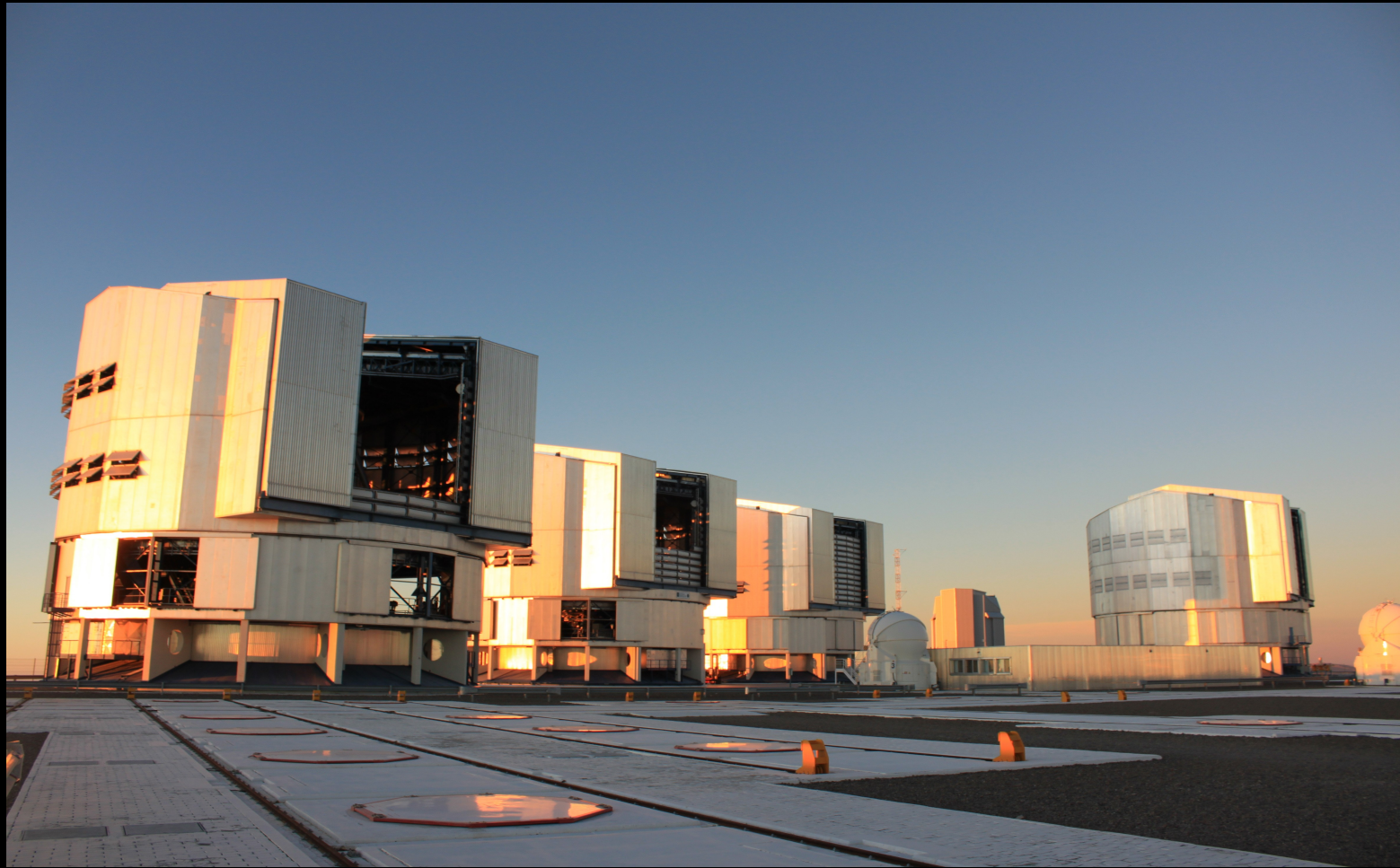


Astronomische Technieken

Hovo Cursus 2010



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



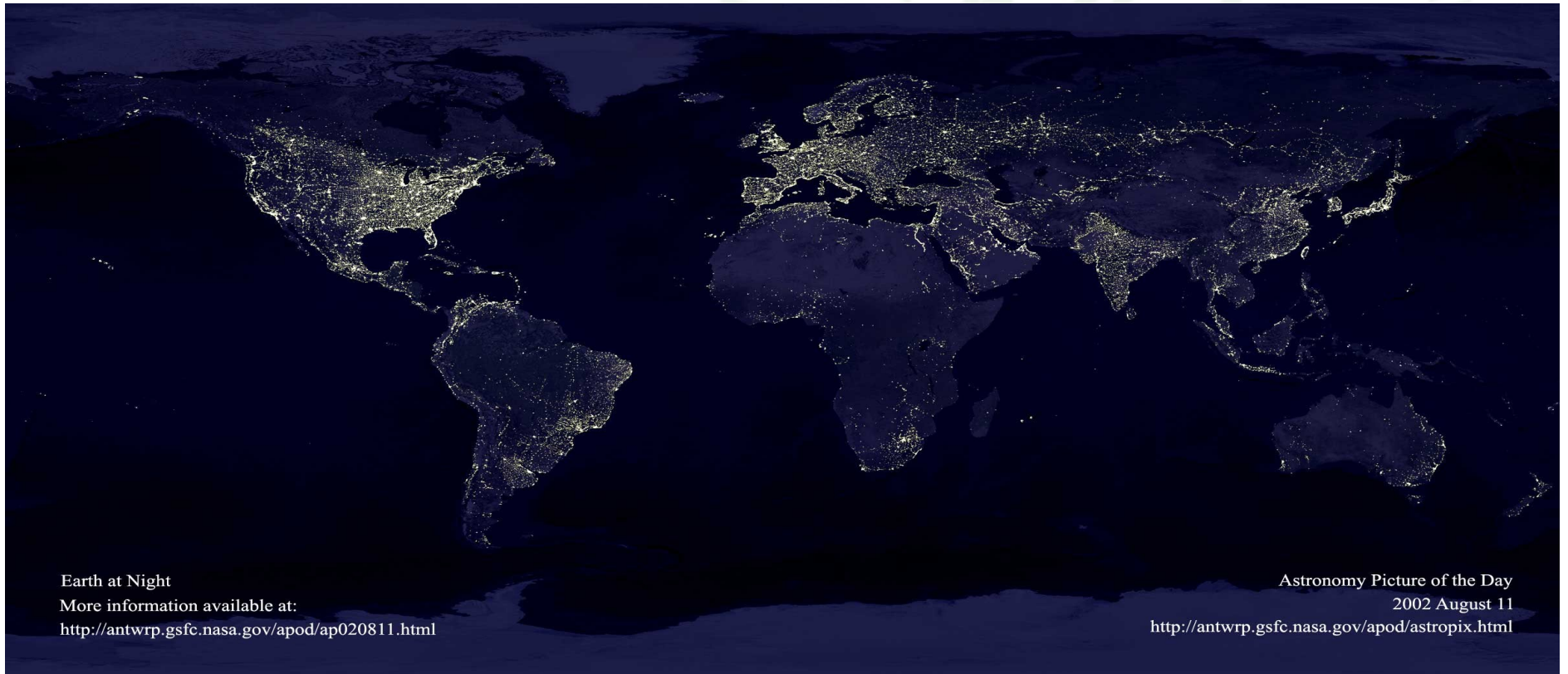
Opbouw van de cursus

- 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

I: Berichten uit de ruimte

Sterrenkunde is uniek:

- *we kunnen niet naar ons onderwerp toe, of het beïnvloeden*
- *we zijn afhankelijk van wat er op ons af komt en wanneer het komt*



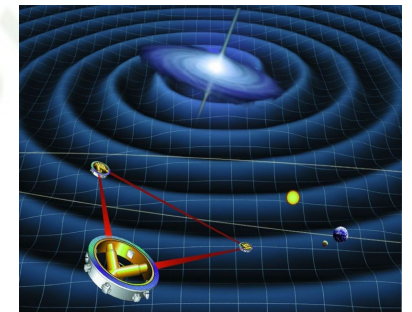
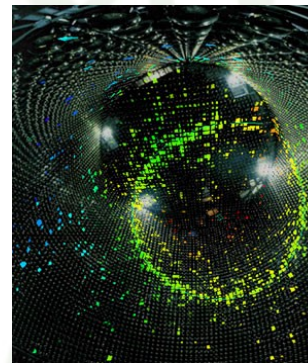
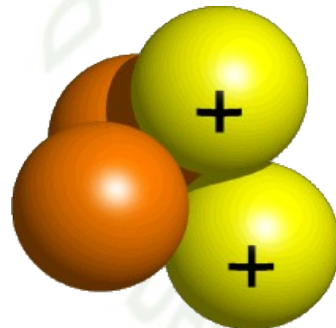
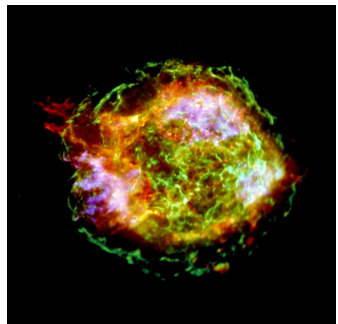


I: Berichten uit de ruimte

Op wat voor manieren komt informatie tot ons vanuit de ruimte?

Wat zijn de *informatiedragers*?

- **Fotonen**, electromagnetische straling (radio, submm, infrarood, optisch/licht/zichtbaar/visueel, UV, röntgen, γ -straling)
- **Meteorieten**, rotsen, vallende sterren
- **Kosmische straling**: elementaire deeltjes (protonen, kernen, muonen, etc.)
- **Neutrinos**: de 'spook'-deeltjes uit het standaard model
- **Zwaartekrachtsgolven, gravitatiegolven**: vervormingen van de ruimte en tijd





Fotonen: electromagnetische straling

Wat is licht?

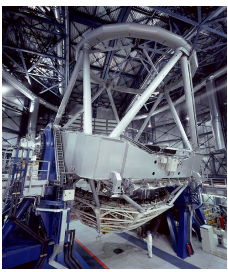
a) Licht is een deeltje

b) Licht is een golf

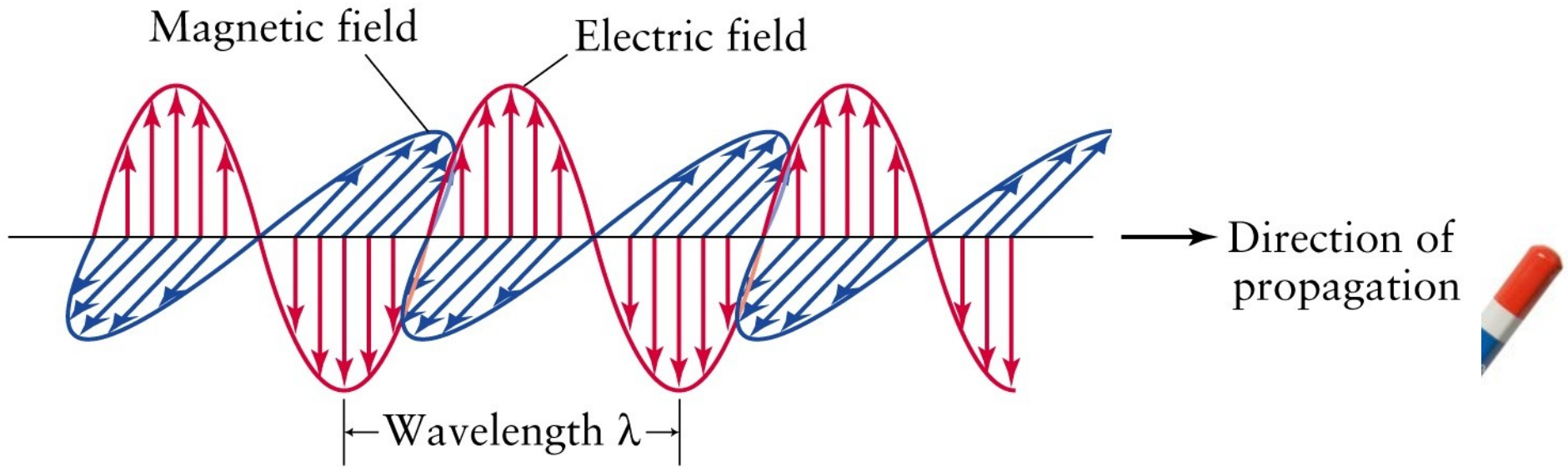
Beide: licht is een golf en een deeltje.

Hoe we het detecteren bepaalt zijn eigenschappen.

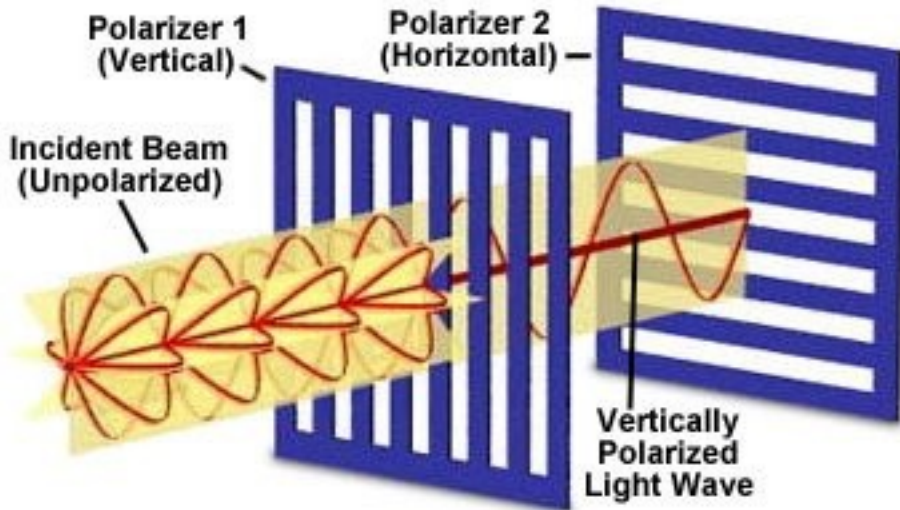
Licht als een golf



OF ASTROPHYSICS



Light Passing Through Crossed Polarizers

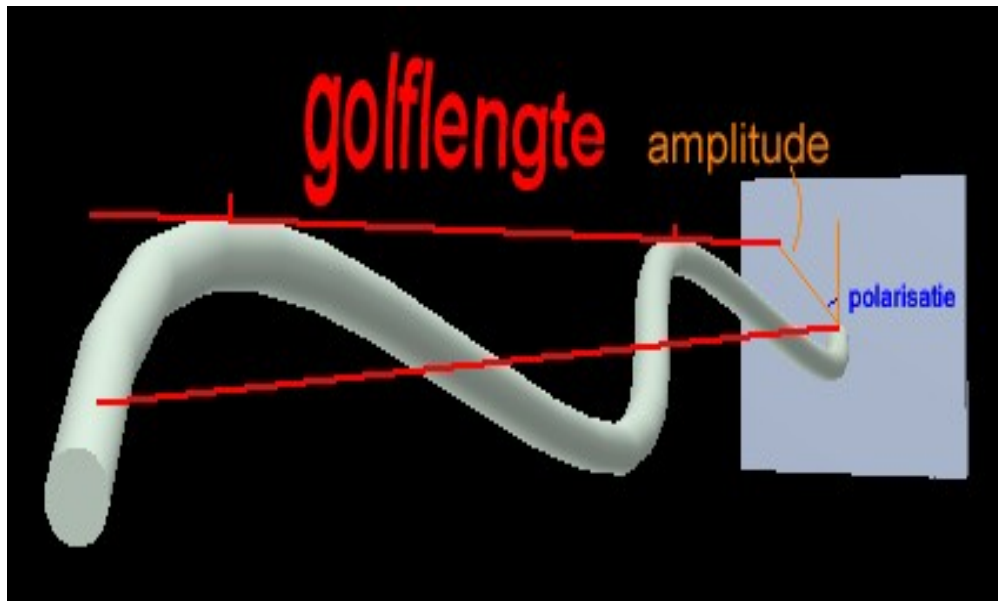


UDBO

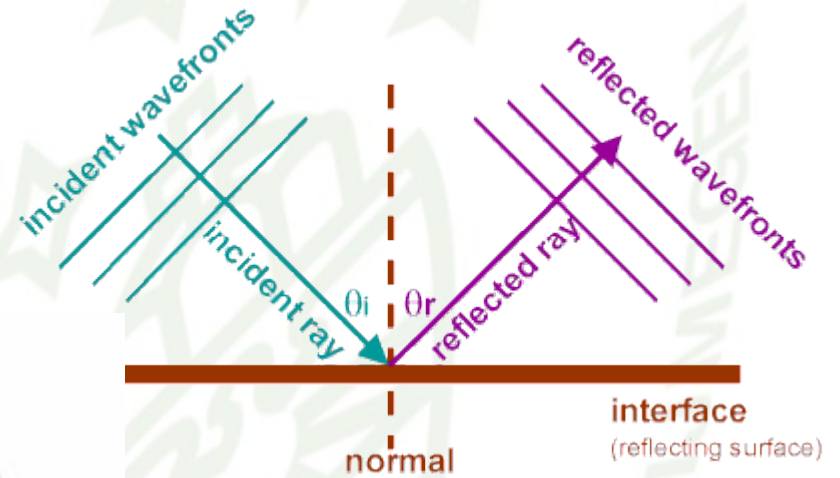
Licht als een golf

Eigenschappen van een golf:

- **Golflengte:** afstand van piek tot piek ('kleur', 'toonhoogte')
- **Amplitude:** hoogte van de piek ('intensiteit', 'sterkte')
- **Polarisatie:** trilrichting van de golf.



