MESSENGER observations of distribution of sodium-group ions near Mercury's space: their dependence on true anomaly angle and escape rates. Weijie Sun[1], Ryan M. Dewey[1], James A. Slavin[1], Jim M. Raines[1] and Gangkai Poh[2], [1]Department of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI 48109, USA (wjsun@umich.edu), [2]Center for Research and Exploration in Space Science & Technology II (CRESST II), Catholic University of America, Washington, DC, USA (gangkai.poh@nasa.gov).

Introduction: Mercury is the closest planet to the Sun and does not have a significant atmosphere but only a surface-bounded exosphere [1-5]. Mariner 10, ground-based solar telescopes and MASCS (Mercury Atmospheric and Surface Composition Spectrometer) onboard MESSENGER [6] have detected a variety of neutral atoms in Mercury's exosphere, including hydrogen (H), helium (He), oxygen (O), sodium (Na), potassium (K) and calcium (Ca), etc. [3, 4, 7-10]. The neutral sodium exosphere shows a clear dependence on True Anomaly Angles (TAAs) [11]. The Fast Imaging Particle Spectrometer (FIPS) onboard MESSENGER [12] measured the ions around Mercury's environment. FIPS measurements include He^+, He^{++}, O^+-group ions, and Na^+-group ions [13-15].

Mercury has a global intrinsic magnetic field, which interacts with the solar wind forming a magnetosphere [16-21]. The planetary ions are enhanced in several regions, such as the northern cusp, the plasma sheet, and the dawn terminator [13, 14, 22-24]. Studies from MESSENGER's measurements have found that of the planetary originated ions, in which sodium-group ions (including Na^+, Mg^+, Al^+, Si^+) are the most abundant and account for approximately 10% of the ions in Mercury's magnetosphere [13, 14, 22].

A few studies have investigated the variations of the sodium-group ions depending on the true anomaly angles (TAAs), i.e., Mercury's solar orbital phase, and are limited to Mercury's northern cusp [14, 25]. It is desirable to do a comprehensive investigation of the distributions of the sodium-group ions near Mercury's space, including the solar wind, magnetosheath, and magnetosphere measured by MESSENGER.

Dataset: The MESSENGER spacecraft orbited Mercury from 18 March 2011 to 30 April 2015, constituting more than 4 years of continuous measurements. We will employ the magnetic field from the magnetometer [26] and the ions measured by FIPS [12]. The highest time resolution of the magnetometer data is 20 vectors per second. The scan time of FIPS is around 10 seconds. The measurements of Na^+-group ions include Na^+, Mg^+, Al^+, Si^+, and other ions with m/q within 21 to 30.

Results: We divide the measurements of sodium-group ions into the regions of the solar wind, magnetosheath, and magnetosphere. We then investigate the distributions of the sodium-group ions in different True Anomaly Angles (TAAs). **Figures 1** and **2** show the distribution of sodium group ions in the magnetosheath under different TAA angle intervals. With similar coverages of the magnetosheath regions, the density of sodium group ions with a TAA from 315° to 45° is higher than the density of sodium group ions with a TAA from 135° to 225° (**Figure 1**). The density of sodium group ions with TAAs between 225° to 315° is higher than the density with TAAs from 45° to 135° (**Figure 2**).

We choose a cross-section of the tail region between X_{MSM} = -6 to -1 R_M to estimate the escape rate of sodium-group ions in the solar wind, magnetosheath, and magnetosphere. The escape rates of sodium group ions are the highest in the magnetosheath, followed by the solar wind, and are the lowest in the magnetosphere (**Table 1**). The total escape rate of sodium group ions is in the order of 10^{25} s^{-1} integrating over the solar wind, magnetosheath, and magnetosphere and the escape rates depend on TAAs.

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Table1. Escape rates of sodium-group ions through solar wind, magnetosheath and magnetosphere.

	Escape Rate (s^{-1})
Solar Wind	4×10^{24}
Magnetosheath	6×10^{24}
Magnetosphere	2×10^{24}

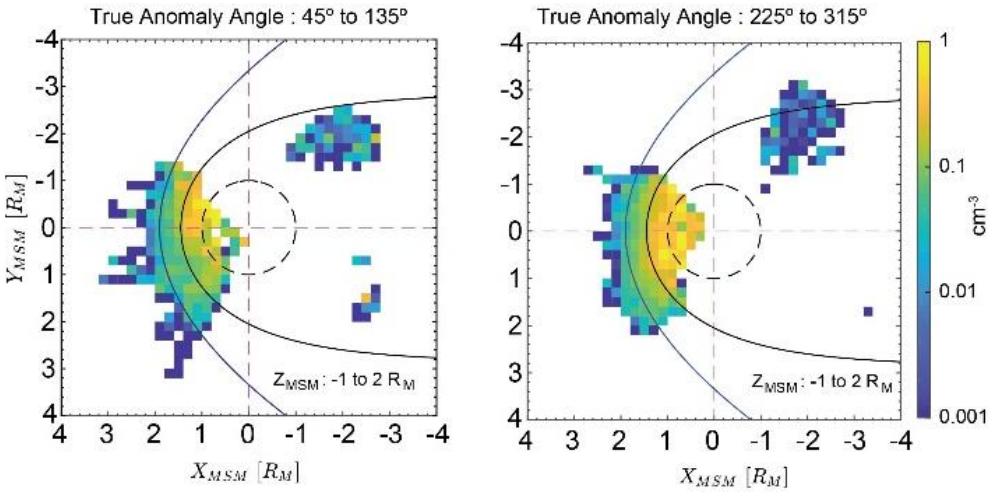

Figure 1. The distribution of the densities of sodium group ions in Mercury's magnetosheath. Left figure is for TAAs from 45° to 135°. Right figure is TAAs from 225° to 315°.

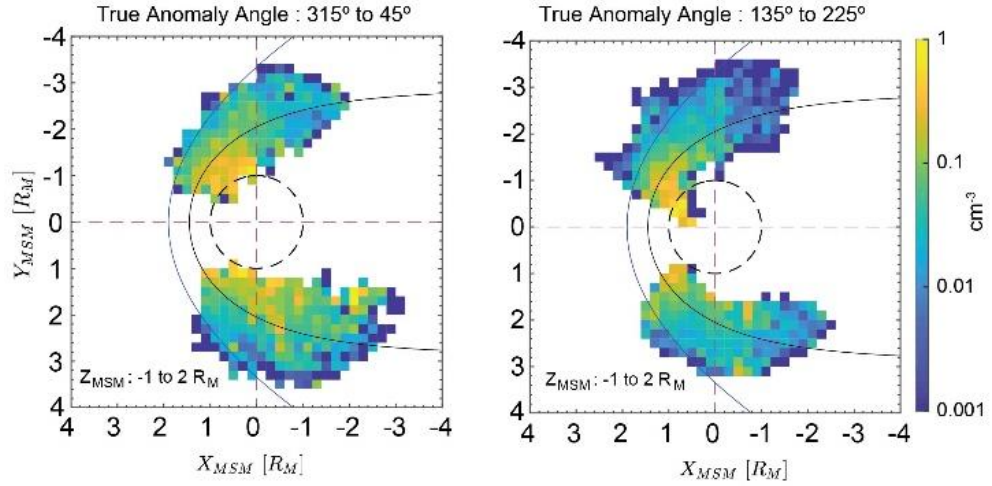

Figure 2. The distribution of the densities of sodium group ions in Mercury's magnetosheath. Left figure is for TAAs from 315° to 45°. Right figure is TAAs from 135° to 225°.