A Solar Spectroscope Exhibit at Utah Valley University

AAPT Summer Meeting · Provo, Utah · 22 July 2019

Objective:

Bright, 2-meter-long display of the Sun's visible spectrum

- made with "live" sunlight
- projected onto a screen
- showing many absorption lines


Nunns
HEATHERIDGE
Wicks
ASPEN
189
Olmstead
Caryhurst
15
Orem
UTAH VALLEY
1941
UNIVERSITY
LITTLE ROCK CANYON
OREM SOUTH
189
EDGEMONT
Lakeview
CARTERVILLE
Utah Lake
AAPT 2019 SUMMER MEETING
JULY 20-24 Provo, Utah
PHYSICS EDUCATION
FORT UTAH
Provo
PROVOST
PROVO BAY
Provo Municipal Airport
SUNSET
EAST BAY
Provo Bay
1 miles
1 km

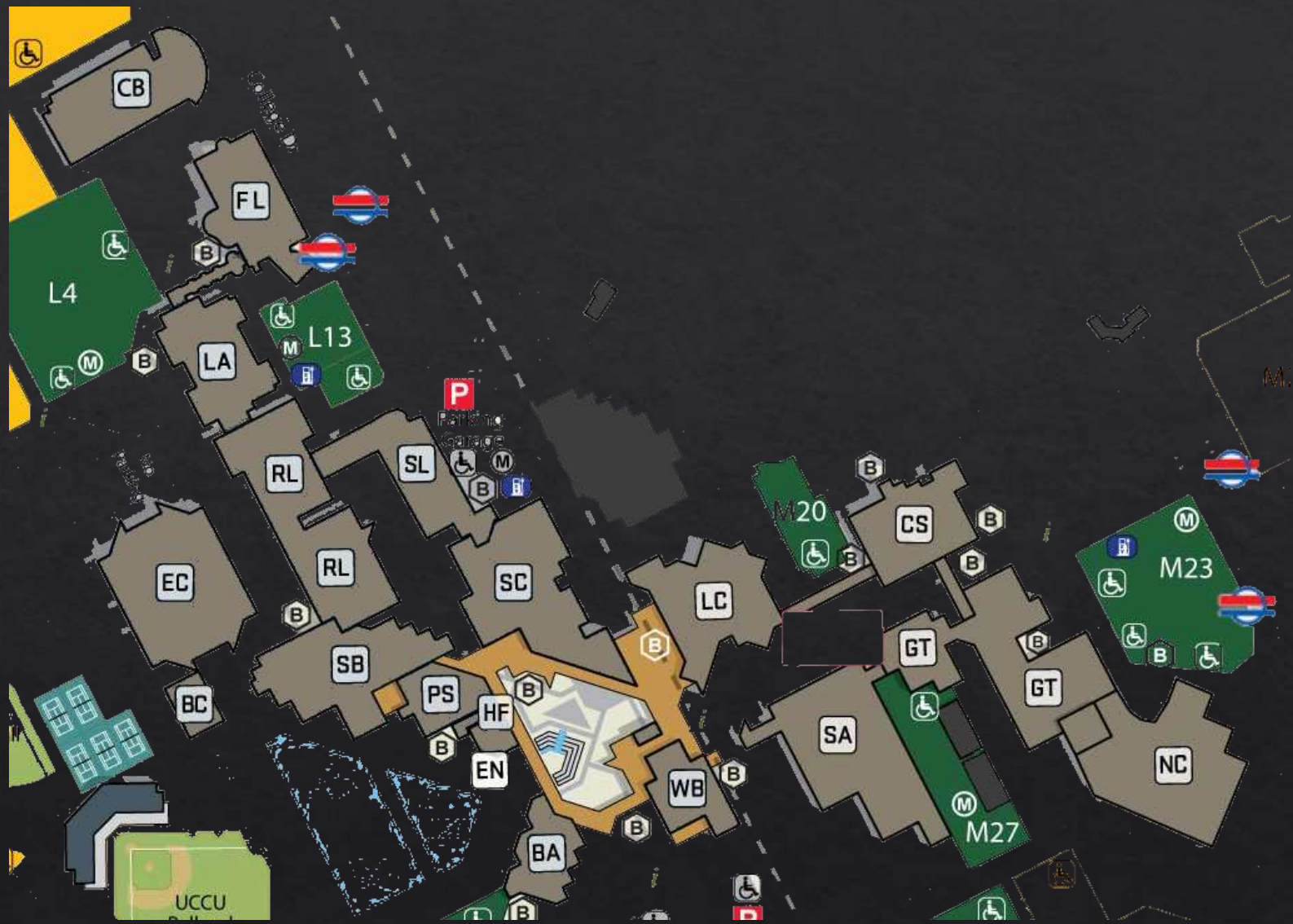
Large public university
(almost 40k students)

Dual mission:
university + community college

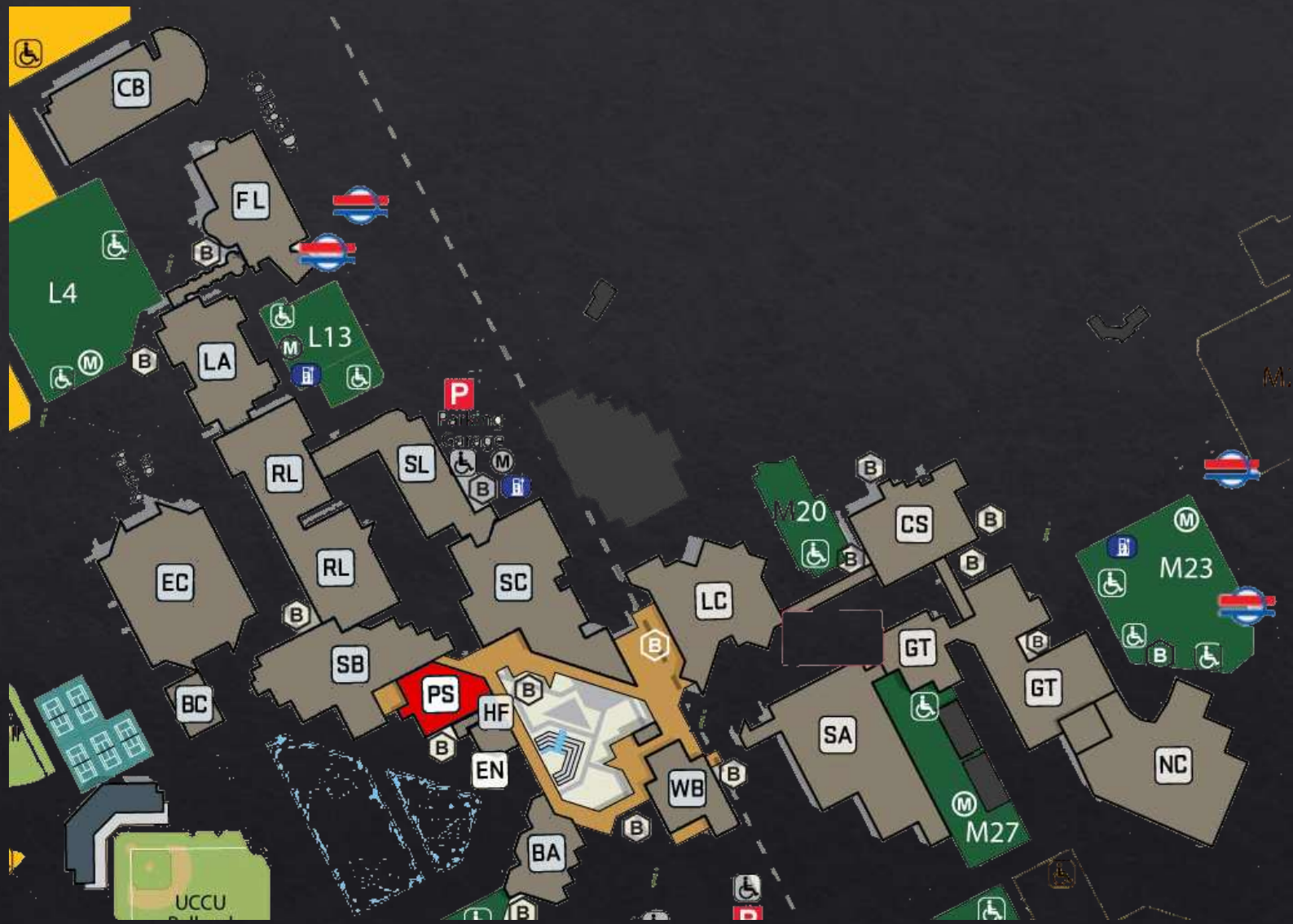
Master's, bachelor's, associate degrees, certificates

