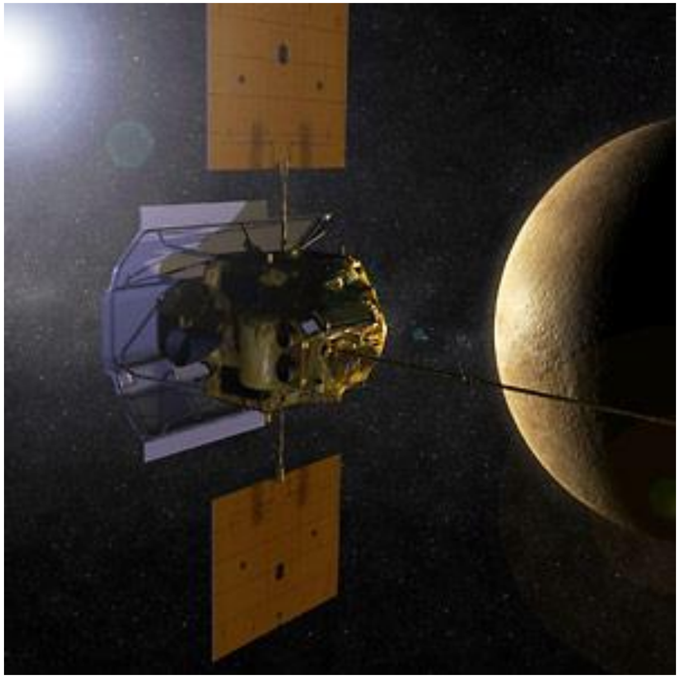


Comparing Observations of the Abundance of Sodium in Mercury's Exosphere

1

Presenter: Alexander Lanzano

Mentors: Aimee Merkel, Timothy Cassidy, Bill McClintock

Motivation

- Mercury is highly vulnerable to the Sun
  - Its exosphere is most likely dependent on the amount of radiation the planet receives
- MESSENGER is one of the first satellites to obtain data about the exosphere from orbit
- We can compare this new data to ground based data to see if there are any corresponding trends
- Discovering how the exosphere is influenced by the Sun can give us an insight into:
  - The chemical composition of Mercury
  - How the planet might have formed
  - How our Solar System might have formed
  - What other planets might be like in other system at similar distances as Mercury is from the Sun

OUTLINE

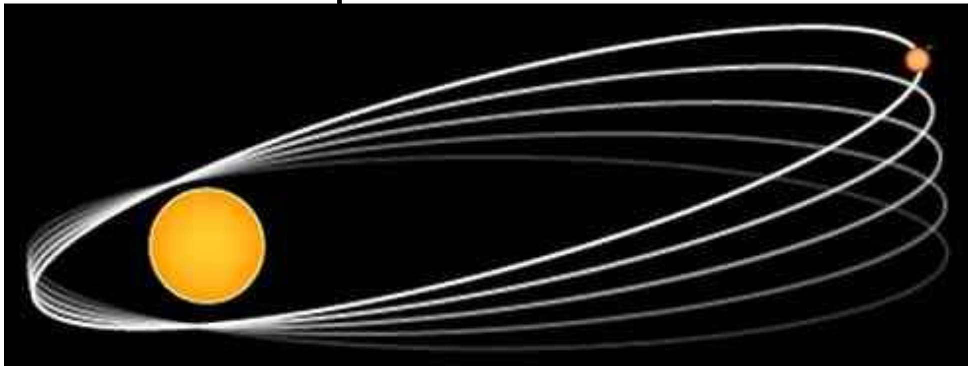
- Background on Mercury and the solar influence on its exosphere
- Variables of interest
- Observations from Earth
- Observations from MESSENGER
- Comparison of the two data sets
- Observed trends

MERCURY

- General Facts
  - Smallest planet, 6% Earth
  - 1 year = 88 Earth days
  - 1 day = 176 Earth days
  - Highly eccentric orbit
  - Magnetic field present
  - Virtually no atmosphere
- Highly influenced by the Sun
  - High energy particle collisions
  - Radiation pressure

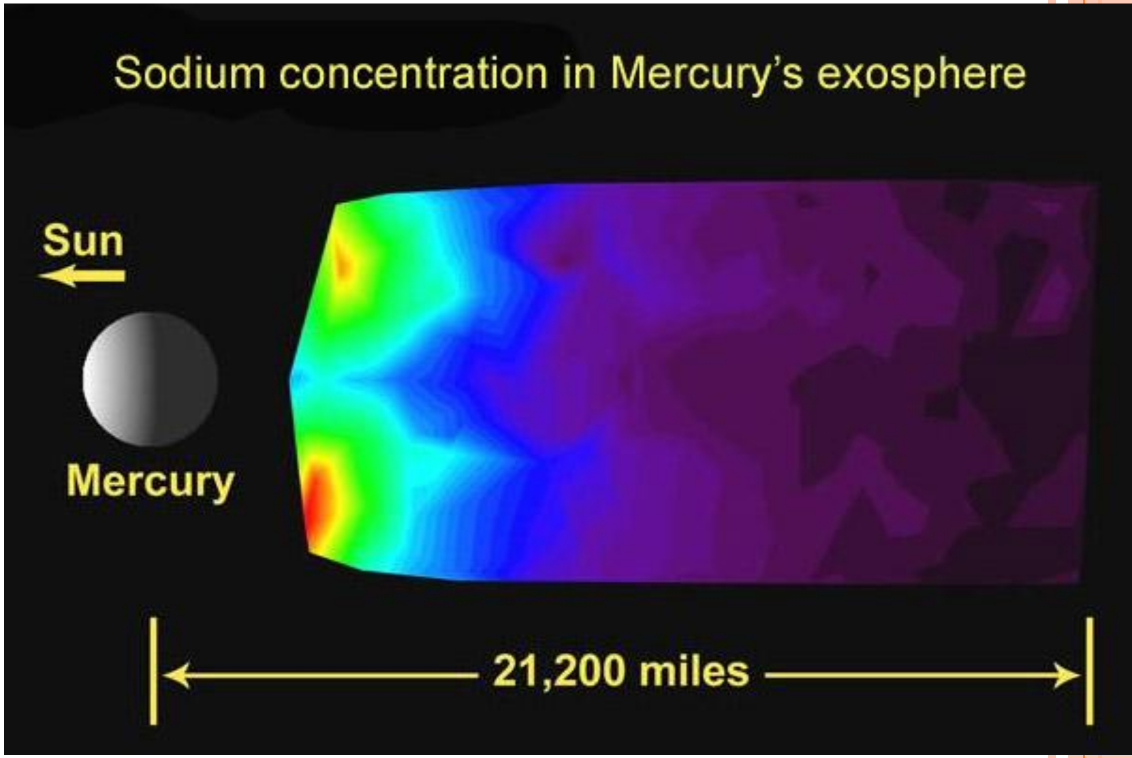
Mercury

Earth's moon



Mercury's Atmosphere

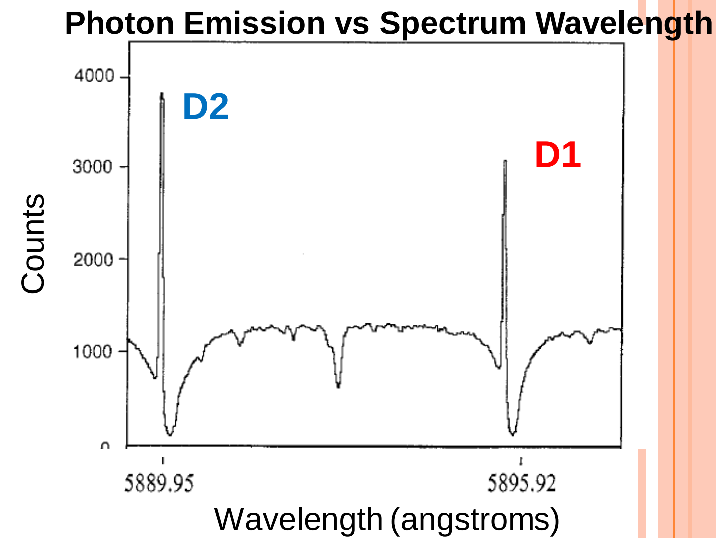
- No sustainable atmosphere
- Thin Exosphere
  - H, He, O, Ca, Mg, K Na
  - Resembles comet tail
- Source of Exosphere
  - Sputtering
  - PSD
  - Thermal Evaporation
  - Impact evaporation

