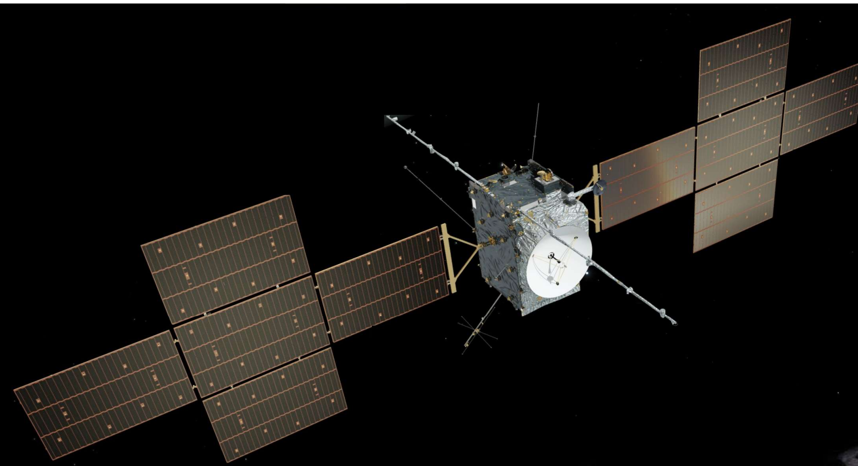

Imaging of Ganymede through Energetic Neutral Atoms sputtered/backscattered from the surface

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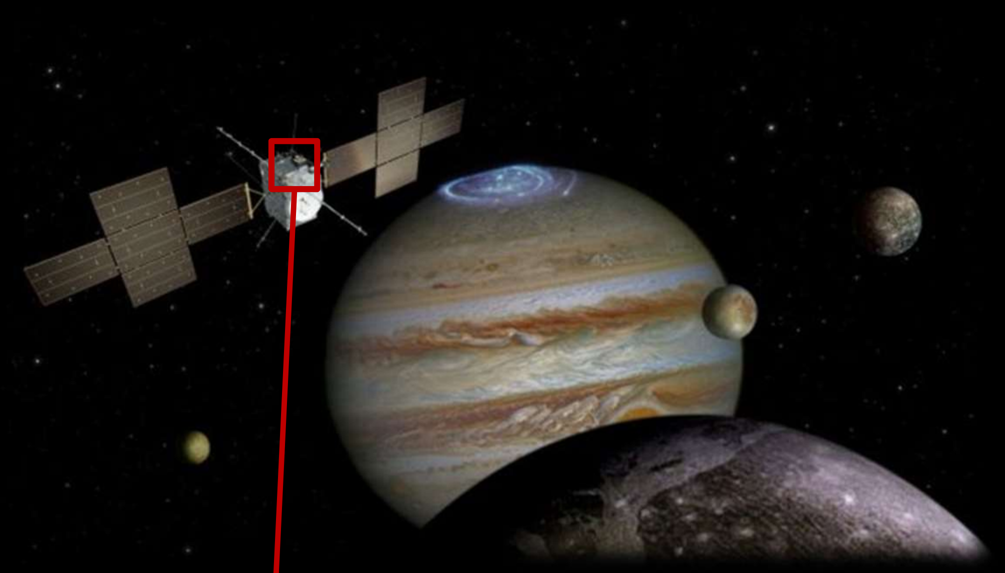
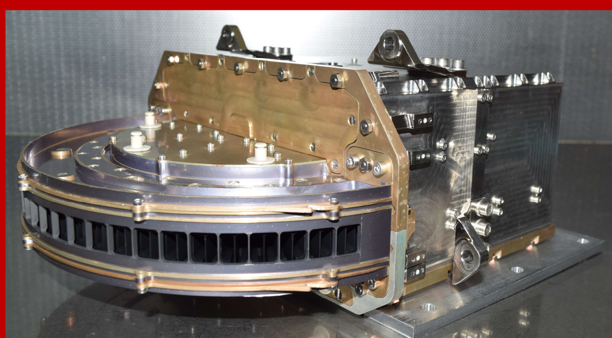
BACKGROUND