Established 1941 as Central Utah Vocational School

UTAH VALLEY UNIVERSITY



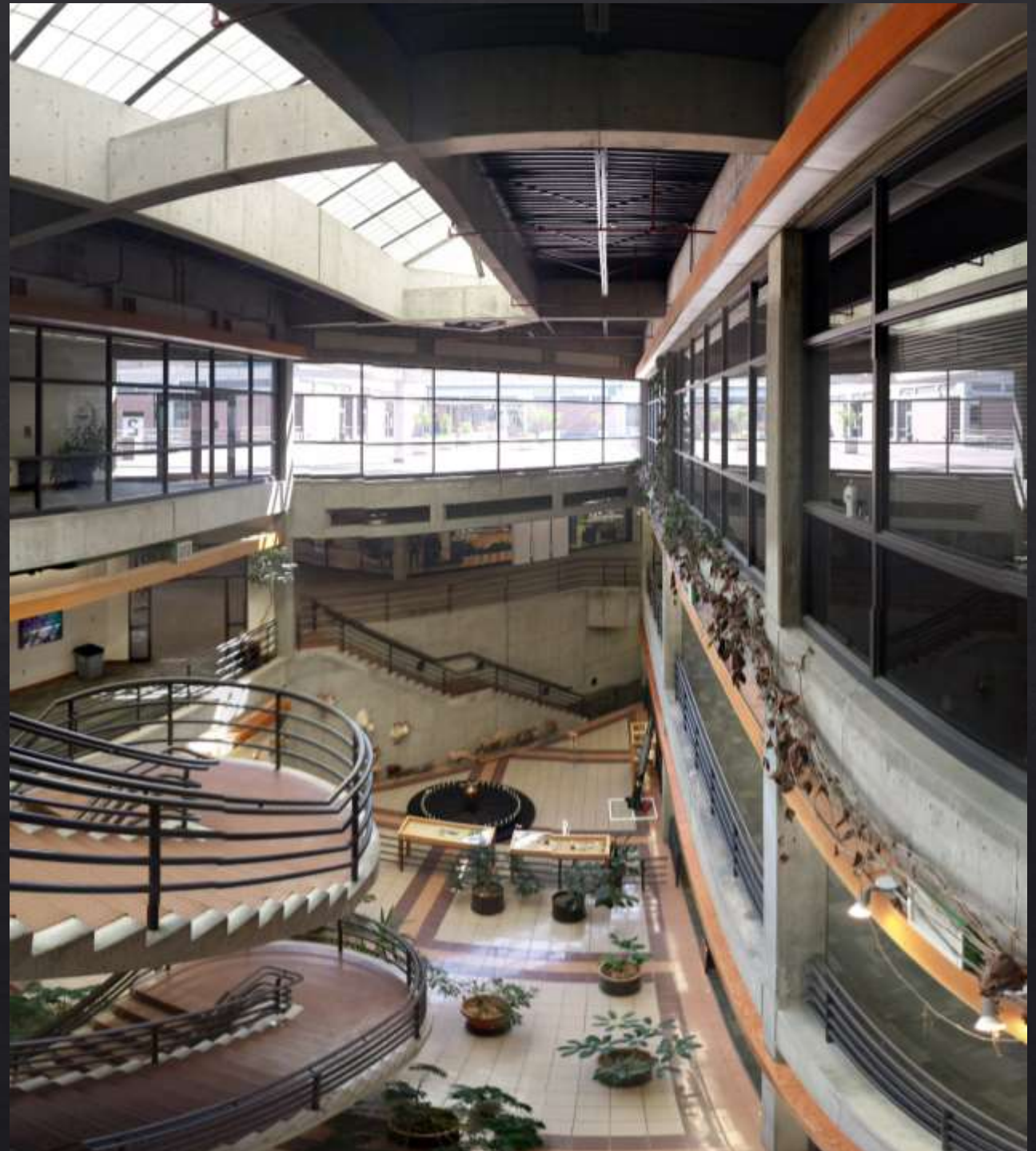
UTAH VALLEY UNIVERSITY



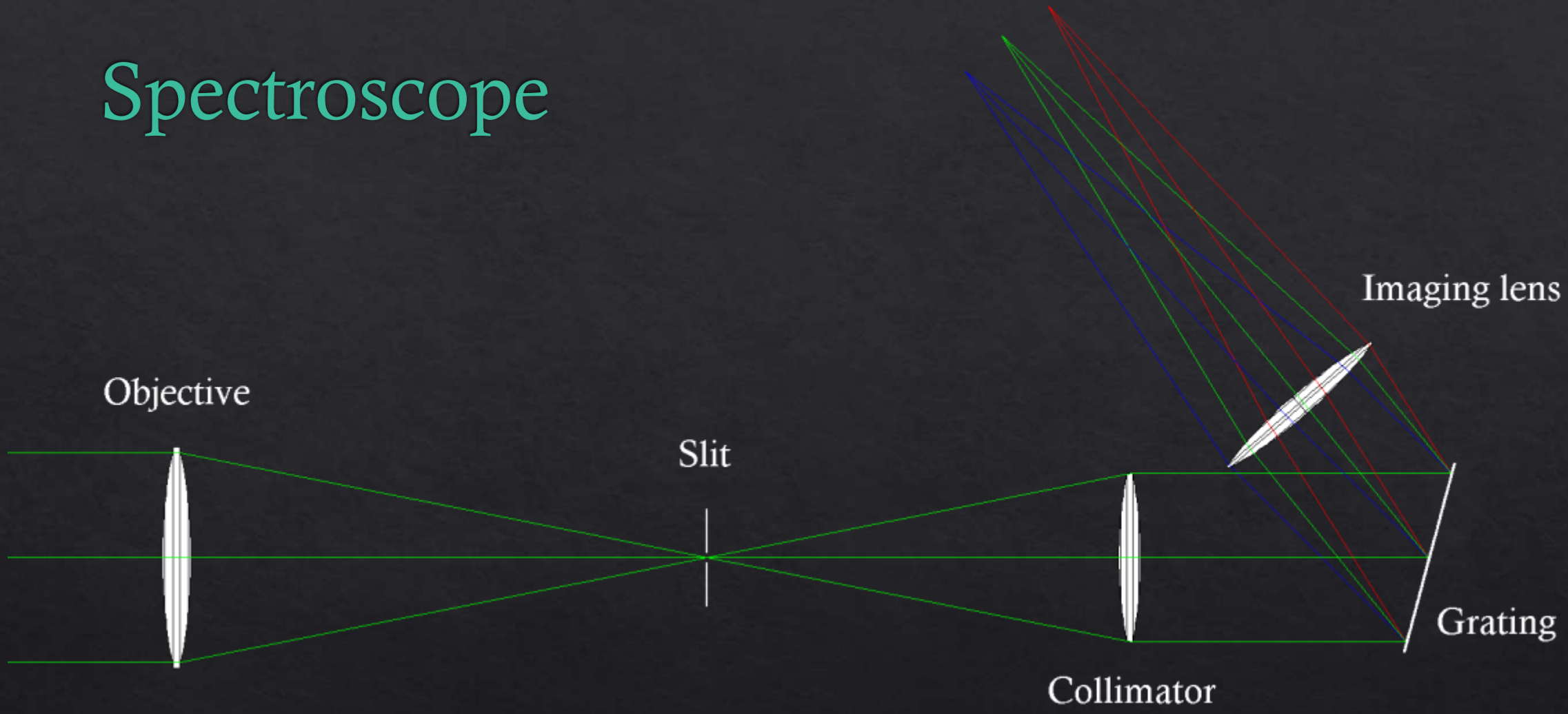

POPE SCIENCE
PS

Pope Science Building

Chemistry
Earth Science
Physics

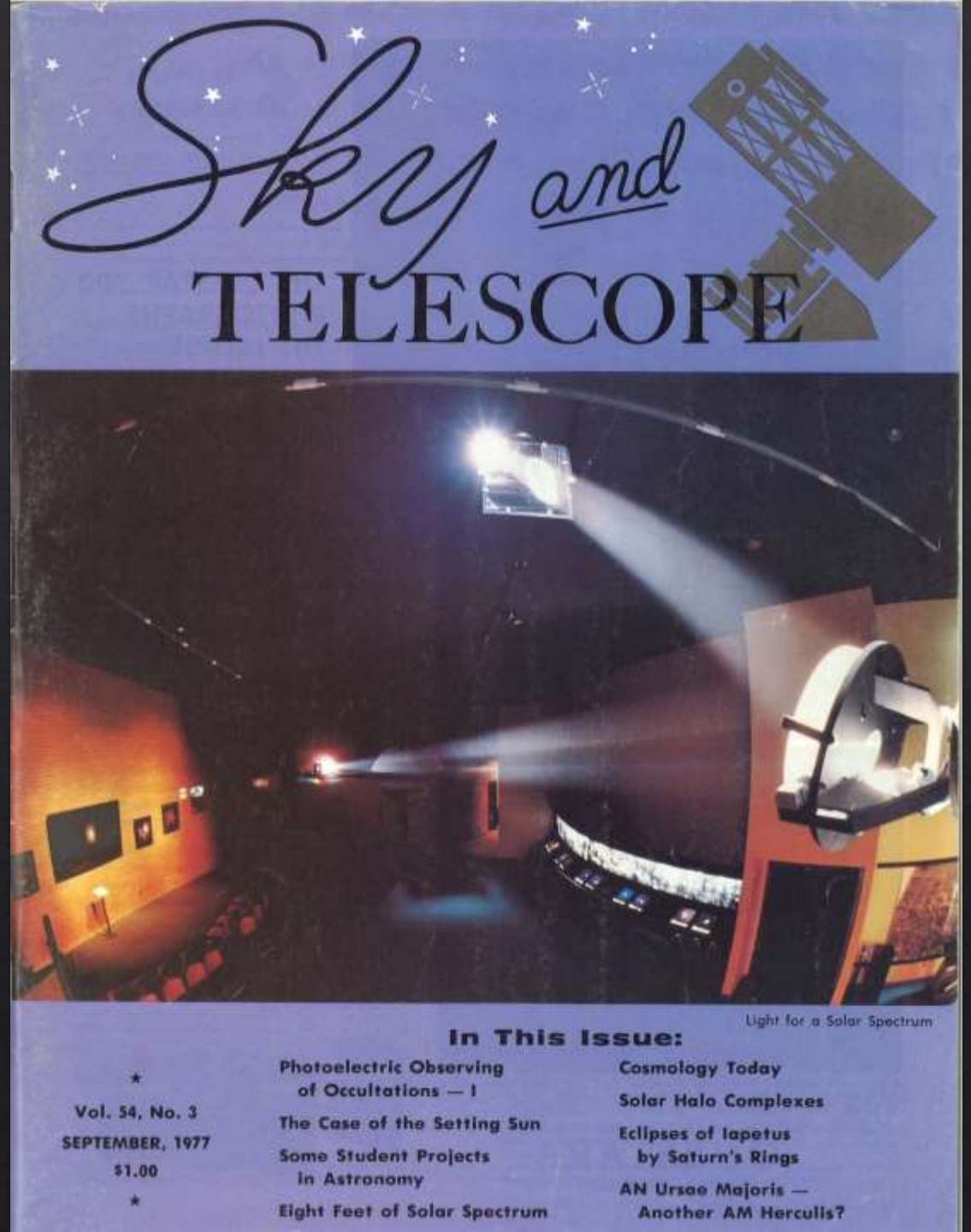


