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Application of spectrometer in research-based astronomy in education



Commercial
spectrometer



New
adaptor



KSA! Leading the Future!
 OPENING A NEW HORIZON
 IN THE FUTURE OF
 SCIENCE BASED ON THE VALUES OF

Astronomy in Our School 2nd , 3rd Year

Korea Science Academy of KAIST

- High-school
- Selective admission process for nationwide (~17:1 competition rate)

Curriculum	Research Activities (observation-oriented)	Club activities
<ul style="list-style-type: none"> • Compulsory (1 out of 2) <ul style="list-style-type: none"> • Astronomy and Lab (40%) • Earth Science and Lab (60%) • Optional <ul style="list-style-type: none"> • Basic Observational Astronomy • Observational Astronomy • Stars and Universe • Space Science and Lab • Astrobiology 	<p>Student-motivated project</p> <ul style="list-style-type: none"> • Photometry <ul style="list-style-type: none"> • Variable stars • Exoplanets • Spectroscopy <ul style="list-style-type: none"> • Red Mars • Planet's spectra • Solar Spectra • Etc <ul style="list-style-type: none"> • Classification of Galaxies 	<ul style="list-style-type: none"> • Astronomy related Club activity <ul style="list-style-type: none"> • ~40 students • 2 times of open day/year in astronomical observatory while school festival

Astronomical observatory

40-cm reflector × 1
30-cm reflector × 2
20-cm refractor × 1
10~12-cm refractor × 6

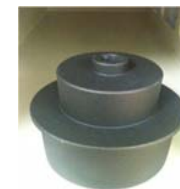


Astronomical spectroscopy in Education

- University
 - Introductory course
 - Universities of Education
 - Majors
- Schools
 - Projects in Middle/high schools
- Public outreach
 - Public Observatories
 - Learning Activities



Commercial
spectroscopy



New
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Astronomical Spectroscopy in Education

- Central topics in introductory astronomy
 - The nature of light
 - The electromagnetic spectrum
 - Spectroscopy
- Spectral features as the “fingerprint”
 - Doppler shift; Wien’s law; Stefan-Boltzmann law; Kirchhoff’s laws
 - Temperature; Elemental composition; Relative motion

Project Development Step I

Project Development Step I



Grating film

Advantages:

