Exploring the Chemical Characteristics of Particulate Matter in Real Household Environments in Bradford, UK

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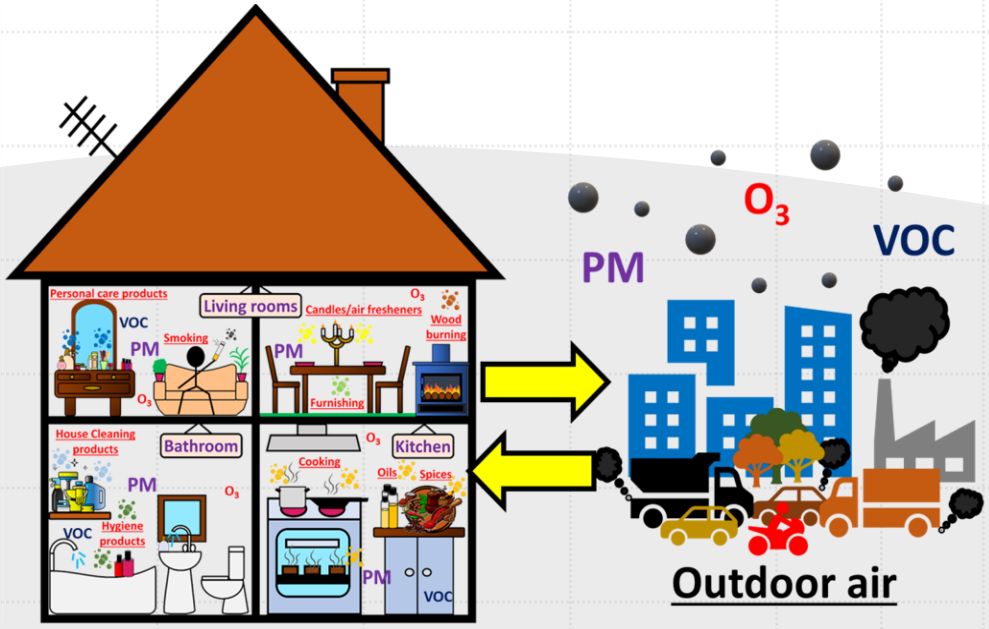
Background

Both short- and long-term exposure to indoor air pollution can cause a range of health issues, including respiratory diseases such as asthma, allergies, lung cancer, and cardiovascular diseases

This study is a subset of a large multi-institute consortium project titled “Understanding the sources, transformations and fates of indoor air pollutants” (INGENIOUS), which aims to understand indoor air pollutants and its affect on people in their homes

This study aims to improve our understanding of indoor air aerosol (PM2.5) exposure patterns in Bradford by identifying the chemical composition and concentration of various sources contributing to indoor air quality, through the integration of measurement data and modelling results

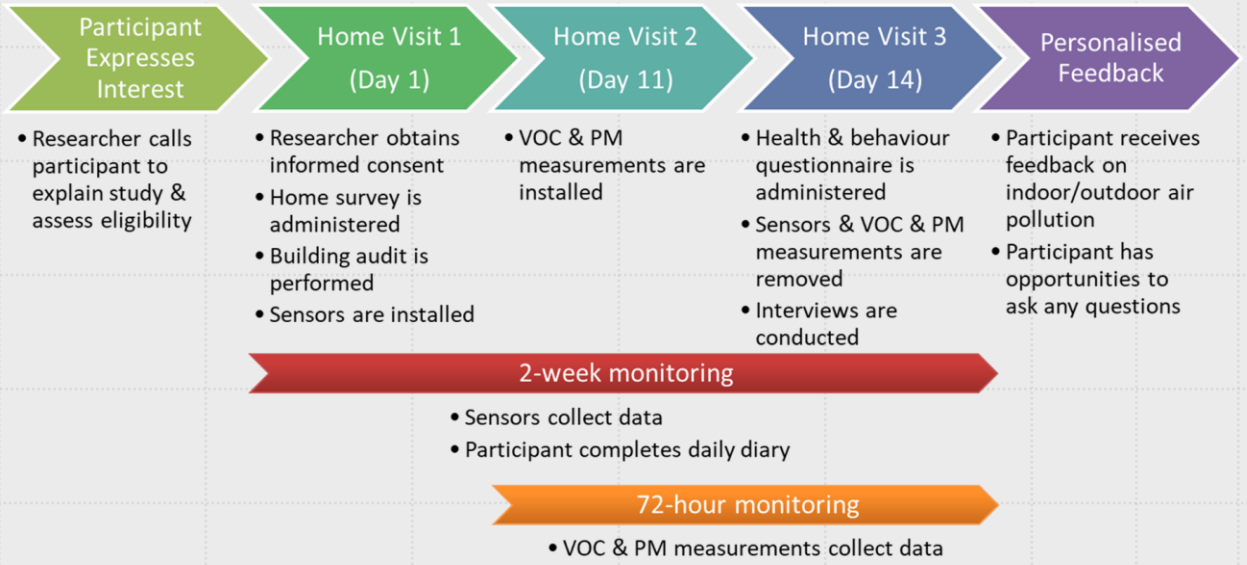


Household Recruitment and Sample Collection Procedure

- Polytetrafluoroethylene (PTFE) membrane was used for PM sampling.

