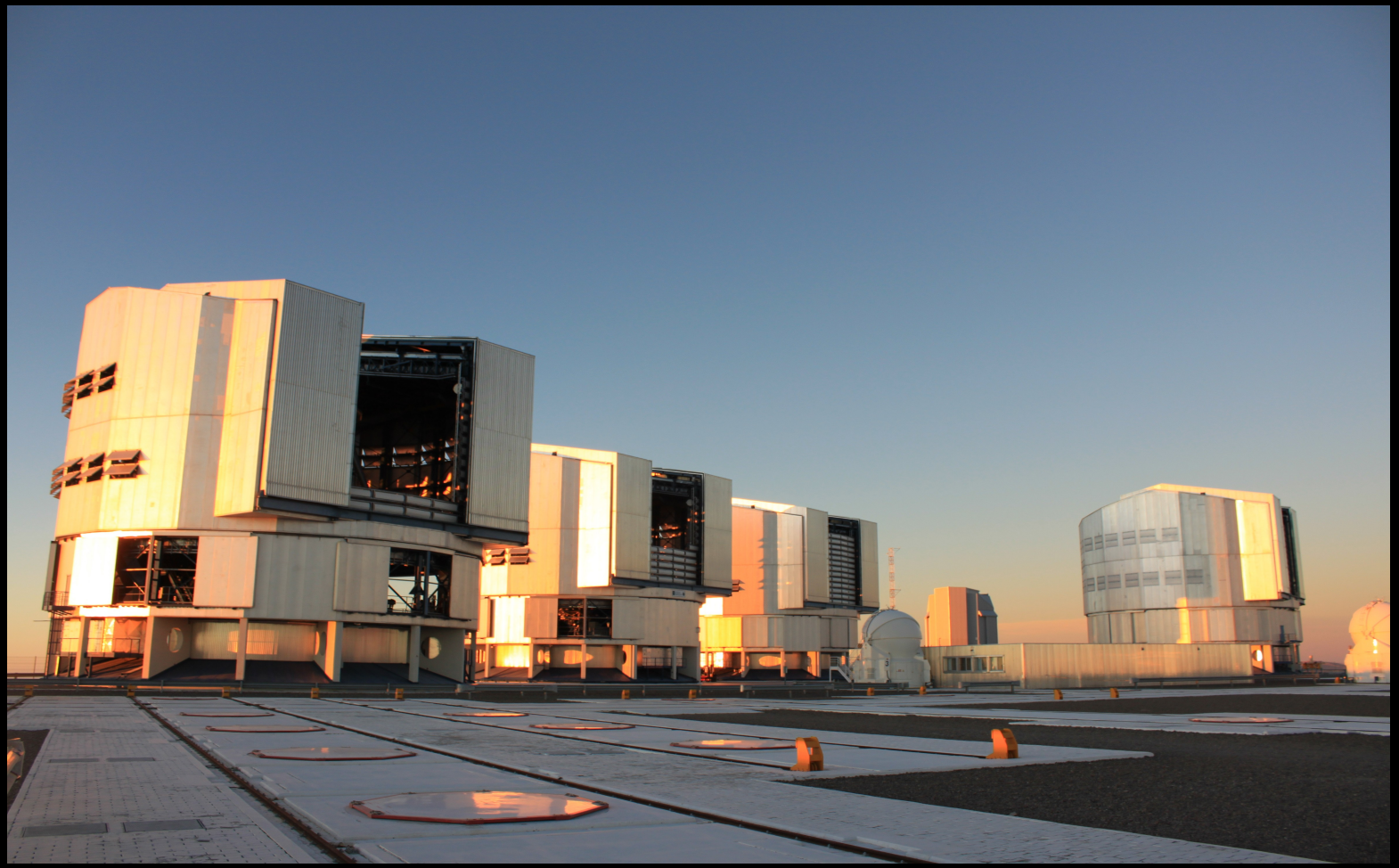
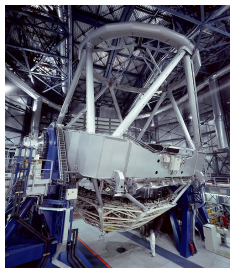
Astronomische Technieken
Hovo Cursus 2010

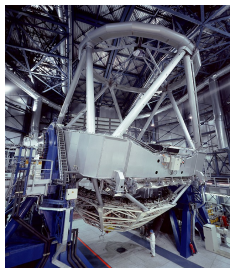


Prof.dr. Paul Groot (RU)
Dr. Gijs Nelemans (RU)



Opbouw van de cursus

15/3:	- Berichten uit de ruimte - Ontvangers op Aarde	 Paul Groot
22/3:	- Telescopen en detectoren - De perfecte waarneming	 Gijs Nelemans
12/4:	- Telescopen in de ruimte - De invloed van de atmosfeer	 Gijs Nelemans
19/4:	- Radio telescopen - Interferometrie: meer met minder	 Paul Groot
26/4:	- Excursie naar sterrenwacht RU - Instrumentontwikkeling Afdeling Sterrenkunde	 Beide
3/5:	- Fotonen voorbij: neutrino's, gravitatiegolven - Telescopen van de toekomst	 Paul Groot



Fotonen: electromagnetische straling

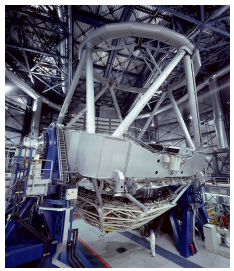
Wat is licht?

a) Licht is een deeltje

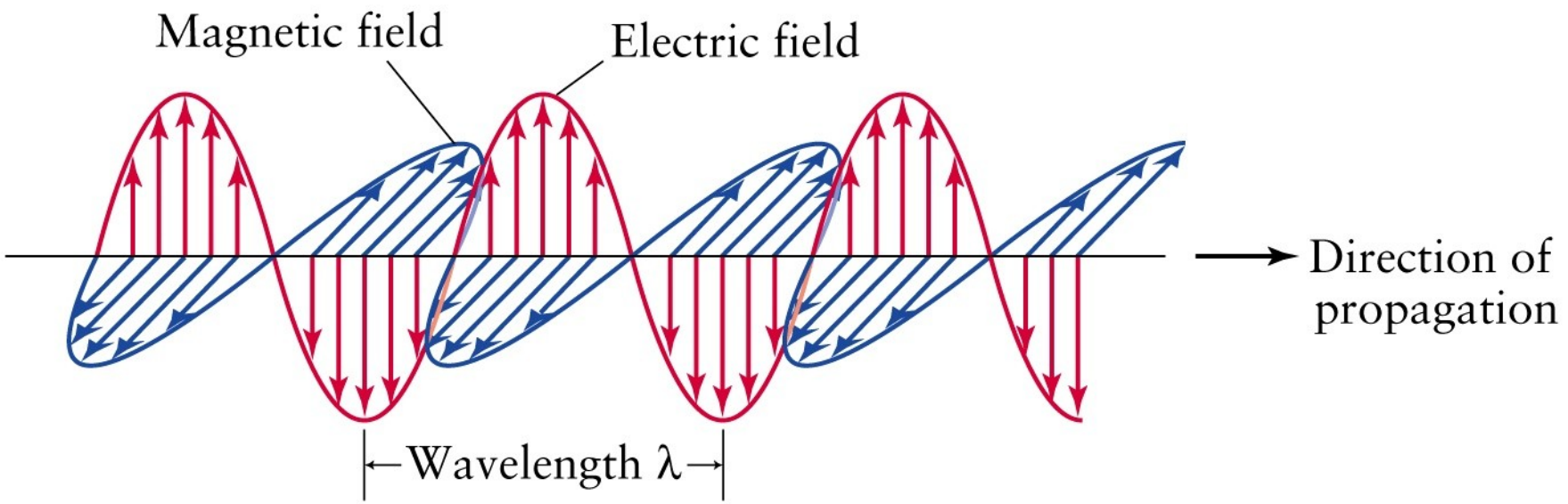
b) Licht is een golf

Beide: licht is een golf en een deeltje.

Hoe we het detecteren bepaalt zijn eigenschappen.

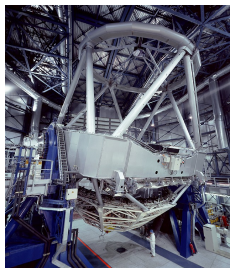


Licht als een golf



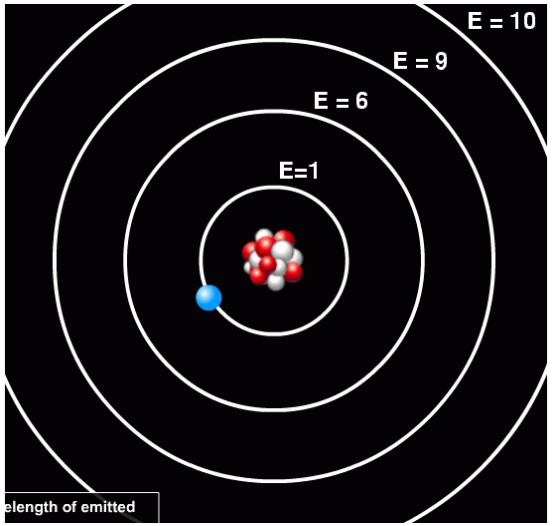
Eigenschappen van een golf:

- **Golflengte:** λ afstand van piek tot piek ('kleur', 'toonhoogte')
  (frequentie ν = c /λ)
- **Amplitude:** hoogte van de piek ('intensiteit', 'sterkte')
- **Polarisatie:** trilrichting van de golf.

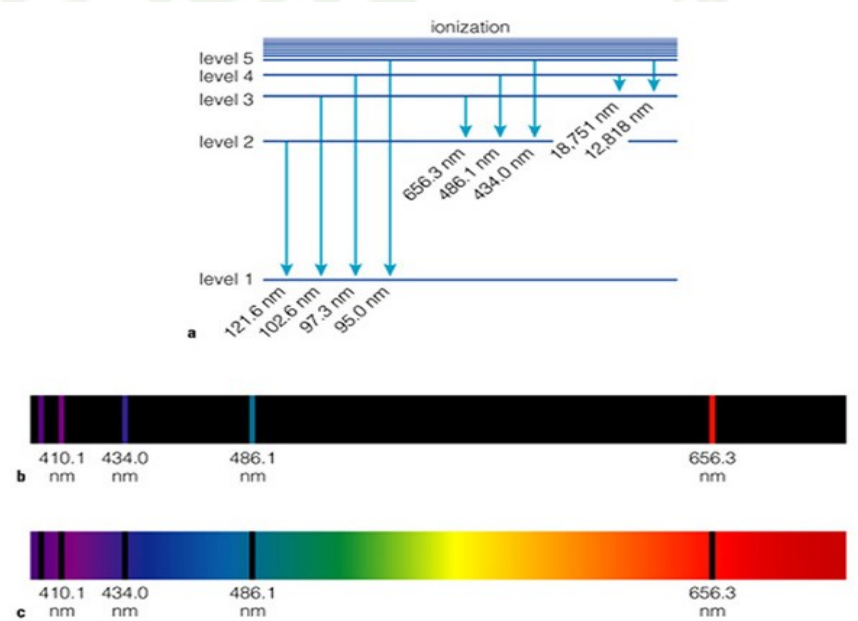


Licht als een deeltje

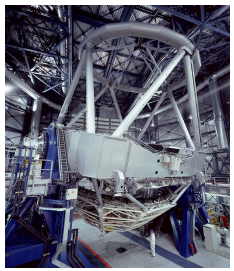
Beide problemen opgeslost als licht een deeltje is *en gekwantiseerd* (in energie) kan worden.



