THE GLITTER PATH: AN EVERYDAY LIFE PHENOMENON RELATING PHYSICS TO OTHER DISCIPLINES

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The many faces of the so called glitter path are presented to draw attention to an optical phenomenon which is not only interesting from a physical point of view but is also important in other contexts. It is shown as well, that this phenomenon may occur in many situations totally different from the original wet ambiance.

The sun's reflection becomes a shining sword on the water stretching from shore to him.
Italo Calvino

Introduction

The phenomenon of the setting sun's reflections painting an elongated shiny path of light on the surface of wavy water is well known. Although physicists will regard it without hesitation as a physical phenomenon, non physicists including our students who experience this glitter path will be more affected by its non physical aspects. Like other natural or everyday life phenomena the glitter path may be regarded from different perspectives.

Fig. 1: Glitter path at the setting sun

First of all it is a popular motif of postcards, where it may be found not only associated with the setting sun but also as light streaks on rivers, channels and wet streets reflecting street lighting and other light sources.

Moreover, the light path is a favoured motif in art throughout the centuries. Some painters as e.g. William Turner and Edward Munch spent much time on it exploiting its imagery and its esthetical and affective dimensions.

In literature the glitter path has been described for many times. Like the painters the poets were not only interested in the natural phenomenon itself but tried to express or intensify emotions and esthetical sensations, or used it as a metaphor to illustrate their philosophical reasoning.

The light path is considered as an example of an everyday life phenomenon qualified to refer to important aspects of learning physics within a non-physical context. We expect that we may take advantage of the motivation originating from the non physical aspects of the phenomenon to get the students interested in the physics behind it. Furthermore, the students should learn that the physical aspect of everyday life matters is just one aspect among others.

We first give a description of the physical background of the phenomenon and then sketch how the various forms occurring in differ-ent situations may be modelled mathematically and reproduced by a simple computer simulation.

Fig. 2: The typical shape of a glitter path when the sun in not to low.

It can be expected that the physical understanding may help the students to detect glitter paths in totally different situations: Light beads on tiled floors, on smooth metal surfaces, on CDs. They all have wavy surfaces in form of ripples and scratches, and their behaviour may be found and be recognised as being based upon the same physical principles.

Finally, it is shown that by looking through transparent plates similar light patterns can be detected, which are no longer due to reflection but to refraction at ripples and scratches.

The glitter path in non-physical contexts

Light paths and light bands can be found in many paintings. First of all they are powerful manifestations of light sources like the sun or street lamps in the surroundings, in that they multiply and modify the light impression by interacting with non luminous objects. Regarding the painting it becomes obvious that the painters often needed more paint for the light path than for the light source from which it originates. Conversely, the reflections are an important means to show the detailed structure of the water surface, which - due to the

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The 2005 conference will be the first time that the international physics community focuses its attention collectively on these themes and the interplay between them. There will be a Programme Committee for each topic that will outline the problems, write white papers proposing contributions that physics can make, and propose follow up actions.

UNESCO, ICTP, IUPAP and SAIP have all pledged their financial support, but additional major funding will be needed to make the conference a success. Because the organizers want to have many participants from developing countries, it will be important to fund their travel expenses.

Minella Alarcon
UNESCO Paris

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transparency of water - cannot be seen directly. Beyond the possibility to represent the material world, the painters exploit the many correspondences and allusions between mental reflections of the mind and light reflections of the water surface.

Fig. 3: William Turner: The Fighting Temeraire 1839. London: National Gallery

After analysing in detail the techniques William Turner uses to represent reflections on water surfaces, John Ruskin states: "There is more... than any philosophy of reflection, or any peculiarity of means can account for or accomplish; there is a might and wonder about which will not admit of our whys und hows" (Ruskin 1900).

