

# Atmospheric Effects are Looking Up

OASI Workshop  
21<sup>st</sup> May 2018

by Olaf Kirchner



**Ever seen one of these ?**



**OK, so how about one of these?**

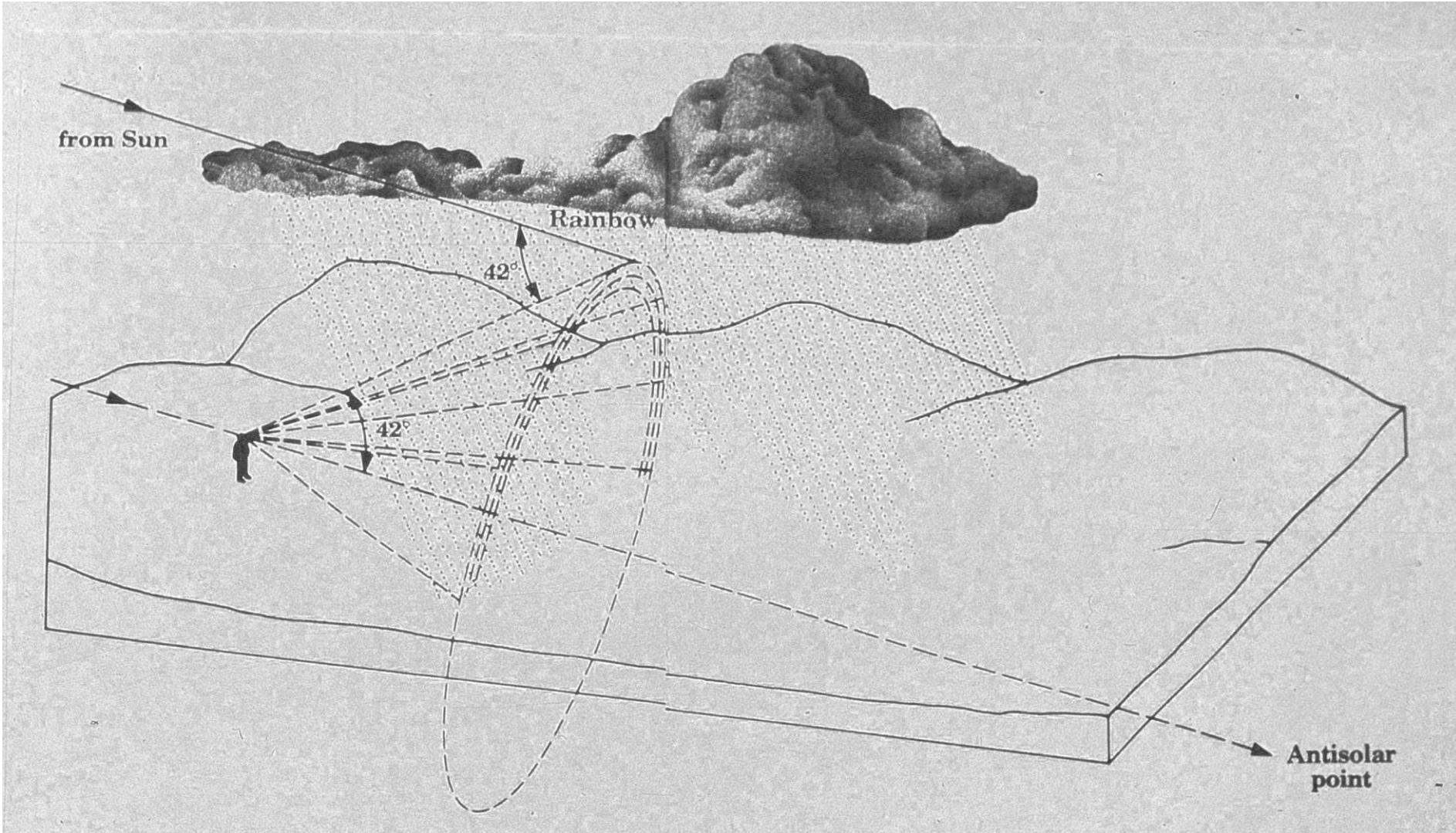
# Atmospheric Effects

- caused by sun- or moonlight interacting with liquid water or ice in the air
- surprisingly common
- always beautiful and one or several phenomena may be seen at the same time
- can be in-your-face obvious or very subtle, and ...
- ... span the entire sky - a challenge to photograph
- very complicated theoretical explanations

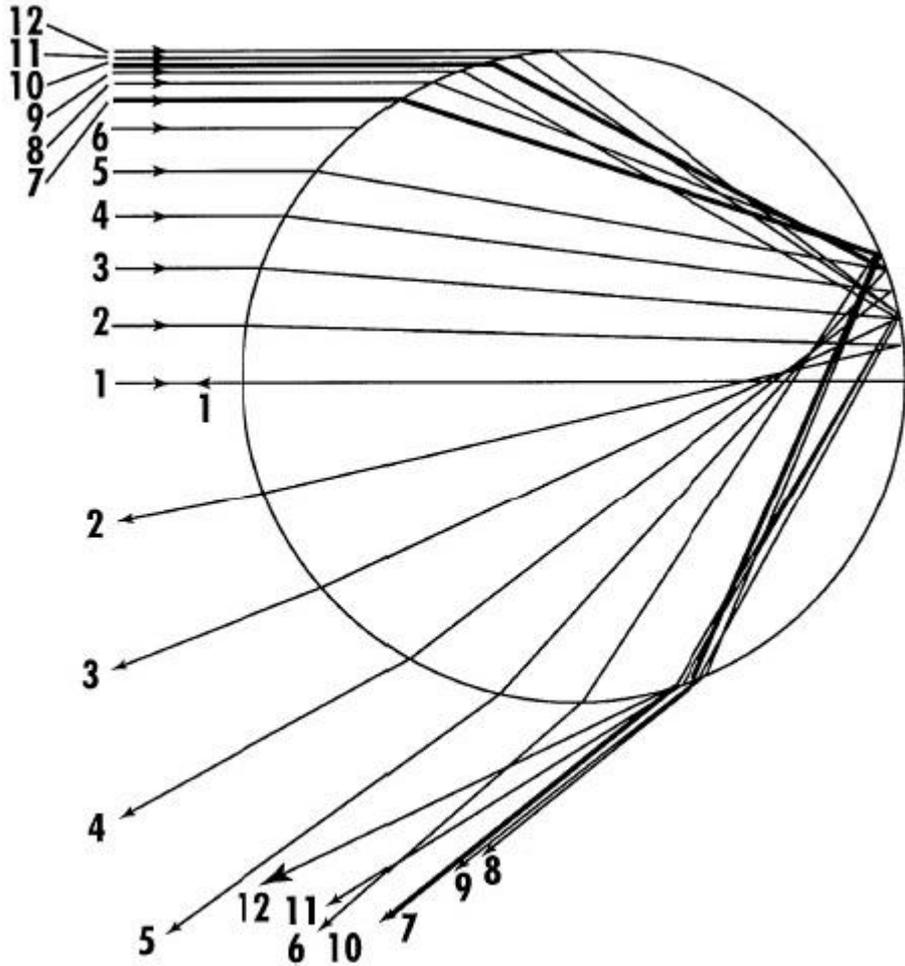
# Effects caused by Liquid Water Droplets

- rainbows
- glories, *Heiligenschein* and the Spectre of the Brocken
- aureoles / coronae
- nacreous / iridescent / Mother-of-Pearl clouds

