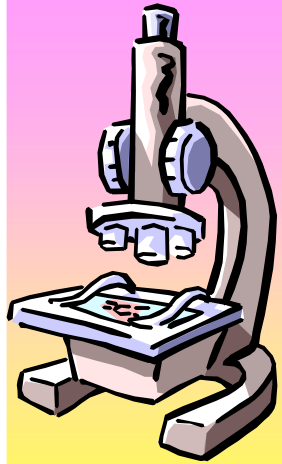
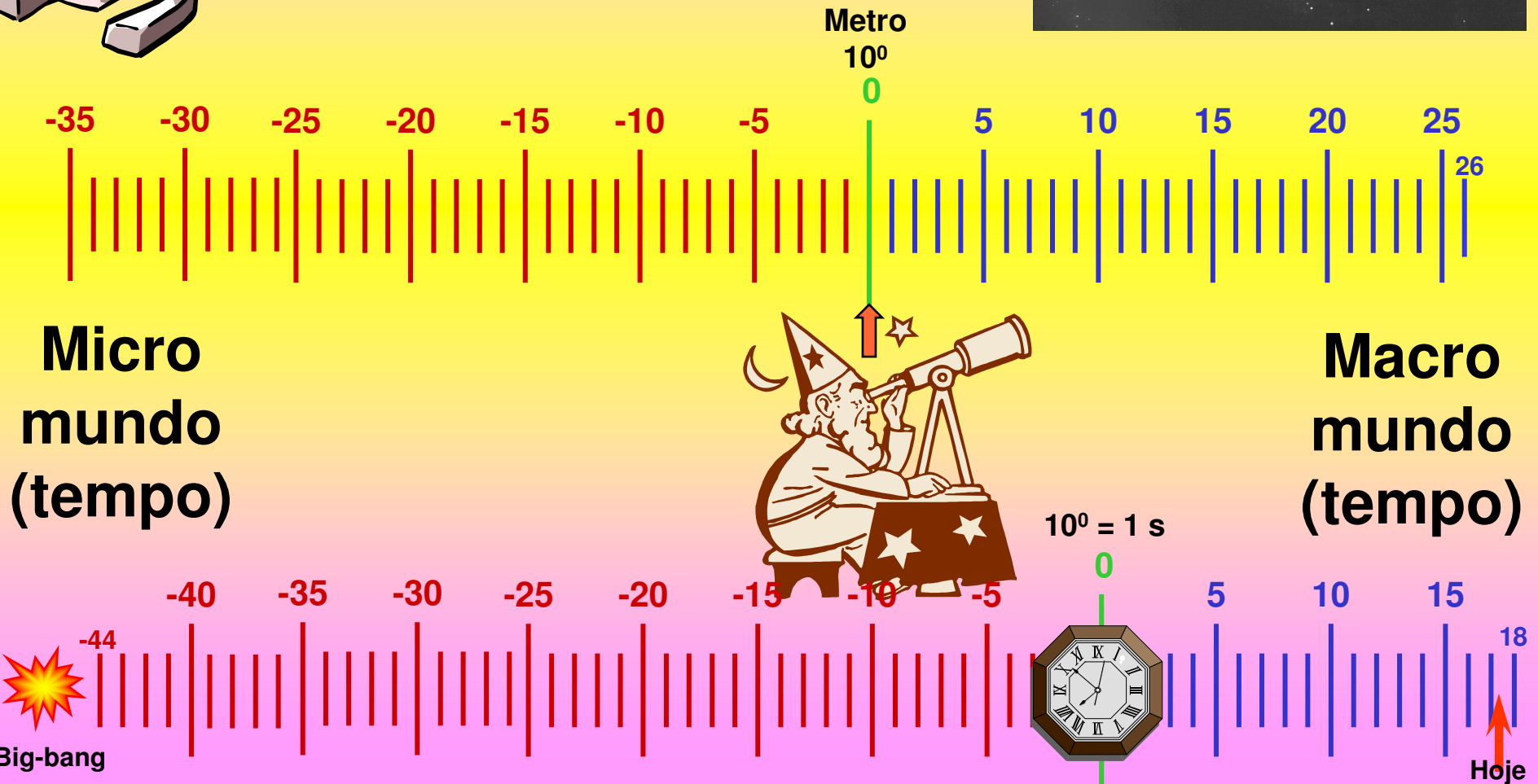
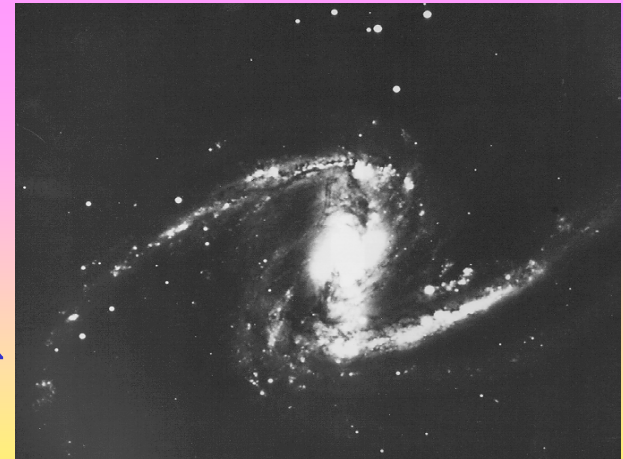


Viagem entre o micro e o macrocosmo

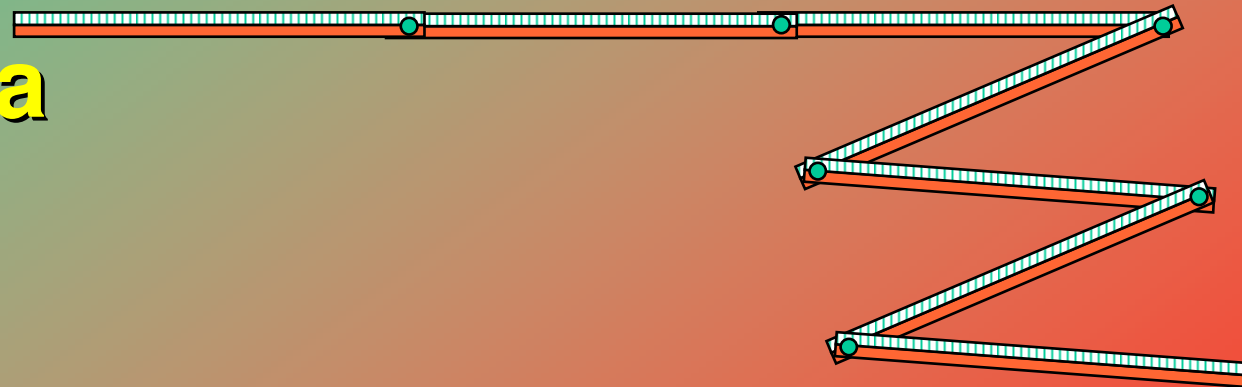


Abrangência da Astronomia



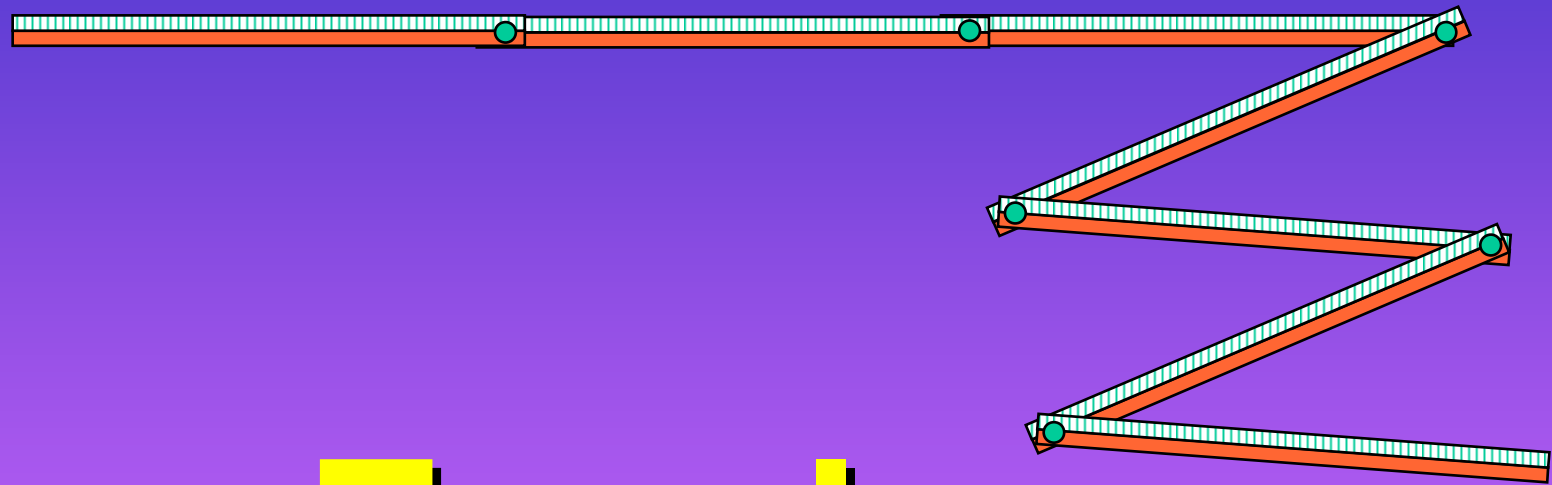
Escalas

Escalas
de distância



Escalas
de tempo



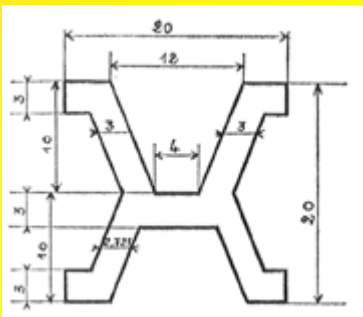
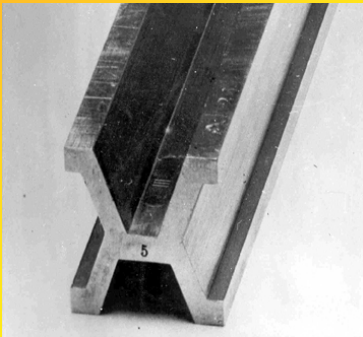


Escalas de distância



Definição Inicial do Metro

Extremidade e secção do padrão de platina no Museu de Sèvres, Paris



1 metro:
1/10.000.000
de 1/4 da
circunferência de
um meridiano
Terrestre



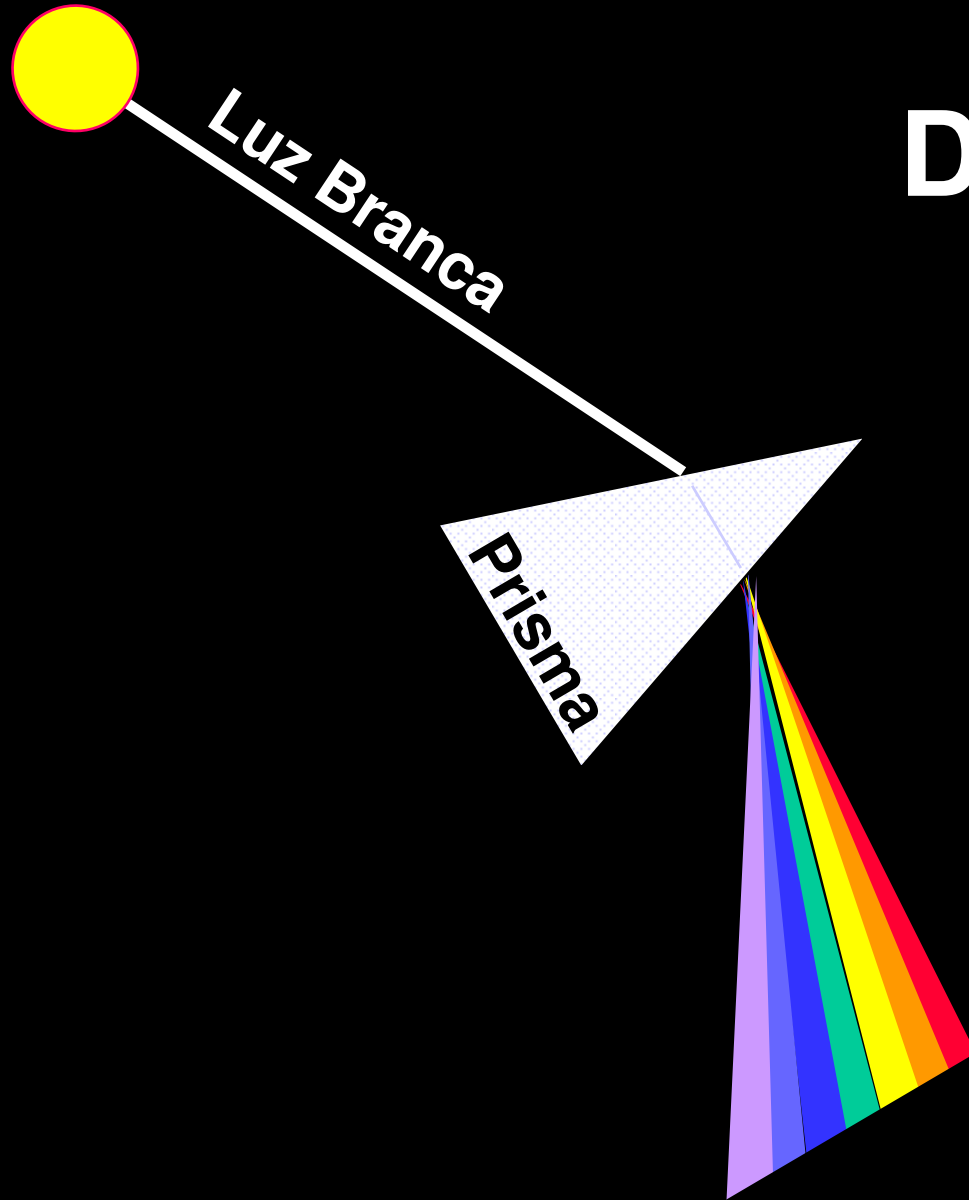
1 metro

▼ Padrão de platina no Museu de Sèvres ▼

Arco-íris



Decomposição da Luz



Espectro contínuo

Natureza da Luz



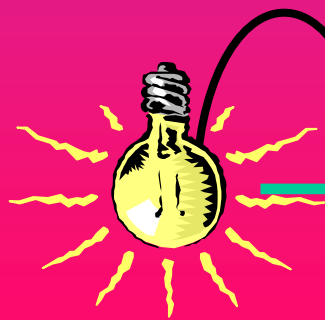
Fóton

Natureza
corpúscular



Natureza
ondulatória

Onda



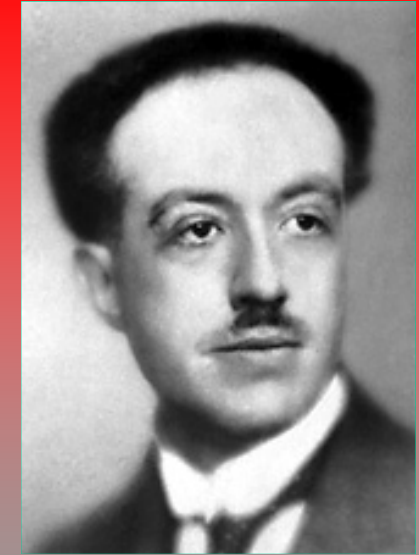
λ

λ

c

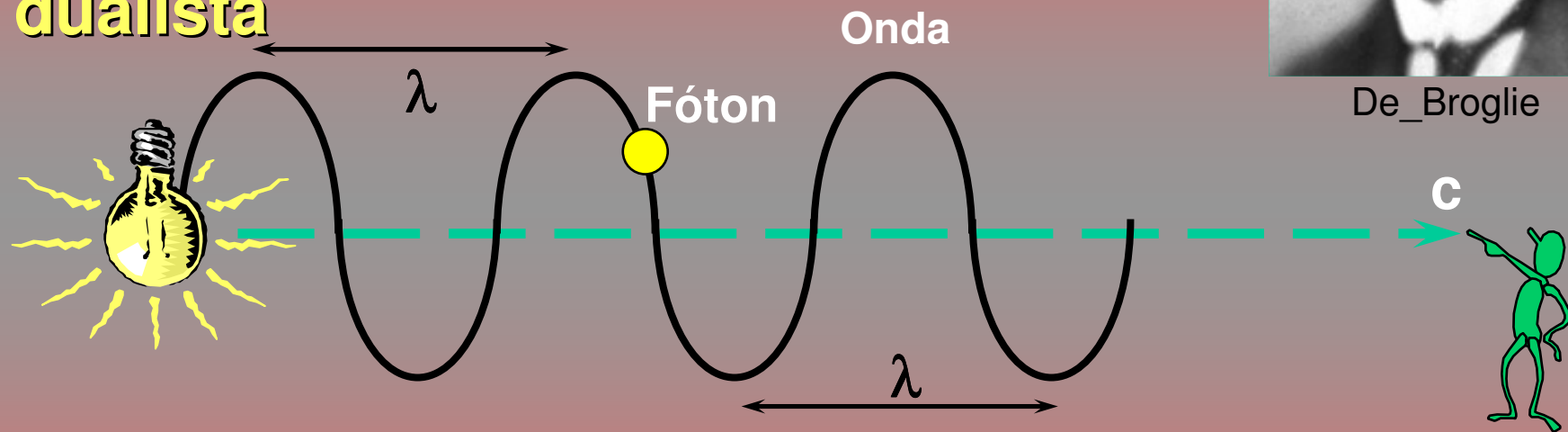


O que é a luz?



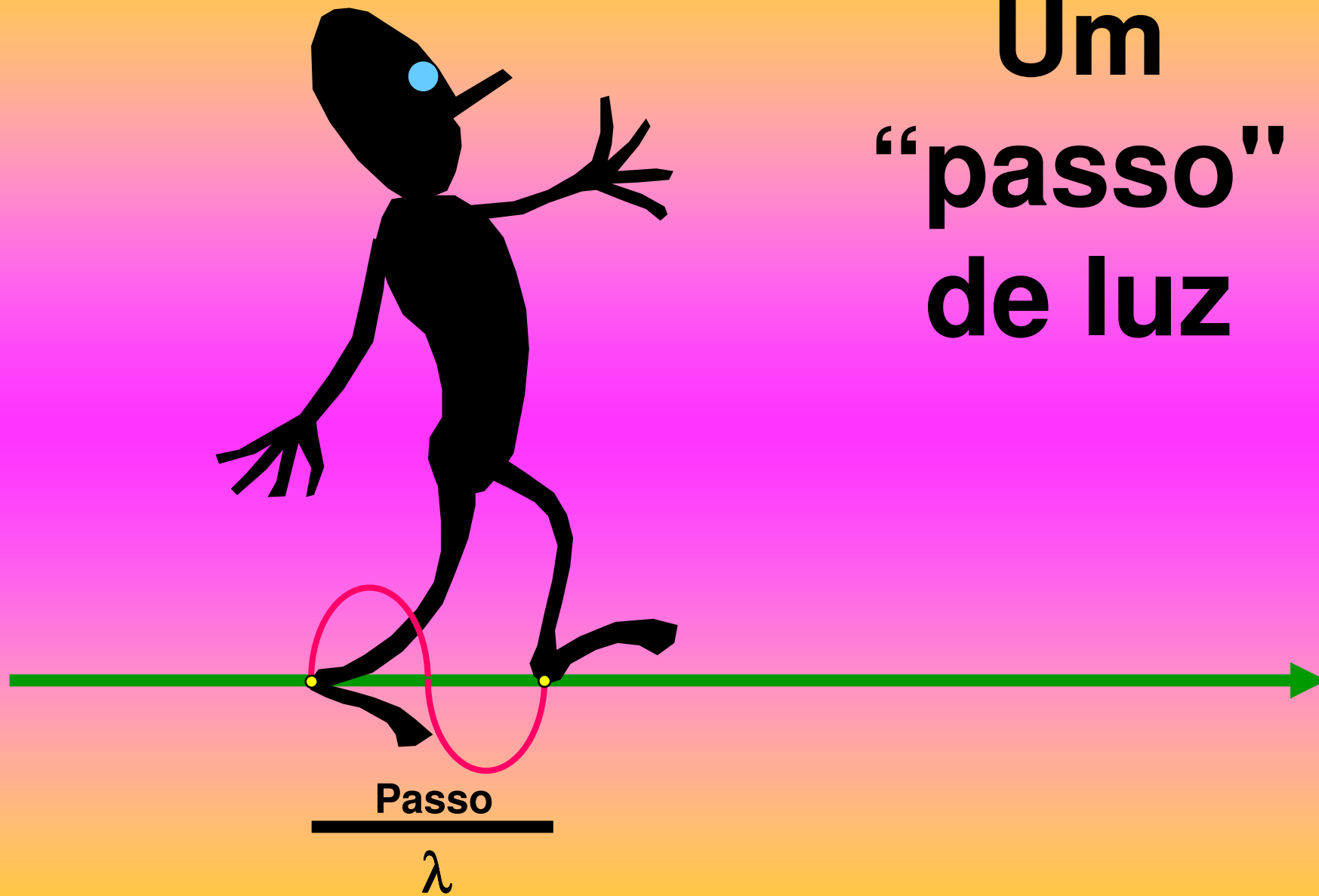
De_Broglie

Natureza
dualista

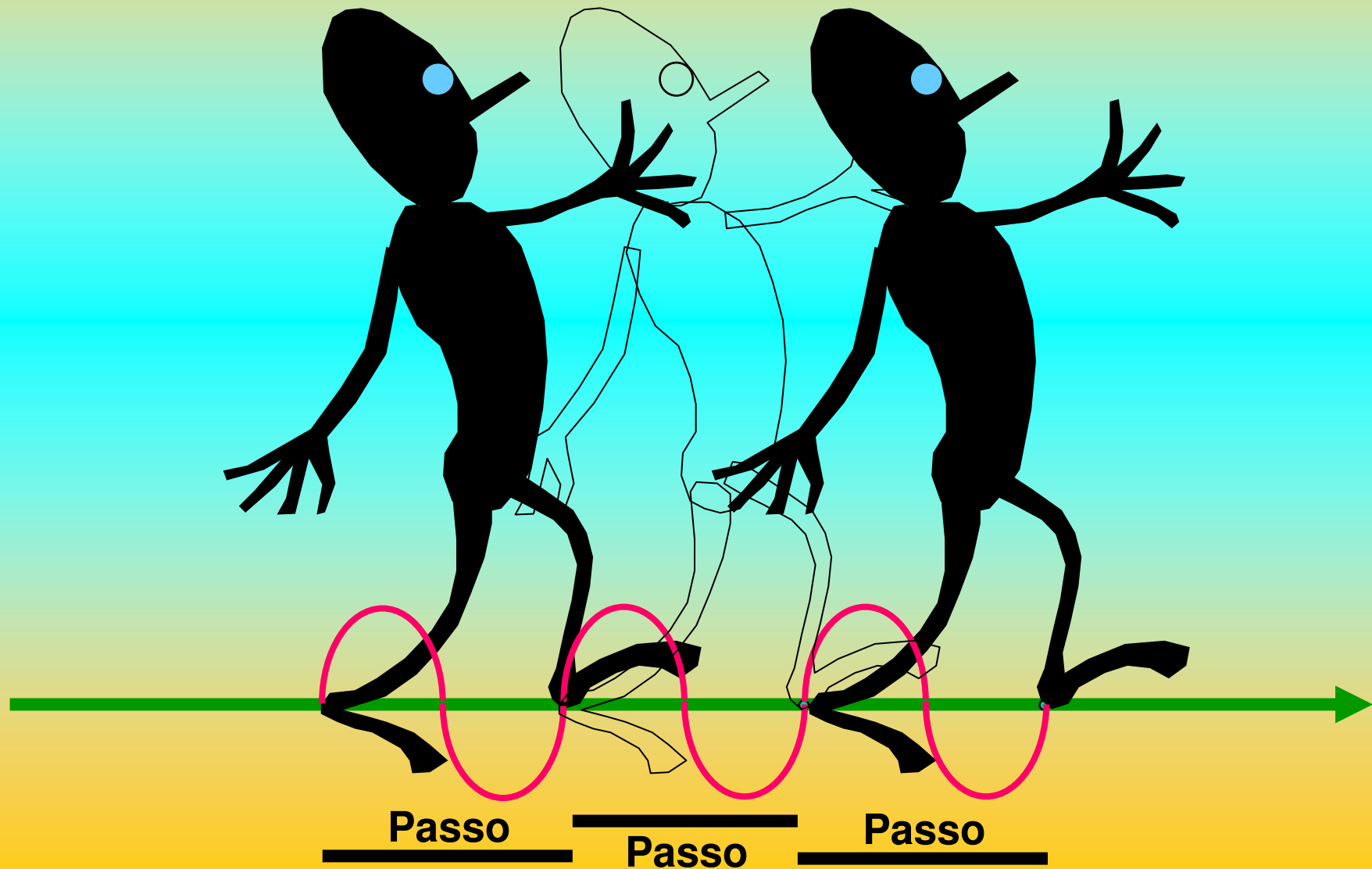


A luz pode (?!) ser considerada como uma partícula energética (fóton) que se propaga na forma ondulatória.

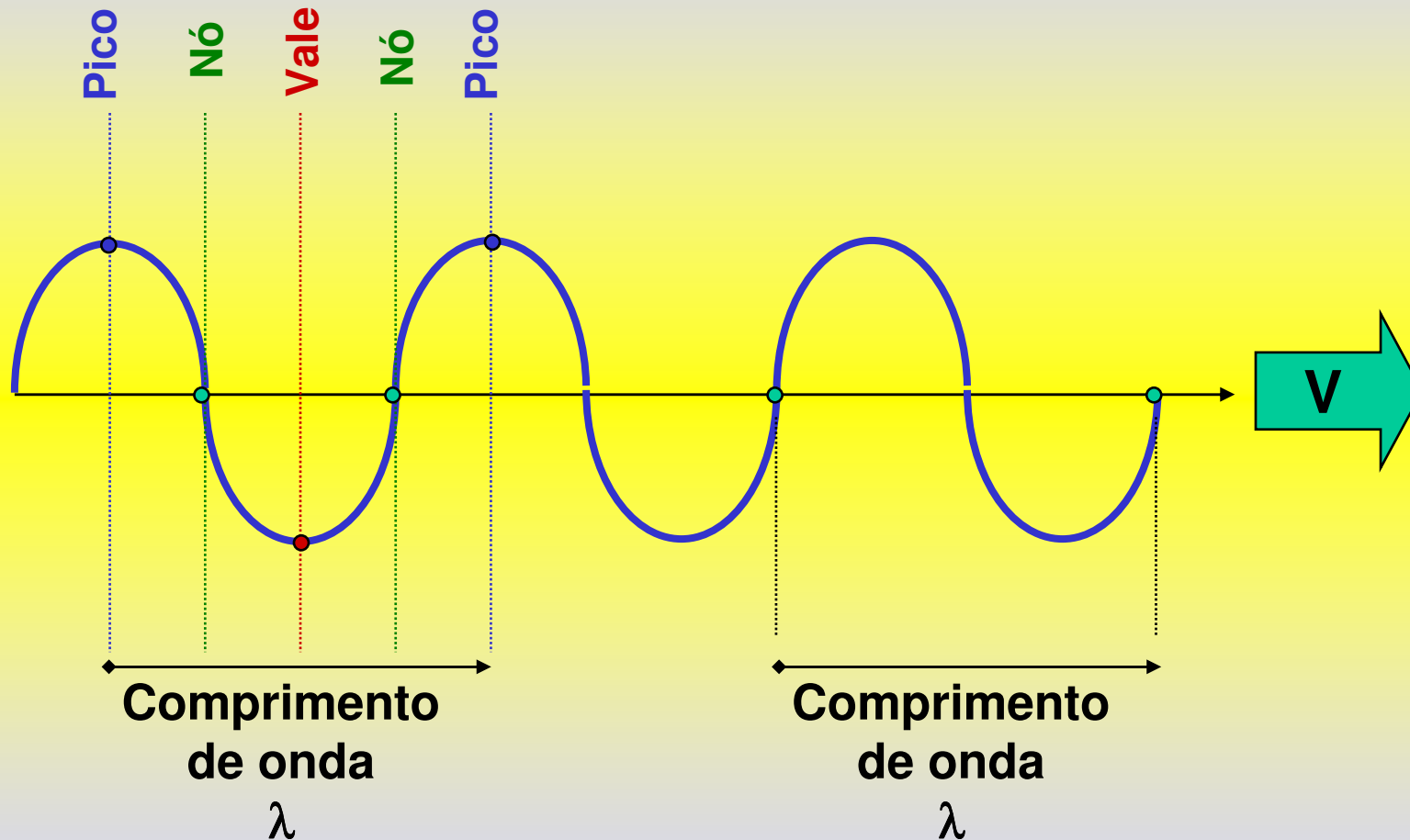
Um “passo” de luz



"Passo" da luz



Onda



λ : comprimento da onda

T : período da onda

v : velocidade de deslocamento

$$\lambda = T v$$

Vermelho

Alaranjado

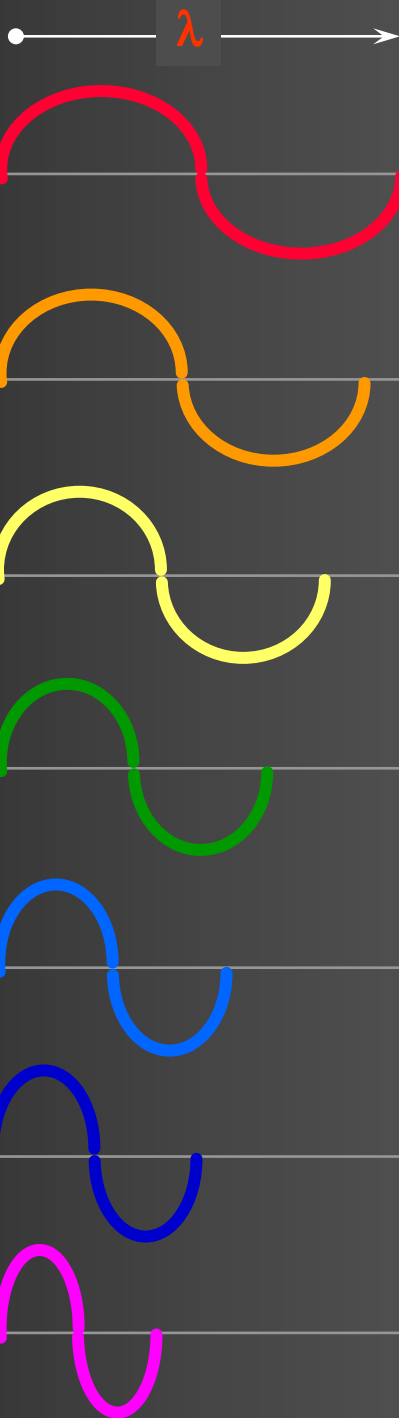
Amarelo

Verde

Azul

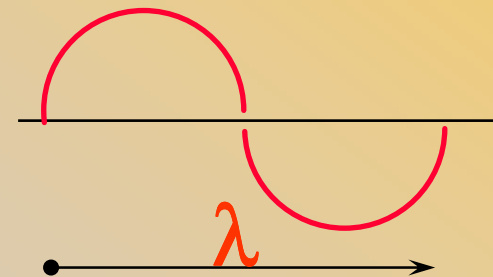
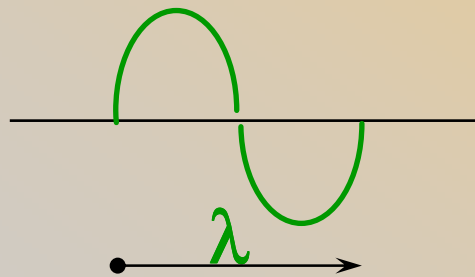
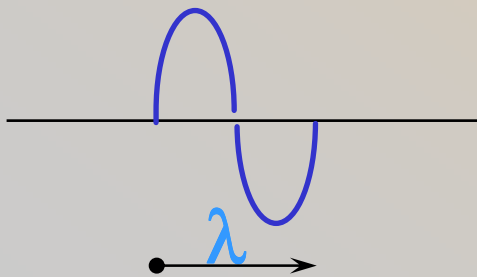
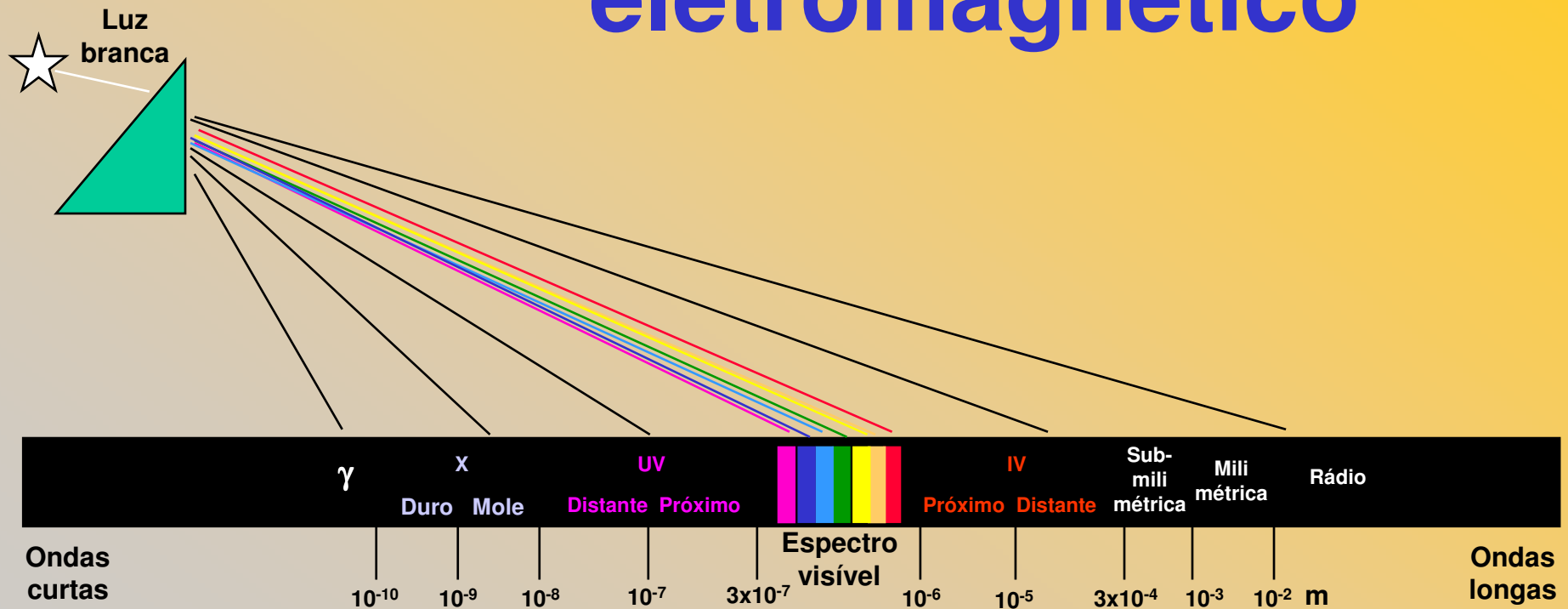
Anil

Violeta



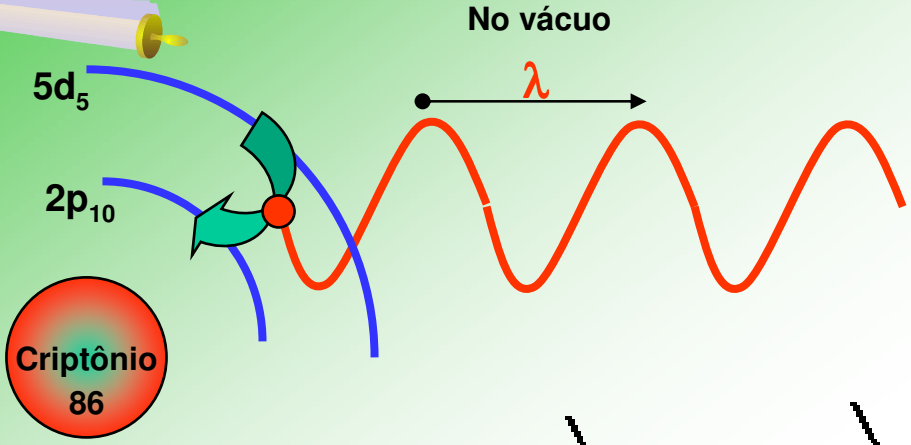
**Espectro
visível**

Espectro eletromagnético





Outra Definição do Metro



1/40.000.000 da circunferência do equador Terrestre

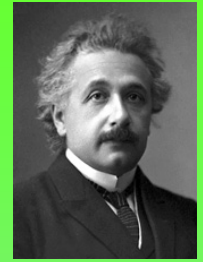
1 metro padrão de platina no Museu de Sèvres

$$1.650.763,73 \lambda$$



**Definição do metro
usando a noção de
constância da
velocidade da luz no
vácuo**

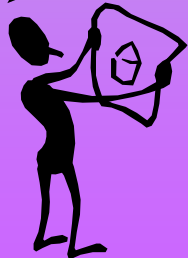
Princípio Fundamental da Teoria da Relatividade de Einstein



Também medi.
E ela deu 300.000
km/s com relação
ao avião.



Medi.
A velocidade da
luz deu 300.000
km/s.



A velocidade **c** da luz no vácuo é a mesma e constante, independentemente do sistema de referência do observador.

