Primary and Secondary Organic Aerosols from Cooking Emissions

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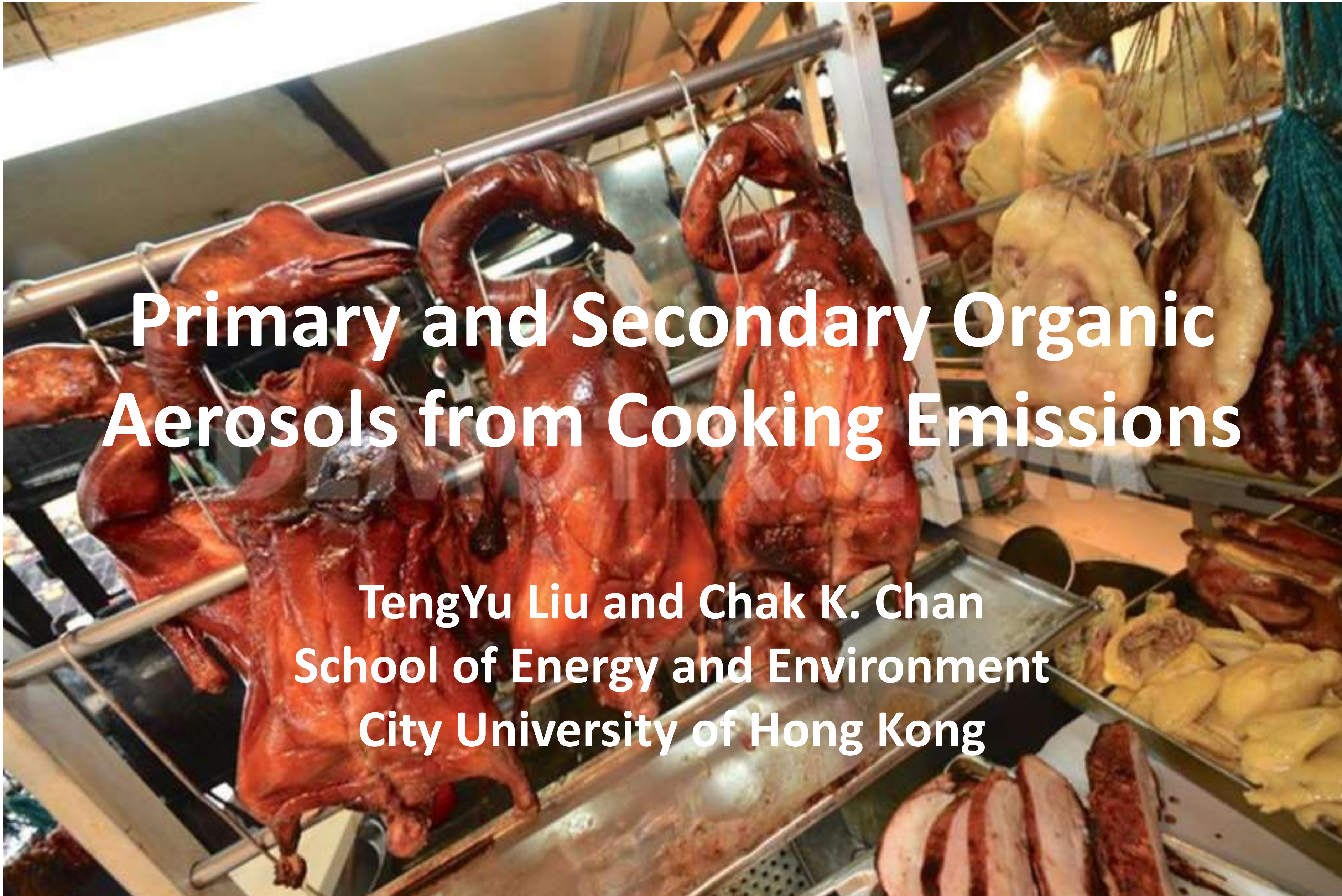

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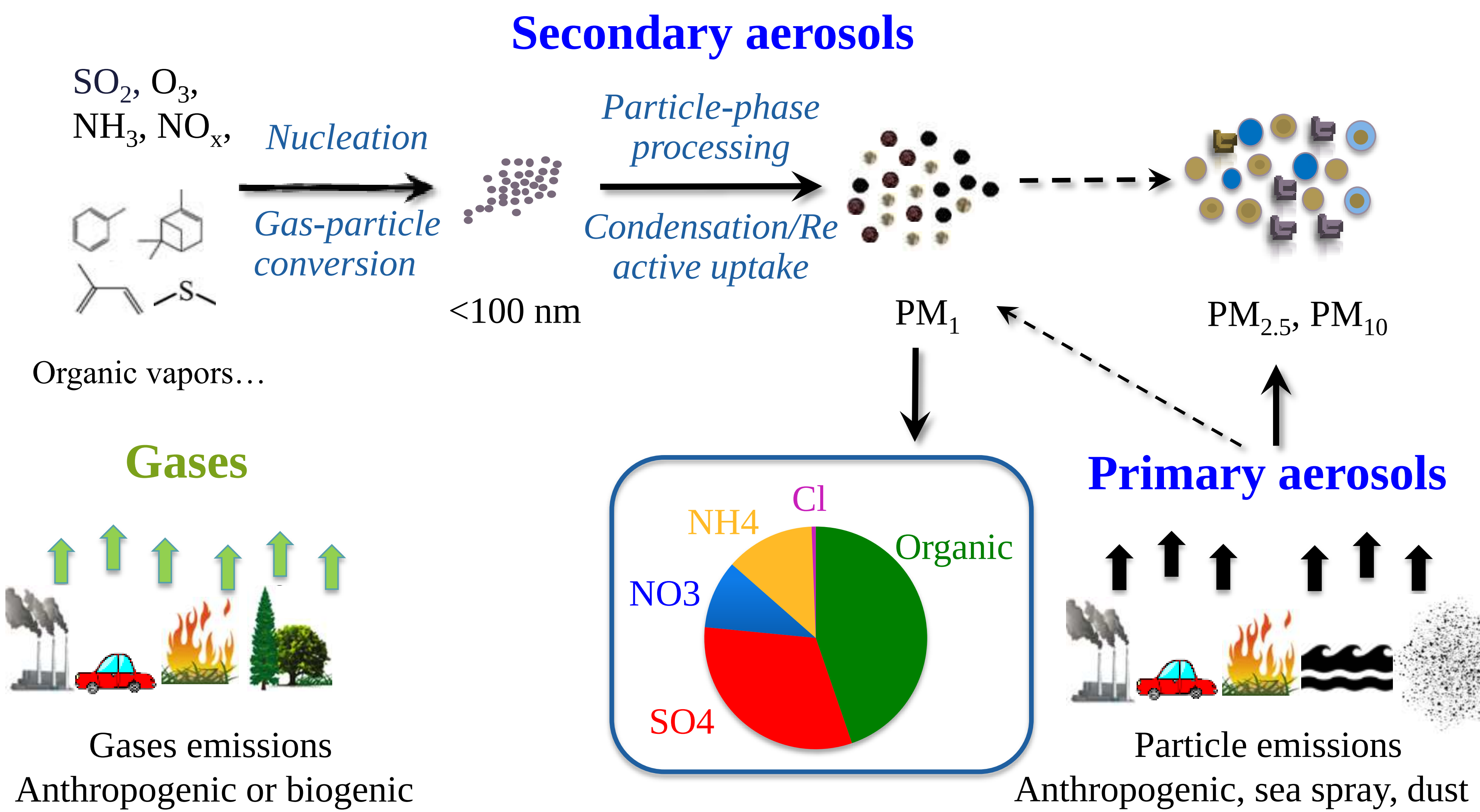
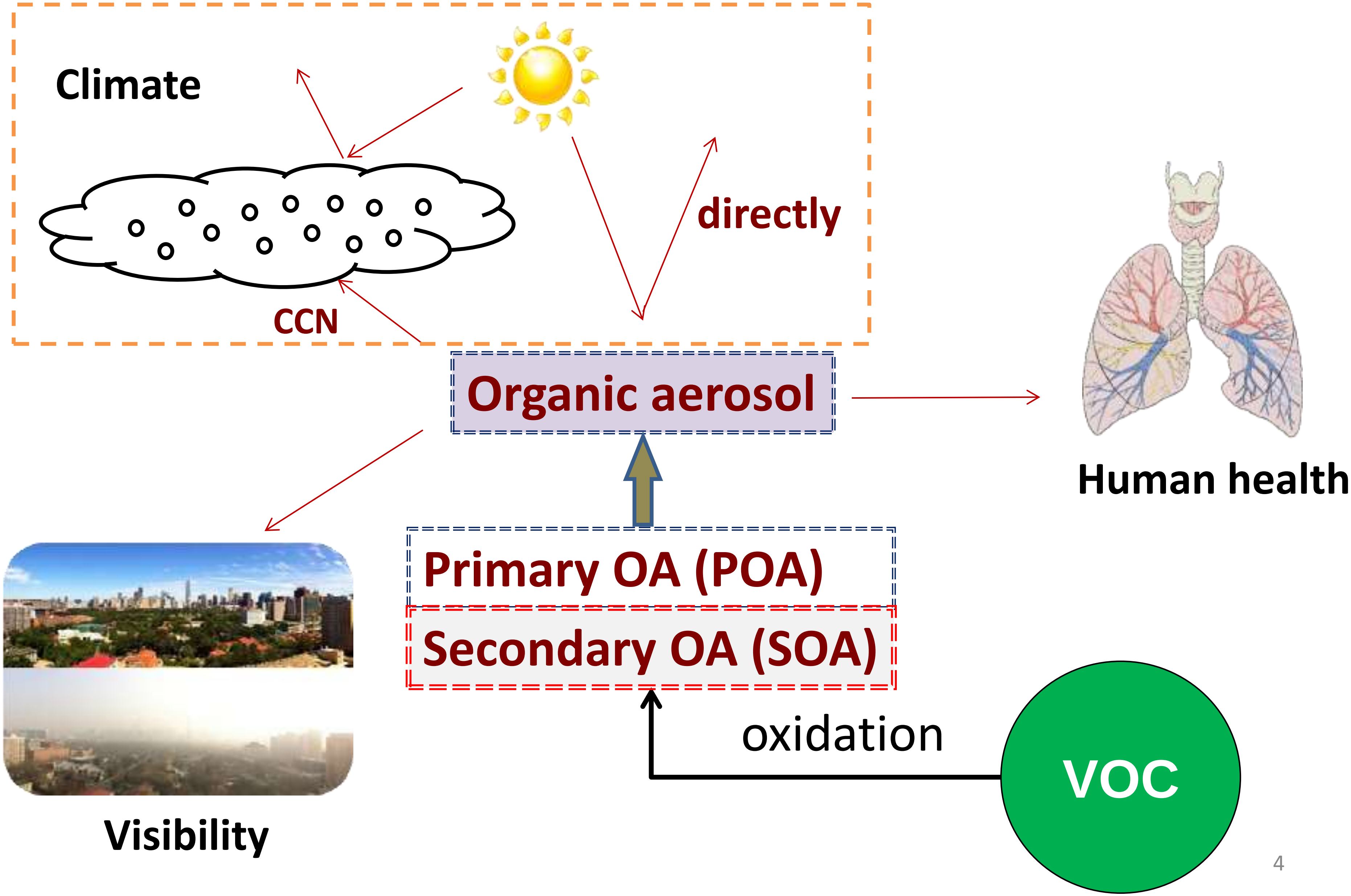
Aerosols



