The Spacecraft Potential‘s Influence on the FOV of Rosetta-ICA at Low Ion Energies

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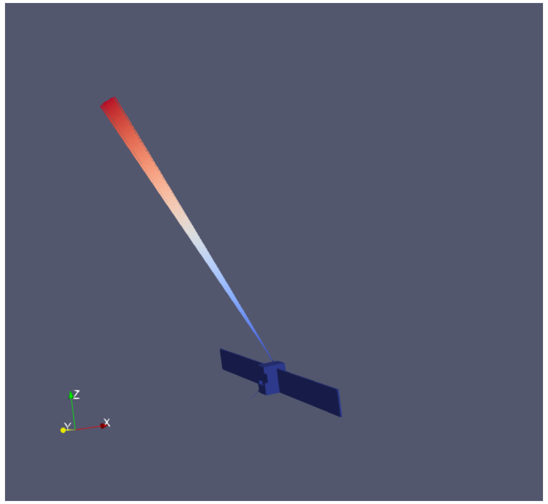
Background

- Spacecraft charging is problematic when doing low-energy ion measurements, since the particles are either attracted to or repelled from the spacecraft prior to detection
- This distorts the effective FOV of the instrument

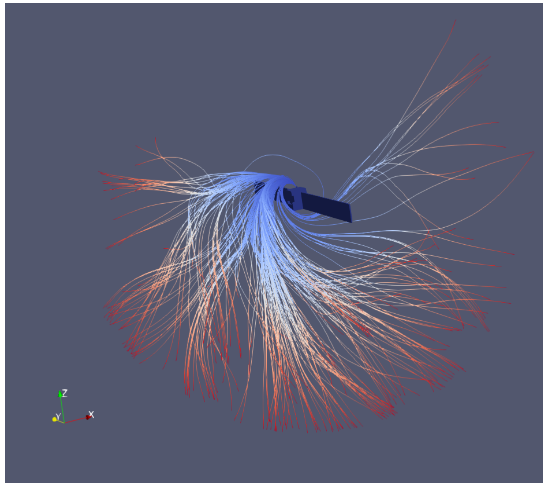
- The Ion Composition Analyzer (ICA) on board Rosetta was measuring positive ions down to energies of a few eV
- Rosetta was commonly charged to a negative potential of -10 to -20 V, which distorted the low-energy part of the ICA data

- In this study we use the Spacecraft Plasma Interaction Software (SPIS) to model the distortion of the effective FOV of ICA at low energies

Trajectories of high-energy ions entering ICA



Trajectories of low-energy (a few eV) ions entering ICA



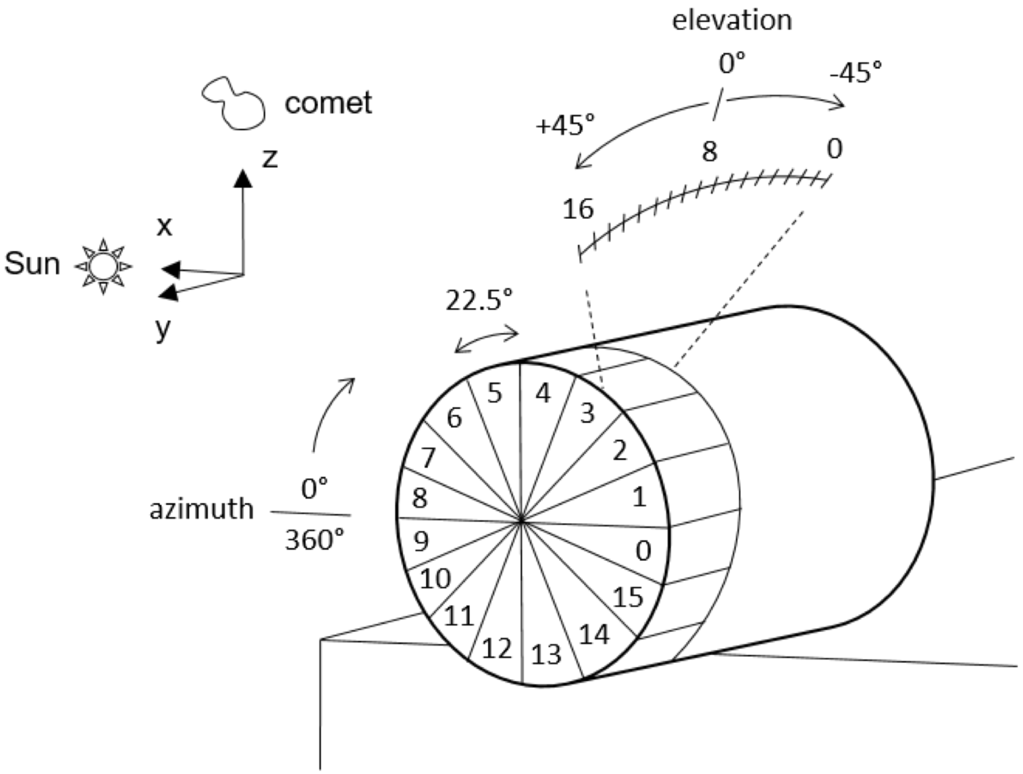
[Bergman et al., 2020a]

