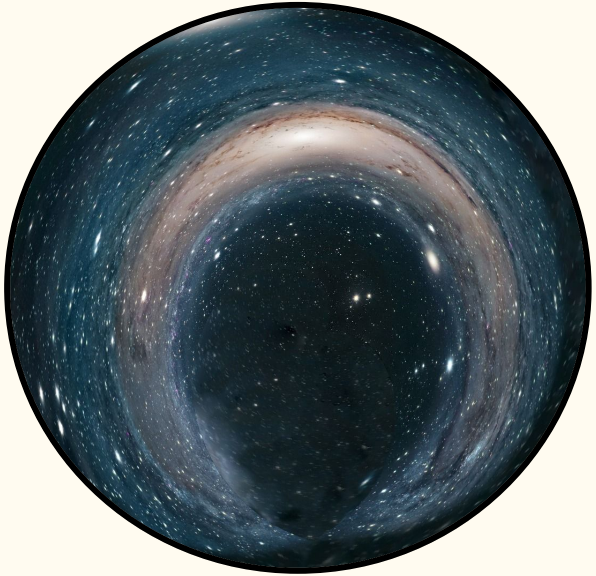
Parte 2

Cefeidas, distâncias e a expansão do universo

o universo de Einstein

o universo de Einstein



simetria esférica

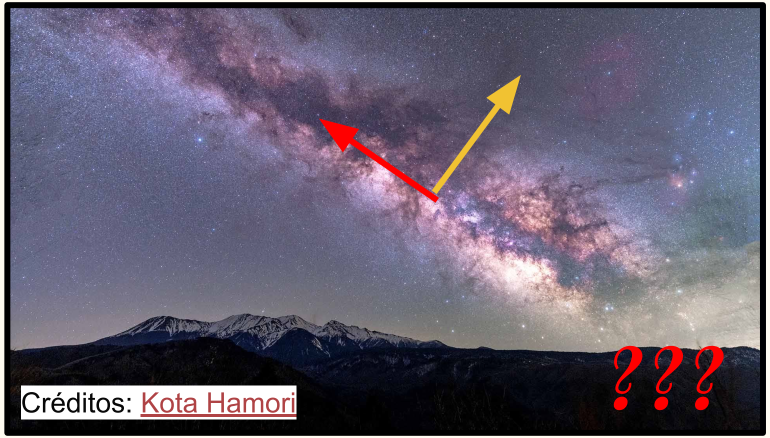
1ª solução cosmológica

§ 3. **The Spatially Finite Universe with a Uniform Distribution of Matter**

According to the general theory of relativity the metrical character (curvature) of the four-dimensional space-time continuum is defined at every point by the matter at that point and the state of that matter. Therefore, on account of the lack of uniformity in the distribution of matter, the metrical structure of this continuum must necessarily be extremely complicated. But if we are concerned with the structure only on a large scale, we may represent matter to ourselves as being uniformly distributed over enormous spaces, so that its density of distribution is a variable function which varies

There is a system of reference relatively to which matter may be looked upon as being permanently at rest. With respect to this system, therefore, the contravariant energy-tensor $T^{\mu\nu}$ of matter is, by reason of (5), of the simple form

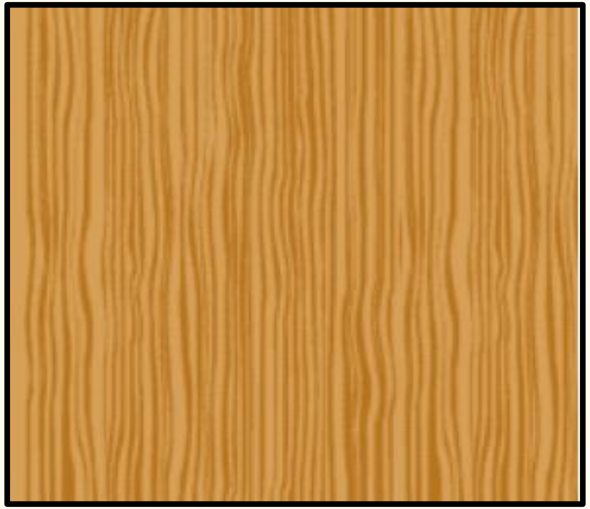
$$\left.\begin{matrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \rho \end{matrix}\right\} \quad . \quad . \quad . \quad (6)$$



Cosmological Considerations on the General Theory of Relativity, Albert Einstein (1917)

homogeneidade e isotropia

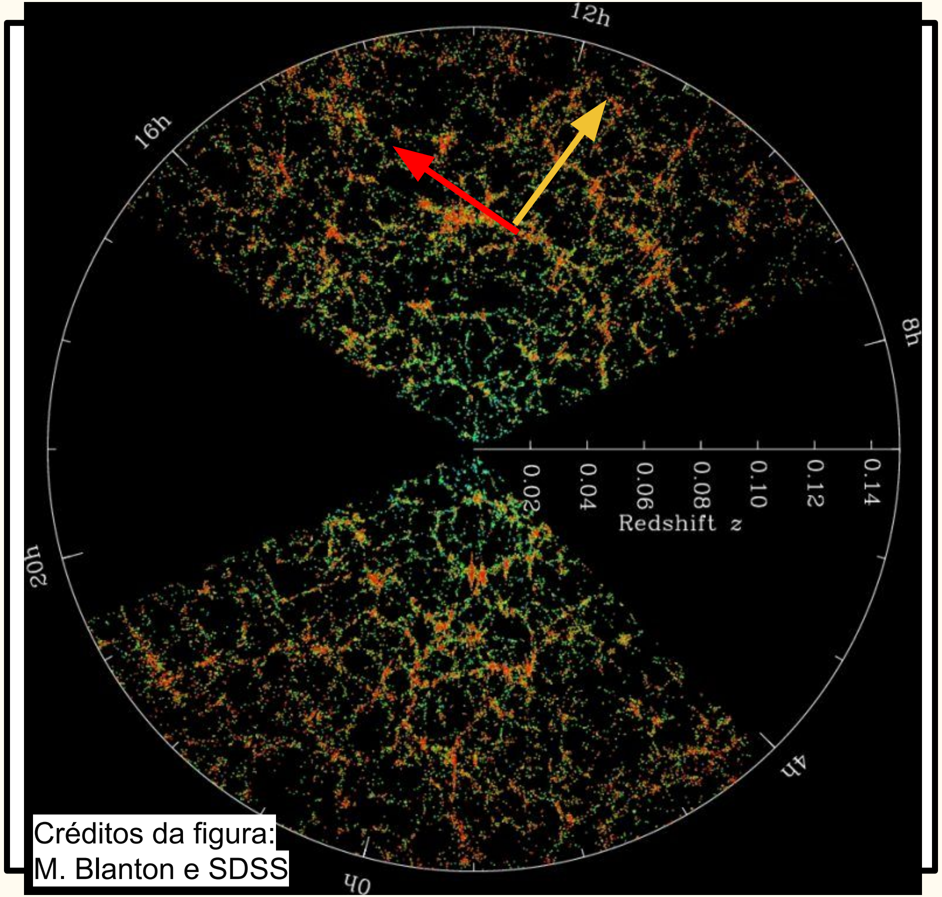
✅ homogêneo
✅ isotrópico



✅ homogêneo
❌ isotrópico

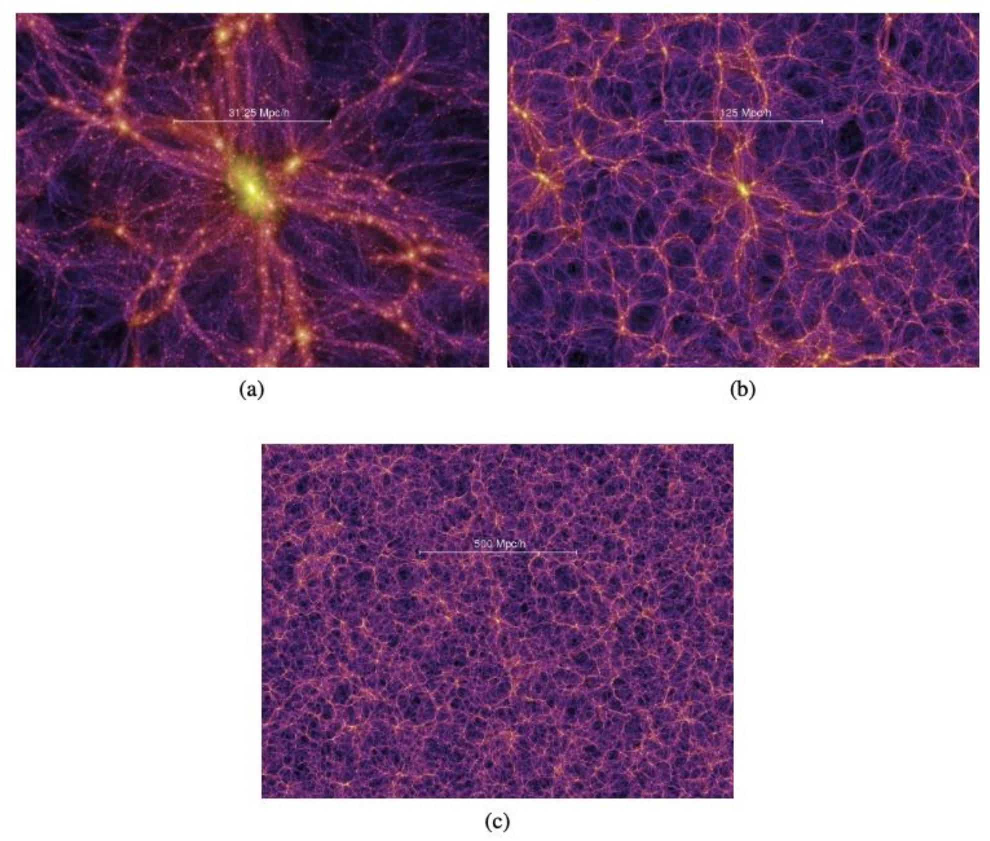
❌ homogêneo
✅ isotrópico

homogeneidade e isotropia



Introduction to Cosmology,
Barbara Ryden (2006)

homogeneidade e isotropia



1ª solução cosmológica

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

$$g_{44} = 1 \quad . \quad . \quad . \quad . \quad (7)$$

Further, as always with static problems, we shall have to set

$$g_{14} = g_{24} = g_{34} = 0 \quad . \quad . \quad . \quad (8)$$

space-time universe is also given us. For the potential $g_{\mu\nu}$, both indices of which differ from 4, we have to set

$$g_{\mu\nu} = -\left(\delta_{\mu\nu} + \frac{x_\mu x_\nu}{R^2 - (x_1^2 + x_2^2 + x_3^2)}\right) \quad . \quad (12)$$

constante

There is a system of reference relatively to which matter may be looked upon as being permanently at rest. With respect to this system, therefore, the contravariant energy-tensor $T^{\mu\nu}$ of matter is, by reason of (5), of the simple form

$$\left.\begin{matrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \rho \end{matrix}\right\} \quad . \quad . \quad . \quad (6)$$

Cosmological Considerations on the General Theory of Relativity, Albert Einstein (1917)

1ª solução cosmológica

My proposed field equations of gravitation for any chosen system of co-ordinates run as follows :—

$$\left.\begin{aligned} G_{\mu\nu} &= -\kappa(T_{\mu\nu} - \tfrac{1}{2}g_{\mu\nu}T), \\ G_{\mu\nu} &= -\frac{\partial}{\partial x_a}\{\mu\nu, a\} + \{\mu a, \beta\}\{\nu\beta, a\} \\ &\quad + \frac{\partial^2 \log\sqrt{-g}}{\partial x_\mu \partial x_\nu} - \{\mu\nu, a\}\frac{\partial \log\sqrt{-g}}{\partial x_a} \end{aligned}\right\} \quad (13)$$

The system of equations (13) is by no means satisfied when we insert for the $g_{\mu\nu}$ the values given in (7), (8), and (12), and for the (contravariant) energy-tensor of matter the values indicated in (6). It will be shown in the next paragraph how this calculation may conveniently be made. So

Cosmological Considerations on the General Theory of Relativity, Albert Einstein (1917)

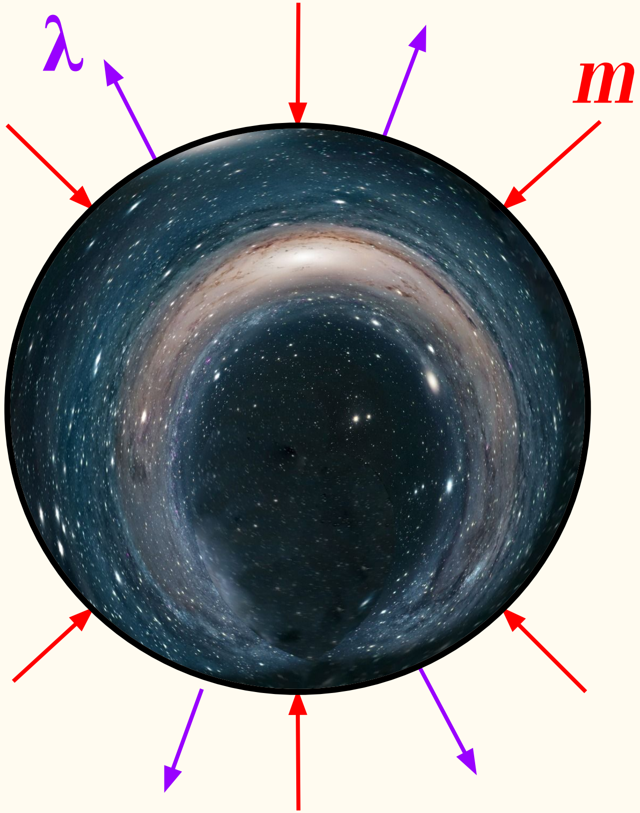
1ª solução cosmológica

constante cosmológica

unknown, without destroying the general covariance. In place of field equation (13) we write

$$G_{\mu\nu} - \lambda g_{\mu\nu} = -\kappa(T_{\mu\nu} - \tfrac{1}{2}g_{\mu\nu}T) \quad . \quad . \quad (13a)$$

will not here be discussed. In order to arrive at this consistent view, we admittedly had to introduce an extension of the field equations of gravitation which is not justified by our actual knowledge of gravitation. It is to be emphasized, however, that a positive curvature of space is given by our results, even if the supplementary term is not introduced. That term is necessary only for the purpose of making possible a quasi-static distribution of matter, as required by the fact of the small velocities of the stars.



