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CONTENT

SOLAR-ECLIPSE OBSERVATIONS IN PAKISTAN: HEALTH AND SAFETY CONSIDERATIONS

Prof. Dr. Syed Aif Kamal*

ABSTRACT

This paper addresses health issues associated with the observations of solar eclipses, in particular, eclipse retinopathy due to observation of partial-solar eclipses without proper protection to eyes. Partial- and total-solar-eclipse expeditions conducted by the author during 1995-2008 are described. Violation of Kepler's second law of planetary motion was witnessed during the 1995 total-solar-eclipse expedition and the same was confirmed during the 1999 total-solar-eclipse expedition. During the 1995 expedition, seconds before the end of totality, the black circular disc changed into an elliptical shape of eccentricity 0.26, with the major axis vertical to horizon. Safe viewing of eclipse is recommended through special glasses made from 2 layers of completely exposed ASA 100 film as well as UV-cutoff glasses.

Keywords: *Partial-solar eclipse, total-solar eclipse, safe viewing of eclipse, eclipse retinopathy*

INTRODUCTION

Solar-eclipse expeditions provide an insight into the wonders of cosmos as well as a realization of man's place in the universe. Therefore, there is a lot of interest by the scientific community as well as the general public in these rare astronomical events. However, lack of education and carelessness in following observation protocols may result in tragic consequences in the form of permanent loss of eyesight. After describing the mechanism of partial- and total-solar eclipses, this paper goes through the scientific value of solar-eclipse observations. Solar-eclipse expeditions led by the author during a period spanning over 13 *years* starting 1995 are documented and finally the hazards of unsafe viewing are discussed.

MECHANISM OF PARTIAL- AND TOTAL-SOLAR ECLIPSES

Mechanism of solar eclipse, from the perspectives of geometry, physics and astronomy, is given below**:**

*PhD (Mathematical Neuroscience); MA (Astrophysics), Johns Hopkins, Baltimore, MD, United States; MS, Indiana, Bloomington, IN, United States; MSc; BSc (Honors), both *summa cum laude*, University of Karachi; 4-Times Gold Medallist; Consultant, Guidance, Navigation and Control Laboratories; Ex-Senior Scientific Officer, Control Systems Laboratories, Pakistan Space and Upper Atmosphere Research Commission (SUPARCO); Ex-Member, American Institute of Aeronautics and Astronautics (AIAA); American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD); Subject Committee (Physical Education, Health and Sport Sciences), National Testing Service (NTS) Pakistan; Special Invitee, Board of Studies of Institute of Space and Planetary Astrophysics (ISPA); Ex-Chairman, Departments of Applied Physics as well as Health, Physical Education and Sports Sciences; Ex-Dean, Faculties of Science and Engineering, University of Karachi • *paper mail*: Professor of Mathematics and Project Director, the NGDS Pilot Project, PO Box 8423, Karachi 75270, Pakistan • *e-mail***:** profdrakamal@gmail.com • *telephone***:** +92 21 3662 0857-9 ext. 249 • *homepage***:** http://www.ngds-ku.org/kamal • *project URL***:** http://ngds-ku.org

The Geometry

Although the moon is smaller as compared to the sun, during a solar eclipse, moon comes between earth and sun, blocking the view almost completely as the moon is nearer to earth. For an observer on earth, the solid angle subtended by sun is 6.87×10^{-5} *steradian*, whereas the solid angle subtended by moon is 6.87×10^{-5} *steradian*. Hence, the moon, almost, covers the sun during a total solar eclipse. A golden disk is seen because the solid angle subtended by moon is slightly lesser than the solid angle subtended by the sun.

As the moon comes between the earth and the sun, light from the sun is blocked and the solar eclipse occurs. According to geometrical optics, the partial-solar eclipse occurs when the earth lies in the penumbra of the moon (partial blockage of light), whereas the total-solar eclipse occurs when the earth comes in the umbra of the moon (total blockage of light).

The Physics

The study of changes in gravitational pull during the solar eclipse is a subject of interest. Wang *et al.* (2000) have tried to conduct precise measurements of gravity variations during solar eclipse, which may be responsible for violation of Kepler's laws (see the next section). Also, the elliptical shape of sun observed by the author during the total-solar eclipse of 1995 may suggest left-right asymmetry and a resulting quadrupole moment.

