Atmospheric Optical Effects

Physics 385 *Optics*

Prof. Menningen

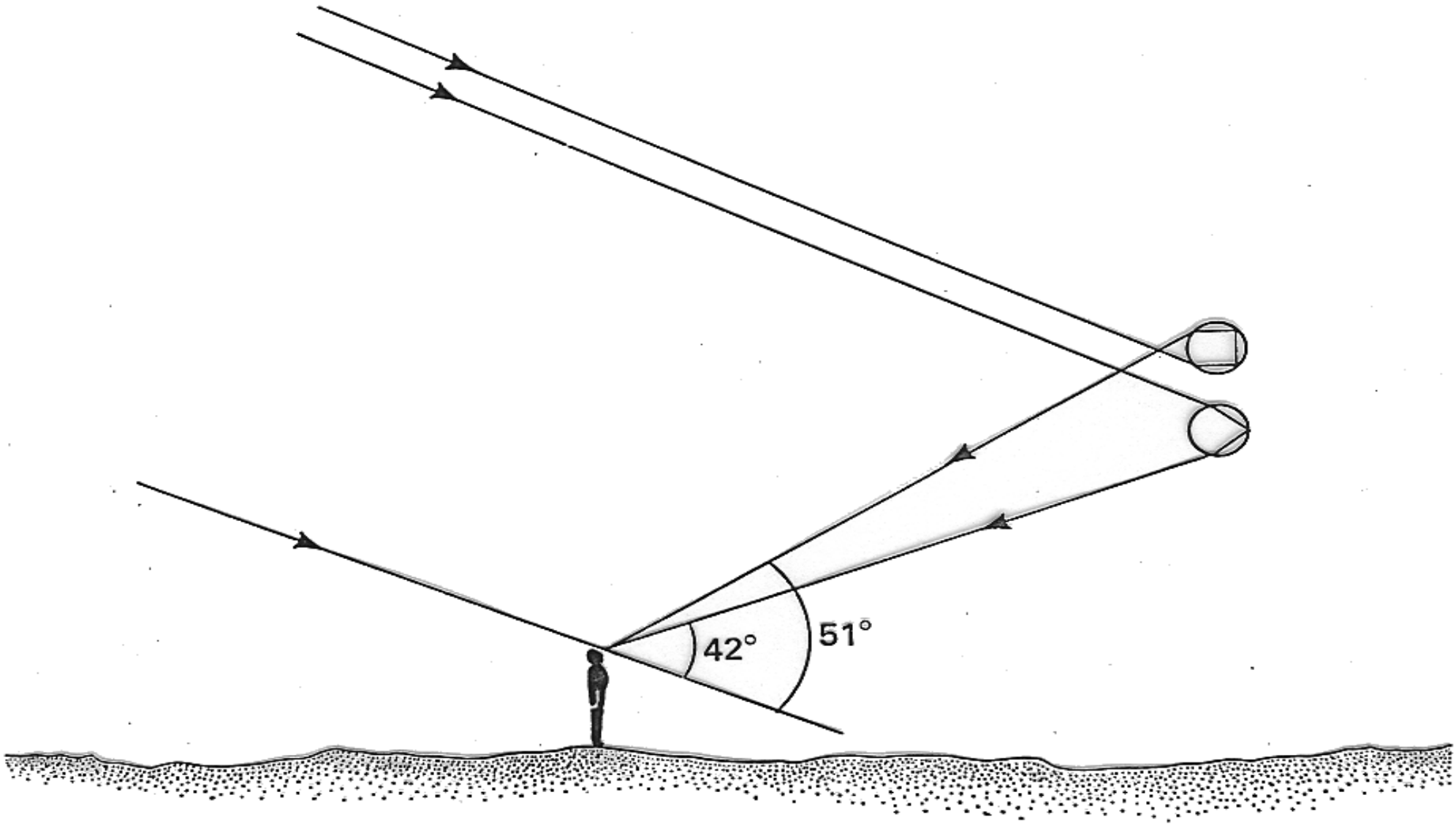
With thanks to Robert Greenler
University of Wisconsin - Milwaukee

Rainbows

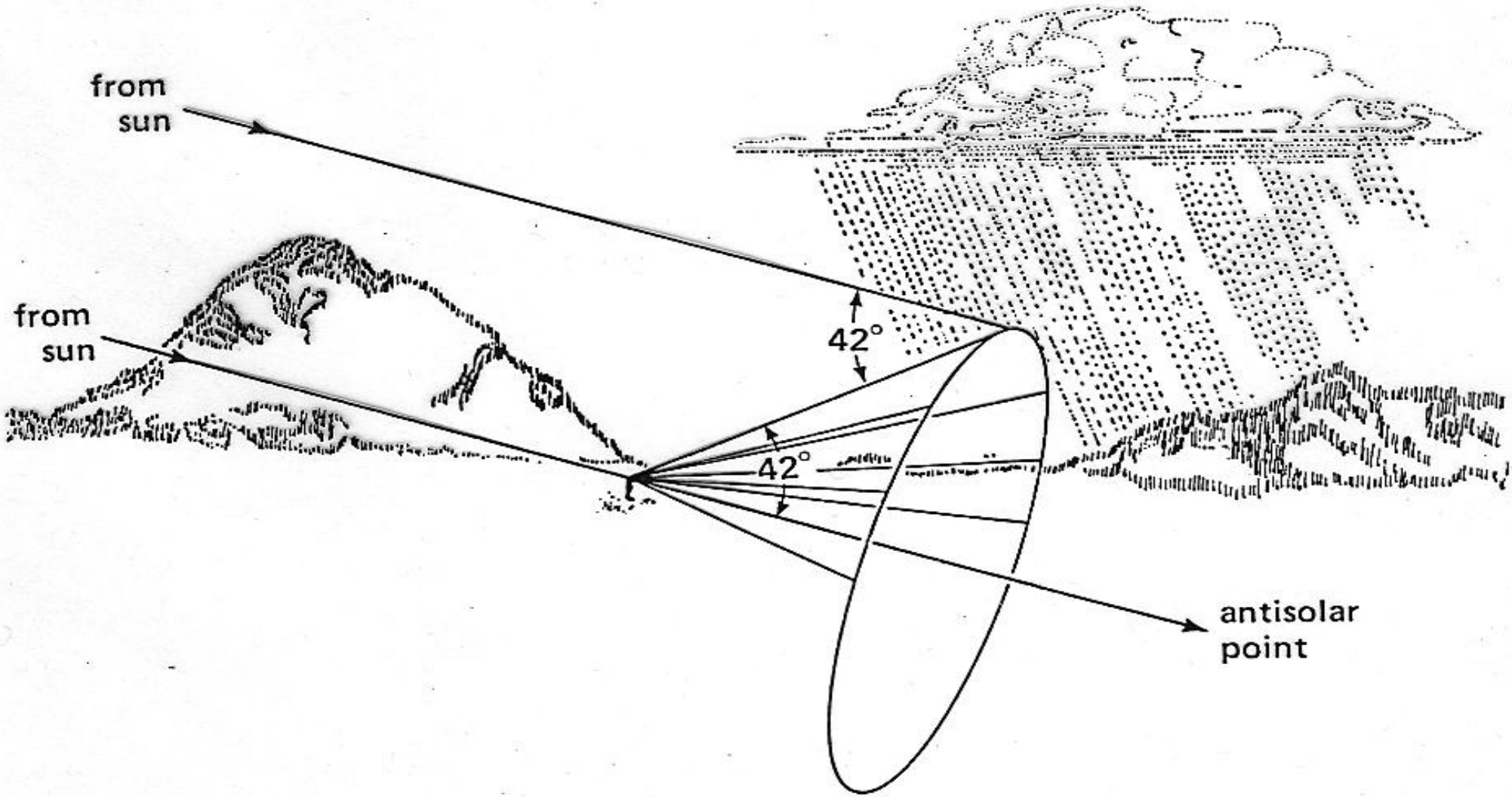
Reflection, refraction, and dispersion working together

See also the terrific website

http://www.atoptics.co.uk



Interactive applet (click on Dispersion)