ICA Instrument Description

- Mass resolving ion spectrometer
- Positive ions
- Energy range: a few eV/q – 40 keV/q

Nominal FOV:

- Total FOV of 360° x 90°
- In azimuthal direction: 16 sectors of 22.5°
- In elevation: 16 elevation steps of 5.6°



[Bergman et al., 2020b]

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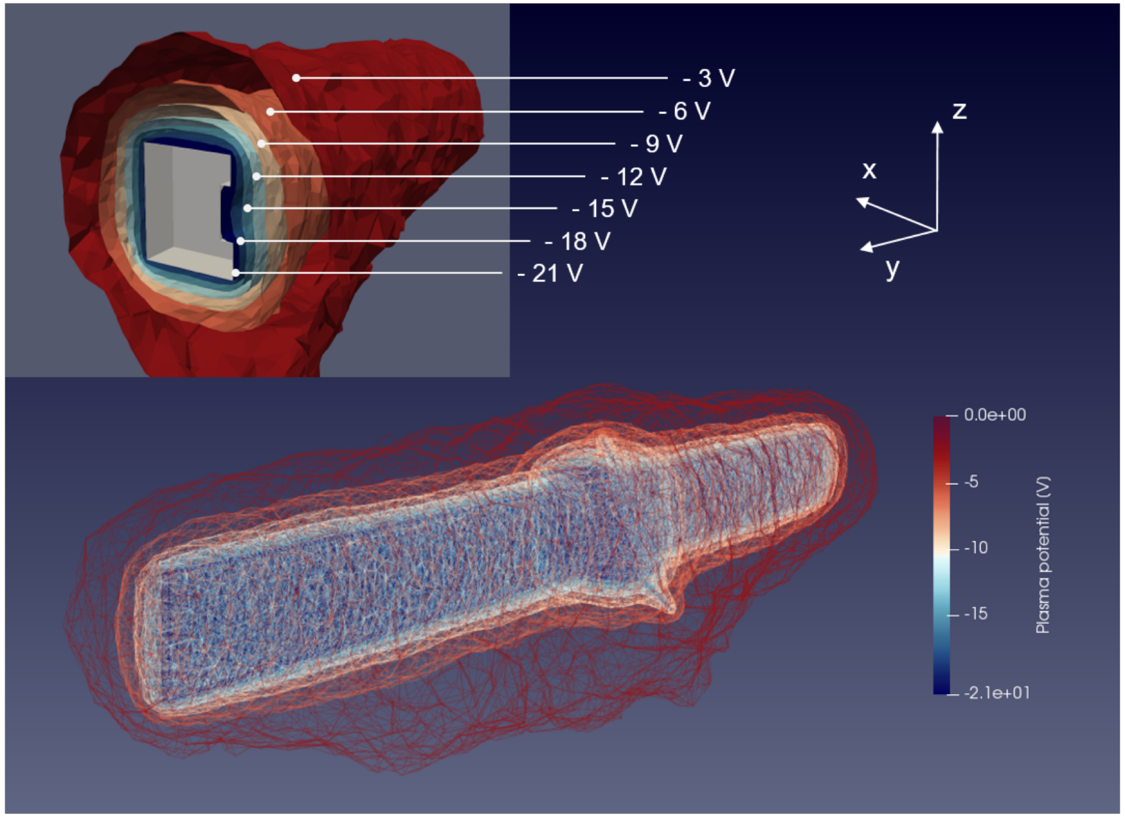
SPIS Simulations

