

# Comparing Observations of the Concentration of Sodium in Mercury's Exosphere

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## Abstract

From years of ground based observations since the mid 1980's we have seen that the chemical composition of Mercury's exosphere is heavily influenced by solar radiation. The MESSENGER mission is the first to analyze Mercury's exosphere from orbit. Given that these data were gathered from a new observation perspective we wish to compare them to the previous ground based studies. We compared the MESSENGER data to ground based data from Sprague et al. 1997<sup>1</sup> by analyzing how the concentration of sodium in the exosphere changes with the time of day on Mercury and its true anomaly (the planet's angular displacement from its closest point to the Sun). We found that both observations show there is a dependence of sodium concentration on both local time and on true anomaly. There is a greater concentration of sodium at earlier times in Mercury's day with the greatest concentration around dawn and the least concentration around dusk. There is also a greater concentration when Mercury's true anomaly is around 180° (its furthest point from the Sun where radiation pressure which disperses the exosphere is minimal). Although the data from the ground based observations are more scattered, the two show the same order of magnitude sodium concentration at similar local times and true anomalies. These findings from two different methods of data gathering show that that sodium concentration is greatest when the intensity of photons incident on the exosphere is greatest with minimal radiation pressure.

## Introduction

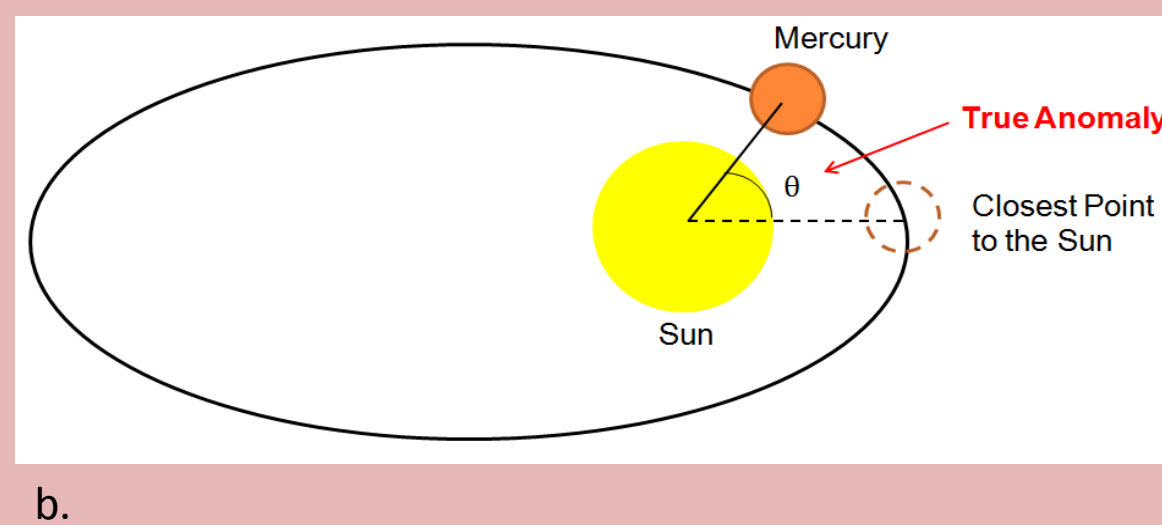
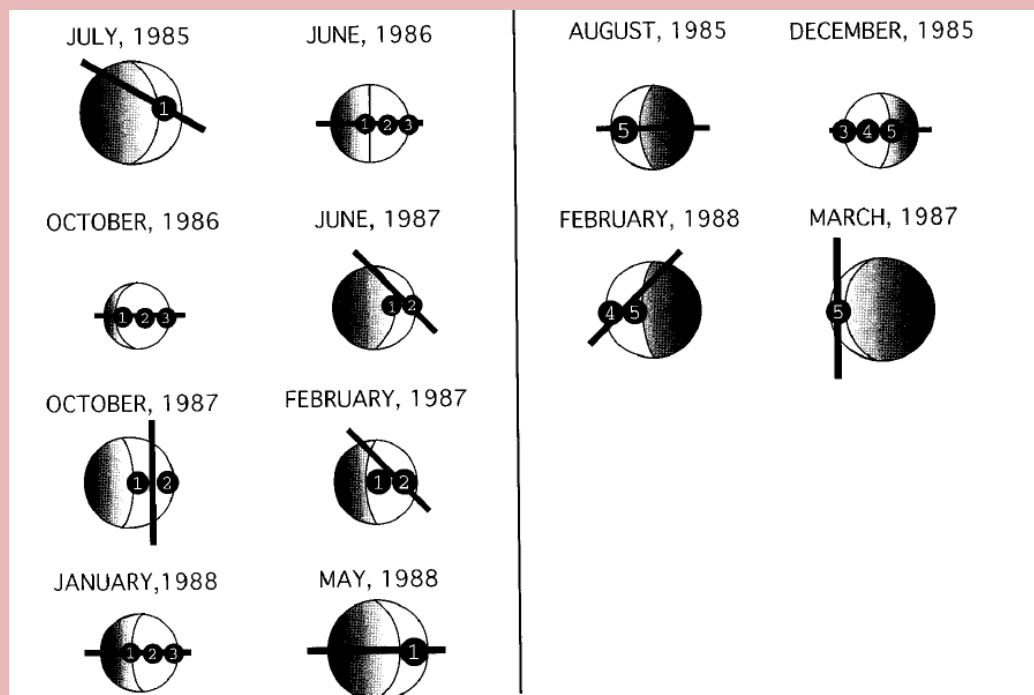
The MESSENGER mission is the first satellite to orbit Mercury and give information on the chemical composition of its exosphere, specifically how the concentration of Sodium varies at different locations in the exosphere. Due to Mercury's close proximity to the Sun it has been theorized that the variability of sodium throughout the exosphere is dependent on the intensity of solar radiation incident on the surface of the planet. We therefore expect the concentration of sodium to change with photon intensity. Given that photon intensity changes both with time of day and time of year on Mercury we wished to observe how the concentration of sodium in the exosphere changes with local time on Mercury and True Anomaly (the planet's angular displacement from its closest point to the Sun). To do so we looked at ground based data from the 1980's published by Sprague et al. 1997 and compared them to data gathered from the MESSENGER mission. If the data from MESSENGER gives similar trends about the nature of the exosphere as passed ground based observations we can draw conclusions about the solar influence on Mercury's exosphere. This will give us a better understanding of the nature of Mercury's exosphere and may also give us an insight into the chemical composition of Mercury as a whole, the nature of planetary atmosphere for bodies as close to their star as Mercury, and perhaps a better understanding of how the planet may have formed.