Handy

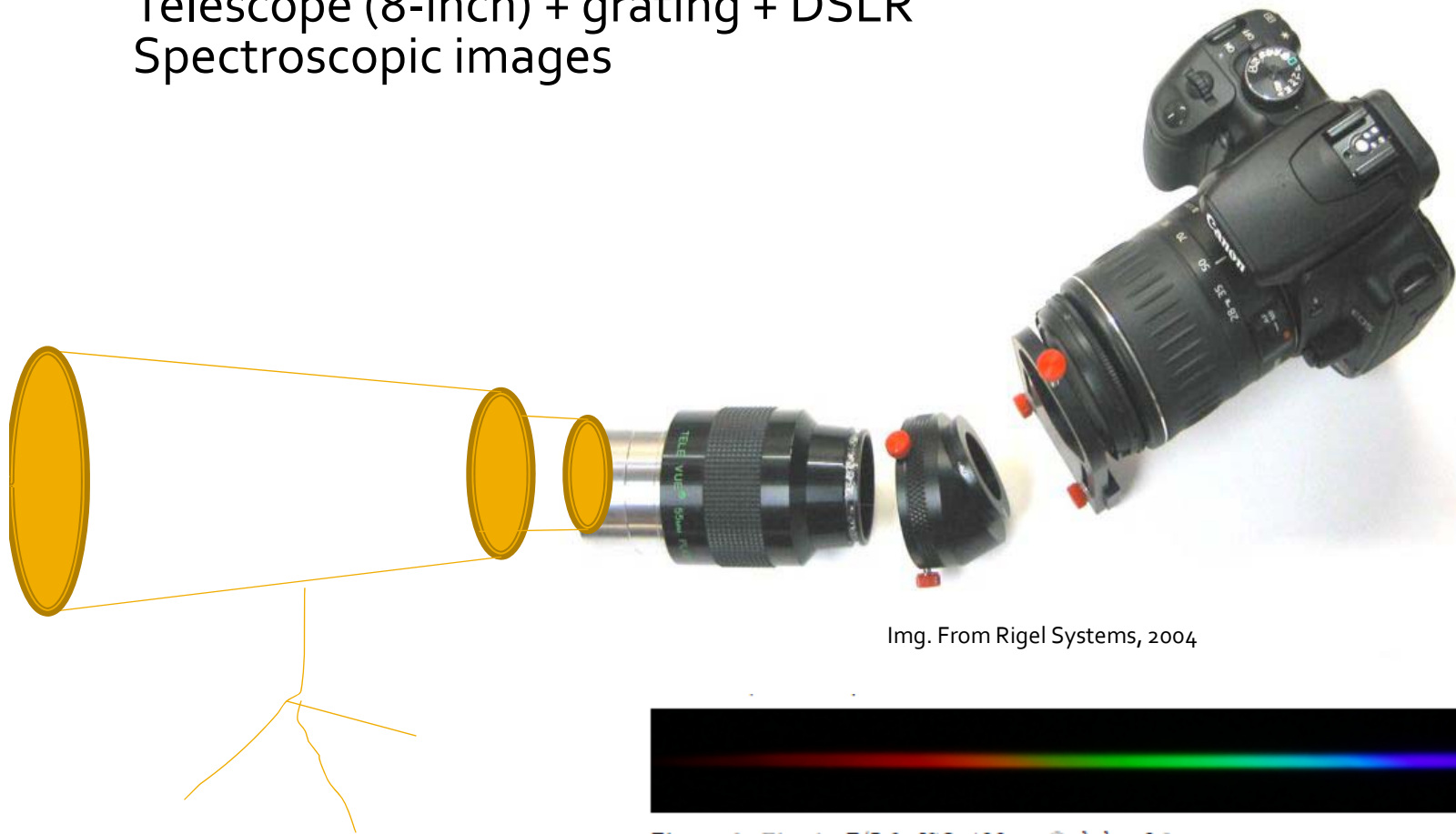
Straightforward understanding

Drawbacks:

No recording for further analysis

Project Development Step II

Telescope (8-inch) + grating + DSLR
Spectroscopic images



Img. From Rigel Systems, 2004

Figure 1. Elnath. F/5.6. ISO 400. 노출시간 : 8초 Sim, Hanseul, 2011 (Project in KSA)

Project Development Step II

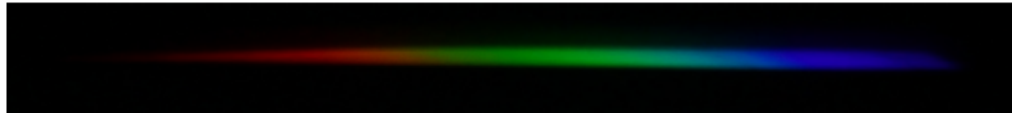


Figure 2. Algol, F/5.6, ISO 400, 노출시간 : 6초

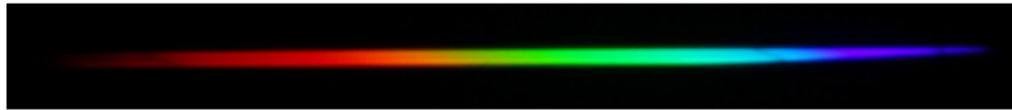


Figure 3. Vega, F/5.6, ISO 400, 노출시간 : 2초

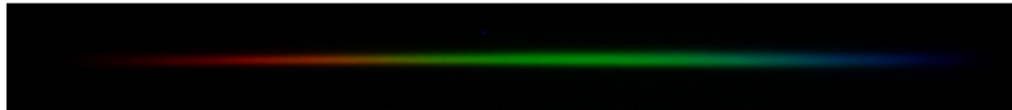


Figure 4. Deneb, F/5.6, ISO 400, 노출시간 : 20초

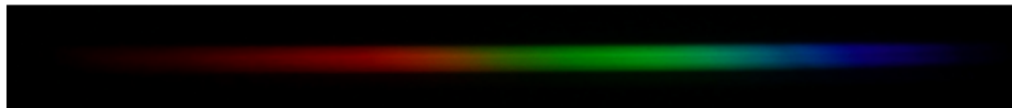


Figure 5. Caph, F/5.6, ISO 400, 노출시간 : 8초



Figure 6. Sadr, F/5.6, ISO 400, 노출시간 : 8초

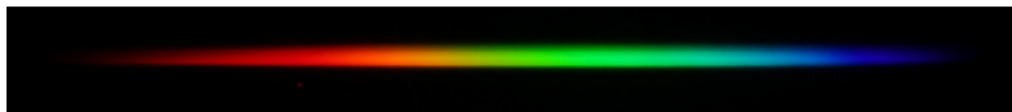


Figure 7. Capella, F/5.6, ISO 400, 노출시간 : 4초

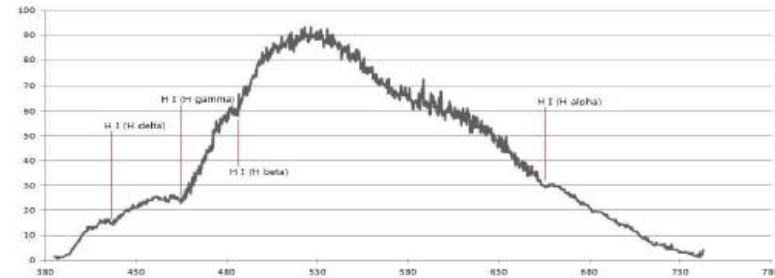
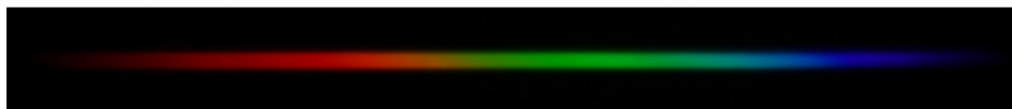


Figure 13. Algol의 스펙트럼

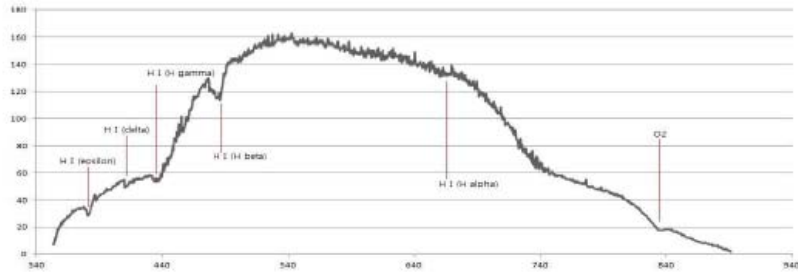


Figure 14. Vega의 스펙트럼

Sim, Hanseul, 2011 (Project in KSA)

