

Remote sensing

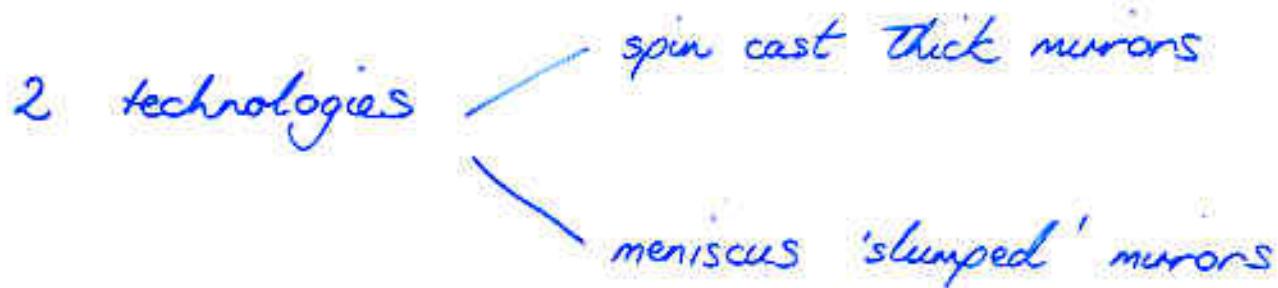
Once we move beyond the Solar System, astronomy gets to be "hands off": no more space probes as distances are so large.

We are almost entirely dependent on electromagnetic radiation reaching us from objects we study, or luminous objects they affect.

Q What are 2 examples of objects we study via light from objects they interact with, not directly?

→ extrasolar planets, dark matter

Mirror construction



Spin cast : Mirror lab at U. of Arizona

Thick mirrors with honeycomb construction

Spinning furnace ($\sim 7 \text{ rpm}$) gives parabolic shape

Fast mirrors (short focal length) steps up polished

6.5m MMT upgrade, Mt Graham 8.4m

Meniscus Thinner, more flexible mirrors

Active support important

Vulnerable to wind

Gemini 8m, Japanese 'Subaru' 8m, VLT

Q

You are beginning to plan for
a new 10m ground-based
telescope.

What do you need to take into
account when you consider
possible locations?

ROSAT

X-ray satellite launched 1990

first all-sky survey in X-rays ;

large increase in sensitivity on earlier
satellites

6 - 124 Å waveband.