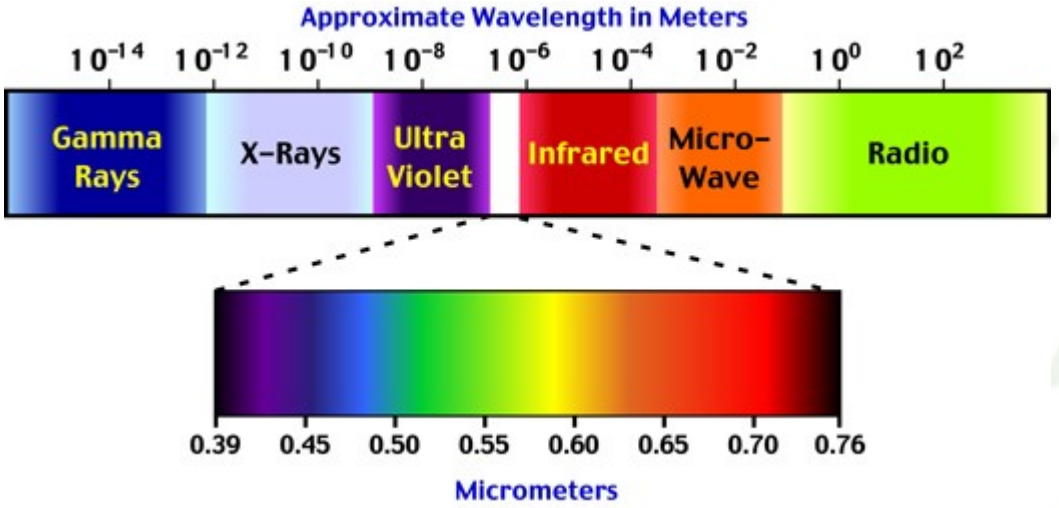
$$E = \frac{hc}{\lambda}$$



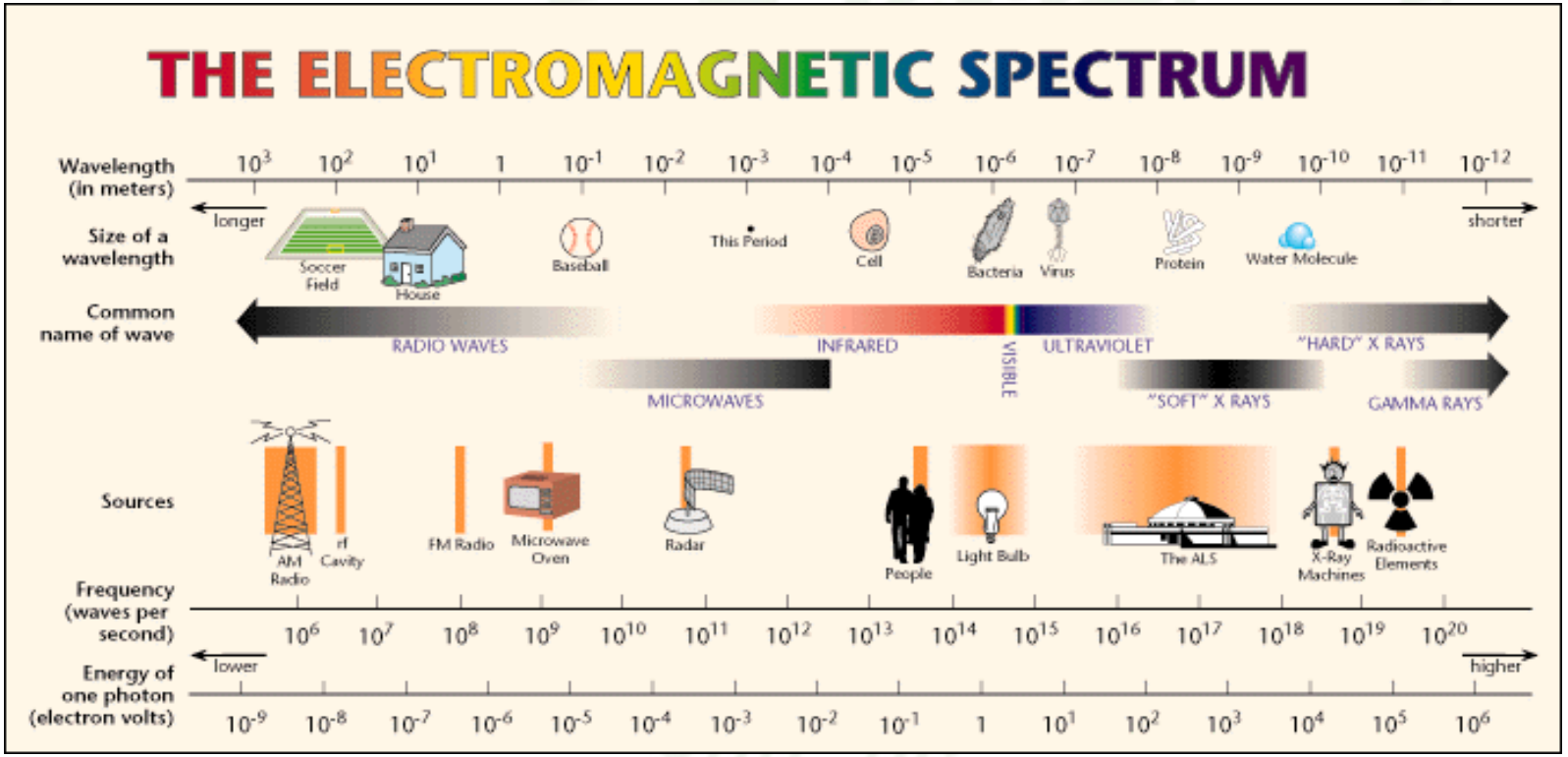
Begin van de astro*fysica*

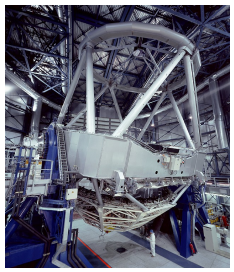


Het electromagnetisch spectrum



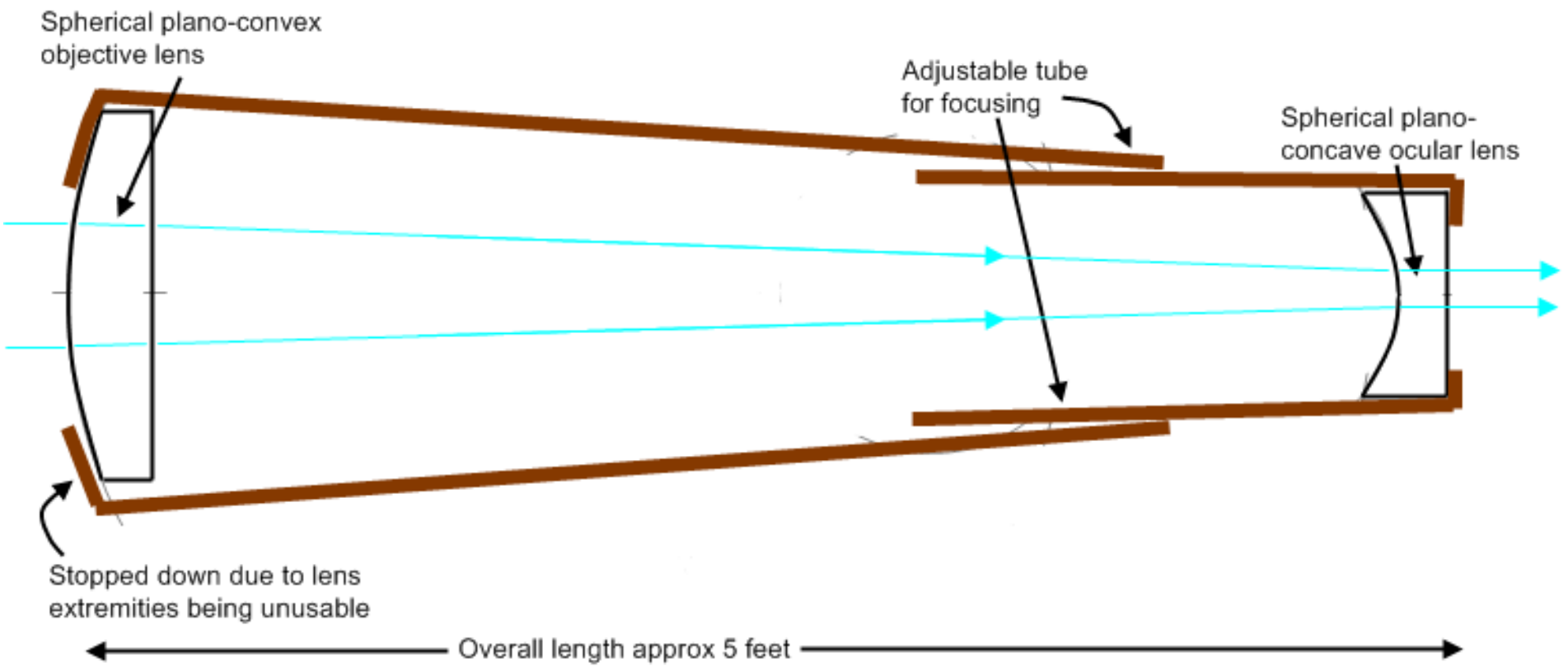
Ordening naar golflengte, frequentie of energie





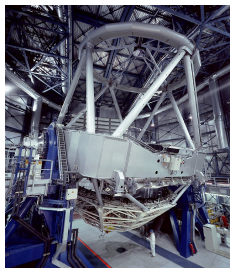
Werking van de telescoop

The Galilean Telescope

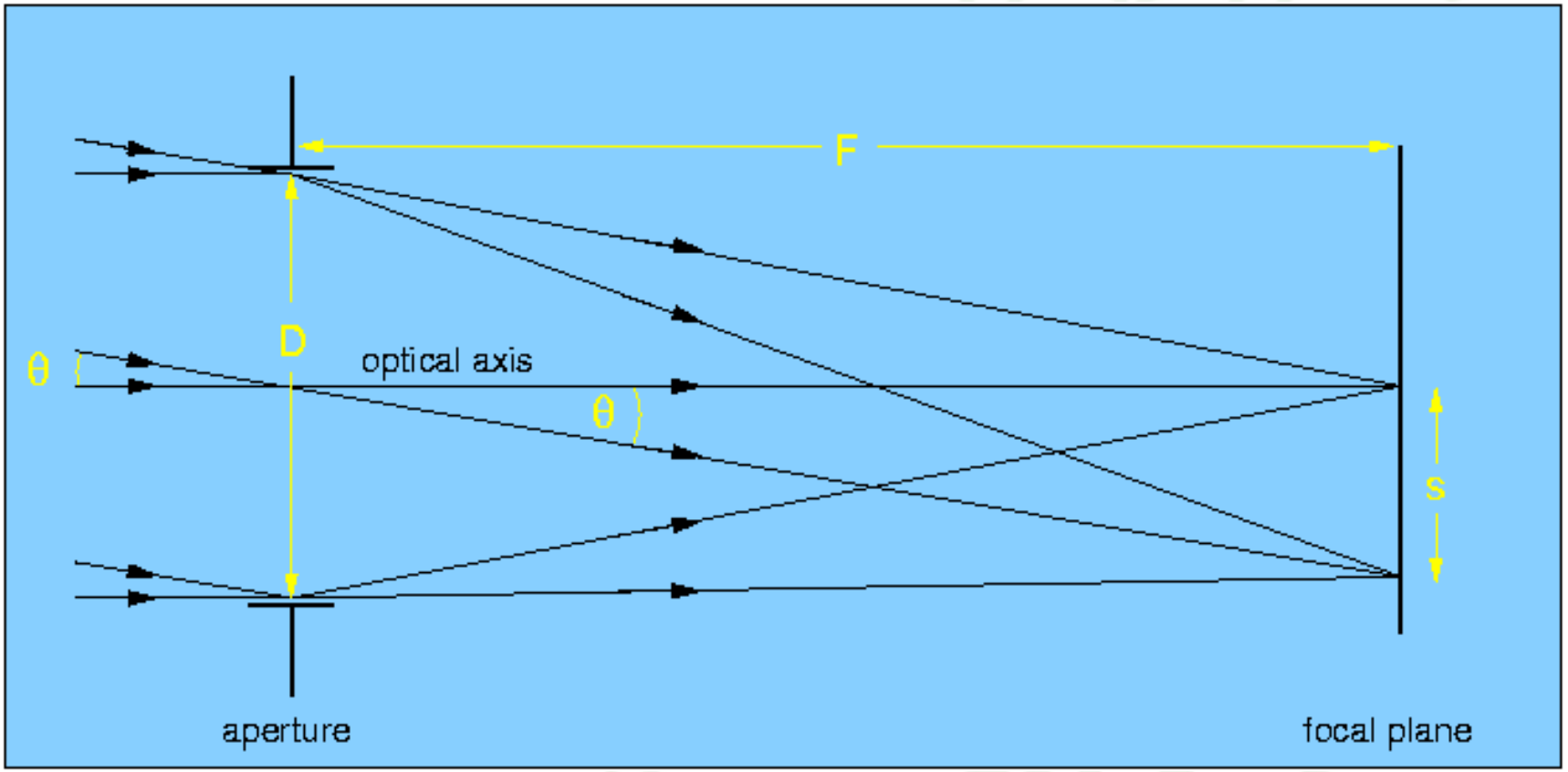


The Good
Cheap, simple and easy to produce.
Tolerant of bad lenses

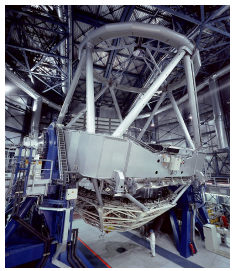
The Bad
Dull image due to poor aperture
Narrow field of view limits magnification <30x
Spherical aberration
Doesn't get much better even if lenses do



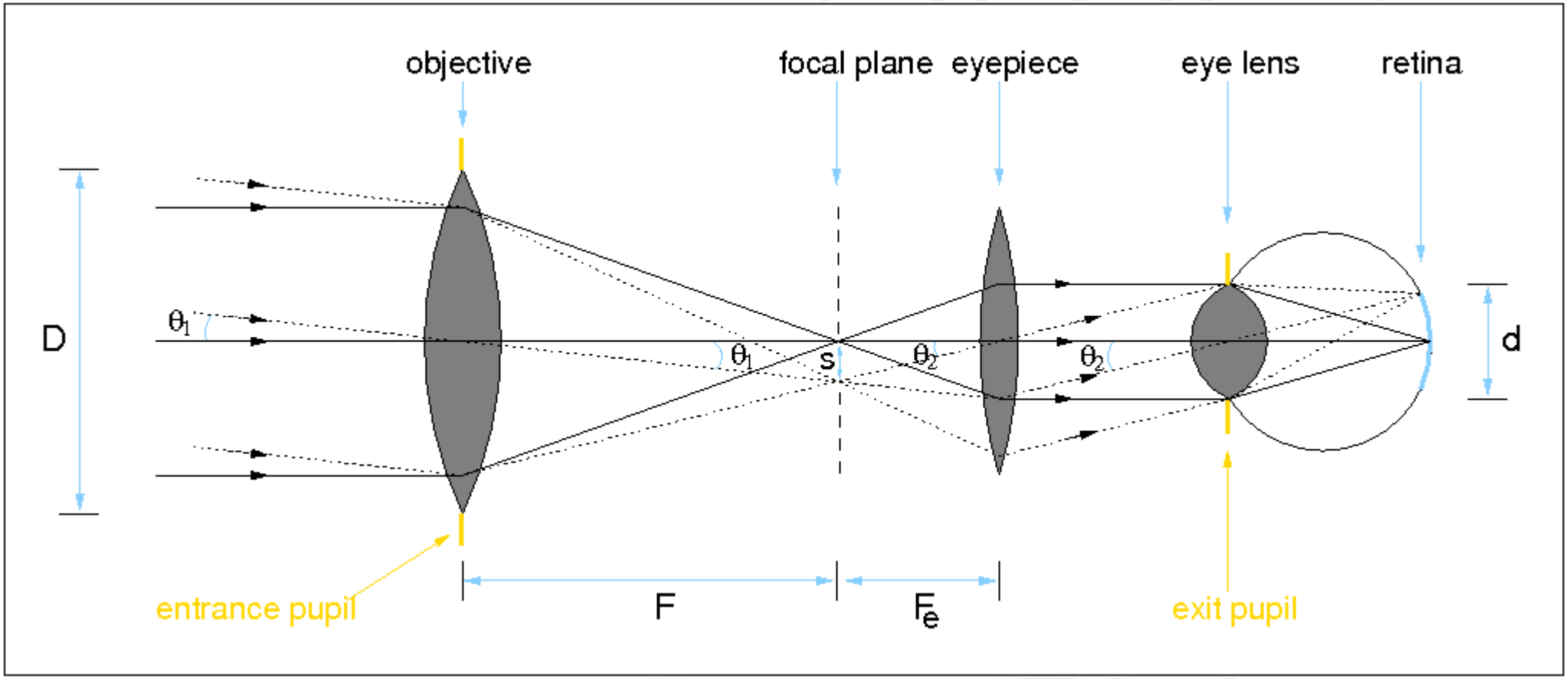
Werking van de telescoop

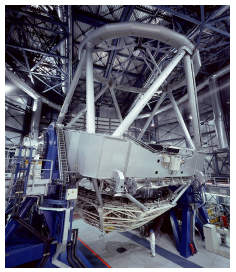


Brandpuntafstand: F
Brandpuntsverhouding: f = F/D
Opening: D
Opgevangen hoeveelheid energie: D^2

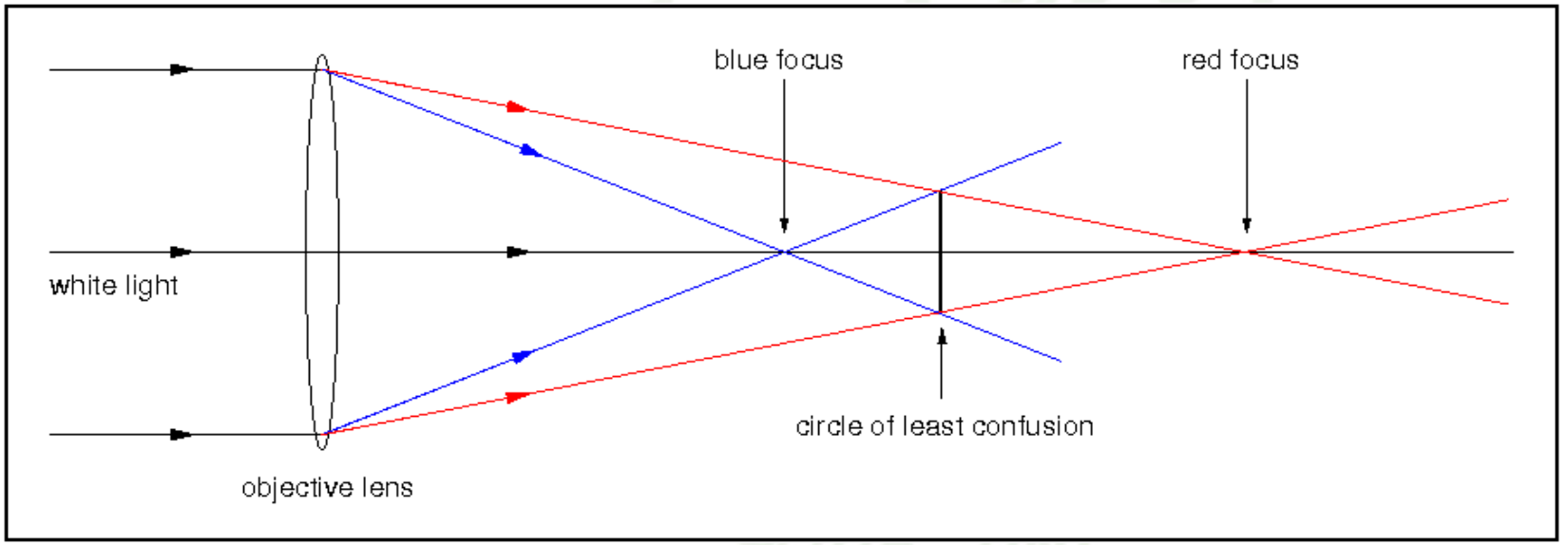


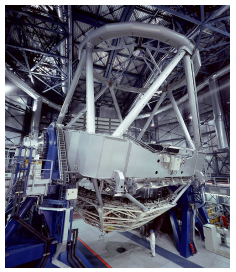
Visuele waarnemingen



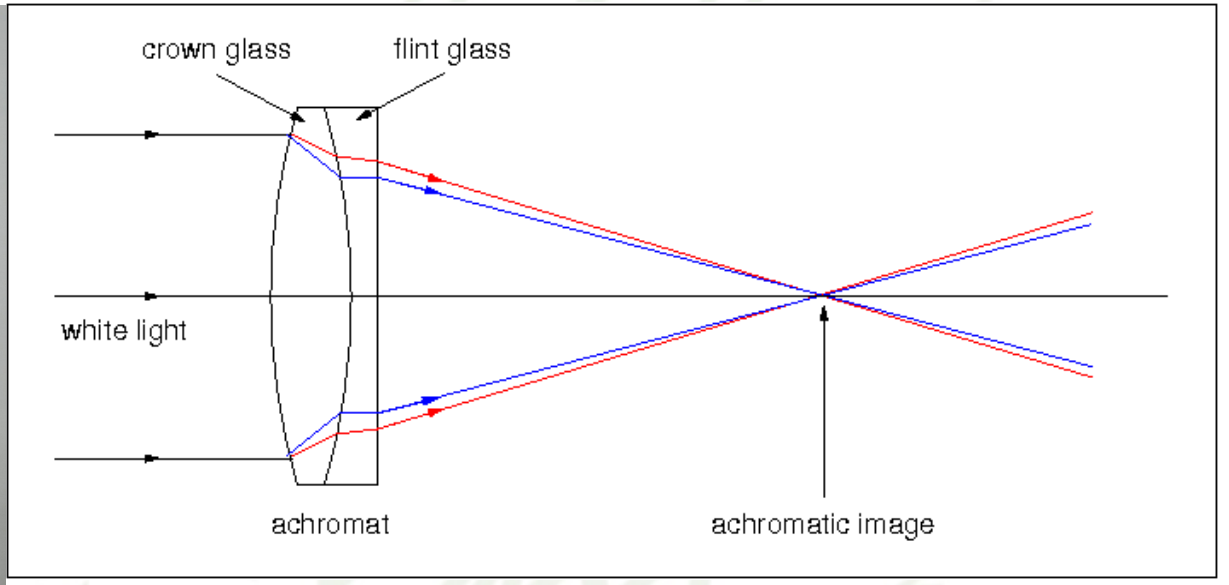


Refractoren: chromatische aberratie



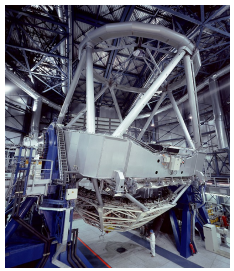


Apochromaten



Nadeel: grote brandspuntsverhoudingen
'langzame' telescopen, nauw blikveld

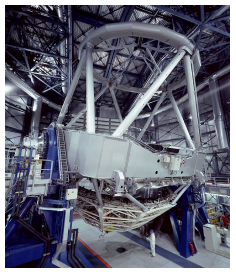
Moeilijk te schalen!