## Methods (Ground Observations)

- For ground observations we used data compiled by Sprague et al. 1997 of observations of Mercury from 1985- 1988. From this data we determined how sodium column density (measured from the intensities of observed light with wavelengths on the order of 580nm, the D1 and D2 spectra) varied with local time and true anomaly.
- Ground based observations were given as a snapshot of Mercury over an x-y plane. The Na concentration for different local times was measured by recording the intensity of the D1 and D2 spectra through an observation slit in the telescope oriented to scan the exosphere of Mercury at different locations see figure (a) below. Using the given Sub-Solar and Sub-Earth points we converted x-y positions of each observation to local times.
- Conversion of x-y coordinates to local time on Mercury:

$$\text{Local Time} = \text{Mod} \left( \left( \text{Subsolar Point} - \left( \text{SubEarth Point} + \arcsin \left( \frac{-x}{\sqrt{1-y^2}} \right) \right) \right) \cdot \frac{24}{360} + 12.24 \right)$$

- In addition to local time we also determined the change in of concentration of Na with Mercury's seasonal variability which is measured by true anomaly (the angular displacement between Mercury's location and its location where it is closest to the Sun in its orbit), see figure (b) below.
- True anomaly was determined by researching the true anomaly on the NASA website, HORIZONS, at the time of the observation<sup>2</sup>.



Sprague et al. 1997

## Methods cont. (MESSENGER Mission)

The MESSENGER mission also recorded Na concentrations for different local times and true anomalies. While in orbit the satellite scanned vertical profiles of the exosphere from a high altitude to the surface and recorded the concentration of Na along each profile. (as seen from the image below).

