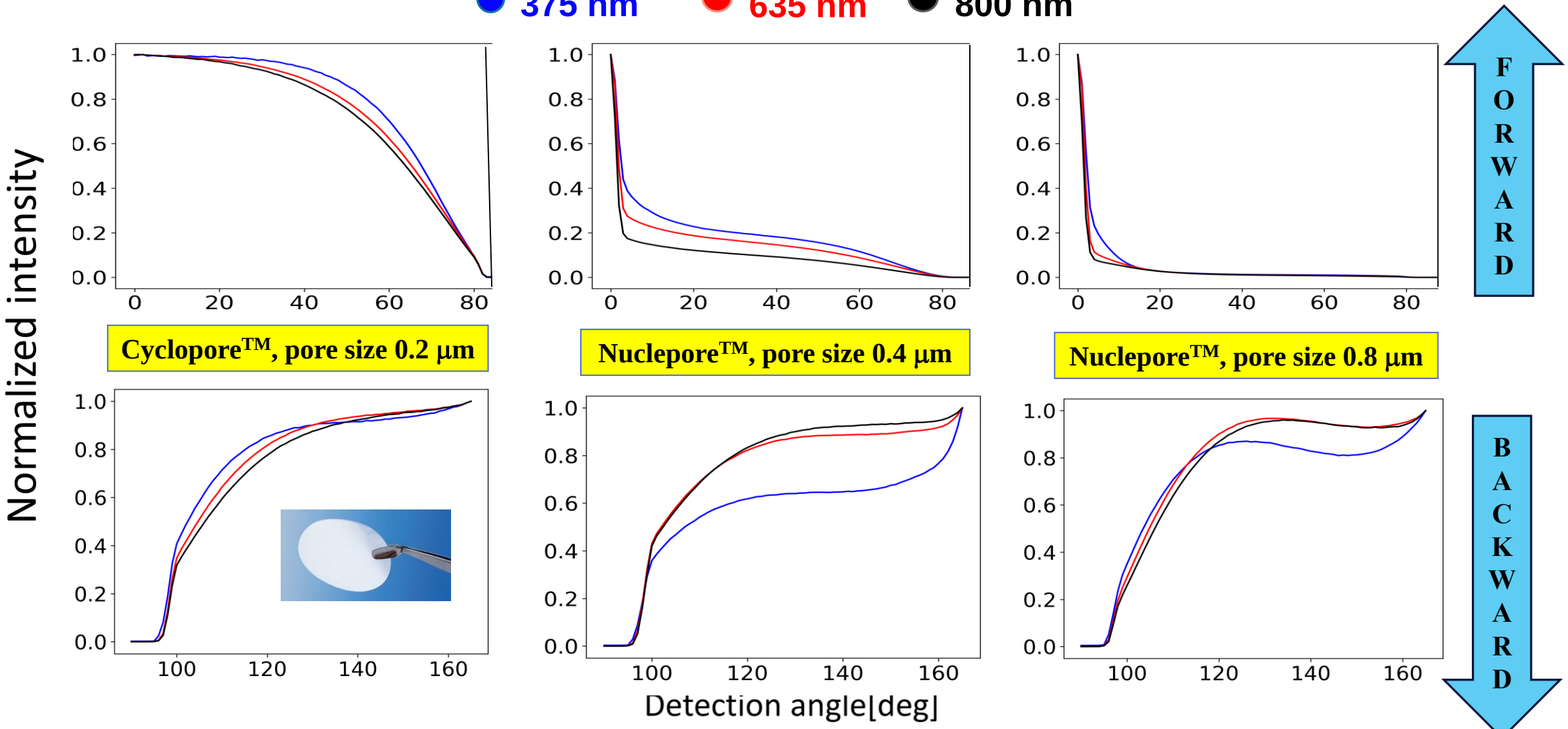
The angular distribution of the radiation scattered in the forward and back hemispheres is directly measured

Scattering profiles of different filtering blank supports



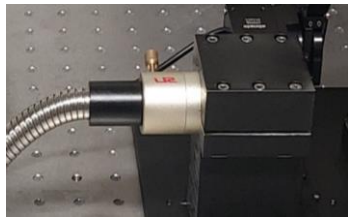
Scattering profiles of different filtering blank supports