Advantages:

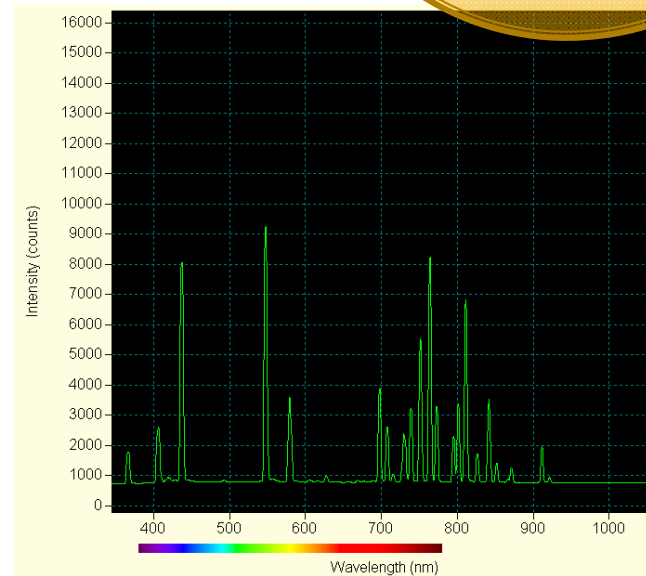
- Possible to obtain astronomical spectra
- Possible to record for analysis

Drawbacks:

- Elaborating to get focus
- Spectral extraction/wavelength calibration

Project Development Step III

Spectroscopic device in chemistry or physics lab



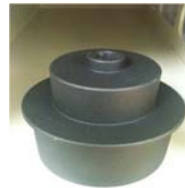
Hg (mercury) spectrum.

Kim, Ha-Young et al. 2012 in class of introductory astronomy in lab

Project Development Step III



Commercial spectroscopy



New adaptor

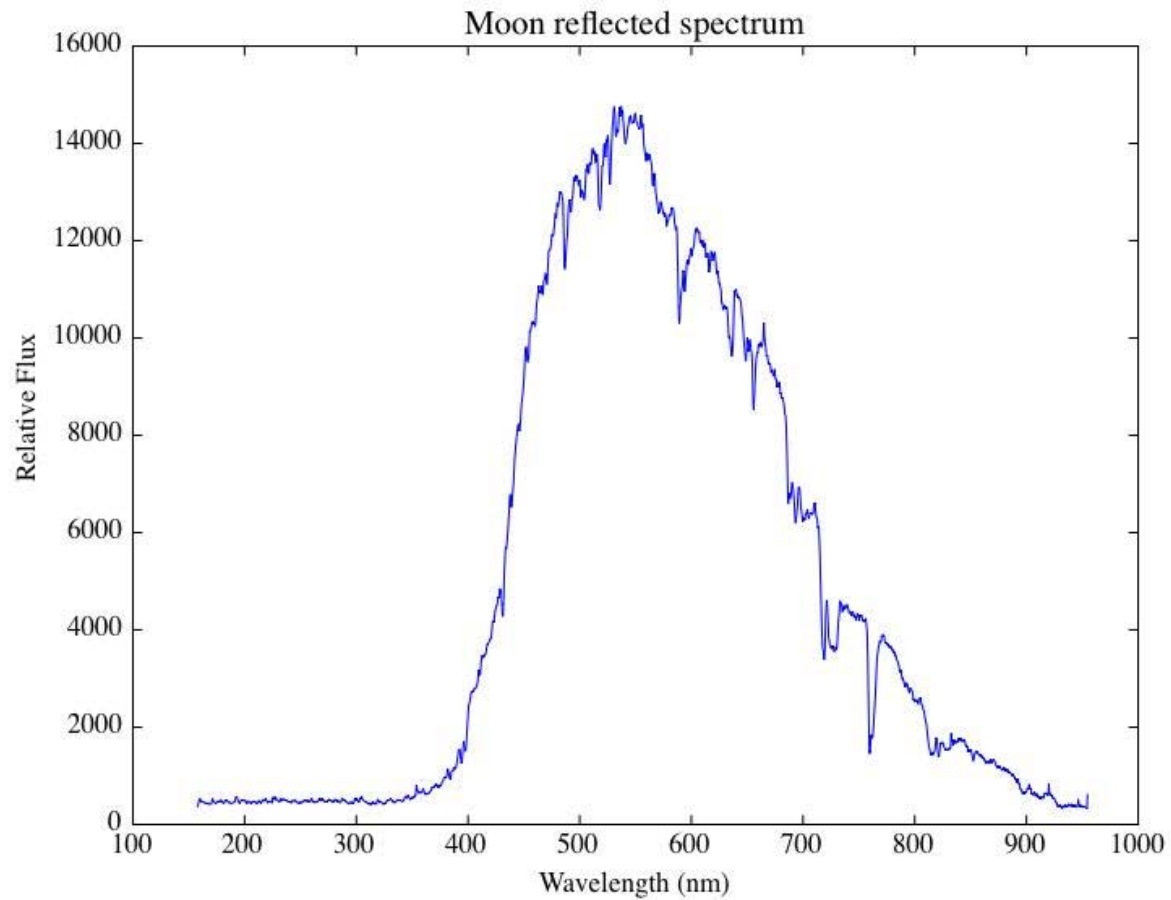


Wavelength Range: 250-800nm
Slit width: 10 μm
Resolution: $\sim 1\text{nm}$
Integration time: 6ms \sim 60 sec
Detector: 1D Si-CCD 2048 pixel
Grating 600 lines/mm
Wavelength calibration done in the supplied software
Price: \$1,000 \sim 3,000

