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Low-energy energetic neutral atoms imaging of Jovian icy moons by JUICE/JNA

Manabu, Shimoyama (1), Angèle Angèle (1), Stefan Karlsson (1), Kazushi Asamura (2), Yoshifumi Futaana (1) , Maike Brigitte Neuland (1), Peter Wurz (3), Martin Wieser (1) and Stas Barabash (1)
(1) Swedish Institute of Space Physics, Kiruna, Sweden, (2) Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Kanagawa, Japan, (3) University of Bern, Bern, Switzerland (shimoyama@irf.se)

Abstract

Jovian Neutral Analyzer (JNA) is one of six sensors in the Particle Environment Package onboard the JUICE mission to Jovian system. The JNA provides the low-energy (10 eV – 3.3 keV) 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 for the first time. Whereas the design is inherited from successful predecessors, the JNA is optimized for a harsh radiation environment in Jupiter. We have built a flight-like technological model to verify the performance. In this paper, we present science objectives and predicted performance of the instrument.

1. ENA imaging technique

A technique for space plasma imaging using energetic neutral atoms (ENAs) is a powerful tool to remotely study global plasma phenomena. ENAs are generated when ions in the plasma are neutralized through charge-exchange with neutral gas. Since ENAs are neutral and not affected by electro-magnetic forces, physical properties are almost kept for a large traveling distances. It is worth mentioning that ENAs can be even utilized to investigate space objects such as planets, moons, comets or asteroid because ion-surface or ion-atmosphere interaction can produce ENAs via backscattering, sputtering or recoiling.

2. Icy moon observation

Jovian Neutral Analyzer (JNA) is one of six sensors in the Particle Environment Package (PEP) onboard the JUICE to Jovian system. The JNA provides low-energy ENA (LENA) 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 [1, 4]. 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 LENAs 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. [2] 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.

3. Instrument

3.1 Principle

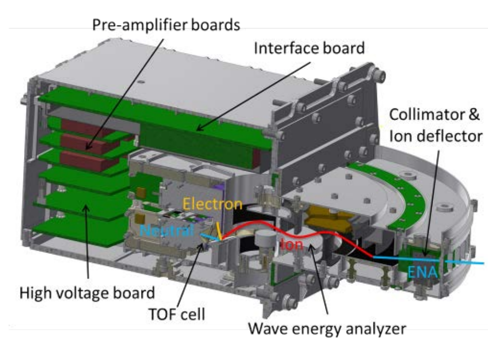

Figure 1: JNA model cut-off with particle trajectory.

The JNA detects LENAs by converting neutrals to ions on a charge conversion surface. Ionized neutrals, namely ions, are subsequently guided through the electrostatic energy analyzer and subjected to time-of-flight (TOF) analysis. Combination of energy and TOF analyses provides information on mass discrimination. Whereas the design is based on successful predecessors, i.e. Chandrayaan/CENA and BepiColombo/ENA analyzers [3], 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 substantially suppress background noises originating in radiation by a single coincidence scheme.

3.2 Performance

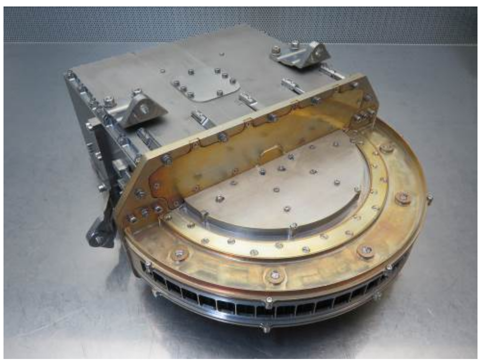

Figure 2: JNA Technological Model.

As shown in Figure 2, the flight-like technological model has been built to evaluate the instrument performance as well as to be subject to environment testing. The performance test was conducted in a vacuum tank with ion/neutral beams and, energy resolution, angular resolution and mass resolution were verified. The performance predicted from tests and simulations is listed in Table 1.

Table 1: JNA performance

Measured particles	ENAs
Energy range	10 eV-3.3 keV (hydrogen)
Energy Resolution	~100%
Mass range	1 – 32 amu
Masses resolved	1, (Heavy)
Field-of-view	15°x150°
Angular resolution	7°x15°, 11 pixels
Time resolution	0.5 s (nominal 15 s)
Geometric factor	Total: 0.21 cm^2sr eV/eV Efficiency: $10^{-4} – 10^{-3}$

4. Observation planning

To start observation planning, expected ENA signal and background noise are estimated for various observation scenarios. ENA flux backscattered and sputtered from the moons is estimated using a simplified ENA model. For Io torus observation, ENA flux calculated by Futaana et al. [2] is used. To predict a background noise, radiation analyses using a detailed instrument model was carried out. An expected signal-to-noise ratio (SNR) for Ganymede and Callisto precipitation mapping is more than a few tens depending on the energy and the species. For Io torus imaging, SNR is sufficiently high because of high foreground ENA fluxes from Io torus. We have started optimization of observation mode for different mission phases and science targets.

5. Summary

We have been developing the Jovian Neutrals Analyzer onboard the JUICE to map ion precipitation on Ganymede/Callisto's surface and to image Io torus through LENA observations. The instrument performance was verified using a technological model. Observation planning was also started.

Acknowledgements

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