# Formation and Destruction Processes of Carbonaceous Interstellar Dust

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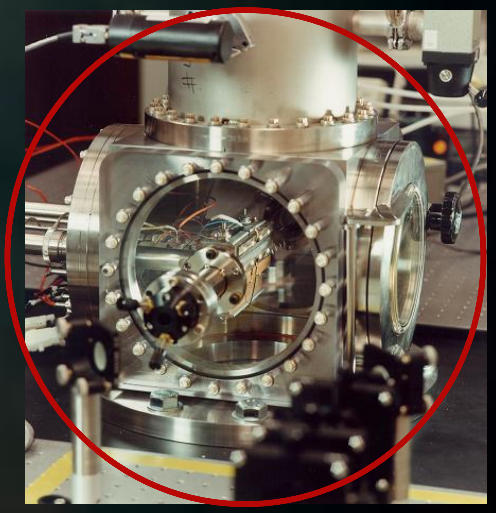
Introduction
Criteria and Methods

- Discharge, Ion Source Apparatus
- Cavity Ring Down Spectrometer
- Reflectron Time of Flight Mass Spectrometer

Results

- Hydrocarbons
- Benzene, Benzene analogs
- Small PAHs
- Mixtures

Summary and Future Work



International Astronomical Union Conference, May 2011

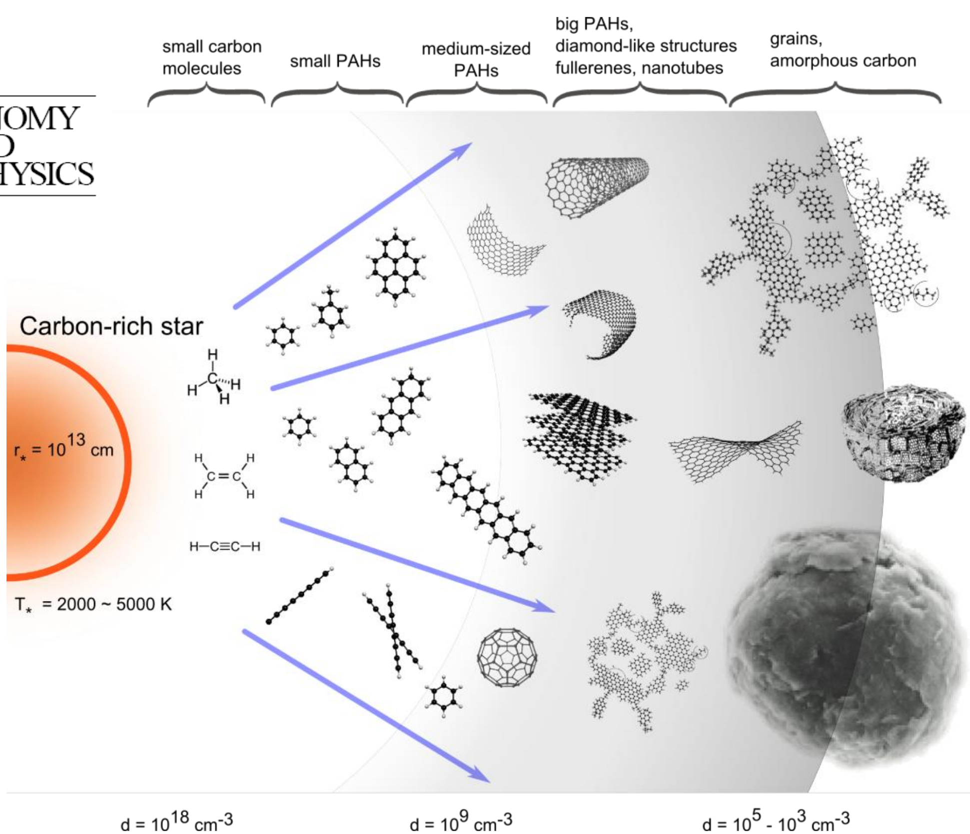
# Introduction

## Carbon Grain Formation

### *NGC 300 (3.3 and 7.8 $\mu$m PAH band overlays)*

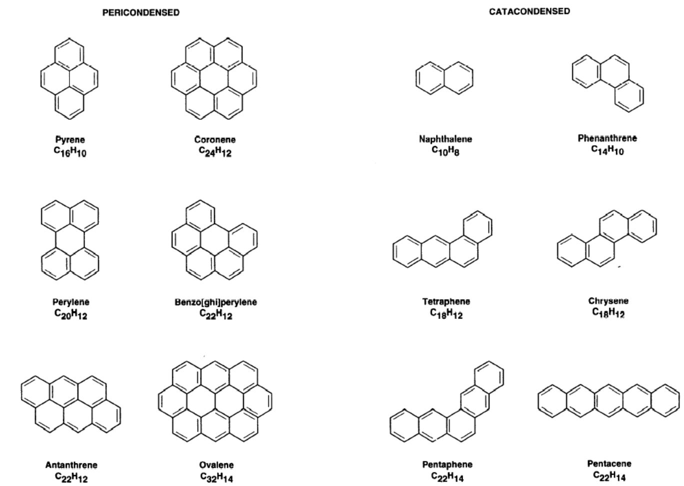
*http://www.spitzer.caltech.edu/features/articles/20050627.shtml*

ASTRONOMY AND ASTROPHYSICS



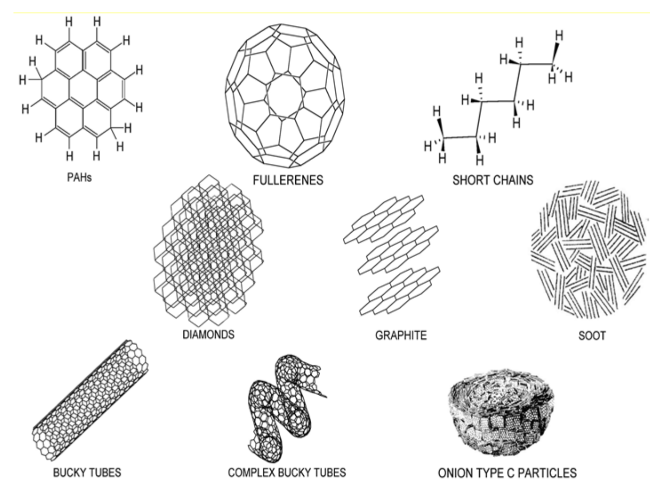

*G. Pascoli, A. Polleux, A&A (2000)*

### *PAH structures*




Salama et al. ApJ (1996)

