

07
06
03

Evolução Estelar

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Nascimento,

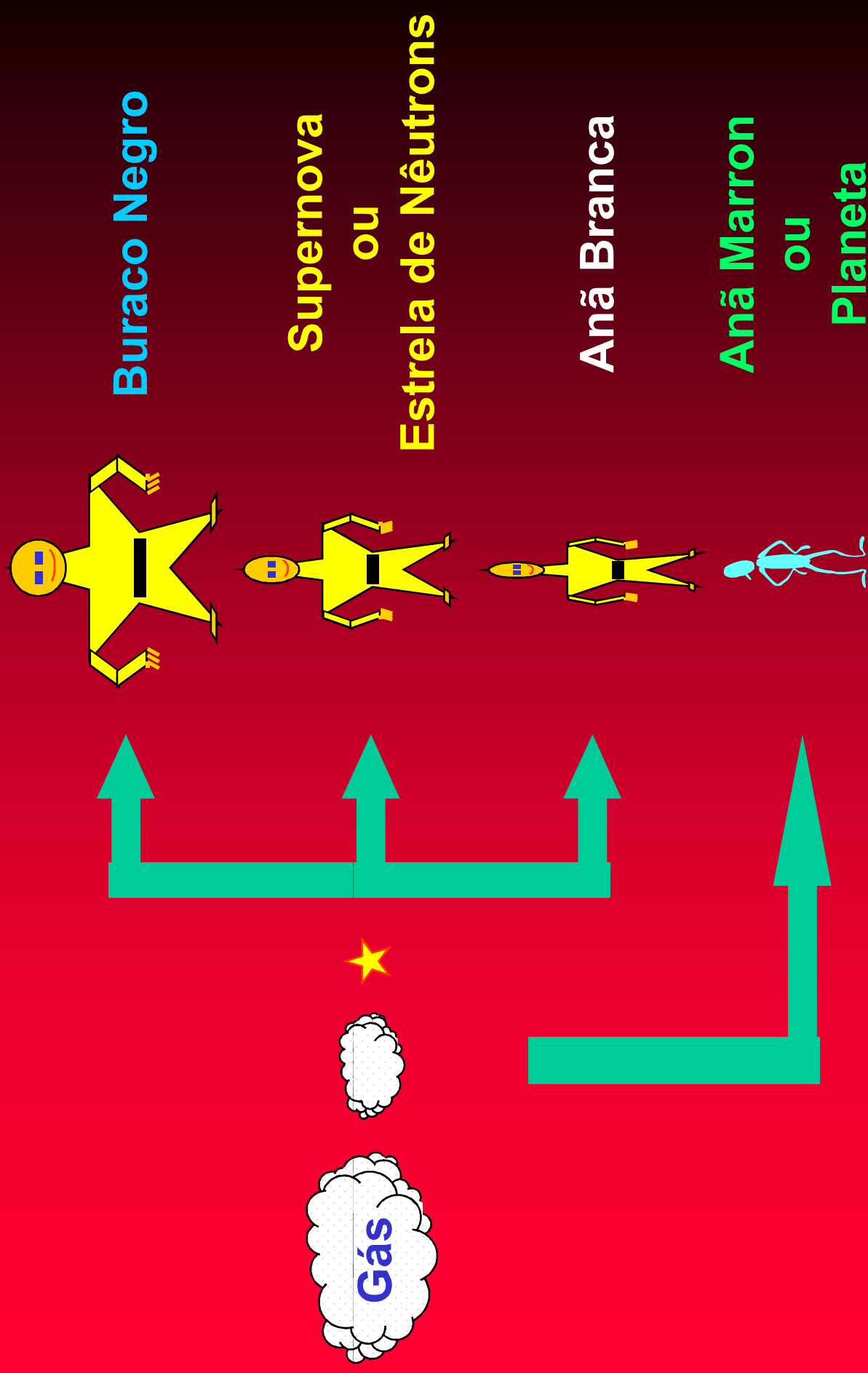
Vida e

Morte de

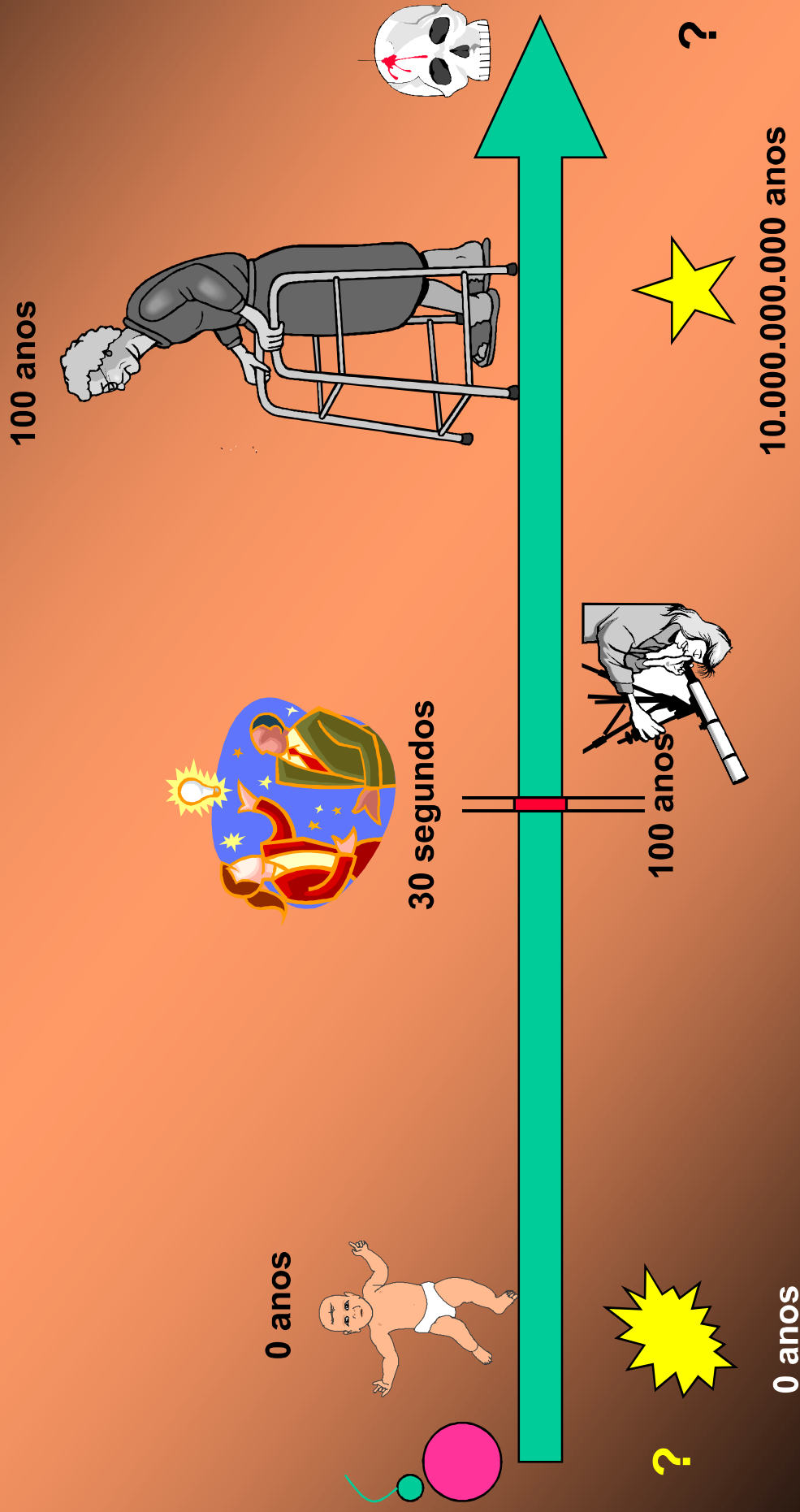
Estrelas



Nascimento, vida e morte de estrelas

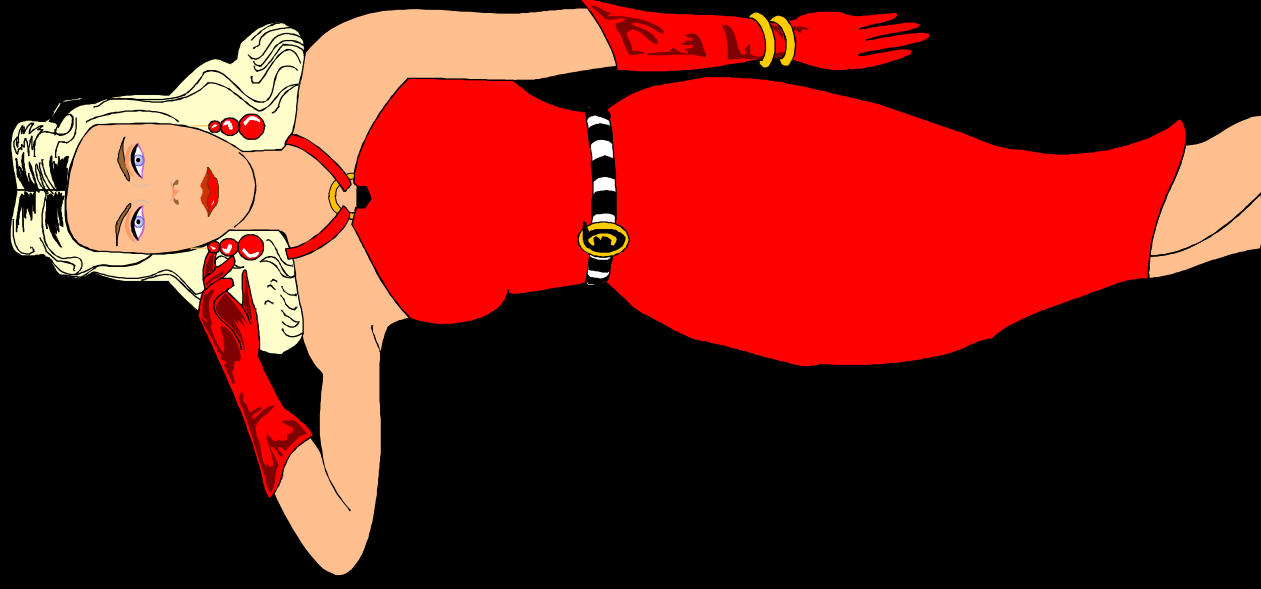


História baseada em modelos físico-matemáticos



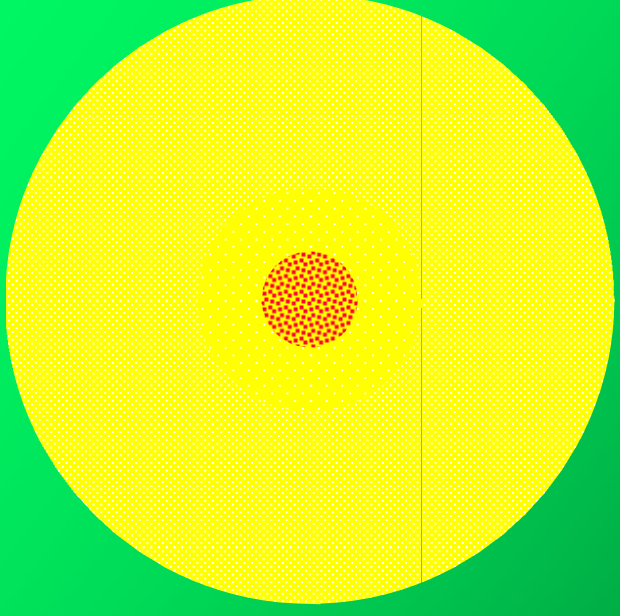
O que é uma
estrela?

É um sistema no
interior do qual
ocorrem reações
maravilhosas.





**o que é uma
estrela?**

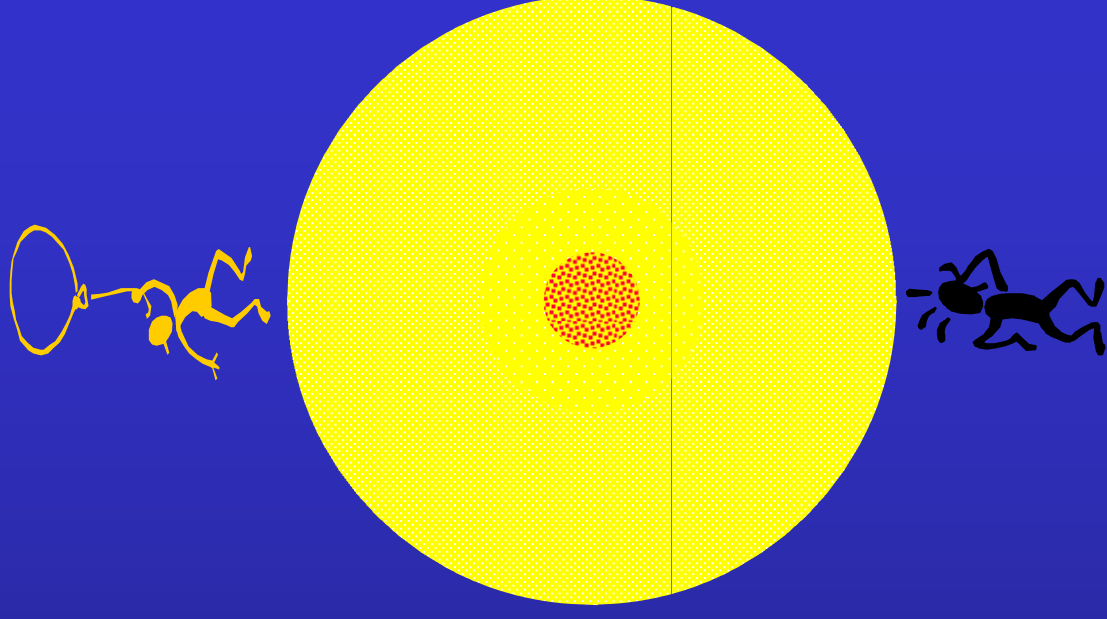


**É um sistema no
interior do qual
ocorrem reações
maravilhosas.**

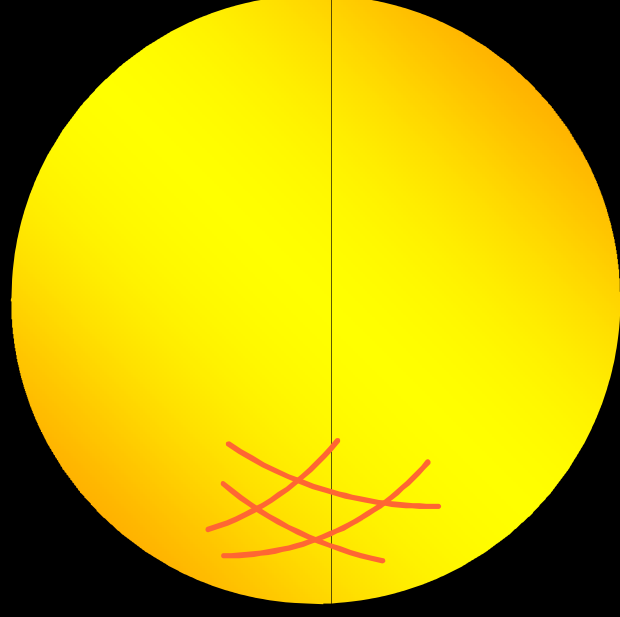
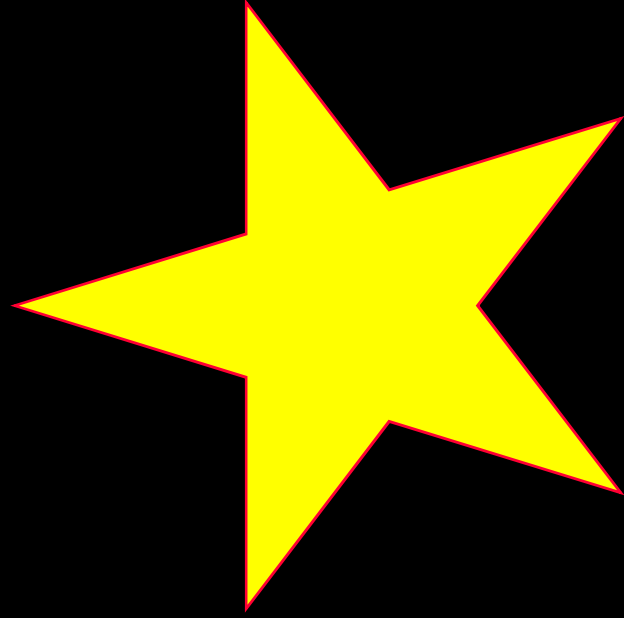
O que é uma estrela?

Agora é sério!

É um corpo **gasoso** no interior do qual ocorrem reações de **fusão nuclear** formando elementos mais pesados.



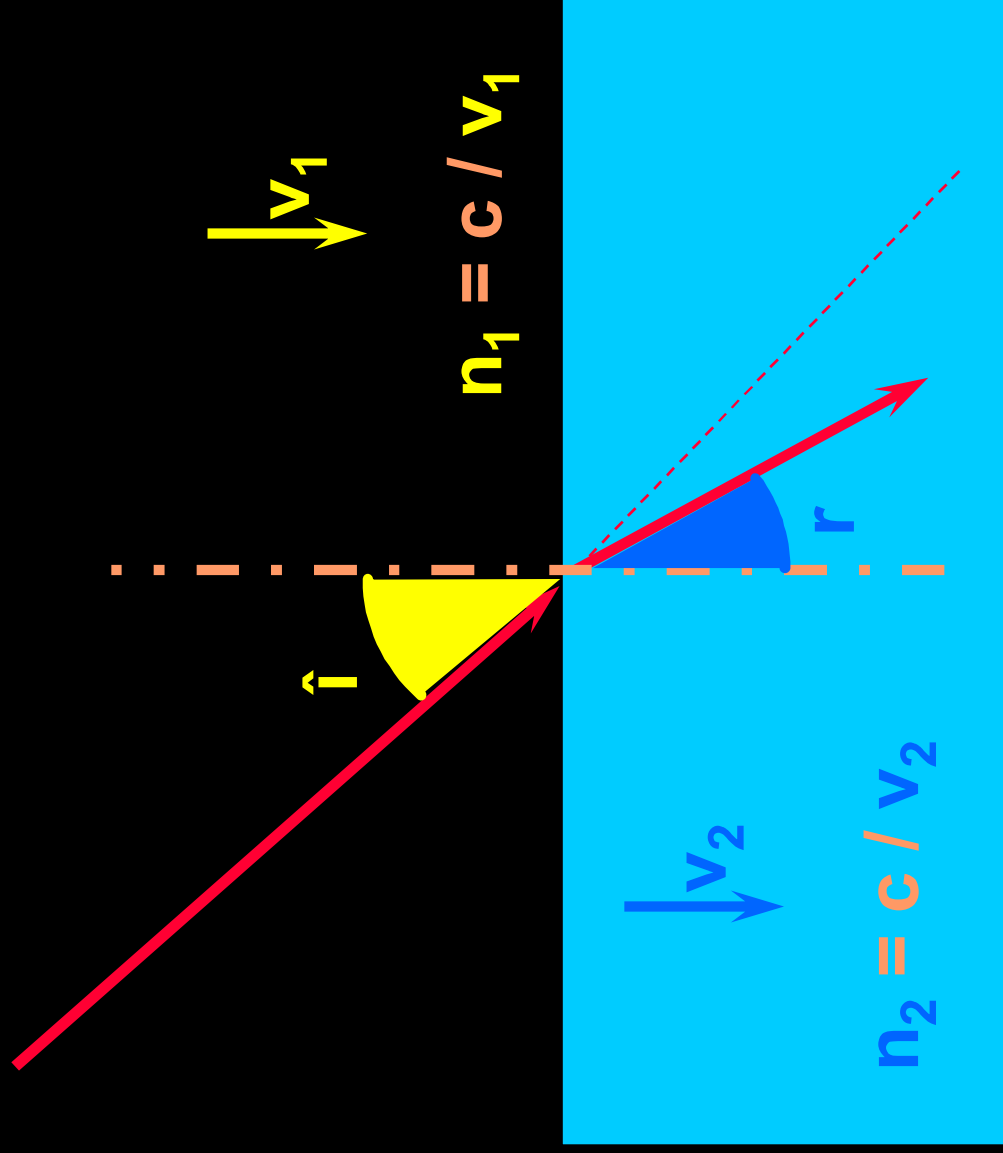
Pontas das Estrelas !?



Afinal :

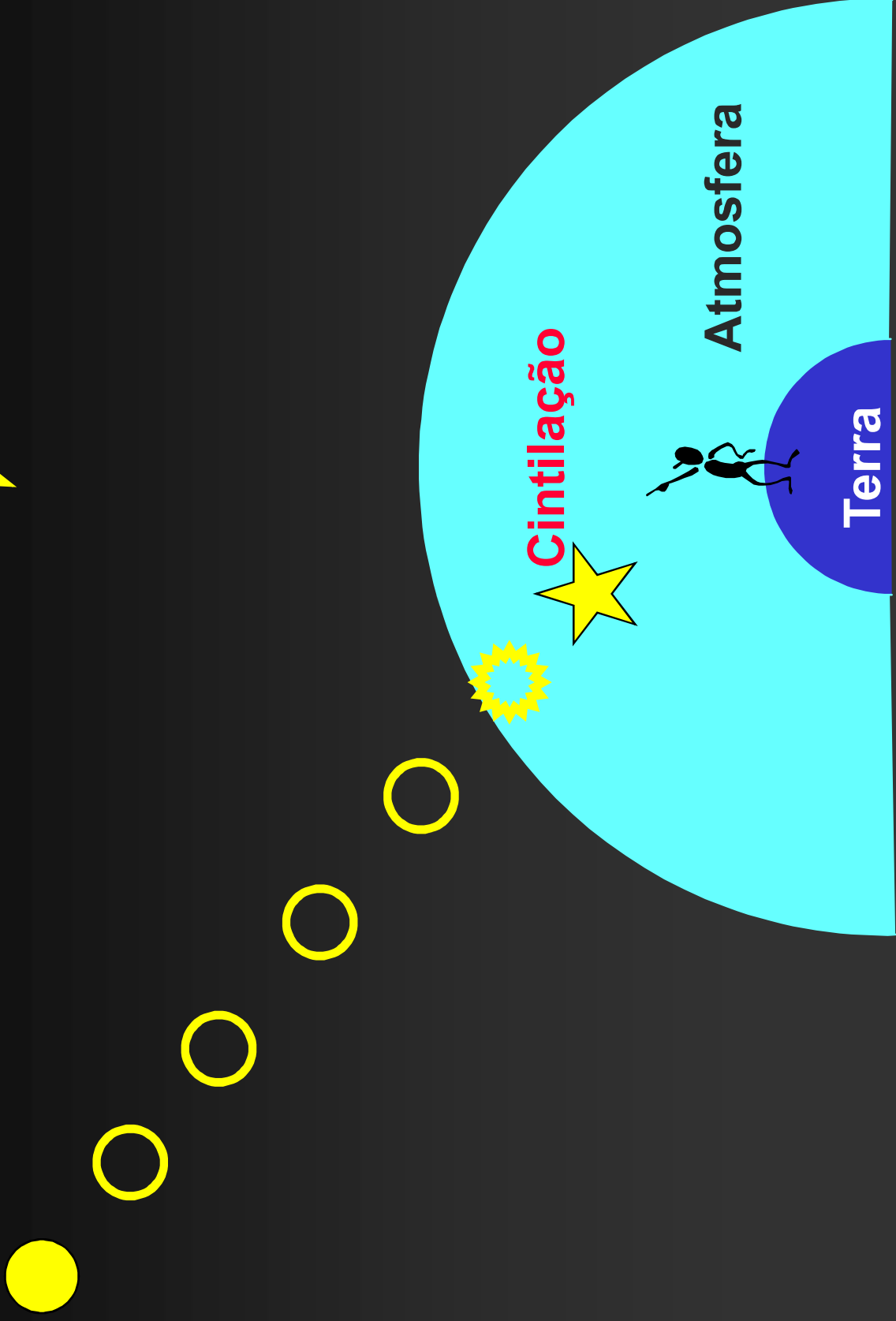
As estrelas têm ou não têm PONTAS ?

Refração da Luz



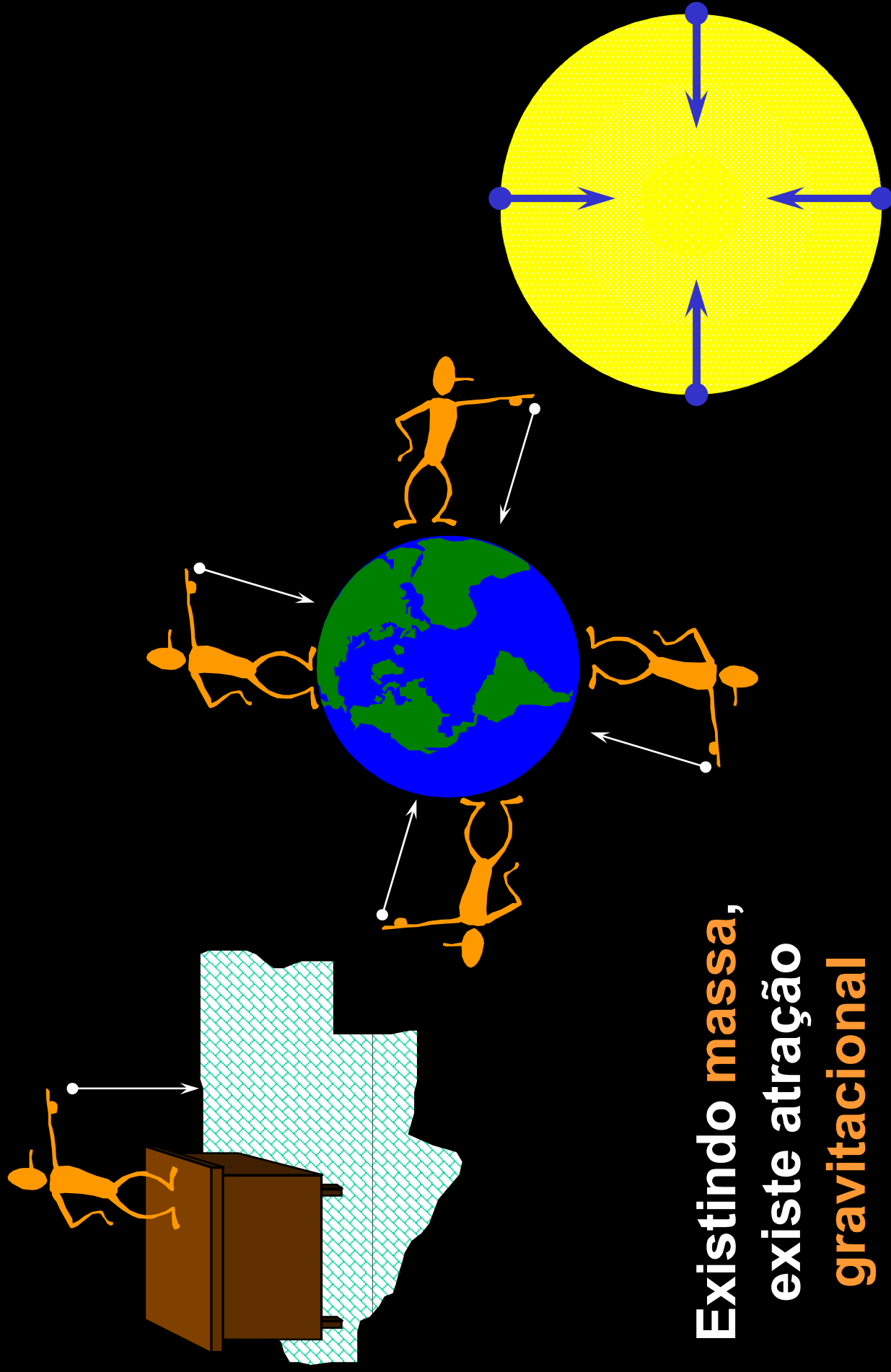
$$n_1 \text{ sen } v_1 = n_2 \text{ sen } v_2$$

“Pontas” das estrelas



**Como se formam as
estrelas?**

Pressão gravitacional



Existindo massa,
existe atração
gravitacional

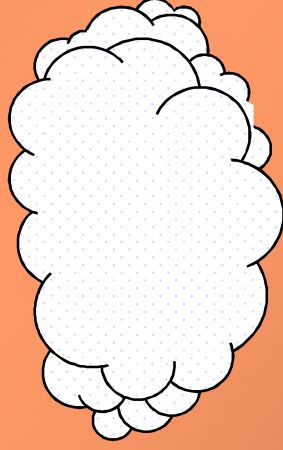
Contração gravitacional de uma nebulosa



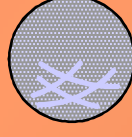
Lei da atração
gravitacional



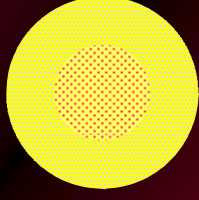
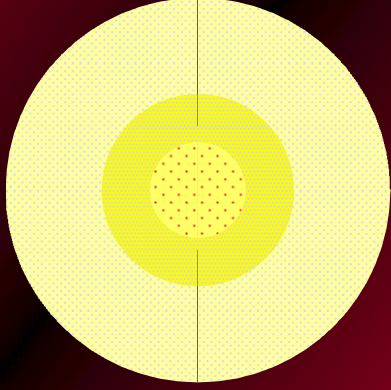
$$F = G m m' / d^2$$



A forma geométrica
de menor energia é a
esfera.



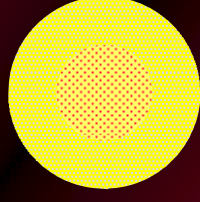
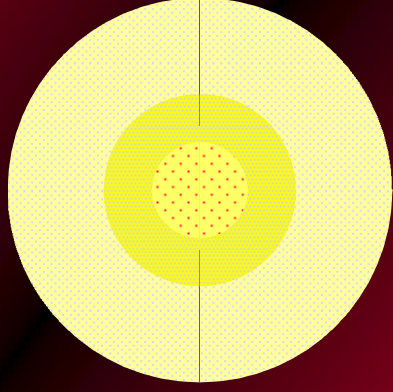
Nascimento de uma estrela



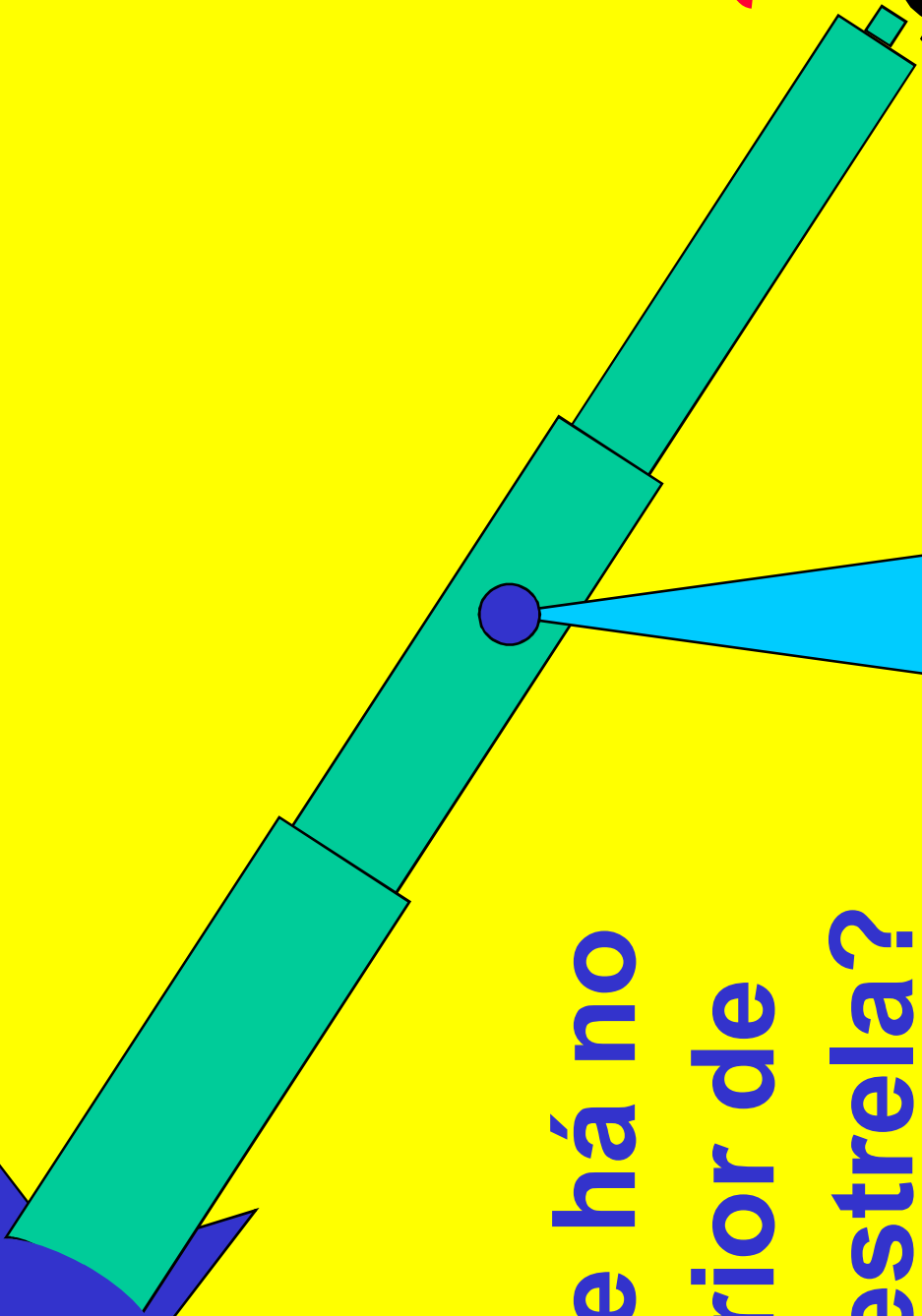
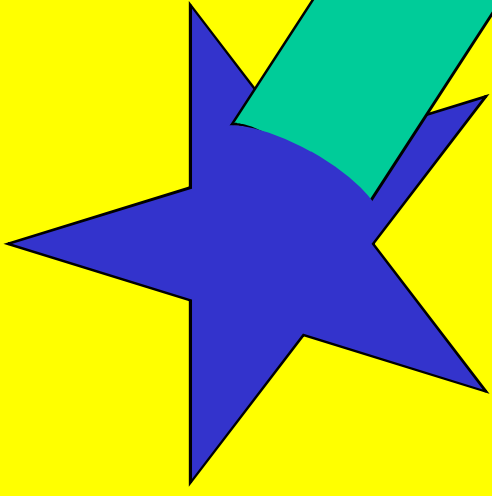
Início das reações de Fusão Nuclear

Nasceu a estrela

Gestação de uma estrela

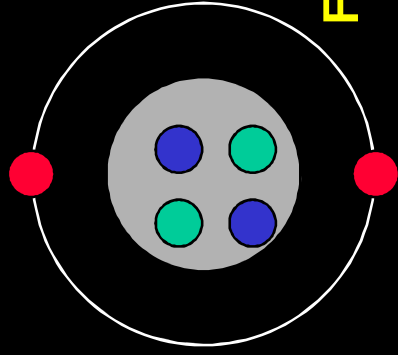


?



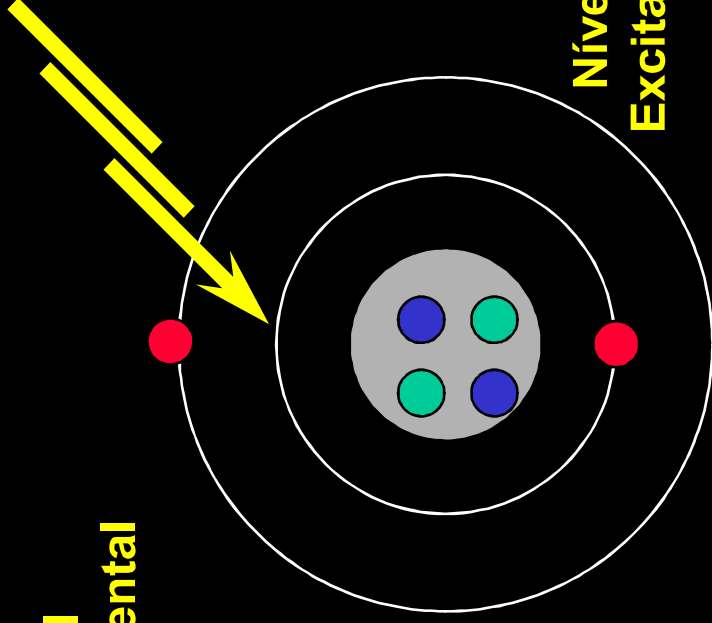
O que há no interior de uma estrela?

Átomos e Íons



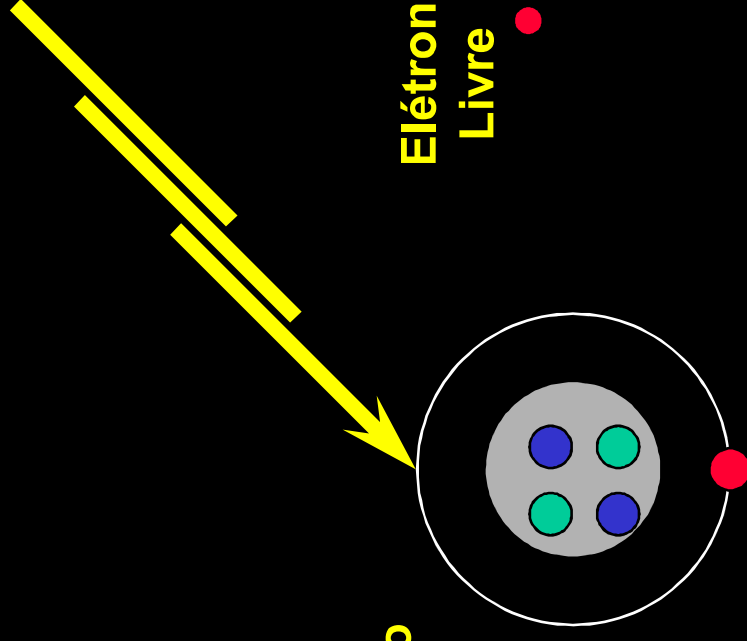
Nível
Fundamental

Átomo neutro
 $N_p = N_e$



Nível
Excitado

Átomo excitado
 $N_p = N_e$



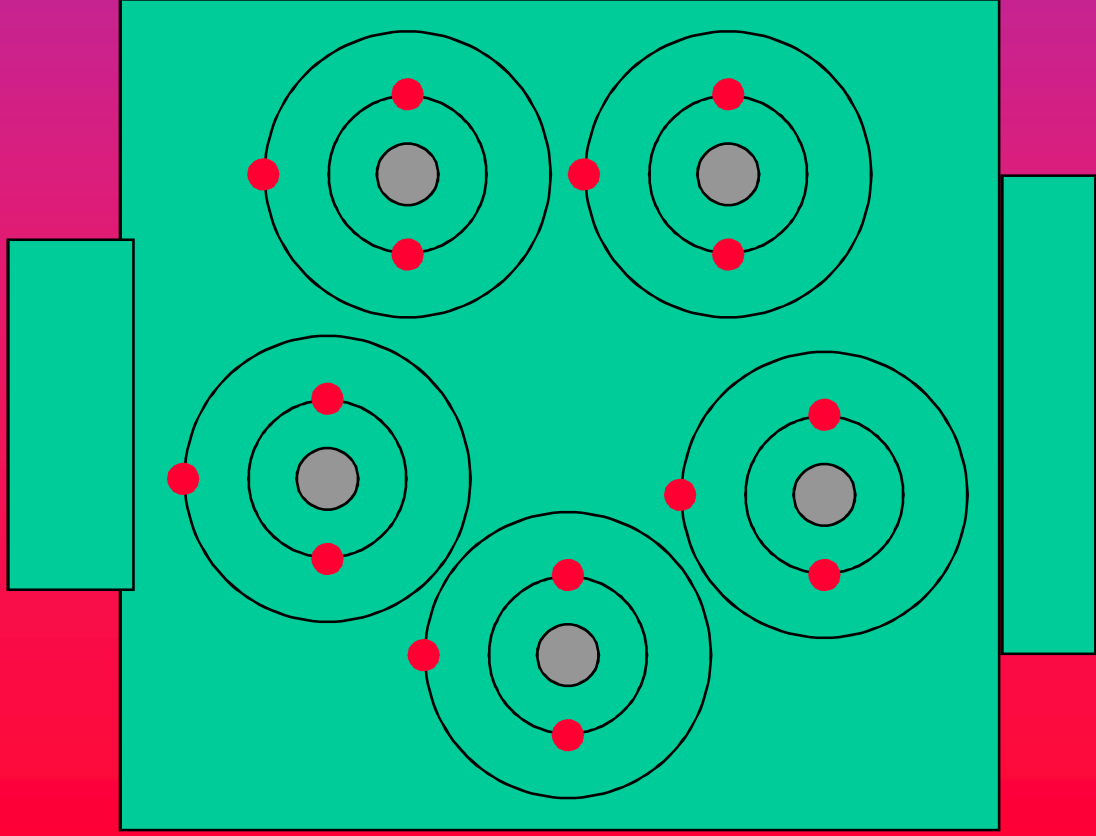
Elétron
Livre

Íon = Átomo ionizado
 $N_p \neq N_e$

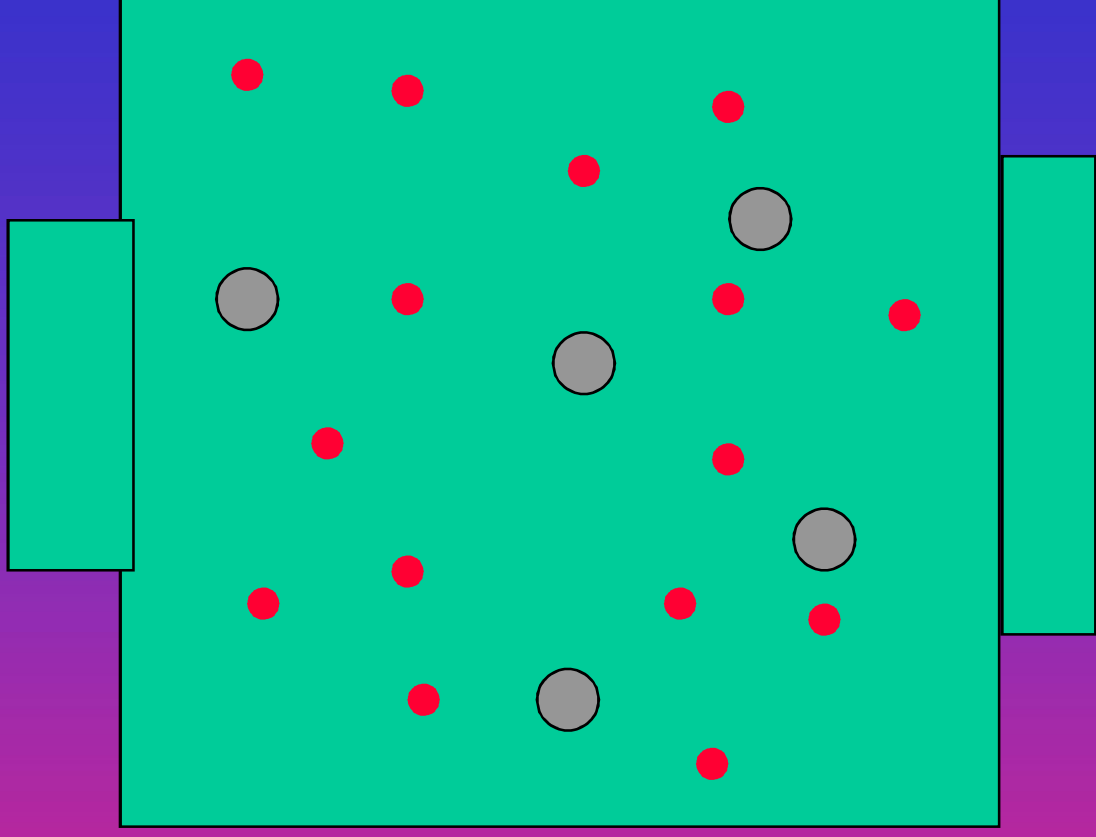
Convenção

- **Próton +**
- **Nêutron -**
- **Elétron -**

Gás e Plasma



Gás

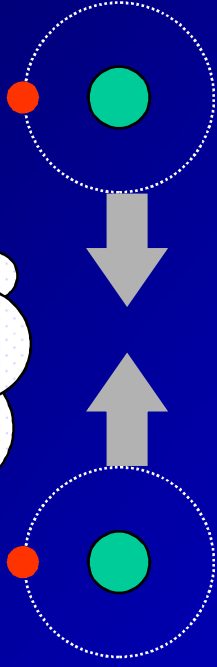


Plasma

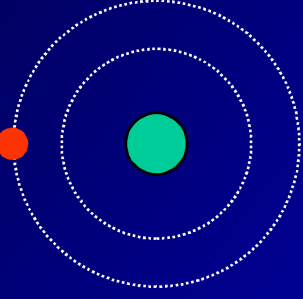
**De proto-estrela
à estrela**

Aquecimento da proto-estrela

Gás Hidrogênio



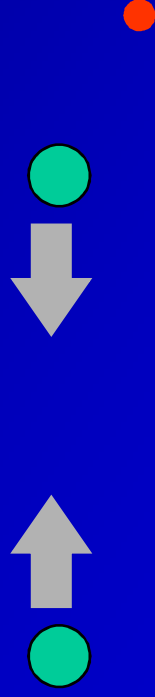
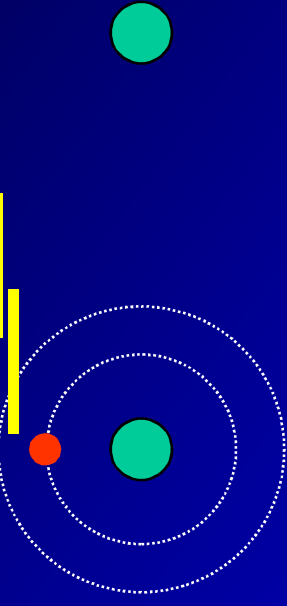
Excitação



Ionização



Desexcitação

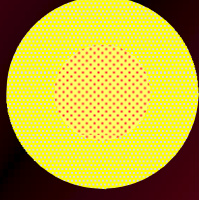
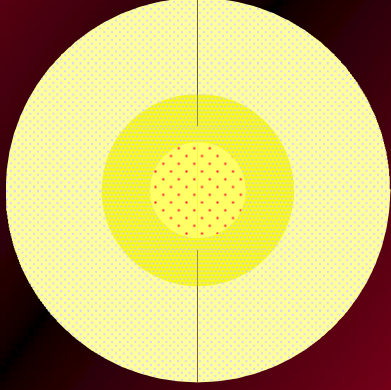


Fusão nuclear

Energia

Elemento mais pesado

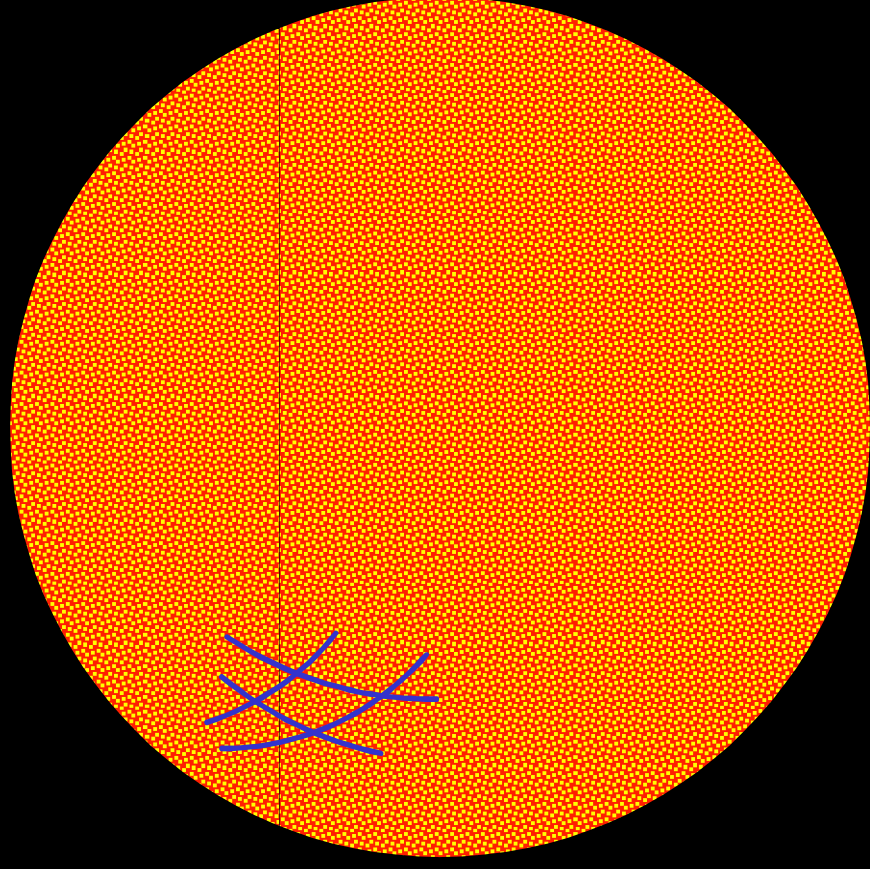
Nascimento de uma estrela



Início das reações de Fusão Nuclear

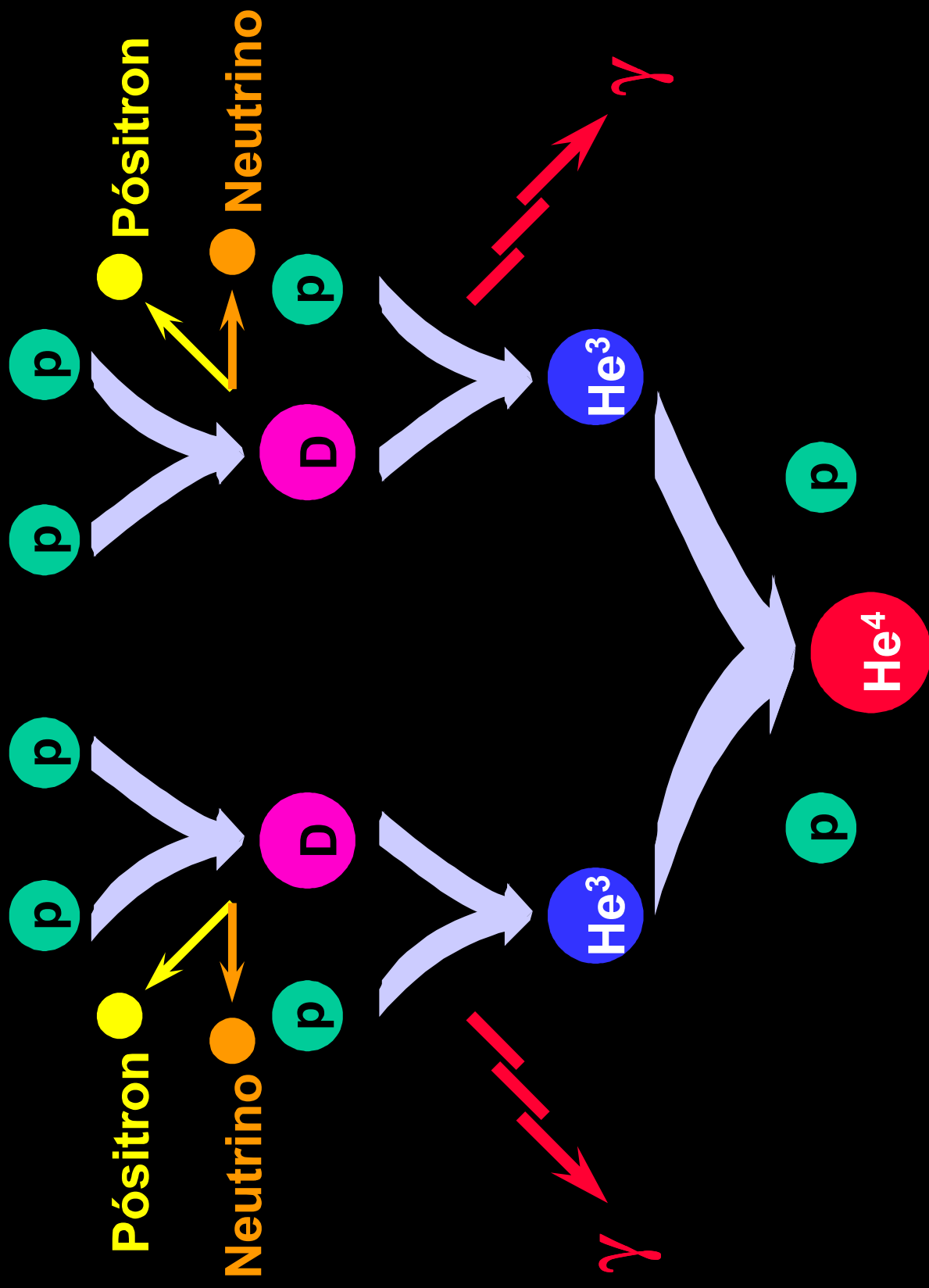
Nasceu a estrela !