375 nm 635 nm 800 nm



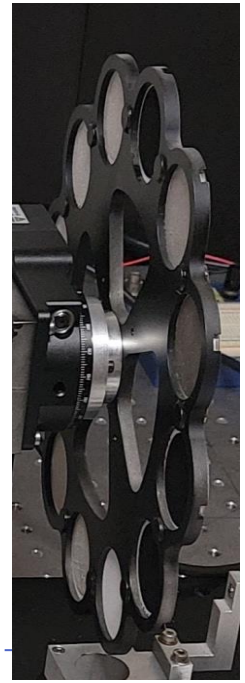
BLAnCA: technical features

Light source
300nm – 1100nm



Light guide

Sample holder wheel



Collimator

θ = 165°

Rotating arm

Spectrometer

Fiber optic cable

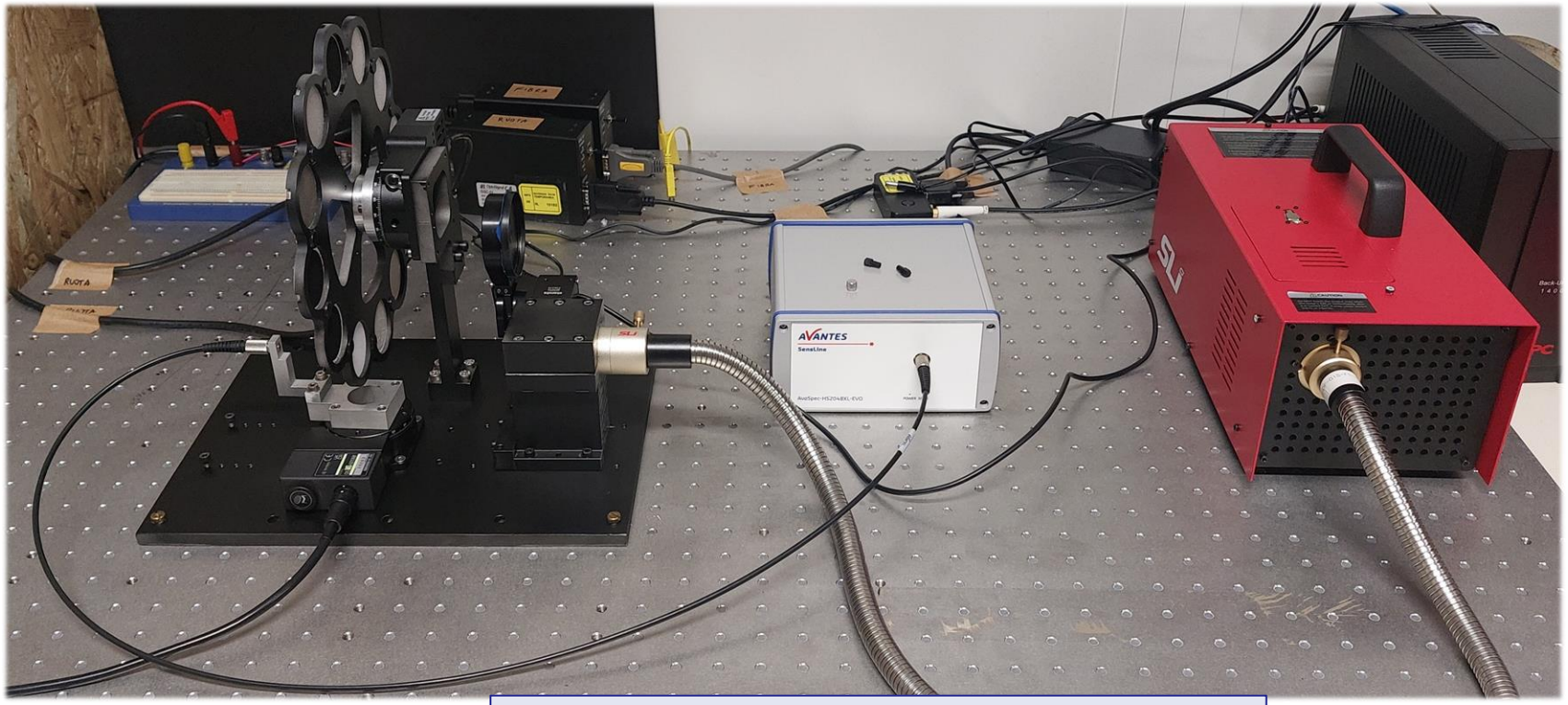
- Optical fibre connected to a spectrometer for high resolution measurements (*Avantes AvaSpec-HS2048XL-EVO*)

→ Spectral resolution 4.5 nm;
Spectral range [350 nm ÷ 900 nm]

BLAnCA: summary of technical features

- Angular resolution up to 0.1 deg
- Spectral resolution of 5 nm
- Spectral range from 350 nm to 900 nm
- Sequential analysis of 12 filters
- Different filtering substrates are supported (quartz, teflon..)

