Physics: effects in air

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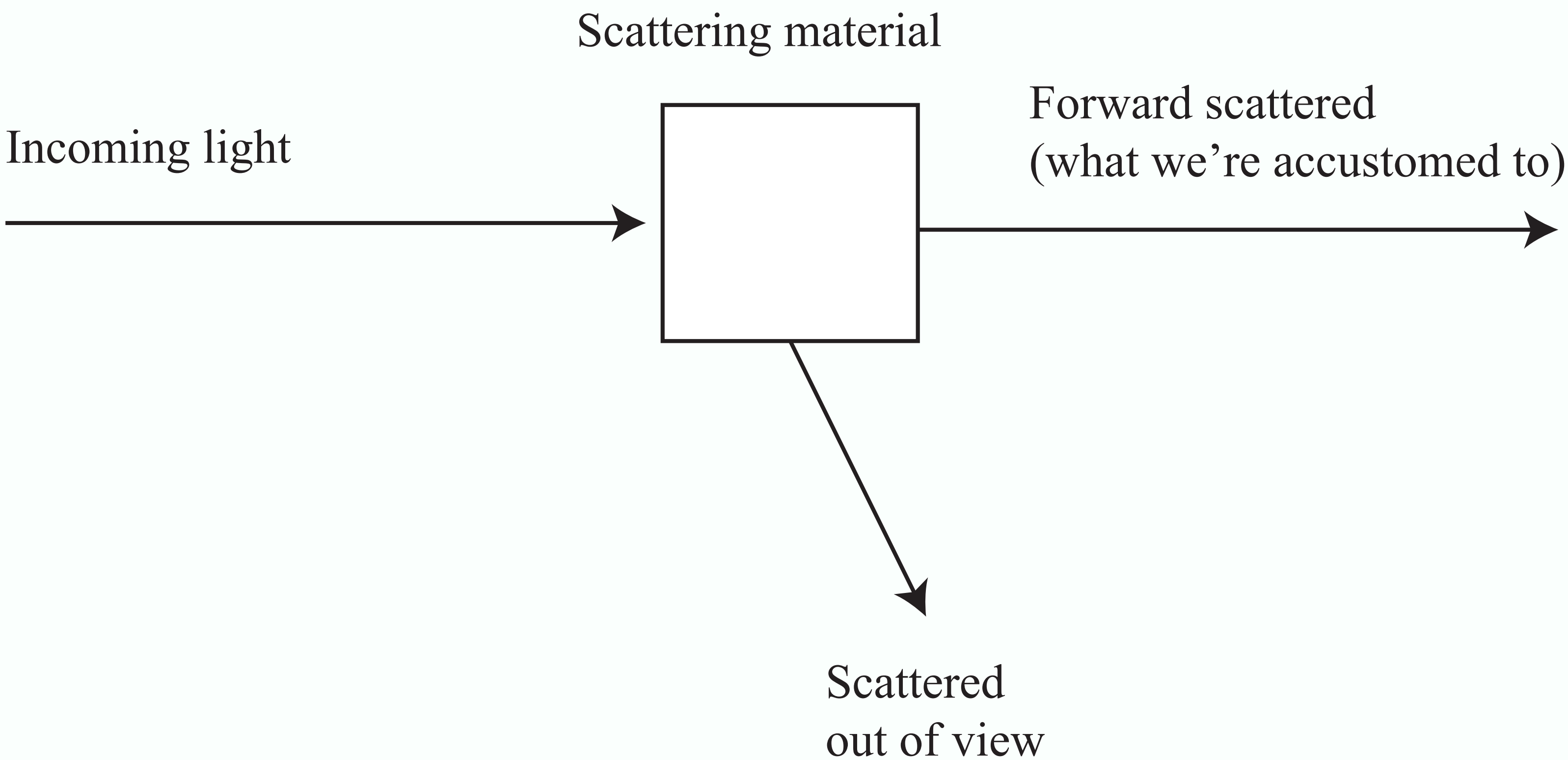
Scattering

- Fundamental mechanism of light/matter interactions
- Visually important for
  - slightly translucent materials (skin, milk, marble, etc.)
  - participating media