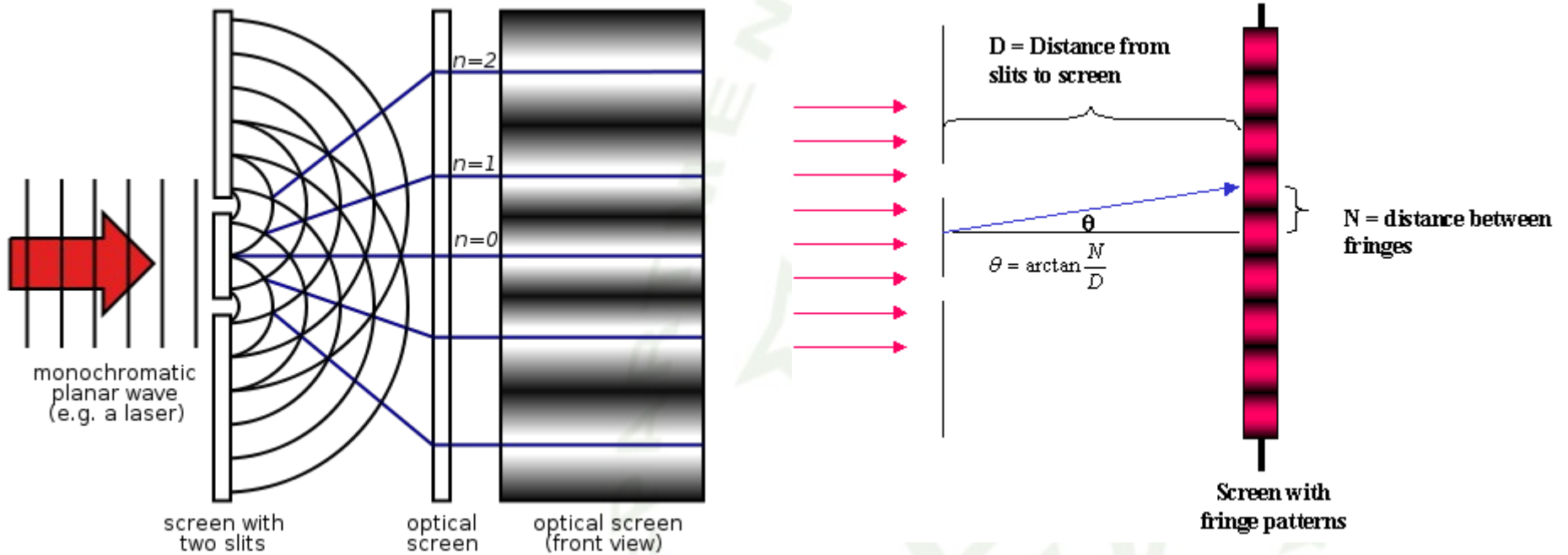
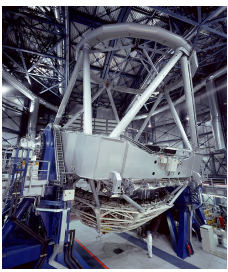
Licht als een golf



Principe van Huygens:
Elk punt is bron van nieuwe golven



Licht als een golf



Klassieke spleten experiment van Young

Licht als een deeltje

Heeft aan de basis van de quantummechanica gestaan:

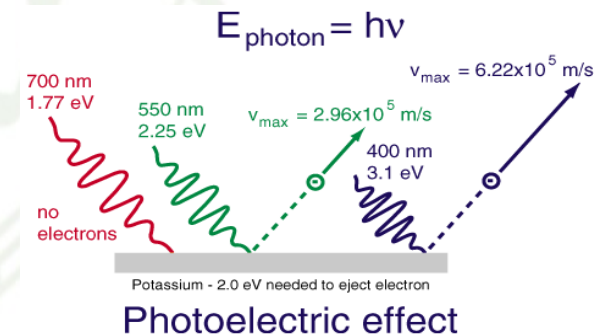
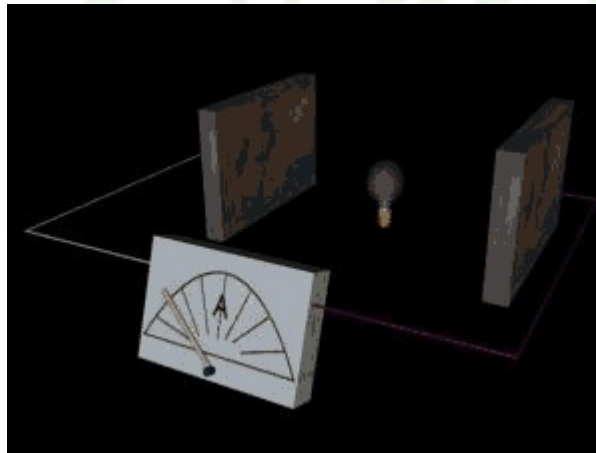
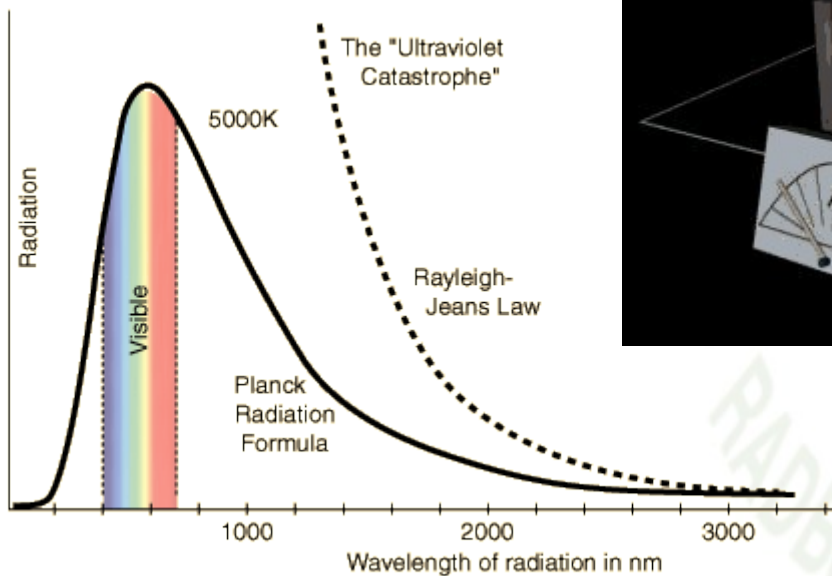


Max Planck

- UV Catastrofe
- Foto-electrisch effect

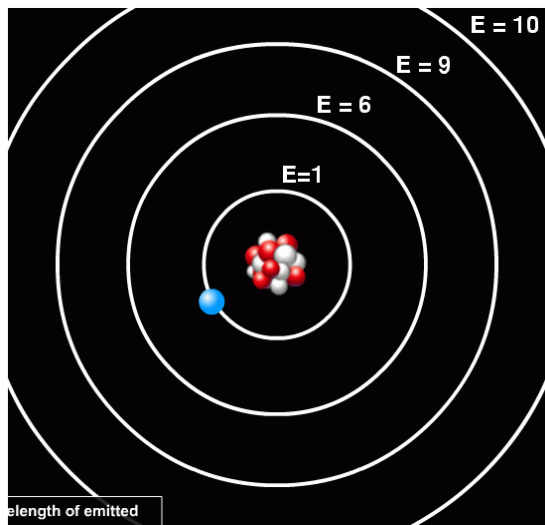


Albert Einstein

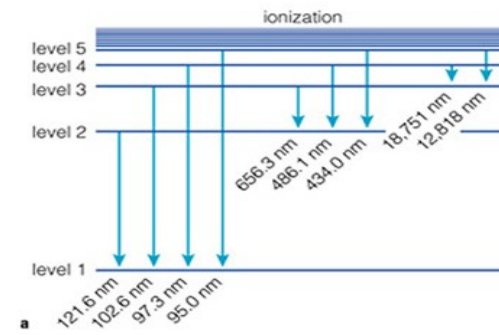


Licht als een deeltje

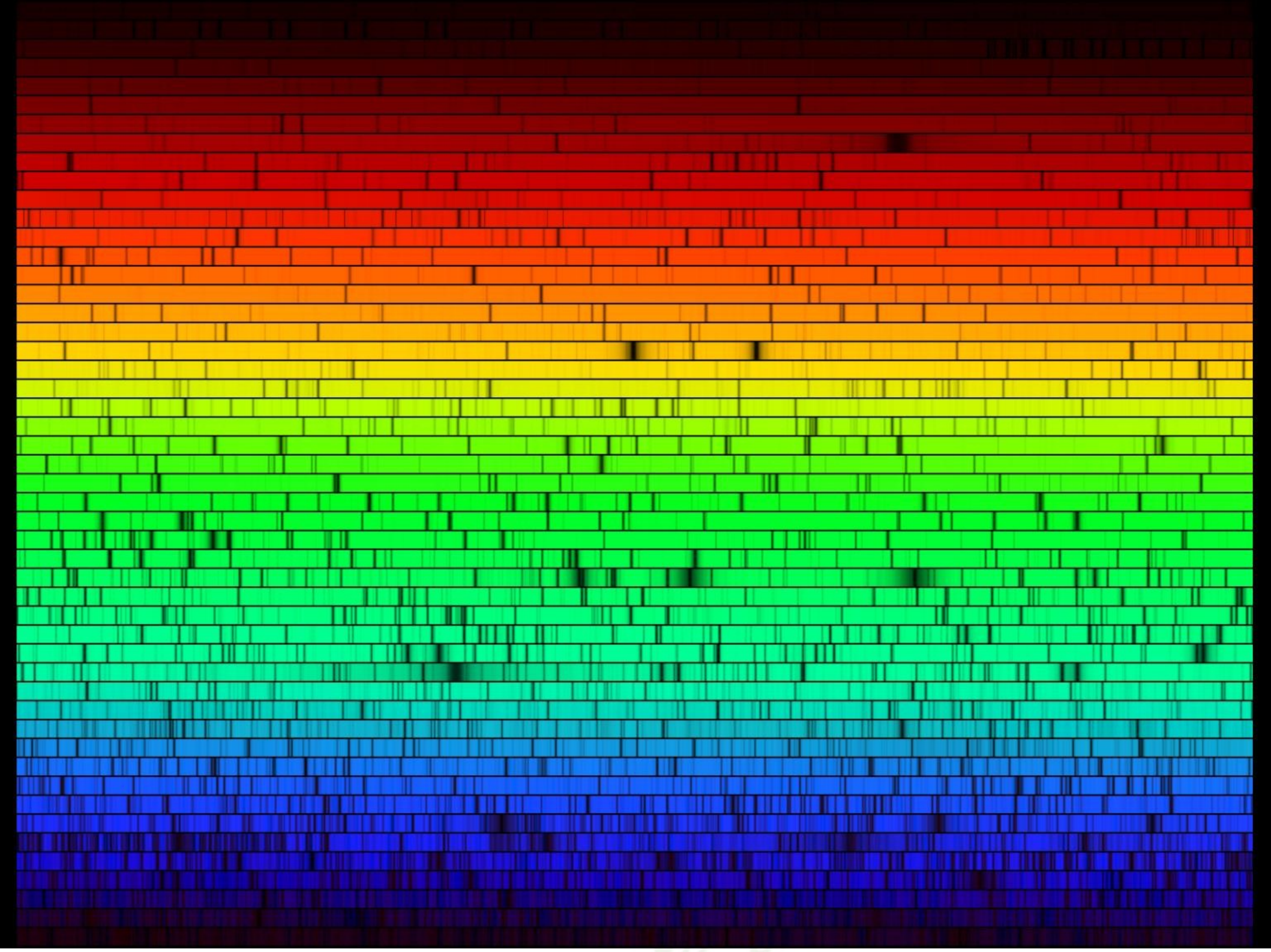
Beide problemen opgelost als licht een deeltje is *en gekwantiseerd* (in energie) kan worden.



