Summer Research Fellowship Scheme 2008-2009 for Science students
Name: Leung Yan Yu Christy
U No.: 2008401664
Project title: Studying the night sky spectrum of Hong Kong
Date: 2009 September 25

Abstract
This study uses an all sky spectrograph to take the nightsky spectrum. The spectral lines of nightsky spectrum, including artificial components like sodium (Na) or mercury (Hg) lamp and natural components are investigated. Four sets of datas were taken at different night or different time for comparison. They all give concrete envidence that one of the source of light pollution in Hong Kong is artificial lamps. Moreover, the intensity of the Na(5688) line decreases with time in the same night, suggesting that the intensity of high pressure sodium lamp also decreases with time. The relative ratios of flux of sodium and mercury lines do not have a fixed pattern but small regularities are found. The Na lines intensity in the nightsky is higher than Hg lines intensity, suggesting that high pressure sodium lamp in Hong Kong is a larger contributor to light pollution than mercury vapour lamps.

Introduction
Light pollution is an environmental degradation due to excessive artificial light which reduces the visibility at night, interferes with astronomical observation, disrupts ecosystem and has adverse health effects. This study focused on taking the night sky spectrum of Hong Kong to investigate on the properties of different emission lines, in particular the artificial components sodium (Na) and mercury (Hg) lines. Sodium lines are originated from street lamps of High Pressure Sodium Lamp and mercury lines are originated from flourescent lamps containing mercury vapour.

Methodology
1) Collection of Data
The datas were taken with a SBIG Self Guided Spectrograph coupled with ST-8 camera in the HKU Dome Observatory. There are two slits for the spectrograph, the narrower one with 25 microns wide and wider one with 100 microns wide, which offers variation of light grasp ability of the spectrograph. During collection of data, the spectrograph was put outside the Dome with light collecting opening (telescope coupling) facing the nightsky. The spectrograph does not fit into a telescope because unilike stars, the nightsky is much brighter and is a diffuse light source.
After the setup of the apparatus, the ST-8 CCD camera was powered on and the cooler was on so that the camera was cooled to avoid thermal noise. The dark frames of the corresponding nightsky spectrums were also taken. The flat field images were taken during twilight with a diffuser put onto the opening of spectrograph to even out the light. Spectrums of Philips Powertone Sodium lamp (70W) and Philips Powertone High Pressure Mercury lamp (50W) were used as wavelength-calibration frames.

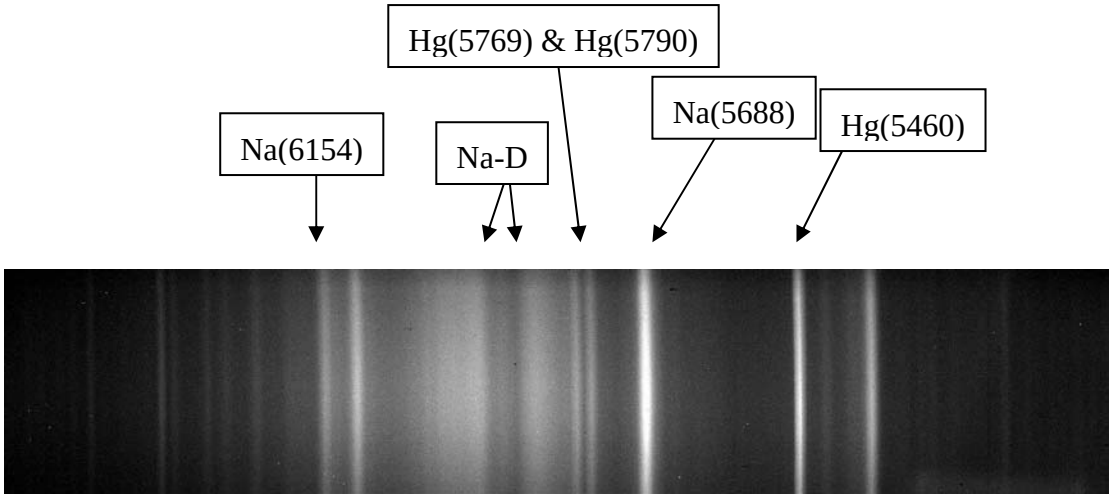
Details of the four spectrum set were shown in Table 1.

