

Developing an ARM-EMSL Joint Capability via Tethered Balloon Deployments

FAN MEI, DARIELLE DEXHEIMER, ZIHUA ZHU, SWARUP CHINA, YADONG ZHOU, CASEY LONGBOTTOM, BEAT SCHMID

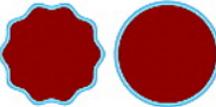
Pacific Northwest National Laboratory, Richland, WA, United States.

Sandia National Laboratories, Albuquerque, NM, United States.

2020 ARM/ASR User Facility PI Meeting, June 24, 11 am – 1 pm

Motivations

- ▶ **Highly Heterogeneous** in aerosol number concentrations, size distribution, chemical composition, mixing state, optical properties, and cloud-nucleating properties, as well as boundary layer properties such as temperature, moisture and winds.
- ▶ **Community needs:** routine in situ sampling to provide the spatial context for the ground measurements.
- ▶ **Potential airborne aerosol data ensemble with the joint capability**
 - Number concentrations & size distribution
 - Optical properties
 - Structural imaging and bulk chemical composition
 - Advanced offline analysis
 - Surface properties, Size-resolved mixing state

Description	Illustration
a Black carbon with aqueous phase	
b Organics on dust	
c Particles surface-enriched in carboxylic acid	
d Inorganic core with organic outer layer	

ARM TBS Deployments

AMF3, Oliktok Point, AK

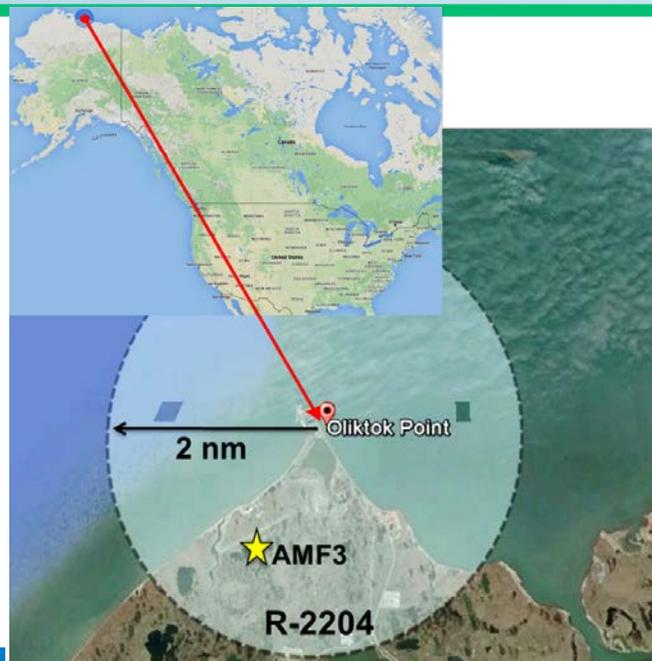
2015 – 2020

600 TBS flight hours

0 – 7,000' (2.1 km) MSL

Restricted Airspace flights:

- In clouds
- At night
- During low visibility



SGP CF, Billings, OK

SGP EF9, Ashton, KS

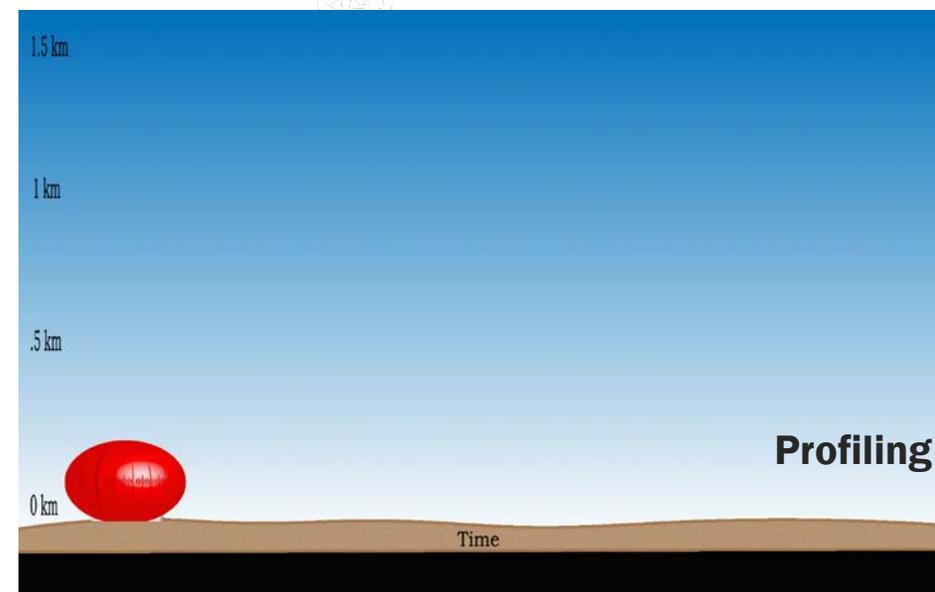
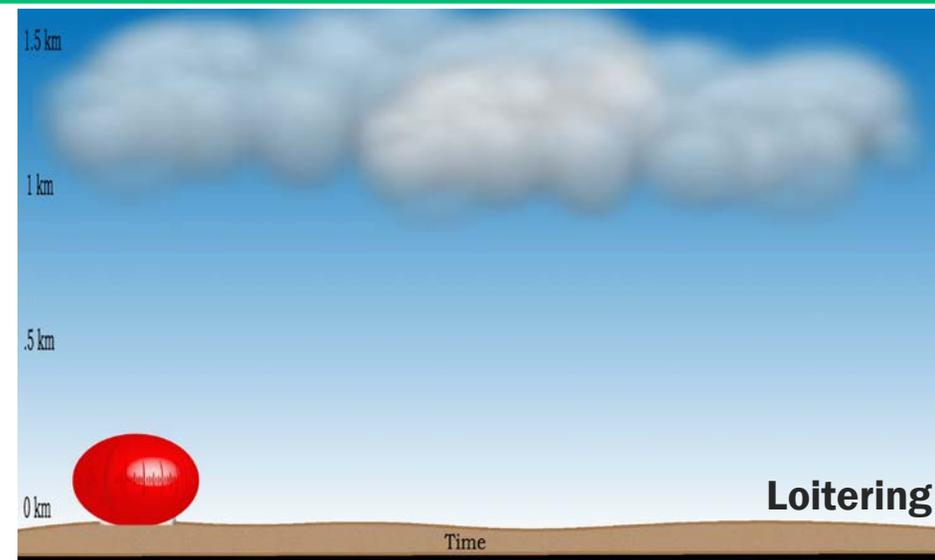
SGP EF36, Marshall, OK