BLAnCA: Broadband Light Analyzer of Complex Aerosol

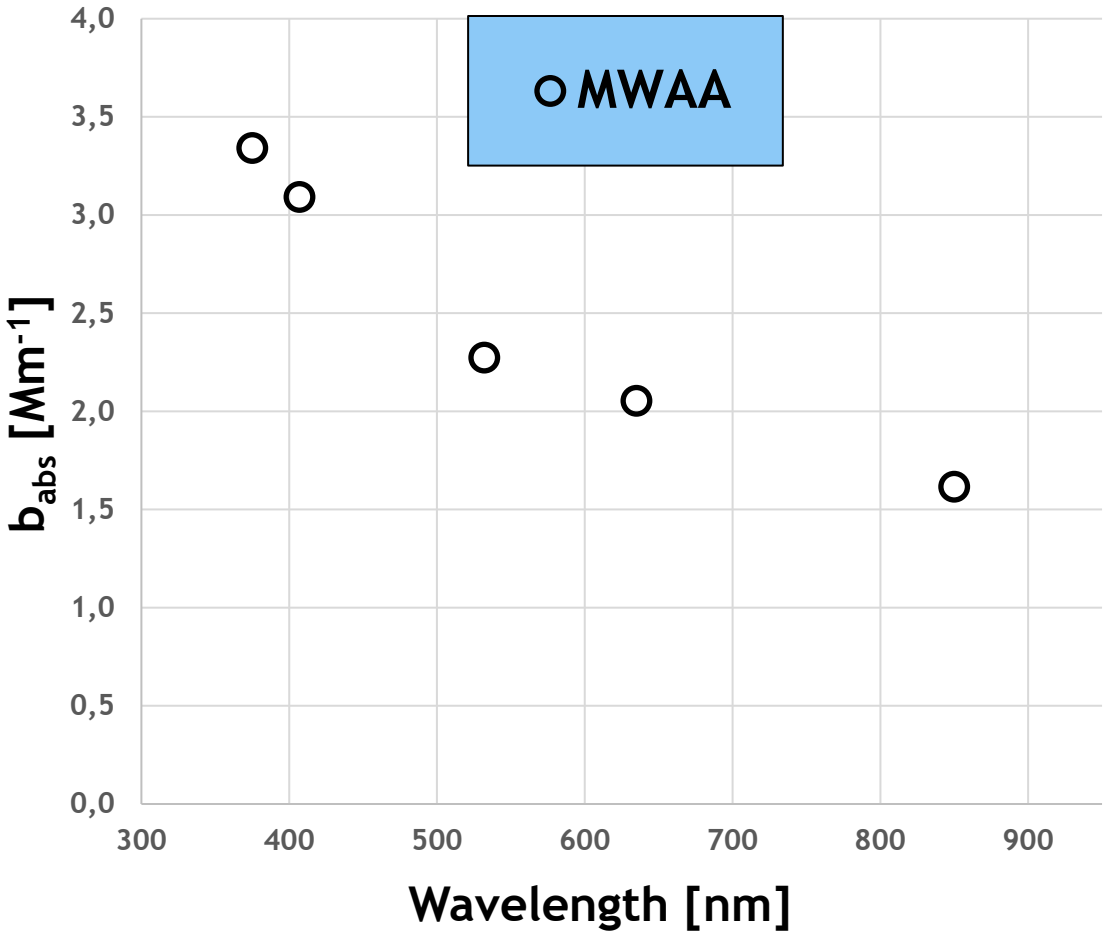


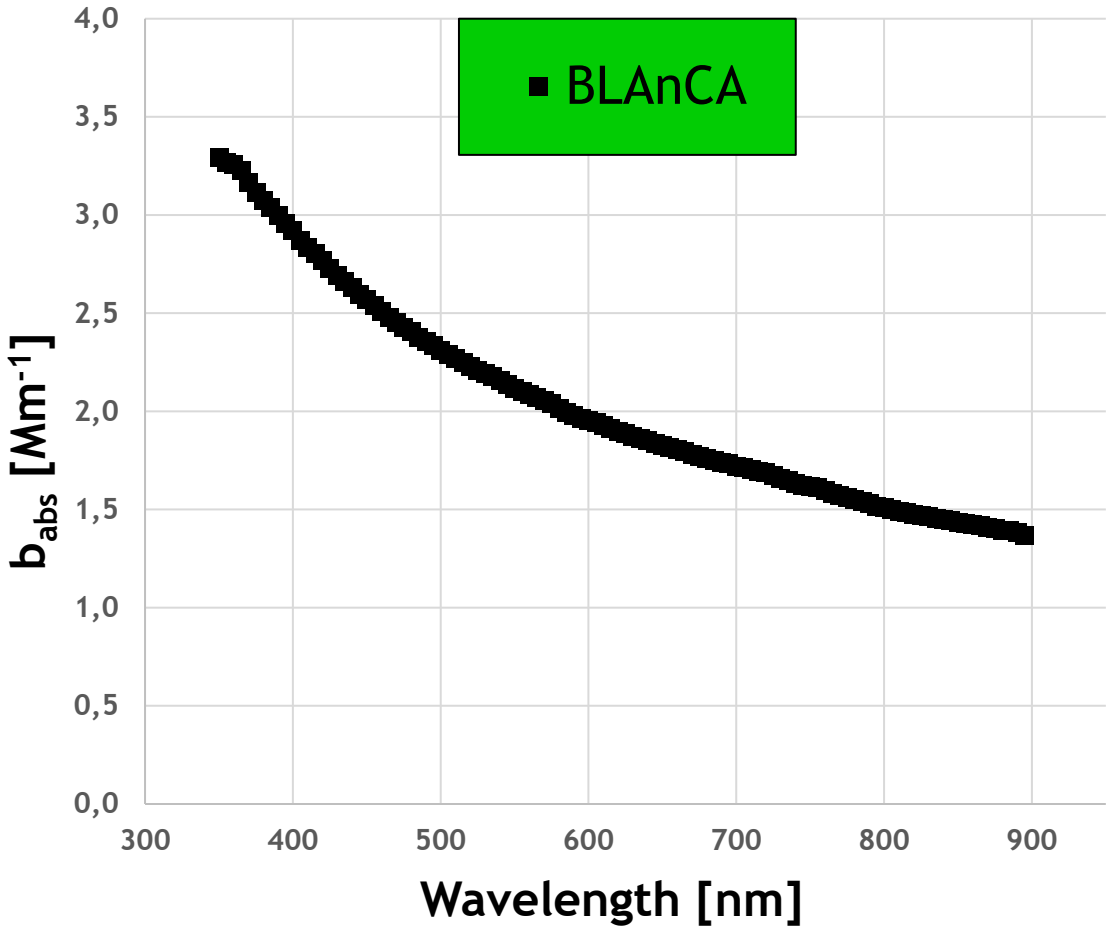
T. Isolabella et al., Il Nuovo Cimento C, 46, 2023

BLAnCA: technical features (III)

B_{abs} values measured by BLAnCA are obtained by following the same minimization algorithm as MWAA, but:

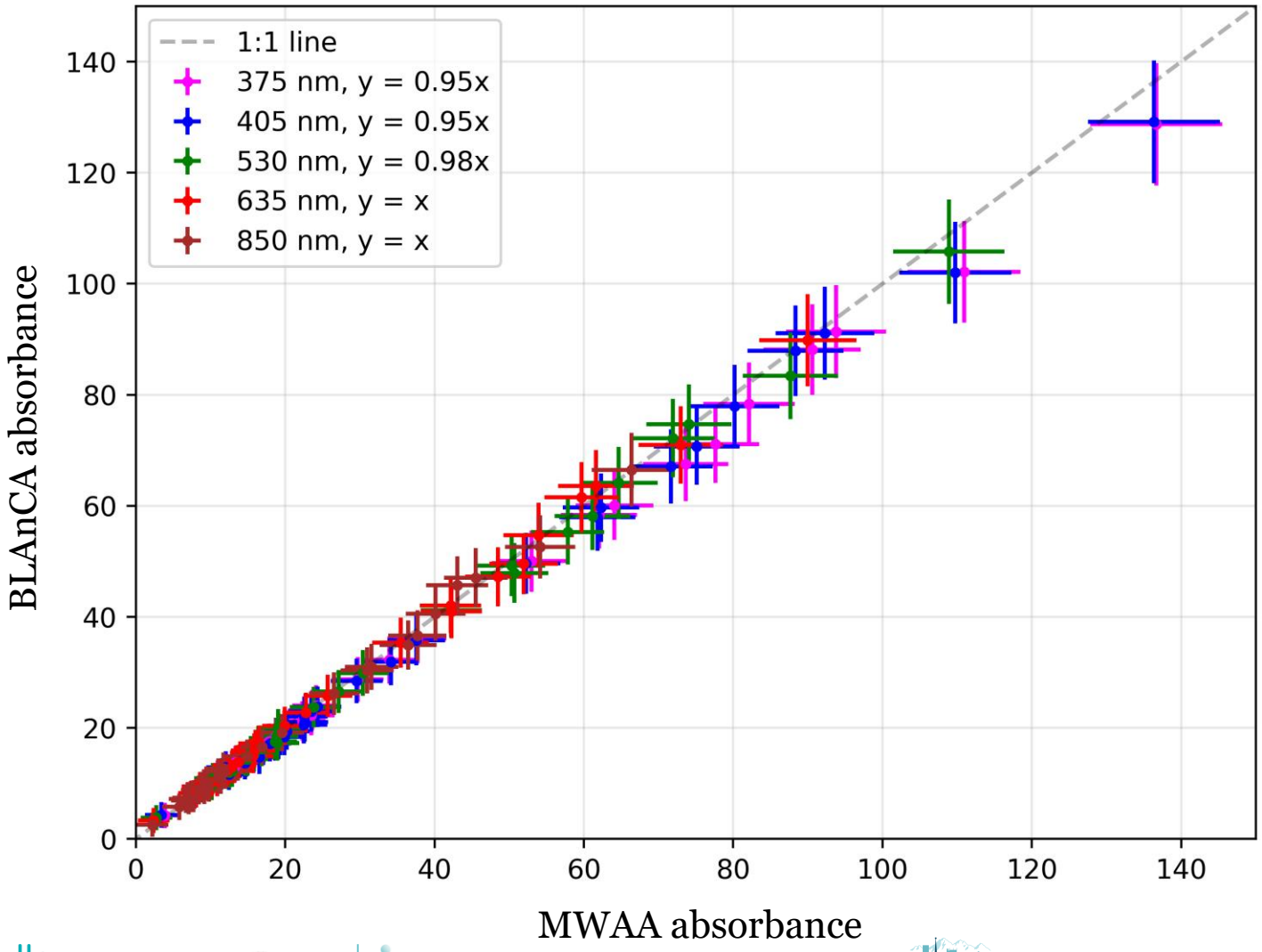
2) **110 values** in the range 350-900 nm instead of 5 values in the range 375-850 nm