Spectrum set	A	B	C	D
Date taken	2/7/09	31/7/09	24/8/09	24/8/09
Exposure time /s	3600	1800	2700	2700
Slit	Narrow	Wide	Wide	Wide
Time start observation	20:30	20:35	20:00	21:00

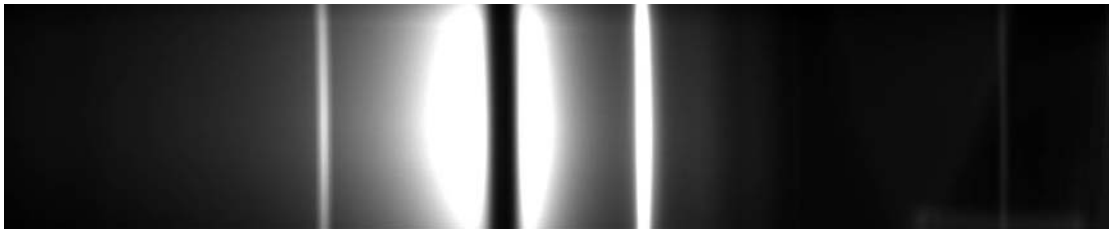
Table 1: details of four data sets

2) Reduction of Data

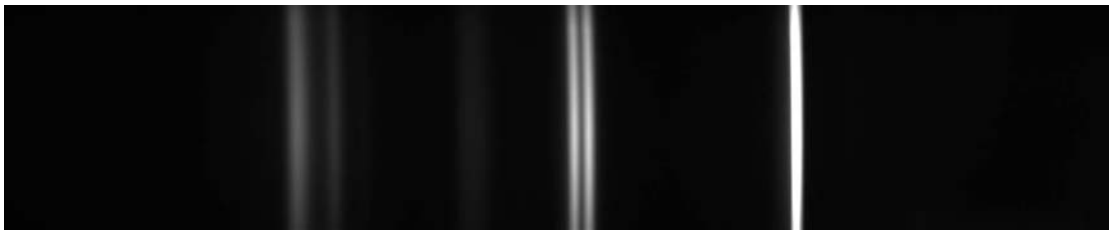
Data frames in FITS format were processed by Image Reduction and Analysis Facility 2.12 software running in Linux (Fedora 7) environment. Dark subtraction, flat field correction was carried out to the raw data frames. Data frames for data set B were shown in figure 1.



Nightsky



Sodium



Mercury

Increasing wavelength

Figure 1: Data frames of data set B (with species and wavelength (in Angstroms) identified in nightsky frame). The horizontal axis is the spectral direction, while the vertical axis is the spatial direction.

Reduction of Spectroscopy data involves two steps, spectrum extraction and wavelength calibration. For spectrum extraction, it was done by the task *apall* under the packages *noao>twodspec>apextract*. Spatial length of about 200 pixels, which was relatively large, was defined in nightsky spectrums because this could increase the signal to noise ratio, thus increasing in spectrum quality. For wavelength calibration, calibration spectra of sodium and mercury were processed in the same manner as above. The spectral lines were marked corresponding to the linelists of a typical sodium or mercury lamp using the task *identify*. The wavelength solution would then be applied to the nightsky spectrum by adding the calibration frame as the reference spectrum. By using the task *dispcor*, the nightsky spectrum would be wavelength-calibrated. The extracted nightsky spectrum for data set B is shown in figure 2.

