SOLAR ECLIPSE EYE SAFETY
AN INTRODUCTION

B. RALPH CHOU
SCHOOL OF OPTOMETRY & VISION SCIENCE
UNIVERSITY OF WATERLOO

AMERICAN ASTRONOMICAL SOCIETY
SOLAR ECLIPSE PLANNING WORKSHOP
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SOLAR RETINOPATHY

• “Retinal burns”
  • Associated with sungazing
    • Galileo
      • first telescopic observations of sunspots
      • poor vision late in life
        • solar retinopathy? (NOT likely!)
    • WWII aircrews
      • retinal burns after missions
    • “Acid heads” of 1970s
      • LSD and sungazing
SOLAR ECLIPSES AND RETINAL BURNS

• Keightley et al 2000
  • solar eclipse of 11 August 1999
  • 70 cases in United Kingdom
    • recognizable retinal burns
    • all resolved over a period of weeks
  • eye protection
    • 35% sunglasses
    • 15% eclipse “glasses”
    • 50% no protection
SOLAR ECLIPSE EYE INJURIES

- Painless
  - no pain sensors in retina
- Latent period
  - 12 to 48 h delay of onset of symptoms
  - wavelength dependent
- Visual recovery highly variable
  - depends on exposure conditions
- Optical aids increase severity
  - thermal effects add to photochemical
WHO IS AT RISK

- Everybody!

- Most likely person to be injured
  - Young adult (more likely male)
    - Unaware of, or ignored warnings
    - No or inappropriate protection
    - Reported symptoms next morning

Chou & Krailo 1981
PHOTOCHEMICAL INJURY

- short wavelength light (blue)
- threshold 3 W.m^{-2}
- usually temporary visual loss
- most common type of injury
THERMAL INJURY

- long wavelength visible, IRA, extended short wavelength visible
- threshold $2.8 \times 10^4 \text{ W.m}^{-2}$
- permanent injury with visual loss
- more common if optical aid was used
ECLIPSE RETINOPATHY

Retinal scotoma

Eclipse mag. 0.12, obs. 5%

Wu et al, 2017
EXAMPLE FROM 2017

- 18 y.o. male
  - Viewed PSE without protection several minutes
  - Seen next day
EYE PROTECTION

• Needed whenever any part of the solar disk is visible
  • Partial phases of TSE
  • All the time during annular eclipse
SHADE 14 WELDER’S GLASS

Transmittance vs. Wavelength (nm)
SOLARSKREEN

Transmittance

Wavelength (nm)
BAADER ASTROSOLAR SAFETY FILM

Transmittance vs. Wavelength (nm)

Transmittance:
- 1.00E-03
- 1.00E-04
- 1.00E-05
- 1.00E-06
- 1.00E-07
- 1.00E-08
- 1.00E-09
- 1.00E-10

Wavelength (nm):
- 200
- 400
- 600
- 800
- 1000
- 1200
- 1400
- 1600
- 1800
- 2000
- 2200
- 2400
1999 SAFETY ISSUE

• Are sputtered metal coatings truly safe?
• Controversy in UK prior to 1999 total solar eclipse
  • “Defects in sputtered coatings are dangerous”
• Several viewers with SolarSkreen lenses found to have bright defects in coatings
DEFECTS IN VIEWER LENSES

Viewer 3-9
Size 450 X 70 μm

Viewer 5-13
Size 680 μm long
40 - 100 μm wide

Viewer 3-10
Size 450 X 80 μm
“JELLYFISH” DEFECT

Window defect in one layer of aluminised polyester
Size 800 X 1000 µm
SAFETY OF “PINHOLES”

• Large defects occur rarely in polyester solar filters
  ○ One of 2 layers of aluminum missing
• Ocular exposure increases if defect centred on pupil
  ○ Critical exposure time $10^5$ times longer than for unprotected eye
• May be a glare source but not hazardous
BLACK POLYMER
SOLAR FILTER STANDARD

- EN 1836: 2005
  - Developed due to controversy of 1999
- ISO 12312-2: 2015
  - Replaced EN 1836: 2005
  - Confirmed by ISO TC172/SC7 in 2020
- A PPE standard (under EC rules)
ISO 12312-2

Eye and face protection – Sunglasses and related eyewear – Part 2: Filters for direct observation of the sun

• Applies ONLY to filters used without optical instruments to observe the Sun directly
• Photographic filters, filters for telescopes and binoculars NOT covered
• Retailers advertising that their products comply
ISO 12312-2

• Requirements
  • Luminous transmittance
  • Material and surface quality
  • Mounting
  • Dimensions
  • Labelling

• Certification to carry ISO logo
  • Accredited test laboratories
2017 AAS CAMPAIGN

• Eye safety flyer
• Specialist package
  • Educators
  • Eye care providers
  • Media
• Included filter compliance with ISO 12312-2
SO HOW DID THINGS TURN OUT?

- Astronomy, optometry and ophthalmology groups all gave the same advice
- High public awareness of safe viewing practice and equipment
  - Good compliance for the most part...
A NOTABLE EXCEPTION
REPORTED EYE INJURIES

Average age 30

Symptoms:
• Blurry vision 19/25
• Metamorphopsia 5/25
• Scotoma 15/25
• No symptoms: 1/25

25 cases, 35 eyes

Retinal findings:
• Yellow lesion in retina 12/35
• Retinal pigment changes 13/35

American Society of Retinal Specialists
REPORTED EYE INJURIES

• Macula Society
  • 10 retinal injuries

• American Optometric Association
  • 13 retinal injuries

48 cases among 350M people!
FOLLOW-UP STUDY ON FILTERS (CHOU, DAIN, FIENBERG 2021)

• Samples
  • Filters submitted for AAS endorsement
  • Archived filters from BRC collection
• Assessed for compliance with ISO 12312-2
RESULTS – 1

• All filters met UV and IR requirements
• Luminous transmittance
  • Ranged from 0.0000083% to 0.00075%
  • SN 16 to 12
• Correlated luminous transmittance with acceptability of solar image
RESULTS – 2

• Most paper “spectacles” met dimension requirements
  • Sunglass frames with hard filters failed
• Many eclipse glasses and filters did not have compliant labels
SOLAR ECLIPSE GLASSES
PROPOSED NEW LIMITS
REVISIONS TO ISO 12312-2

• Luminous transmittance limits
• Dimensions for paper “frames”
• Allowance for handheld viewers and filters in sunglass frames
• Remove “best before date”
QUESTIONS?

Bucharest, 1999