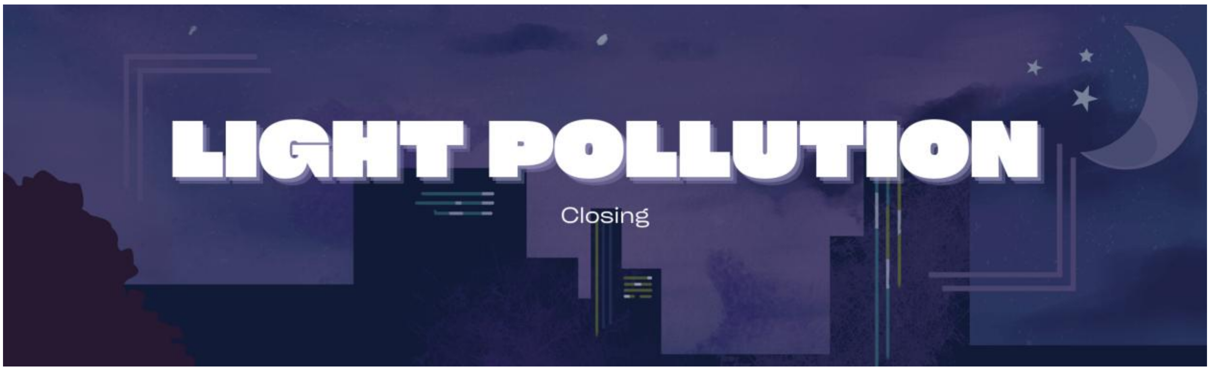

Collection and Analysis of Observational Data

Duration	45-90 minutes
Age group	15-19 yo.
Aim and objectives	**Aim:** To help students understand how observational data are collected, processed, analysed, and presented using appropriate scientific methods and visualization tools. **Objectives**: Students will: • understand the three types of twilight (civil, nautical, astronomical) and recognise them in observational data, • learn what airglow is and how solar radiation and solar activity influence it, • plan and conduct systematic brightness measurements, • reduce, clean, and analyse datasets to identify natural and artificial sources of sky brightness changes, • detect clouds, artificial lights, Moon influence, and airglow using graphs, • compare night-sky brightness between nights, weekdays, and seasons, • investigate whether solar activity correlates with night-sky brightness,

	• classify the local night sky according to the Bortle Scale, • summarize results critically and understand uncertainties.
Learning Outcomes in Line with Curriculum	**Natural Sciences / Physics / Astronomy:** • Explain natural factors affecting night-sky brightness (twilight, airglow, Moon, atmosphere). • Identify civil, nautical and astronomical twilight phases based on Sun altitude ($h_\odot = -6°, -12°, -18°$). • Collect and structure quantitative observational data. • Recognize patterns and correlations in brightness curves (e.g., clouds, city glow, airglow). **Mathematics / ICT:** • Use spreadsheets for calculations (average, min, max, trend lines, correlation). • Create scatter plots, line graphs, and comparative charts. • Interpret Pearson correlation coefficient values to evaluate correlations (brightness vs sunspot number). **Civic Education / Sustainable Development:** • Understand the environmental importance of protecting natural darkness. • Recognize the importance of transparency and objectivity in reporting results. **Cross-Curricular Skills (Key Competences for Lifelong Learning – European Reference Framework):** • **Scientific literacy:** Applying scientific reasoning to real-world data.

	• **Digital competence:** Using online and software-based tools for data presentation. • **Cultural awareness:** Evaluating the reliability and limits of conclusions.
Teaching Methods	• **Expository:** Short theoretical introductions, guided presentation. • **Problem-solving:** Group analysis of sample datasets, interpretation tasks. • **Practical:** Data collection, spreadsheet exercises, visualization creation. • **Interactive:** Reflection, discussion, peer feedback.

