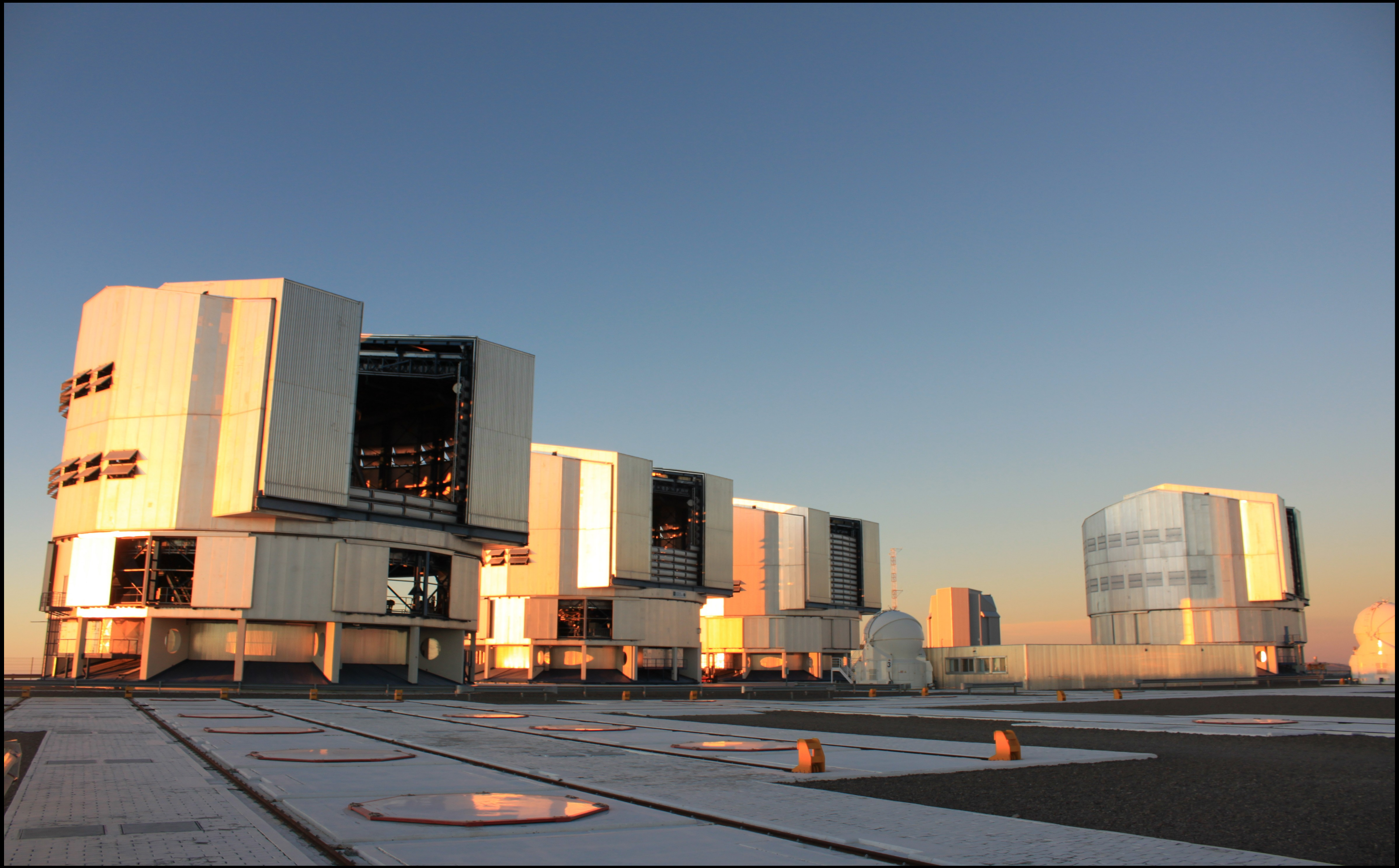
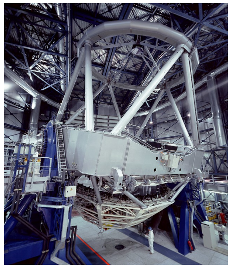
Astronomische Technieken
Hovo Cursus 2010

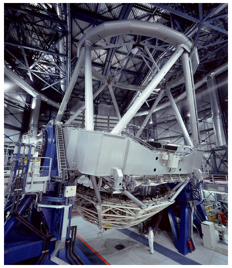


Prof.dr. Paul Groot (RU)
Dr. Gijs Nelemans (RU)

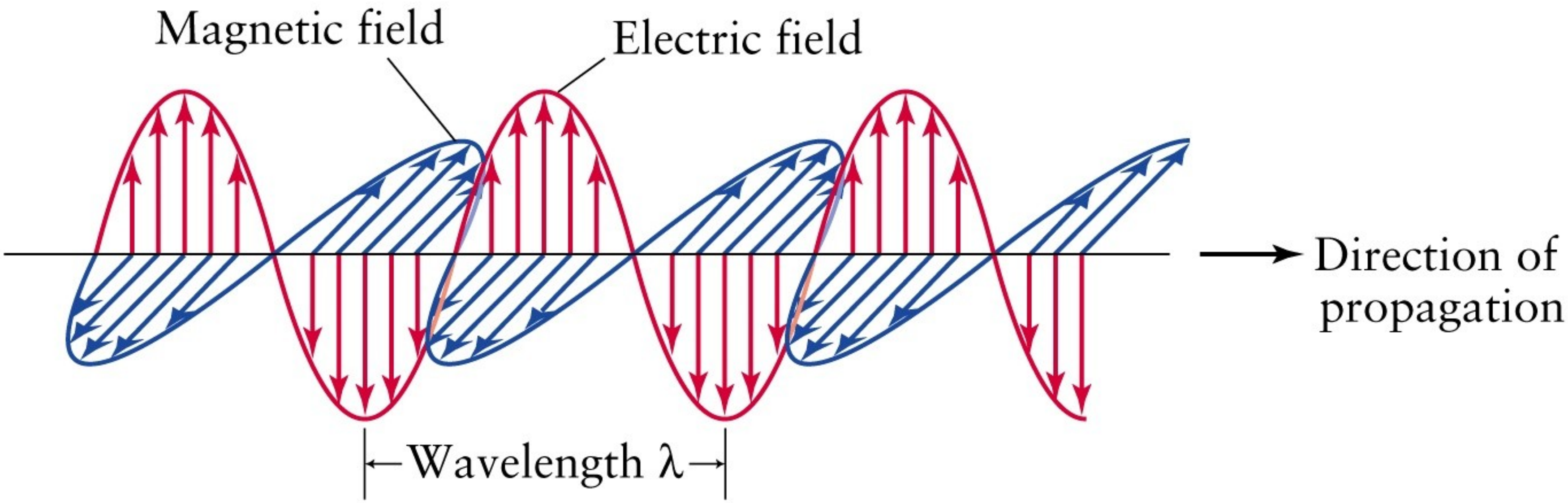


Opbouw van de cursus

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:	- Radiotelescopen - Interferometrie: meer met minder	Paul Groot
26/4:	- Excursie naar sterrenwacht RU - Instrumentontwikkeling Afdeling Sterrenkunde	Beiden
3/5:	- Fotonen voorbij: neutrino's, gravitatiegolven - Telescopen van de toekomst	Paul Groot

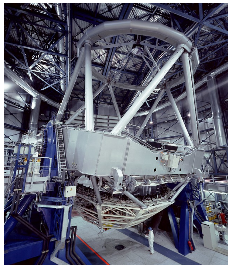


Licht als een golf



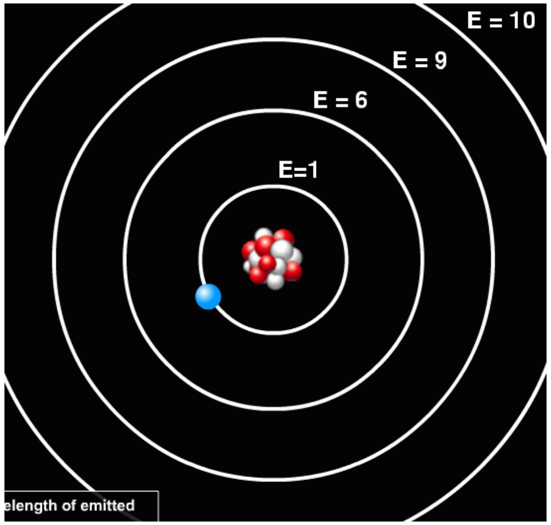
Eigenschappen van een golf:

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

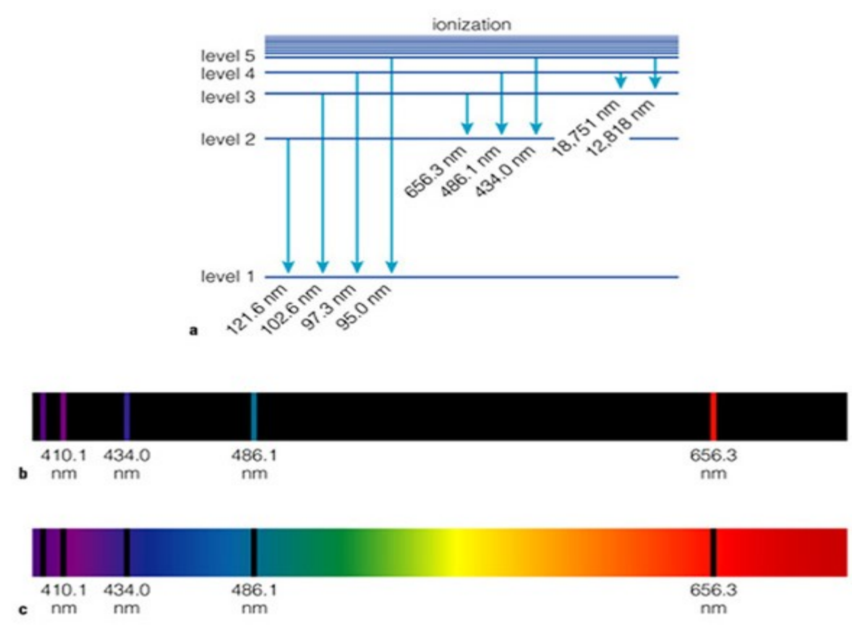


Licht als een deeltje

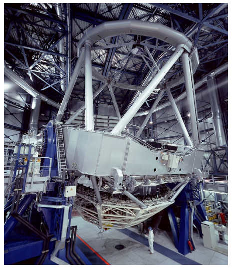
Beide problemen opgeslost als licht een deeltje is *en gekwantiseerd* (in energie) kan worden.



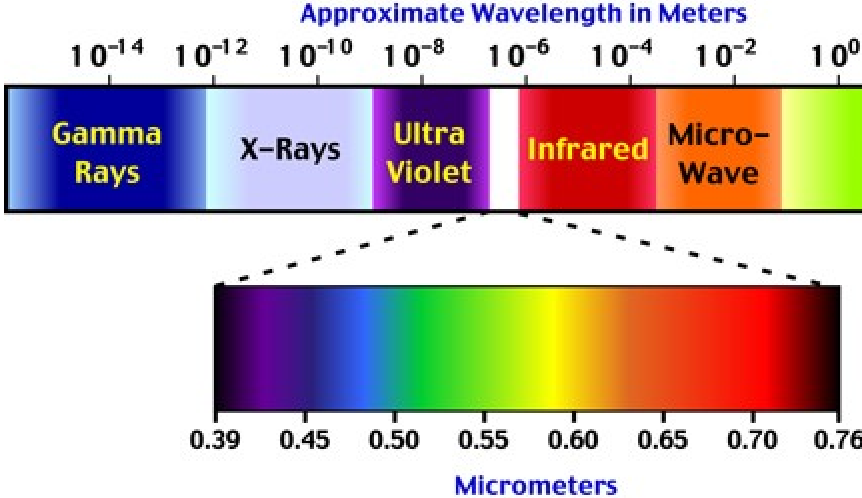
$$E = \frac{hc}{\lambda}$$



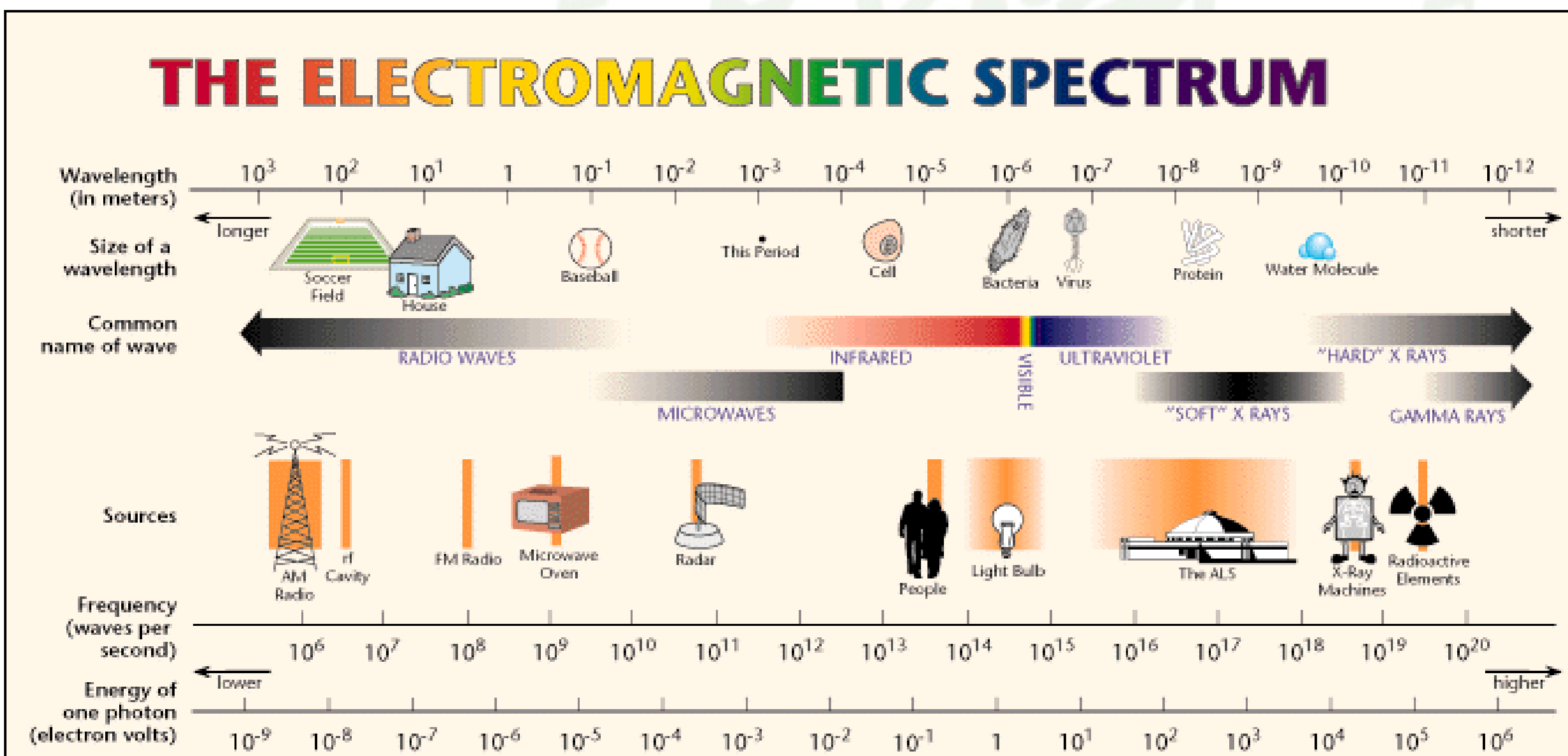
Begin van de astro*fysica*

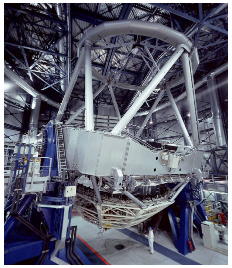


Het electromagnetisch spectrum



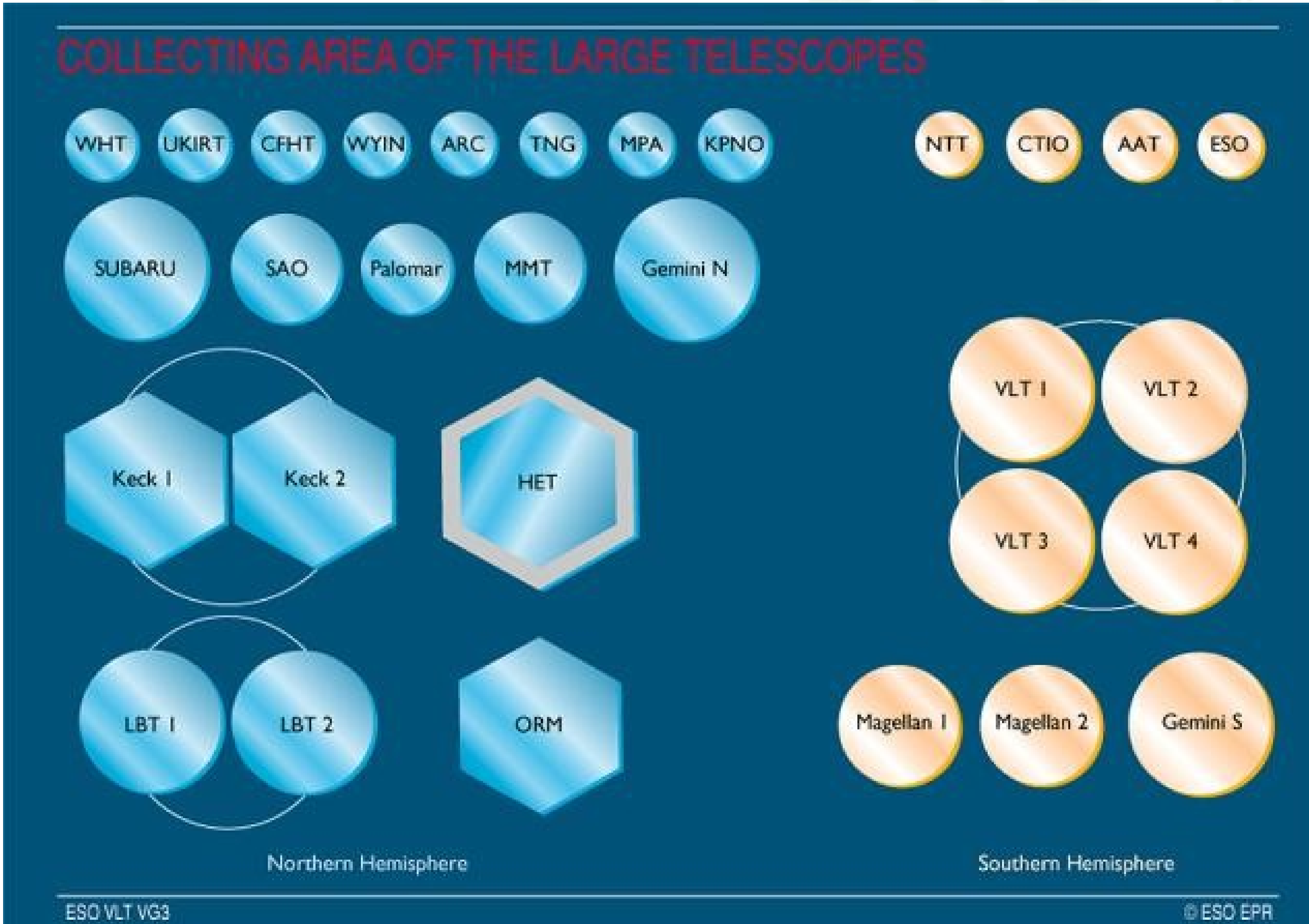
Ordening naar golflengte, frequentie of energie

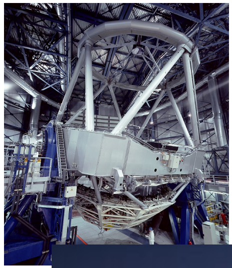




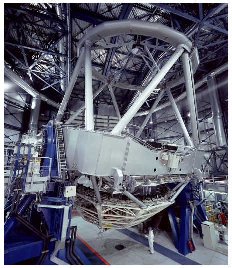
Nieuwe reuzen

Alle drie de oplossingen zijn toegepast!