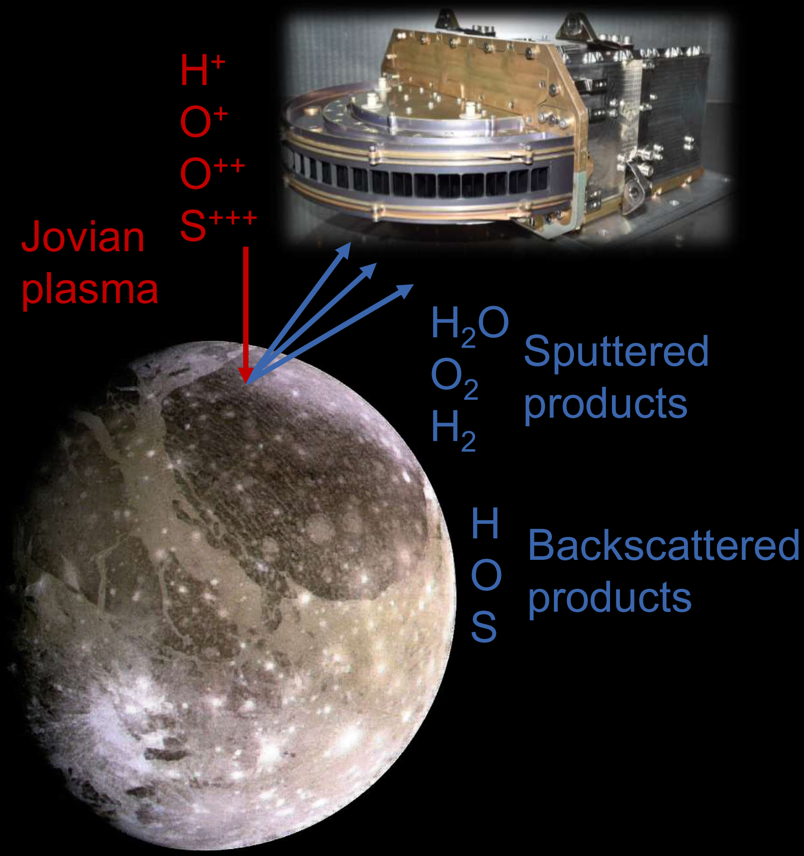
- The **JUICE** spacecraft will investigate **Jupiter and its icy moons** in the 2030s, with a **focus on Ganymede**
- Onboard JUICE, the **Jovian Neutrals Analyzer (JNA)** will measure low energy **Energetic Neutral Atoms (ENAs)**



JNA specifications

Energy range	Energy resolution dE/E	Mass range	Masses resolved	Field-of-View	Angular resolution	Time resolution
10 eV – 3.3 keV	100%	1 – 32 amu	1, Heavy	15° x 150°	7° x (15° - 20°), 11 pixels	0.5 seconds

MOTIVATION



- **Energetic ions** hit the surface of Ganymede (water ice) and **sputter (or are backscattered as) Energetic Neutral Atoms**
- By measuring **ENAs** at Ganymede, JNA can **map ion precipitation** at the surface
- **To optimize operations planning at Ganymede, estimates of emitted neutral fluxes at Ganymede are needed**

