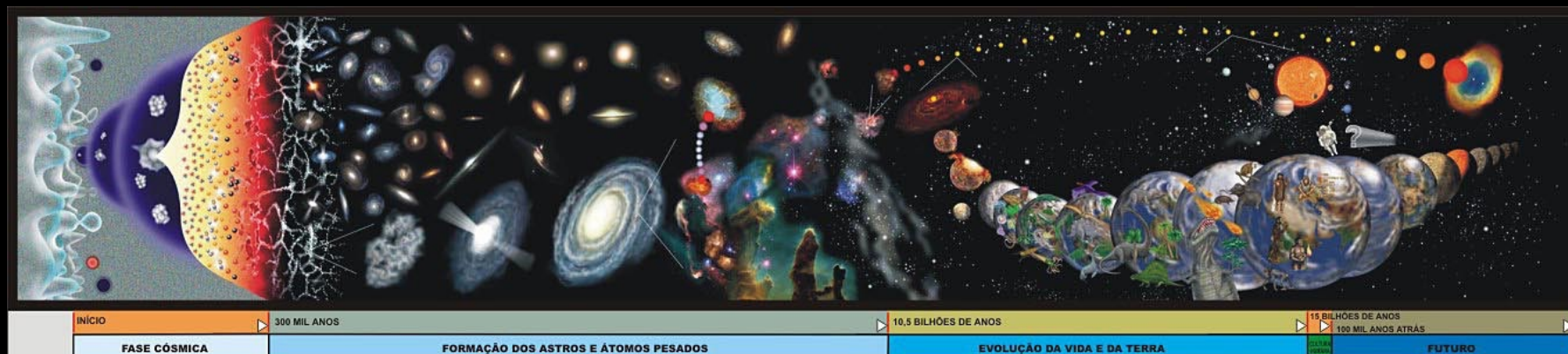


Explorando o Universo

<http://ufrgs.br/astrofisia/explorando-o-universo>



Tamanho, idade e conteúdo do Universo

Kepler

Instituto de Física – UFRGS

Porto Alegre, 2026

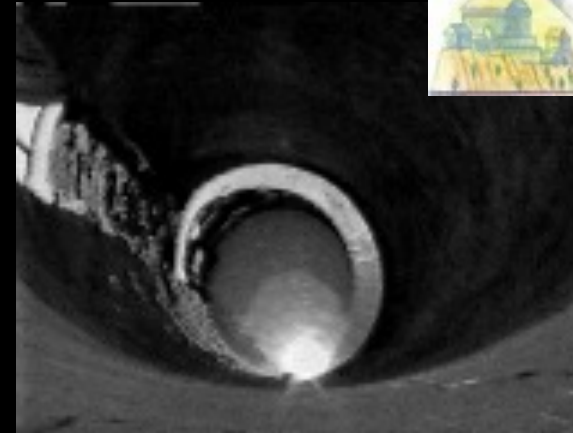




Aristóteles (IV a.C.) já tinha notado que a sombra da Terra na Lua era sempre **circular**.

$$R_{\text{Lua}} = 1338 \text{ km} = \frac{1}{5} R_{\text{Terra}}$$

Eratóstenes de Cirênia (276-194 a.C.) calculou o raio da Terra: 6350 km

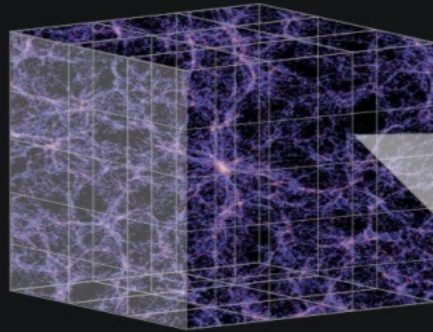


Em Siena (Aswân) , ao meio dia do primeiro dia de Verão, luz atinge fundo do poço

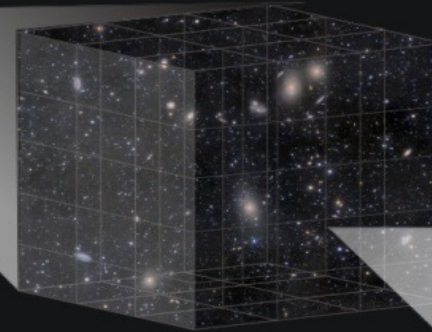


Em Alexandria, sombra de 7 graus = $\frac{1}{50} \times 360$ graus $\rightarrow 2\pi R_{\text{Terra}} = 50 \times d_{\text{A-S}}$

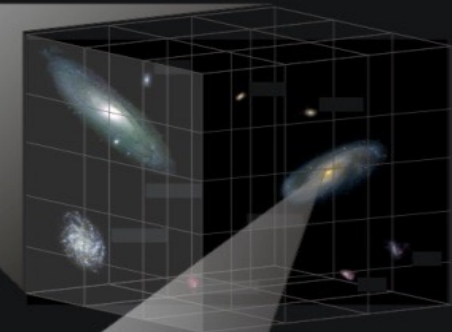
Localizando o planeta Terra no Universo



Universo

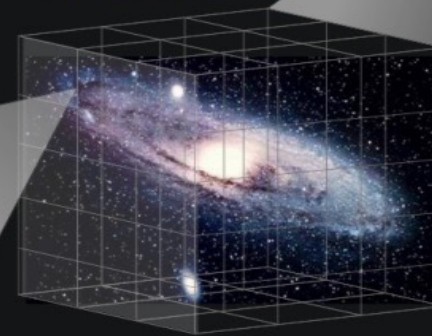


**Superaglomerado
de Virgem**

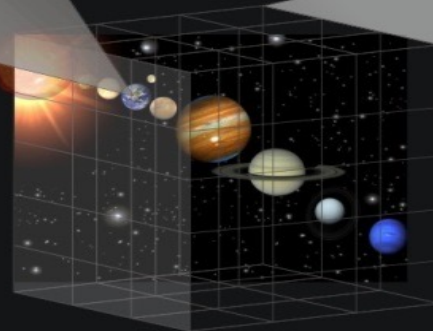


**Grupo Local
de Galáxias**

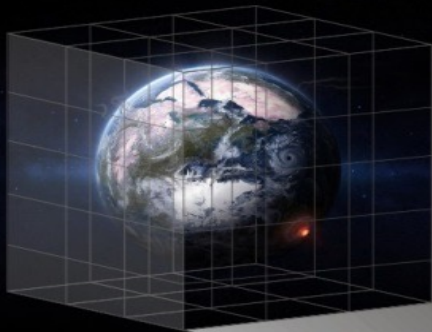
Via Láctea



Sistema Solar



Planeta Terra



Tamanho do Sistema Solar



- Raio da Terra: 6370 km

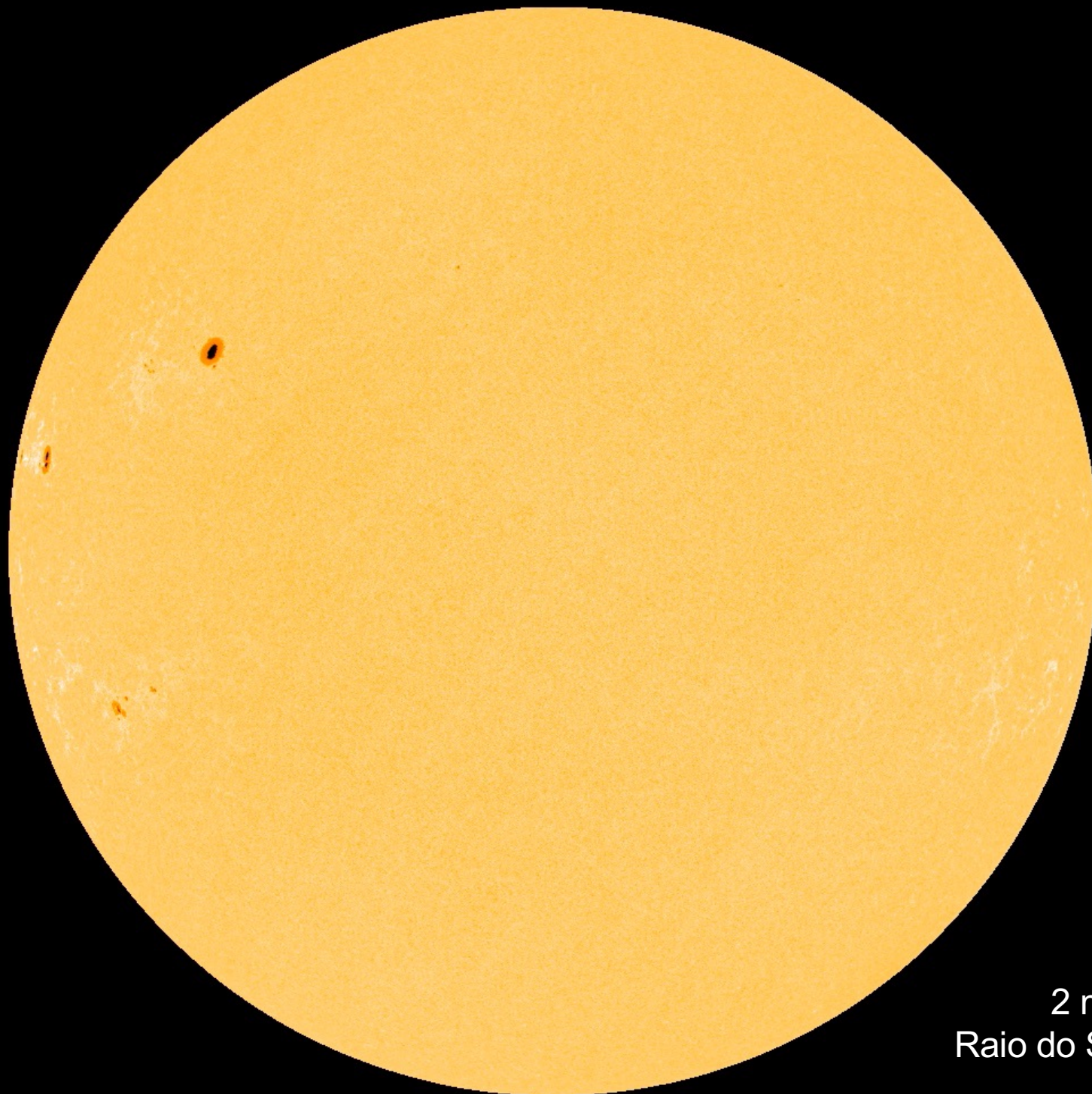
Distância Terra-Lua: 384 000 km = 1,3 segundos-luz

- Raio do Sol: 700 000 km = 109 R_{Terra}

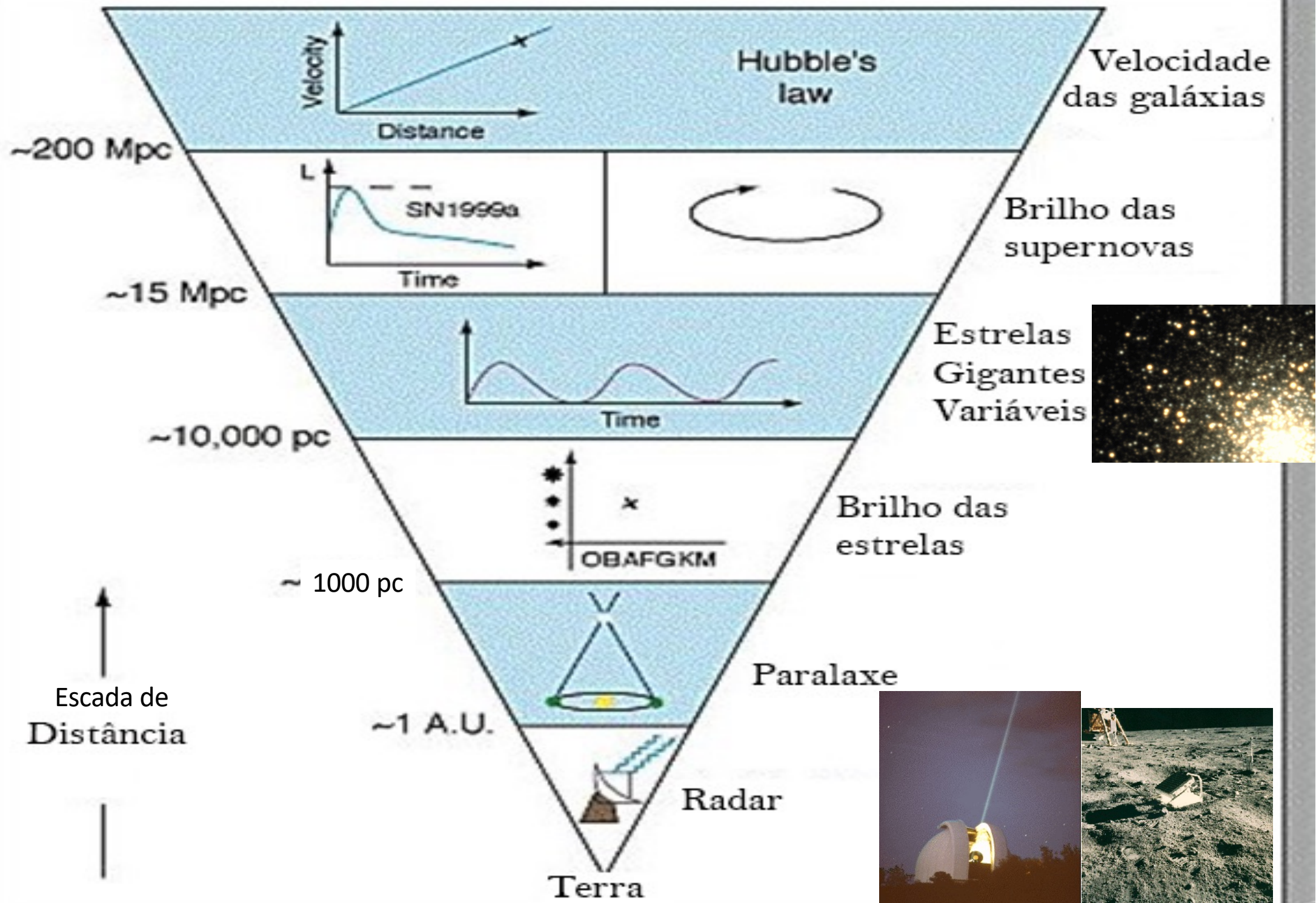
- Distância Sol-Terra = 1 U.A. = 150 milhões km = 214 R_{sol} = 8 m-l

- Distância até Plutão d_p = 40 U.A. = 6 bilhões km = 5,6 horas-luz

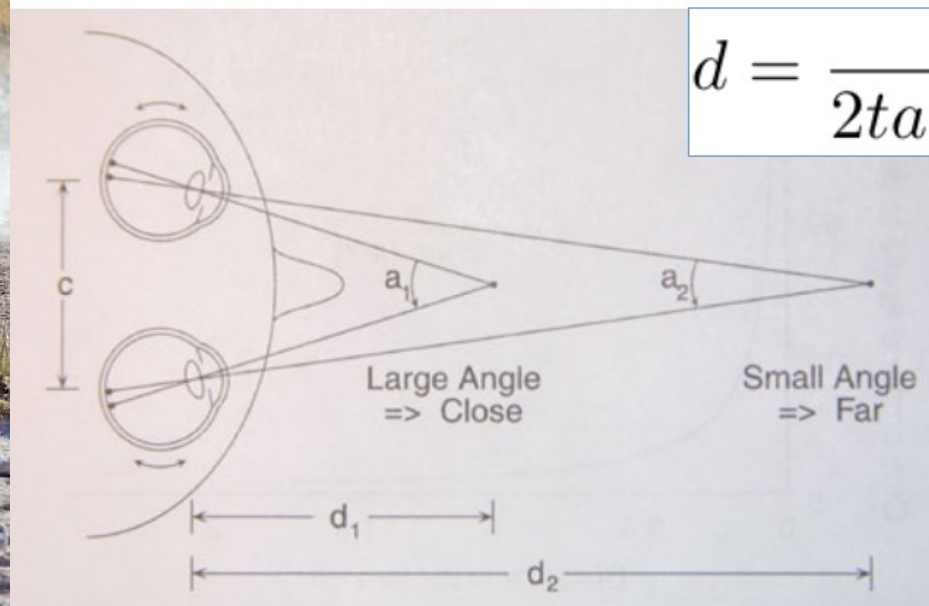
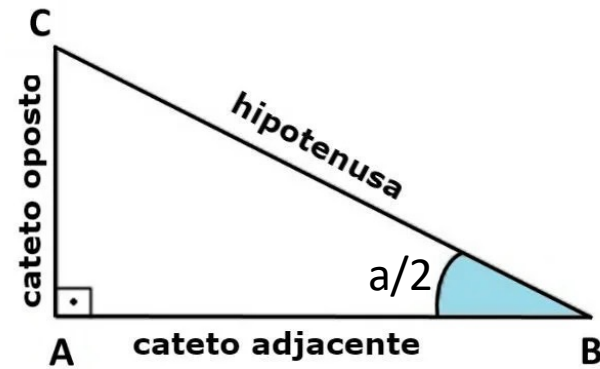
150 a.C. Hiparcos determinou a paralaxe da Lua e em 1672 Cassini a paralaxe de Marte -> U.A.



2 março 2026
Raio do Sol = 700 000 km
= 109 R_{Terra}



Paralaxe



$$d = \frac{c}{2 \tan(a/2)}$$

Determinação de distâncias: paralaxe

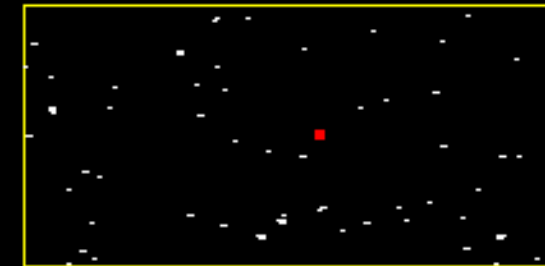
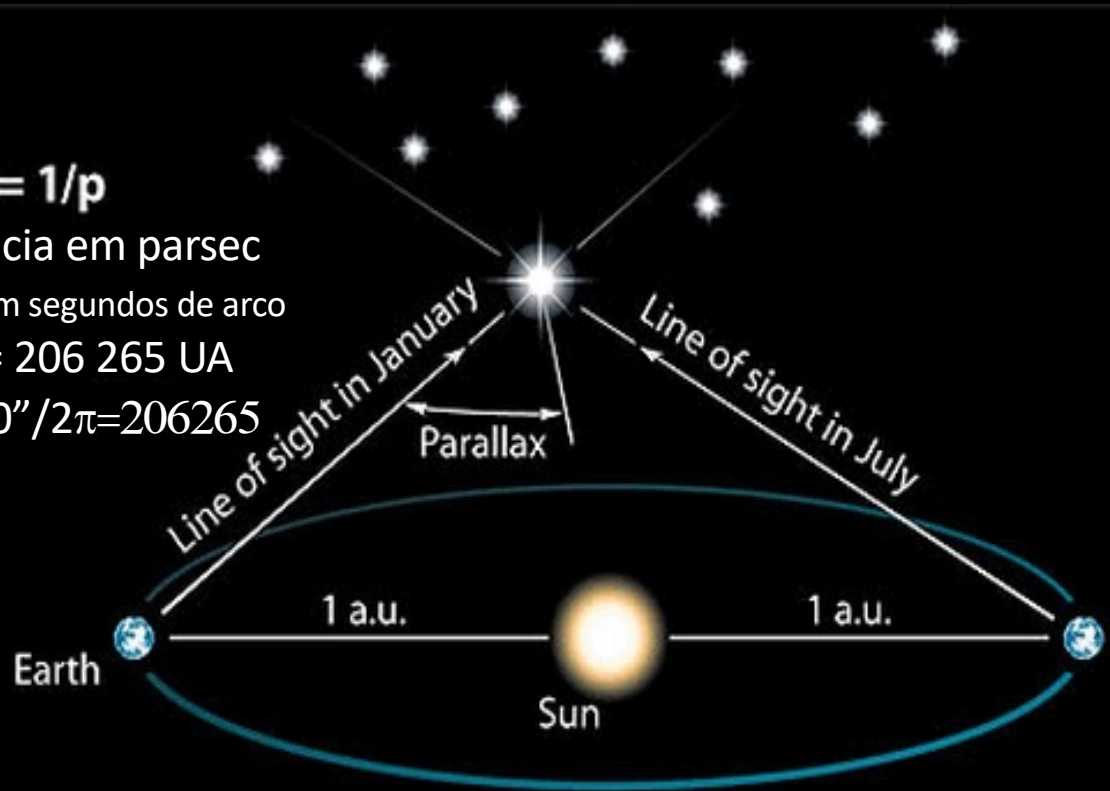
$$d = 1/p$$

d = distância em parsec

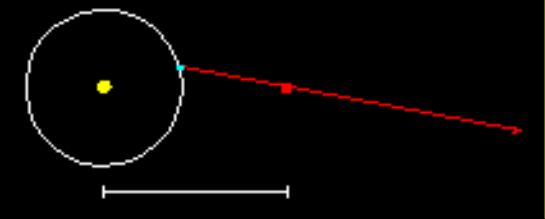
p=paralaxe em segundos de arco

parsec = 206 265 UA

$$360^\circ \times 60' \times 60'' / 2\pi = 206265$$



Jan



$$p(\text{rad}) = \frac{1(\text{U.A.})}{d(\text{U.A.})} \times 206265 \left(\frac{''}{\text{rad}} \right)$$

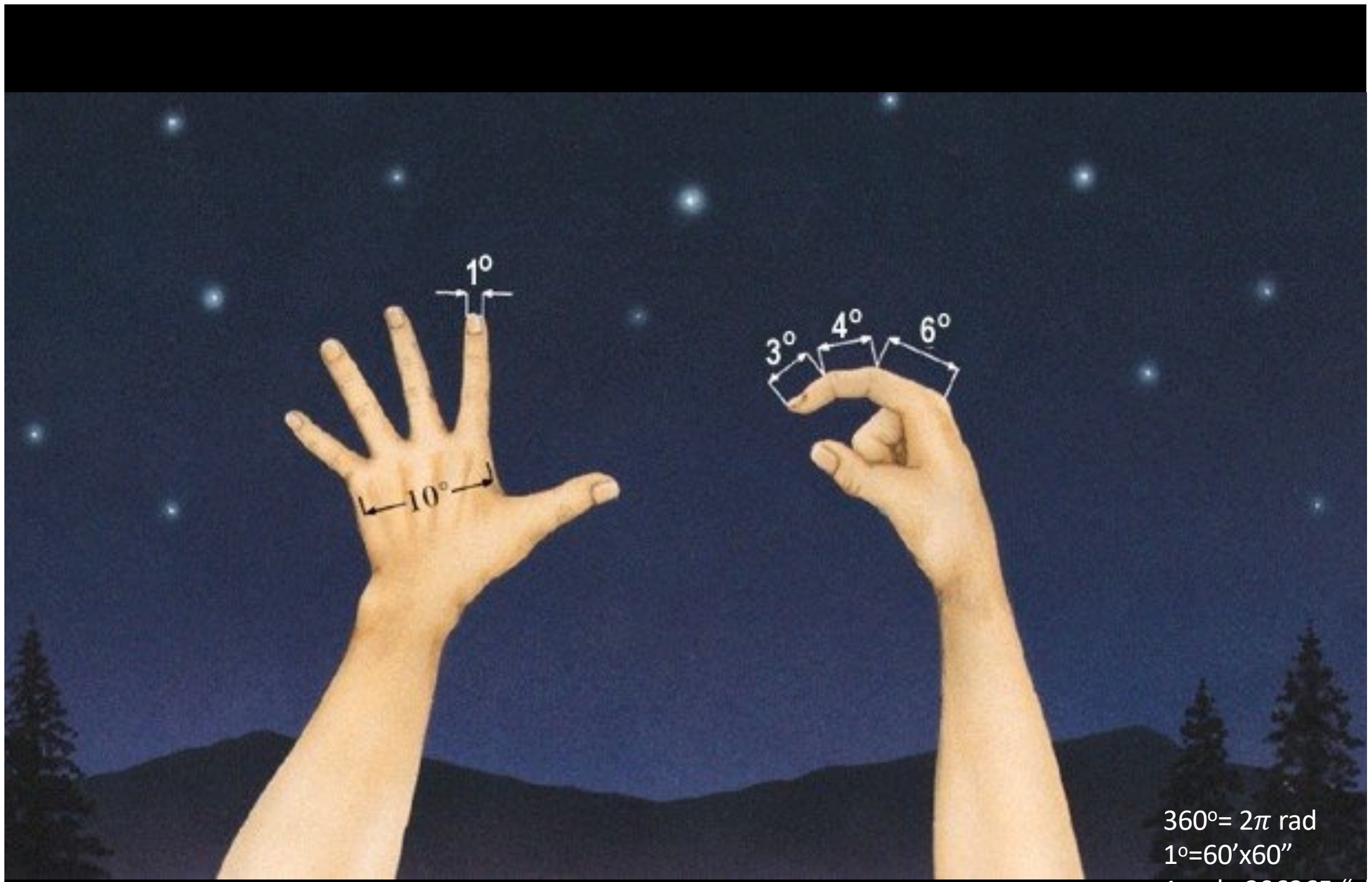
$$p('') = \frac{206265(\text{U.A.})}{d(\text{U.A.})} = \frac{1\text{pc}}{d(\text{pc})}$$

$$d(\text{pc}) = \frac{1\text{pc}}{p('')}$$

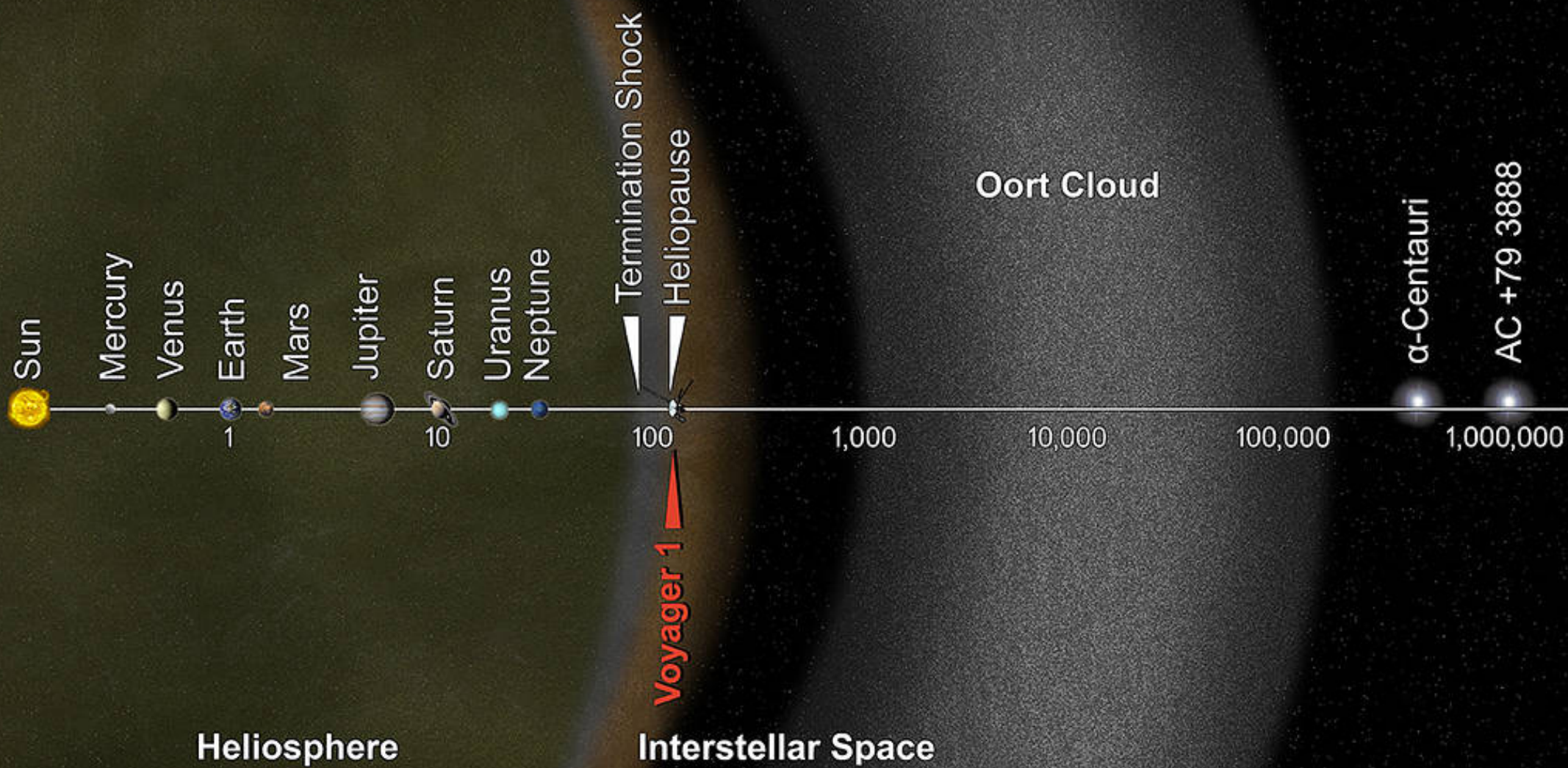
Bessel 1838 primeira paralaxe estelar

Estrela mais próxima: Proxima Centauri, paralaxe=0,77'', distância=1,3 pc = 4,2 a.l.

1 parsec = distância que uma estrela tem com uma PARalaxe de 1 SEGundo de arco

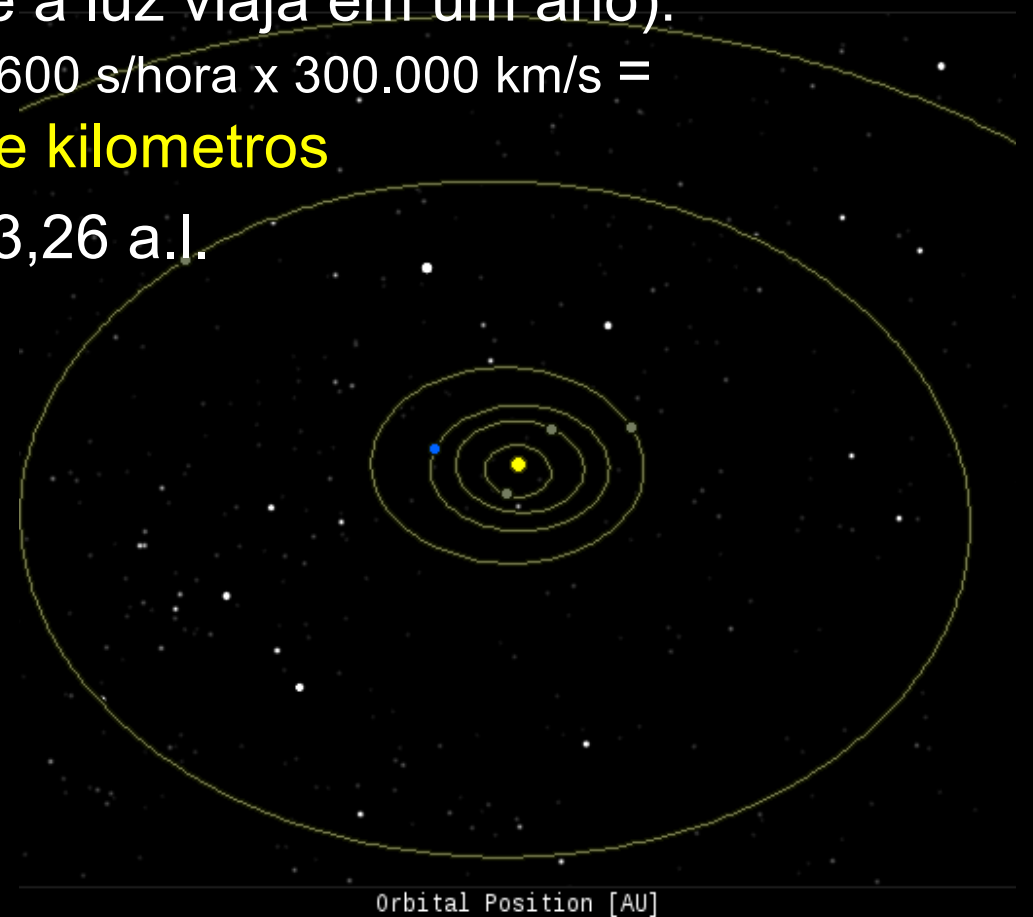


$360^\circ = 2\pi \text{ rad}$
 $1^\circ = 60' \times 60''$
 $1 \text{ rad} = 206265''$
 $360^\circ / 24\text{h} = 15^\circ/\text{h}$



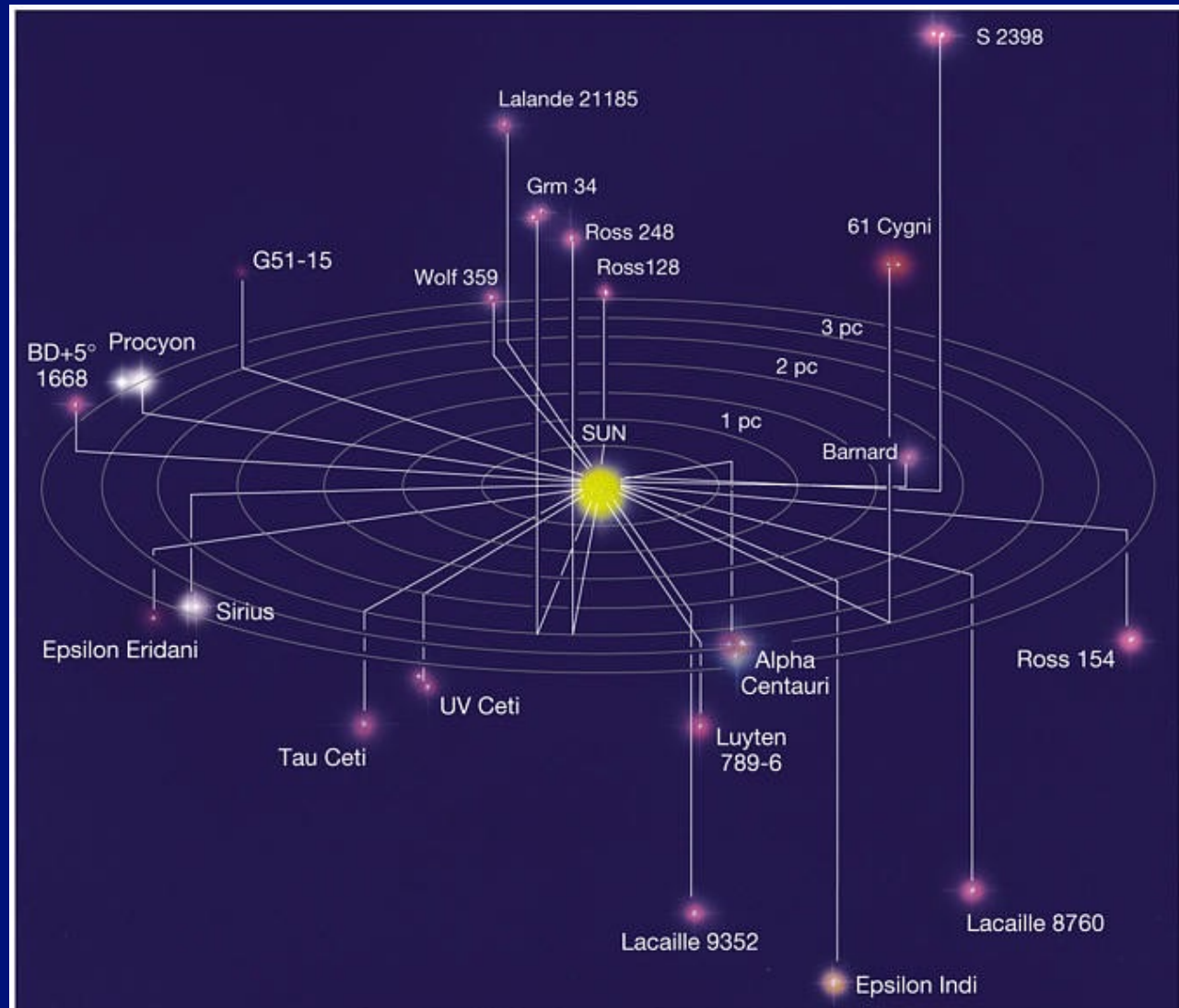
Unidades de distância Astronômicas

- Unidade Astronômica (U.A.— distância Terra-Sol):
150 milhões de km
- **Ano-Luz** (a.l. — **distância** que a luz viaja em um ano):
 $365,25 \text{ dias/ano} \times 24 \text{ horas/dia} \times 3600 \text{ s/hora} \times 300.000 \text{ km/s} =$
 $9,5 \times 10^{12} \text{ km} = 9,5 \text{ trilhões de quilômetros}$
- Parsec (pc): $206\,265 \text{ U.A.} = 3,26 \text{ a.l.}$
- Kiloparsec = 1.000 pc
- Megaparsec = $1.000.000 \text{ pc}$

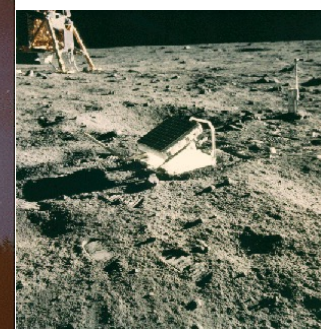
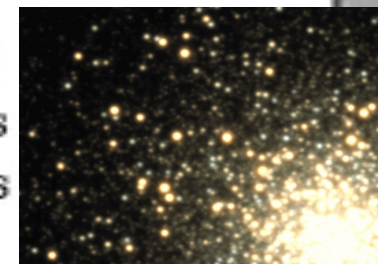
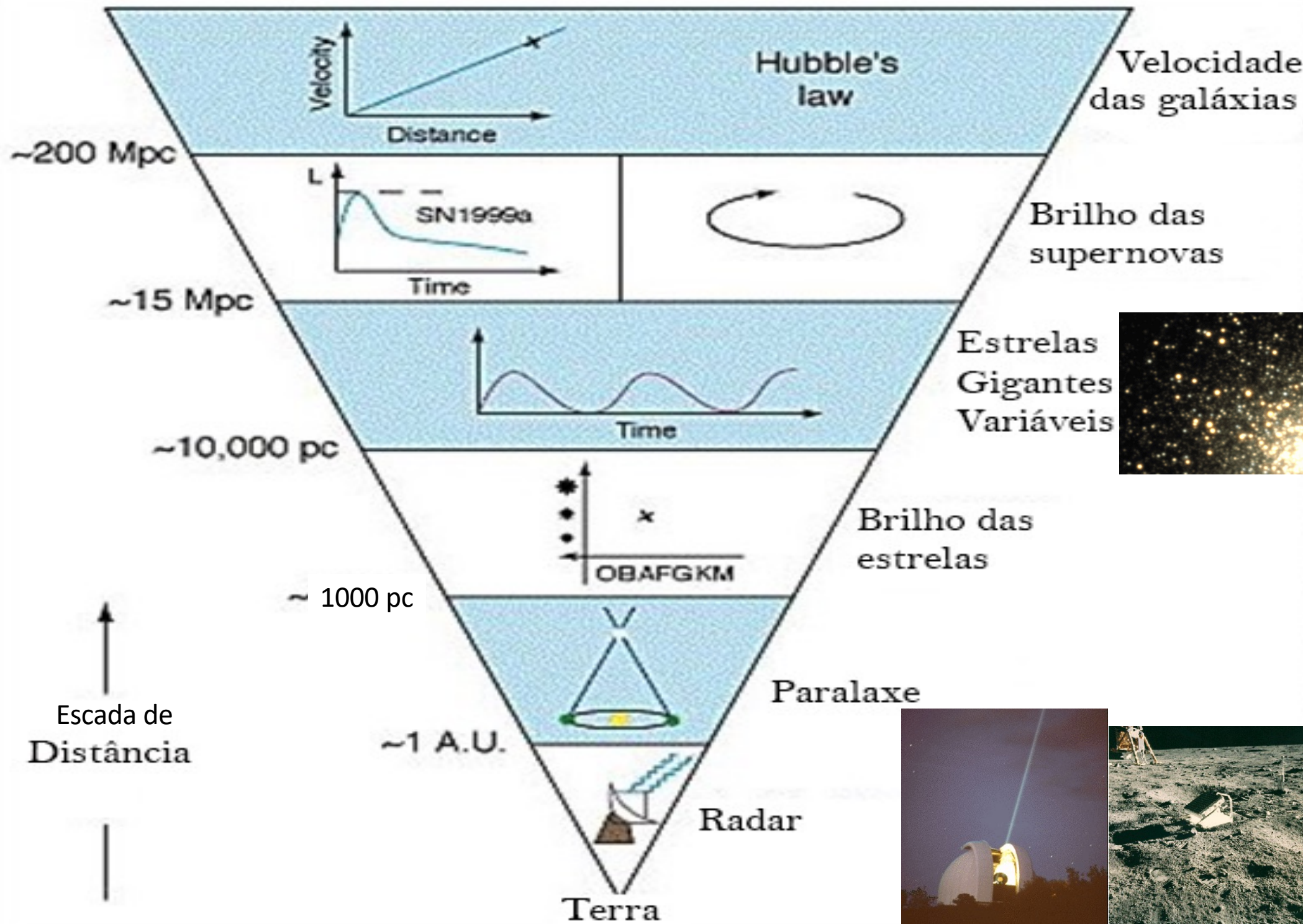


Distância entre as estrelas

- **Estrela mais próxima:** Próxima Centauri: $d=4,22$ a.l.