Materials Needed

☐ Printed or digital Observation Sheet template (for recording measurements)

☐ SQM meter or light detector coded with TUNIOT (recommended)

☐ Computers/tablets with spreadsheet software (Excel, Google Sheets, LibreOffice Calc)

☐ Sunspot number data from SILSO

☐ Bortle Scale chart

☐ Observation Plan Sheet (attachment 31)

☐ Template of Thingspeak output: file example.csv (attachment 32)

☐ Data Analysis Worksheet (attachment 33)

Workshop/Lesson Plan

Duration	Description	Notes
10 minutes	**Introduction: Planning the Observation** Students begin by planning how their brightness measurements should be conducted. Working in small groups, they review the light detector they programmed in the previous lessons and discuss how often measurements should be taken (e.g. every 1–5 minutes) and for how long observations should last. The teacher explains the concept of sampling interval and why regular measurements are important for detecting patterns in environmental data. Students also decide which additional factors should be recorded during observations, such as Moon phase, clouds, or nearby artificial lights. Each group completes an **Observation Plan Sheet**, specifying the measurement interval, observation time, and observation location.	Observation Plan Sheet (attachment 31)
20 minutes	**Preparing and Cleaning the Dataset** Students access the ThingSpeak platform, where their light detector has been sending brightness measurements. They open their channel and download the dataset by selecting Export → CSV file. The teacher explains that a CSV file (Comma Separated Values) stores data as text, where values in each row are separated by commas. The dataset typically contains rows similar to the	Template: file example.csv (attachment 32) Data Analysis Worksheet (attachment 33)

	example below: created_at,entry_id,field1 2026-03-10T19:32:15Z,1,312 2026-03-10T19:37:15Z,2,298 2026-03-10T19:42:15Z,3,287 Students open the file in Excel or another spreadsheet program. They observe that the dataset contains columns such as *created_at*, *entry_id*, and the sensor measurement (*field1*). When opening the CSV file, students may see all values placed in a single column because the data are separated by commas. The teacher demonstrates how to fix this. Students select the column and use **Data → Text to Columns**, choose **Delimited**, and select **Comma** as the separator. The spreadsheet then splits the data into separate columns. Students keep only the relevant columns: the timestamp (*created_at*) and the brightness measurement (*field1*). They rename the columns to *Date & Time* and *Sky Brightness.* Students then check the dataset for obvious errors (e.g., unusually high values caused by shining a flashlight on the detector) and remove incorrect entries. To help students understand why unusual measurements should be removed, the teacher may show the video Outliers: What Are They? How To Spot Them? How Do They Affect The Three Measures Of Central Tendency?, which explains how extreme values can influence	Outliers: What Are They? How To Spot Them? How Do They Affect The Three Measures Of Central Tendency: http://youtube.com/watch?v=9m64Zi41rmw

	data analysis and statistical results. Students organise the dataset so that measurements are ordered chronologically. If necessary, they separate the timestamp into two columns (Date and Time) using the **Text to Columns** tool again. They verify that measurement intervals are consistent and check whether their detector recorded data at the expected frequency. Students discuss possible reasons for missing or irregular measurements.	
15 minutes	**Data Analysis** Students perform basic statistical calculations using spreadsheet functions. They calculate: average brightness, minimum value, maximum value, and optionally standard deviation. The teacher demonstrates functions such as =AVERAGE(), =MIN(), and =MAX(). Students interpret the results and discuss what these values say about the brightness of their sky during the observation period. Students create a line graph showing Sky Brightness vs Time in Excel or Google Sheets. They label axes and add a title. The teacher explains how line graphs help reveal temporal patterns. Students examine the brightness curve and identify periods of rapid or slow change in brightness.	
15 minutes	**Identifying Twilight Phases** Students use their brightness graph to estimate the transitions between civil, nautical, and astronomical twilight. The teacher explains that these twilight phases	timeanddate.com

correspond to specific Sun altitudes below the horizon:

- 6° – end of civil twilight
- 12° – end of nautical twilight
- 18° – end of astronomical twilight

Students analyse their graph to determine when these transitions likely occurred.

First, students examine the slope of the brightness curve, which shows how quickly the sky becomes darker after sunset. Twilight typically progresses in three stages. During civil twilight, brightness decreases very rapidly and the sky is still relatively bright, which appears on the graph as a steep downward slope. During nautical twilight, the sky continues to darken but at a slower rate, so the slope becomes less steep. During astronomical twilight, the brightness changes only slightly and the curve becomes almost flat. After this stage, the graph usually shows stable low brightness, indicating true night conditions.