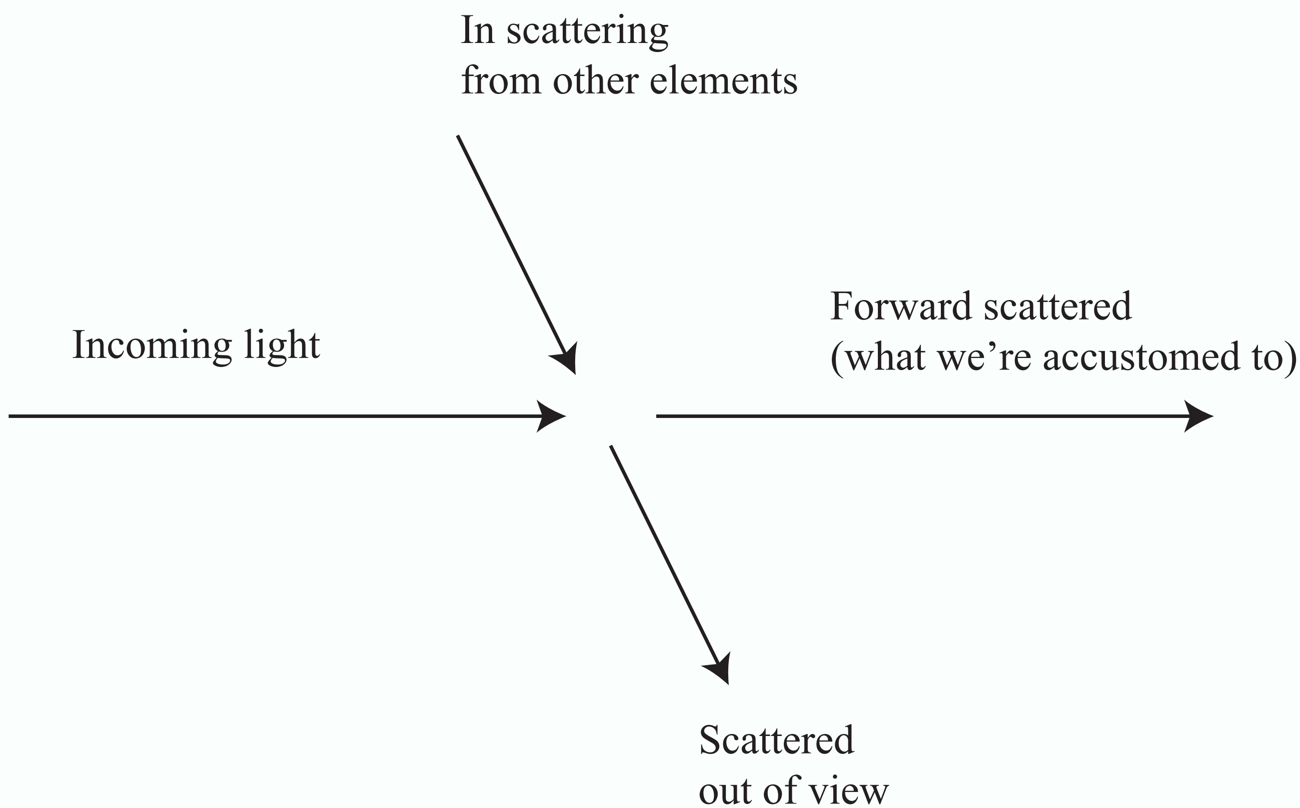
Participating media

- for example,
  - smoke,
  - wet air (mist, fog)
  - rain
  - dusty air
  - air at long scales
- Light leaves/enters a ray travelling through space
  - leaves because it is scattered out
  - enters because it is scattered in
- New visual effects

