

A.C.A. - Associazione Cernuschese Astrofili

# FATTI DI POLVERE DI STELLE



by Andrea Grieco

FISSE ?

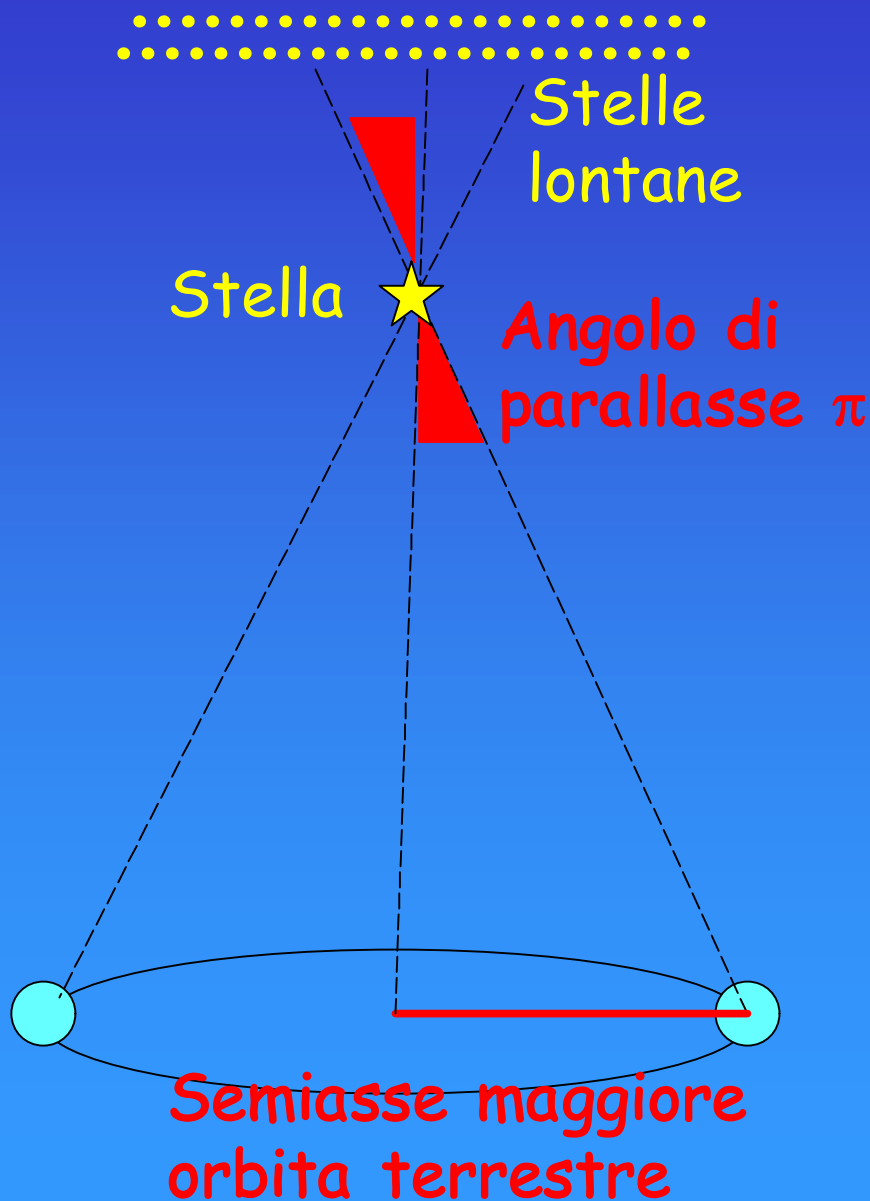
IMMUTABILI?

ETERNE ?

Twinkle, twinkle little star  
I don't wonder what you are  
For the spectroscopic ken  
I know that you are hydrogen  
I.D. Bush



# DISTANZA DELLE STELLE



W. Bessel 1837 61  
Cygni  $\pi=0",762$   $d=11,1$  al

W. Struve 1838  $\alpha$  Lyrae  
 $\pi=0",123$   $d=26$  al

Metodo della parallasse

Hipparcos  $\sim 500$  al

$1$  pc  $\approx 3,26$  al



# LA NOSTRA GALASSIA



1918 H. Shapley Prima stima della struttura della Via Lattea

Galassia M101 - Pinwheel in Ursa Major a 27 Mly

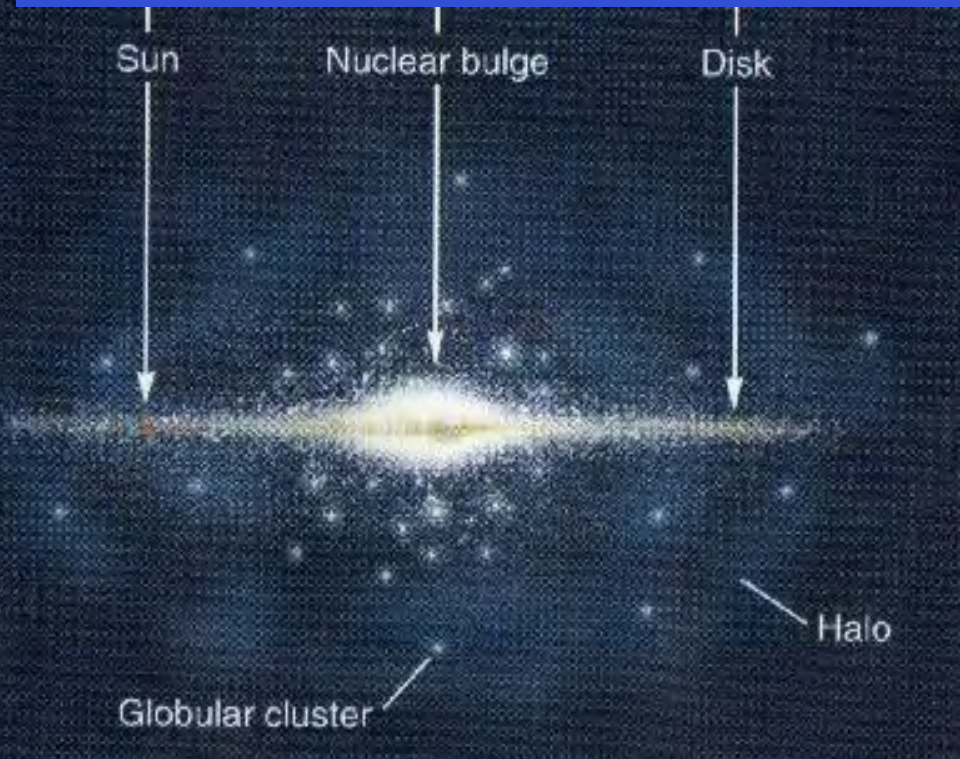
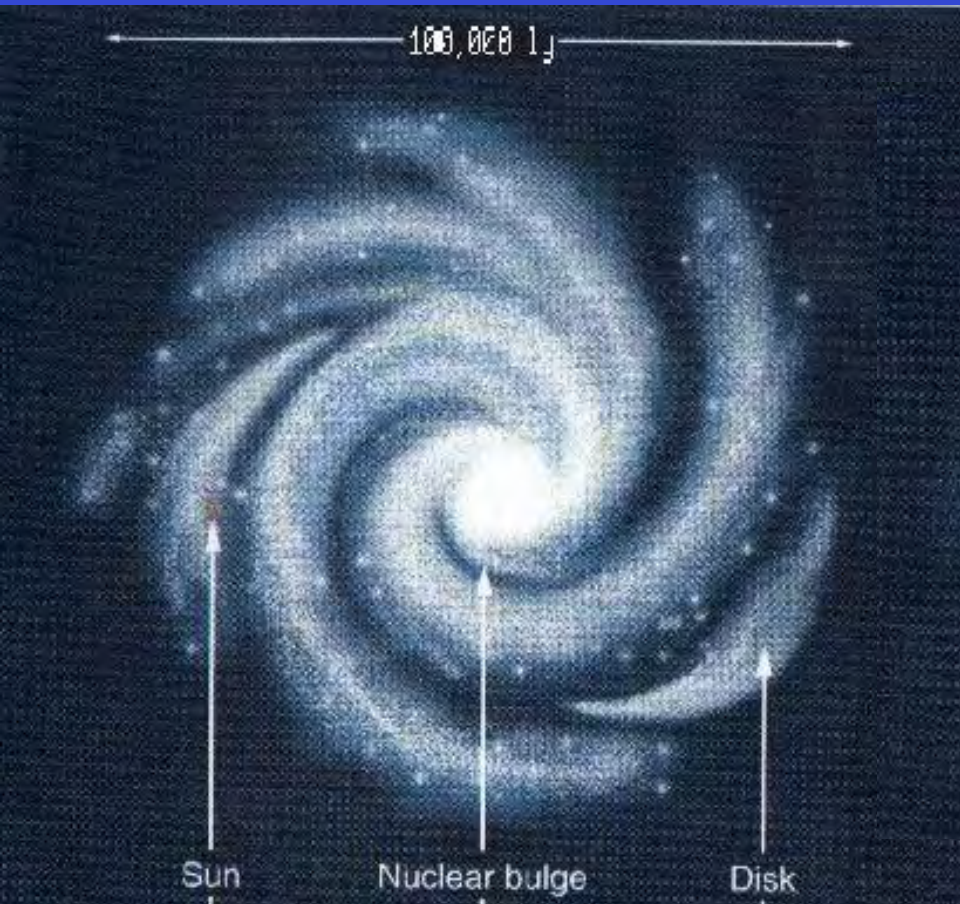
La Via Lattea ha una struttura simile.