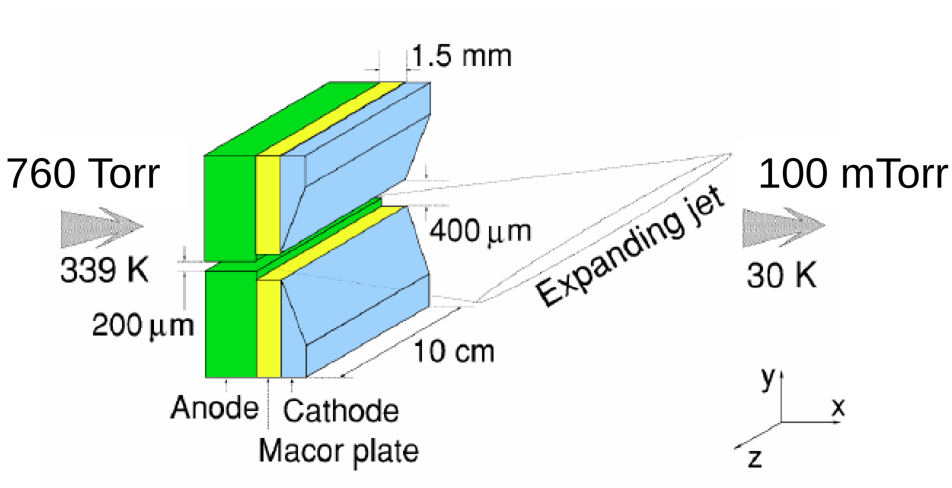
### *Carbon nanoparticles*

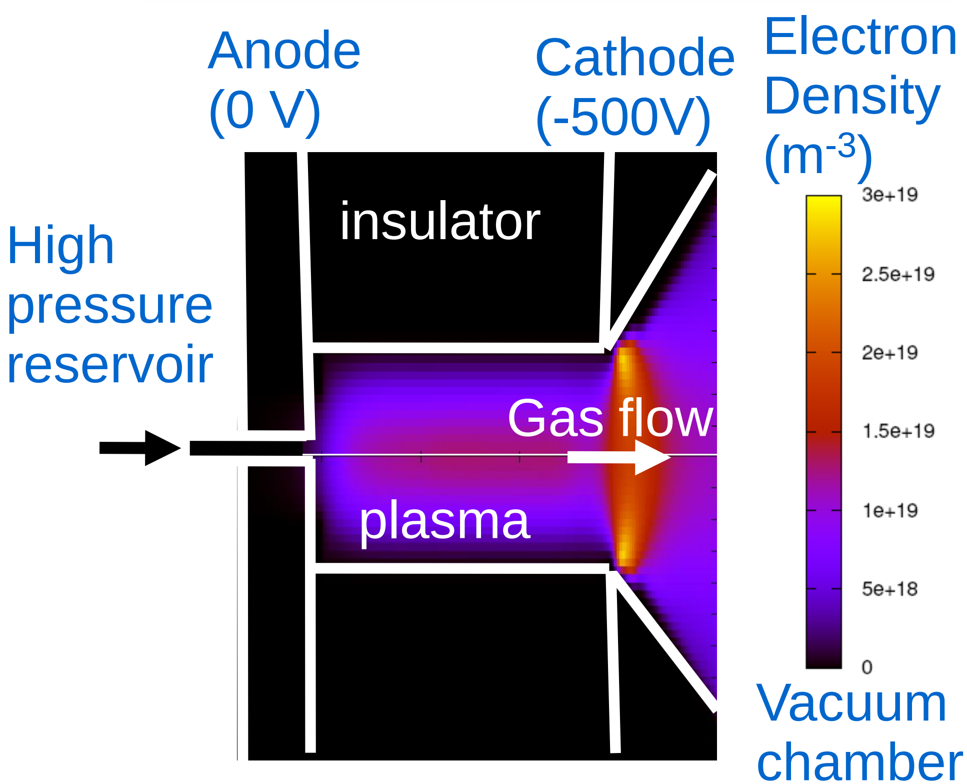



Courtesy from R. Ruiterkamp

# Methods – Pulsed Nozzle Discharge

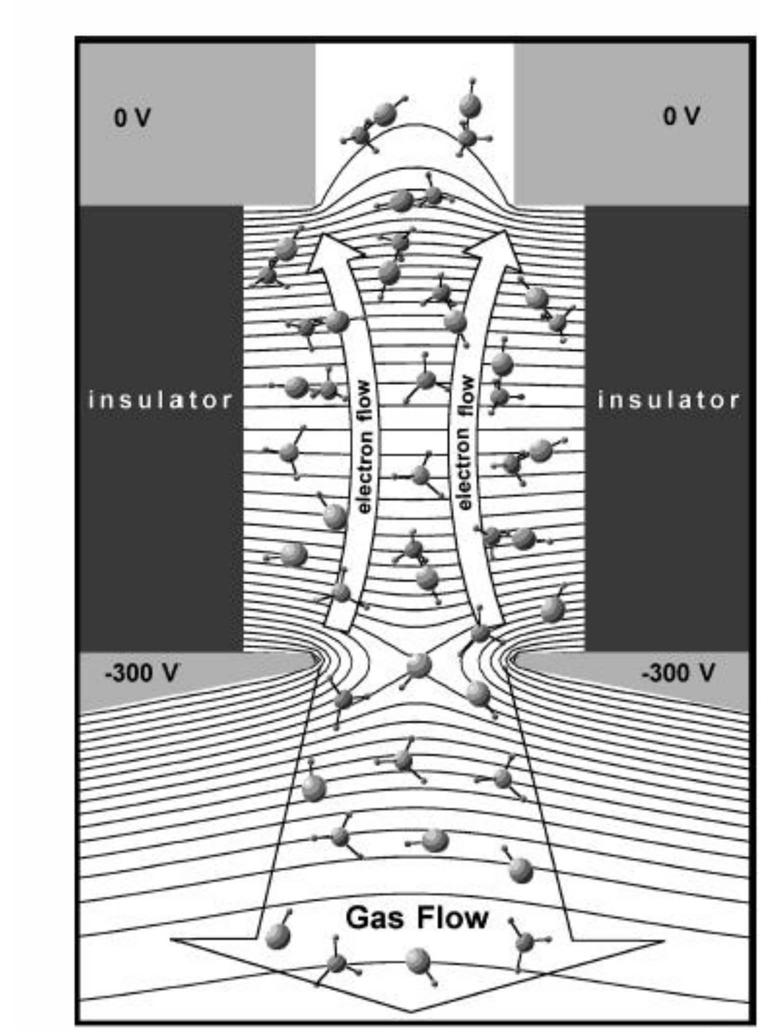
### *Pulsed Nozzle Discharge setup*




*B. Broks et al., Phys. Rev. E, (2005)*

