Fogged Lenses and Pollen Coronae

Ian Jacobs, Physics advisor, KVIS, Rayong, Thailand

Multi-ring coronae surrounding the sun and full moon with two and sometimes three outer rings are due to diffraction by water droplets in distant clouds. The droplets are randomly spaced, well-separated. If they are not of nearly the same size only the central disc (the aureole) is seen: bluish in the centre, changing through yellow to reddish on the outer edge.

Fig 1 – The aureole surrounds the sun in a reflected image. No outer rings are seen because the droplets that formed the diffraction pattern are not of uniform size.

Fogged lenses

Water droplets are close-packed on a fogged lens, not randomly distributed and well separated as they are in a cloud.

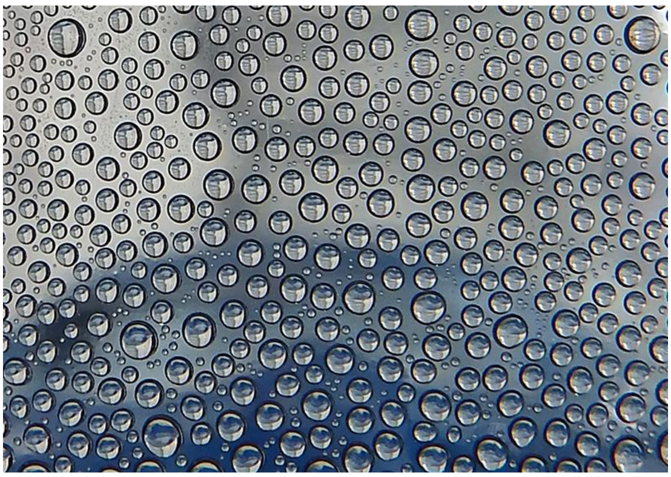

Fig 2 – Close-packed droplets with a non-random distribution.

Short irregular lines of drops produce radial interference streaks.

Fig 8 – Sunlight reflections and diffraction due to lens fogging.

Figure 3 has been darkened a little to bring out the colours in the diffraction patterns. Only the aureoles are seen, transitioning from blue through yellow to red. The radial streaks, not present in cloud coronae, are due to interference caused by the non-random distribution of close-packed droplets.

Changes over time

If the lens temperature is above the dew point water droplets evaporate at a rate that is proportional to their surface area. For spherical droplets $A = 4\pi r^2$ and the volume of water remaining is proportional to r^3. The rate of change of radius is constant, independent of droplet size. The smallest droplets are cleared first and the average size increases over time. As water evaporates the aureole shrinks.

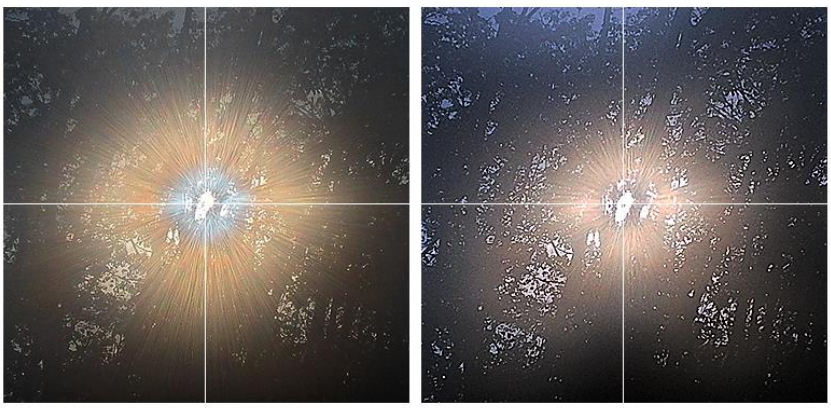

Fig 4 – The aureole shrinks over 10 seconds (left to right) as evaporation *increases* the average droplet size.

Figure 4 shows enhanced images of the aureole taken ten seconds apart, the first on the left, second on the right. The lens was fogged by breathing on it. In figure 4 the aureole shrank to about half the original size indicating that the average droplet size had doubled. The number of radial interference streaks also decreased over time. A 90º sector contains 36 – 40 streaks in the left-hand image and 20 – 24 streaks on the right.

A question

The image below was taken by Andrew Boyd from the beach at Bang Chang on the Gulf of Thailand**.** A breeze was blowing mist off the ocean**.**

Fig 5 – a diffraction pattern showing the aureole and first outer diffraction ring taken at Bang Chang on the gulf of Thailand

From what you have read give an informed opinion …..

a Is the corona local, due to condensation on the lens?

b Is the corona local in the sense of being formed in mist above the beach?

c Is the corona due to diffraction in distant clouds?