Estrela: corpo plasmático

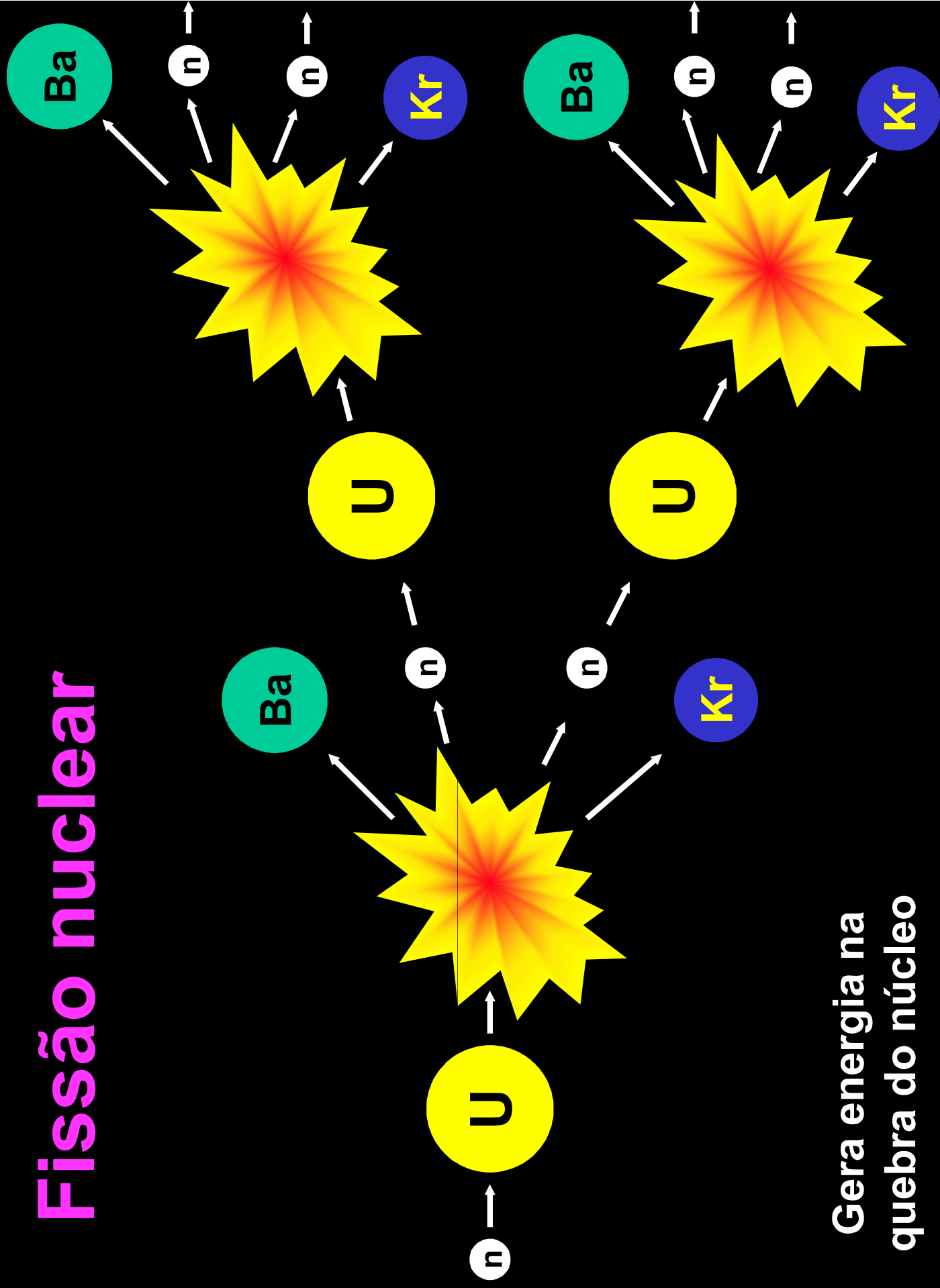


**Como é gerada a
energia no interior de
uma estrela?**

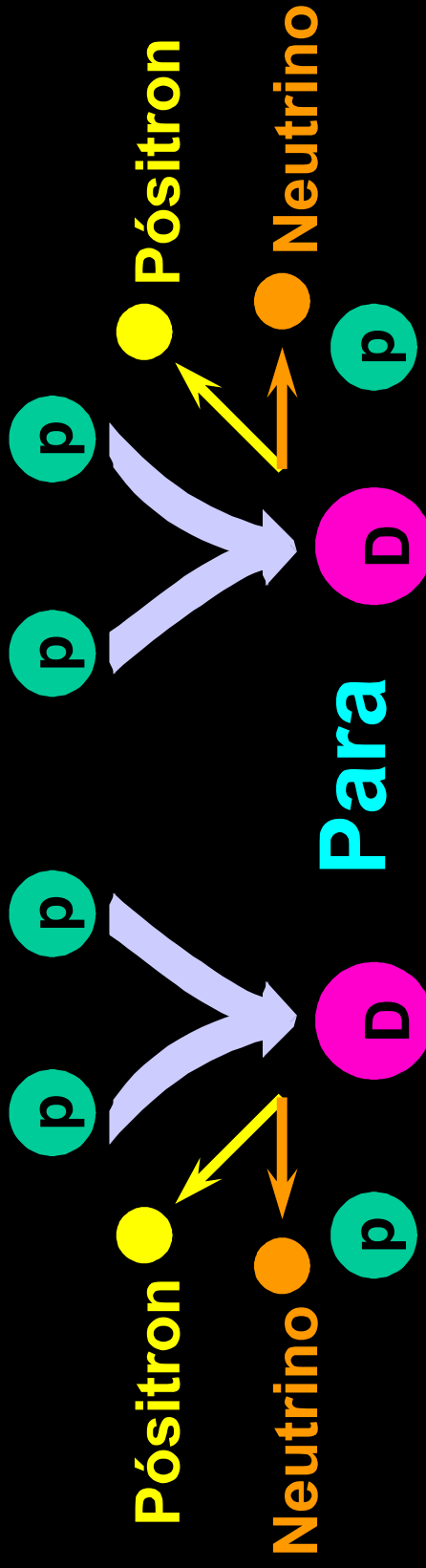
Fusão do hidrogênio



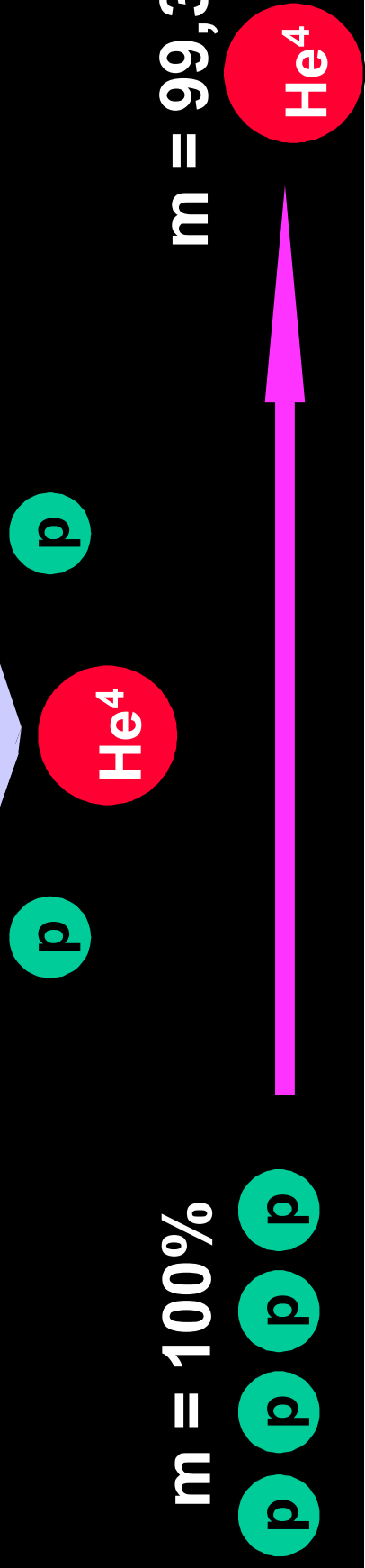
Fissão nuclear



Gera energia na quebra do núcleo

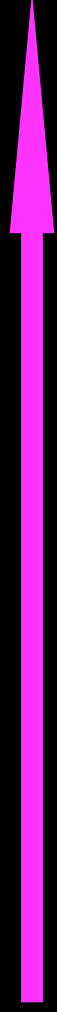


Para onde foi a massa faltante?



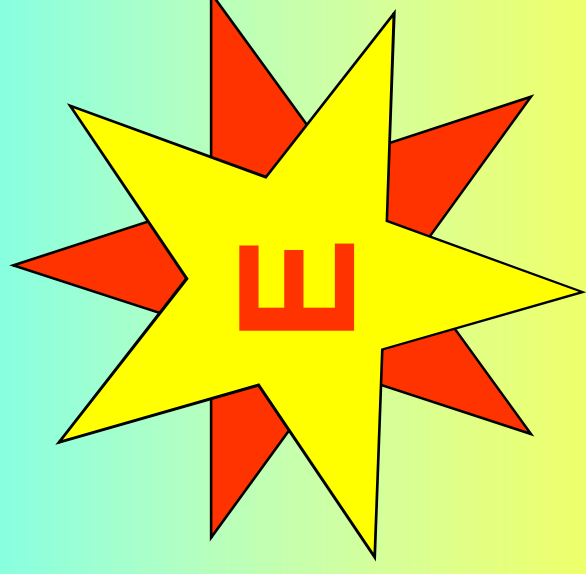
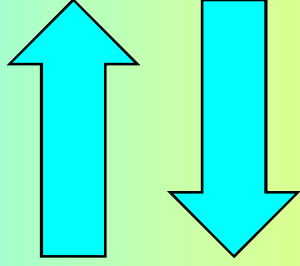
$m = 100\%$

$m = 99,3\%$



Relação entre massa e energia

m

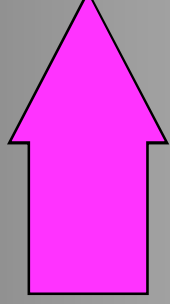
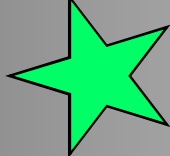
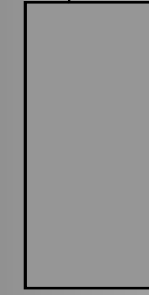


$$E = m c^2$$

c = velocidade da luz no vácuo

Fases da formação e da vida de uma estrela

Proto-estrela
Pré-sequência principal



Estágios finais

Nasceu a estrela!

Seqüência principal

Seqüência Principal

Quando uma estrela nasce,
diz-se que ela entrou no
Período Principal de sua vida,
também chamado de
Seqüência Principal.

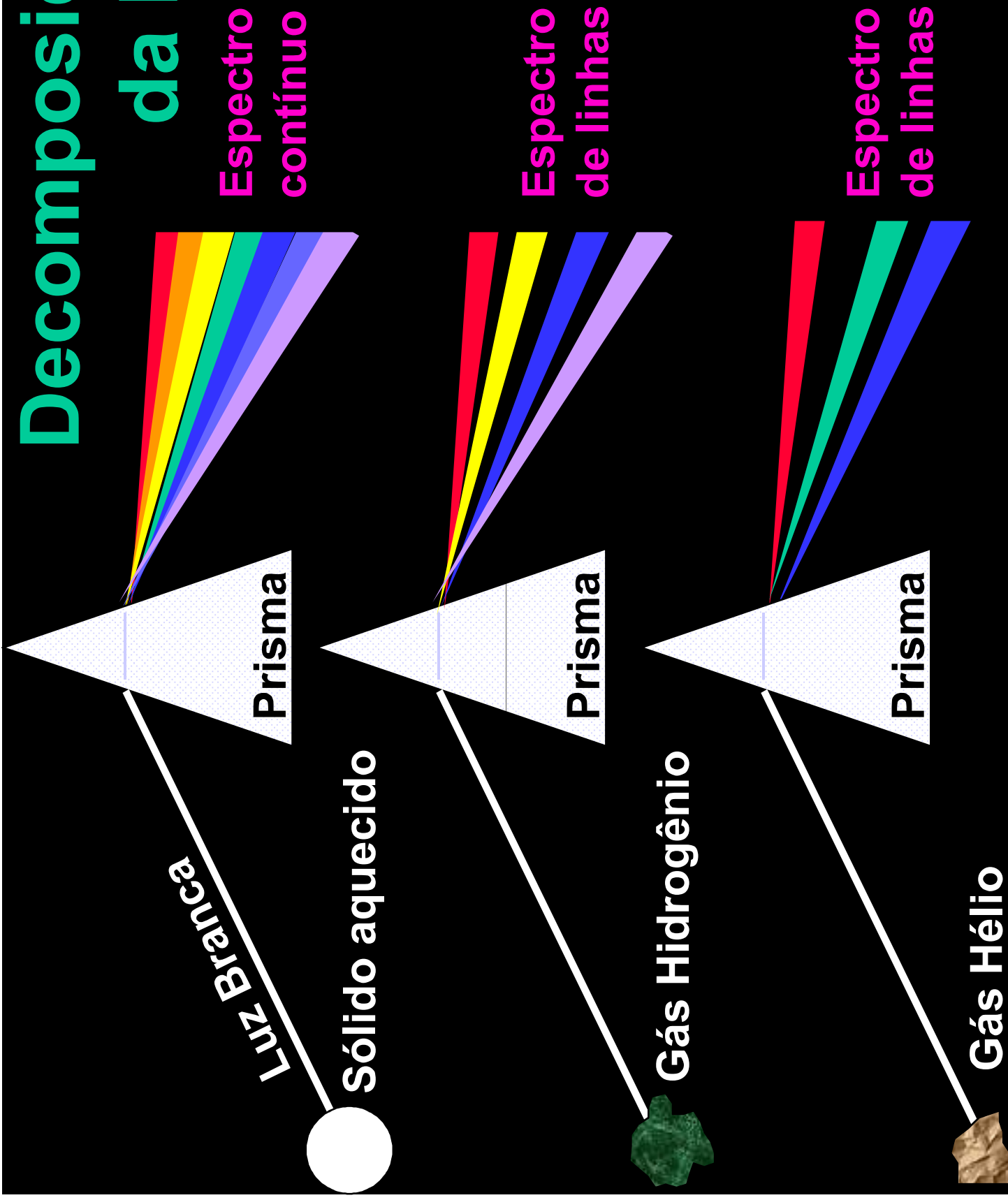
A **Seqüência Principal** dura enquanto
houver **Hidrogênio** no núcleo da estrela.

**Como se descobre a
composição química
de uma estrela?**

Arco-íris



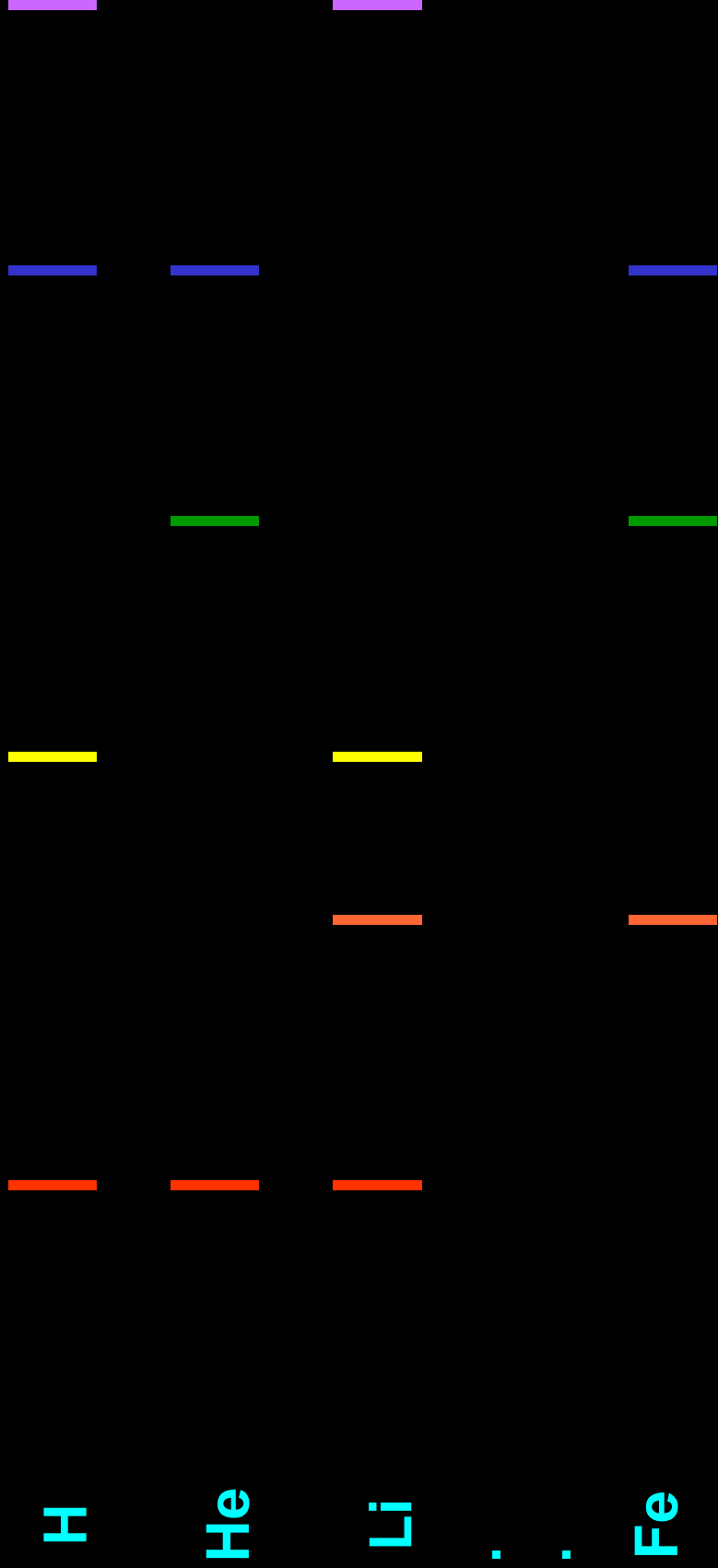
Decomposição da Luz



Catálogo de espectros



Contínuo



H

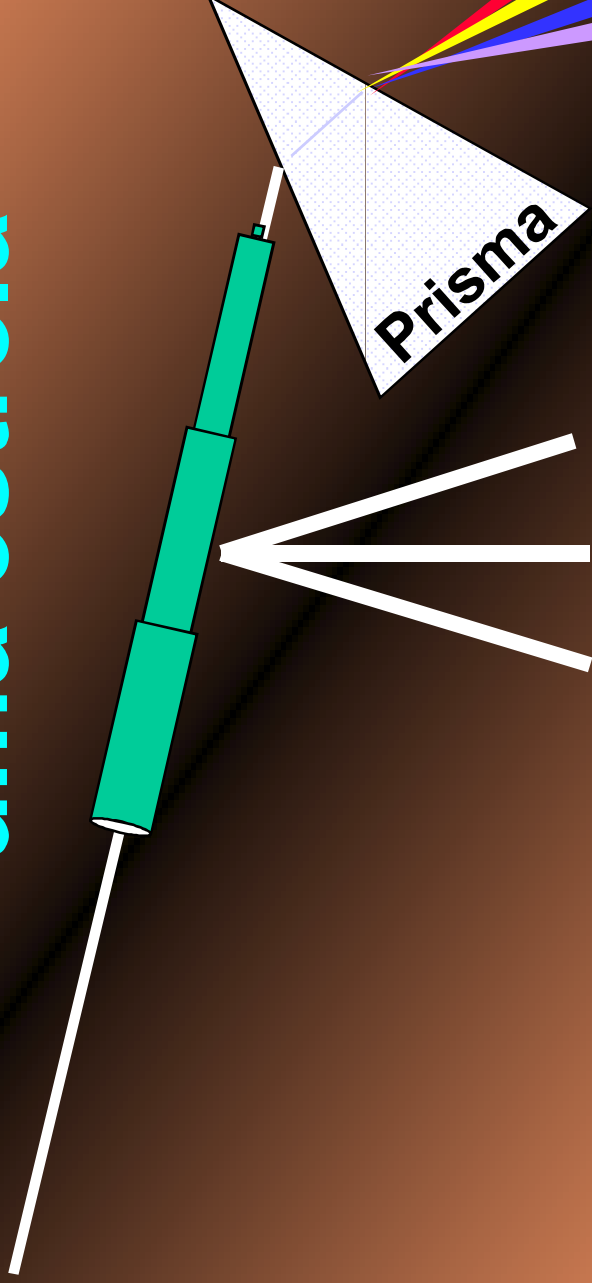
He

Li

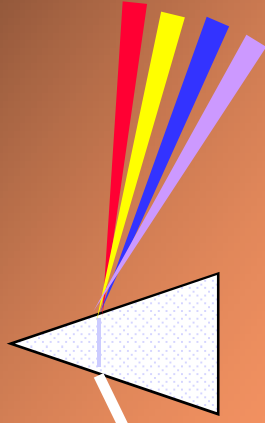
.

Fe

Composição química de uma estrela



No Laboratório



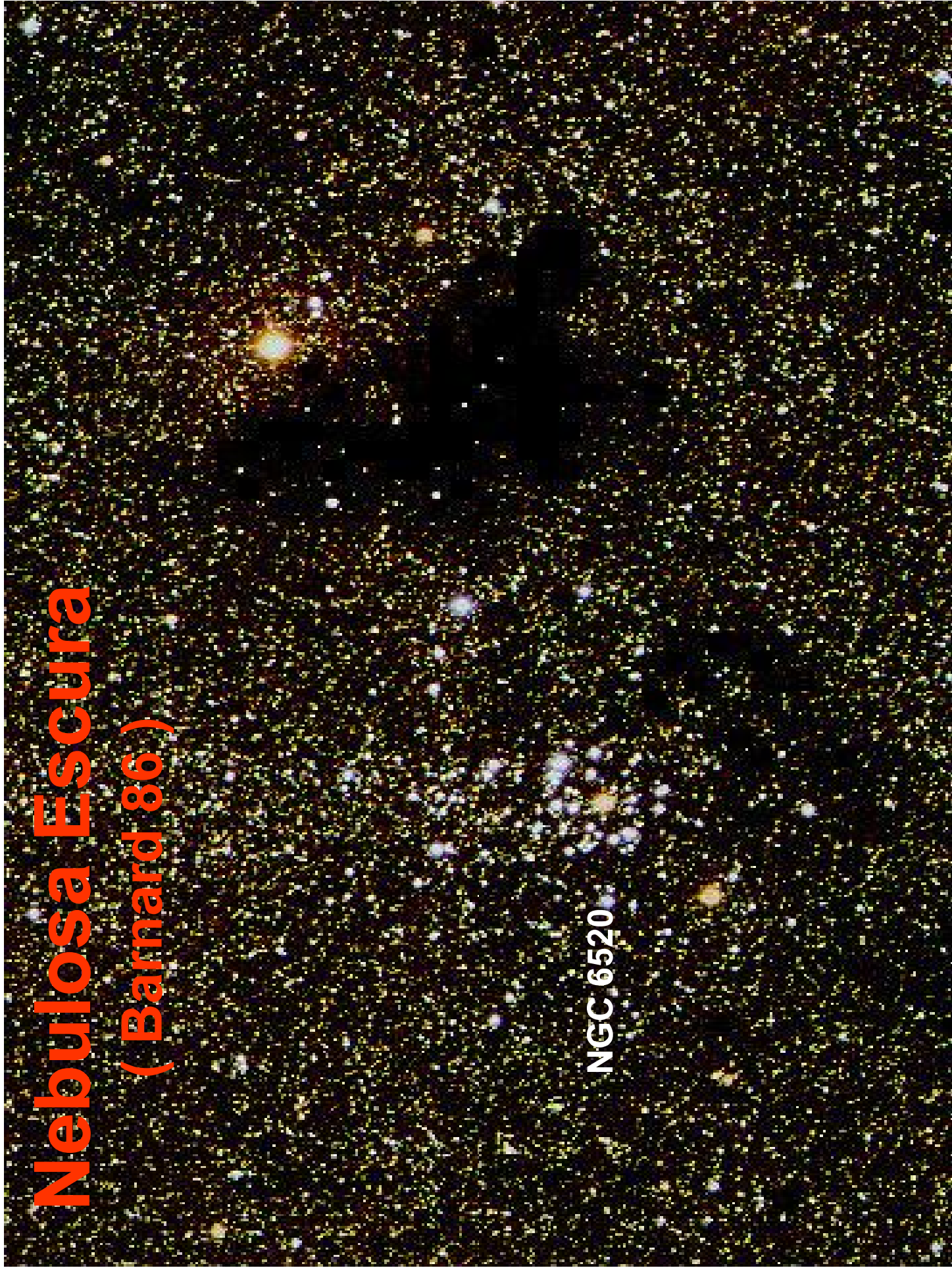
Gás Hidrogênio

Hidrogênio!

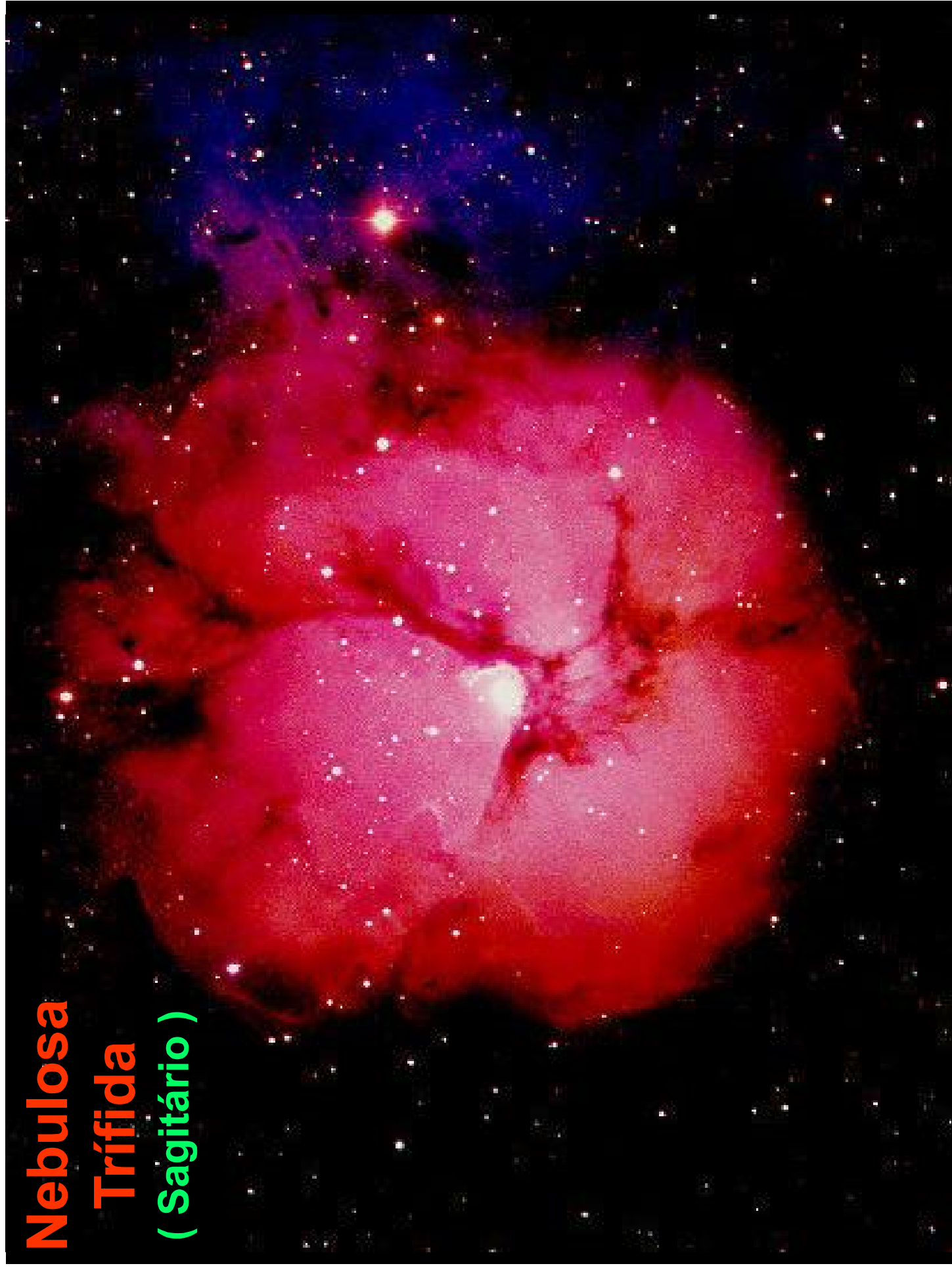
Onde nascem as estrelas?

Nebulosa Escura (Barnard 86)

NGC 6520



**Nebulosa
Trífida
(Sagitário)**



**Nebulosa escura
da Cabeça do
Cavalo**



Proto-estrelas (NGC 2237)

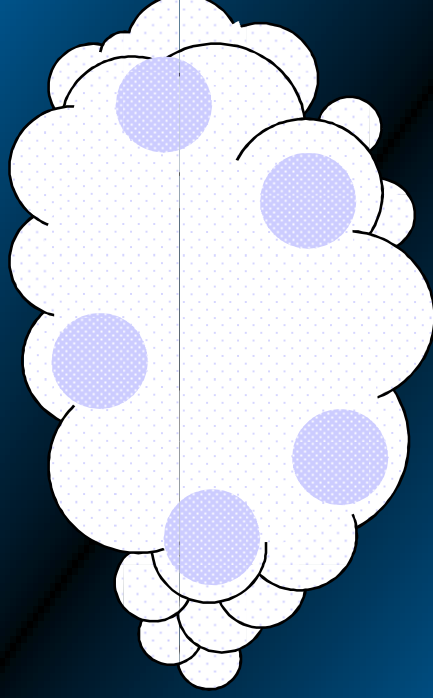


Estrelas irmãs

Aglomerado Estelar



Nuvem
Inicial



Glóbulos
de Bok

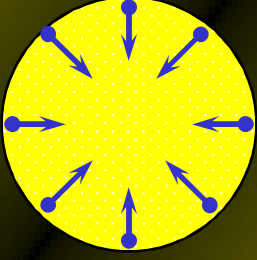
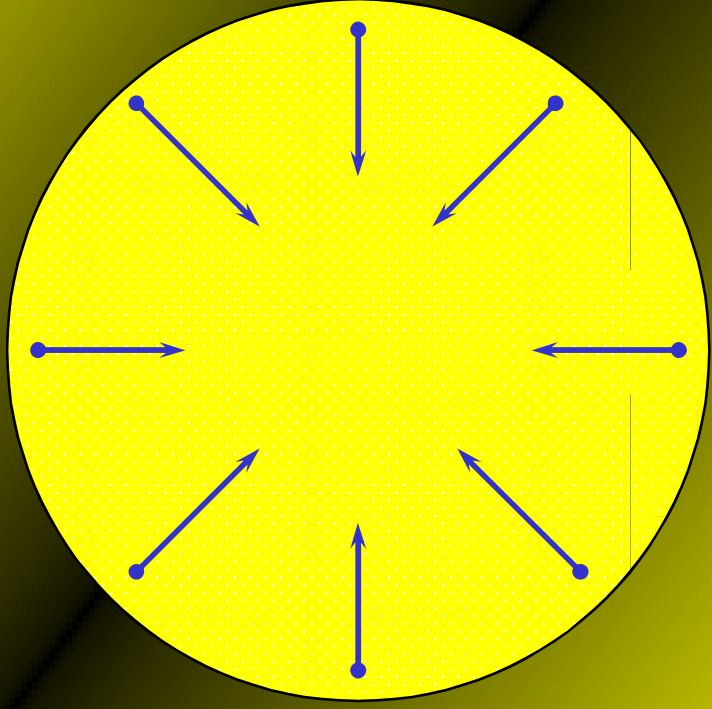


Aglomerado Estelar

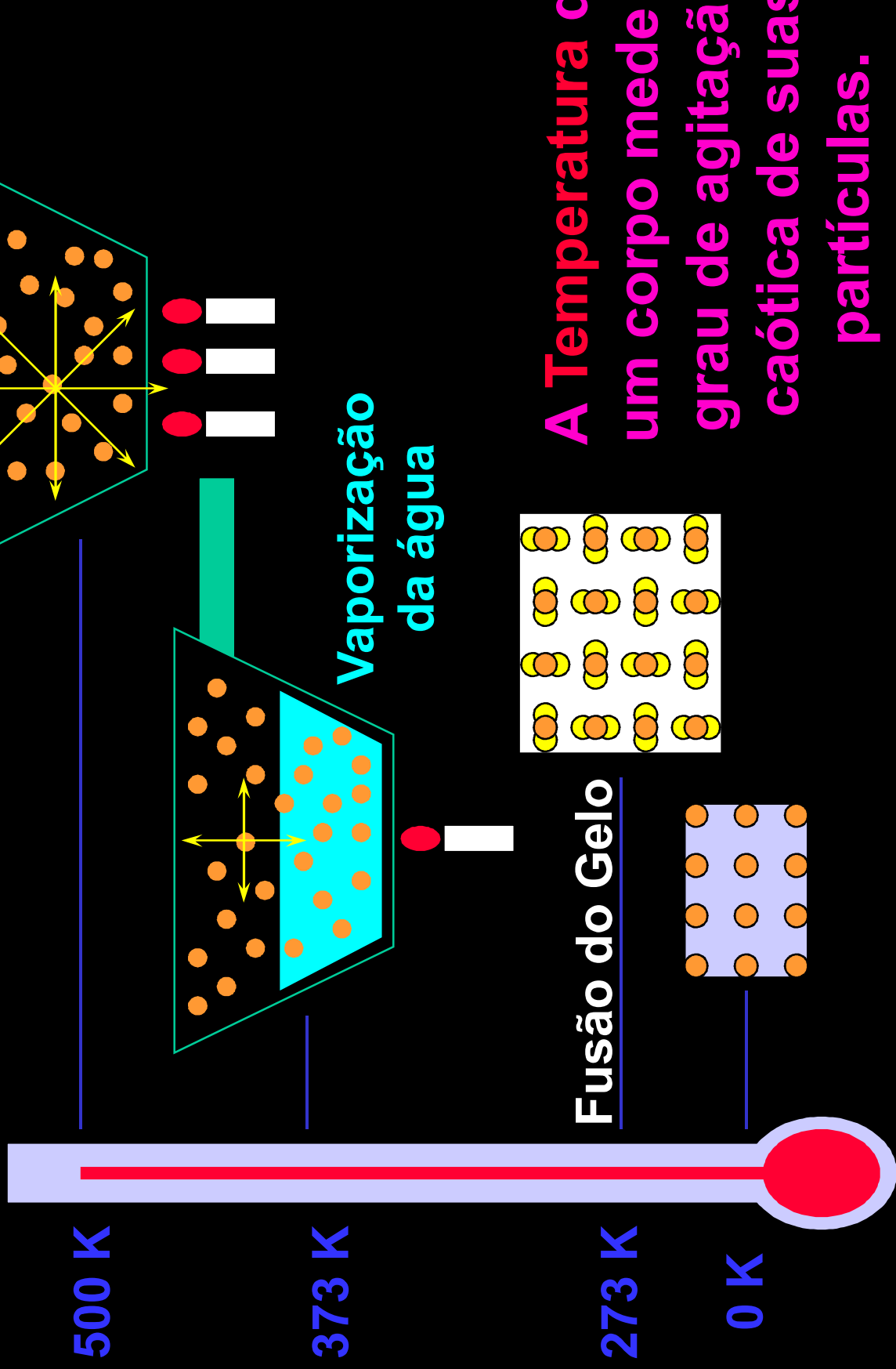
Aglomerado Jovem (NGC 3293)



Porque a estrela não colapsa?



Temperatura

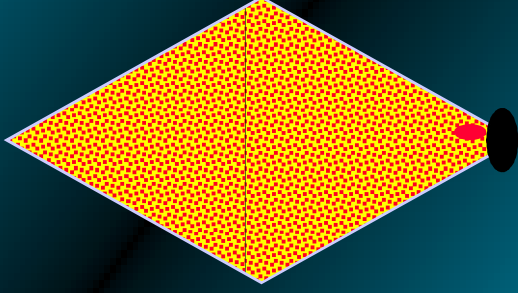


A Temperatura de um corpo mede o grau de agitação caótica de suas partículas.

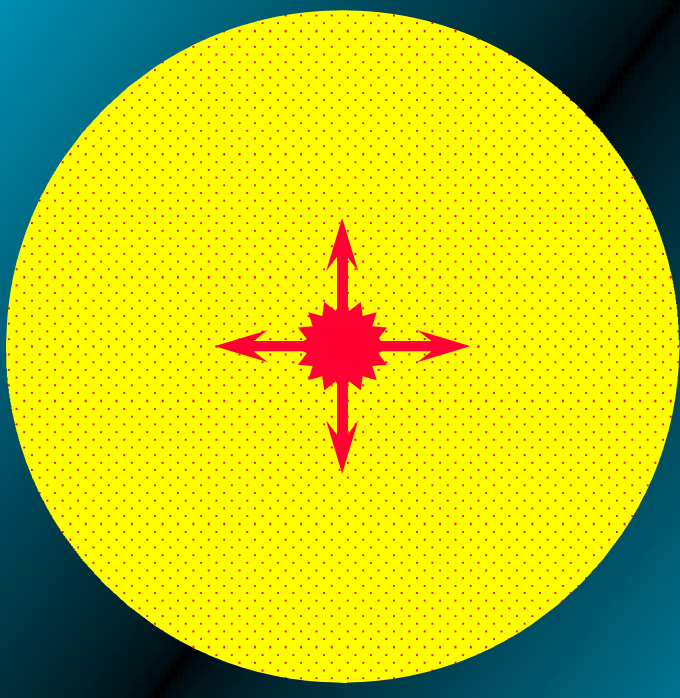
Pressão Térmica



Balão com
mecha apagada

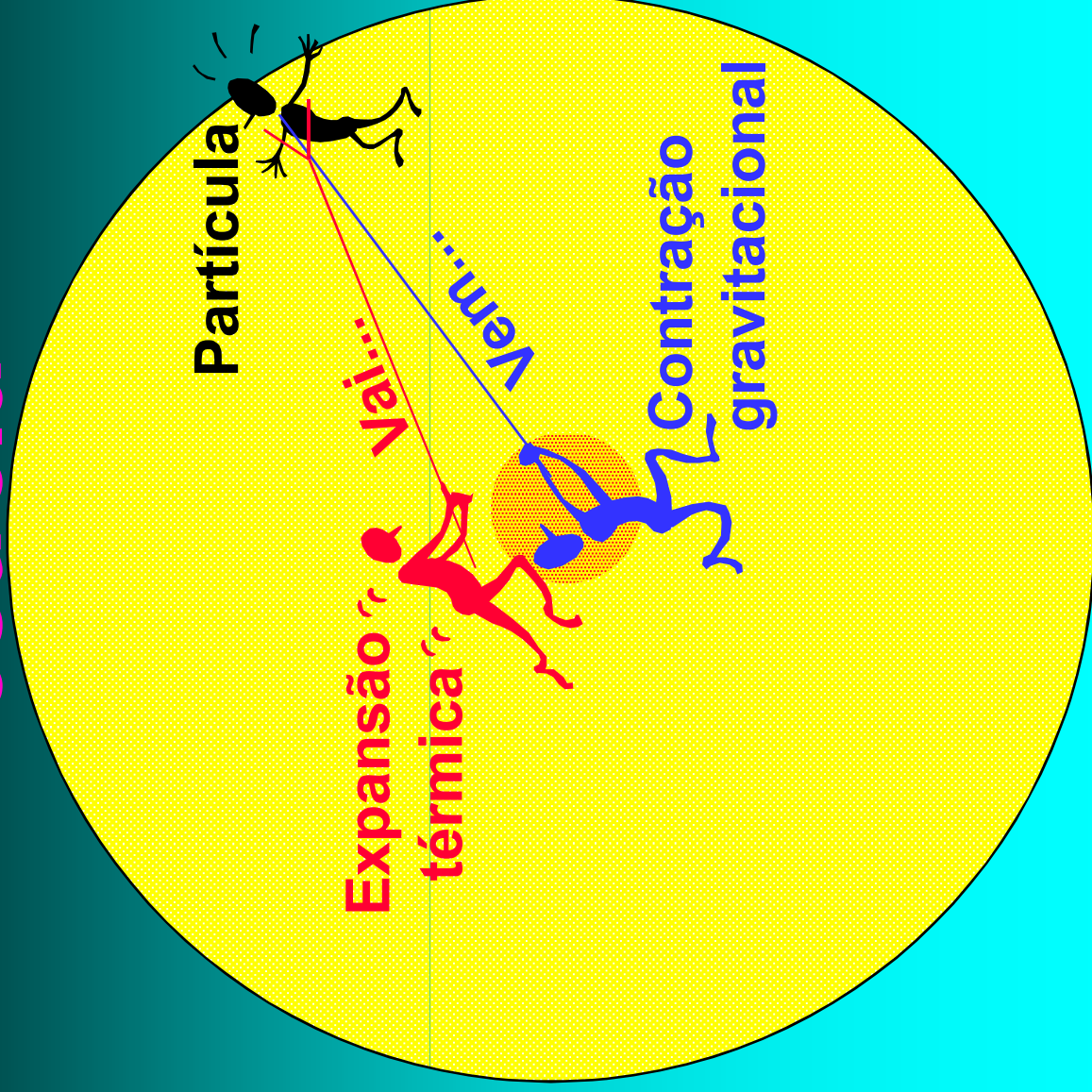


Mecha acesa

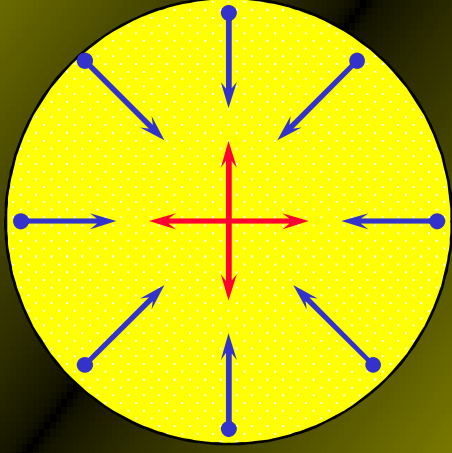


Devido à **temperatura**,
existe a **pressão térmica**.

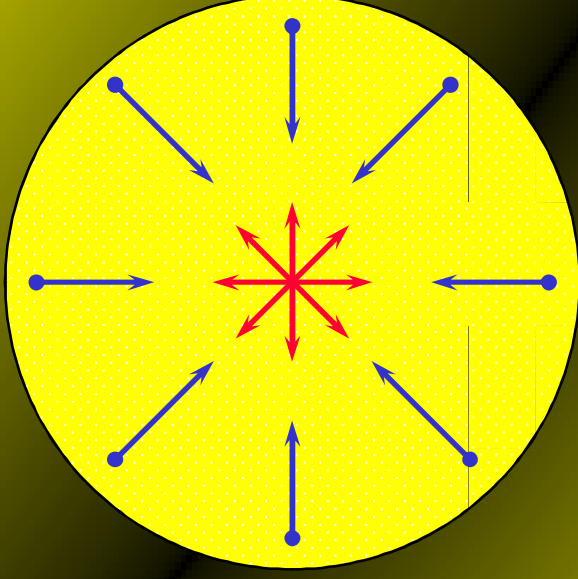
Pressões atuantes numa estrela



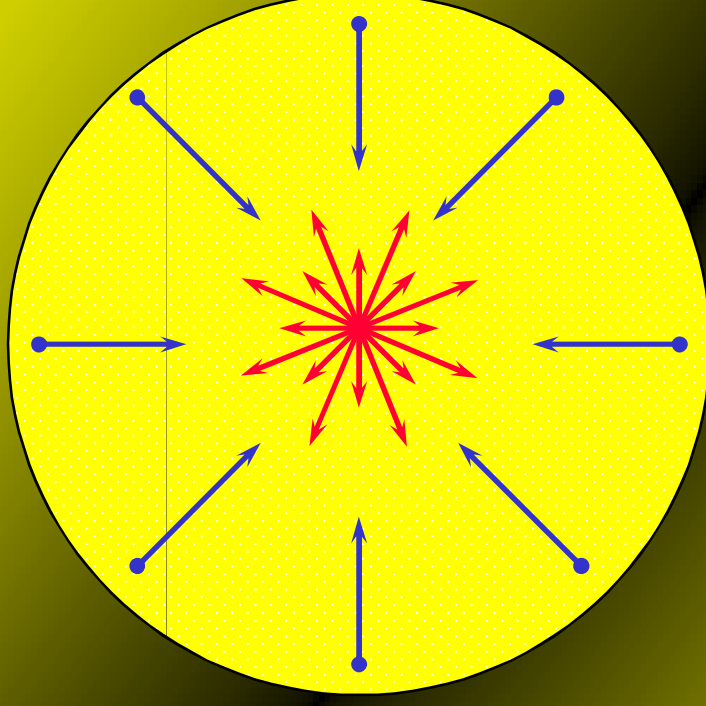
(Des)equilíbrio Estático



$P_T < P_G$
Contração



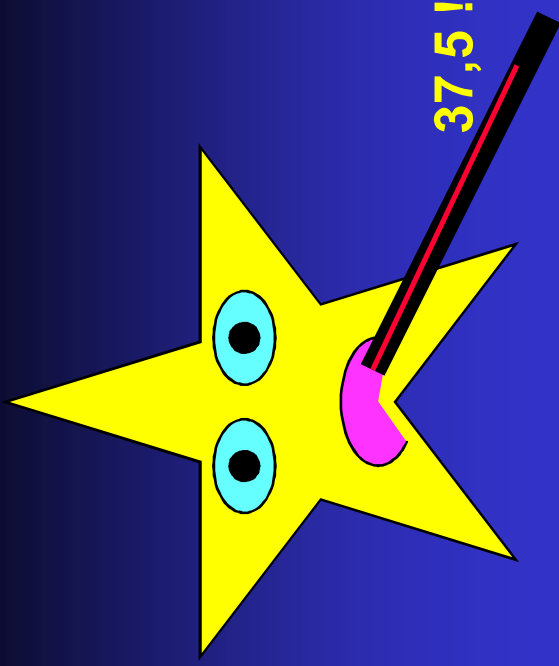
$P_T = P_G$
Equilíbrio



$P_T > P_G$
Expansão

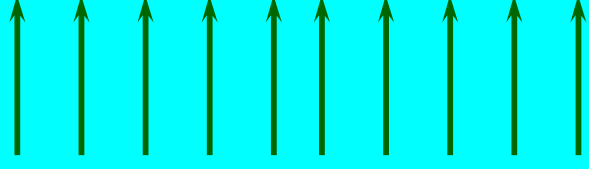
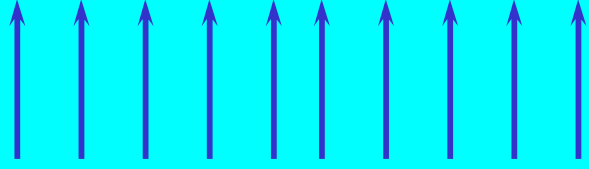
P_T = Pressão Térmica
 P_G = Pressão Gravitacional

Como determinar a temperatura de uma estrela?



Corpo Negro

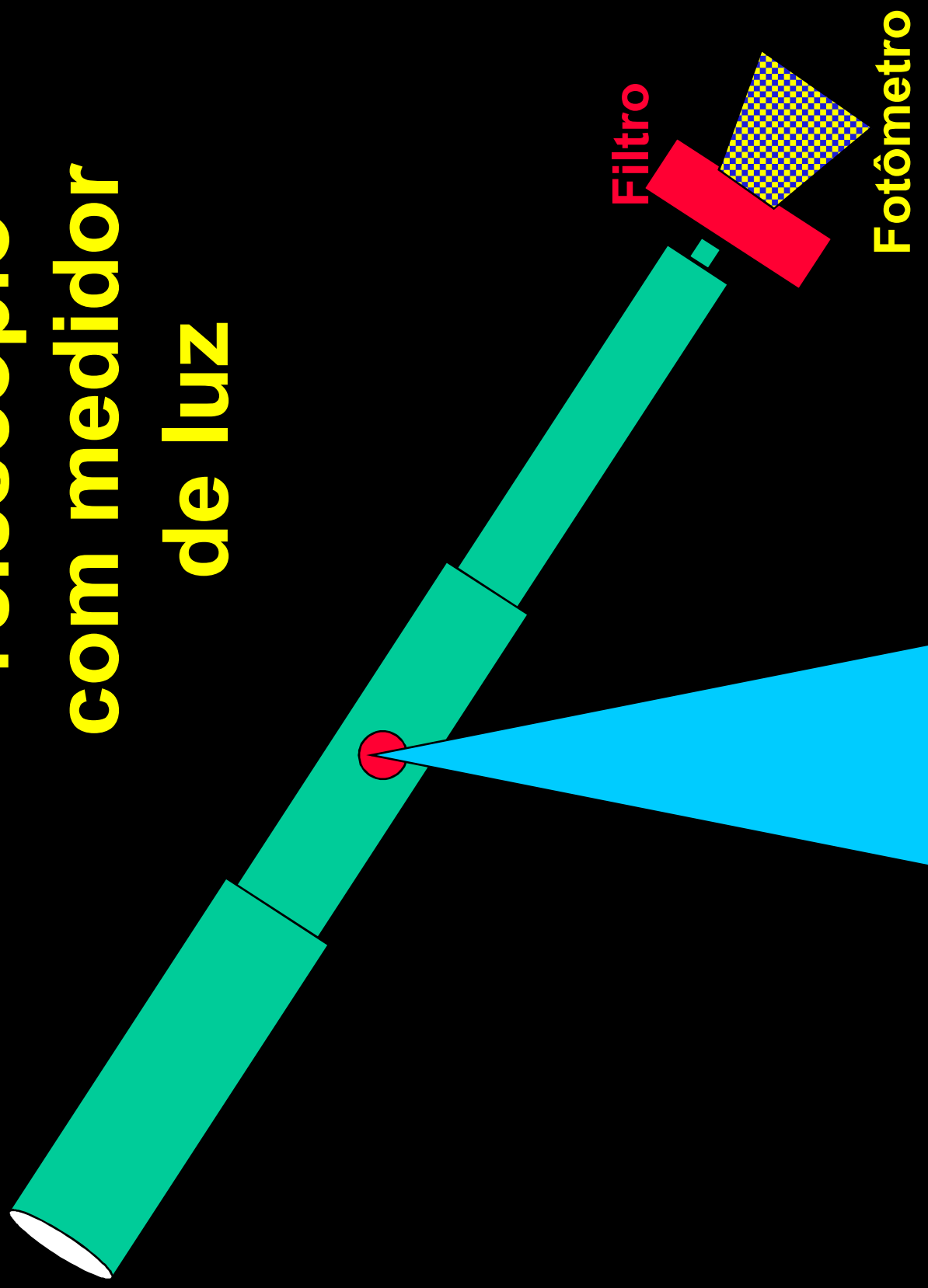
**Absorve toda
a energia que
possa incidir
sobre ele.**



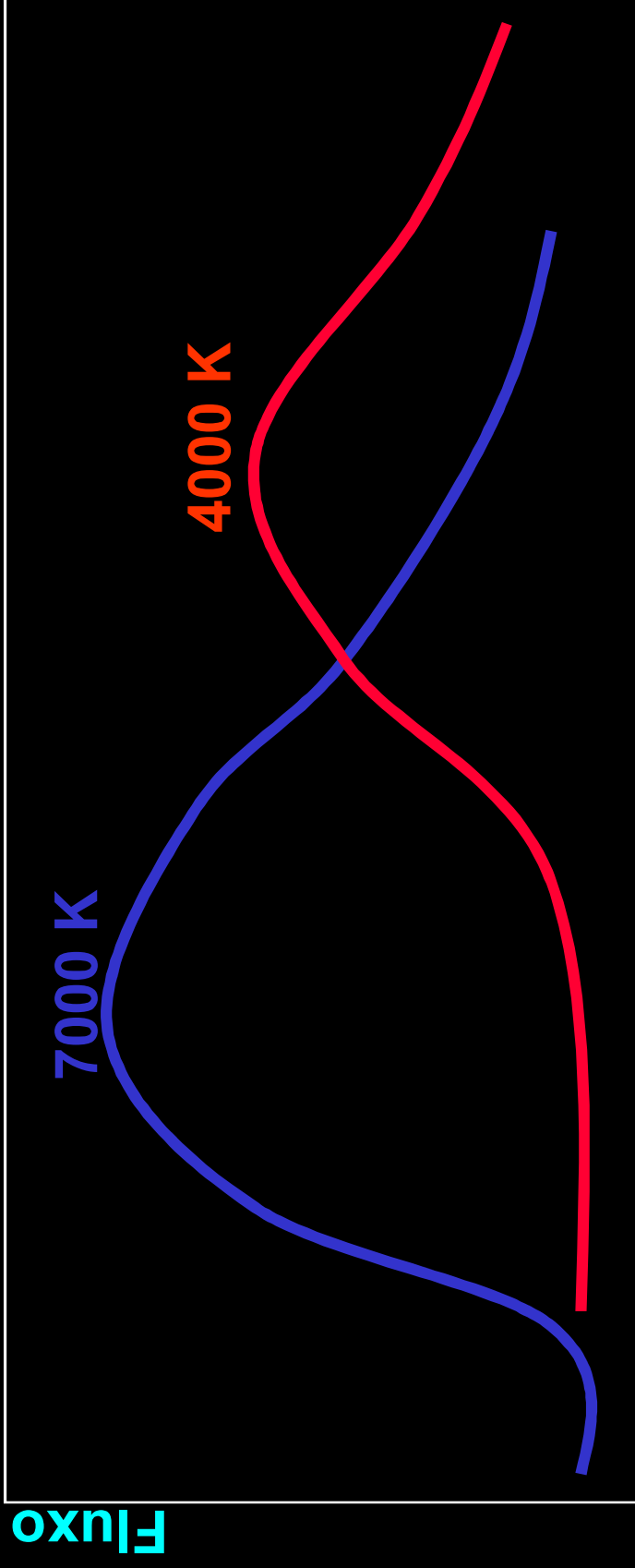
**Emite o máximo
de energia em
todos os
comprimentos
de onda
para uma dada
temperatura.**



Telescópio com medidor de luz



Lei de Stefan - Boltzmann

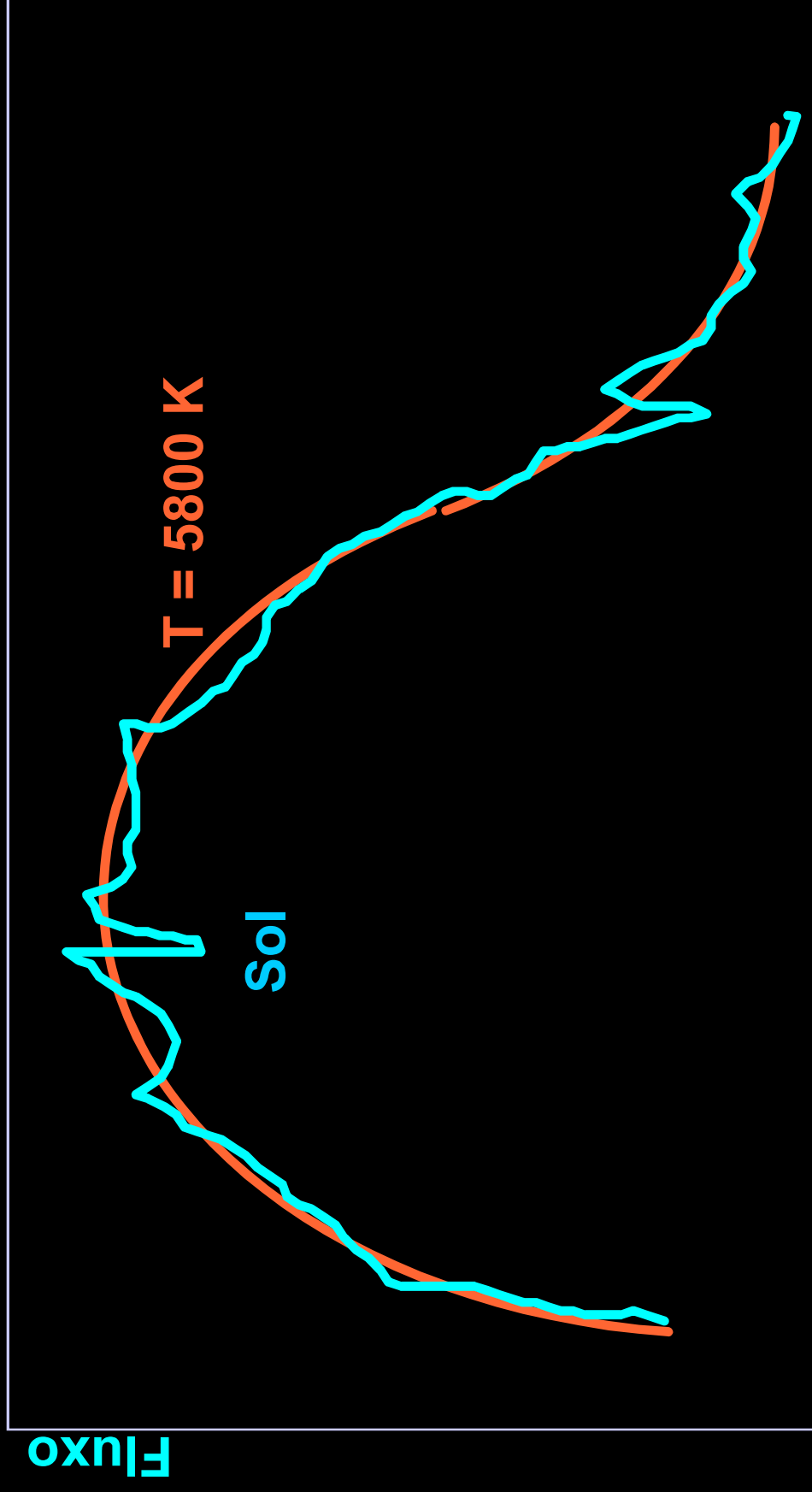


Comprimento de onda

$$F = \sigma T^4$$

Estrela como Corpo Negro

(Função de Planck)



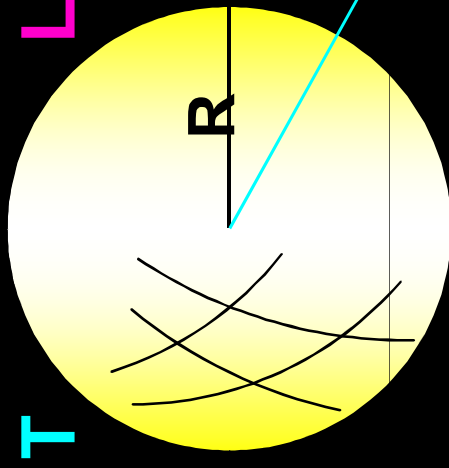
Comprimento
de onda

Classificação espectral



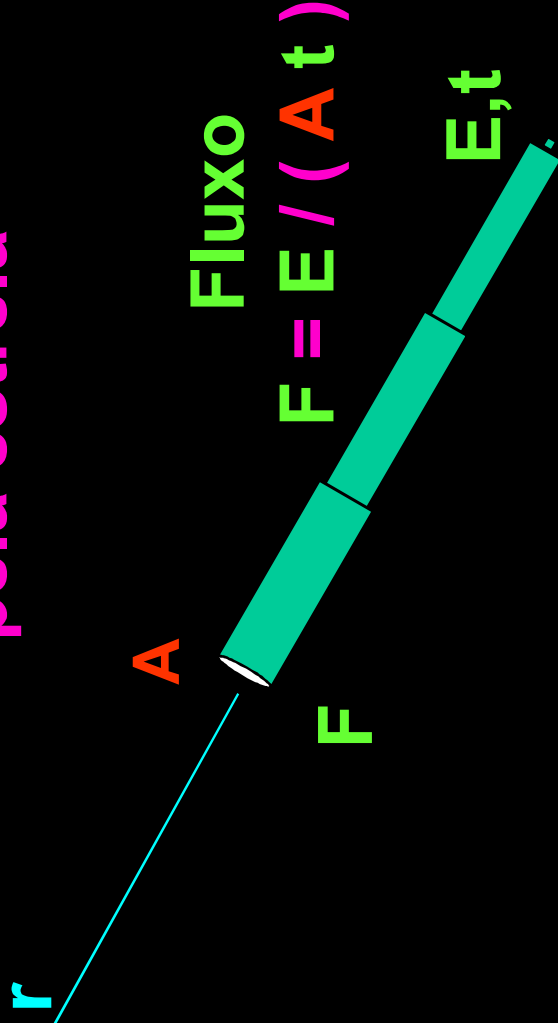
Oh! Be A Fine Girl, Kiss Me!