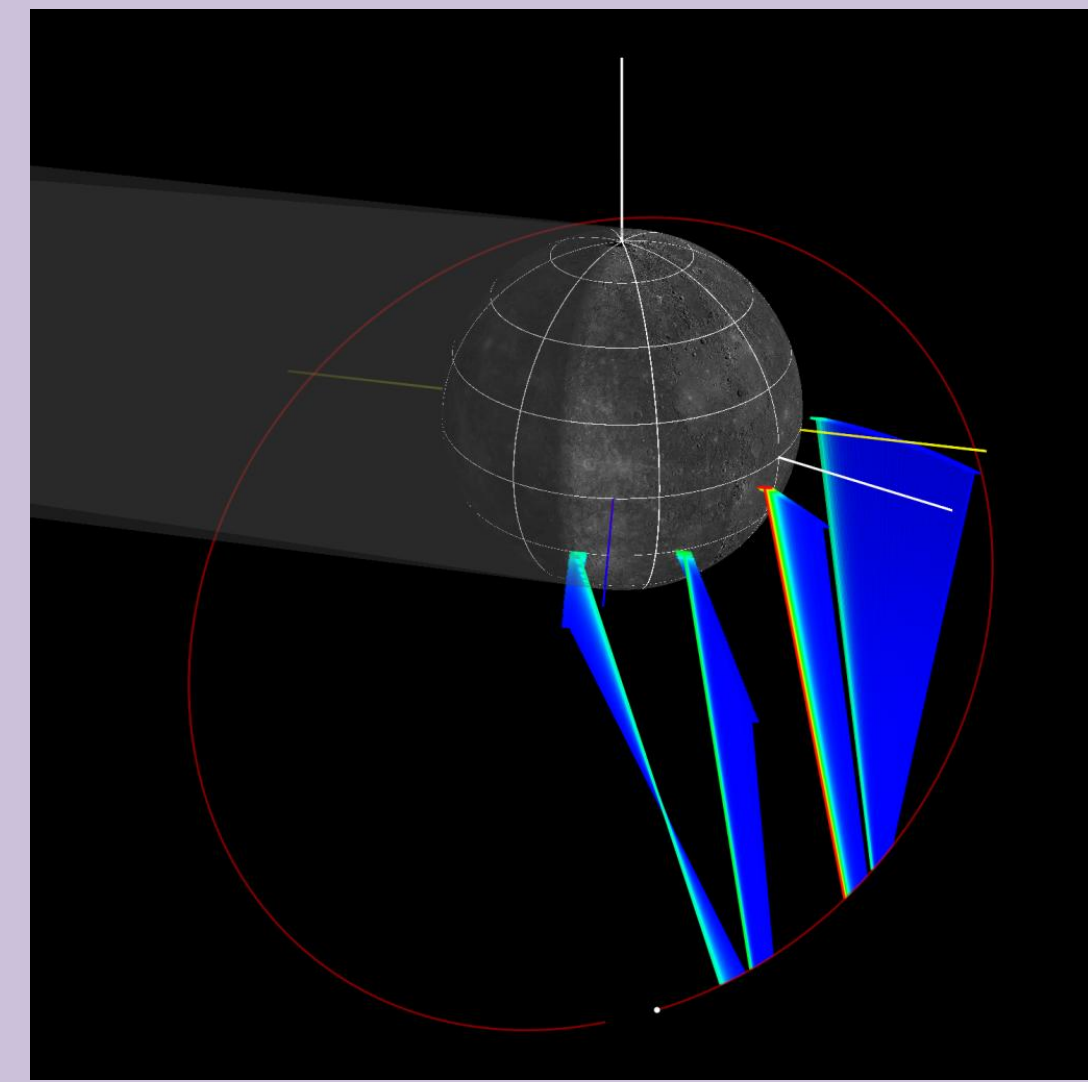
