SUNSET PROJECT: CREATION OF COMPUTER AND OBSERVATIONAL NETWORK FOR STUDENT EDUCATIONAL RESEARCH

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ABSTRACT
A pilot project is presented, aimed at creation of an educational network of astronomical observations performed by middle-school, high-school and university students at different geographical latitudes. Project participants are supposed to do their research studies in close link via Internet, to computer-process and compare their observational results contributing to the joint database, to exchange experience and ideas. In the observations, full time t is measured of the solar disc passage through the line of horizon at sunset. From the value of t, geographical latitude φ of the point of observation may be calculated. Observations need no equipment except for the timers measuring seconds, wrist watches will do. That allows to involve unlimited groups of students (middle or high school and university level) and to obtain a big array of experimental data in one observation. Then, statistical procession is performed, mean value of t is determined, observational errors estimated. Computer simulation and animational explanation of the Sun motion seen from the Earth are planned to be performed. Project homepage will be created and updated regularly. Links with the existing educational Internet sites will be established.

KEYWORDS
Hands-on group educational activities in Physics and Astronomy, inquiry-based education, computer simulation in Physics and Astronomy, interactive Web-based learning, Web design

INTRODUCTION

Despite the sorrowful crisis in middle- and high-school scientific education, there are highly encouraging examples of class and extra-curricular activities developed by creative teachers in order to make Science and Physics the favorite school subjects. Analyzing the foundations of their success in teaching topics generally thought to be “unpopular”, we should emphasize the significance of the group, or rather, *team* involvement of students into mastering the material.

Thus, in an incredible “people demos” activities developed by Chiaverina and Hicks (1983) for teaching high-school course of Physics, students themselves become the principal “equipment” to demonstrate and study the laws of kinematics, dynamics, acoustics, gas laws and even optics! In such an approach instead of ineffective rote memorization, students comprehend the basic principles of Physics through the most creative, enjoyable, co-operative learning.

“Making measurements, reporting data, and interpreting one’s results are crucial to gaining an appreciation of what science is all about. Students at all levels, but perhaps especially middle-school students, require material that is interesting to them. Hands-on activities are the order of the day.” (Hubisz, 2003). Unmissing words, yet standard textbooks and traditional classes are known to be poor with quantitative measuring activities. School labs – even performed on modern equipment – seldom induce a thrilling interest among the students. Positively, they can. Even the seemingly simplest and the most routine measurement – weighing – may become an unforgettable and highly instructive labwork. We strongly recommend everyone to get acquainted with the “car pushing” experiment (Chiaverina, 2002), an undisputable educational masterpiece, enjoyed for years by so many the students at New Trier High School, Winnettka, IL, USA. In this labwork performed in the school parking lot, the mass of the vehicle is determined by pushing it with the bathroom scales. The car’s track is marked by plastic cones dropped onto the road by the passenger student every two seconds. Measuring the distance traveled by car during each two-second interval, and graphing it versus time, students obtain the law of vehicle’s motion. Since the pushing force is fixed, they apply their knowledge of the Newton’s Second Law to determine the mass of the car (the force of friction is taken into account and measured the most instructive way).

Again, we notice that the inevitable group involvement of the students is important, in fact decisive for the success of this excellent educational activity. And of course this involvement is encouraged to be creative.

Needless to say that modern communicational resources open fantastic possibilities of co-operative educational activities of students learning Science worldwide. Physics and in no less way Astronomy provide for the experimental and observational problems, which are very natural to be solved by joint efforts of students from different points of the Globe (see a stimulating paper of Szostak, 1998). As an example of a successful international (and inter-latitudal, so to say) educational project of the kind, measuring of gravity acceleration g in Japan, China, Columbia and UK should be mentioned (Satoh, Kotani, Takemoto, 2003). Joint database created on-line by the inter-continental team of young researchers and their teachers, allowed them to check and explain the differences in g values obtained from oscillating pendulum experiments at different latitudes and altitudes.

Below we propose another cycle of observations and measurements to be performed by middle-school, high-school and university students at different latitudes. Participants of the project are supposed to do their research studies in close link via Internet, including joint observations by means of Web-cameras, to computer-process and compare their observational results contributing to the on-line database. Computer simulation, animations, Web-design, exchange of ideas could make this activity attractive for students of a variety of ages, experience and abilities.

RESEARCH METHODS

The proposed educational activities are focused on definition of the geographical latitude φ by measuring time interval needed for solar disk to pass through the line of horizon on sunset. This method suggested by Zholonko, Pombo, Kazachkov (2000) involves ordinary watch as the only measuring instrument, which hinted the title of the project: “Watching Sunsets”. Below, measurements and procession of results needed to determine the latitude of the point of observations, are discussed in some detail.

