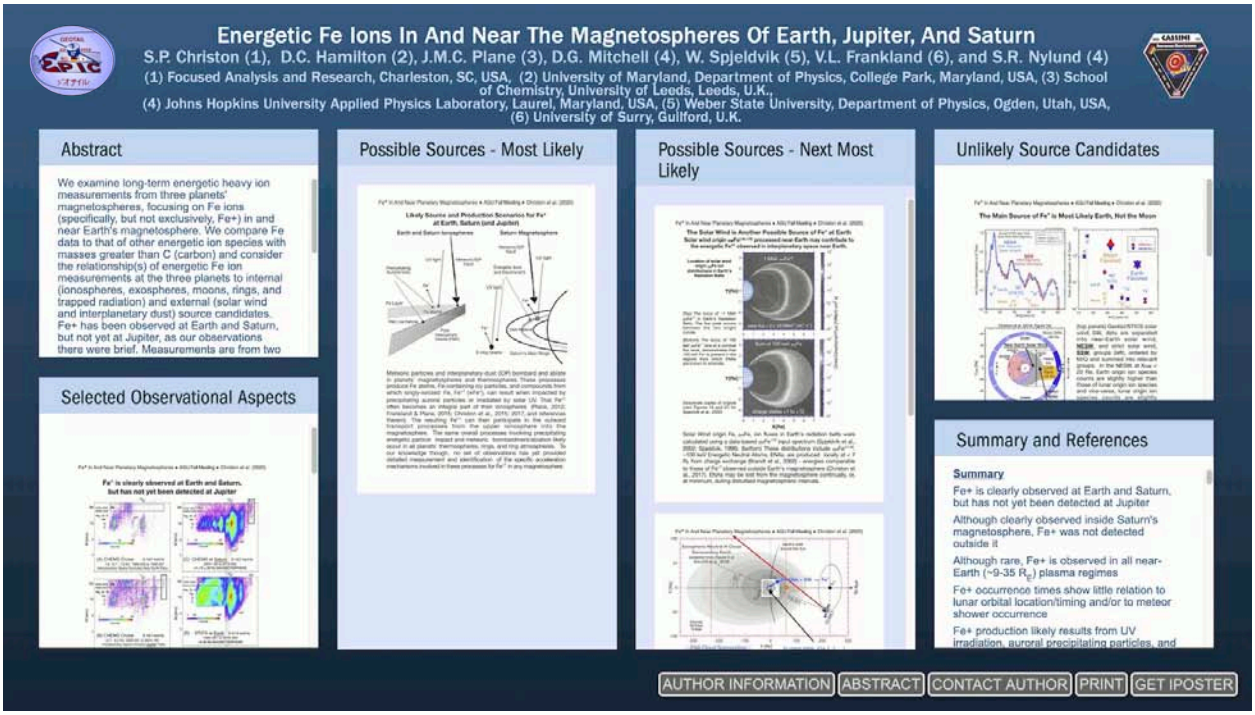
Energetic Fe Ions In And Near The Magnetospheres Of Earth, Jupiter, And Saturn



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ABSTRACT

We examine long-term energetic heavy ion measurements from three planets' magnetospheres, focusing on Fe ions (specifically, but not exclusively, Fe+) in and near Earth's magnetosphere. We compare Fe data to that of other energetic ion species with masses greater than C (carbon) and consider the relationship(s) of energetic Fe ion measurements at the three planets to internal (ionospheres, exospheres, moons, rings, and trapped radiation) and external (solar wind and interplanetary dust) source candidates. Fe+ has been observed at Earth and Saturn, but not yet at Jupiter, as our observations there were brief. Measurements are from two functionally identical charge-energy- mass ion spectrometers: one on Geotail (~87-212 keV/e), orbiting Earth at ~9-30 Re; and the other on Cassini (~83-167 keV/e), in interplanetary space, during Jupiter flyby, and at ~4-20 Rs on its constantly varying orbits around Saturn. These ion spectrometers efficiently separate energetic light and heavy ions by mass, as well as lower charge state ions from higher charge state ions by mass-per-charge. Energetic low-charge-state ions often derive from magnetospheric sources, while energetic high-charge-state ions most often derive from the solar wind. Data from Geotail locations in the near Earth solar wind indicate that Earth, not the Moon, is the likely Fe+ source. Heavy ion measurements from AMPTE/CCE, closer to Earth, are used for C and Fe radiation-belt-modeling content, consideration, and estimation.