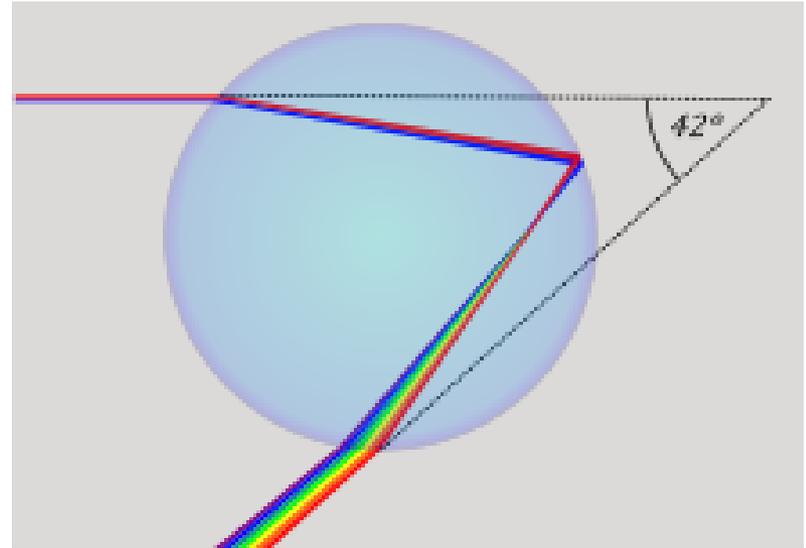
# Rainbow



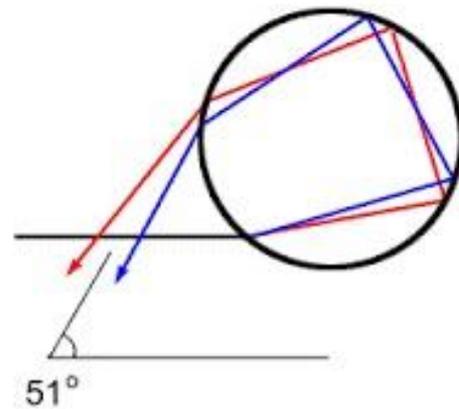
# Rainbow



Ray paths through a spherical water drop



Ray paths for primary rainbow



Ray paths for secondary rainbow

# Secondary Rainbow



Secondary rainbow

Alexander's Band

↑  
Supernumerary rainbow

Primary rainbow

# Rainbow

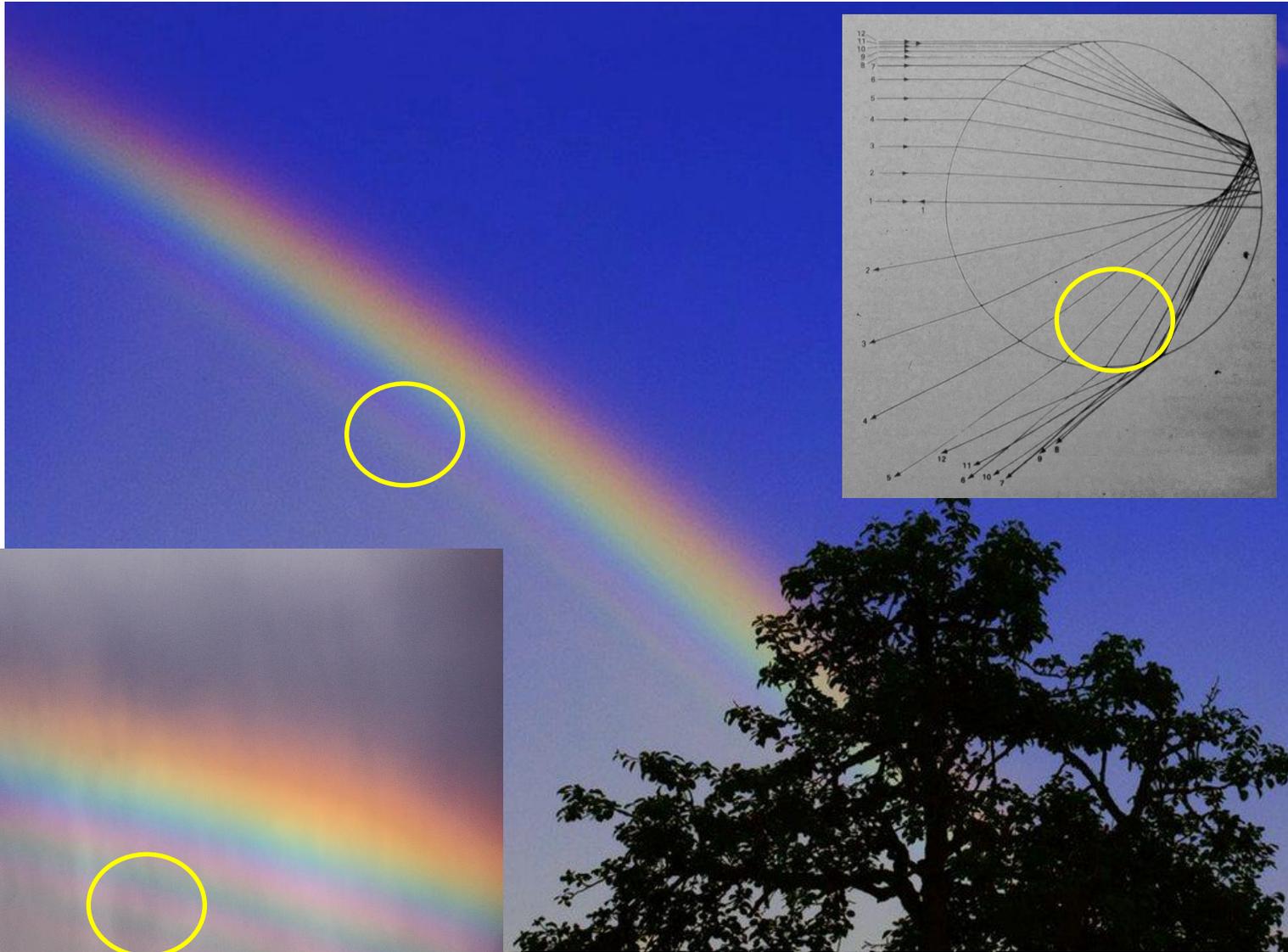


Rainbow in spray, Geneva *Jet d'Eau*



Gap in cloud behind observer = partial rainbow

# Supernumerary Rainbow

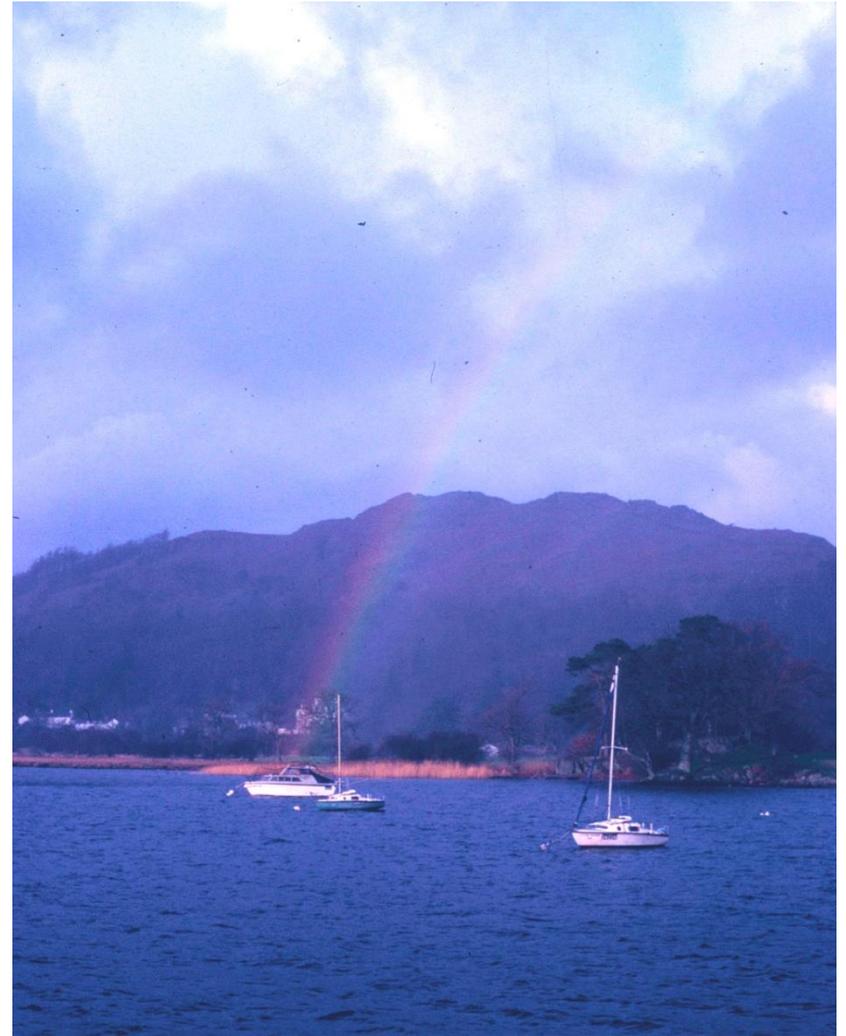


Interference colours from different lengths of light path

# Rainbow



Circular rainbow seen  
from an aircraft

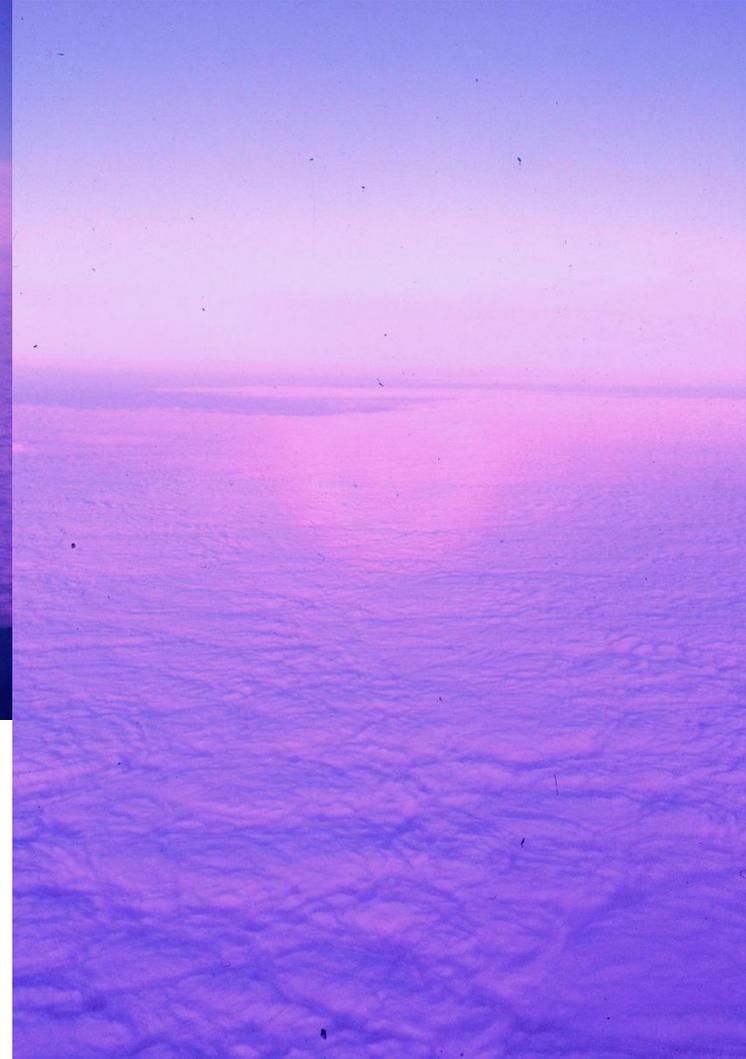


Rainbows don't reflect ...

# Glory

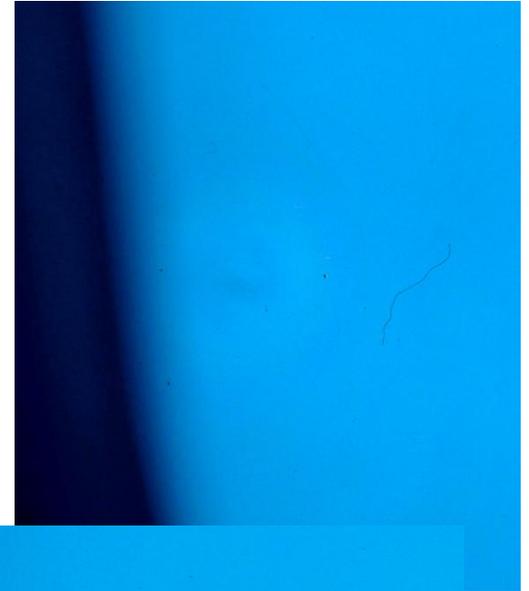


Colourful diffraction rings centred on the antisolar point, caused by reflection from spherical droplets

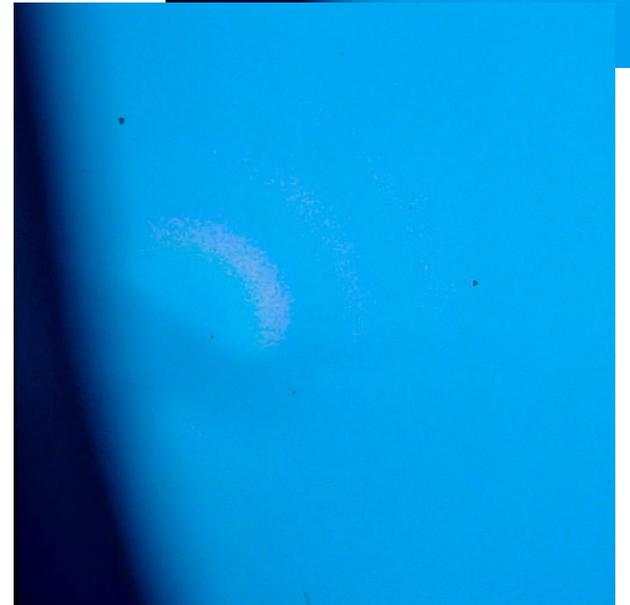