Sotto: immagine della Via Lattea nell'infrarosso ripresa da satellite IRAS





# STRUTTURA DELLA VIA LATTEA




# LE GALASSIE

1924 E. Hubble Molte nebulose sono sistemi stellari simili alla Via Lattea

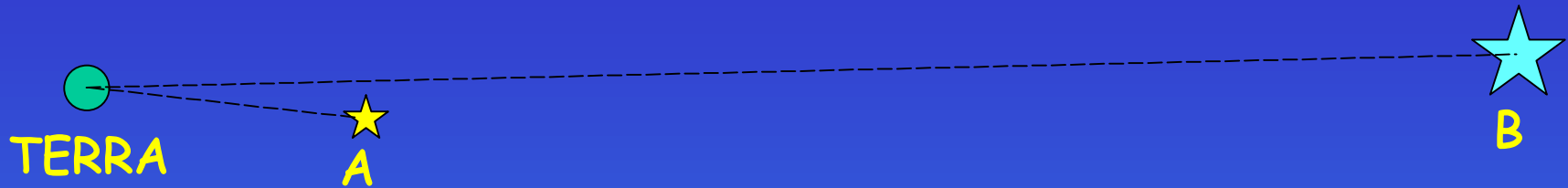


Fonte HST - NASA

The Hubble Deep Field North  HUBBLESITE.org



# LA LUMINOSITA' DELLE STELLE



LUMINOSITA' ASSOLUTA  $L_B > L_A$

MAGNITUDINE ASSOLUTA  $M_B < M_A$

LUMINOSITA' APPARENTE  $I_B < I_A$

MAGNITUDINE APPARENTE  $m_A > m_B$

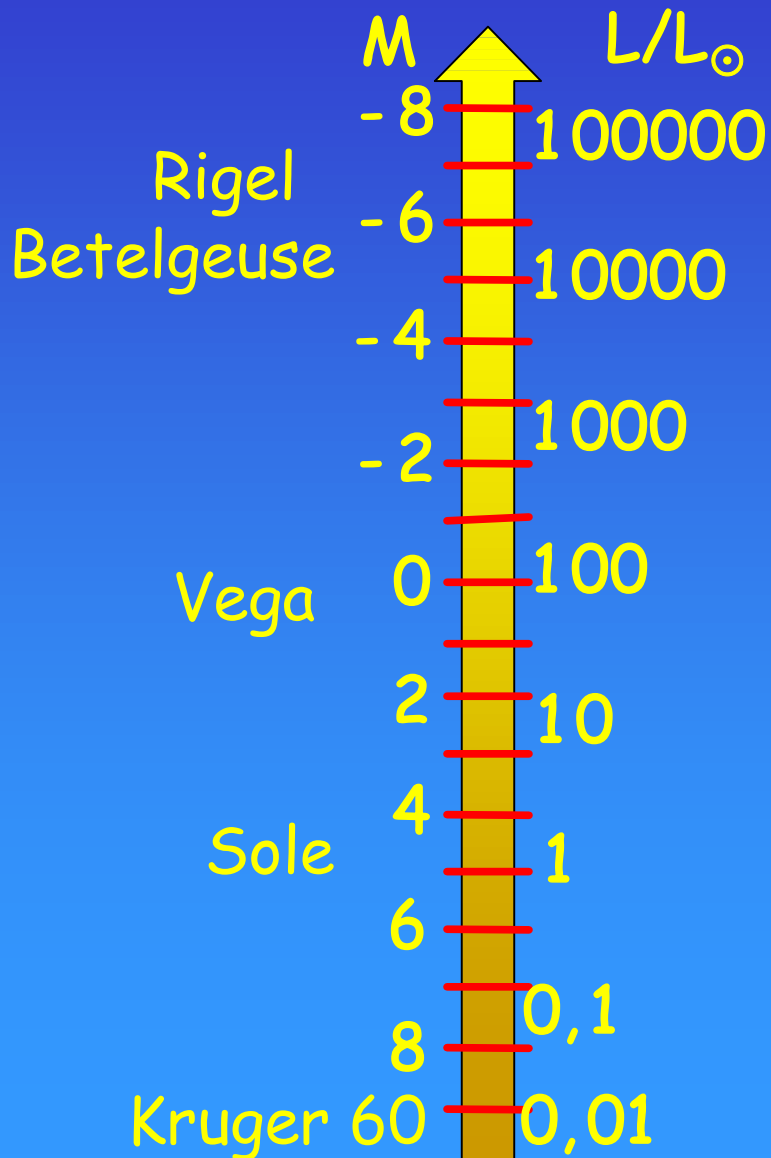


**Relazione di Pogson**

$$m_A - m_B = -2,5 \text{Log}(I_A / I_B)$$



# MAGNITUDINI ASSOLUTE



LA MAGNITUDINE ASSOLUTA M E' LA MAGNITUDINE DI UNA STELLA POSTA A

$$10 \text{ pc} = 32,6 \text{ ly}$$

$$M_{\odot} = +4,87$$

$$M_{\text{Bet}} = -5,26$$

$$L_{\text{Bet}}/L_{\odot} = 11.000$$

$$L_{\odot} = 3,86 \times 10^{26} \text{ W}$$



# I COLORI DELLE STELLE

## ORION

Betelgeuse

Rigel

ANCHE AD OCCHIO NUDO  
IN UNA NOTTATA LIMPIDA  
E' POSSIBILE DISTINGUERE  
STELLE DI COLORE DIVERSO

## TAURUS

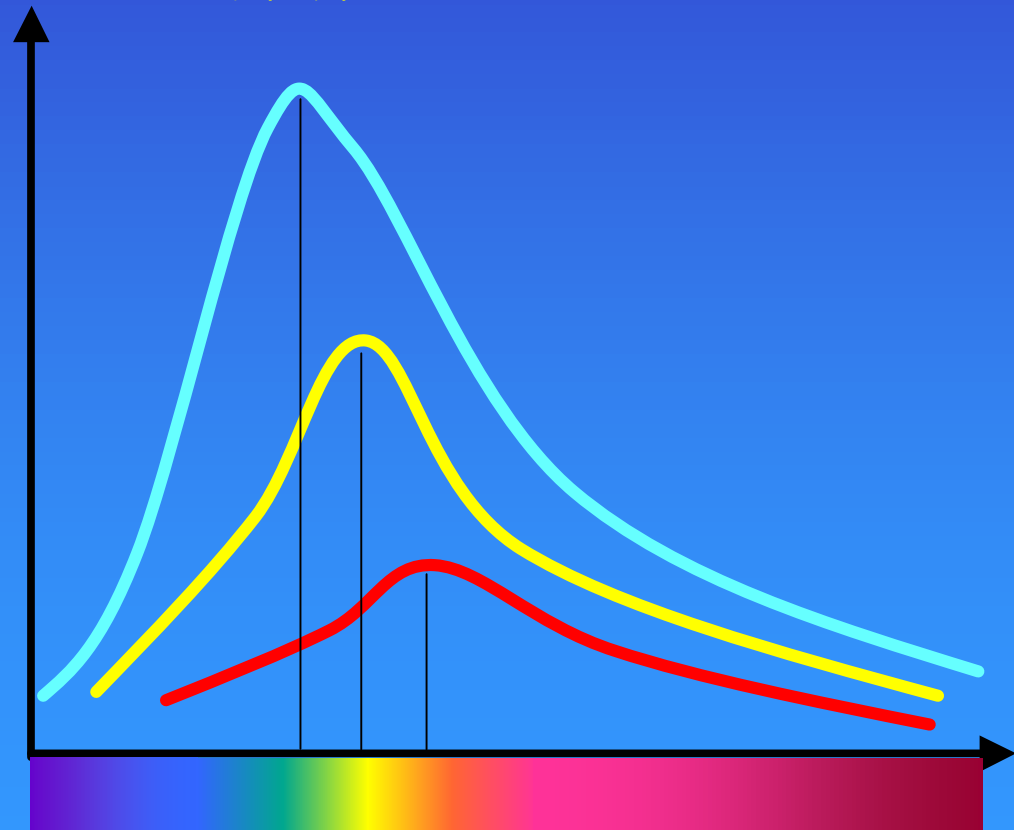
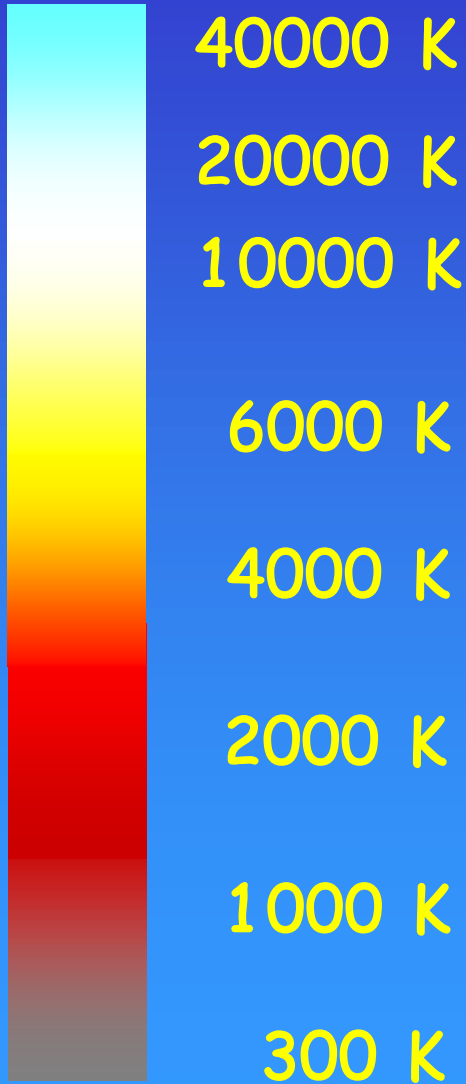
Aldebaran



# IL TERMOMETRO DEI COLORI

## LEGGE DI WIEN

$$\lambda_{MAX} T = \text{cost.}$$





# QUANTO SONO GRANDI?



LUMINOSITA'  $\div$  (RAGGIO)<sup>2</sup>



LUMINOSITA'  $\div$  (TEMPERATURA)<sup>4</sup>



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



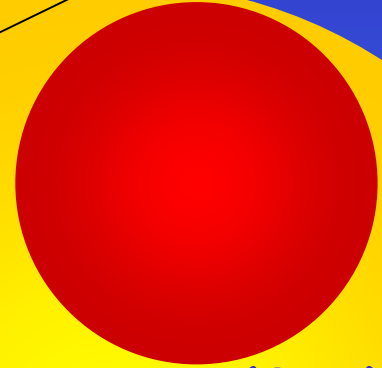
# RAGGI STELLARI



Rigel (19)

Sole (1)

Scheat (112)



Nana Rossa (0,3)

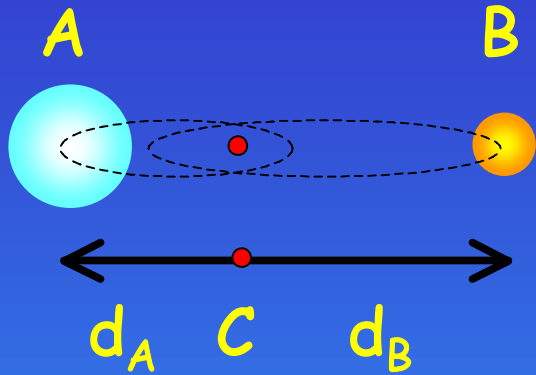
Sirio B  
(0,01)

Sole (1)

$R_{\odot} \approx 0,7 \times 10^9 \text{ m}$

Betelgeuse (400)

# LE MASSE



SISTEMA BINARIO



$$T^2/d^3 \div (M_A + M_B)$$

$$M_{\odot} \approx 2,0 \times 10^{30} \text{ Kg}$$

$$M_A/M_B \div d_B/d_A$$

$$M_{\star} \approx 0,04 - 100 M_{\odot}$$

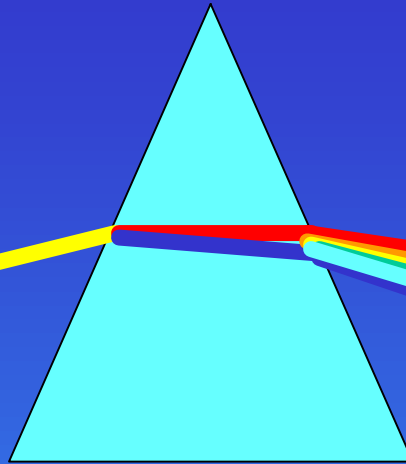


# L'IMPRONTA DELLA LUCE

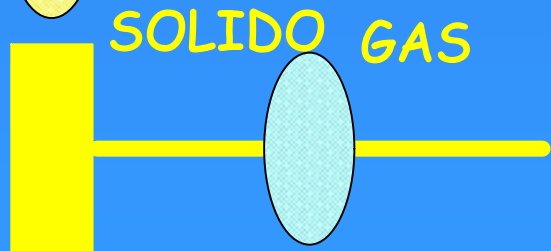
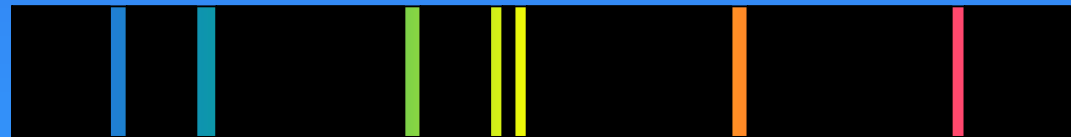
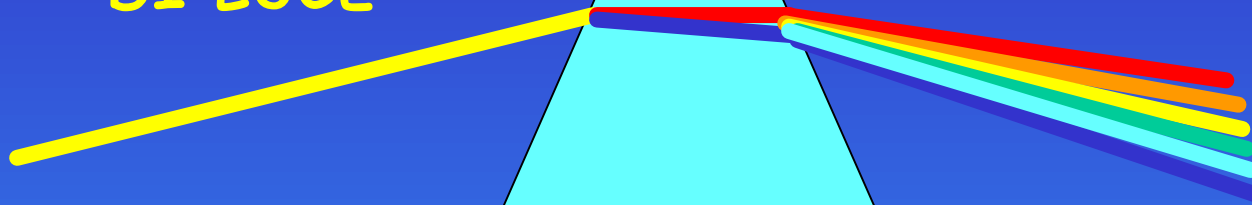
RAGGIO  
DI LUCE

1666 I. Newton

SPETTRO



PRISMA



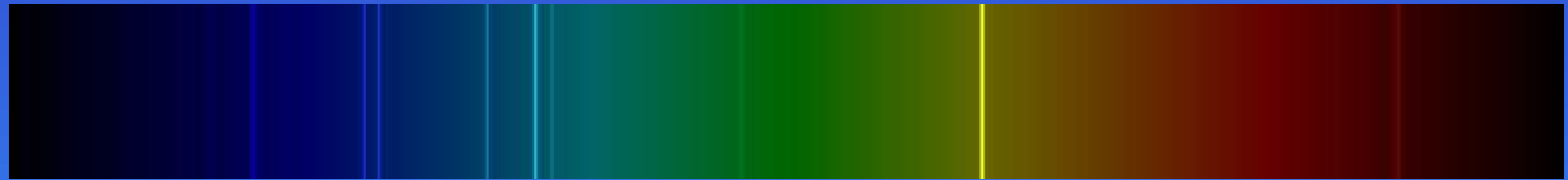


# GLI SPETTRI DEGLI ELEMENTI

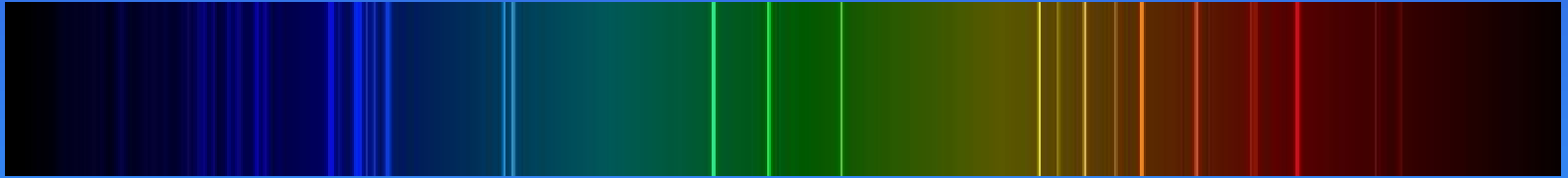
H



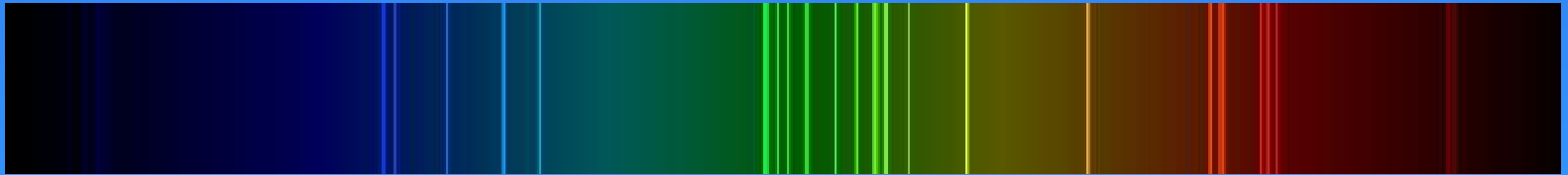
He



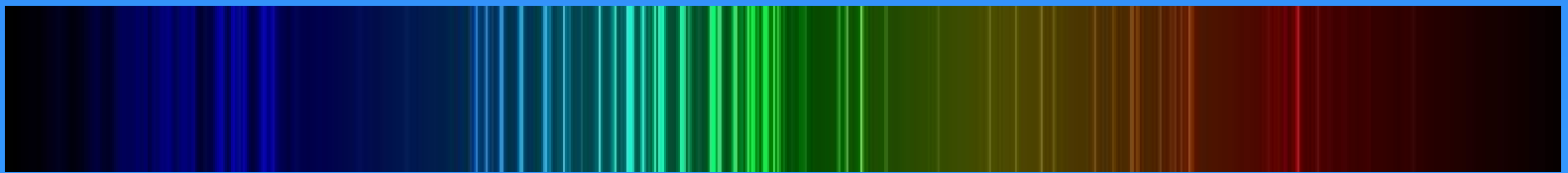
O



S

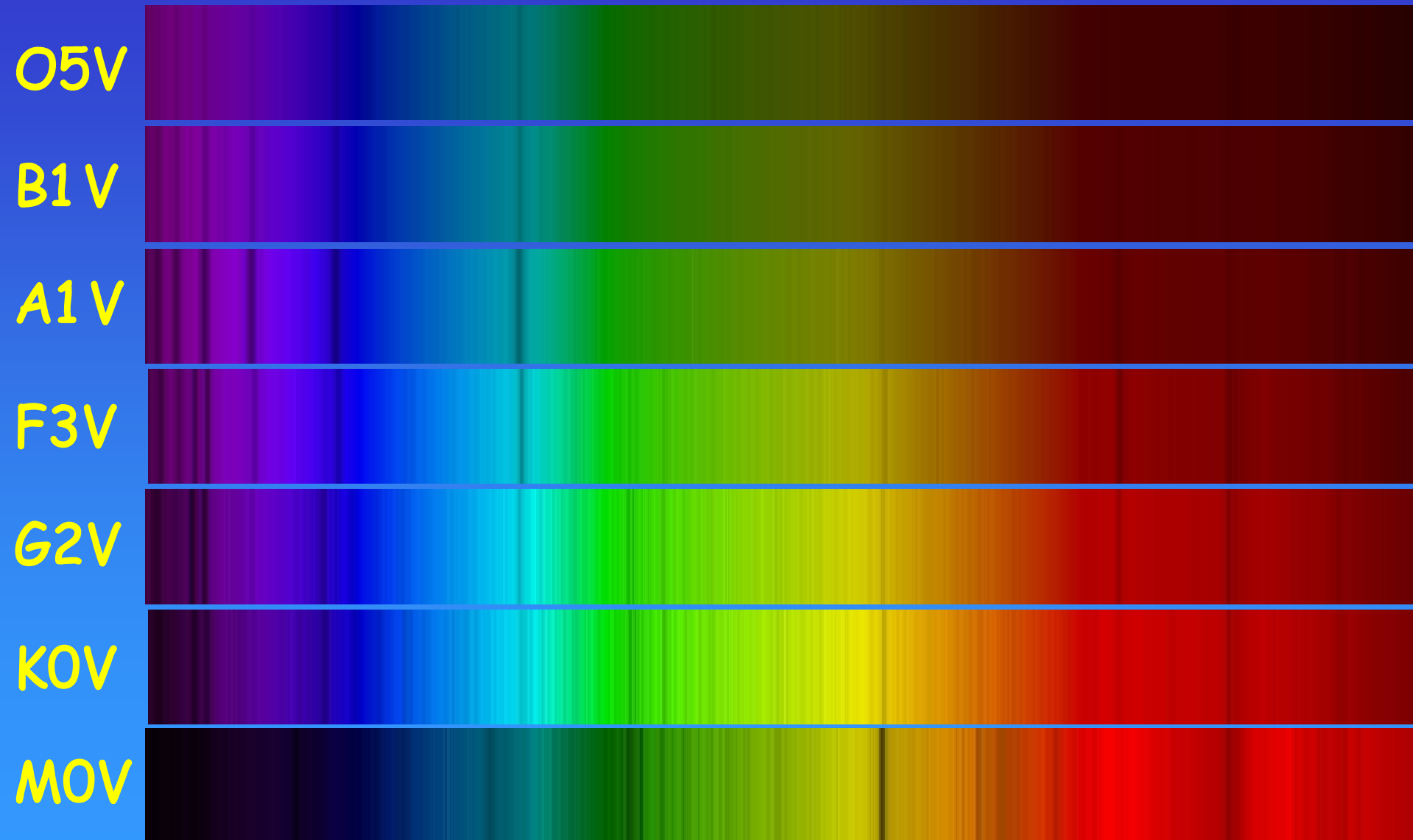


Fe





# GLI SPETTRI STELLARI

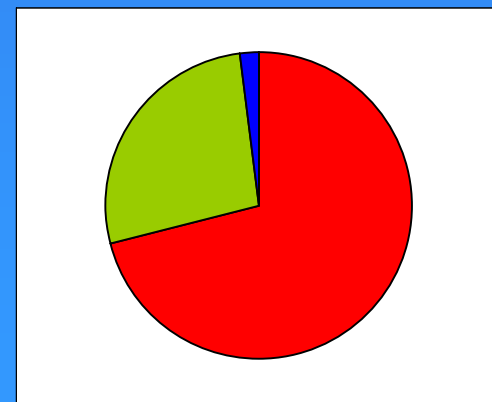
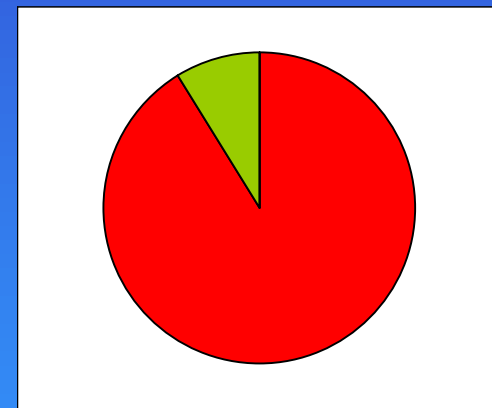




