# Analyzing Enceladus' Plume Constituents: First Steps to Experimentally Simulating Hypervelocity Impacts

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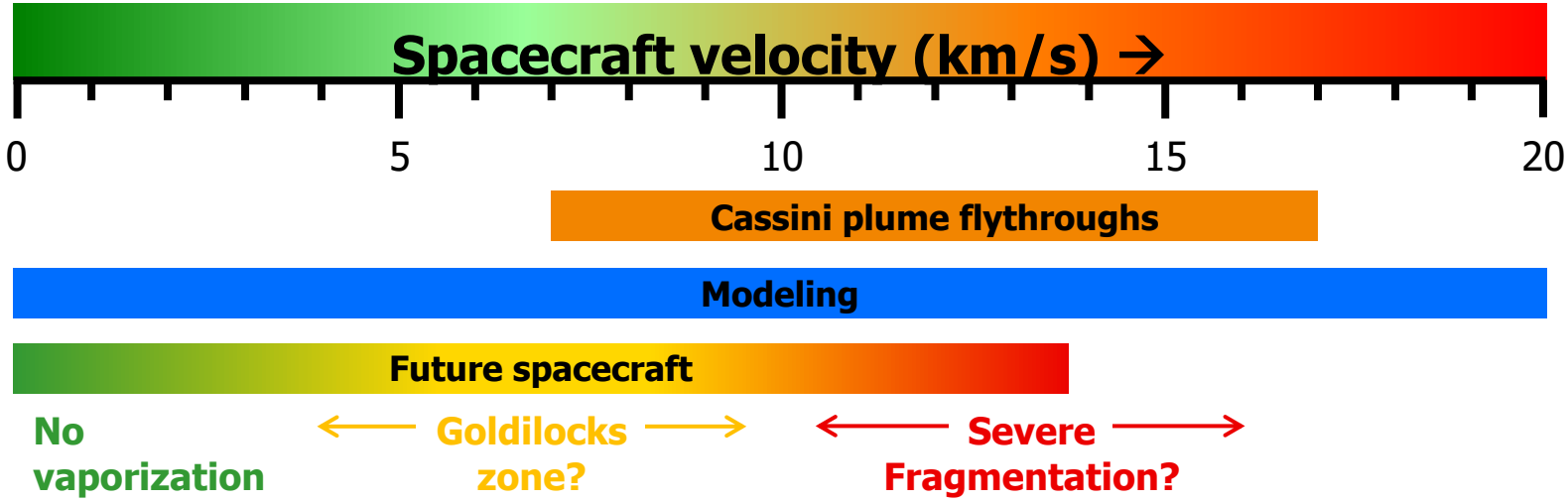
California Institute of Technology

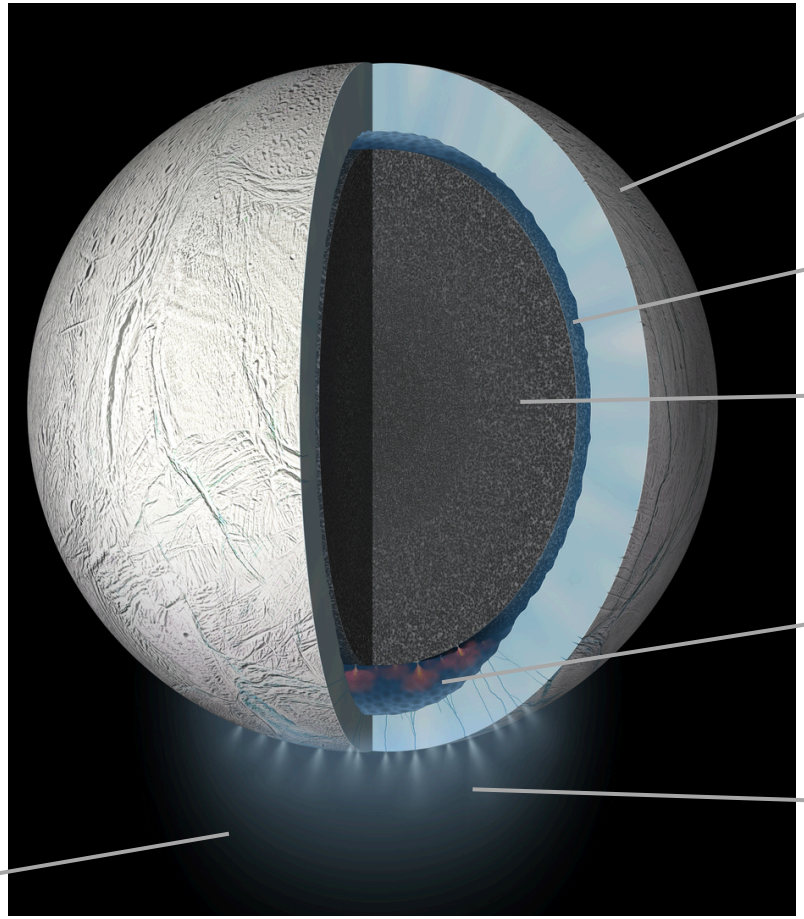
Image: NASA/JPL

# Hypervelocity sampling

- Cassini sampled the plume of Enceladus at hypervelocity (>1 km/s)
- Hypervelocity sampling presents challenges
  - Need to balance volatilization, ionization, and fragmentation



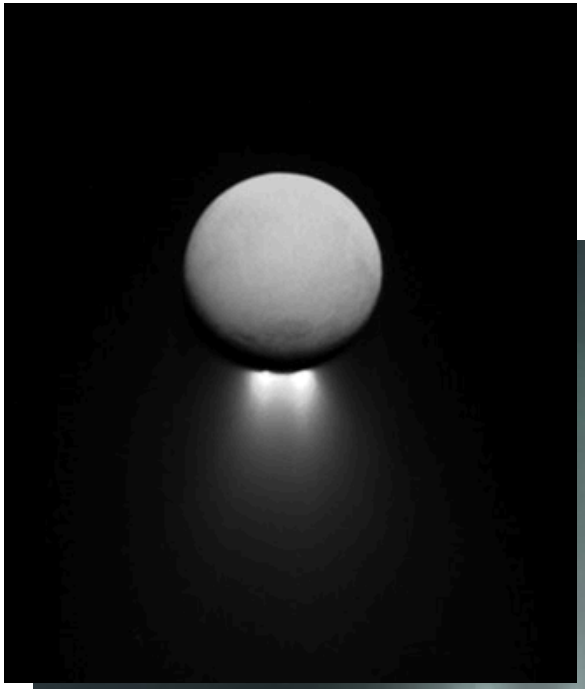
# Why Enceladus?