10-cm refractor	20-cm reflector
Moon	Mars Jupiter Arcturus ...

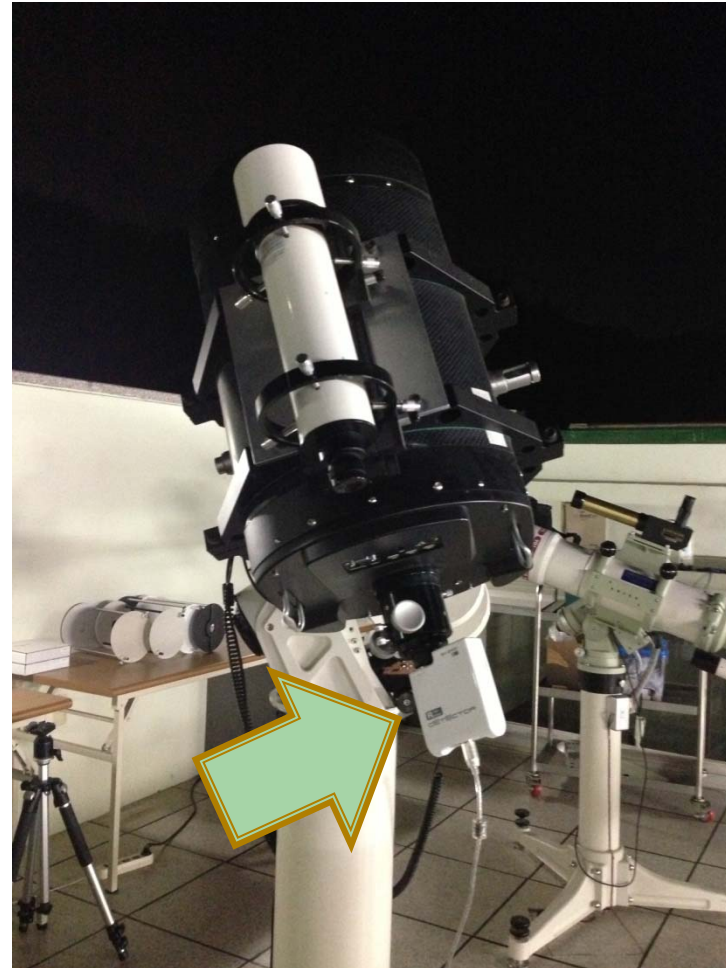
KSA observatory
(Busan, 2nd Biggest City in Korea)