Zhang et al.[2007]; Glasius and Goldstein [2016]

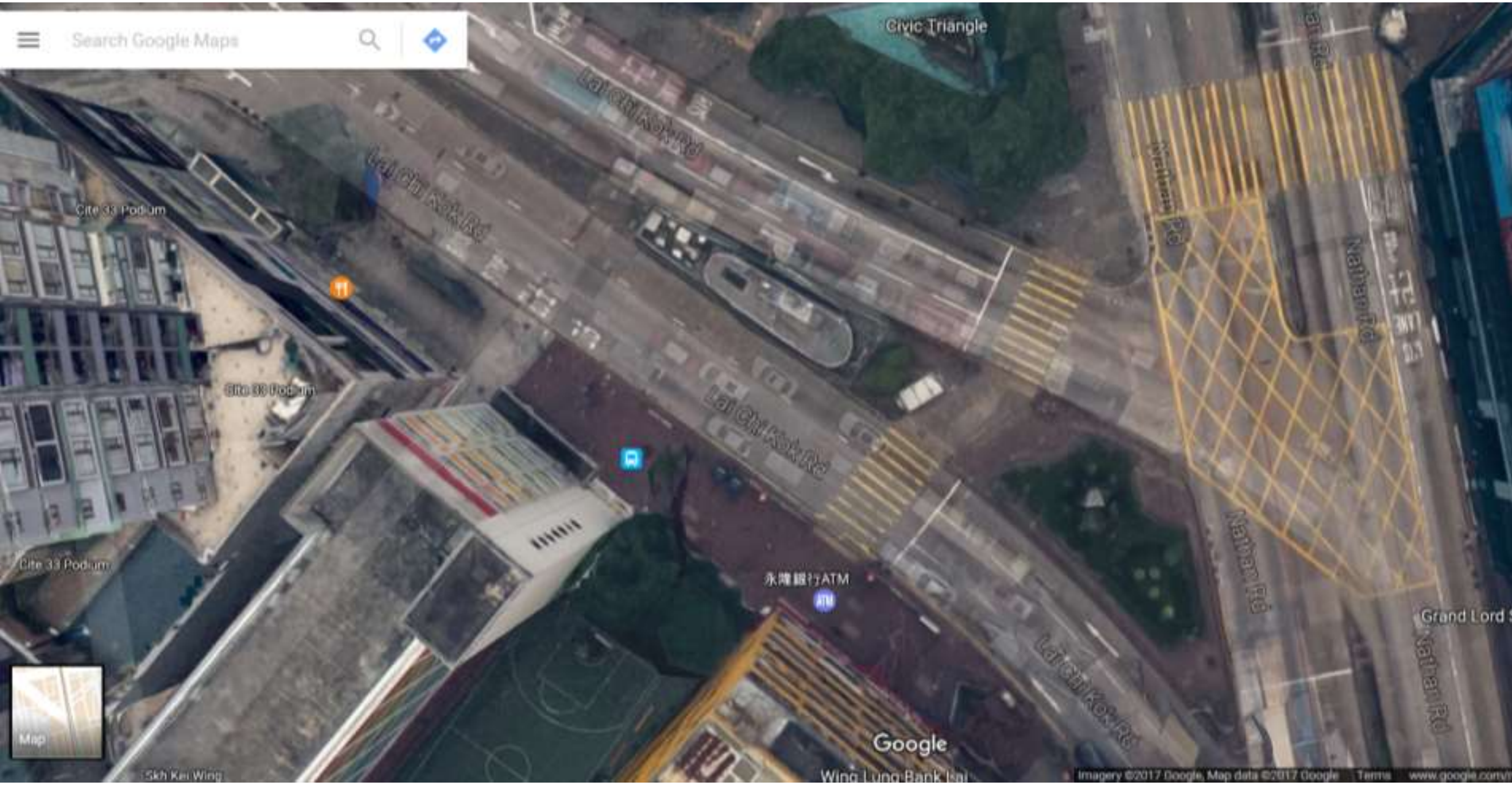
Organic aerosols (OA)



Mong Kok (MK) Roadside

PM2.5 inlet (3m above ground)