tamanho do cosmos

Na época, cosmos = Via Lactea

Distância do diâmetro angular não ajudava

fim do séc XVIII	contagem de estrelas em diferentes direções	~mil anos-luz
fim do séc XIX	paralaxe, estimativa da magnitude aparente das estrelas	~mil a 100 mil anos-luz
início do séc XX	velas padrão • aglomerados globulares estrelas variáveis	~100 mil anos-luz

universos-ilhas

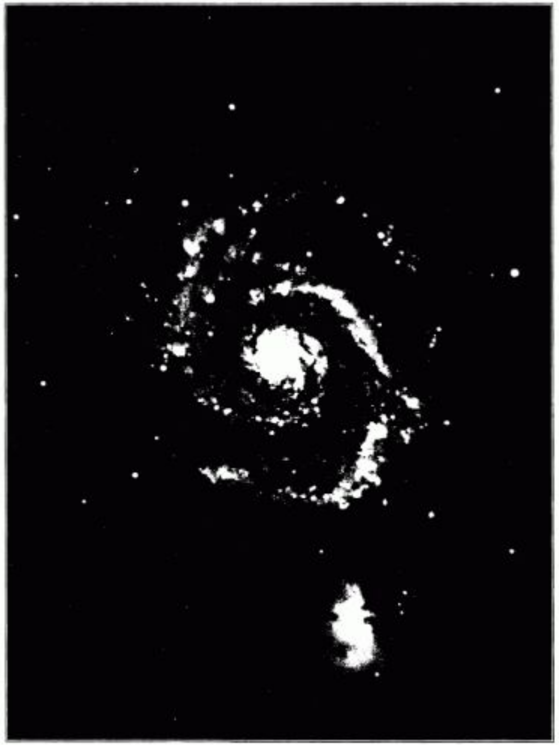


PLATE IV

South

SPIRAL NEBULA *Messier 51 Canum Venaticorum*

Photographed with 60-Inch Reflector on Seed 23 plate, February 7 and 8, 1910
Exposure $3^h\ 55^m$. Enlargement from negative 6.4 diameters. Scale: 1 mm = 4.″2

Credit: *G. W. Ritchey, 1910, ApJ 32, Plate IV*

universos-ilhas

nebulosa espiral

vs

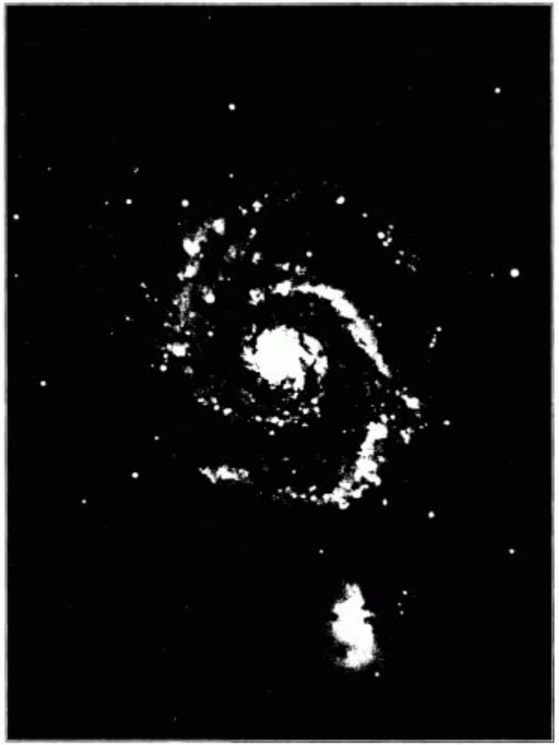
outra galáxia

Algumas referências:

- Hubble's Announcement of Cepheids in Spiral Nebulae, Berendzen, R. & Hoskin, M. (1967)
- site da Nasa sobre o Grande Debate

PLATE IV

South



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universos-ilhas

nebulosa espiral

Harlow Shapley

VS

outra galáxia

Heber Curtis

link da fofoca

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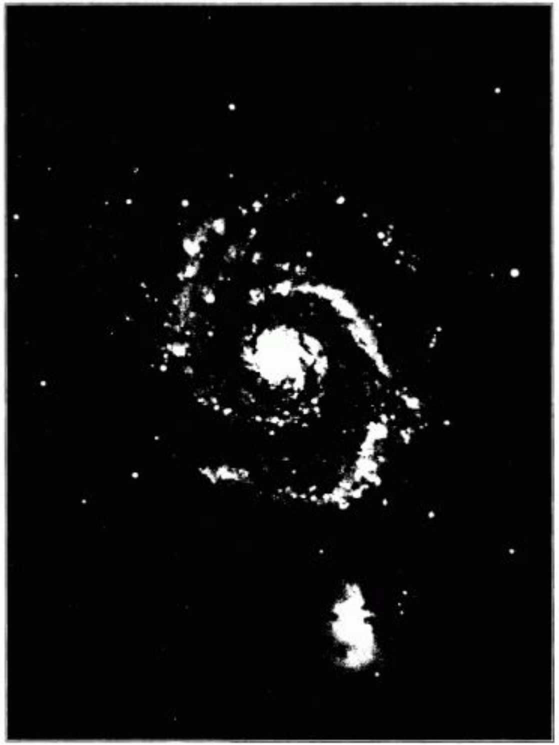

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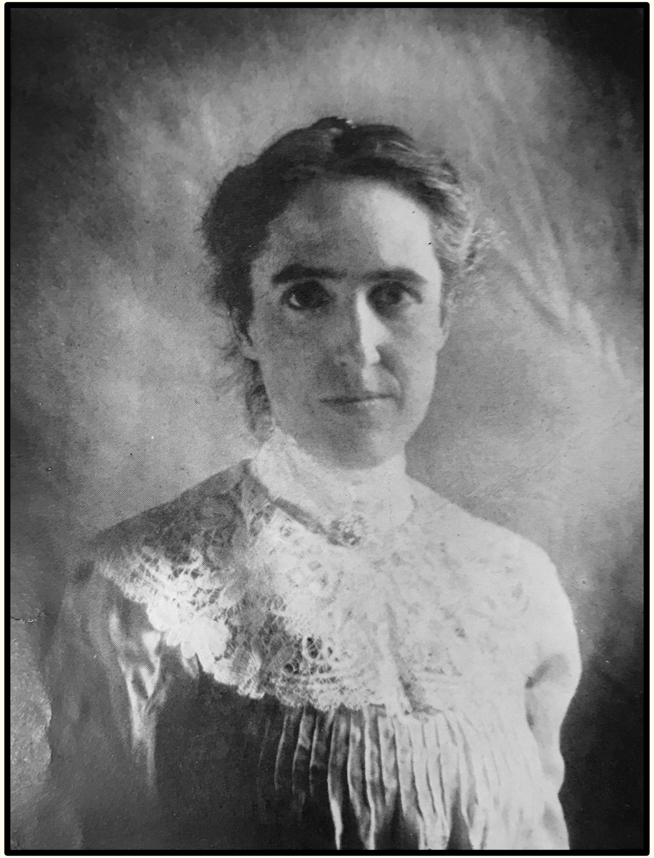
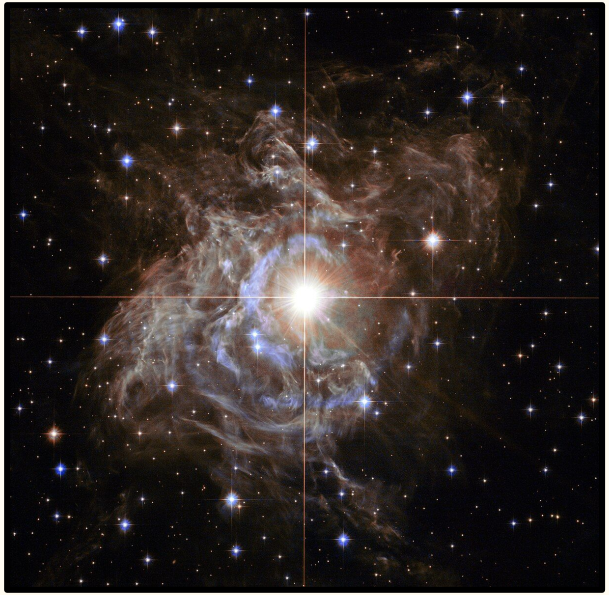
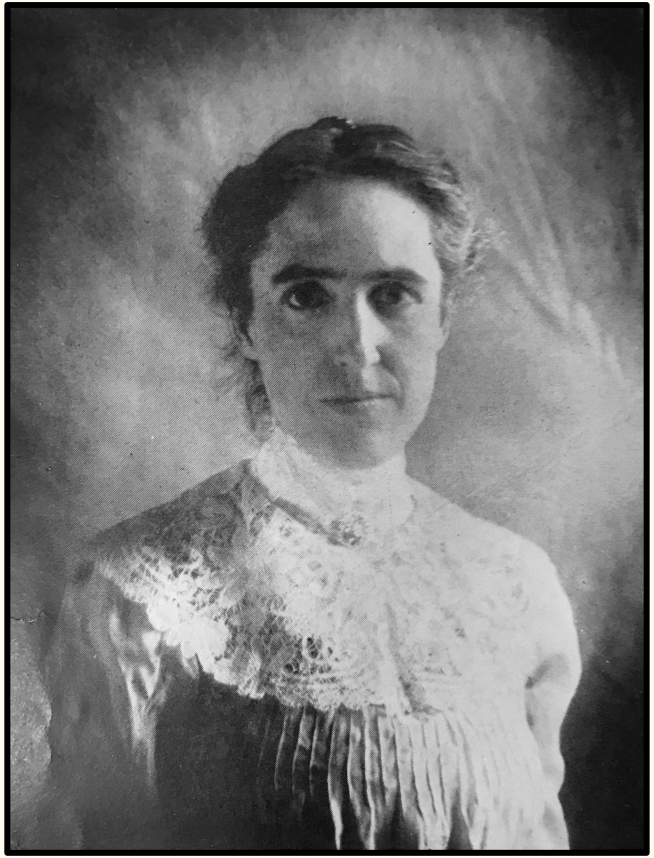
Henrietta Leavitt

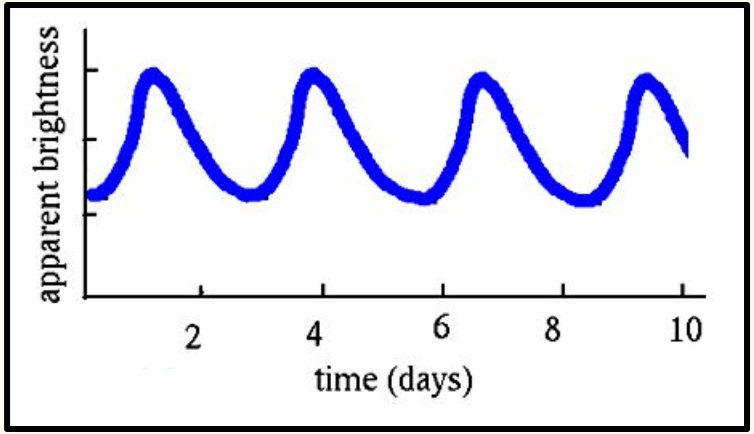




- Observações na Grande Nuvem de Magalhães (1912)
- Estrelas variáveis (como RR Lyrae de Shapley)
- Mais brilhantes

Henrietta Leavitt





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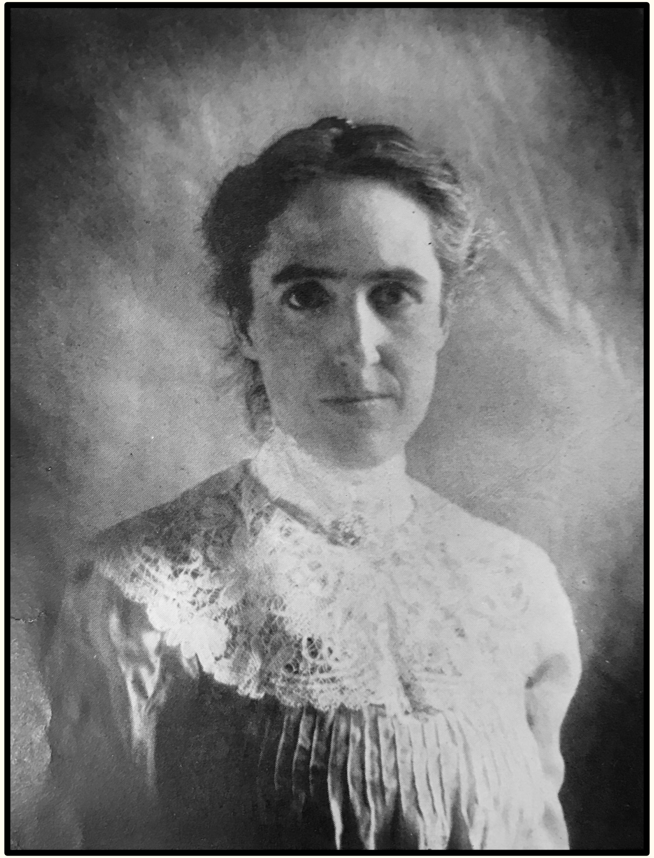

