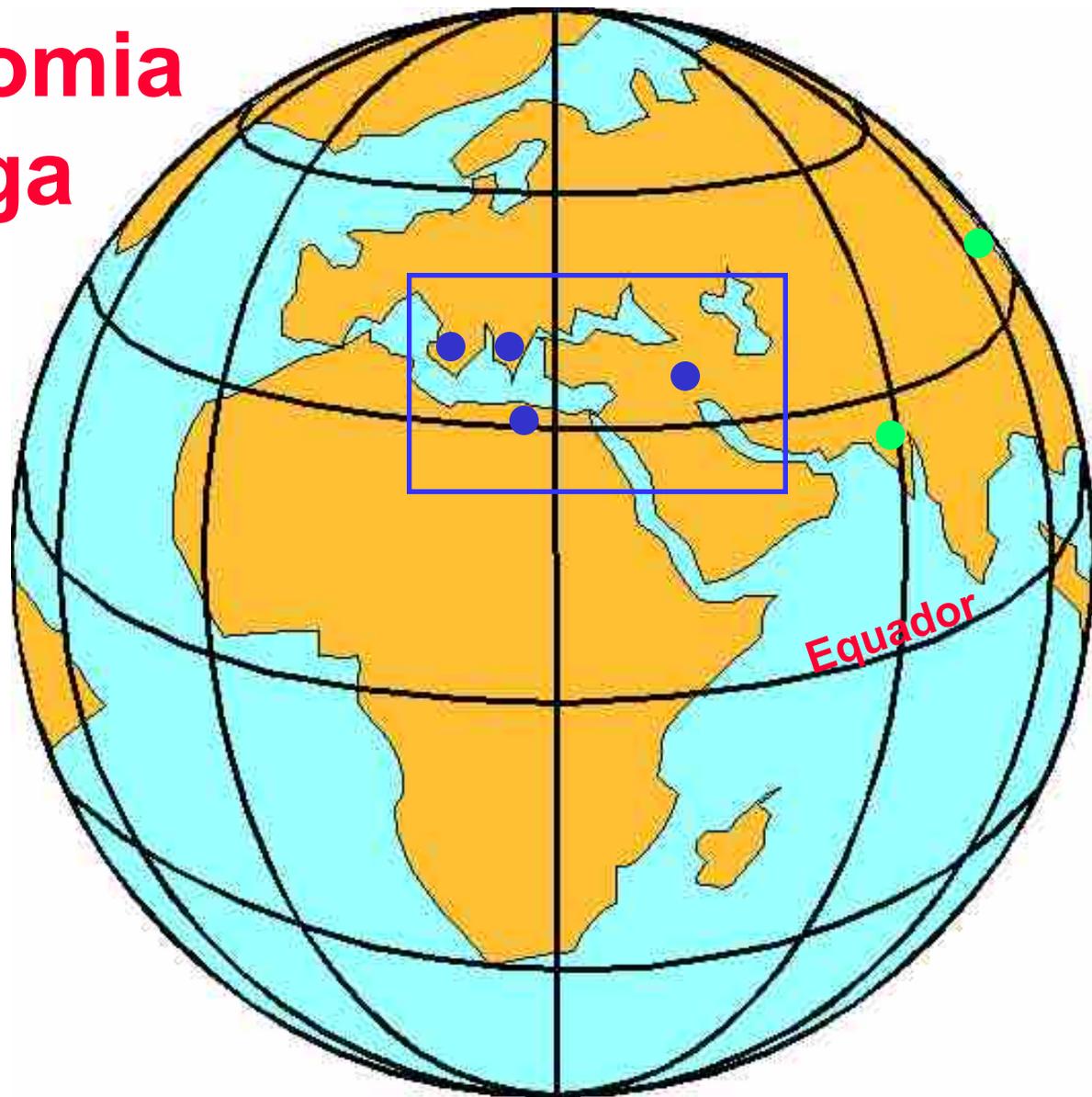


Início da Astronomia: História e Métodos

R. Boczko
(mod. R. Costa)
IAG-USP

Astronomia Antiga



Filósofos e Astrônomos Antigos Famosos

Pitágoras

Heráclides

Aristóteles

Aristarco

Eratóstenes

Hiparcos

Ptolomeu

Al Qarismi

Ulugh Beg

400

200

0

200

400

600

800

1000

1200

1400

1600

Copérnico

Tycho Brahe

Galileu

Kepler

Newton

Tales

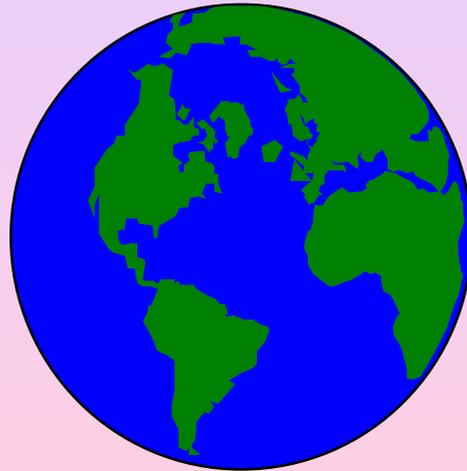
(Grego, séc. VI a.C.)



A Terra é um disco chato num
Universo infinito de água

Pitágoras

(Grego, séc. VI a.C.)

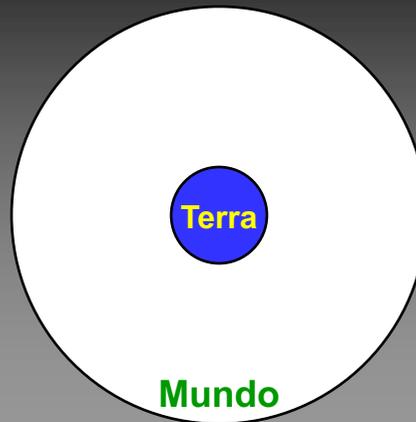


Propôs de que a Terra fosse esférica

Aristóteles

(Grego, séc. IV a.C.)

**Geocentrismo por
convicção filosófica!**

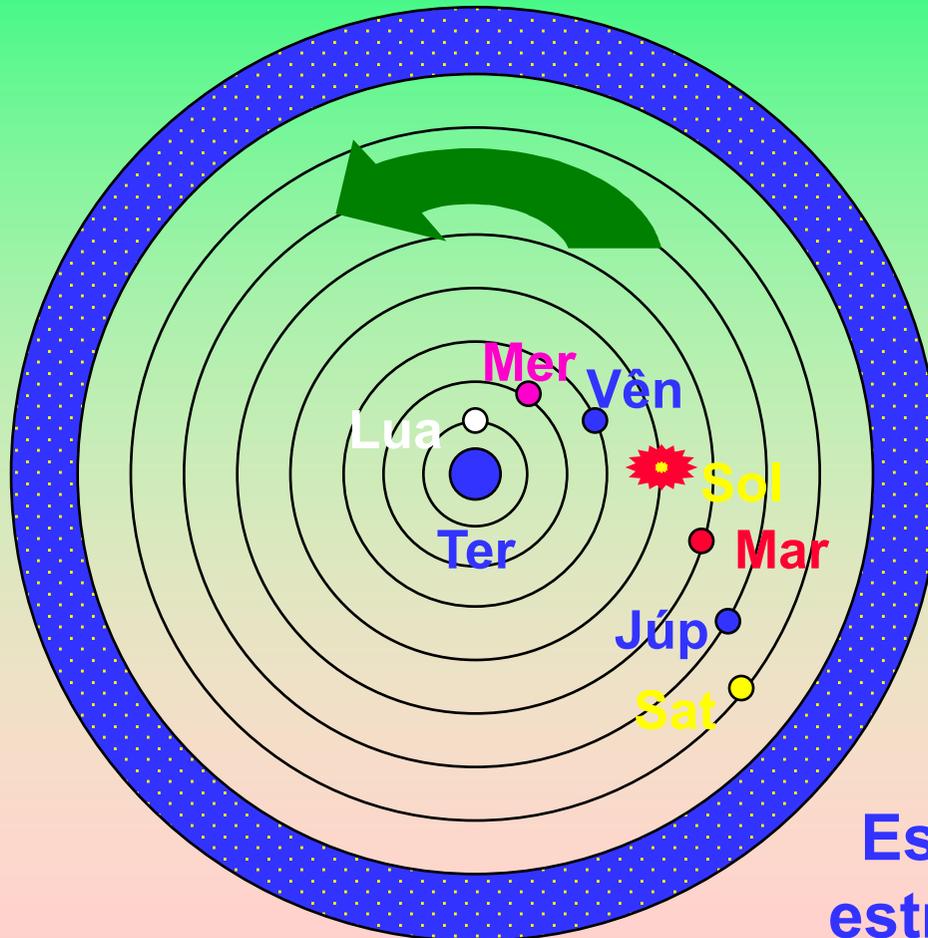


Sistema Geocêntrico



Sistema Geocêntrico

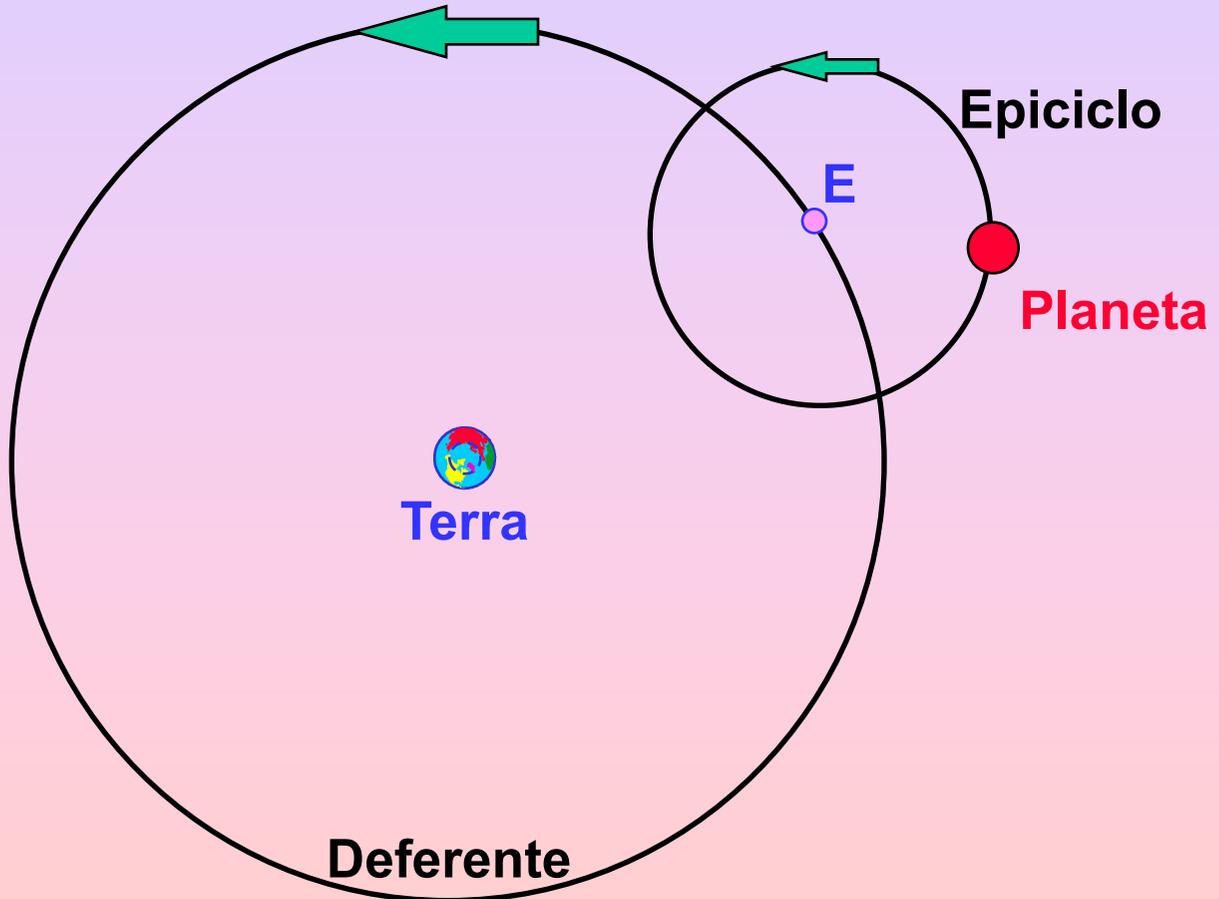
(Grego, Ptolomeu, séc. II)