from
sun
from
sun
42°
42°
antisolar
point

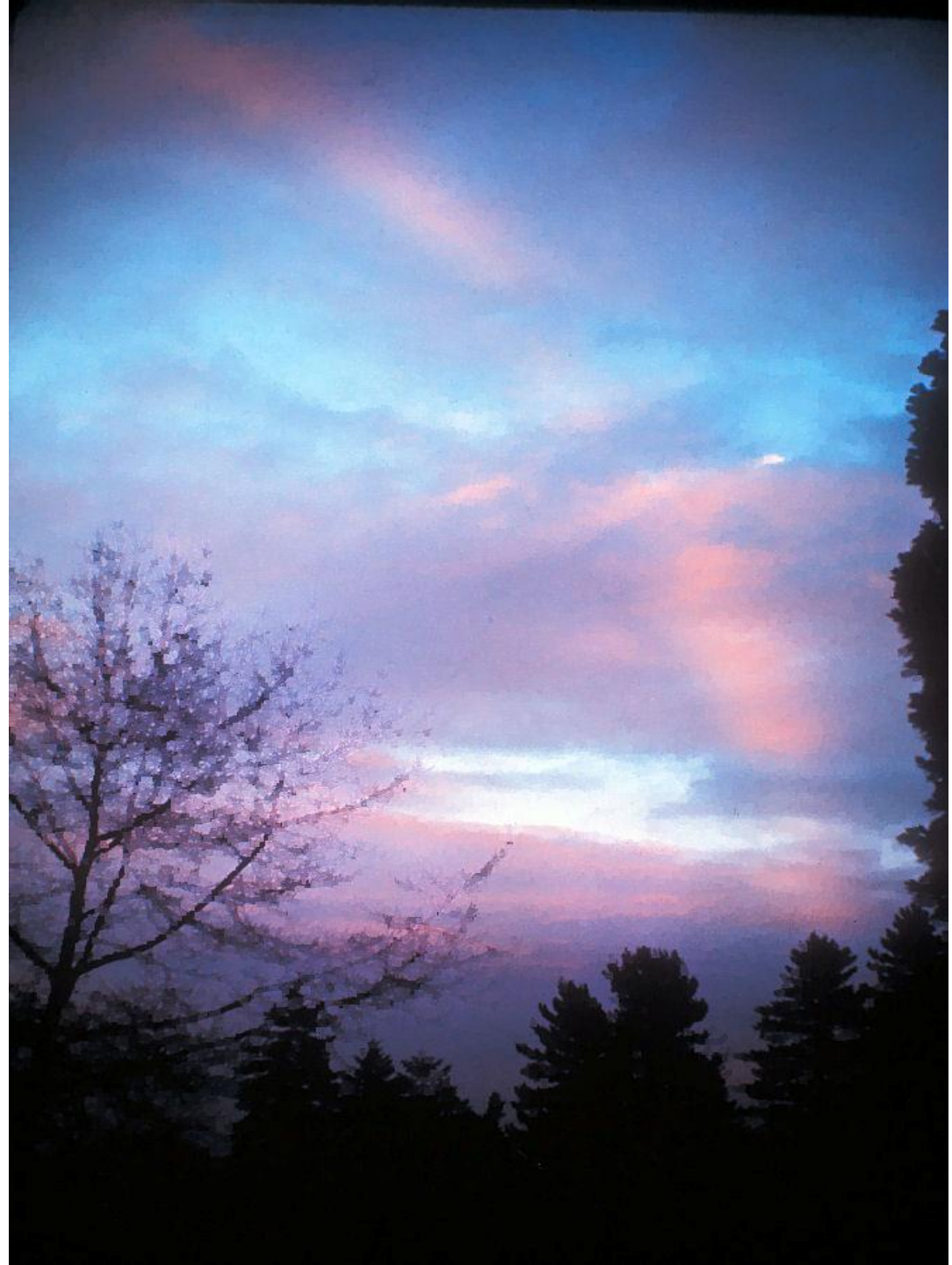
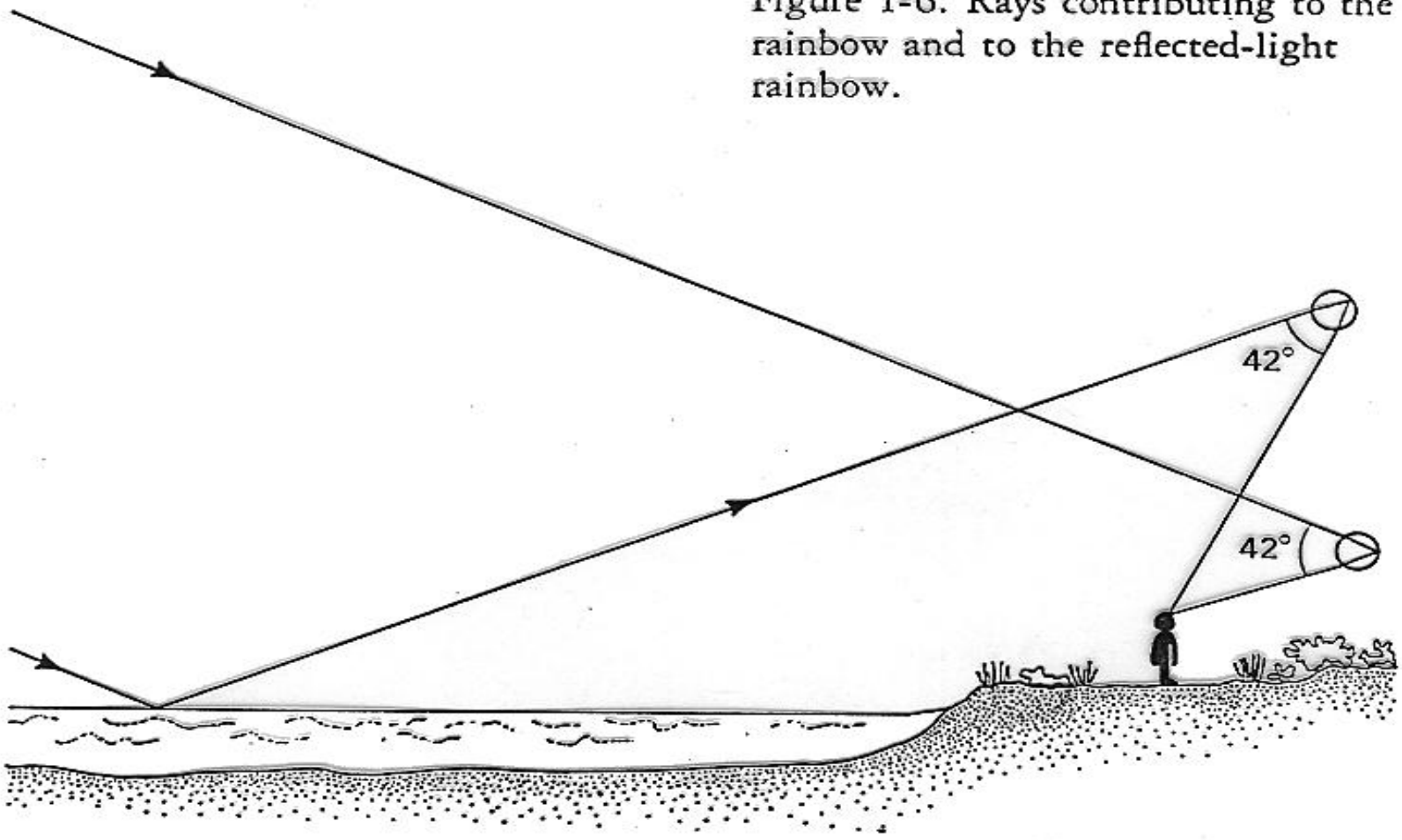


Figure 1-6. Rays contributing to the rainbow and to the reflected-light rainbow.



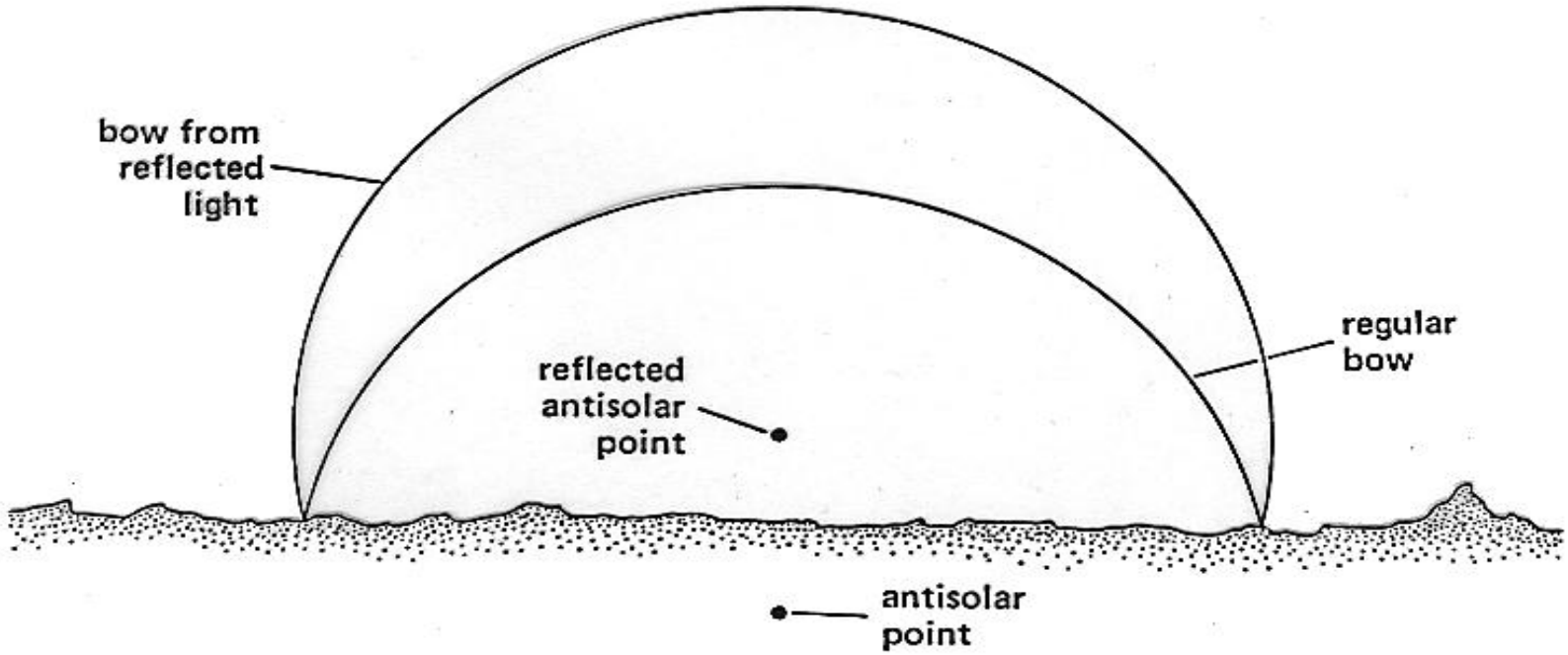


Figure 1-7. The ordinary rainbow is centered on the antisolar point; the reflected-light bow, on a point located at the sun's elevation above the horizon.