Copyright © 2005 Pearson Prentice Hall, Inc.

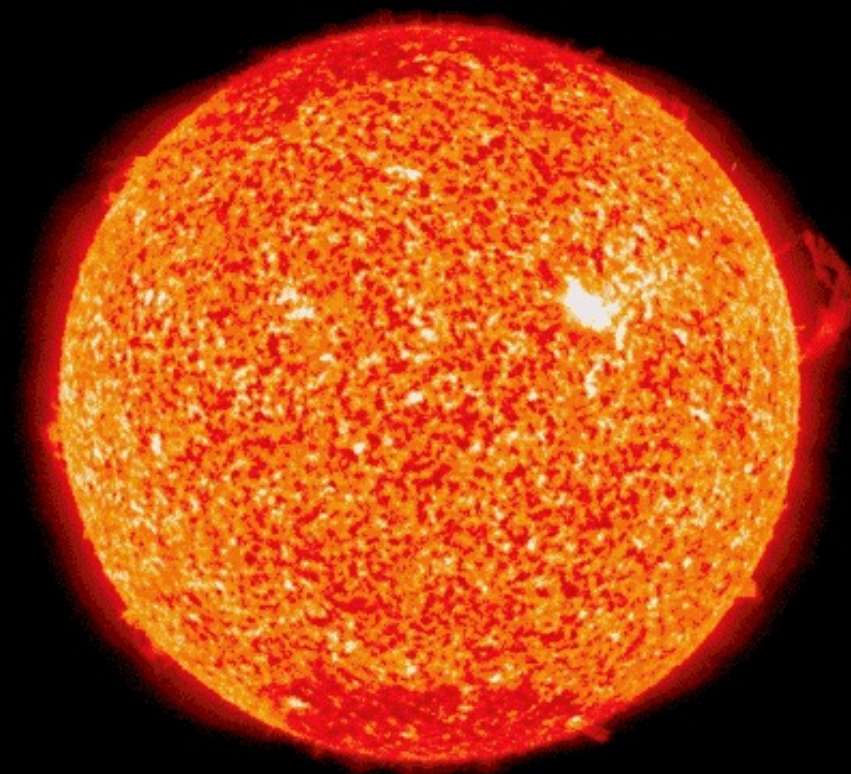
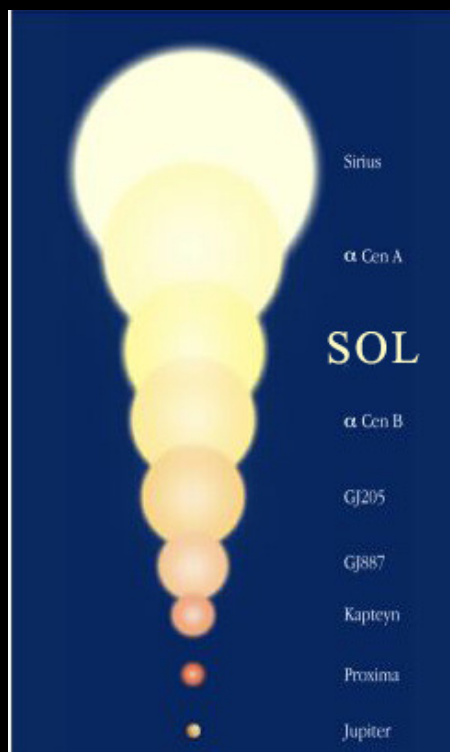


Brilho $\sim \frac{L}{d^2}$



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

Estrelas de todos os tamanhos



Tamanho da estrela

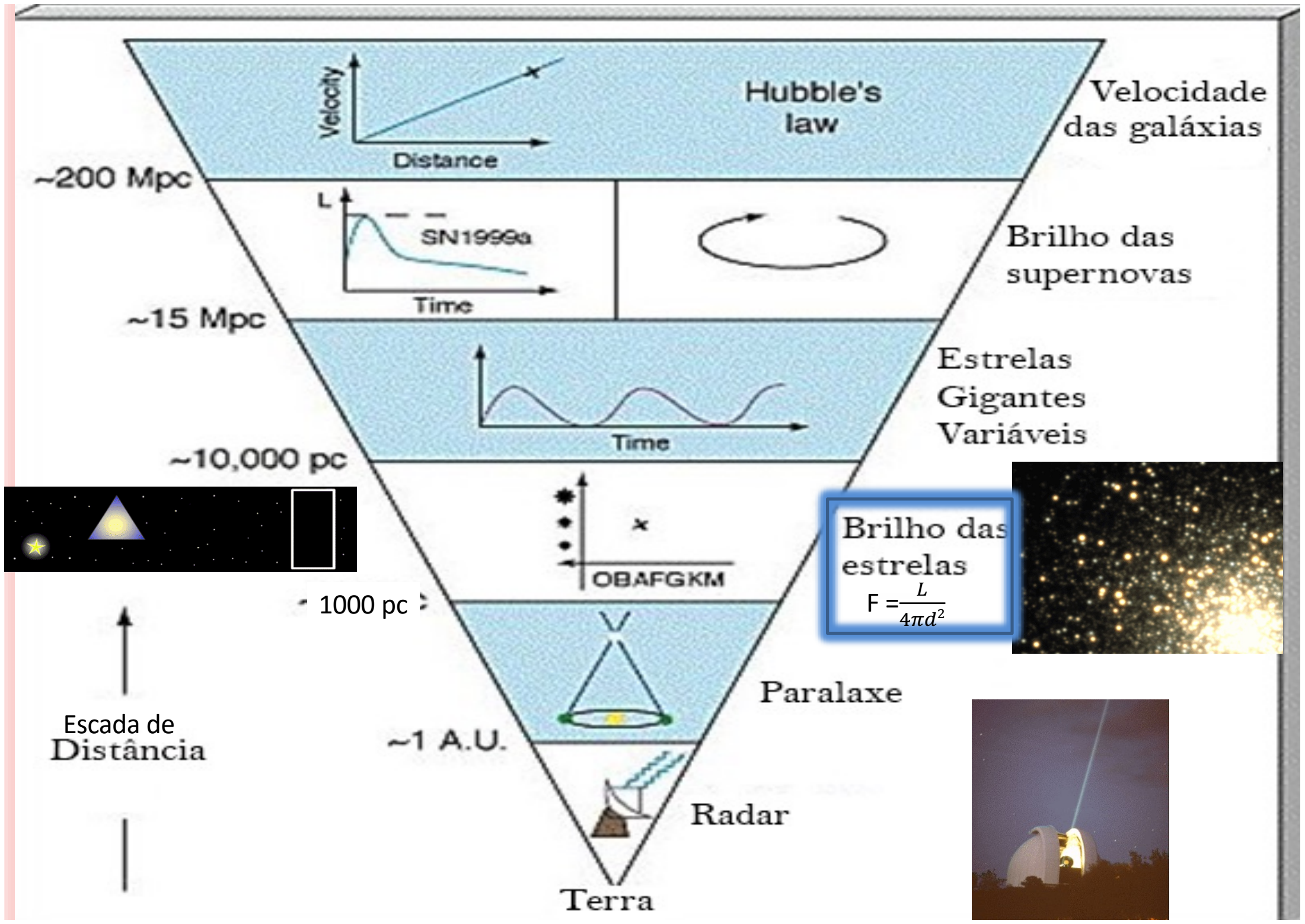
Tamanho da órbita da Terra

Tamanho da órbita de Júpiter



Atmosfera de Betelgeuse

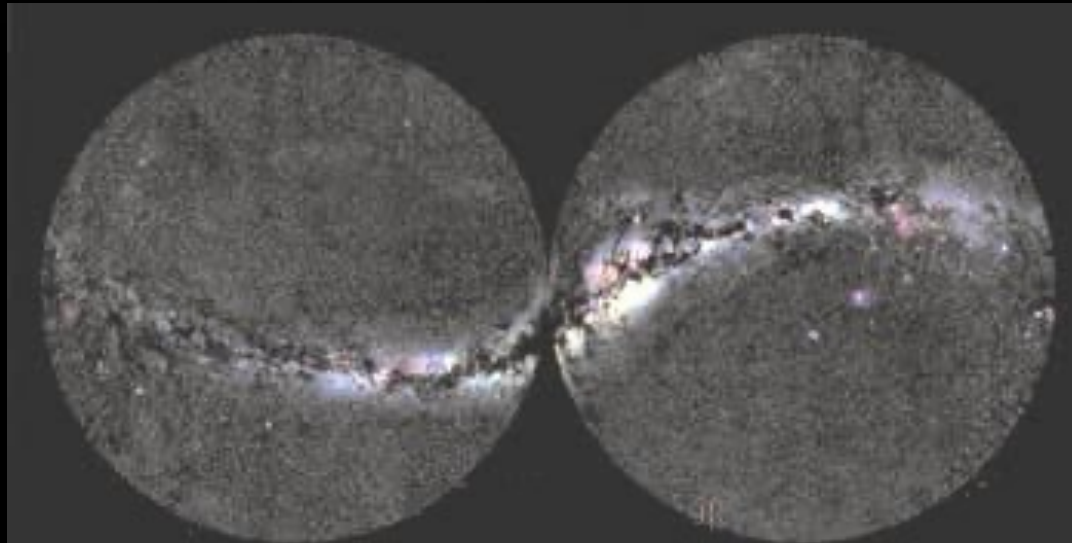






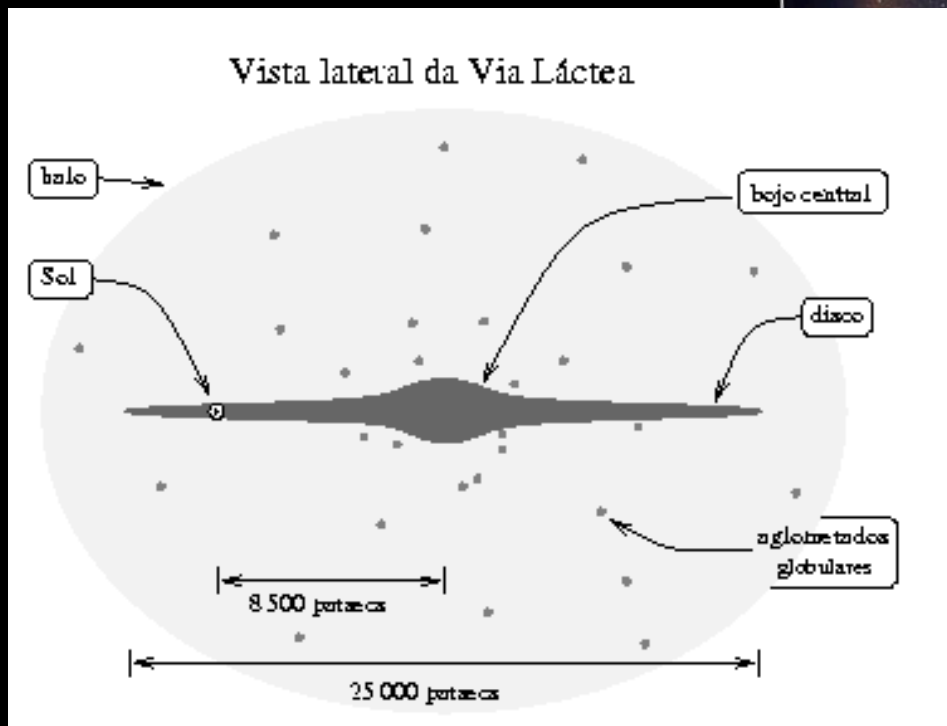
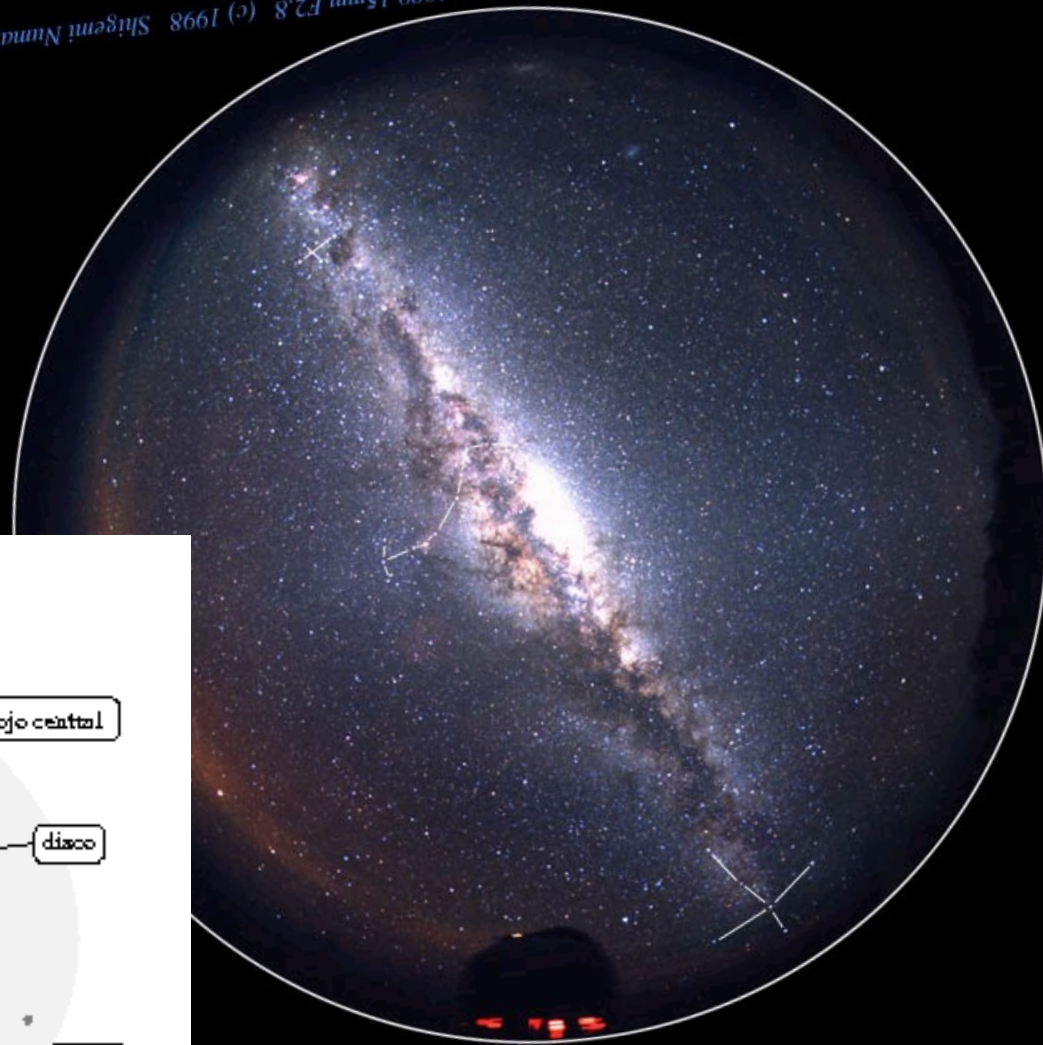


A Via Láctea

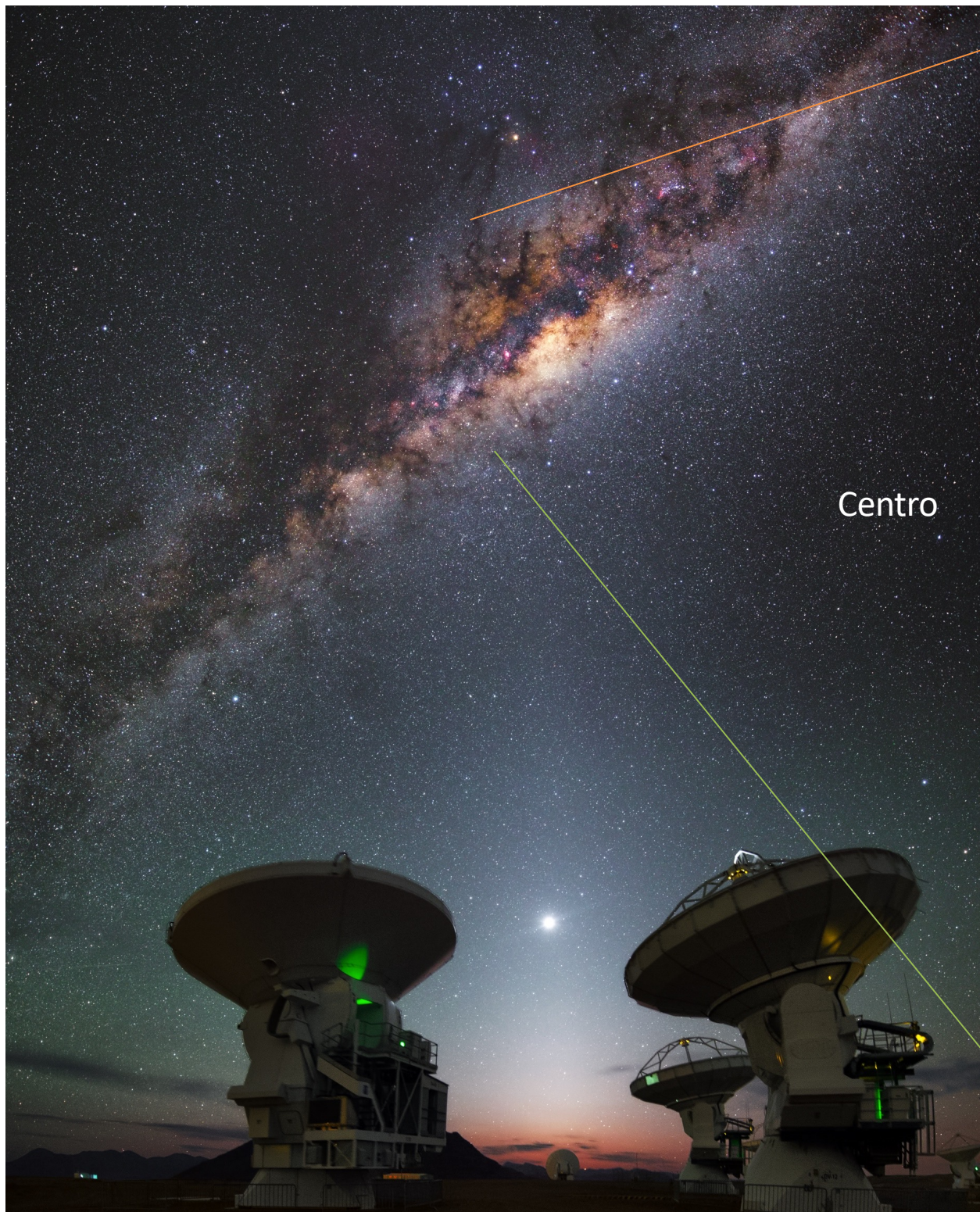


Tamanho da Via Láctea

MILKY WAY at Las Campanas Obs. CHILE May. 1989 15mm F2.8 (c) 1998 Shigemi Numazawa



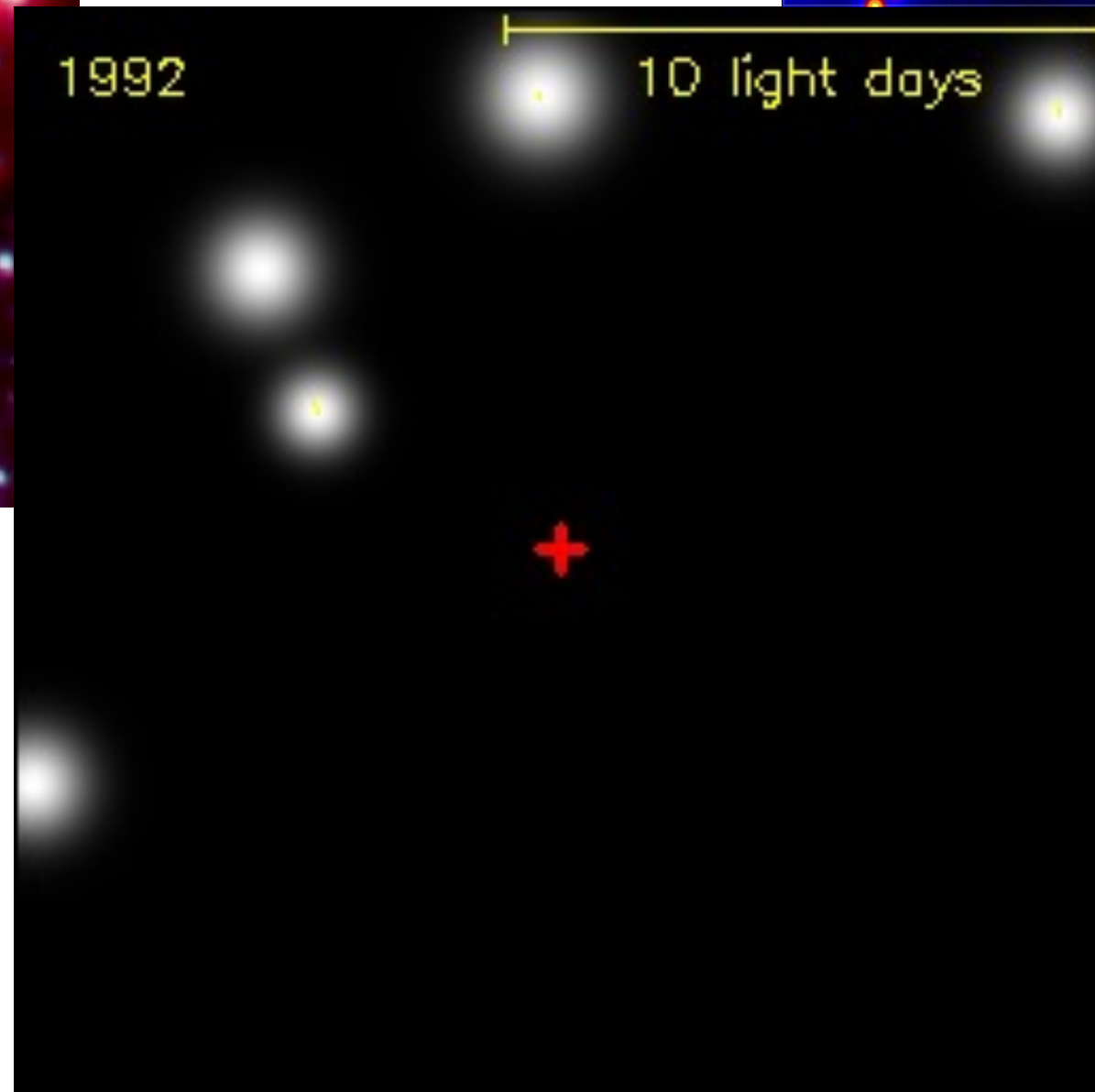
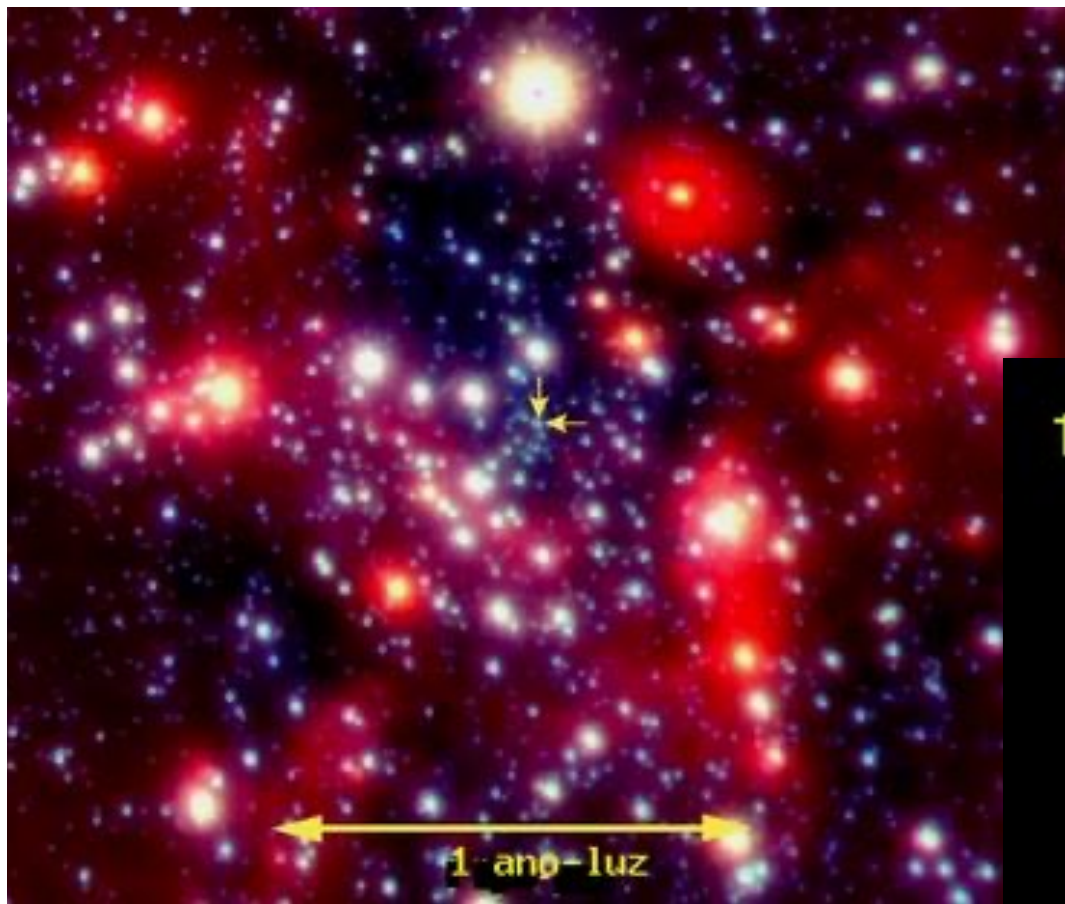
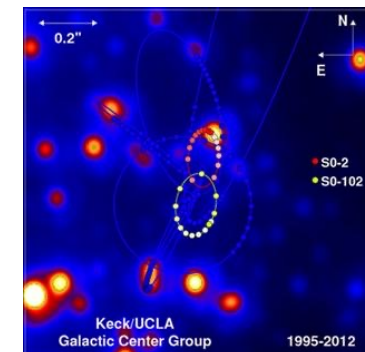
Diâmetro: 100 000 anos luz



Centro



Centro da Via Láctea



$$F = -\frac{GMm}{r^2}$$

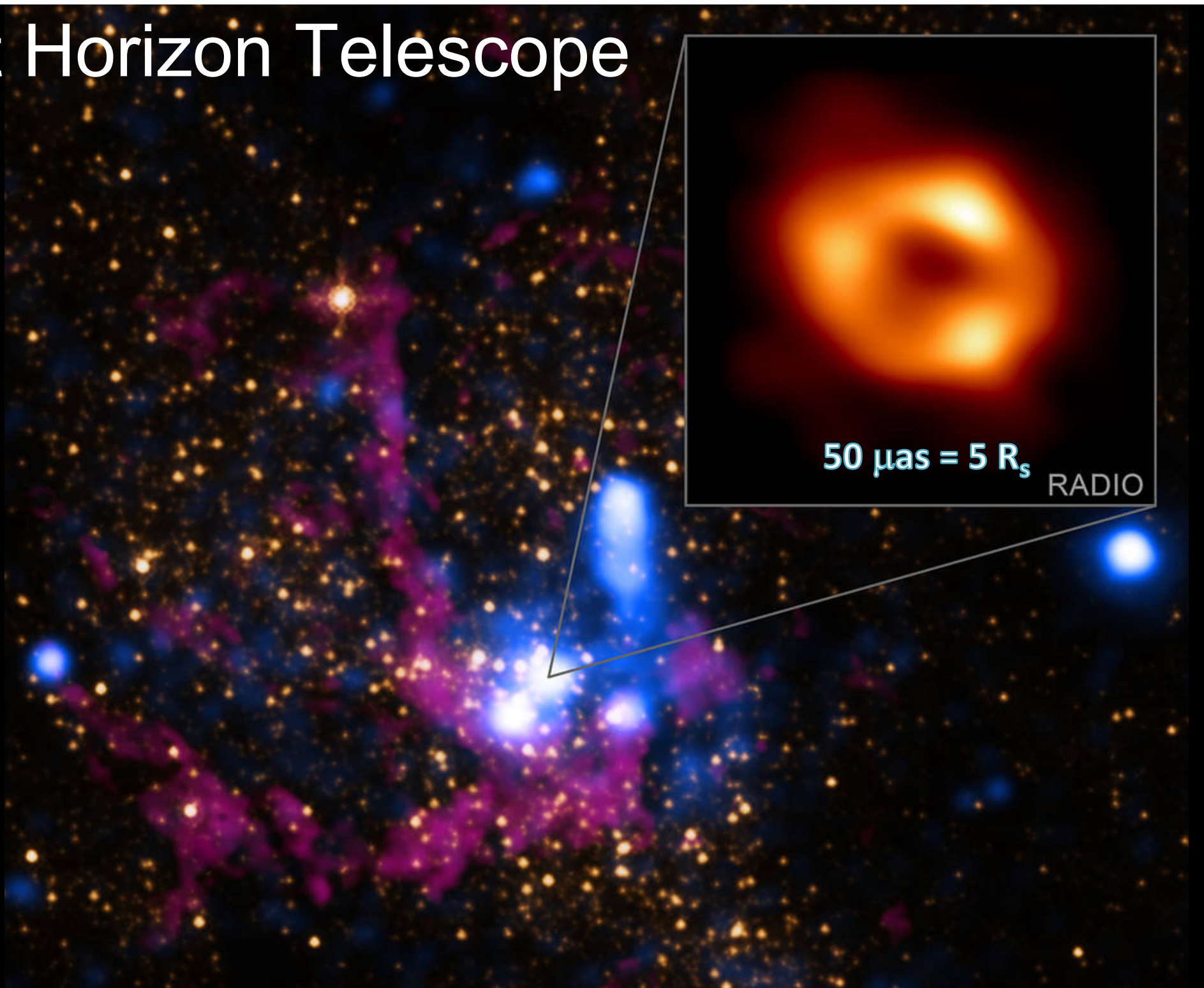
$$P^2 = \frac{4\pi^2}{G(M_* + M_{\text{BN}})} a^3$$

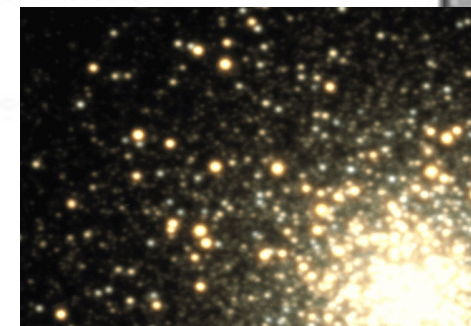
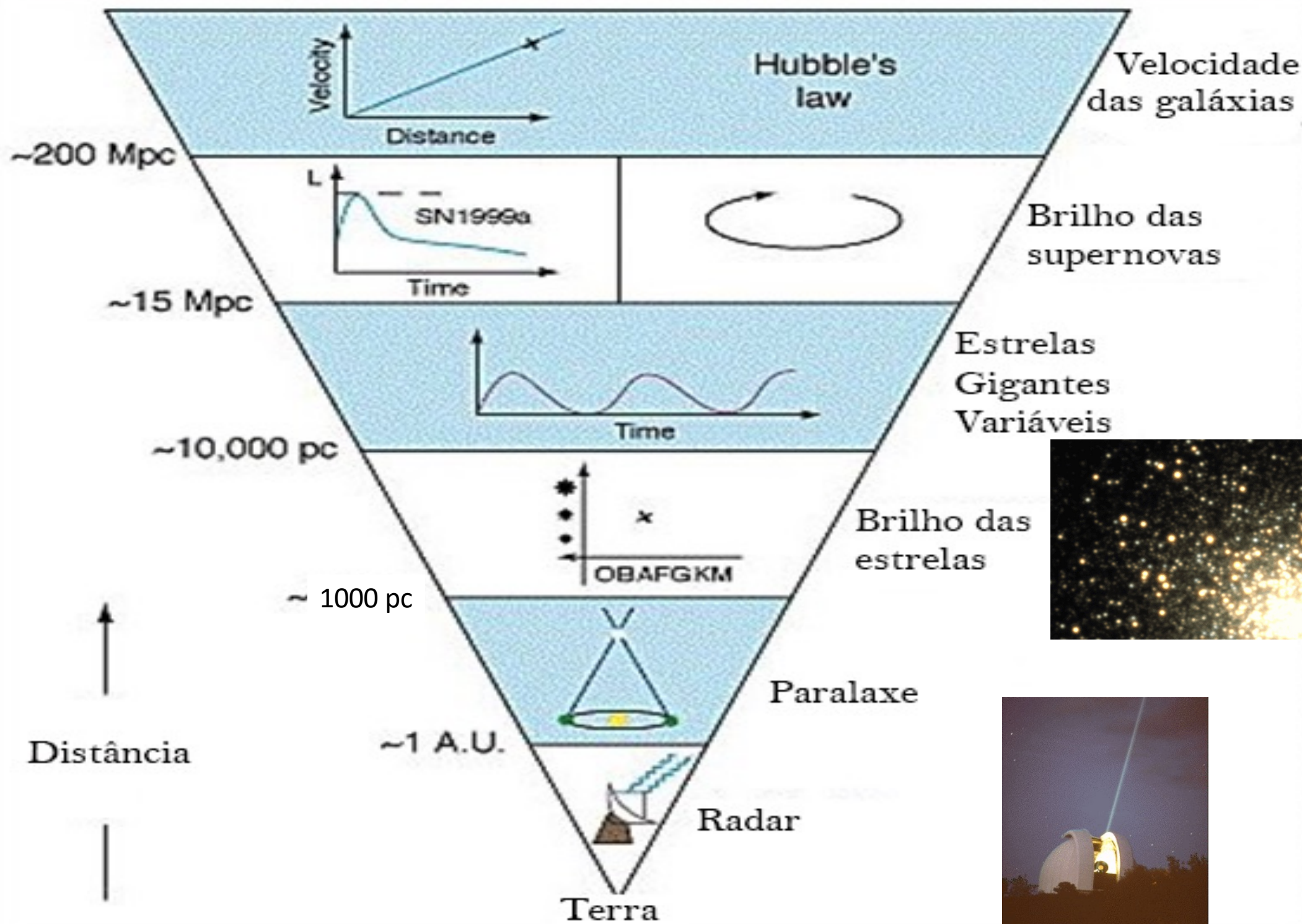
$M_* = 15 M_{\text{sol}}$, $P = 15,6$ anos, $a = 984$ U.A., $d_{\text{min}} = 120$ U.A.

