# Resolving M/q ambiguity on space based ESA-TOF instruments

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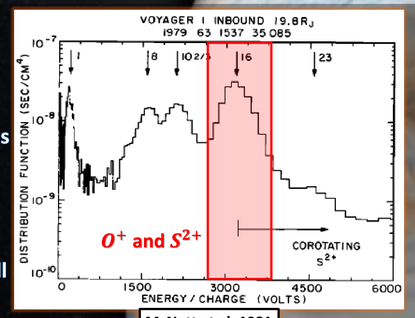
## 1. Abstract

Instruments comprising of an ESA, TOF mass spectrometer are commonly used in space applications to measure energetic multi-ion plasmas in space environment. Measurements from such instruments provide ion species determination and energy spectrograms for individual ion species. However, species with similar M/q (e.g. $O^+$ and $S^{2+}$ in the Jovian magnetosphere), can raise ambiguity in the TOF measurements. In this study, we introduce an analysis technique to resolve this issue on ESA-TOF instruments. Our case study with JADE-I instrument onboard NASA's Juno Mission show that M/q ambiguity may be resolved for atomic ions.

## 2. Motivation

- Voyager and Galileo revealed species with $M/q \approx 16$ in the Jovian magnetosphere.
- These species are identified as $O^+$ and $S^{2+}$ which are considered as major ions in the Jovian magnetosphere.
- Relative abundances are studied with physical assumptions due to M/q ambiguity.
- Resolving M/q ambiguity on JADE-I will improve our knowledge on the Jovian magnetosphere.

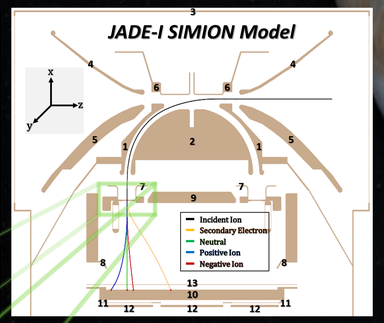



McNutt et al. 1981

## 3. Simulation Model and Carbon Foil Effects

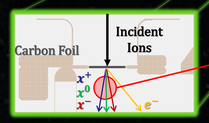
Carbon foils are used to give start pulse to the TOF mass spectrometers via secondary electron emission. Other carbon foil effects include charge state yield, energy loss of incident ions. By characterizing these effects for each voltage step $V_{ESA}$ and individual ion species, better mass determination can be achieved.

| PA # | Description |
|---|---|
| 1 | Outer ESA |
| 2 | Inner ESA |
| 3 | Instrument Housing |
| 4 | Deflector-Up |
| 5 | Deflector-Down |
| 6 | Top Plate of ESA |
| 7 | Post Acceleration (Harp) |
| 8 | TOF Grid |
| 9 | Disc Shield |
| 10 | Chevron Stacked MCP |
| 11 | Suppression Grid for Anode |
| 12 | Anode |
| 13 | Suppression Grid for MCP |




**ESA Section**
- Allow incident ions with specific E/q.
- 1 keV $O^+$ and 2 keV $S^{2+}$ have same E/q.

**TOF Section**
- Measure of M/q (or TOF) of Incident ions.
- $O^+$ and $S^{2+}$ have similar M/q.

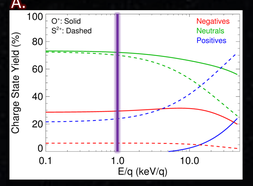



Carbon Foil Effects on transmitted ions

A. Charge State Yield → Gonin's Model → $Q_{Residue}$
B. Angular Scattering → Meyer's Theory → $\theta_{Scattered}$
C. Energy Loss → SRIM 2013 → $E_{Residue}$

→ Randomly Coupled per incident ion

A.

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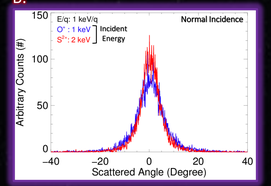
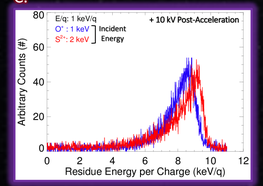
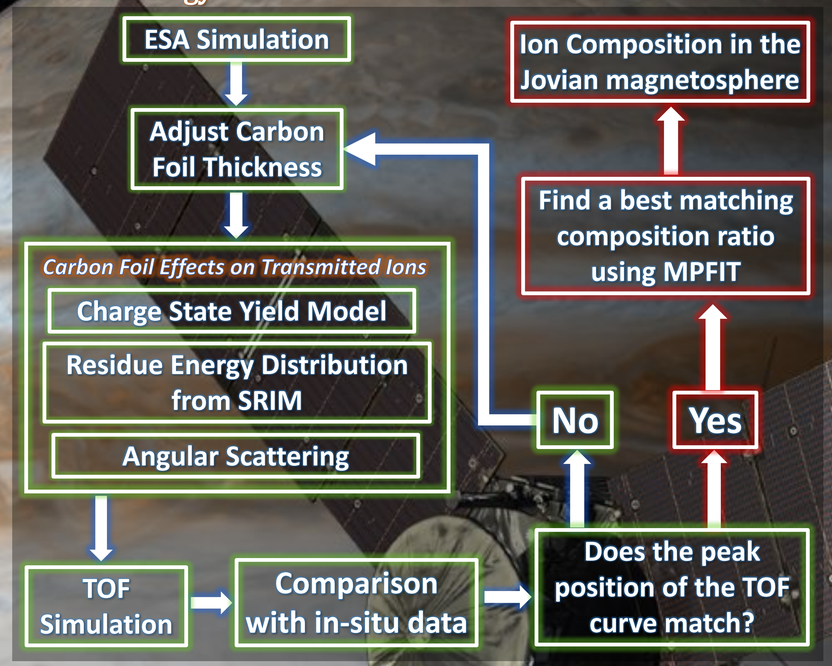



C.