- PIC approach to model the environment
- Test particles traced from the instrument
- Plasma model (valid close to perihelion):

H_2O^+	e^-
$n = 1000\ cm^{-3}$	$n = 1000\ cm^{-3}$
$T = 0.5\ eV$	$T = 8\ eV$
$v = 4\ km/s$	

- → Spacecraft potential of -21 V



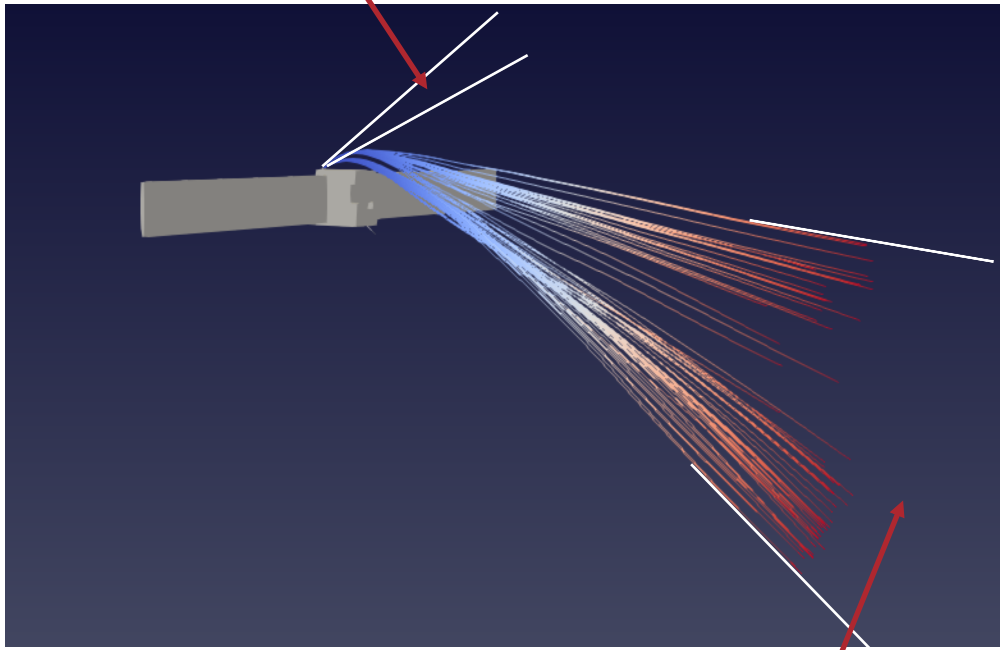
[Bergman et al., 2020a]