Enceladus is one of the prime targets to search for aqueous-based life

Image: NASA/JPL

# Plume discovery –Cassini



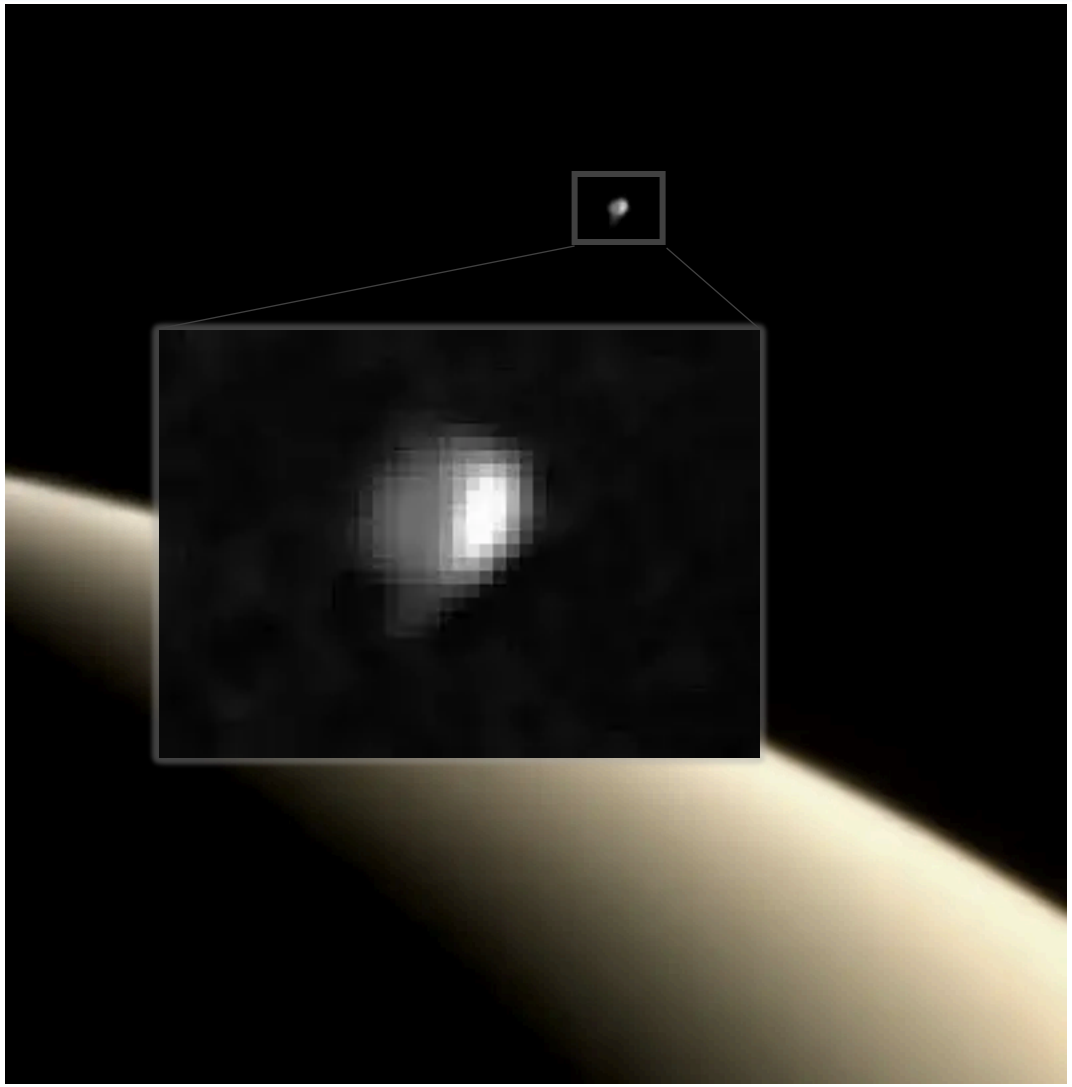
Images: NASA/JPL-Caltech; NASA/JPL/SSI

# An epic photobomb

Image: NASA/JPL/Ted Stryk

T.Stryk (2017) 48th LPSC, Abstract #1603

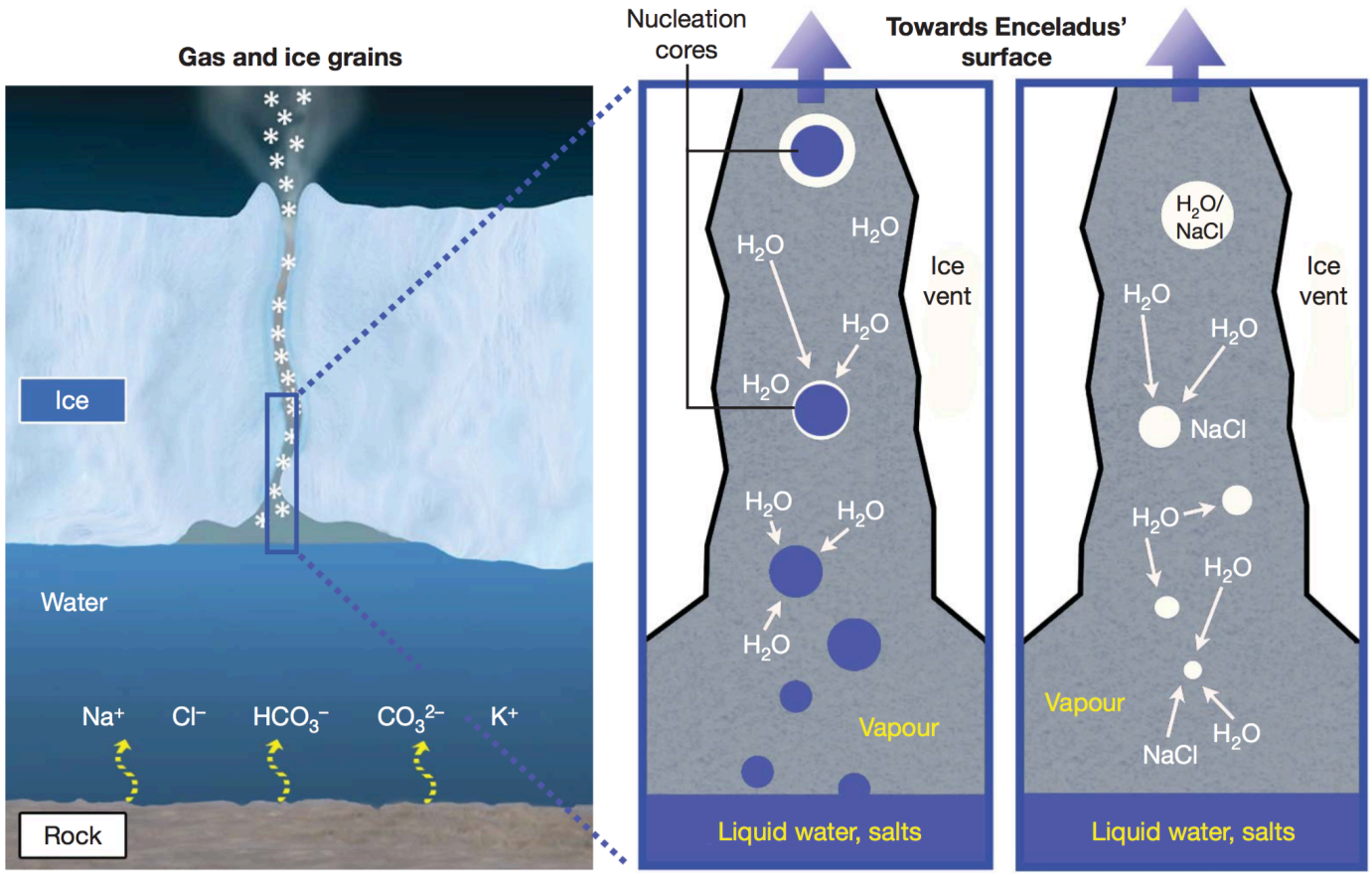
# An epic photobomb



Images: NASA/JPL/Ted Stryk

T.Stryk (2017) 48th LPSC, Abstract #1603

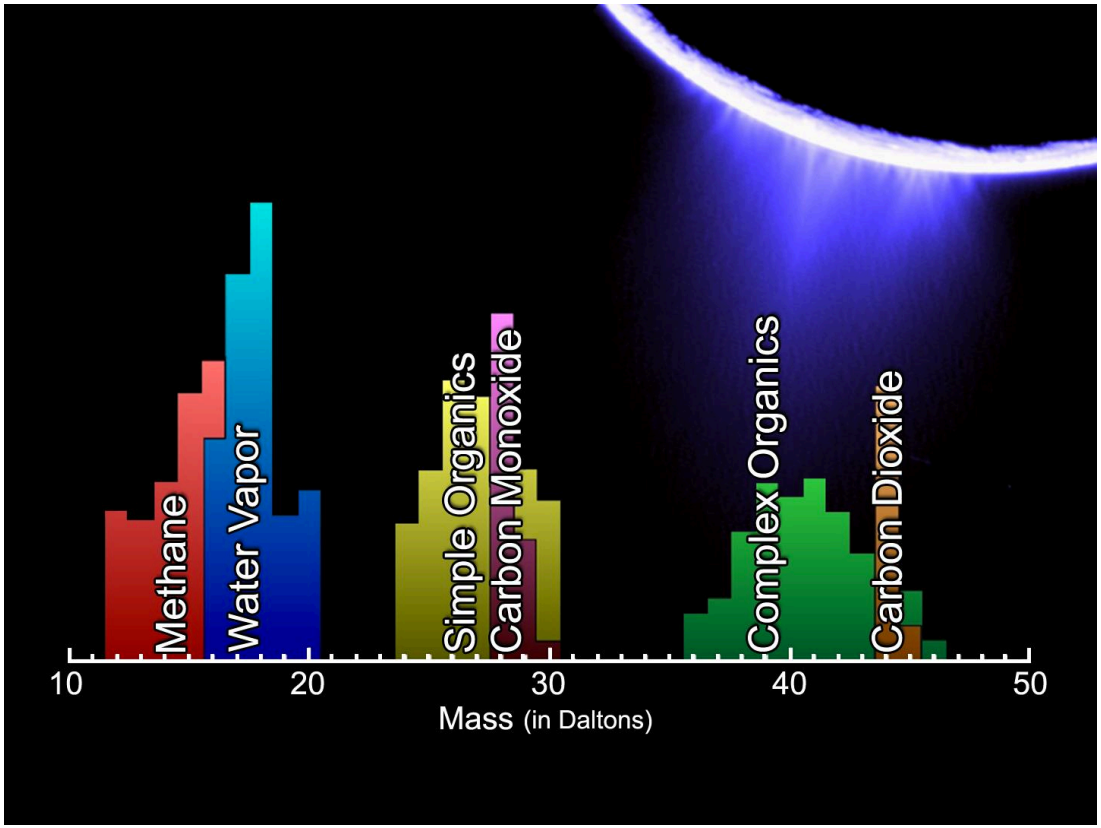
# Cryovolcanic plume




The plume expresses the subsurface ocean into space.

Postberg et al. (2009) Nature, 459, 1098-1101.

# Plume composition –Vapor



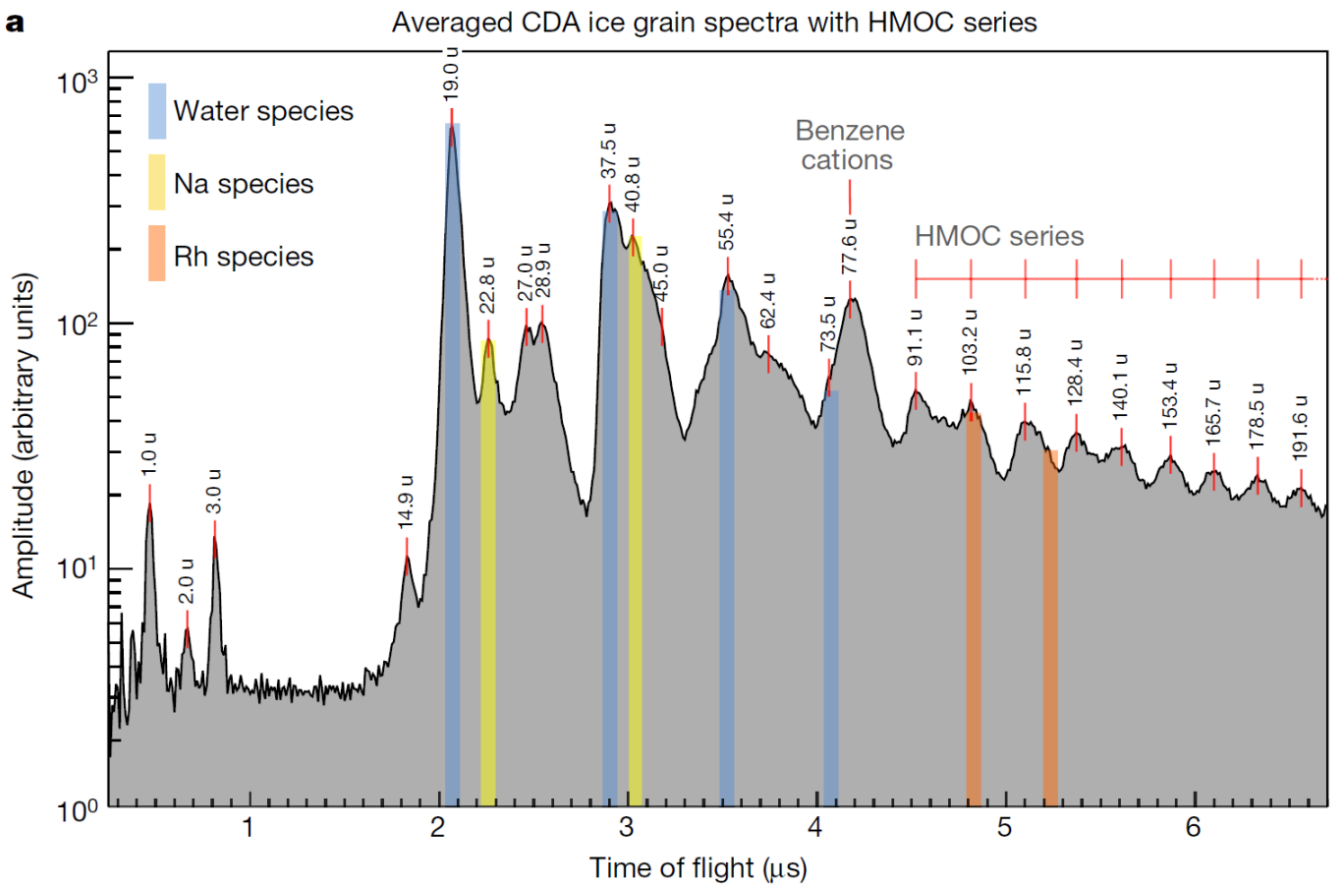

Gas component

- $H_2O$, $CO_2$, $CH_4$, $NH_3$, and $H_2$
- Heavier hydrocarbons
- <u>Simple and complex organics</u>

| Constituent | Mixing ratio (%) |
|---|---|
| $H_2O$ | 96 to 99 |
| $CO_2$ | 0.3 to 0.8 |
| $CH_4$ | 0.1 to 0.3 |
| $NH_3$ | 0.4 to 1.3 |
| $H_2$ | 0.4 to 1.4 |

Waite et al. (2009) Nature 460, 487-490.
Waite et al. (2017) Science 356, 155-159.