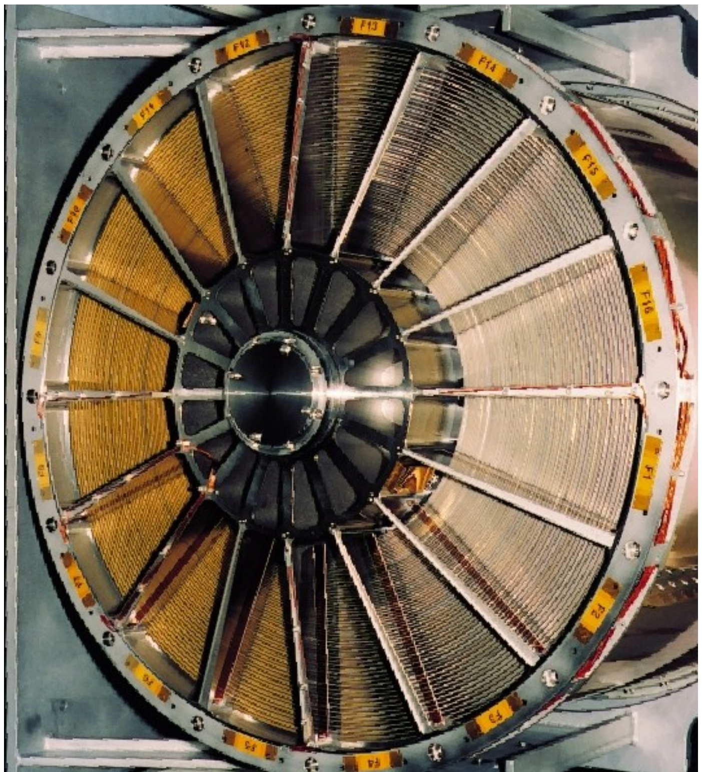




The Very Large Telescope

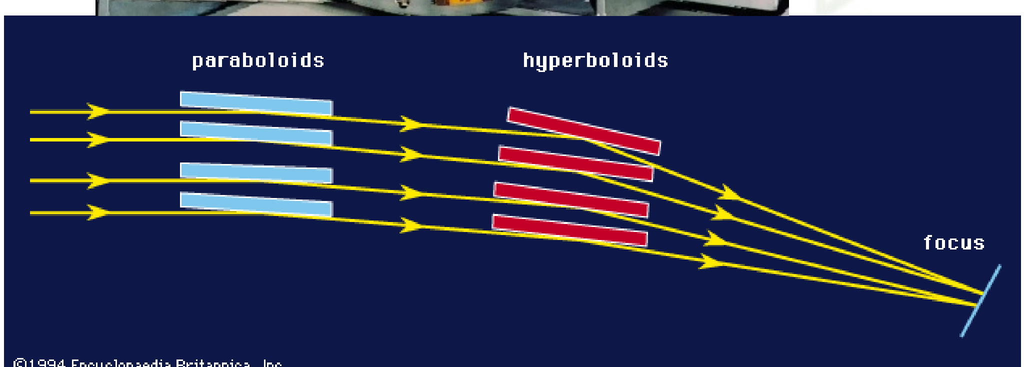


Ander soort telescopen

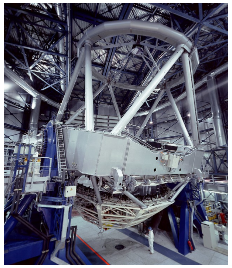


PARKES RADIO TELESCOPE (CSIRO / ATNF)

Radiostraling vang je makkelijk op



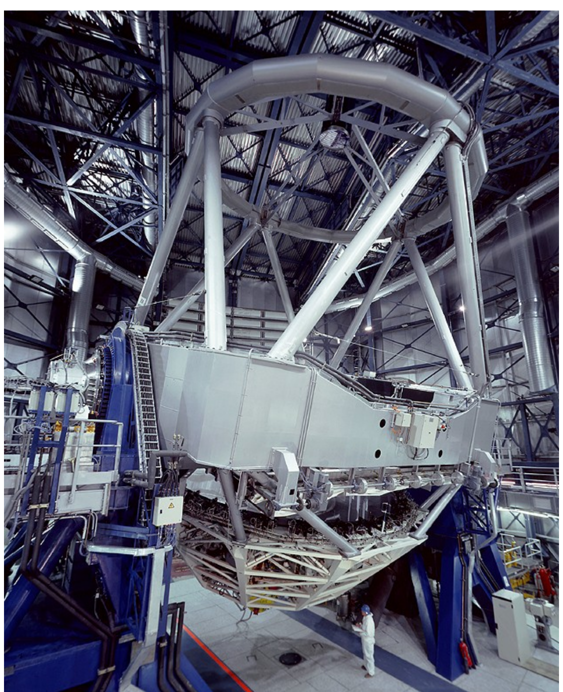
Rontgenstraling gaat door spiegel heen!

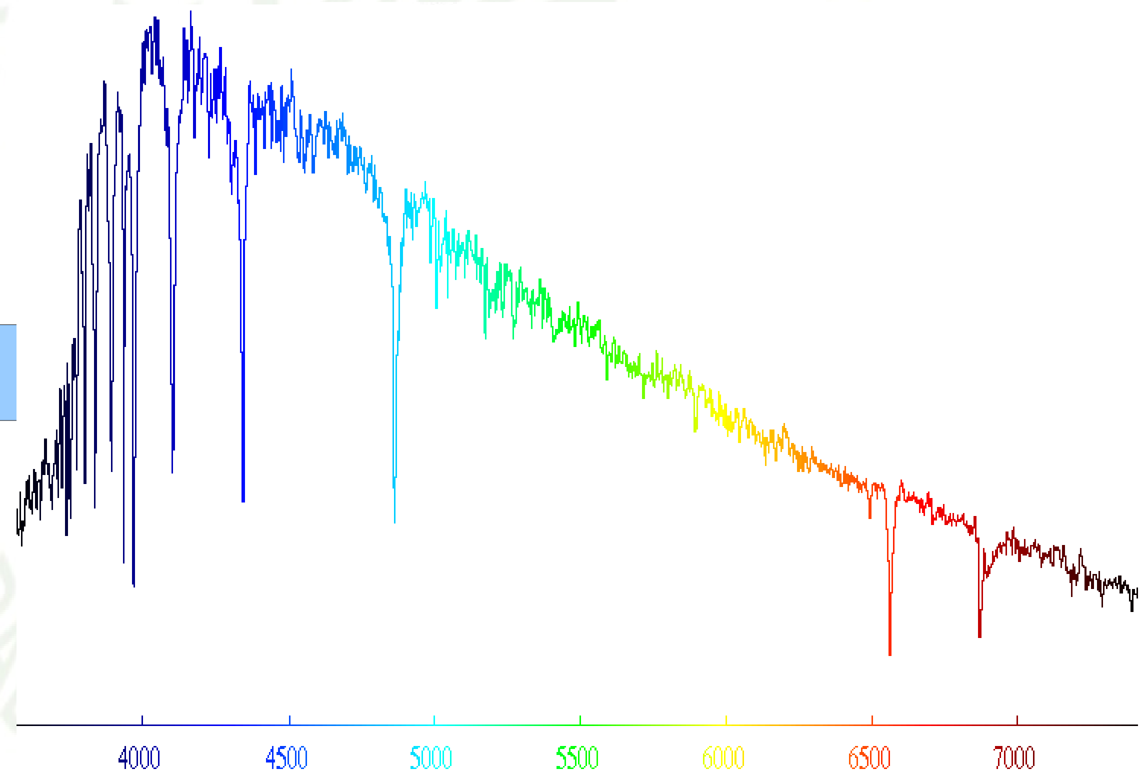


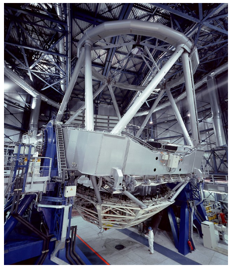
Detectoren

Eigenschappen van EM straling:

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





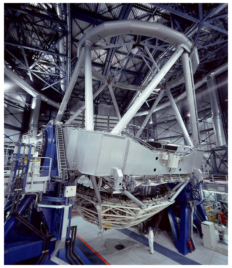


De atmosfeer

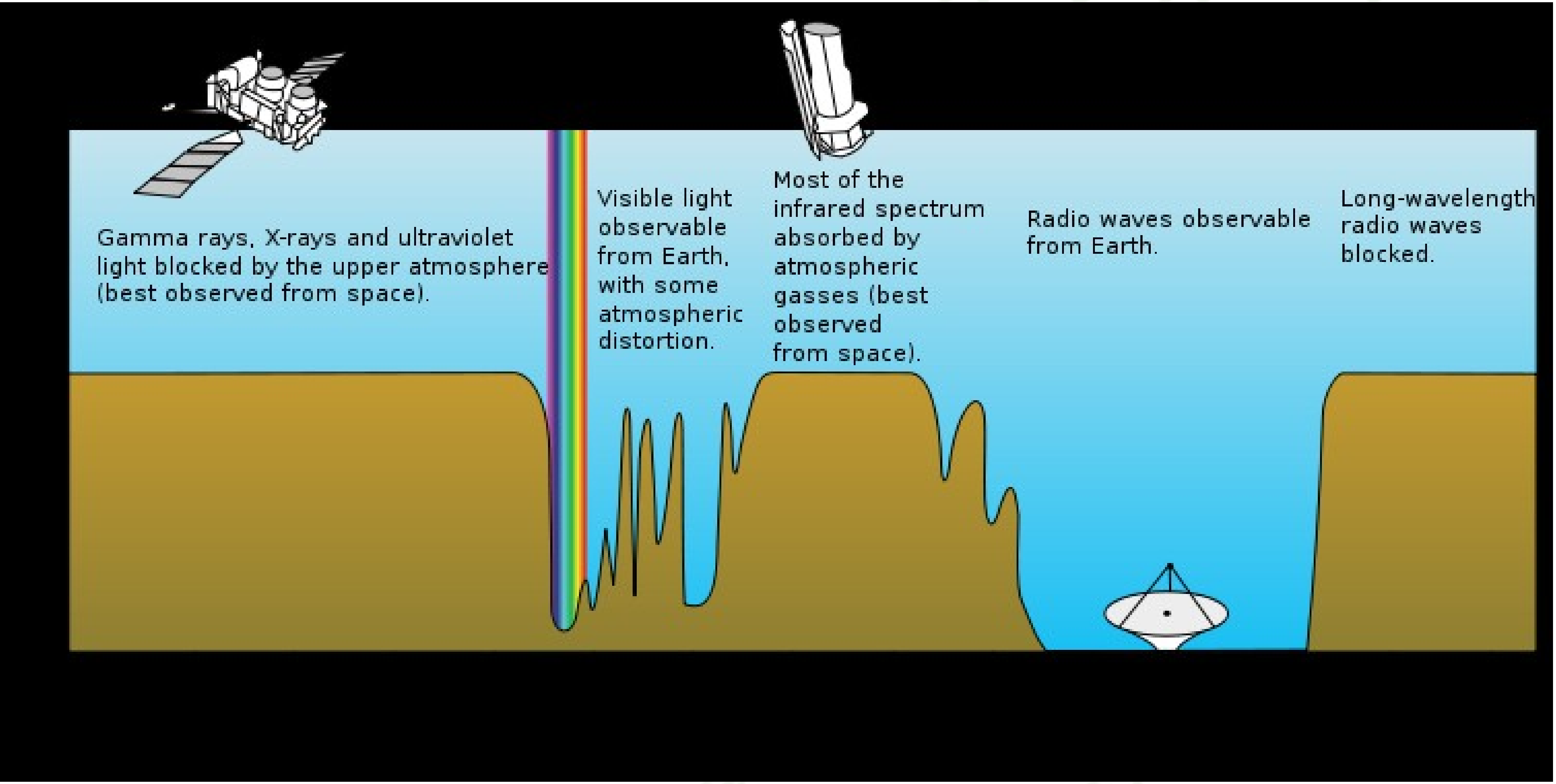
Levensredder en hindernis

Twee effecten:

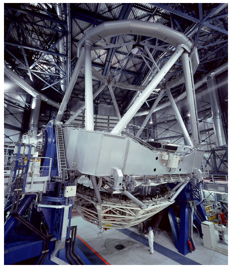
- Absorptie van straling in de atmosfeer
- Vervorming van beelden door turbulentie (“seeing”)



Absorptie

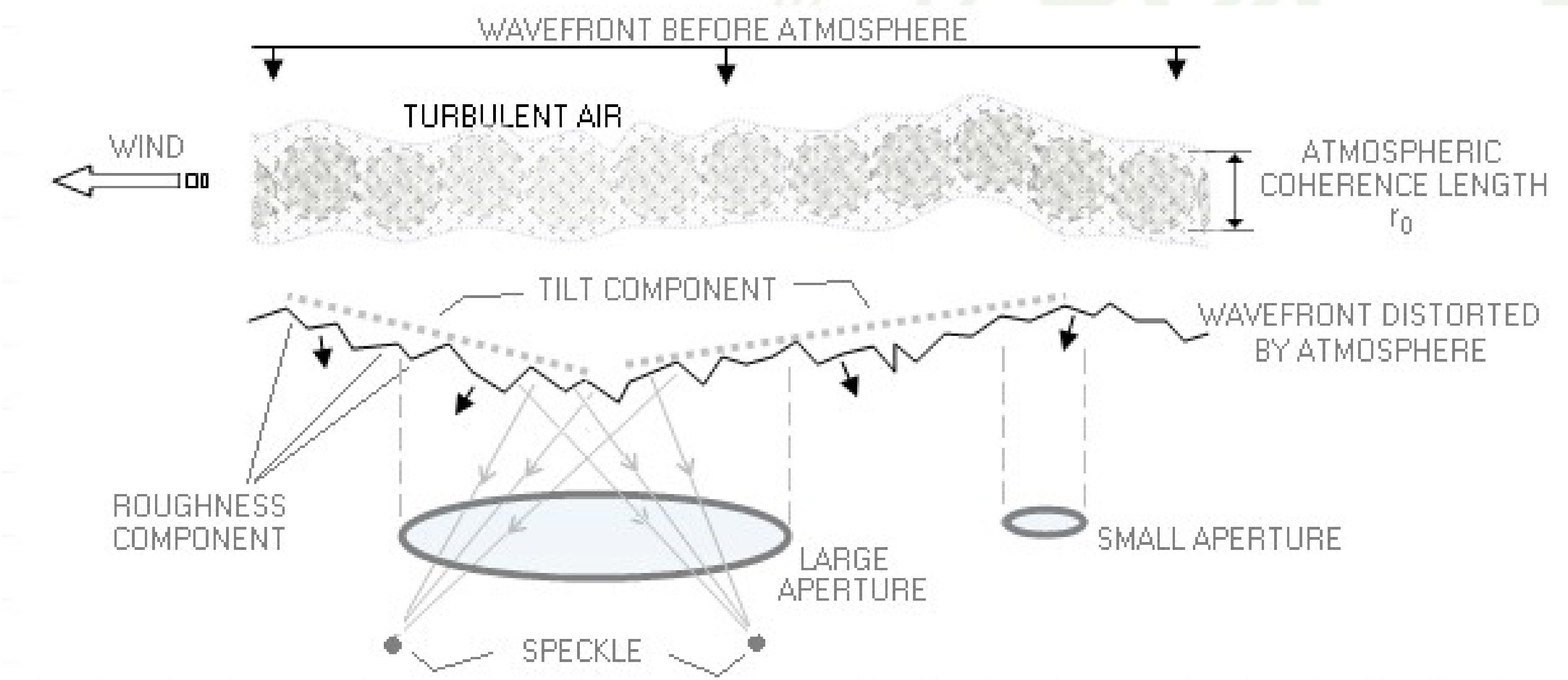


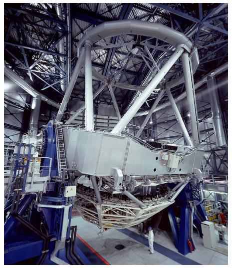
Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.



Turbulentie

Turbulentie in de lucht (door warmte, wind etc.) vervormt golffronten





Turbulentie

Dramatisch effect
op beeldkwaliteit!