The enhanced ultraviolet (UV) radiation activity during a partial solar eclipse is of interest to physicists, too.

The Astronomy

A beautiful non-mathematical description of statements of the Kepler's laws of planetary motion is given by Zielik (2009). They are summarized as**:**

*The First Law — The Law of Ellipses***:** This law states that the orbit of each planet takes the shape of an ellipse. Sun is situated at one of the foci, whereas the other focus is called the vacant focus.

*The Second Law — The Law of Equal Areas***:** This law states that a line drawn from a given planet to the sun sweeps out equal areas in equal times as the planet revolves around the sun. A corollary of this law is that the orbital speeds are non-uniform.

*The Third Law — The Harmonic Law***:** This law brings to light the fact that the planets with larger orbits move more slowly around the sun. It suggests that the sun-planet force decreases with distance, in a manner that the square of orbital period of a planet is directly proportional to the cube of its average distance from the sun.

Solar eclipse provides opportunities to study whether these laws are valid during the period of eclipse. Iqbal & Quamar (1997; 2003) have studied planetary orbits in axisymmetric gravitational fields as well as around a spinning gravitational star. They have suggested that the second law of planetary motion might require revision. The total-solar-eclipse expeditions led by the author are, also, indicating the same. Henriksson (2009) commented that the Lunar Laser Ranging (LLR) of the distance to the moon could make it possible to check if there is any significant deviation from Keplar's third law of motion

SOLAR-ECLIPSE OBSERVATIONS

Solar-eclipse observations are of utmost interest to the general public and the scientific community alike. However, the public needs to be educated about proper methods of viewing to protect eyes and skin from harmful effects of UV rays. Farooqui (1999) observes in a popular article that solar eclipses are not only important for cultural and traditional reasons, they, also, provide opportunities to study the characteristics of the sun.

Methods of Observations

The methods of observation of partial solar eclipse include observation of reflected image through water (light coming from water is polarized reducing its intensity), through tinted glass, through leaves (local children in Kirani farms, Ahmedpur Sharqia, Punjab, Pakistan, were seen to employ this method during the 1995 expedition) and through special viewing glasses made from 2 layers of completely exposed photographic film, ASA 100 (high sliver content). The last one is as per recommendations of IAU (International Astronomical Union). This method was used in all the solar-eclipse expeditions led by the author.

Telescopes, cameras and video recording equipment were also employed to record the eclipse.

Total solar eclipse could be observed from the naked eye. However, extreme care need to be exercised as a very brief exposure of eyes to harmful ultraviolet (UV) rays of partial eclipse (as the partiality starts after the totality ends — the exposed portion of sun being very small) may render a person blind. It is strongly recommended that total UV-cutoff sunglasses be worn during the observation of total phase as extra protection.

Enthusiasm of the General Public

The general public is very enthusiastic about the solar-eclipse observations. People come out like festivals to witness this rare event. Communities organize programs in local planetariums and science centers. As the time and place of happening of these events is known well ahead of time, expeditions may be planned accordingly. It is an irony that such future astronomical events are documented well in advance many years before their occurrence, but the weather conditions suitable for the observations (clear sky) may not be known even before a short time. The author experienced clear bright sky during the 1995 expedition away from the city, but cloudy sky (with smog) during the 1999 expedition in a large metropolis.

Significance for the Scientific Community

The 1919 total solar eclipse provided test for Einstein's general theory of relativity. Coles (2001) has given a beautiful description of these exciting discoveries including a picture of changes in star positions during the eclipse of 1922.

Observation of solar eclipse and the related orbital phenomena motivated the author to set up two-body problem in the elliptic-astrodynamical- (Kamal & Latif, 2012) and the hyperbolic-astrodynamical-coördinate meshes (Kamal & Latif, 2014) as well as put forward a new branch of mathematics, termed as *astromathematics*, in which the force expressions do not appear, explicitly (Kamal & Latif, 2012; Kamal,

2014; 2015). Even if there appears a need to study force interactions, these were expressed as space-time-curvature equivalents.