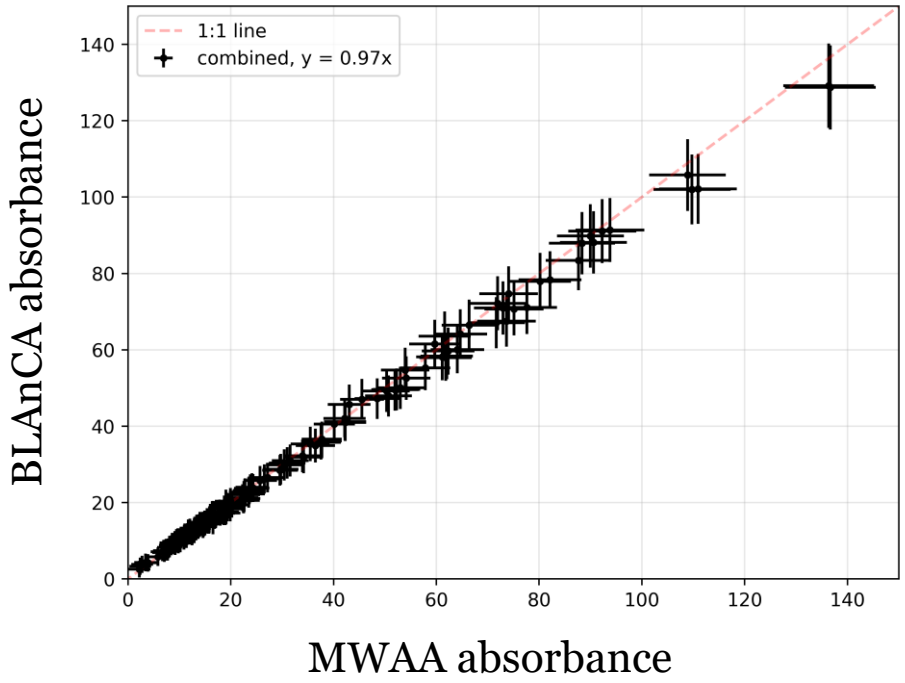




Validation Results: MWAA vs BLAnCA

Synthetic soot on quartz-fibre filters

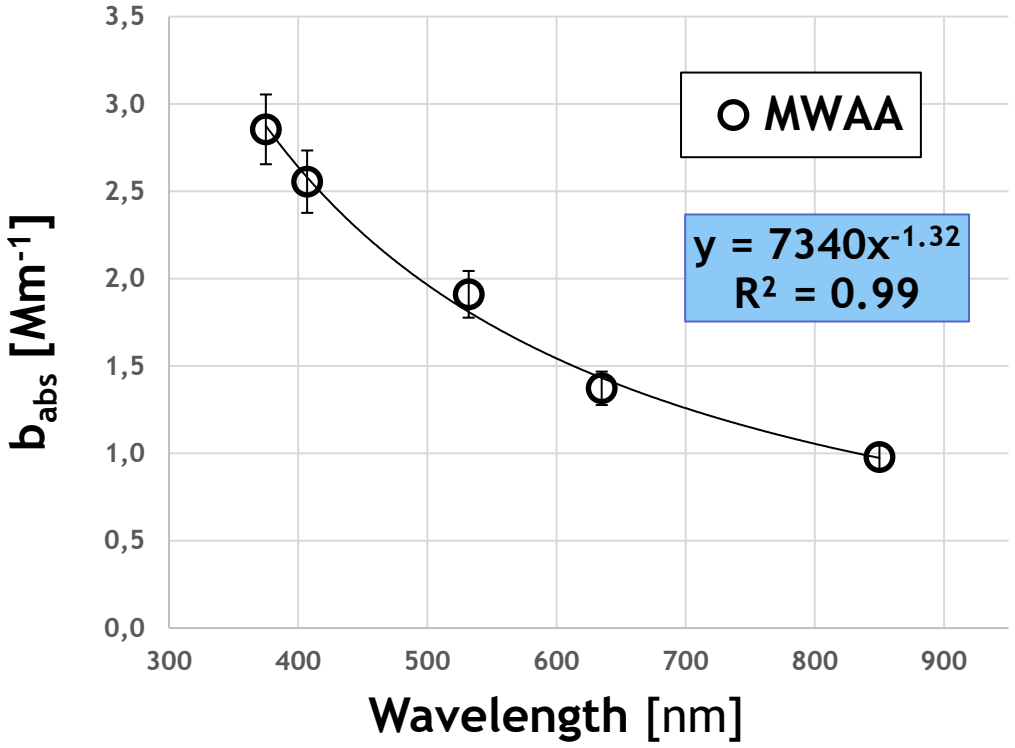




The validation of the new instrument showed excellent results → overall difference of ≈ 3% between BLAnCA and the MWAA!

Is higher spectral resolution important (5 nm)?

- 24h low-volume sampling of PM10, urban background site
- Quartz-fibre filter analyzed by **MWAA** and **BLAnCA**



