Mass Spectroscopy of Medium Energy Ion in Space by Utilising the Time-of-Flight Method

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In the past decades, space plasmas have been extensively investigated by satellite-borne in-situ measurements. They revealed that charged particles have a broad energy range from less than 1[eV] up to more than 10[MeV] and they form a number of plasma structures in the earth's magnetosphere. However, acceleration processes and transport of mass, momentum, and energy in the magnetosphere is not fully understood.

For instance, the earth's ring current ions are characterised by energies of ˜10-˜200[keV], while typical energies of ions in the ionosphere and solar wind are considerably lower (less than 1[eV] and ˜1[keV/nuc], respectively), though they are considered to be the source particles. Thus build-up processes of the ring current are the subjects of intensive research.

For the investigations of the transport processes and energisation mechanisms of ions, important quantities are energy (E), mass (m), charge state (q) of each ion. Mass and charge state of each ion provide information on their origins (solar wind or the terrestrial ionosphere). Furthermore, measurements of their three-dimensional distribution functions are also required, since non-gyrotropy and temperature anisotropy of ions are thought to be relevant to the acceleration and the wave generation. However, despite such importance, measurement techniques of medium energy (10-200[keV]) ions are not well established due to technical difficulties.

In order to obtain above information (i.e. E, m, q, and the incoming direction) at future magnetospheric missions (such as 'Cross Scale' and 'ERG' missions), we think of the combination of an electrostatic analyser (ESA), a time-of-flight mass spectrometer (TOF), and solid-state detectors (SSDs). They can simultaneously and independently measure energy-per-charge (E/q), velocity (v), and energy (E) of incoming ions, respectively; E, m, and q can be deduced from the above values. Incoming directions are decided from detected positions. Instead of conventional ESAs that have been mostly used for the low energy range (less than ˜40[keV]), we use 'cusp type' electrostatic analyser. This design provides us a relatively small instrument that has an energy range up to ˜200[keV/q] (with applied voltages of +-5kV) with a full solid angle coverage (by using satellite spin motions). The ESA has sufficient sensitivity to acquire ion 3D distribution in less than one minute during magnetic disturbance times. The TOF unit has been designed to be suitable for the electrostatic analyser. It detects start and stop electrons by a single unit of MCPs, which enables a simple, light, and small sensor system. We have fabricated the test model of the TOF mass spectrometry unit and tested its performance through laboratory experiments. The results show a sufficient mass resolution; various ions such as H+, He+, He++, and N+ are well discriminated. We will present the performance of the mass spectrometer and discuss the future work.