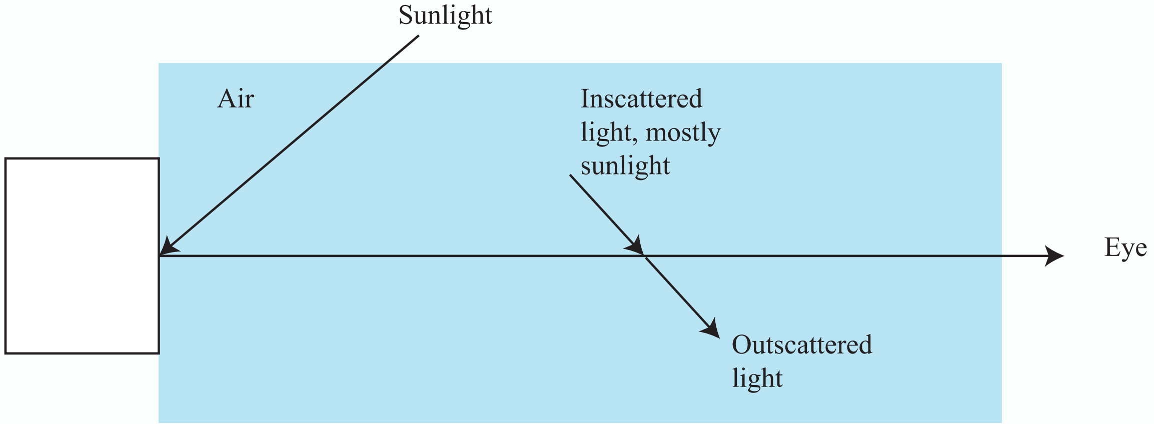
Light hits a small box of material



A ray passing through scattering material

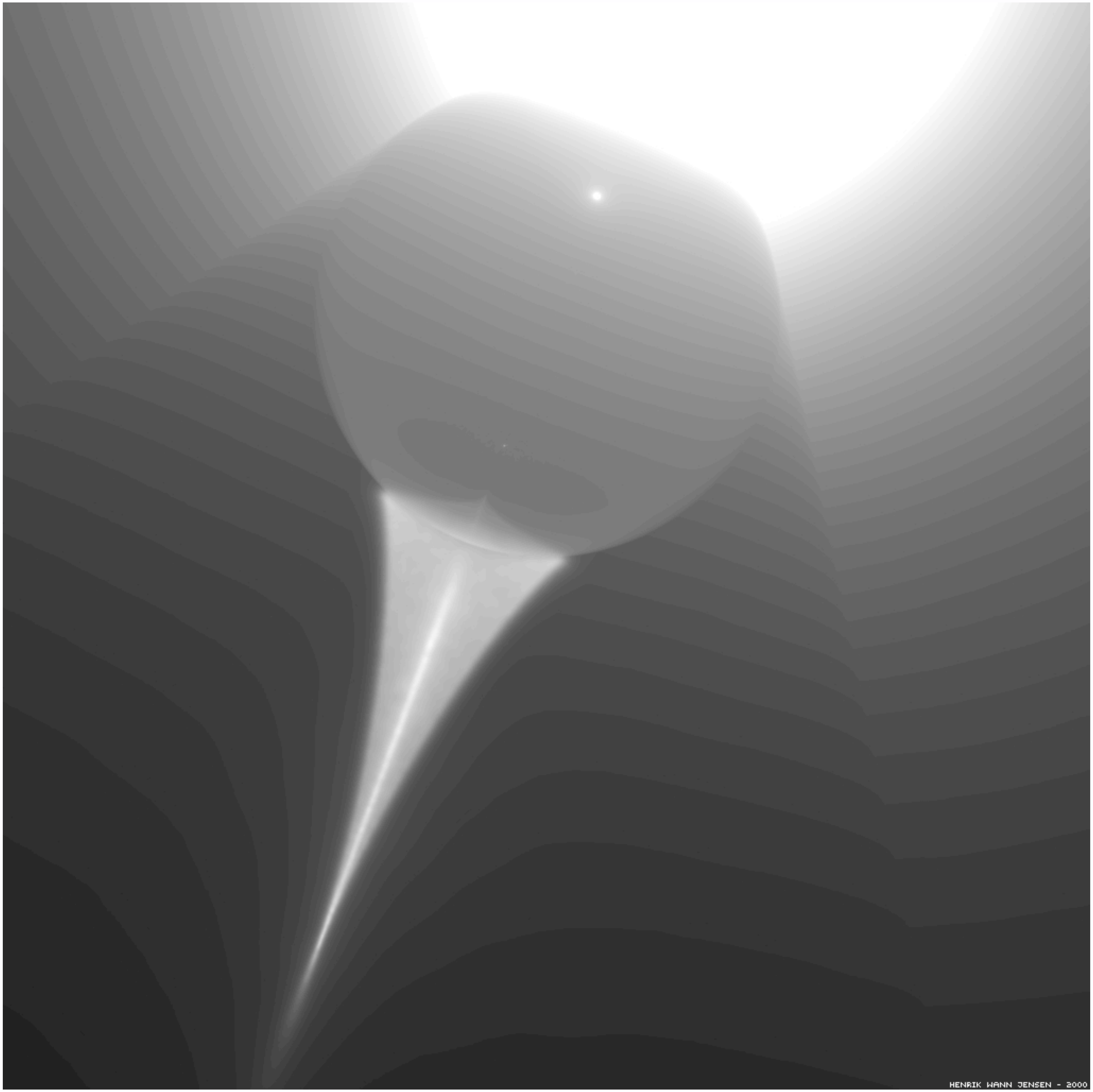


Airlight as a scattering effect



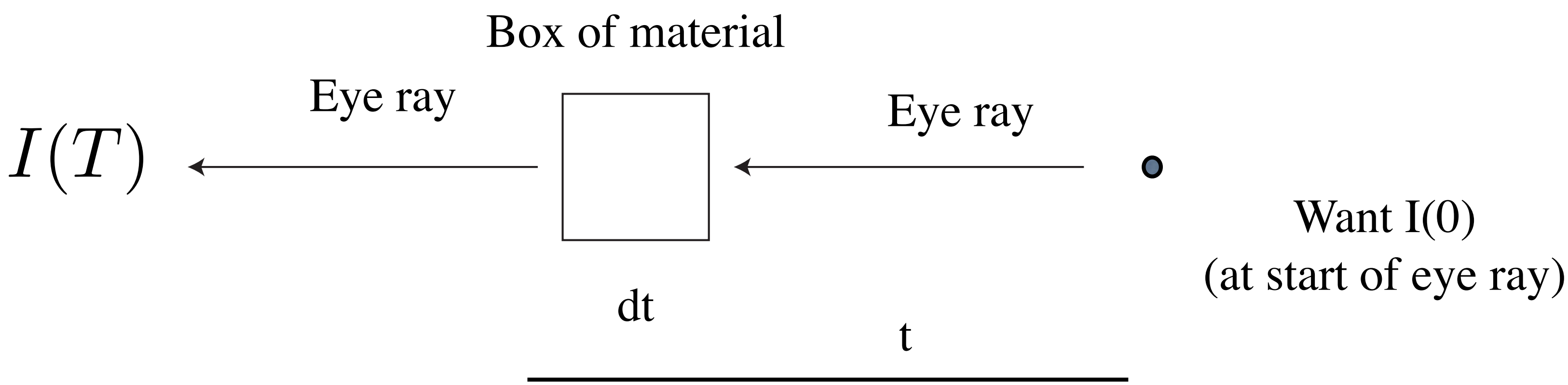

original unique filename: 20180329-141700_baie_des_fourmis.jpg
hosted by www.carto.net
photo ©André M. Winter