# Plume composition –Solid




Grain component

- Water-ice
- Salts (mostly NaCl)
- <u>High mass organic cations (HMOC)</u>

Average grain size:
**0.6 µm**


Postberg et al. (2009) Nature, 459, 1098-1101.
Postberg et al. (2018) Nature, 558, 564-568.

# The trouble with plumes…

- Hypervelocity sampling (>1 km/s)
- At what velocity will molecules volatilize or fragment?
- Test with laboratory measurements
  - Accelerate *intact* molecules/ice grains
  - Impact those species and analyze with mass spectrometry

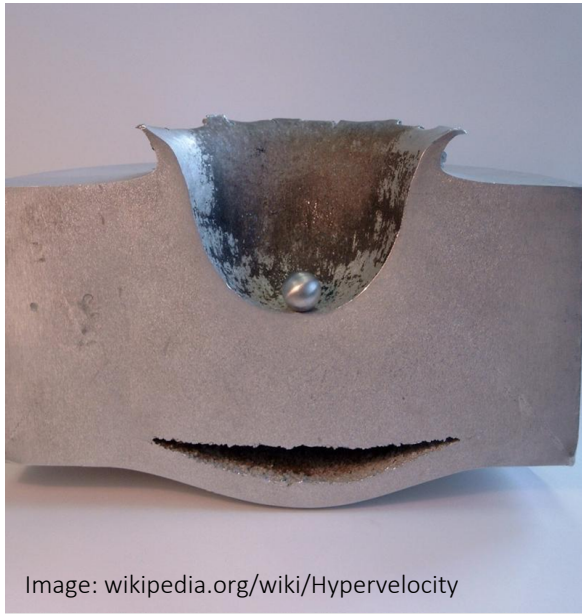
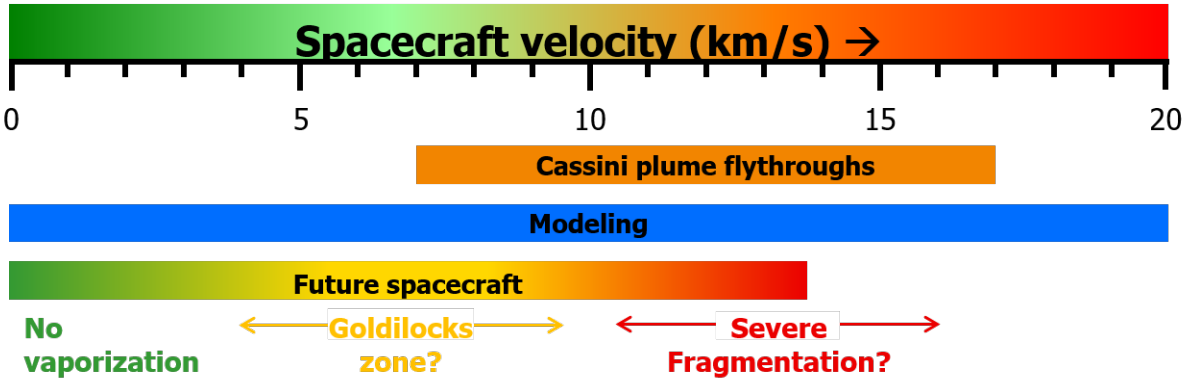
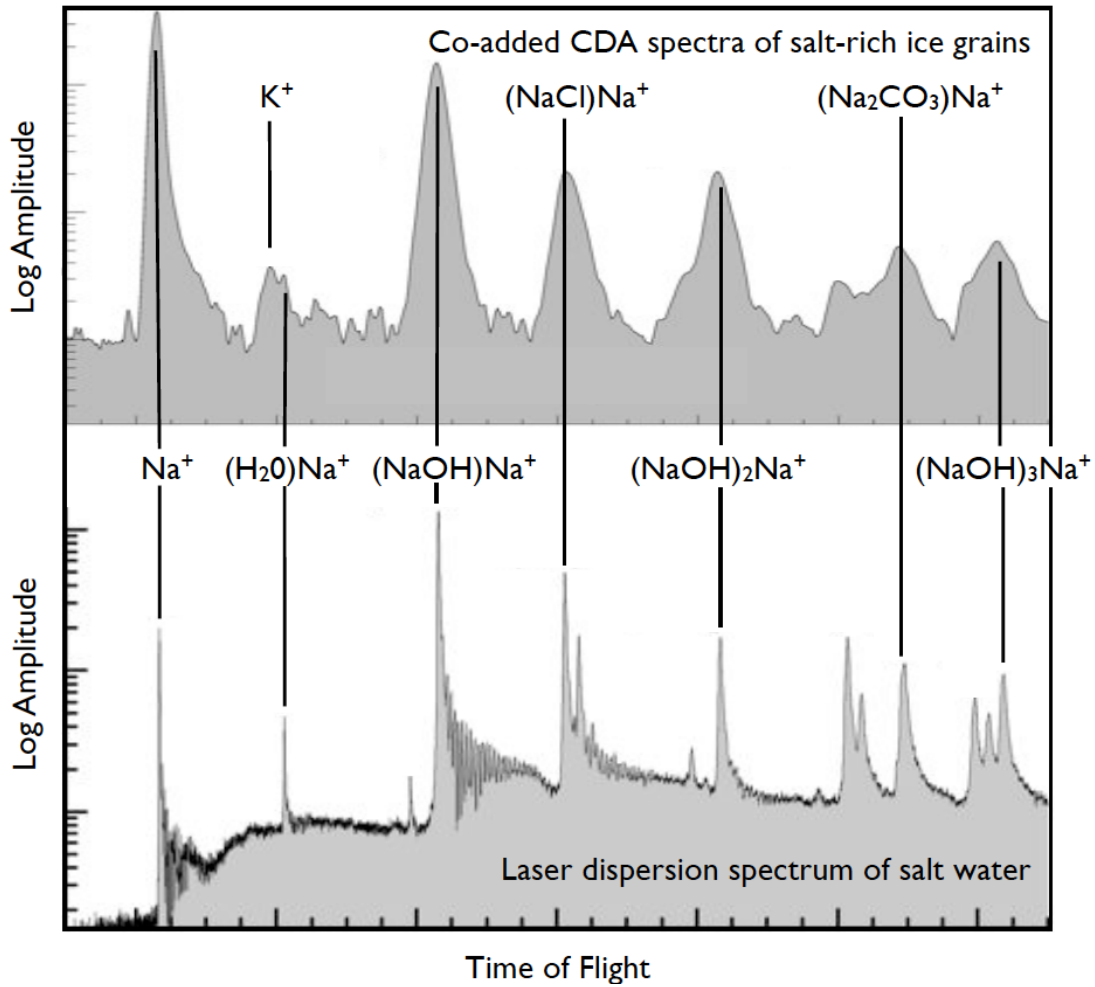
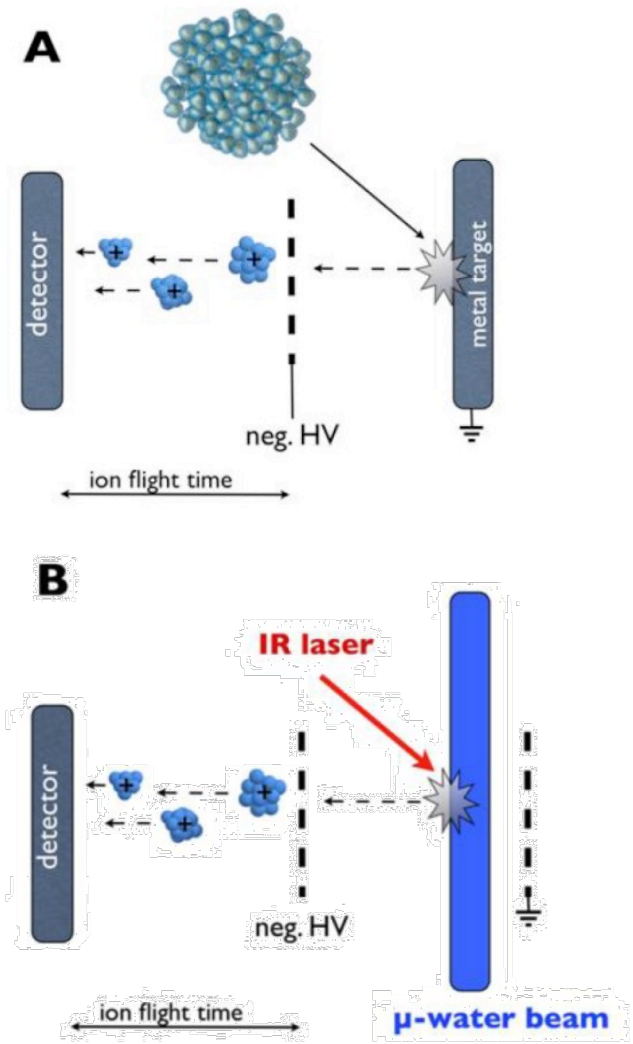