Grote lenzenkijkers

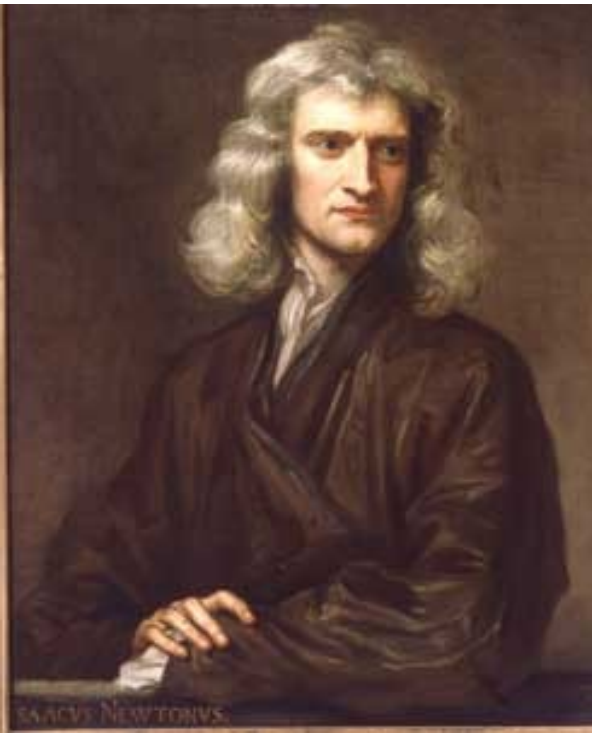
1-meter lens van de
Yerkes 4-inch refractor

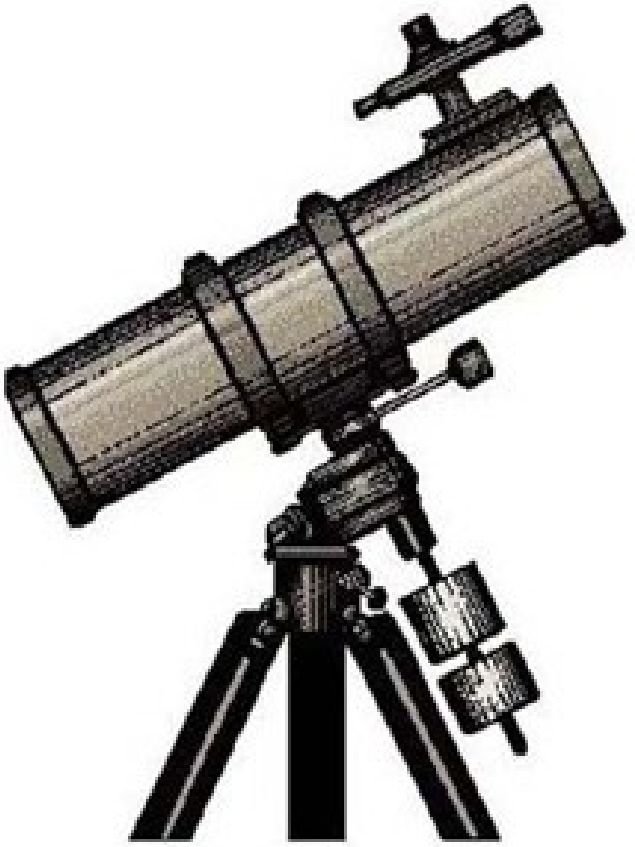
Grootste ter wereld,
In gebruik sinds 1893

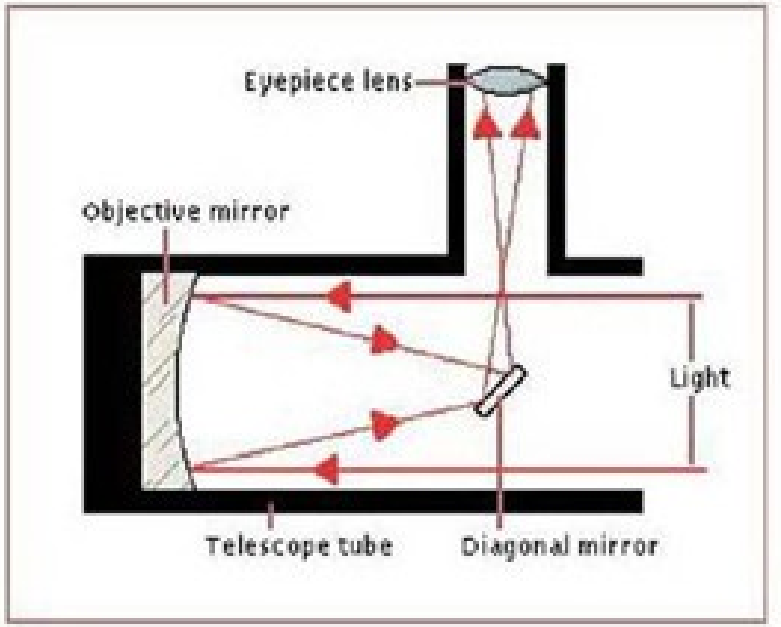


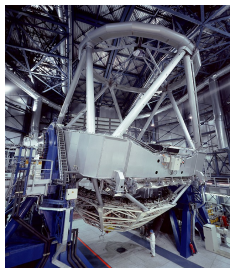
Spiegelkijkers

Voor het eerst toegepast door: Newton

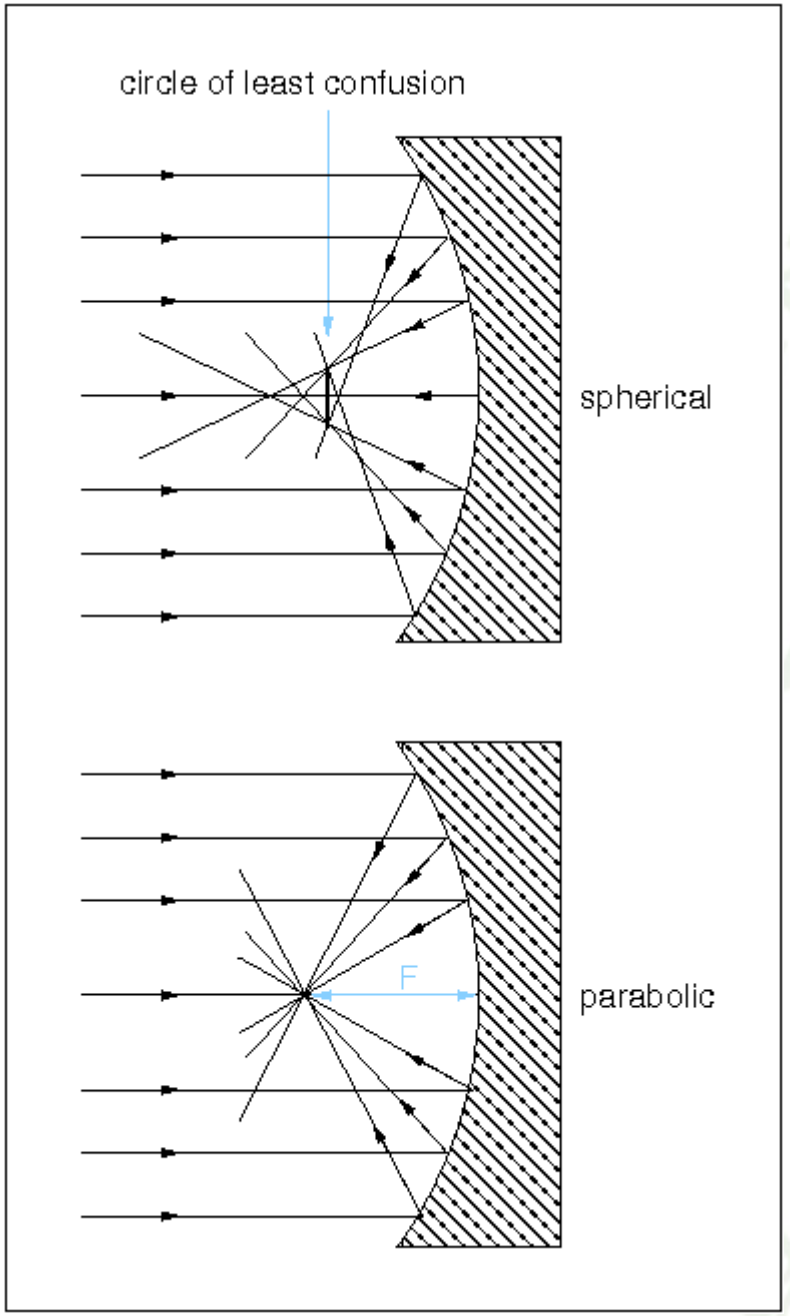








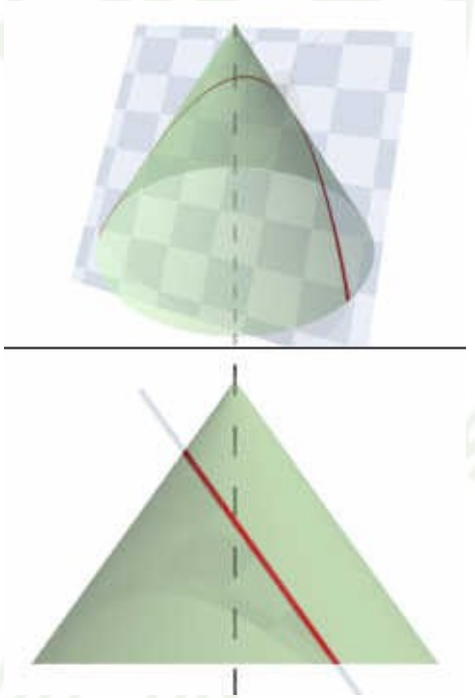
Spiegelkijkers



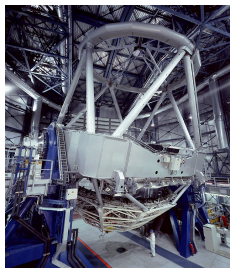
Een parabolische spiegel werkt beter dan een sferische spiegel!

Sferisch: constante kromtestraal
(deel van een cirkel)

Parabolisch: veranderende kromtestraal
(kegelsnede)

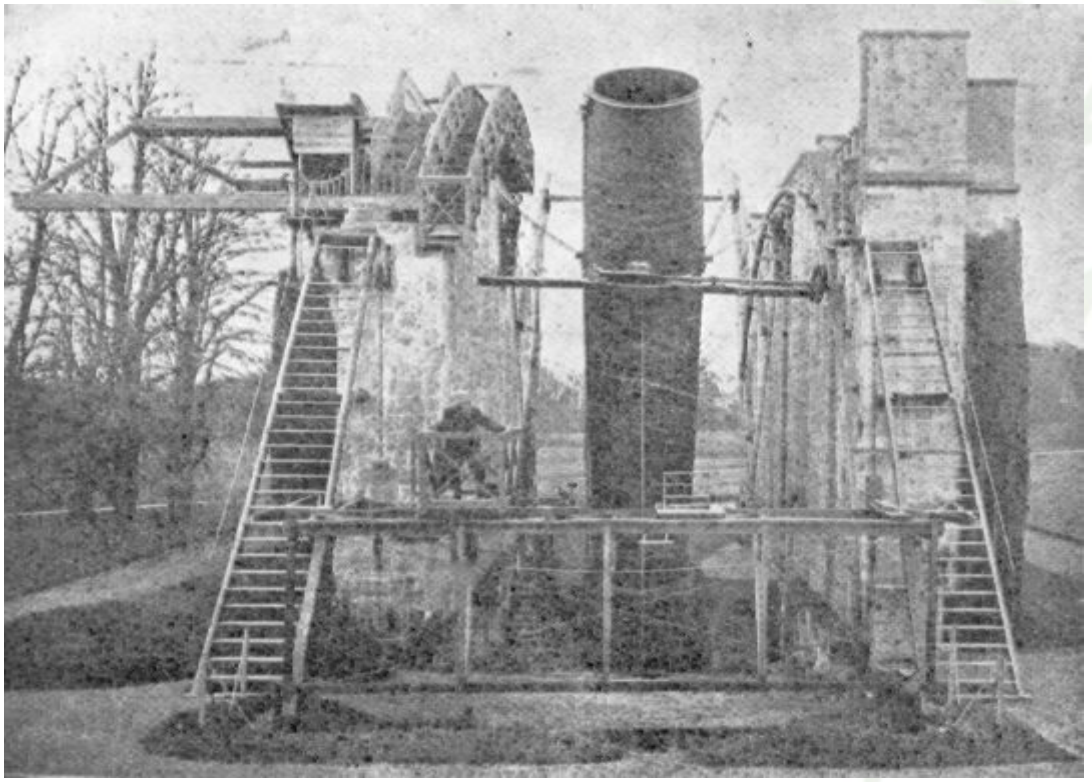


$$y^2 = 4p\,x$$



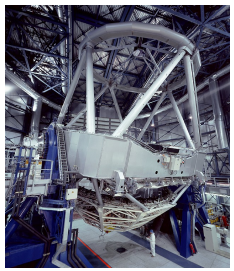
Spiegelkijkers

Ondersteuning aan de onderkant is mogelijk!



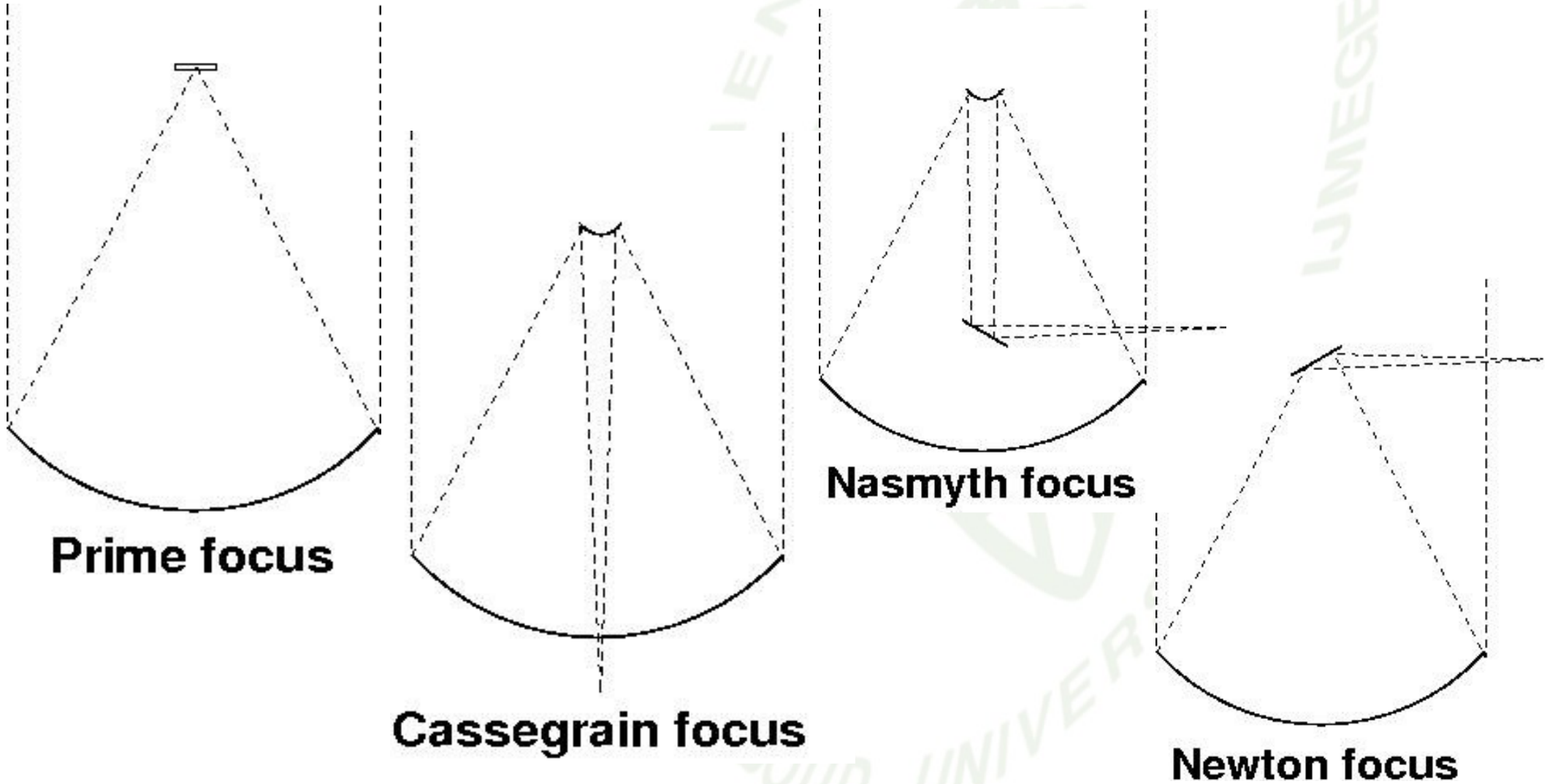
Lord Rosse's Leviathan:

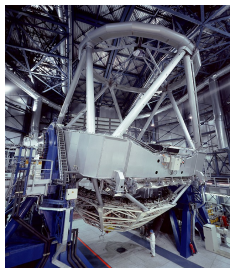
1.8 meter spiegeldiameter,
Voltooid in 1845!



