LIKE A BRIDGE TO THE SKY

La fisica degli arcobaleni

Simona Ghizzardi – astrosiesta 23/4/15

Everybody knows that….

Raindrops act like prisms and diffract light.
Different wavelengths are differently refracted when they cross over the boundary from one medium to another (air→ water → air)
The result is a rainbow.

Simple questions and curiosities

- Where is the sun when we look at a rainbow?

Rainbow @ Rome observatory

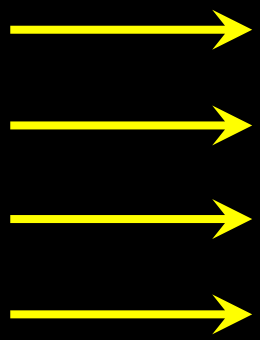
Where is the sun?

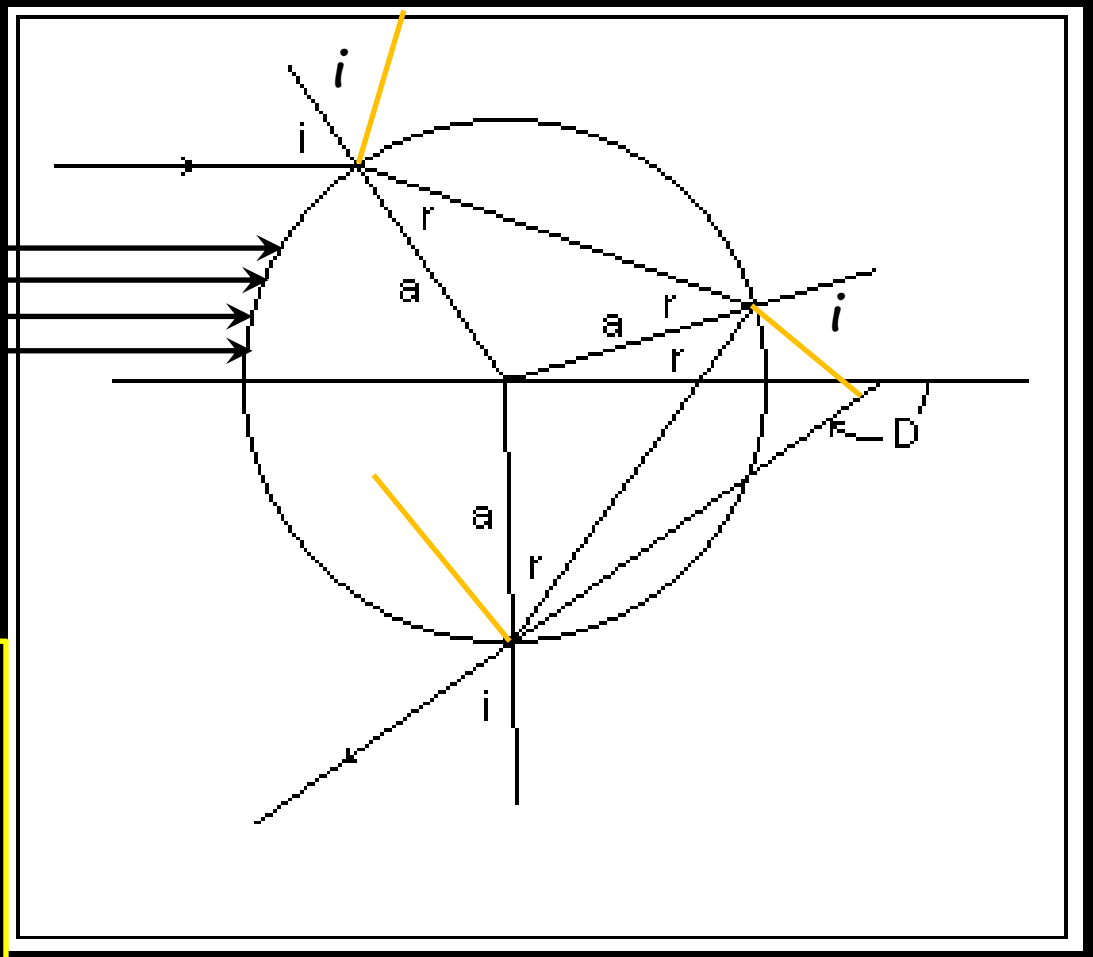
Simple questions and curiosities

- Where is the sun when we look at a rainbow?
- When and where can we see a rainbow?
- If each raindrop creates a rainbow, why do I see a single large rainbow?
- How big is a rainbow?
- What's the color sequence in a rainbow?
- Is there any difference between the sky brightness inside and outside the rainbow?
- How many rainbows can I see simultaneously? 2? 3? 10?
- If another rainbow is there, what's its color sequence?
- Is the rainbow light polarized?