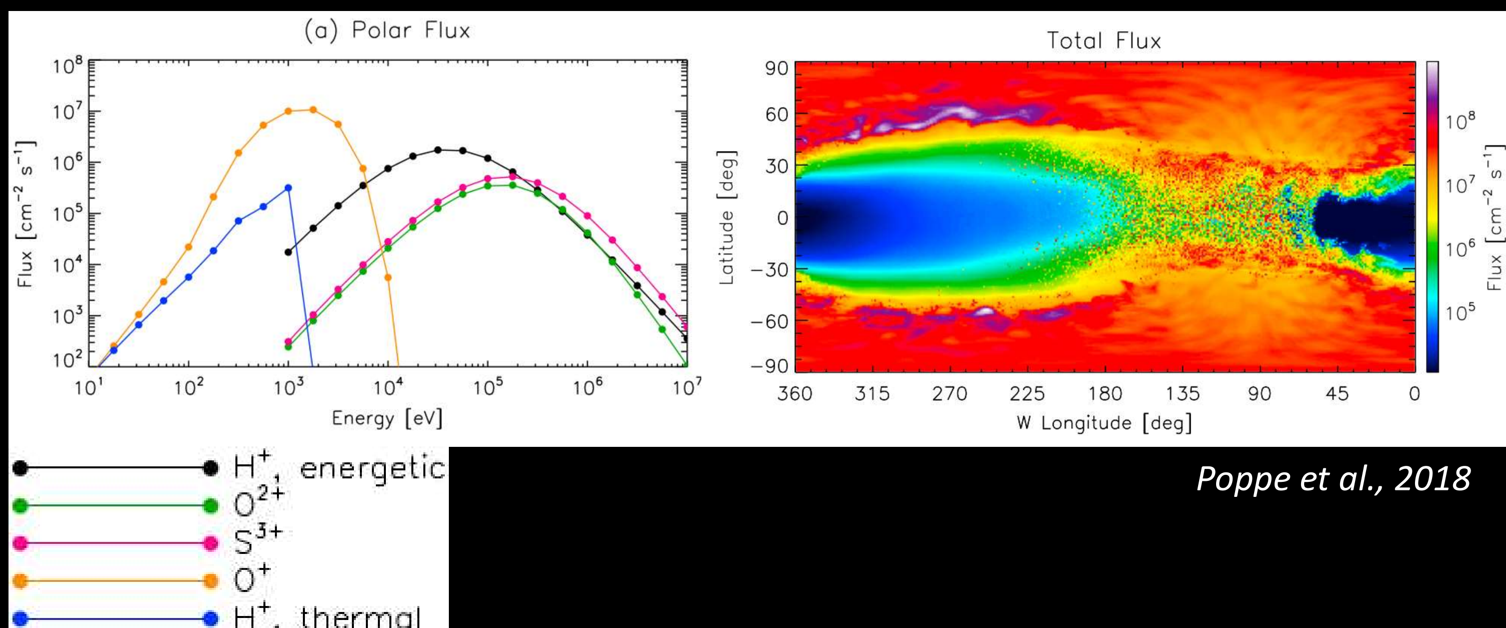
METHOD

Velocity distribution of impinging ions

- H2O, H2 and O2 yield
- Sputtered velocity distribution

Neutral flux map

- Input: ion velocity distribution for **energetic H+, O++, S++ (1 keV - 10 MeV)** and **thermal H+, O+ (10 eV – 10 keV)**
- Obtained through a three dimensional **hybrid simulation** *(Fatemi et al. 2016, Poppe et al. 2018)*