Princípio fundamental da Teoria da Relatividade

A velocidade da luz **no vácuo** é constante e nenhum corpo material pode atingi-la.

$$c \cong 299.792.458 \text{ m/s}$$

↑
Medição

Velocidade da luz no vácuo

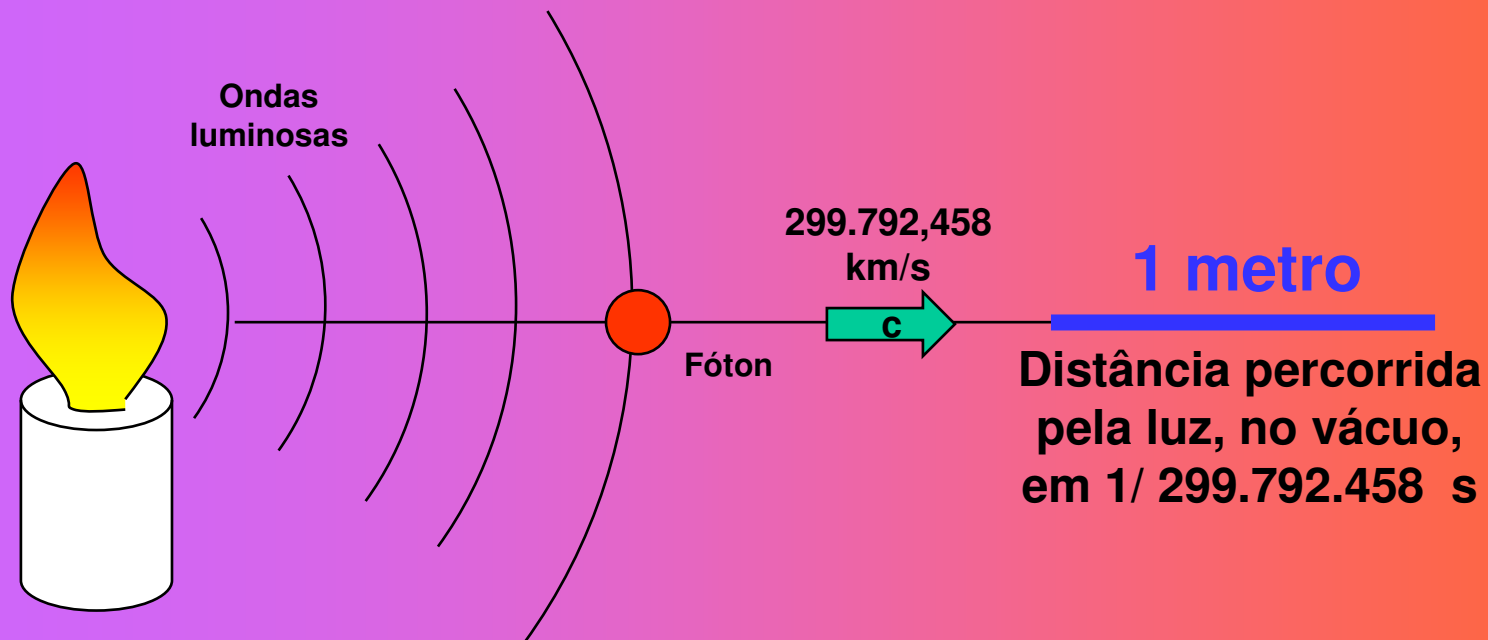
A velocidade da luz no vácuo, por definição, é considerada uma grandeza fundamental e vale, exatamente:

$$c \equiv 299.792.458 \text{ m/s}$$

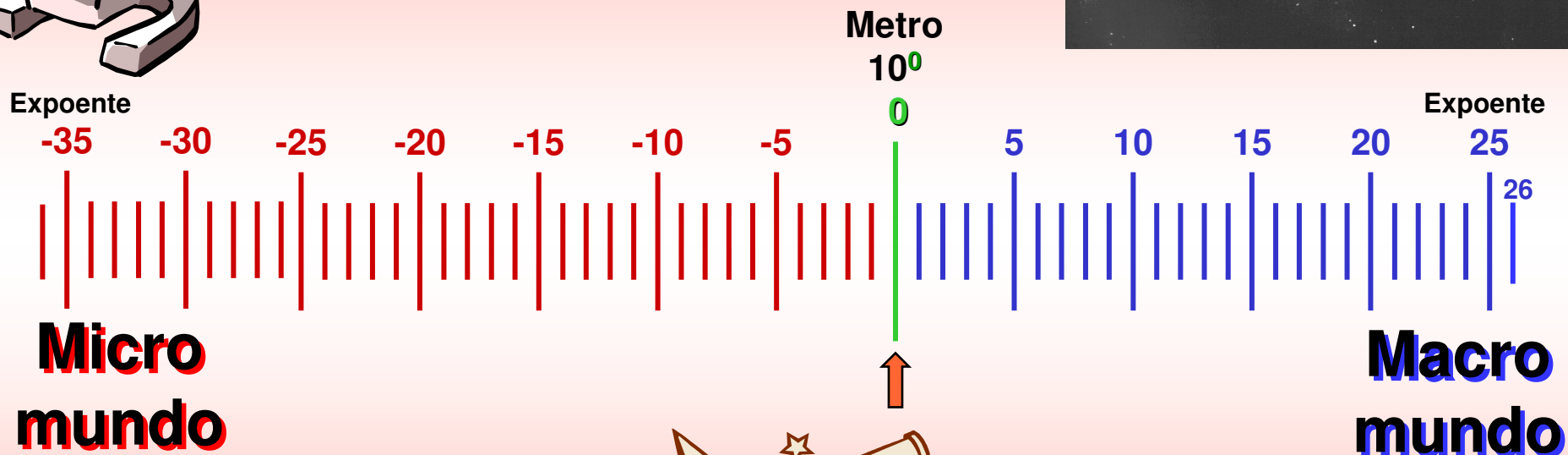
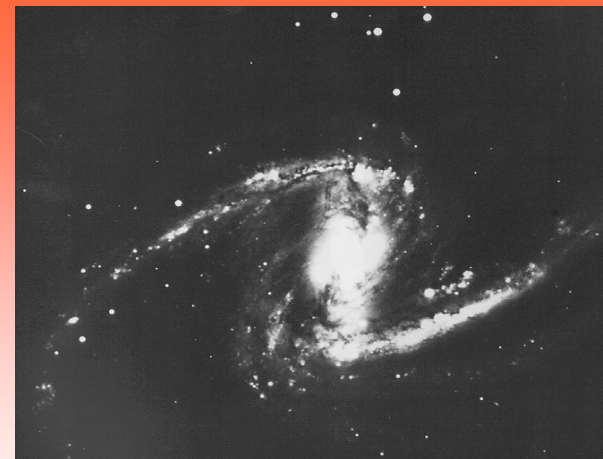
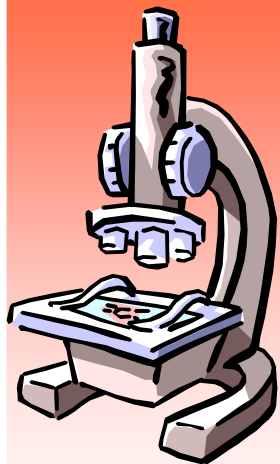
↑
Por definição

Definição atual do metro

(a partir de 1983)



Do micro ao macro



Cada traço à esquerda significa o traço da direita **dividido** por 10

Cada traço à direita significa o traço da esquerda **multiplicado** por 10



Múltiplos e submúltiplos de 10

Submúltiplos

- 10^{-00} = base
- 10^{-01} = d = deci
- 10^{-02} = c = centi
- 10^{-03} = m = mili
- 10^{-06} = μ = micro
- 10^{-09} = n = nano
- 10^{-12} = p = pico
- 10^{-15} = f = femto
- 10^{-18} = a = atto
- 10^{-21} = z = zepto
- 10^{-24} = y = yocto

Múltiplos

- 10^{24} = Y = yotta
- 10^{21} = Z = zetta
- 10^{18} = E = exa
- 10^{15} = P = peta
- 10^{12} = T = tera
- 10^{09} = G = giga
- 10^{06} = M = mega
- 10^{03} = k = kilo
- 10^{02} = h = hecto
- 10^{01} = da = deca
- 10^{00} = base

1000

Nome	Símbolo	Fator de multiplicação da unidade	
yotta	Y	10^{24}	= 1 000 000 000 000 000 000 000 000 000
zetta	Z	10^{21}	= 1 000 000 000 000 000 000 000 000
exa	E	10^{18}	= 1 000 000 000 000 000 000 000
peta	P	10^{15}	= 1 000 000 000 000 000
tera	T	10^{12}	= 1 000 000 000 000
giga	G	10^9	= 1 000 000 000
mega	M	10^6	= 1 000 000
quilo	k	10^3	= 1 000
hecto	h	10^2	= 100
deca	da	10^1	= 10
UNIDADE	-	10^0	= 1
deci	d	10^{-1}	= 0,1
centi	c	10^{-2}	= 0,01
mili	m	10^{-3}	= 0,001
micro	μ	10^{-6}	= 0,000 001
nano	n	10^{-9}	= 0,000 000 001
pico	p	10^{-12}	= 0,000 000 000 001
femto	f	10^{-15}	= 0,000 000 000 000 001
atto	a	10^{-18}	= 0,000 000 000 000 000 001
zepto	z	10^{-21}	= 0,000 000 000 000 000 000 001
yocto	y	10^{-24}	= 0,000 000 000 000 000 000 000 001

Prefixos das unidades SI

Sistema Internacional de Unidades

SI



Implantação: 1960

Adoção no Brasil: 1962

Ratificação: 1988

Resolução 12 do ConMetro

Conselho Nacional de Metrologia, Normalização e Qualidade Industrial

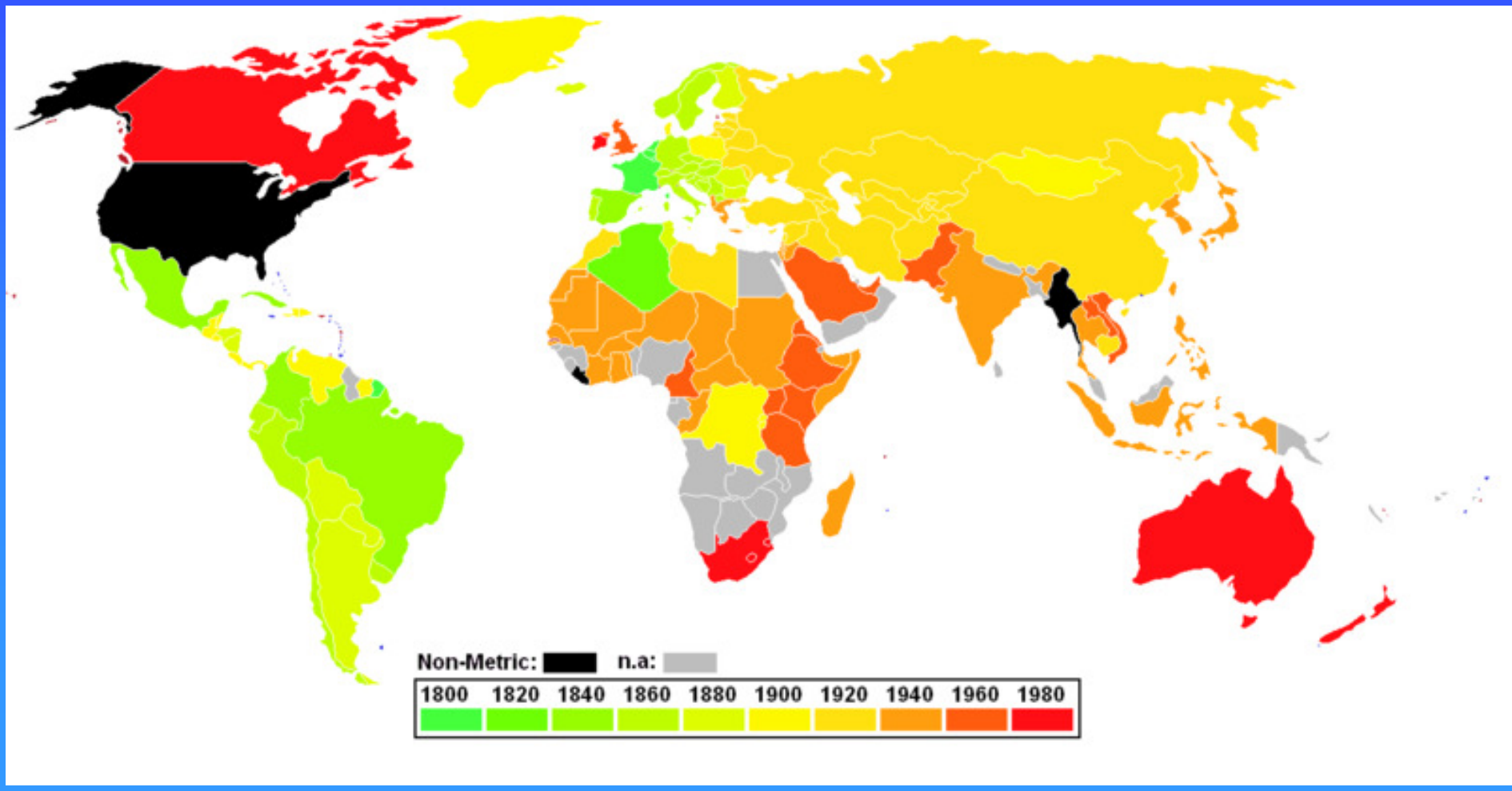
Pronúncia dos prefixos das unidades

Os prefixos das unidades **NUNCA** são acentuados,

com as seguintes **EXCEÇÕES:**

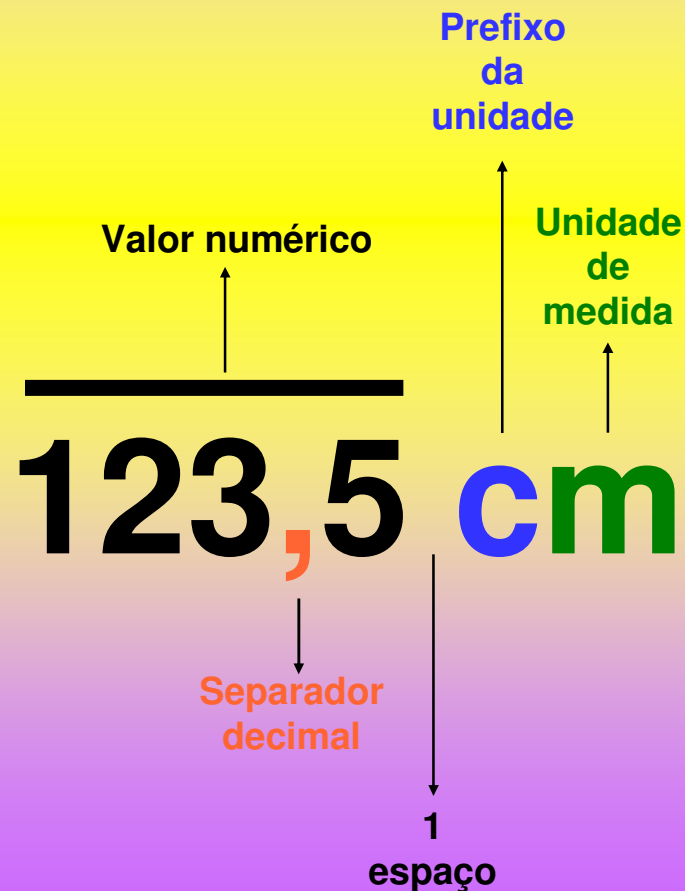
quilômetro, decímetro, centímetro e milímetro

Adoção do Sistema Internacional nos diversos países



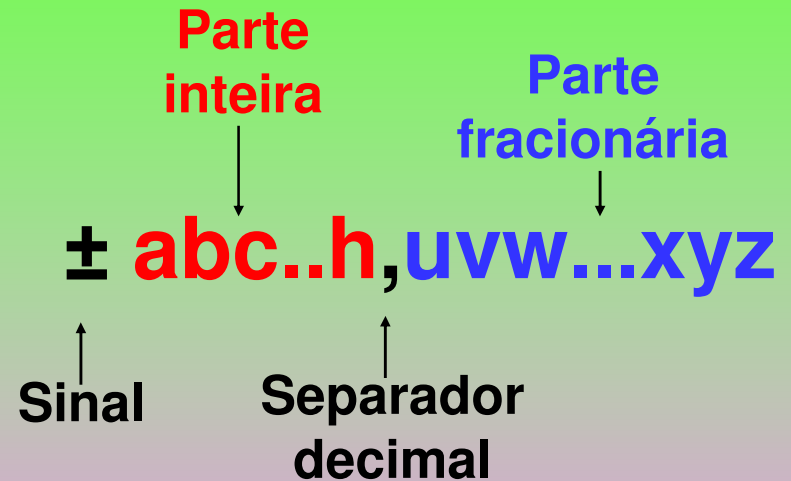
Representação e notação de uma grandeza

Representação de uma grandeza com sua unidade dimensional

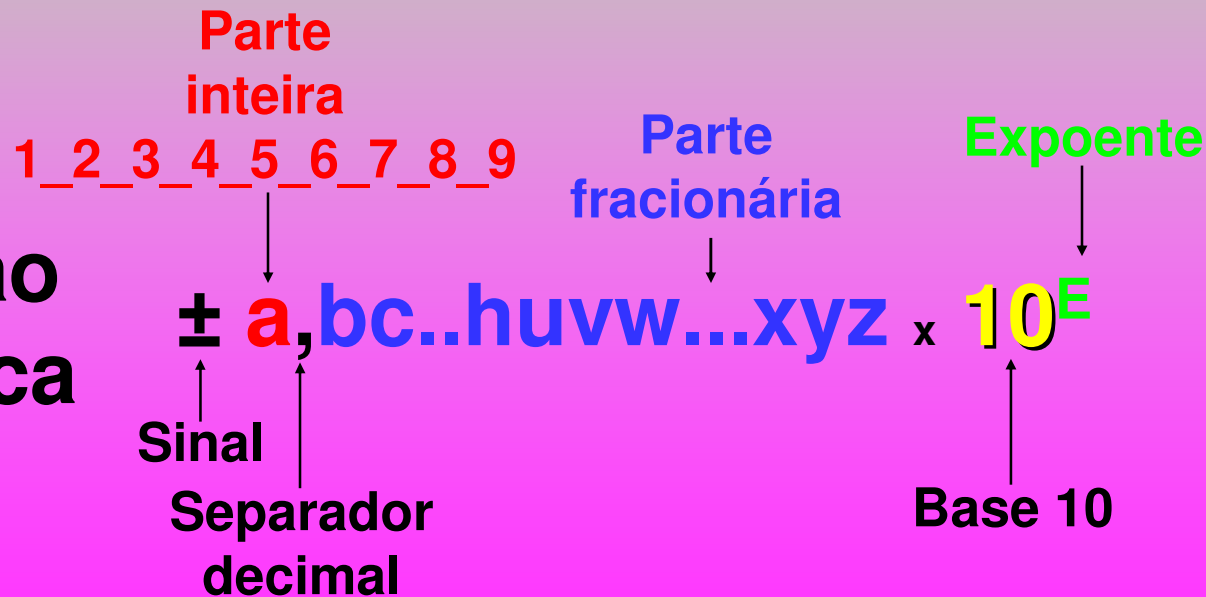


Notação do valor de uma grandeza

Notação decimal



Notação científica



$$7123,456 \Rightarrow 7,123456 \times 10^{+3}$$


De notação
decimal para
científica


$$- 81234560, \Rightarrow - 8,123456 \times 10^{+7}$$

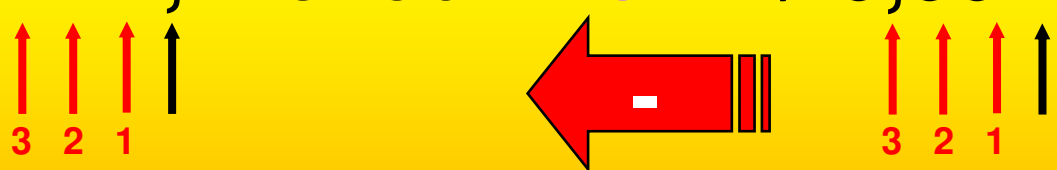
$$0,007123456 \Rightarrow 7,123456 \times 10^{-3}$$


$$- 0,0000008123456 \Rightarrow - 8,123456 \times 10^{-7}$$

De notação científica para decimal

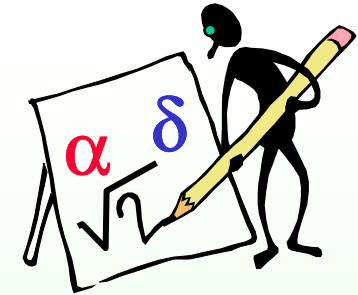
$$7,123456 \times 10^{+3} \Rightarrow 7123,456$$


$$- 8,123456 \times 10^{+7} \Rightarrow - 81234560, = - 81\ 234\ 560$$


$$7,123456 \times 10^{-3} \Rightarrow 0,007123456$$


$$- 8,123456 \times 10^{-7} \Rightarrow - 0,0000008123456$$


Mudança de unidades



Enunciado:

Transformar 56,432 cm em km.

quilo	k	10^3	= 1 000
hecto	h	10^2	= 100
deca	da	10^1	= 10
UNIDADE	-	10^0	= 1
deci	d	10^{-1}	= 0,1
centi	c	10^{-2}	= 0,01

Valor $\times 10^{\text{Inicial} - \text{Final}}$

$$56,432 \text{ cm} \times 10^{(-2 - +3)}$$

$$56,432 \text{ cm} \times 10^{-5}$$

$$56,432 \text{ cm} \times 0,000.01$$

$$0,000.56 \ 432 \text{ km}$$

$$\text{☺} \ 0,000.564.32 \text{ km}$$

$$\text{☺} \ 0,000 \ 564 \ 32 \text{ km}$$

$$0,00056432 \text{ km} \ \text{☹}$$

E

Múltiplos

P

T

G

M

k

h

da

#

d

c

m

μ

n

p

f

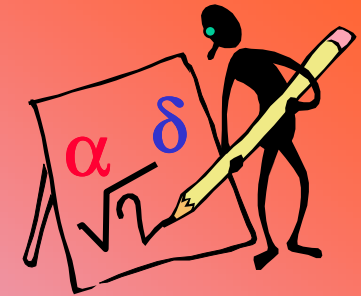
a

Submúltiplos

Mudança de unidades



E Múltiplos



Mudança de unidades

56 4320000, n

56 4320000,000

56,4320000000

56,432 c

56,432 c

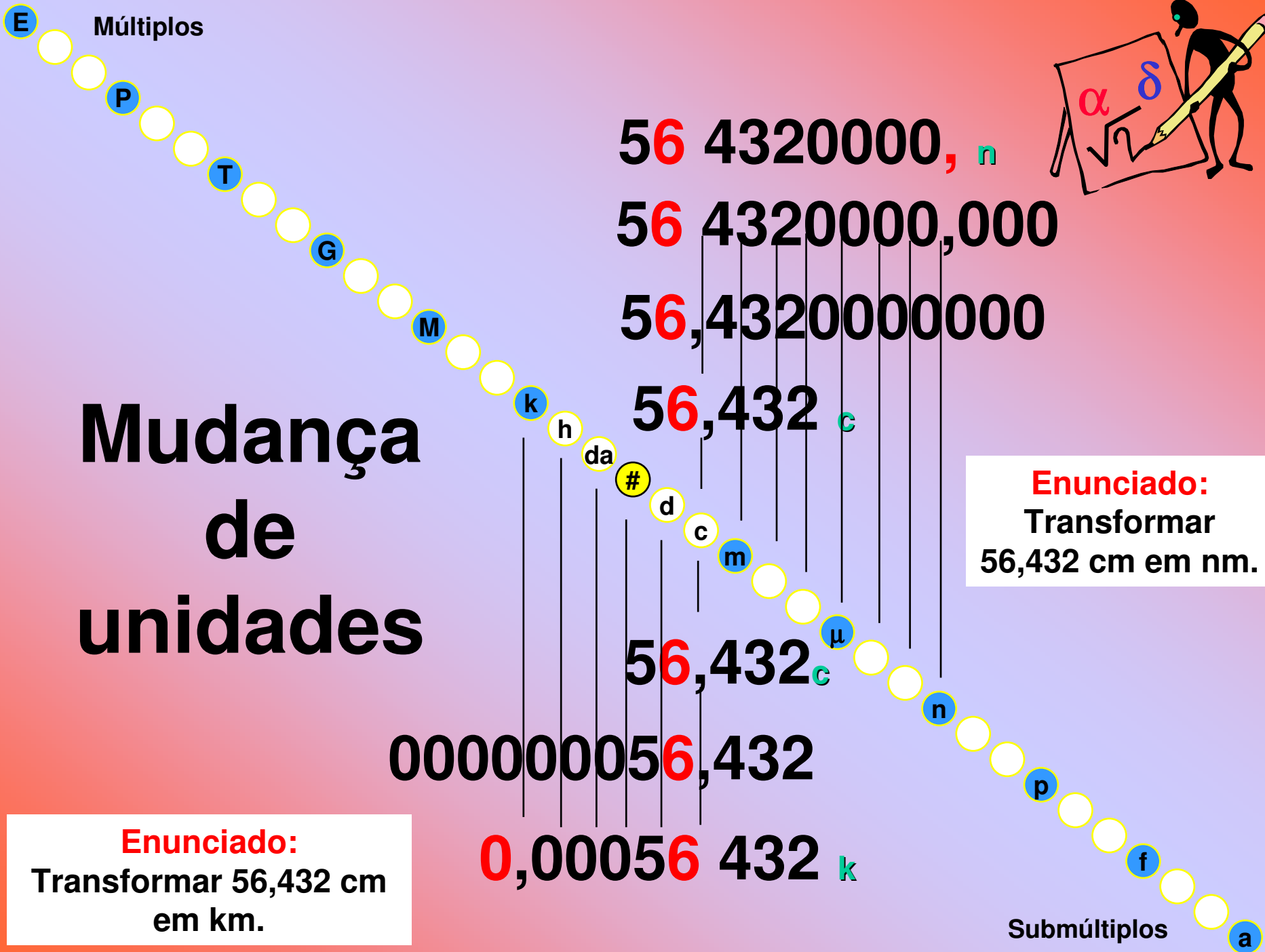
00000056,432

0,00056 432 k

Enunciado:
Transformar 56,432 cm em nm.

Enunciado:
Transformar 56,432 cm em km.

Submúltiplos a



Grandeza	Nome	Plural	Símbolo
comprimento	metro	metros	m
área	metro quadrado	metros quadrados	m ²
volume	metro cúbico	metros cúbicos	m³
ângulo plano	radiano	radianos	rad
tempo	segundo	segundos	s
freqüência	hertz	hertz	Hz
velocidade	metro por segundo	metros por segundo	m/s
aceleração	metro por segundo por segundo	metros por segundo por segundo	m/s ²
massa	quilograma	quilogramas	kg
massa específica	quilograma por metro cúbico	quilogramas por metro cúbico	kg/m ³
vazão	metro cúbico por segundo	metros cúbicos por segundo	m³/s
quantidade de matéria	mol	mols	mol
força	newton	newtons	N
pressão	pascal	pascals	Pa
trabalho, energia	joule	joules	J
quantidade de calor	watt	watts	W
potência, fluxo de energia	ampère	ampères	A
corrente elétrica	coulomb	coulombs	C
carga elétrica	volt	volts	V
tensão elétrica	ohm	ohms	Ω
resistência elétrica	siemens	siemens	S
condutância	farad	farads	F
capacitância	grau Celsius	graus Celsius	°C
temperatura Celsius	kelvin	kelvins	K
temp. termodinâmica	candela	candelas	cd
intensidade luminosa	lúmen	lúmens	lm
fluxo luminoso	lux	lux	lx
iluminamento			

Unidades fundamentais e derivadas do SI

Algumas unidades em uso com o SI, sem restrição de prazo

Grandeza	Nome	Plural	Símbolo	Equivalência
volume	litro	litros	l ou L	0,001 m³
ângulo plano	grau	graus	°	$\pi / 180$ rad
ângulo plano	minuto	minutos	'	$\pi / 10\,800$ rad
ângulo plano	segundo	segundos	''	$\pi / 648\,000$ rad
massa	tonelada	toneladas	t	1\,000 kg
tempo	minuto	minutos	min	60 s
tempo	hora	horas	h	3\,600 s
velocidade angular	rotação por minuto	rotações por minuto	rpm	$\pi / 30$ rad/s

Algumas unidades fora do SI, admitidas temporariamente

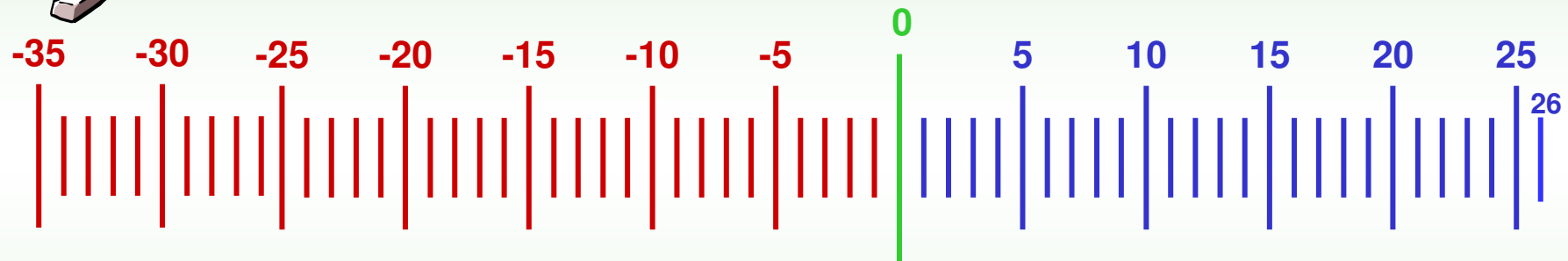
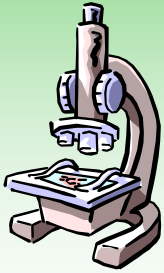
Grandeza	Nome	Plural	Símbolo	Equivalência
pressão	atmosfera	atmosferas	atm	101 325 Pa
pressão	bar	bars	bar	10^5 Pa
pressão	milímetro de mercúrio	milímetros de mercúrio	mmHg	133,322 Pa aprox.
quantidade de calor	caloria	calorias	cal	4,186 8 J
área	hectare	hectares	ha	10^4 m ²
força	quilograma- força	quilogramas- força	kgf	9,806 65 N
comprimento	milha marítima	milhas marítimas		1 852 m
velocidade	nó	nós		(1852/3600) m/s

Le système SI d'unités de mesure

7 unités de base :

Mètre	m	Longueur du trajet parcouru dans le vide par la lumière pendant $1/299\,792\,458$ de seconde.
Kilogramme	kg	Masse du prototype en platine iridié qui a été sanctionné par la Conférence Générale des Poids et Mesures tenue à Paris en 1889 et qui est déposé au Bureau International des Poids et Mesures.
Seconde	s	Durée de $9\,192\,631\,770$ périodes de la radiation correspondant à la transition entre les deux niveaux hyperfins de l'état fondamental de l'atome de césium 133.
Ampère	A	Intensité d'un courant électrique constant qui, maintenu dans deux conducteurs parallèles, rectilignes, de longueur infinie, de section circulaire négligeable et placés à une distance de 1 mètre l'un de l'autre dans le vide, produirait entre ces conducteurs une force de $2 \cdot 10^{-7}$ newton par mètre de longueur.
Kelvin	K	Le kelvin, unité de température thermodynamique, est la fraction $1/273,16$ de la température thermodynamique du point triple de l'eau.
Mole	mol	Quantité de matière d'un système contenant autant d'entités élémentaires qu'il y a d'atomes dans 0,012 kilogramme de carbone 12.
Candela	cd	La candéla est l'intensité lumineuse, dans une direction donnée, d'une source qui émet un rayonnement monochromatique de fréquence $540 \cdot 10^{12}$ hertz et dont l'intensité énergétique dans cette direction est $1/683$ watt par stéradian.

Para o micromundo



$\div 10$

Micromundo

Cada traço à esquerda
significa o traço da
direita **dividido** por 10

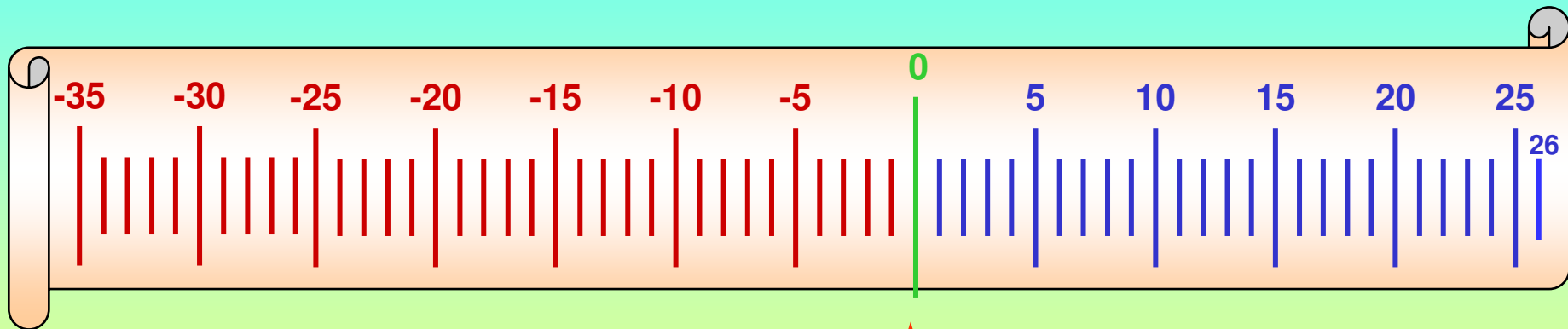




Metro: unidade fundamental

$$f = 10^0$$

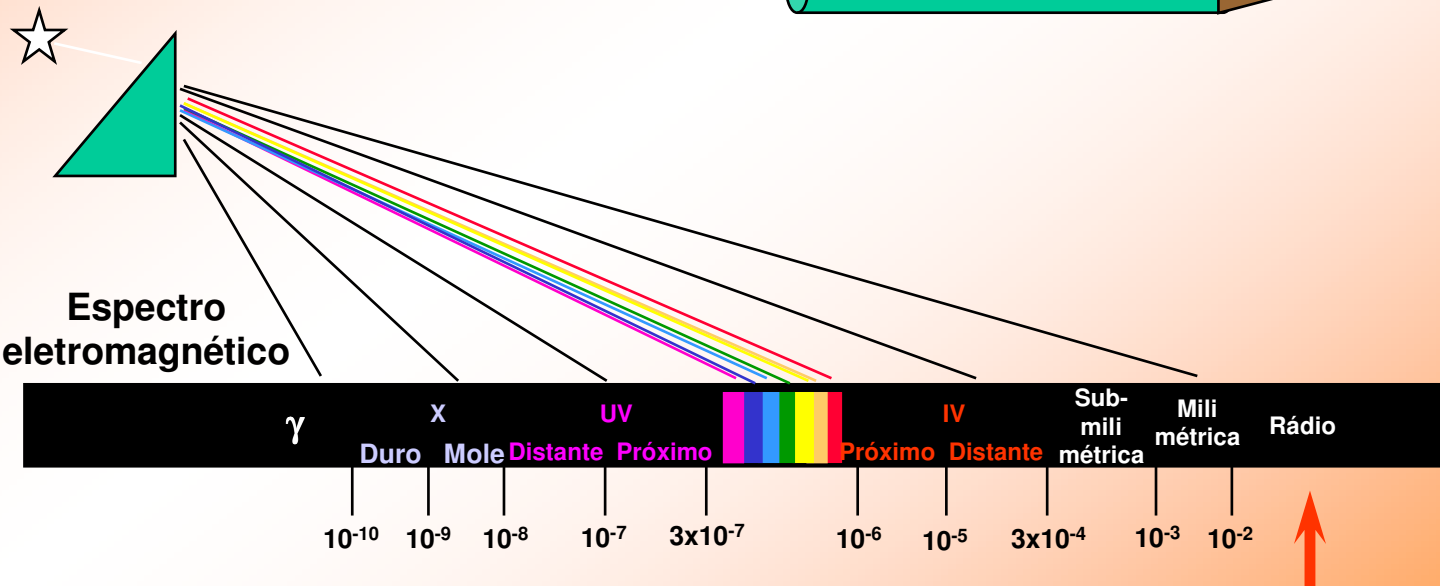
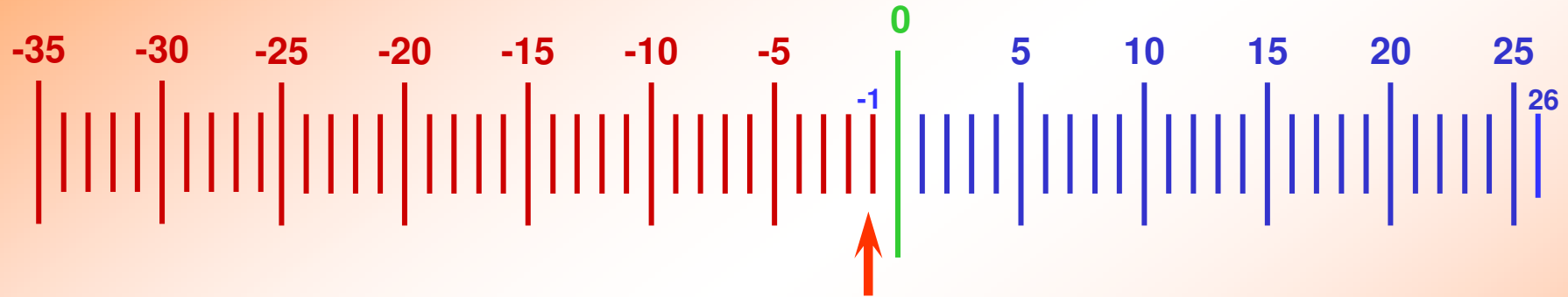
$$10^0 \text{ m} = 1 \text{ m}$$



Elemento
representativo
da escala

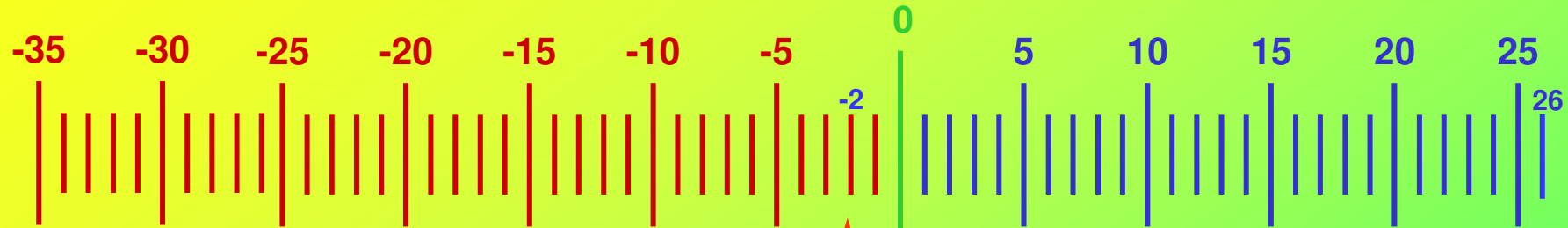
Decímetro $f = 10^{-1}$

$10^{-1} \text{ m} = 0,1 \text{ m}$



Centímetro $f = 10^{-2}$

$10^{-2} \text{ m} = 0,01 \text{ m}$



Espectro
eletromagnético



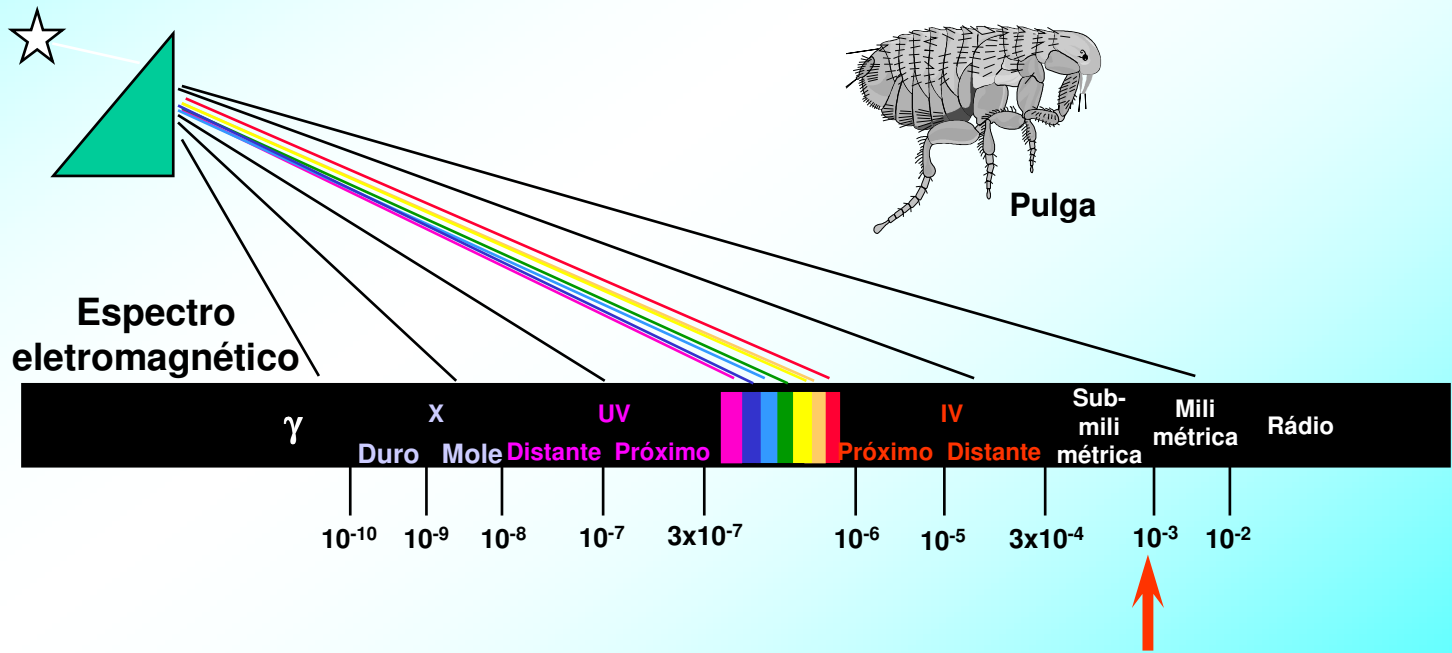
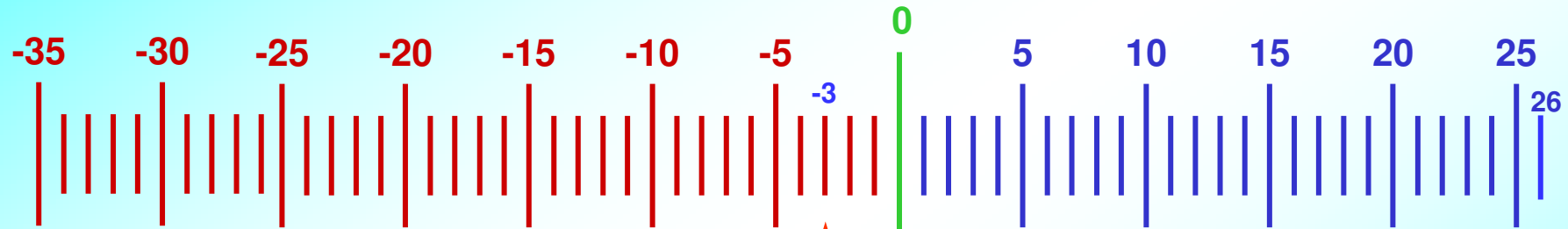
10^{-10} 10^{-9} 10^{-8} 10^{-7} 3×10^{-7} 10^{-6} 10^{-5} 3×10^{-4} 10^{-3} 10^{-2}





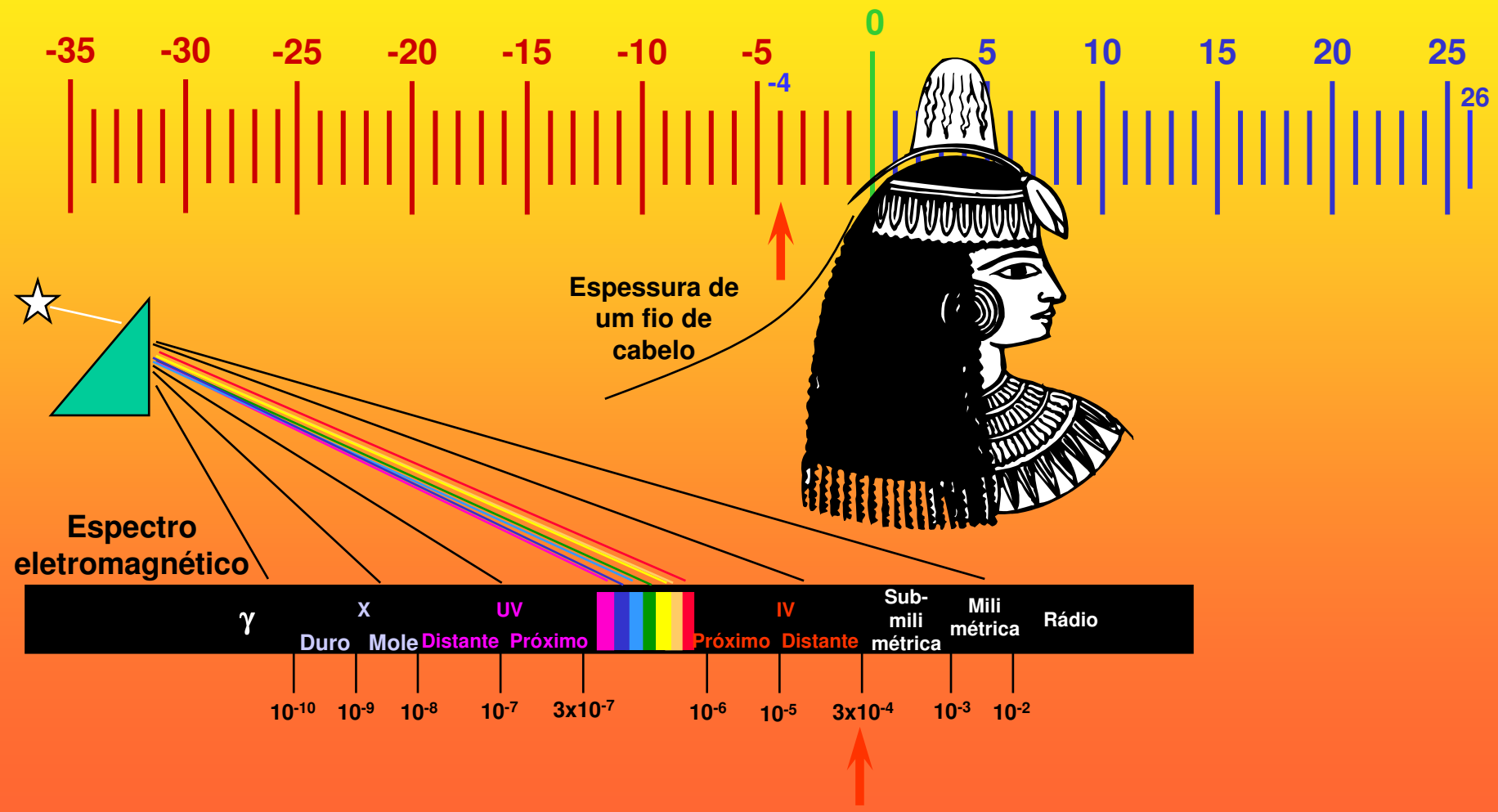
Milímetro $f = 10^{-3}$

$$10^{-3} \text{ m} = 0,001 \text{ m}$$

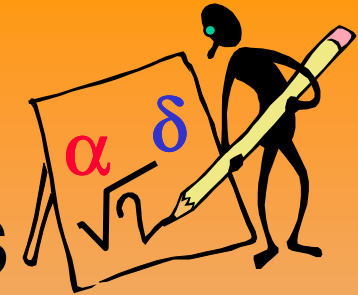


$$f = 10^{-4}$$

$$10^{-4} \text{ m} = 0,000.1 \text{ m}$$



Razão entre dimensões



Enunciado:

A espessura de um lápis é de 0,8 cm. A espessura do cabelo da rainha Cleópatra era de 0,04 mm. Quantas vezes seu cabelo é mais fino que um lápis?