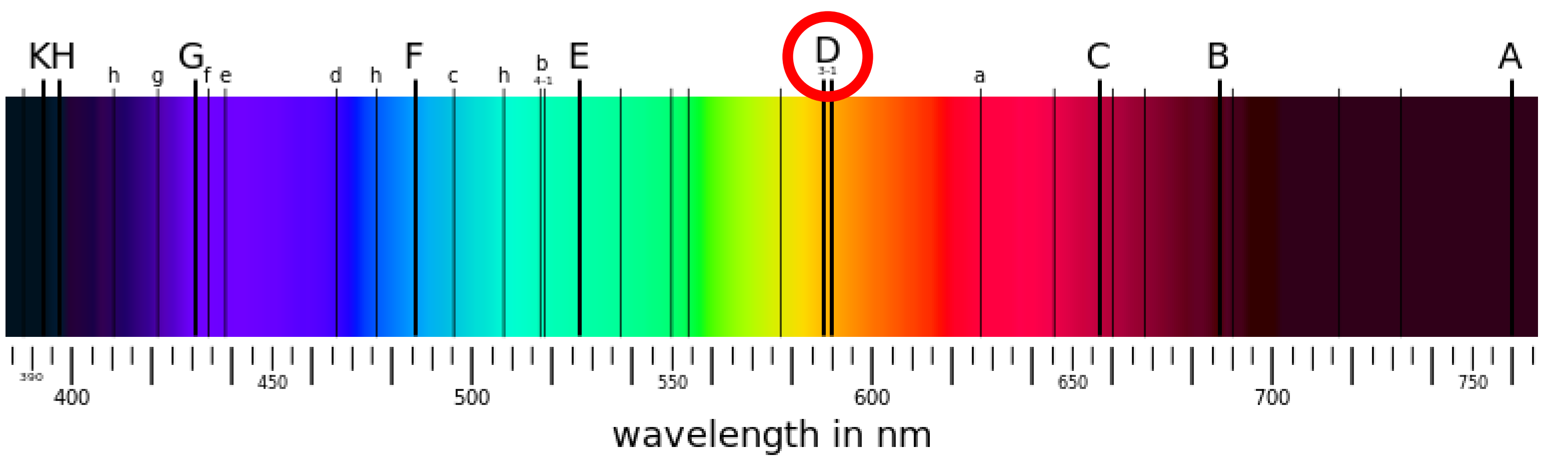


DETERMINE SOLAR INFLUENCE BY VARIATION IN OBSERVED NA

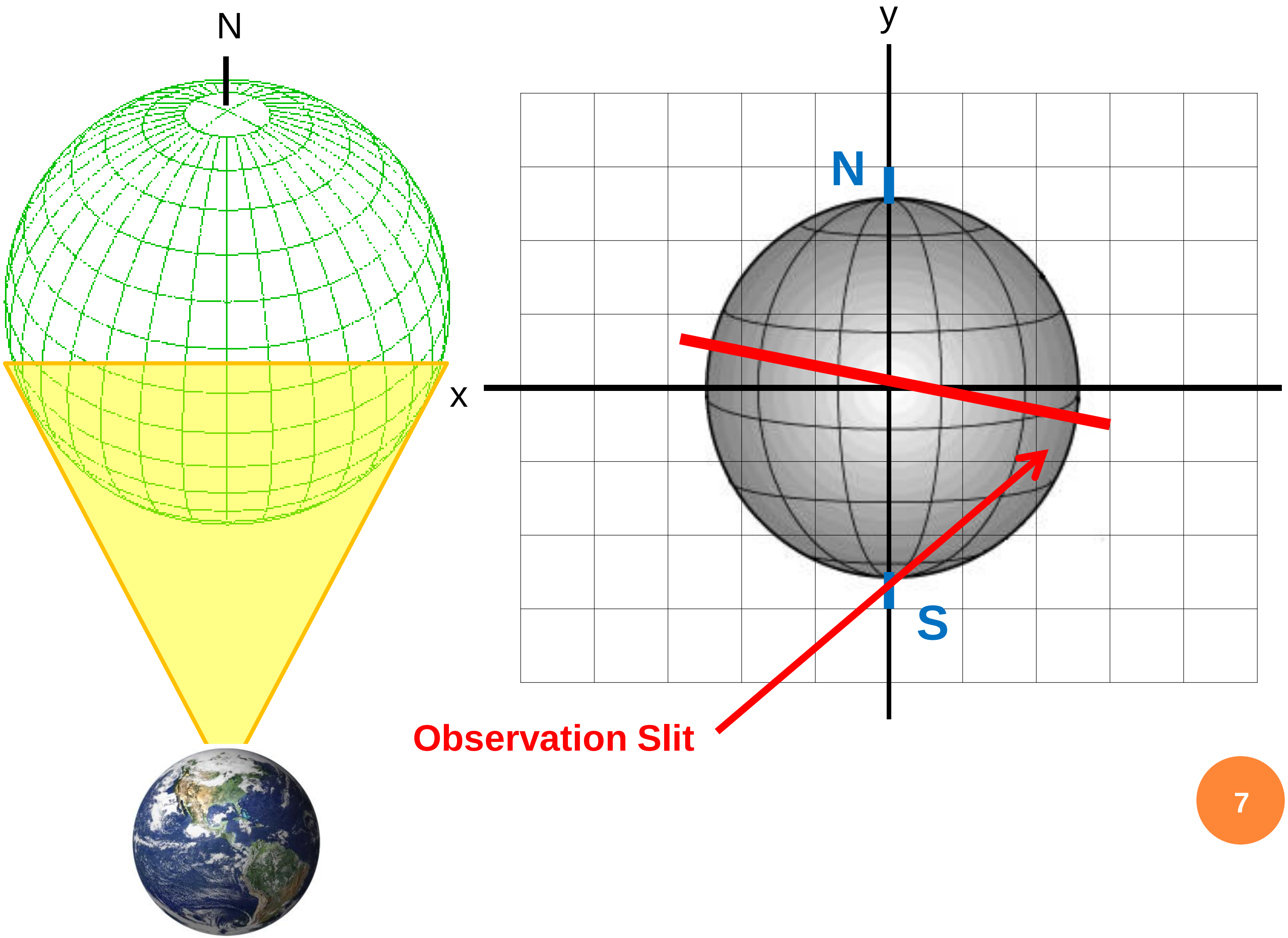
- Search for increase in Na density:
  - D1 and D2 (yellow) spectrum 580 nm
- How does it change with respect to:
  - Time of Day
  - Change of season

Sprague et al. 1997



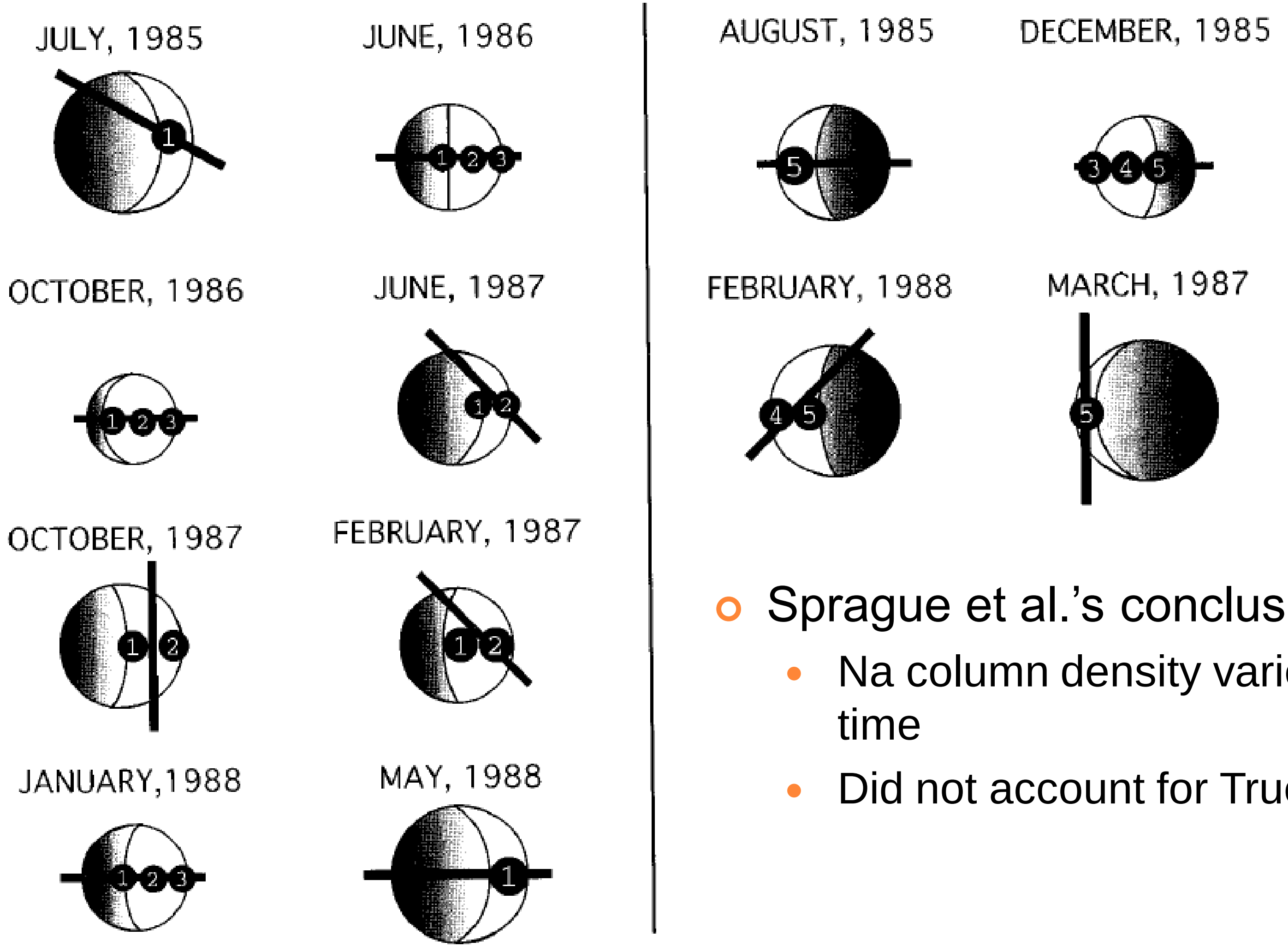


Ground Based Observation Method



SPRAGUE ET AL. OBSERVATIONS

Sprague et al. 1997



- Sprague et al.'s conclusions:
  - Na column density varies with local time
  - Did not account for True Anomaly