- The Minivol Tactical Air Sampler was positioned in each kitchen for a three-day period, collecting samples at a flow rate of 3 litres per minute

- A total of 114 homes in Bradford City participated in the particulate matter sampling process, 78 Homes filter samples analyzed by the UOM team, and 36 filter samples analyzed by the UOY team.



PM Sample analyzed by GCxGC-TOFMS

- Samples were extracted using accelerated solvent extraction into ethyl acetate
- -Separates by volatility in the first dimension and polarity in the second
- -Allows for more detailed characterisation via more comprehensive separation
- -142 compounds used to create calibration curves to allow for quantitation. Compounds were chosen based on prevalence in home environments and potential for toxicity. Compound classes include phthalates, alkanes, PAHs, etc.

Preliminary result of GCxGC-TOFMS

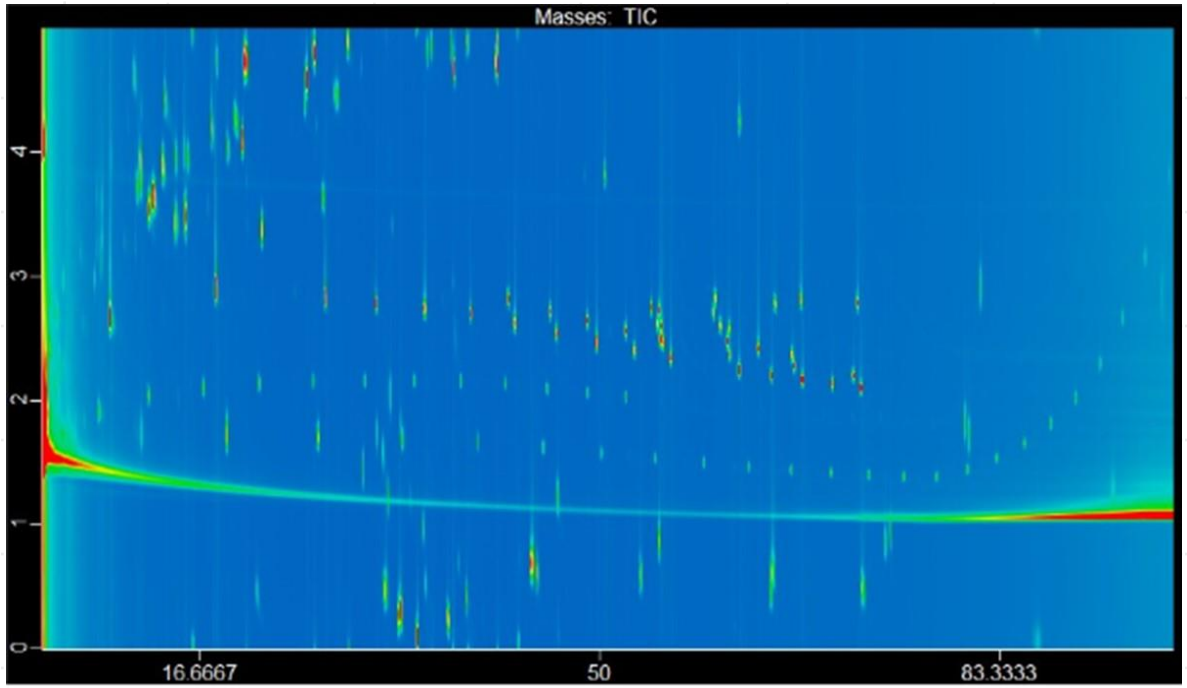


Figure: Target analytes at 1.0 µg/ml

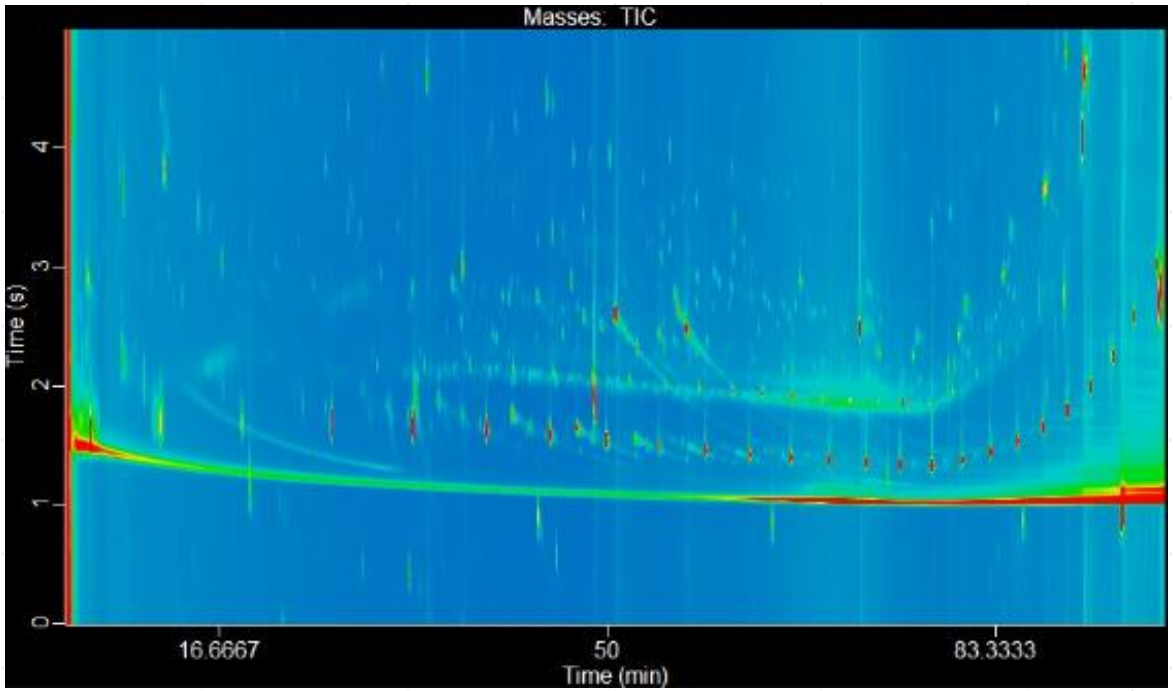


Figure: Sample taken from participants' home

Target analysis of PM via GCxGC-TOFMS

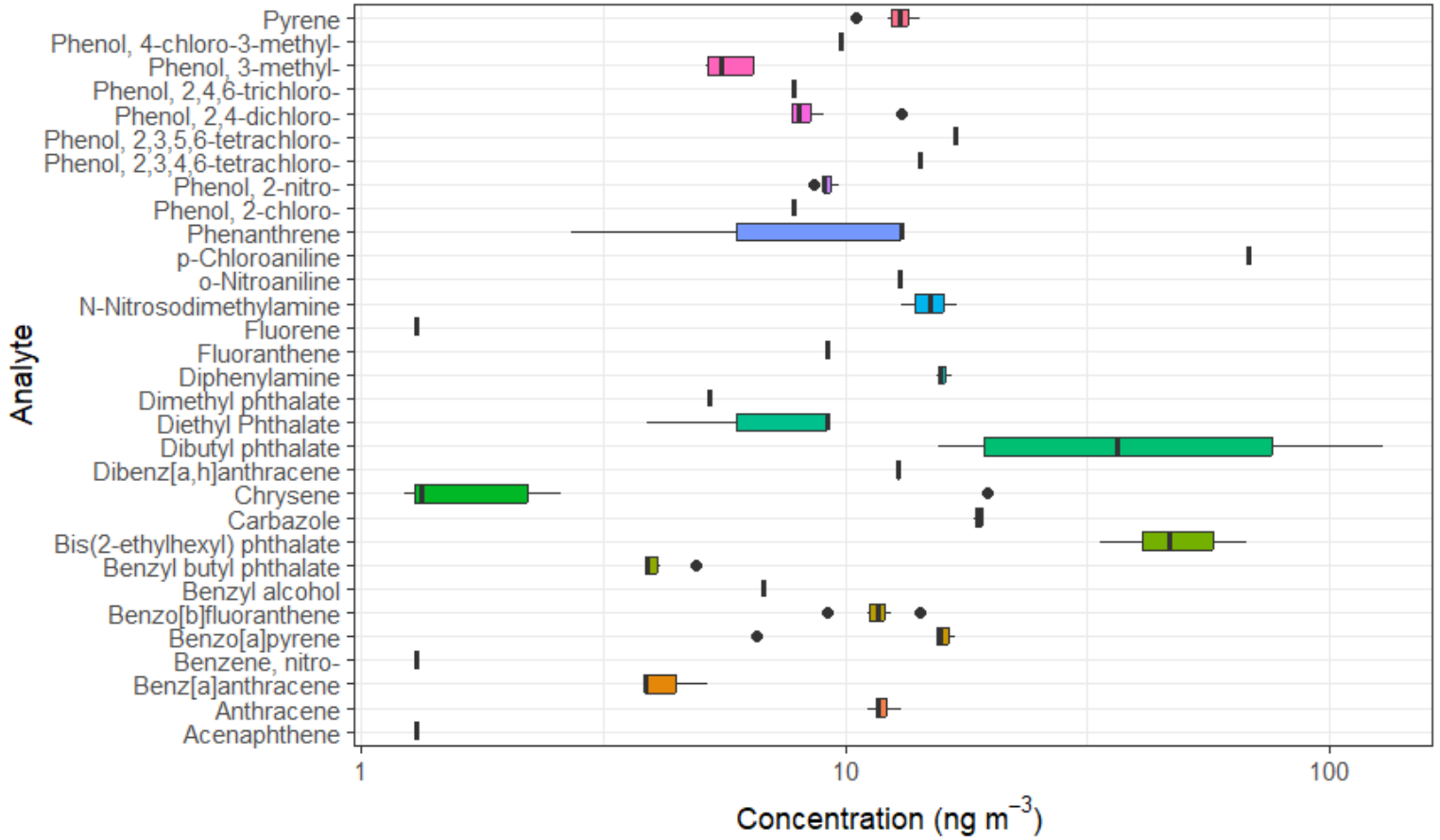
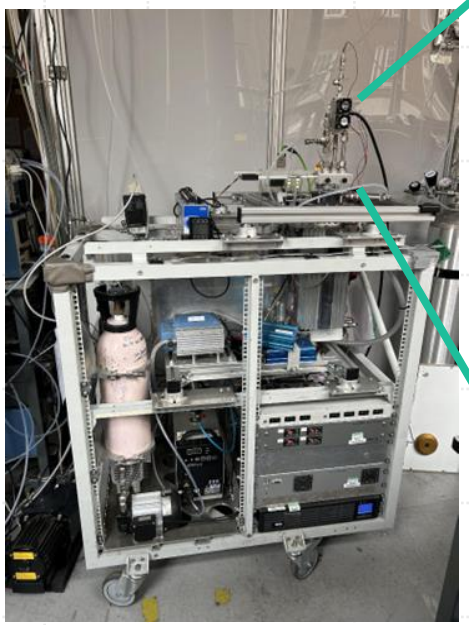