EXPERIMENTAL

The idea of the “Watching Sunsets” activities originates from the kinematical method of estimation of the mean visual angle diameter δ – see Figure1 – of Sun (Zholonko, Pombo, Kazachkov, 2000). Small angular size of solar disk seen by an earth observer (about 0.5°) makes it impossible for the students to measure the value of δ by an ordinary protractor. So, in educational practice an instructive “pinhole” method of measuring δ is used (Hewitt, 2000, Trowbridge, 2001).

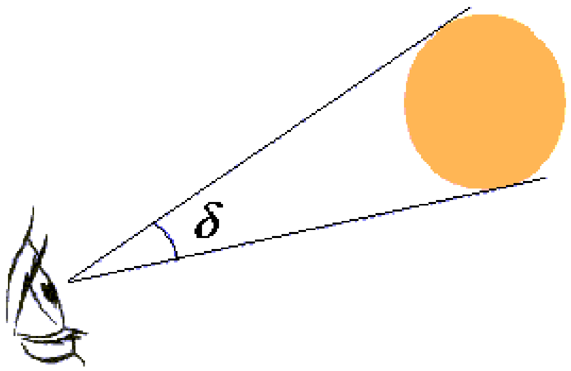

Figure 1. Angular visual diameter of Sun

Meanwhile, the regularity of the daily visual motion of the Sun provides for another simple method to determine δ. It is of a common knowledge that it takes 24 hours for the Sun to make the full "circle" round the sky. So, an average angular velocity ω of the solar visual motion is easily calculated to be as big as 360/24 angular degrees per hour or rather $\omega = 15\ '/\text{min}$. As it is seen in Figure 2, when passing through the fixed diameter of its circular visual orbit (moving from position A to B in the Figure 2) solar disc travels just an angular distance in question, δ. If one determines the time t of such a passage, a visual angular diameter of Sun is calculated to be

$$\delta = \omega\, t \qquad (1)$$

That classifies such a measuring technique as a kinematical solution of a geometrical problem (Lyubich, Shor, 1966).

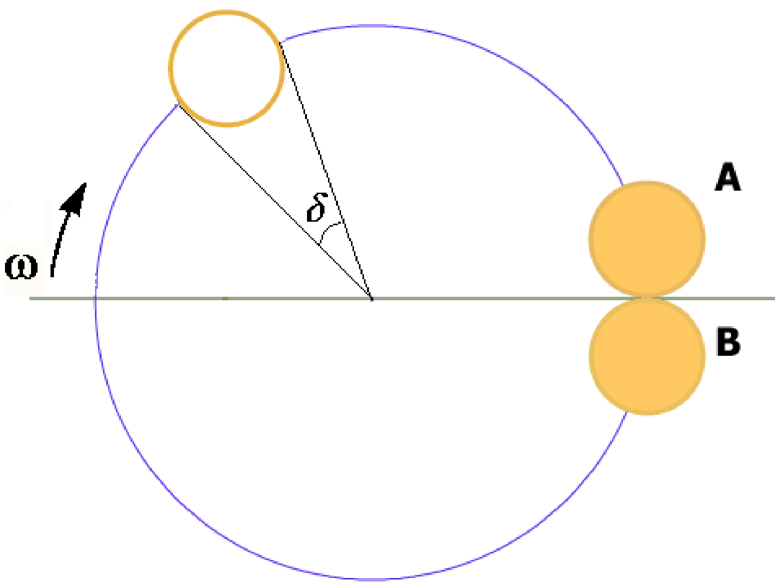

Figure 2. Kinematical method of measuring mean visual diameter of solar disc

Importantly, Earth horizon provides for a natural line crossing the visual path of the Sun. An angle between the planes of horizon and of a celestial equator depends on the observer's latitude and equals to $90\,° - \varphi$. So, on equinox, when the Sun sets down strictly westwards, vertical component of its visual motion on sunset is $\omega \cdot \sin\,(90° - \varphi) = \omega \cdot \cos\varphi$ and instead of (1) we have

$$\delta = \omega\, t(\varphi)\, \cos\varphi\ , \qquad (2)$$

where visual angular diameter δ of solar disc and angular velocity of solar visual motion ω are constant while the time of solar disc passage down the line of horizon measured in the observation ("sunset time") depends on latitude: $t = t(\varphi)$. Finally, we transform (2) into

$$\varphi = arcos(\delta/\omega t), \qquad (3)$$

to obtain a simple formula for calculation of geographical latitude.

