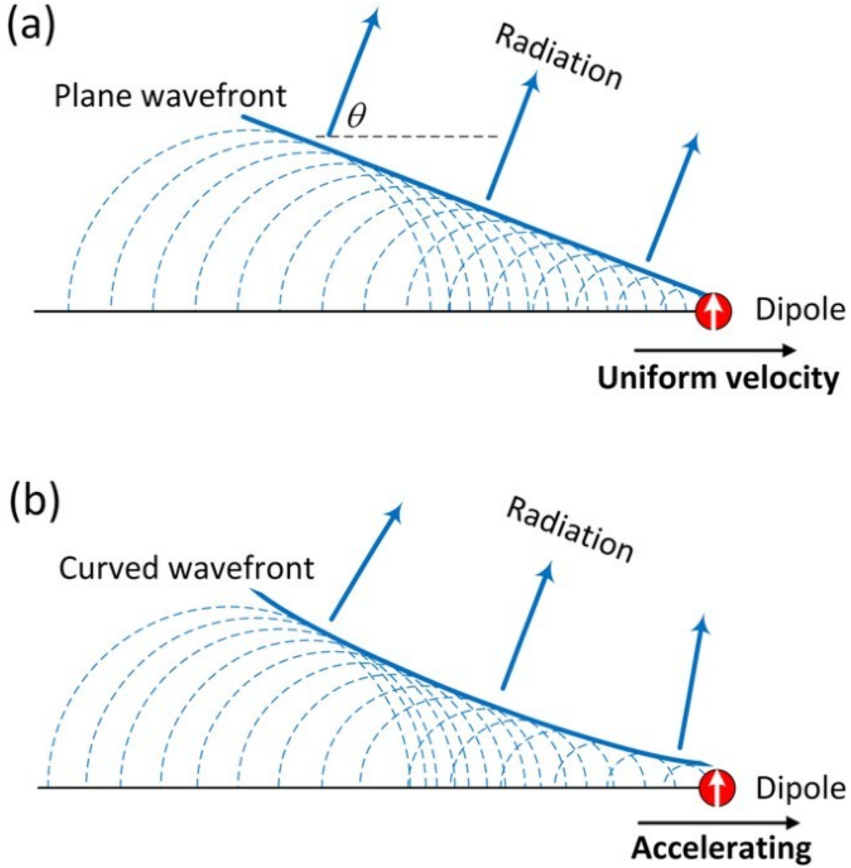
Cherenkov Radiation

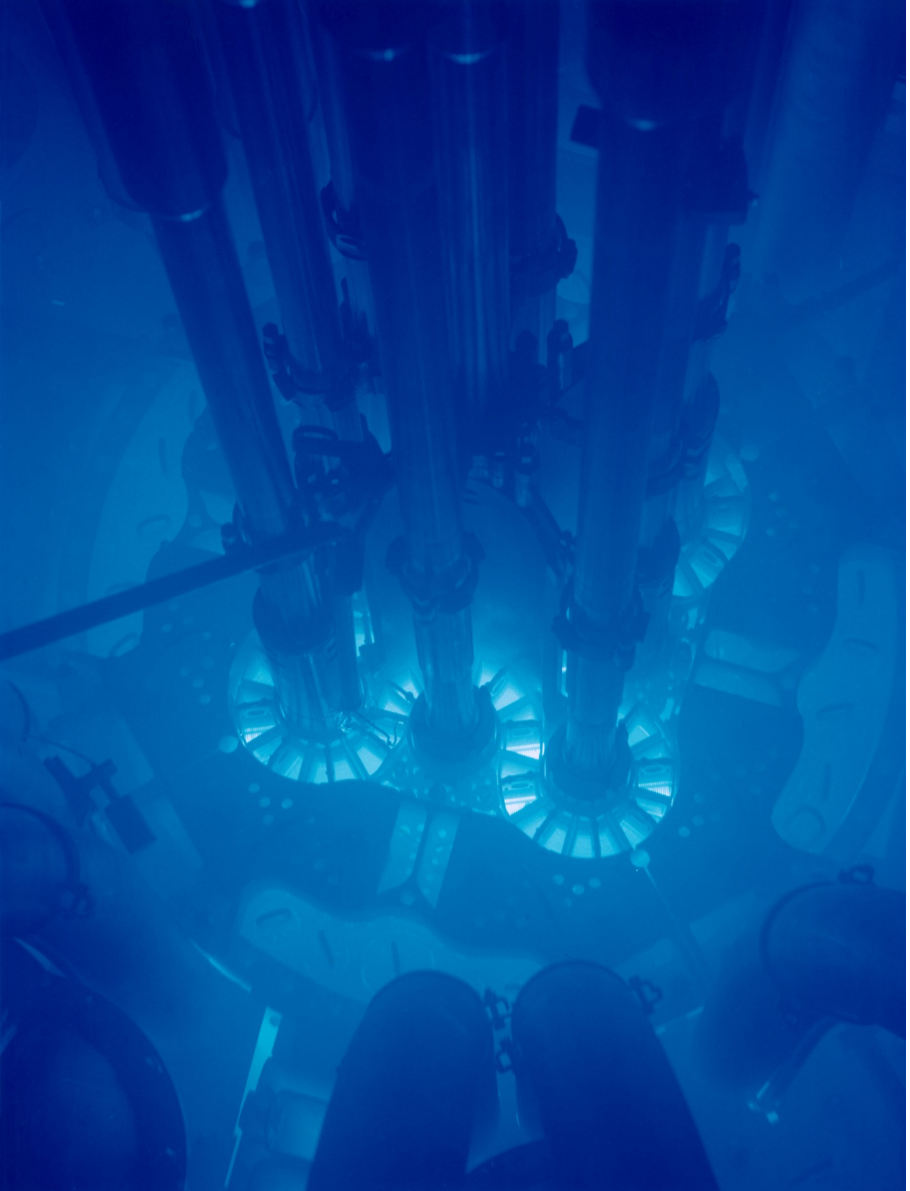


A charged particle emits Cherenkov light when it moves through a medium faster than light propagates in that medium

$$u > v_{phase} = \frac{c}{n(v)} = \frac{\omega}{k}$$

The light is emitted on a cone:

$$\cos\theta = \frac{1}{\beta n(v)}$$



Cherenkov Radiation

Light can travel slower than c in a dielectric medium.
The charge moving relativistically can overtake the electromagnetic wave and form a “sonic boom” of light.
This is Cherenkov radiation

C-light in Astrophysics