Spectroscope

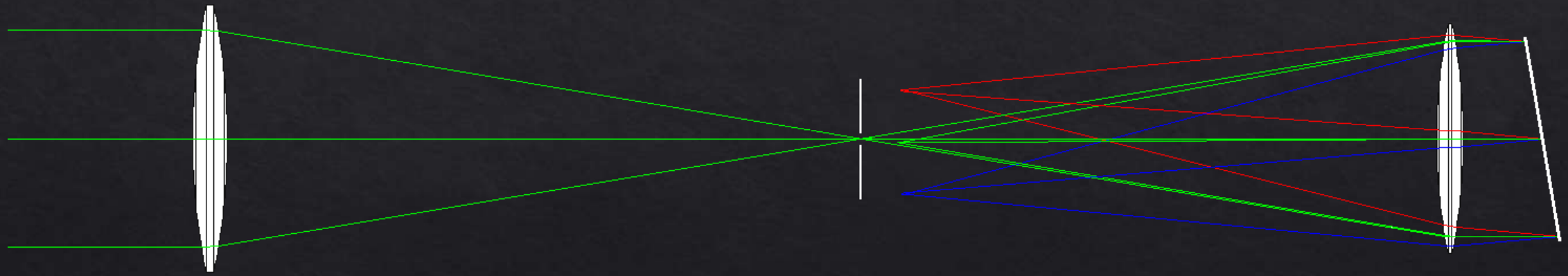


Eight Feet of Solar Spectrum

Grace Flandrau Planetarium, University of Arizona



Collimator and
Imaging lens



Slit width

Trade-off between

bright spectrum

and

good spectral resolution

Rough calculations!