Figure: Concentrations of target analytes across homes

PM Sample analyzed by FIGAERO-CIMS



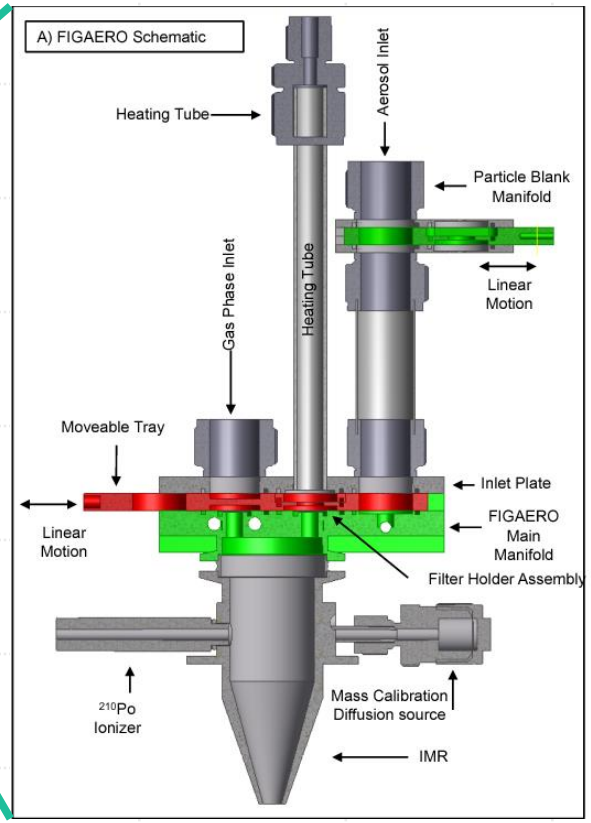


Figure from : F.D.Lopez-Hilfiker *et al.*, Atmos.Mes.Tech.,7,983-1001.2014

❖ **F**ilter **I**nlet for **G**ases and **AERO**sols- **T**ime **O**f **F**light-**C**hemical **I**onisation **M**ass **S**pectrometer (FIGAERO-CIMS)

- 25 mm punch is excised from the 47 mm filter and placed into the FIGAERO unit's filter holder.
- Thermal desorption is applied to the filter punch, with the temperature gradually increasing from 25°C to 180°C, heating the particles to release chemical species into the gas phase.
- The vaporized compounds are ionized using chemical ionization, with methyl iodide serving as the reagent ion source, and are then subsequently analysed by the mass spectrometer.
- The FIGAERO-CIMS (with Iodide reagent Ion) has good sensitivity toward organic species that are slightly to highly oxidised.

Source Apportionment Method

- **Source Sample collected from the related HIP-Tox consortium project**

Wood Burning

Diesel Engine

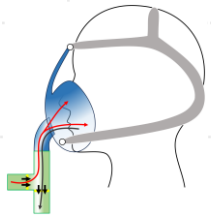
Cleaning SOA

Cooking:
(1) Pork Frying
(2) Chicken Curry Receipt
(3) Mixed Vegetable Frying

Candle Burning

Manchester Aerosol Chamber

The 47 mm filter is connected to the aerosol chamber for PM sampling at a flow rate of 2 L/min for 3 hours