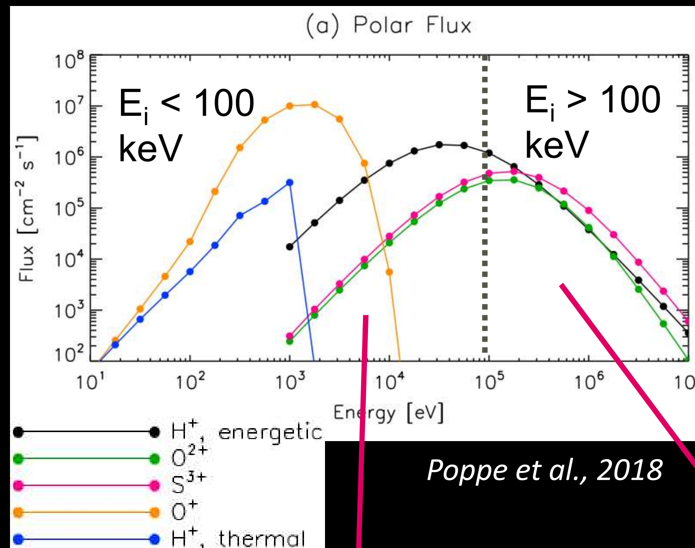
Poppe et al., 2018

METHOD

Velocity distribution of impinging ions

- H_2O, H_2 and O_2 yield
- Sputtered velocity distribution

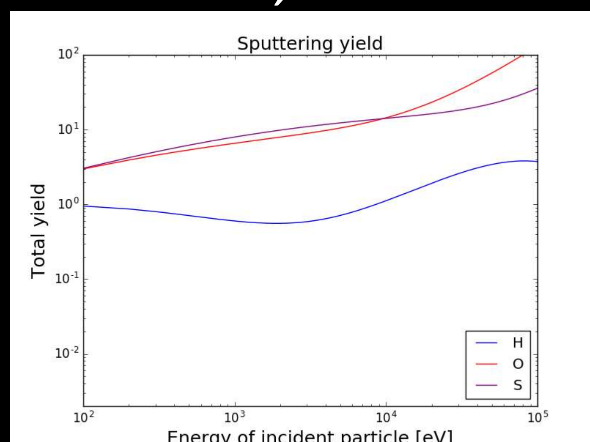
Neutral flux map



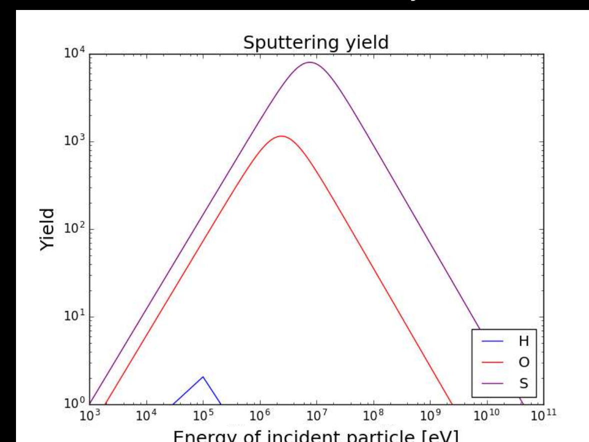
Poppe et al., 2018

- Yield = number of particles sputtered (assumed neutral) by one particle impinging on water ice
- **Sputtering yield** formulas derived in ***Fama et al., 2008*** **for E_i<100 keV** and in ***Johnson et al., 2004*** **for E_i>100 keV**

E_i<100 keV
=> Fama et al., 2008



E_i>100 keV
=> Johnson et al., 2004



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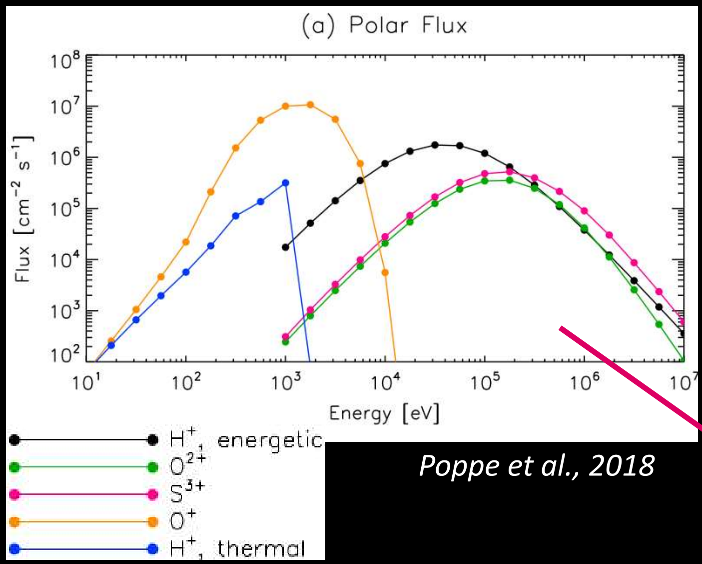
METHOD