$$B = \frac{\text{Average irradiance of spectrum on screen}}{\text{Irradiance of direct sunlight}}$$

$$B \approx (0.0035\ \text{m})\frac{D^2 G^2\ \Delta\lambda}{L^2}$$

$D =$ "diameter" of grating

$G =$ grating constant (lines per unit width)

$\Delta\lambda =$ spectral resolution

$L =$ length of spectrum

Experiments in Pope Science suggest that we need $B > 0.007$ to obtain a "bright" spectrum.

With

$$D = 170 \text{ mm}$$
$$G = 1200 \text{ lines per mm}$$
$$\Delta\lambda = 0.25 \text{ nm}$$
$$L = 2000 \text{ mm}$$

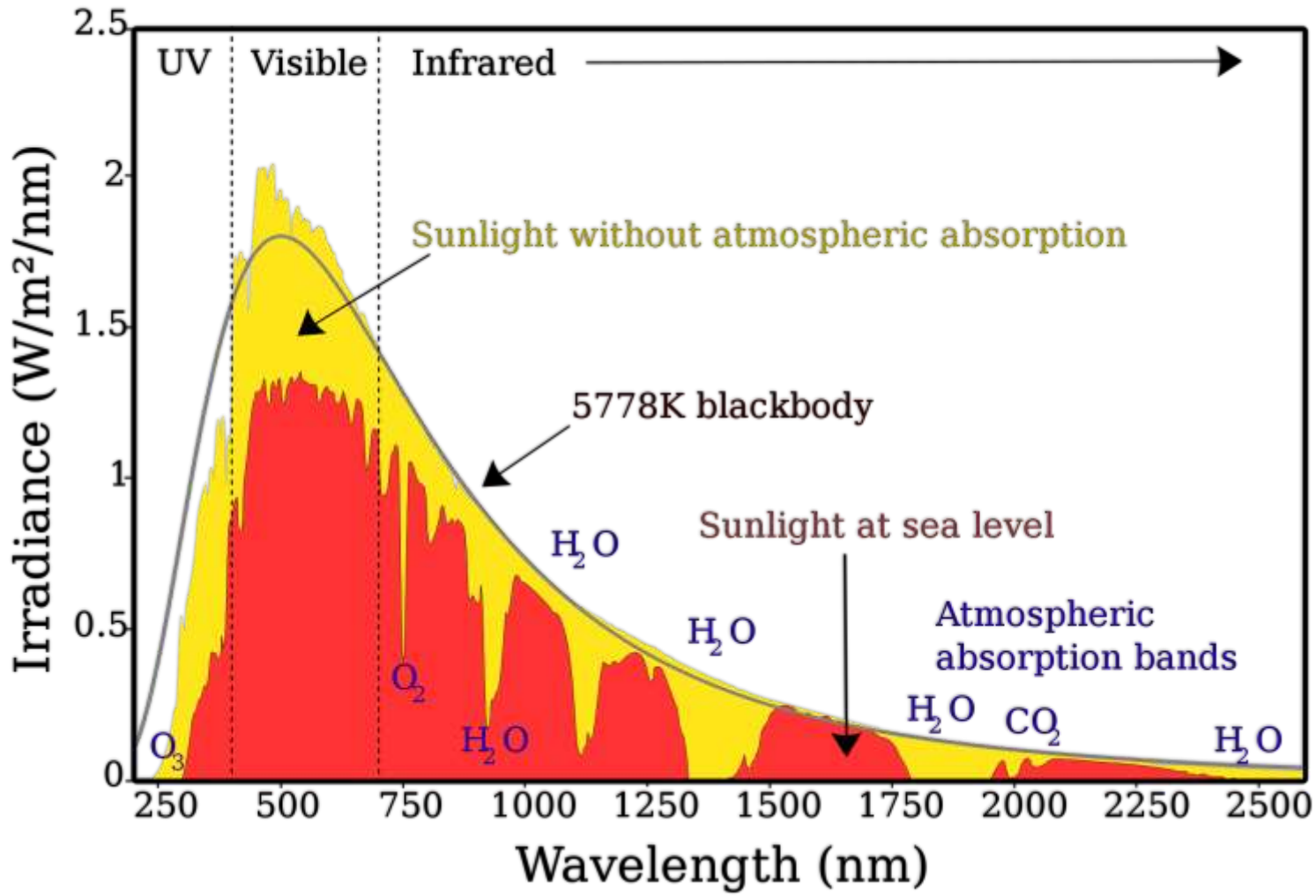
we get

$$B = 0.009$$

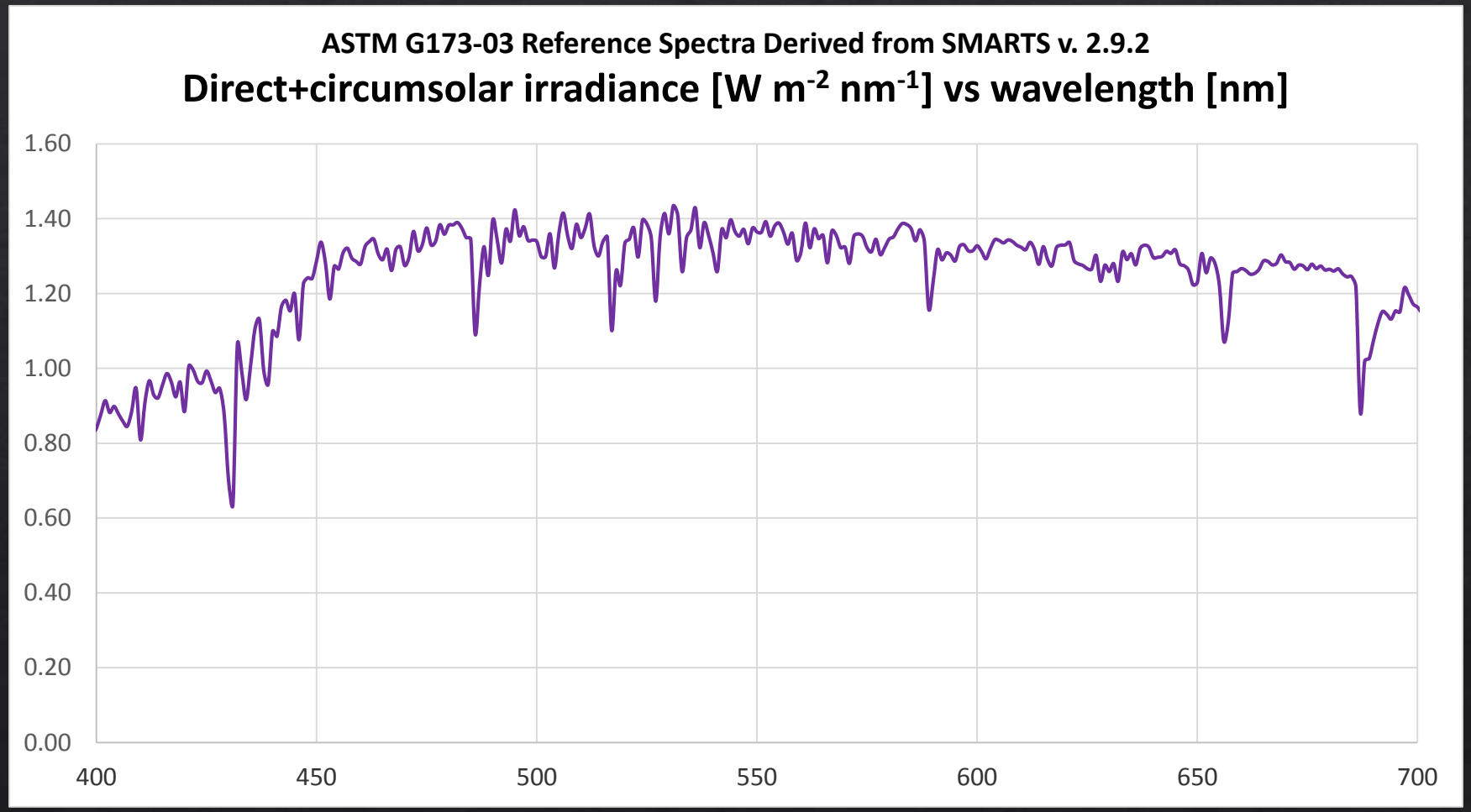
Étendue

- Étendue = “geometrical extent”
- Also known as $A\Omega$ product
- Related to Lagrange invariant

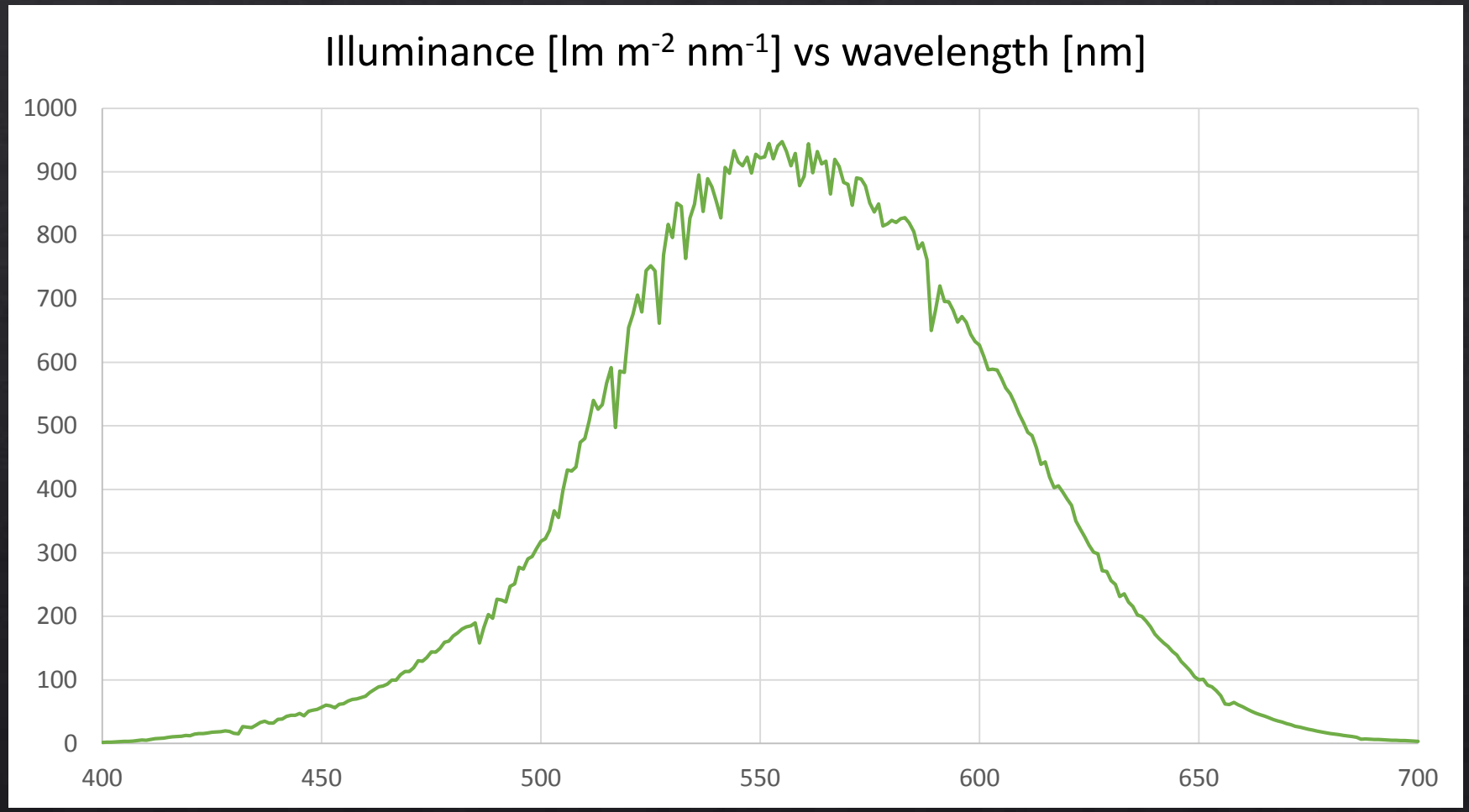
(area of image of slit on screen) x
(solid angle of imaging lens viewed from screen) ≈
(area of objective lens/mirror) x
(accepted solid angle on sky)