Exposure to human

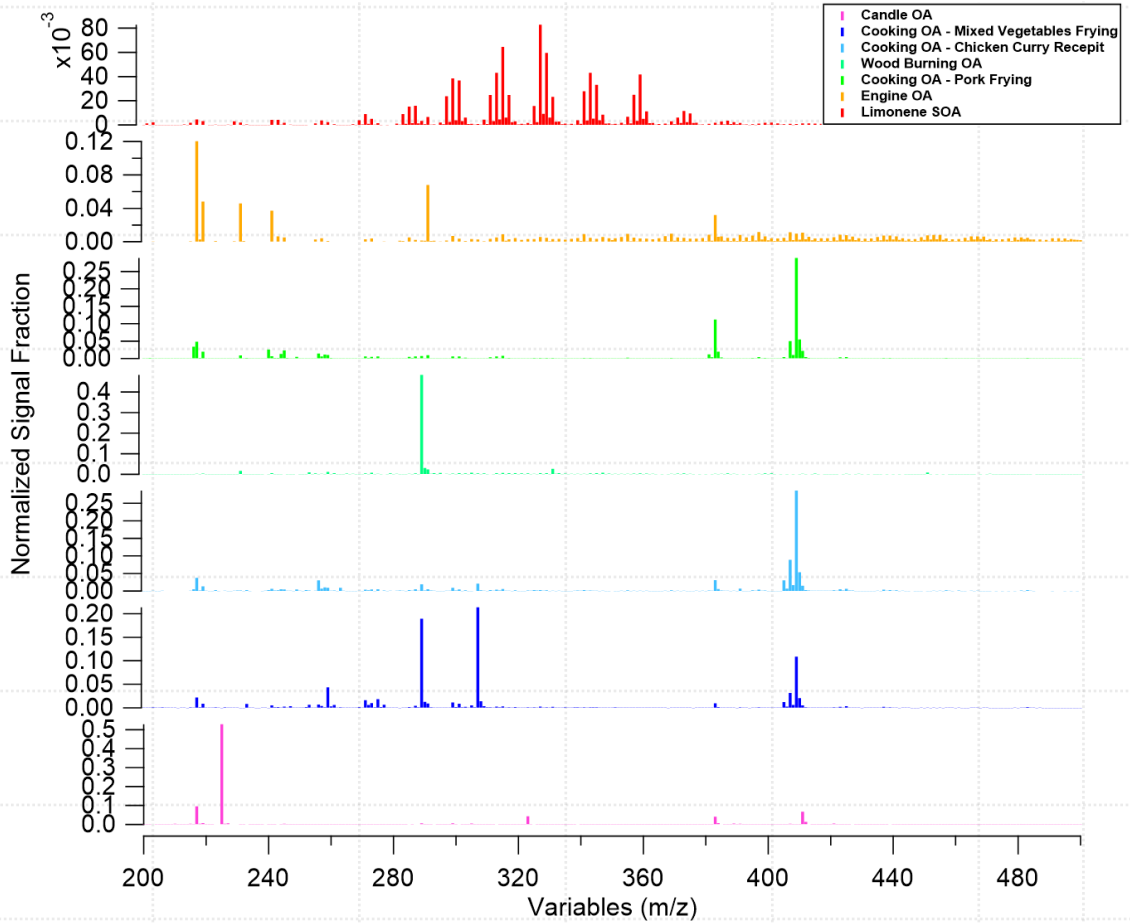
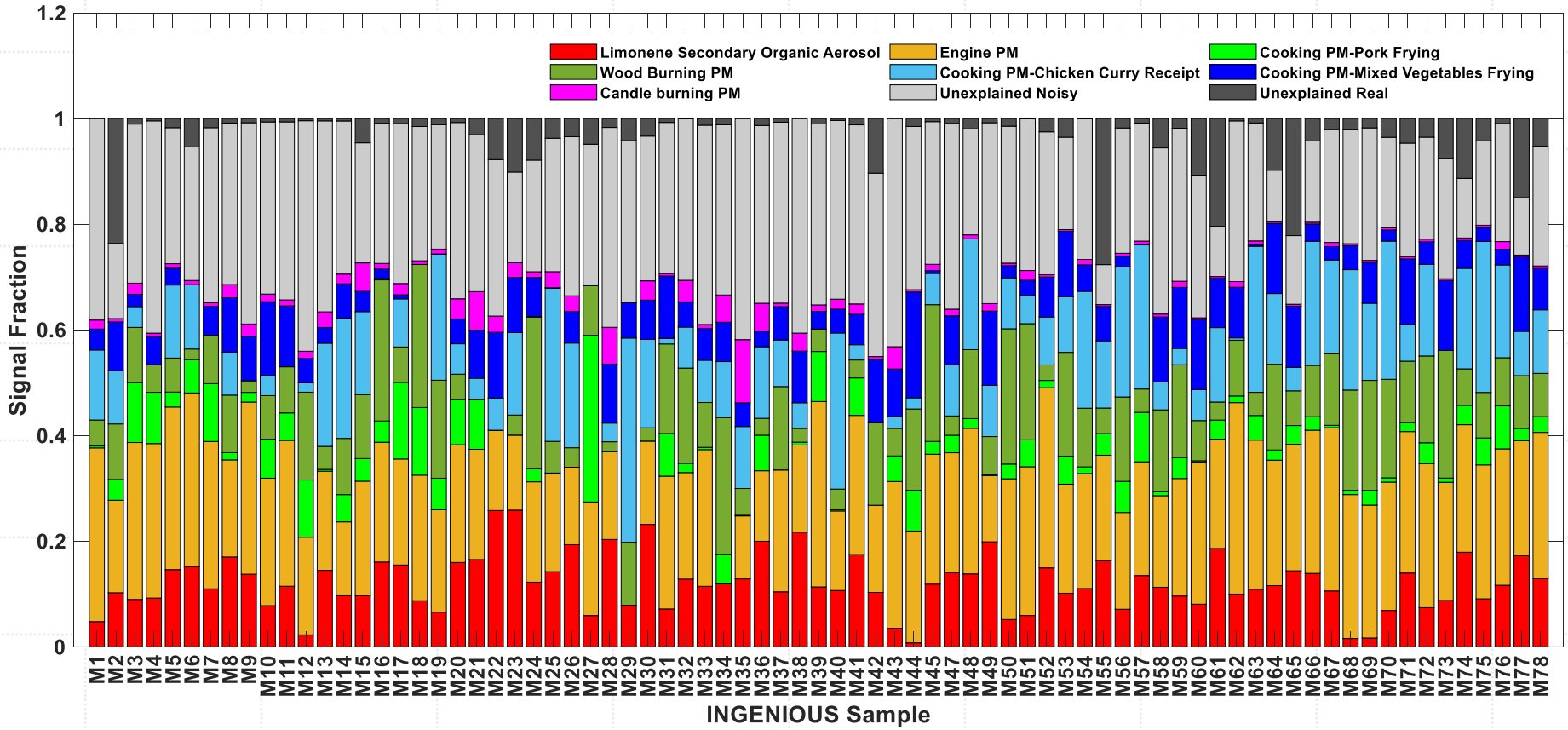