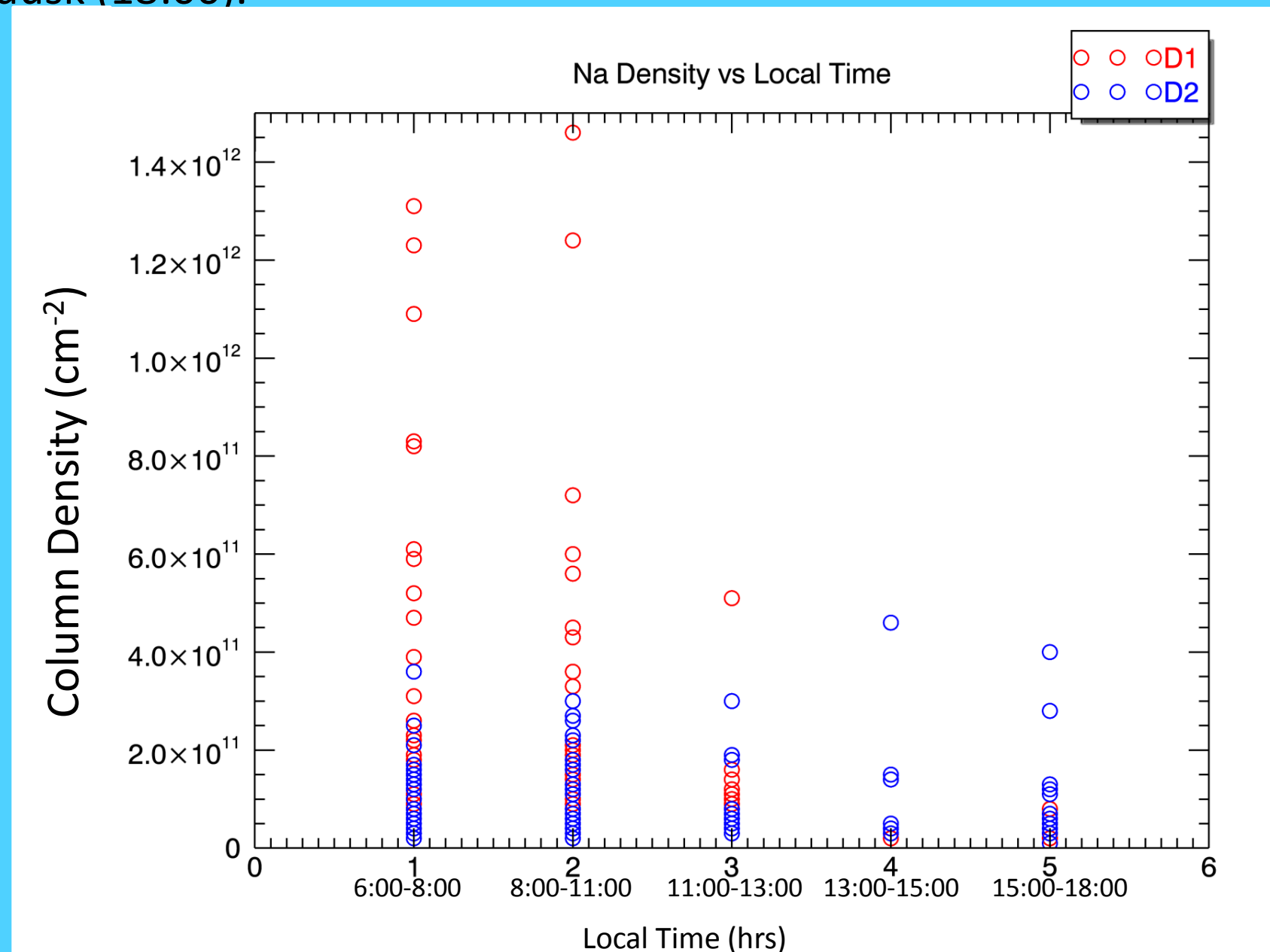