Raindrop and sunlight: refraction and reflection

For a spherical raindrop





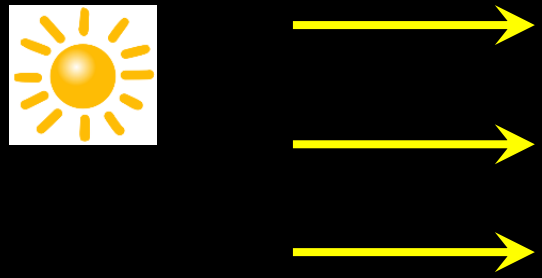
Snell law

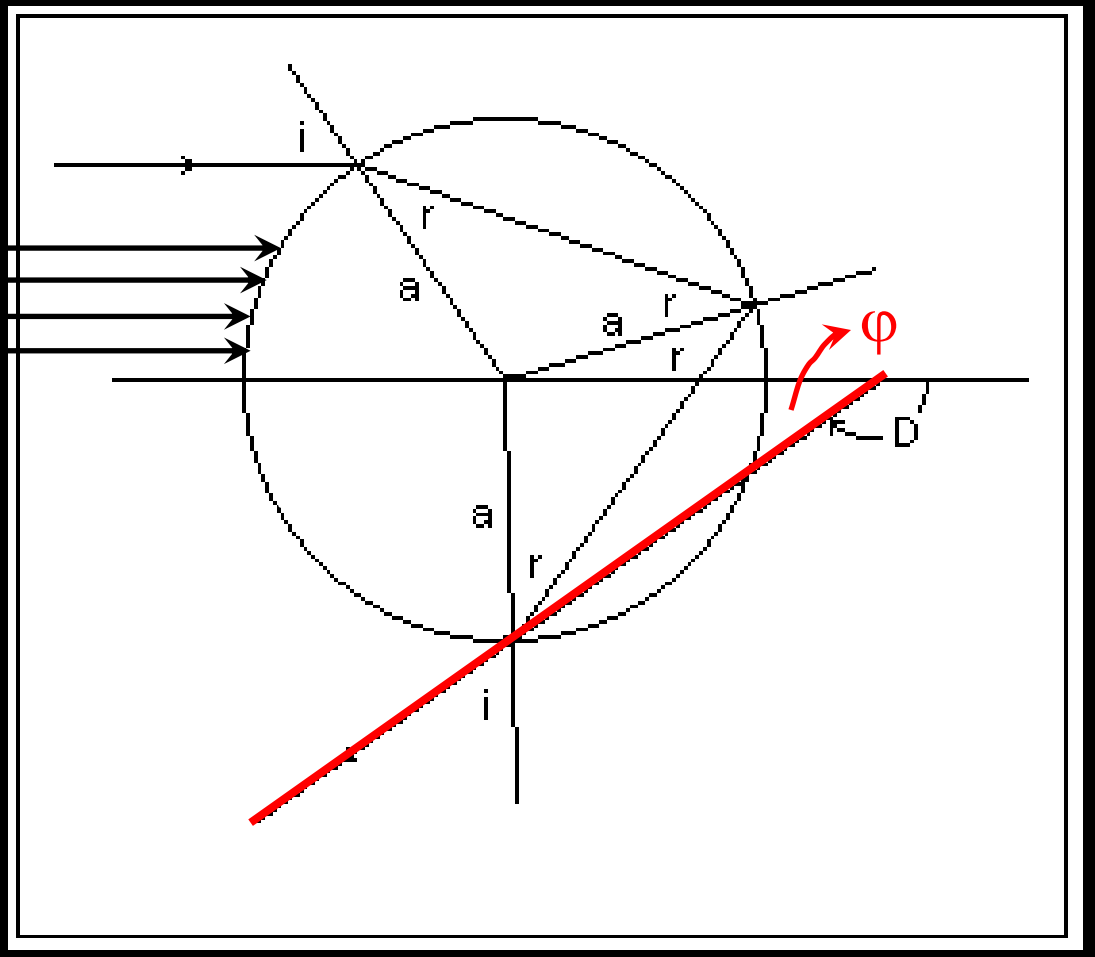
$n_{air} \sin i = n_{water} \sin r$

n (air) = 1.003 n (water) ~1.333

Deviation angle: φ

For a spherical raindrop





$\sin i = n \sin r$

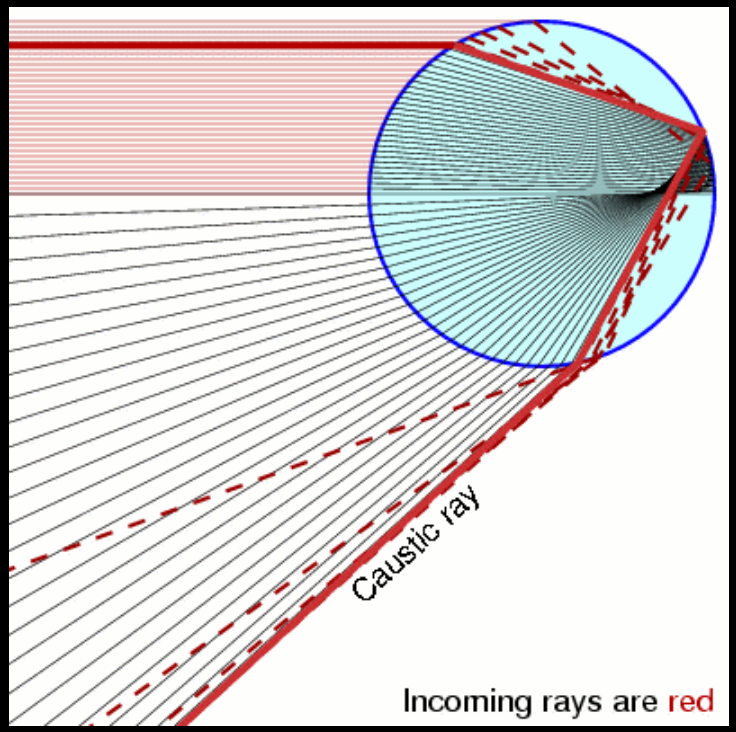
$\varphi = 4r - 2i$

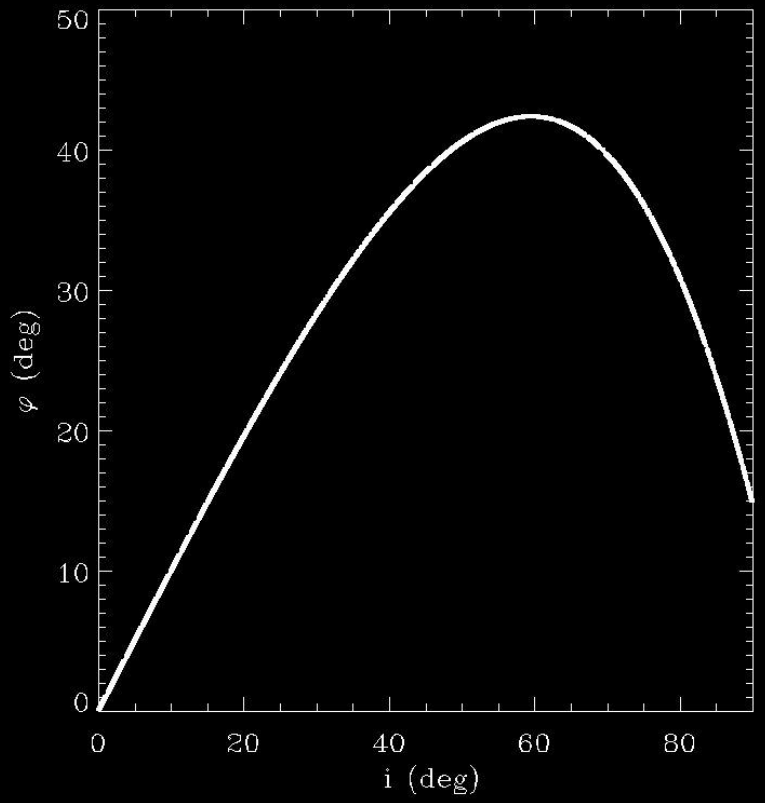
φ does not depend from the raindrop radius.

For n = 1.336

φ_max = 41.6;