Luminosidade de uma estrela



$$L = (4 \pi R^2) (\sigma T^4)$$

Luminosidade é a potência total emitida pela estrela

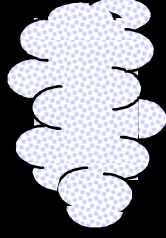
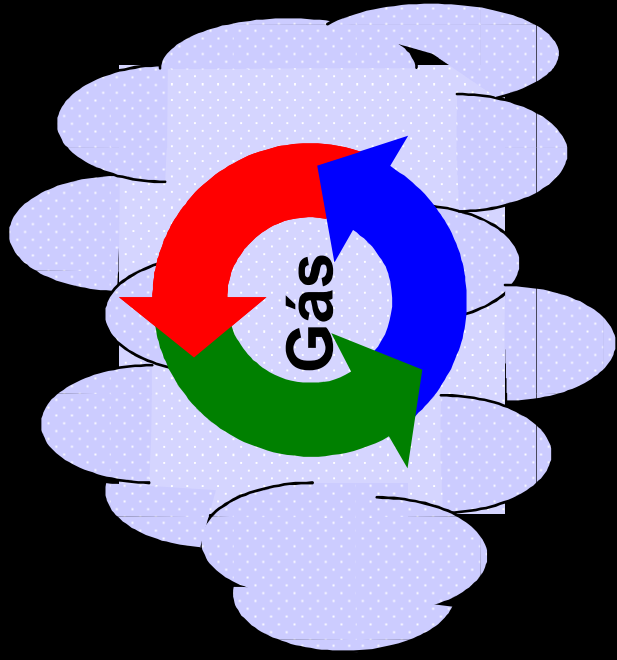


$$F = L / (4 \pi r^2)$$

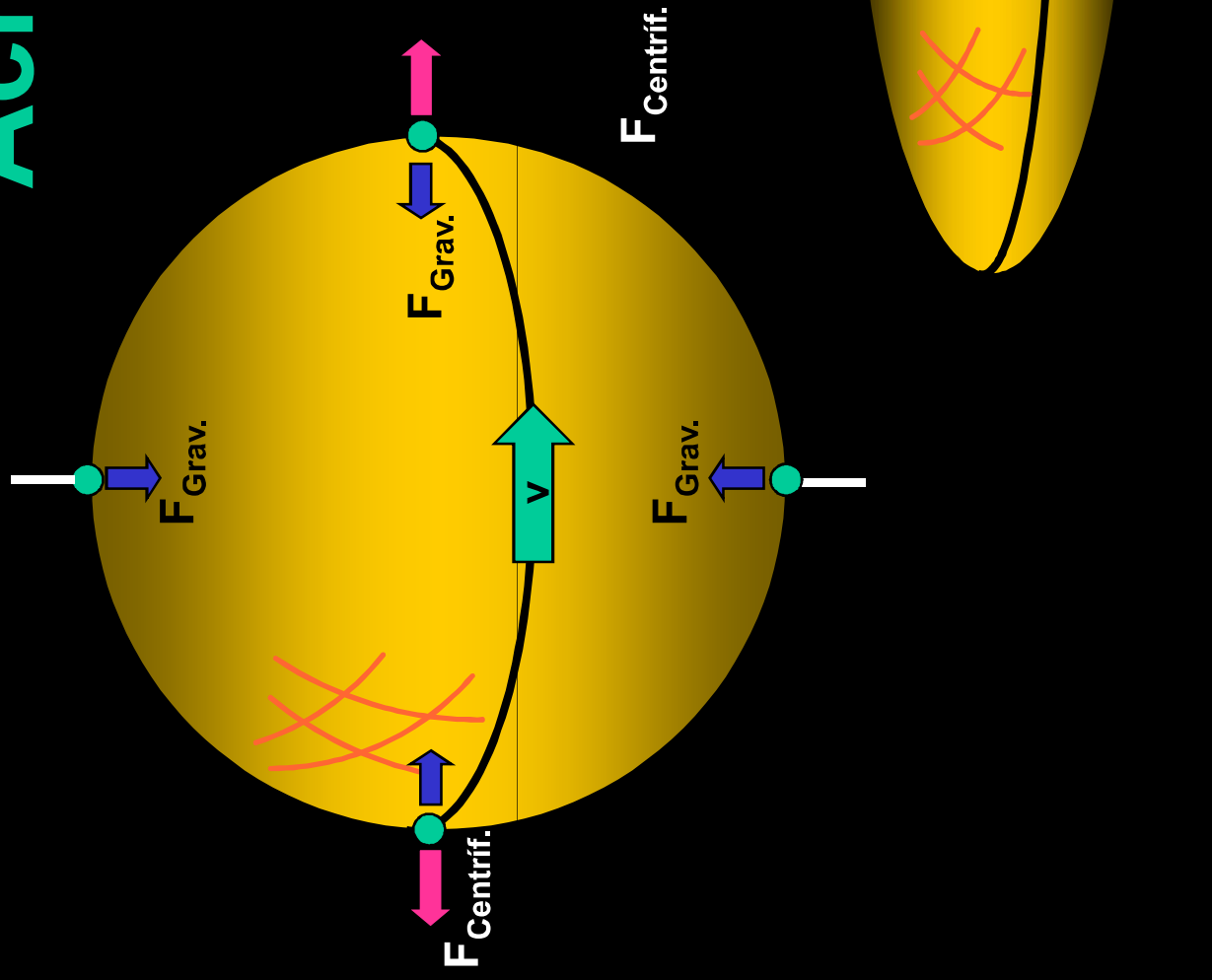
Como se formou o Sol e o Sistema Solar ?

(Cosmogonia)

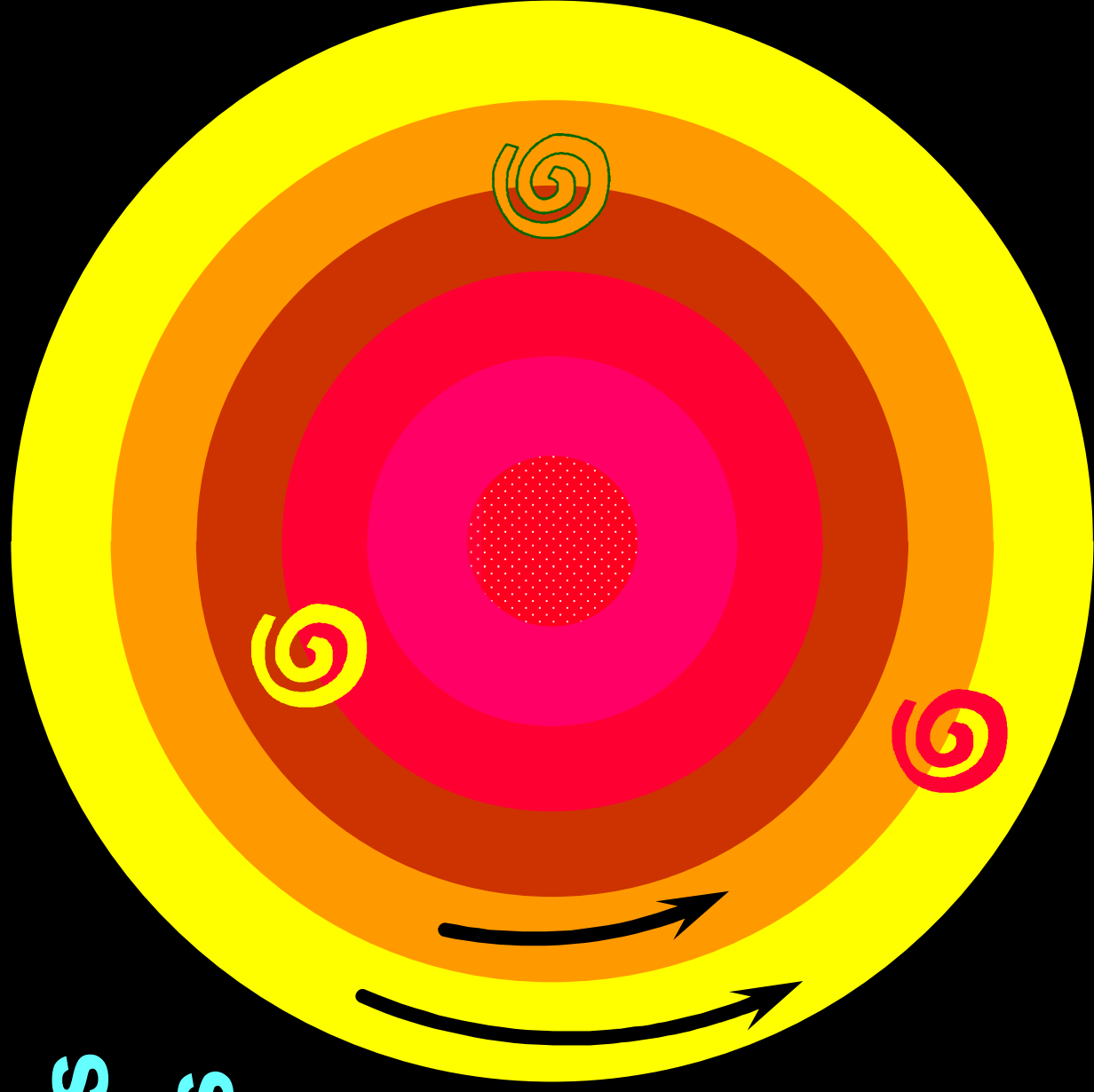
Contração da Nebulosa Solar



Achatamento da nebulosa



Formação do Sol e dos Planetas



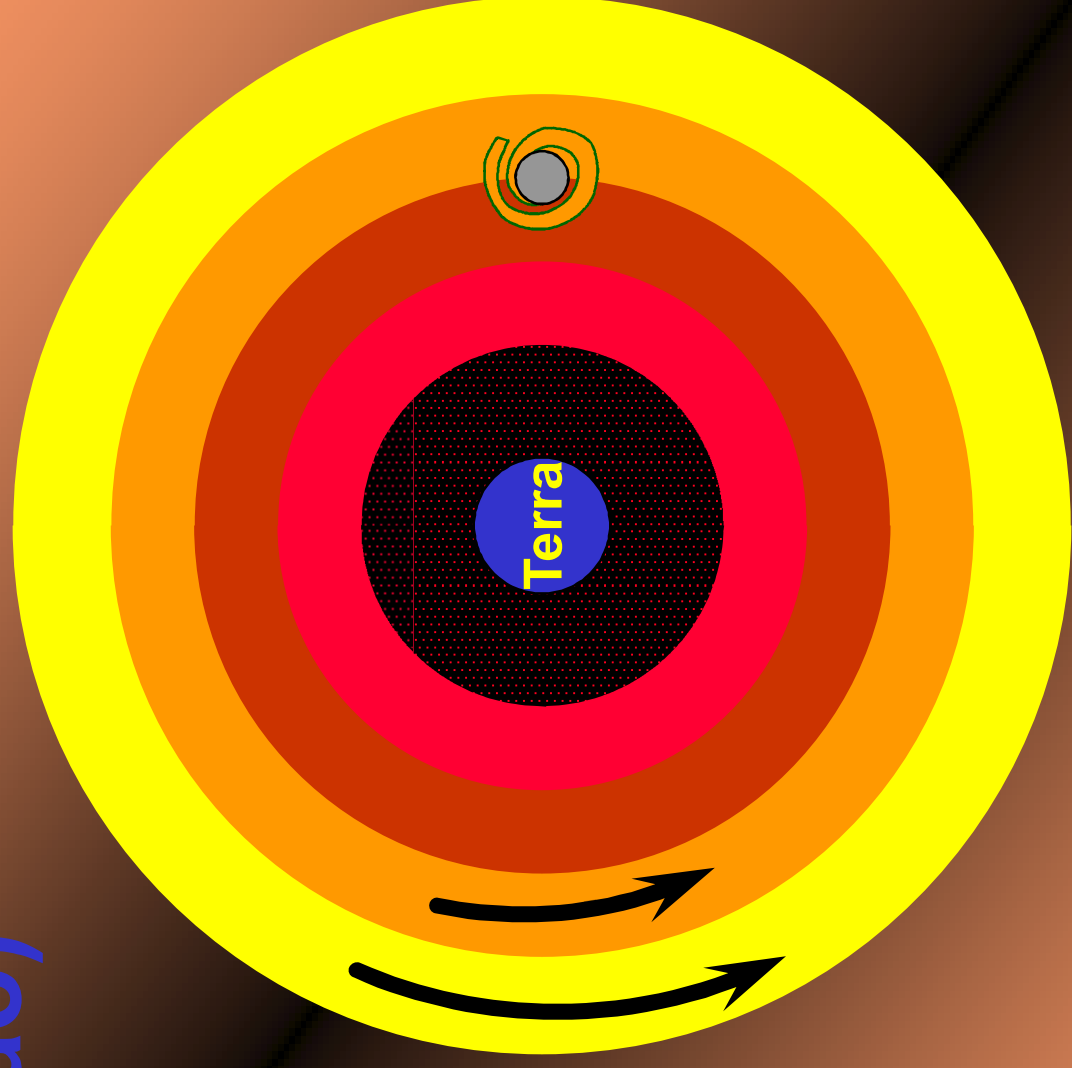
Formação do Sistema Solar



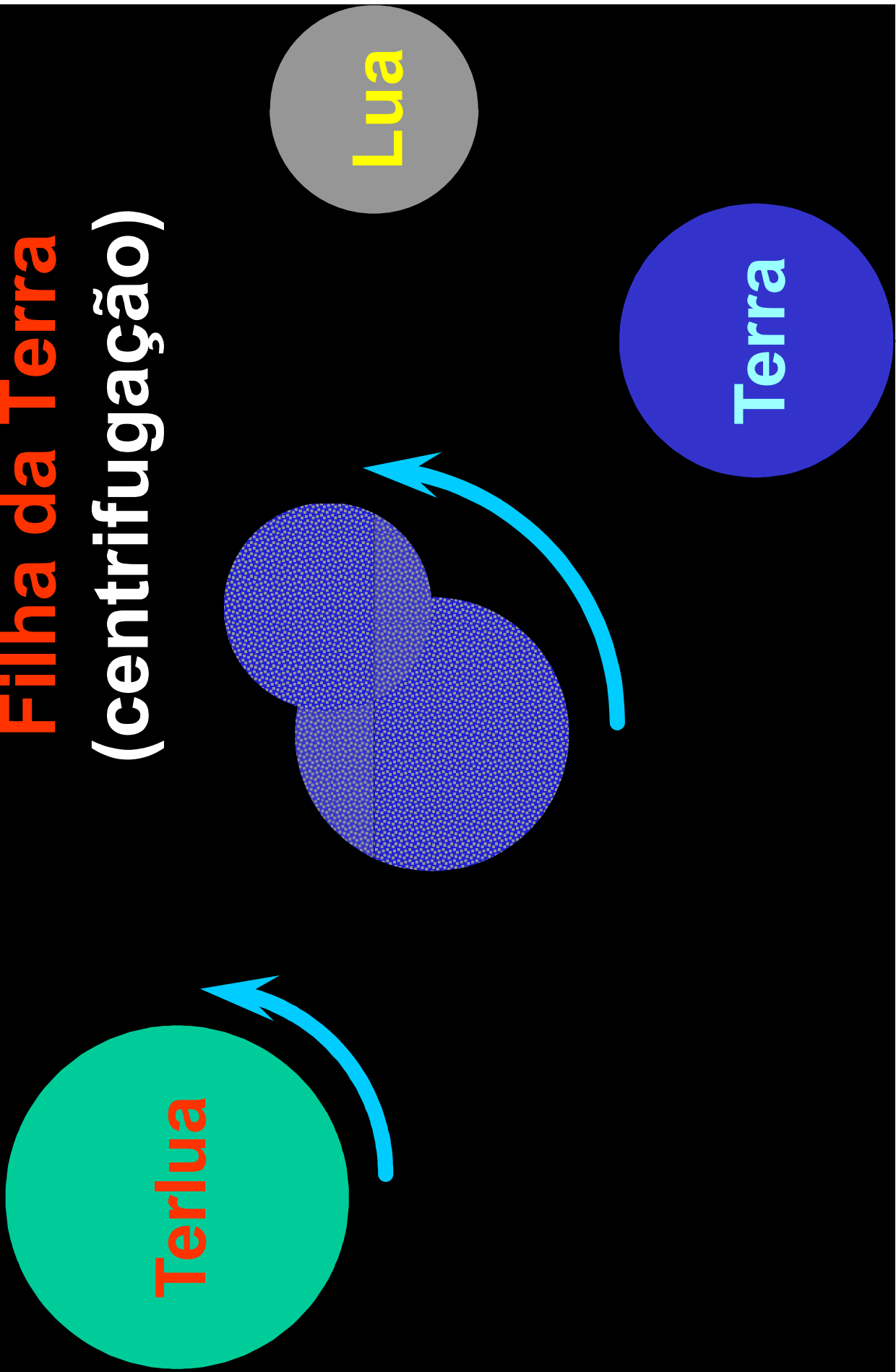
E a Lua, como se formou?

- **Irmã da Terra**
- **Filha da Terra**
- **Namorada da Terra**
- **Irmã Siamesa da Terra**

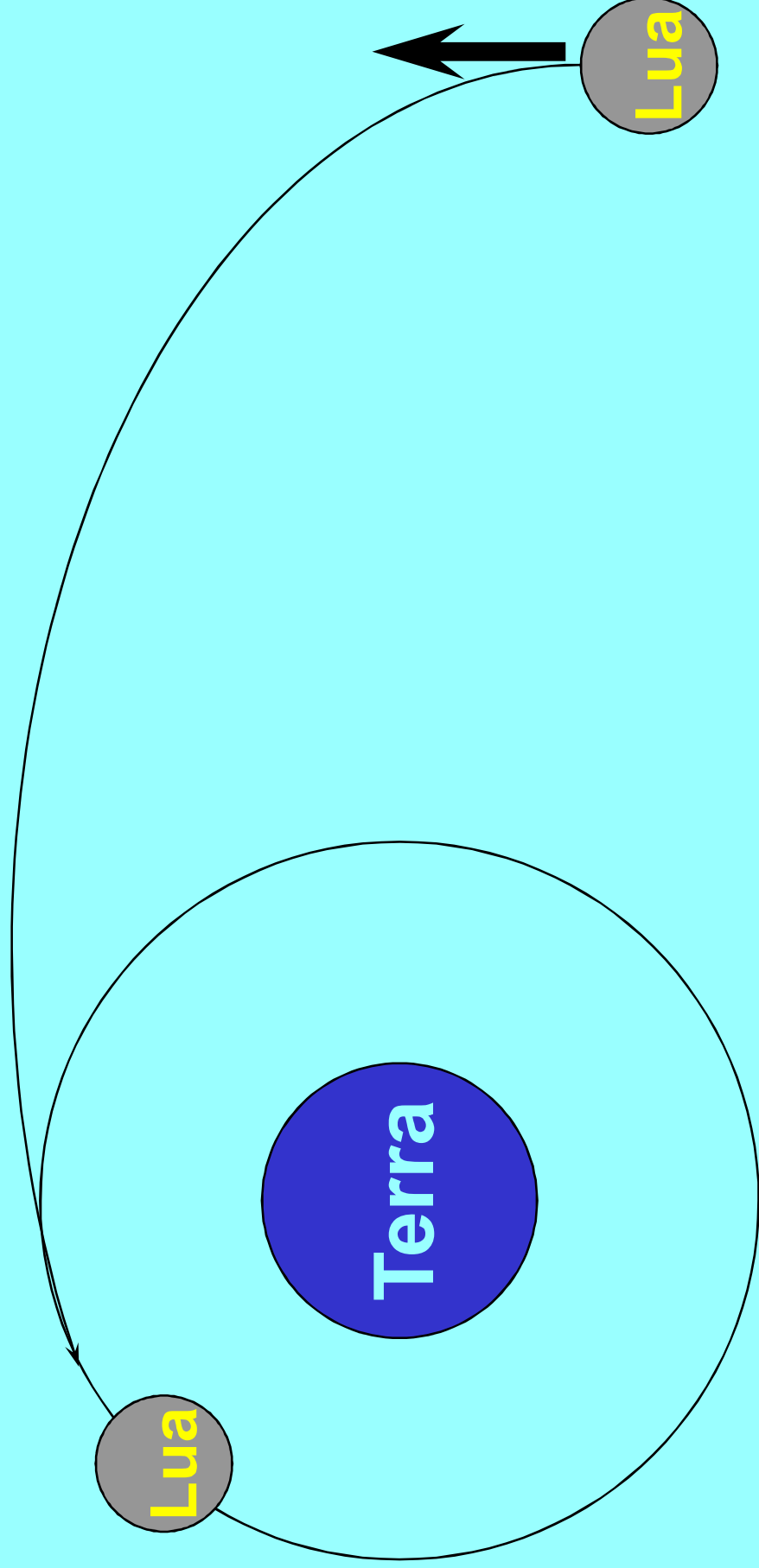
Lua: Irmã da Terra (co-formação)



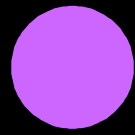
Lua:
Filha da Terra
(centrifugação)



Lua: Namorada da Terra (captura gravitacional)

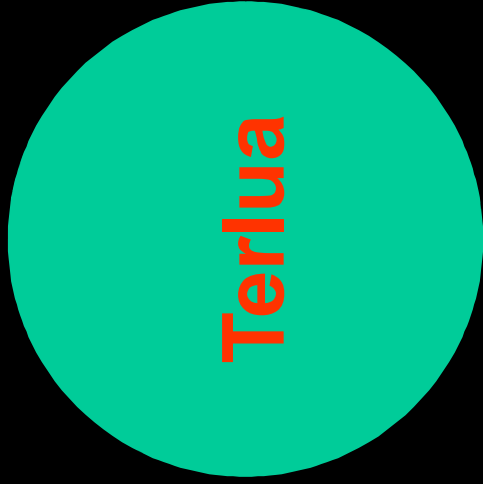


Asteróide (?)

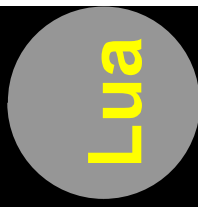
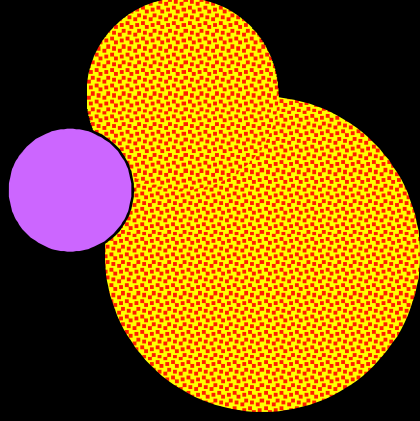


Lua e Terra:

Irmãs siamesas separadas
(choque catastrófico)



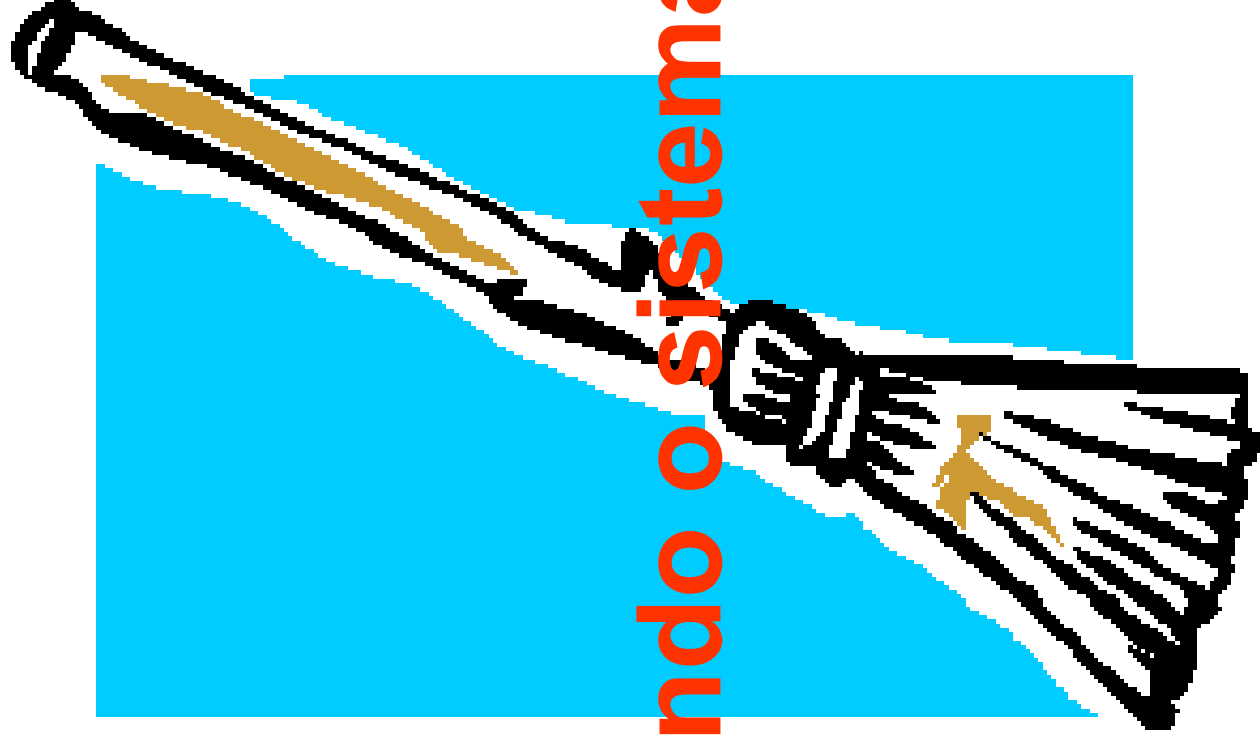
Terlua



Lua

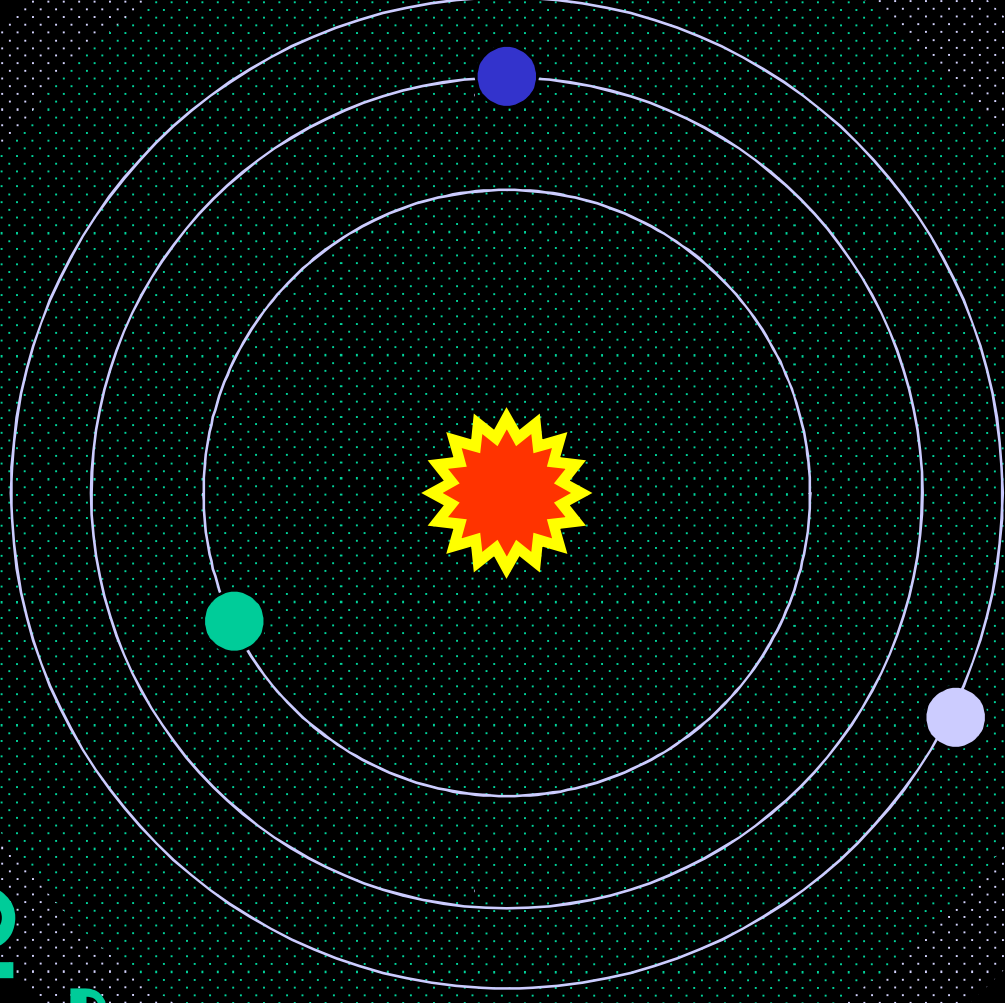


Terra

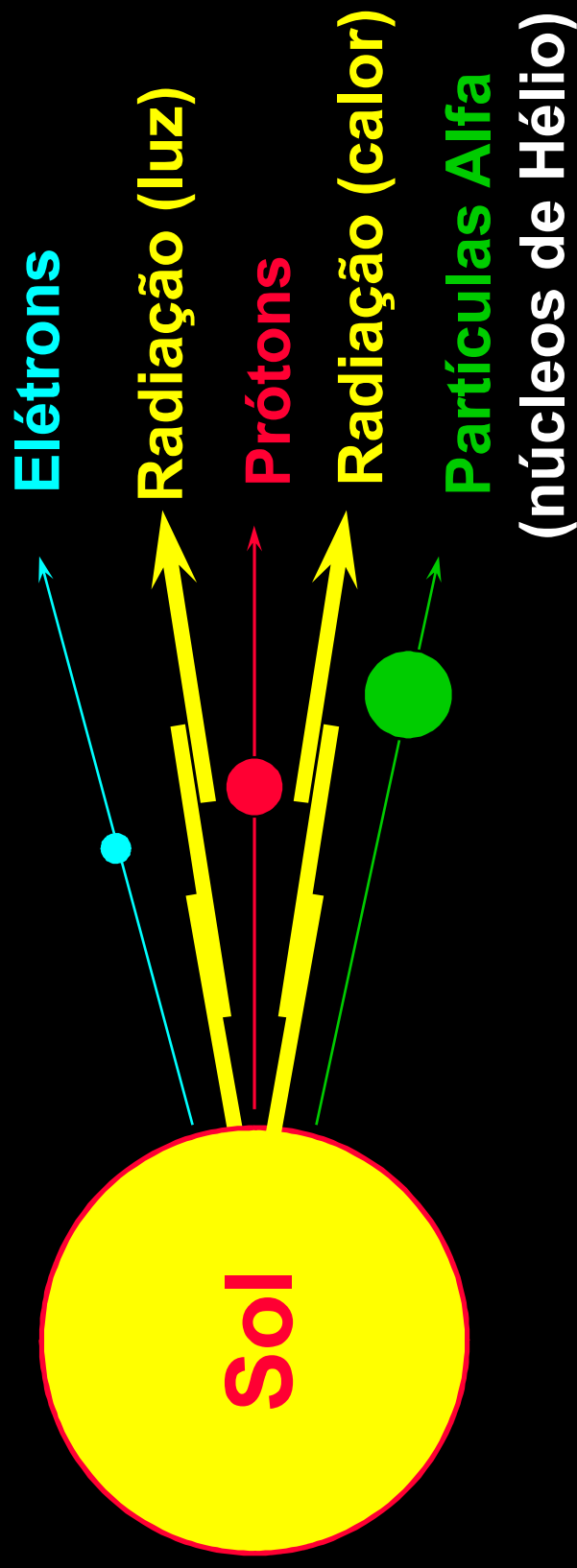


Limpando o sistema solar

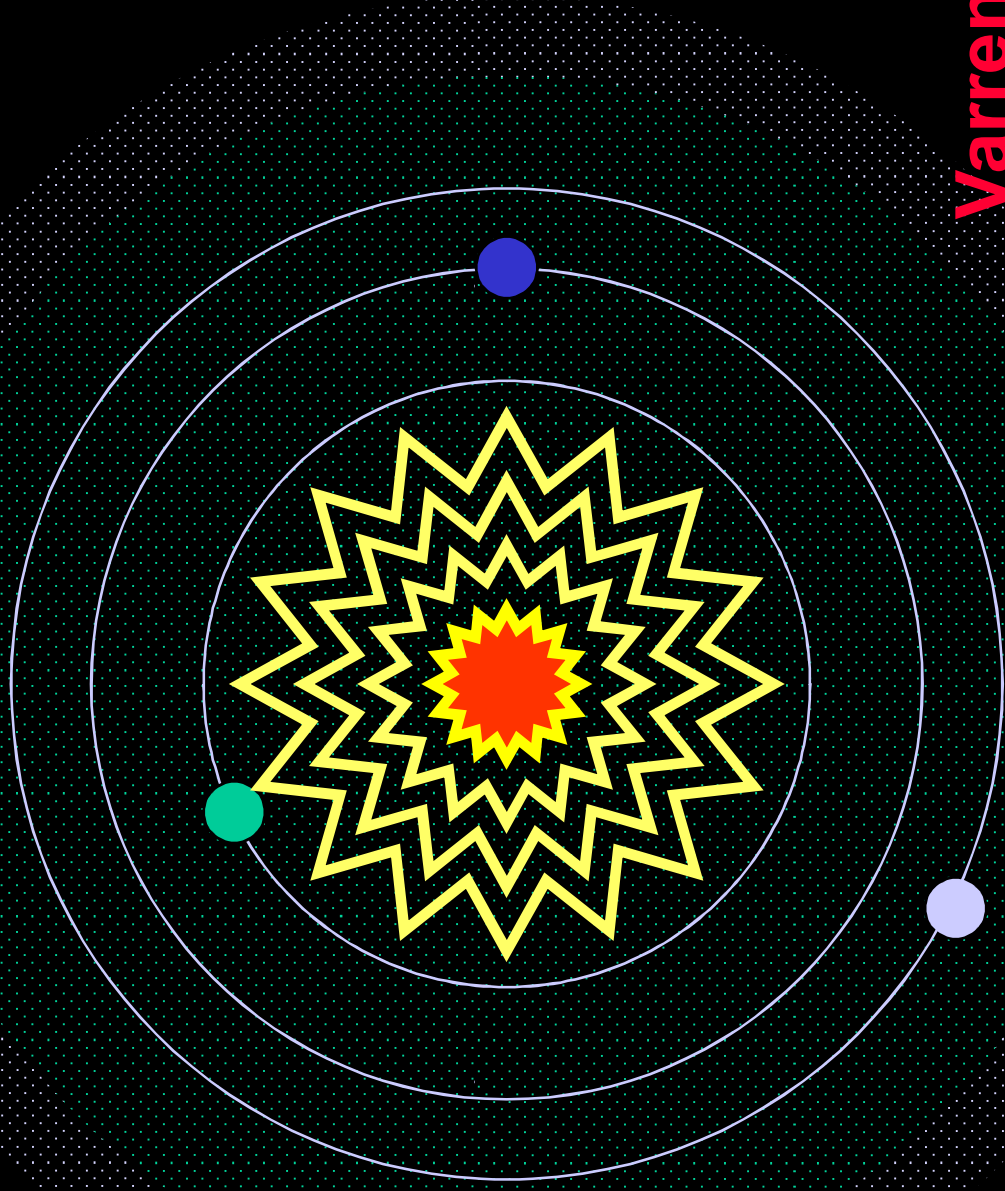
Sistema Planetário “Sujo”



Vento Solar



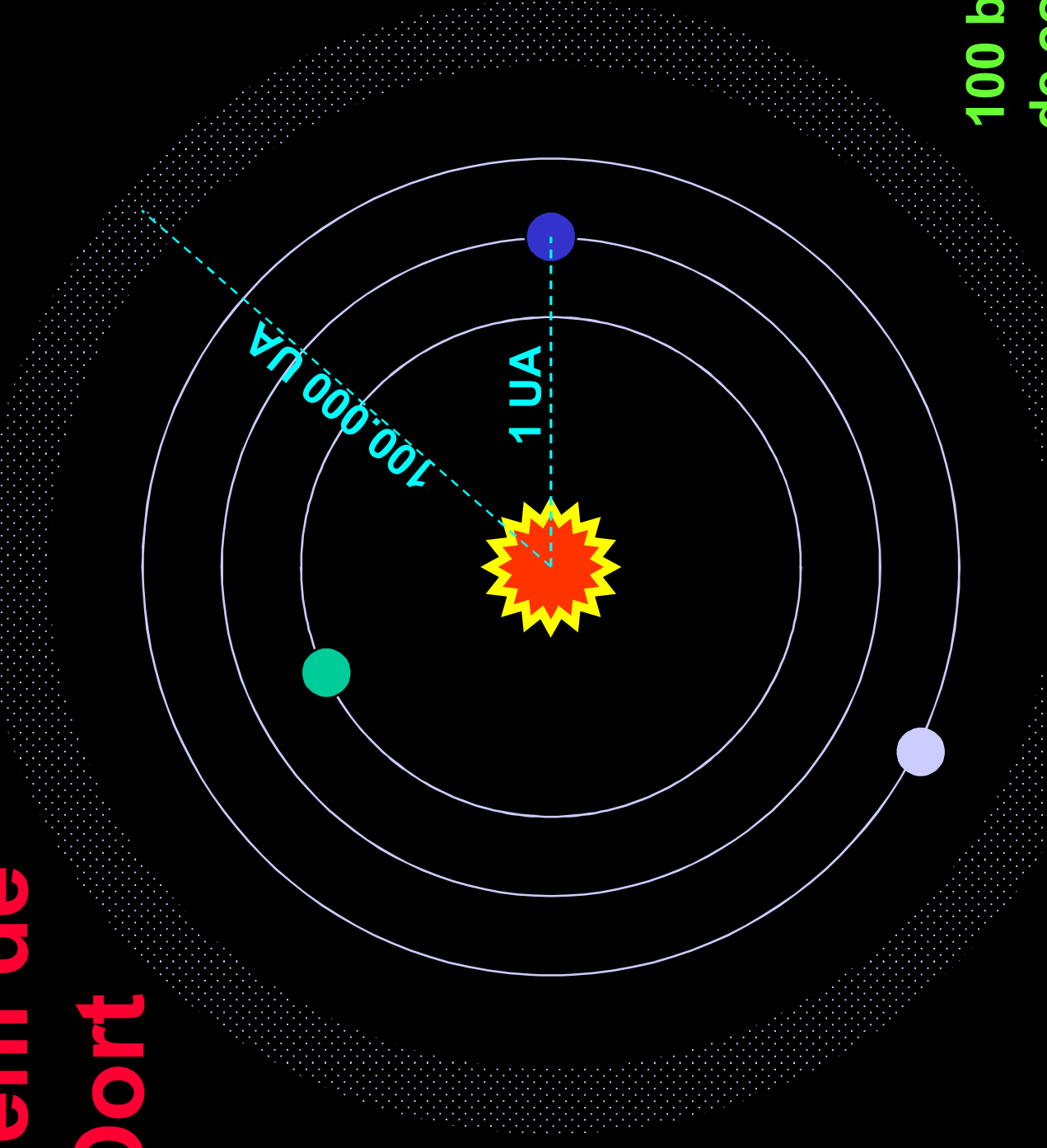
Vento Solar



**Varrendo
as imediações
do Sol.**

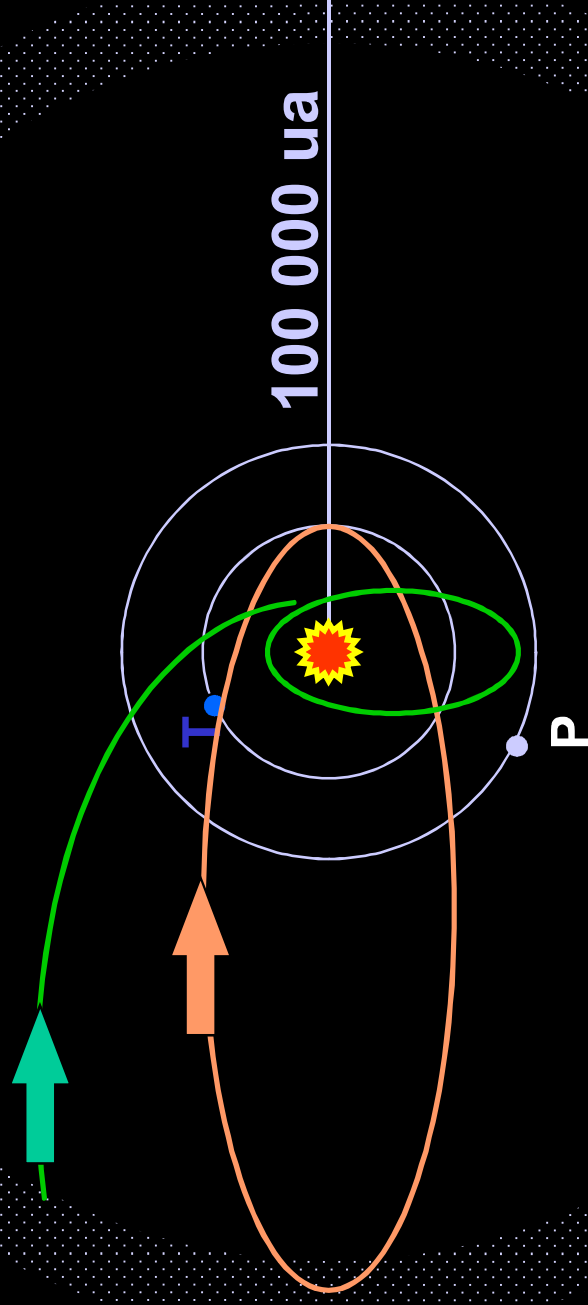
Nuvem de Oort

100 bilhões
de cometas



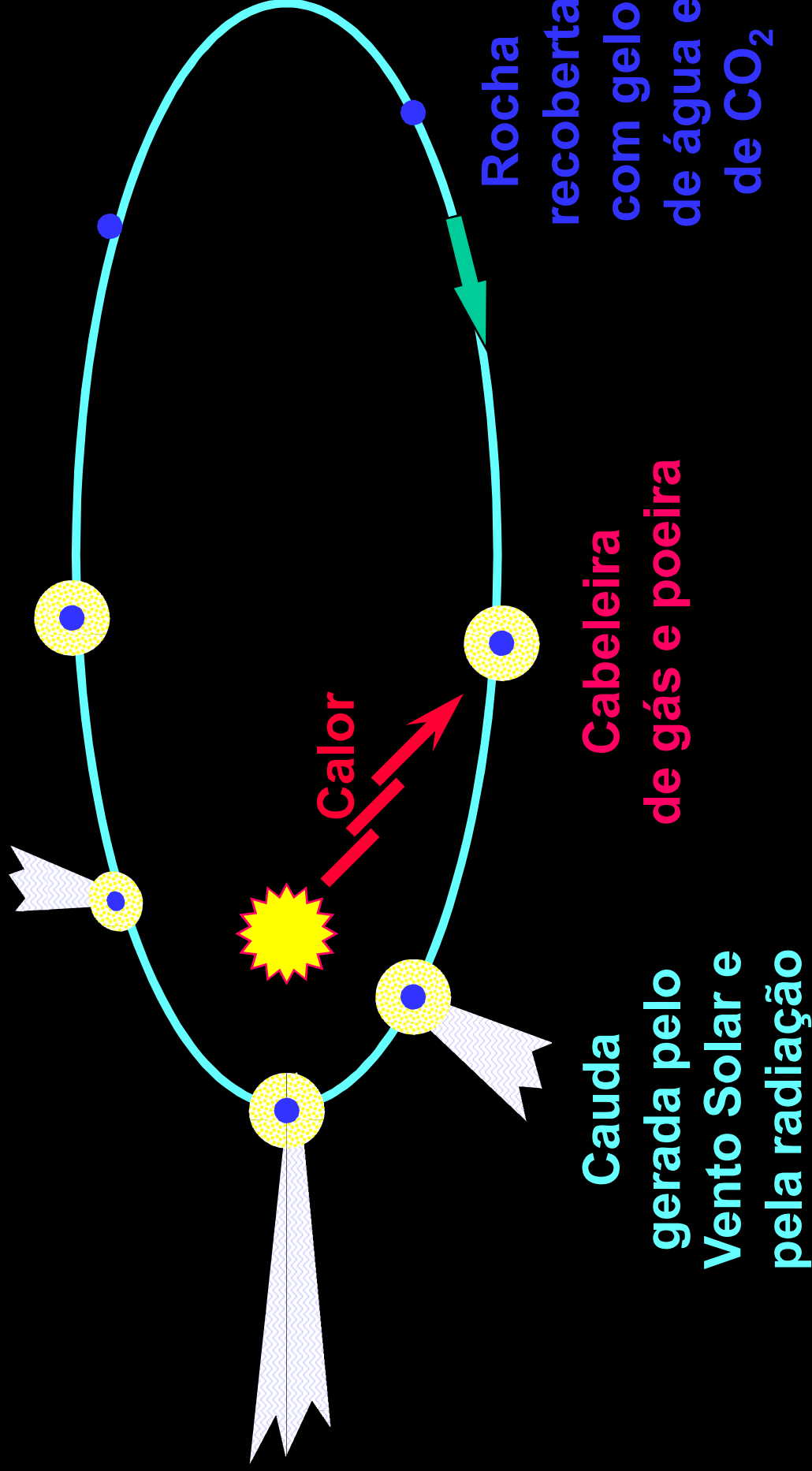
Origem dos Cometas

Distância
entre Sol e Terra:
1 Unidade Astronômica



100 bilhões
de cometas

Estrutura de um cometa

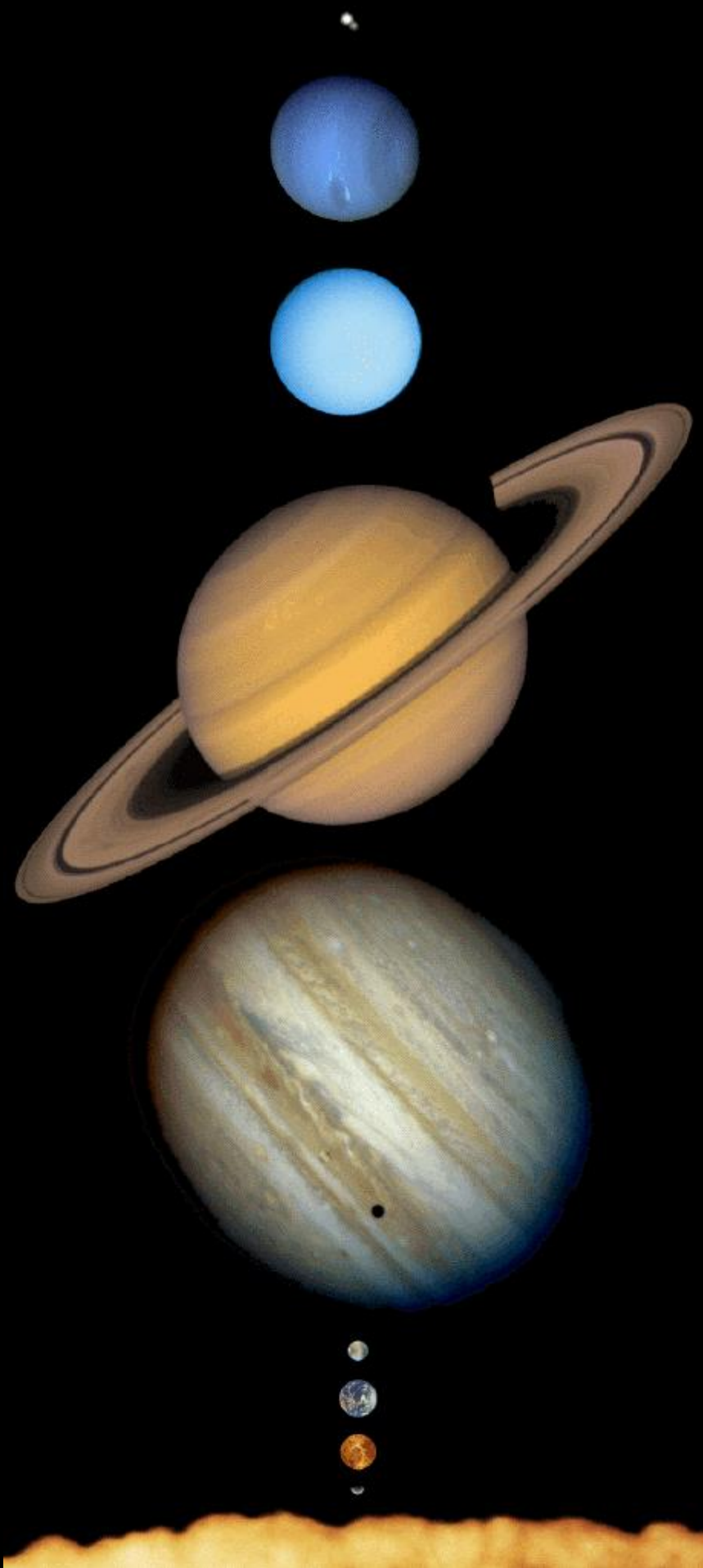




**Cometa
West**

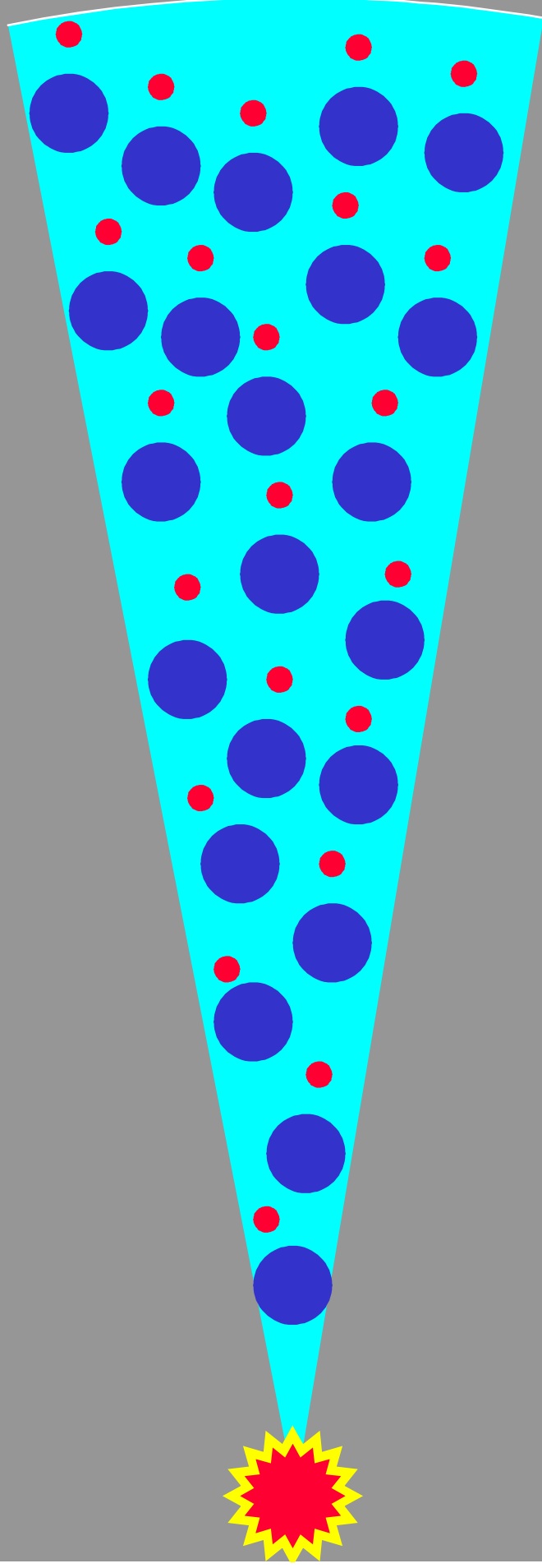
**Como se formou e
evoluiu a Terra ?**

Sistema Solar



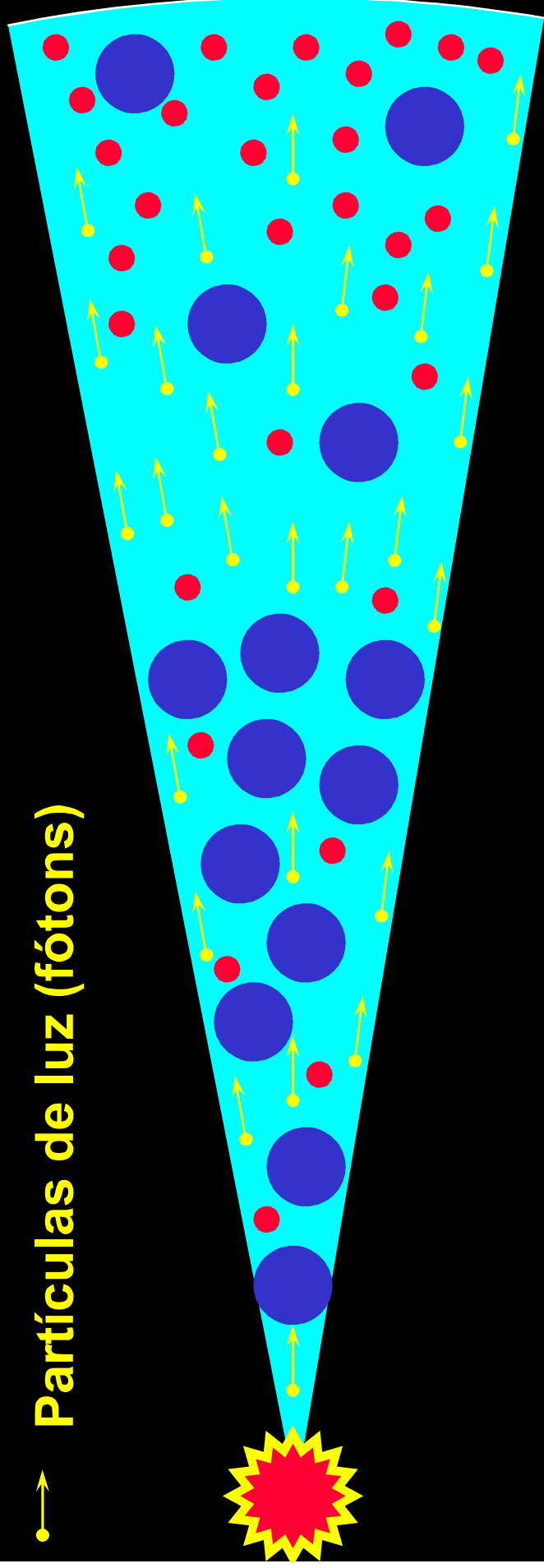
Distribuição inicial dos elementos químicos do Sistema Solar