- 10L/min (FMPS)
- 0.08 L/min (AMS)
- 6.5 L/min (Excess flow pump)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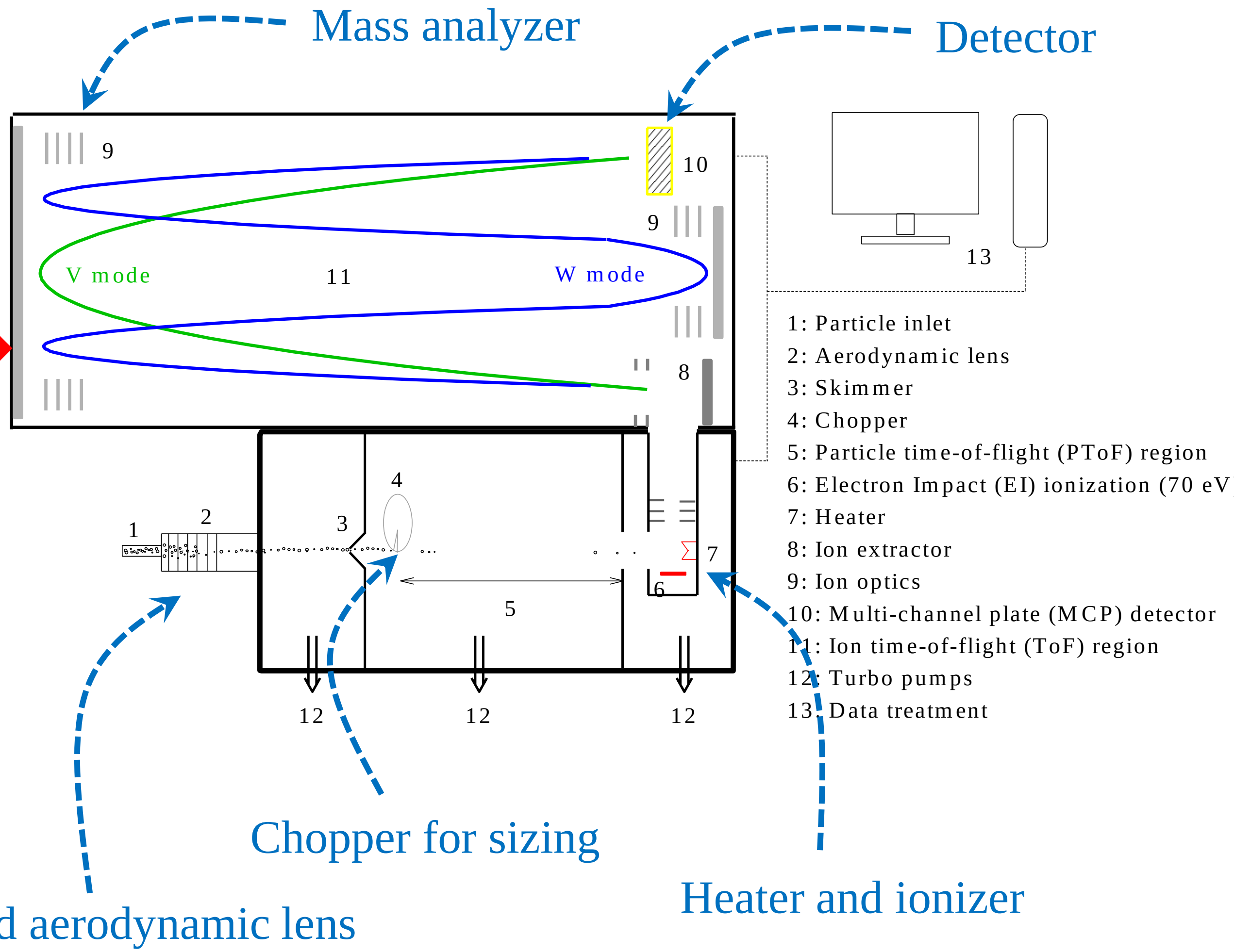
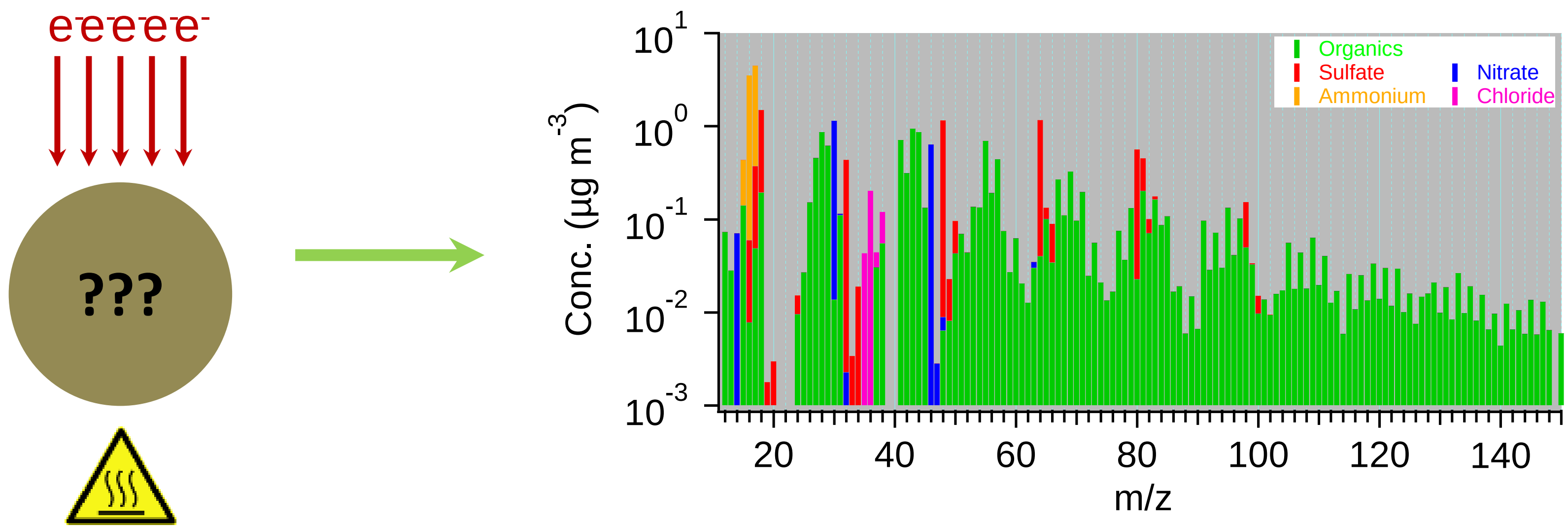
Aerodyne Aerosol Mass Spectrometer (AMS)

HR-ToF-AMS



High-resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS

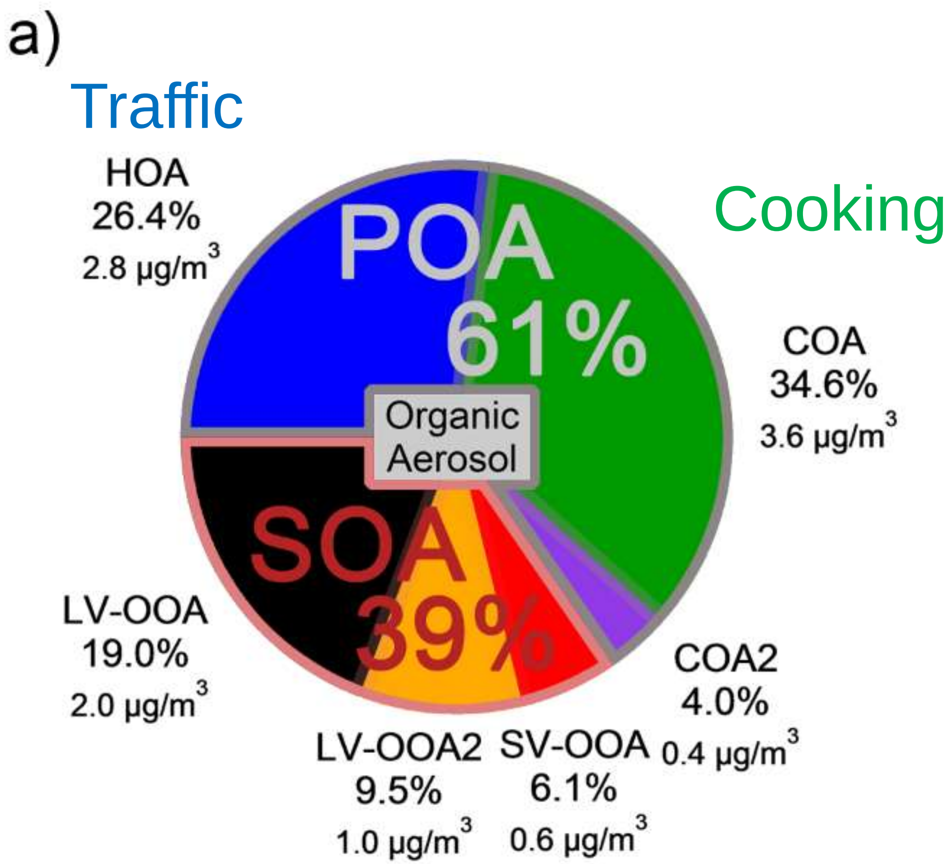
AMS: ionization and fragmentation of species



Group	Molecule/Species		Ion Fragments	Mass Fragments
Water	H_2O	e^- →	H_2O^+ , HO^+ , O^+	18, 17, 16
Ammonium	NH_3	e^- →	NH_3^+, NH_2^+, NH^+	17, 16, 15
Nitrate	HNO_3	e^- →	HNO_3^+, NO_2^+, NO^+	63, 46, 30
Sulfate	H_2SO_4	e^- →	$H_2SO_4^+$, HSO_3^+, SO_3+ SO_2^+, SO^+	98, 81, 80 64, 48
Organic *(Oxygenated)*	$C_nH_mO_y$	e^- →	CO_2^+ $H_3C_2O^+$, HCO_2^+, $C_{n'}H_{m'}^+$	44 43, 45, ...
Organic *(hydrocarbon)*	C_nH_m	e^- →	$C_{n'}H_{m'}^+$	27,29,41,43,55,57,69,71...