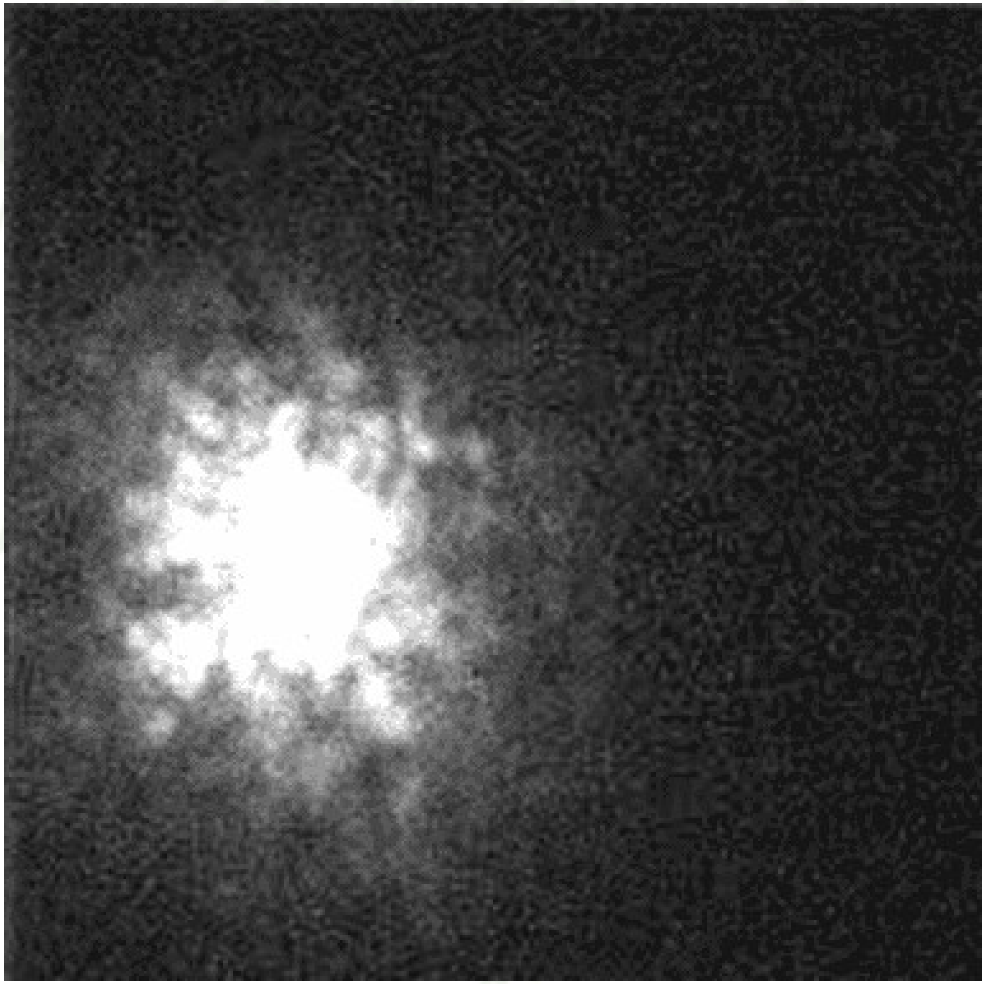
Scheidend vermogen
telescoop:

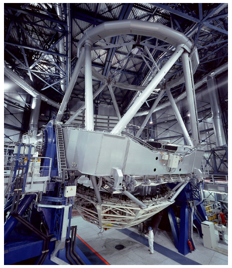
λ/D

Bijv William Hershel
Telescope (4.2m) op
420 nm:

10^{-7} = 0.02”

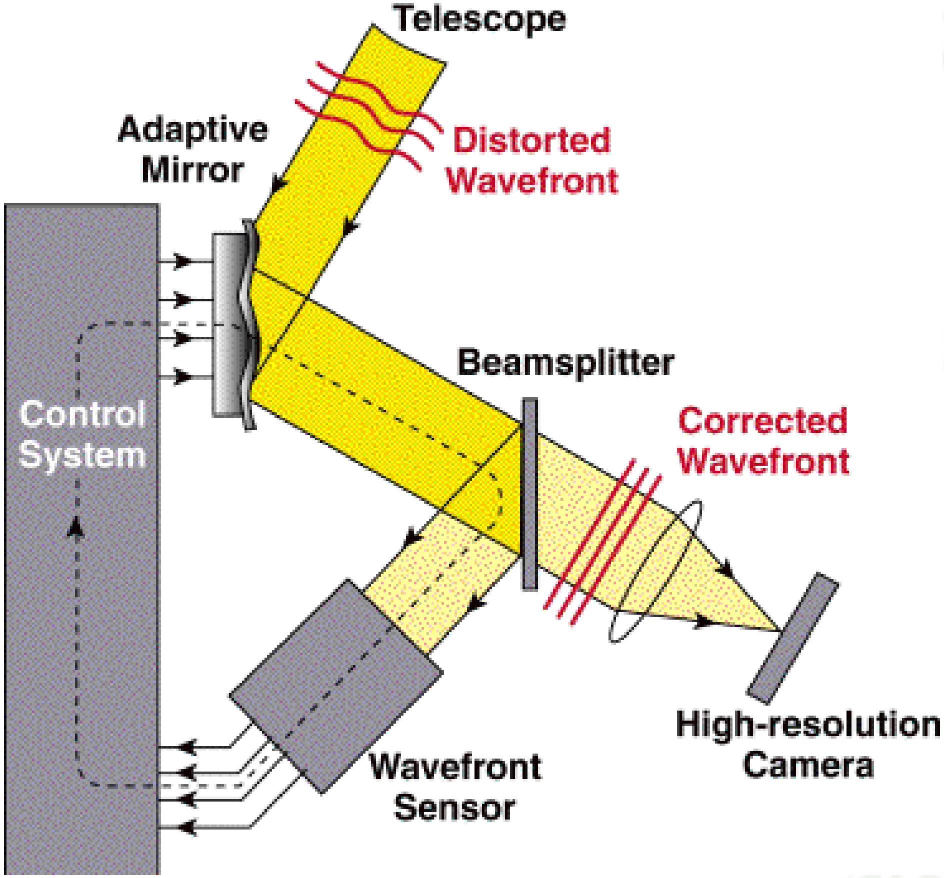
Werkelijk: ~1”

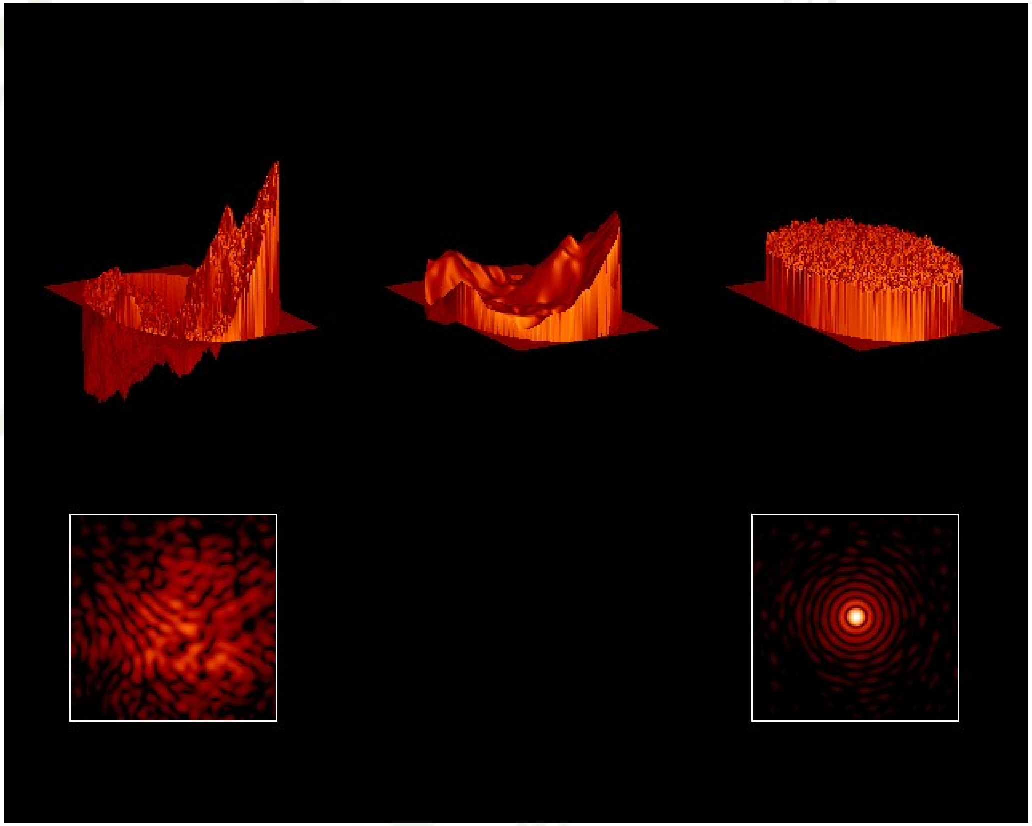


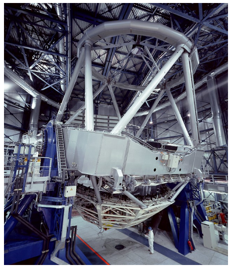


Corrigeren voor de turbulentie: Adaptive optics

Meet vervorming en corrigeer

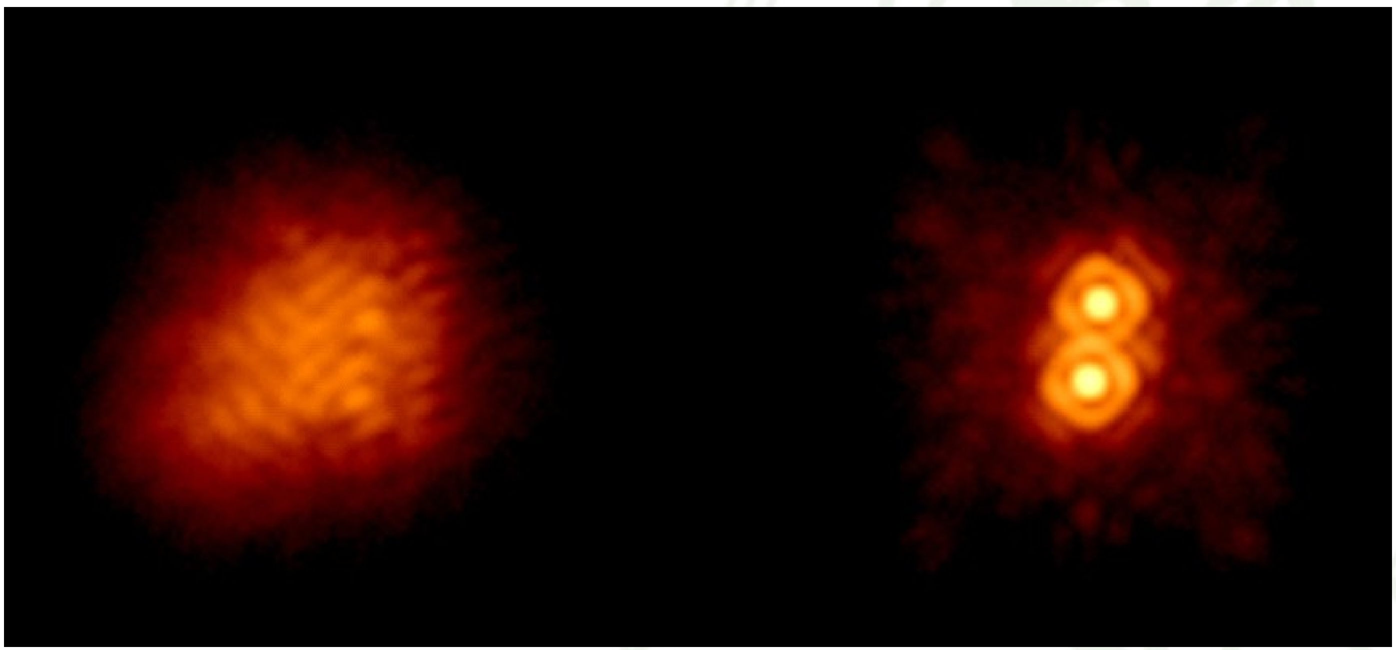




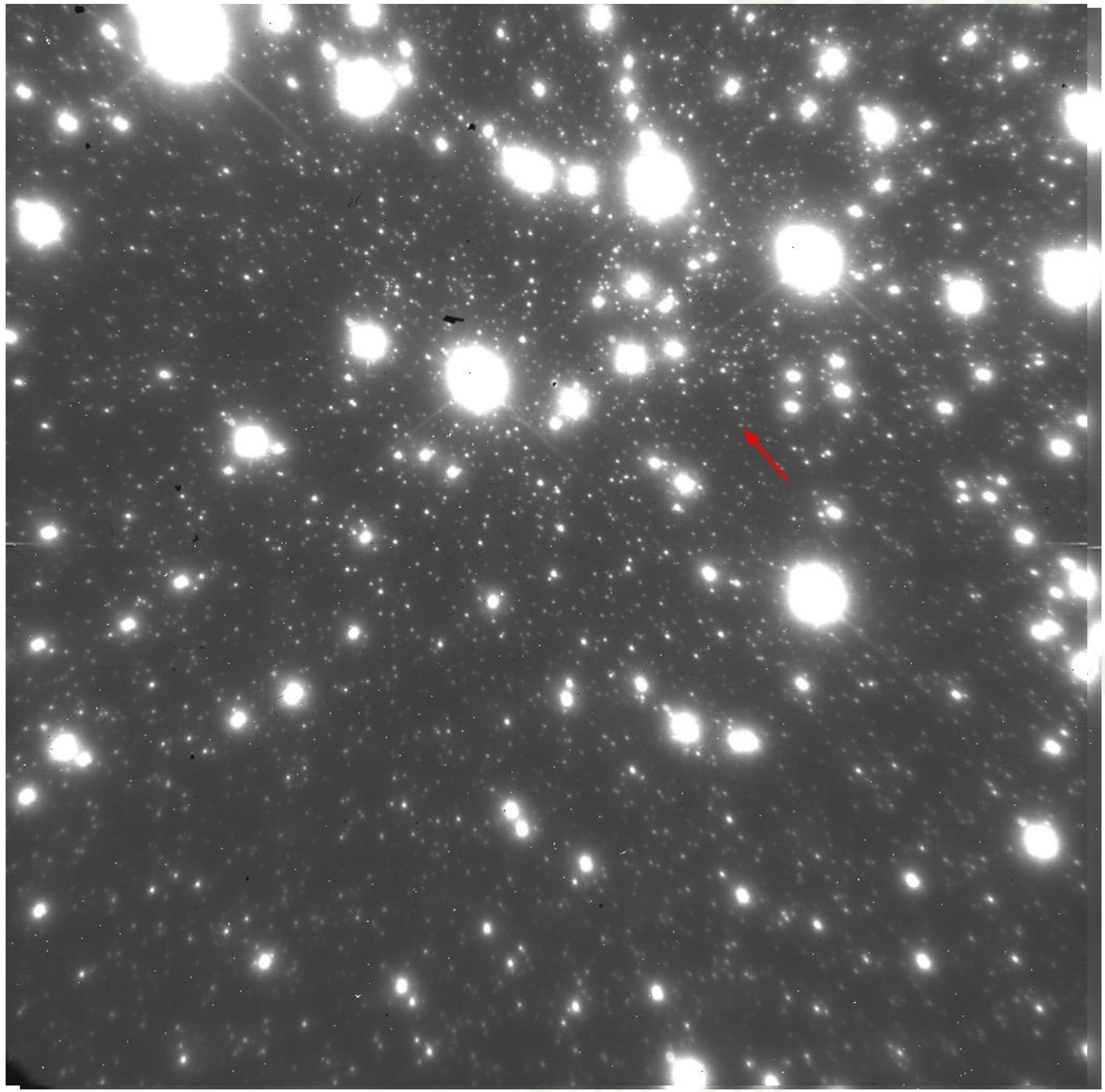


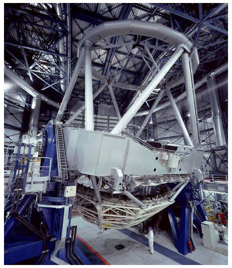
Adaptive optics

Spectaculaire resultaten



VLT + NAOS/Conica

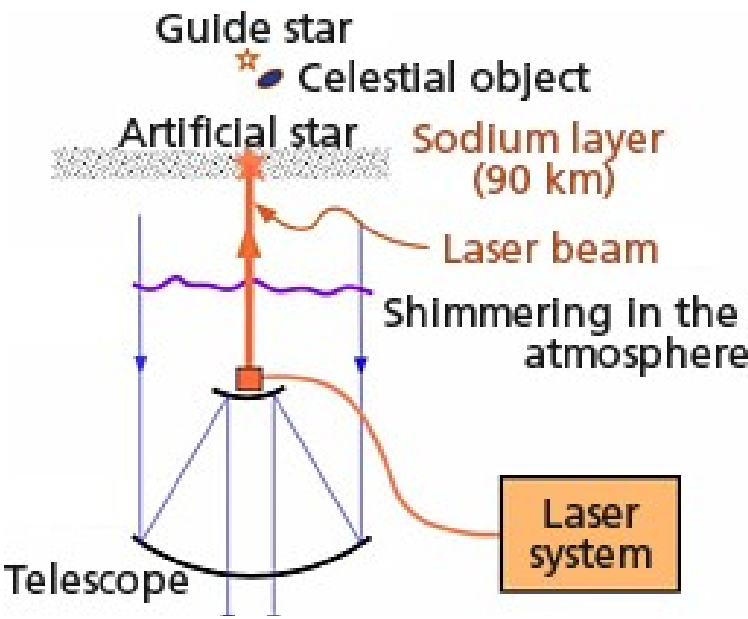


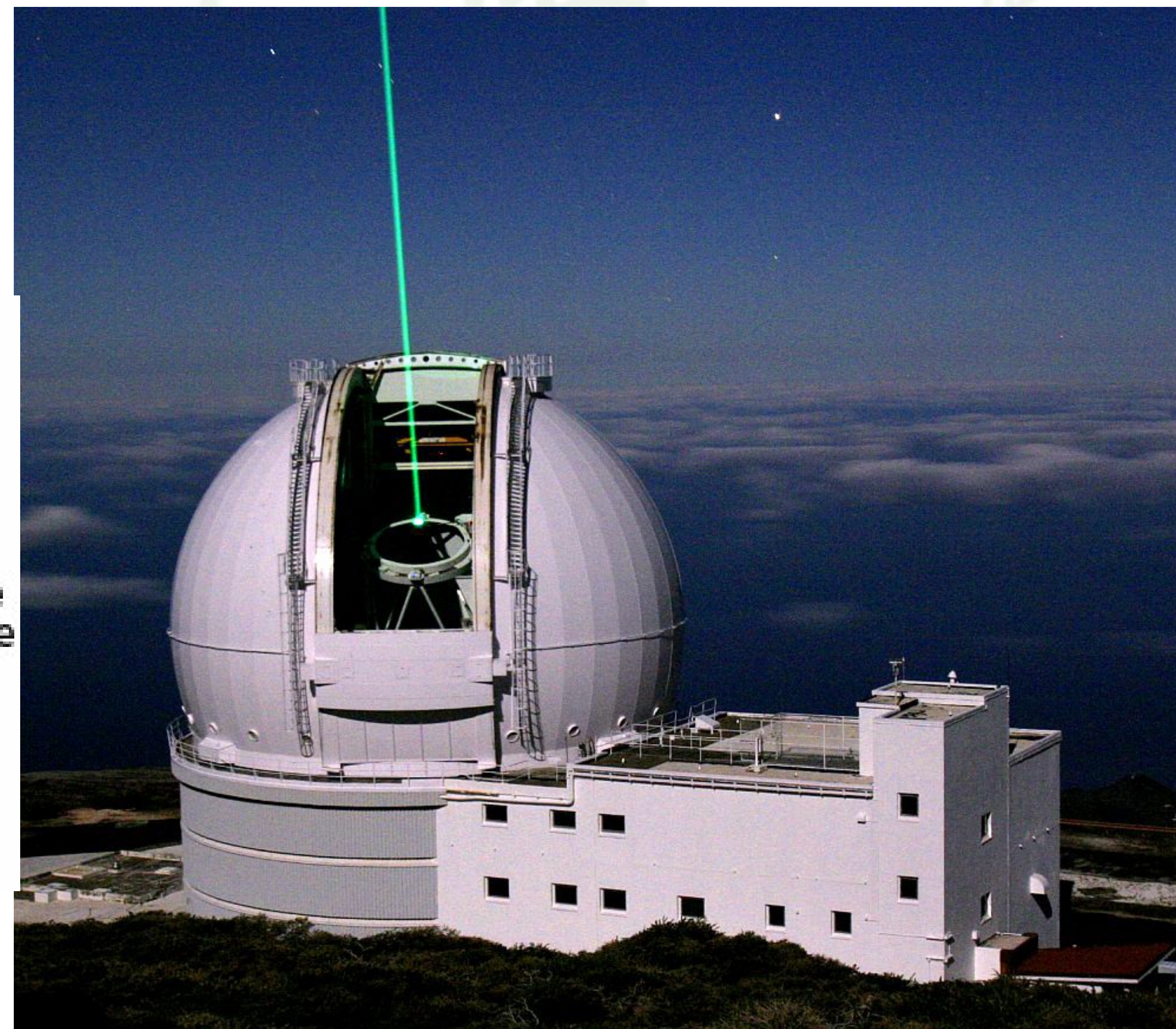


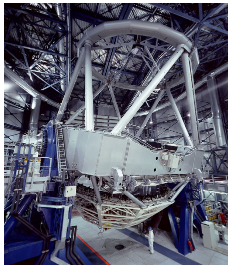
Laser guide star

Voor correctie is een heldere ijkbron nodig

Als er geen ster beschikbaar is: laser!