Image: wikipedia.org/wiki/Hypervelocity



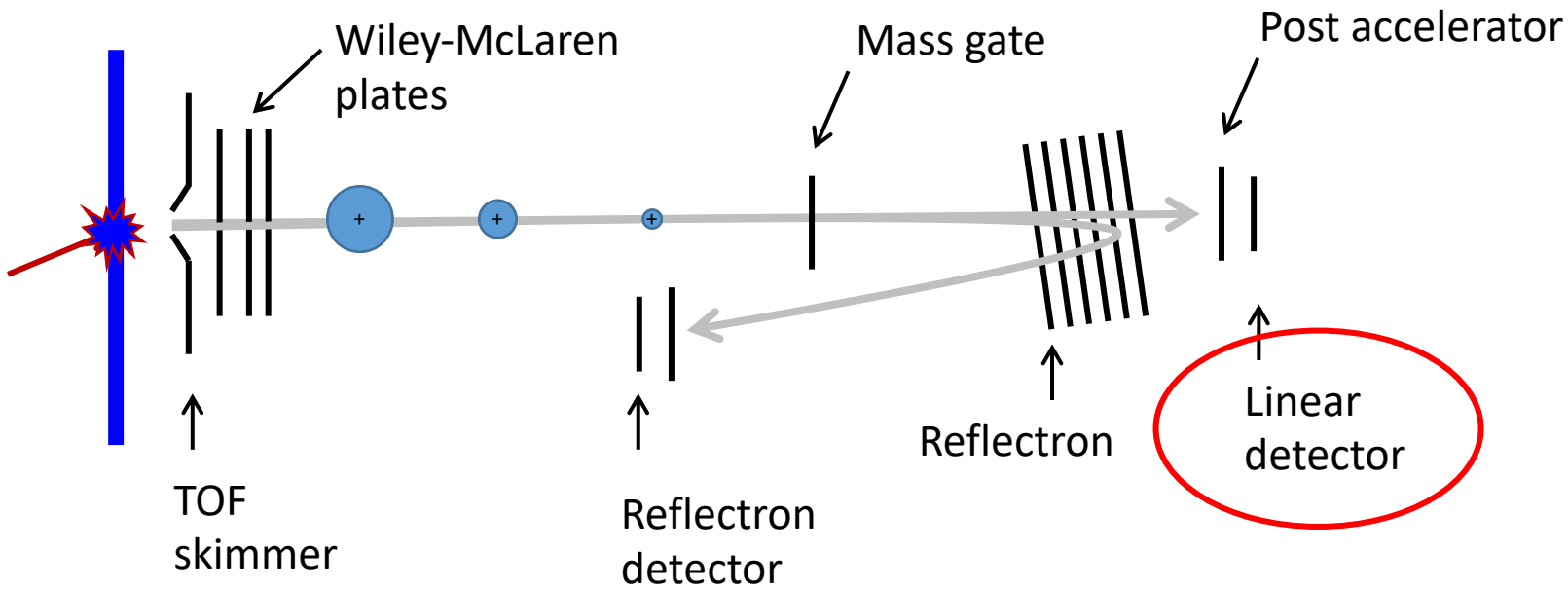
# Reproducing CDA's Data




Postberg et al. (2009) Nature, 459, 1098-1101.
Beinsen, (2008)

# Hypervelocity Ice Grain System




- Generates ice grains, hydrated clusters, and bare ions that travel at hypervelocity
  - Laser-induced ion desorption (LID) source
  - Time-of-flight (TOF) mass spectrometry

- Currently measuring LID product velocities

# Hypervelocity Ice Grain System

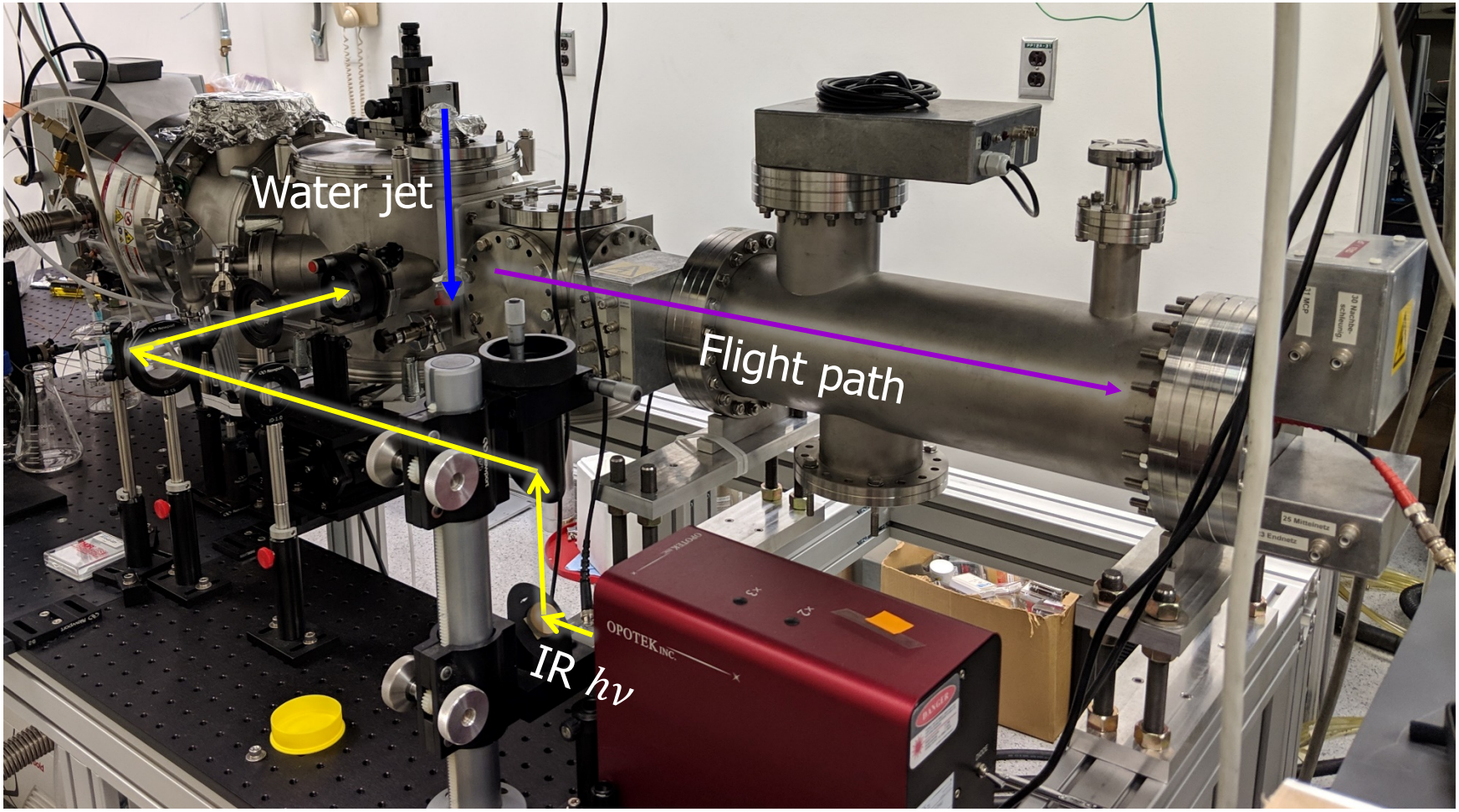
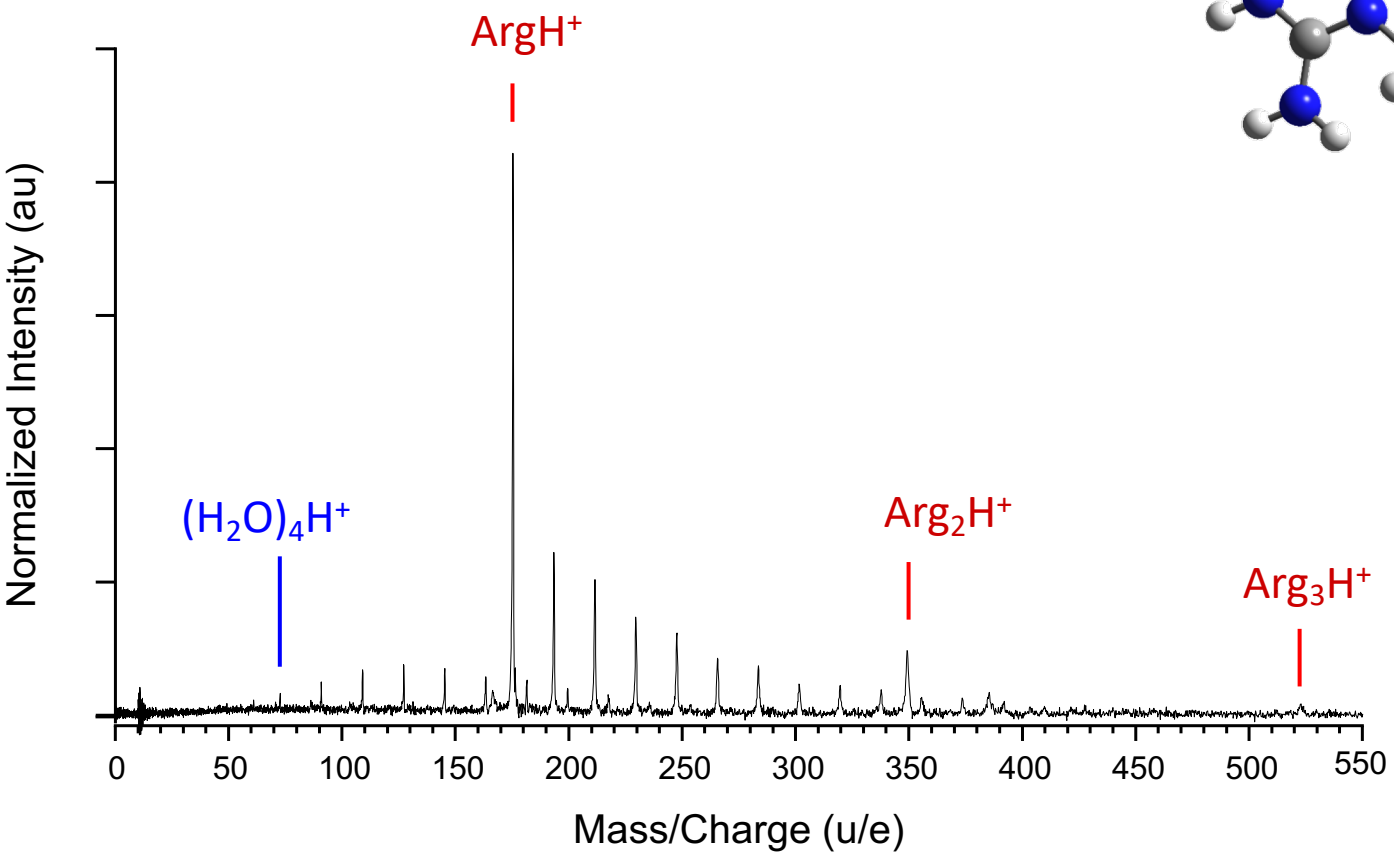
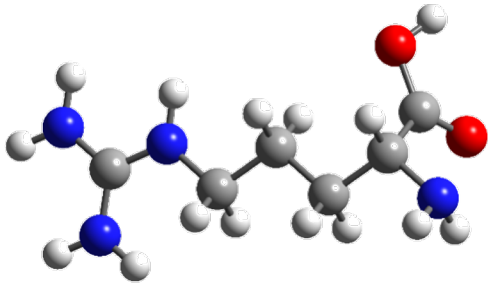