It should be noticed that the days of equinox present a unique possibility to apply Formula (3), since all over the rest of the year a complicated account of the declination of the Sun is necessary. And though Dr. Andrey Gretsky (Kharkov National University, Ukraine) was kind enough to draft the corresponding dependences, the authors of the "Watching Sunsets" project leave that creative inquiry to advanced students interested in Astronomy or majoring in the subject.

Angular diameter δ is either determined by "pinhole" technique any time of the day or taken as big as $\delta = 32'$ (season variations of the solar visual diameter are known to be less than $2'$). So, with or without an account of declination, the time t of solar disc passage down the line of horizon remains the only value to be measured by an observer on sunset. This observational experiment could be made a highly instructive one for the students of different grades and experience.

SUNSET OBSERVATIONS: ADVANTAGES AND PITFALLS

All the students need to do is to notice an instant of a solar disc touching the remote line of horizon and to measure (by wrist watch or any other timer) how long does it take the Sun to hide below the skyline.

Figure 3 presents a graphed formula (3) calculated in the simplified assumption of $\delta \approx 30'$, so in fact we have plotted a

$$\varphi = arcos(2/\, t) \qquad (4)$$

dependence there, with "sunset time" t measured in minutes. As it is well seen, observation of sunset on equinox takes reasonable time, from 2 min to 4 min for the most of the densely populated regions. It must be no problem for the middle-school and high-school students to remain concentrated on measurements that long. Evidently, an accuracy of an individual observation cannot be better than one second, though in our experience, five seconds is an optimistic estimation. That is why involvement of big groups of observers is so crucial. Mean values of "sunset time", observational errors, gross mis-measurements (so typical for younger students!) could be determined and discussed.

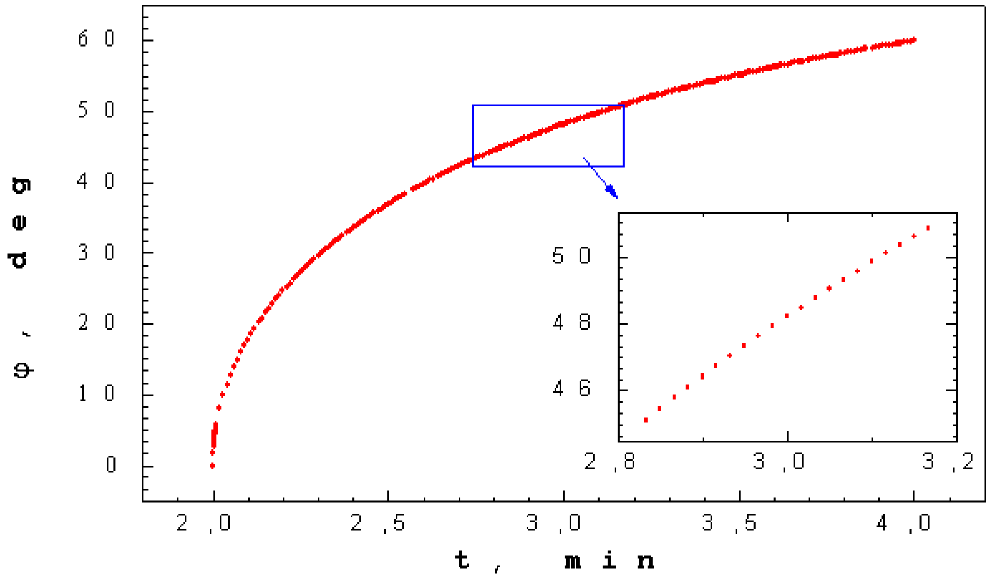

Figure 3. Latitude/'sunset time' dependence *φ(t)* on equinox

The closer to an Earth equator we are, the higher the accuracy we need. Even at considerably higher latitudes (Figure 4) a 3-second mistake in "sunset time" measurement yields an essential (about 1°) error in geographical positioning of the observers.