$D=0,8 \text{ cm}$

$D/d = ?$

$d=0,04 \text{ mm}$

Passar as medidas para a mesma unidade

$D=0,8 \text{ cm} = 0,8 \times 10^{-2} \text{ m}$

$d=0,04 \text{ mm} = 0,04 \times 10^{-3} \text{ m} = 0,4 \times 10^{-4} \text{ m}$



$D/d = 0,8 \times 10^{-2} \text{ m} / 0,4 \times 10^{-4} \text{ m}$

$D/d = 0,8 / 0,4 \times 10^{-2} / 10^{-4}$

$D/d = 2 \times 10^{-2-(-4)}$

$D/d = 2 \times 10^{-2+4}$

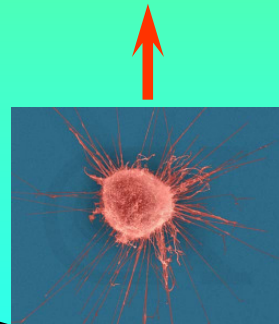
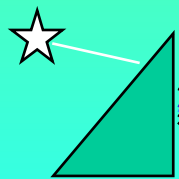
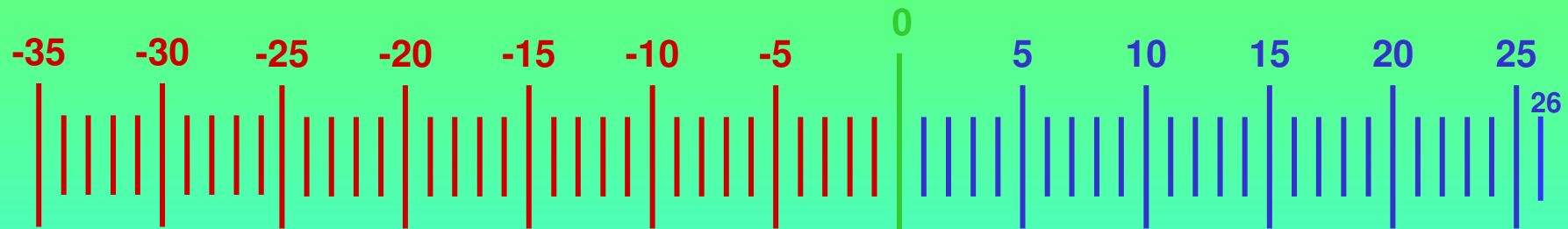
$D/d = 2 \times 10^2$

$D/d = 200$

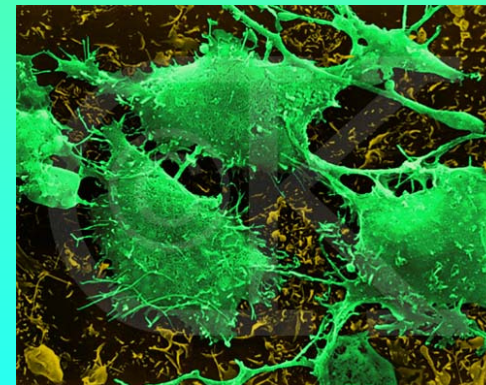
O cabelo é 200 vezes mais fino que o lápis

$$f = 10^{-5}$$

$$10^{-5} \text{ m} = 0,000.01 \text{ m}$$



Célula viva

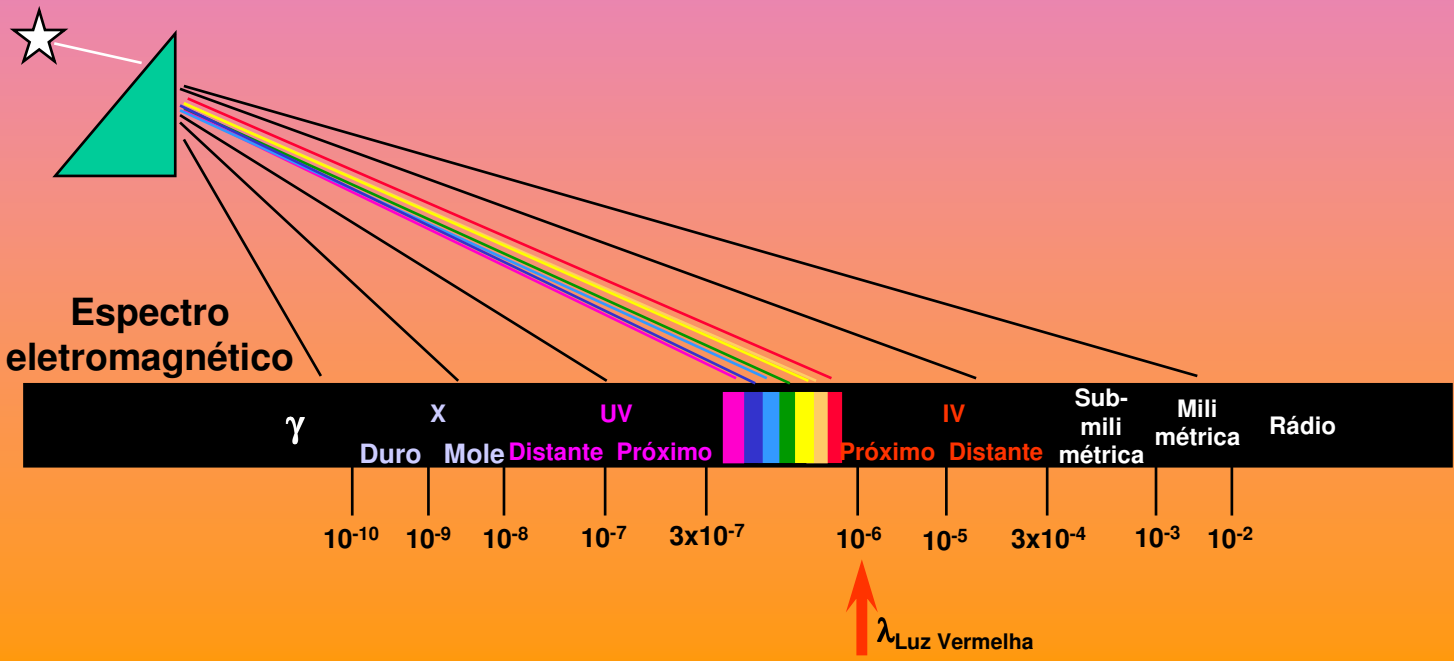
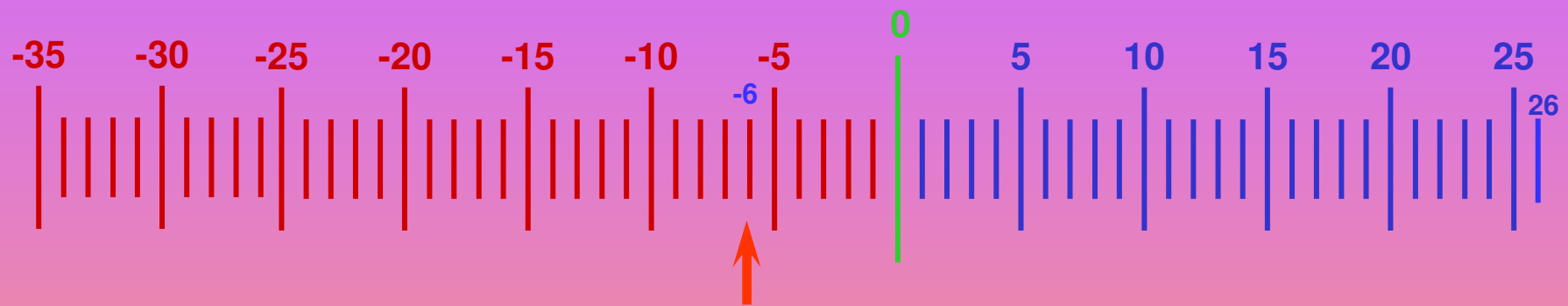


Espectro eletromagnético



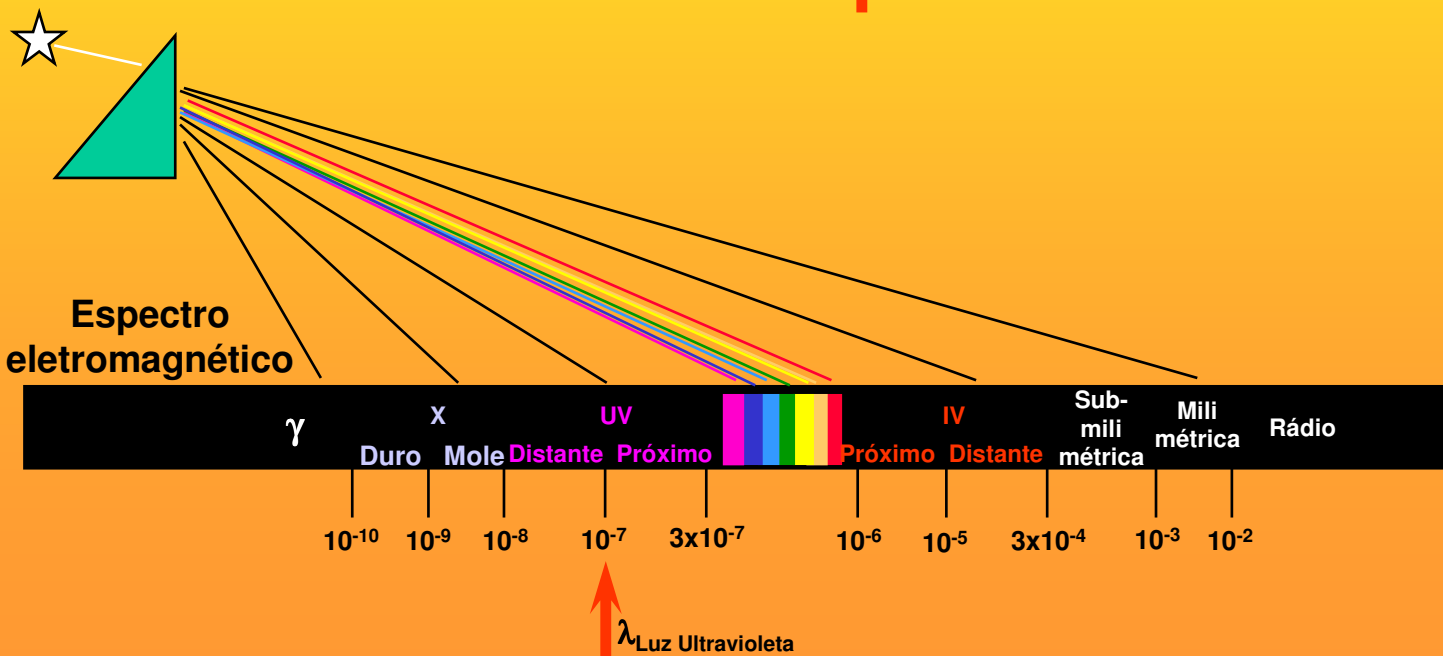
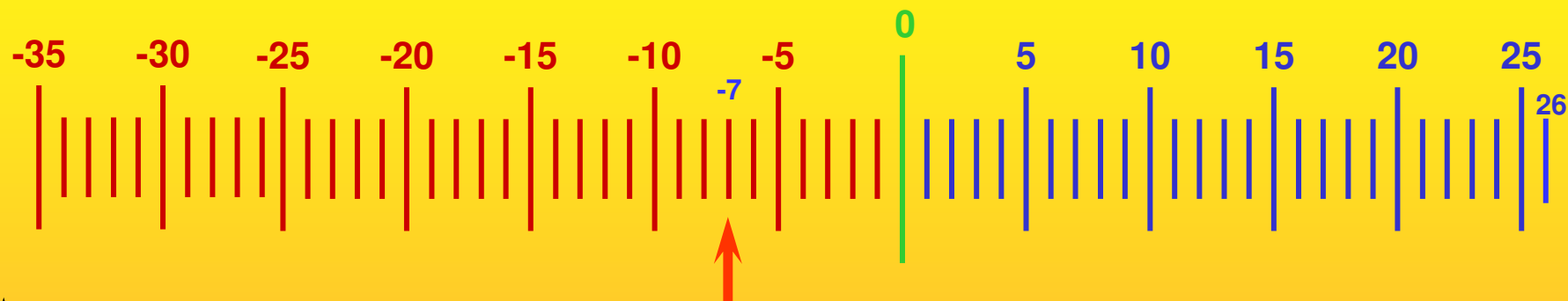
Micro f = 10^{-6}

$10^{-6} \text{ m} = 0,000.001 \text{ m}$



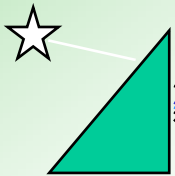
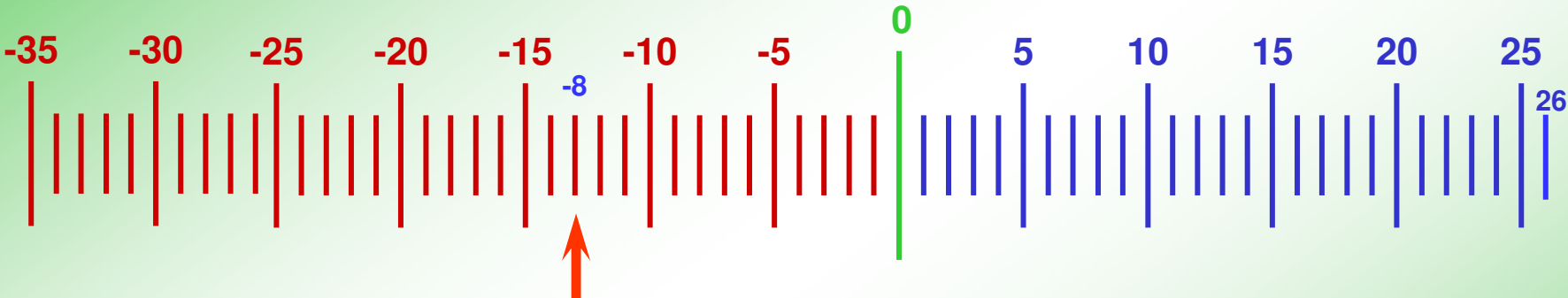
$$f = 10^{-7}$$

$$10^{-7} \text{ m} = 0,000.000.1 \text{ m}$$



$$f = 10^{-8}$$

$$10^{-8} \text{ m} = 0,000.000.01 \text{ m}$$



Espectro
electromagnético

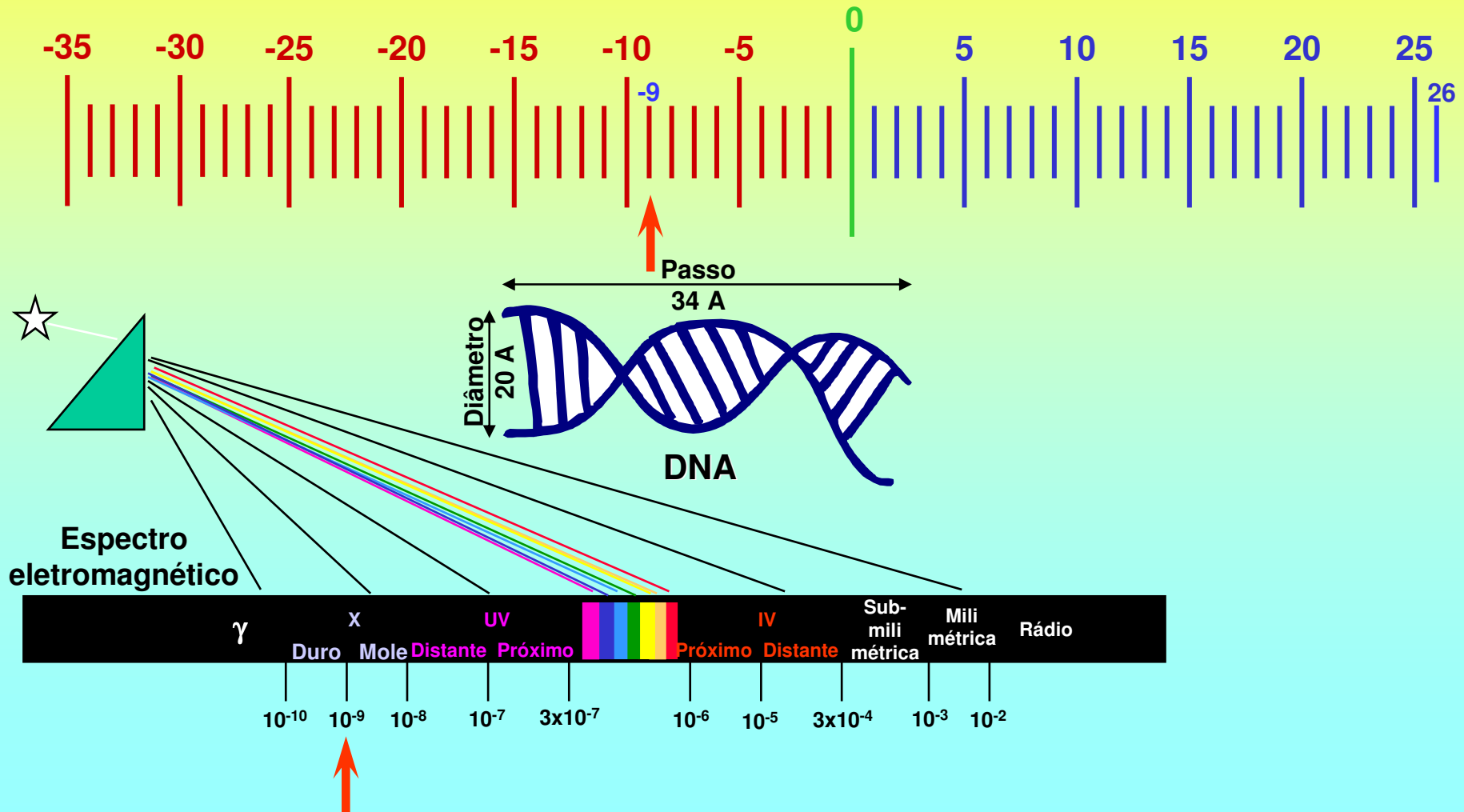


10^{-10} 10^{-9} 10^{-8} 10^{-7} 3×10^{-7} 10^{-6} 10^{-5} 3×10^{-4} 10^{-3} 10^{-2}



Nano f = 10⁻⁹

10⁻⁹ m = 0,000.000.001 m

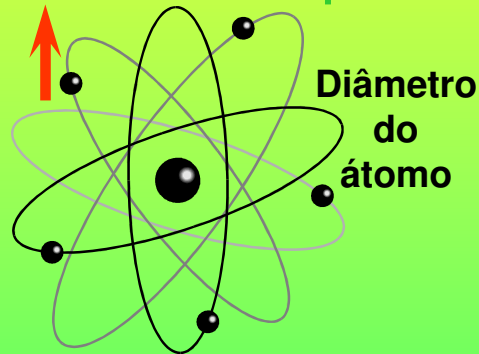
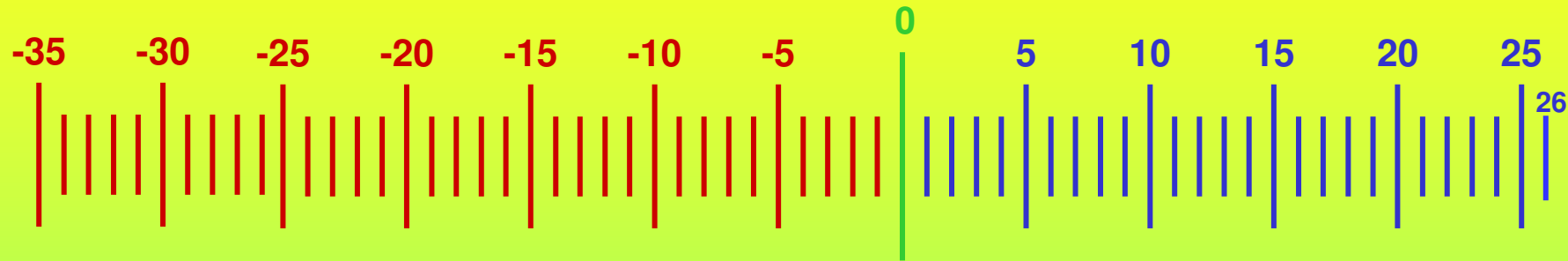




Angstrom $f = 10^{-10}$

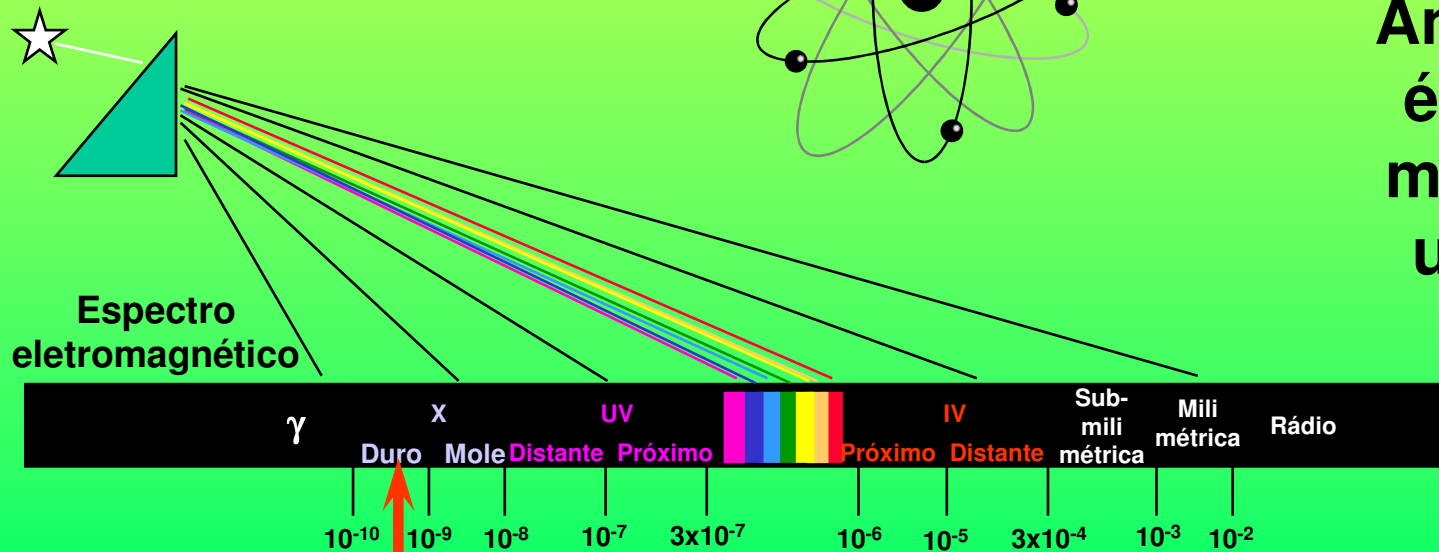
(ångstrom = Å)

$$10^{-10} \text{ m} = 0,000.000.000.1 \text{ m}$$



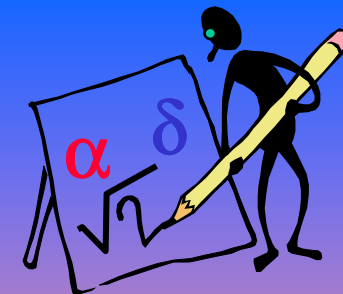
$$1 \text{ Å} \equiv 10^{-10} \text{ m}$$

Angstrom **não** é unidade SI mas pode ser usada junto com elas.



E Múltiplos

Relacionar Angstrom com unidades SI



Enunciado:

O Sol emite uma forte linha espectral chamada H α cujo comprimento de onda é de 6562,80 Å (também representado por λ 6562,80). Represente essa grandeza em nm, μ m, mm e m.

$$1 \text{ \AA} \equiv 10^{-10} \text{ m}$$

$$1 \text{ \AA} = 10^{-7} \text{ mm}$$

$$1 \text{ \AA} = 10^{-4} \mu\text{m}$$

$$1 \text{ \AA} = 10^{-1} \text{ nm}$$

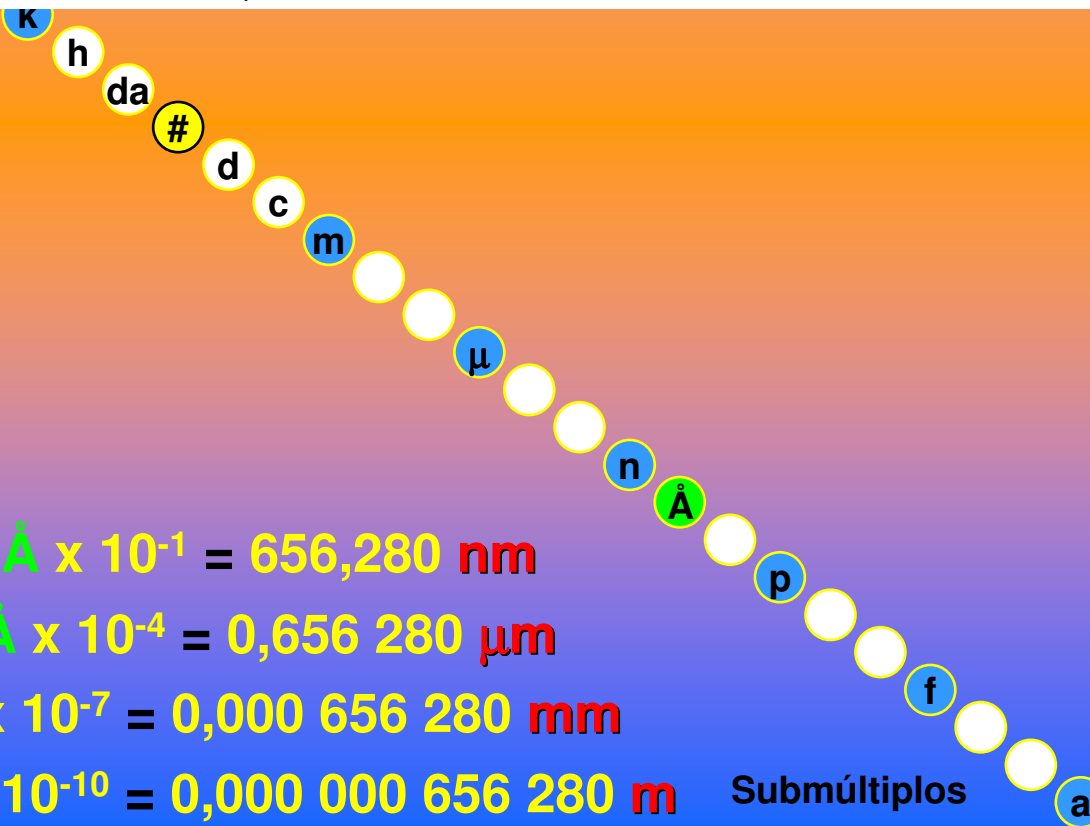
$$6562,80 \text{ \AA} \times 10^{-1} = 656,280 \text{ nm}$$

$$6562,80 \text{ \AA} \times 10^{-4} = 0,656 280 \mu\text{m}$$

$$6562,80 \text{ \AA} \times 10^{-7} = 0,000 656 280 \text{ mm}$$

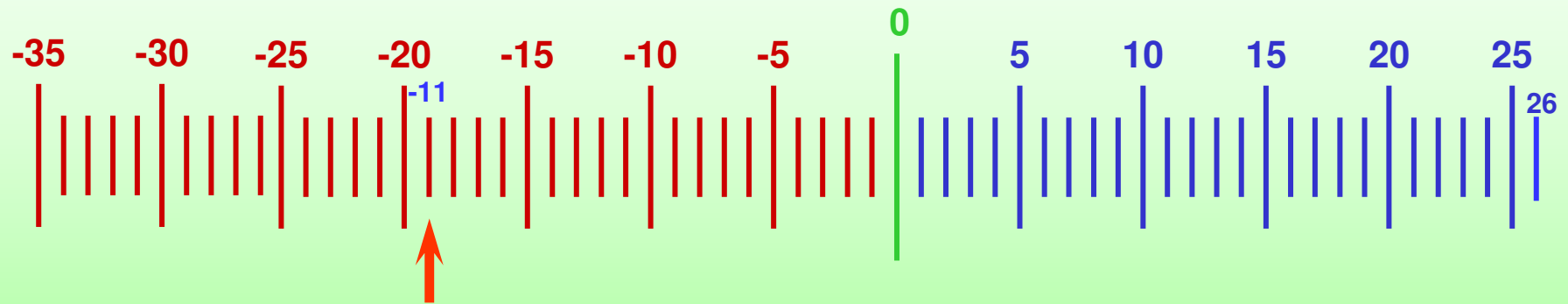
$$6562,80 \text{ \AA} \times 10^{-10} = 0,000 000 656 280 \text{ m}$$

Submúltiplos



$$f = 10^{-11}$$

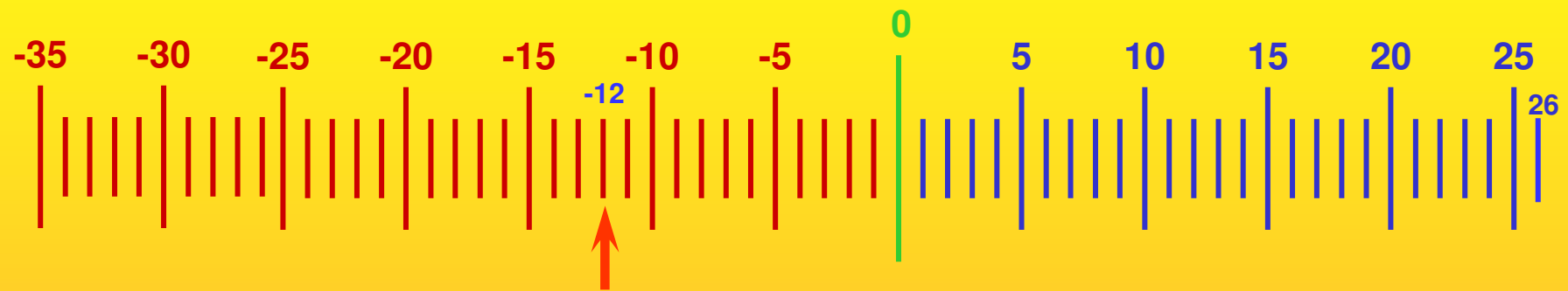
$$10^{-11} \text{ m} = 0,000.000.000.01 \text{ m}$$





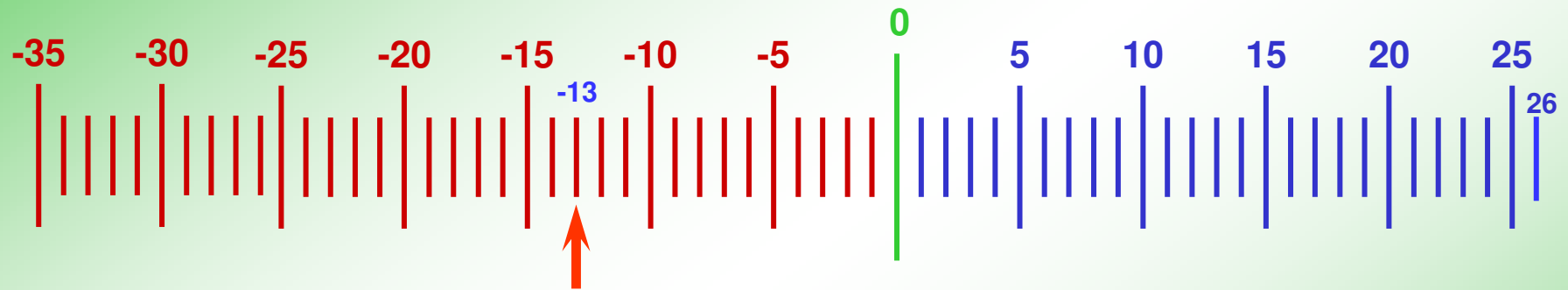
Pico f = 10^{-12}

$$10^{-12} \text{ m} = 0,000.000.000.001 \text{ m}$$



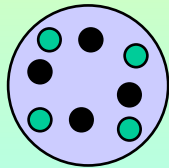
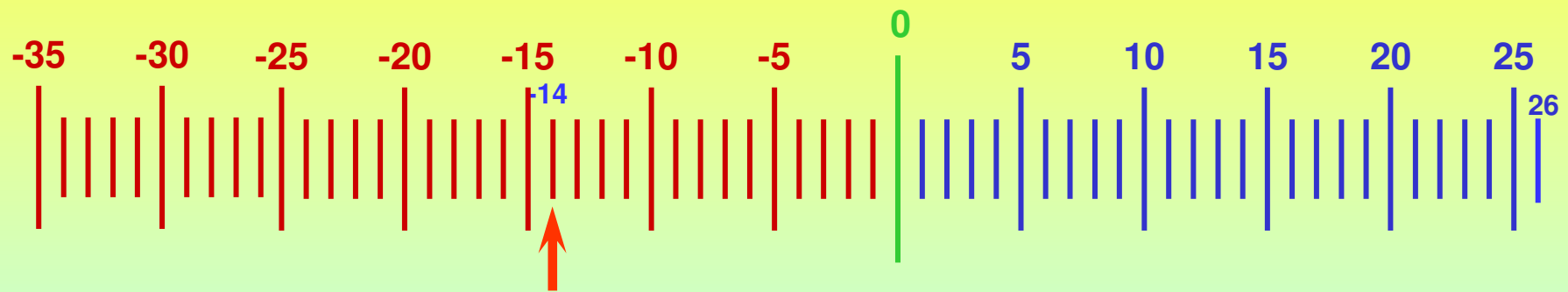
$$f = 10^{-13}$$

$$10^{-13} \text{ m} = 0,000.000.000.000.1 \text{ m}$$



$$f = 10^{-14}$$

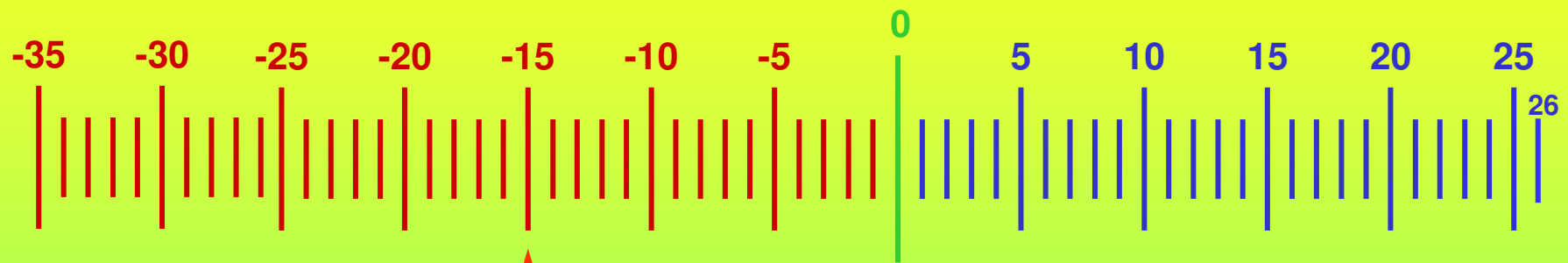
$$10^{-14} \text{ m} = 0,000.000.000.000.01 \text{ m}$$



**Diâmetro do
núcleo de
átomos pesados**

Femto $f = 10^{-15}$

$10^{-15} \text{ m} = 0,000.000.000.000.001 \text{ m}$



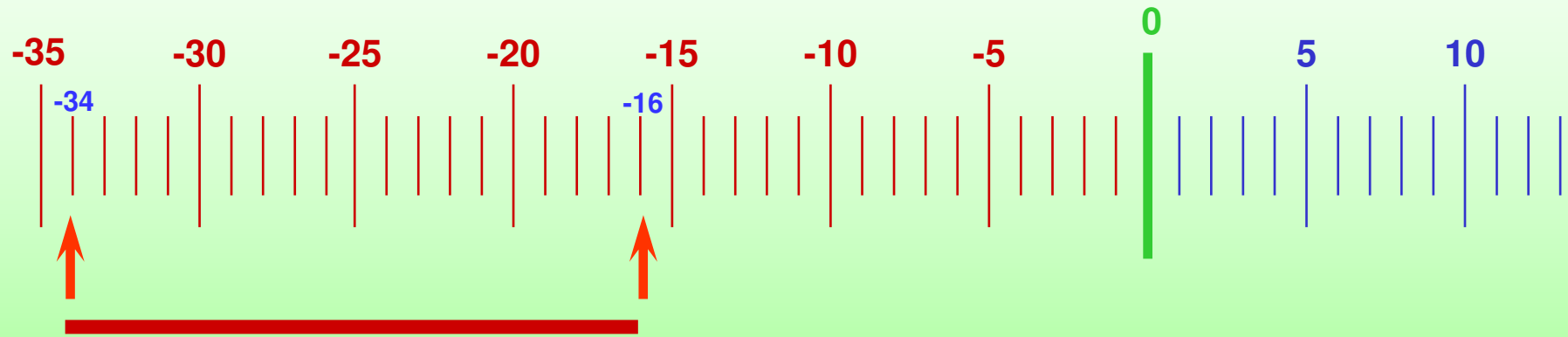
● Próton

● Nêutron

$$f = 10^{-16} \text{ a } 10^{-34}$$

$$10^{-16} \text{ m} = 0,000.000.000.000.000.1 \text{ m}$$

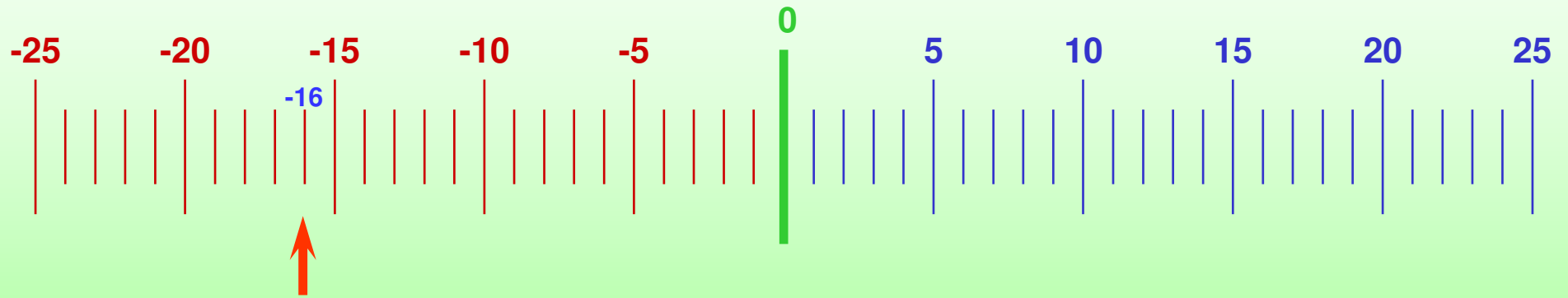
$$10^{-34} \text{ m} = 0,000.000.000.000.000.000.000.000.000.000.000.1 \text{ m}$$



Pular!