Figure: UMR mass spectra for various sources: Wood Burning Organic Aerosol (OA), Cooking OA, Cleaning Products OA (Limonene Ozonolysis SOA), Diesel Engine OA, and Candle OA, obtained from FIGAERO-CIMS offline filter analysis.

Preliminary result of source apportionment

- Data Analysis Approach: Positive Matrix Factorization

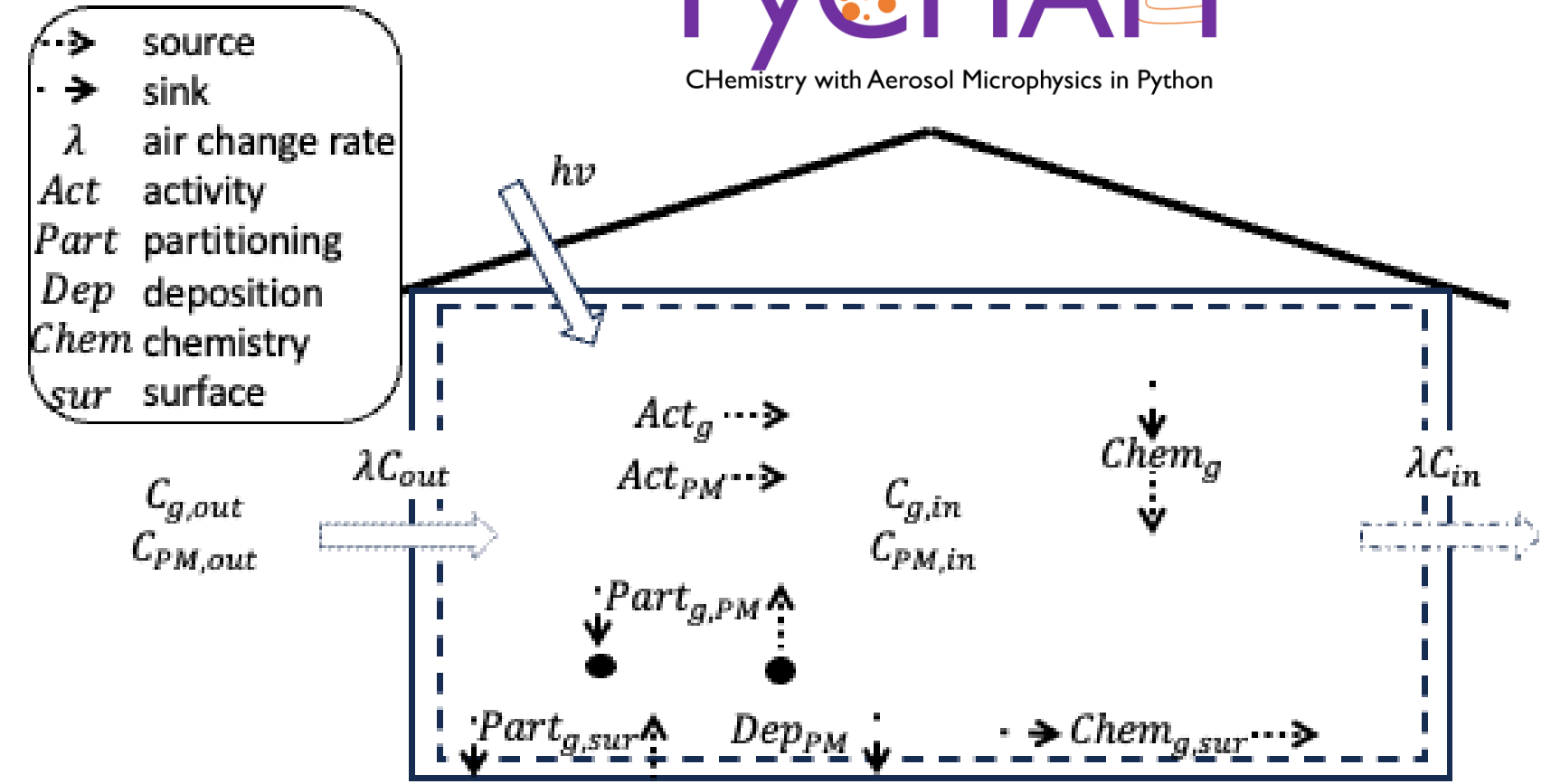
ME-2 algorithm(***Multi-Environment Multi-Scale Model Evaluation Framework)*** allows solving PMF model with prior information such as time series /mass spectra of known source



