

Universo e entropia

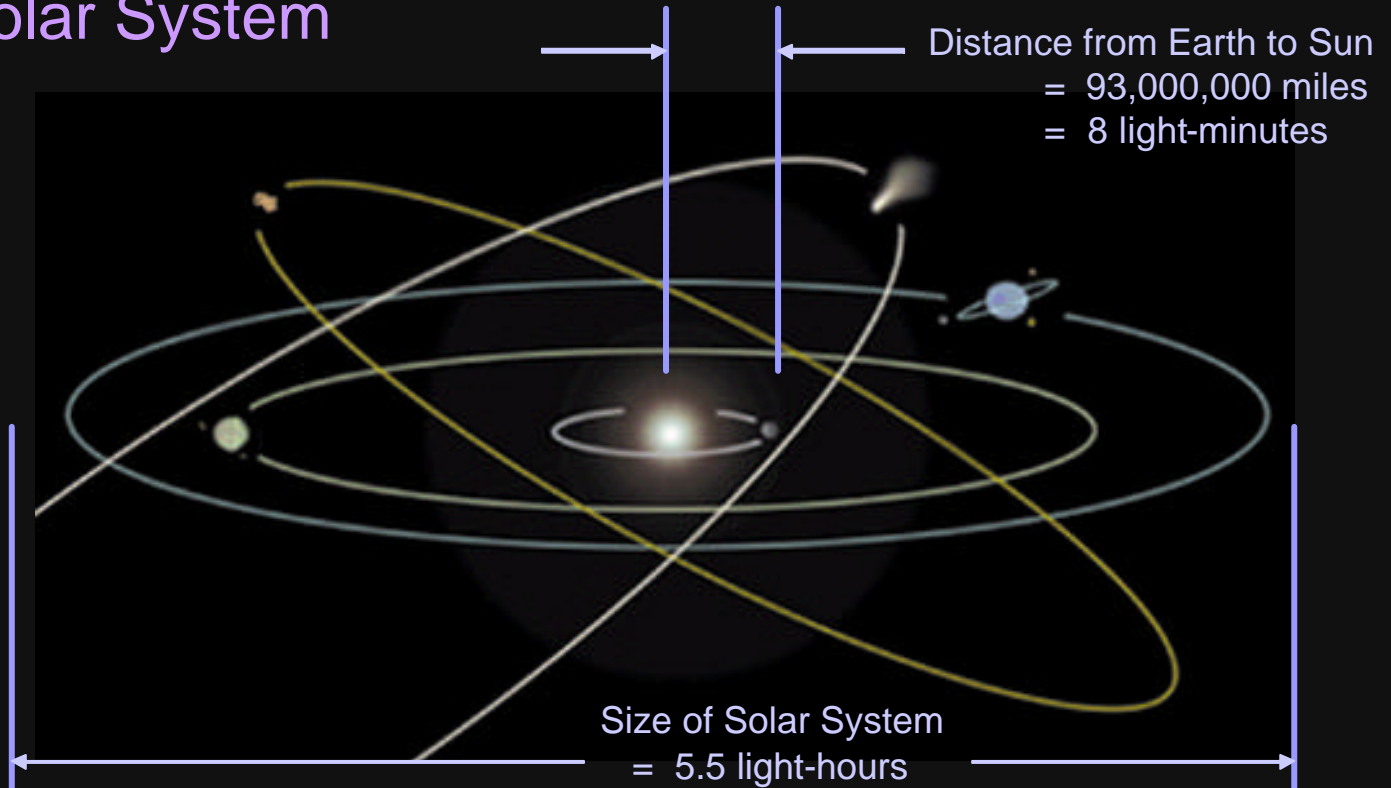


Hubble Deep Field

HST WFPC2

What is a Galaxy ?

Solar System



What is a Galaxy?

Stellar Region

Sun
(solar system
too small to be
seen on this scale)

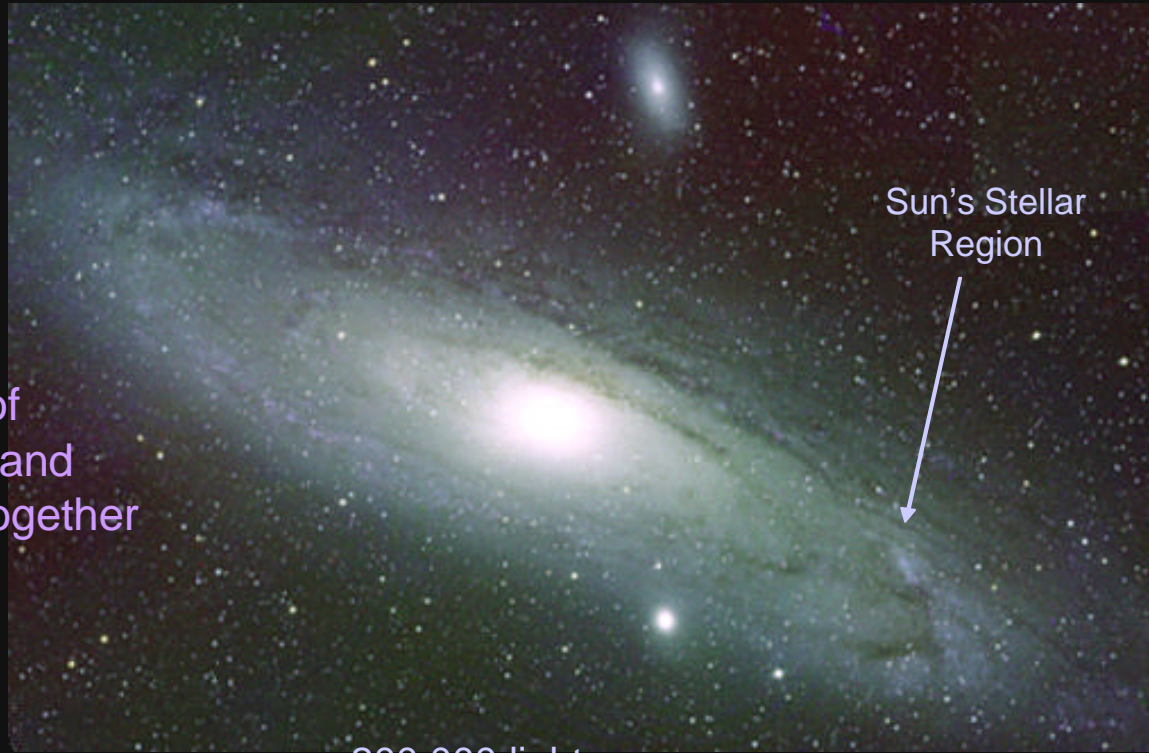


30
light-years

What is a Galaxy?

Galaxy

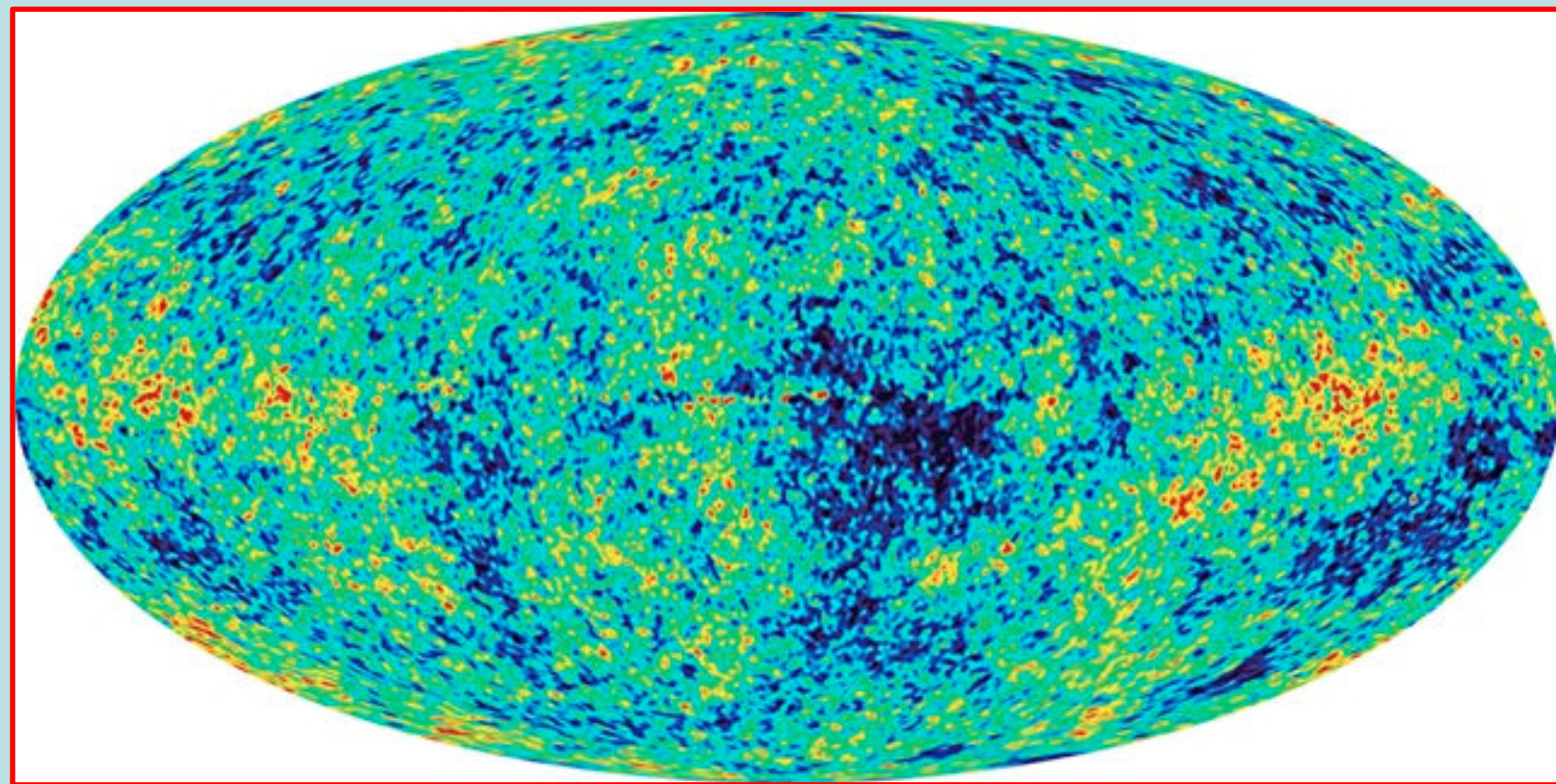
a massive collection of stars, gas, and dust kept together by gravity

