NEUTRAL ATOM IMAGING NEAR MERCURY. M. Holmström, S. Barabash, *Swedish Institute of Space Physics (IRF), PO Box 812, SE-98128 Kiruna, Sweden, (matsh@irf.se),* A. Lukyanov, *School of Mathematics and Information Science, Coventry University, Coventry, CV1 5FB, UK.*

The interaction between energetic ions and a planetary atmosphere produces energetic neutral atoms (ENA) when an ion charge-exchange with a neutral atom, e.g.,

$$H^+ + O \to H + O^+.$$

Since momentum is conserved the neutral will have the same velocity as the ion. A property of ENAs is that they, in the absence of gravity, travel in straight lines since they, as neutrals, are unaffected by magnetic and electric fields. Thus, using an ENA imager it is possible to extract *global* information about the plasma and neutral populations that generated the ENAs. ENA imaging has successfully been applied for Earth's magnetosphere, the most recent example being NASA's IMAGE mission. The next planet to be imaged in ENAs will be Mars. There are two ENA imagers, as parts of the ASPERA-3 instrument, onboard ESA's Mars Express mission (launch 2003). Due to its global nature, ENA imaging is an attractive method of exploring the largely unknown Hermean exospheric and magnetospheric environment on future Mercury missions [1].

Given the phase space distribution of ions and neutrals, and the charge-exchange cross sections, one can compute ENA images. One purpose of such simulated images is to predict typical fluxes that can be expected, and thereby provide design constraints for instruments. Simulated images can also help in interpreting large scale features in observed images. For a more detailed, quantitative, analysis of observed images one can use inversion techniques to extract parameters from a mathematical model. For Mercury, this is a challenging problem for future research.

The key to successfully model the ENA production in the vicinity of Mercury is knowledge of the distribution of neutrals and ions. In this work we consider the problem of computing the ion distribution near Mercury and present simulation results. The magnetic and electric fields are assumed to be external. The magnetic field is a scaled version of the Tsyganenko model of Earth's magnetosphere. The electric field is the convected solar wind field. Then the Vlasov equation

$$\frac{\partial f}{\partial t} + \mathbf{a} \cdot \nabla_v f + \mathbf{v} \cdot \nabla_r f = P - Q,$$

governs the phase space distribution of ions and neutrals. The unknown distribution, or phase space density, function is $f = f(\mathbf{r}, \mathbf{v}, t)$, where $\mathbf{r}$ is position, $\mathbf{v}$ is velocity and t is time. Then $f\Delta\mathbf{r}\Delta\mathbf{v}$ is the number of particles in a small phase space volume element. The acceleration acting on the particles is $\mathbf{a} = \mathbf{a}(\mathbf{r}, \mathbf{v}, t)$. For gravity we have $\mathbf{a} = -GM/|\mathbf{r}|^3\mathbf{r}$, where G is the gravitational constant and M is the mass of the attracting body. In the presence of electric, $\mathbf{E}$, and magnetic, $\mathbf{B}$, fields the Lorentz force gives $\mathbf{a} = q/m(\mathbf{E} + \mathbf{v} \times \mathbf{B})$, where q and m is the charge and mass of each particle, respectively. The gradients, ∇_v and ∇_r, are with respect to the three velocity components and position coordinates, respectively. Sources and sinks are given by $P = P(\mathbf{r}, \mathbf{v}, t)$ and $Q = Q(\mathbf{r}, \mathbf{v}, t)$, e.g., $P\Delta\mathbf{r}\Delta\mathbf{v}$ is the number of particles produced in a small phase space volume element per time unit.

The Vlasov equation is simply mass conservation in the six-dimensional phase space. When solving the equations we must specify particle sources and sinks, e.g., photoionization and charge-exchange. We also must specify boundary conditions at the outer simulation boundary and at the planet surface. Simulations of the ion distribution,with a photoionization source, have been done for Mars [2], and with a magnetotail proton source for Mercury [3]. The dimensionality of the problem require careful selection of the method to solve the Vlasov equations, otherwise the computational time or memory requirement can be too large. A fast, and highly accurate, characteristic method of solving the Vlasov equations by integrating backwards in time along the phase space trajectories is used. If only point values of the distribution are needed (as when generating simulated ENA images) the memory requirement is minimal. When computing the global distribution, we use an adaptive, hierarchical, grid method to reduce memory requirements. We solve the Vlasov equations near Mercury for the ion distribution, with photoionization of neutrals as the ion source, and present the results of the simulations. Since the neutral and ion distributions are coupled by the the source and sink terms and the surface boundary condition, a topic of future research is to solve for the two distributions simultaneous.

An interesting feature of Mercury is the presence of low energy (1-10 eV) neutral atoms (LENA) such as K and Ca, sputtered from the surface by precipitating magnetospheric ions. ENAs are usually considered to travel in straight lines. For LENAs we can not ignore the effect of gravity, due to their low velocity, and must take into account that they travel along ballistic trajectories. This complicates the task of deducing surface emissions from a LENA image. At these low velocities the detector velocity will also affect the images. We show computed trajectories and simulated images of LENAs sputtered from Mercury's surface. The results indicate that it is possible to infer the local emission rates from a LENA image. The fact that LENAs follow ballistic trajectories can even be advantageous, since we can detect atoms emitted from the far side of the planet.

References. [1] Barabash, S., A. Lukyanov, P. C:son Brandt, and R. Lundin, Energetic neutral atom imaging of Mercury's magnetosphere. 3. Simulated images and instrument requirements, *Planet. Space Sci.*, in press. [2] Barabash, S., A. Lukyanov, M. Holmström, and E. Kallio, Energetic neutral atoms at Mars: Imaging of the oxygen escape. Submitted to *J. Geophys. Res.* [3] Lukyanov, A., S. Barabash, R. Lundin, and P. C:son Brandt, Energetic neutral atom imaging of Mercury's magnetosphere. 2. Distribution of energetic charged particles in a compact magnetosphere, *Planet. Space Sci.*, in press.