i=60, r = 40.4 deg





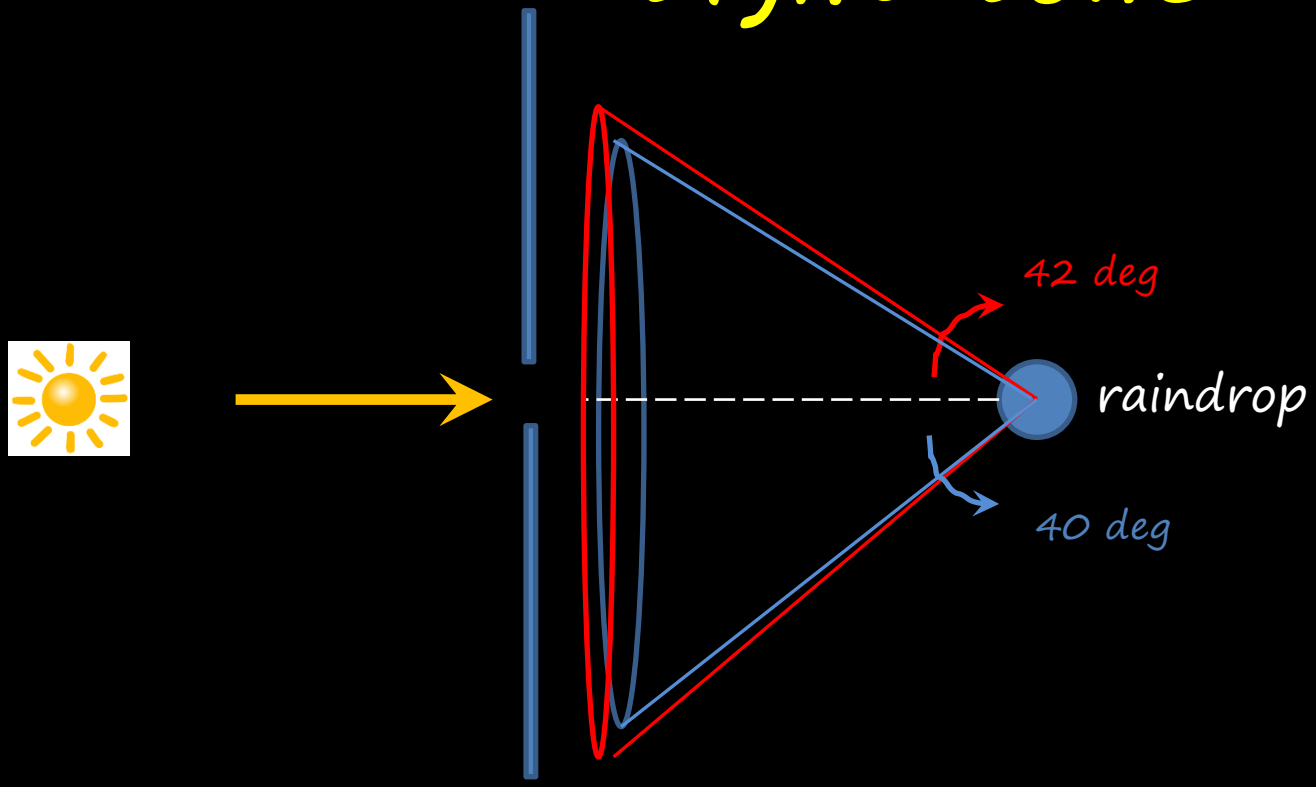
For red light : n=1.331

For blue/violet light: n=1.343

For red light φ_max= 42.4 deg

For blue light φ_max= 40.6 deg

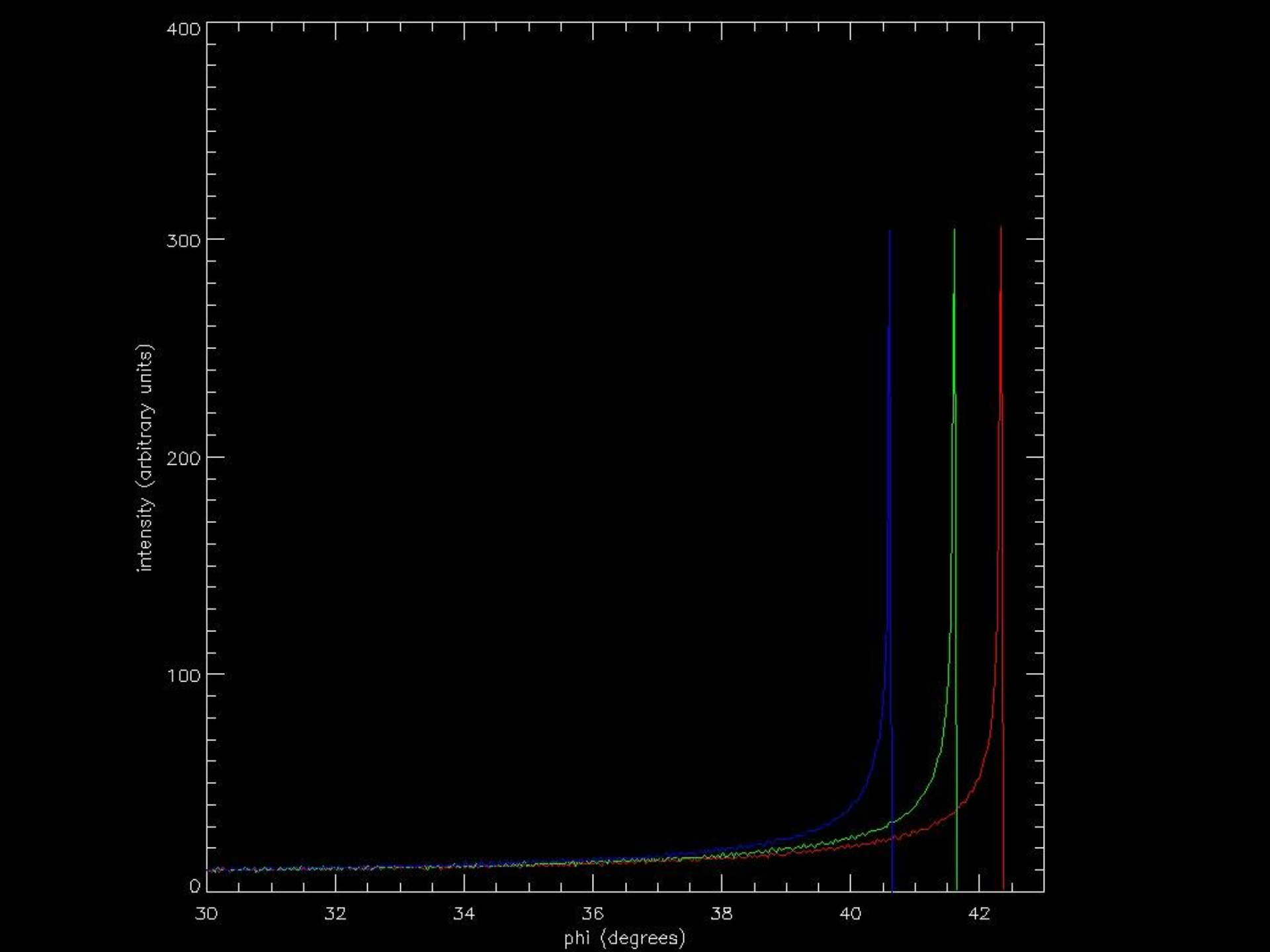
Light cone



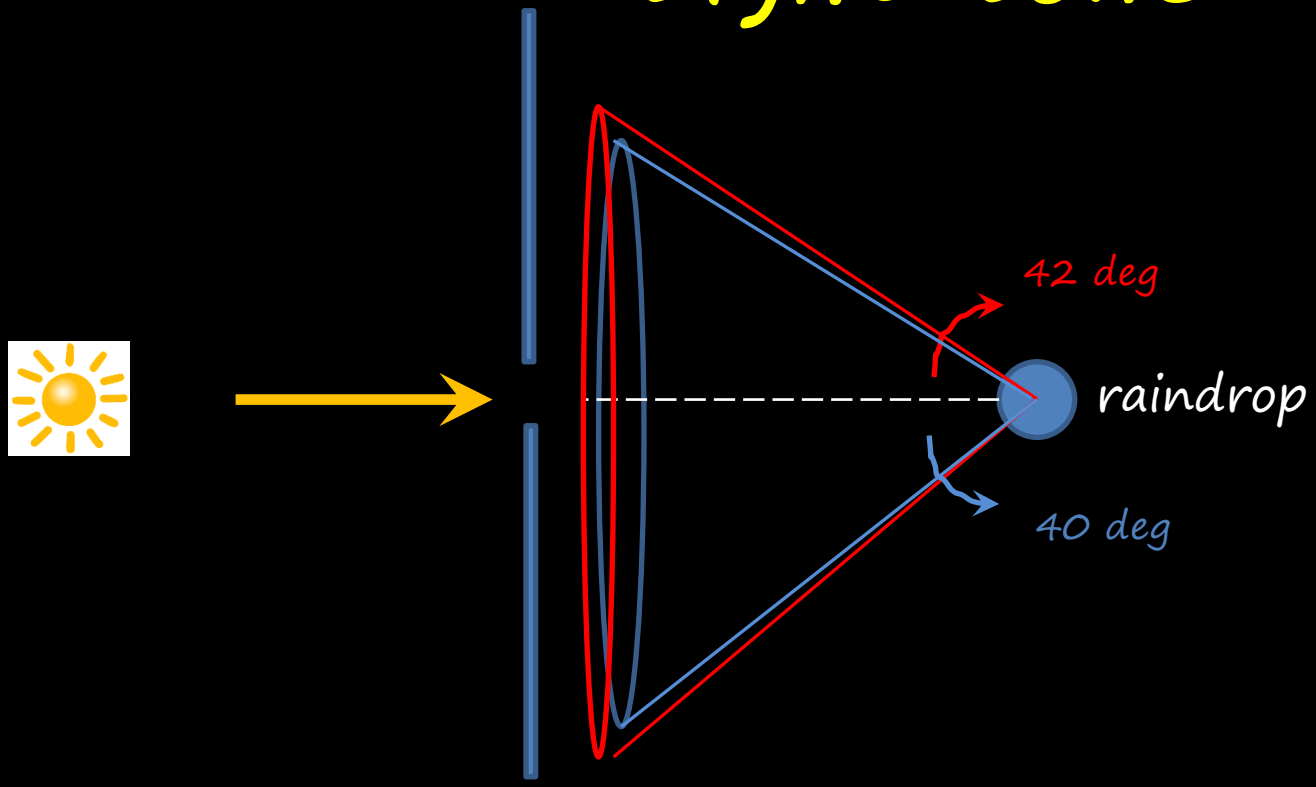
$\varphi > 42^{\circ}$: DARK!!!

$\varphi < 40^{\circ}$: WHITE LIGHT

$\varphi \approx 42^{\circ}$: RED LIGHT


400
300
200
100
0
intensity (arbitrary units)
30
32
34
36
38
40
42
phi (degrees)

Light cone



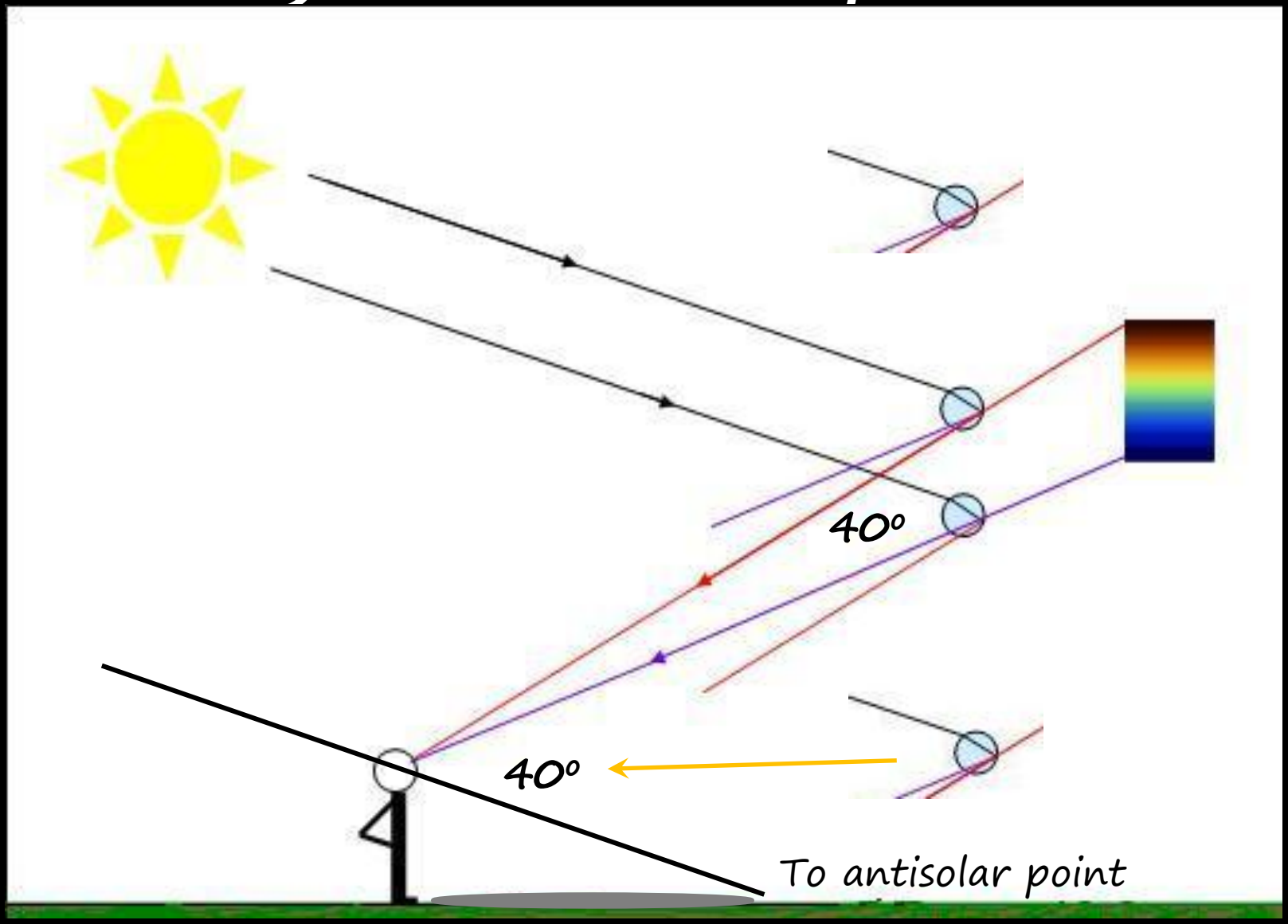
φ > 42° : DARK!!!

φ < 40° : WHITE LIGHT

φ @ 42° : RED LIGHT

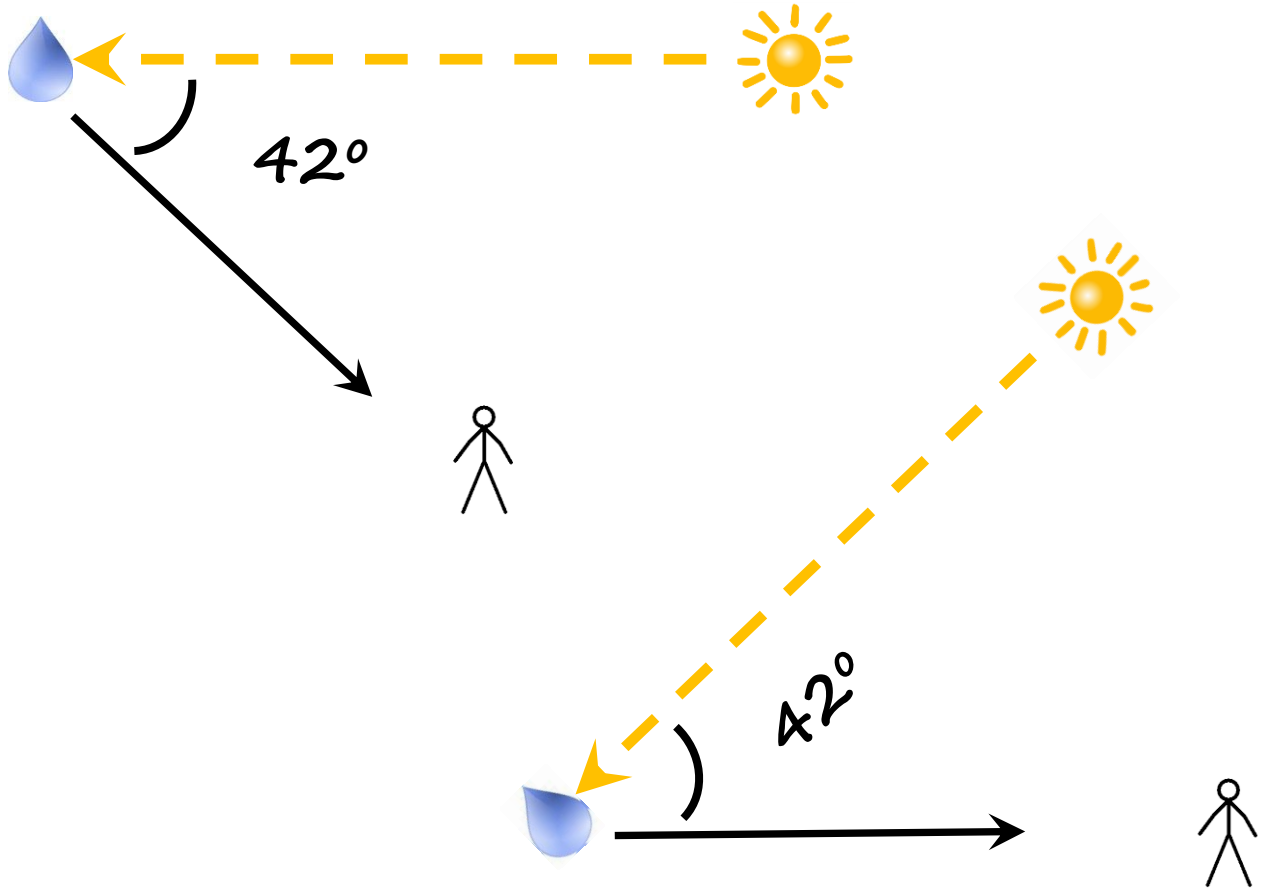
φ @ 40° : BLUE LIGHT

Myriads of droplets



Everybody has his own personal rainbow!