Religion, Customs and Beliefs

Muslims are advised to offer long prayers during the entire duration of eclipse. The rationale seems not only spiritual (repenting *Allah Subhanahu Ta'ala* during this time of fault line in orbits of astronomical objects; it is believed that frequency of such events shall increase as the day of judgment approaches closer) but also to encourage people to stay inside *masajid* (the word 'mosque' should not be used for Muslim place of worship, as its origins are related to some degrading description) and not observe the sun in the open damaging their eyes and possibly skin. It is a custom in this part of the world to advise pregnant women to lay in bed still and not cut anything during an eclipse to prevent birth defects to fetus.

SOLAR-ECLIPSE EXPEDITIONS IN PAKISTAN

The timings of solar eclipses in Pakistan have been documented (Ansari & Faruqi, 1987; Parker & Pasachoff, 1993). These have been used to make plans for these expeditions. All of the following expeditions were led by the author**:**

The Total-Solar-Eclipse Expeditions — 1995 and 1999

The total-solar eclipse of Tuesday, October 24, 1995 was observed by Department of Mathematics, University of Karachi Team in Kirani Farms, Ahmedpur Sharqia (East), Punjab, Pakistan. Other teams present on the site were those of Institute of Space and Planetary Astrophysics (ISPA), University of Karachi, Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), University of Bahawalpur as well as a team from Japan.

The eclipse started at 0655h (Pakistan Standard Time) and achieved totality at 0758h. The totality, visible for 40 seconds, ended at 0759h. The golden crescent started appearing from the top and the sun regained its uneclipsed circular shape at 0910h. There was, therefore, an asymmetry present in the time span from start of the eclipse to assume the totality and the time span from out of the totality to end of the eclipse suggesting a variable aerial velocity — violation of the Kepler's second law of planetary motion. Following were the salient features of this astronomical event:

- Weather was ideal for observations with a clear sky.
- As the moon started to cover the surface of sun, birds became disoriented.
- As the moon proceeded to cover the entire surface there was a sharp drop of temperature. The temperature becoming normal as soon as the total eclipse ended.
- As the totality was being achieved, the wind suddenly stopped.
- The rooster gave its morning cry as the totality was being achieved.
- A star was observed on the sky during the total phase.
- The diamond ring was seen during the total phase. There was a greenish prominence present for a few seconds.
- Seconds before the end of total darkness, the black circle changed into an ellipse of eccentricity 0.26 with its minor axis parallel to the horizon.

This expedition was covered in a local-language newspaper (Correspondent — the Jang, 1995*a*; *b*).

The last total solar eclipse of the second millennium at the University of Karachi Campus on Wednesday, August 11, 1999 by a team headed by the author and included an Assistant Professor of Physics as well as 3 graduate students. The eclipse started at 1618h (Pakistan Standard Time). The moon started to cover the solar disk from the bottom right. Totality was achieved at 1726h lasting for 73 seconds. At 1727h the moon started drifting and the golden crescent started appearing from the bottom right. The sun looked like a golden crescent during the partial solar eclipse. The solar eclipse ended at 1827h. The weather was cloudy. However, a few good glimpses of the sun were obtained through special goggles made from locally available material. As the totality was being achieved the birds become disoriented and a drop in the ambient temperature was felt. During the totality planet Venus was observed near the top left of the darkened solar disk. Before the start of eclipse our team organized educational programs in the Mathematics Department to create interest in the phenomenon and warn people against directly viewing the sun during the partial phase.

This expedition was, also, mentioned in the local-language newspaper (Correspondent — the Jang, 1999). The English-language newspaper published the following report (Correspondent — the News International, 1999)**:**

> "A team of academicians and their assistants observed Venus in the sky during the 73-*second* period of total darkness besides witnessing the violation of Kepler's second law of planetary motion in form of variation in aerial velocity. A team of scientists from the University of Karachi headed by Associate Professor of Mathematics, Dr. Syed Arif Kamal, observed and studied the last solar eclipse of the third millennium from the campus. The team leader had, also, led the Mathematics Department Team, which observed the total solar eclipse on October 24, 1995 at Kirani Farms, Ahmedpur Sharqia. As per their observations, the diamond ring was seen during the total solar eclipse with a greenish tinge for a few seconds. Second before the end of total darkness, the black circle changed into an oval shape with minor axis parallel to the horizon."