# LA MATERIA DELLE STELLE

ELEMENTO	% ATOMI	% MASSA
Idrogeno	91.2	71.0
Elio	8.7	27.1
Ossigeno	0.078	0.97
Carbonio	0.043	0.40
Azoto	0.0088	0.096
Silicio	0.0045	0.099
Magnesio	0.0038	0.076
Neon	0.0035	0.058
Ferro	0.030	0.014
Zolfo	0.15	0.040

Composizione  
chimica del  
Sole

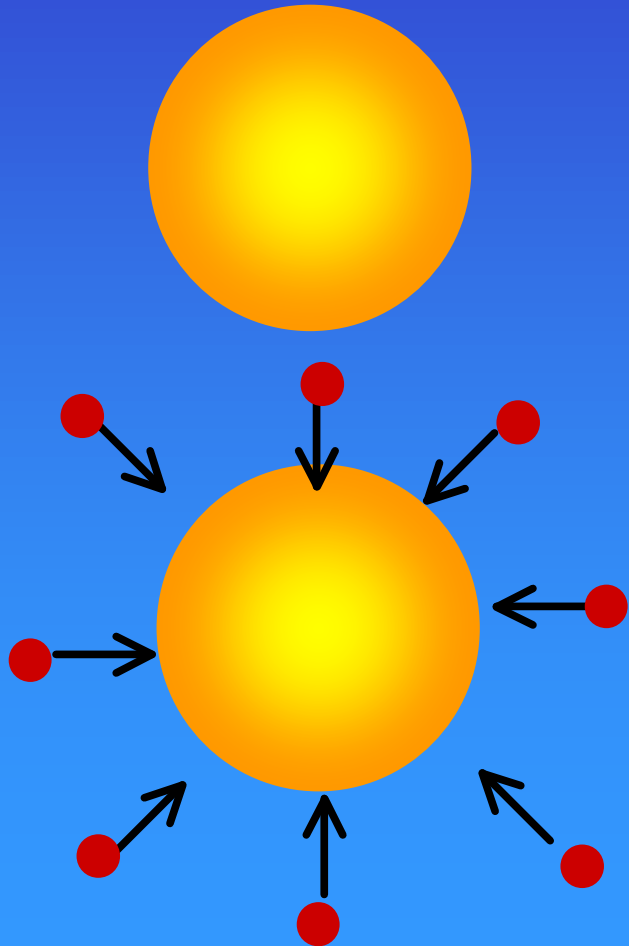




# DA DOVE VIENE L'ENERGIA?

CONSERVAZIONE DELL'ENERGIA  $\Rightarrow$  DA DOVE VIENE L'ENERGIA?

SOLE  $L \approx 3,8 \times 10^{26} \text{ W}$



~1850 J. V. MAYER  
COMBUSTIONE CHIMICA

$t \approx 6.000 \text{ My}$

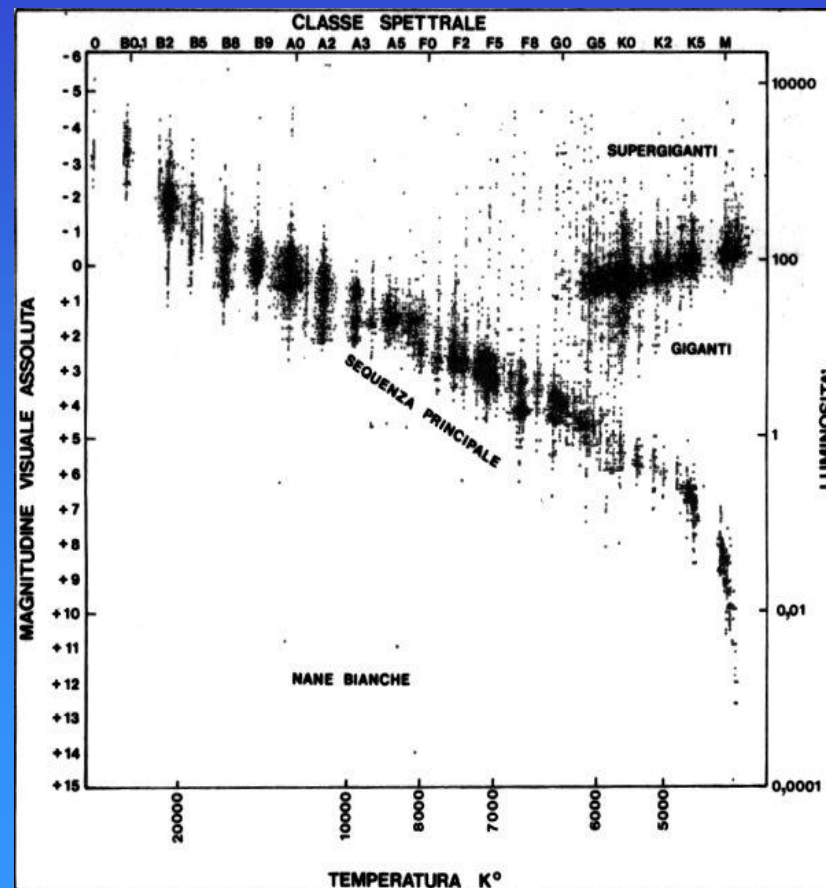
~1850 J. V. MAYER  
CADUTA DI METEORITI

W. T. LORD KELVIN  
VARIAZIONE ORBITE  
INCOMPATIBILE



# IL DIAGRAMMA H-R

1905-14 E. Hertzsprung e H.N. Russel In un diagramma Luminosità-**Temperatura** le stelle si distribuiscono in modo non casuale