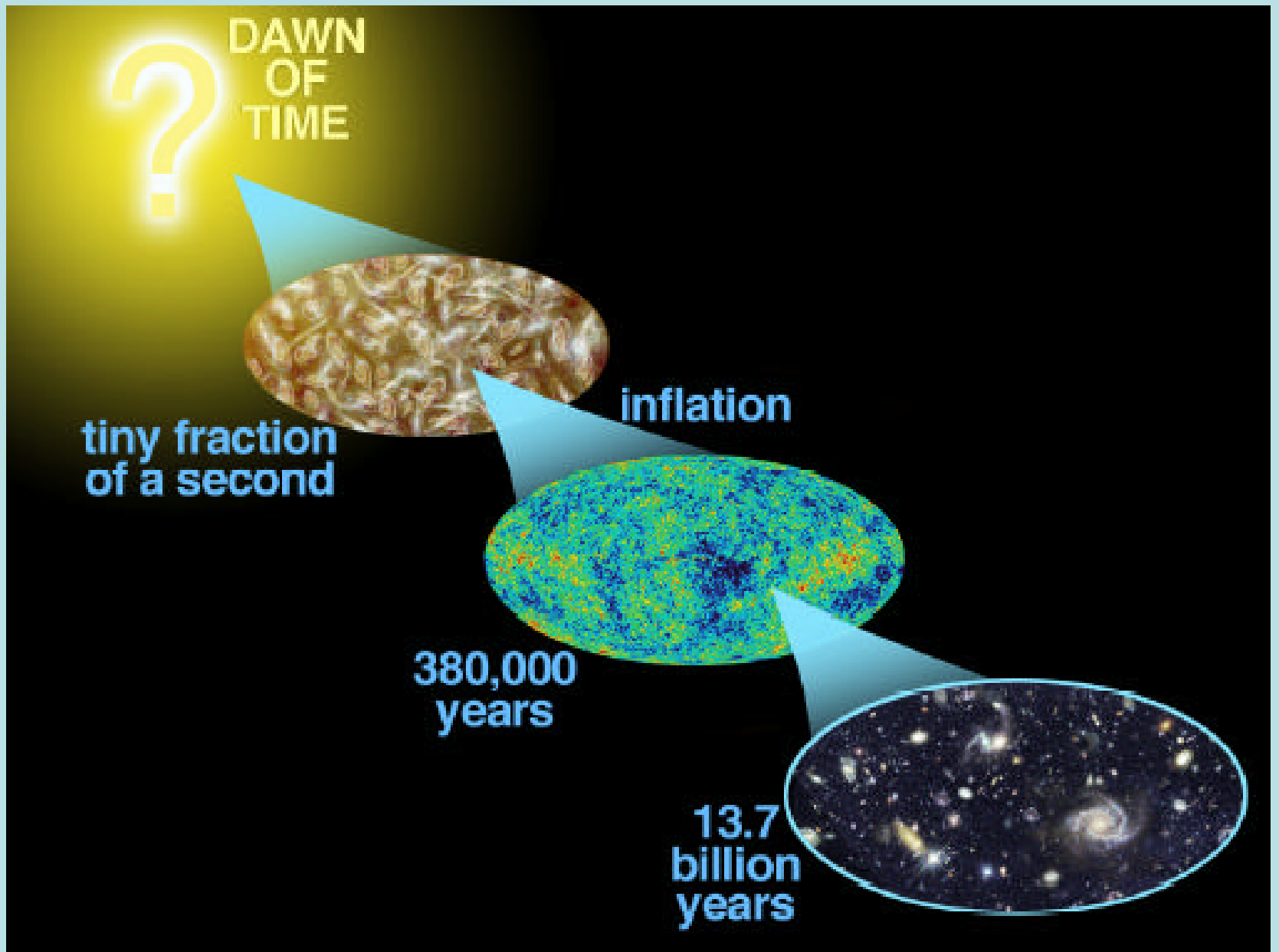


200,000 light-years

Boomerang

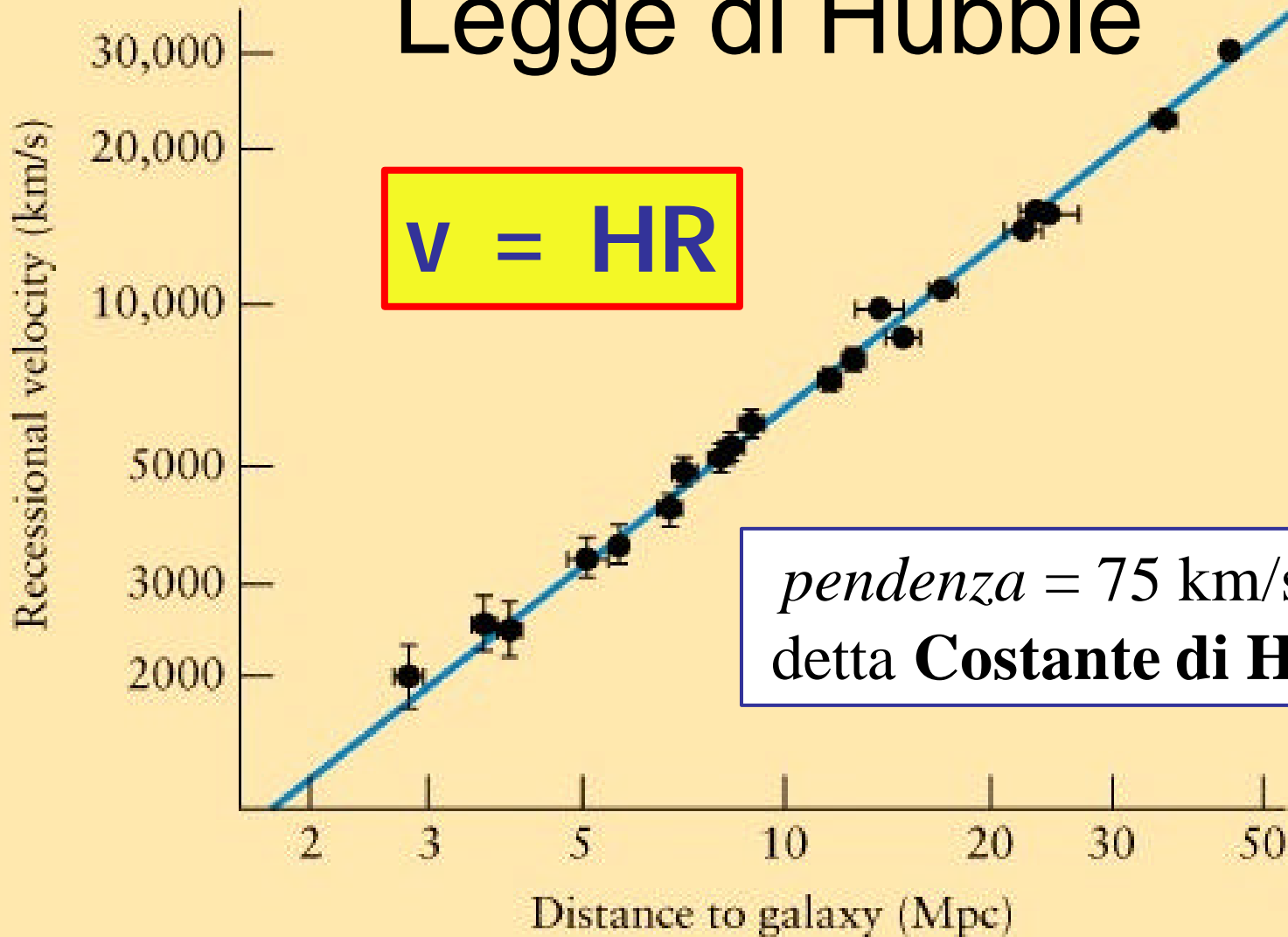






Legge di Hubble

$$v = H R$$

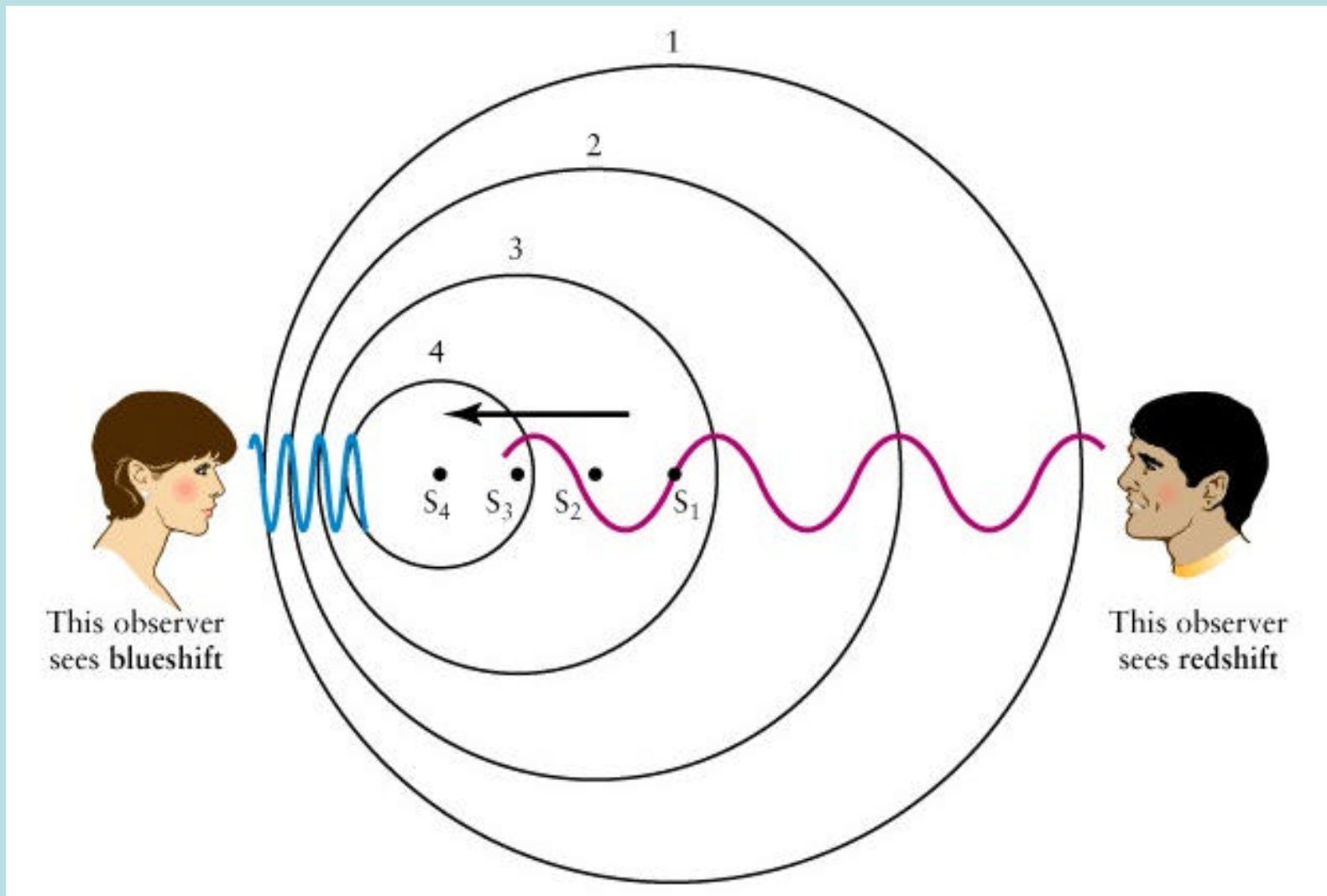


"Standard Candles"

If we know how luminous an object is then we can translate it's apparent brightness into it's distance.

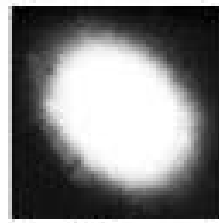


La frequenza della luce cambia per il moto relativo tra sorgente e osservatore

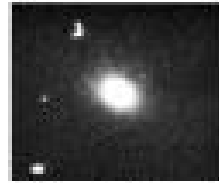


Ma anche quello delle galassie dallo spostamento verso il rosso (red-shift) delle righe spettrali.