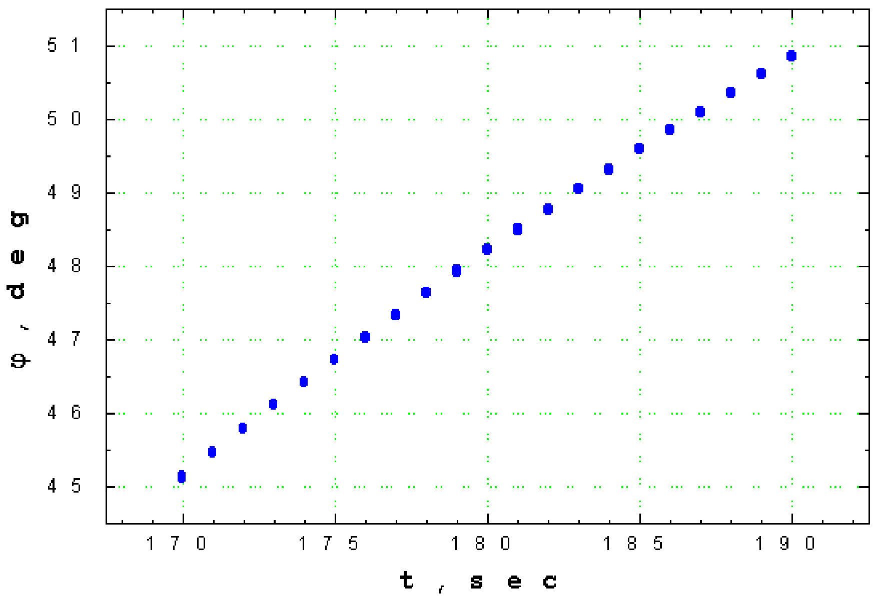

Figure 4. Latitude/'sunset time' dependence (4) rebuilt to estimate possible observational errors

It should be emphasized that seemingly equally suitable period of sunrise is in fact unacceptable for the students' observations. Indeed, an idea to be on foot at dawn for the sake of a five-minute research, will hardly excite the kids. Evening is another thing.

Importantly, students obtain 'by no facilities at all' a meaningful information, which can later be checked through consulting the map or by the modern techniques, like Global Positioning System (see interesting educational applications of GPS in the paper of Caporaloni, Ambrosini, 2003).

Sunset provides for the unique possibility to safely watch the solar disk for minutes with unprotected eye, a great advantage of the method. A strong visible distortion of the Sun near the horizon due to refraction has – somewhat surprisingly for the students – no essential effect on the result of observations. "Sunset" measurements are almost refraction-free. Lower and upper edges of the solar disc are observed passing through the same skyline ("null" method of measurement), so the rays originated from both, experience nearly the same atmospheric refraction, and from the determined "sunset time" *t* true values of *mean* angular diameter of Sun and geographical latitude are obtained.
The possibility of group observations balances an obvious disadvantage of the method connected with its strong dependence on the quality of atmosphere, which is often poor above horizon on sunset. To find a clear flat horizon is a special problem in urban areas and in mountains. On the other hand, sea or lake sunsets let the students obtain a plenty of the relevant information, in particular, to estimate the distance to the horizon (Wickramasinghe, 2000).

COMPUTER-BASED RESOURCES OF 'WATCHING SUNSET' PROJECT

Many the mentioned disadvantages are overcome due to involvement of computer-based educational technologies and modern communicational facilities.

Creation of an on-line database, joint procession of observational results is one thing only. With the Web-cameras applied, real time simultaneous measurements of "sunset time" on different latitudes become possible for world-wide students without any limitations. Properly recorded sunsets will also do for repeated and more thorough educational research (with an account of the time difference between the possible participants of the project, such video clips must be very convenient).

Animated explanations of the solar kinematics could be designed related to the "sunset" activities. The pilot version of the project, hosted by the *Vsesvit* educational resource (Watching Sunsets, 2003), presents simple animations of the visual daily motion of Sun, as seen by the observer at different latitudes – Figures 5, 6.