Sun inclination to see a rainbow

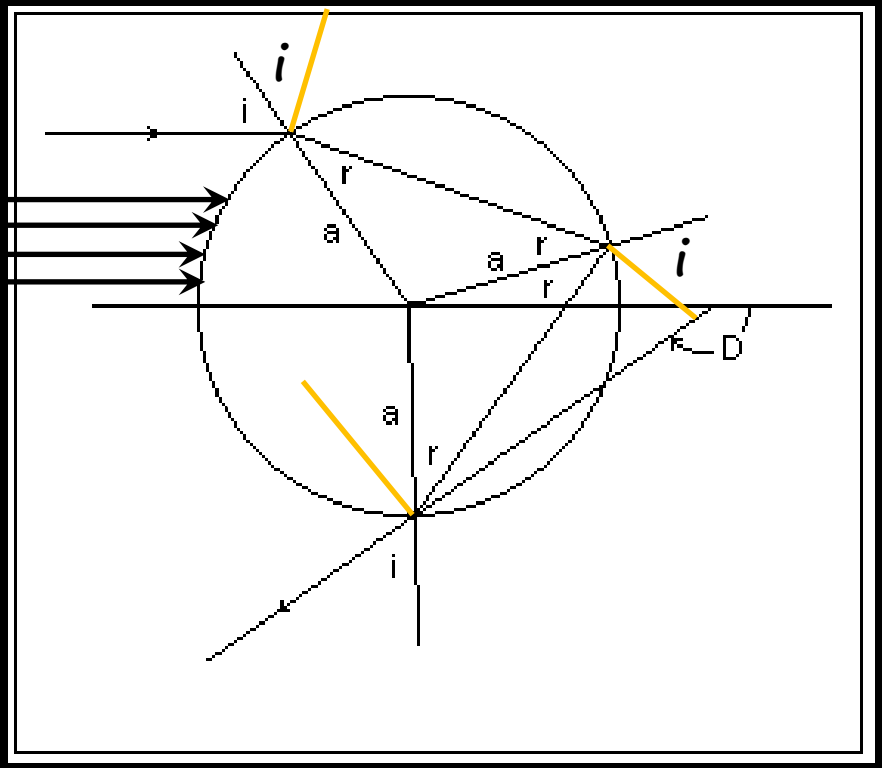


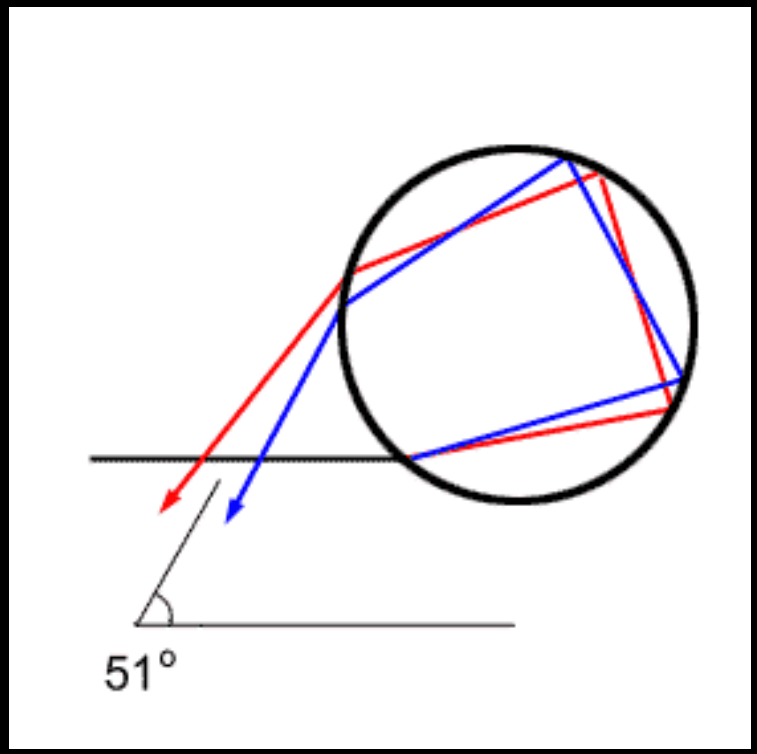
At ground level the highest sun inclination to see a rainbow is 42 deg