Cherenkov radiation is usually not the astrophysical source emission itself. It is a detection channel.

Main cases:

Gamma-ray astronomy:
Very-high-energy gamma rays hit the atmosphere, create particle cascades, and the secondary charged particles emit short Cherenkov flashes. Imaging Atmospheric Cherenkov Telescopes reconstruct the original gamma-ray direction and energy. CTAO targets roughly 20 GeV–300 TeV.

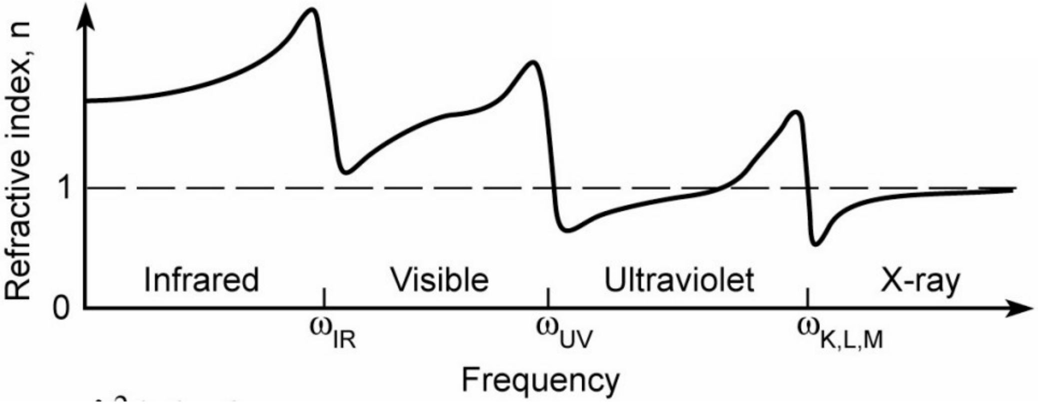
Neutrino astronomy:
A neutrino interaction in ice or water produces charged secondary particles. Their Cherenkov light lets detectors like IceCube infer the neutrino direction and energy.