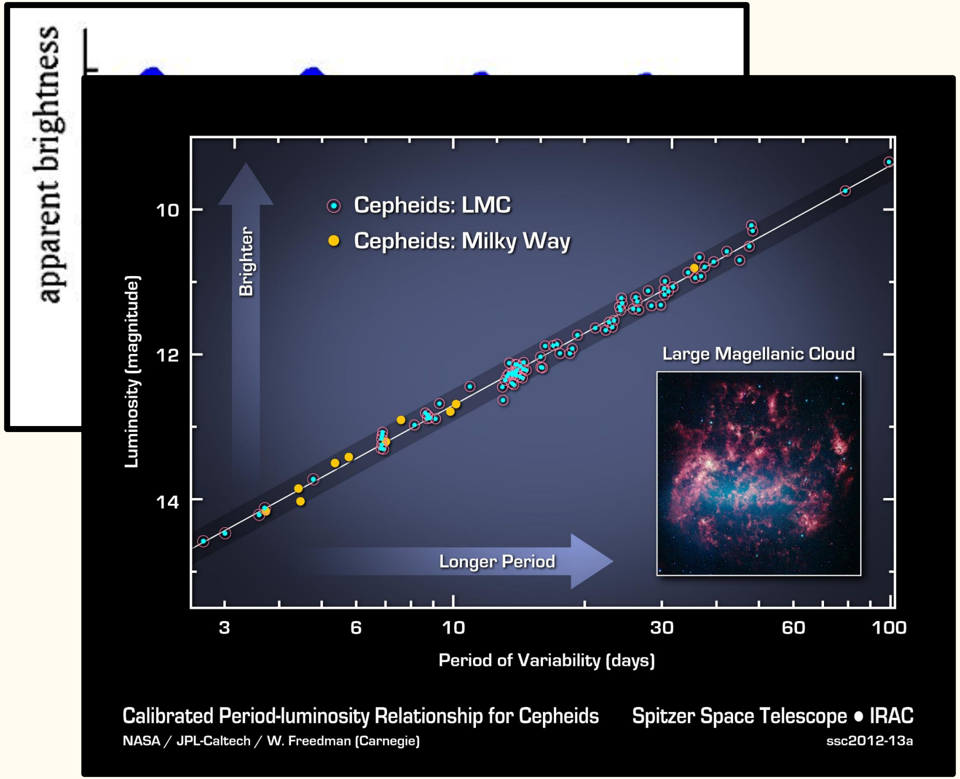

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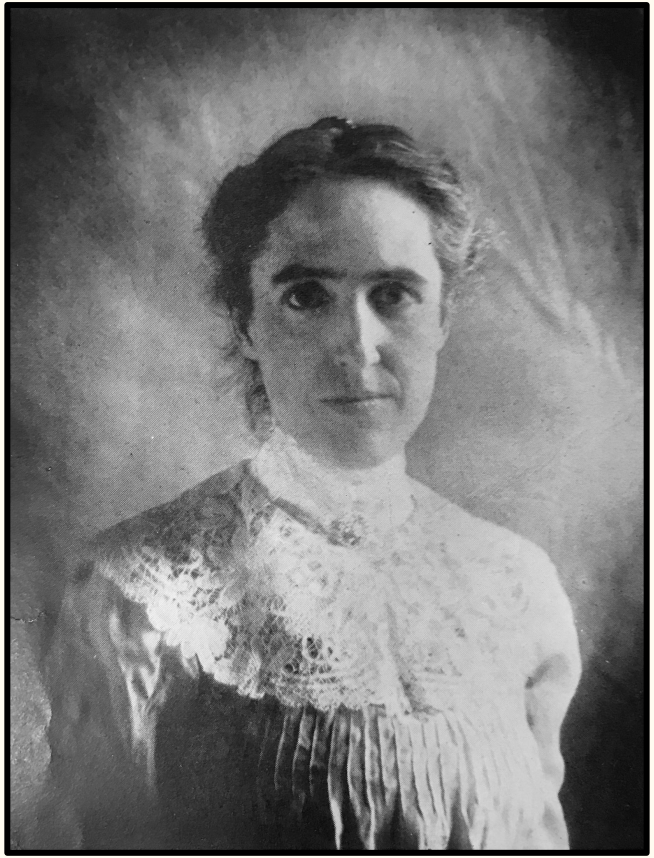
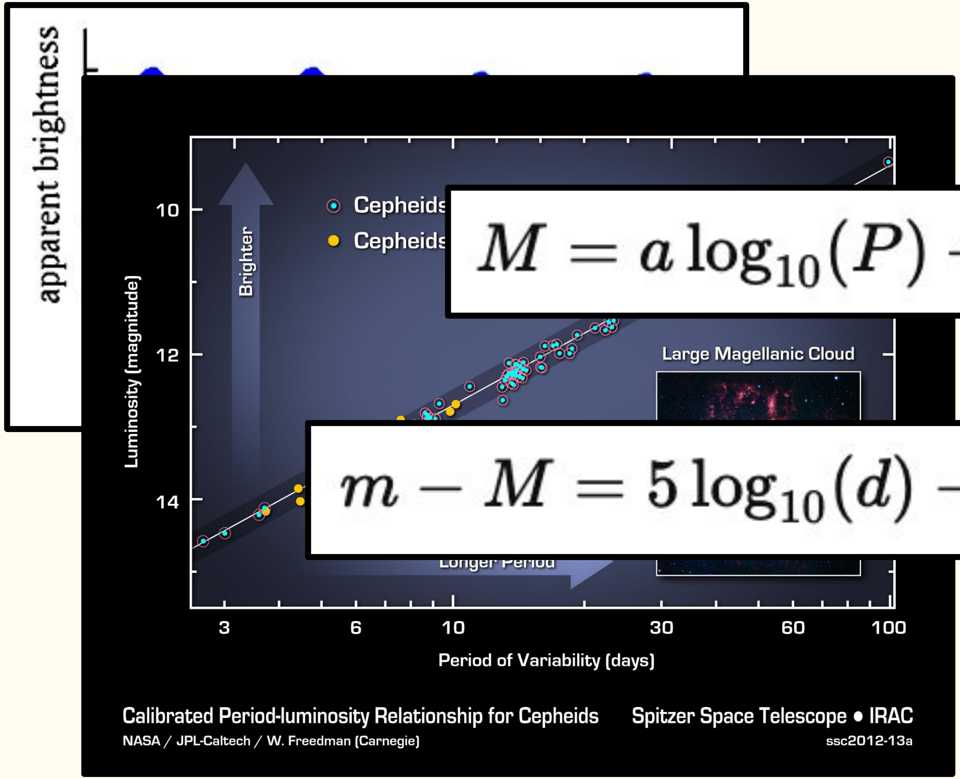


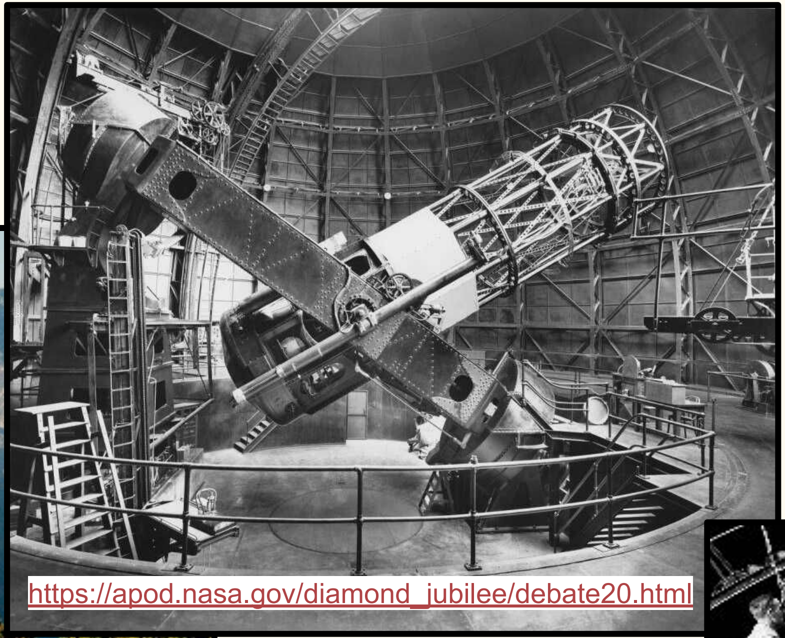


$$M = a\log_{10}(P) + b$$

$$m - M = 5\log_{10}(d) - 5$$

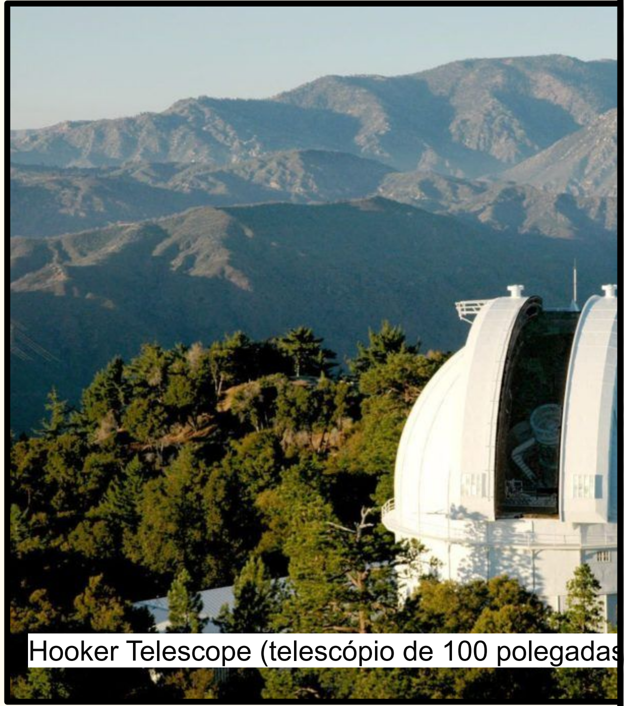
Hubble

Hooker Telescope (telescópio de 100 polegadas) no Monte Wilson

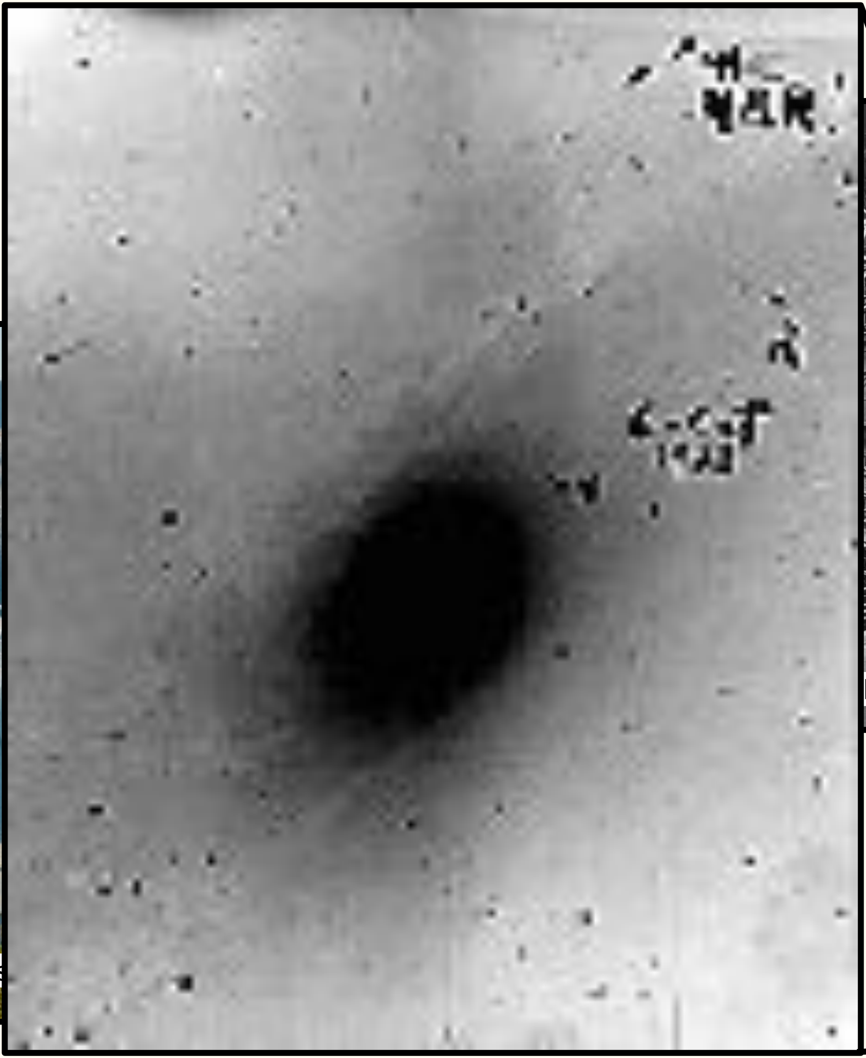


https://apod.nasa.gov/diamond_jubilee/debate20.html

Hubble



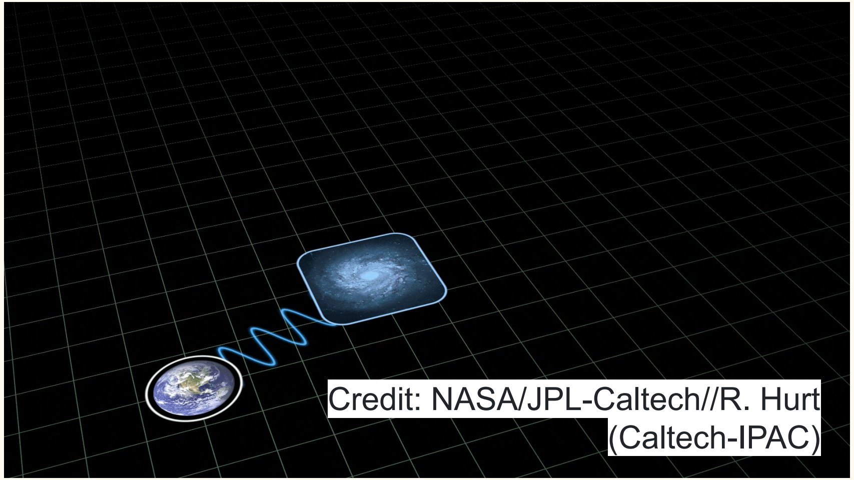
Hooker Telescope (telescópio de 100 polegadas



html

expandindo a(s) galáxia(s)

1. *usar cefeidas para calcular distâncias de outras nebulosas espirais*
2. *estudar o comportamento delas, como a* ***velocidade***



redshift *(ou avermelhamento)****:***

"efeito doppler" das ondas eletromagnéticas

$$\boxed{z = \frac{\lambda_{\mathrm{obs}} - \lambda_0}{\lambda_0}}$$

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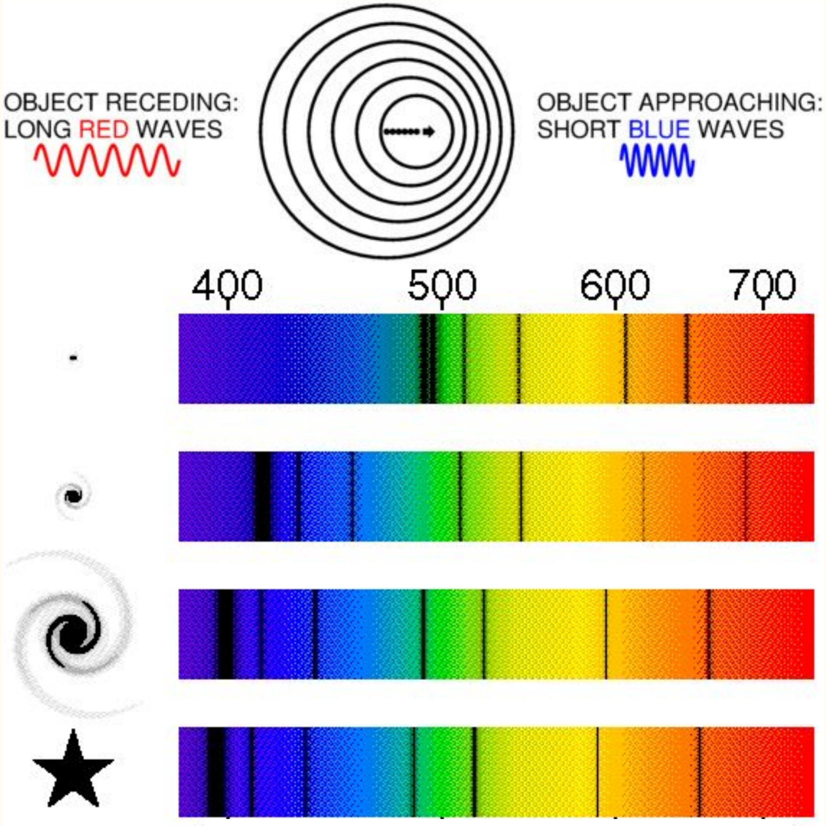
$$\boxed{v \approx cz}$$