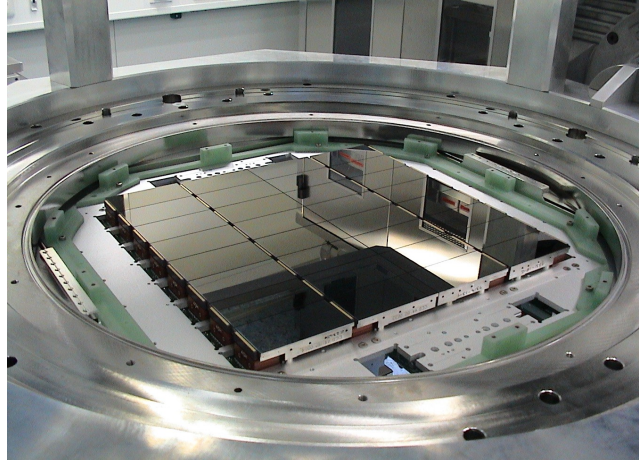
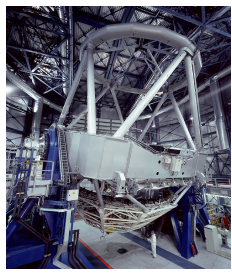
$$E = \frac{hc}{\lambda}$$



Begin van de astrofysica



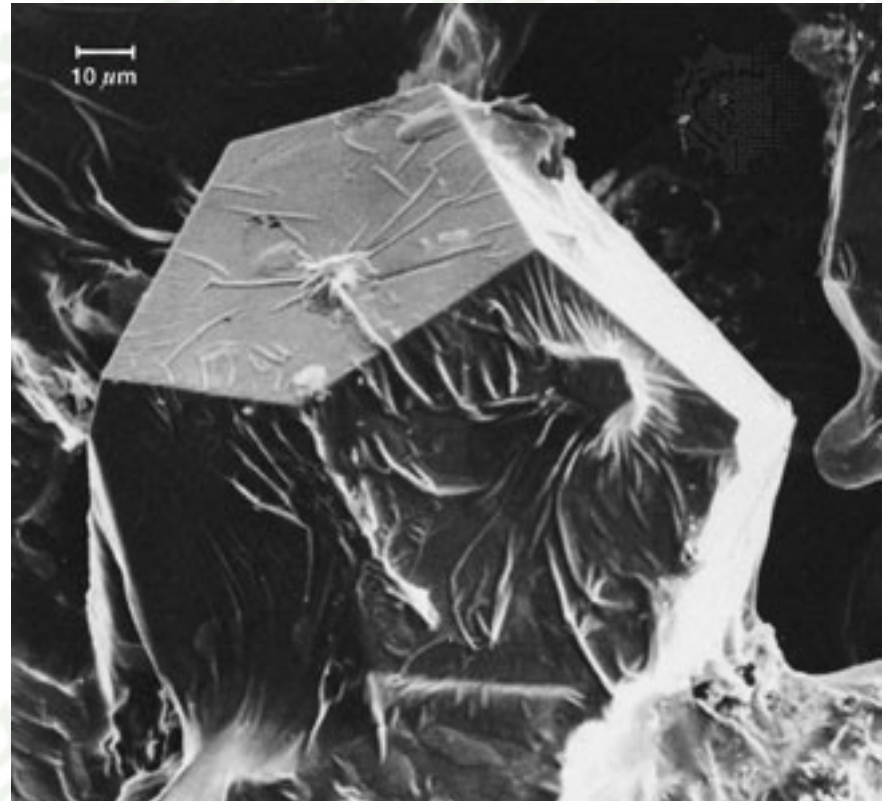
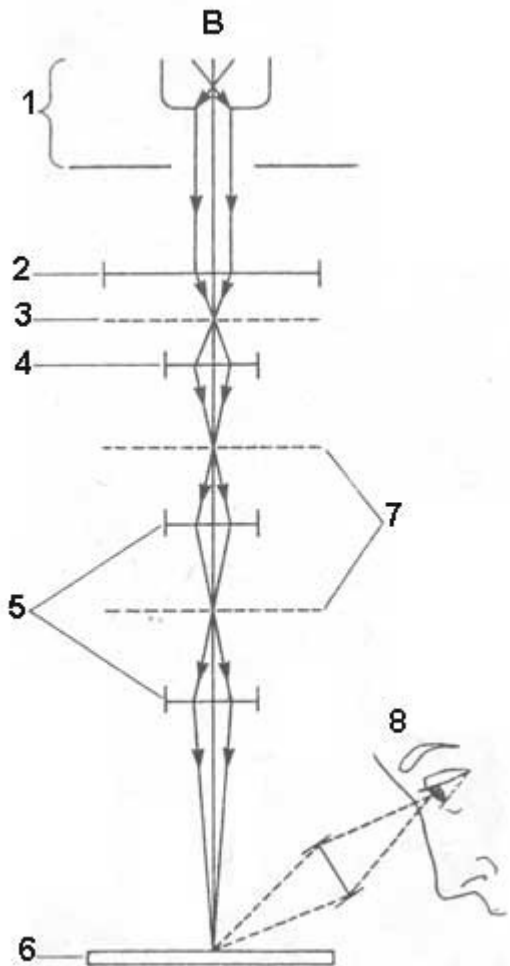
Licht als een deeltje



OF ASTROPHYSICS

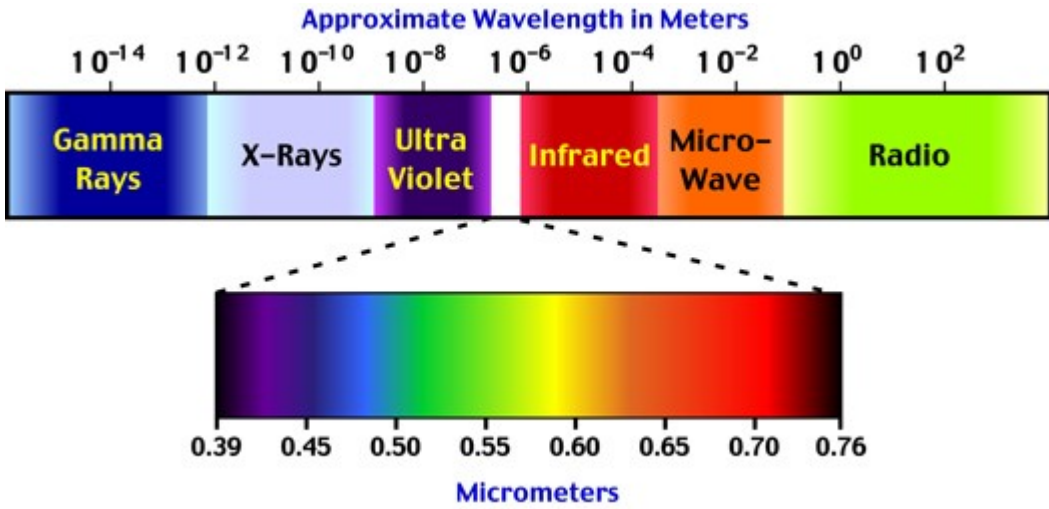
Dualisme in de QM

Niet alleen fotonen vertonen duaal gedrag
Alle elementaire deeltjes zijn ook golven

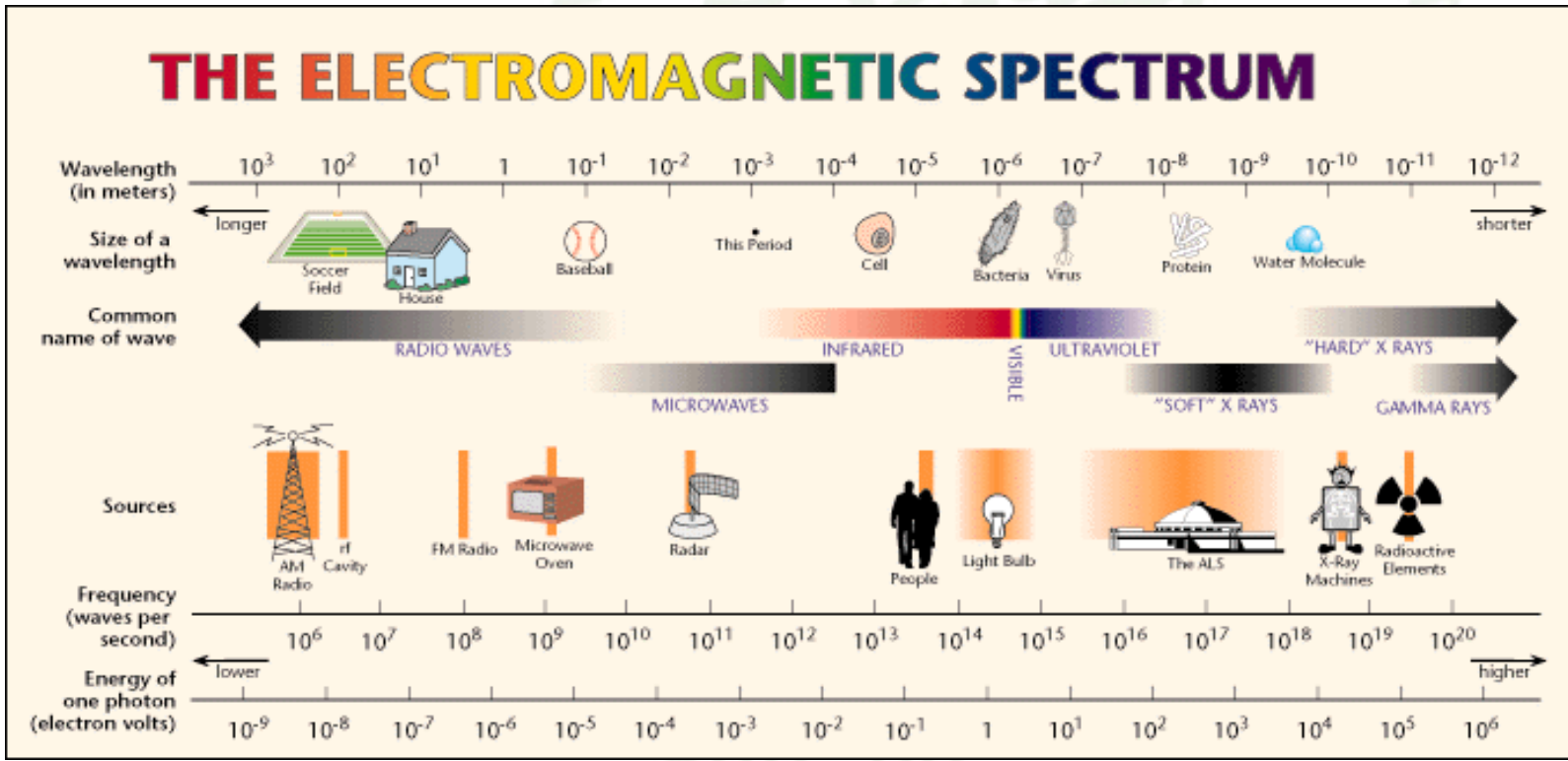


Scanning Electron Microscope

Het electromagnetisch spectrum

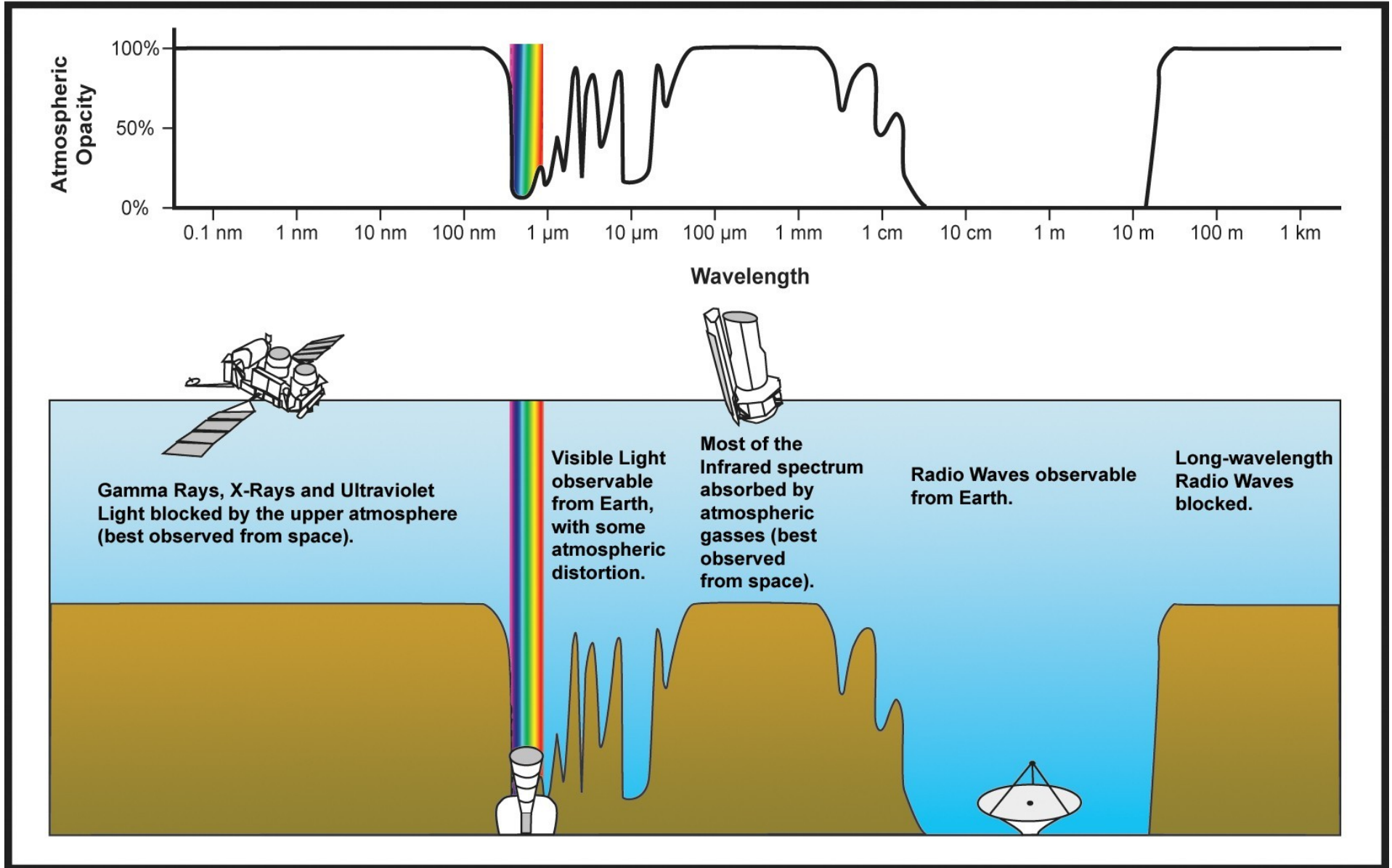


Ordering naar golflengte, frequentie of energie





Het elektromagnetisch spectrum



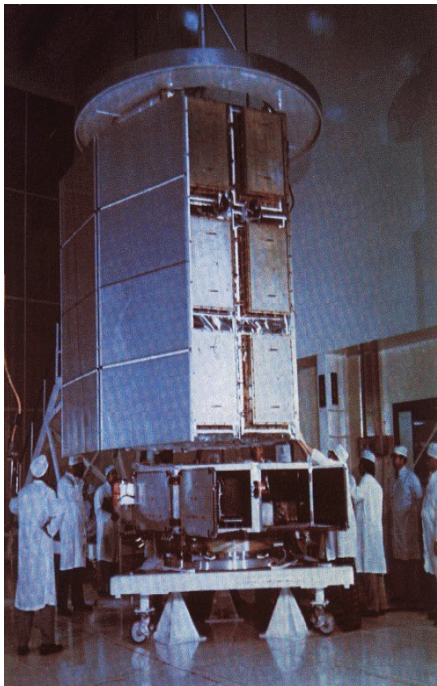


Ontsluiting EM Spectrum

Vanaf de grond: Optisch, Radio en beetje Infrarood en submm

Vanuit de ruimte: Röntgen, UV, IR, γ -rays

**Grote bloei van de sterrenkunde:
ontwikkeling van de ruimtevaart!**

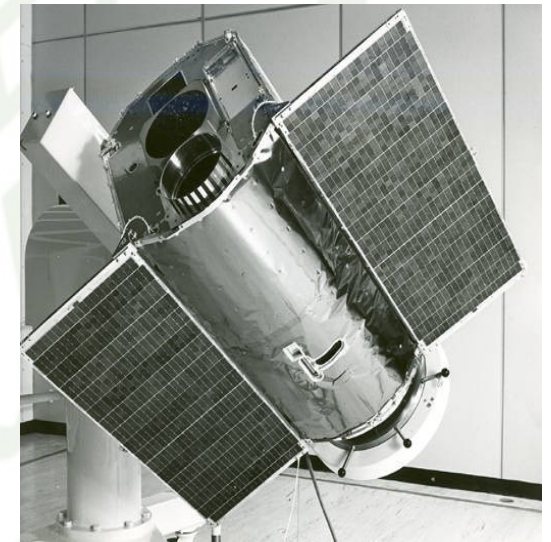


Vela

Heao-I



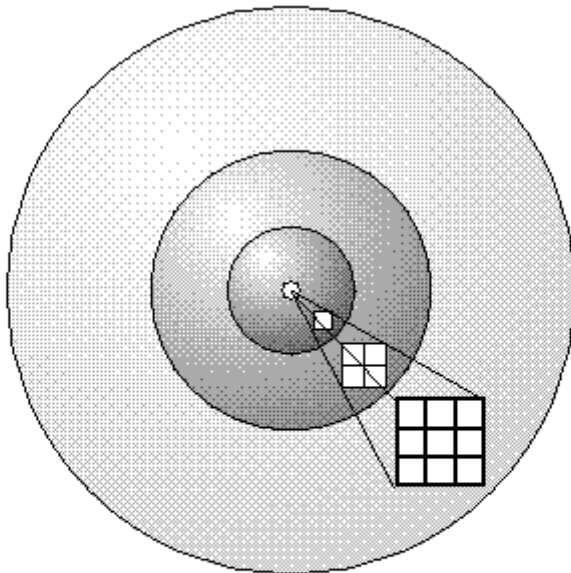
IRAS



ANS

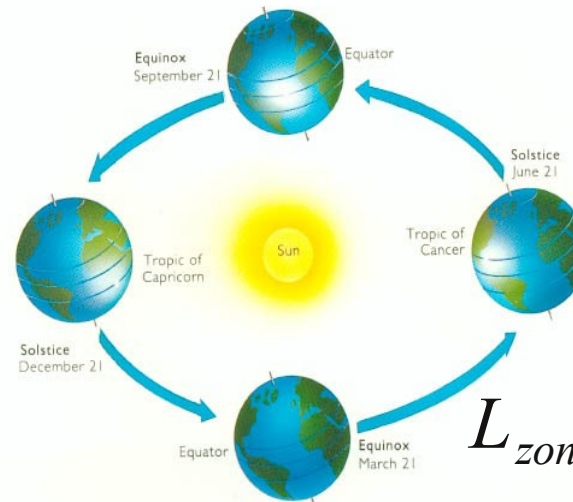
Energiebehoud

Voor interpretatie van gegevens: energiebehoud van essentieel belang



Light spreads out with the **square** of the distance. Through a sphere twice as large, the energy covers an area **four** times larger. Through a sphere three times as large, the energy covers an area **nine** times larger.