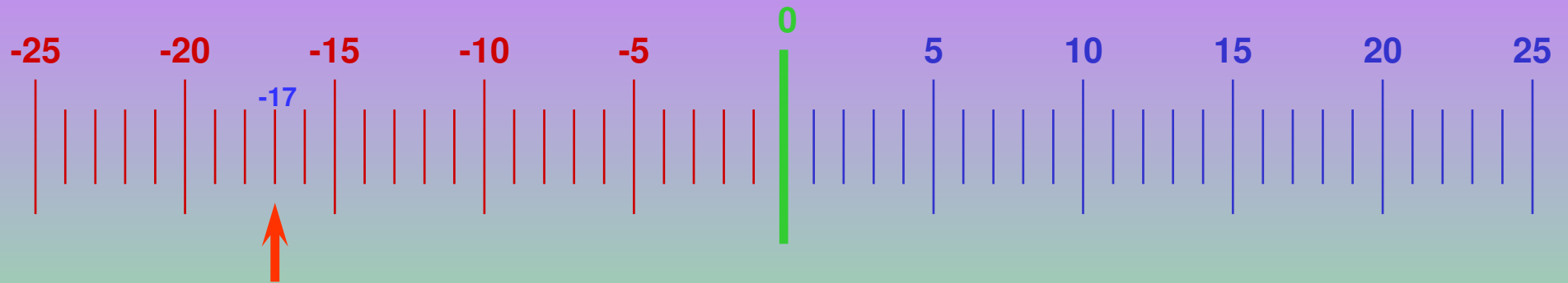
$$f = 10^{-16}$$

$$10^{-16} \text{ m} = 0,000.000.000.000.000.1 \text{ m}$$



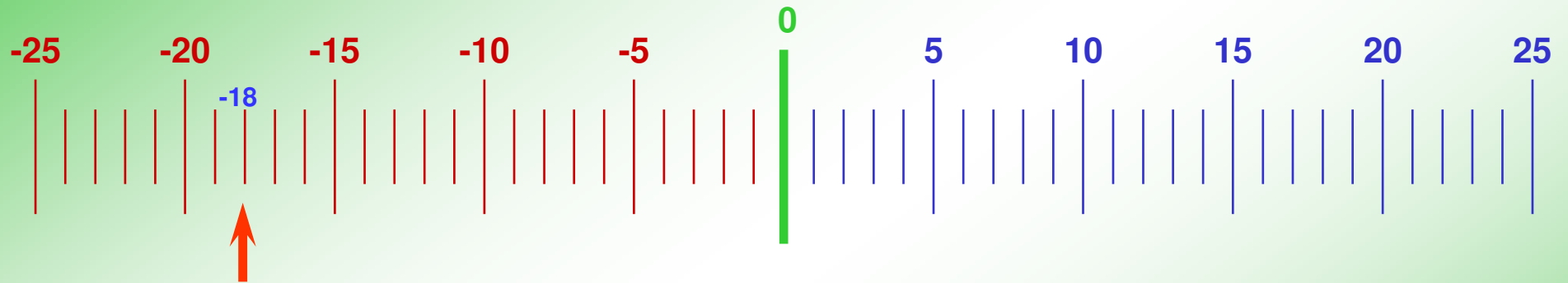
$$f = 10^{-17}$$

$$10^{-17} \text{ m} = 0,000.000.000.000.000.01 \text{ m}$$



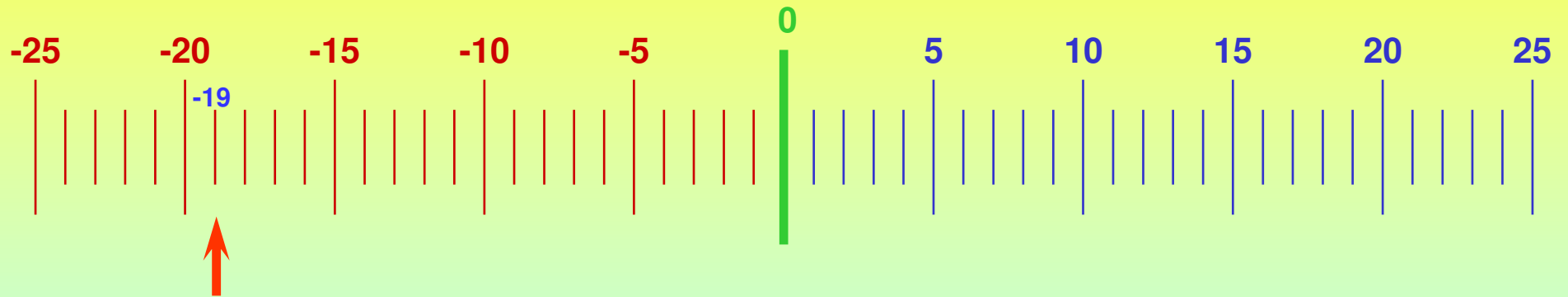
Atto f = 10^{-18}

10^{-18} m = 0,000.000.000.000.000.001 m



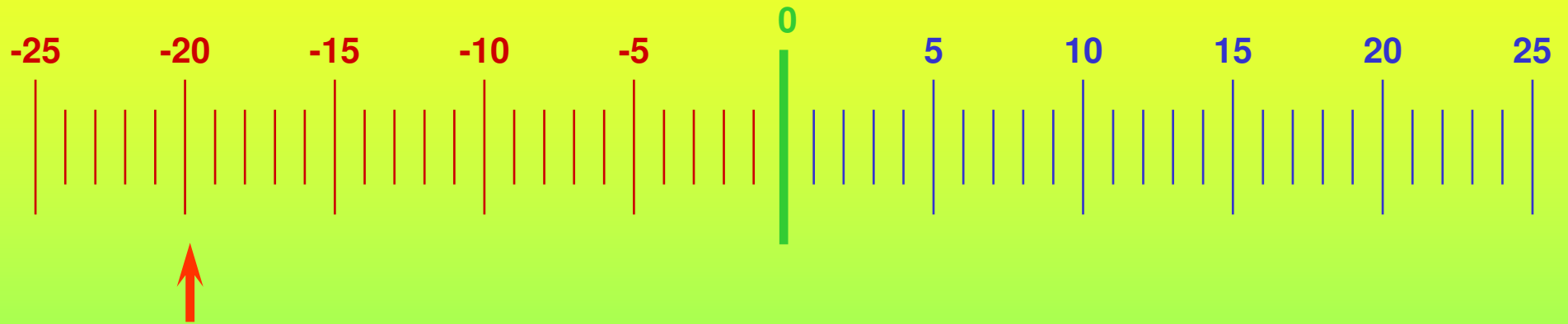
$$f = 10^{-19}$$

$$10^{-19} \text{ m} = 0,000.000.000.000.000.000.1 \text{ m}$$



$$f = 10^{-20}$$

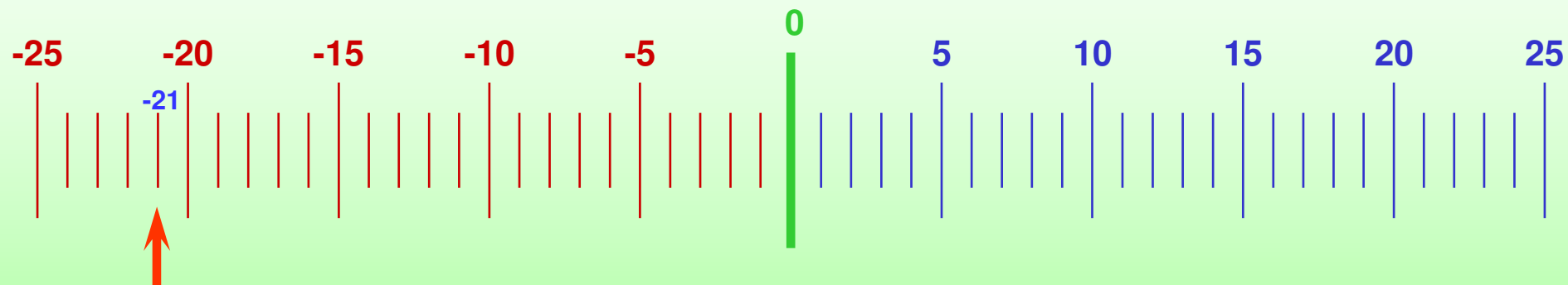
10^{-20} m = 0,000.000.000.000.000.000.01 m





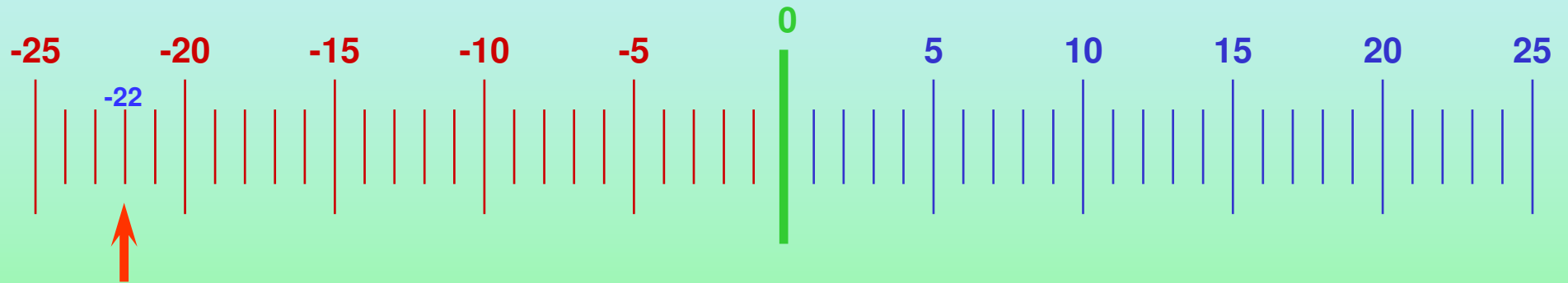
Zepto $f = 10^{-21}$

10^{-21} m = 0,000.000.000.000.000.000.001 m



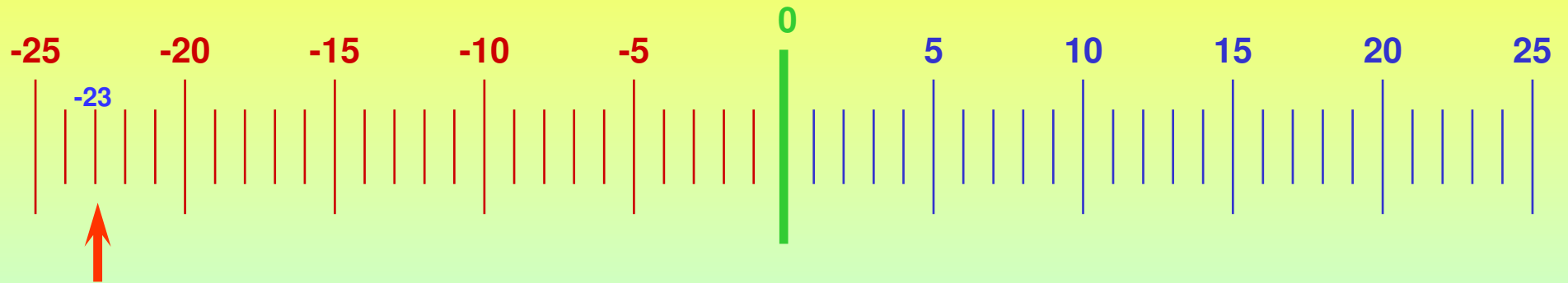
$$f = 10^{-22}$$

10^{-22} m = 0,000.000.000.000.000.000.000.1 m



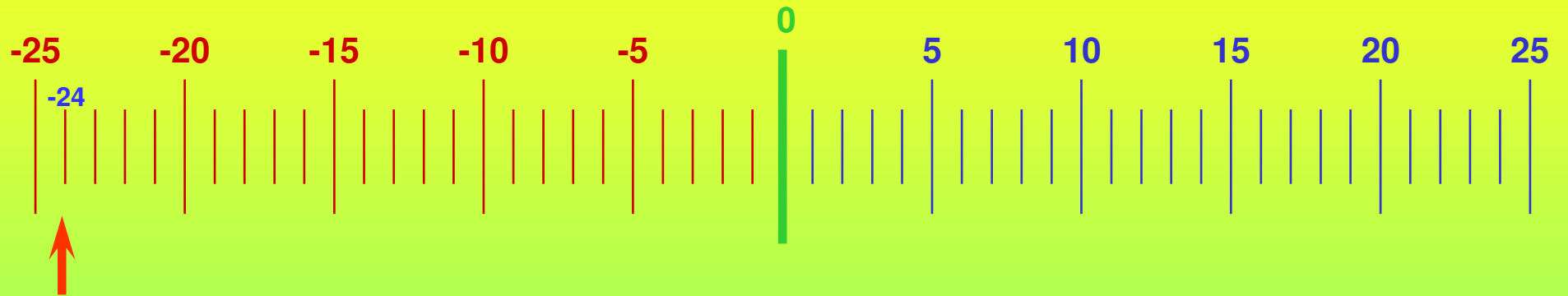
$$f = 10^{-23}$$

$$10^{-23} \text{ m} = 0,000.000.000.000.000.000.000.01 \text{ m}$$



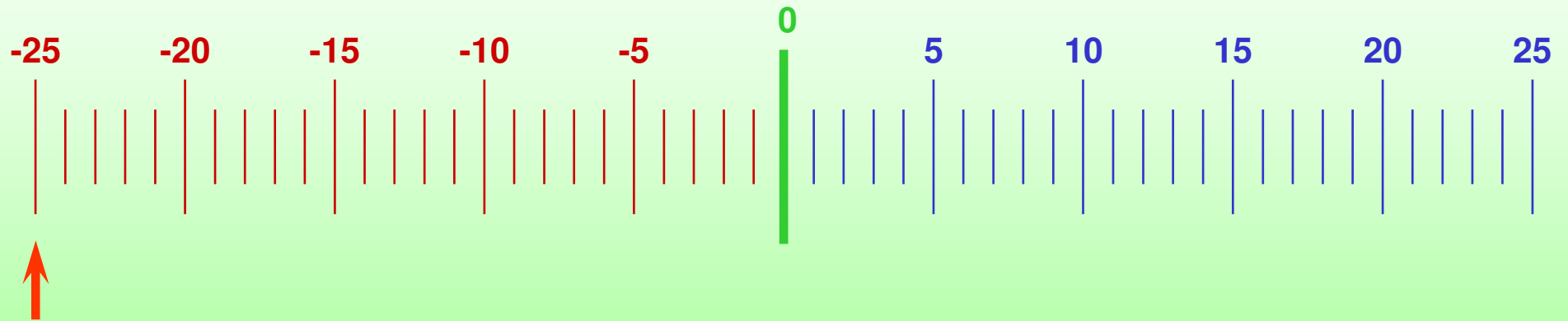
Yocto $f = 10^{-24}$

$10^{-24} \text{ m} = 0,000.000.000.000.000.000.000.001 \text{ m}$



$$f = 10^{-25}$$

10^{-25} m = 0,000.000.000.000.000.000.000.000.1 m



$$f = 10^{-35}$$

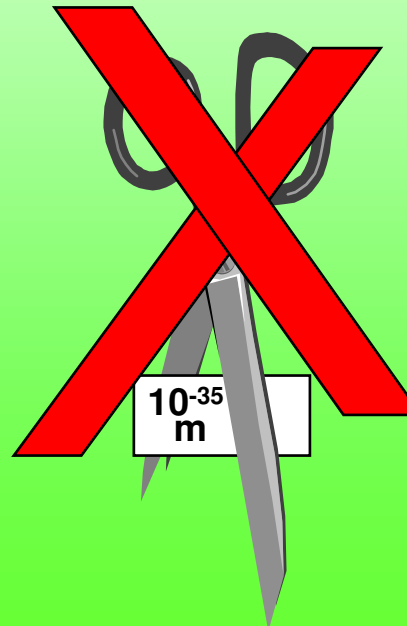
$10^{-35} \text{ m} = 0,000.000.000.000.000.000.000.000.000.000.000.000.01 \text{ m}$



Tamanho
Planck

Quantum
de espaço

Menor
tamanho de
um espaço



Para o macromundo



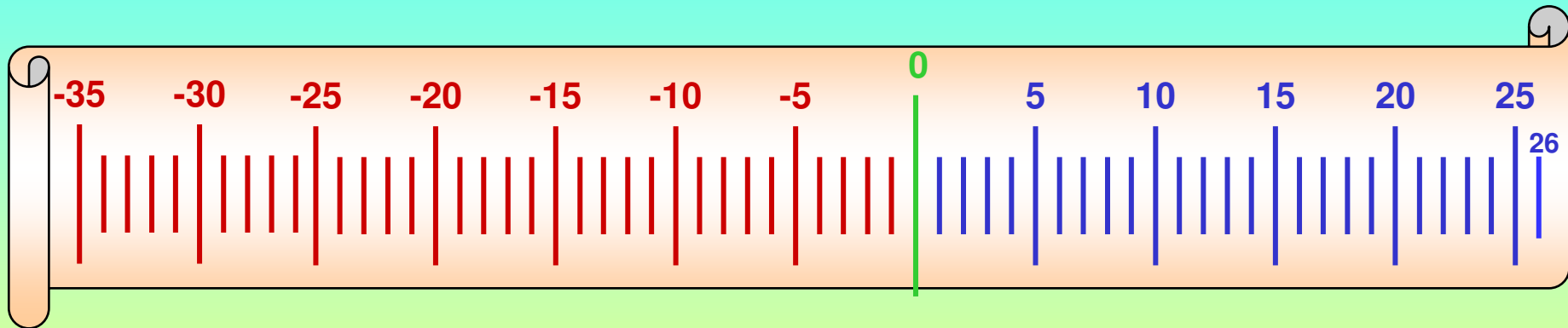
x 10

Macromundo

Cada traço à direita
significa o traço da
esquerda **multiplicado**
por 10

Metro $f = 10^0$

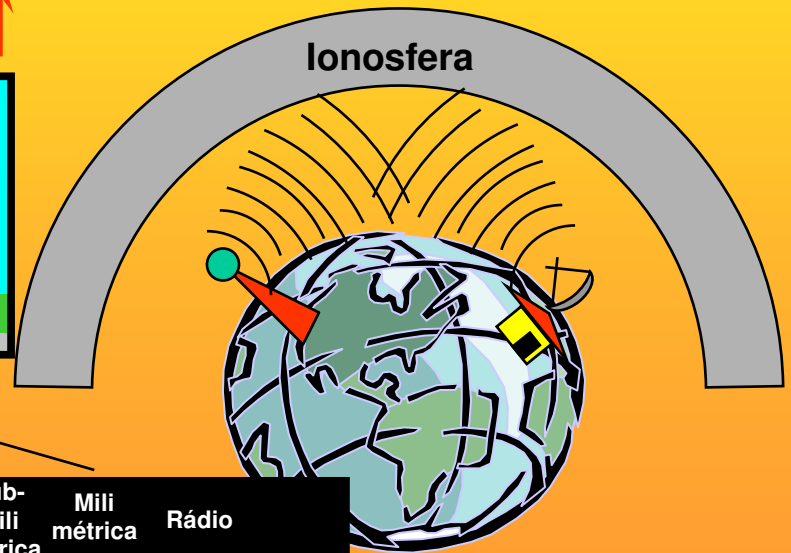
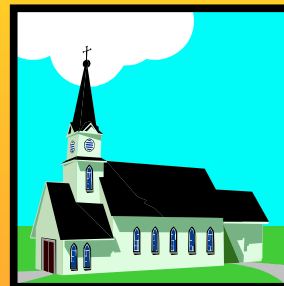
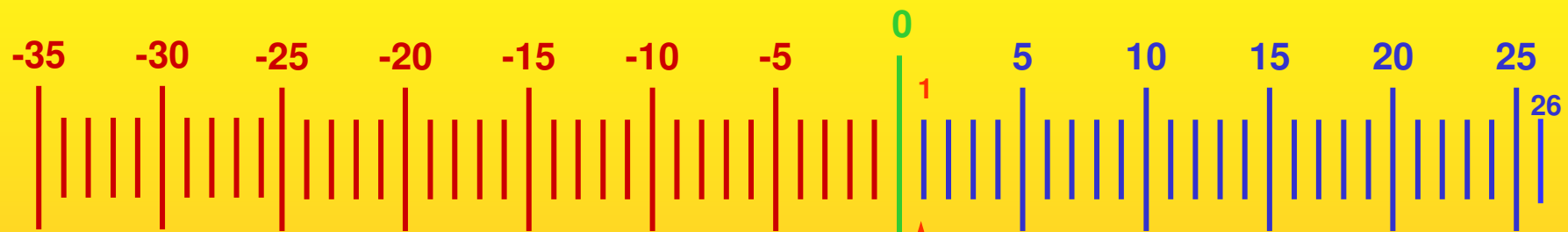
$$10^0 \text{ m} = 1 \text{ m}$$



Elemento
representativo
da escala

Decametro $f = 10^1$

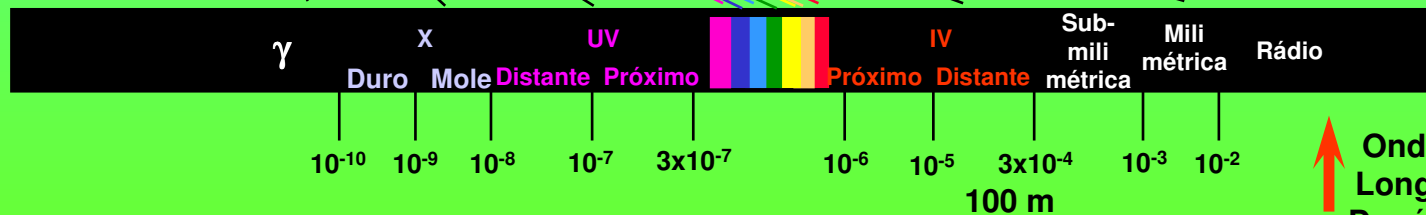
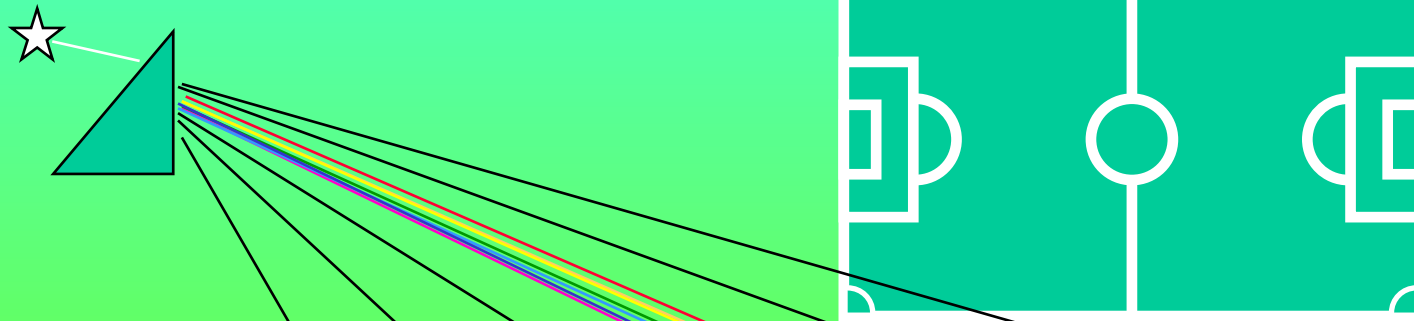
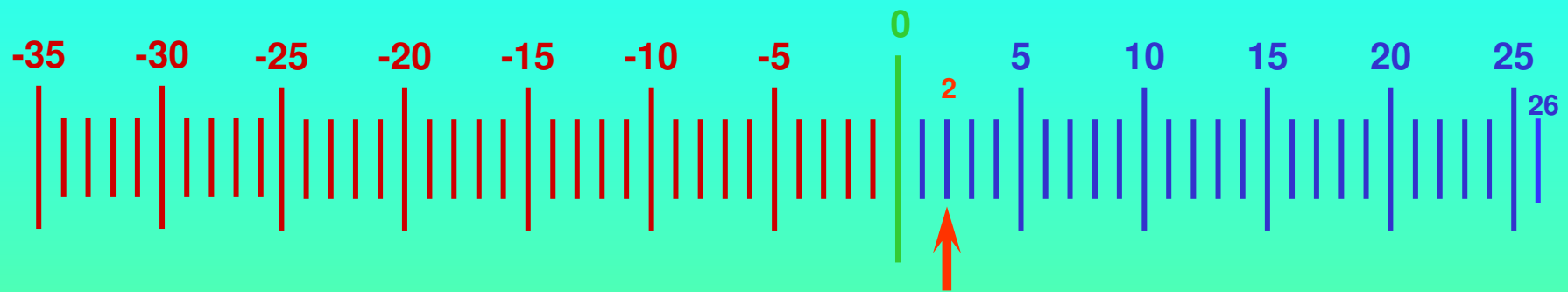
$10^1 \text{ m} = 10 \text{ m}$



Ondas curtas de rádio

Hectometro $f = 10^2$

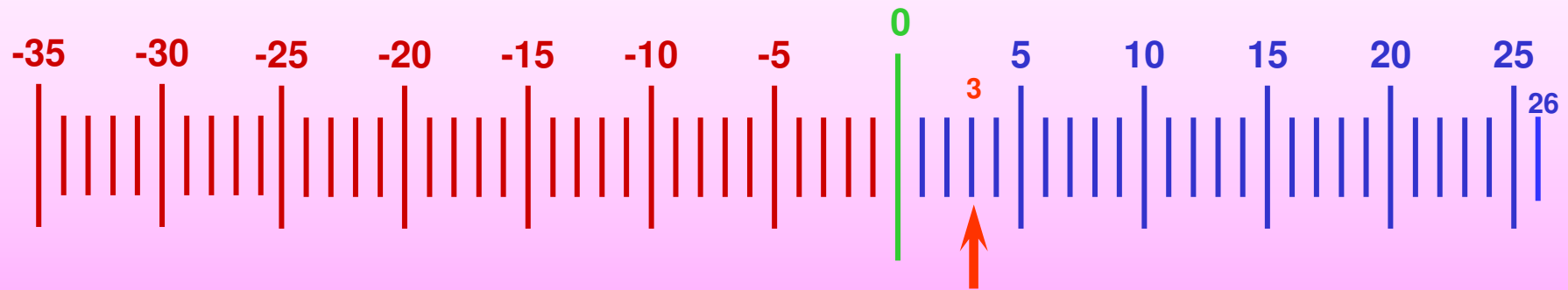
$10^2 \text{ m} = 100 \text{ m}$



Ondas Longas De rádio

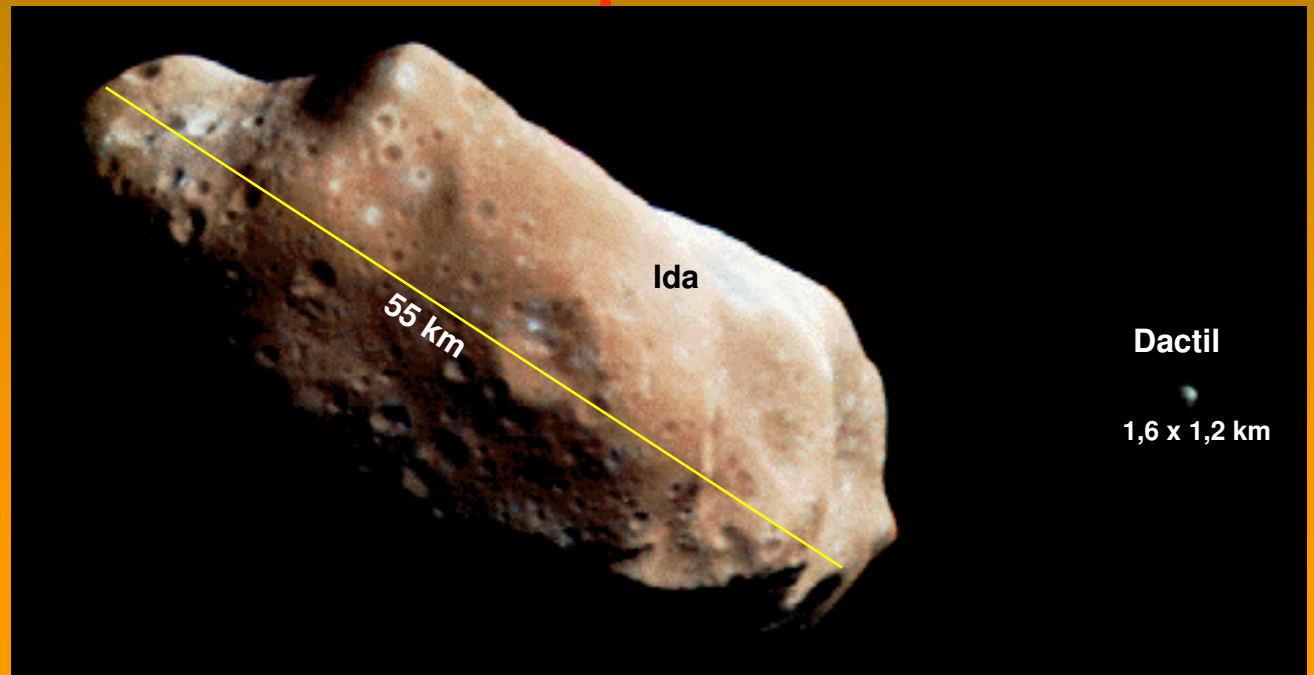
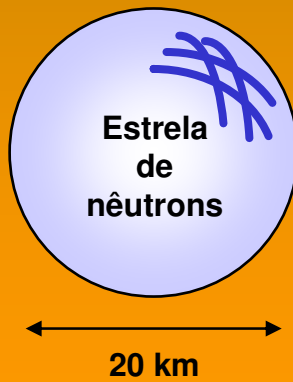
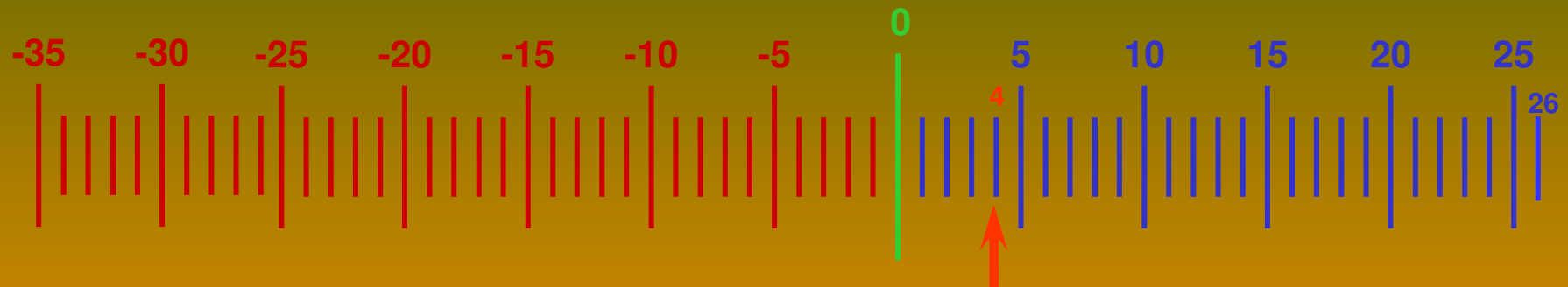
Kilômetro $f = 10^3$

$10^3 \text{ m} = 1.000 \text{ m}$



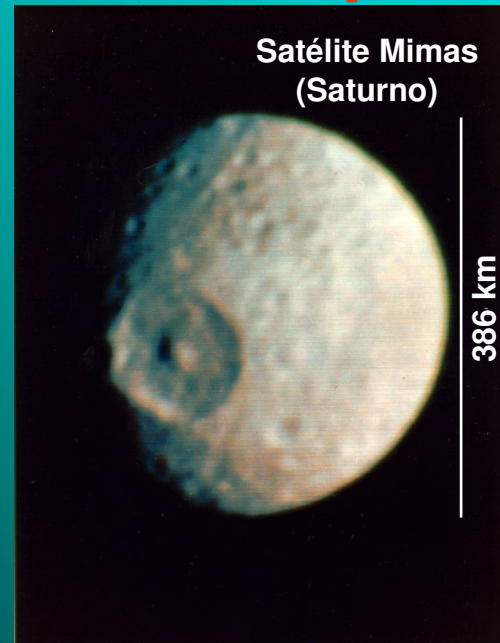
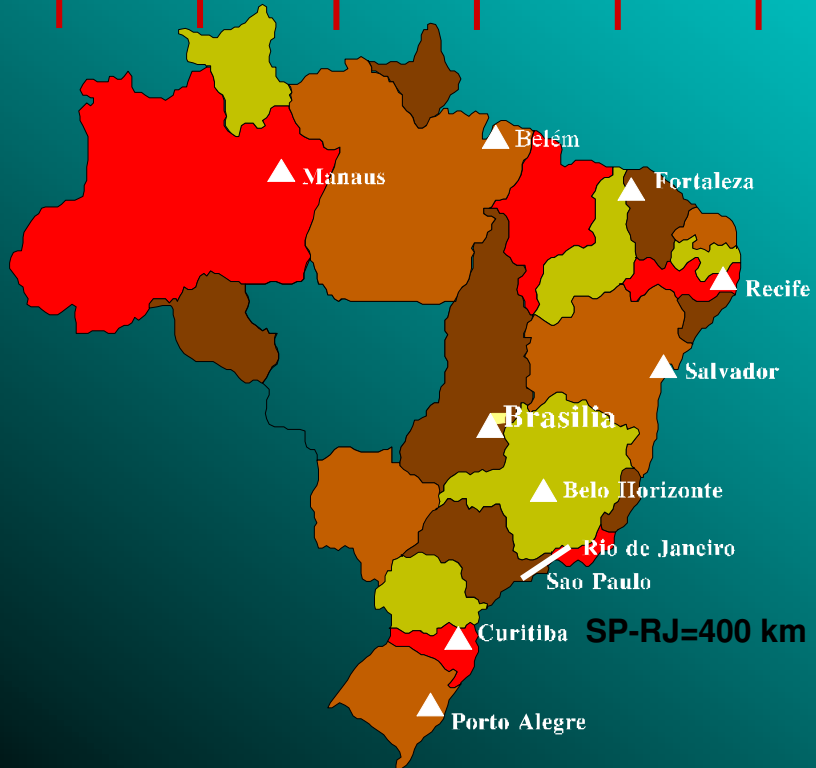
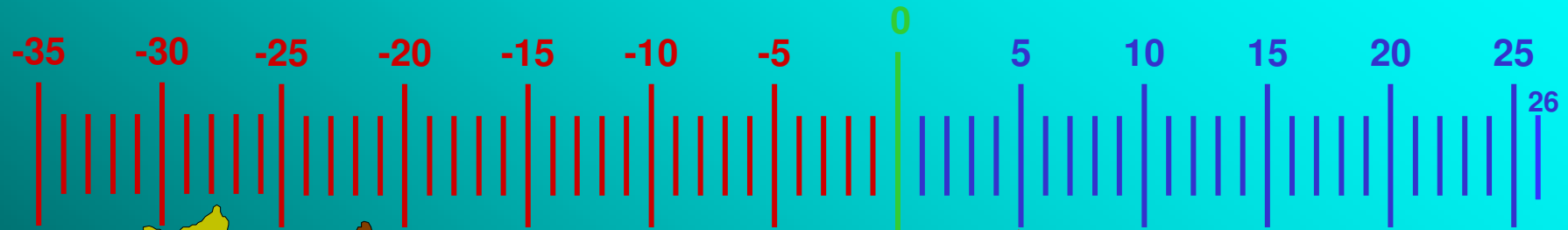
$$f = 10^4$$

$$10^4 \text{ m} = 10.000 \text{ m}$$



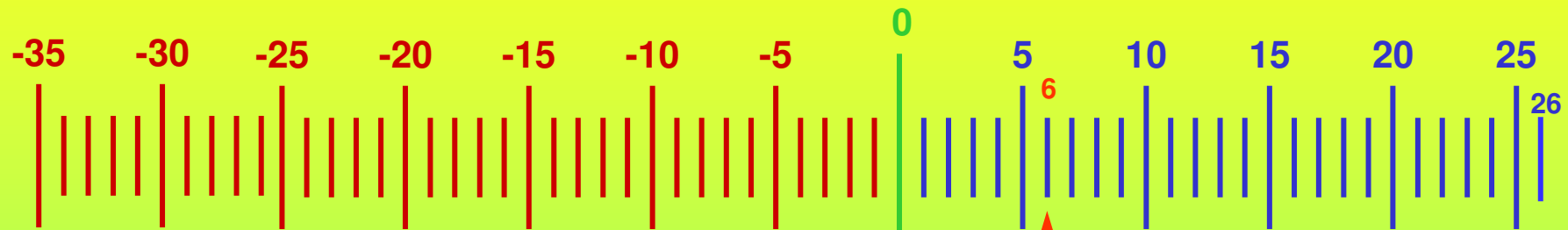
$$f = 10^5$$

$$10^5 \text{ m} = 100.000 \text{ m}$$



Mega f = 10^6

$10^6 \text{ m} = 1.000.000 \text{ m}$

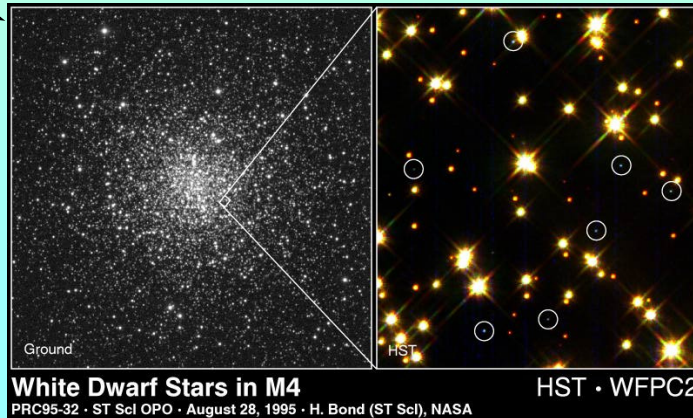
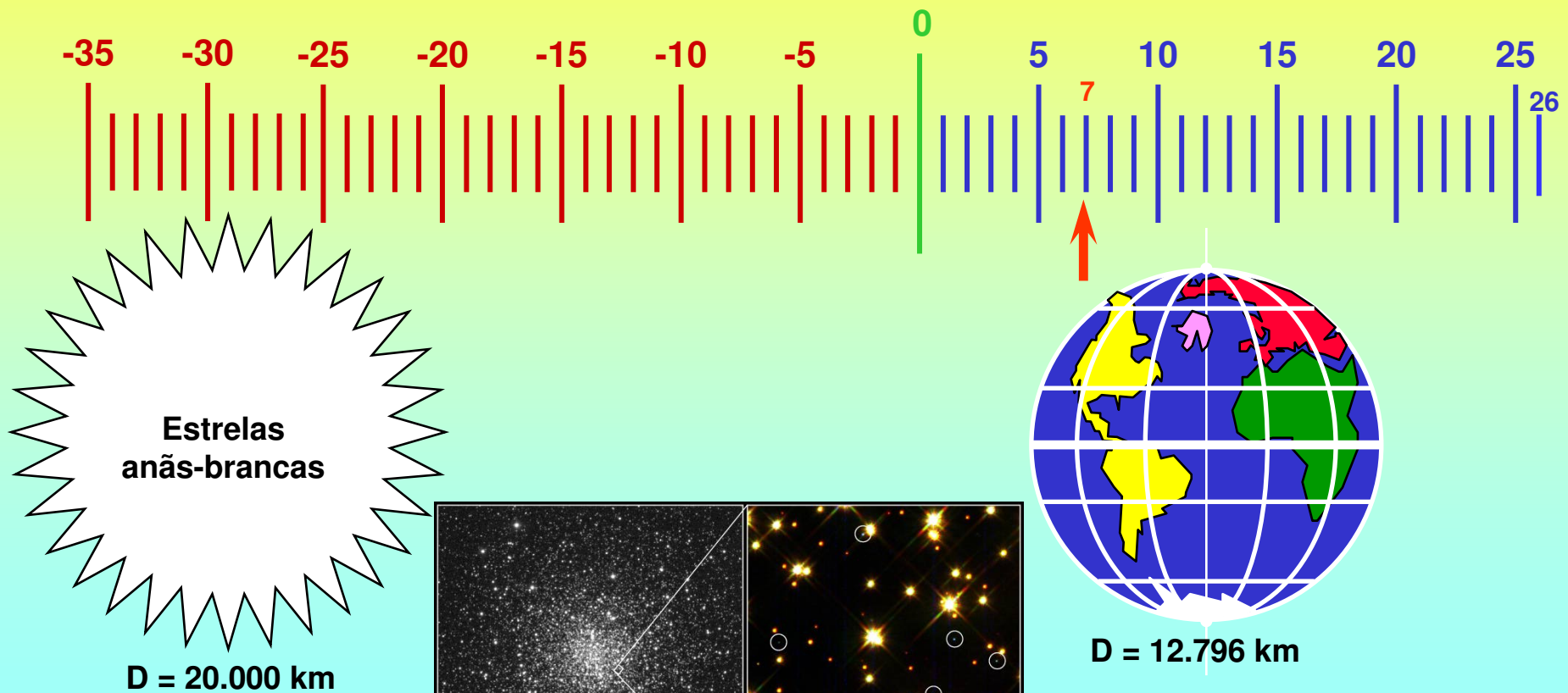