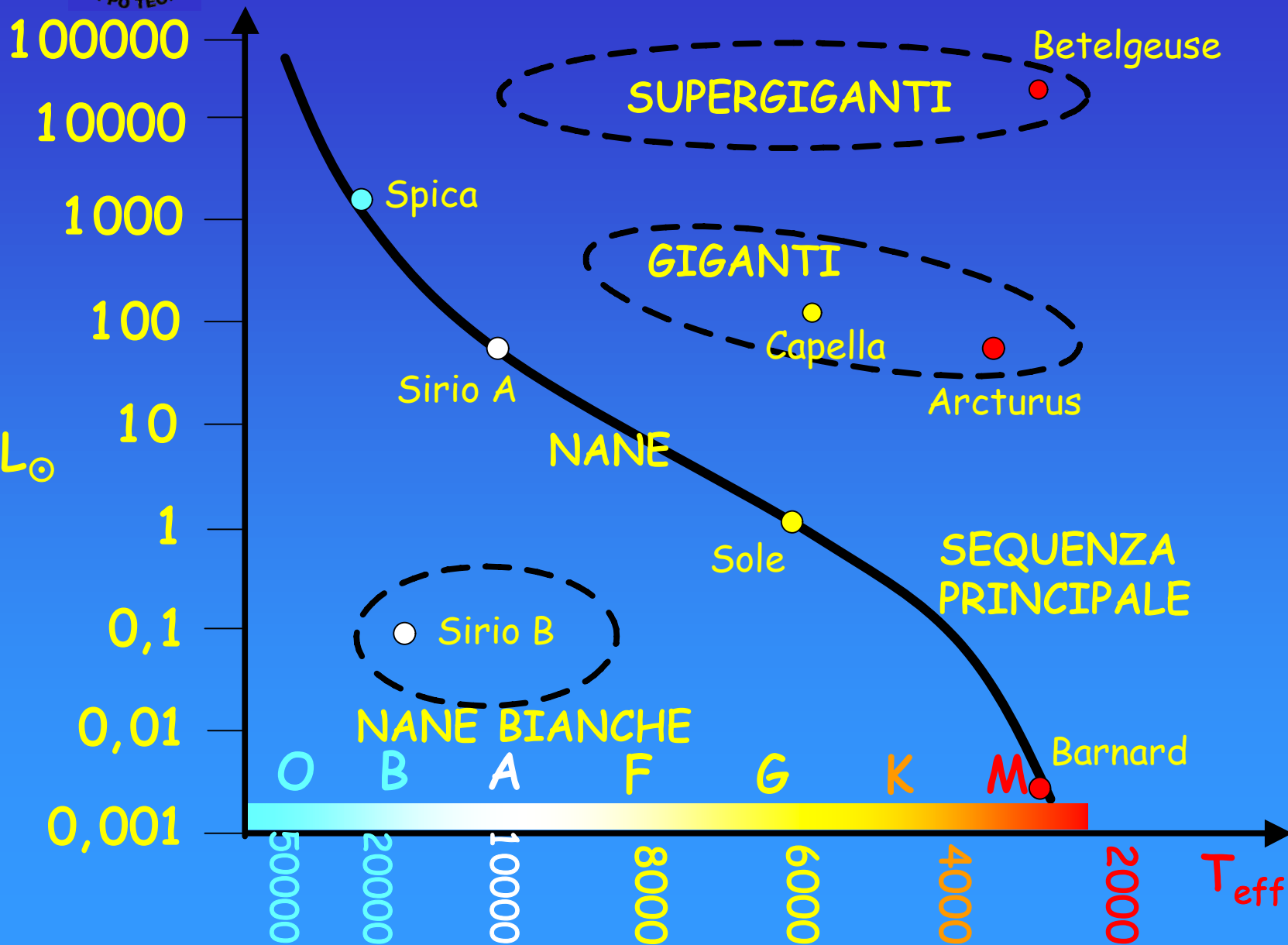


1914 H.N. Russel "Nature"

H-R con dati da terra



# IL DIAGRAMMA H-R

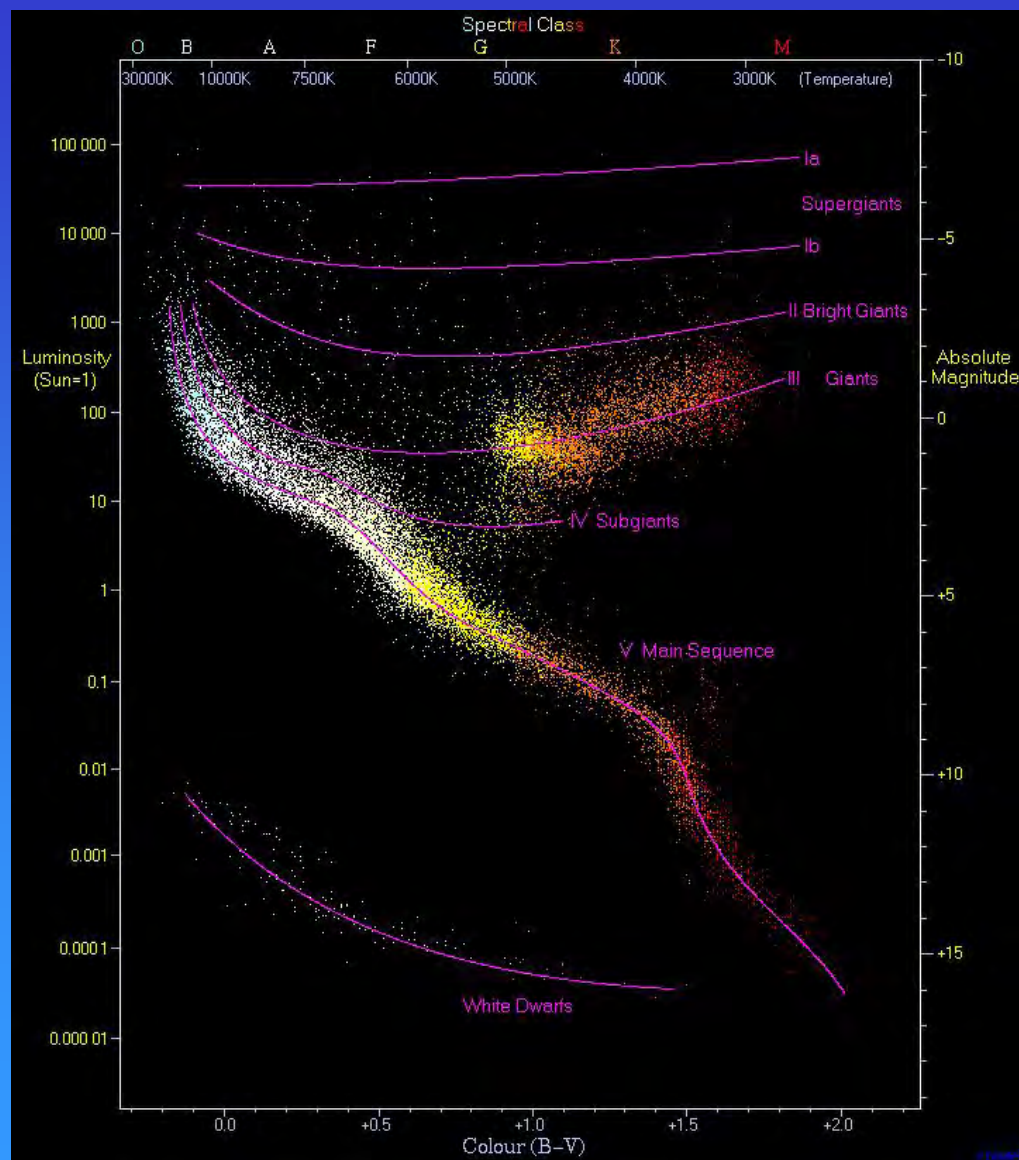




# DATI RECENTI

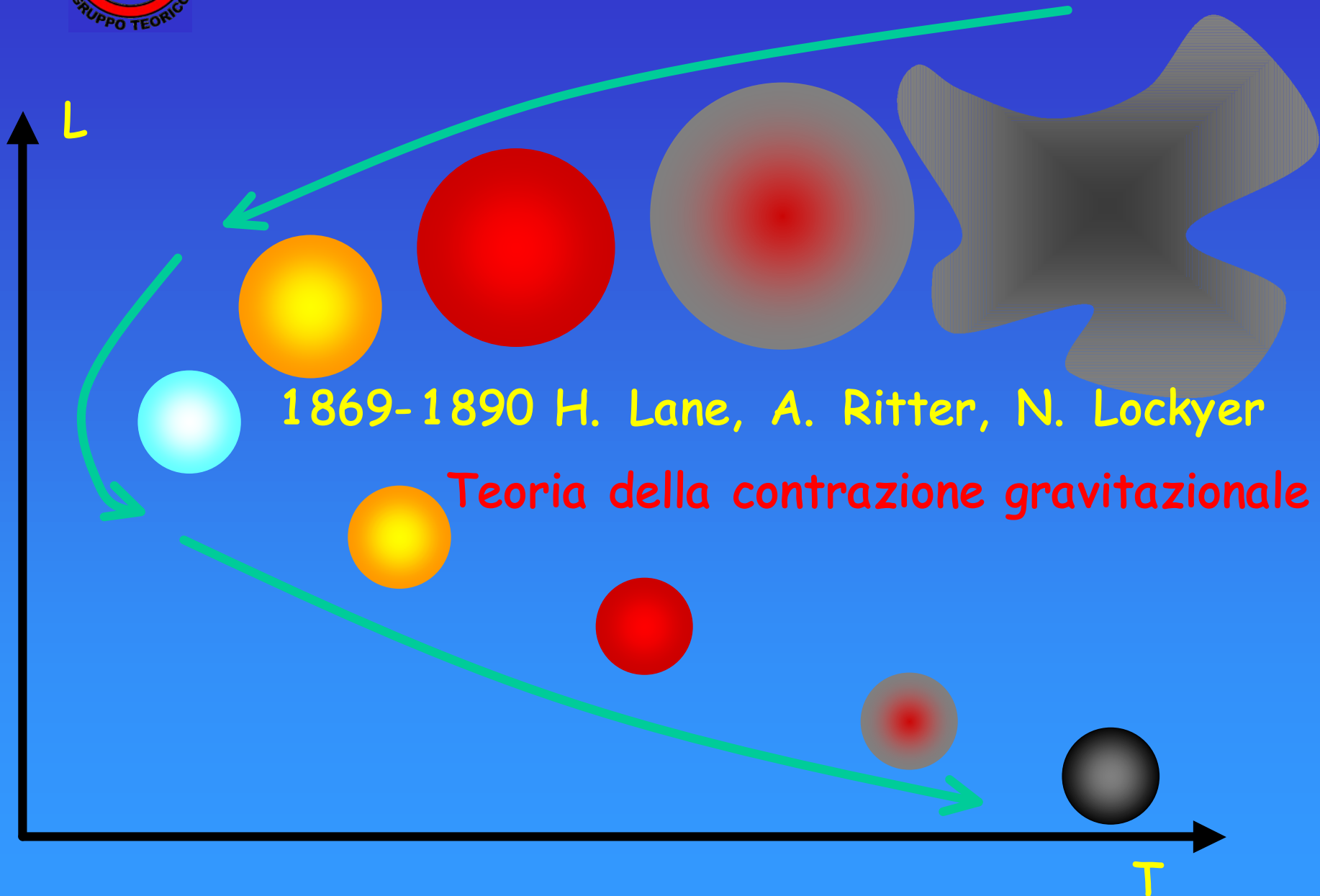
UTILIZZANDO  
DATI RECENTI  
SONO BEN  
VISIBILI LE  
REGIONI IN CUI  
È SUDDIVISO IL  
DIAGRAMMA H-R

H-R dati da  
Hipparcos e Gliese  
by R. Powell





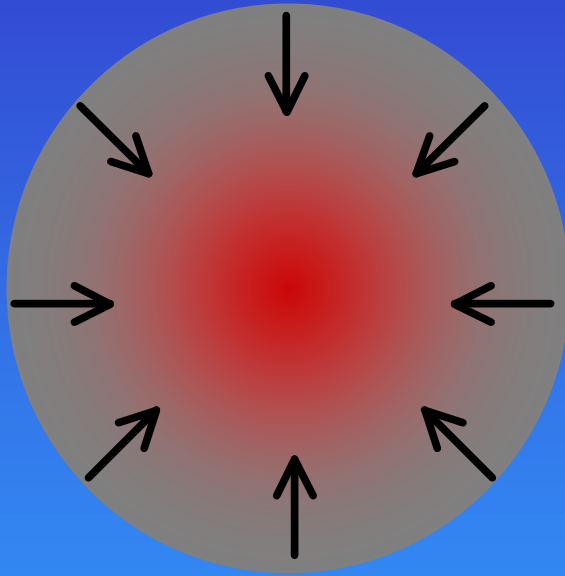
# UNA PRIMA TEORIA





# ENERGIA GRAVITAZIONALE

CONTRAZIONE GRAVITAZIONALE  $\Rightarrow$  AUMENTO DI TEMPERATURA



~ 1890 Lockyer, Emden  
Helmholtz, Kelvin



PER IL SOLE

$$E \approx 3,8 \times 10^{41} \text{ J}$$

$$L \approx 3,8 \times 10^{26} \text{ W}$$

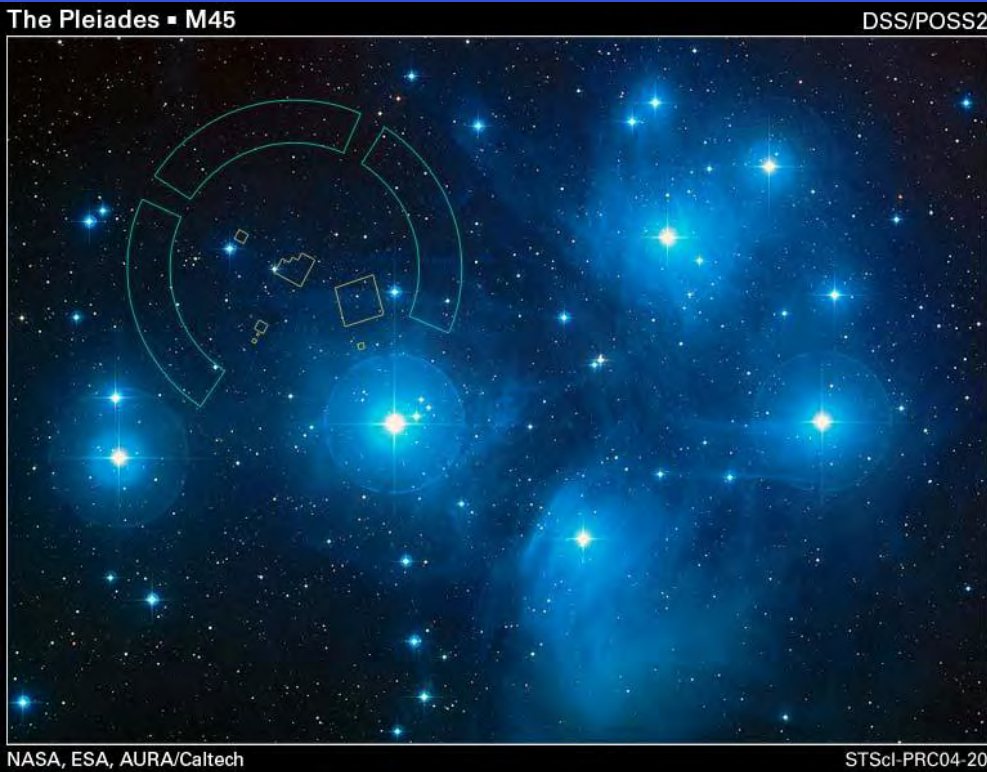
ENERGIA LIBERATA  
 $E \approx GM^2/R$

$$t \approx 2,5 \times 10^{14} \text{ s} \approx 30 \text{ My}$$



# LE DUE POPOLAZIONI

1944 Baade Nella Galassia vi sono due sistemi stellari distinti per caratteristiche dinamiche e composizione chimica



Popolazione I

$$Z \approx Z_{\odot}$$



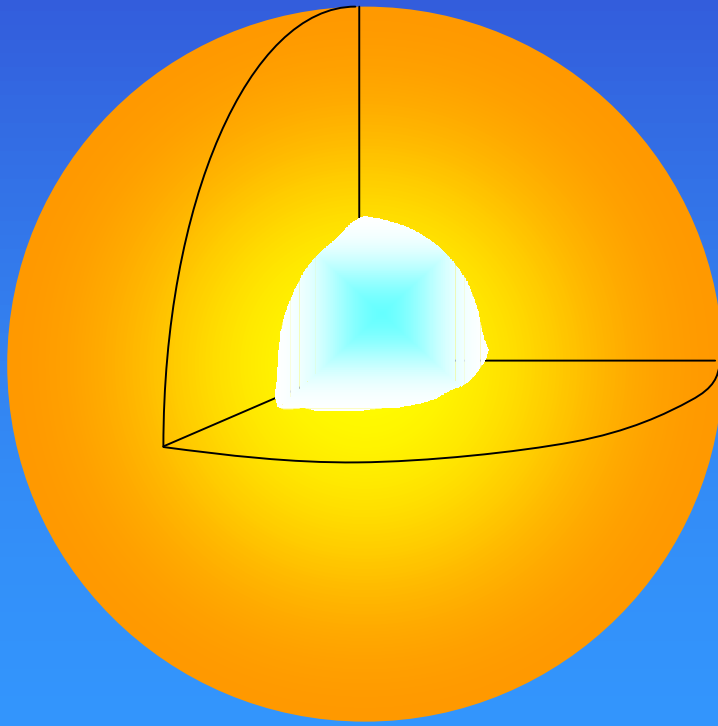
Popolazione II

$$Z \approx 0,01Z_{\odot}$$



# LE CONDIZIONI INTERNE

1890-1940 MODELLI MATEMATICO-FISICI  
DELL'INTERNO STELLARE



$$T \approx 5 - 15 \times 10^6 \text{ K}$$

$$P \approx 10^9 \text{ Pa} \approx 10^4 \text{ Atm}$$

$$\rho \approx 10^2 \text{ g/cm}^3$$



# IL "FUOCO" NUCLEARE

1896 H. Bequerel **SCOPERTA DELLA RADIOATTIVITA'** ⇒ ENERGIA NUCLEARE

1919 E. Rutherford **PRIMA TRASMUTAZIONE RADIOATTIVA ARTIFICIALE**



1920 A. Eddington

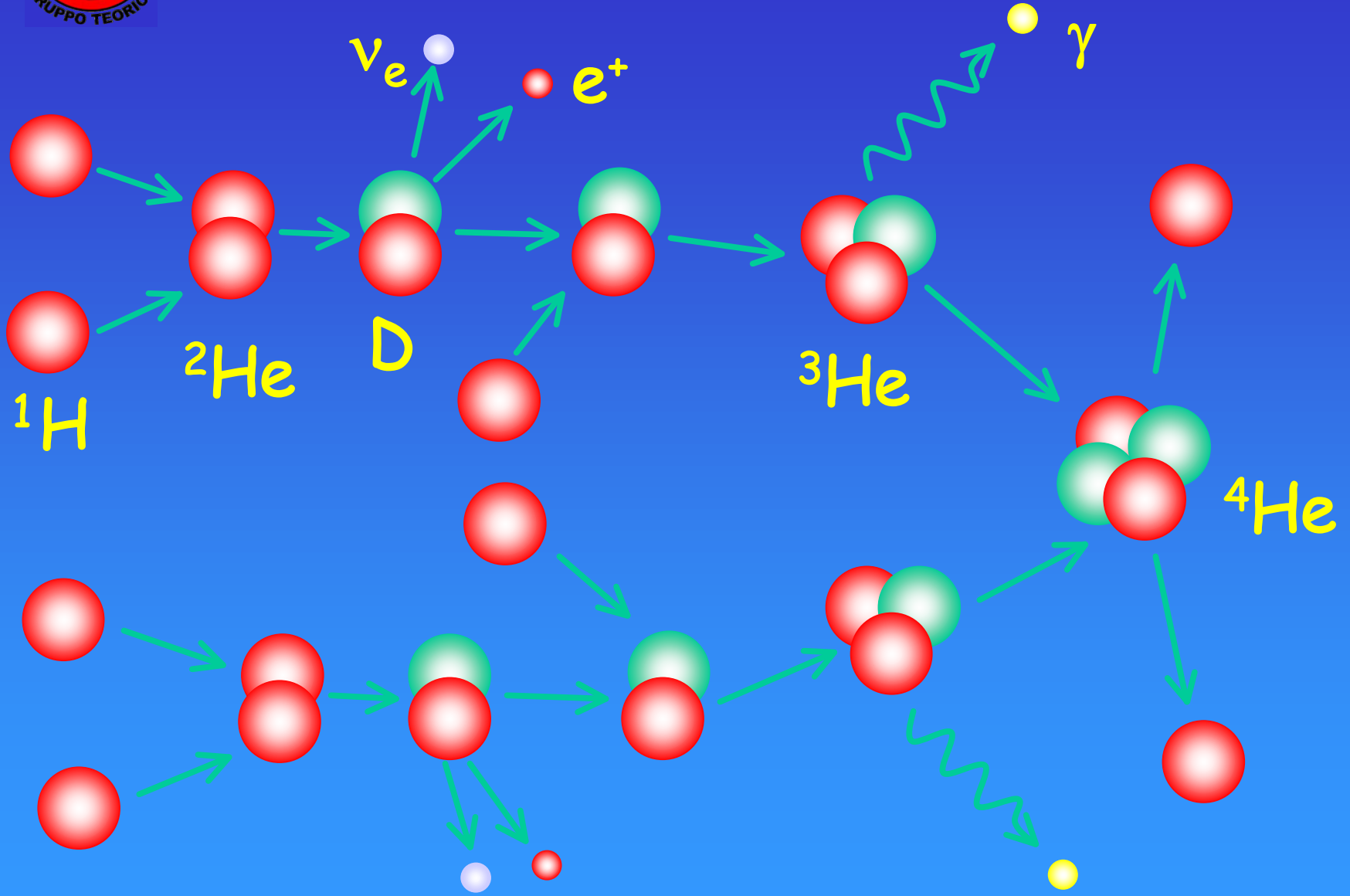
**REAZIONI TERMONUCLEARI** ⇒ ENERGIA STELLARE

1939 H. Bethe

**CICLO PROTONE-PROTONE E CARBONIO**

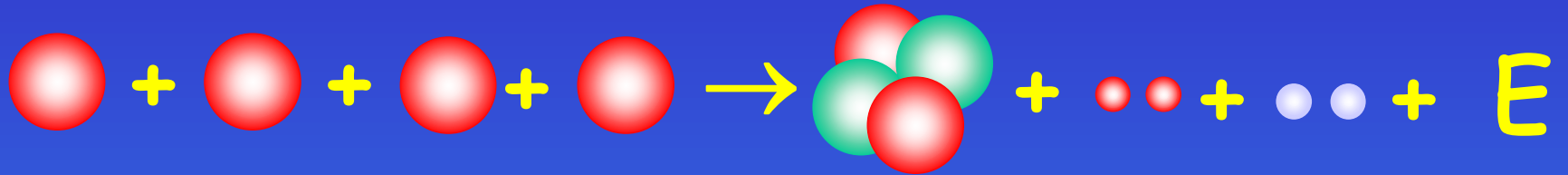


# I NUCLEI SI FONDONO





$$\underline{E=mc^2}$$



Massa H  $m_{\text{H}} = 1,672 \times 10^{-27} \text{ Kg} = 1,007276 \text{ uma}$

Massa He  $m_{\text{He}} = 6,642 \times 10^{-27} \text{ Kg} = 4,001505 \text{ uma}$

