1.1 Sun4all. The solar rotation.

Name of the Institution: University of Coimbra

Title of the educational scenario template: Inquiry-based teaching

Title of the educational scenario: Sun4all. The solar rotation.

Version: 1.2

Educational problem:

The Sun is the nearest star to the Earth. Our planet is, therefore, dependent from this star since its formation. This dependency isn't just because of the yearly Earth translation movement around the Sun. It is much more than that. The Sun is the Earth's main source of heat and light, essential to all the life it holds. The phenomena that occur (occurred or will occur) inside the Sun and on its surface cause impact on Earth's surface. It is not always easy to understand or measure this impact and, in many cases it is equally complex to establish cause-effect relations. It all depends on the phenomenon and its intensity. However, there are confirmed results, which show the Sun-Earth interaction.

But the Sun-Earth interaction can be observed in different ways besides the ones related to the climate. Solar flares, being extremely energetic, can interfere with daily life. On the 30th of October of 2003, a solar "storm" damaged North American's power-station systems, causing a 9 hour blackout in many Canadian cities. On the "Space Weather" web site (http://www.solarstorms.org/SRefStorms.html) one can find a journalistic register of many solar storms that occurred between 1859 and 2003, many of them responsible for material damages. Therefore, studying the Sun, besides being interesting itself, presents an important tool to understand much of what happens on our Planet's surface. Specifically, studying the Sun through the analysis of solar activity, which turns out to be the key theme of this particular project and the activities proposed below. The majority of these activities are mainly focused on sunspots. In the next chapter a privileged space is given to this issue. The other manifestations of solar activity such as prominences and faculae will also be part of the proposed activities.

The project is based on an asset of over 30000 images of the Sun (spectroheliograms) that are kept at the Astronomical Observatory of the University of Coimbra, as result of a work of over 80 years of daily solar observations, started in 1926. Presently all images are digitized images available to the general Public.

Educational scenario objectives:

K-7 – Physics – Universe and Solar System

Learning Objectives:

- ☼ Know that the Sun is the biggest object in the Solar System
- ☼ Know that the Sun has cooler regions in its surface – sunspots
- ☼ Know the differential rotation in Sun.

Characteristics and needs of students:

The scenario will be an opportunity for students to solve problems related to the analysis of real data, obtained by a professional observatory. This will be accomplished through interactive tools, which are much more direct than school textbooks.

The exercise will also allow students to interact (e.g. by working in pairs) and develop social and collaboration skills, allowing them to see that Science can be a group activity and not only a solitary one. This change of perception may trigger an increased interest in Science in many of them, and possibly a turn to Science careers.

Rationale of the Educational approach and Parameters guaranteeing its implementation:

- ☼ In this exercise students will increase their understanding of our nearest star – the Sun.
- ☼ They will use the same images as professional astronomers did and figure out an explanation for the behavior of the Sun. It's important to emphasize that these activities aim to guide teachers and students interest in the use of spectroheliograms and its database.
- ☼ Students will use Salsa J to analyze images of the Sun kept in the Astronomical Observatory of the University of Coimbra http://www.mat.uc.pt/sun4all/index.php/pt/

Learning activities:

Phase 1: Question Eliciting activities

Discussions, led by the teacher or leader, on the following topics

- what is Sun made of ?
- how the Sun is comparable to the earth (temperature, mass, radius, etc.)
- Sunspots: what is it ?
- What is the size of a sunspot compared with the Sul ? and the Earth ?

Phase 2: Active investigation

Procedure:

1. In the "Arquivo Obs. Solares" search the K1-v spectroheliograms referring to two different (but close) dates in which you can identify sunspots. For example the spectroheliograms of the 21st and the 24th November 1992. (see figure).
2. Select one after the other each of the obtained images on the research and print them in A4 size sheets.

3. Choose a sunspot observable on both days' images (see figure).

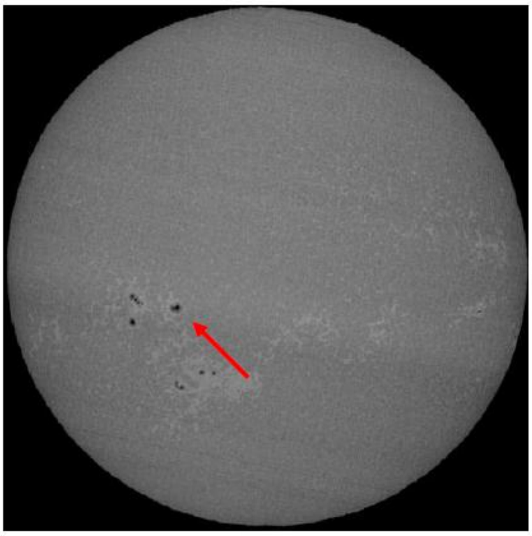
4. Figure out the latitude and longitude of the sunspot on both days, using the Stoneyhurst disc. In appendix 4 there is one of these discs, which should be printed on a transparency so that you can place it over the Sun images, taking into account that they must have the same diameter. A single disc only valid to the aforesaid dates, because the Sun and Earth's rotation axes don't remain parallel along the annual translation movement, since these discs vary through the year. For other dates search the respective discs at http://ottawa.rasc.ca/articles/taylor_richard/sun/stoney.html.