COMPILING THE DATA

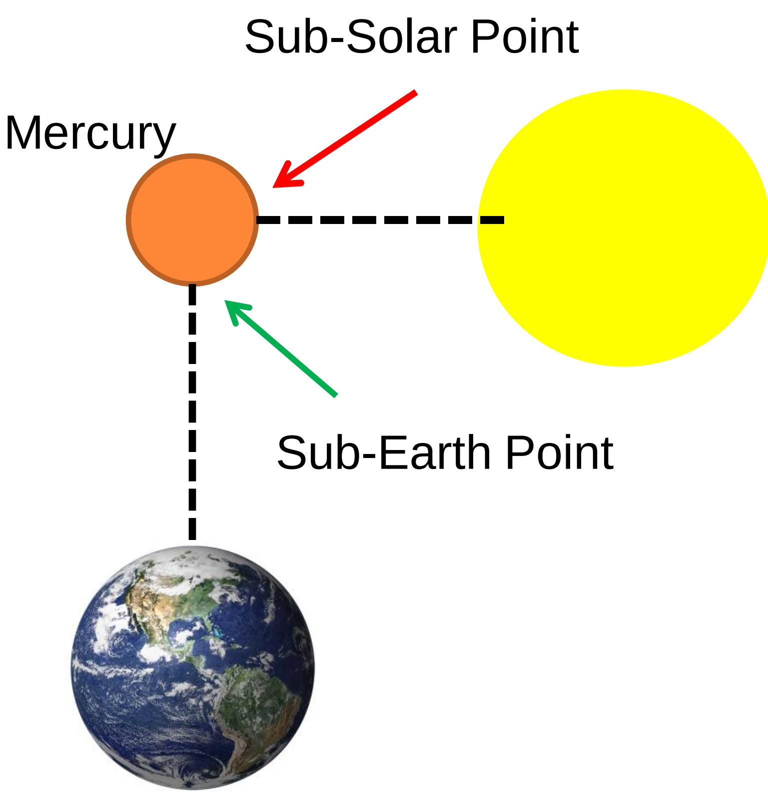
Sprague et al. 1997

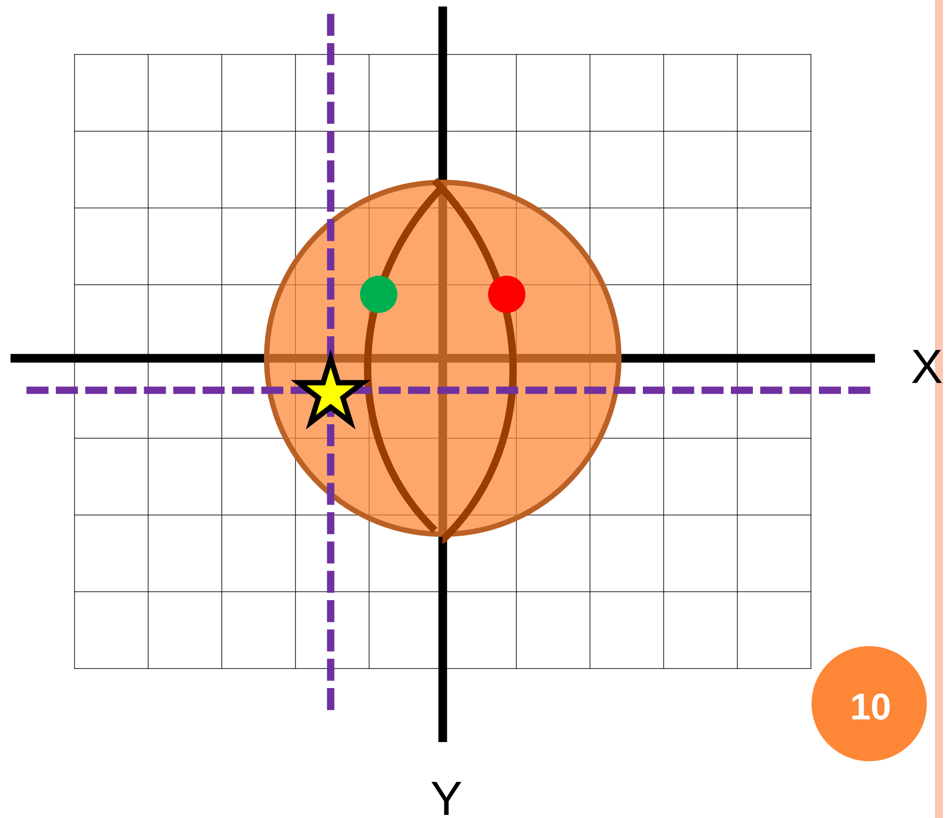
Physical and Geometric Parameters for Mercury Observations

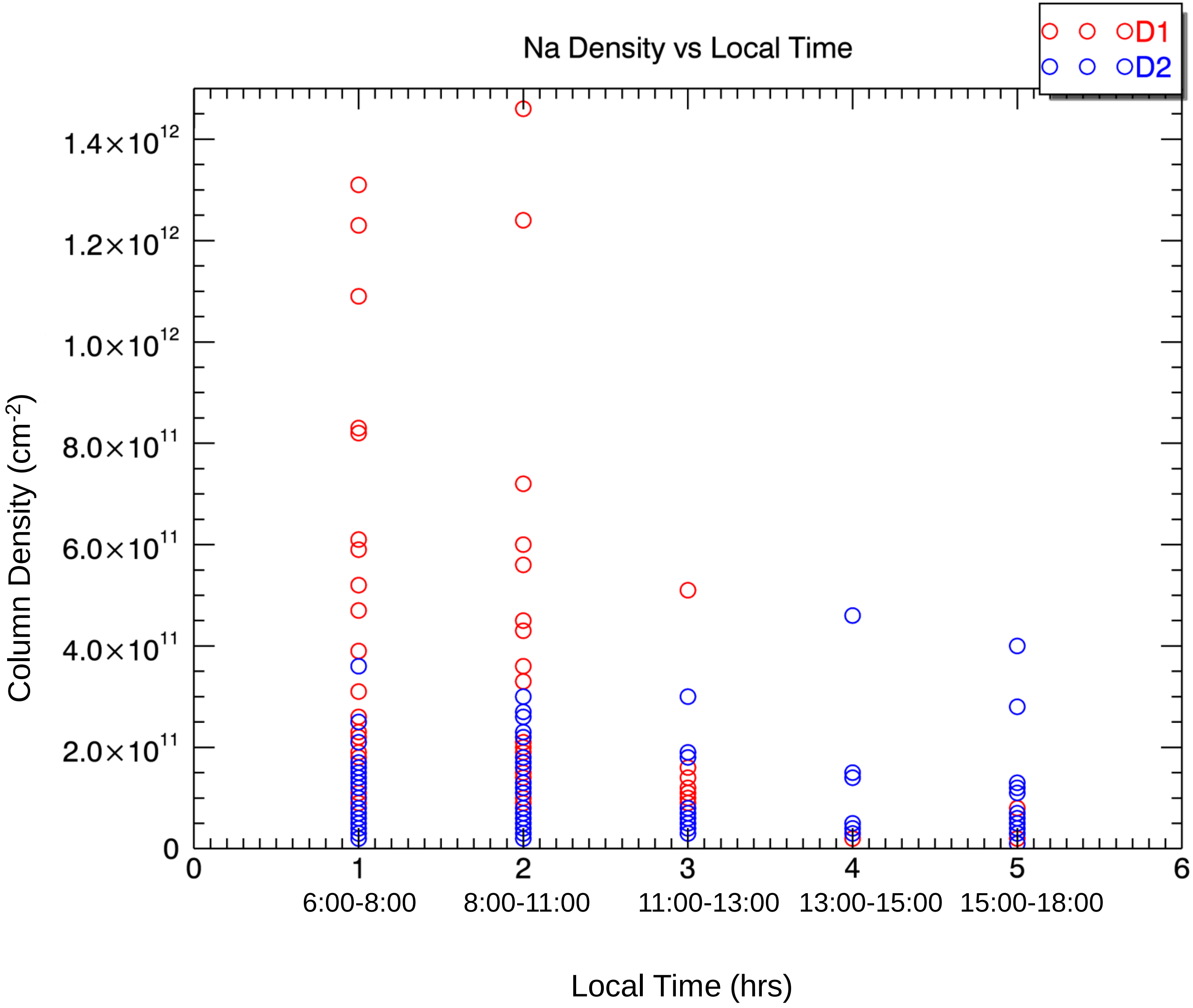
UT Date	Frame #	UT Time h	UT Time m	Air Mass	Slit Offset arcsec	Slit Rot. ccw deg	Phase Angle deg	Diam. arcsec	Heliocentric Distance AU	Doppler Shift mA	gd2 1/sec	gd1 1/sec	Total Rad. Accel. (cm sec^{-1})	Mercury Local Time	Sub-Earth Long. deg	Sub-Earth Lat. deg	Sub-Solar Long. deg	Seeing Sigma arcsec	Hapke Reflec.	Flux At Mercury (10^{14}q cm^{-2}sec^{-1})	Calibration Factor (kRsec DN^{-1})
07/24/85	785-095	2	32	4.9	0.0	45	118.9	9.53	0.466	-24	2.7	1.4	12	early am	37.8	9.7	278	2.4	0.025	2.4	757
	785-096	2	37	5.4	0.0	45	118.9	9.54	0.466	-24	2.7	1.4	12	early am	37.8	9.7	278	1.5	0.037	2.4	825
	785-097	2	42	6.0	0.0	45	118.9	9.54	0.466	-24	2.7	1.4	12	early am	37.8	9.7	278	1.6	0.036	2.4	922
08/26/85	885-143	12	15	6.8	0.0	90	-107	7.77	0.327	-150	37.4	20.5	171	late pm	252.4	7.9	360	1.7	0.049	4.9	1042
	885-144	12	22	5.8	0.0	90	-107	7.77	0.327	-150	37.4	20.5	171	late pm	252.4	7.9	360	1.9	0.046	4.9	523
	885-145	12	30	5.0	-2.2	90	-107	7.77	0.327	-150	37.4	20.5	171	late pm	252.5	7.9	360	1.7	0.043	4.9	1244
	885-147	12	35	4.6	2.2	90	-107	7.77	0.327	-150	37.4	20.5	171	late pm	252.5	7.9	360	2.0	0.035	4.9	3898
	885-148	12	48	3.8	-4.0	90	-106.9	7.77	0.327	-150	37.4	20.5	171	late pm	252.5	7.9	360	1.9	0.014	4.9	2295
08/27/85	885-226	12	50	3.7	0.0	90	-102.1	7.54	0.323	-136	34.4	18.5	156	late pm	257.9	7.6	0	2.0	0.052	5.0	811
12/14/85	1285-361	13	31	5.6	2.0	90	-84.2	7.05	0.358	194	36.2	22.8	174	noon-pm	102.1	-4.1	186	4.9	0.028	4.1	1438
	1285-362	13	37	5.1	-2.0	90	-84.2	7.05	0.358	194	36.2	22.8	174	noon-pm	102.1	-4.1	186	4.1	0.034	4.1	1380
	1285-363	13	52	4.1	0.0	90	-84.1	7.05	0.358	194	36.2	22.8	174	noon-pm	102.1	-4.1	186	3.4	0.052	4.1	1286
06/18/86	686-028	21	15	1.0	0.0	90	87.4	7.11	0.415	169	23.9	15.4	116	am-noon	295.6	4.7	208	2.6	0.062	3.0	557
06/19/86	686-093	23	37	1.2	0.0	90	89.8	7.26	0.421	161	21.8	14.3	106	am-noon	300.9	5.0	211	2.5	0.062	2.9	503
06/20/86	686-101	0	24	1.4	0.0	90	89.9	7.26	0.421	161	21.8	14.3	106	am-noon	301.1	5.0	211	2.1	0.073	2.9	449
06/21/86	686-139	1	1	1.59	3.0	18	92	7.41	0.426	153.8	20.52	13.62	101	am-noon	306.1	5.2	214	1.5	0.078	2.9	382
