Variations in Titan's FUV airglow as function of the Solar Cycle and Saturn Local Time

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Background

The Ultraviolet Imaging Spectrograph (UVIS) onboard Cassini measured the extreme ultraviolet (EUV 56-118 nm) and far ultraviolet (FUV 110-190 nm) domain at Saturn. These UVIS observations can be used to study nitrogen airglow in Titan's Atmosphere (900-1100 km) There are two major sources of airglow:

- Solar XUV radiation
- Magnetospheric particle precipitation

This study focuses on FUV airglow spectrum including the Lyman-Birge-Hopefield band (120-170 nm), Nitrogen 1200 & 1493 atomic emission lines, and Vegard-Kaplan Band (165-180 nm). Measurements were made with UVIS across all 126 Titan flybys at wide range of solar incidence angles and Saturn Local Time (SLT).

Saturn Local Time is the measurement of Titan's orbital position around Saturn. Multiple measurements were recorded around noon (12) SLT, when Titan is closest to Saturn's magnetopause, and midnight (24) SLT, when Titan is deep in Saturn's magnetosphere. Observations at both locations also occurred during solar minima (2008-2009) and solar maxima (2013-2015).

Saturn Local Time

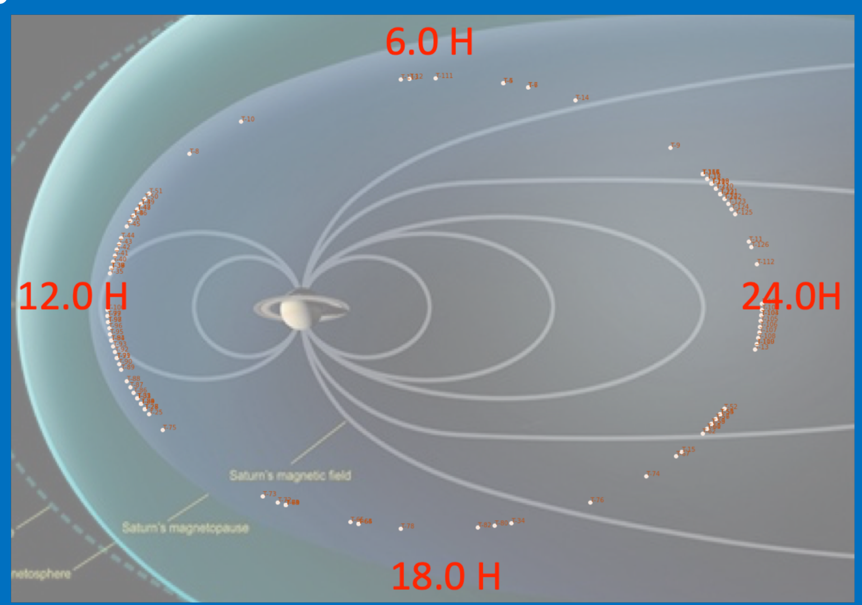

Figure 1: Graph of Saturn Local Time for all 126 flybys

Saturn local time was calculated for the closest approach of each flyby

Determination of Saturn Local Time

1. Calculation of Titan-Saturn Vector and Sun-Saturn vector
2. Calculation of angle between Titan-Saturn and Sun-Saturn via subtraction of Sun-Saturn angle from Titan-Saturn angle.
3. Divide sunangle by 15, the equivalent of dividing 24 hours by 360 degrees

To simplify calculations the slight tilt to Titan's orbit around Saturn was ignored, thus the z-coordinate of the vectors was excluded. This choice seems to be justified as all calculated SLT matched existing literature (Simon, Roussos, & Paty 2015)

Analysis Parameters

- Dayglow = solar incidence angle <110°
- Nightglow = solar incidence angle ≥ 110°
- Airglow measurements were taken between a rayheight of 900-1200 km to exclude solar reflection
- Measurements are taken around 12 (+/- 2.5 H) and 24 (+/-2.5 H) SLT at both the solar minima and solar maxima

Results

Airglow was initially graphed as a function of Saturn Local Time without consideration of the solar cycle. The 24 H dayglow being brighter than 12 H lead to the realization that 9 out of 10 of the 24 H flybys occurred during 2014 around Solar Maxima. In contrast the 12 H flybys mixed data from around solar minima (2007-2008) and solar maxima (2013-2014).