From Lynch and Livingstone, Color and Light in Nature

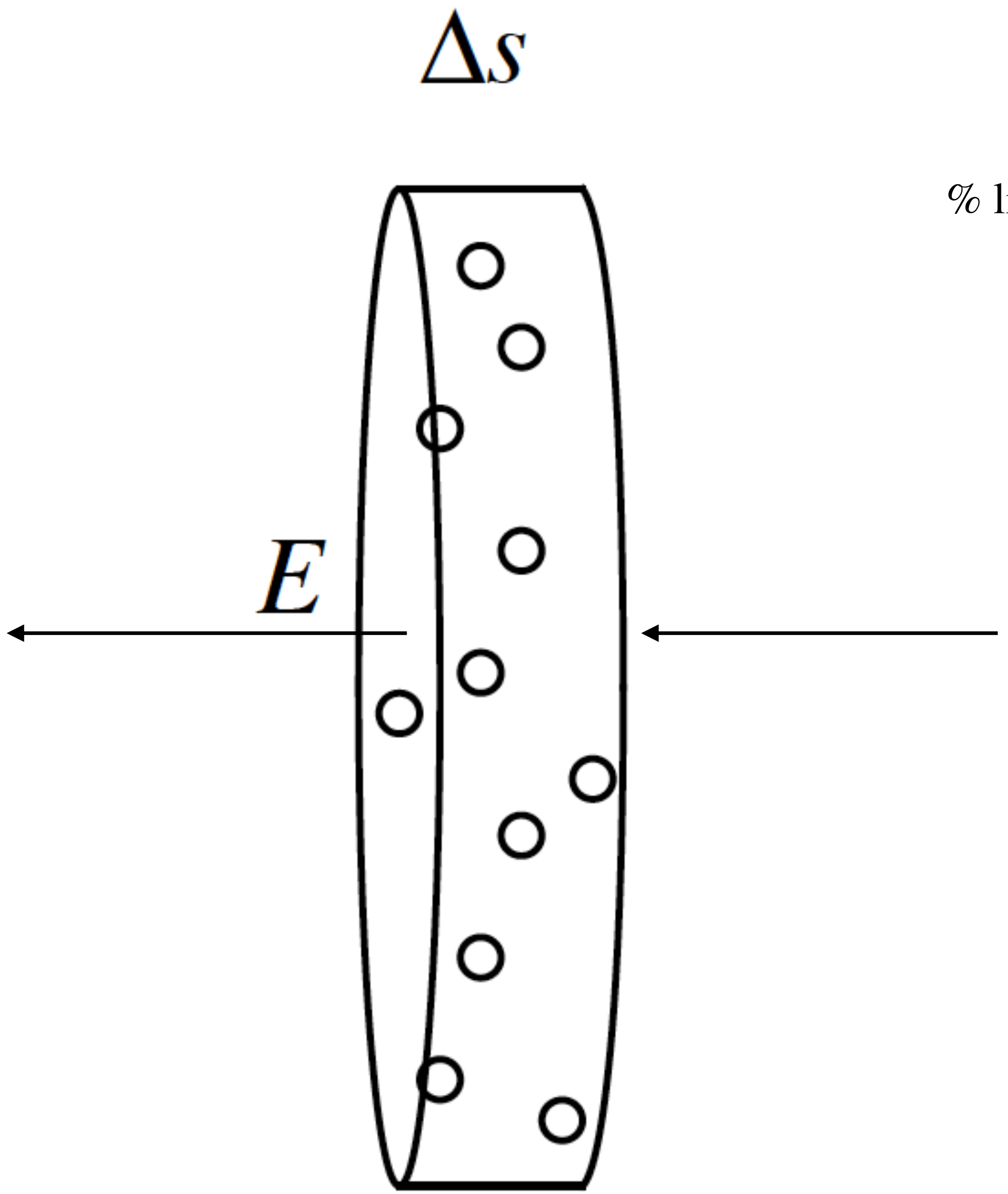

HENRIK WANN JENSEN - 2000

From Lynch and Livingstone, Color and Light in Nature

Absorption



- Ignore in-scattering
  - only account for forward scattering
- Assume there is a source at t=T
  - of intensity I(T)
  - what do we see at t=0?



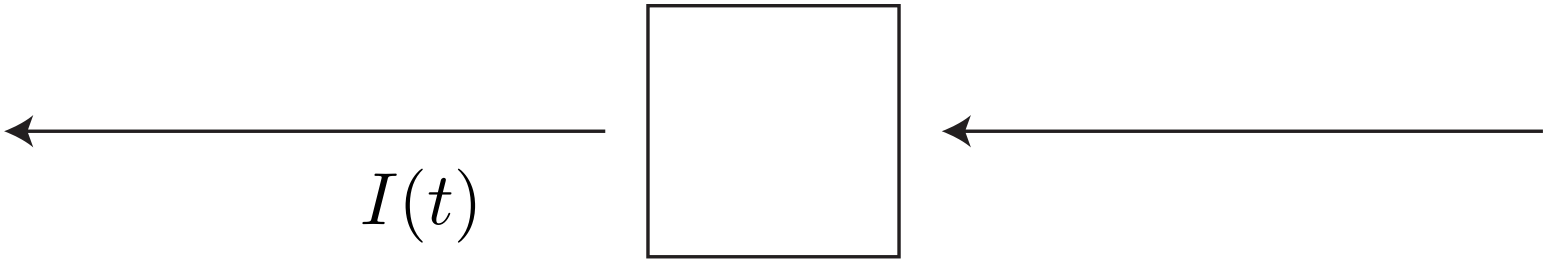
Cross sectional area of “slab” is E
Contains particles, radius r, density rho

Too few to overlap when projected

% light absorbed = (area of projected particles)/(area of slab)