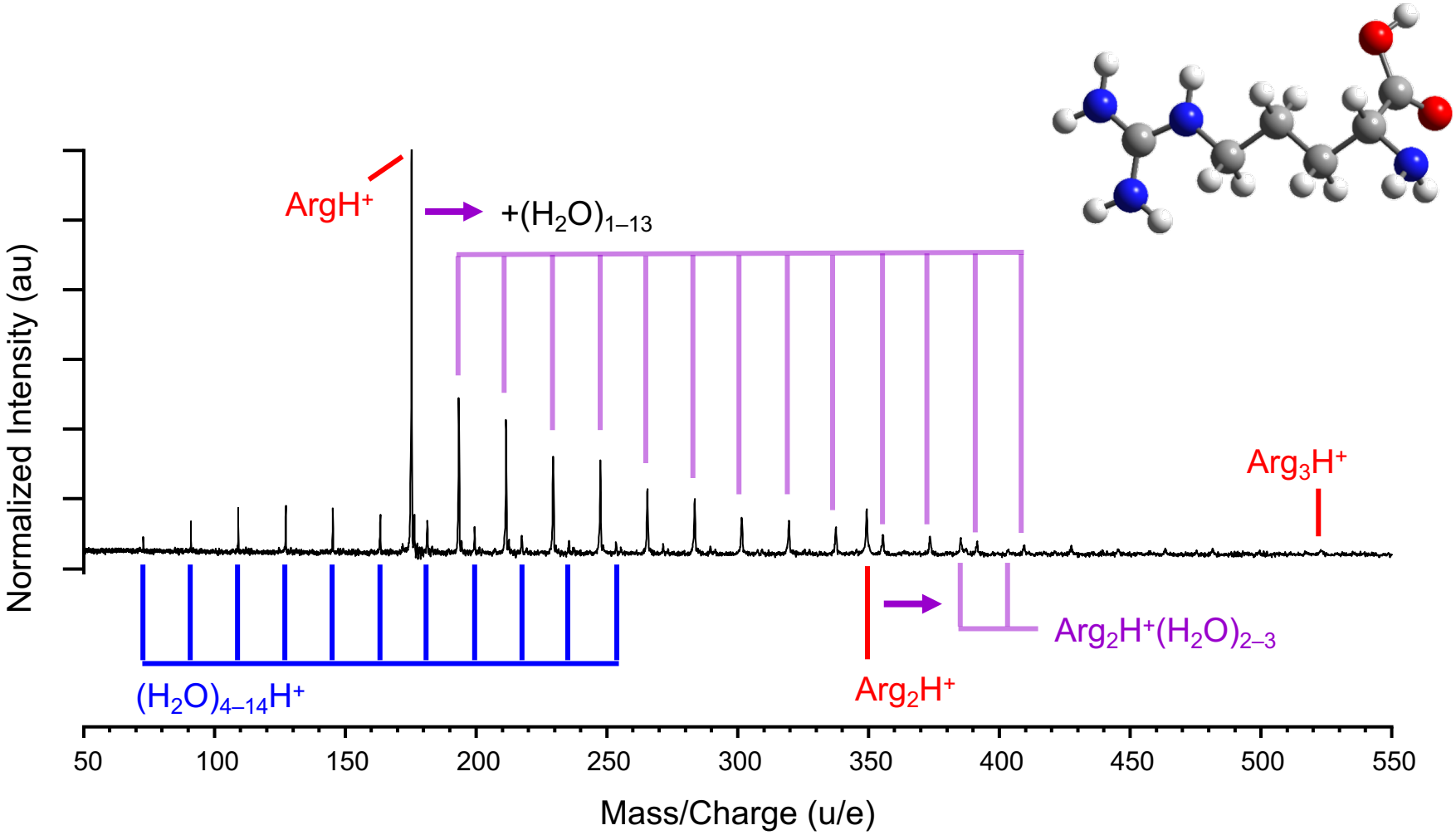

Image: Waller

# 10mM Arginine



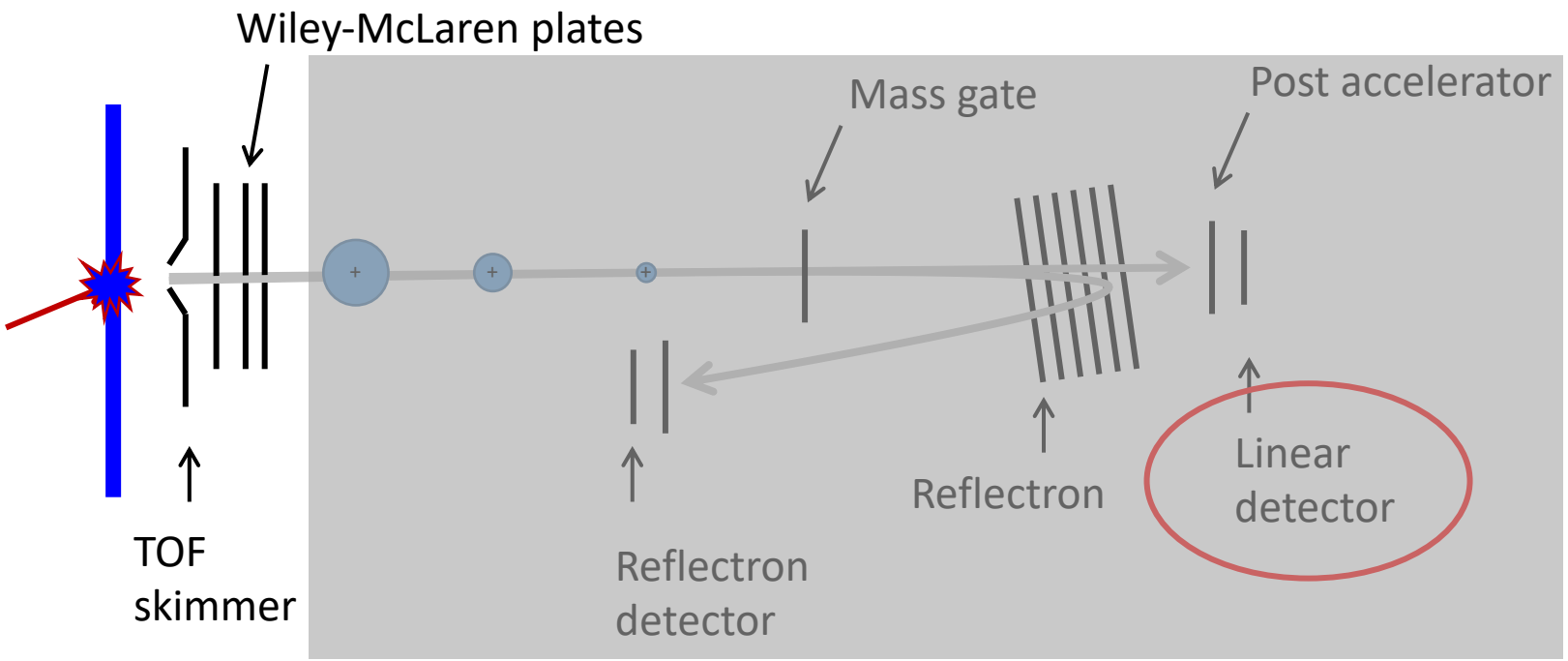
# A closer look –10mM Arg

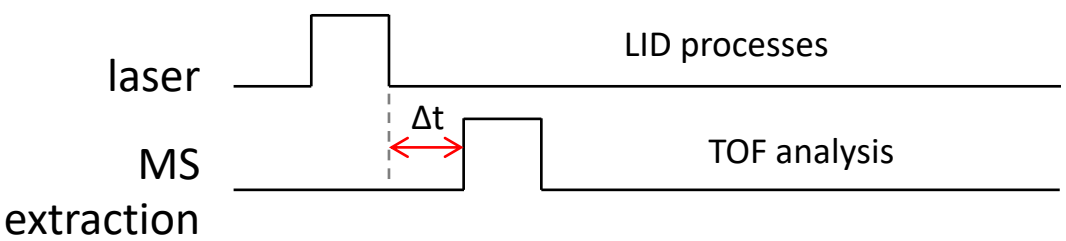


# $C_{16}$ fatty acid (Palmitic)

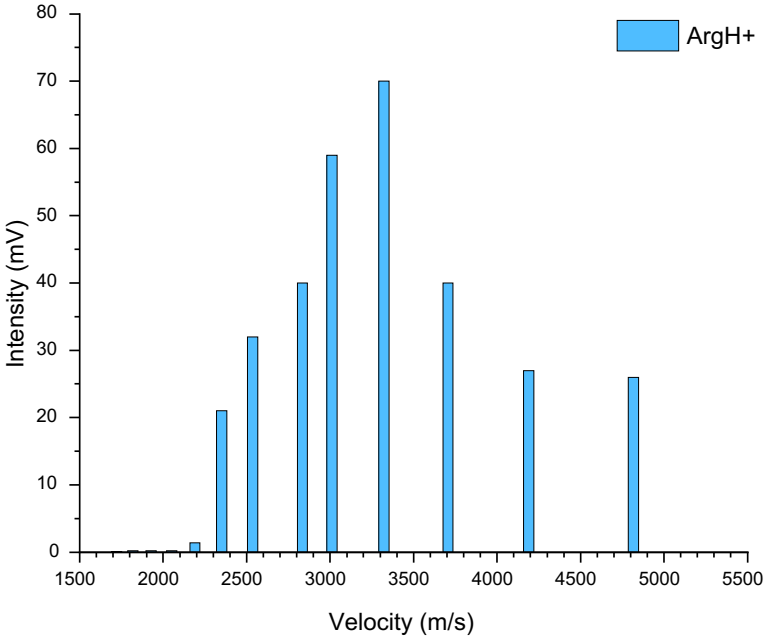
Placeholder for the fatty acid MS

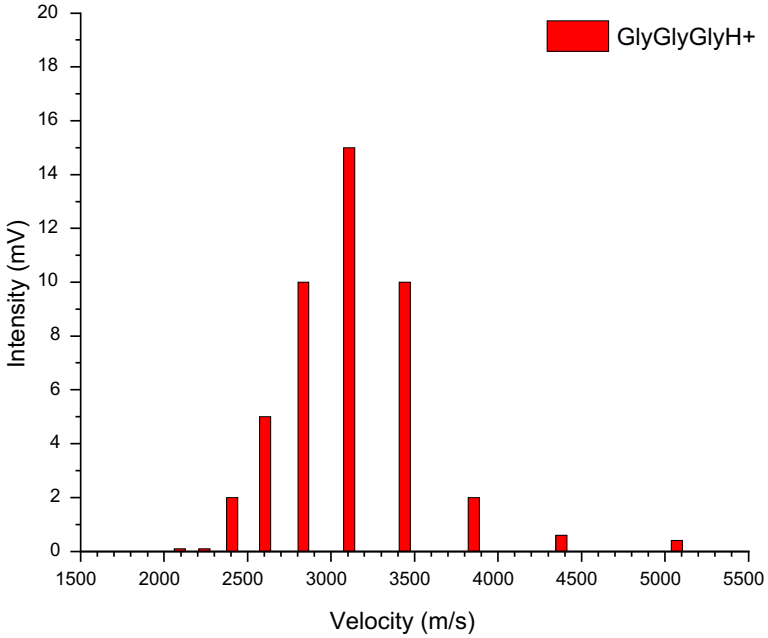
# Ion velocities



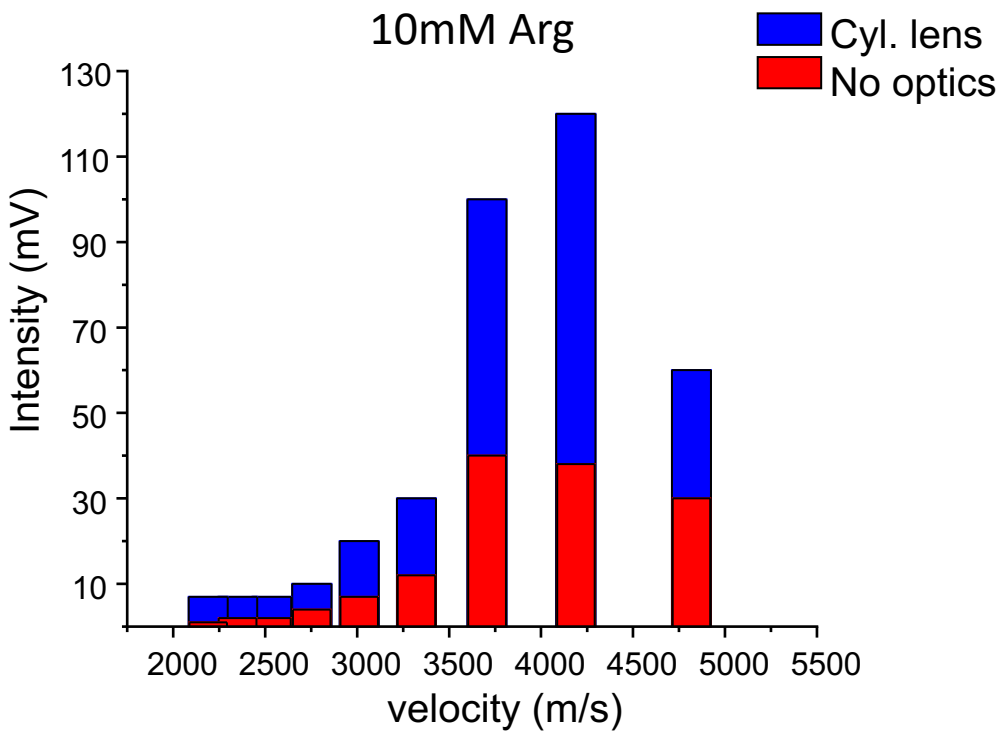
# Ion velocities –Small organics




- These are LID velocity distributions collected by monitoring a specific ion in the mass spectrum while varying the delay between the laser and the MS analysis pulse

