Contribution ID: **25** Type: **Poster**

Micro-Raman imaging of neural tissues and multicomponent spectral analysis towards label-free detection of Parkinson's disease biomarkers

Owing to the global increase in life expectancy, neurodegenerative disorders currently represent a significant challenge both in terms of diagnosis and treatment. Specifically, Parkinson's disease (PD) is characterized by the gradual loss of dopaminergic neurons, resulting in the onset of symptoms such as muscle rigidity and coordination difficulties. Unfortunately, these clinical manifestations often become apparent only years after the initial stages of the disease; consequently, early detection is becoming increasingly essential.

Recently, given its non-invasiveness and versatility, Raman spectroscopy (RS) has emerged as a promising tool for early diagnosis in various medical fields, including neurology [1][2]. However, RS requires being complemented by specific and robust analysis [3], particularly when dealing with biological samples, that present intrinsic challenges such as fluorescence noise and complex overlaps of multiple signals.

To this end, the aim of this work is to investigate the potential and capabilities of Raman micro-spectroscopy, combined with specific data-processing methods, to identify differences in the biochemical composition of brain tissues and the presence of putative biomarkers.

We acquired hyperspectral images of brain slices from a murine model of PD and analyzed them with a robust preprocessing (desaturation, baseline subtraction, despiking, and normalization) followed by Principal Component Analysis (PCA), a multivariate method that decomposes the spectra into signals with reduced dimensionality, helping the identification of subtle spectral differences.

Combining chemometric and spatially resolved information, we show that our approach can localize possible biochemical differences within the samples, offering a promising, non-destructive technique for label-free detection of neurodegenerative disorders with high spatial resolution.

[1] Bufka et al, Adv Photonics Res (2025): 10.1002/adpr.202500087
[2] Chen et al, Front Neurosci (2024): 10.3389/fnins.2024.1301107
[3] Guo et al, Nat Protoc (2021): 10.1038/s41596-021-00620-3

Biography

Alberto Lucchin is a BSc student in Physics at the University of Padua's Department of Physics and Astronomy "Galileo Galilei". He is currently working on his Bachelor's thesis regarding micro-Raman imaging of neural tissues and hyperspectral analysis, aiming for label-free detection of biomarkers linked to Parkinson's disease.

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Session Classification: Poster Session

Track Classification: Poster: P5