$$f = \frac{L}{4\pi d^2}$$



$$L_{zon} = f_{zon} 4\pi d_{zon}^2$$

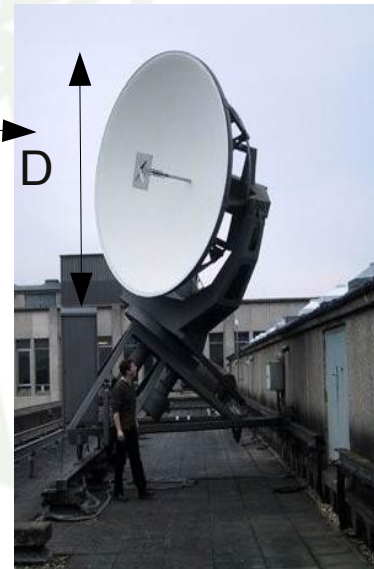
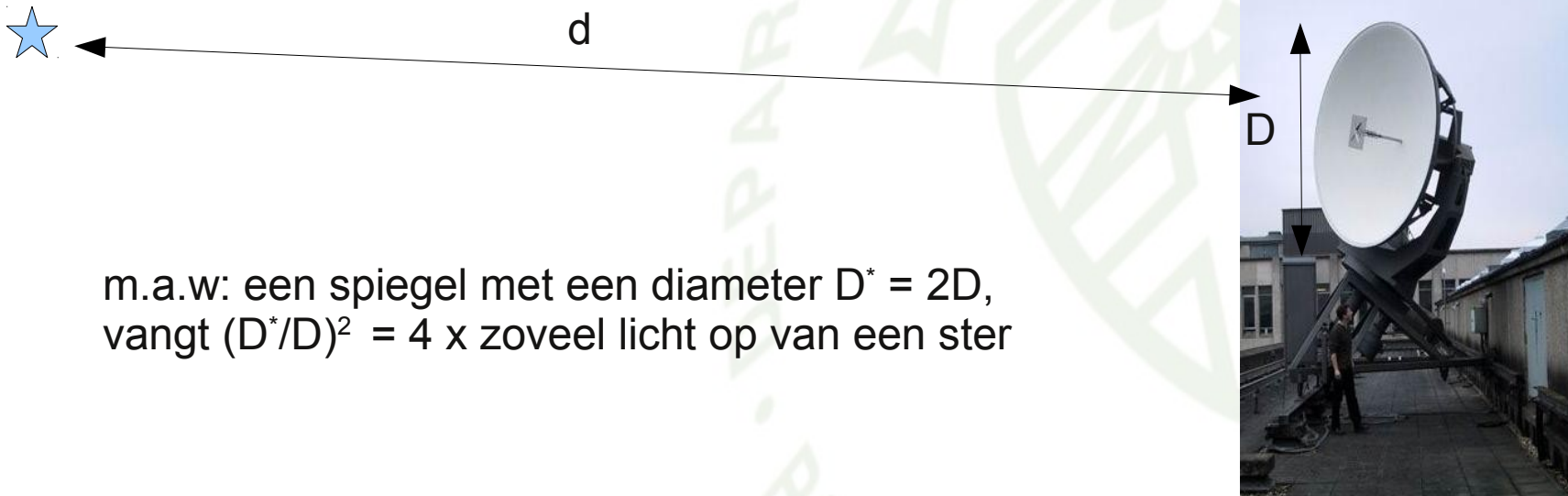
f_{zon} = de zonneconstante = 1366 W/m²

d_{zon} = afstand Aarde-Zon = 1 AE = 150 miljoen km

Bron in oneindig

Binnenkomende golffronten zijn vlak (oneindig klein deel van bol)

Diameter telescoop (D) \ll afstand tot de bron (d)

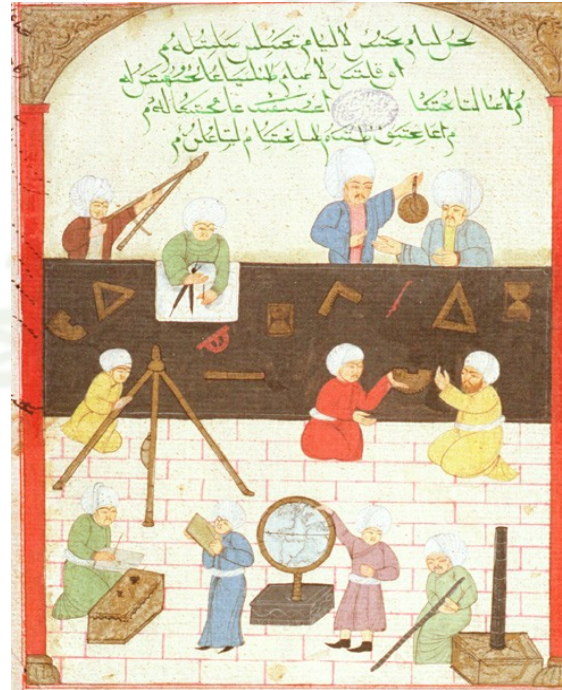
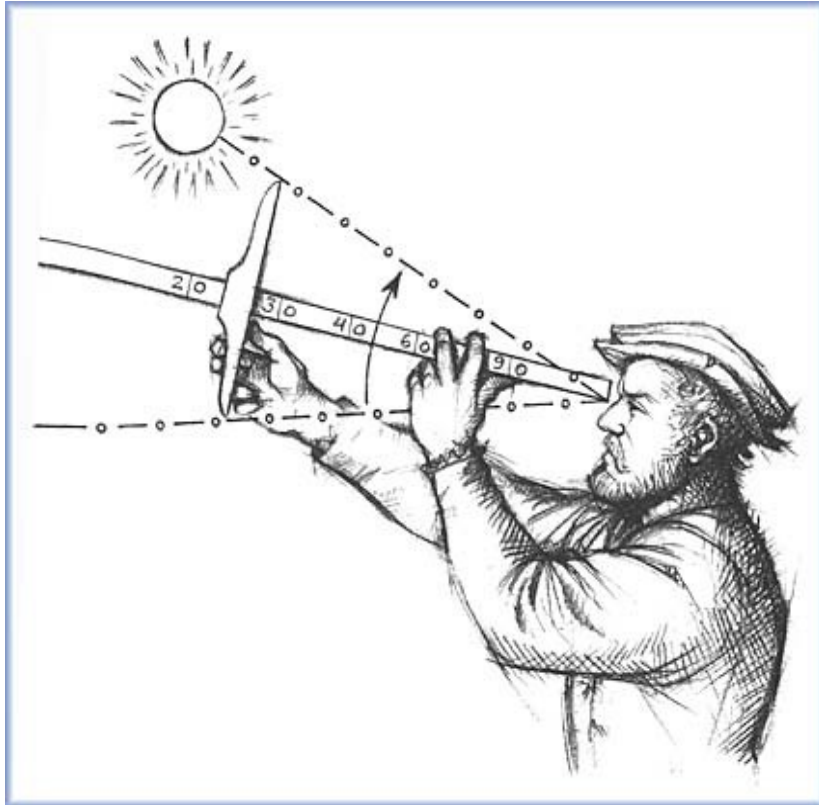
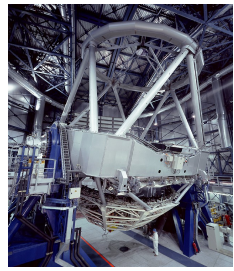


Ontwikkeling van de telescoop

Vroegste astronomische waarnemingen allemaal visueel (i.e. met het blote oog)
Ontwikkeling van sterrenkunde voor landbouw en navigatie



Simpele hulpstukken



Blote oog waarnemingen



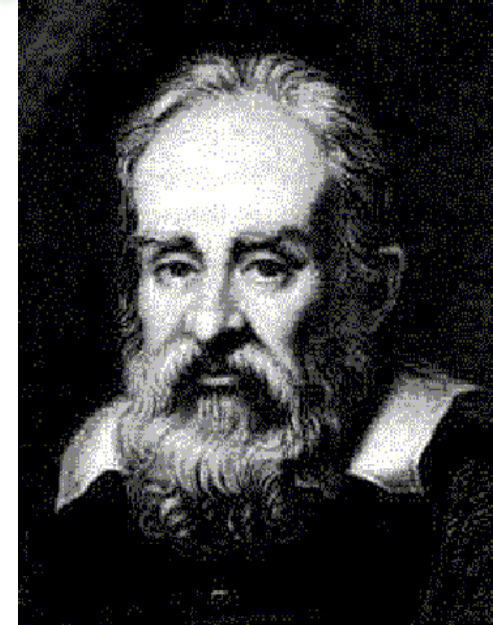
ASTROPHYSICS

UNIVERSITY

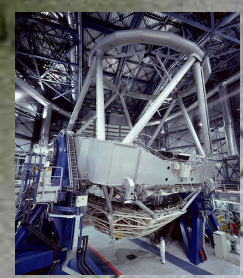
Ontwikkeling v/d telescoop



In 1608 Lippershey in Middelburg



Galileo Galilei, 1609



Enorme ontdekkingen

Scipio Principe.

Milij Hamilton. Scru

... et de ogni spacio di potere no solam scorgere
 alcuni che non della Lettera di Mademati^{ca} nelle Scu-
 ole di Padova,

Si viene dunque determinato di presentare al Scipio Principe
 l'Orchiale et il p^{ro} essere di giornamento inestimabile p^{er} ogni
 negozio et in terra marittima o terrestre shmo di tenere qual-
 che nuovo artificio nel maggior segreto et solam a disposizione
 di S. M. L'Orchiale auato dalle piu u^{ol}te speculazioni di
 profetia in l'uantaggio di scoprire Legni et Vele dell' inimico
 p^{er} via terre et piu di tempo prima di esse scuopra noi et distinguendo
 il numero et la qualita de i Vasselli giudicare la sua forte
 pallesirsi alla caccia al combattimento o alla fuga, o pure nasc
 nella campagna aperta uidero et particolarly distinguere ogni suo
 moto et preparatione.

Adi 7. di Gennaio

Gioue si uede u^{ol}te

Adi 8. u^{ol}te

ora d'uy diretto et no retrogrado

Adi 12. si uede in tale u^{ol}te u^{ol}te

Il 13. si uede u^{ol}te u^{ol}te in Gioue 4 Stelle

Adi 14. è anglo

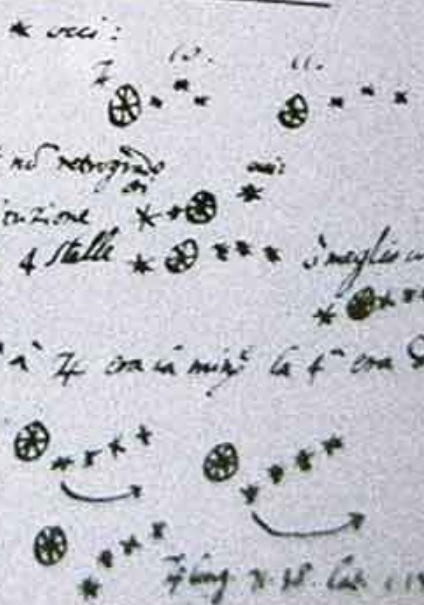
Il 15. la pro^{ss}ima a 74 ora in m^ore la 4^a ora di

stante dalla 3^a il doppio l'aria

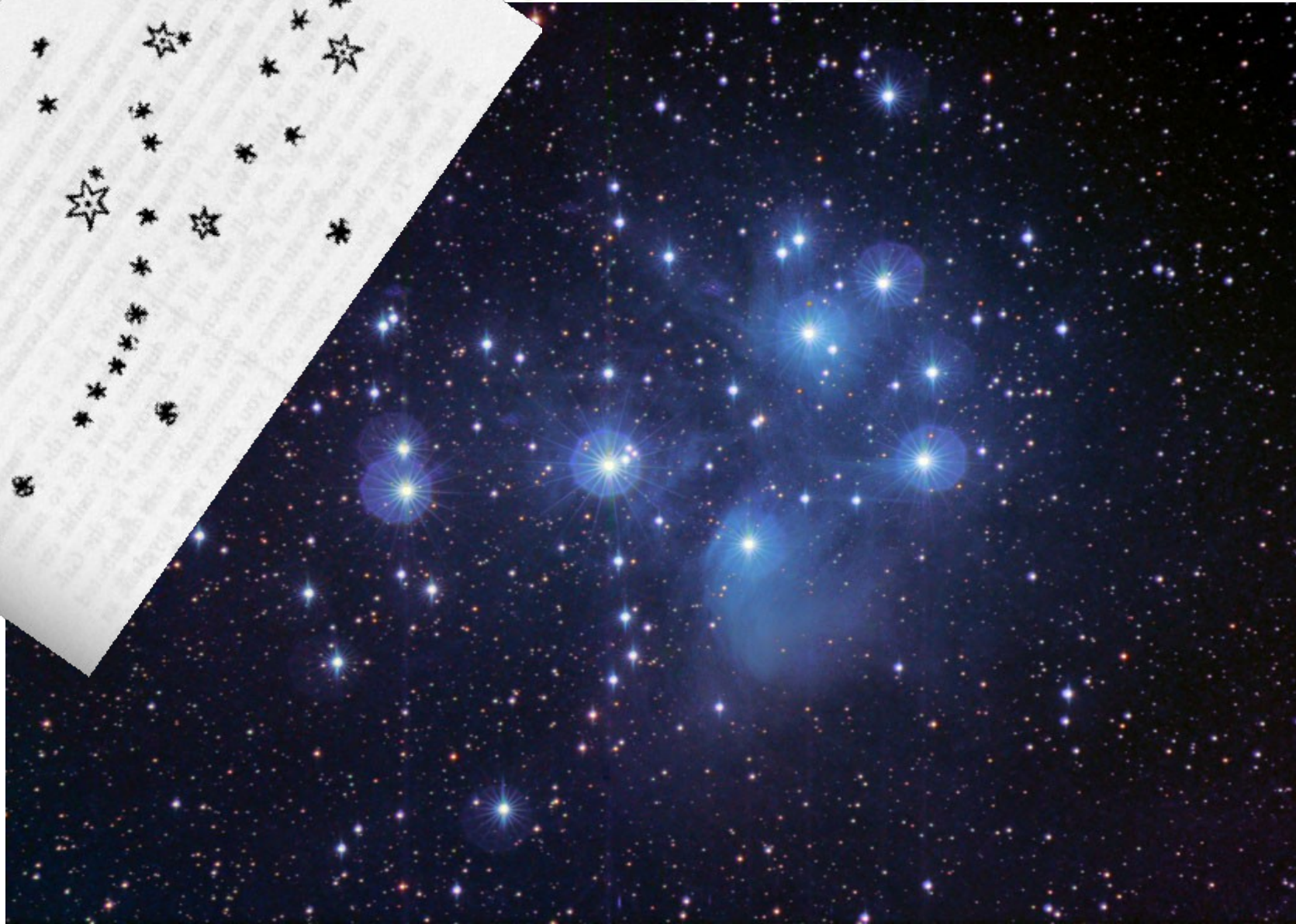
Lo spazio delle 3. au^{ol}te u^{ol}te con

maggior del diametro di 74 et con

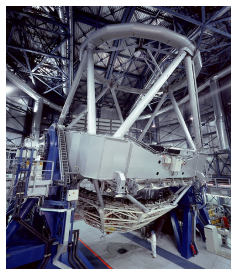
mo in linea retta.