Glory



... i.e. centred on where the shadow of your head would be!



# *Brockengespenst* = Spectre of the Brocken



Taken against fog from Golden Gate Bridge

# Brocken (1142 m)



Highest point in the Harz mountains



# *Heiligenschein* = Halo



Antisolar point in hydrothermal steam ... scary stuff

# *Heiligenschein*



... i.e. a glory centred on your head



## *“Dry Heiligenschein”*

Light area around  
antisolar point  
(around aircraft  
shadow)

# *“Dry Heiligenschein”*



... caused by leaves shading leaves

# Aureole (Corona)



More diffraction  
going on



# Aureole (Corona)



Beautiful colours if you're lucky

# Nacreous / Mother-of-Pearl / Iridescent Cloud



Diffraction effect -  
colours depend on  
angular distance from  
the sun and droplet  
size !

# Nacreous / Mother-of-Pearl / Iridescent Cloud

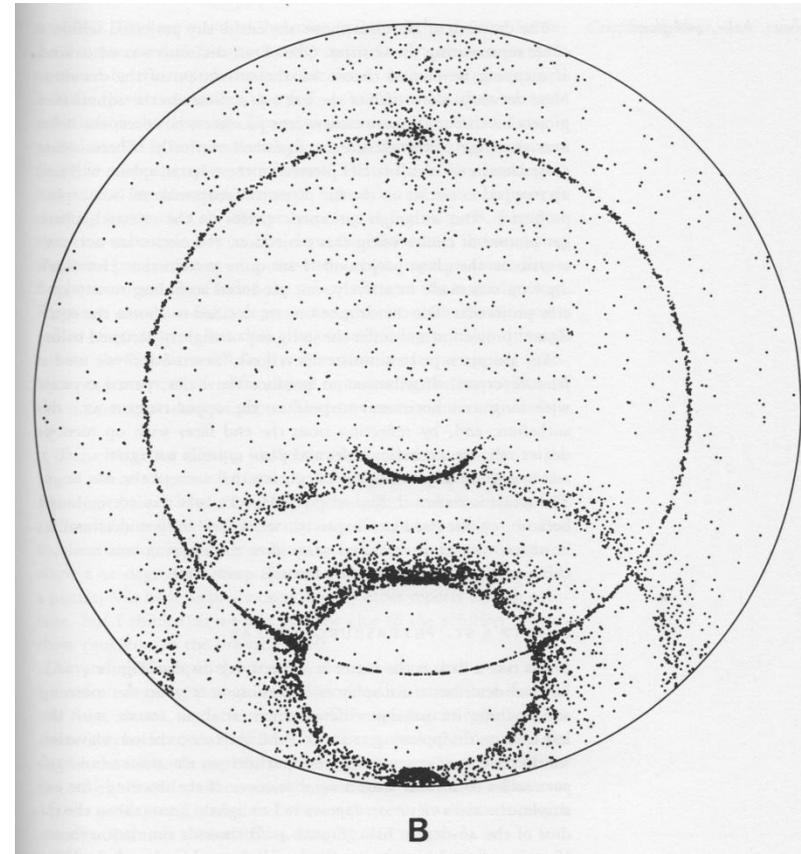
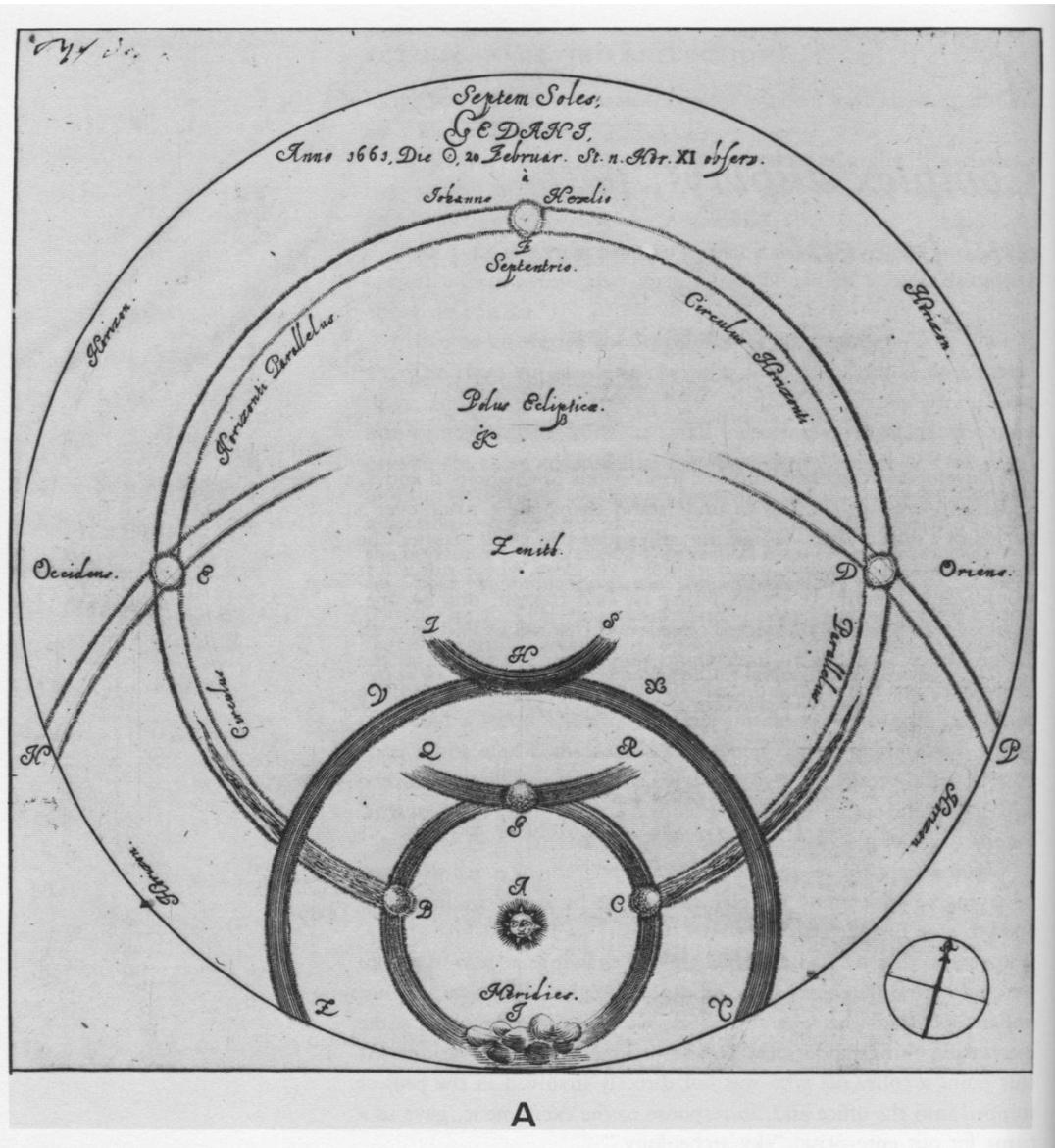