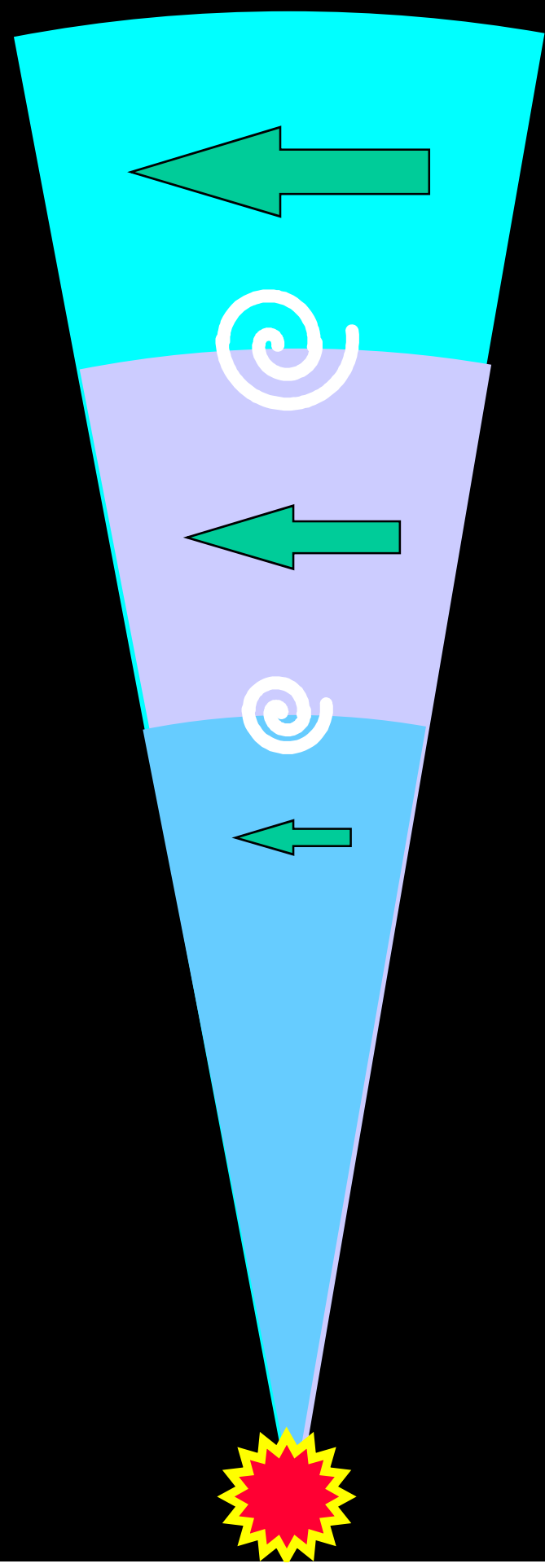
- Elementos pesados
- Elementos leves



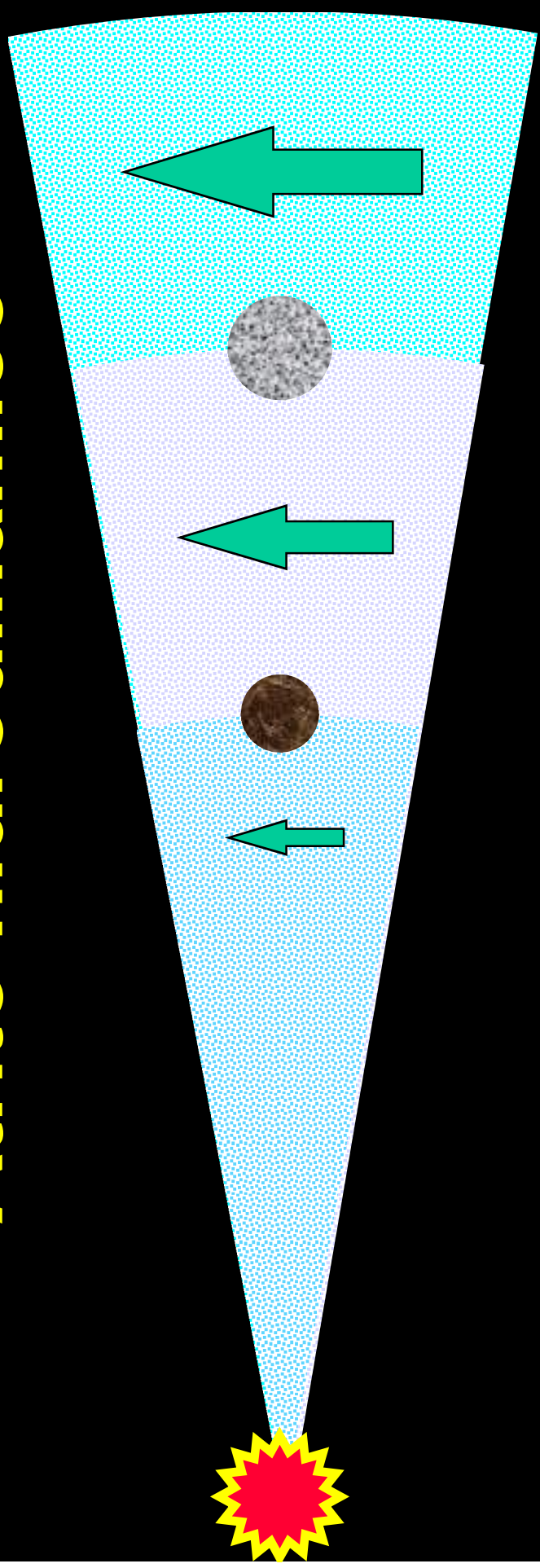
Redistribuição dos elementos dependendo de seus pesos atômicos

- Elementos pesados
- Elementos leves
- Partículas de luz (fótons)



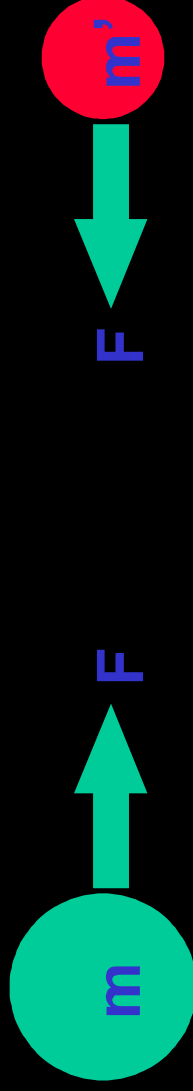


Atrito hidrodinâmico

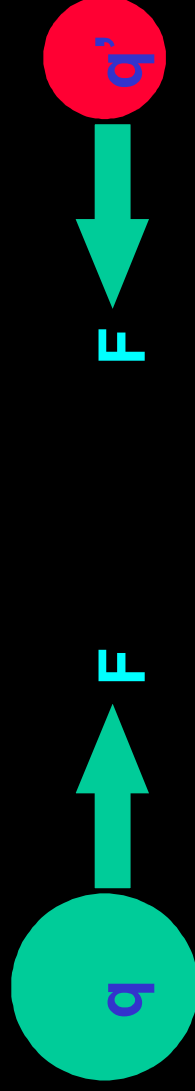


As 4 forças da natureza

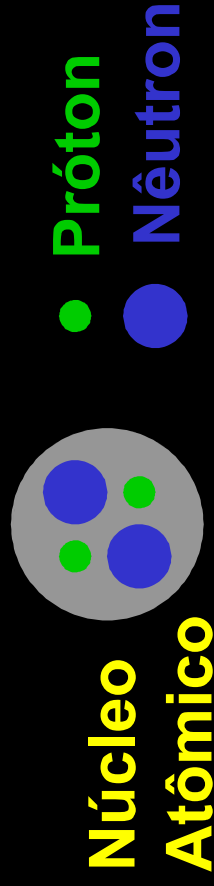
GRAVITACIONAL: ocorre entre dois corpos com massas



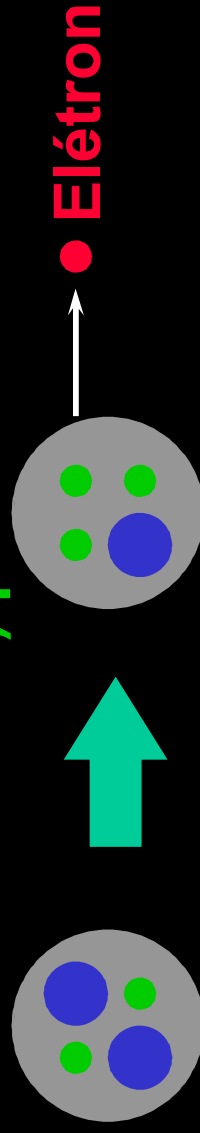
ELETROMAGNÉTICA: associada com cargas elétricas/fótons



FORTE: (intranuclear) mantém o núcleo atômico agregado

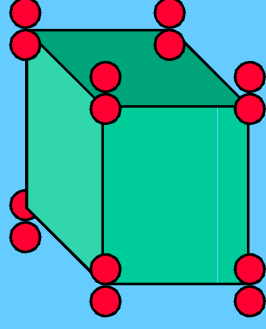
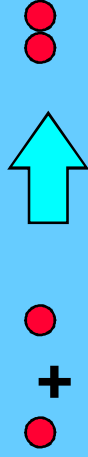


FRACA: (decaimento beta) permite a radiatividade beta



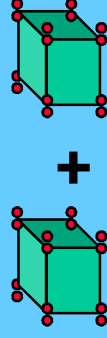
Átomos, moléculas, grãos, planetesimais

Átomos Molécula

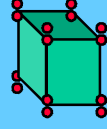


Estrutura
cristalina
ou amorfa

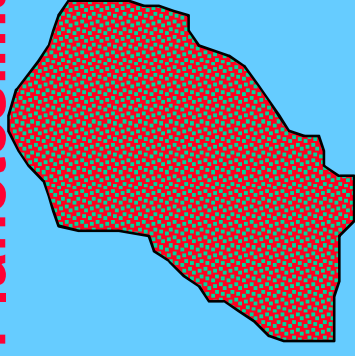
Grão



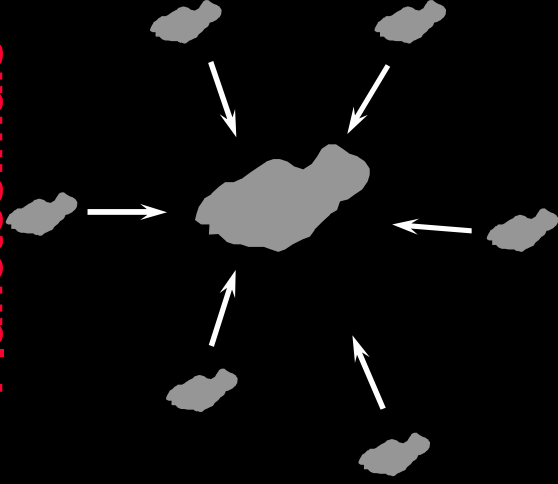
+



Planetesimal



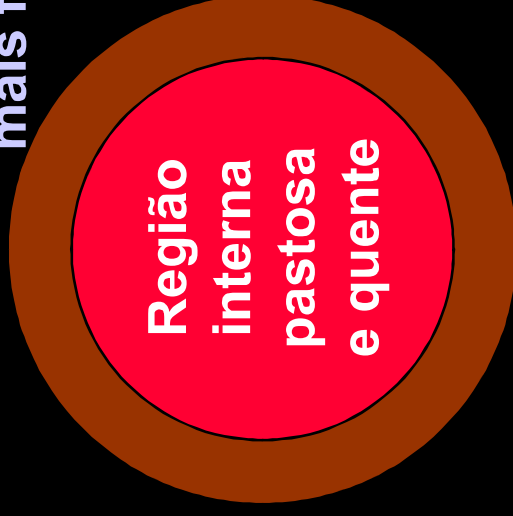
Agregação de Planetesimais

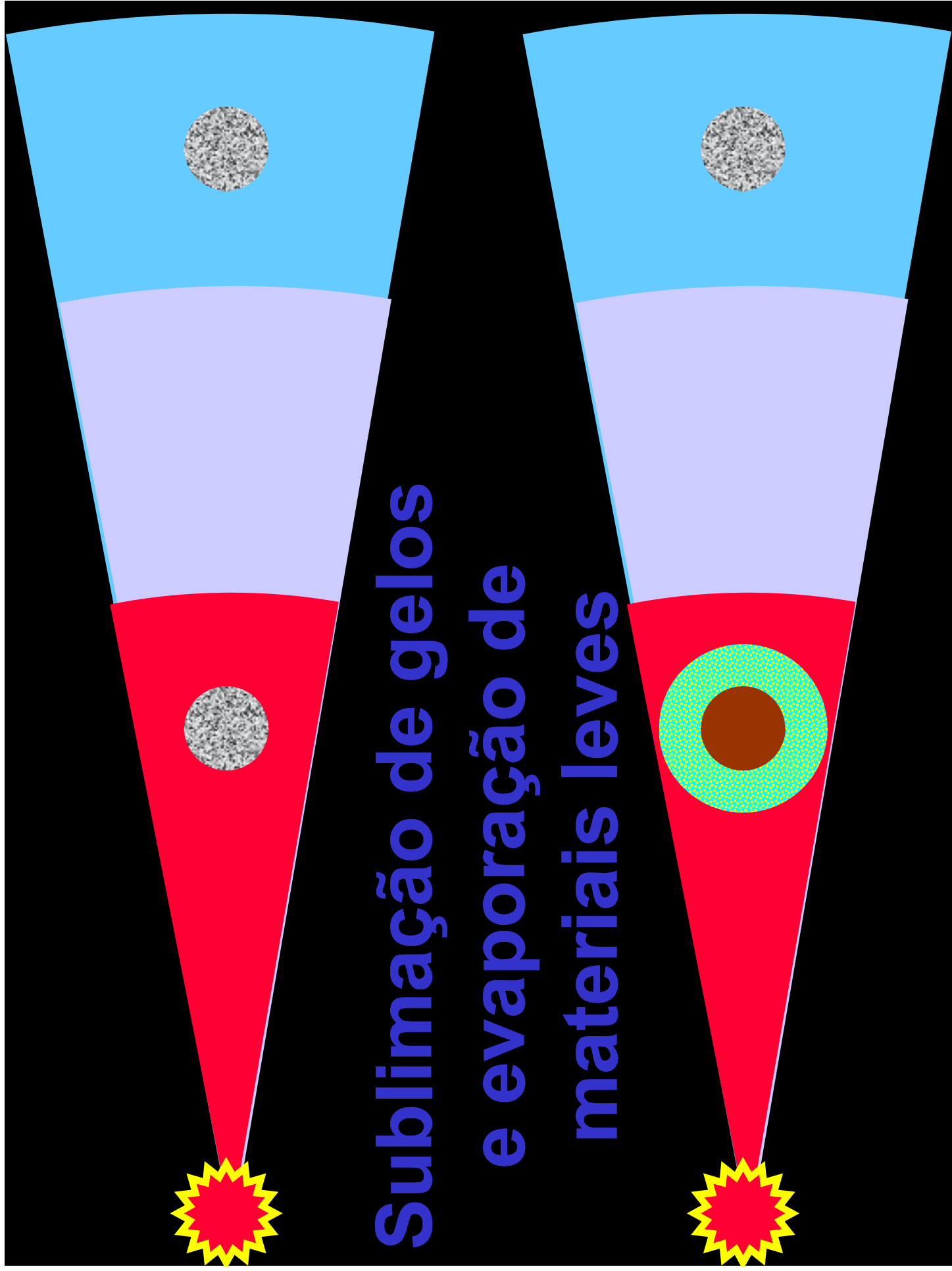


Formação da Terra



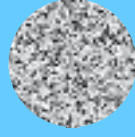
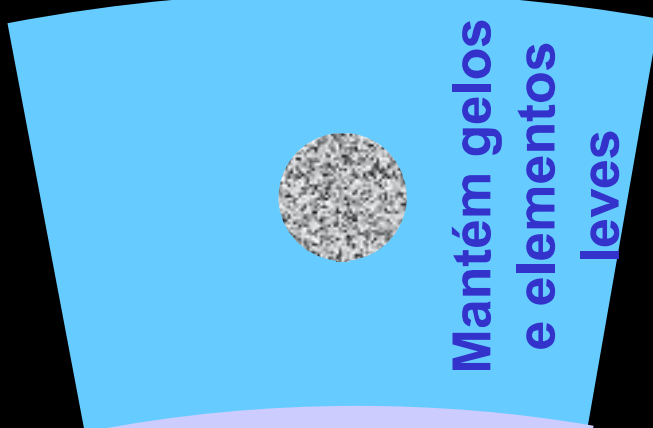
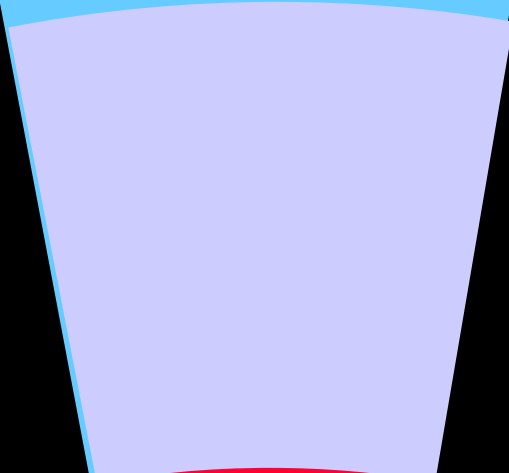
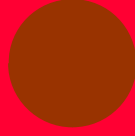
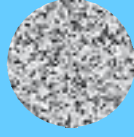
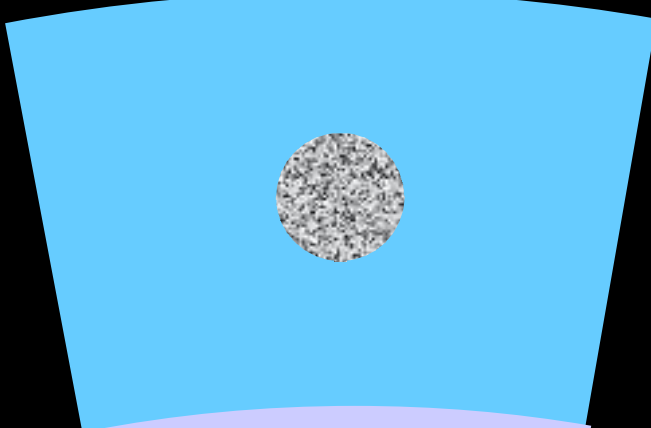
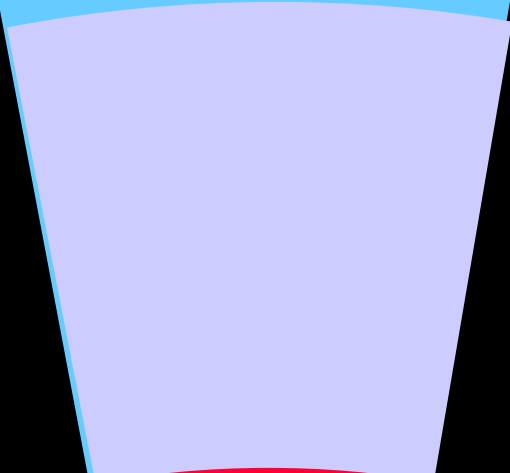
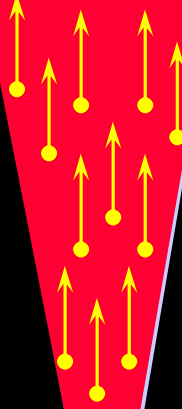
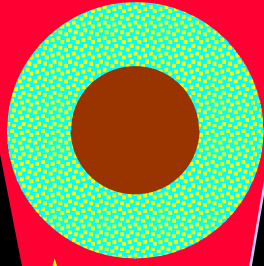
Crosta sólida e mais fria





**Sublimação de gelos
e evaporação de
materiais leves**

**Limpeza de gelos e
materiais leves**



**Perde gelos
e elementos leves**

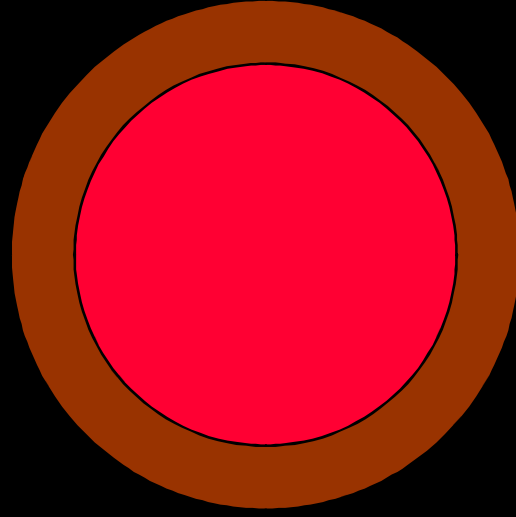
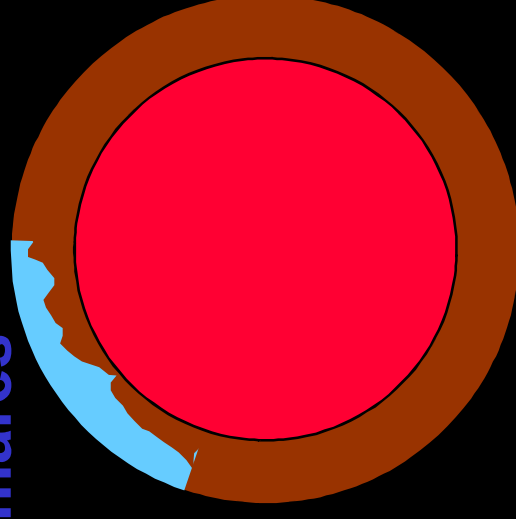
**Mantém gelos
e elementos
leves**

Molhando a Terra...

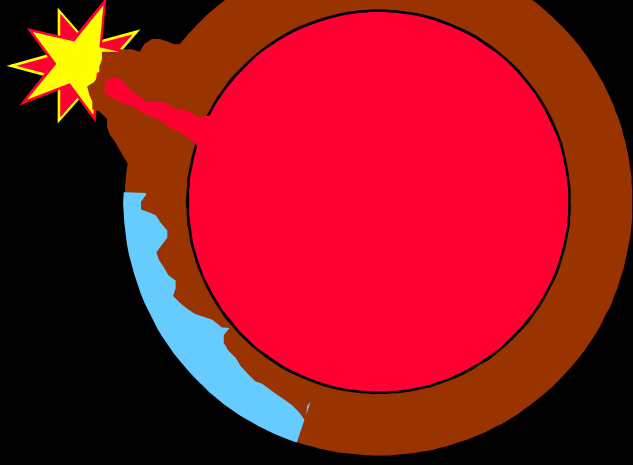
Planetesimal
(ou cometa)
de gelo



Formando
os mares



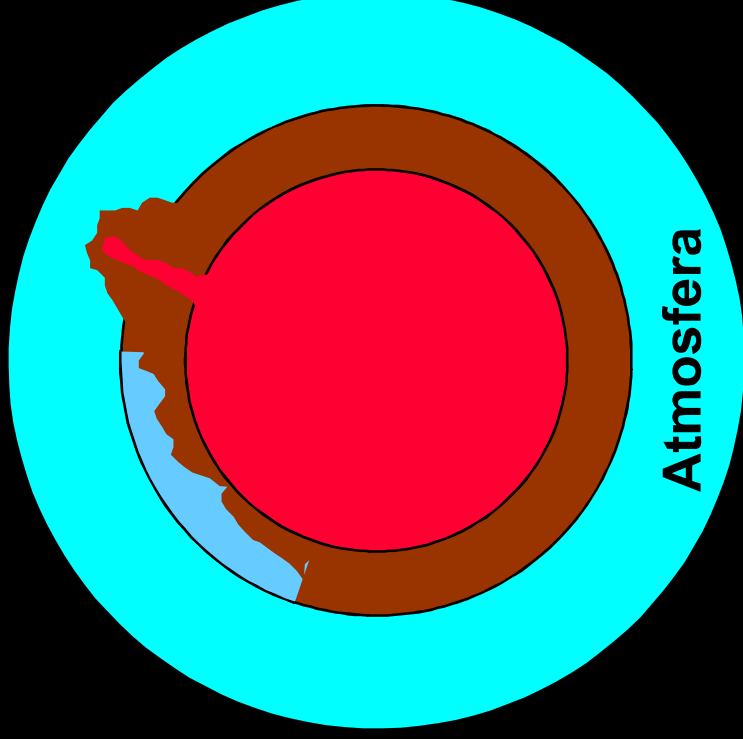
Criando a atmosfera da Terra



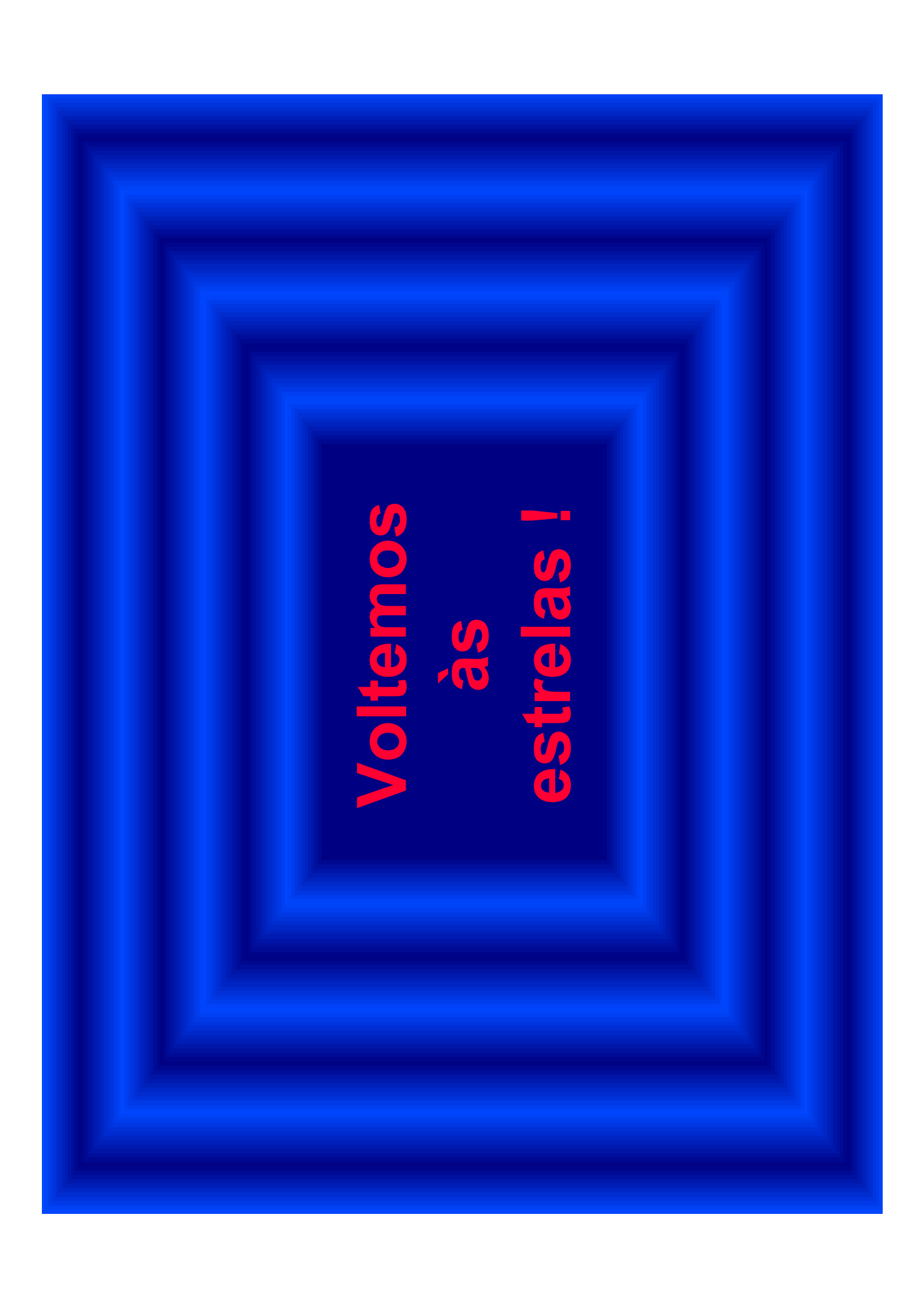
**Erupção
vulcânica**



**Liberou gases
presos nos
materiais do
interior da Terra
(não havia oxigênio livre)**



Atmosfera



**Voltemos
às
estrelas !**

Plêiades

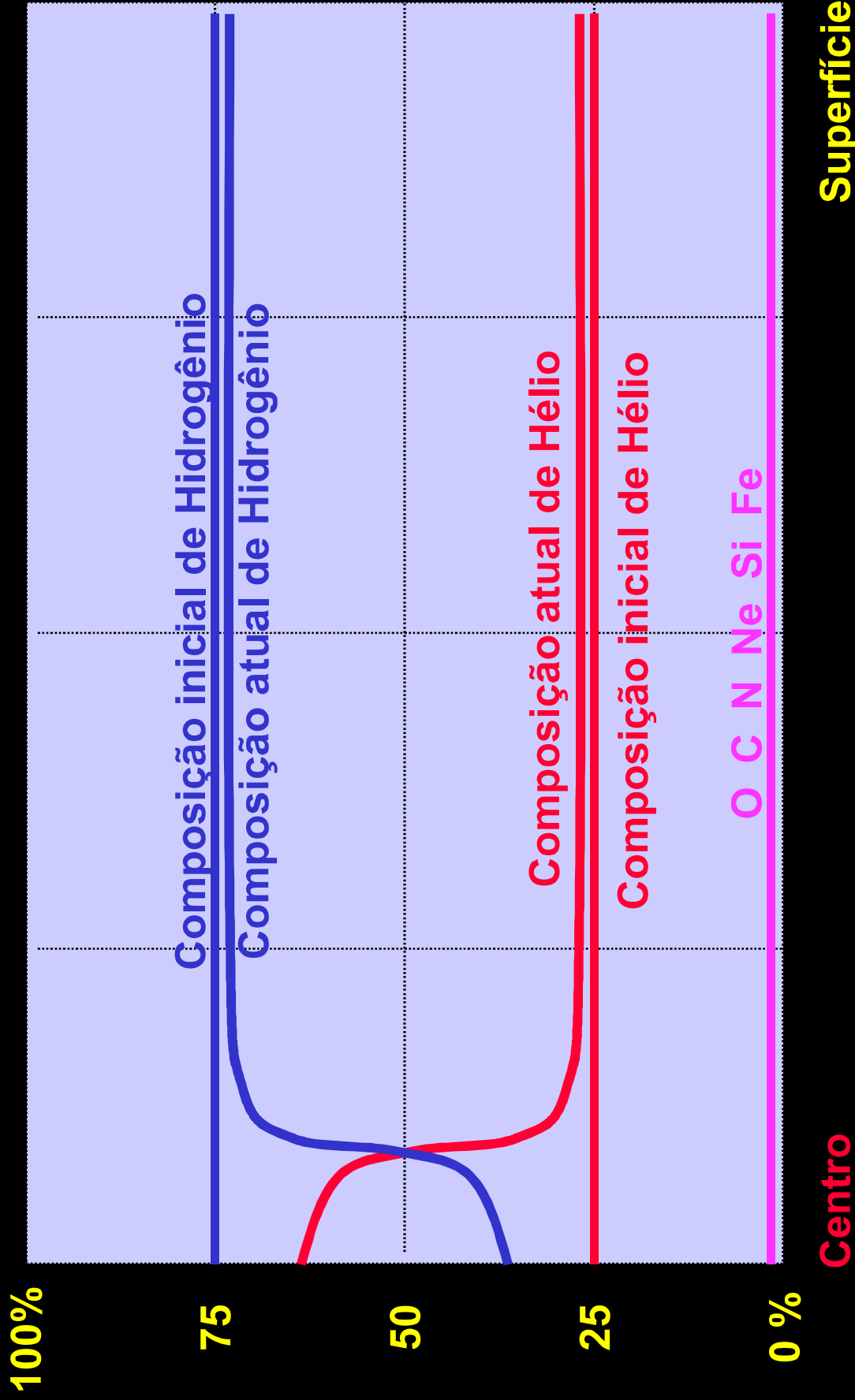
Estrelas Jovens



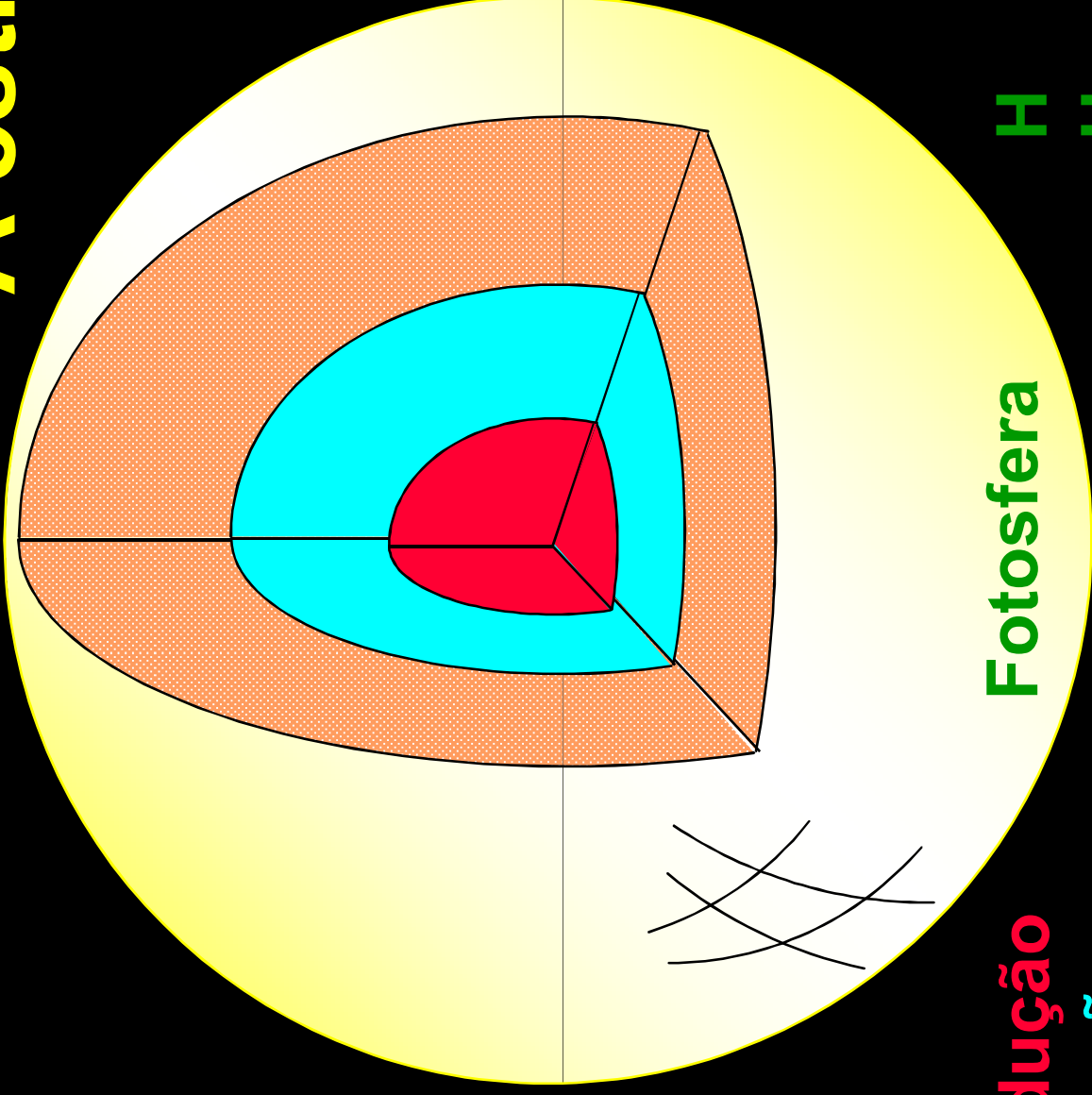
Sol



Mudanças na composição química do Sol



A estrela Sol



● **Condução**

● **Radiação**

● **Convecção**

Fotosfera

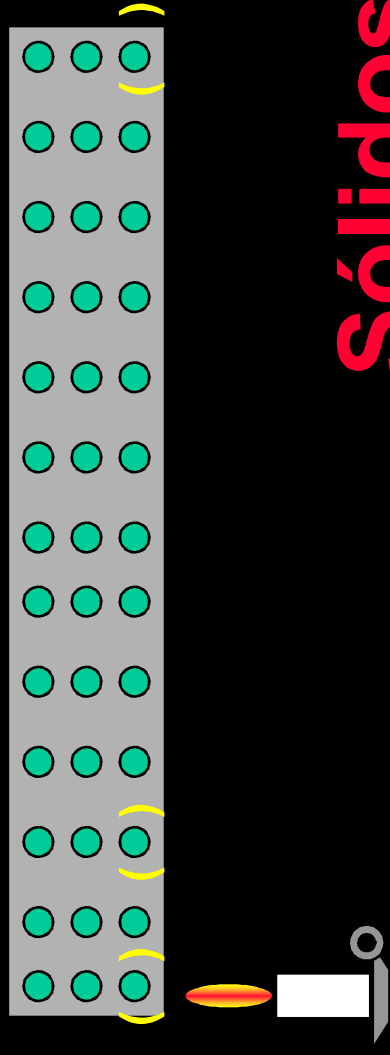
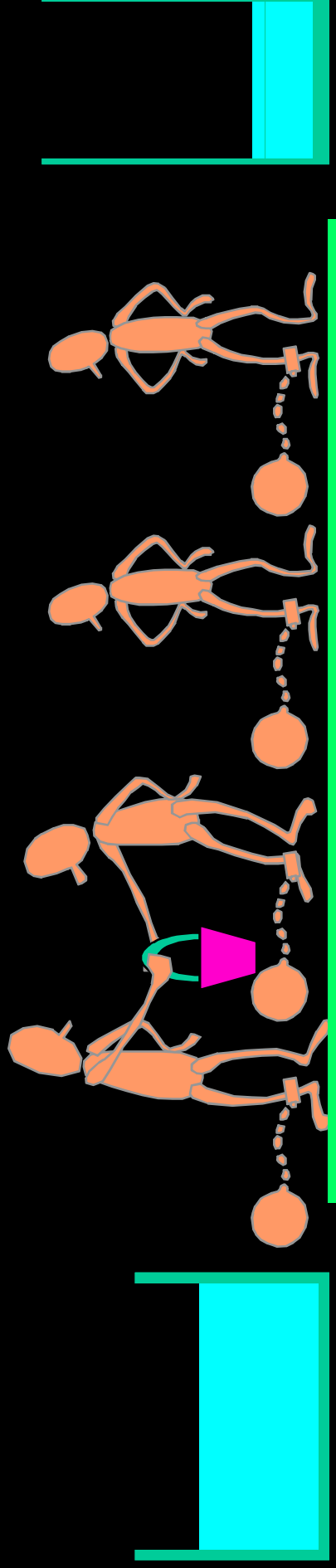
Composição

H = 73,0%

He = 24,5%

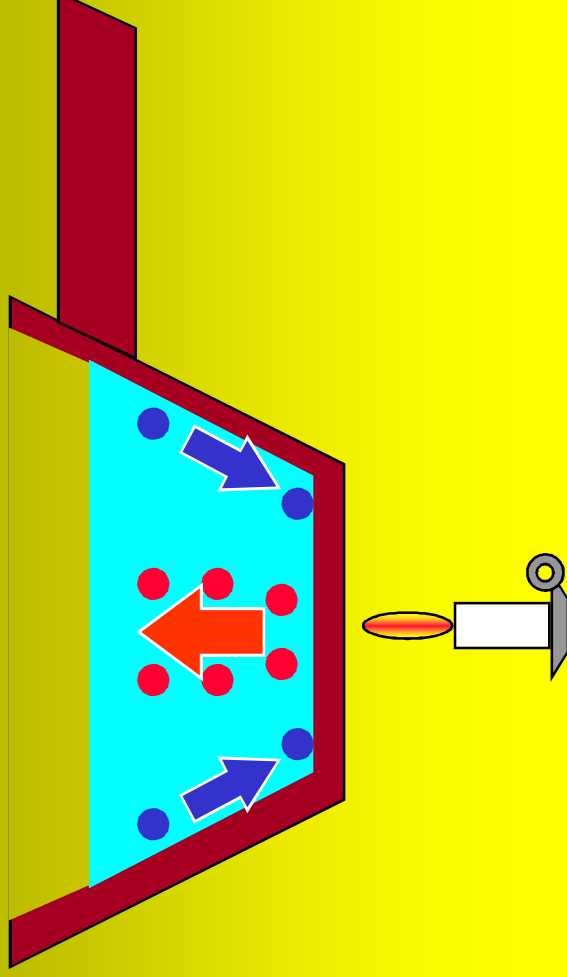
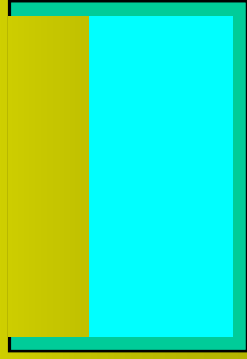
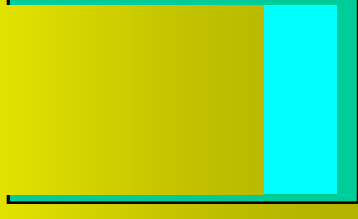
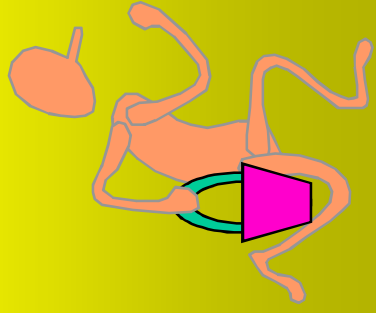
Outros = 02,5%

Propagação do calor por Condução



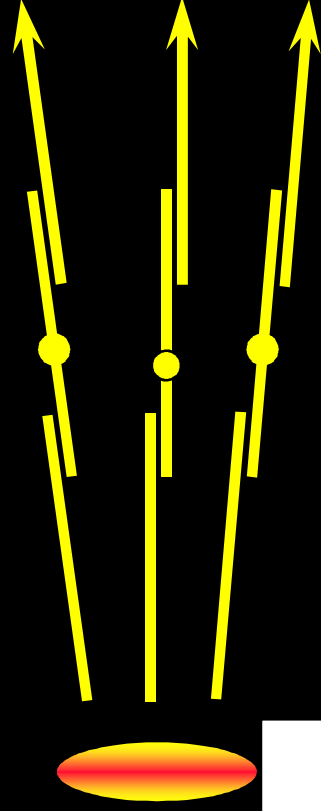
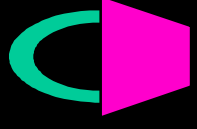
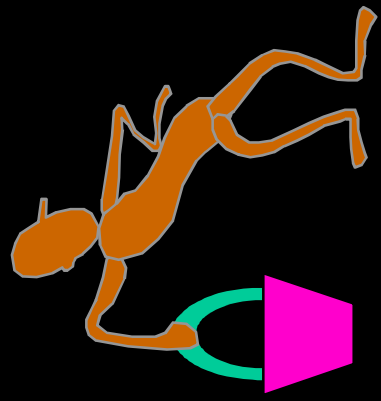
Sólidos

Propagação de calor por Convecção



Fluidos

Propagação de calor por Irradiação

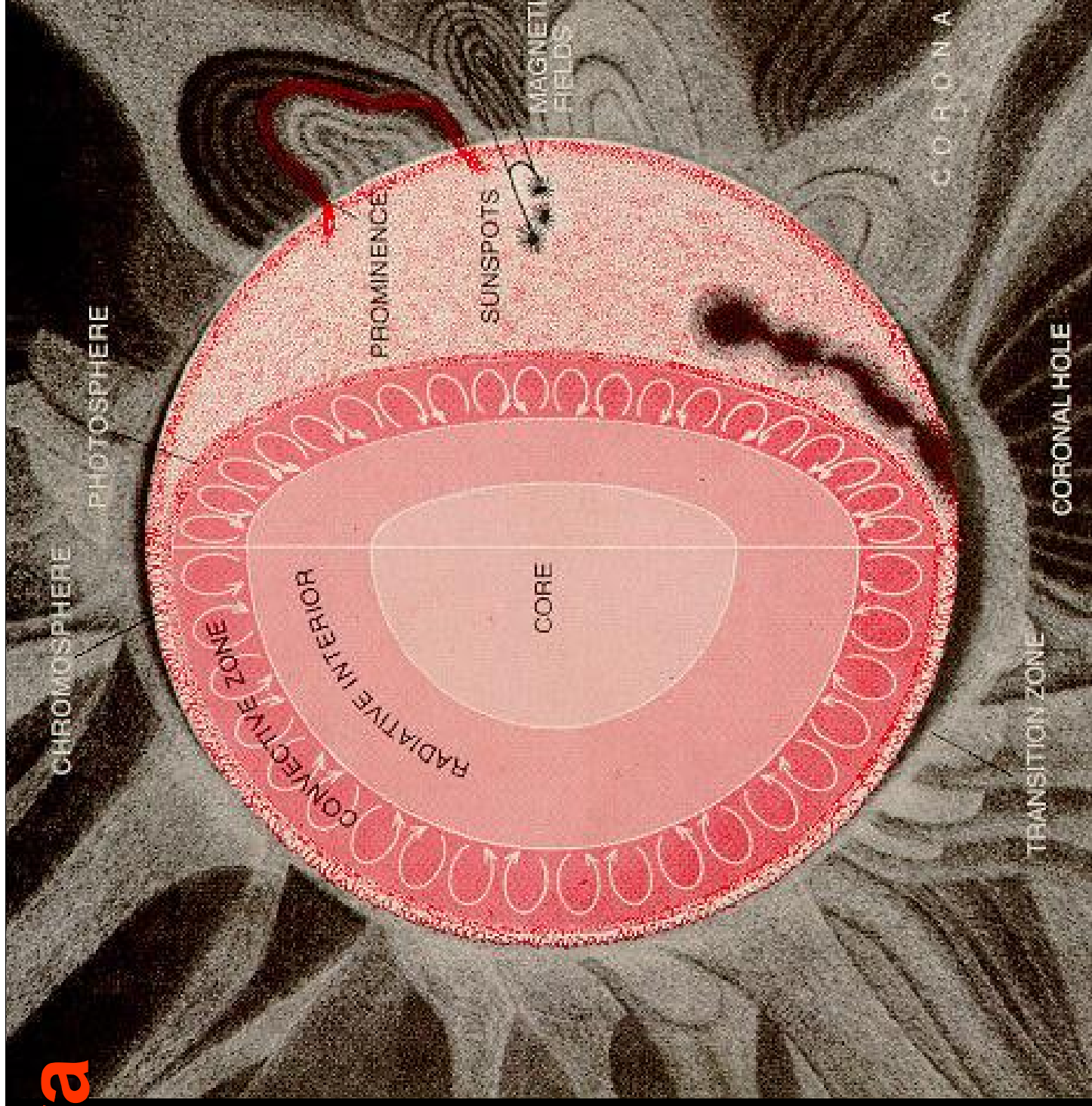


Fóton



Qualquer meio

Estrutura do Sol



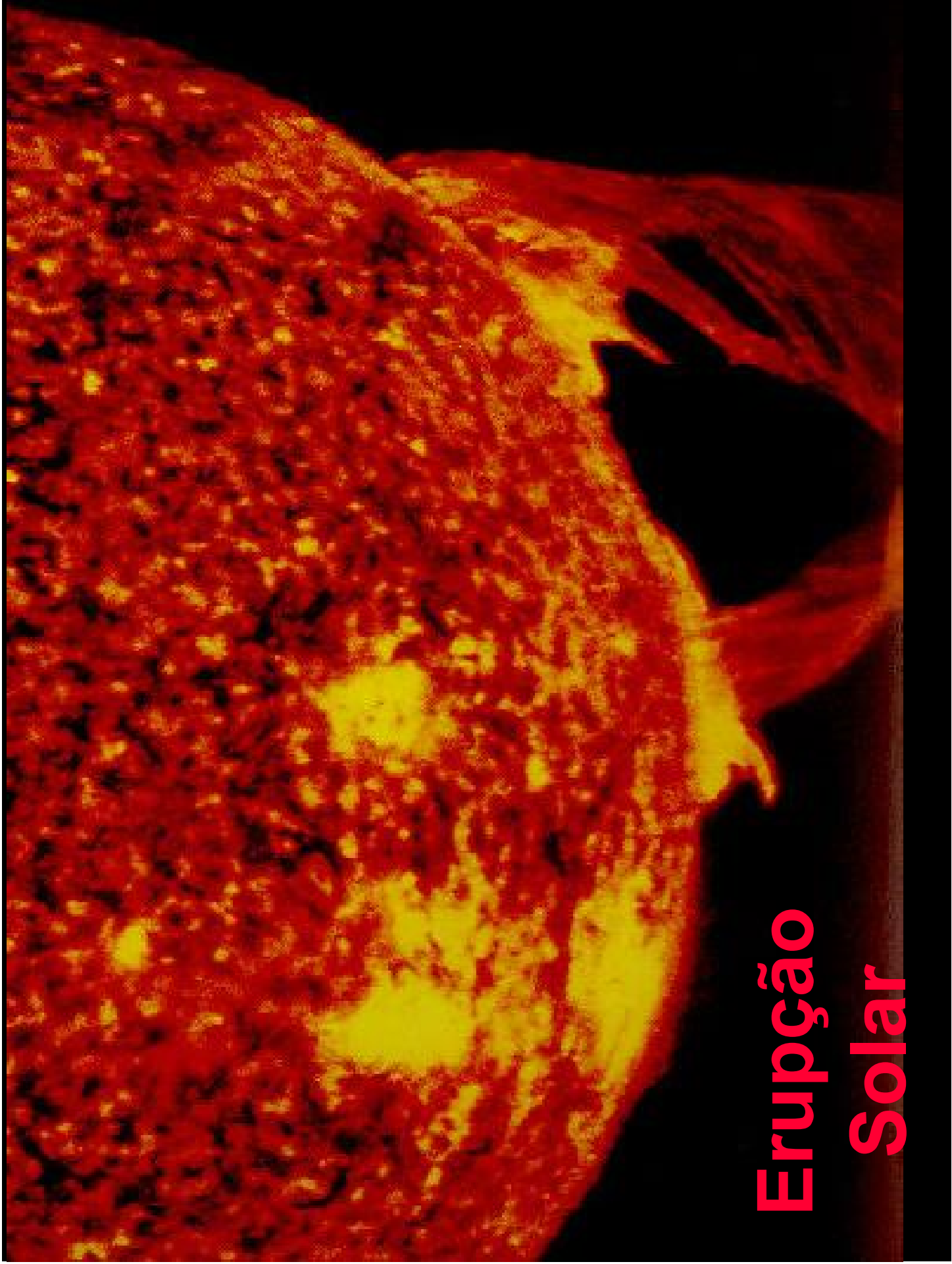
Estrutura Alveolar do Sol

- **Regiões Claras**
 - Subida de gás quente
- **Regiões Escuras**
 - Descida de gás frio

**Diâmetro típico de
um alvéolo:**

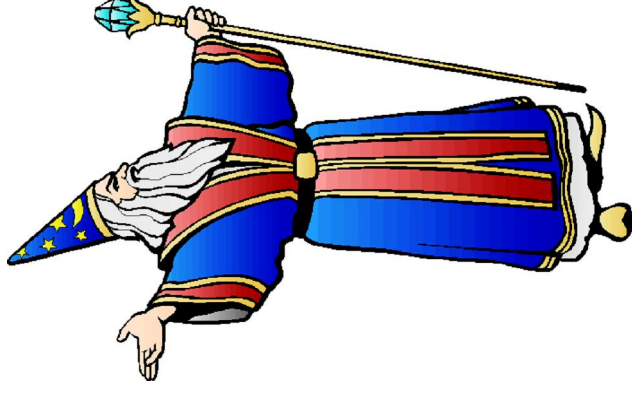
1000 km



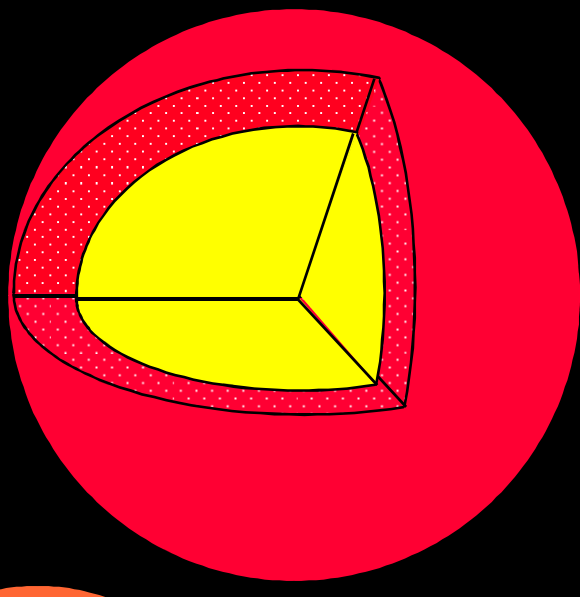
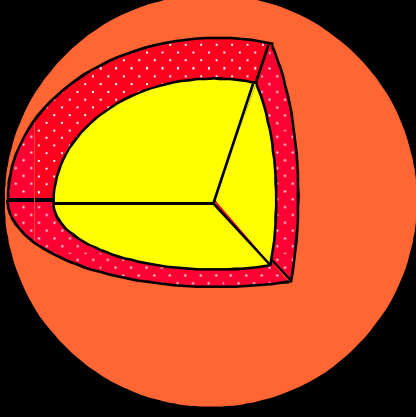
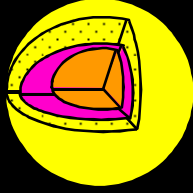
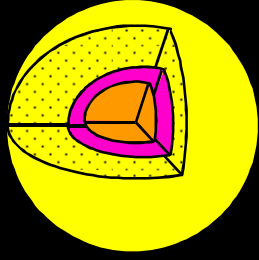
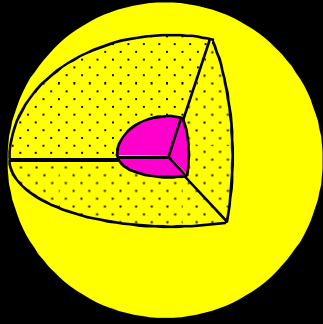


Erupção Solar

E ... qual será o futuro do Sol ?