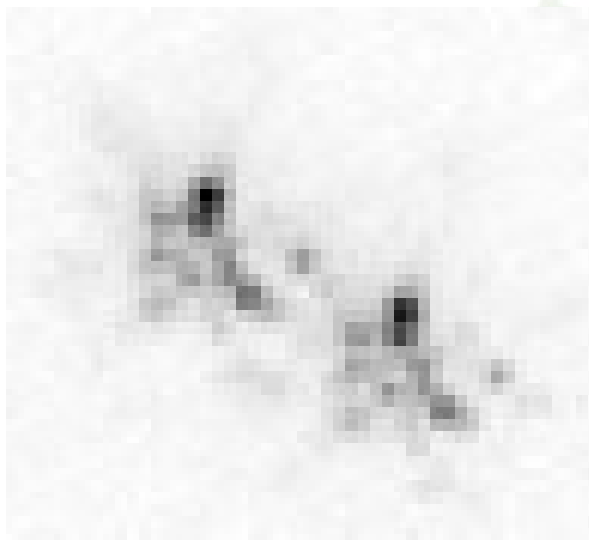






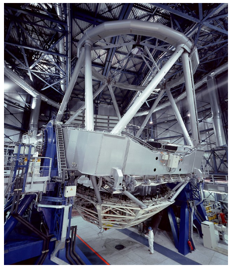
Speckle en Lucky imaging

Alternatieven: neem korte opname en verschuif ze

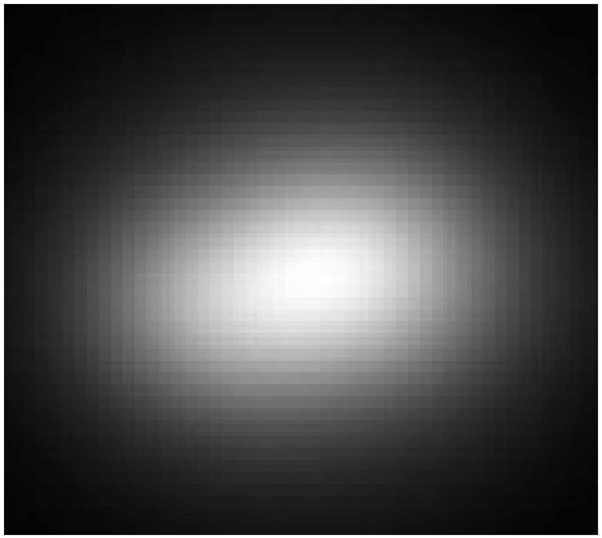


“Speckle imaging”

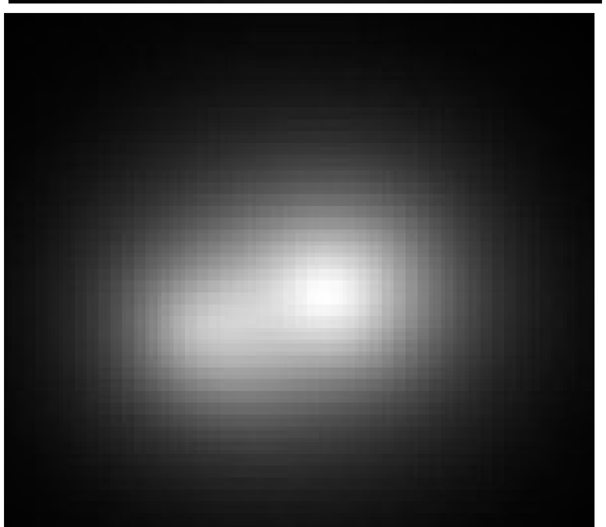
Of nog beter: selecteer alleen de beste plaatjes
“Lucky imaging”



Lucky imaging



50 000 opnamen



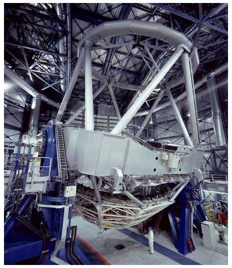
ieder verschoven

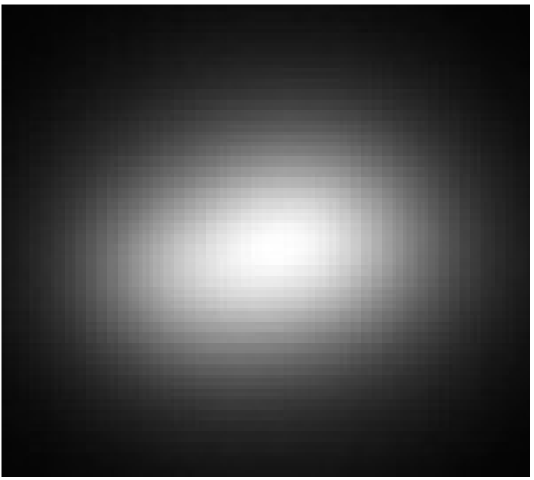
beste 50%

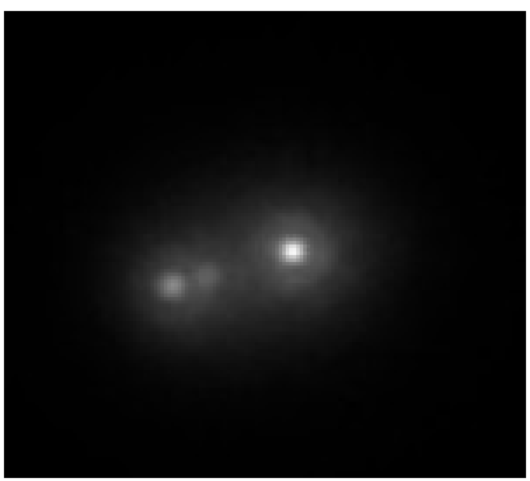
beste 10%

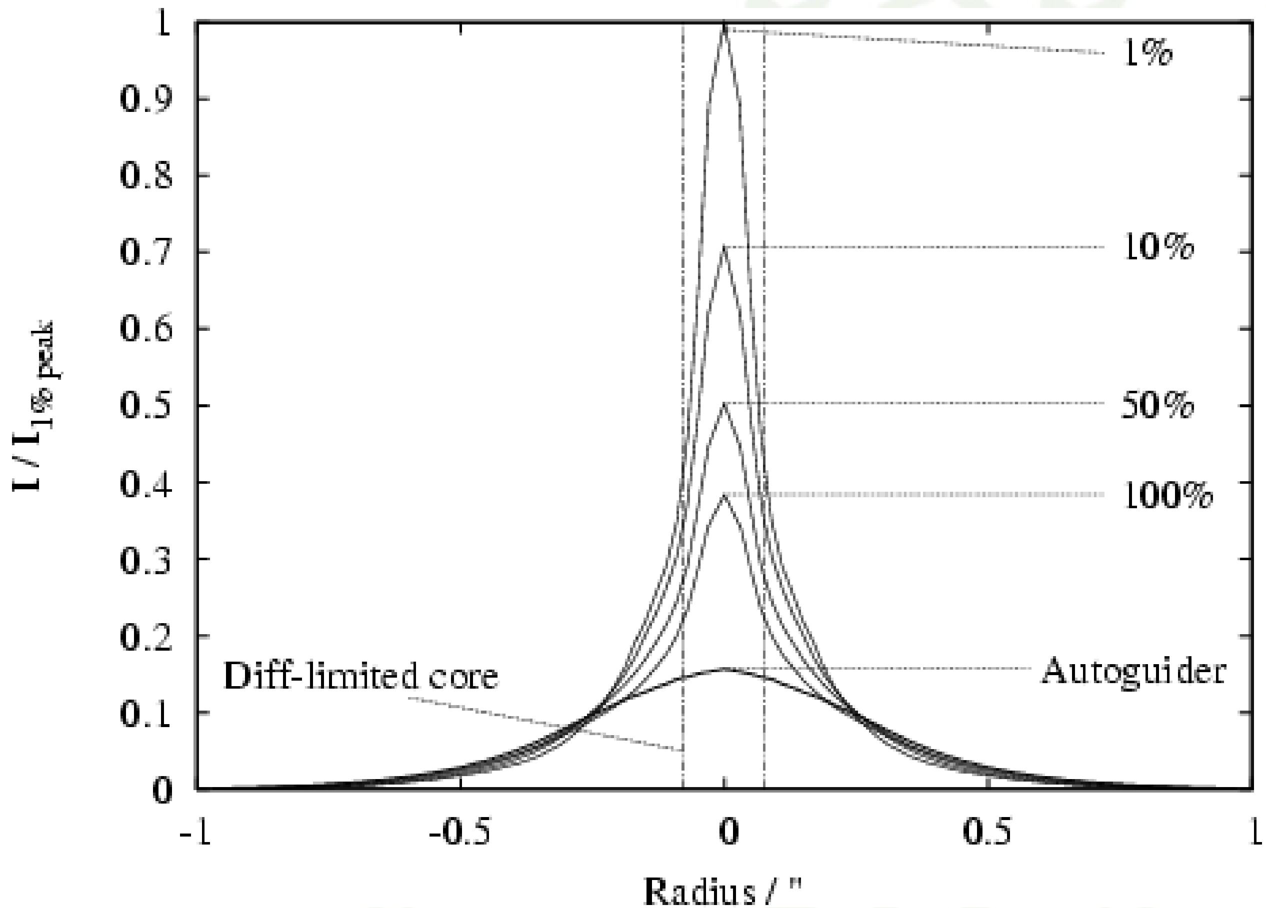
beste 1%

Lucky imaging



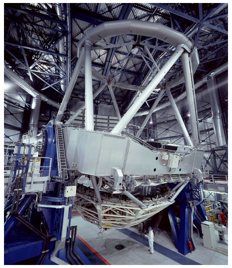






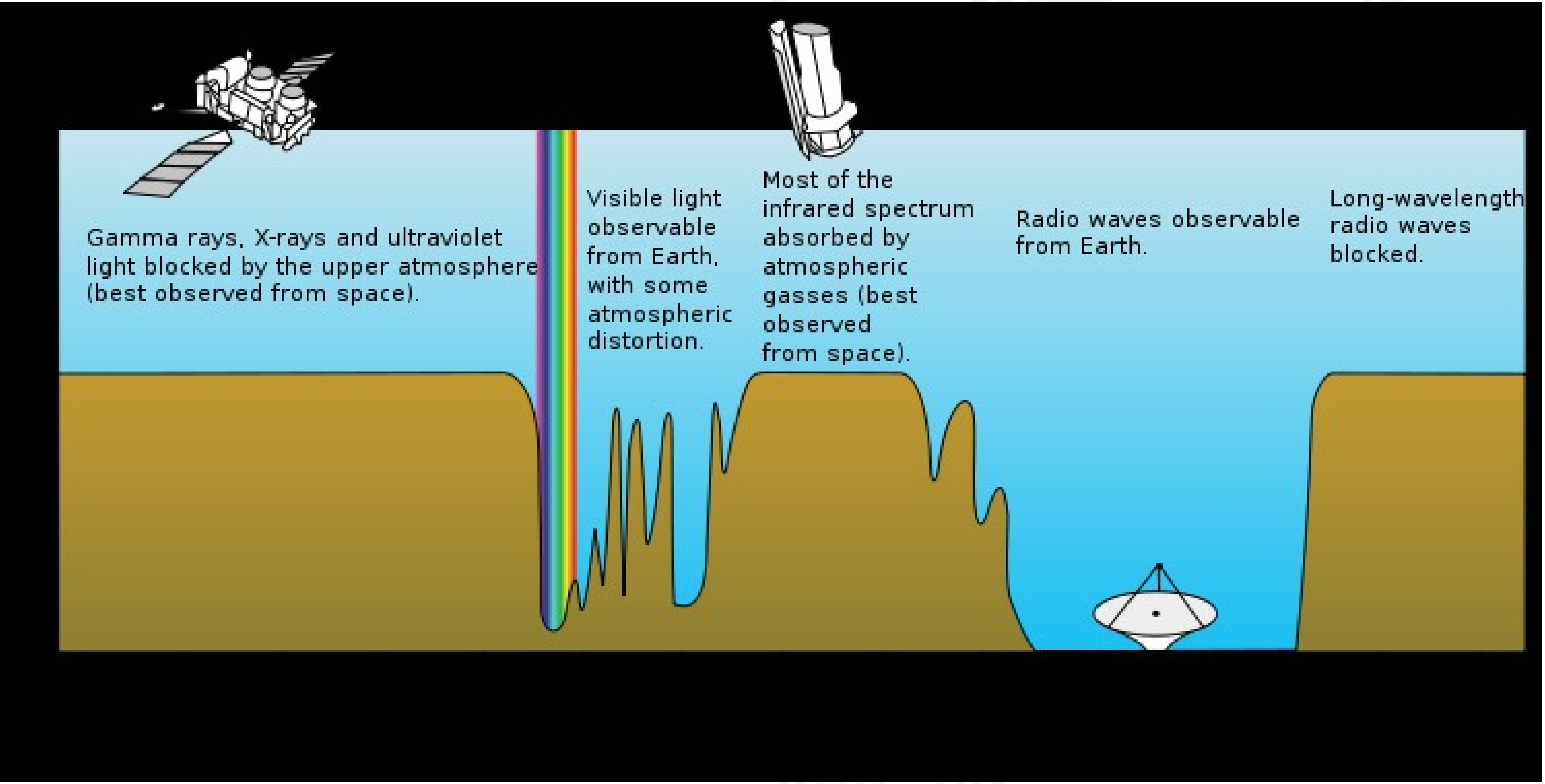
Strehl ratio: I_{narrow}/I_{total}

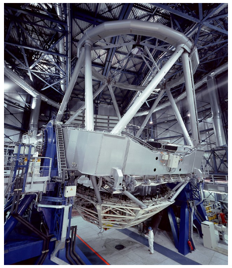
AO: 20-40%$_{l}$



Ruimtevaart

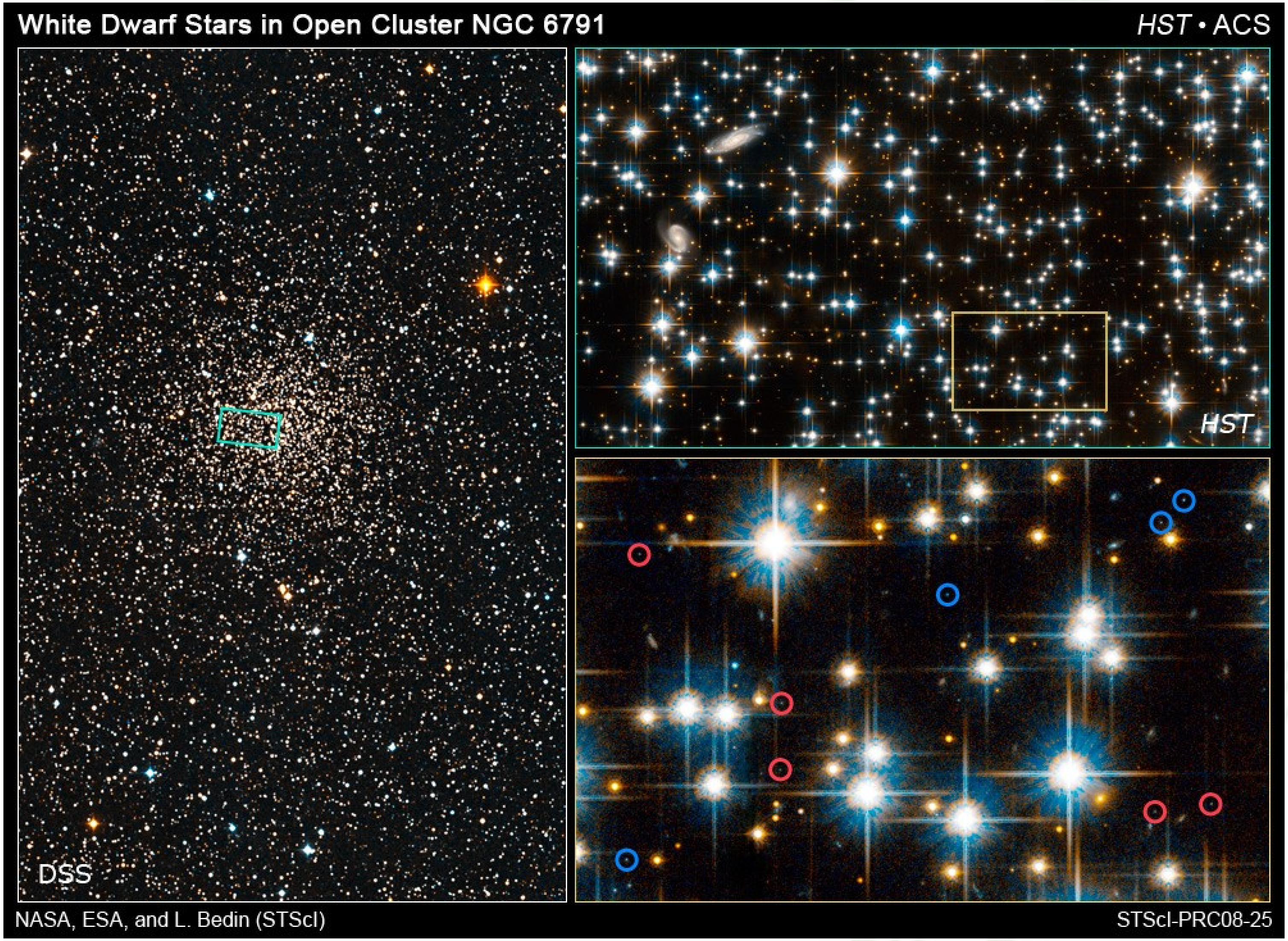
Gechiedenis: voortbouwen op WWII
Vooral belangrijk voor: gamma, X, UV en IR

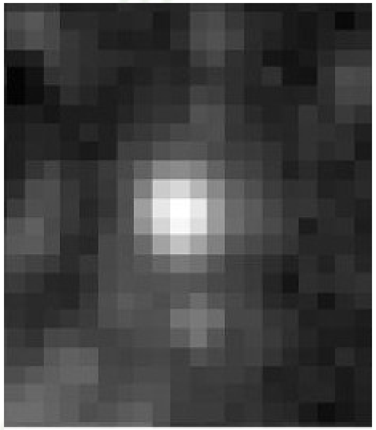


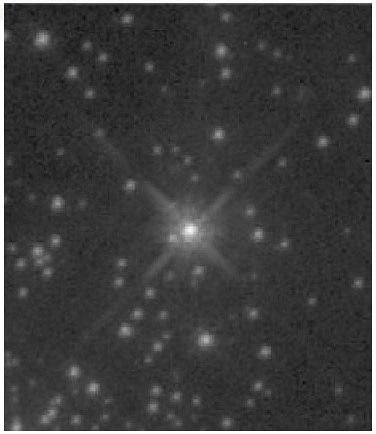


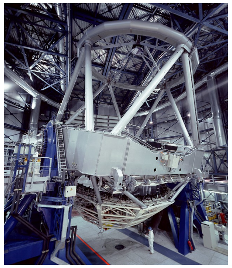
Hubble

Boven atmosfeer ook geen last van seeing!