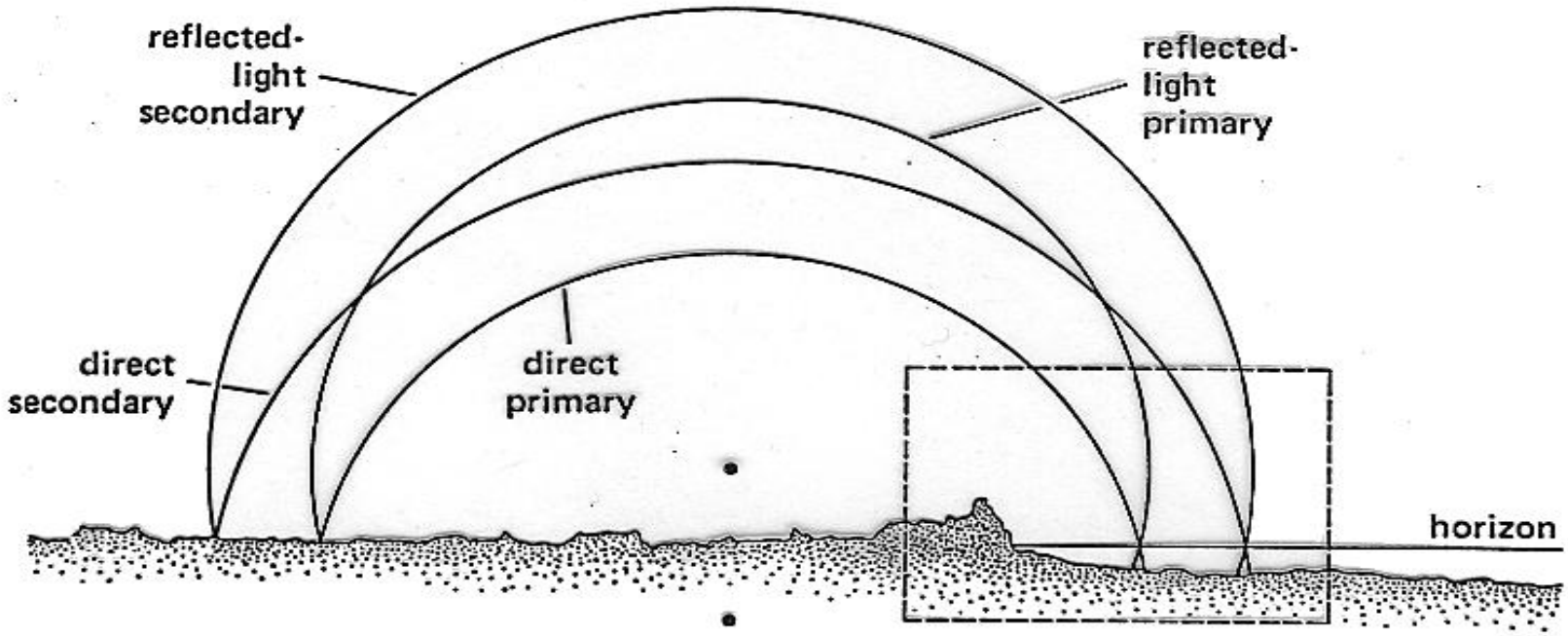
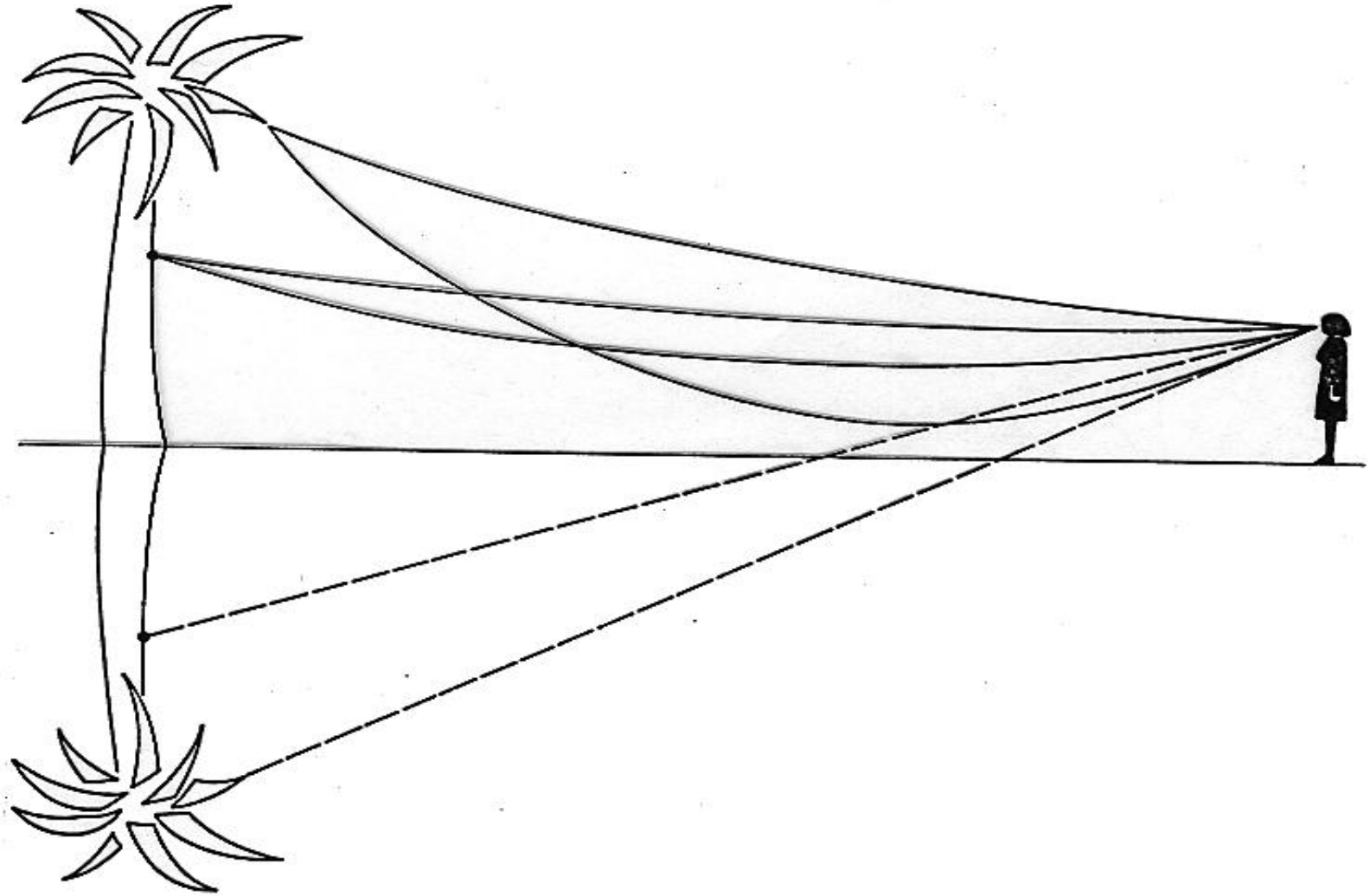


Figure 1-8. The predicted form of the direct and reflected-light primary and secondary bows. The dotted line is the area covered by the photograph of Plate 1-9.

Mirages

Refraction caused by thermal air layers



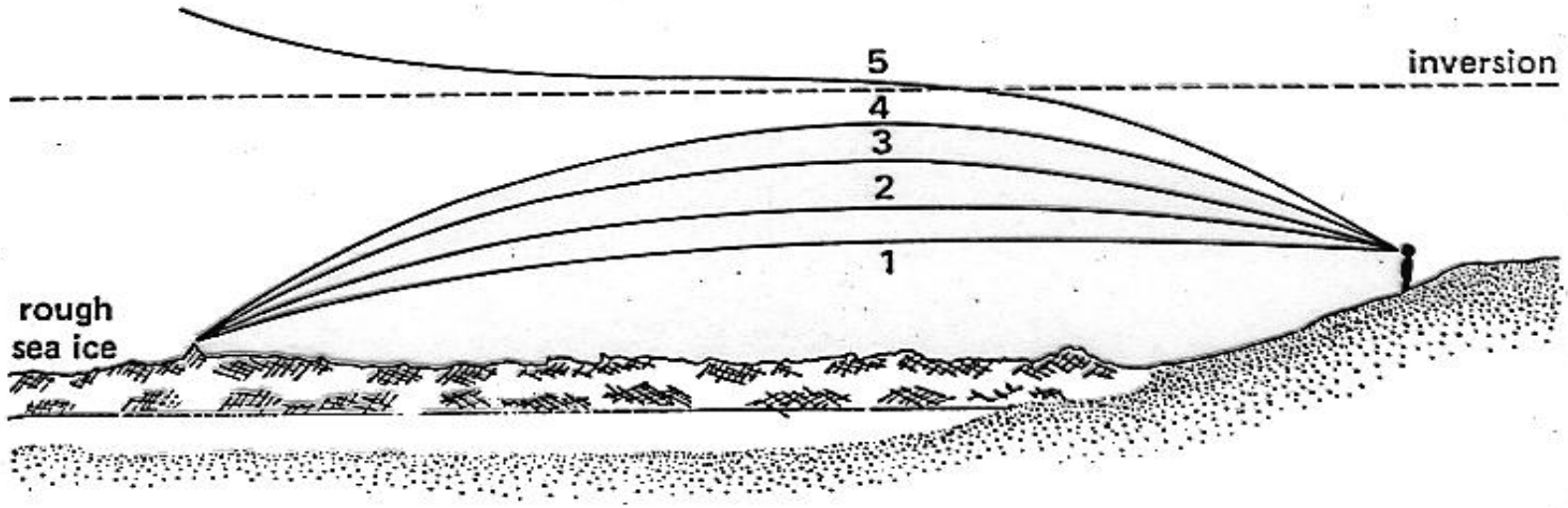
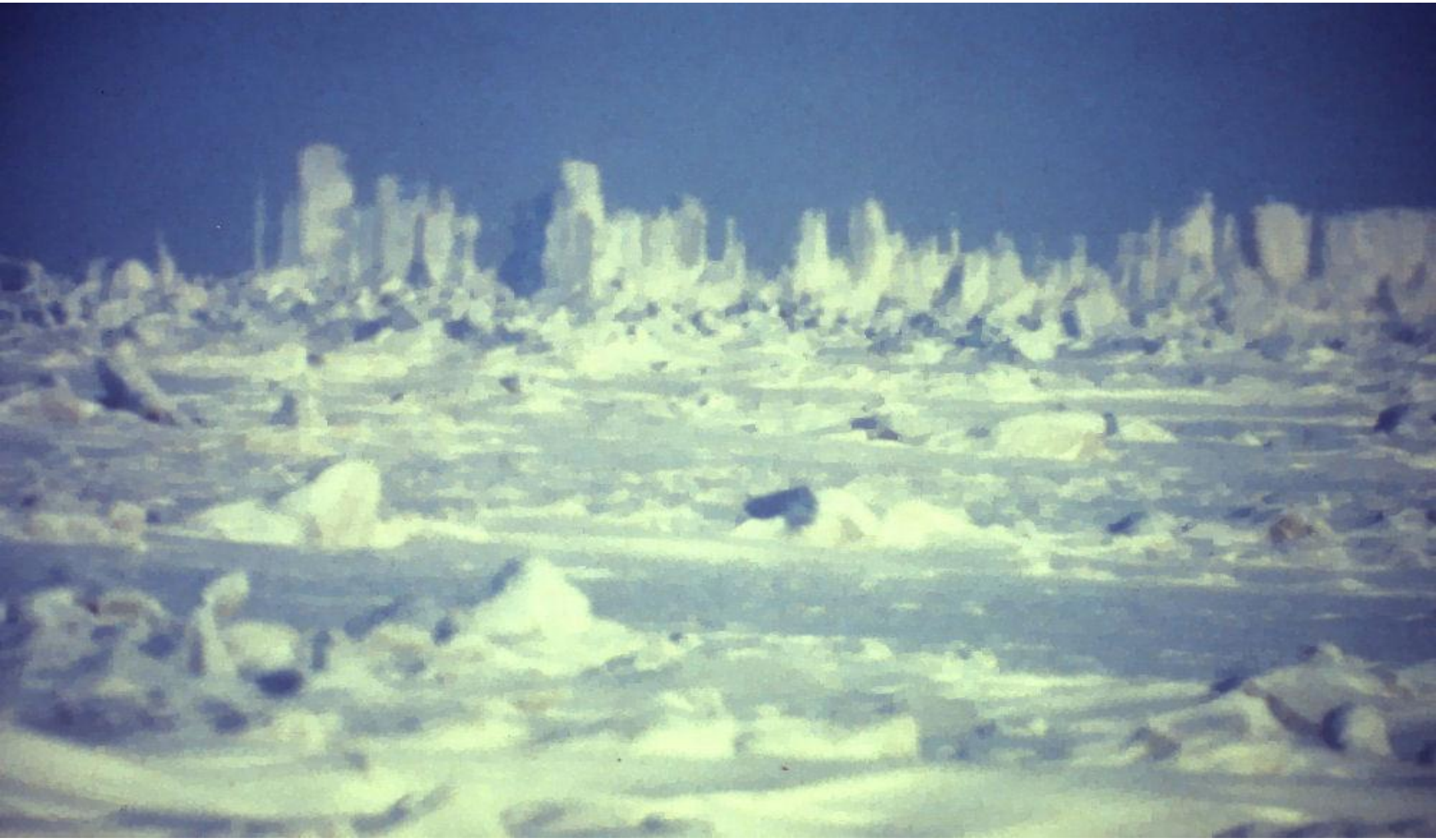