Characterization of Organic Aerosol (OA) at Mong Kok

Positive Matrix Factorization (PMF) for source analysis



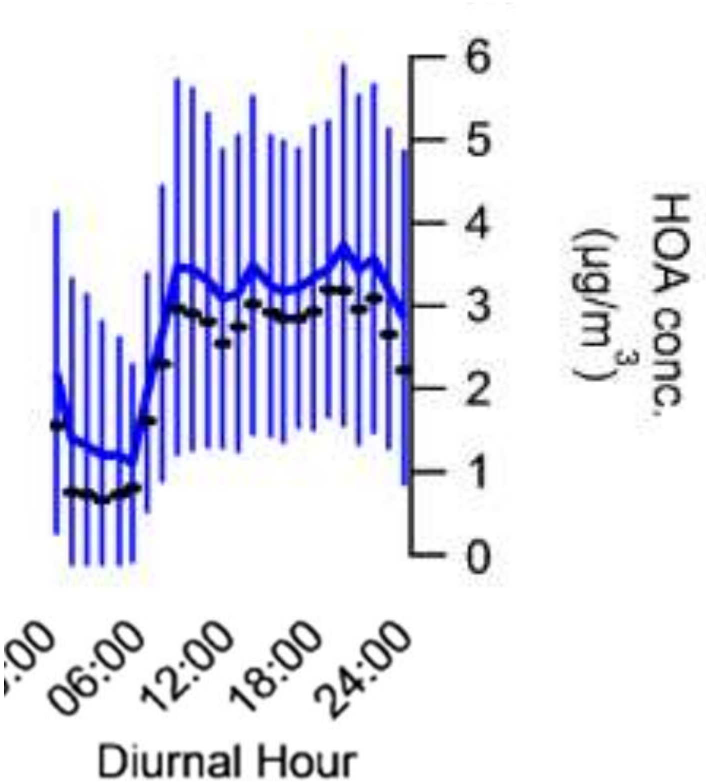
POA = Primary Organic Aerosol
Directly emitted from sources
= Traffic + Cooking
= 61% of total OA

SOA = Secondary Organic Aerosol
From atmospheric reactions
= 39% of total OA

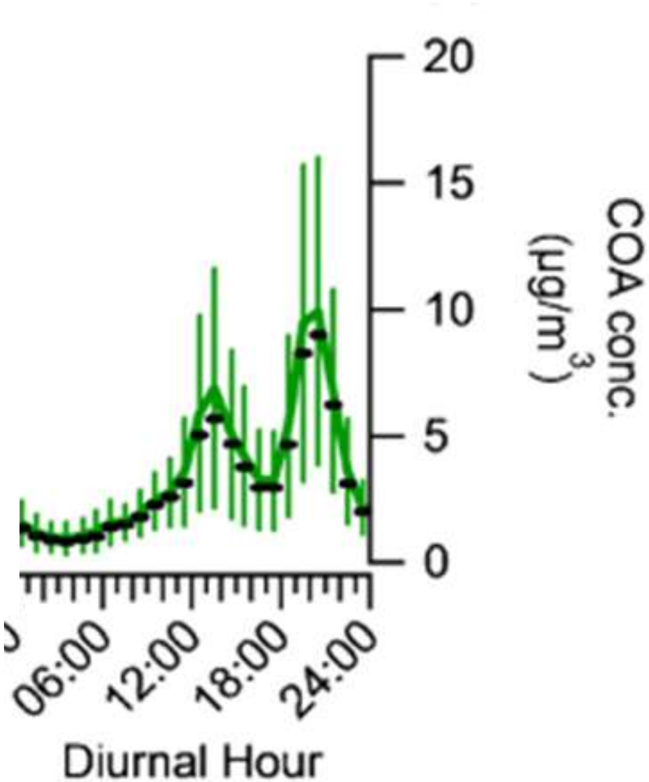
Lee et al. JGR, 2015

Primary Organic Aerosol (OA) in Mong Kok

Traffic



Cooking



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ATMOSPHERIC ENVIRONMENT

Review

Emissions and indoor concentrations of particulate matter and its specific chemical components from cooking: A review

CrossMark

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National emission rates in US:
PM2.5 from total charbroiling = 79,300 tonnes yr^{-1}
PM2.5 from flat griddle frying = 15,700 tonnes yr^{-1}
PM2.5 from highway vehicles = 135,000 tonnes yr^{-1}

Table 2
National emissions rate (tonnes $year^{-1}$) of criteria pollutants from commercial cooking in the USA (Roe et al., 2005) and for highway vehicles (Chappell et al., 2003).

Pollutant	Total charbroiling	Deep frying	Flat griddle frying	Clamshell griddle frying	Under-fired charbroiling	Conveyorized charbroiling	Highway vehicles
VOC	115	1170	39	940	7200	2100	4,400,000
CO	33,000		1900		23,700	7400	48,400,000
$PM_{2.5}$	79,300		11,900	910	58,300	8200	135,000
PM_{10}	85,500		15,700	1100	60,300	8500	192,000
PAH total	206		41		122	43	


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13 AUGUST 2015

Scientists track air pollution by meal times

Posted by lcooper

By Leigh Cooper

Cars and trucks shouldn't take all of the blame for air pollution in Hong Kong. Smoke from cooking adds more of a specific type of pollution – organic aerosols – to the city's air than traffic emissions, a new study finds.

Fossil fuel burning, vehicle emissions, cooking smoke, and chemical reactions of particles in the sun add organic aerosols to the atmosphere. These tiny particles are a major component of airborne particle pollution and can cause heart and lung problems in humans and reduce visibility, according to the U.S. Environmental Protection Agency.

Hong Kong, a city of more than 7 million people, has struggled with air pollution. At times, much of the city's famous skyline along the coast is masked by a thick layer of smog, according to the study's authors.

The new study sought to identify the sources of organic aerosols in Hong Kong by continuously monitoring fine particles on an urban street in the Mong Kok area of downtown Hong Kong.

The study found that from March to July 2013, cooking aerosols accounted for 35 percent of organic aerosols in the air, while 25 percent of the organic aerosols came from traffic. The remaining 40

Berto Lee (left) and Chak Chan (right) stand in a shelter in Hong Kong's Mong Kok next to the Aerodyne High Resolution Aerosol Mass Spectrometer, used to sample airborne particulate matter. *Credit: Chak Chan*