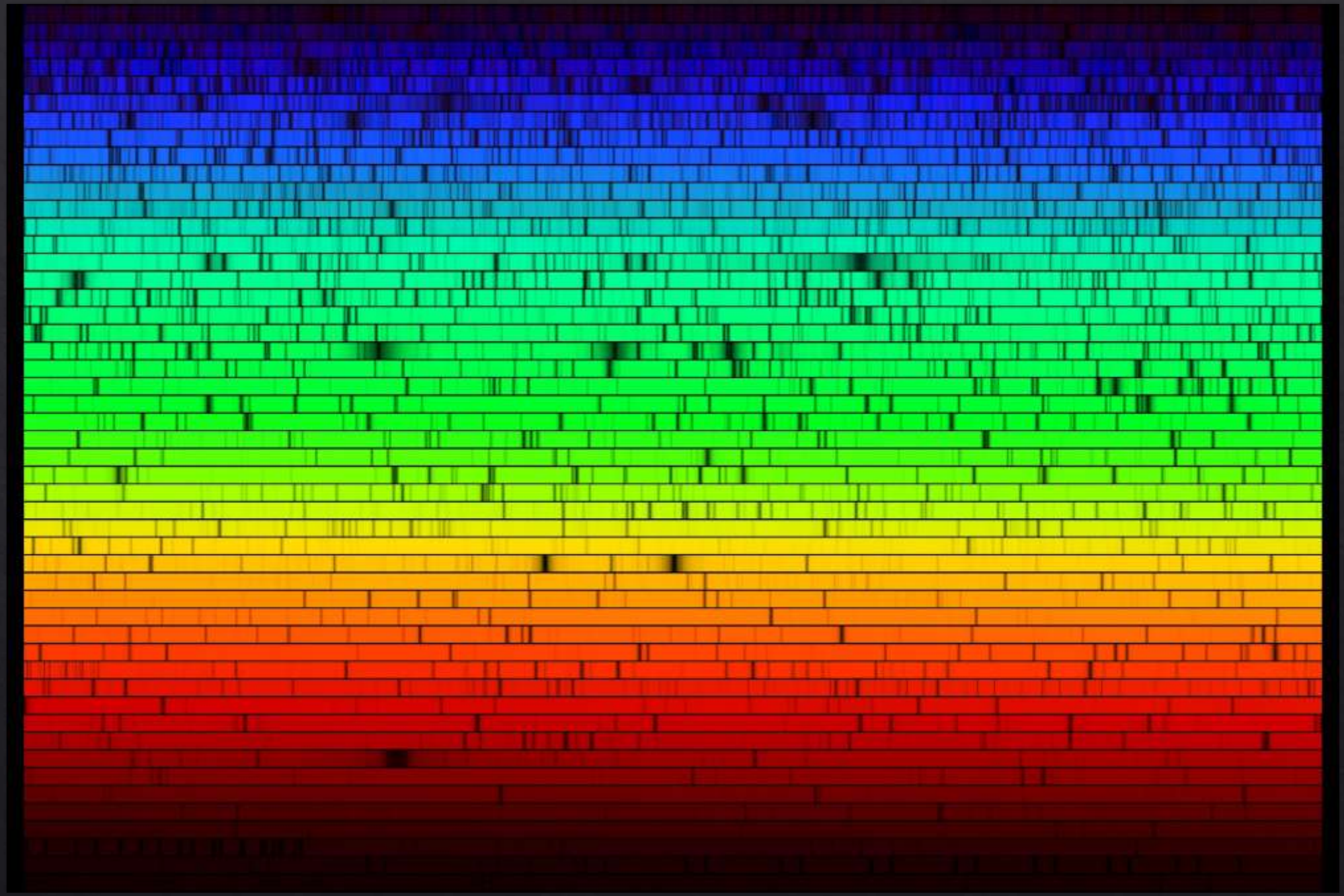


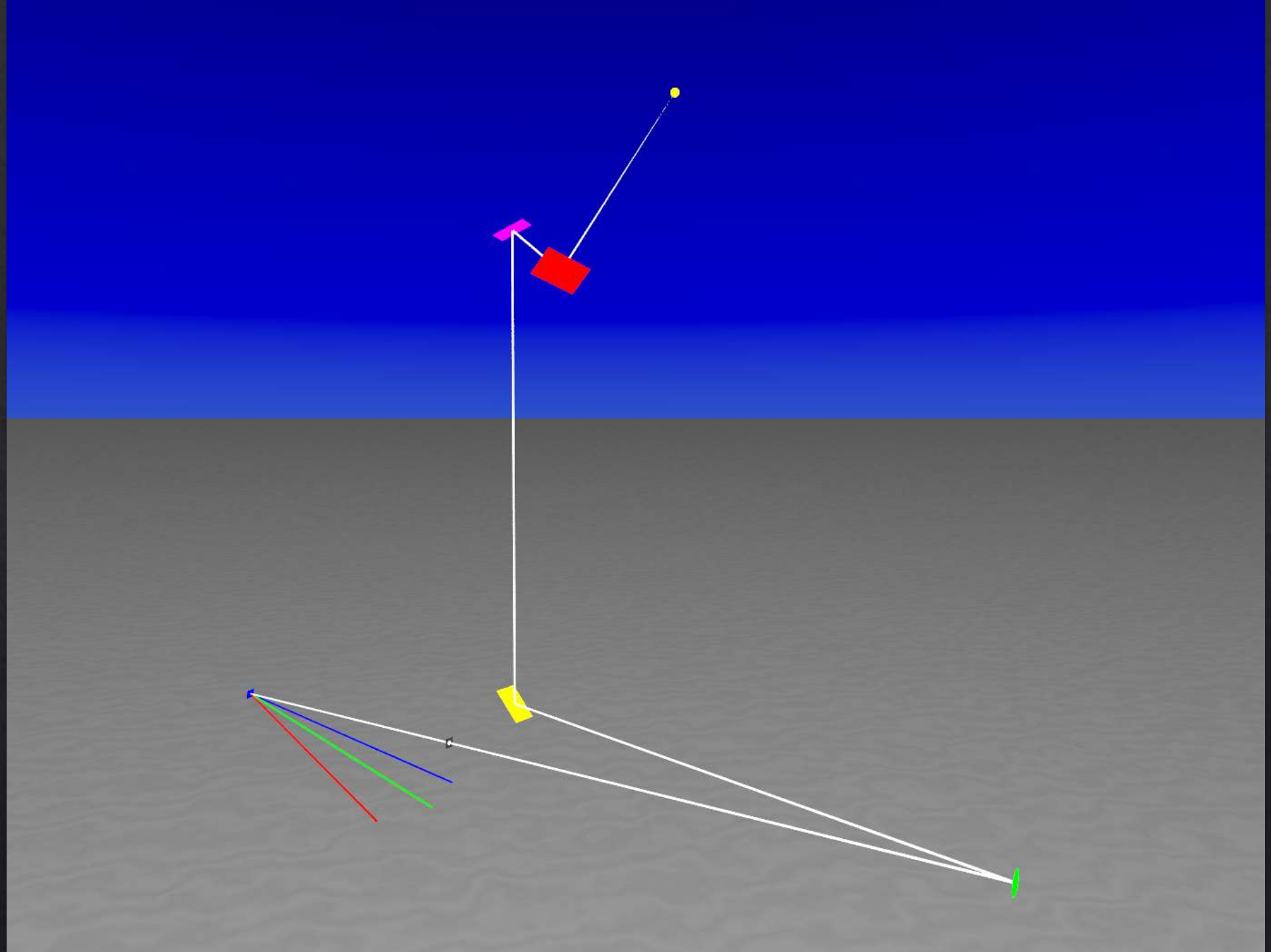
ASTM reference spectra
sea level irradiance:
air mass 1.5
(solar zenith angle 48.19°)


ASTM G173-03 Reference Spectra Derived from SMARTS v. 2.9.2
Direct+circumsolar irradiance [W m-2 nm-1] vs wavelength [nm]
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
400
450
500
550
600
650
700