# Ion velocities –better LID

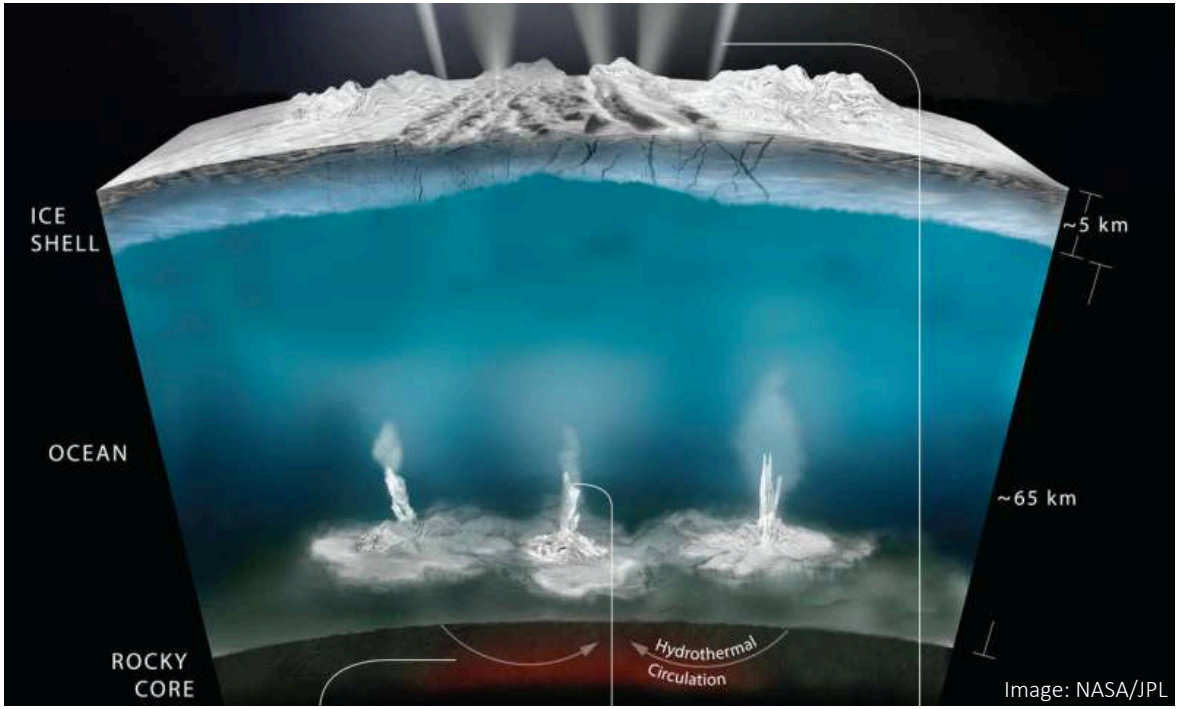



Hardware pic placeholder

Image: Waller

- Changing the laser shape yields *more* ions, not faster/slower ions

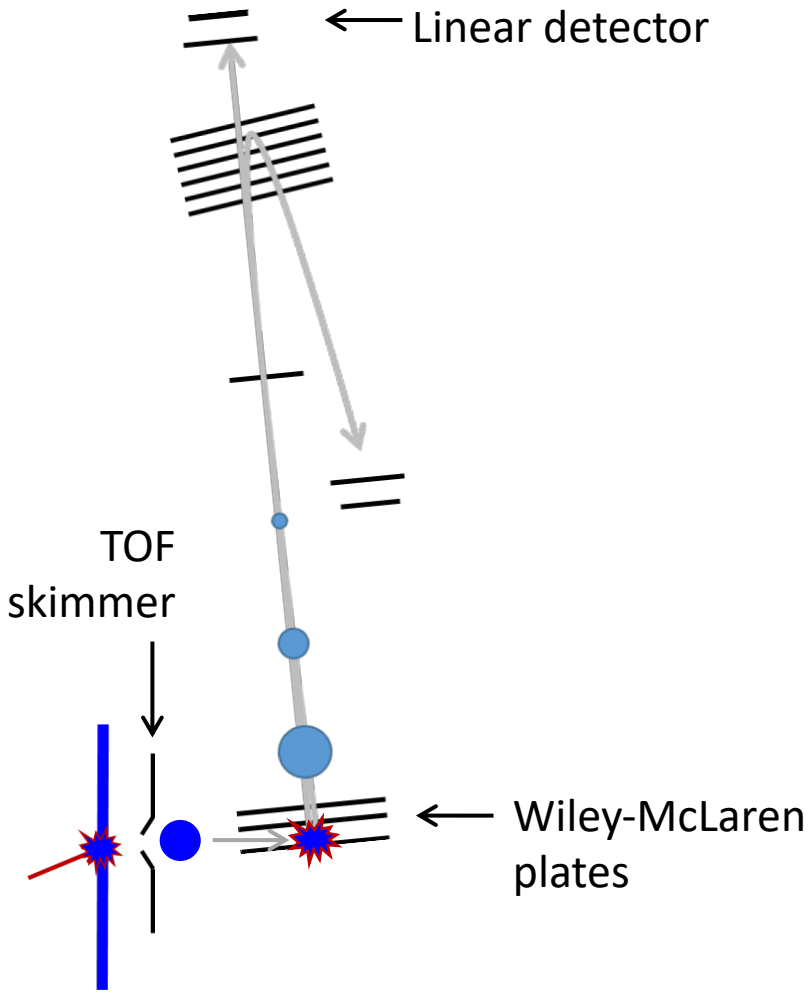
# Upcoming experiments




- Enceladus brines
  - NaCl, KCl
- Enceladus pH's (8.5-11)
  - $NaHCO_3$, $Na_2CO_3$
- Cation & Anion distributions

Glein et al. (2015) *Geochim. Et Cosmo. Acta*, 162, 202-219.
Postberg et al. (2009) Nature, 459, 1098-1101.
Glein et al. (2018) "The Geochemistry of Enceladus: Composition and Controls" in *Enceladus and the Icy Moons of Saturn*, Eds. P.M. Schenck, et al., pp. 39-56.