	686-156	2	35	1.90	2.7	18	92.2	7.42	0.426	153.8	20.49	13.60	100	am-noon	306.5	5.2	214	1.5	0.081	2.9	510
10/17/86	1086-007	1	8	7.9	0.0	90	65.5	6.14	0.445	-116	14.5	7.5	65	am-noon-epm	197.0	2.7	131	3.2	0.066	2.6	1132
	1086-008	1	12	8.8	0.0	90	65.5	6.14	0.445	-116	14.5	7.5	65	am-noon-epm	197.0	2.7	131	2.7	0.082	2.6	1488
10/19/86	1086-066	0	30	4.2	0.0	90	69.4	6.33	0.438	-132	17.8	9.5	80	am-noon-epm	206.8	2.6	137	2.3	0.086	2.7	489
	1086-069	1	3	7.3	-2.0	90	69.4	6.33	0.438	-132	17.8	10.0	82	am-noon-epm	206.9	2.6	138	3.1	0.046	2.7	826
	1086-071	1	13	9.5	2.0	90	69.4	6.33	0.438	-132	17.8	10.0	82	am-noon-epm	207.0	2.6	138	3.1	0.046	2.7	830
	1086-072	1	19	11.6	0.0	90	69.4	6.34	0.438	-132	17.8	10.0	82	am-noon-epm	207.0	2.6	138	2.8	0.071	2.7	1889
10/21/86	1086-126	0	52	6.0	1.8	0	73.6	6.55	0.429	-148	21.7	11.8	99	am-noon-epm	217.0	2.4	143	2.0	0.093	2.8	2500
	1086-127	1	0	7.0	2.0	0	73.6	6.55	0.429	-148	21.7	11.8	99	am-noon-epm	217.1	2.4	143	2.6	0.071	2.8	783
	1086-128	1	8	8.6	1.0	0	73.7	6.55	0.429	-148	21.7	11.8	99	am-noon-epm	217.1	2.4	143	4.9	0.028	2.8	1674
02/11/87	287-213	1	12	3.8	3.6	27	82.3	6.87	0.309	-51	8.5	4.3	38	am-noon	82.7	-7.1	0	1.5	0.063	5.4	395
02/12/87	287-263	1	31	5.0	2.4	27	87.6	7.07	0.308	-29	6.4	3.4	29	am-noon	87.8	-7.3	0	2.4	0.063	5.5	459
03/12/87	387-021	13	19	7.1	-3.8	0	-122	9.61	0.428	150	19.4	13.1	96	late pm	274.0	-8.3	36	2.4	0.021	2.8	1553
	387-022	13	29	5.7	-3.8	0	-122	9.61	0.428	149	19.4	12.7	95	late pm	274.0	-8.3	36	2.4	0.021	2.8	692
03/13/87	387-068	13	26	5.7	-4.5	27	-119	9.4	0.433	142	17.1	12.0	86	late pm	280.0	-8.1	39	1.6	0.038	2.8	1010
06/08/87	687-010	2	10	2.5	3.3	0	106.1	8.3	0.426	153	20.5	13.6	100	early am	320.8	4.2	215	1.5	0.037	2.9	730
	687-016	2	59	4.1	-3.3	90	106.2	8.31	0.427	153	20.4	13.6	100	early am	320.9	4.2	215	1.7	0.028	2.9	452
	687-017	3	14	5.2	3.3	90	106.2	8.31	0.427	153	20.4	13.6	100	early am	321.0	4.2	215	1.6	0.030	2.9	556
10/10/87	1087-081	19	32	1.7	2.2	0	93.5	7.62	0.416	-168	25.5	14.3	117	am	245.0	4.1	151	2.2	0.059	3.0	995
10/12/87	1087-158	1	17	9.9	2.1	0	97.2	7.82	0.410	-175	26.7	15.1	123	am	252.0	4.1	155	2.8	0.039	3.1	3754
10/14/87	1087-273	18	30	1.9	3.0	0	106.3	8.29	0.395	-189	30.2	17.2	140	am	267.7	4.0	161	2.5	0.038	3.3	214
	1087-275	18	58	1.8	2.7	0	106.3	8.29	0.395	-189	30.3	17.2	140	am	267.8	4.0	161	2.4	0.038	3.3	262
	1087-278	19	24	1.7	2.7	0	106.4	8.29	0.395	-189	30.3	17.2	140	am	267.9	4.0	161	3.2	0.027	3.3	331