Results - Example

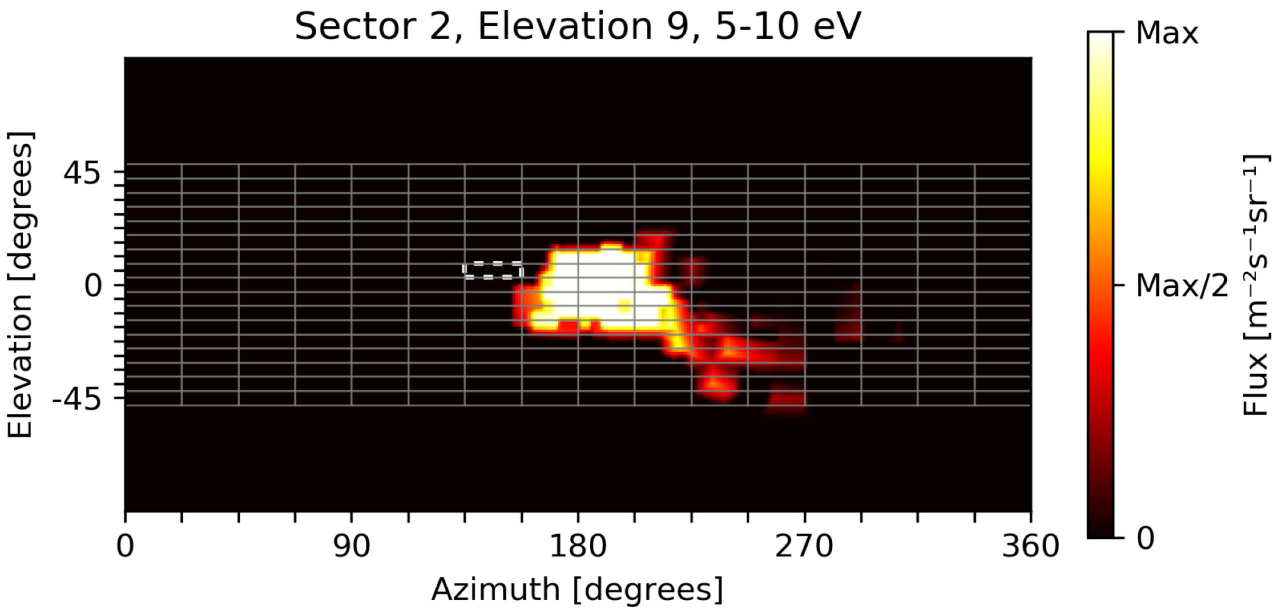
Nominal FOV

Results for one pixel of the instrument
E = 5-10 eV (at infinity)

[Bergman et al., 2020a]