https://astro.ucla.edu/~wright/doppler.htm

diagrama de Hubble

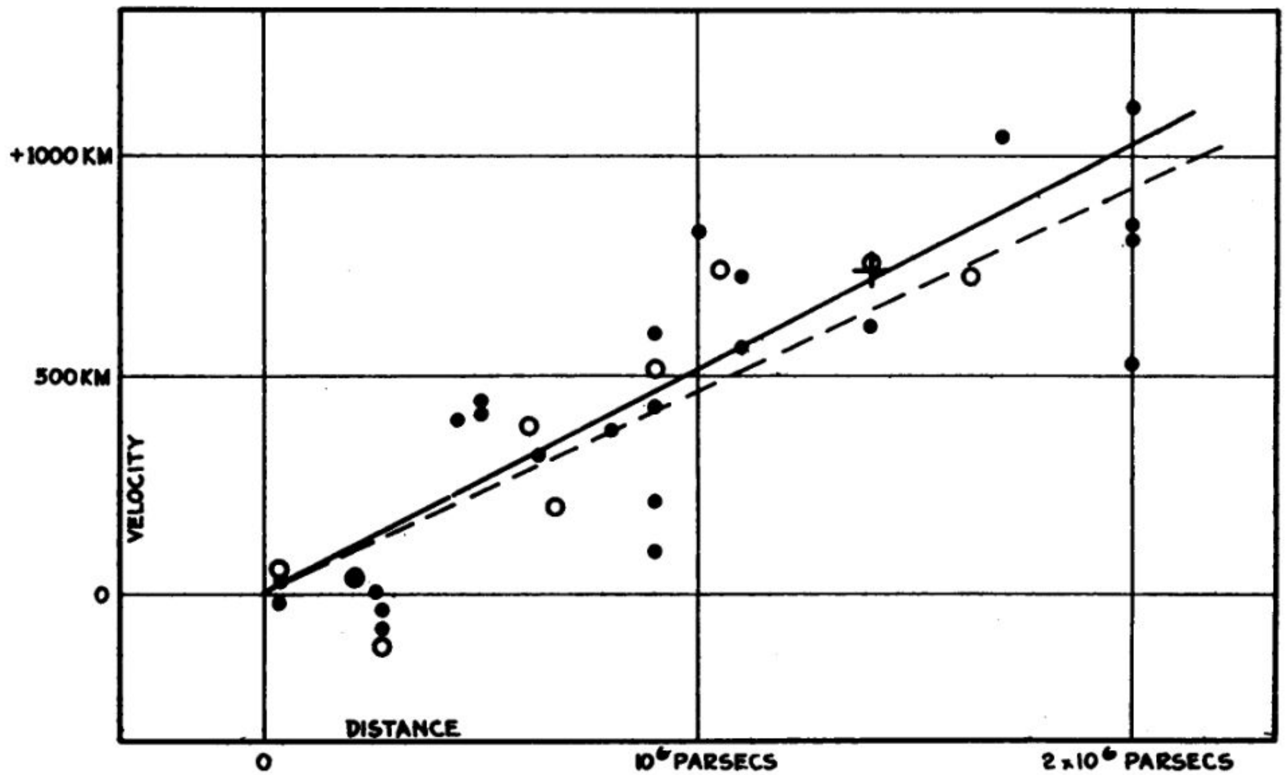


FIGURE 1

$$v = H_0 d$$

$$[H_0] = \frac{[v]}{[d]} = \frac{km}{s}\frac{1}{Mpc} = \frac{km/s}{Mpc}$$

“For this reason it is thought premature to discuss in detail the obvious consequences of the present results.”

A relation between distance and radial velocity among extra-galactic nebulae,
Edwin Hubble (1929)

Friedmann

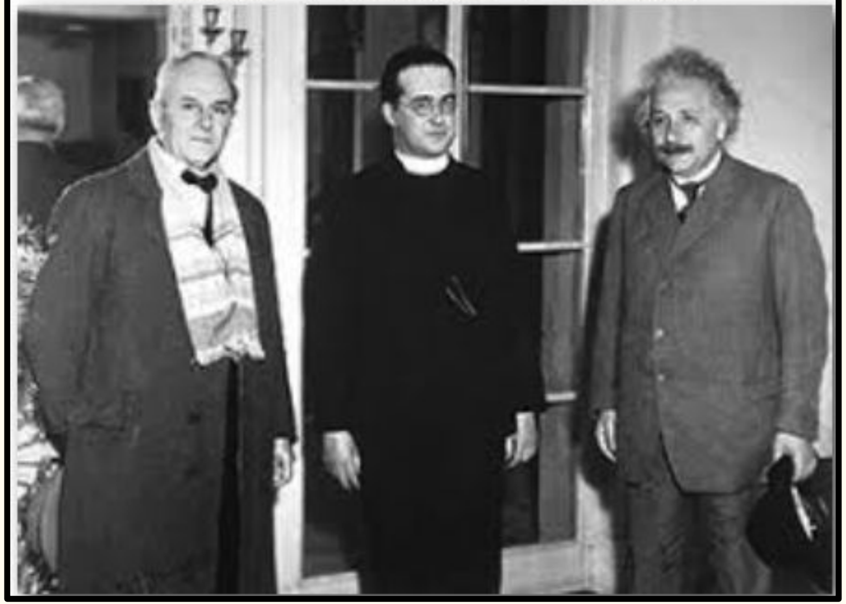
Lemaître

Robertson

Walker

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

Hubble , Lemaître , Einstein



Friedmann

Lemaître

Robertson

Walker

$$g_{\mu\nu} = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & a^2(t) & 0 & 0 \\ 0 & 0 & a^2(t) & 0 \\ 0 & 0 & 0 & a^2(t) \end{pmatrix}$$

$$T^{\mu}{}_{\nu} = \begin{pmatrix} -\rho & 0 & 0 & 0 \\ 0 & p & 0 & 0 \\ 0 & 0 & p & 0 \\ 0 & 0 & 0 & p \end{pmatrix}$$

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

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$$R_{\mu\nu} - \tfrac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$$\left(\frac{\dot{a}}{a}\right)^2 + \frac{kc^2}{a^2} = \frac{8\pi G}{3}\rho + \frac{\Lambda c^2}{3}$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda c^2}{3}$$

entendendo $a(t)$

$$d(t) = a(t)d_0$$

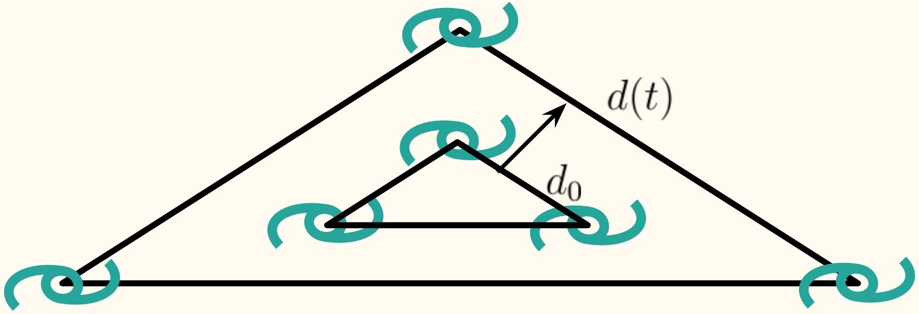
$$\dot{d}(t) = \dot{a}(t)d_0$$

$$v = \dot{a}(t)d_0$$

$$\frac{v}{d} = \frac{\dot{a}}{a}\frac{d_0}{d_0}$$

$$v = \frac{\dot{a}}{a}d$$

$$v = H(t)d$$



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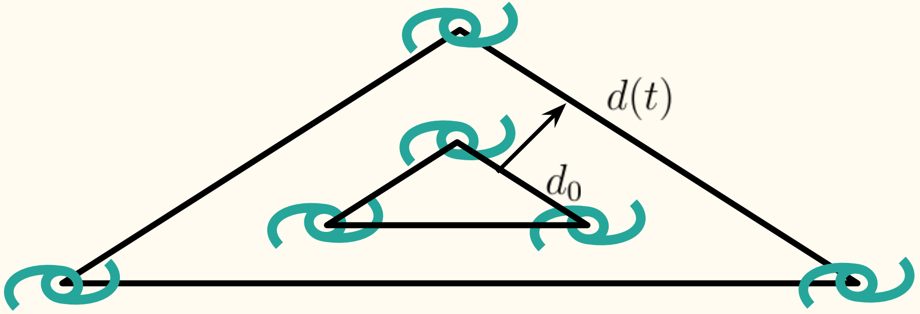
$$\boxed{H(t) \equiv \frac{\dot{a}(t)}{a(t)}}$$

parâmetro de Hubble



entendendo $a(t)$

$$d(t) = a(t)d_0$$

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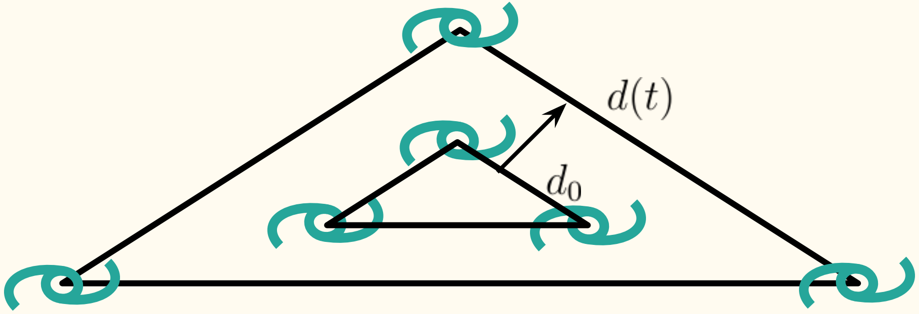

$$\boxed{H(t) \equiv \frac{\dot{a}(t)}{a(t)}}$$

parâmetro de Hubble

$$\boxed{H(t_0) \equiv H_0 \sim 70km/s/Mpc}$$

hoje em dia

universo observável e idade

1. E se d for grande o suficiente para que $v = c$?

$$c = H_0 D_H$$

$$D_H = \frac{c}{H_0}$$

$$D_H = \frac{3 \cdot 10^5 km/s}{70 km/s/Mpc} = 4 \cdot 10^3 Mpc = 4 Gpc$$

universo observável e idade

1. E se d for grande o suficiente para que $v = c$?

$$c = H_0 D_H$$
$$D_H = \frac{c}{H_0}$$
$$D_H = \frac{3 \cdot 10^5 km/s}{70 km/s/Mpc} = 4 \cdot 10^3 Mpc = 4 Gpc$$

2 Qual o tempo que a luz leva para percorrer essa distância?

$$\begin{aligned} T_H &= \frac{D_H}{c} \\ &= \frac{c}{cH_0} \\ &= \frac{1}{H_0} \\ &= \frac{1}{70 km/s/Mpc} = \frac{1}{70} \frac{1}{3,24 \cdot 10^{-20} s{-1}} = 4,4 \cdot 10^{-17} s \\ &= 14 Gyr \end{aligned}$$

universo observável e idade

1. E se d for grande o suficiente para que $v = c$?

$$c = H_0 D_H$$

$$D_H = \frac{c}{H_0}$$

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2 Qual o tempo que a luz leva para percorrer essa

Qual o problema com essas contas??

$$= \frac{c}{cH_0}$$

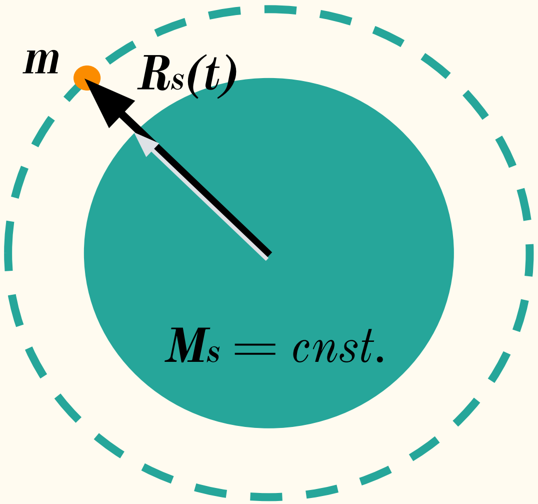
$$= \frac{1}{H_0}$$

$$= \frac{1}{70 km/s/Mpc} = \frac{1}{70} \frac{1}{3,24 \cdot 10^{-20} s{-1}} = 4,4 \cdot 10^{-17} s$$

$$= 14 Gyr$$

FLRW "newtoniano"

$$\boxed{F = -\frac{GM_s m}{R_s^2(t)}}$$



FLRW "newtoniano"

$$F = -\frac{GM_s m}{R_s^2(t)}$$

$$\frac{d^2R_s}{dt^2} = -\frac{GM_s}{R_s^2(t)}$$

Multiplicando ambos os membros por dR_s/dt e integrando, obtemos:

$$\frac{1}{2}\left(\frac{dR_s}{dt}\right)^2 = \frac{GM_s}{R_s(t)} + U$$

, sendo U uma constante de integração.