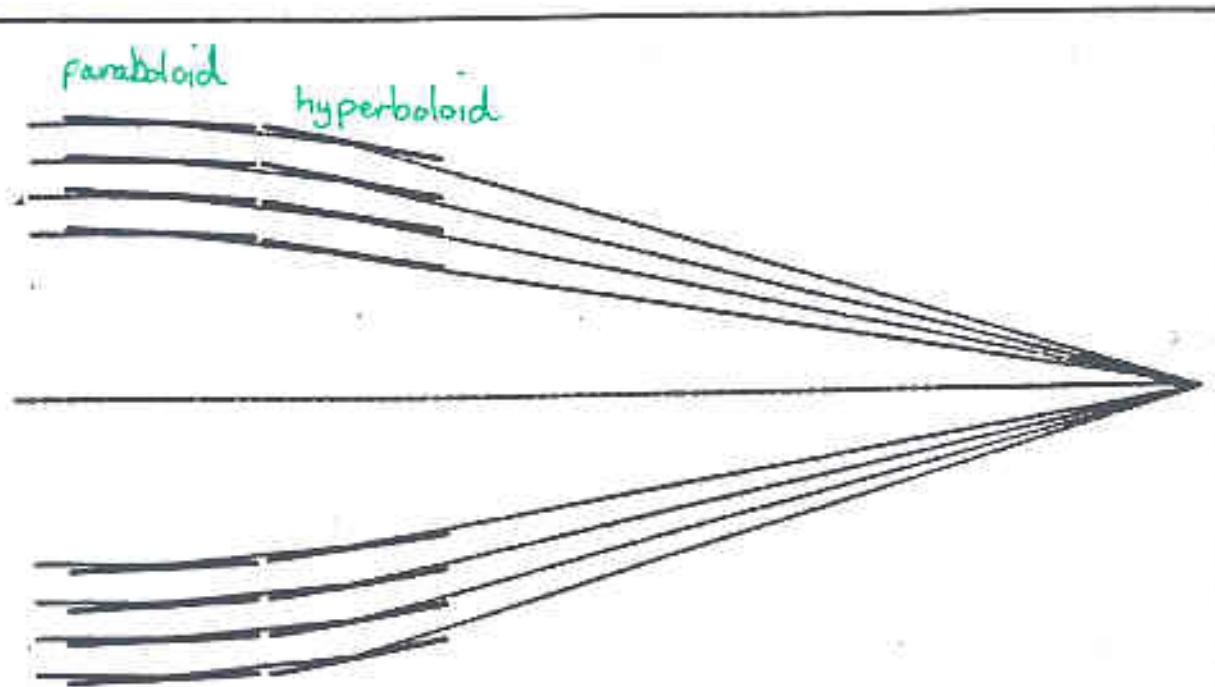
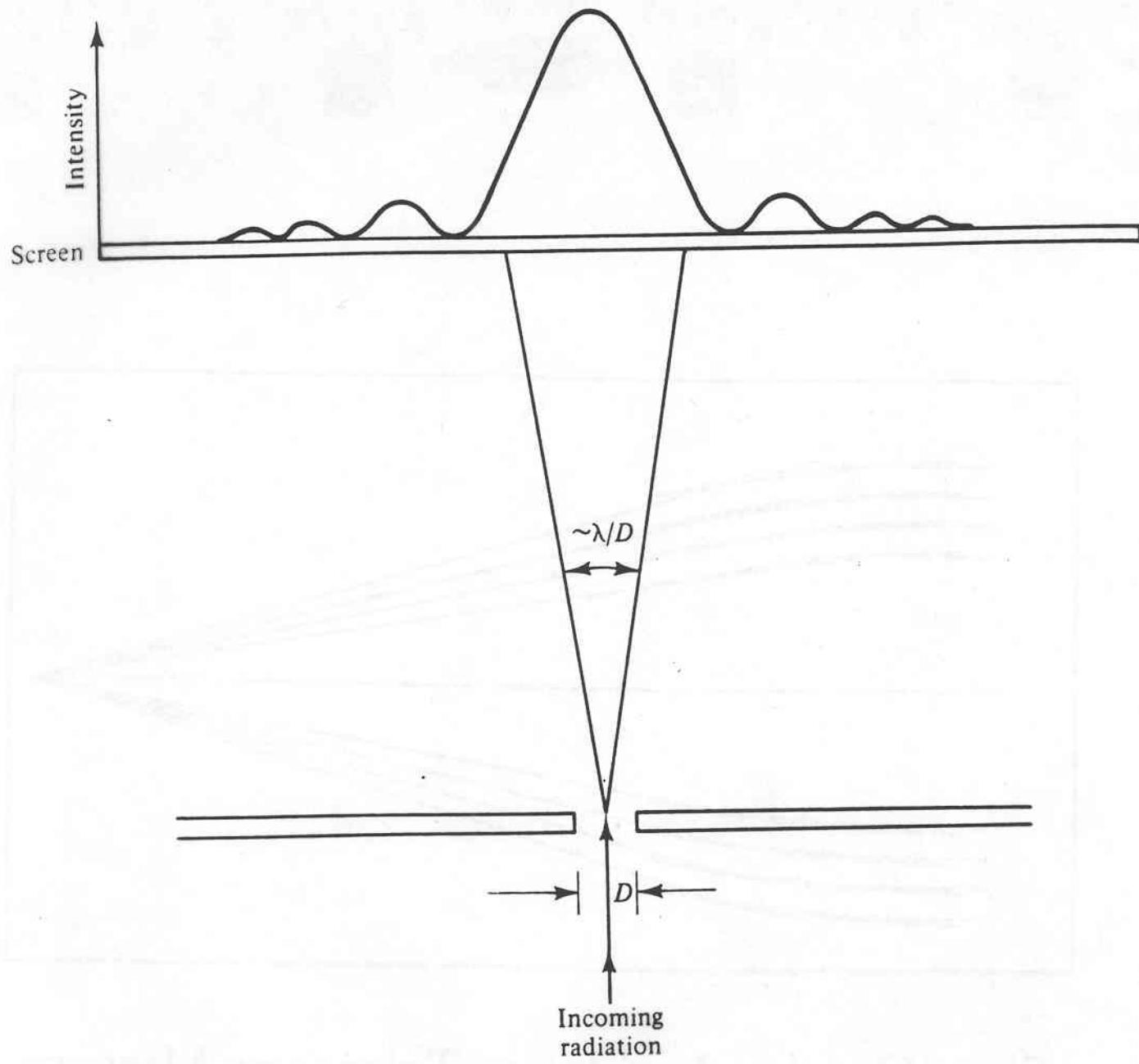