Circular rainbows


harald edens

Secondary rainbow



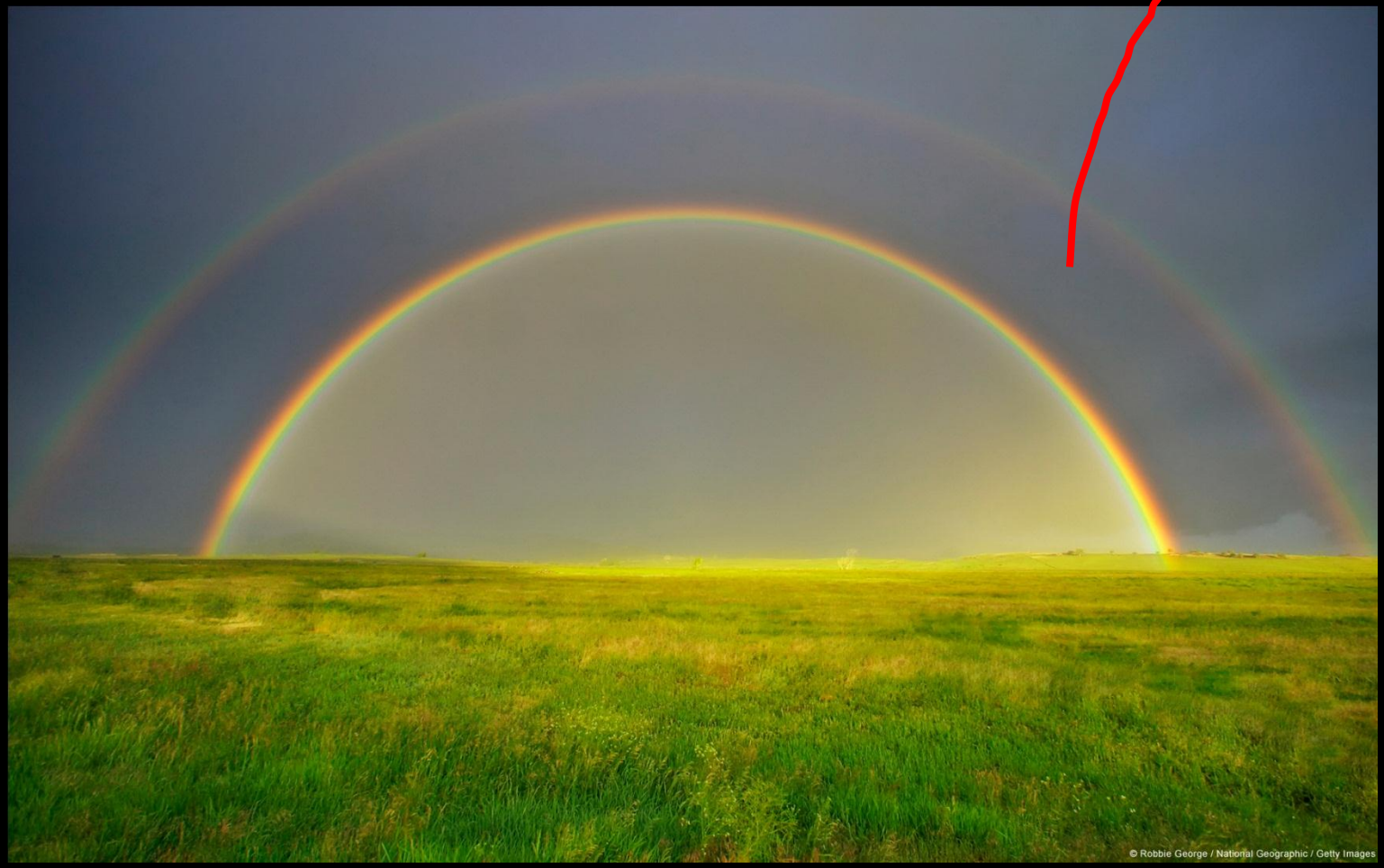


$\varphi = \pi - 6r + 2i$

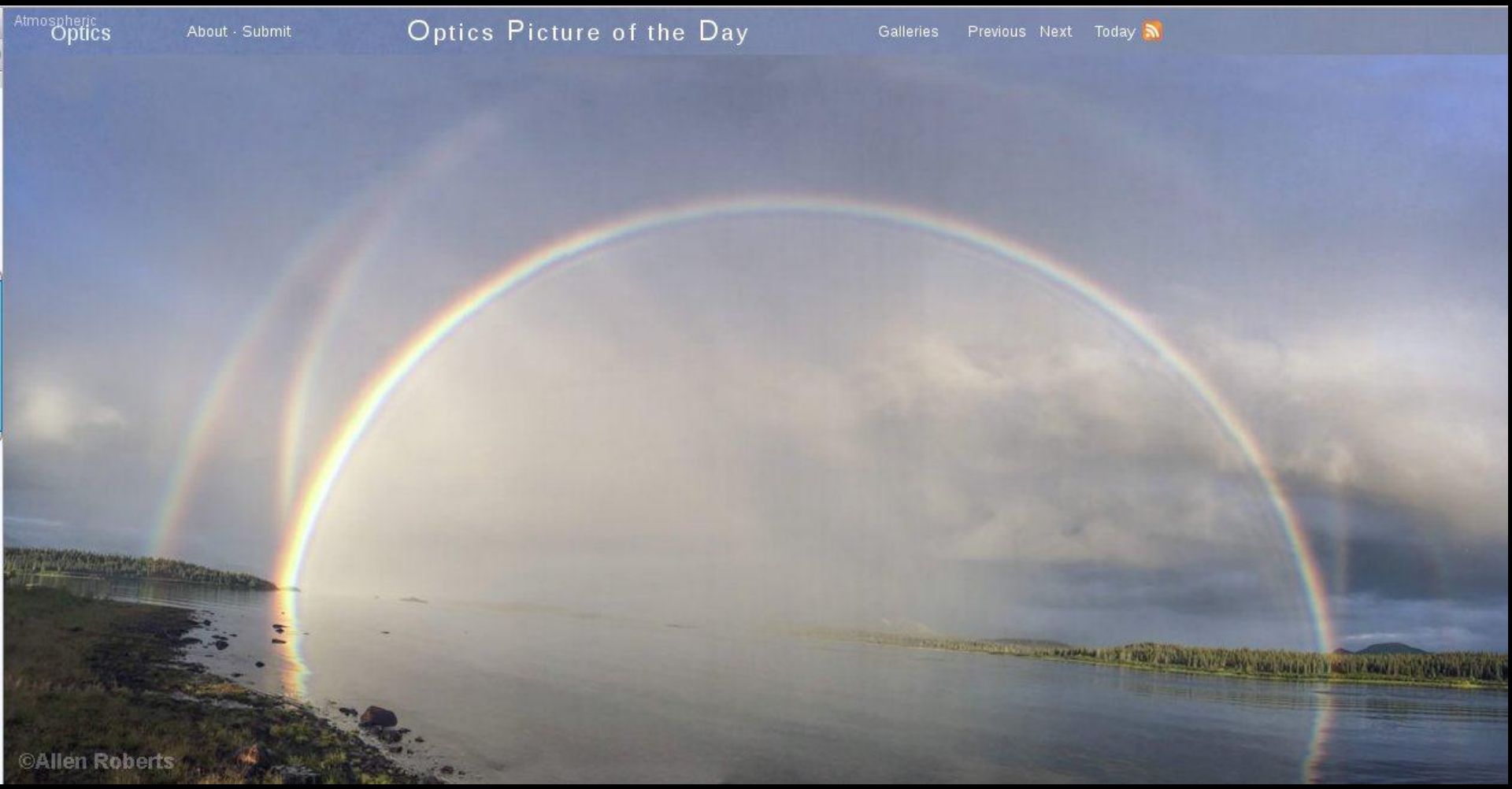
$\varphi\_min = 51\ deg$

Secondary rainbow

Alexander dark band

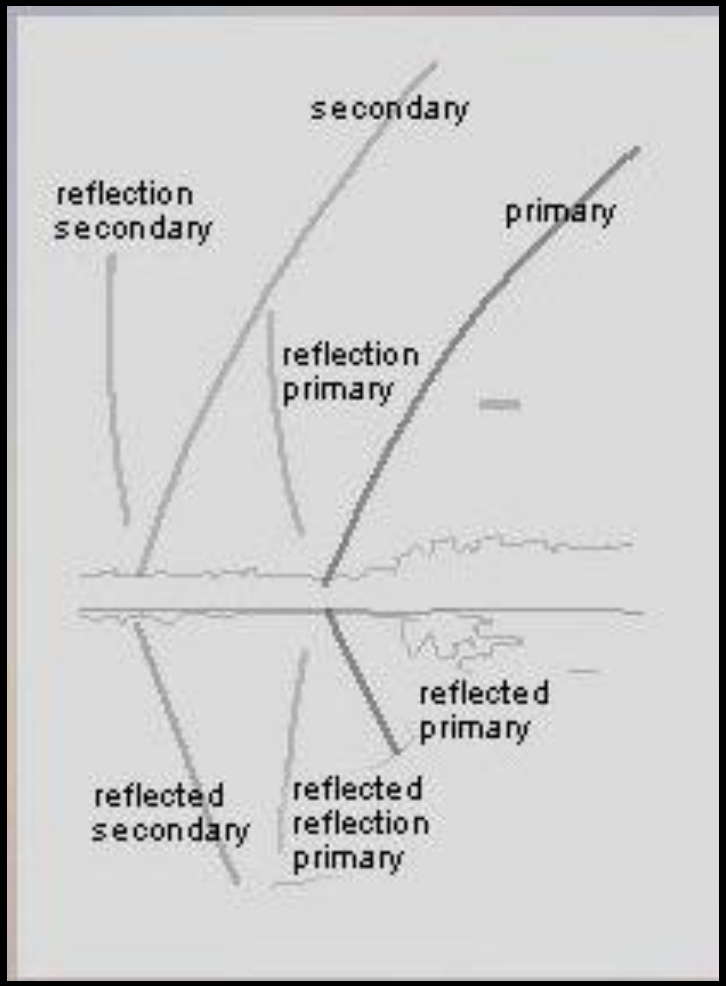


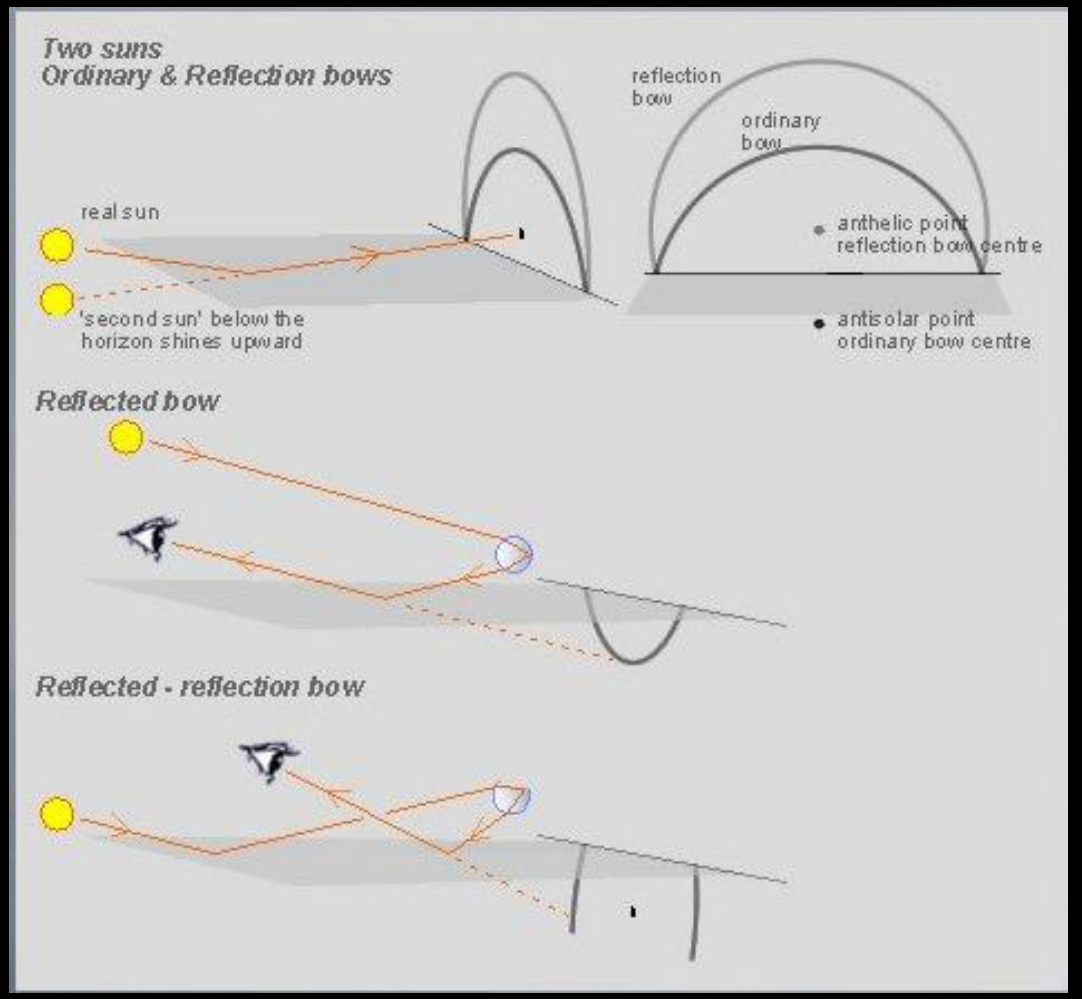
Reflection bows



Reflection and reflected bows:

the combination of two effects





Inverted colors??????

Only the secondary rainbow, low on the horizon!!!! Sun is higher than 42 deg but lower than 51 deg.