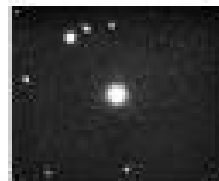
GALAXIES in



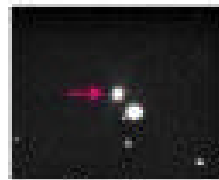
Virgo



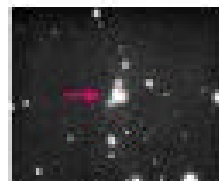
Ursa Major



Corona Borealis

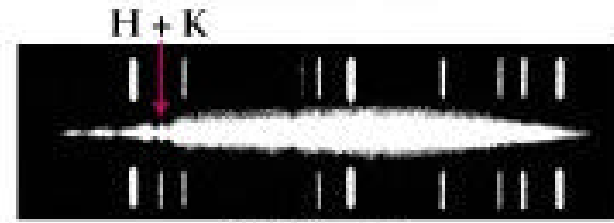


Boötes

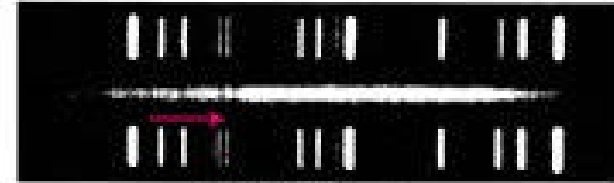


Hydra

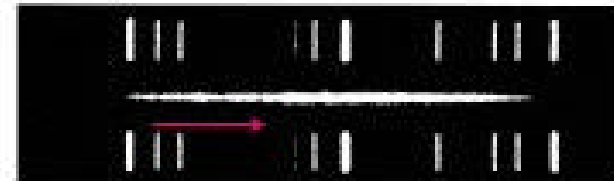
REDSHIFTS



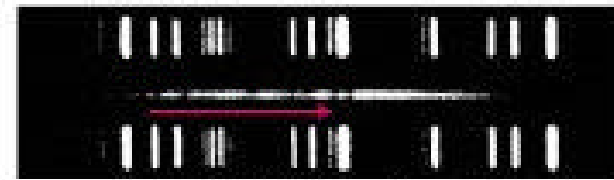
1,200 km/s



15,000 km/s



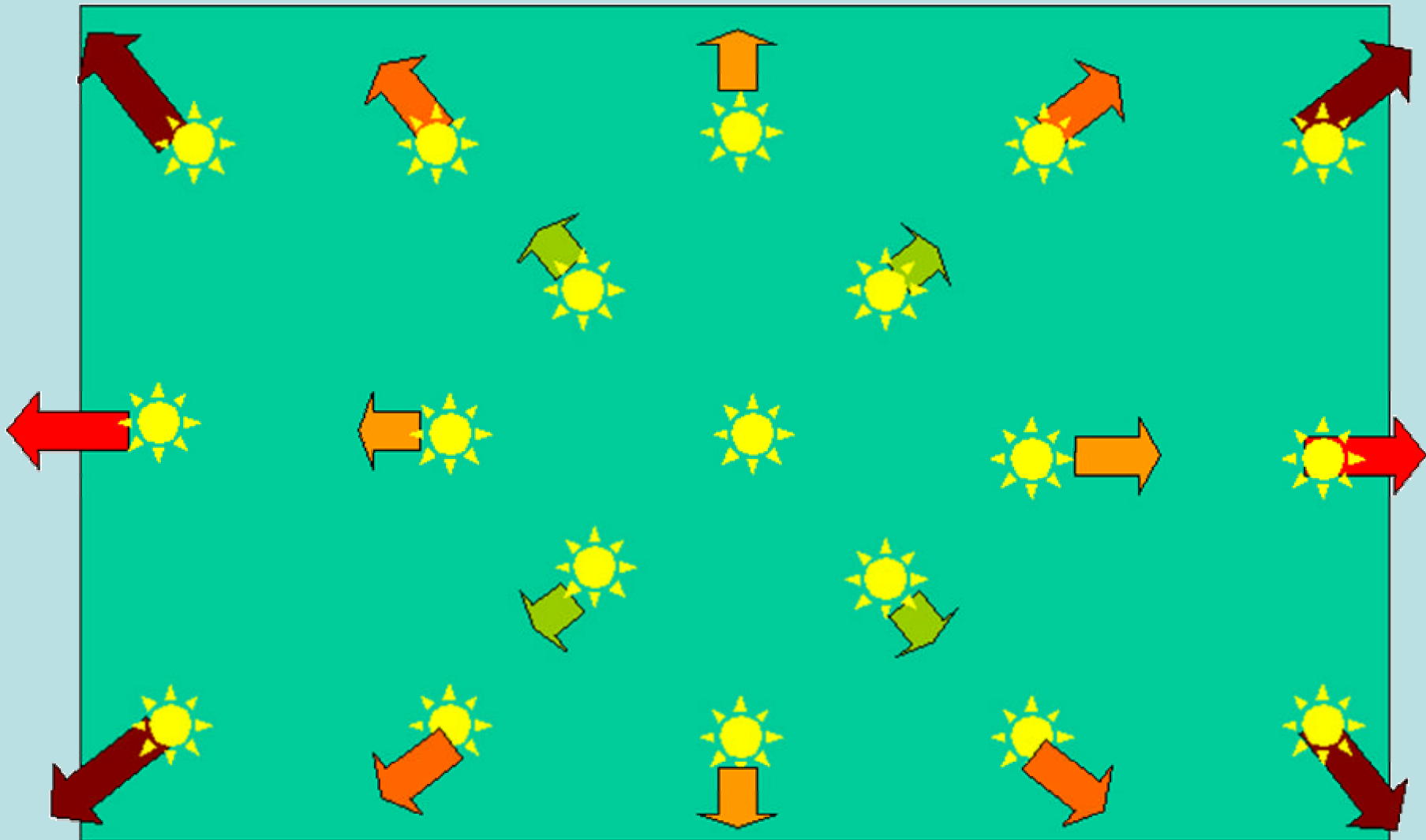
22,000 km/s

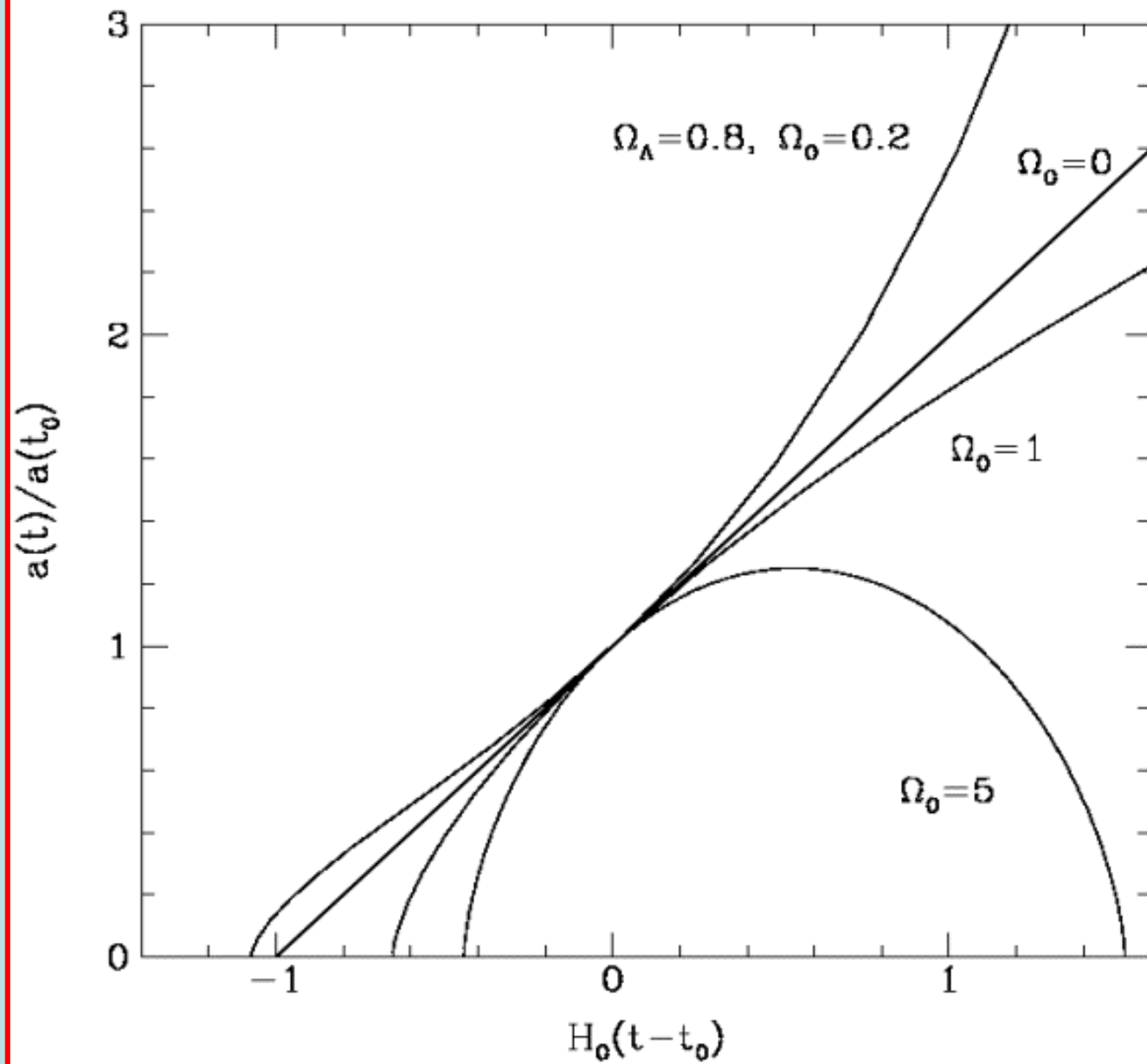


39,000 km/s

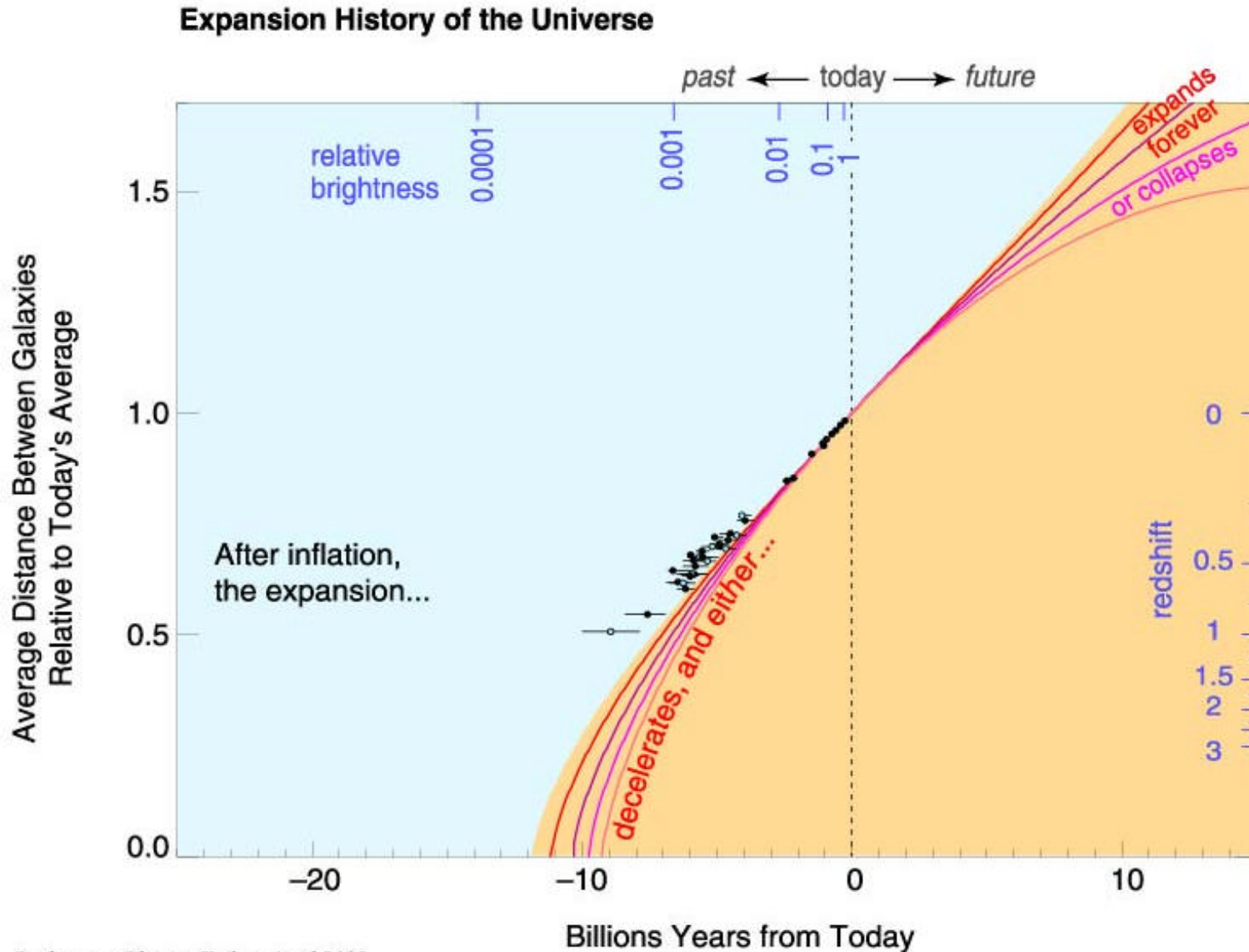


61,000 km/s