The Partial-Solar-Eclipse Expeditions — 2006 and 2008

The partial-solar eclipse of Wednesday, March 29, 2006 started at 1553h. The moon started covering the sun from the lower-right-hand side. At 1635h maximum coverage was achieved, with one-third of the solar disk from the right invisible because of presence of moon. The moon, then, started drifting away towards top and made a complete exit from the upper-right side at 1720h. The exit angle was more than the entrance angle. Aerial velocity was not constant as the moon took 42 *minutes* to achieve the maximum covered area, whereas it took only 45 *minutes* to go back to the uncovered position. There were no effects of eclipse on temperature, wind pattern and bird behavior, as opposed to the observations during the total expeditions of 1995 and 1999.

The partial-solar eclipse of Friday, August 1, 2008 was observed (Figure-1) by

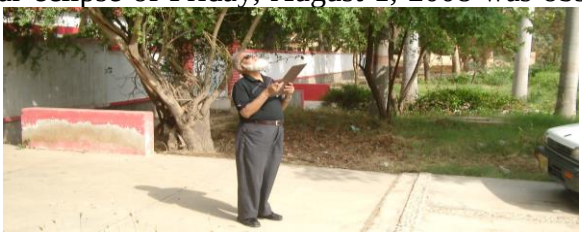

Figure-1. The author observing partial solar eclipse of August 1, 2008 wearing special googles

Figure-2. Photograph of partial solar eclipse of August 1, 2008 — smog somewhat blurred the image

the University of Karachi Team to verify the effects observed during the partial eclipse, which took place in 2006. The eclipse started at 1640h, with moon covering the sun from the upper-right-hand side (Figure-2). At 1740h maximum coverage was achieved, with one-third of the solar disk from the top obscured by moon. The moon, then started drifting away towards left and made a complete exit from the upper-left side at 1826h. Aerial velocity was not constant as the moon took 60 *minutes* to achieve the maximum covered area, whereas it took only 46 *minutes* to go back to the uncovered position. No effects on temperature, wind pattern and bird behavior were observed, which confirmed the findings of the 2006 Expedition.

Both partial eclipses confirmed violation of Kepler's second law of planetary motion, as indicated in the total solar eclipses of 1995 and 1999.

HEALTH AND SAFETY CONSIDERATIONS DURING OBSERVATIONS

Protection of Eyes

Observing solar eclipse without proper protection may damage eyes. Michaelides *et al.* (2001) conducted active case study in England during July-September 1999 to assess the damage to retina due to viewing of the last solar eclipse of the third millennium. There were 70 reported cases of visual loss (average age 29.5±12.9 *years*). Juan-López & Peña-Corona (1993) have described strategy for preventing eye injuries due to observing the solar eclipse in Mexico. Arda *et al.* (2007) have studied sun damage following the solar eclipse of 29 March 2006.

Protection of Skin

As UV radiation increases during the partial phase of solar eclipse, it may damage skin in addition to eyes. It is, therefore, recommended to cover exposed parts of body through sunscreen of an appropriate SPF (Sun-Protection Formula).

CONCLUSION AND FUTURE DIRECTIONS

Study of solar eclipse would continue to interest the communities throughout the world. In future, eclipse may be observed from spacecrafts and high-altitude flying aircrafts eliminating the effects of atmospheric disturbance. Home computers may be converted into observation screens, which will allow the public to get into the thrill of activity without exposing their bodies to harmful effects.

The problems, which should be investigated by astronomer-biologist during the coming years, should include study of quadrupole radiation due to asymmetry of shape of sun during the total solar eclipse (also suggested by theoretical calculations),

health effects on pregnant women (scientifically-justified relationship) as well as further investigation of effects UV radiation on human skin during a partial solar eclipse.

'Astronomy' is considered as a branch of natural science, which studies celestial objects. Astronomical models are based on geometric ideas, physical concepts, aesthetic notions and basic assumptions. Babylonians, Greeks, Chinese and Muslims all contributed to astronomy, given sophistication by the monumental contributions of Galileo, Kepler, Newton and others. A nexus of astronomy and biology should bring out fresh challenges for the inquiring mind of the third millennium.

