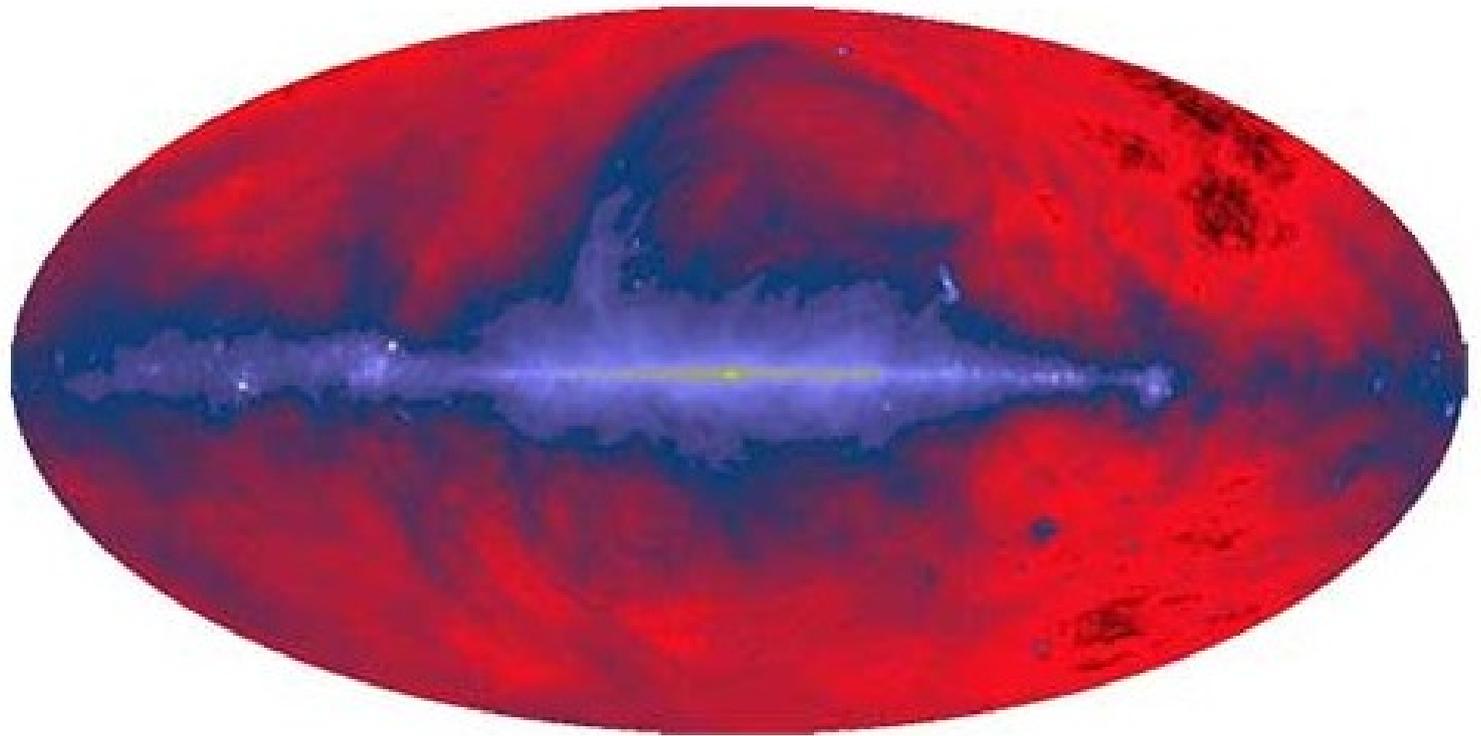
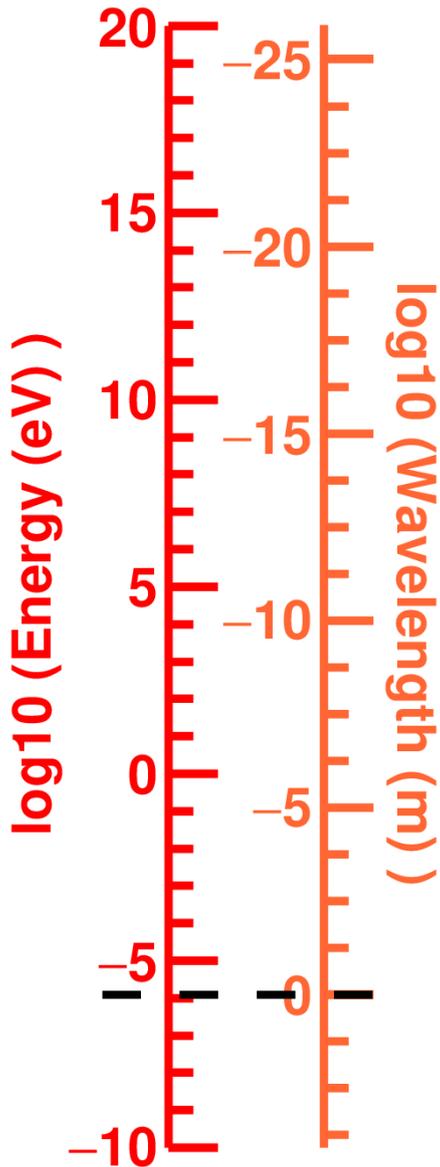


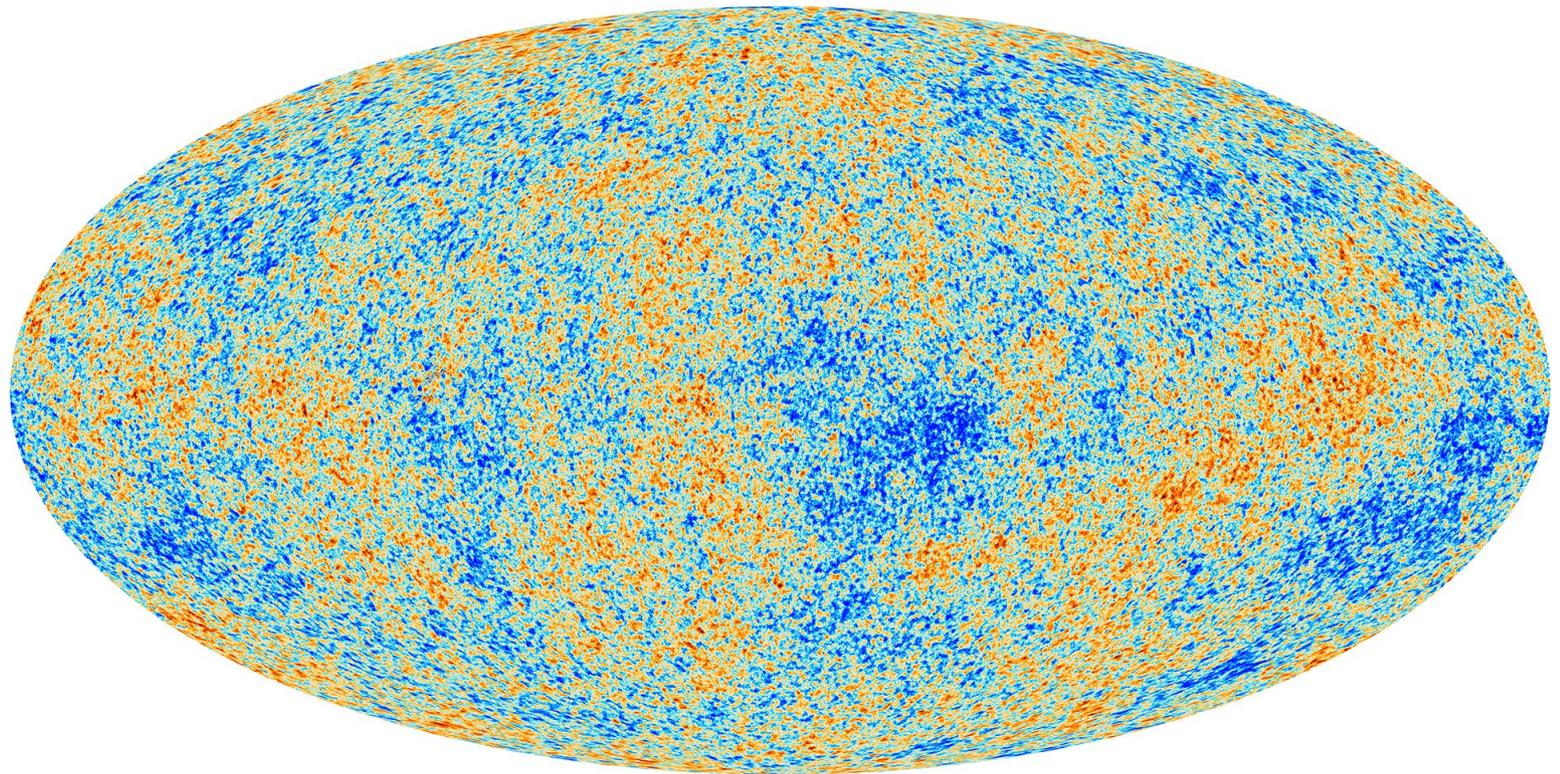
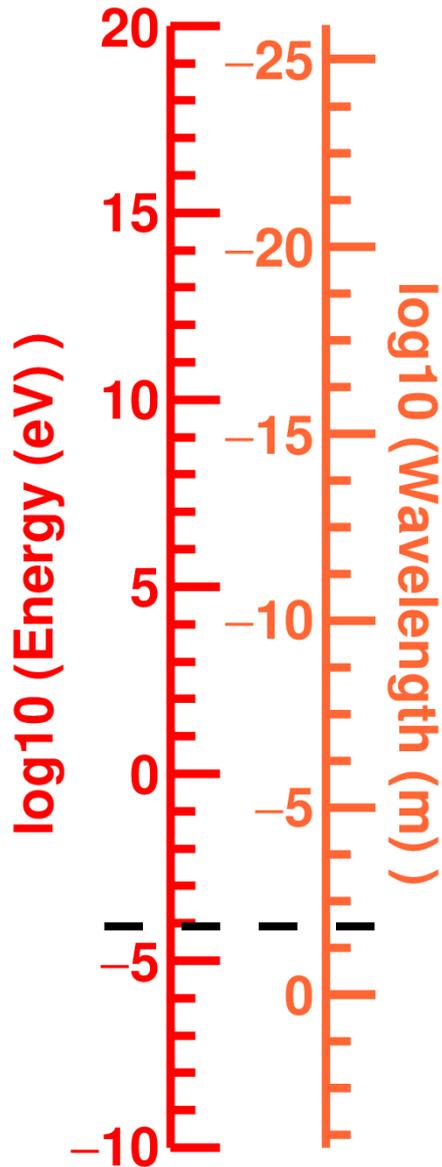
Radio

$$E \sim 10^{-6} \text{ eV} \Leftrightarrow \lambda \sim 1 \text{ m}$$



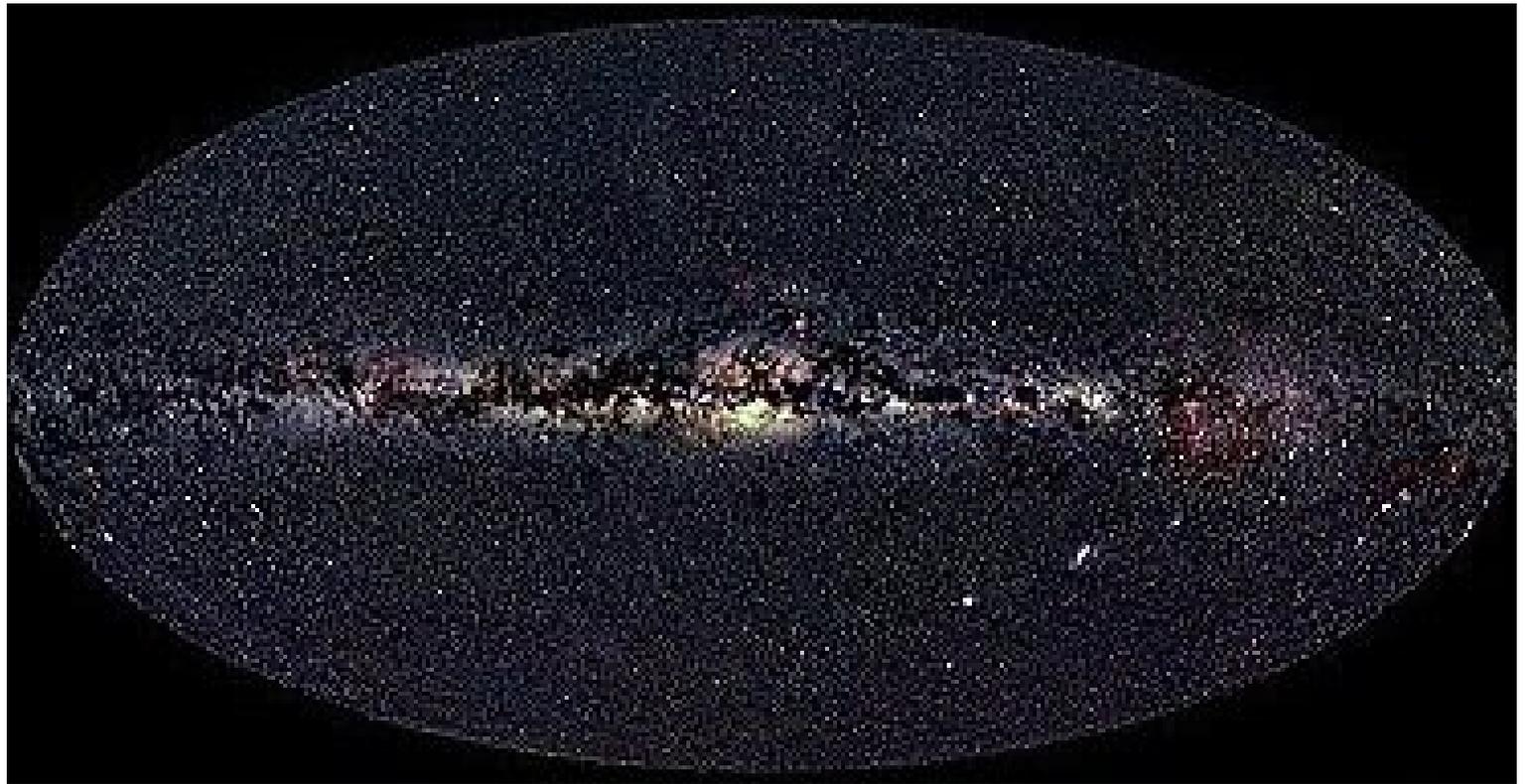
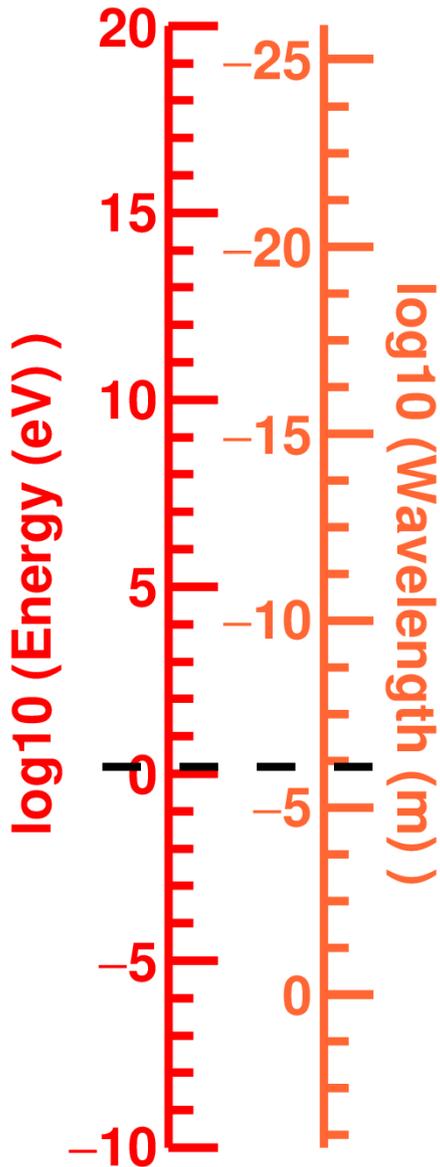
Cosmic Microwave Background

$$E \sim 10^{-4} \text{ eV} \Leftrightarrow \lambda \sim 10^{-2} \text{ m}$$



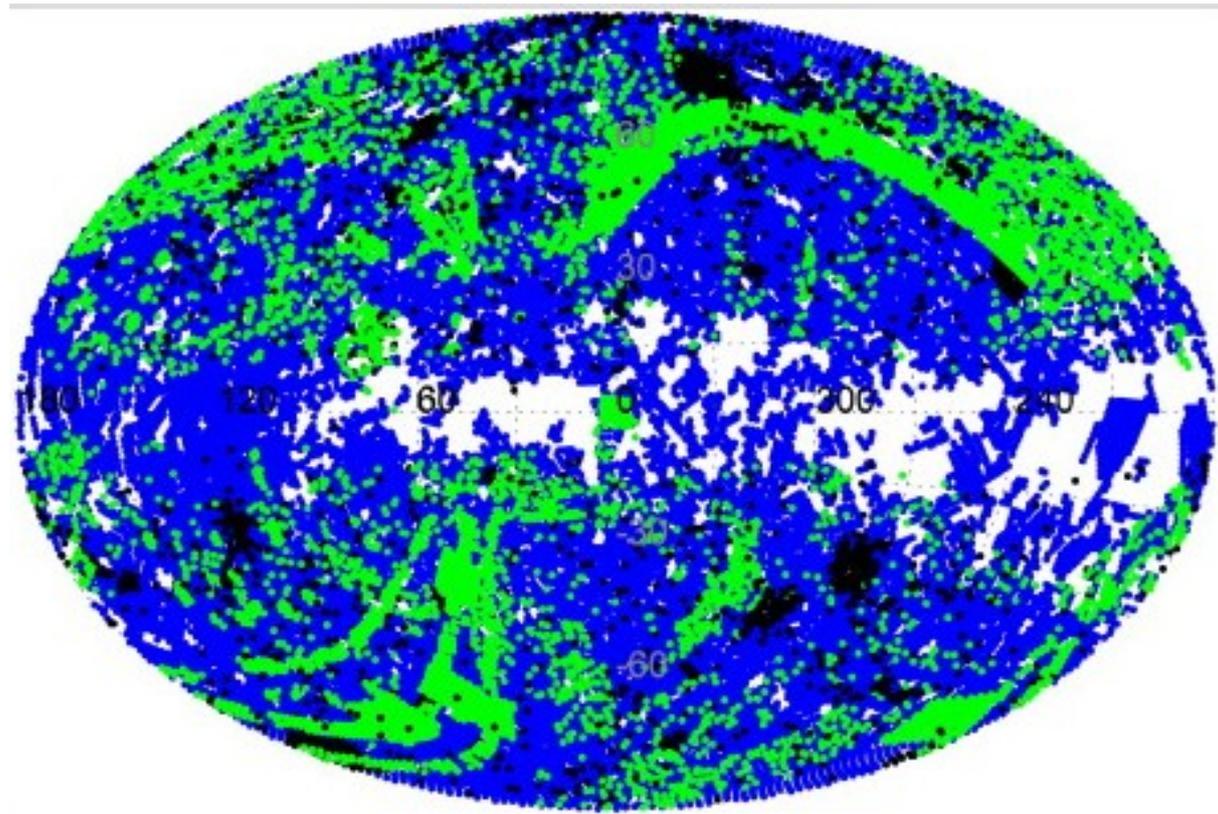
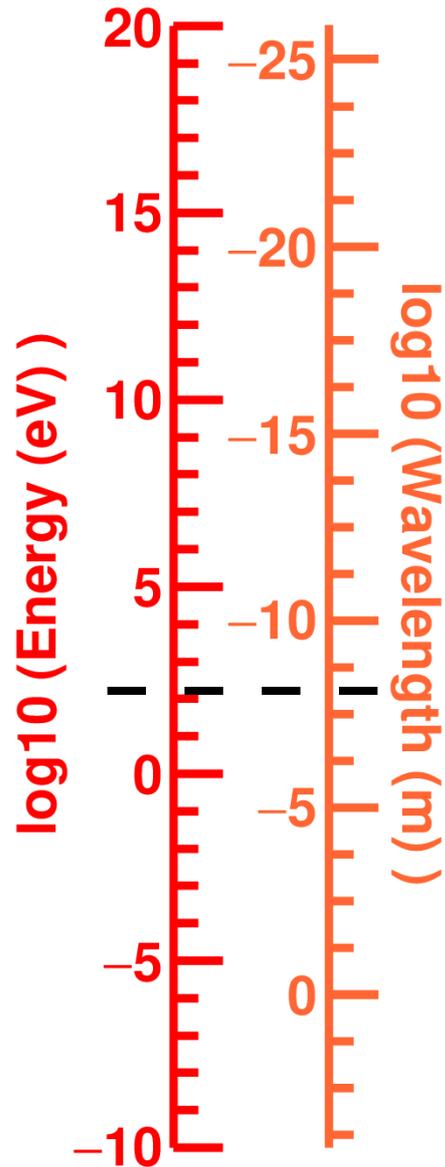
Visible

$$E \sim 1 \text{ eV} \Leftrightarrow \lambda \sim 10^{-6} \text{ m}$$



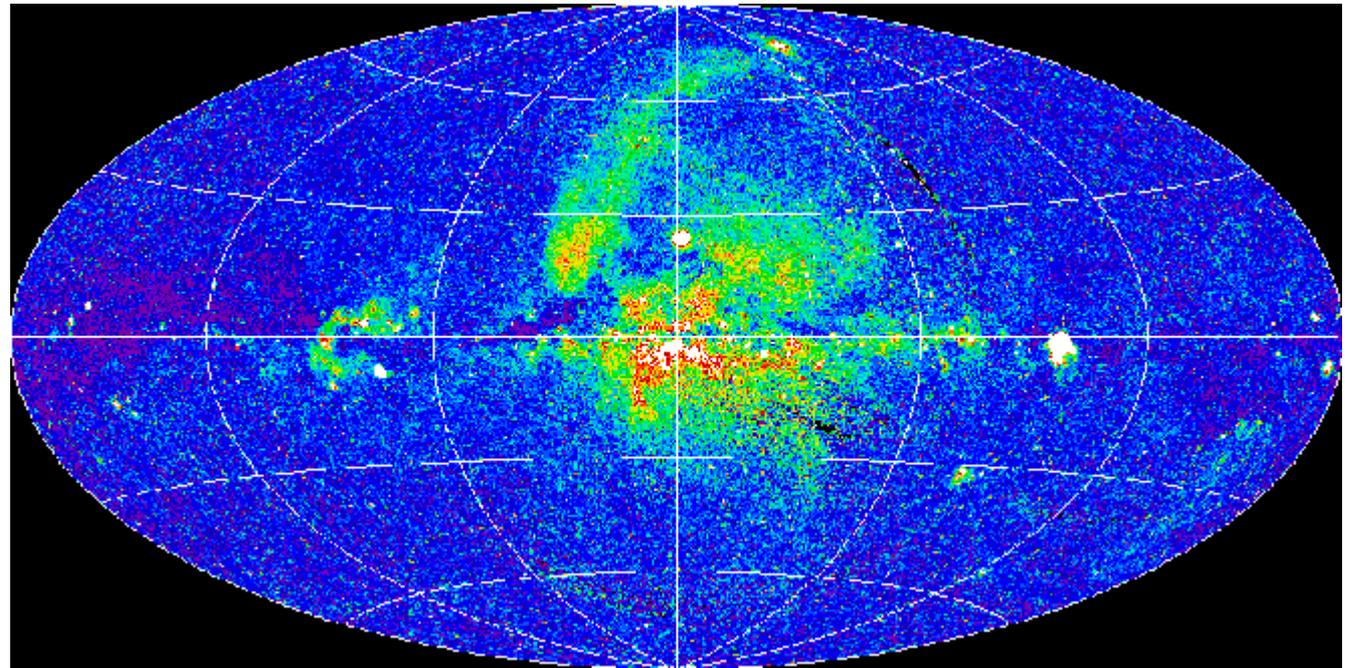
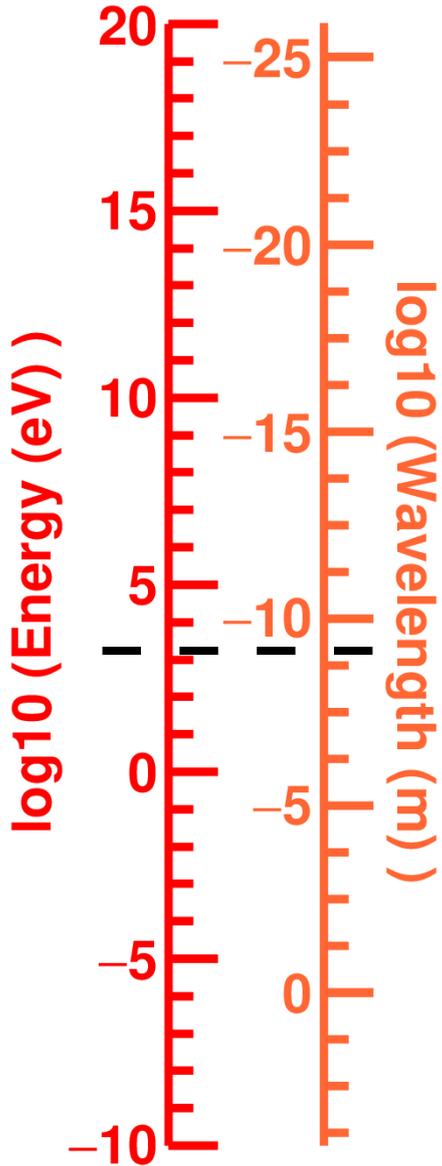
Ultraviolet

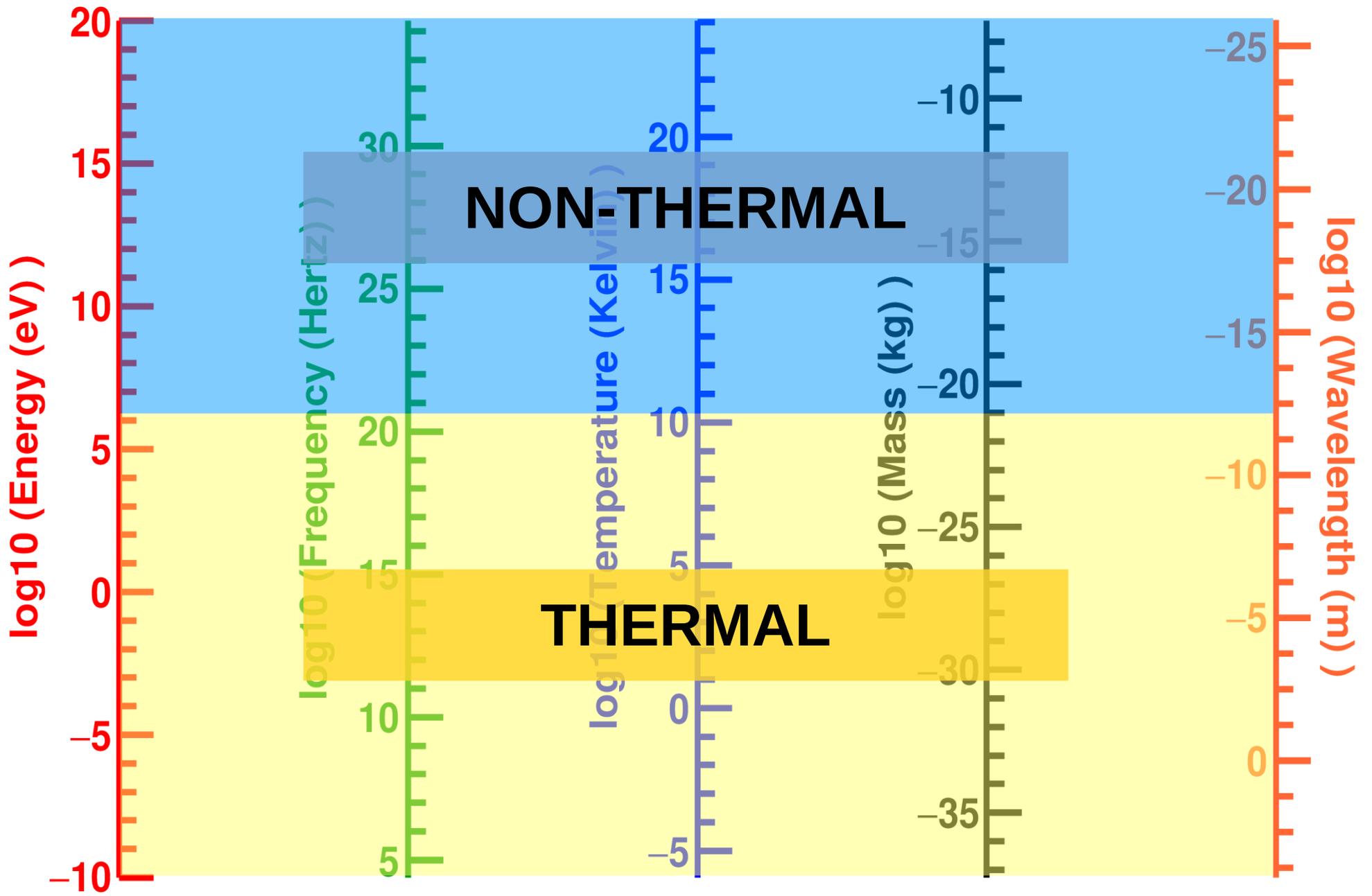
$$E \sim 100 \text{ eV} \Leftrightarrow \lambda \sim 10^{-8} \text{ m}$$



X-rays

$$E \sim 1500 \text{ eV} \Leftrightarrow \lambda \sim 10^{-9} \text{ m}$$

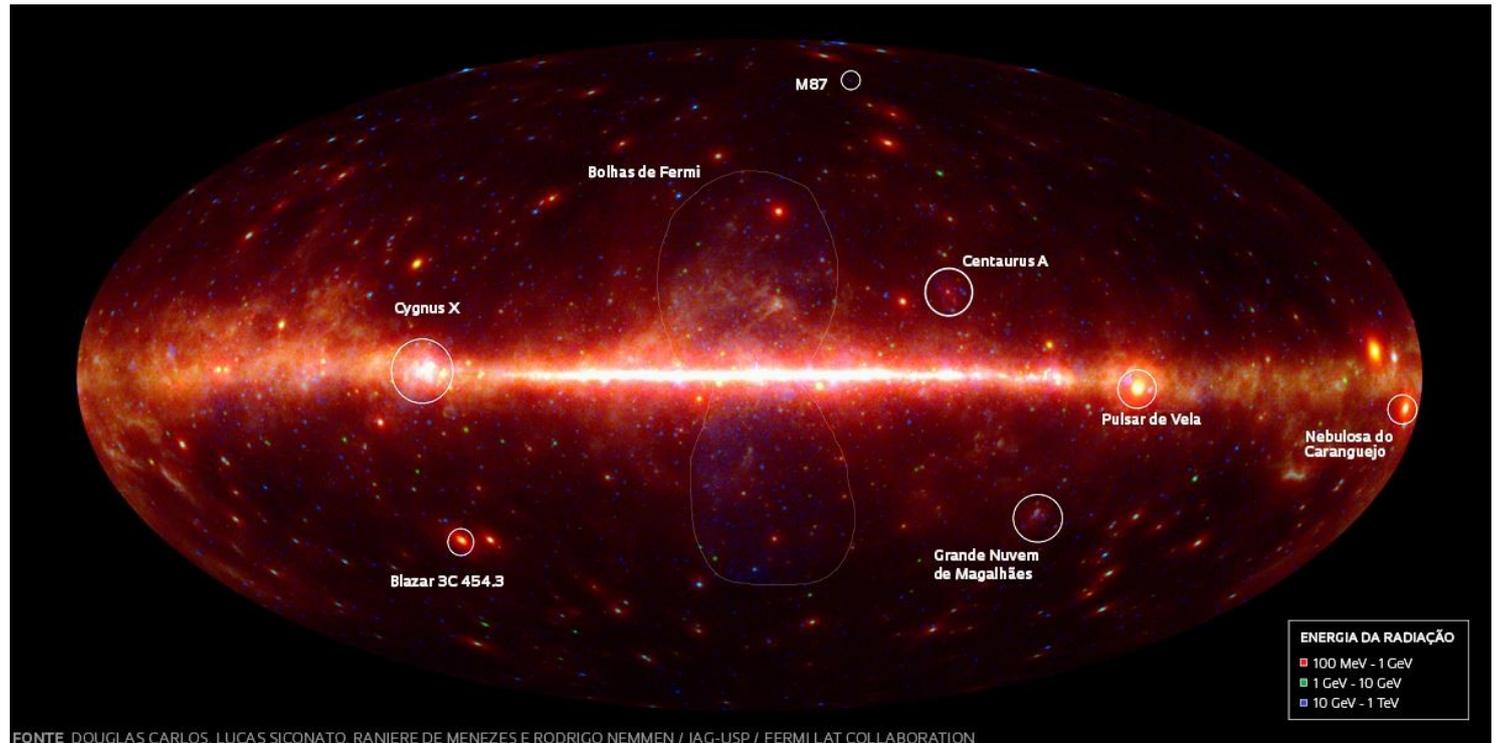
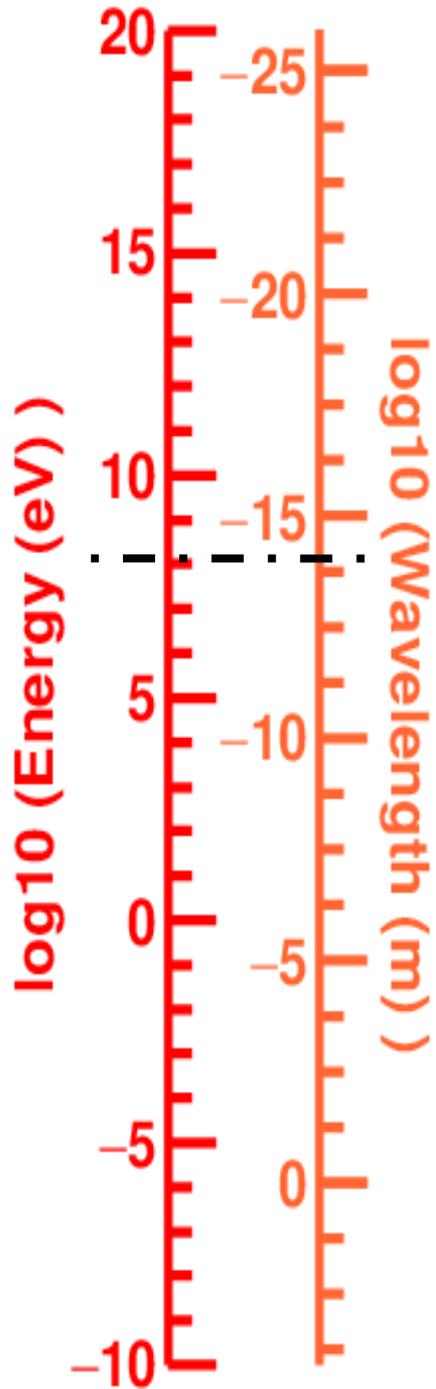