The glitter path has been described for many times in many different situations by poets and writers, not only as an appealing phenomenon accompanying the sun set and as a projection of affections but also as a philosophical metaphor. The protagonist in a story of Italo Calvino, Mr. Palomar, notes during his evening swim: "When the Sun begins to go down, its reflection takes form on the sea: from the horizon all the way to the shore a dazzling patch extends composed of countless swaying glints; the sun's reflection becomes a

Fig. 4: Vincent van Gogh: Starry night over the Rhone. Paris: Musée d'Orsay 1888

shining sword in the water stretching from shore to him. He swims in that sword . . ." But what about the other swimmers at that time of the day, are they swimming in the same or each in their own sword? Where is the sword situated, everywhere or nowhere? "The sword is imposed equally on the eye of each swimmer; there is no avoiding it. 'Is what we have in common precisely what is given to each of us as something exclusively his?' " Palomar reflects on the light reflections: "Perhaps it was not the birth of the eye that caused the birth of the sword, but vice versa, because the sword had to have an eye to observe it at its climax." Finally "he has become convinced that the sword will exist even without him" (Calvino 1985).

Reading this text students may be interested to find out if the peculiarities, especially that the sword is always directed to the observer, may find a sound physical explanation.

Physical reflections on the light reflections

The glitter path is due to the reflection of some light source. Normally, this is recognised even by younger students. But how is the light forced in such long-ish shapes?

Starting from a flat surface only one reflection (at the point P in Fig. 5) hits the eyes of the observer. In order to receive light from other points of a plane

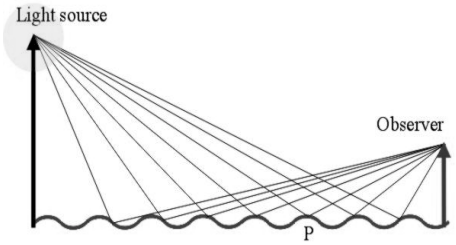

Fig. 5: A wavy water surface contains many inclinations from which light originating from the source is reflected to the observer.

there must be a suitable inclination so that the angle of incidence equals to the angle of reflection. The more distant those points are from point P the larger must be the inclination. Therefore, given a distribution of slopes below a maximal value, reflected light can only be seen within a certain area around P the extent of which increases with the maximum height of the waves. Apparently, the frequency with which the slopes change suffices to give the impression of a nearly continuous lit area to our eyes, apart from some fluctuations of the intensity – the glittering. Thus, the glitter path is the ensemble of countless reflections of some light source at suitably tilted water waves.

The extension of the glitter path can be estimated by simple arguments. As can be concluded from Fig. 6 the aperture angle is just 4 times the tilt angle of the waves.

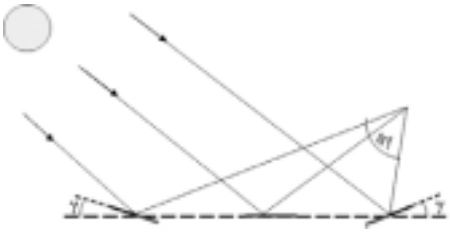

Fig. 6: The more the waves are inclined, the larger the area of possible reflections may be.

The calculation of the boundary leads to a curve of 6th order and shall not be given here. Instead, we sketch the algorithm of a computer simulation for the shape of the glitter path. Given are the maximum slope of the waves and the heights of the light source and the observer. Representing the water surface by a blue coloured plane for each point (pixel) between light source and observer the slope necessary to reflect light from this point into the eyes of the observer is calculated. If the calculated slope is less than the maximum slope the point is coloured yellow, if not it is left unchanged.

As the observed shape of the glitter path is affected by the perspective, especially in the case of the low sun, the corresponding change was included in the program. For instance, when the sun is low the light band seems to have the same width all along the path. As one knows e.g. from the rails of a railway track, which converge towards the horizon, this means, that in reality the light path broadens towards the sun. Indeed, if this situation is calculated without taking perspective into account one gets a kind of triangle.