2019 – 2020

175 TBS flight hours

0 – 6,000' (1.5 km) MSL

Flight Patterns



ARM TBS Instrumentation

Atmospheric States and TBS States

Instrument	Property Measured	Status
iMet RSB-1 and RSB-4 radiosondes (multiple)	Pressure, Temperature, RH, 3D GPS	ARM Facility
iMet XQ2 UAV Sensor (multiple)	Pressure, Temperature, RH, 3D GPS	ARM Facility
Sensornet Oryx DTS Siliax XT DTS	Distributed temperature sensing at 2 m and 0.5 m spatial resolution and 0.08 °C accuracy	SNL owned
40C cup anemometers (8 units)	1 Hz wind speed	ARM Facility



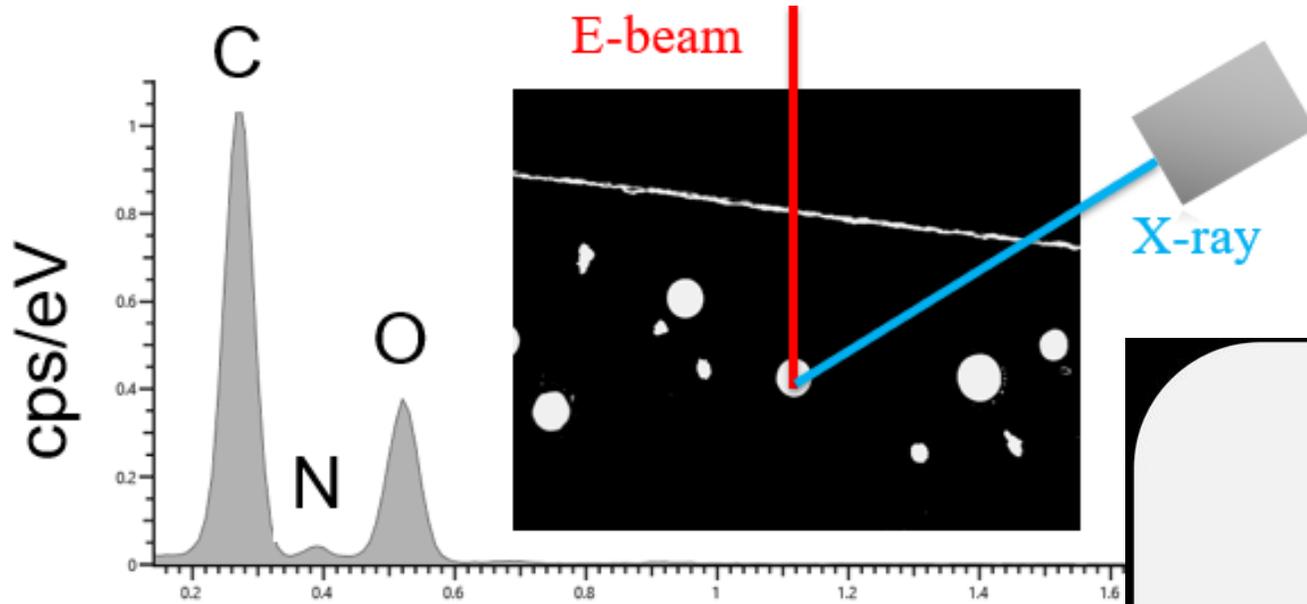
SGP

Aerosol Properties

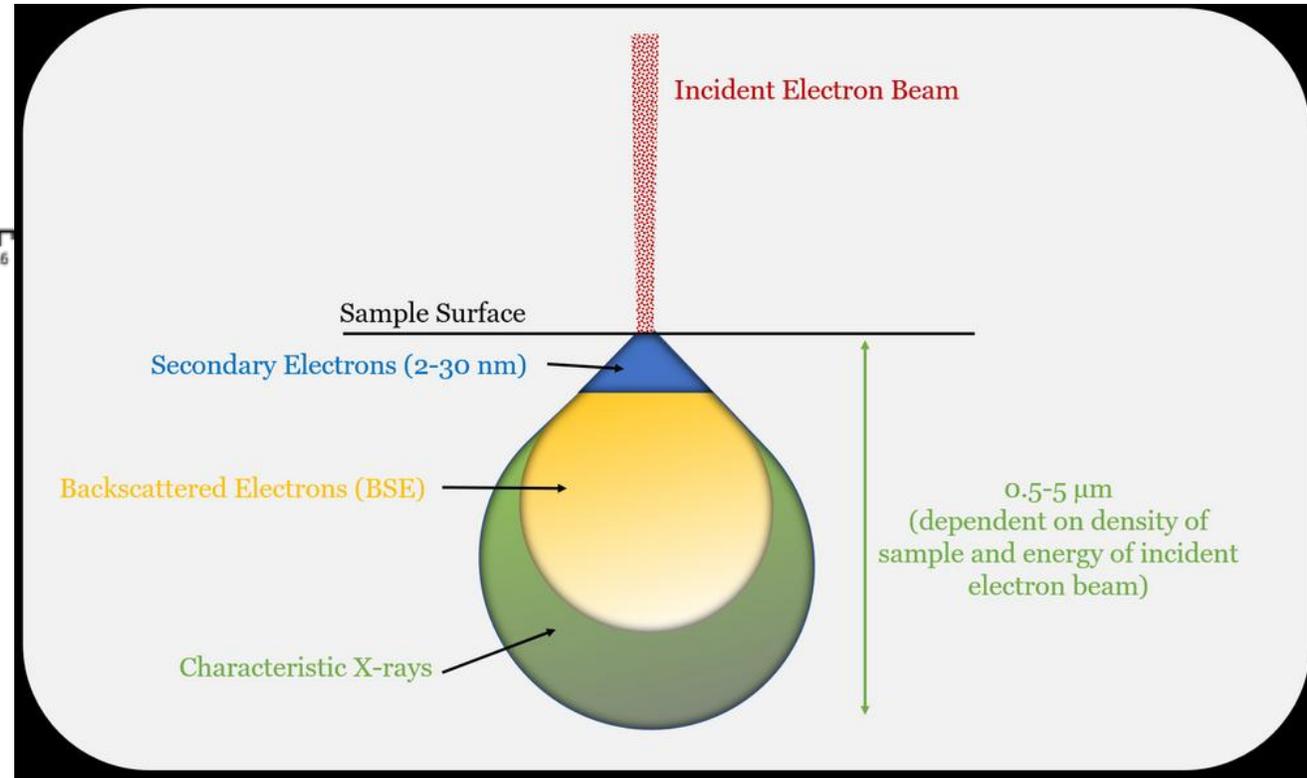
Instrument	Property Measured	Status
Printed Optical Particle Spectrometer (POPS) 4 units by summer 2020	Aerosol size distribution from 140 nm to 3 μm	ARM Facility