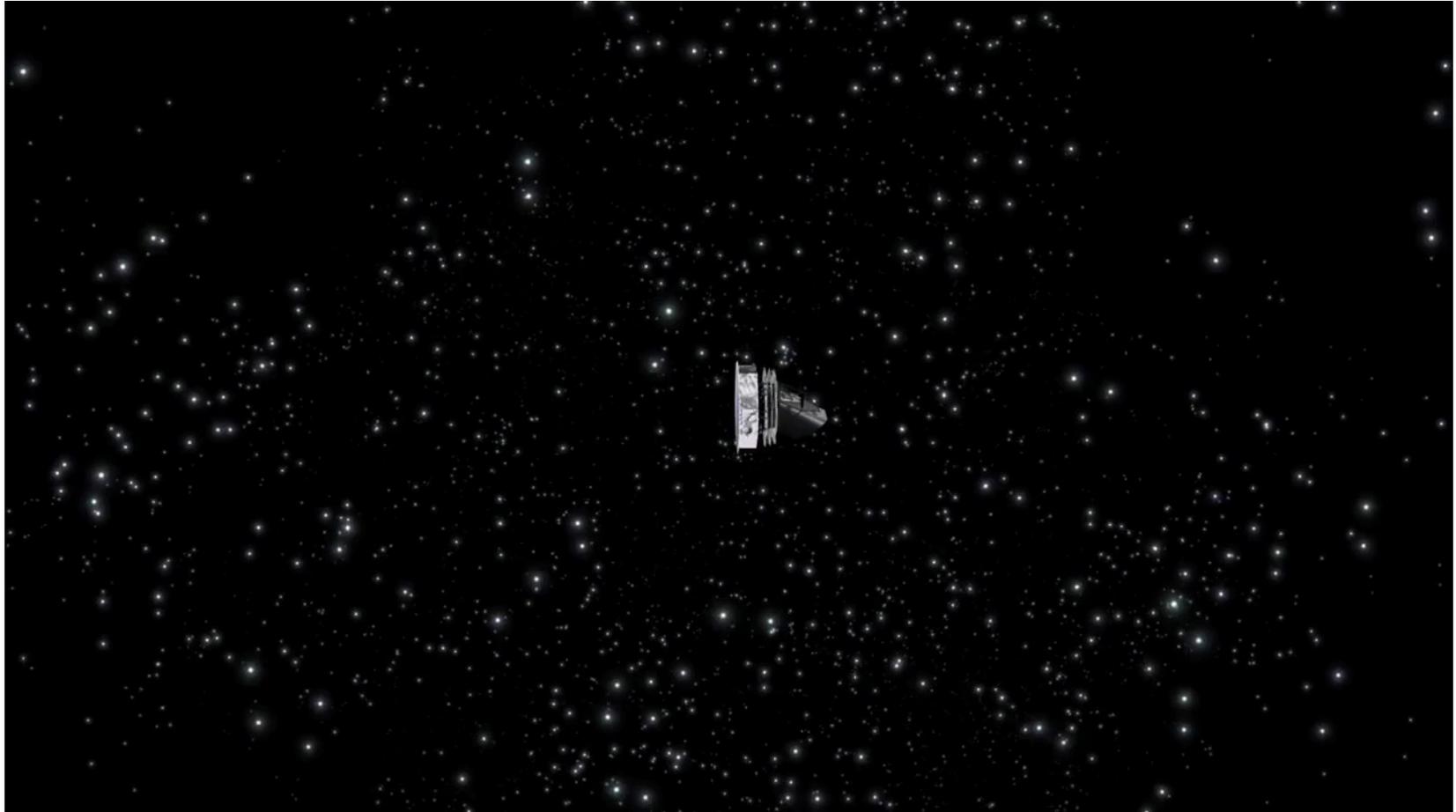




Gamma rays

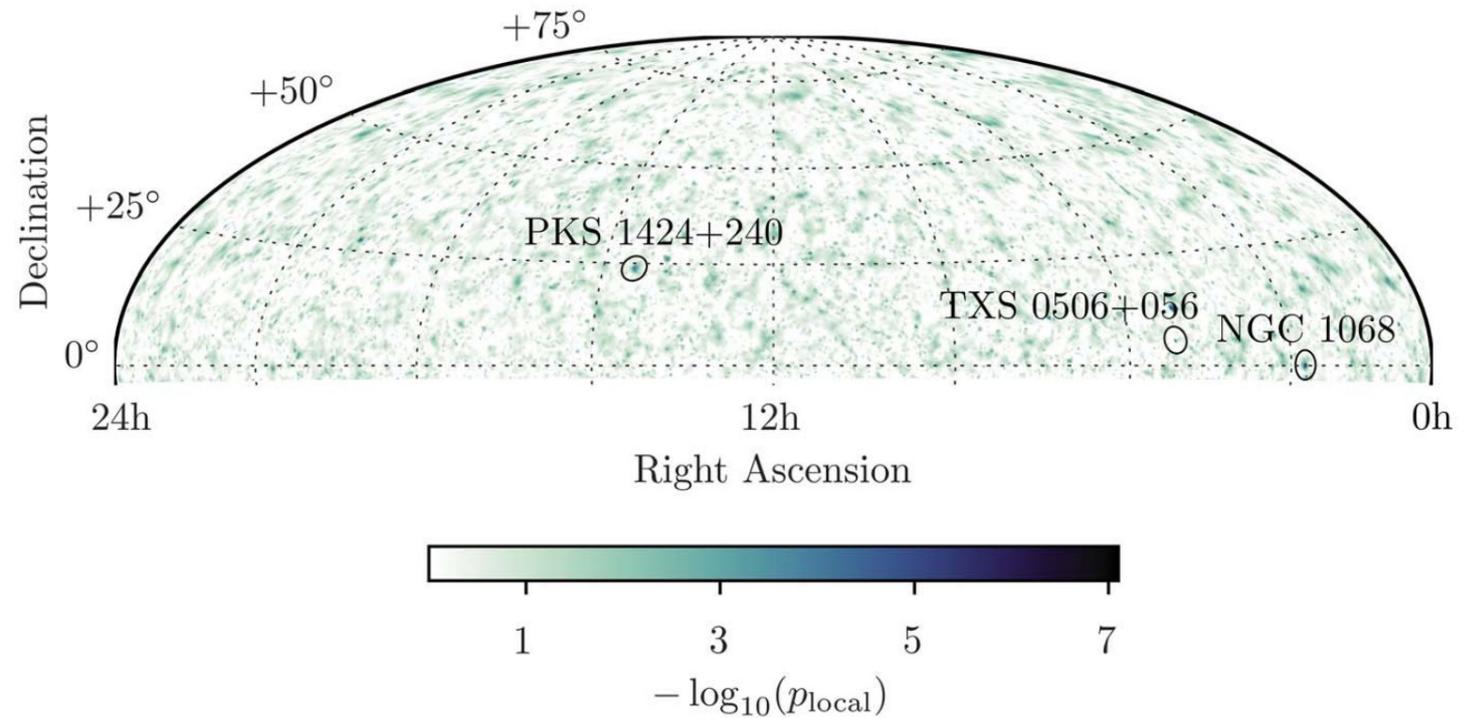
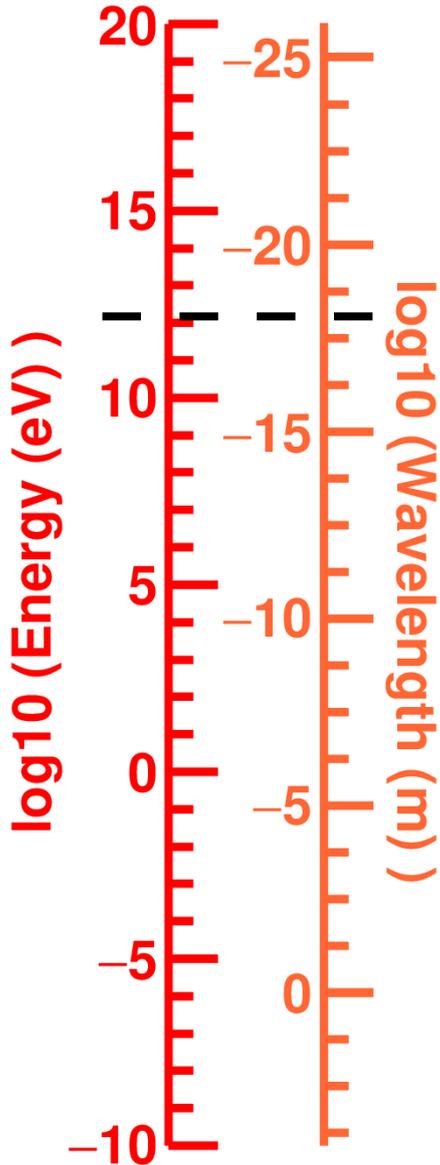
$$E > 10^8 \text{ eV} \Leftrightarrow \lambda < 10^{-14} \text{ m}$$





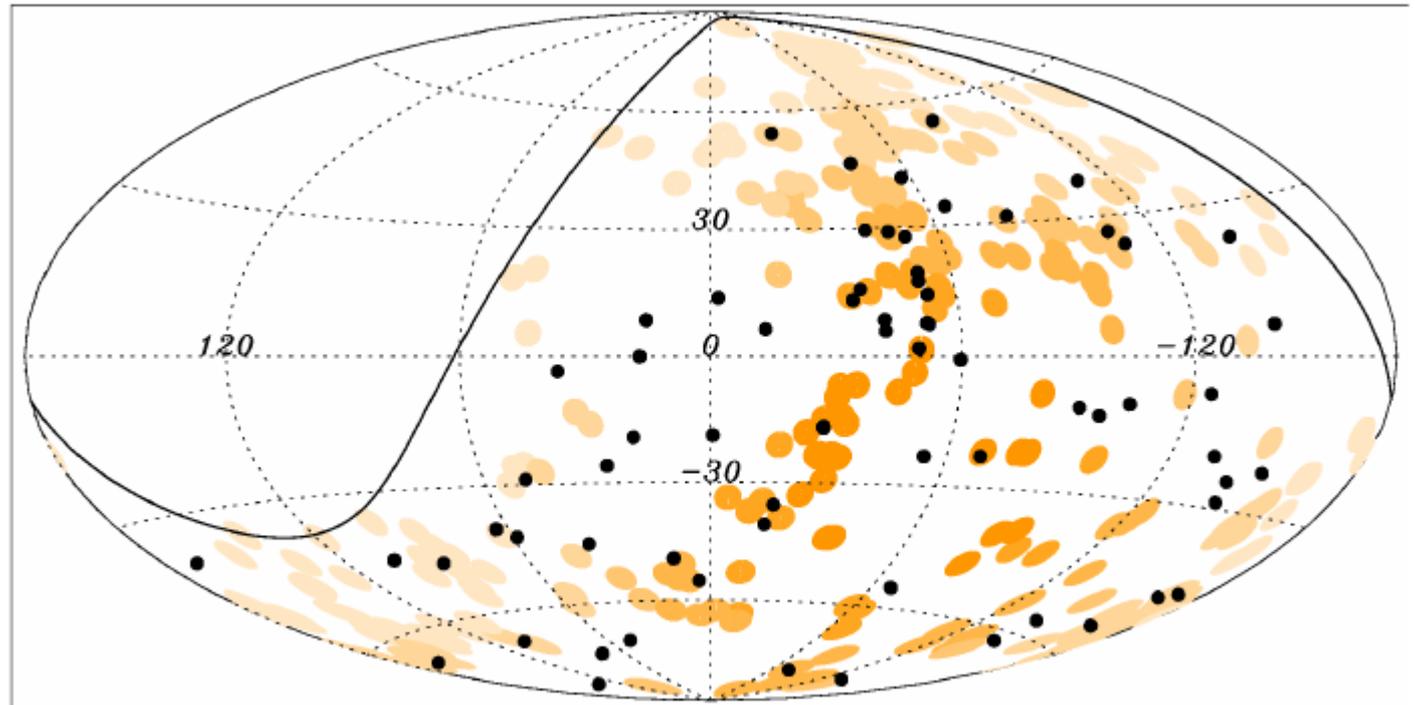
Neutrinos TeV

$$E > 10^{12} \text{ eV} \iff \lambda < 10^{-17} \text{ m}$$



Charged Particles

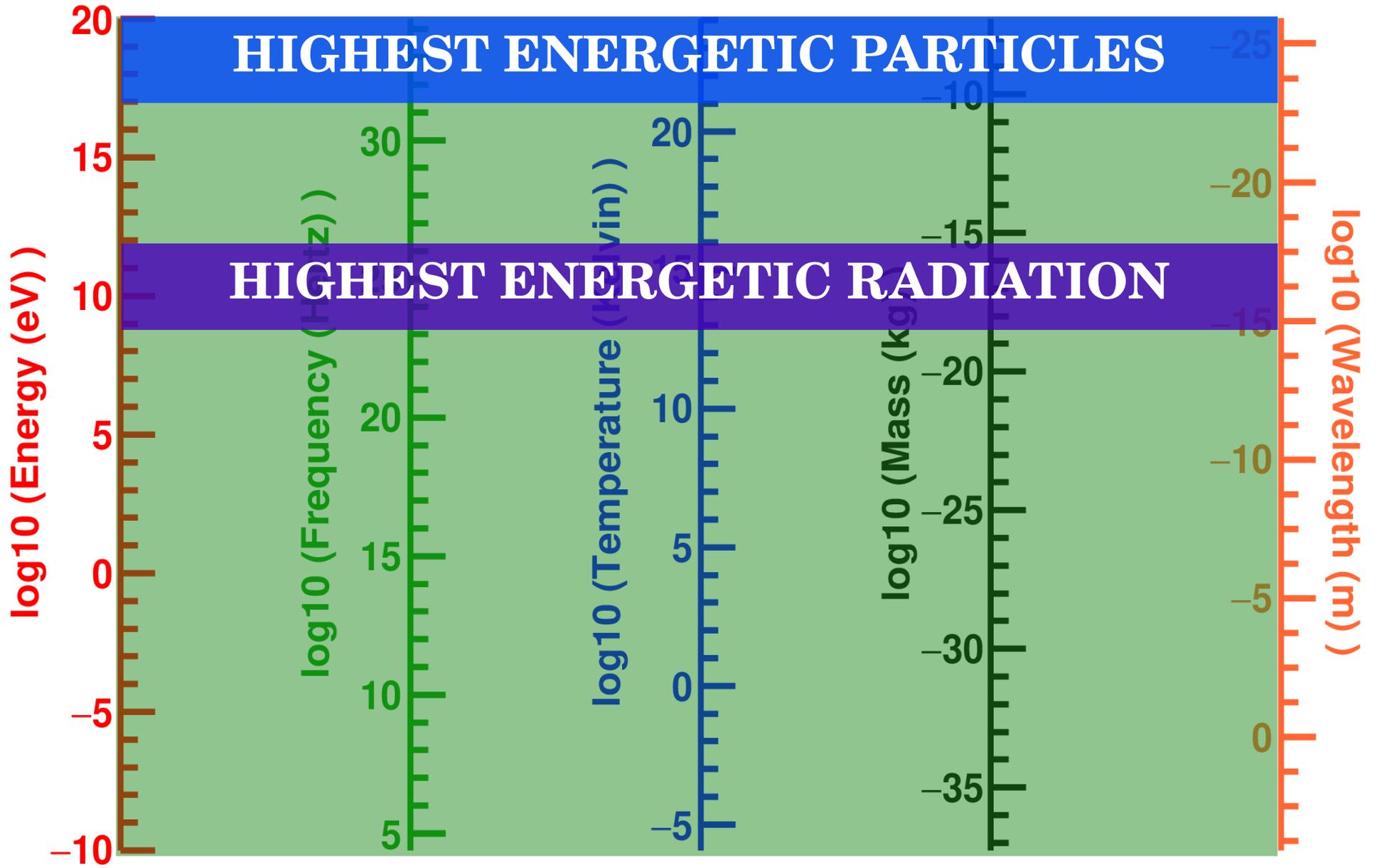
$$E > 10^{19} \text{ eV} \Leftrightarrow \lambda < 10^{-25} \text{ m}$$



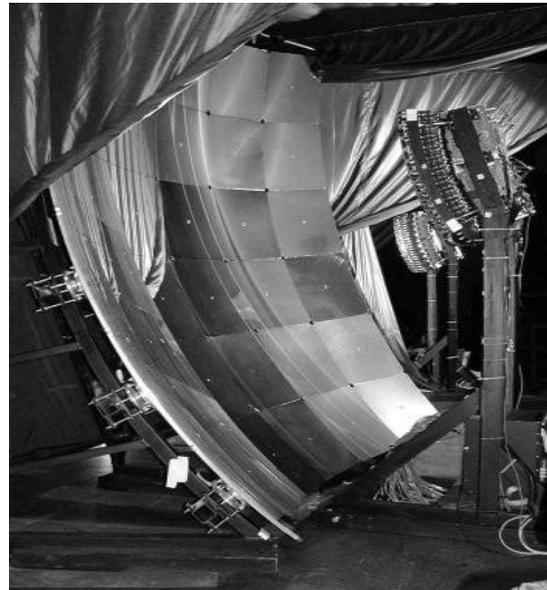
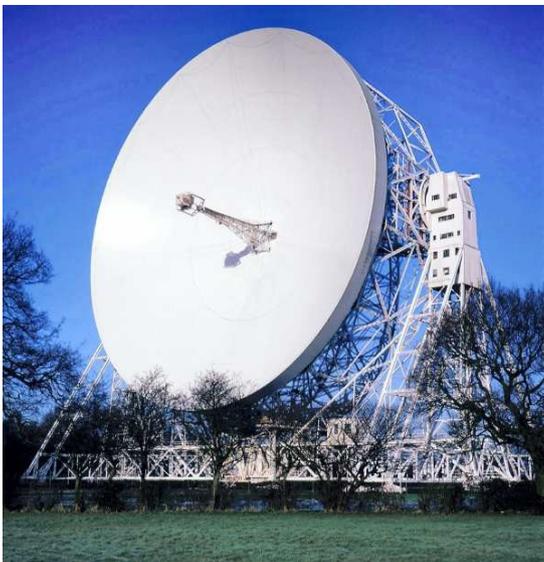
$$E > 10^{18} \text{ eV}$$

1 eV = 1.6×10^{-19} Joule

Pierre Auger Observatory



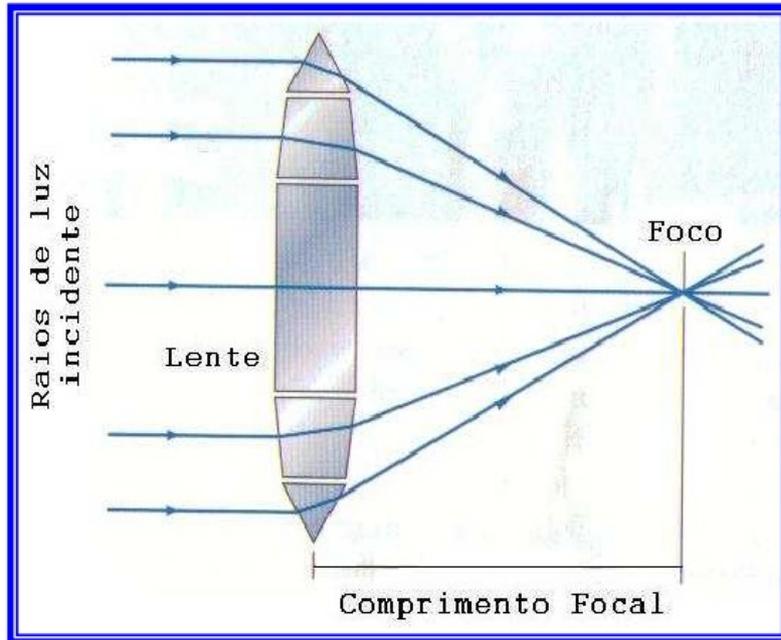
Telescópios



O que se deseja de um telescópio:

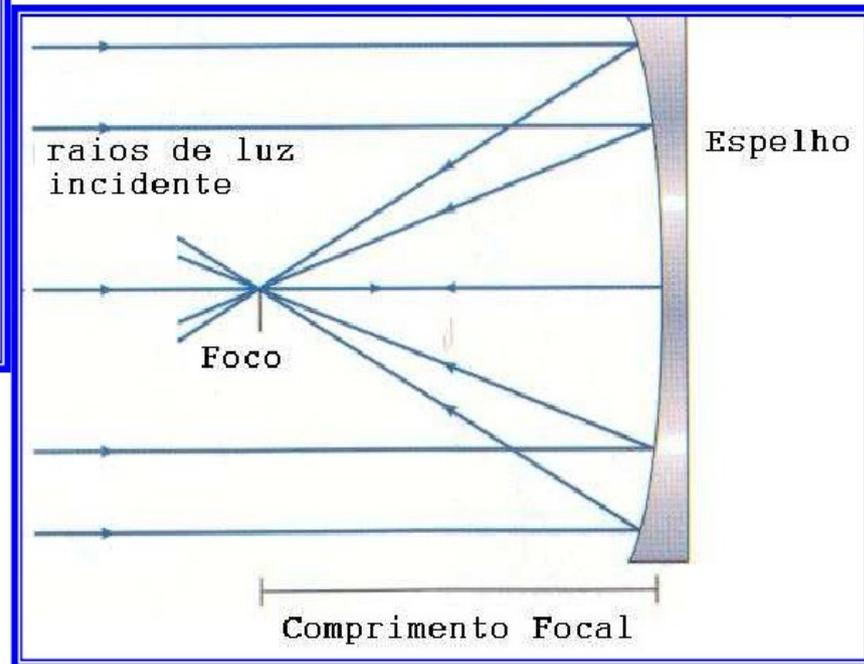
- Colete a maior quantidade possível de luz;
- Tenha boa resolução;
- Não distorça;
- Não seja absurdamente caro.

Refração e Reflexão da Luz



Telescópio refrator: usa lente para focalizar imagem do feixe

Telescópio refletor: usa um espelho curvo para concentrar o feixe de luz no foco

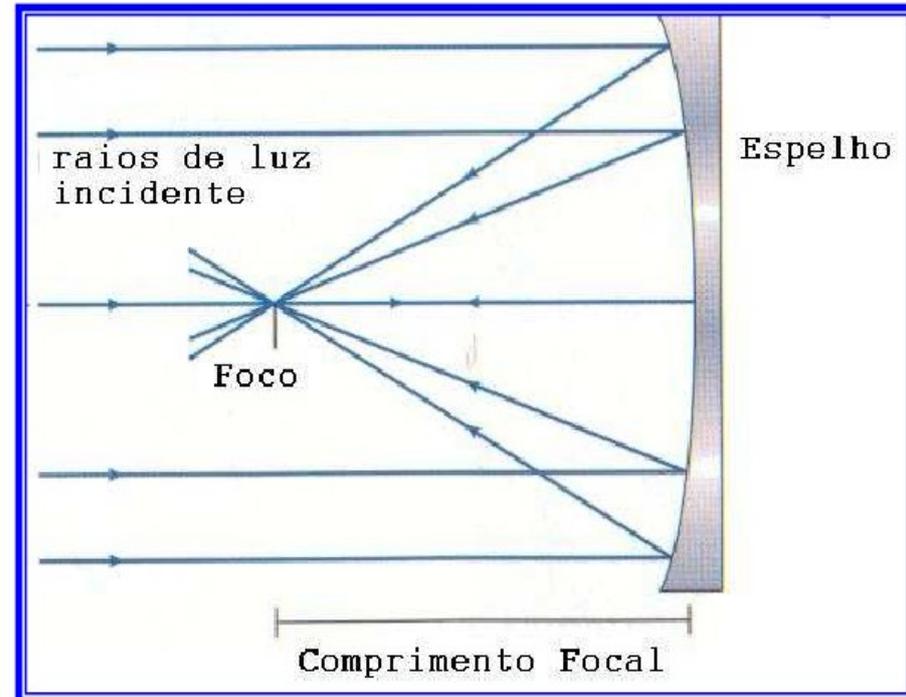


Conceitos Básicos

- Razão Focal:

$$f = F / D$$

→ comprimento focal / diâmetro do espelho

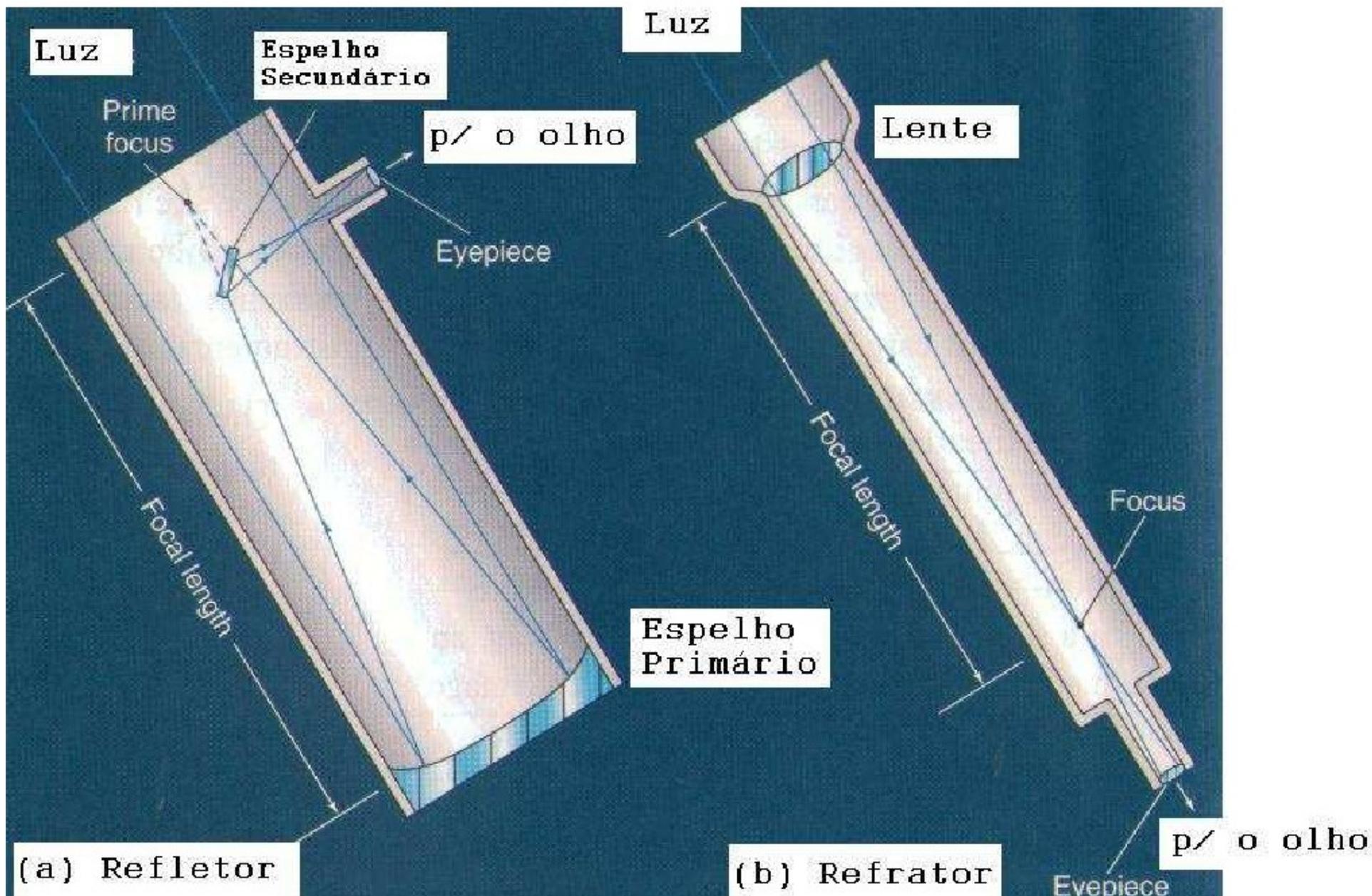


Ex. 1:
F=1m; D=20cm

$$\left. \begin{array}{l} \text{Ex. 1:} \\ F=1\text{m; } D=20\text{cm} \end{array} \right\} \frac{F}{D} = \frac{1}{0,2} = 5$$

Notação $R_f = "f/5"$

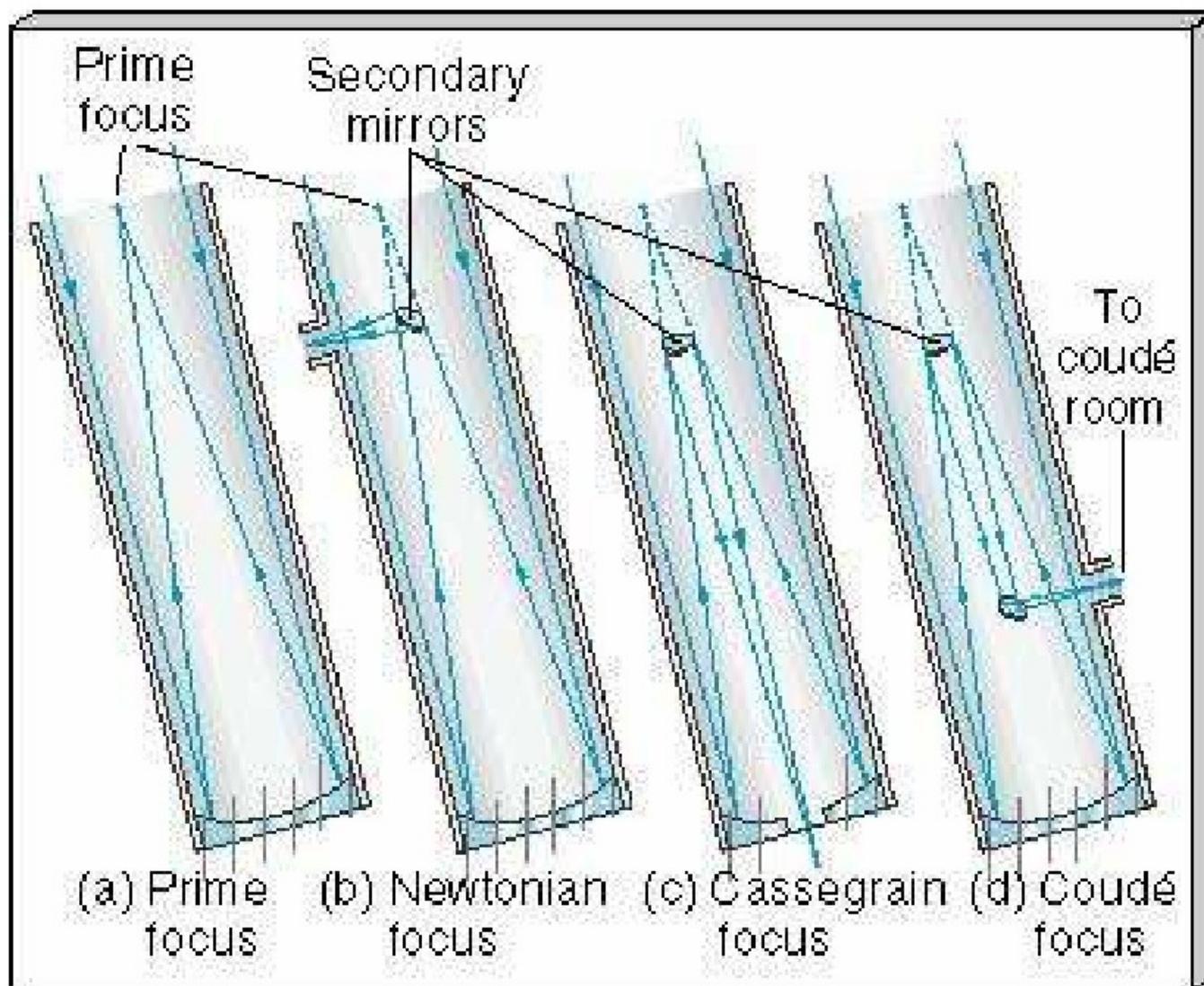
Tipos de Telescópios



Desvantagens de Telescópios Refratores

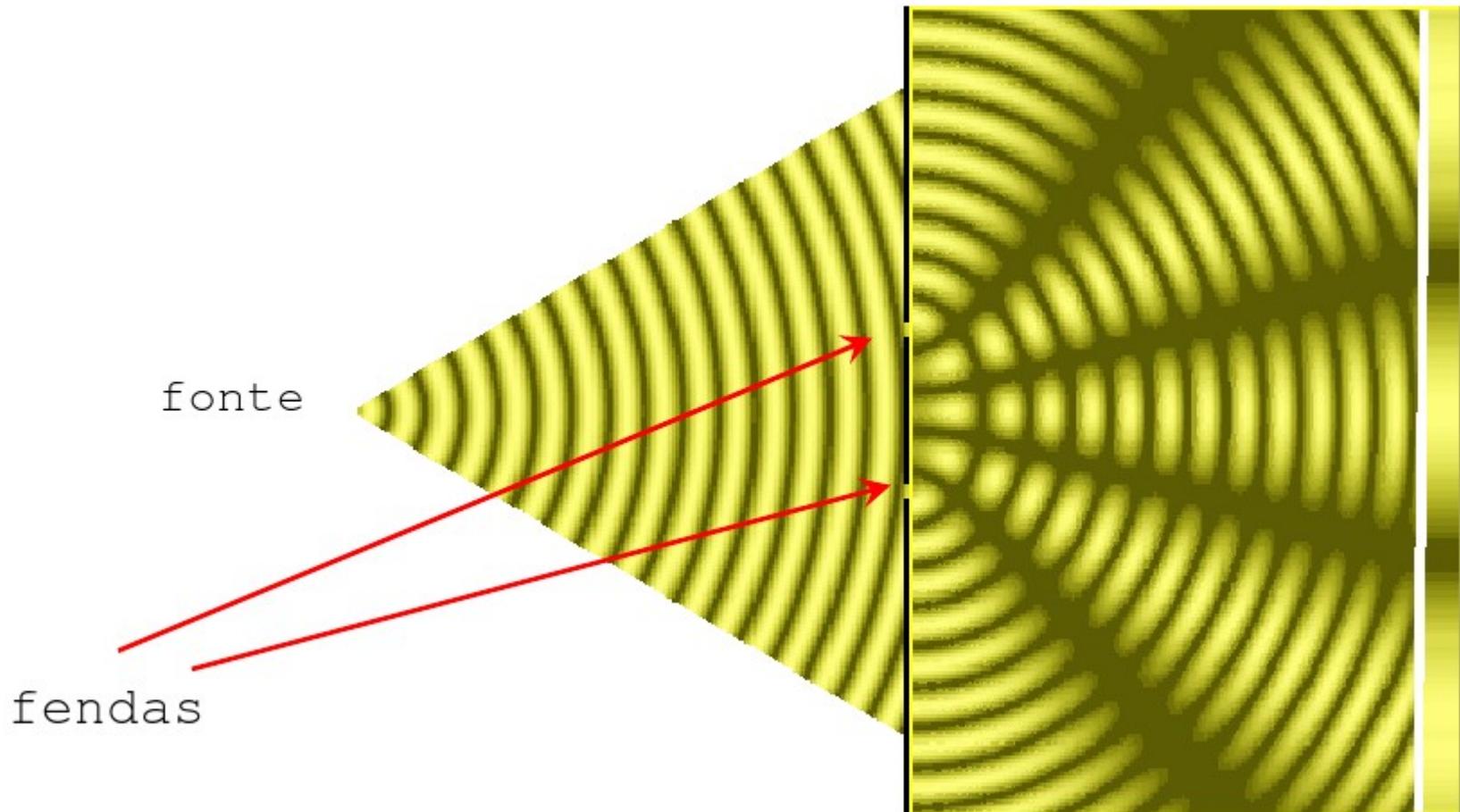
- Não é possível fazer uma estrutura de sustentação que apoie lentes,
- As lentes decompõem a luz -> Aberração cromática
- Lentes tem duas faces o que encarece a fabricação

