Development and Validation of an Airglow Photometer for Upper Atmospheric Chemistry

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Abstract

Airglow is a phenomenon caused by chemical reactions in the mesosphere and thermosphere, and can also be used as a proxy to measure important parameters in upper atmosphere. Due to this reason, we have built a simple airglow photometer system and plan to deploy it for long term ground-based observations at Lulin Observatory in Taiwan (120°52'25''E, 23°28'07''N). We have selected three airglow emission channels (557.7nm, 589nm, 630nm) as our observation target, which have been the subject of several past studies. In order to get reasonable data from our airglow observations, we need to validate all parts of our system, design, calibration, and the data processing procedure. We have used an integrating sphere to determine the response of our photometer to different levels of irradiance at different channels, and have performed three nights of airglow observations. In the future, we will use our observation results to compare with some atmospheric events and determine chemical changes in the mesosphere and thermosphere. After demonstrating that the data we use is reliable, we will provide long-term observations and monitoring of airglow emission rates and chemical processes over Taiwan.

Background & Motivation

Oxygen concentration

[O] affects:
- Satellite drag in LEO.
- Atmospheric vertical structure.
- Ionospheric plasma lifetime.

Airglow emission

Proxy for [O]:
- Produced by O photochemical reactions.
- Variation of airglow intensity proportional to [O].

Ground based observation

Our objectives:
- Develop the photometer system.
- Long term ground based observation.

OI Red Line (630 nm)

$$O^+ + O_2 \rightarrow O_2^+ + O$$
$$O_2^+ + e^- \rightarrow O(^1D) + O(^3P) or O(^1S) + O(^3P)$$
$$O(^1D) \rightarrow O(^3P) + h\nu(630\ nm)$$

OI Green Line (557.7 nm)

$$O + O + M \rightarrow O_2^* + M$$
$$O_2^* + O \rightarrow O_2 + O(^1S)$$
$$O(^1S) \rightarrow O(^1D) + h\nu\ (557.7)$$