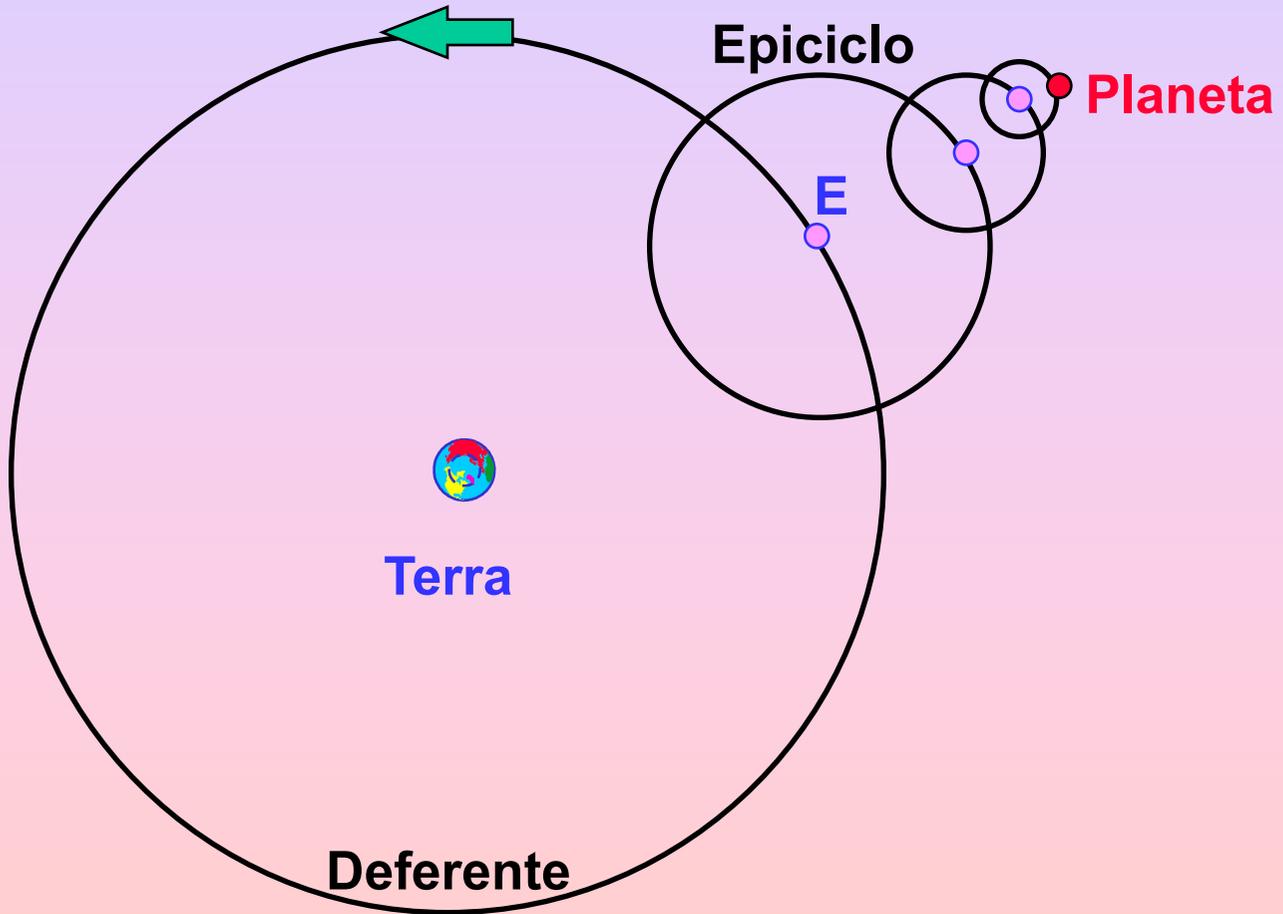
Esfera das
estrelas fixas

Sistema de Epiciclos

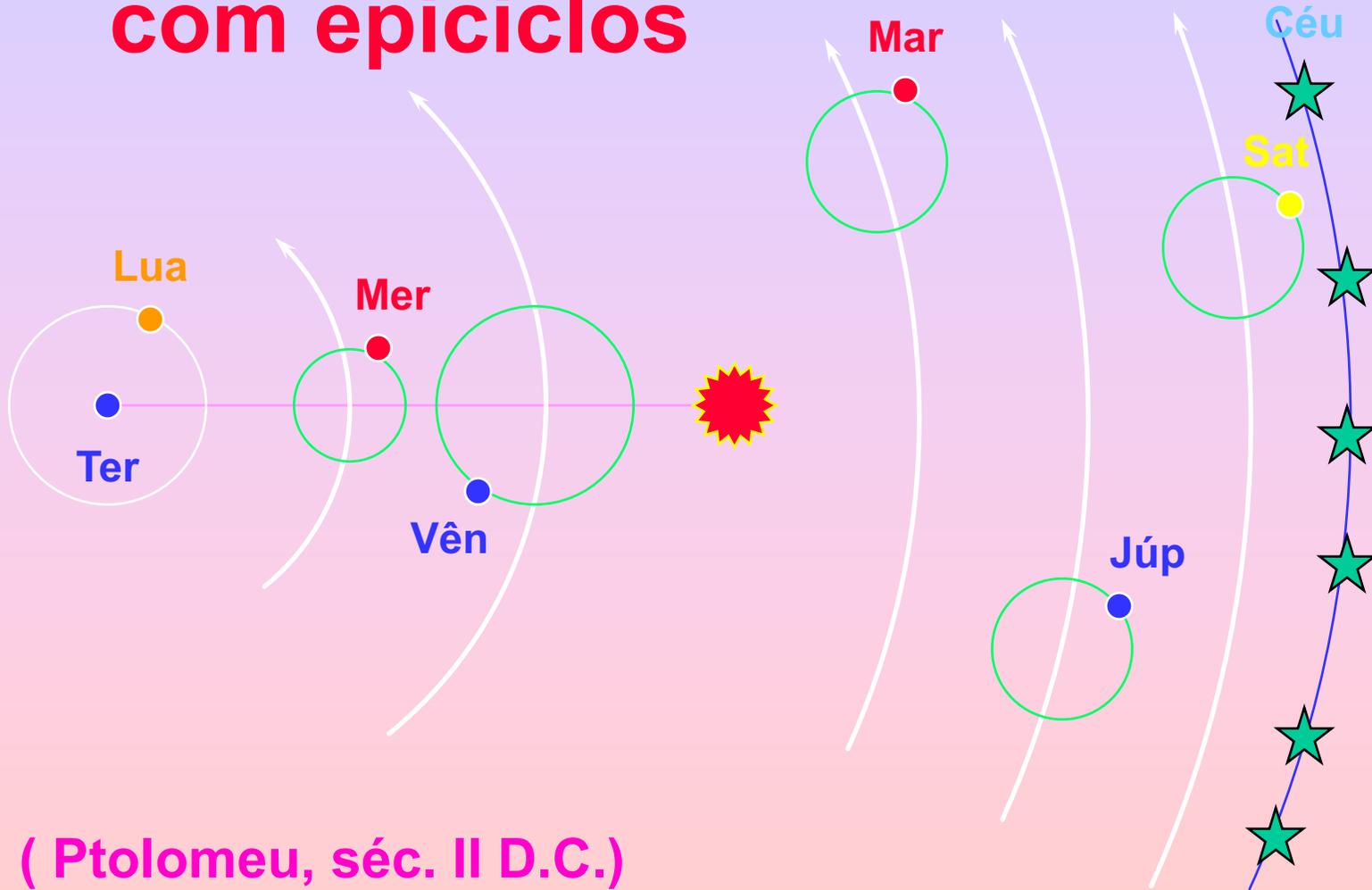
(Apolônio de Perga, 261 a.C. – 190 a.C.)



Sistema Complexo de Epiciclos



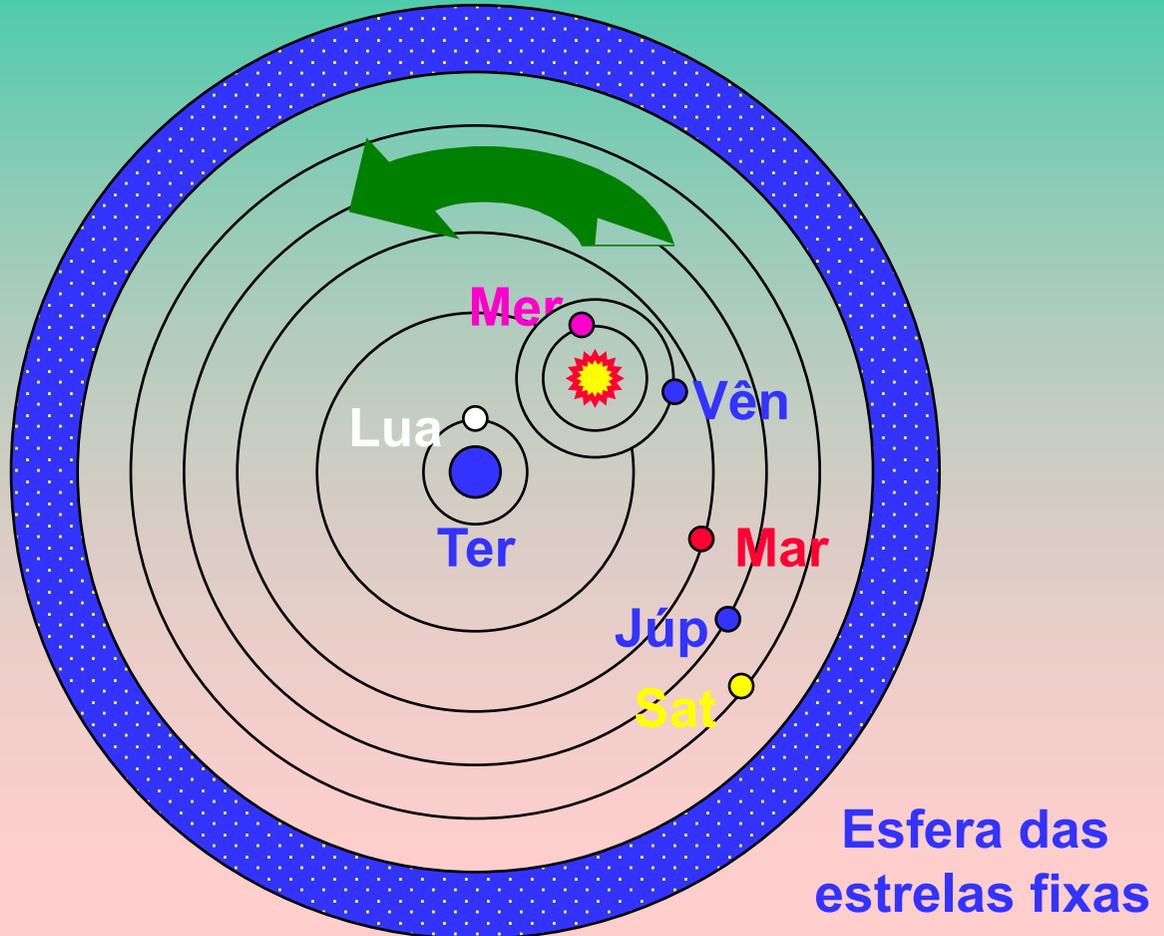
Geocentrismo com epiciclos



(Ptolomeu, séc. II D.C.)

Sistema Híbrido

(Heráclides, séc. IV a .C.)



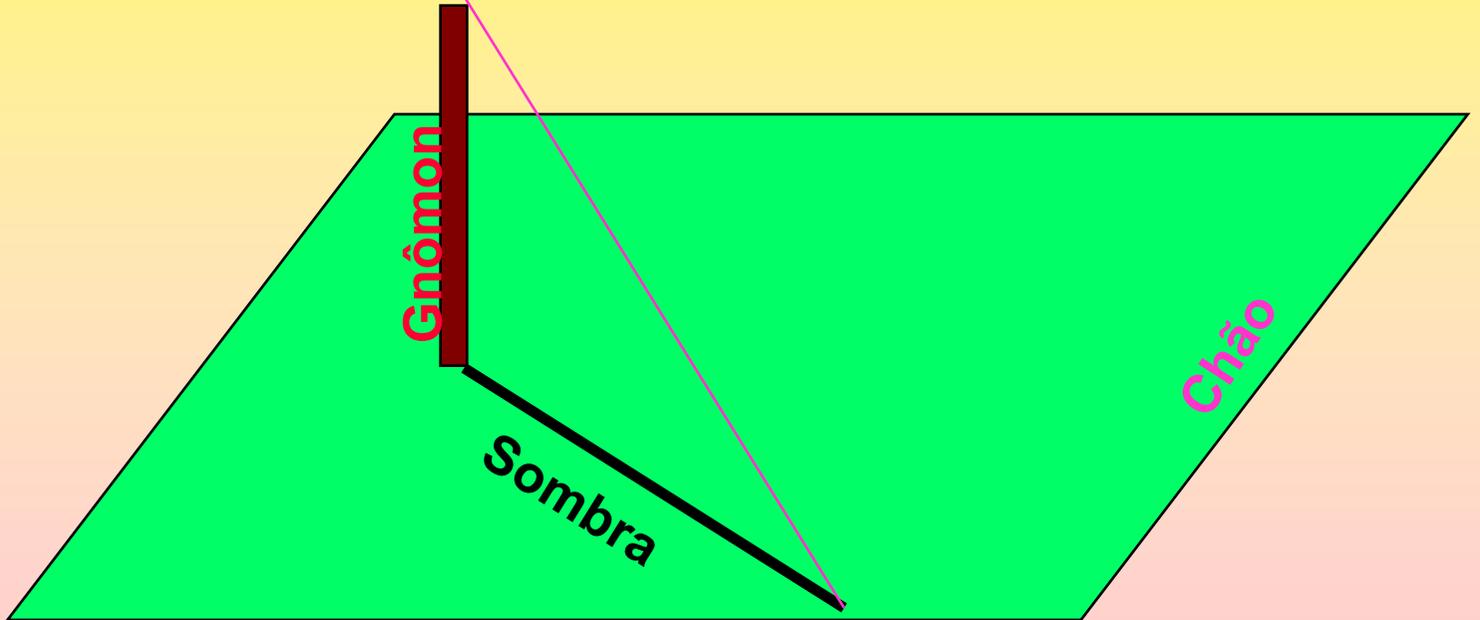
**Instrumentos
Astronômicos
Antigos**

Sol

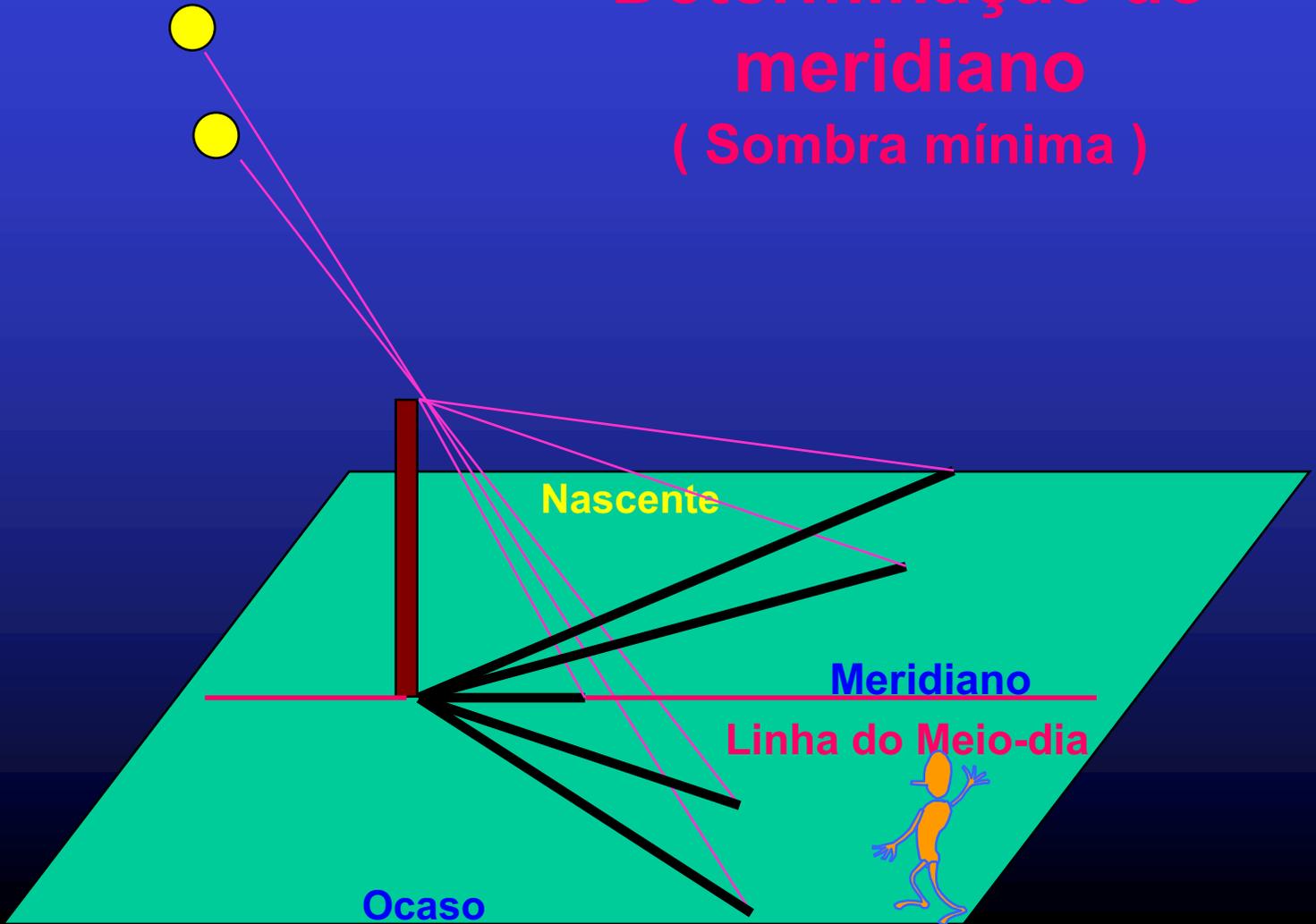


Gnômon

(Relógio de Sol)