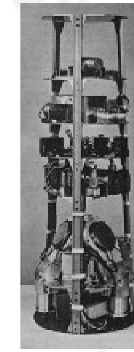


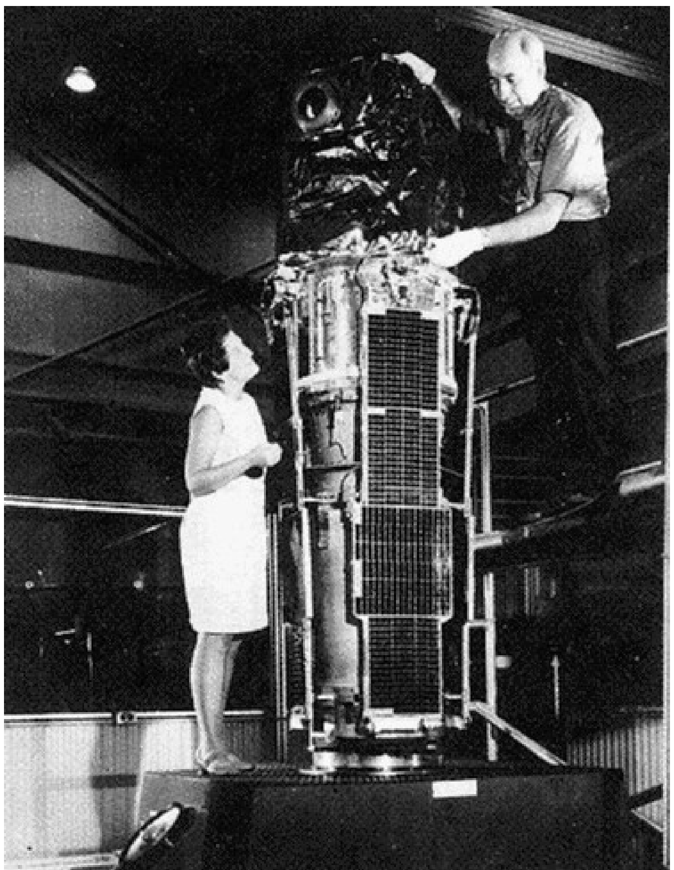




Röntgensterrenkunde

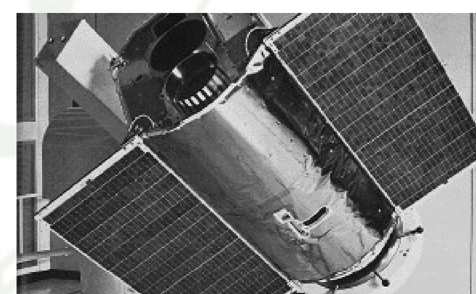
Aerobee 150: 1962 eerste Röntgenbron





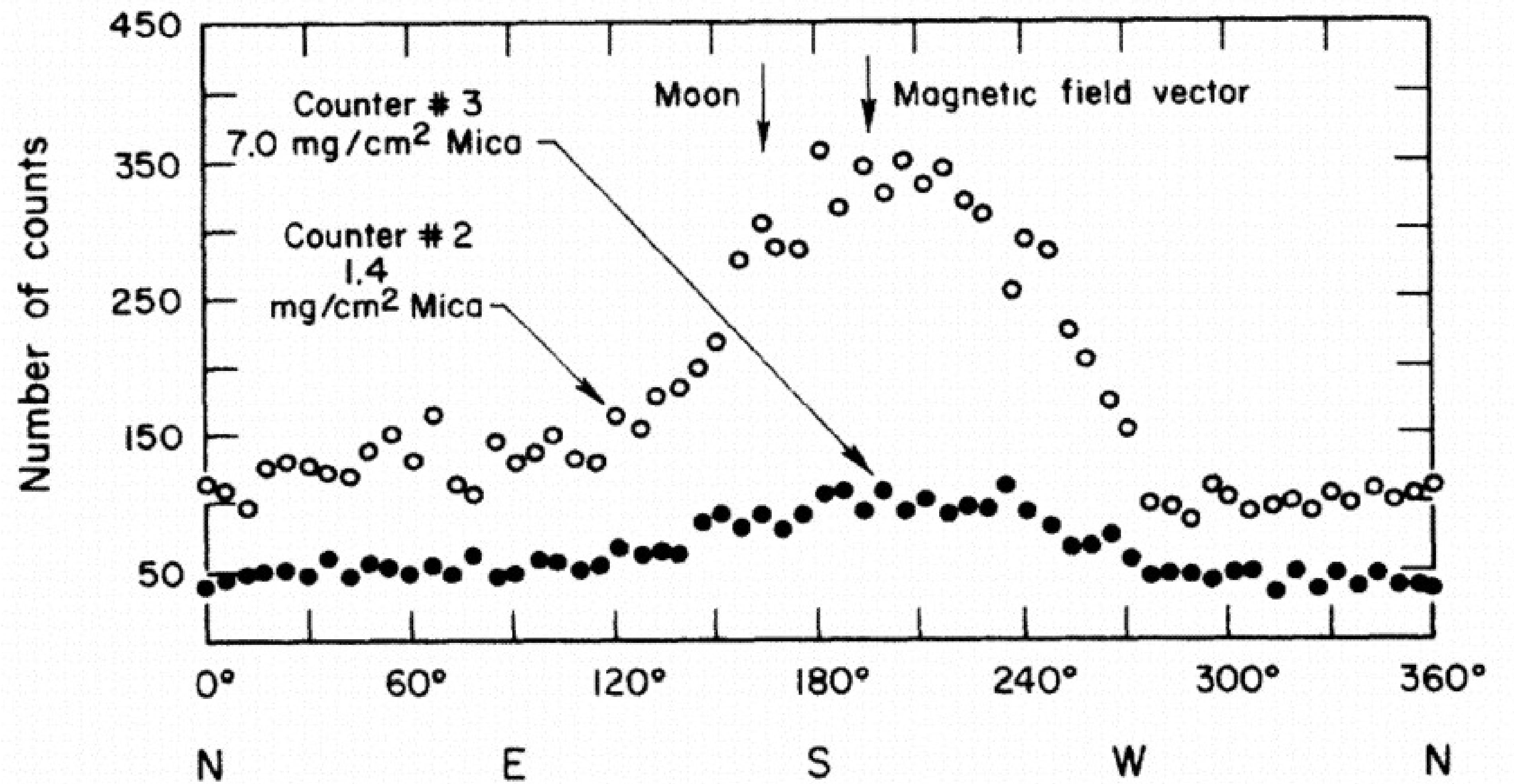
jaren 60 Vela

Uhuru, jaren 70

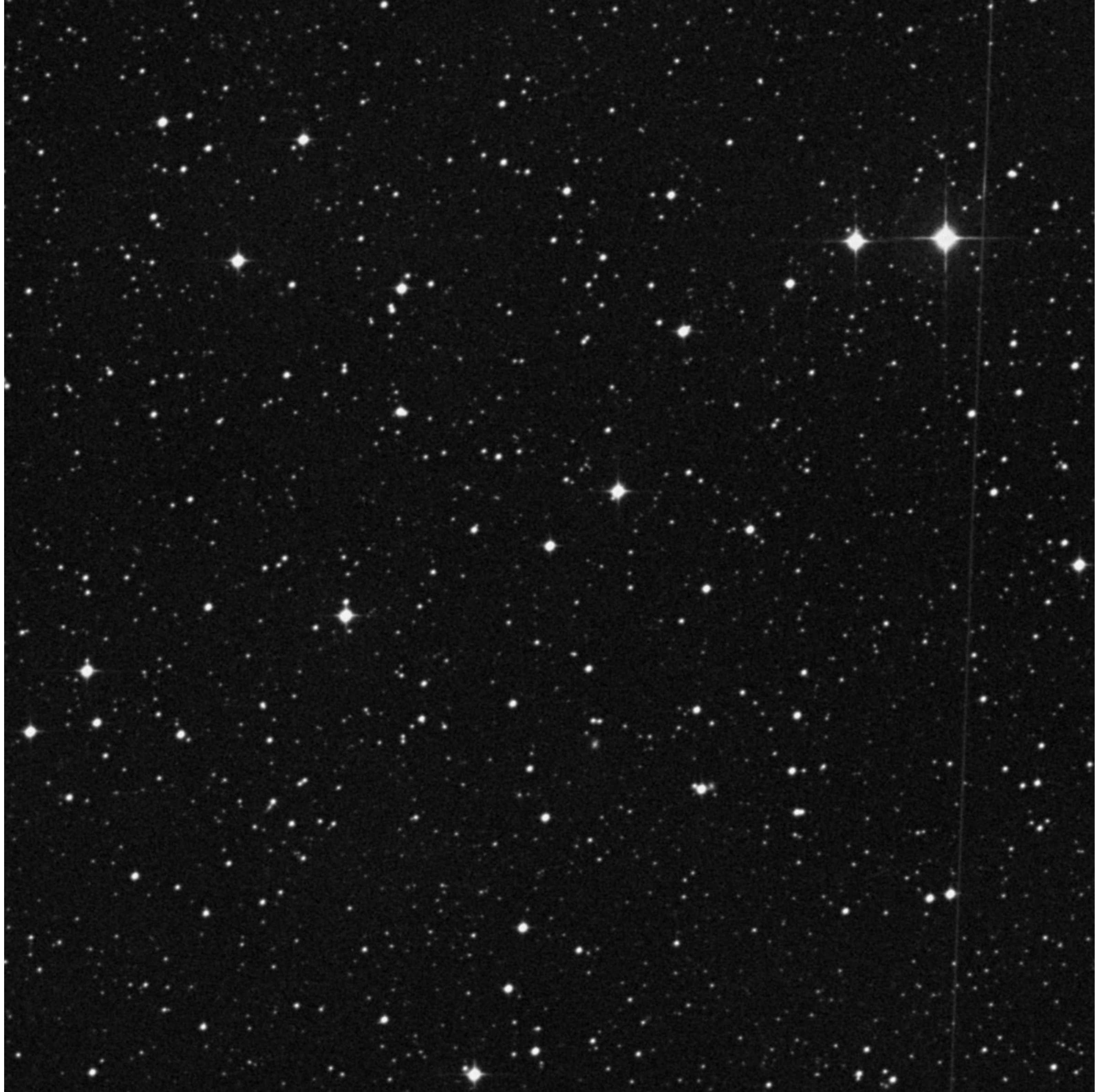


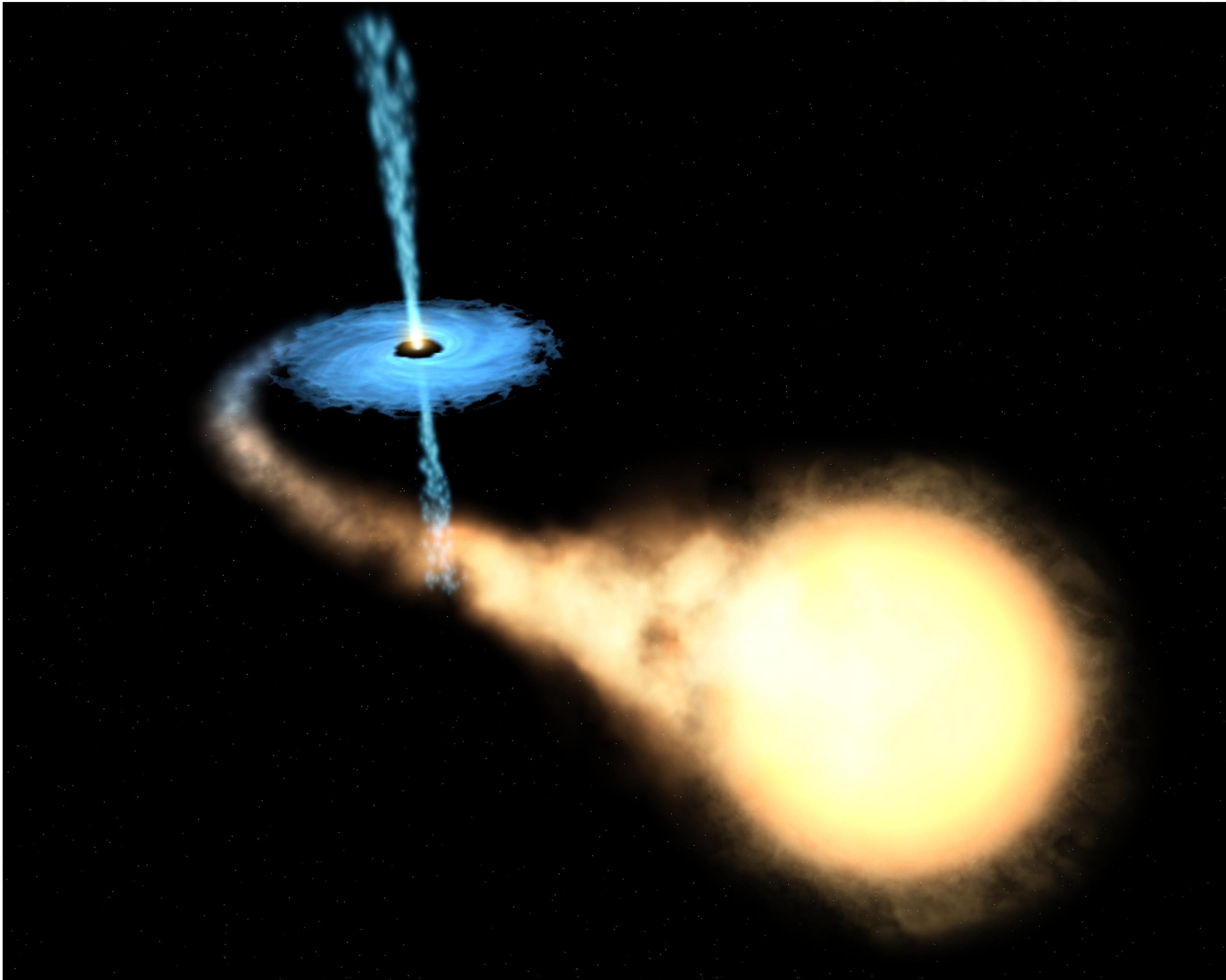
jaren 70 ANS
Astronomische Nederlandse Satelliet