A very simple experimental approach to the glitter path is sketched in Fig. 7. A tilted mirror the slope of which

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can be adjusted to different values and which has a pen on its bottom side can be moved along the boundary, thus plot-

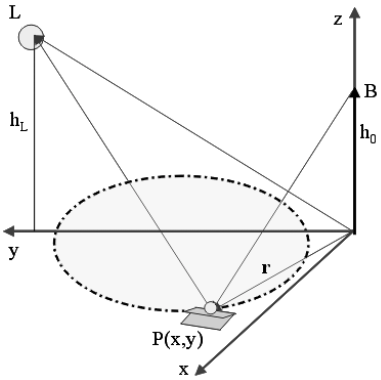

Fig. 7: The boundary of the area lighted up by reflected light depends on the heights of the light source L and the observer B and on the maximal slope of the waves

ting it on a sheet of paper. This can be done by looking through a small hole at B and controlling that the image of the light bulb L can always be seen in the mirror. The area surrounded by this curve can then be compared with the bright area calculated by means of the computer program (See Fig. 8).

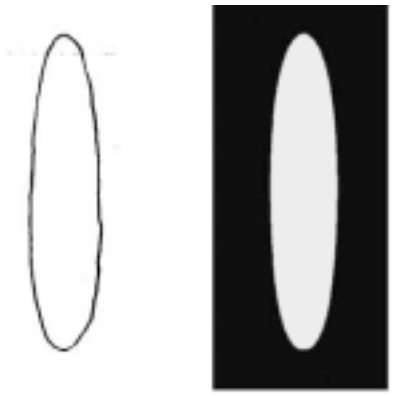

Fig. 8: Left: Plotted boundary. Right: Calculation of the reflecting area of the same situation.

The glitter path is not restricted to wavy water surfaces. Looking e.g. at a plate of glass lubricated by some grease, we can observe light paths of different shapes just by looking on it from a suitable angle.

The glitter path is a specular reflection phenomenon. Therefore, in many cases, especially at short distances, the many times reflected images of the light source can be seen in the water below the surface like a reflected picture behind the mirror.

As is well known from other reflection phenomena, e.g. the rainbow or the "heiligenschein", each glitter path is unique therein that it "belongs" to the observer. Due to the physical fact, that only those points of the rippled surface appear lit by the light source which – according to the law of reflection – had an appropriate slope, the location of the "sword of the sun" depends crucially on the observer's position. This explains, why Mr. Palomar saw the sword always directed to him.

Ubiquitous glitter paths

Light paths are not only detected on wavy water surfaces. On a rainy day the head- and backlights of cars draw beautiful light beads on – respectively: in – the streets (see Fig. 9). The fact that streets are not

Fig. 9: Light swords pointing into the wet street.

smooth but slightly irregularly rippled brings about a similar situation as on the wavy water. Under certain conditions it is even not necessary that the surface was wetted. For instance, smooth floors which have been grated by use can be excellent displays for glitter paths (see Fig. 10). But also surfaces, which look perfectly smooth, like table tops, metallic plates or lids (see Fig. 11)may show light streaks when displayed at a light source (at best a point source) and thus reveal tiny scratches which cannot be seen by the naked eye. These scratches fulfil the same function as the waves on the water in that their varying slopes provide for appropriate angles to the light

Fig. 10: Light streak on the tiled floor of a church.

to be reflected into the observer's eye.

To derive the structure of the surface by examining the form of the light paths correspond in some respect to methods of surface science, where the microstructure of surfaces is investigated by analysing the reflected "light" (not necessarily visible: X-rays, electrons) of a known source.

The more our eyes get trained to detect light paths in the everyday life world the more subtle become the phenomena, which will be recognized as such.

The well known light streaks appearing on records which bend in various shapes when viewed from different angles. This phenomenon emerges as well on compact discs, where the white light splits up in spectral colours due to the interference phenomena which become important at this dimensions.

Fig. 11: Light paths on a lid deformed due to the curvature of the surface.

Until now we only took into account light paths due to reflection. Transparent plates may also display light streaks when looking through it at a light source. For instance looking through the window pane of a bus or a train to a distant light source

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this source may appear endowed with a long straight almost vertical light beam. The beams are not caused by reflection but by refraction of the passing light at an array of parallel tiny gratings on the panes oriented orthogonally to the light beams. Due to the transparency and invisibility of the panes the light beams are not associated with the panes but with the light sources. The origin of the gratings may be e.g. grooves caused by the rotating brushes of the cleaning machines.