One of my favourite lamp post pictures

# Atmospheric Effects caused by Ice Crystals

- historical observations
- what shapes are the crystals and why are their effects so complex?
- reflections from crystals (subsuns, sun pillars)
- halos and associated zoo (sundogs, circumscribed halos, tangent arcs, circumzenithal arcs, parhelic circles etc. etc.)

# Historical Observations of Atmospheric Effects

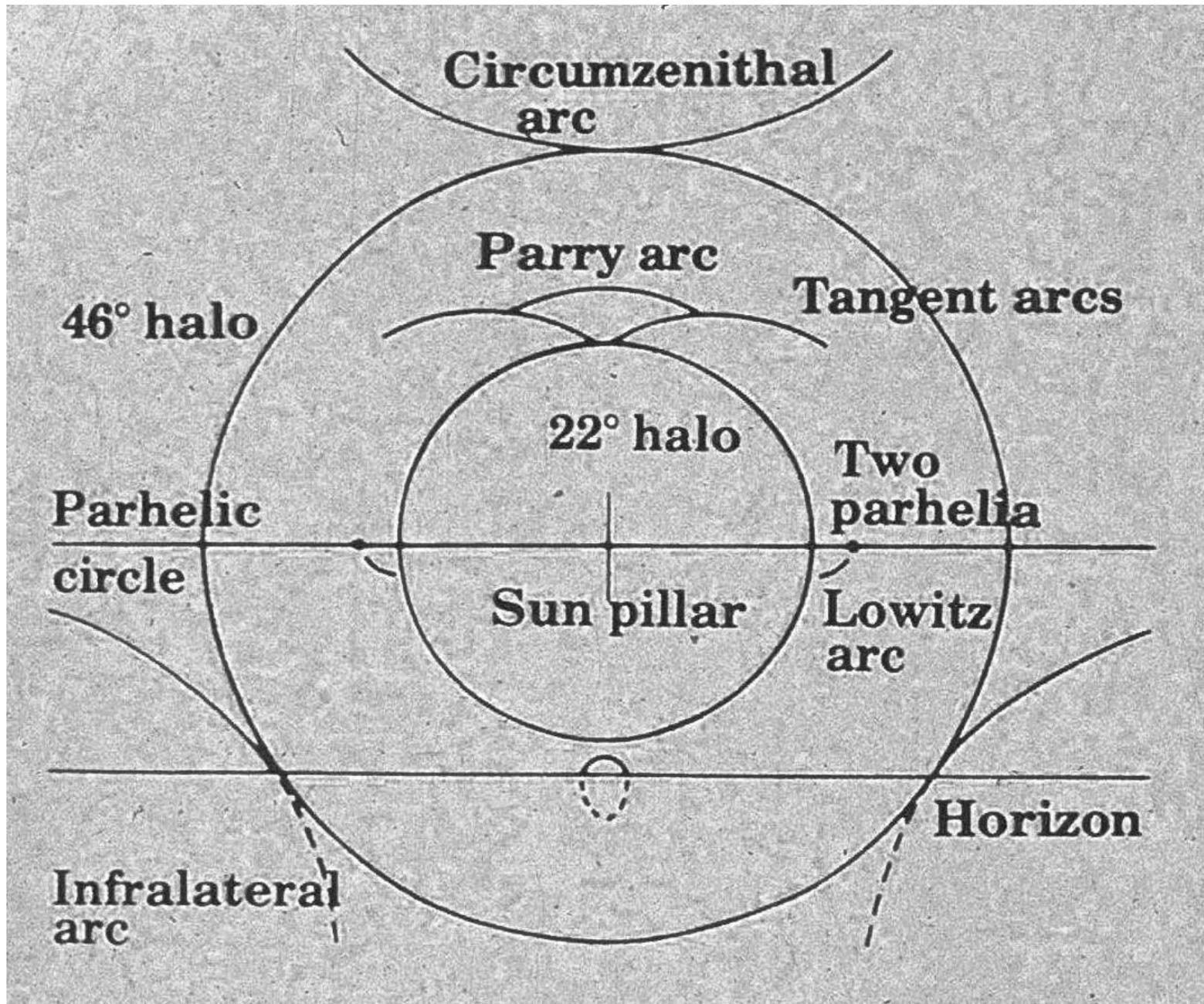


Computer  
Simulation

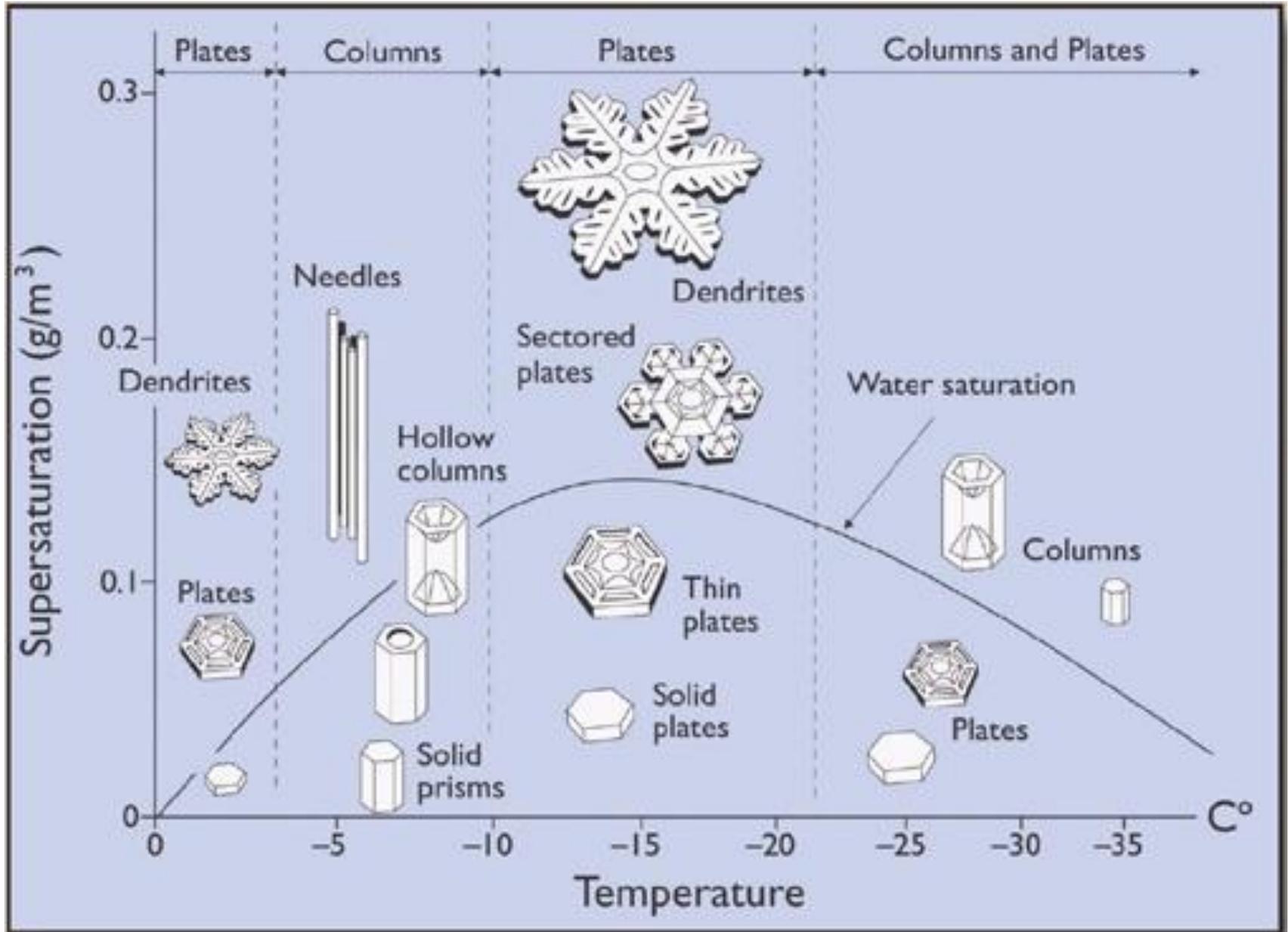
*Seven Suns* by Hevel (Hevelius), Gdansk / Danzig 1662



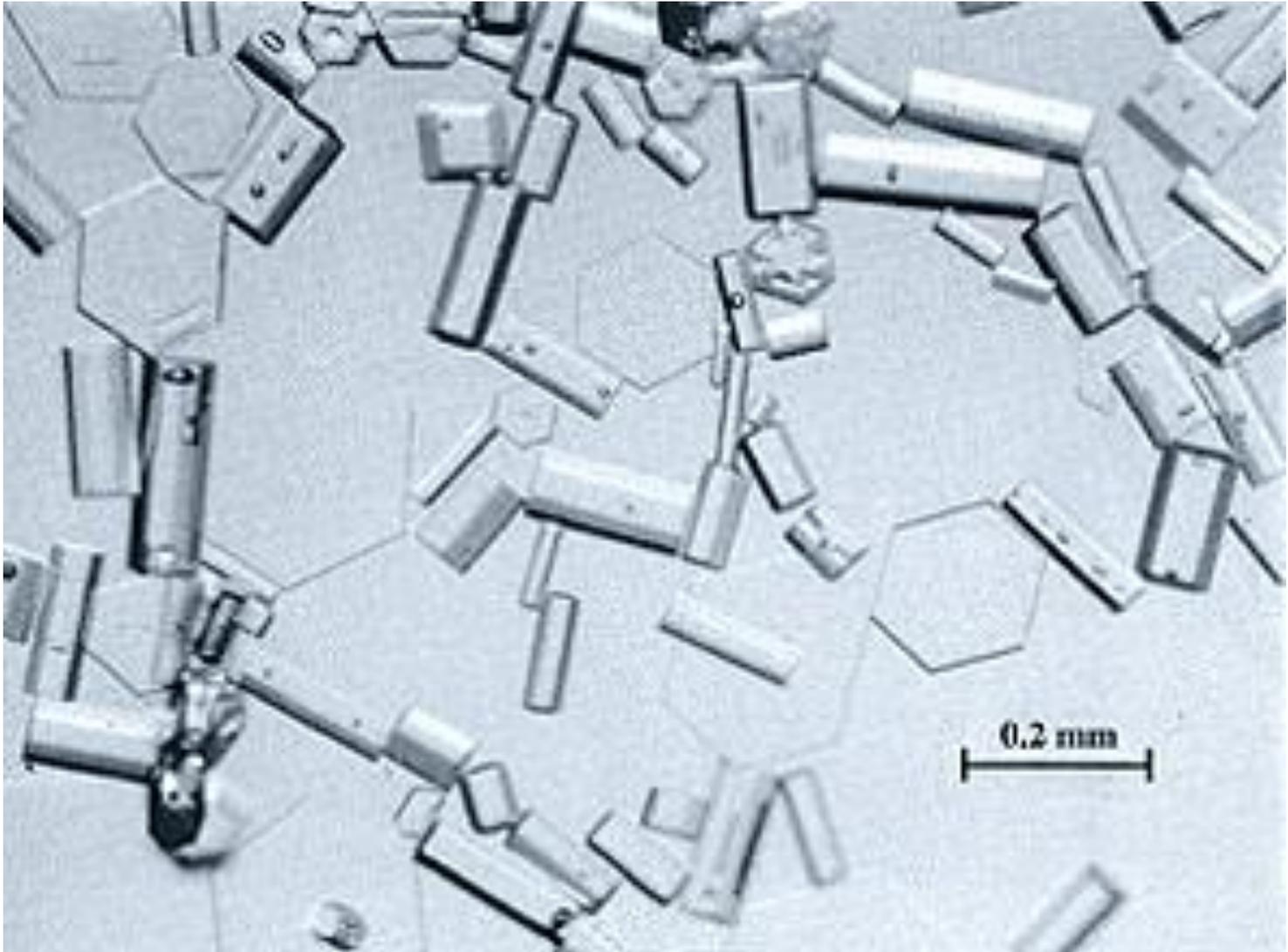
# Common Atmospheric Effects



# Ice Crystals

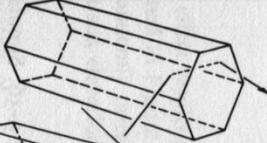
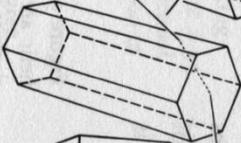
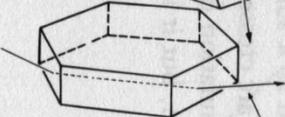
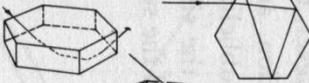
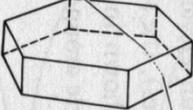
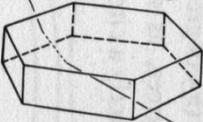
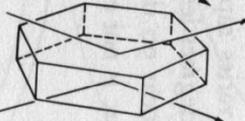
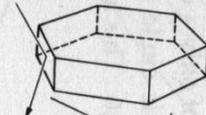
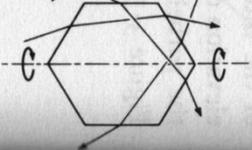


# Ice Crystals



Perfect hexagonal plates and pencils / needles (rare!)

# Ice Crystals: Plates and Pencils / Needles

Crystal type and orientation	Name of effect	Path of light ray	Figure showing simulation of effect	Comment
Pencil or plate crystals with random orientations	22° halo		2-7	Seen for all sun elevations
	46° halo		2-25	Seldom, if ever, seen complete
Plate crystals with nearly horizontal bases	22° parhelia (sun dogs)		2-8	Cannot be formed for sun elevations greater than 61°; additional internal reflection off base results in subsun dogs
	120° parhelia			Probable mechanisms for 120° parhelia: sketch on left for high sun elevations, on the right for low elevations
	Circumzenithal arc		2-28	Can occur only for sun elevations below 32°
	Circumhorizontal arc		2-29	Can occur only for sun elevations greater than 58°
	Sun pillar and subsun		3-4	Can also be produced by reflection from sides of pencil crystals with long axes horizontal
	Parhelic circle			Can also be produced by reflection from ends of pencil crystals with long axes horizontal
Plate crystals spinning about a horizontal axis that passes through opposite points of a hexagonal base	Lowitz arcs		2-23	Explanation not well verified; few photos available