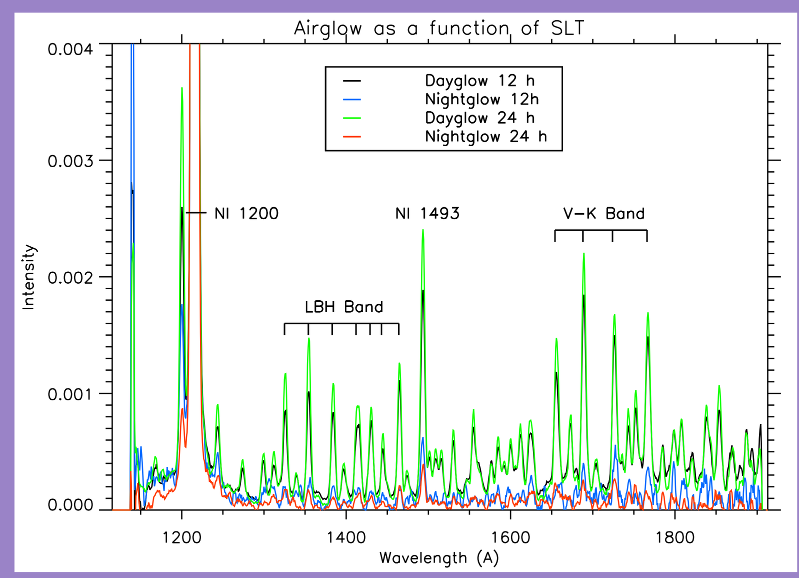

Figure 2: Graph of Averaged Day and Nightglow spectra around 12H and 24 H (+/- 1), The brightest dayglow occurs deep in the magnetosphere at 24 H .

Airglow was then graphed as a function of both the Solar Cycle and Saturn Local Time. This involved widening the window of SLT from +/- 1H to +/- 2.5 H

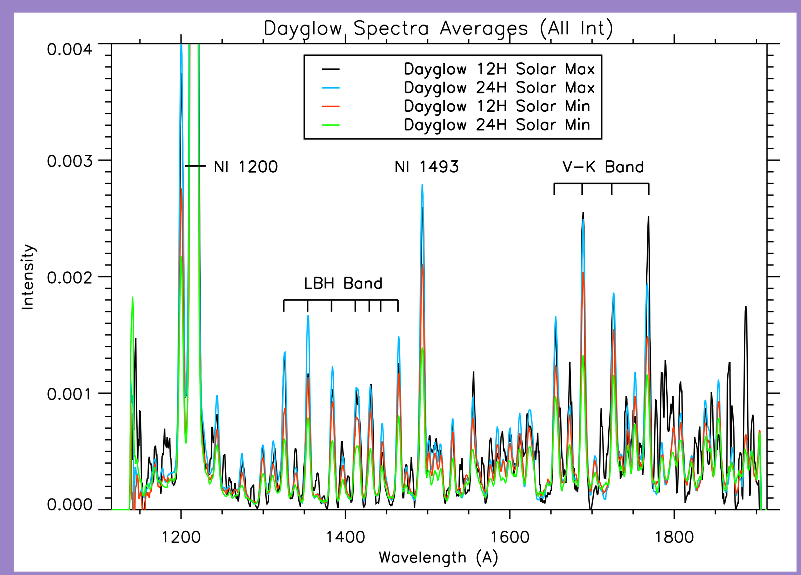

Figure 3: Graph of Averaged Dayglow at 12 and 24 H solar minimum and maxima, with any integration time

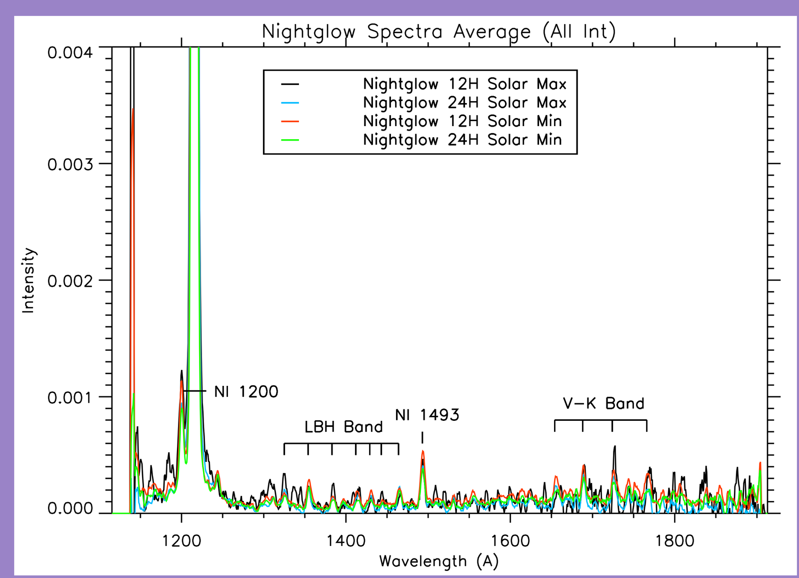

Figure 4: Graph of Averaged Nightglow at 12 and 24 H solar minimum and maxima with any integration time

Analysis of dayglow peak height compared to geometry suggested 24 H solar maxima most intense reading correlated to longer integration time (1200 s), thus the graphs were replotted with integration time limited to 240 seconds (the standard).