Condensation Particle Counter (CPC) Model 3007 (2 units)	Total aerosol concentration from 0.01 μm to 1 μm	ARM Facility
Cascade impactors (6 units)	Size-resolved chemical composition at four cut-off sizes (0.25, 0.5, 1.0, 2.5 μm)	ARM Facility
ADI MAGIC 200 CPC (3 units)*	Total aerosol number concentration from 1 nm to 1 μm; aerosol size distribution from 1 nm to 3 nm	BNL owned



Elemental information obtained from Computer Controlled SEM (CCSEM) & Energy Dispersive X-Ray Spectroscopy (EDS)



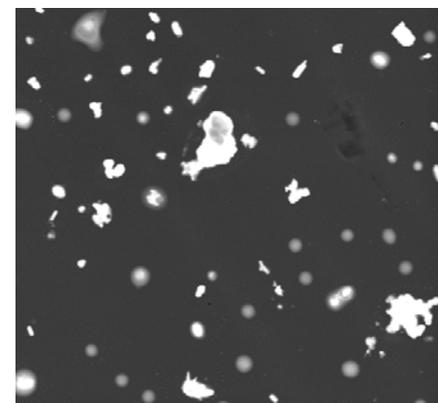
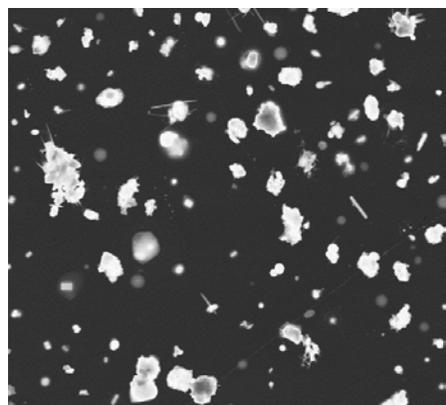
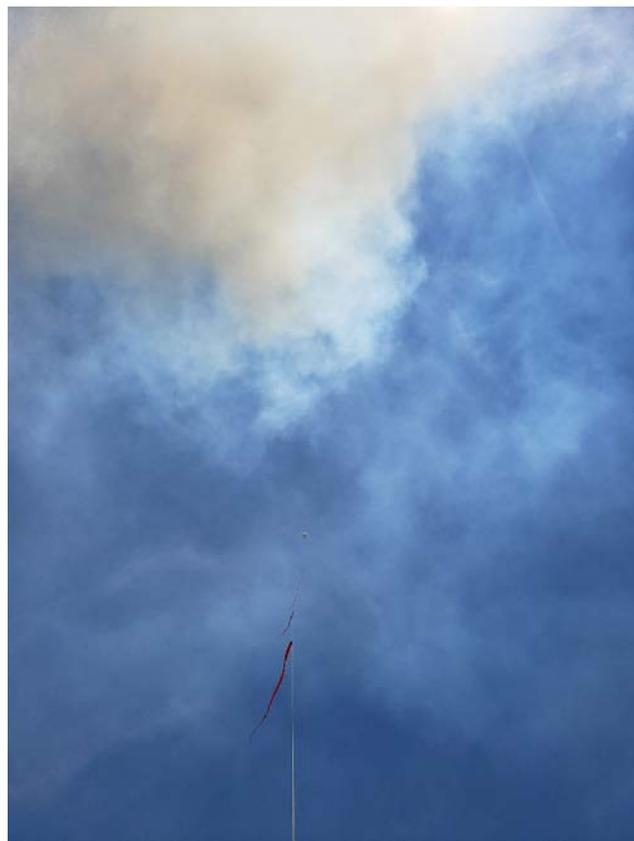
- Structural imaging – Morphology
- Bulk chemical composition
- Elemental composition