# Sun Pillar

Reflection off  
horizontal surfaces



# Subsun



Reflection off horizontal surfaces of ice crystals below

# Subsun

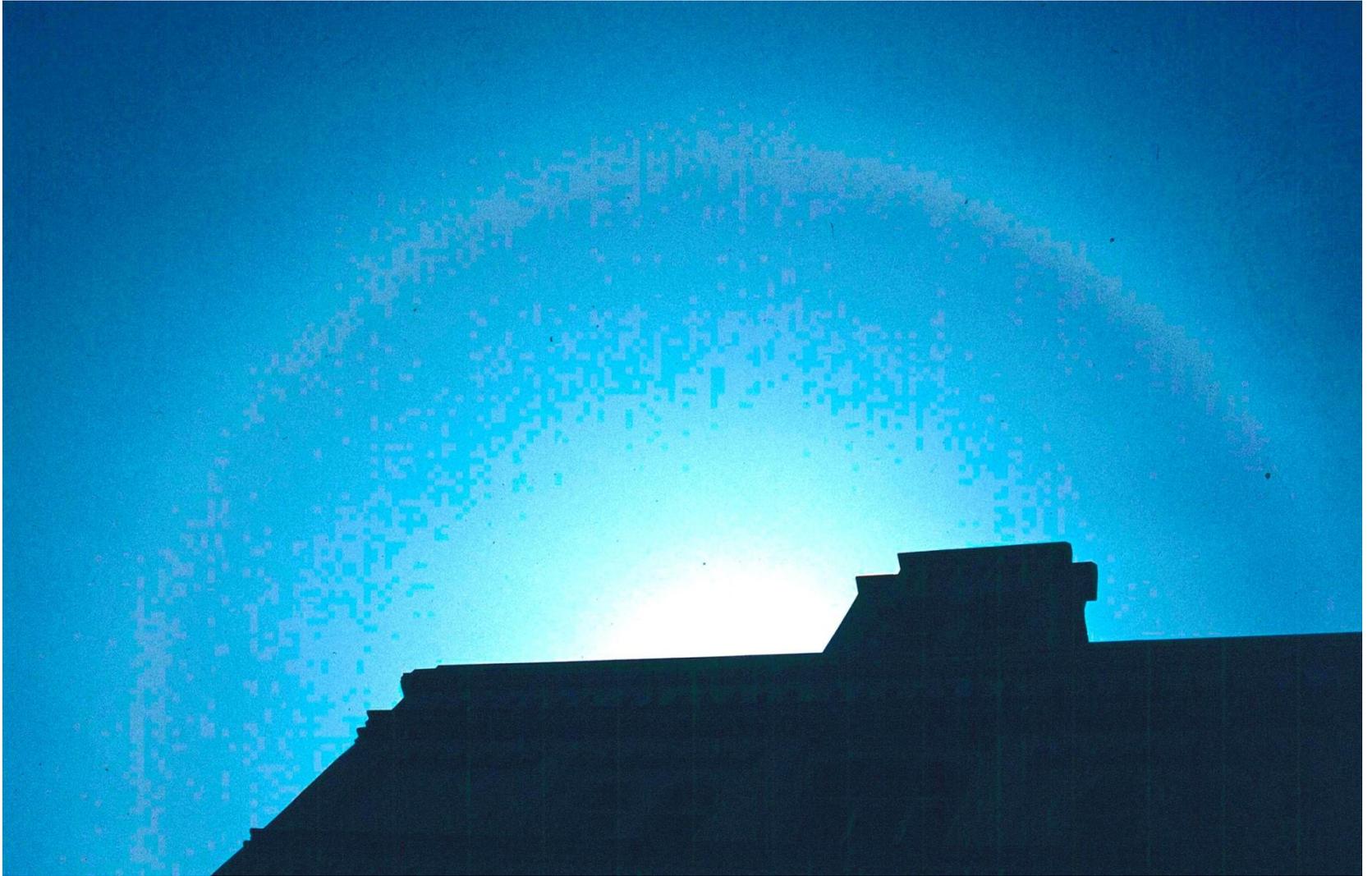


No layer of ice crystals,  
sun reflects from ocean



Layer of ice crystals below = subsun

# 22° Halo



Well formed randomly oriented hexagonal ice crystals

# 22° Halo

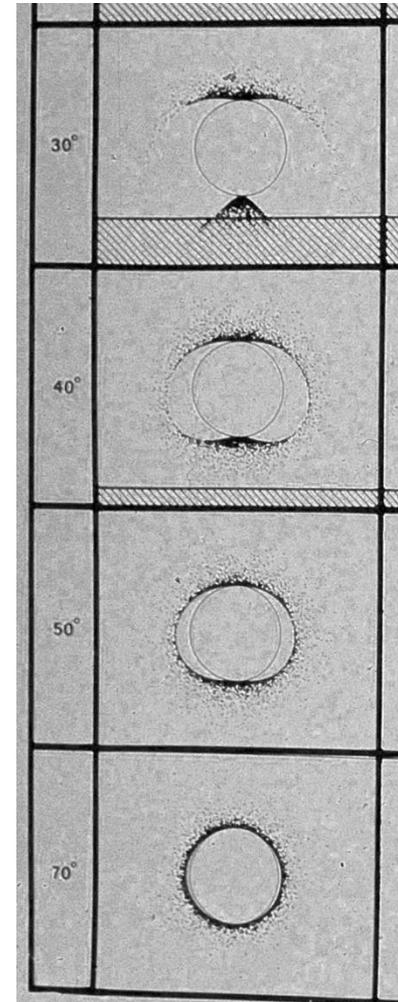


... a professional shot

# Circumscribed Halo



Frequently see just top and bottom edges of 22° halo



# Sun Dogs (Parhelia)



... caused by well formed, falling pencil ice crystals

# Sun Dogs (Parhelia)



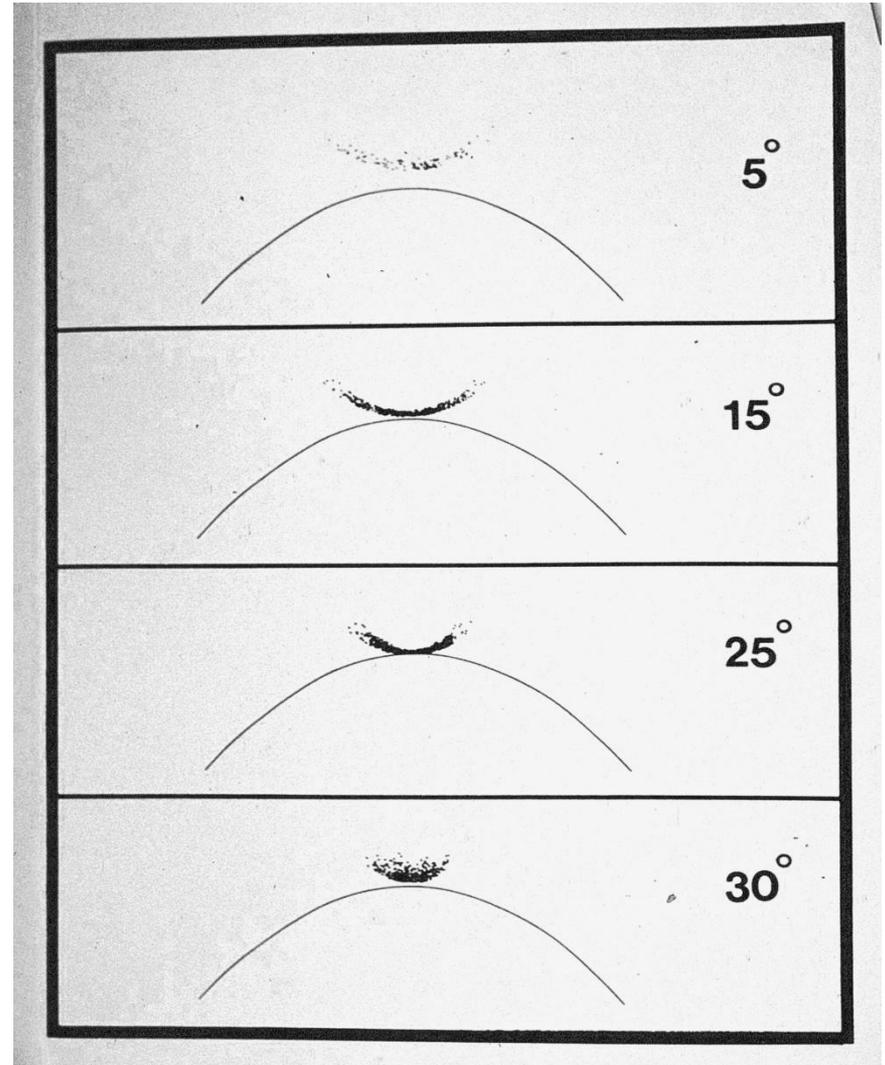
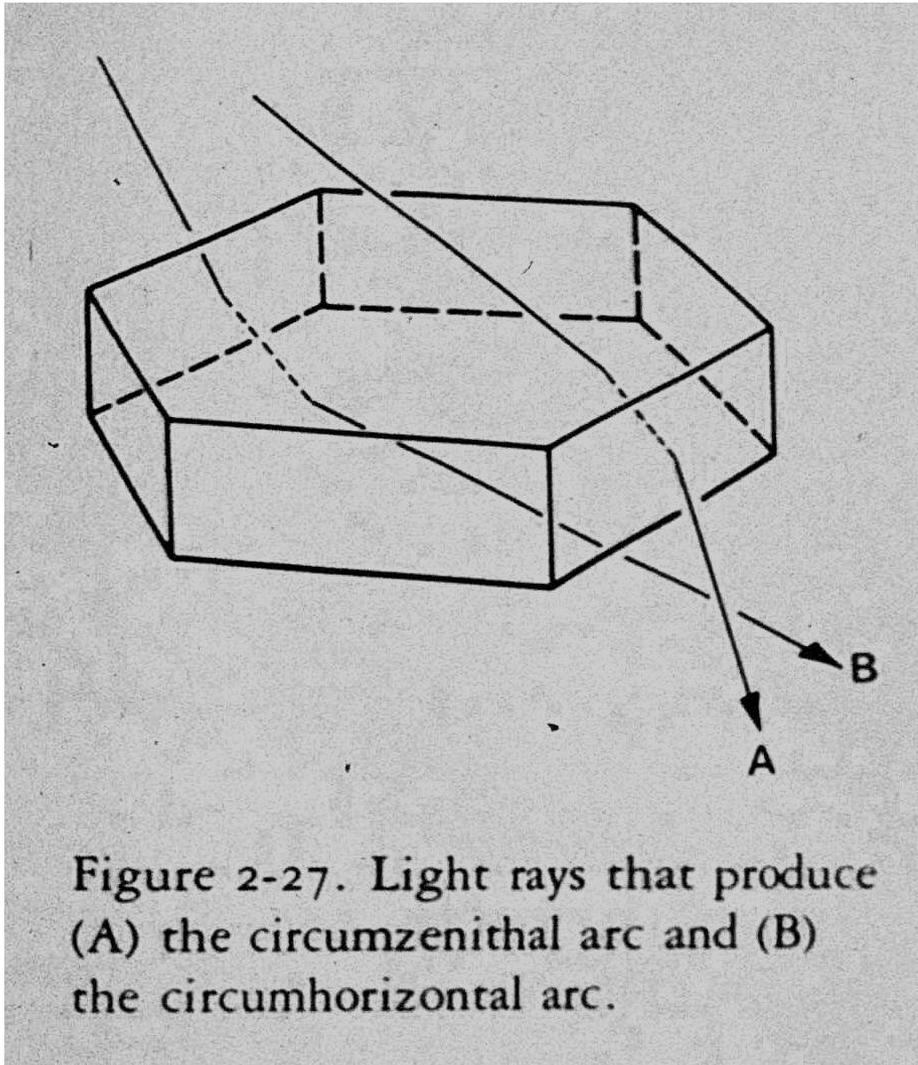
Sunset from above