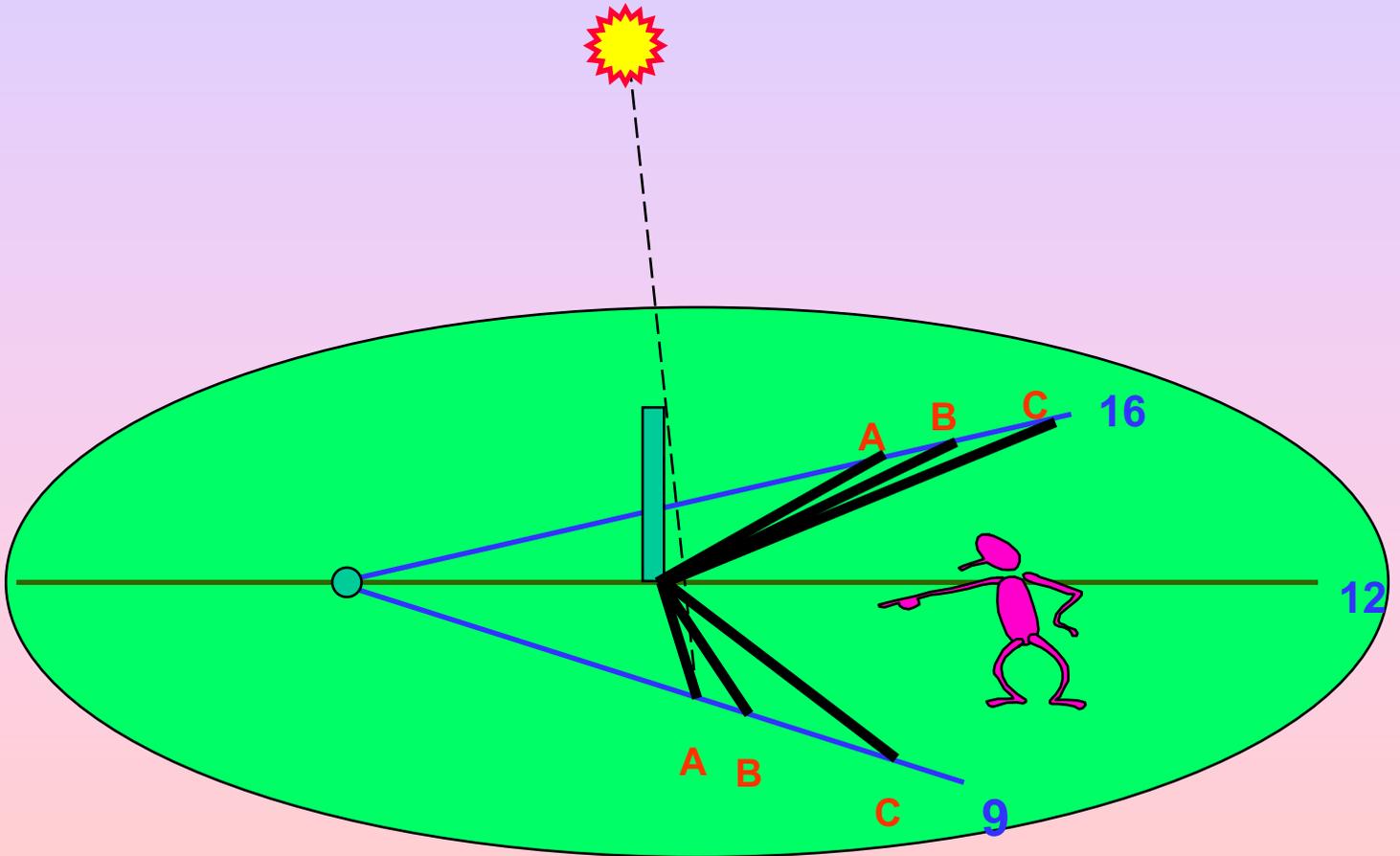


Determinação do meridiano (Sombra mínima)

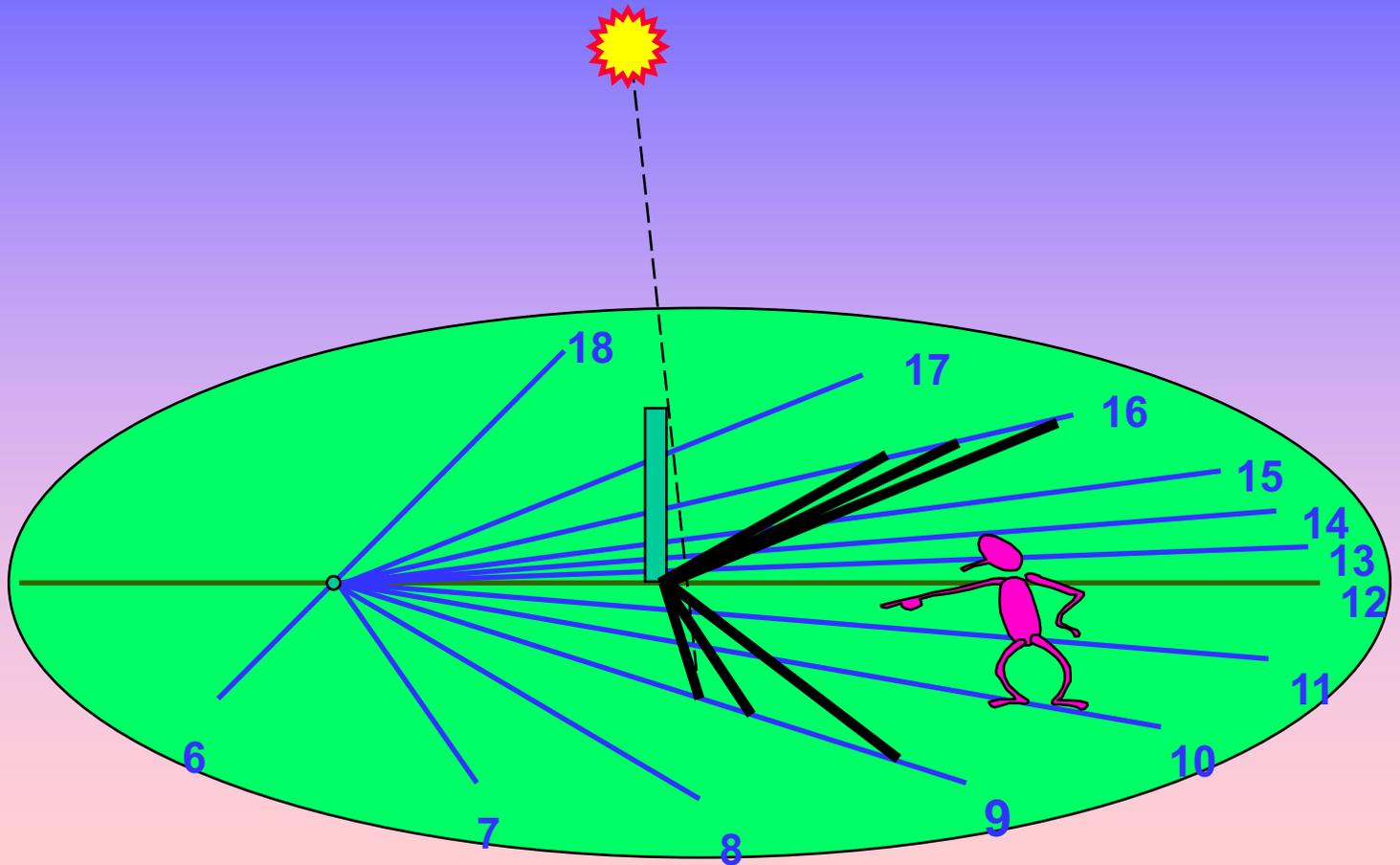


Relógios de Sol

Fundamentos do Gnômon com mostrador horizontal

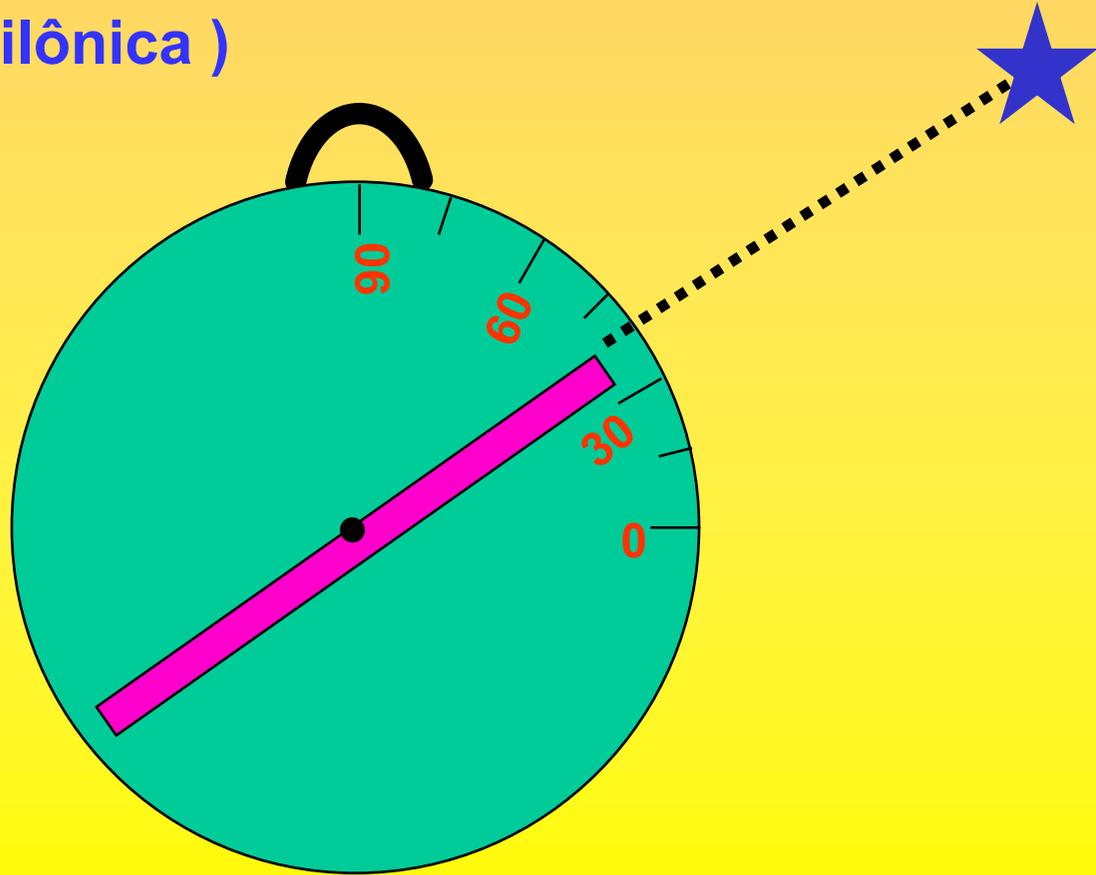
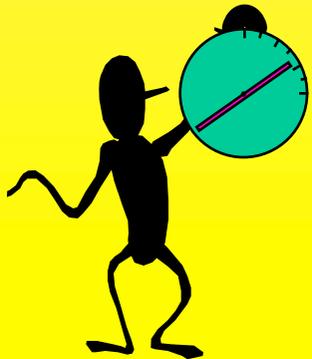


Gnômon com mostrador horizontal



Astrolábio

(Origem Babilônica)





Astrolábio astronômico

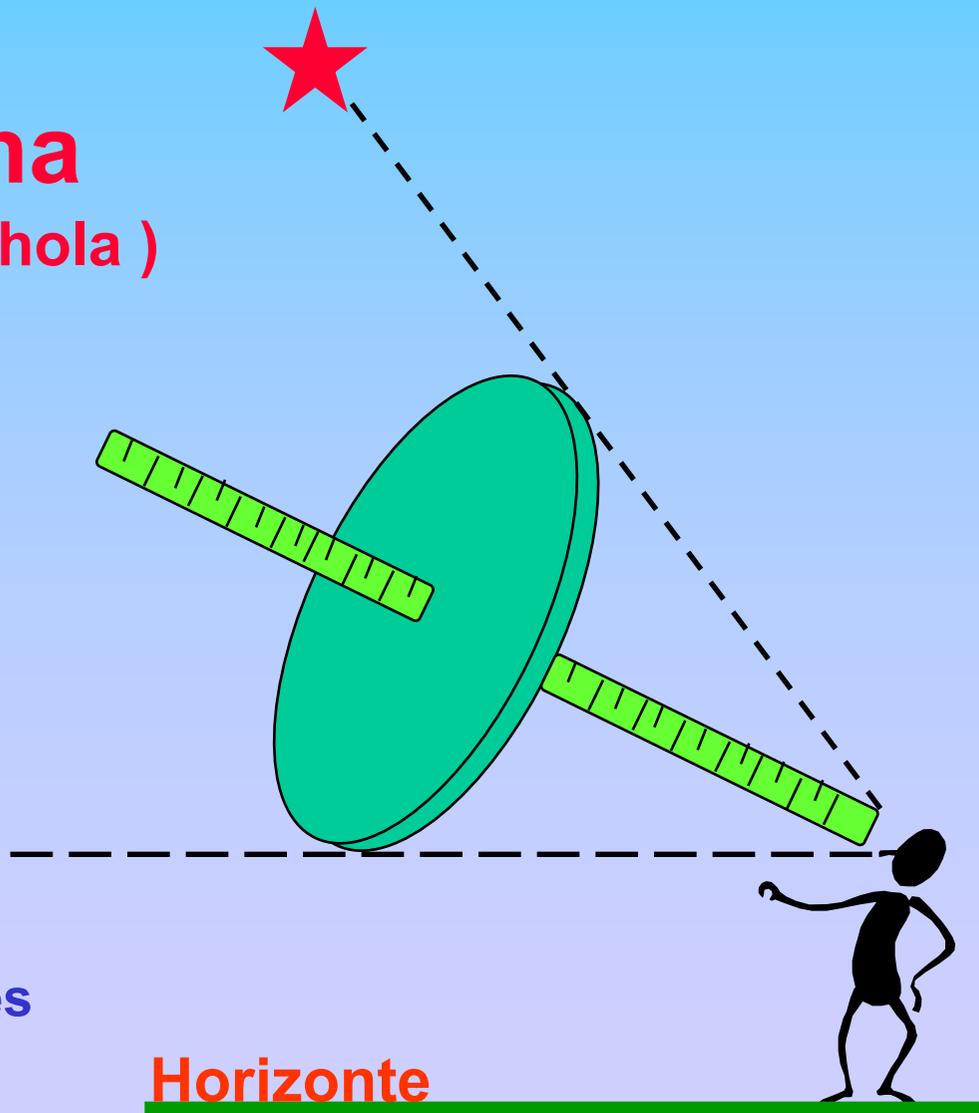


Astrolábio de marinheiro



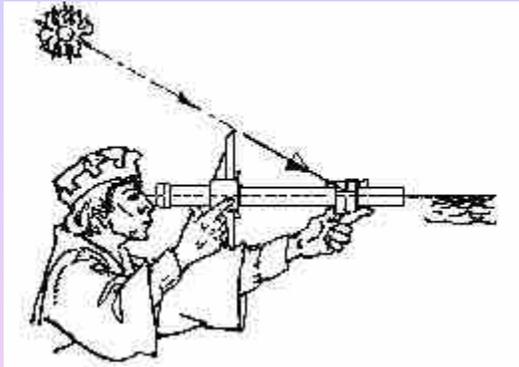
Balestilha

(Origem espanhola)