Telescópios Refletores



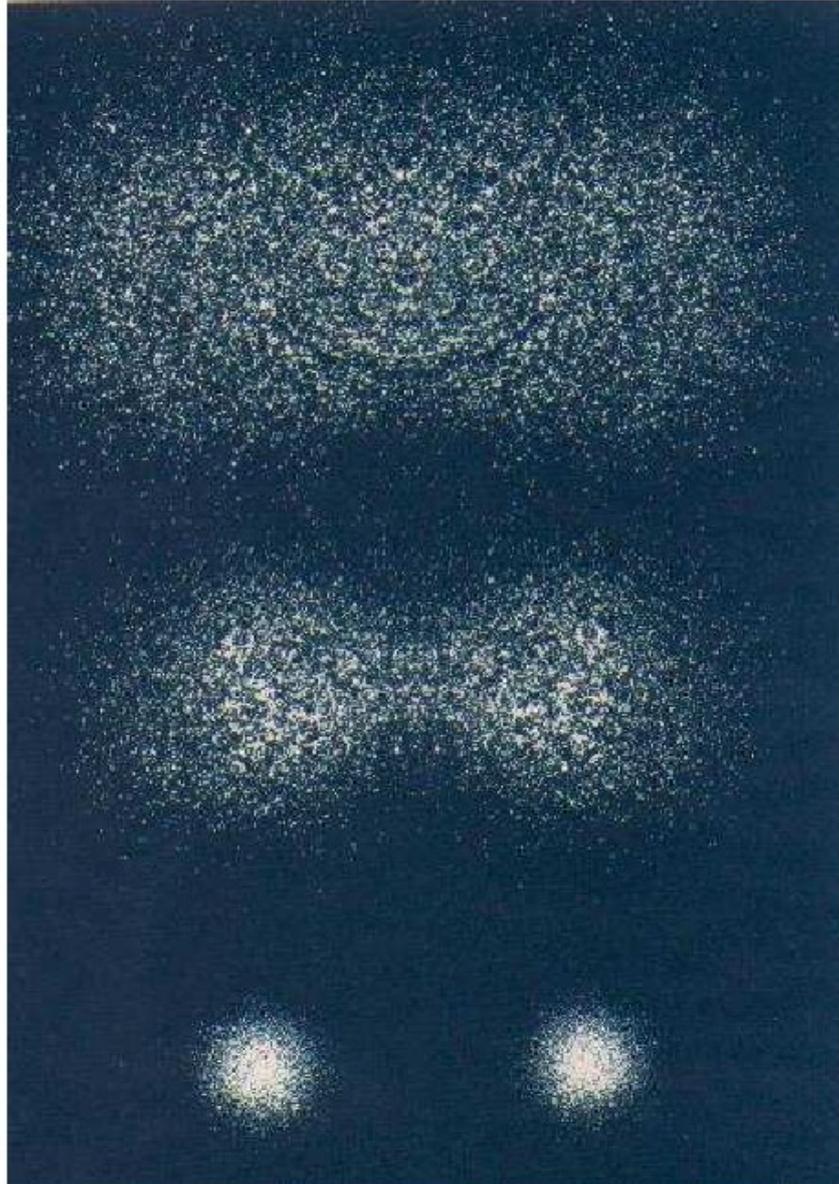
Principais tipos de focos utilizados na construção de telescópios refletores.

Difração: Problema 1



Largura do Primeiro Máximo é : $\theta = \lambda/D$

Difração



Difração

10'



(a)



(b)

1'

5"



(c)



(d)

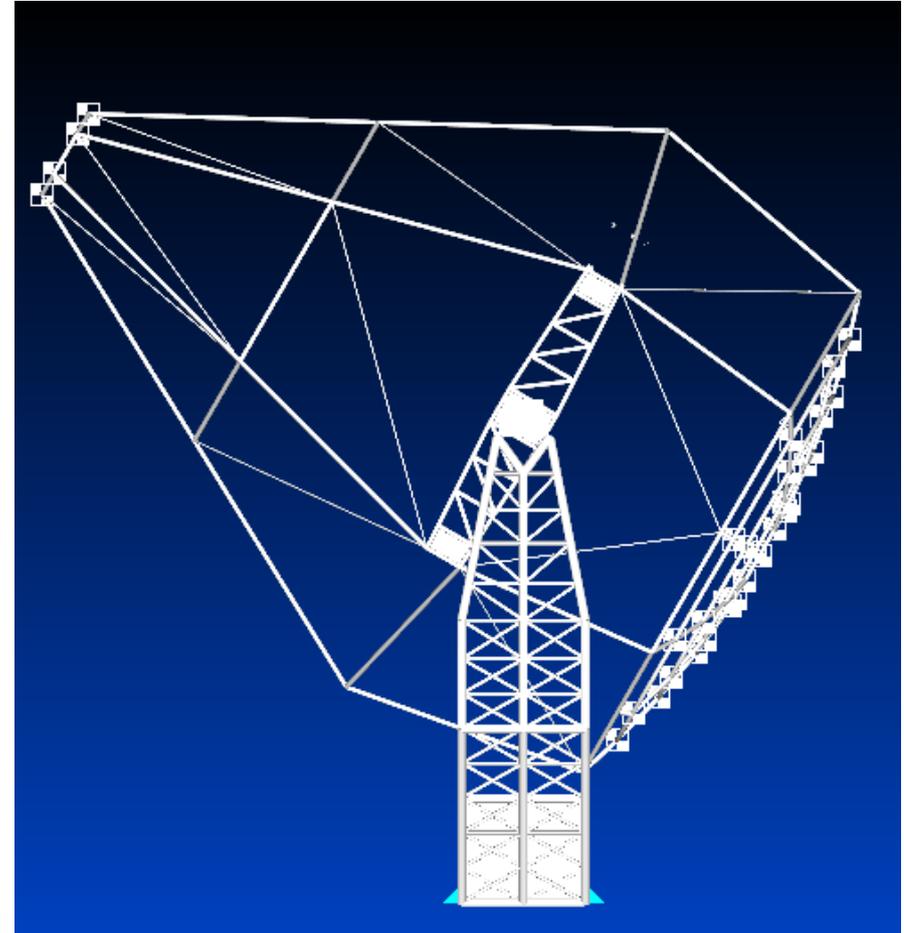
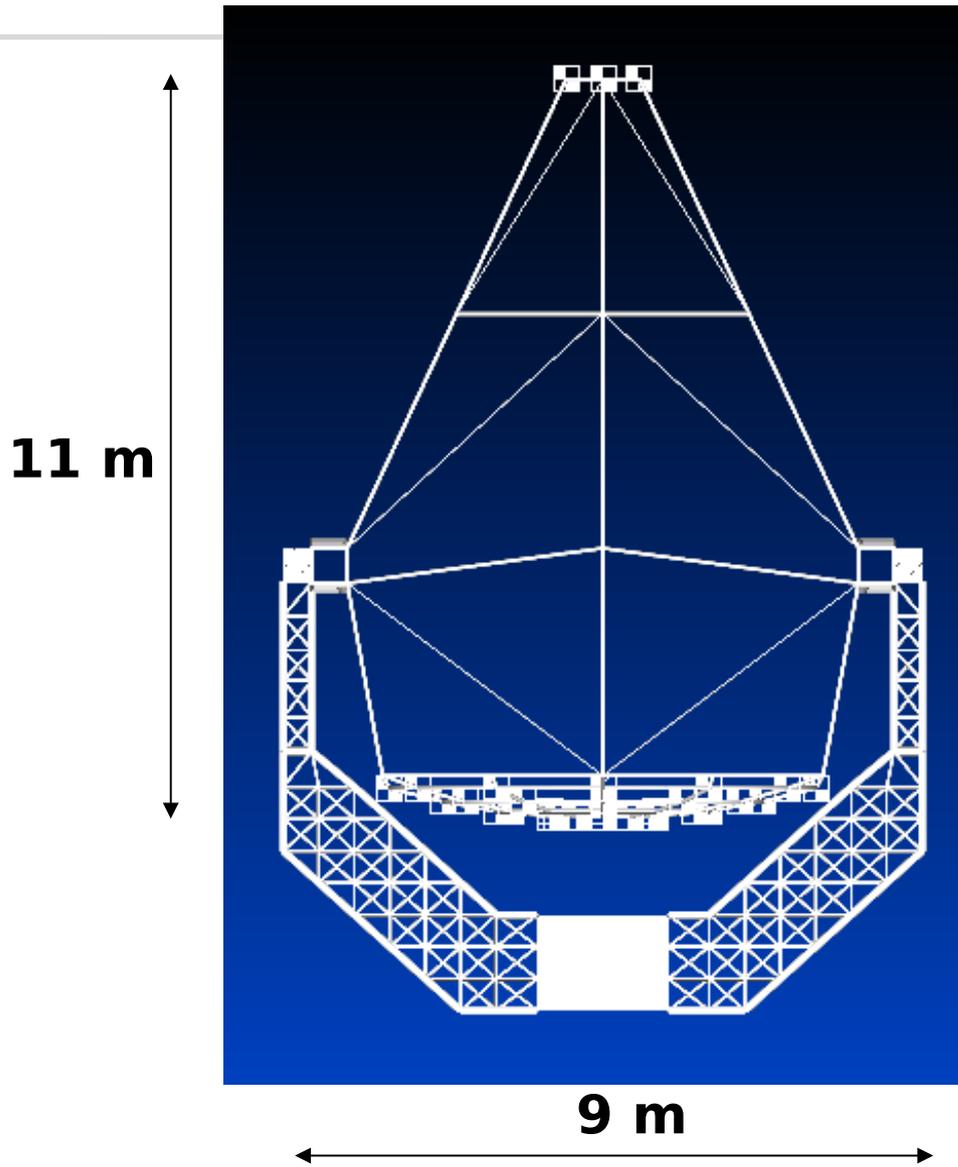
12"

Galáxia de Andrômeda

Optica perfeita: Problema 2

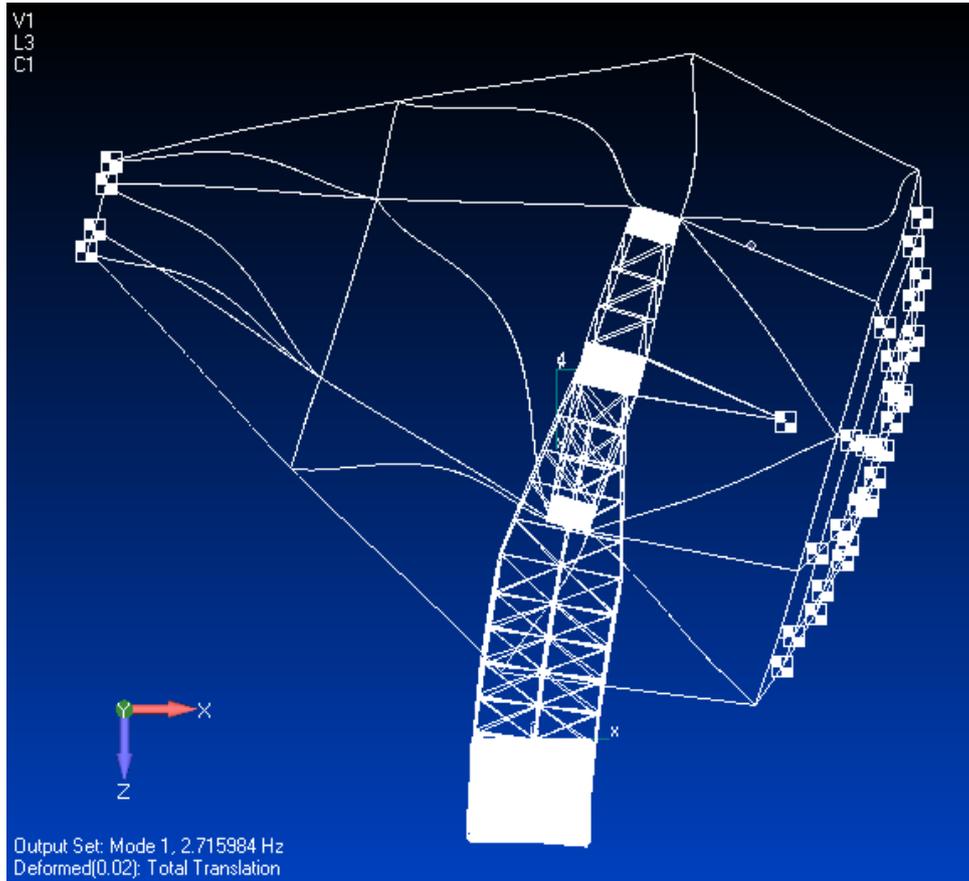
- Fabricação de espelho
- Construção de estruturas

Imágenes del diseño del telescopio de 6m

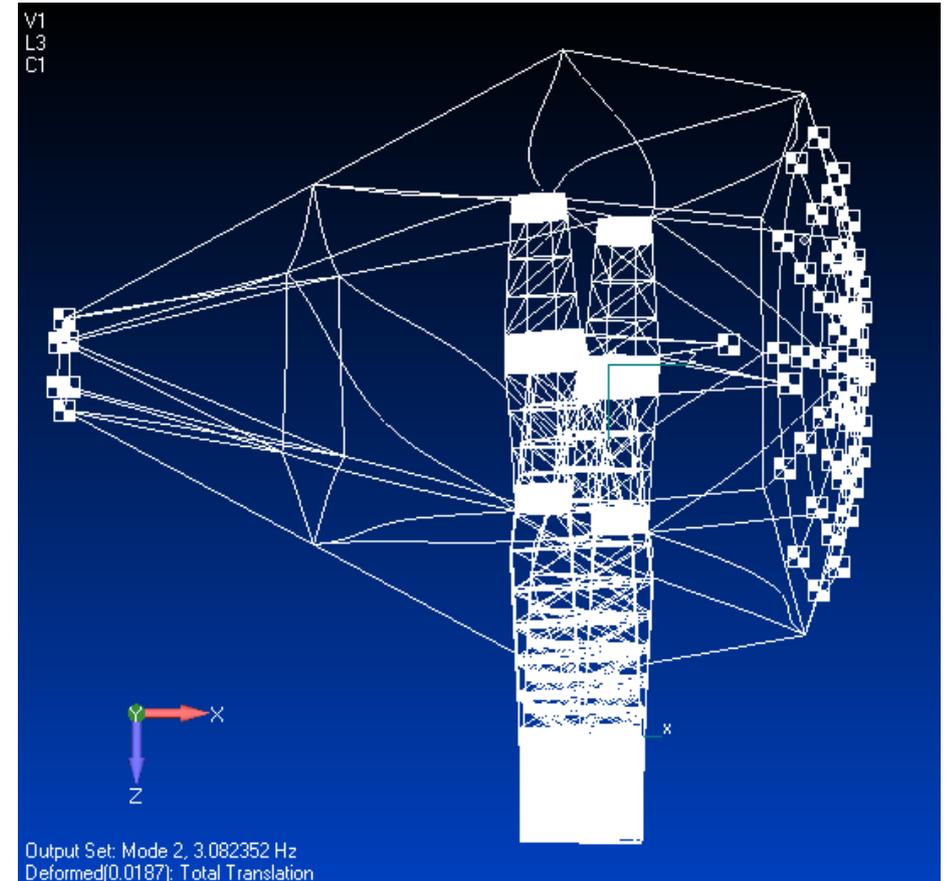


Análisis Estructural - Resultados

- Análisis Modal



1er modo - 2.7Hz



2do modo - 3Hz

Análisis Estructural - Resultados

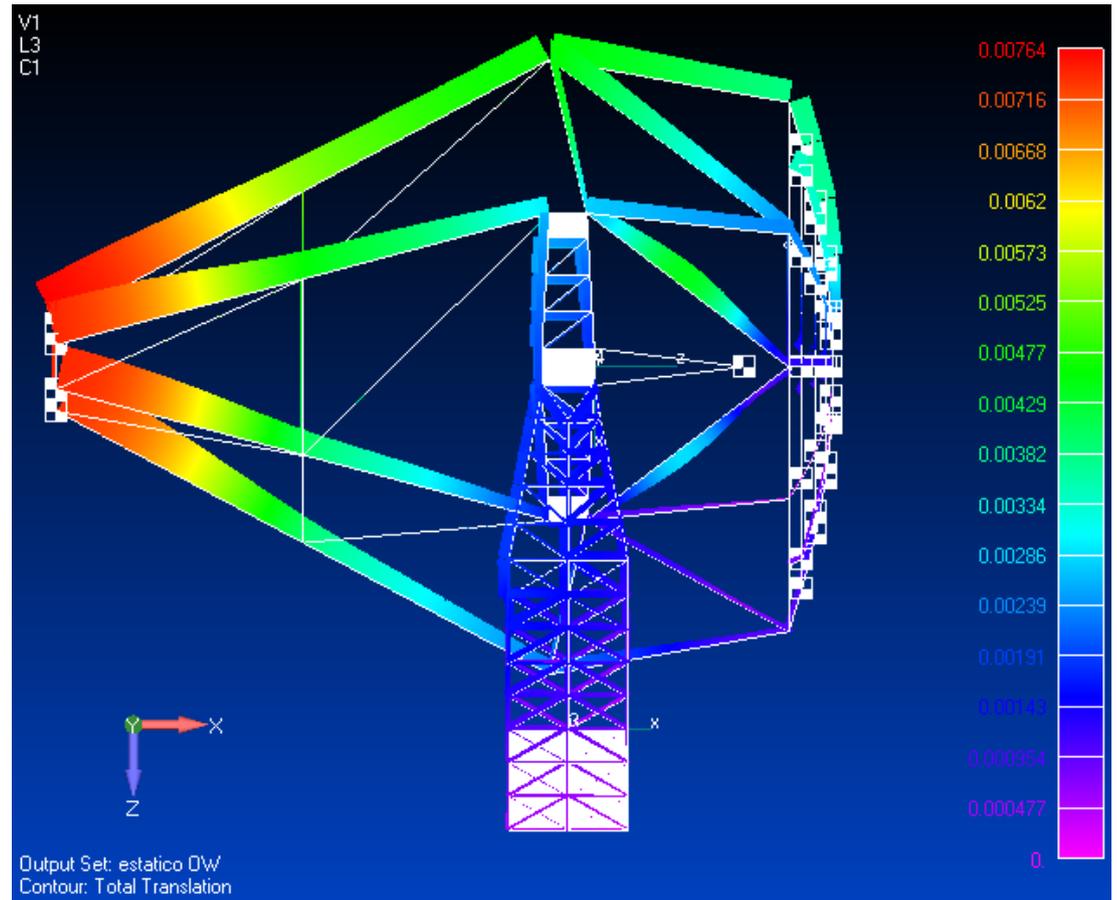
- Análisis Estático Lineal Elástico (Tensiones Y deformaciones)

LC	Analysis type	Load	Elevation	Max Stress [MPa]	$\delta C[m]$	$\delta C[m]_x$	$\delta C[m]_y$	$\delta C[m]_z$	$\delta M[m]$	$\delta M[m]_x$	$\delta M[m]_y$	$\delta M[m]_z$
1	Static	OW	0°	58	7.7E-03	-1.3E-03	6.3E-06	7.6E-03	3.7E-03	-3.7E-03	5.9E-06	7.1E-05

$\delta C[m]$ Camera maximum displacement
 $\delta M[m]$ Mirror maximum displacement

OW own weight

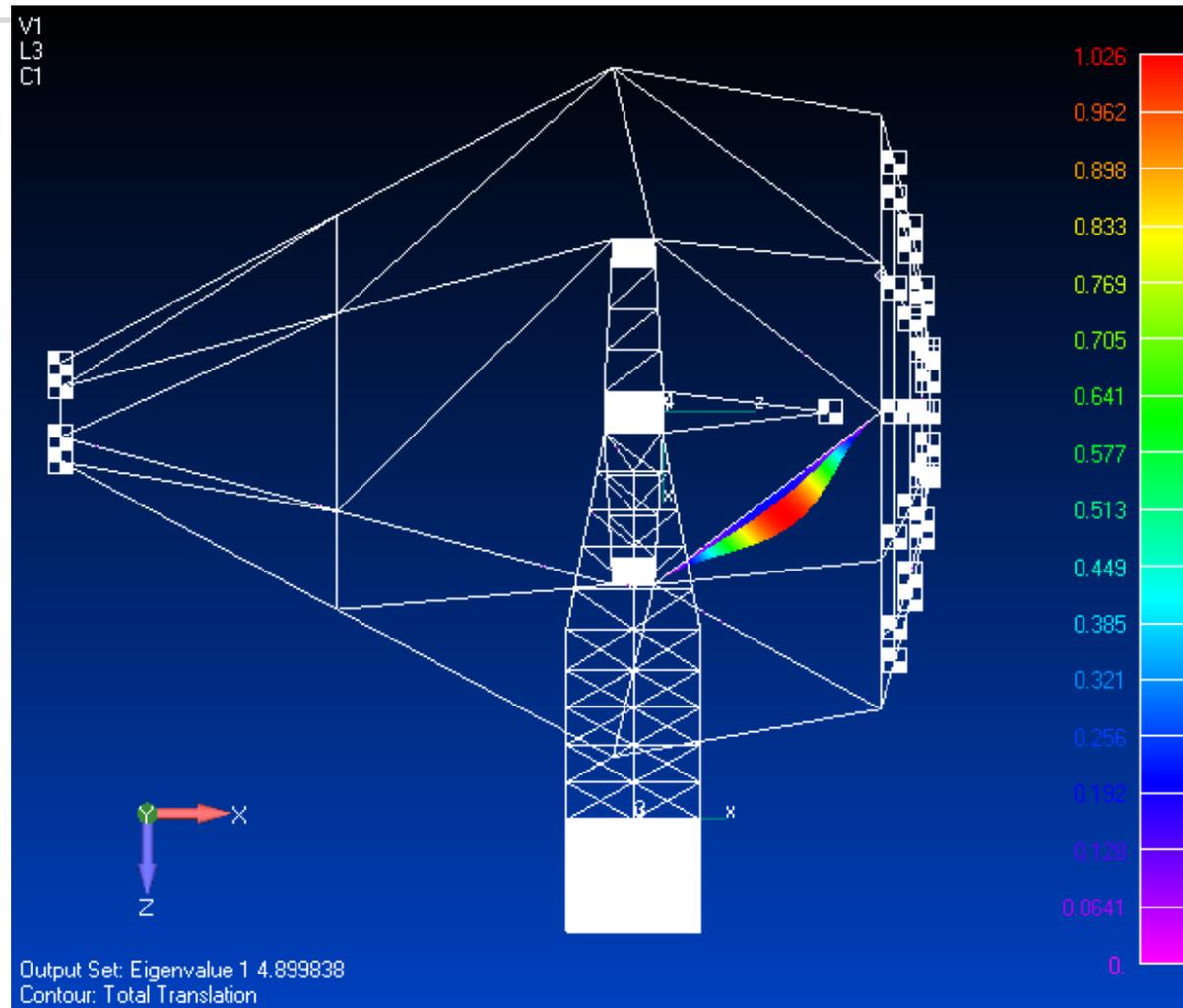
Elevation support	7294	Kgf
Azimuth support	4791	Kgf



LC:1 - Desplazamiento Total

Structural analysis - Results

- Análisis de Pandeo



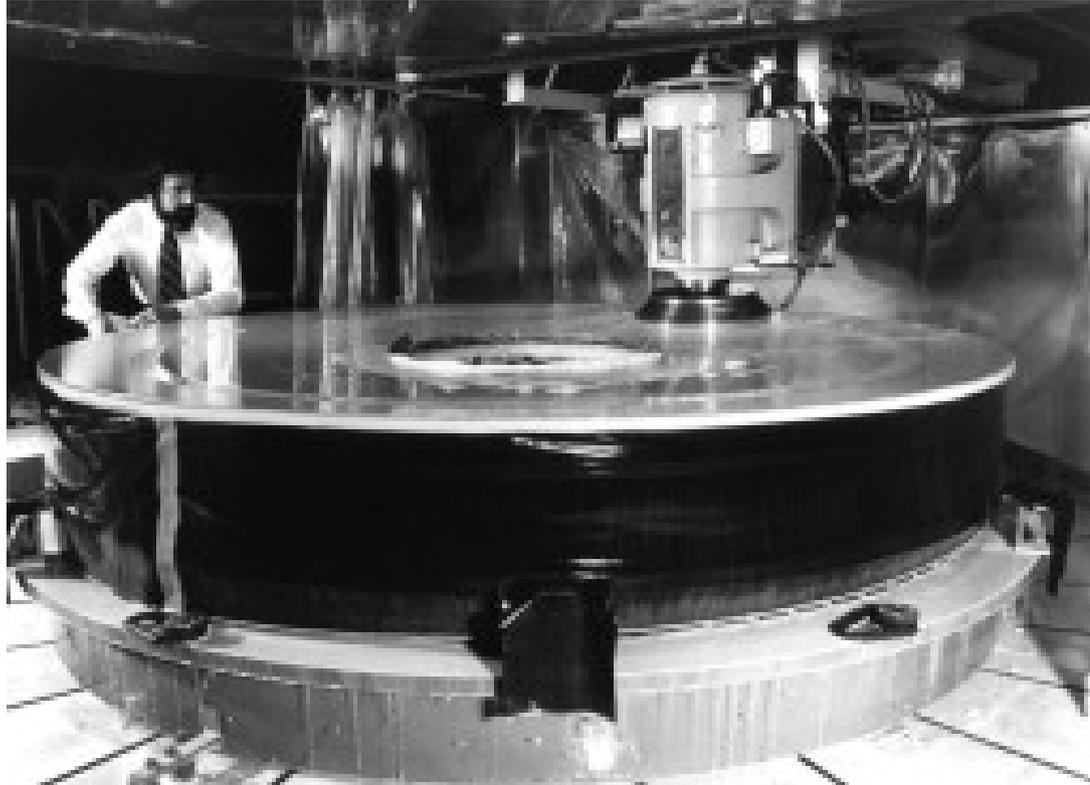
1er autovalor (0° elevation)

Óptica adaptativa



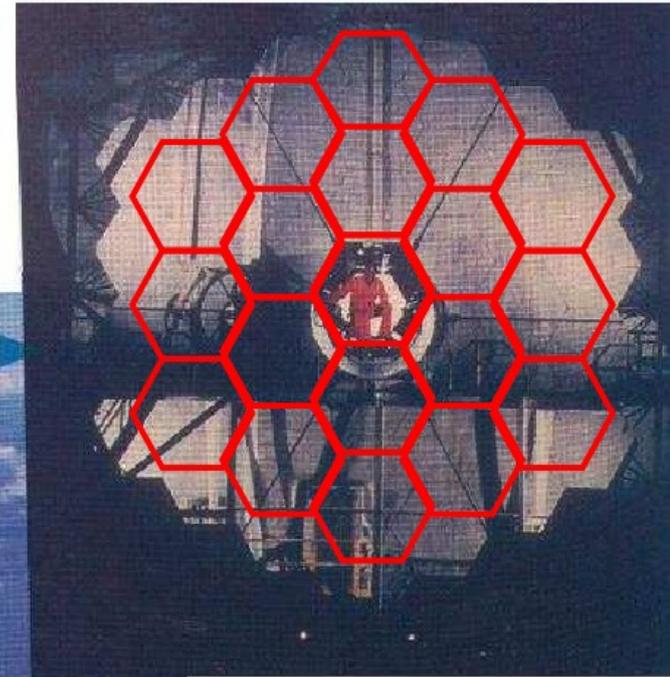
Atua sobre o espelho primário e corrige deformações a cada segundo.

Espelhos



Observatório Mauna Kea

(a)

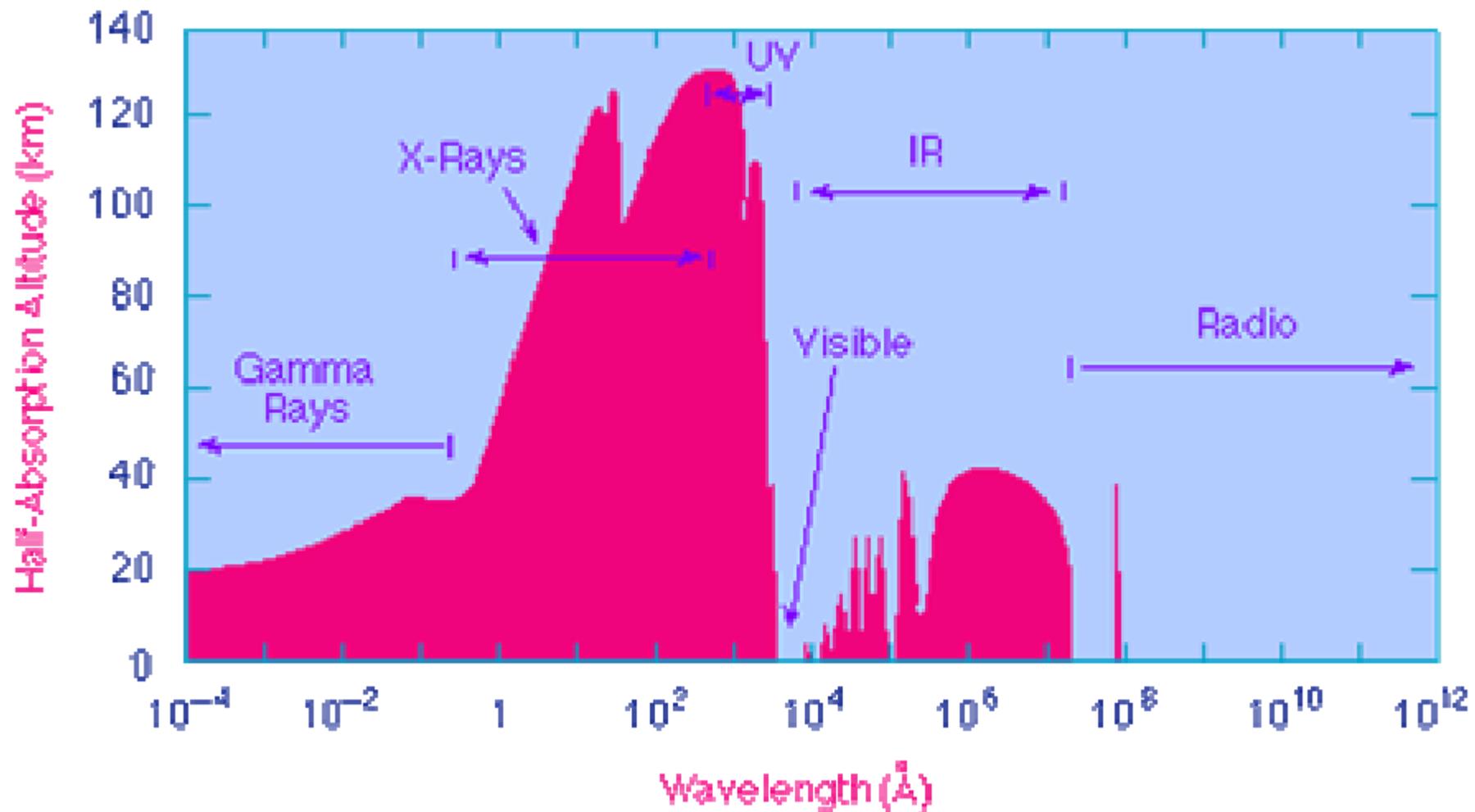


(b)

(a) Observatório localizado no Havaí (4 km altitude). Os domos abrigam telescópios diferentes.