# Circumzenithal Arc



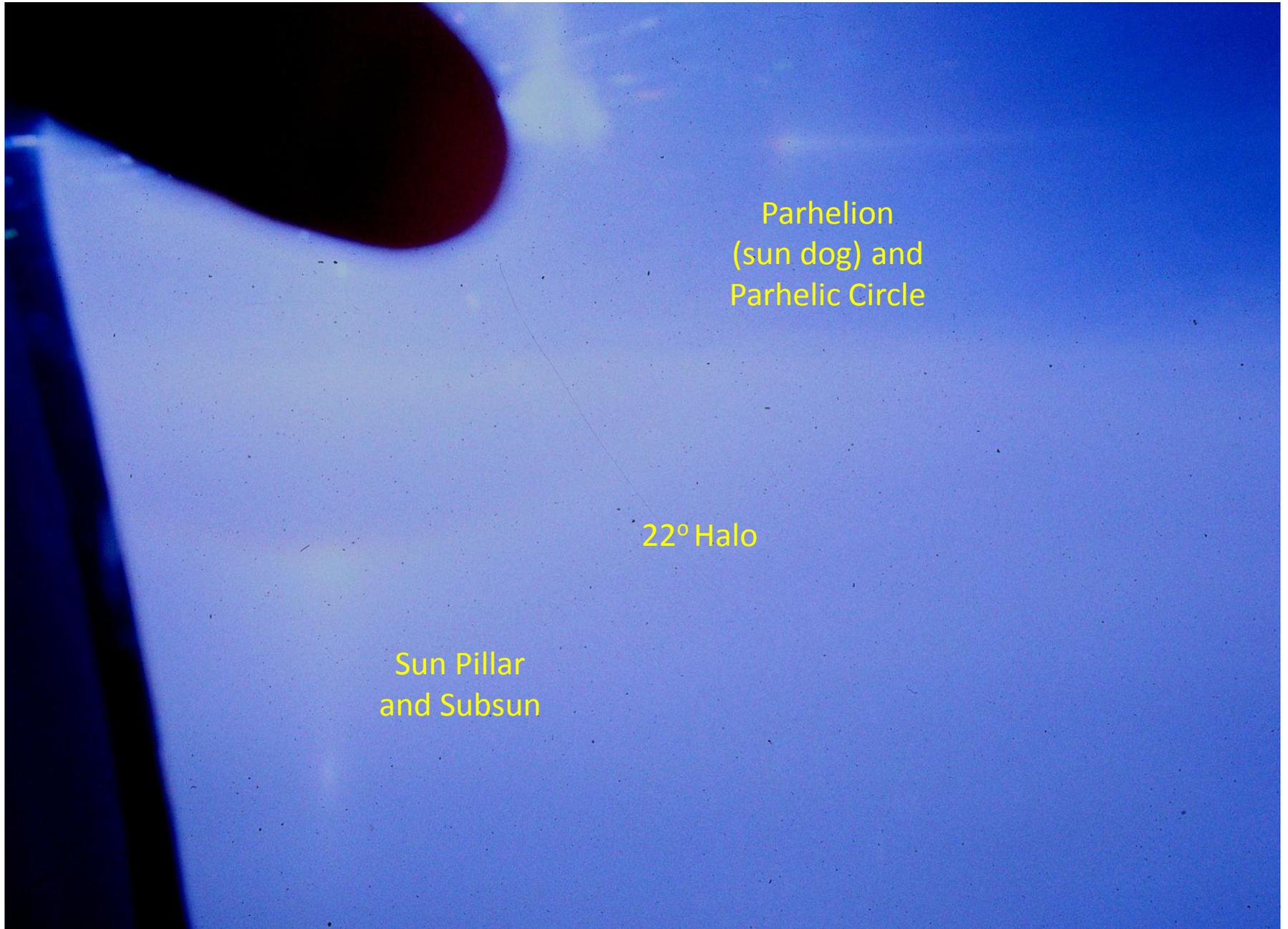
Don't forget to look right up!