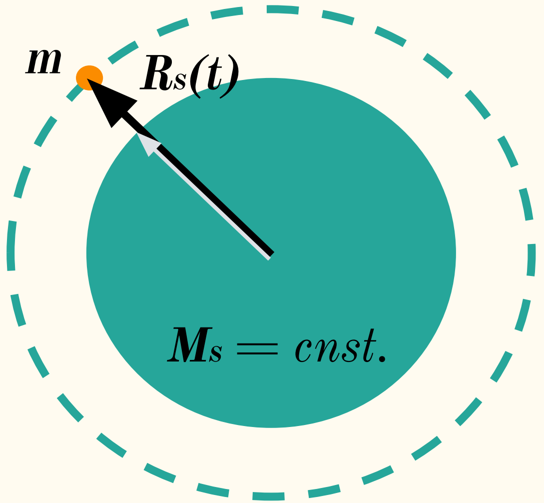
Energia cinética por unidade de massa

Energia potencial gravitacional por unidade de massa

FLRW “newtoniano”

$$\boxed{\frac{1}{2}\left(\frac{dR_s}{dt}\right)^2 = \frac{GM_s}{R_s(t)} + U}$$

a soma dessas duas grandezas se conserva para uma massa na superfície da esfera, enquanto e esfera se expande ou se contrai



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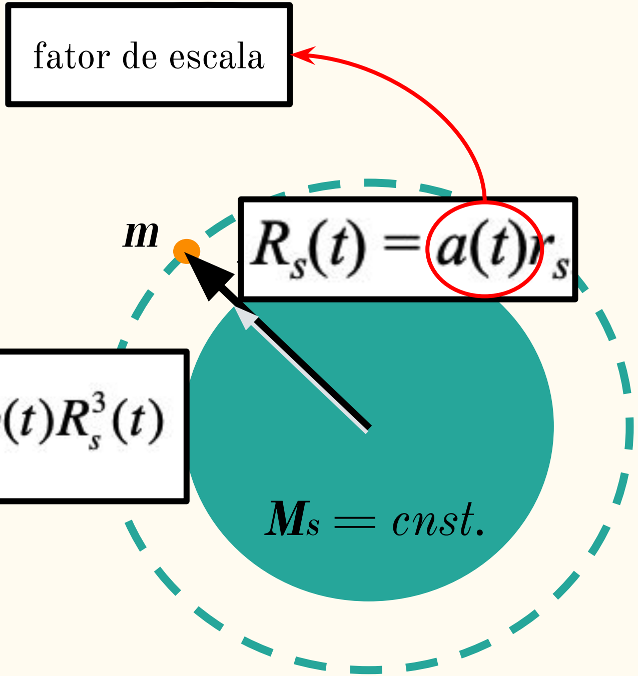
$$\boxed{M_s = \frac{4\pi}{3}\rho(t)R_s^3(t)}$$



FLRW "newtoniano"

$$\frac{1}{2}\left(\frac{dR_s}{dt}\right)^2 = \frac{GM_s}{R_s(t)} + U \rightarrow \frac{1}{2} r_s^2 \dot{a}^2 = \frac{4\pi}{3} G r_s^2 \rho(t) a^2(t) + U$$

a soma dessas duas grandezas se conserva para uma massa na superfície da esfera, enquanto e esfera se expande ou se contrai

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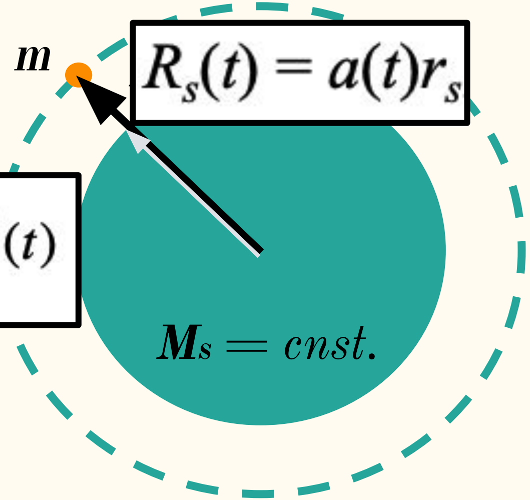
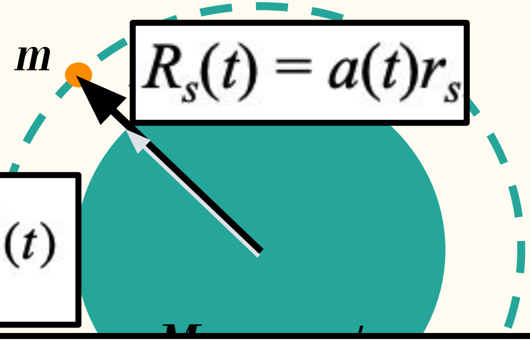


FLRW “newtoniano”

$$\frac{1}{2}\left(\frac{dR_s}{dt}\right)^2 = \frac{GM_s}{R_s(t)} + U \;\rightarrow\; \frac{1}{2} r_s^2 \dot{a}^2 = \frac{4\pi}{3} G r_s^2 \rho(t) a^2(t) + U$$

a soma dessas duas grandezas se conserva para uma massa na superfície da esfera, enquanto e esfera se expande ou se contrai



$$R_s(t) = a(t) r_s$$

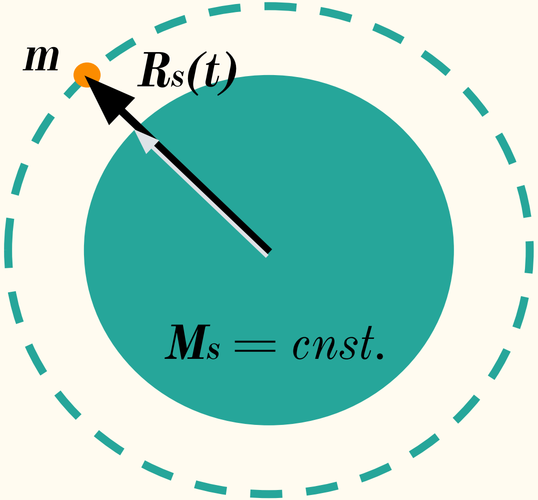
$$M_s = \frac{4\pi}{3}\rho(t) R_s^3(t)$$

Dividindo os membros por $r_s^2 a^2/2$ $\Rightarrow \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t) + \frac{2U}{r_s^2}\frac{1}{a^2(t)}$

FLRW "newtoniano"

densidade $\rho(t)$ → energia relativística $E^2 = m^2c^4 + p^2c^2$

$\frac{2U}{r_s^2}$ → $-kc$



1ª equação de Friedmann

$$\boxed{\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t) - \frac{kc}{a^2(t)}}$$

FLRW "newtoniano"

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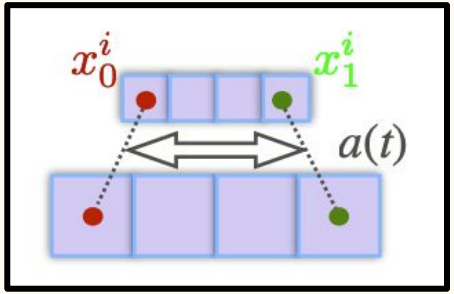
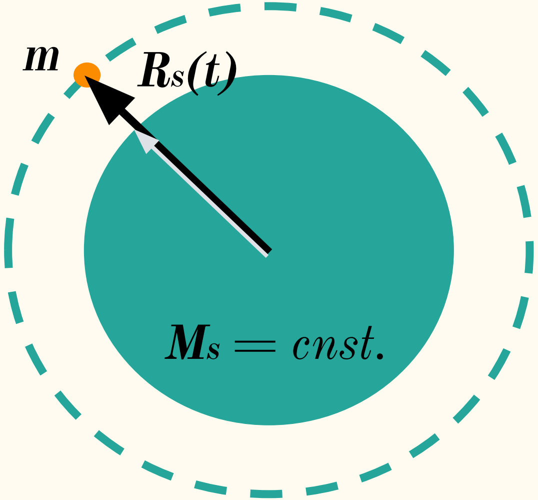
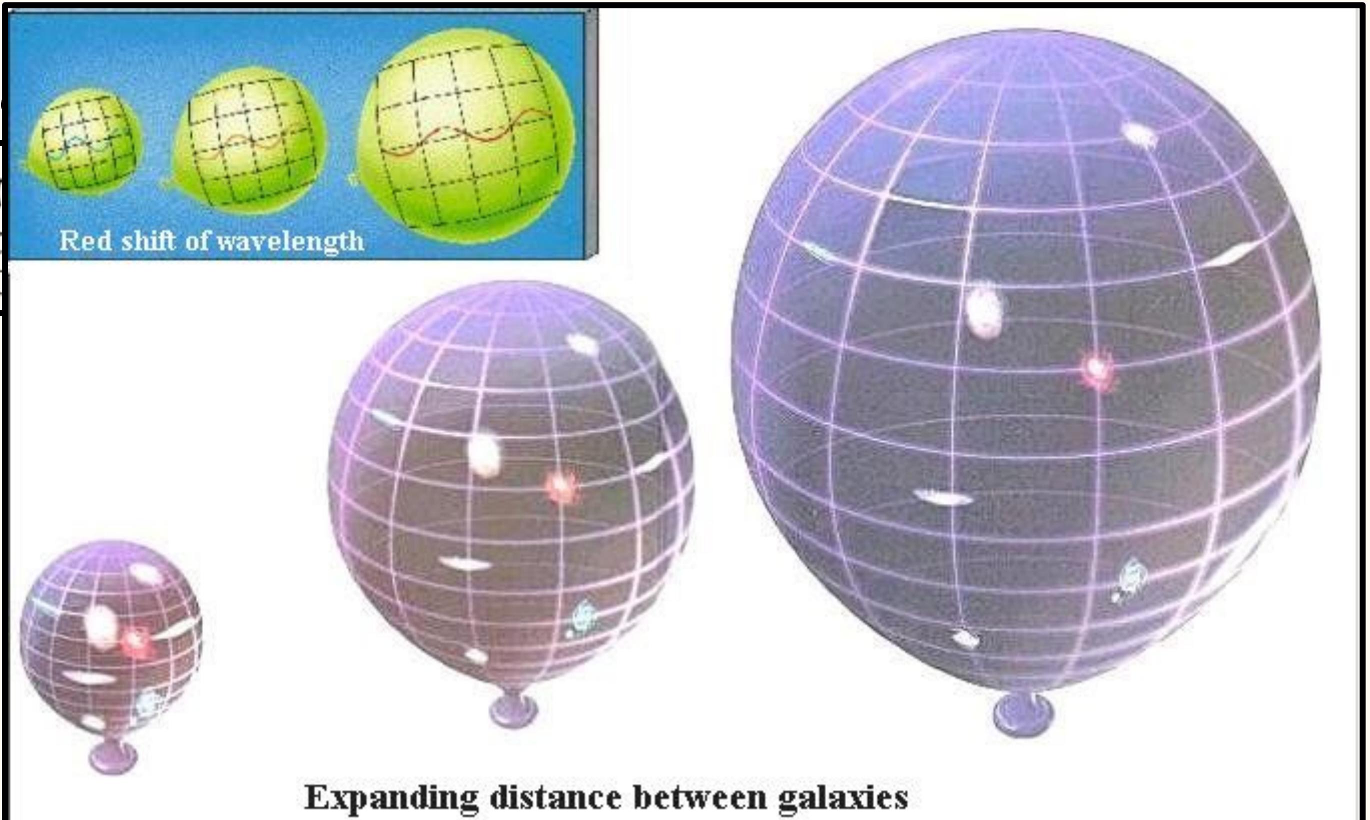




FLRW “newtoniano”

1ª equação



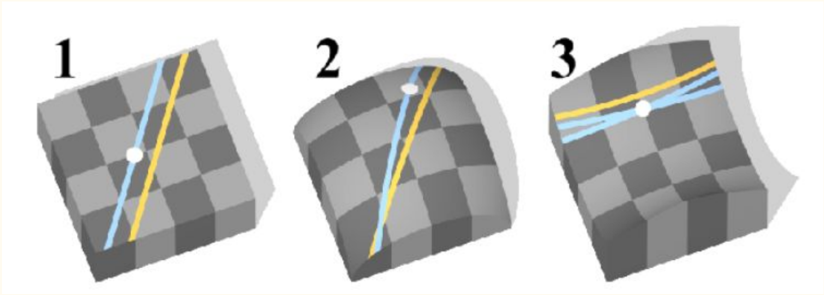
https://universe-review.ca/R15-17-relativity08.htm

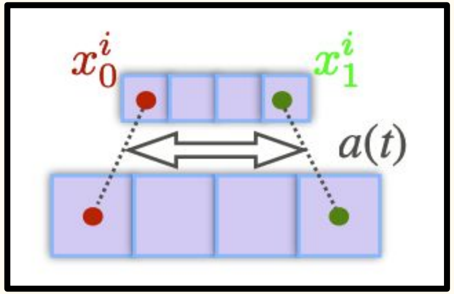
FLRW “newtoniano”

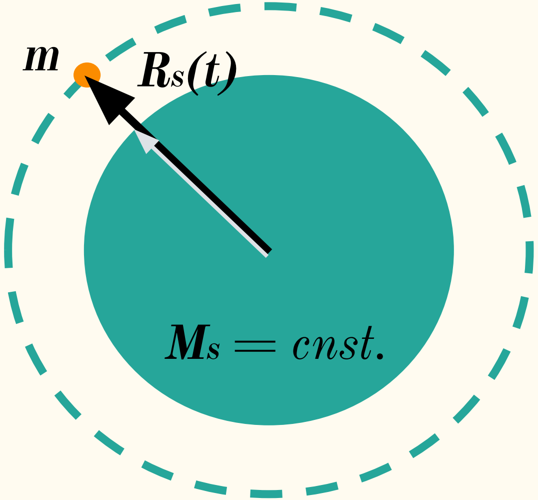
1ª equação de Friedmann

$$\boxed{\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t) - \frac{kc}{a^2(t)}}$$

$$\begin{cases} \mathrm{k} = +1 & \text{(curvatura positiva)} \\ \mathrm{k} = -1 & \text{(curvatura negativa)} \\ \mathrm{k} = 0 & \text{(geometria plana)} \end{cases}$$







FLRW “newtoniano”

1ª equação de Friedmann

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t) - \frac{kc}{a^2(t)}$$

mas

$$\rho(t) = \rho_m(t) + \rho_r(t) + \rho_\Lambda(t) + \ldots$$
$$= \frac{\rho_{m,0}}{a^3(t)} + \frac{\rho_{r,0}}{a^4(t)} + \rho_{\Lambda,0} + \ldots$$

$$H(t) \equiv \frac{\dot{a}}{a}$$

FLRW "newtoniano"

1ª equação de Friedmann

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho(t) - \frac{kc}{a^2(t)}$$

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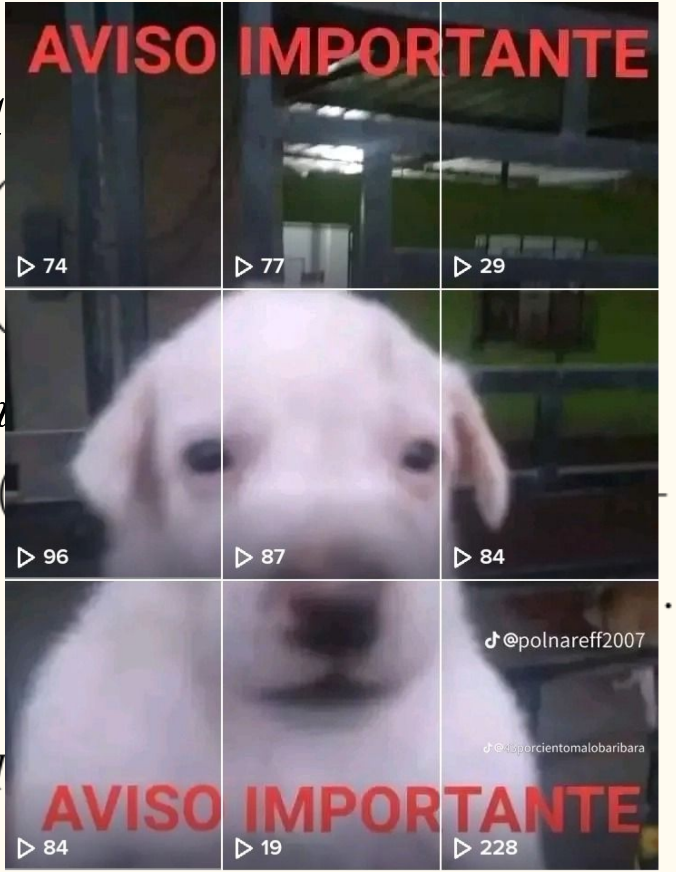
$$H(t) \equiv \frac{\dot{a}}{a}$$

$$H^2(t) = \frac{8\pi G}{3}\left(\frac{\rho_{m,0}}{a^3(t)} + \frac{\rho_{r,0}}{a^4(t)} + \rho_{\Lambda,0}\right) - \frac{kc}{a^2(t)}$$

$$\boxed{H^2(t) = H_0^2\left(\frac{\Omega_m}{a^3(t)} + \frac{\Omega_r}{a^4(t)} + \Omega_\Lambda + \frac{\Omega_k}{a^2(t)}\right)}$$