This is:

$$\frac{(\rho E \Delta s)\pi r^2}{E} = \sigma(s)\Delta s$$



$$I(t - \delta t) = I(t) - \sigma(t) I(t) \delta(t)$$

Extinction coefficient

$$\frac{dI}{dt} = \sigma(t) I(t)$$

$$\frac{d \log I}{dt} = \sigma(t)$$

$$I(T) = I(0) e^{\int_0^T \sigma(t) dt}$$

$$I(0) = I(T) e^{-\int_0^T \sigma(t) dt}$$

Eye is at 0

Intensity at T

Airlight as a scattering effect

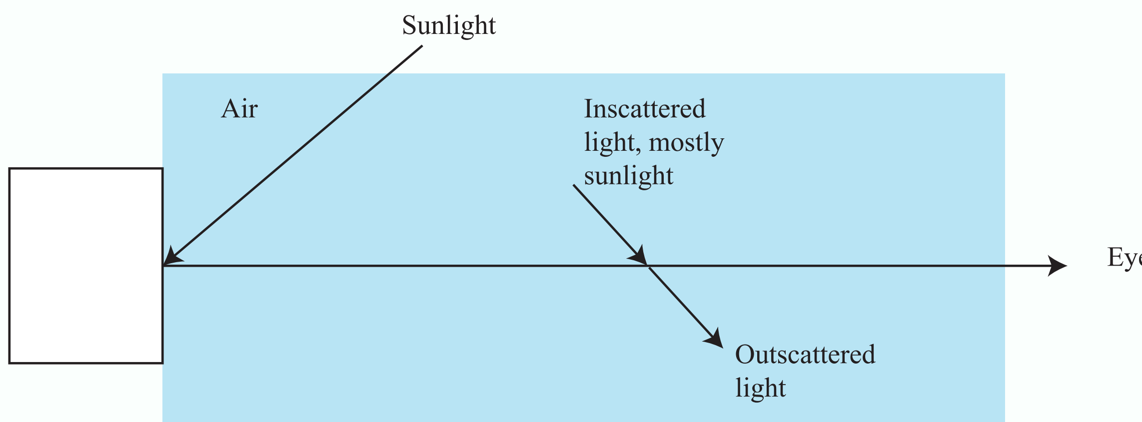
Airlight color at p

$$I(p) = J(p) \times T(p) + A(p) \times (1 - T(p))$$

Image color at p

Surface radiance color at p

Absorption term, exponential in depth, at p



Dehazing and airlight

Airlight color at p

$$I(p) = J(p) \times T(p) + A(p) \times (1 - T(p))$$

Image color at p

Surface radiance color at p

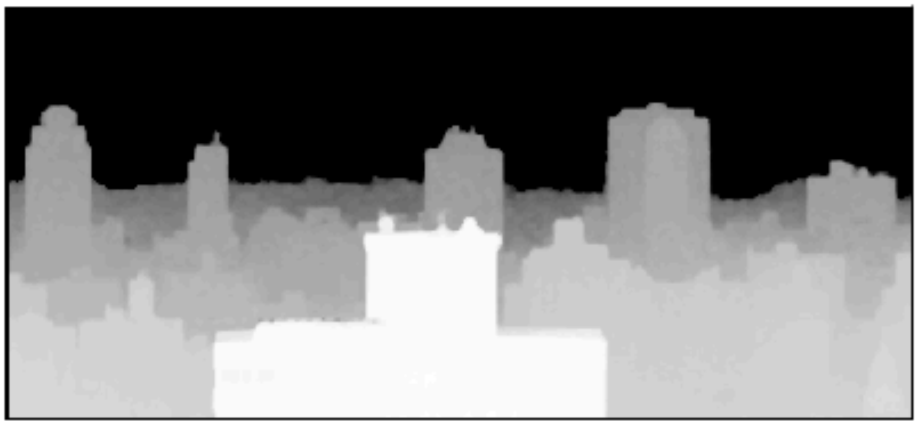
Absorption term, exponential in depth, at p

- Consequences
  - Brightness is a depth cue
  - Reasoning about airlight color yields dehazed image

Airlight yields a depth cue

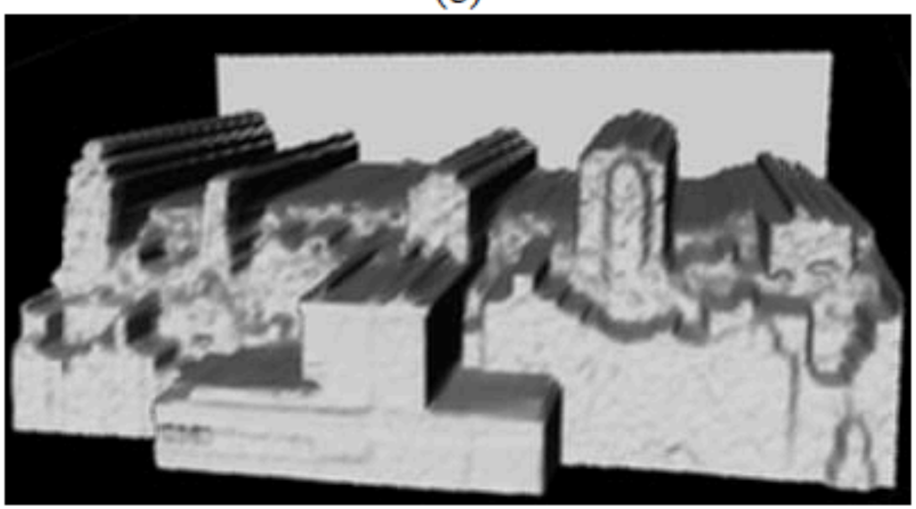
- Assume that airlight is dominant
  - (i.e. most of light arriving at camera is airlight)
  - then you can recover depth from a single image
- Disadvantages
  - requires significant fog (but not too much) or large scales

(a)



(b)

Nayar and Narasimhan, 1999



(c)

Model

Airlight color - same at all points

$$I(p) = J(p) \times T(p) + A(p) \times (1 - T(p))$$

Observed

Shading x albedo

Independent of shading

- With work, this yields
  - neighboring pixels with same albedo produce
    - constraints on shading and T
  - assume shading and T independent
    - estimate A to yield “most independent” shading and T
  - result: J(p)

Figure 1: Dehazing based on a single input image and the corresponding depth estimate.