$M_{\text{BN}} = 4$ milhões M_{sol} $R_S = 12\,000\,000$ km

Event Horizon Telescope

16 maio 22



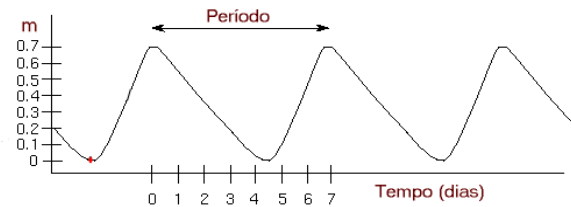
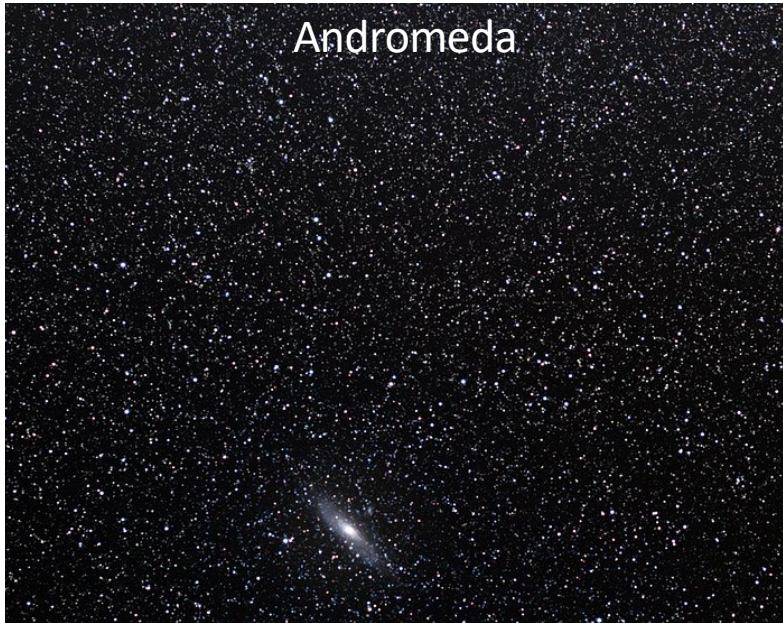




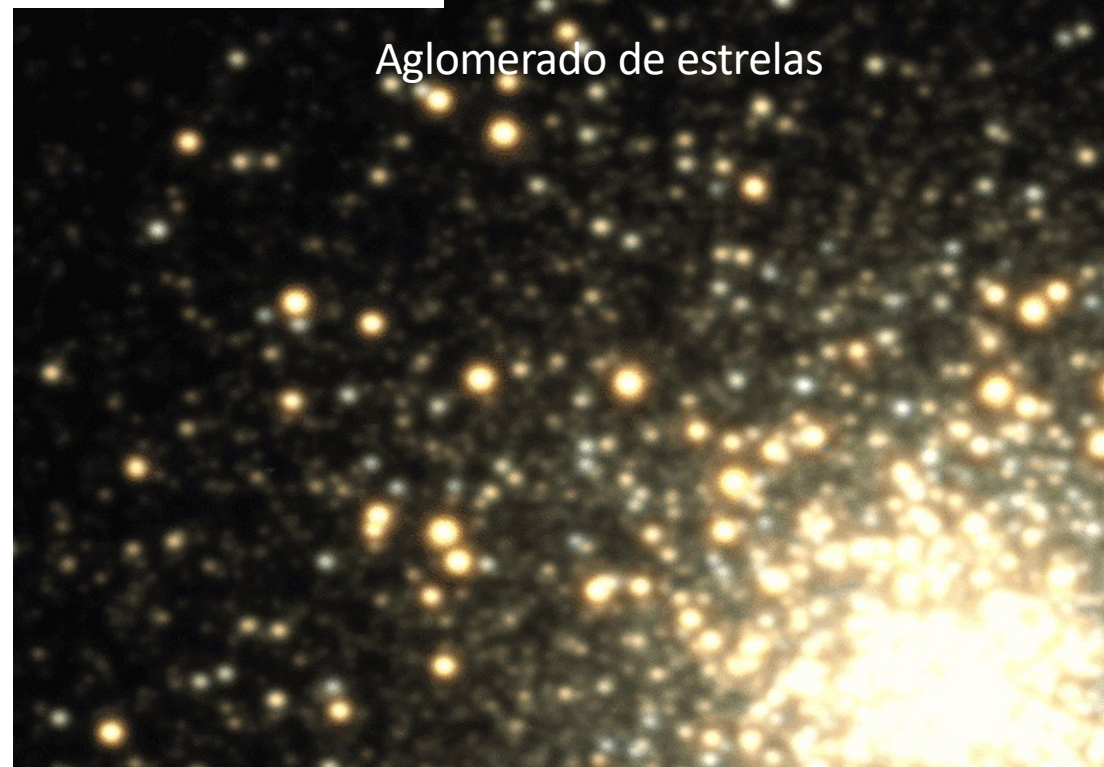
5° + 2° d=22° Al Sufi 964, Fernão de Magalhães 1520

Edwin Hubble 1929

Andromeda



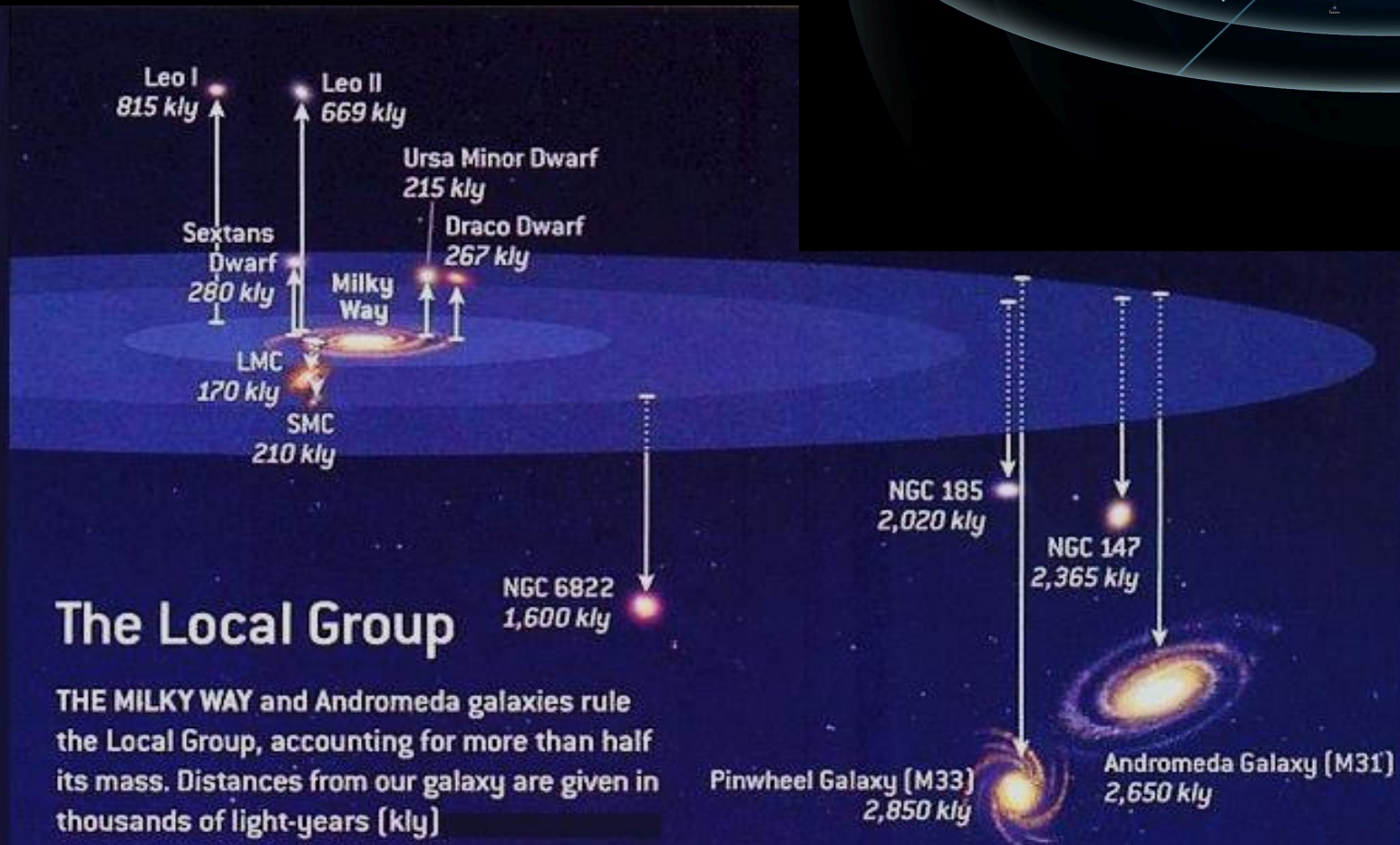
Aglomerado de estrelas



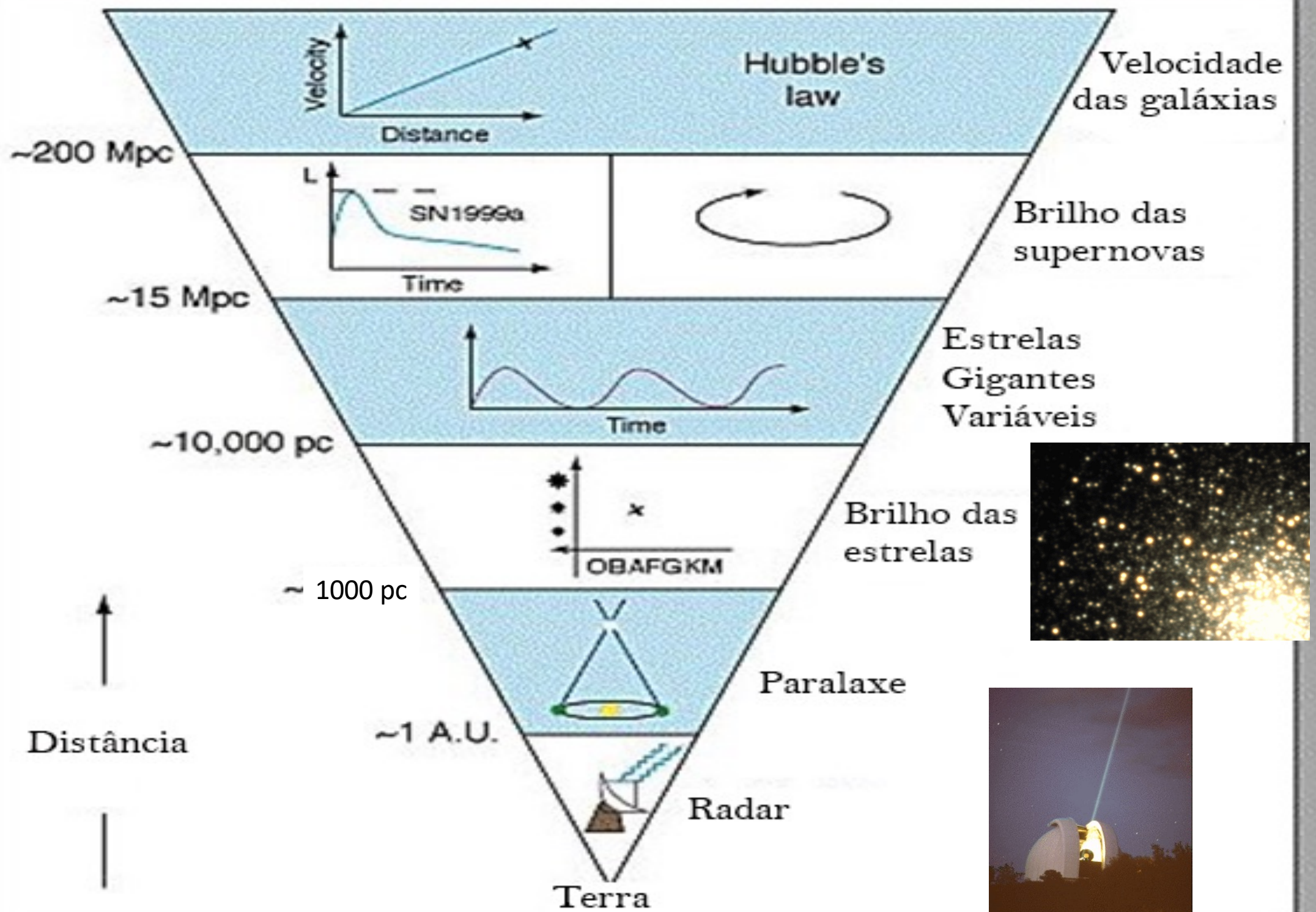
Tamanho 3° , distância = 2,54 milhões de anos-luz

Distância entre galáxias:

o Grupo Local



Cerca de 104 galáxias
Raio=5 milhões de a.l.

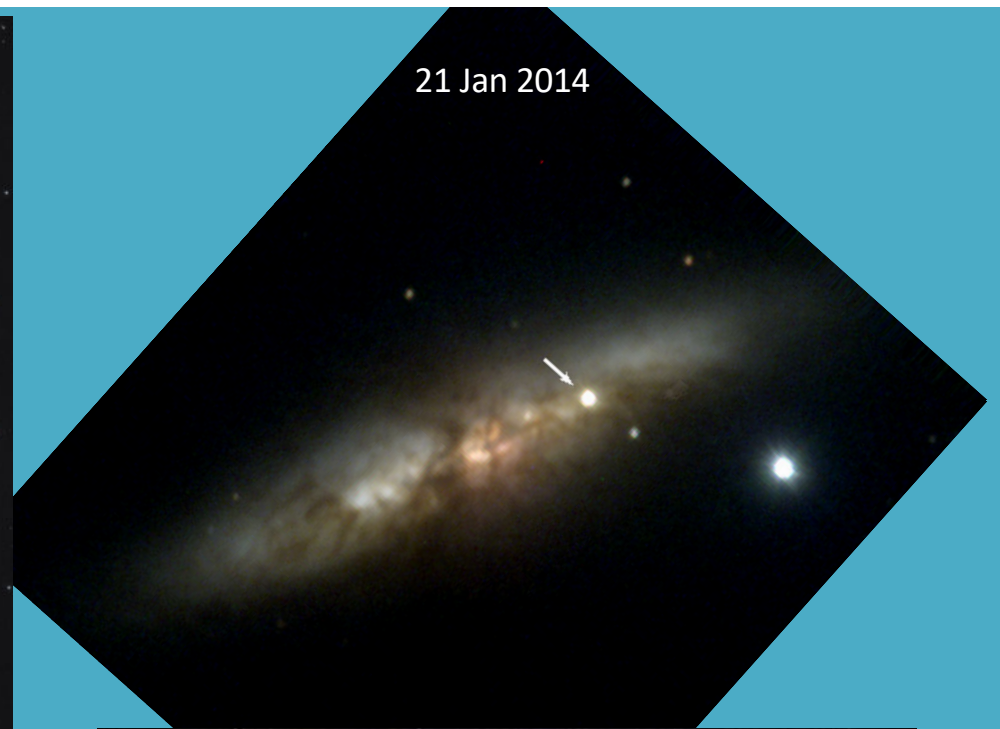


- Estrelas
supernovas
"velas padrão"

$$F = \frac{L}{4\pi r^2} \rightarrow r = \sqrt{\frac{L}{4\pi F}}$$



SN1987A GNM 168 000 anos-luz de distância



Como se buscam supernovas



Charles Messier (1730-1817)

Aglomerado de Virgem

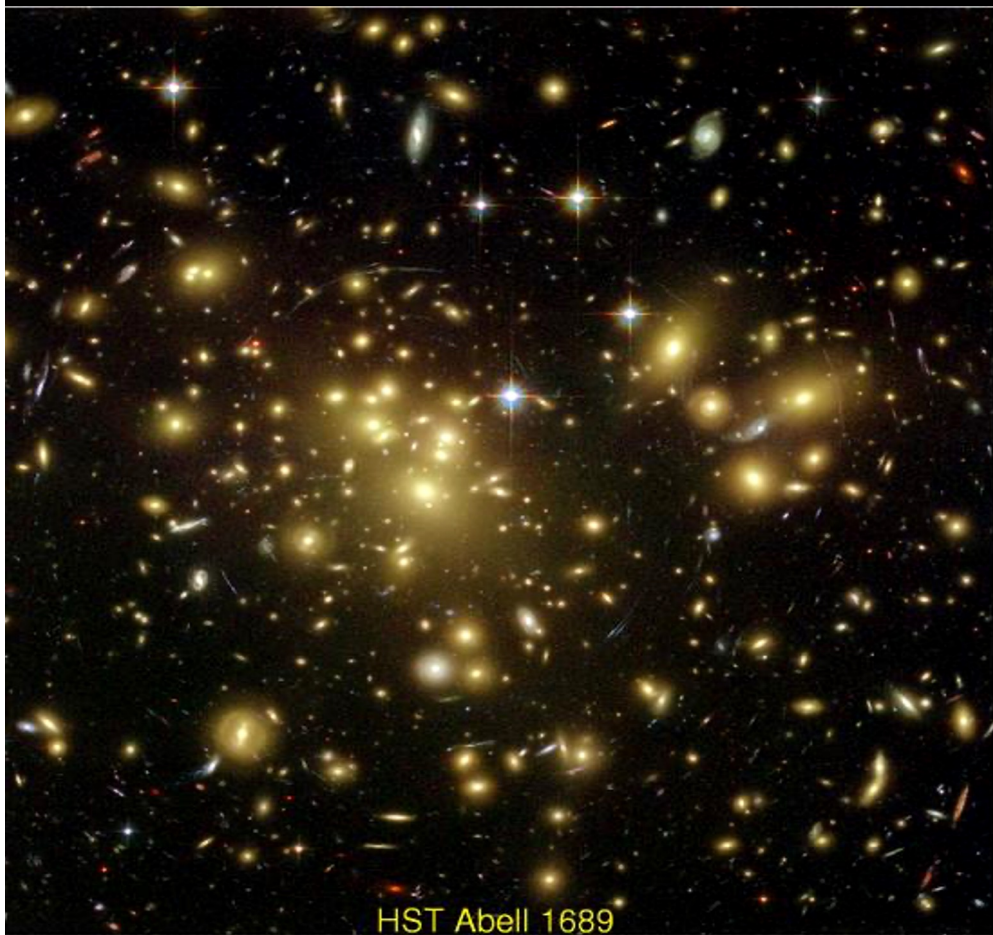
M87

A 60 milhões de anos-luz,
contém mais de 2000
galáxias.

É o centro do
super-aglomerado local.

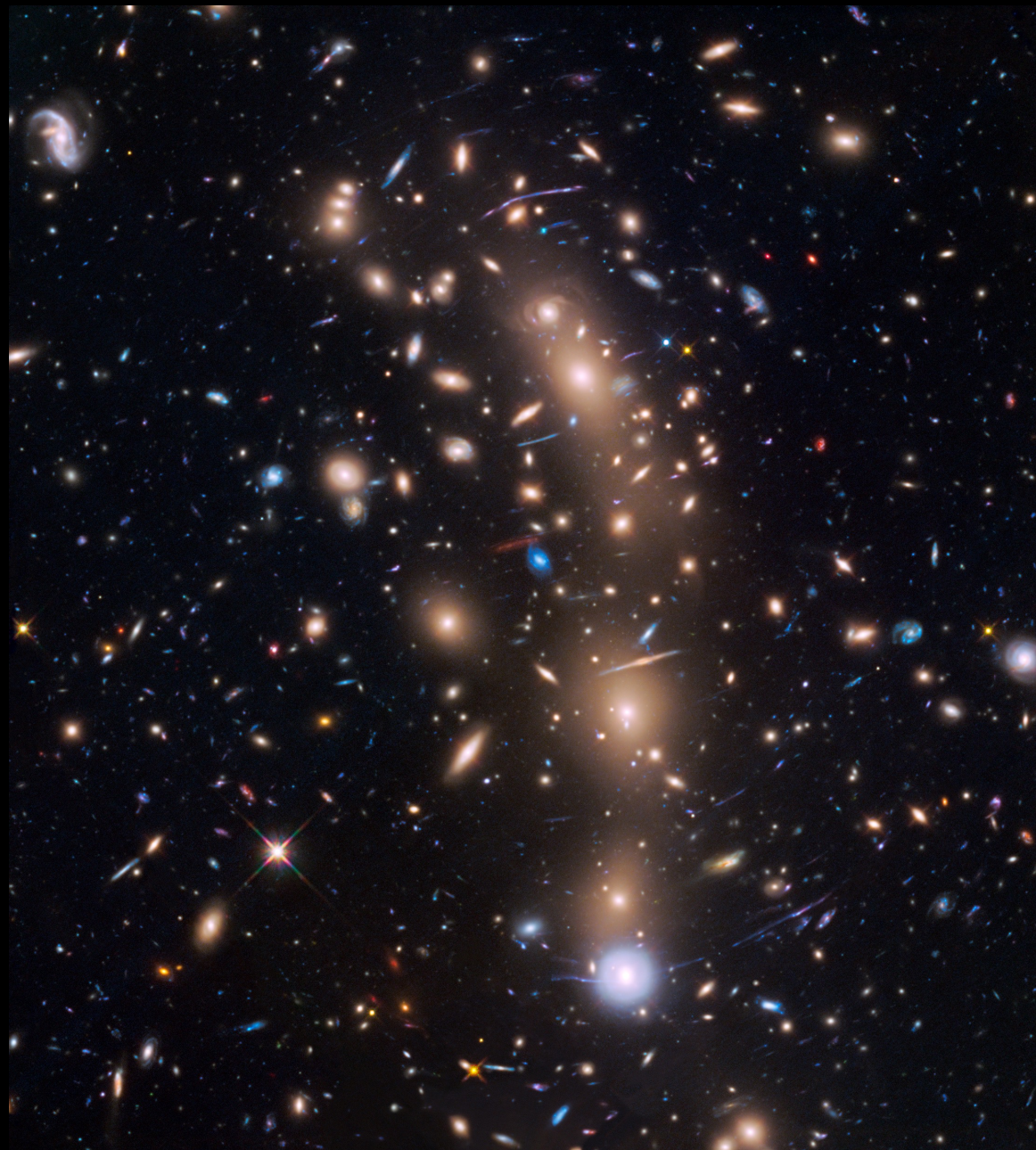
Rogelio Bernal Andreo
DeepSkyColors.com

Aglomerados de Galáxias

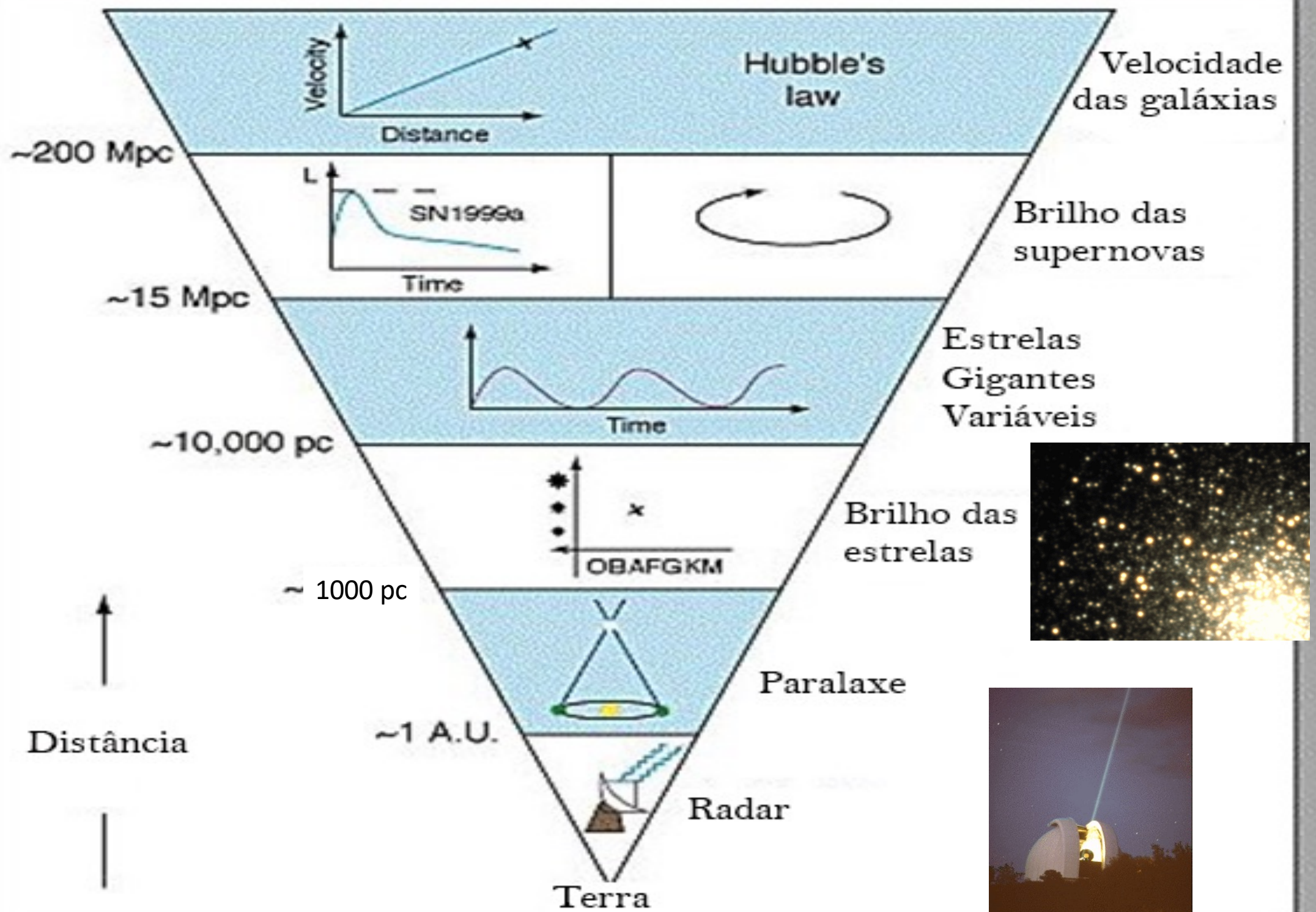


HST Abell 1689

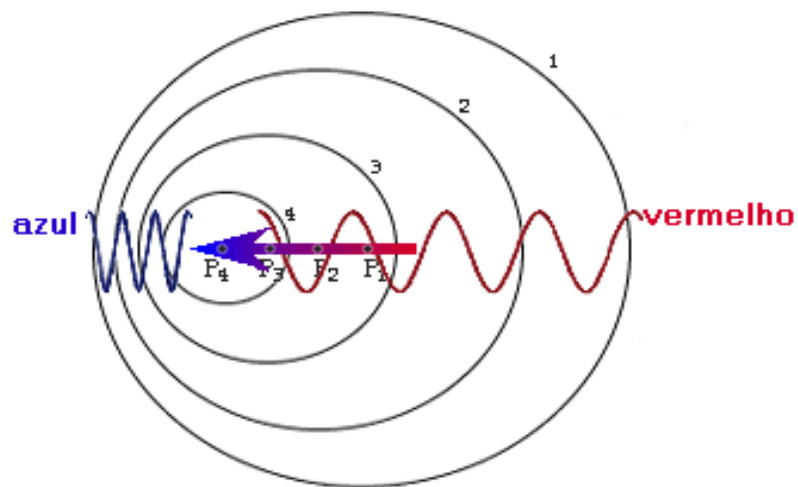
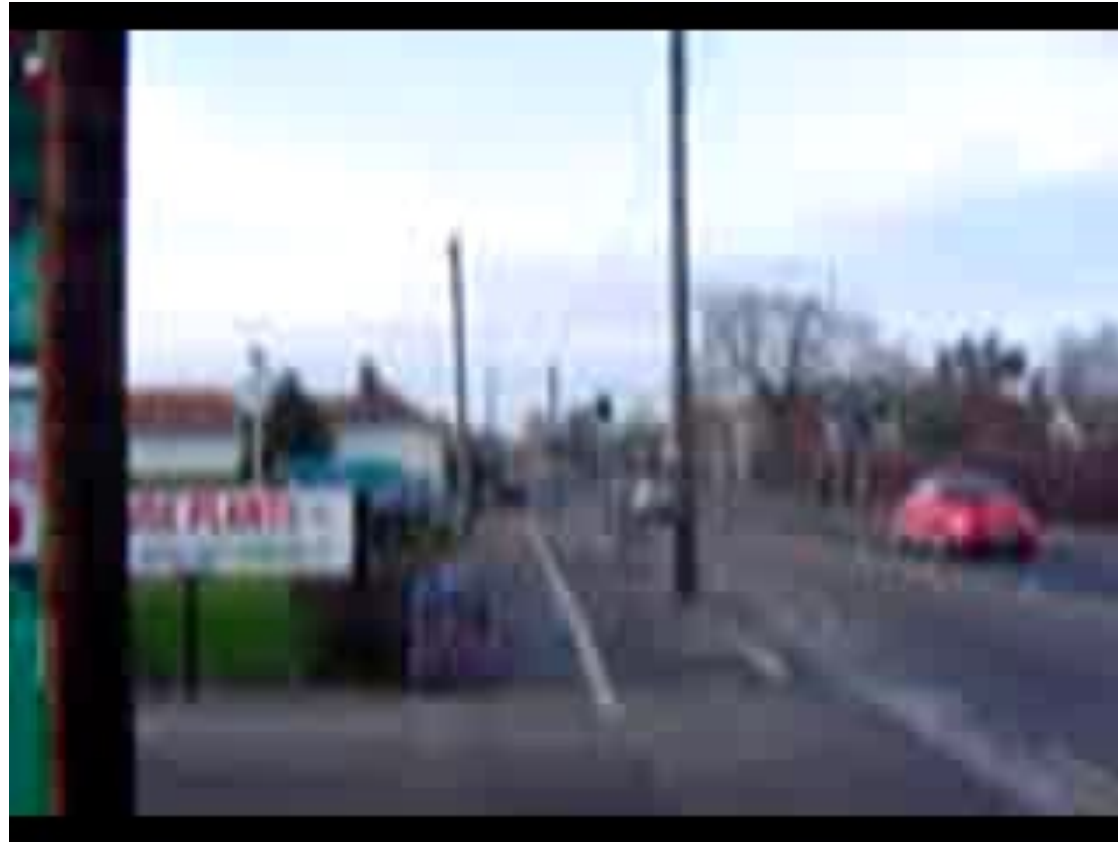
$z=0,1842$, $d=2,2$ bilhões a.-l.



MACS J0416.1-2403 $z=0,396$, $d=4,2$ bilhões de a.-l.

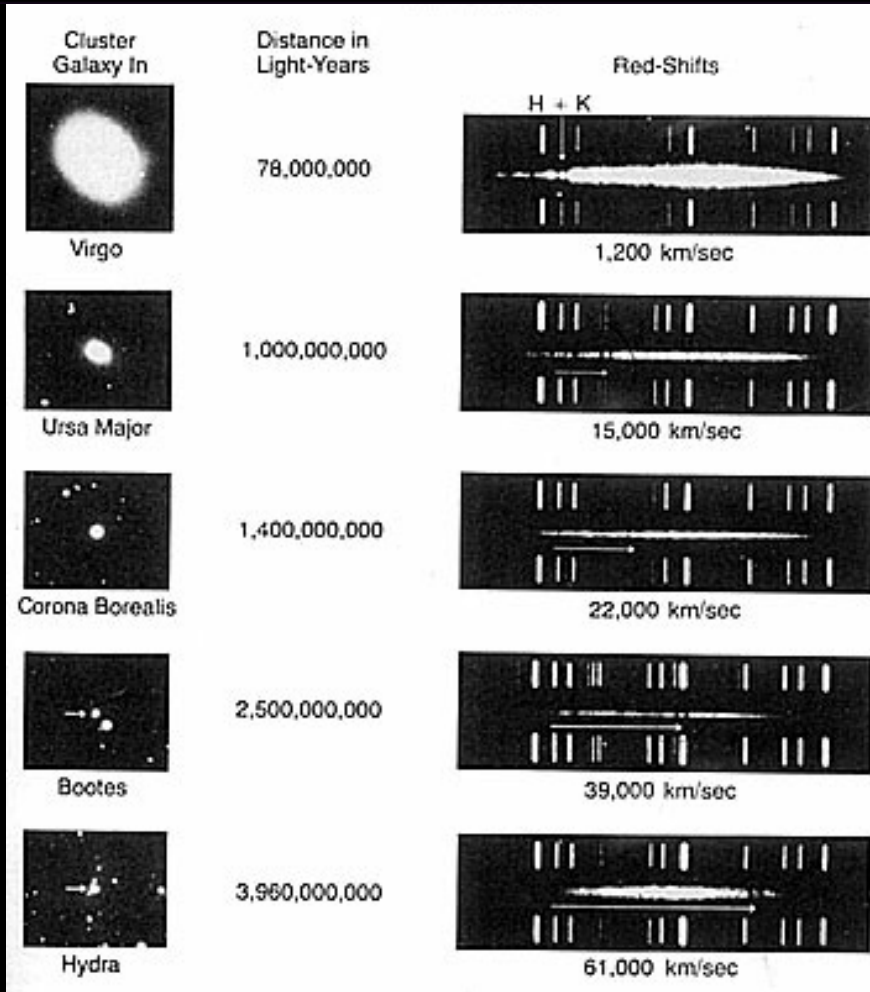
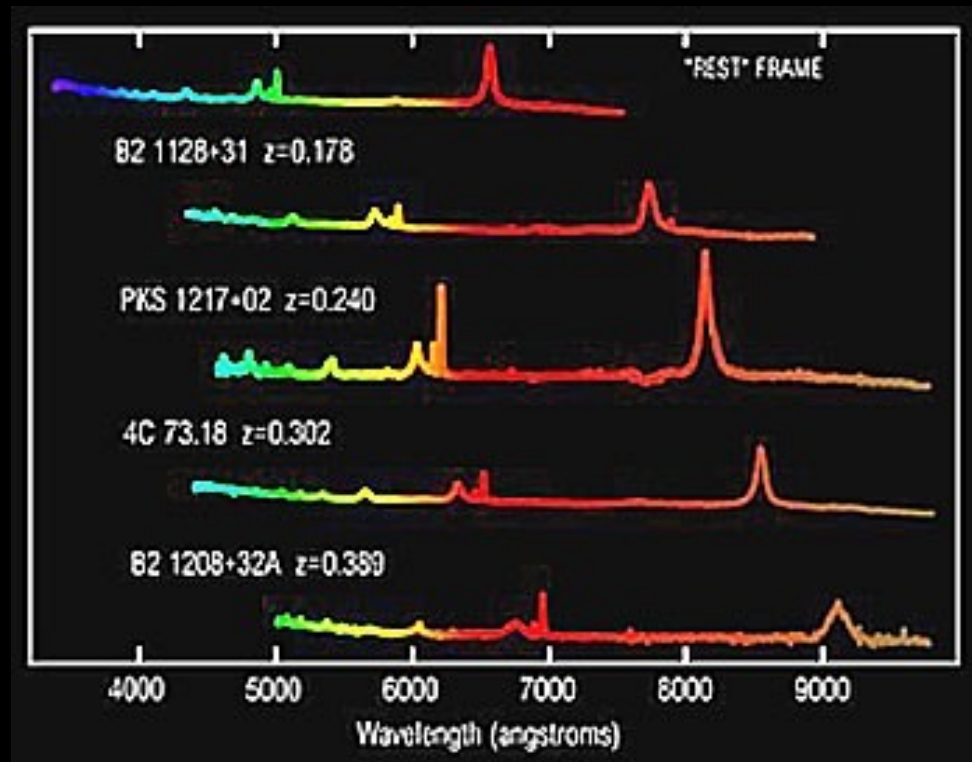
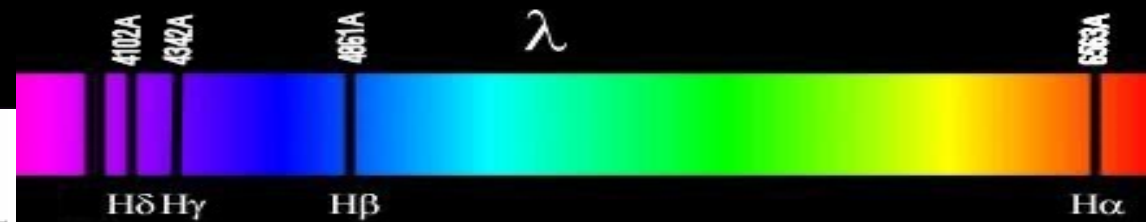


Efeito Doppler



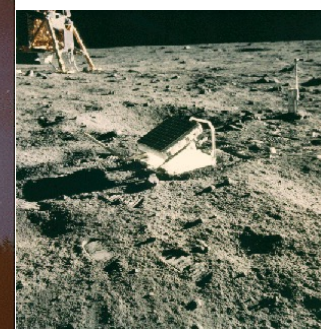
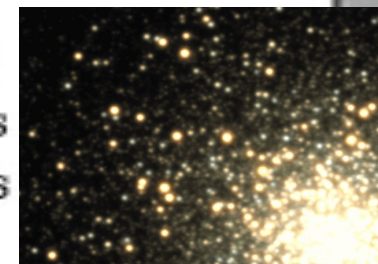
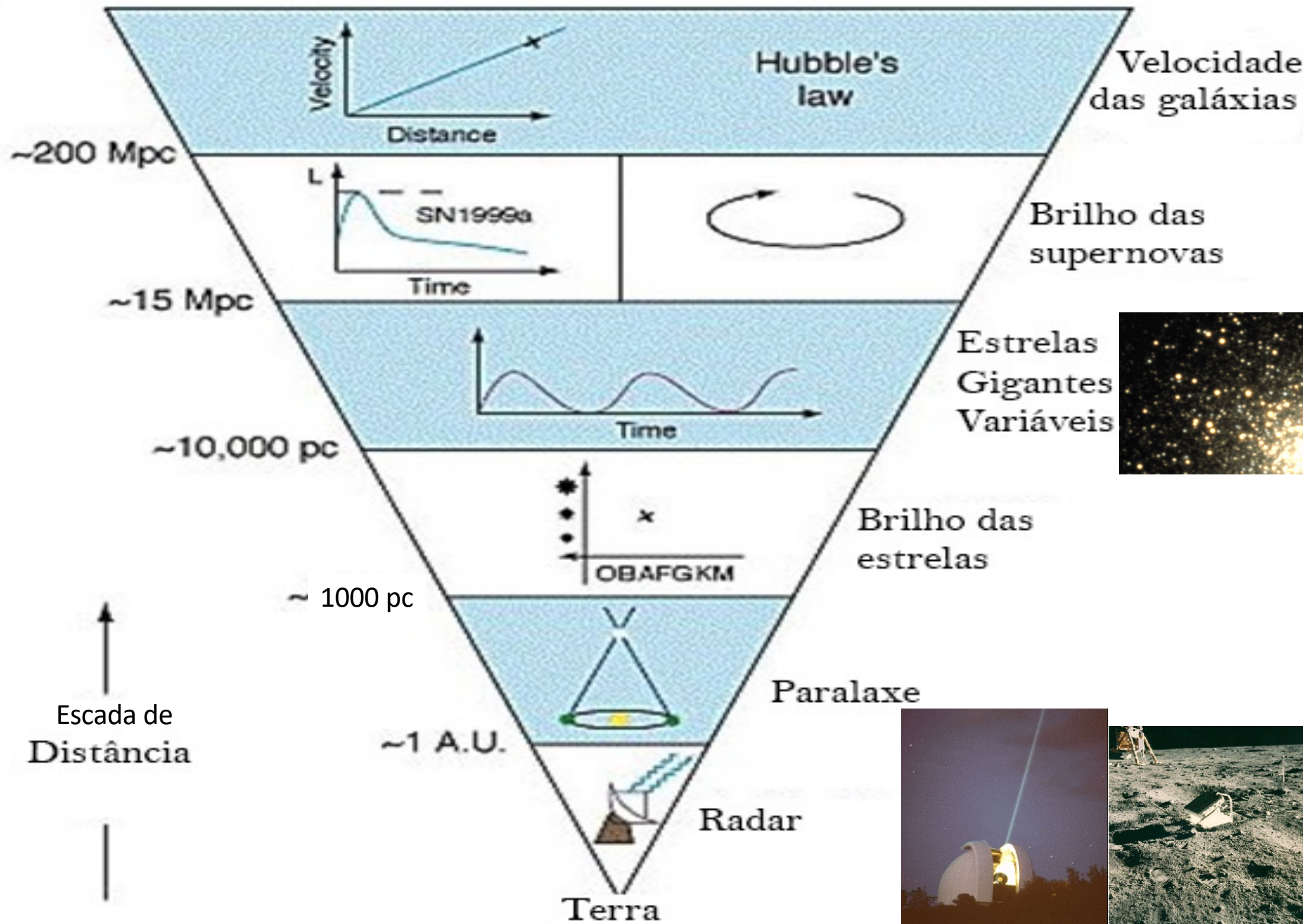
$$z \equiv \frac{\Delta\lambda}{\lambda} = \frac{v}{c} \cos \theta \left(\frac{1}{1 - \frac{v^2}{c^2}} \right)^{1/2}$$

Medindo deslocamento para o vermelho:
efeito Doppler

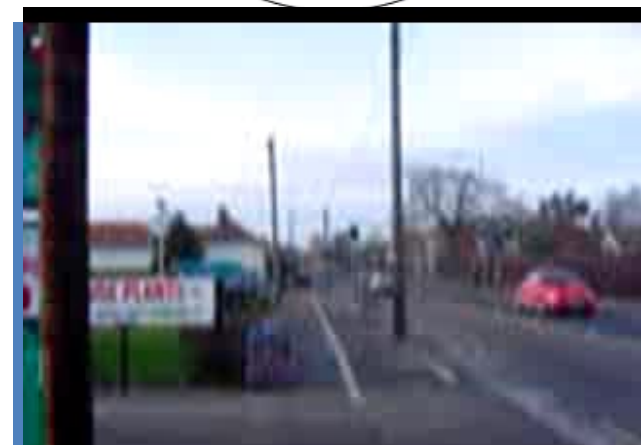
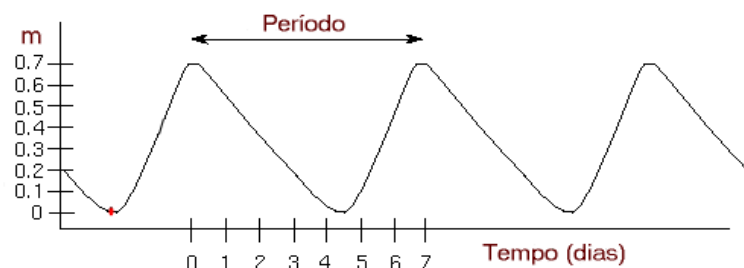
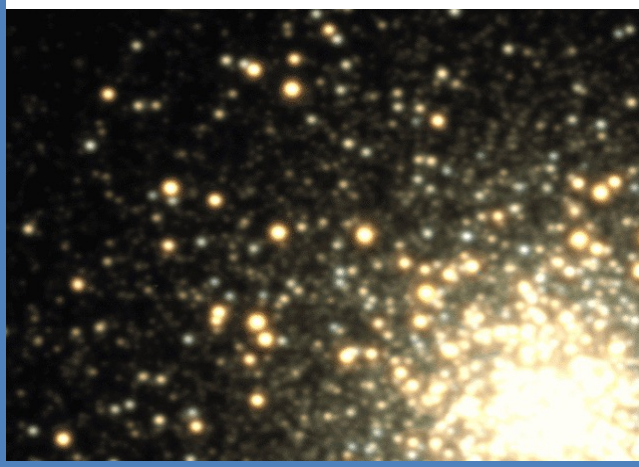
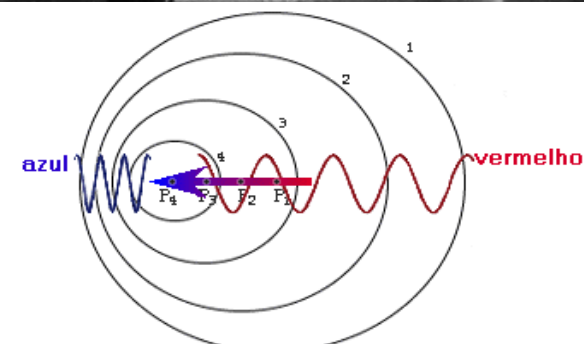
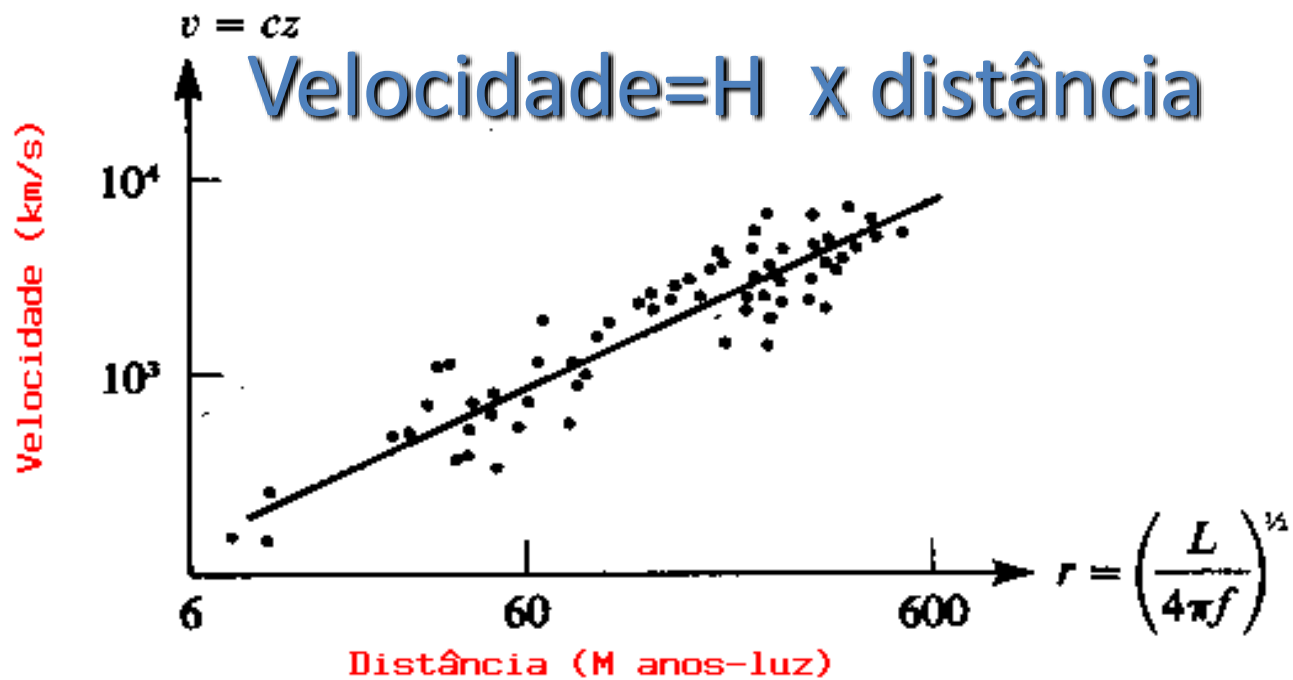