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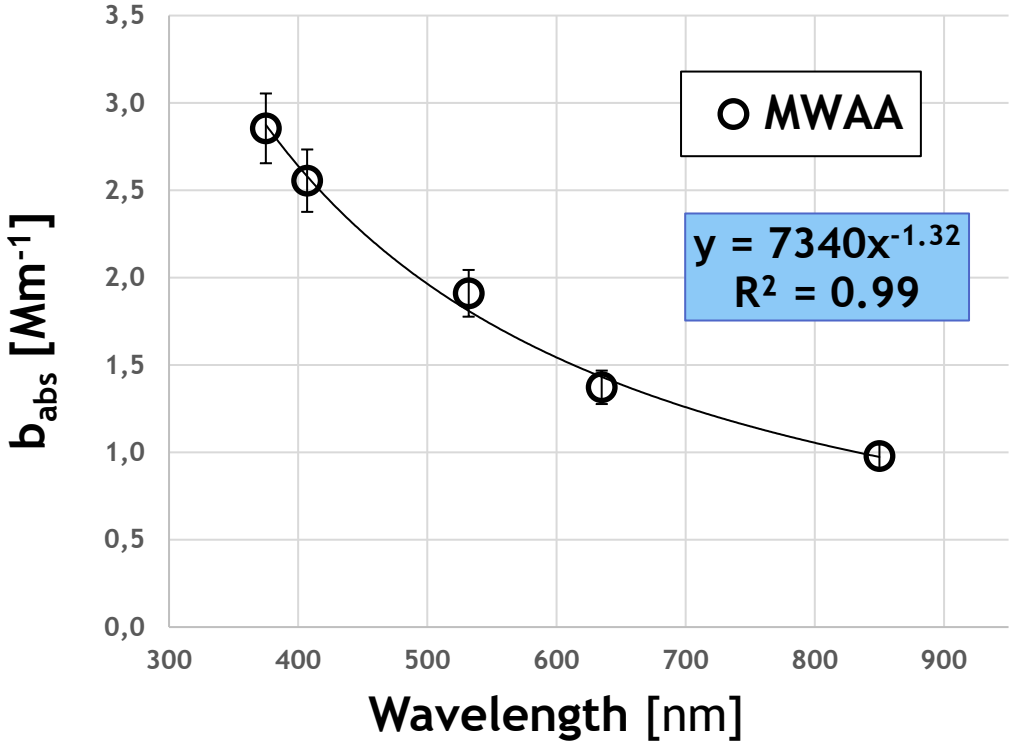
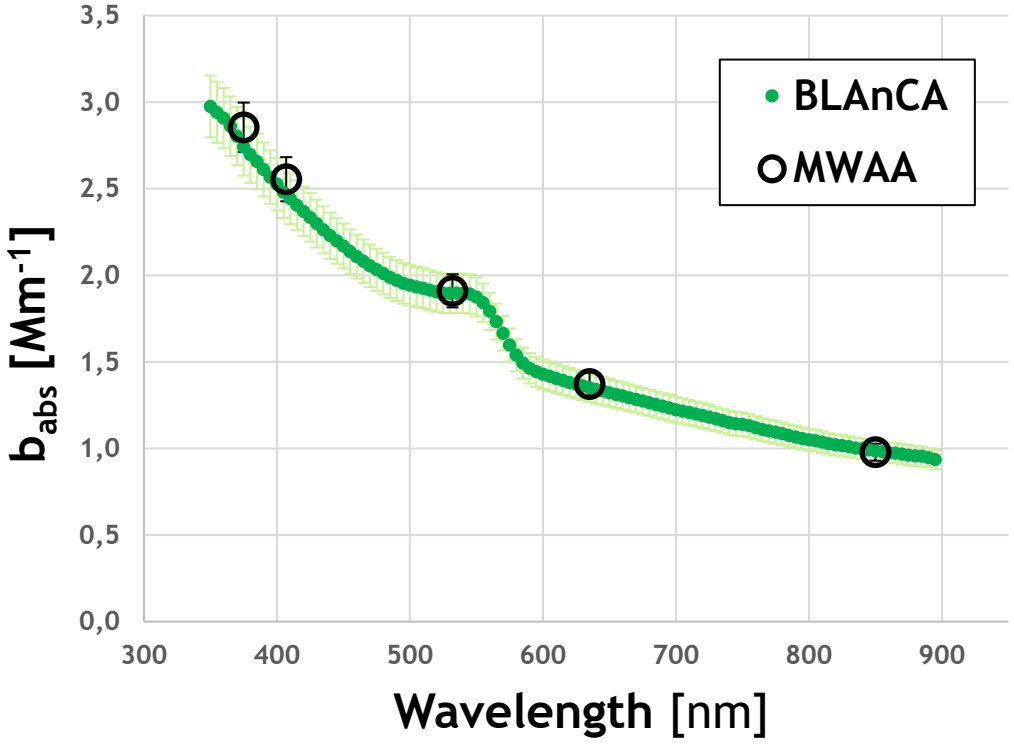
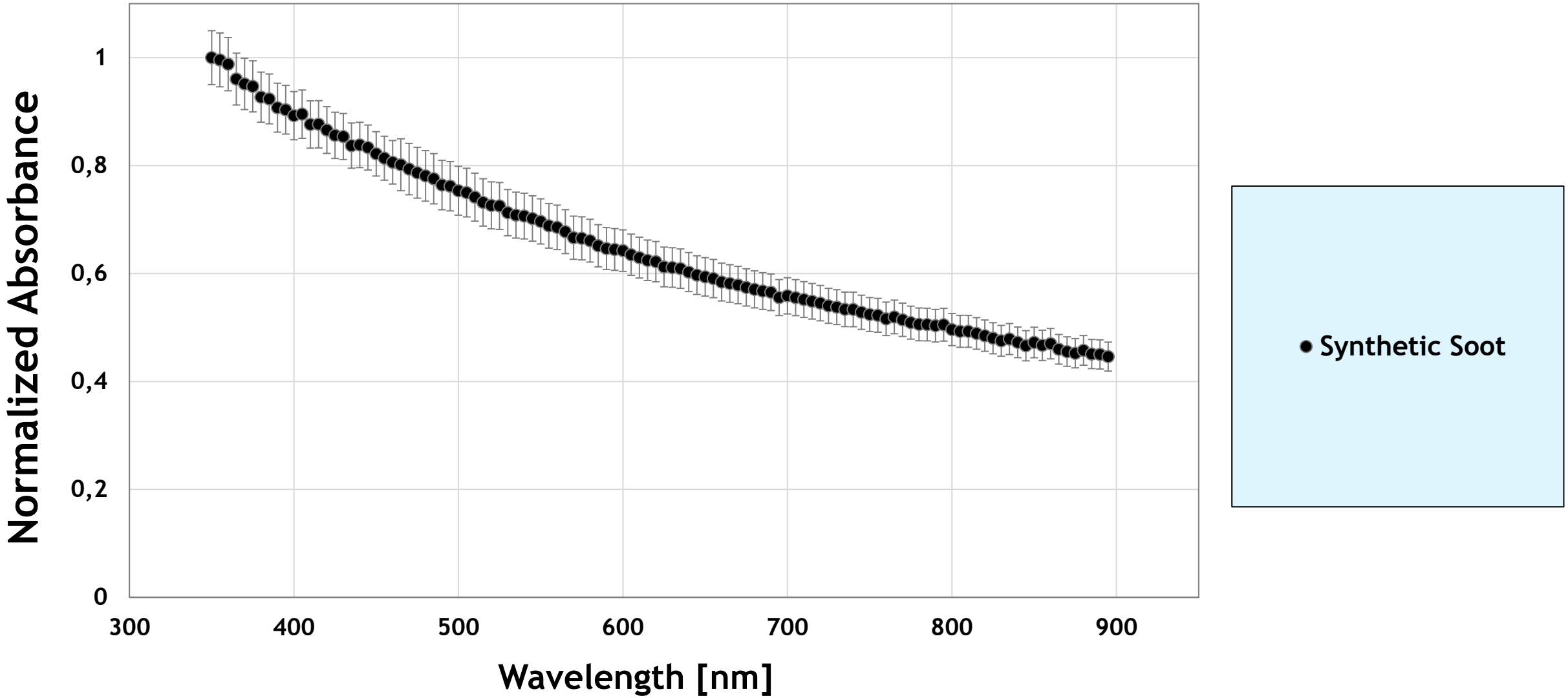