Modelling Method

PyCHAM

CHemistry with Aerosol Microphysics in Python

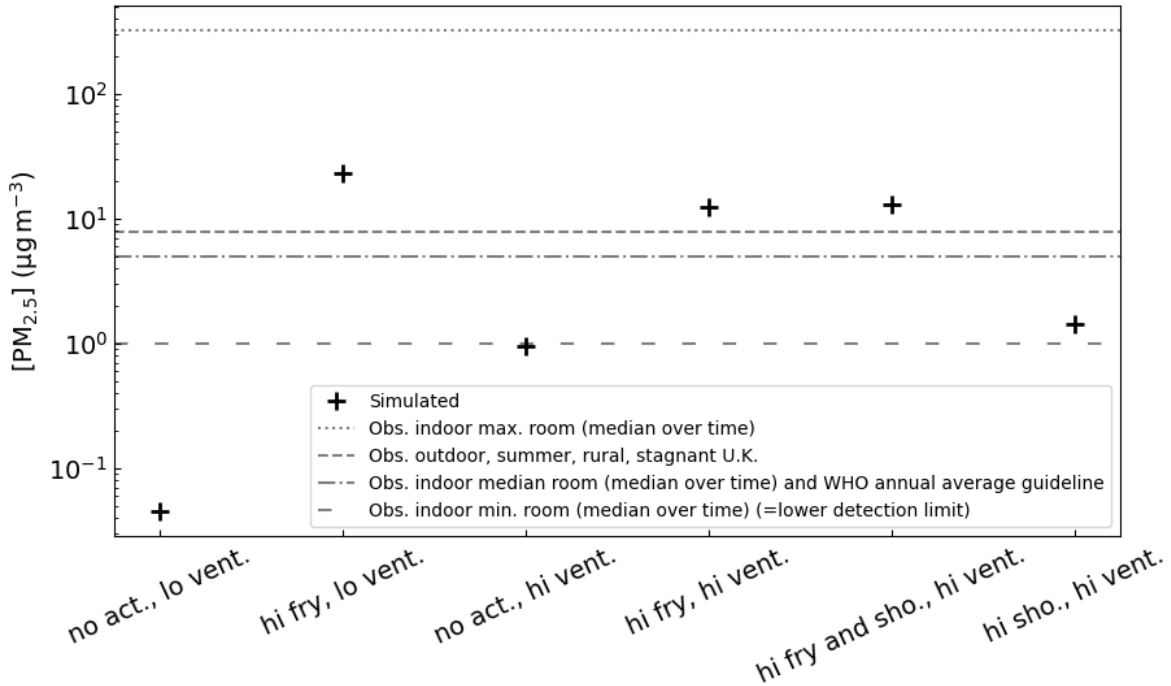


- Computer Model
- Zero dimensional
- Calling upon:
  - Outdoor observations
  - Indoor activity emission rates
  - Indoor activity timeline

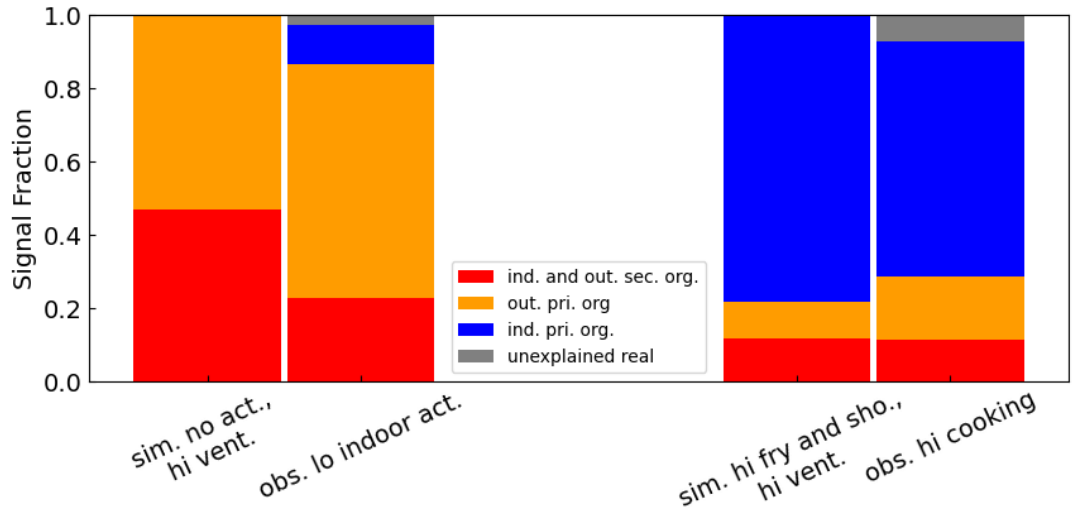
O'Meara et al. 2021: 10.5194/gmd-14-675-2021