Quaoar: diâmetros comparados



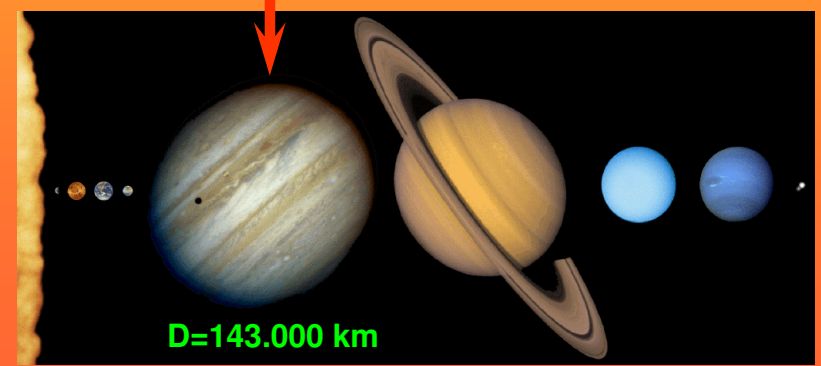
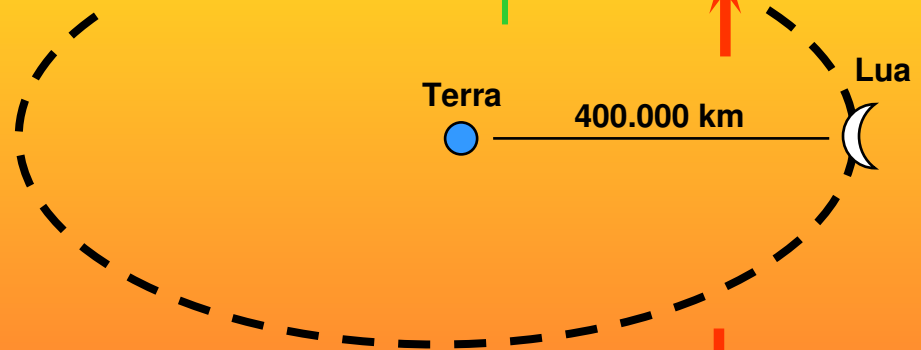
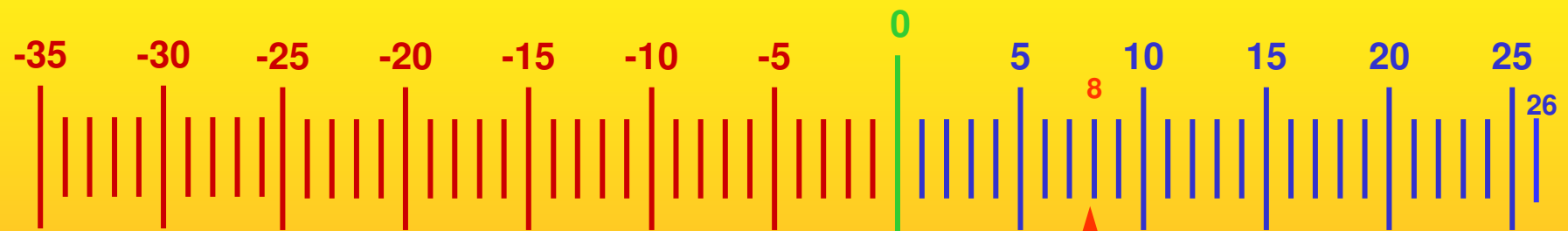
$$f = 10^7$$

$$10^7 \text{ m} = 10.000.000 \text{ m}$$



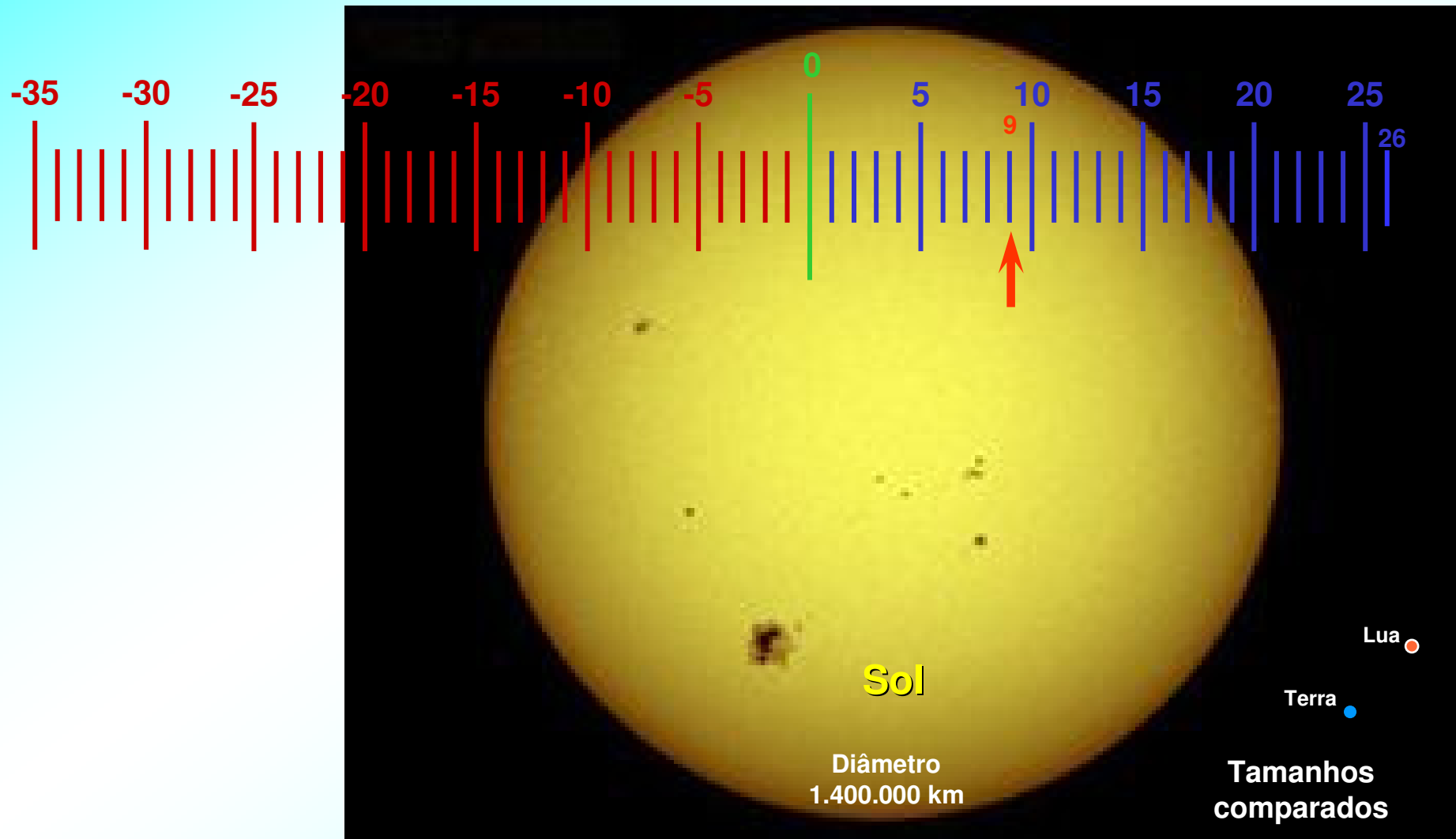
$$f = 10^8$$

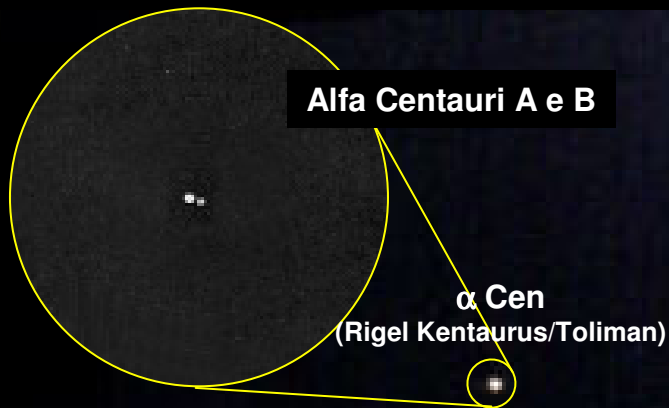
$10^8 \text{ m} = 100.000.000 \text{ m}$



Giga f = 10⁹

10⁹ m = 1.000.000.000 m

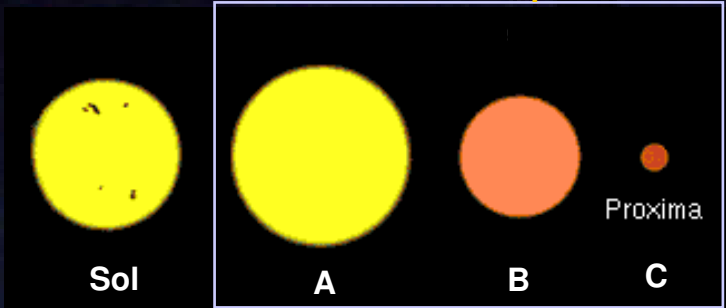




Alfa Centauri A e B

α Cen
(Rigel Kentaurus/Toliman)

Tamanhos comparados



Sol

A

B

C

Proxima

α Cen A

ζ Cen

ε Cen

β Cen

Cruzeiro do Sul

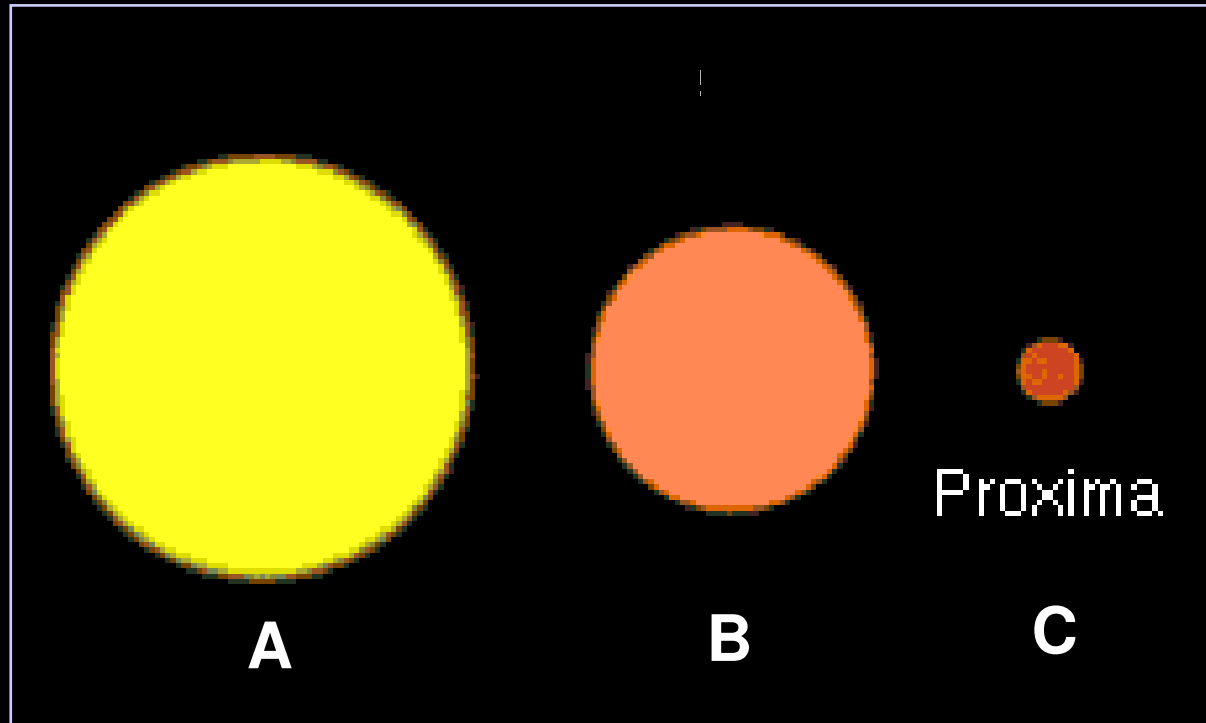
Tamanho da Estrela Próxima



Tamanhos relativos do Sol e das estrelas de α Cen



Sol



A

B

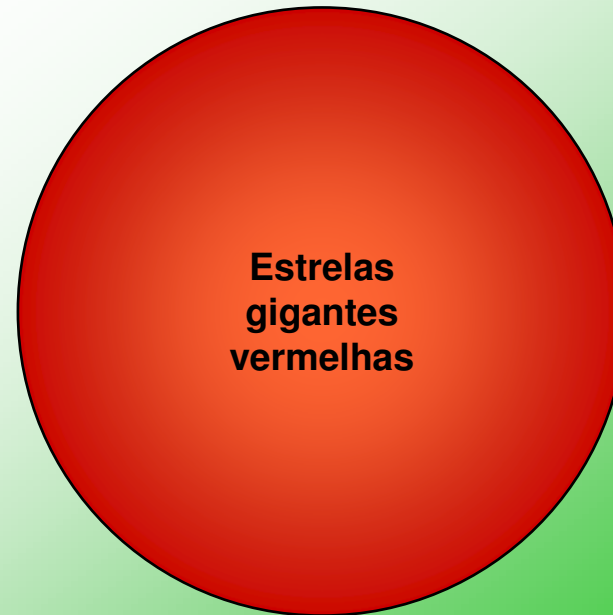
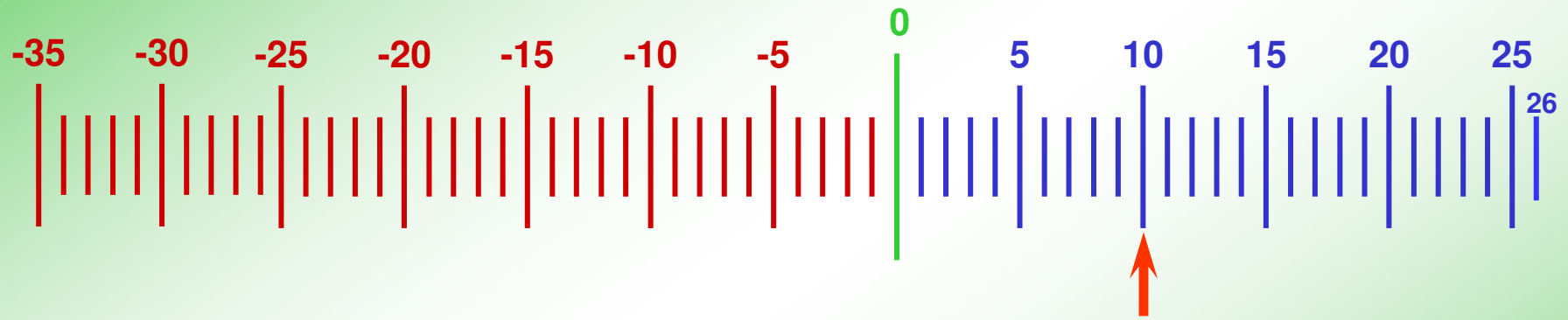
C

Proxima

α Cen

$$f = 10^{10}$$

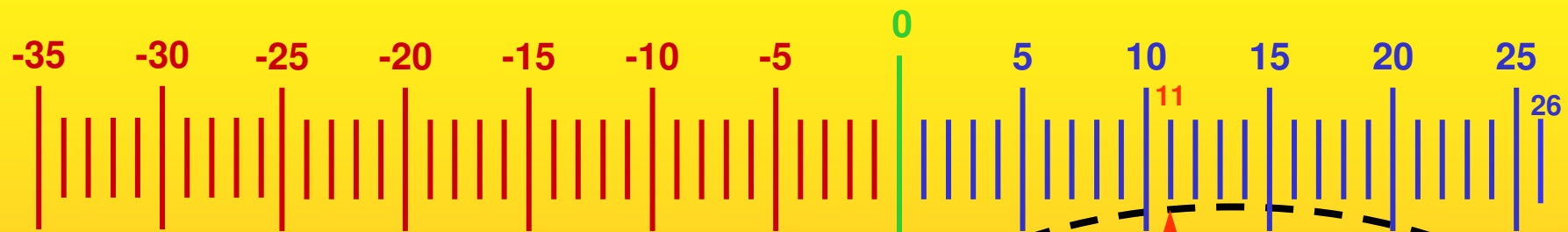
$$10^{10} \text{ m} = 10.000.000.000 \text{ m}$$



Estrelas
gigantes
vermelhas

$$f = 10^{11}$$

$$10^{11} \text{ m} = 100.000.000.000 \text{ m}$$



Betelgeuse
Super gigante vermelha

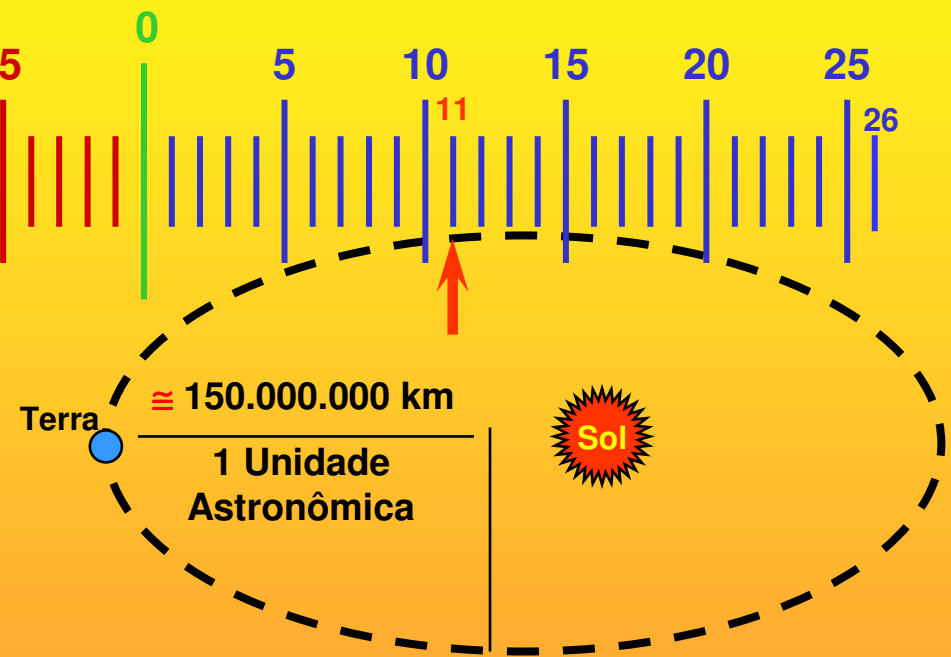
D = 800.000.000 km

Size of Star

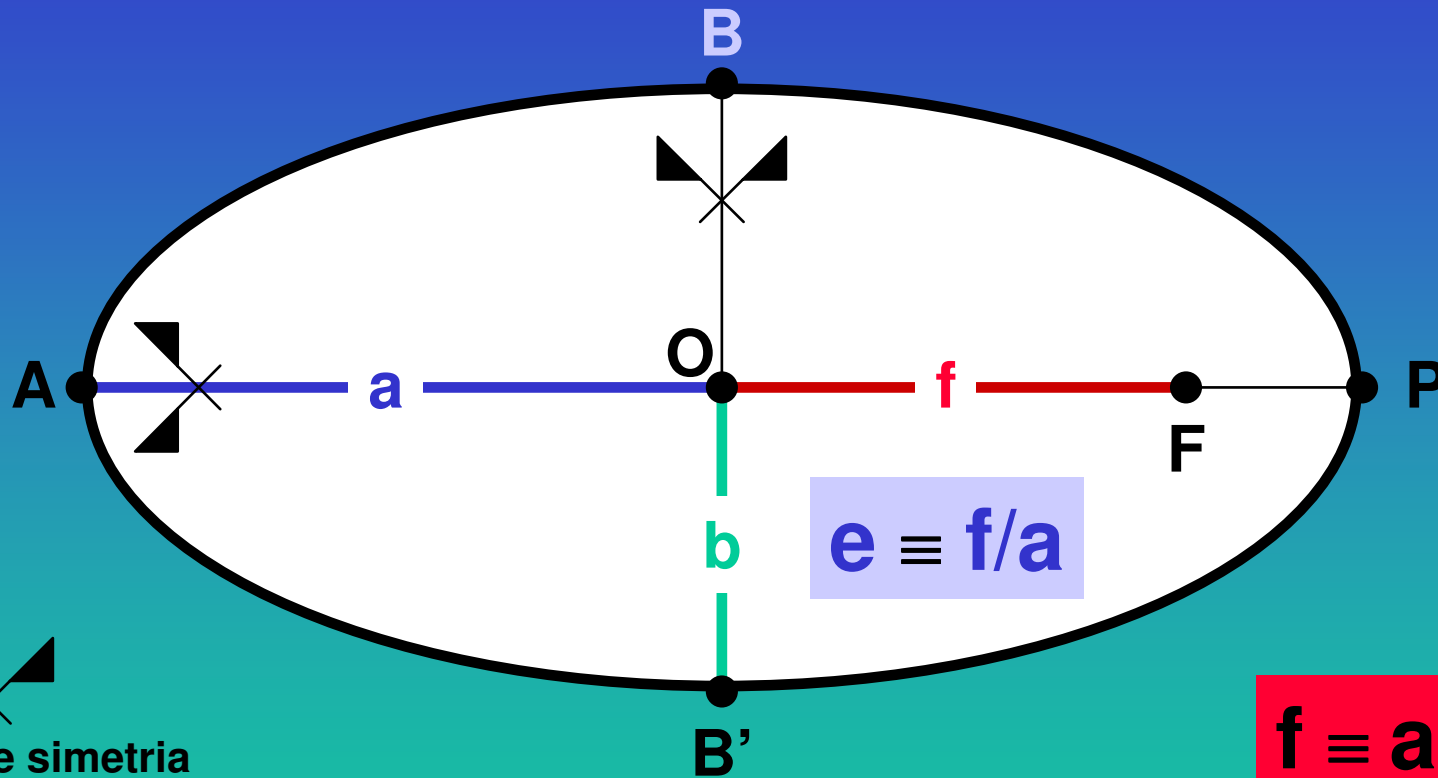
Size of Earth's Orbit

Size of Jupiter's Orbit

Constelação de Orion



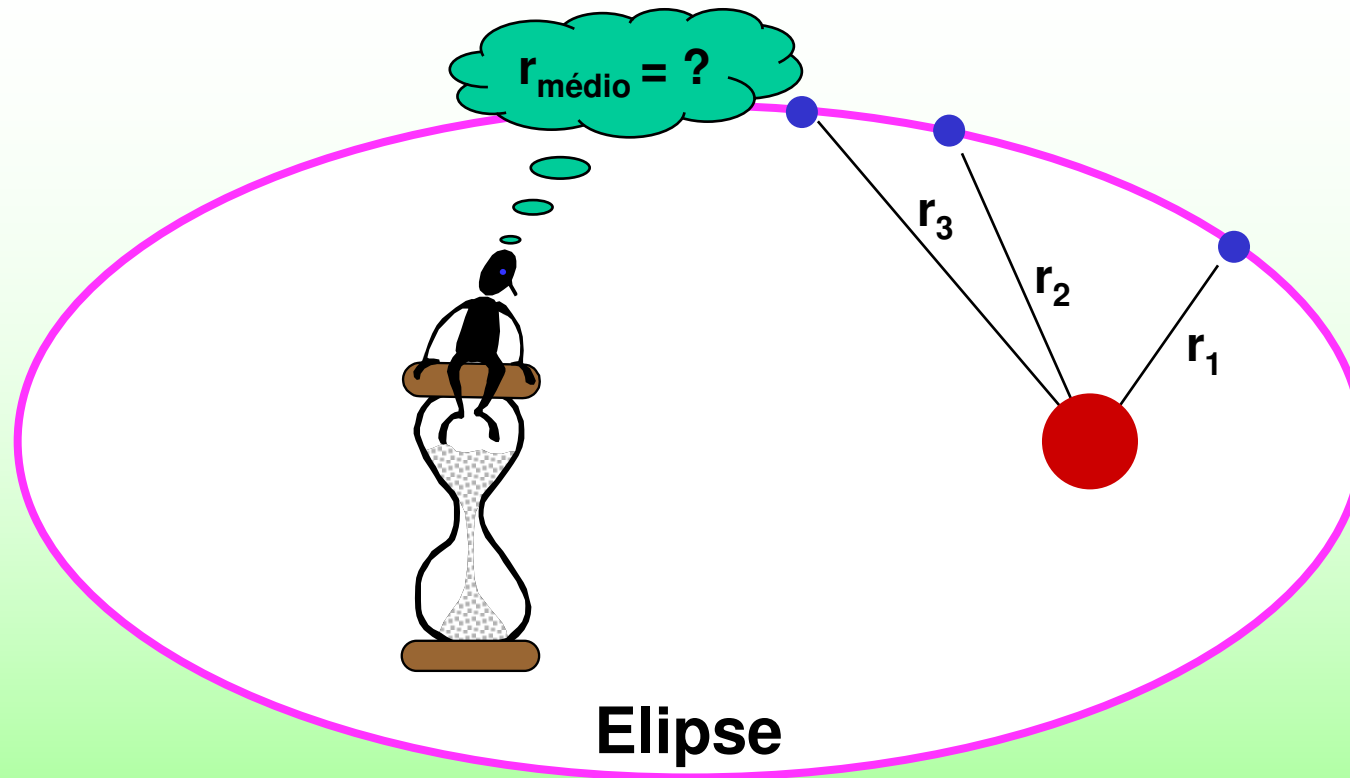
Elementos de uma elipse



Símbolo de simetria

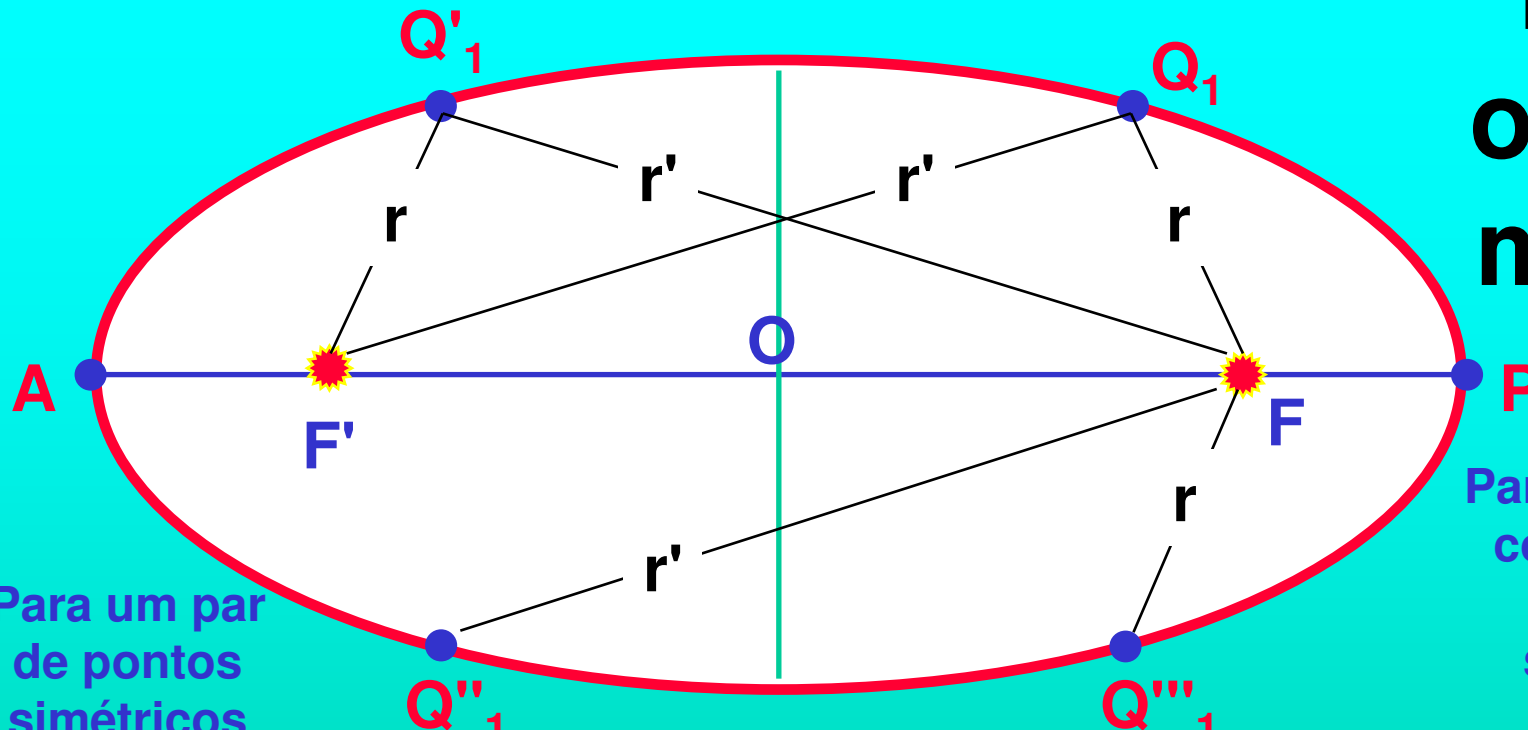
a = semieixo maior
 b = semieixo menor
 f = distância focal
 e = excentricidade

$$f \equiv ae$$



Quanto vale o raio orbital médio ao longo de um ciclo?

Raio orbital médio



Para todos os 4 conjuntos de pontos simétricos

Para um par de pontos simétricos

$$Q_1 \Rightarrow r + r' = 2a \quad \textcircled{1}$$

$$Q'_1 \Rightarrow r' + r = 2a \quad \textcircled{2}$$

Para os 4 pontos simétricos

Q_1, Q'_1, Q''_1, Q'''_1

a média r_1 pode ser dada por:

$$r_1 = (r + r' + r + r') / 4 \quad \textcircled{3}$$

Substituindo $\textcircled{1}$ e $\textcircled{2}$ em $\textcircled{3}$ a média será:

$$r_1 = a$$

$$Q_1, Q'_1, Q''_1, Q'''_1 \Rightarrow r_1 = a$$

$$Q_2, Q'_2, Q''_2, Q'''_2 \Rightarrow r_2 = a$$

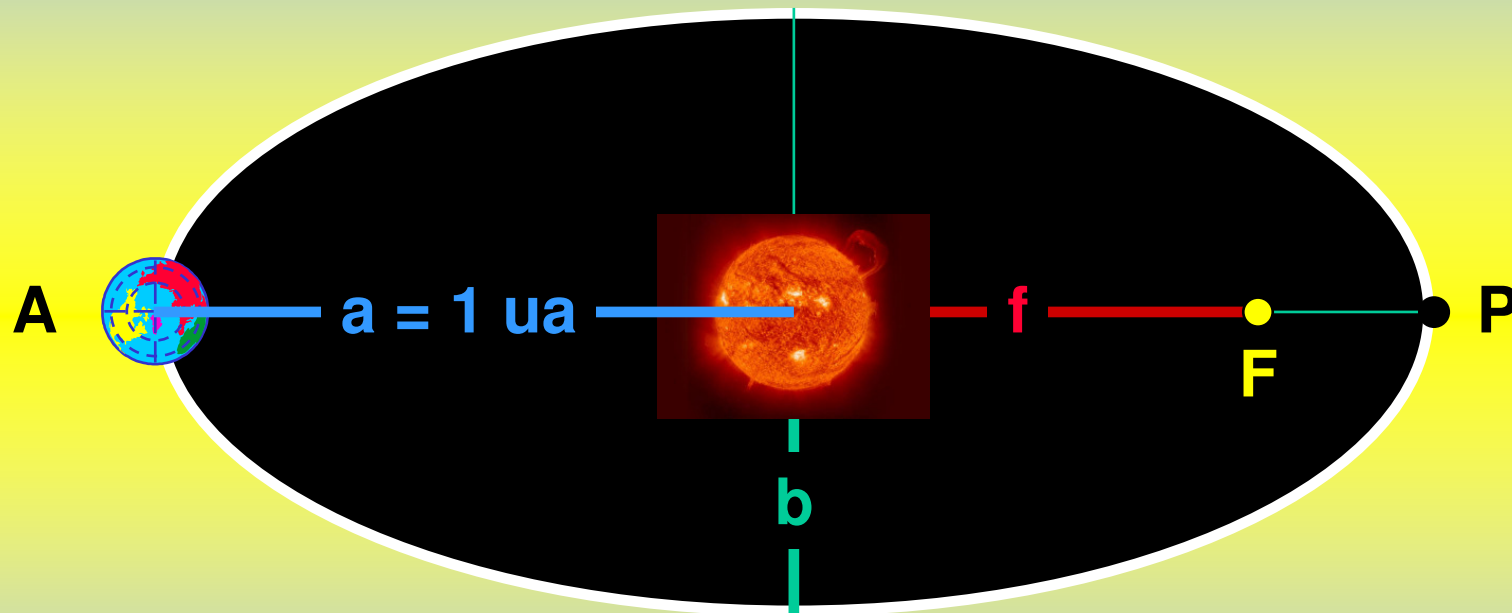
$$Q_N, Q'_N, Q''_N, Q'''_N \Rightarrow r_N = a$$

$$r_1 + r_2 + \dots + r_N = N \cdot a$$

$$(r_1 + r_2 + \dots + r_N) / N = a$$

$$\underline{r} = a$$

Definição da Unidade Astronômica



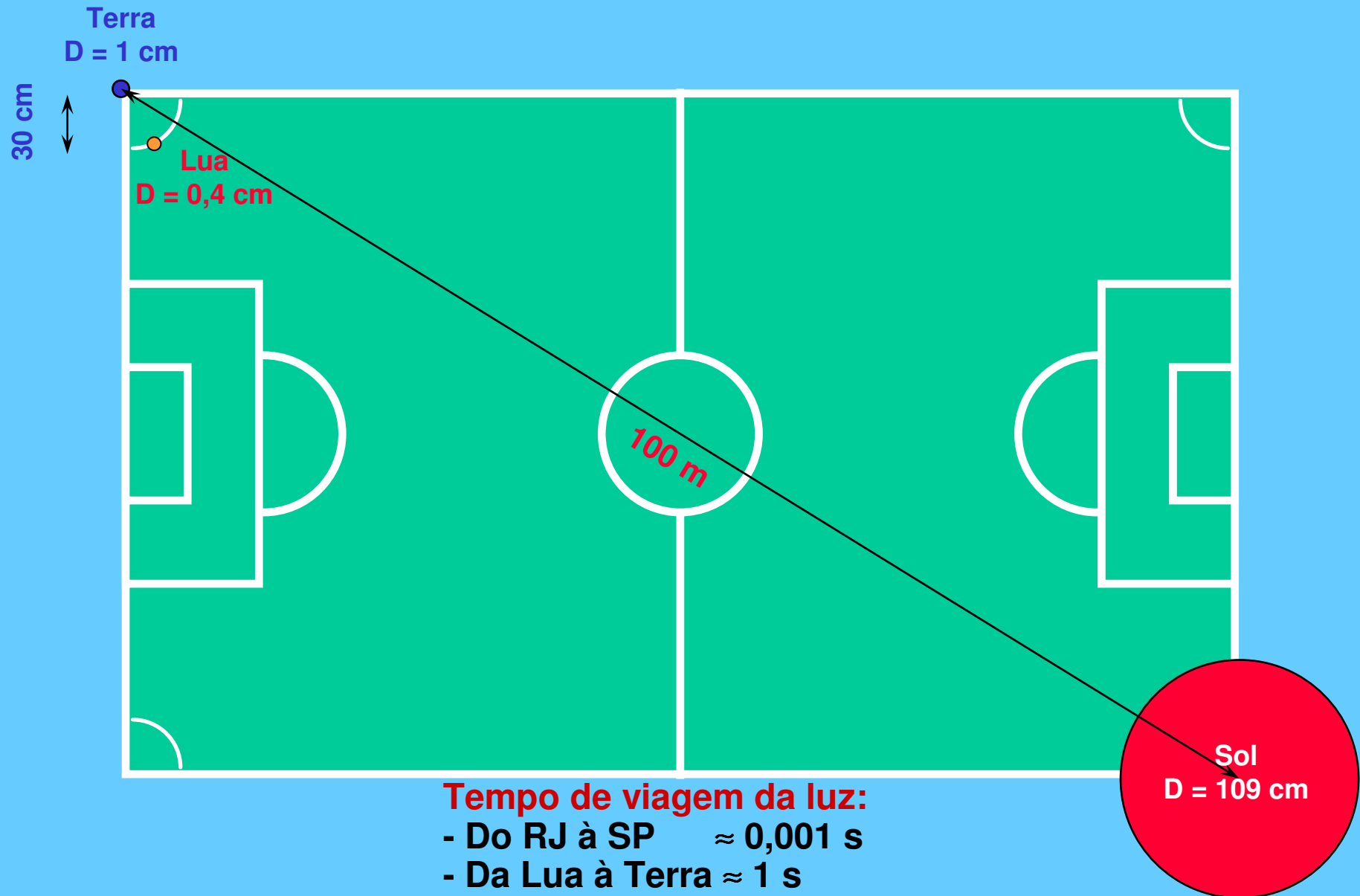
ua

Distância média (semieixo maior) da Terra ao Sol ao longo de um período orbital.