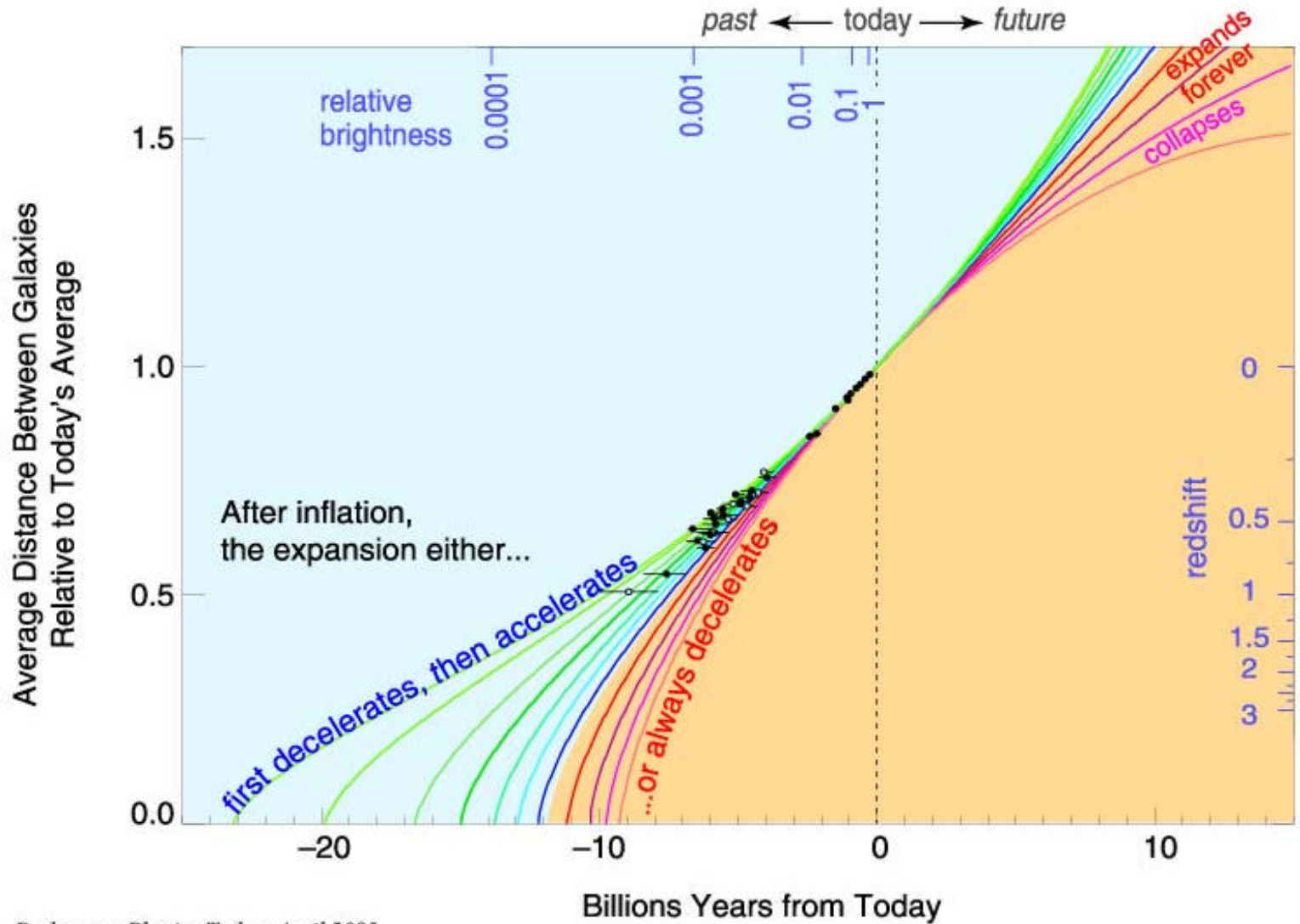




Supernovae: Mapping Expansion



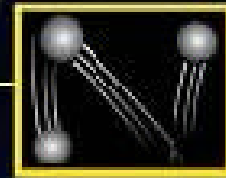
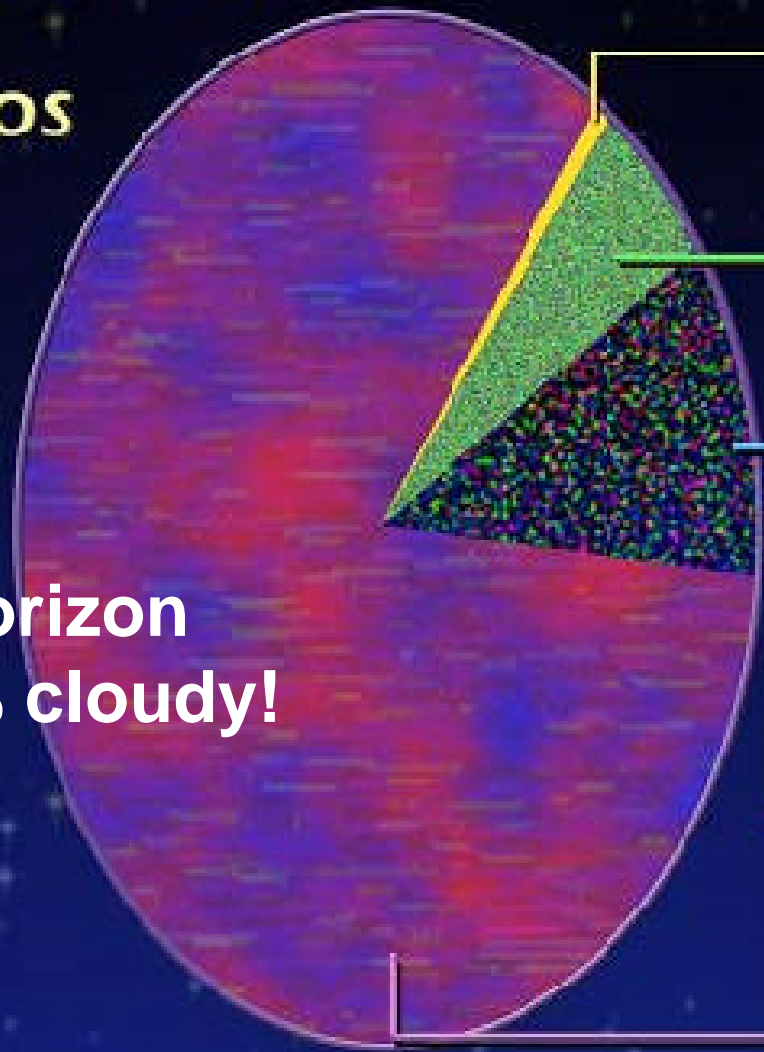
Expansion History of the Universe



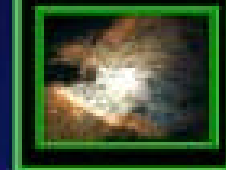
Perlmutter, *Physics Today*, April 2003

Composition of the Cosmos

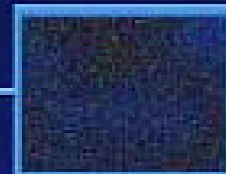
The horizon is 95% cloudy!



Neutrinos:
0.6%



Baryons (atoms):
comprising
stars, heavy
elements, and
helium and
free hydrogen:
4.4%



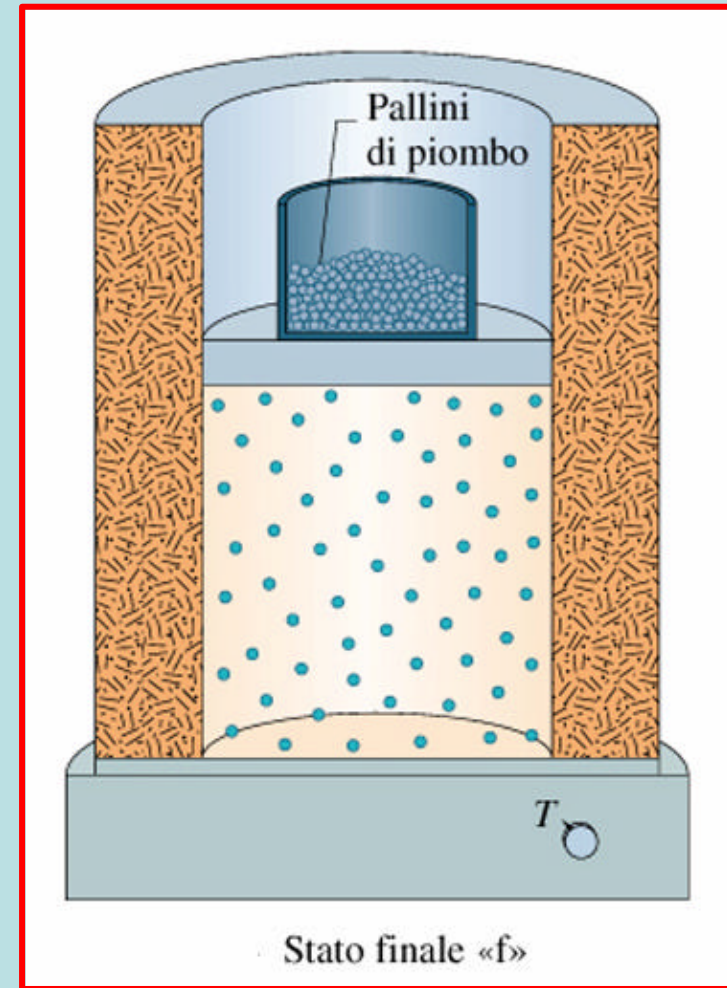
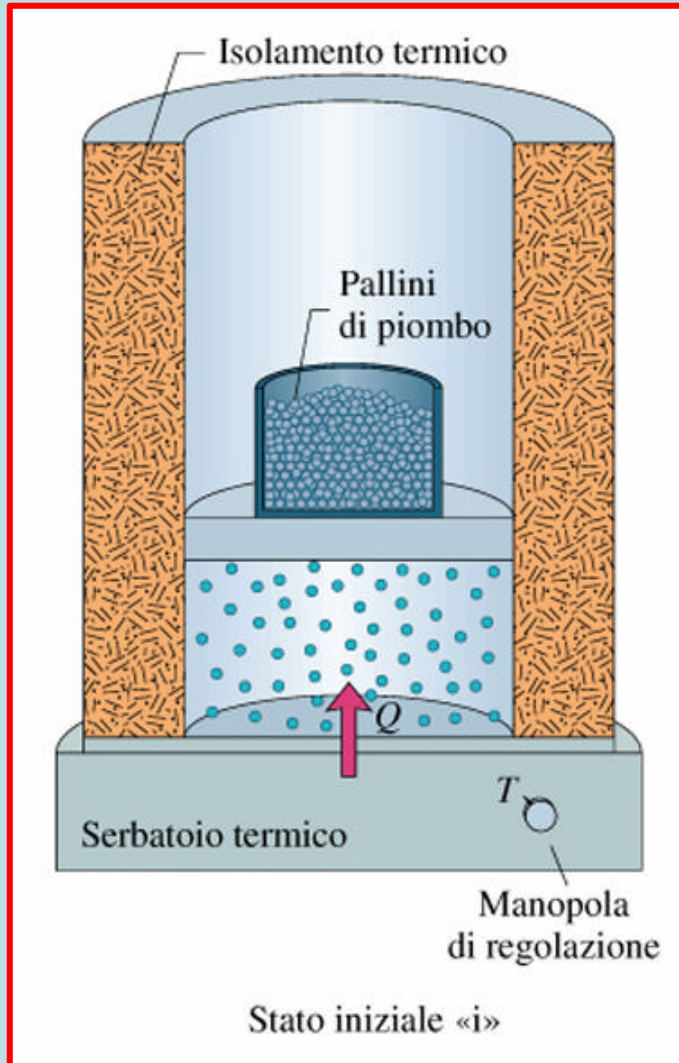
Dark
matter:
22%