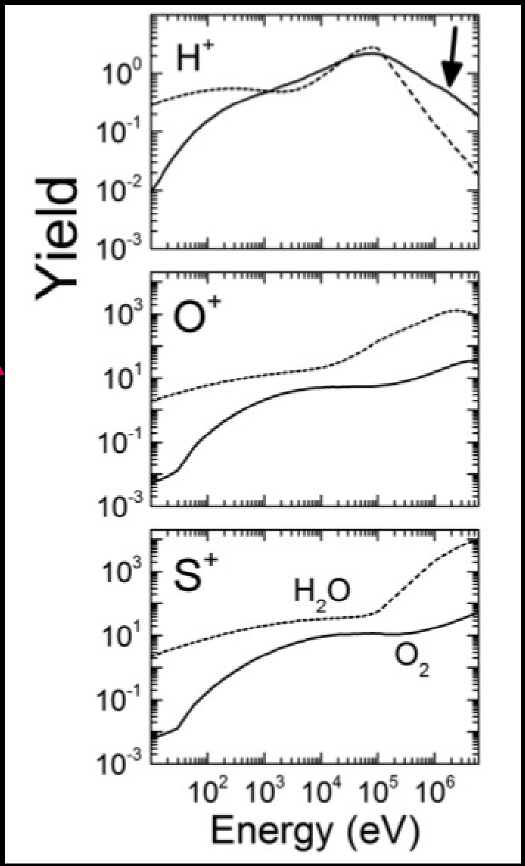
Velocity distribution of impinging ions

- H2O, H2 and O2 yield
- Sputtered velocity distribution

Neutral flux map



Poppe et al., 2018



Teolis et al., 2017

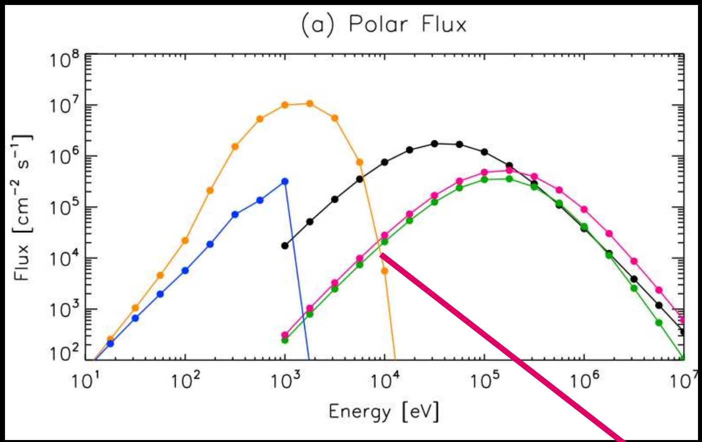
- Yield = number of particles sputtered by one particle impinging on water ice
- Sputtering yield formula derived in ***Teolis et al., 2017 for particles of all energies***

