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Spectral analysis of energetic neutral atoms emitted from Mars: MEX/ASPERA-3 results

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Abstract

We report the analysis of the energy spectra of energetic neutral atoms (ENA) emitted from Mars as observed by Mars Express. We used the data with 256 energy channels. We selected typical backscattered and charge-exchange populations of ENAs measured on the dayside of Mars. The results show different spectral characteristics for the two populations: the spectrum of backscattered ENAs is a straight line in a log-log plot, whereas that of charge-exchange ENAs shows a bend at certain energy. This difference can be used to separate these two populations. Comparisons with simulations and other relevant ENA observations are also discussed.

1. Introduction

Energetic neutral atoms (ENAs) are generated via the charge-exchange process between the space plasma and neutral particles. Charge-exchanged ENAs maintain the composition, momentum and energy distribution of their parent ions. Meanwhile, ENAs may collide elastically with neutral particles and thus change their energy and direction distribution. The ENA fluxes are given by the line-of-sight integrals over plasma and neutral gas distributions. Therefore ENAs can serve as a diagnostic tool to study the plasma and neutral gas distributions.

The Neutral Particle Detector (NPD) is composed of 2 identical sensors, NPD1 and NPD2. Each sensor is an NPD camera with 10°×90°field of view divided into three viewing sectors. The angular resolution for each sector is 5°×~40° (the full width of half maximum; FWHM). NPD is a time-of-flight velocity analyzer. The time between the start and stop signals from an incident ENA is measured to determine its velocity/energy. The two NPD sensors are accommodated such that their FOV planes are almost perpendicular to the spacecraft velocity.

2. Data processing

In order to investigate the spectral characteristics, we use the Raw and TOF operation mode of the instrument which provides higher energy resolution. The time resolution of the dataset is 1 second, i.e., we can get a full TOF spectrum within 1 second. In the Raw mode, the time of flight of the first 512 incident ENAs within 1 second is recorded. In the TOF mode, the TOF spectrum/histogram of the TOFs of ENAs was recorded, in 256 TOF channels. We first applied following criteria to restrain the population of backscattered ENAs: 1) the SC was in the dayside of Mars and inside the bow shock; 2) an instrument sector was totally covered by the disk of Mars; 3) the total particle flux was high enough to fill 512 events within 1 second. We then converted selected data to TOF spectra, i.e., the count rate of ENAs as a function of TOF, from 0 ns to 2048 ns, in a resolution of 8 ns. We removed the background noise (yellow dashed line in Figure 1, left panels), and reconstructed the TOF spectrum (thick histogram in Figure 1, left panels) by applying a low-pass filter. Then we converted the TOF spectrum to the energy spectrum (Figure 1, right panels). Energy channels with higher noise than the flux were discarded. Valid energy spectra were recorded for further analysis.

3. Results

For comparison, we also produced the spectra of charge-exchange ENAs during the same period in the same processing method as for the backscattered ENAs. An example is shown in Figure 2. The presented measurements are sufficient to distinguish between charge-exchange ENAs and backscattered ENAs. The typical spectrum of backscattered ENAs (Figure 1) is almost a straight line in the log-log plot within the valid energy range, whereas that of charge-exchange ENAs exhibits a bend in the spectrum (Figure 2). The peak in the TOF spectrum for backscattered ENAs is wider due to more collisions with the neutral particles. This difference is also present in the binning-mode dataset which have only 16 energy channels instead of 256. With this much larger dataset, some statistical characteristics of the energy spectra of backscattered ENAs and charge-exchange ENAs can be revealed, and they may be correlated to the morphology of ENA emissions at Mars.

The differential flux value within the overlapped energy range in our measurements is comparable to that from simulations [2]. This is a validation of the models used in the simulations. More comprehensive comparisons with simulations and other dataset, such as the ENAs from lunar surface [1], are ongoing.

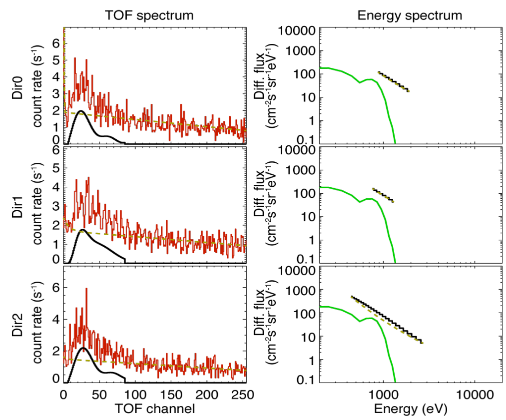

Figure 1: From time-of-flight spectra (left) to energy spectra (right). This event was observed by NPD2 on 2004-02-27. The green curve is the simulation result of backscattered ENAs [2].

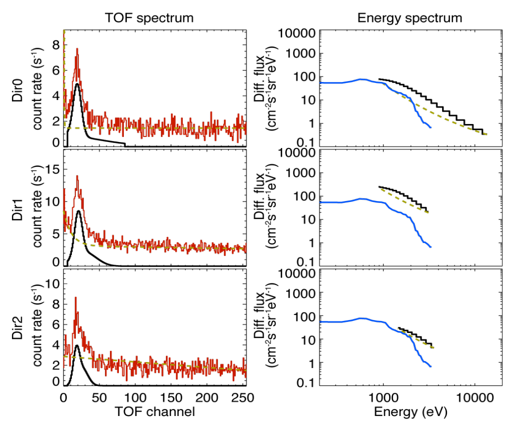

Figure 2: TOF and energy spectra measured by NPD1 from the same period as Figure 1. The blue curve is the simulation result of charge-exchange ENAs [2].

Acknowledgements

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References

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