Justify your answer (a, b or c) with a paragraph reporting your detailed observations of the image.

Evaporation

In any evaporation process at constant temperature the rate of change of volume, is proportional to the surface area, $dV/dt = kA$.

$$dV/dt = dV/dr.\ dr/dt \qquad \text{… by the chain rule}$$

For spherical droplets the volume V is $^4/_3\pi r^3$ and $dV/dr = 4\pi r^2$, the surface area A.

$$kA = A\ dr/dt \qquad \text{... (the rate of change of radius is independent of drop size.)}$$

The same relationship holds for hemispherical drops on a surface.

Almost spherical drops rest on a hydrophobic leaf

Fig 6 – Five minutes later, on the right, the average droplet size has increased because many smaller drops have been removed by evaporation.

Something to think about ... At open-air events and in beer gardens there are fans that blow mist over the people and tables. Why is this done? Why are the water droplets in the mist made as small as possible?	

Five possible projects

Lens fog coronae

Fragments of the first outer ring of the diffraction pattern can be seen in the image below. The lens was fogged by breathing on it. No particular care was taken with the fogging process and the lens was above the dew point. The relative humidity was 75% and the ambient temperature was 24ºC, the same as the lens temperature.

Fig 7 – A lens-fog corona showing fragments of the first outer ring.

Project 1

Experiment with different methods of fogging a lens under different conditions of ambient temperature, lens temperature, and humidity. If conditions can be found that lead to the deposition of droplets of near uniform size outer coronal rings will become visible.

Report your findings with images of droplets and coronae.

Pollen coronae

The image below is by the well-known atmospheric optics photographer Mika-Pekka Markkanen from Finland.

https://commons.wikimedia.org/wiki/File:Pinus_Sylvestris_Pollen_Corona.jpg

Fig 8 – A pine pollen corona photographed in Kuusamo, Finland on the 11th of June 1010.

Pine tree pollen is in the upper atmosphere. Notice the regularity of the corona, the faint outer reddish edge of the aureole and the first, second and third outer rings indicating that the particles responsible for the diffraction are of the same size. The solar disc does not appear in the image but inspection shows that the corona is smaller than most cloud-drop coronae indicating that the particles are somewhere near 50 microns in diameter. Notice also that the rings, although regular, are not perfectly round, indicating that the pollen grains are not spherical and are falling with the same orientation. The reader is asked to search for an image of *Pinus sylvestris* pollen on the web to confirm the size, shape, and orientation of the falling pollen.

Project 2

Collect different pollens from local plants and spores from ferns and fungi, (puff-balls etc.)

Experiment with lens dustings and photographing coronae as above and/or by dusting screens and projecting onto a wall with a green laser pointer.

Relate the characteristics of the coronae to the shape, size and distribution of the different particles.