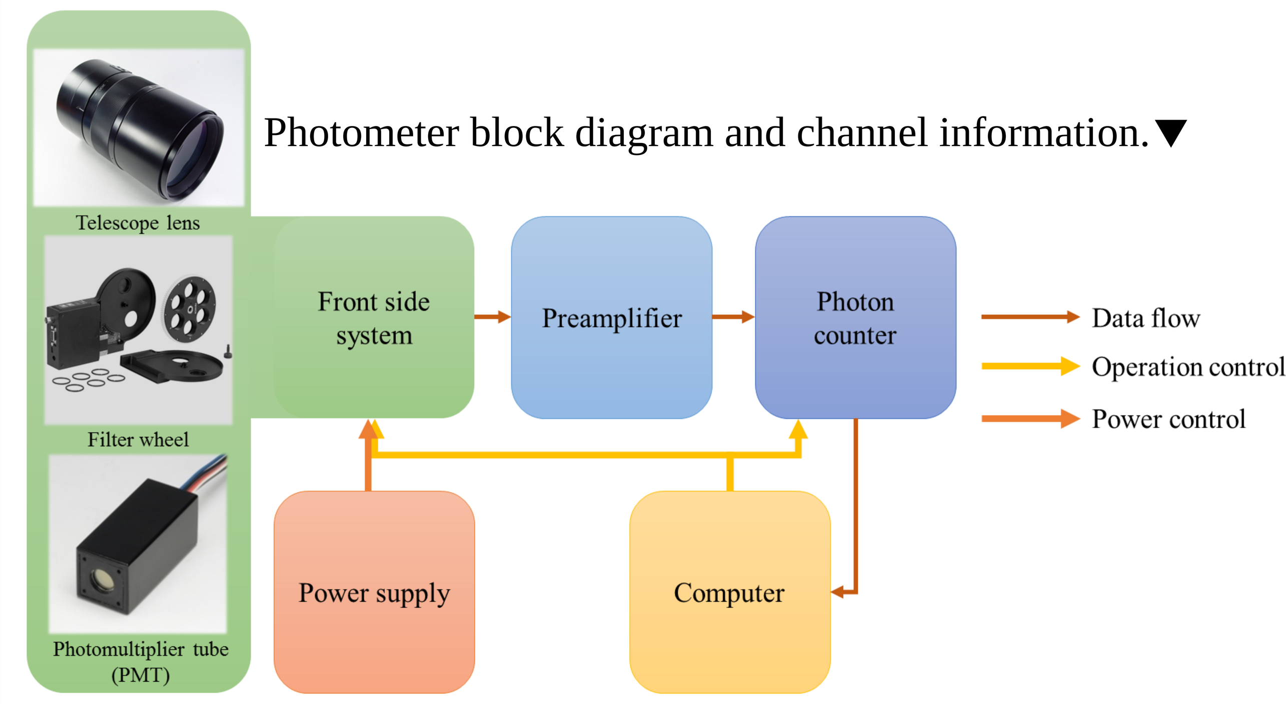
Na D Line 589.0 & 589.6 nm

$$Na + O_3 \rightarrow NaO + O_2$$
$$NaO + O \rightarrow Na(^2P_{1/2}) + O$$
$$\rightarrow Na(^2P_{3/2}) + O$$
$$Na(^2P_{1/2}) \rightarrow Na(^2S) + h\nu(589.0\ nm)$$
$$Na(^2P_{3/2}) \rightarrow Na(^2S) + h\nu(589.6\ nm)$$

Airglow emissions observed ▲

Instrument

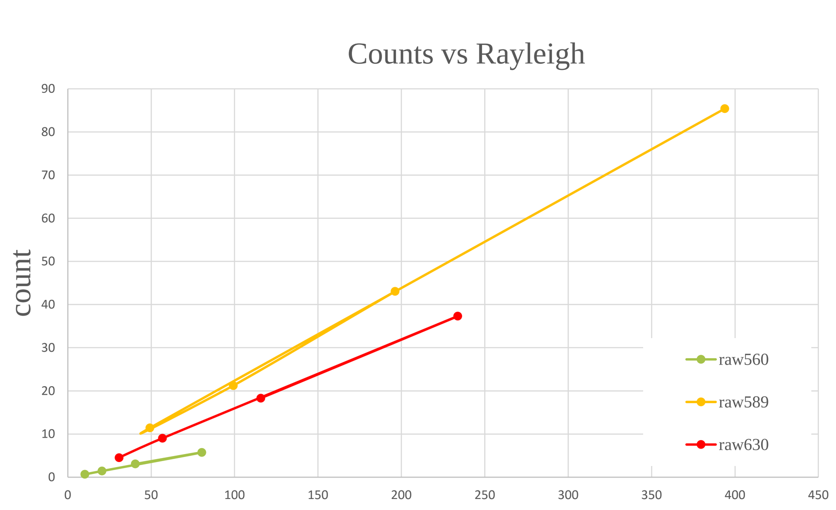
Photometer block diagram and channel information.▼

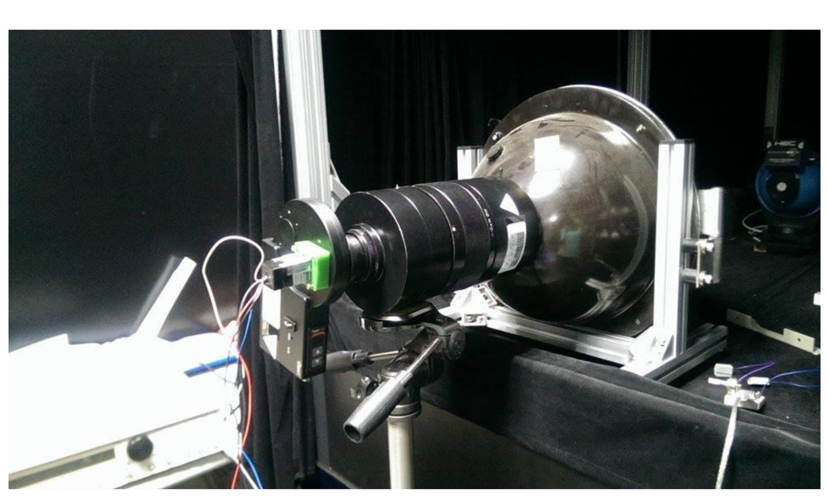


Channels	Wavelength (nm)	Bandwidth (nm)	Transmission	Function
1	530	10	50 %	Clear sky
2	560	10	65 %	OI green line
3	589	5	33 %	Na D line
4	630	10	60 %	OI red line
5	Black mask	-	-	Dark current
6	-	-	-	-