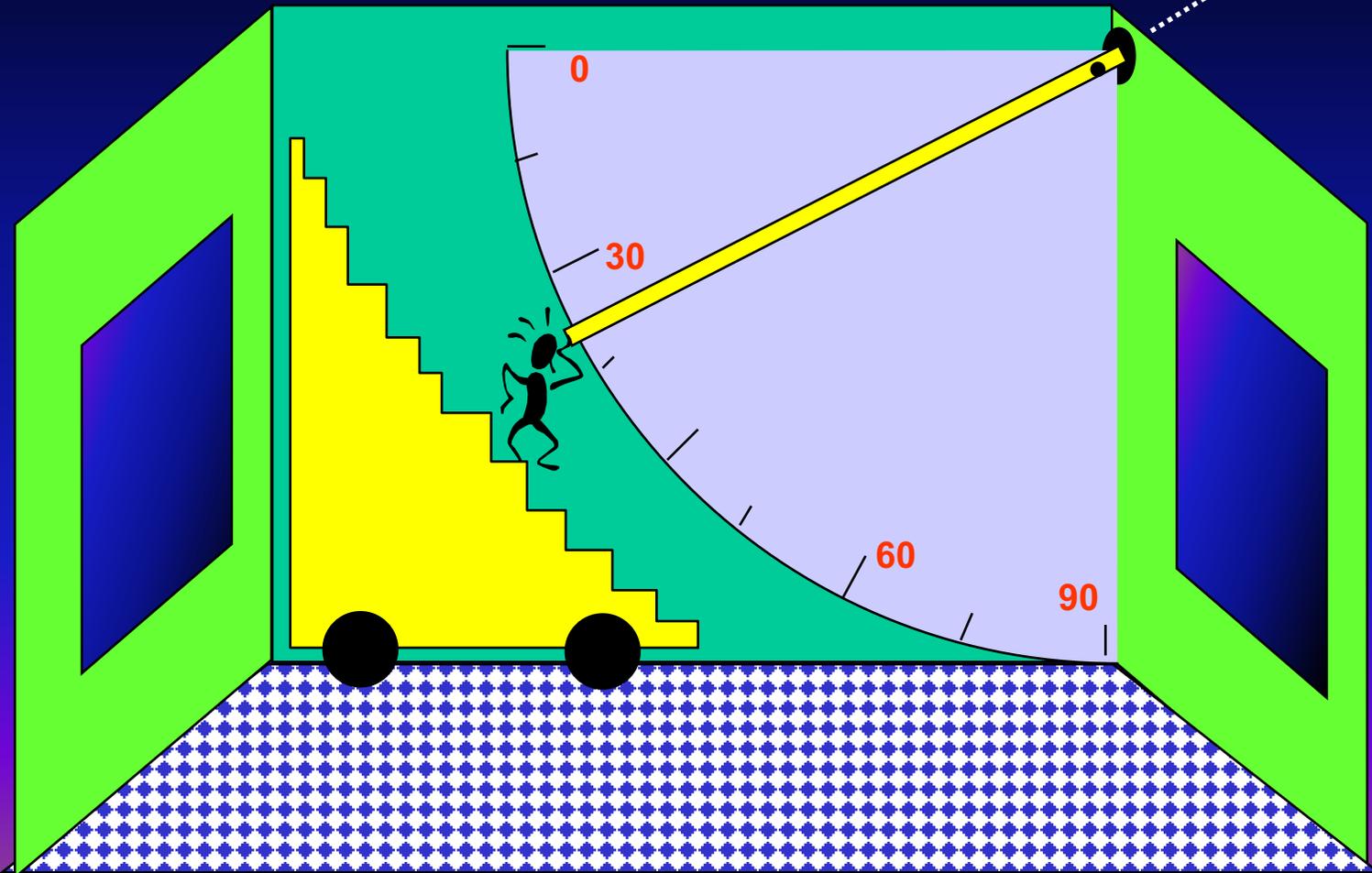


Usado pelo
Fernão de Magalhães

Horizonte



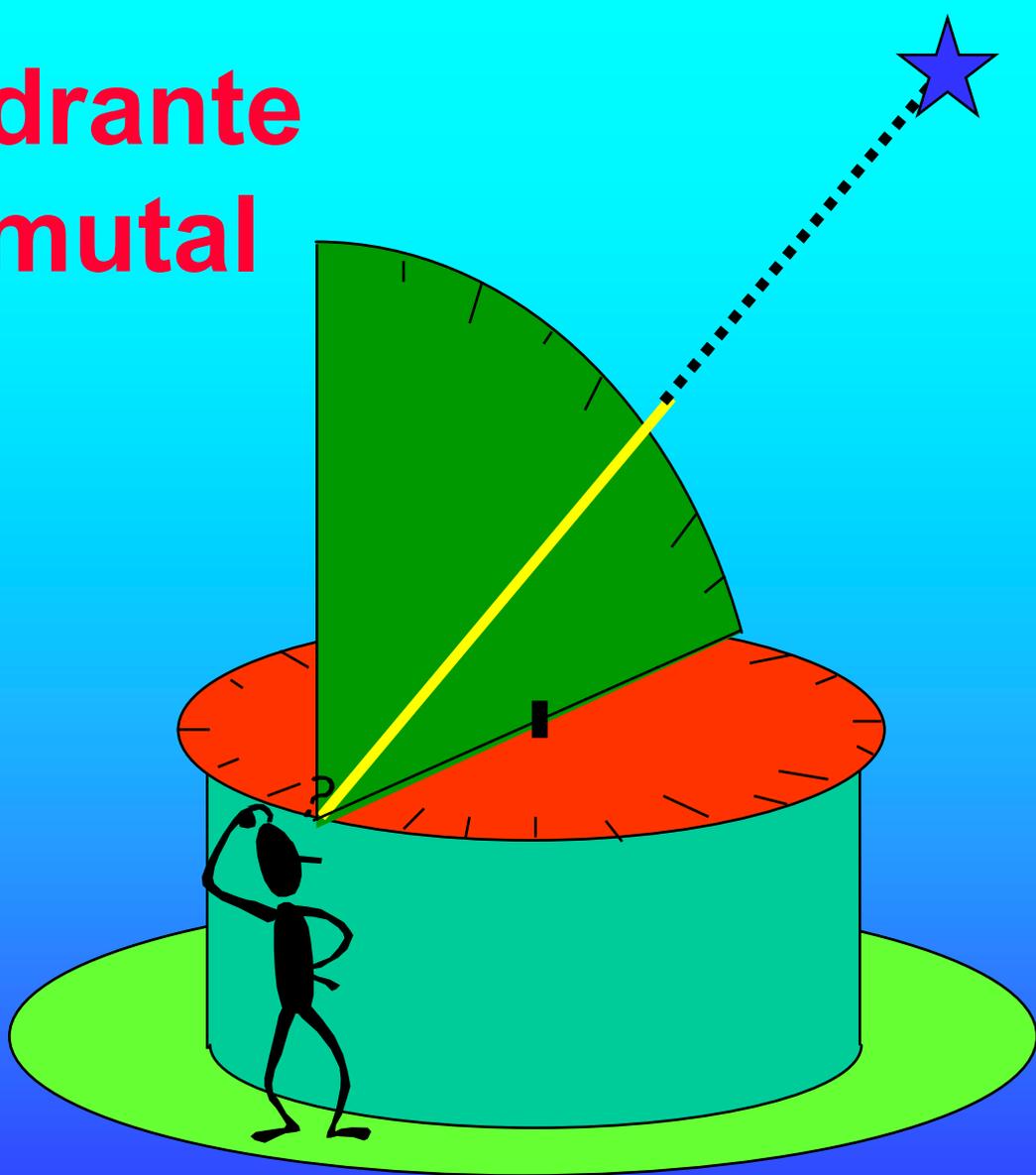
Quadrante Mural



Quadrante
mural do
Observatório
de
Tycho Brahe
da
Ilha de Ven
(Dinamarca)

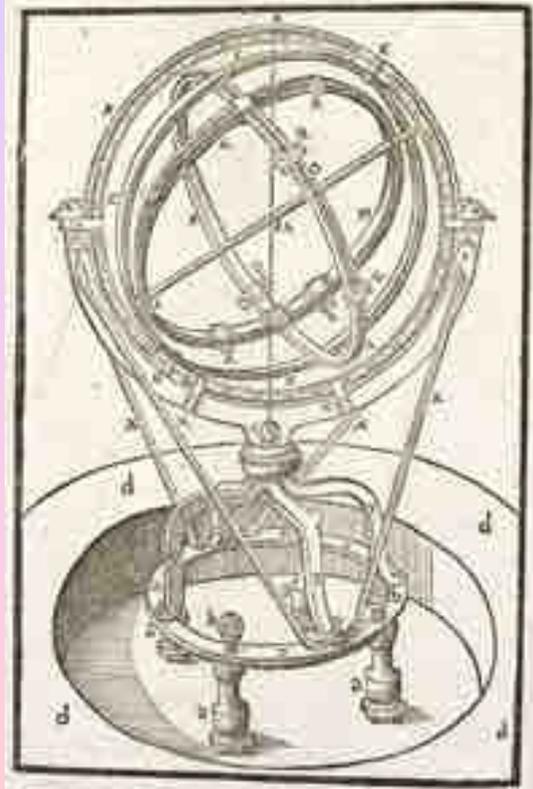


Quadrante Azimutal



Extraído de uma obra de Tycho Brahe

ARMILLÆ ZODIACALES.

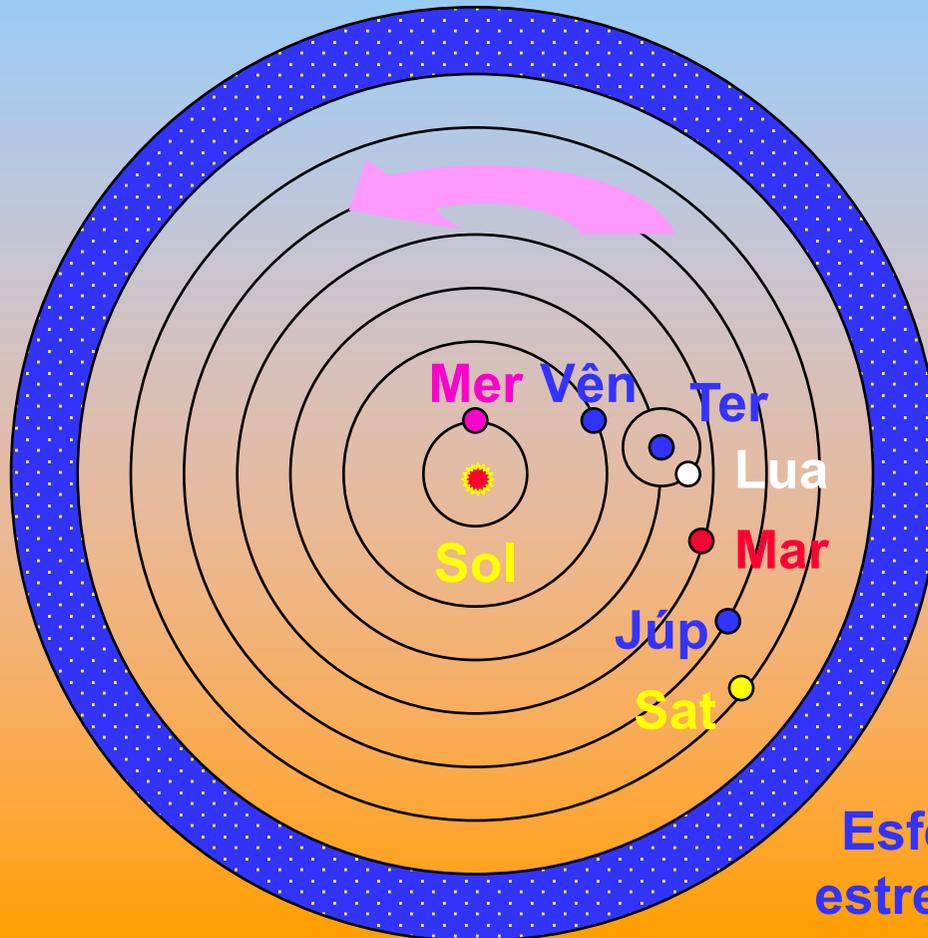


Esfera armilar moderna

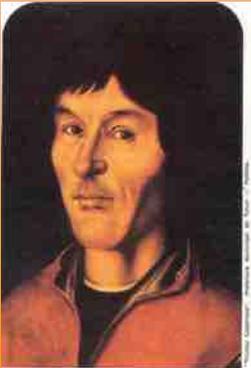


Sistema Heliocêntrico

(Copérnico, séc. XVI)



Copérnico
(Polônia)
1473 - 1543



Esfera das
estrelas fixas

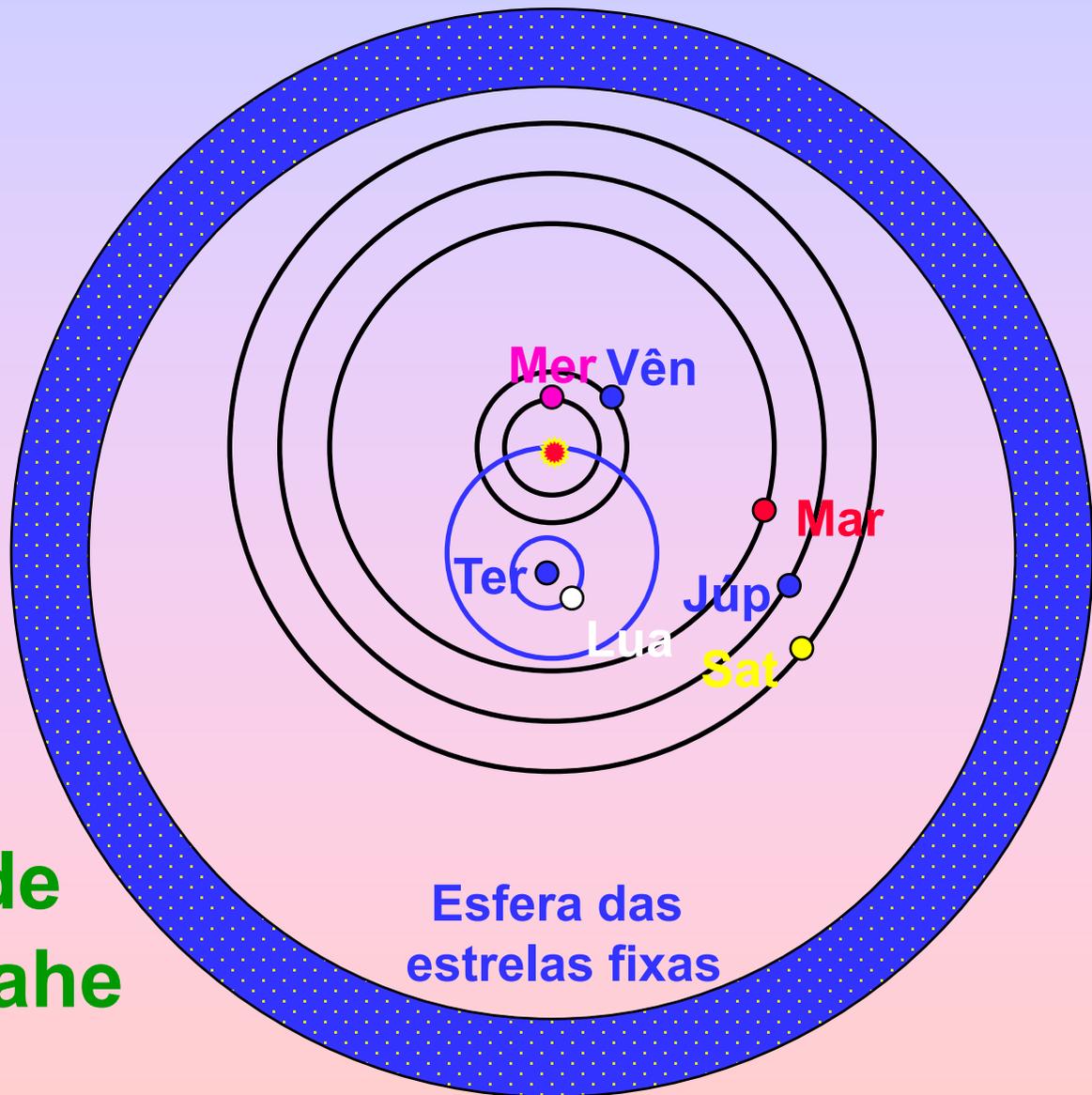
Sistema Heliocêntrico

PLANISPHERIVM
Sive
VNIVERSI TO
EX HYPO
COPERNI
PLANO

COPERNICANVM
Systema
TIVS CREATI
THESI
CANA IN
EXHIBITIVM



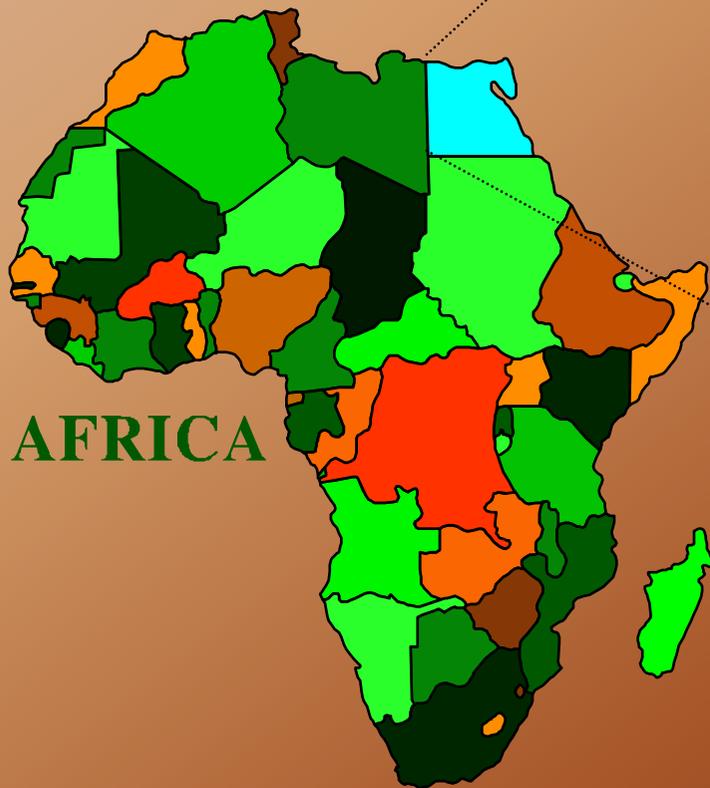
“O Universo Segundo Copérnico”, In “Harmonia Macroscópica”, Andreas Celarius.