Condensation

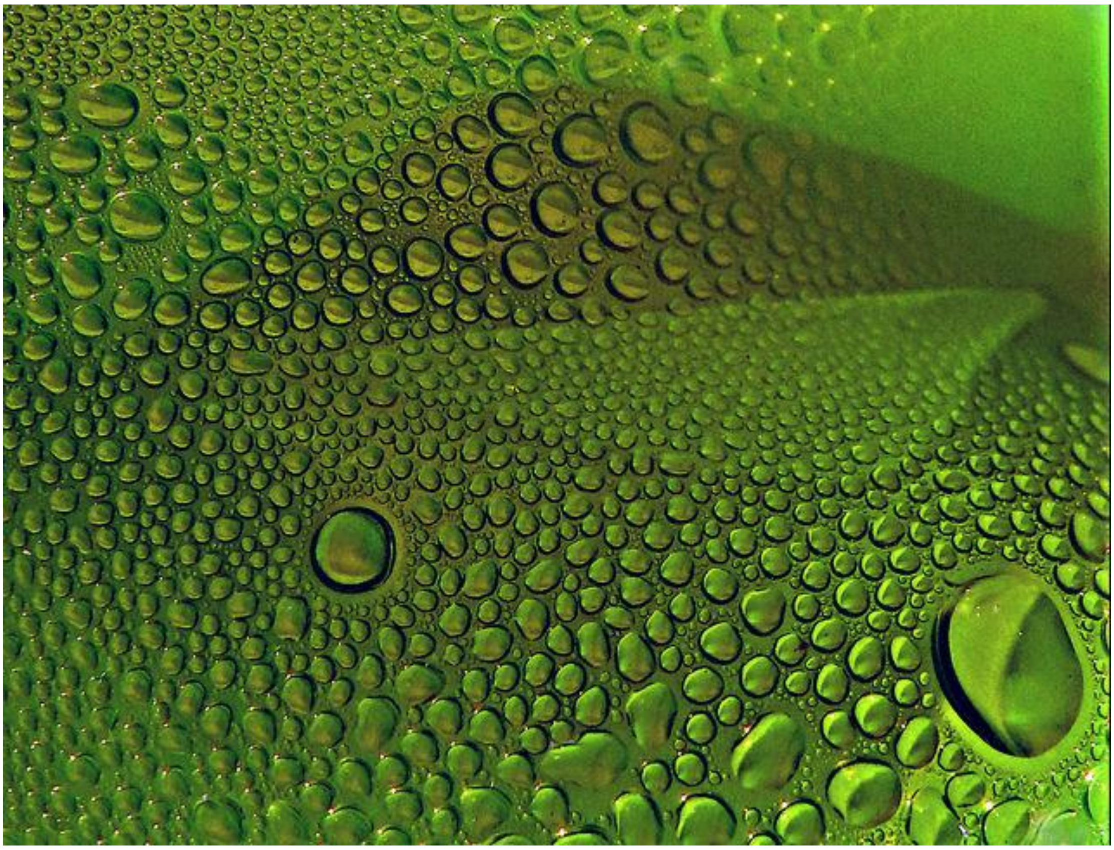

Fig 9 – water droplets condensed on the inside of a PET bottle that had been left outside for some hours.

We make the following observations.

The droplets are close-packed and not randomly distributed. There appear to be two populations of different sizes, large and small. The largest drops are surrounded by small drops with the smallest closest to the large drop. Without studying the history of formation it is not possible to determine the role played by the initial condensation, coalescence and evaporative transfer in the saturated atmosphere inside the closed bottle.

Project 3

By the analysis of photographs find the reduction in radius over time of several spherical droplets of different initial sizes resting on a lotus leaf.

Compare this rate with the reduction in radius over time of several near hemispherical droplets from a plastic (PET) surface under the same conditions.

Investigate the effect of salt concentration on evaporation rates.

Project 4

A sealed PET bottle contains a little water. *By taking photographs at intervals study the formation of droplet patterns similar to figure 8 above.*

Can you discover why the droplets are in two populations and why the largest drops are surrounded by a regular array of smaller drops?

Suggestions

Investigate condensation patterns at different constant ambient temperatures.

Investigate the effect of raising or lowering the temperature after the initial condensation has formed.

Add alcohol in known concentration to the water in the bottle.

Increase the pressure in the bottle.

Change the atmosphere to one of CO_2.

Project 5

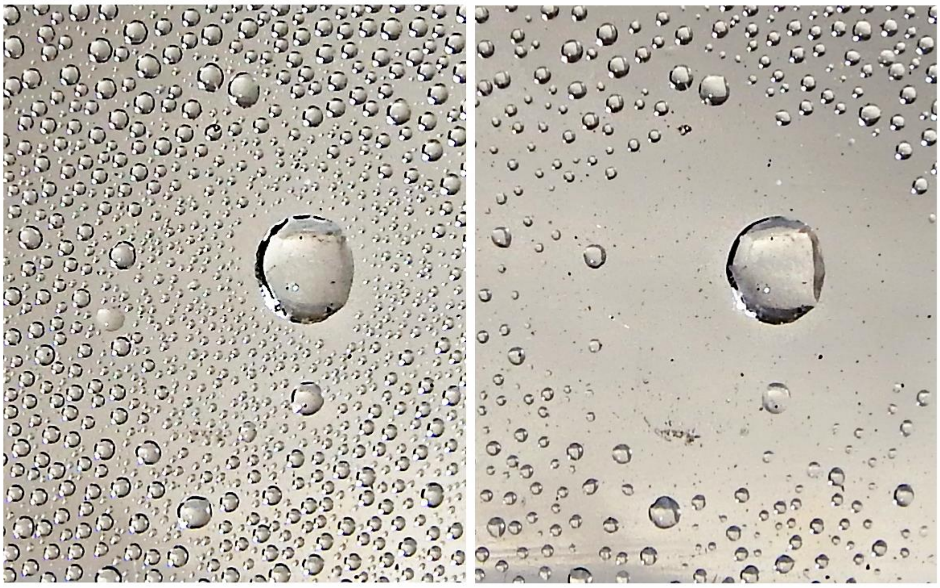

Fig 10 – water droplets evaporate over time.

Collaborate with a student in the computing department to write a program that will plot a histogram of the size distribution of droplets from photographs like those above.

Determine the changes in the size distribution of droplets over time as they evaporate from different surfaces, under controlled conditions.