Multiplied by photopic response function of human eye…








adidas


POPE
SCIENCE BUILDING


POPE
SCIENCE BUILDING

Test setup

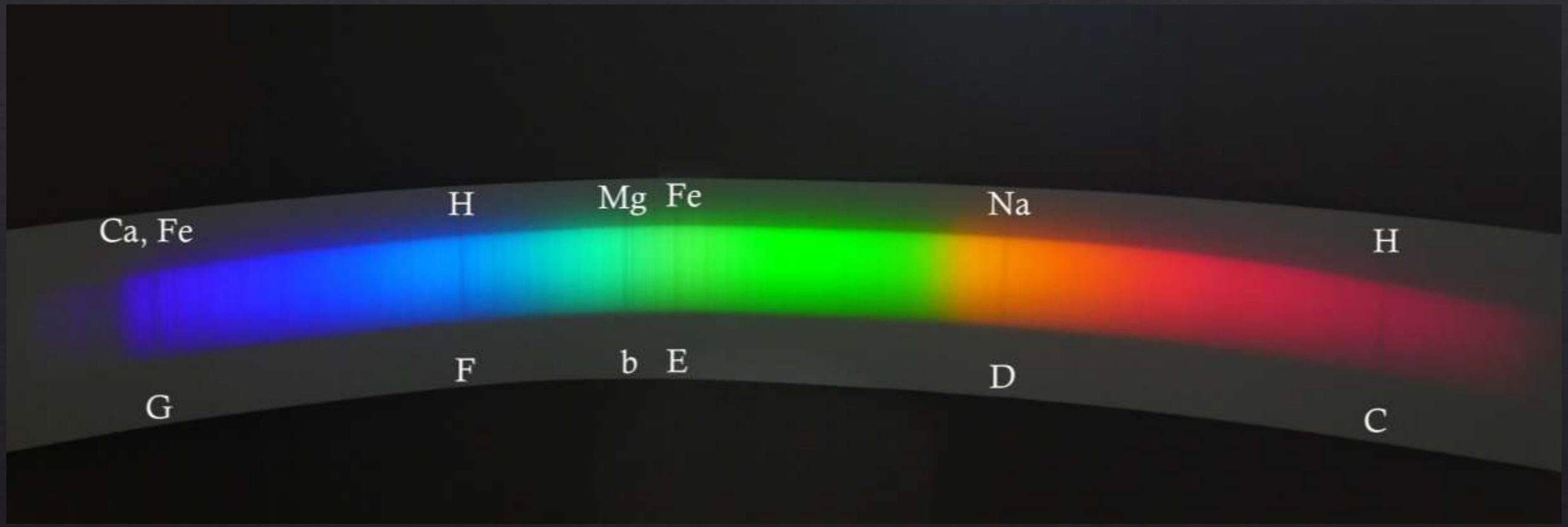
300 mm concave mirror

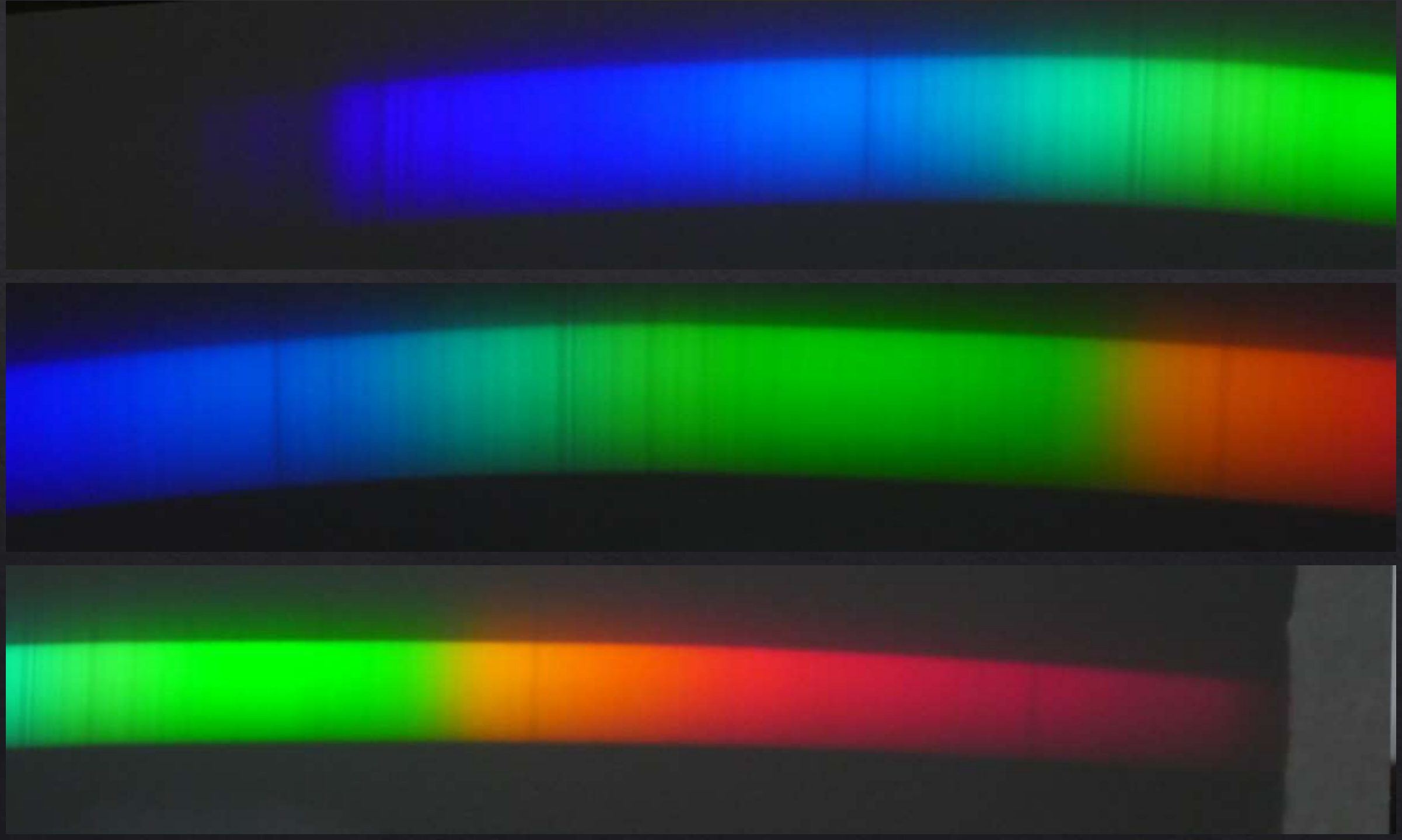
140 mm collimator/
imaging lens

206mm x 154 mm grating
(plastic cover on!)