Deslocamento para o vermelho z:

$$z \equiv \frac{\Delta\lambda}{\lambda} = \frac{v}{c} \cos \theta \left(\frac{1}{1 - \frac{v^2}{c^2}} \right)^{1/2}$$



Edwin Hubble 1929



Métodos de determinação de distâncias Astronômicas

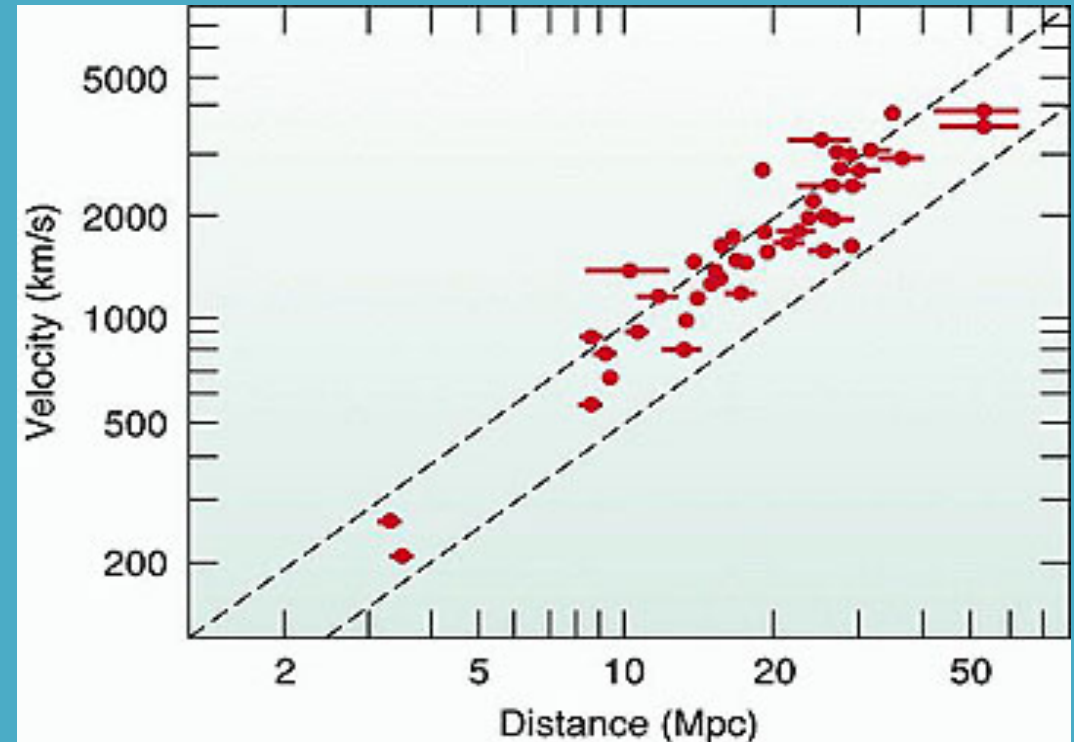


Lei de Hubble

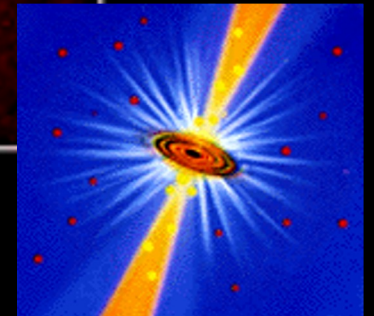
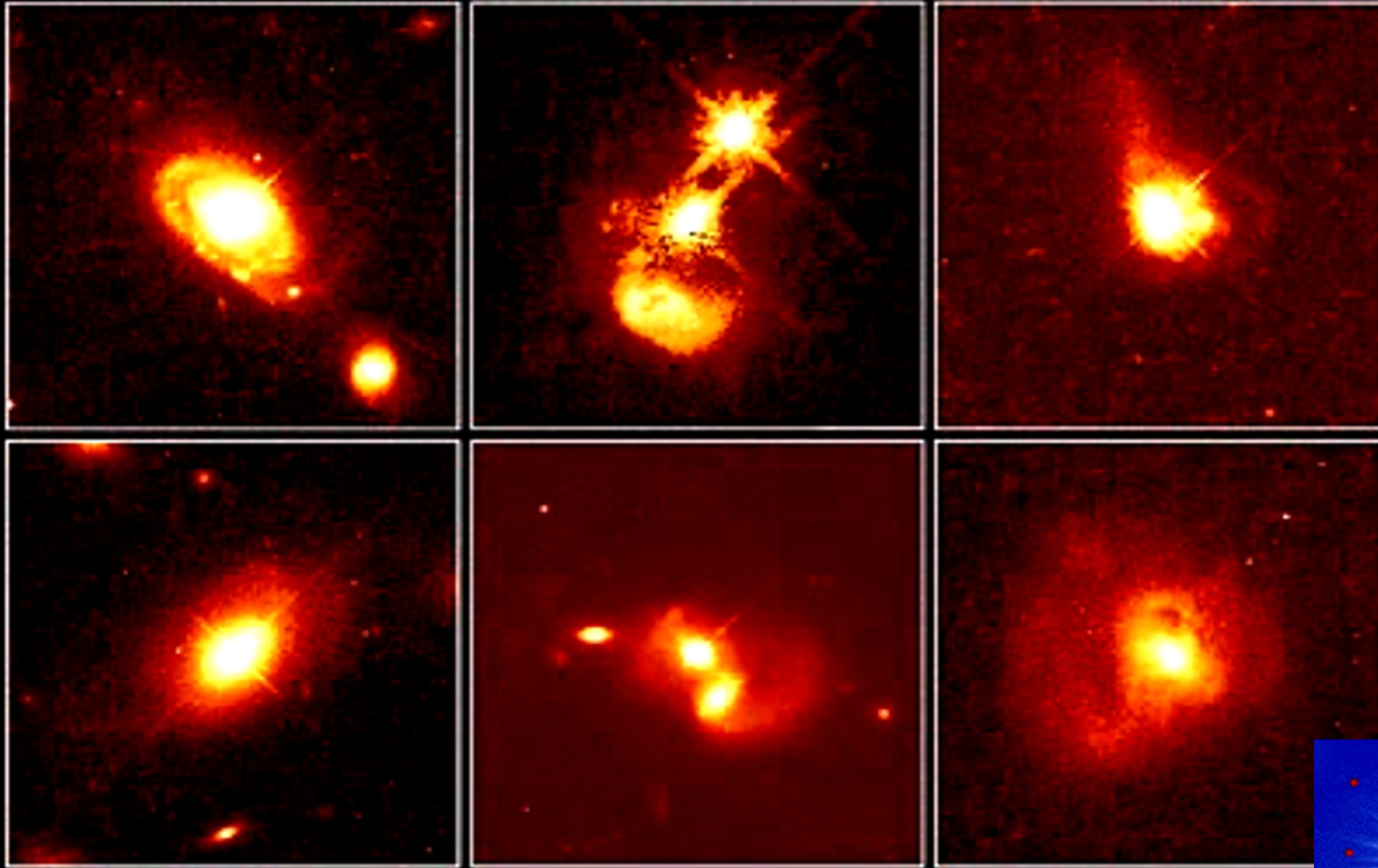
$$v(\text{km} / \text{s}) = H \left(\frac{\text{km} / \text{s}}{\text{Mpc}} \right) \times d(\text{Mpc})$$

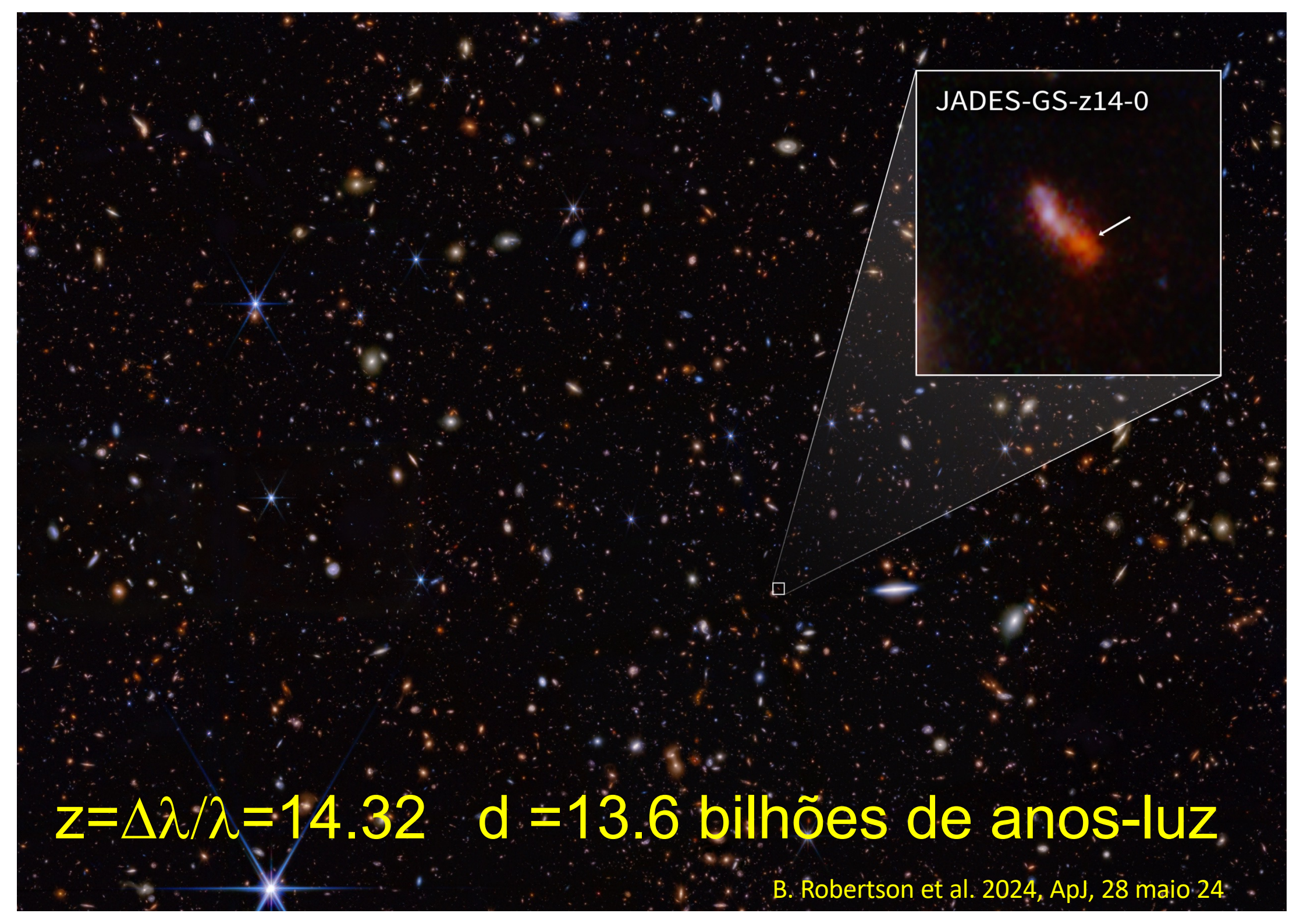
$$d(\text{Mpc}) = \frac{v}{H}$$

$$H = 67,4 \text{ km/s/Mpc}$$

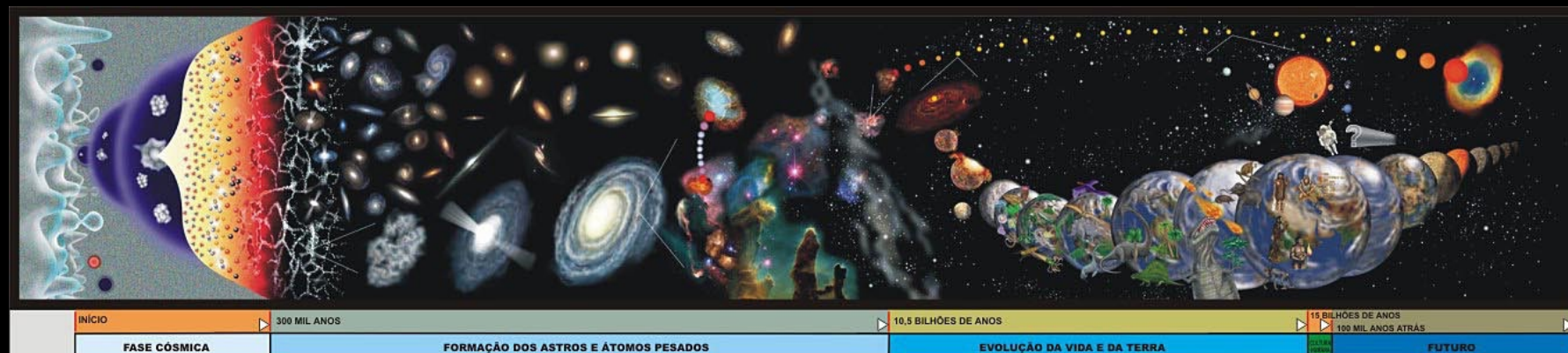


Quasares: galáxias com buraco negro central acretando massa





$z = \Delta\lambda/\lambda = 14.32$ $d = 13.6$ bilhões de anos-luz



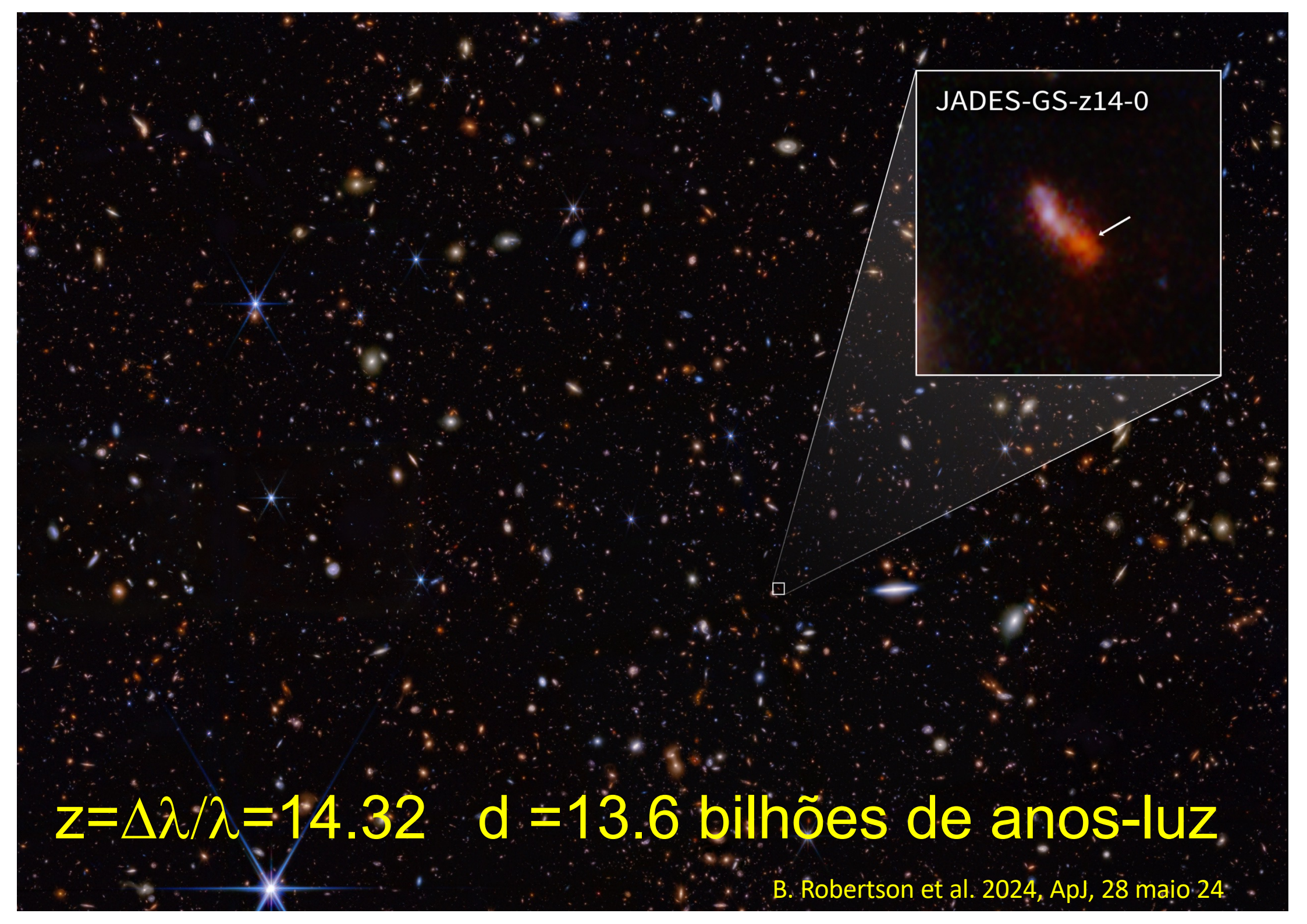
Tamanho, idade e conteúdo do Universo

Kepler

Instituto de Física – UFRGS

Porto Alegre, 2026





JADES-GS-z14-0

$z = \Delta\lambda/\lambda = 14.32$ $d = 13.6$ bilhões de anos-luz

O céu é escuro, logo o Universo é finito!



JWST
12,5 horas
2022

Galileo Galilei 1610



S I D E R E V S N V N C I V S

MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò

PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO

Patauini Gymnasij Publico Mathematico

P E R S P I C I L L I

Nuper à se reperiit beneficio sunt obferuata in LV. N. A. F. A. C. I. E. F. I. X. I. S. I. N. C. I. R. C. V. L. O. S. T. E. L. L. I. S. N. E. B. U. L. O. S. I. S.

Apprime verò in

Q V A T V O R P L A N E T I S

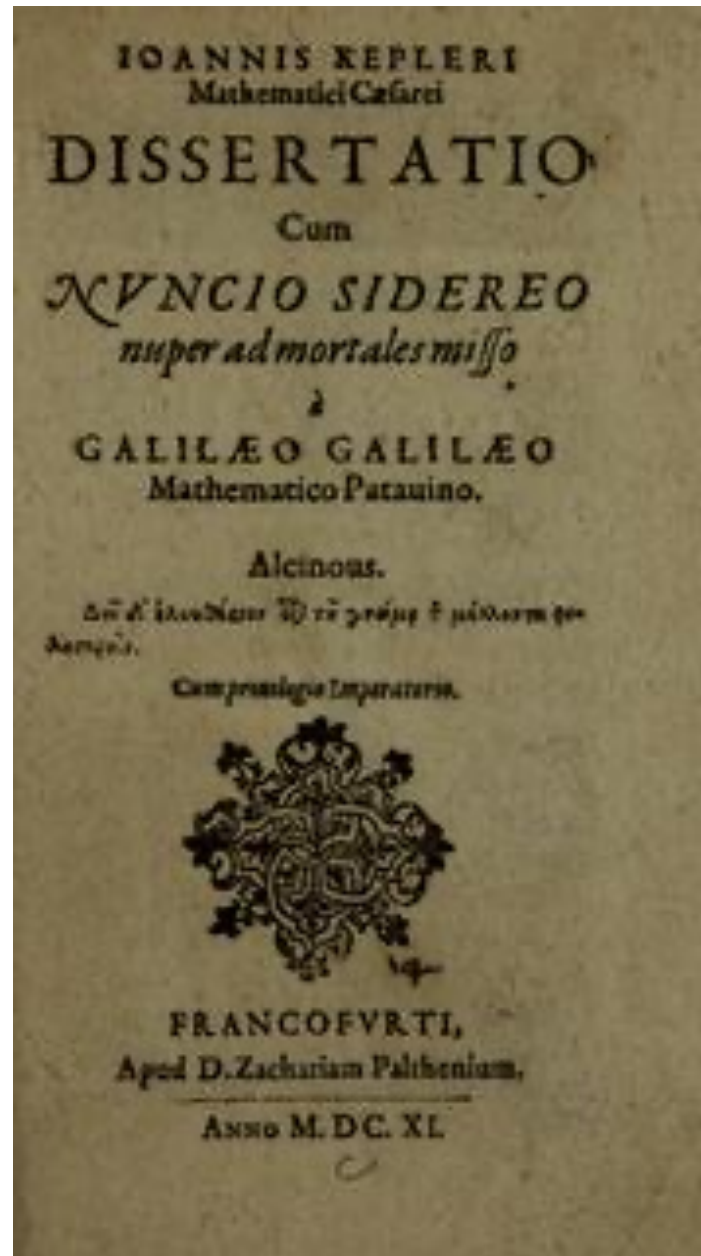
Circa I O V I S Stellam disparibus intervalis, atque periodicis, celeritate mirabili circumuolutis; quos, nemini in hanc usque diem cognitos, nouissimè Author deprehendit primus; atque

M E D I C E A S I D E R A
N V N C V P A N D O S D E C R E V I T.

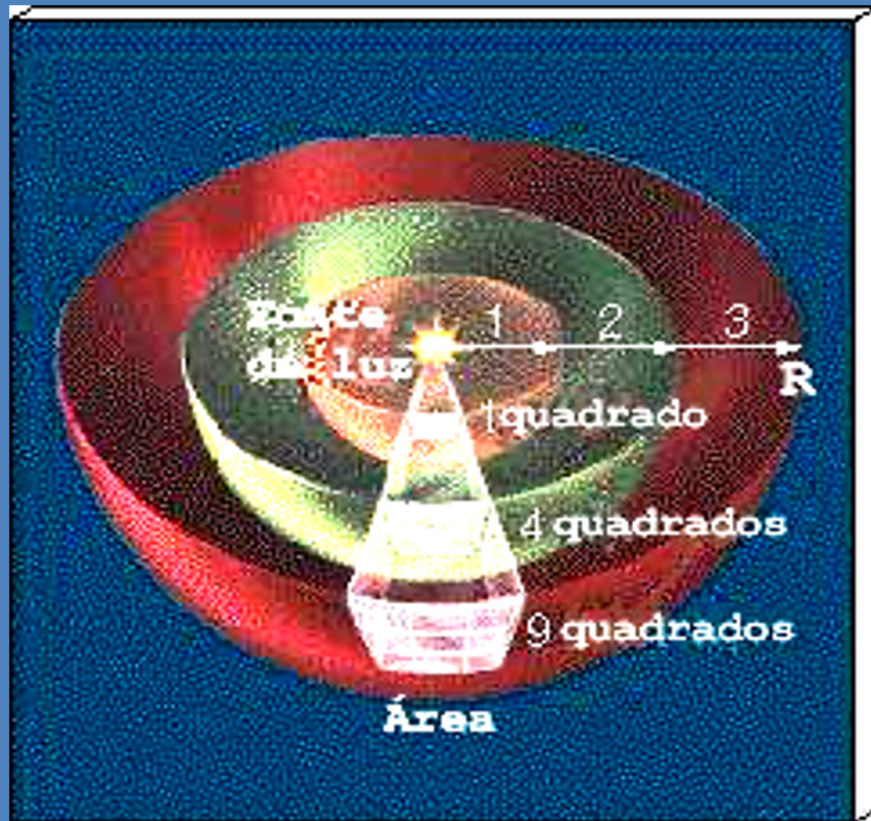


VENETIIS, Apud Thomam Baglionum. M D C X.
Superiorum Permissu, & Privilegio.

Johannes Kepler 1611



Céu seria brilhante se Universo infinito



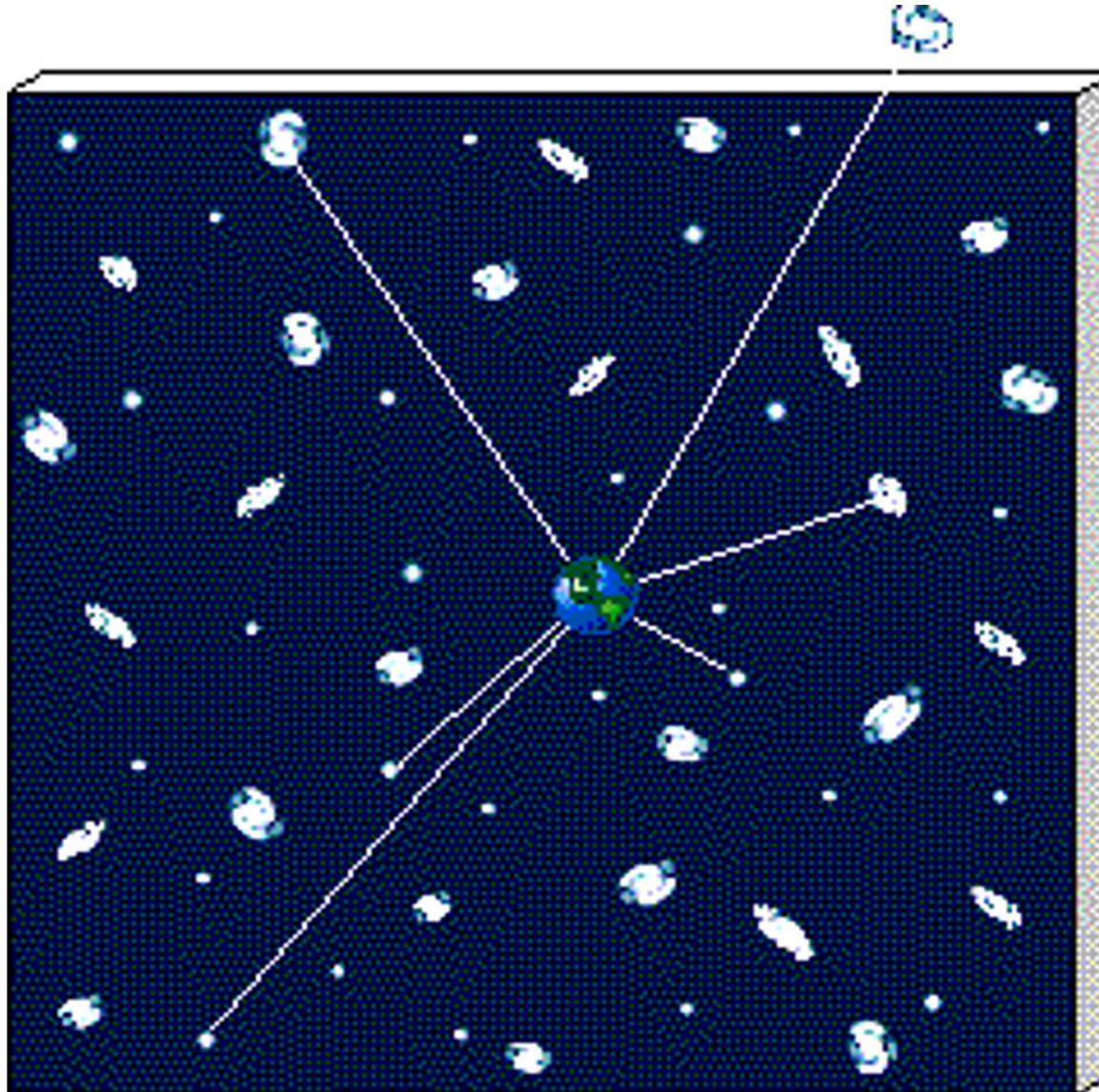
$$\text{Área} = 4\pi R^2$$

Brilho = $\frac{\text{Intensidade}}{4\pi R^2}$

(de uma estrela)



Paradoxo de Olbers



Heinrich Wilhem Mattäus Olbers (1826)

Céu seria brilhante se Universo infinito



$$\text{Área} = 4\pi R^2$$

$$\text{Brilho} = \frac{\text{Intensidade}}{4\pi R^2}$$

(de uma estrela)

$$\Delta \text{Volume} = 4\pi R^2 \Delta r$$

$$\text{Brilho} = \text{Intensidade}$$

(do céu)

Solução do Paradoxo

Se estrelas têm raio médio de $R=700\,000\text{ km}$ → seção reta $\sigma=\pi R^2$

Se a separação média entre as estrelas é de $r=4\text{ a.l.}$ → seção reta $\Sigma=\pi r^2$

Razão entre as áreas dá o nº. mínimo de estrelas necessárias para tapar todo o céu): $N= (\pi r^2)/(\pi R^2) = 3 \times 10^{15}$ estrelas

A densidade média das estrelas é $n=1/(4\text{ a.l.})^3$, a distância d mínima necessária para acumular o número acima de estrelas:

$$N = nV = n\Sigma d = n\pi r^2 d$$
$$d = \frac{N}{n\pi r^2} = \frac{3 \times 10^{15}}{\frac{1}{(4\text{ a.l.})^3} \pi (4\text{ a.l.})^2} = 4 \times 10^{15} \text{ a.l.}$$

A distância $4 \times 10^{15} \text{ a.l.}$ é 300 000 vezes maior do que o raio observável do Universo (13,8 bilhões de a.l.)!

Conclusão: o Universo é escuro à noite porque seu raio observável é menor do que o necessário para acumular o número de estrelas suficientes para tornar todo o céu brilhante!

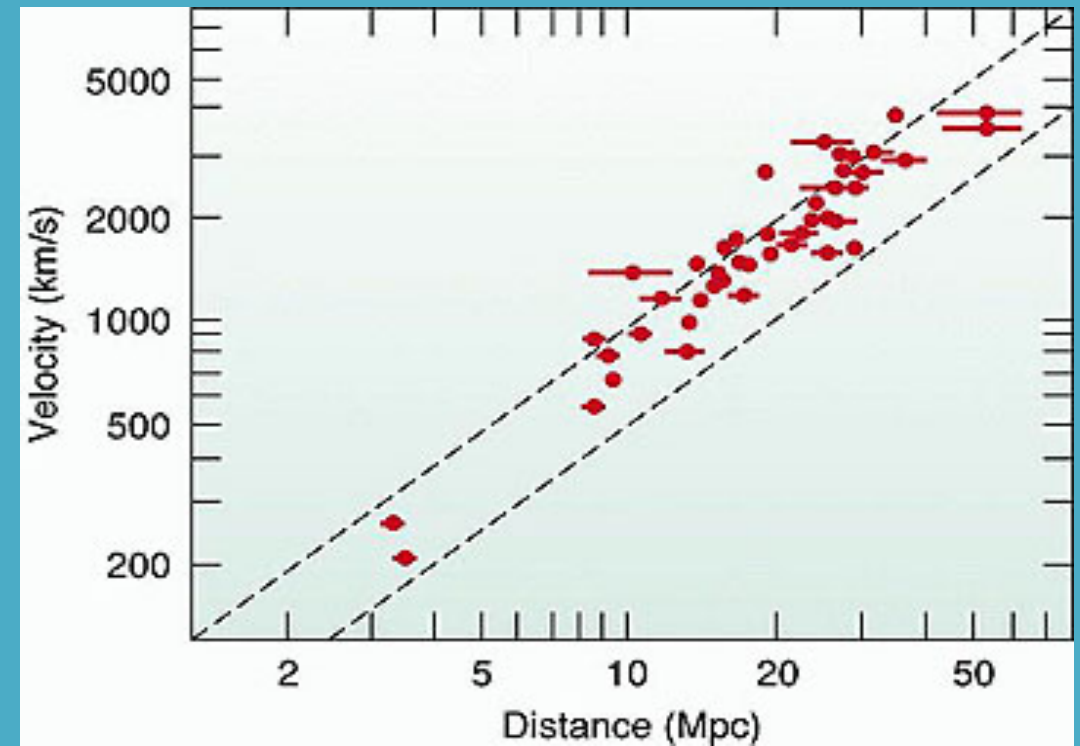
Lei de Hubble-Lemaître

$$v = H \times d$$

$$H = 67,4 \text{ km/s/Mpc}$$

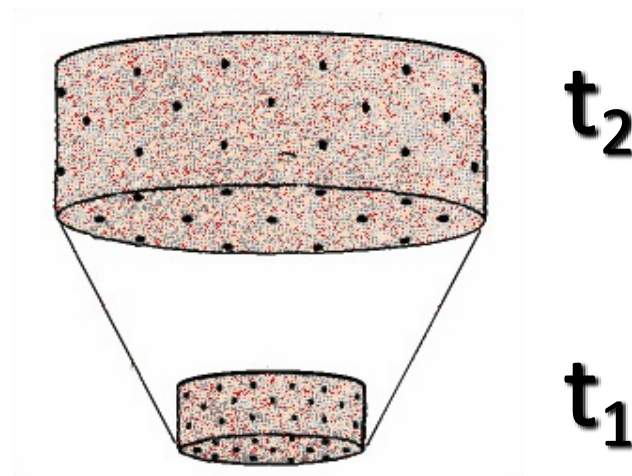
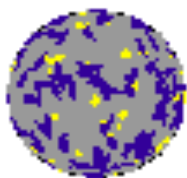


1929



Expansão do Universo

Lei de Hubble: $v = H d$



Modelo do bolo de passas:

Num tempo $t_i=0$, as distâncias das passas em relação a uma passa de referência são:

passa A: $d_i = 1$ cm

passa B: $d_i = 3$ cm

passa C: $d_i = 4$ cm

Após 1 hora, o bolo dobra de tamanho, e as distâncias entre as passas serão:

passa A: $d_f = 2$ cm

passa B: $d_f = 6$ cm

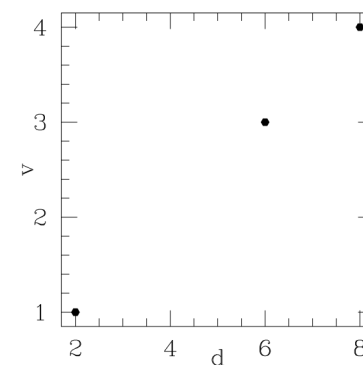
passa C: $d_f = 8$ cm

As **velocidades** são:

passa A: $v = 1$ cm/h

passa B: $v = 3$ cm/h

passa C: $v = 4$ cm/h



Velocidade em função de suas distâncias, reta com

$$H = (1\text{cm/h})/2\text{cm} = (3\text{cm/h})/6\text{cm} = (4\text{cm/h})/8\text{cm} = 0,5/\text{h}$$

Expansão

Velocidade = $H \times \text{distância}$

Velocidade = distância / Tempo

$$\text{Tempo} = 1/H$$



$H = 67,4 \text{ km/s/Mpc}$ ➡ Tempo = 13,8 bilhões de anos

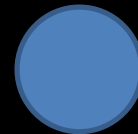
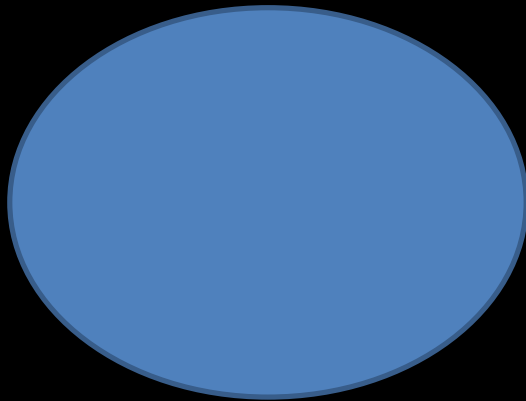
1 Mpc = 3,26 M anos-luz = $3 \times 10^{19} \text{ km}$

Big Bang



$$P = NkT$$

O Universo era quente quando pequeno



$$E = kT = \frac{1}{2} mv^2$$

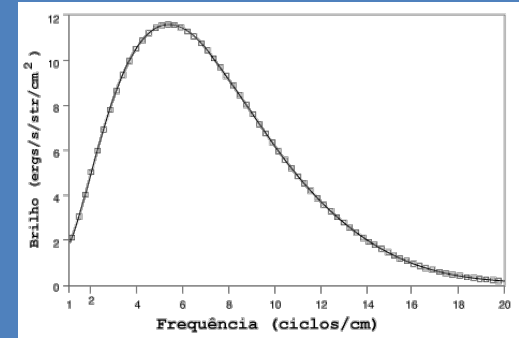
Arno Penzias e Robert Wilson

1964



Holmdel, NJ
Nobel 1978

Radiação do Fundo do Universo



George Gamow

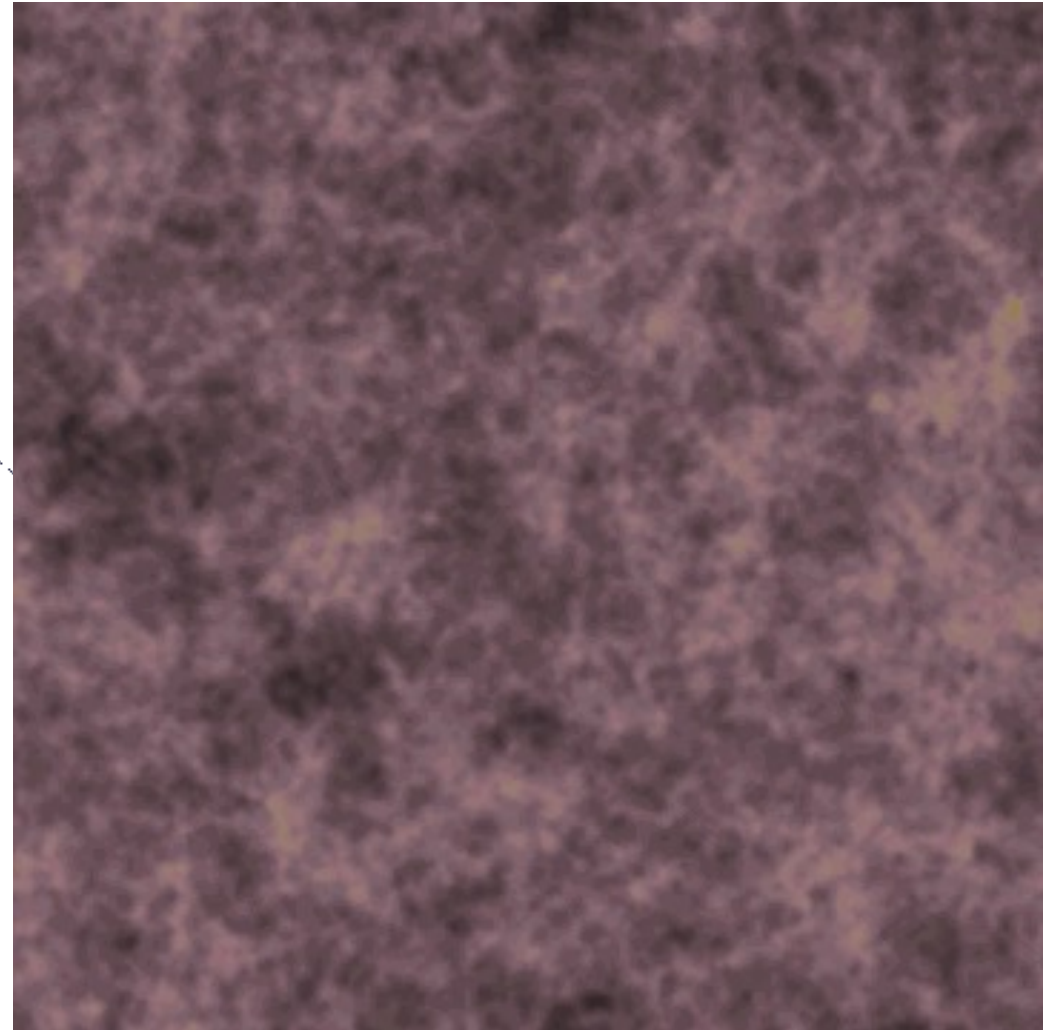
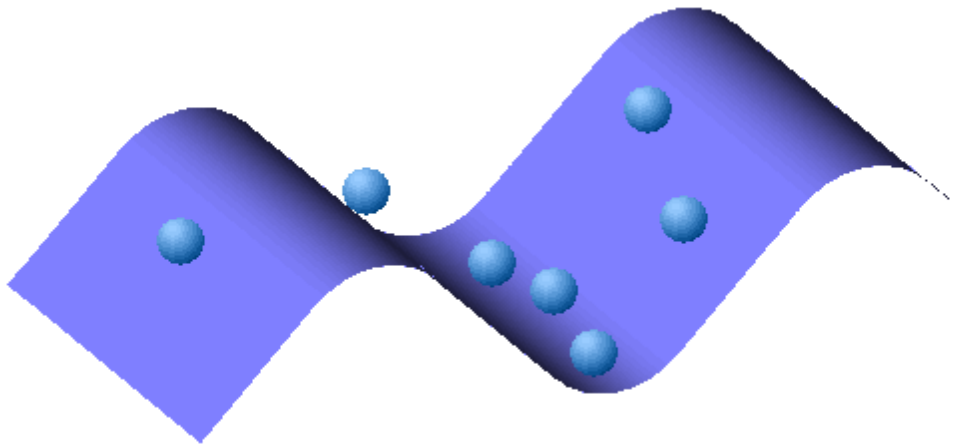