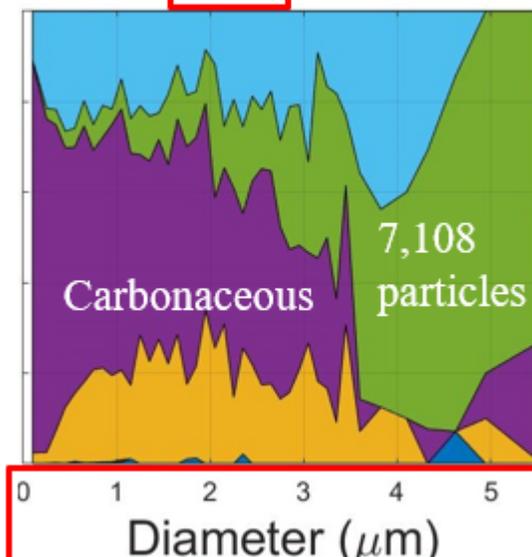
Ensembled Dataset from a Biomass Burning Event

July 26th, 2019 Biomass burning event

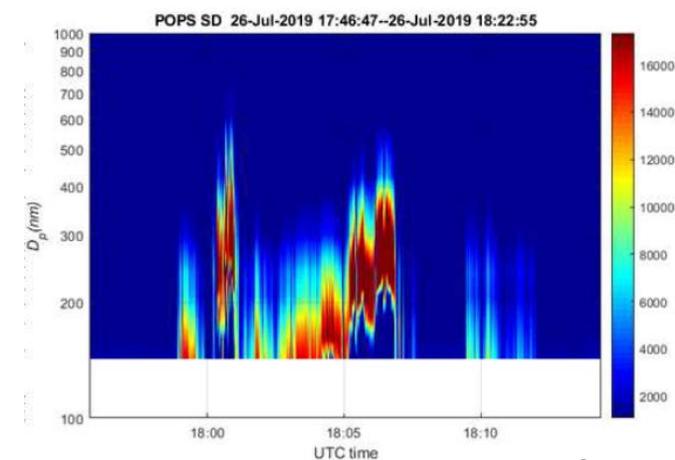
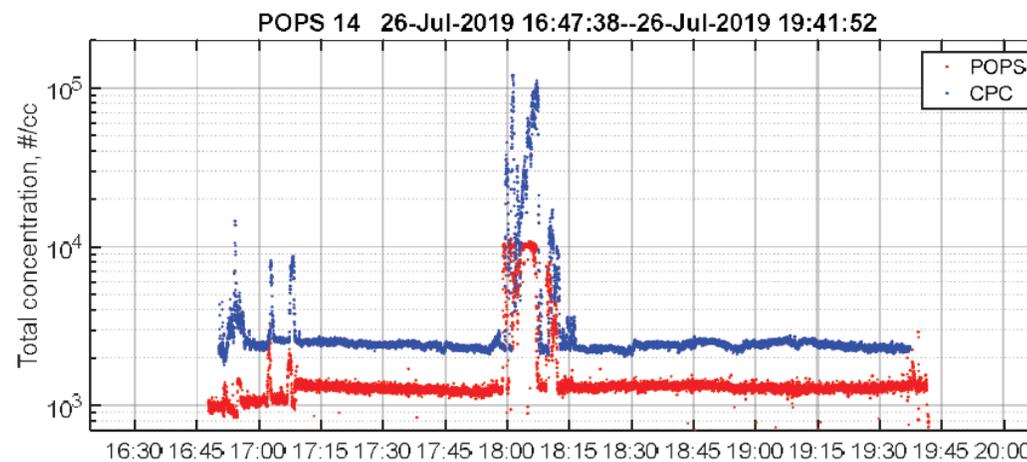
Particle morphology