### *Simulation of the plasma*

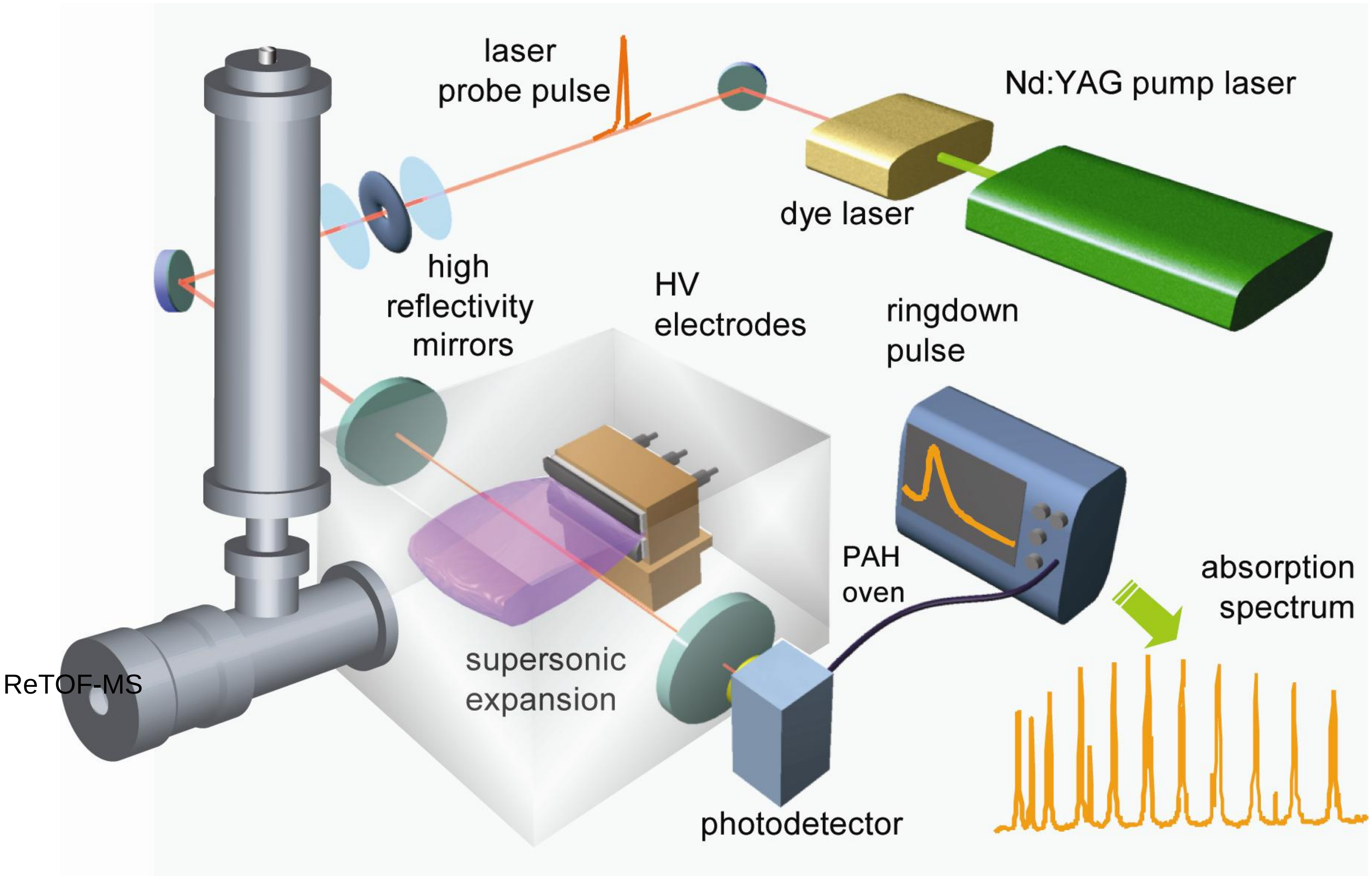



*Davis et al., J. Chem. Phys. (1997)*

# Methods - System

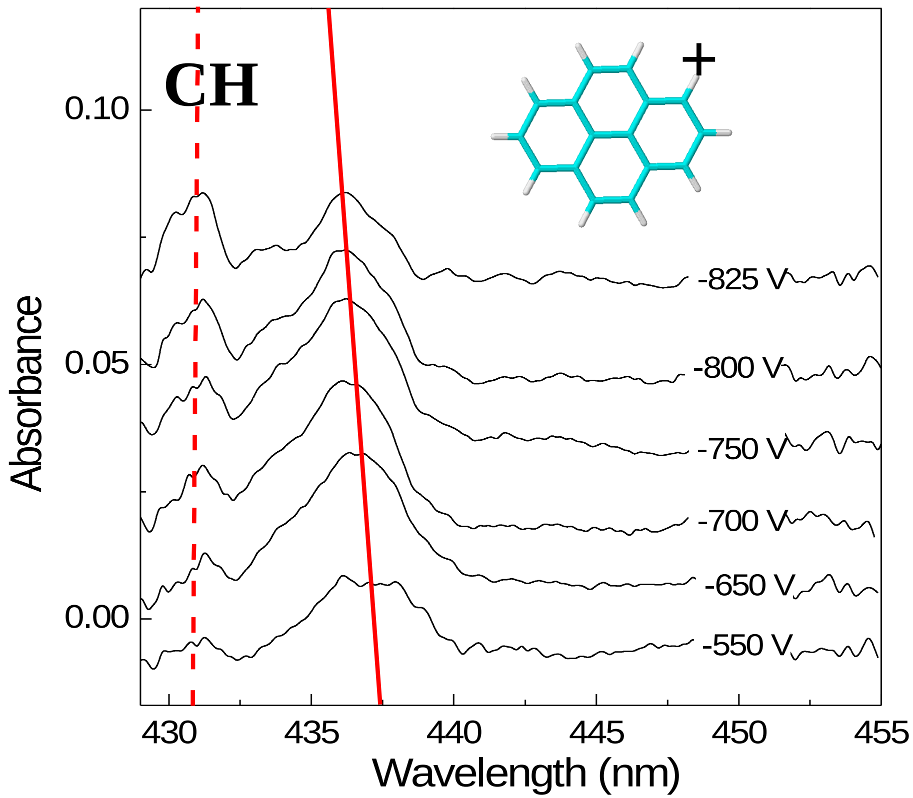
**The setup now combines:**

- **Pulsed discharge nozzle**
- **Cavity ring down spectrometer**
- **Reflectron Time-of-Flight mass spectrometer**