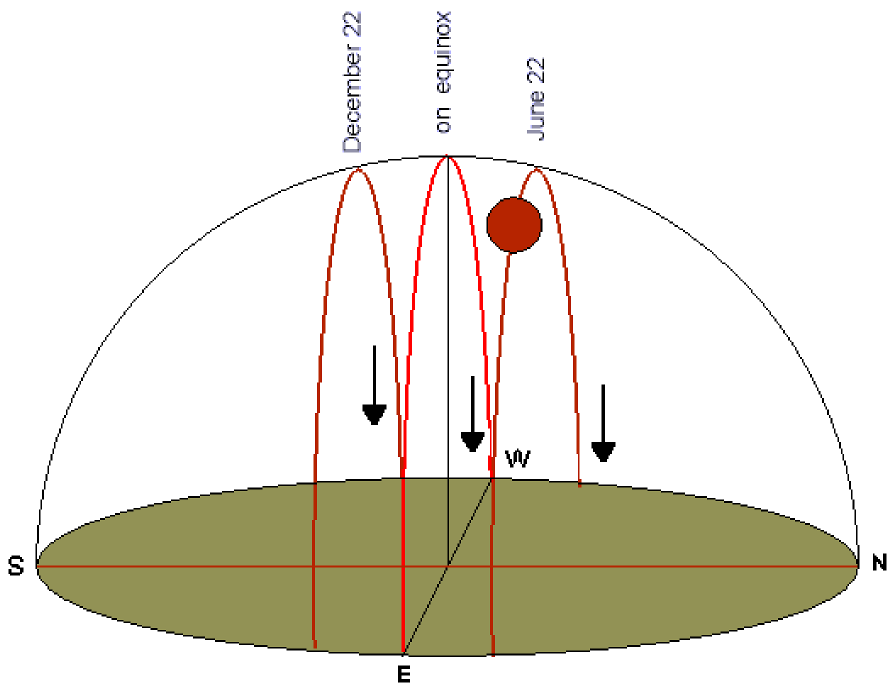

Figure 5. Trajectories of the visible daily motion of Sun observed from equator (animated)

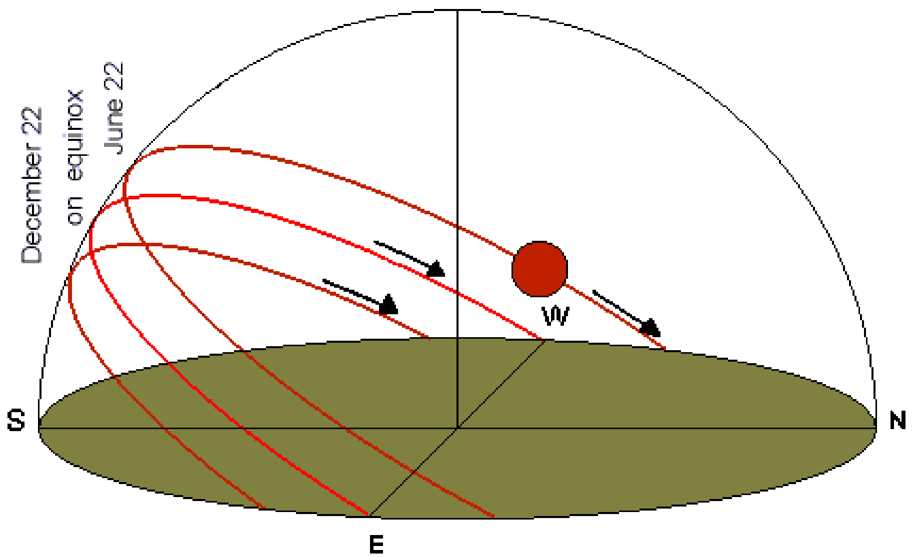

Figure 6. Daily motion of Sun seen by the observer in Noth hemisphere (animation)

Computer-simulated sunsets could account for the Sun declination, atmospheric refraction-caused effects, low clouds, non-flatness of the line of horizon and insufficient sharpness of the solar image (the latter effect complicating students' measurements is modeled in the computer simulation, put on-line at *Vsesvit* resource – see consecutive stages in Figure 7).

Figure 7. Sunset on equinox as observed at 35° North, consecutive stages (computer simulation, no account of atmospheric refraction effects)

CONCLUSIONS AND FUTURE DEVELOPMENT

Preliminary series of proposed observations were first performed in Ukraine and Portugal (Zholonko, Pombo, Kazachkov, 2000) at 40° and 50° North. They have proved the possibility to achieve reasonable accuracy (better than 1°) of geographical latitude definition by "watching sunset" method. Typical values of sunset duration time measured by wristwatches on equinox (Kharkov city, Ukraine) varied from 3 min 15 sec to 3 min 20 sec.

Interest and involvement expressed by the students participating in "watching" of sunsets encourage development of the international PC- and Internet-based network of observations, procession of obtained results, creative simulation of visual motion of celestial bodies and other relevant educational activities.

In our experience, presented methods of definition of solar angular diameter and/or geographical latitude should not be the matter of extra-curricula studies only. Proposed for solution at the lesson of Physics, the "sunset" problem will enliven learning of kinematics of circular motion. Students taking courses of Informatics, Computer Science and Astronomy will also gain from class discussion of "watching sunset" activities.

School and university teachers, students, planetariums, museums of Science, Exploratoriums and everyone interested are very warm welcome to participate in this novel educational research studies.

Note: For more detail please contact the authors and visit the regularly updated homepage of "Watching Sunsets" project at http://www.khpg.org/vsesvit/physics/i.php?l=4

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