FLRW “newtoniano”



$$H^2(t) = \frac{8\pi G}{3}\left(\frac{\rho_{m,0}}{a^3(t)} + \frac{\rho_{r,0}}{a^4(t)} + \rho_{\Lambda,0}\right) - \frac{kc}{a^2(t)}$$

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átomo primordial de Lemaître

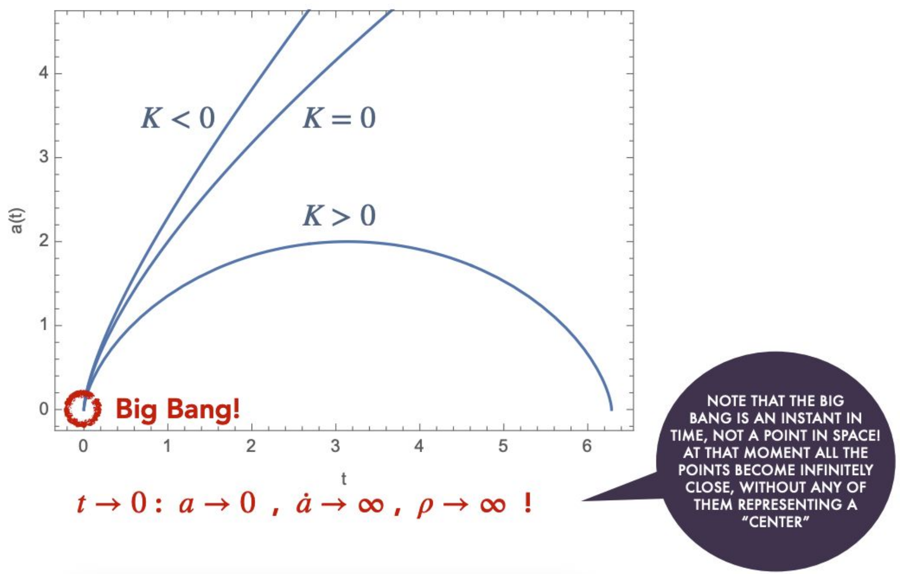
$$H^2(t) = H_0^2 \left(\frac{\Omega_m}{a^3(t)} + \frac{\Omega_r}{a^4(t)} + \Omega_\Lambda + \frac{\Omega_k}{a^2(t)} \right)$$

$$\rho_{cr} = \frac{3H_0^2}{8\pi G}$$

$$\Omega_i = \frac{\rho_{i,0}}{\rho_{cr}}$$

$$\Omega - 1 = \frac{ck}{H_0^2}$$

- The ***general solution*** (for all K) is shown in the plot below



distâncias cosmológicas

1. Não medimos distâncias, **inferimos** porque elas dependem de um modelo cosmológico

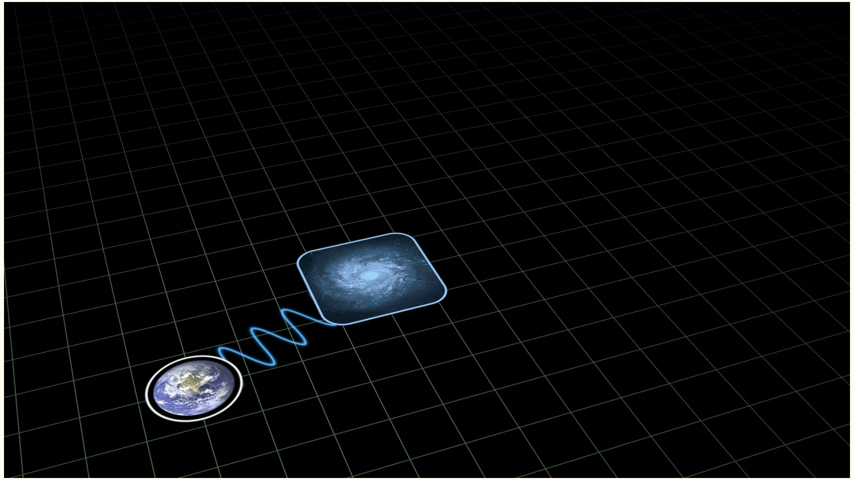
2. distância ⇄ redshift
   distância ⇄ fator de escala
   saber distância = saber a cosmologia

3. distância física

   distância comóvel

   distância diâmetro-angular

   distância luminosidade



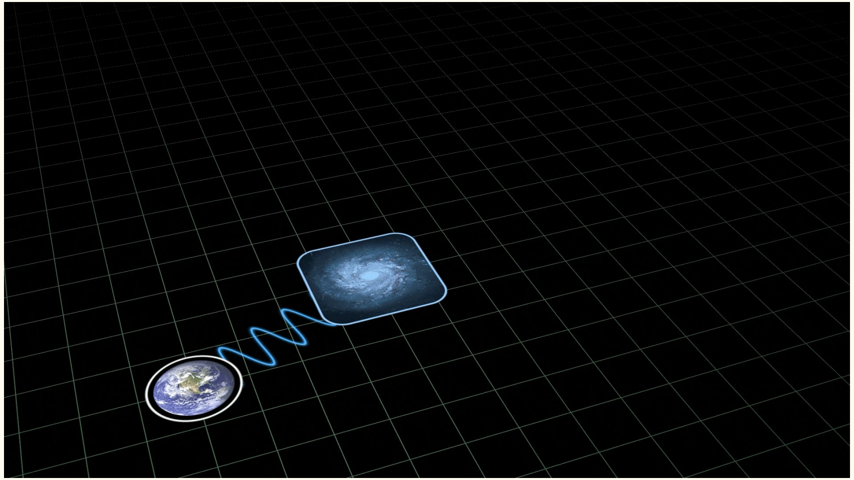
Credit: NASA/JPL-Caltech//R. Hurt (Caltech-IPAC)

hoje:	$a = 1$ e $z = 0$
big bang:	$a = 0$ e $z =$ infinito

distância **comóvel**

A distância entre Terra e galáxia aumenta, mas a quantos "quadradinhos" de distância elas estão?

$$D_c \equiv c \int_{t_0}^{t} \frac{dt}{a(t)}$$
$$= c \int_{a}^{1} \frac{da}{a^2 H(a)}$$
$$= c \int_{0}^{z} \frac{dz}{H(z)}$$



Credit: NASA/JPL-Caltech//R. Hurt (Caltech-IPAC)

hoje:	$t = t_0$,	$a = 1$ e $z = 0$
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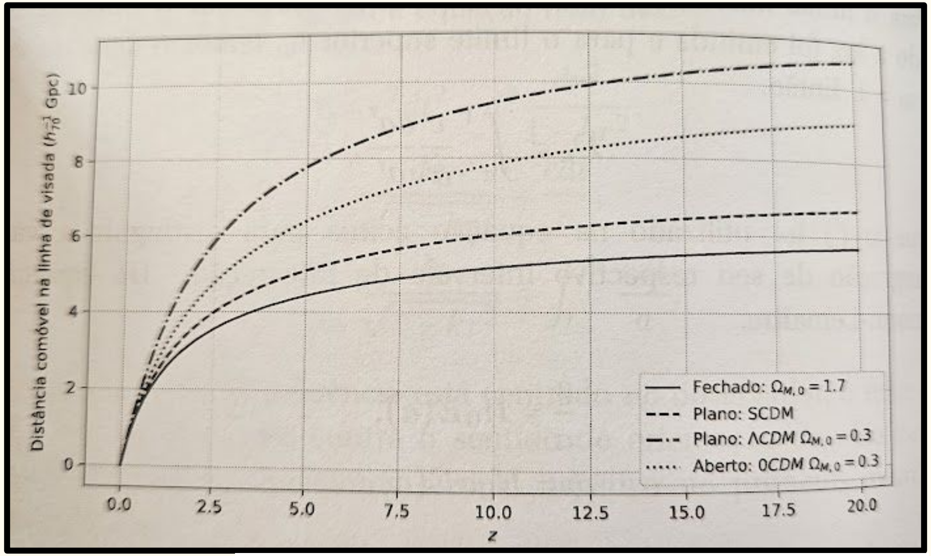


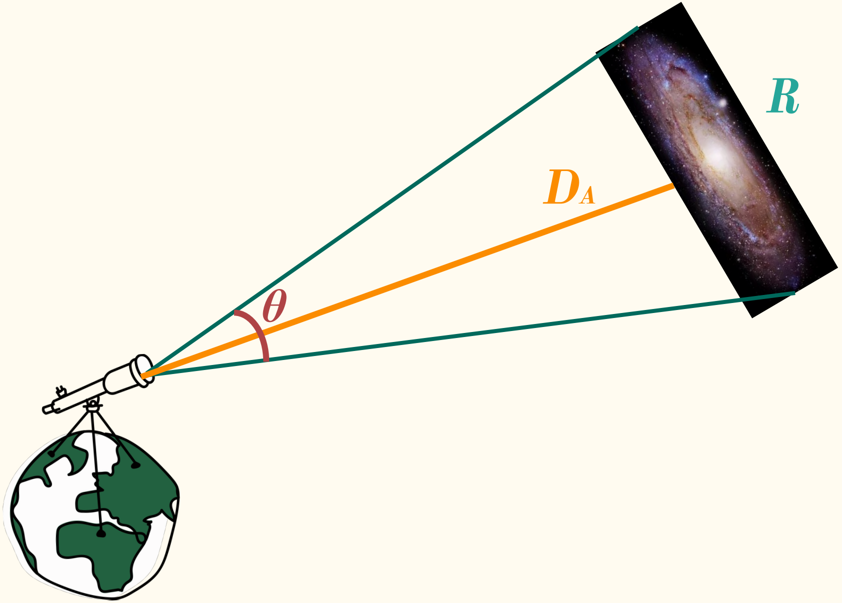
Introdução à Cosmologia, um curso de graduação, A. Zabot (2023)

hoje:	$t = t_0$,	$a = 1$ e $z = 0$
big bang:	$t = 0$,	$a = 0$ e $z =$ infinito

distância **diâmetro angular**

Se sabemos o tamanho de um objetos, inferimos sua distância pelo ângulo que ele forma no céu

$$D_A = \frac{R}{\theta}$$



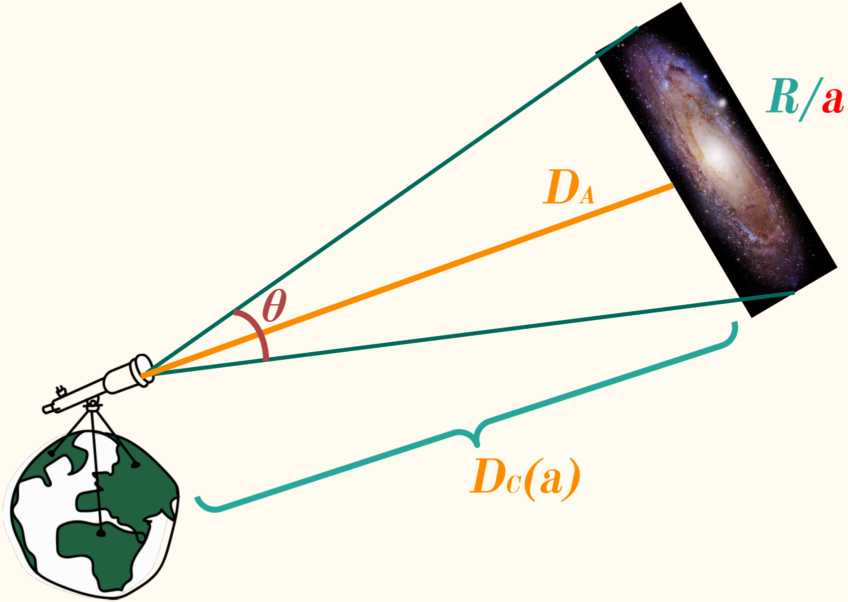
hoje:	$t = t_0$,	$a = 1$ e $z = 0$
big bang:	$t = 0$,	$a = 0$ e $z =$ infinito

distância **diâmetro angular**

Se sabemos o tamanho de um objetos, inferimos sua distância pelo ângulo que ele forma no céu

$$D_A = \frac{R}{\theta} \qquad \theta = \frac{R/a}{D_C(a)}$$

$\boxed{\text{físico}}$ $\boxed{\text{comóvel}}$



hoje:	$t = t_0$,	$a = 1$ e $z = 0$
big bang:	$t = 0$,	$a = 0$ e $z =$ infinito

distância **diâmetro angular**

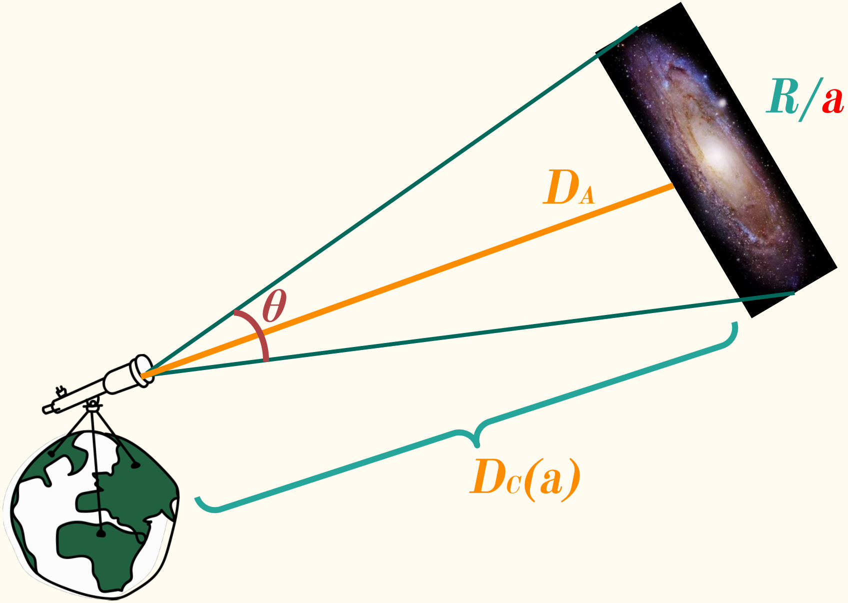
Se sabemos o tamanho de um objetos, inferimos sua distância pelo ângulo que ele forma no céu

$$D_A = \frac{R}{\theta} \qquad \theta = \frac{R/a}{D_C(a)}$$

físico — comóvel

$$\boxed{D_A = aD_C = \frac{D_C}{1+z}}$$

*para um universo plano



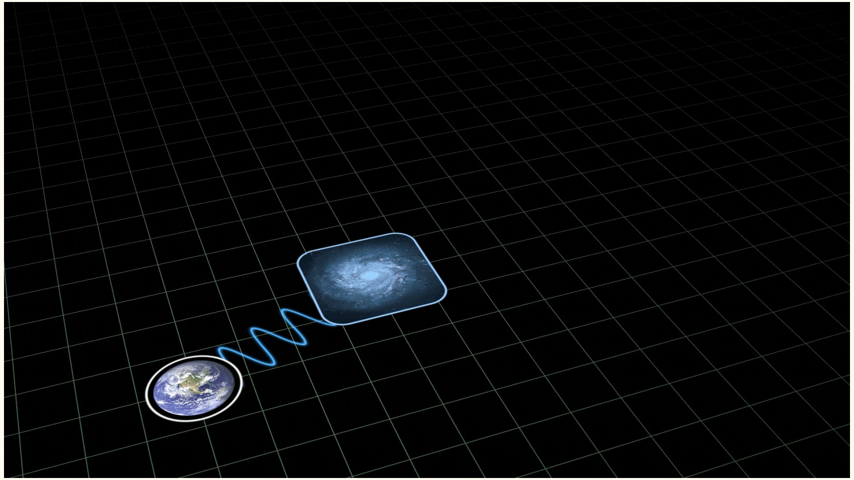
hoje:	$t = t_0$,	$a = 1$ e $z = 0$
big bang:	$t = 0$,	$a = 0$ e $z =$ infinito

distância **luminosidade**

$$\lambda_e = \frac{\lambda_o}{1+z} = a\lambda_o \qquad a \equiv \frac{1}{1+z}$$

$$E = hf = \frac{hc}{\lambda} \qquad T \propto \frac{1}{f} \propto \lambda$$

$$v = \lambda f$$



Credit: NASA/JPL-Caltech//R. Hurt (Caltech-IPAC)

hoje:	$t = t_0$,	$a = 1$ e $z = 0$
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distância luminosidade

