COMPUTATIONAL STUDY OF THE LUNAR TIME-OF-FLIGHT MASS SPECTROMETER (LTMS): METEORITE IMPACTS AND OUTGASSING EVENTS. Terik Daly, Jani Radebaugh, and Daniel E. Austin, Department of Chemistry and Biochemistry and Department of Geological and Planetary Sciences, Brigham Young University, Provo, UT, 84602, terik.daly@gmail.com, jani.radebaugh@byu.edu, dea@byu.edu.

Introduction: Two important processes believed to occur on the lunar surface have not yet been observed: outgassing of subsurface gases, and meteorite impacts below the limits of seismic detection. Recently-outgassed species are obscured by the larger population of background atmosphere, and cannot be distinguished from background using a typical mass spectrometer. Impacts of meteorites in the mg- to g-range cannot be observed seismically or optically, and are too infrequent for observation on small (~m^2) surfaces.[1-2] We are developing a novel instrument and method that would allow direct measurement of both of these processes.

A previous abstract [3] described a compact mass spectrometer and methodology for characterization of outgassing phenomena and impact-induced vaporization on the Moon. This instrument, the Lunar Time-of-flight Mass Spectormeter (LTMS) combines double-coincidence detection and an imaging detector, enabling analysis of the composition of gases. More importantly, however, the instrument uses a novel pattern analysis approach to separate neutrals emitted from brief events from the much larger population of background atmospheric neutrals.[4-5] This approach allows determination of distance and direction to the event using a single instrument, and will further provide data on the temperature, magnitude, and duration of gas-evolving events. The instrument will detect vapor produced from millimeter-sized and larger meteorites impacting over a very large area (~10^{12} m^2), providing direct data on neutral speciation in hypervelocity impacts, and data on meteorite flux.[6]

We have carried out simulations that predict the detected signals resulting from meteorite impacts and outgassing events of varying size, distance, and temperature. These variables are important to assessing the detection limits and spatial resolution of the LTMS instrument.

Instrument Operation: Figure 1 shows the LTMS instrument, the operation of which is discussed in more detail in [3]. Neutrals enter from the top of the device and are ionized by a continuous, focused electron beam. These ions then enter the imaging cone through a small aperture, and pass through the cone and acceleration grid. When an ion reaches the acceleration grid, its position is representative of the azimuthal and elevational angles it had as an incoming neutral. Ions

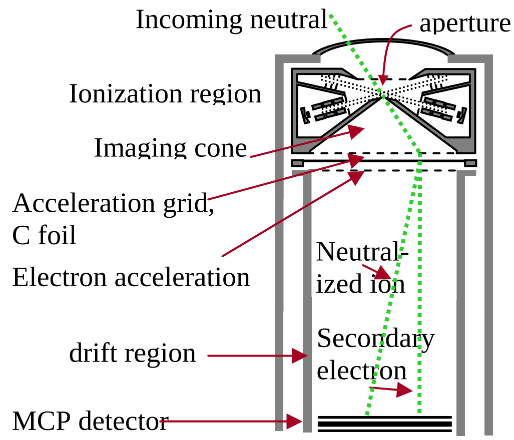

Figure 1. Diagram of the LTMS instrument.

reaching the accelerating grid are accelerated, pass through a thin (2 μg/cm^2) carbon foil, and continue through the electron acceleration grid to a position-sensitive microchannel plate (MCP) detector. As an ion passes through the thin foil it releases a secondary electron, which is accelerated toward the MCP detector. The ion is generally neutralized after passage through the foil.

The electron and ion reach the detector, separated in time by a few microseconds (corresponding to the time-of-flight, and hence, the mass of the ion). The electron strikes the detector at the same location that the ion passed through the foil. The ion/neutral may scatter by several degrees because of the foil, but will still reach the detector in most cases.[7-9] The coincidence of two pulses appropriately spaced in time allow separation of real signal from noise. The position of the electron on the detector gives the azimuthal and elevational angles of the incoming neutral. Due to scatter, the detected position of the ion is not useful.