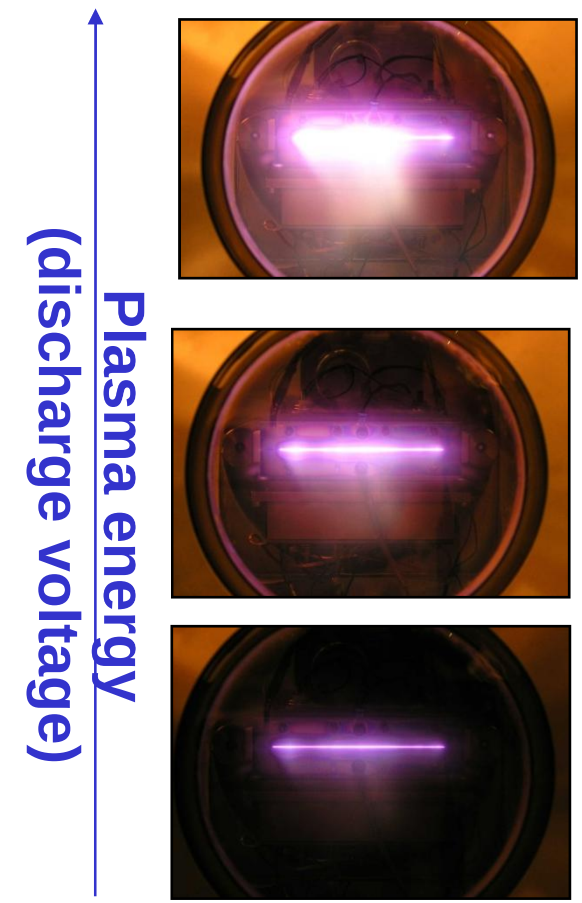


# Fragmentation & Detection of Carbon Particles

**Spectrum of Pyrene ($C_{16}H_{10}^{+}$) plasma versus discharge energy**

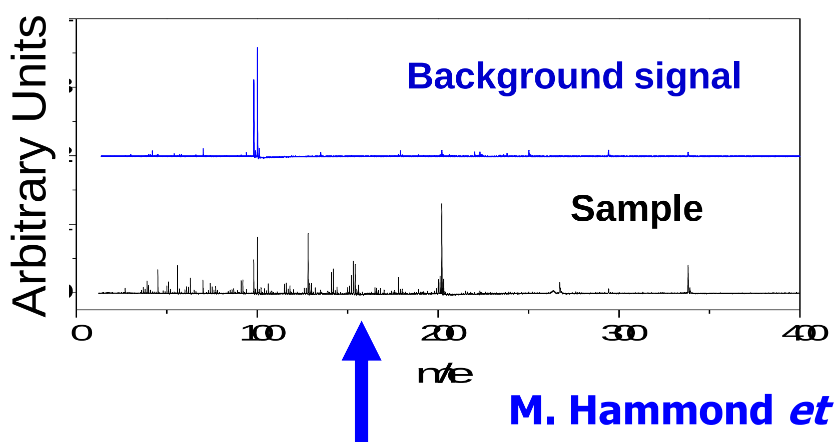



**Observation of soot on the electrodes**



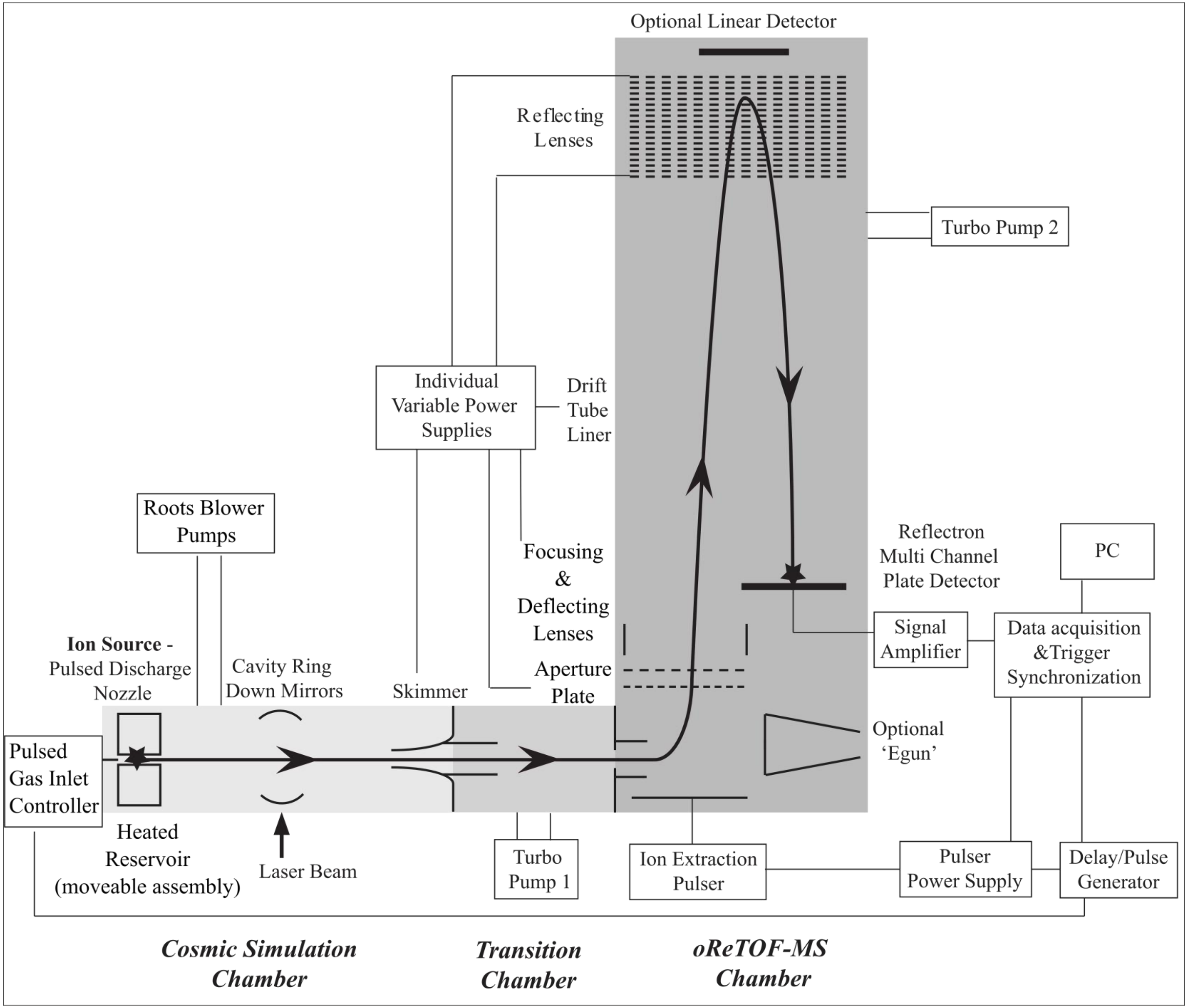

Biennier *et al.* - 2005

**μL²MS of soot formed from $C_{12}H_{10}$ (154 amu) precursor.**



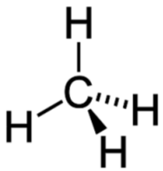

**M. Hammond *et al.* , 2006**

# Methods – ReTOF-MS

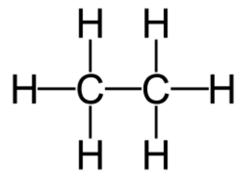



Ricketts, C.L., Contreras, C.S., & Salama, F., 2011, Int. J. Mass Spectrom. Ion Processes, 300, 26