Students mark three points on their graphs where the slope clearly changes:

- the transition from rapid darkening to slower darkening (approximate end of civil twilight),
- the transition from moderate darkening to very slow changes (approximate end of nautical twilight),
- the point where brightness becomes nearly constant (approximate end of astronomical twilight).

To verify their estimates, students compare their observations with astronomical data using **timeanddate.com**. They open the website and type the name of their city to

	access the location page. Then they navigate through the menu: Sun, Moon & Space → Night Sky → Sun & Moon Today → Night, Twilight, and Daylight Times. On this page, students find a table showing the times when the Sun reaches the key altitudes: civil twilight end, nautical twilight end, astronomical twilight end. They compare these calculated times with the points on their brightness graph where the slope changes. This comparison helps students understand how observational data corresponds to astronomical calculations. For more advanced students, the teacher may introduce a quantitative approach by calculating the brightness change between consecutive measurements in a spreadsheet: *brightness change = brightness(n) – brightness(n−1)* Large changes indicate rapid darkening (civil twilight), while very small changes indicate stable night conditions after astronomical twilight. Simple rule for interpreting the graph: Civil twilight → steep drop in brightness Nautical twilight → moderate drop Astronomical twilight → almost flat curve	
10 minutes	**Recognizing Patterns in Brightness Curves** Students analyse their graphs and identify patterns caused by environmental factors. The teacher presents typical examples: sudden spikes caused by artificial lights, gradual	

	increases caused by Moon rise, large fluctuations caused by clouds reflecting city lights, and small natural variations potentially related to airglow. Students annotate their graphs and explain the patterns they observe.	
20 minutes	**Influence of Solar activity** Students obtain daily Sunspot Numbers from the SILSO database and add them to their dataset: *Daily Estimated Sunspot Number -> CSV* Since sky brightness measurements are collected every 5 minutes (or similar) while sunspot numbers are reported once per day, students first need to aggregate the brightness measurements to daily averages to make a meaningful comparison. <u>Step 1 – Aggregate brightness</u> Ensure your dataset has at least two columns: Date & Time and Brightness. If your timestamp includes both date and time, create a Date column by extracting the date portion. For text timestamps like YYYY-MM-DD HH:MM, use the formula: =DATEVALUE(LEFT(A2,10)) This converts the first 10 characters of the timestamp into a proper Excel date. Select your data and go to Insert → Pivot Table.	https://www.sidc.b e/SILSO/datafiles

Drag the Date column into Rows.

Drag the Brightness column into Values and set Value Field Settings → Average.

The pivot table now shows the daily average brightness for each day.

Step 2 – Processing SILSO CSV Data

The SILSO data file (EISN_current.csv) is provided in CSV format:

Column	Description
1	Gregorian Year
2	Gregorian Month
3	Gregorian Day
4	Decimal date
5	Estimated Sunspot Number
6	Estimated Standard Deviation
7	Number of Stations calculated
8	Number of Stations available

Instructions to prepare the sunspot dataset for comparison:

Open the CSV file in Excel.

If all the data appear in a single column, split them into separate columns using *Data → Text to Columns → Delimited → Comma*, as done previously for the brightness CSV.

Keep only the relevant columns.

Retain Year (1), Month (2), Day (3), and Estimated Sunspot Number (5). Delete other columns to simplify the dataset.

Convert Year, Month, Day into a single Excel date. In a new column, use the formula:

=DATE(A2,B2,C2)

A2 = Year, B2 = Month, C2 = Day.

Excel will create a date in its internal date number format (e.g., 45959).

Change the cell format to "General" to ensure the date is stored as a number, which matches the format of aggregated brightness dates.

Ensure alignment with brightness data.

The daily average brightness dates must also be in Excel date numbers.

Step 3 – Combine Datasets

Add the sunspot numbers.

Copy the daily sunspot numbers from the processed SILSO CSV next to the daily average brightness values in the Pivot Table.

Ensure correct date alignment.

Since both datasets now use Excel date numbers, each daily average brightness matches the correct sunspot number.