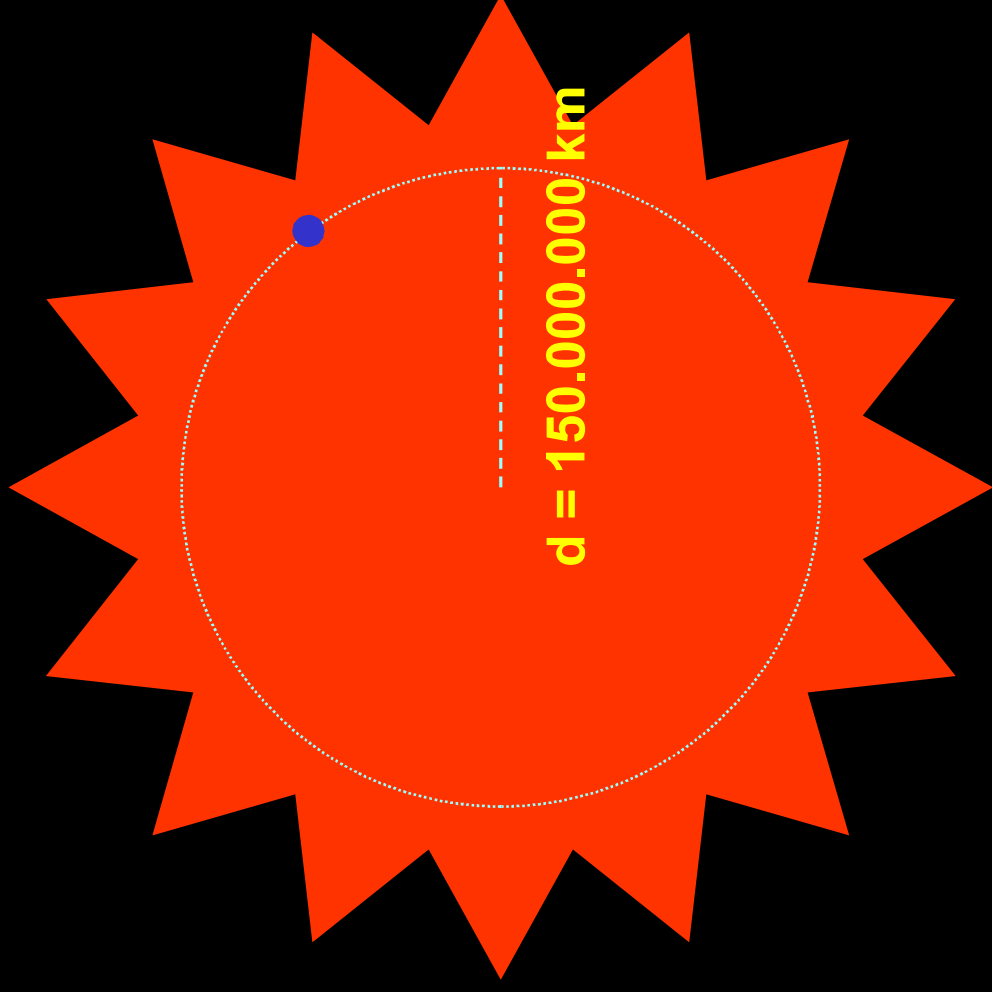


Evolução para Gigante Vermelha

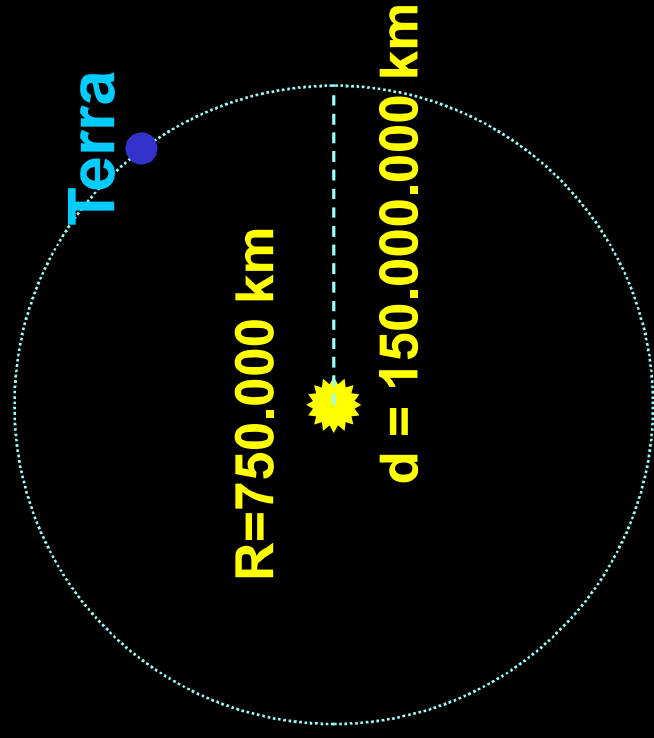


Região de fusão nuclear

A gigante vermelha Sol

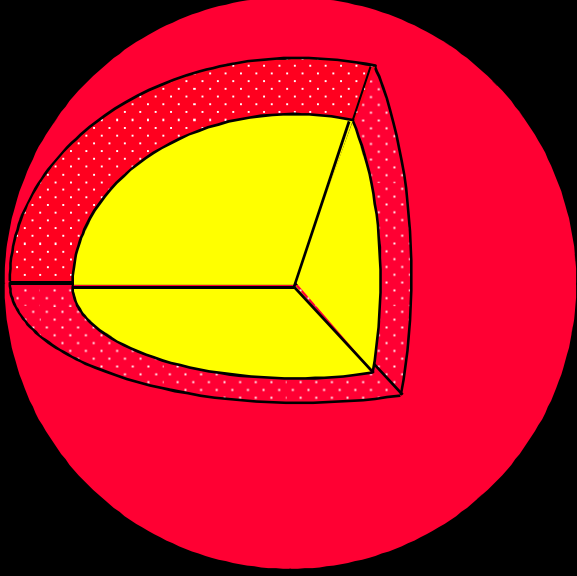


Num futuro muito distante
(4,5 bilhões de anos)

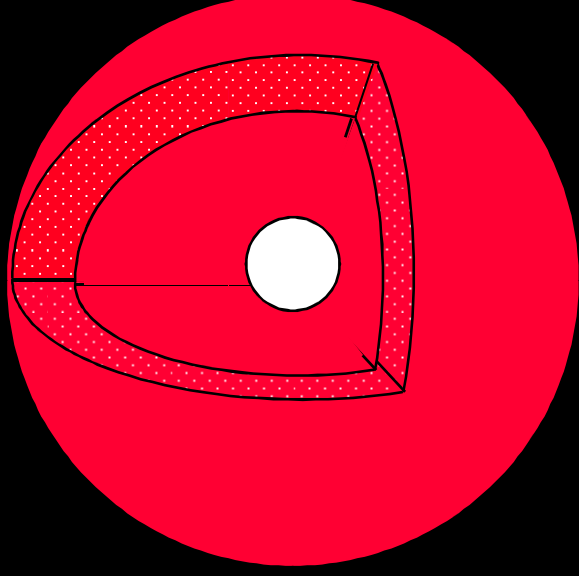


Hoje

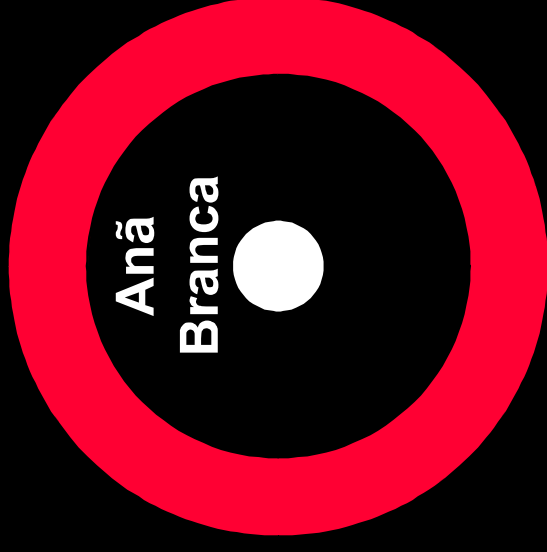
Evolução para Nebulosa Planetária



Gigante vermelha



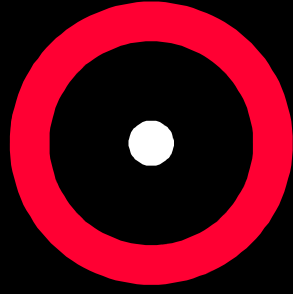
Nebulosa Planetária



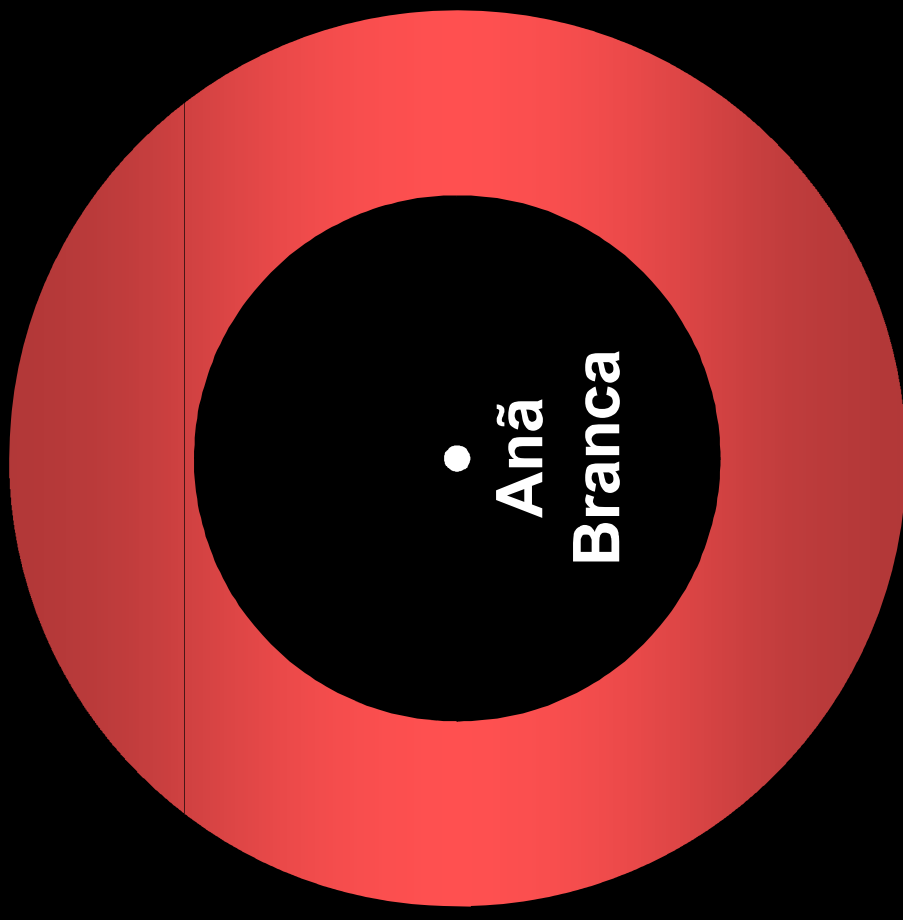
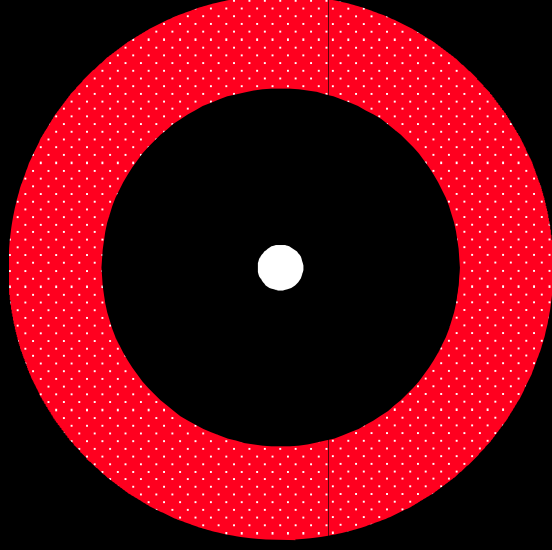
Anã Branca

Visão de uma
Nebulosa Planetária

Evolução para Anã Branca



Gases que vão se espalhar
pelo meio interestelar



Ocorre:

- ◆ Expansão da Casca
- ◆ Contração do núcleo

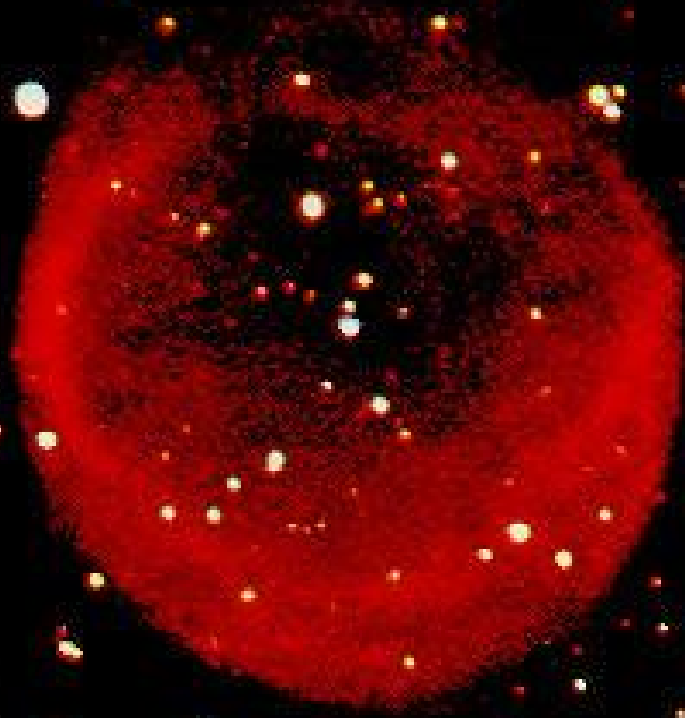
Nebulosa Planetária do Anel

(Constelação da Lira)



Nebulosa Planetária

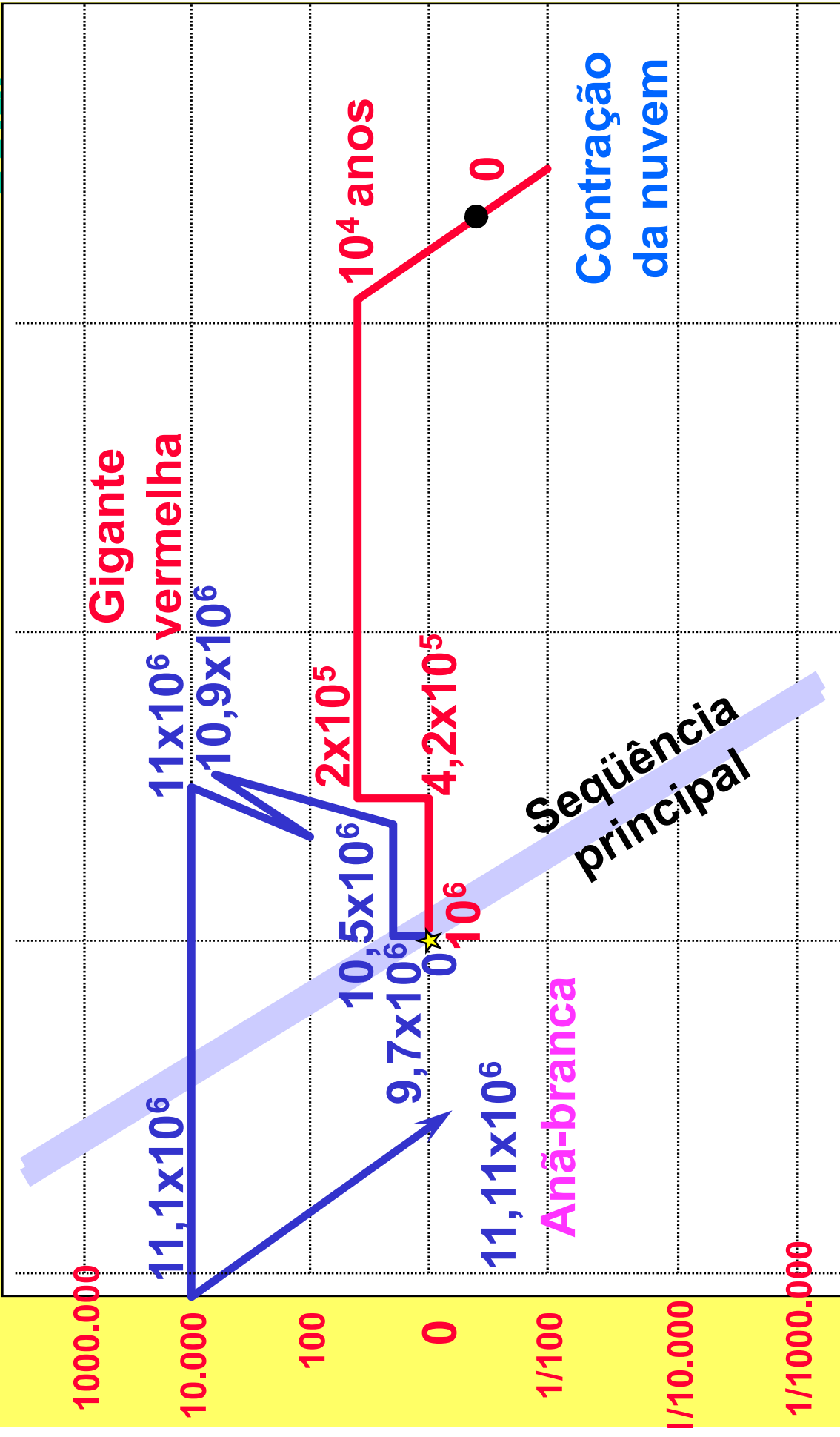
(Constelação da Águia)



Caminho evolutivo das estrelas no diagrama de H-R

HR de uma estrela de 1M_{Solar}

L/L_{Sol}



100.000 K

10.000

1.000

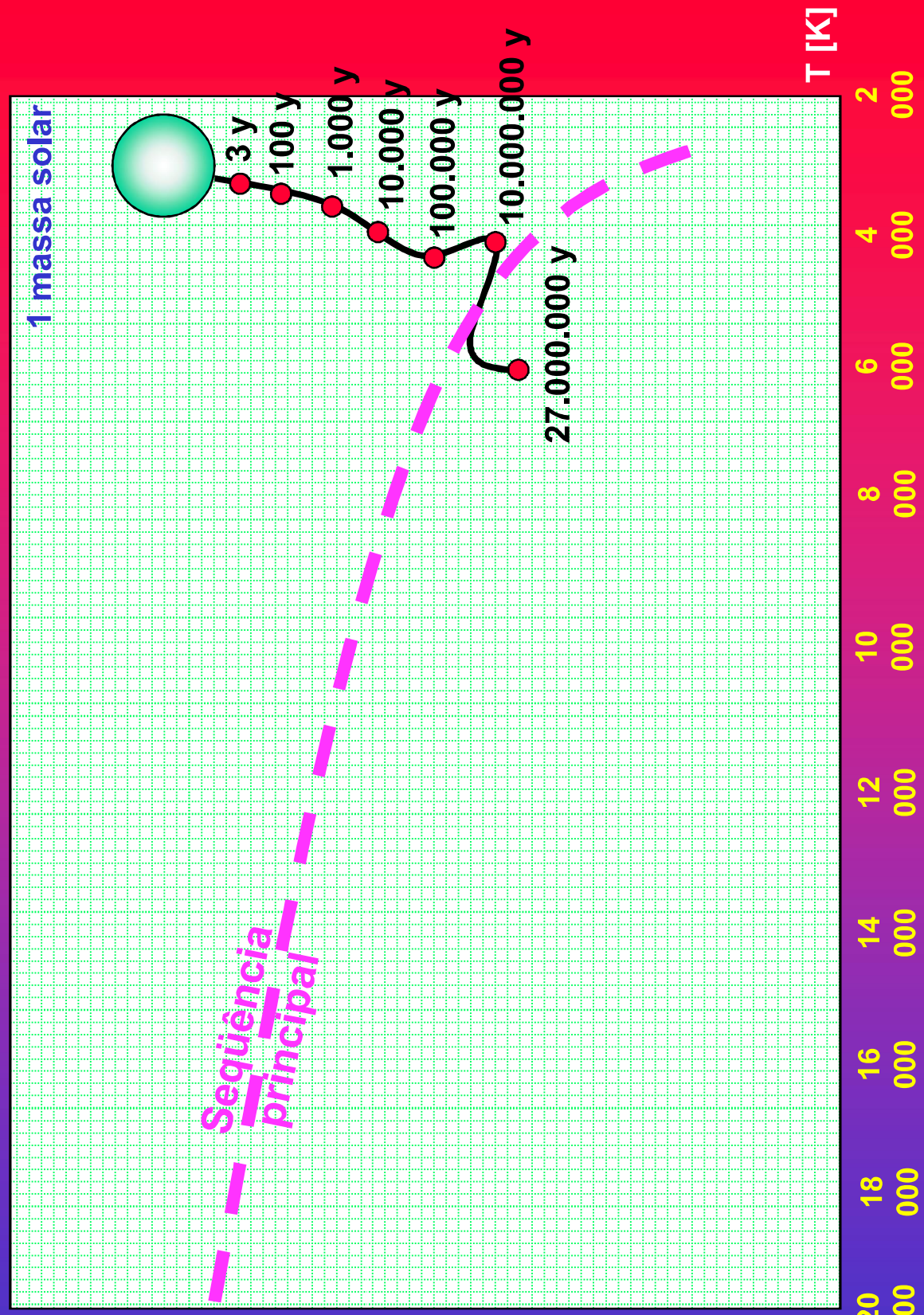
100

10

H-R de uma proto-estrela

L/L_{Sol}

1000.000
100.000
10.000
1.000
100
10
0
1/10
1/100
1/1.000
1/10.000
1/100.000
1/1000.000



HR na e pós-Sequência Principal

L/L_{Sol}

1000.000

100.000

10.000

1.000

100

10

0

1/10

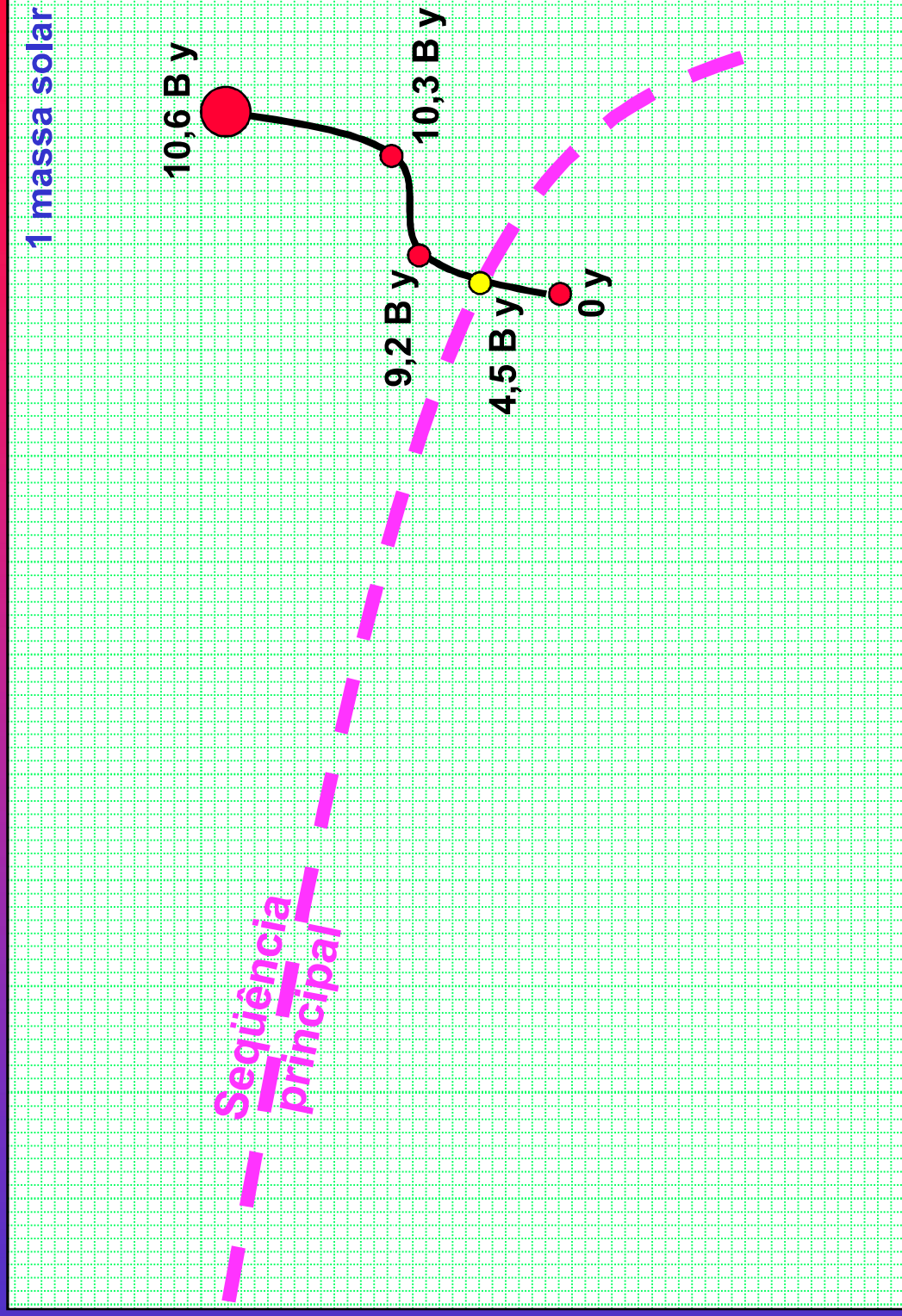
1/100

1/1.000

1/10.000

1/100.000

1/1000.000



T [K]

20 000

18 000

16 000

14 000

12 000

10 000

8 000

6 000

4 000

2 000

HR pós-Gigante Vermelha

L/L_{Sol}

1000.000

100.000

10.000

1.000

100

10

0

1/10

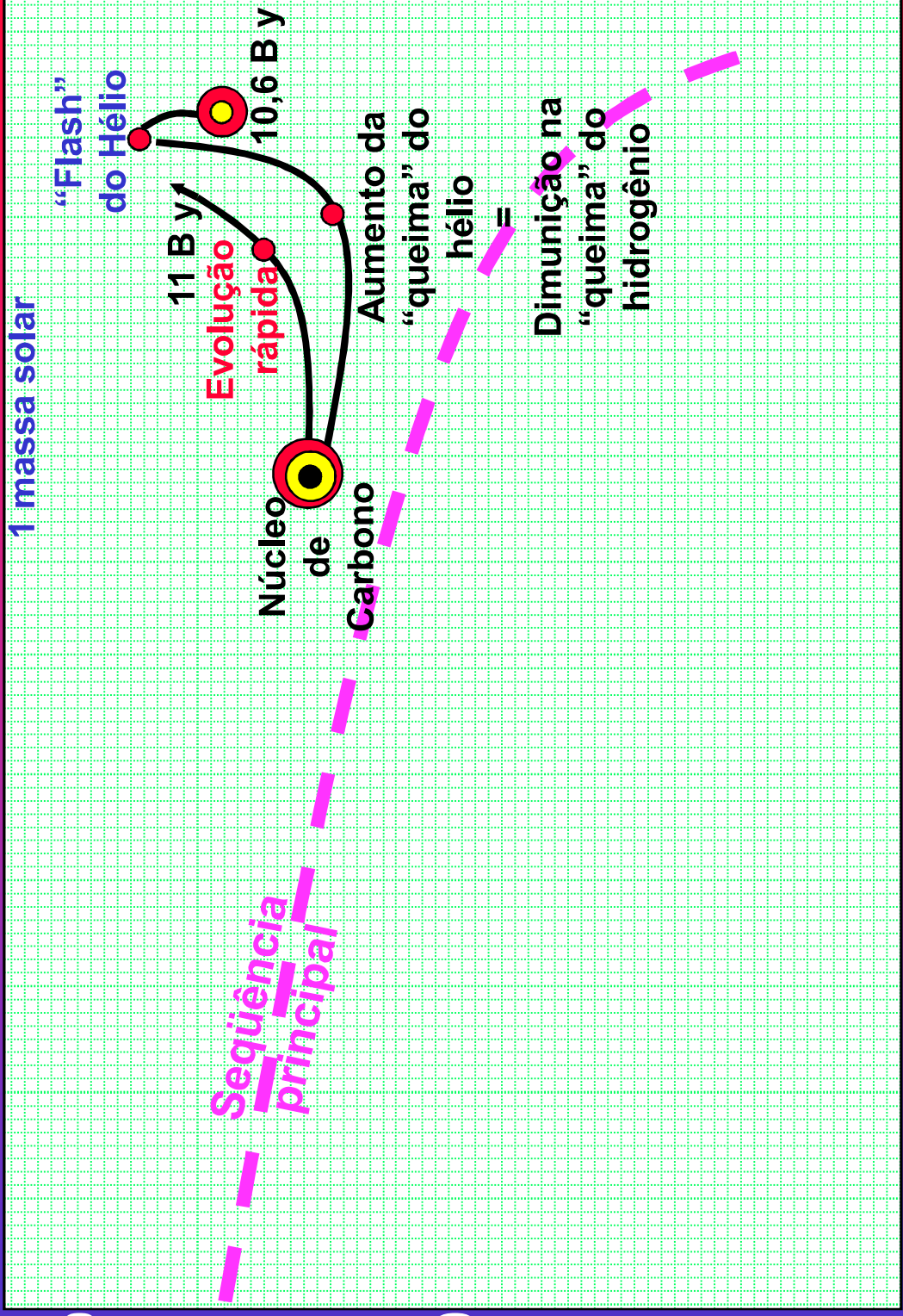
1/100

1/1.000

1/10.000

1/100.000

1/1000.000



1 massa solar

"Flash" do Hélio

11 B y

Evolução rápida

Núcleo de Carbono

Carbono

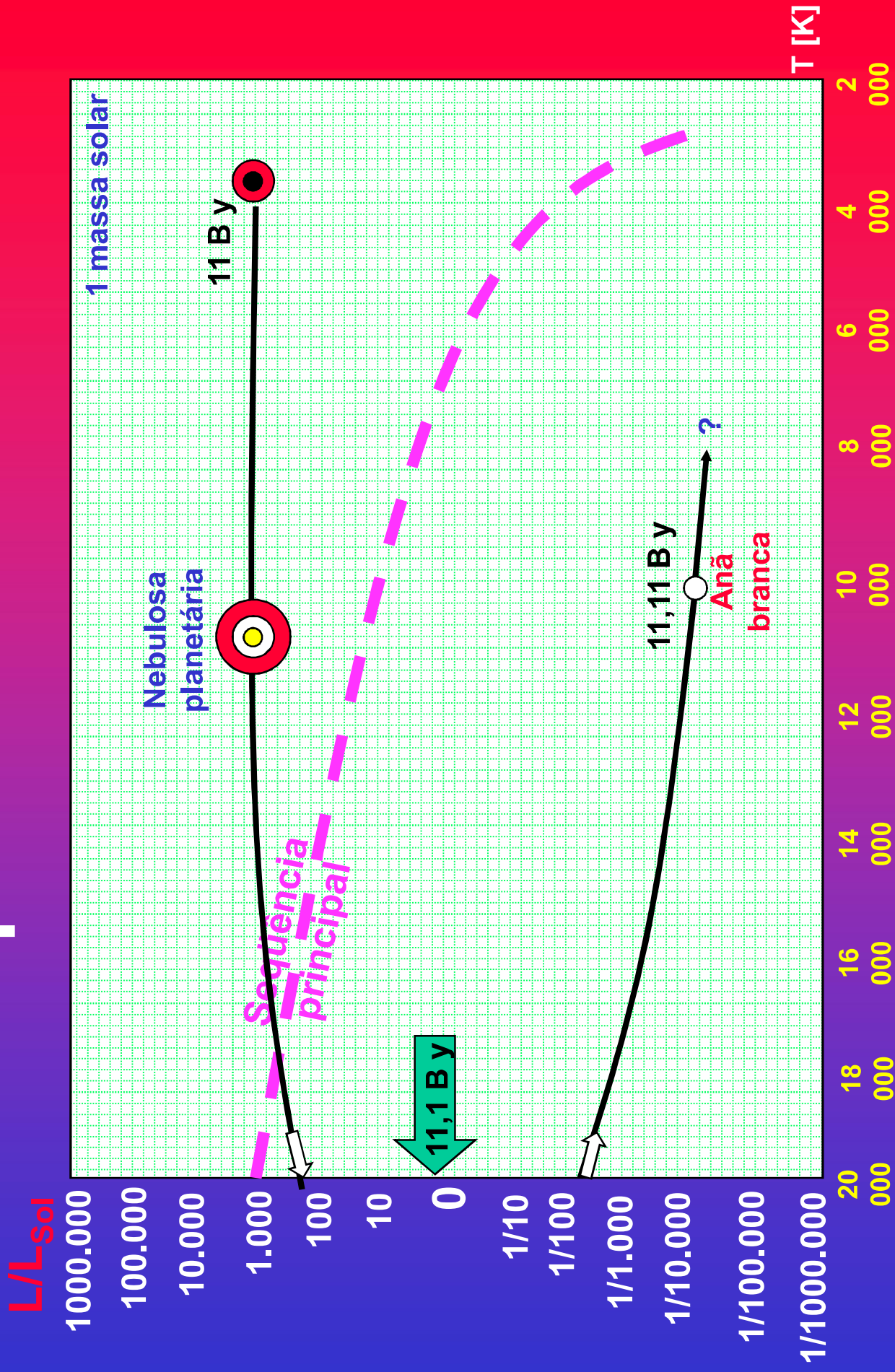
Aumento da "queima" do hélio

Diminuição na "queima" do hidrogênio

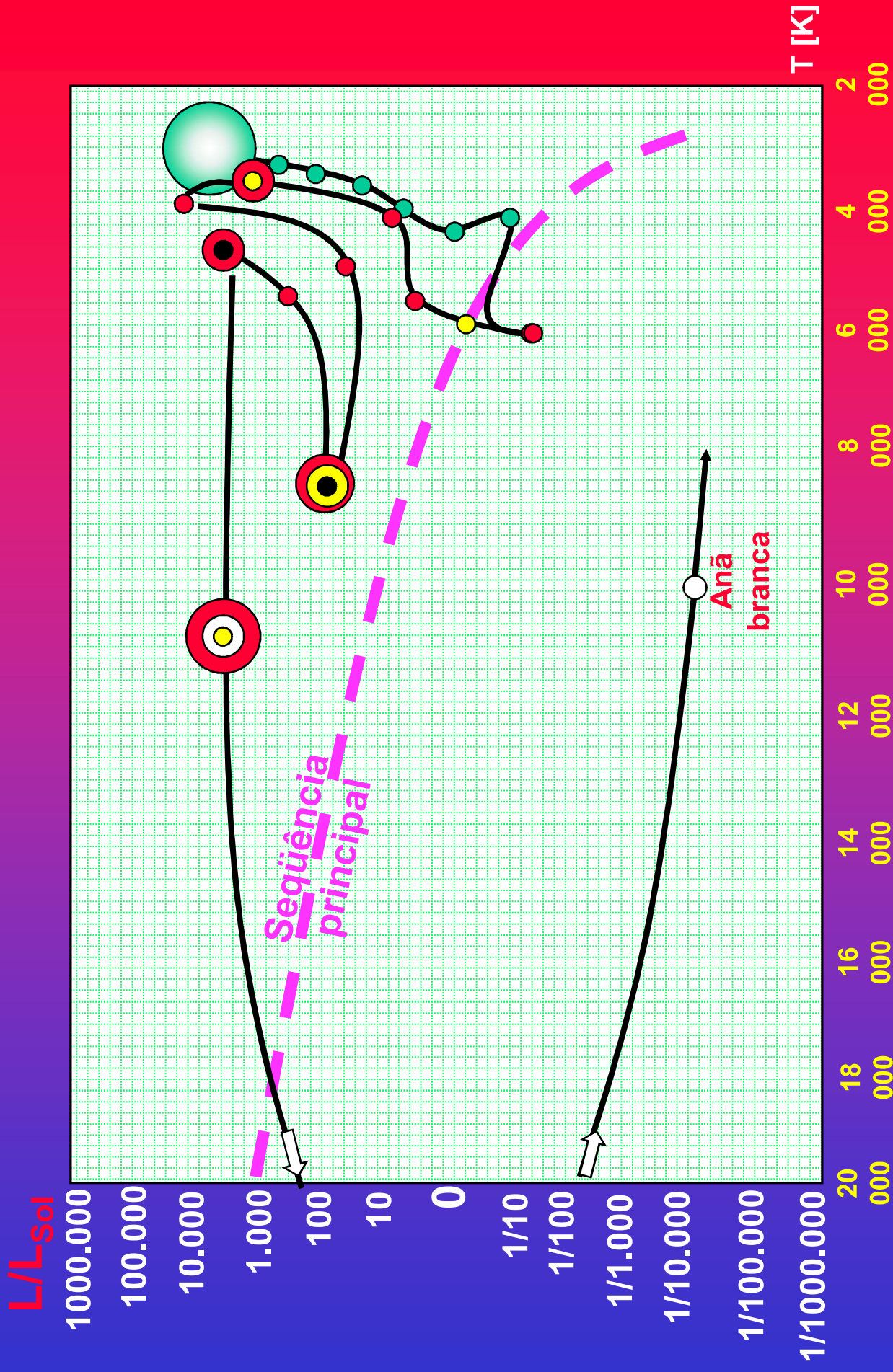
T [K]

20000 18000 16000 14000 12000 10000 8000 6000 4000 2000

HR para Anã-branca

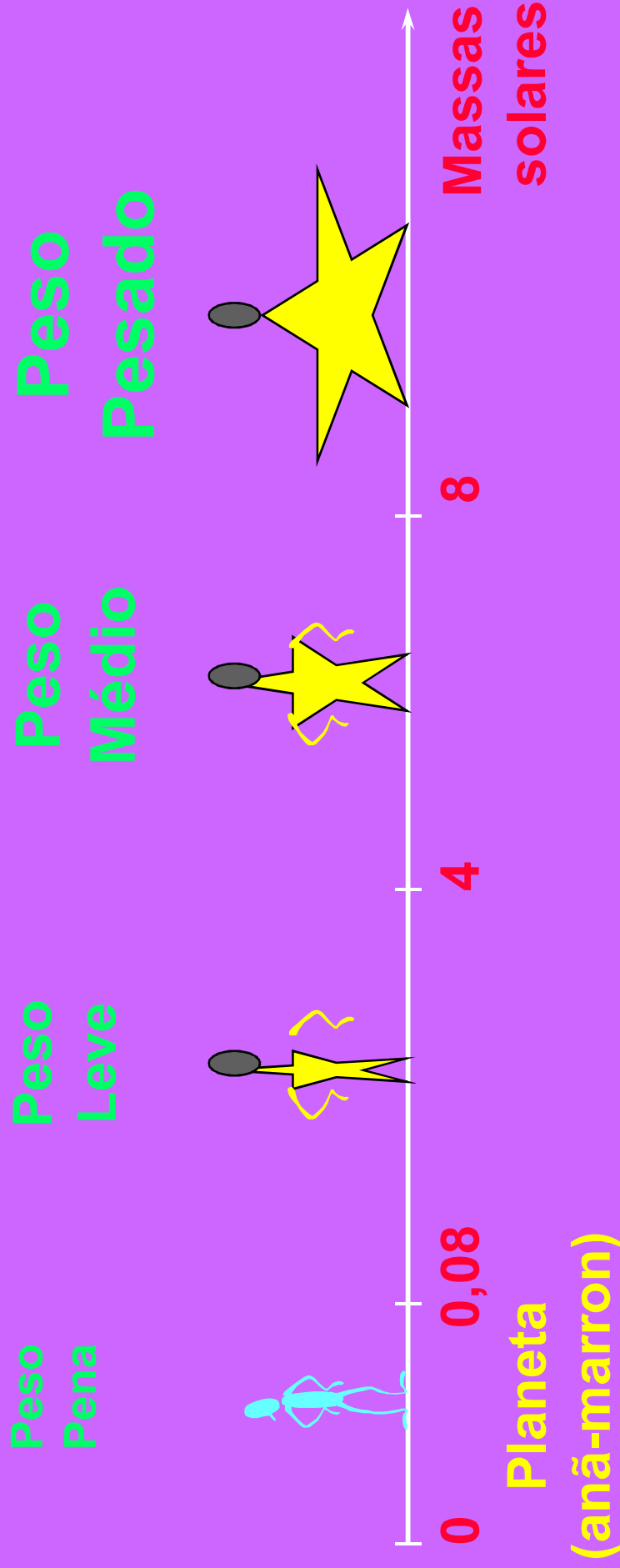


HR de uma estrela de 1 massa solar

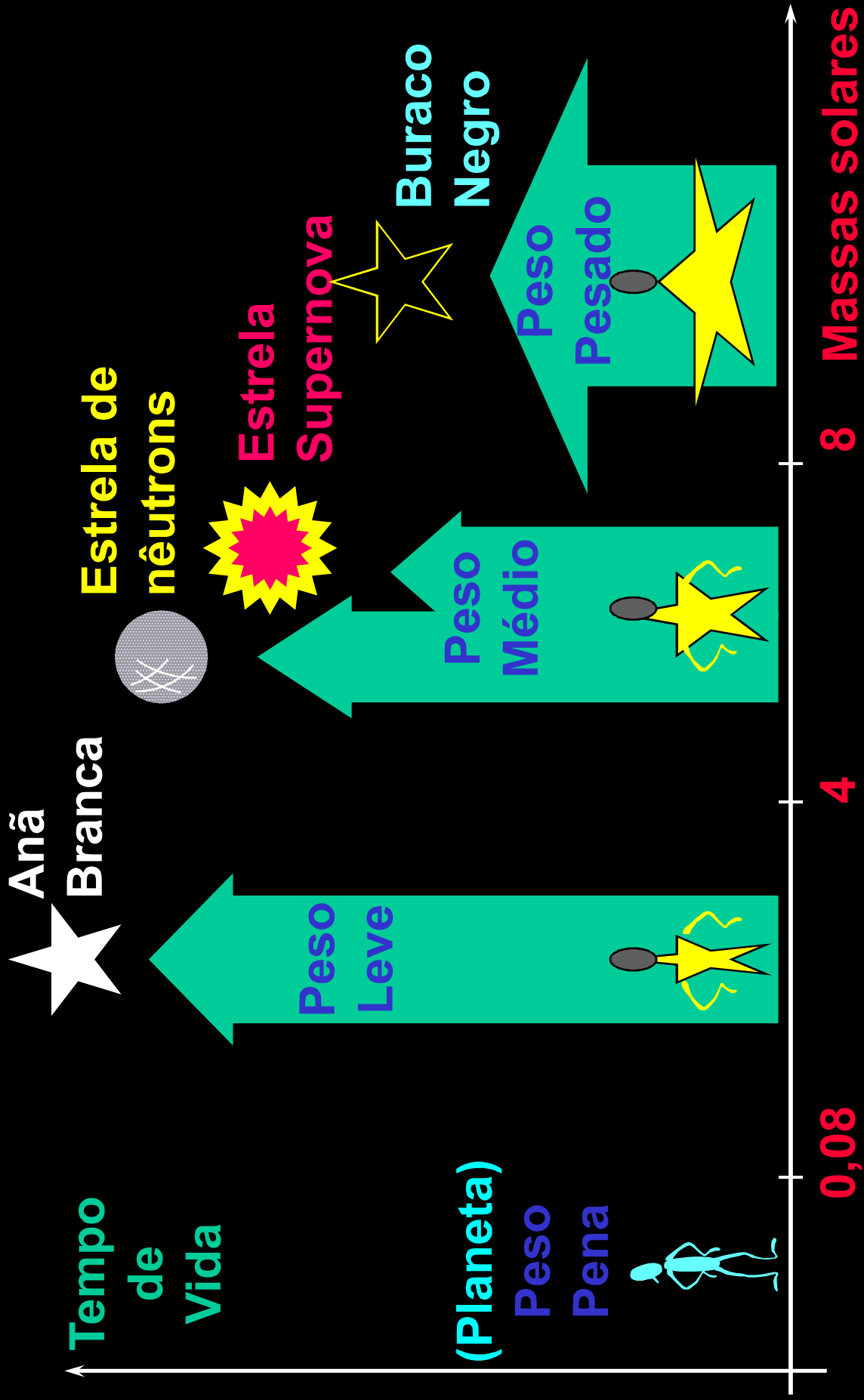


**Todas as estrelas
evoluem como o Sol ?**

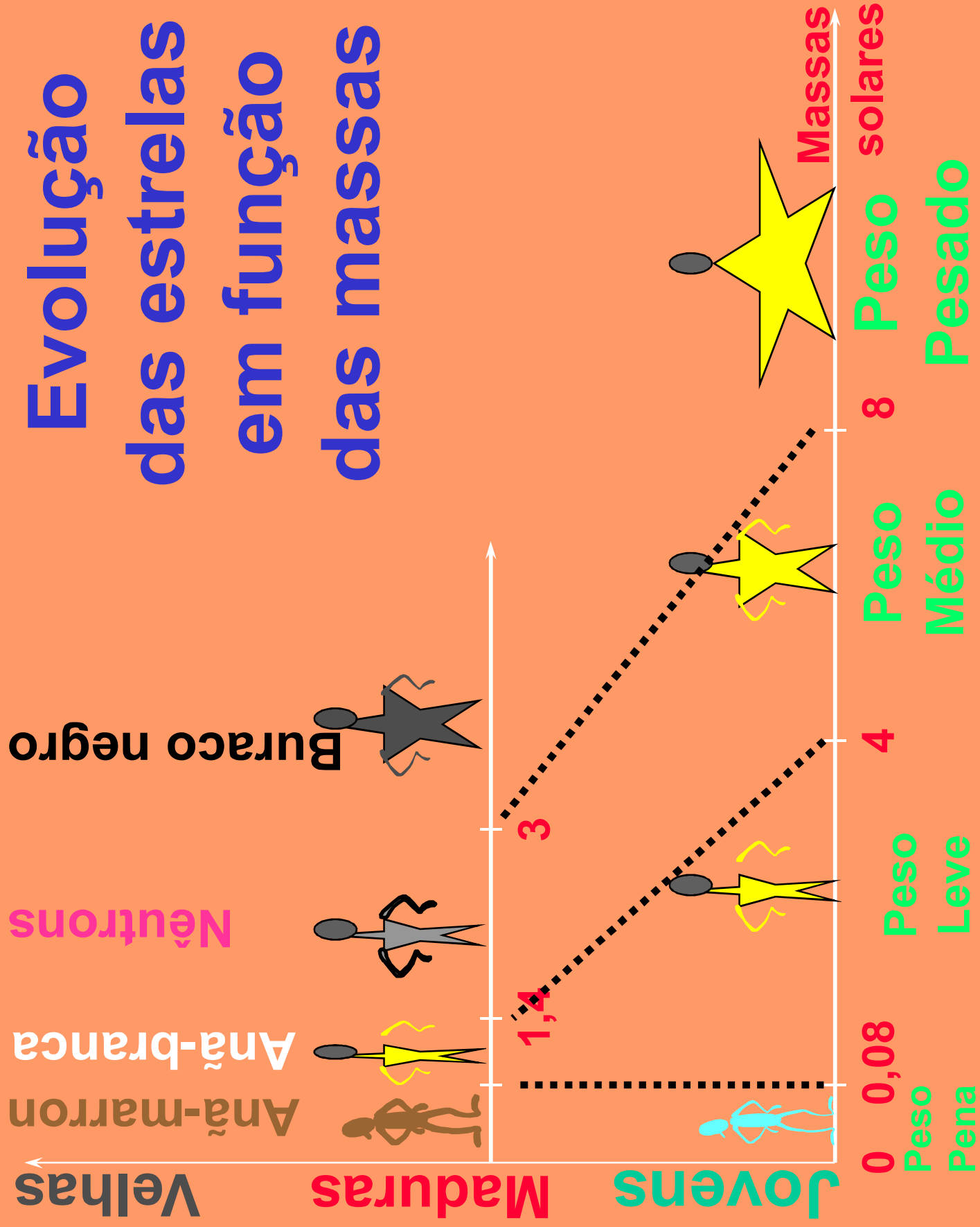
Classificação mássica das estrelas



Tempo de vida de uma estrela

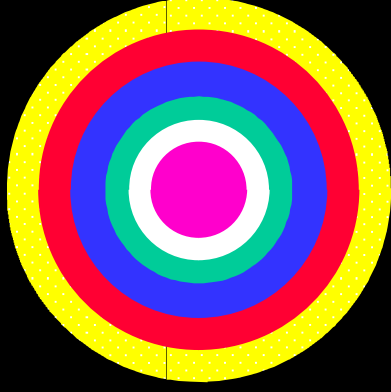
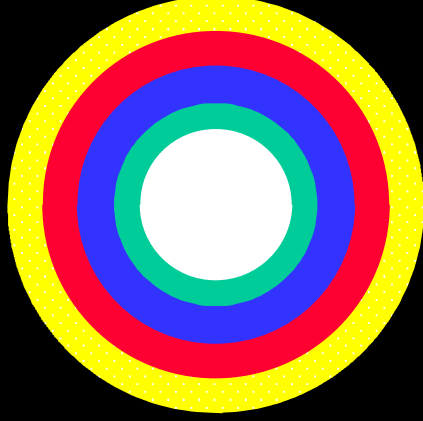
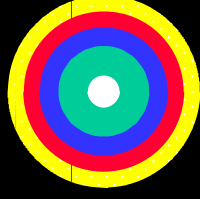
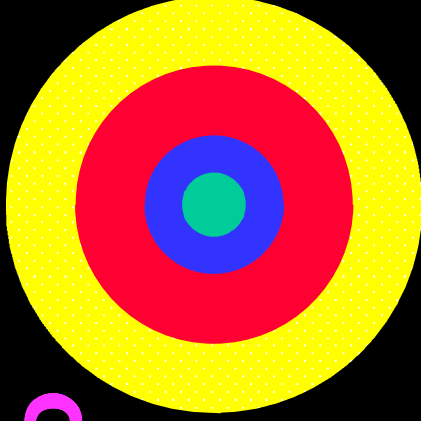
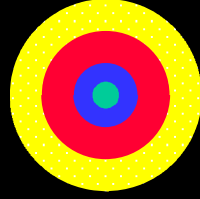
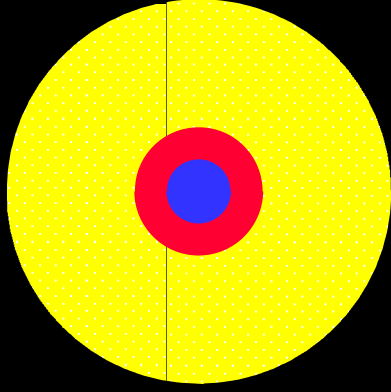
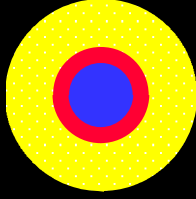
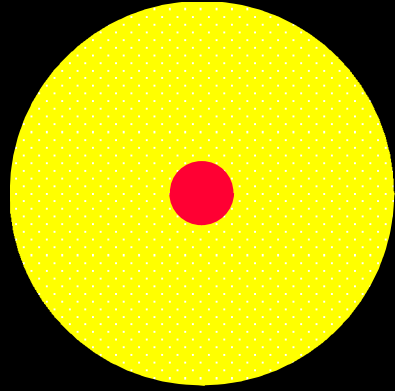
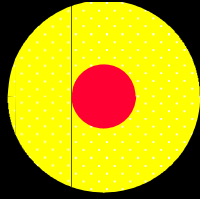