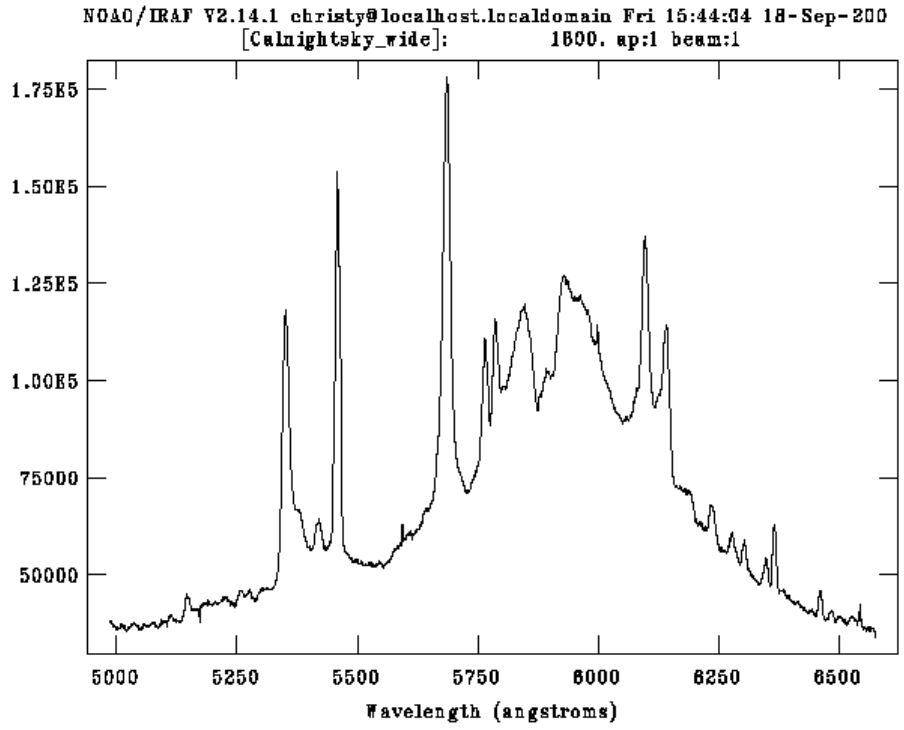


Figure 2: Extracted nightsky spectrum for data set B. The vertical axis represents the intensity.

The software Matlab R2009a was used to fit the guassian profile of the nightsky spectrum. The line under investigation would be isolated from the spectrum and fit a guassian with linear background. The function was then integrated by the command *quad* to find the flux of the corresponding line. Figure 3 shows one of the fitted lines.