Step 4 – Create Scatter Plot and Calculate Correlation

Insert a scatter plot:
X-axis: Sunspot Number

Y-axis: Daily average Sky Brightness

Calculate the Pearson correlation coefficient:

Use the Excel formula:

=CORREL(range_sunspot_numbers, range_daily_brightness)

Interpret the correlation coefficient (r).

r value	Strength of relationship
0.0 – 0.2	Very weak / negligible
0.2 – 0.4	Weak
0.4 – 0.6	Moderate
0.6 – 0.8	Strong
0.8 – 1.0	Very strong
Negative values	Inverse relationship (higher X → lower Y)

Positive r means higher sunspot numbers are associated with higher brightness, while negative r indicates the opposite.

Step 5 – Analyze and Discuss

Students evaluate whether higher solar activity corresponds to higher or lower sky brightness.

Discuss potential sources of variability:

- Cloud cover or weather conditions
- Local light pollution
- Measurement errors or outliers in the data.

15 minutes	**Comparative Data Visualization** Students compare brightness measurements from different nights or groups. They create a comparative chart (for example a line graph showing two nights or two locations). Students discuss differences caused by clouds, Moon phase, or local artificial lights.	
10 minutes	**Reflection and Scientific Interpretation** Students summarize the results of their investigation. They discuss which factors most strongly influenced sky brightness and whether any correlation with solar activity was observed. The teacher highlights the importance of long-term measurements and careful interpretation of observational data.	

Reflection Questions

• What patterns or trends did you notice when analyzing your data in the spreadsheet?

• How did organizing the data into tables or charts help you understand the results?

• Were any of the results surprising or different from what you expected?

• How could similar measurements be used by scientists to monitor environmental changes?

• What skills did you develop during this activity (e.g., measurement, data analysis, visualization)?

• What additional questions or investigations could be explored based on your results?

Kahoot Quiz

1. Which unit is most commonly used to measure illuminance (light intensity reaching a surface)?

A. Lumen
B. Candela
C. Lux
D. Watt

- Correct: C.

2. What does a higher lux value indicate?

A. Lower light intensity
B. Higher light intensity on a surface
C. A higher temperature of the light source
D. A longer wavelength of light

- Correct: B

3. Which factor could most strongly distort outdoor light measurements at night?

A. The phase of the Moon
B. The number of nearby trees
C. The temperature of the air
D. The altitude of the observer

- Correct: A

4. 6. In data analysis, what is an outlier?

A. The average value of the dataset
B. A value significantly different from the others
C. The smallest measurement

D. The most frequently occurring value

 Correct: B

5. When analyzing a dataset, which statistical value represents the central value of an ordered dataset?

A. Range
B. Median
C. Maximum
D. Deviation

 Correct: B

6. At what Sun altitude does astronomical twilight end?

A. -6° below the horizon
B. -12° below the horizon
C. -18° below the horizon
D. -24° below the horizon

 Correct: C

7. What does a high sunspot number usually indicate?

A. Lower solar activity
B. Higher solar activity
C. Lower solar temperature
D. A smaller Sun diameter

 Correct: B

8. What is airglow?

A. Light reflected from the Moon
B. Faint natural emission of light from Earth's upper atmosphere
C. Light produced by satellites
D. Radiation from distant galaxies

 Correct: B

9. What does the Pearson correlation coefficient (r) measure in a correlation plot?

A. The number of measurements in a dataset
B. The strength and direction of a linear relationship between two variables
C. The average value of a dataset
D. The difference between two measurements

- Correct: B

10. What does a Pearson coefficient close to 0 suggest?

A. Perfect positive correlation
B. Strong negative correlation
C. No significant linear correlation
D. Identical values in the dataset

- Correct: C

Additional materials

- Data visualization examples: https://datavizcatalogue.com
- NASA educational materials about the Sun, solar activity, and Earth's atmosphere https://science.nasa.gov/sun
- Excel or Google Sheets tutorials: https://edu.gcfglobal.org/en/excel
- Stellarium - free planetarium software for exploring the night sky and astronomical conditions: https://stellarium.org

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