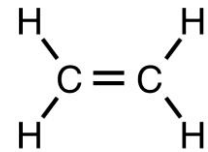
# Results - Hydrocarbons



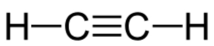
| Methane (CH4) | | |
|---|---|---|
| | Plasma | EI |
| m/z | (Intensity) | (Intensity) |
| 12 | 173 | 613 |
| 13 | 823 | 1632 |
| *13.3 | -- | 249 |
| 14 | 37858 | 2855 |
| 15 | 133201 | 15228 |
| 16 | 106703 | 17336 |
| 17 | 24048 | 24 |
| *18 | -- | 344 |
| *20 | 4370 | 11516 |
| 27 | 2959 | -- |
| 28 | 3397 | 359 |
| 29 | 32796 | -- |
| *36 | 2737 | 401 |
| *38 | 207 | -- |
| *40 | 176840 | 68668 |
| *80 | 476 | -- |



| Ethane (C2H6) | | |
|---|---|---|
| | Plasma | EI |
| m/z | (Intensity) | (Intensity) |
| 12 | -- | 228 |
| 13 | 131 | 288 |
| *13.3 | 469 | -- |
| 14 | 497 | 801 |
| 14.5 | 94 | 207 |
| 15 | 3803 | 1147 |
| *18 | -- | 325 |
| *20 | 6941 | 12932 |
| 24 | 133 | 220 |
| 25 | 736 | 932 |
| 26 | 17477 | 4525 |
| 27 | 36461 | 6221 |
| 28 | 85369 | 17306 |
| 29 | 23337 | 3582 |
| 30 | 27236 | 4598 |
| *36 | -- | 435 |
| *40 | 108857 | 72026 |
| 55 | 240 | -- |



| Ethylene (C2H4) | | |
|---|---|---|
| | Plasma | EI |
| m/z | (Intensity) | (Intensity) |
| 12 | -- | 526 |
| 13 | -- | 877 |
| 14 | 246 | 1217 |
| *18 | -- | 301 |
| *20 | 395 | 10029 |
| 24 | -- | 745 |
| 25 | 281 | 2524 |
| 26 | 22190 | 11823 |
| 27 | 40599 | 12133 |
| 28 | 59414 | 18578 |
| 29 | 7781 | 158 |
| *36 | -- | 486 |
| 39 | 1411 | 63547 |
| *40 | 76050 | -- |
| 41 | 13008 | -- |
| 53 | 1051 | -- |
| 55 | 1432 | -- |
| 67 | 186 | -- |
| 68 | 329 | -- |
| 69 | 298 | -- |
| *80 | 252 | -- |



| Acetylene (C2H2) | | |
|---|---|---|
| | Plasma | EI |
| m/z | (Intensity) | (Intensity) |
| *13.3 | 271 | -- |
| 15 | 417 | 377 |
| *18 | -- | 389 |
| *20 | 4896 | 10832 |
| 24 | 1218 | 2306 |
| 25 | 5888 | 7233 |
| 26 | 50733 | 27732 |
| 27 | 851 | 293 |
| *36 | 638 | 521 |
| *38 | 152 | -- |
| 39 | 120 | -- |
| *40 | 103094 | 66939 |
| 43 | 192 | -- |
| 50 | 6147 | -- |
| 51 | 9581 | -- |
| 58 | 881 | 308 |
| 59 | 356 | -- |
| 66 | 1265 | -- |
| 74 | 131 | -- |
| 75 | 175 | -- |
| 76 | 248 | -- |
| 77 | 176 | -- |
| *80 | 140 | -- |