Evolução das estrelas em função das massas



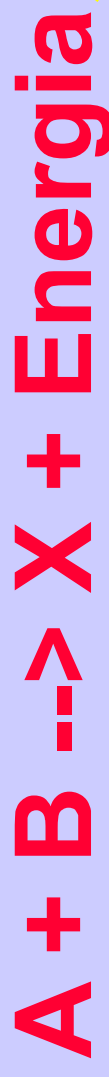
Evolução de uma estrela peso médio

Evolução de estrelas peso médio



Tipos de Reações de Fusão

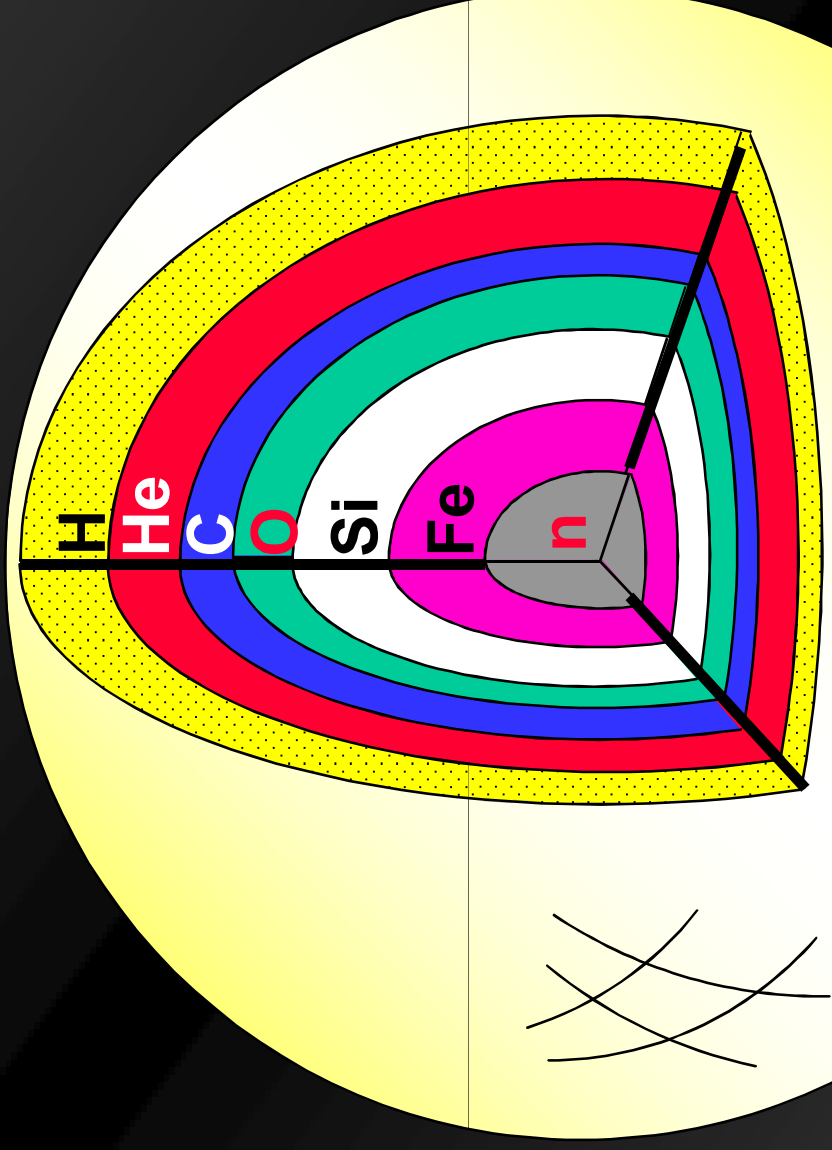
Exotérmicas



Endotérmicas



Estrutura inicial de uma estrela de nêutrons

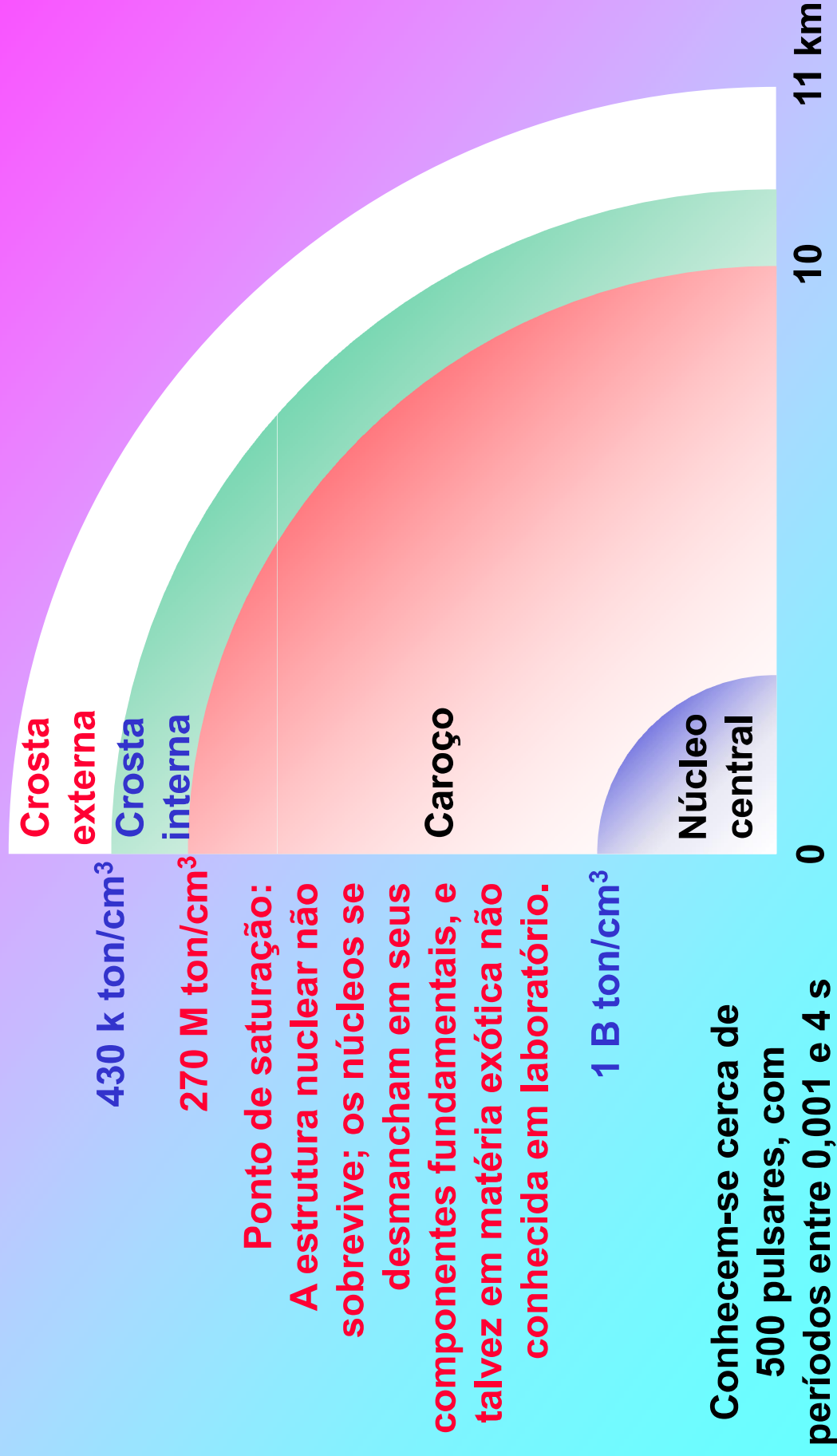


Prótons + Elétrons ==> Nêutrons

Estrela de
nêutrons



Estrutura de uma estrela de nêutrons



H-R dependendo da massa

L/L_{Sol}

1000.000

100.000

10.000

1.000

100

10

0

1/10

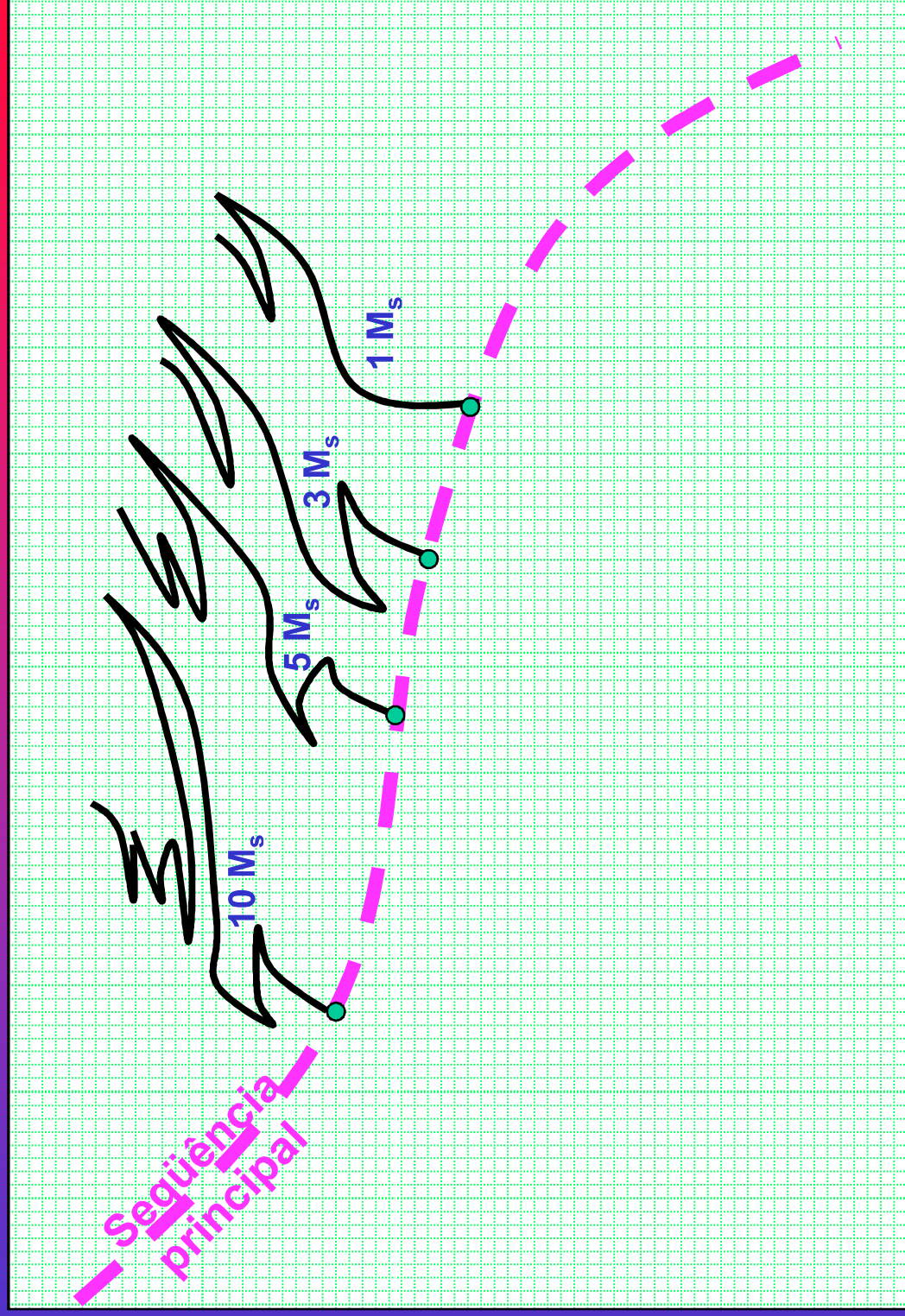
1/100

1/1.000

1/10.000

1/100.000

1/1000.000



T [K]

100
000

10
000

0
000

Reações de nucleossíntese estelar

Fusão nuclear

Elemento
Leve

+

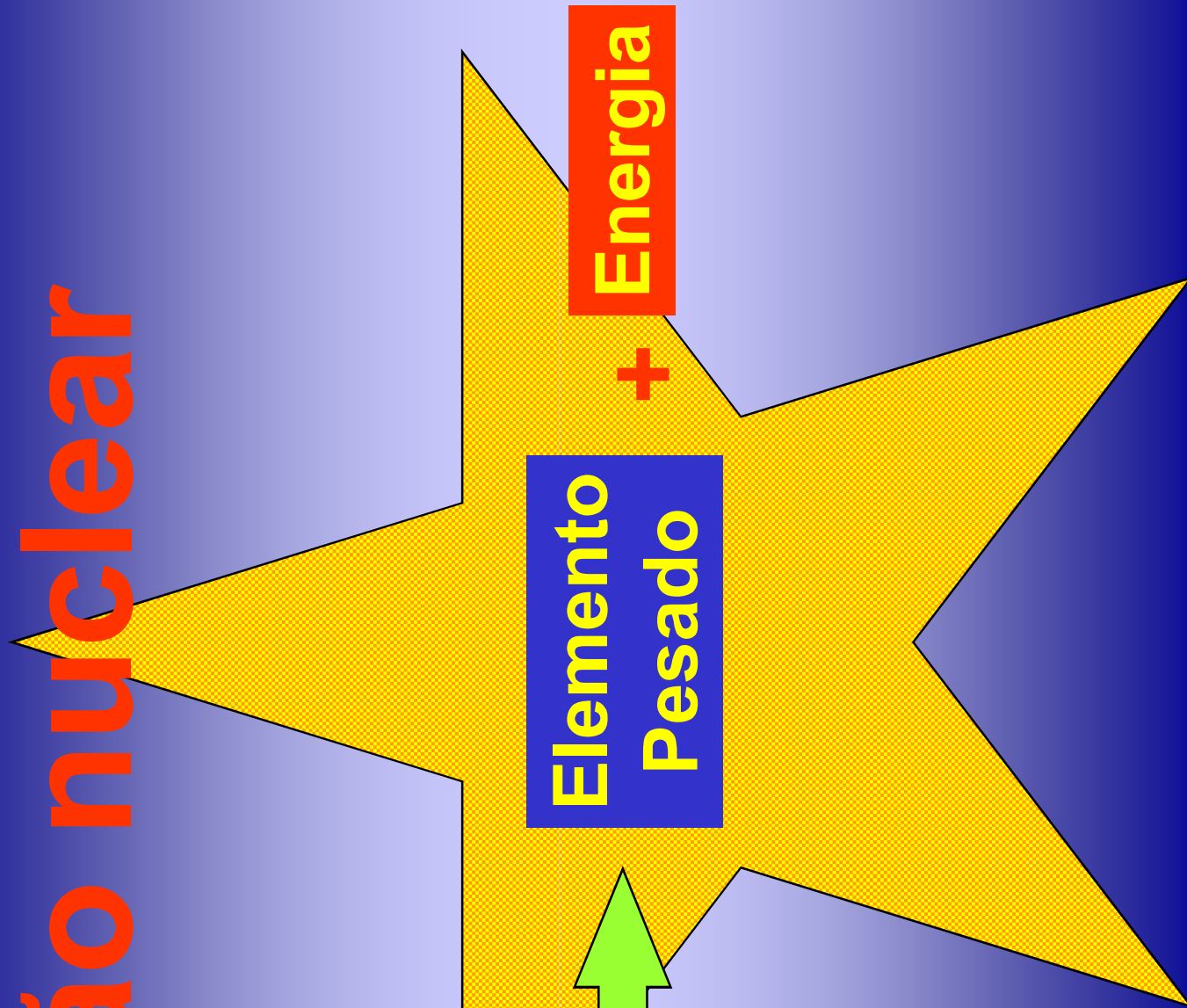
Elemento
Leve



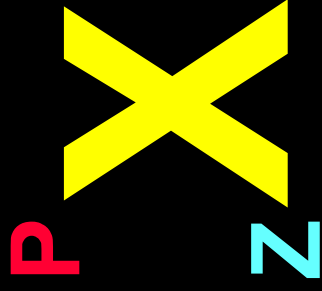
Elemento
Pesado

+

Energia



Representação de um elemento químico X



P = Número de Massa = Z + Nêutrons

Z = Número de Prótons

Cadeia próton-próton gerando He



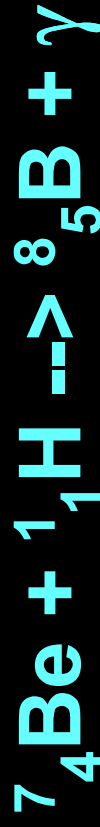
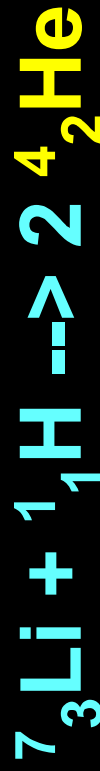
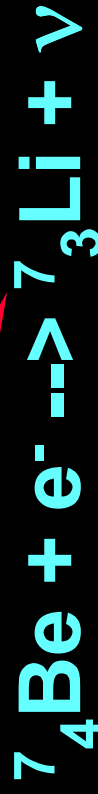
69%

31%



99,7%

0,3%



Cadeia CNO gerando He



99,7%

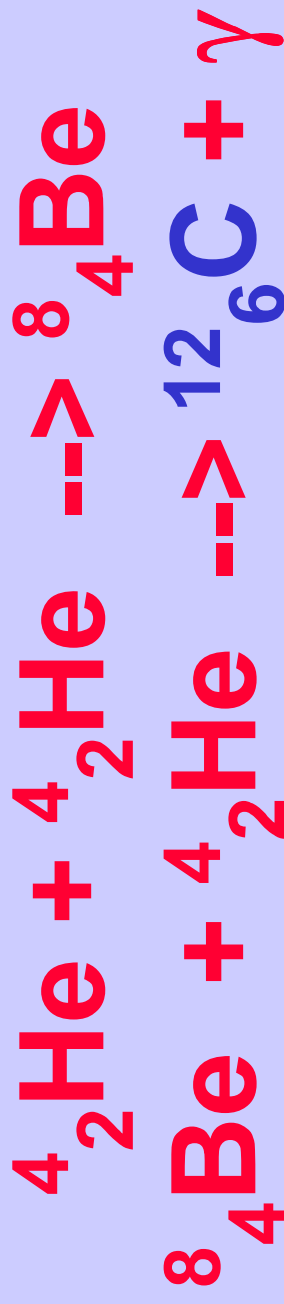


0,3%



Processo triplo alfa gerando C

Para $T > 10^8$ K



Reações C-C

$T > 6 \times 10^8 \text{ K}$



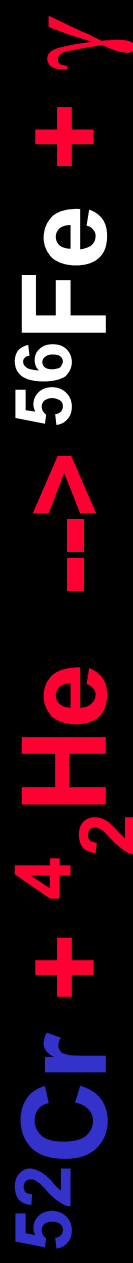
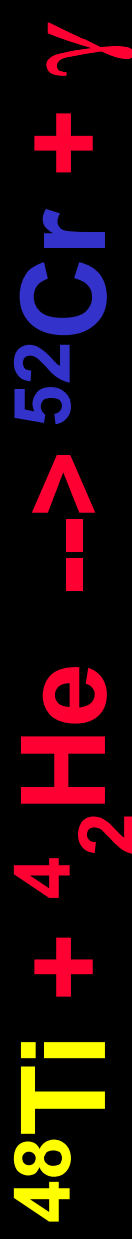
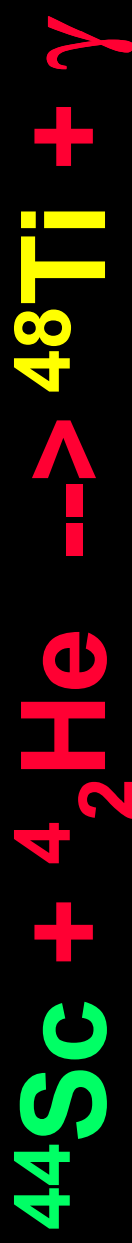
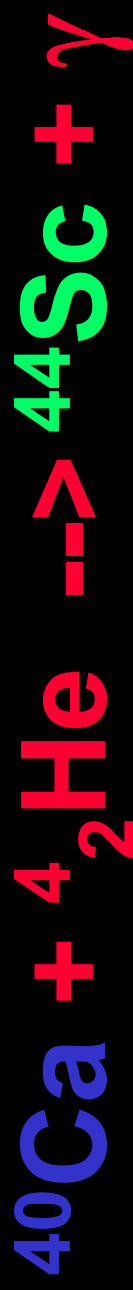
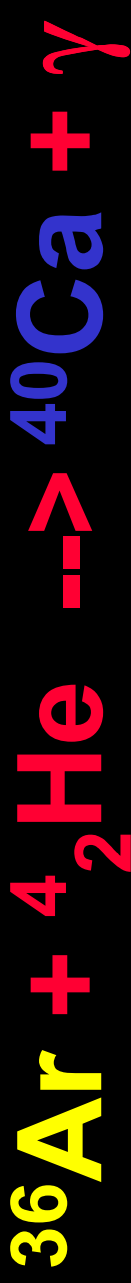
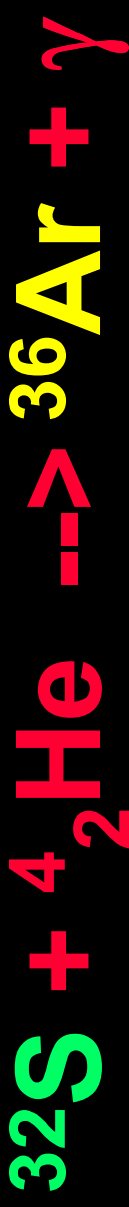
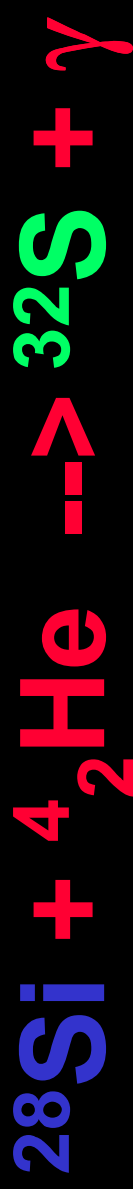
Reações O-O

$T > 10^9 \text{ K}$



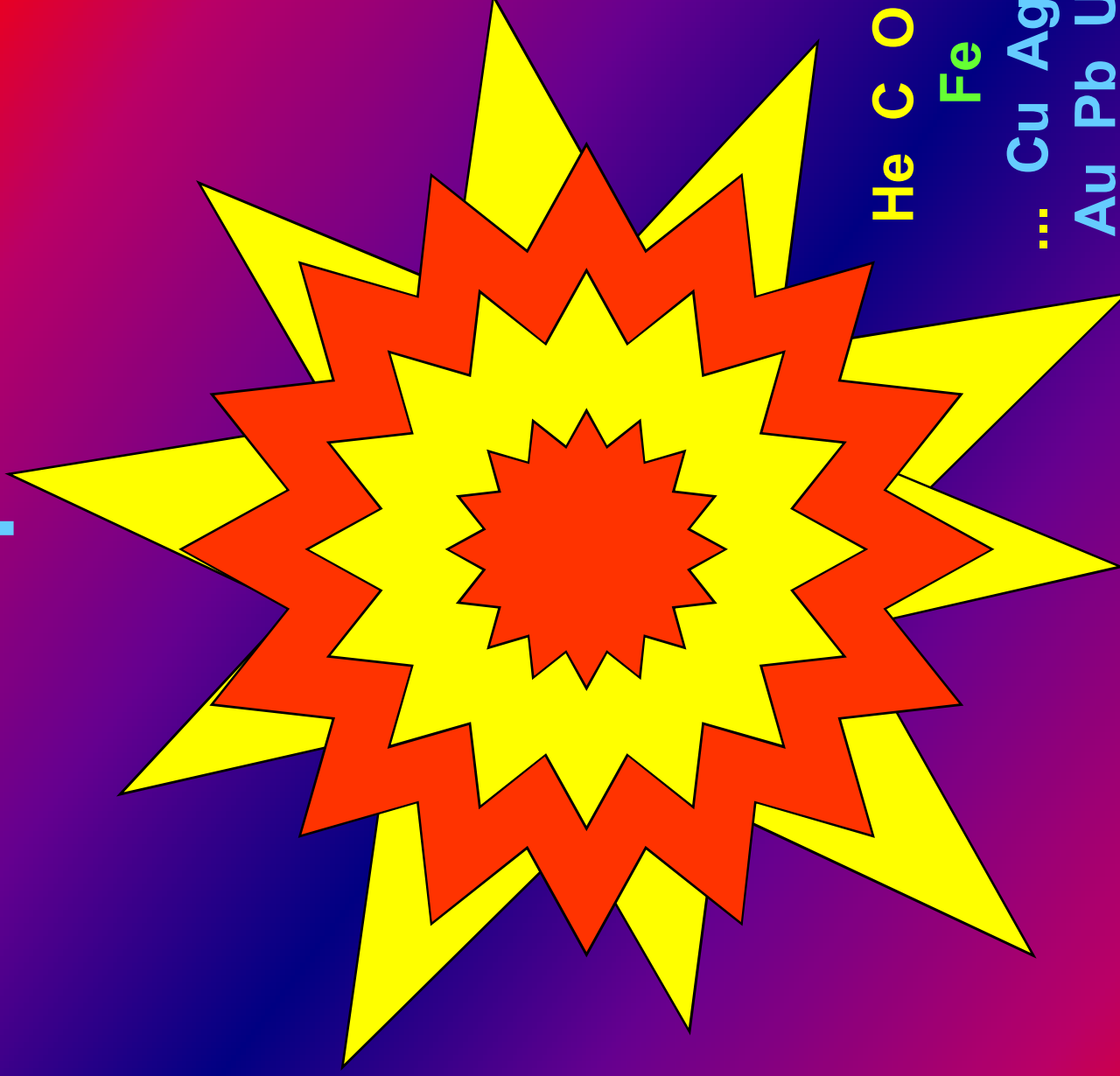
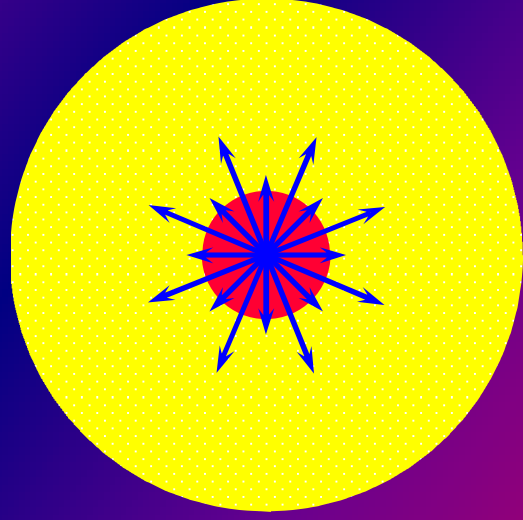
Processos

Alfa



Morte violenta de uma estrela

Estrela Supernova



He C O Si
Fe
... Cu Ag Pt
Au Pb U ...

Supernova 1987A (Grande Nuvem de Magalhães)



Antes

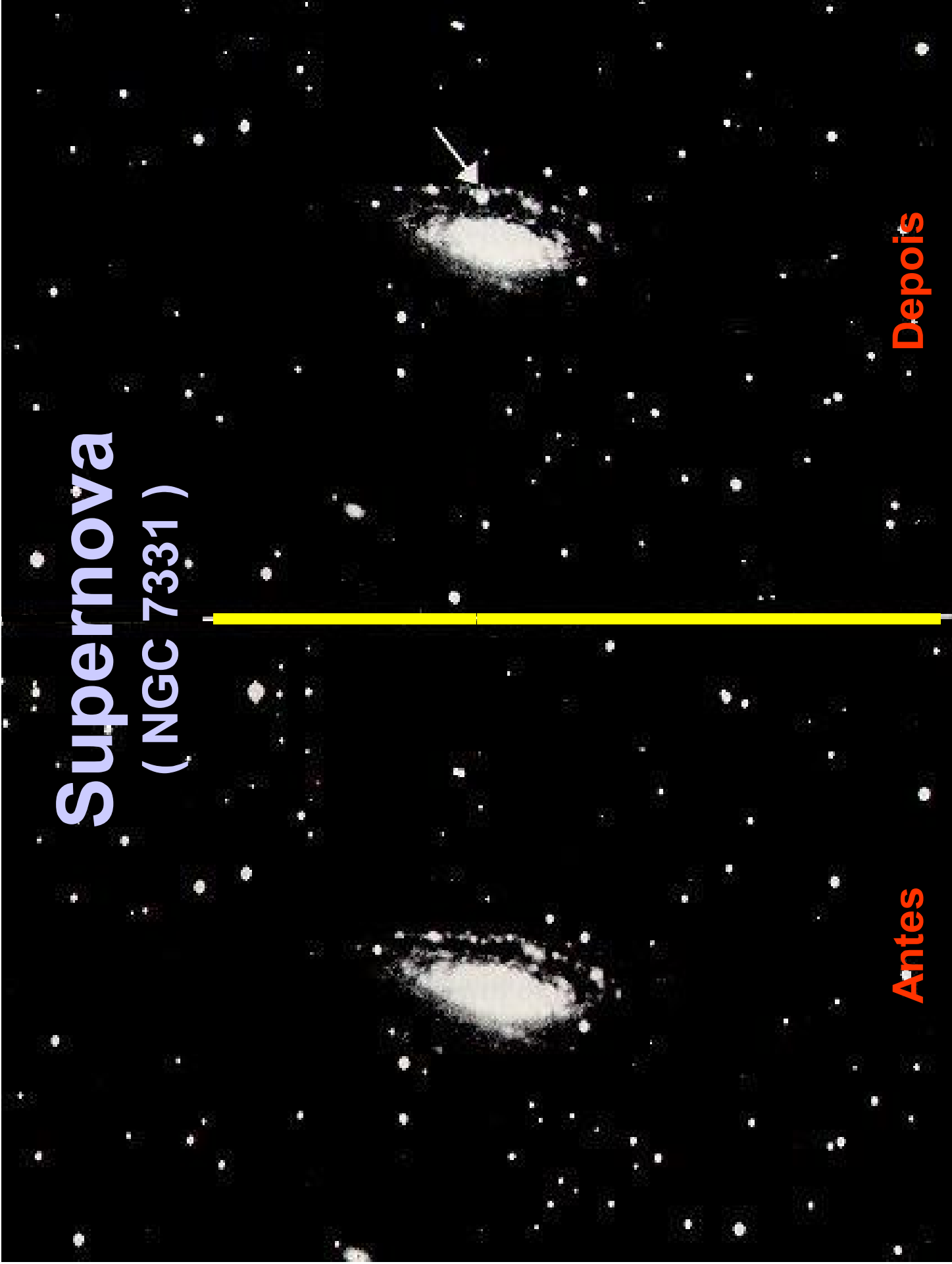


Depois

Supernova (NGC 7331)

Antes

Depois



Supernova

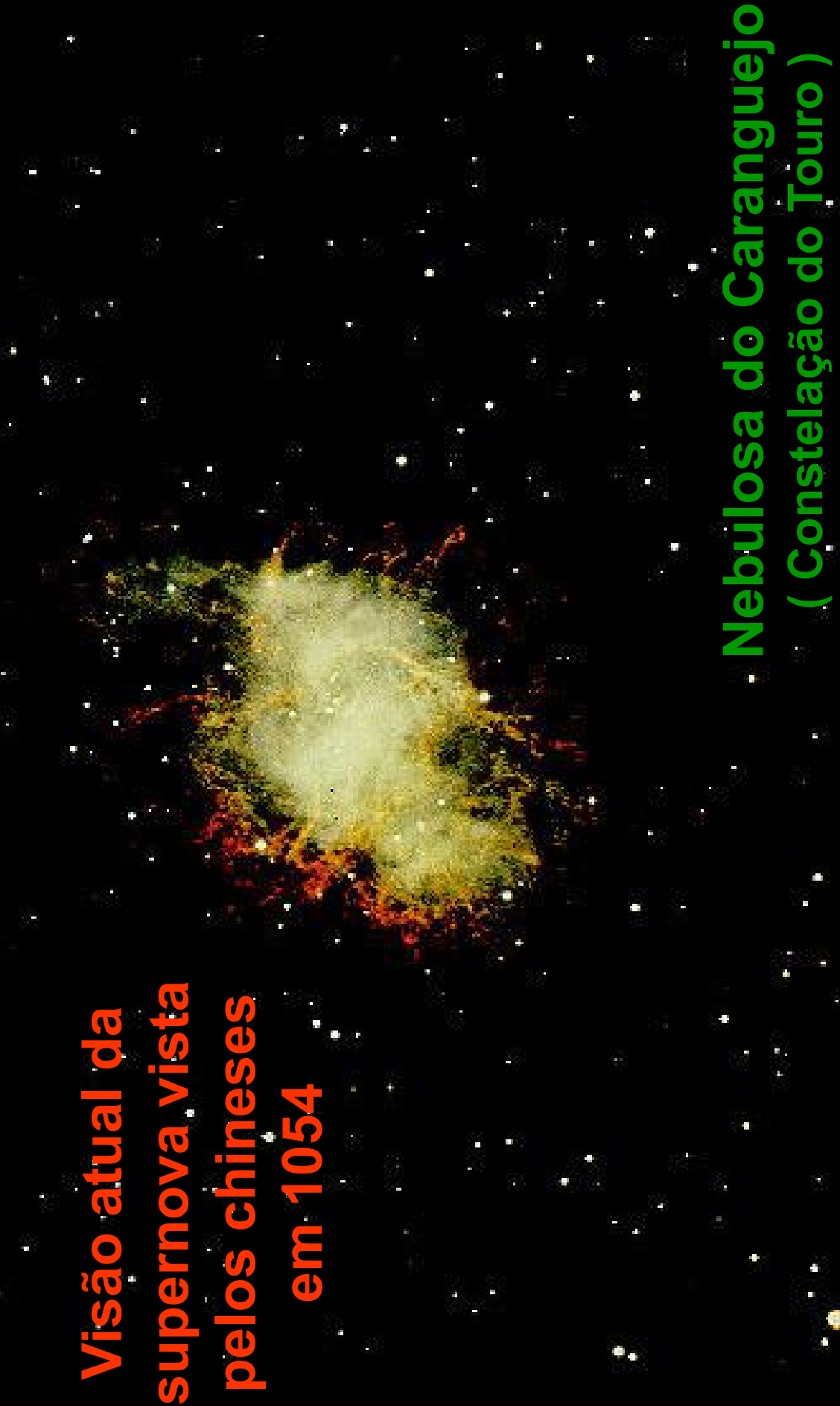


© Anglo-Australian Observatory

Remanescente de Supernova

Visão atual da
supernova vista
pelos chineses
em 1054

Nebulosa do Caranguejo
(Constelação do Touro)



Remanescente de Supernova



Remanescente de Supernova (Vela)



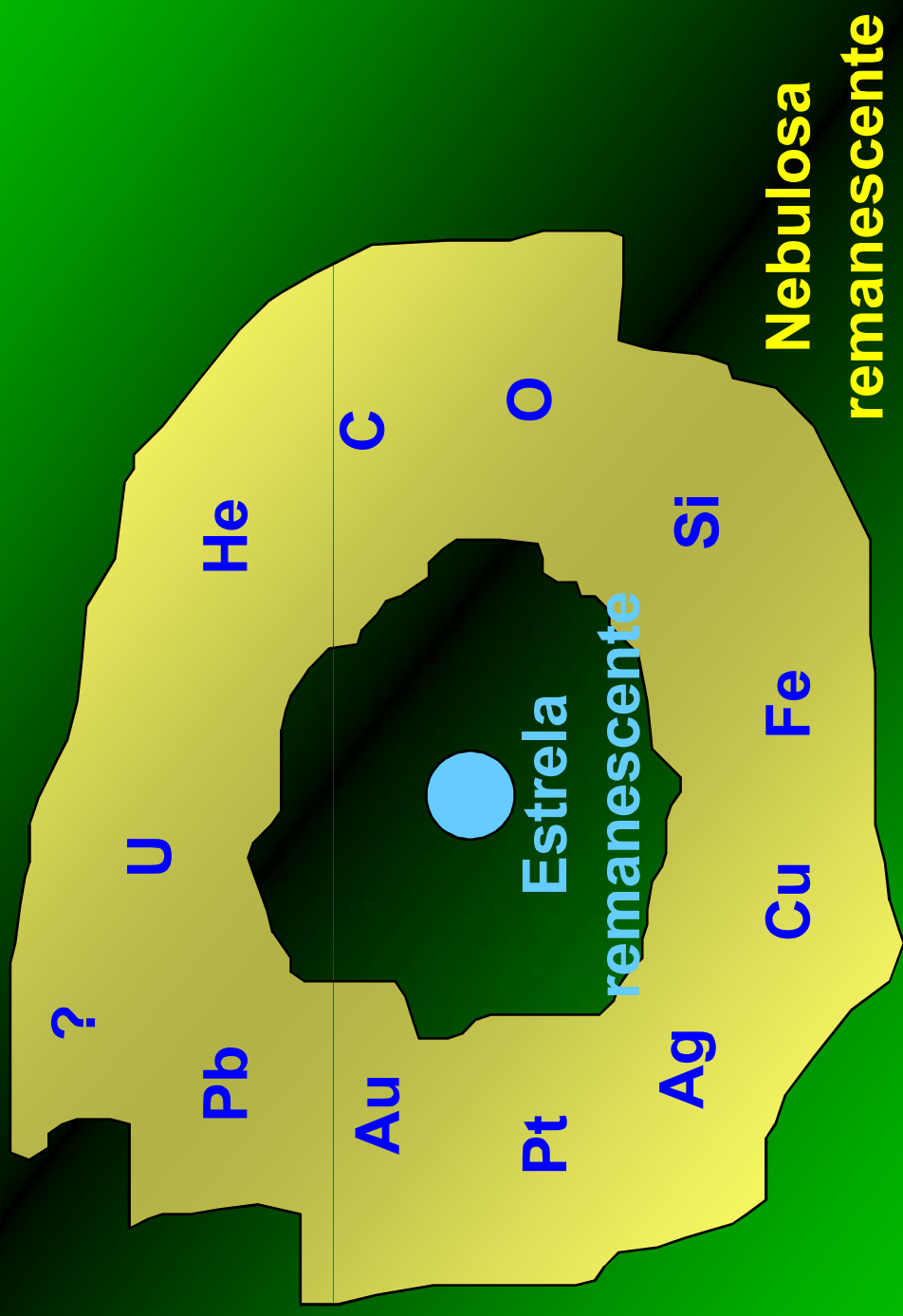
Remanescente de Supernova (Vela)



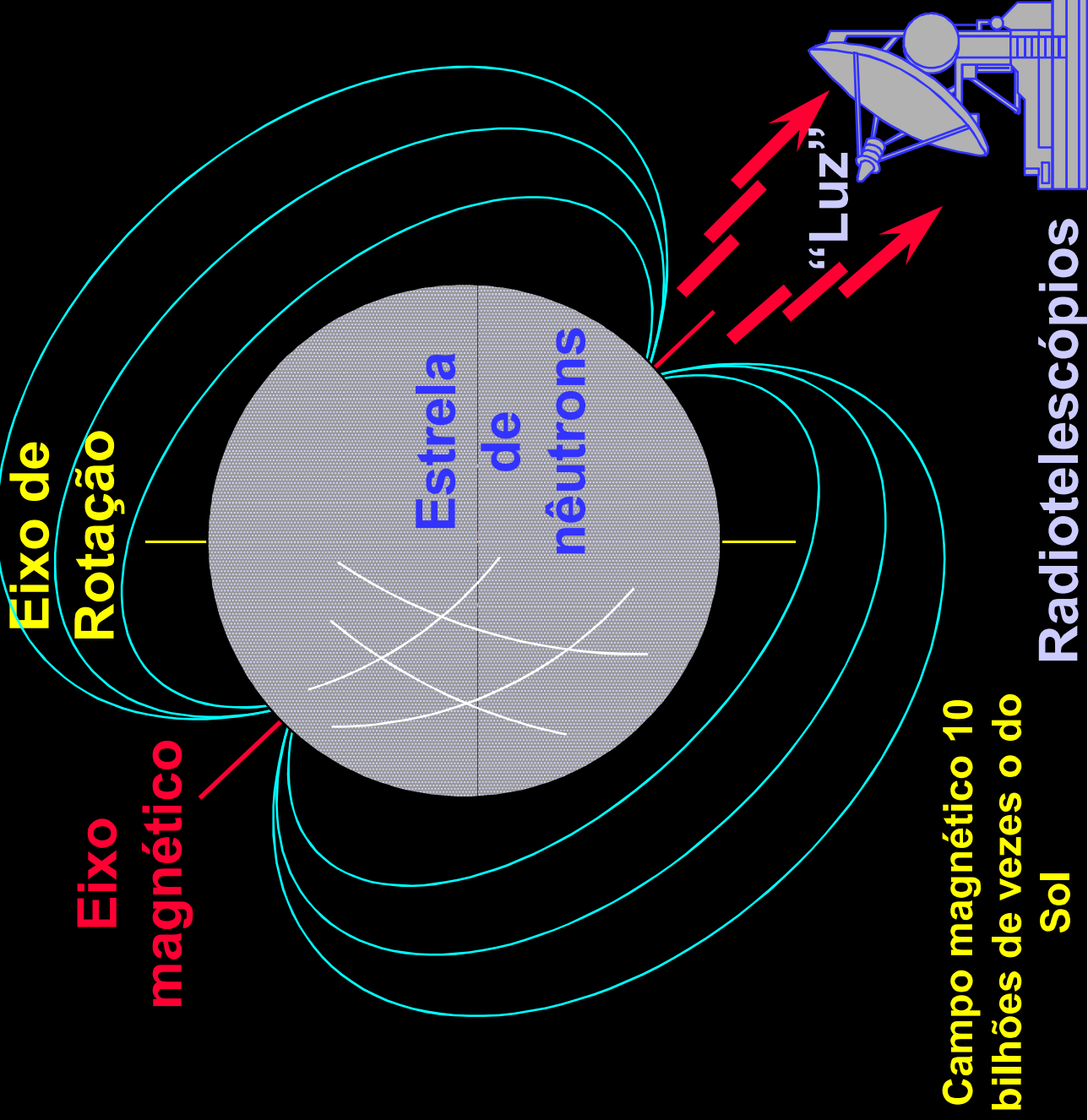


Remanescente de Supernova
(Cisne)

Restos de Supernova



Pulsar



Eixo de Rotação

Eixo magnético

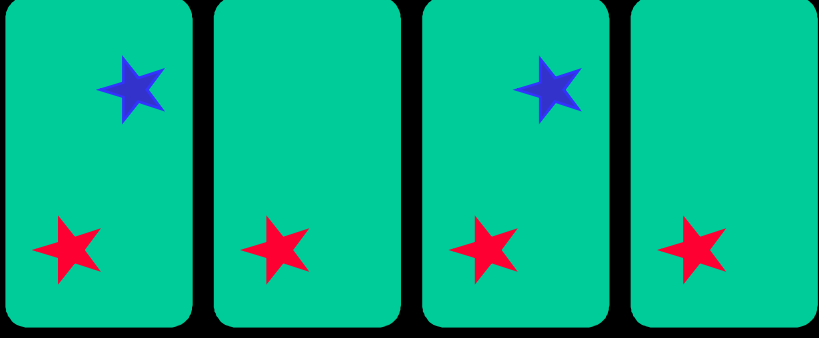
Estrela de nêutrons

"Luz"

Radiotelescópios

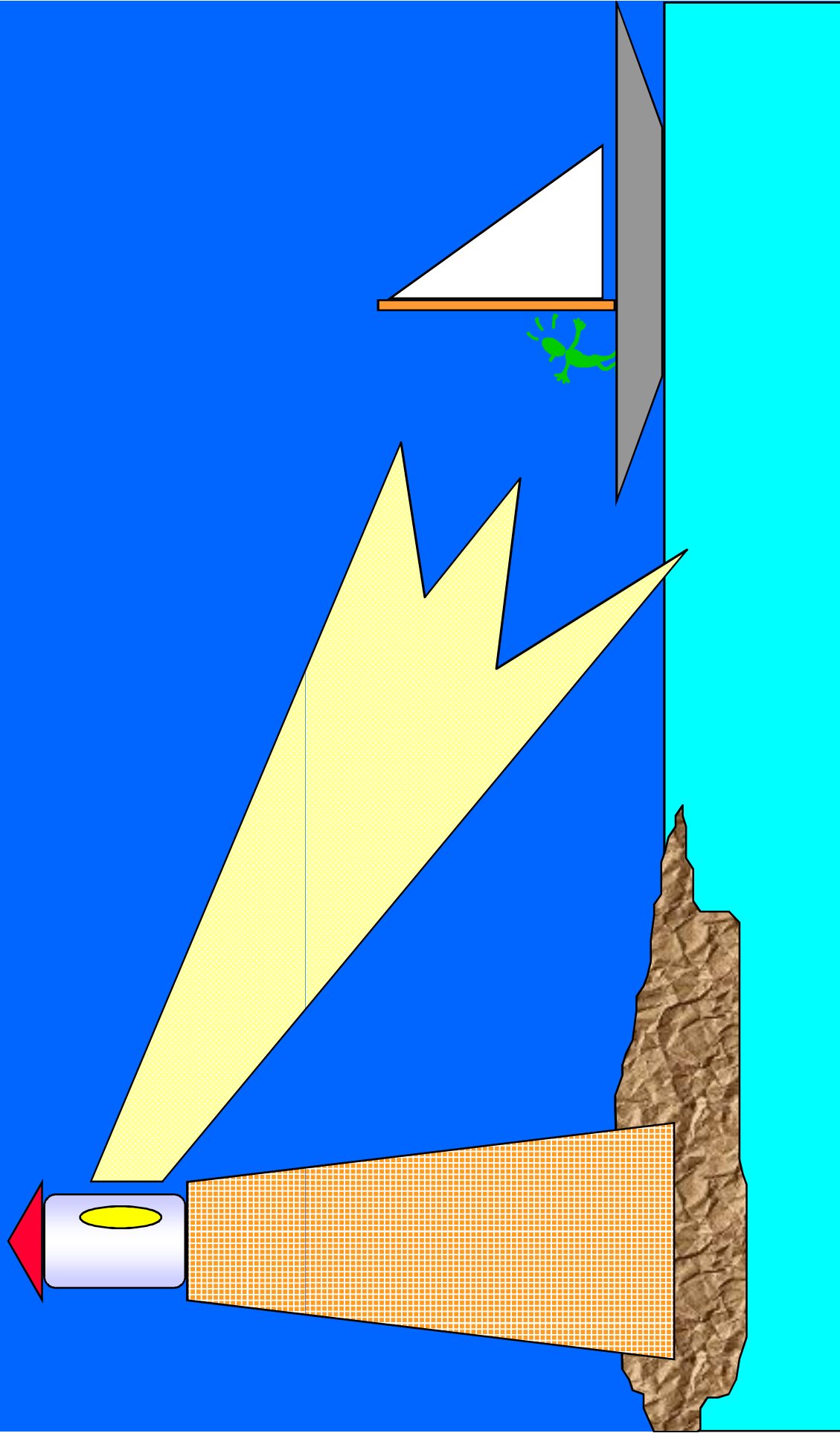
Campo magnético 10 bilhões de vezes o do Sol

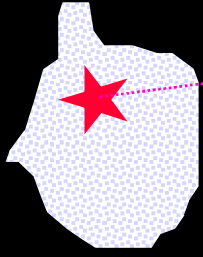
"Visão"



Descobertos em 1967

Farol de Navegação





Grande Nuvem
de Magalhães
(SN 1987 A)

Supernovas “próximas”

160 000
anos-luz

Kepler
1604

Tycho
1572

1006

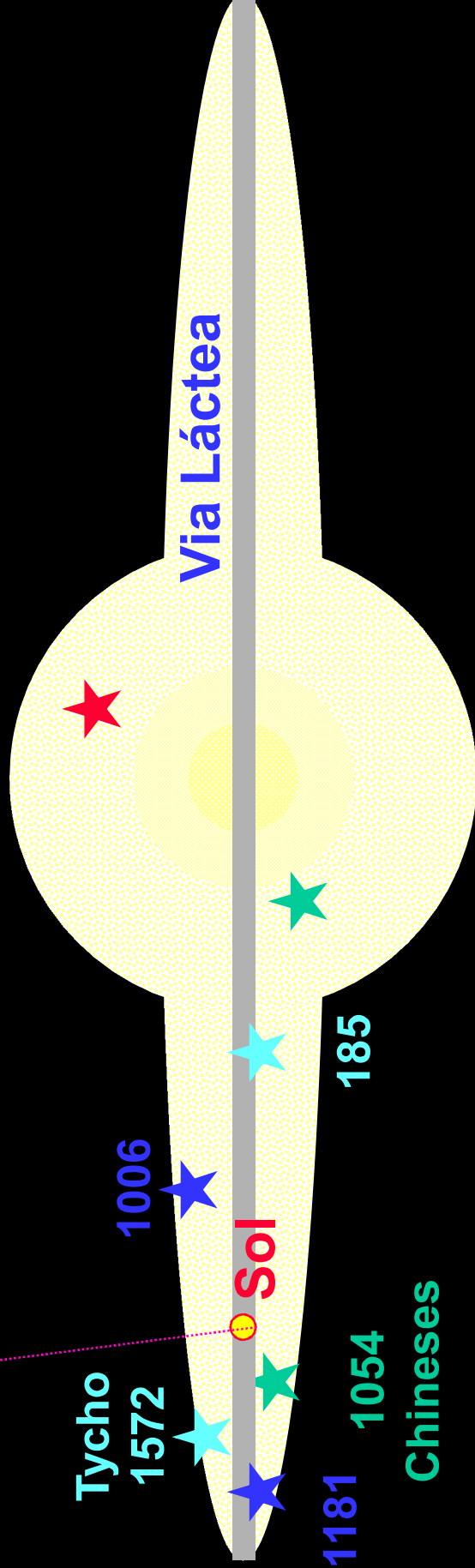
1181

1054

Chineses

185

393



Via Láctea

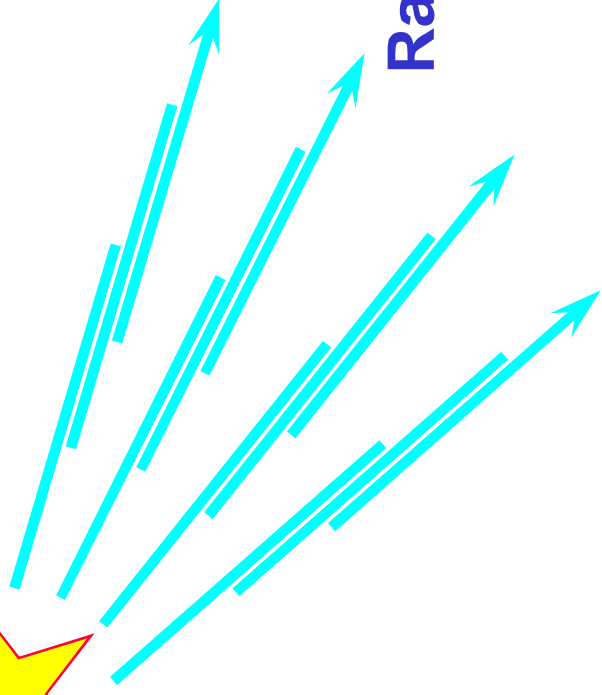
Sol

Processos de extinção de seres vivos em massa

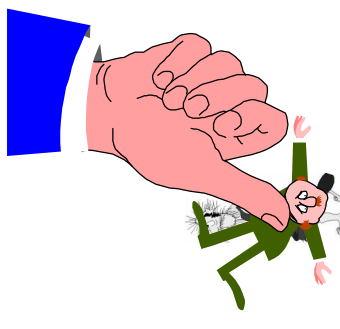
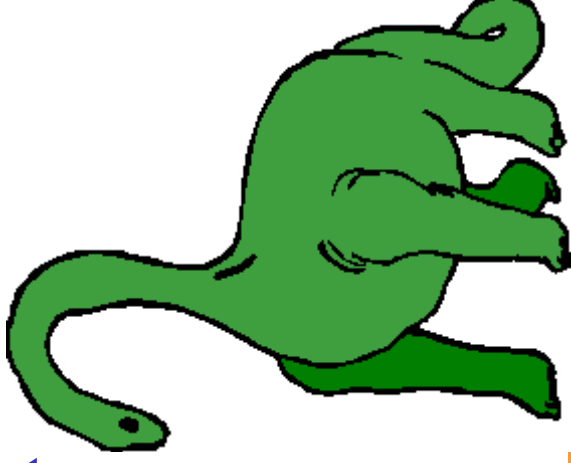
Extinção dos Dinossauros

(65 milhões de anos atrás)