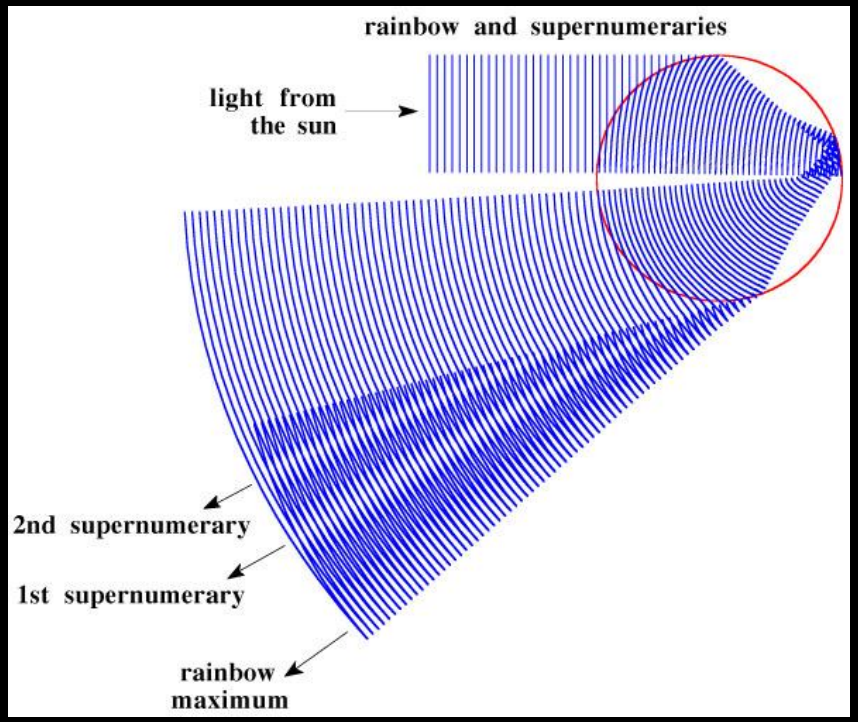
At sunset only red light: red bows

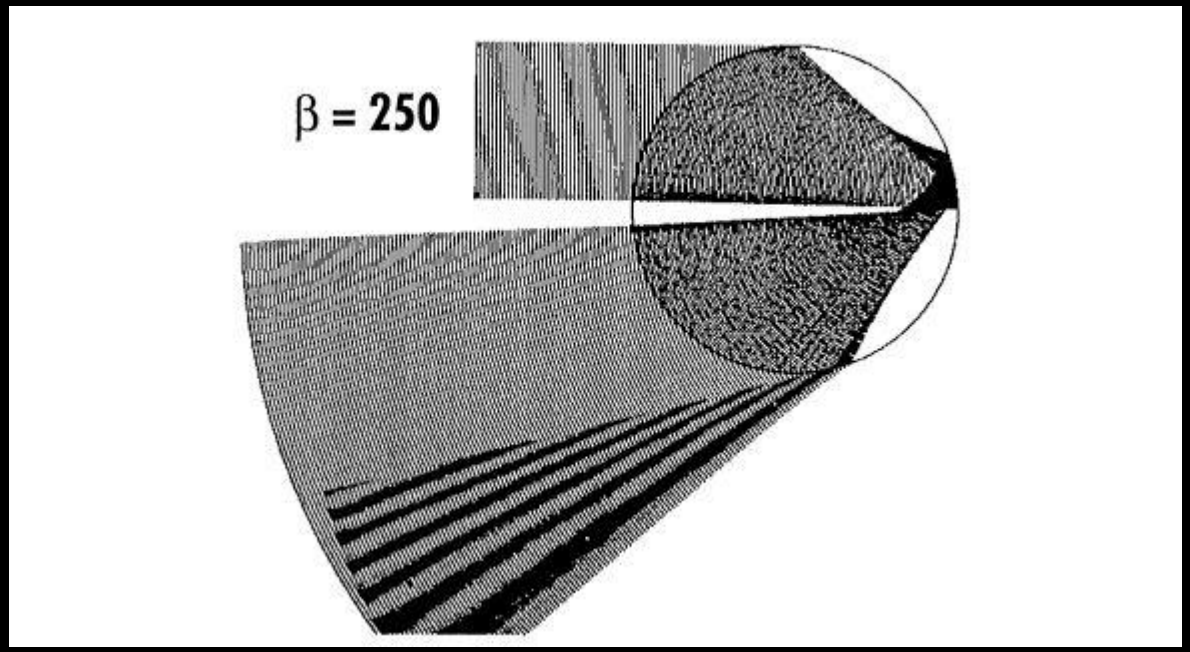
Moonbow

Supernumerary bows

Drop size ~ 1mm-2 mm

When drop size < 0.5 mm
interference becomes important

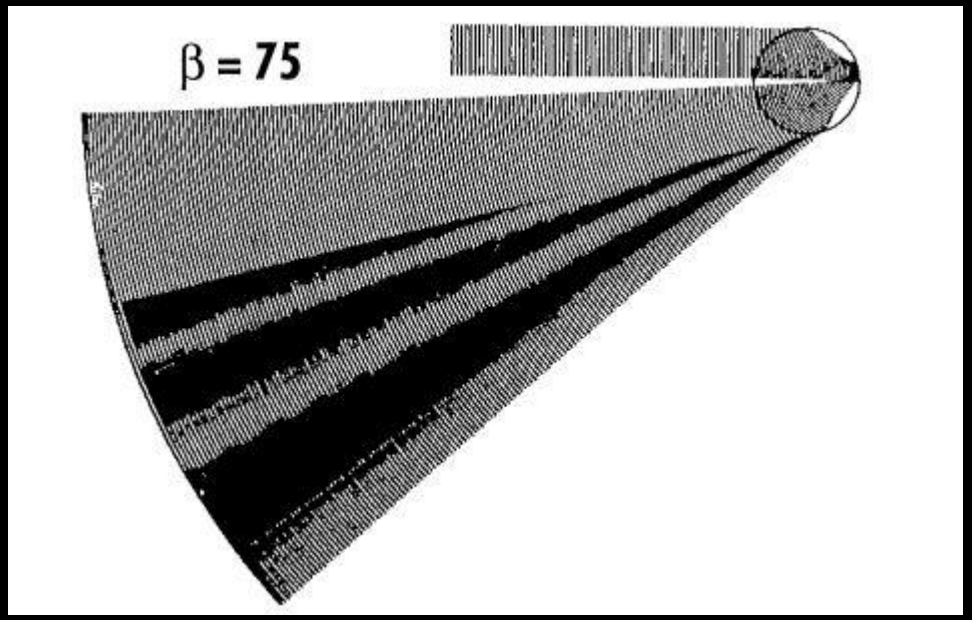




The number and the size of supernumeries depens on the drop size

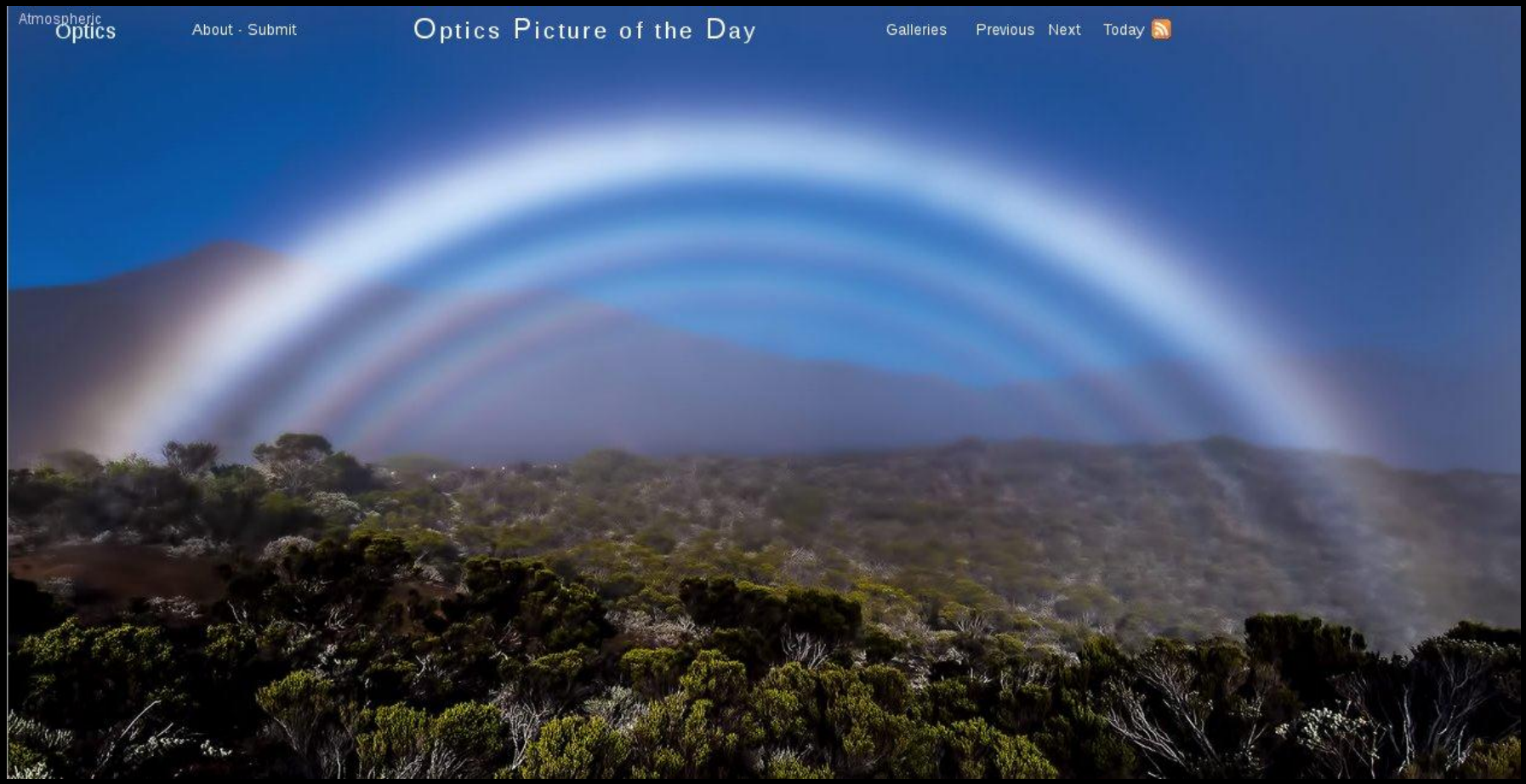
$\beta = 2\pi a/\lambda$

(a = drop size)