DETERMINE LOCAL TIME

$$Local\ Time = \mathrm{Mod}\left\{\left[\text{Subsolar Point} - \left(\text{SubEarth Point} + \arcsin\left(\frac{-x}{\sqrt{1-y^2}}\right)\right)\right] * \frac{24}{360} + 12{,}24\right\}$$

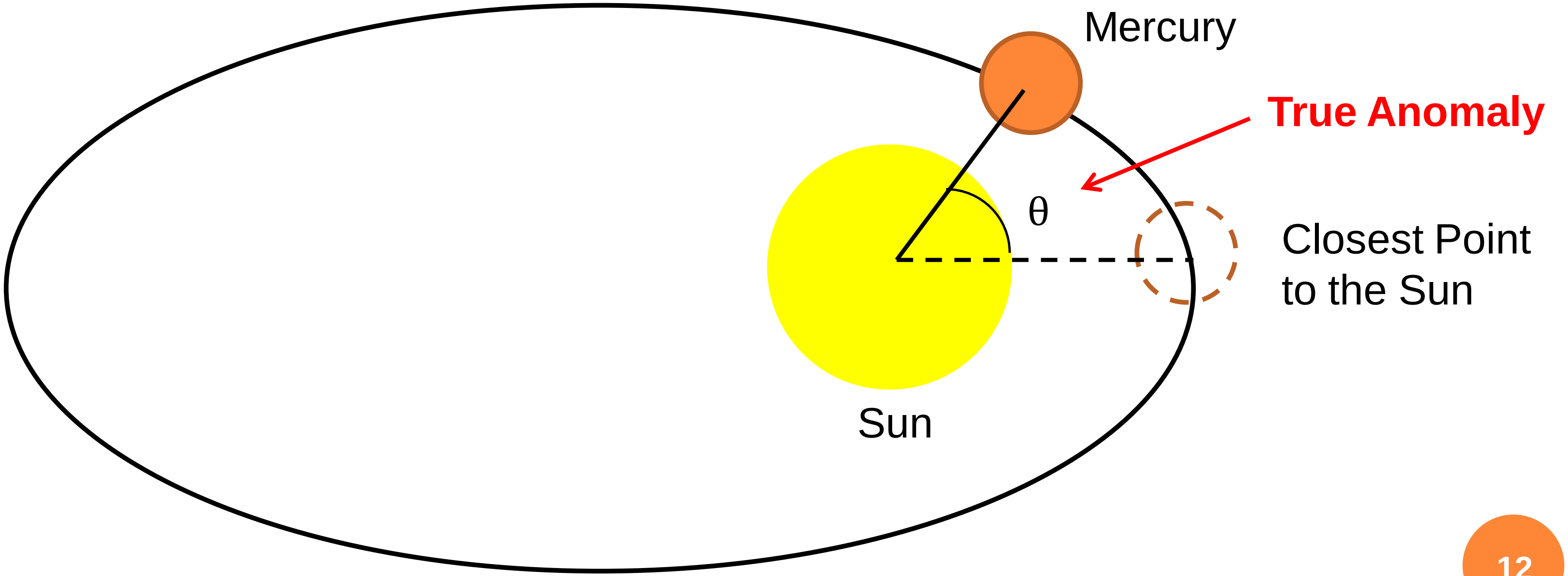


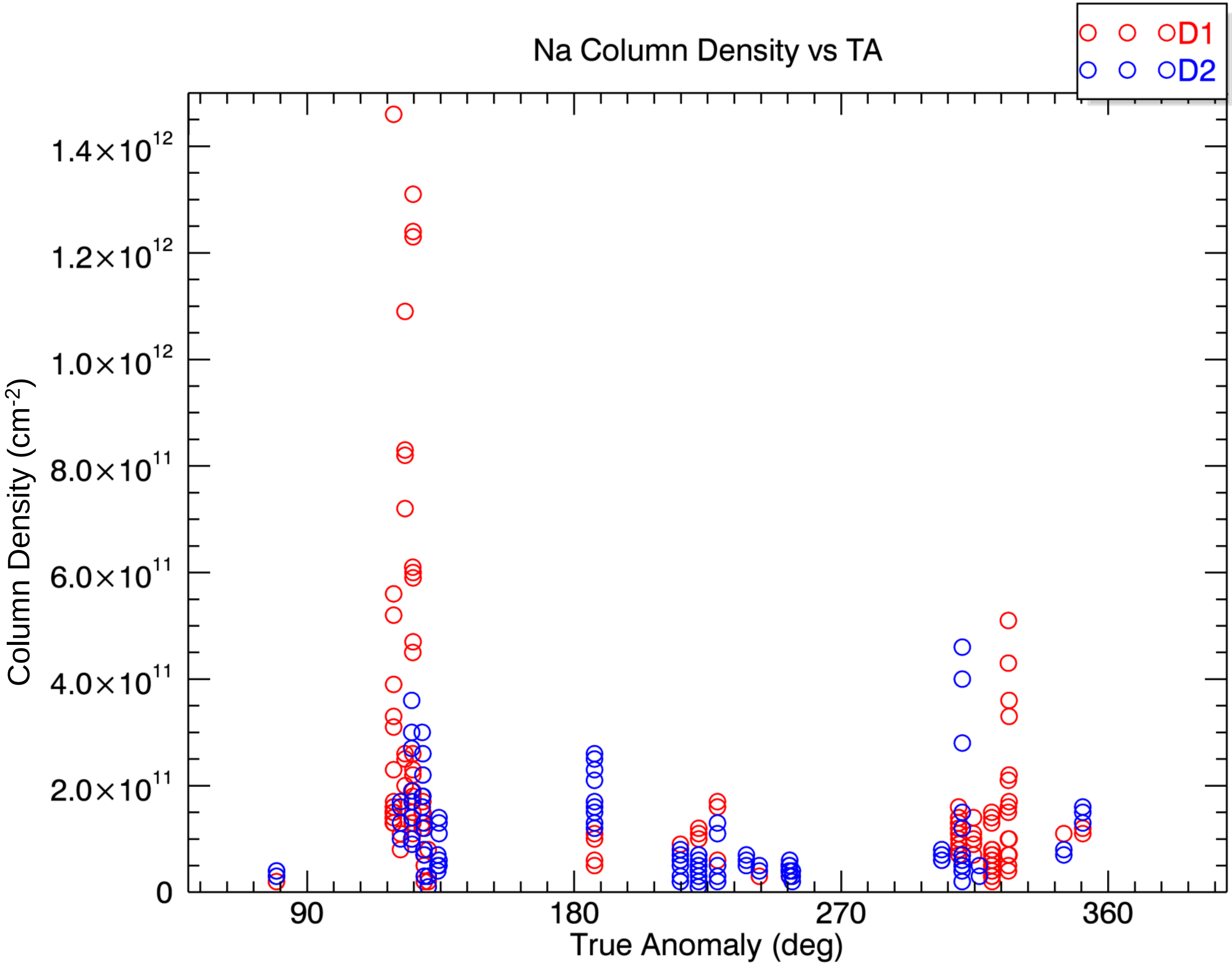



Na Density vs Local Time
D1
D2
Column Density (cm-2)
1.4×10^12
1.2×10^12
1.0×10^12
8.0×10^11
6.0×10^11
4.0×10^11
2.0×10^11
0
0
1
2
3
4
5
6
6:00-8:00
8:00-11:00
11:00-13:00
13:00-15:00
15:00-18:00
Local Time (hrs)

New Parameters of Interest

- True Anomaly
  - Used to determine seasonal variability of Na density

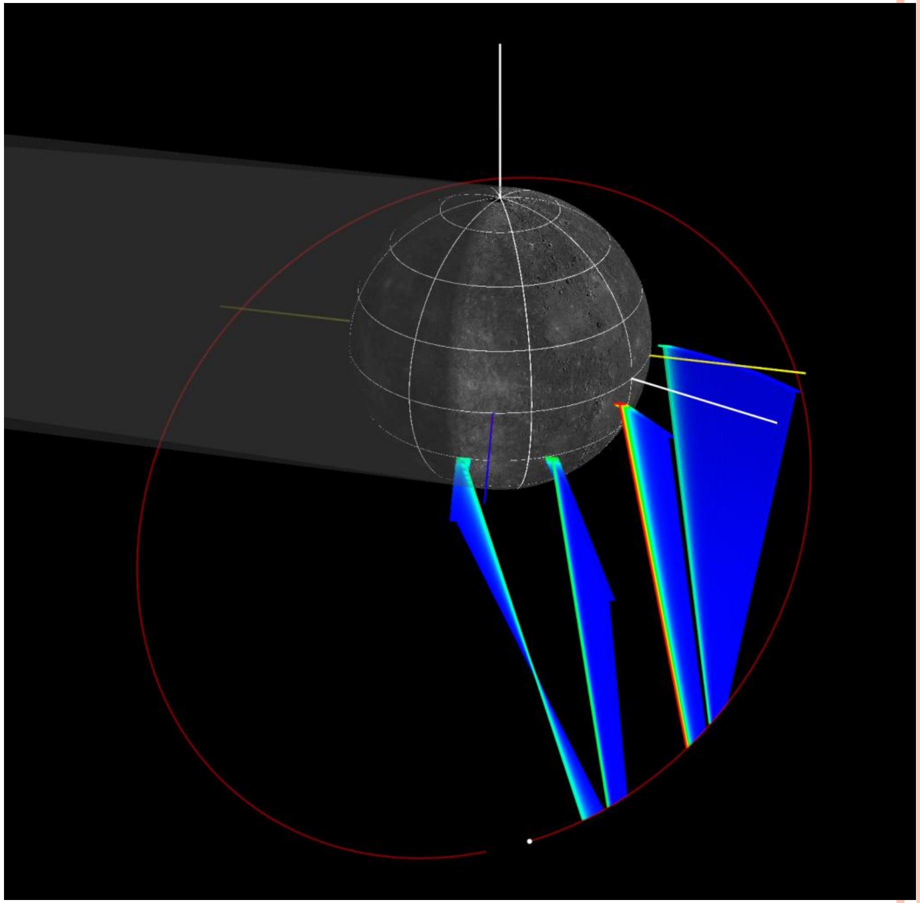


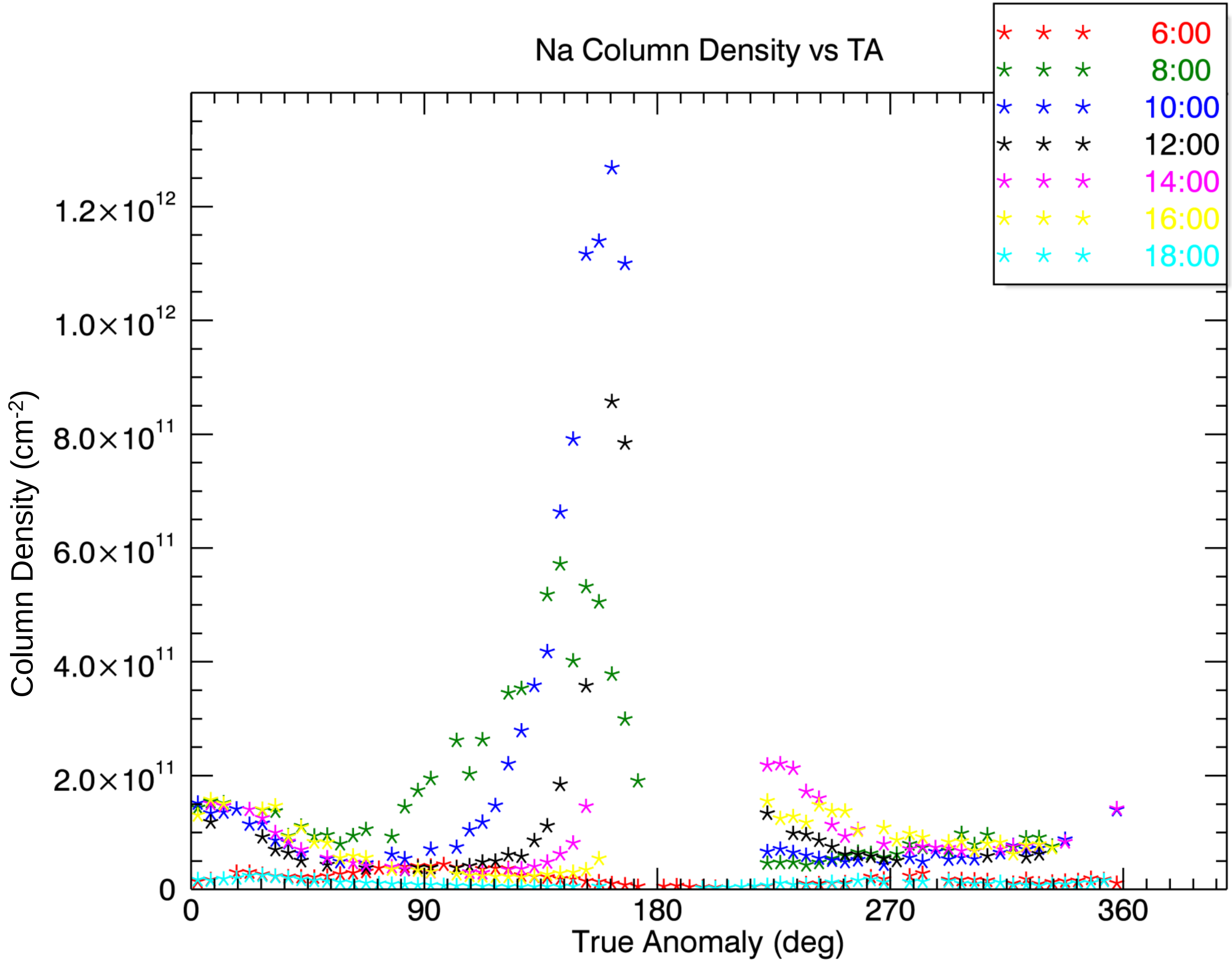


Na Column Density vs TA
D1
D2
Column Density (cm-2)
1.4×10^12
1.2×10^12
1.0×10^12
8.0×10^11
6.0×10^11
4.0×10^11
2.0×10^11
0
90
180
270
360
True Anomaly (deg)