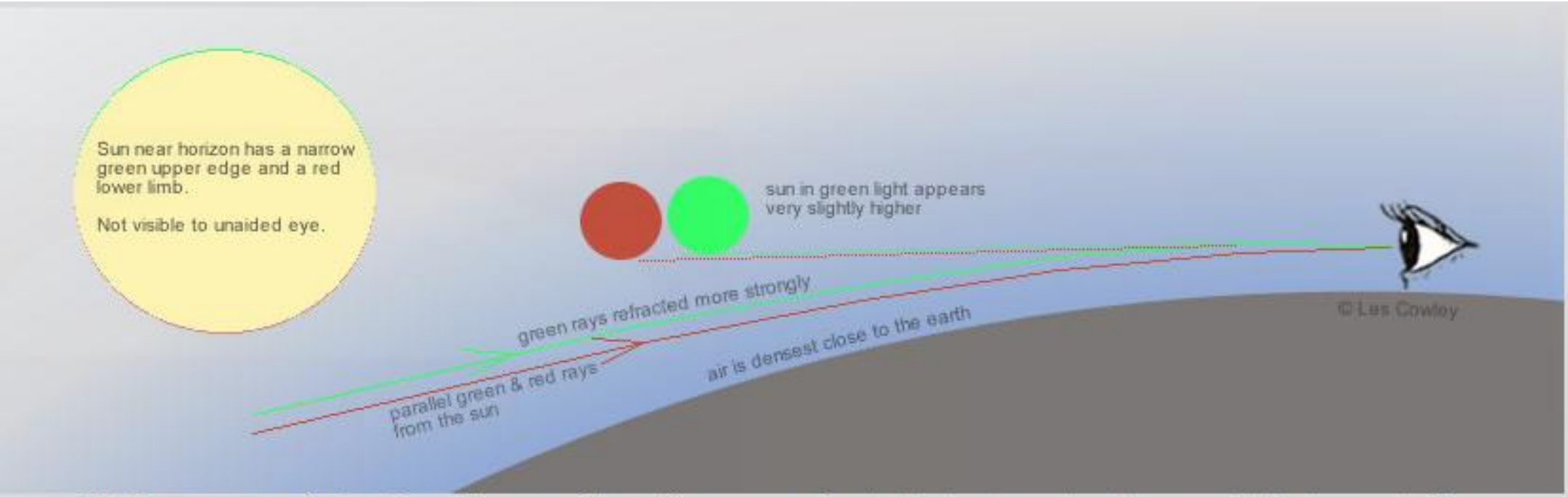
Figure 7-18. Ray paths for the fata morgana.



The Green Flash

A combination of atmospheric scattering, refraction, ray curvature, and mirage formation

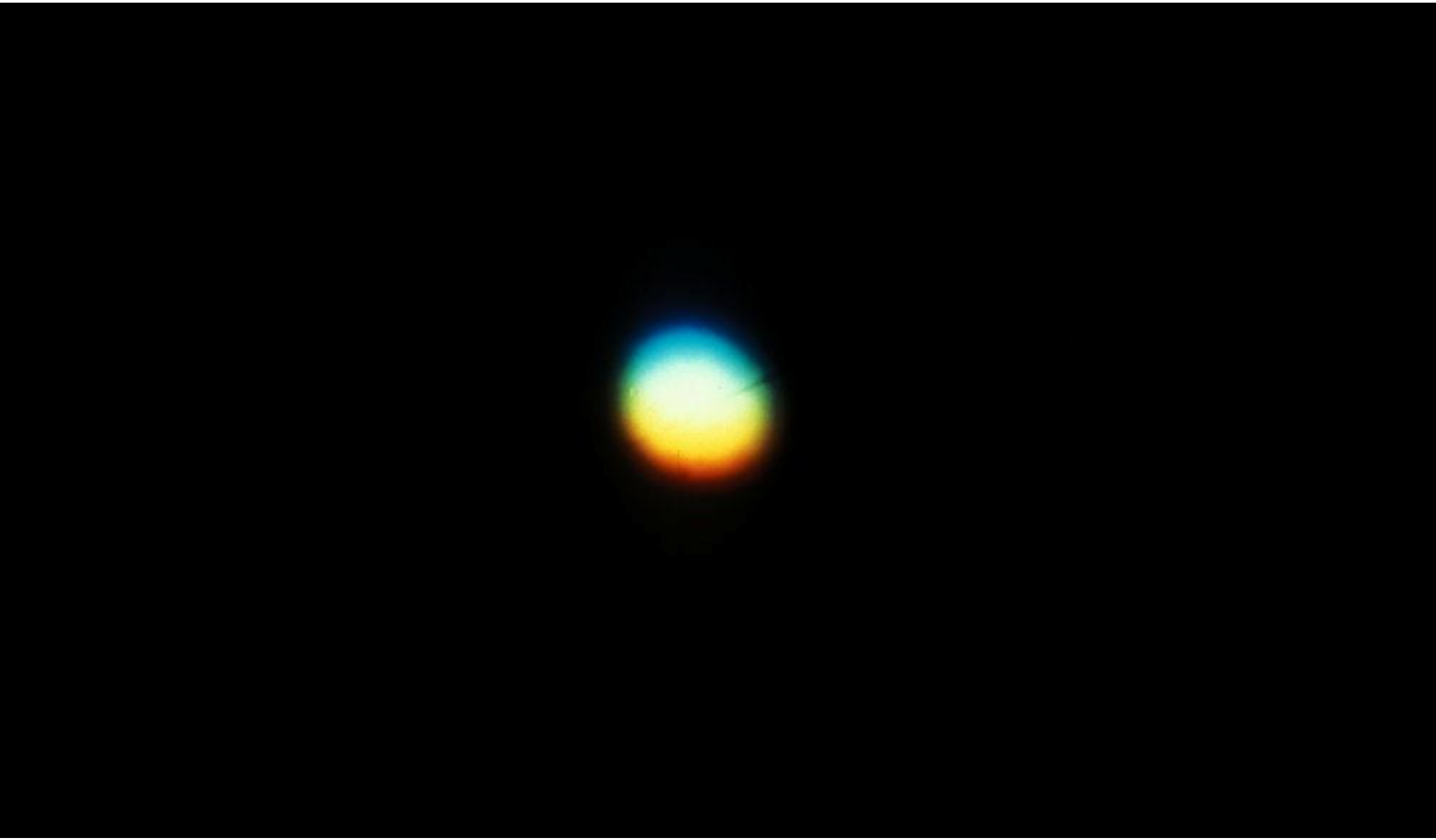
Green Flash from http://www.atoptics.co.uk/atoptics/gfim2.htm