$1 \text{ ua} \cong 1,495.978\ 706\ 91\ (30) \times 10^{11} \text{ m}$

Imprecisão

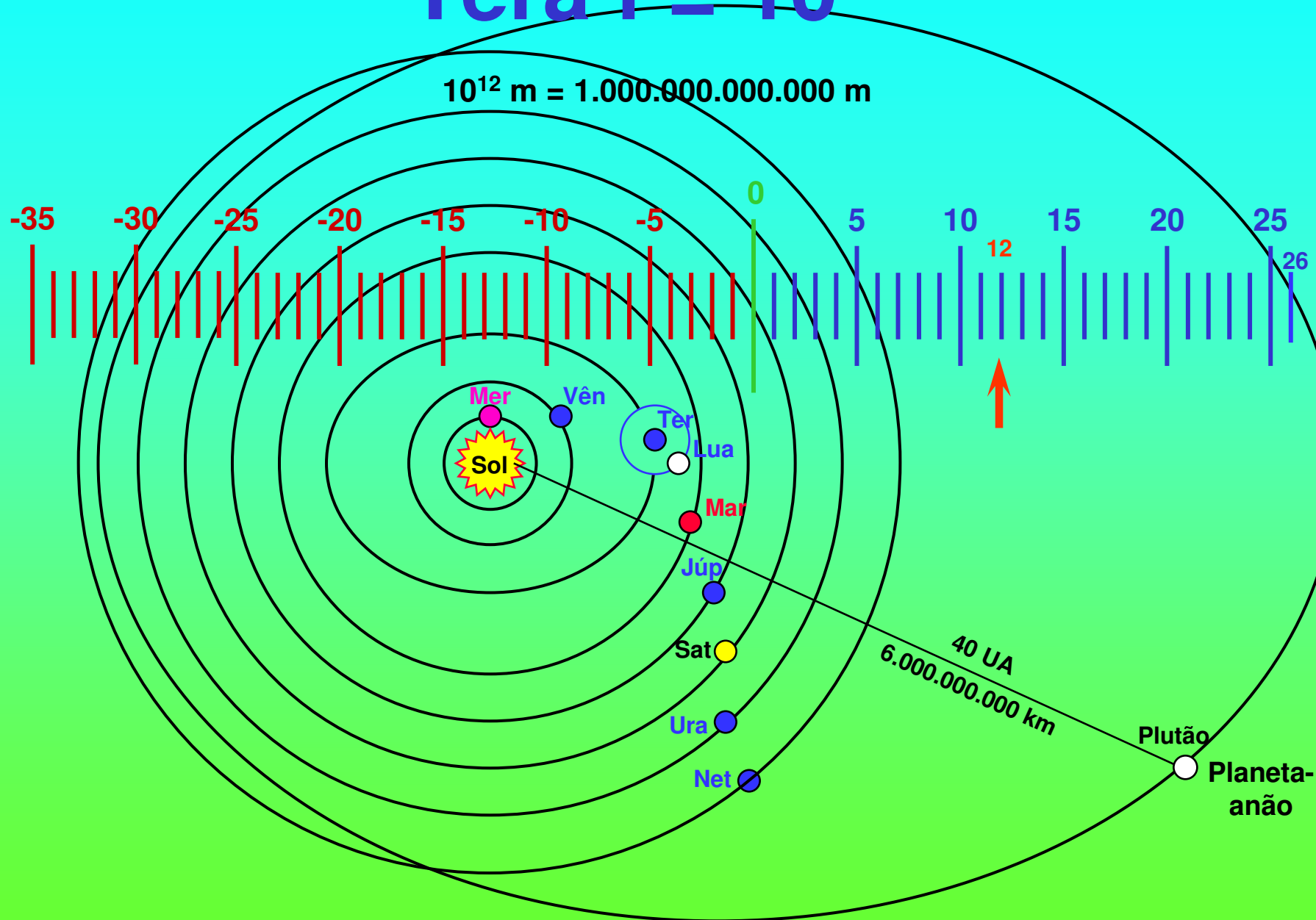
Distâncias e tamanhos comparados



Tempo de viagem da luz:

- Do RJ à SP $\approx 0,001$ s
- Da Lua à Terra ≈ 1 s
- Do Sol à Terra ≈ 8 min 15 s

Tera f = 10^{12}



Distâncias e tamanhos comparados no Sistema Solar

Se a Terra
D = 1 cm



Sol

4 km = 40 campos de futebol

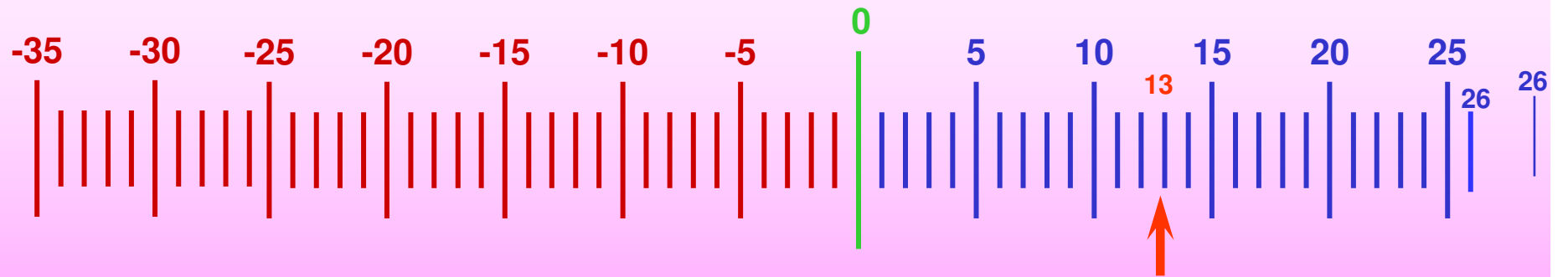
Plutão

Tempo de viagem da luz:

- Do RJ à SP $\approx 0,001$ s
- Da Lua à Terra ≈ 1 s
- Do Sol à Terra ≈ 8 min 15 s
- De Plutão à Terra ≈ 5 h

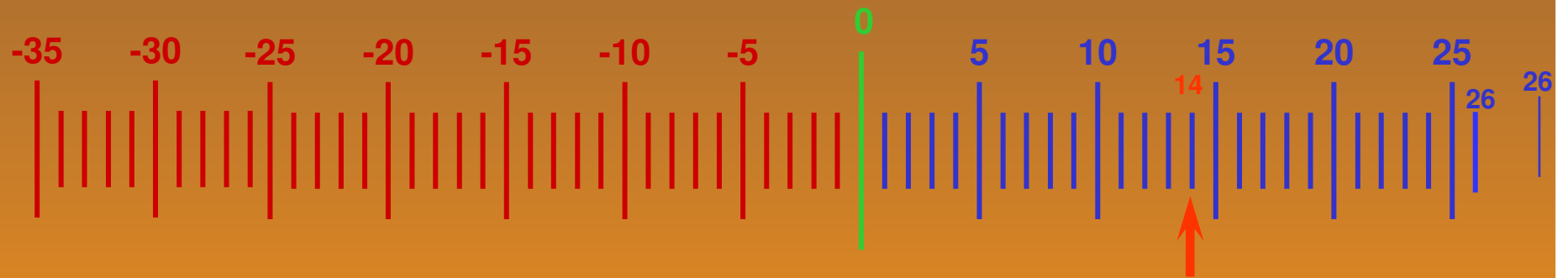
$$f = 10^{13}$$

$$10^{13} \text{ m} = 10.000.000.000.000 \text{ m}$$



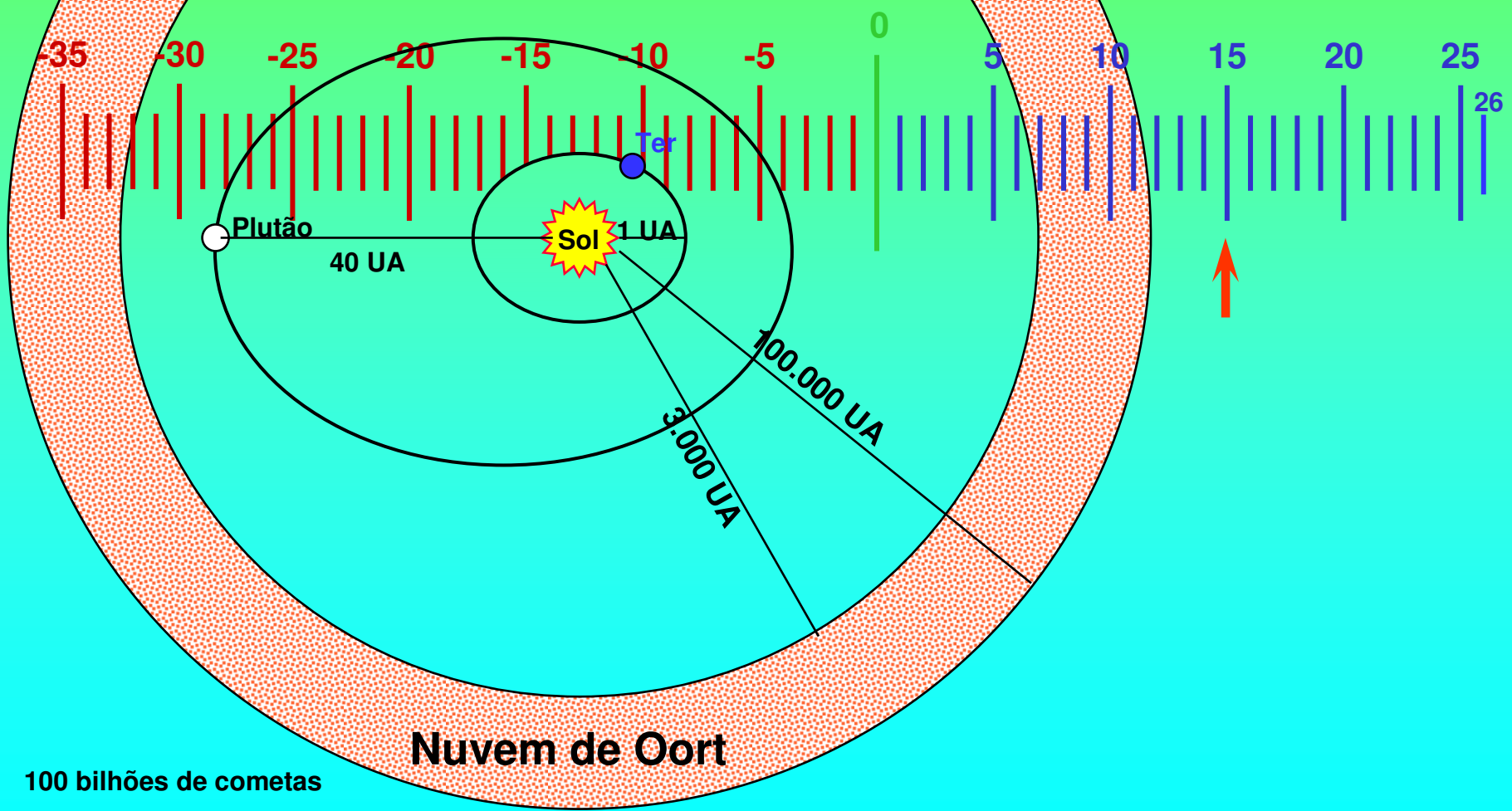
$$f = 10^{14}$$

$$10^{14} \text{ m} = 100.000.000.000.000 \text{ m}$$



Peta f = 10^{15}

10^{15} m = 1.000.000.000.000.000 m



100 bilhões de cometas

Nuvem de Oort

O Sistema Solar

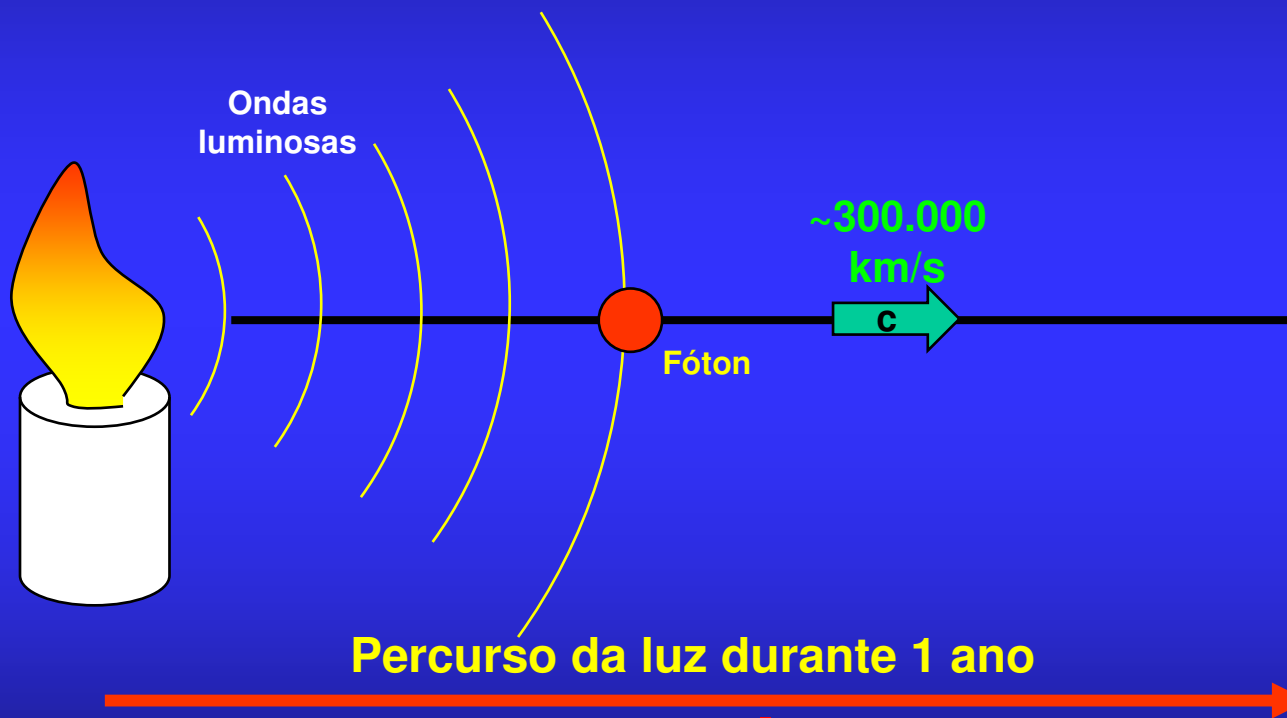


7,5 trilhões de km

Cinturão de Kuiper

Nuvem de Oort

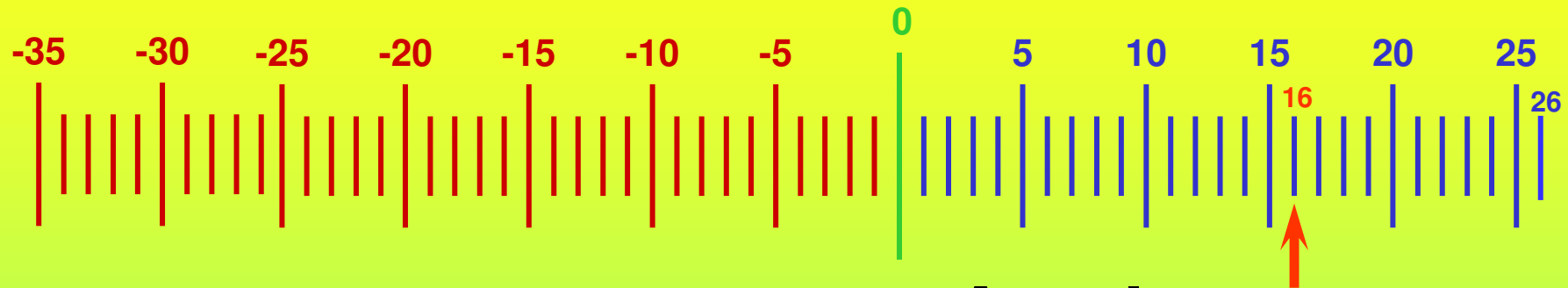
Ano-luz



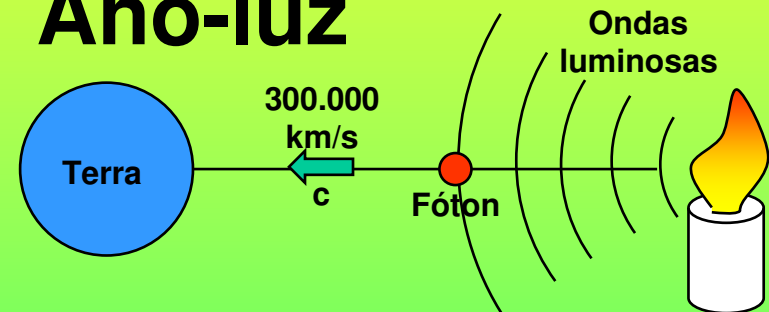
1 ano-luz
~9,5 trilhões de km
~63.240 UA

$$f = 10^{16}$$

$$10^{16} \text{ m} = 10.000.000.000.000.000 \text{ m}$$



Ano-luz



Percurso da luz durante 1 ano
9,5 trilhões de km = 1 ano-luz

Tempo de viagem da luz:

- Do RJ à SP $\approx 0,001 \text{ s}$
- Da Lua à Terra $\approx 1 \text{ s}$
- Do Sol à Terra $\approx 8 \text{ min } 15 \text{ s}$
- De Plutão à Terra $\approx 5 \text{ h}$
- Alfa Centauro à Terra $\approx 4,4 \text{ anos}$

Terra



40.000.000.000.000 km

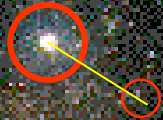
4,4 a-l

Estrela
Próxima



Estrela Próxima

Alfa Centauri



4,4 a-l da Terra



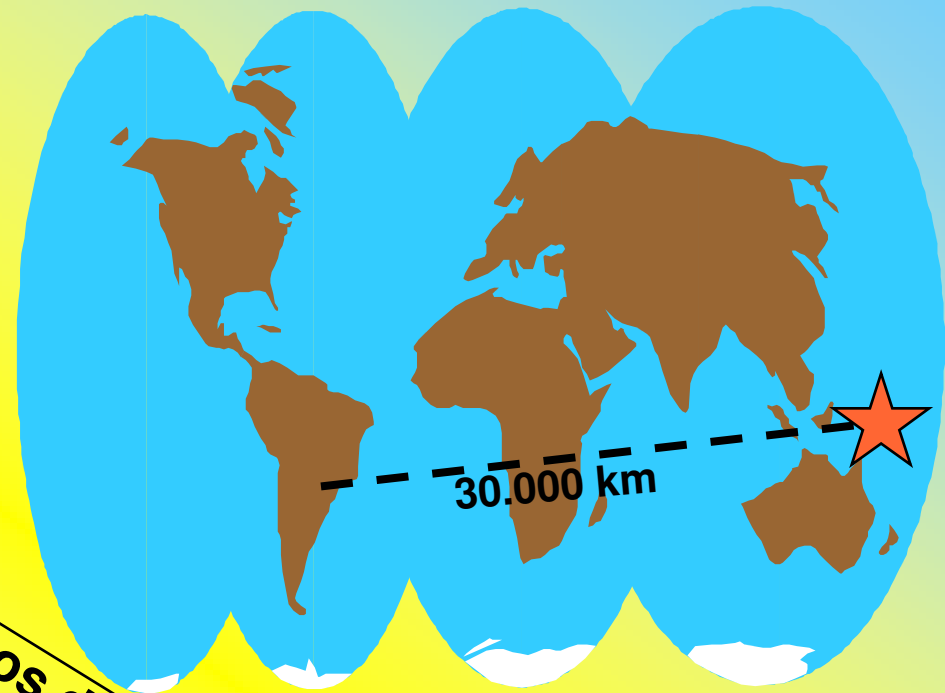
Distâncias e tamanhos comparados

Se a Terra
D = 1 cm



Sol

4 km = 40 campos de futebol



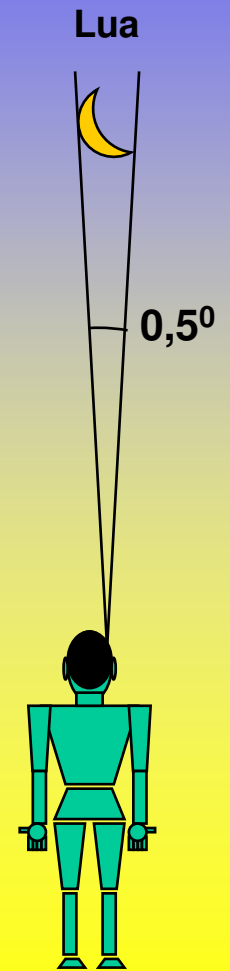
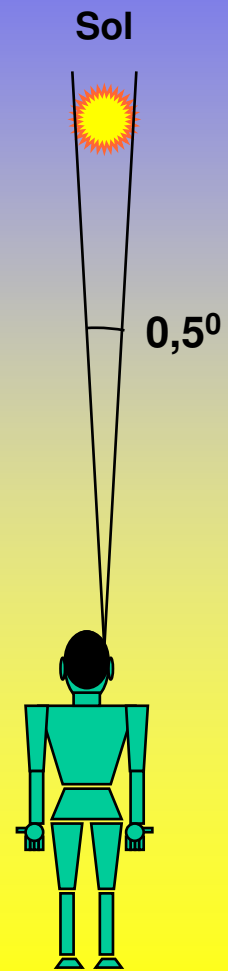
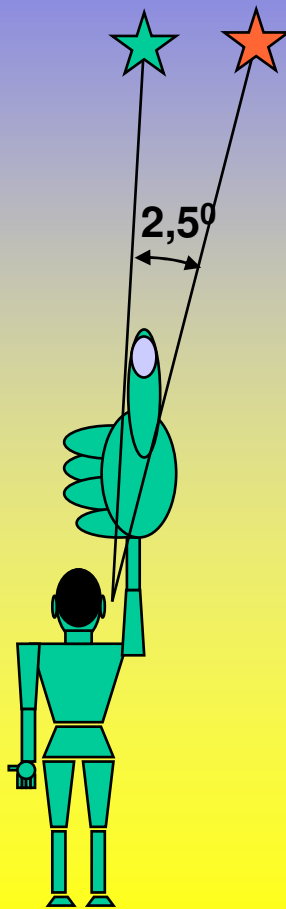
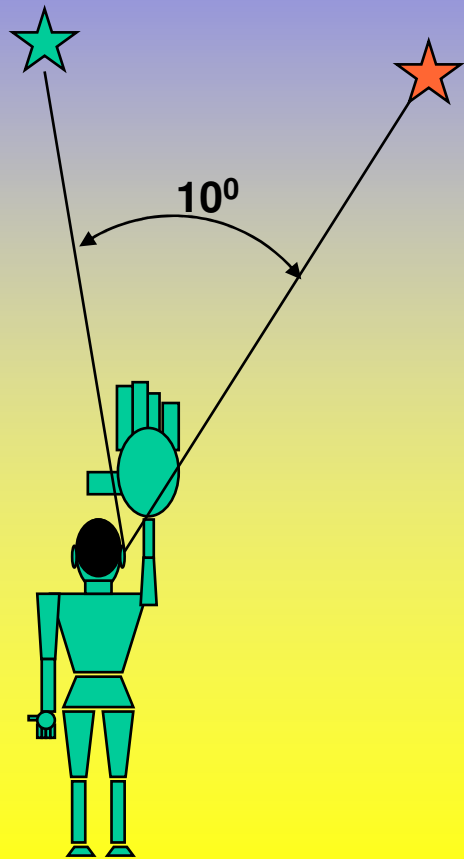
30.000 km

Plutão

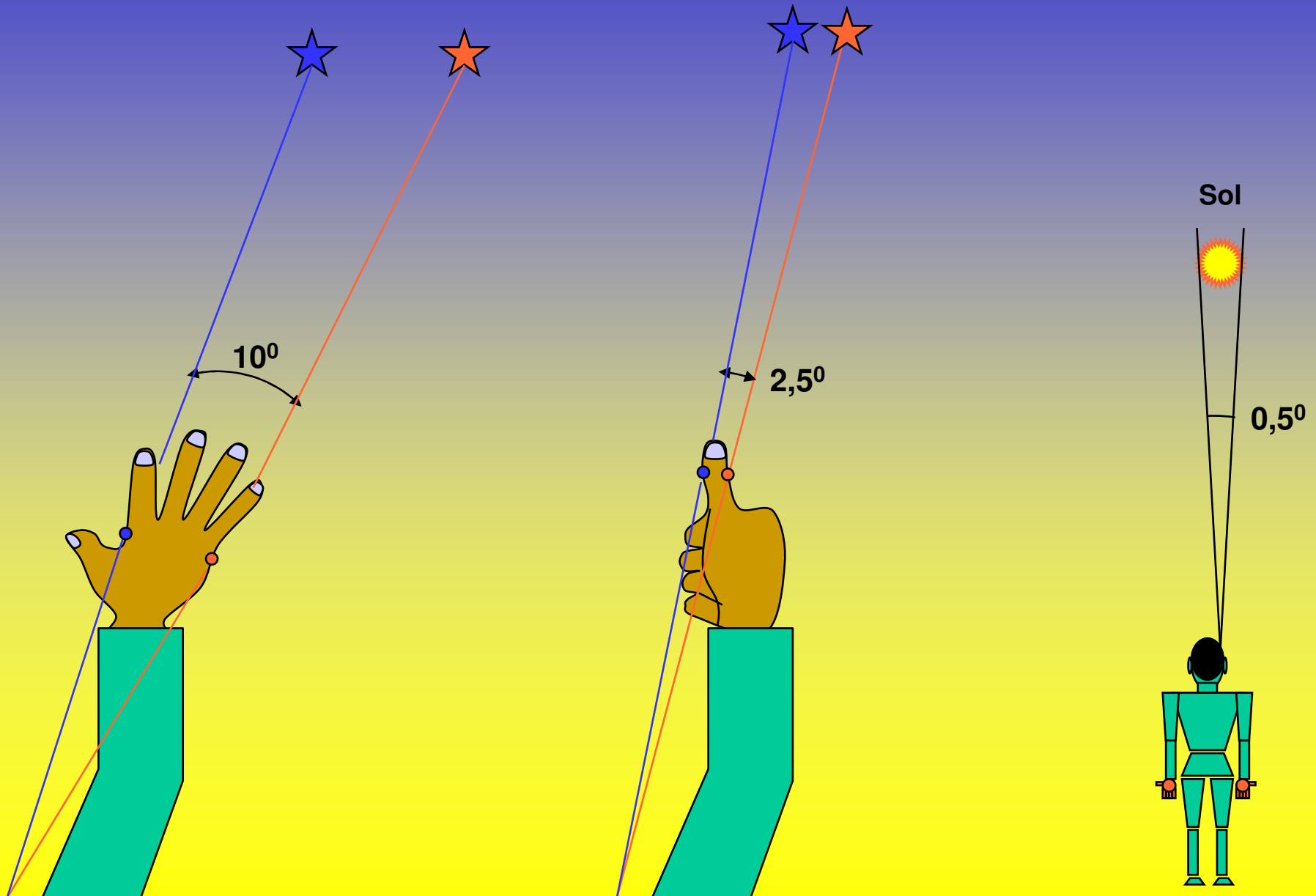
Tempo de viagem da luz:

- Do RJ à SP $\approx 0,001$ s
- Da Lua à Terra ≈ 1 s
- Do Sol à Terra ≈ 8 min 15 s
- De Plutão à Terra ≈ 5 h
- Alfa Centauro à Terra $\approx 4,4$ anos

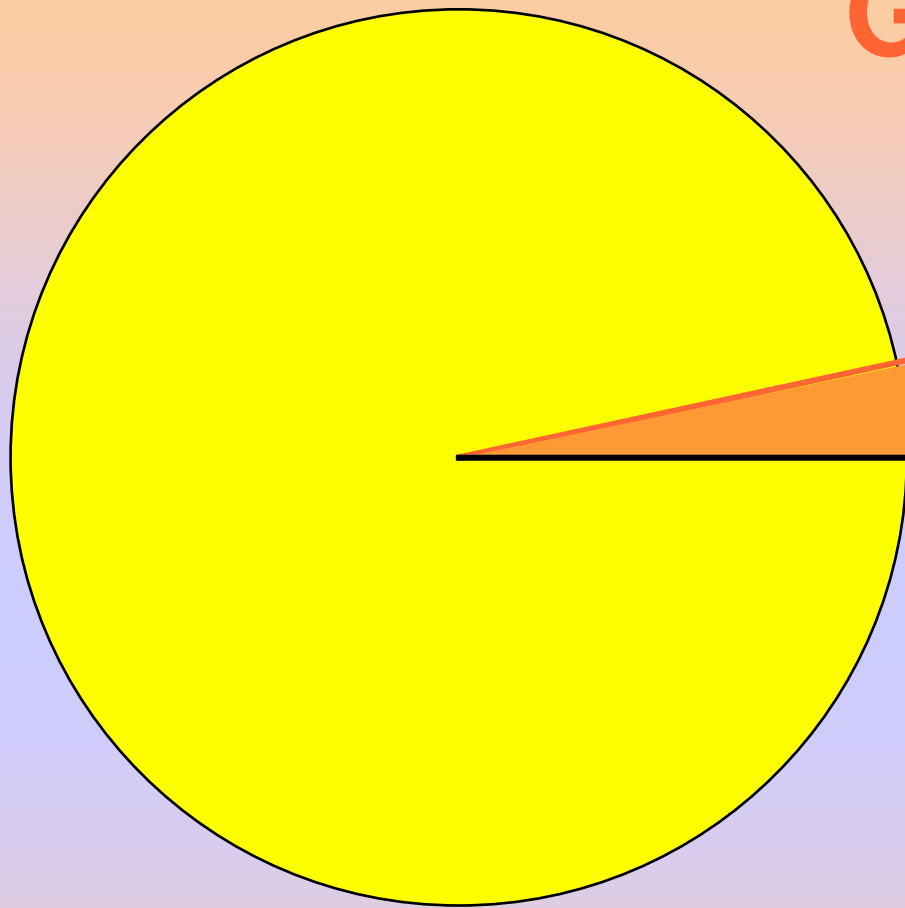
Medidas angulares



Medidas angulares



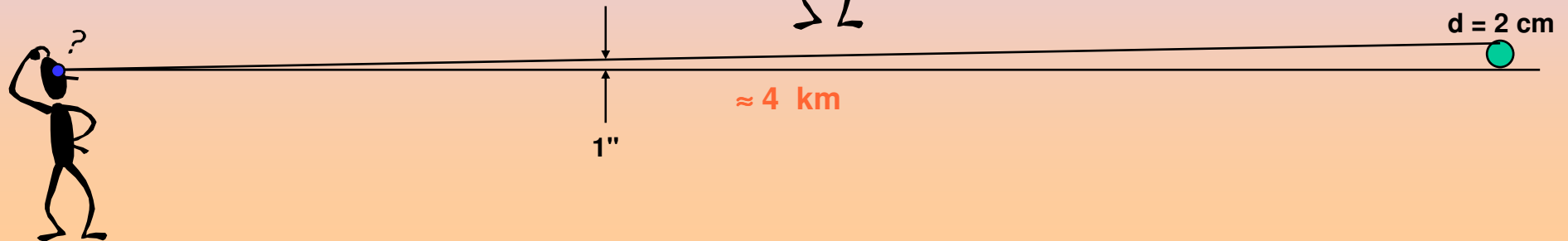
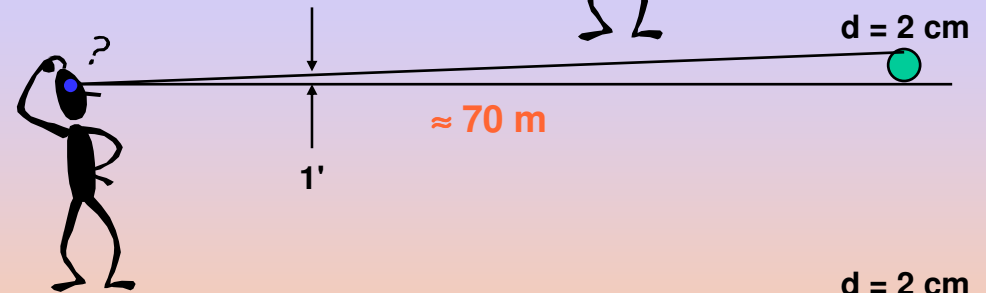
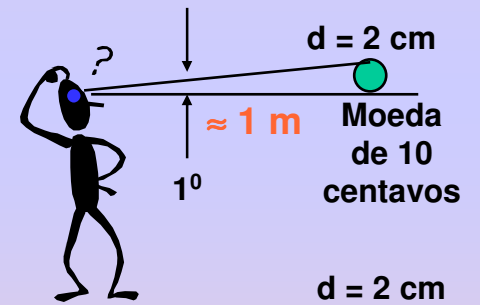
Grau, minuto e segundo



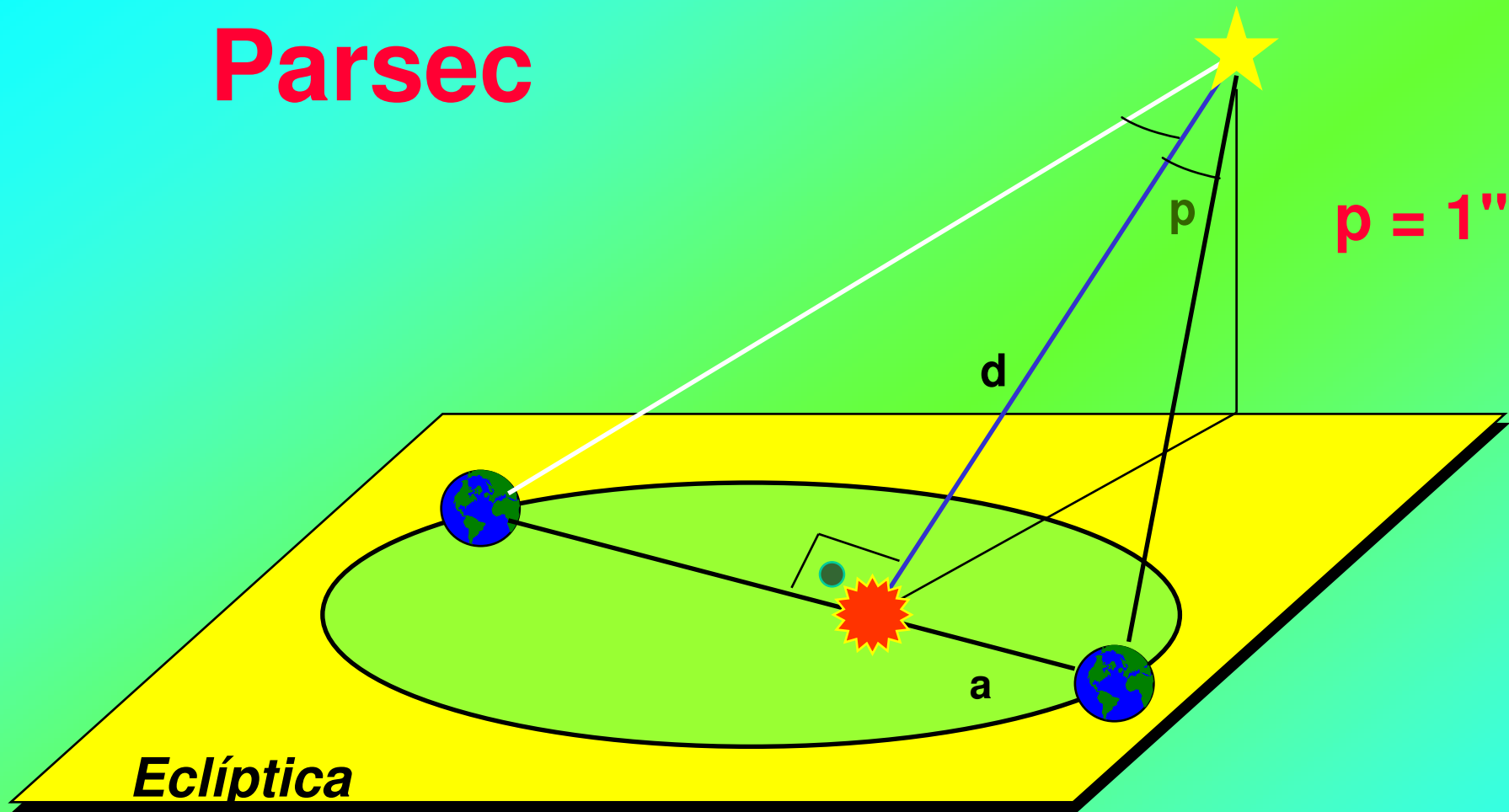
$1^\circ = 1/360$
da circunferência

$1' = 1/60$
do grau

$1'' = 1/60$
do minuto



Parsec



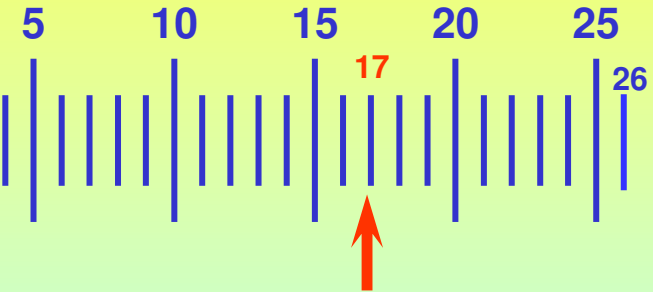
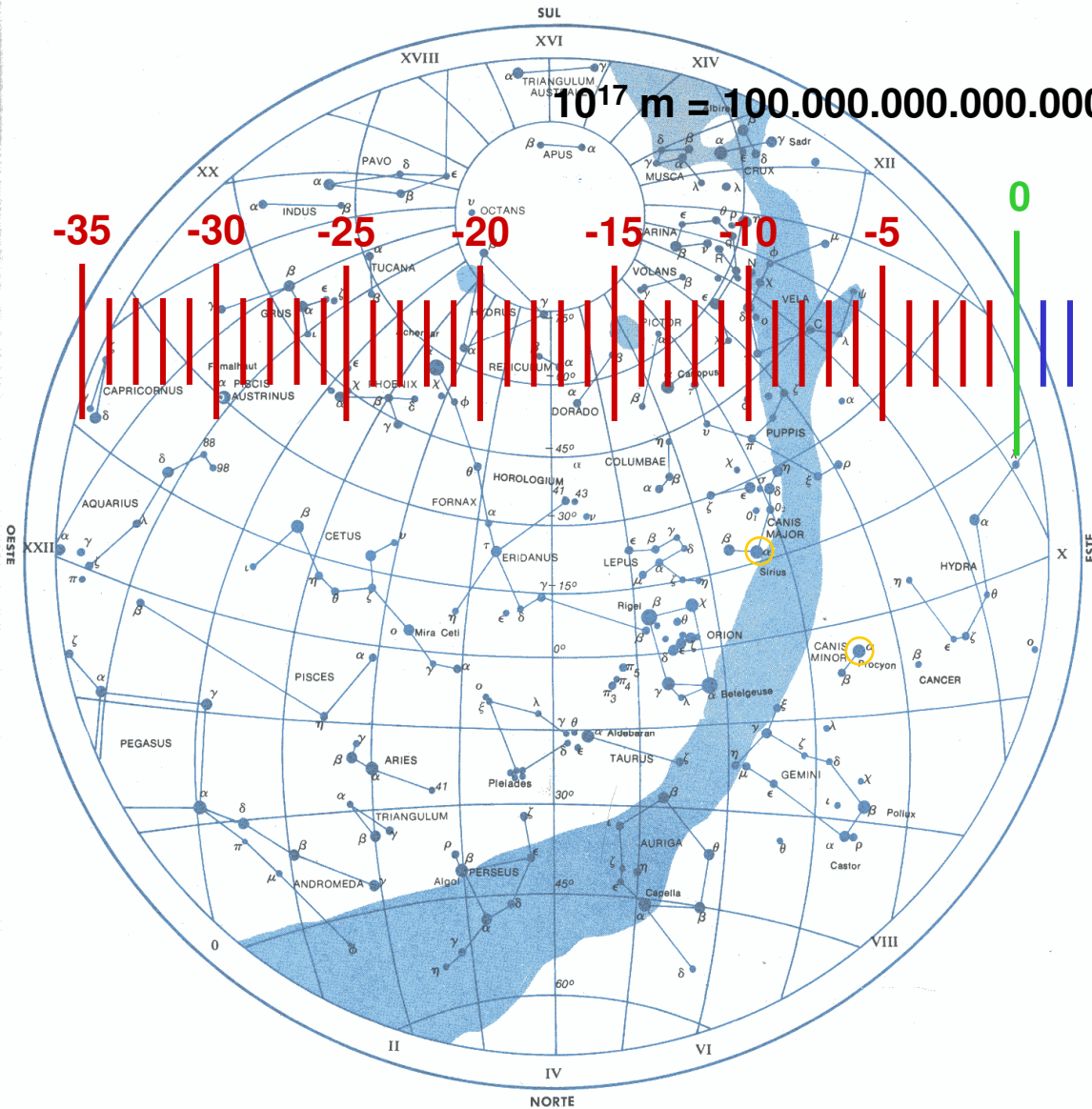
Se $p = 1'' \Rightarrow d \equiv 1 \text{ parsec} = 1 \text{ pc}$