# Upcoming modifications




These mods will allow us to investigate post-impact MS distributions

# Conclusions

- Generate lab-based analogs to hypervelocity ice grains
- Study MS distributions after hypervelocity impacts
- Determine Goldilocks zone thresholds
- Ease mass spectral analysis of Enceladus' plume

# Acknowledgements

Hypervelocity Sampling Team:

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Josh Wiley
Bob Continetti
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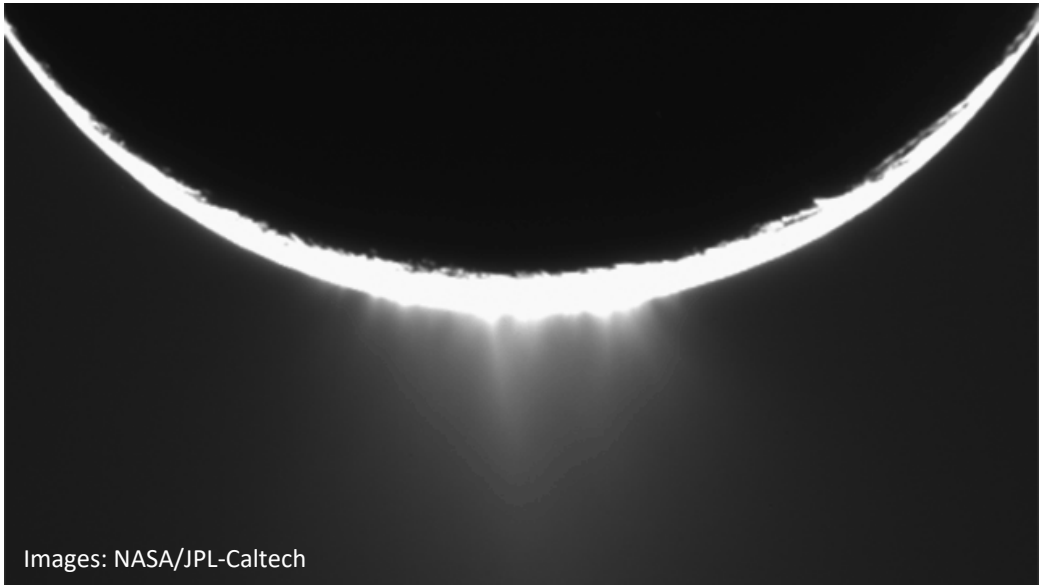
Images: NASA/JPL-Caltech

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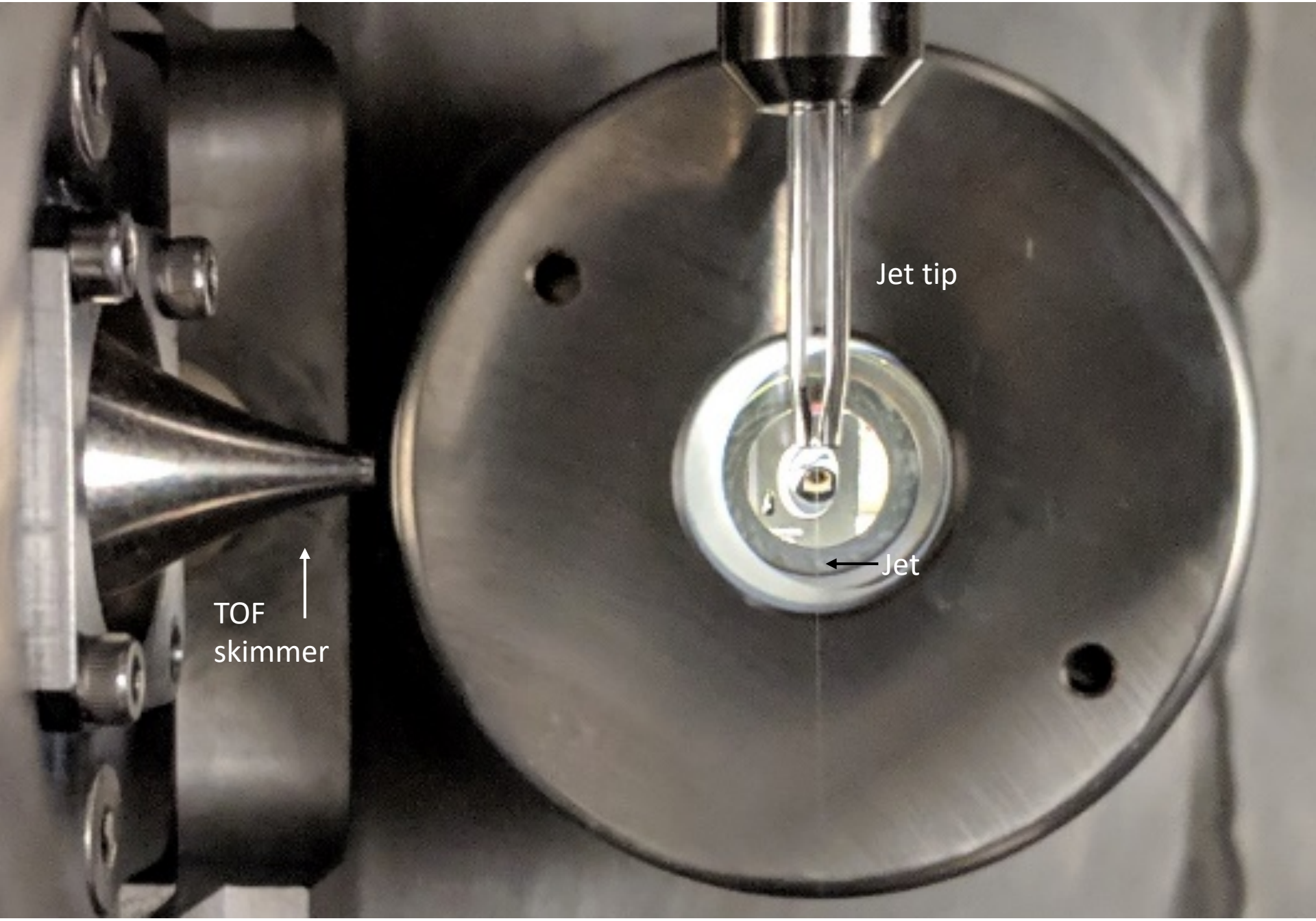
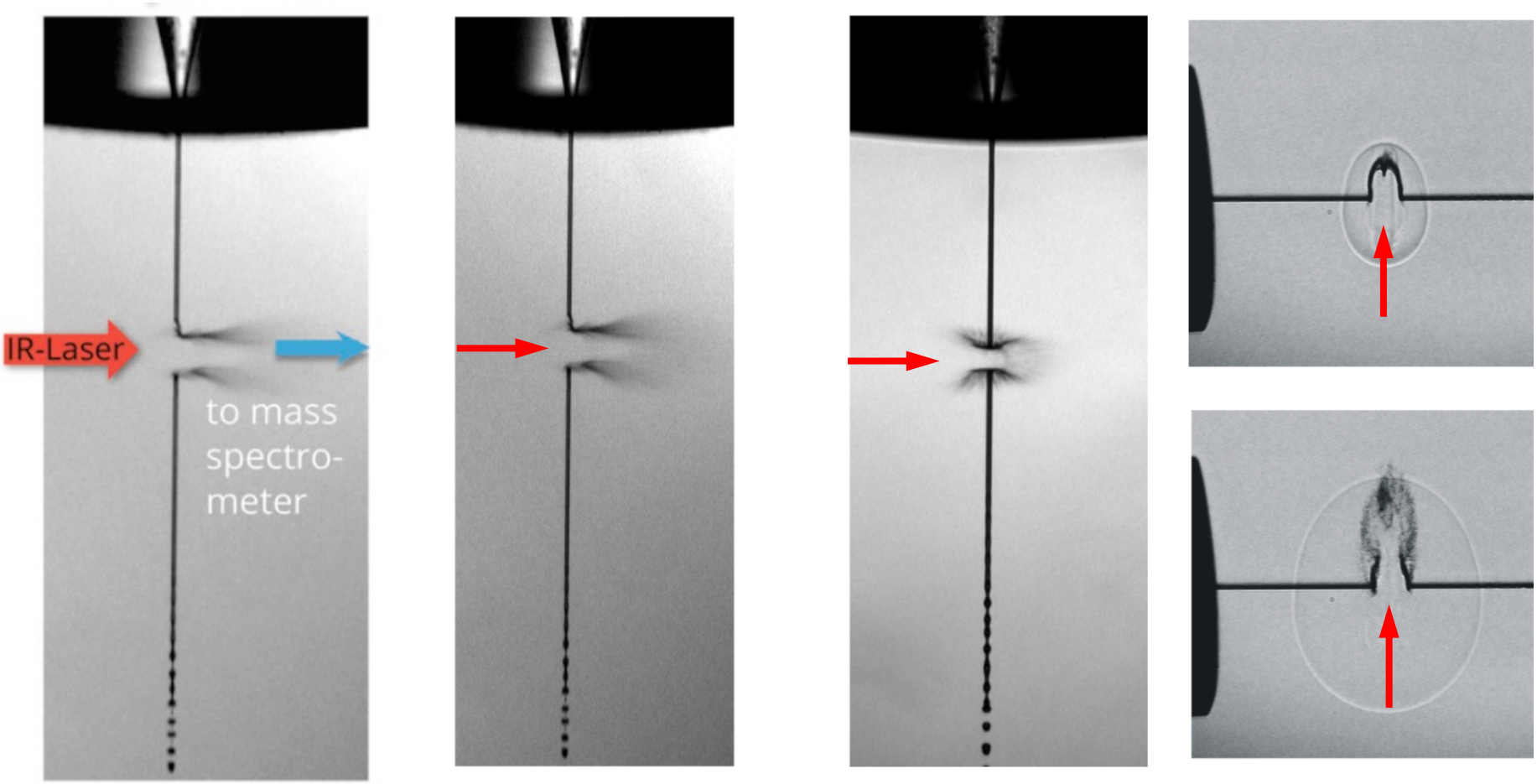



Image: Waller

# Laser induced desorption




Wiederschein et al. (2015) PCCP, 17, 6858-6864.

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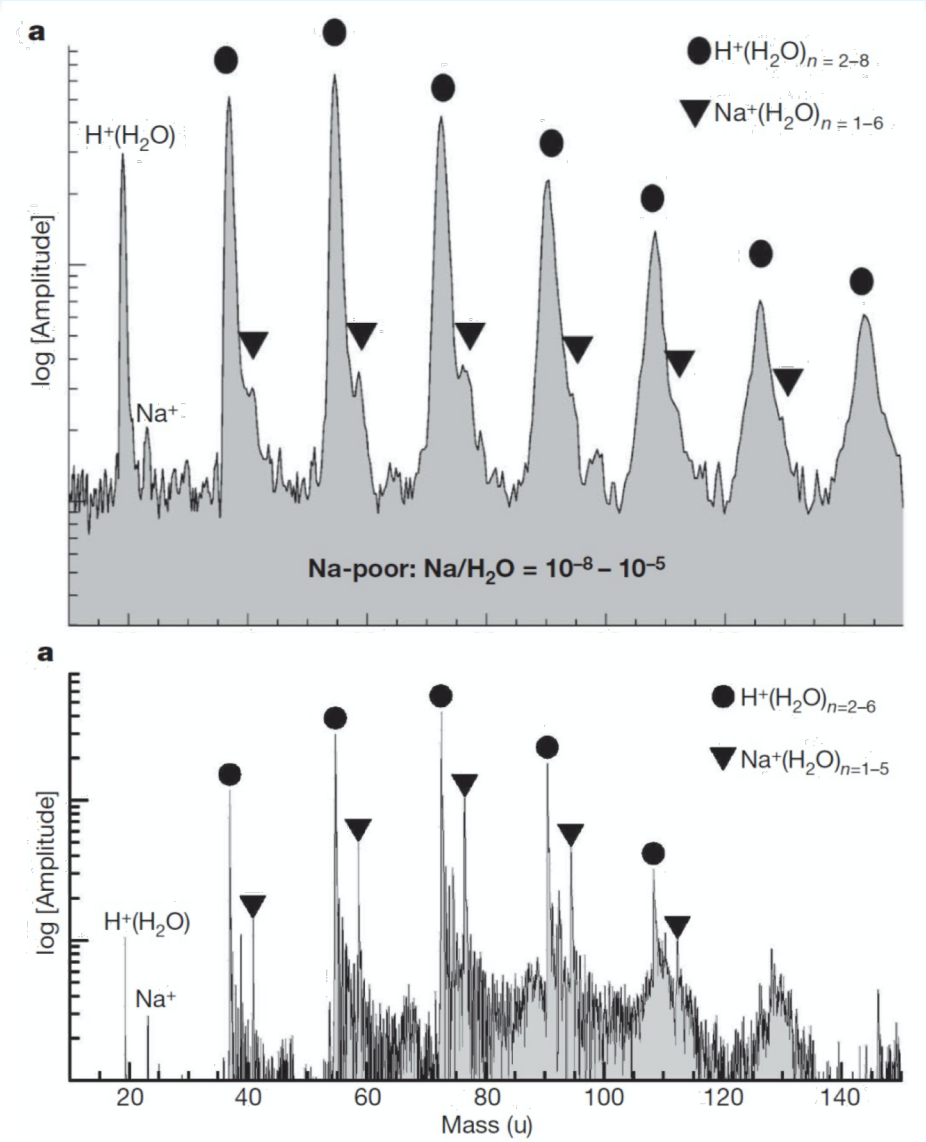