Project Development Step III



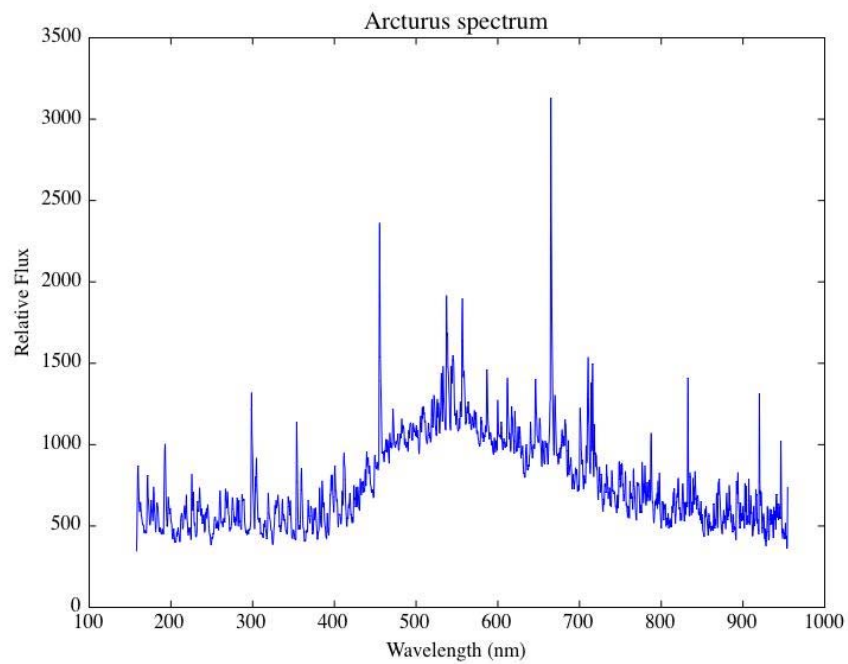
Project Development Step III

- 12-inch reflector

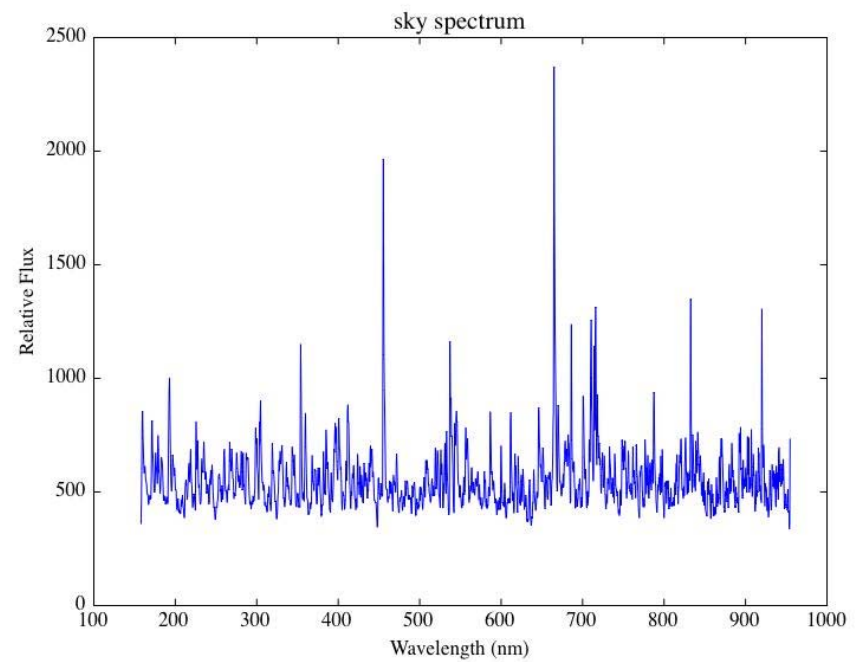


Project Development Step III

- 12-inch reflector



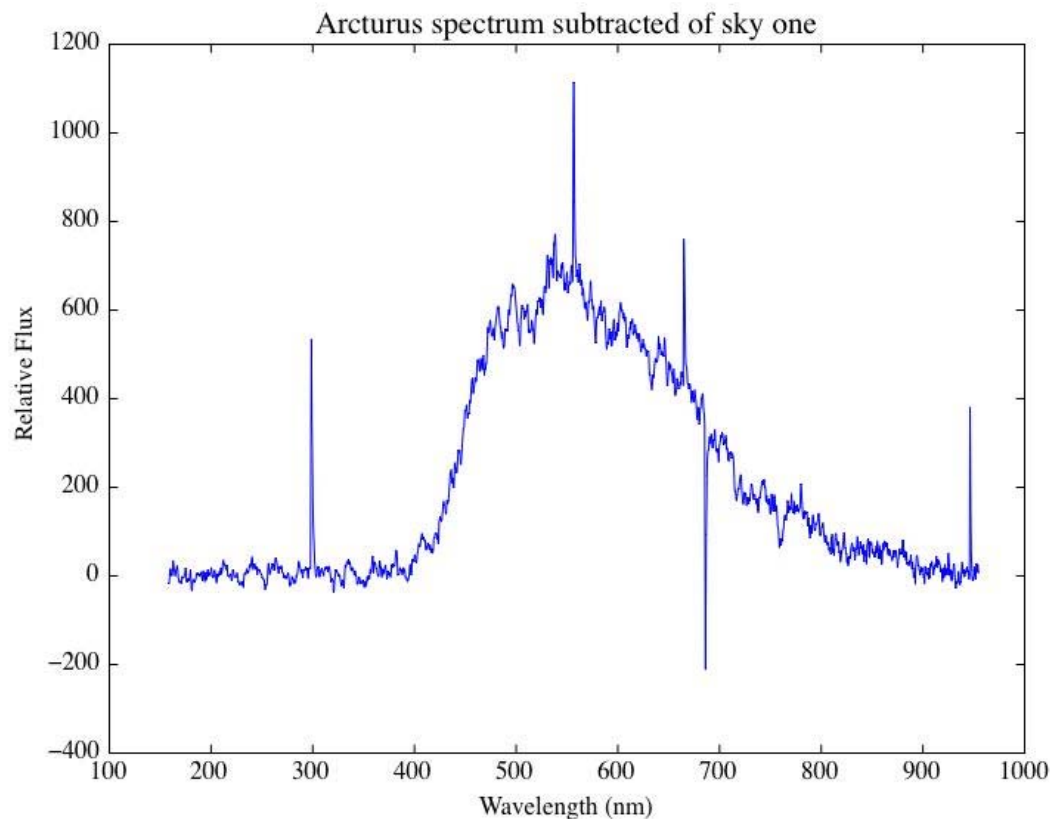
Arcturus's Spectrum



Sky Spectrum (Dark Current)

Project Development Step III

■ 12-inch reflector



Advantages:

- No effort for wavelength calibration/spectral subtraction
- Full-coverage of visible wavelength*

Drawbacks:

(relatively) expensive in school
Easy

Dark-subtracted Arcturus Spectrum

* Without Intensity (or QE) calibration

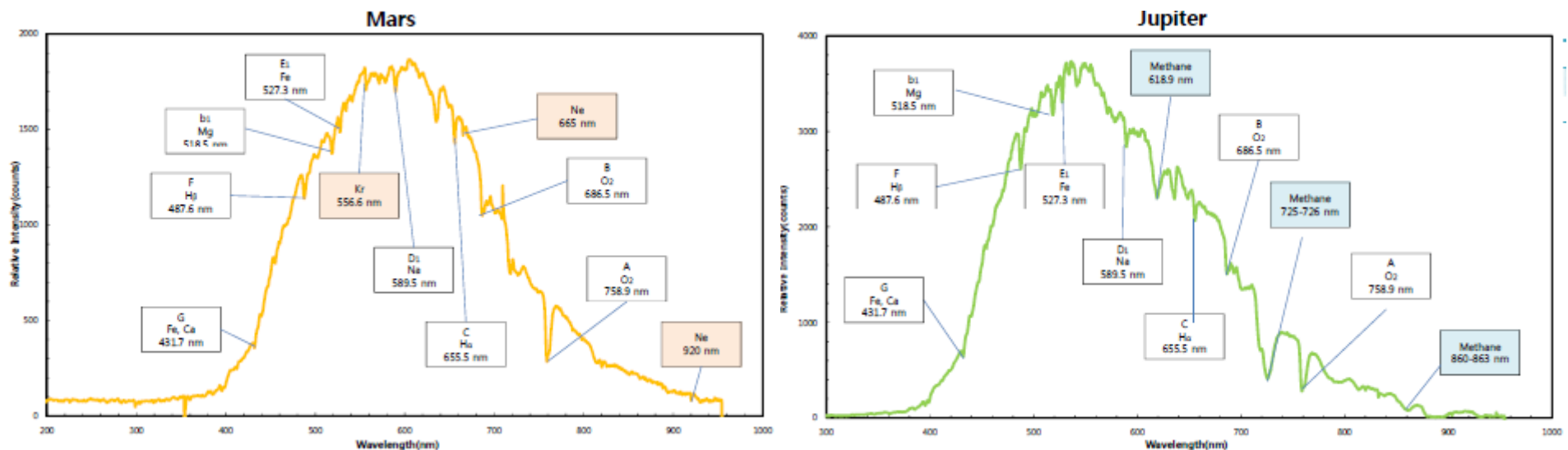
Projects



Photo altogether
3 number of classes (each class having ~15 students)