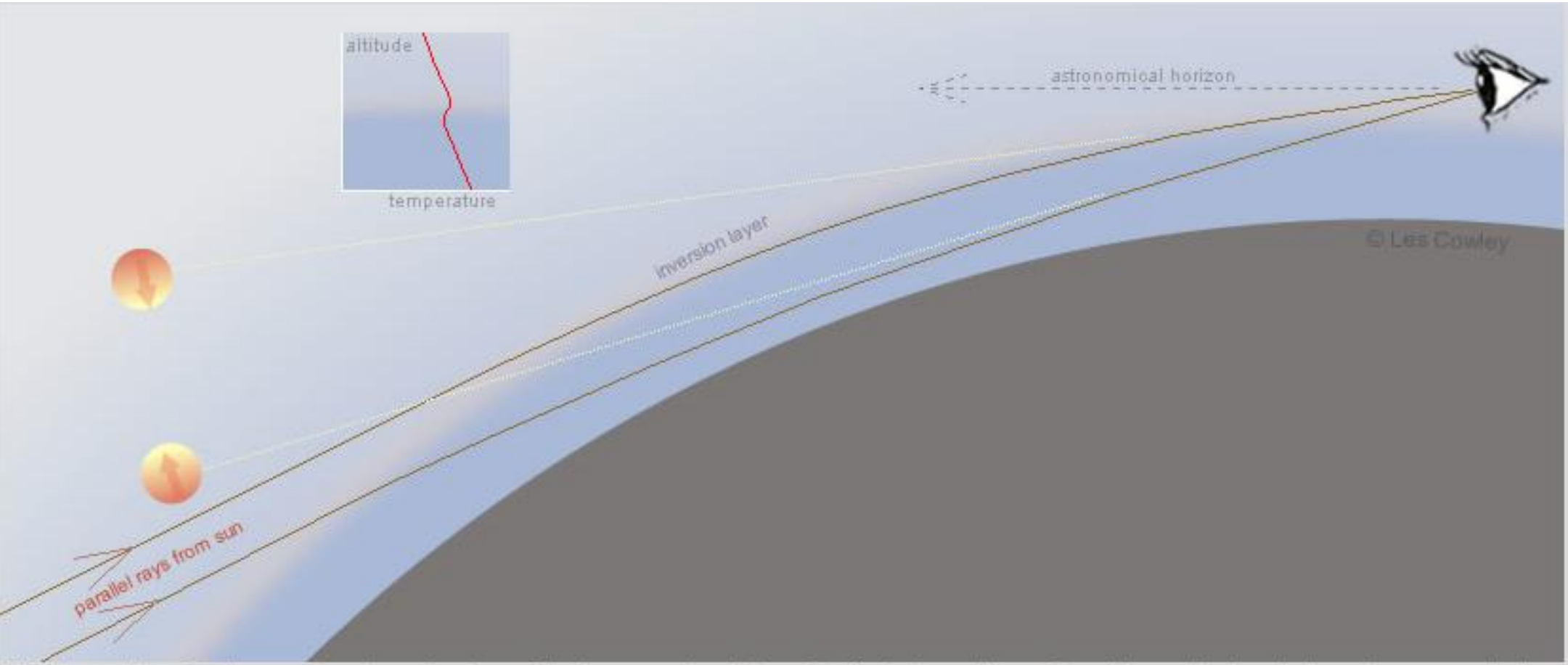


Not the way green flashes form. *The rays of the setting sun are refracted by the atmosphere to curve slightly downwards. The sun appears flattened and raised in the sky. Green light is refracted more and the 'green sun' is very slightly higher than the red one. But the effect is small and cannot be seen with the unaided eye. Green flashes need something more!*

Green Rim formation from http://www.atoptics.co.uk/atoptics/gf15.htm

You can see the effect in the following two telescopic photos of Venus as it is setting





Miraging action of a temperature inversion layer. The layer need only be a few feet above the surface (the vertical scale here is exaggerated). Parallel rays from the setting sun follow two paths to the observer above the layer and up to three solar images are seen (the uppermost is erect and for clarity is not shown here). The mirage can greatly magnify small angular differences in ray directions. The separation between red and green images is enhanced and can give a green flash.

Green Flash formation from http://www.atoptics.co.uk/atoptics/gfmmform.htm

See Andrew Young's additional explanation and a set of computer simulations

Sunset at De Panne, Belgium *. Florian Schaaf (site) took this sequence on 31st March '03. This 'Etruscan Vase' or 'Omega' sunset ends with a 1-2s long green flash. The sunset was mainly an inferior mirage event but, as usual, nature is richer - the sun is unusually distorted and look at the two other green flashes 42 and 11s before the sun disappeared! Larger images do better justice to this fine sequence, check #1, 2, 3*

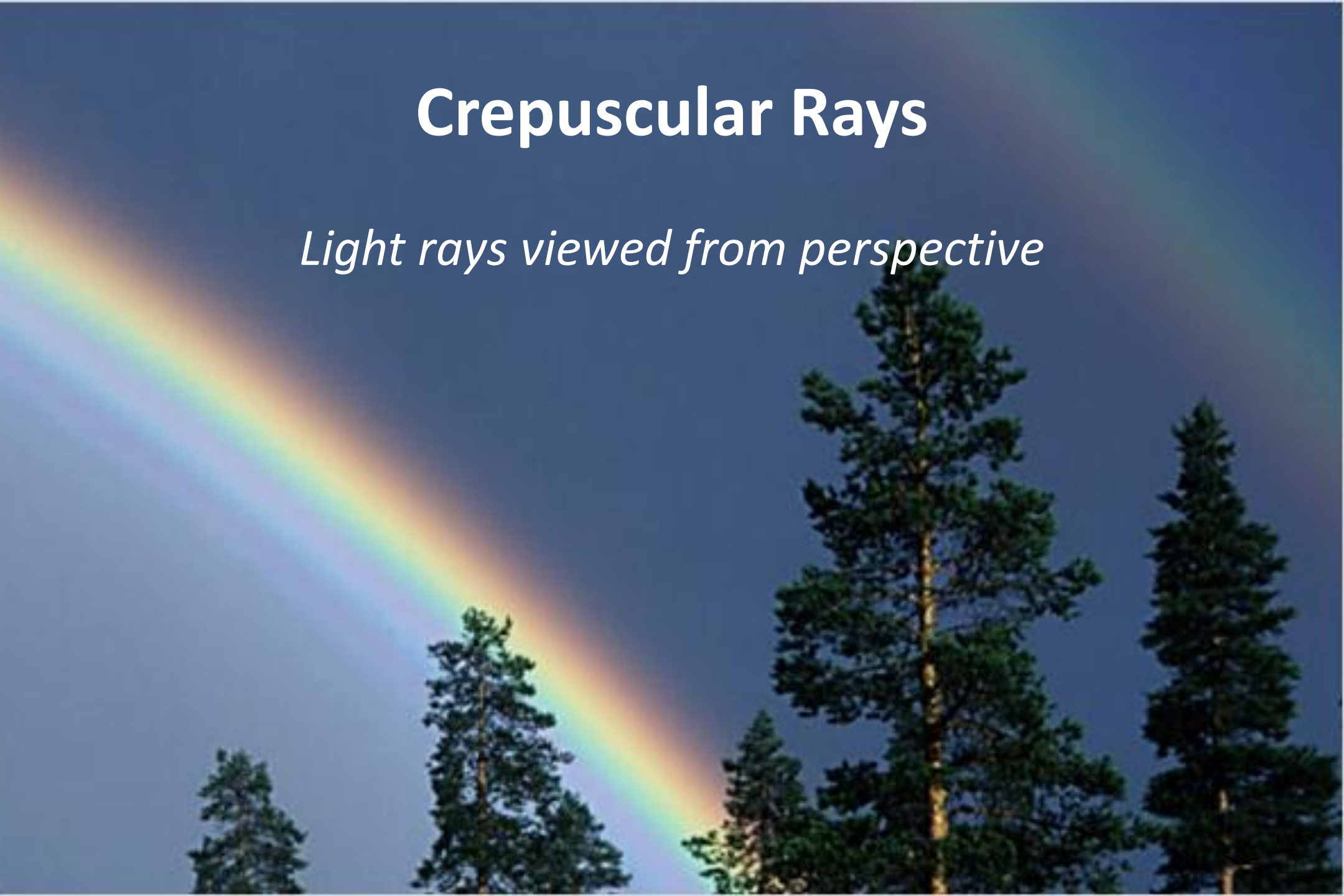
From http://www.atoptics.co.uk/atoptics/gf2.htm

Heiligenschein

Retroreflection by water droplets

Crepuscular Rays

Light rays viewed from perspective



Shuttle Atlantis Launch 7 February 2001
Credit & Copyright: Anthony DeVito
View from Orlando, FL
http://antwrp.gsfc.nasa.gov/apod/ap010512.html