(b) Destaque para o **telescópio Keck de 10 m de diâmetro**: composto de um **mosaico de espelhos hexagonais** (Note o técnico no centro)

Problema 3: Atmosfera





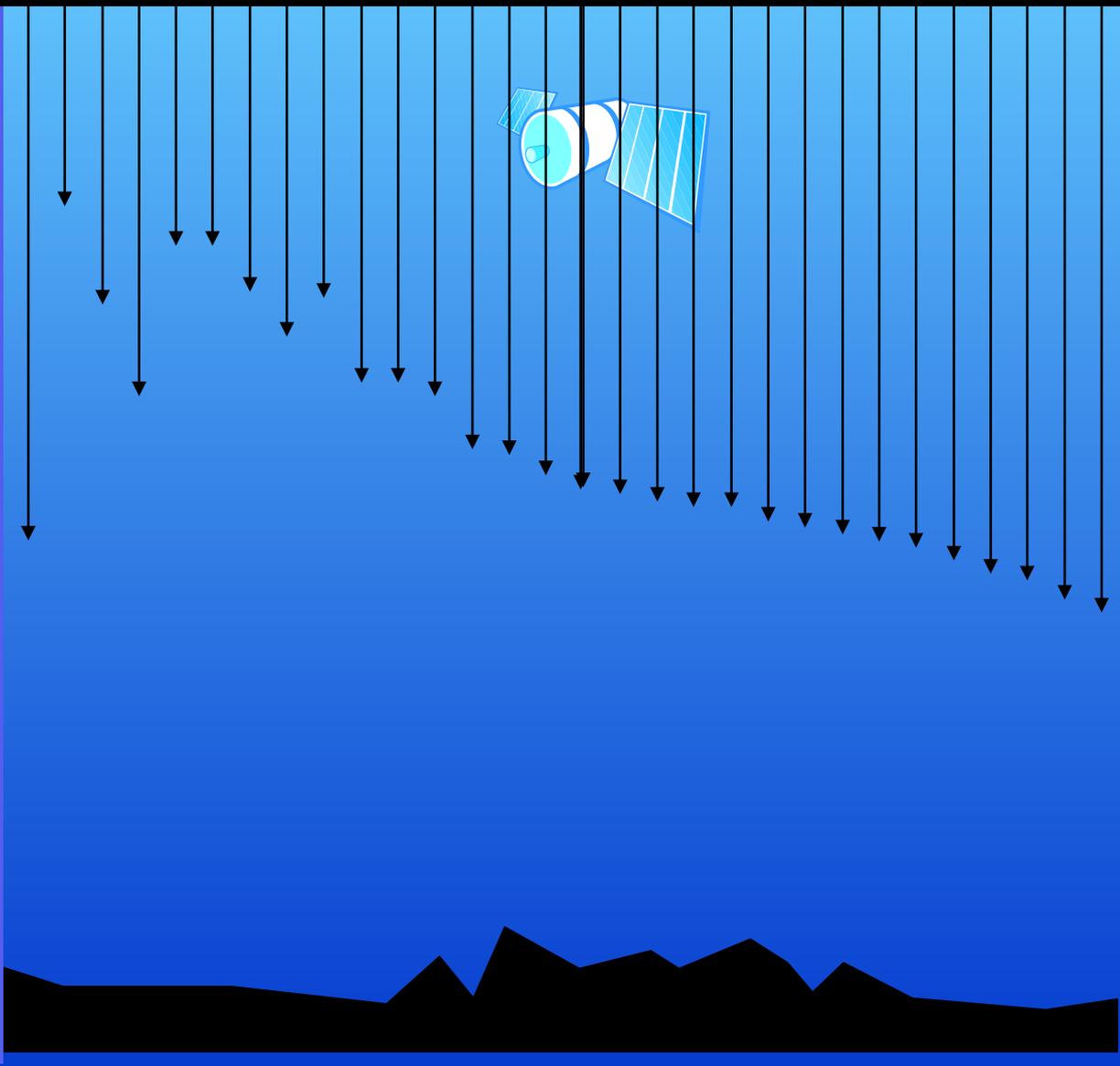
Radio mm IR 0 UV X-rays γ -rays γ -rays
HE VHE

500 km

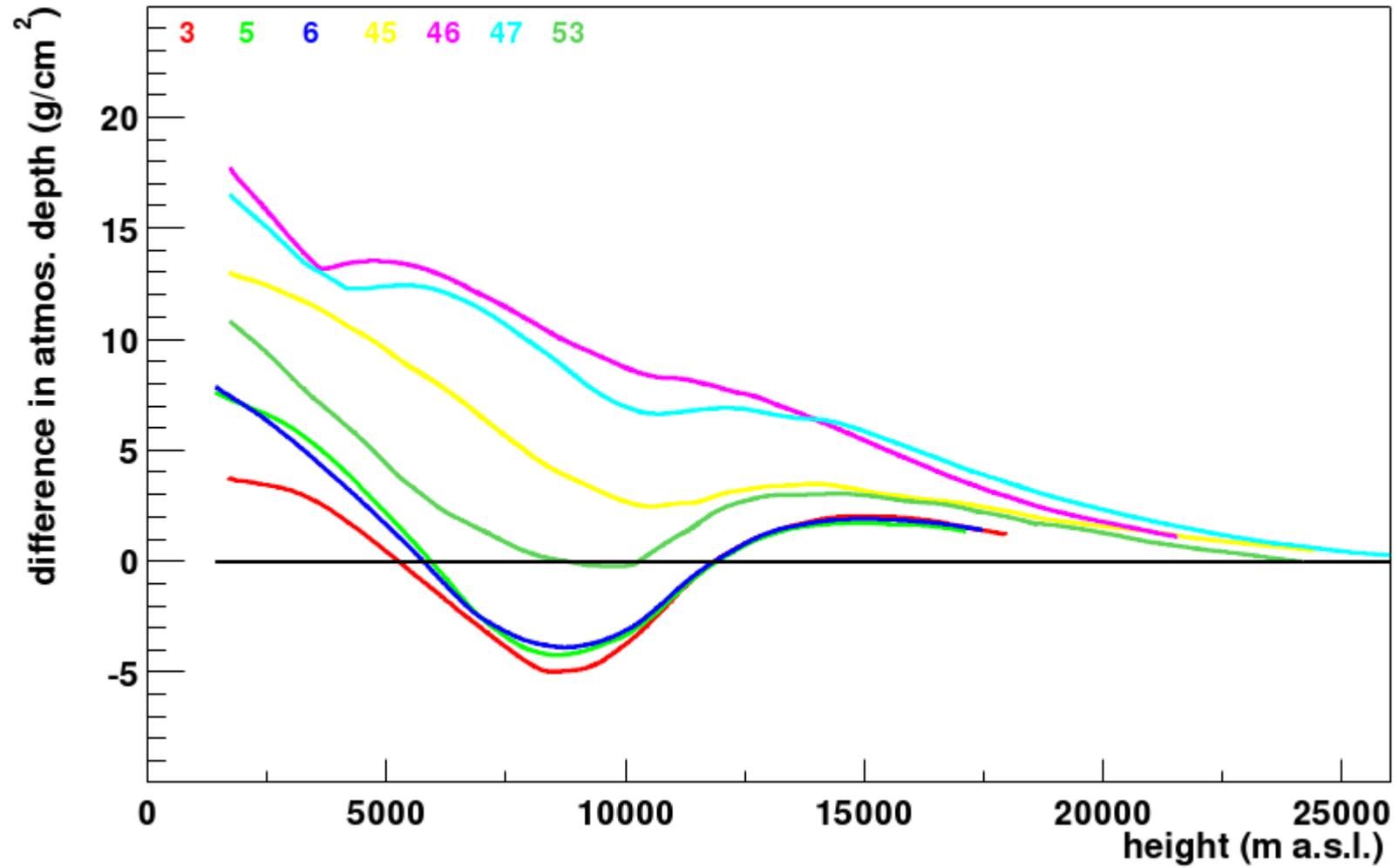
100 km

10 km

0 km



Atmosfera Muda



Óptica Ativa



Verifica-se a atmosfera com um disparo de laser.
Modifica-se a estrutura dos espelhos com atuadores mecânicos de forma a corrigir as distorções do laser devido a irregularidades da atmosfera.

Óptica Ativa



(b)

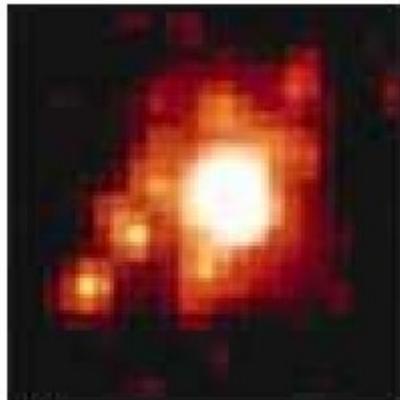


Estrela Procyon

Hubble



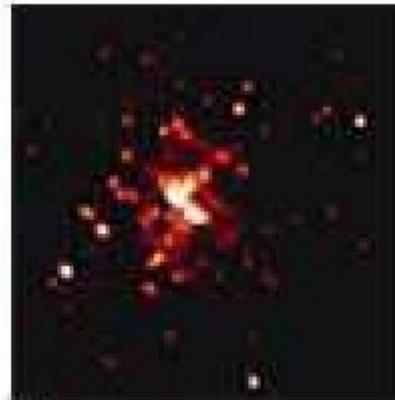
Hubble



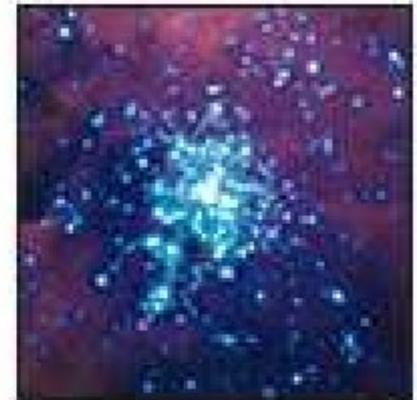
(a)



(b)



(c)



(d)

Um aglomerado na Nuvem de Magalhães visto por:

a) Um telescópio de 1 m na superfície terrestre

b) Pelo Hubble antes do reparo

c) Pelo Hubble depois do reparo

d) Pelo Hubble após tratamento computacional da imagem

Hubble x Webb





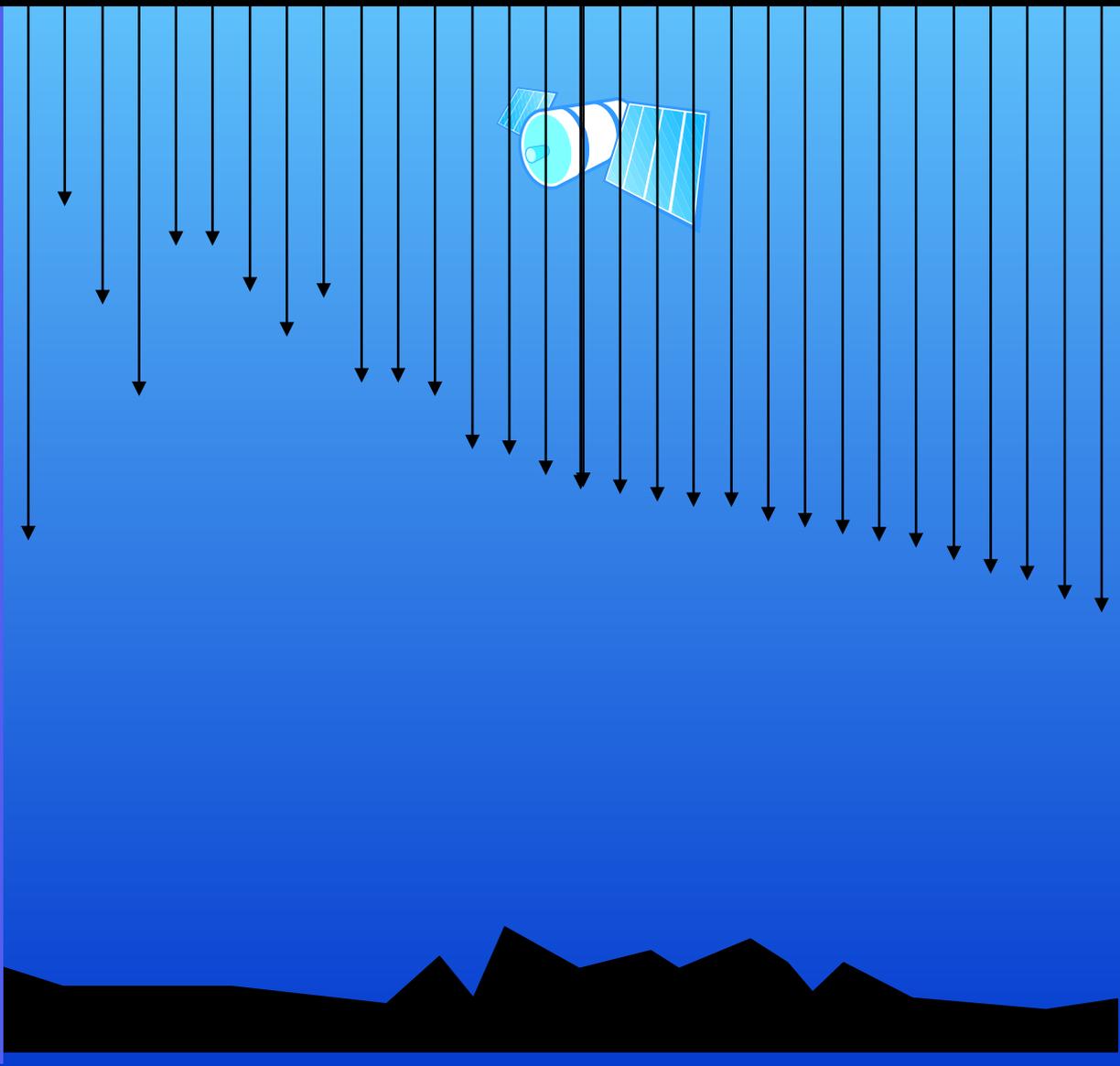
Radio mm IR 0 UV X-rays γ -rays γ -rays
HE VHE

500 km

100 km

10 km

0 km



Telescópios de Radio



Reber's first "dish radio telescope - Wheaton, IL 1937

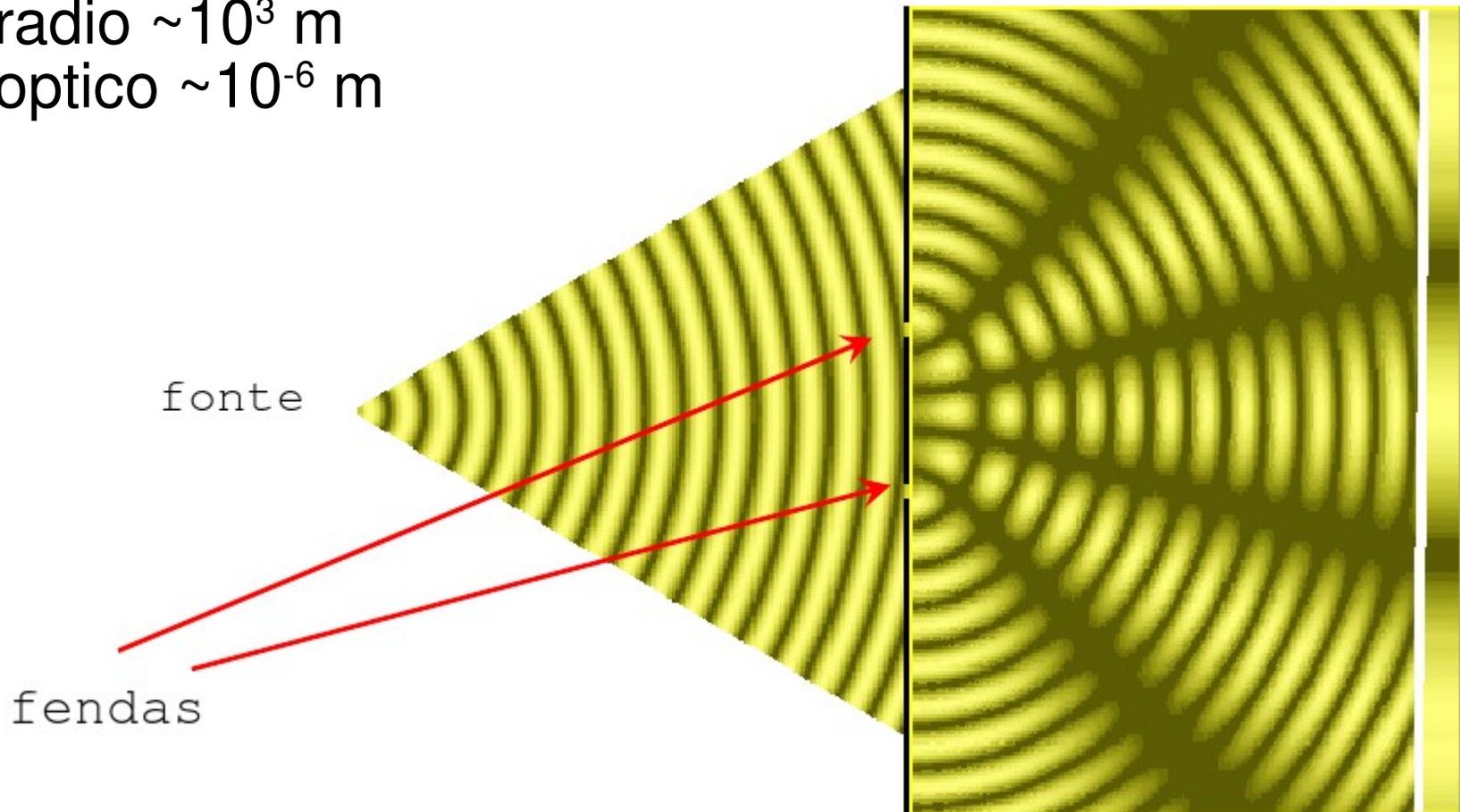
Telescópios de Radio



World's largest single-aperture radio telescope at Arecibo Observatory in Puerto Rico

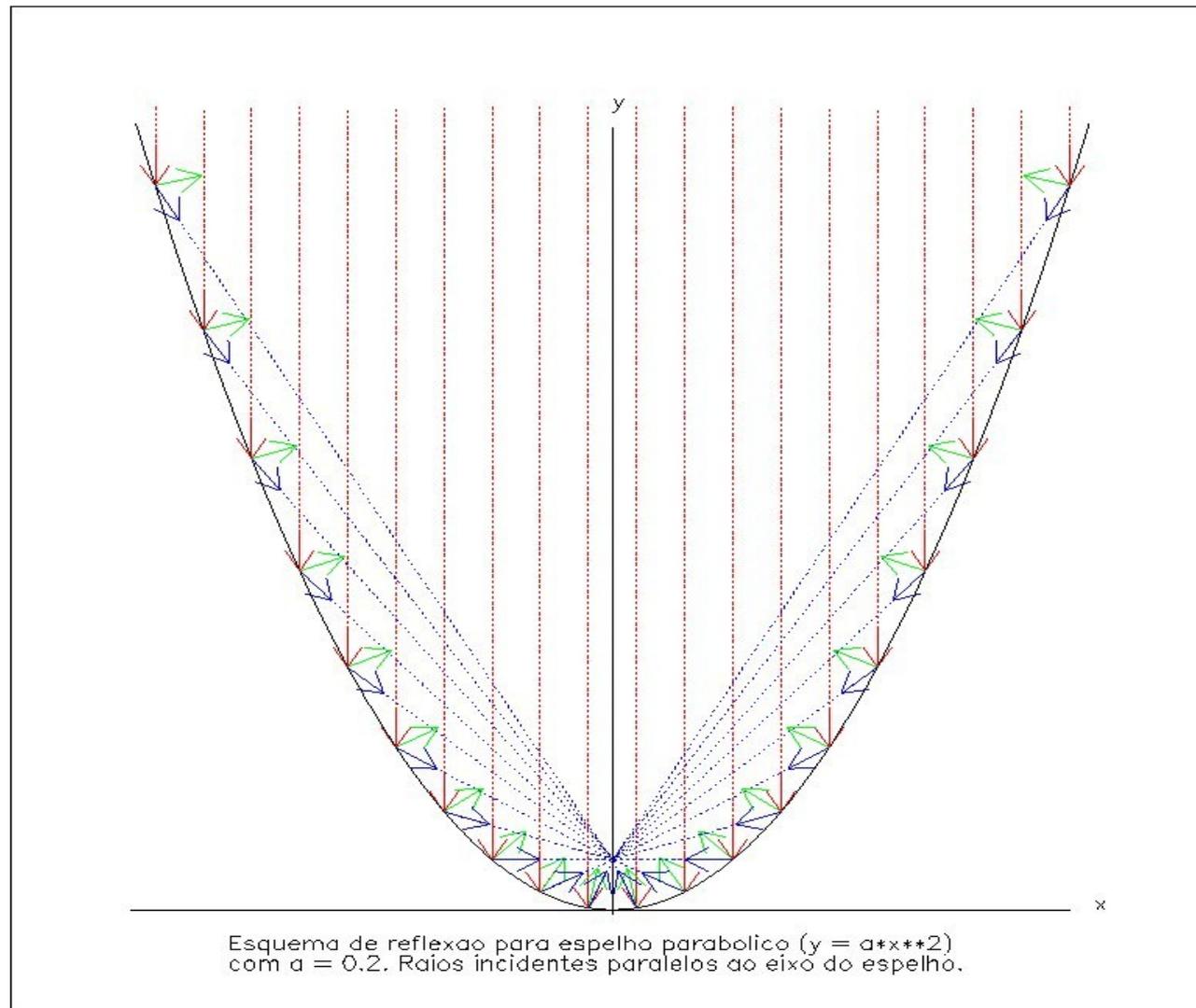
Difração: Problema 1

$\lambda_{\text{radio}} \sim 10^3 \text{ m}$
 $\lambda_{\text{optico}} \sim 10^{-6} \text{ m}$

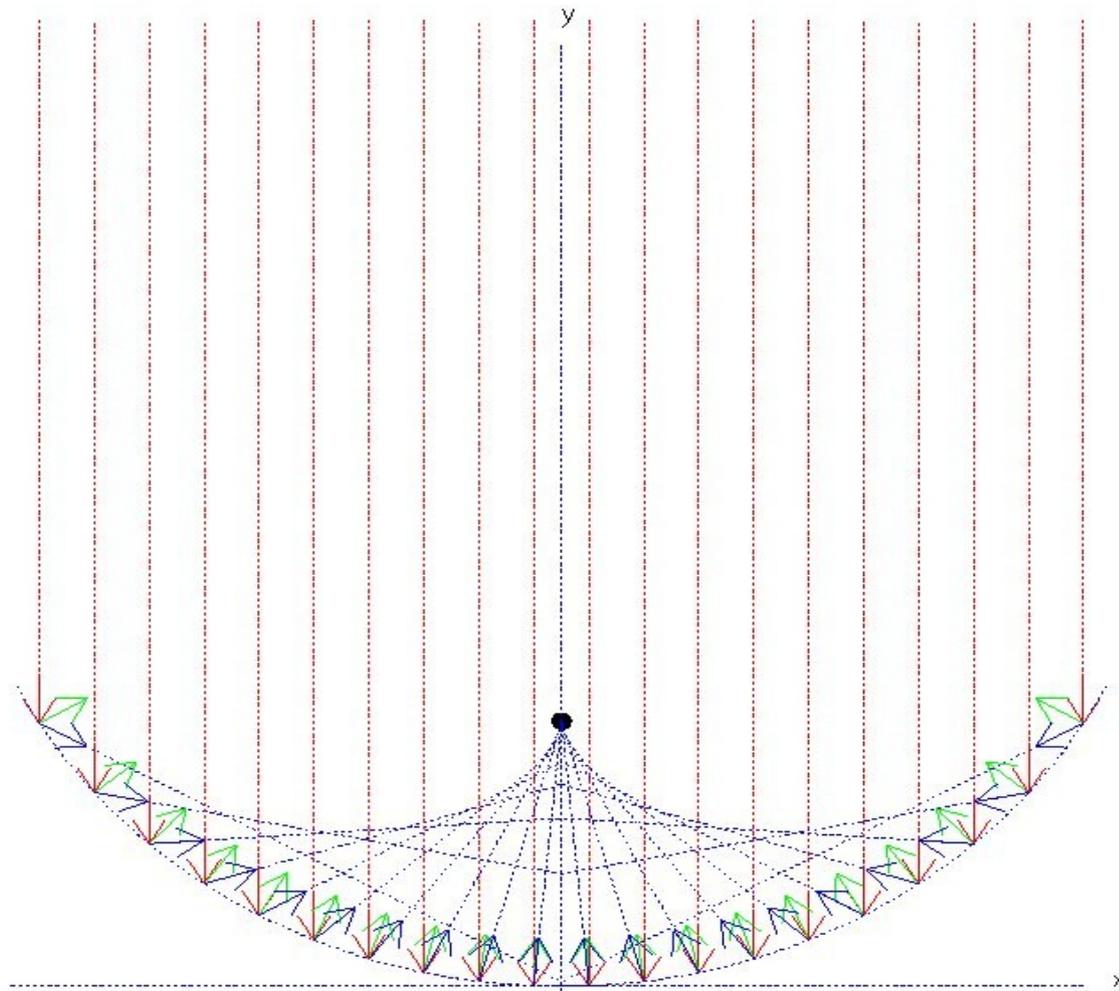


Largura do Primeiro Máximo é : $\theta = \lambda/D$

Refletores parabólicos

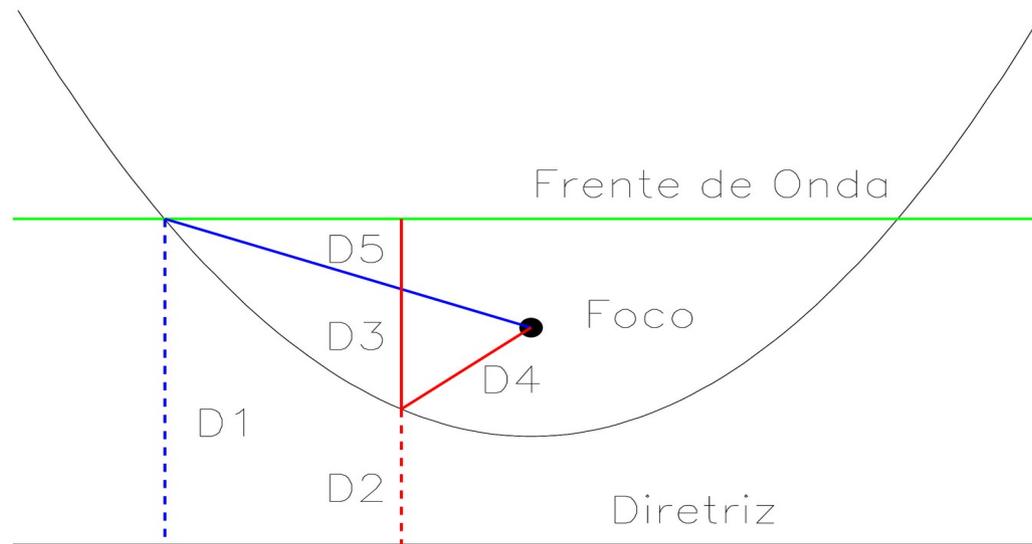


Refletores esféricos



Aberações esféricas

Refletores parabólicos

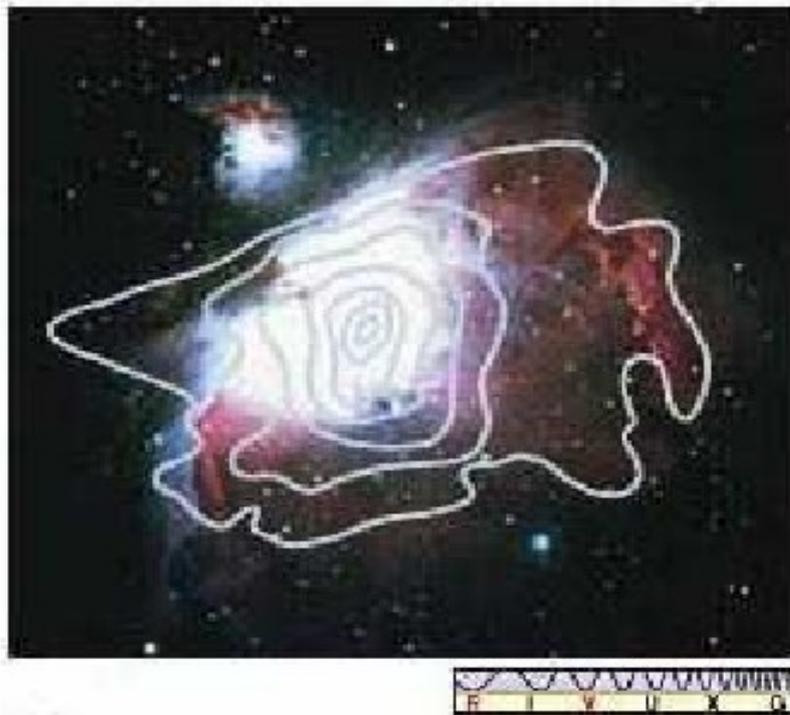


$$D1 = D2 + D3$$

$$D2 = D4 \text{ e } D1 = D5$$

$$D5 = D4 + D3$$

Nebulosa de Órion



Resolução no óptico = 1"
Resolução em radio = 1'

Very Large Array





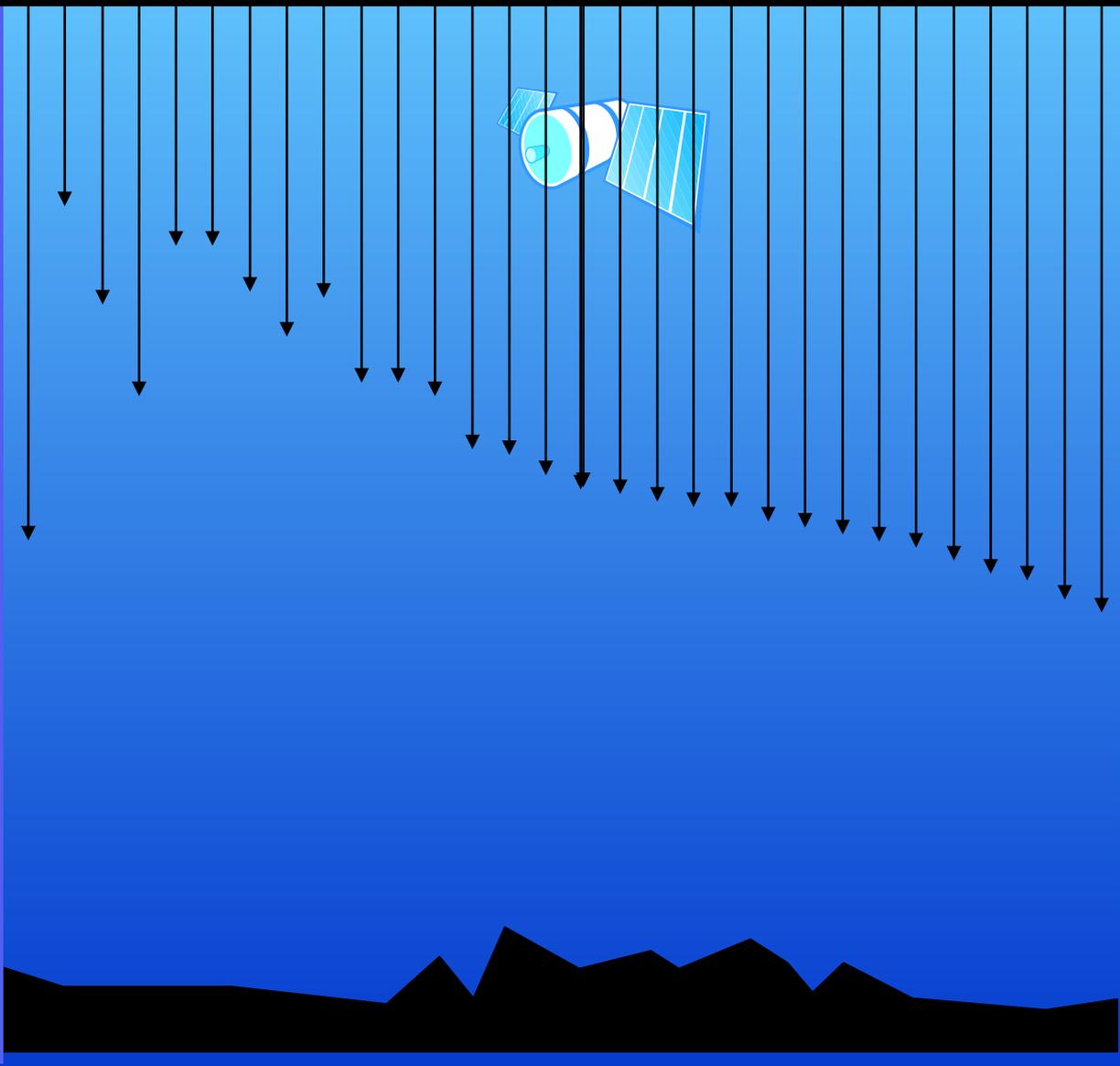
Radio mm IR 0 UV X-rays γ -rays γ -rays
HE VHE