Robert Herman & Ralph Alpher

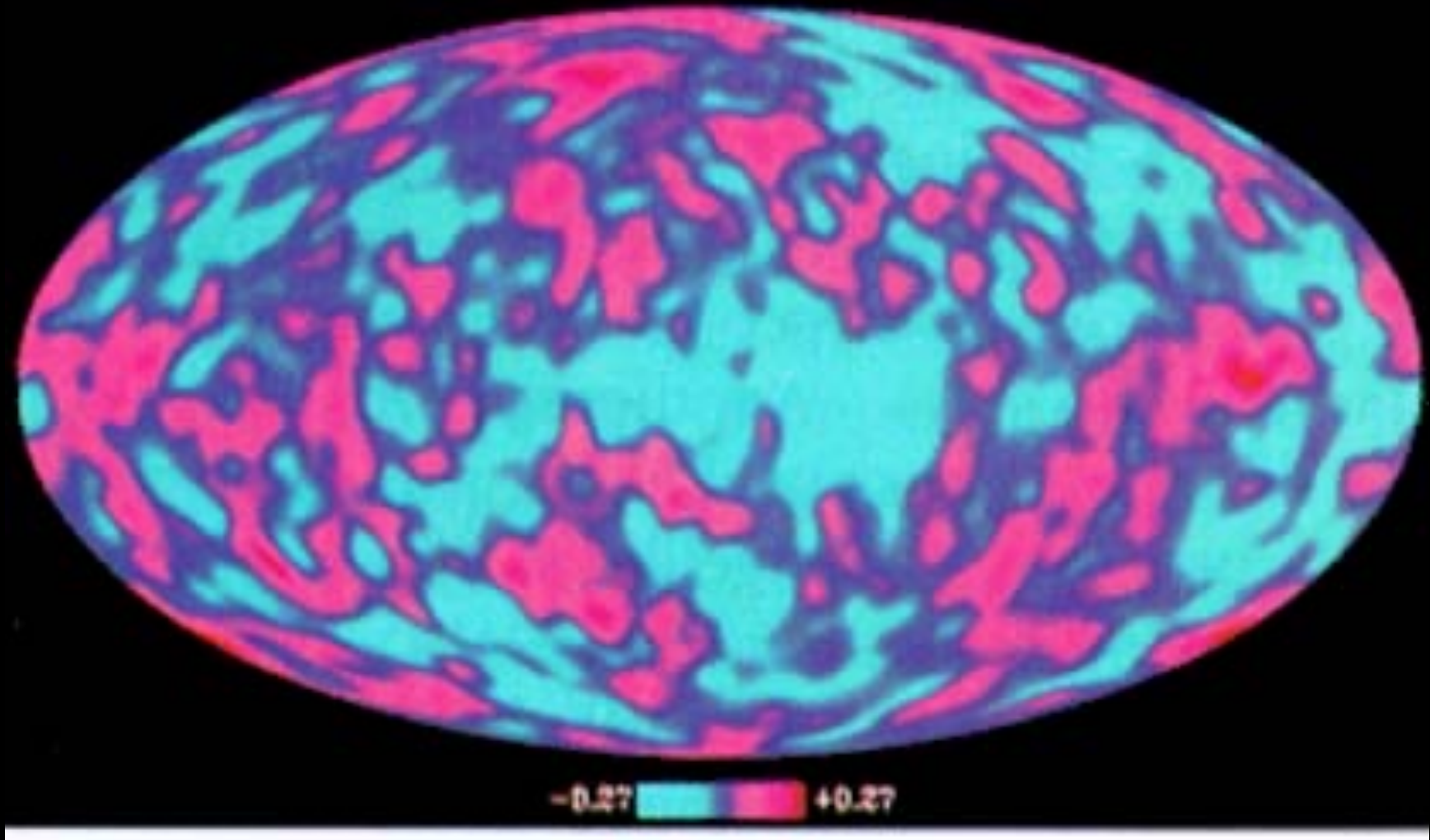
$$E=kT$$
$$T=3K$$

1948

Instabilidade gravitacional



COBE: 7° , $T = 2,73\text{K}$

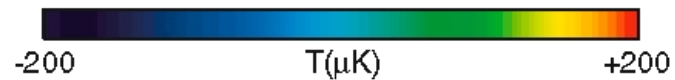
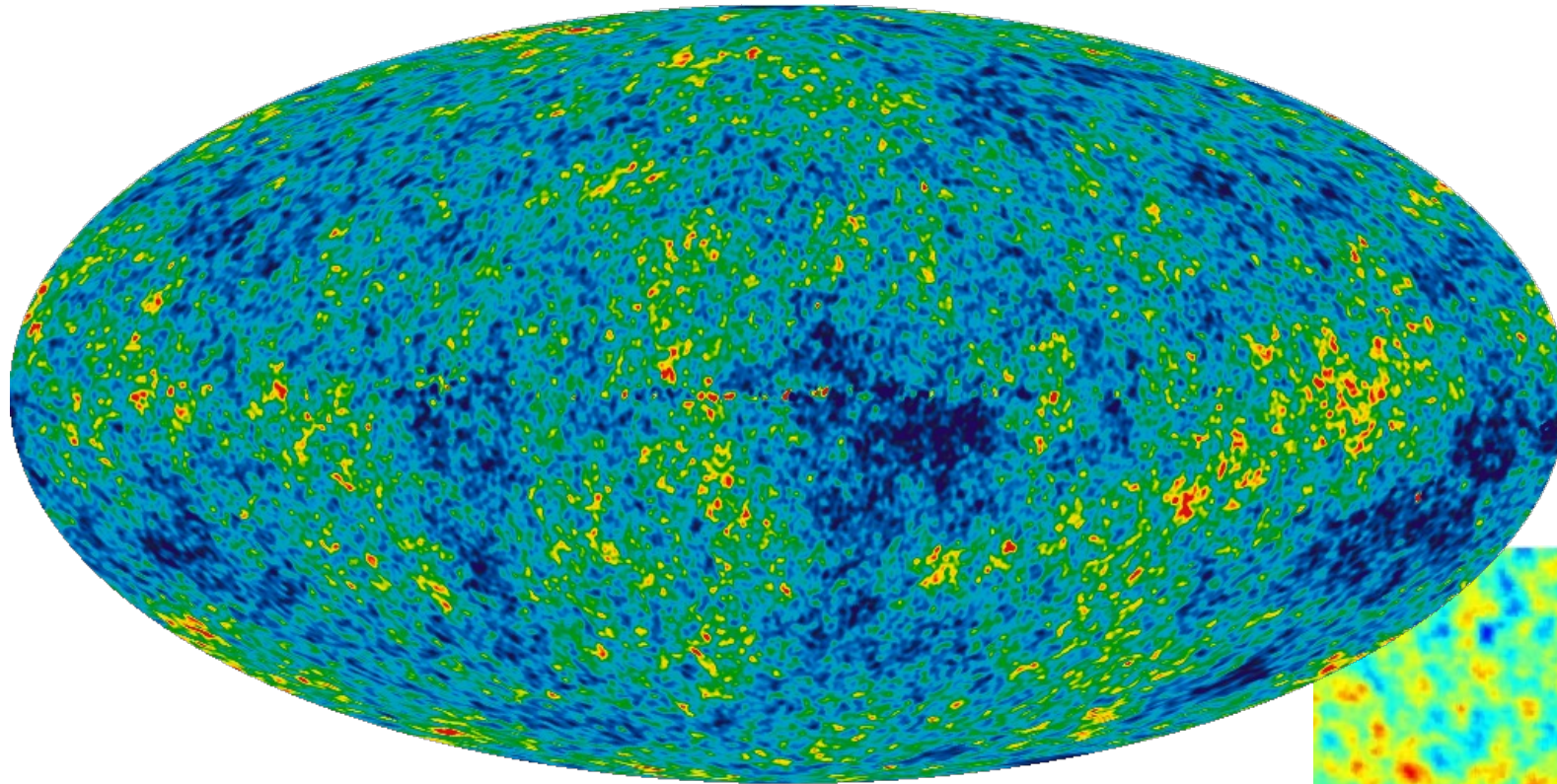


Nobel 2006: John C. Mather e George F. Smoot

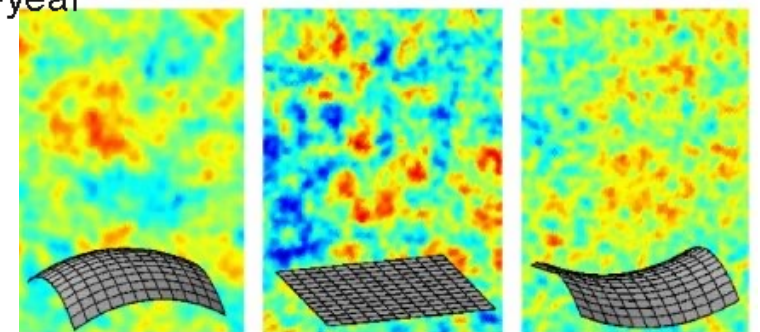
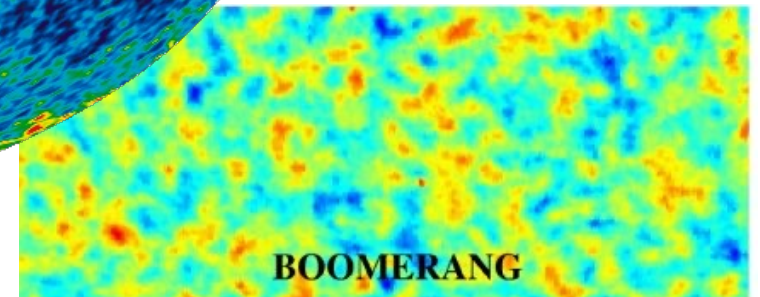
1989

WMAP Radiação do Fundo: 1º

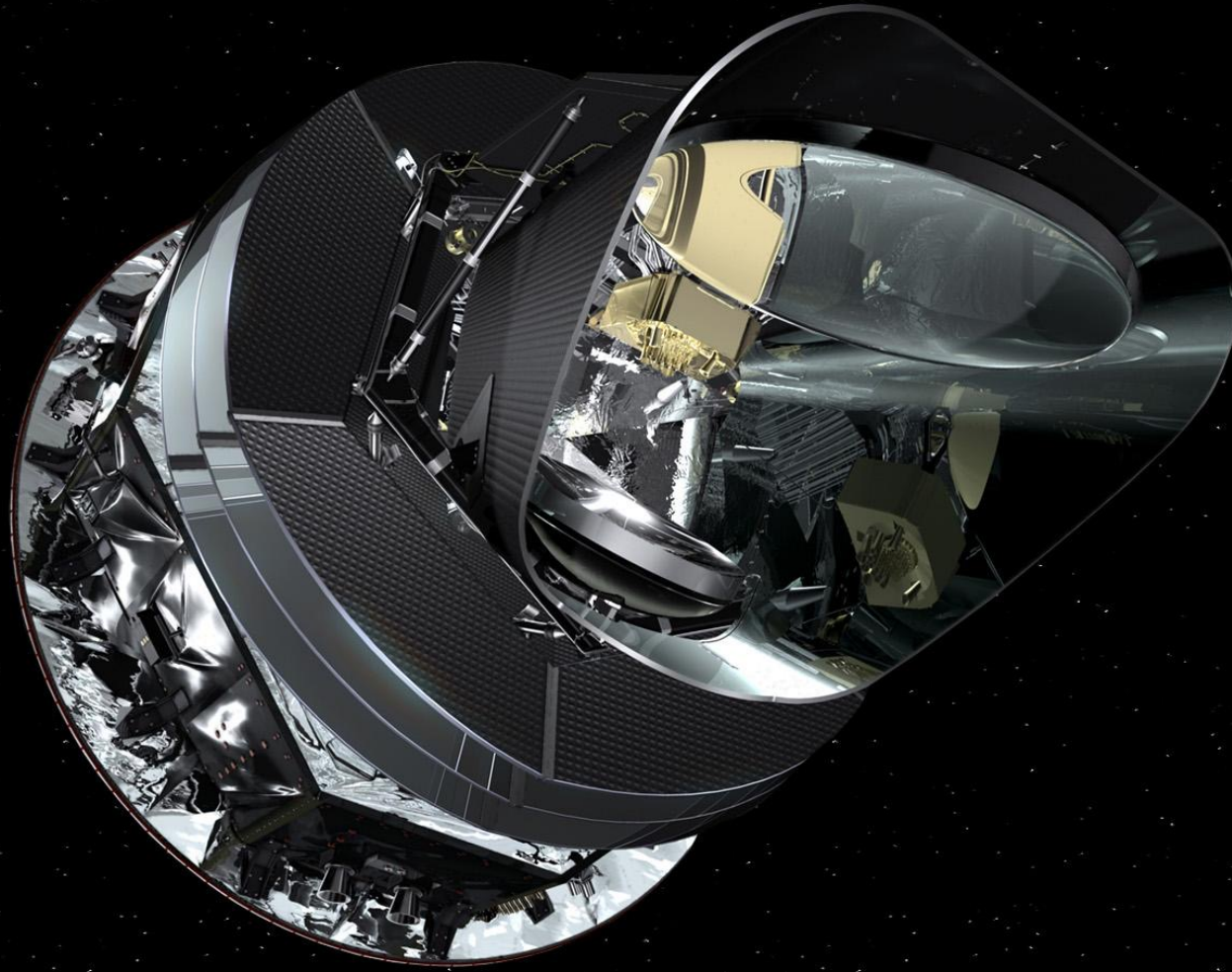
Wilkinson Microwave Anisotropy Probe 2001



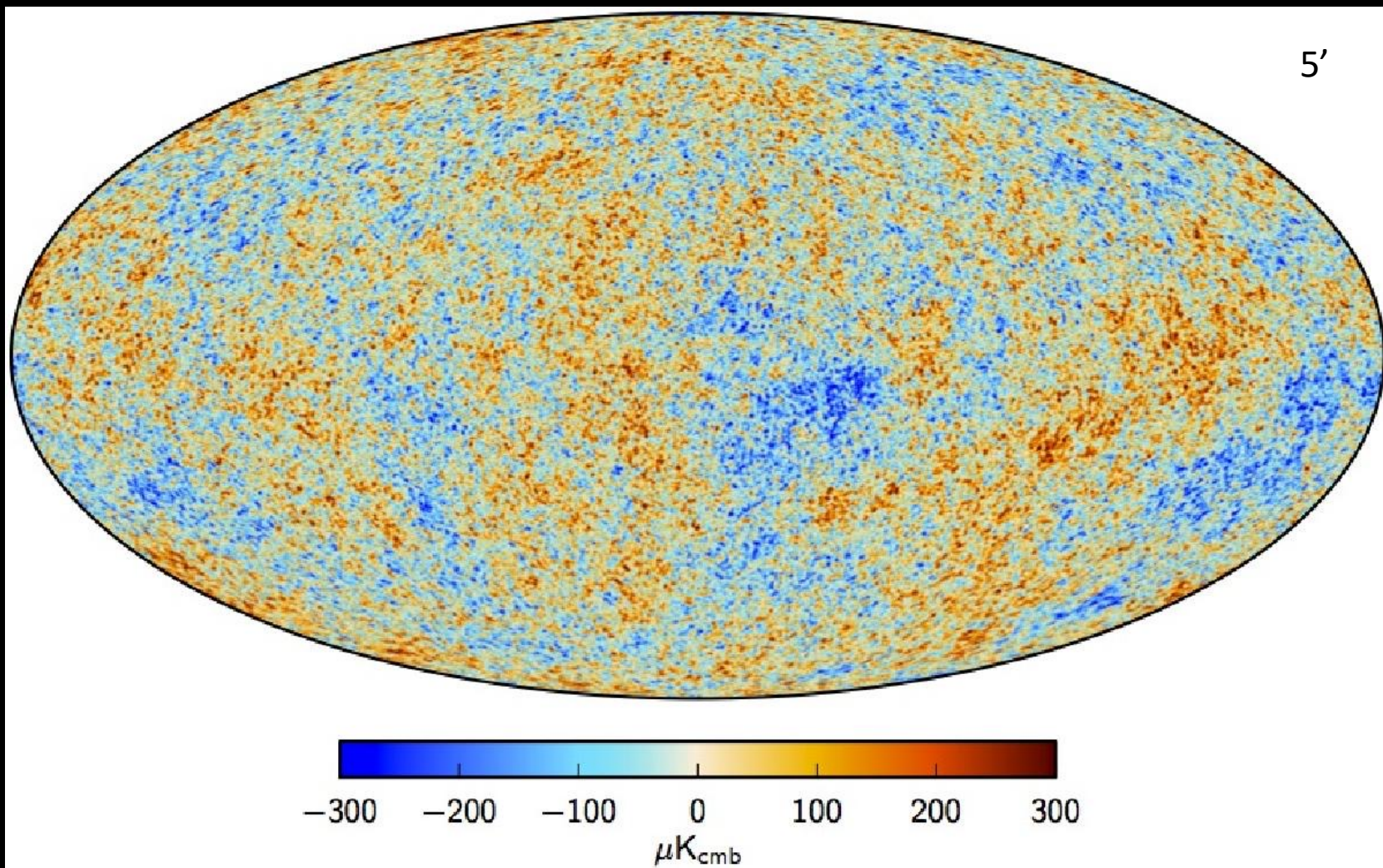
WMAP 5-year



Satélite Planck ESA 2009-2012: $5' = 0,08^\circ$



Superfície do último espalhamento, quando **Universo se tornou transparente ao formar o primeiros átomos**, 52 000 anos após o **Big Bang** → radiação cósmica de fundo em microondas, mapeada pelo satélite **Planck** ($\theta=0,5965\pm0,0002^\circ$).



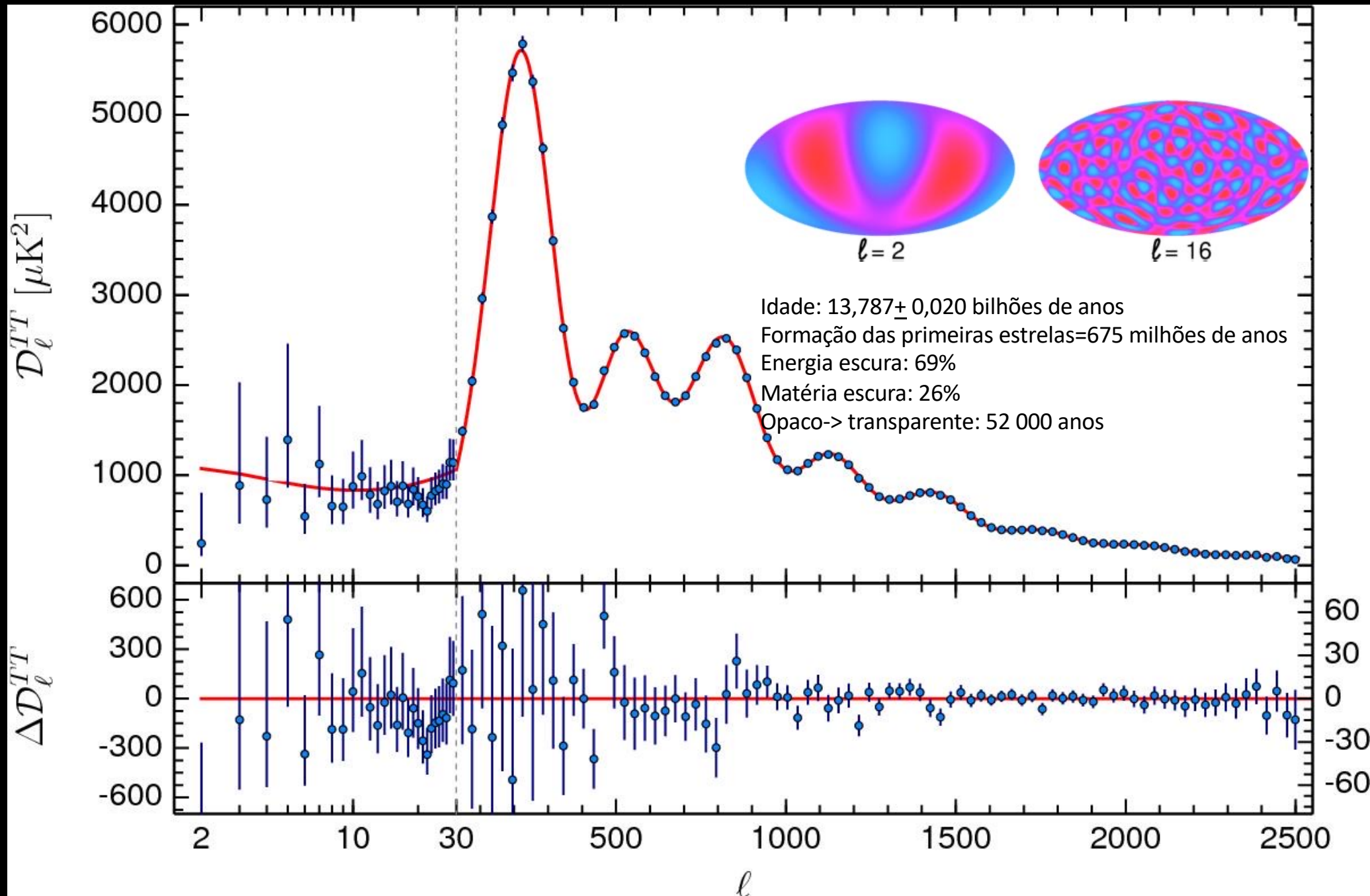
Escala Angular das Diferenças

90°

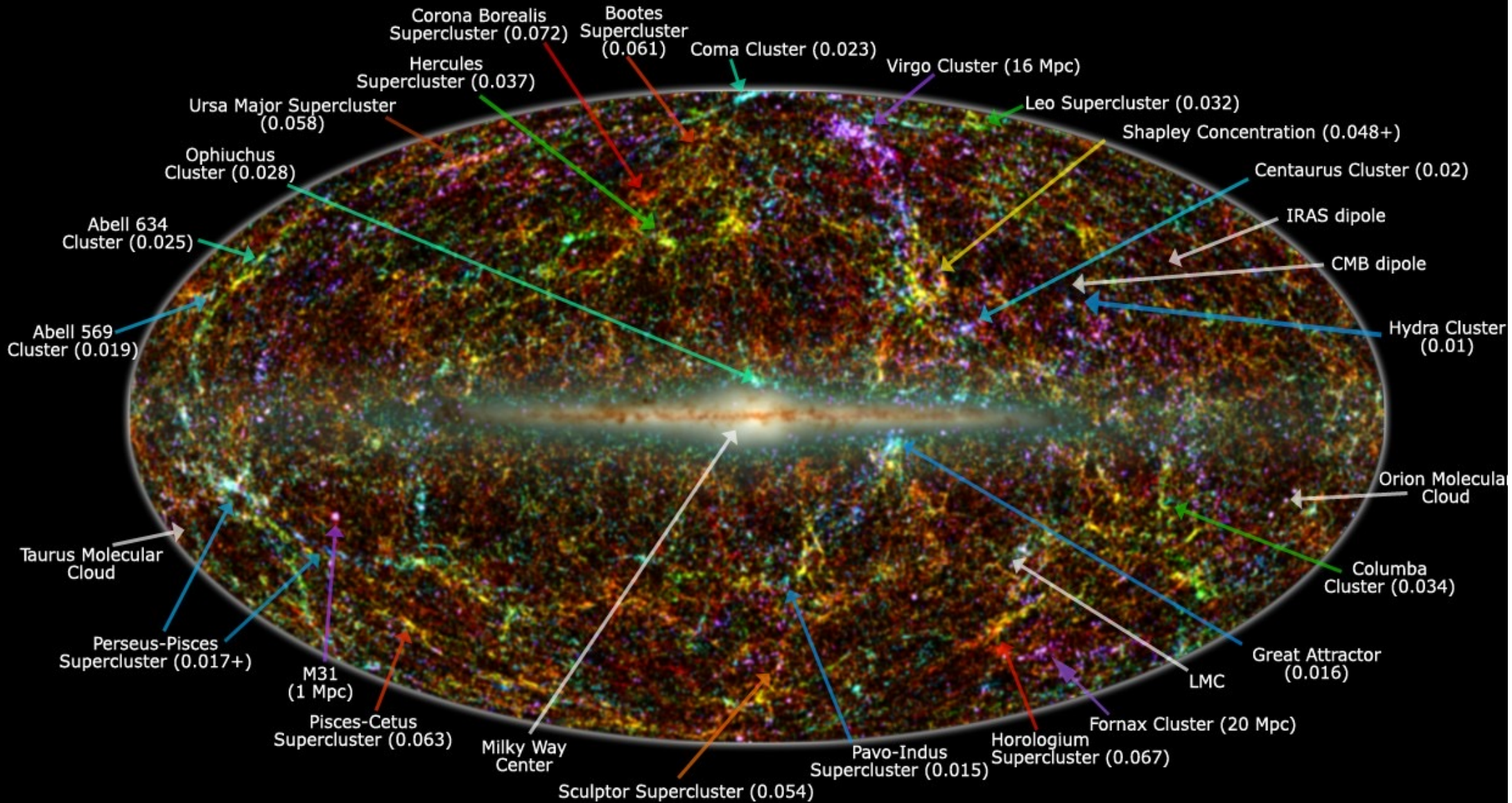
1°

0,2°

0,08°



Large Scale Structure in the Local Universe

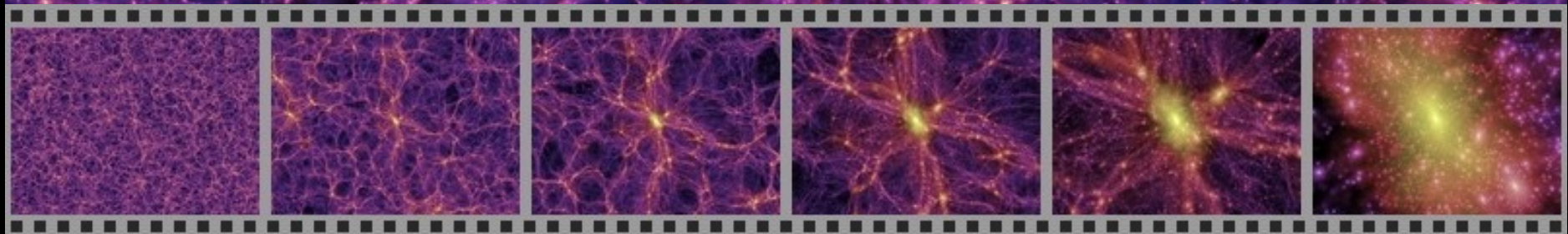


Distribuição de Galáxias

Estrutura em grande escala: Millennium simulation

maior simulação cosmológica já realizada, com 10^{10} partículas

31.25 Mpc/h



Cosmic Reionization

COSMIC MICROWAVE BACKGROUND

About 13.7 billion years ago
(370,000 years after the big bang)

BIG BANG

13.8 billion years ago

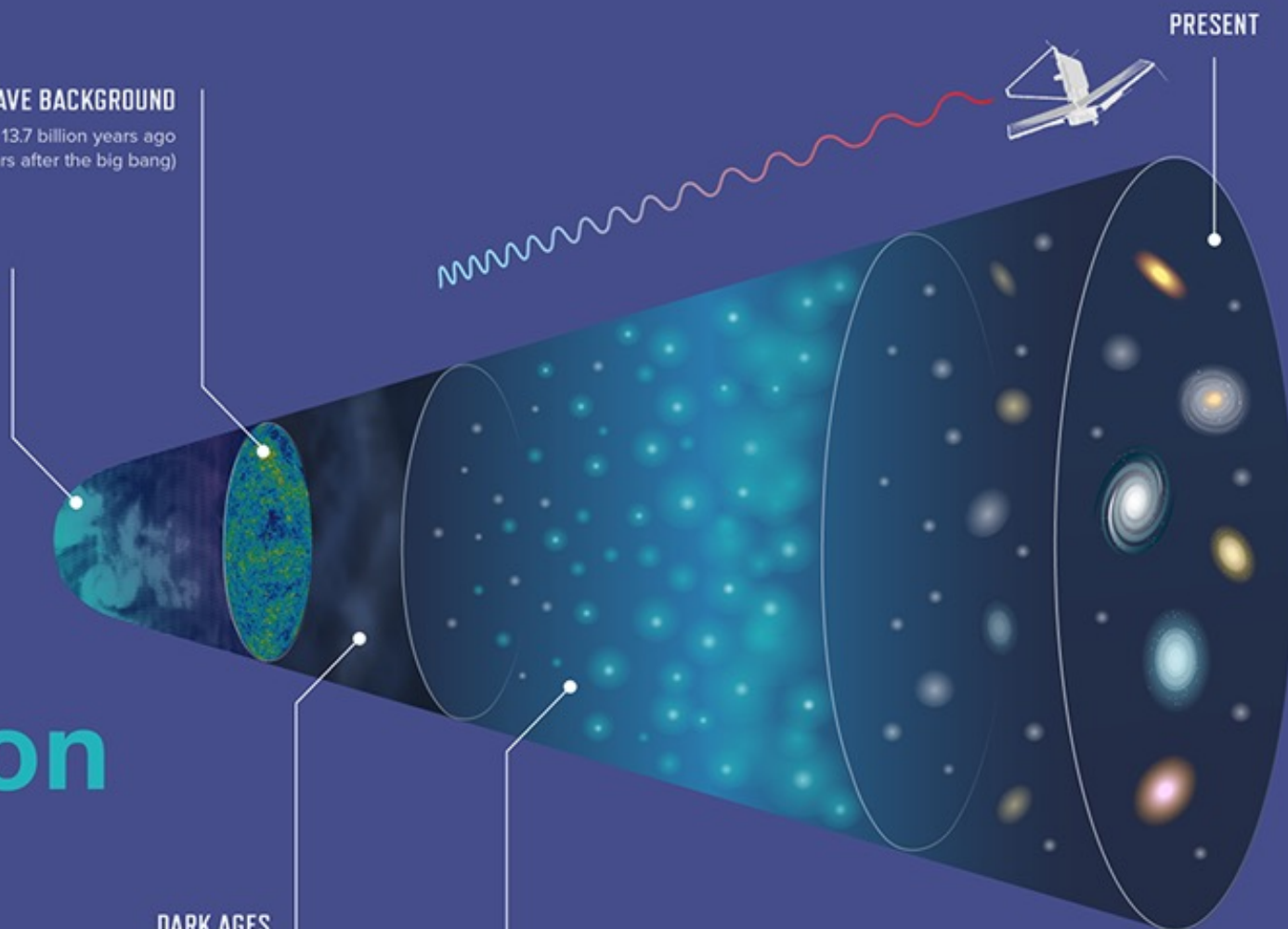
DARK AGES

Ended 13.6 billion years ago

ERA OF REIONIZATION

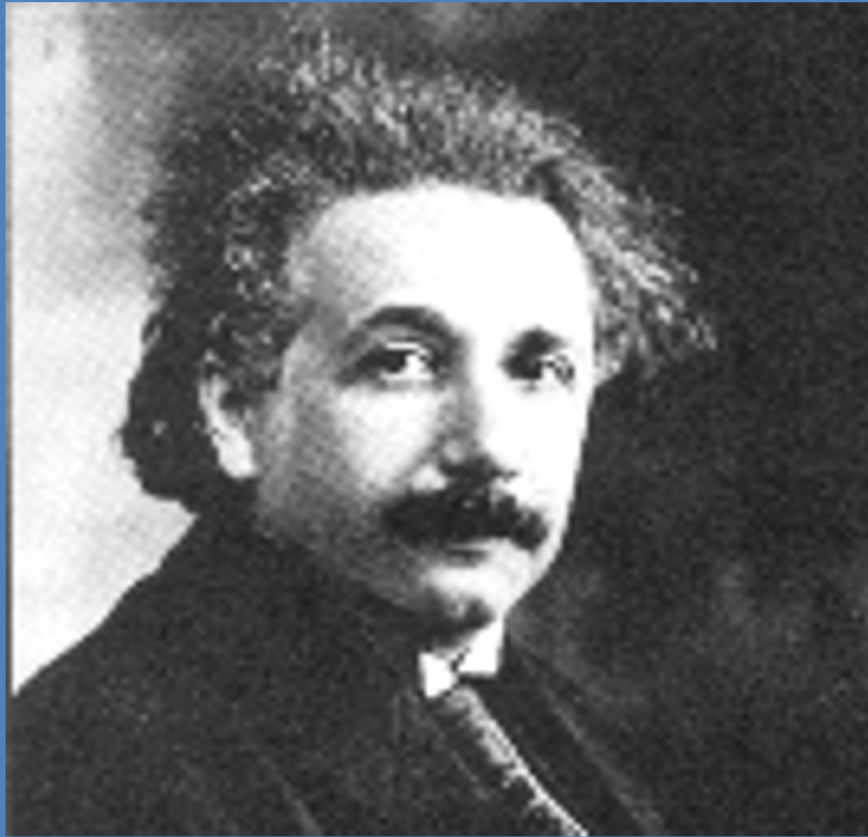
Ended 12.8 billion years ago

PRESENT



Albert Einstein

1915 Teoria da Relatividade Geral



$$V_{\max} = c$$

$$c = 300\,000 \text{ km/s}$$

$$E = mc^2$$

$$G_{ij} = \frac{8\pi G}{c^4} T_{ij}$$

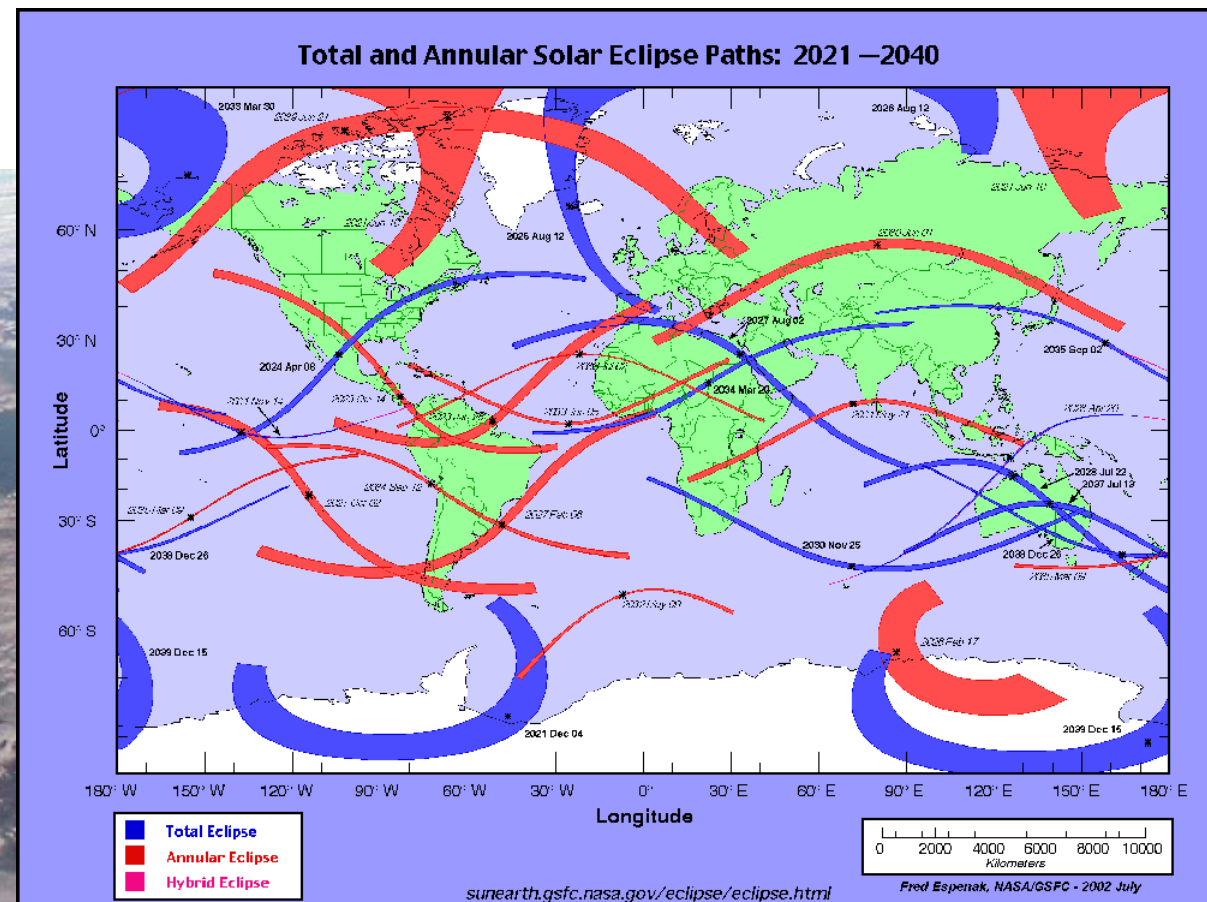
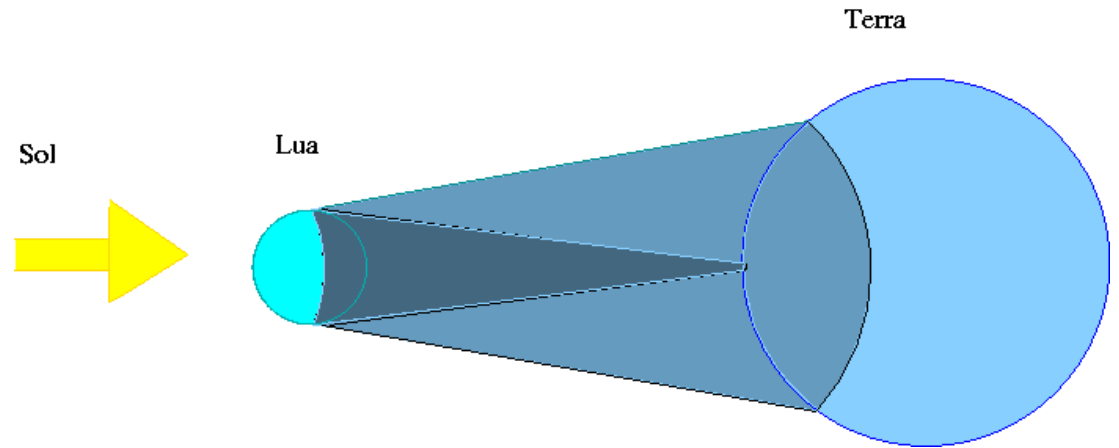
Relatividade Geral: Espaço-tempo = $8\pi G/c^4$ x Energia-Momentum