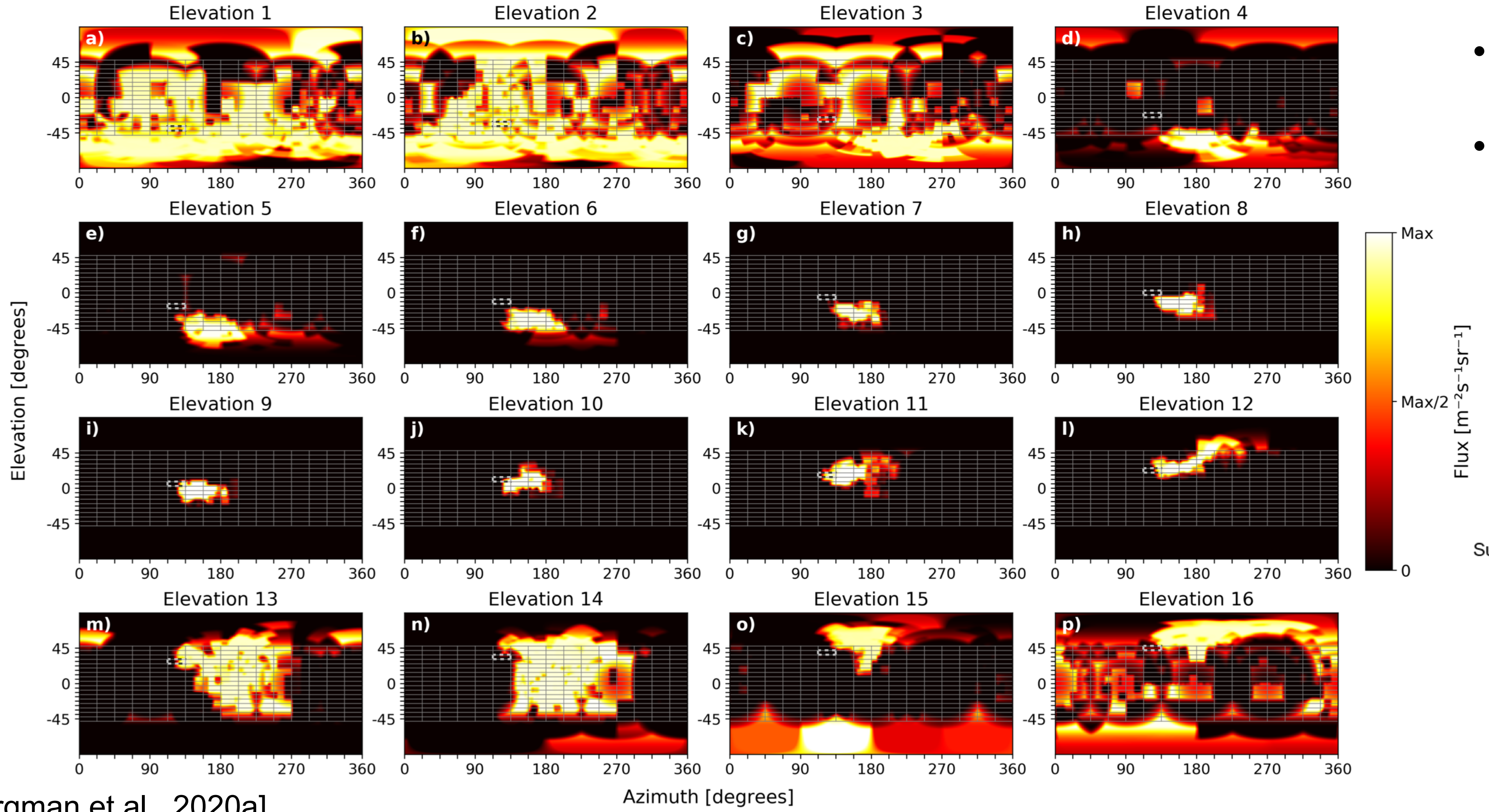


Effective FOV



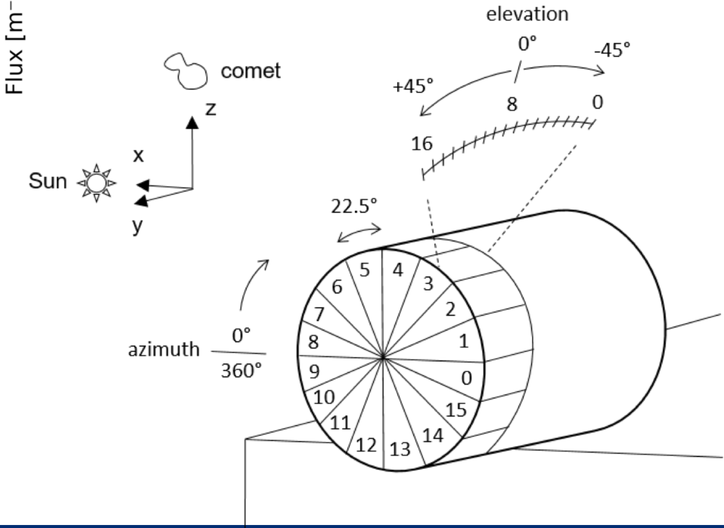
- Dashed square: Nominal FOV of the studied pixel
- Color scale: Flux of particles at the simulation boundary that are reaching the studied pixel
- The colored area hence corresponds to the effective FOV of this pixel

Results – Effect on Different Elevation Angles



[Bergman et al., 2020a]

- Sector 3, E=5-10 eV
- Extreme elevation angles are much more severely distorted than angles close to the aperture plane