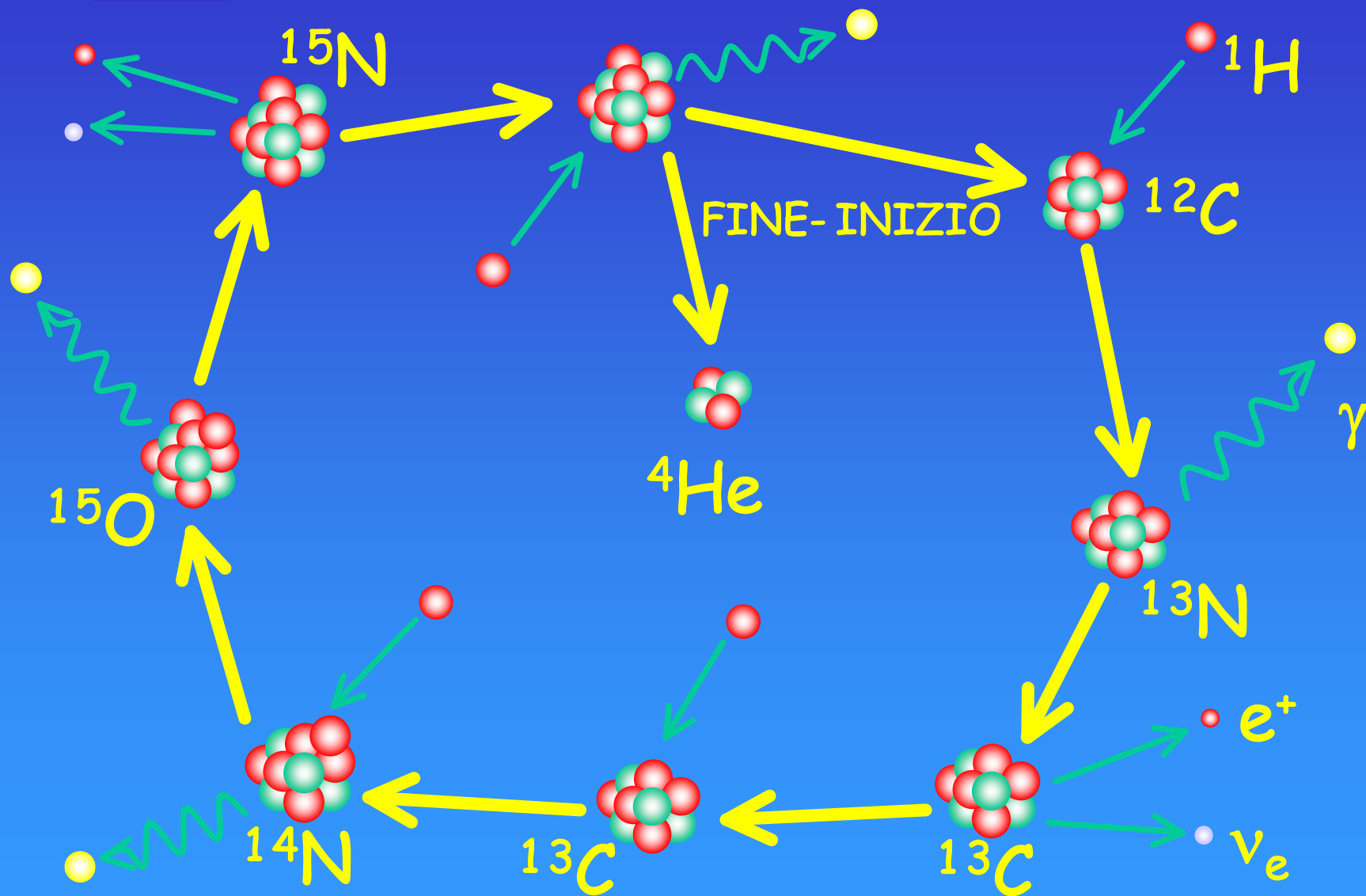
$$\Delta m = 4m_{\text{H}} - m_{\text{He}} = 0,68 \% 4m_{\text{H}} = 0,027599 \text{ uma} = 4,12 \times 10^{-12} \text{ J}$$

**Per 1 g di H si sviluppano  $6,12 \times 10^{11}$  Joule**

**fabbisogno energetico medio di una famiglia per 15 anni**

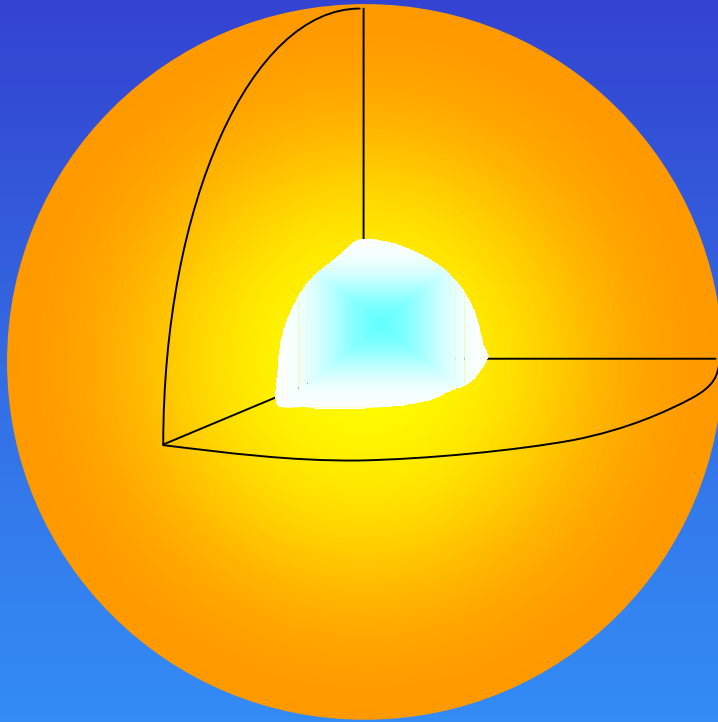


# IL CICLO CNO





# LA VITA SI ALLUNGA!



$$M_{\odot} \approx 2,0 \times 10^{30} \text{ Kg}$$

$$M_{\odot H} \approx 1,4 \times 10^{30} \text{ Kg}$$

$$15\% M_{\odot H} \approx 0,21 \times 10^{30} \text{ Kg}$$

$$E_{\odot H} \approx 1,3 \times 10^{44} \text{ J}$$

$$L_{\odot} \approx 3,8 \times 10^{26} \text{ W}$$

$$t \approx E_{\odot H} / L_{\odot} \approx 3,4 \times 10^{17} \text{ s} \approx 11 \times 10^9 \text{ y}$$



# CHI PIU' BRILLA...



## GIGANTE AZZURRA

$$M_{\star} \approx 20 M_{\odot} \quad t_{\star} \approx 22 \times 10^6 \text{ y}$$
$$L_{\star} \approx 10^4 L_{\odot}$$

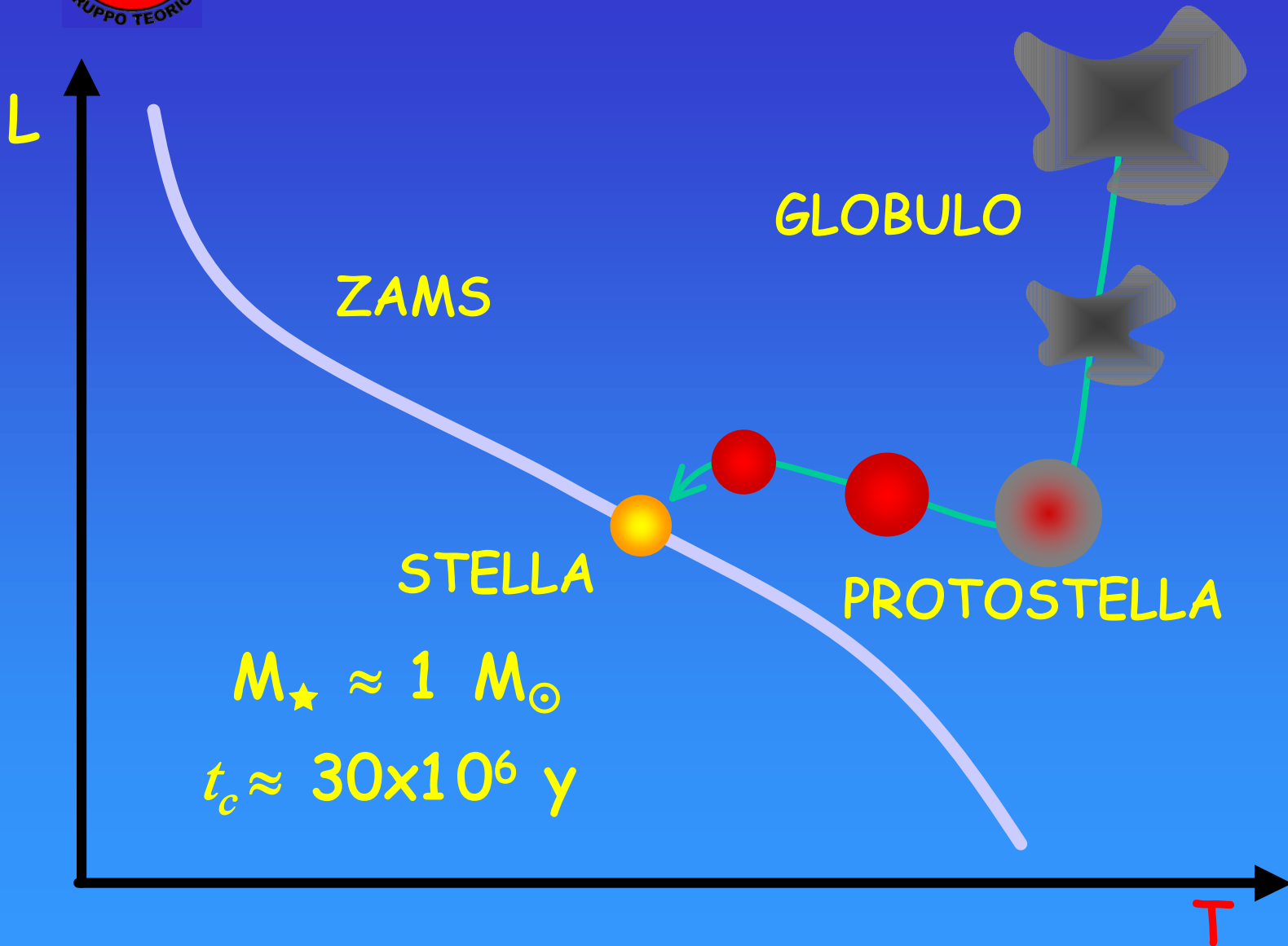


## NANA ROSSA

$$M_{\star} \approx 0,2 M_{\odot} \quad t_{\star} \approx 220 \times 10^9 \text{ y}$$
$$L_{\star} \approx 10^{-2} L_{\odot}$$

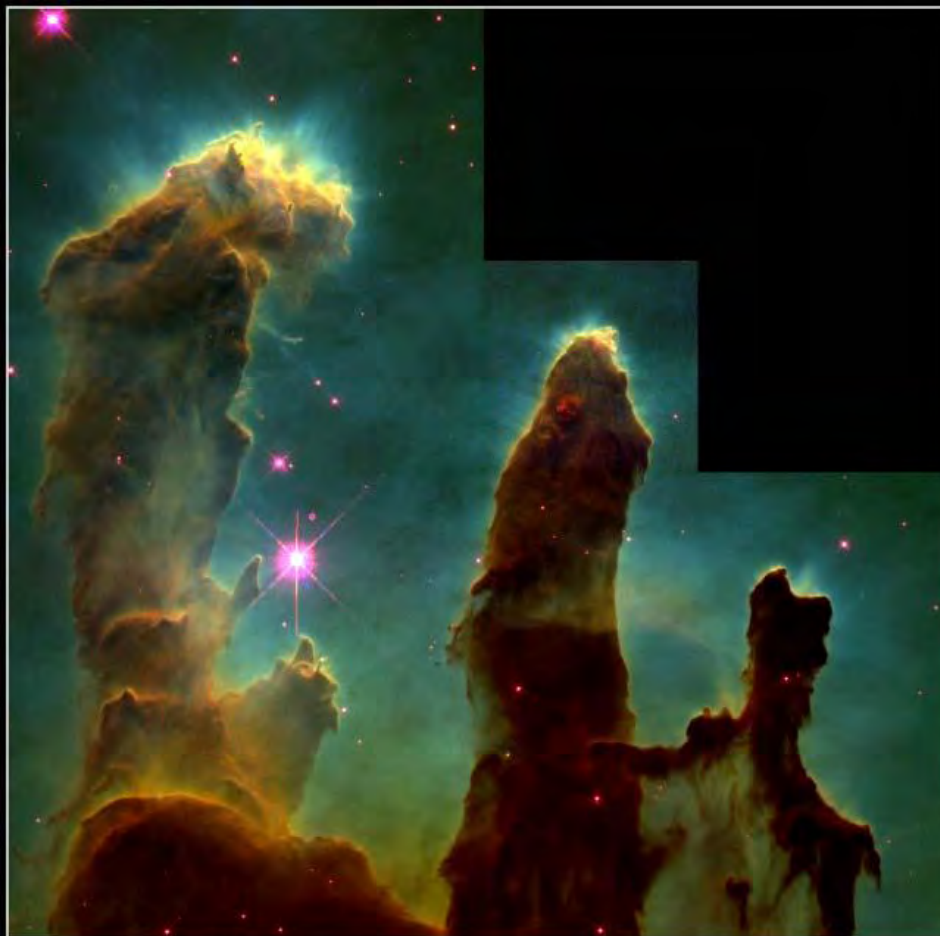


# LA NASCITA DI UNA STELLA





# LA CULLA DELLE STELLE



**Gaseous Pillars · M16**  
PRC95-44a · ST ScI OPO · November 2, 1995  
J. Hester and P. Scowen (AZ State Univ.), NASA

**HST · WFPC2**



*HST WFPC2*  
*STScI-PRC95-45a*  
*C.R. O'Dell (Vanderbilt)*

**Fonte HST - NASA**



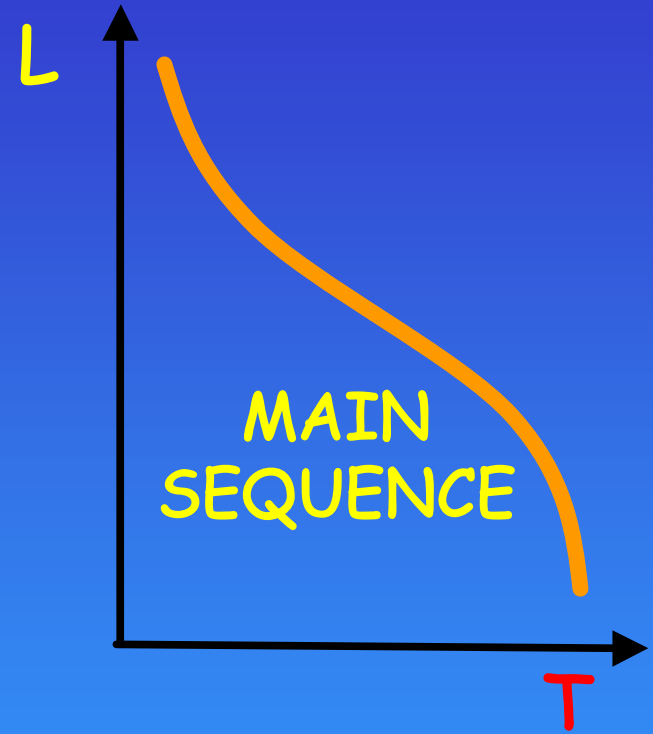
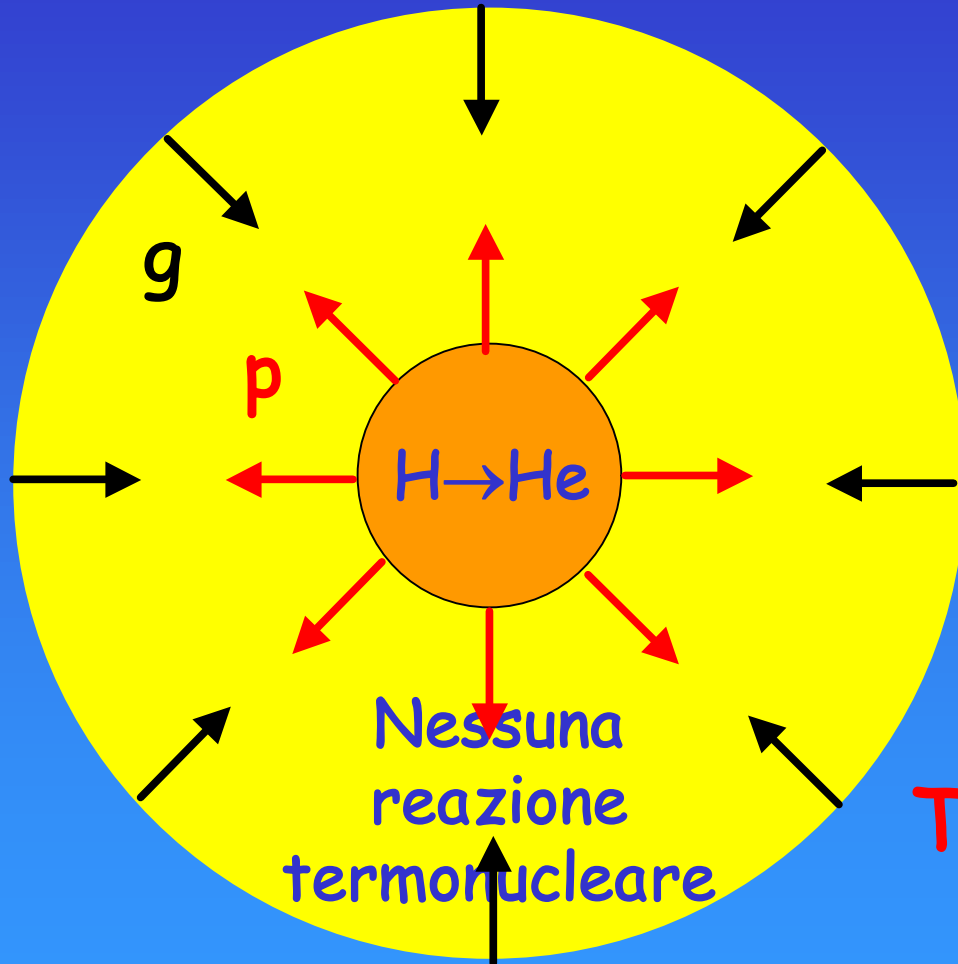
# PRIMI VAGITI