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A12

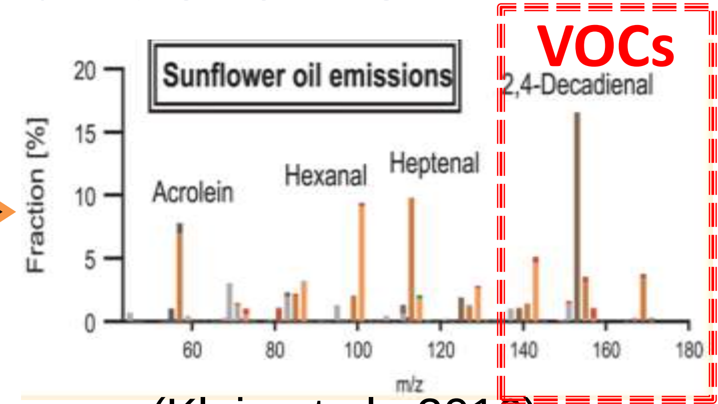
科大量度旺角數據首發現

食肆油煙佔路邊空氣污染15%

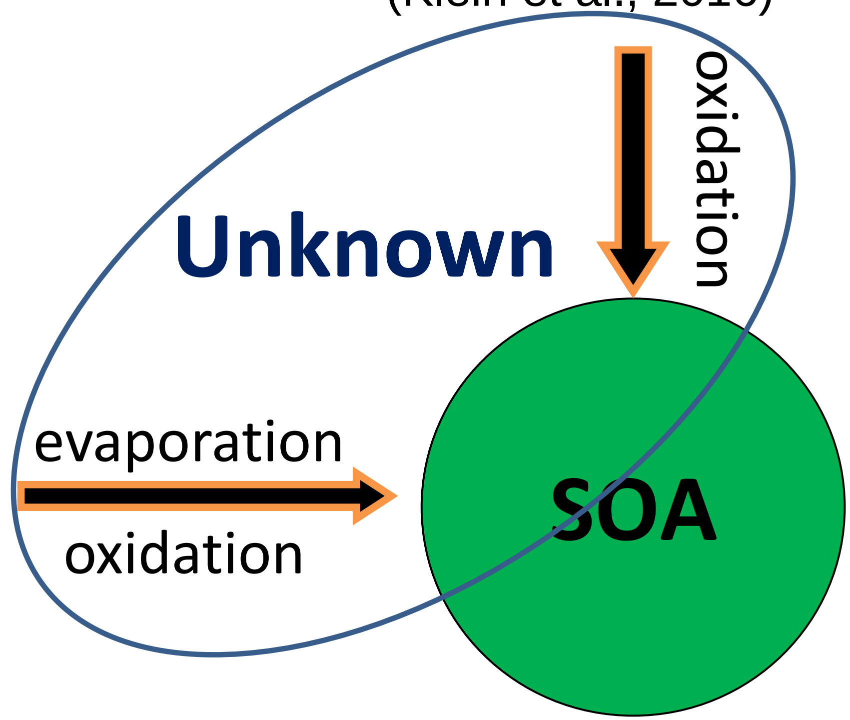
特稿

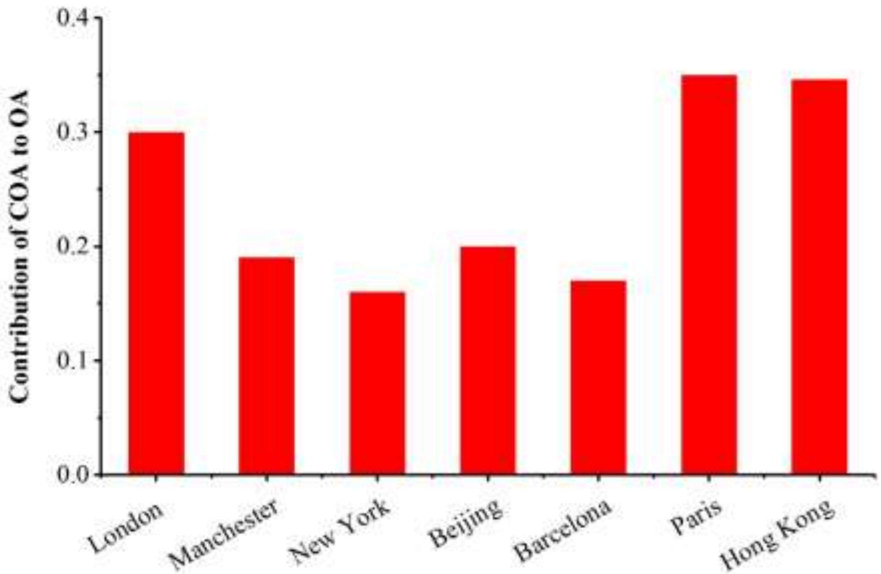
15.8%

Cooking: important source of OA



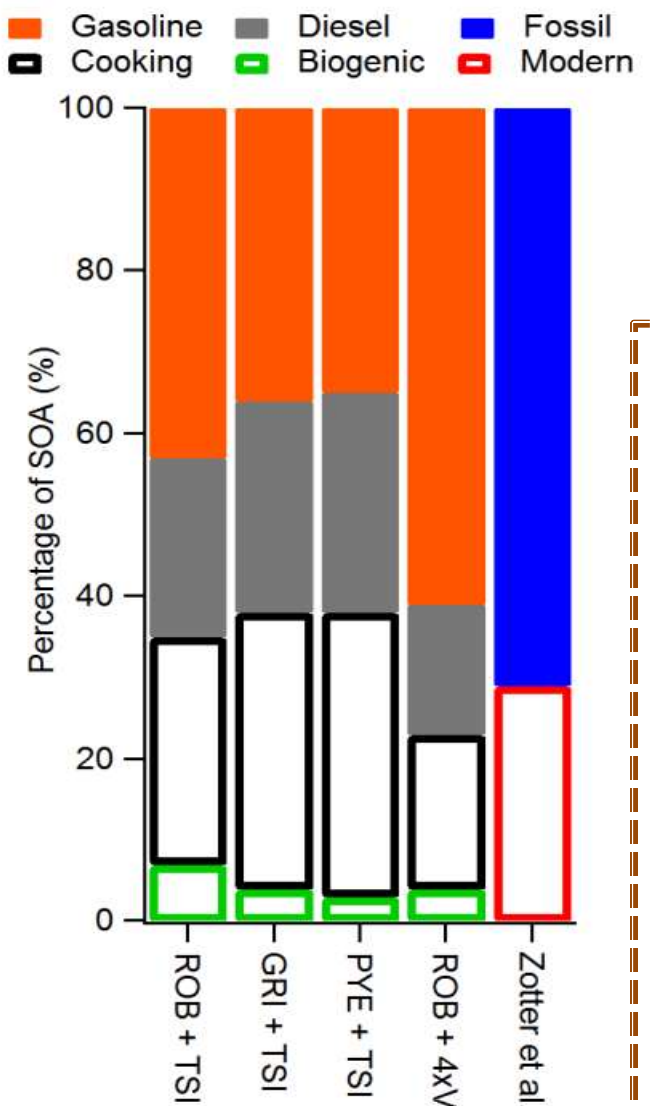
(Klein et al., 2016)





(Allan et al., 2010; Sun et al., 2011; 2013; Mohr et al., 2012; Crippa et al., 2013; Lee et al., 2015)

A model study in California in 2010

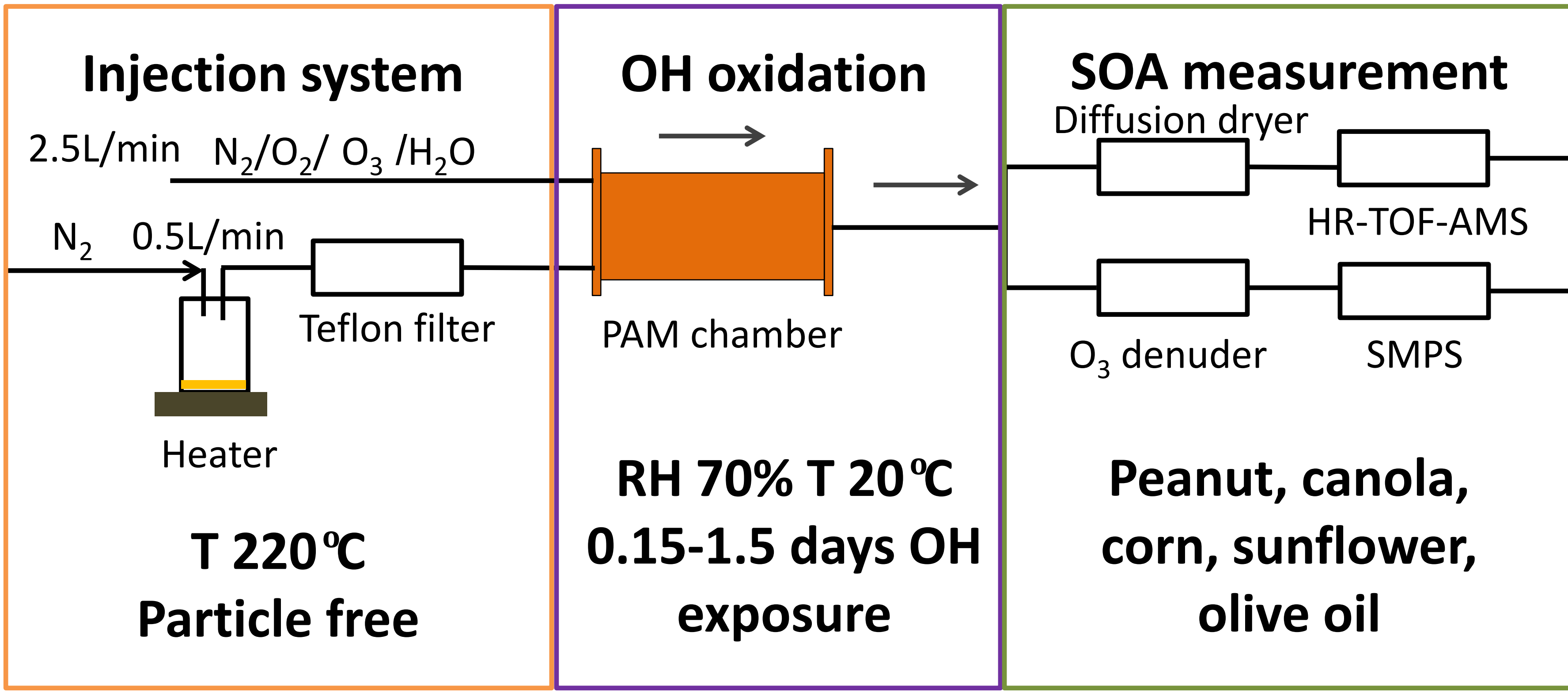


(Hayes et al., 2015)

Parameters were assumed to be same with **gasoline vehicle exhaust**!!!