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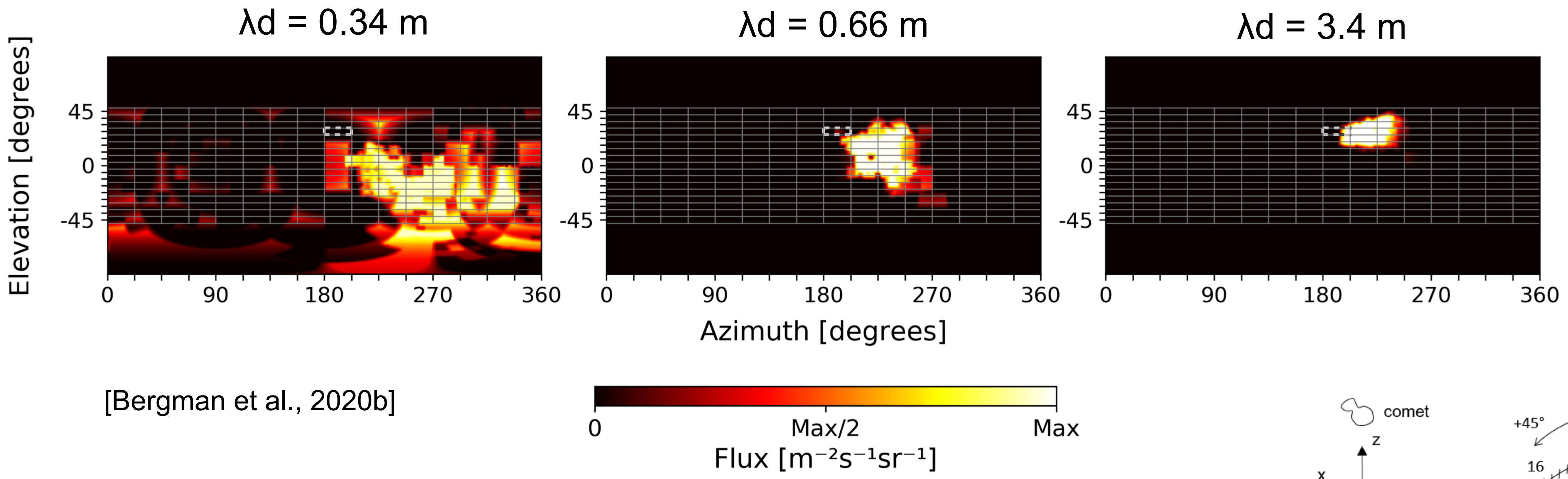
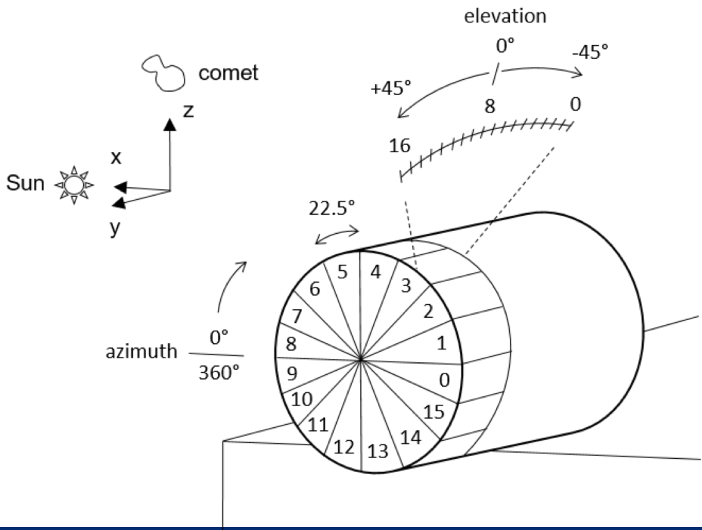
Results – Different Debye Lengths of the Surrounding Plasma



[Bergman et al., 2020b]

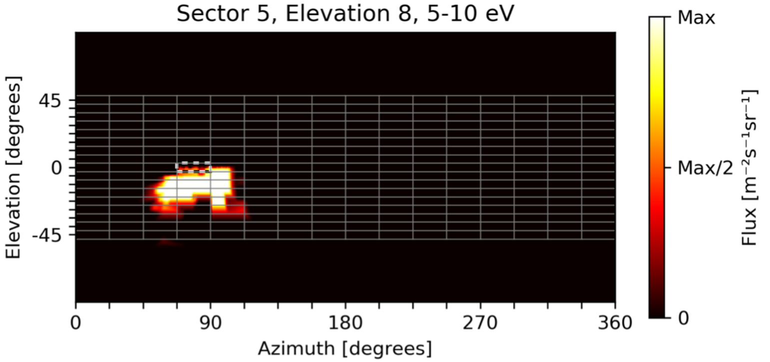


- $U_{s/c}$ = -21 V in all cases
- The FOV distortion is more severe when the Debye length is shorter
- The sensitivity to a changing Debye length varies, however, between different instrument pixels

Results – Varying Spacecraft Potentials

Question: Does the FOV distortion scale linearly with the spacecraft potential?