Fig. 3 Grazing Incidence Telescope Mirrors

X-rays will only reflect at grazing incidence
Paraboloid/hyperboloid (roughly cylindrical)
nested mirrors



Resolution :

$$\Delta\theta \text{ (radians)} \approx \frac{\lambda}{d}$$

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Diffractive limit :

- Keck 10m telescope at 5000 \AA :

$$\Delta\theta \approx \frac{\lambda}{d} = \frac{5000 \times 10^{-10} \text{ m}}{10 \text{ m}} = 0.01 \text{ arcsec}$$

at 2μ :

$$\Delta\theta \approx \frac{2 \times 10^{-6} \text{ m}}{10 \text{ m}} = 0.04 \text{ arcsec}$$

(Note that seeing at a good site is $\sim 0.5 \text{ arcsec}$)

- Parkes 64m radio telescope at 21cm :

$$\Delta\theta \approx \frac{0.21}{64} = 11 \text{ arcmin}$$

$$\Delta\theta \approx \frac{0.021 \text{ m}}{64 \text{ m}} = 65 \text{ arcsec}$$

• 2.4 m Hubble Space Telescope at 1000 \AA

$$\Delta\theta \approx \frac{1000 \times 10^{-10} \text{ m}}{2.4 \text{ m}} = 0.008 \text{ arcsec}$$

at 5000 \AA

$$\Delta\theta \approx 0.04 \text{ arcsec}$$

Note instruments have pixel sizes $0.1''$

$0.05''$

$0.014''$

Active and adaptive optics

active mirror support

tip / tilt

whole enchilada : adaptive optics / natural
laser
guide stars

DETECTORS

① Photographic plates

large area, glass for positional stability

emulsion : gelatin + silver halide grains (AgBr , AgCl)
(semiconductor)

photon \rightarrow ~~an~~ electron raised to conduction band
leads to formation of small no of Ag atoms

developer - works faster on these grains than
on unexposed ones

low QE (quantum efficiency) : 1-5%

Hard to characterise response accurately
(flat field*)