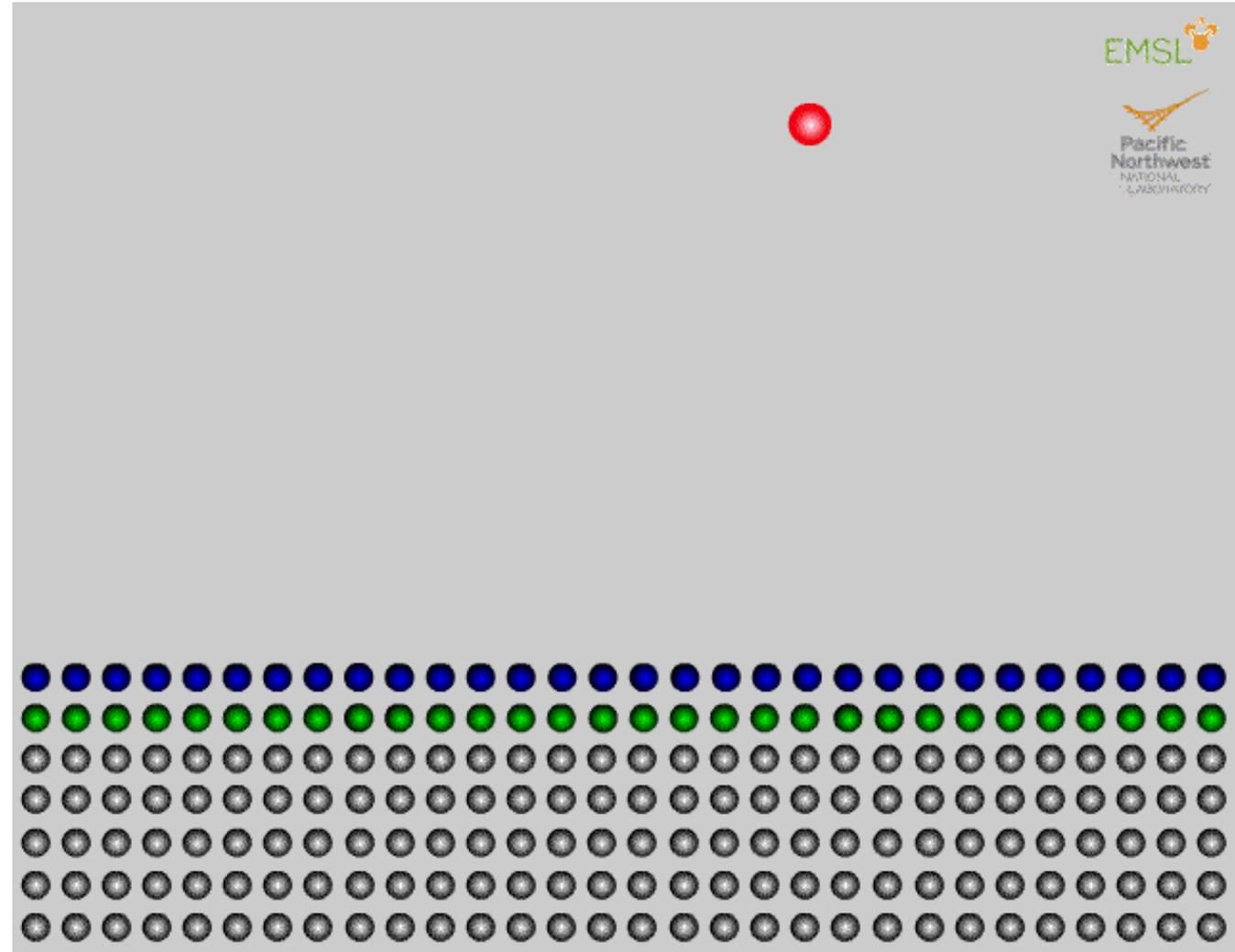
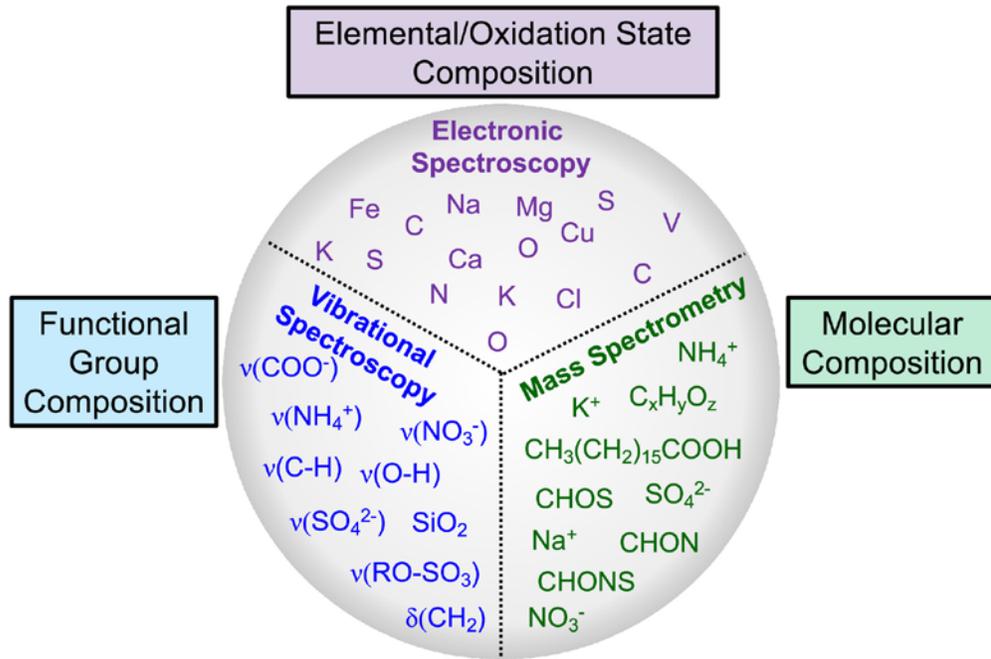
072619 850m 1.5hr