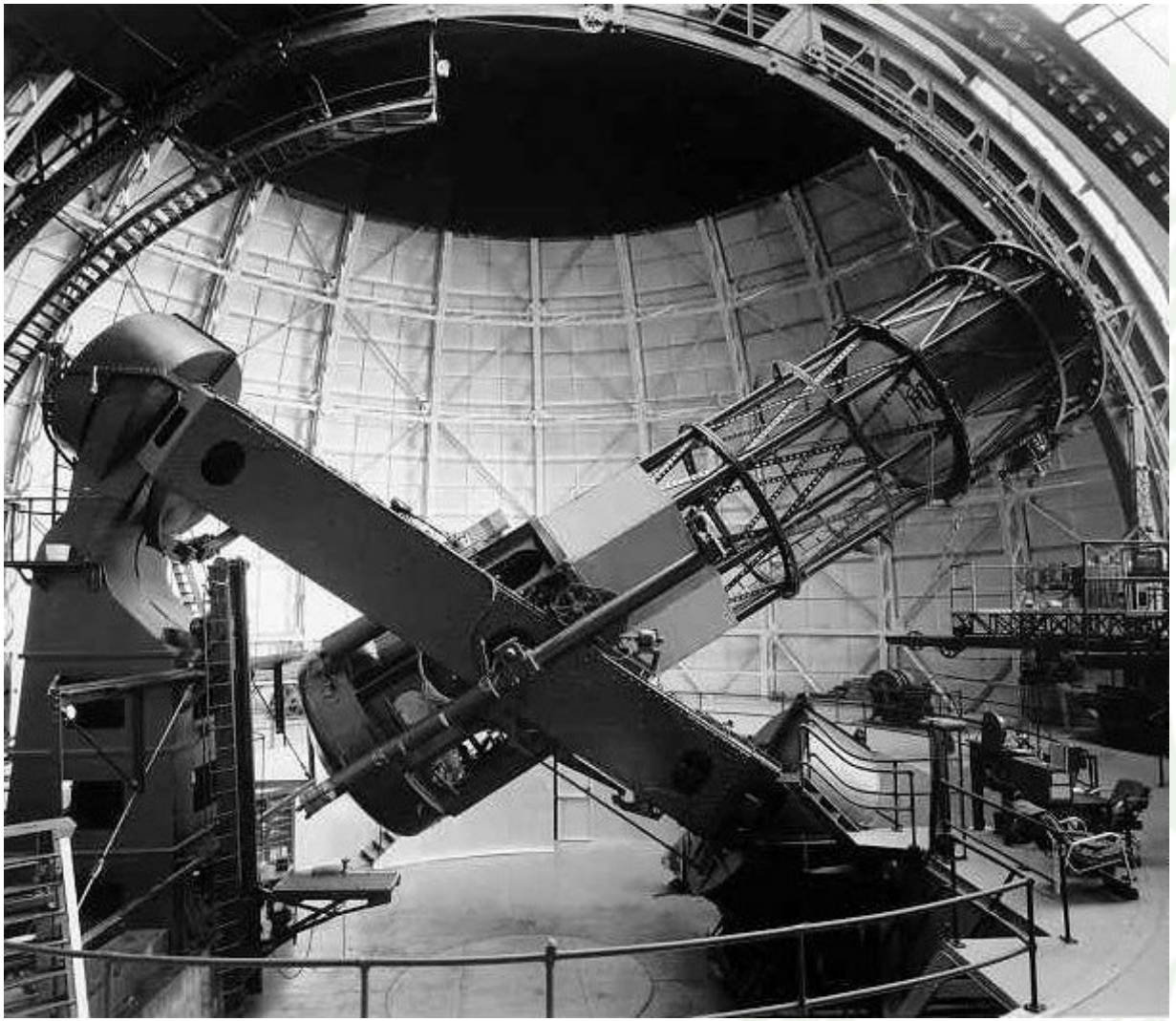
Variofocus

Met spiegels verschillende manieren van focuseren

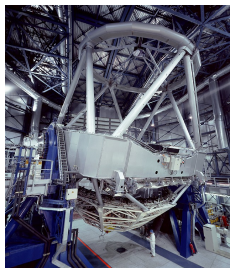




Moderne Spiegelkijkers



2.5 meter
Hooker-telescoop
op Mt. Wilson

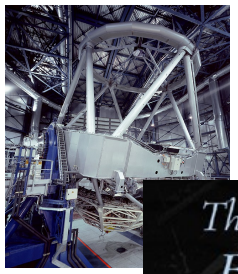


Groter en groter

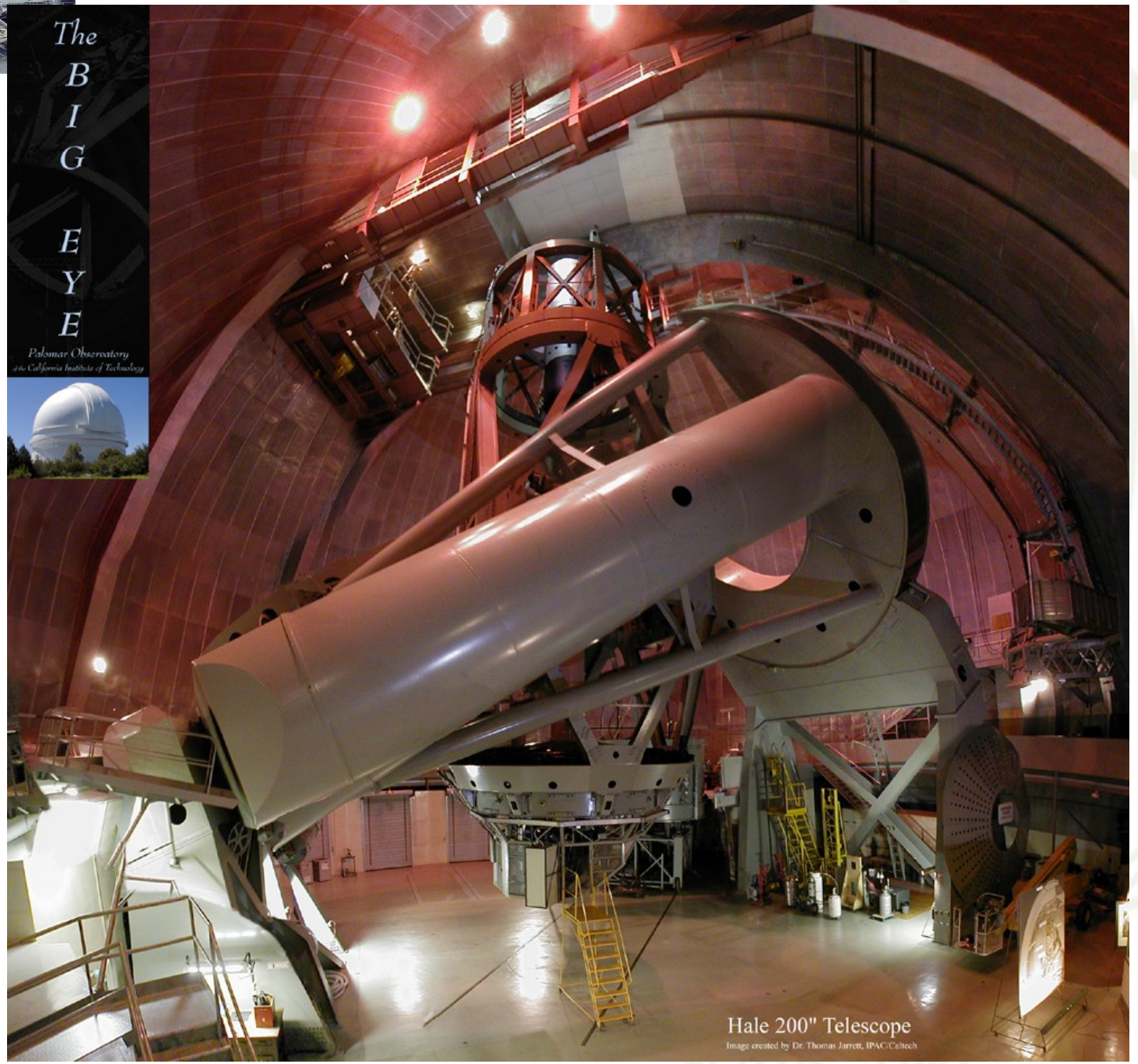
Waarom steeds groter?

1/ Hoe groter de spiegel, hoe meer licht je opvangt (D^2)
Dus hoe verder weg je vergelijkbare objecten kan zien
Hoe zwakkere objecten je kan zien
Hoe sneller je opnames kan maken

2/ Hoe groter de spiegel hoe scherper het beeld!
Beeldresolutie: λ/D

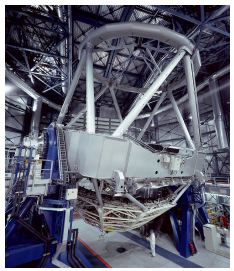


Moderne Spiegelkijkers



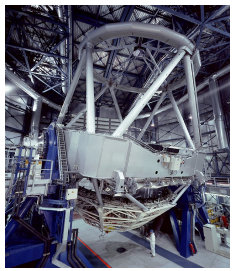
5-meter
Hale telescoop
op Mt. Palomar
In 1949

Ook meteen een
limiet!