Ice Crystal Displays

Refraction through hexagonal ice crystals

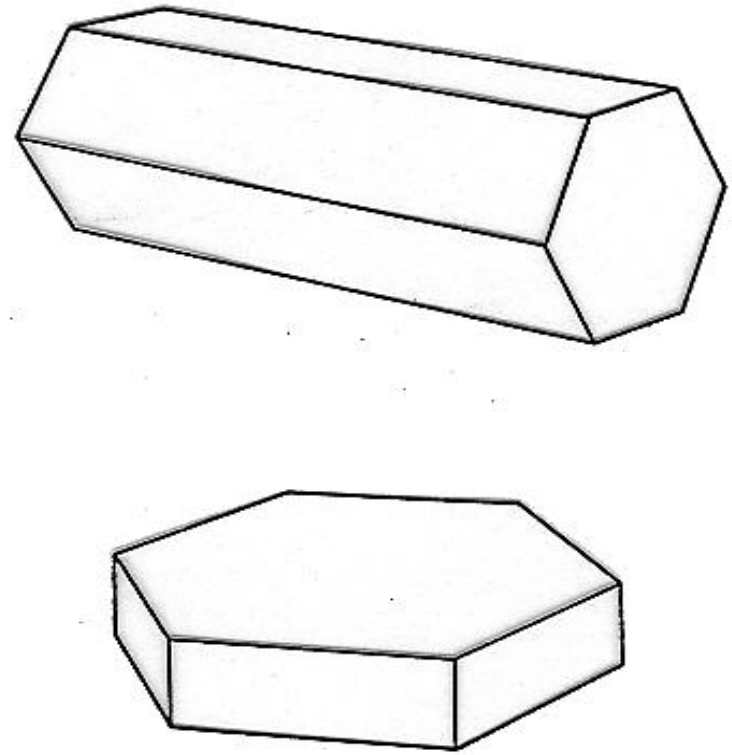
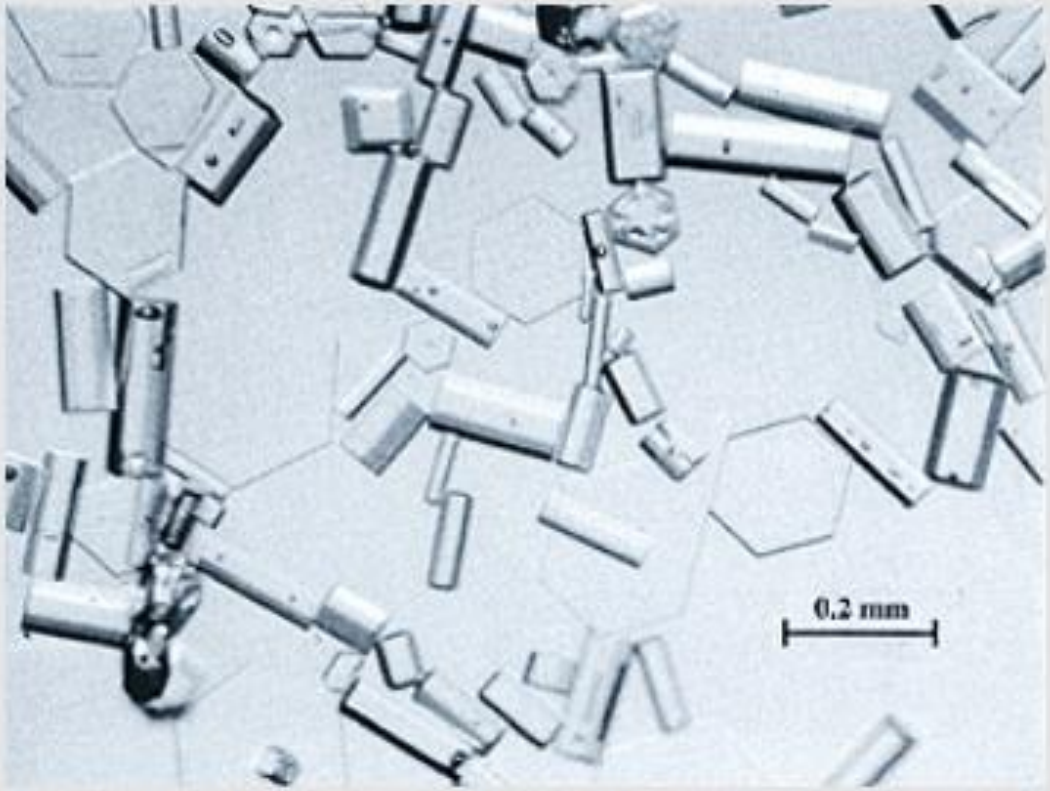


Figure 2-1. Two simple ice-crystal forms: *top*, a columnar or pencil crystal; *bottom*, a plate crystal.

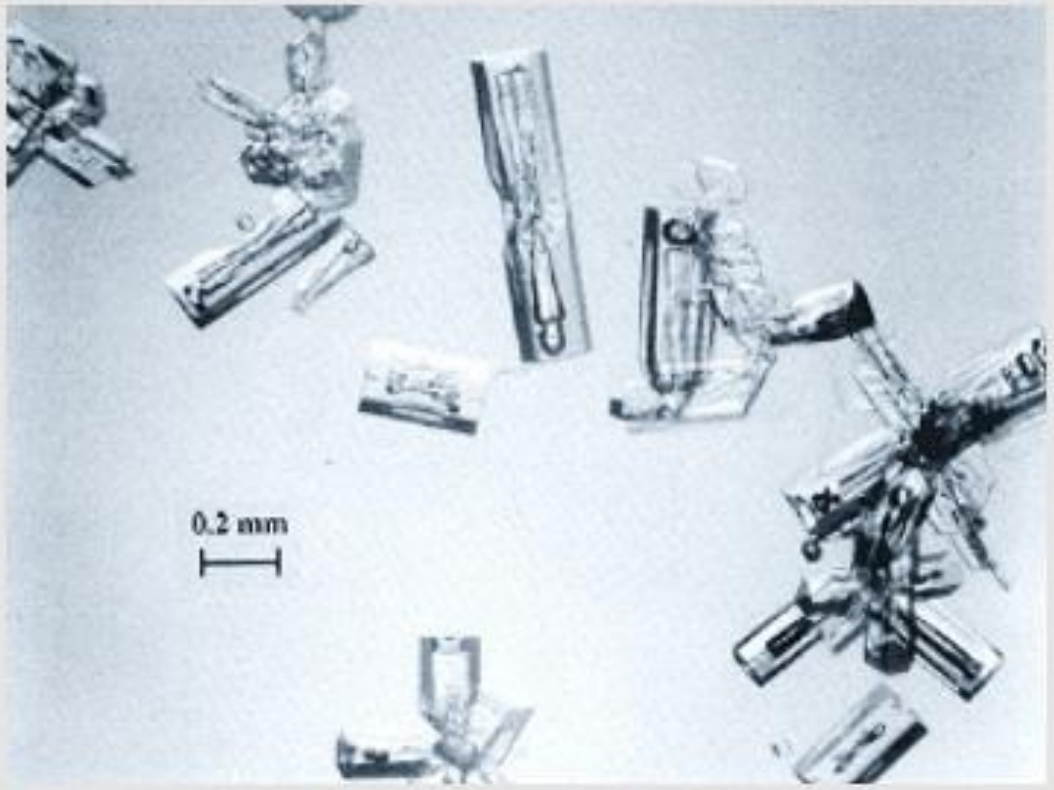
Halo forming ice crystals sampled during a display at the South Pole by Walter Tape. The crystals are thin hexagonal plates and six sided columns. ©Walter Tape, shown with permission

From http://www.atoptics.co.uk/halo/crystals.htm

Real ice crystals

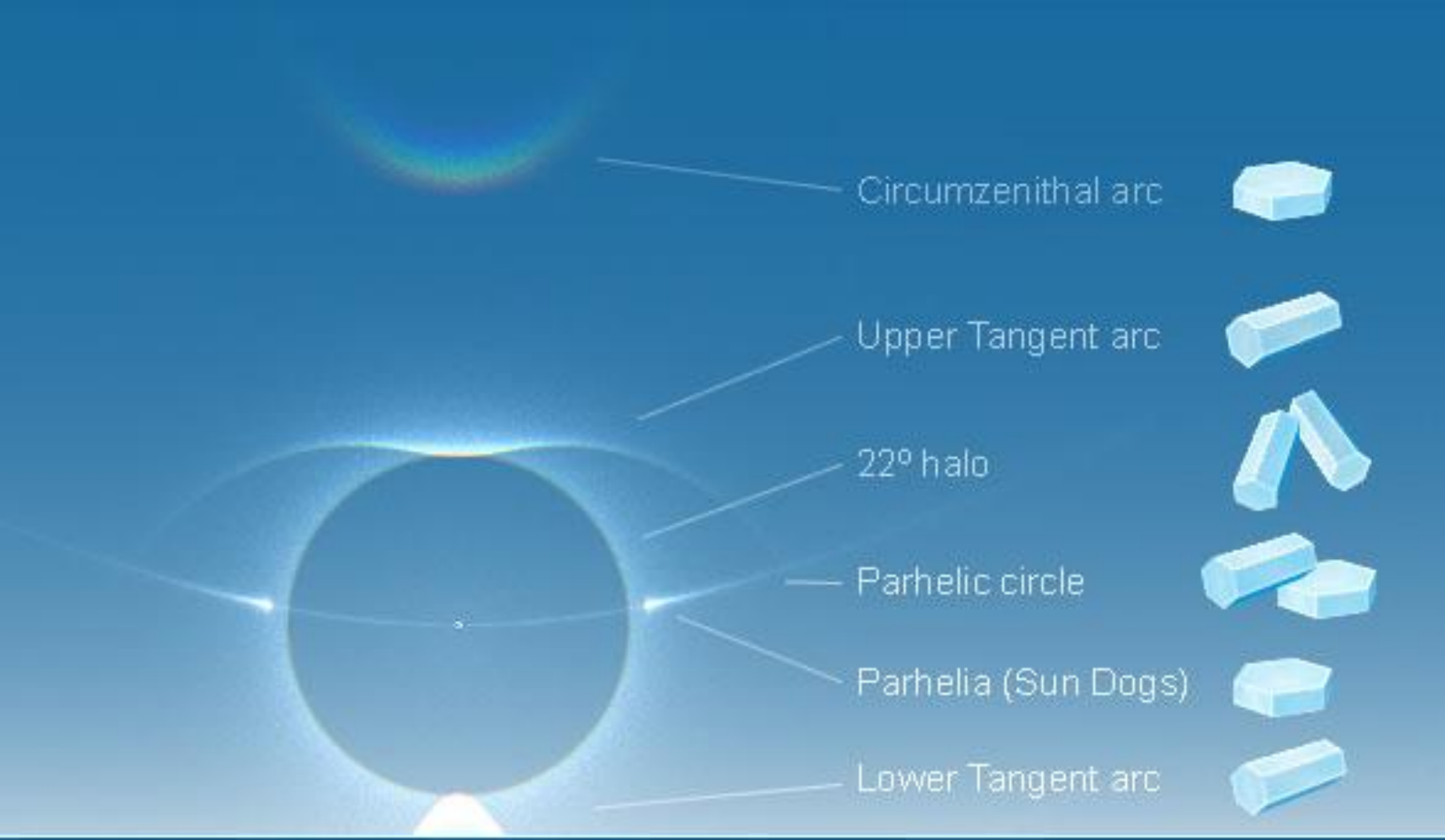


Crystals collected during a superb South Pole display on 17th January 1986. Apart from a few small air bubble inclusions, the crystals really are like their hexagonal plate and column ideals.



