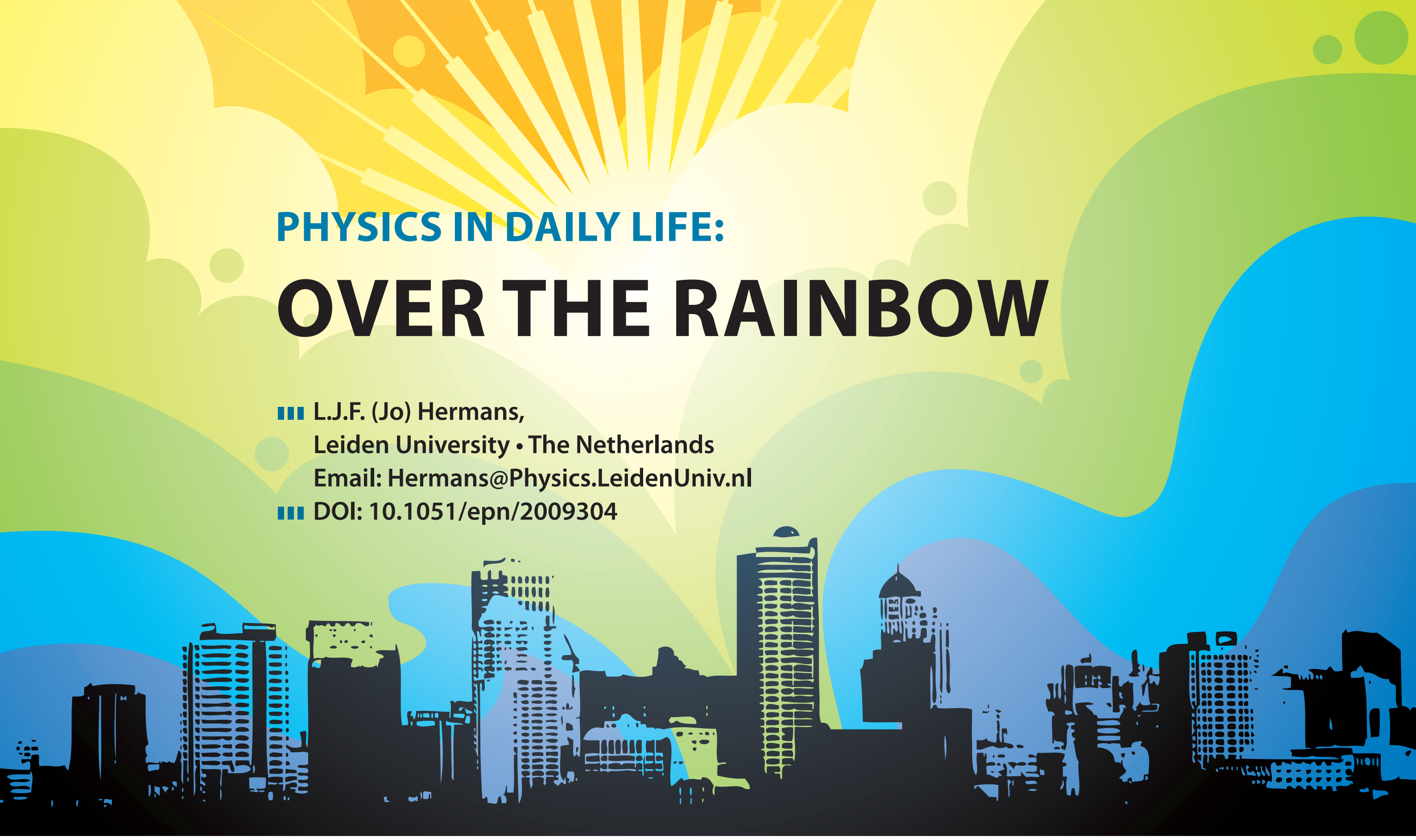

PHYSICS IN DAILY LIFE:

OVER THE RAINBOW

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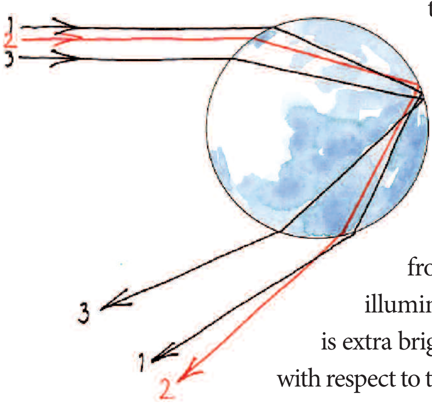
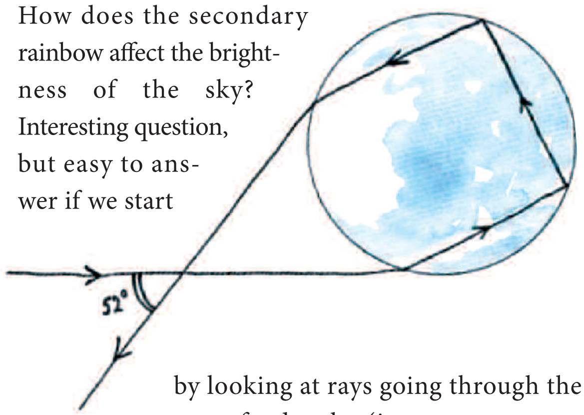
Everybody knows the rainbow, and most physicists know its optical background.

But there is one question about rainbows that even most physicists cannot answer off-hand: What about the brightness of the sky above and below the rainbow? In order to find the answer, let us first remember how the rainbow itself comes about. Geometrical optics will do, if we assume the size of rain droplets to be large compared to the wavelength of light. The key is that light rays making one internal reflection inside a raindrop have an extreme in their deviation as a function of 'impact parameter' if we put it in molecular collision language. That is, outgoing ray no. 2 in the figure makes the largest angle with respect to the horizontal, although it has incoming neighbours at either side (a fact that can easily be demonstrated by slowly moving a cylindrical glass of water through a laser beam). Consequently, when we turn away from the sun and look at a rain cloud illuminated by the sun, the reflected light is extra bright at this angle of about 42 degrees with respect to the sun's rays: the *rainbow angle*. Due to dispersion, the angle is different for each colour, and we see a colourful cone of light: the rainbow.



So far for the rainbow itself. Now what about the brightness of the sky next to it? From the figure it is obvious that there is also light reflected at angles *smaller* than 42 degrees, but not at larger angles. Conclusion: the sky is brighter inside than outside the rainbow.

But wait: this was only about the primary rainbow. What if there is also a secondary rainbow, having an angular radius of about 52 degrees? We recall that the secondary bow is caused by the extreme in the deviation of rays which leave the droplets after **two** internal reflections. It has inverted colours since the light rays have turned the other way around inside the droplets. How does the secondary rainbow affect the brightness of the sky? Interesting question, but easy to answer if we start by looking at rays going through the center of a droplet (impact parameter zero, or a 'head-on collision'). After two internal reflections, such a ray continues to move along its original trajectory. With increasing impact parameter, the outgoing rays will gradually move over toward the incoming direction until they reach their extreme: the (secondary) rainbow angle of 52 degrees. Consequently, they will not reach the 'dark' area in between the two rainbows. So the conclusion emerges that the sky is brightest inside the primary and outside the secondary bow. Complicated though it may seem, it reminds us of a well-known song. The sky is bright, *somewhere over the rainbow*. But not *everywhere*. ■



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