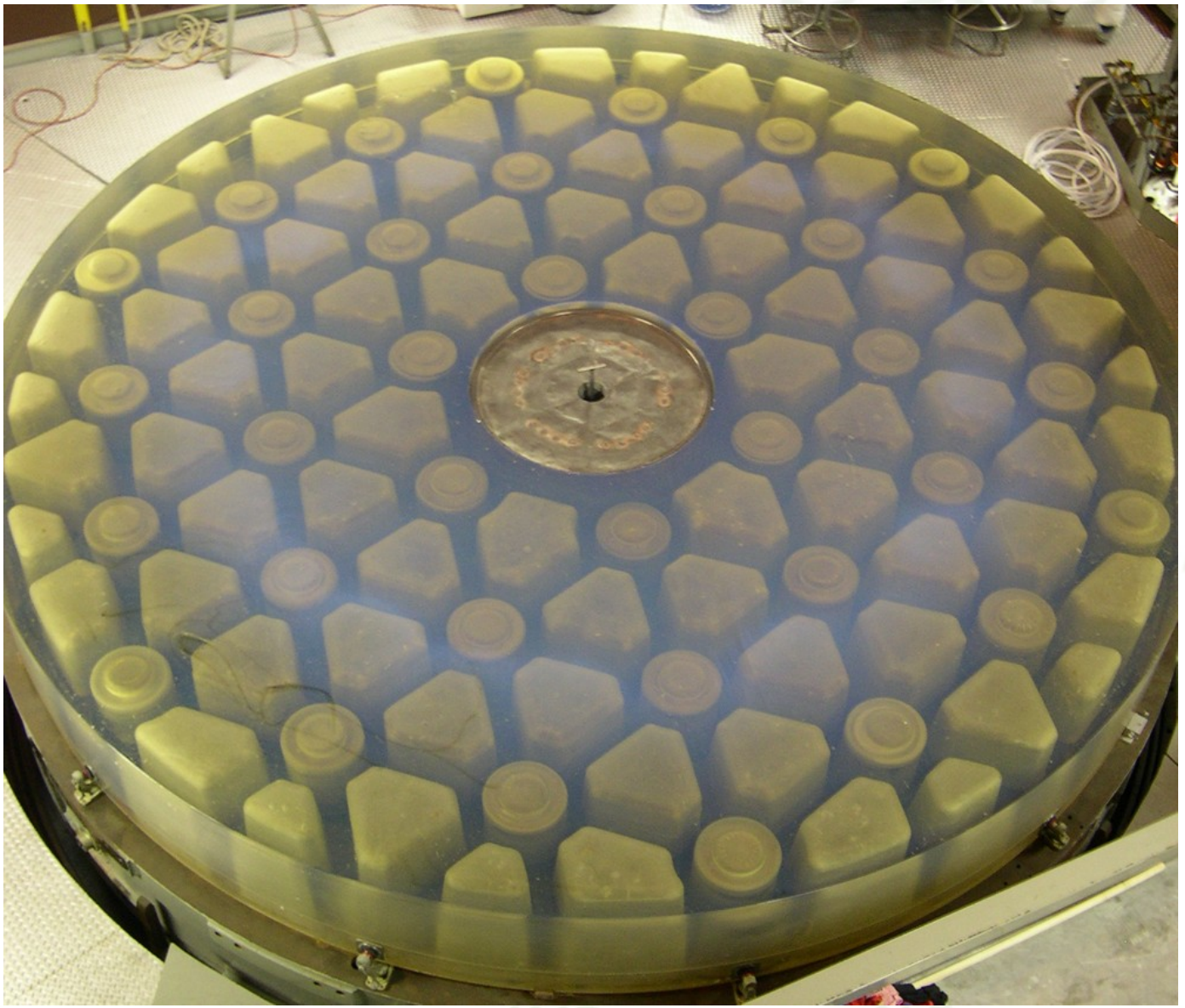


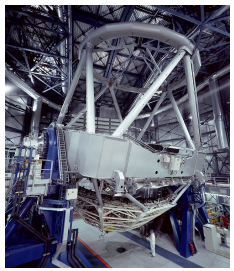
Dikte spiegels

Hale spiegel: 5 meter doorsnede, 14.5 ton

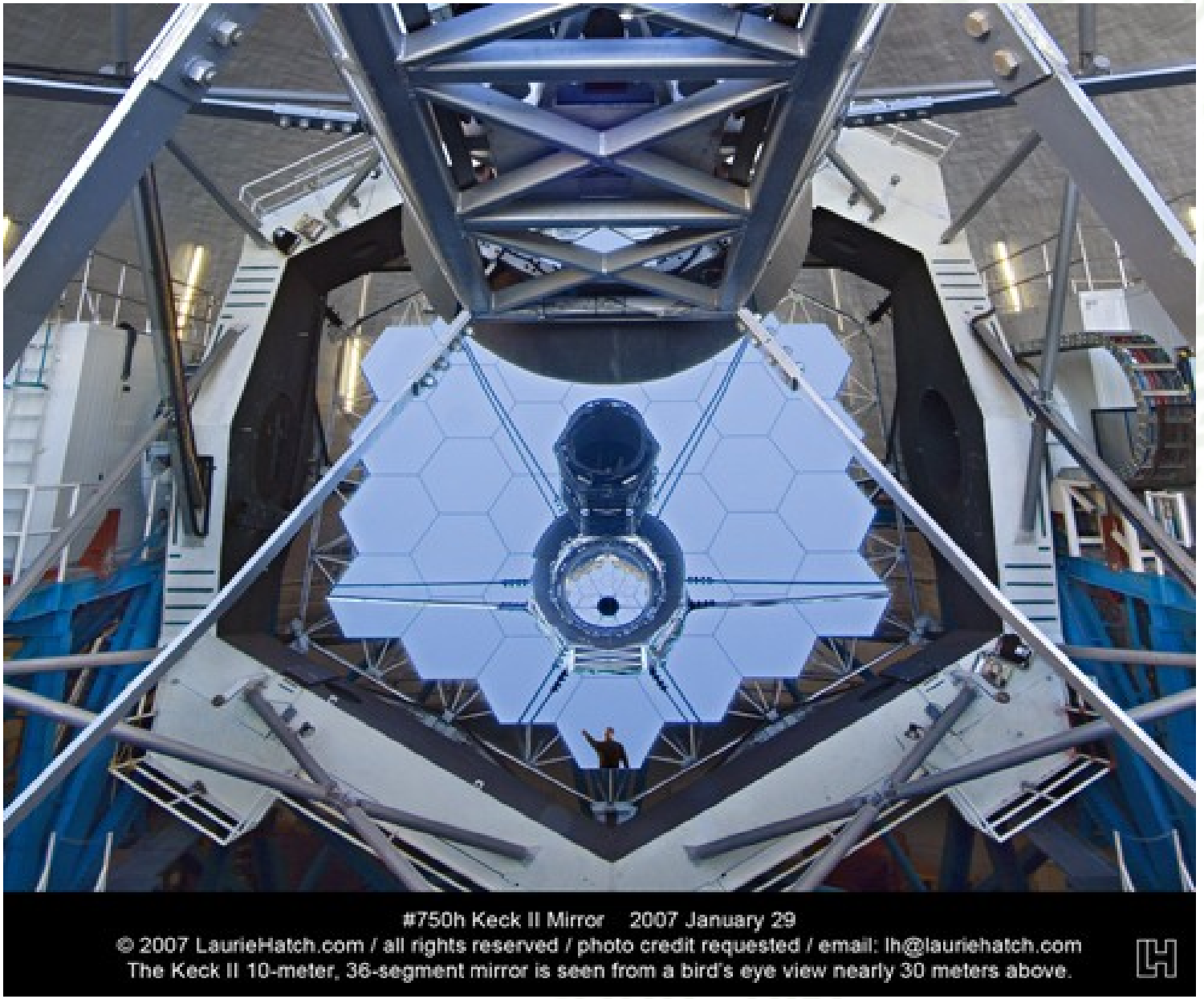


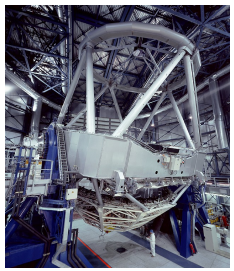
Lichte spiegels: uitgehold



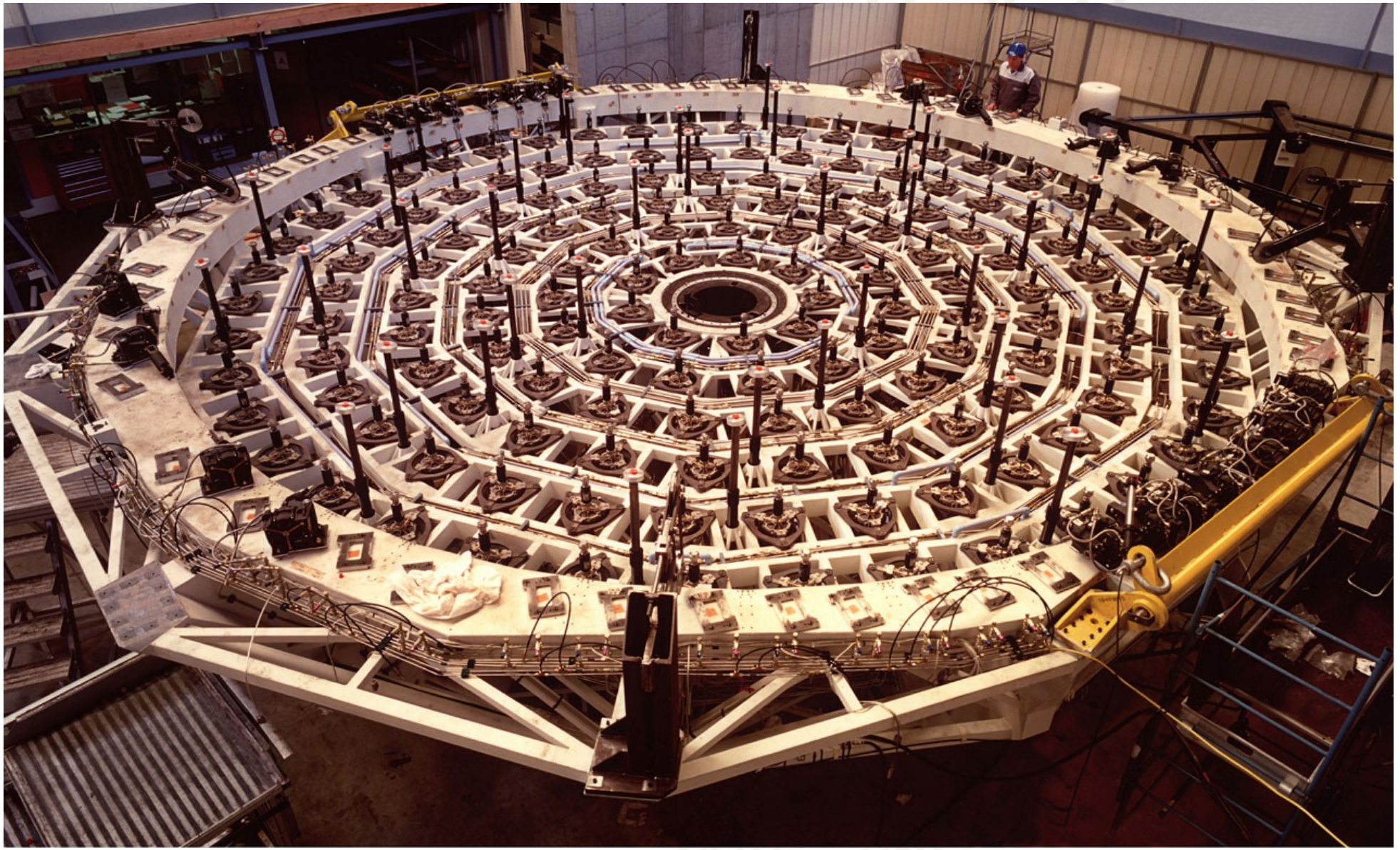


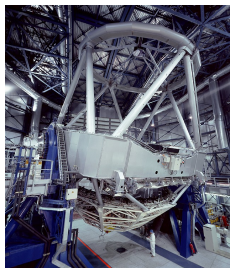
Lichte spiegels: in stukken





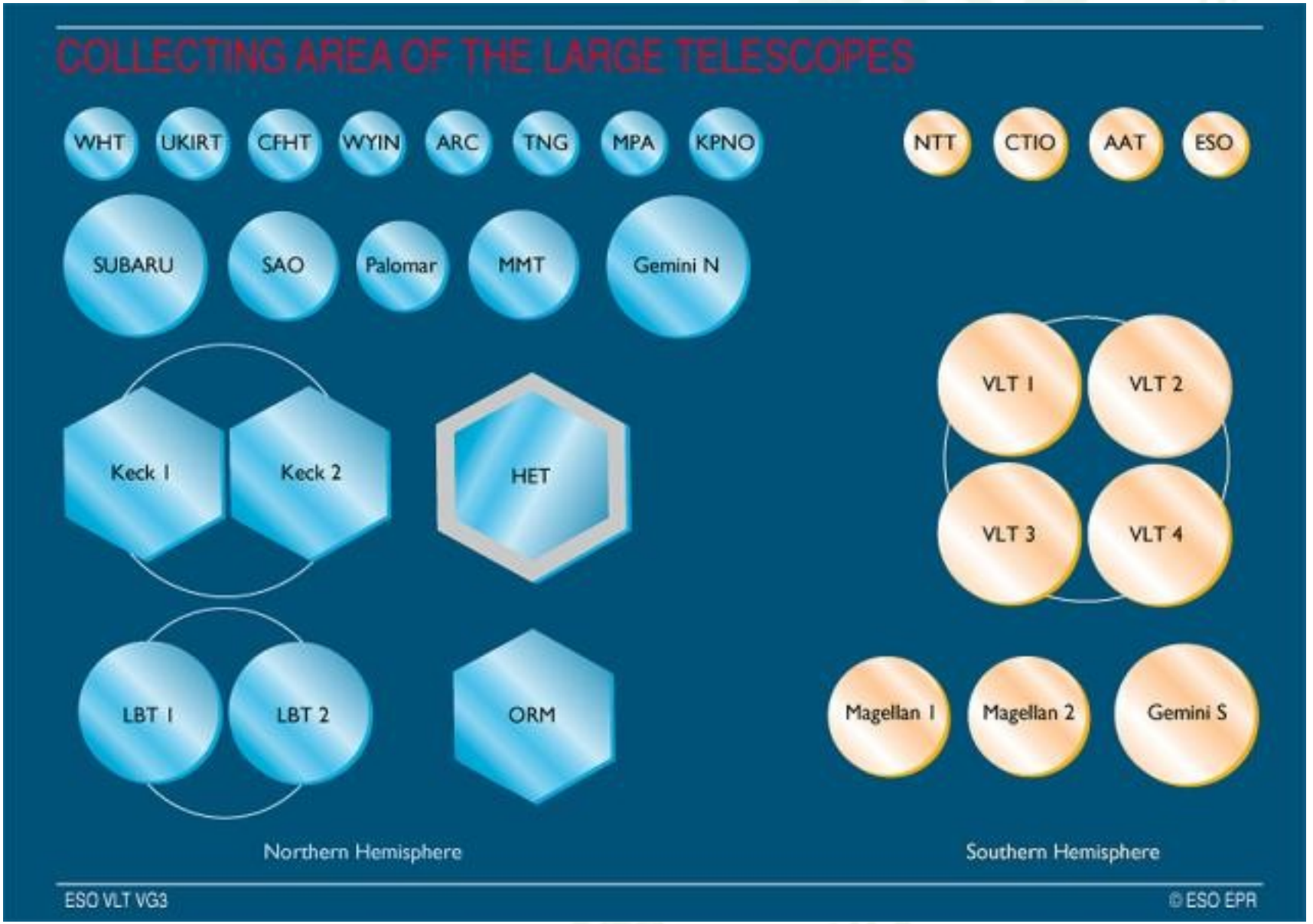
Lichte spiegels: dun, ondersteund

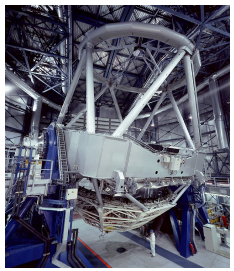




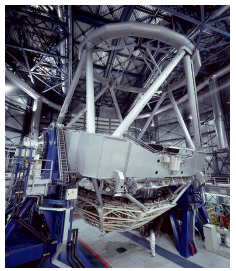
Nieuwe reuzen

Alle drie de oplossingen zijn toegepast!