Spectrum of C-light

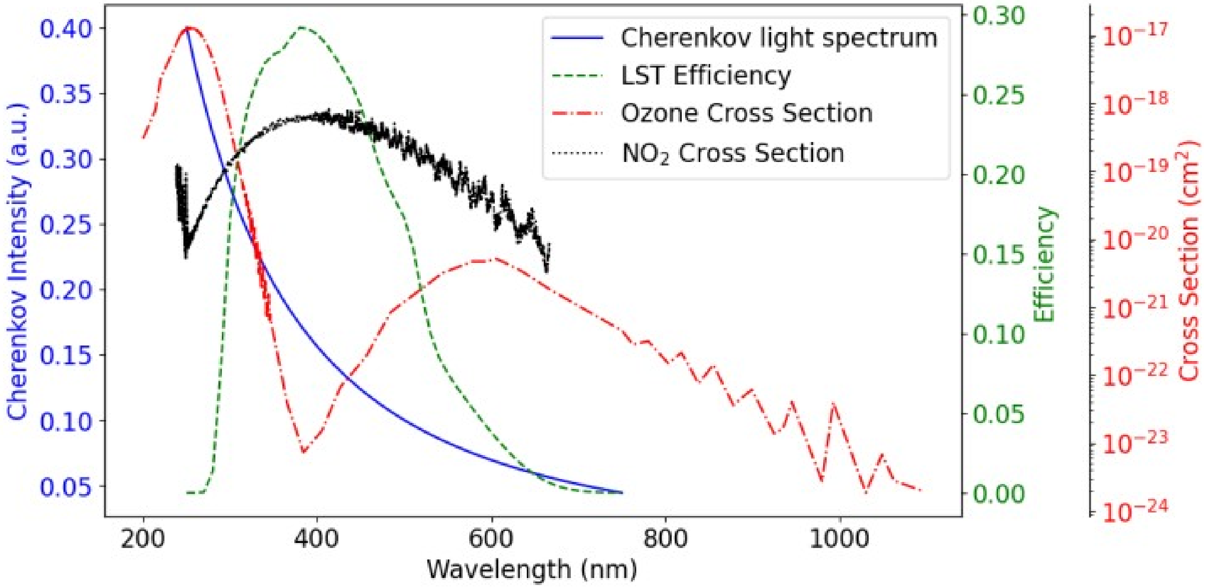
Cherenkov emission is broadband, but it is stronger at shorter wavelengths. Approximately, the number of emitted photons scales as:

$$\frac{dN}{d\lambda} = \lambda^{-2}$$

So more photons are emitted in the blue/near-UV than in the red. This is why Cherenkov light is often described as “blue light”. The exact photon yield depends on the medium. Note that if you go to shorter wavelengths (e.g., X-rays), **the refractive index changes and becomes <1**, so Cherenkov light cannot be created.



Spectrum of C-light



For Cherenkov radiation, emission coefficient is not thermal and not isotropic. It is concentrated around the Cherenkov cone.

In atmospheric Cherenkov astronomy, this means the camera does not image the intrinsic gamma-ray source directly. It images the optical/UV Cherenkov brightness produced along the atmospheric particle shower. The astrophysical gamma ray is inferred from the shape, timing, and brightness of that secondary light pattern.