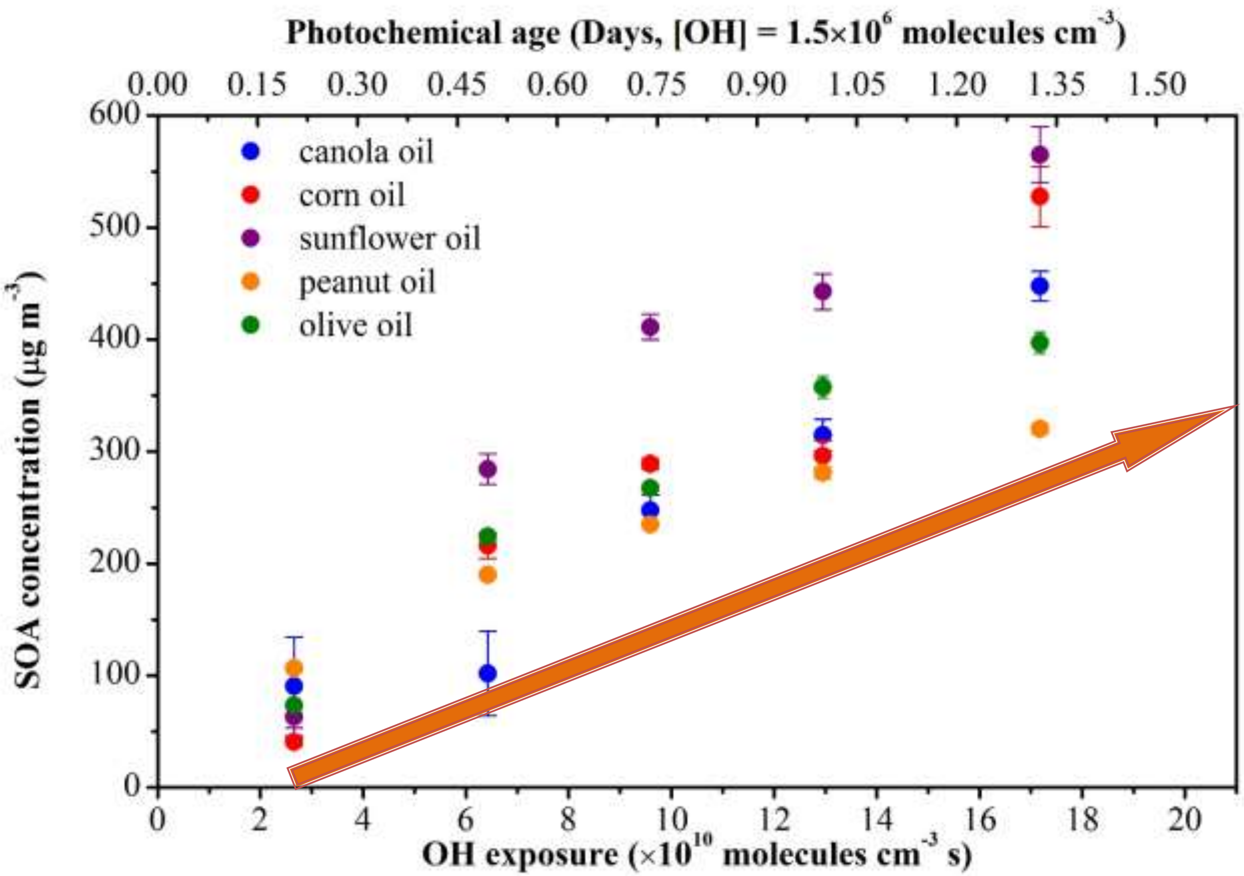
- Previous studies have been focused on **primary emissions** from cooking activities.
- Only **one study** regarding SOA from meat charbroiling was reported (Kaltsonoudis et al., 2016).
- Our objective is to characterize SOA formation from cooking emissions including the key SOA precursors and SOA formation potential.

SOA formation from heated cooking oil



Liu et al., ACP, 2017

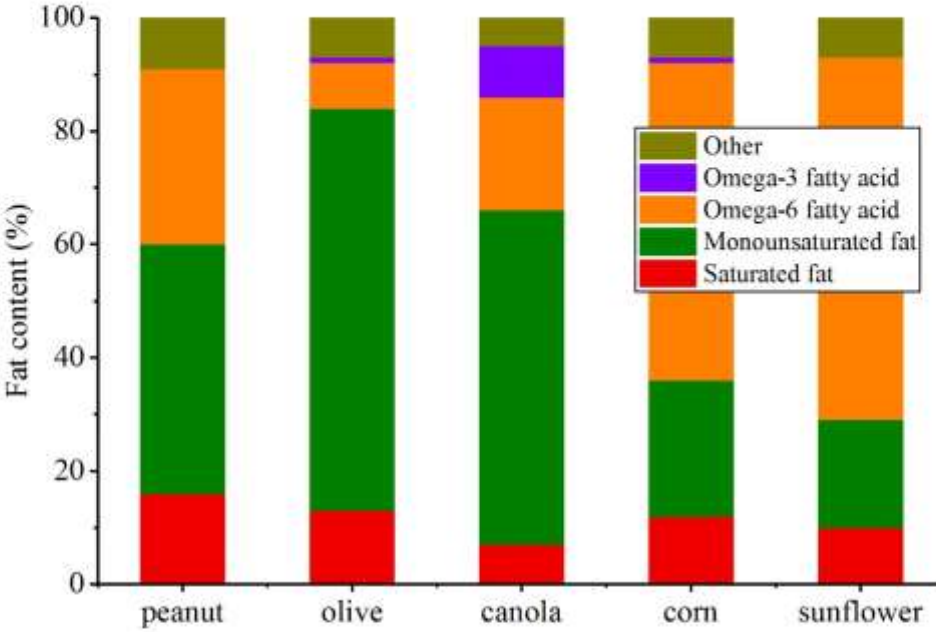
SOA formation from gas-phase emissions of heated cooking oils



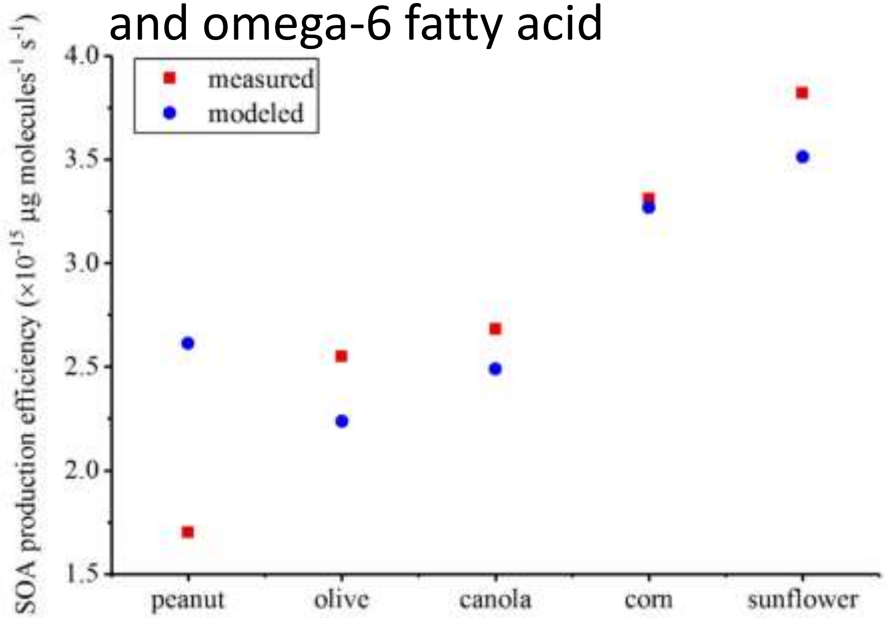
SOA production rate:**1.35±0.30 μg min^{-1}**

$PM_{2.5}$ emission rate:**3.7-54 mg min^{-1}** (Amouei Torkmahalleh et al., 2012)

Relationship between SOA production efficiency and the fat content of oil

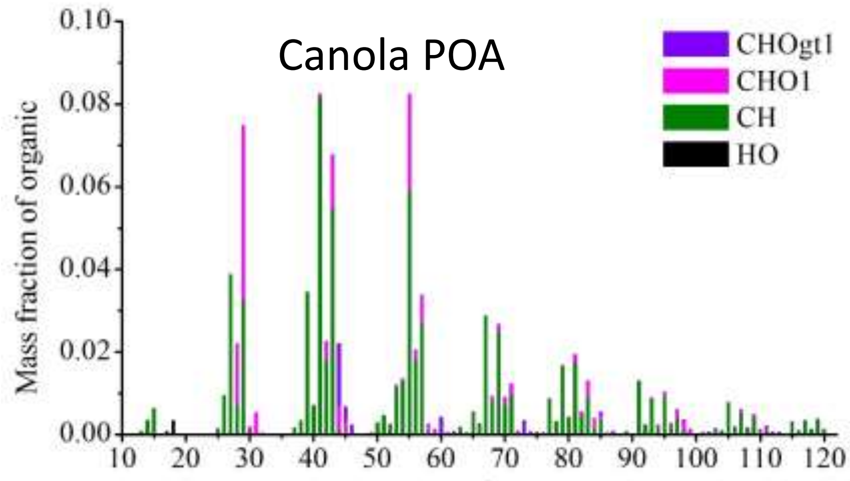


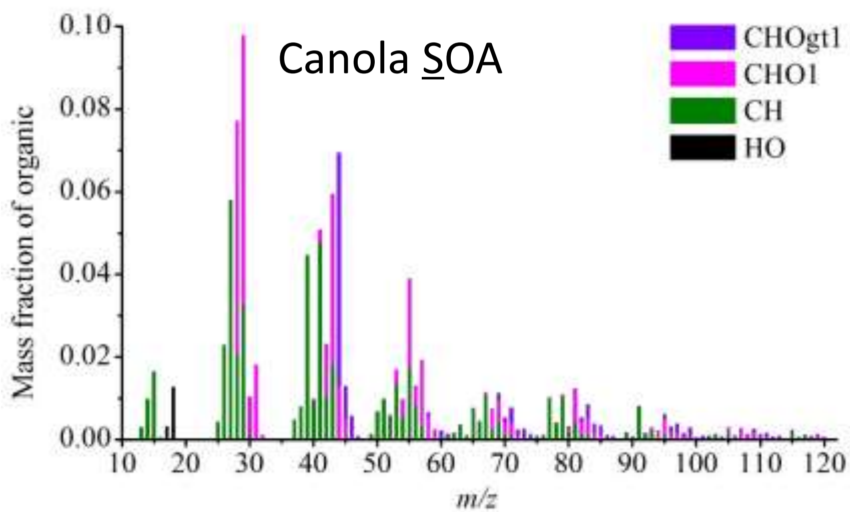
Modeled with monounsaturated fat and omega-6 fatty acid