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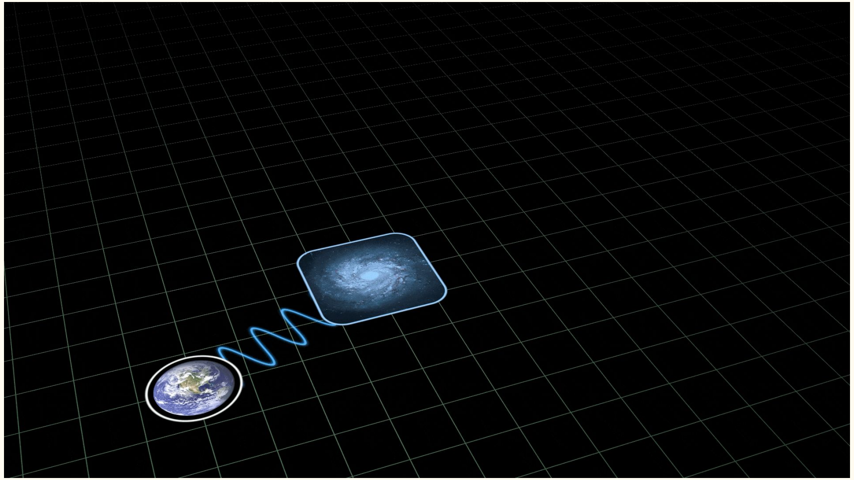


Credit: NASA/JPL-Caltech//R. Hurt (Caltech-IPAC)

$$L = \frac{energia}{tempo} \qquad E_e = E_o(1+z) \qquad T_e = \frac{T_o}{1+z}$$

$$\frac{L_o}{L_e} = \frac{T_e}{E_e}\frac{E_o}{T_o} = \frac{1}{(1+z)^2}$$

$$\boxed{F = \frac{L}{4\pi d^2} \Rightarrow F_o = \frac{F_e}{(1+z)^2} = \frac{L_e}{4\pi(1+z)^2 D_c^2}} \Rightarrow D_L \equiv (z+1)D_C = \frac{D_C}{a}$$

distâncias cosmológicas

$$
\left\{
\begin{aligned}
D_c &\equiv c\int_{t_0}^{t}\frac{dt}{a(t)}\\
&= c\int_{a}^{1}\frac{da}{a^2H(a)}\\
&= c\int_{0}^{z}\frac{dz}{H(z)}\\
D_A &= aD_C = \frac{D_C}{1+z}\\
D_L &\equiv (z+1)D_C = \frac{D_C}{a}
\end{aligned}
\right\}
$$

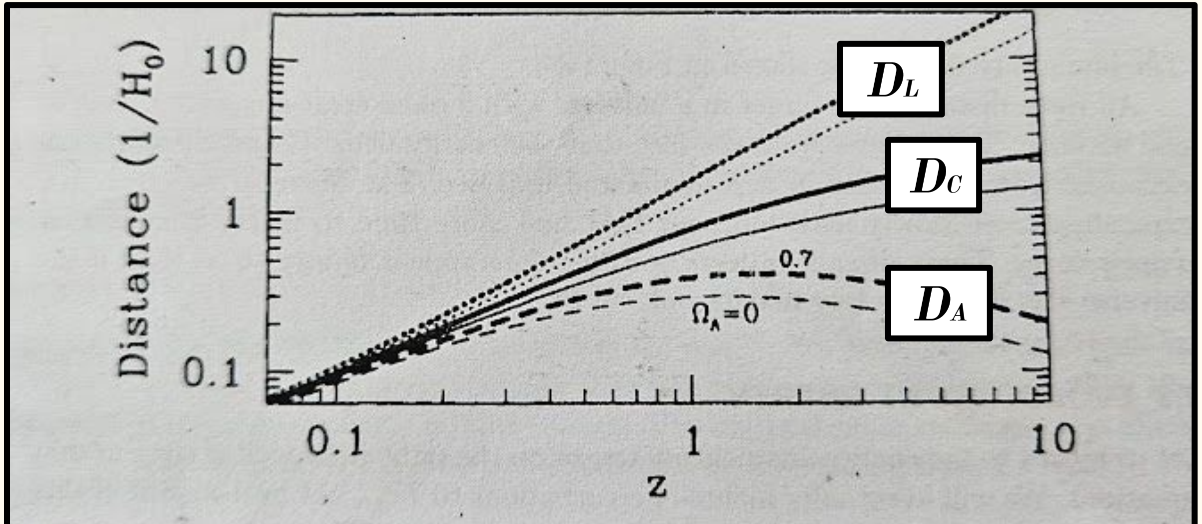


Figure 2.3. Three distance measures in a flat expanding universe. From top to bottom, the luminosity distance, the comoving distance, and the angular diameter distance. The pair of lines in each case is for a flat universe with matter only (light curves) and 70% cosmological constant Λ (heavy curves). In a Λ-dominated universe, distances out to fixed redshift are larger than in a matter-dominated universe.

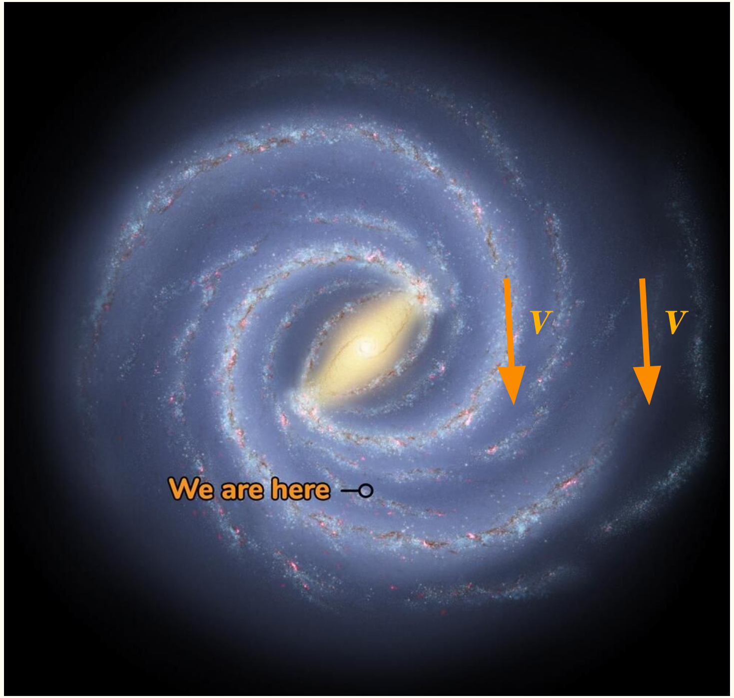
matéria escura?

1. Em 1930, Fritz Zwicky analisa por meio de **paralaxe vs distância luminosidade** que galáxias em aglomerados estão se movendo muito rápido para ainda estarem “em órbita”.
2. Conclui que deve ter ~5–6x mais matéria do que pode ver, mas medidas são muito imprecisas para serem conclusivas
3. Denomina essa matéria ausente de **matéria escura**

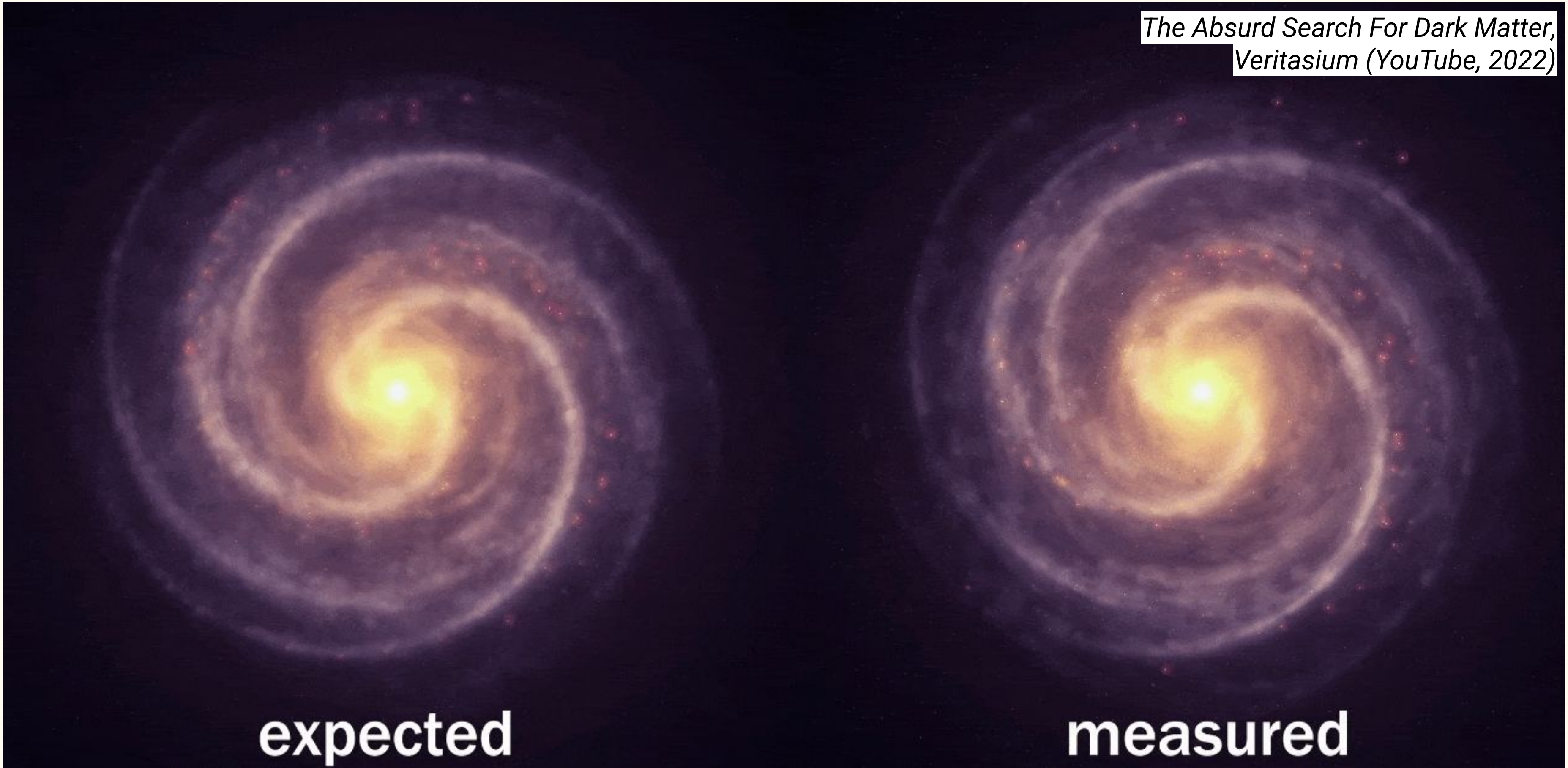
Dark Matter: Crash Course Astronomy #41, Crash Course (YouTube, 2016)

Vera Rubin (1960)

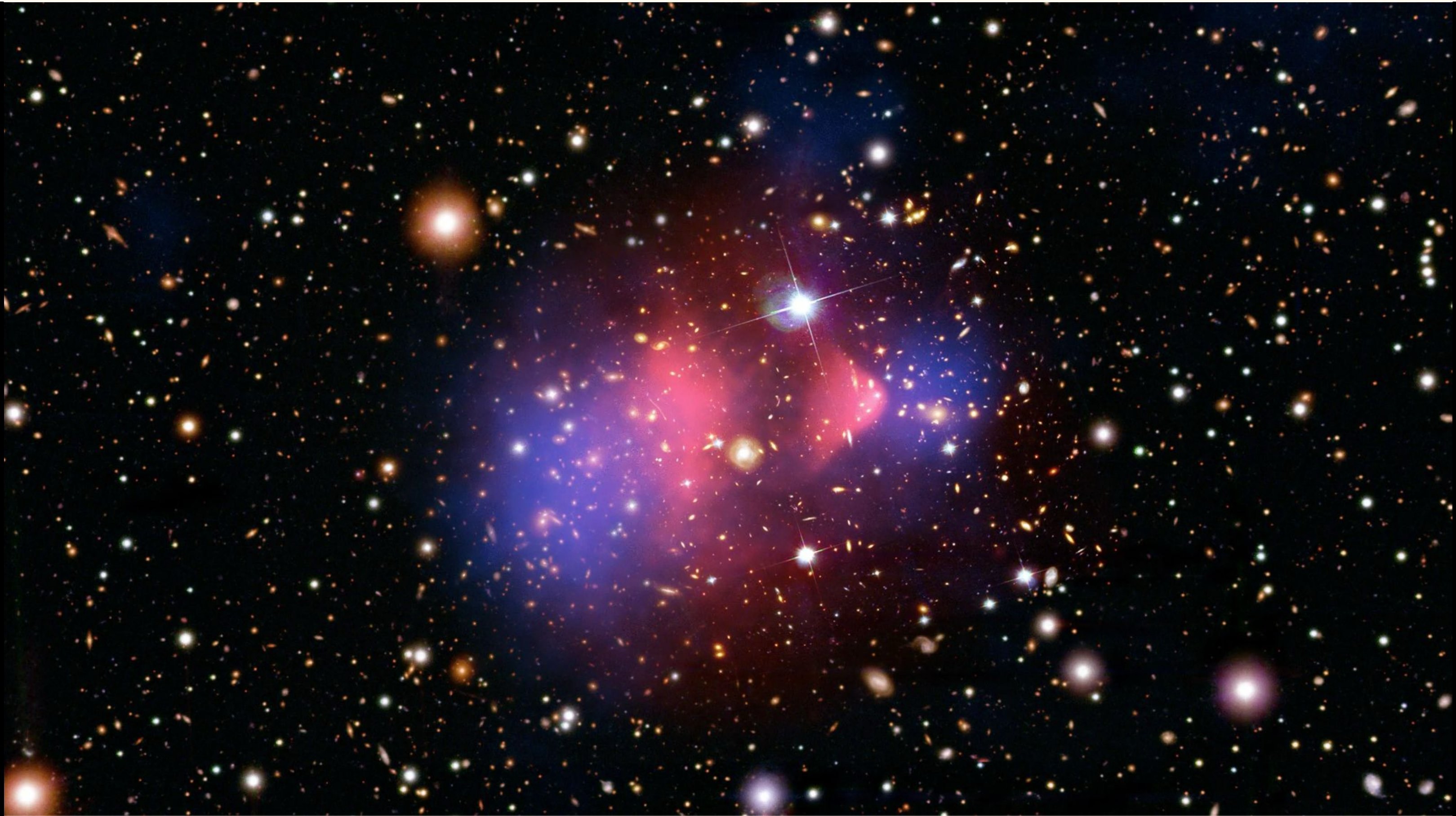
velocidade peculiar



Vera Rubin (1960)