Crystals from a mediocre halo display 16 days earlier. They have large inclusions and their faces are imperfect. *Photographs from 'Atmospheric Halos by Walter Tape' reproduced with permission.*

From http://www.atoptics.co.uk/halo/xtalreal.htm


Circumzenithal arc
Upper Tangent arc
22° halo
Parhelic circle
Parhelia (Sun Dogs)
Lower Tangent arc

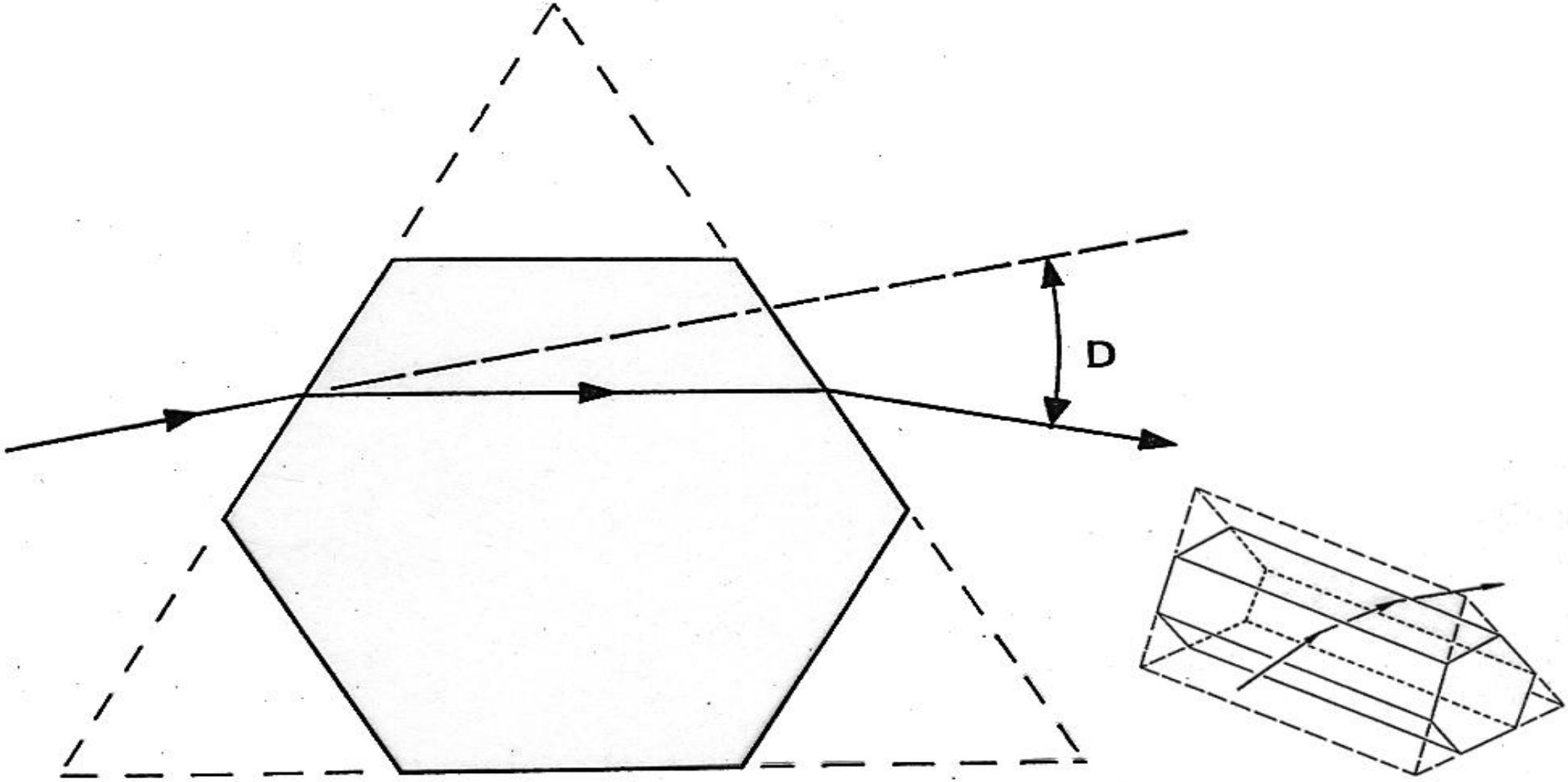
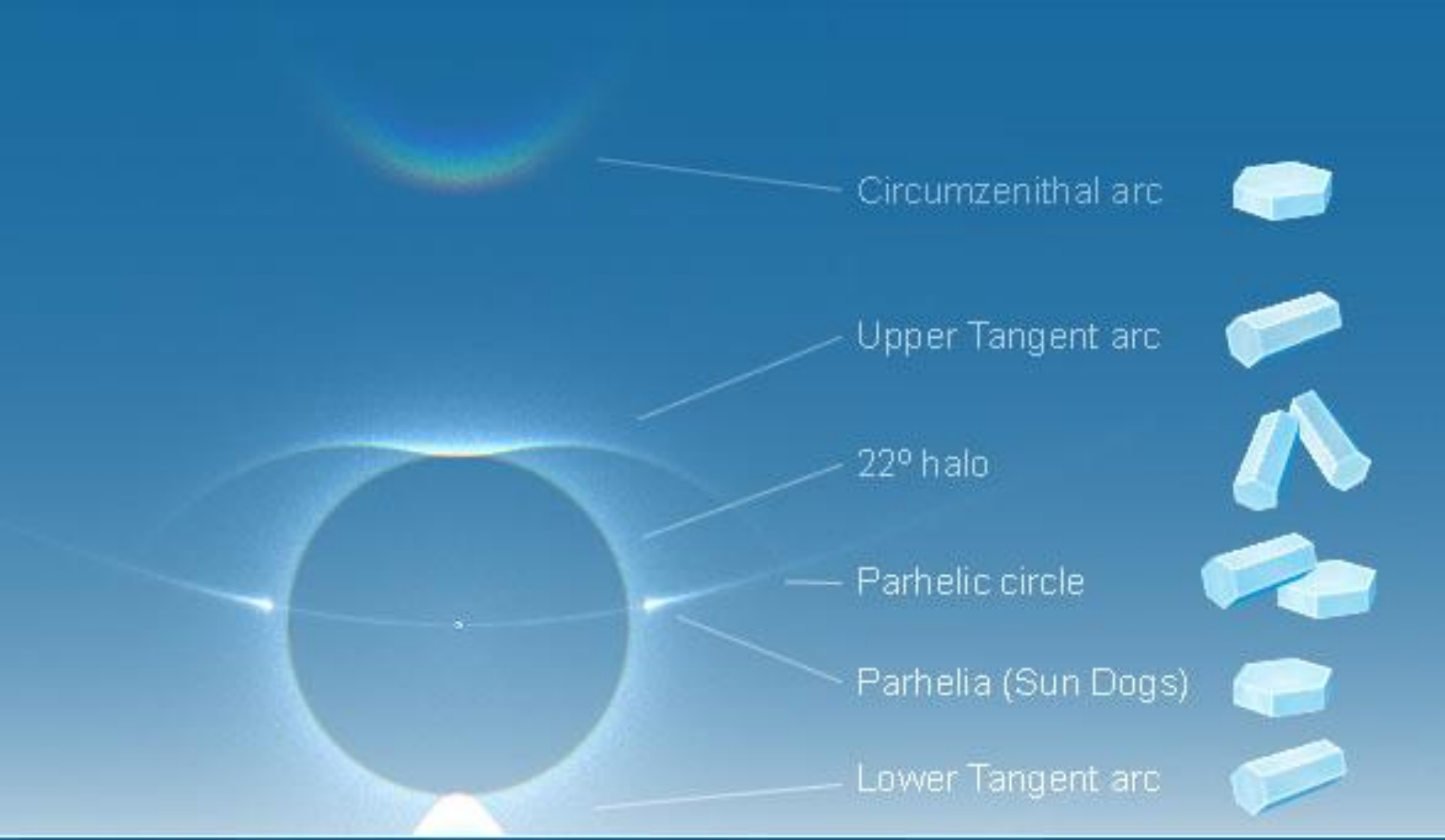
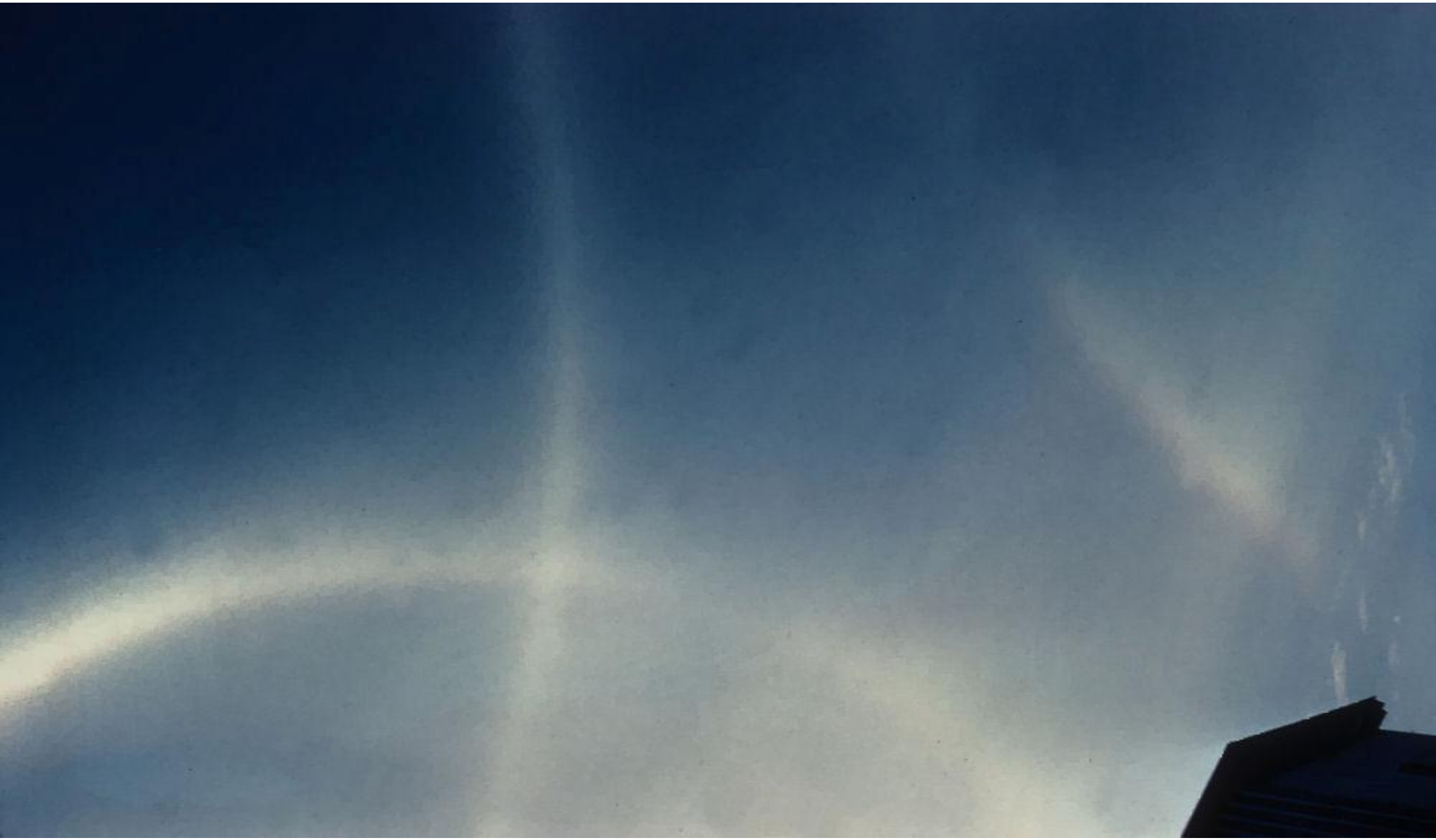


Figure 2-4. A light ray passing through a pencil crystal is refracted as if it were passing through a 60-degree prism.