500 km

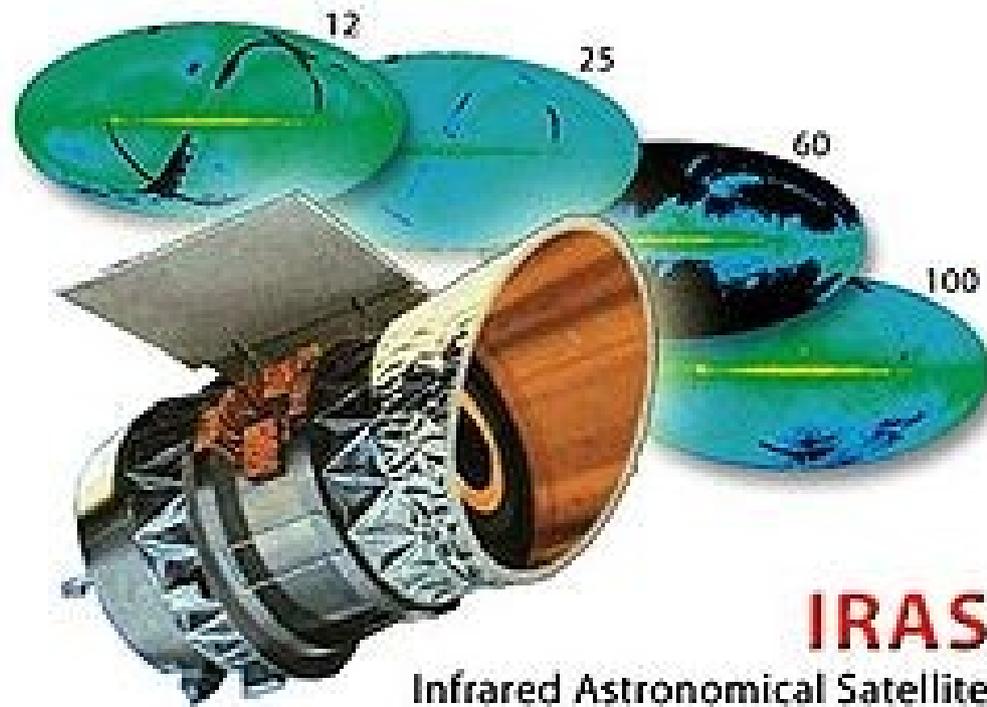
100 km

10 km

0 km

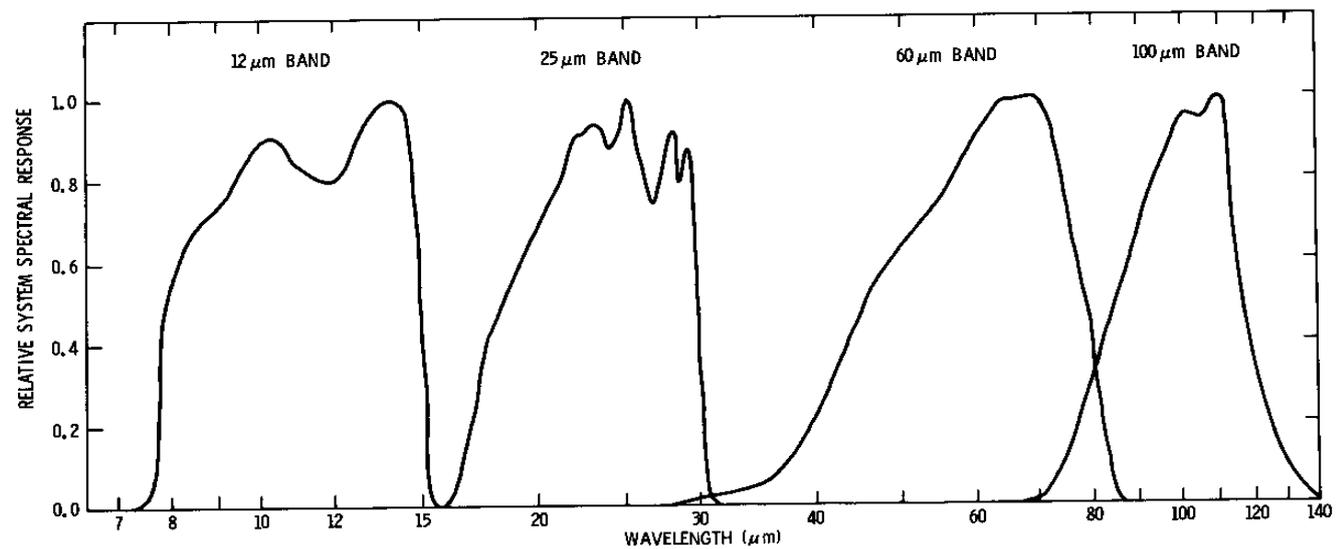
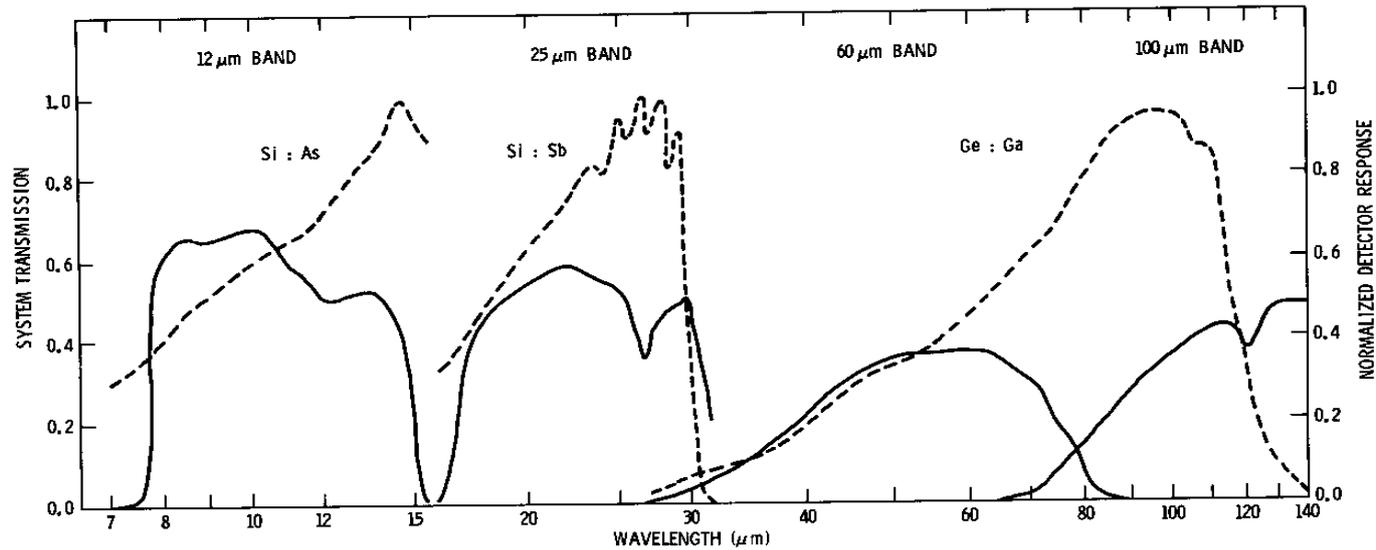


IRAS Satellite

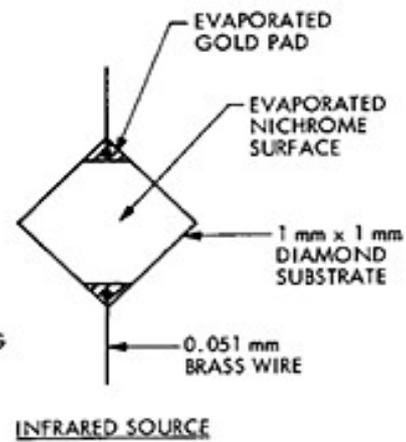
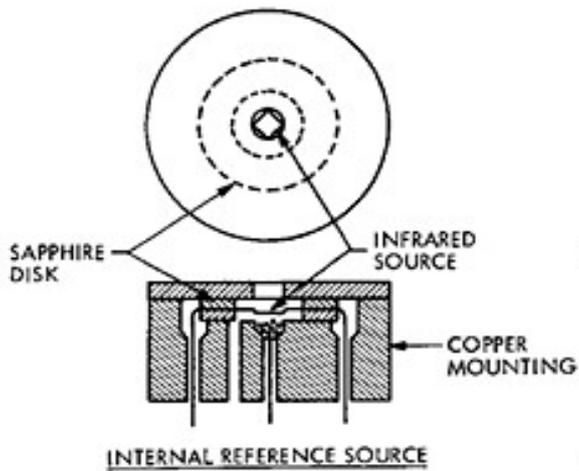
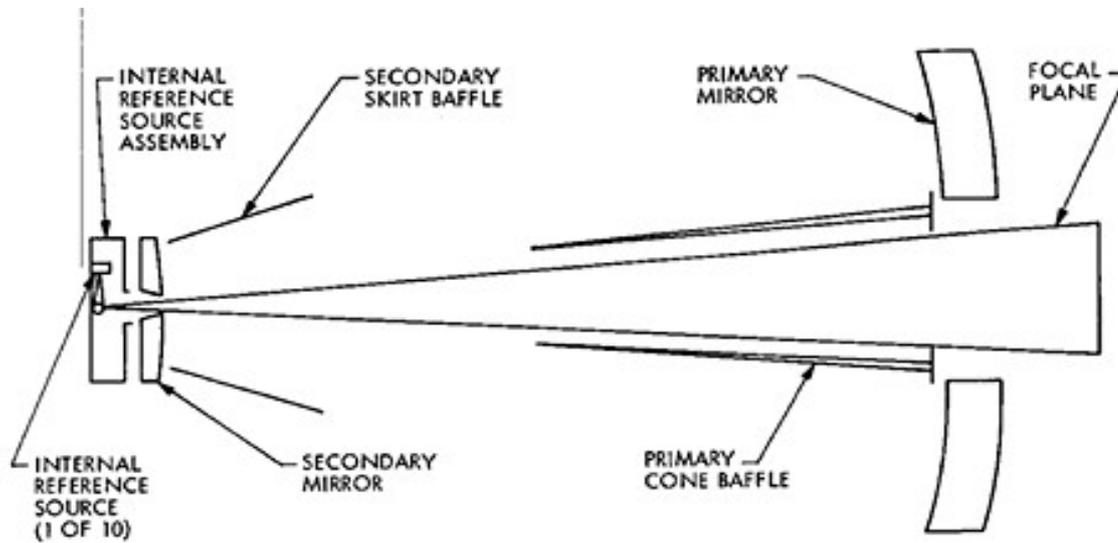


Lançado em 1983 funcionou por 10 meses

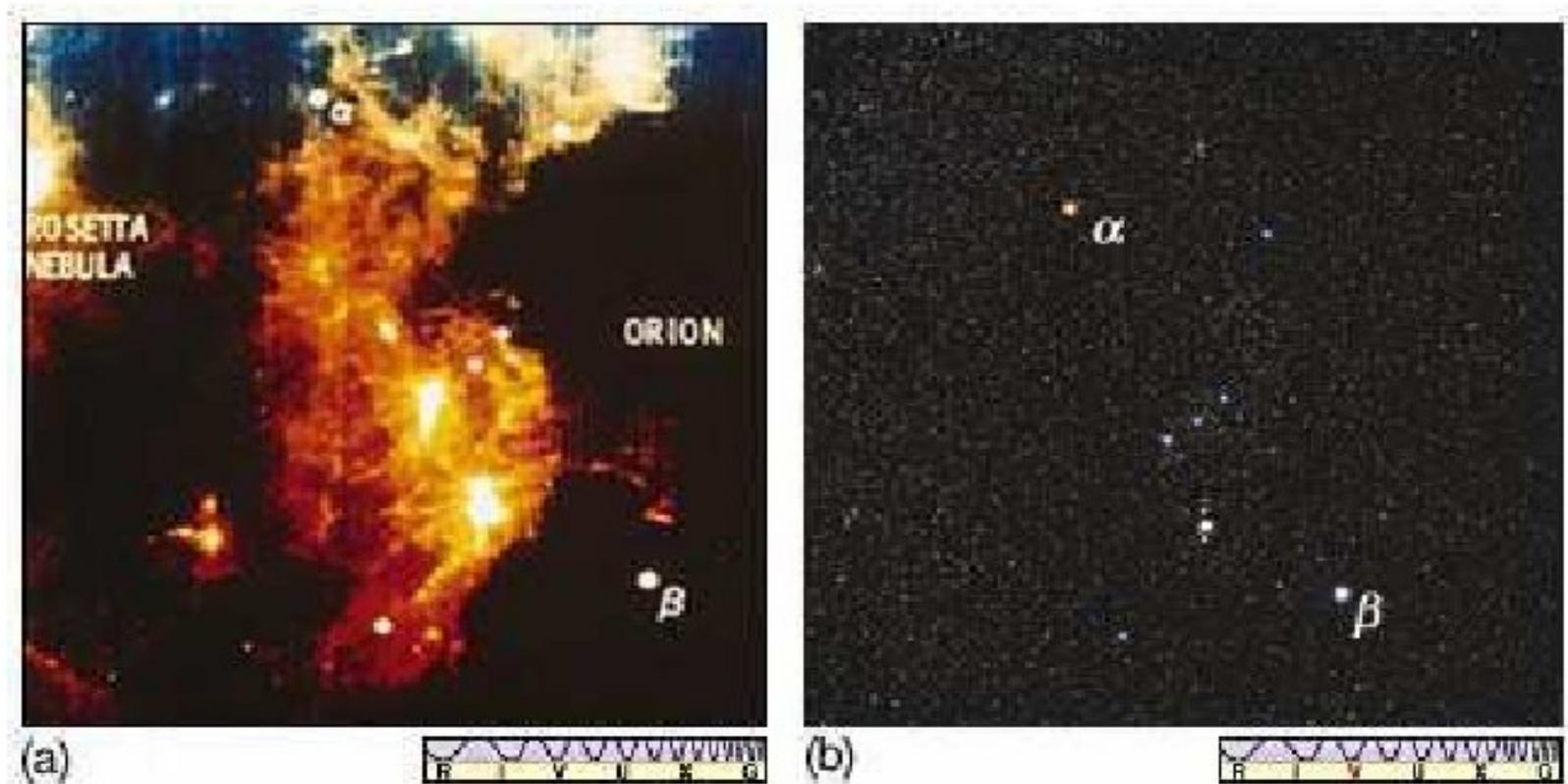
Satellite IRAS



Satellite IRAS



Nebulosa de Orion



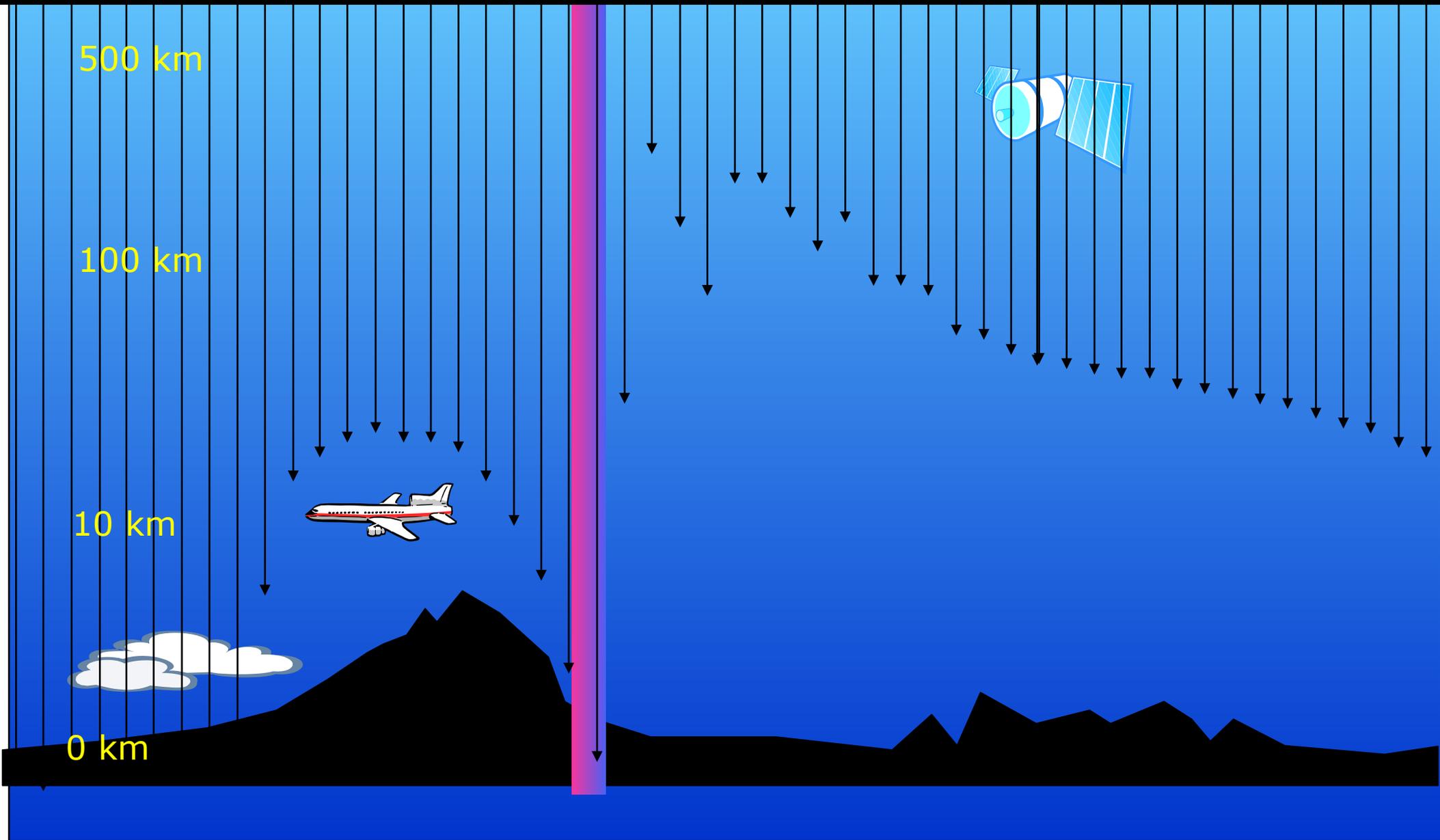
Infravermelho e óptico

Descobertas

- Detected about 500,000 infrared sources, doubling the number of cataloged astronomical sources.
- Discovered 6 new comets
- Discovered a disk of dust grains around the star Vega
- Cataloged over 12,000 variable stars, the largest collection known to date
- Revealed for the first time the core of our galaxy
- Detected ~75,000 starburst galaxies



Radio mm IR 0 UV X-rays γ -rays γ -rays
HE VHE



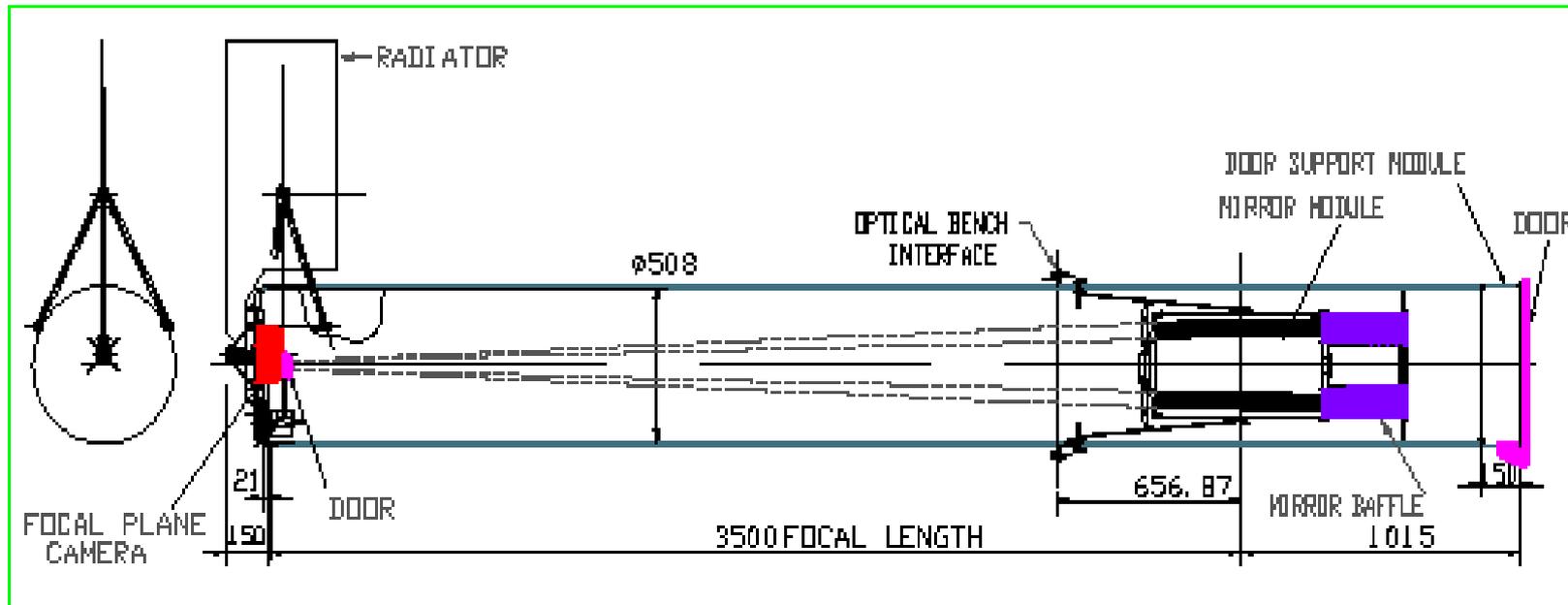
500 km

100 km

10 km

0 km

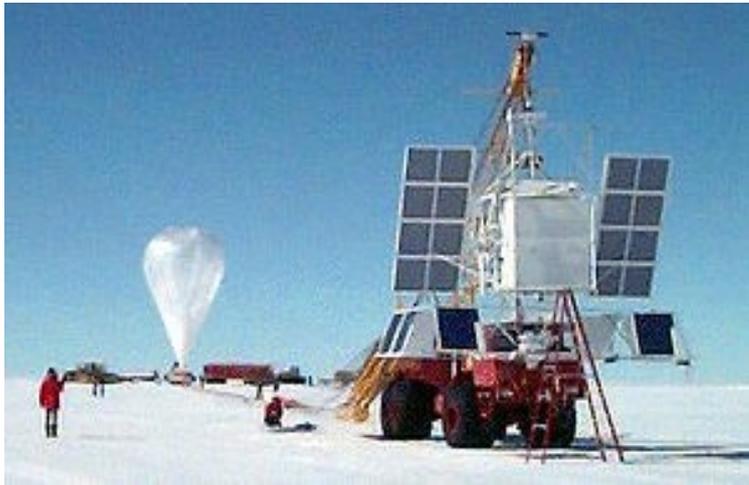
Astronomia de Raios X



Swift: espelhos de cerâmica ou metal

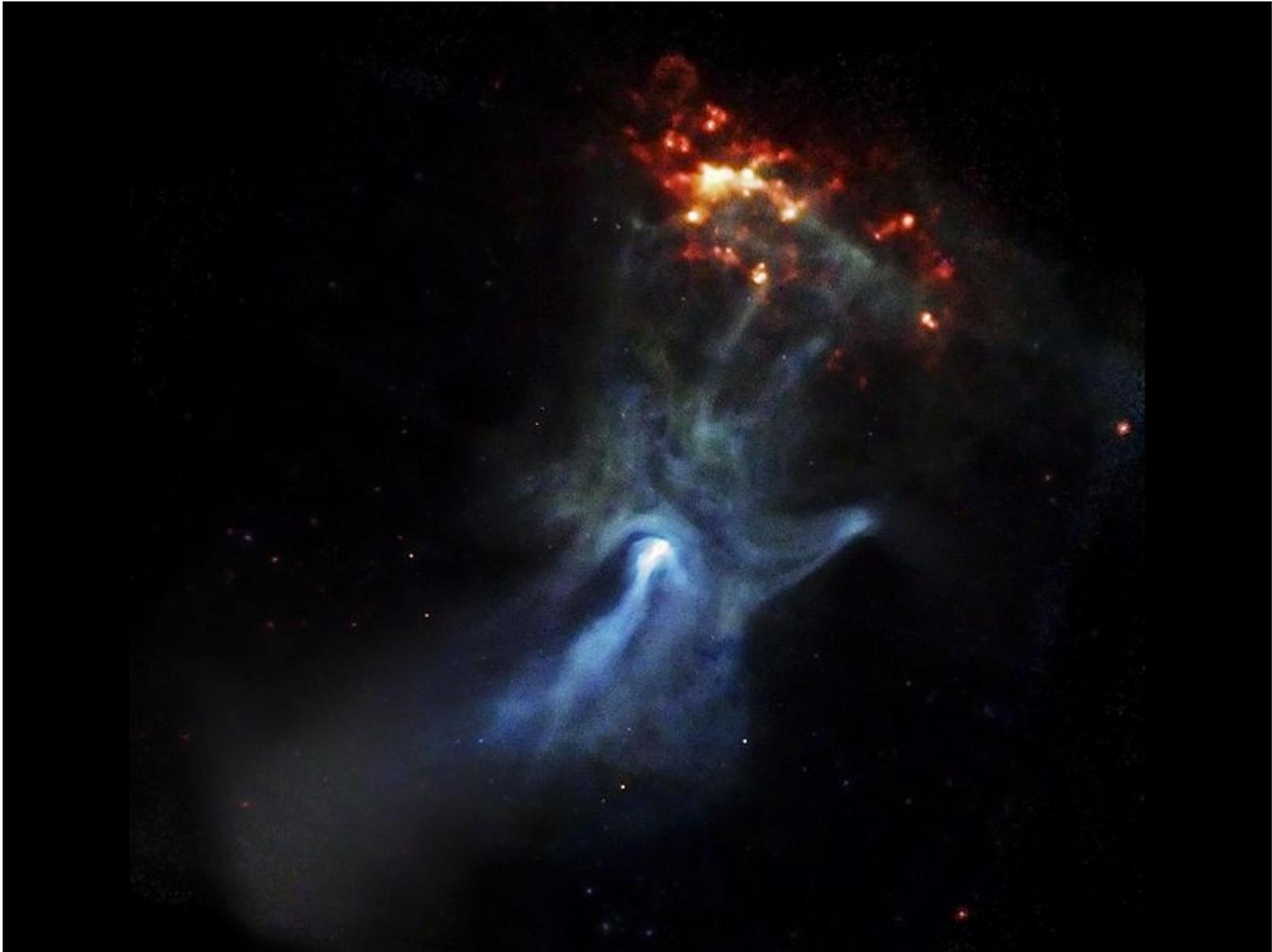
Astronomia de Raios X

HIREGS



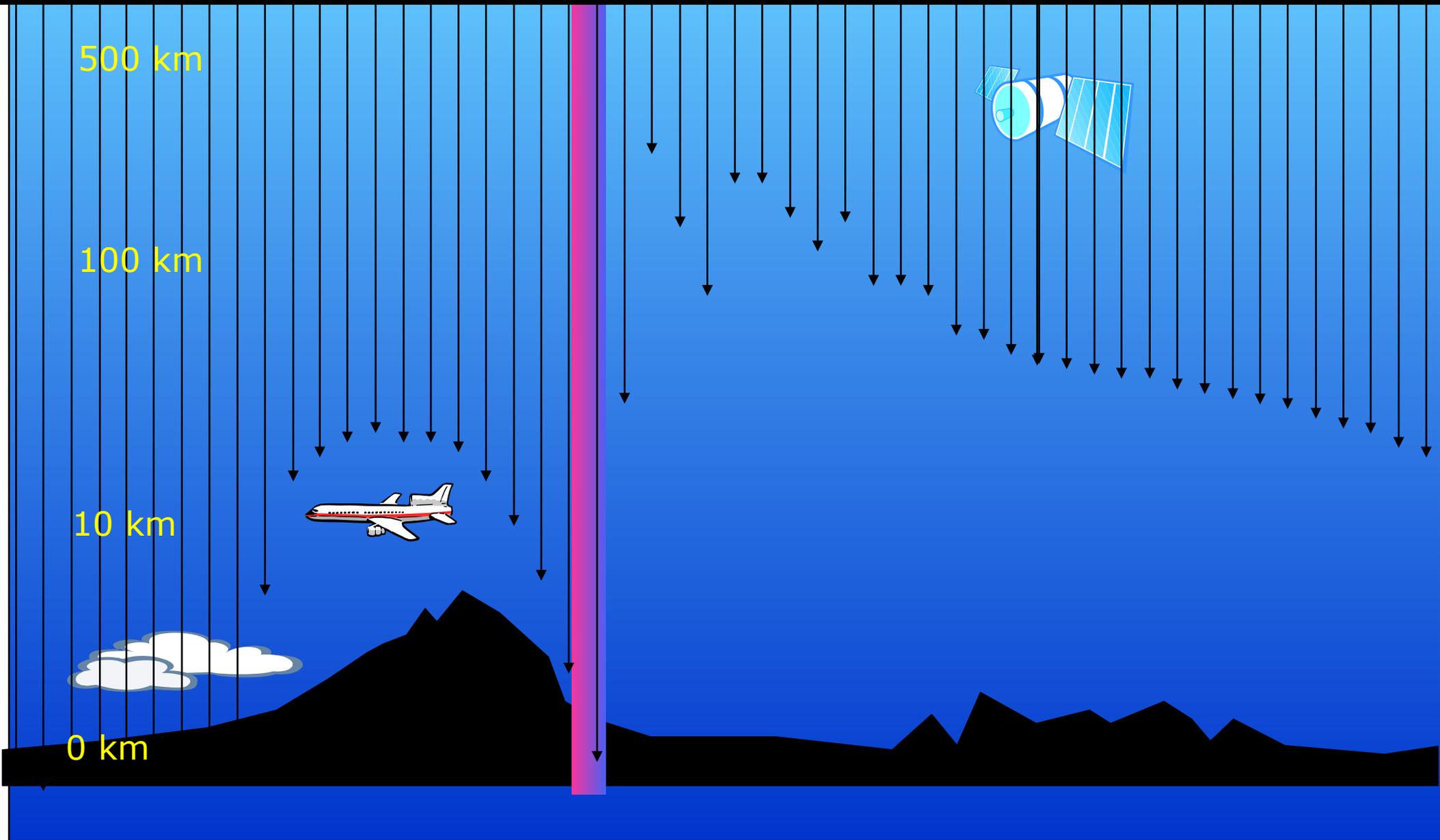
Chandra

Nebulosa - Pulsar

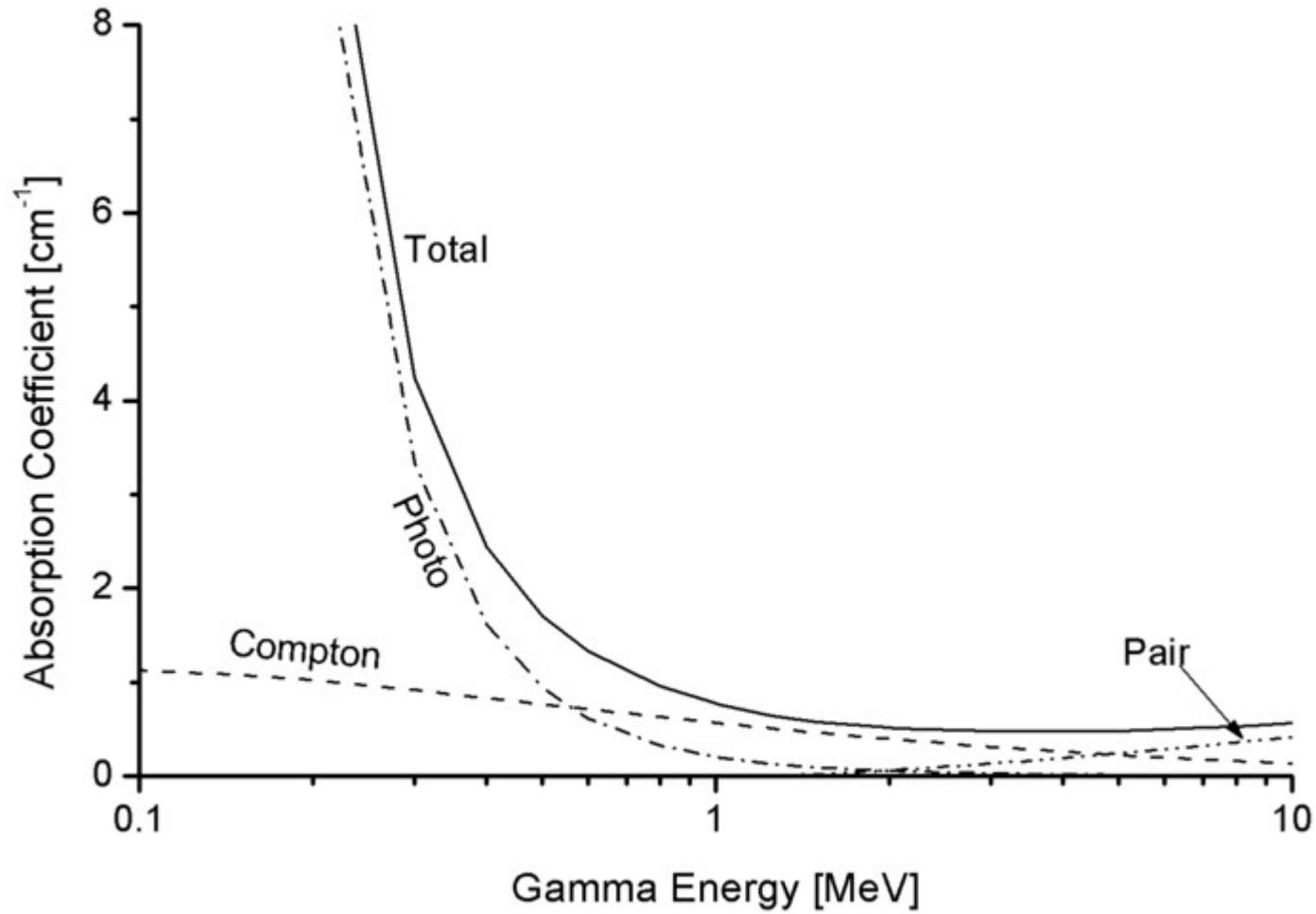




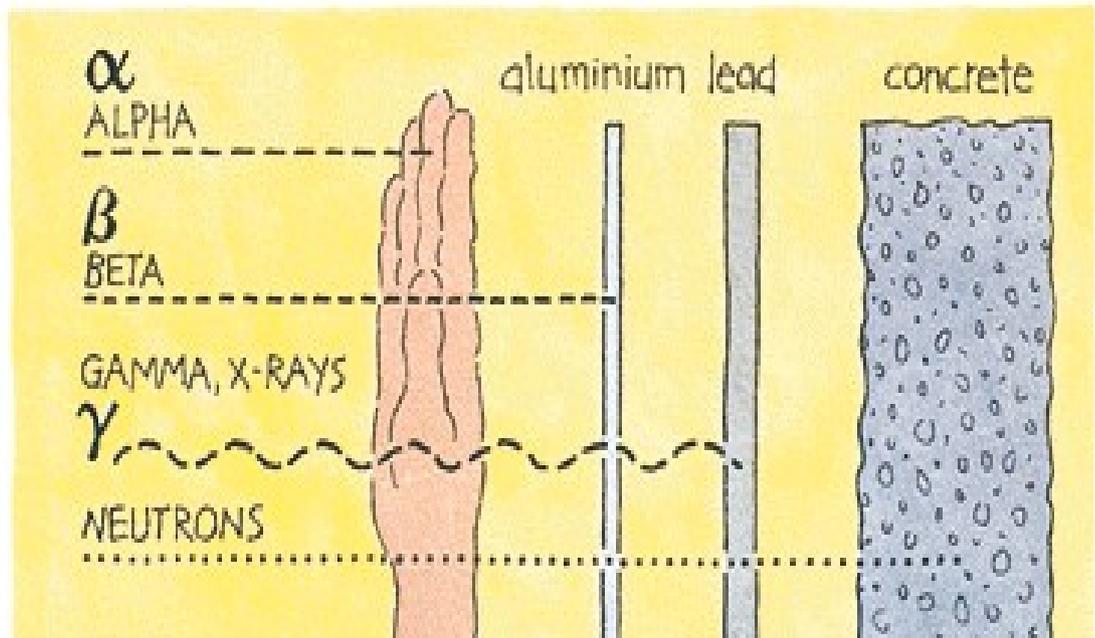
Radio mm IR 0 UV X-rays γ -rays γ -rays
HE VHE