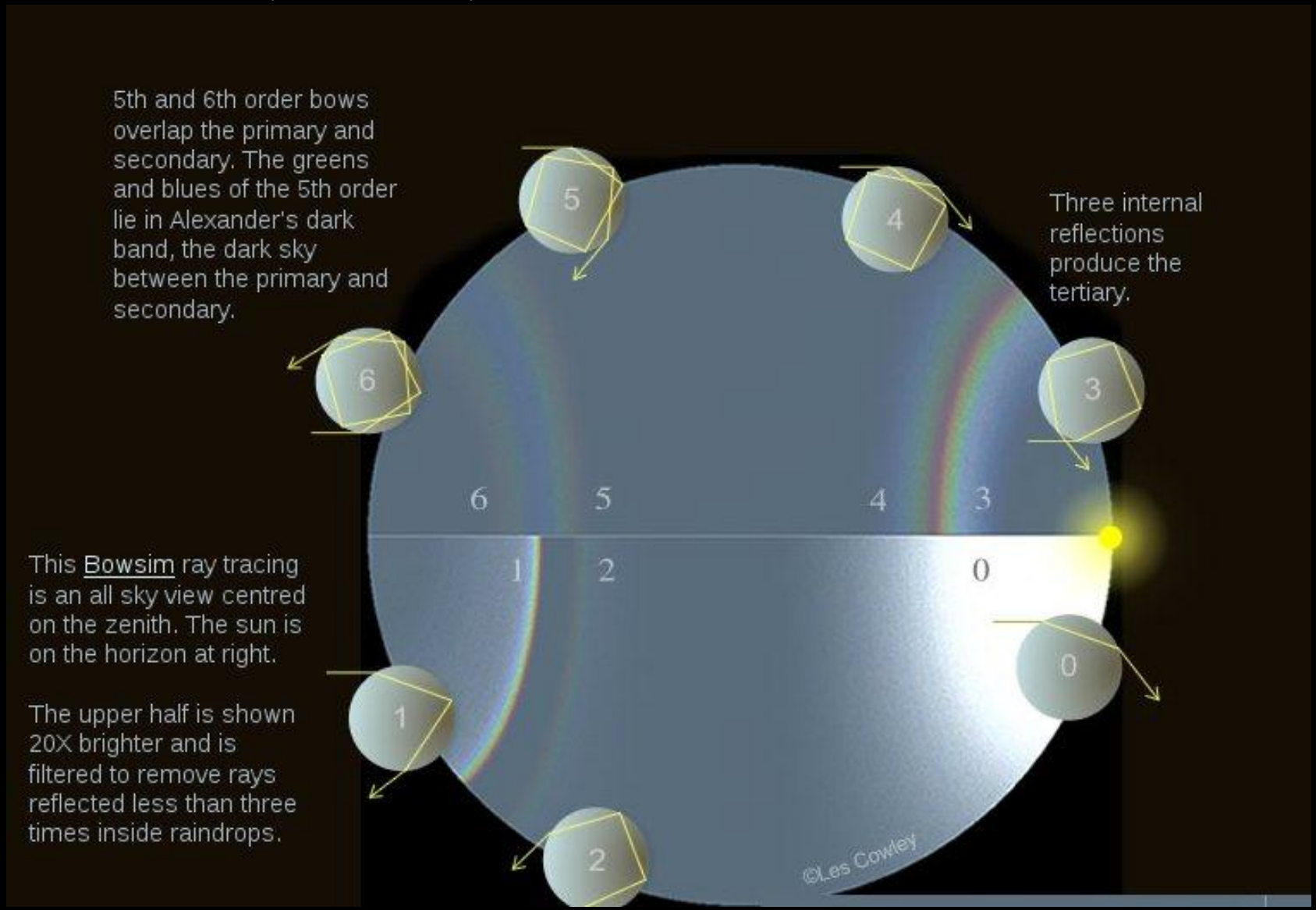


Fogbow

For very small droplets (~ 30 μm) like in fog, the bow light is white

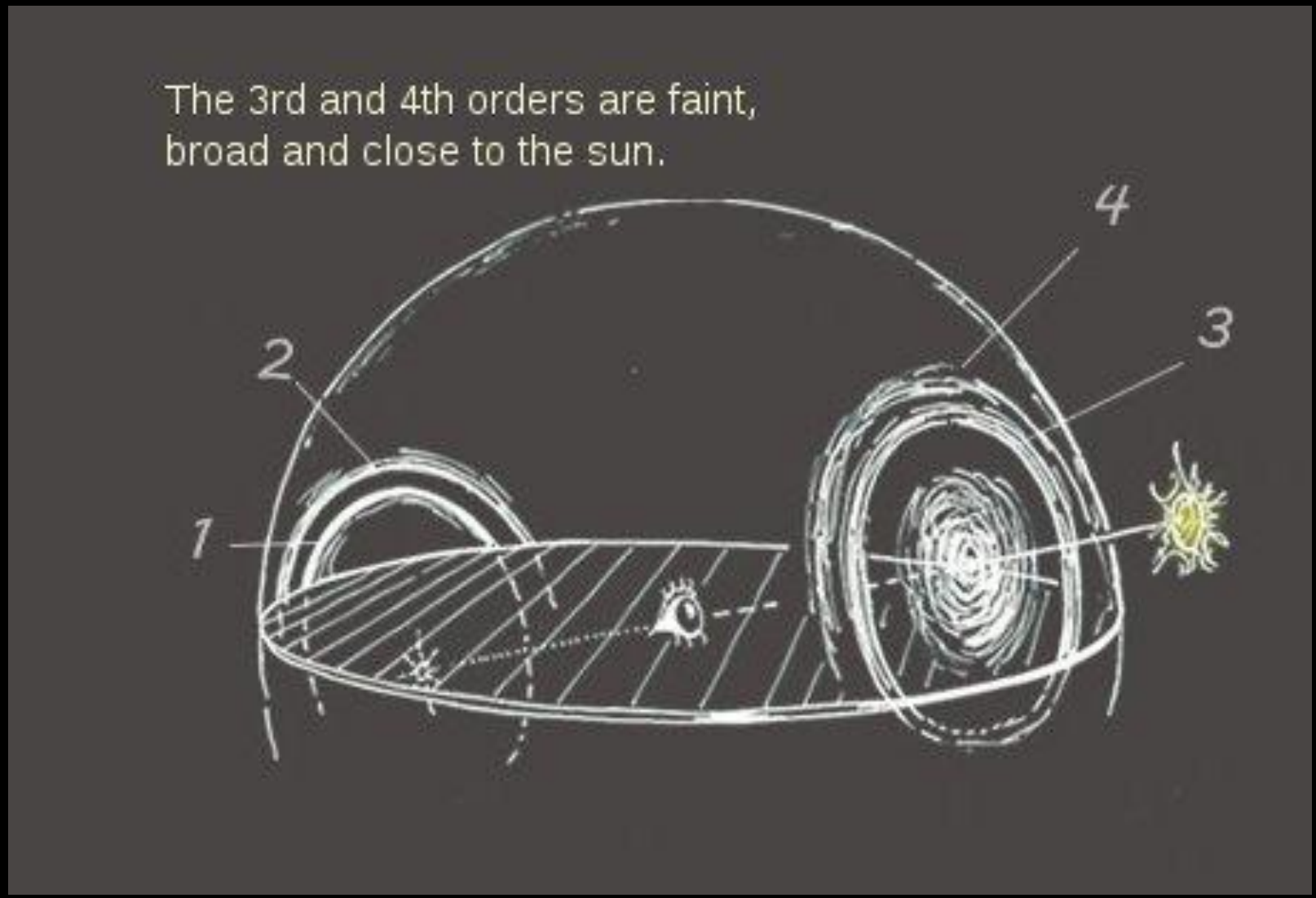


0^{th}, 3^{rd}, 4^{th} 5^{th} … orders



Zero order glow

3rd and 4th orders



3rd and 4th orders

3rd and 4th order rainbows

5^{th} and 6^{th} orders

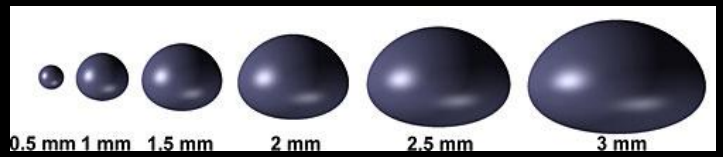
5^{th} order

Adjusting contrast and luminosity...

5^{th} order


3rd September 2009
© Harald Edens - www.weatherscapes.com
© Harald Edens - www.weatherscapes.com