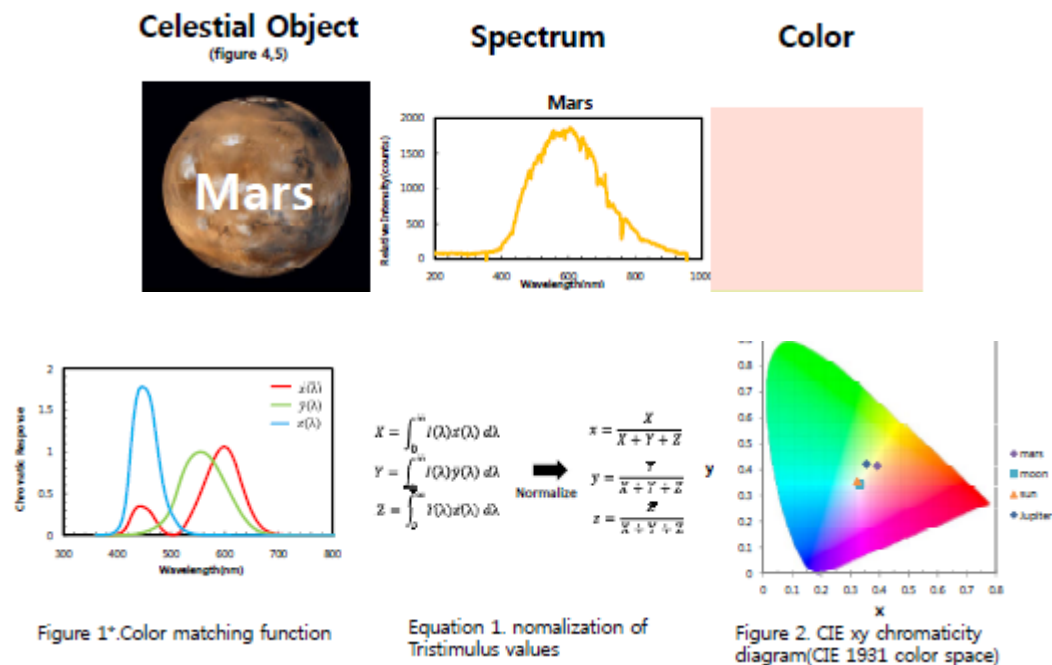
Projects I

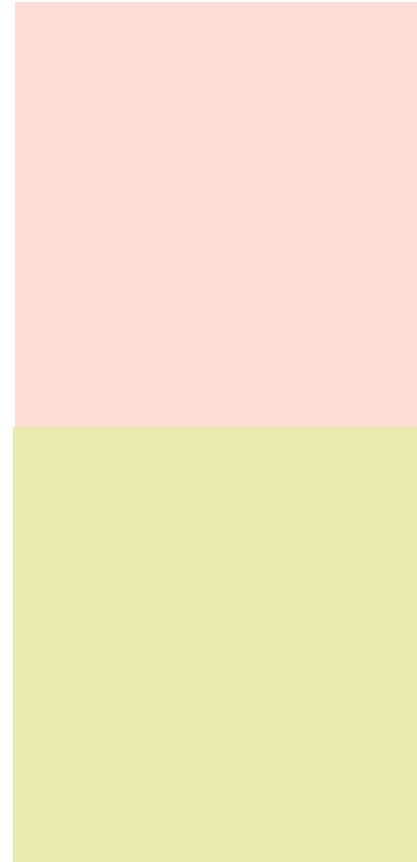
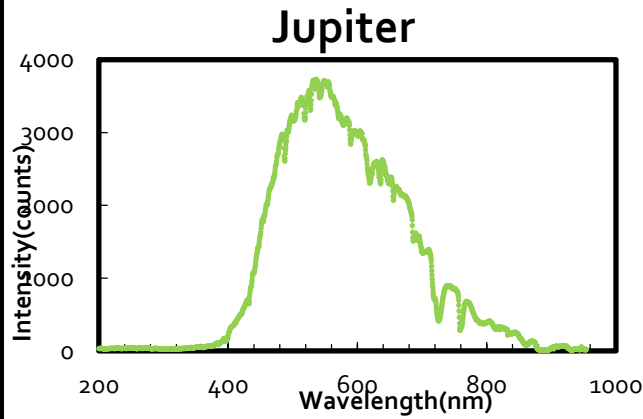
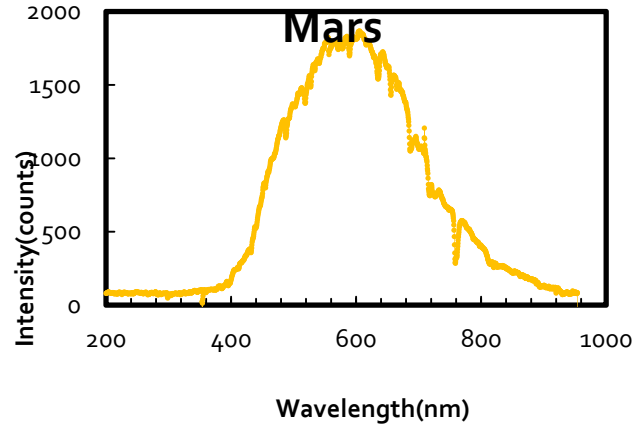
- Student's project (3rd year, 1 student)
 - Are the spectra different for terrestrial and jovian planet?
 - Spectra of Mars and Jupiter



Projects II

- Student's project (2nd year; 3 students)
 - Why does Mars look Red when incoming radiation is from the Sun and it is the same for all planets?
 - Red color of Mars





* Without QE calibration (yet): pixel efficiency is different depending on the wavelength

Projects III

- Student's project (2nd , 3rd year; 3 students)
 - Limb Darkening
 - Can we see the temperature variant?



(h)
SUN_20140414_1600_image1

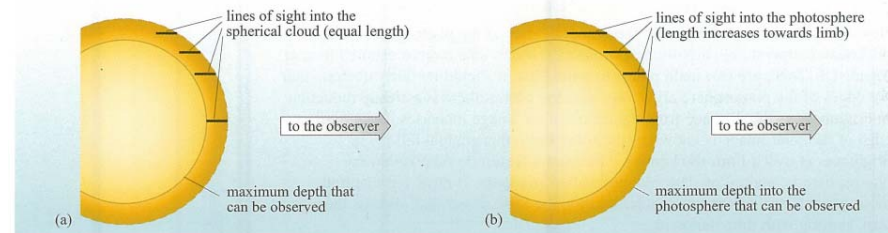


Figure 1.4 (a) For a gaseous spherical cloud of uniform density, we can see a uniform distance along the line of sight into the cloud. The depth below the surface of the furthest point that is visible becomes shallower as lines of sight approach the limb of the cloud. (b) In the Sun, the density changes with depth, and the lengths of lines of sight within the cloud increase as they approach the solar limb. However, the overall result is similar to case (a) in that the depth below the surface of the furthest point that we can see again becomes shallower as lines of sight approach the limb of the Sun. (Note that the relative distances that the lines of sight penetrate into the Sun are grossly exaggerated in this diagram.)

An Introduction to the Sun and Stars, ed.
By Green and Jones (The Open University,
2004)