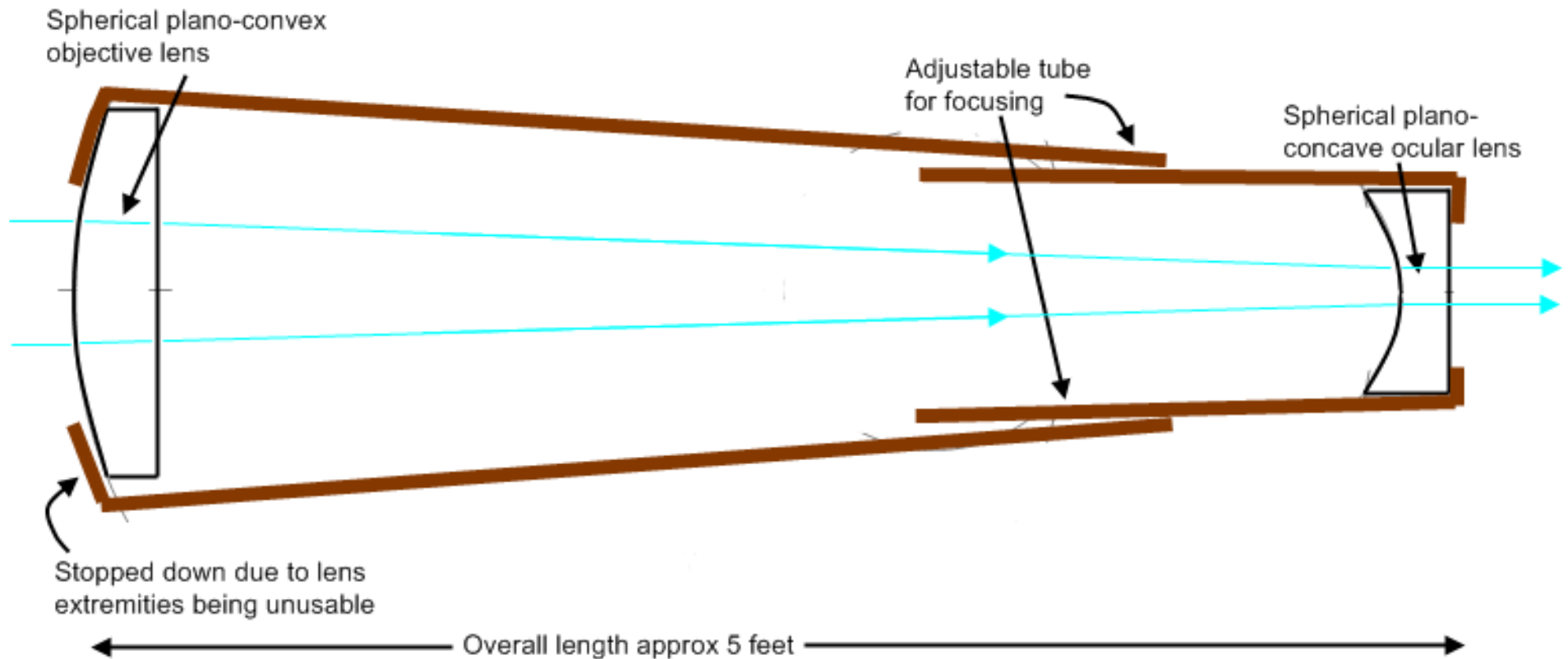
Enorme ontdekkingen



Werking van de telescoop



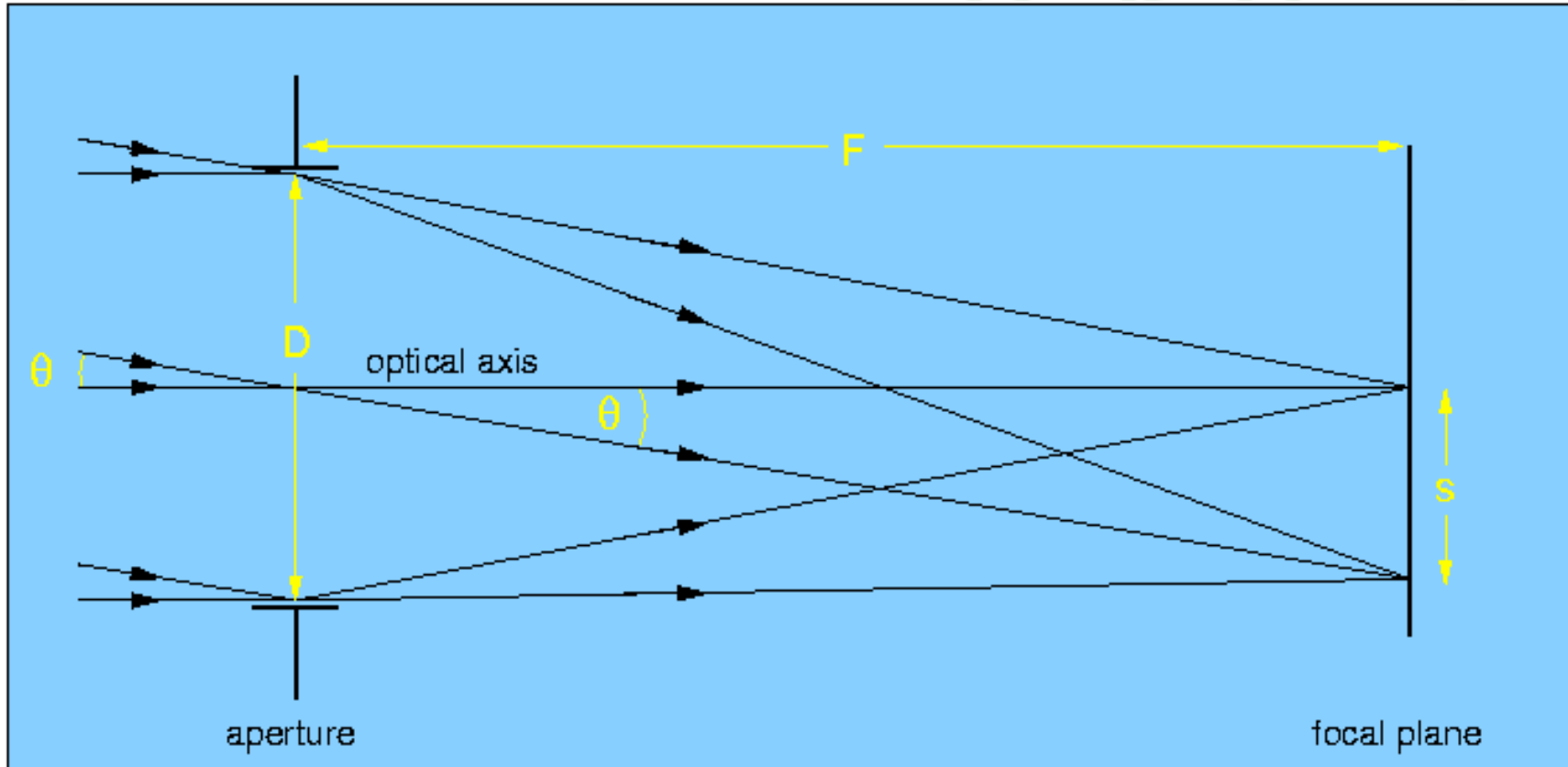
The Galilean Telescope



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



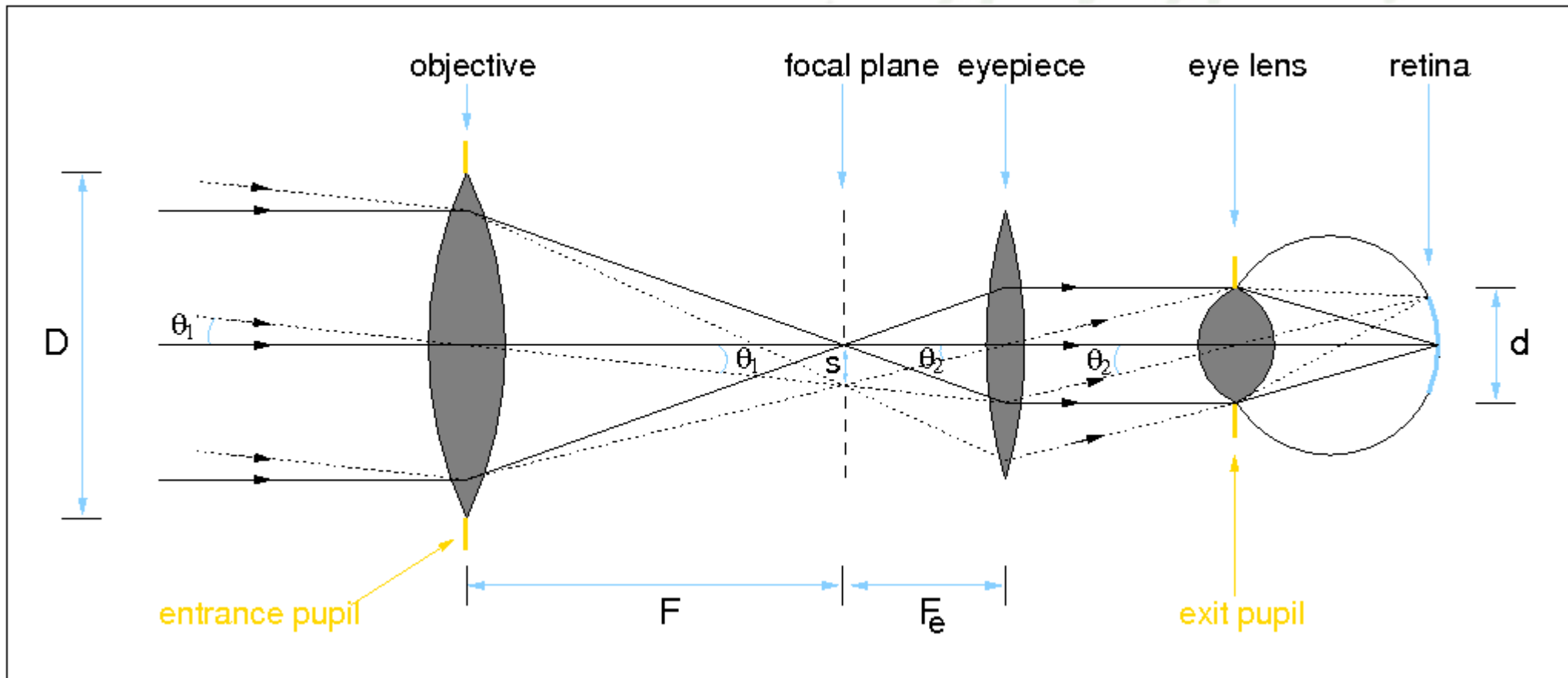
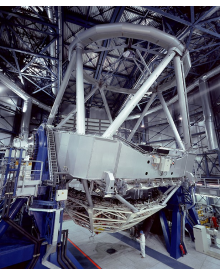
Brandpuntafstand: F

Brandpuntsverhouding: $f = F/D$

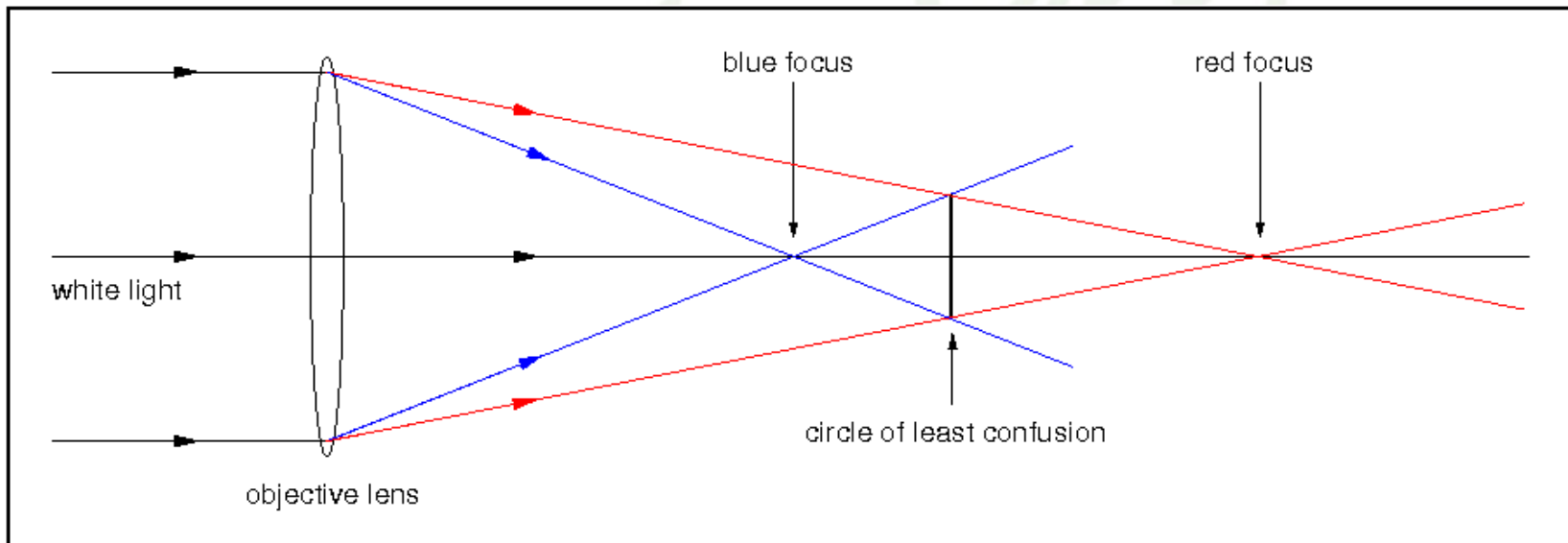
Opening: D

Opgevangen hoeveelheid energie: D^2

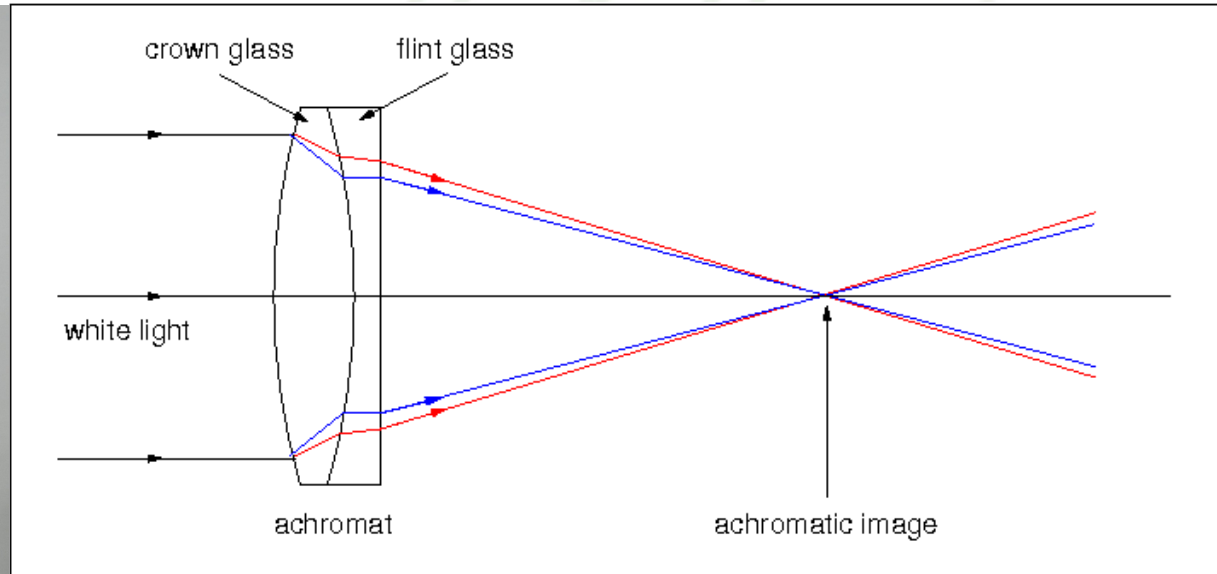
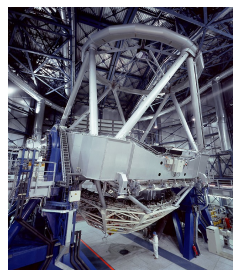
Visuele waarnemingen