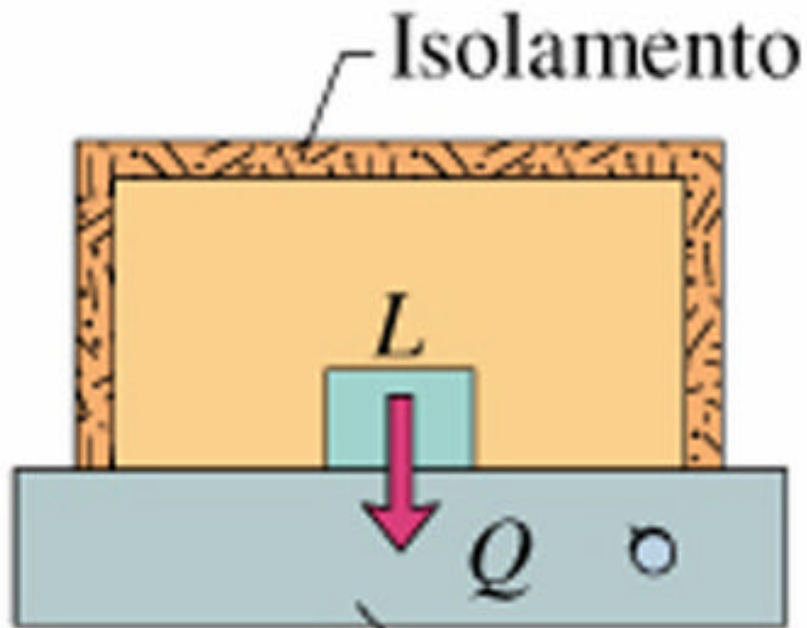


Dark
energy:
73%

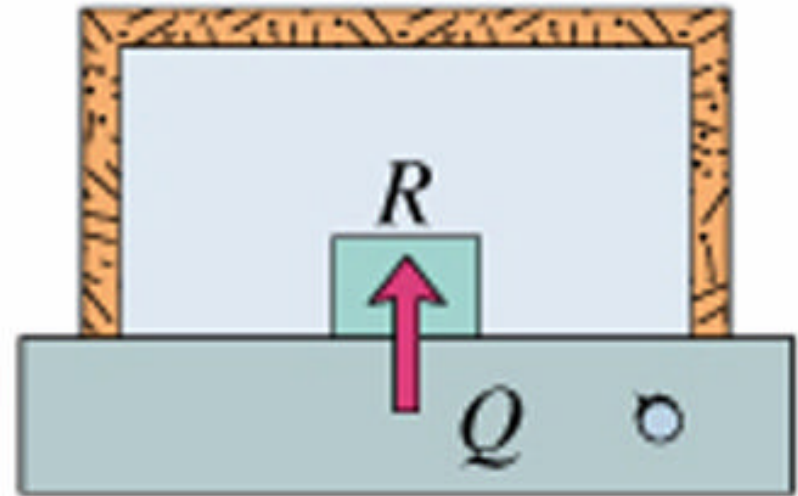
SI ScI

Esempio di trasformazione reversibile



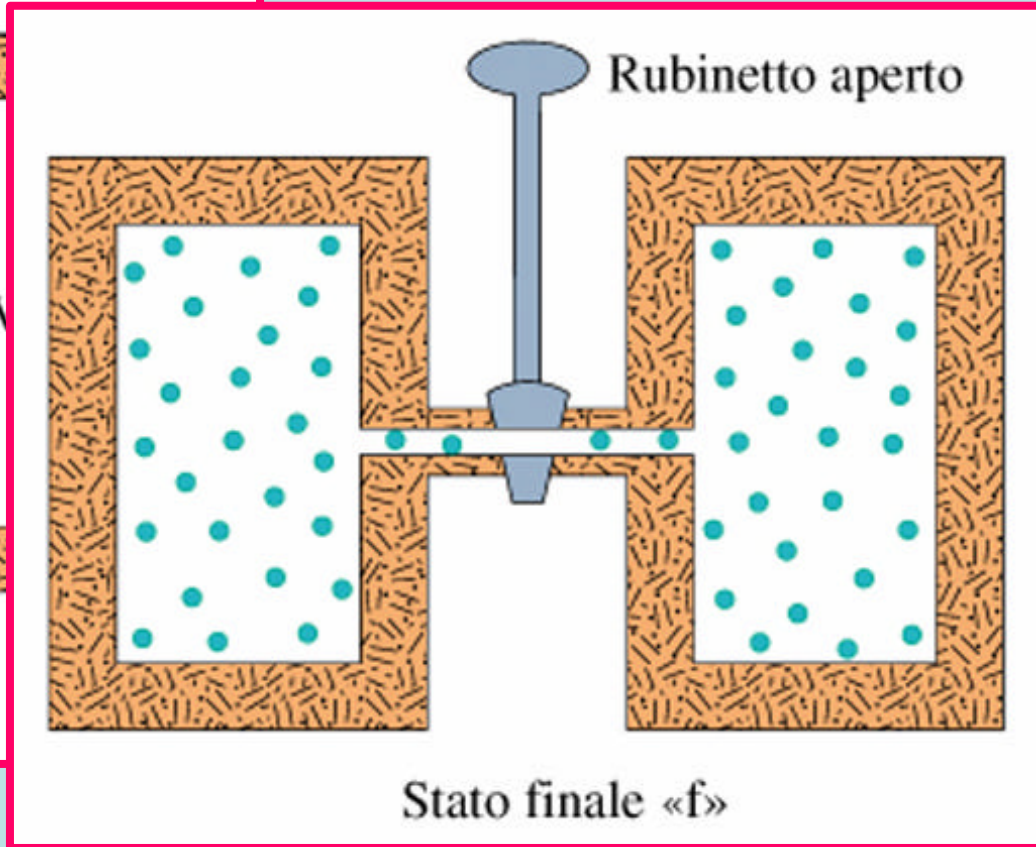
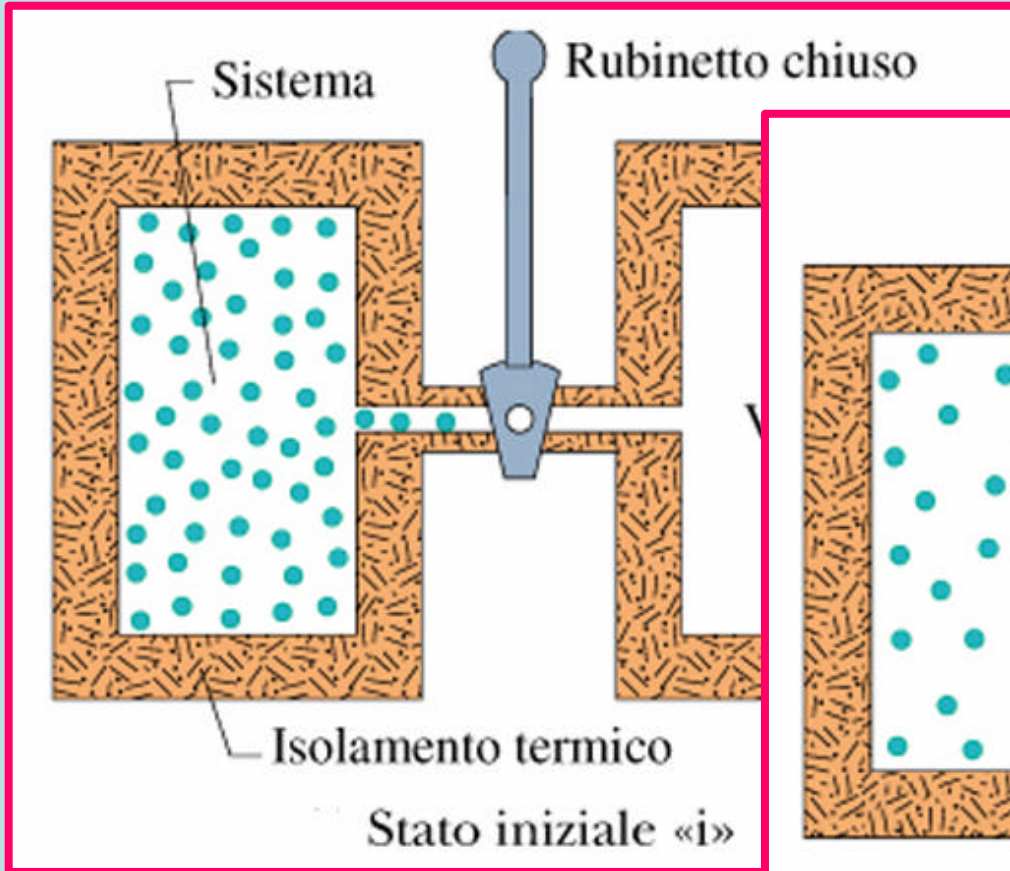


(a) Stadio 1

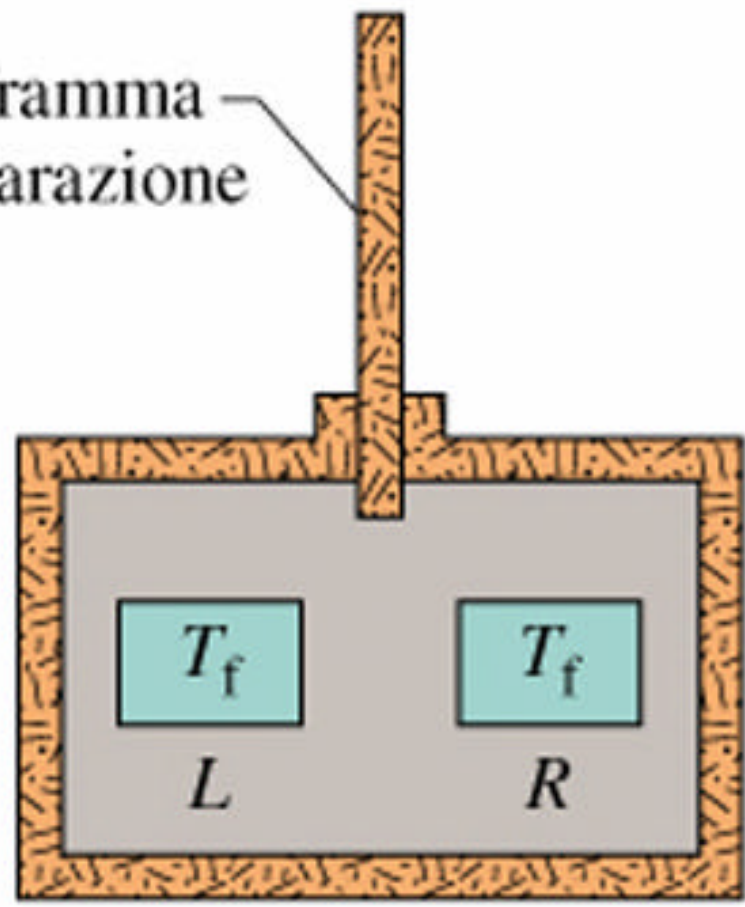
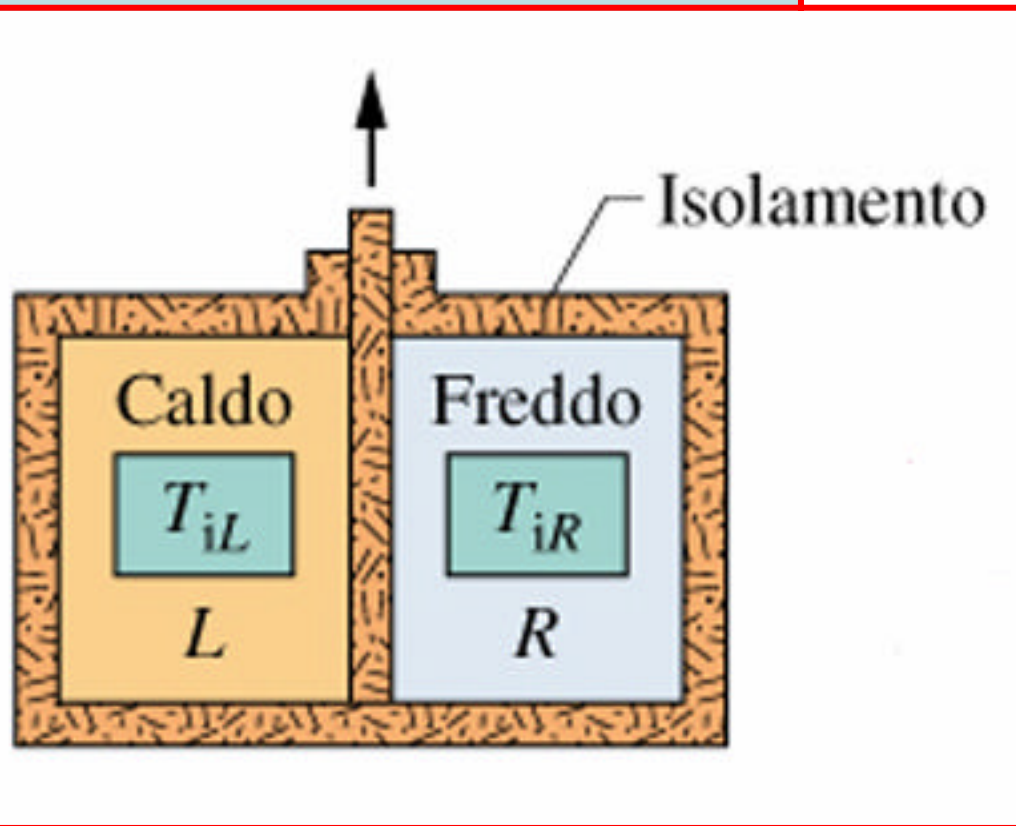