Fonte HST - NASA



# L'IDROGENO "BRUCIA"

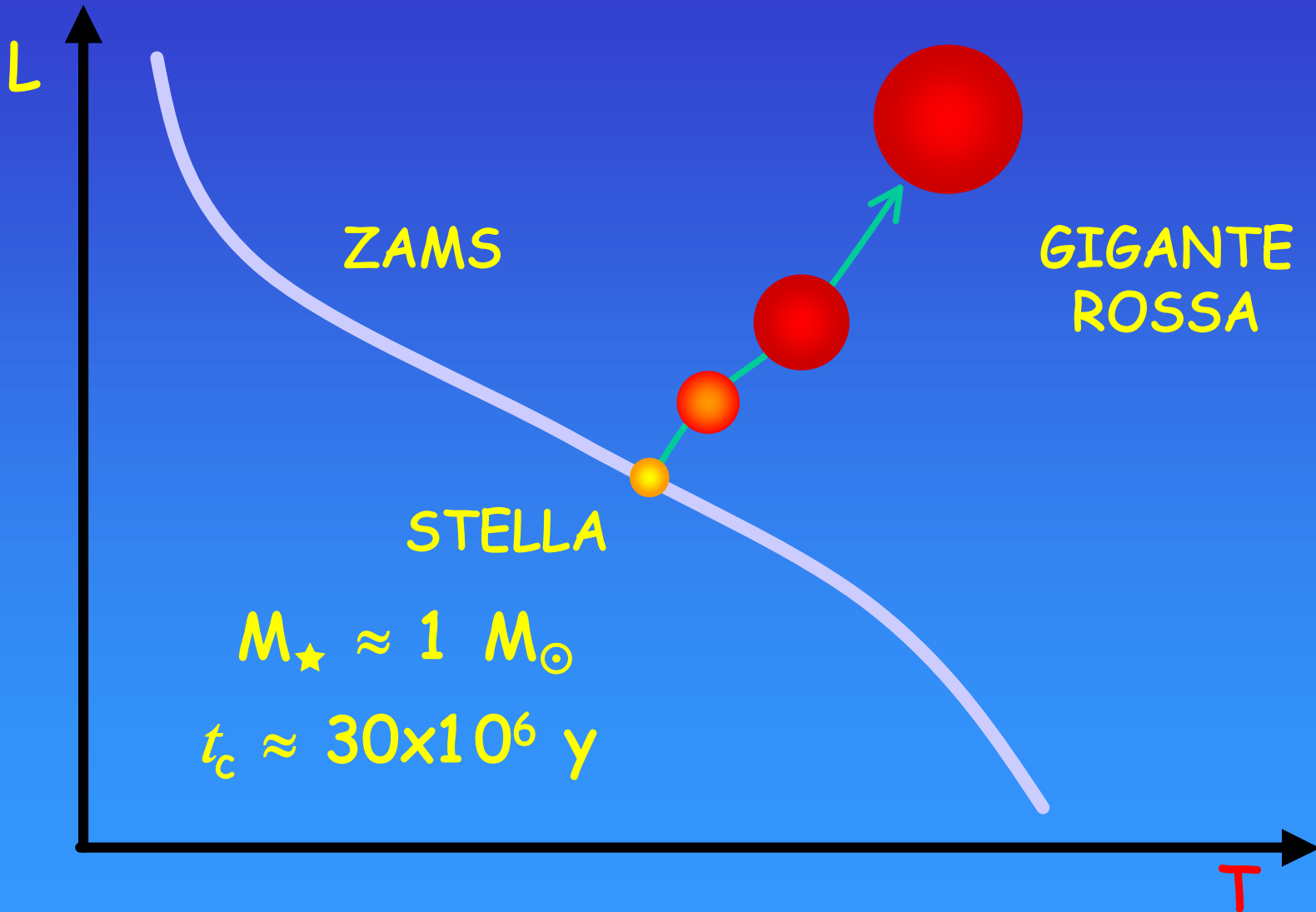


$$T_N \approx 5 - 30 \times 10^6 \text{ K}$$

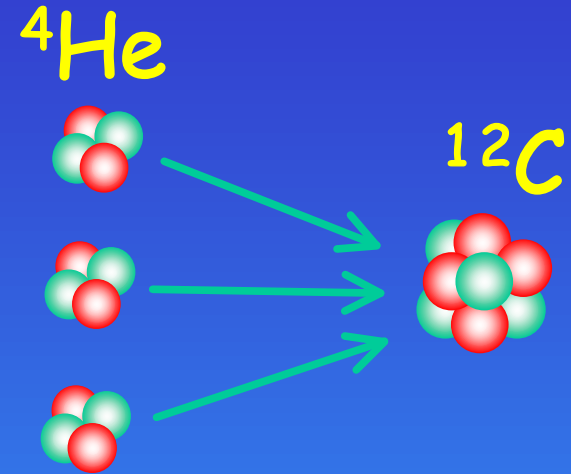
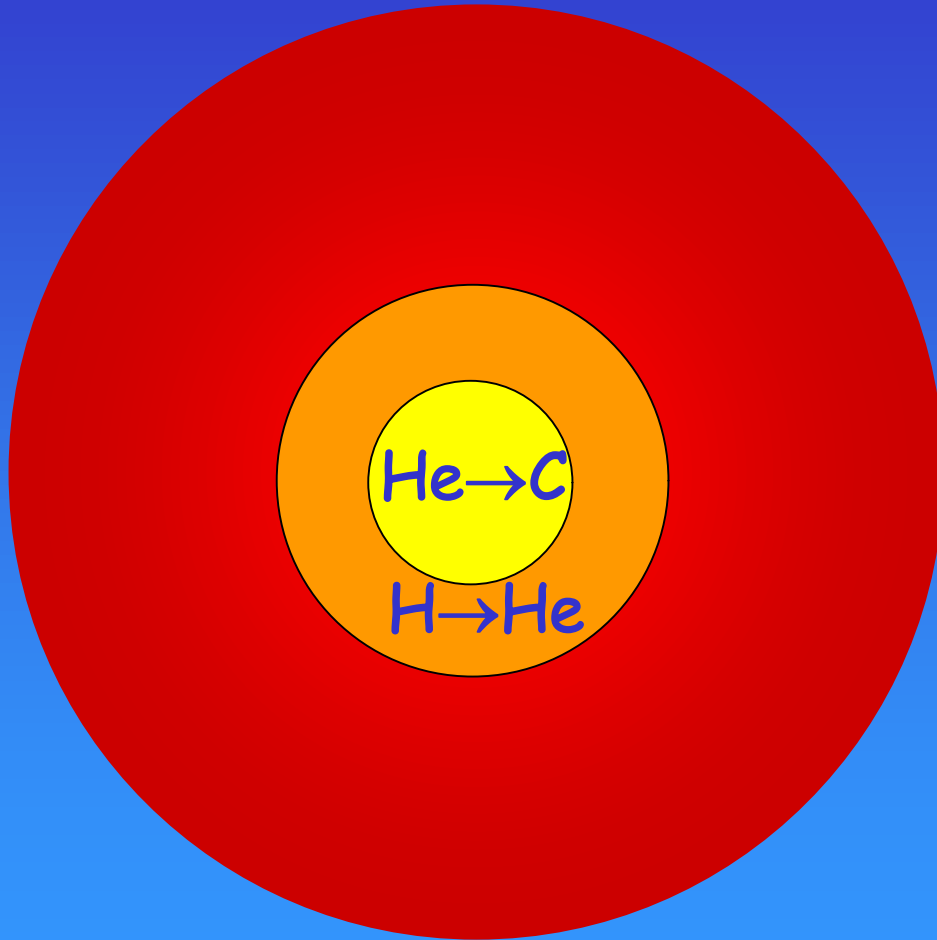
$$t_H \approx 0,02 - 200 \times 10^9 \text{ y}$$



# DOPO L'IDROGENO



# HELIUM FLASH



PROCESSO  $3\alpha$

$$T_N \approx 100 \times 10^6 \text{ K}$$

$$t_{\text{He}} \approx 100 \times 10^6 \text{ y}$$



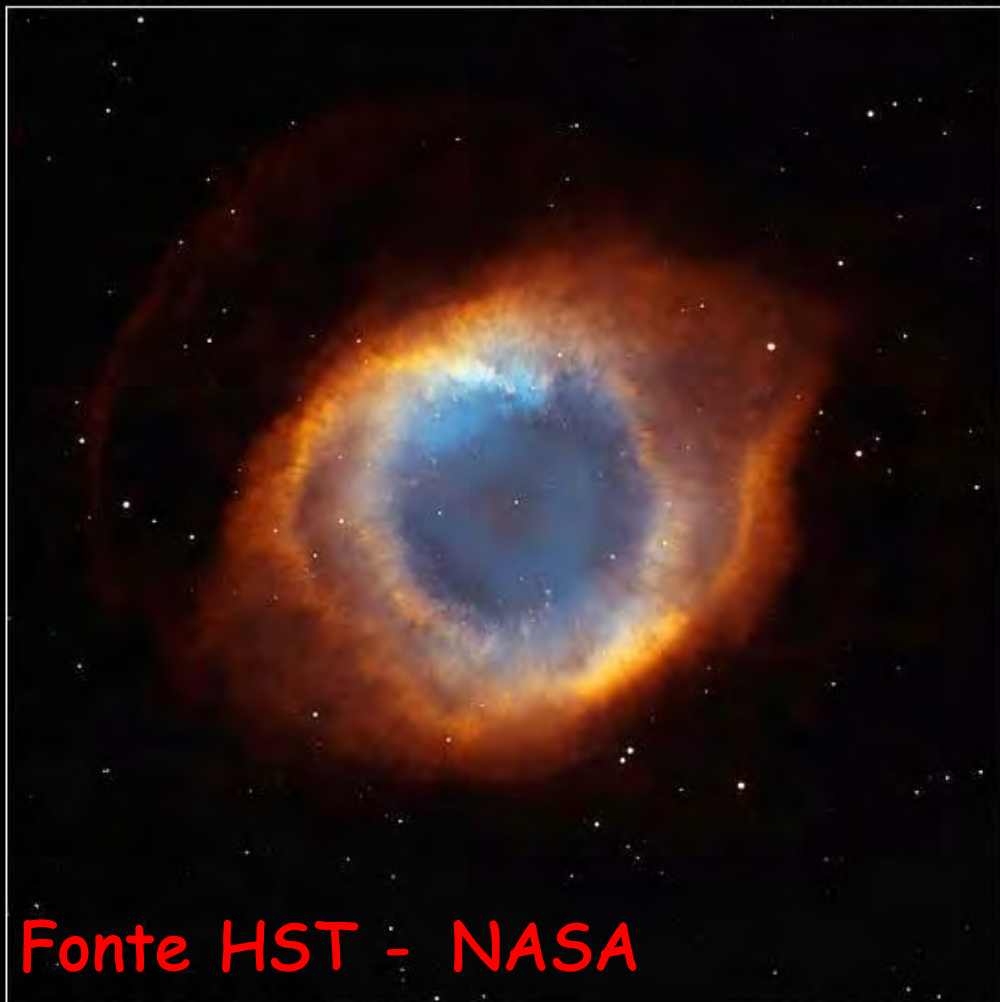
# LE NEBULOSE PLANETARIE

Helix Nebula  
NGC 7293

HST ■ ACS

NOAO 0.9m ■ Mosaic I Camera

Cat's Eye Nebula • NGC 6543



Fonte HST - NASA

Hubble  
Heritage

NASA, NOAO, ESA, The Hubble Helix Team,  
M. Meixner (STScI), and T.A. Rector (NRAO)

STScI-PRC03-11a

NASA, ESA, HEIC and The Hubble Heritage Team (STScI/AURA)  
Hubble Space Telescope ACS • STScI-PRC04-27

# LE NEBULOSE PLANETARIE



Fonte HST - NASA

Hourglass Nebula • MyCn18 HST • V

PRC96-07 • ST ScI OPO • January 16, 1996  
R. Sahai and J. Trauger (JPL), the WFPC2 Science Team and NASA