Other
Dust
Carbonaceous
Sulfates
Na-rich Sulfates
Na-rich particles

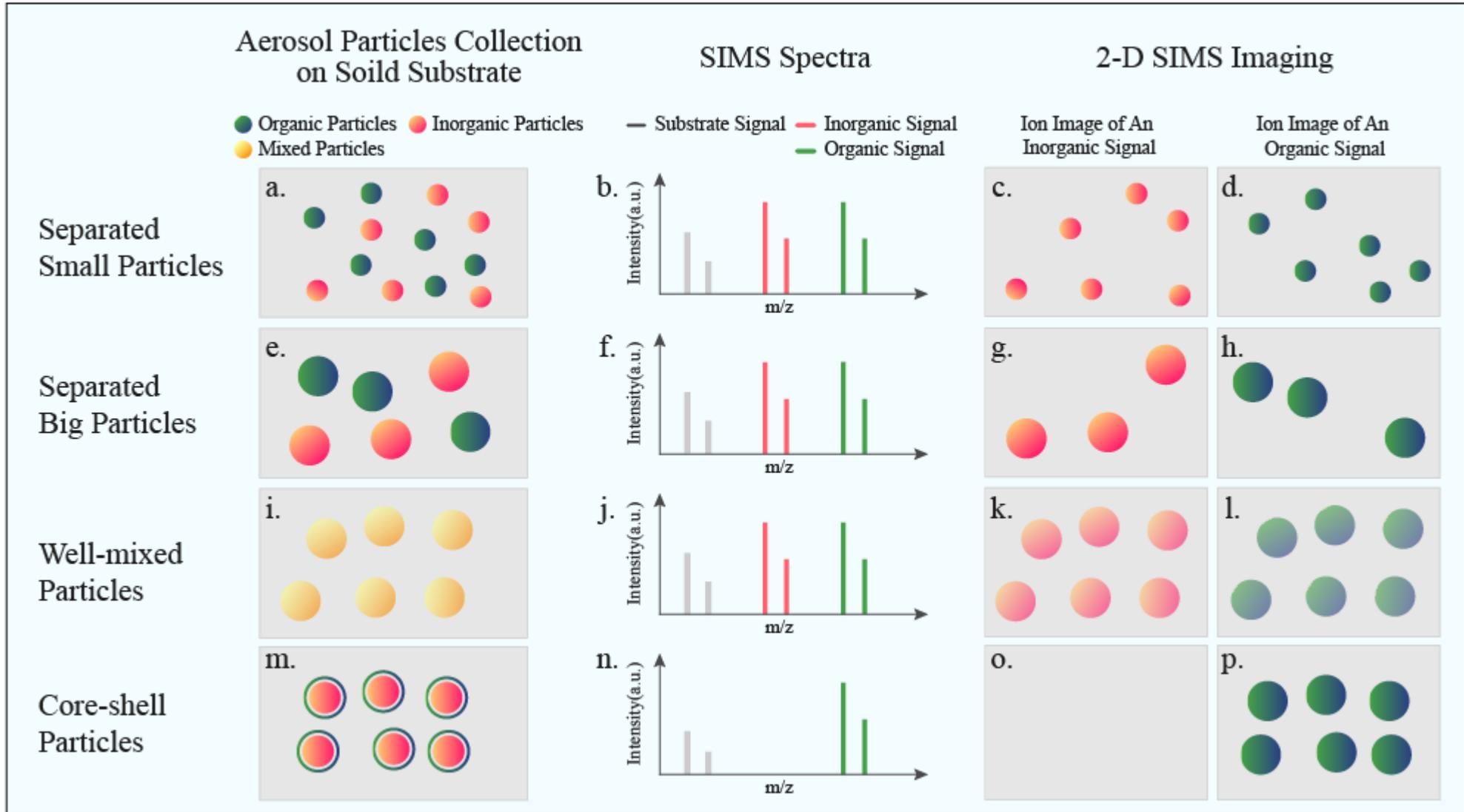


Principle of Secondary Ion Mass Spectrometer (SIMS)



- A unique surface analysis tool.
- Spatial resolution of several nanometers
- Molecular composition

SIMS Spectra and Imaging – Identify the Mixing State and Core-shell Detection



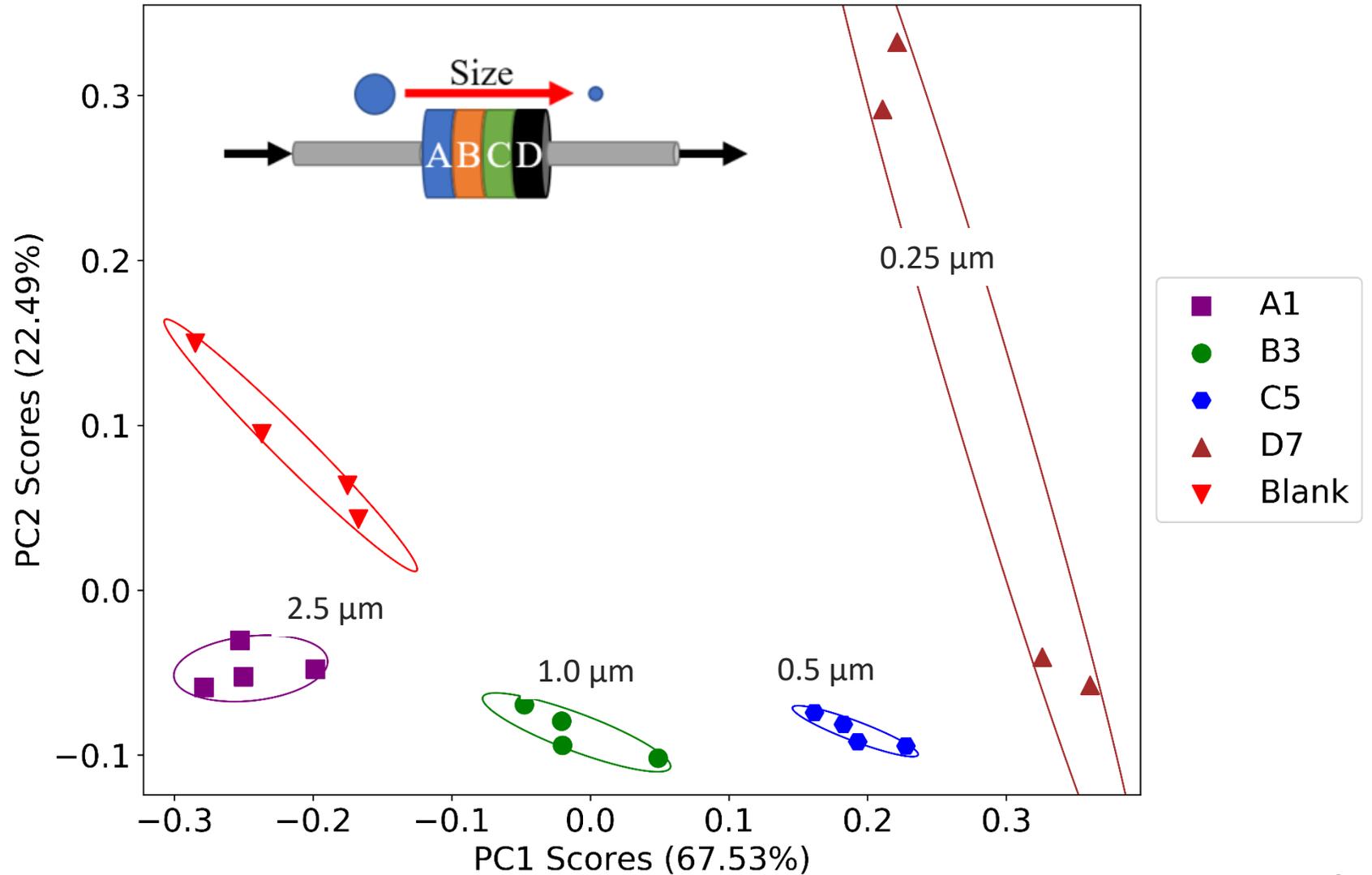
Principle Component Analysis (PCA)

PC1 vs PC2 Scores Plots, Positive Ion Spectra



The PC1 scores indicate surface organic coverage increases comparing with the inorganic mineral, while aerosol size decreases.