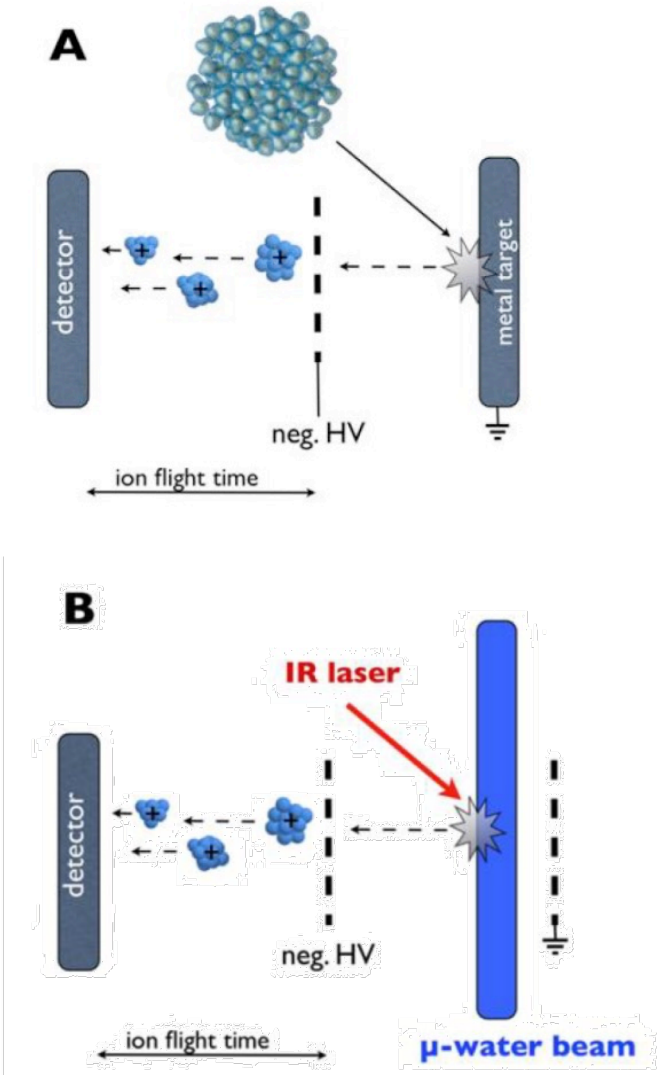


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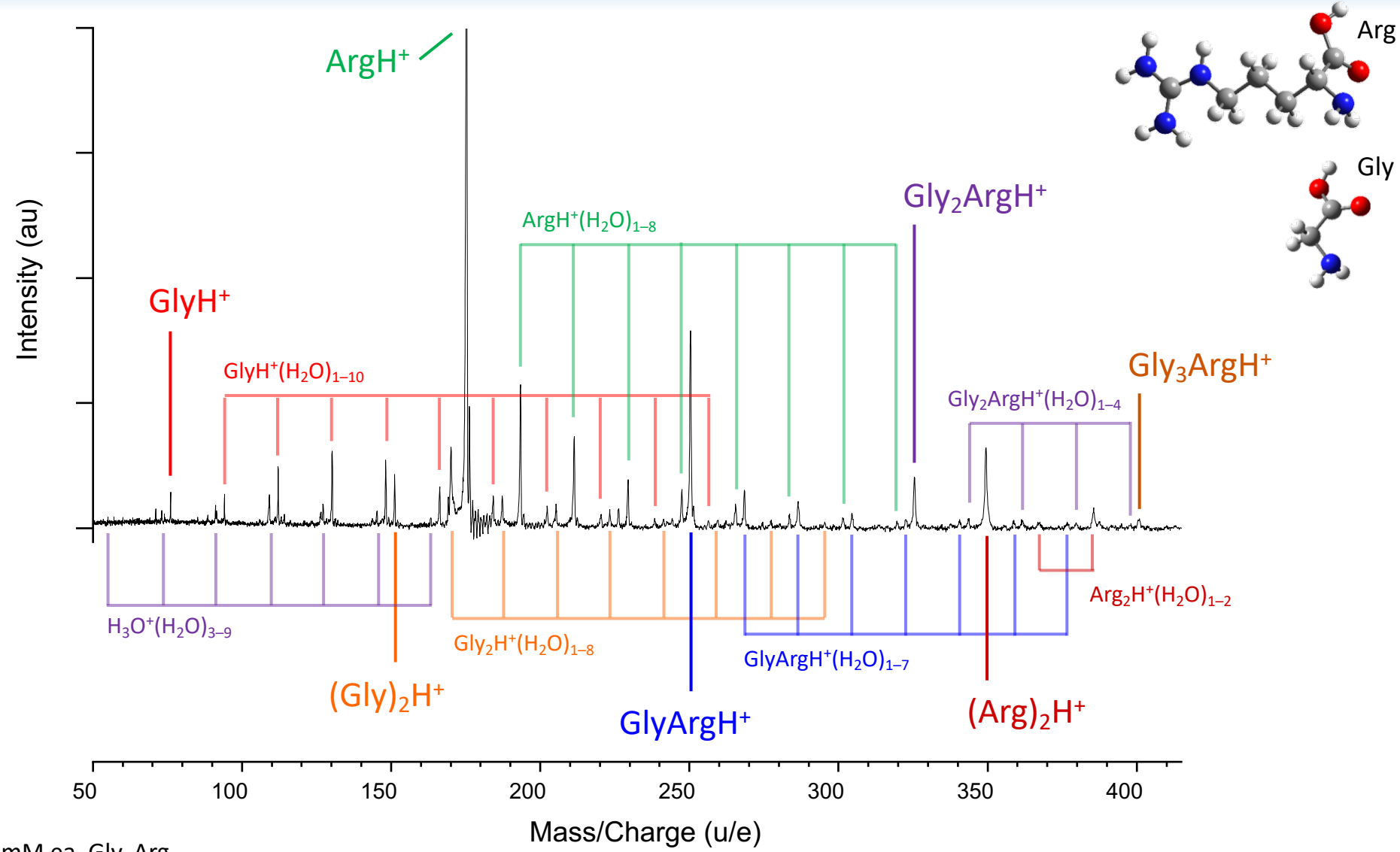
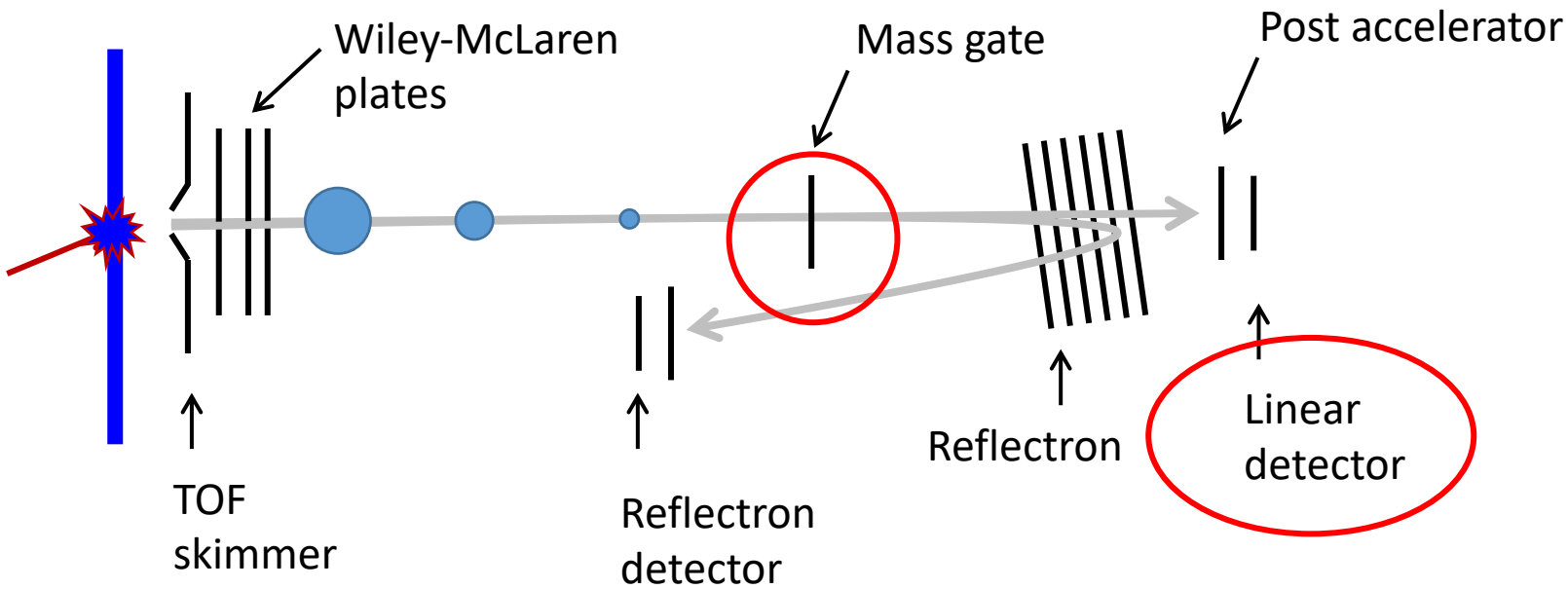
Beinsen, (2008)

# Glycine/Arginine mixture




5 mM ea. Gly, Arg

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