Fattal, 08 - note depth map AND dehaze; note also slightly odd colors

Improved estimation by cleaner model

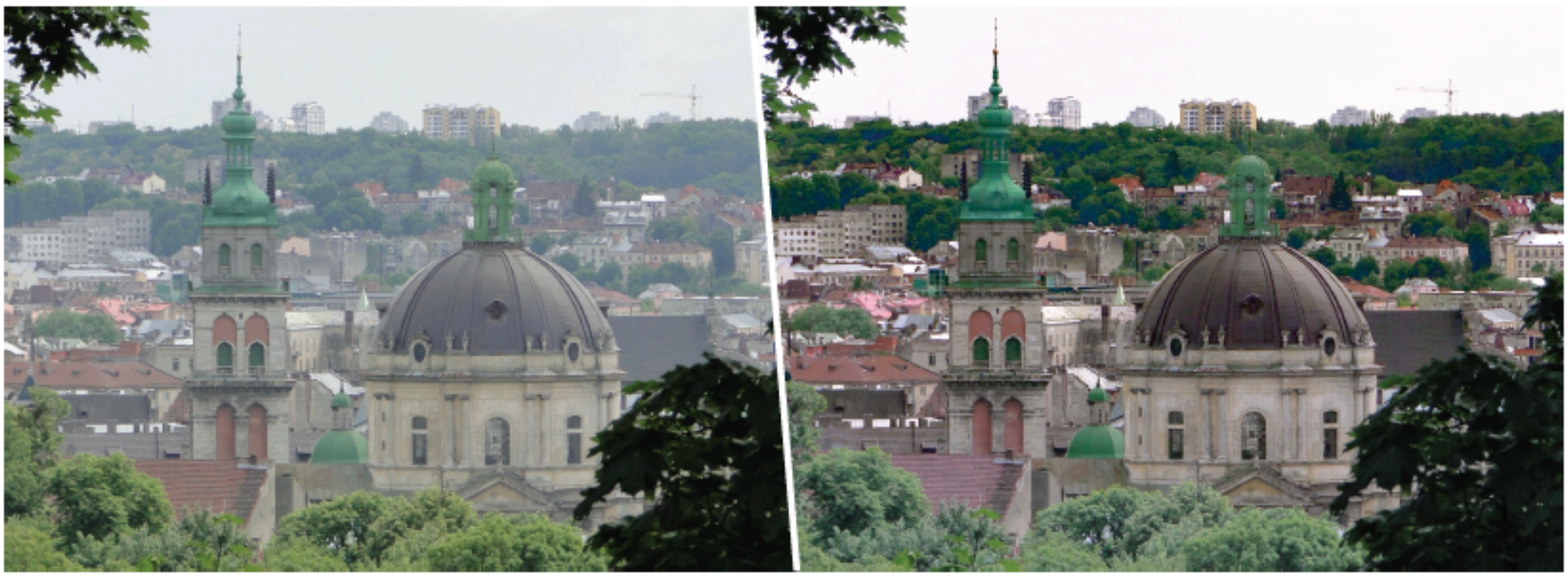
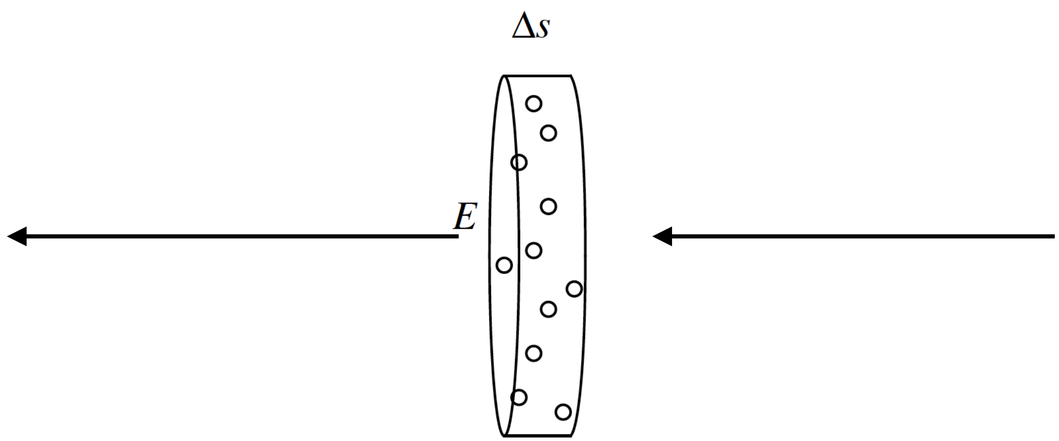


Fig. 1. Old Town of Lviv. Input image on the left, our result on the right.