**Sistema de
Tycho Brahe**
(séc. XVI)

Distâncias no Sistema solar

Egito



Alexandria

Cairo

Egito

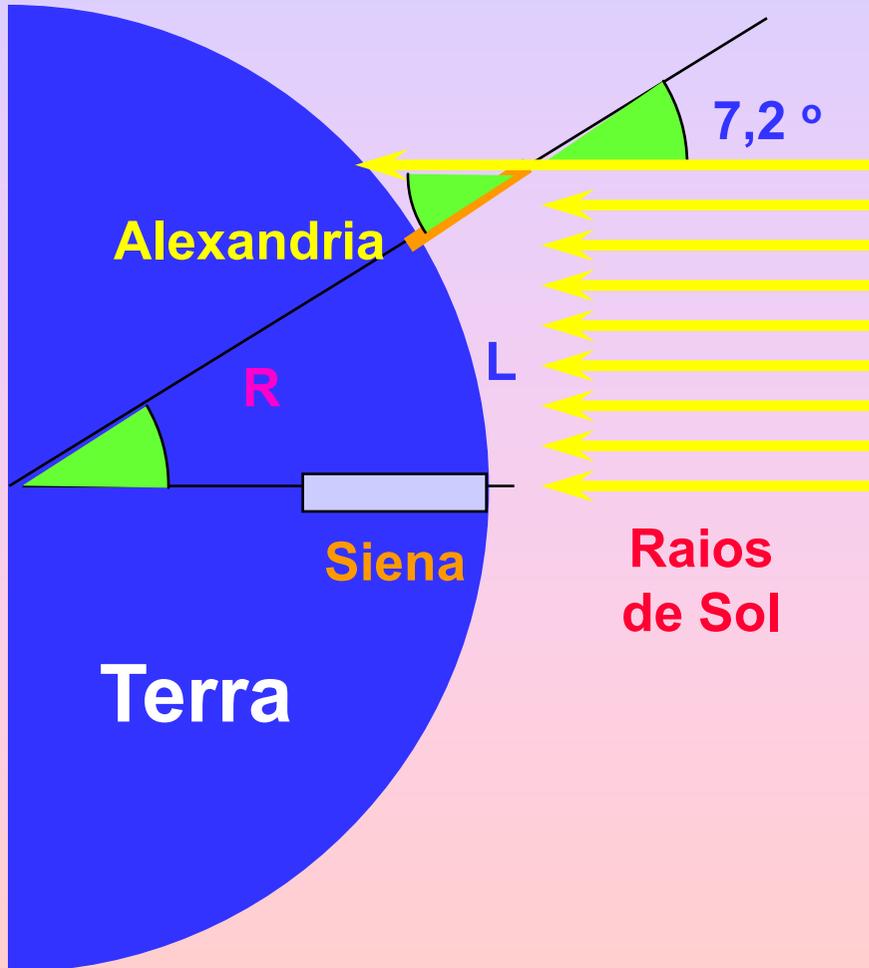
Siena
(Assuan)



Raio da Terra

Eratóstenes

276 a.C. – 196 a.C.

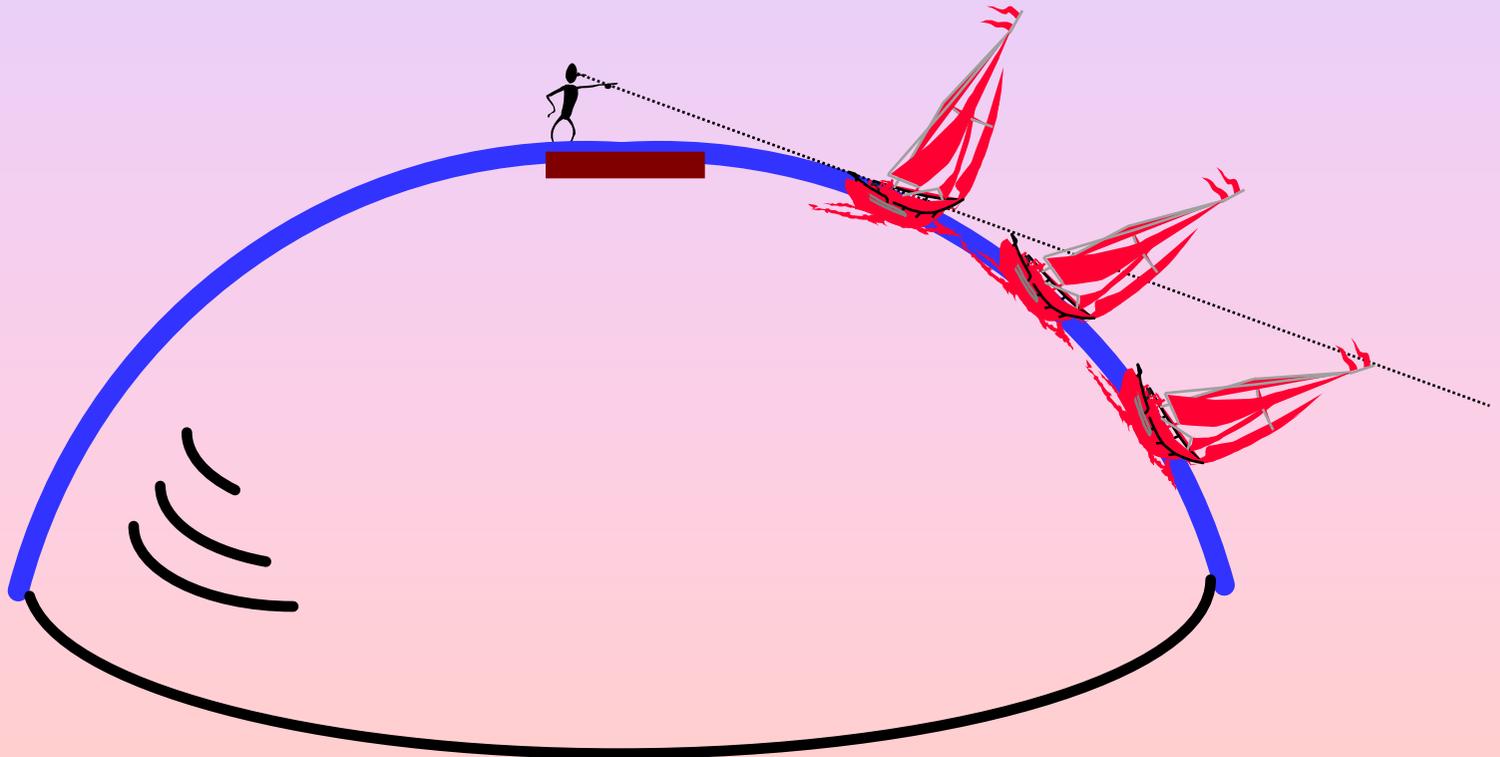


$$\begin{array}{l} 360^\circ \quad \underline{\hspace{1cm}} \quad 2\pi R \\ 7,2^\circ \quad \underline{\hspace{1cm}} \quad L \end{array}$$

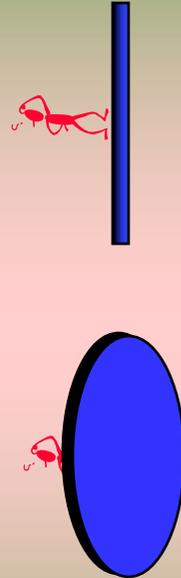
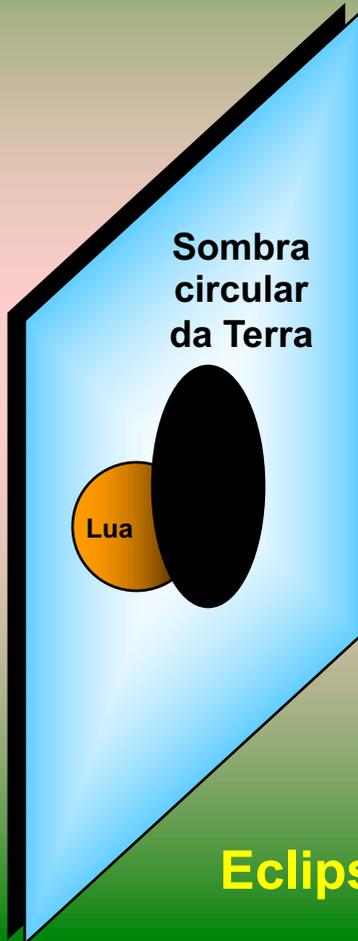
Raios
de Sol

**Mas... já se sabia que a
Terra era esférica naquela
época?**

Esfericidade da Terra



Terra plana?



Terra plana



Eclipse lunar à meia-noite

Funciona!

Terra não é plana!



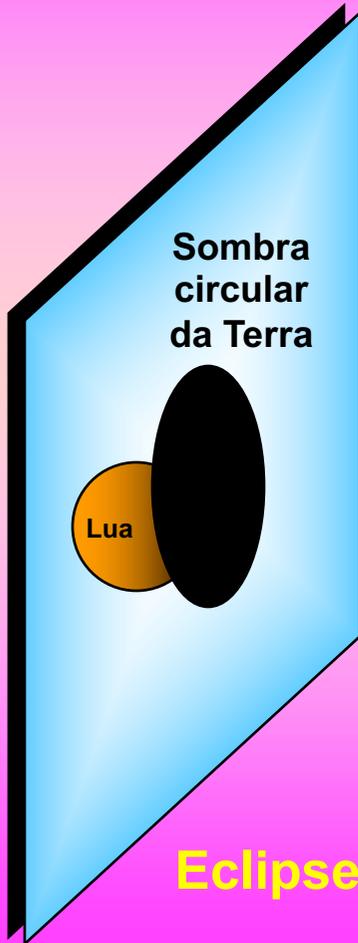
Terra plana



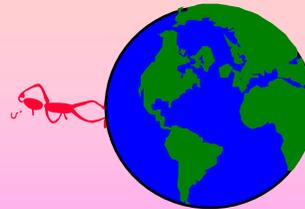
Eclipse lunar ao nascer ou ao ocaso do Sol

Não funciona!

Terra tem que ser esférica!



Eclipse lunar a qualquer hora



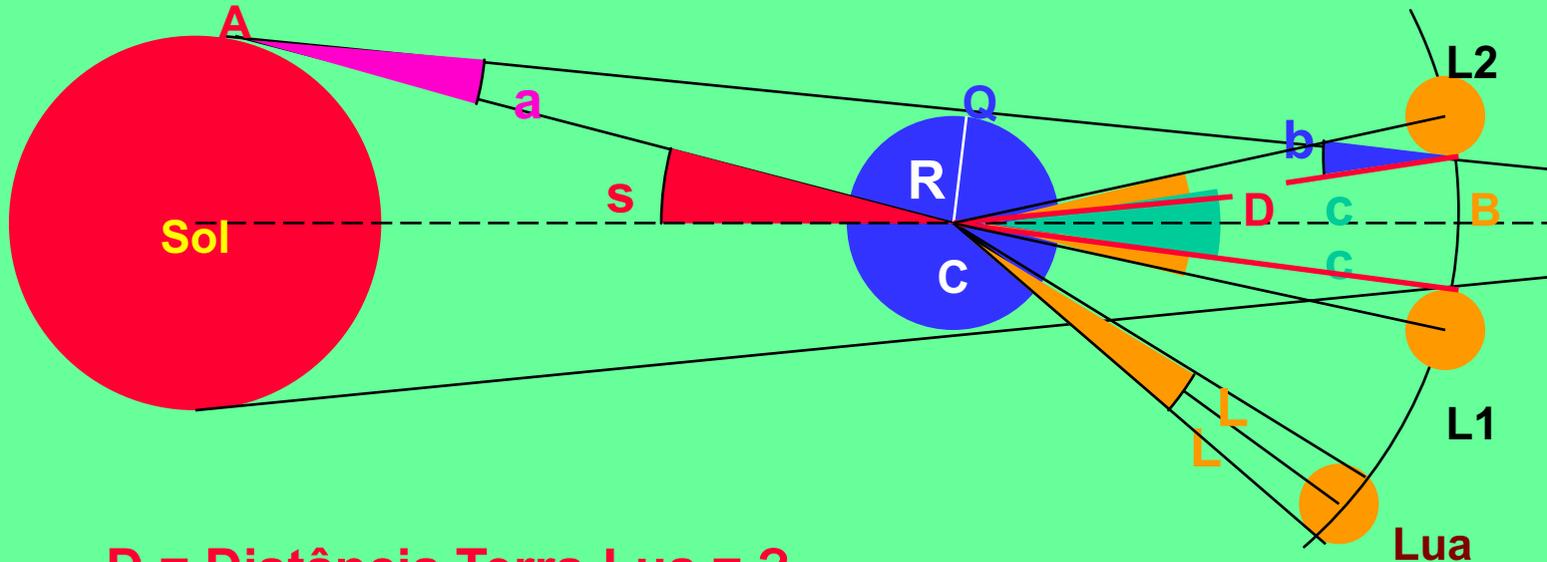
Terra esférica



Funciona!

Distância da Terra à Lua

(Hiparcos, séc. II a .C.)



D = Distância Terra-Lua = ?