# Circumzenithal Arc

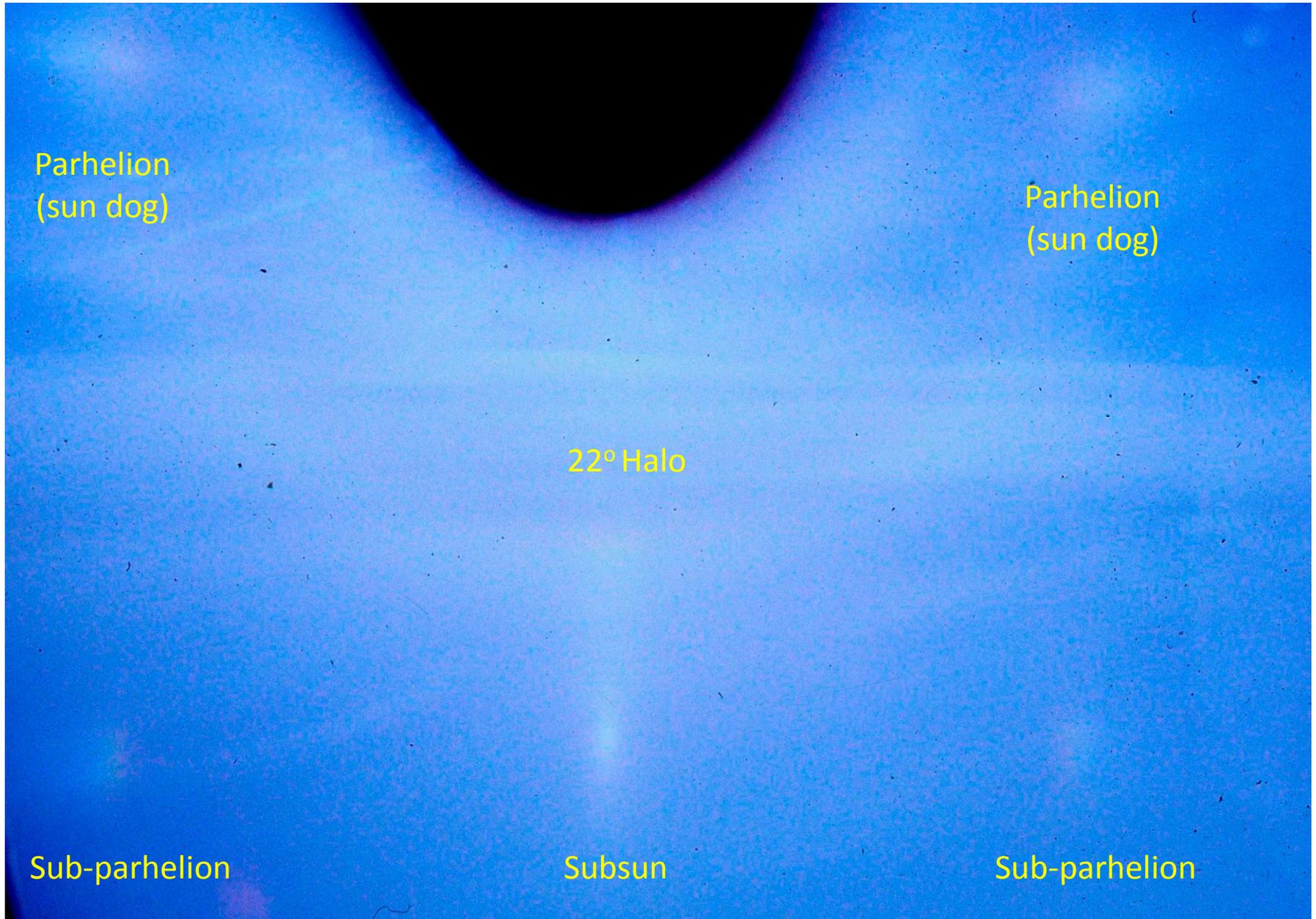


Ray path and simulation

# Multiple Atmospheric Effects

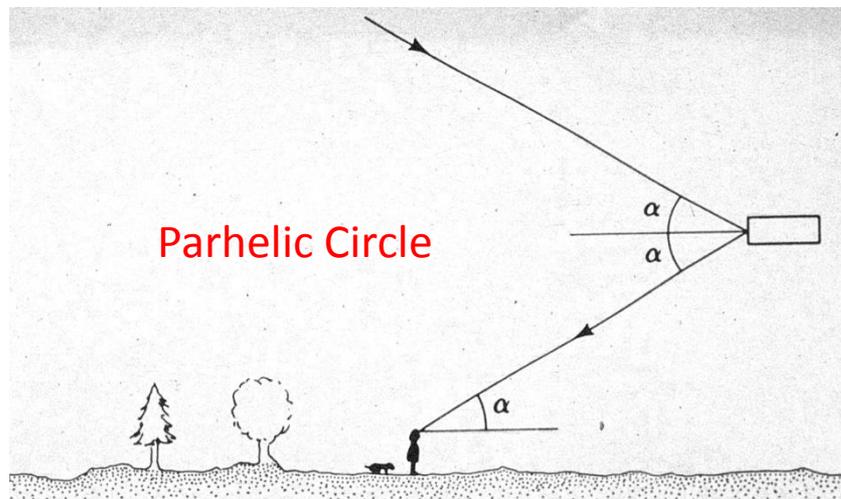


# Multiple Atmospheric Effects – 5 minutes later



Parhelic Circle and 120°  
Brightening

# Parhelic Circle



Parhelic Circle and 240°  
Brightening



# Multiple Atmospheric Effects



... once on a lifetime sight

# Multiple Atmospheric Effects



Shown with permission. © [www.ice-halo.net](http://www.ice-halo.net)

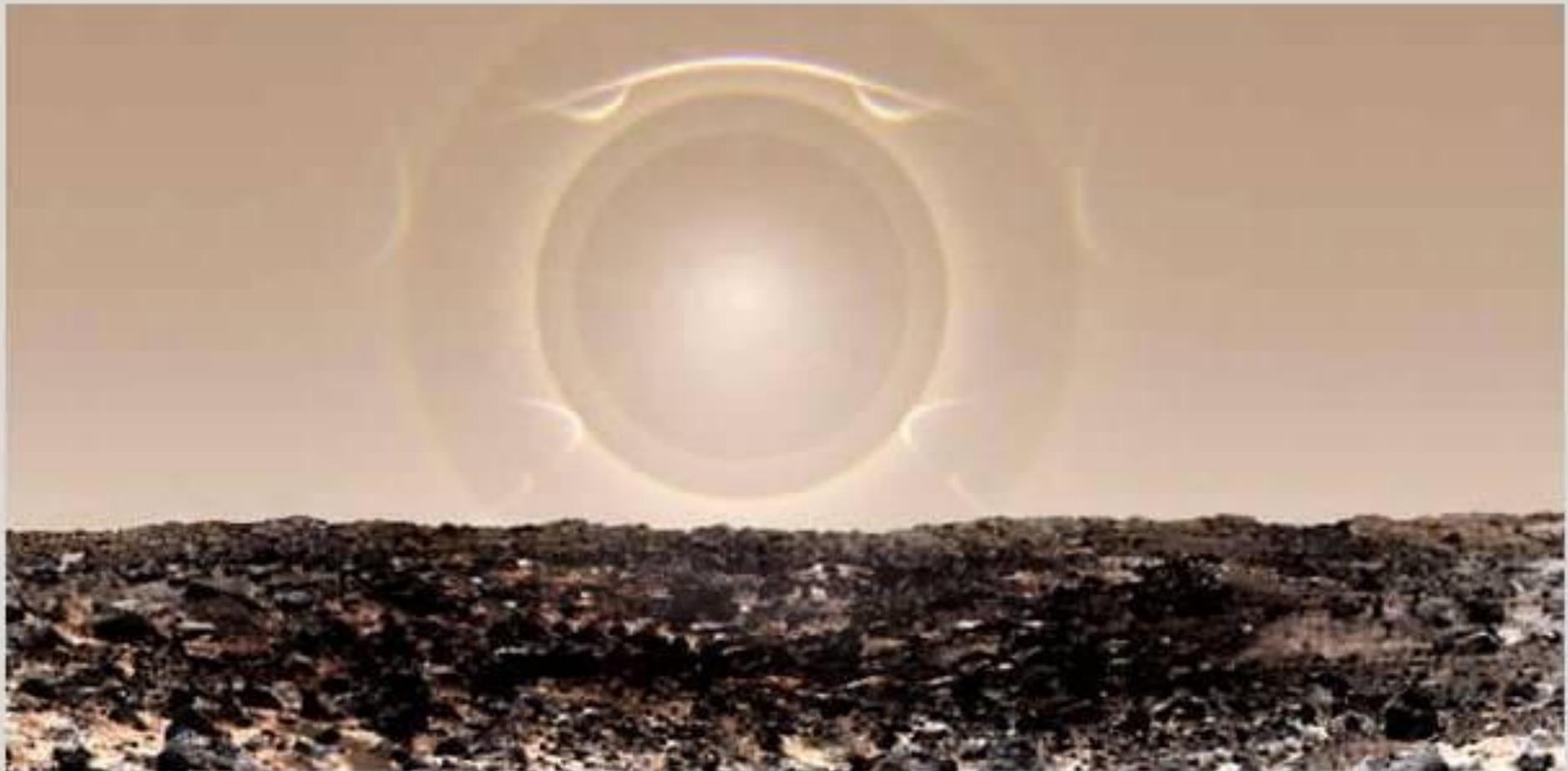
# If you want to know more ...

“Rainbows, Halos, and Glories” by Robert Greenler (1980) = The Book

“The nature of Light and Colour in the Open Air” (1954) by Marcel Minnaert = The Other Book

Downloadable simulations program (including for extraterrestrial displays) from [atoptics.co.uk](http://atoptics.co.uk)

atoptics.co.uk



*Halos formed by clouds of frozen carbon dioxide shine in a dusty Martian sky. Familiar water-ice crystals form the inner 22° halo. CO<sub>2</sub> cuboctahedral crystals produce the next of 26° radius and the outer 39° halo is from octahedra and cuboctahedra. Cuboctahedral platelike crystals generate multiple parhelia and the bright uppermost arc. Fainting & HaloSim3 simulation by Les Cowley*