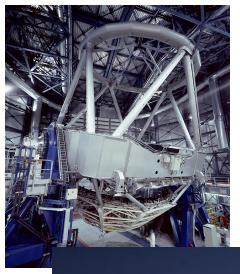




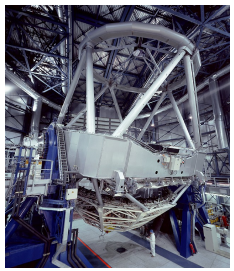
Keck Observatory



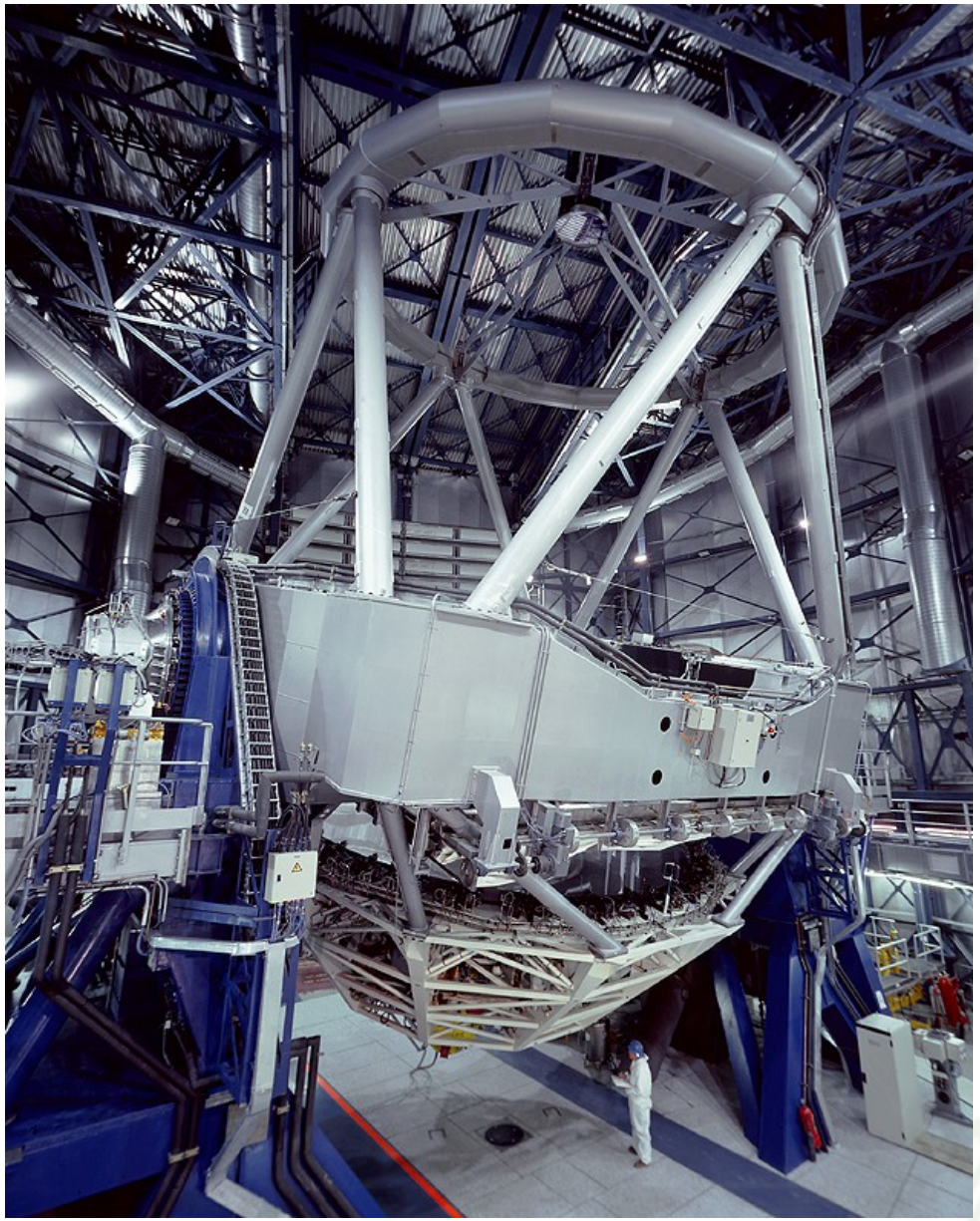
Geminis, Magellans, Subaru

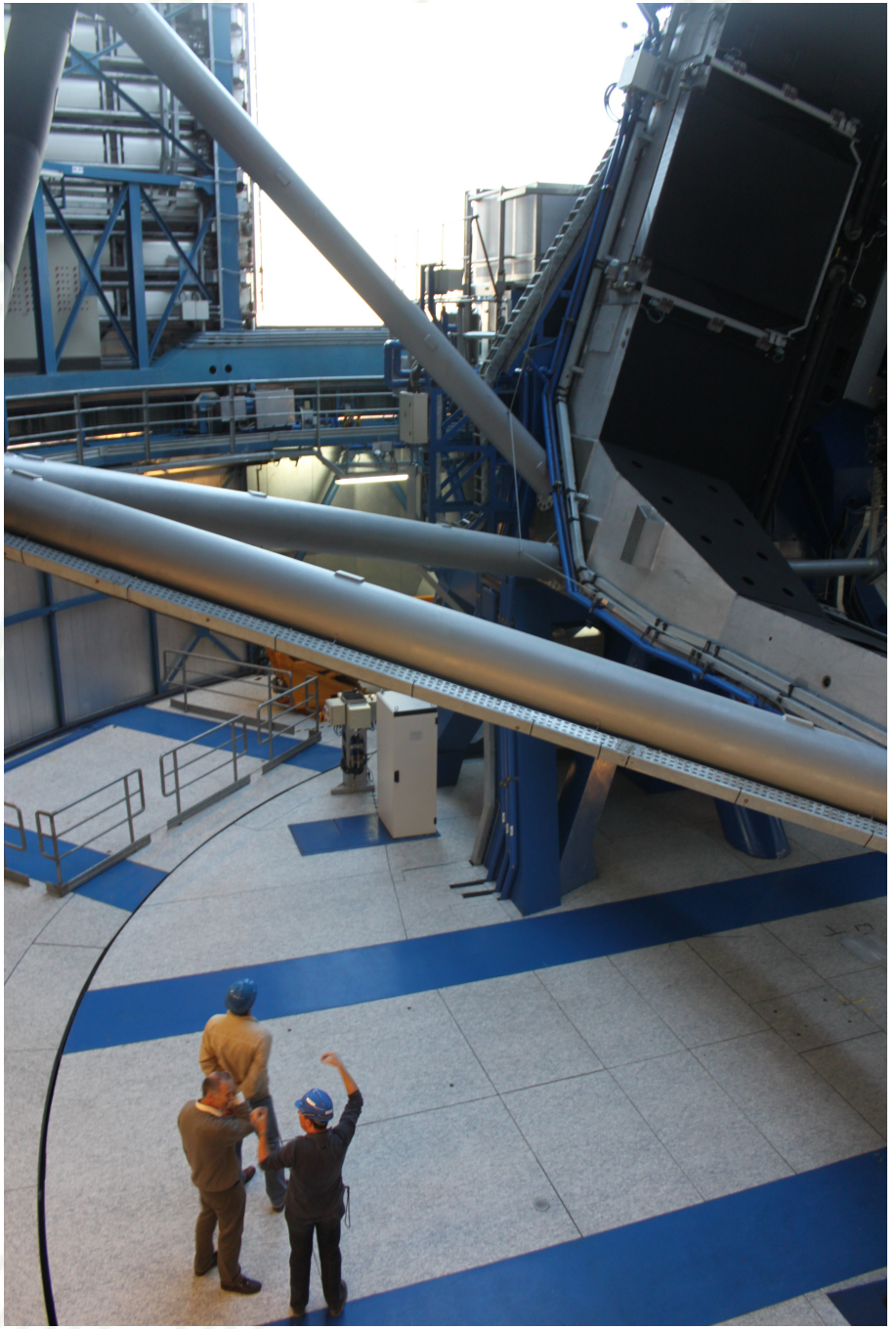


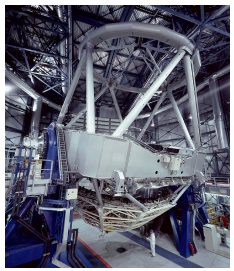
The Very Large Telescope



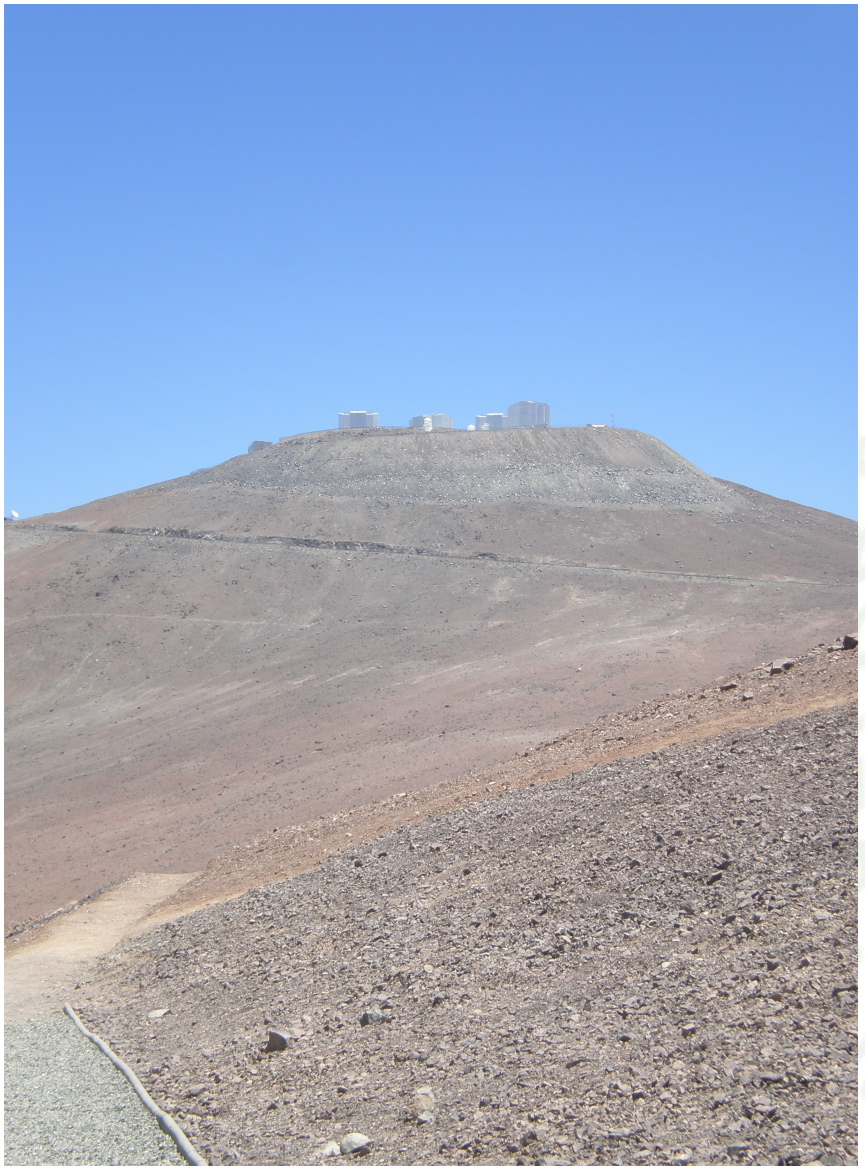
The Very Large Telescope

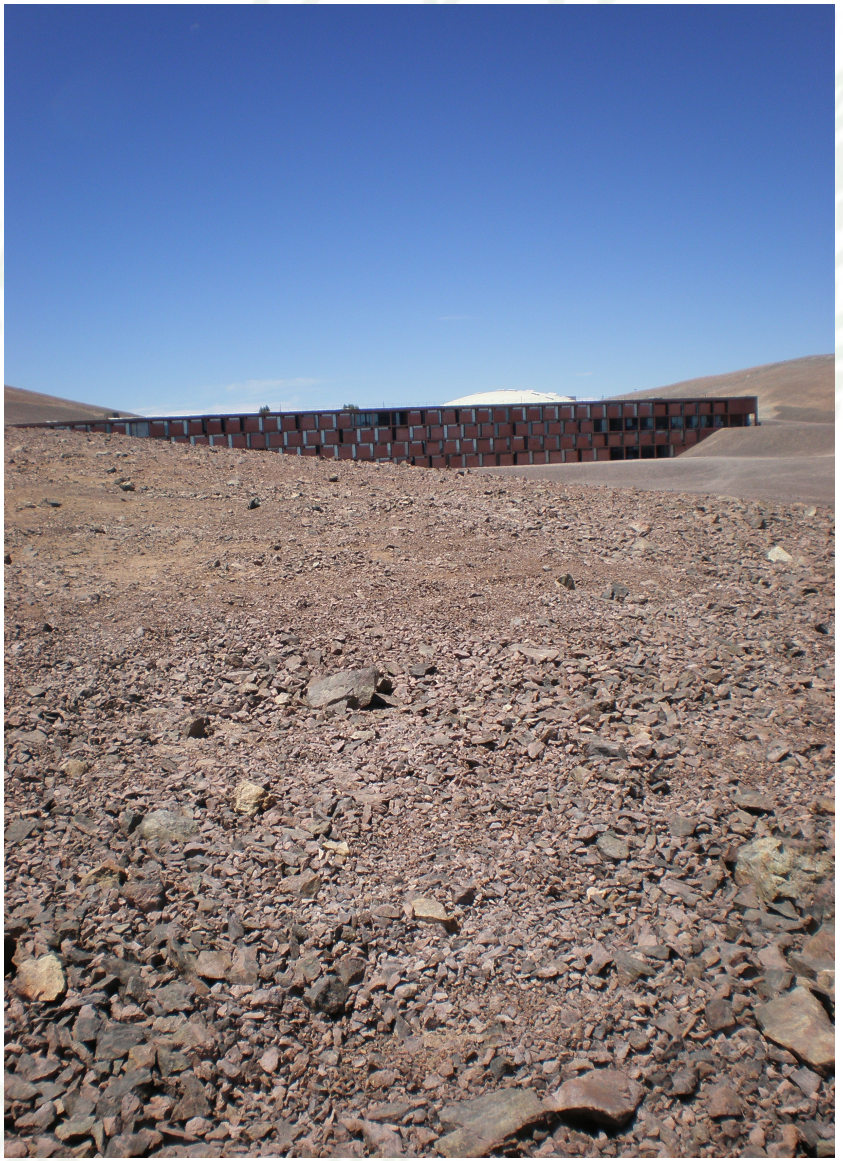


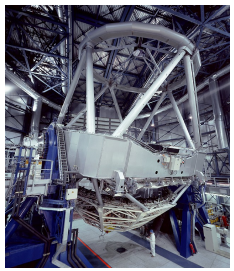




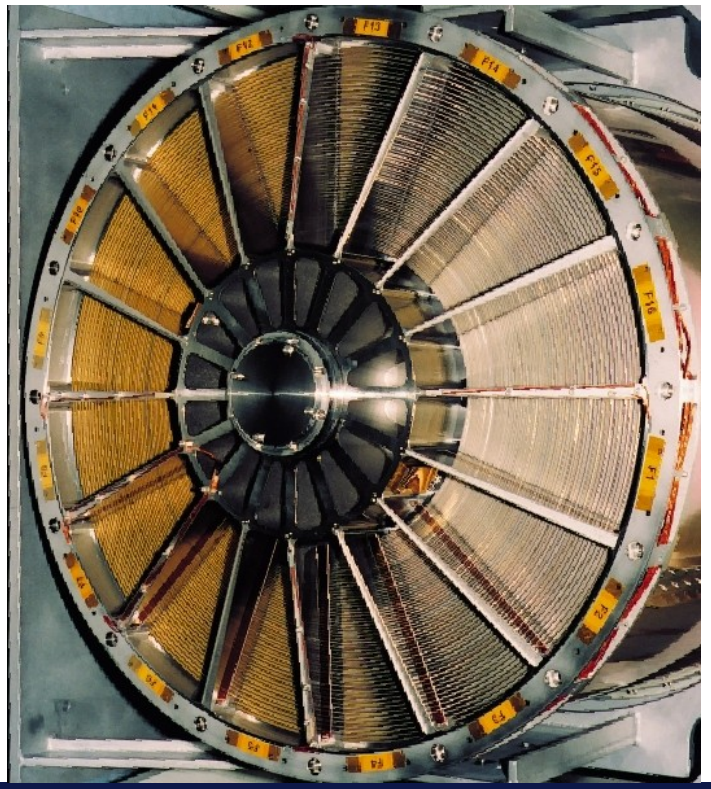
The Very Large Telescope

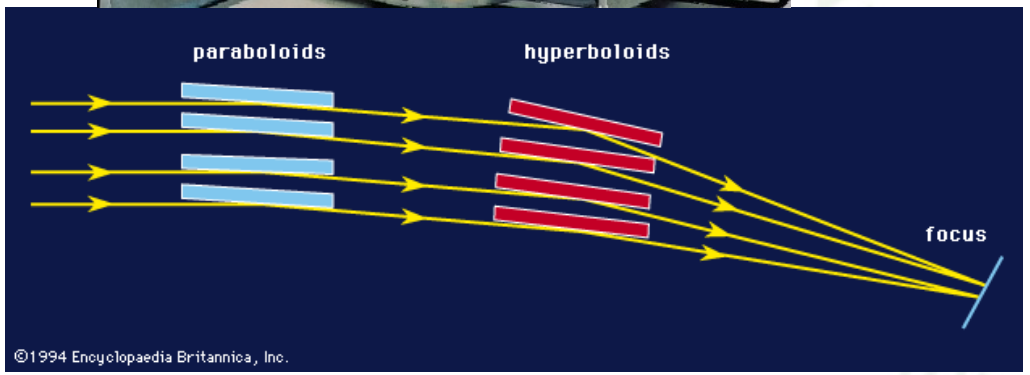






Ander soort telescopen

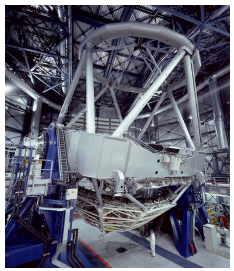





PARKES RADIO TELESCOPE (CSIRO / ATNF)

Radiostraling vang je makkelijk op

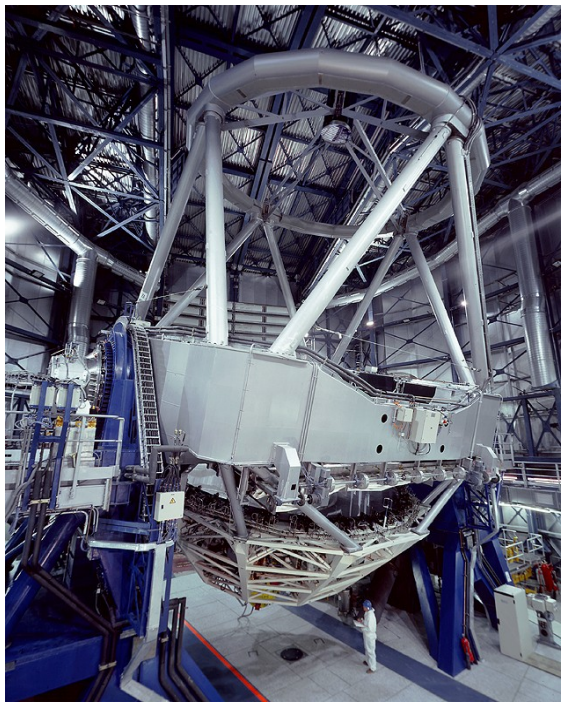
Rontgenstraling gaat door spiegel heen!

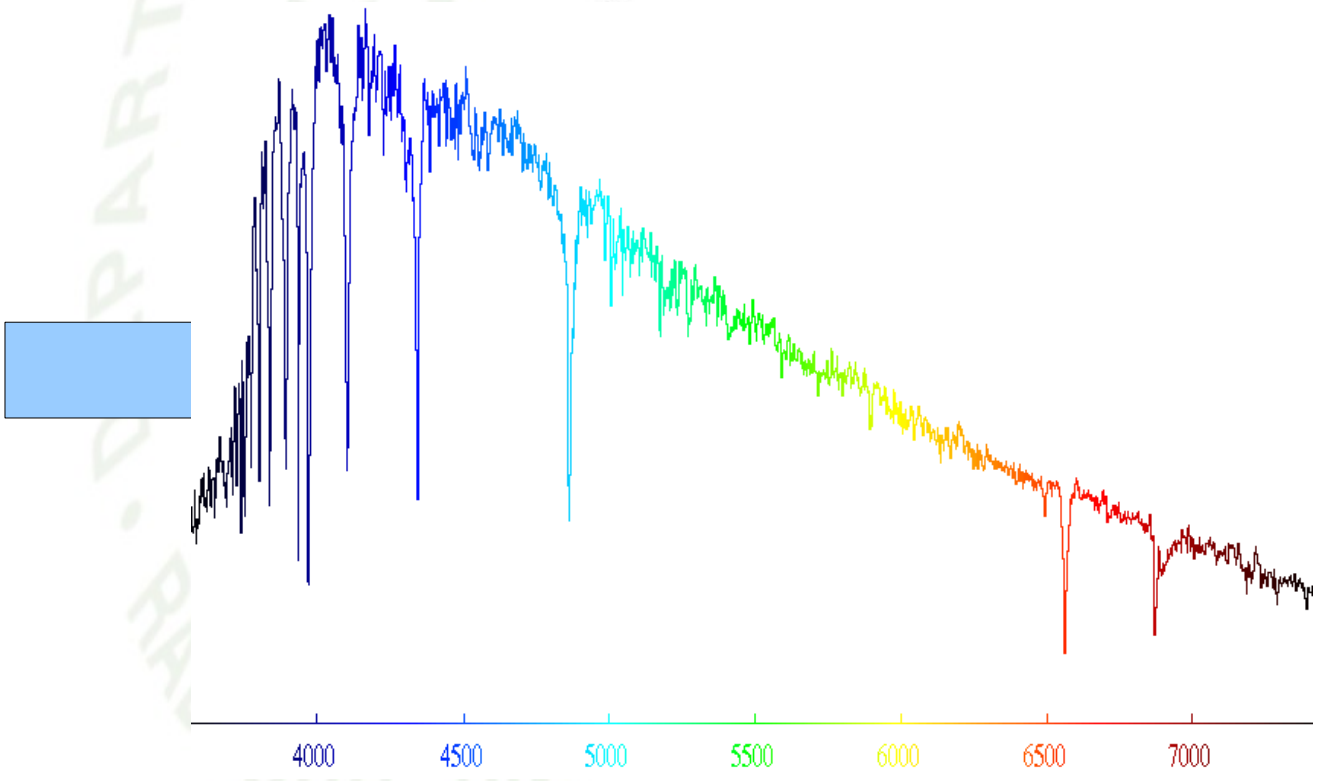


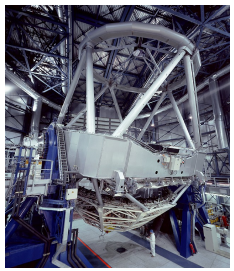
Detectoren

Eigenschappen van EM straling:

- **Golflengte:** λ afstand van piek tot piek ('kleur', 'toonhoogte')
  (frequentie ν = c /λ)
- **Amplitude:** hoogte van de piek ('intensiteit', 'sterkte')
- **Polarisatie:** trilrichting van de golf.
- **Energie:** E = h ν = hc/ λ