Supernova

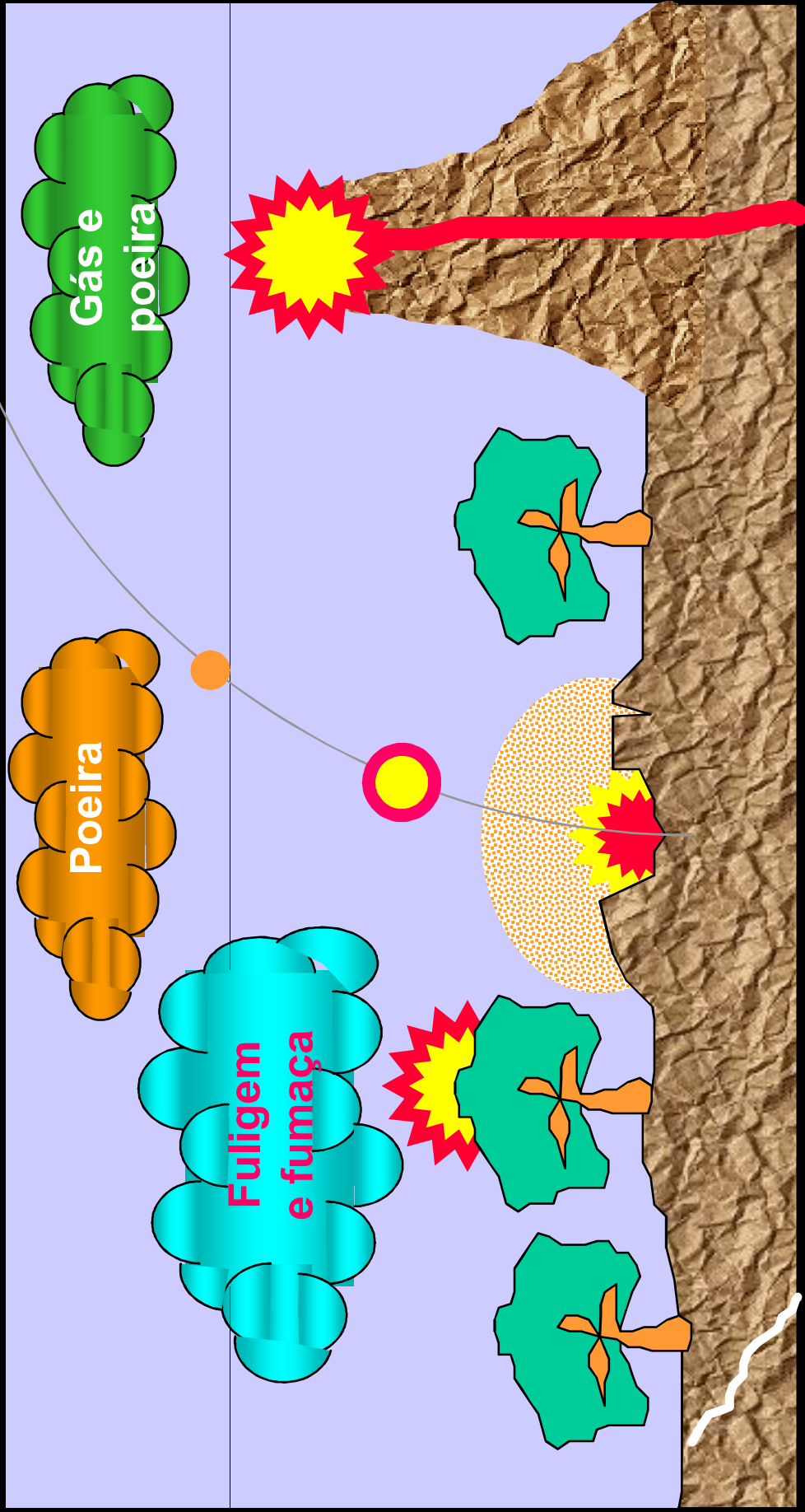


Raios X

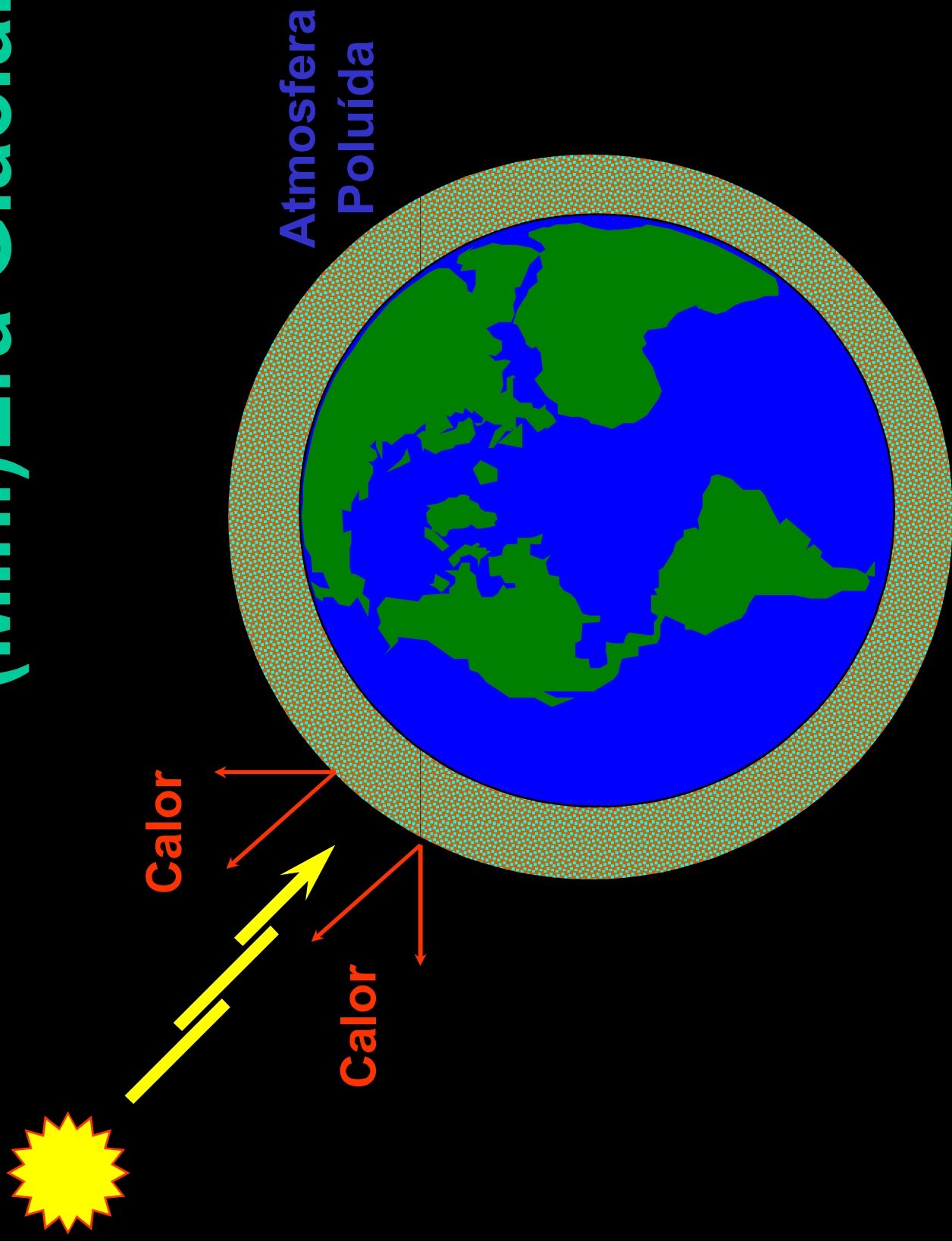


Choque de asteróide com a Terra

Asteróide

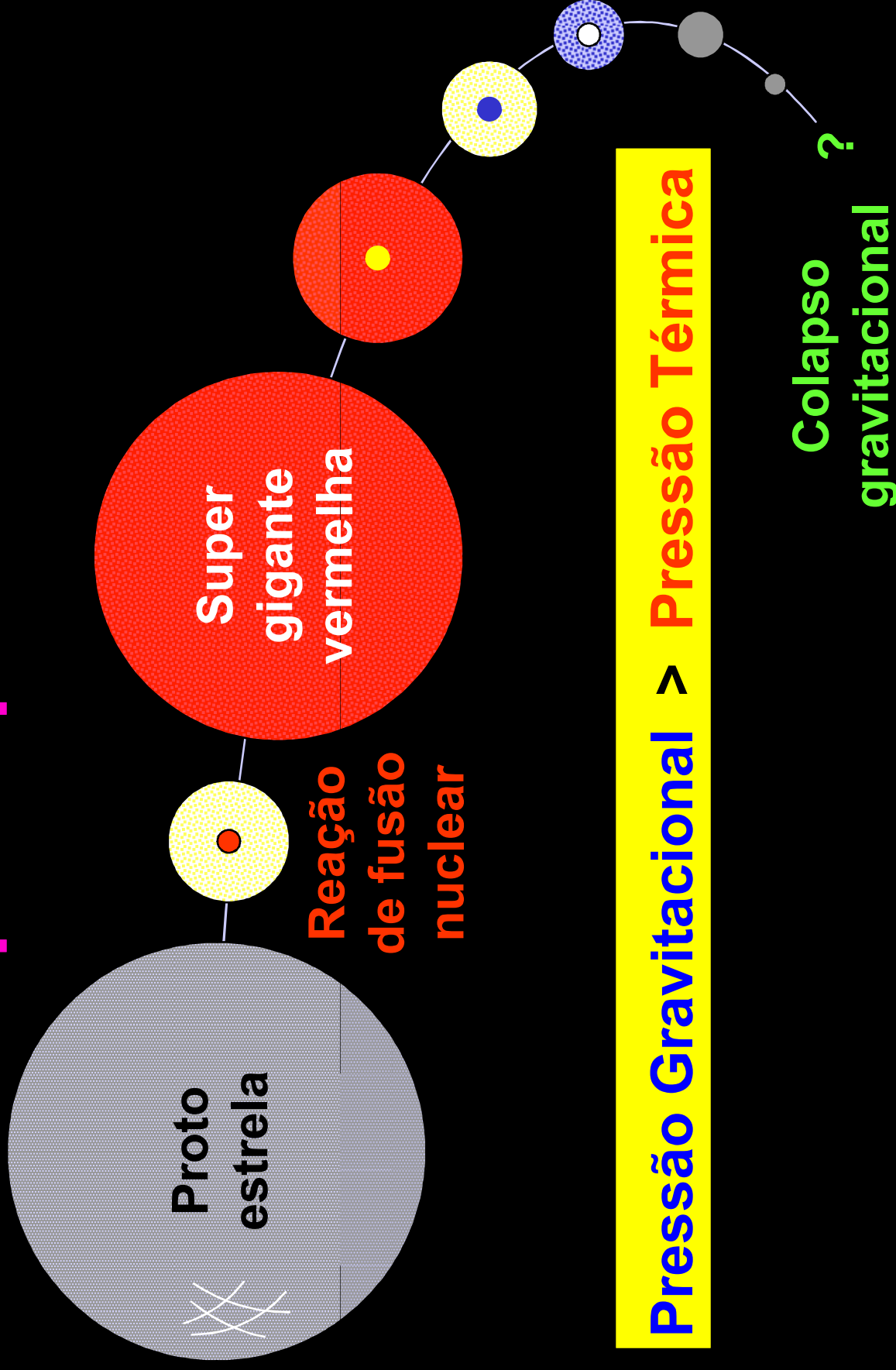


(Mini)Era Glacial

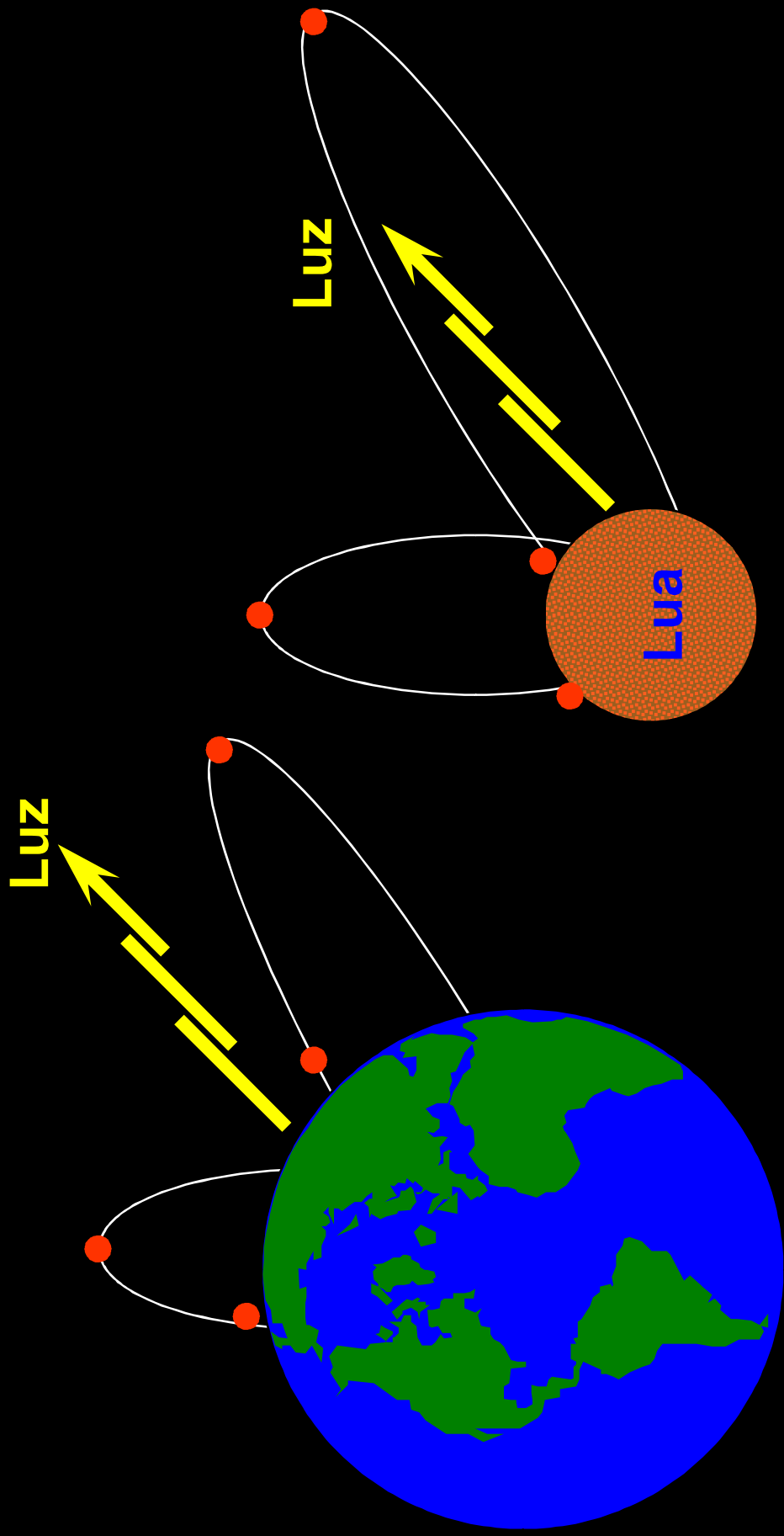


Evolução de uma estrela peso pesado

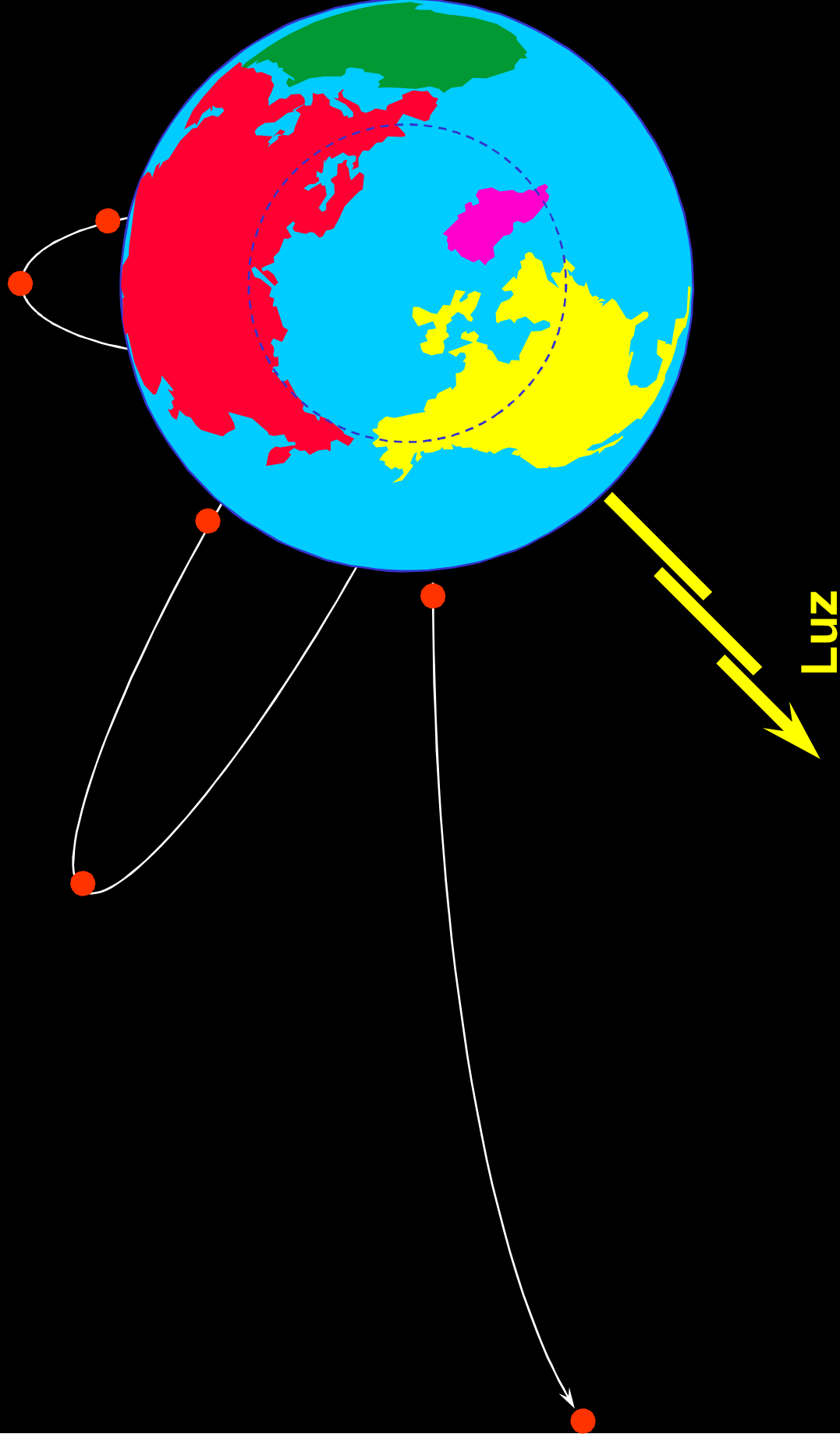
Evolução de uma estrela peso pesado



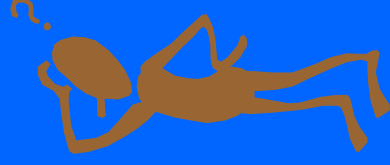
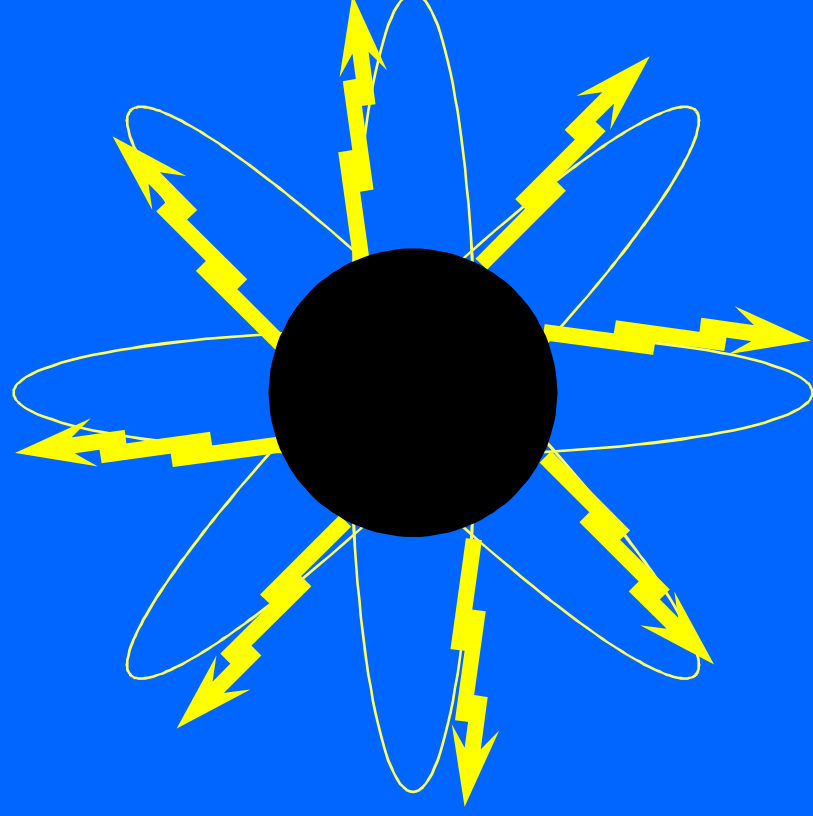
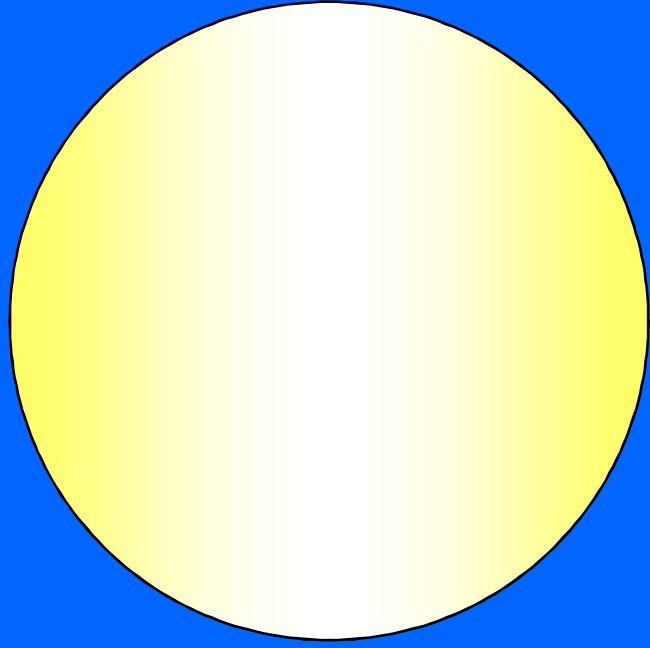
Lançamento de corpos



Lançamento de corpos num campo gravitacional



Estrela Colapsada



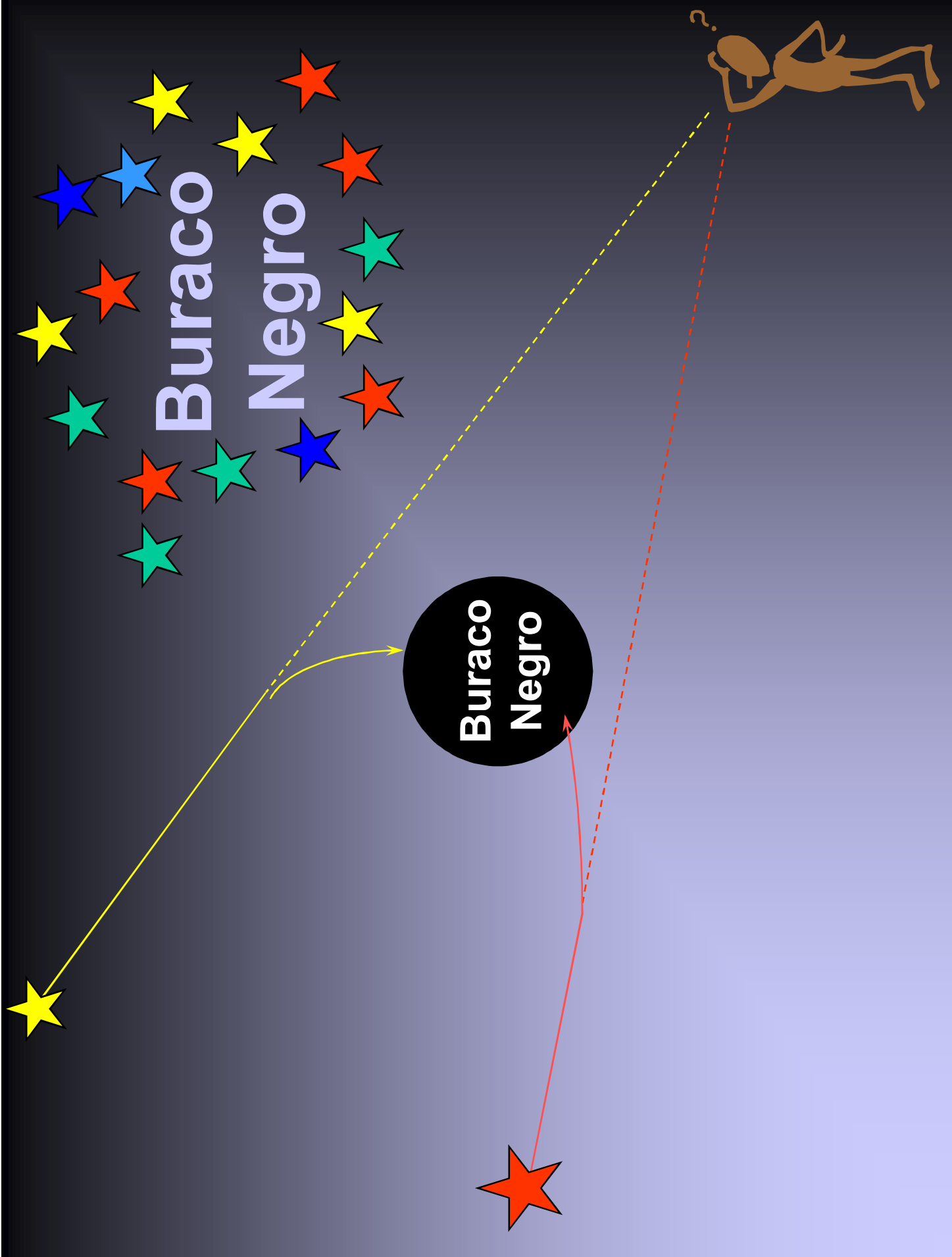
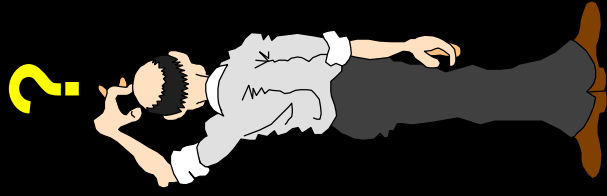
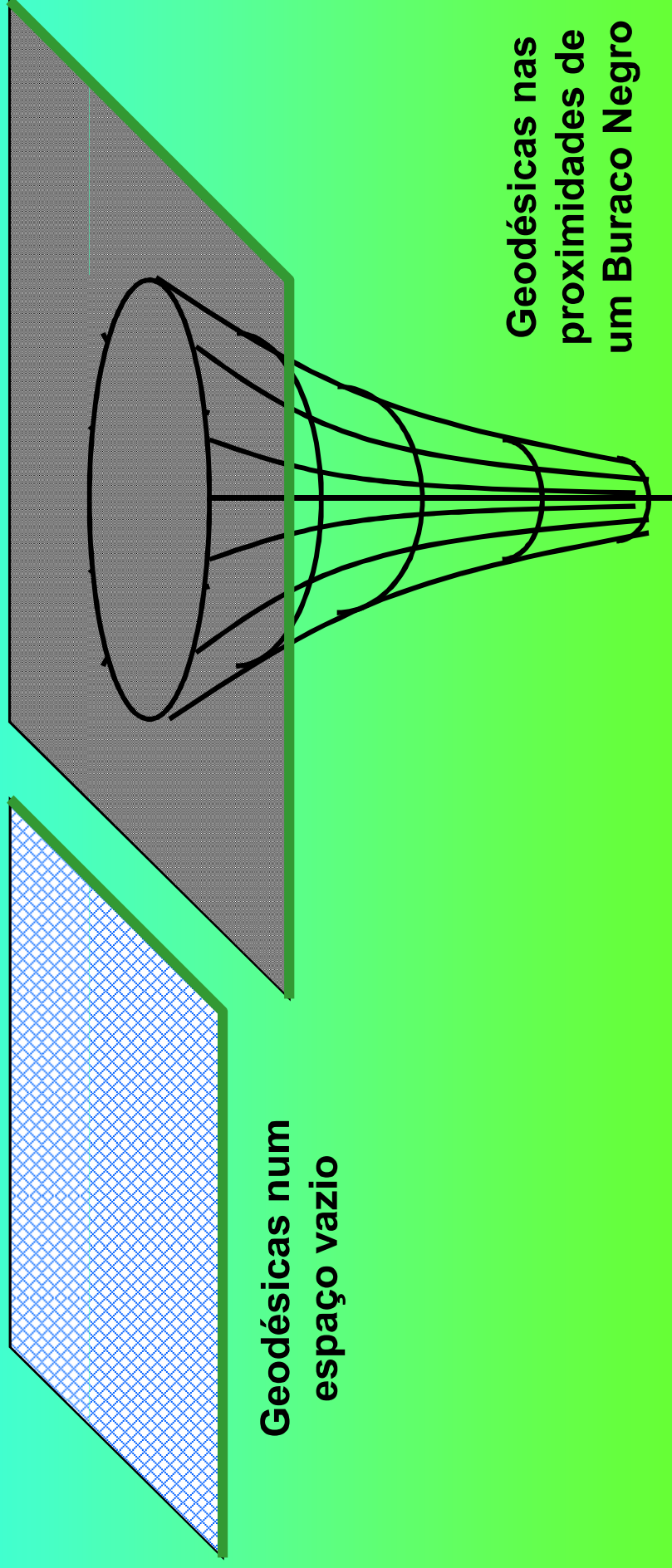


Foto de um Buraco Negro



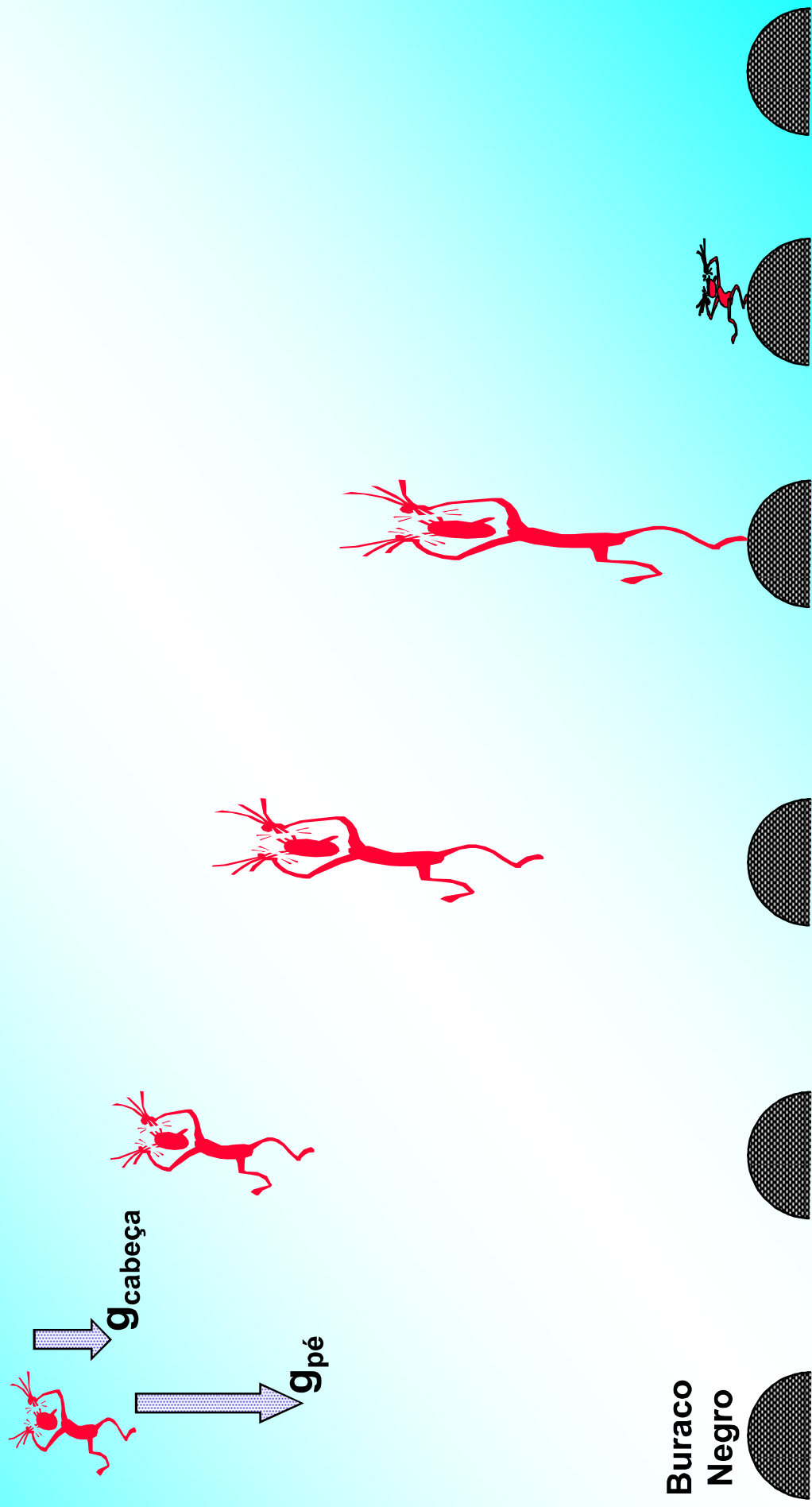
Representação geométrica de um Buraco Negro



Geodésicas num
espaço vazio

Geodésicas nas
proximidades de
um Buraco Negro

Forças de maré num Buraco Negro



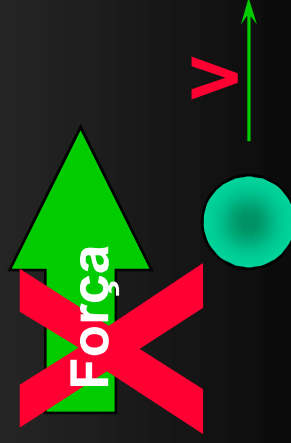
Detecção de Buracos Negros

Se não é possível
ver um
Buraco Negro,
como posso saber
que ele existe ?

Princípio da Inércia

(Newton, 1642- 1727)

Um corpo, sobre o qual não age nenhuma força, tende a manter seu estado de movimento ou de repouso.

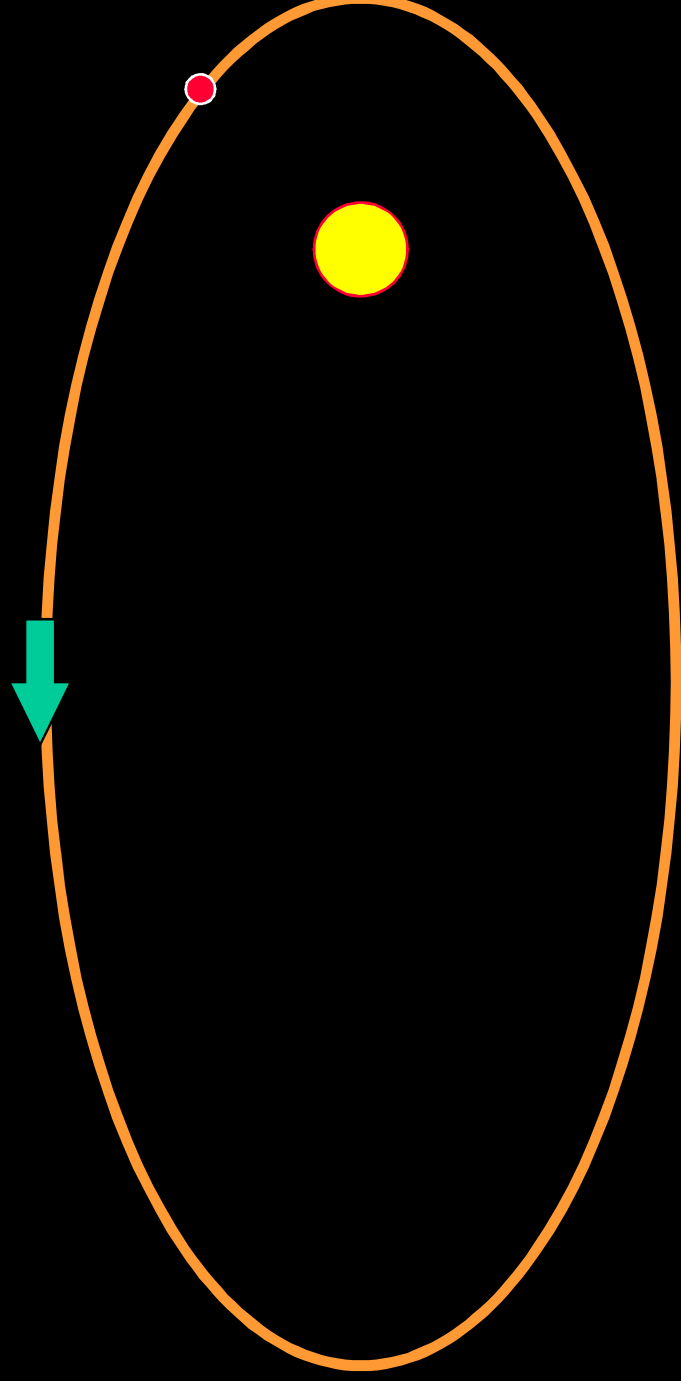


Movimento
retilíneo
uniforme



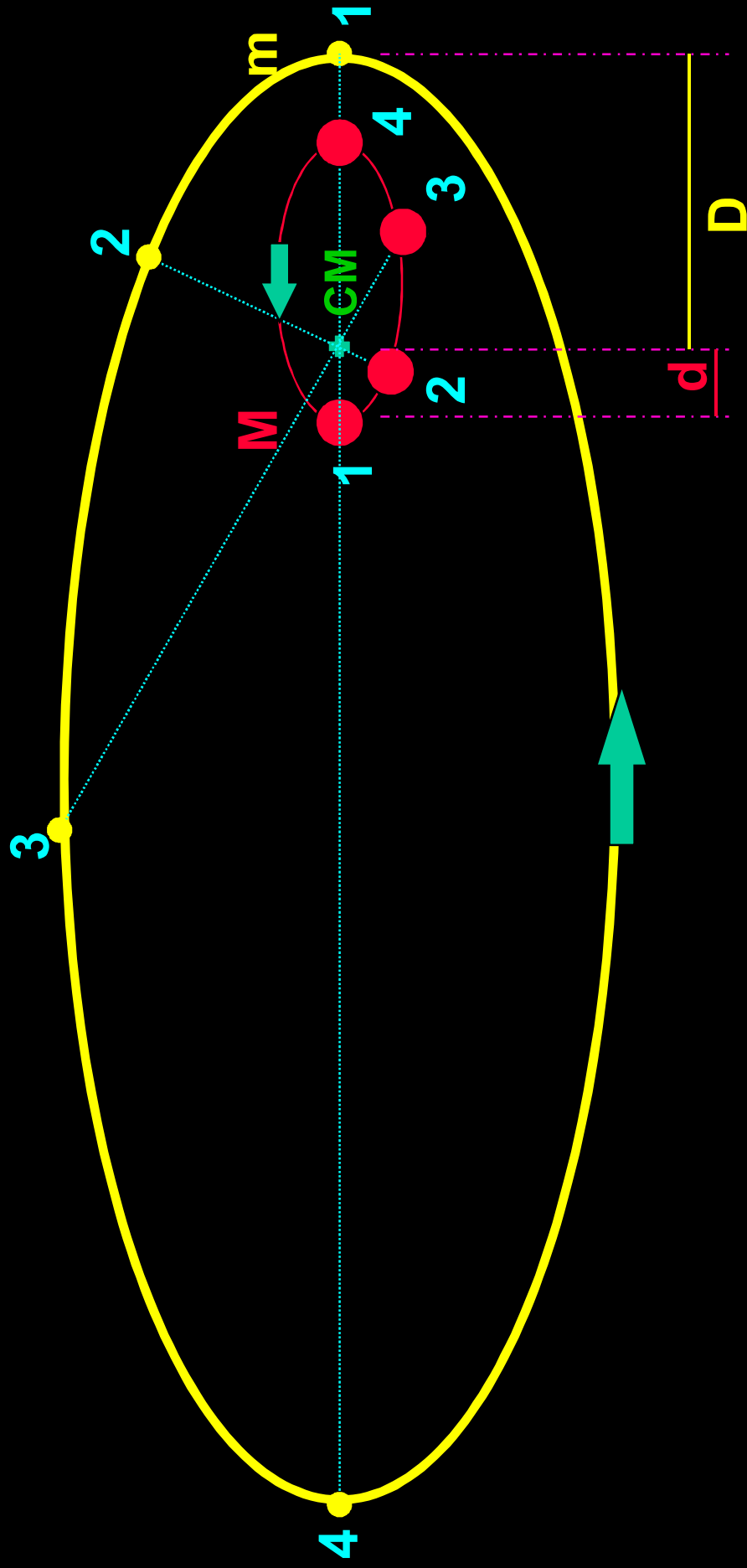
Primeira Lei de Kepler

(1571 - 1630)



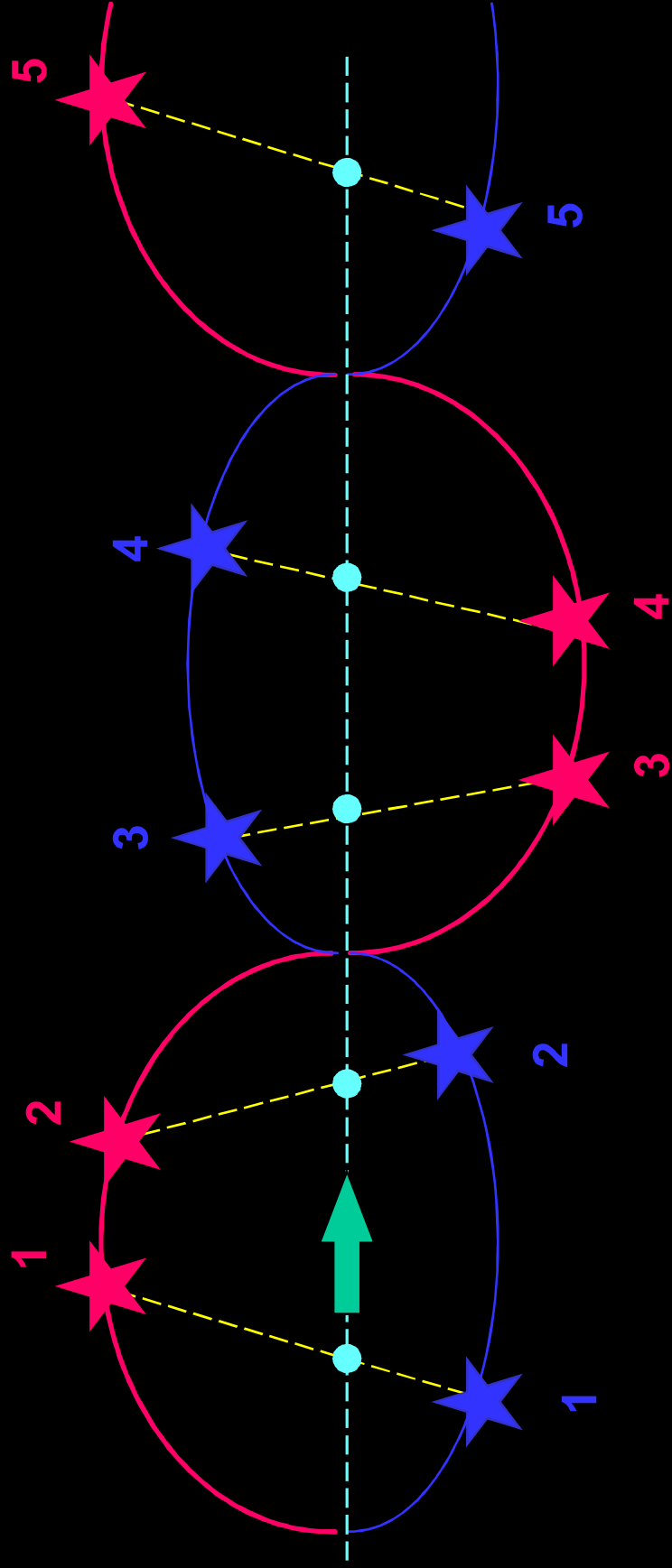
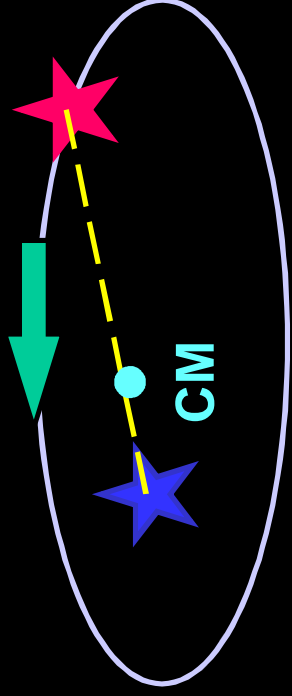
Um corpo ligado a outro, gravitacionalmente, gira em torno dele numa órbita elíptica.

Movimento em torno do Centro de Massa Comum

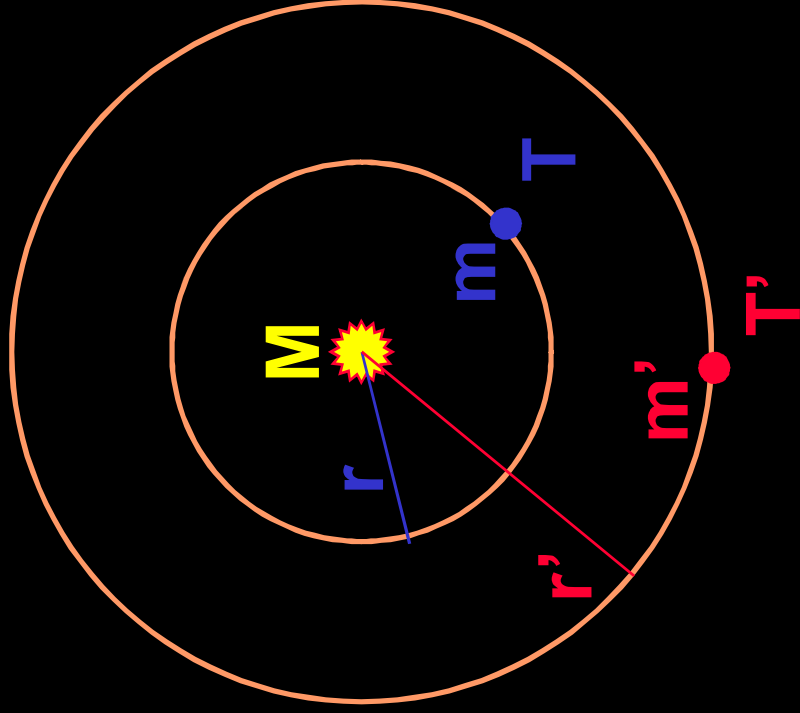


$M d = m D$

Sistema Binário de estrelas



Terceira Lei de Kepler



$$(r/r')^3 = (T/T')^2$$

$$r^3 = k T^2$$

Expressão correta:

$$r^3 = [G/(4\pi^2)] (M + m) T^2$$

$$(r/r')^3 = ((M + m) / (M + m')) \times (T/T')^2$$

Massas das estrelas de Sistemas Binarios

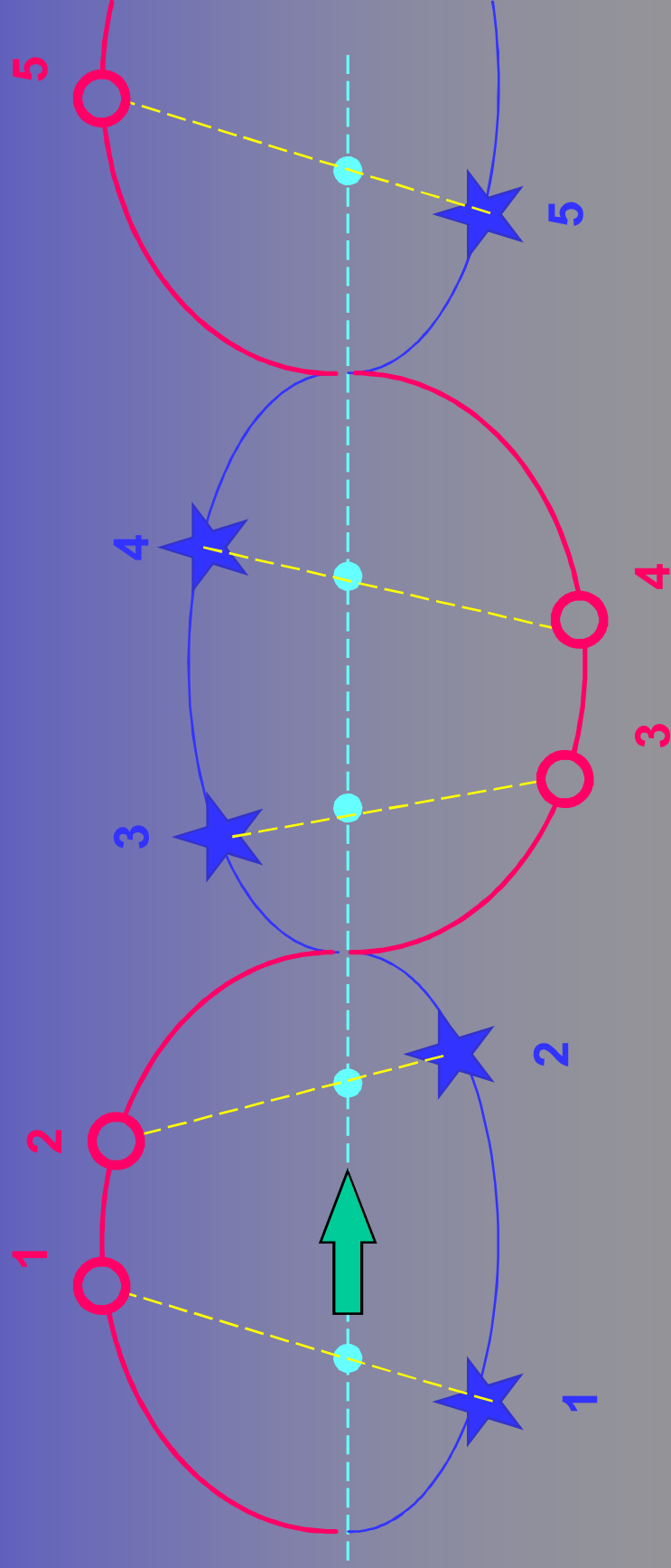
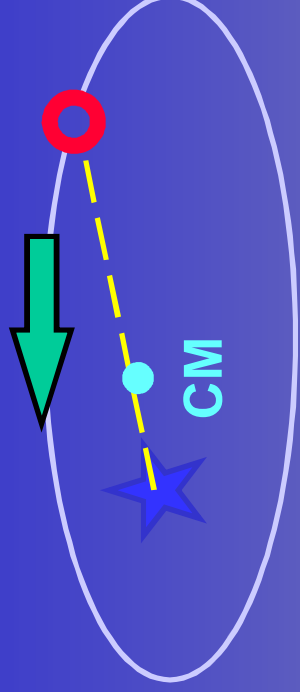
$$r = d + D$$

$$r^3 = [G/(4\pi^2)] (M + m) T^2$$

$$M d = m D$$

$$M, m$$

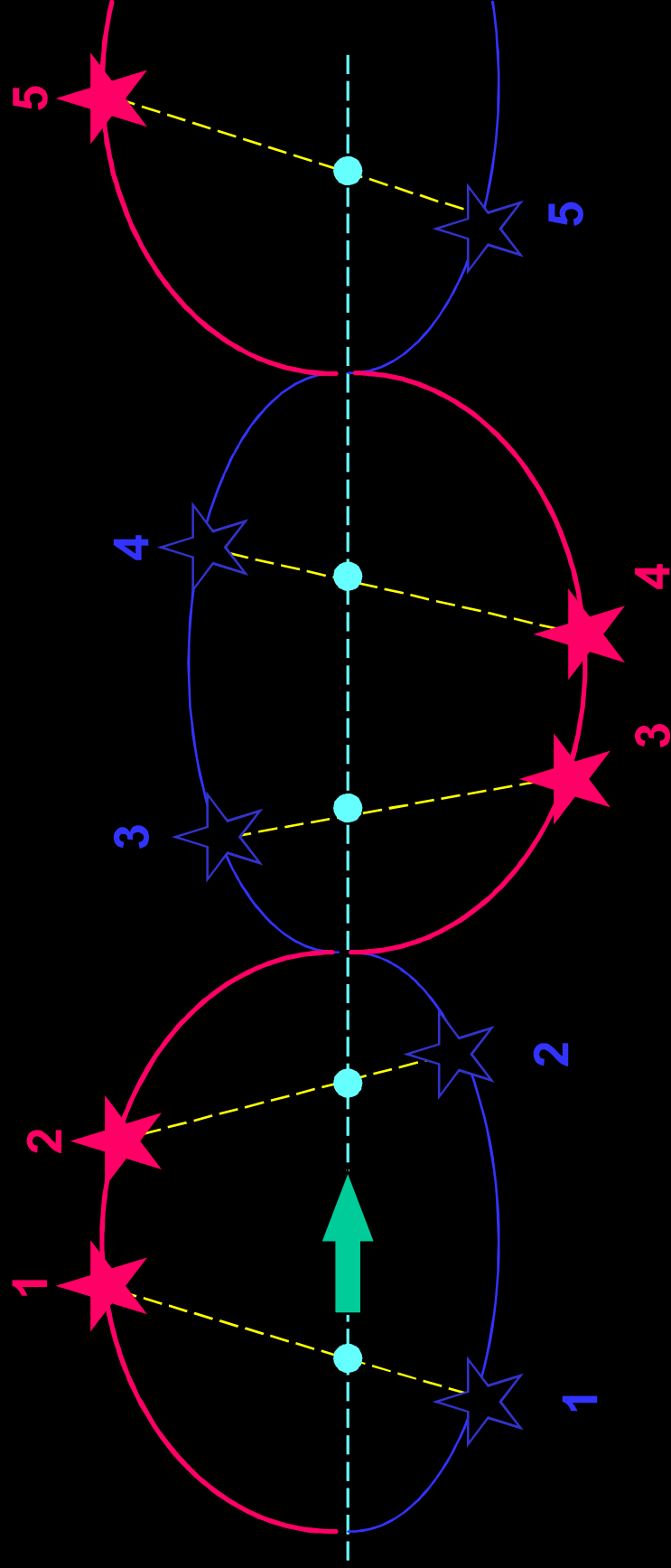
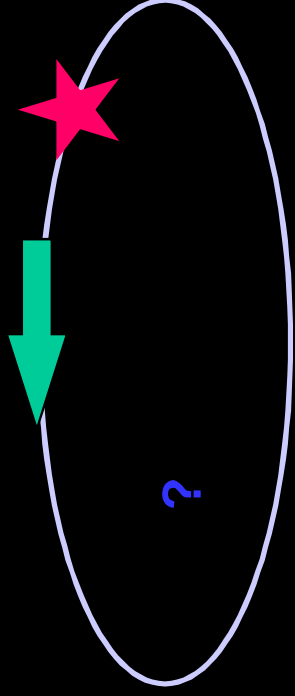
Sistema Planetário



$$m \lll m_{\text{Sol}}$$

○ Planeta !

Sistema Binário de estrelas

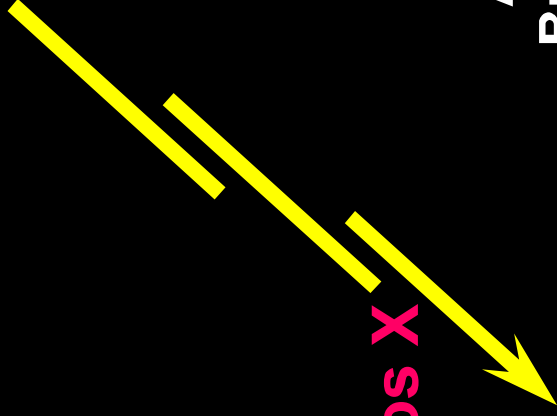


$m \gg m_{\text{sol}}$

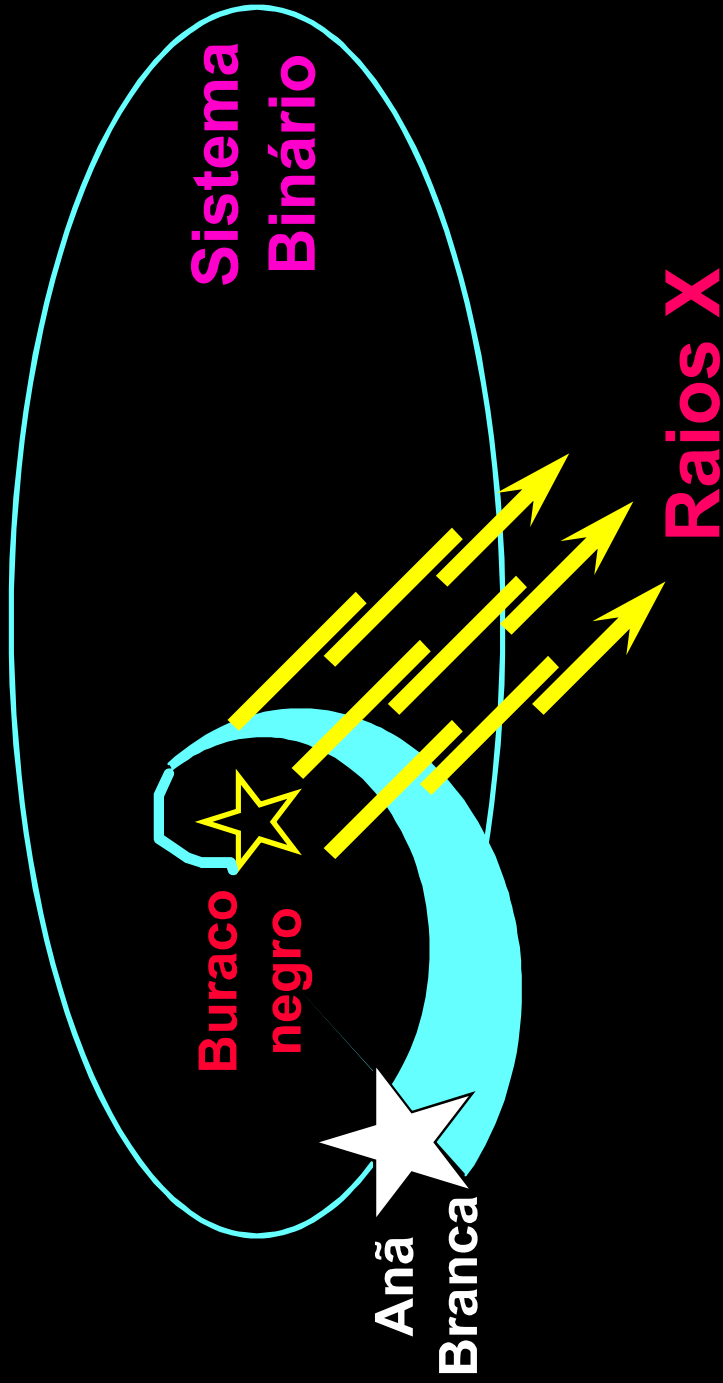


Buraco Negro !