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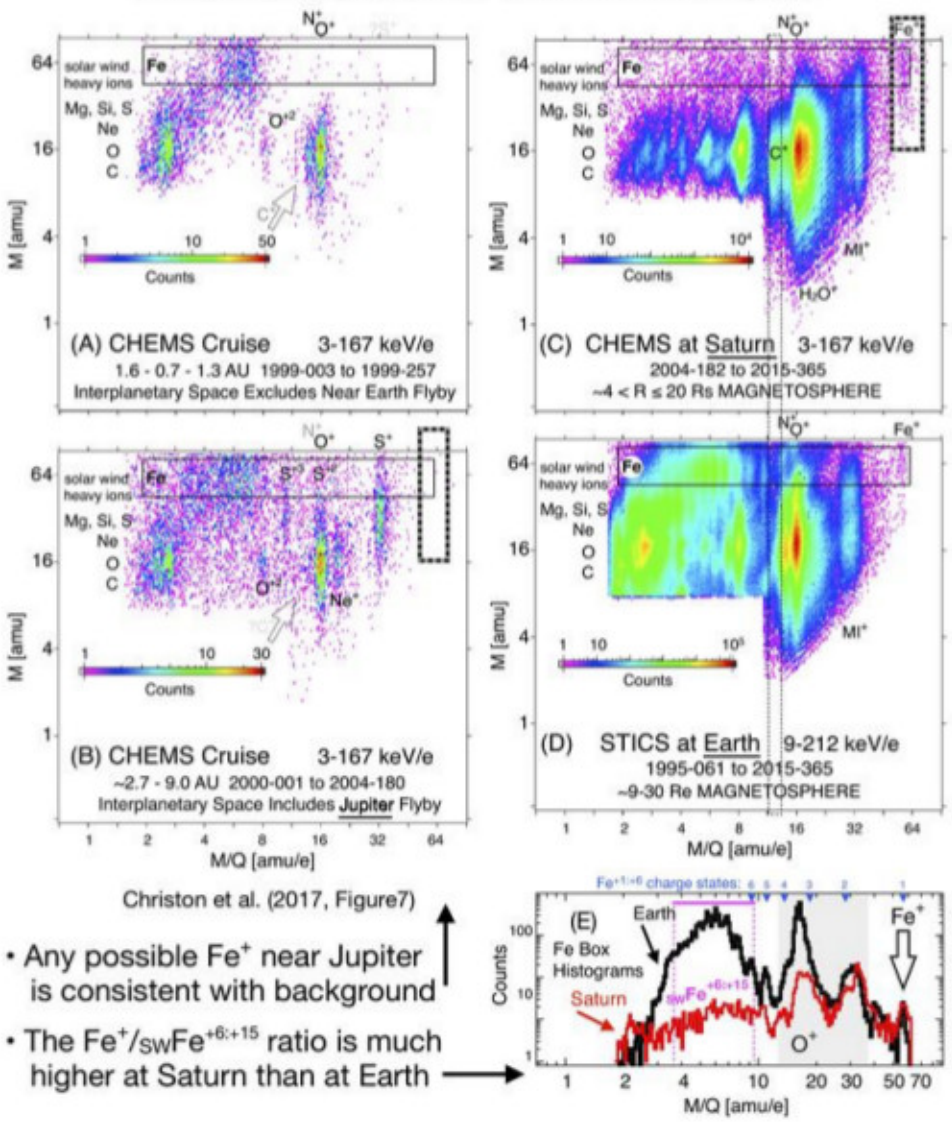
SELECTED OBSERVATIONAL ASPECTS

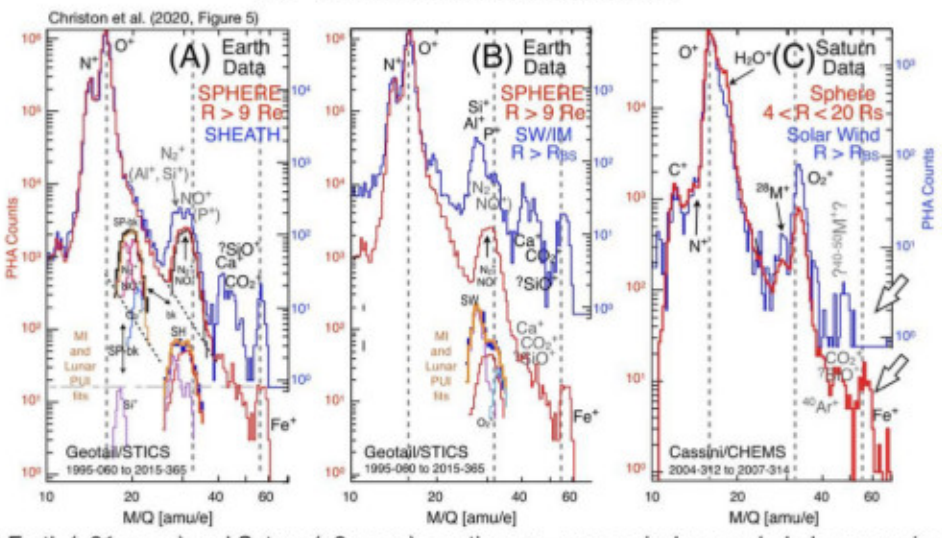
Fe+ is clearly observed at Earth and Saturn, but has not yet been detected at Jupiter