Photographic plates

2.1 Basic operation

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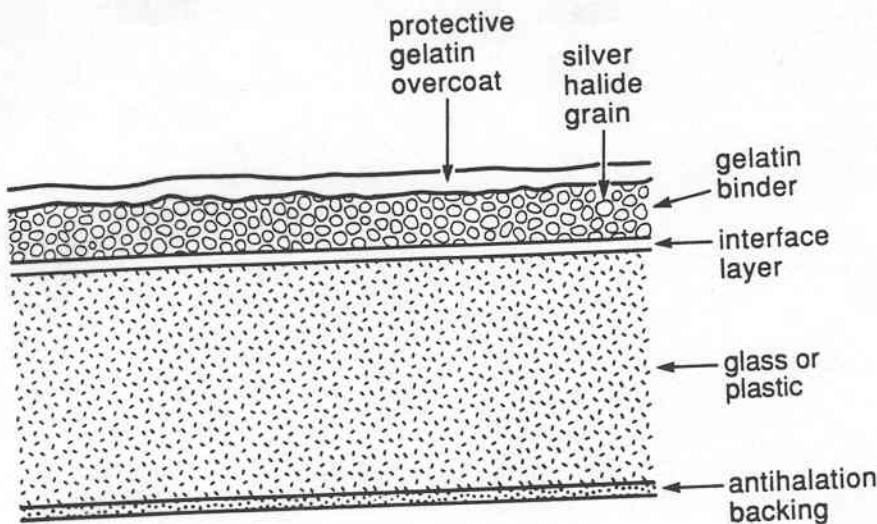


Figure 2.1. Cross-section of a typical photographic plate.