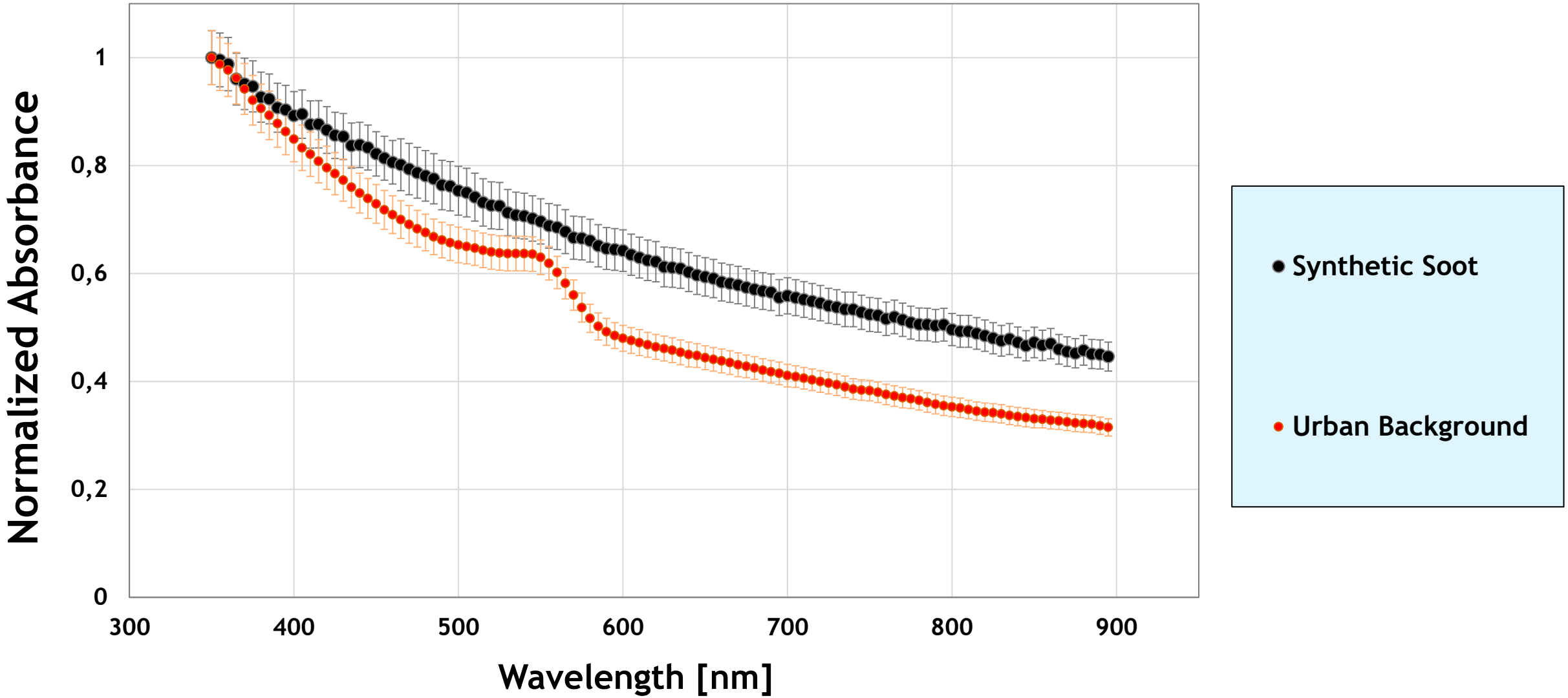


The high resolution allows to resolve the fine structure of the absorption spectrum, providing additional information related to specific aerosol constituents

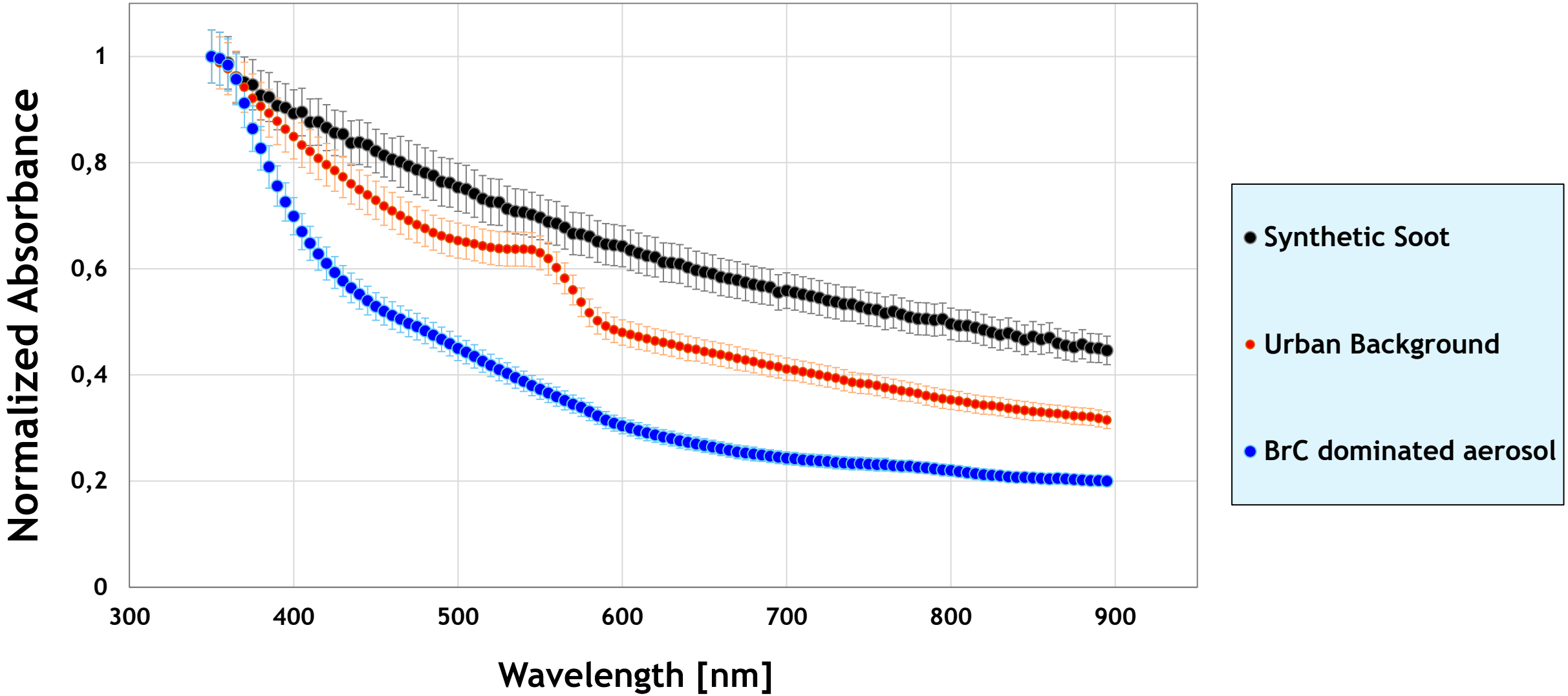
High spectral resolution of different aerosols