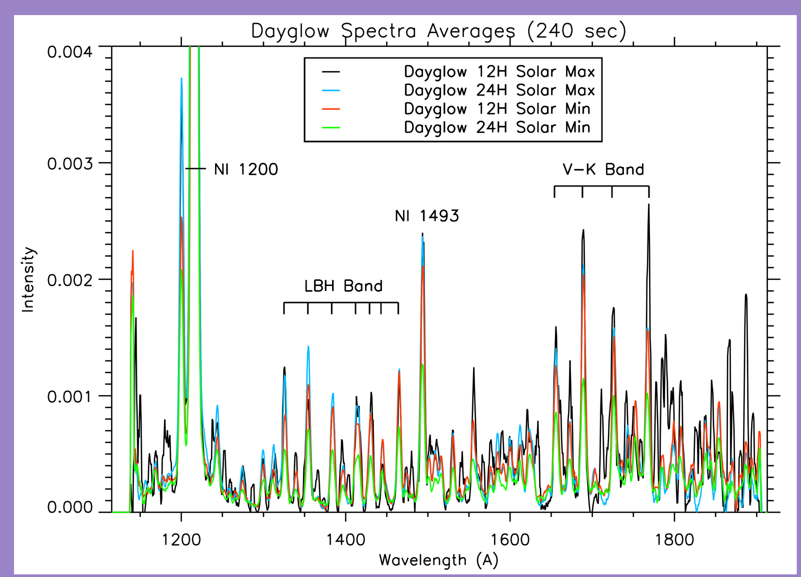

Figure 5: Graph of Averaged Dayglow at 12 and 24 H solar minimum and maxima, 240 sec integration

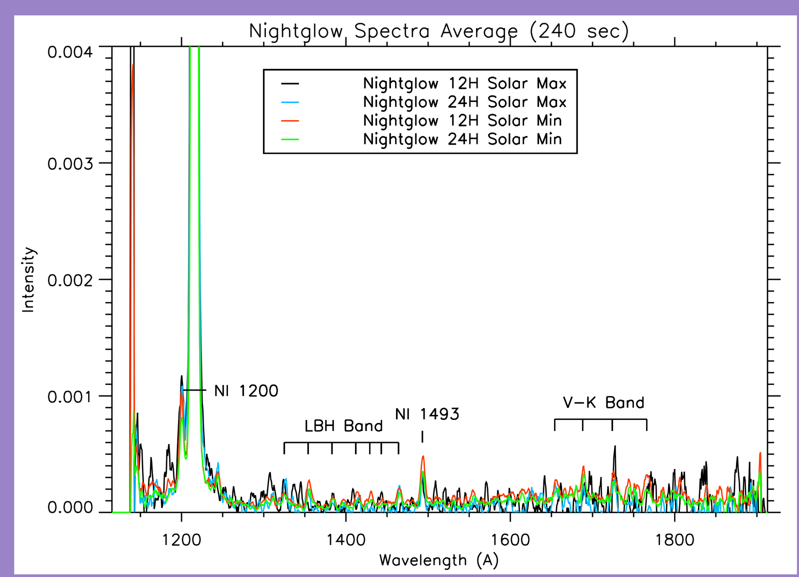

Figure 6: Graph of Averaged Nightglow at 12 and 24 H solar minimum and maxima, 240 sec integration

When replotted the 12 H Solar max is the tallest peak for 7 of the selected 13 peaks. The nightglow becomes essentially undisguisable from noise apart from the N1200, N 1493, and VK 1724.