Luz = Fóton

Newton $m_{\text{fóton}}=0 \rightarrow F_G = -Gm_1m_2/r^2=0$

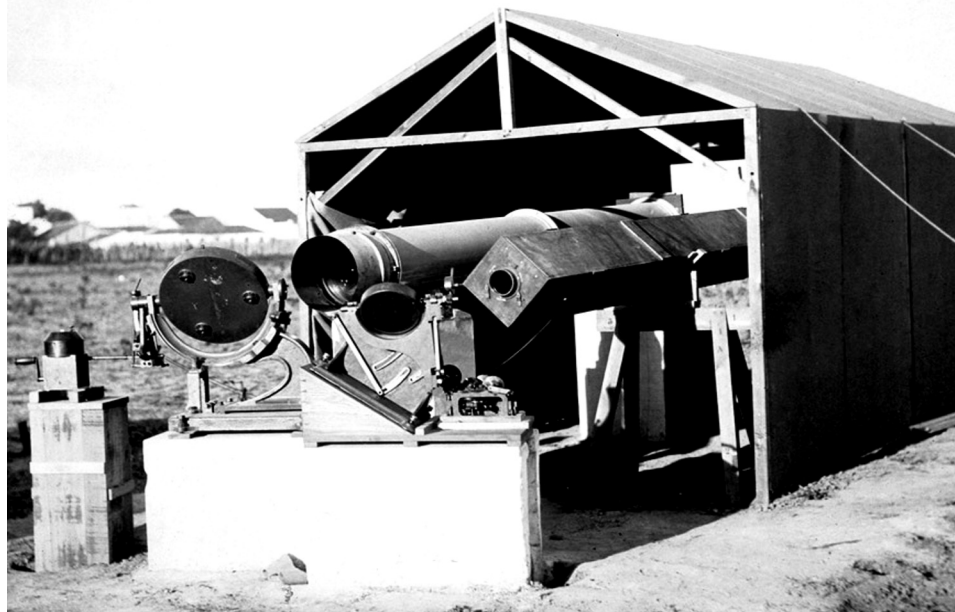
Einstein: $E_{\text{fóton}}=hf \rightarrow m_{\text{fóton}}^{\text{equivalente}}=E/c^2$

Eclipses

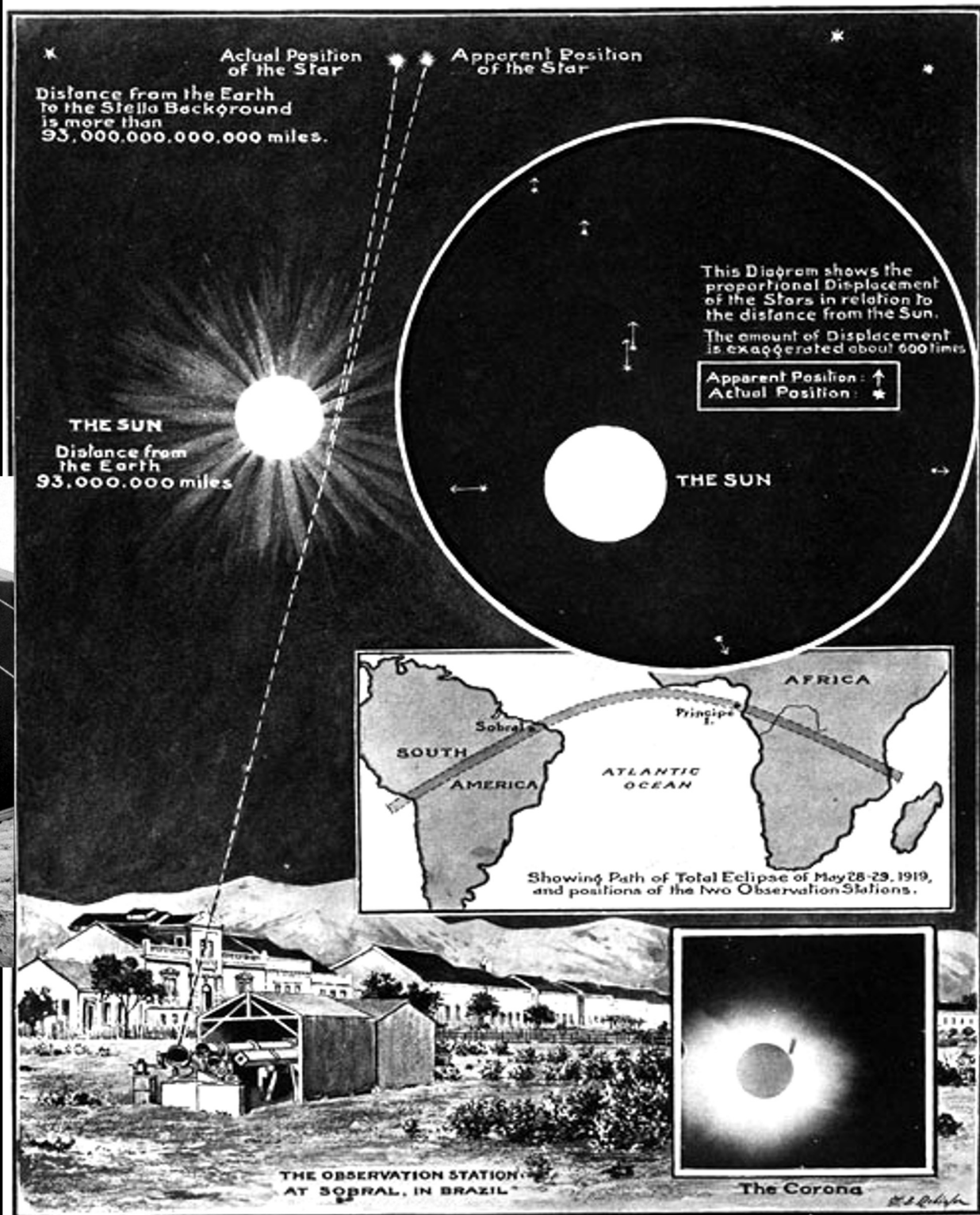


Eclipse

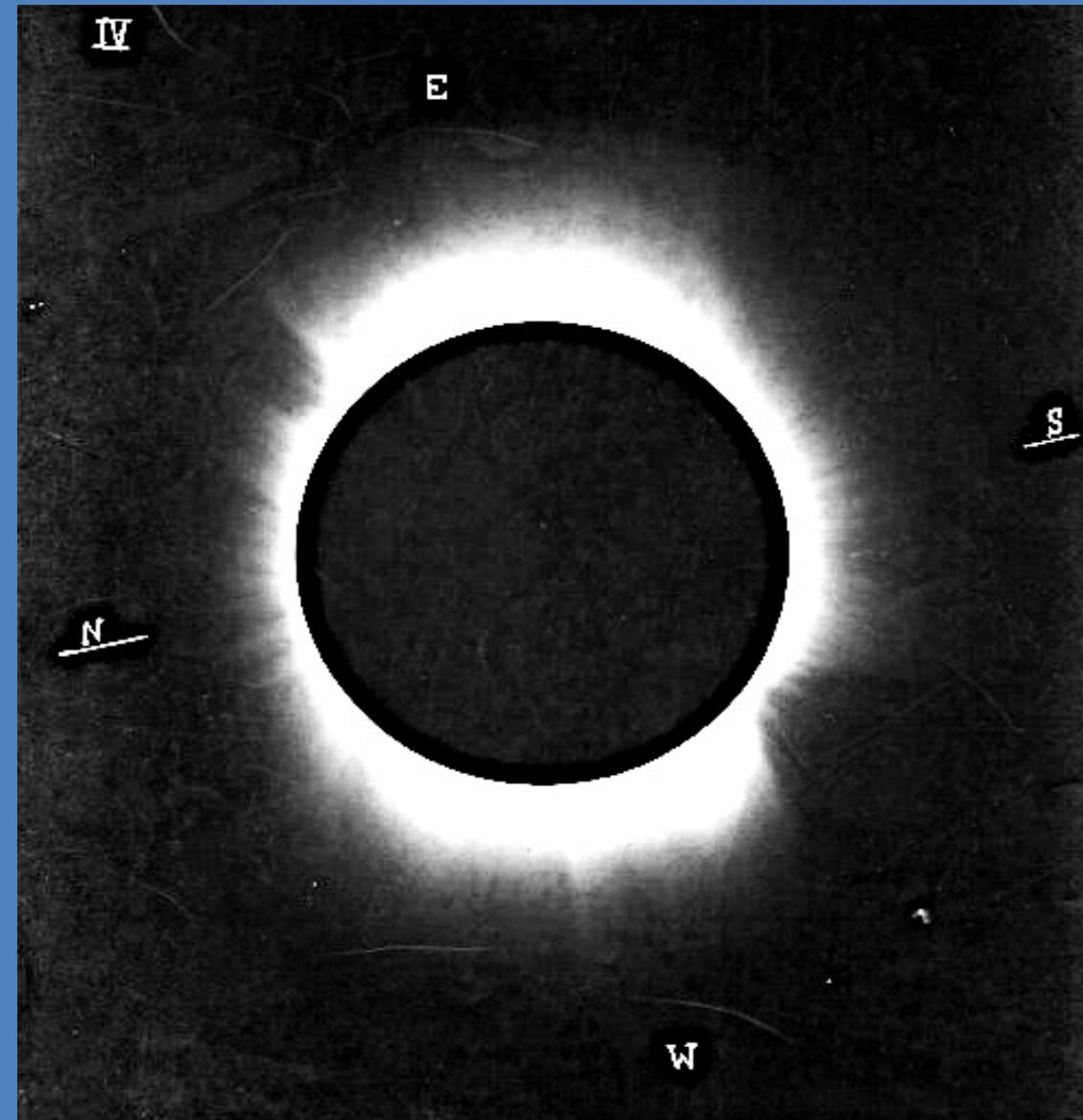
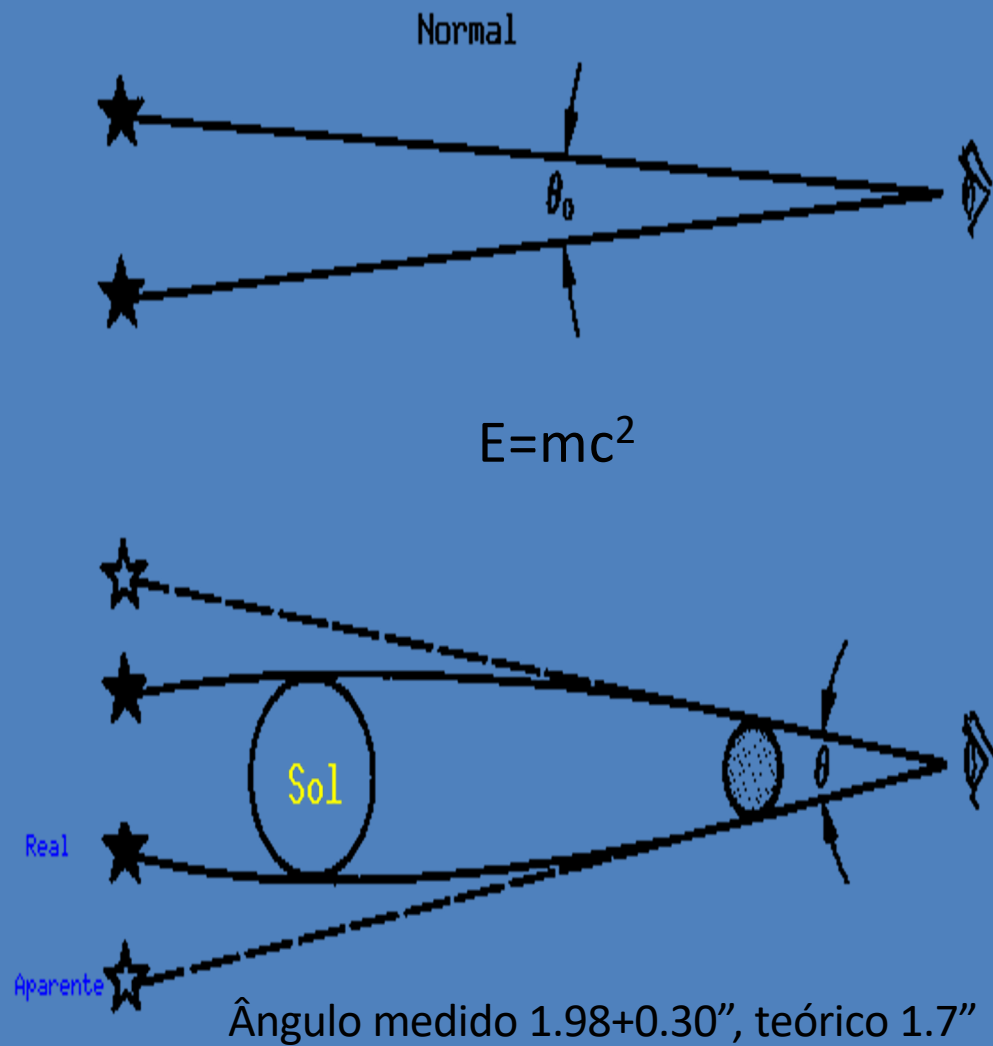
29 de maio de 1919



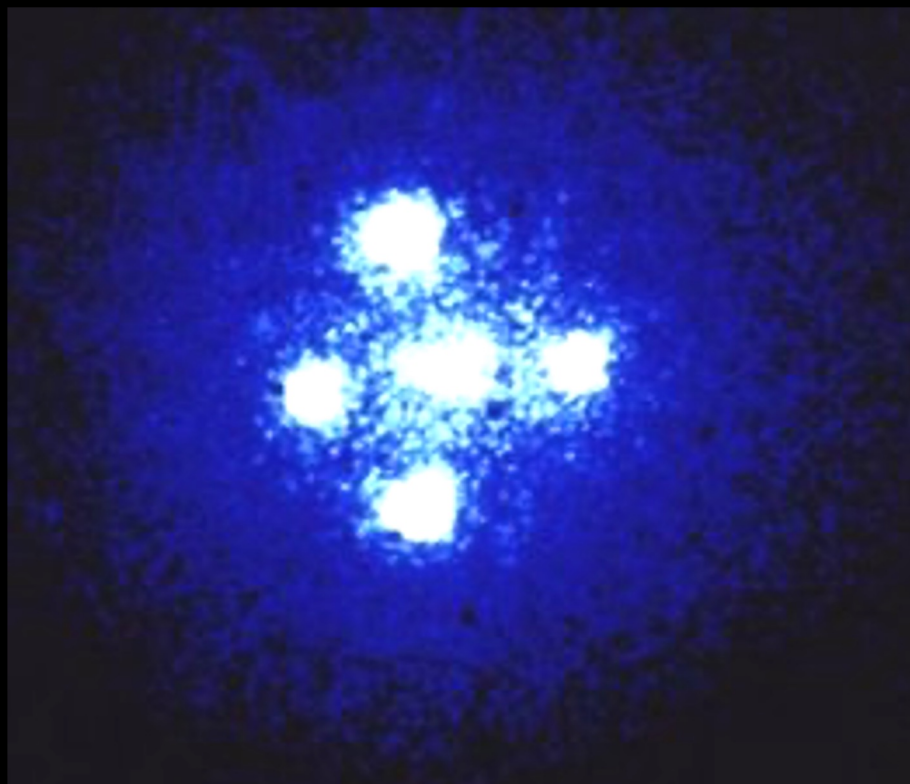
Sobral, CE



Eclipse em Sobral, CE, 29 maio 1919



Lente Gravitacional

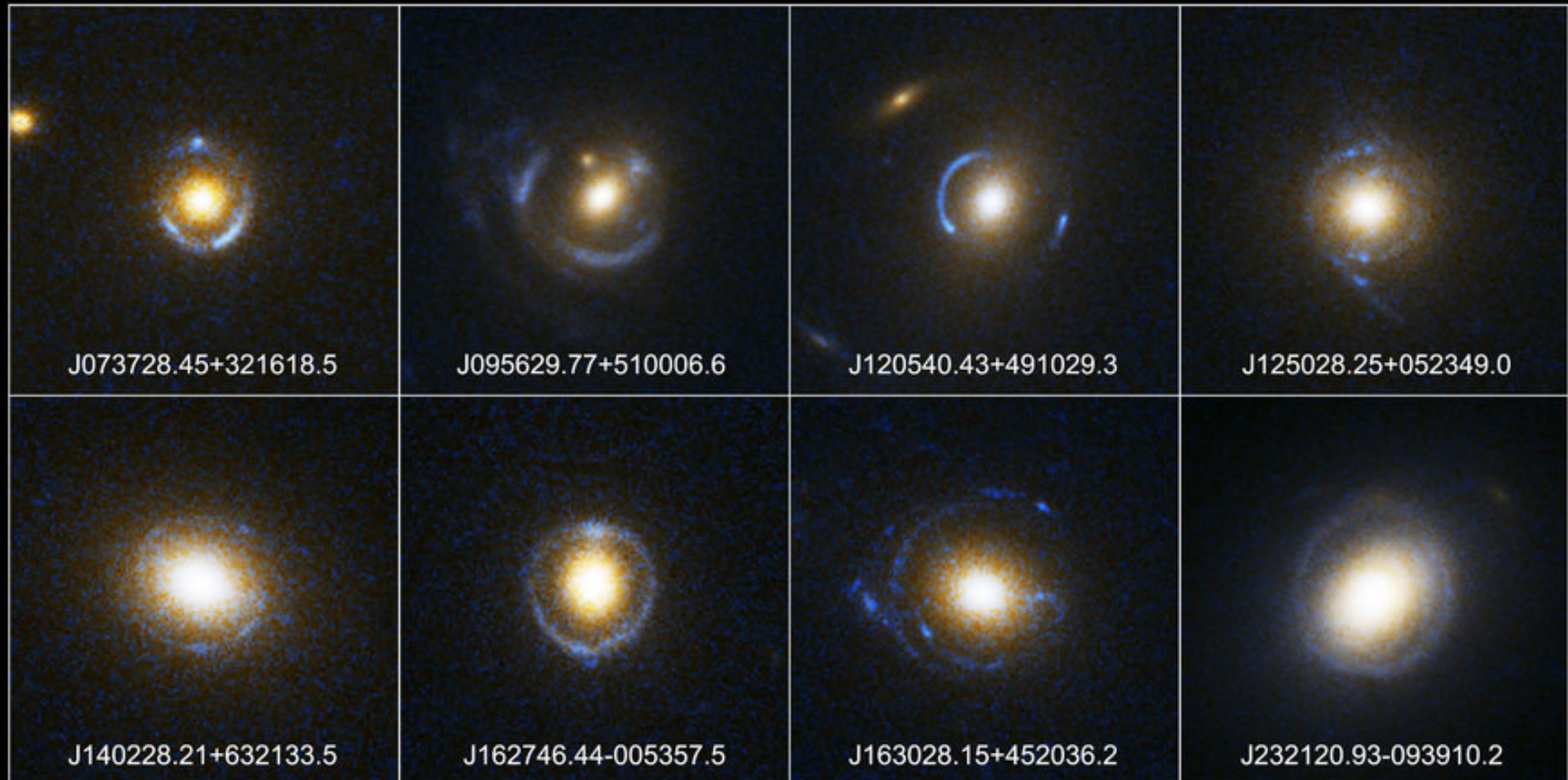


Cruz de Einstein

(quasar a 8 bilhões de anos-luz imageado
por galáxia a 400 milhões de anos luz)

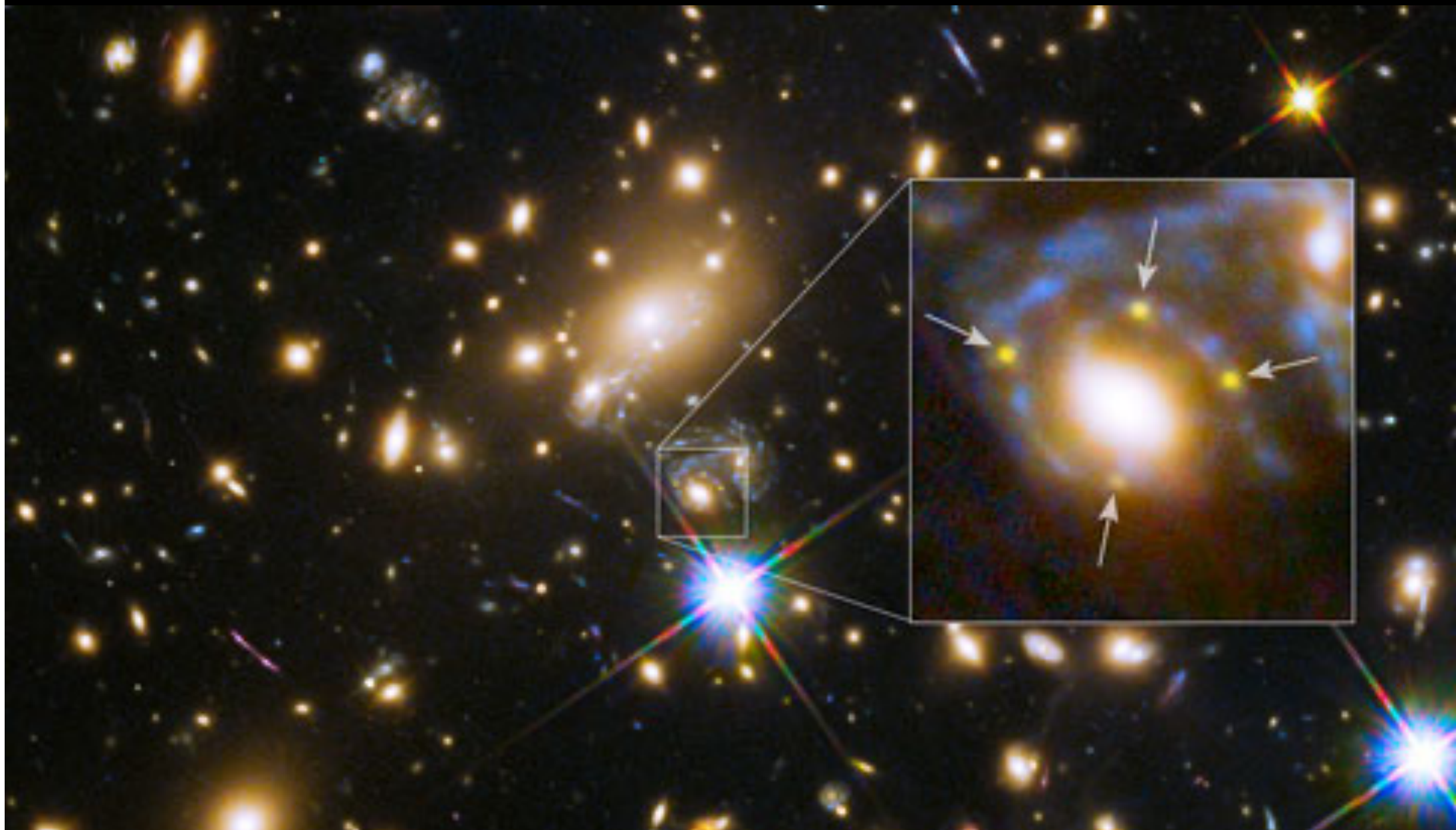


Anéis de Einstein

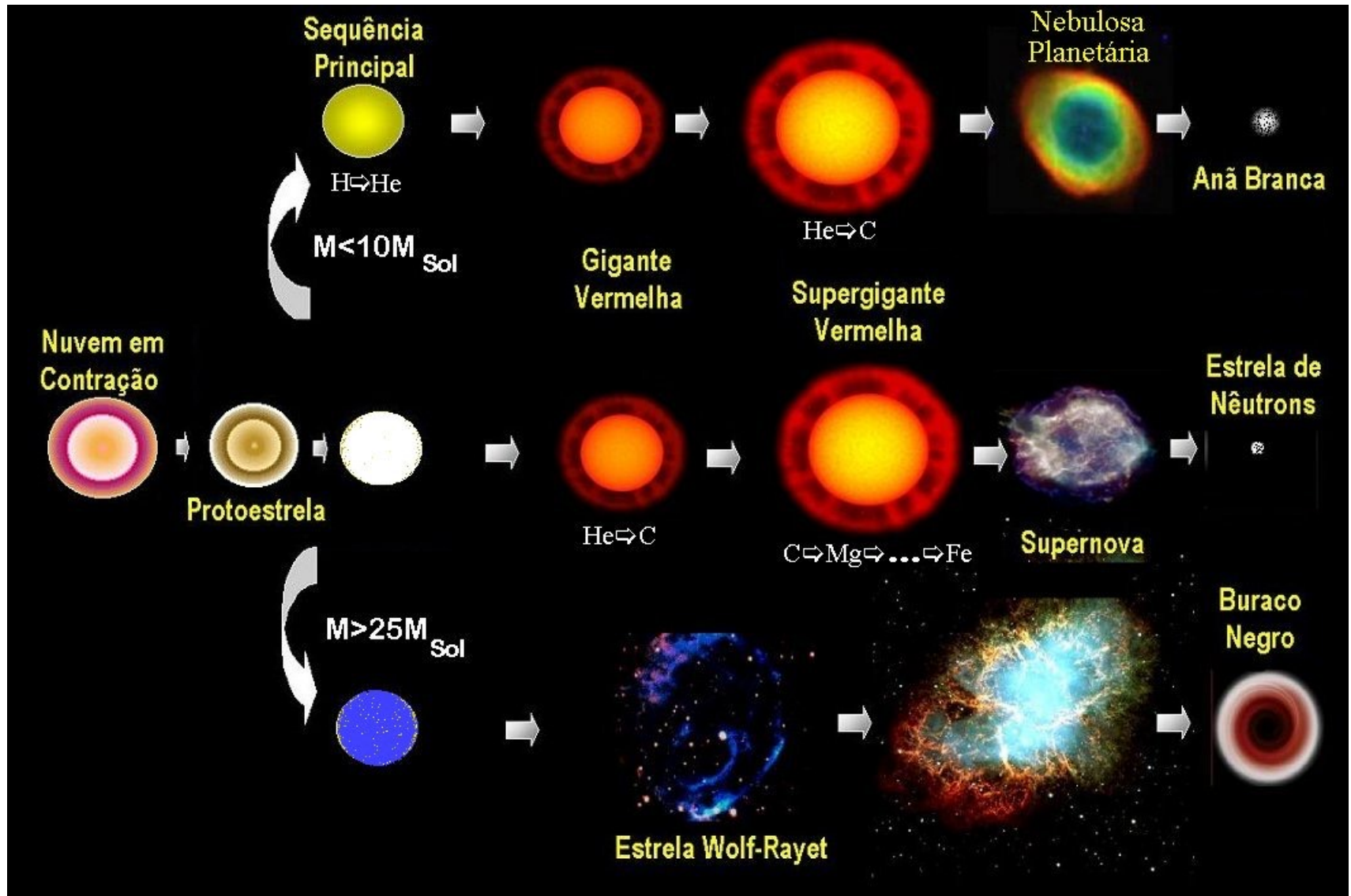


Einstein Ring Gravitational Lenses
Hubble Space Telescope • Advanced Camera for Surveys

Nov 2014: $z=1,49$ SN, $z=0,54$ galáxia



Evolução estelar

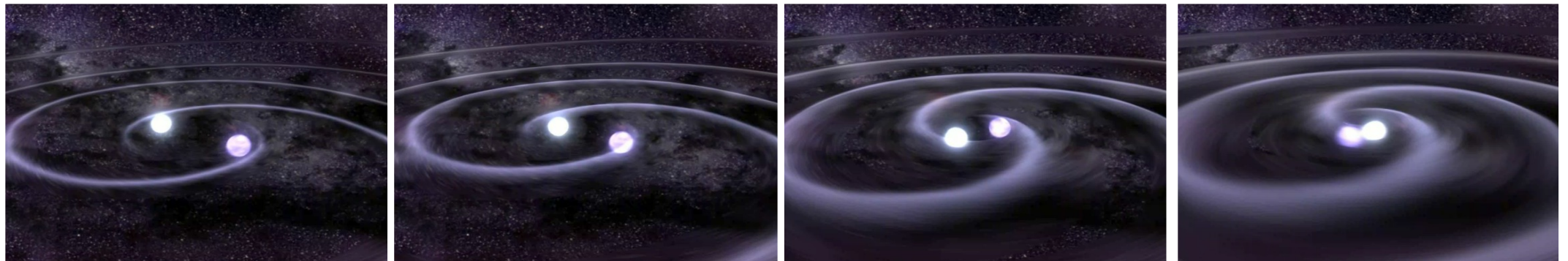


$$E_G = -\frac{GMm}{r} \qquad E_C = -\frac{Kq_1q_2}{r}$$

Energia Coulomb: ondas eletromagnéticas

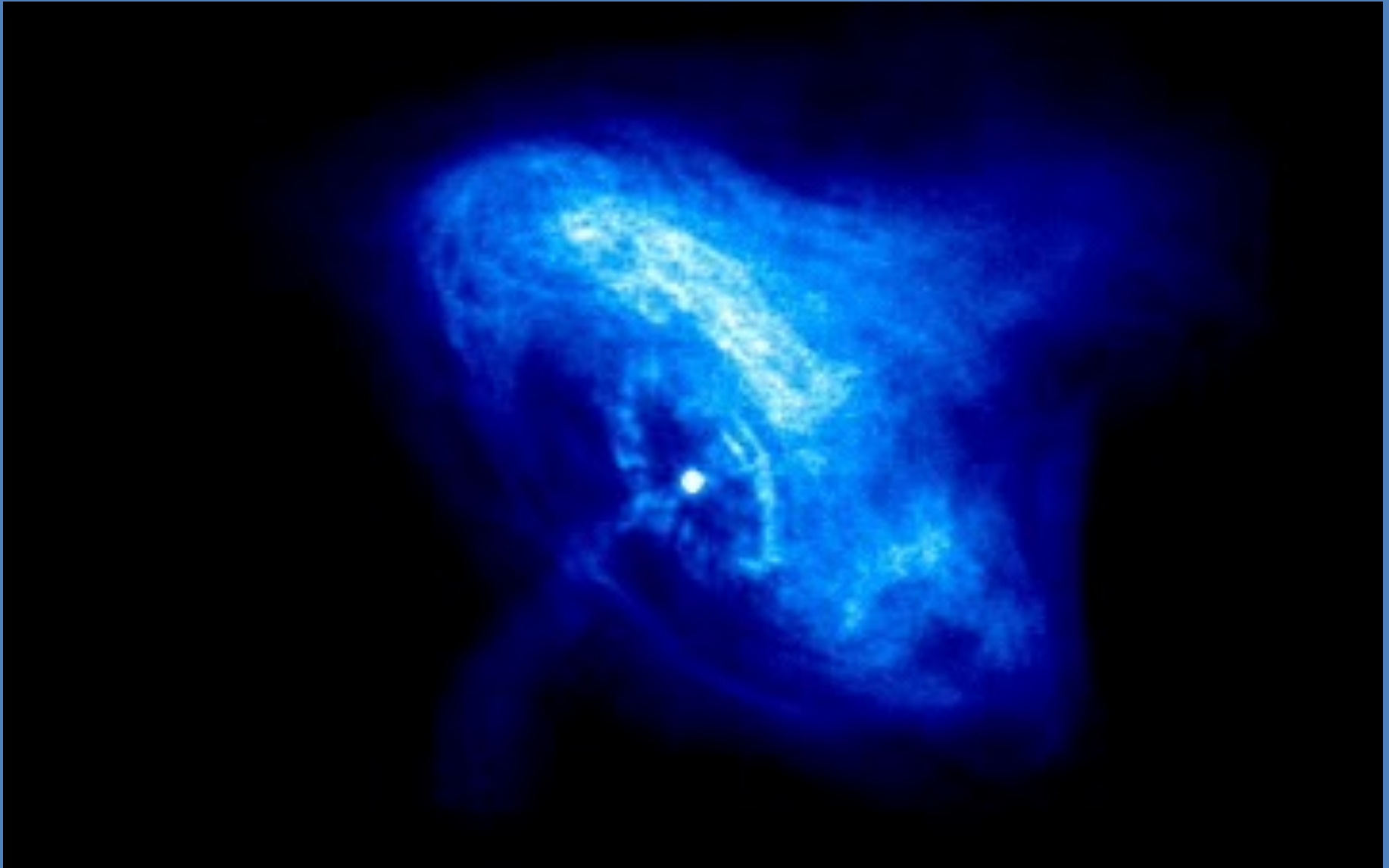
Energia Gravitacional: ondas gravitacionais

Evidência de Ondas Gravitacionais



Pulsar de 1054

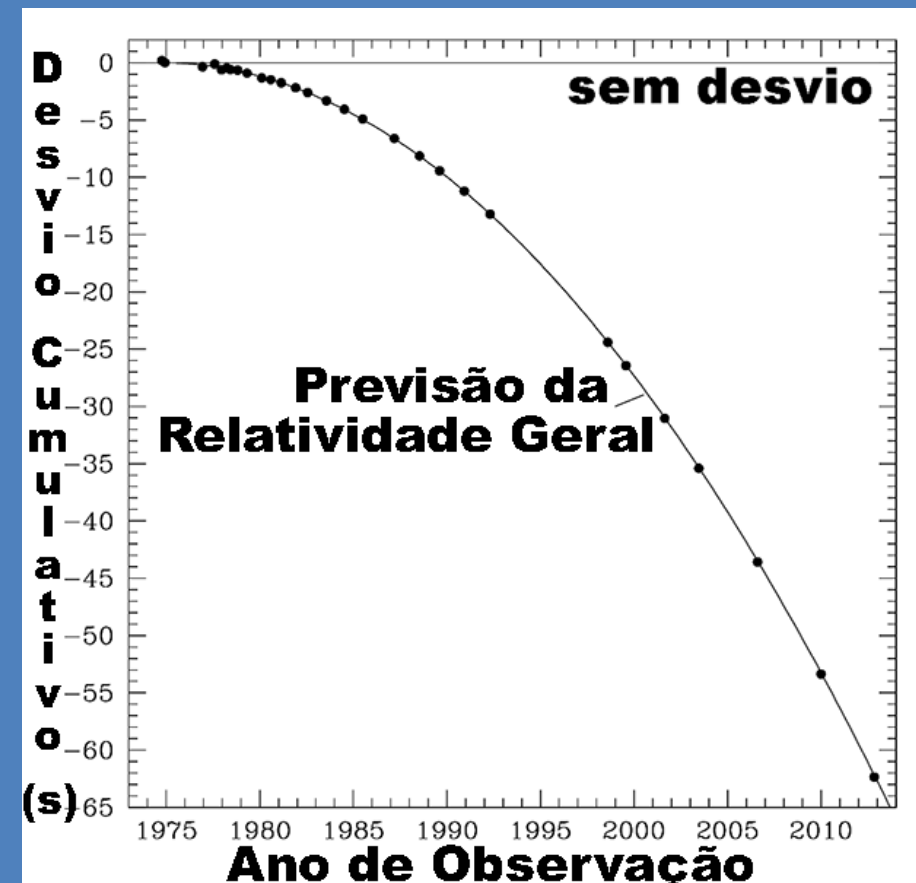
Nobel 1974: Antony Hewish (1924-2021)



Pulsar binário PSR1913+16

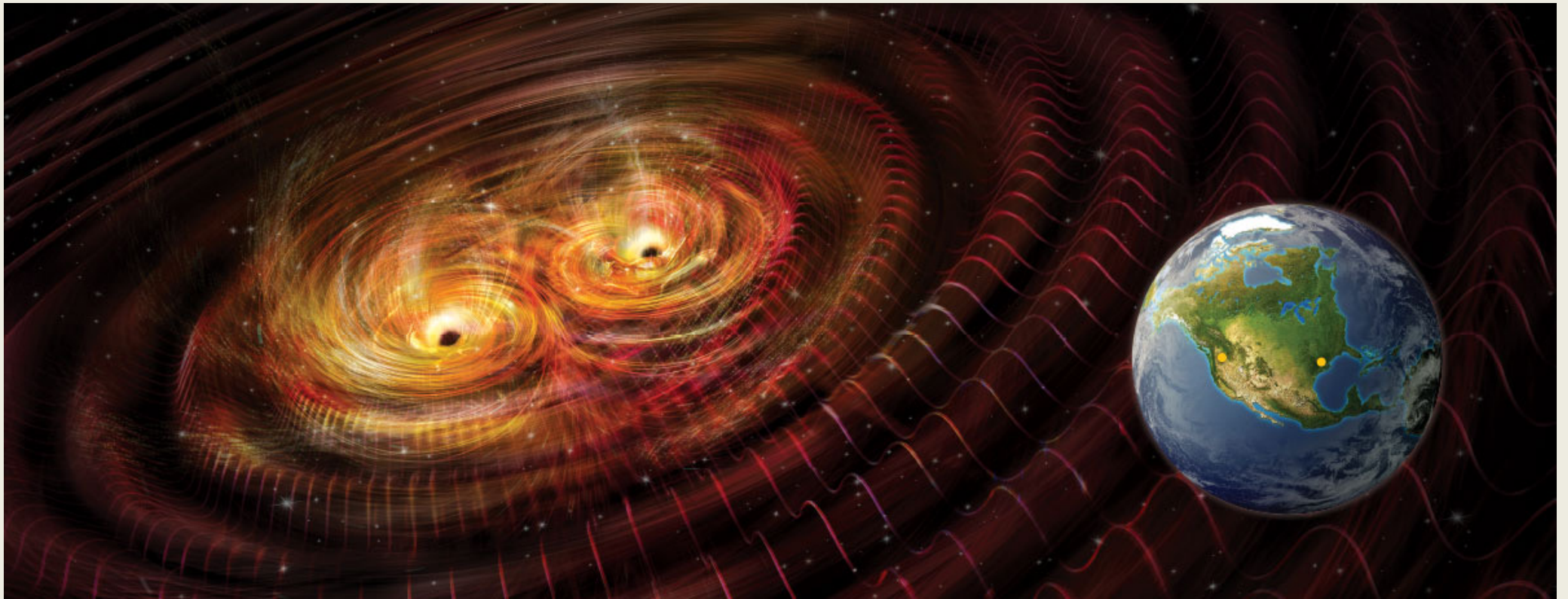
- Duas estrelas de nêutrons
- Período orbital = 7,75 horas
- Período de rotação do pulsar 59 milisegundos
- $\Delta P/\Delta t = (75,8 \pm 0,1) \mu\text{s/ano}$

Incerteza na Relatividade Geral é menor que $1/10^{18}$



Nobel 1993: Russell Alan Hulse (1950-) e Joseph Hooton Taylor Jr. (1941-)