Refractoren: chromatische aberration



Apochromaten



Nadeel: grote brandspuntsverhoudingen
'langzame' telescopen, nauw blikveld

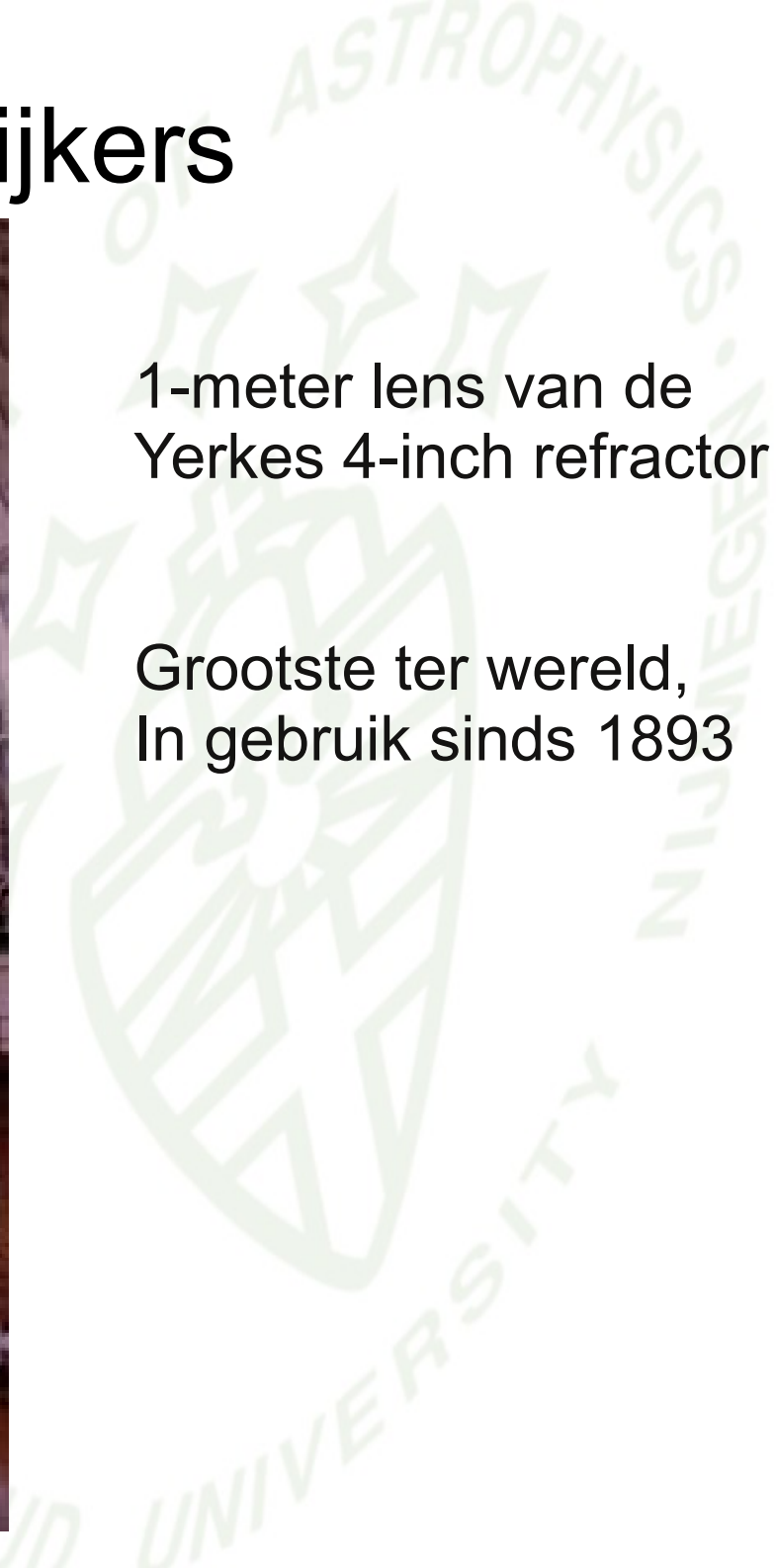
Moeilijk te schalen!

Grote lenzenkijkers



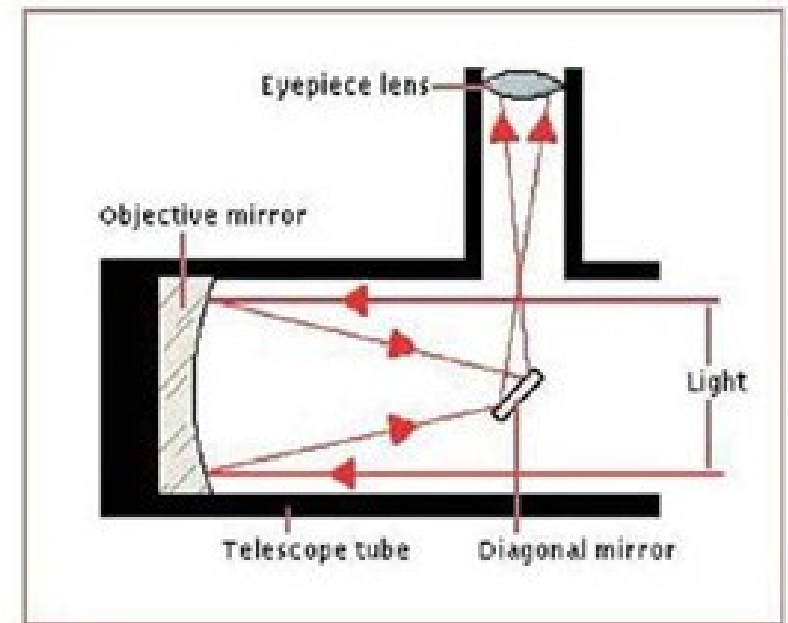
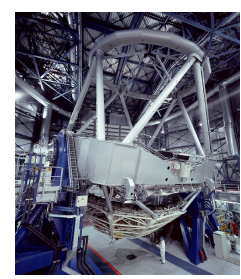
1-meter lens van de
Yerkes 4-inch refractor

Grootste ter wereld,
In gebruik sinds 1893

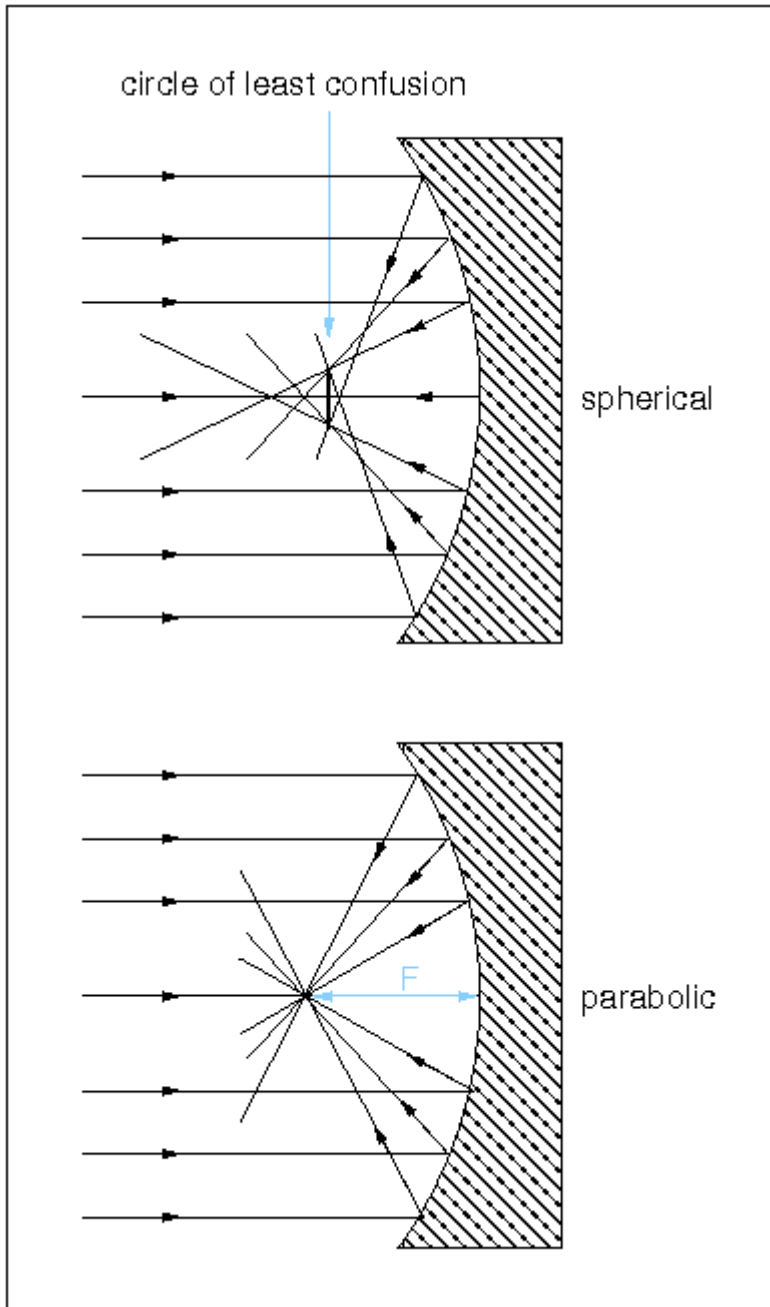


Spiegelkijkers

Voor het eerst toegepast door: Newton



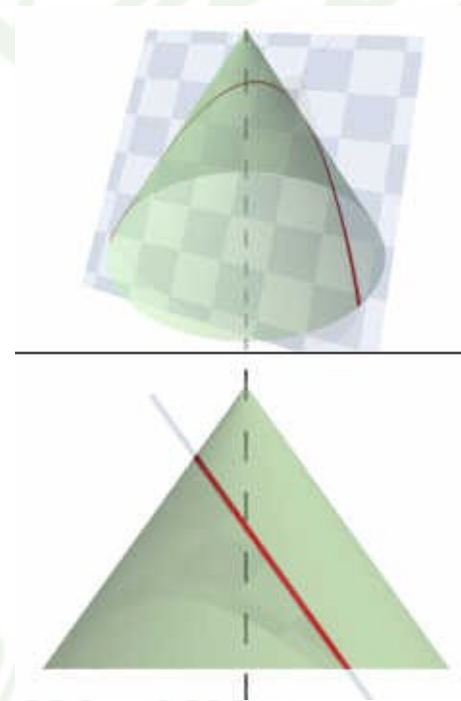
Spiegelkijkers



Een parabolische spiegel werkt beter dan een sferische spiegel!

Sferisch: constante kromtestraal
(deel van een cirkel)

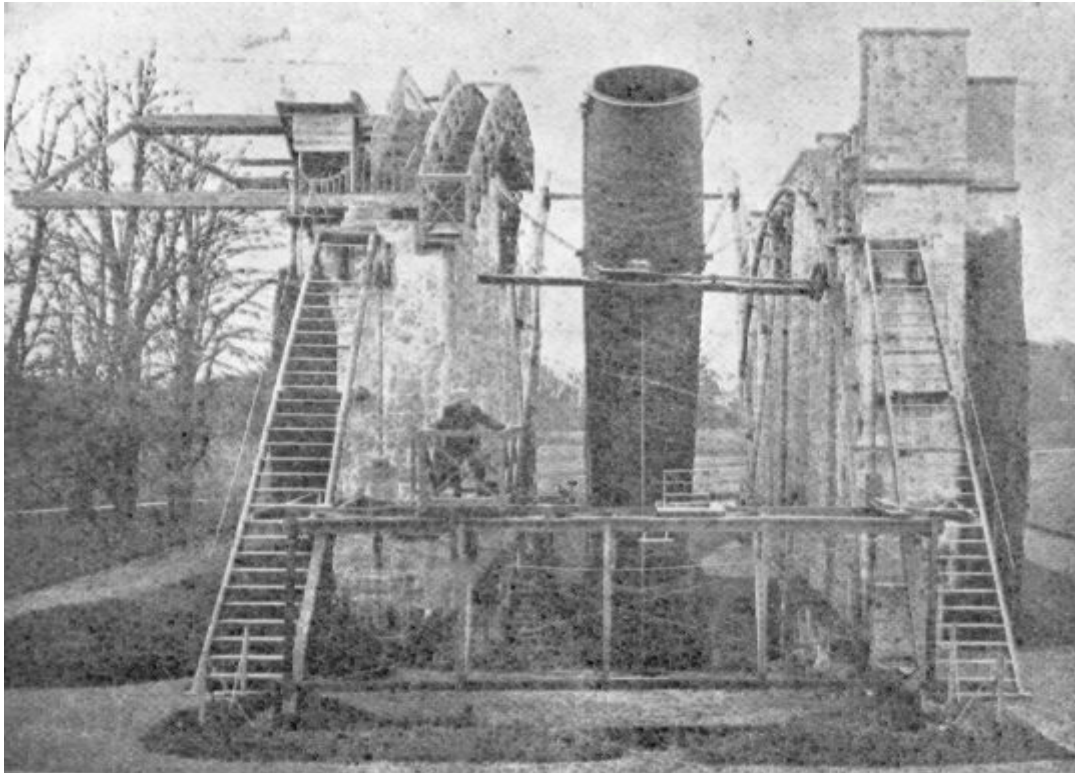
Parabolisch: veranderende kromtestraal
(kegelsnede)



$$y^2 = 4p x$$

Spiegelkijkers

Ondersteuning aan de onderkant is mogelijk!

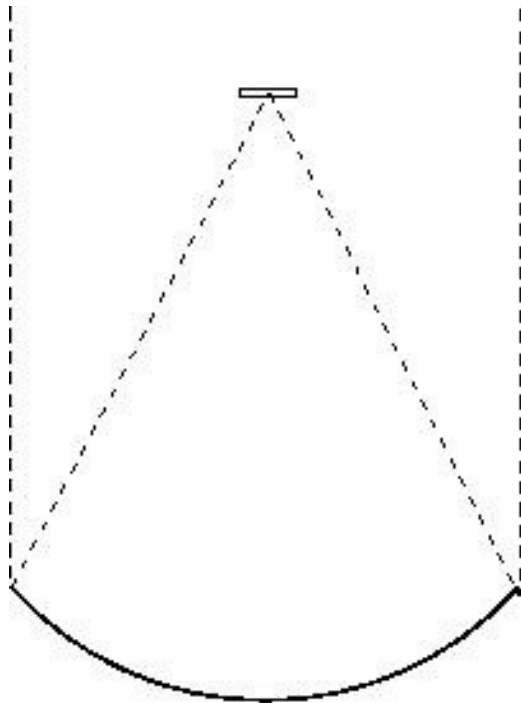


Lord Rosse's Leviathan:

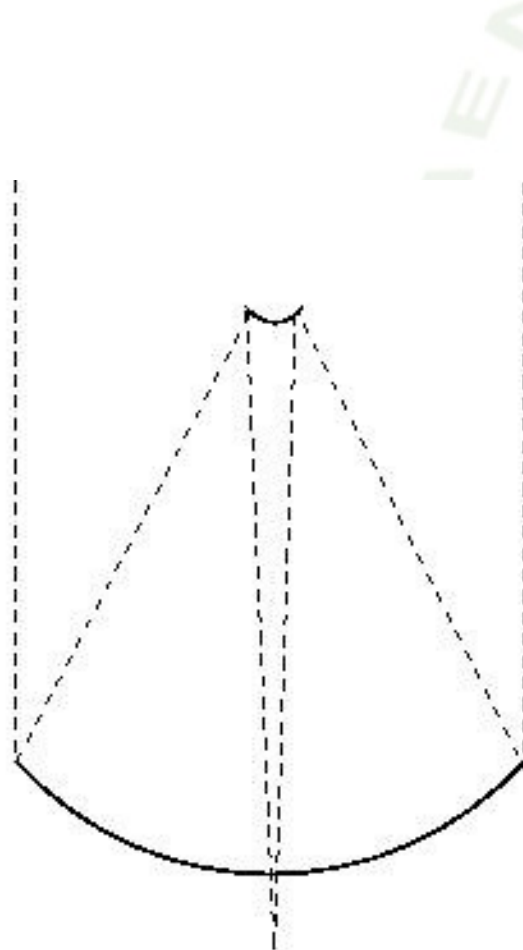
1.8 meter spiegeldiameter,
Voltooid in 1845!