Projects III

- Student's project (2nd, 3rd year; 3 students)
 - Limb Darkening

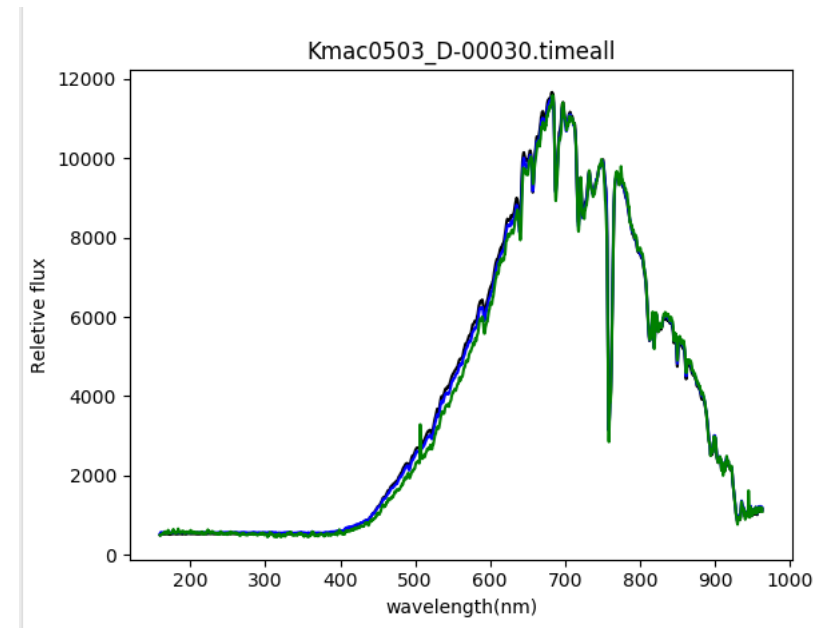
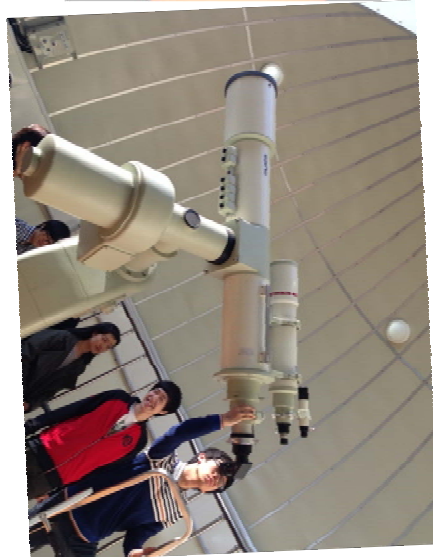


(h)
SUN_20140414_1600_image1
8-inch
Cannon 70D DSLR on focus



Projects III

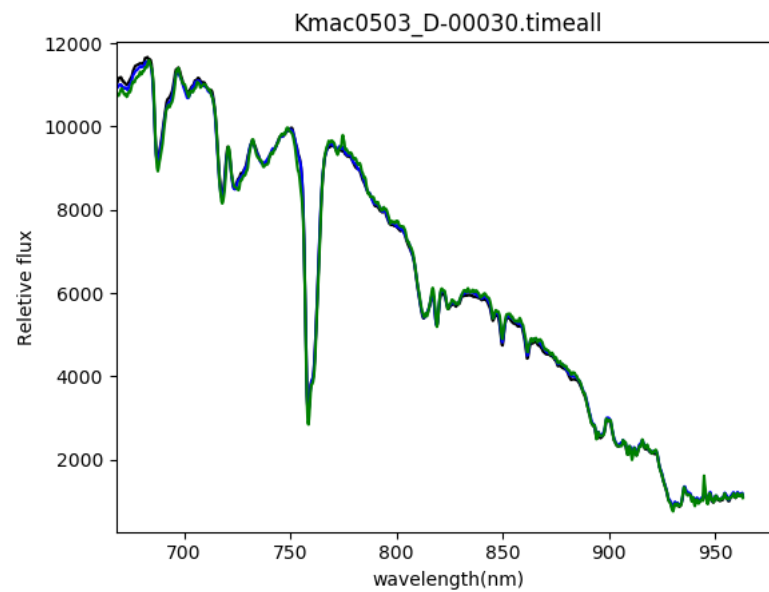
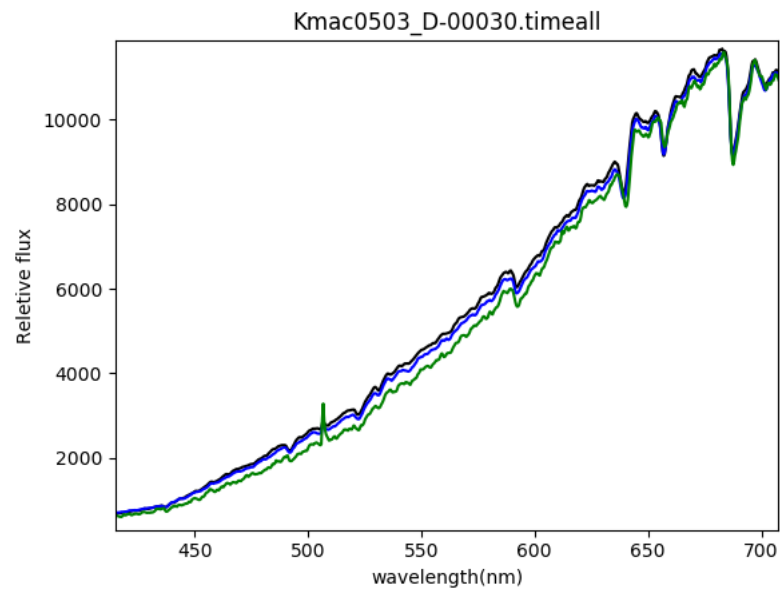
- Student's project (2nd , 3rd year; 3 students)
 - Limb Darkening



Intensity scaled to fit

Projects III

- Student's project
 - Limb Darkening



Summary and futures

- Astronomical spectroscopy in education
 - Handy and easy astronomical spectroscopy
 - **Projects**
 - Planet spectra (reflected sunlight)
 - Color of Planets
 - Limb darkening
- Future works
 - Calibration (QE of pixels depending on wavelength)
 - Survey-type student project
 - Temperature derived from blackbody radiation curve and intensity of chemical composition

Thank you!