The MESSENGER Mission

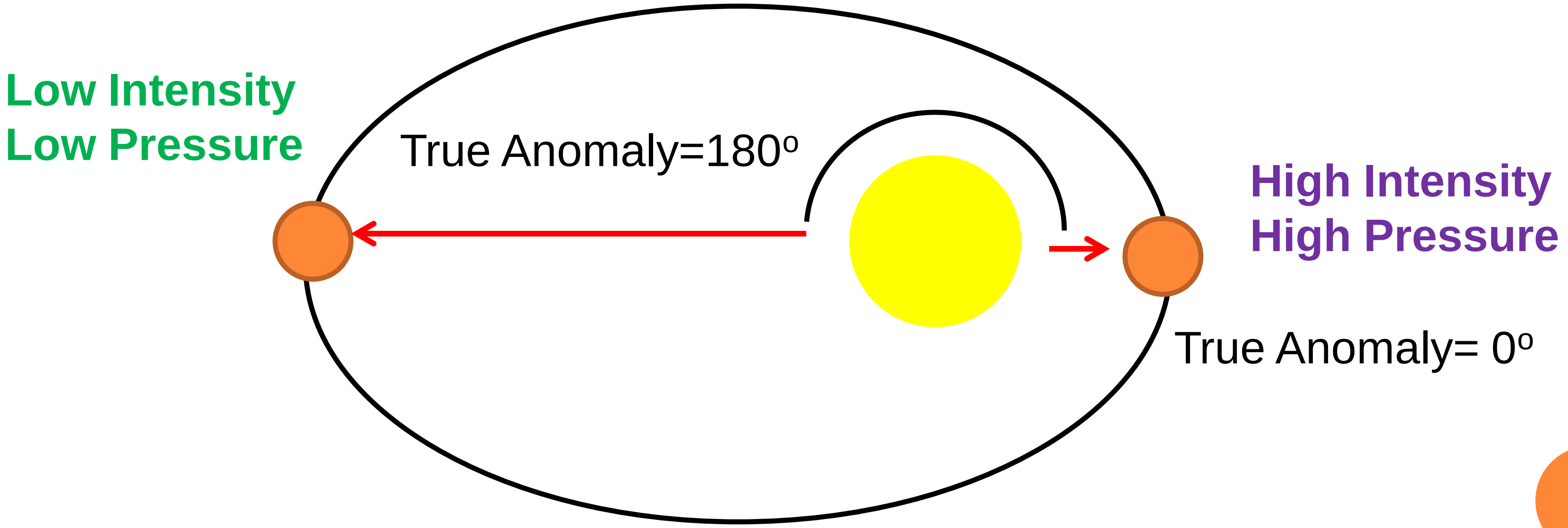
- Takes vertical profile scans of Mercury's exosphere
- Uses UVVS
- Records Na Column density for:
  - Local time
  - Seasonal variability
- 8 Mercury years of data (2 Earth years)

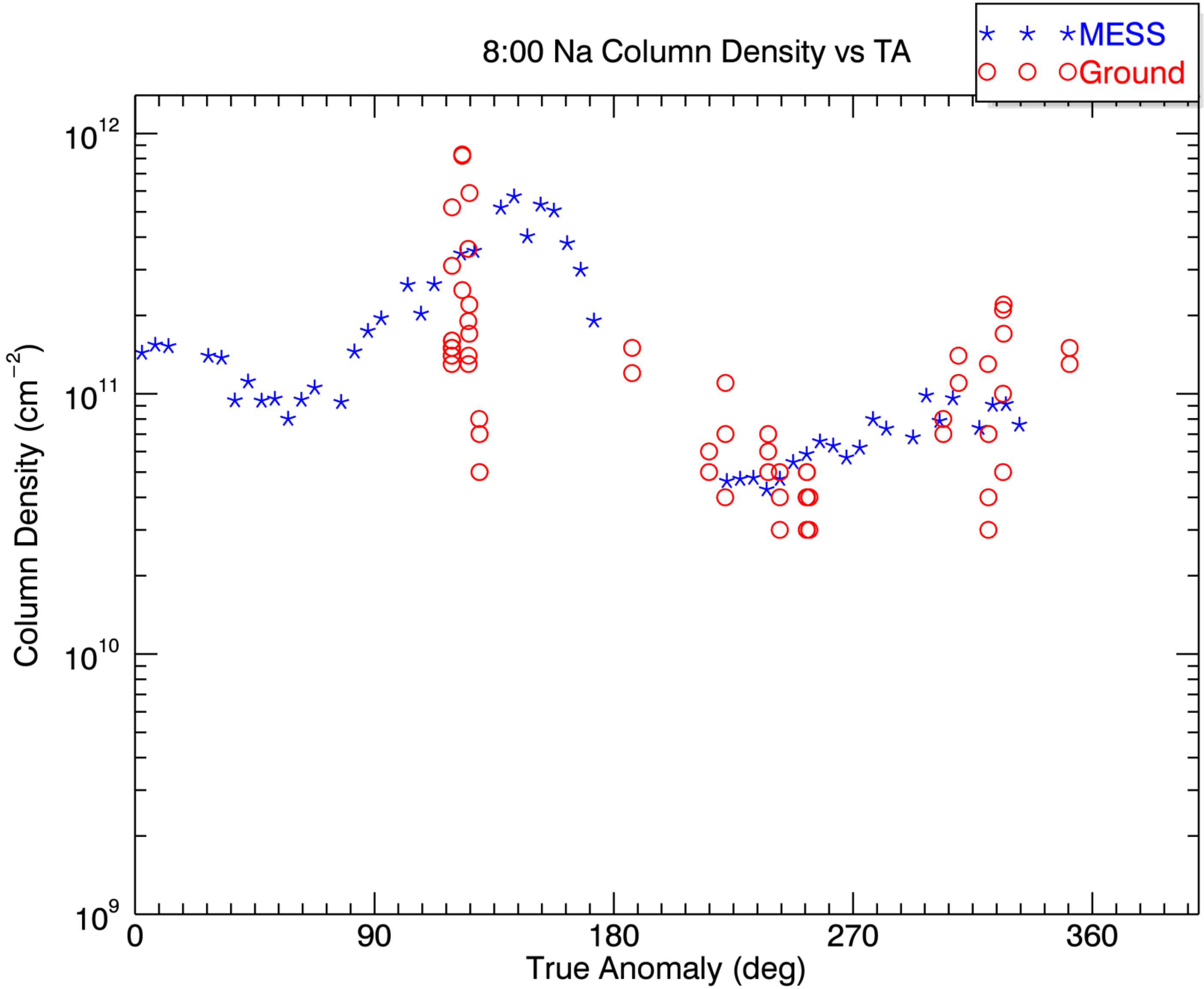



Na Column Density vs TA
6:00
8:00
10:00
12:00
14:00
16:00
18:00
Column Density (cm^{-2})
1.2×10^{12}
1.0×10^{12}
8.0×10^{11}
6.0×10^{11}
4.0×10^{11}
2.0×10^{11}
0
0
90
180
270
360
True Anomaly (deg)

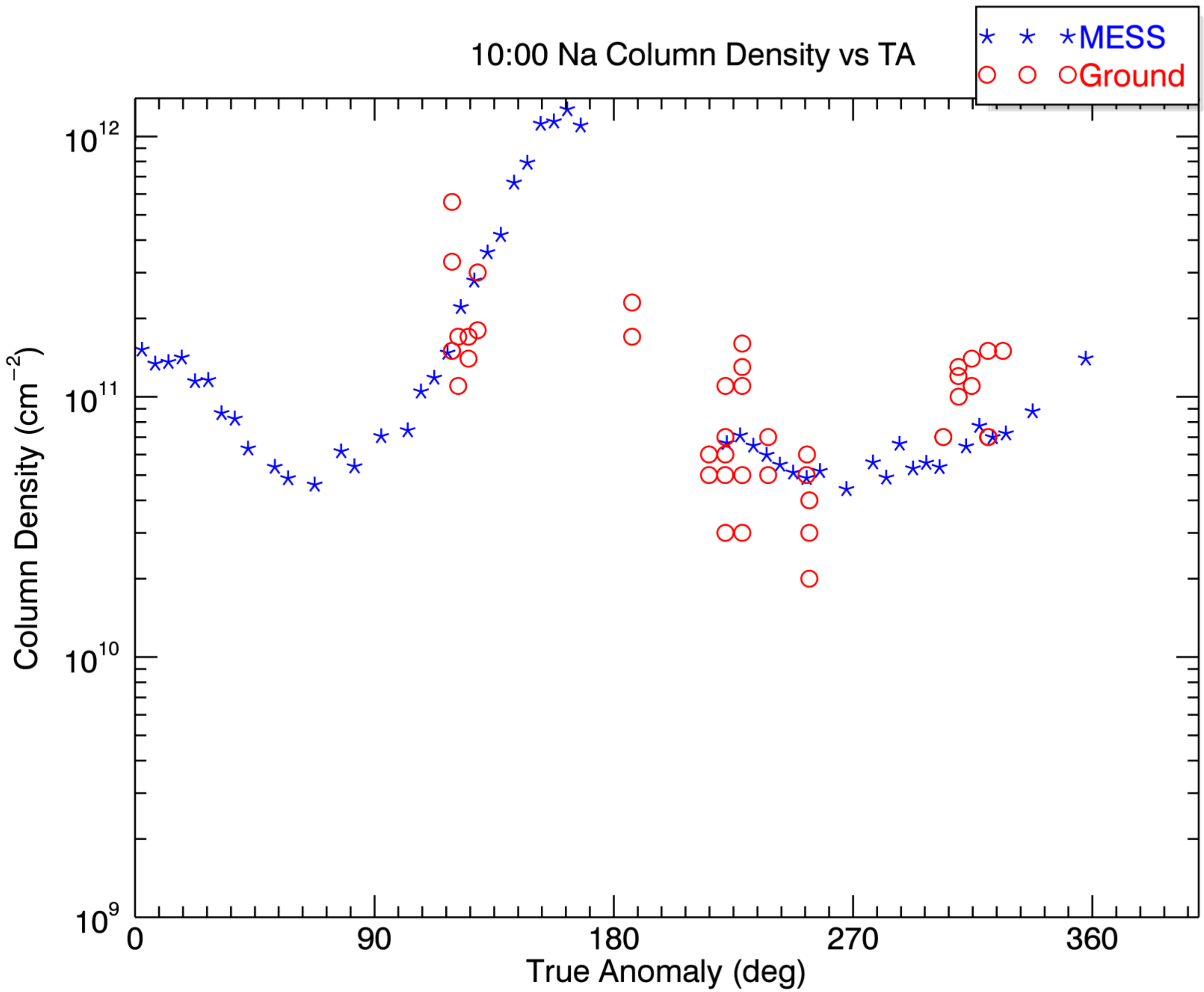
Competing Factors

- Sunlight Exposure vs Radiation Pressure
  - Greater photon intensity closer to the sunlight means more Na vaporization, but…
  - Being closer to the sun means more radiation pressure that disperses the exosphere