De allereerste röntgen (X-ray) bron

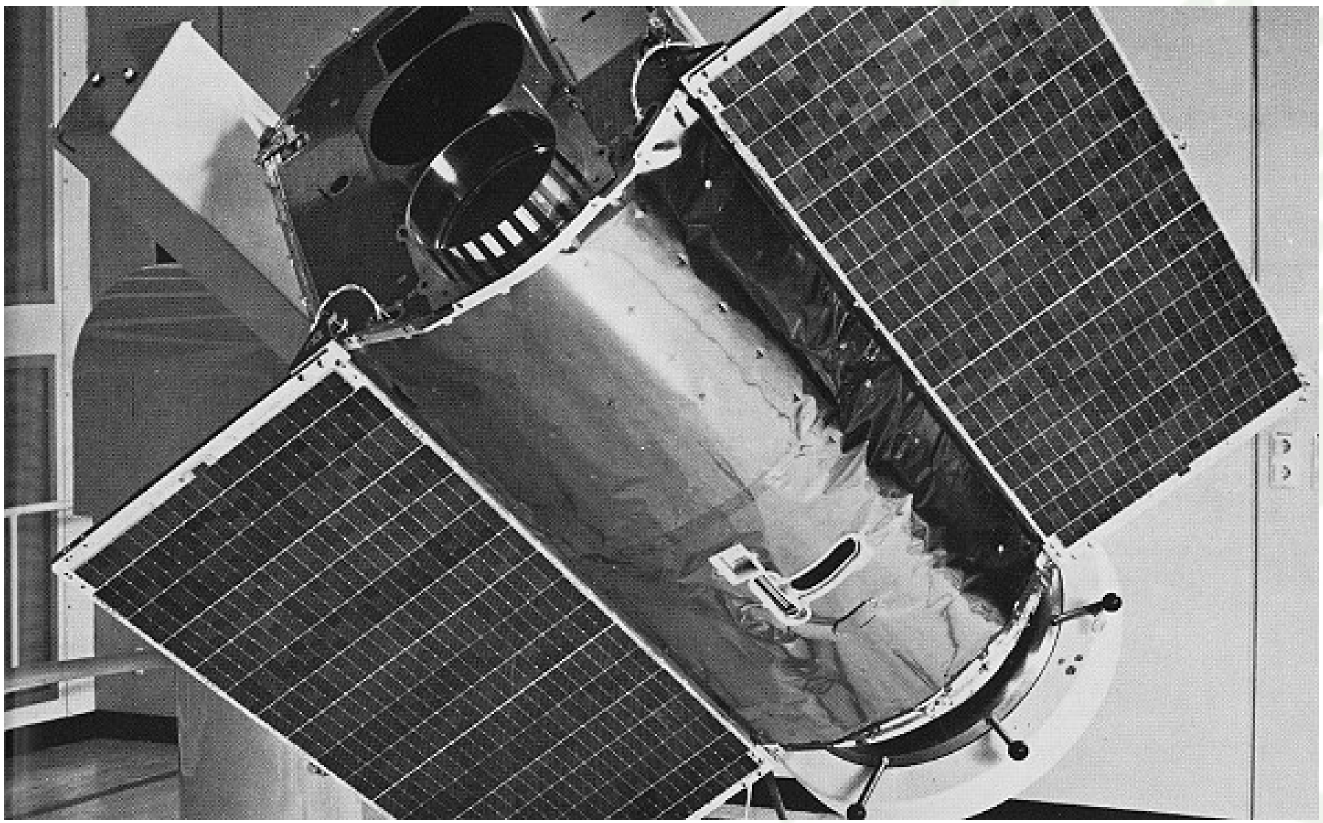


Sco X-1

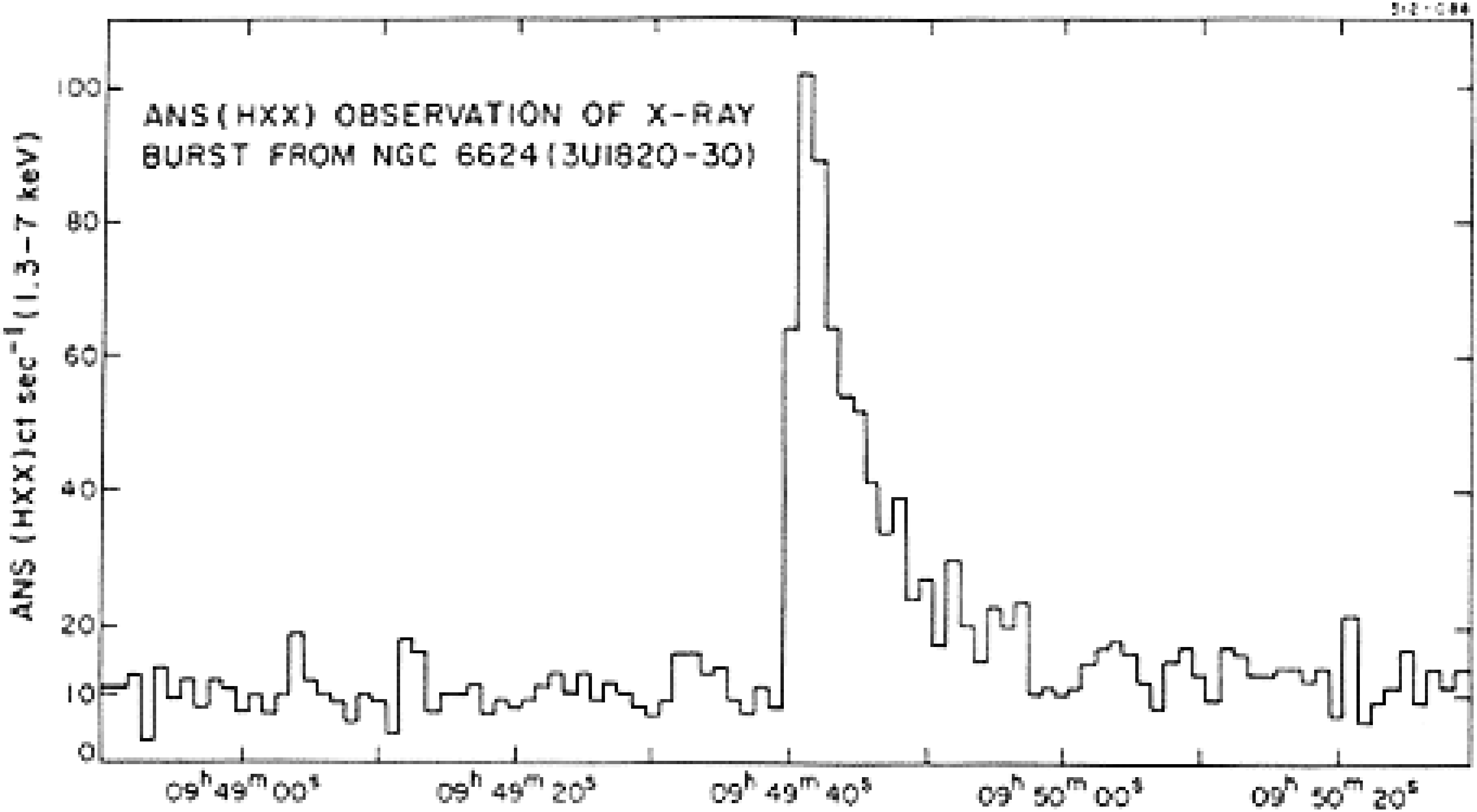




ANS: de ontdekking van X-ray bursts

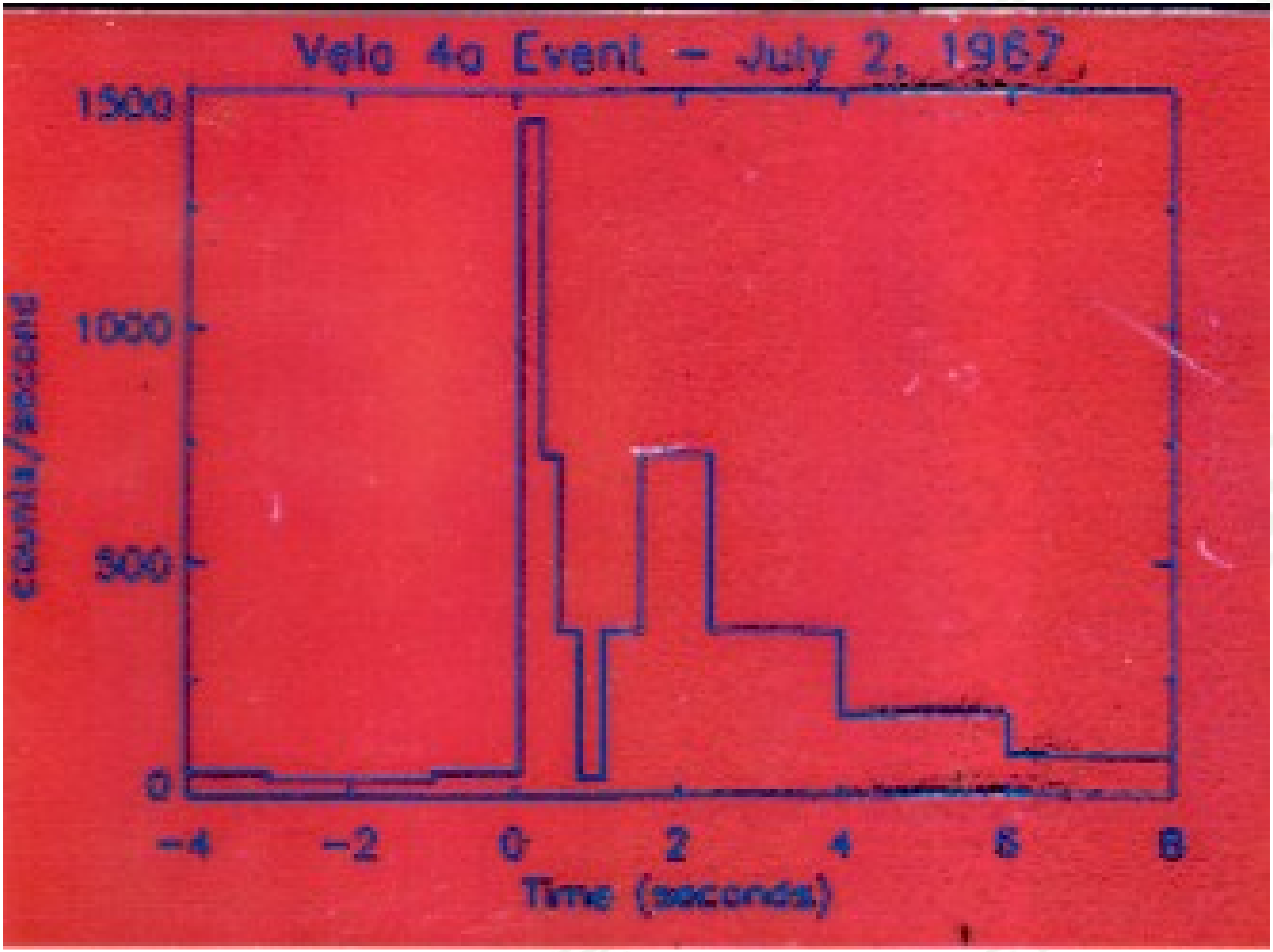


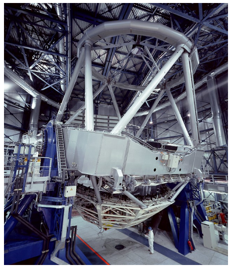
NL: UV en soft X-ray
VS: hard X-ray



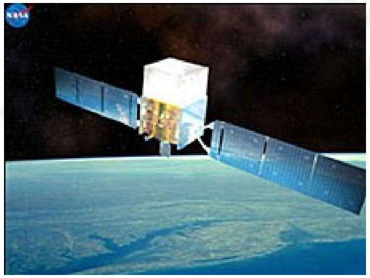
ANS(HXX) OBSERVATION OF X-RAY BURST FROM NGC 6624(3U1820-30)
ANS (HXX) ct sec⁻¹ (1.3-7 keV)
0
10
20
40
60
80
100
09h 49m 00s
09h 49m 20s
09h 49m 40s
09h 50m 00s
09h 50m 20s

Vela: detectie van de eerste Gamma-Ray Burst

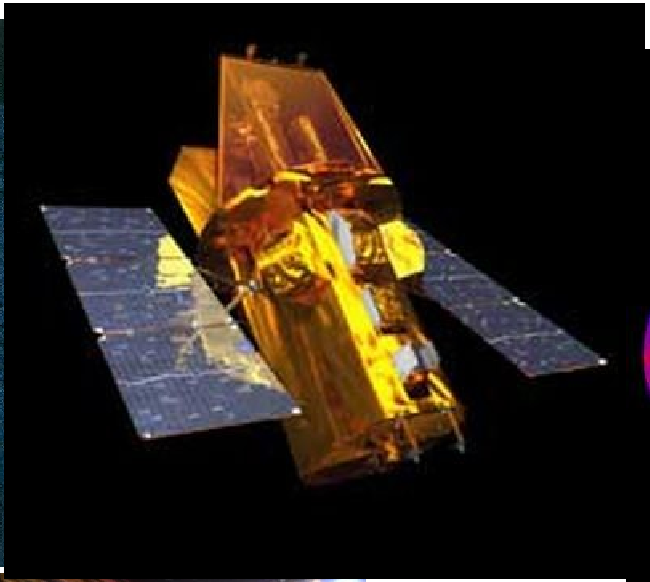


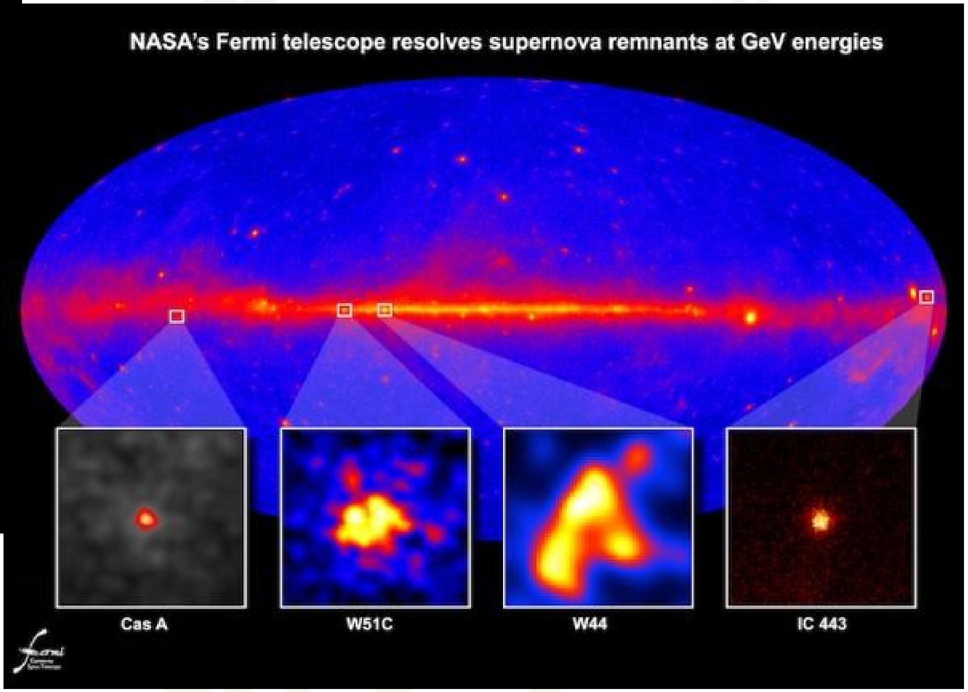


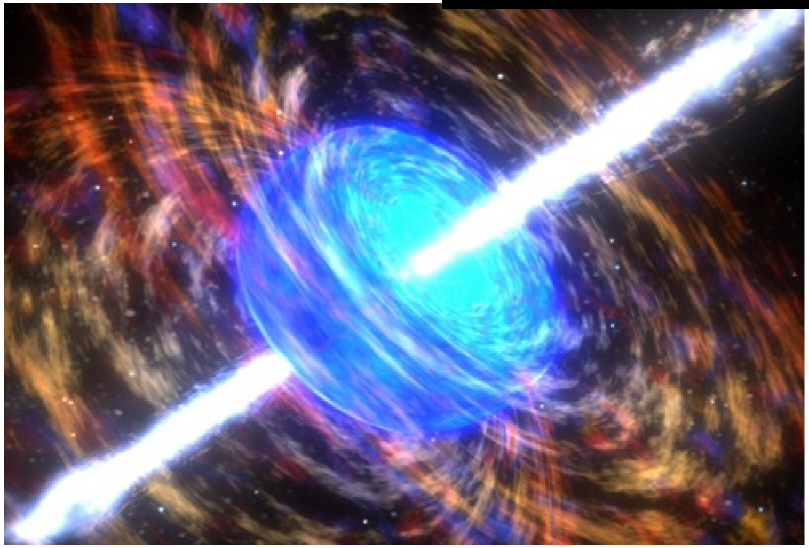
Moderne gamma-ray satellieten



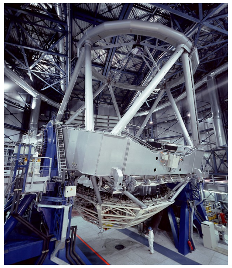
BeppoSAX, Swift, Fermi







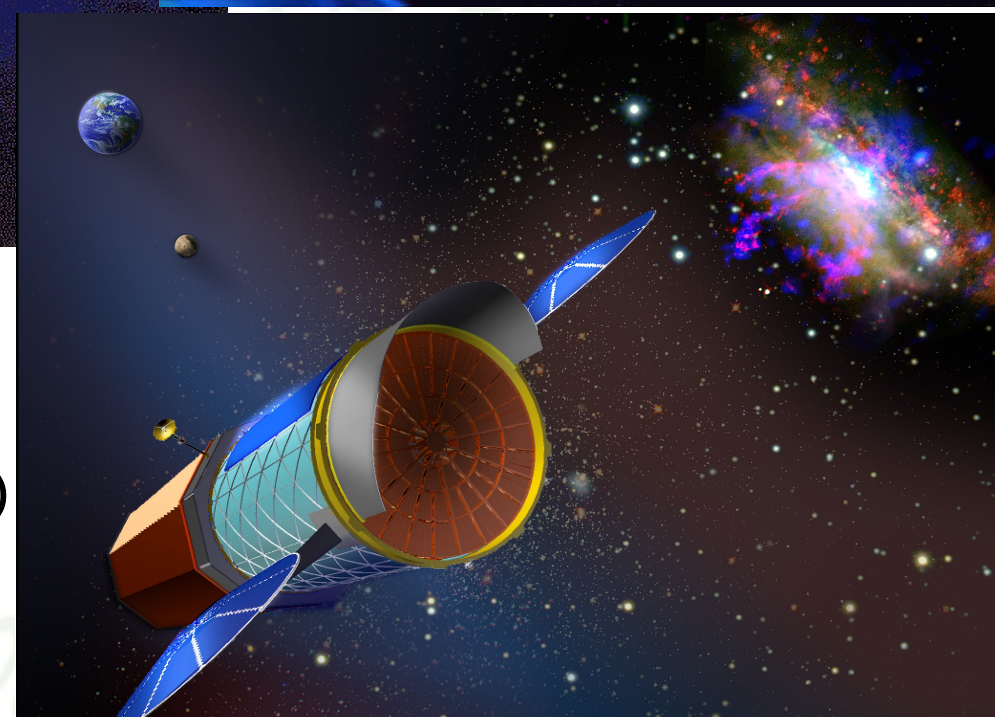
BeppoSax: identificatie GRB
Swift: statistiek
Fermi: gamma sterrenkunde



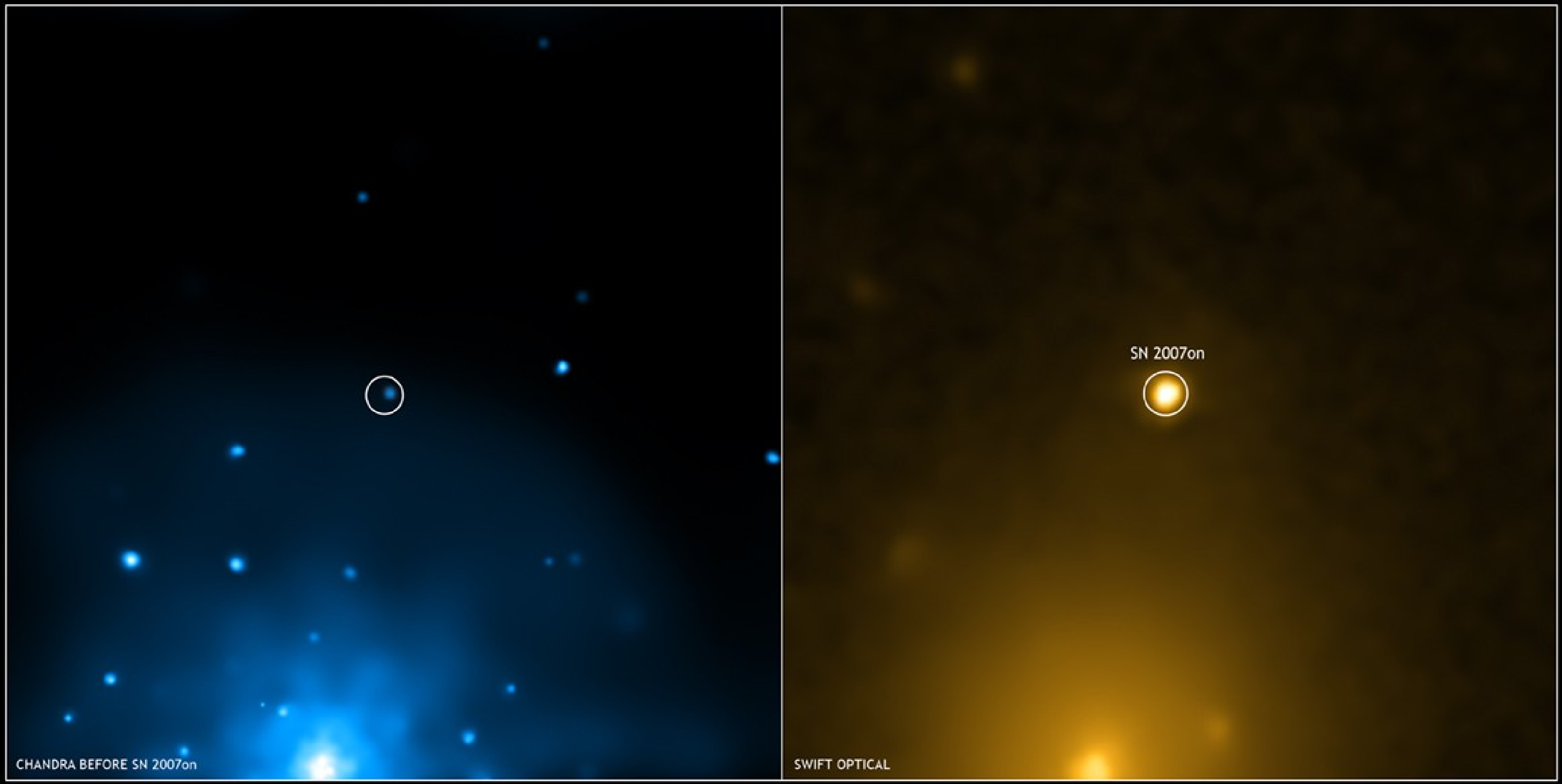
Moderne X-ray satellieten

Exosat, Rosat, Chandra, XMM, en in de toekomst ... IXO

Rosat: survey
Chandra, XMM: gevoelig (spectra)
Chandra: beeldkwaliteit



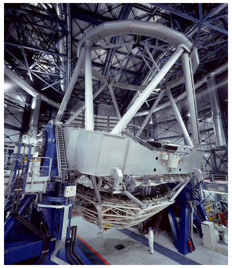
Direct detection progenitors possible



X-ray source
4 years earlier

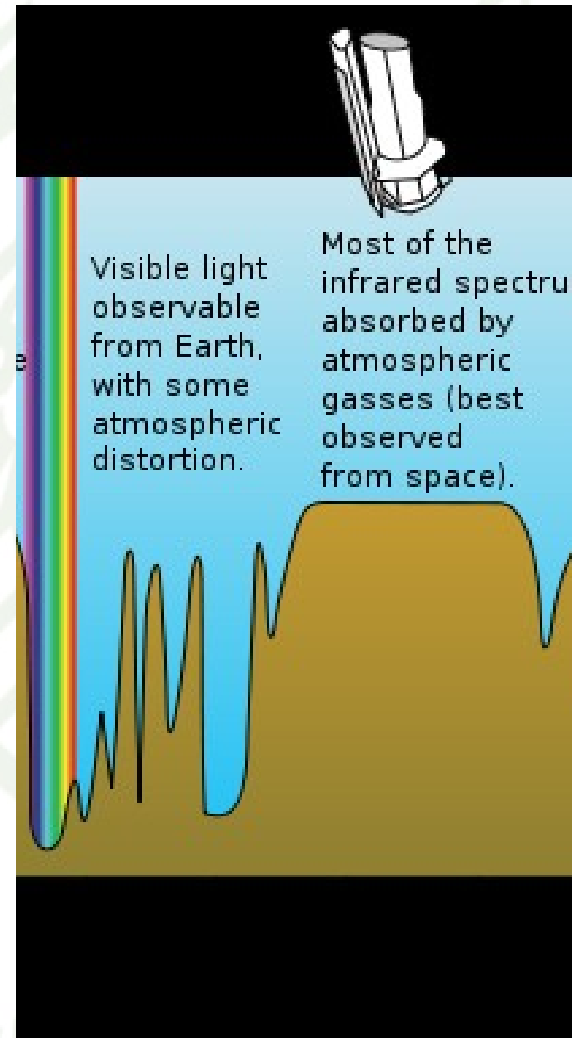
SN last November
(optical)

