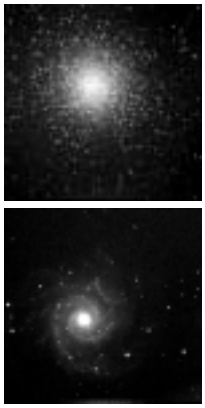
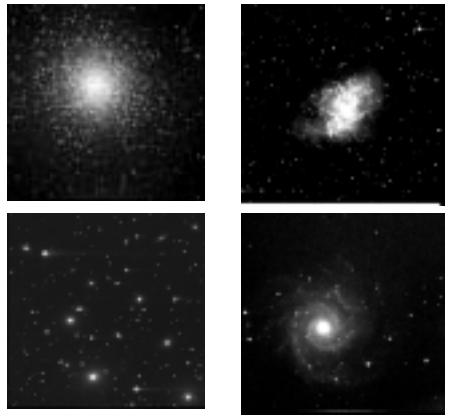
- A star → **a point source**
  → flux/magnitude
  e.g., m_V=15.7
- A galaxy or central part of a globular cluster
  → **an extended source**
  → integrated flux, or
  surface brightness
  e.g., 18.2 mag/sq arcsec
- The sky is an extended source. In a dark site, sky~20-21 mag/sq arcsec



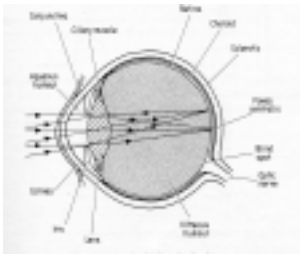


Detectors

Eye as a detector

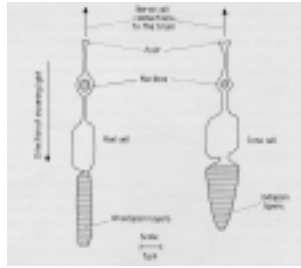
Pupil diameter

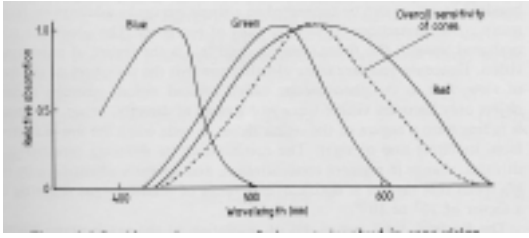
- determines resolving and light-gathering power
- adapts to existing light levels
- 8 mm (age 20) to 2.5 (age 80)



Light Sensitive Retinal Cells

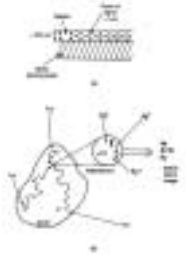
- **rods**
  night vision λ_{max}~507 nm
  V_{lim}~8 mag
  in practice 5.5-6.5 mag
  outer periphery of retina
  → averted vision
- **cones**
  color vision λ_{max}~555 nm
  central retina=fovea





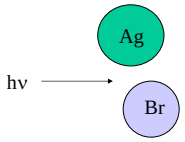
Photography

- **Emulsion（感光乳劑）**:
  micron-sized grains of some silver halide （鹵化銀）,
  e.g., silver bromide (溴化銀；AgBr), suspended in a thin layer of gelatin
- In astronomical applications, add a glass base for support
  → **photographic plate**



Photographic Process

- Photon → grain
  - → e^- excited
  - + Ag^+ (e.g., from thermal excitation)
  - → Ag + Ag + Ag …..
  - ➔ **latent image**
  - + reducing agent (adding hydrogen or removing oxygen or, in this case, removing bromine)
  - → conversion of entire grain to pure silver
- **Stop** once a clear image is obtain

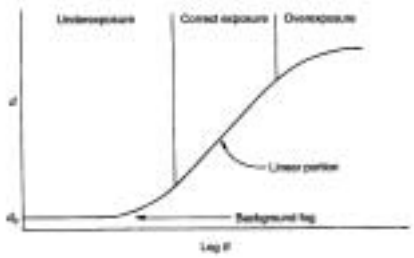


Developing（顯影）—— 加大分開效果

Stop （急制）

Fixing （定影）—— 除去 Br 及剩下的 AgBr

- There is always some partially-developed grains remain → a 'fog' on the film



'**Reciprocity failure**' --- increasing inefficiency of photographic emulsions with longer exposure times

Note Most photoelectrons do not survive long enough to meet with a silver ion
→ **process very inefficient**
e.g., ~1000 photons → 1 developed grain

Quantum Efficiency (QE)
= The efficiency a device records the incident photons
= [# of records] / [# of incoming photons]

Photographic plates QE ~ a few %, at best < 10%

Note To increase the sensitivity, some measures can be taken

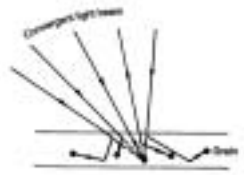
- Adding chemical sensitizers to the emulsion
- Baking or soaking in nitrogen or hydrogen

➔Process of **hyersensitization**

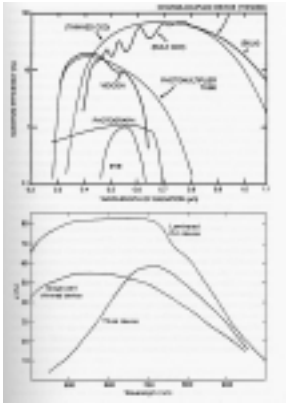
Note In addition to **low sensitivity**, another disadvantage of a photographic plate is **non-linearity**
→ a given exposure may be correct for some stars, but overexposed for bright stars and underexposed for fainter stars

Even for a correctly exposed star, the density of the image does not directly reflect the brightness of a star, because of internal scattering

Incident photons are scattered within emulsion before being absorbed → enlarged, circular image with size ~ # of scattering



Brightness of a star: a complicated function of total density *and* image size



Photography --- Summary

Disadvantages

- ➢low sensitivity
- ➢complex procedures, thus prone to error
- ➢density --- rather than intensity --- recorded

Advantages

- ➢Cheapness
- ➢long exposure (cf. eye ~ 0.1s)
- ➢ease of storage
- ➢familiar techniques
- ➢Large field of view (suitable for observations)

Field of View

- Schmidt telescopes use photographic plates 30 cm square, corresponding to a sky area ~6^ox6^o
- Some plates are 50 cm square
- In comparison, electronic detectors < 5 cm (1^o FOV)

Plate Scale

CCD ↑ Primary ↑

P ["/pixel]=(206,265) x μ[micron] / 1,000 x f [mm]

LOT (Lulin One-meter Telescope)

- D=1000 mm
- f/8
- CCD camera has 24 micron x 1024 x 1024 pixels
- Calculate the FOV of the camera

Photomultiplier Tubes