Circumzenithal arc
Upper Tangent arc
22° halo
Parhelic circle
Parhelia (Sun Dogs)
Lower Tangent arc

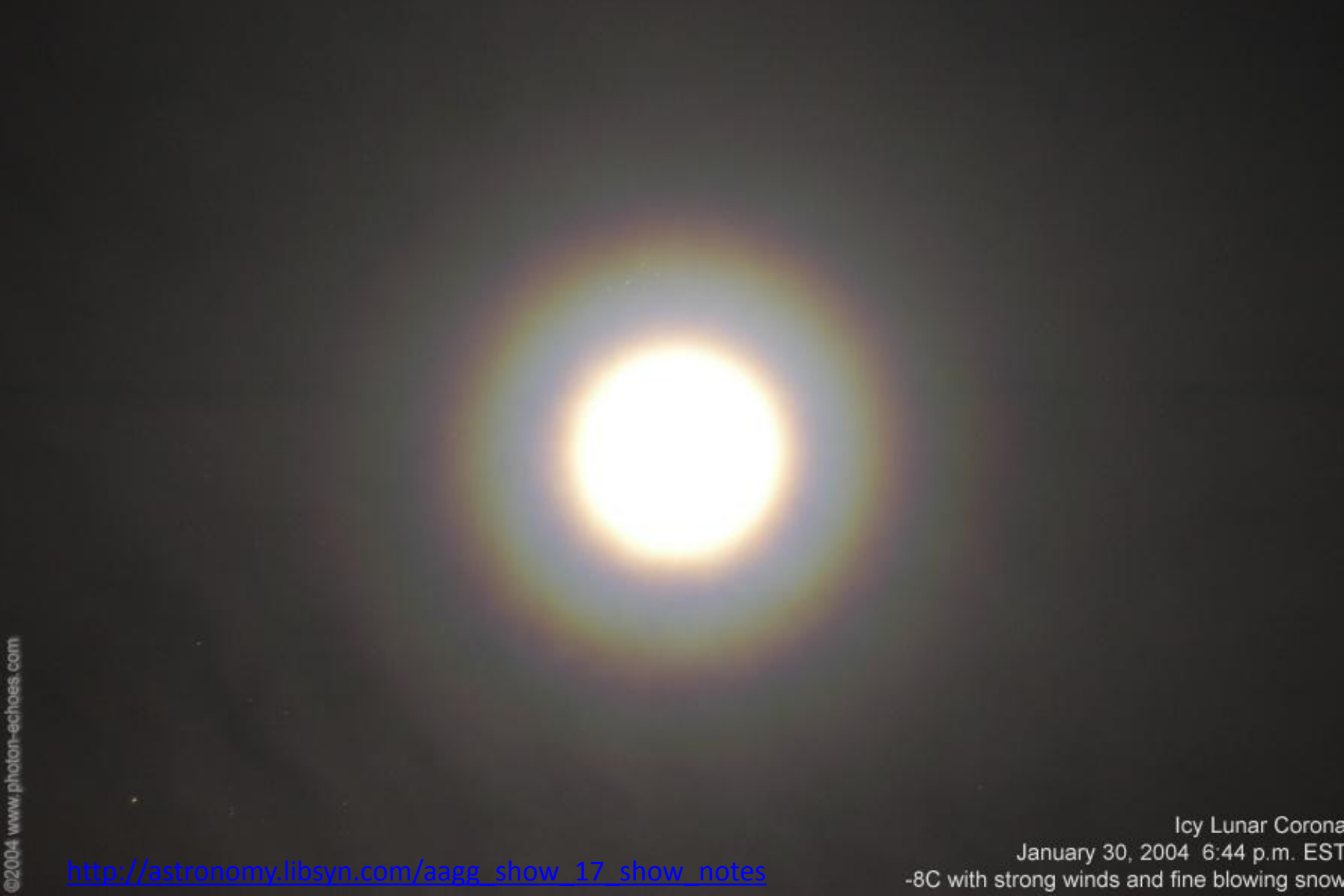


Glories and Coronas

Diffraction around spherical water droplets

Corona of the Sun caused by pollen
Copyright Harald Edens
http://www.weatherscapes.com/photo.php?cat=photo_month&id=w-846-13

Corona of the Sun from supercooled water droplets
Photographed by Ed Stockton
http://gizmodo.com/5868181/the-skies-of-greenland-are-full-of-alien-optical-effects



http://astronomy.libsyn.com/aagg_show_17_show_notes

Iridescent clouds showing Airy rings
http://pvastro0714.blogspot.com/2007/11/25-iridescent-cloud-over-colorado.html

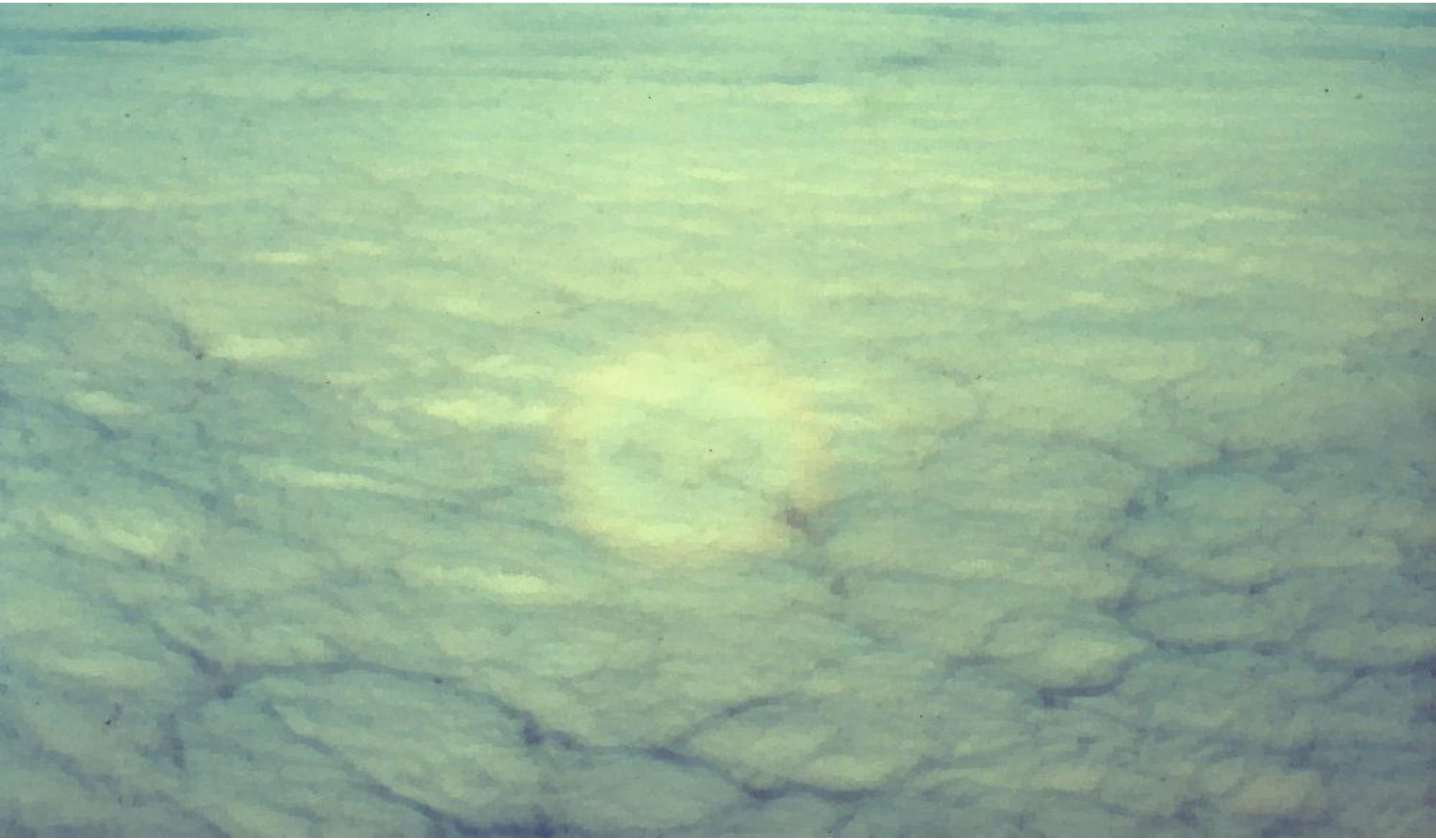
Iridescent clouds
http://www.uapreporting.org/?p=1261

Airplane glory

http://astrobob.areavoices.com/files/2012/06/Glory-diffraction-Wiki-credit-1024x590.jpg

From http://www.atoptics.co.uk/droplets/gloim21.htm

Jonathan Lansey (site) saw this unusually bright glory while descending into Houston. It is centred on the position where he was seated.



Specter of the Brocken

From http://www.atoptics.co.uk/droplets/gloim29.htm

From Royal Air Force Mountain Rescue Service

Brocken specter In thin mist

From http://www.atoptics.co.uk/droplets/brockim1.htm