NGC 2392 • "Eskimo" Nebula

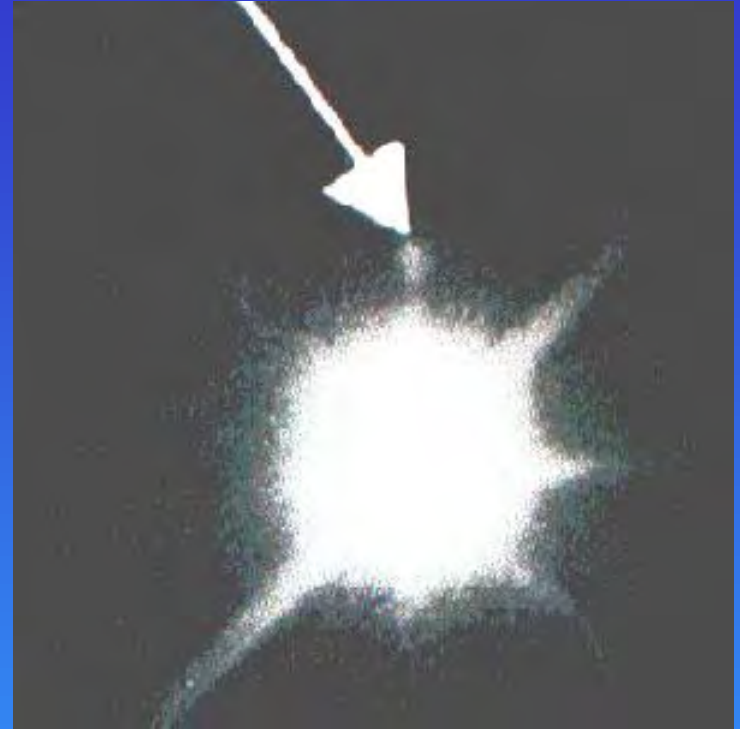
HST • WFPC2

NASA, A. Fruchter and the ERO Team (STScI) • STScI-PRC00-07

# LE NANE BIANCHE



15.000 Km



$$M_{\star} < 1,44 M_{\odot}$$

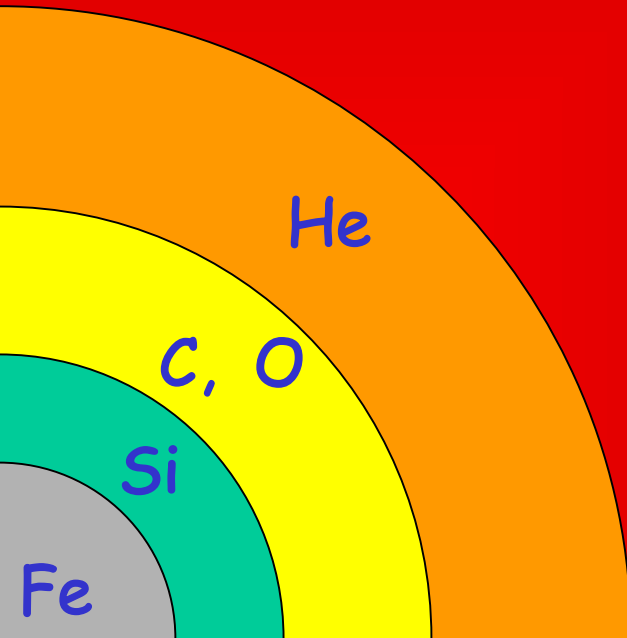
$$\rho \approx 10^6 \text{ g/cm}^3$$

$$T_s \approx 10^5 \text{ K}$$



# OLTRE IL CARBONIO

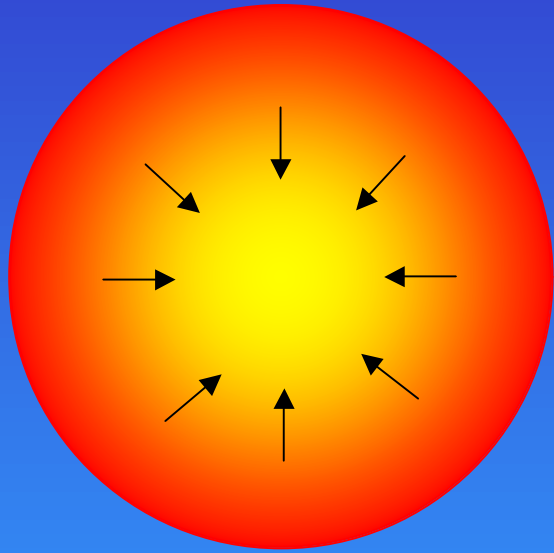
H, He



$$T_N \approx 4 \times 10^9 \text{ K}$$

$$t_{\text{He}} \approx 10^4 \text{ y}$$

# LE SUPERNOVAE



COLLASSO DEL  
NUCLEO



SUPERNOVA



# PROCESSI r E s

## CATTURA NEUTRONICA

S=SLOW

Basso flusso di  
neutroni

$10^5 - 10^{11}$  n/cm<sup>2</sup>s



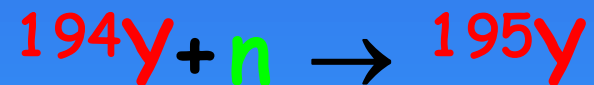
STELLE GIGANTI

Elementi fino a  
A~210

R=RAPID

Alto flusso di  
neutroni

$> 10^{22}$  n/cm<sup>2</sup>s



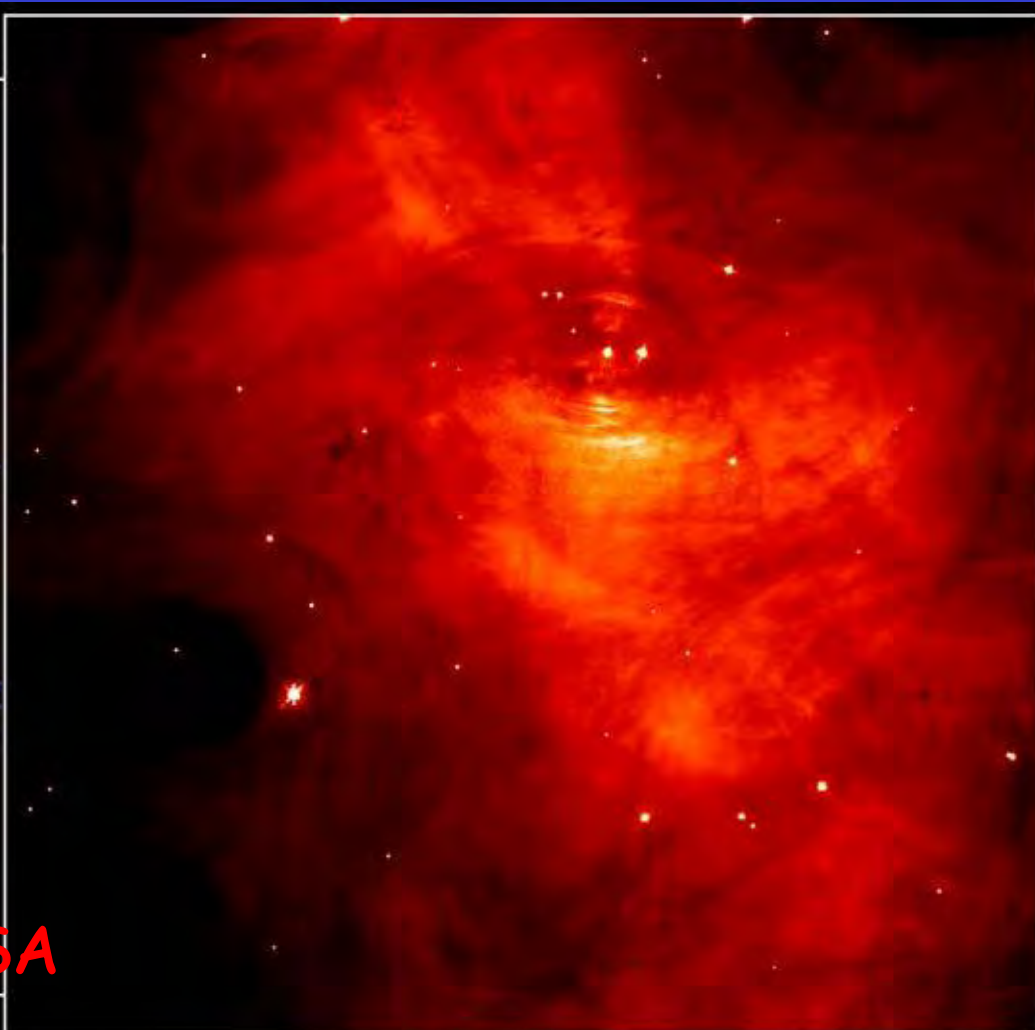
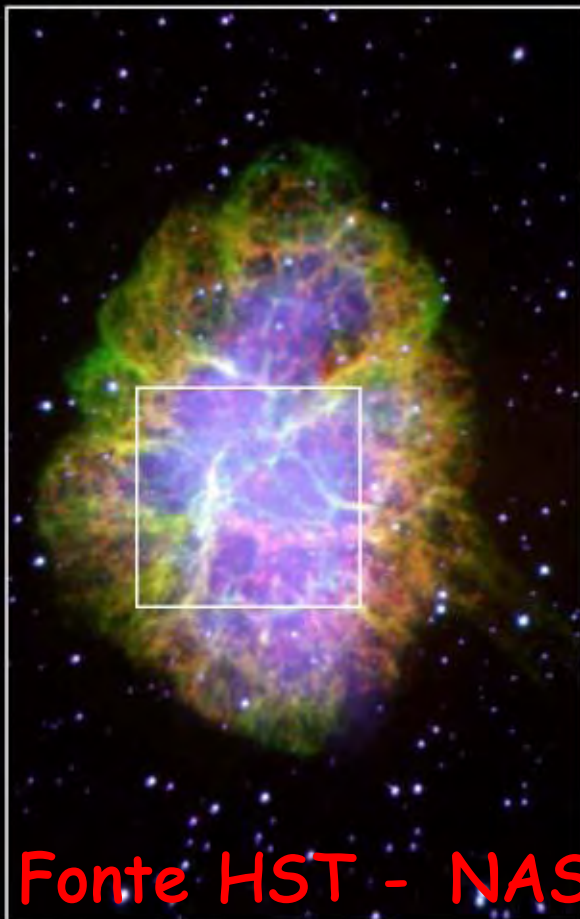
SUPERNOVAE

Elementi fino a  
A~270



# LE SUPERNOVAE

## Crab Nebula



Fonte HST - NASA

Palomar

PRC96-22a · ST Sci OPO · May 30, 1996

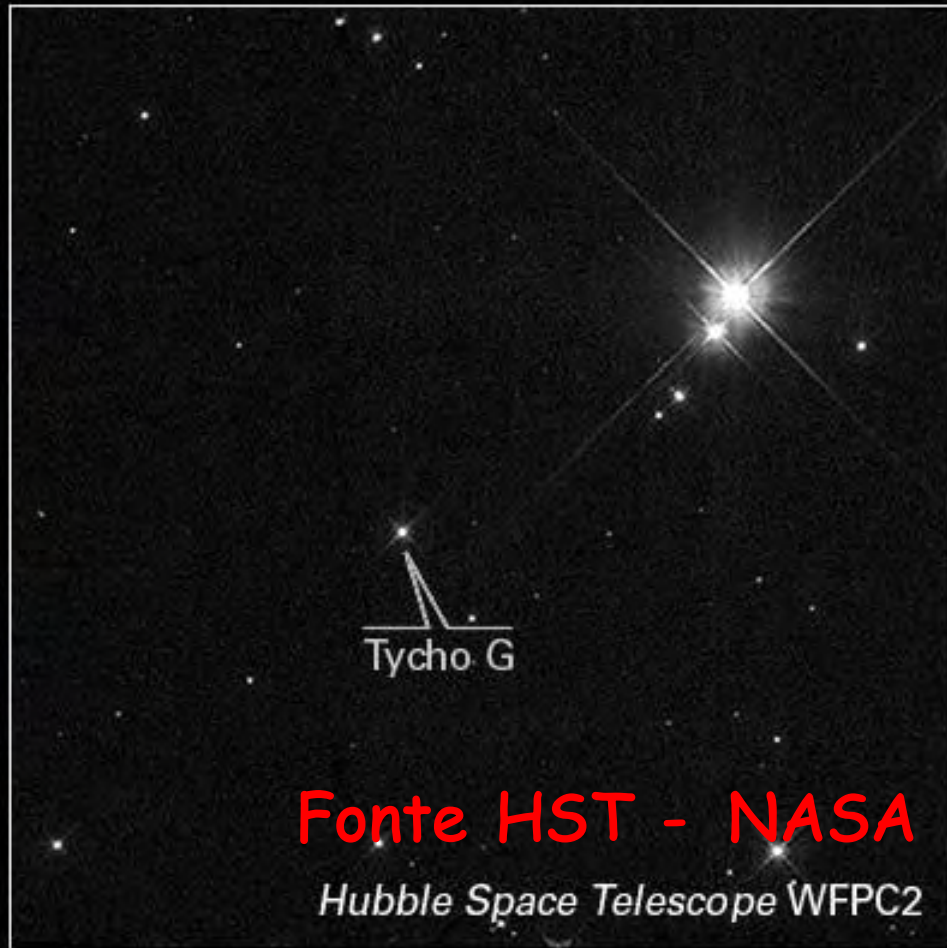
J. Hester and P. Scowen (AZ State Univ.) and NASA

HST · WFPC2



# LE SUPERNOVAE

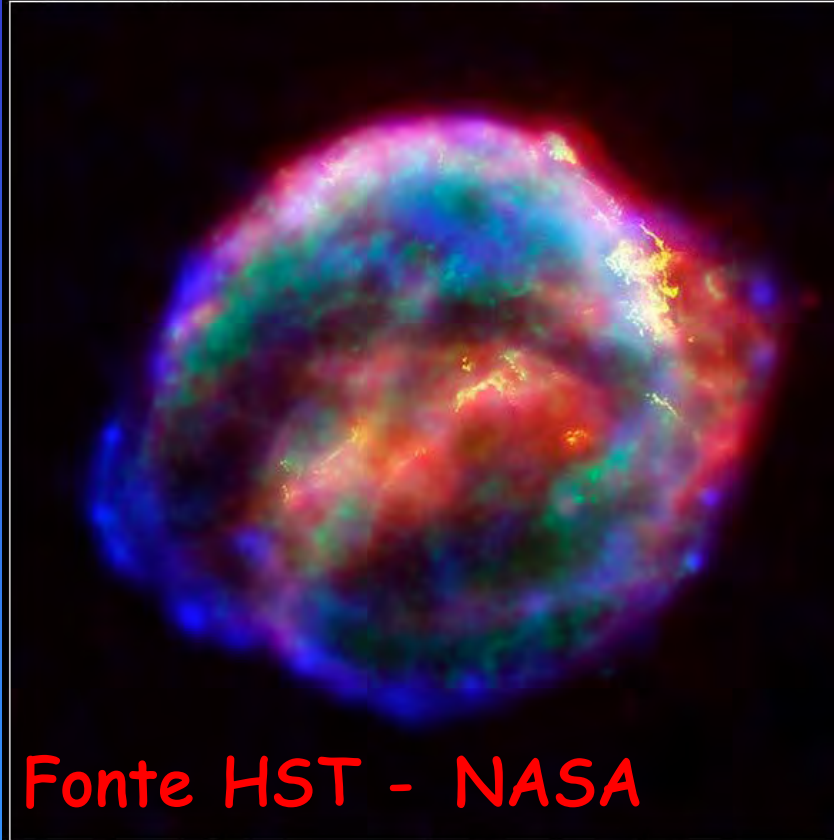
## Candidate Progenitor Companion to Tycho's Supernova 1572



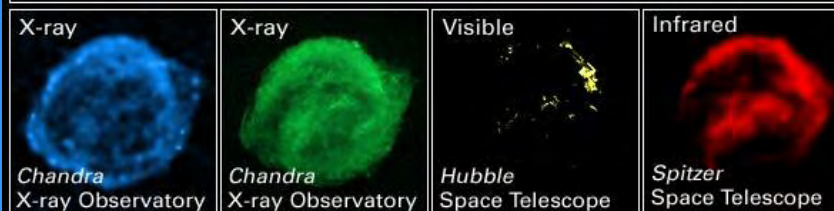


# LE SUPERNOVAE

Kepler's Supernova Remnant • SN 1604



Fonte HST - NASA



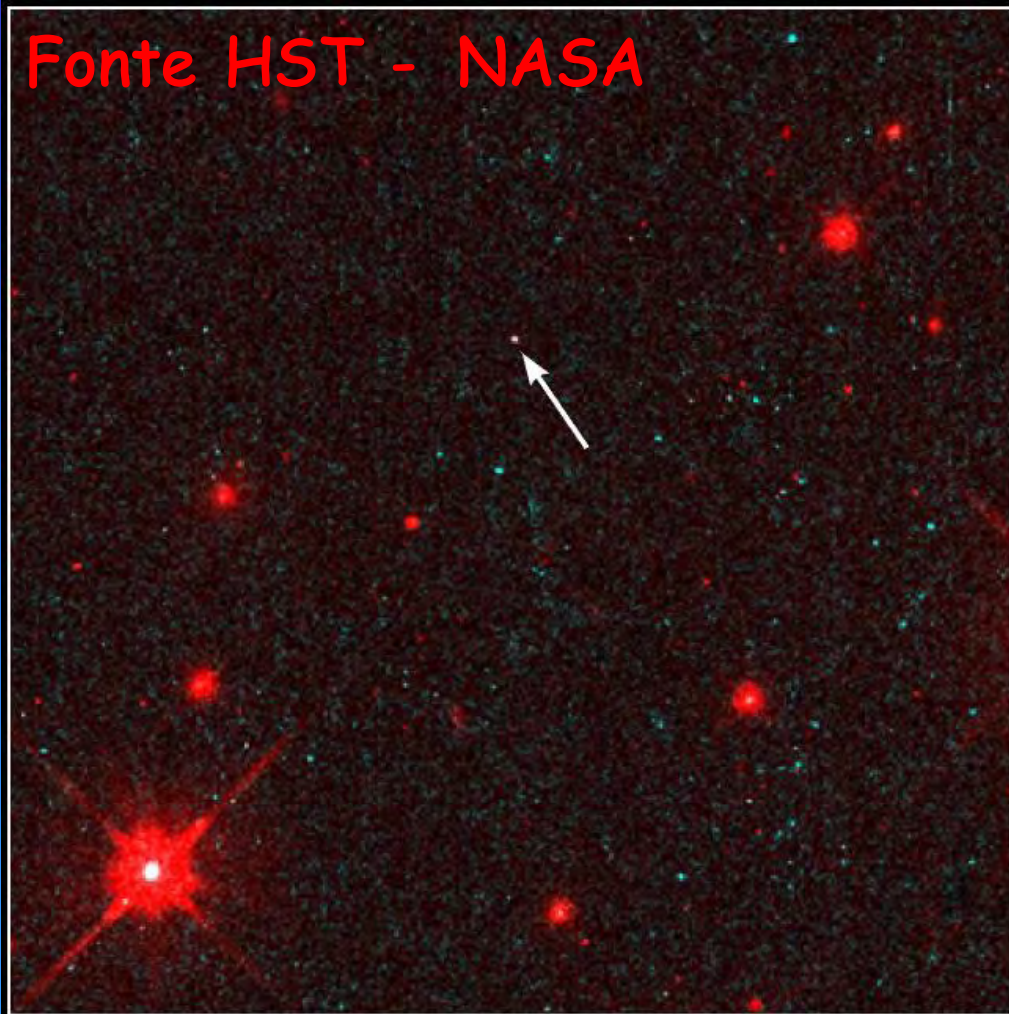
NASA, ESA, R. Sankrit and W. Blair (Johns Hopkins University)