(thin clouds)

spectrum 1.1 m long


Ca, Fe
H
Mg
Fe
Na
H
G
F
b
E
D
C



Plans

- Design of optical system using WinLens3D and homemade ray tracing program
- Reduce curvature of image
- Prepare proposal to UVU College of Science and UVU Facilities
- Phase Two: spectrometer (view spectrum through eyepiece) with 0.01 nm resolution; user can scan spectrum

Students

Jonah Allen
Joseph Burton
Ryan Fullmer
Spencer Grierson
David Miller
Scott Olsen
Tyler Olsen
Keely Stevenson
Bailee Thackeray
Caroline Torgersen

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- UVU College of Science
- UVU Department of Physics
- NASA Rocky Mountain Space Consortium

Bibliography

"Eight Feet of Solar Spectrum," O.R. Norton, Sky and Telescope, September 1977, p 176.

ASTM G-173 reference solar spectral irradiance at
https://rredc.nrel.gov/solar//spectra/am1.5/ASTMG173/ASTMG173.html

CIE color matching functions at http://cvrl.ucl.ac.uk/cmfs.htm

Etendue figure by Jcc2011 at English Wikipedia, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=63304311

Please send me your ideas and suggestions!

Steve Wasserbaech

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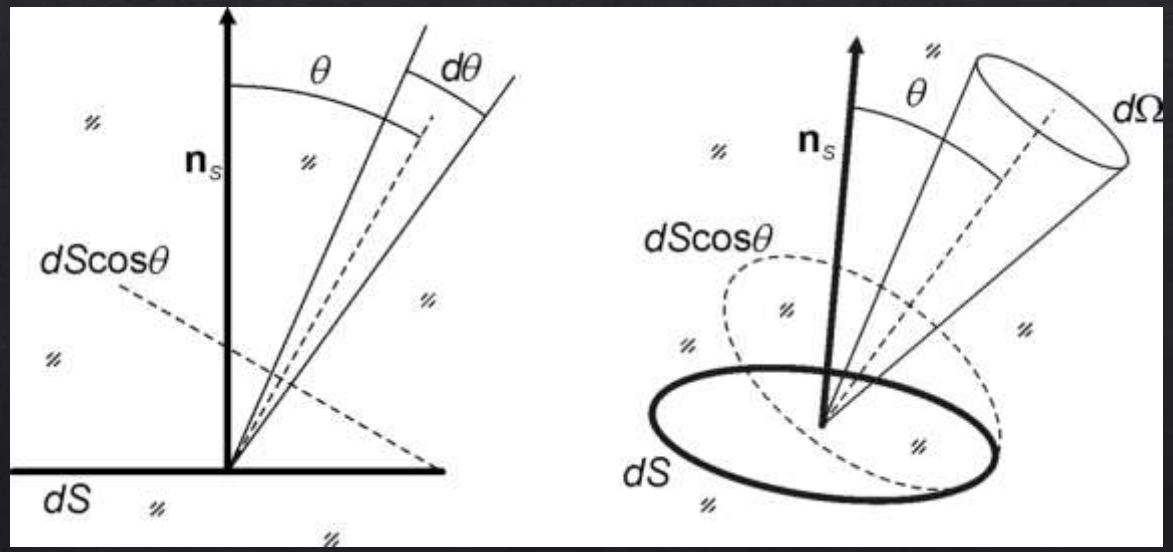
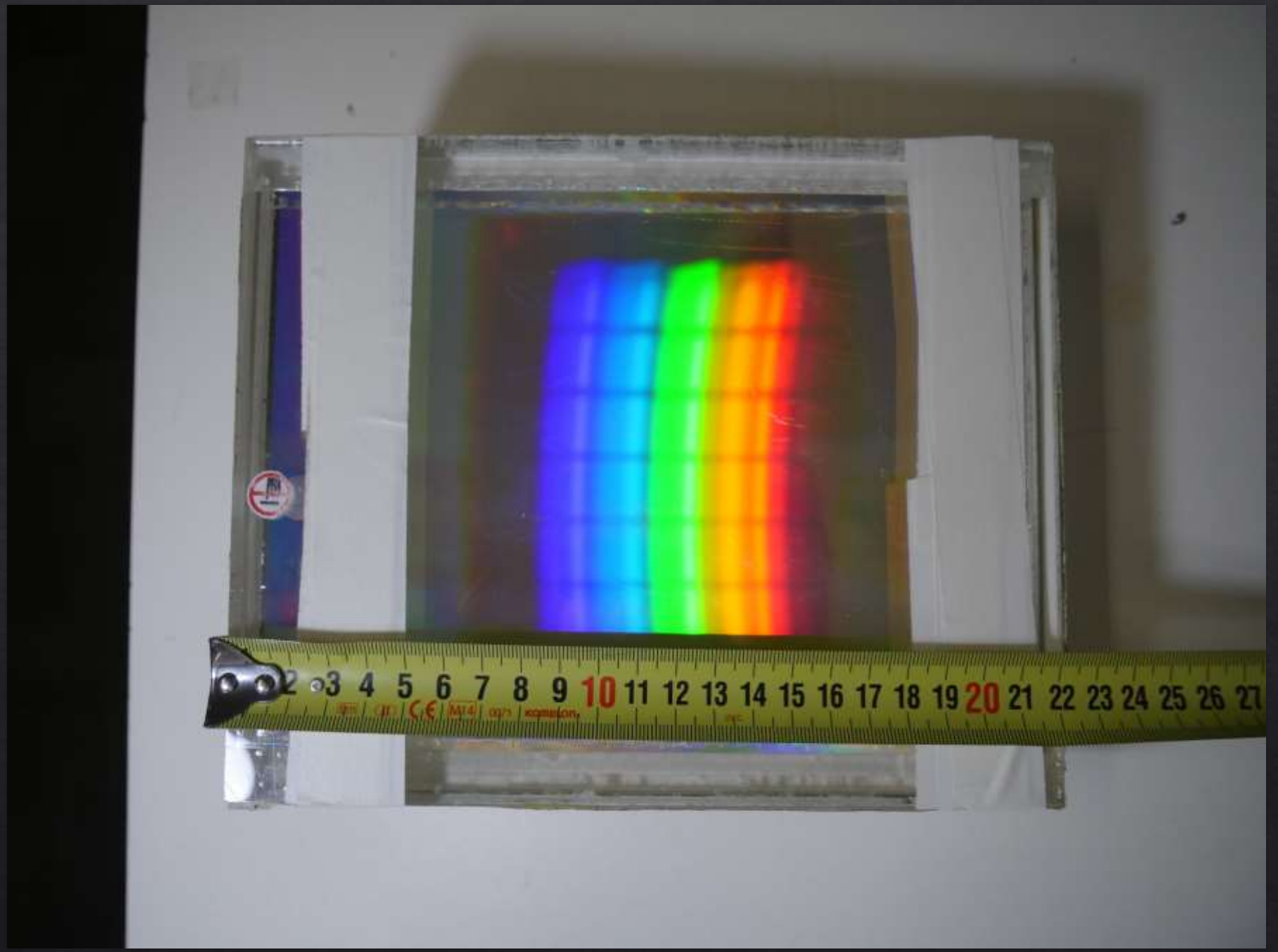
Thank you!

Étendue

$$d(\text{etendue}) = n^2 \; dS \; \cos\theta \; d\Omega$$

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