Micro-Thruster Plume Characterization

Modeling neutral molecules in EMI-BF4 plume in an effort to extend the lifetime of electrospray thrusters from weeks to years

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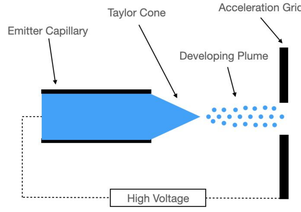
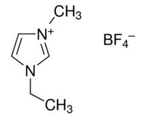
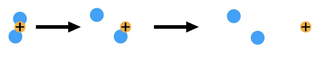
Motivation

Electrospray thrusters are an attractive choice for applications where onboard mass and mission longevity are of concern such as drag compensation in LEO for internet constellations, deep space cubist missions, and LISA, the gravitational wave observatory. For **Ionic liquid ion source (ILIS)** electrospray however, **fragmentation** of ions causes **neutrals** to develop in the plume, which can have **lifetime limiting effects**.

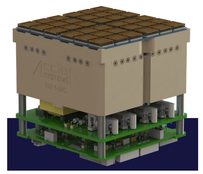




Propellants are organic liquid salts

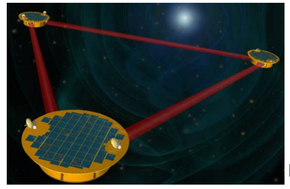


Fragmentation of EMI-BF4 trimer yielding two neutrals and one monomer



[1]

Accion's TILE 3, capable of 1650s ISP and a maximum thrust of 0.45mN, fitting in only 1U

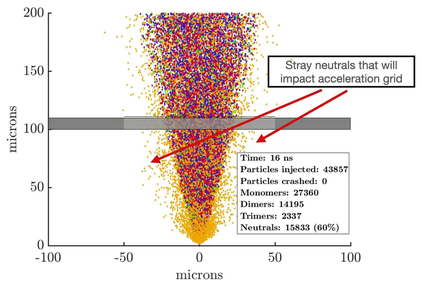


[2]

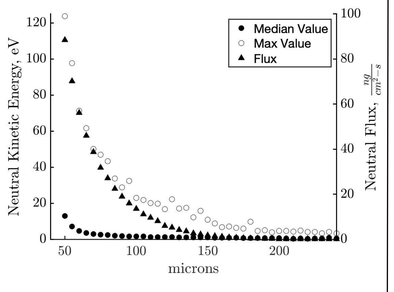
Laser Interferometer Space Antenna (LISA)

N-body Simulation

A novel **simulation** is built to track **neutrals** that are created as a result of **fragmentation of accelerated ions**. **Neutral energies and fluxes** can then be predicted throughout the electrospray plume.



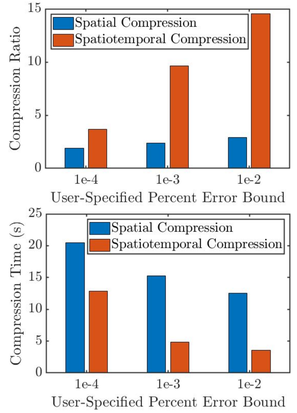
Electrospray plume simulation



Predicted impact energies and fluxes of neutrals striking the acceleration grid

Data Compression

Currently, the **N-body simulations** can output over **100 GB** of data, which will grow with more advanced simulations. We are studying **data compression** techniques to aid in storing results more efficiently, and initial tests result in a file **size reduction of almost an order of magnitude**, improving upon other techniques by over a factor of three.