METHOD

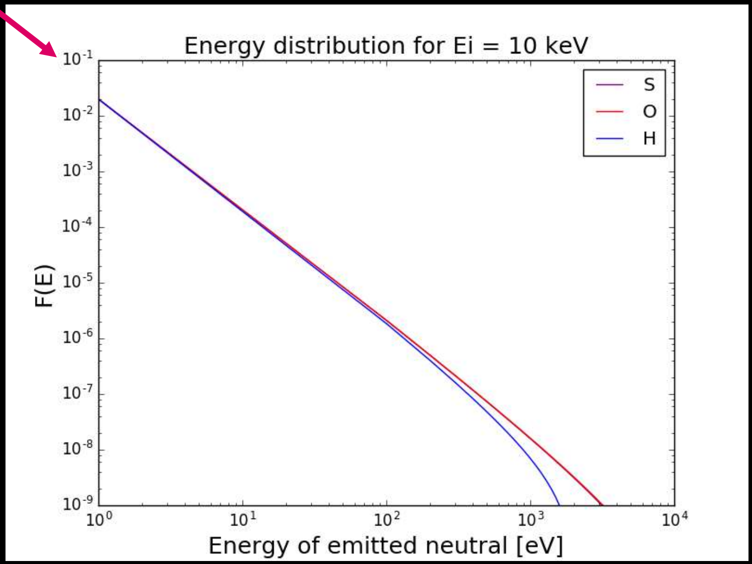
Velocity distribution of impinging ions

- H2O, H2 and O2 yield
- Sputtered velocity distribution

Neutral flux map



Poppe et al. 2018



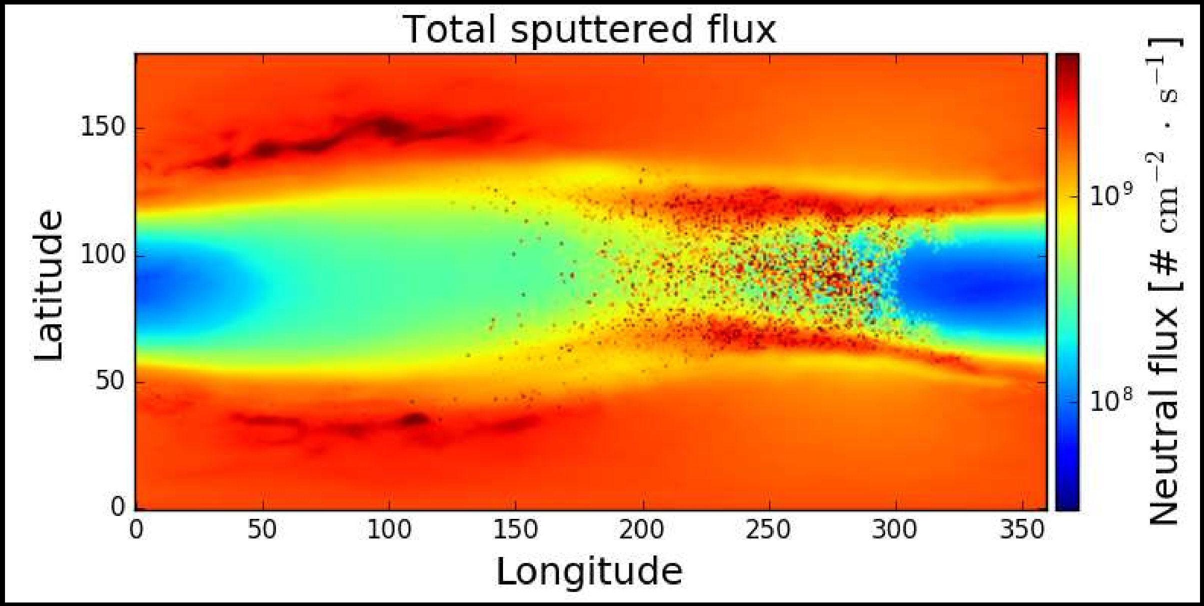
➢ We use a **Thompson-Sigmund** law *(Sigmund, 1969)* to estimate the **energy distribution of emitted ENAs**

PREVIOUS WORK

Velocity distribution of impinging ions

- H2O, H2 and O2 yield
- Sputtered velocity distribution

Neutral flux map



Results shown in *Poppe et al., 2018*, replotted here for better comparison with our results (next slide)