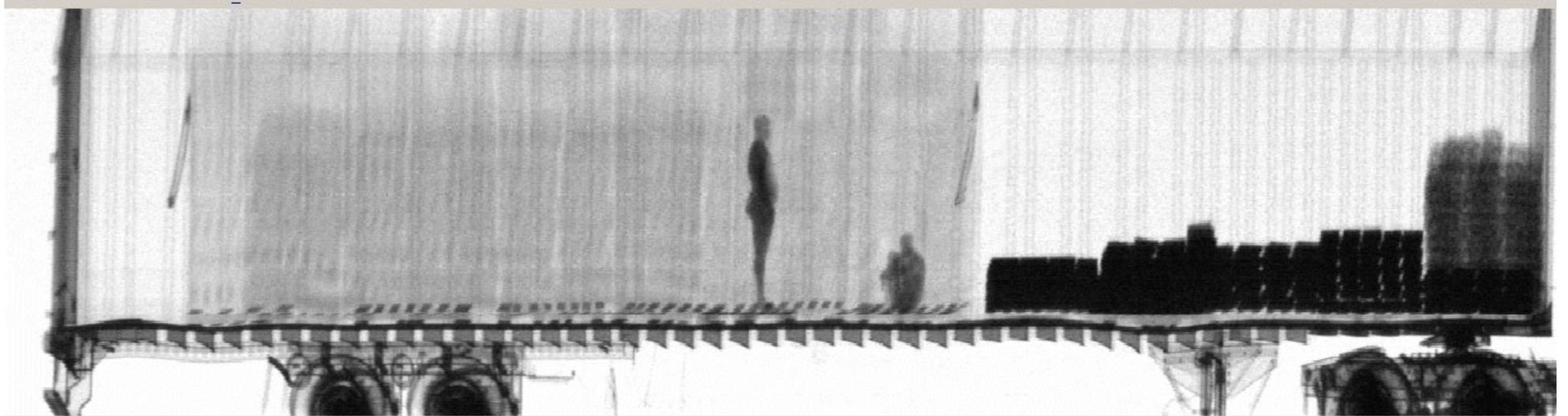
Astronomia Gama



Em chumbo



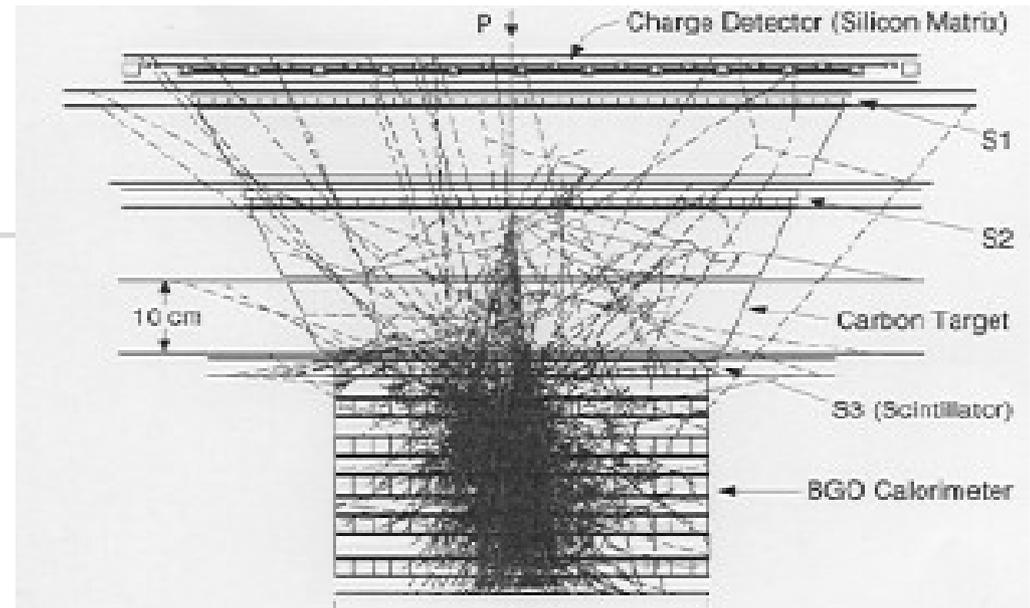
Raios gama



CGRO



Instrumentos



ATIC

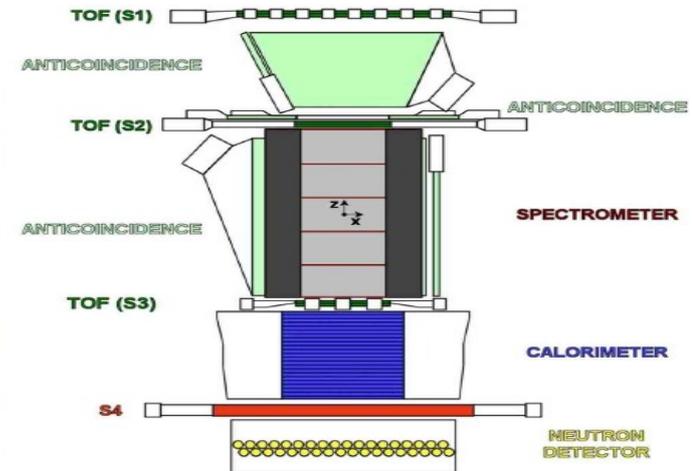
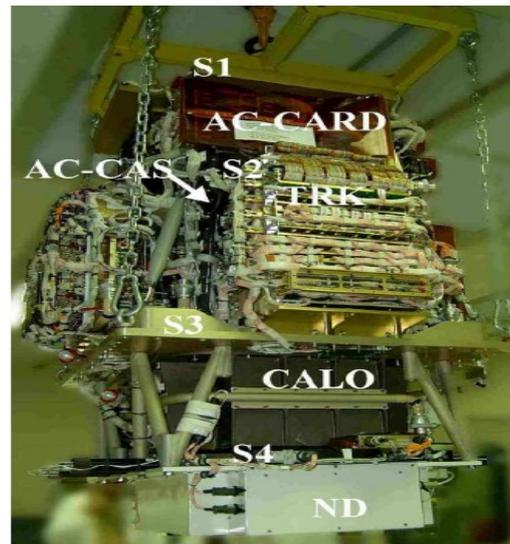
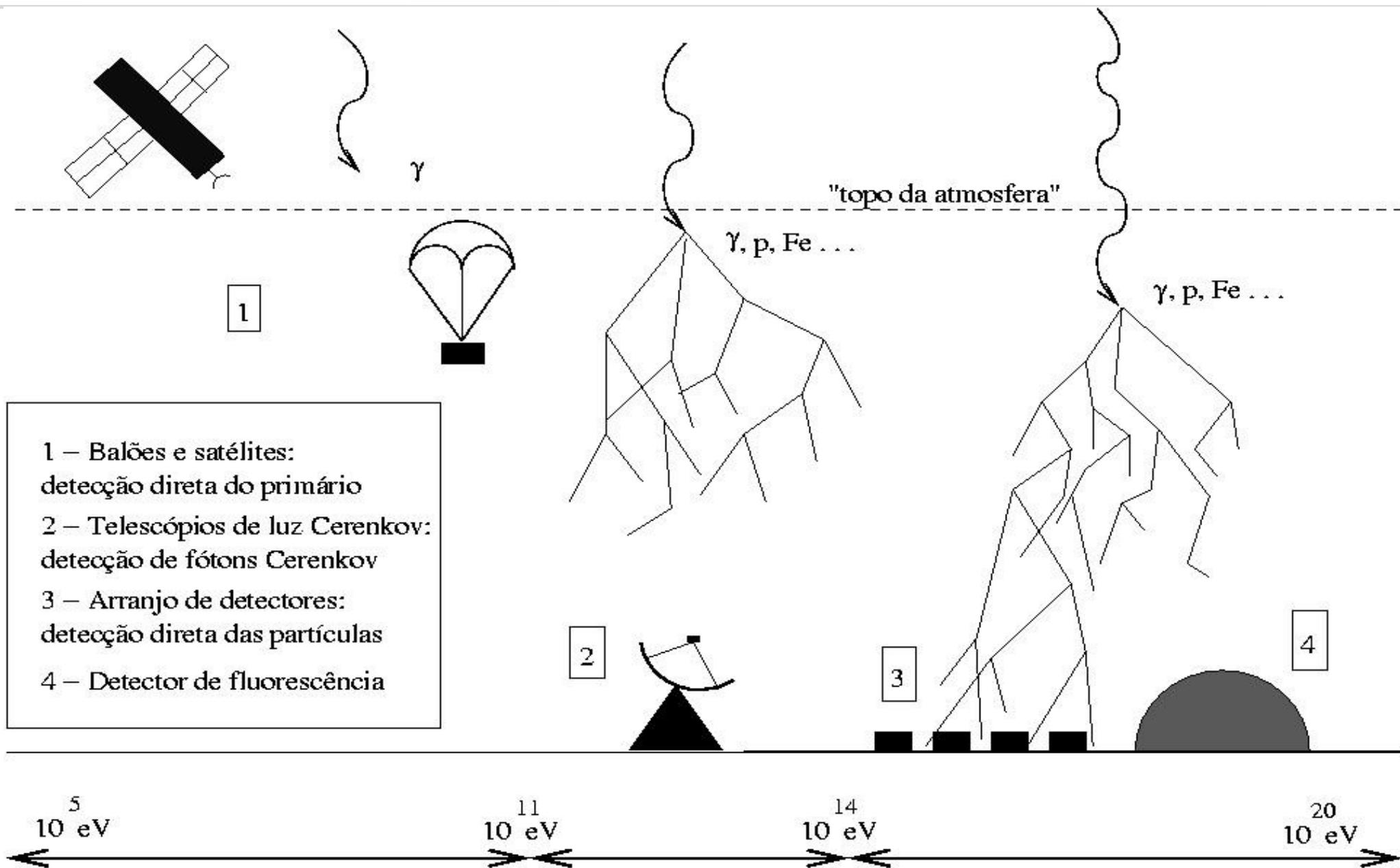


Fig. 3. Left: Photo of the PAMELA detector during the final integration phase in Tor Vergata clean room facilities, Rome. It is possible to discern, from top to bottom, the topmost scintillator system, S1, the electronic crates around the magnet spectrometer, the baseplate (to which PAMELA is suspended by chains), the black structure housing the Si-W calorimeter, S4 tail scintillator and the neutron detector. Right: scheme - approximately to scale with the picture - of the detectors composing PAMELA.



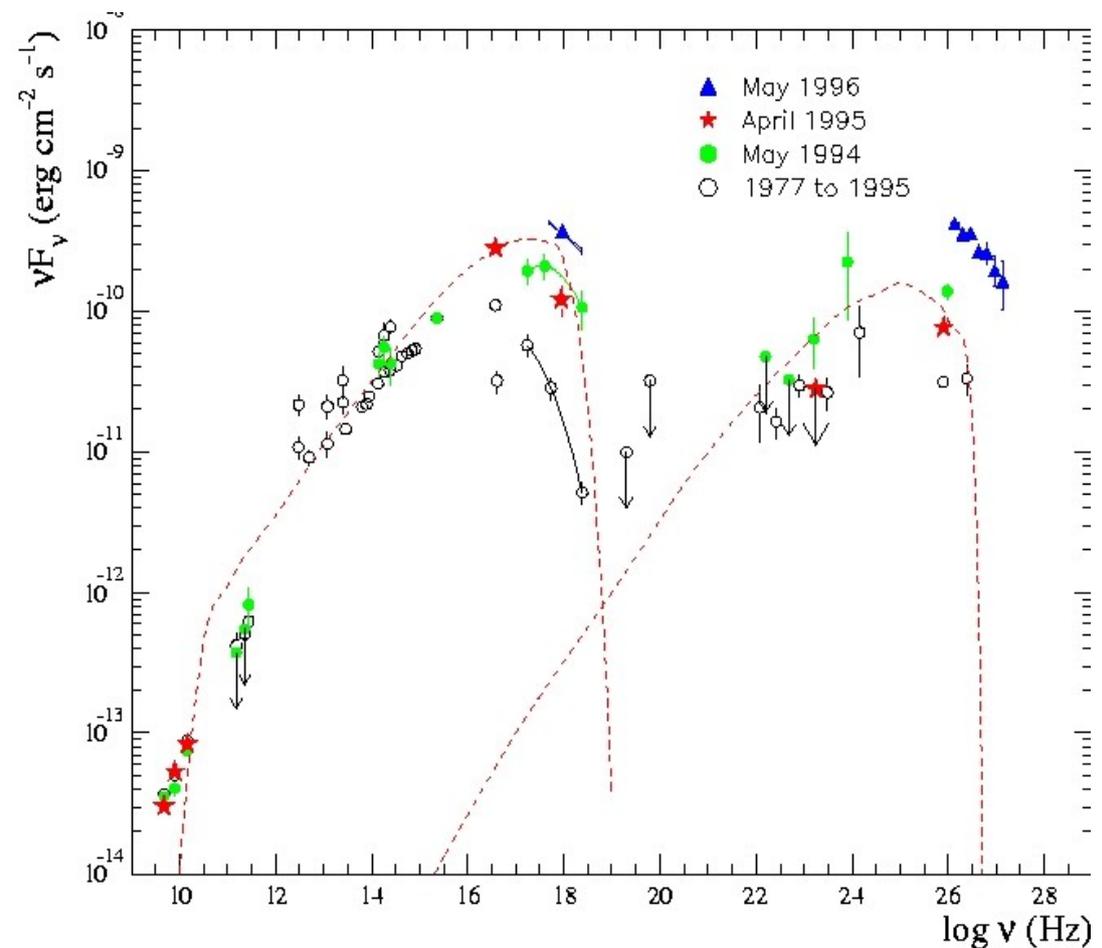
- 1 – Balões e satélites: detecção direta do primário
- 2 – Telescópios de luz Cerenkov: detecção de fótons Cerenkov
- 3 – Arranjo de detectores: detecção direta das partículas
- 4 – Detector de fluorescência

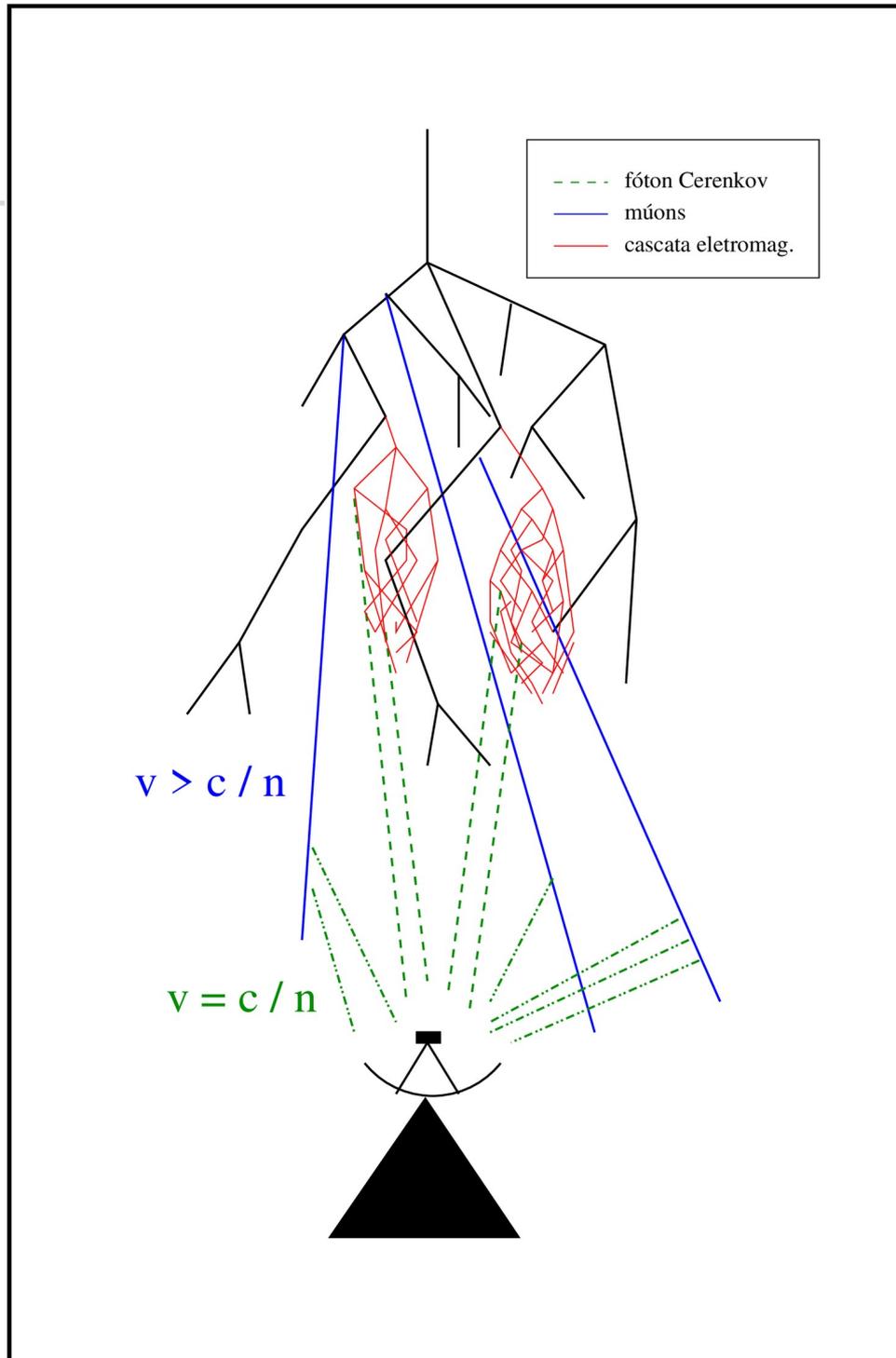
Experimentos de Astropartículas

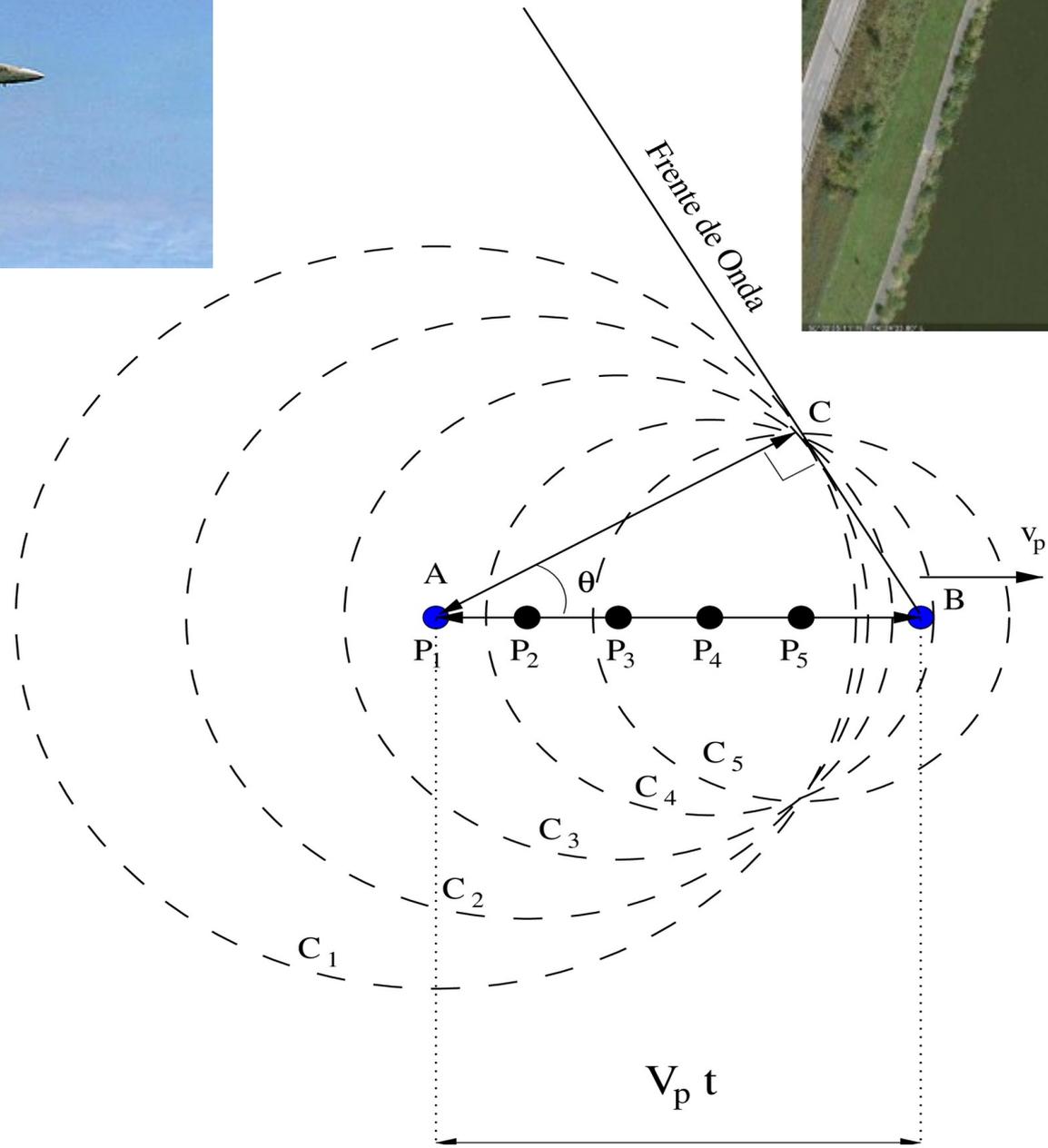


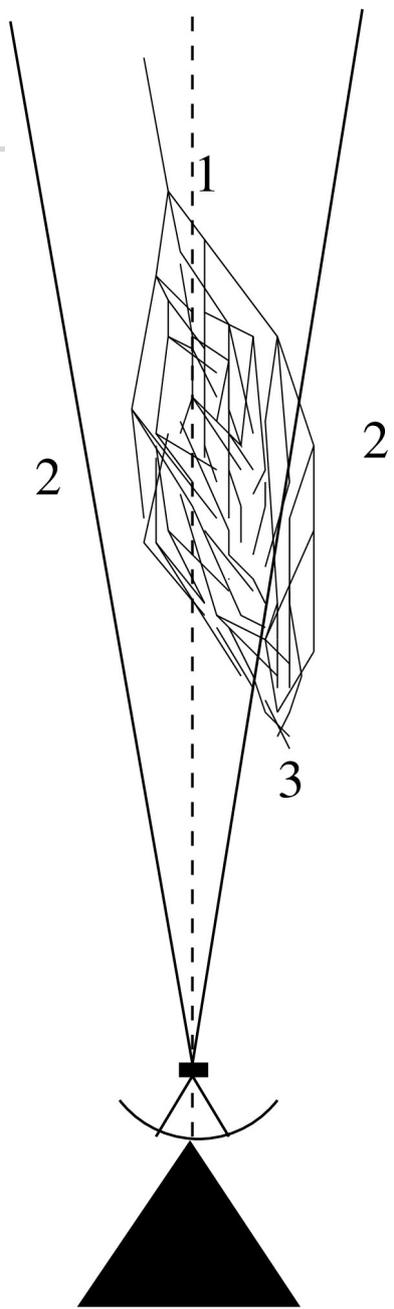
Telescópio Whipple - Arizona (EL)

Detector de raios gama com energia entre 10^9 e 10^{12} eV

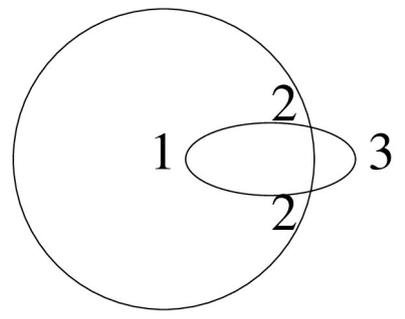






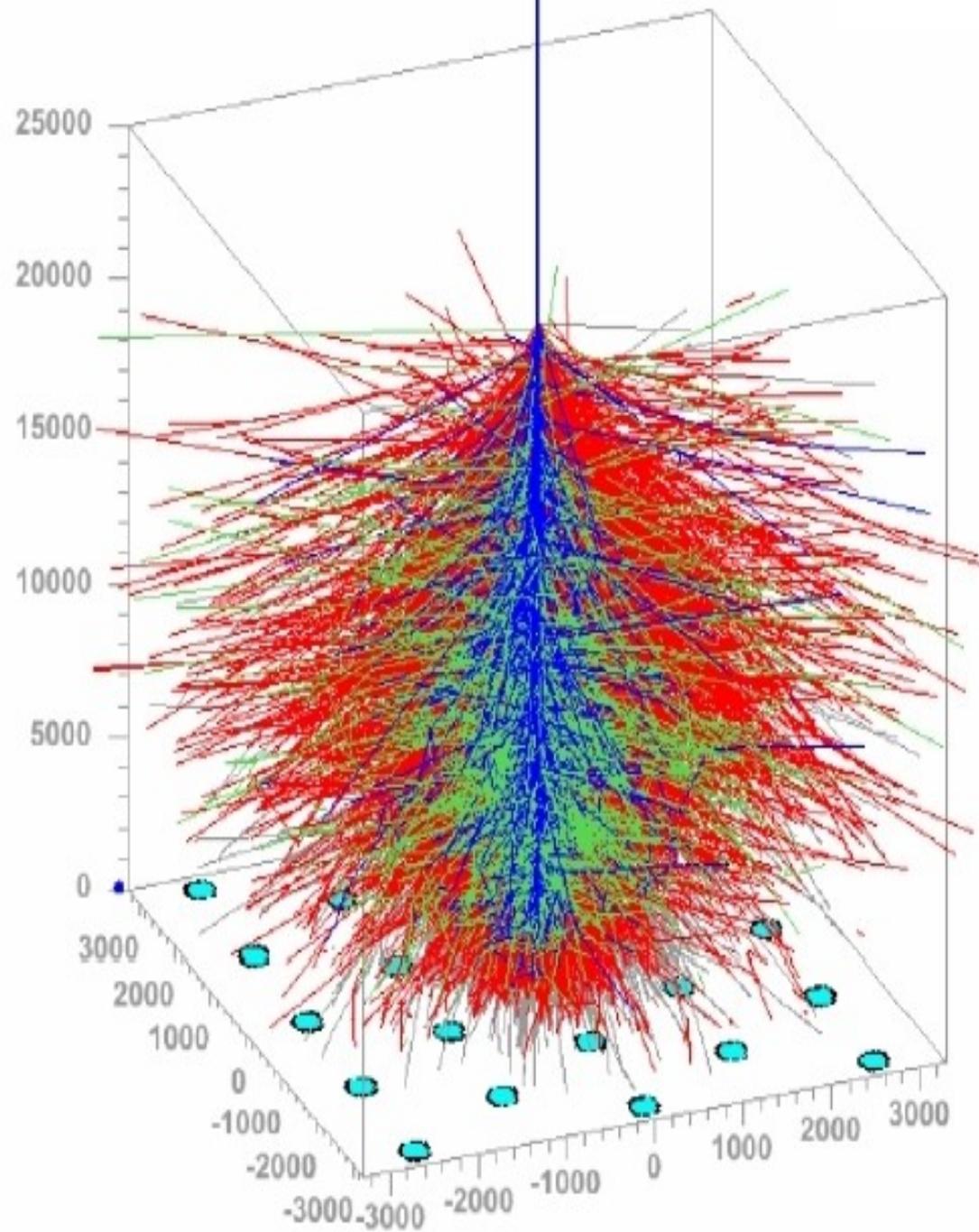


CAMPO DE VISÃO



hadrons muons electrs neutrs

$71.00 \cdot 10^{-6}$ sec



Detectar um chuveiro de raios c3smicos

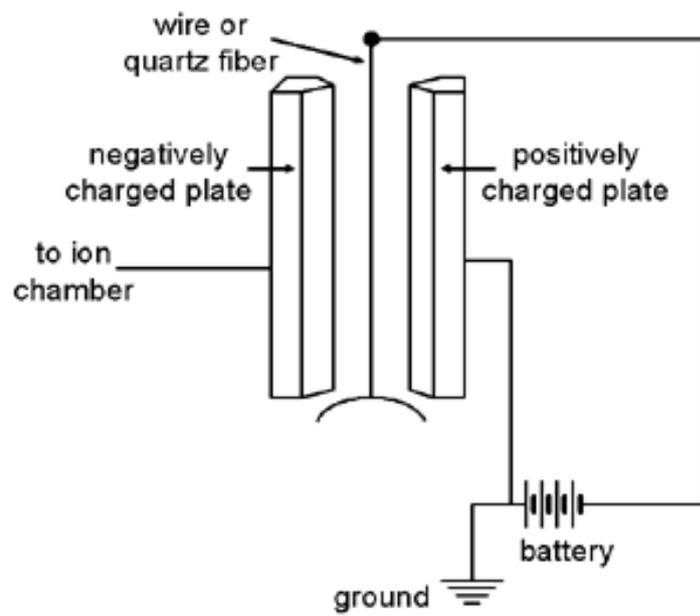
H3drons, m3ons e el3trons:
Medir part3culas carregadas
3 f3cil