Fattal, 08 - note depth map AND dehaze; note also slightly odd colors

More interesting…

- Intensity is "created along the ray"
  - by (say) airlight
  - Model - the particles glow with intensity C(x)



Cross sectional area of "slab" is E
Contains particles, radius r, density rho

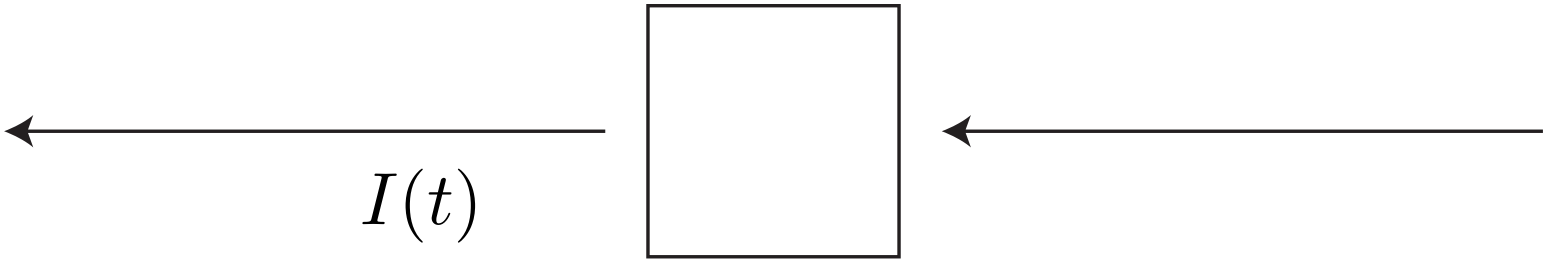
Too few to overlap when projected

Light out = Light in -
Light absorbed+
Light generated

Light generated: C x (area fraction
of proj. particles)

which is

$$C(\mathbf{x}(s))\frac{(\rho E \Delta s)\pi r^2}{E} = C(\mathbf{x}(s))\sigma(s)\Delta s$$



$$I(t - \delta t) = I(t) - \sigma(t)I(t)\delta t + \mathbf{c}(\mathbf{x}(t))\sigma(t)\delta t$$

Absorption

Generation

$$I(0) = \int_0^T \mathbf{c}(\mathbf{x}(s))\sigma(s)e^{-\int_0^s \sigma(u)du} ds$$

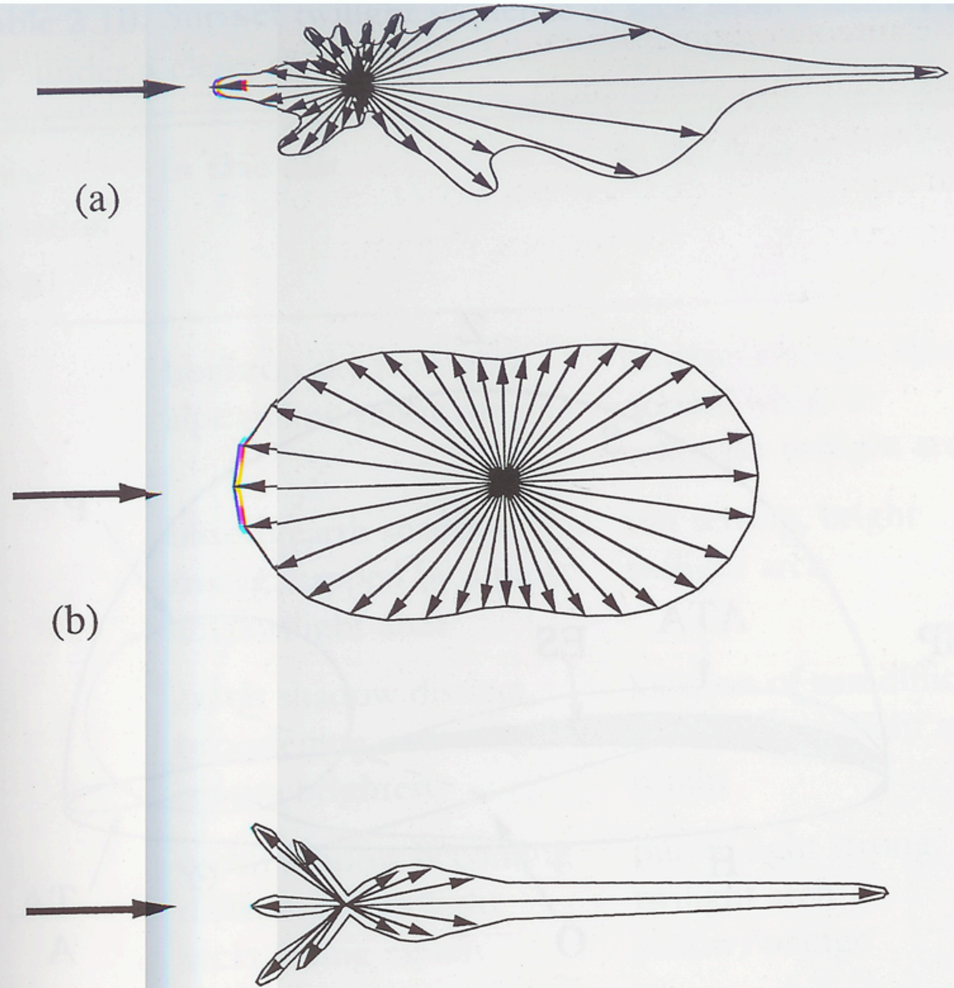
$$I(0) = \int_0^T \underline{\mathbf{c}(\mathbf{x}(s))\sigma(s)}\,\underline{e^{-\int_0^s \sigma(u)du}}\,ds$$