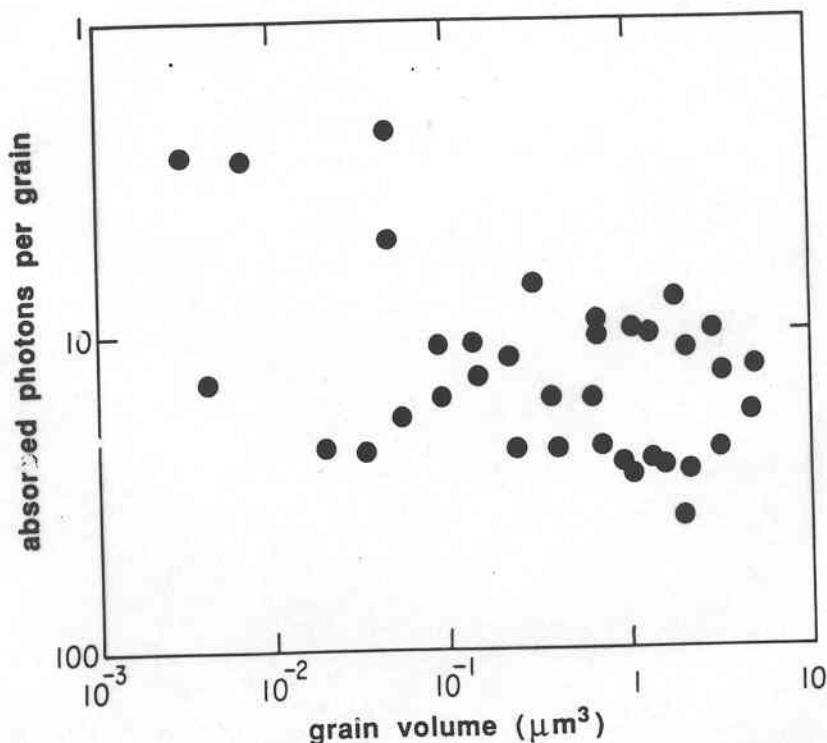


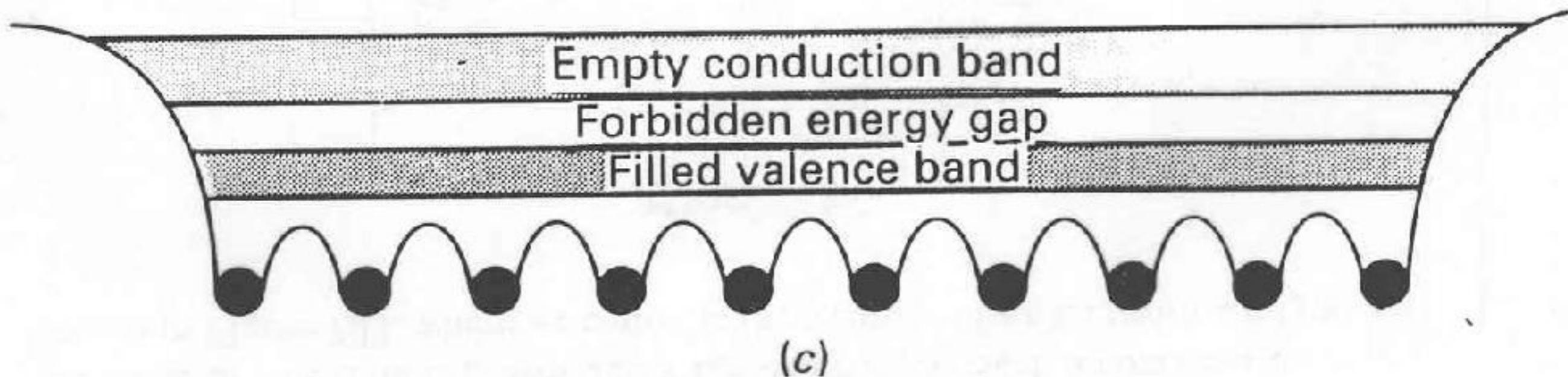
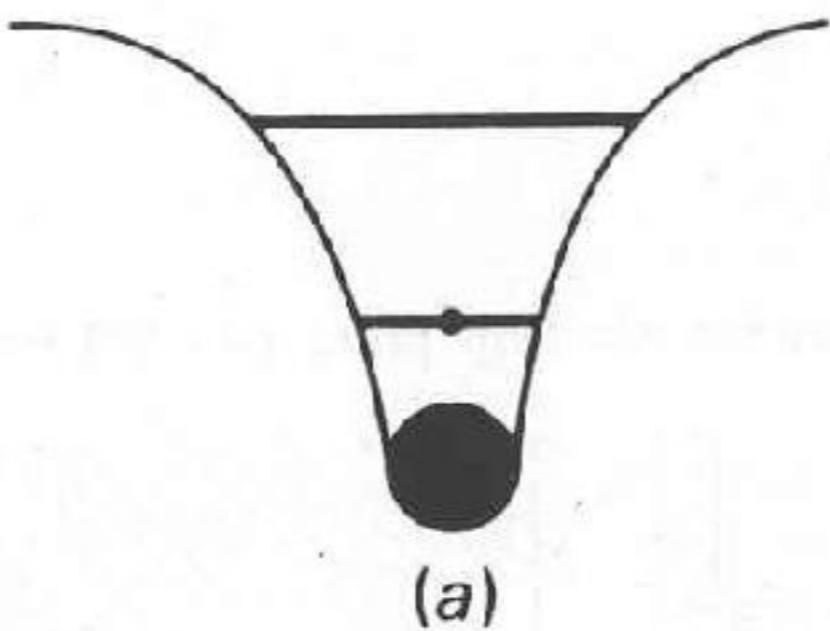
Figure 2.6. Average number of photons that must be absorbed per grain to make half the grains developable (from Tani, 1989).

CCDs

Made of Si (semiconductor)

- photon in, raises e^- to conduction band,
constrained in potential well (pixel)
- QE in ^{uv} blue (photon absorption)
red (bandgap)
- Front & backside - illuminated
dye coated

Charge-coupled devices



The development of a conduction band and a valence band of electrons in a solid

- Biggest devices 2048×4096 pixels
- Readout : charge transfer close to 100% efficient down columns, out bottom row (horiz. transport register)
 - clocking CCD via digital circuit
 - diffusion time of e^- limits readout time
- on-chip amplifier (source of readout noise)
 - capacitor
 - voltage sensed on capacitor, amplified to $\sim 1-5$ V
 - analog-to-digital converter (ADC)
- Bias
- Dark current & liquid N_2
- Measuring pixel response (flat fielding)
- Cosmic rays