- SOA production efficiency: Peanut<Olive<Canola<Corn<Sunflower
- **Correlated with the content of monounsaturated fat and omega-6 fatty acids**

POA and SOA mass spectra of Canola oil



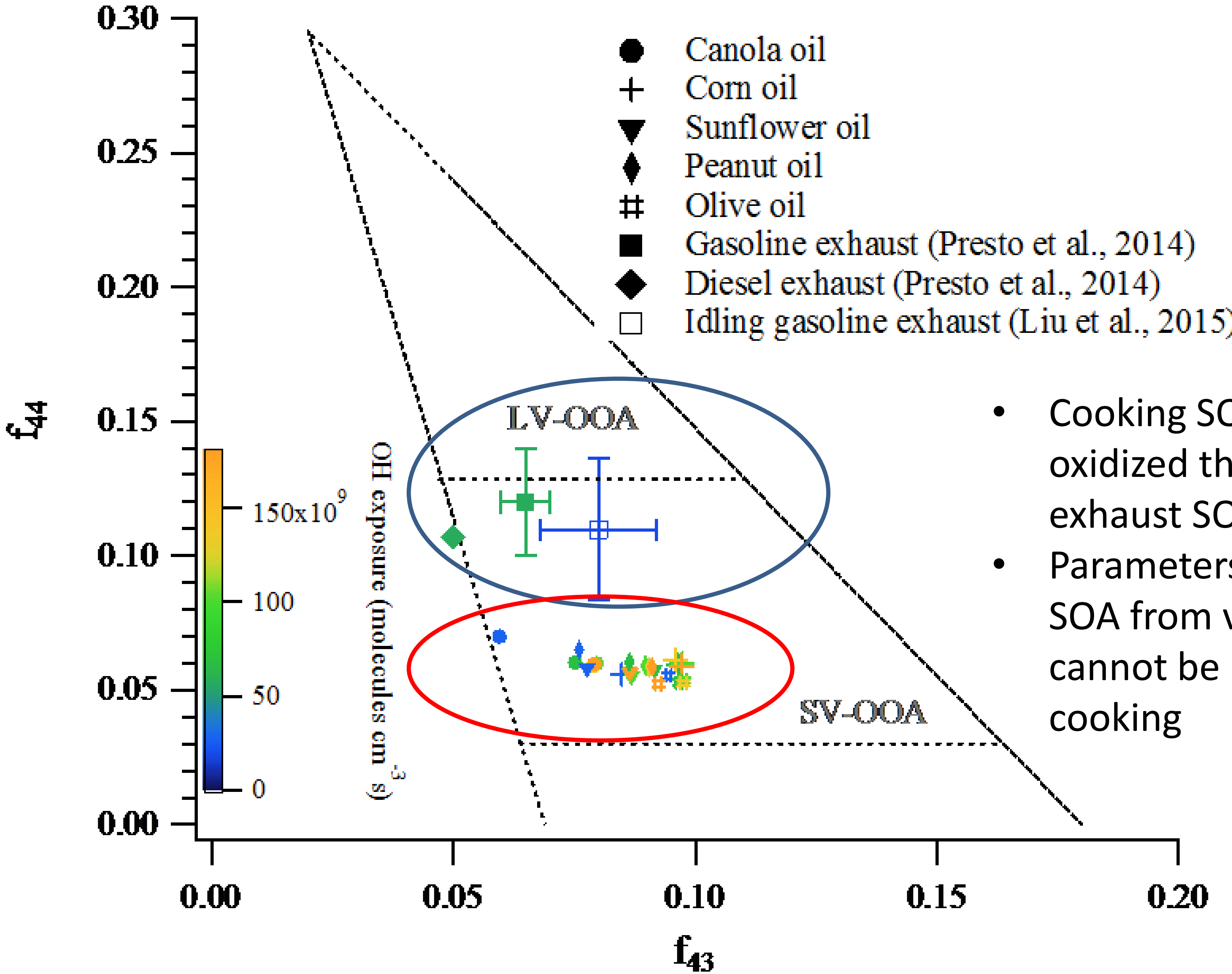


From POA to SOA

$C_xH_yO_z$ m/z 28, 29, 44 ↑

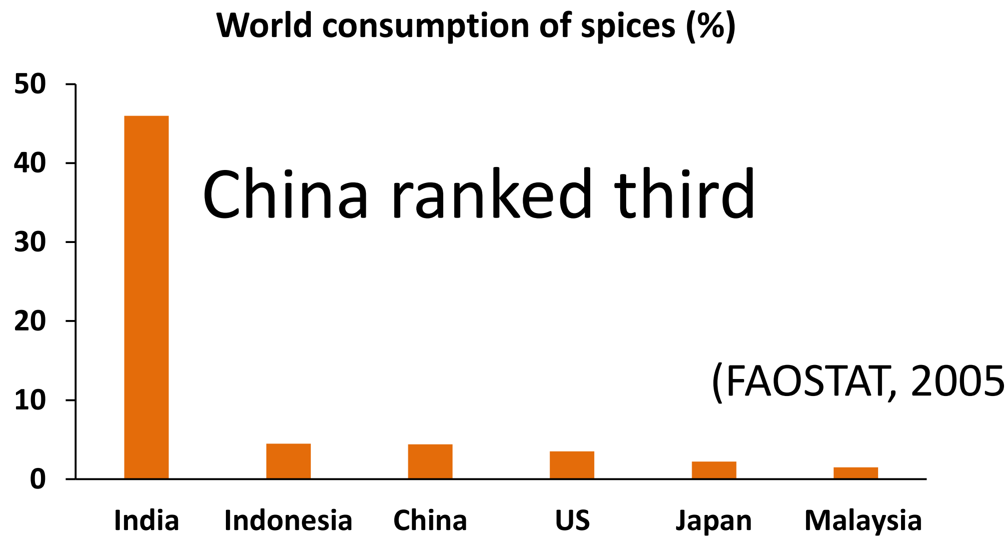
C_xH_y m/z 41, 43, 55, 57 ↓

Portions of oxygen-containing ions increased

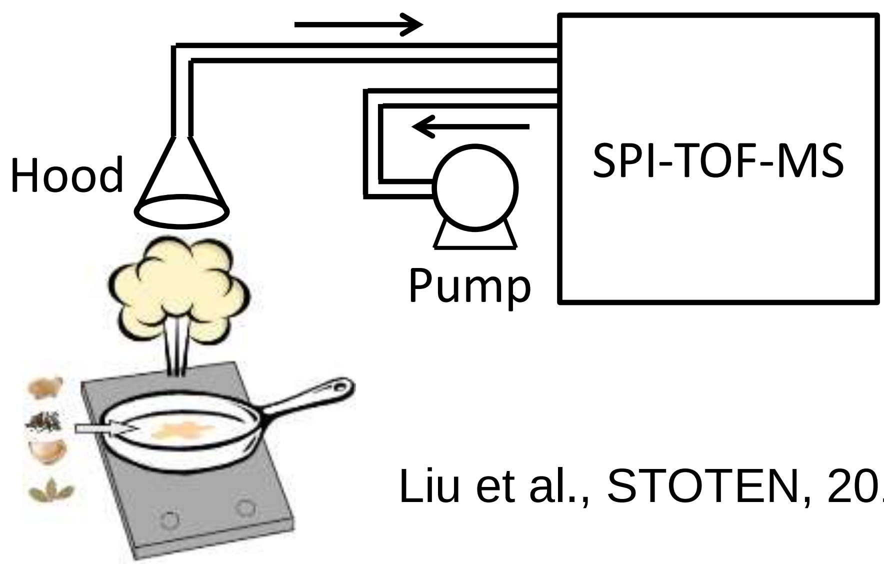


- Cooking SOA is less oxidized than vehicle exhaust SOA
- Parameters used for SOA from vehicles cannot be used for cooking