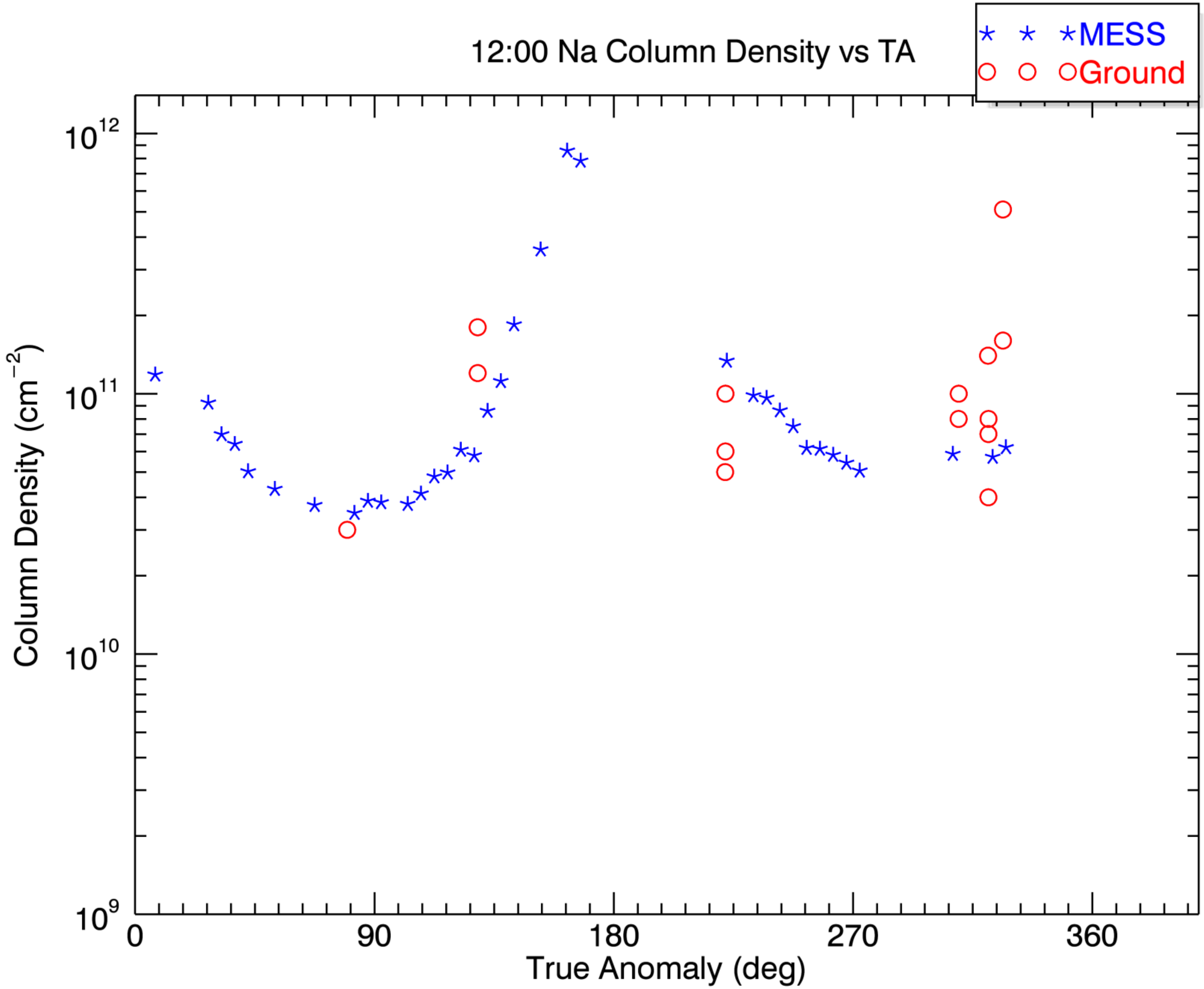




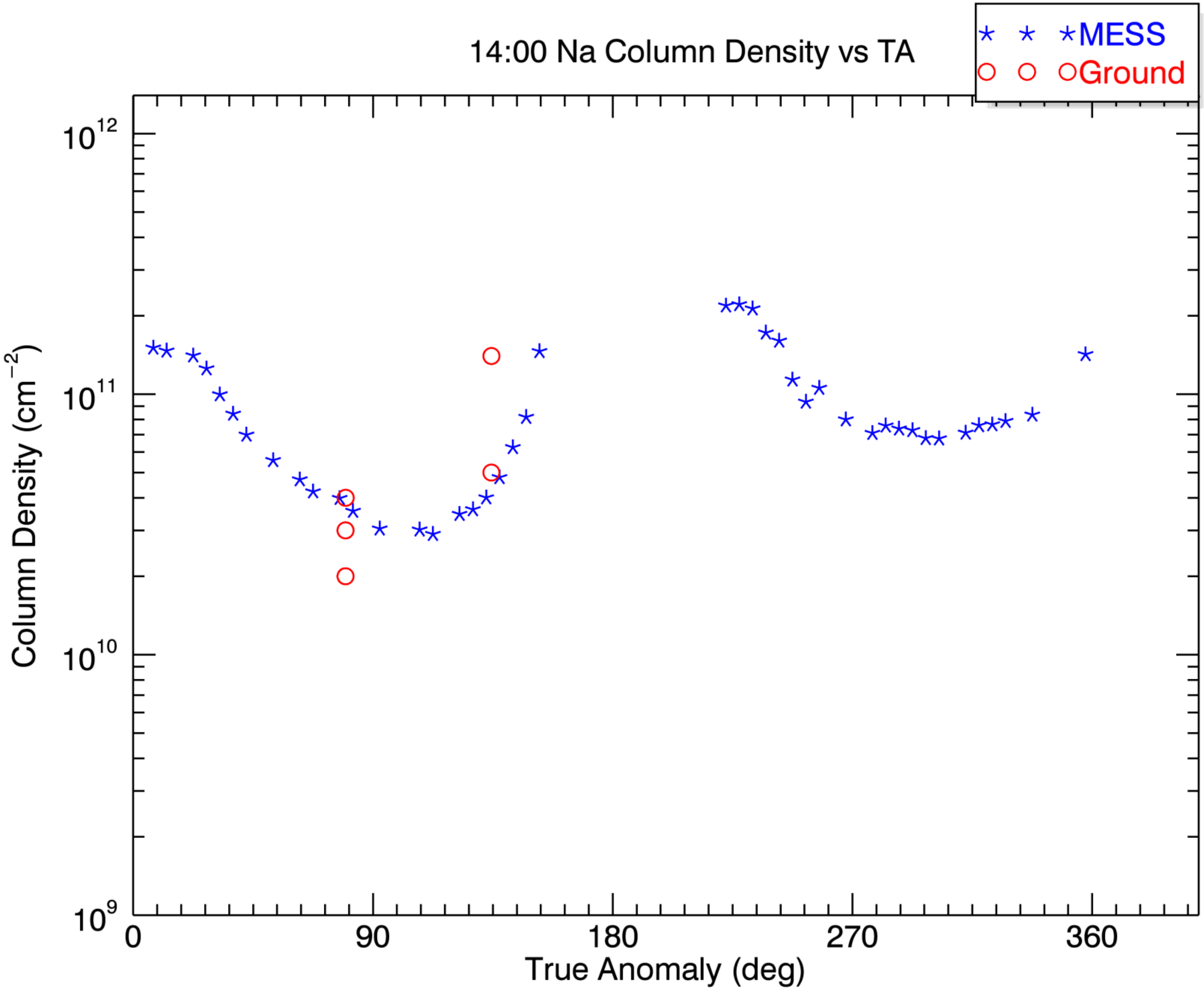
8:00 Na Column Density vs TA
MESS
Ground
Column Density (cm⁻²)
10¹²
10¹¹
10¹⁰
10⁹
0
90
180
270
360
True Anomaly (deg)