Made at s

Absorbed in transit
from s to 0

Accumulate along ray

Scattering profiles can be complicated



Big (dust, smoke)

Air molecules

Water drops

Fig. 2.7C Scattering patterns for different particles. (a) Large irregular particles, like those comprising dust and smoke, are irregular in the sense that they are not symmetric. They do, however, have a strong forward scattering peak and a smaller though still pronounced backscattering peak. (b) Air molecules have a scattering function that is symmetric fore and aft: they scatter the same amount of light in both the forward and backward directions but lack both the forward and backscattering peak. (c) Large water drops have a strong forward and backscattering peak and also show strong enhancements at the primary and secondary rainbow angles.

From Lynch and Livingstone, Color and Light in Nature

Fig. 2.7A (LEFT) Aureole around the sun. The sun is hidden by a street lamp. To the eye, the sky appeared clear.

Fig. 2.7B (RIGHT) The next day the sky was exceptionally clear and there was no aureole.

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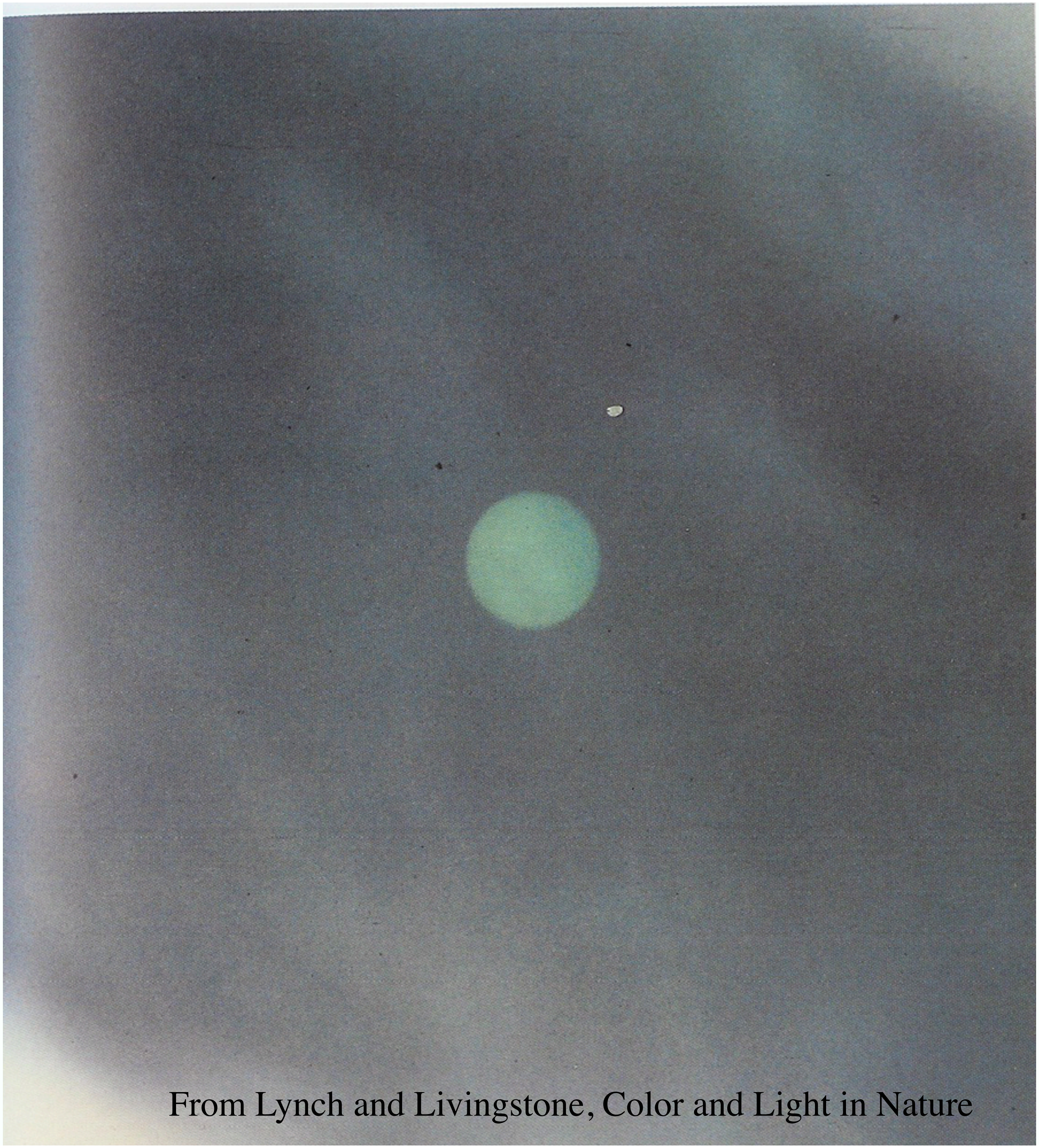

From Lynch and Livingstone, Color and Light in Nature

Minnaert, Light and Color in the outdoors

Notice flattened sun,
sparkles