Fontes de Raios X



Raios X



Sistema Binário

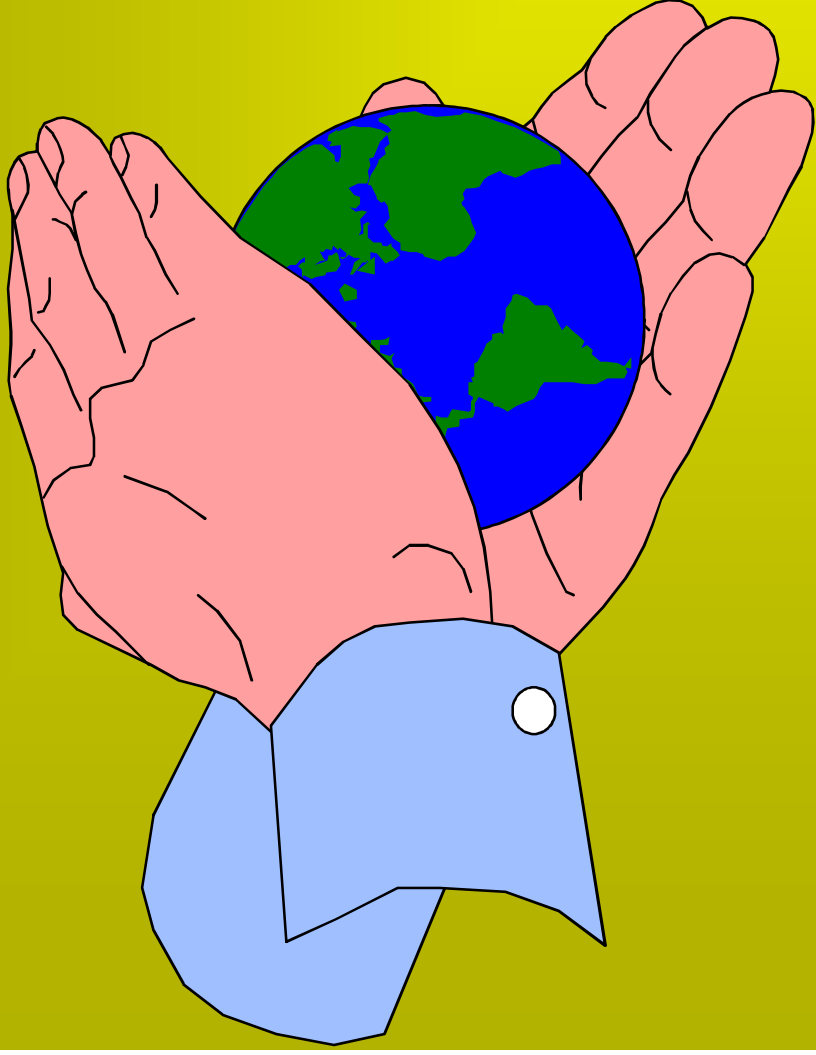
Buraco negro

Anã Branca

Raios X

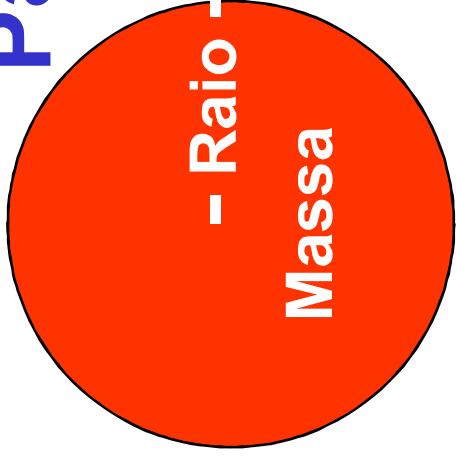
**Será que a Terra pode vir a
ser um buraco negro?**

Fabricar um Buraco Negro !



**Buraco
Negro
Terra**

Para se tornar um Buraco Negro



R=?



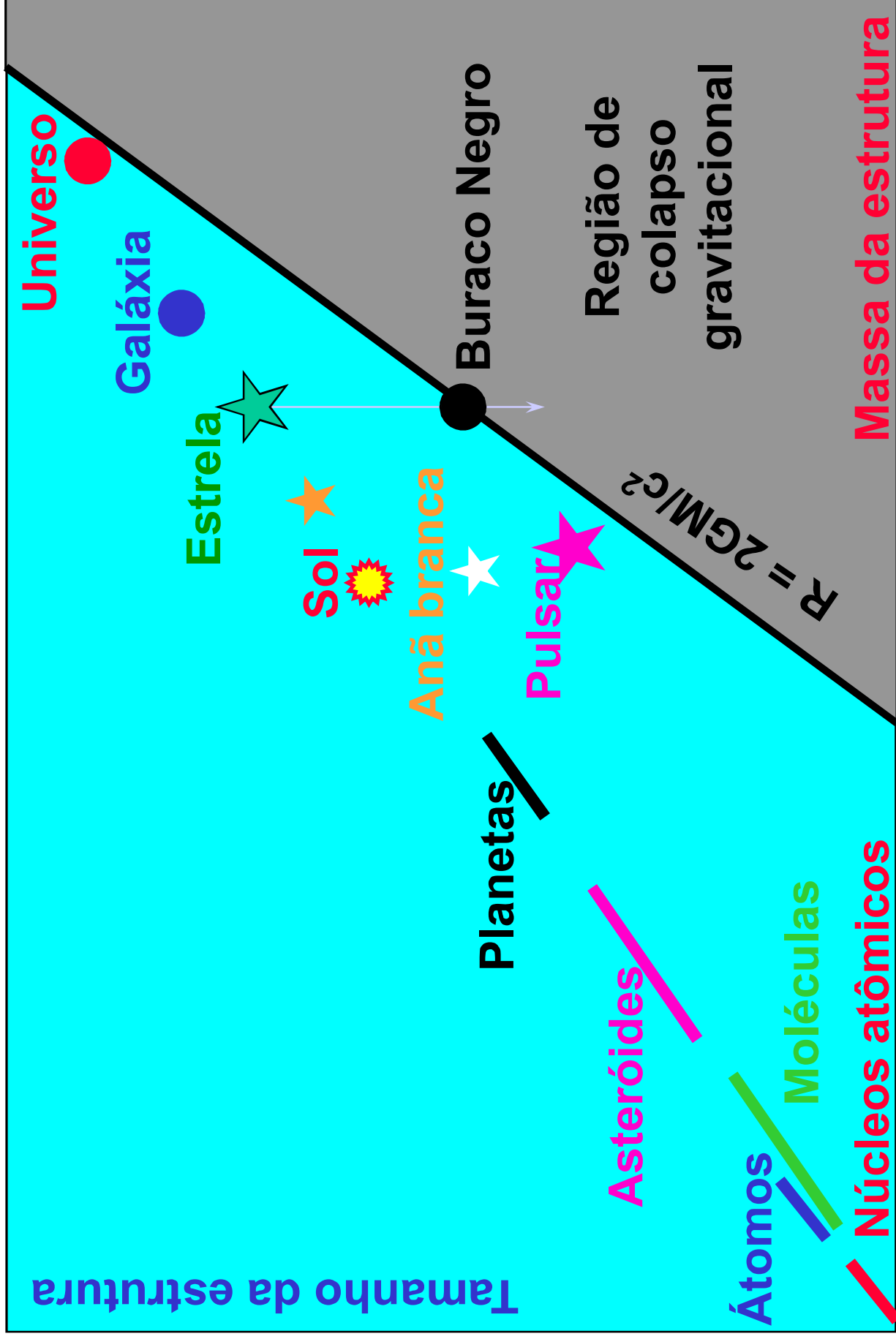
Raio de Schwarzschild:

$$R = (2GM) / c^2$$



	Massa	Raio	Densid.
Asteróide	10^{18}	10^{-9} m	10^{41}
Terra	6×10^{24}	1 cm	10^{27}
Sol	$M = 2 \times 10^{30}$	3 km	10^{16}
Estrela Pesada	10 M	30 km	10^{14}
Galáxia	10^{11} M	0,03 AL	10^{-6}
Universo	?	?	?

Relação entre tamanho e massa



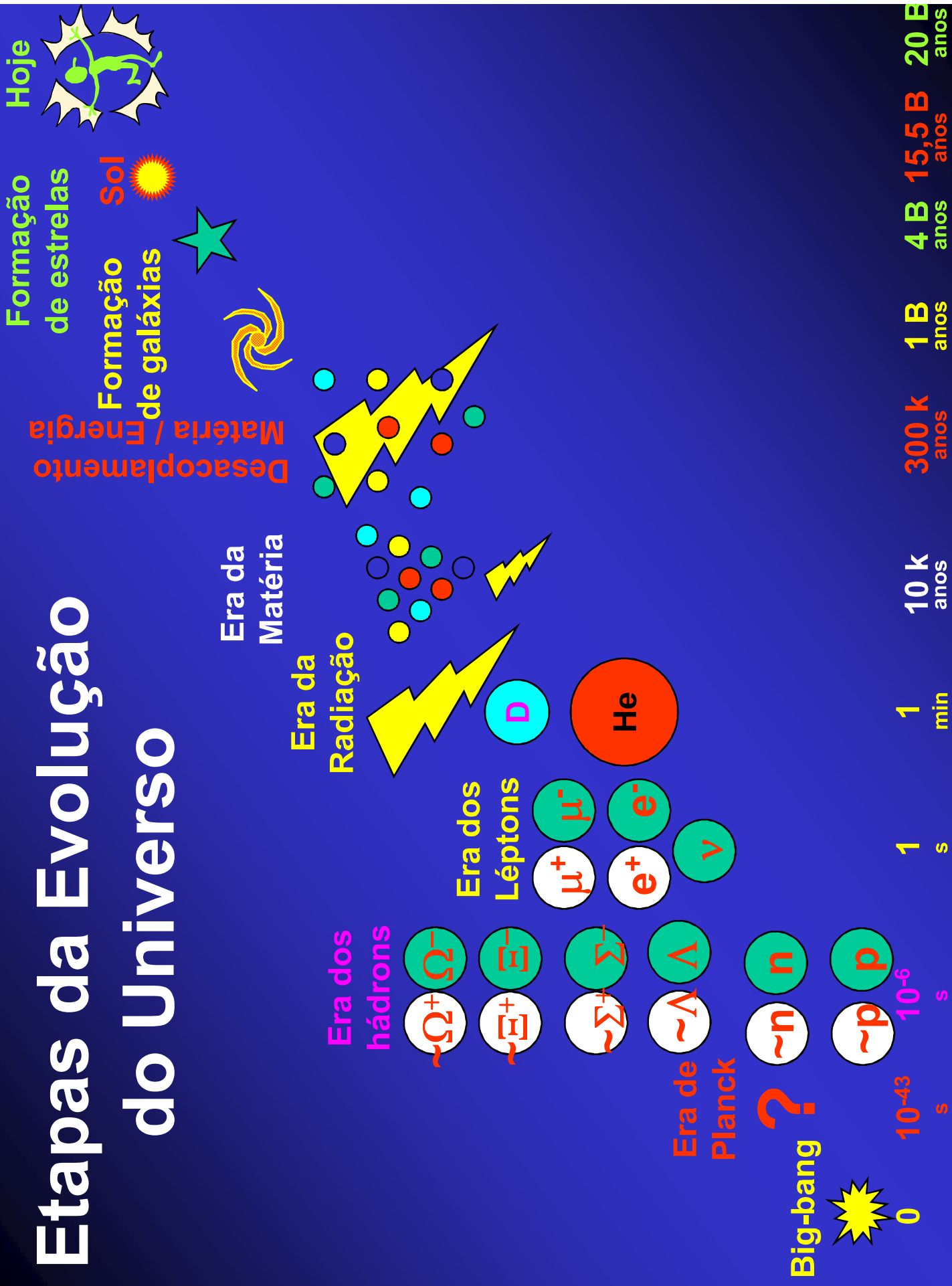
Conclusão

Pode ser que Nosso Universo
se comporte como um
Buraco Negro

- **Nada do que está dentro pode sair;**
- Para “outro” Universo, somos invisíveis.

Evolução do Universo

Etapas da Evolução do Universo



Uma dúvida...

“Big-bang”



Óvulo
primordial



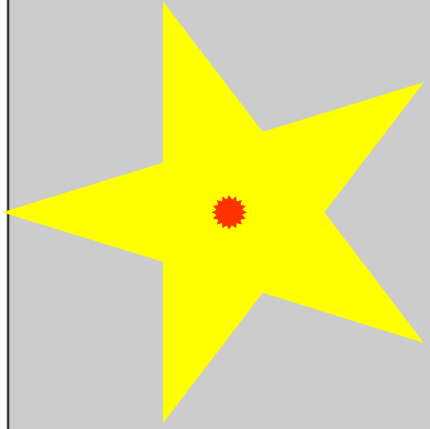
Big-bang



Universo
(H₂ e He)

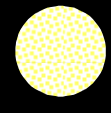
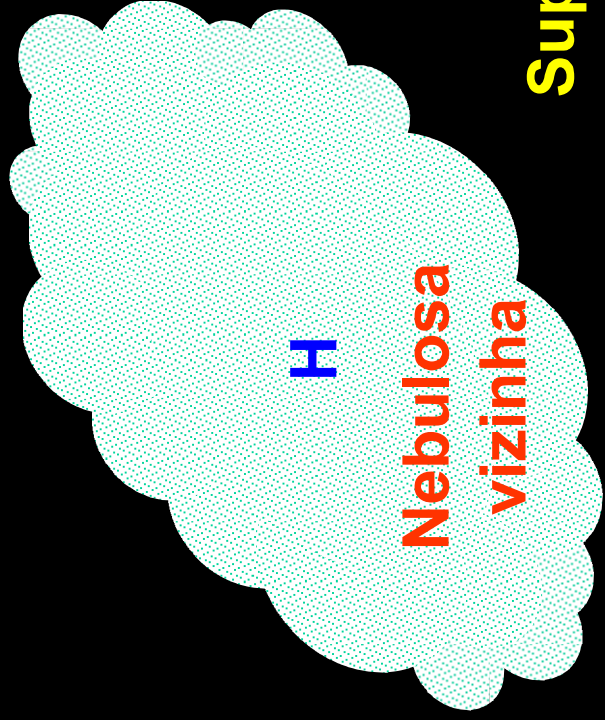
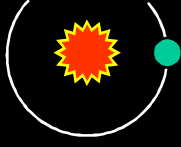
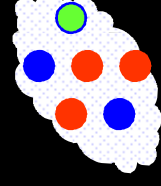
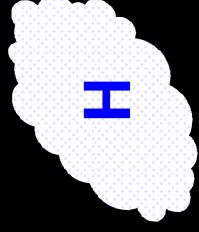
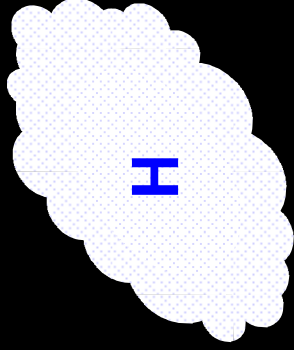
Como surgiram os elementos pesados?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H	Li 3	Be 4	B 5	C 6	N 7	O 8	F 9	Ne 10	He 2								
Na 11	Mg 12	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18										
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Fr 87	Ra 88	Ac 89															

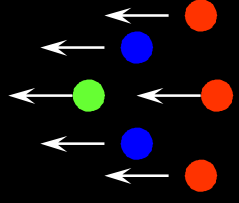


Se o **Sol** é uma estrela
peso leve, sem poder
gerar **Ferro**, por exemplo,
então
como surgiram os
elementos pesados do
Sistema solar?

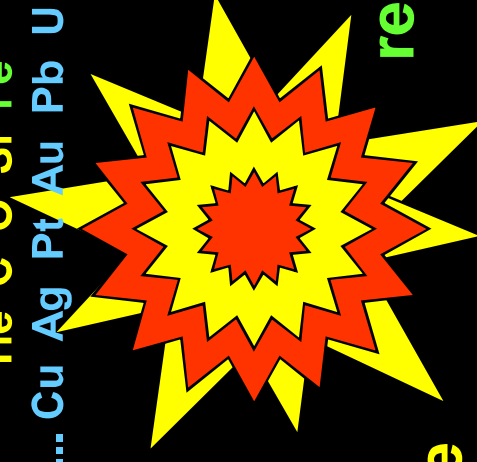
Sol: uma estrela de segunda mão



**Estrela
Supergigante**



He C O Si Fe
... Cu Ag Pt Au Pb U ...

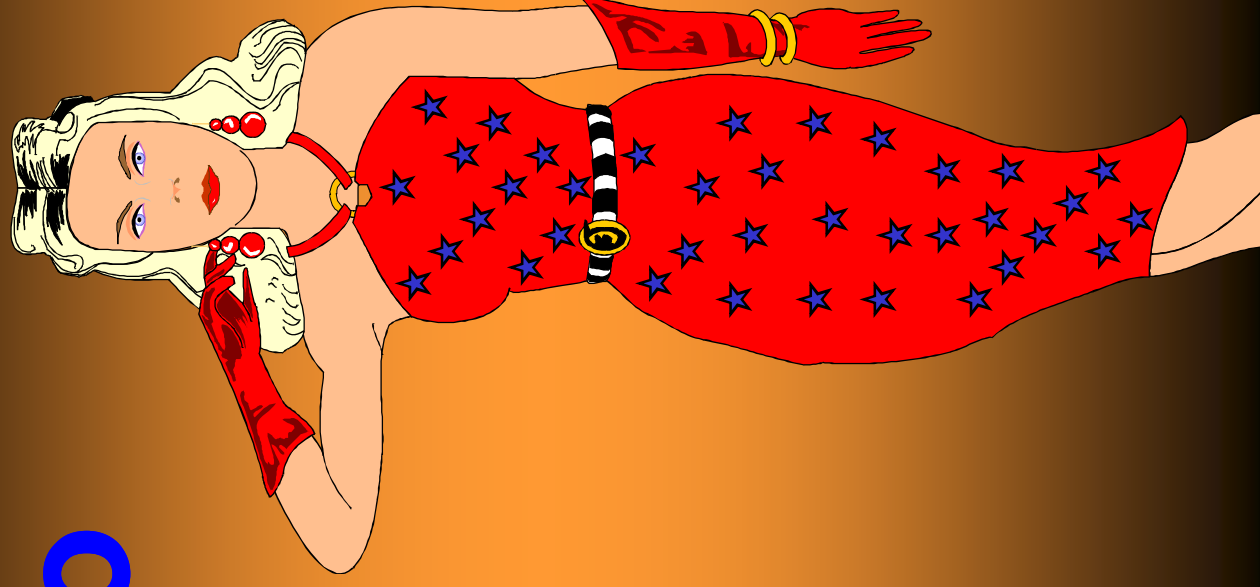


Supernova



**Estrela
remanescente**

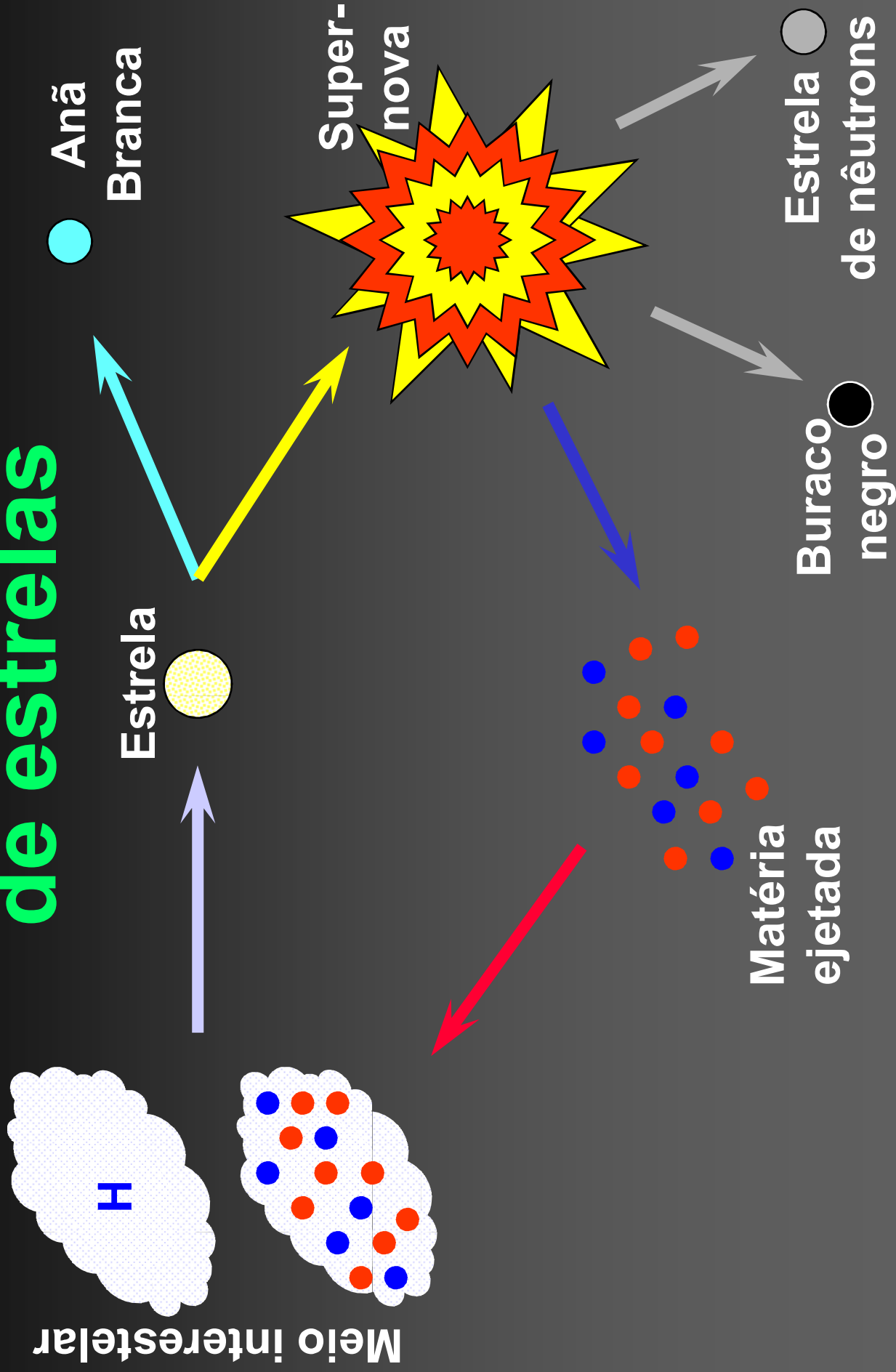
Ser Humano

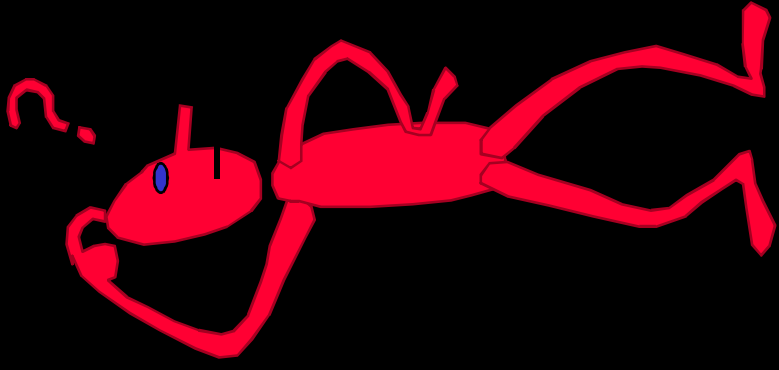


Matéria prima:

- ◆ Hidrogênio
- ◆ Pedacos de estrelas que explodiram!

Formação contínua de estrelas





E ... a vida ?

Como surgiu na Terra ?

Vida

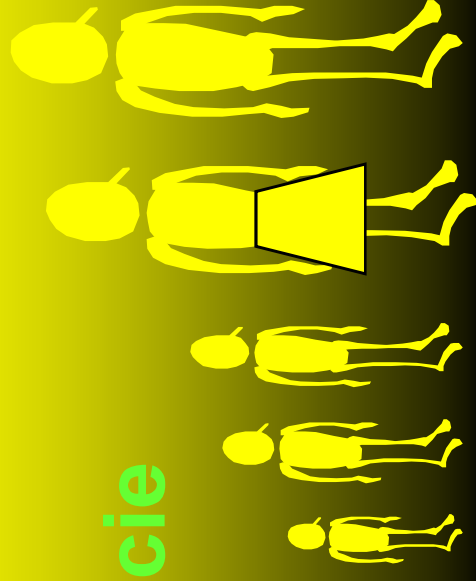
Uma definição de ser vivo:

Um ser vivo é aquele que consegue:

- se manter

e

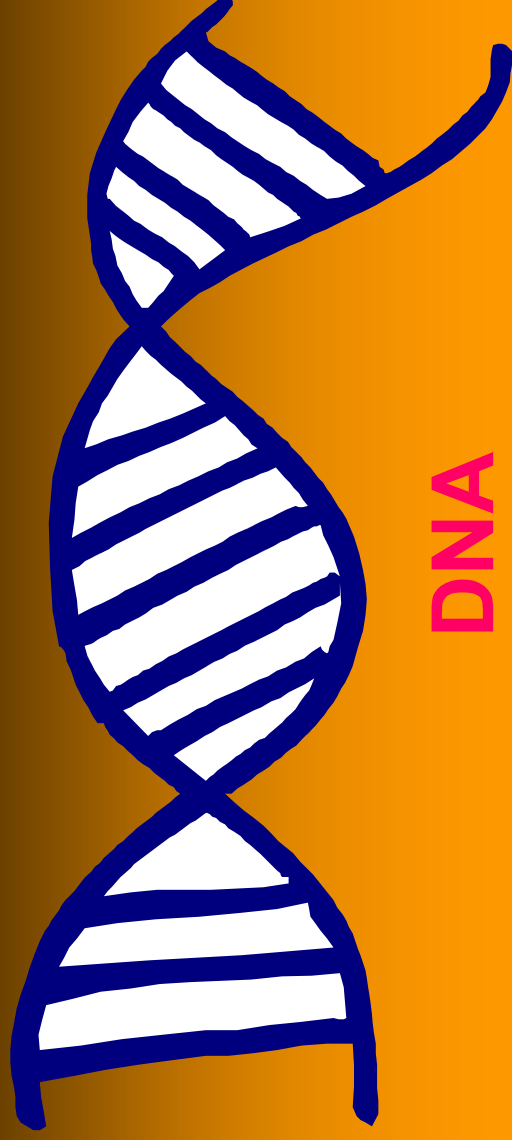
- perpetuar a espécie



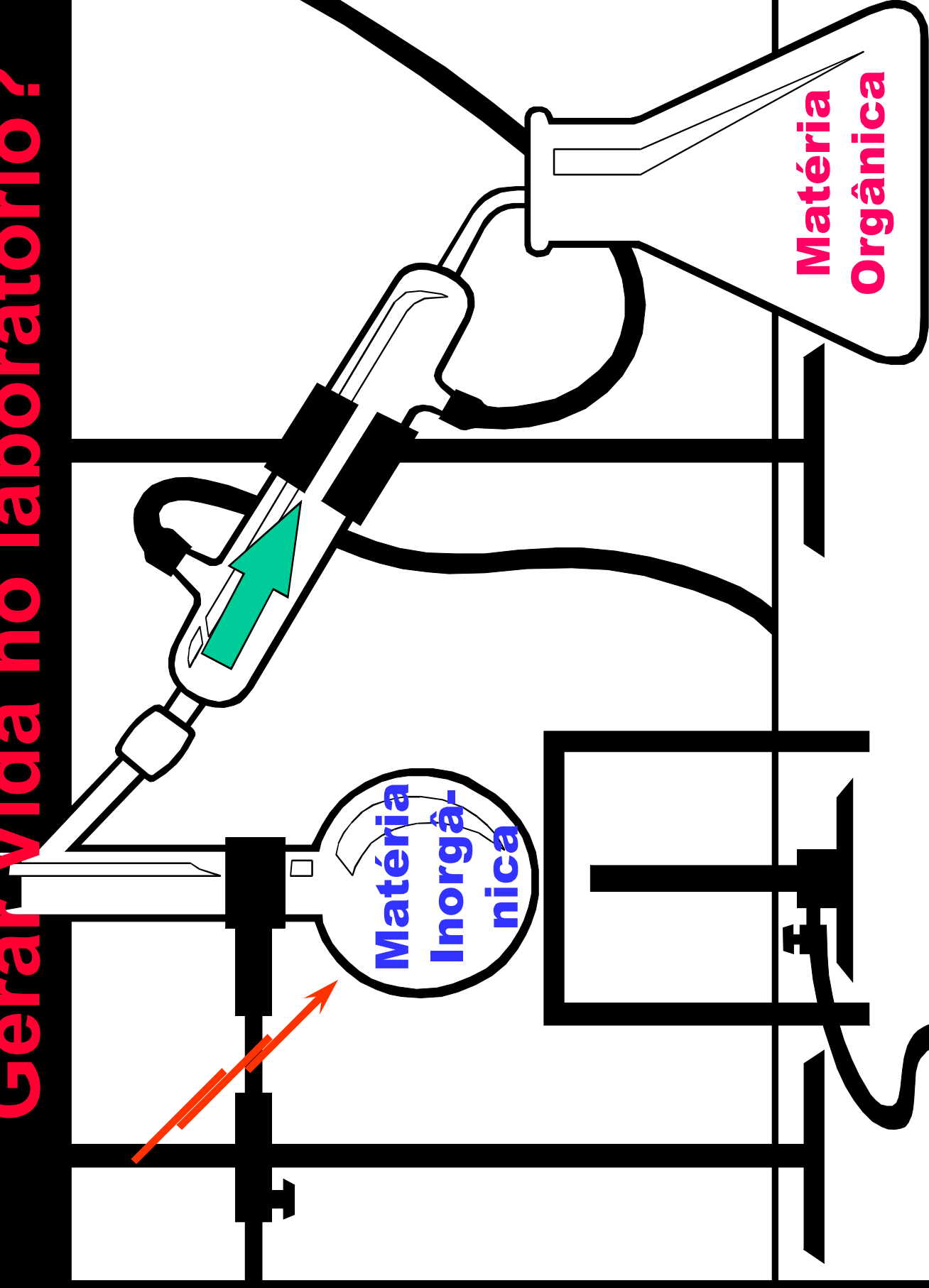
Vida Terrestre

Toda forma de vida na Terra é composta pelos mesmos “tijolinhos” básicos:

- ◆ Aminoácidos
- ◆ Nucleotídeos



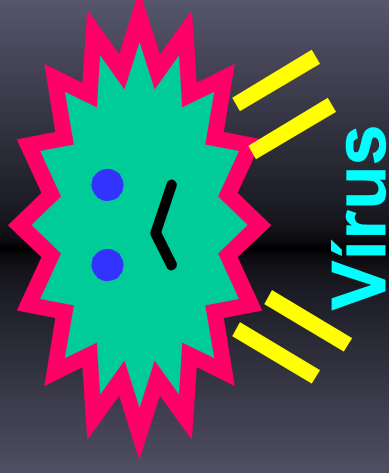
Gerar Vida no laboratório?



Seres “quase” vivos

Vírus são entes que estão “entre” os seres vivos e os inanimados

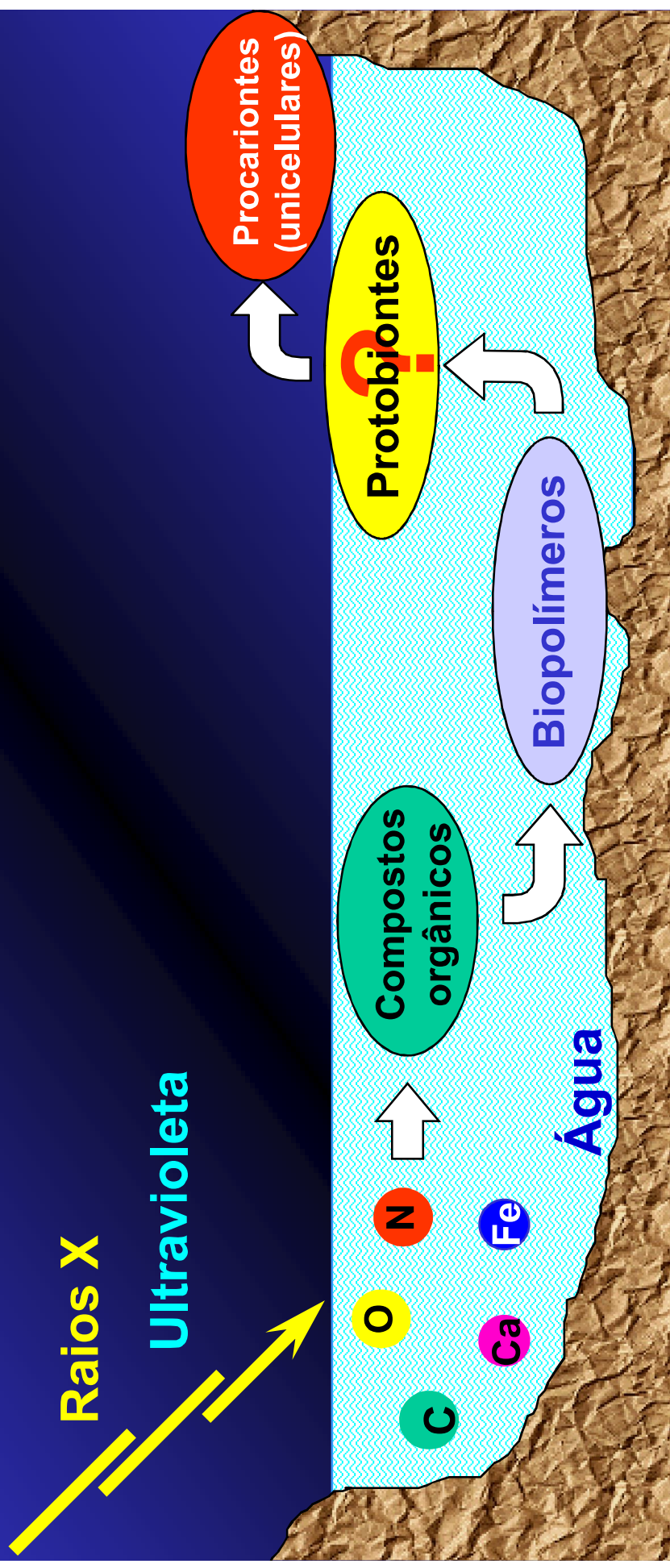
Ser ou
não ser ?

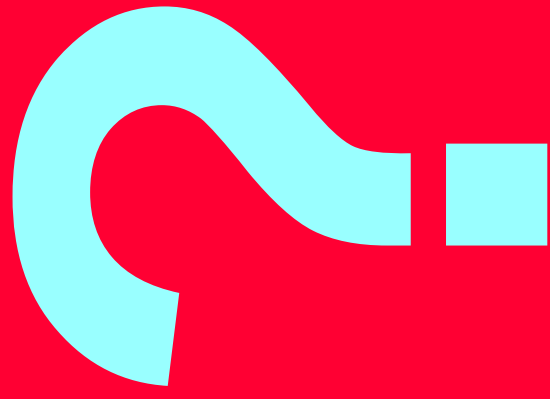


Geração de Vida na Terra

VIDA:

Feliz coincidência de propriedades
Físicas e Químicas
num determinado local e momento?





**Será que os Terráqueos
são, mesmo, originários
da Terra ?**

A vida surgiu na Terra?

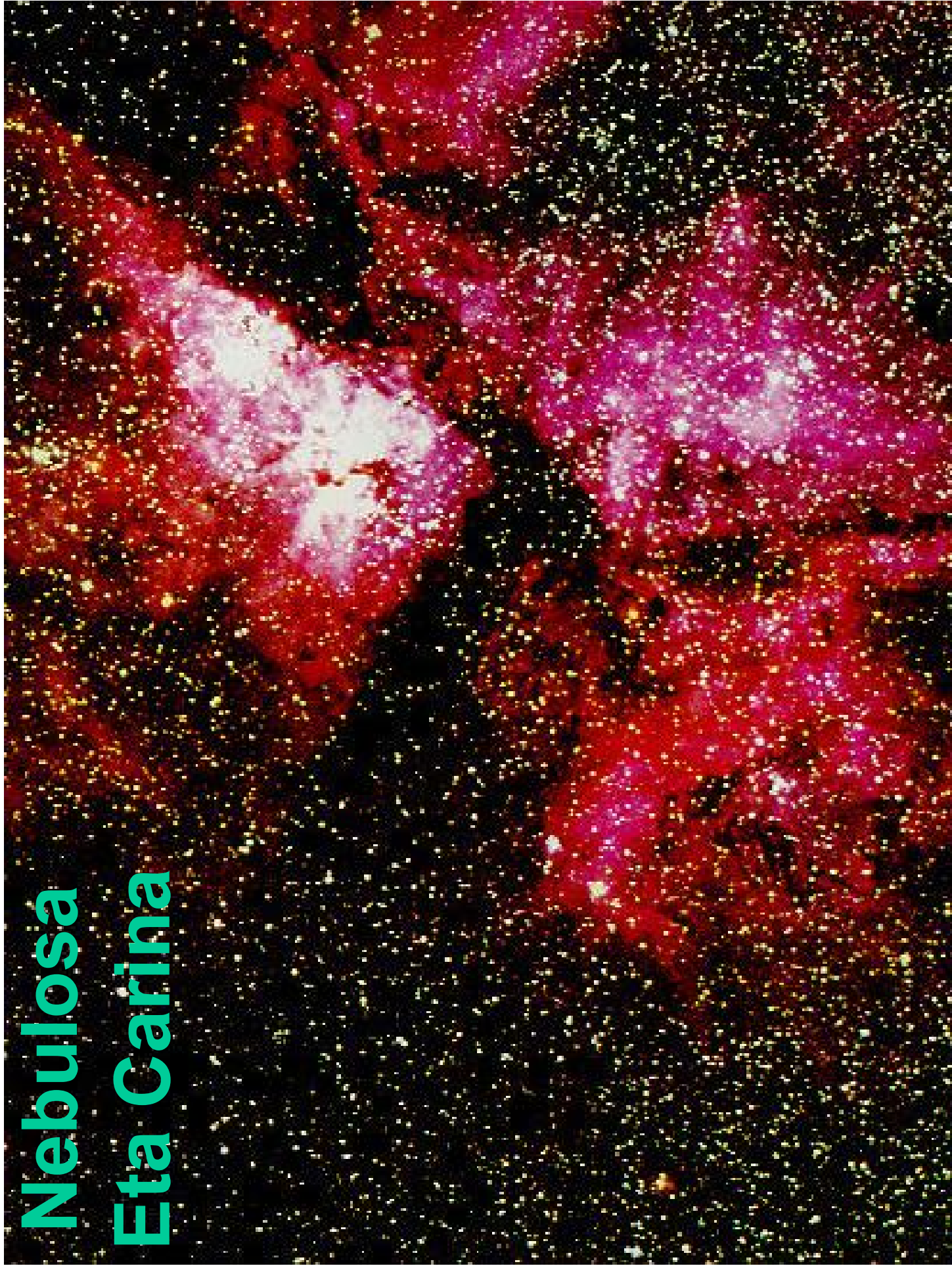
Cada passo necessário para a origem da vida é de pequena probabilidade de ocorrência.

A seqüência toda exige uma quantidade de matéria muito maior do que a existente na Terra!

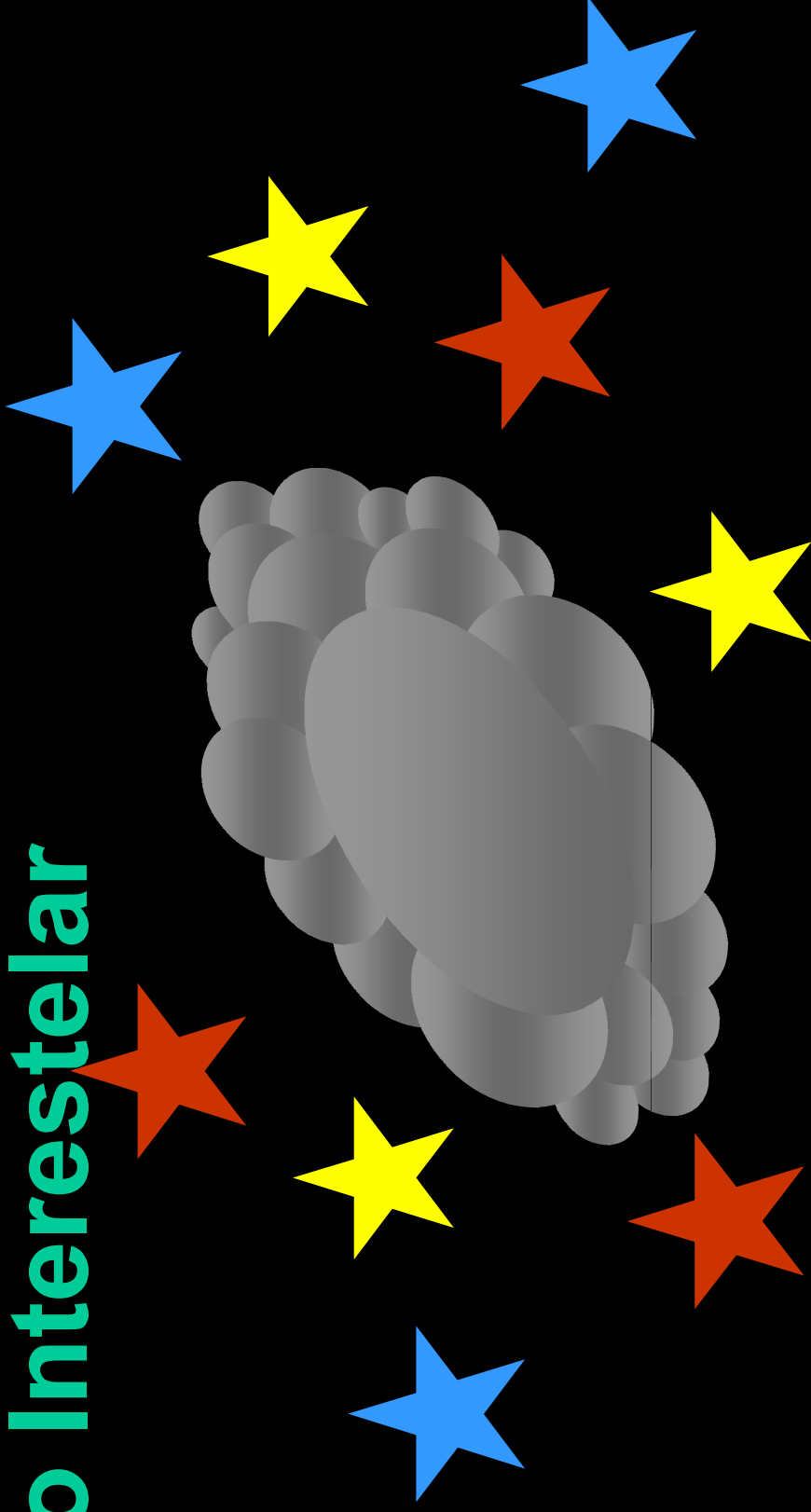
Onde, então?



Nebulosa Eta Carinae



Meio Interestelar



Ar nas CNPT = 10^{19} partículas/cm³

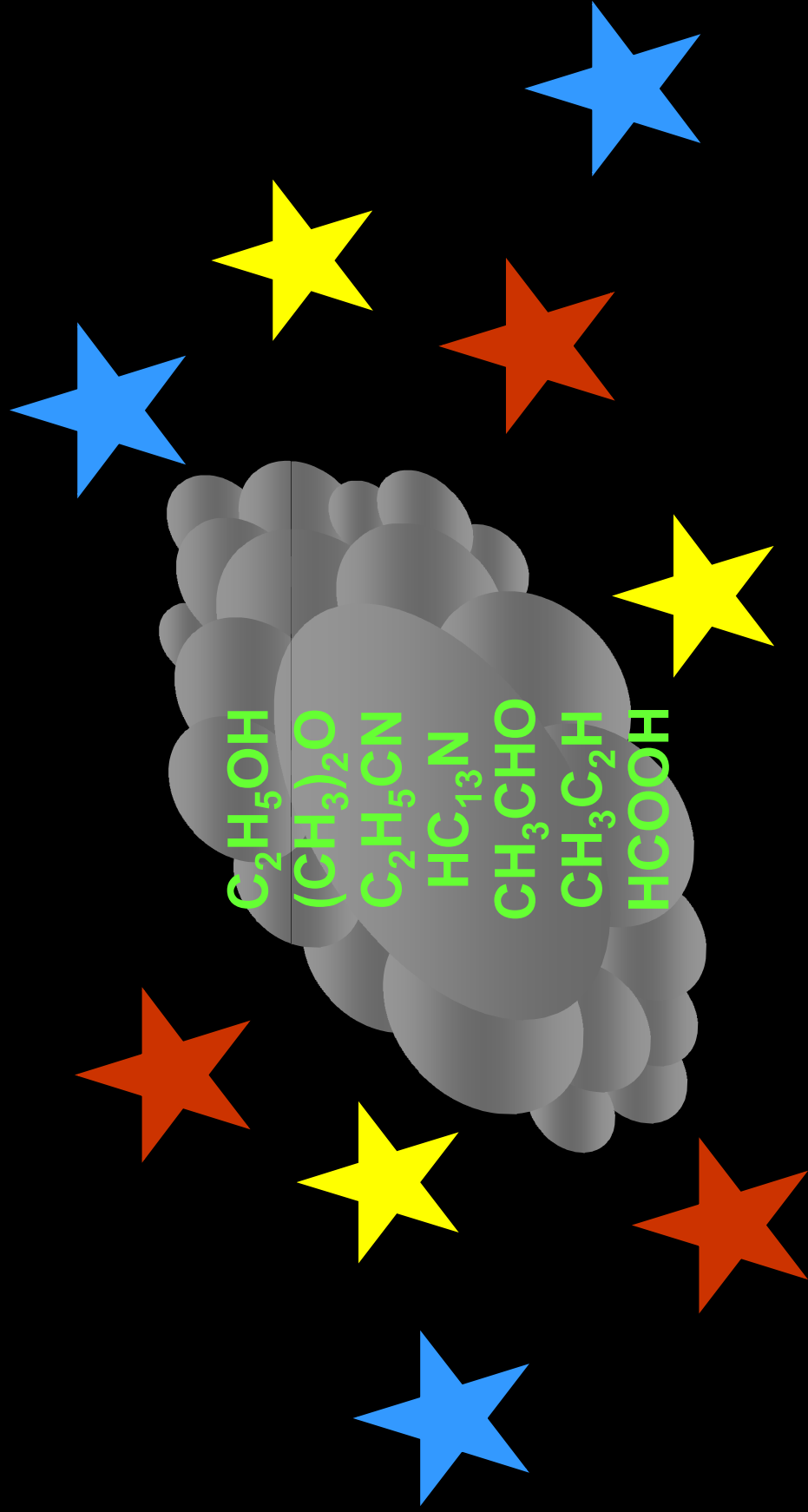
Fotosfera do Sol = 10^{17}

Nuvens Moleculares = $10^6 - 10^3$

Meio Internuvens = 0,1

Massa da nuvem = milhões de massas do Sol

Algumas moléculas orgânicas descobertas no meio interestelar

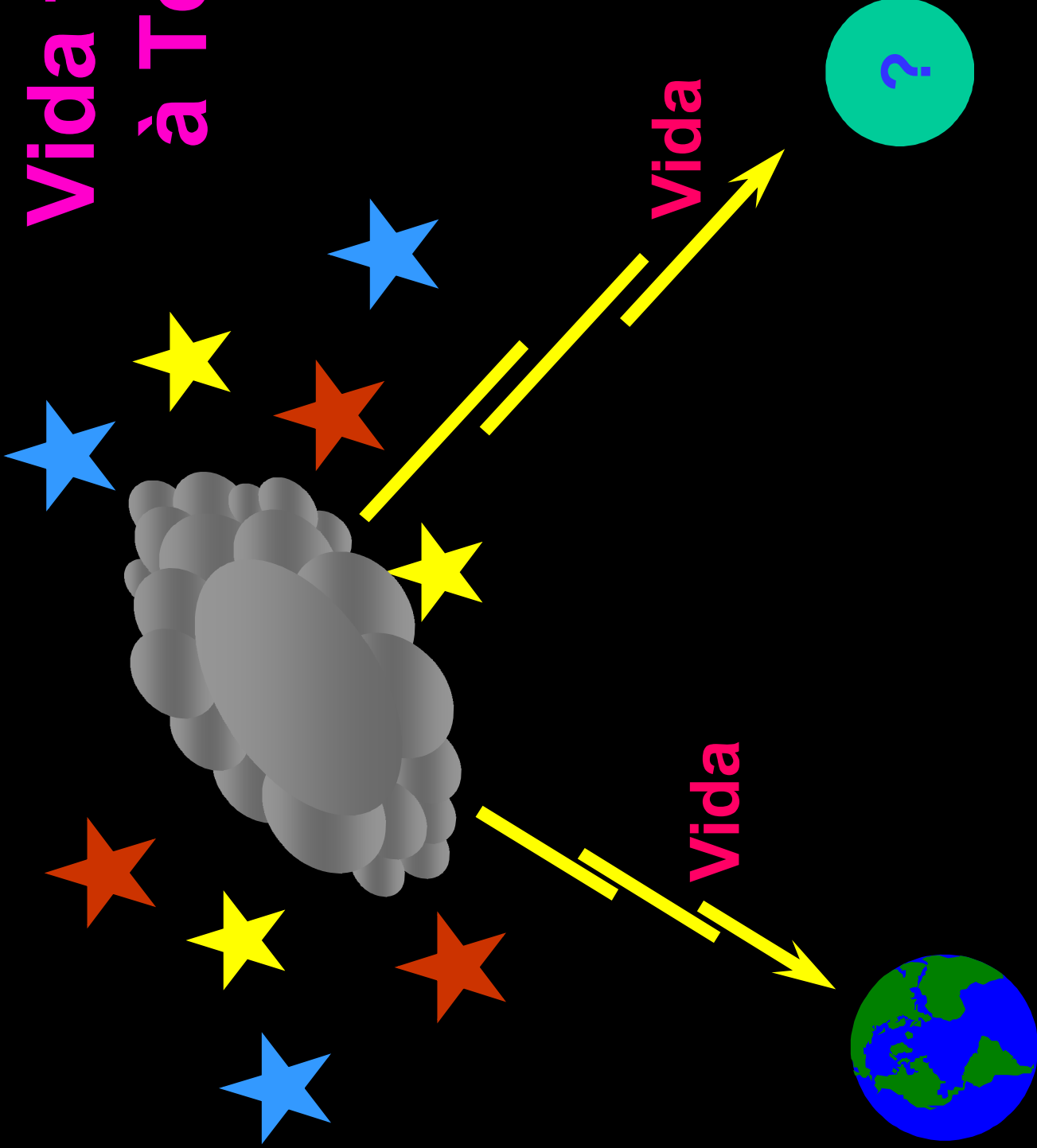


Moléculas interestelares

C_2H_5OH
 $(CH_3)_2O$
 C_2H_5CN
 $HC_{13}N$
 CH_3CHO
 CH_3C_2H
 $HCOOH$

$HC_{11}N$, HC_9N , HC_5N
 CH_3OH (alcohol metílico)
 CH_3CH_2CN
 $HCOOCH_3$
 CH_4 (metano)
 NH_3 (amoníaco)
 H_2O (água)
 H_2CO (formol)
 C_2H_2 (acetileno)
 CO (monóxido de Carbono)
 H_2 , C_2 , OH , CH
 CH_3NH_2 , HNO , CN
 OCS , $HNCS$, SO_2

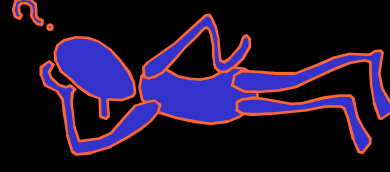
Vida trazida à Terra?





Conclusão

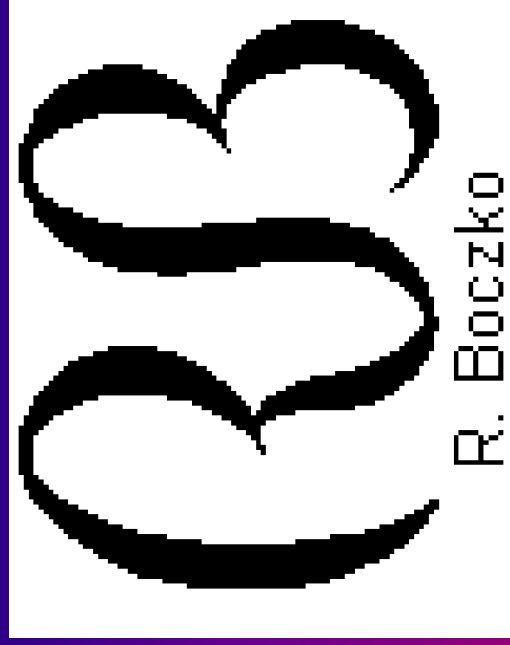
É possível que cada um de nós
tenha tido um ancestral
extraterrestre!



Importante!

- Não há nenhuma prova da existência de Vida fora da Terra.

- Mas ... também não há nenhuma prova de que ela não exista!



R. Boczek

Film