Voss & Nelemans, 2008, Nature



Infraroodsterrenkunde

Infrarood ook vanaf de aarde waar te nemen, maar aleen in bepaalde “windows”

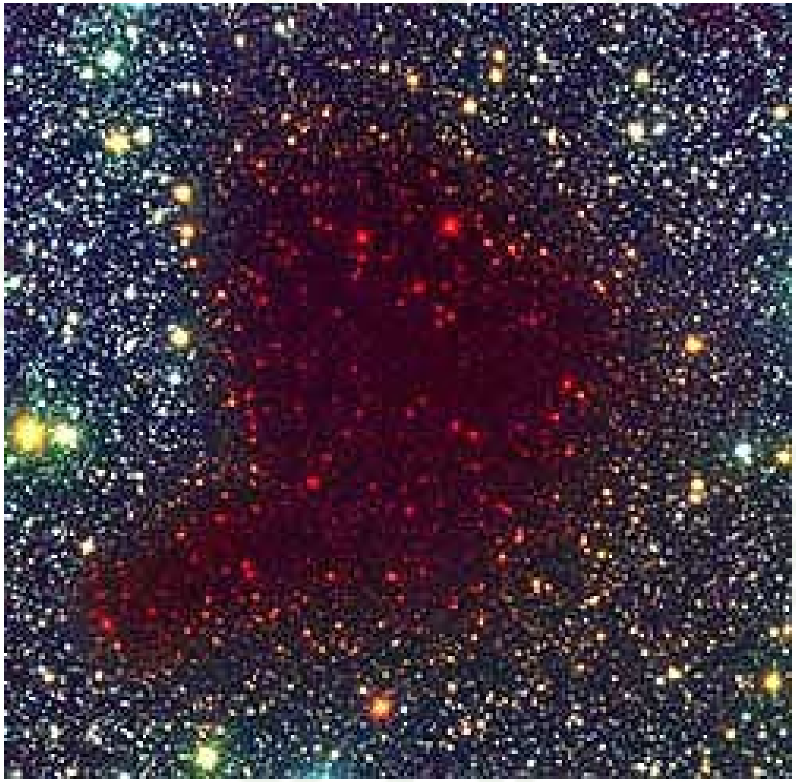


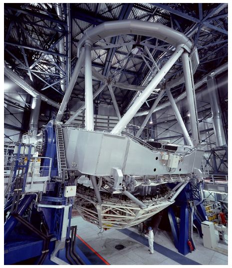
Geschiedenis begint dus op de grond (jaren 20)

1967: telescopen op Mauna Kea (Hawaii): hoge berg, goed voor IR

Maar veel last van atmosfeer en achtergrond zeker voor langere golflengtes (>2 micron)

Dus... ruimtevaart





Infraroodsterrenkunde

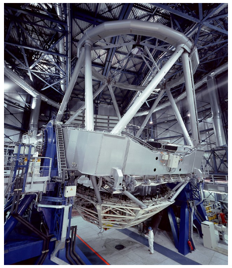
1974: Kuiper Airborne Observatory

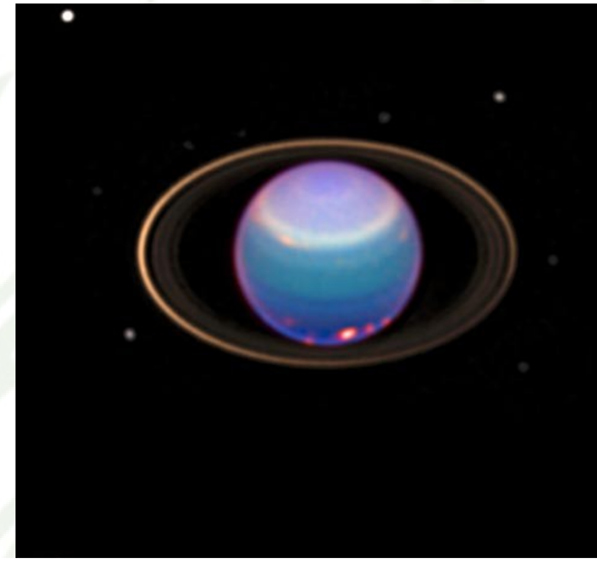
1983: IRAS

COBE

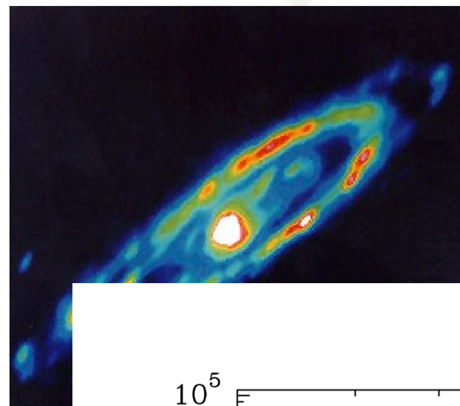
ISO

Infraroodsterrenkunde





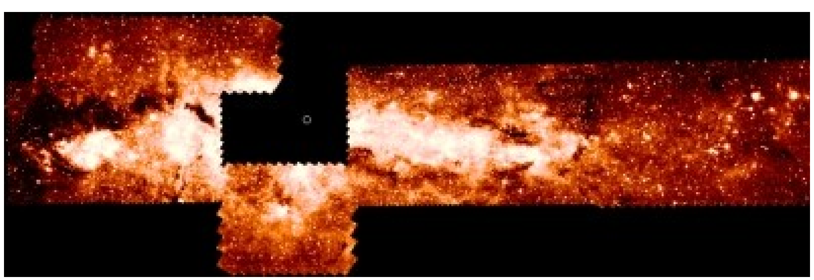
1974: Kuiper Airborne Observatory

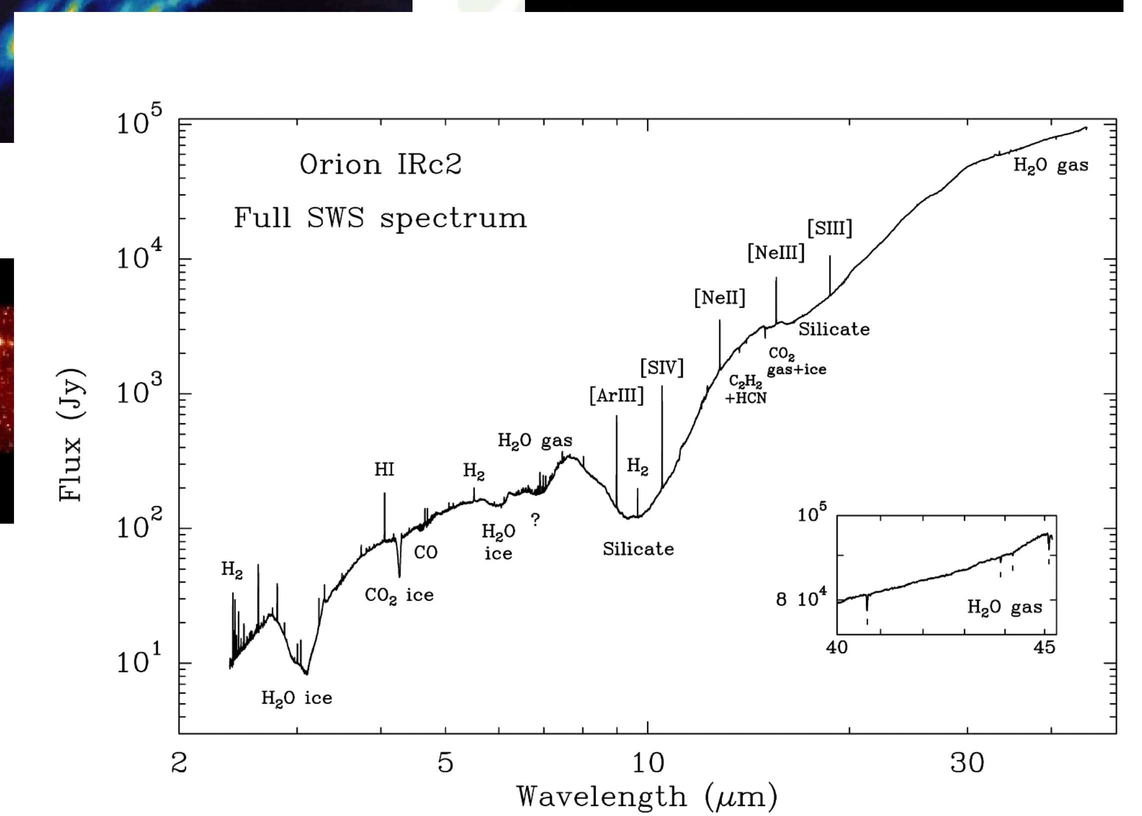


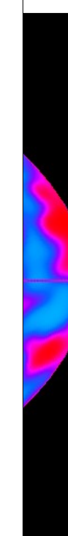
1983: IRAS

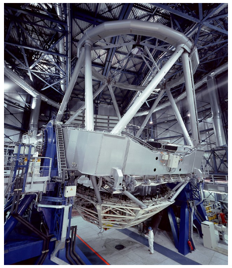
COBE

ISO



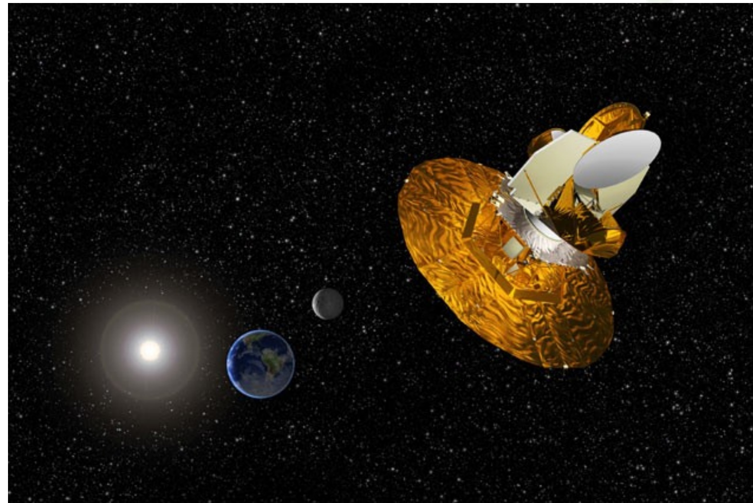


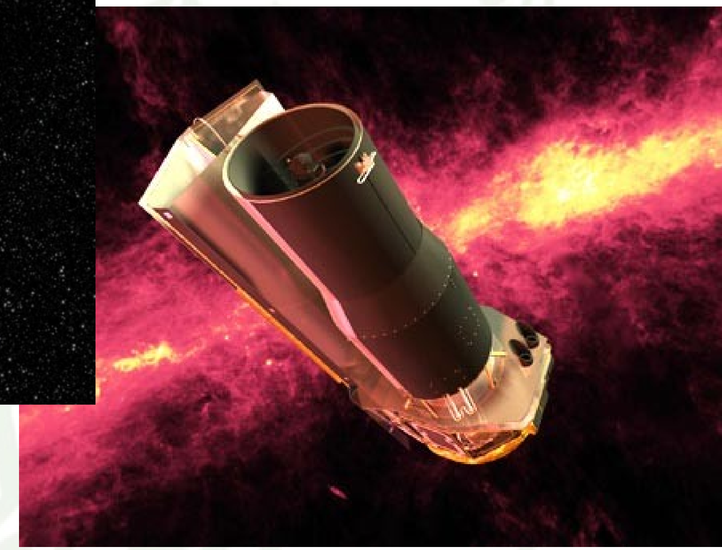


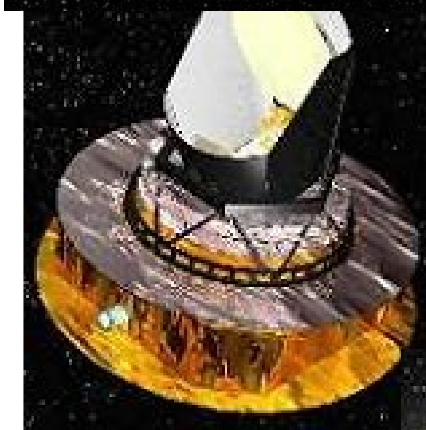


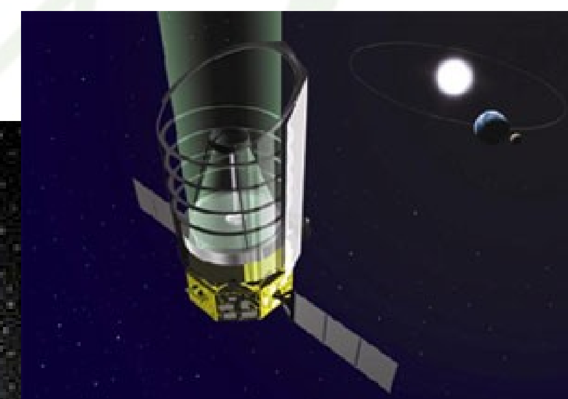
Moderne IR satellieten

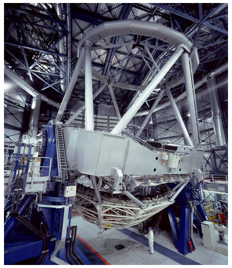
- WMAP
- Spitzer
- Hershel
- Planck
- JWST
- SPICA