R = raio da Terra

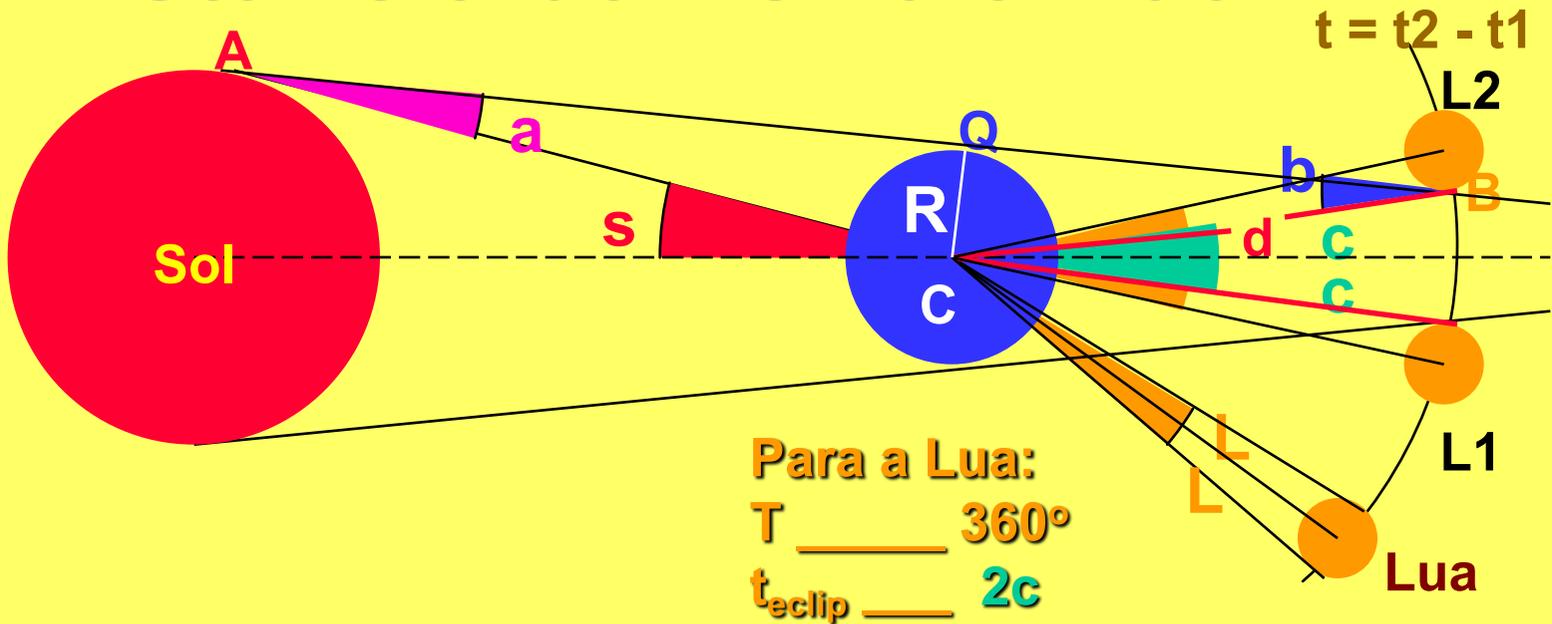
L = semi-diâmetro angular da Lua $\sim 16'$ (medido)

s = semi-diâmetro angular do Sol $\sim 16'$ (medido)

a = semi-diâmetro angular da Terra vista do Sol $\sim 8,794''$

T = período orbital da Lua $\sim 27,3$ dias

Distância da Terra à Lua



No triângulo ABC: $a + b + x = 180^\circ$

Ângulo raso em C: $s + x + c = 180^\circ$

$$a + b + x = s + x + c$$

$$a + b = s + c$$

$$a \sim 0$$

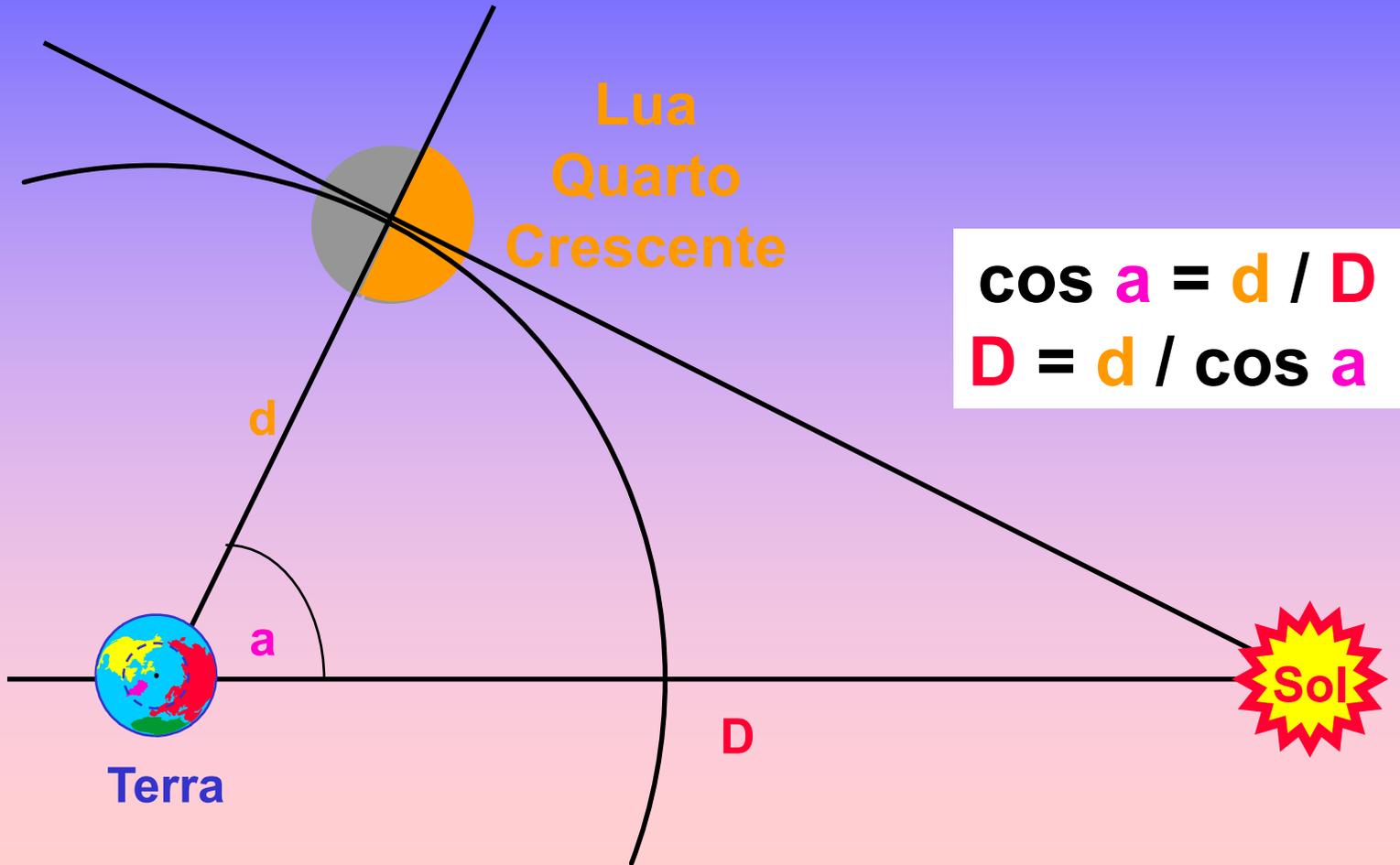
$$b = s + c$$

No triângulo BCQ: $\text{sen } b = R / d$

Logo: $d = R / \text{sen } b$

Distância da Terra ao Sol

(Aristarco, grego, 320 a.C. – 250 a.C.)

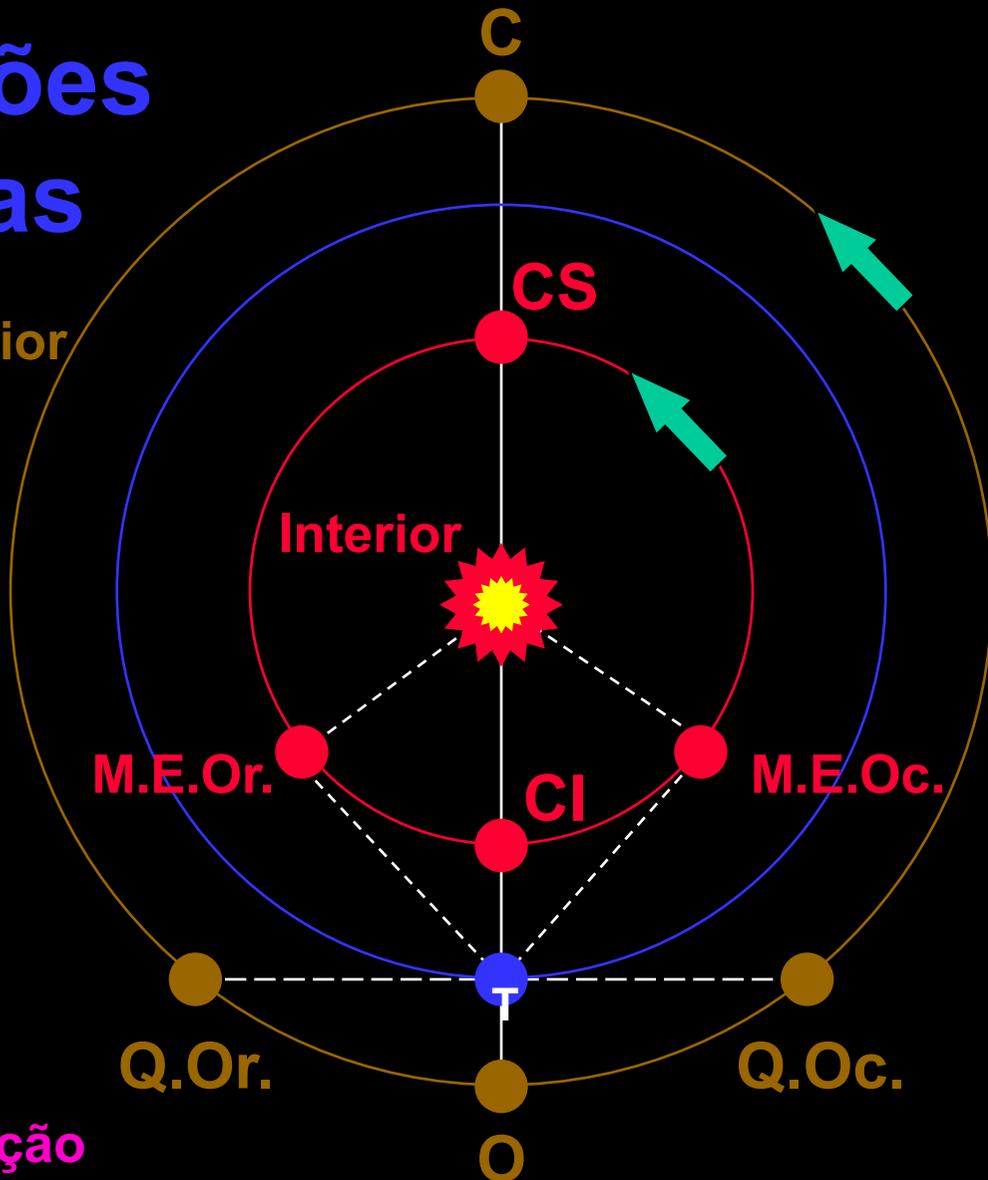


Configurações Planetárias

Exterior

Interior

C = Conjunção
O = Oposição
Q = Quadratura
Oc. = Ocidental (W)
Or. = Oriental (E)
S = Superior
I = Inferior
ME = Máxima Elongação



M.E.Or.

CI

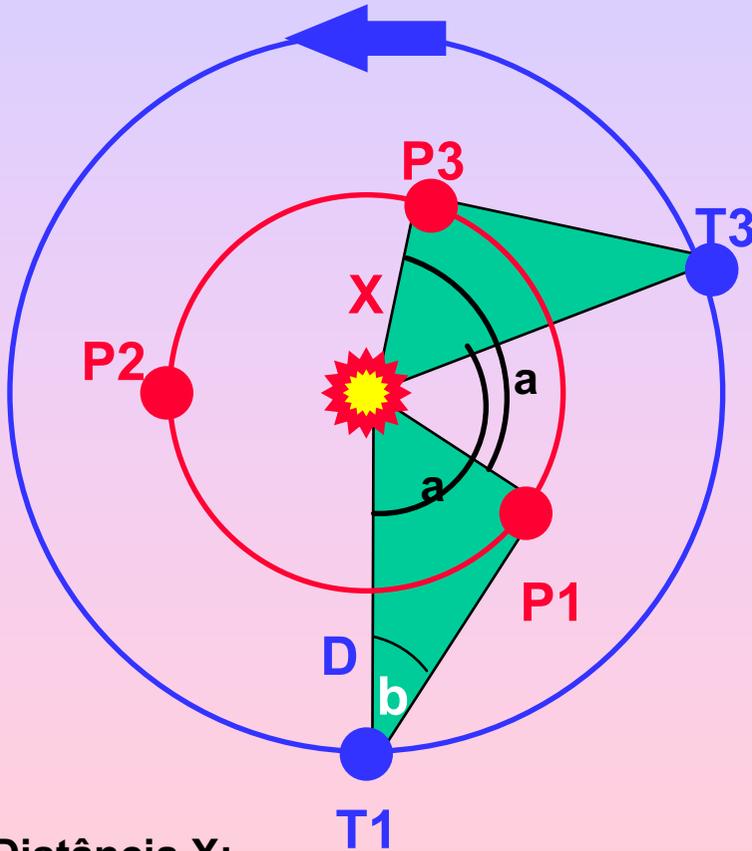
M.E.Oc.

Q.Or.

Q.Oc.

O

Método de Copérnico para calcular raios orbitais e períodos dos Planetas Interiores



Períodos: em dois períodos sinódicos sucessivos

$$S = t_3 - t_1 = \text{Per. Sinódico}$$

$$T = ? = \text{Per. Orbital}$$

$$A = 365,25 \text{ (Orb. da Terra)}$$

Terra

$$A \text{ ____ } 360^\circ$$

$$S \text{ ____ } a$$

Planeta

$$S \text{ ____ } 360 + a$$

$$T \text{ ____ } 360^\circ$$

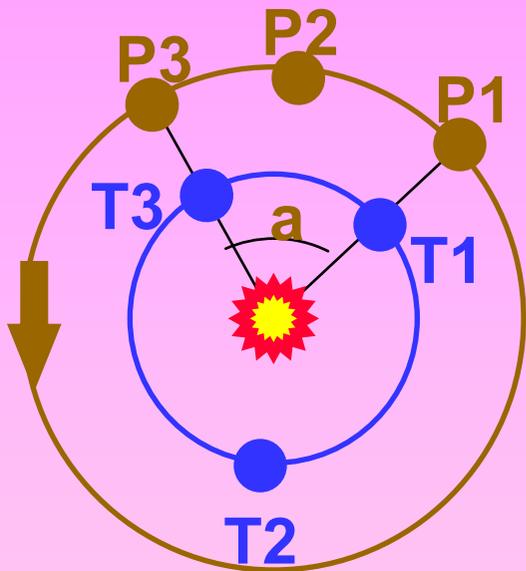
$$1/T = 1/A + 1/S$$

Distância X:

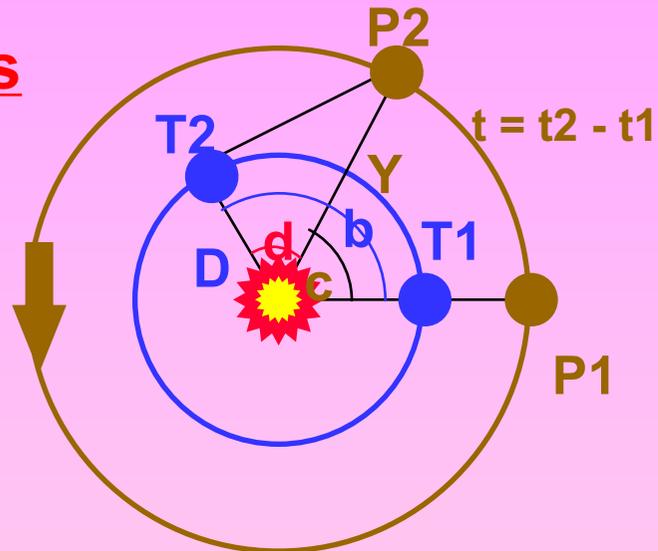
Na máxima elongação

$$\text{sen } b = X / D$$

$$X = D \cdot \text{sen } b$$



Planetas Exteriores



Período: em duas oposições sucessivas

Terra

$$A \text{ ___ } 360^0$$

$$S \text{ ___ } 360 + a$$

Planeta

$$S \text{ ___ } a$$

$$T \text{ ___ } 360^0$$

$$1/T = 1/A - 1/S$$

Raio orbital: numa oposição à próxima quadratura

Terra

$$A \text{ ___ } 360^0$$

$$t \text{ ___ } b$$

Planeta

$$T \text{ ___ } 360^0$$

$$t \text{ ___ } c$$

$$d = b - c$$

$$\cos d = D / Y$$

$$Y = D / \cos d$$

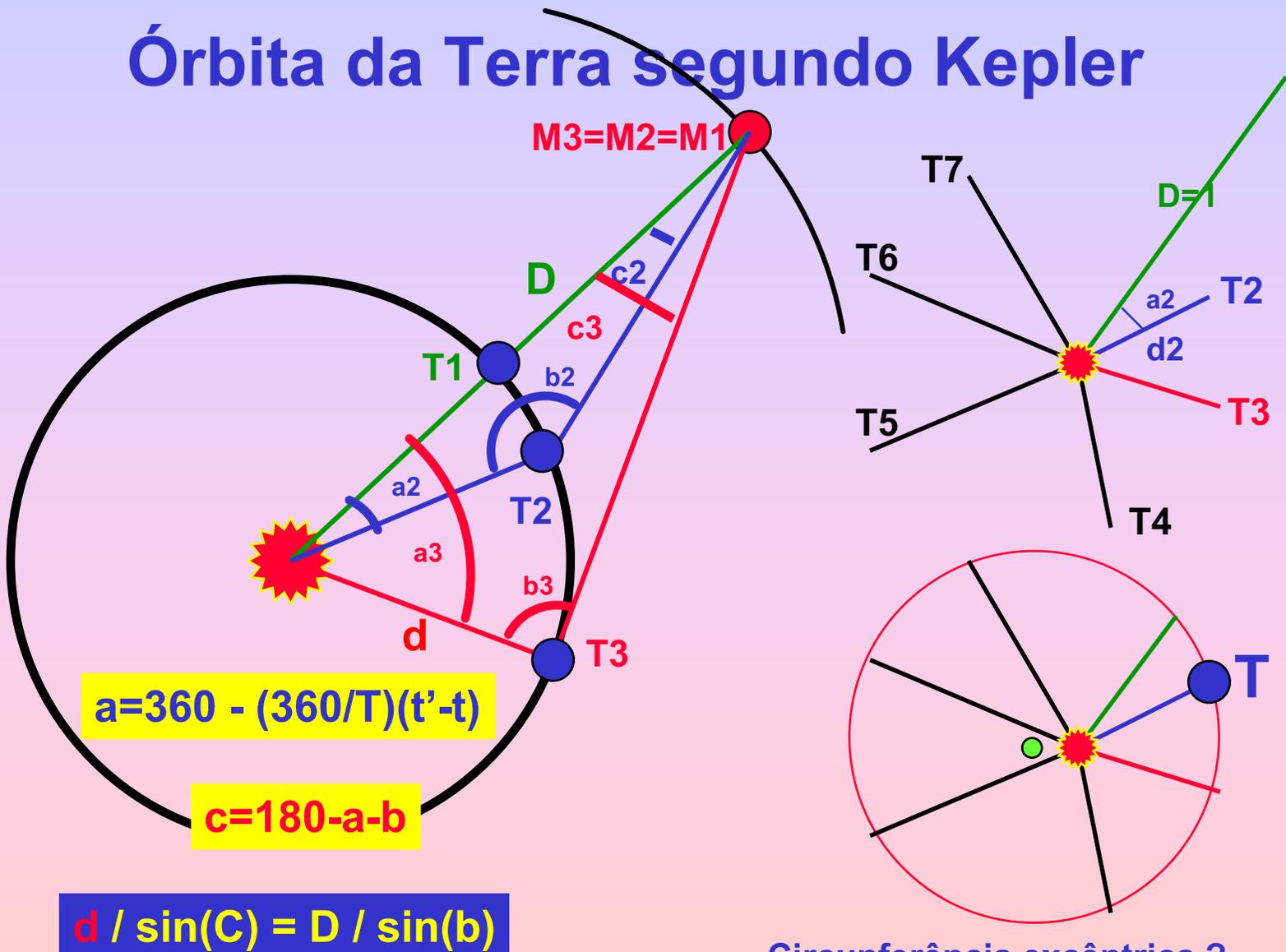
**Mas será que
as órbita
dos planetas
são
mesmo
circulares?**



Johann Kepler

1571 - 1630

Órbita da Terra segundo Kepler



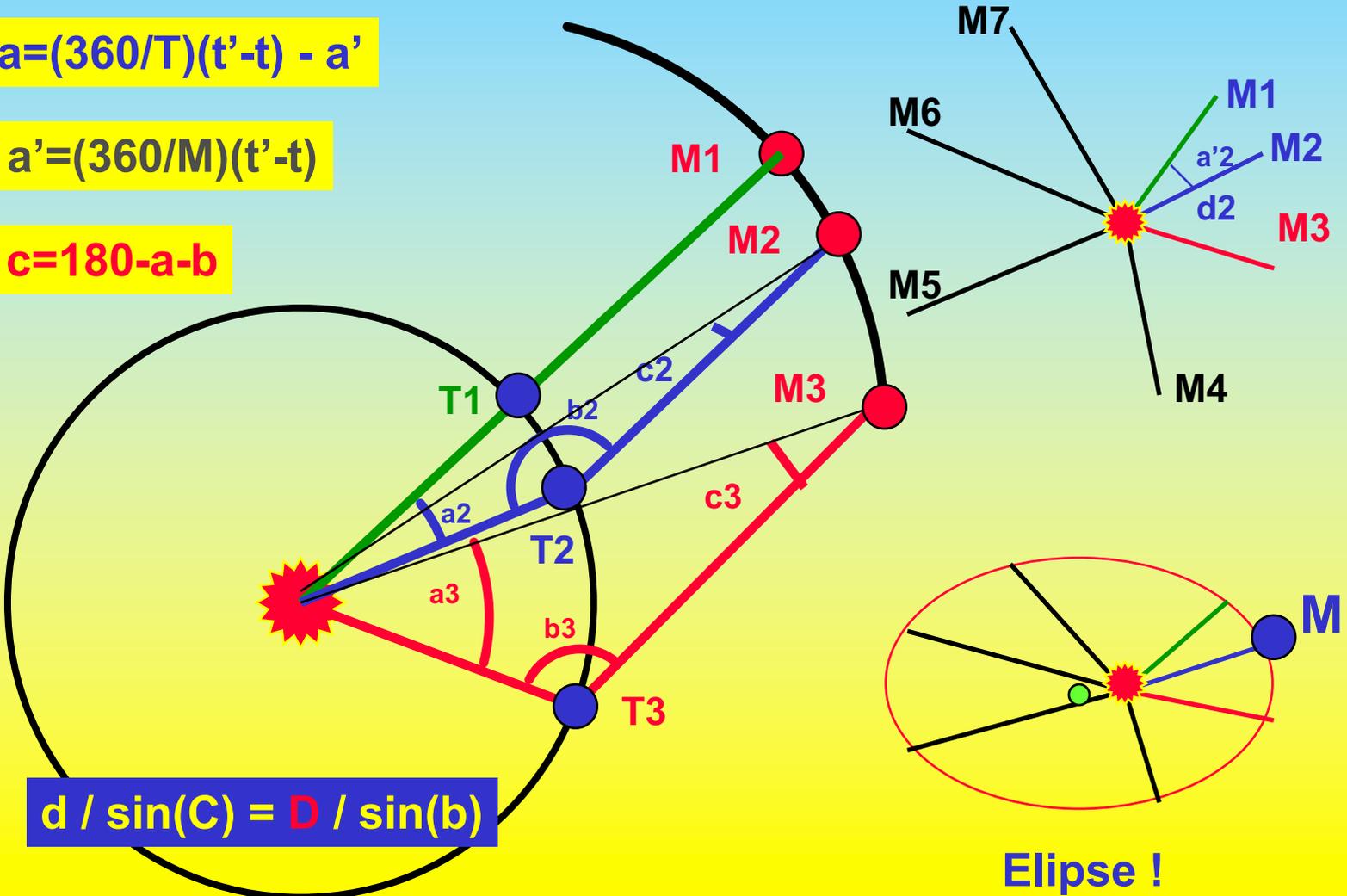
Circunferência excêntrica ?

Órbita de Marte segundo Kepler

$$a = (360/T)(t' - t) - a'$$

$$a' = (360/M)(t' - t)$$

$$c = 180 - a - b$$

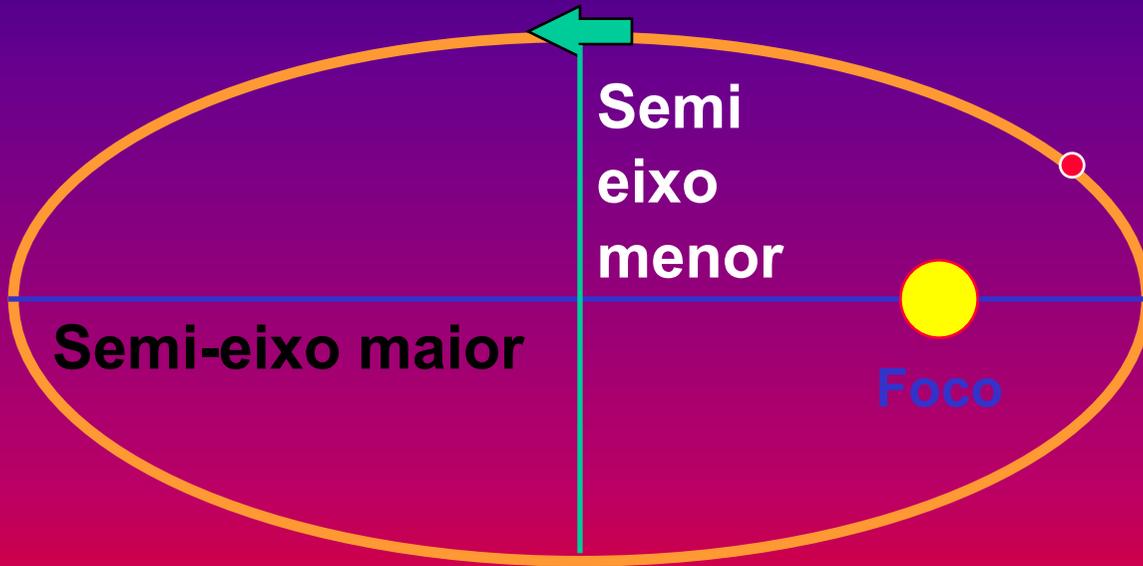


$$d / \sin(C) = D / \sin(b)$$

Elipse !

Leis de Kepler

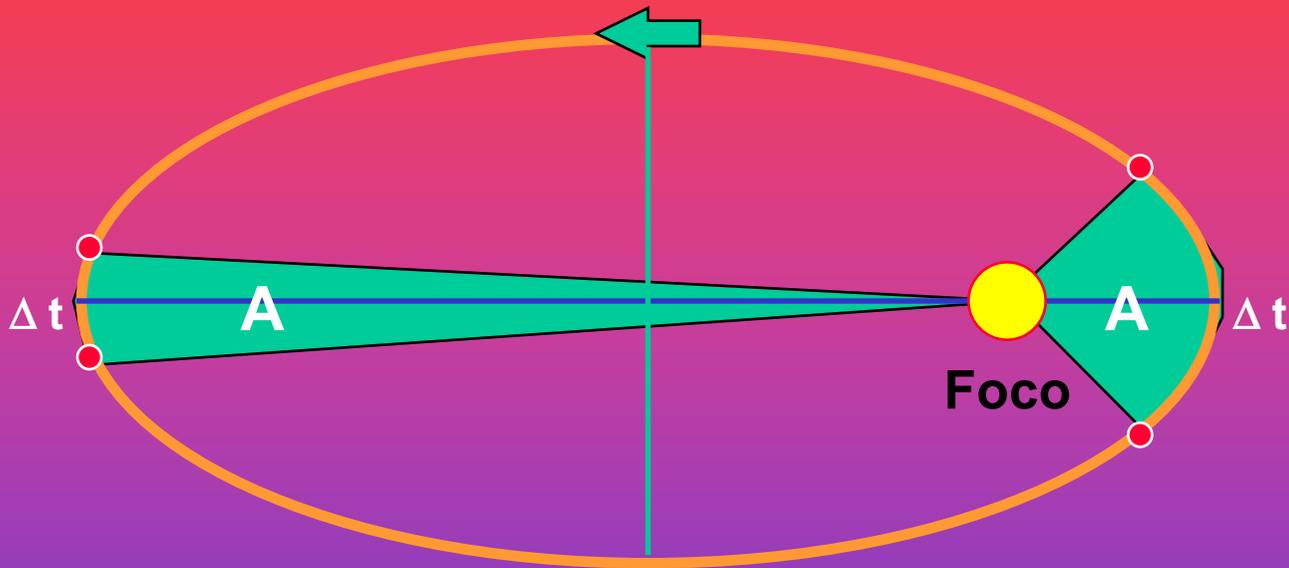
Primeira Lei de Kepler (1571 - 1630)



Um corpo ligado a outro gravitacionalmente gira em torno dele numa órbita elíptica, sendo que um deles ocupa o foco da elipse.

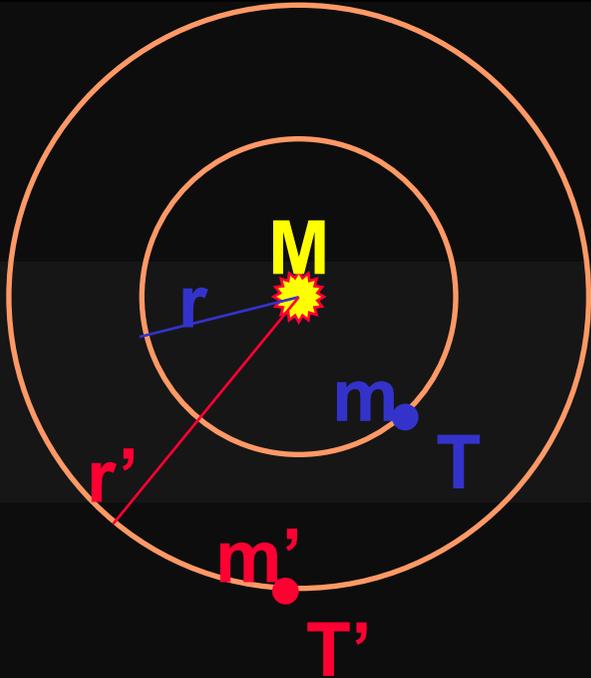
Segunda Lei de Kepler

(1571 - 1630)



Um corpo ligado a outro gravitacionalmente gira em torno dele, com seu raio vetor varrendo áreas iguais em tempos iguais.