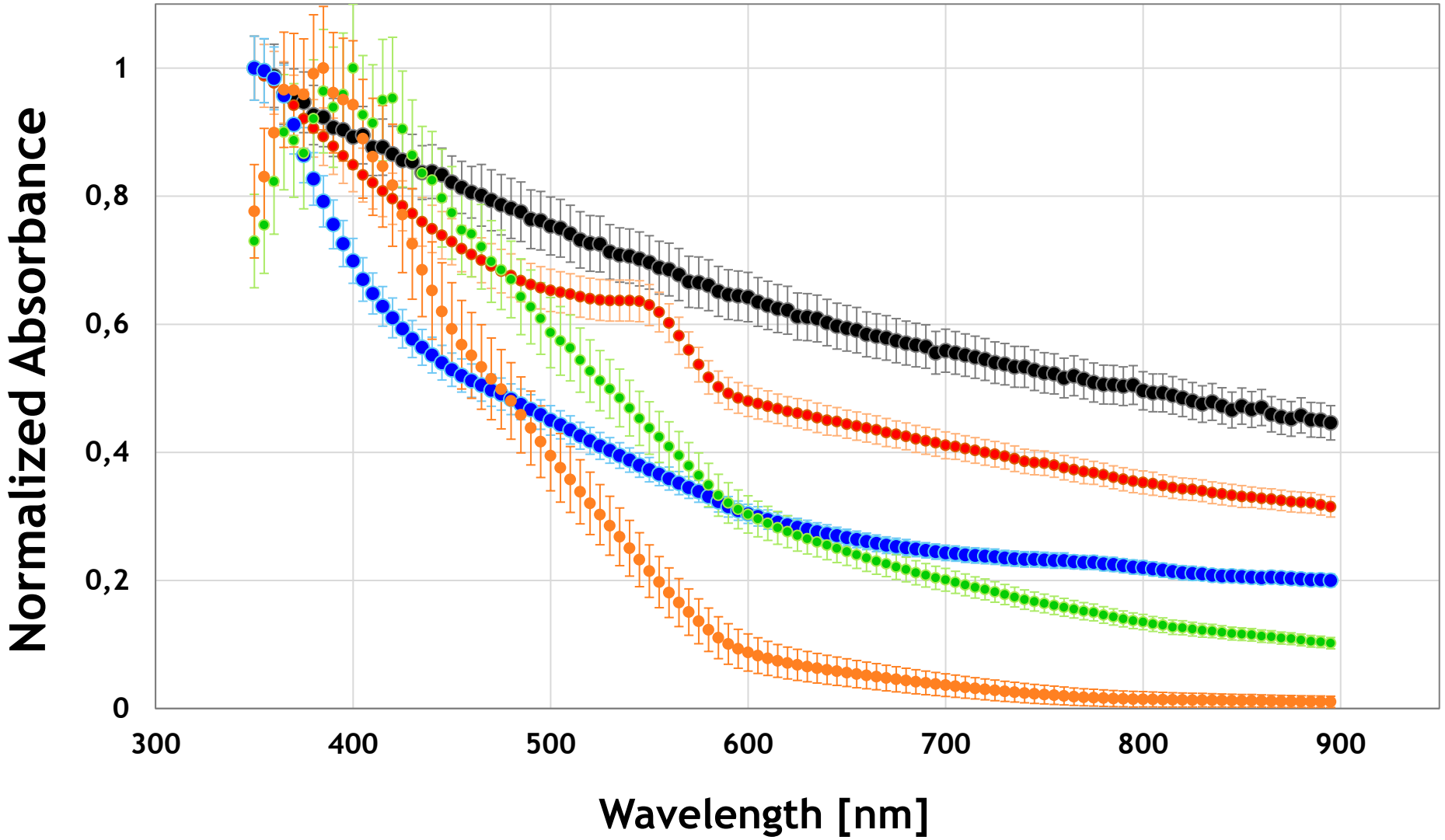
High spectral resolution of different aerosols



High spectral resolution of different aerosols



High spectral resolution of different aerosols



- Synthetic Soot
- Urban Background
- BrC dominated aerosol
- Arizona Dust
- Gobi Dust

Very different absorption spectra!

Conclusions *and Outlook*

We introduce **a new instrument (BLAnCA),** for the measurement of the **absorption coefficient** of aerosol collected on filters, with high resolution (5 nm) in the range 350-900 nm

- The possibility to measure the light phase function on membrane filters fits much better with the radiative transfer model…**other interesting physical parameters to be extracted** (e.g., scattering coefficients, asymmetry parameters, refractive index…)?

- The high resolution (110 points each sample) can be useful to extract **spectrally resolved physical parameters** (e.g., b_{abs}, Mass Absorption Cross-section, AAE,…) of real aerosol -or even aerosol produced in controlled conditions (ASC)- to link characteristics such as chemical composition, ageing and size distribution to a fine structure in optical properties.

- The fine structure of the absorption coefficient -and/or other parameters- could be useful in advanced source apportionment studies (e.g., ME-2)…what about a **source apportionment based on optical properties only?**

Acknowledgements

Department of Physics and INFN group @ Genoa, Italy

- We thank the Italian National Institute for Nuclear Physics for financing BLAnCA through the CSN5-ISPIRA project

- Special thanks to Dr. Paola Formenti and Dr. Vaios Moschos for providing us Dust and BrC samples!

Thank you for your kind attention!