VOCs emissions and SOA formation from stir-frying spices

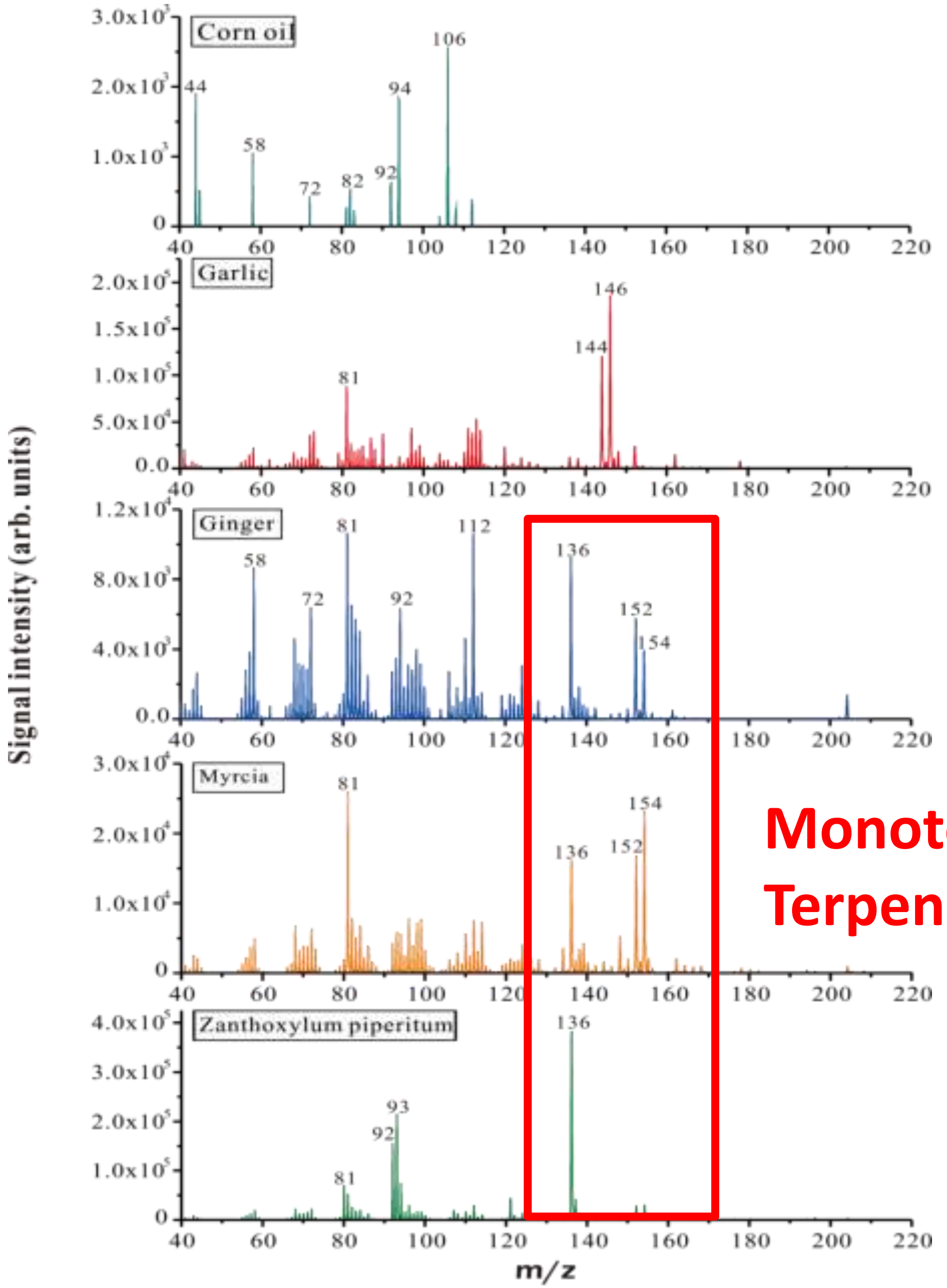


Garlic
Ginger
Myrcia香叶
Zanthoxylum piperitum (Sichuan pepper)

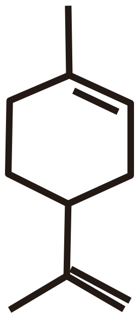


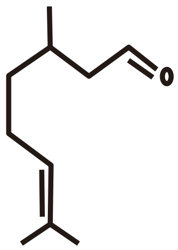
Liu et al., STOTEN, 2017

Mass spectra of VOCs

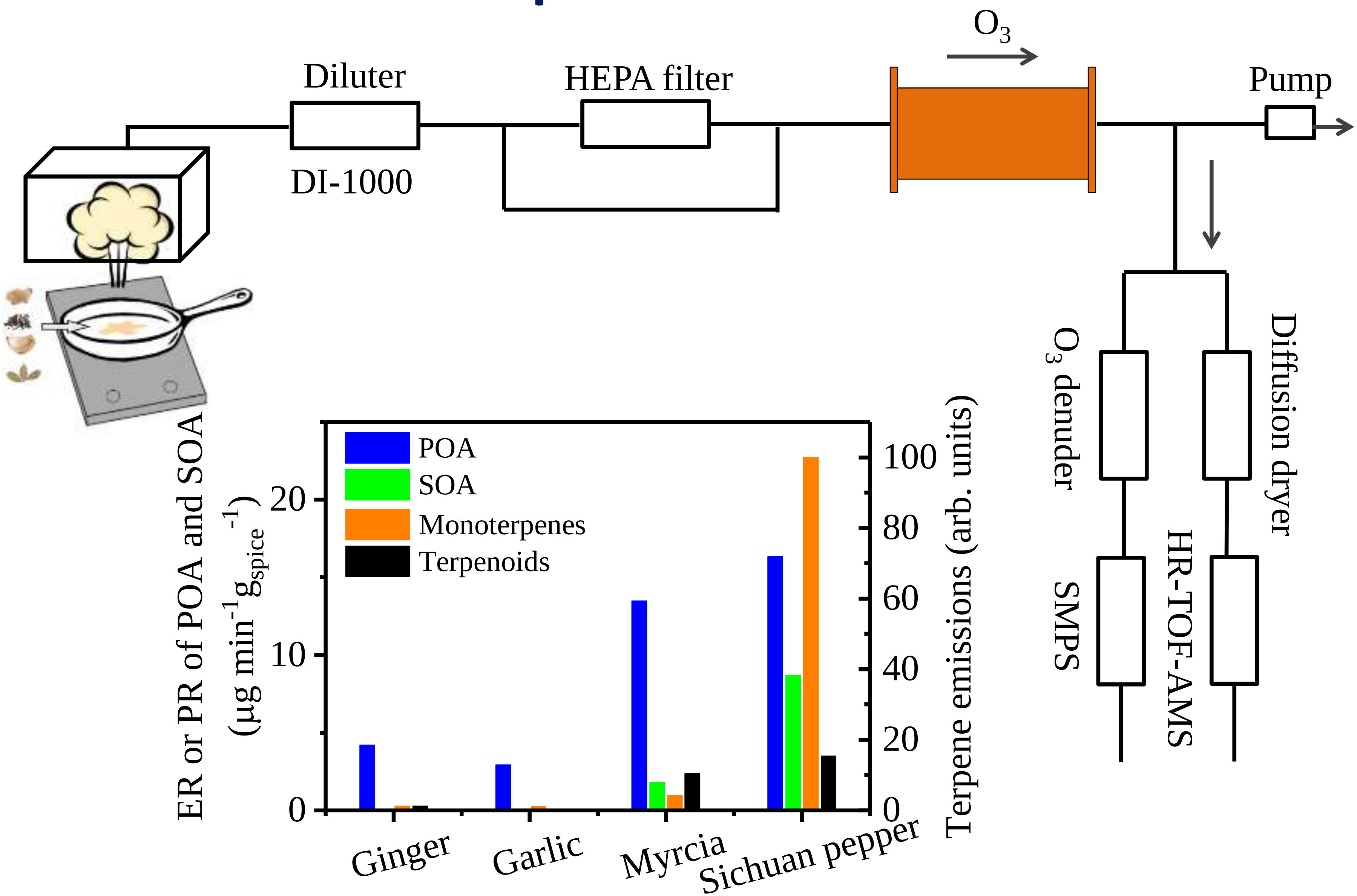


Monoterpenes
Terpenoids





SOA production rate



SOA/POA for myrcia and Sichuan pepper: 0.13 and 0.53

Summary

- **Cooking** contributions in primary OA (POA) **exceeded** those related to **vehicles** in Mong Kok, an urban site in Hong Kong.

- The efficiency of **SOA production** from gas-phase emissions of cooking oil, in ascending order, was **peanut oil < olive oil < canola oil < corn oil < sunflower oil**. **SOA << POA.**

- The major SOA precursors from heated cooking oils were related to the content of **mono-unsaturated fat and omega-6 fatty acids** in cooking oils. SOA in these experiments was only **lightly oxidized**, different from traffic SOA.

- The contribution of **stir-frying spices** to ambient organic aerosol levels is likely **dominated by POA**.

- All the above experiments did not have seed particles, which may **underestimate** SOA formation.

R7: ROB, GRI and PYE represent different parameterization for SOA from SVOCs and IVOCs; TSI represent parameterization for SOA from VOCs. Our objective is to characterize SOA formation from cooking emissions including the key SOA precursors and SOA formation potential.

R9: PR=[SOA]×Dilution ratio×Flow rate; It is not on a per mass basis because production rates did not depend on the mass of oil used.

R10: Model results are obtained by multiple linear regression of contents of monounsaturated fat and omega-6 fatty acids. It is based on our own measurements.

R11: Figures were modified. Ogt1 means that the oxygen number is greater than 1; O1 means the oxygen number is 1.

R12: SOA formed from gas-phase emissions of heated cooking oil was less oxidized than those from vehicle exhaust, indicating their difference in SOA precursors. Then parameters of gasoline vehicle exhaust can not be used to represent those of cooking (slide 7).

R13: The main message is that the O:C ratios fell in the range 0.2-0.4, which was lightly oxidized.

R14: Myrcia means 香叶. If all audiences can read Chinese, it would be better to put its Chinese name.

R15: Revised.