Non-spherical droplets: twinned rainbows



Rainbow polarization

$\theta_{Brewster} \sim 37^{\circ}$

Rainbow light is 96% linearly polarized

Not a rainbow

- Many optical phenomena look like rainbows but are not rainbows

Circum-zenital halo

Circum-horizontal arc

Glory

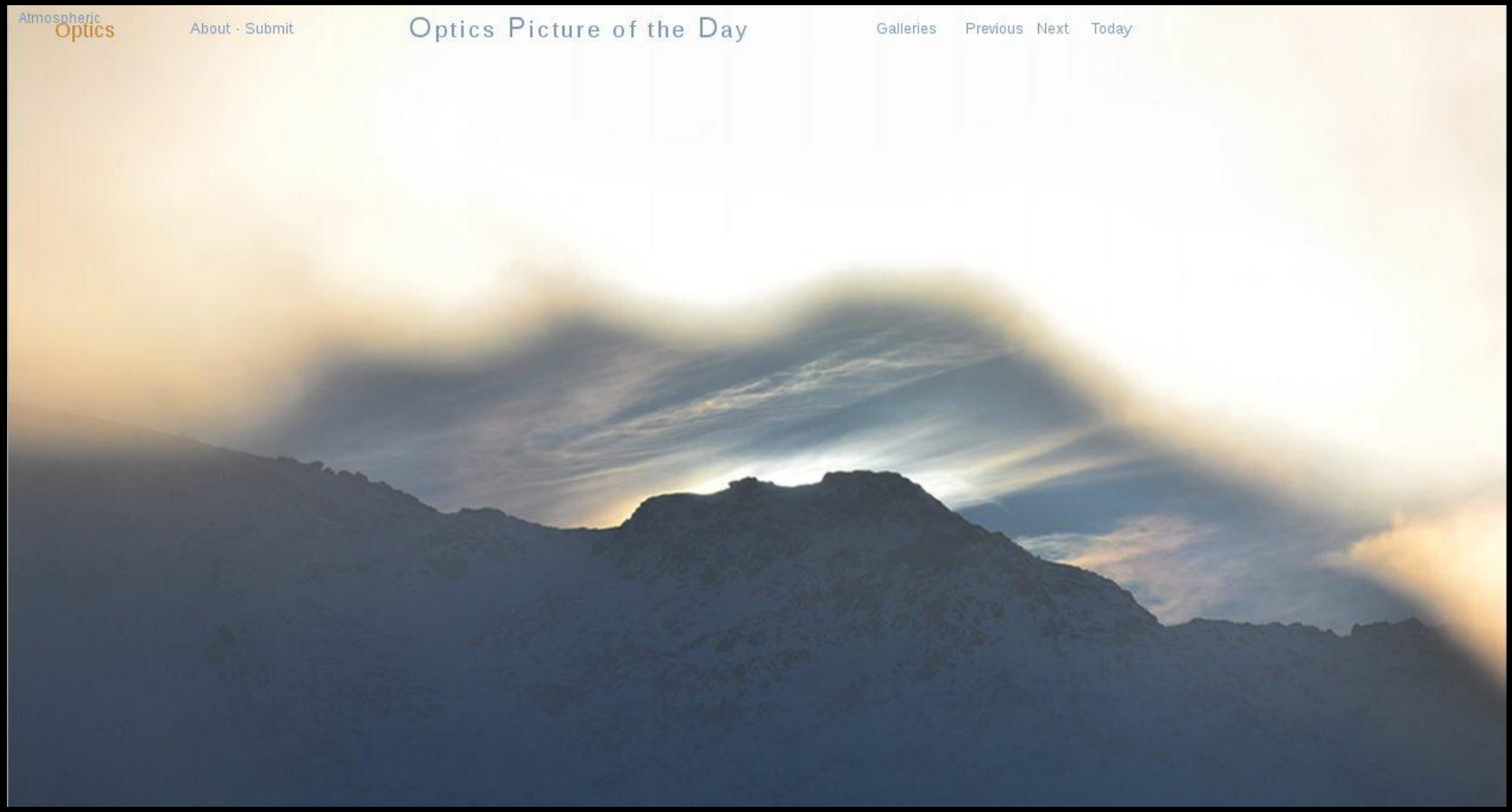
Light pillars

Sun halo

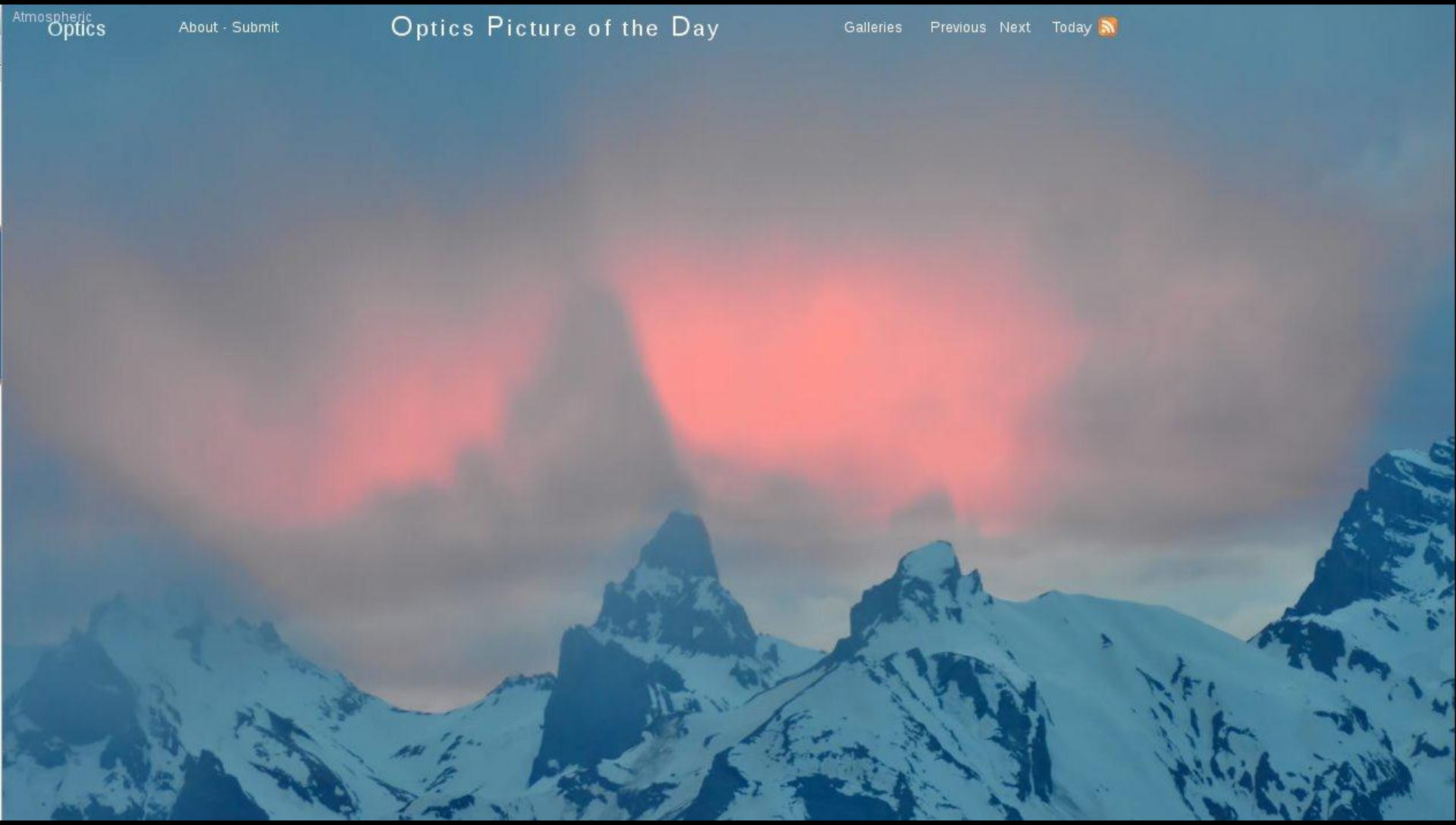
sundogs

Other optical effects

Mountain shadow

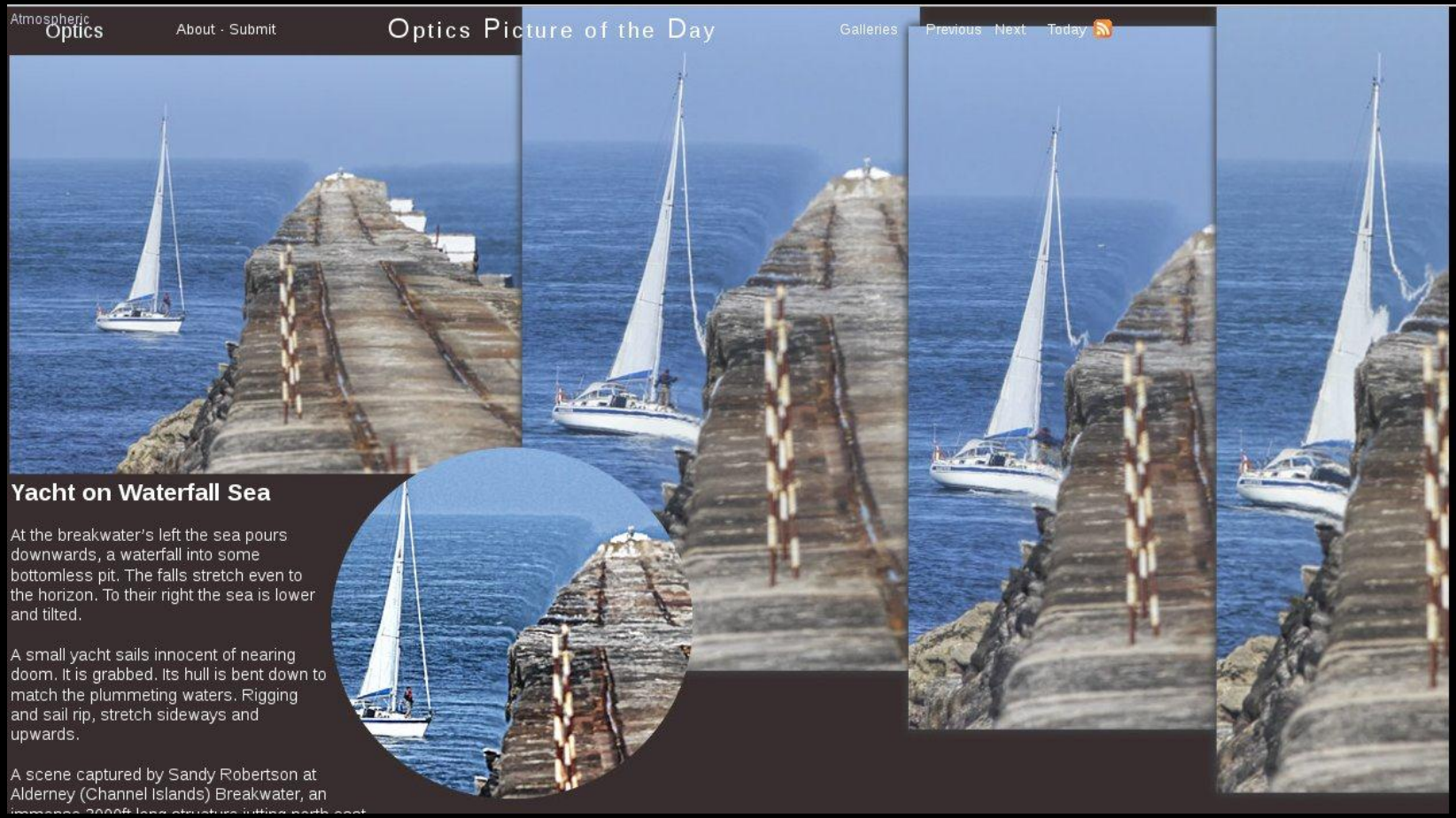


Mountain shadow



Mirage

Mirage


Atmospheric Optics
About · Submit
Optics Picture of the Day
Galleries
Previous Next Today
Yacht on Waterfall Sea
At the breakwater's left the sea pours downwards, a waterfall into some bottomless pit. The falls stretch even to the horizon. To their right the sea is lower and tilted.
A small yacht sails innocent of nearing doom. It is grabbed. Its hull is bent down to match the plummeting waters. Rigging and sail rip, stretch sideways and upwards.
A scene captured by Sandy Robertson at Alderney (Channel Islands) Breakwater, an