Looking through the front shield of a car at a light source one may detect light streaks similar to the reflection beams of a record. Circular gratings caused by the action of the windscreen wiper are the reason.

A rather peculiar class of light paths consists of short light tracks which seem to form concentric circles around the image of a reflected light source on a smooth surface (see Fig. 12). In a strict

Fig. 12: Circular light rings around the image of a reflected light source on a spoon.

sense the surface is not smooth but has invisibly small grooves or scratches. If there are many scratches and if they are randomly distributed there will be always short sections of it exhibiting a suitable range of slopes for the light being reflected into the observer's eye. For symmetry reasons the sections of the same slope are oriented along a circle around the reflected image. The extent of the illuminated area depends on the angular range of the scratches. Normally, the origin of the randomly oriented scratches is due to abrasion by daily use. A corresponding phenomenon can be observed when light shines through a grated transparent plate. The light is refracted at randomly distributed scratches giving rise to similar circular light pattern as in the case of reflected light. Light sources regarded through an airplane window, in most cases, appear surrounded by circular oriented illuminated light lines.

Fig. 13: Circular light rings on an airplane window.

Summary

Starting with the glitter path as a common natural phenomenon which has attracted special attention, especially by painters and poets, it has been shown, that there are also interesting physical aspects.

From a physical point of view the glitter path is both simple and complex. It is complex inasmuch the shape of the reflected light trail is not related in a direct way to a specular reflection of the sun. It can be shown by simple hands-on experiments at least qualitatively that the glitter path may be conceived as a composition of many tiny mirrors irregularly distributed on the water plane. The mirrors are made up by the slopes of the waves.

Against the background of this approach the observer is prepared to detect "glitter paths" in many different ambiances, as e.g. the headlight of a car reflected on the wet road or the light bands of a street lamp in a water puddle. Finally, even light paths on totally dry grounds, e.g. on a tiled floor or even those light streaks apparently attached to light sources looked at through transparent media may attract attention.

The problem of explaining complex phenomena within an every day life situation is in most cases not as much due to the complicacy of the physics behind it but due to the difficulty to recognize and to elaborate physical aspects in a non-physical context.

Although the physical explanation represents an extreme reduction of a complex, multiperspective phenomenon to the simple law of reflection or – in the case of transparent plates – to the law of refraction, this must not necessarily be experienced as a disenchantment. On the contrary, the physical perspective may intensify and enrich our view and thus contribute to detect further interesting related phenomena.

Moreover, according to our experience, both the esthetical effect of the phenomena and the satisfaction of the learner felt in successfully elaborating a complex problem are a source of a high motivation.

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SKILLS... *from page 8*

is getting more difficult to understand because it has been changed into English and now my maths is getting worse. Can you help give some tips.
Response: you should understand the concepts that are going to be taught first. Discuss with the teachers. Memorise the formula and read reference book in Malay. If you don't understand then ask the teacher.
Problem: I cannot follow the lessons in additional maths, chemistry, physics and biology. It's difficult to target science subjects. Please help how to score.
Response: Science is something that happens around us. It needs understanding in a given topic. Ask teachers or parents if you don't understand. Once understood, do some experiments and memorise. Science is easy if we really understand. It is not difficult if we always study, revise and most importand, understand one by one what is to be expressed. Everything is related to common sense that happens in everyday life. If you really study, it is not surprising that you will say science is very easy. Best of luck in trying.
Response: Read and understand, then memorise what is required. Do mind mapping. If lazy, do it in the head. Visualise until you get clear picture of the scientific processes in the mind. Study not to score but to understand. If you still want to target then do past questions.

It was not clear whether these mails were from the teachers or the stduents. However, analysis of the comments made pointed out several things. Physics is learnt through memorization of tips and formula, and practice of past examination questions.

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