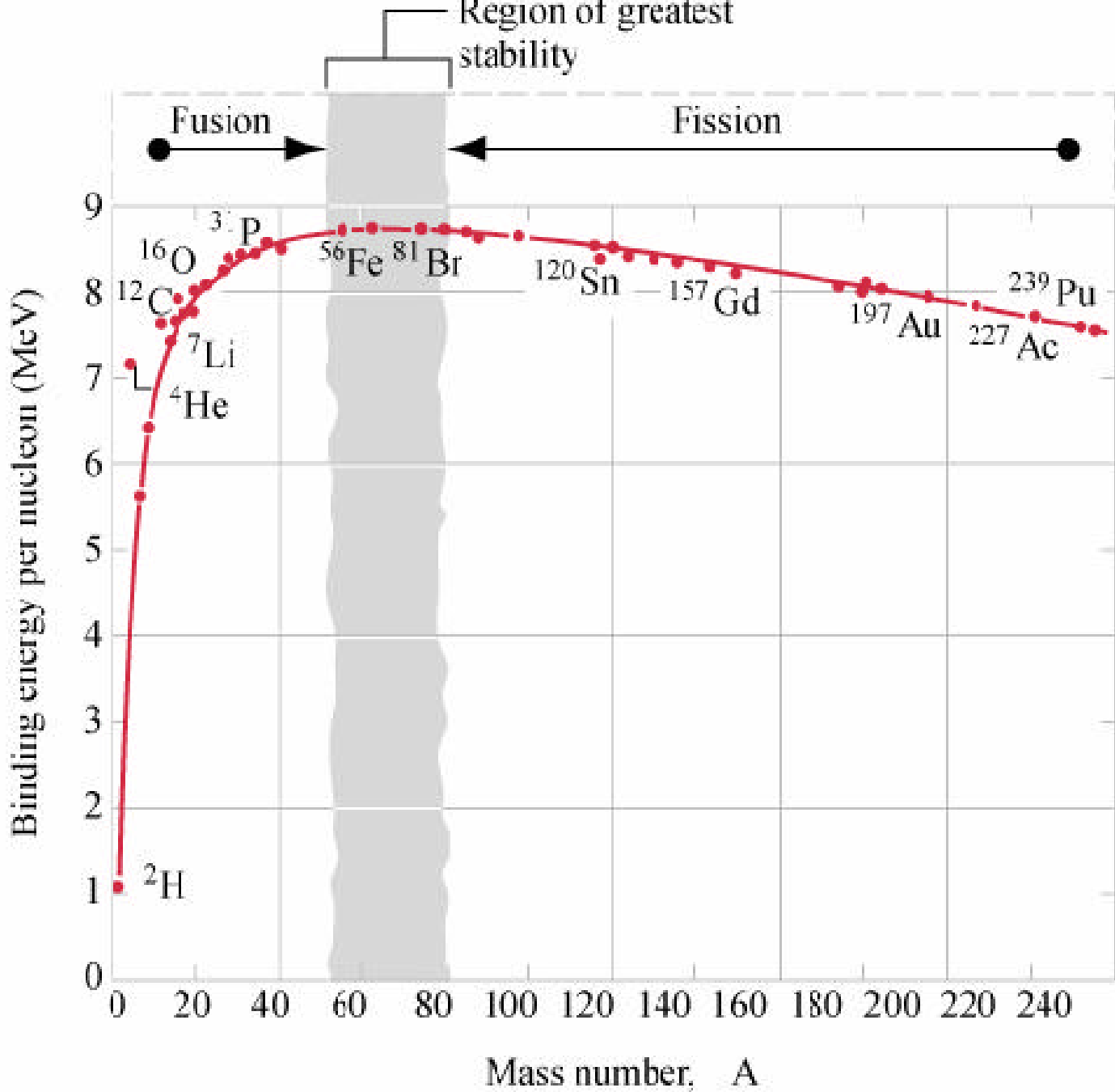
(b) Stadio 2

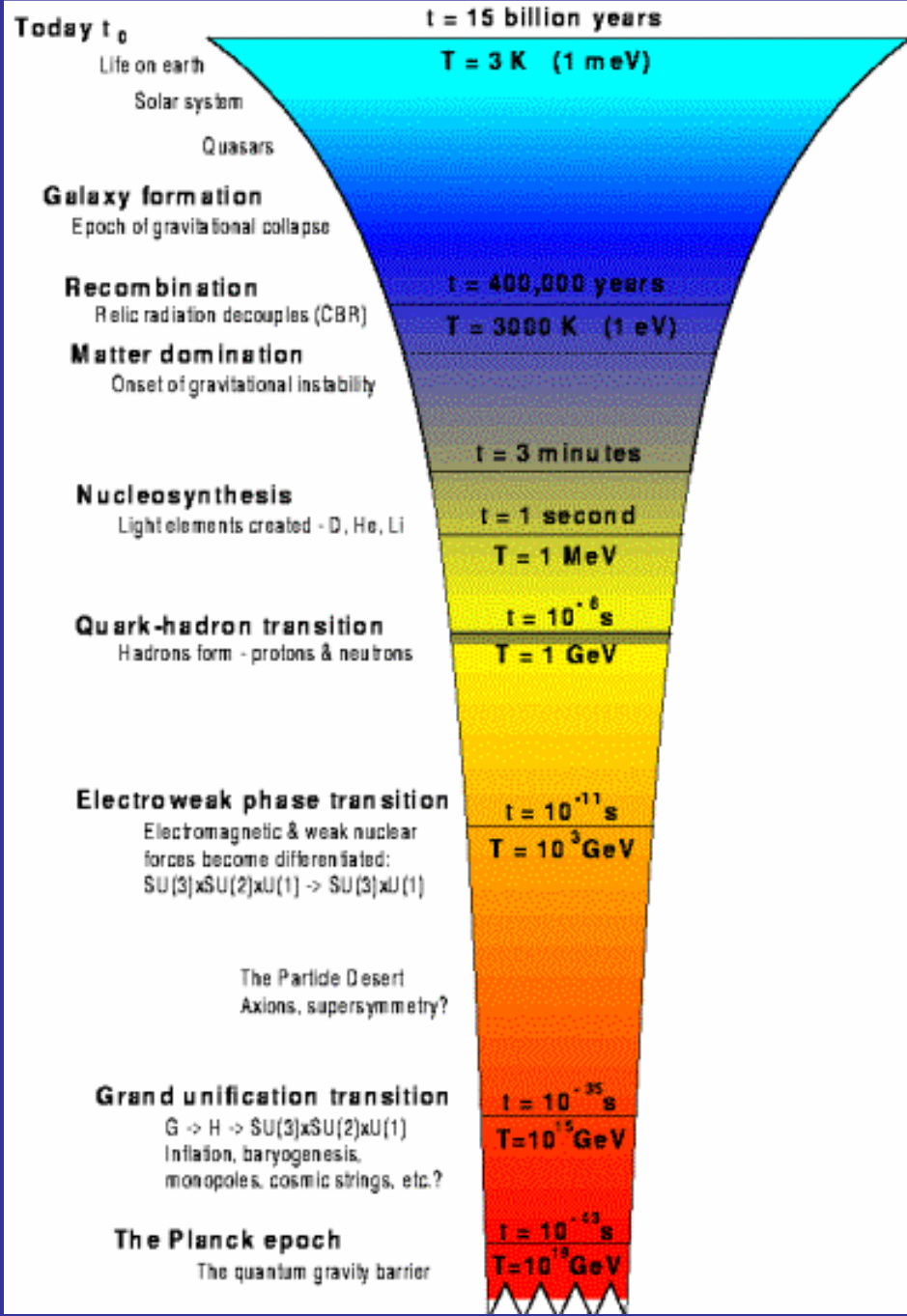
Esempio di trasformazione irreversibile



Diaframma
di separazione

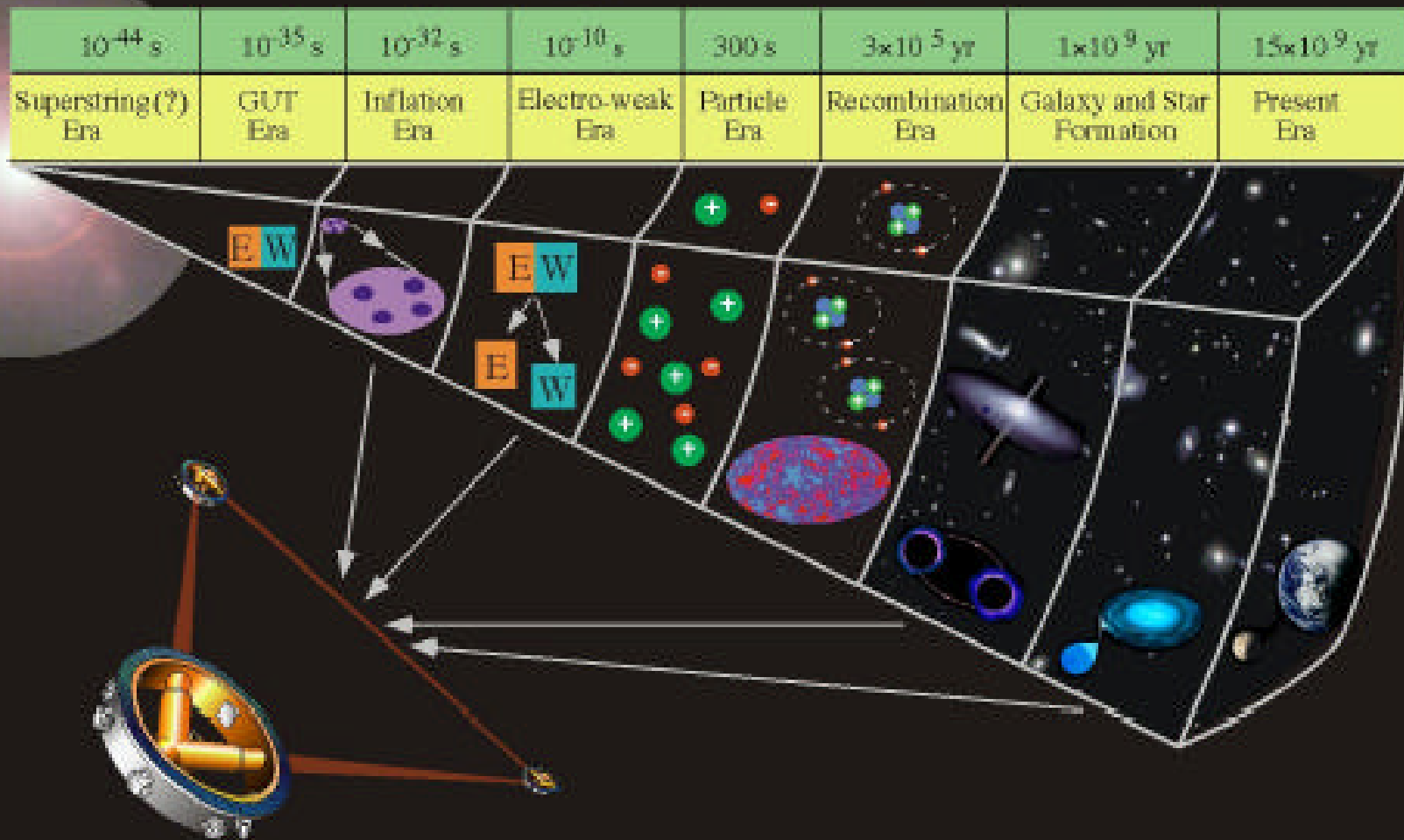






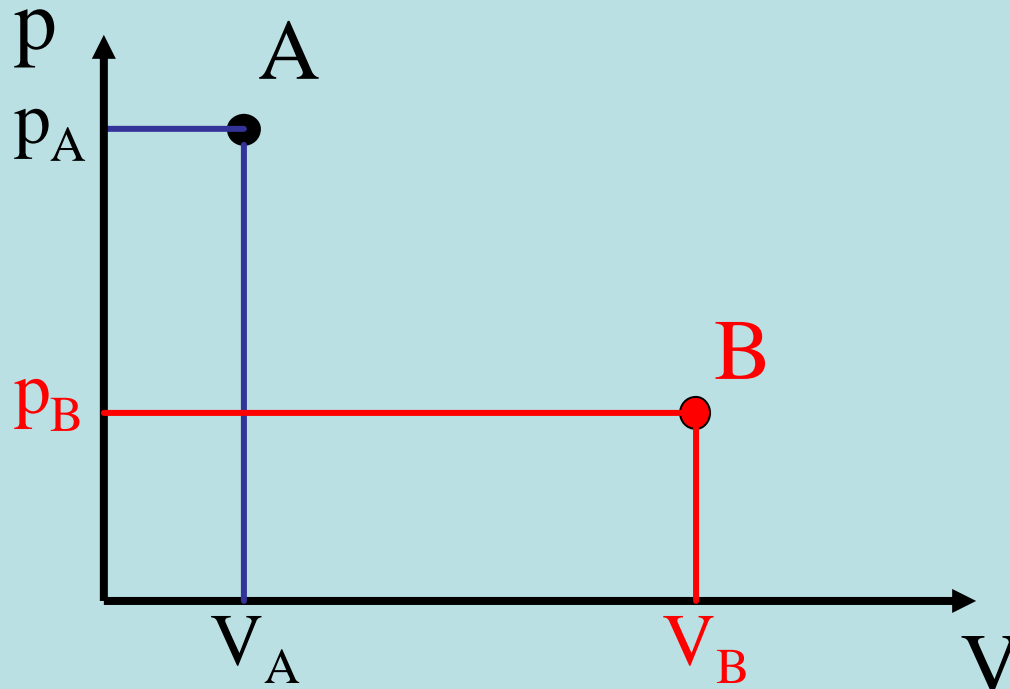
Big Bang

Time \longrightarrow



-Stato termodinamico:

Un gas che si trovi in un certo stato A è caratterizzato da 3 grandezze: p_A , V_A , T_A . In genere questo gas si rappresenta in un sistema di riferimento i cui assi sono p e V .



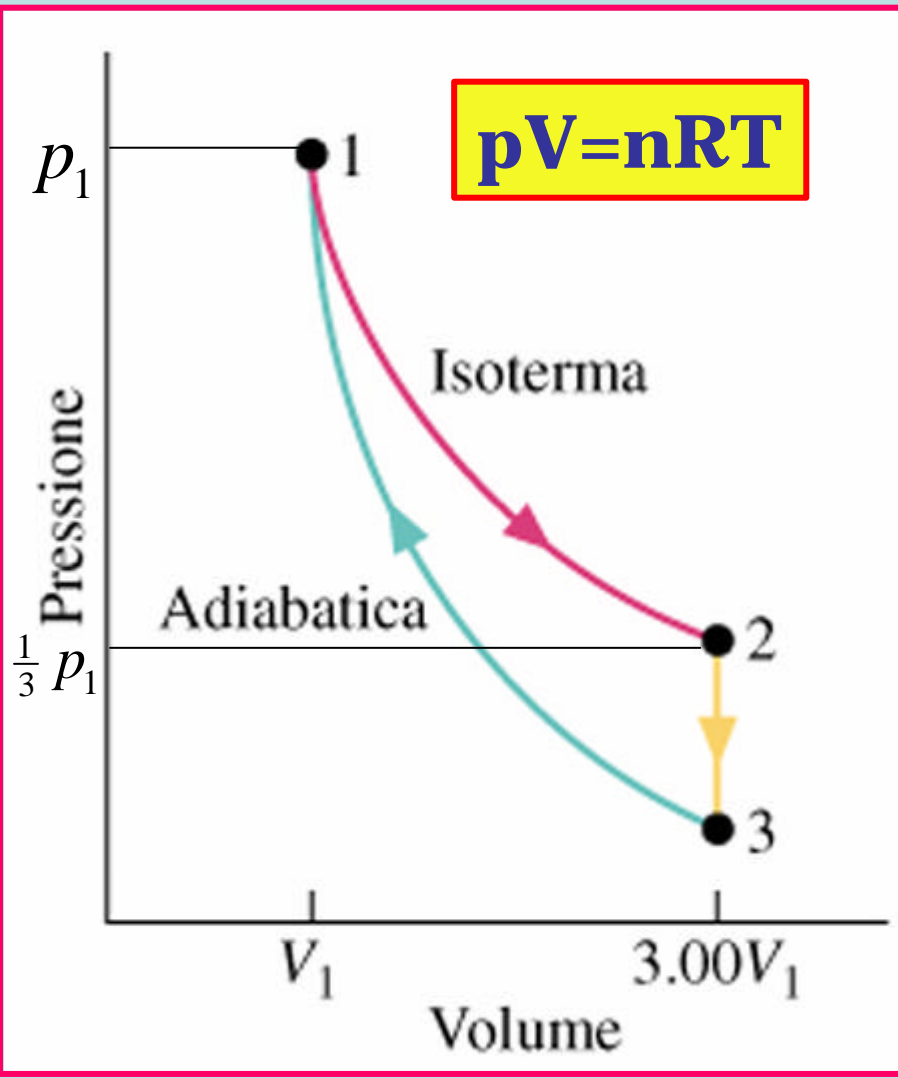