Ondas gravitacionais



Ondas Gravitacionais

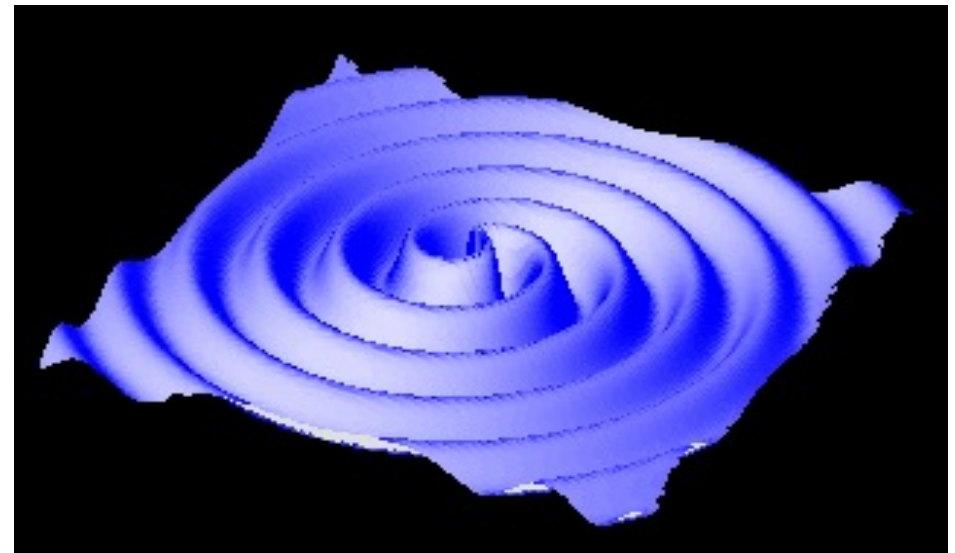
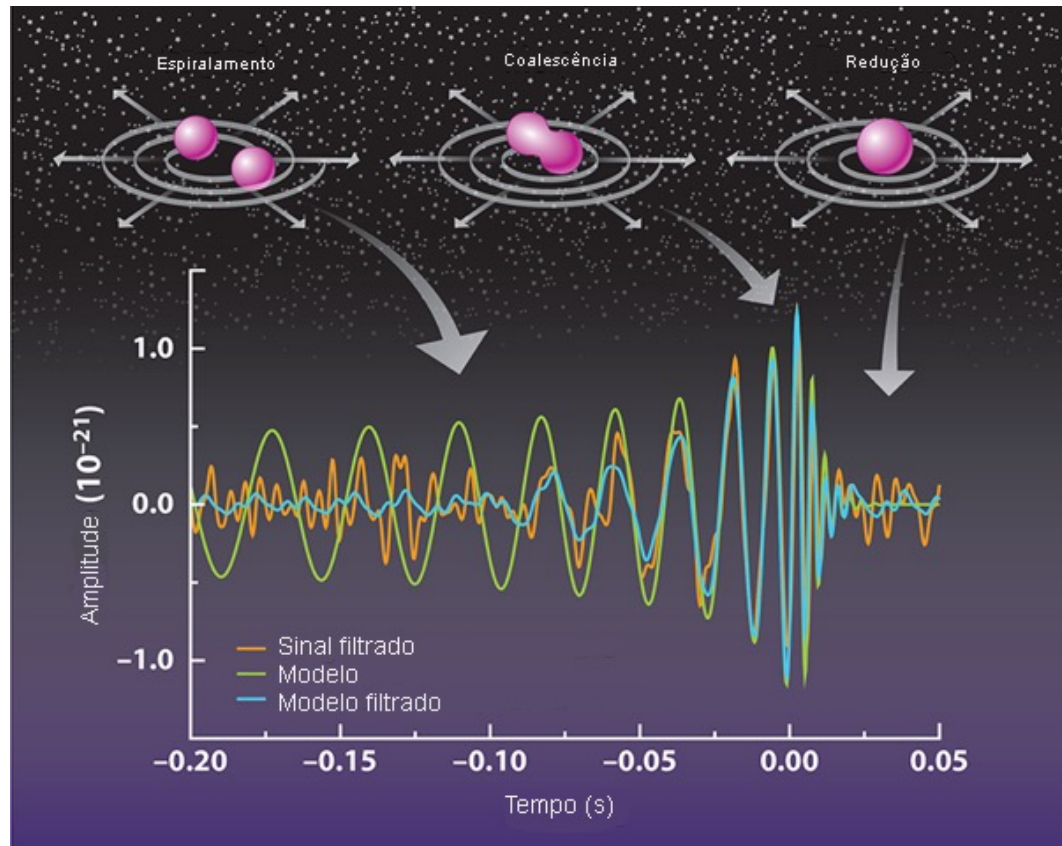
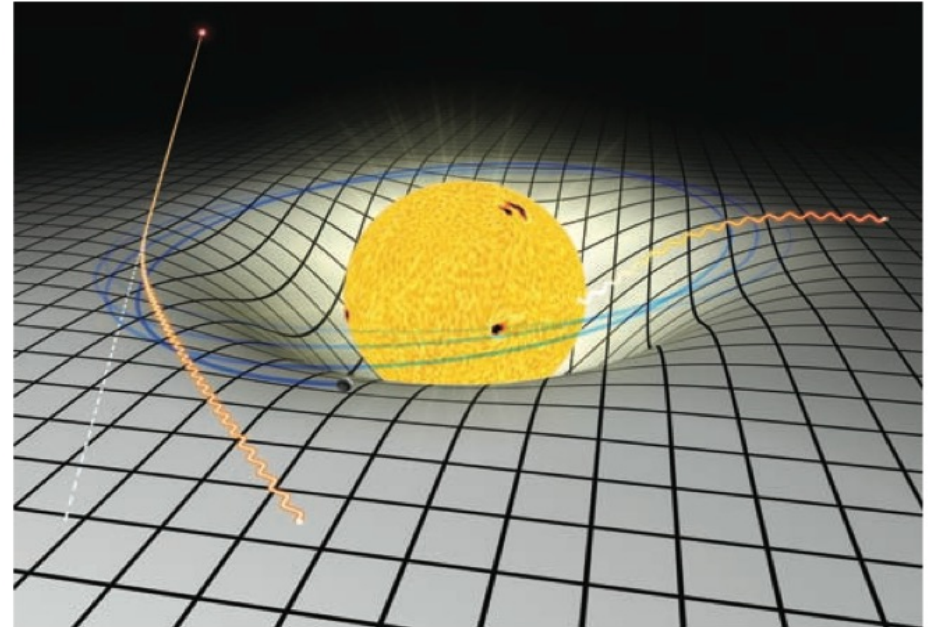
Gravidade deforma o espaço

Massas em movimento emitem ondas

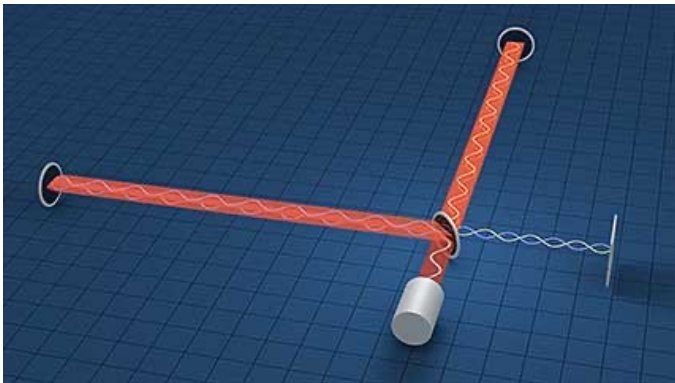
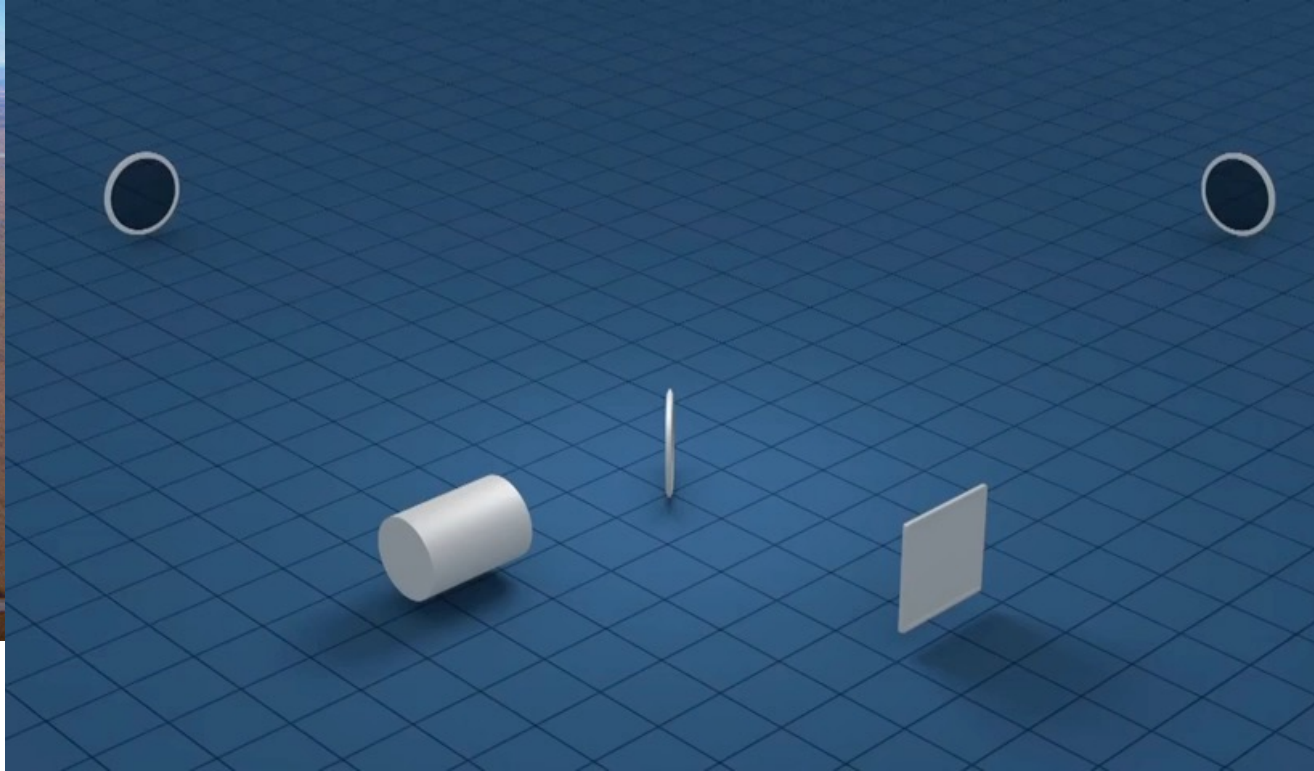
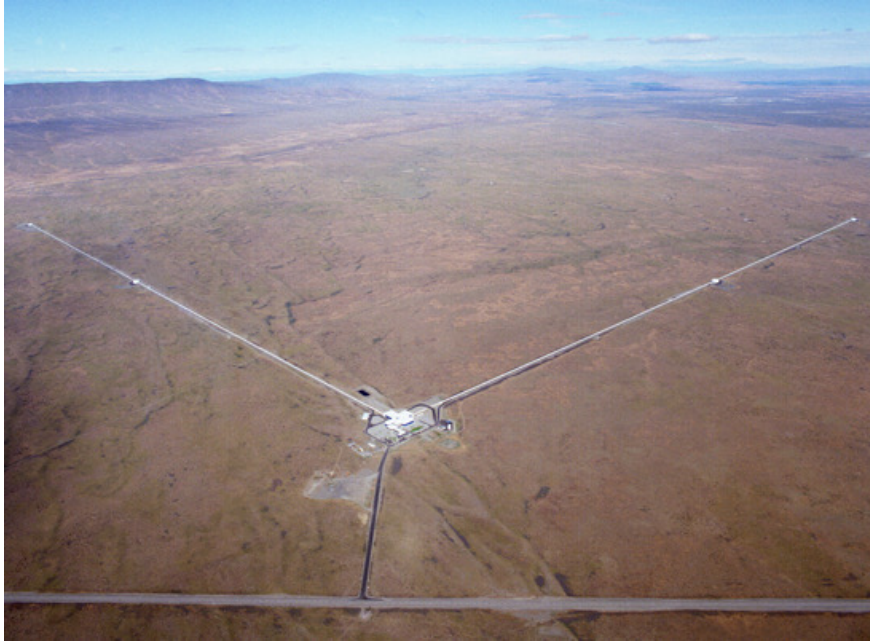
Ondas carregam energia

Perda de energia reduz a órbita

Ondas gravitacionais foram observadas Set/15 e Dez/15 pelo LIGO ($\Delta r/r \sim 10^{-22}$)

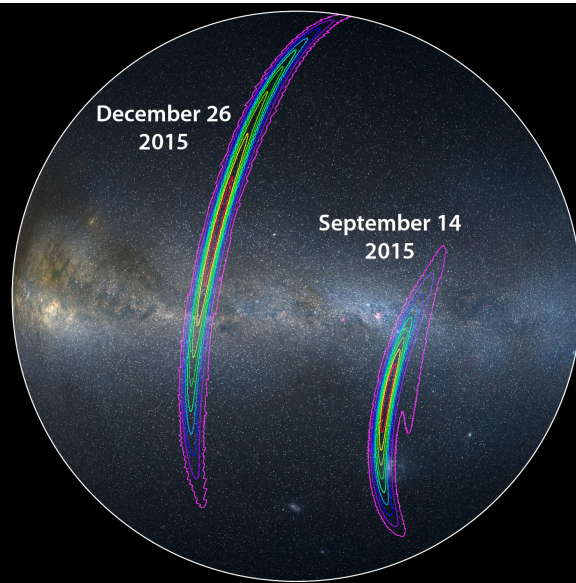


LIGO/Virgo/Kagra: onda gravitacionais



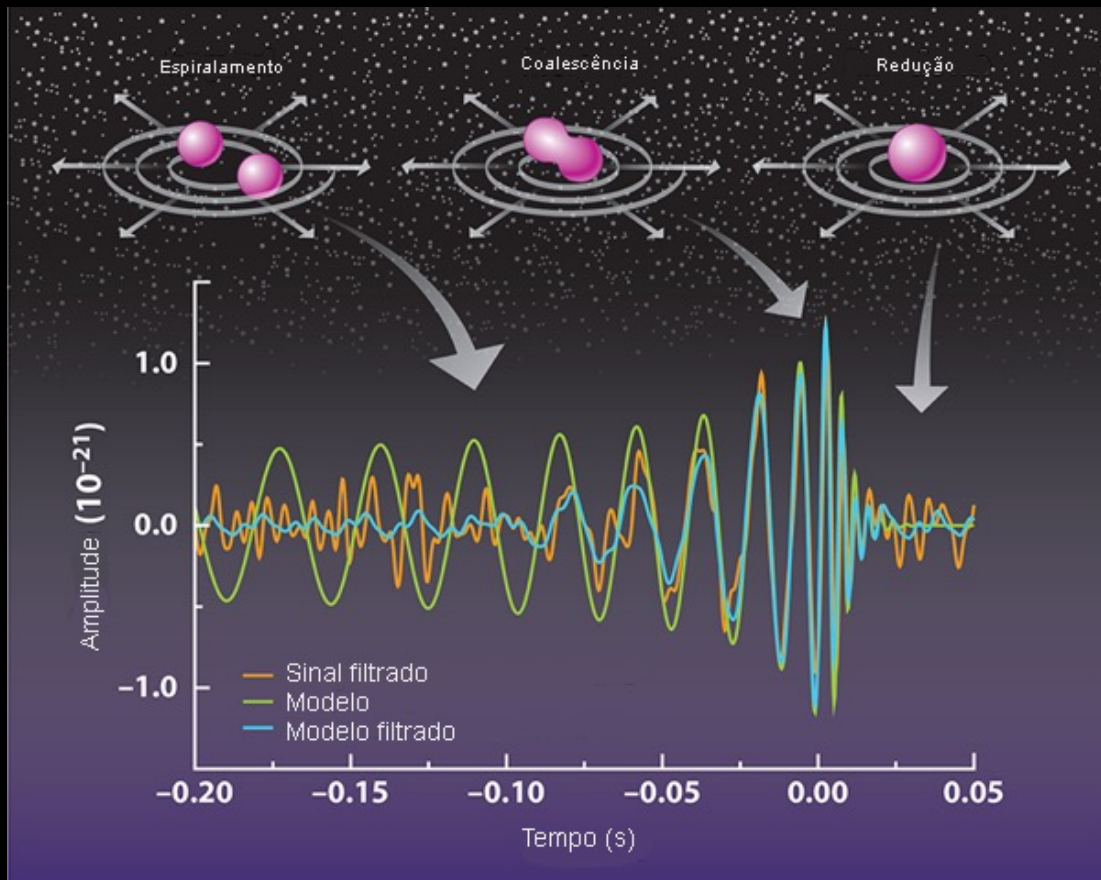
4 km tubos em vácuo

Prêmio Nobel 2017: Rainer Weiss, Barry C. Barish e Kip S. Thorne

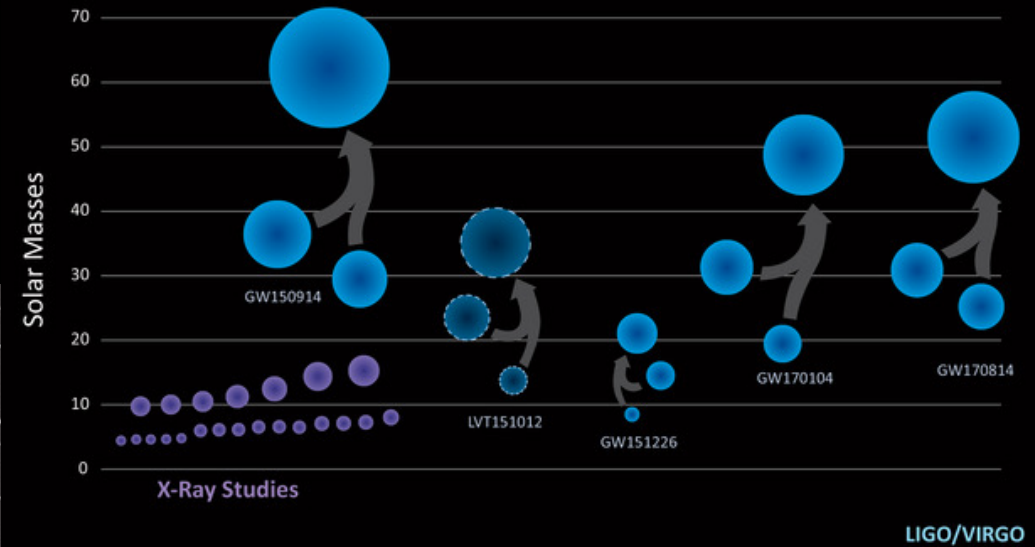


14 Set 2015
35+30 M_{Sol}

26 Dez 2015
8+14 M_{Sol}



Buracos Negros



$$\Delta r/r \sim 10^{-22}$$

Universo é finito,



Qual é o tamanho do horizonte? idade $\times c$

Raio onde as partículas estão agora = $3,38 \times \text{horizonte} = 14 \text{ Gpc}$

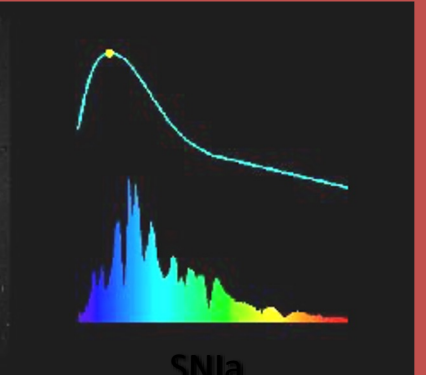
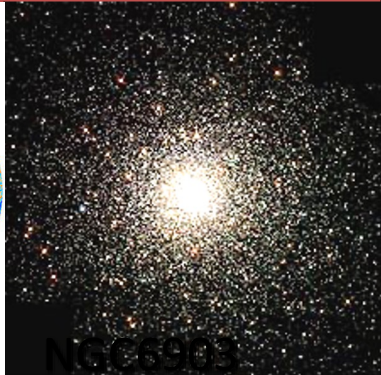
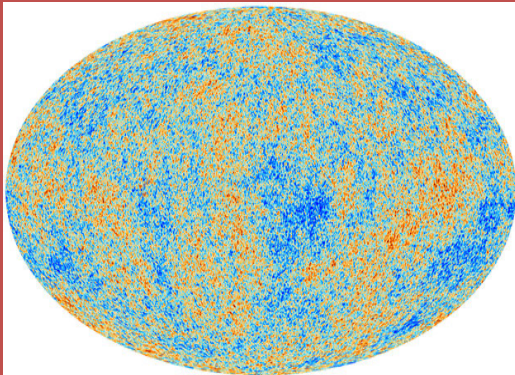
- O Universo está se expandindo e a luz também

<http://astro.if.ufrgs.br/univ/mat/tempo/>

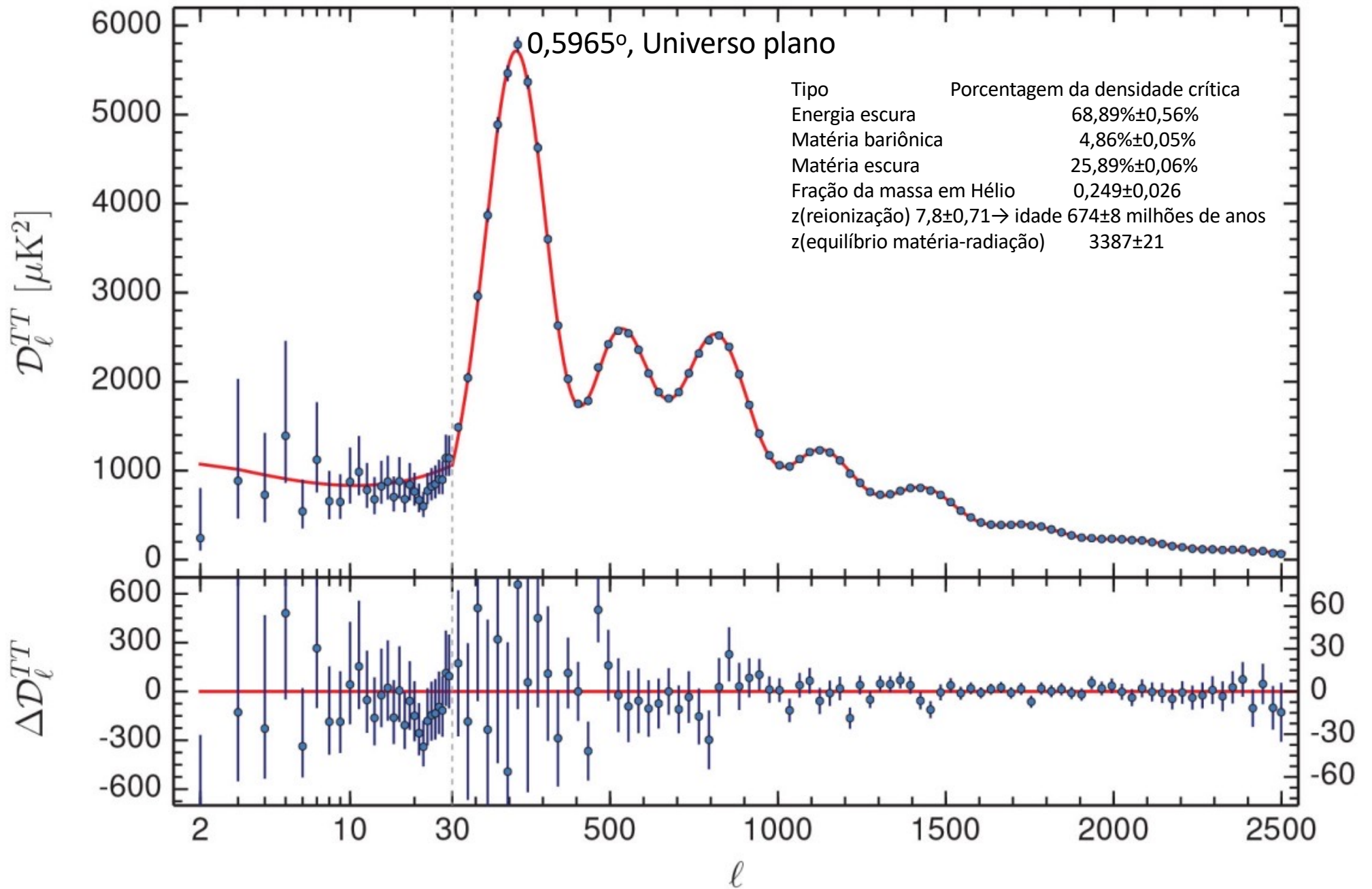


Idade do Universo em 2026

- Espectro da Radiação do Fundo do Universo = $(13,767 \pm 0,014)$ Ganos
- Taxa de Expansão do Universo - Idade: $1/H = (13,8 \pm 1)$ Ganos
- Cúmulos Globulares - Idade: $(13,5 \pm 0,3)$ Ganos
- Decaimento Radiativo - Idade: $(12,5 \pm 3)$ Ganos
- Esfriamento das Anãs Brancas - Idade: $(13,0 \pm 0,7)$ Ganos
- Distância às Supernovas Tipo I - Idade: $13,0 \pm 1,2 (0.72/h)$ Ga, Λ



FT



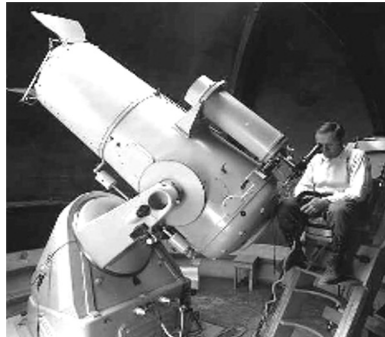
Matéria Escura



$$E = \frac{1}{2}mv^2 - \frac{GMm}{r}$$

Energia Gravitacional = Energia Cinética

$$v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$$



Matéria Escura ~ 5 Matéria Luminosa

Fritz Zwicky (1898-1974) **1937**, *Astrophysical Journal* 86, 217 – On the masses of nebulae and of clusters of nebulae

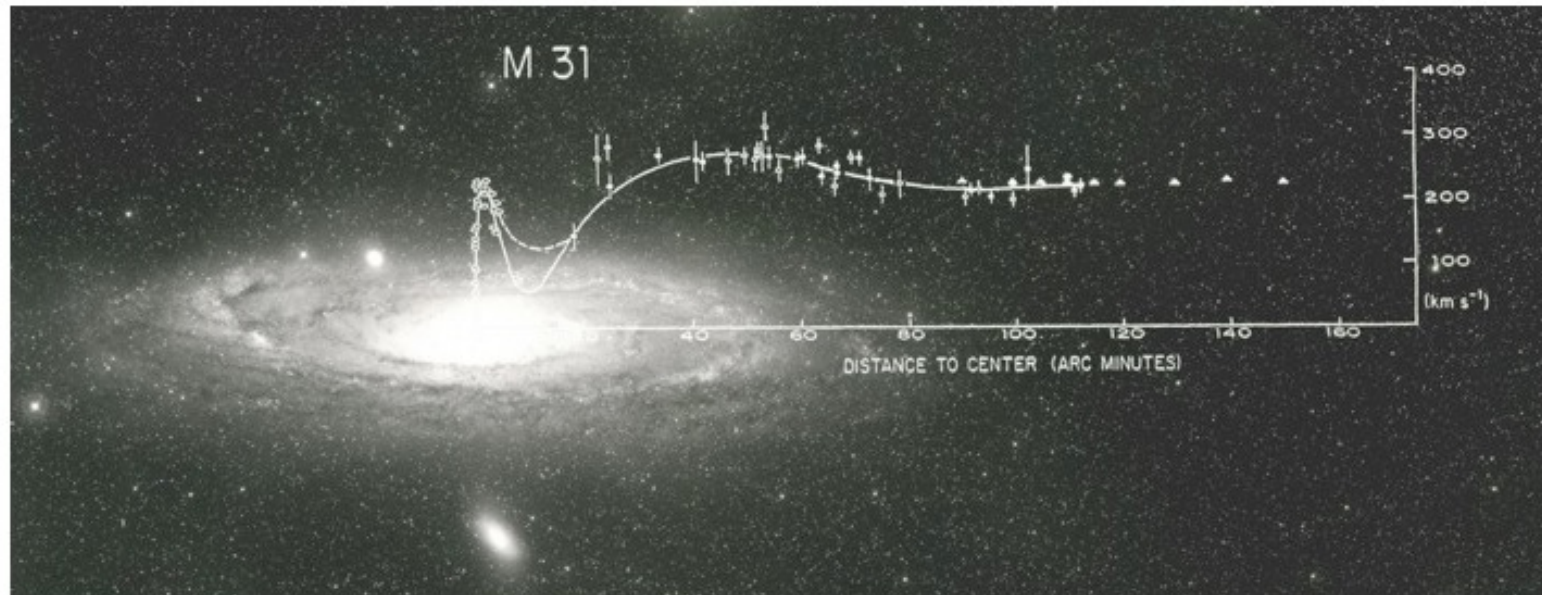
Matéria Escura dentro das galáxias



Vera C. Rubin (1928-2016) & William Kent Ford Jr. (1931-2023)

1970, *Astrophysical Journal*, 159, 379

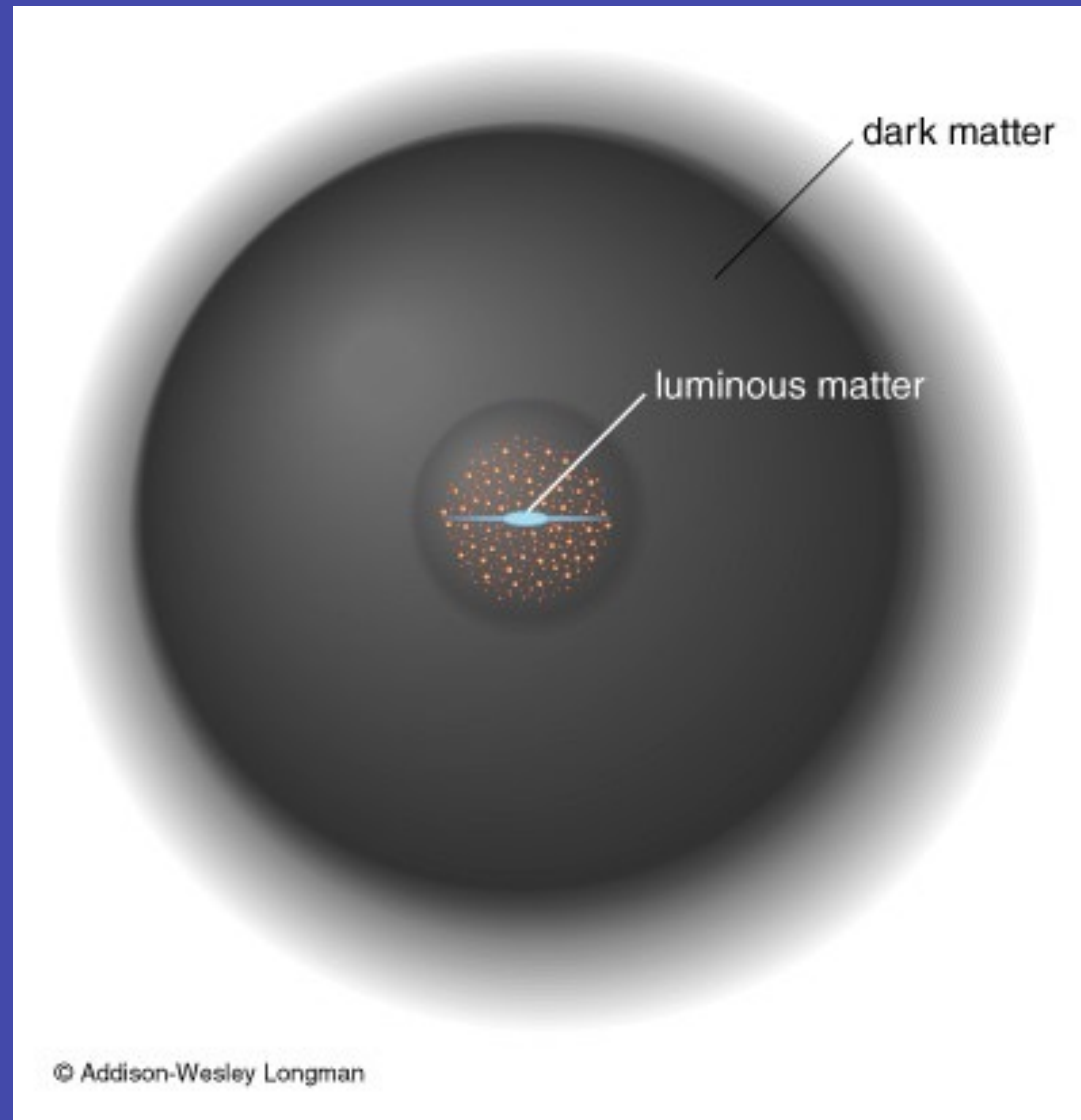
Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions



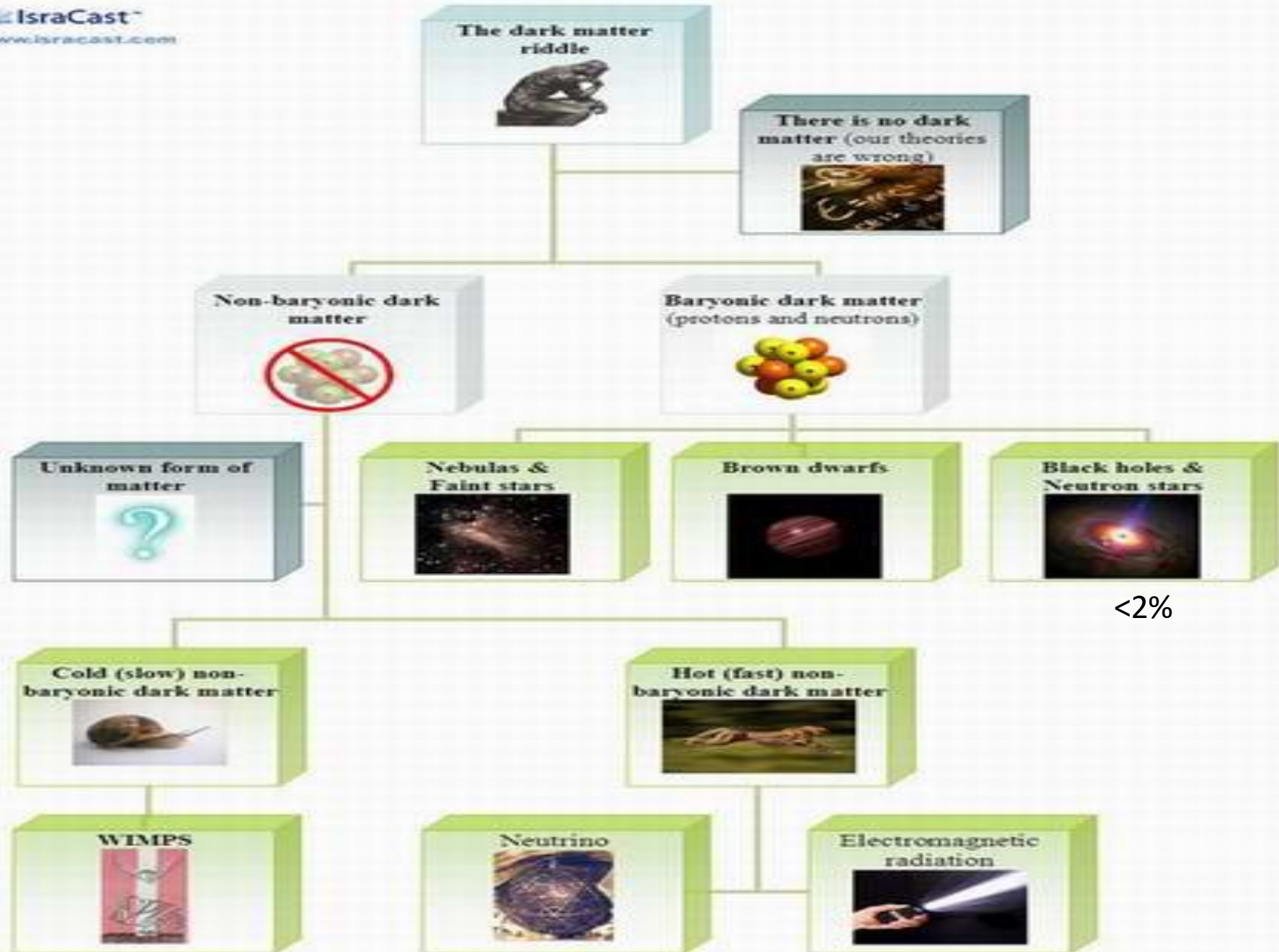
Triângulos são medidas de HI de Roberts & Whitehurst 1975

Matéria Escura

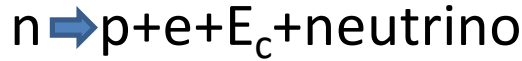
O movimento rápido das estrelas longe do centro das galáxias indica um halo estendido de matéria escura, com massa 5 vezes maior do que a da matéria bariônica.



Matéria Escura: o que é?



Neutrinos



Previstos teoricamente por Wolfgang Pauli (1900-1958) em 1930, para explicar a variação da energia dos elétrons emitidos em decaimentos beta.

A vida média de um nêutron livre é de aproximadamente 12 minutos.

Pauli propôs que a diferença de energia estava sendo carregada por uma partícula neutra de difícil detecção, o neutrino. Ele recebeu o prêmio Nobel em 1945.

Em 1956 os neutrinos foram detectados por Frederick Reines (1918-1998) e Clyde L. Cowan Jr (1919-1974), emitidos de um reator nuclear

"The Neutrino", Frederick Reines & Clyde L. Cowan, Jr., Nature 178, 446 (1956)

Reines recebeu o prêmio Nobel em 1995 pela descoberta.

Mas como $m(\text{neutrinos}) < 0,1 \text{ eV}$, só 1% da matéria escura é feita de neutrinos.

Matéria e Antimatéria não são simétricas

CP violation



James Cronin (1931-2016)

Valentine Longsdon Fitch (1923-2015)

Princeton University

Evidence for the 2π Decay of the K_2^0 Meson

J. H. Christenson, J. W. Cronin, V. L. Fitch &
R. Turlay, Phys. Rev. Lett. **13**, 138 (1964)

Violação carga-paridade Nobel 1980

Synchrotron: Brookhaven National Lab 1959

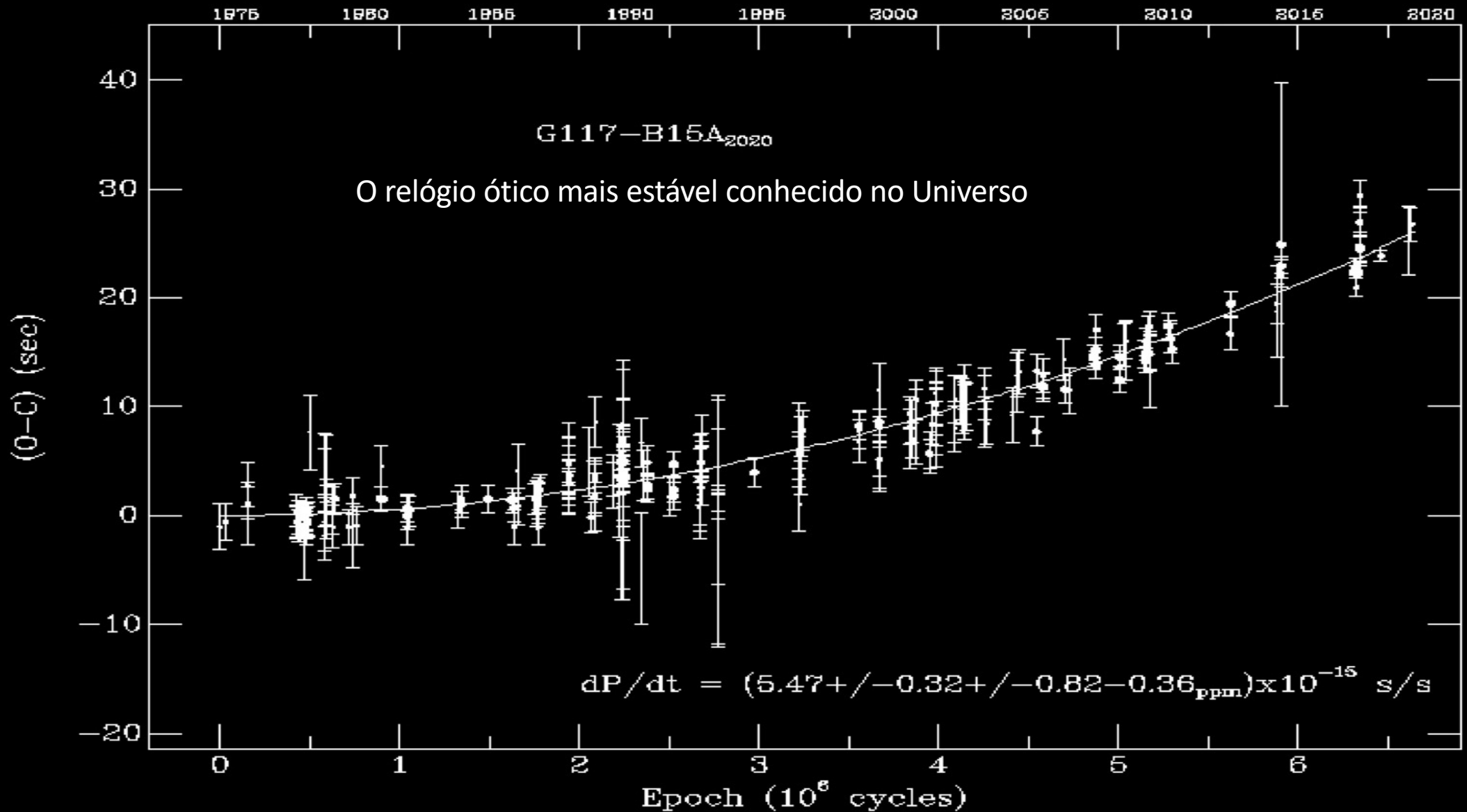


Áxions propostos por Roberto Daniele Peccei (1942-2020) & Helen R. Quinn (1943-) em 1977 para explicar a assimetria Carga-Paridade.