Comparison of the average compression ratio and compression time of a single snapshot

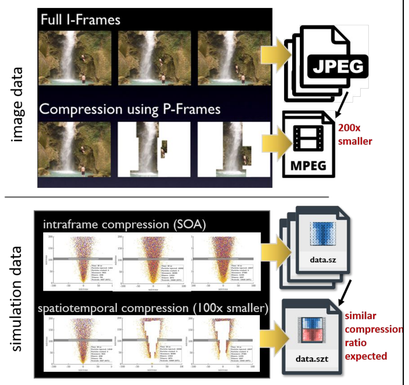


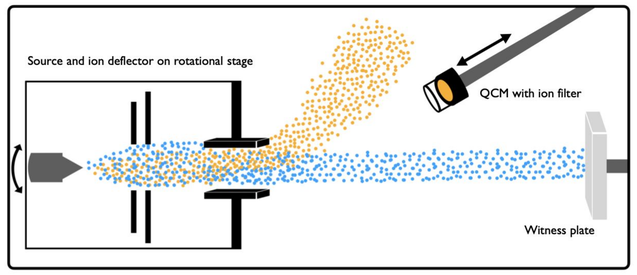
Image compression and analogous n-body compression techniques

Typically, N-body simulation data is compressed with **spatial compression**, which is analogous to compressing each frame of a video as a JPEG. **Spatiotemporal** compression draws inspiration from MPEG compression, which extends JPEG compression to video files by **only updating new information between frames**. **Spatiotemporal compression uses the physics of the simulation to predict particle movement through time, and only store new or unpredictable information.**

Experimental Validation

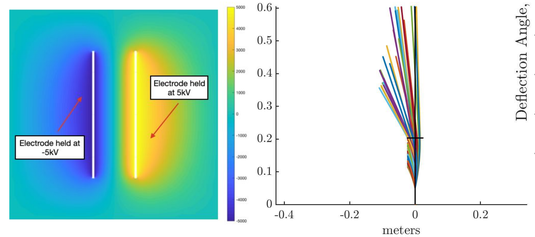
First ever measurement of neutral portion of the plume

We aim to experimentally characterize the energy and deposition rates of neutrals in an EMI-BF4 plume using a **quartz crystal microbalance (QCM)**, something which has **never been done before**.



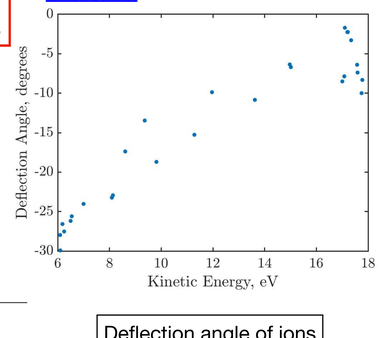
Experimental setup

We will build an **energy based deposition model** by deflecting ions in such a way that a section of the deflected ion plume will have a **known energy range.**



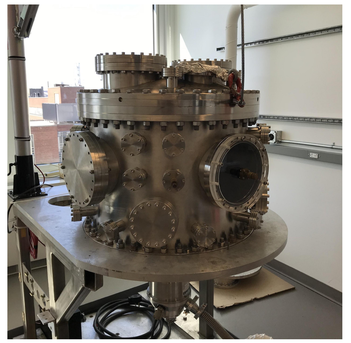
Parallel plate model with propagated ions

https://cornell.zoom.us/j/93579204330?pwd=VEx3TmJ6N09VWXU5bWRhRHZLNmdsQT09

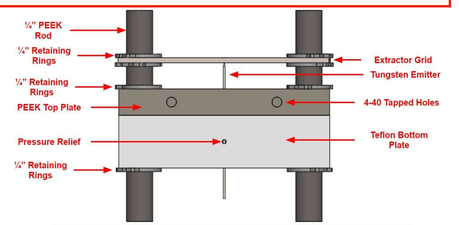


Deflection angle of ions

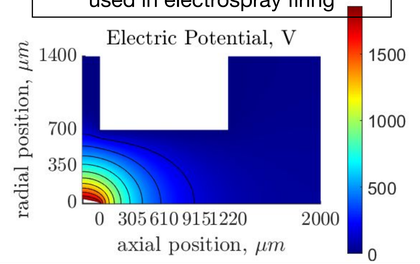
Our ion source uses an **externally wetted, electrochemically sharpened tungsten needle** and **grounded extractor grid.**



ASTRA Lab vacuum chamber



Front view of ion source that will be used in electrospray firing



Model of the electric potential near emitter tip

Thank you to our sponsors and collaborators

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