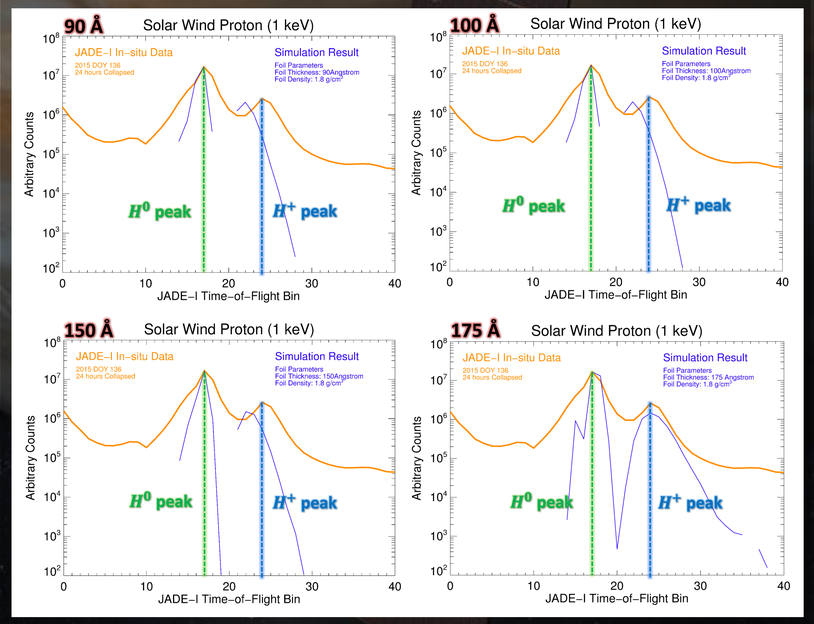



## 4. Methodology




## 5. Foil Thickness Determination

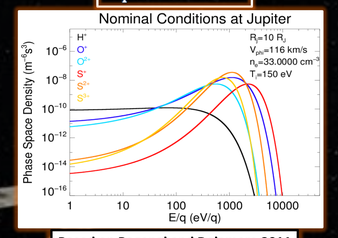
Carbon foil effects on transmitted ions vary with thickness.
We compared the simulation results with JADE-I in-situ measurements to estimate the average thickness of carbon foils that are used in JADE-I.




## 6. Estimated Response of JADE-I at 10 $R_J$ from Jupiter

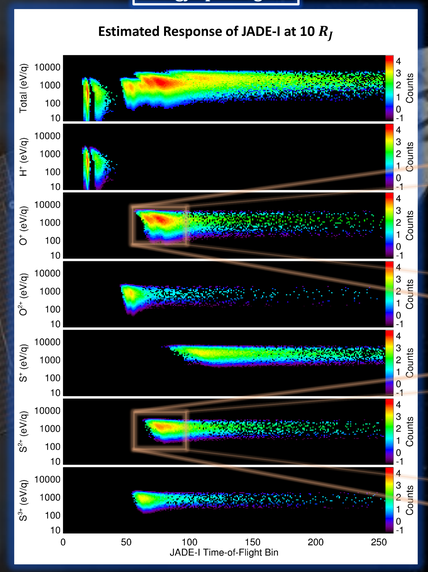
*JADE-I Simulation Model*

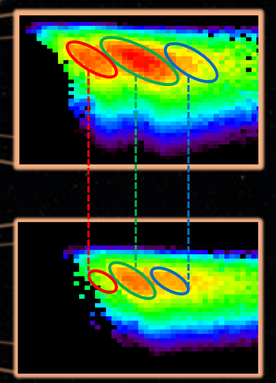
Input Distribution: Nominal Conditions at Jupiter



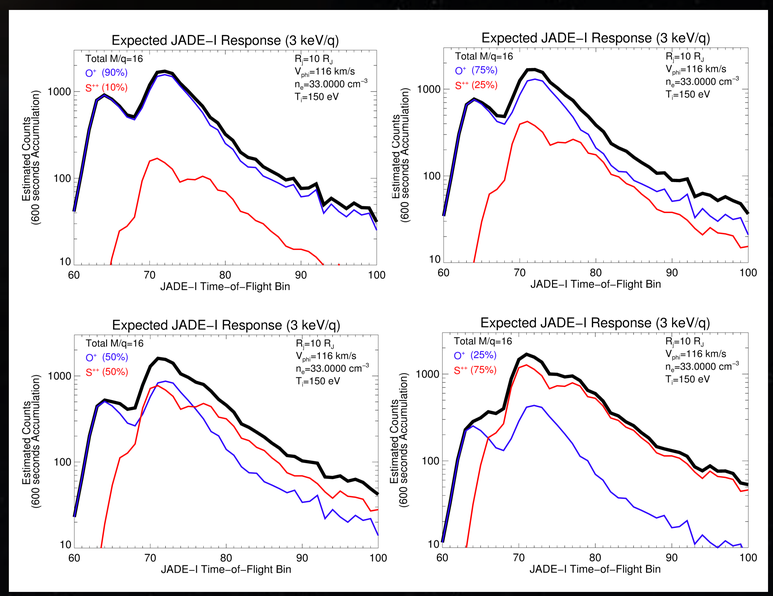

Based on Bagenal and Delamere 2011

Energy Spectrogram




## 7. Various Abundance Ratios of $O^+$ and $S^{2+}$ ($M/q \approx 16$)




## Acknowledgements

This work is supported by NASA Contract No. NNM06AA75C.
Visit https://www.missionjuno.swri.edu/ for more information about NASA's Juno mission to Jupiter.

## References

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