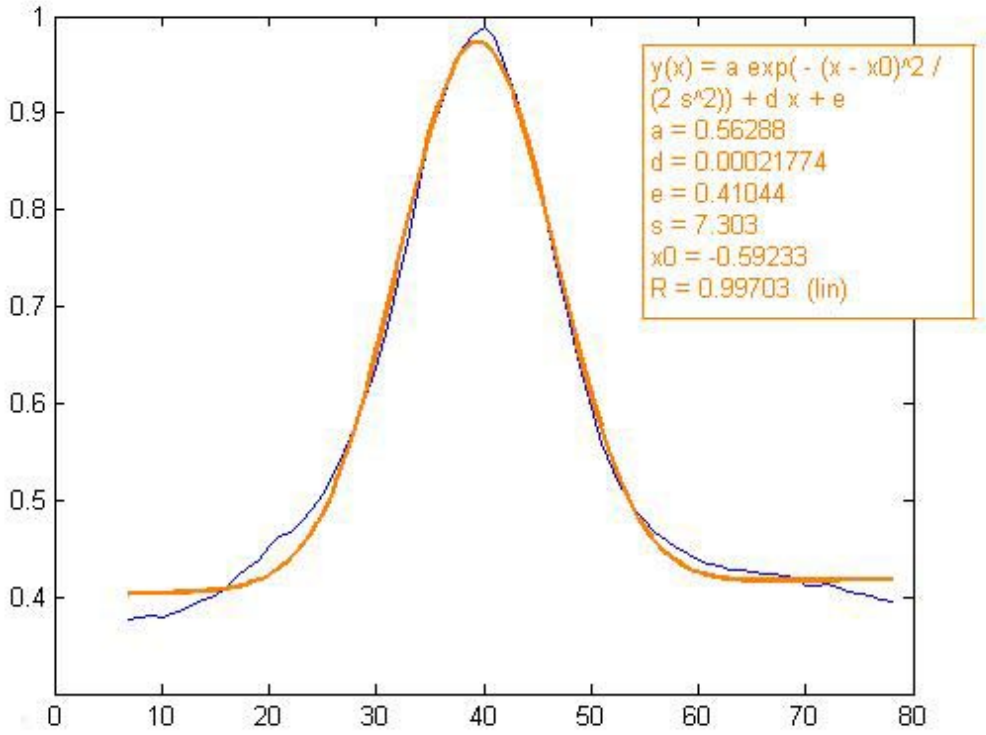


Figure 3: Fitted line of Na(5688) of data set B where y axis represent the normalised intensity and x axis is the wavelength direction (The line in blue represent the orignial line profile while the line in orange represent the fitted guassian with linear background)

Results

As shown in the nightsky frames in figure 4, the artificial components in the nightsky spectrum include two sodium lines with wavelength 5688 and 6154 Angstroms, and three mercury lines with wavelength 5460, 5769 and 5790 Angstroms. These artificial components can be found in street lamps like high pressure sodium lamps and mercury-vapour lamps in Hong Kong.

Fluxes of the emission lines are compared to the Na(5688) line, which is normalised. The result is plotted in firgure 4. From the four data sets, it can be found that there is no fixed pattern in the ratio of lines. But some regularities can be found. Comparing data sets C and D, which was taken in the same night, the ratio of Hg(5769) and Hg(5790) stays relatively the same while Hg(5460) fluctuates. Comparing the four data sets, though they are taken at different dates or time, the line ratio of the two Na lines are higher than that of Hg. This suggests that Na lines intensity in the nightsky is higher than Hg lines intensity which further implies that high pressure sodium lamp in Hong Kong is a larger contributor to light pollution than mercury vapour lamps.

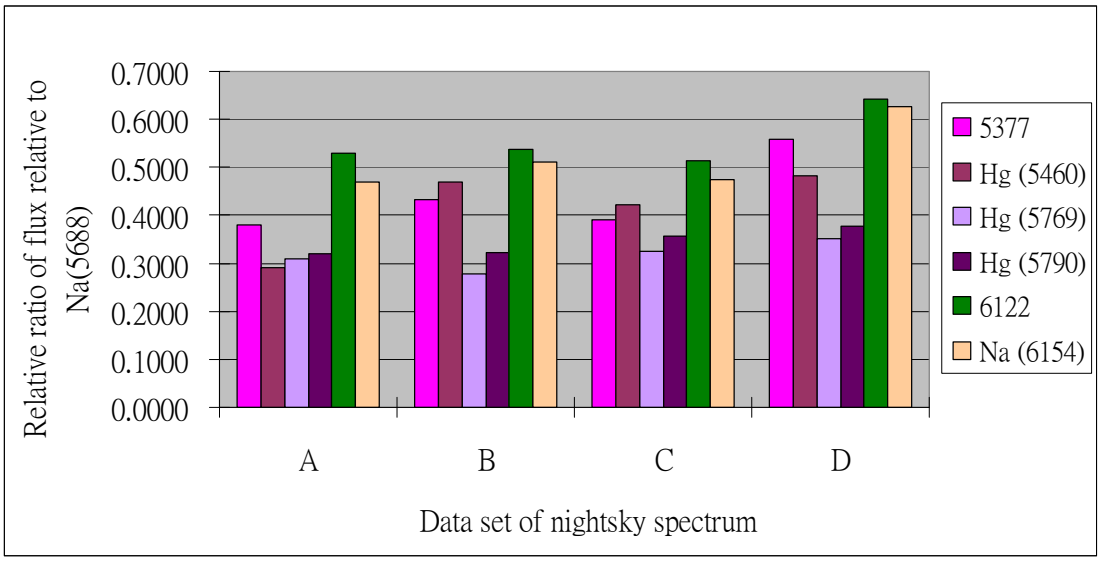


Figure 4: A graph showing the relative ratio of flux of different lines in the nightsky spectrum of the four data sets. (Wavelength of each line included with units Angstroms)

The intensity of Na(5688) line is shown in figure 5. Comparing data sets C and D, the intensity of Na(5688) line decreases with time. This suggests that the intensity of high pressure sodium lamp also decreases with time during the same night.