Dedication

The author would like to dedicate this paper to the loving memory of Stephen W. Hawking (January 8, 1942-March 14, 2018), Lucasian Professor of Mathematics, who passed away at the age of 76 *years* on the world freedom day, the pie day and the birthday of Albert Einstein. He was born on the 300th anniversary of Galileo's death. Defying every personal and scientific expectation, Hawking has been decorated with Commander of the Order of the British Empire, (US) Presidential Medal of Freedom, the Dirac Medal, the Albert Einstein Award, the Wolf Prize and many other awards. His book 'A Brief History of Time' (1998) is one of the most widely read books in the world. His other notable publications are 'God Created the Integers' (2005) and 'The Nature of Space and Time' — with Roger Penrose (1996). His main contributions include the Hawking radiation, the Hawking energy and the Penrose-Hawking theorems. While at the Johns Hopkins University, the author wrote him a letter expressing the former's desire to work with the legendary astrophysicist.

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Contributors

Toshaba Channa, Director Physical Education, Government Girls College Latifabad, Hyderabad and **Syed Asim Hussain**, Assisstant Professor, Centre for Physical Education, Health & Sports Science, University of Sindh, Jamshoro. "**An assessment of student perception about coaching performance of college female directress sports**"

Muhammad Zeeshan Ashraf, (1UET Lahore, Nwl Campus), **Dr. Saira Husnain** Hajveri University Lahore and **Dr. Nazia Parveen Gill**, Department of Statistics, University of Sindh, Jamshoro "**Concepts of Cosmology regarding its Evolution**"

Dr. Soniha Aslam, Associate Professor, Centre for Physical Education, Health & Sports Science, University of Sindh, Jamshoro, and **Javed Shaikh**, Director Physical Education, Post Gradaute Government Degree Boys College, Latifabad, Hyderabad "**Awareness and attitude of Parents about female participation in Sports**".

Prof. Iqbal Ahmed Qureshi (Late), Founder Director, Centre for Physical Education, Health & Sports Science, University of Sindh, Jamshoro and Dean Faculty of Social Sciences, University of Sindh, Jamshoro, **Shahzaman Khan**, Assistant Professor Department of sports Sciences & Physical Education University of Lahore and **Prof. Dr. Yasmeen Iqbal**, Department of Sports Sciences & Physical Education University of Lahore. "**Implication of Mental Efforts Designing Exer-games Curriculum in Modern Times in Pakistan**".

Prof. Dr. Syed Arif Kamal, PhD (Mathematical Neuroscience); MA, Johns Hopkins, Baltimore, MD, United States; MS, Indiana, Bloomington, IN, United States; MSc; BSc (Honors), both *summa cum laude*, University of Karachi; 4-Times Gold Medallist; Project Director, the NGDS Pilot Project; Ex-Member, American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD); Subject Committee (Physical Education, Health and Sport Sciences), NTS Pakistan; Ex-Chairman, Department of Health, Physical Education and Sports Sciences; Ex-Dean, Faculty of Science, University of Karachi. "Solar-Esclipse Observations in Pakistan: Health and Safety Considerations"

Dr. Abdul Roof Rather, Department of Physical Education, Aligarh Muslim University, Aligarh U.P. India, **Ms. Nazia Khan**, Department of Physical Education, Aligarh Muslim University, Aligarh U.P. India and **Mr. Abdul Kaisar**, Department of Physical Education, Aligarh Muslim University, Aligarh U.P. India. "**Sport workout and participation associated menstrual problem among adolescent athletes of Aligarh**".

Prof. Dr. Syed Aif Kamal, PhD (Mathematical Neuroscience); MA, Johns Hopkins, Baltimore, MD, United States; Project Director, the NGDS Pilot Project; Ex-Member, American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD); Subject Committee (Physical Education, Health and Sport Sciences), NTS Pakistan; Ex-Chairman, Department of Health, Physical Education and Sports Sciences; Ex-Dean, Faculty of Science, University of Karachi and **Shahid Ali Khan**, MSc (Health and Physical Education), University of Karachi; MPhil Candidate (Health, Physical Education and Sports Sciences), University of Sindh; Director, Physical Education, Government Degree Boys College, Korangi, Karachi.

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0092 321 304 7286