

Can two people see the same rainbow?

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Two people standing together point to an arc above the same landscape. Calling it “the same rainbow” is perfectly reasonable: they share a shower, illumination and a recognisable pattern. But they do not receive identical rays at identical positions. The question becomes more interesting when we distinguish a shared atmospheric event from the light reaching each observer.

A rainbow is not a coloured object suspended at a fixed distance, like a painted hoop. It is a pattern in the directions from which light reaches an observer. Its position depends on the geometry linking sunlight, water droplets and that observer [1]. That dependence is physical and predictable. It does not mean people can place rainbows wherever they wish.

1. What is shared, and what changes?

The rain and sunlight can be common to both observers. Their eyes, however, occupy different positions. A droplet sends light in a range of directions, with a structured distribution of intensity and wavelength. Moving the receiving point changes which outgoing directions connect droplets to the eye.

It would be too strong to say that no droplet can ever contribute to both views. The Sun has a finite angular size, droplets scatter over angular ranges, and natural bows have finite width. The robust statement is that the two observers do not receive the same bundle of rays. Their contributing droplet populations can overlap without being identical.

We should likewise distinguish the angular pattern from the background. A rainbow can appear to end at a tree because its arc overlaps that tree along the viewing direction. The tree is not necessarily where the relevant droplets are, and walking towards it does not turn the apparent overlap into a fixed physical endpoint.

2. How a droplet selects directions

For the primary rainbow, the elementary ray construction includes refraction on entering a droplet, one internal reflection, and refraction on leaving it. Refraction changes direction at the boundary because the refractive index differs between water and air. Its wavelength dependence separates the angular distributions of colours [1].

Not every ray emerges at the rainbow angle. A bundle of parallel incident rays meets a spherical drop at different distances from its centre. The outgoing directions vary with that impact parameter. Near a particular direction, the deviation changes especially slowly. Many nearby incident rays then contribute to a relatively narrow outgoing angular region. This concentration explains the bright primary bow in geometrical optics.

We can make the construction explicit without treating 42° as a universal constant. Let i be the incidence angle and r the refracted angle, both measured from the local surface normal. For air approximated by refractive index 1 and a homogeneous spherical droplet with relative index n , Snell's law is $\sin i = n \sin r$. For one internal reflection, the deviation is $D = \pi + 2i - 4r$. The bow's angular radius about the antisolar direction is $\alpha = \pi - D$.

At the stationary deviation, differentiation gives $2 \cos i = n \cos r$ and hence $\cos^2 i = (n^2 - 1)/3$. Choosing the illustrative index $n = 4/3$ gives $i \approx 59.4^\circ$, $r \approx 40.2^\circ$ and $\alpha \approx 42.0^\circ$. This is an ideal calculation for a specified index, not a measured universal angle or a claim that water has exactly that index at every wavelength.

3. Where the observer enters

The antisolar direction points directly away from the Sun as seen from the observer. A set of directions making approximately the same angle with that axis forms a cone, whose tip is at the observer. The primary bow is the bright circular pattern associated with those directions, where suitable illuminated droplets are present.

For distant sunlight, observers near one another have nearly parallel antisolar axes, but the tips of their viewing cones are displaced. Their selected paths through the shower therefore differ. In a sufficiently extensive, fairly uniform shower, both can see very similar arcs. In patchy rain or changing illumination, one can see a segment that the other does not.

The familiar arc is part of a possible circle. The visible portion depends on where the droplets are and on obstruction by the ground or other objects. NOAA notes that a complete circular rainbow can be seen from an aircraft in suitable conditions [1]. Geometry supplies the possible directions; it does not guarantee that every direction contains an illuminated droplet.

4. What a ray drawing leaves out

The simple construction predicts the main angular concentration but does not describe all the fine structure. Light is also a wave. Interference and diffraction affect the detailed intensity around the bow, including the additional bands known as supernumeraries. Drop size matters when comparing those features.

Airy's treatment describes wave behaviour near the rainbow concentration. Mie scattering supplies an electromagnetic treatment for an ideal homogeneous sphere. These are not rival realities. They describe the same interaction at different levels of approximation, and the spherical model itself has limits when applied to deformed or compositionally complex droplets.

Lee's abstract reports that, for cloudbows and fogbows, integrating over realistic drop-size distributions reduces most perceptible differences between Airy and Mie predictions [2]. This concerns perceived colour and luminance, not numerical identity at every wavelength.

A good match to a photograph therefore need not identify a unique droplet distribution. Camera response, exposure, illumination and the mixture of drop sizes can affect what is recorded. Conversely, a small numerical difference at one wavelength need not create a visible difference in the natural bow. A claim about rays, a claim about a spectrum and a claim about appearance require different comparisons.

5. What would be measured?

An angularly calibrated image can locate the arc relative to the antisolar direction. Spectral measurements can resolve how intensity varies with wavelength. Measurements of the shower can constrain droplet sizes and locations. These observations address different parts of the explanation; no single photograph supplies all of them.

A useful test with two observers would record their positions, the solar direction and the time, rather than comparing two uncalibrated pictures taken under changing conditions. Agreement of angular radii would support the common optical geometry. Differences in visible segments could reflect the rain distribution or obstruction, without implying disagreement about the physical law.

The ideal calculation above cannot determine the distance to "the rainbow". It contains an angle and a refractive index, not a measured range to a single object. Recovering the

three-dimensional distribution of contributing droplets would require additional information. An angular location alone does not establish a fixed endpoint on the ground.

6. An observer-dependent phenomenon that is still public

The answer is yes if “same” refers to a shared atmospheric event and corresponding optical pattern. It is no if “same” requires identical received rays. Neither answer should erase the distinction that makes the question useful.

The observer's location is a boundary condition in the optical problem, not a mysterious force acting on the weather. Another person or a camera at a specified position can record a pattern governed by the same geometry. The droplets need no awareness of being watched.

What is firmly established is the connection between droplet optics and the angular pattern. What remains to be specified for an individual event includes the droplet distribution, illumination and viewing geometry needed to predict fine detail. We can explain why two people share a recognisable rainbow while receiving different light, without pretending that the pattern is either a fixed painted object or a private creation of each mind.

Related reading

IDE-023 discusses observation and KNO-018 discusses visualisation. They are optional conceptual companions; the argument here concerns the specific geometry of a rainbow.

References

- [1] NOAA NESDIS. What Causes a Rainbow?
<https://www.nesdis.noaa.gov/about/k-12-education/optical-phenomena/what-causes-rainbow>
- [2] Lee, R. L. Mie theory, Airy theory, and the natural rainbow. *Applied Optics* 37, 1506–1519 (1998).
<https://doi.org/10.1364/AO.37.001506>