The PC2 scores majorly reflect different mineral components in the aerosol samples.



- ▶ During a pilot study at the Southern Great Plains (SGP) atmospheric observatory in July 2019, TBS was flown with aerosol and meteorology sensors, which include condensation particle counters, printed optical particle spectrometers, cascade particle impactors, iMet radiosondes, fiber optic distributed temperature sensing, and anemometers.
- ▶ Multimodal micro-spectroscopy of single particle and molecular-level information of atmospheric aerosol collected at different altitudes will be characterized by novel capabilities, such as secondary ion mass spectrometry, scanning electron microscopy with energy-dispersive X-ray spectroscopy, and X-ray photoelectron spectroscopy, at Environmental Molecular Sciences Laboratory (EMSL).
- ▶ These analyses will provide their physical, chemical, optical, and microphysical properties at an unprecedented level. Results from this study will be crucial to be incorporated into climate models to improve their predicational capability.

Thank you very much!

Any questions?



SGP



AMF3



SGP



SGP



SGP



SGP

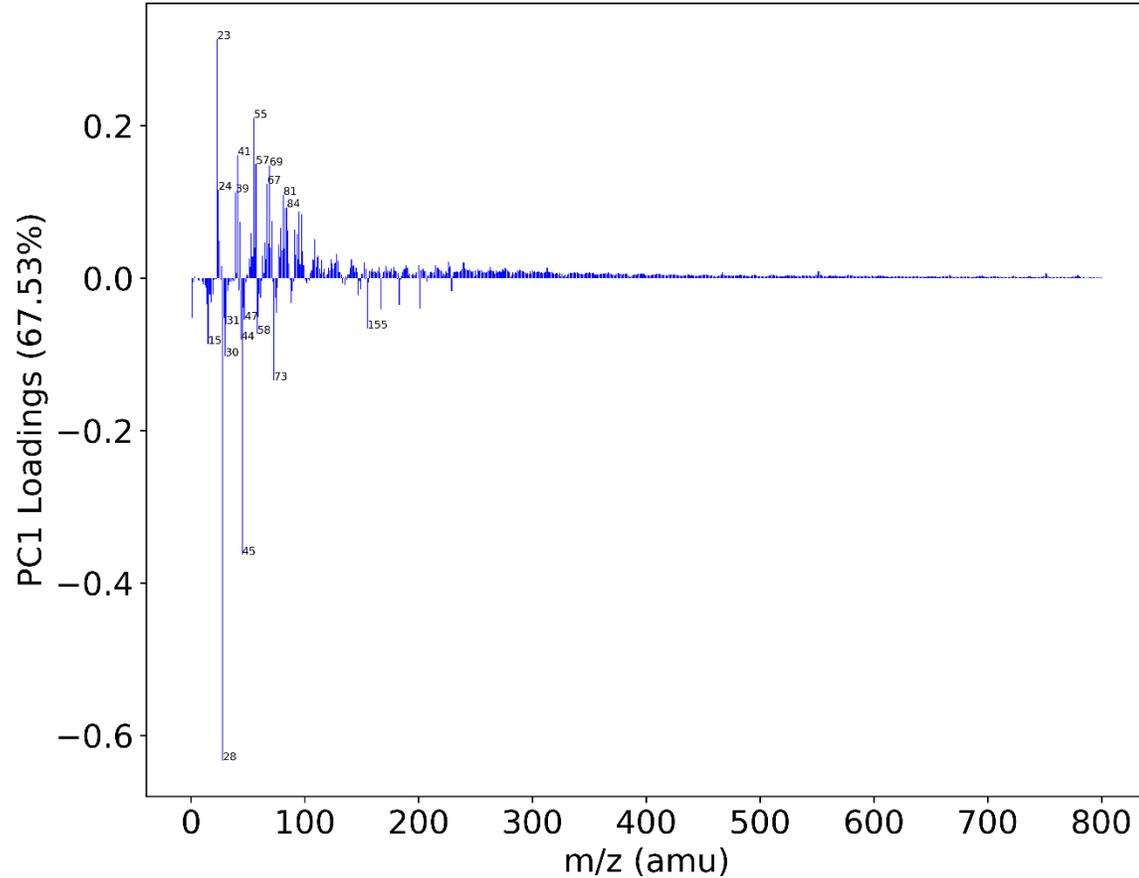


SGP



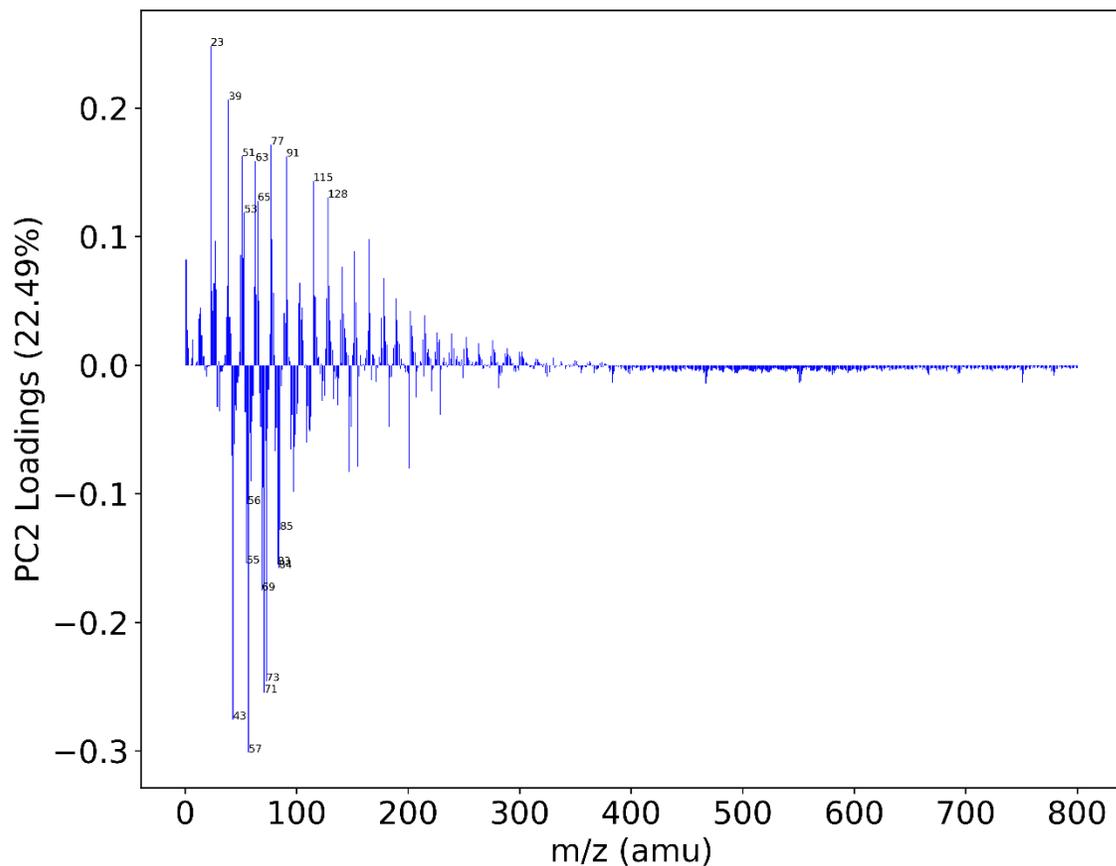
AMF3

PC1 Loadings Plot (Positive Ion Spectra)



+ loading	No. #	UnitMass	Accurate Mass	Peak assignment
	1	23	22.989	Na+
	2	55	55.055	C4H7+
	3	41	41.039	C3H5+
	4	57	57.035/57.071	C3H5O+/C4H9+
	5	69	69.074	C5H9+
	6	67	67.0561	C5H7+
	7	24	23.985	Mg+
	8	39	38.964/39.023	K+/C3H3+
	9	81	81.076	C6H11+
	10	84	84.087	C6H12+
	11	83	83.092/83.056	