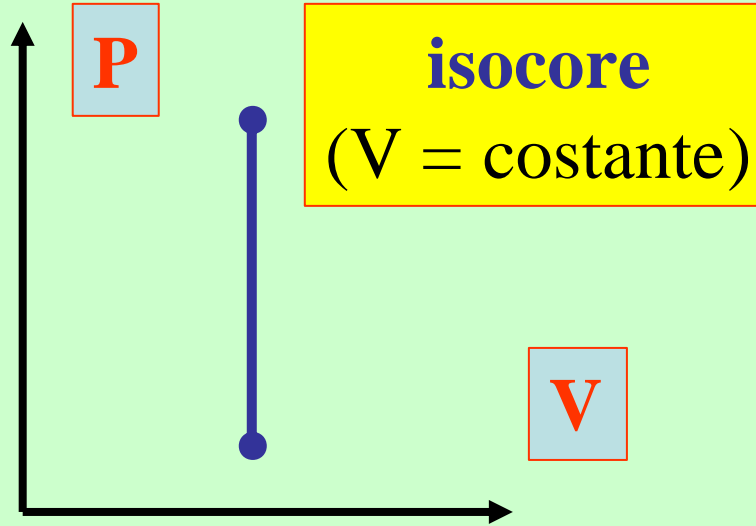
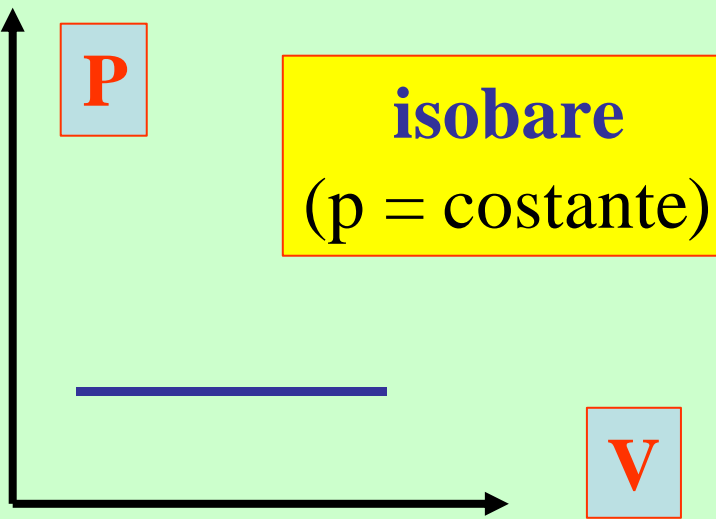
Trasformazioni termodinamiche

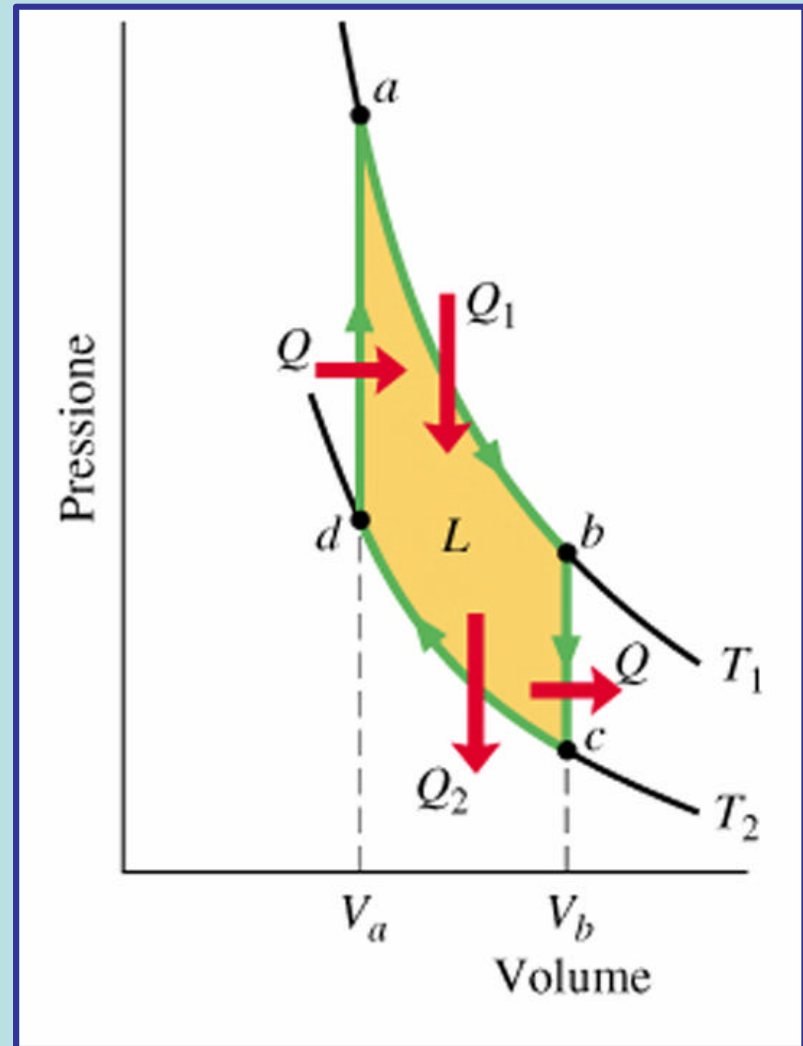
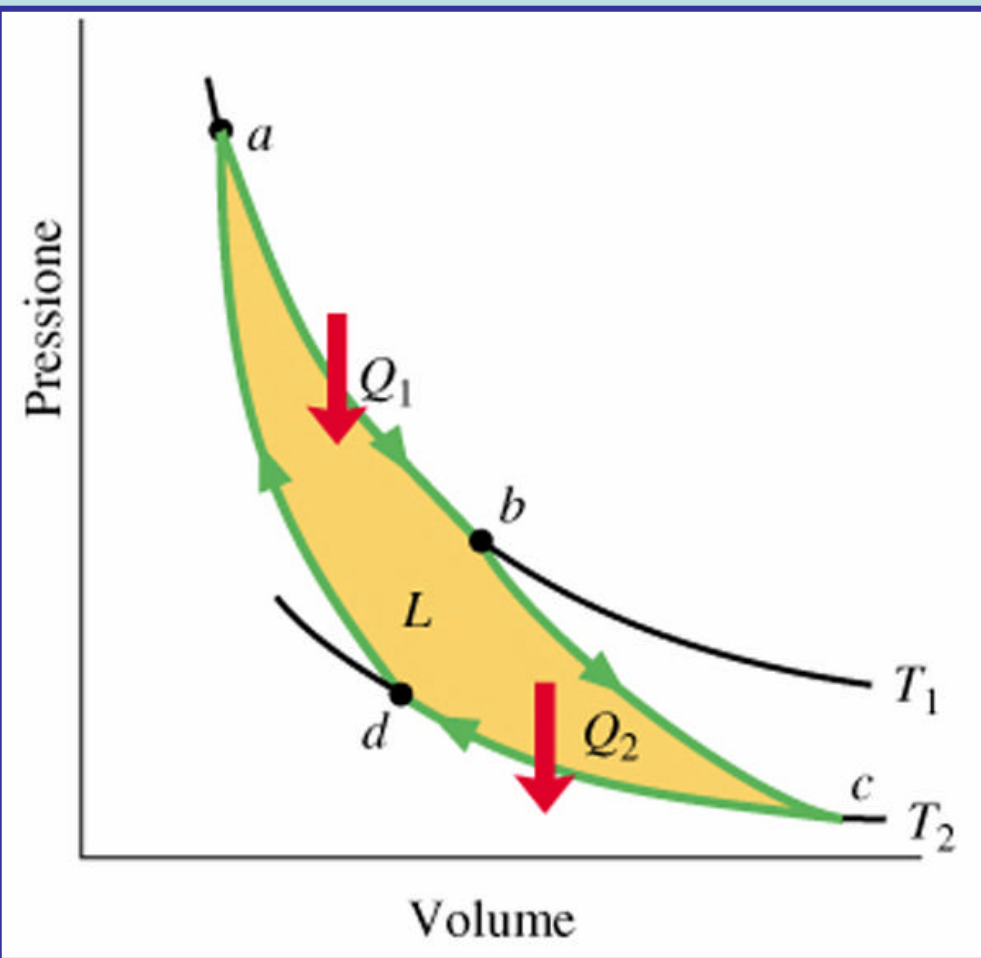
Si ha una trasformazione termodinamica quando un sistema passa da uno stato iniziale $(p_0V_0T_0)$ a uno stato finale (pVT) attraverso successivi stati di equilibrio. In genere questo fatto comporta variazioni di U , Q e L , calcolabili in modo preciso se e' specificato il tipo di trasformazione.