Christon et al. (2017, Figure7)

- Any possible Fe^+ near Jupiter is consistent with background
- The $Fe^+/_{SW}Fe^{+6:+15}$ ratio is much higher at Saturn than at Earth

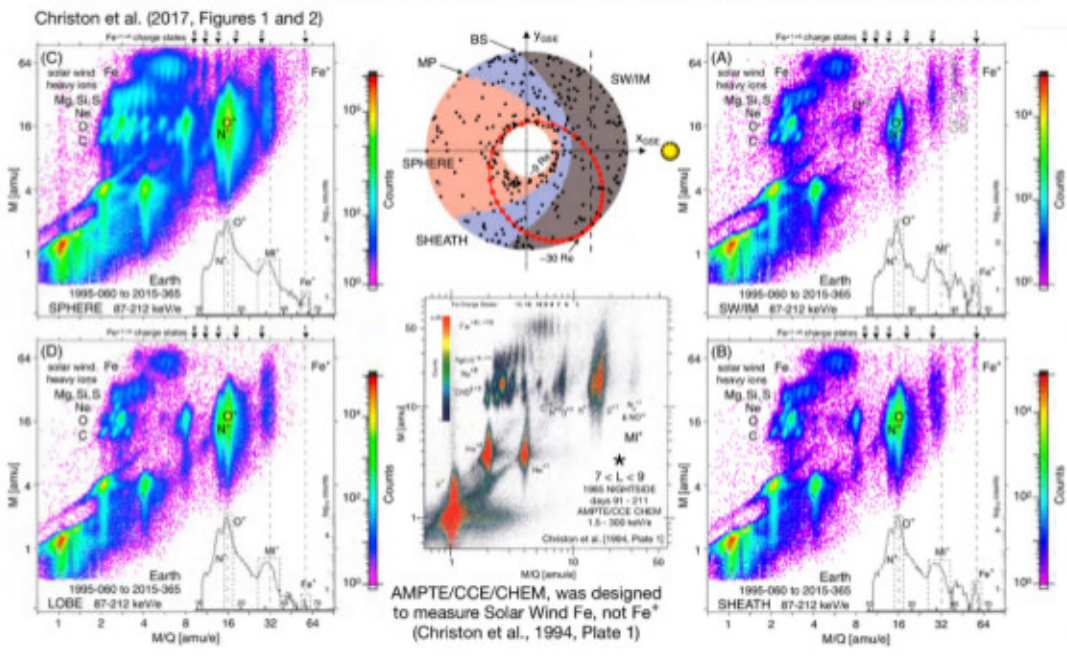
Although clearly observed inside Saturn's magnetosphere, Fe+ was not detected outside it



- At Earth (~21 years) and Saturn (~3 years), continuous, successively-sampled plasma regime intervals of Solar Wind (Sheath) and Sphere are compared
- No Fe^+ was measured outside Saturn's magnetosphere during these intervals (right panel)
- A lack of Fe^+ escape from Saturn's magnetosphere might result from internal dynamics or its size. In contrast, other unique internal heavy-ion species escape (i.e., $^{28}M^+$, O_2^+, $?^{40\text{-}50}M^+?$)

Although rare, Fe+ is observed in all near-Earth (~9-35 R_E) plasma regimes

Christon et al. (2017, Figures 1 and 2)



Q: Is Fe^+ The Only Ion Observed At M/Q > 50 amu/e?

PHA M/Q histograms (with eyeball-fit ellipses) compare ion data at:

Saturn : red, R < 20 Rs.....2004-181 (SOI) to 2013-365; and

Jupiter : blue, bow shock-to-sheath.....2000-363 to 2001-091.

For the molecular ions $^{28}M^+$, O_2^+, and CO_2^+ (?or SiO^+), nearly equal-mass atoms, gray bars extend from the ion's true M/Q to its peak's M/Q centroid location which is found at higher M/Q - as the molecular ion's energy losses are higher than those of its independent atomic ions, resulting in a lower time-of-flight.

$^{59}Co^+$ and $^{59}Ni^+$, likely IDP products, may be present at M/Q ~ 60 amu/e

*or possibly $H^+(H_2O)_3$, as suggested by Cassini/CDA (Postberg et al., 2018)

A: Probably Not At Saturn!