$m(\text{axions}) = 19 \pm 2 \text{ meV} \rightarrow \text{Dark matter?}$

$f_A = (3,5 \pm 0,3) \times 10^8 \text{ GeV}$ Kepler et al. 2021



Energia escura 1998

Riess et al. 1998
Permuter et al. 1999

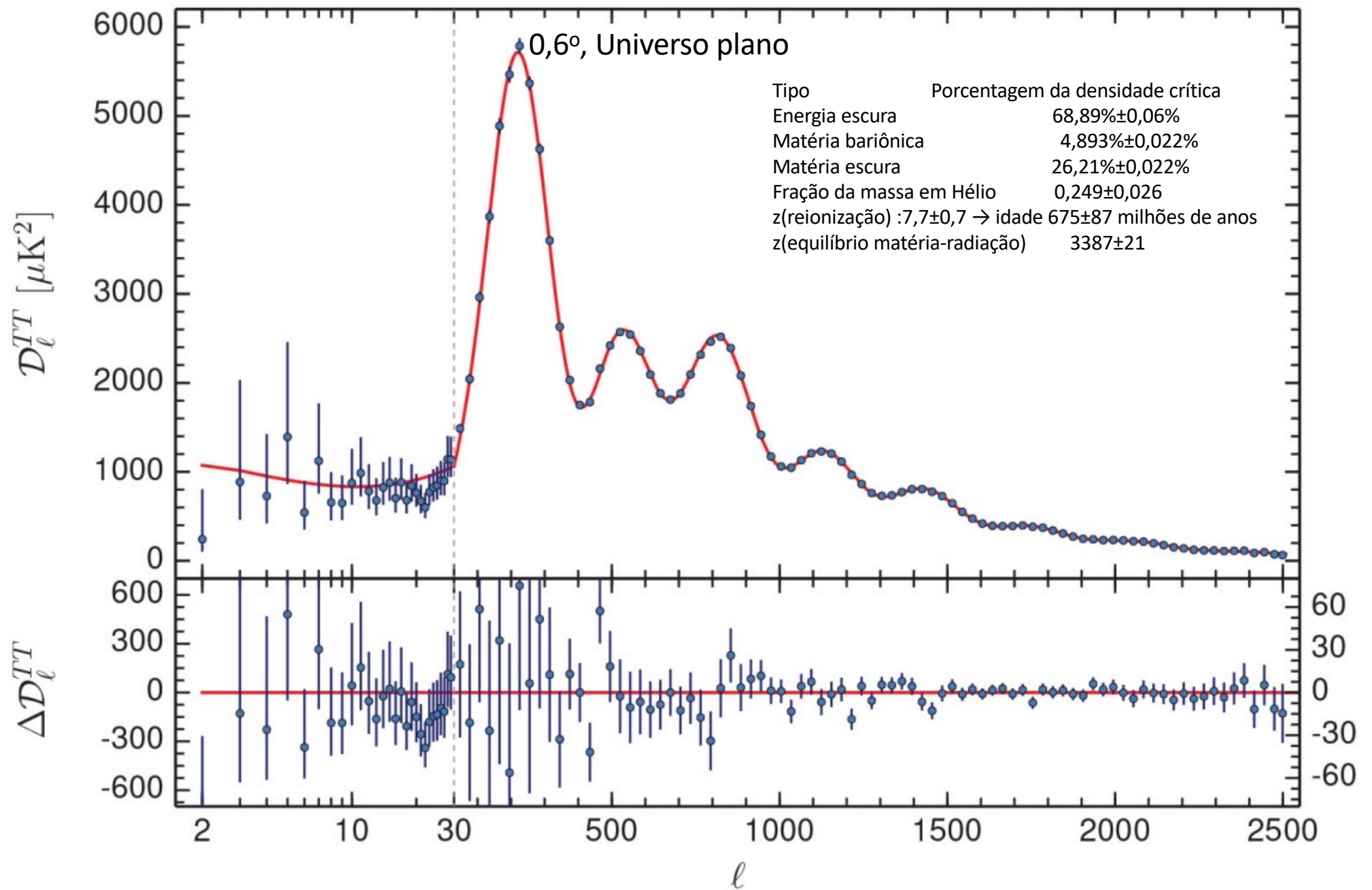
Nobel 2011: Saul Perlmutter (1959-), Brian P. Schmidt (1967-) e Adam G. Riess (1969-)

SN Ia – explosão termonuclear de anã branca de C/O

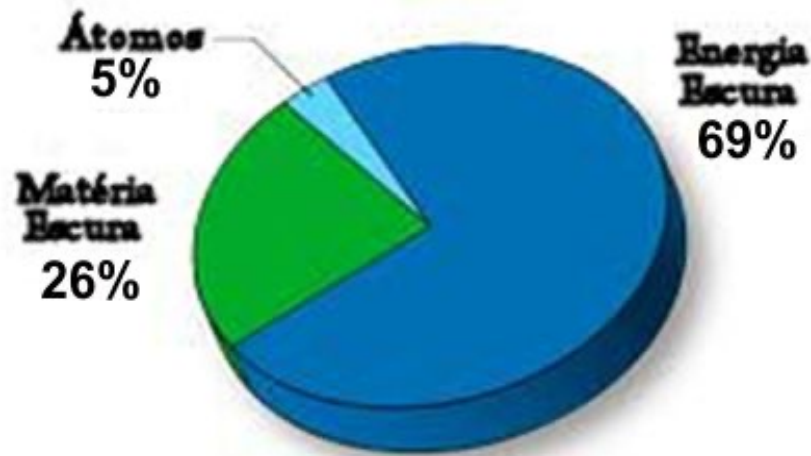


Máximo brilho: candela padrão

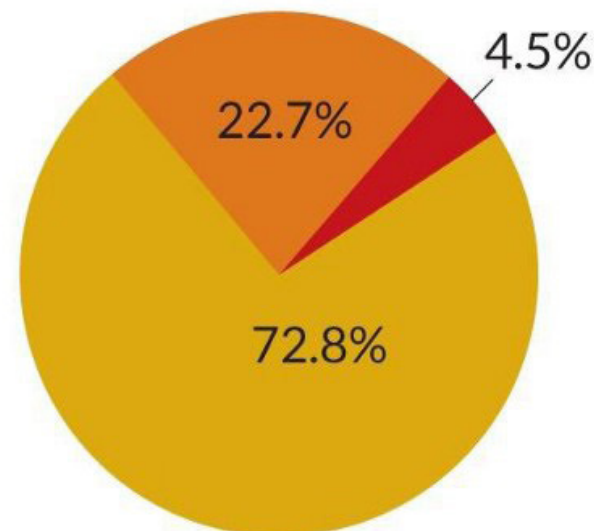
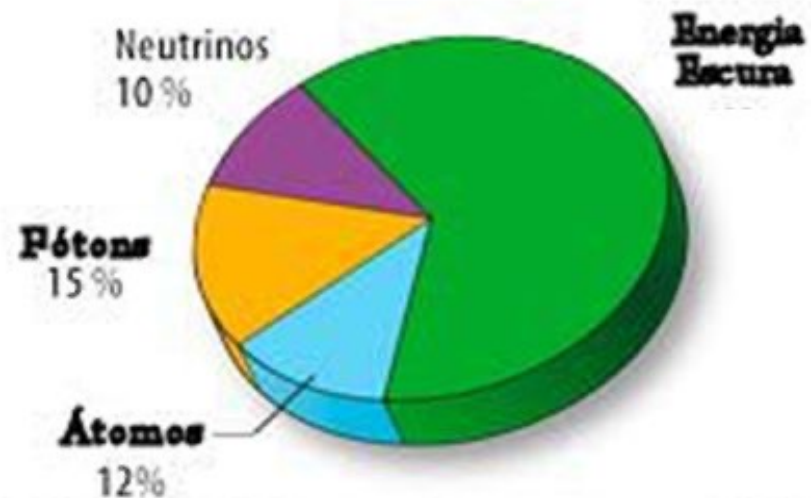
FT



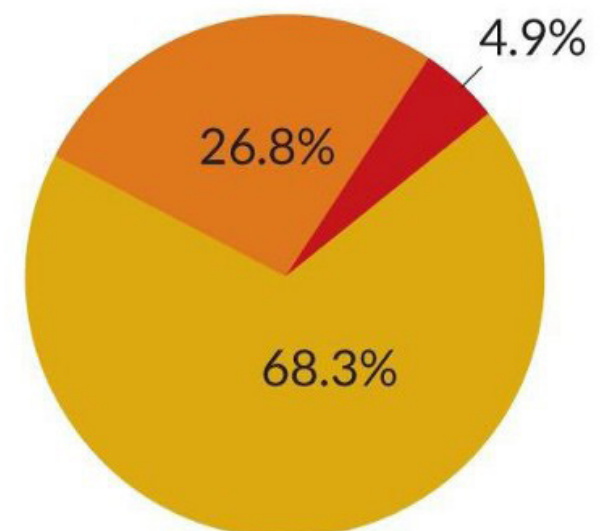
Energia Total do Universo



Hoje



WMAP

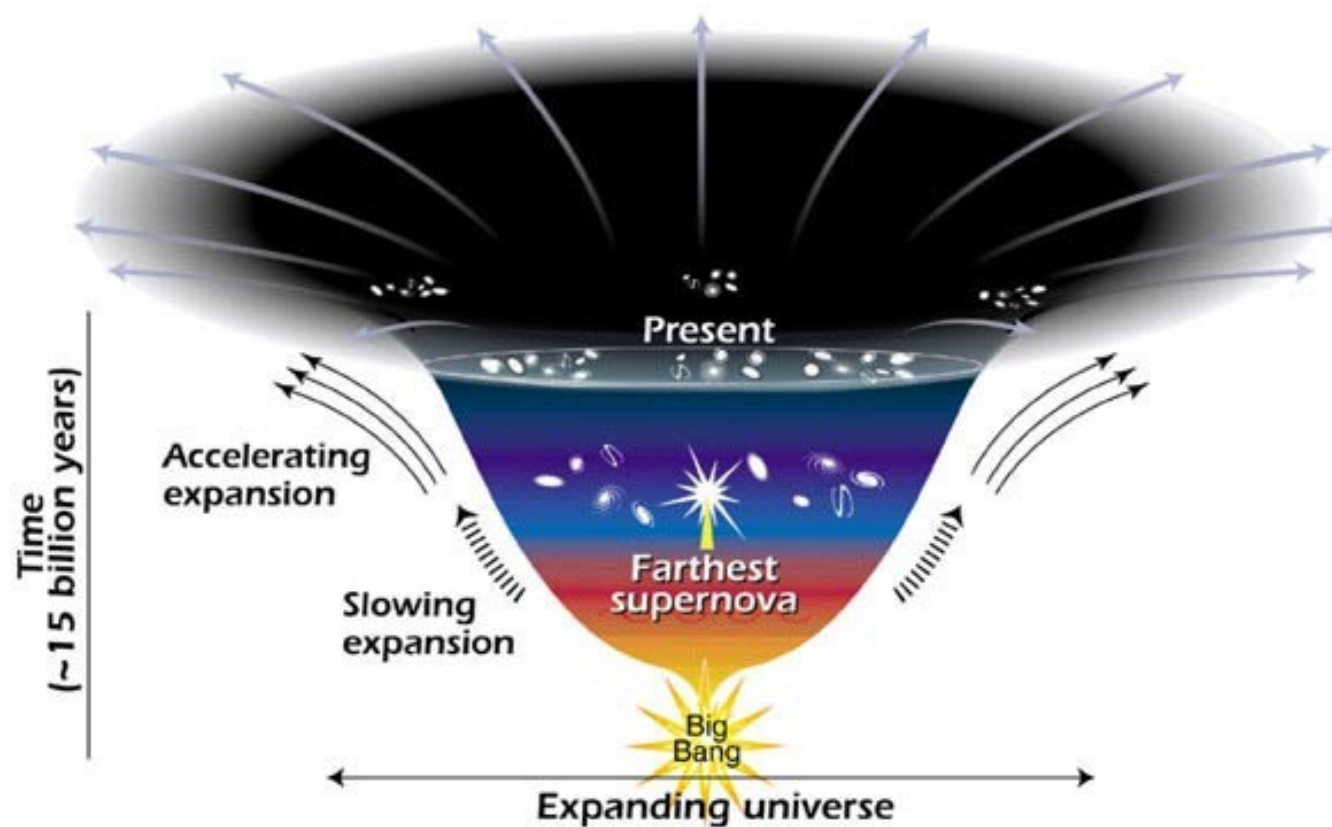


Planck

■ Energia Escura ■ Matéria Escura ■ Matéria Bariônica

Quando o Universo ficou transparente
aos 52 mil anos

Expansão acelerada: é preciso uma energia que aja contra a gravidade para acelerar a expansão: a Energia Escura



O futuro

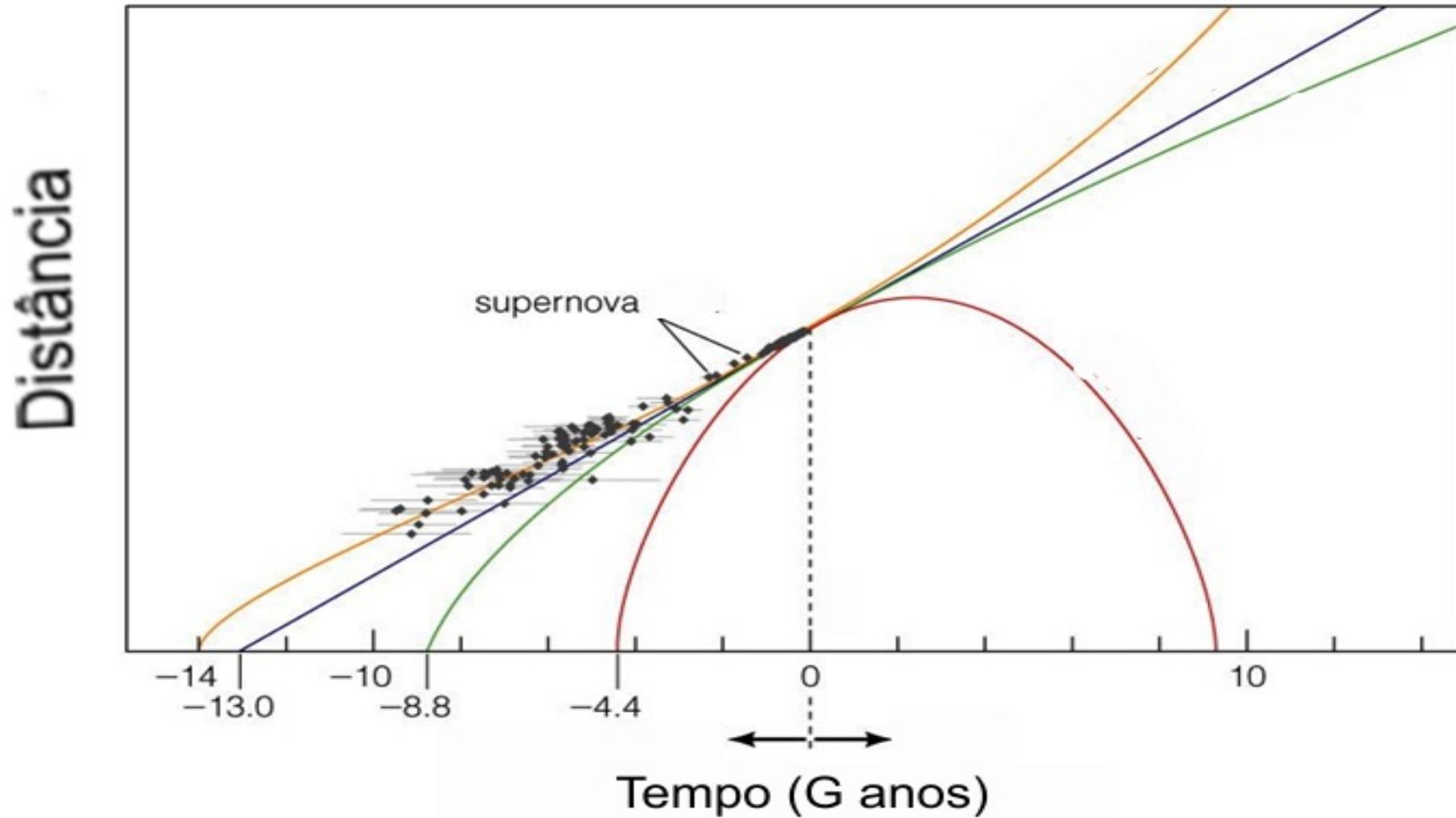


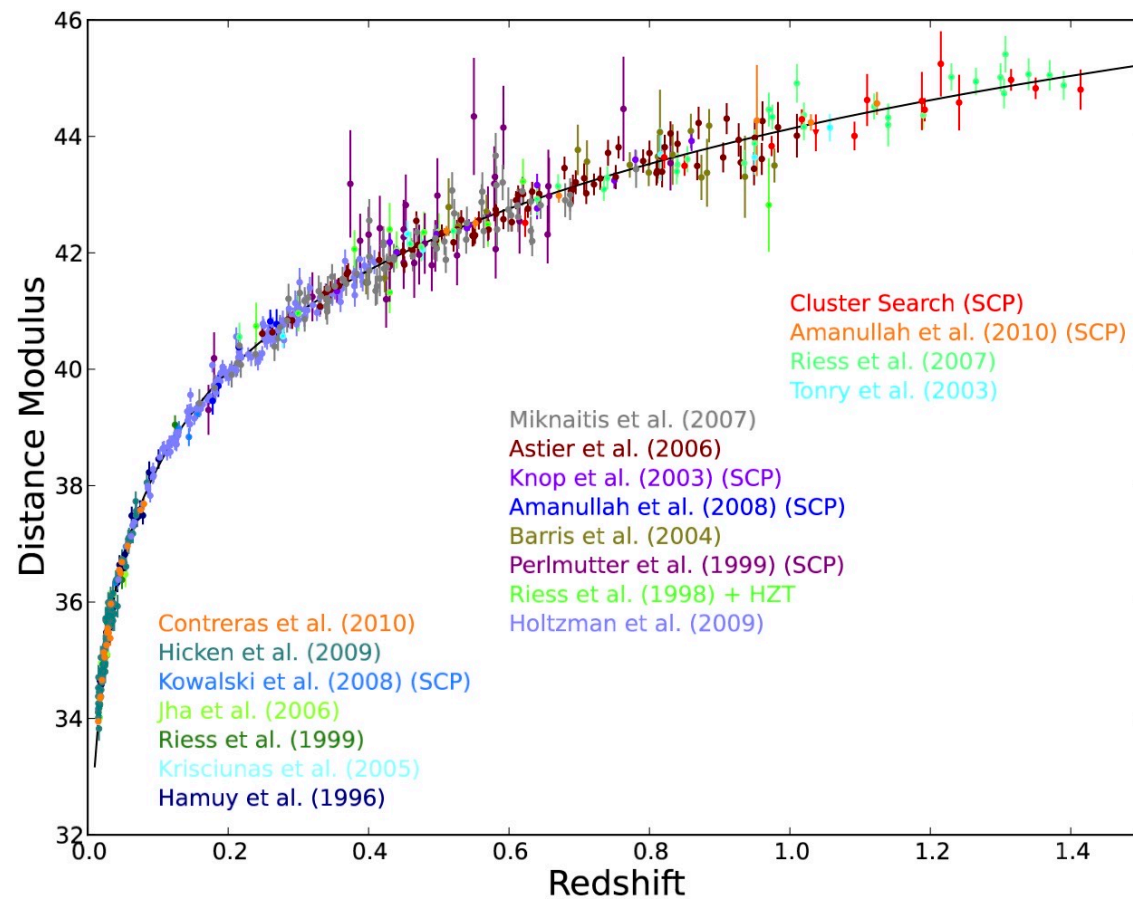
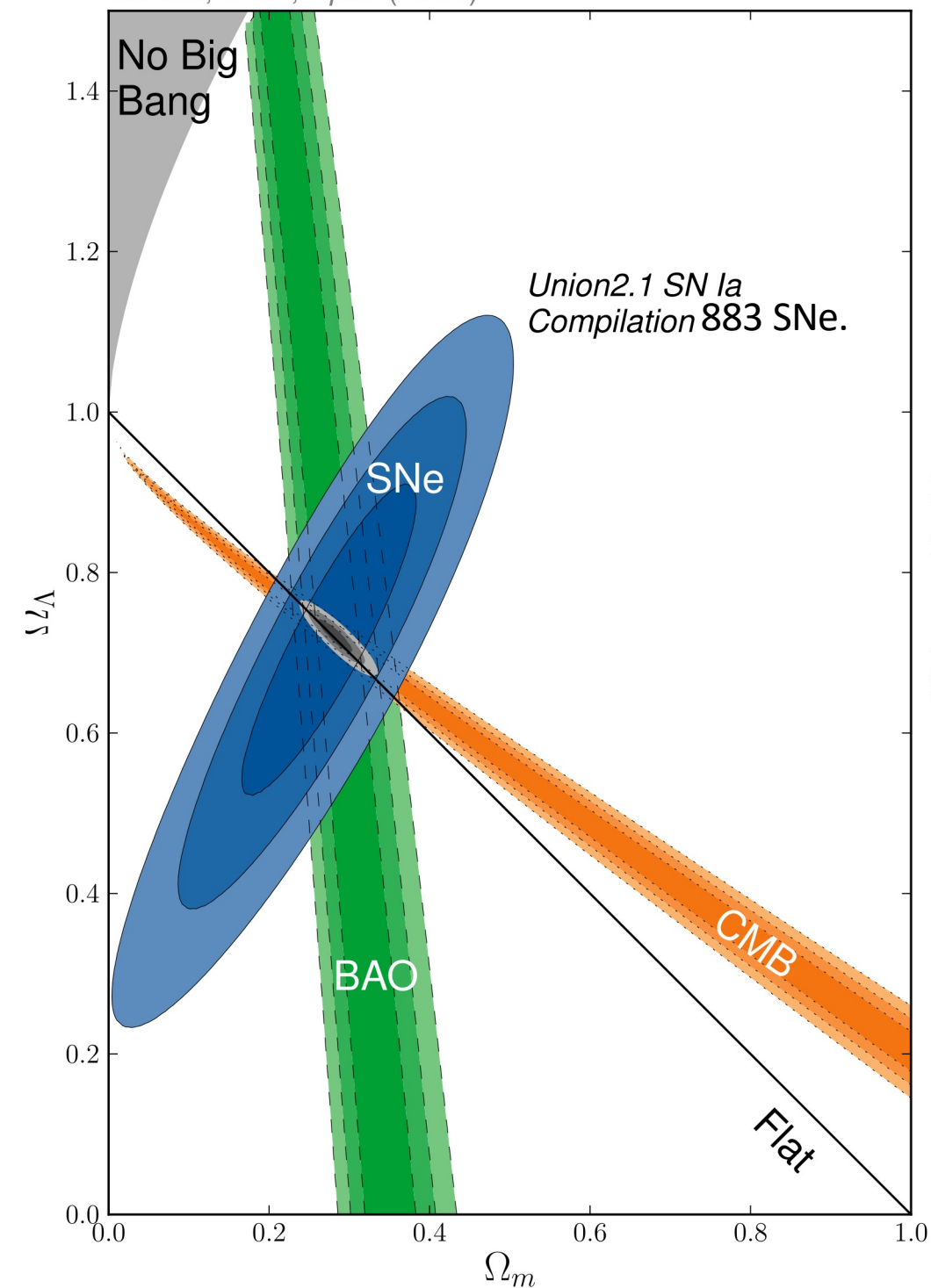
- $t=10^{14}$ anos: Fim da era estelar. Estrelas consomem todo o H em He.
- $t=10^{38}$ anos: Era das estrelas degeneradas: anãs brancas, estrelas de nêutrons, buracos negros.
- $t=10^{100}$ anos: Após $t=10^{38}$ anos, prótons começam a decair e partículas começam a se aniquilar; no fim só sobram buracos negros, que começam a evaporar pela radiação Hawking.
- $t>10^{100}$ anos: Era das trevas: prótons decaíram e buracos negros evaporaram, sobram fótons de baixíssima energia com comprimento de onda tendendo a infinito, neutrinos, elétrons e pósitrons.

Explorando o Universo

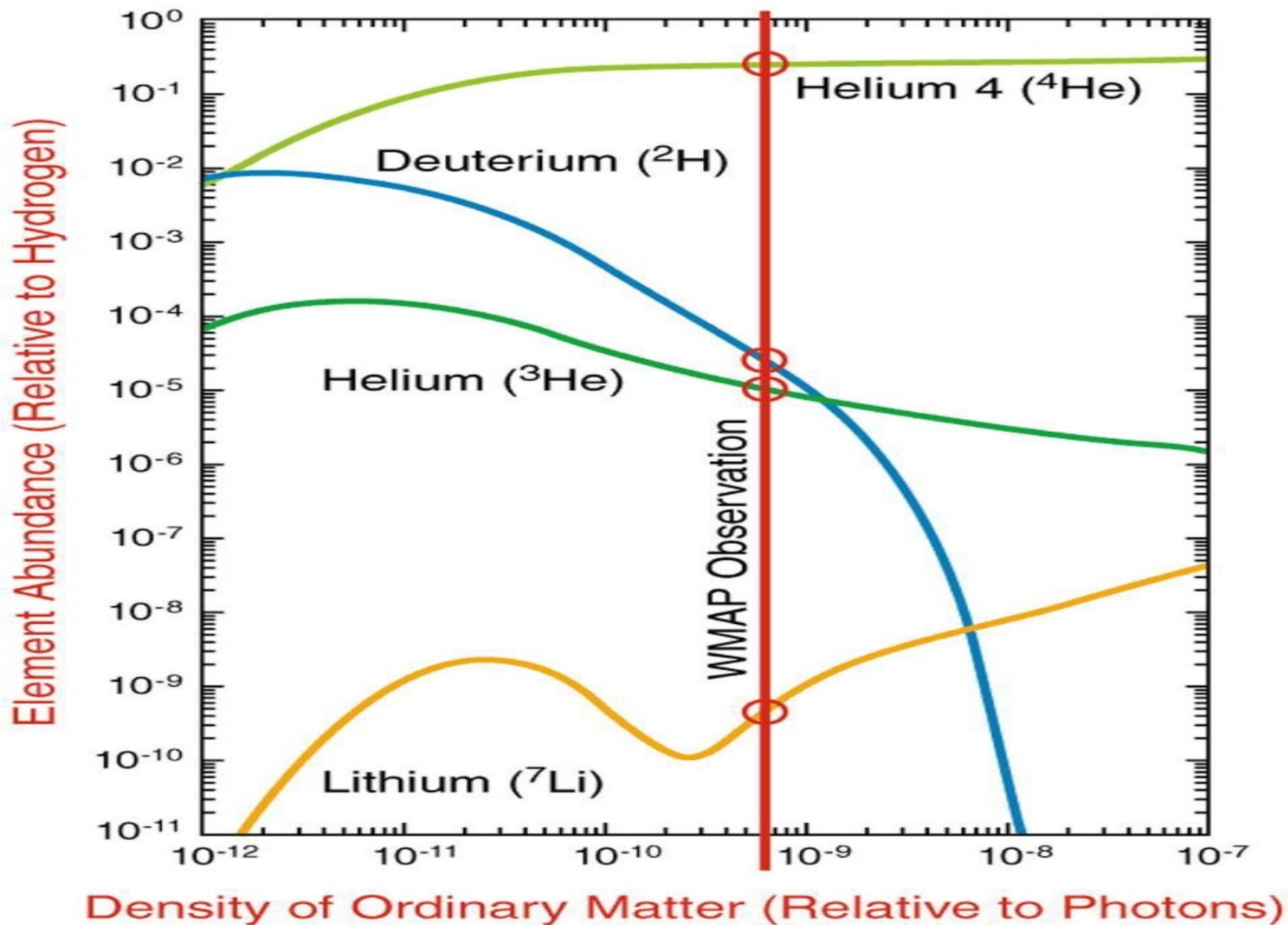
<http://astro.if.ufrgs.br/ExplorandooUniverso.html>

Energia Escura: observações de supernovas distantes de tipo Ia revelam aceleração da expansão do Universo

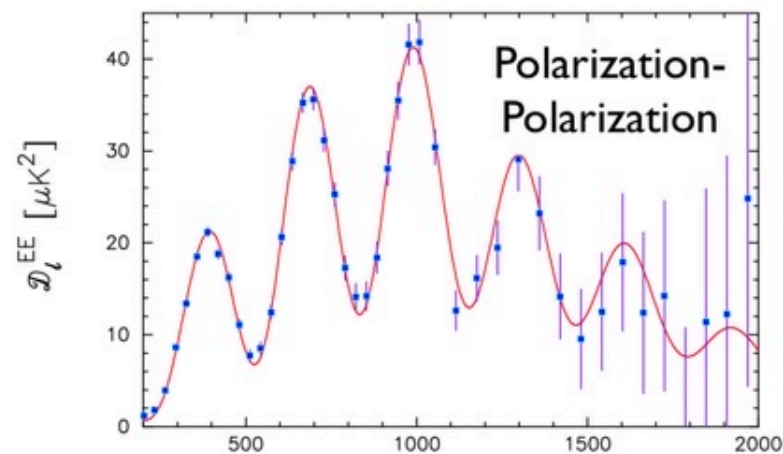
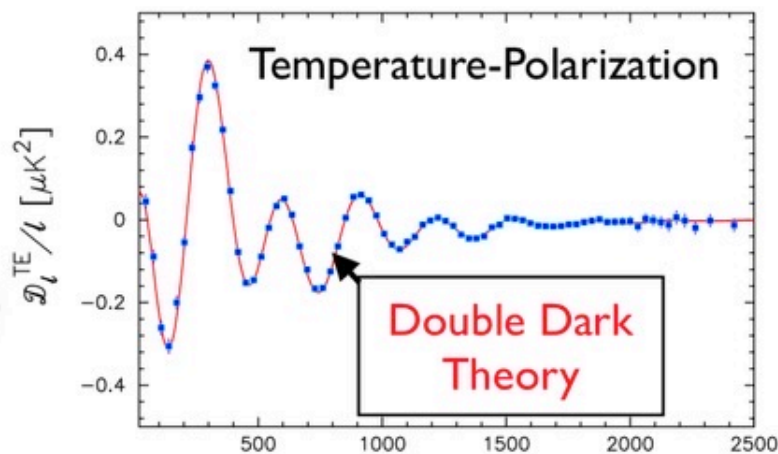
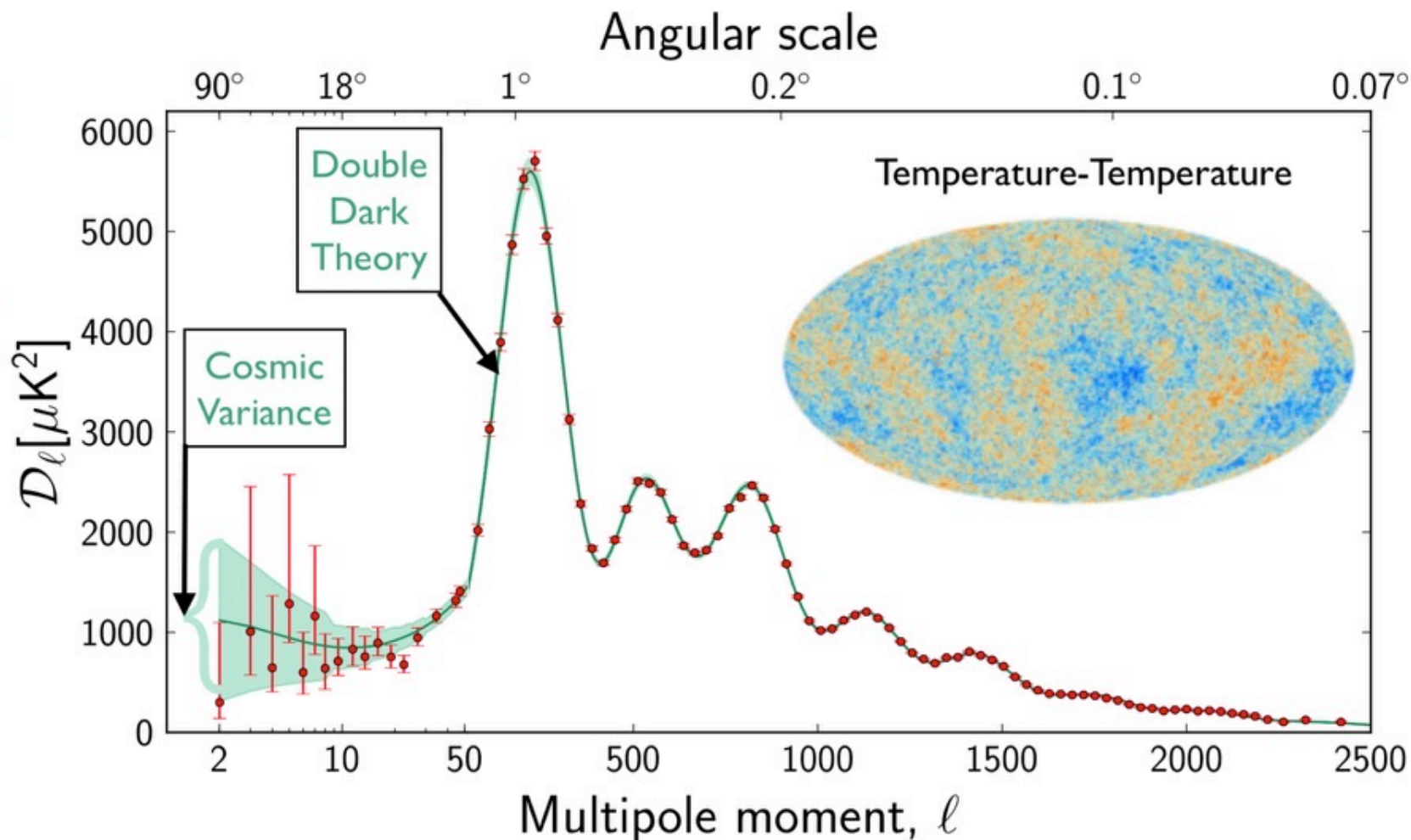
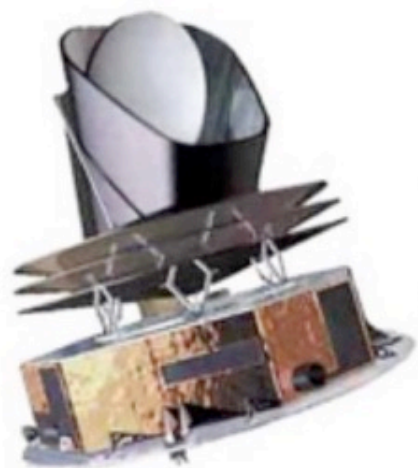




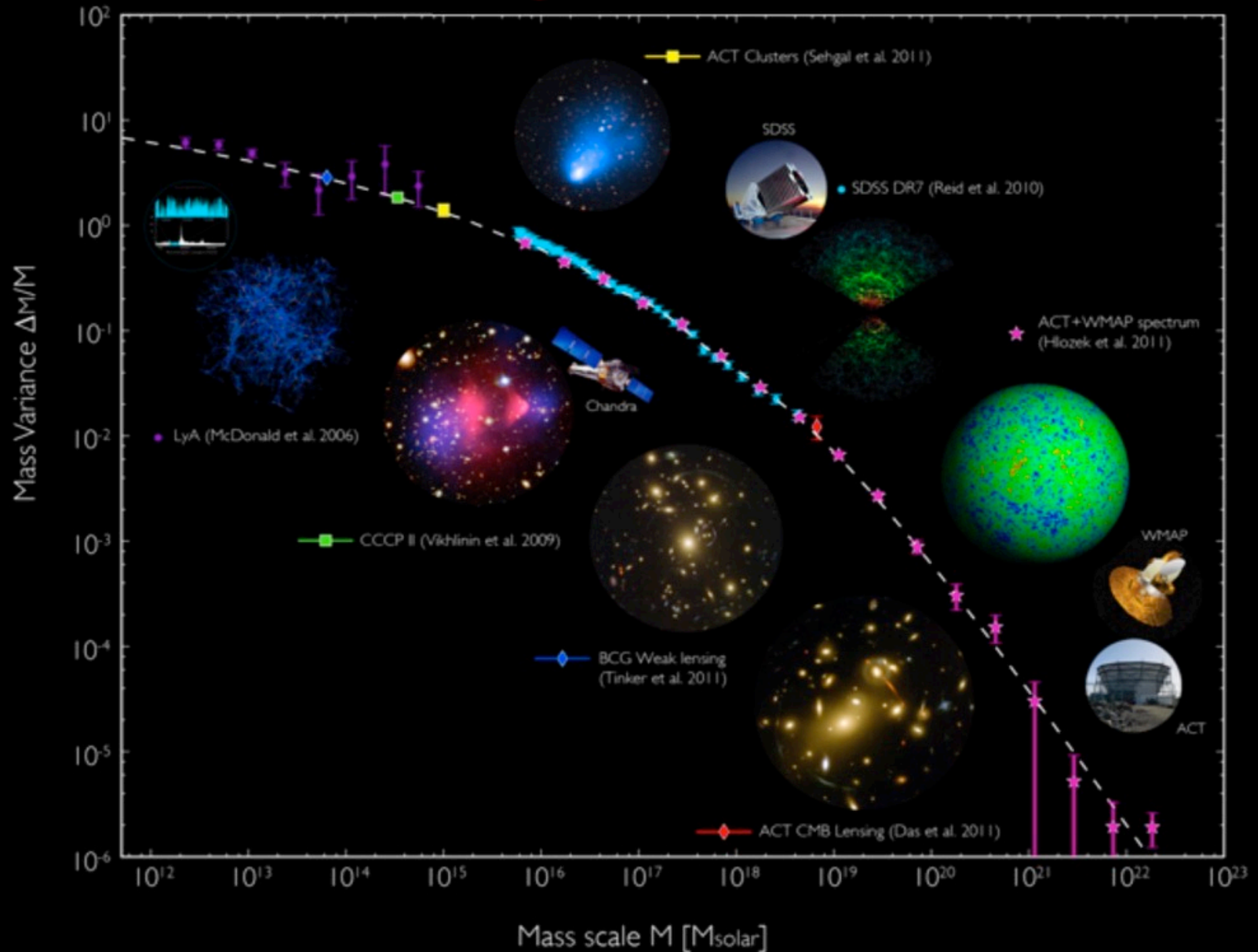
The solid line represents the best-fit flat Λ CDM Universe for SN data alone: $\Omega_\Lambda = 0.705 \pm 0.04$
 $\Omega_\Lambda = 0.729 \pm 0.014$ (SN + CMB + BAO + H_0)



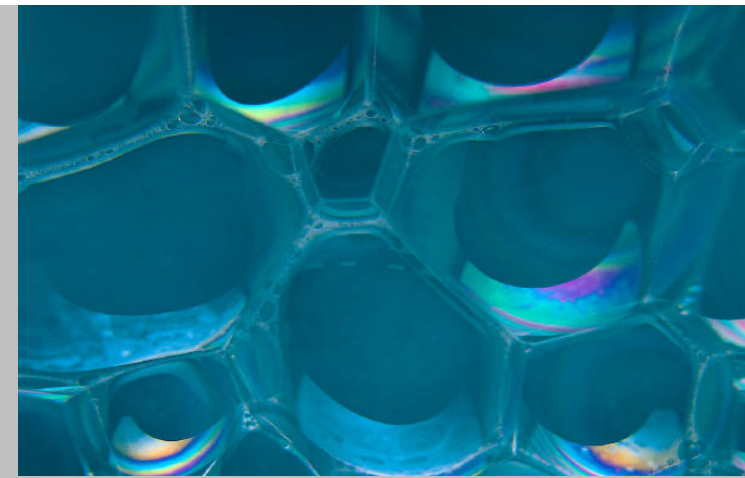
European
Space
Agency
PLANCK
Satellite
Data



Matter Distribution Agrees with Double Dark Theory!



Multiversos



Flutuações quânticas podem levar a:
Mútiplos universos, bolhas: diferentes universos - Andrei Linde.

Infinitos universos com histórias diferentes - Stephen Hawking.