STScI-PRC04-29a



# LE STELLE DI NEUTRONI

Fonte HST - NASA



Isolated Neutron Star RX J185635-3754 HST • WFPC2

PRC97-32 • ST ScI OPO • September 25, 1997  
F. Walter (State University of New York at Stony Brook) and NASA



**12 Km**

**$M_{\star} < 3 M_{\odot}$**

**$\rho \approx 10^{14} \text{ g/cm}^3$**



# LA MATERIA SI CONTRAE





# I BUCHI NERI

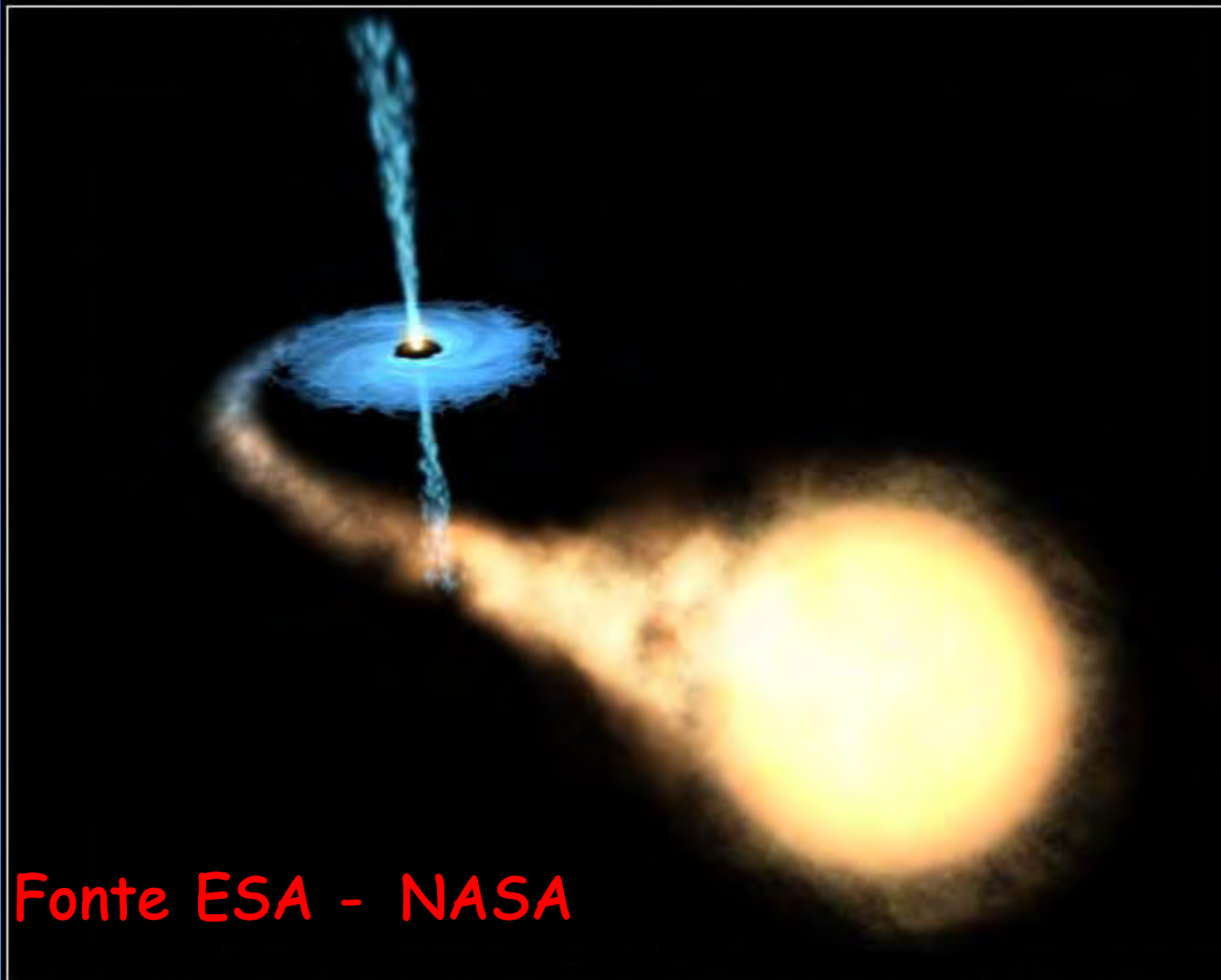


6 Km

$$R_S = 2GM / c^2$$

$$M_{\star} > 3 M_{\odot}$$

# DIVORATORI DI MATERIA



Fonte ESA - NASA

**Artist's View of Black Hole and Companion Star GRO J1655-40**

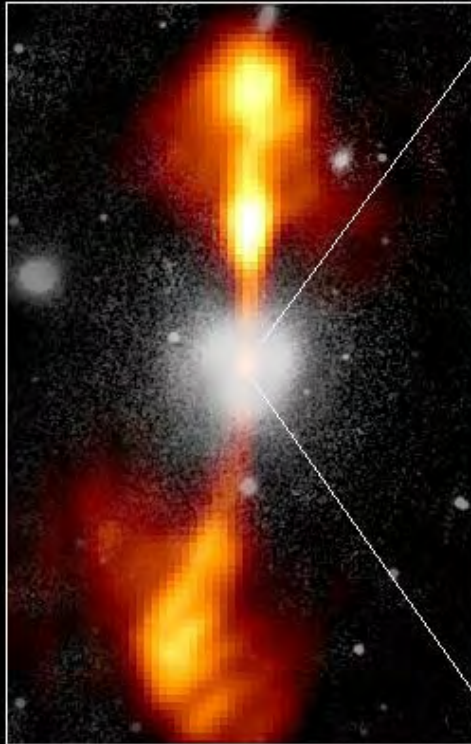
ESA, NASA and F. Mirabel (CEA) ■ STScI-PRC02-30

# NEL CUORE DELLE GALASSIE

## Core of Galaxy NGC 4261

Hubble Space Telescope  
Wide Field / Planetary Camera

Ground-Based Optical/Radio Image



380 Arc Seconds  
88,000 LIGHT-YEARS

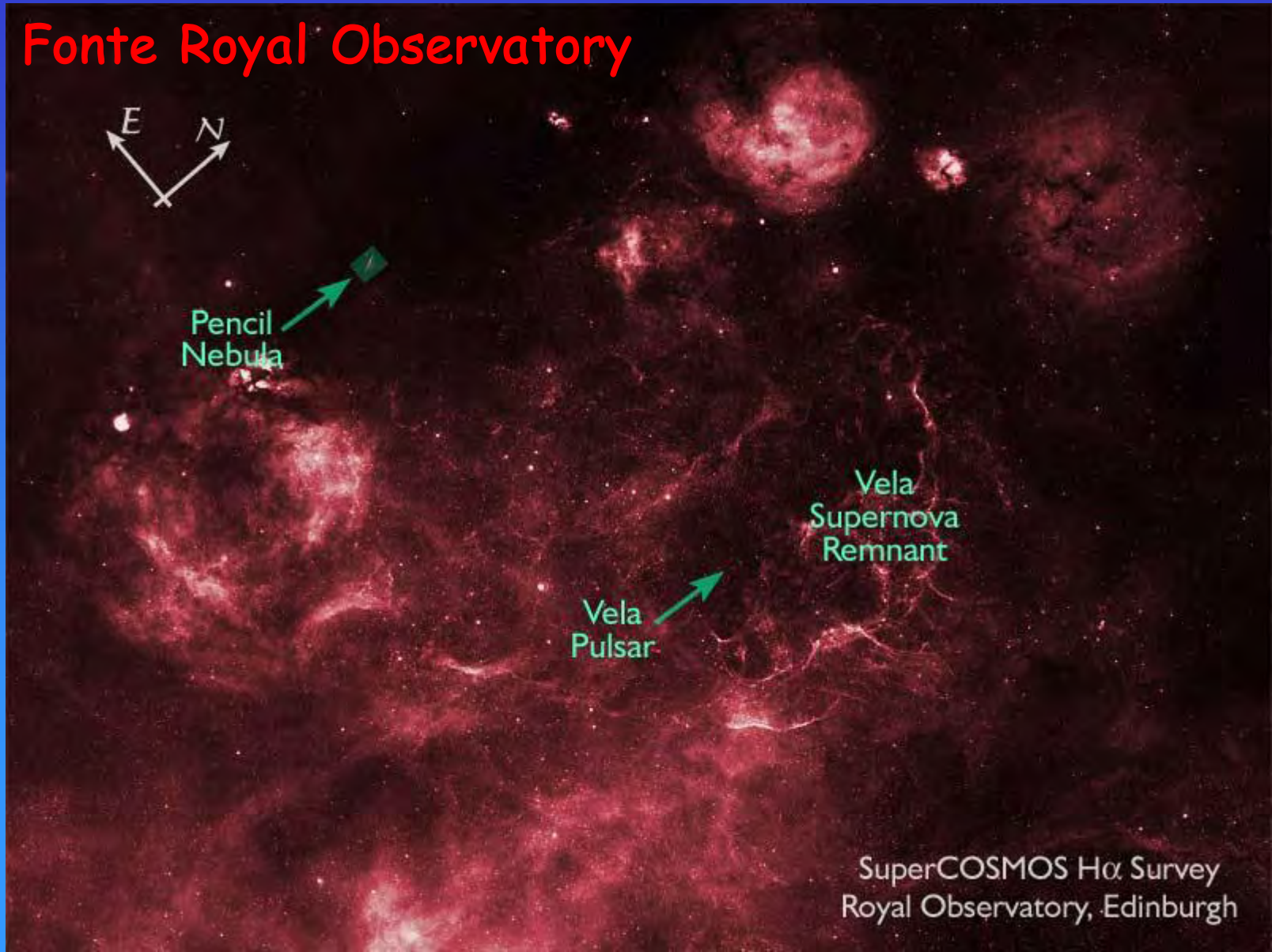
HST Image of a Gas and Dust Disk



17 Arc Seconds  
400 LIGHT-YEARS

# COME LA FENICE

## Fonte Royal Observatory



# COME LA FENICE

Supernova Remnant Cassiopeia A



**Fonte HST - NASA**

Hubble  
Heritage



# TAVOLA PERIODICA

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	In	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Unq	Unp	Unh												
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu				
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw				

NUCLEOSINTESI PRIMORDIALE

NUCLEOSINT. POST SEQUENZA

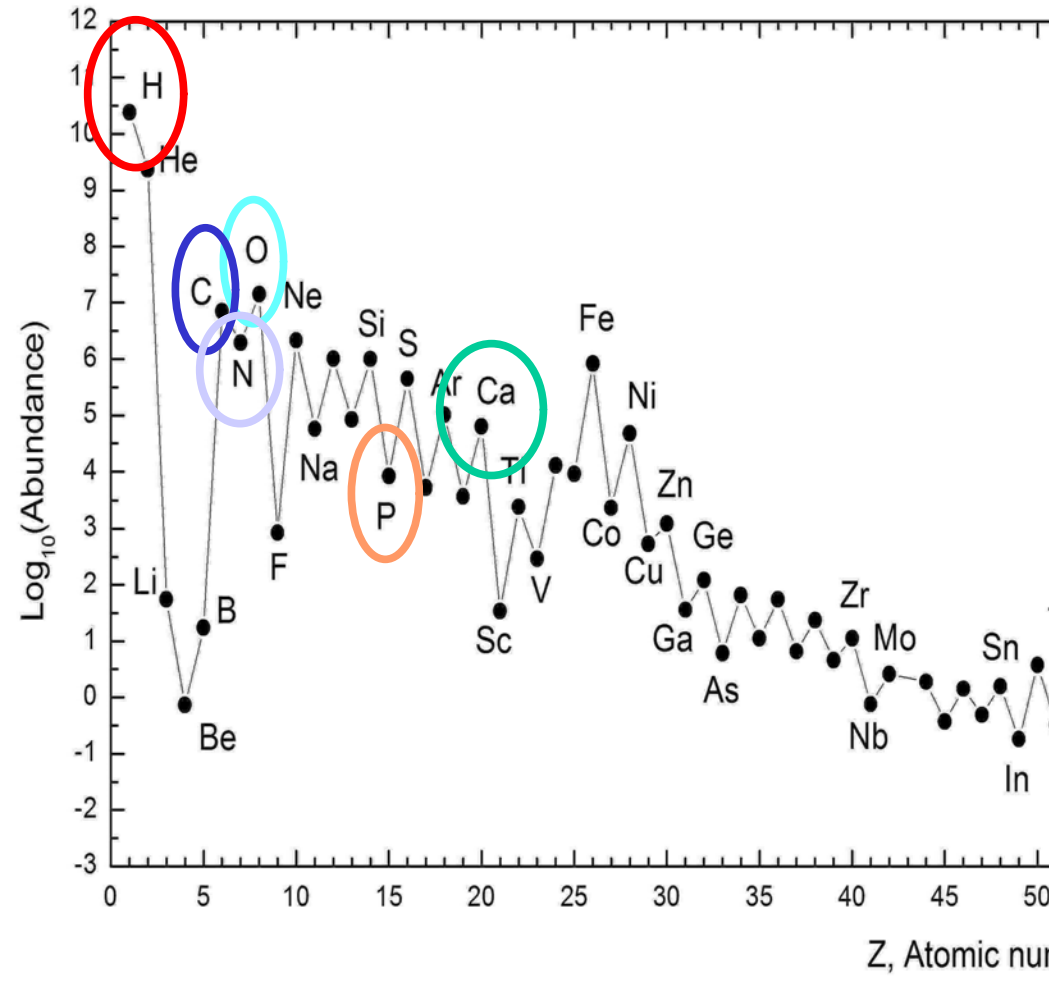
NUCLEOSINT. PROCESSI s E r

NUCLEOSINT. PROCESSI r



# ABBONDANZE COSMICHE

## ABBONDANZE CORPO UMANO



ELEMENTO	% MASSA
Ossigeno	65
Carbonio	18
Idrogeno	10
Azoto	3
Calcio	1,5
Fosforo	1,2
K, S, Cl	0,2
Sodio	0,1
Magnesio	0,05
Fe, Co, Cu, Zn	< 0,05

ABBONDANZE COSMICHE NEL SISTEMA SOLARE  
 Fonte K. Lodders Ap. J n° 591



# FATTI DI POLVERE DI STELLE

GRAZIE PER  
L'ATTENZIONE  
DOMANDE?