F3tons Fluoresc3ncia e Cerenkov
Medir f3tons 3 um pouco mais
dif3cil: ru3do

Medir neutrinos 3 quase
imposs3vel

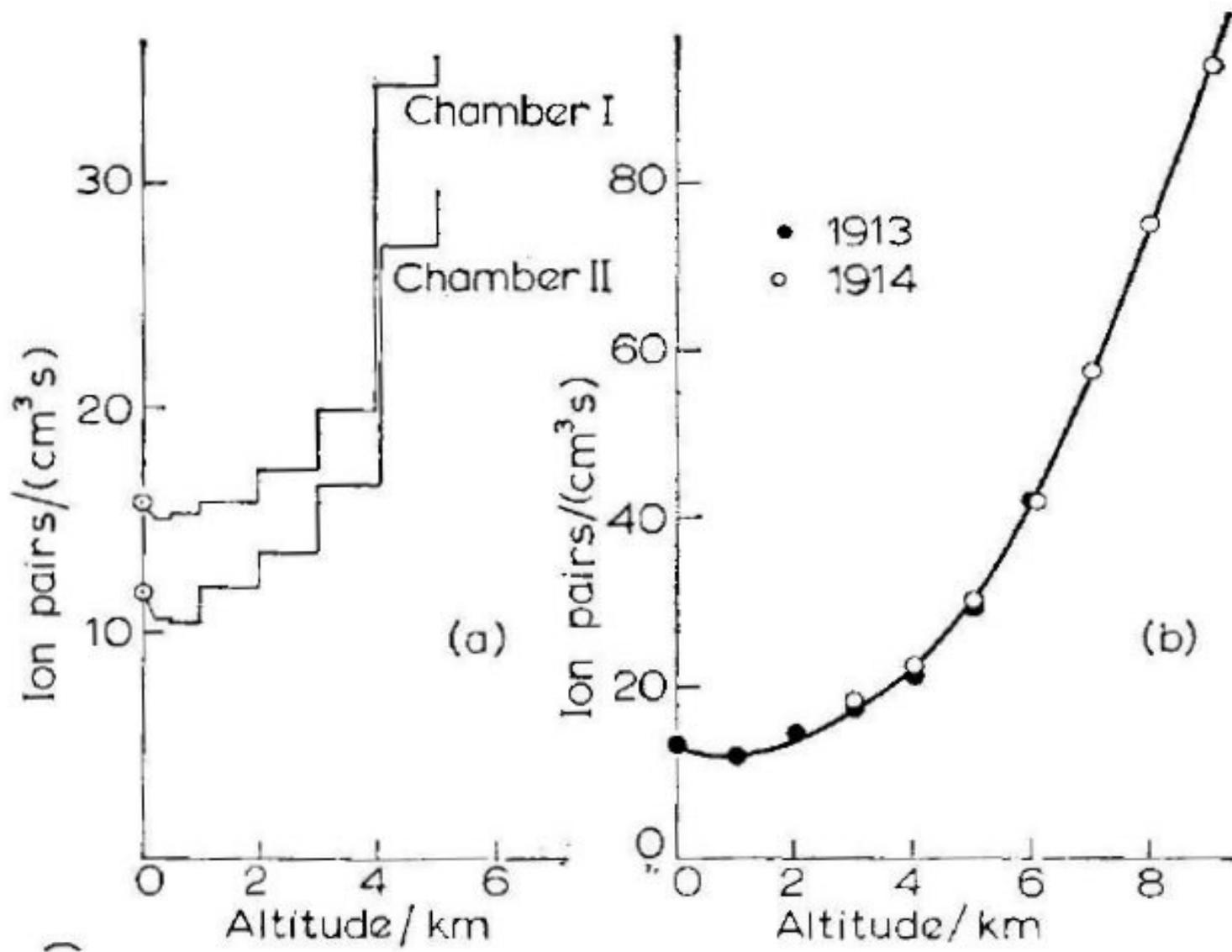
Victor Hess (1911)

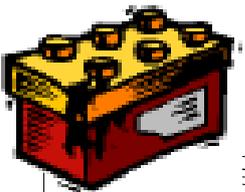
Eletrômetro ou Eletroscópio



NN	Time	Mean absolute m	Height relative m	Apparatus 1 para q_1	Apparatus 2 para q_2	q_3	Apparatus 3 q_3 (reduced)	
1	16 ^h 40 – 17 ^h 40	156	0	15.6	11.5	–	–	from the
2	17 ^h 40 – 18 ^h 40	156	0	18.7	11.8	21.0	21.0	take-off
3	18 ^h 40 – 21 ^h –	156	0	17.8	11.6	19.5	19.5	point in
4	21 ^h 30 – 22 ^h 30	156	0	17.8	11.3	20.0	20.0	the Klub-
5	23 ^h 26 – 0 ^h 26	300	140	14.4	9.6	19.4	19.8	platz.
6	0 ^h 26 – 1 ^h 26	350	0	16.2	9.9	17.4	17.9	Vienna
7	1 ^h 26 – 2 ^h 26	300	140	14.4	10.1	17.7	18.1	
8	2 ^h 26 – 3 ^h 32	330	160	15.0	9.6	18.2	18.7	
9	3 ^h 32 – 4 ^h 32	320	150	14.4	9.8	18.5	19.0	
10	4 ^h 32 – 5 ^h 35	300	70	17.2	13.2	20.6	21.0	
11	5 ^h 35 – 6 ^h 35	540	240	17.8	11.8	19.6	20.8	
12	6 ^h 35 – 7 ^h 35	1050	800	17.6	10.0	18.1	20.3	
13	7 ^h 35 – 8 ^h 35	1400	1200	12.2	8.8	17.3	20.3	
14	8 ^h 35 – 9 ^h 35	1800	1600	17.5	10.9	17.3	21.3	

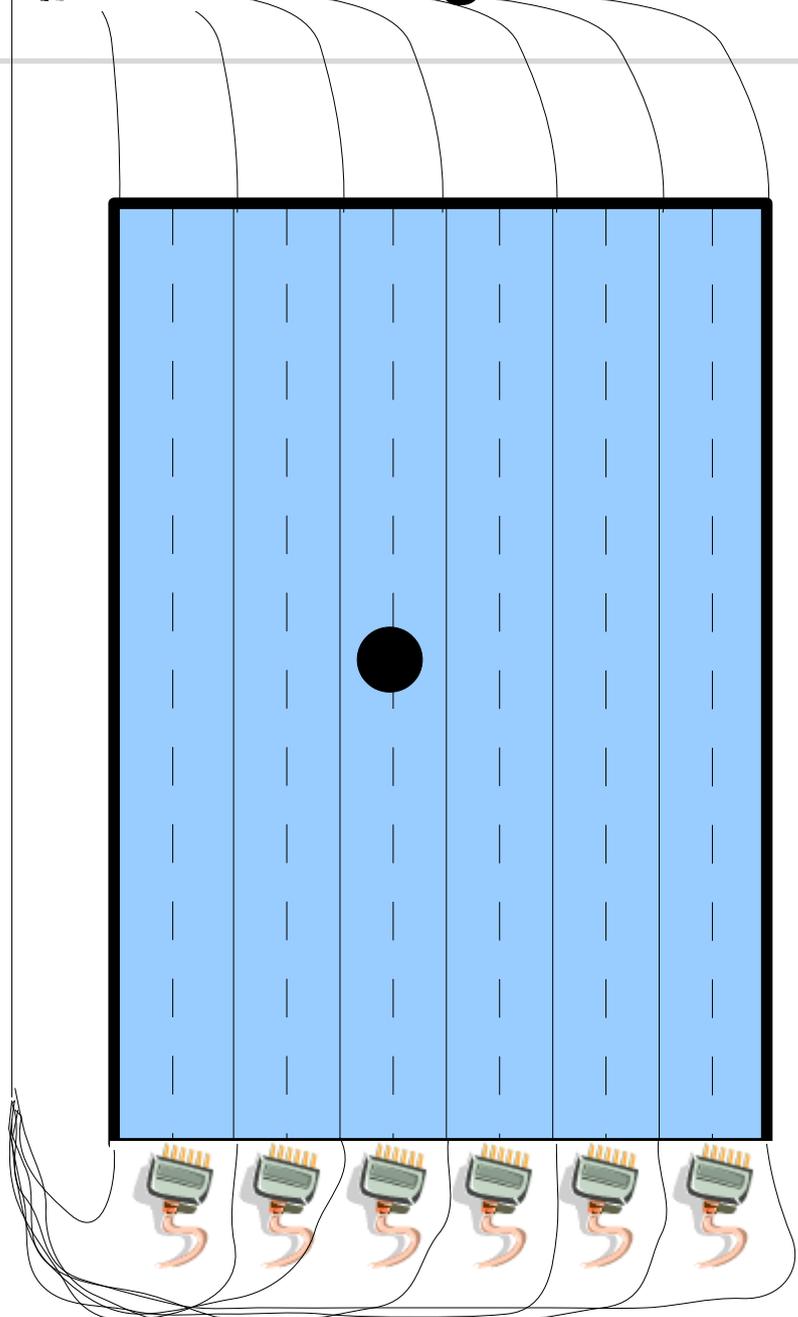






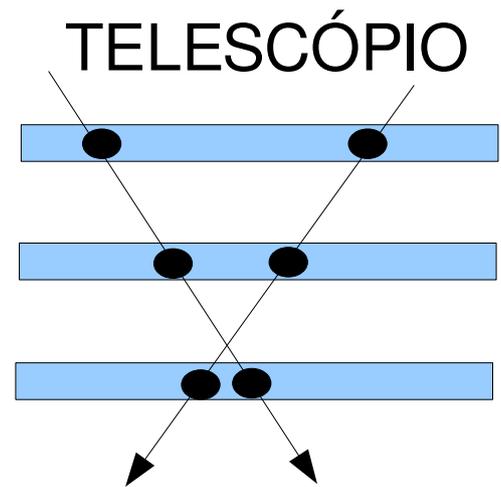
Câmeras Multi Fio

Energia liberada ioniza o meio

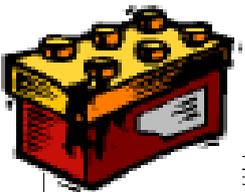


Resolução Espacial e Temporal

- Modos de operação:
- 1) Proporcional: baixa tensão e fluxo
 - 2) Contador de Partículas: alta tensão -> caminho ionizado

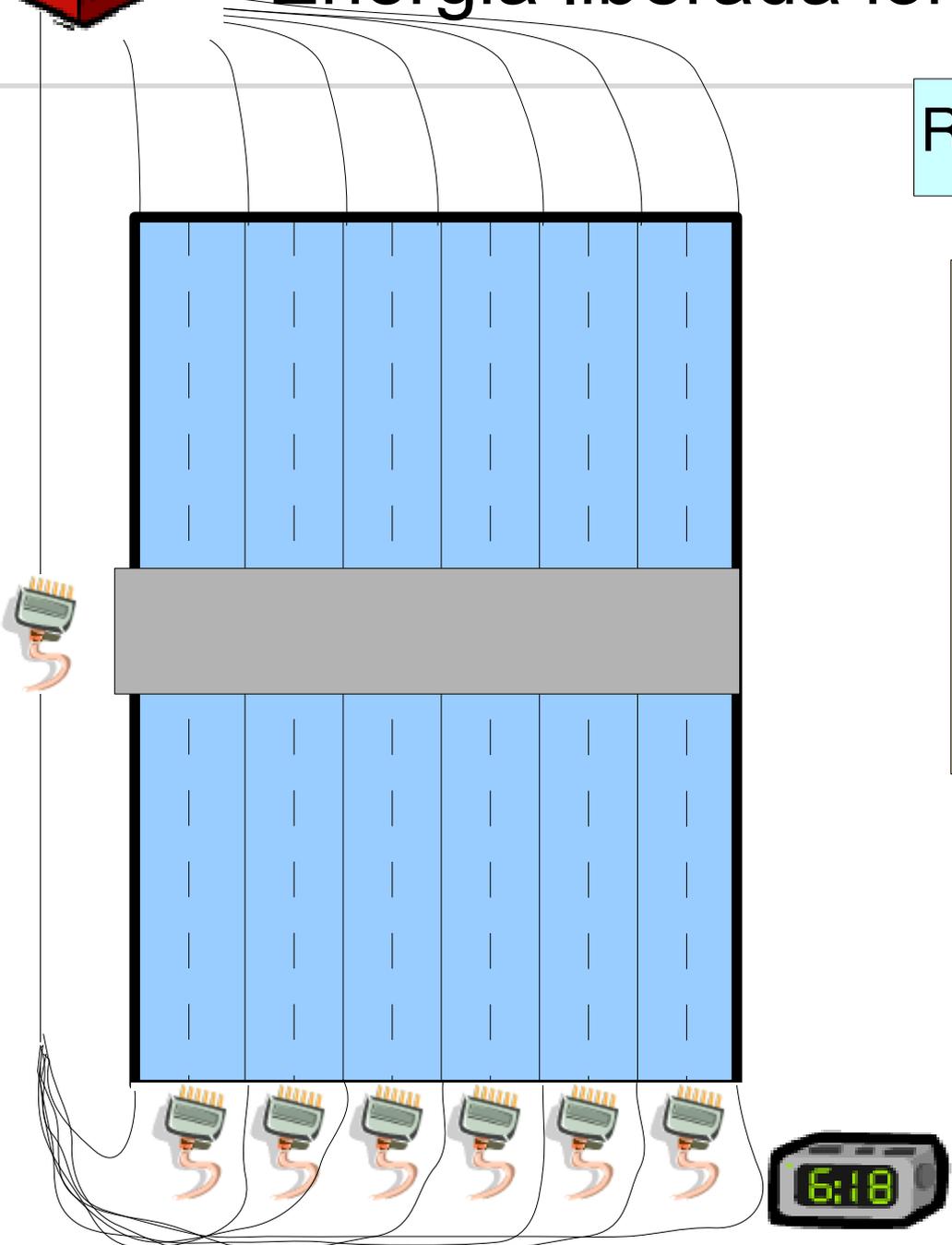


Resolução Temporal: ordem de microsegundo



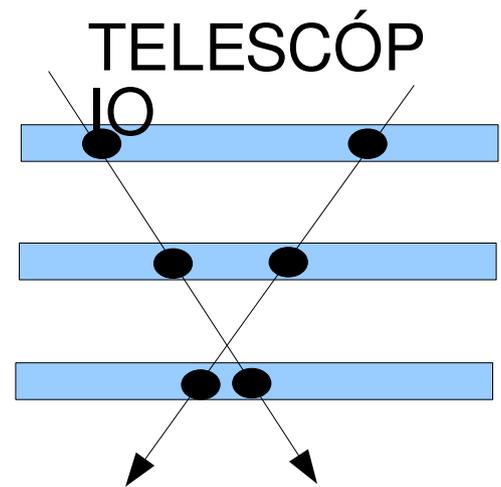
Câmeras Multi Fio

Energia liberada ioniza o meio



Resolução Espacial e Temporal

- Modos de operação:
- 1) Proporcional: baixa tensão e fluxo
 - 2) Contador de Partículas: alta tensão -> caminho ionizado



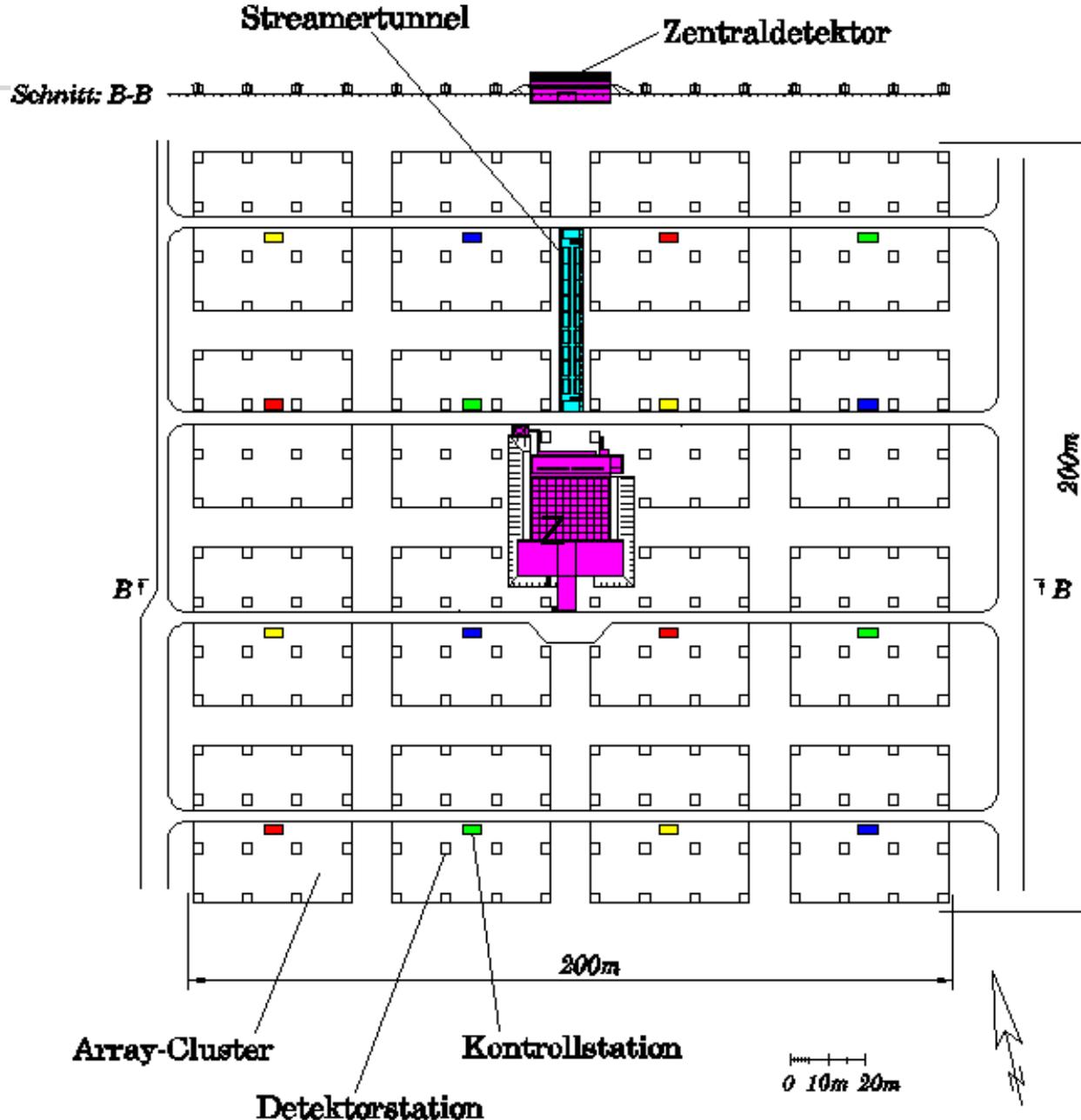
Resolução Temporal: ordem de microsegundo

KASCADE

Karlsruhe Shower Core and Array DEtector



KASCADE



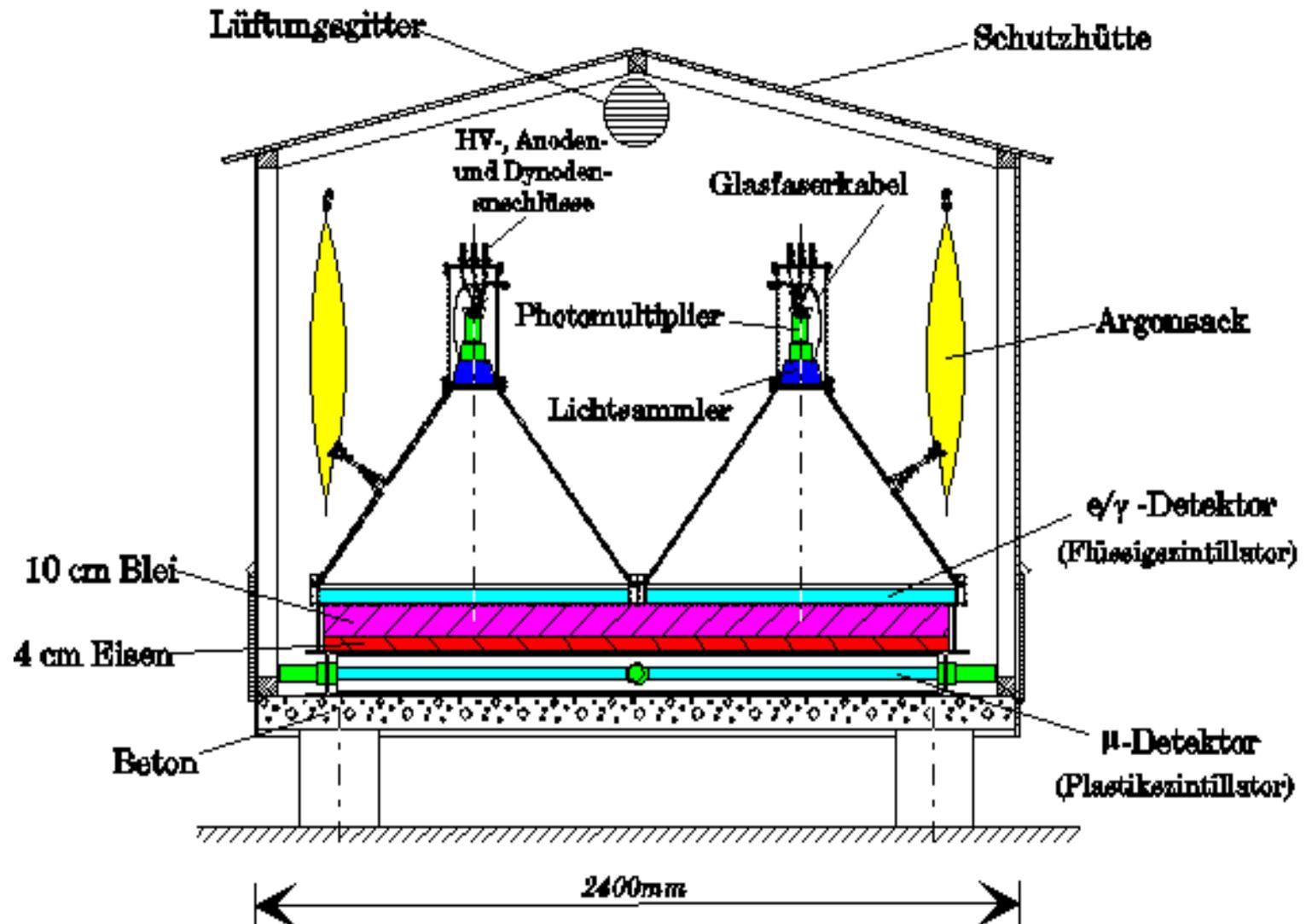
Karlsruhe Shower Core and Array Detector

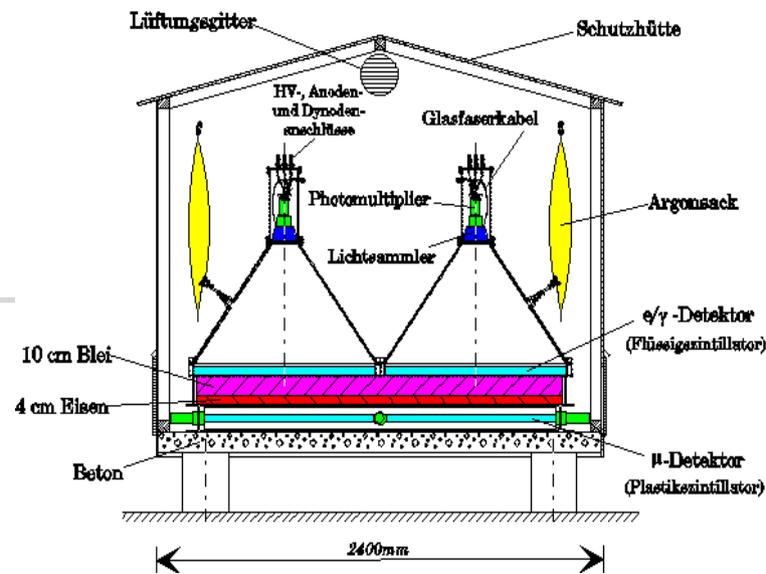
- 1) Detector Array:
252 stations
13 m spacing
- 2) Central
Detector:
Calorimeter
- 3) Muon tracking
detector

Array Detector



Array Detector

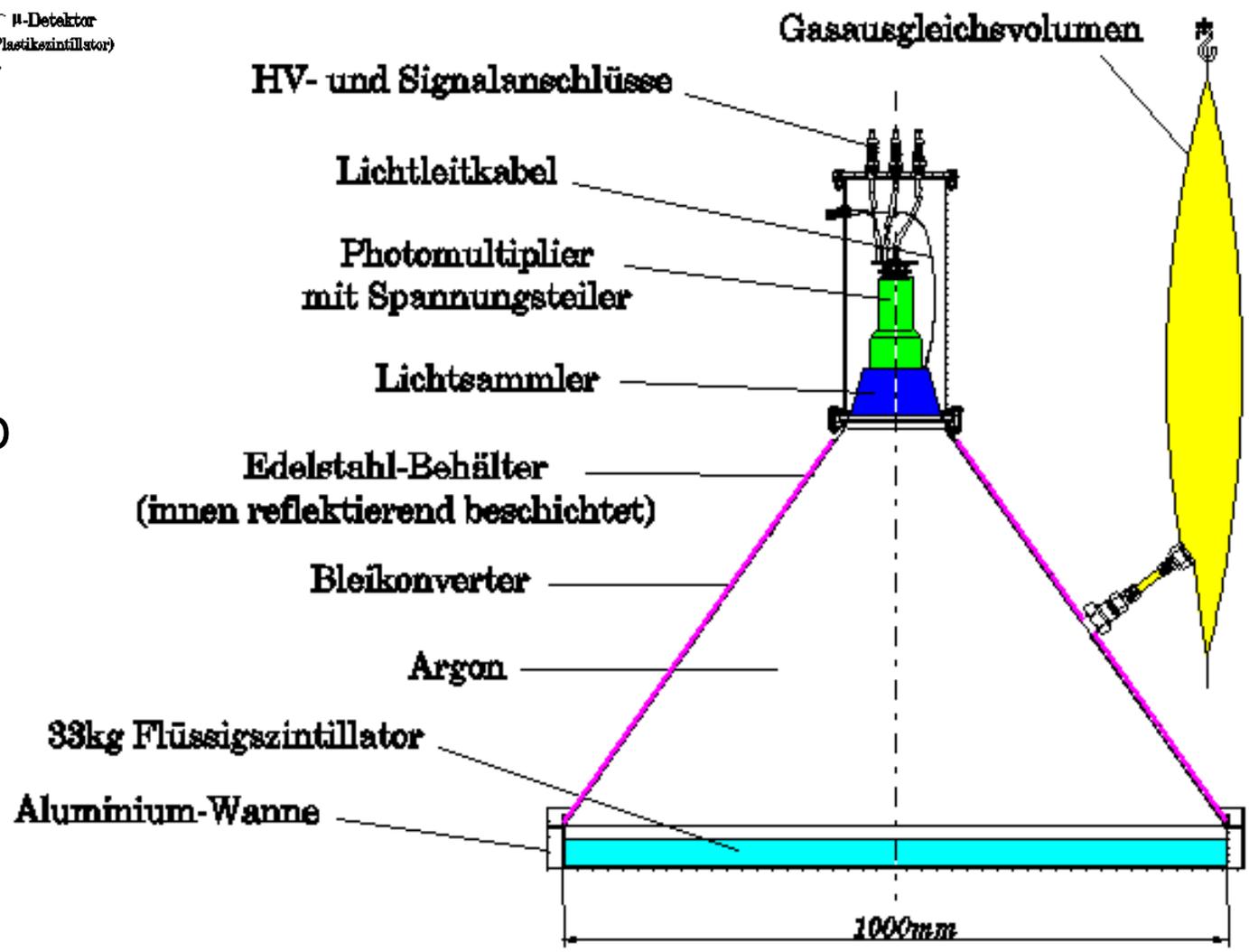




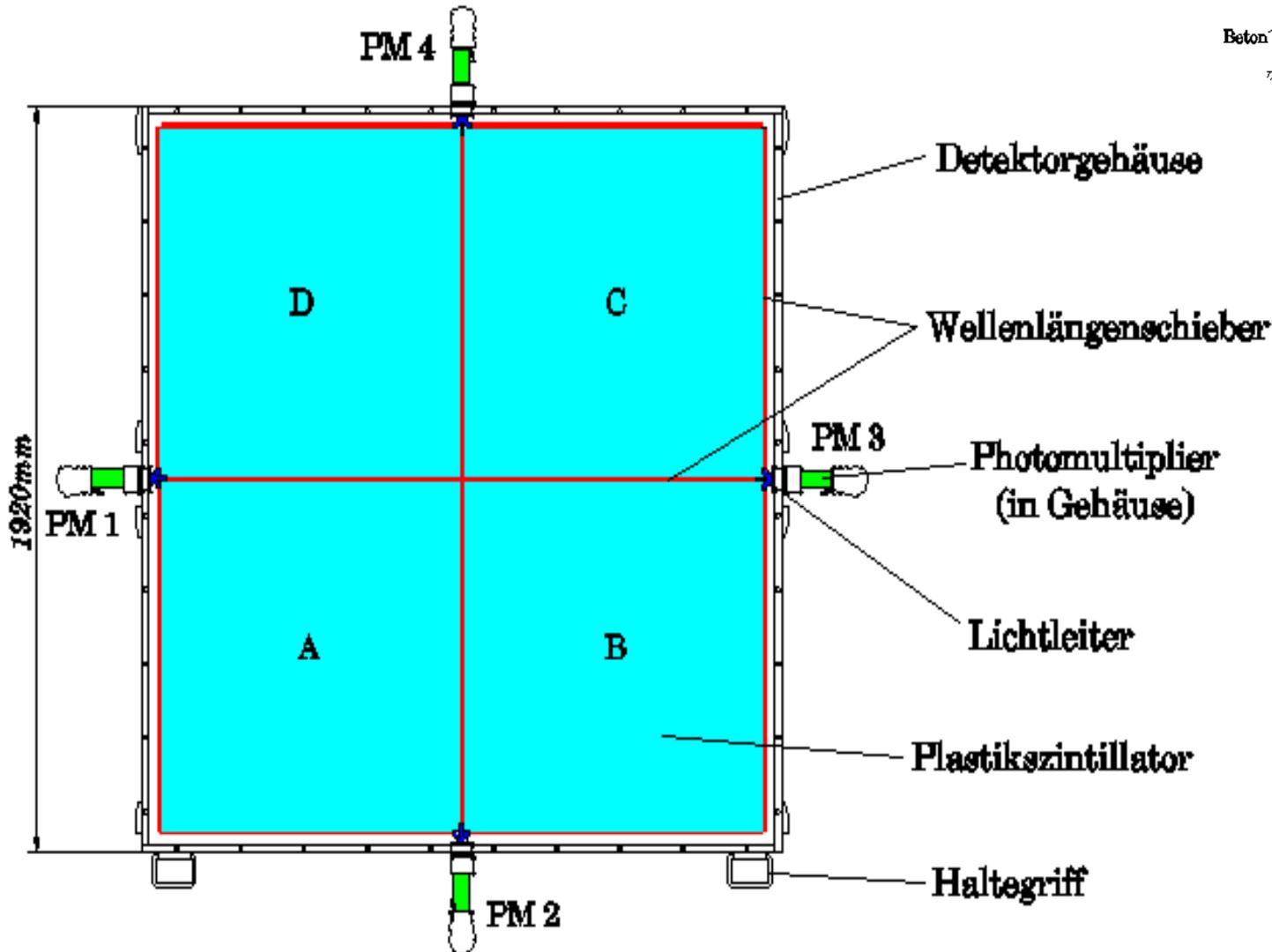
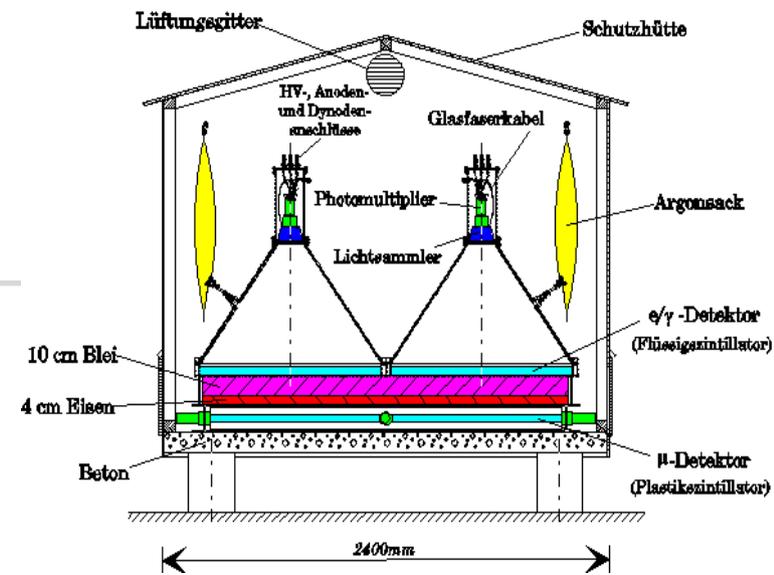
tor

Mede a energia depositada pelas partículas durante a passagem pelo cintilador e o tempo de chegada