$U_{s/c}$ = -21 V
E = 5-10 eV



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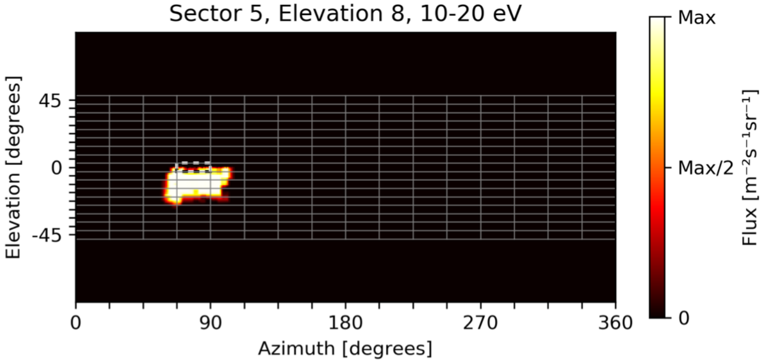
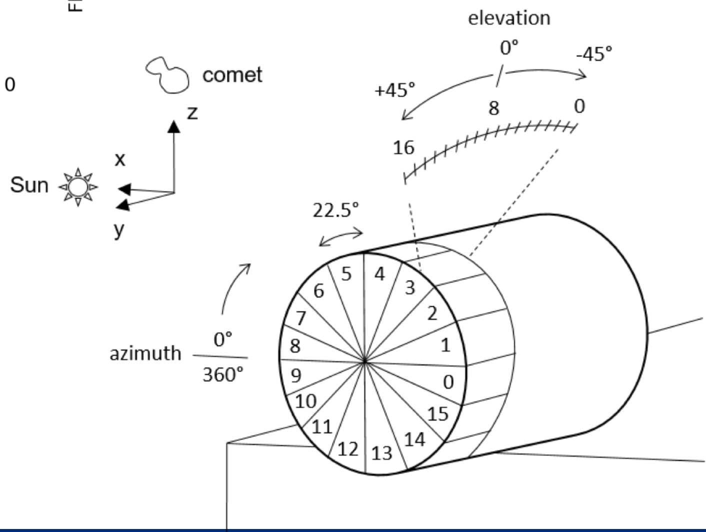
$U_{s/c}$ = -42 V
E = 10-20 eV



[Bergman et al., 2020b]



- The Debye length is the same in both cases
- If the ion energy is scaled according to the potential of the spacecraft, the FOV distortion is not necessarily the same
- The small nonlinearity observed is mainly caused by the photoemission and bulk flow of the cometary plasma

Conclusions

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- The FOV of ICA is distorted at low ion energies
- The distortion varies between different instrument pixels
- The distortion is sensitive to changes in the Debye length, but the sensitivity varies between different instrument pixels
- A small nonlinearity exists in the relation between FOV distortion and spacecraft potential, mainly caused by the photoemission and bulk flow of the cometary plasma
- **The distortion is considered insignificant at an energy above twice the spacecraft potential**

Publications:

Bergman et al. (2020a). *JGR: Space Physics*. https://doi.org/10.1029/2019JA027478
Bergman et al. (2020b). *JGR: Space Physics*. https://doi.org/10.1029/2020JA027870

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Publications

Bergman, S., Stenberg Wieser, G., Wieser, M., Johansson, F. L. & Eriksson, A. (2020a). The influence of spacecraft charging on low-energy ion measurements made by RPC-ICA on Rosetta. *Journal of Geophysical Research: Space Physics*, 125. https://doi.org/10.1029/2019JA027478

Bergman, S., Stenberg Wieser, G., Wieser, M., Johansson, F. L. & Eriksson, A. (2020b). The influence of varying spacecraft potentials and Debye lengths on in situ low-energy ion measurements. Submitted to *Journal of Geophysical Research: Space Physics*. https://doi.org/10.1029/2020JA027870

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