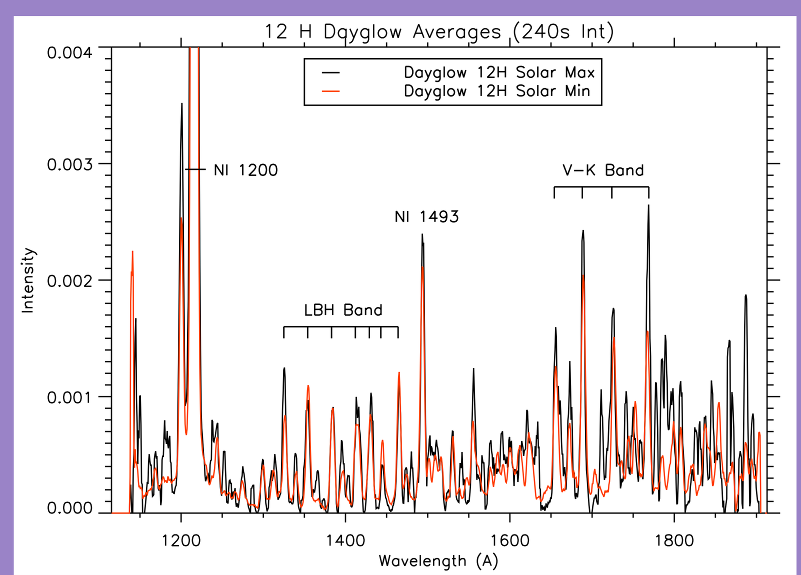

Figure 7: Graph of Averaged 12 H Dayglow at Solar Min and Max

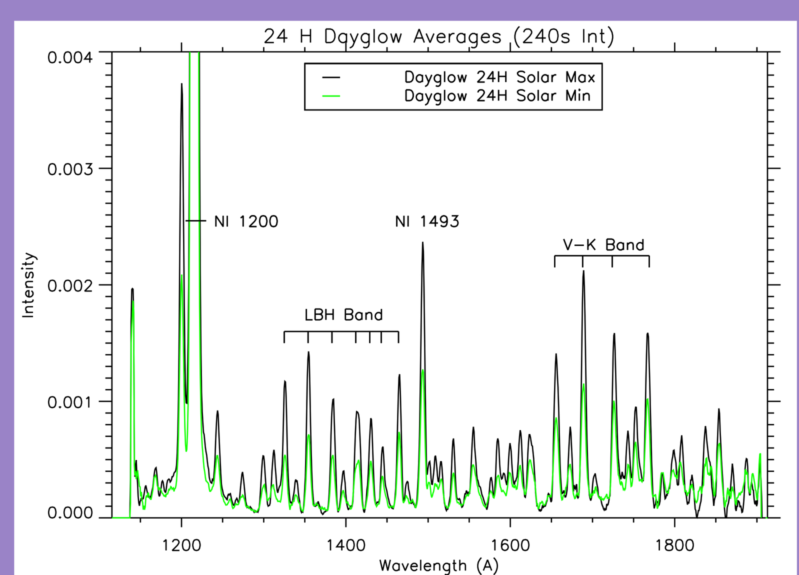

Figure 8: Graph of Averaged 24 H Dayglow at Solar Min and Max

The 12 H min spectra is close to the 12 H max (Max-Min ratio: 0.68-1.39) while there is large difference between the 24 H solar minima and maxima spectra (Max-Min ratio: 1.42 – 2.09).

Conclusions

There are four major conclusions from the data and its analysis.

1. *Confirmation that nightglow is rare.*
   There were a total number of 84 (all integration) datasets included of which only 15 % had a visible spectra on the nightside.

2. *The V-K Band is important in airglow*
   With the removal of solar reflection (using the rayheight) the V-K band becomes prominent. It is generally more intense then the LBH. There has been little study on the V-K band.

3. *The NI 1200-1493 Ratio is between 1.2 - 1.7*

   The Nitrogen I lines are the most intense lines on spectra. This ratio agrees with ~1.5 ratio found by Ajello et al (2012) . This varies from Earth. Additionally the NI lines are correspond best with magneotospheric particle precipitation

4. *The Solar Cycle more greatly influences airglow intensities in the magnetotail*
   The ratio difference between the Solar Min-Max at 12 H is much smaller than the ratio difference between the Min-Max at 24 H.

Going Forward

Follow up on this data is planned to offer further insights. Future research plans include but are not limited to

- Changing the ratio analysis from peak height to integration under peaks to improve data analysis
- Further study and comparison of Dayglow ratios, particularly the N1200-1493 ratio
- Further study on the nightglow including identifying all nightglow data sets and analyzing their N I ratio
- Graphing nightglow via solar zenith angle

Acknowledgements

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Citations:

Ajello et al. 2012. Cassini UVIS observations of Titan nightglow spectra. Journal of Geophysical Research 117: A112315

Simon,Sven., Roussos, E., Paty, C.S. 2015. The Interaction between Saturn's Moons and their Plasma Environments. Physics Reports. 602: 1-65