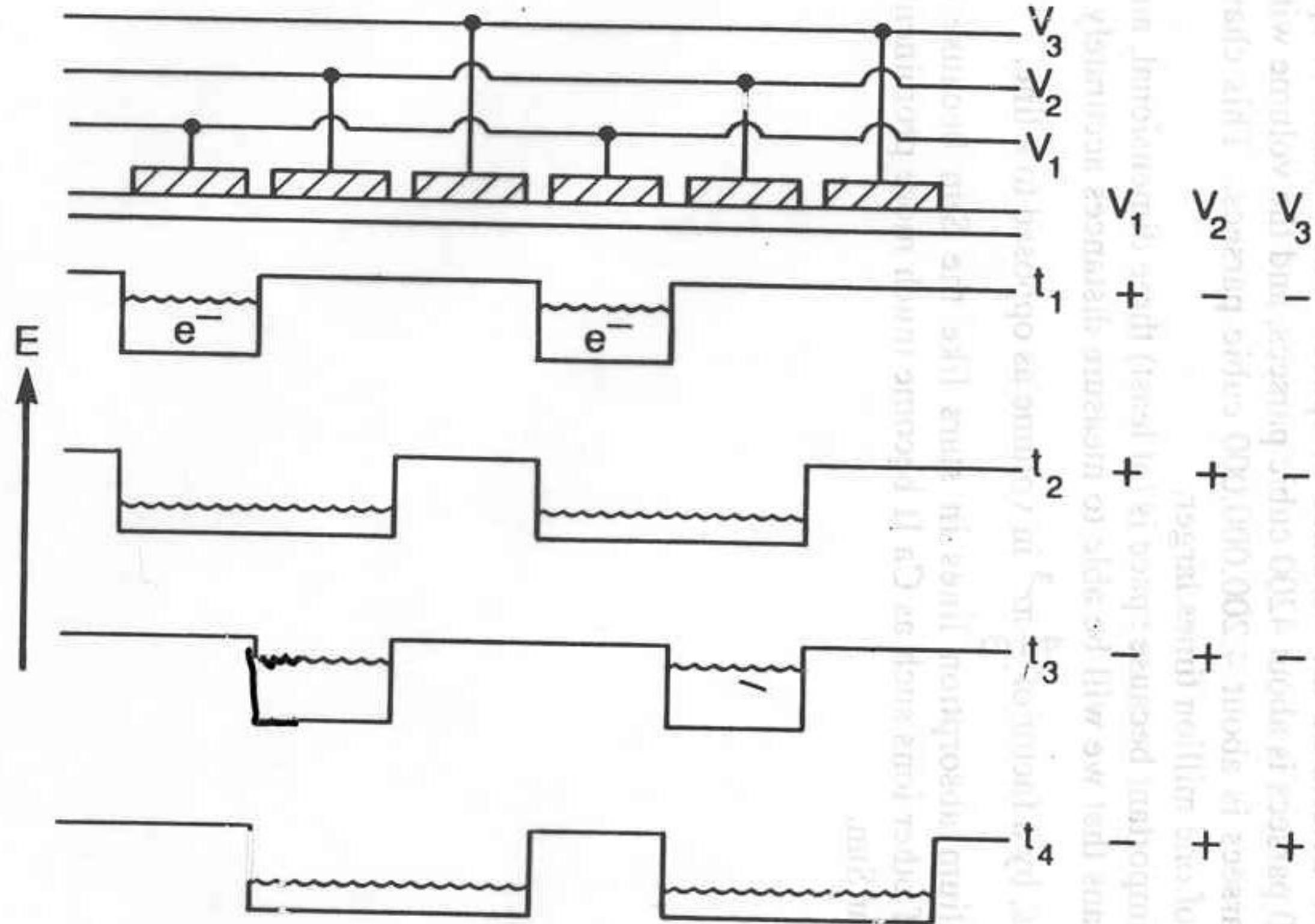


Figure 7.7. Charge transfer in a 3-phase CCD.