Terceira Lei de Kepler



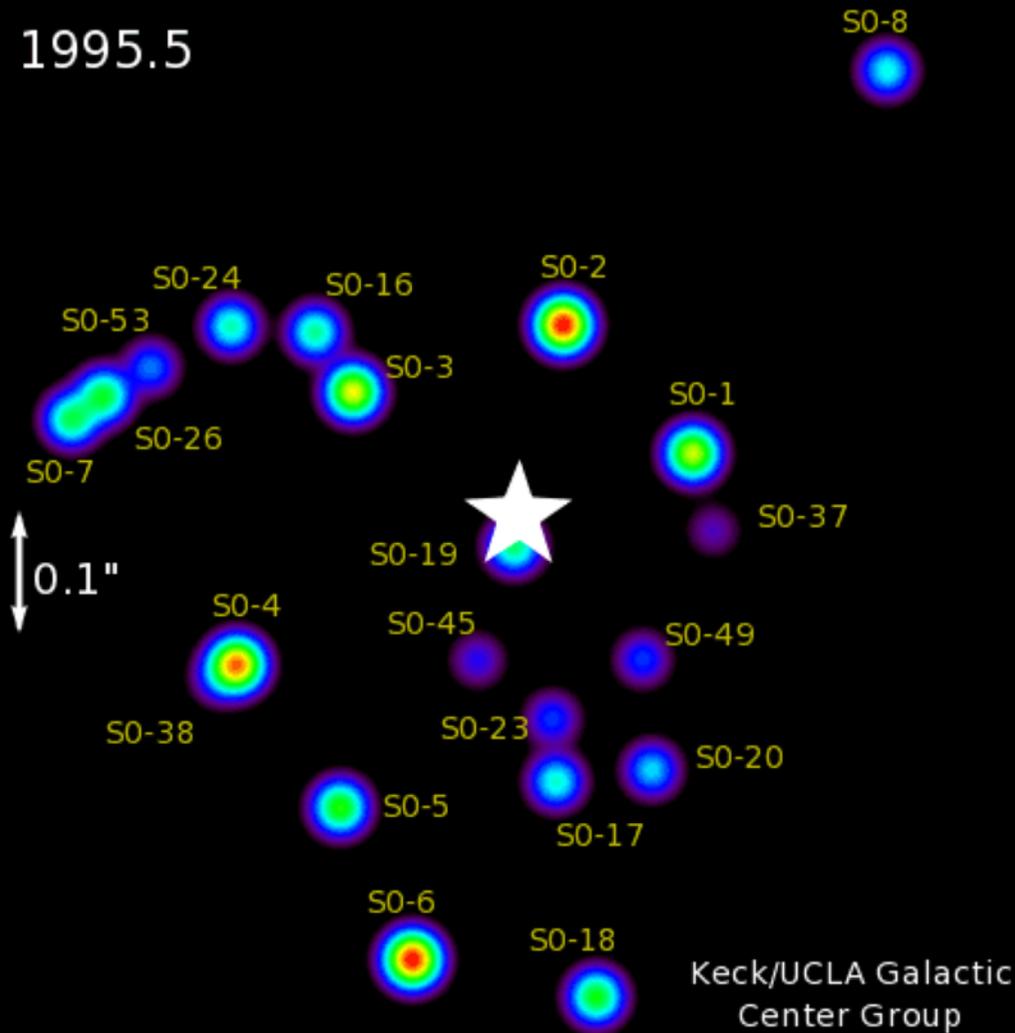
$$(r / r')^3 = (T / T')^2$$

Expressão correta:

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

$$r^3 = G (M + m) T^2$$

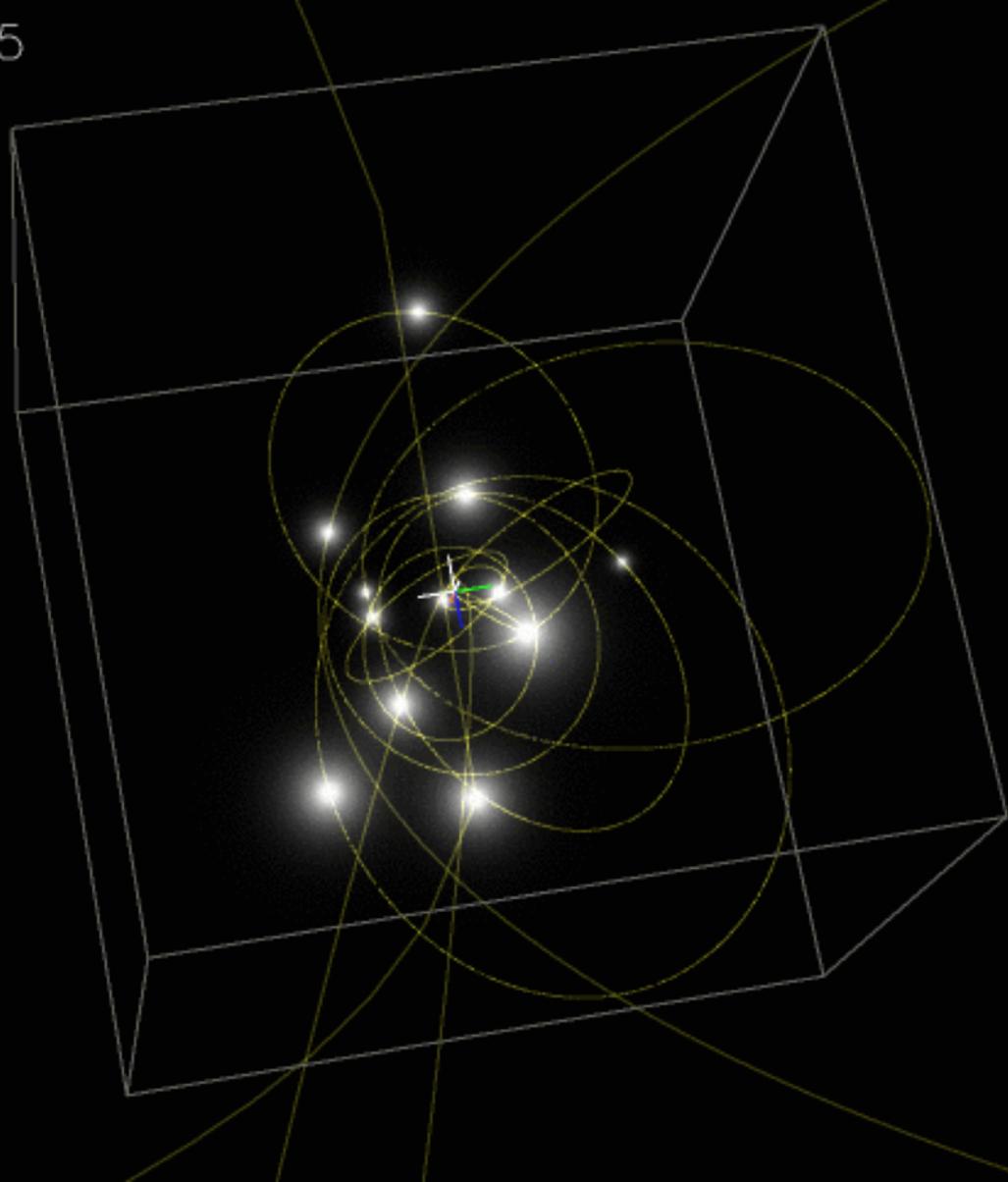
1995.5



As leis de Kepler dum modo que ele jamais teria pensado:

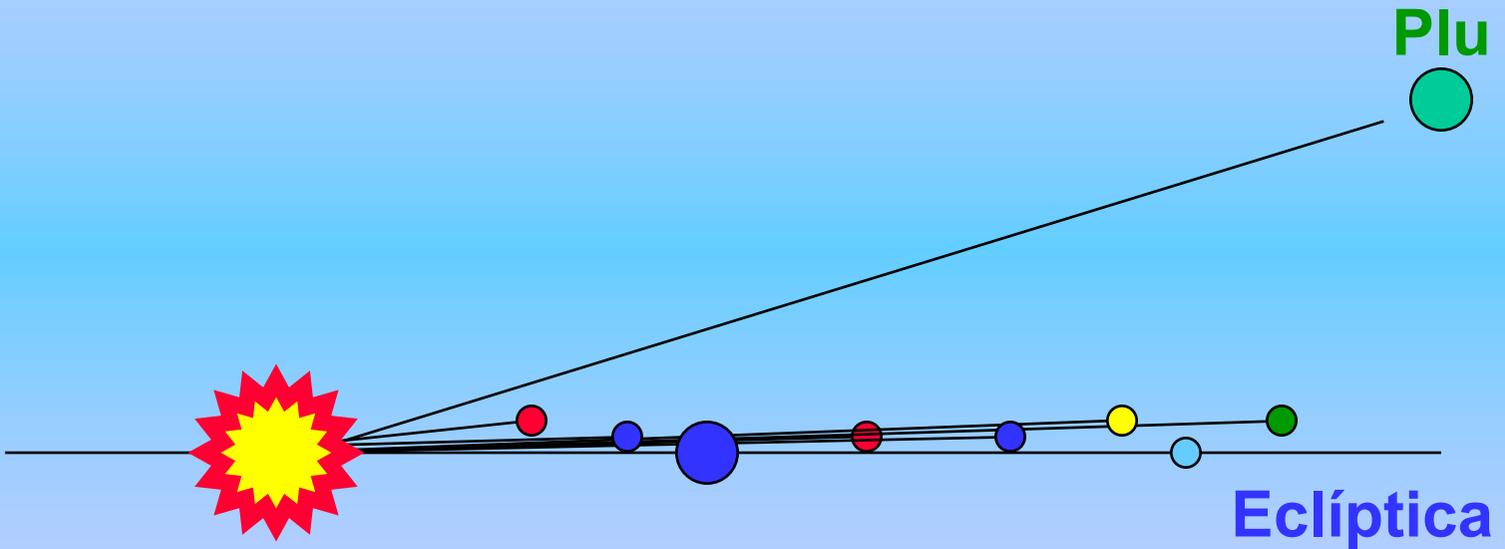
O cálculo da massa do Buraco Negro central da Galáxia, que é de 3.3 milhões de M_{\odot}

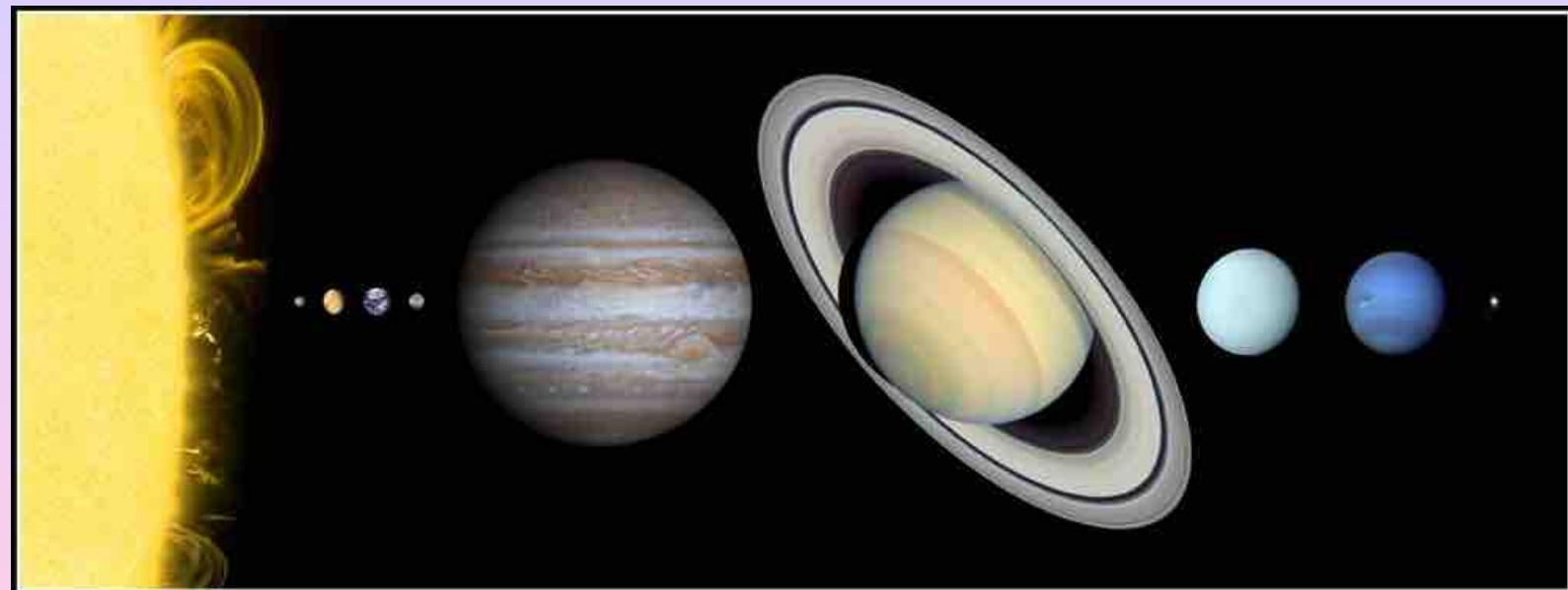
Year: 1995.5



Estrutura atualmente conhecida do Sistema Planetário

Órbitas não coplanares

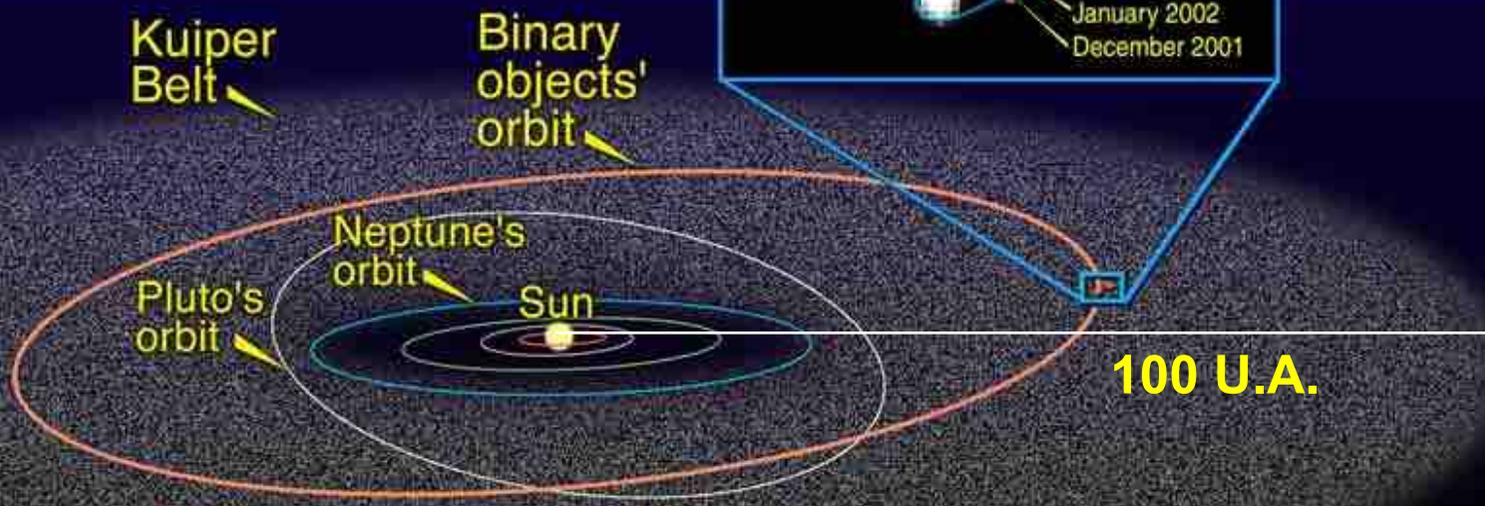




The Sun and Nine Planets

Copyright © Calvin J. Hamilton

Kuiper Belt Object 1998 WW31



**Binary objects
orbit each other**

July 2001
August 2001
September 2001
February 2002
January 2002
December 2001

This inset diagram shows a close-up of the binary orbit of 1998 WW31. It features two small blue squares representing the components of the binary system, connected by a blue elliptical orbit. A larger, brighter white square represents the primary component. The orbit is tilted relative to the horizontal. Specific dates are marked along the orbit: July 2001, August 2001, and September 2001 are on the upper arc, while December 2001, January 2002, and February 2002 are on the lower arc. A small red square is located at the bottom right of the inset, corresponding to the position of the binary object in the main diagram.

100 U.A.

50.000 U.A.