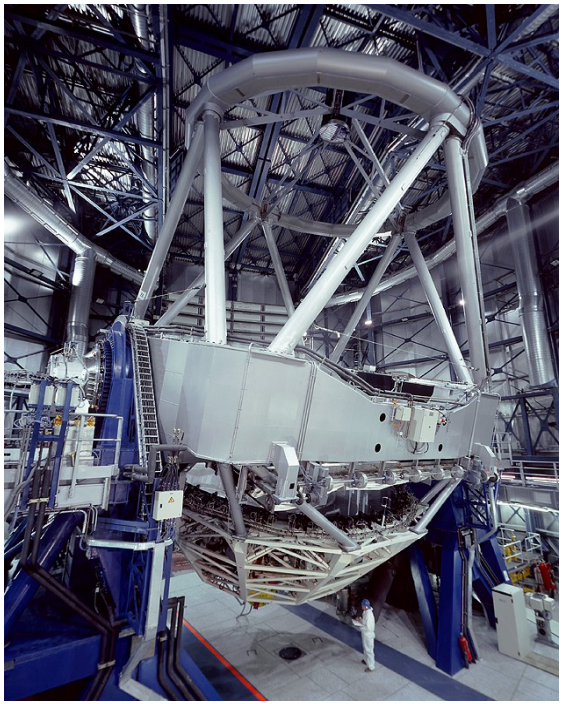


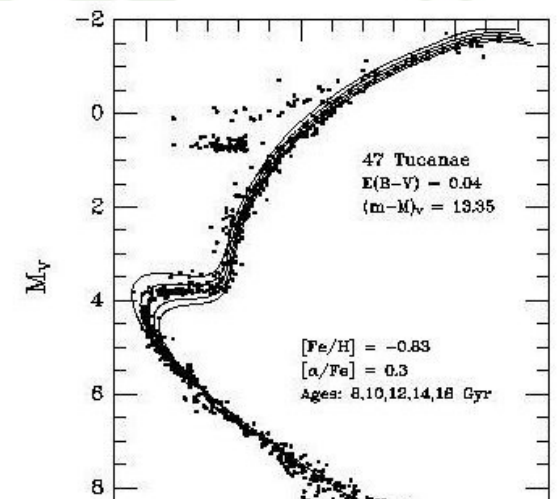


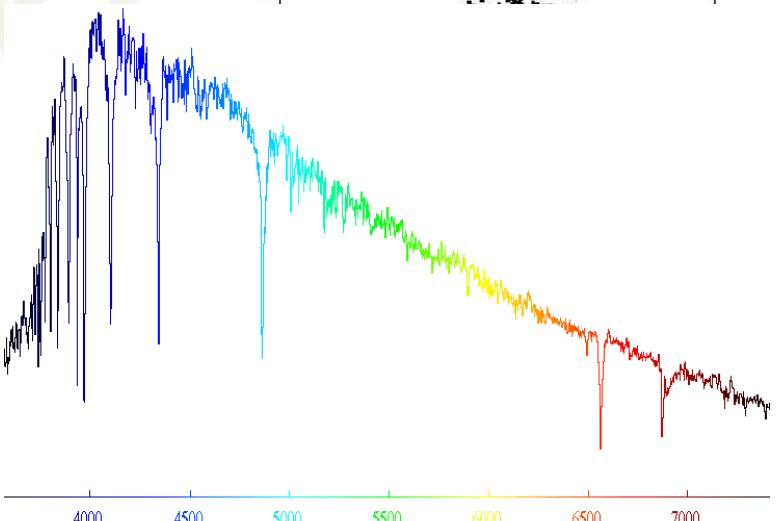
De ideale waarneming

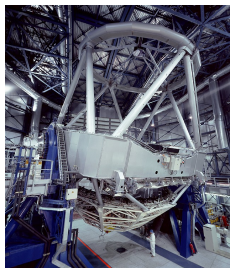
Wat willen we allemaal weten?

-
- ….
- ….
- …
- ….







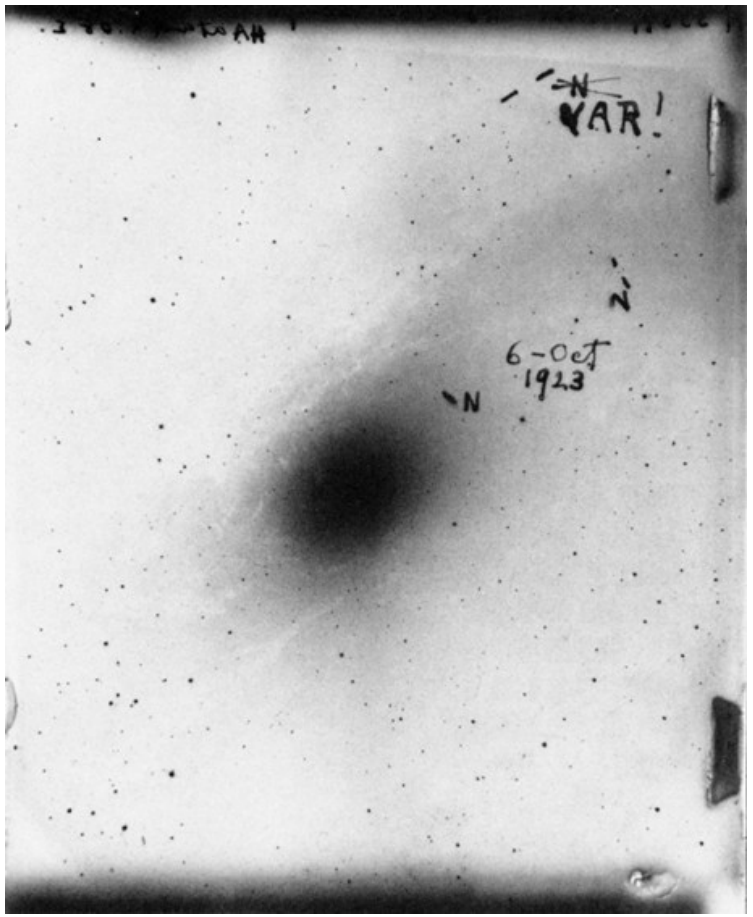


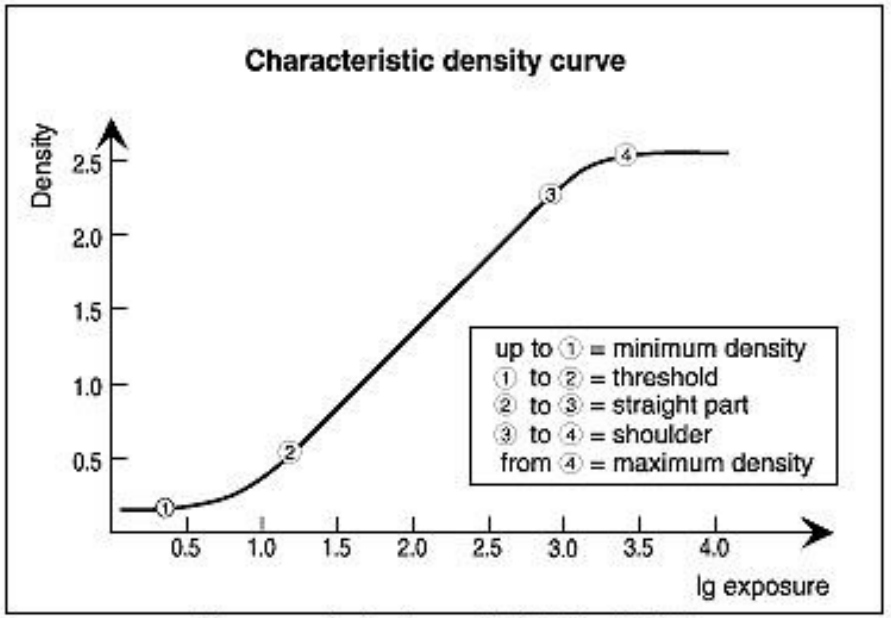
Fotografie (t/m jaren 70)

$$Ag^{+}Br^{-}\ (\text{crystal}) + h\nu\ (\text{radiation}) \rightarrow Ag^{+} + Br + e^{-}$$

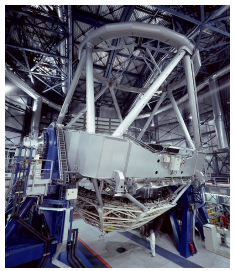
The silver ion can then combine with the electron to produce a silver atom.

$$Ag^{+} + e^{-} \rightarrow Ag^{0}$$

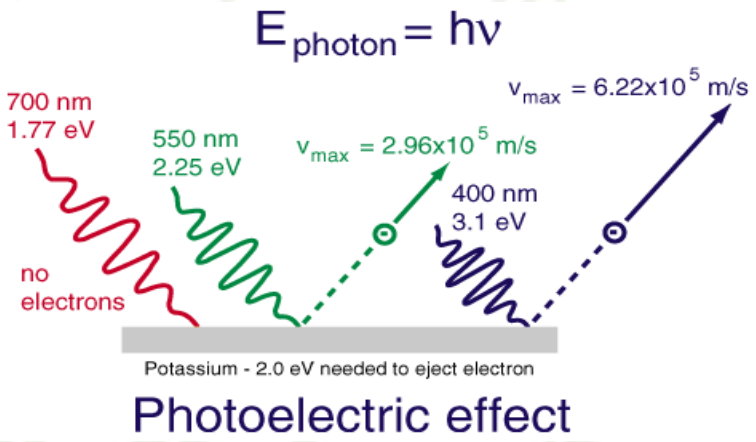




Characteristic Curve ® AGFA (1999)



Photomultiplier (tube) PMT



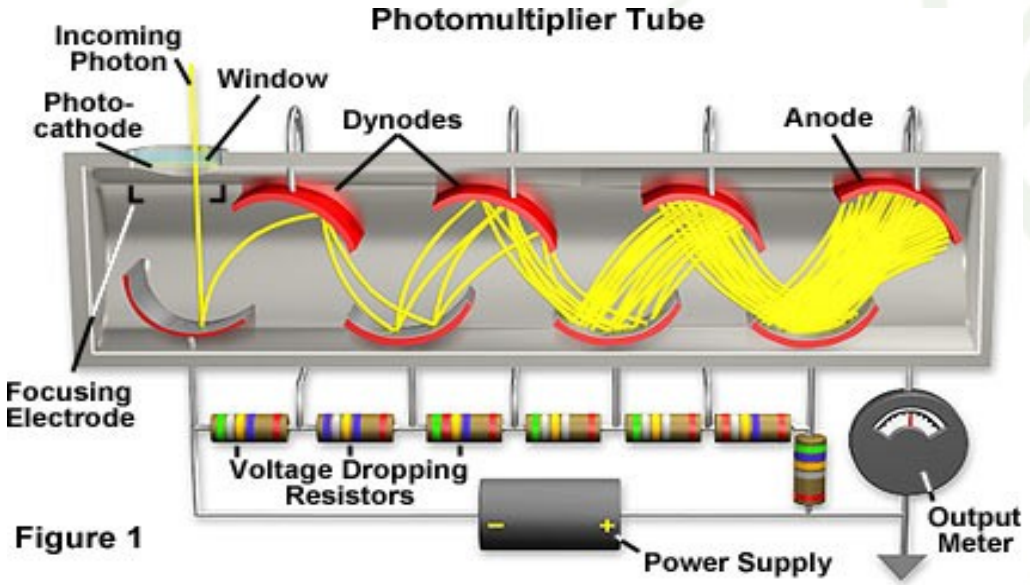
Maak gebruik van foto-elektrisch effect:

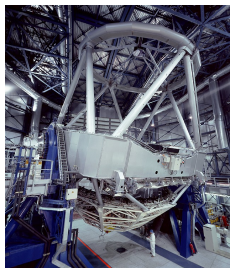
- Foton met energie > E_{min}

→ electron vrij

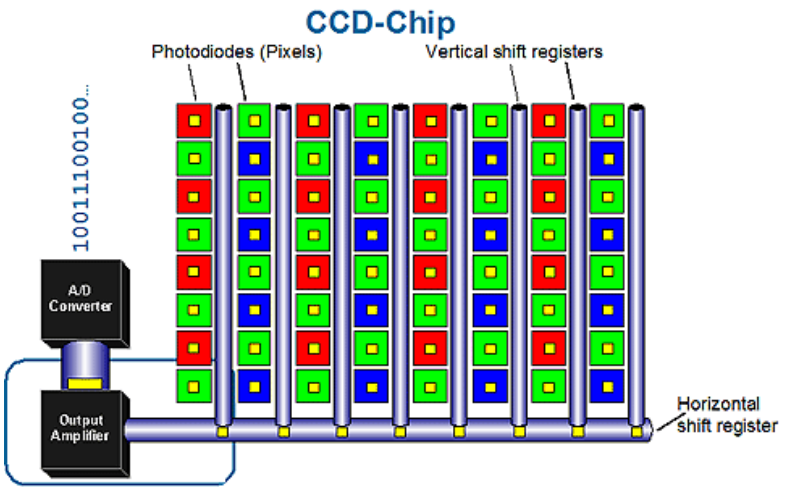
- In electrisch veld

→ versnelt, extre energie → lawine





Charge coupled devices



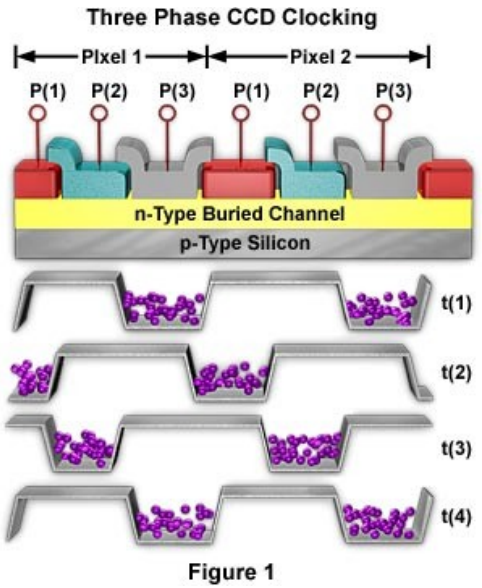
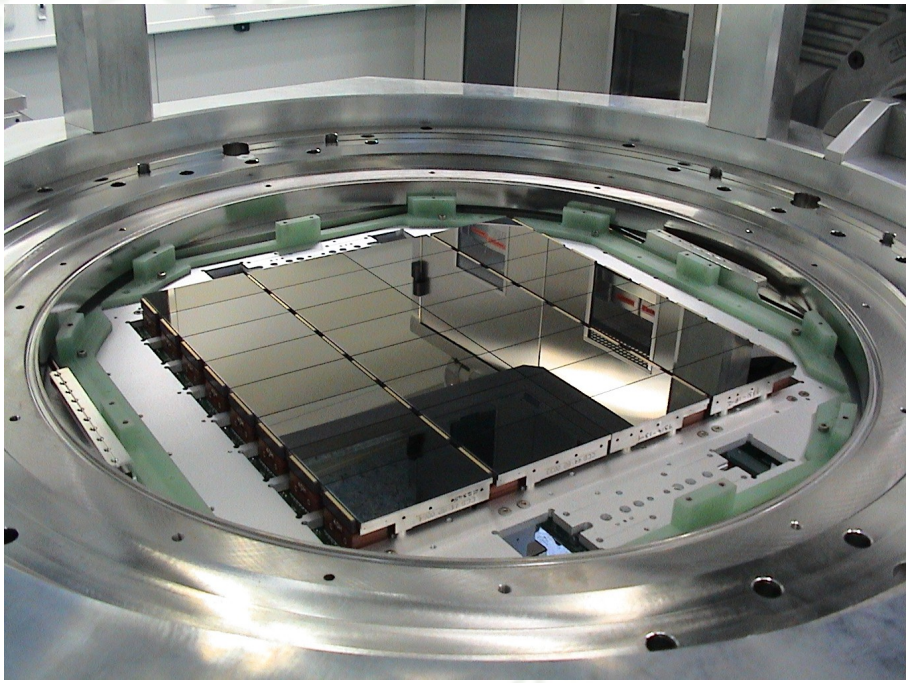


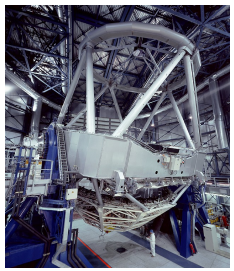
Figure 1

Weer foto-elektrisch effect:

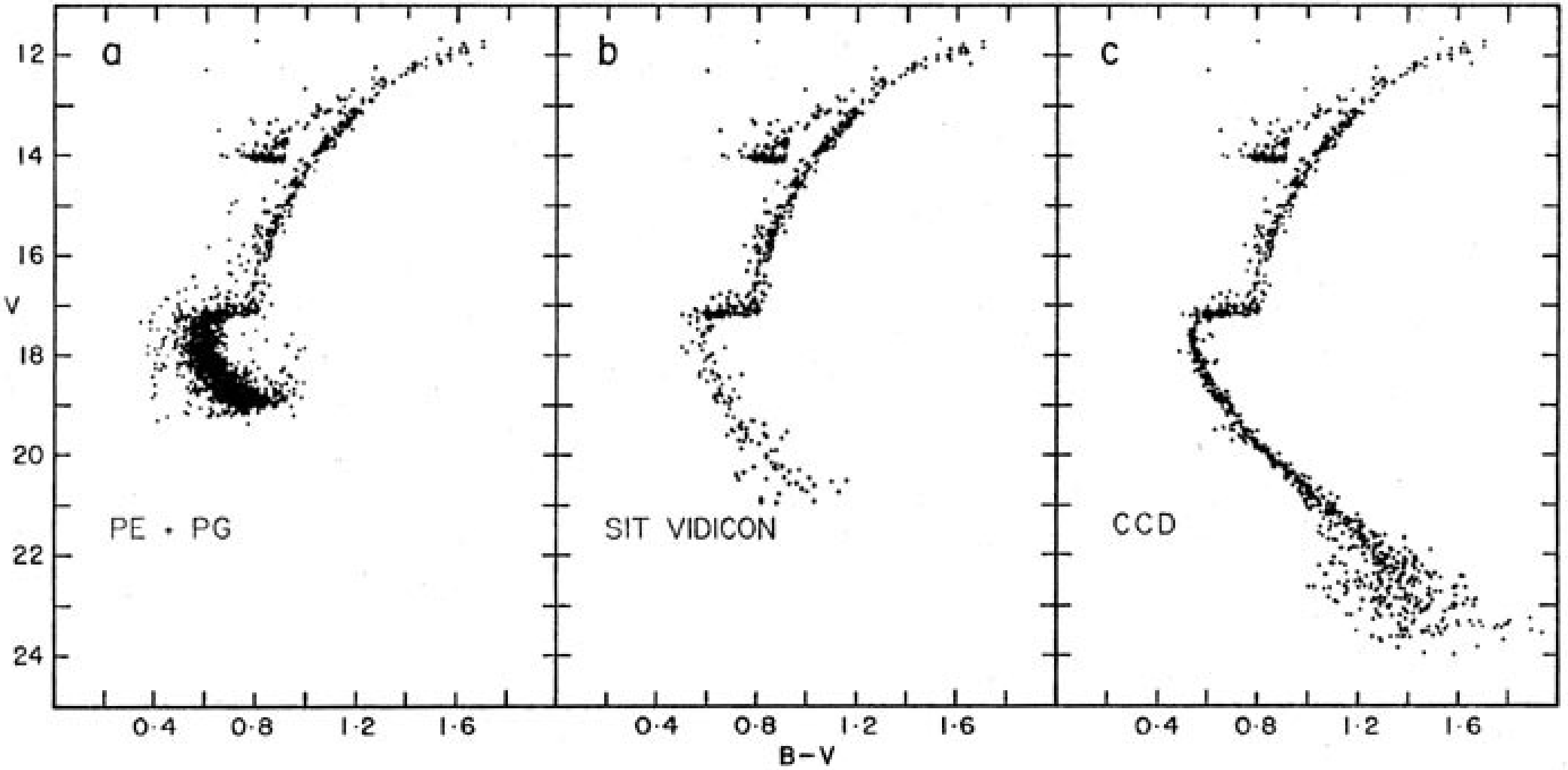
- Ieder pixel → N foton = N e
- "Verschuif" lading in een richting
- "Verschuif" dan in andere richting
- Reconstrueer lading van ieder pixel

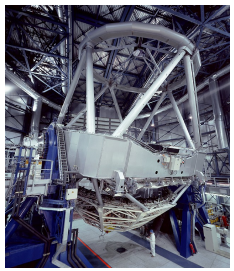


OmegaCam: 32 CCDs van 2000x4000 pixelsl



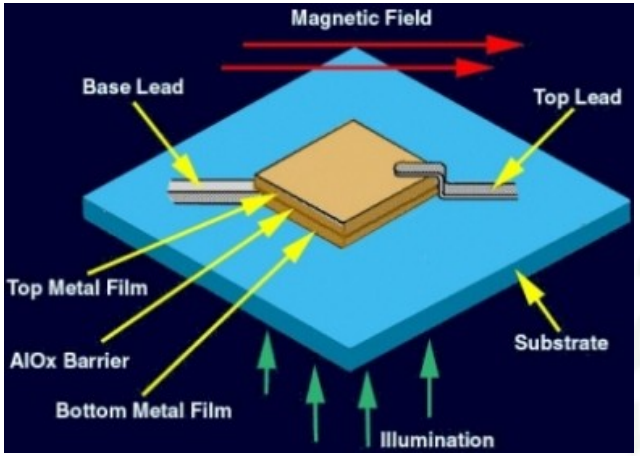
Een wereld van verschil!

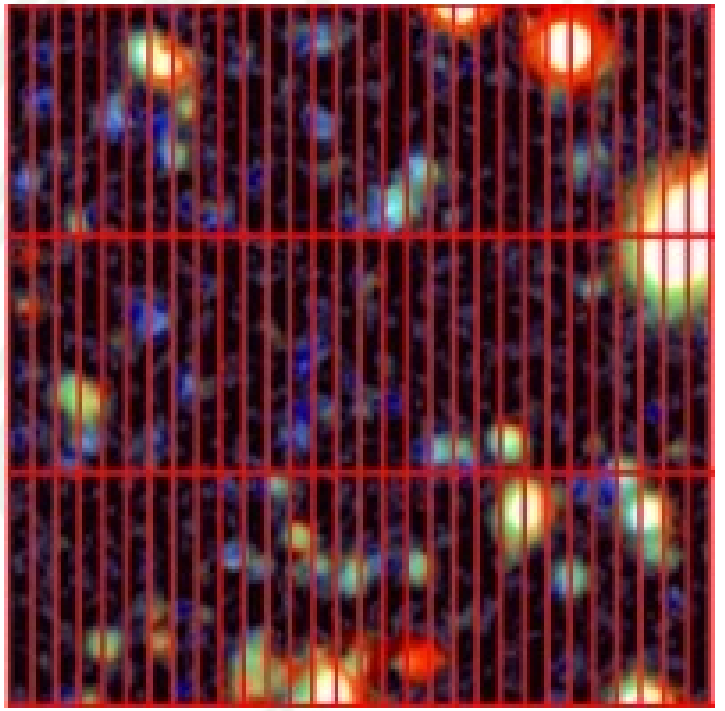




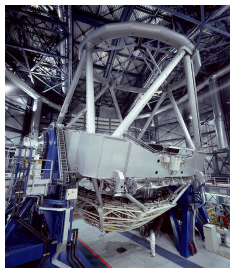
Een stap verder: Superconducting Tunnel Junctions

Energie van foton veel groter dan energie om electronen vrij te maken:
aantal electronen evenredig met energie van foton!





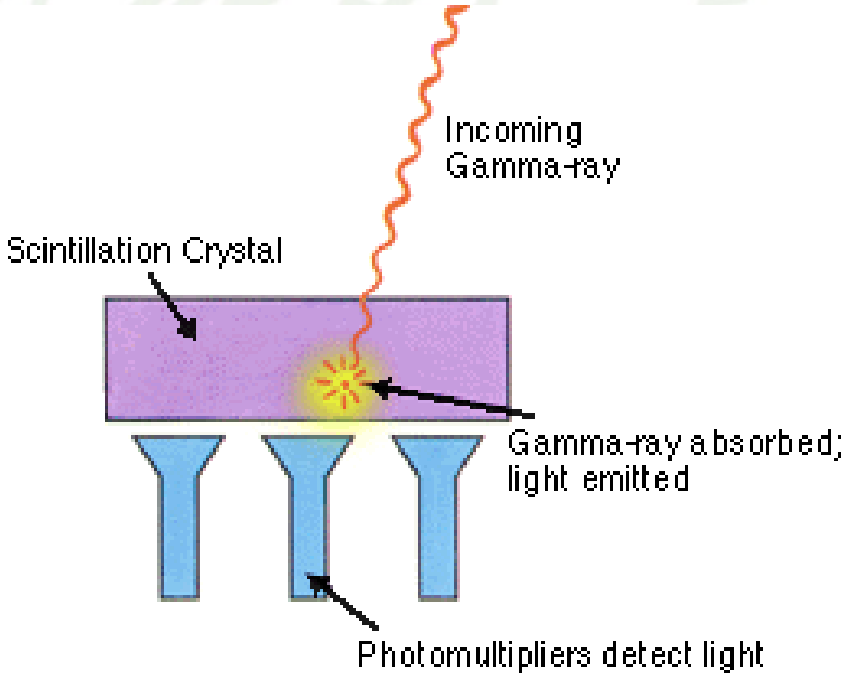
S-Cam 4 in ontwikkeling bij ESA

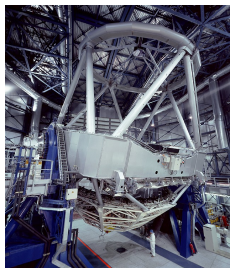


Wat als energie te hoog is?

Fotonen vliegen dwars door je CCD heen (gamma straling)

Scintillator detectors (“rem eerst foton af”)

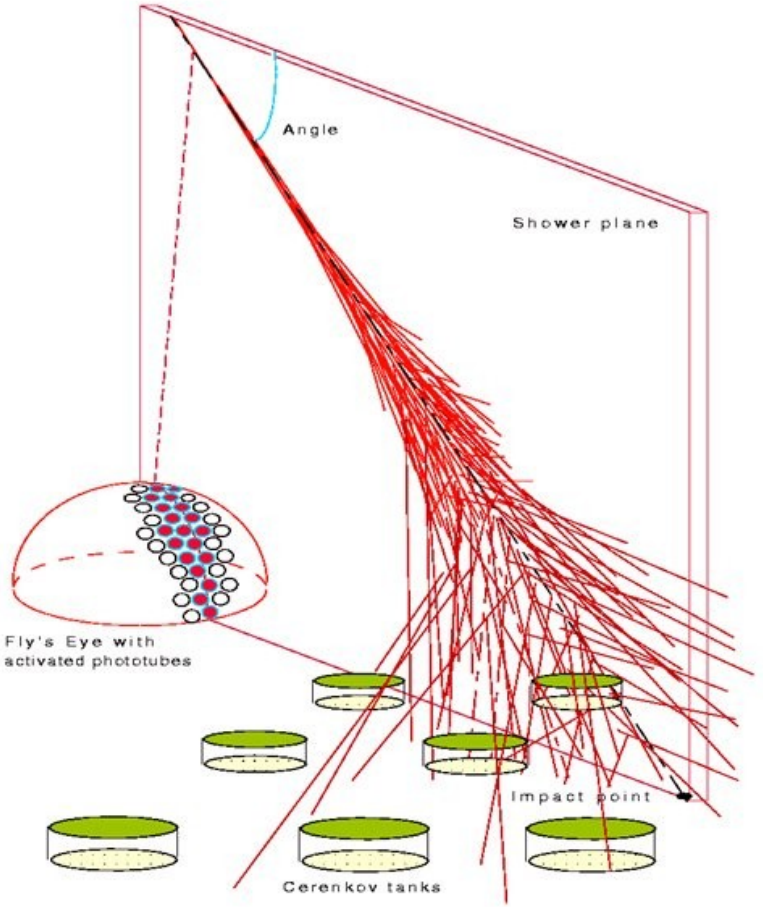


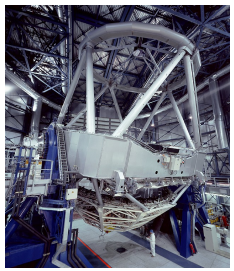


Wat als energie te hoog is?

Nog hogere energie:
Interactie foton (of kosmische straling) in atmosfeer veroorzaakt

“Air shower”

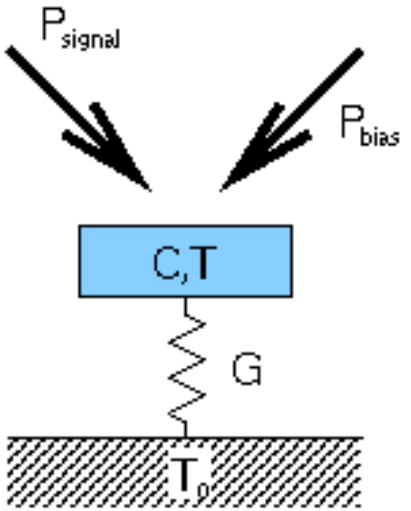




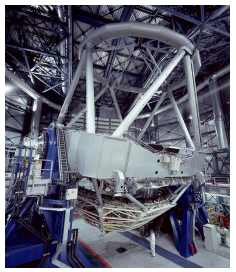
Wat als energie te laag is?

Optie 1:
Maak gebruik van energie foton, maar niet foto-electrisch effect:
→ Energie = warmte

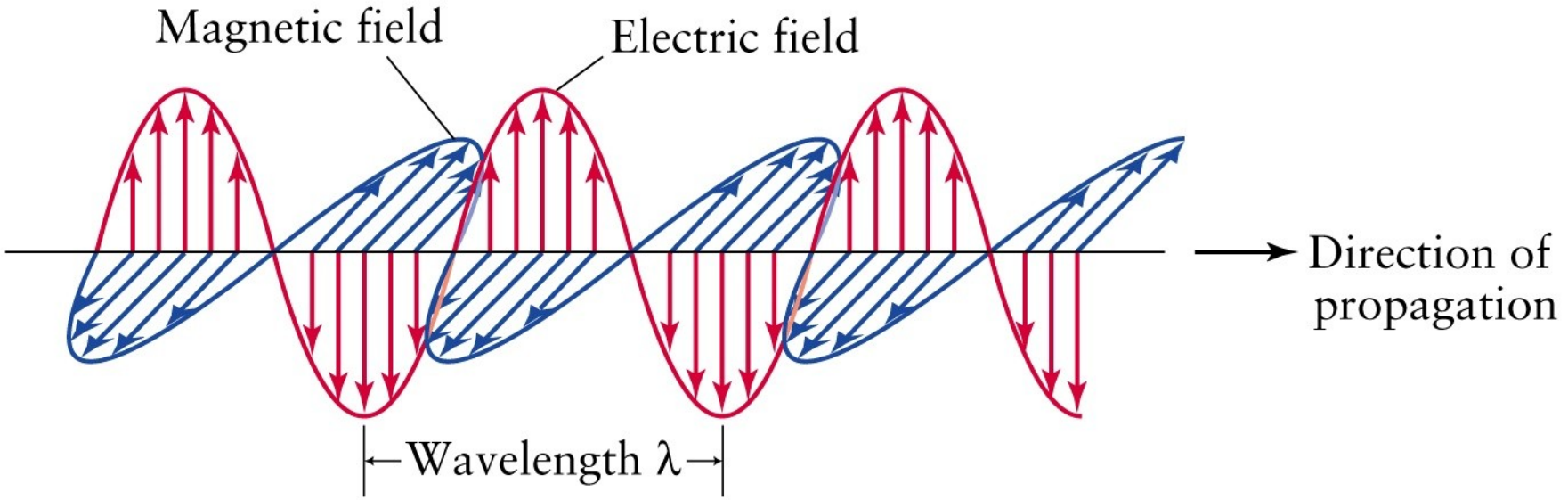
Bolometer

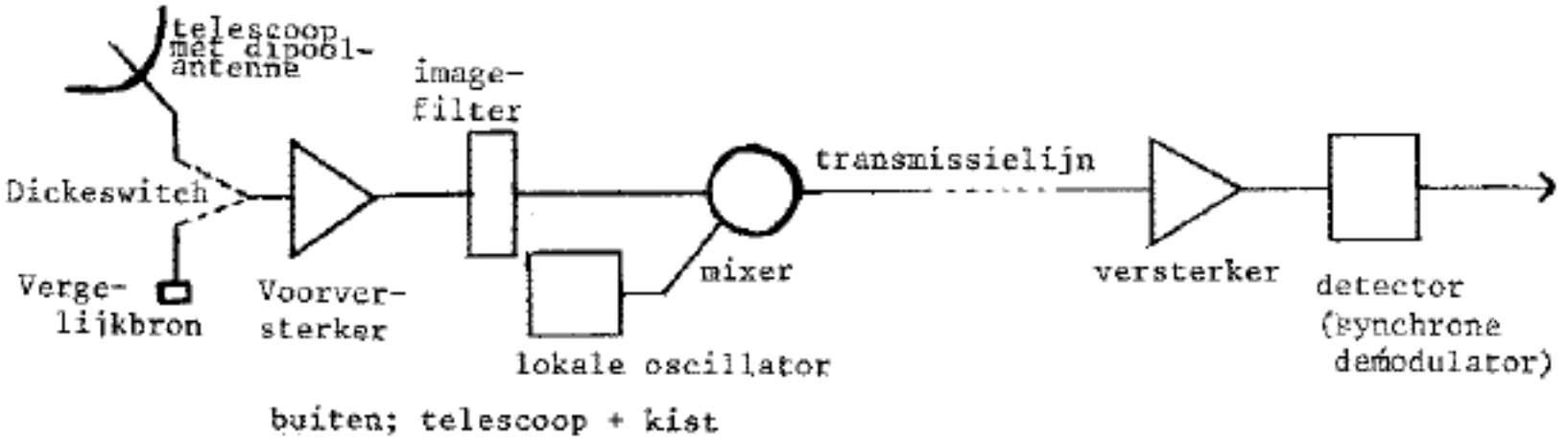


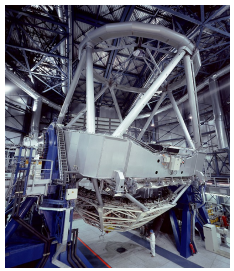
Optie 2:
Maak gebruik van golf-karakter licht!



Radio-detectie: licht als EM golf

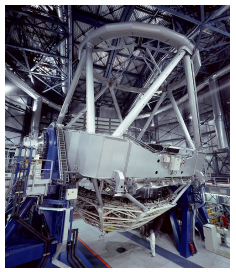






Radio telescopen en detectoren

PARKES RADIO TELESCOPE (CSIRO / ATNF)

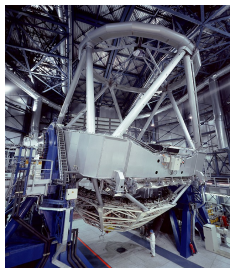


LOFAR
(Low Frequency ARray)

Hele simpele antennes

Veel bij elkaar

Gebruik computer om alles te combineren (college 4)



Volgende college:
12 april (over 3 weken)

De atmosfeer en Ruimtevaart