When multiple neutrals from a single, brief outgassing event are detected in this manner, a recognizable pattern is produced, as shown in Figure 2. In this case neutrals reach the instrument at the same azimuthal angle, but differing elevational angles. The way these elevational angles change over time is a result of two factors: 1) the time distribution of the outgassing event itself, and 2) the kinetic energy and elevational angle of the neutral species. The time-variation of the elevational angle can be used to determine the distance to the event and also the energies of neutrals coming from that event. Data from many neu-

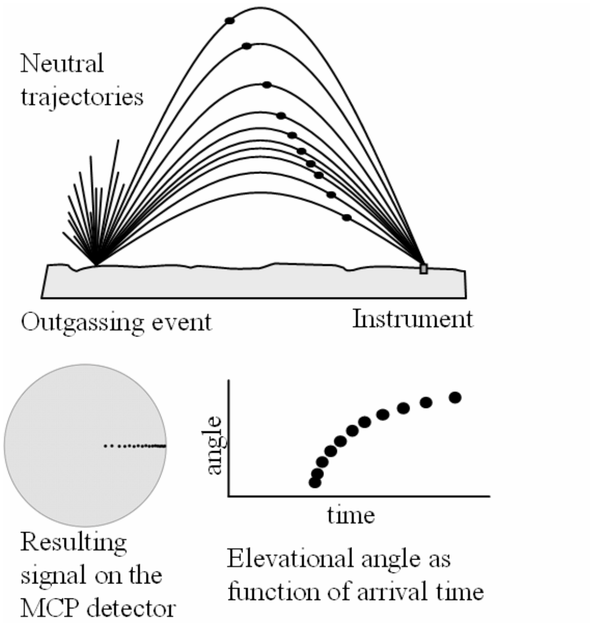

Figure 2. Detection of signal from outgassing event.

trals originating from the same event will follow a curve of the form:

$$\frac{dt}{d\theta} = \frac{2v_0}{g}\cos\theta$$

which can be used to separate outgassing events from the much larger population of background species. The width of the fit to the above curve indicates the duration of the outgassing event. The variation of initial velocity, mass, and angle indicates the distance to the outgassing event. That combined with the azimuthal angle give the absolute event location.

This method relies on the fact that many neutrals will reach the instrument directly from the outgassing event, before their first bounce on the lunar surface. Upon first bounce and the resulting scatter, all trajectory information is lost, and the neutral becomes part of the atmospheric background.

Performance Simulations: A spreadsheet in Excel was set up to simulate the detected signal from both background neutrals and neutrals originating from a localized event. Neutrals arrive at the instrument based on a Maxwell distribution of kinetic energy, with statistical factors to take into account angular distribution at the source, distance to source, source magnitude and duration, electron ionization, detection efficiency, foil scatter, lensing from the electron beam, variation of aperture corss section with elevational angle, and other instrument considerations. The resulting simulated signals provide estimates of the effects that range, amount of gas released, temperature, event duration, and gas profile through the event have on the detection limit and spatial resolution of the instrument. These simulations also provide a useful check for the algorithms being developed to extract information out of the data. Figures 3 and 4 show two results from simulated signals.

References: [1] Austin, D.E. 39th LPSC (2008) Abstract 1350. [2] Love, S.G. et al. (1993) *Science 262*, 550-553. [3] Jaffe, L.D. et al.(1970) *Science 17*0, 1092-1094. [4] Hoffman J.H. et al. (1974) *Space Res. 14*, 607-614. [5] Hodges R.R. et al. (1974) *Icarus, 21*, 415-426. [6] Grun E. et al. (1985) *Icarus*, *62*, 244. [7] Babenko, P.Y. (2001) *Tech. Phys. Lett. 27*, 44-48. [8] McComas, D.J. *Rev. Sci. Instr*. *75*, 2004, 4863-4870. [9] Allegrini, F. (2006) *Rev. Sci. Instr*. 77, 044501.

Figure 3. Signals from events at various temperatures. The different angular profiles can be used to estimate gas temperature at the event.

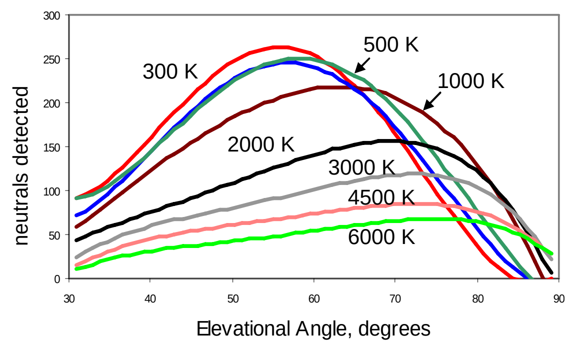

Figure 4. Two signals showing how pattern angle varies with distance to the event (50, 100, and 500 km, respectively). The signal produced by an event varies predictabley with range, allowing the determination of event location based solely on the data collected by LTMS.