Moderne IR satellieten

WMAP

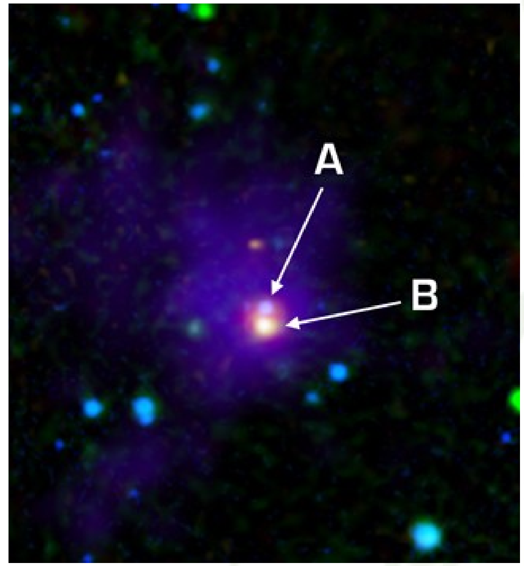
Spitzer

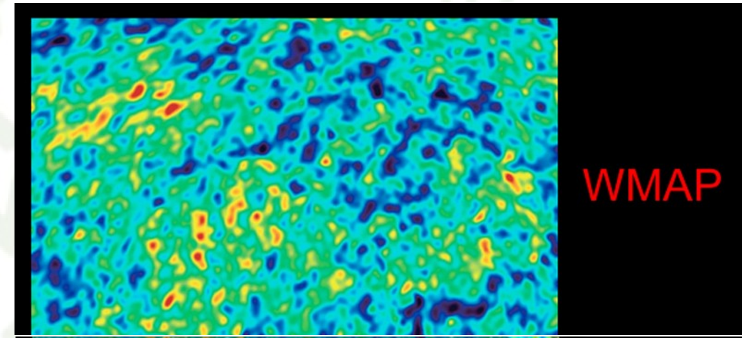
Hershel

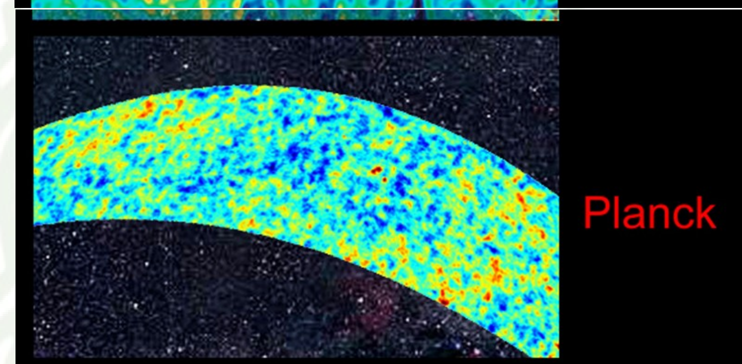
Planck

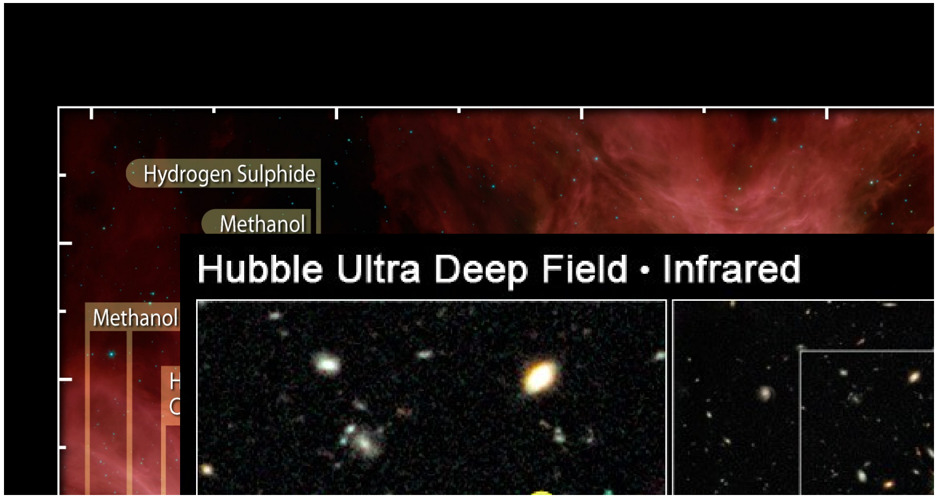
JWST

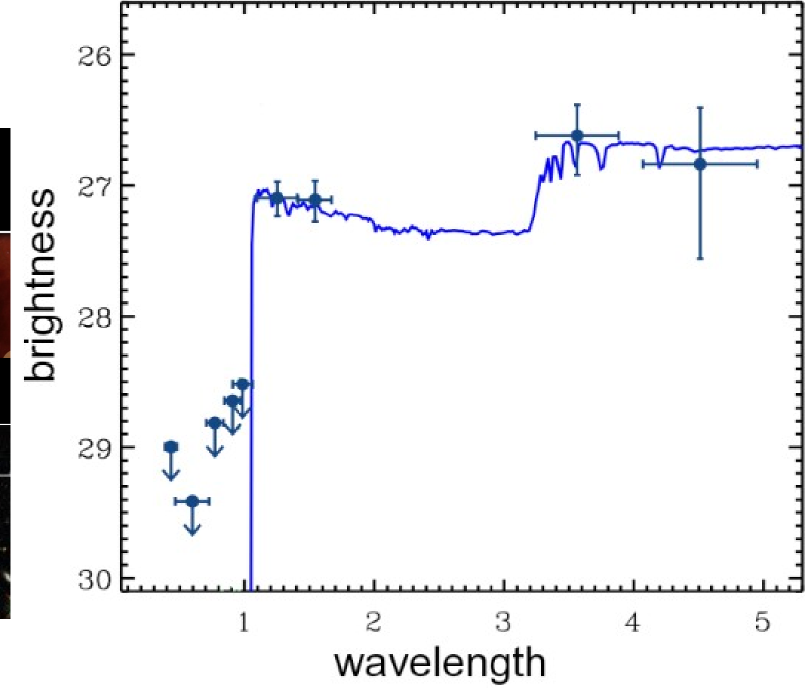
SPICA

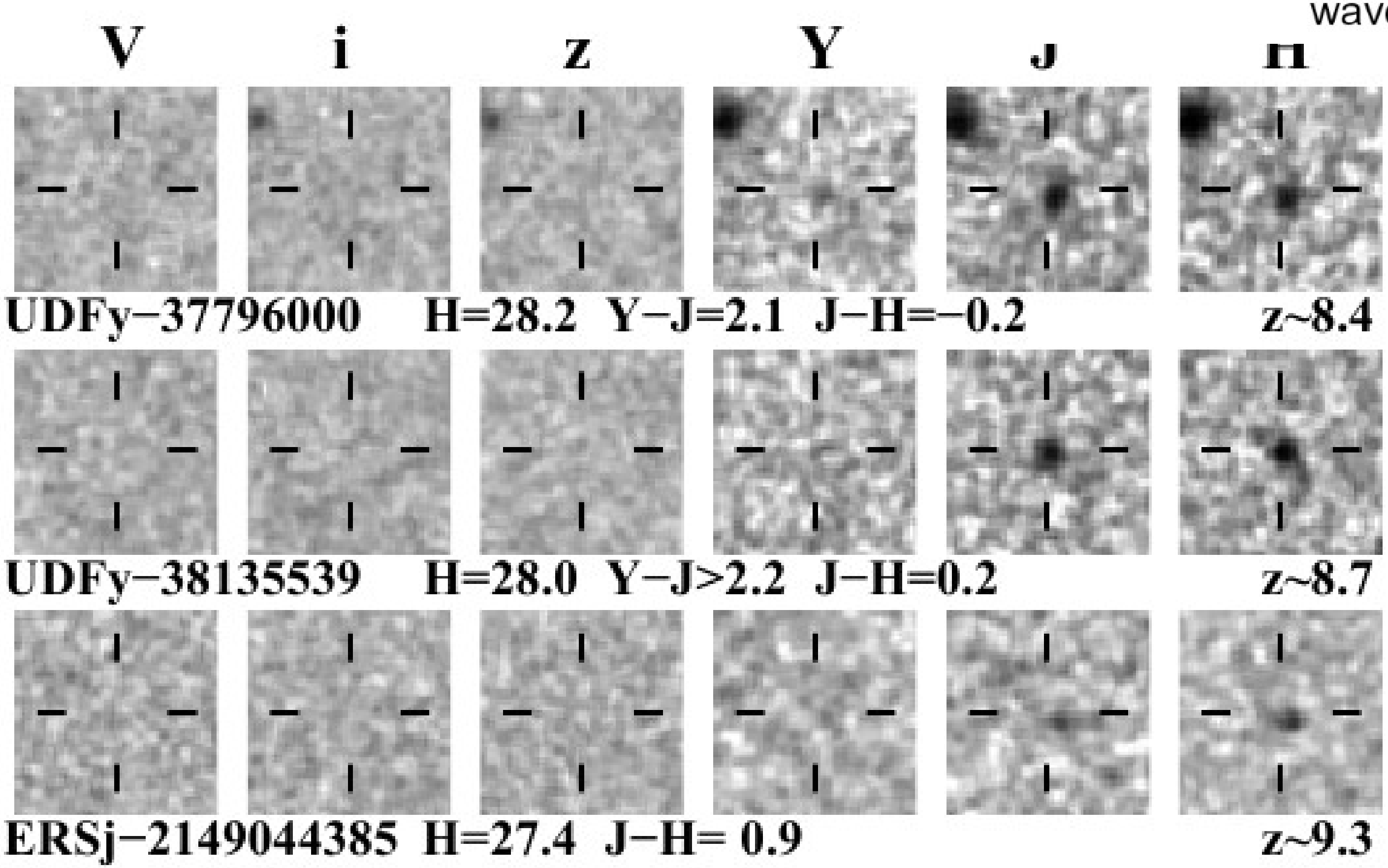


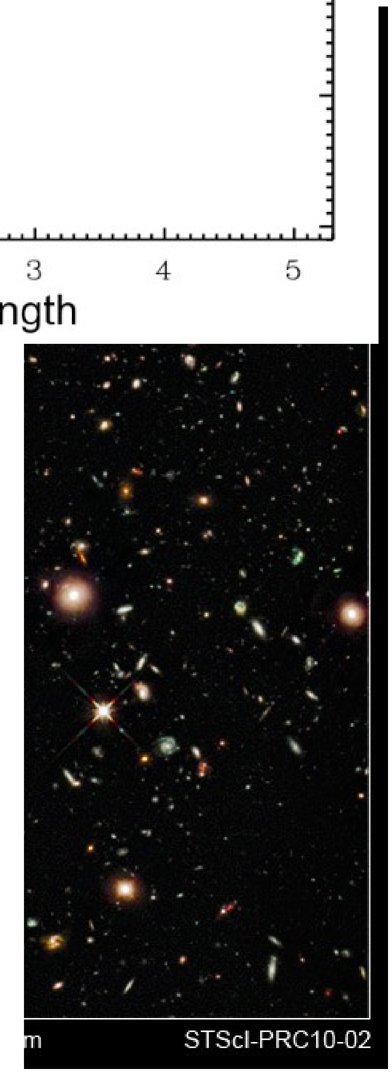


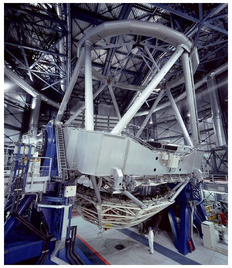



Hydrogen Sulphide
Methanol
Methanol
Hubble Ultra Deep Field • Infrared


brightness
wavelength
26
27
28
29
30
1
2
3
4
5


V i z Y J H
UDFy−37796000 H=28.2 Y−J=2.1 J−H=−0.2 z~8.4
UDFy−38135539 H=28.0 Y−J>2.2 J−H=0.2 z~8.7
ERSj−2149044385 H=27.4 J−H= 0.9 z~9.3


STScI-PRC10-02

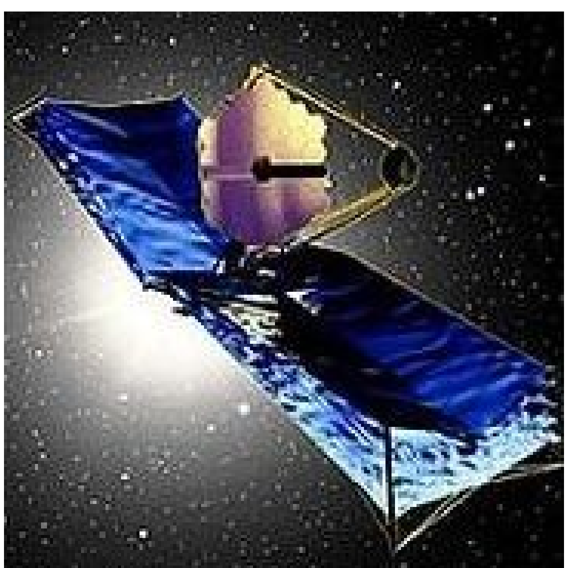


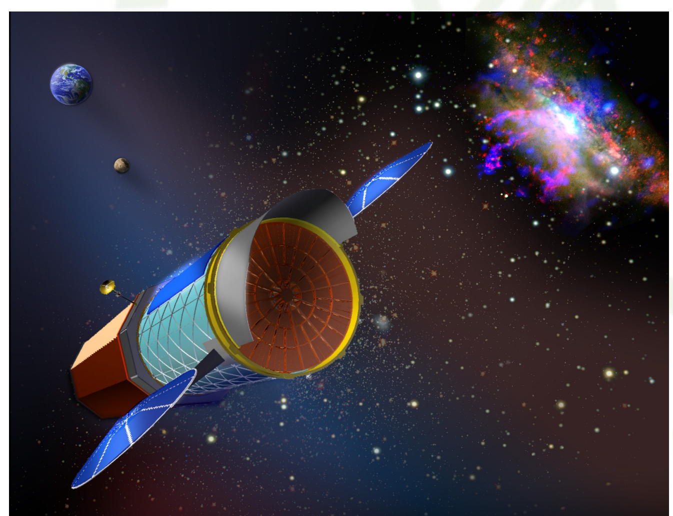
Waarom niet alles in de Ruimte?

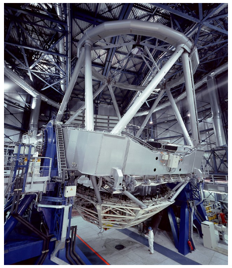
$$$$$$$! Lancering: ~100 M€

Hershel: 1100M€
JWST: ~6000 M$
IXO: ~3000M$

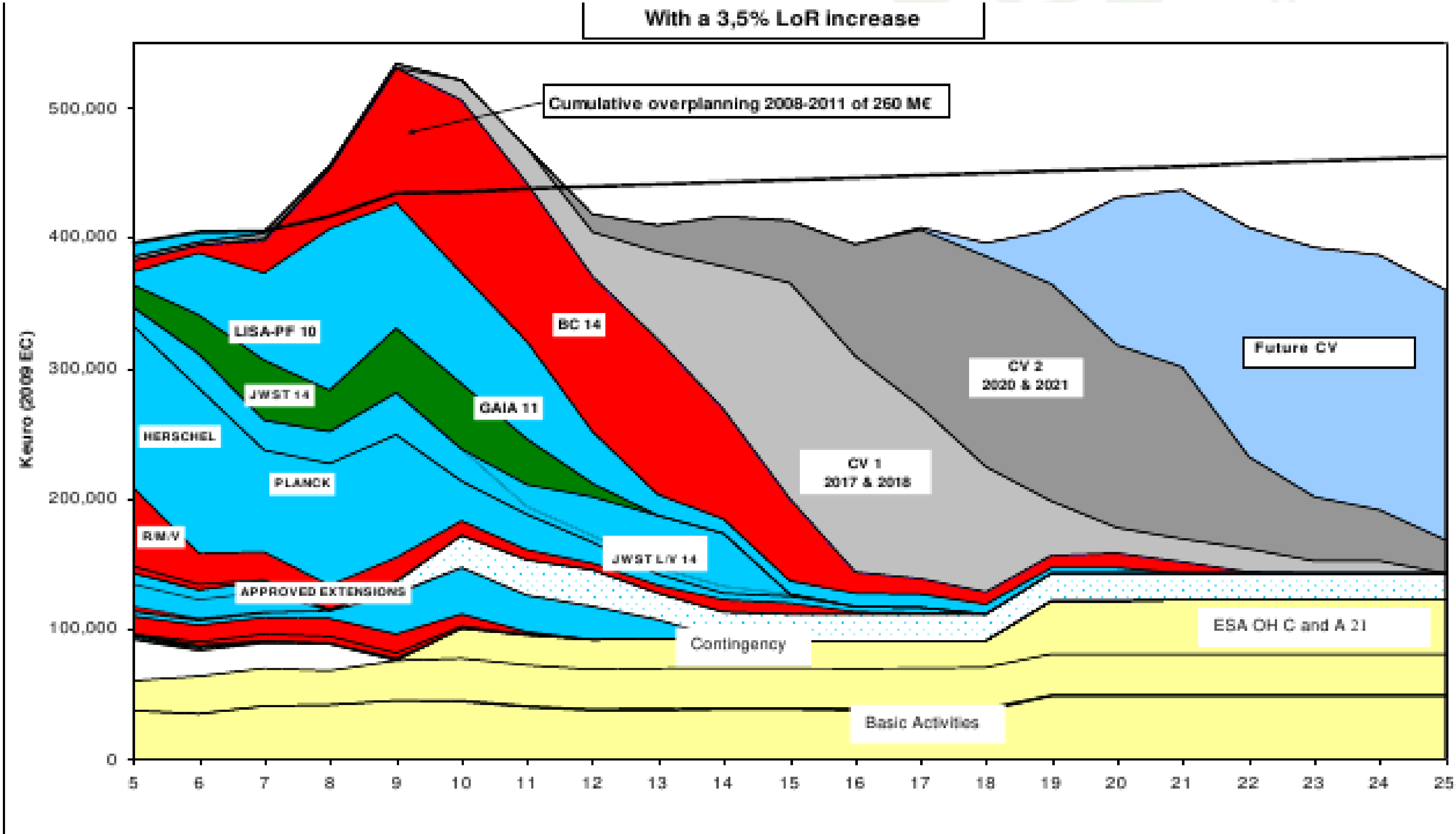
Missies worden duurder er duurder







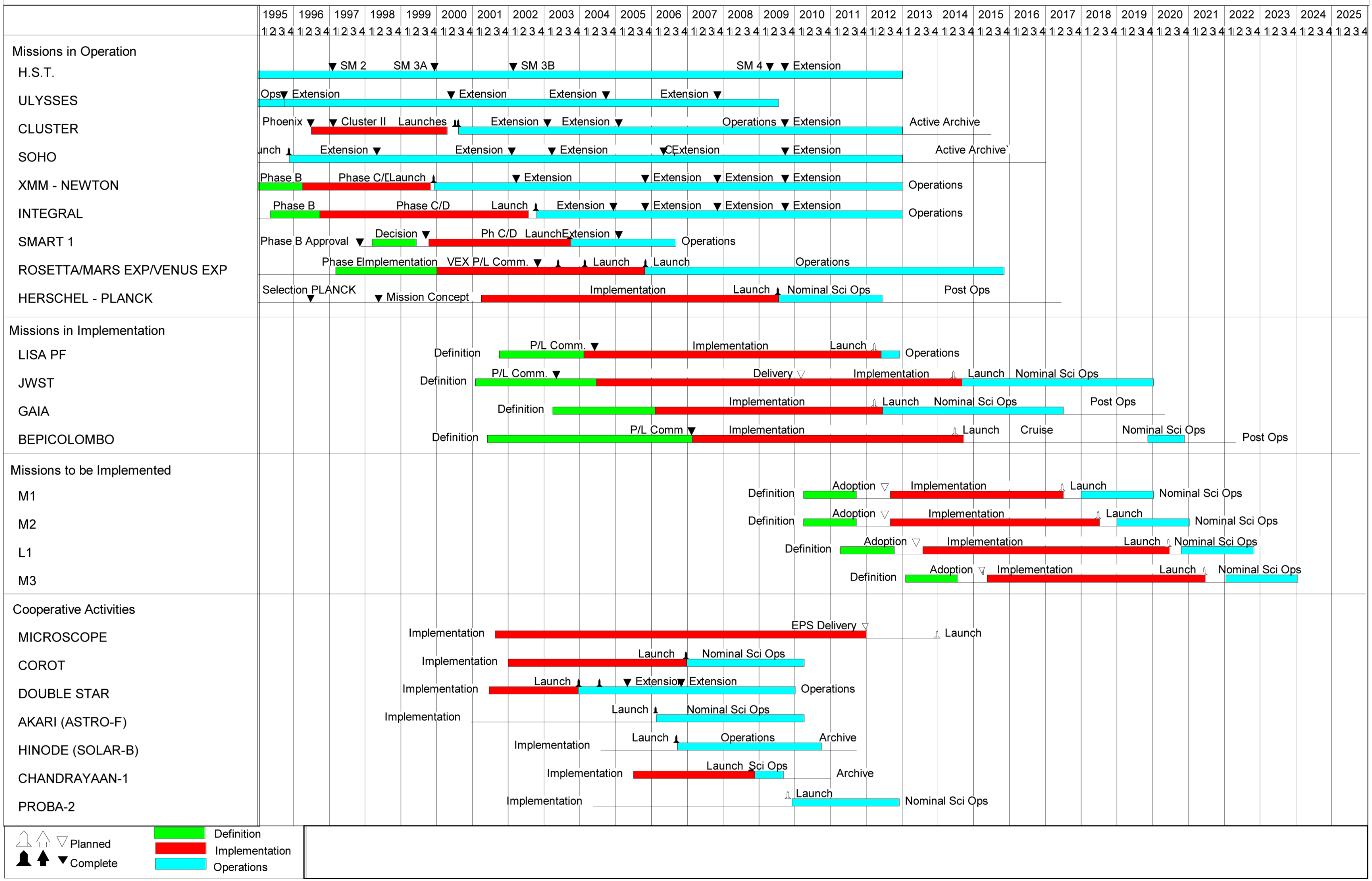
ESA budget

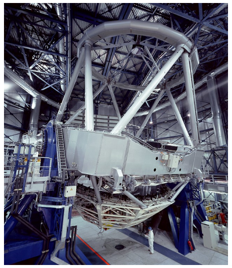


With a 3,5% LoR increase
Cumulative overplanning 2008-2011 of 260 M€
500,000
400,000
300,000
200,000
100,000
0
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
LISA-PF 10
BC 14
JWST 14
GAIA 11
HERSCHEL
PLANCK
R/M/V
JWST L/V 14
APPROVED EXTENSIONS
Contingency
CV 1
2017 & 2018
CV 2
2020 & 2021
Future CV
ESA OH C and A 21
Basic Activities

COSMIC VISION

Status as of: 23 Oct 2009
Schedule by: SRE-M





De toekomst

NASA Astronomy budget: 1100 M$ (~800M€)
ESA Science budget 400 M€

Voor nieuwe missies: 800 M€

Typische kosten missie: 600-2000 M€
→ 1 missie/2 yr!

Plannen:

- JWST
- EUCLID
- JDEM
- PLATO
- Solar Orbiter
- IXO
- LISA (laatste college)
- .....