	12	95	95.09/95.053	
	13	97	97.073	
	14	71	71.053/71.092	
	15	43	42.999/43.055	
	16	79	78.989/79.058	
	17	91	91.056	
	18	85	85.11	
	19	53	53.039	
	20	93	93.074	
- loading	No. #	UnitMass	Accurate Mass	Peak assignment
	1	28	27.977	Si+
	2	45	44.978	SiOH+
	3	73	73.053/72.957	PDMs
	4	30	30.042	CNH4+
	5	15	15.023	CH3+
	6	44	44.05	CHCa+
	7	58	58.067	C3H8N+
	8	155	155.151	C10H19O+
	9	31	31.018	COH3+
	10	47	46.974/46.995	SiF+/SiH3O+
	11	29	29.039	C2H5+
	12	1	1.007	H+
	13	59	59.049	
	14	75	75.029	
	15	167	167.113	
	16	201	201.133	
	17	46	45.978	
	18	183	183.179	
	19	14	14.015	CH2+
	20	88	87.942/88.024	

PC2 Loadings Plot (Positive Ion Spectra)



+ loading	No. #	UnitMass	Accurate Mass	Peak assignment
	1	23	22.989	Na+
	2	39	38.964/39.023	K+/C3H3+
	3	77	77.01/77.043	Si2H7N+/C3H9S+
	4	51	51.022	C4H3+
	5	91	91.056	SiCH9N3+
	6	63	63.023	C5H3+
	7	115	115.054	C9H7+
	8	128	128.06	C10H8+
	9	65	65.039	C5H5+
	10	53	53.039	C4H5+
	11	165	165.06	
	12	78	78.05	
	13	27	27.023	C2H3+
	14	152	152.06	
	15	50	50.014	
	16	52	52.03	
	17	1	1.007	H+
	18	141	141.064	
	19	178	178.06	
	20	103	103.053/102.97	
- loading	No. #	UnitMass	Accurate Mass	Peak assignment
	1	57	57.035/57.071	C3H5O+/C4H9+
	2	43	42.999/43.055	SiCH3+/C3H7+
	3	71	71.053/71.092	C4H7O+
	4	73	73.053/72.957	PDMs
	5	69	69.074	C5H9+
	6	84	84.087	C6H12+
	7	83	83.092/83.056	C6H11+/C4H7N2+
	8	55	55.055	C4H7+
	9	85	85.11	C6H13+
	10	56	56.05/56.061	C3H6N+/C4H8+
	11	97	97.073	
	12	70	70.072	
	13	59	59.049	C3H7O+
	14	147	147.08	
	15	201	201.133	
	16	155	155.151	C10H19O+
	17	42	42.034/41.997	
	18	81	81.076	C6H11+
	19	95	95.09/95.053	
	20	98	98.097	