$1 \text{ pc} \cong 3,27 \text{ anos-luz}$

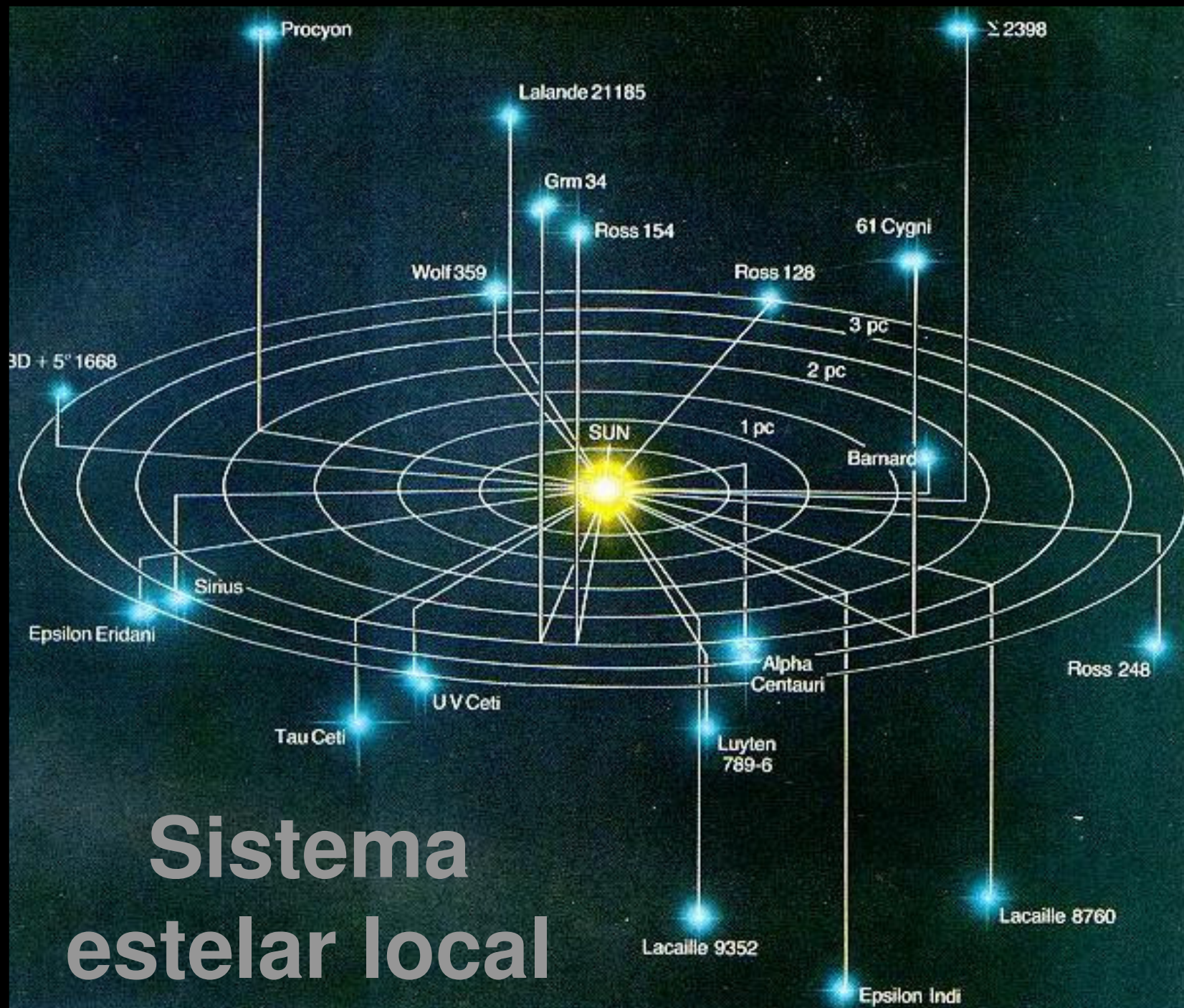
$1 \text{ pc} \cong 206.265 \text{ UA}$

$$f = 10^{17}$$

$10^{17} \text{ m} = 100.000.000.000.000.000 \text{ m}$



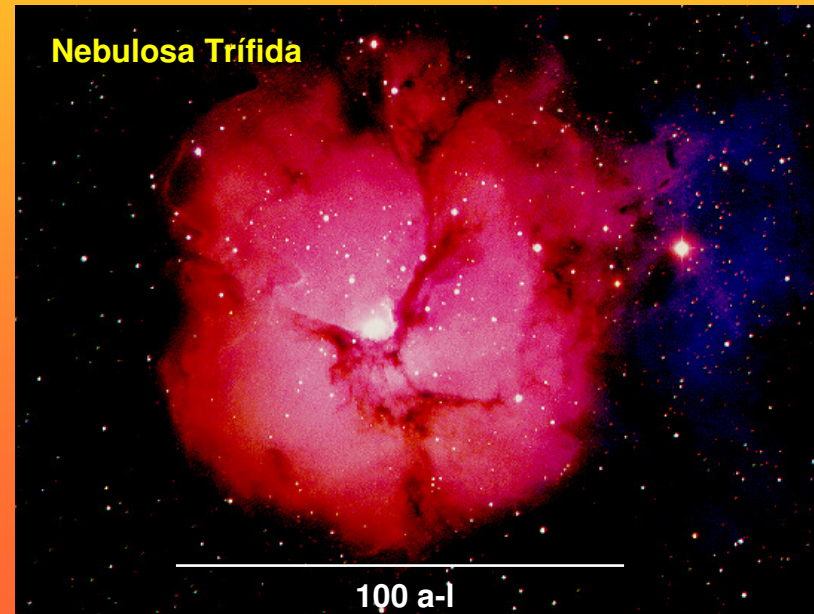
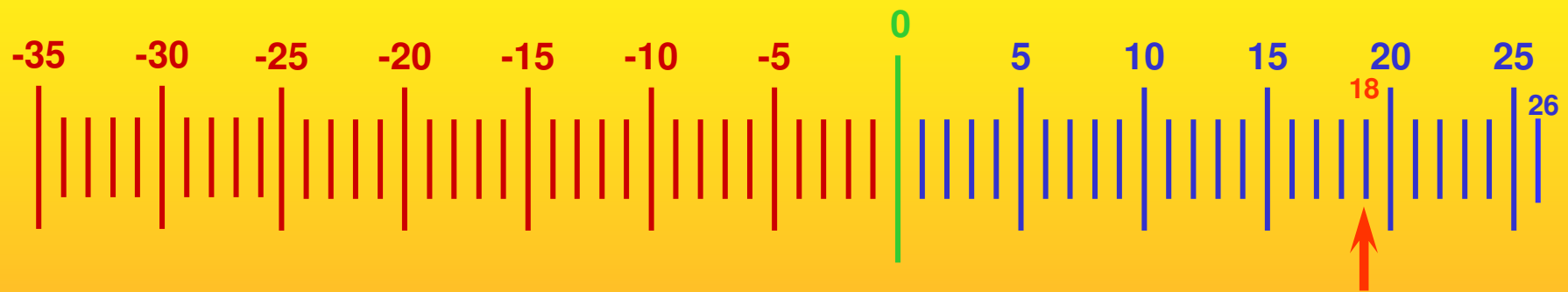
Sirius (α Cão Maior) $\cong 8,8 \text{ a-l}$
Procyon (α Cão Menor) $\cong 11 \text{ a-l}$



Sistema estelar local

Exa f = 10^{18}

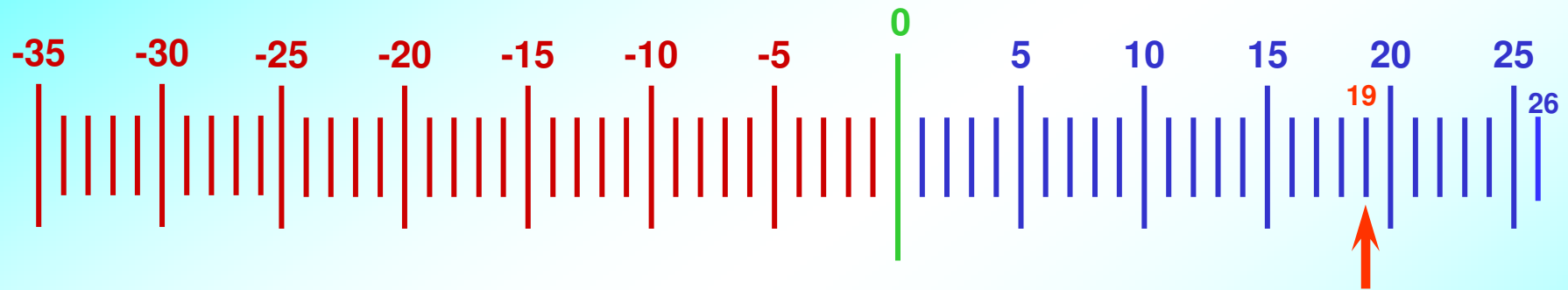
$$10^{18} \text{ m} = 1.000.000.000.000.000.000 \text{ m}$$



100 a-l

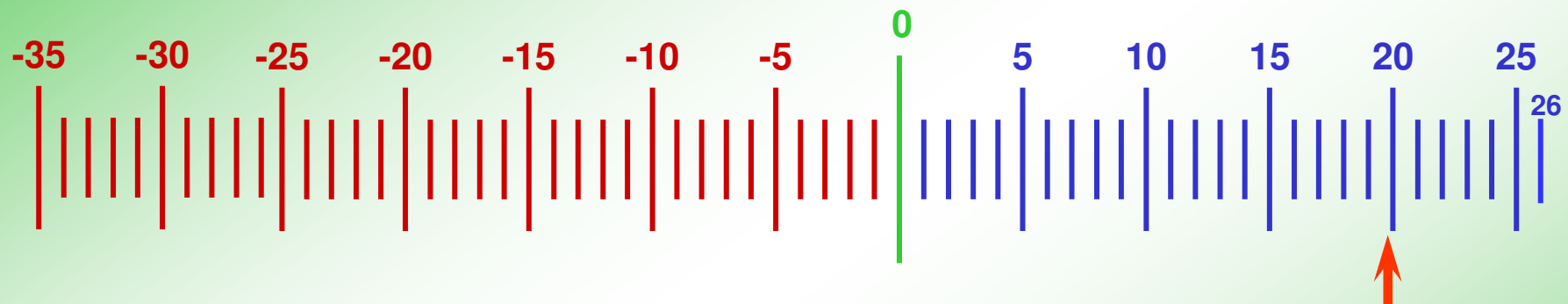
$$f = 10^{19}$$

$$10^{19} \text{ m} = 10.000.000.000.000.000.000 \text{ m}$$



$$f = 10^{20}$$

10^{20} m = 100.000.000.000.000.000.000 m



Terra



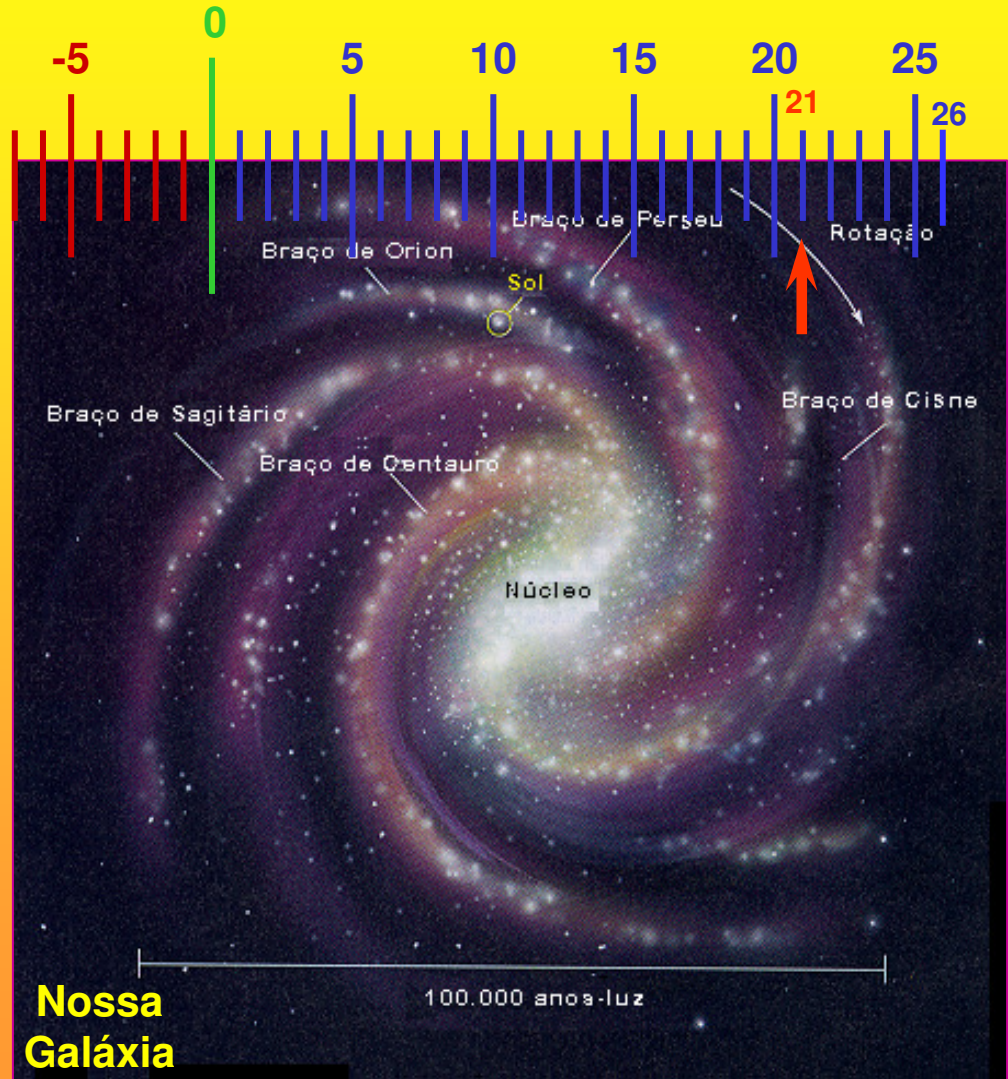
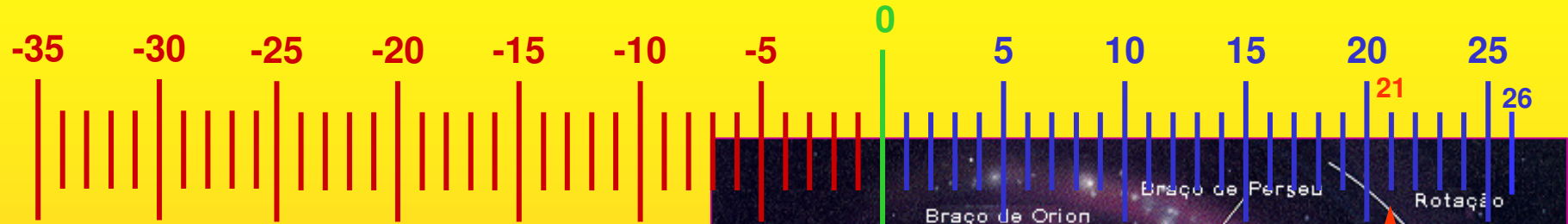
~160.000 a.l.



~30.000 a-l

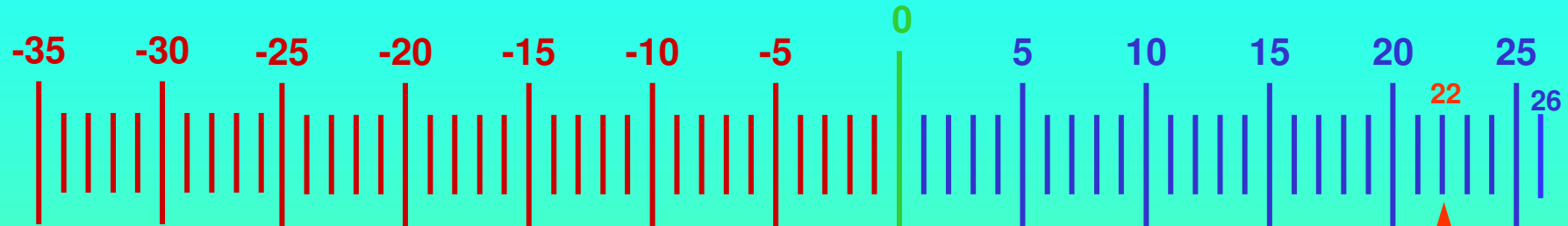
Zetta $f = 10^{21}$

10^{21} m = 1.000.000.000.000.000.000.000 m

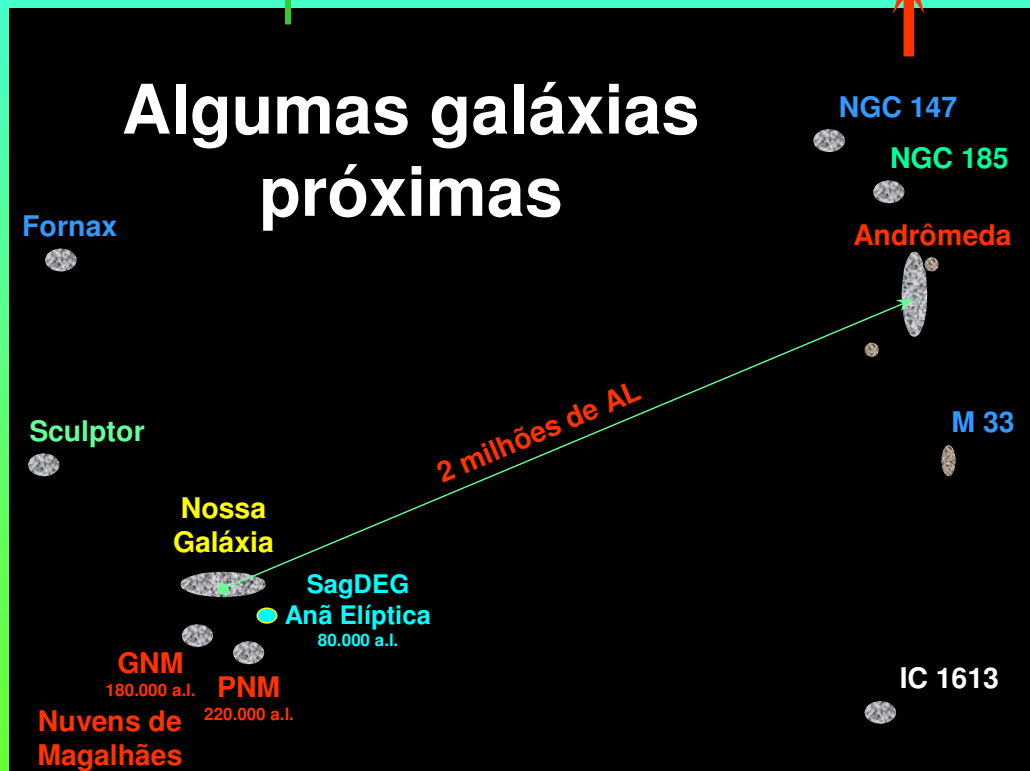


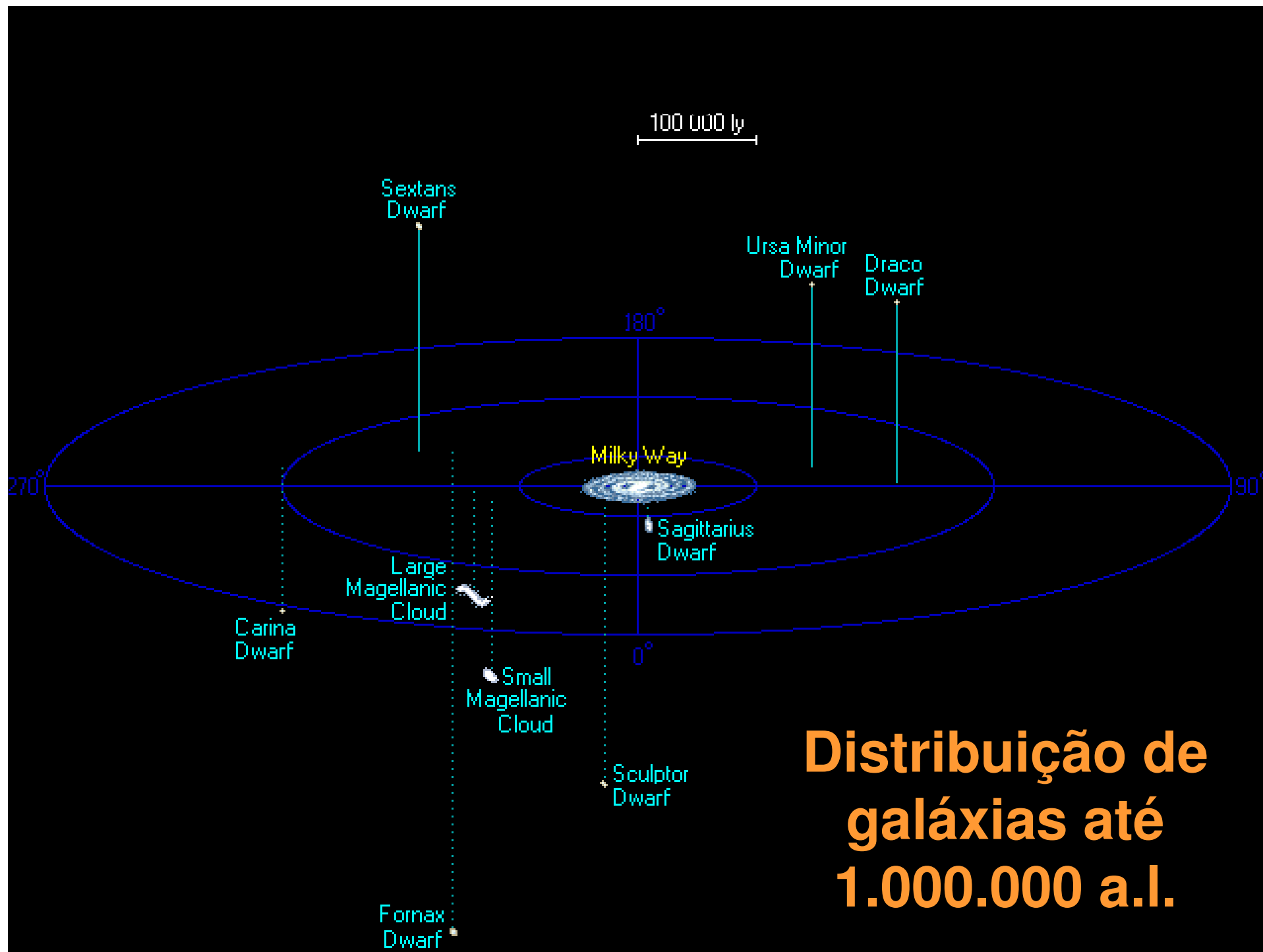
$$f = 10^{22}$$

10^{22} m = 10.000.000.000.000.000.000.000 m



Algumas galáxias próximas

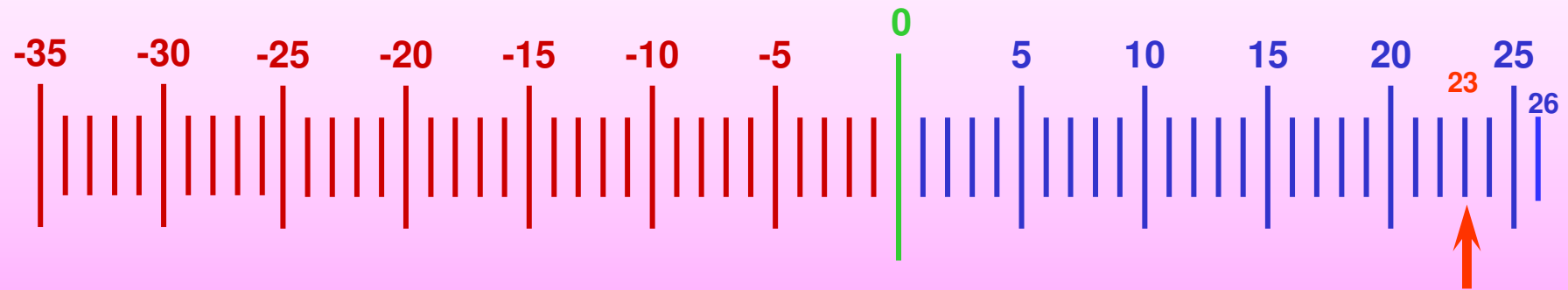




Distribuição de galáxias até 1.000.000 a.l.

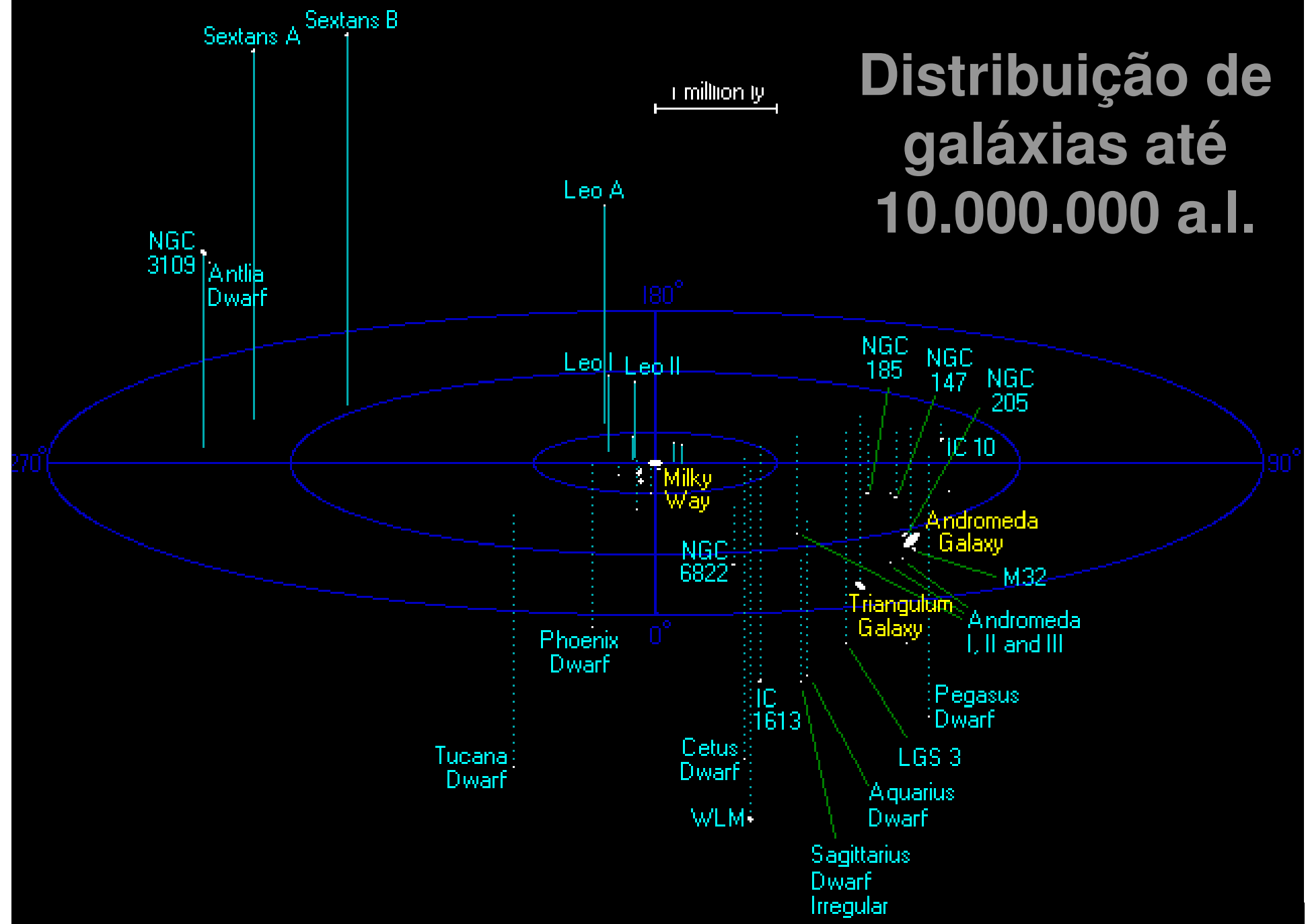
$$f = 10^{23}$$

$$10^{23} \text{ m} = 100.000.000.000.000.000.000.000 \text{ m}$$



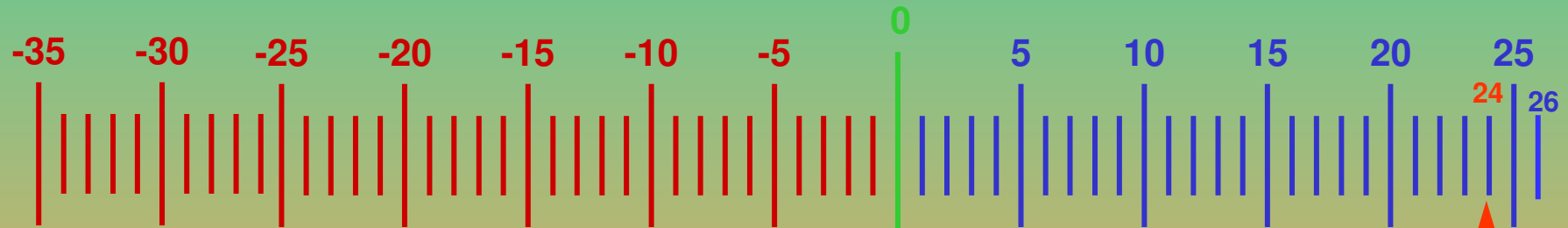
Aglomerado
de galáxias

Distribuição de galáxias até 10.000.000 a.l.



Yotta $f = 10^{24}$

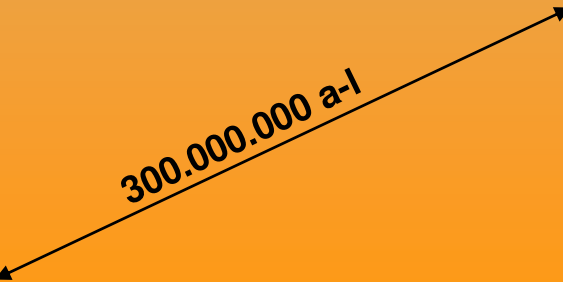
10^{24} m = 1.000.000.000.000.000.000.000.000 m



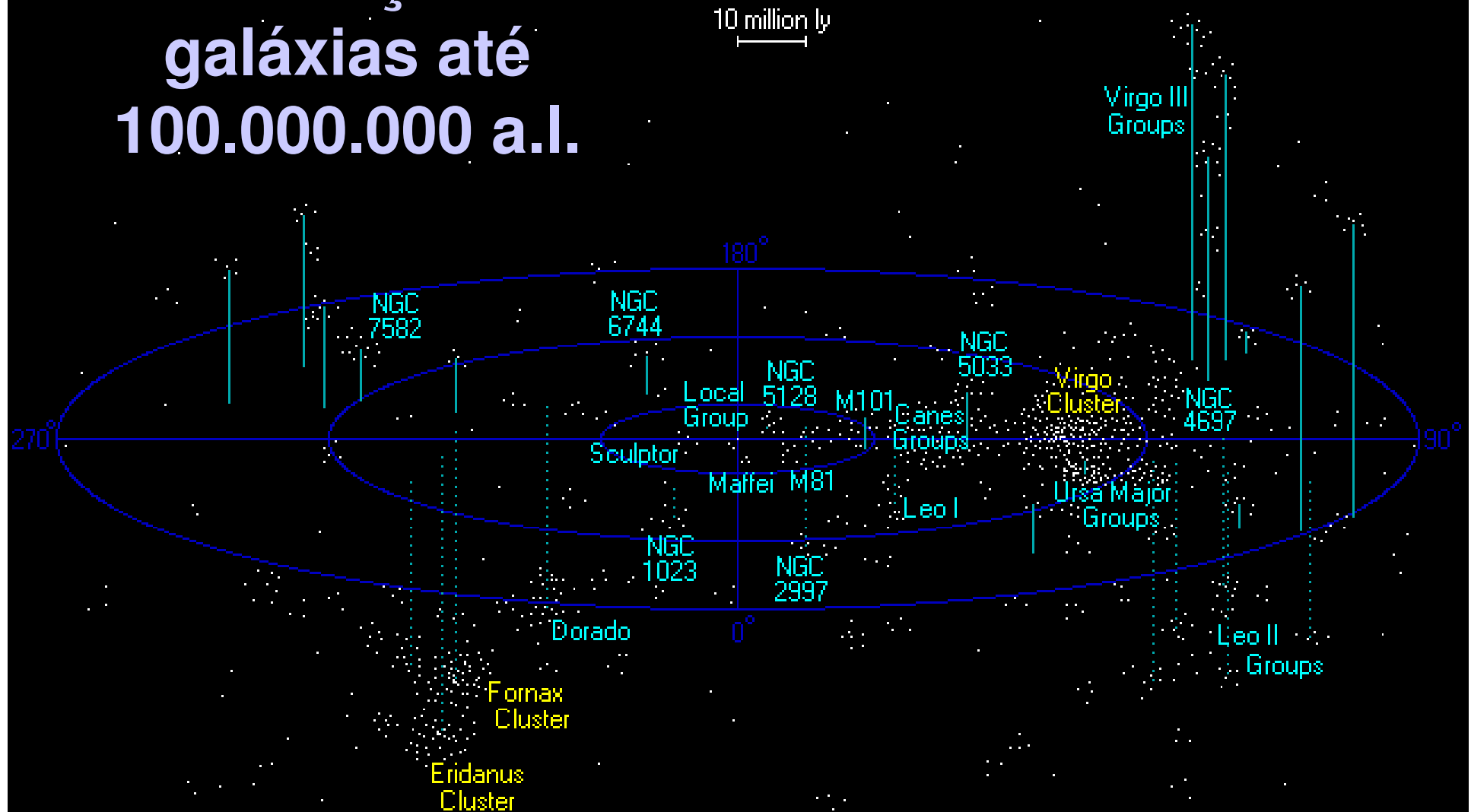
Super aglomerado em Cabeleira de Berenice



300.000.000 a-l

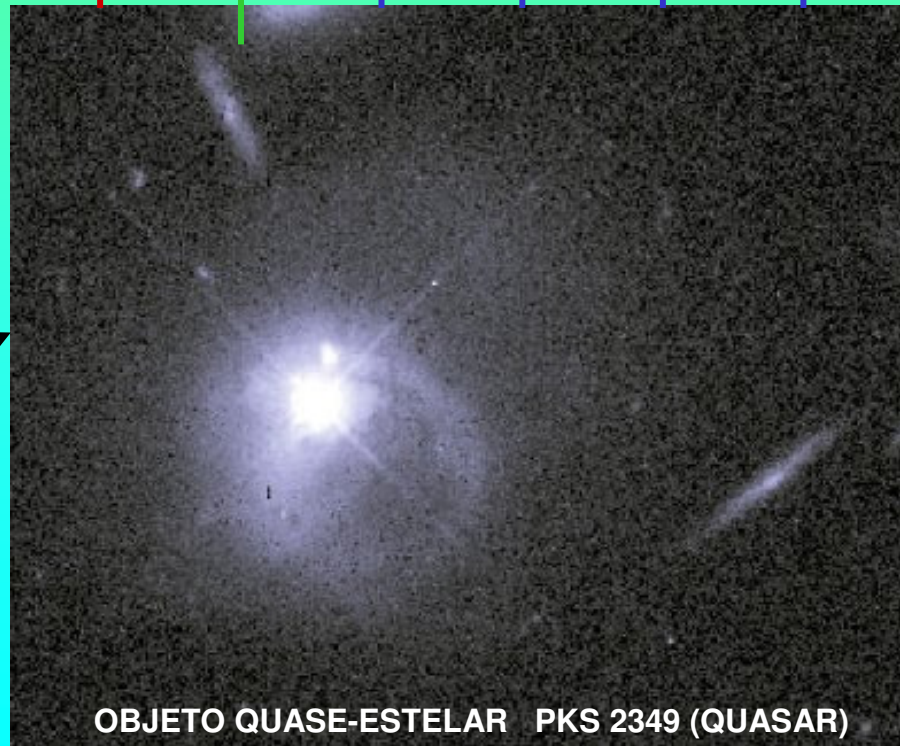
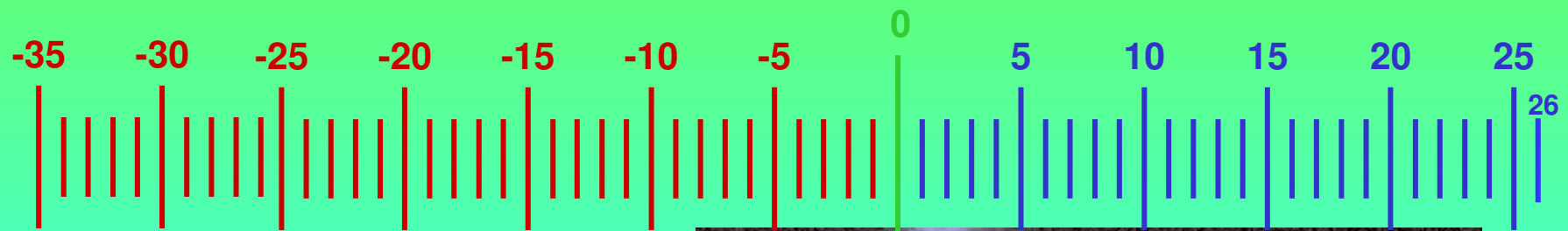


Distribuição de galáxias até 100.000.000 a.l.



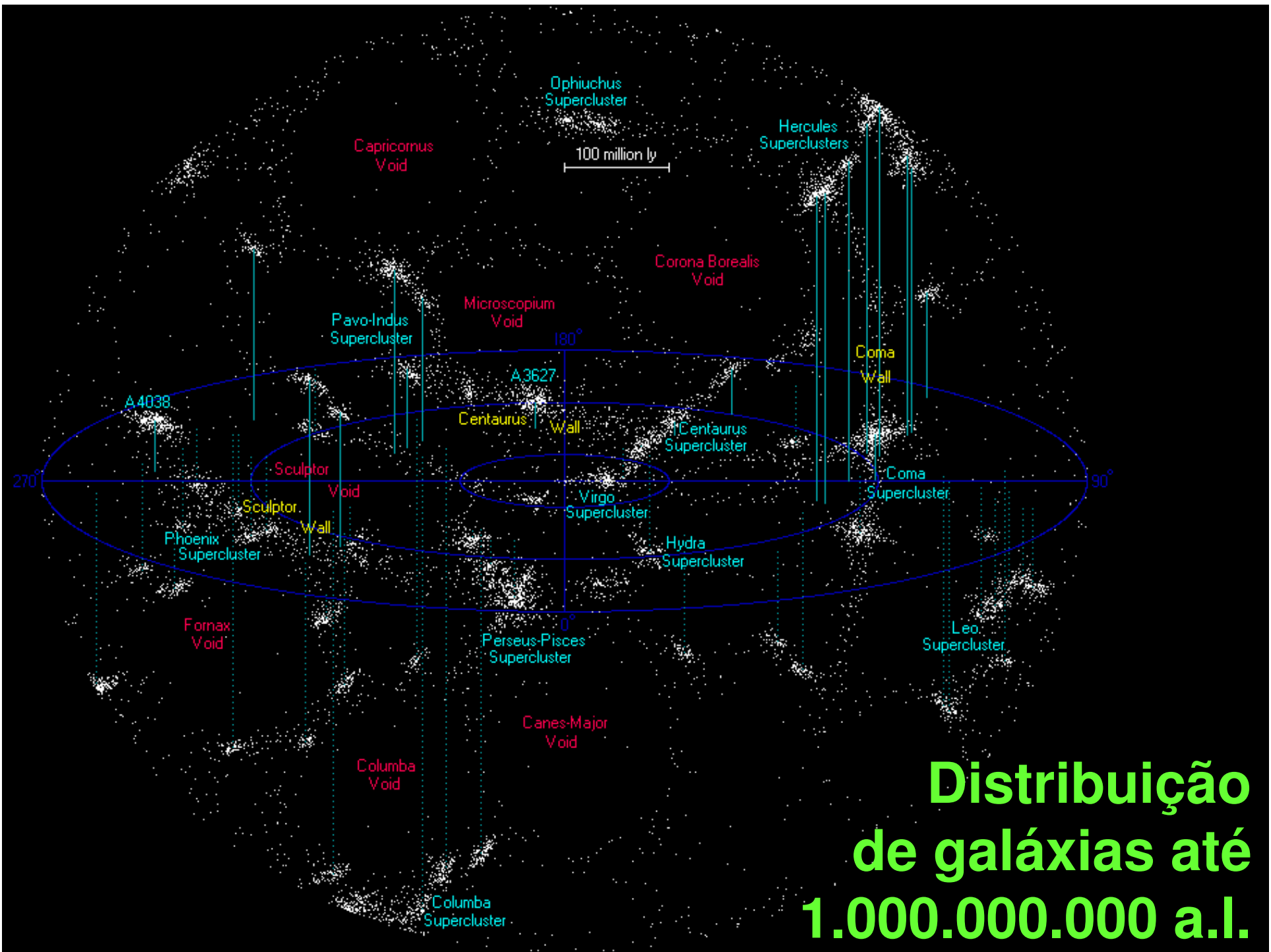
$$f = 10^{25}$$

10^{25} m = 10.000.000.000.000.000.000.000.000 m

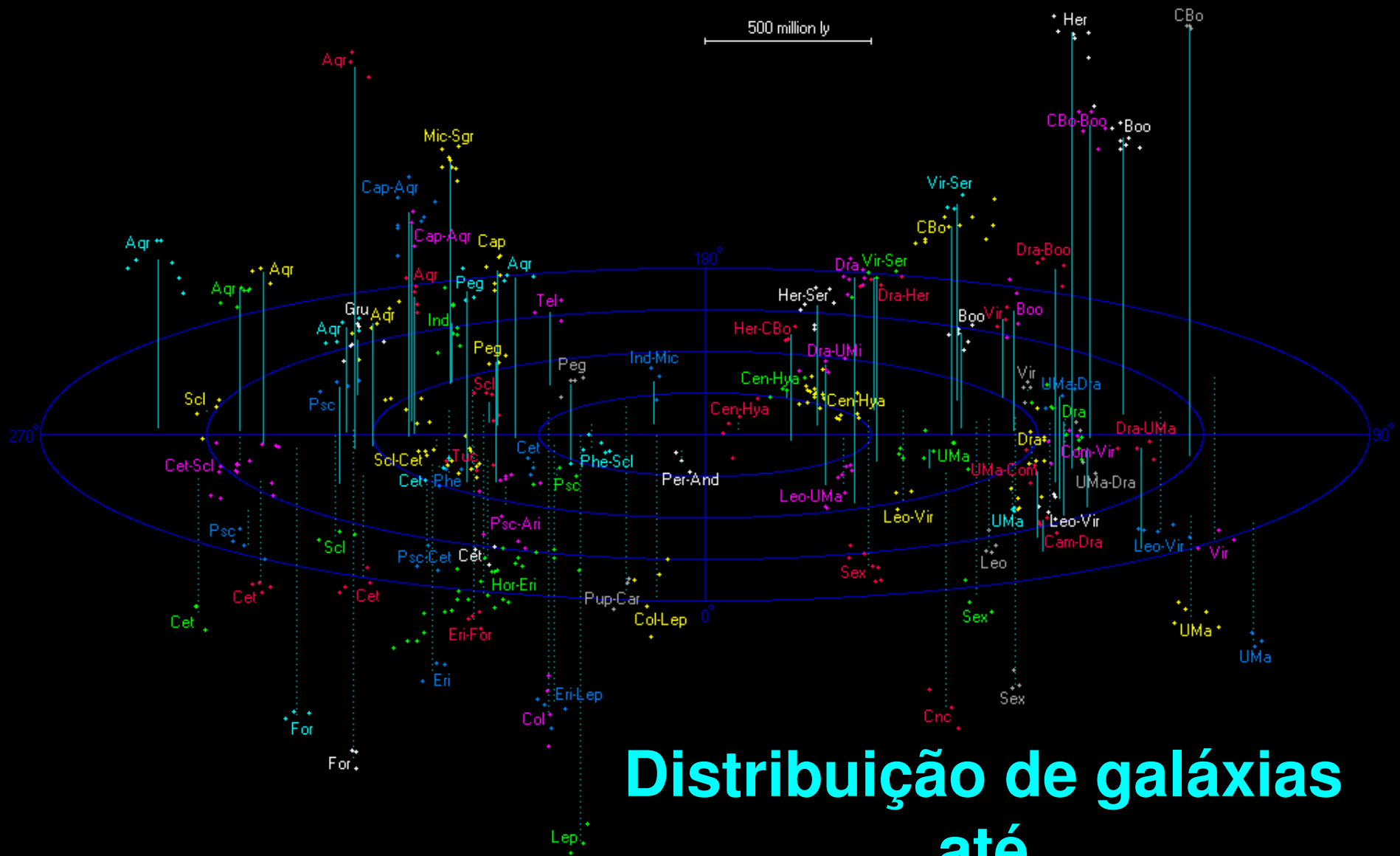


10.000.000.000 a-l

OBJETO QUASE-ESTELAR PKS 2349 (QUASAR)



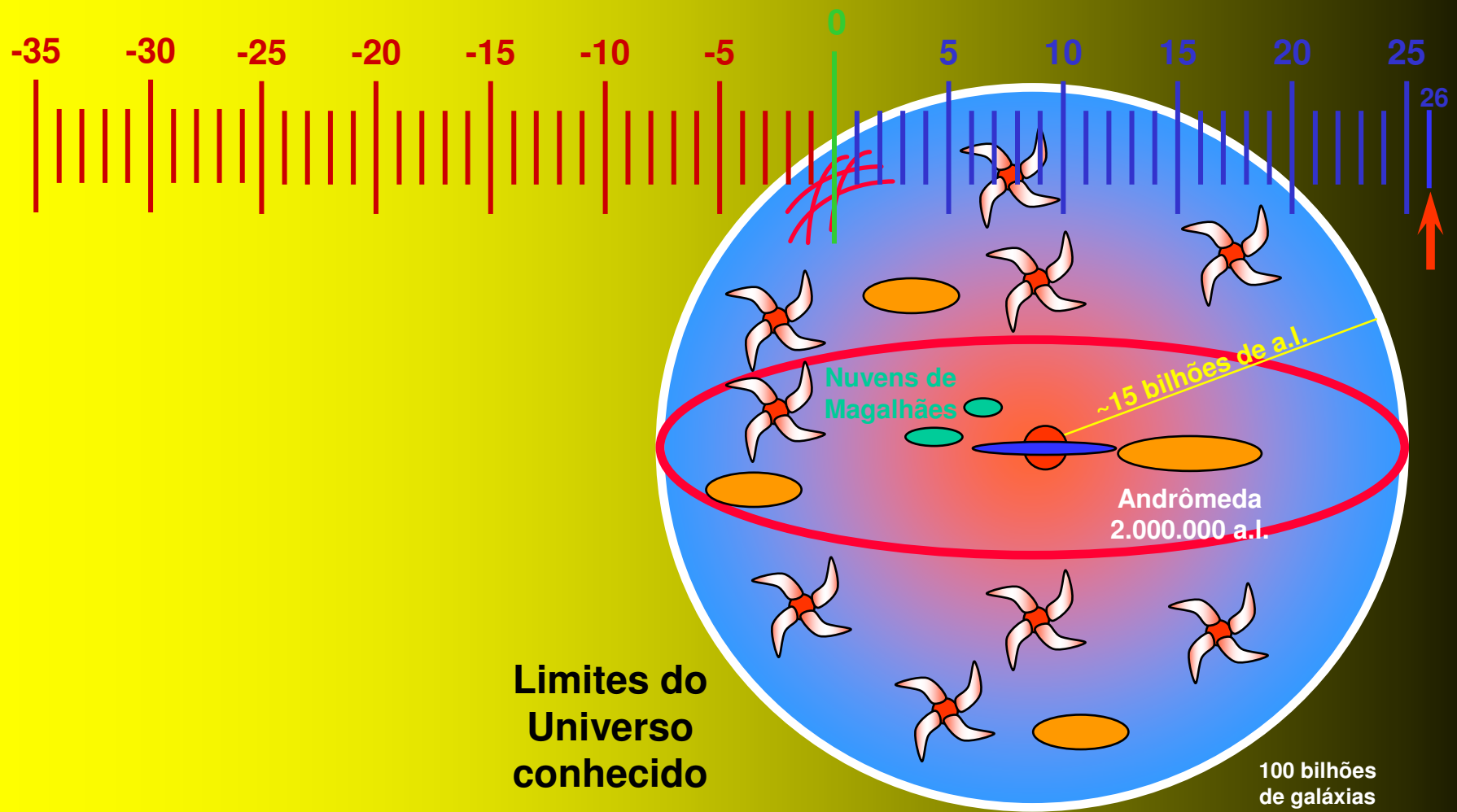
**Distribuição
de galáxias até
1.000.000.000 a.I.**



Distribuição de galáxias até 2.000.000.000 a.l.

