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ON THE CONSIDERATION OF SELF-ABSORPTION FOR SOOT SIZING BY ANGULAR LIGHT SCATTERING IN LAMINAR FLAMES

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RÉSUMÉ

Soot particles, harmful to health and environment, require reduction in green energy efforts. Their complex characterization, especially in sizing, uses angular light scattering for detailed, non-intrusive analysis. However, post-processing errors and signal trapping effect affect accuracy. This study introduces a noise-free Abel inversion method using spline functions to correct these errors, applicable to all flame types. Tested on an academic ethylene flame, it improves soot aggregate measurements, offering robust gyration radius and forward scattering estimations while addressing trapping effects.

MOTS-CLEFS : *Angular light scattering, Extinction, Soot aggregates, Axisymmetric flame.*

1. INTRODUCTION

In efforts to reduce soot's health and environmental impacts [1], accurate soot particulate characterization is essential for understanding soot formation and oxidation. The development of non-intrusive techniques [2, 3] for precise soot size data in controlled combustion is key to refining models and advancing cleaner technologies. The challenge of creating comprehensive models that capture soot dynamics is important for environmental science progress. This study presents an innovative inversion tool to address optical measurement challenges in soot analysis, using a noise-free approach and cubic splines for accurate soot size distribution. It tackles signal trapping in light scattering, enhancing soot characterization accuracy.

2. METHODOLOGY AND RESULTS

An academic laminar ethylene/air diffusion flame is studied in a Gülder burner. A multispectral LED source and CCD camera system captured extinction and scattering at multiple angles and wavelengths.

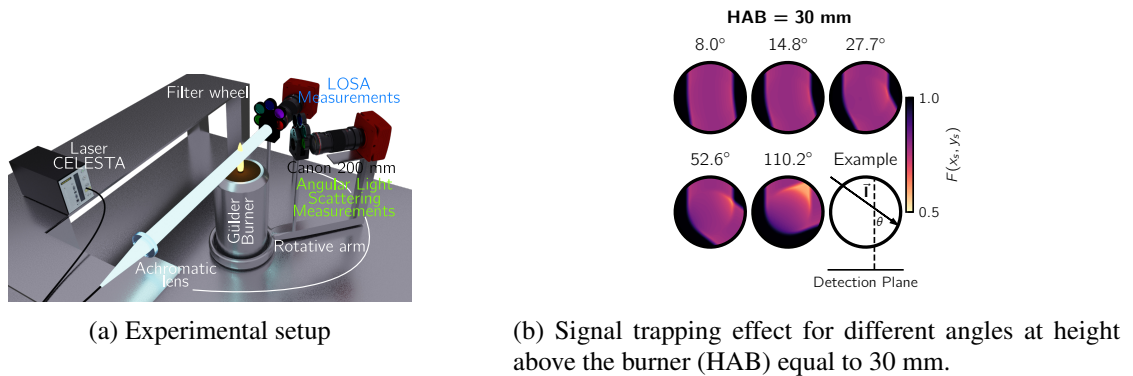


FIGURE 1 – Experimental and modeling methodology for signal trapping correction on angular light scattering measurements

In angular light scattering experiments, light from a source is scattered through the flame, due to soot particles, and then detected. In the detection path, the light is attenuated giving rise to a phenomenon called signal trapping (c. f. Fig. 1b). Knowing how the light attenuates in the flame, it is possible to correct this effect. The impact of this correction is shown below.

Fig. 2a) captures scattered light from a flame at angles of 8.0° , 27.7° , and 52.6° , showing soot distribution at specific heights and radial positions. Fig. 2b) and c) detail the scattered signals $S_{VV}(x)$ and their deconvolution, highlighting signal trapping's effect on measurement symmetry. Fig. 2d) demonstrates how correcting for signal trapping has a minimal impact on gyration radius R_g^* but significantly alters $\kappa_{VV}(0^\circ)$, indicating a more accurate assessment of soot volume and optical properties.

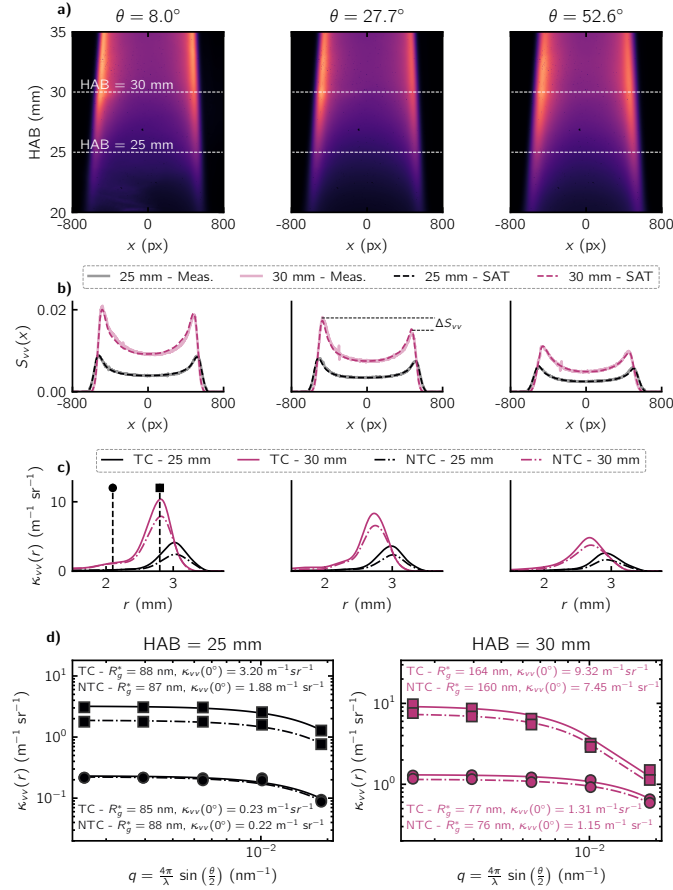


FIGURE 2 – a) Images of the scattered signal of the flame at different angles : 8.0° , 27.7° and 52.6° . b) Measured scattered signal S_{VV} . c) Deconvoluted scattered signal κ_{VV} . The re-convolution of these signals are shown in dashed lines in b). d) Angular dependence of scattering coefficient for vertical-vertical polarization κ_{VV} at two different radial positions : $r = 2.1$ mm and $r = 2.8$ mm. The angular dependence is expressed through the scattering wave vector q .

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