Simulated vs Observed Bulk

Total $PM_{2.5}$

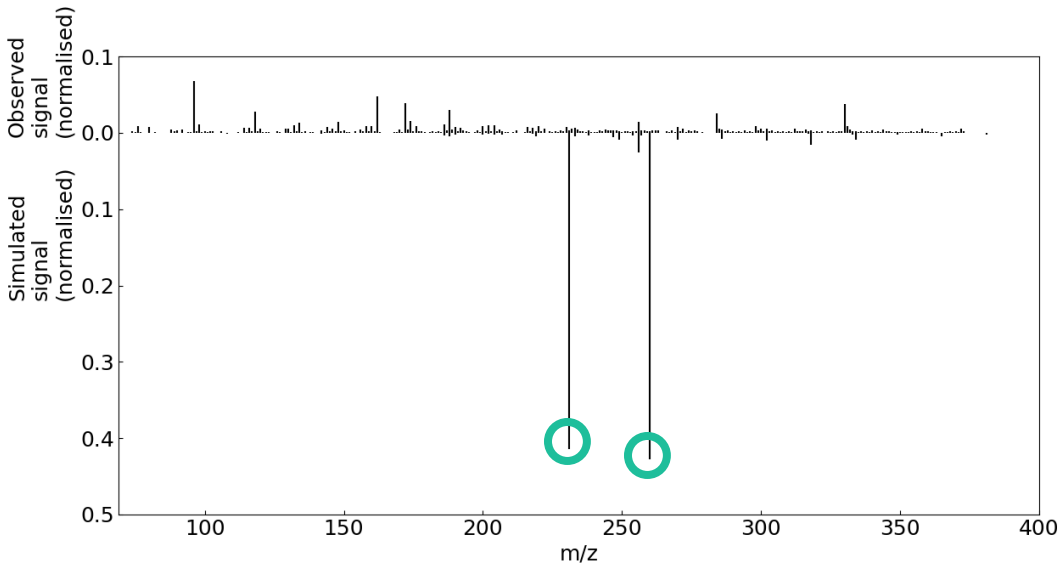


Sources



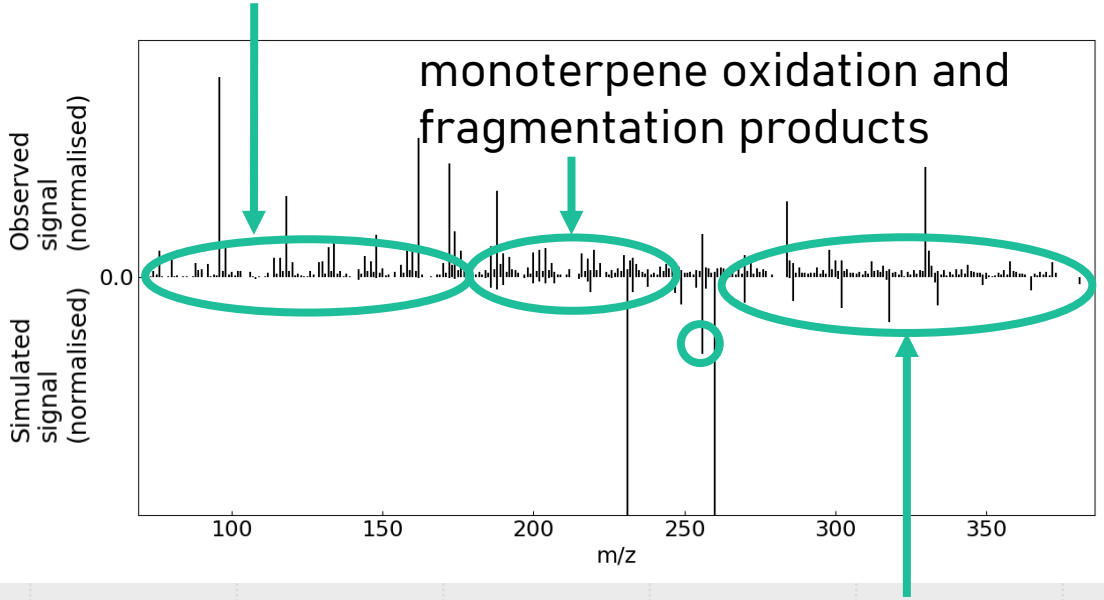
Bulot et al. 2019:
10.1038/s41598-019-43716-3

Simulated vs Observed Mass Spectrum



Simulated primary organics

simulation doesn't know



monoterpene autoxidation products

Summary and Future Work

- The basis and preliminary results of particle-phase composition work in INGENIOUS has been presented
- GCxGC-TOFMS measurement will be used to predict health effects of exposure to PM inside households. Sensitivity of particle-phase concentrations to cooking activity and manner of cooking will be quantified based on controlled laboratory-based cooking experiments
- FIGAERO-CIMS analysis with source apportionment revealed that known sources couldn't explain all the organic compounds detected in Bradford City households, indicating additional indoor sources. Ongoing optimization of the SOFI-PMF solution is necessary to identify these unknown sources. The source apportionment results will be applied to explore the determinants of indoor aerosol exposure by comparing factors such as residential layout, cooking habits, ventilation, household activities, and proximity to outdoor pollution sources
- Early indication of model verification (and therefore predictive ability of health effects) for simulated $PM_{2.5}$ mass and source, though simulation of specific species is very limited