Variofocus

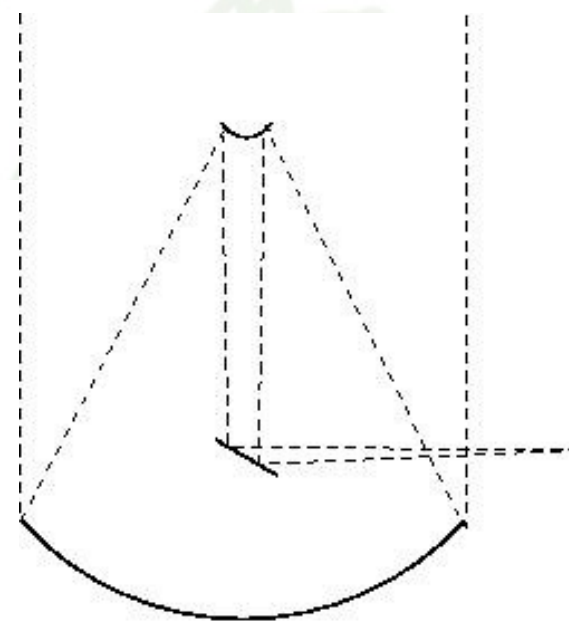
Met spiegels verschillende manieren van focuseren



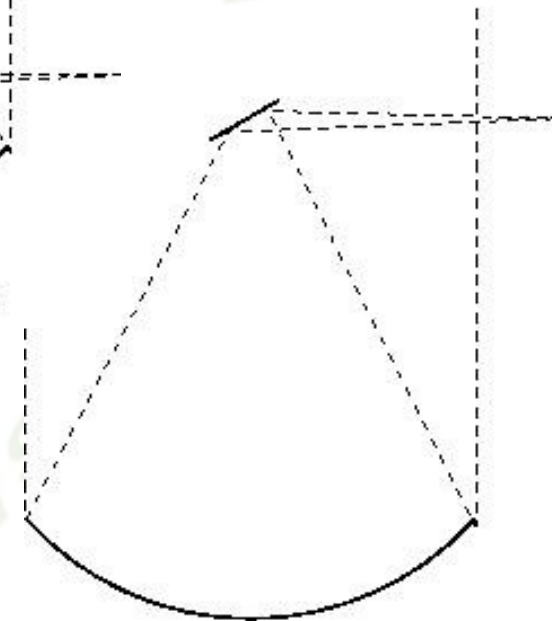
Prime focus



Cassegrain focus

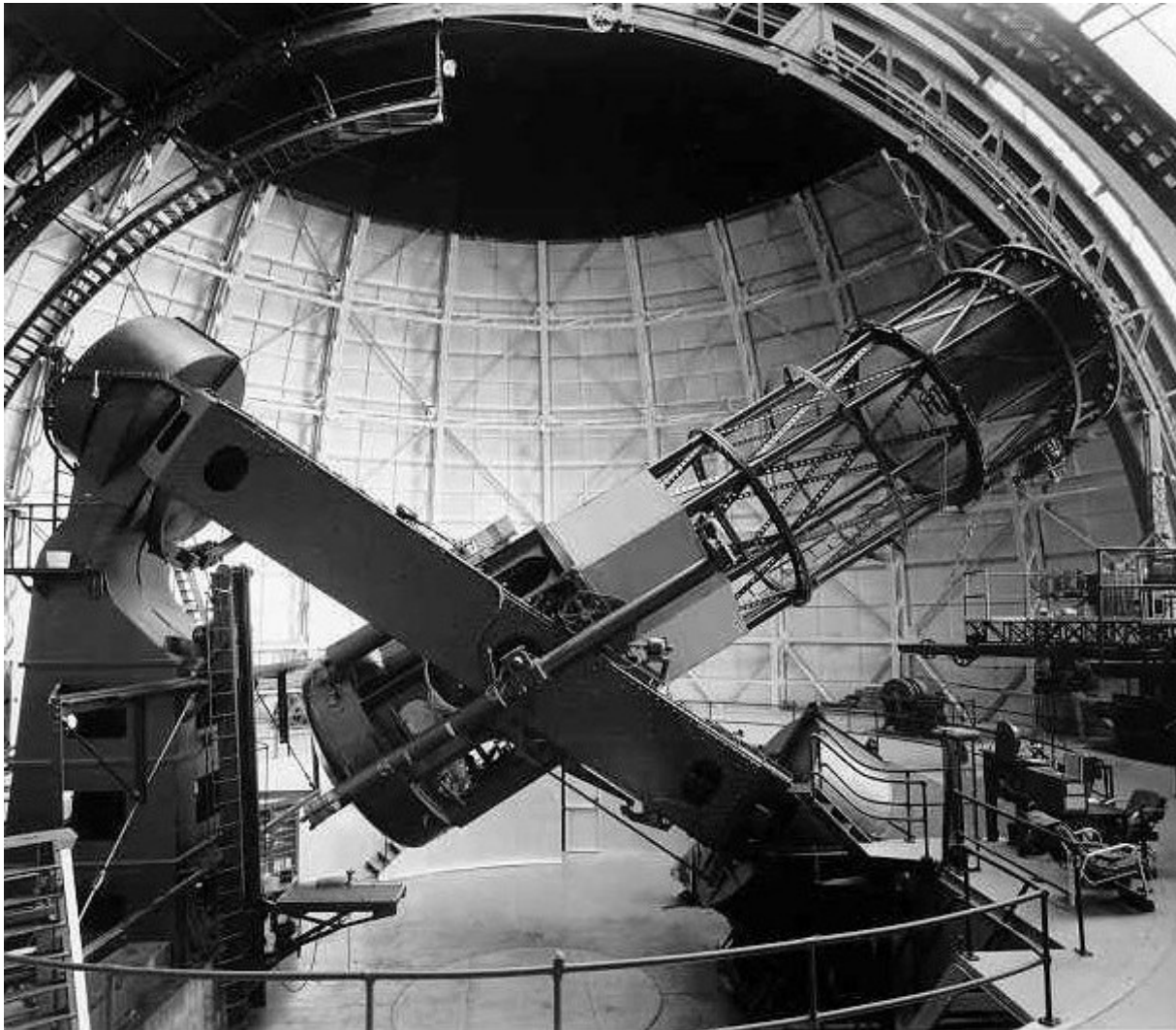


Nasmyth focus



Newton focus

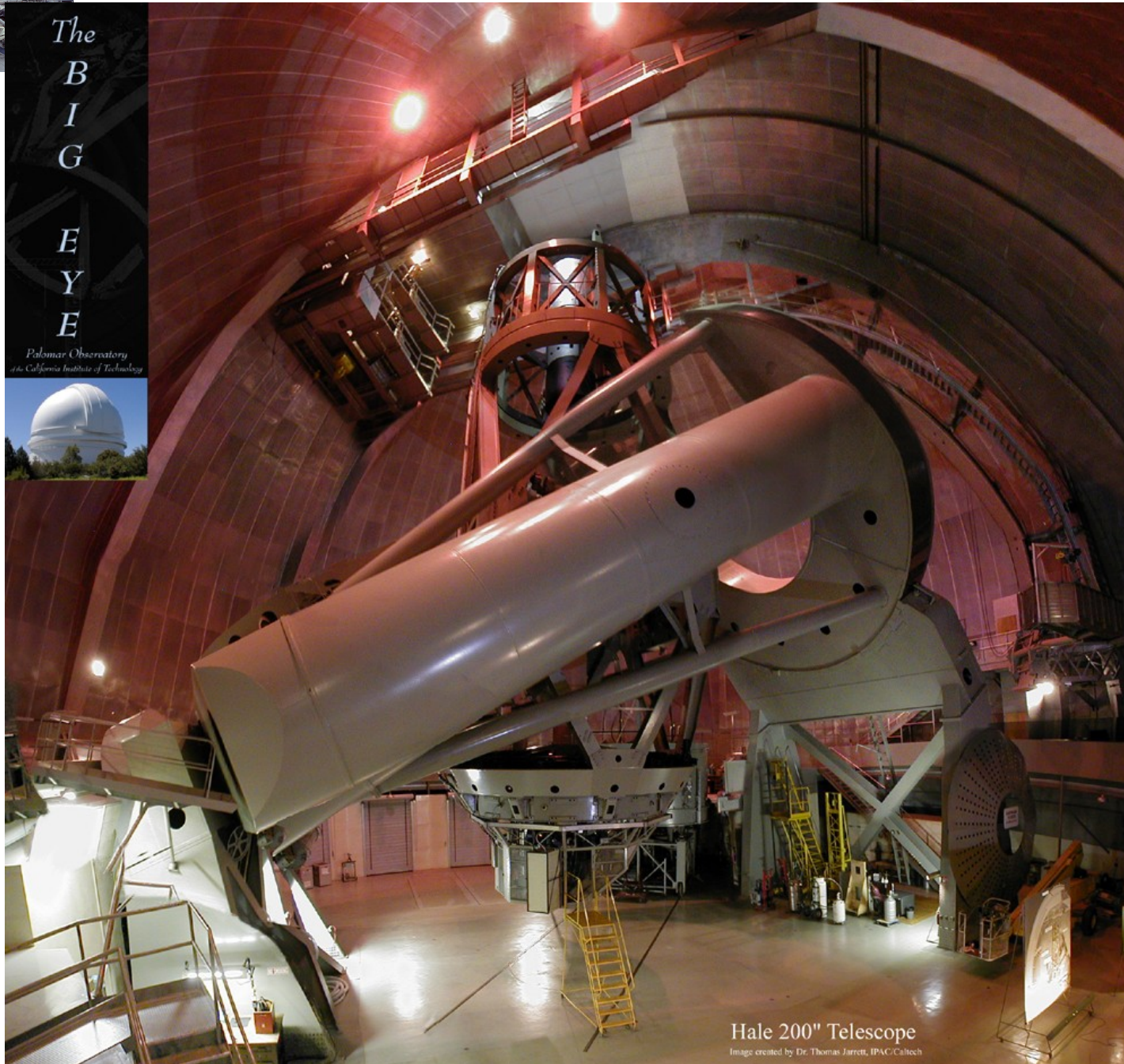
Moderne Spiegelkijkers



2.5 meter
Hooker-telescoop
op Mt. Wilson



Moderne Spiegelkijkers



5-meter
Hale telescoop
op Mt. Palomar
In 1949

Ook meteen een
limiet!