Per definizione, se una forza F esercita la pressione p su di una superficie S e ne produce lo spostamento s , compie il lavoro:

$$\mathbf{L = Fs = pSs = pDV.}$$

Quindi il lavoro e' nullo se $\Delta V = 0$, ossia nelle trasformazioni a volume costante.





Considerando in dettaglio queste trasformazioni, le principali in termodinamica. Dalle definizioni date in precedenza si ha:

isobare: $DU = Q - L = nC_pDT - pDV$

isocore: $DV = 0, L = 0$, da cui $DU = Q = nC_vDT$

isoterme: $DU = 0, Q = L = ?$ $pdV = nRT \ln V_2/V_1$

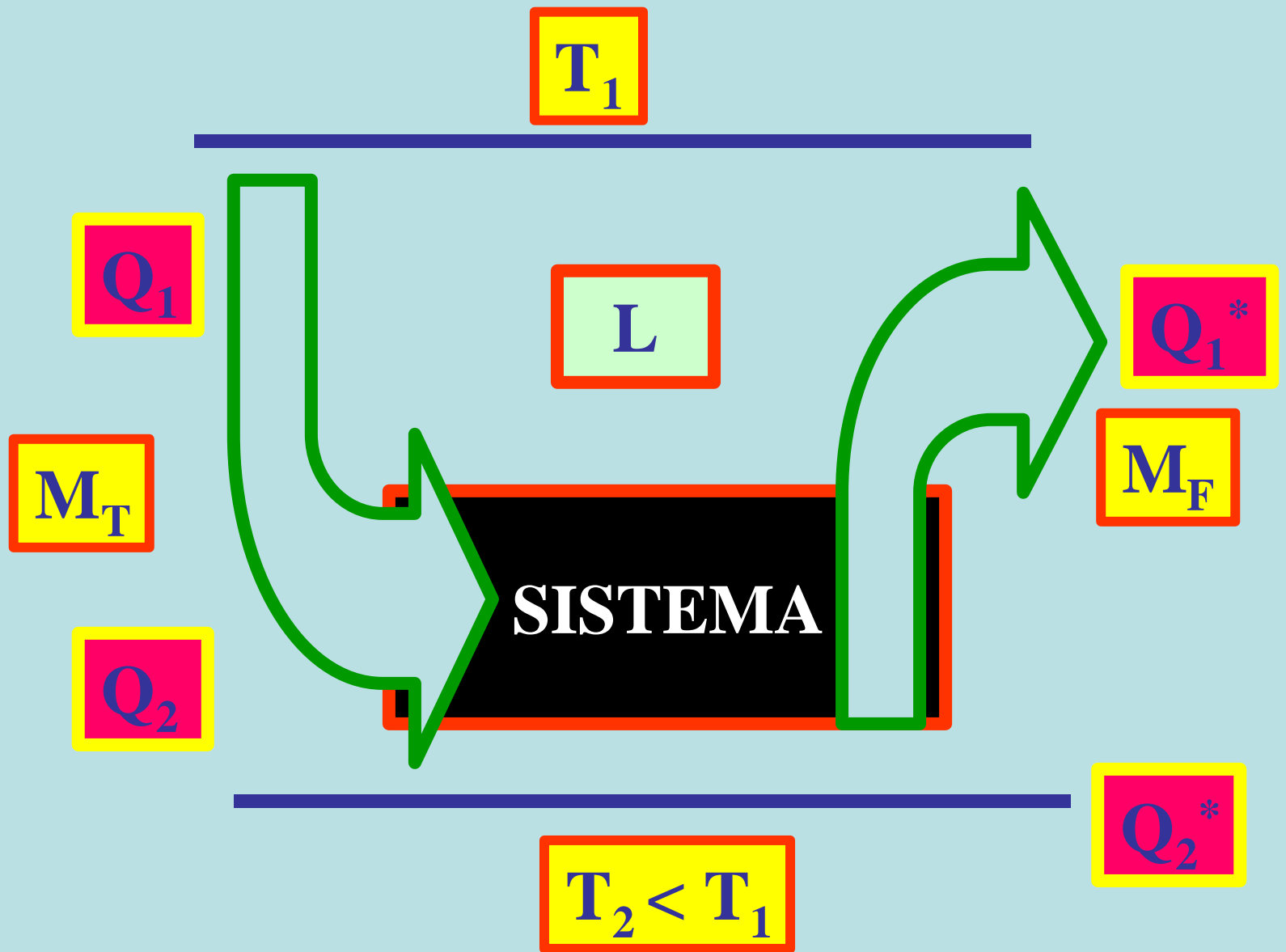
adiabatiche: $Q = 0, DU = -L, pV^{\gamma} = \text{costante}$

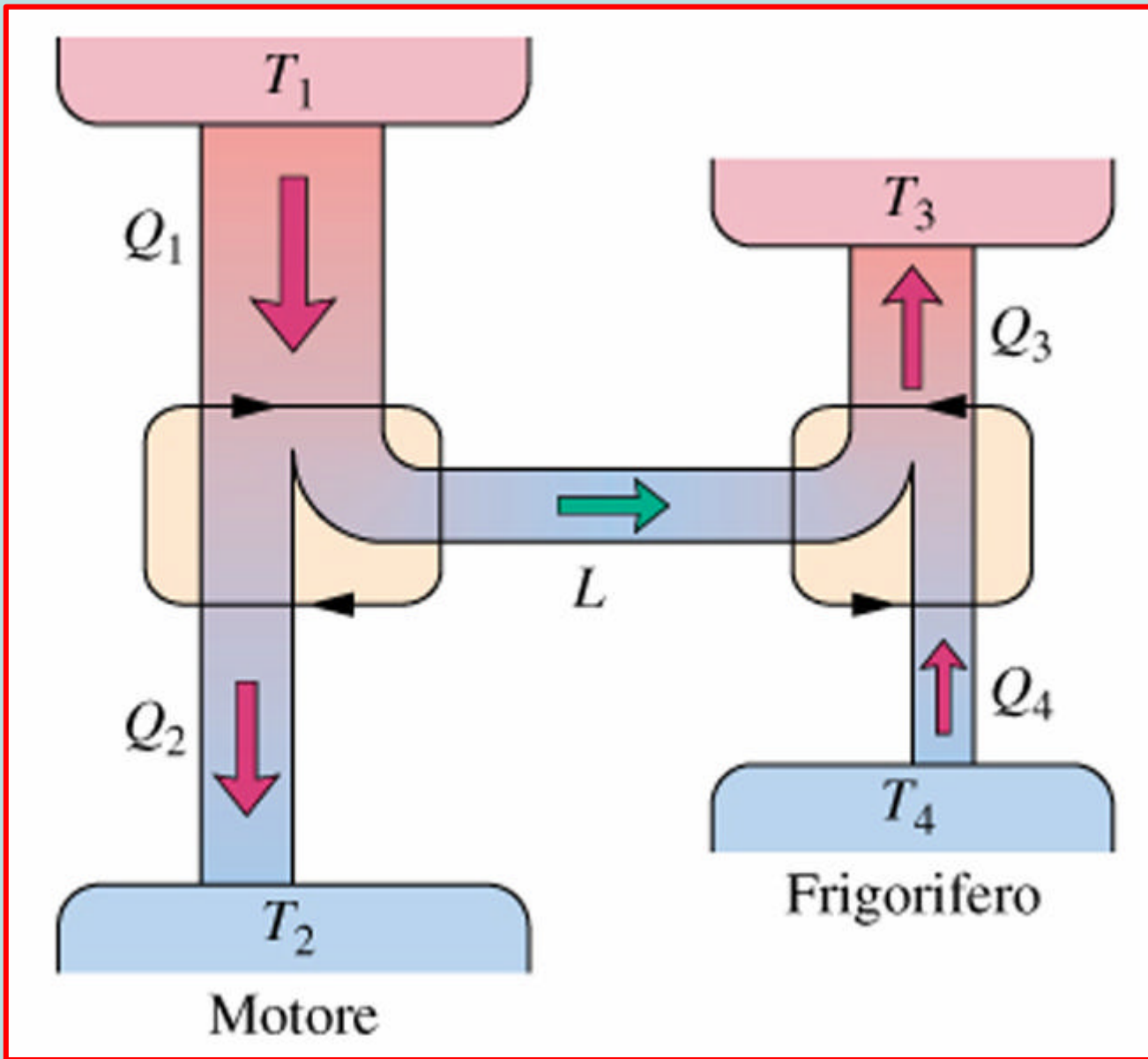
Lo stato di un sistema (per es. acqua solida, liquida o gassosa) è caratterizzato da rapporti ben definiti tra energia termica e potenziale delle particelle del sistema. I cambiamenti di stato (o **transizioni di fase**) avvengono **a temperatura costante**: tutto il calore viene utilizzato per cambiare questo rapporto.

SECONDO PRINCIPIO DELLA TERMODINAMICA

Questo principio limita la trasformazione di energia termica in energia meccanica, ma non il contrario. Le macchine termiche e le macchine frigorifere operano ciclicamente ($\Delta U = 0$) tra due sorgenti di calore, che supponiamo alle temperature T_1 e $T_2 < T_1$, con scambio delle quantità di calore Q_1 e Q_2 , e compiendo il lavoro $L = Q_1 - Q_2$. L'efficienza, o rendimento del ciclo, è:

$$\eta = L/Q_1 = 1 - Q_2/Q_1.$$





Entropia

dal primo principio della termodinamica si ha:

$$dQ = dU + pdV = nC_V dT + nRTdV/V$$

e il valore integrale di Q , ossia $\int dQ$, dipende dal particolare processo considerato, ossia è necessario conoscere $T = T(V)$ per calcolare il secondo termine. La quantità $dS = dQ/T$ è invece un differenziale esatto, da cui segue che in un processo **reversibile** $dS = 0$, e che

l'entropia dell'universo non può diminuire per la presenza di processi irreversibili.

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Supernova 1987A

23 February 1987

