Spectacular rainbows

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Figure 1. Primary and secondary rainbows over Paul Mistral Park in Grenoble on April 5, 2012, according to L'air et l'eau, 2013, EDP Sciences [Source: © EDP sciences]

After a fairly heavy rainfall, in a sky still full of fine **droplets**, on the side opposite to the Sun that has just reappeared, rainbows similar to those in the attached photograph (Figure 1) are often visible. The fine droplet spray jets used by gardeners to water their plants also produce these beautiful coloured arches. Similarly, at the seaside, rainbows can be seen in the spray above the waves that explode on rocky coasts.

This is due to the **refraction of light**, an expression that refers to the deviation of light rays as they pass through an interface between two media, such as air and water. It is this refraction phenomenon that explains why a straight stick appears broken when it enters the water. This deflection of light is a function of wavelength, i.e. colour. It is a dispersive phenomenon often highlighted by **a prism** that splits white light into various wavelengths or colours, and can be seen behind the edge of a window or glass shard.

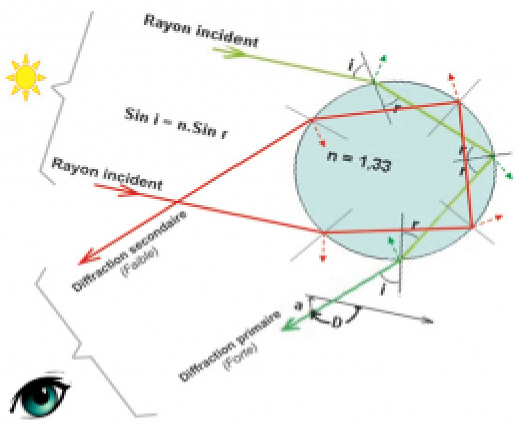

Figure 2. Path of the rays responsible for the primary (light green) and secondary (red) arc.

What is it about? Let us consider a ray of white light that penetrates a spherical drop of water. It is deflected when it undergoes a first refraction through the air/water interface (Figure 2). The ray light then reaches the back surface of the drop, where it is partially reflected. The fraction thus reflected returns to the front face and passes through the water/air interface again, undergoing a second refraction, accompanied by attenuation since part of this ray is reflected towards the inside of the drop. The theory of these two refractions, separated by a reflection, makes it possible to show that the ray reaching the observer's eye comes from droplets located on the lateral surface of a cone, whose axis is the straight line going from the Sun to the observer's eye (Figure 3), and whose half-angle at the top varies slightly around 41° according to the wavelength, i.e. according to the colour: 40° for the blue seen inside the cone, 42° for the red seen outside. An important point: these angles are independent of the size of the drop if it is really spherical, which requires that it must be small enough so that the capillary force, or surface tension, should be preponderant over its weight and over friction of the ambient air.

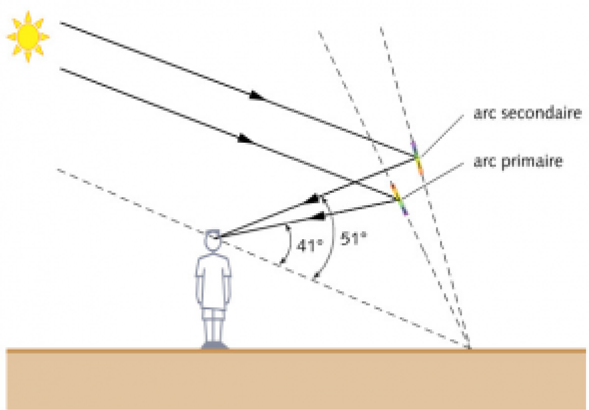

Figure 3. Respective positions of the Sun, the observer and the primary and secondary arcs, based on L'air et l'eau, 2013, EDP Sciences [Source: © EDP sciences]

The secondary arc, which is concentric to the first one, is more blurred and located outside the primary arc. It is due to a second reflection of the light beam (Figure 2) on its way back to the front surface, before crossing the latter and undergoing its second refraction. This drop, which has therefore produced two reflections and two refractions, is then located on a cone whose half-angle varies between 50° for red (inside the cone) and 53° for blue (outside the cone). The attentive observer can distinguish these two concentric rainbows, and notice the inversion of the order of colours between them due to additional reflection (Figures 1 and 3). The fact that the secondary arc is systematically less distinct than the primary arc is due to the four energy losses it has undergone, during its refractions and reflections, instead of three for the primary arc. René Descartes (1596-1650) was the first to explain the rainbows.