EPSC Abstracts
Vol. 12, EPSC2018-1042, 2018
European Planetary Science Congress 2018

Jovian Neutrals Analyzer for the Particle Environment Package onboard JUICE

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Abstract

Jovian Neutral Analyzer (JNA) is one of six sensors in the Particle Environment Package onboard the JUICE to Jovian system. The JNA provides the low-energy energetic neutral atom (ENA) images originating from the Jovian magnetospheric plasma interaction with the surface/magnetosphere of the Galilean icy moons, and Io torus images through ENA emissions generated from charge-exchange between the co-rotating plasma and the neutral torus. The JNA design is based on successful predecessors and optimized for a harsh radiation environment in Jupiter. We have built a flight-like test model and characterized the performance. In the paper, the design features of JNA together with predicted scientific performance are shown.

1. Introduction

Jovian Neutral Analyzer (JNA) is one of six sensors in the Particle Environment Package onboard the JUICE to Jovian system. The JNA provides low-energy ENA (L-ENA) images of the Jovian magnetospheric plasma interaction with the surfaces of Ganymede, Callisto, and Europa. The neutrals are produced via sputtering of ice by high-energy particles, and by backscattering of the original incident projectiles [2, 5]. ENA images in the low energy range map the plasma flux distribution at the surface and thus display precipitation regions on Ganymede, directly showing the open/close field lines boundary. The plasma precipitation maps from Callisto directly reveal the different modes of the plasma interaction. JNA also aims to detect L-ENAs from charge – exchange of the co-rotating hot plasma and neutral tori of Io and Europa in the inner magnetosphere. For Io torus imaging, the Io torus is not visible in high-energy ENAs due to low energetic ion fluxes in these regions. Futaana et al. [3] shows that the expected ENA fluxes in the 100–200 eV energy range is a factor of 10 higher than those from the Ganymede surface and thus readily detectable.

2. Instrument

3.1 Principle

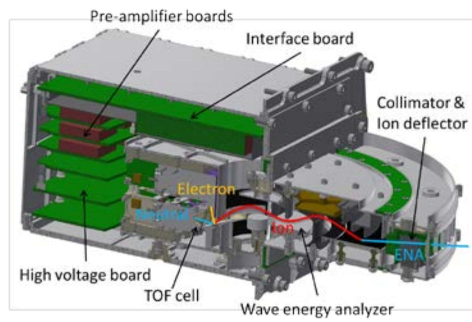

Figure 1: JNA model cut-off with particle trajectory.

The JNA detects L-ENAs by converting neutrals to ions on a charge conversion surface. Ionized neutrals, namely ions, are subsequently guided through “wave-type” electrostatic energy analyzer and subjected to time-of-flight (TOF) analysis as shown in Figure 1. Combination of energy and TOF analyses provides information on mass discrimination. Although the design is based on the Chandrayaan/CENA and BepiColombo/ENA analyzers [4], a TOF system is optimized to mitigate extremely harsh radiation environment in the Jovian system. JNA uses 11 Ceramic Channel Electron Multipliers (CCEMs) for start signal detection and 11 CCEMs for stop signal detection for the TOF measurement, which allow us to determine incident angle of ENAs. The performance of JNA is listed in the Table 1.

Table 1: JNA performance

Measured particles	ENAs (optionally ions)
Energy range	10 eV-3.3 keV (hydrogen)
Resolution, DE/E	~100%
Mass range	1 – 32 amu
Masses resolved	1, (Heavy)
Field-of-view	15°x150°

Angular resolution	7°x15°, 11 pixels
Time resolution	Nominal 15s
G-factor	Total: 0.21 cm^2sr eV/eV Efficiency: $10^{-4} – 10^{-3}$

3.2 Surfaces

A surface material is a key element to characterize the instrument. Two types of surfaces are used: a charge conversion surface (CS) for ionization of ENAs and a start surface for generating secondary electrons for start signal of the TOF. A highly polished Si-waver coated with Al_2O_3 is a baseline for the CS, which shows high ionization yield and low angular scattering. For the start surface, a CVD diamond attached on Al substrate is used because of low secondary electron yield from gammas owing to a low-Z material, excellent secondary electron yield for ions and very low angular scattering [1].

3.3 Radiation mitigation

We optimized the design to adapt to the harsh radiation by (1) using a high-Z material for shielding of detectors and electronics, (2) use of CCEMs, which are less susceptible to radiations, (3) shortened TOF path length (5-15 mm) to minimize TOF window, (4) small TOF cell volume to minimize the detector size and shrink the exposed surface area to radiation, on which background electrons and gammas are generated.

3. Performance characterization

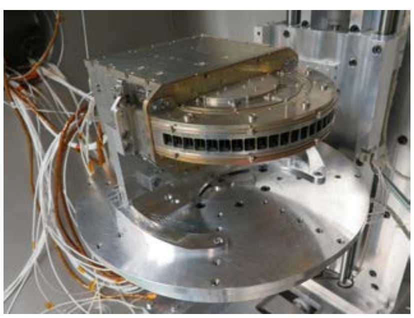

Figure 2: JNA TM testing in a vacuum tank

The performance of JNA is studied using a flight-like model. The instrument is exposed to a well-characterized particle beam and the response is investigated (Figure 2). According to the preliminary analysis, the fundamental performance, such as mass resolution and energy resolution, is verified, though full characterization requires additional analyses.

4. Performance analysis

To estimate the JNA scientific performance during observation of the Jovian moons, a signal-to-noise ratio (SNR) is calculated with help form a radiation analysis of the instrument and ENA modelling. Expected SNR for Ganymede precipitation mapping is 14 to 140 depending on the energy and species, and 30 to 240 for Callisto. For Io torus imaging, the SNR is largely dependent on the position of the spacecraft, but we expect the SNR is sufficiently high because of high foreground ENA fluxes for Io torus.

5. Summary

We have developed the Jovian Neutrals Analyzer onboard the JUICE primary to map ion precipitation on Ganymede/Callisto’s surface and to image Io torus by observing L-ENAs. The basic performance is verified using a flight-like model. By combining the JNA performance, the detailed JNA radiation model and the ENA foreground model, the SNR is predicted to be sufficiently high to fulfil the scientific requirements for the instrument. A flight model is to be delivered to the spacecraft in 2019.

Acknowledgements

The project is supported by Swedish National Space Board.

References

[1] Neuland, M. B., et al., Self-supporting CVD diamond charge state conversion surface for high resolution imaging of low-energy neutral atoms in space plasmas, Appl. Surf. Sci. Vol. 313, pp. 293-303, 2014.

[2] Famá, M., et al., Sputtering of ice by low-energy ions, Surface Science, Vol. 602, pp. 156-161, 2008.

[3] Futaana, Y., et al., Low-energy energetic neutral atom imaging of Io plasma and neutral tori, Planet. Space Sci., Vol. 108, pp. 41-53, 2015.

[4] Kazama, Y., et al., Energetic neutral atom imaging mass spectroscopy of the Moon and Mercury environments, Adv. Space Res., Vol. 37, pp. 38-44, 2006.

[5] Plainaki C., et al., Neutral particle release from Europa’s surface, Icarus, Vol. 201, pp. 385-295, 2010.