Resolução:
 Temporal < 1ns
 Energia < 10%



Muon Detector

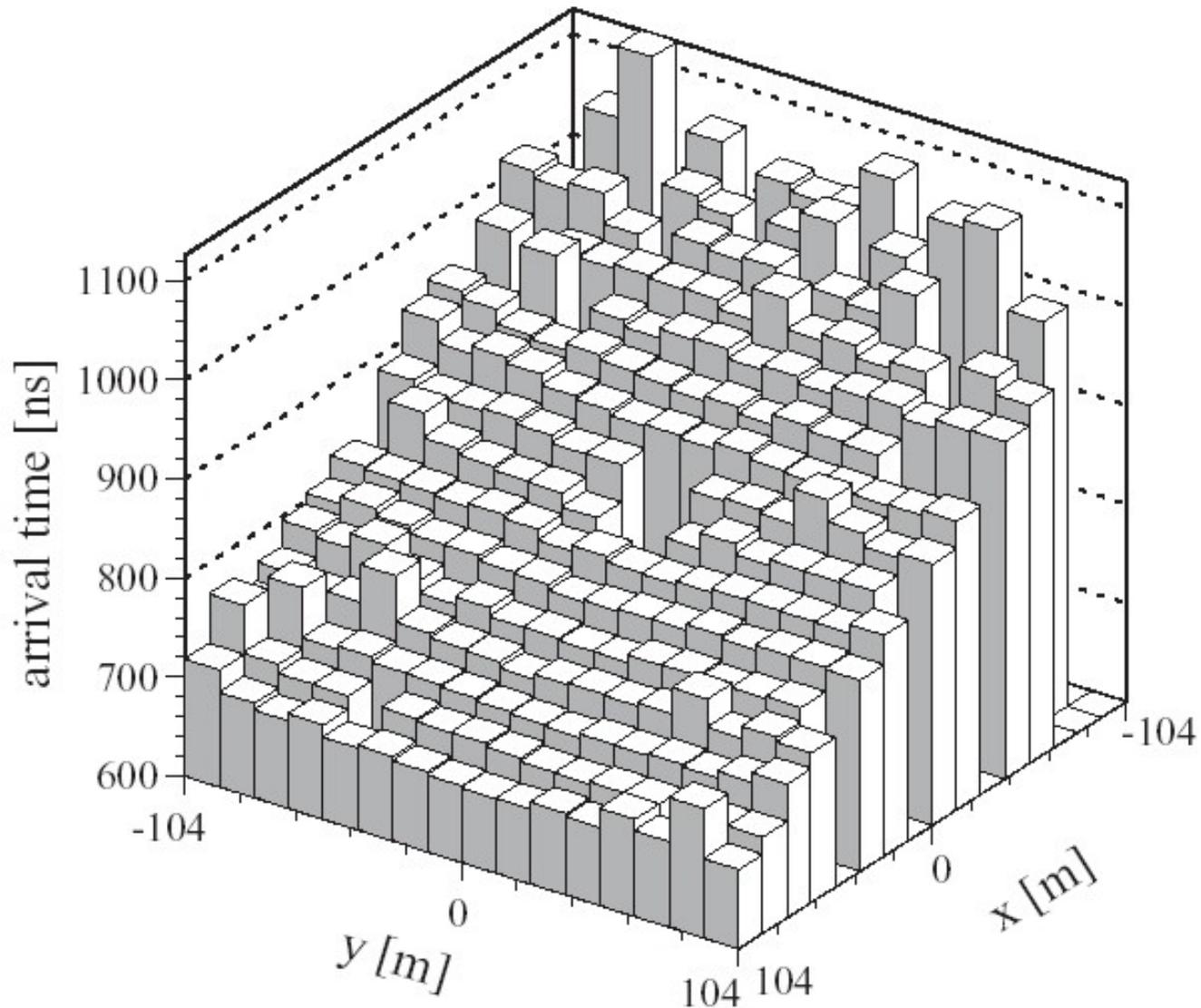


Mede a energia depositada por múons com energia acima de 230 MeV

Resolução:
Energia < 10 %

Array Detector: Reconstruction: Arrival Direction

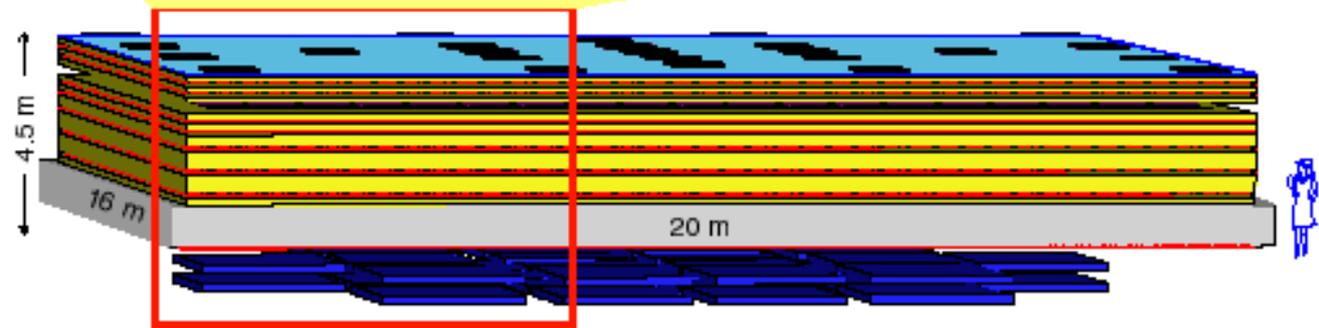
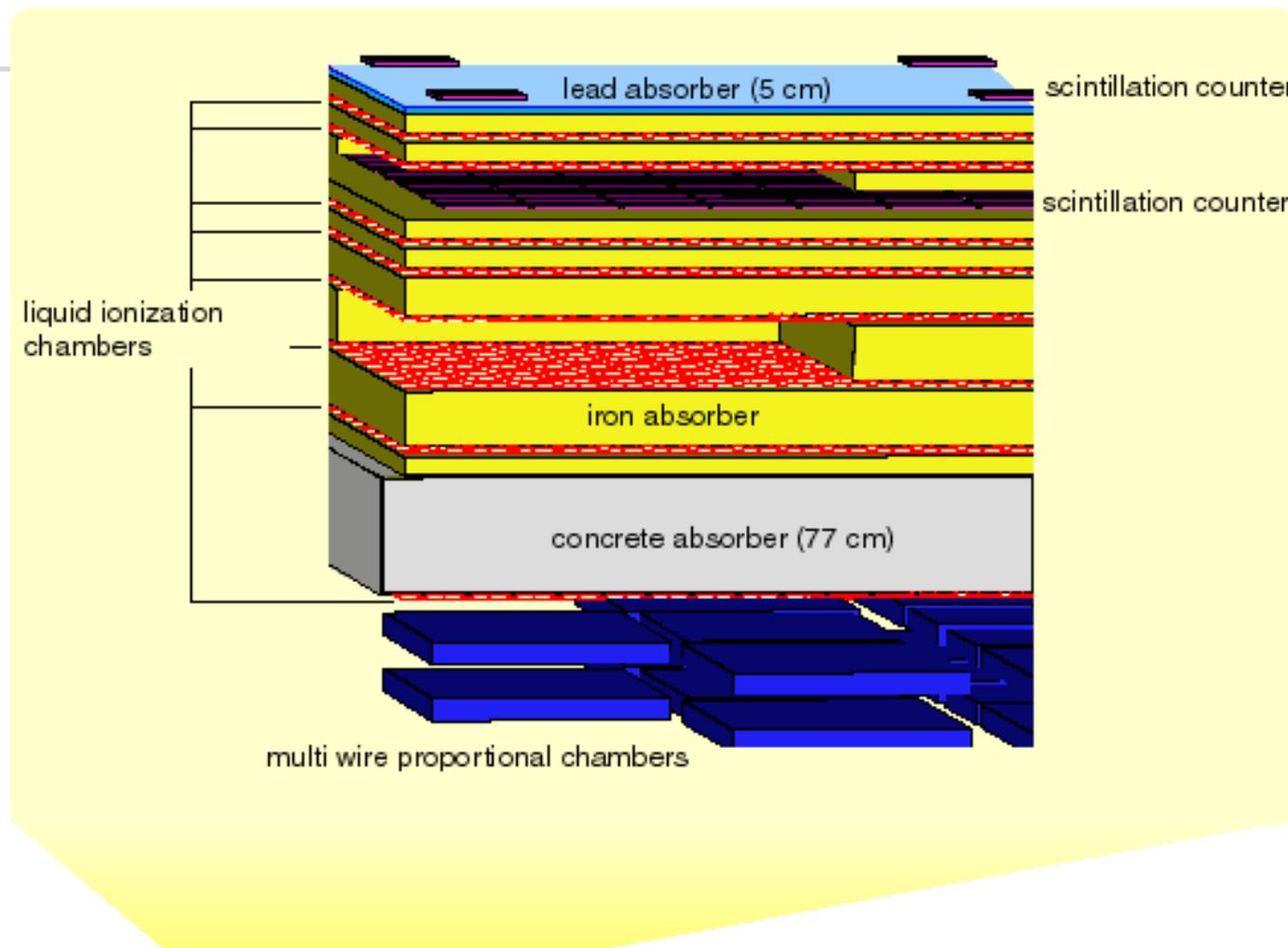
Arrival Direction: Arrival times: EM detectors

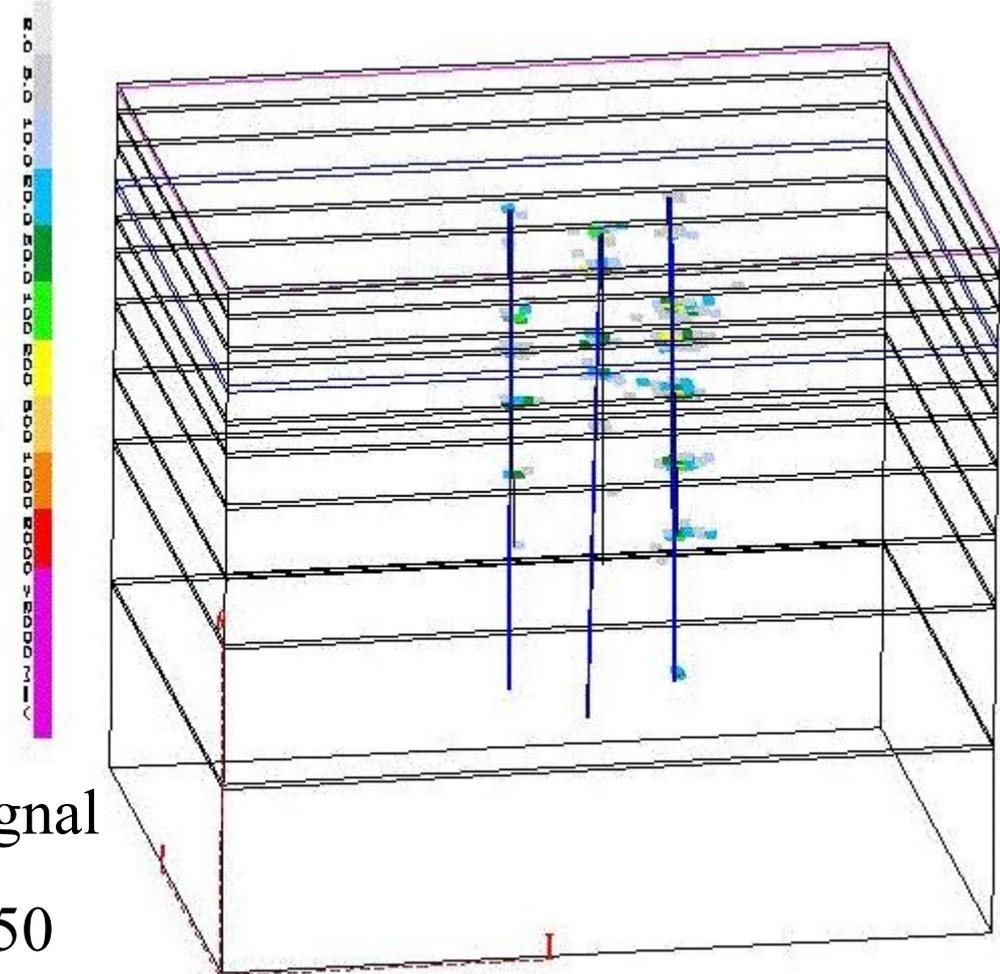
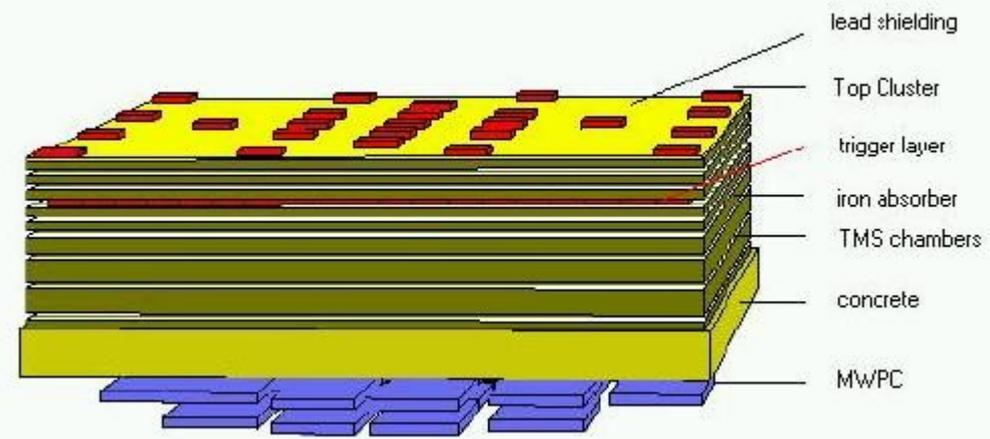
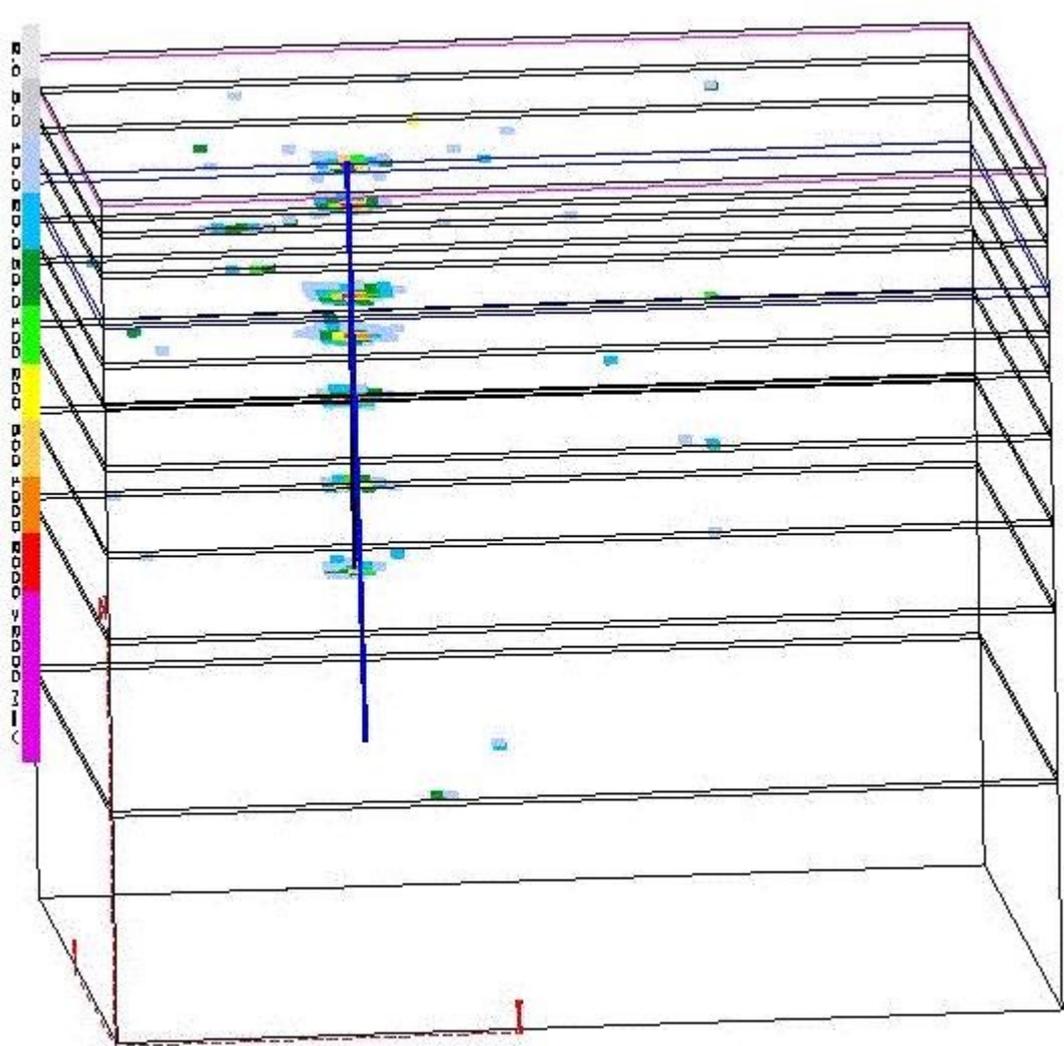


Central Detector



Central Detector



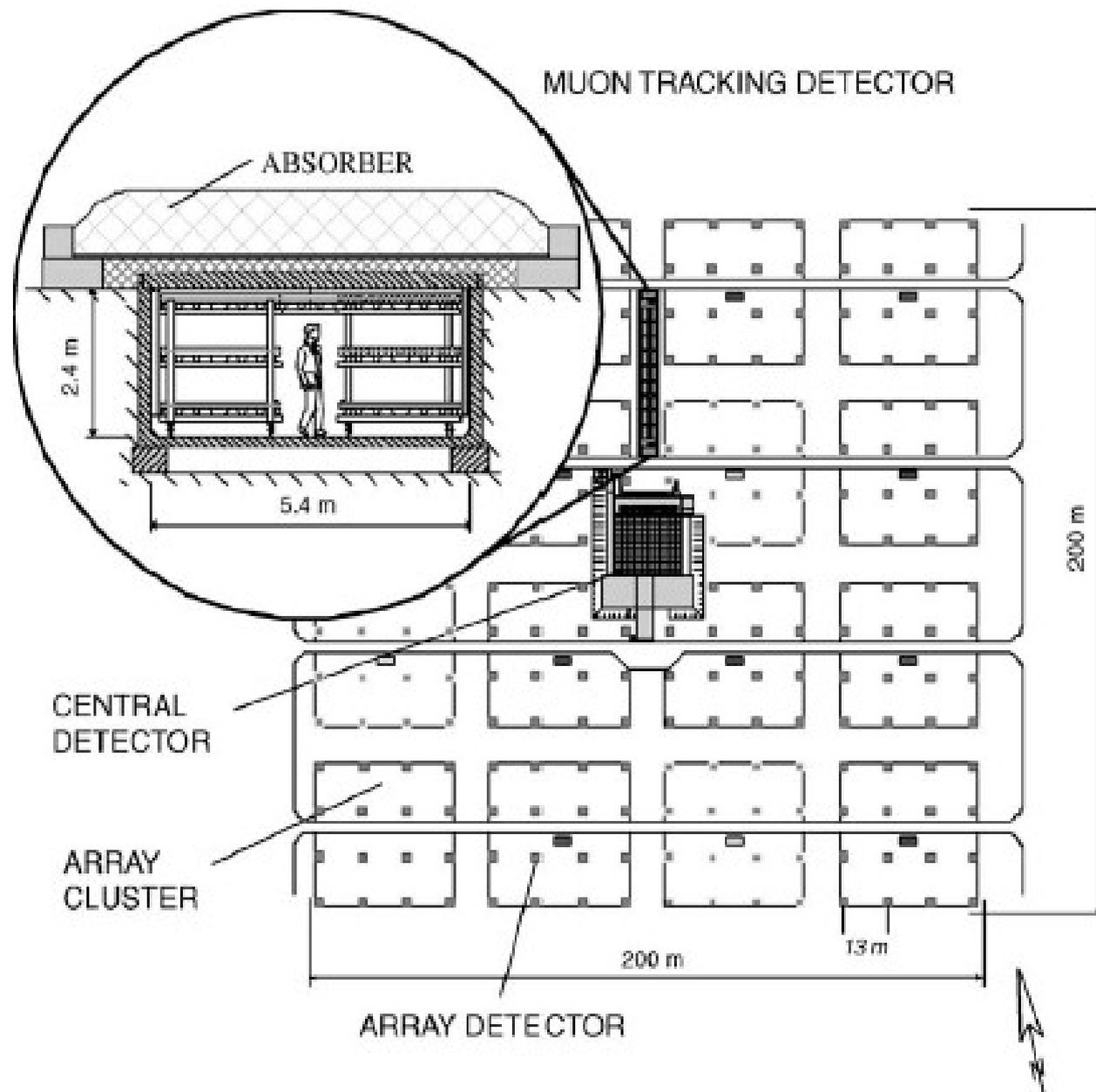


Trigger Layer: 456 plastic scintillators

Trigger Conditions:

- 1) at least 8 scintillator with $1/3$ muon signal
- 2) at least 1 scintillator with more than 50

Muon detector: streamer tubes



Muon detector: streamer tubes



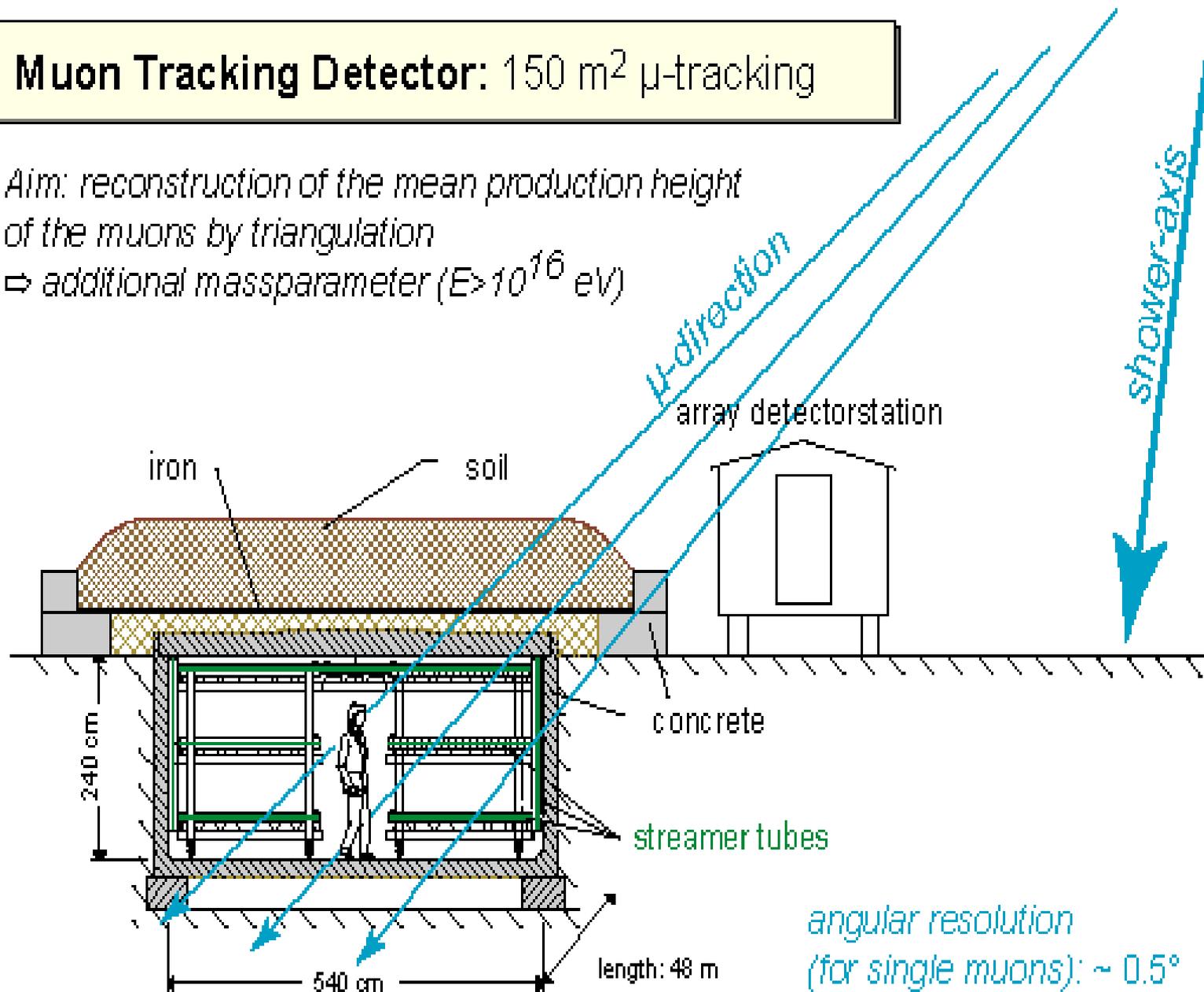
Fig. 7. The MTD in the tunnel.

Muon detector: streamer tubes

Muon Tracking Detector: 150 m² μ -tracking

Aim: reconstruction of the mean production height of the muons by triangulation

\Rightarrow *additional massparameter ($E > 10^{16}$ eV)*





Técnica

Sugerida em 1960 por Greisen,
Annual Rev. of Nuclear Physics.

Idéia Geral:

1) Partículas no chuveiro ionizam as moléculas de nitrogênio no ar.

2) Ao desexcitar as moléculas emitem luz de fluorescência

3) Detectar a luz de fluorescência e reconstruir o número de partículas no chuveiro

Emissão Fluorescência

Eficiência de emissão = 5×10^{-5}

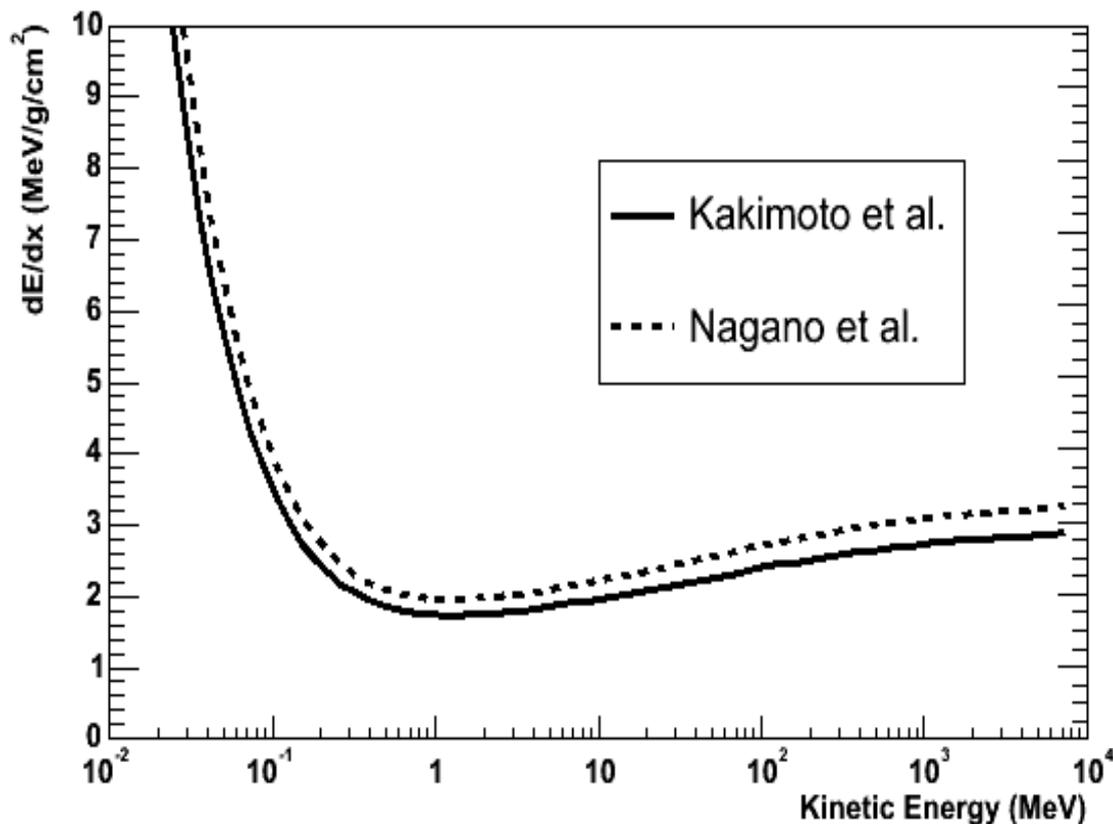
Em média

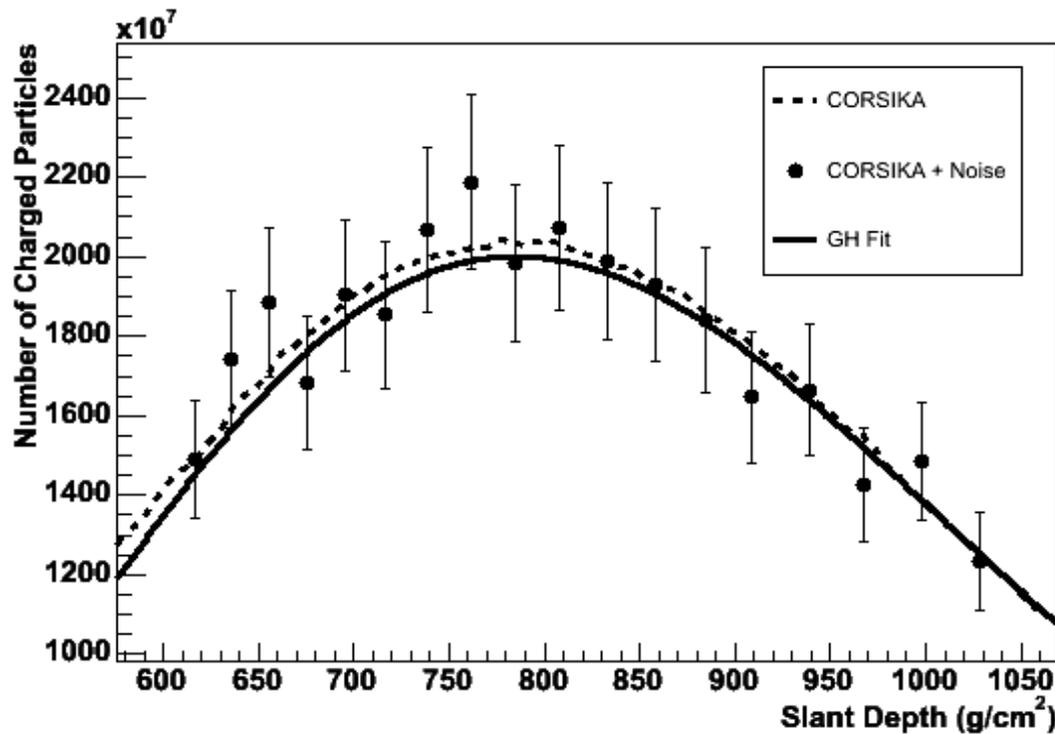
1 elétron relativístico
deposita aprox. 3 MeV/g/cm^2

$3 \times 5 \times 10^{-5} \text{ MeV/g/cm}^2$
é transformado
em luz de fluorescência
= $1.5 \times 10^{-4} \text{ MeV/g/cm}^2$

Eletron 80 MeV
Stop Range = 27.3 g/cm^2

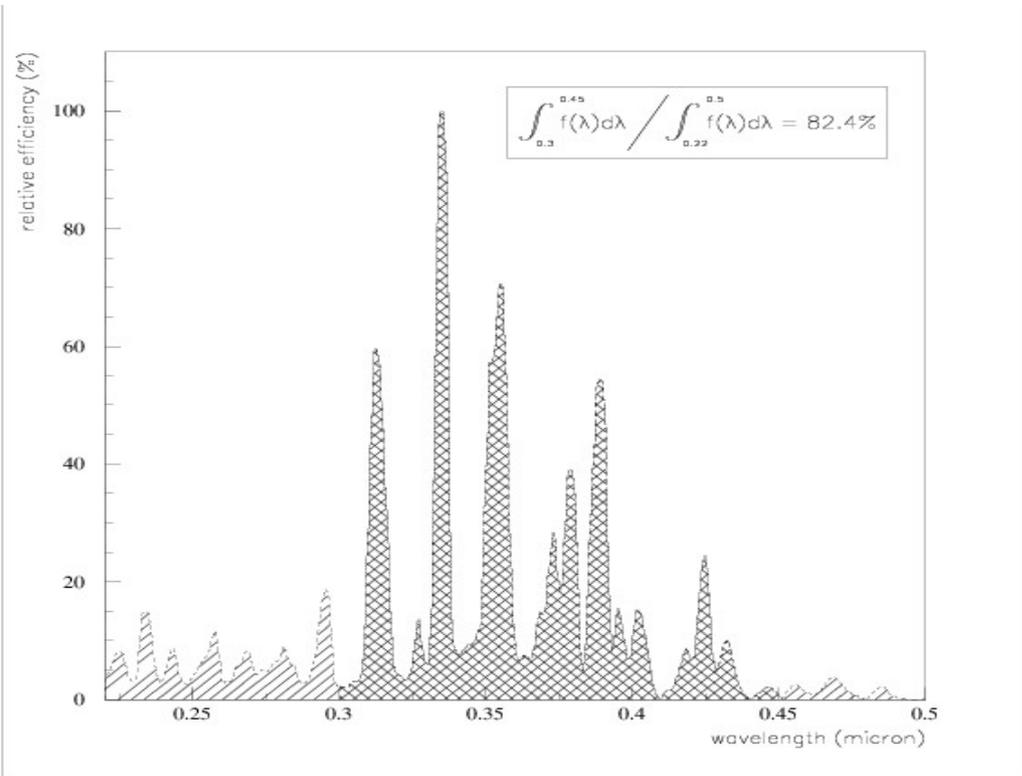
1 elétron transforma
 $4 \times 10^{-3} \text{ MeV}$ em luz de
fluorescência





Chuveiro de 10^{20} eV tem 10^{10} partículas no máximo

Energia total liberada no máximo do chuveiro:
 4×10^7 MeV



Supondo emissão monocromática com $\lambda = 350$ nm
 $E = h\nu = hc/\lambda = 3.4$ eV

Ou $N = 1.1 \times 10^{13}$ fotons emitidos isotropicamente pelo chuveiro

Pierre Auger Observatory

Argentina Site

Tour with Google Earth

See <http://www.auger.org/>

Cherenkov Telescope Array