Image generated by NASA

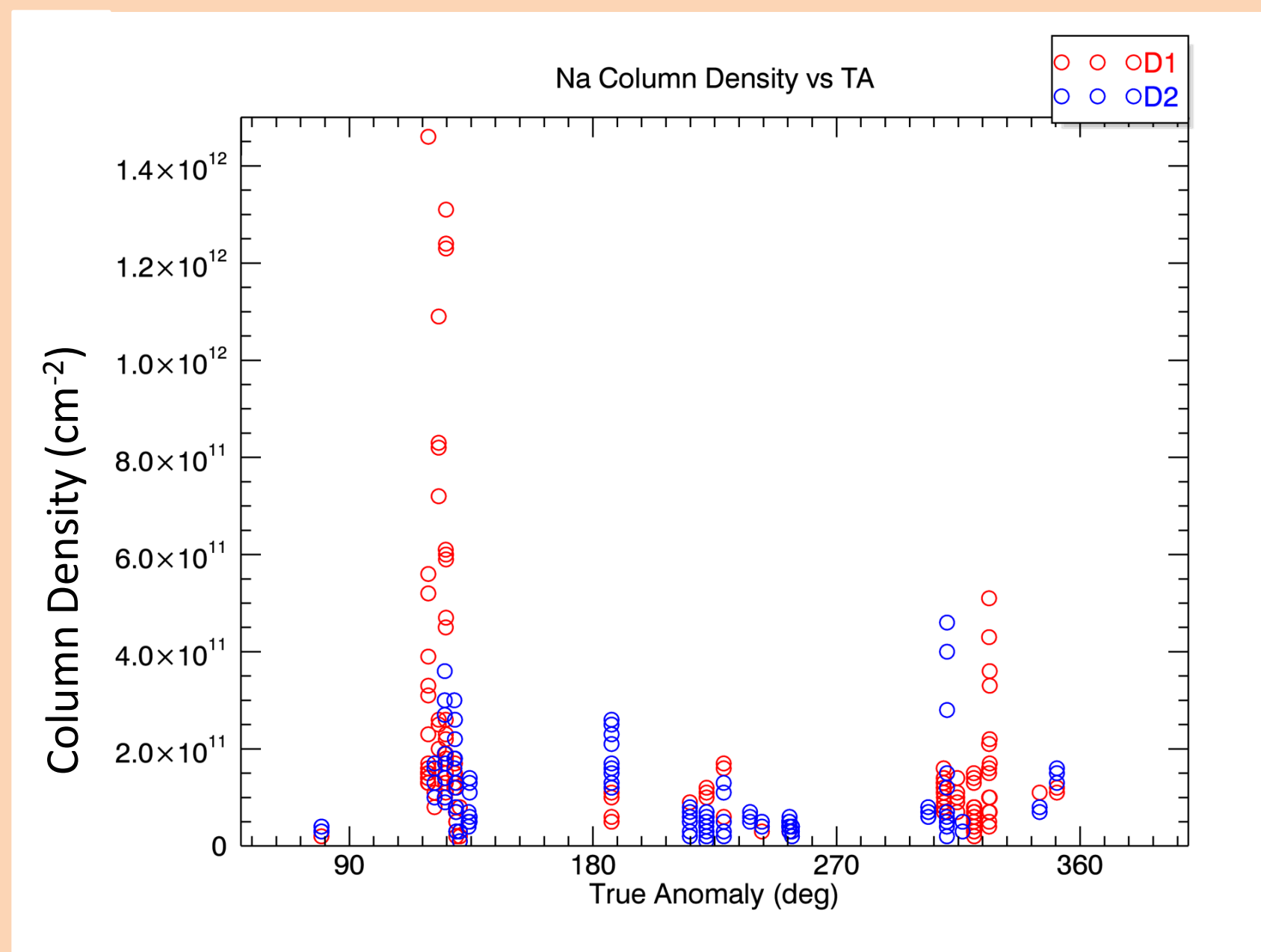
## Results: (Na Concentration vs Local Time)

The plot below is a replication of data from Sprague et al. 1997 showing the dependence of Na concentration on Mercury's local time. From the ground based data we found higher Na concentration present closer to dawn (6:00) than dusk (18:00).



## Results:(Na Concentration vs True Anomaly)

The plot below shows an increase in Na abundance only for specific true anomalies. This also demonstrates a dependence of Na concentration on true anomaly in addition to local time.