*13.3 - $Ar^{3+}$

*18 - $H_2O^+$

*20 - $Ar^{2+}$

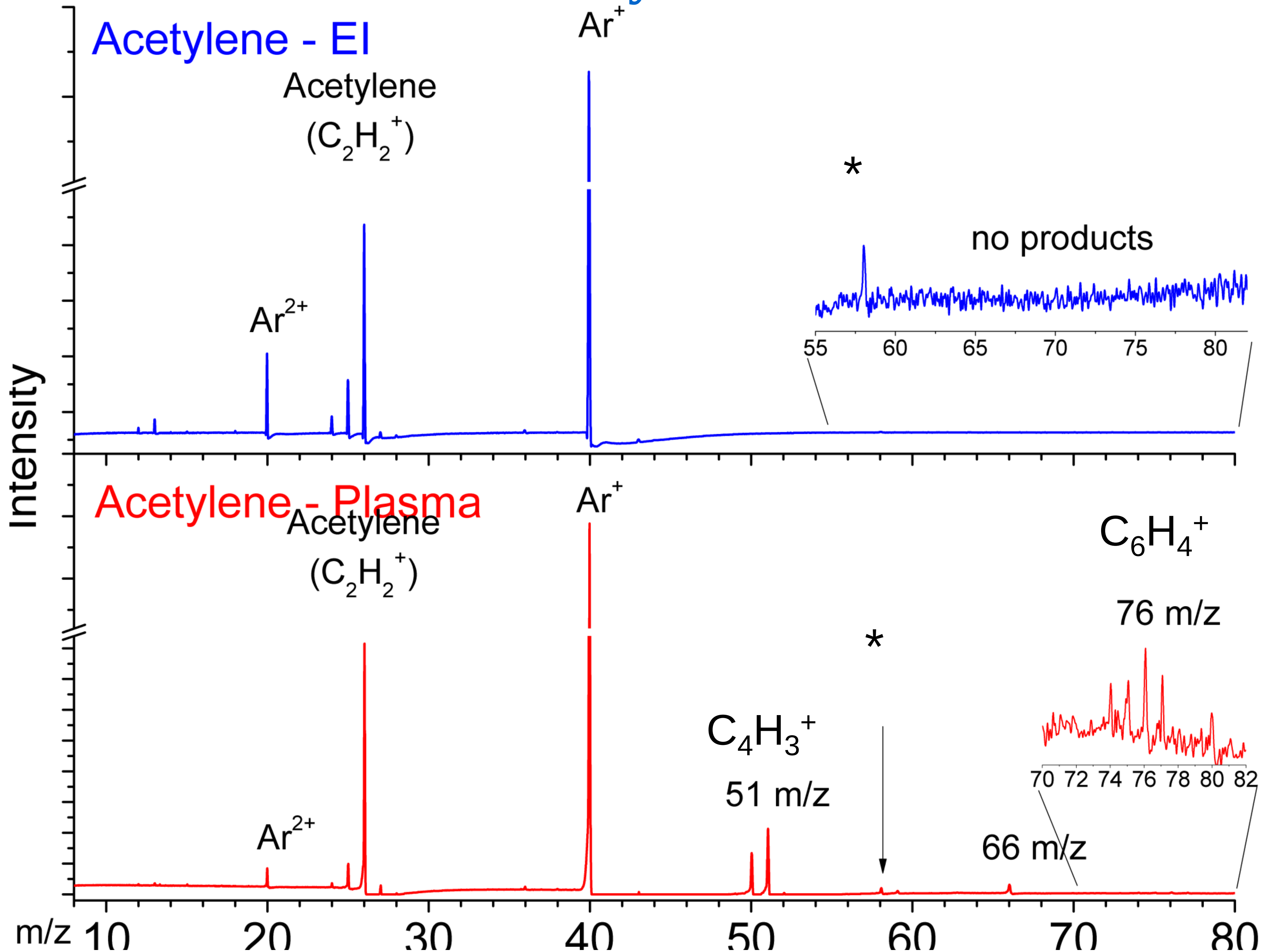
36 - $^{36}Ar^+$

38 - $^{38}Ar^+$

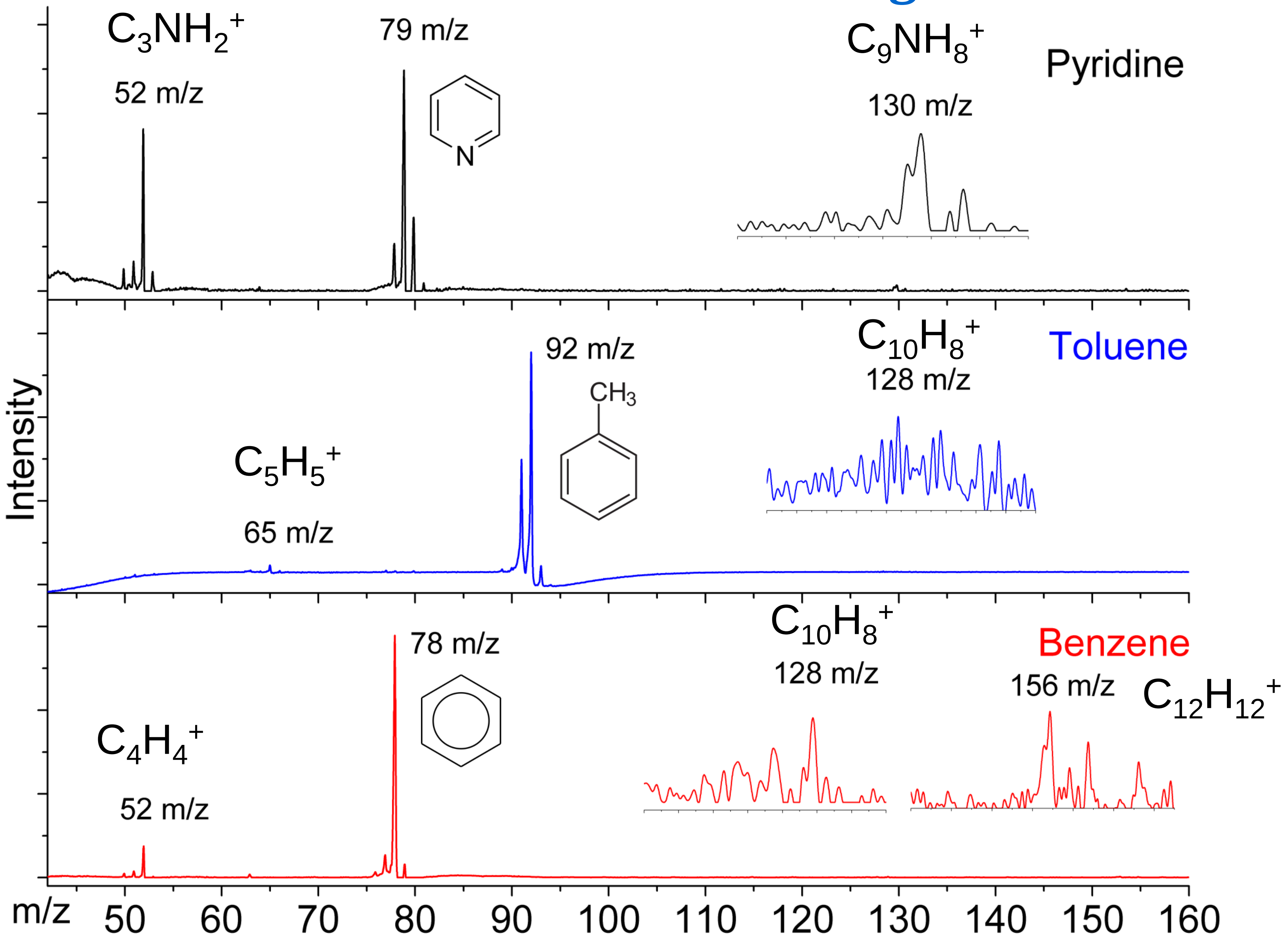
40 - $Ar^+$

80 - $Ar_2^+$

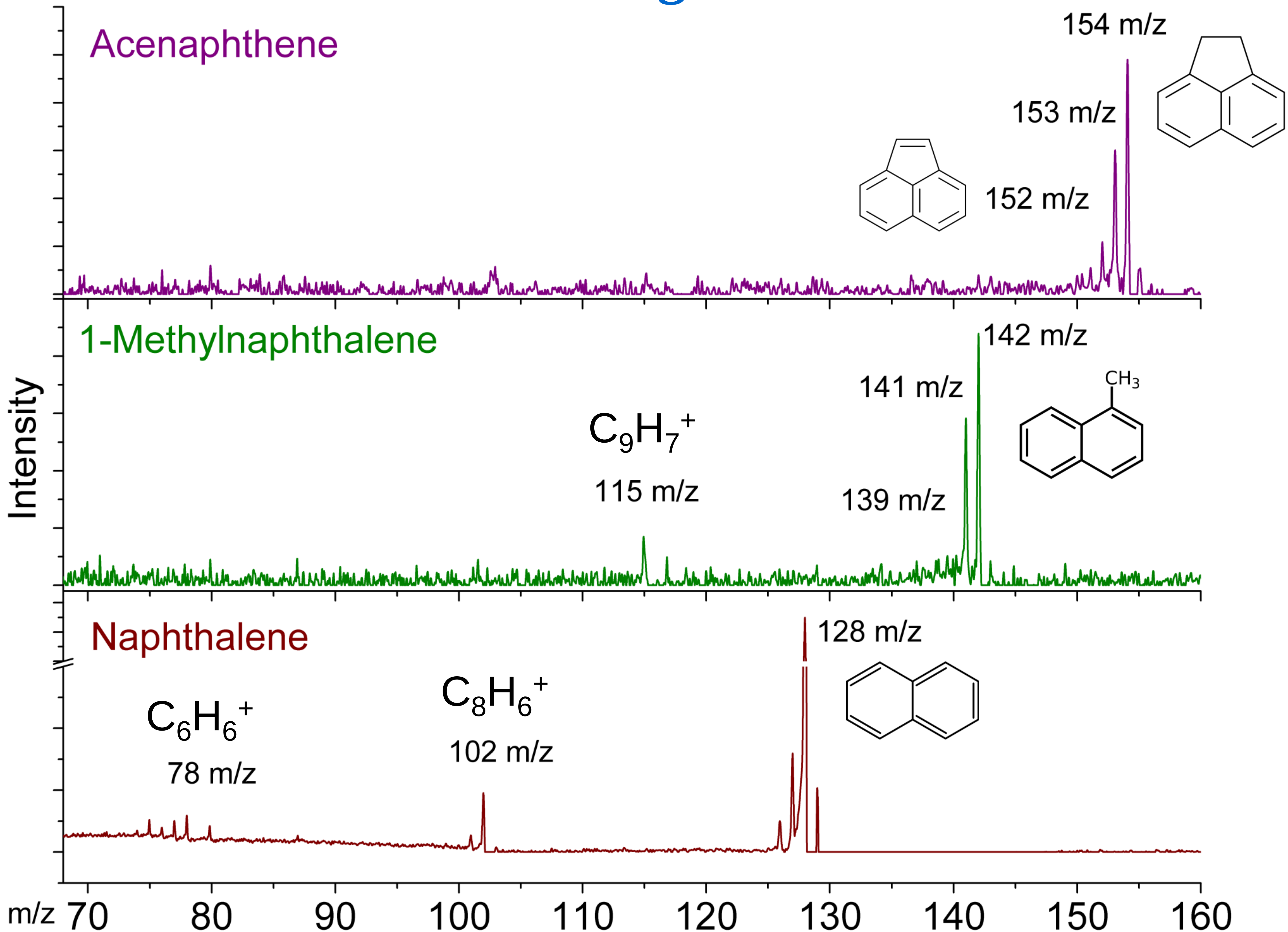
# Results - Hydrocarbons



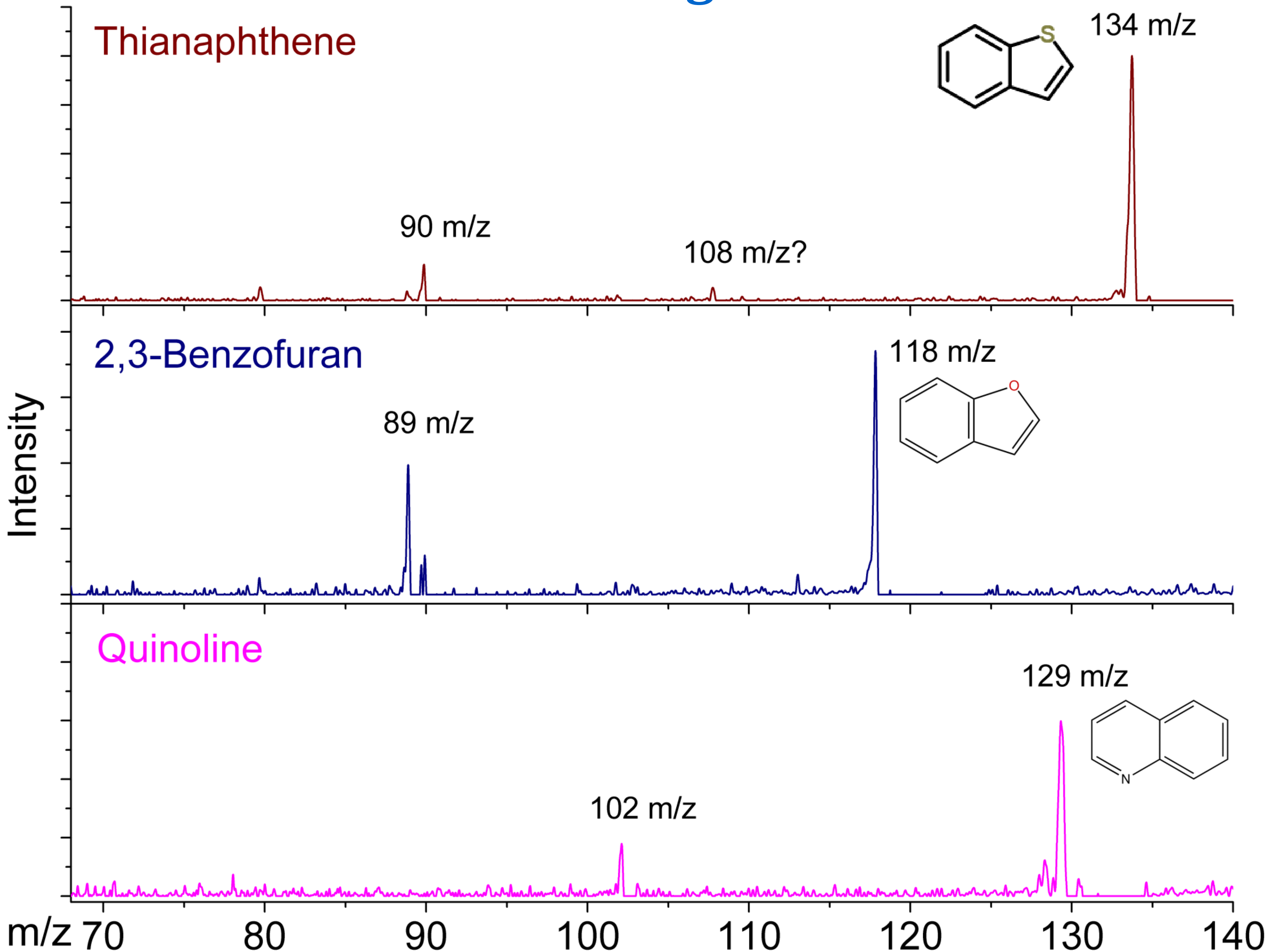
# Results – Benzene Analogs



# Results – Homogenous PAHs



# Results – Heteregenous PAHs



# Results – Mixtures of Benzene Analogs with Acetylene

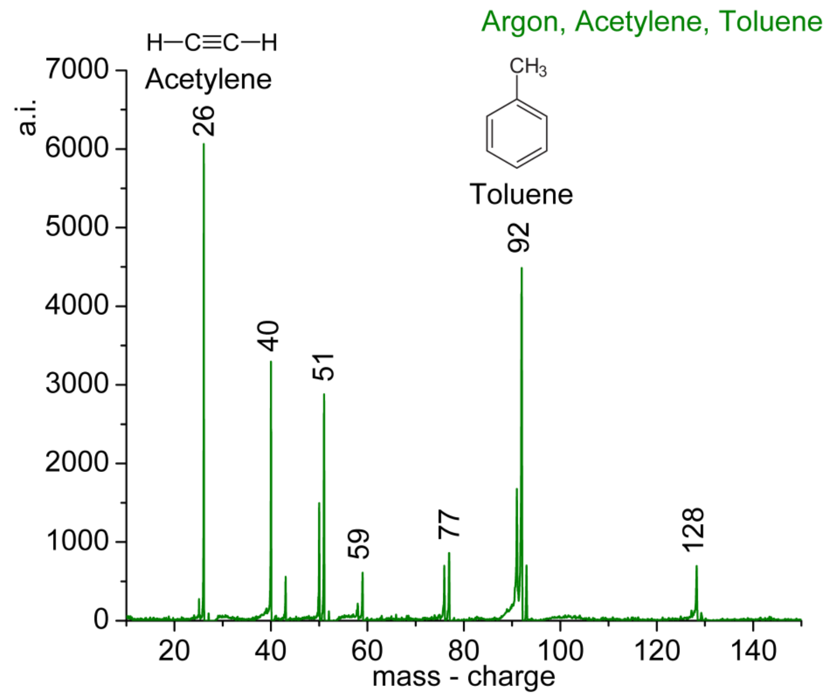
| Benzene | | | |
|---|---|---|---|
| | | w/C2H2 | |
| m/z | Intensity | m/z | Intensity |
| 76 | 0.03 | 76 | 0.07 |
| 77 | 0.10 | 77 | 0.13 |
| 78 | 1.00 | 78 | 1.00 |
| 79 | 0.04 | 79 | 0.14 |
| 128 | 0.02 | 128 | 0.10 |
| 153 | 0.02 | 129 | 0.07 |
| 155 | 0.01 | | |