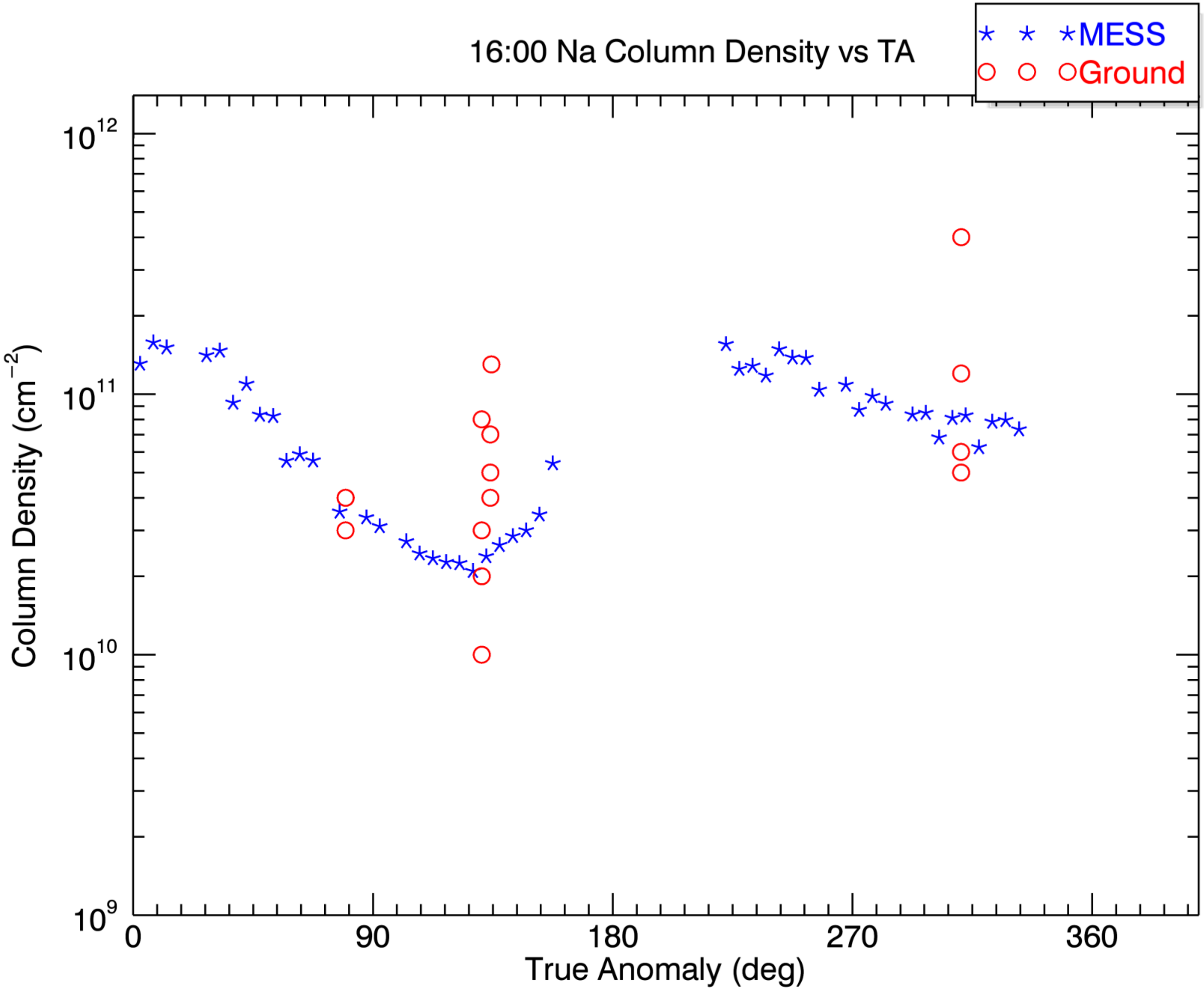


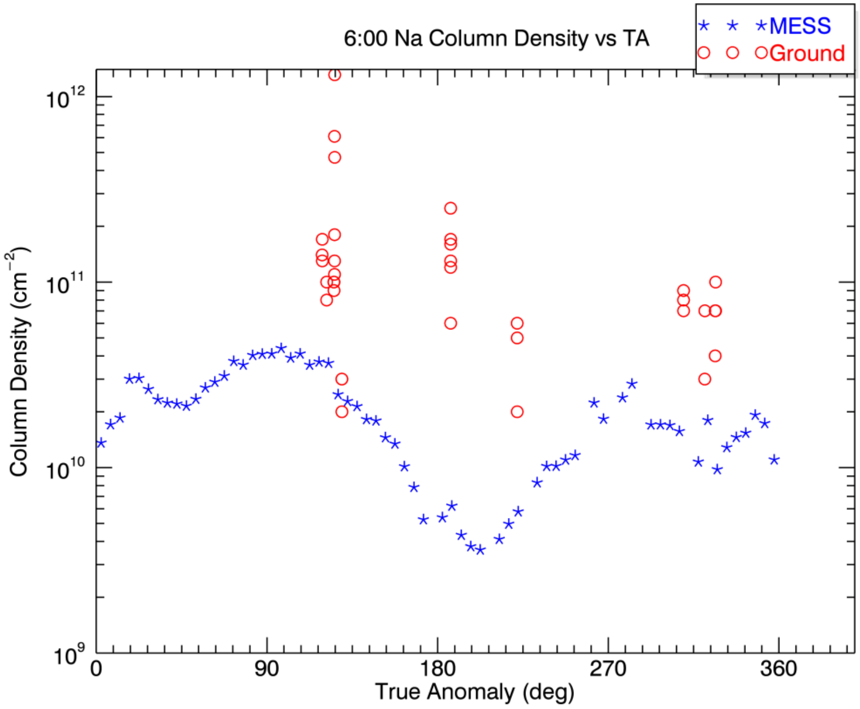
10:00 Na Column Density vs TA
MESS
Ground
Column Density (cm^{-2})
10^{12}
10^{11}
10^{10}
10^{9}
0
90
180
270
360
True Anomaly (deg)

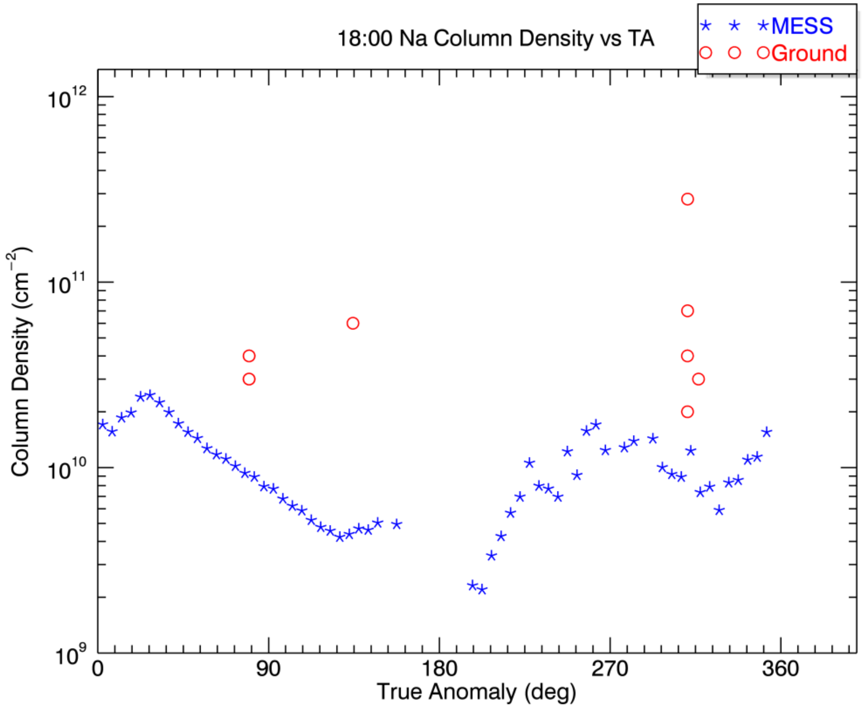


12:00 Na Column Density vs TA
MESS
Ground
Column Density (cm^{-2})
10^{12}
10^{11}
10^{10}
10^{9}
0
90
180
270
360
True Anomaly (deg)


14:00 Na Column Density vs TA
MESS
Ground
Column Density (cm^{-2})
10^{12}
10^{11}
10^{10}
10^{9}
0
90
180
270
360
True Anomaly (deg)


16:00 Na Column Density vs TA
MESS
Ground
Column Density (cm^{-2})
10^{12}
10^{11}
10^{10}
10^{9}
0
90
180
270
360
True Anomaly (deg)


6:00 Na Column Density vs TA
MESS
Ground
Column Density (cm^{-2})
10^{12}
10^{11}
10^{10}
10^{9}
0
90
180
270
360
True Anomaly (deg)


18:00 Na Column Density vs TA
MESS
Ground
Column Density (cm^{-2})
10^{12}
10^{11}
10^{10}
10^{9}
0
90
180
270
360
True Anomaly (deg)

CONCLUSIONS

- Increases in Na density depends on:
  - True Anomaly
  - Local time
- Both ground based and MESSENGER data are same order of magnitude
- Overall: Data show similar trends!

FUTURE WORK

- Conduct an analysis of outliers in Sprague data
  - Attempt to account for difference in D1 an D2 spectra
- Compare to other ground based data that used different observation techniques
  - Potter et al.

REFERENCES AND IMAGES

- Image slide 1: http://nssdc.gsfc.nasa.gov/image/spacecraft/messenger.jpg
- Images slide 4:
  - http://history.nasa.gov/EP-177/i2-6.jpg
  - http://www.8planets.co.uk/wp-content/themes/8planets/images/moon_surface_apollo_11_lg.jpg
  - http://undsci.berkeley.edu/images/us101/mercury.gif
- Image slide 5: http://www.windows2universe.org/mercury/Atmosphere/mercury_exosphere_sodium_oct_2008_sm.jpg
- Image slide 5: http://upload.wikimedia.org/wikipedia/commons/2/2f/Fraunhofer_lines.svg
- Plot slide 5: Sprauge, Kozlowski, Hunten. *Distribution and Abundance of Sodium in Mercury's Atmosphere, 1985-1988. 1997.* Icarus 129, page 512

References and Images Cont.

- Image slide 8: Sprauge, Kozlowski, Hunten. *Distribution and Abundance of Sodium in Mercury's Atmosphere, 1985-1988. 1997.* Icarus 129, page 514
- Image slide 9: Sprauge, Kozlowski, Hunten. *Distribution and Abundance of Sodium in Mercury's Atmosphere, 1985-1988. 1997.* Icarus 129, page 508
- Image slide 14: Cassidy, Timothy. PowerPoint presentation