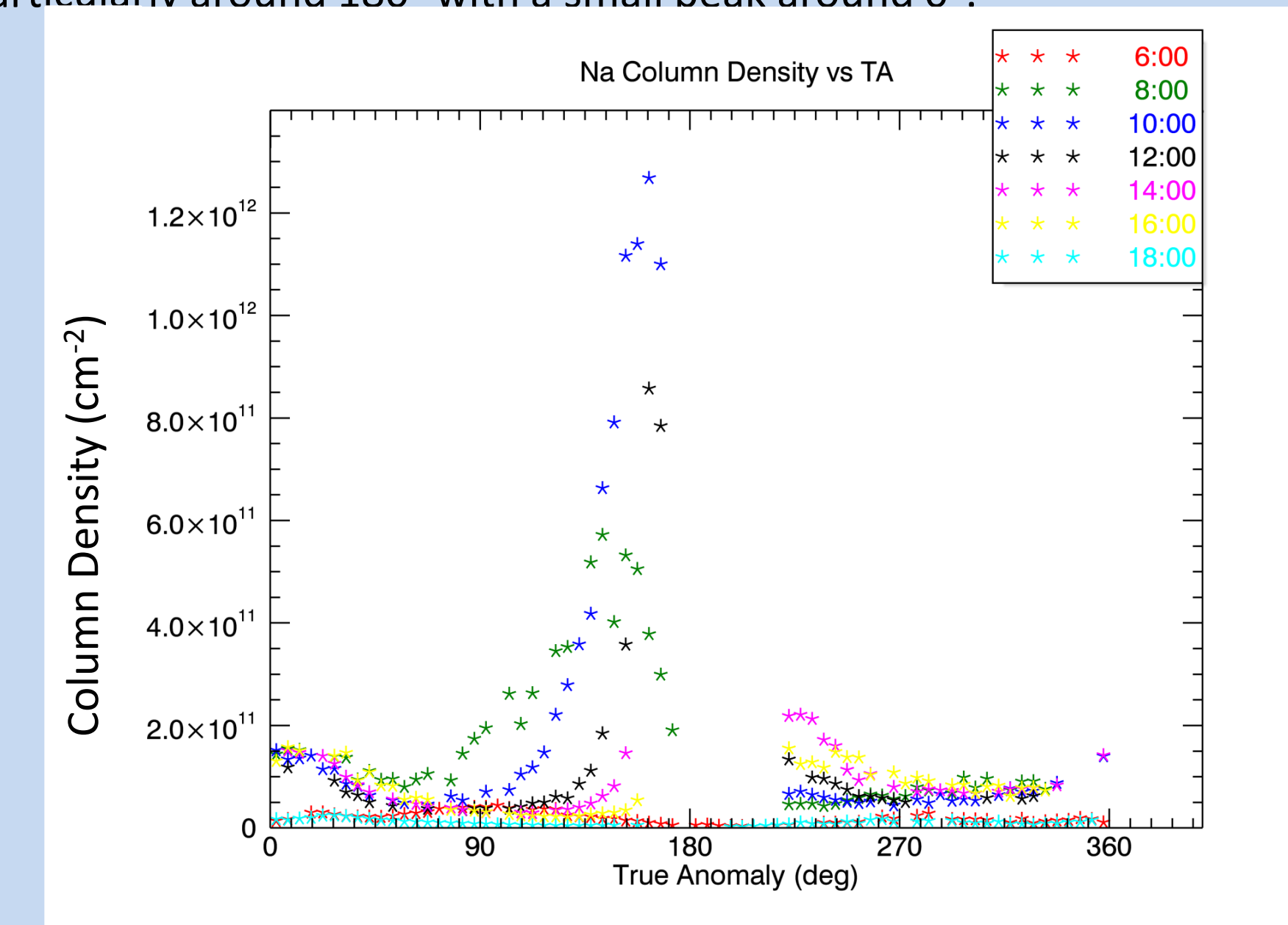


## References:

1. Sprague, Kozlowski, Hunten. *Distribution and Abundance of Sodium in Mercury's Atmosphere, 1985-1988*. 1997. Icarus 129
2. <http://history.nasa.gov/EP-177/i2-6.jpg>