Calibration

Intensity of our target. → Rayleigh-Radiance transform. → Count response curve. → Count-Rayleigh transform





▲ Integrating sphere calibration ▲

- The airglow intensity is so weak that we should use photon counting, by measuring the electrical pulses from the PMT.
- We also need to know the absolute airglow intensity in Rayleighs, so we used an integrating sphere to obtain calibration curves in different airglow channels.
- Calibration curves show that our system is more sensitive to Na D line airglow emission and least sensitive to OI green line emission.

Summary

- Completed assembly, calibration, and functional testing of an airglow photometer for mesosphere and thermospheric monitoring.
- Cloudiness and ambient temperature are important factors in our observation.
- The variation for each channel is similar to previous observations.
- We shall build up a long term ground station at Lulin Observatory, and the system will be the remote controlled.

Reference

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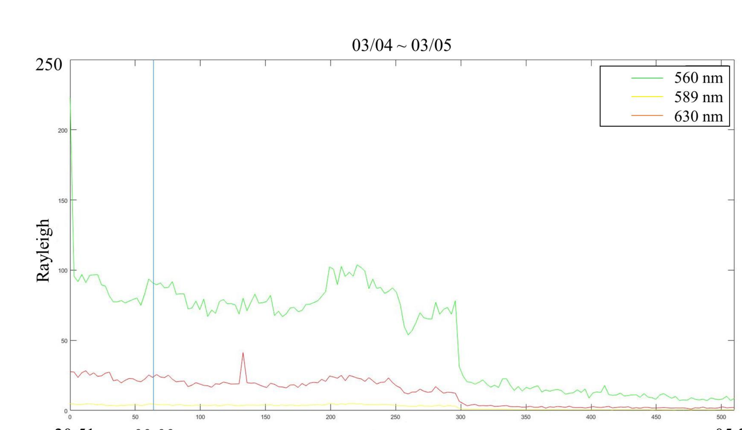
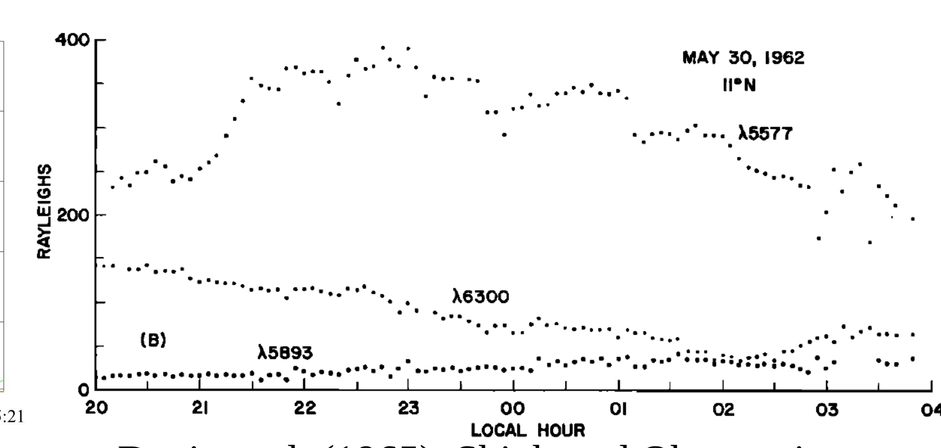
Observation