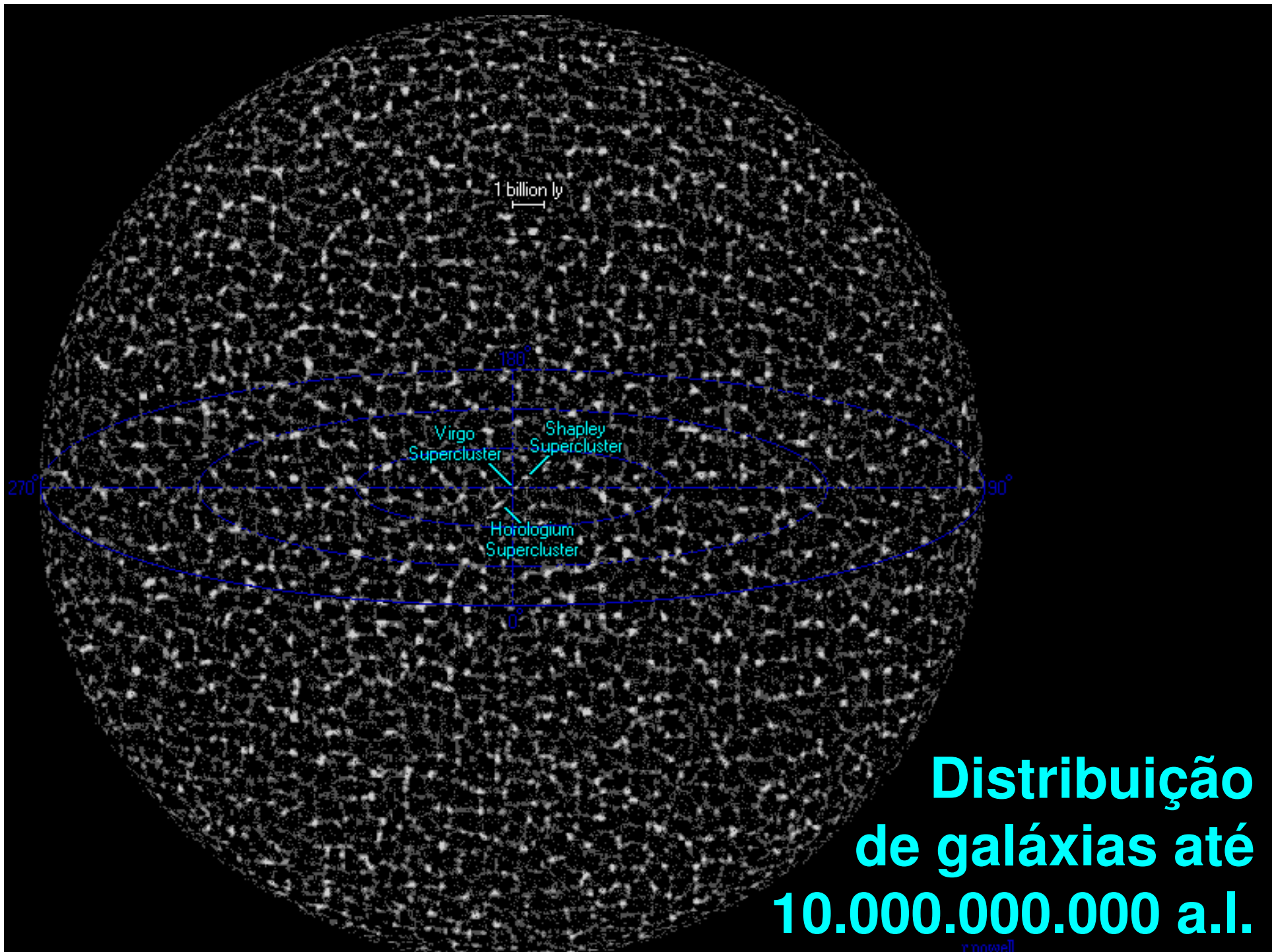
$$f = 10^{26}$$

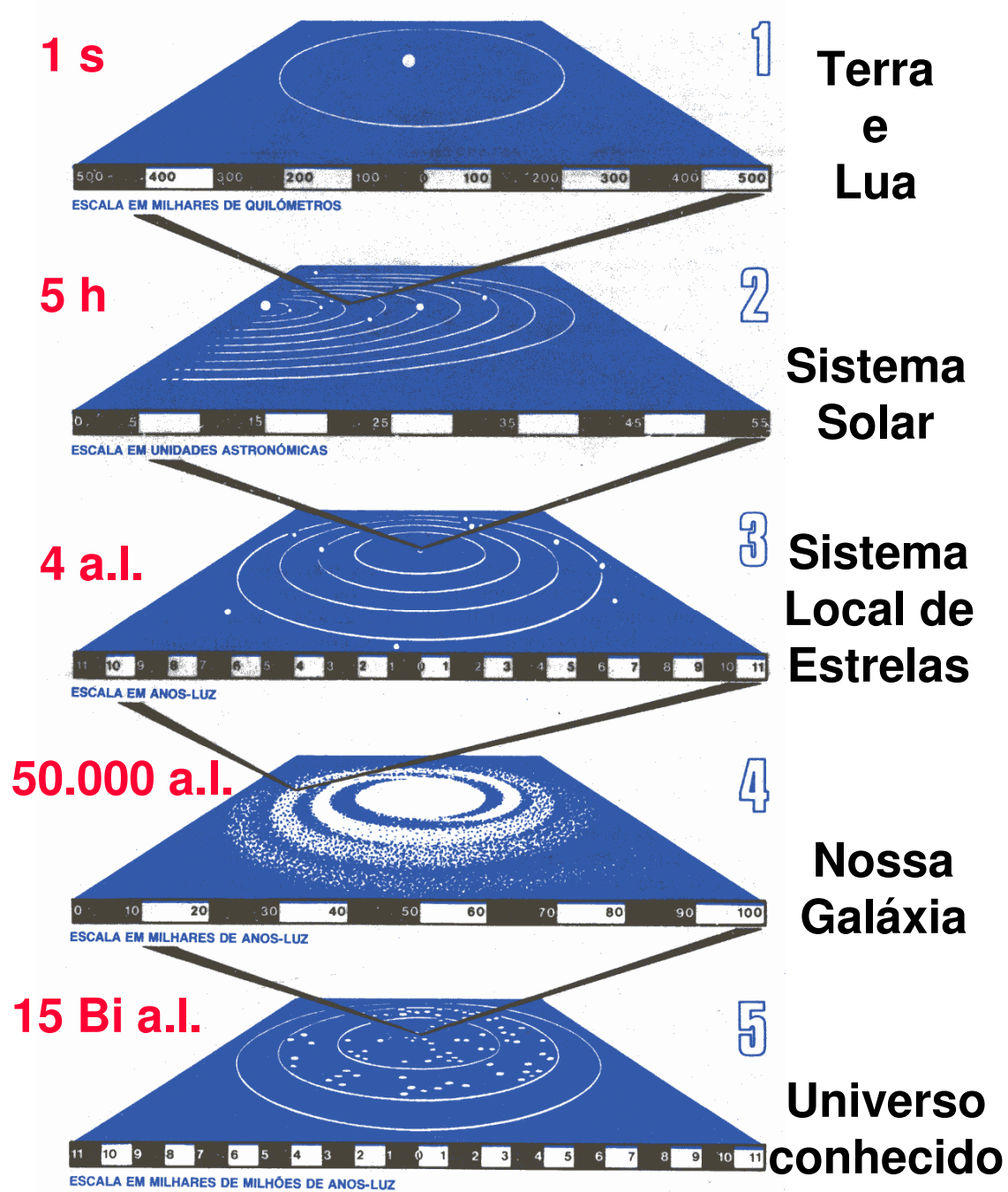
10^{26} m = 100.000.000.000.000.000.000.000.000 m



**Limites do
Universo
conhecido**

100 bilhões
de galáxias





Resumo das estruturas e das escalas no Universo

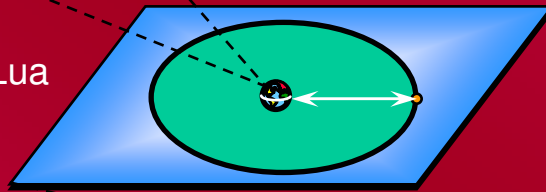
Ser humano



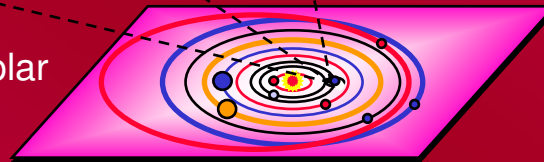
Terra



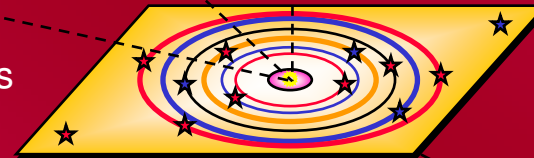
Terra & Lua



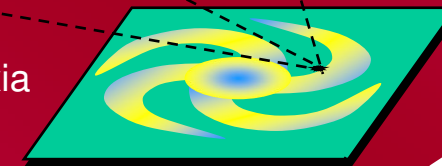
Sistema Solar



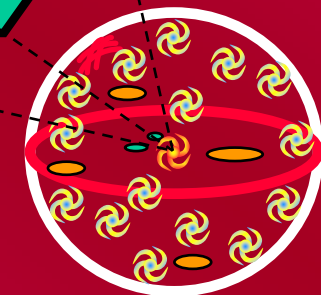
Sistema Local de Estrelas



Nossa Galáxia



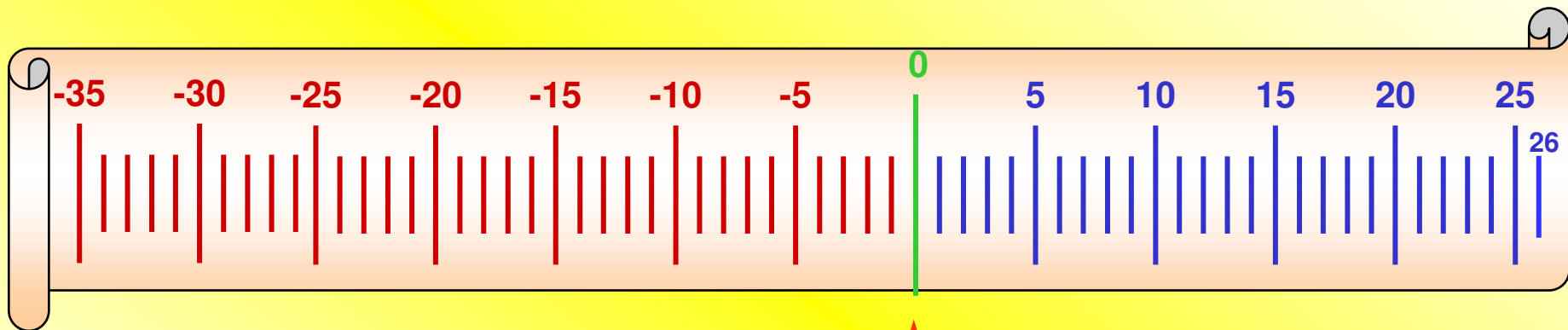
Universo

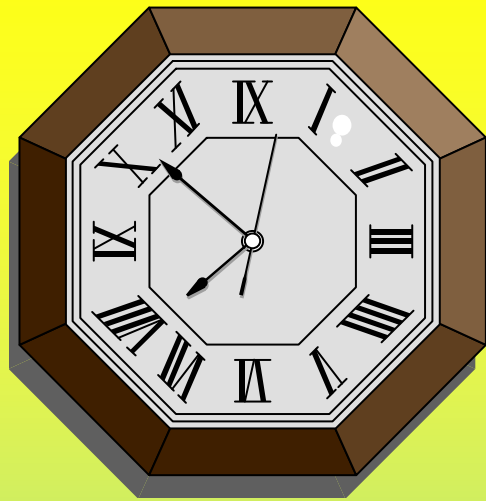


A Terra no Universo

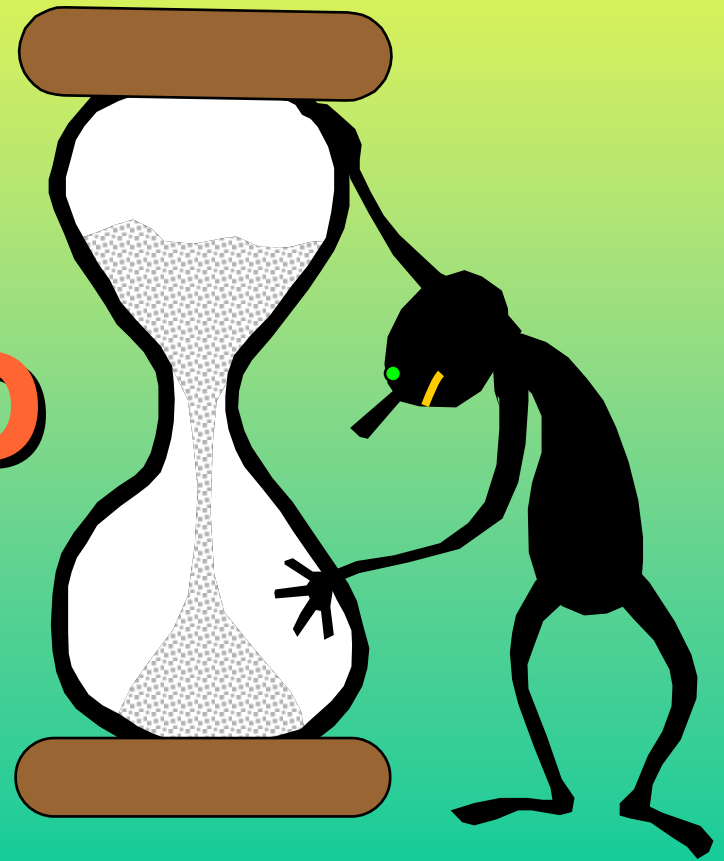
Voltemos à nossa escala!

$$10^0 \text{ m} = 1 \text{ m}$$

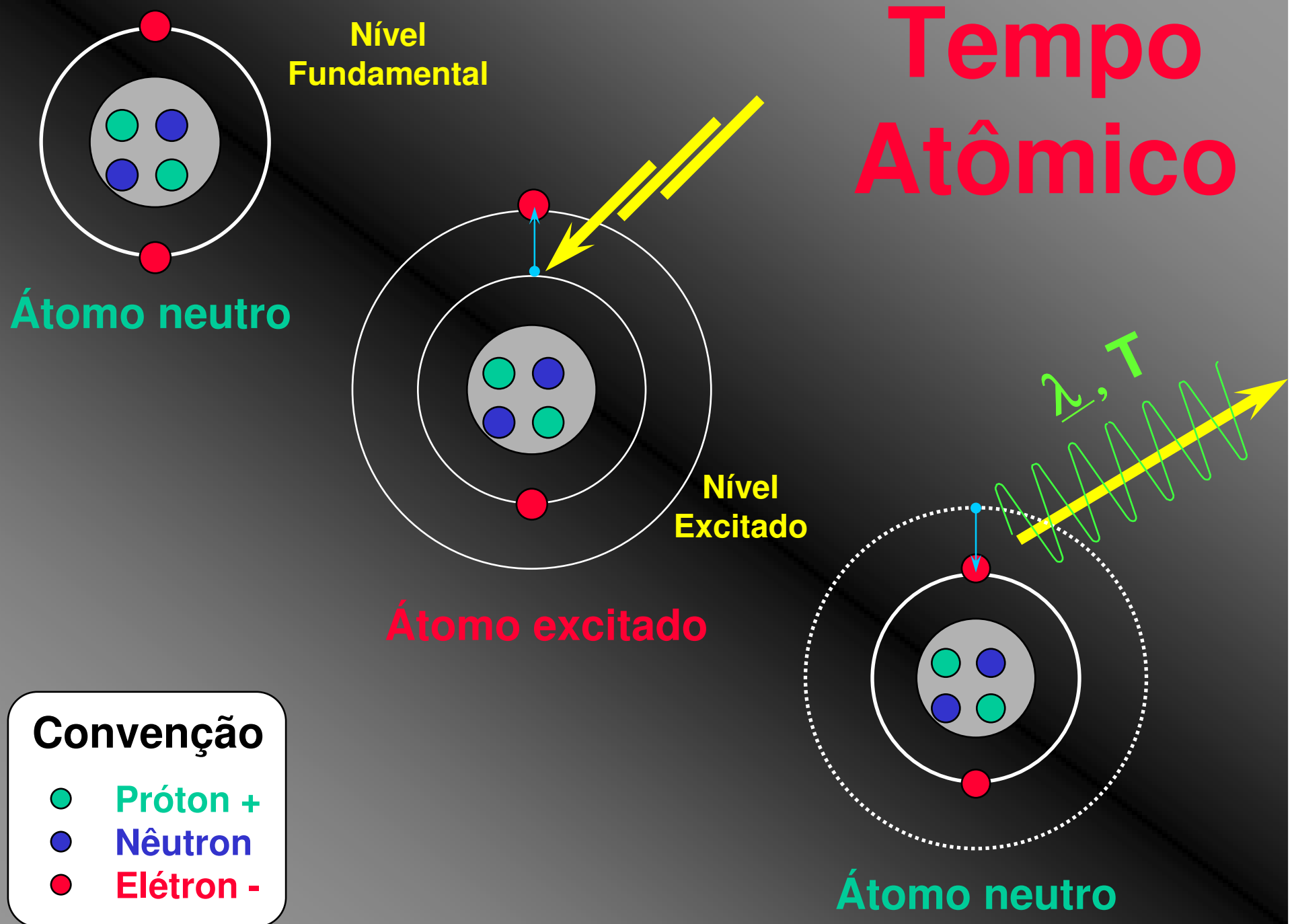




Escalas de Tempo



Tempo Atômico



Convenção

- Próton +
- Nêutron
- Elétron -

Segundo Internacional

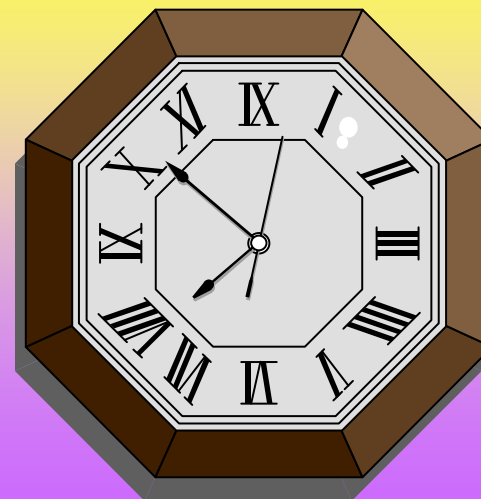
É o intervalo de tempo correspondente a

9.192.631.770

períodos da radiação emitida durante a
transição entre dois níveis hiperfinos do
estado fundamental do átomo de

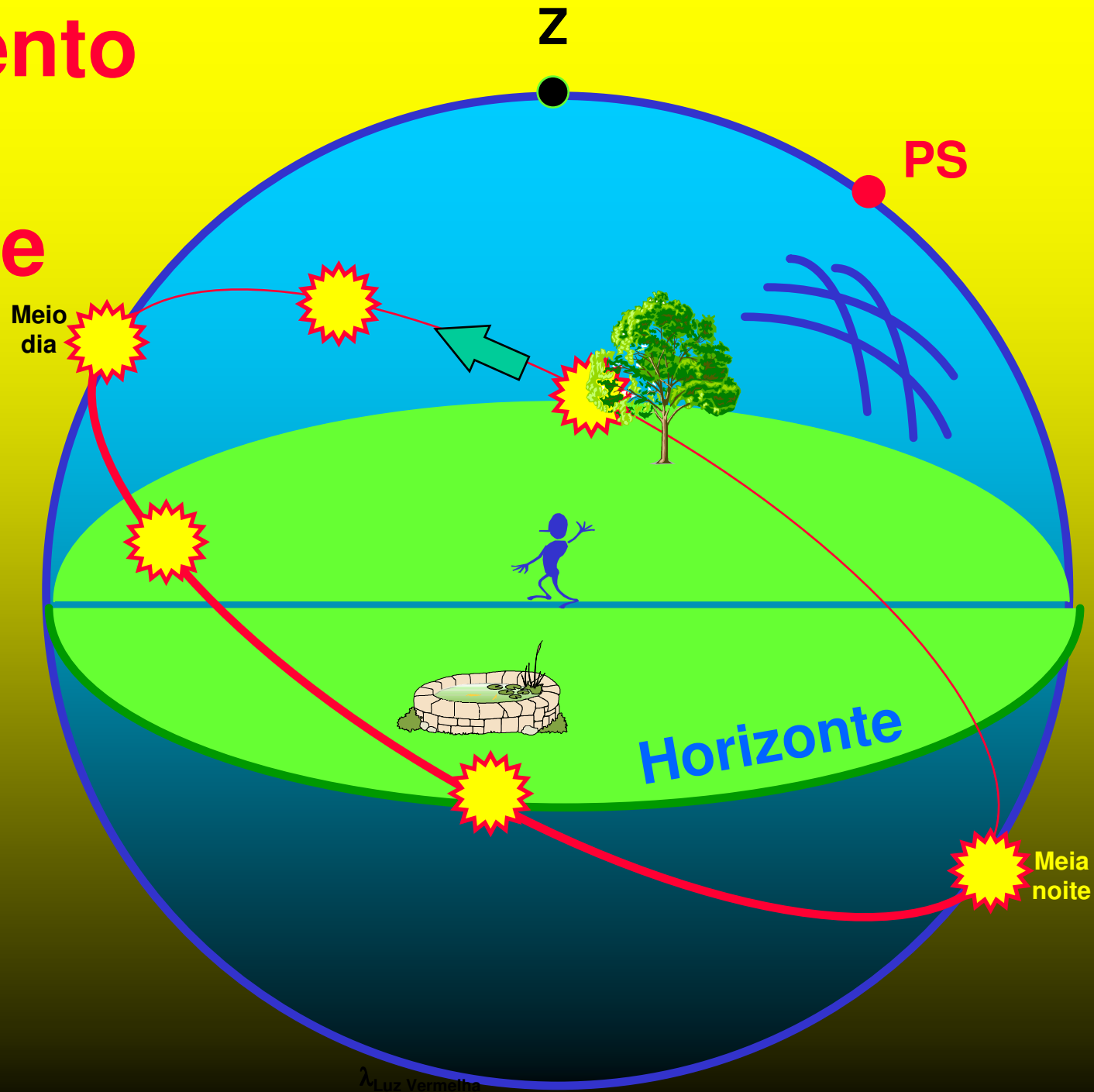
Césio 133

Escalas de Tempo

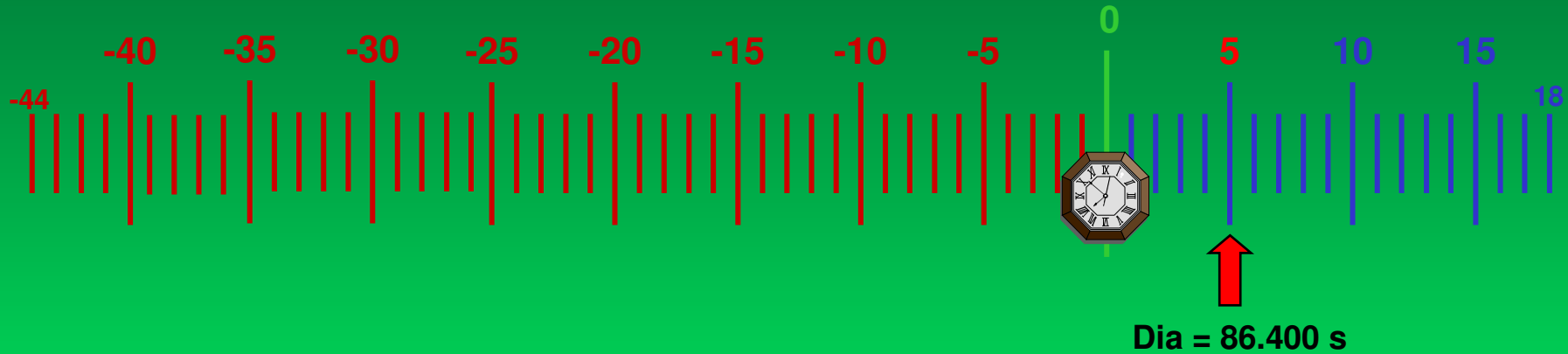


**Unidade primordial
de tempo:
Dia**

Movimento diurno aparente do Sol



Dia



Dia Civil

0.1.212.....24 h

Nascer

Meio
Dia

Ocaso

Meia
Noite

Nascer

Meio
Dia

Ocaso

Meia
Noite

Nascer

Dia Claro

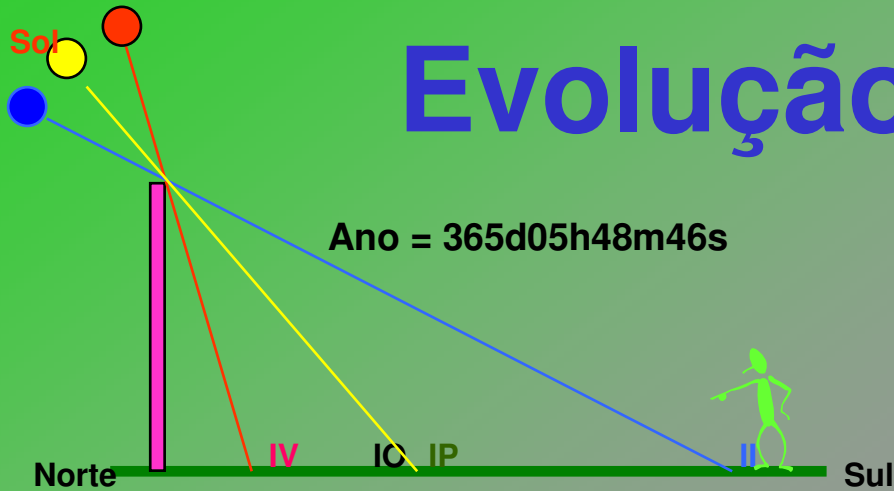
Noite

Dia Claro

Noite

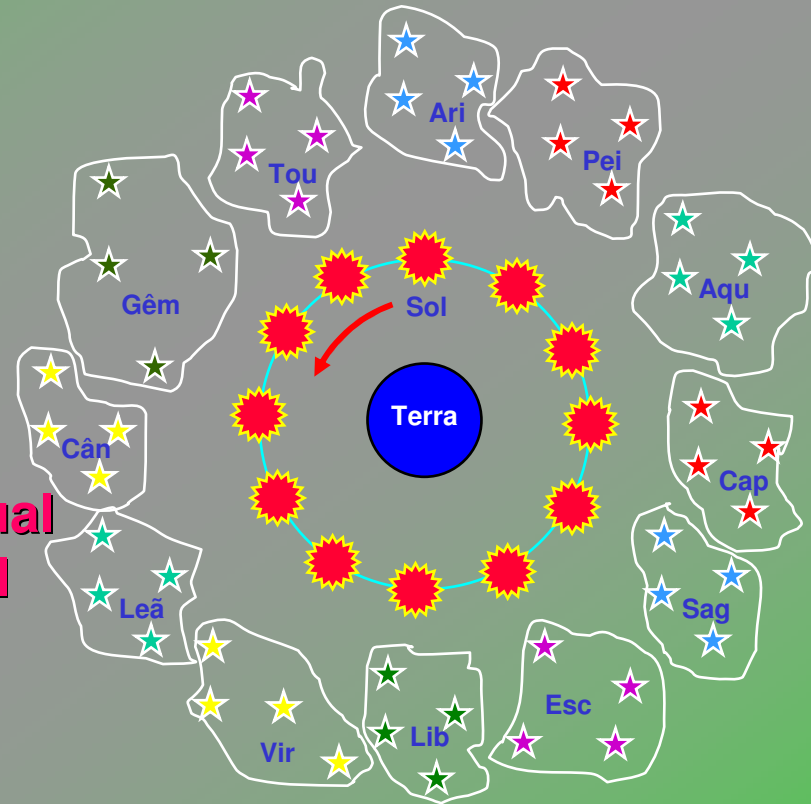
ANO

Evolução da idéia de Ano

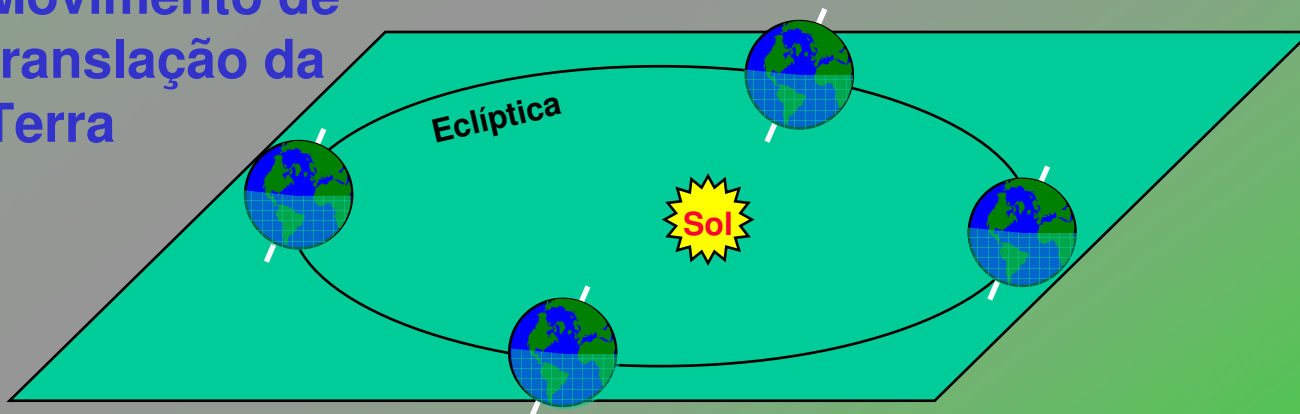


Ano das Estações

Movimento Anual aparente do Sol



Movimento de translação da Terra



Ano

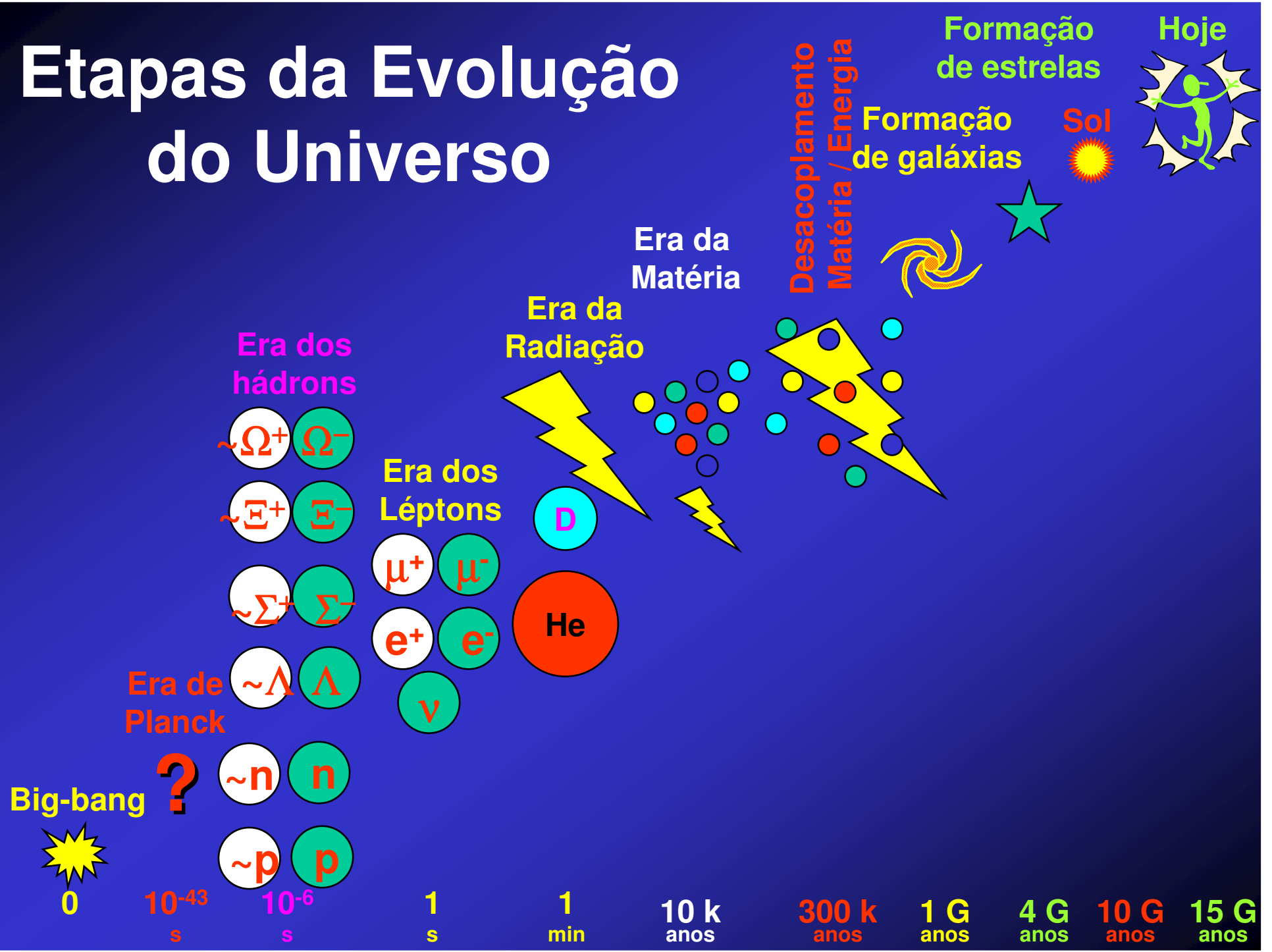


Ano \approx 31.557.600 s



Evolução do Universo

Etapas da Evolução do Universo



Ordens de grandeza no Universo

Size or Distance	(m)	Mass	(kg)	Time Interval	(s)
Proton	10^{-15}	Electron	10^{-30}	Time for light to cross nucleus	10^{-23}
Atom	10^{-10}	Proton	10^{-27}	Period of visible light radiation	10^{-15}
Virus	10^{-7}	Amino acid	10^{-25}	Period of microwaves	10^{-10}
Giant amoeba	10^{-4}	Hemoglobin	10^{-22}	Half-life of muon	10^{-6}
Walnut	10^{-2}	Flu virus	10^{-19}	Period of highest audible sound	10^{-4}
Human being	10^0	Giant amoeba	10^{-8}	Period of human heartbeat	10^0
Highest mountain	10^4	Raindrop	10^{-6}	Half-life of free neutron	10^3
Earth	10^7	Ant	10^{-4}	Period of Earth's rotation	10^3
Sun	10^9	Human being	10^2	Period of Earth's revolution around the Sun	10^7
Distance from Earth to the Sun	10^{11}	Saturn V rocket	10^6	Lifetime of human being	10^9
Solar system	10^{13}	Pyramid	10^{10}	Half-life of plutonium-239	10^{12}
Distance to nearest star	10^{16}	Earth	10^{24}	Lifetime of mountain range	10^{15}
Milky Way galaxy	10^{21}	Sun	10^{30}	Age of Earth	10^{17}
Visible universe	10^{26}	Milky Way galaxy	10^{41}	Age of universe	10^{18}
		Universe	10^{52}		

Bibliografia:

Cosmic view: the Universe in forty jumps
(Kees Bieke, 1957)

Powers of ten
(Charles Eames & Ray Eames & Philip Morrison & Phylis Morrison, 1985)
(Filme e livro)



Film