## Results: (MESSENGER Data)

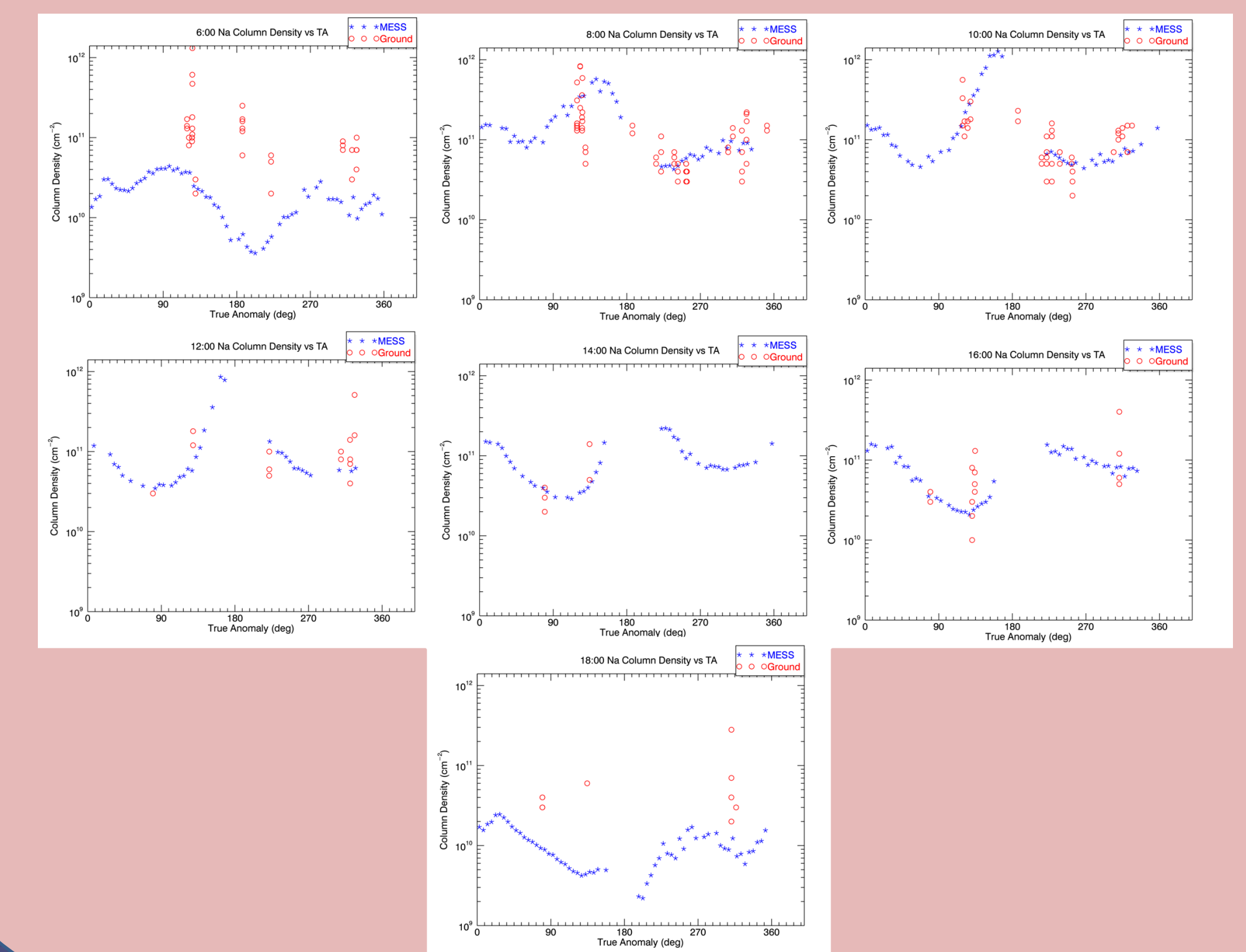
Data from MESSENGER also shows a dependence of Na concentration on both local time and true anomaly. There is a peak in Na concentration particularly around 180° with a small peak around 0°.



## Comparison of the two data sets

For local times between 8:00 and 16:00 there is general agreement between the ground based data and the MESSENGER data.

- The data follow similar trends for different true anomalies.
- Although the ground based data is also very scattered with several points differing by an order of magnitude, when compared to the MESSENGER data, the average density for the ground based is both on the same order of magnitude and almost matches the density reported by MESSENGER. The exception is at dawn (6:00) and dusk (18:00) when the average of the ground based data differs from MESSENGER by an order of magnitude.



## Interpretation and Conclusions

- Both ground based data and orbital data show a dependence of Na concentration in Mercury's exosphere on local time and true anomaly.
- This demonstrates that chemical composition of Mercury's exosphere is highly dependent on the intensity of solar radiation incident on the surface of the planet.
- The ground based data shows there is a greater concentration of sodium earlier in Mercury's day. The explanation given by Sprague et al. for this trend is that frozen sodium on the surface of the planet during Mercury's night is rapidly evaporated when direct sunlight at dawn strikes the surface of the planet. The concentration of sodium then diminishes as the day progresses while the evaporated sodium disperses throughout the exosphere.
- The fact that the MESSENGER data shows there is also a greater concentration at a true anomaly of 180° is a consequence of the influence of radiation pressure in the exosphere composition. At this true anomaly Mercury is farthest from the Sun and therefore receives the least amount of radiation pressure from the Sun (illustration below).