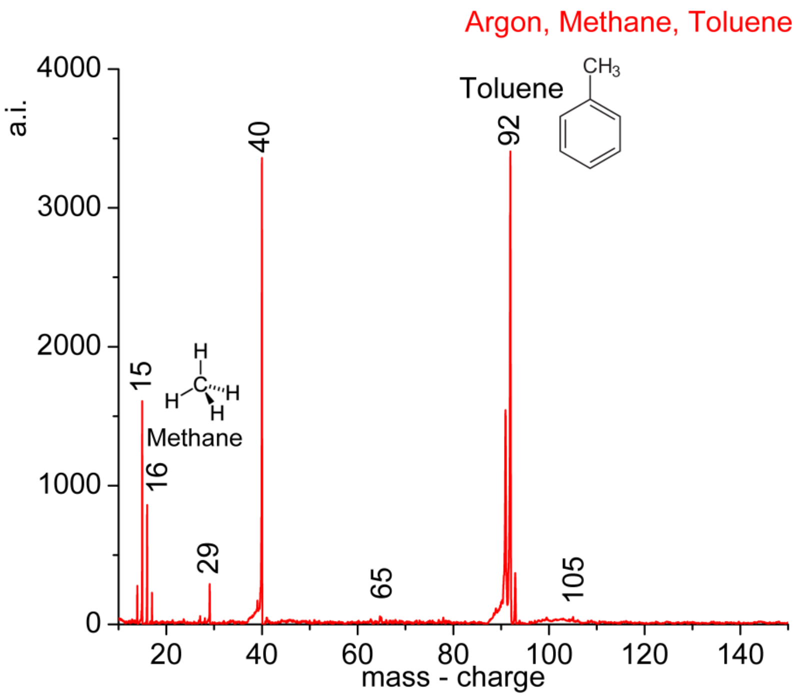
| Pyridine | | | |
|---|---|---|---|
| | | w/C2H2 | |
| m/z | Intensity | m/z | Intensity |
| 78 | 0.24 | 76 | 0.19 |
| 79 | 1.00 | 77 | 0.14 |
| 80 | 0.33 | 78 | 0.26 |
| 81 | 0.03 | 79 | 1.00 |
| 89 | 0.04 | 80 | 0.90 |
| 90 | 0.03 | 81 | 0.18 |
| 90 | 0.04 | 104 | 0.18 |
| 91 | 0.04 | 105 | 0.13 |
| 92 | 0.07 | 130 | 0.28 |
| 117 | 0.06 | 131 | 0.12 |
| 119 | 0.04 | | |
| 130 | 0.10 | | |
| 131 | 0.07 | | |

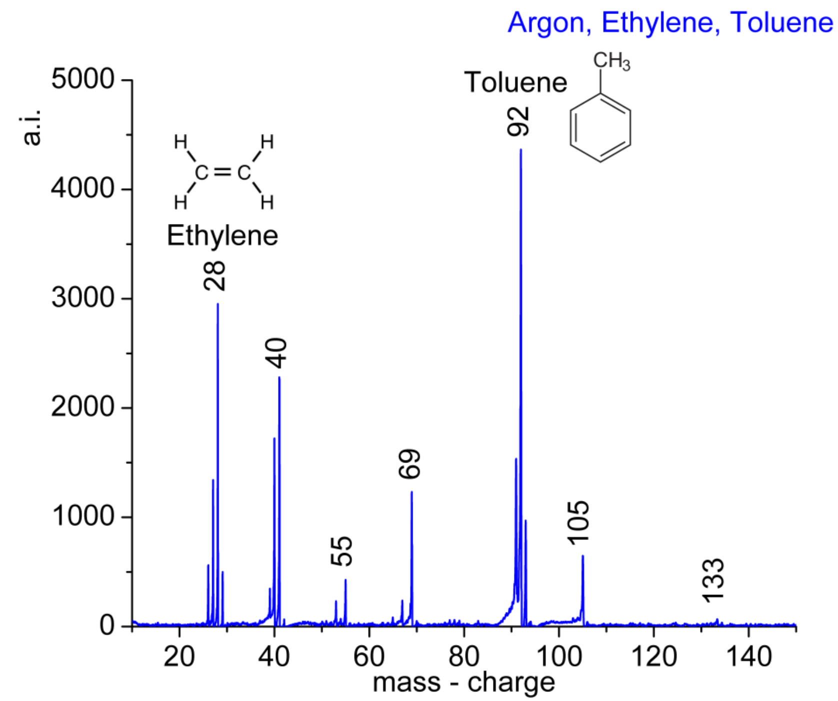
| Toluene | | | |
|---|---|---|---|
| | | w/C2H2 | |
| m/z | Intensity | m/z | Intensity |
| 77 | 0.08 | 76 | 0.14 |
| 78 | 0.14 | 77 | 0.16 |
| 89 | 0.12 | 78 | 0.05 |
| 90 | 0.13 | 91 | 0.36 |
| 91 | 1.20 | 92 | 1.00 |
| 92 | 1.00 | 93 | 0.12 |
| 93 | 0.10 | 127 | 0.05 |
| | | 128 | 0.15 |

Mixtures of PAH precursors with Acetylene did not produce any formation products…

# Results – Mixtures: Toluene/Hydrocarbon Examples



# Experiment Summary

- Formation of larger ions observed for hydrocarbons and benzene analogs

- Small PAH formation may be efficient and possible by using acetylene as a precursor, either in a mixture or by itself

- Formation up to $C_6H_5$ is observed for Acetylene in an Argon plasma

- Larger PAH formation was not observed for the PAH precursors for the energies and concentrations studied

# Future Work

- Complete reaction monitoring and reaction rates for Acetylene/Benzene experiments
- Study larger PAH precursors and their fragmentation patterns
- Optical Spectroscopy – Spectra of ions observed from MS, that meet the abundance criteria, for direct comparison with observations
- Further analysis of soot material produced, in collaboration with Richard Zare (Stanford U.) and Ludovic Biennier (Université de Rennes 1)

# Acknowledgements

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