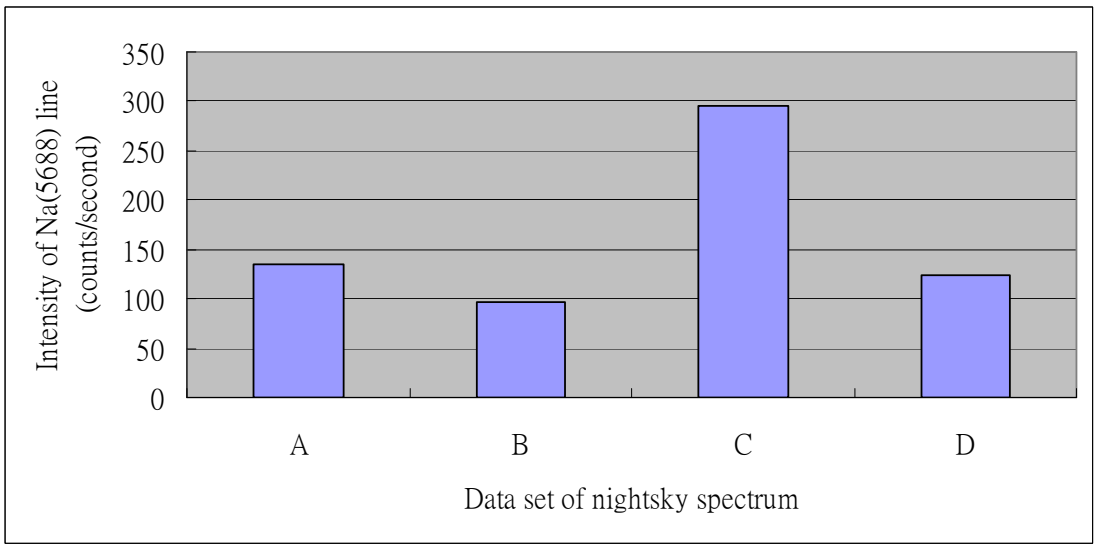


Figure 5: A graph showing the counts per second of Na(5688)line in the four data sets.

Discussion

The sources of errors in the experiment include the difference in CCD temperature between data sets which would lead to inconsistent comparison. Moreover, the fitting of the lines was not exactly the same as the original one which would lead to inaccuracy in the flux ratio.

The project can be improved by investigating the effect of different amount of clouds on the spectral lines of nightsky spectrum. Subsequent night observations would be preferred to see the trend.

For futher investigation, the nightsky spectrum can be correlated with the photometry

of nightsky to see how the variation of brightness affects the flux ratio of lines in the spectrum. Moreover, the nightsky spectrum in urban and rural areas can be compared to find out the extent of light pollution.

Reference

Self Guiding Spectrograph official site --- SBIG
http://www.sbig.com/sbwhtmls/spectrometer2.htm
A survey of light pollution in Hong Kong --- The University of Hong Kong
http://nightsky.physics.hku.hk/
Image Reduction and Analysis Facility project official site
http://iraf.noao.edu/
MATLAB official site
http://www.mathworks.com/
“An introduction to analysis of single dispersion spectra with IRAF” by Asiago Monografie
http://ulisse.oapd.inaf.it/Astro/AsMon/Vol 1/
“Manual for Operating the HKU SGS Spectrograph (vol 1)” by C.W.So, department of Physics, HKU
“Operating instructions for the SBIG Self Guided Spectrograph and Spectra analysis software” by Alan Holmes