- Poppe et al., presented the **first estimate** of **emitted neutrals** at Ganymede, **using Johnson's** formula for yield
- However, **Fama'**s formula for sputtering yield is **more accurate** than Johnson's **for E_i<100 keV** (see *Cassidy et al., 2013*)

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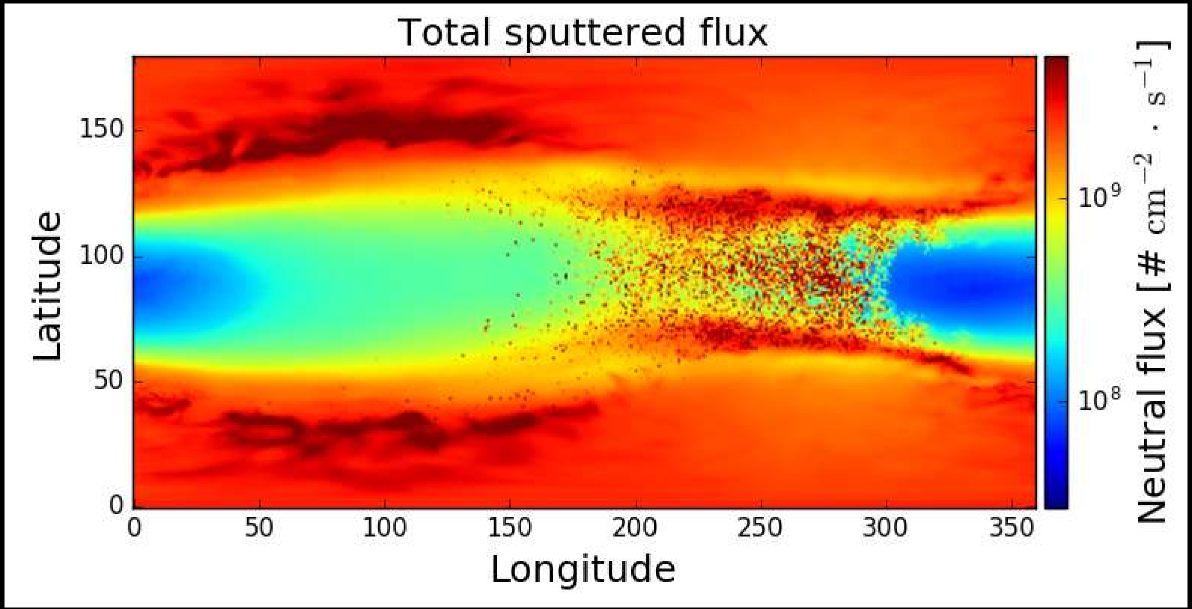
FIRST RESULTS

Velocity distribution of impinging ions

- H2O, H2 and O2 yield
- Sputtered velocity distribution

Neutral flux map



- Using **Johnson's** formula for **E_i>100 keV** and **Fama's** for **E_i<100 keV**, we calculated the **estimated neutral H2O flux** at Ganymede (shown above)
- Results show **higher fluxes** than previously calculated (up to x2 higher)
- The **difference is largest** where the ion flux **is dominated by thermal ions**, for which **Johnson's** formula **underestimates the sputtering yield** (e.g. at the poles on the trailing side (left-hand side)

CONCLUSION

- We identified a **method to estimate the sputtered neutral fluxes** that **JNA** will observe **at Ganymede** in the 2030s using:
    1. Results from **hybrid simulations of ion precipitation** at Ganymede
    2. Experimentally derived expressions to calculate the **sputtering yield of water ice** and the **energy distribution** of sputtered products

- Our calculation of **sputtered neutral H_20** at the surface of Ganymede showed **higher fluxes than previously estimated in Poppe et al., 2018**

- **Future steps** include investigating the **energy distribution** of emitted neutrals, calculating **H_2 and O_2 fluxes**, accounting for the **angular distribution** of emitted neutrals, accounting for **backscattering** of impinging ions, and converting fluxes **to JNA counts**