bullet cluster



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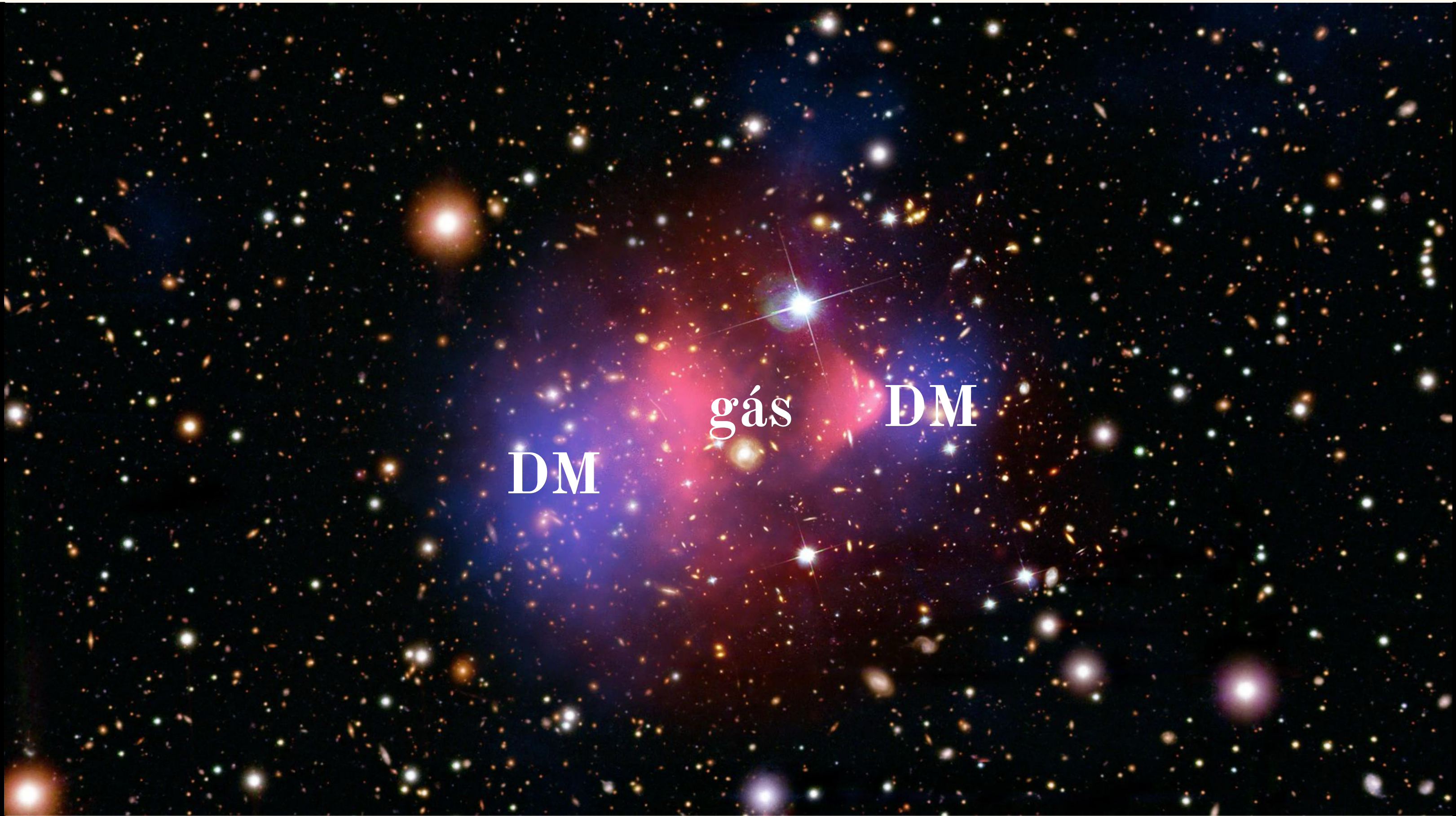

matéria escura

matéria escura

pesquisa

Enhancing weak lensing redshift distribution characterization by optimizing the Dark Energy Survey Self-Organizing Map Photo-z method

A. Campos[1,2,*], B. Yin[3], S. Dodelson[1,2], A. Amon[4,5], A. Alarcon[6,7], C. Sánchez[8], G. M. Bernstein[8], G. Giannini[9,10], J. Myles[11], S. Samuroff[12], O. Alves[13], F. Andrade-Oliveira[13], K. Bechtol[14], M. R. Becker[6], J. Blazek[12], H. Camacho[15,16,17], A. Carnero Rosell[15,18,19], M. Carrasco Kind[20,21], R. Cawthon[22], C. Chang[23,9], R. Chen[3], A. Choi[24], J. Cordero[25], C. Davis[26], J. DeRose[27], H. T. Diehl[28], C. Doux[8,29], A. Drlica-Wagner[9,23,28], K. Eckert[8], T. F. Eifler[30,31], J. Elvin-Poole[32], S. Everett[30], X. Fang[31,33], A. Ferté[34], O. Friedrich[5], M. Gatti[8], D. Gruen[35], R. A. Gruendl[20,21], I. Harrison[36], W. G. Hartley[37], K. Herner[28], H. Huang[31,38], E. M. Huff[30], M. Jarvis[8], E. Krause[31], N. Kuropatkin[28], P.-F. Leget[26], N. MacCrann[39], J. McCullough[26], A. Navarro-Alsina[40], S. Pandey[8], J. Prat[41,23], M. Raveri[42], R. P. Rollins[25], A. Roodman[26,34], R. Rosenfeld[43,15], A. J. Ross[44], E. S. Rykoff[34,26], J. Sanchez[45], L. F. Secco[9], I. Sevilla-Noarbe[46], E. Sheldon[17], T. Shin[47], M. A. Troxel[3], I. Tutusaus[48], T. N. Varga[49,50,51], R. H. Wechsler[26,52,34], B. Yanny[28], Y. Zhang[53], J. Zuntz[54], M. Aguena[15], J. Annis[28], D. Bacon[55], S. Bocquet[35], D. Brooks[56], D. L. Burke[26,34], J. Carretero[10], F. J. Castander[7,57], M. Costanzi[58,59,60], L. N. da Costa[15], J. De Vicente[46], P. Doel[56], I. Ferrero[61], B. Flaugher[28], J. Frieman[9,28], J. García-Bellido[62], E. Gaztanaga[7,55,57], G. Gutierrez[28], S. R. Hinton[63], D. L. Hollowood[64], K. Honscheid[44,65], D. J. James[66], K. Kuehn[67,68], M. Lima[15,69], H. Lin[28], J. L. Marshall[70], J. Mena-Fernández[71], F. Menanteau[20,21], R. Miquel[10,72], R. L. C. Ogando[73], M. Paterno[28], M. E. S. Pereira[74] A. Pieres[15,73], A. A. Plazas Malagón[26,34], A. Porredon[46,75], E. Sanchez[46], D. Sanchez Cid[46], M. Smith[76], E. Suchyta[77], M. E. C. Swanson[21], G. Tarle[13], C. To[44], V. Vikram[78], and N. Weaverdyck[27,33]

DES Collaboration

pesquisa

Enhancing weak lensing redsh
optimizing the Dark Energy S

A. Campos[1,2★], B. Yin[3], S. Dodelson[1,
G. Giannini[9,10], J. Myles[11], S. Samuroff[12],
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R. H. Wechsler[26,52,34], B. Yanny[28], Y.
S. Bocquet[35], D. Brooks[56], D. L. Burk
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Bellido[62], E. Gaztanaga[7,55,57], G. Gutier
D. J. James[66], K. Kuehn[67,68], M. Li
F. Menanteau[20,21], R. Miquel[10,72], R. L.
A. A. Plazas Malagón[26,34], A. Porredon[46
M. E. C. Swanson[21], G. Tarle[13], C. To[44], V

DES Collaboration

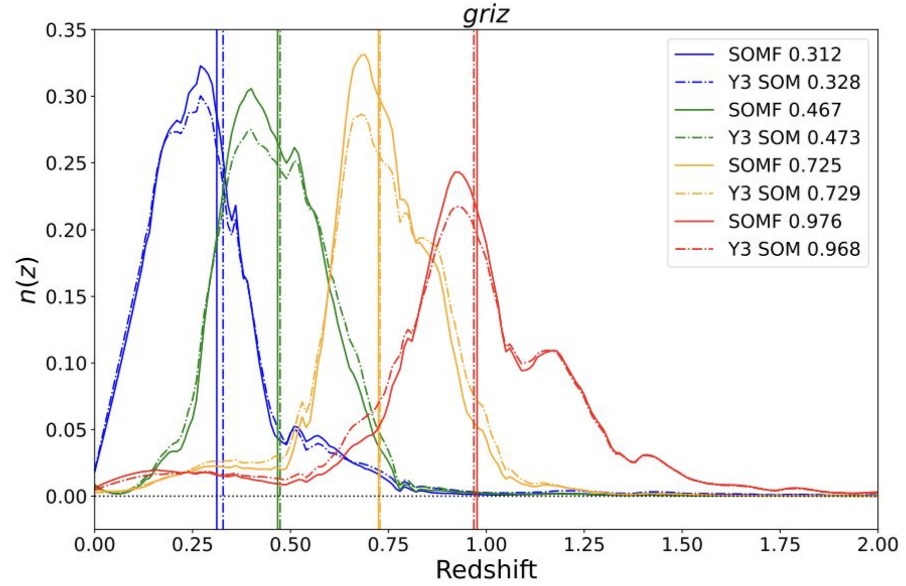

Figure 6. Photometric redshift distribution obtained from the *griz* bands, using the Y3 SOM (dot-dashed line) and the SOMF algorithm (filled line). The two methods show good agreement regarding the shape of each bin, and their mean redshifts values, shown in the legend on the top right. However, the addition of the *g*-band further emphasizes the ability of SOMF to produce better defined bins.

pesquisa

Observationally Determining the Properties of Dark Matter

Wayne Hu*, Daniel J. Eisenstein, and Max Tegmark†
Institute for Advanced Study, Princeton, NJ 08540

Martin White
Departments of Astronomy and Physics, University of Illinois at Urbana-Champaign, Urbana, IL 61801

Determining the properties of the dark components of the universe remains one of the outstanding challenges in cosmology. We explore how upcoming CMB anisotropy measurements, galaxy power spectrum data, and supernova (SN) distance measurements can observationally constrain their gravitational properties with minimal assumptions on the theoretical side. SN observations currently suggest the existence of dark matter with an exotic equation of state $p/\rho \lesssim -1/3$ that accelerates the expansion of the universe. When combined with CMB anisotropy measurements, SN or galaxy survey data can in principle determine the equation of state and density of this component separately, regardless of their value, as long as the universe is spatially flat. Combining these pairs creates a sharp consistency check. If $p/\rho \gtrsim -1/2$, then the clustering behavior (sound speed) of the dark component can be determined so as to test the scalar-field "quintessence" hypothesis. If the exotic matter turns out instead to be simply a cosmological constant ($p/\rho = -1$), the combination of CMB and galaxy survey data should provide a significant detection of the remaining dark matter, the neutrino background radiation (NBR). The gross effect of its density or temperature on the expansion rate is ill-constrained as it is can be mimicked by a change in the matter density. However, anisotropies of the NBR break this degeneracy and should be detectable by upcoming experiments.

pesquisa

"The 'Dark' Universe May Be Full of Strange Interactions"

"The light and fuzzy side of dark matter"

"Relieving the Hubble tension with Early Dark Energy"

"If dark matter is fuzzy, then how fuzzy is it? - A gravitational lens has the answer"

"In a Monster Star's Light, a Hint of Darkness"

ABOUT ME

I am an Assistant Professor at the Kavli IPMU. Until 2024 I was also a professor at the Institute of Physics of the University of São Paulo. I received my PhD from McGill University.
My field of research is in the interface between cosmology, astrophysics, and high energy physics. My work focuses mostly on studying the dark sector. I am mostly worried about dark matter, focusing on ultra-light dark matter. I am also interested in the late expansion of the universe, studying the phenomenology of dark energy. I also study several topics in early universe cosmology, including the initial singularity, the early evolution of the universe, and reheating. Testing those models using the current observational probes and new observational windows is also part of my research.
I am a Serrapilheira Institute grantee since 2021.

https://www.elisagmferreira.com/

pesquisa:

Testando modelos de matéria escura ultra-leve com levantamentos astrofísicos
Fernanda Lima
Raul Abramo
Elisa Ferreira

A matéria escura constitui cerca de 85\% da densidade de matéria do universo. Contudo, sua natureza fundamental ainda é desconhecida, representando uma grande lacuna no nosso entendimento do universo. Há muitos modelos para essa componente elusiva. A matéria escura ultra-leve (ULDM), ou os axions ultra-leves (ULA), são os candidatos a matéria escura mais leves, e, dada sua microfísica bem motivada e rica fenomenologia, se tornaram um dos principais candidatos a matéria escura. Neste projeto, queremos usar os mais recentes levantamentos astrofísicos para vincular propriedades físicas de ULDM.

pesquisa:


Observations
from 21 cm hydrogen
Pioneira
Expected from visible disk
Matéria Escura
20
30
40
50
1000 ly)
Dra. Ivone Albuquerque


09.09
quinta-feira
16h00
Prof. Enrico Bertuzzo
IFUSP
PORTALS TO THE
DARK WORLD
colóquio
IFUSP