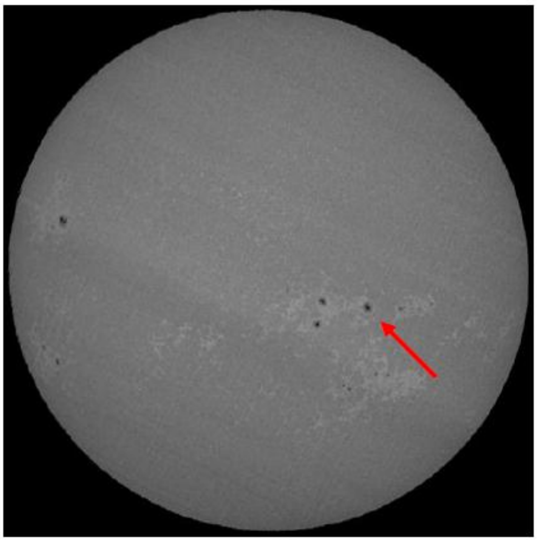
5. Open the Excel file "solar_rotation. xls".

6. Insert the data corresponding to the yellow cells. The latitude, longitude and time ought to be inserted using decimal format (ex: 40º36’= 40.6º and 2h 57m = 2.95h). The spreadsheet will determine two quantities (in the red cells): the average speed (Km/h) and rotation period (days). See below how to determine these quantities.

7. This procedure can be repeated to any other sunspot.

8. Comment on the respective results regarding what you know about Earth rotation.

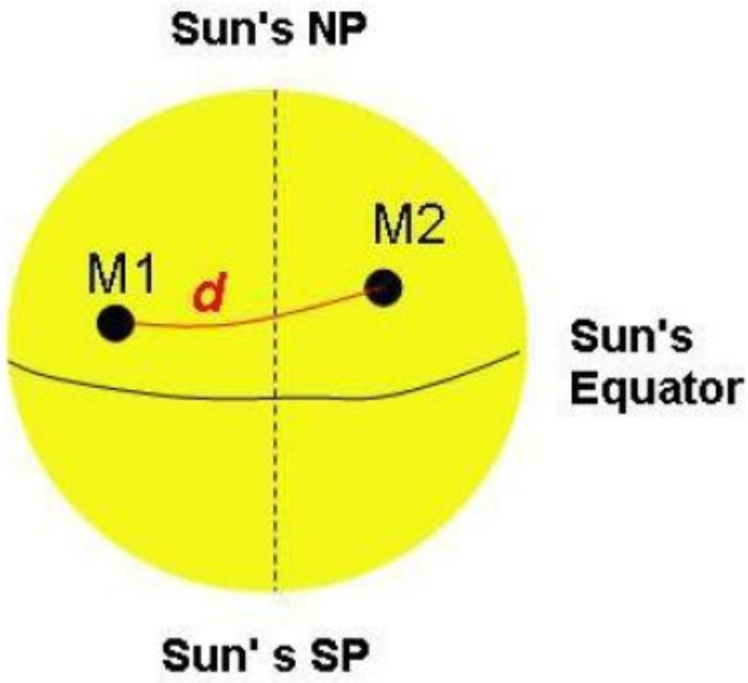




The determination of the Sun rotation speed and, consequently, the calculation of the period, is based on the assumption that a sunspot has a uniform movement, therefore a constant velocity. To calculate the average speed (v) we use the formula

$$v = d / t,$$

where d is the distance covered by the sunspot on the considered day, t is the time lag between observations. This way the problem boils down to calculating d. This situation can be schematically represented this way:



Where M1 and M2 are the sunspot positions in two different moments. By knowing the solar latitude and longitude of the sunspot in the moments (phy1,l1) and (phy2,l2), the determination of d is done by using the Fundamental Formula of Spherical Trigonometry

$$\cos(d) = \sin(\varphi_1)\sin(\varphi_2) + \cos(\varphi_1)\cos(\varphi_2)\cos(\lambda_1 - \lambda_2)$$

The demonstration and properties of this formula exceed this activity's ambit. Nevertheless, the interested reader can learn more in http://en.wikipedia.org/wiki/Law_of_cosines_%28spherical%29. Notice that the result of the previous formula, d, is an angle ranging somewhere between 0º and 180º. The conversion into Km is simple if you use the formula:

$$d(km) = \frac{d \times 2\pi \times R_{SUN}}{360^{o}}$$

where RSUN represents the Sun radius = 690000 Km. Finally, the rotation period is estimated by the time that, at the previously calculated speed, the sunspot would take to cover a distance as far as the Sun perimeter.

Phase 3: Discussion

After doing the determination of the velocity of rotation, students should discuss about the comparable values between Earth and the Sun. This should be an opportunity to discuss the enormous difference of scales between Sun and Earth.

Phase 4: Reflection

Students appreciate the implication of their results and begin to see a connection with current topical research. For example,

- Is the velocity constant in different latitudes ?
- Differential rotation: what is it ?

Students should now be invited to participate in the motivation activities and brief introduction. They will learn about the history of Solar observation and how Galileo concluded that the spots are part of the solar disc.

- **Solar movies – ESA vodcast:**
  http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=46594&fattributeid=885

1.History of sunspots observations
http://galileo.rice.edu/sci/observations/sunspots.html

Participating roles:

Students

- Access to the site www.mat.uc.pt/~sun4all
- Gain experience of data taking
- Estimate what results are to be expected and compare with measurements
- Consider the implications of their results

Teacher

- Encourages the students to read the Manual as a starting point.
- Guides the students in their investigations on the WWW.
- Helps the students in evaluating their results
- Guides the student to further open-ended study

Tools, services and resources:

Time required:

- ☼ 3 didactic hours.

Prerequisites:

- ☼ Excel Spreadsheet use.
- ☼ SalsaJ use.
- ☼ Know the Solar System.
- ☼ Know the Sun as an energy supplier.

Technical Requirements

- ☼ Computers with Salsa J.
- ☼ Internet access for research purposes.
- ☼ Images of the Sun kept in the Astronomical Observatory of the University of Coimbra.