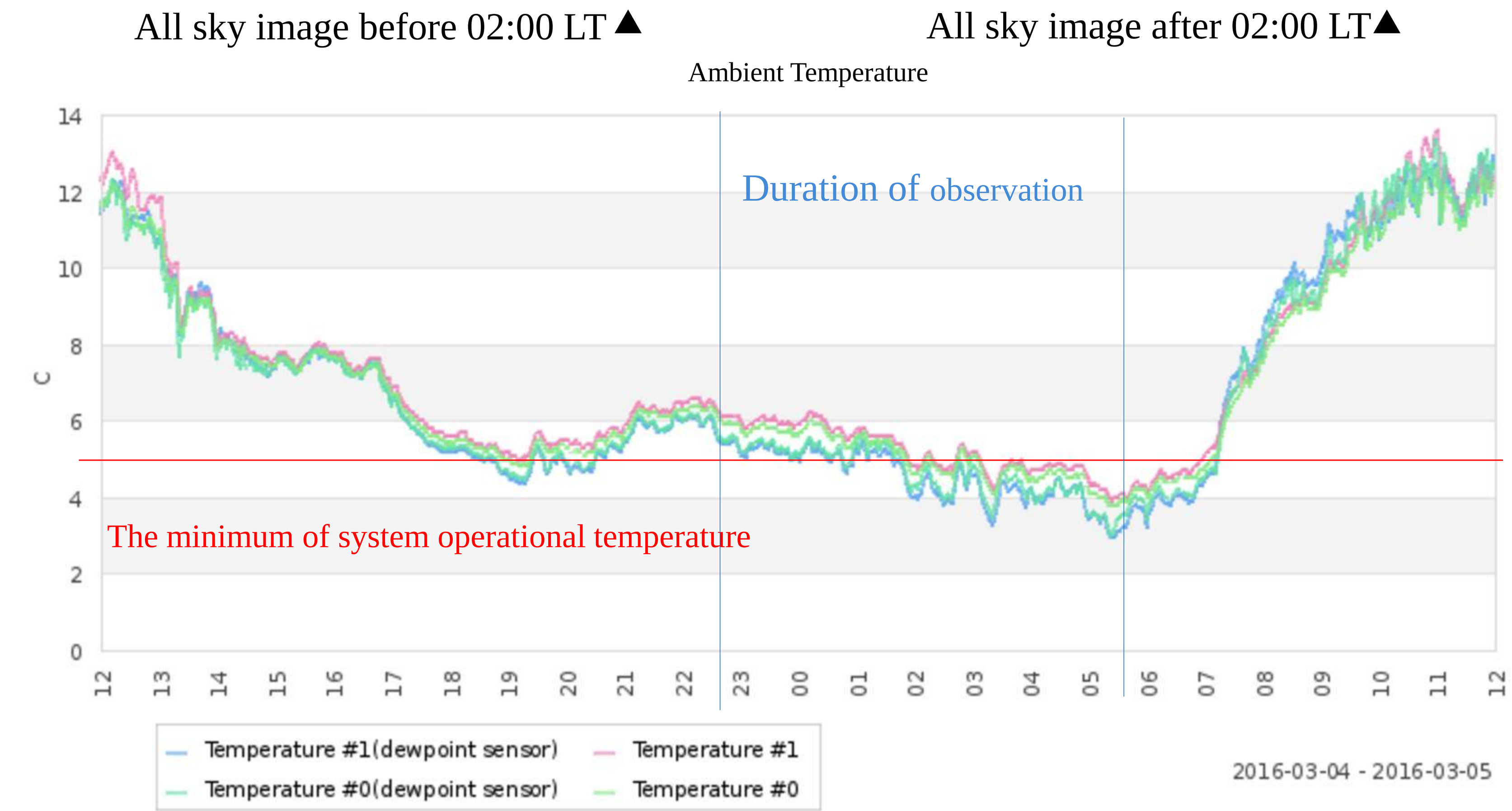
Photometer observations. Lulin Observatory. (120°52'25''E, 23°28'07''N) ▲



Davis et al, (1965). Shipboard Observations. ▲

All sky image before 02:00 LT▲

All sky image after 02:00 LT▲



The ambient temperature at Lulin Observatory on 2016/03/034- 2016/03/05 ▲

- The most recent observational test was performed at Lulin Observatory from 2016/03/04 – 2016/03/05.
- The related differences of functional test results are similar as previous observations (Davis et al, 1965).
- The decrease airglow intensity after 02:00 LT is not related to cloud cover since the all sky camera shows fewer clouds after 02:00 LT. It is related to the lower ambient temperature after 02:00 LT.