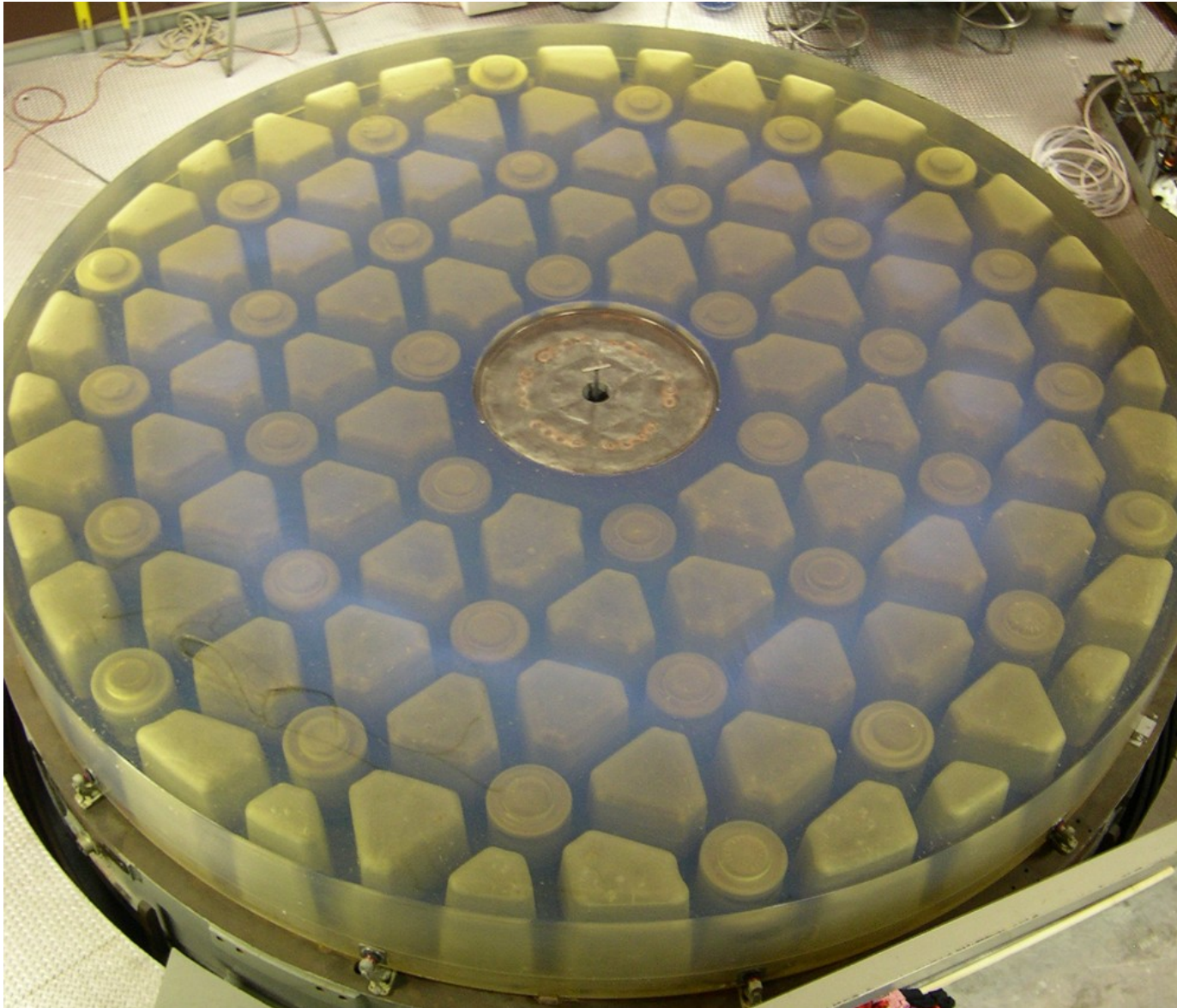
Dikte spiegels

Hale spiegel: 5 meter doorsnede, 14.5 ton



ASTROPHYSICS
WIEGEN

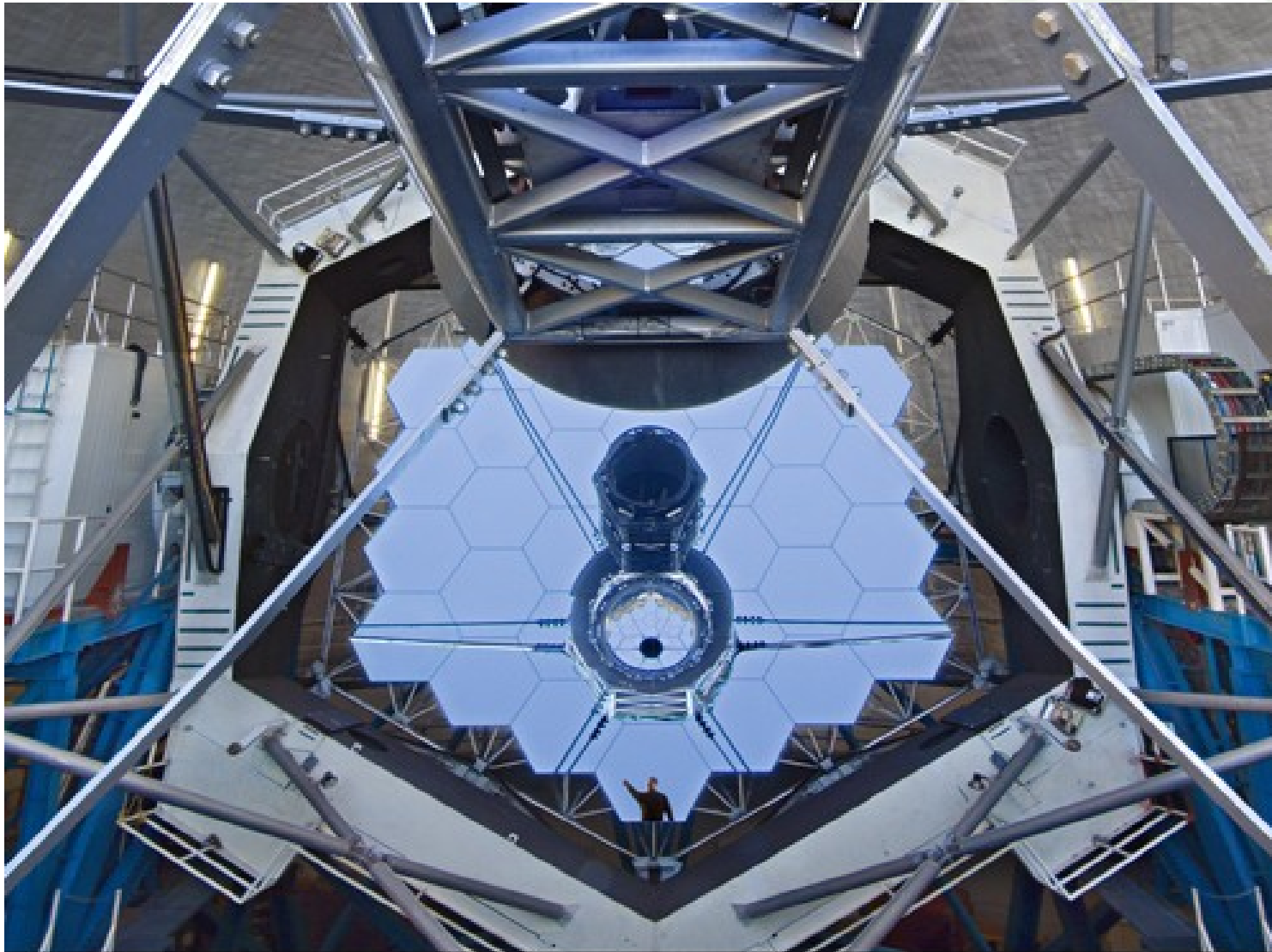
Lichte spiegels: uitgehold



ASTROPHYSICS
NIJMEGEN

UBOUD UNIV

Lichte spiegels: in stukken

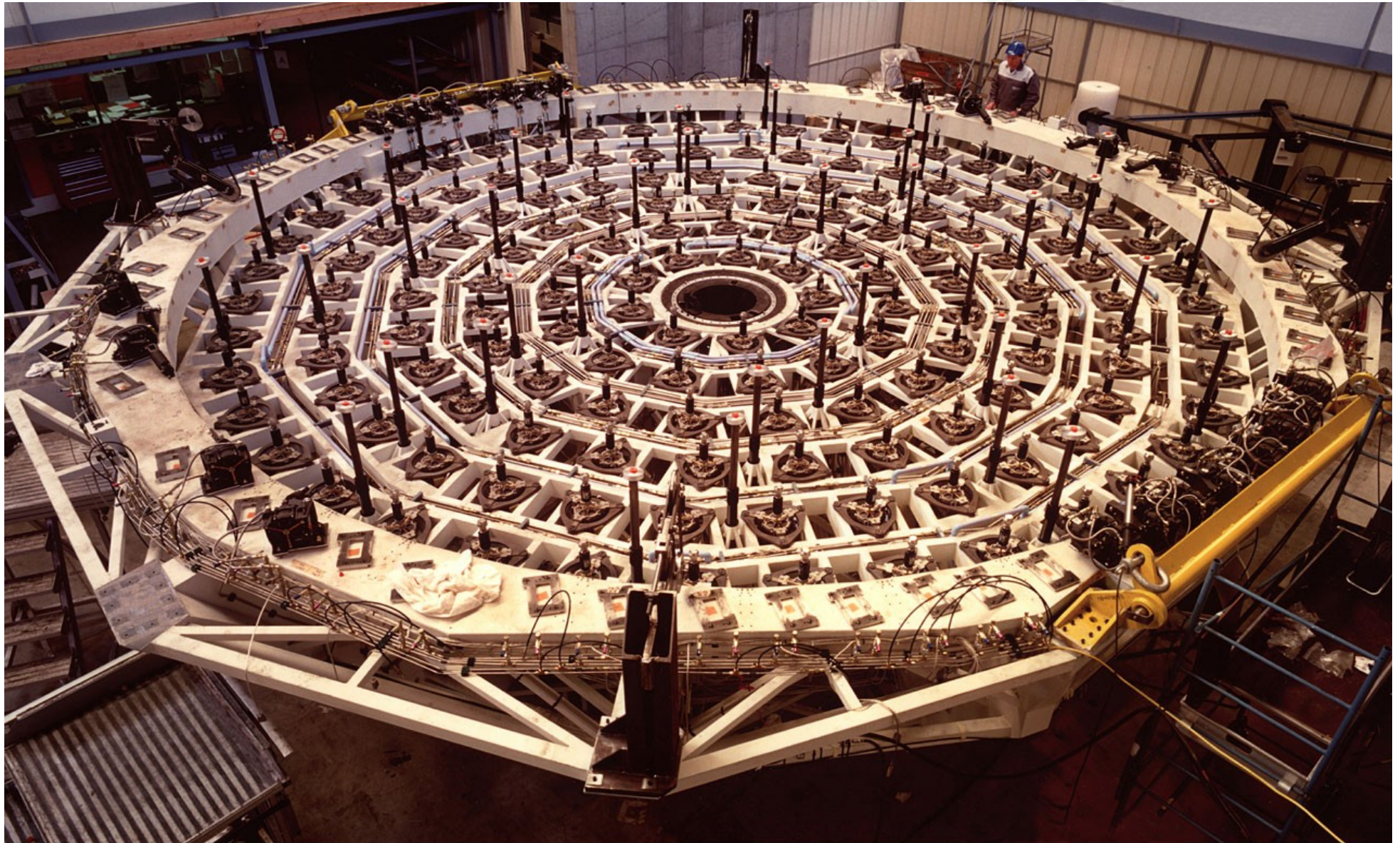


#750h Keck II Mirror 2007 January 29

© 2007 LaurieHatch.com / all rights reserved / photo credit requested / email: lh@lauriehatch.com
The Keck II 10-meter, 36-segment mirror is seen from a bird's eye view nearly 30 meters above.



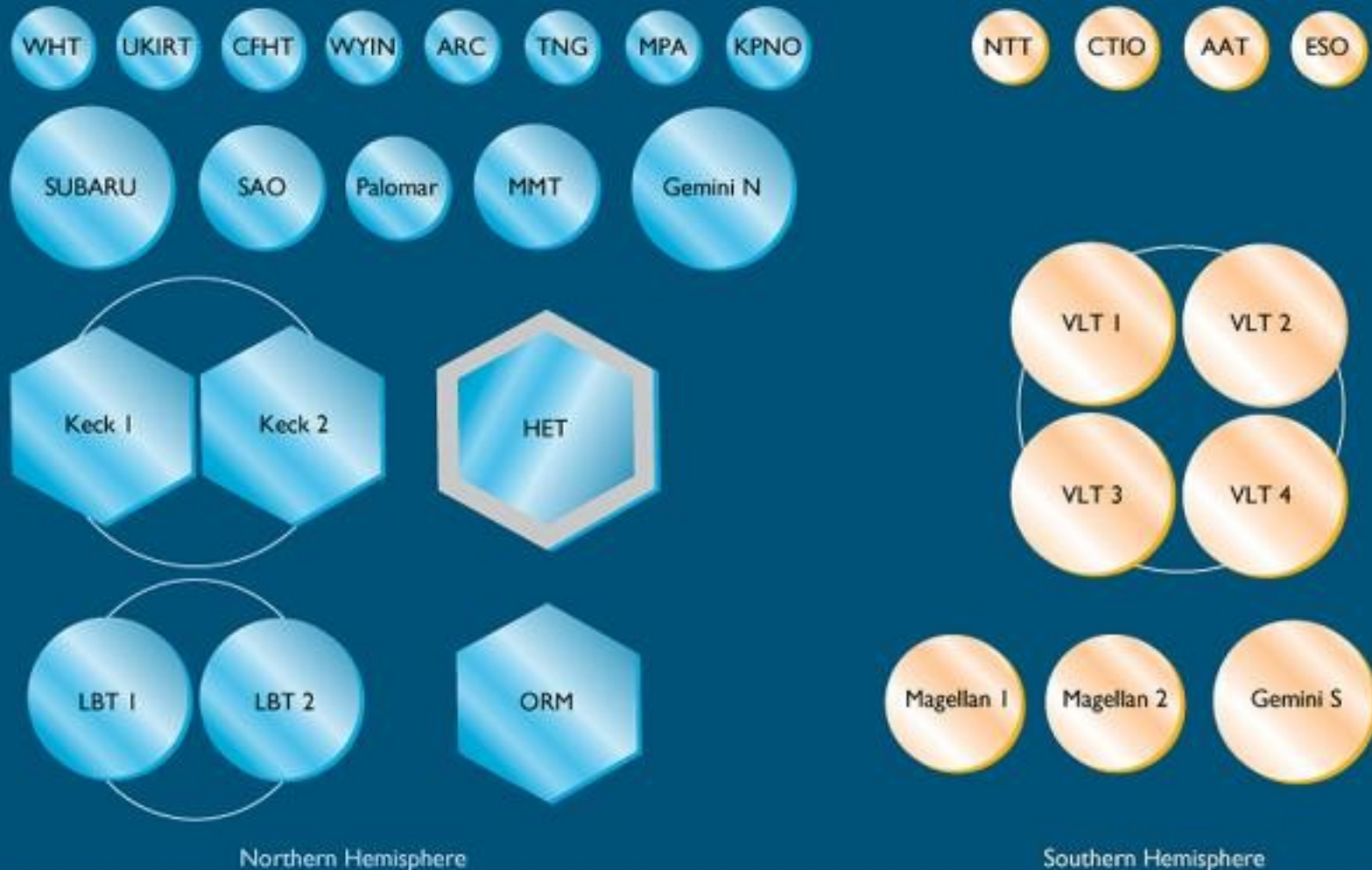
Lichte spiegels: dun, ondersteund



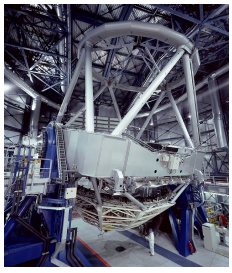
Nieuwe reuzen

Alle drie de oplossingen zijn toegepast!

COLLECTING AREA OF THE LARGE TELESCOPES



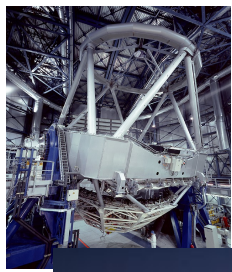
Keck Observatory



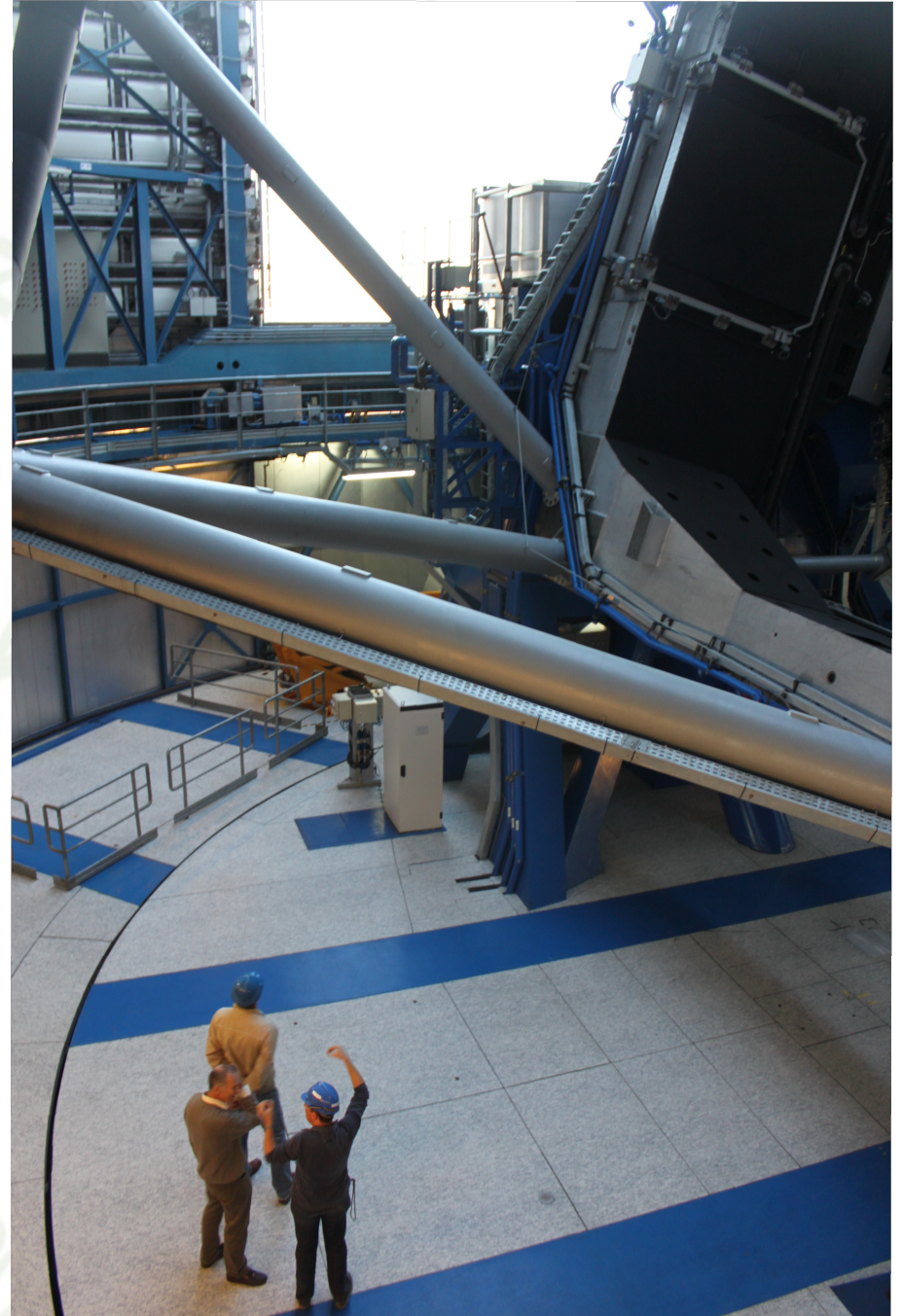
Geminis, Magellans, Subaru



The Very Large Telescope



The Very Large Telescope



The Very Large Telescope

