Aggiornamenti 2023 - LNF

5 luglio 2023

Big Bang

Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI FRASCATI

Barbara Sciascia

Astronomia

[descrizione]

Astrofisica

[comprensione]

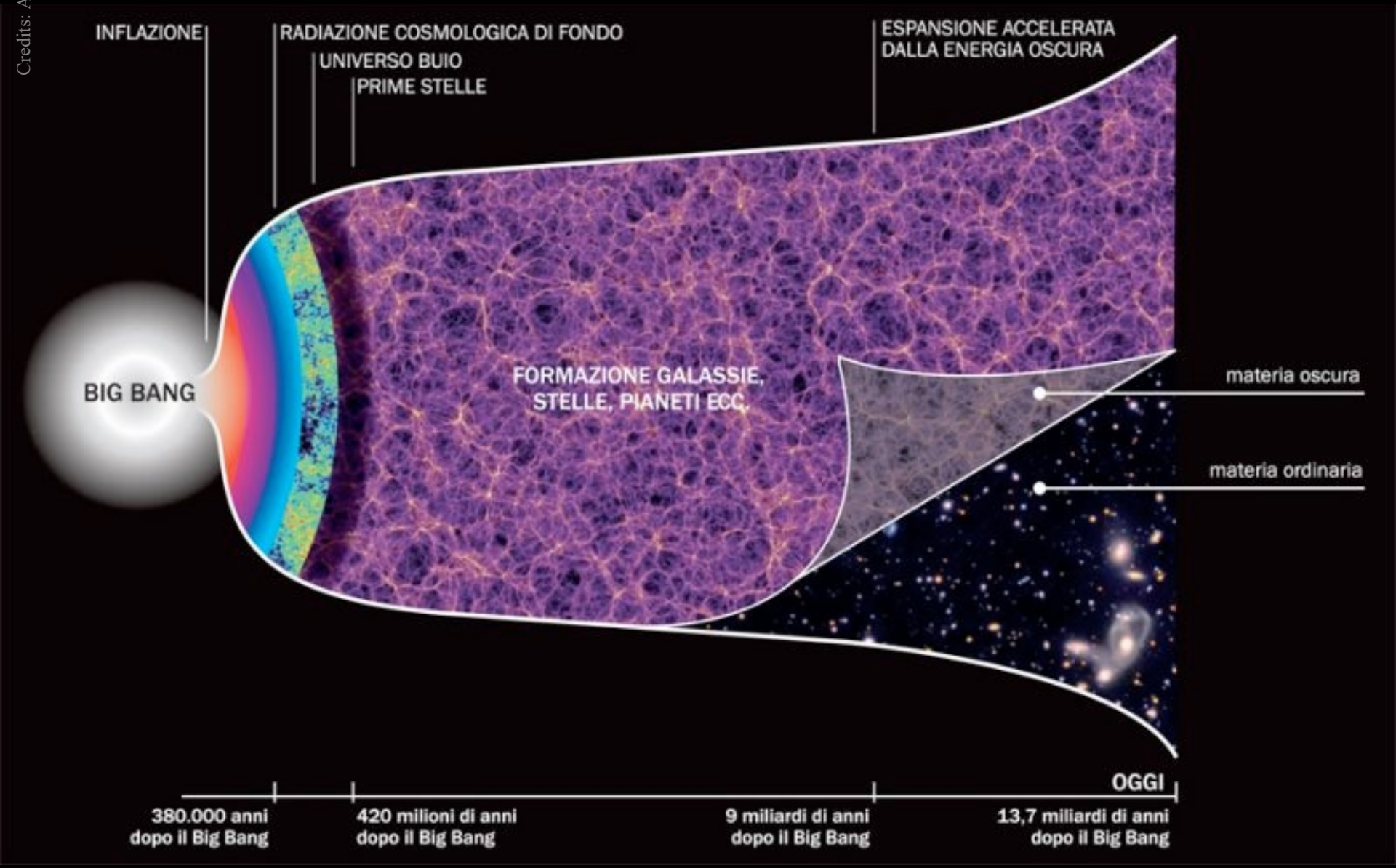
Cosmologia

[comprensione degli inizi]

Fred Hoyle, BBC

«Una specie di grande botto iniziale»

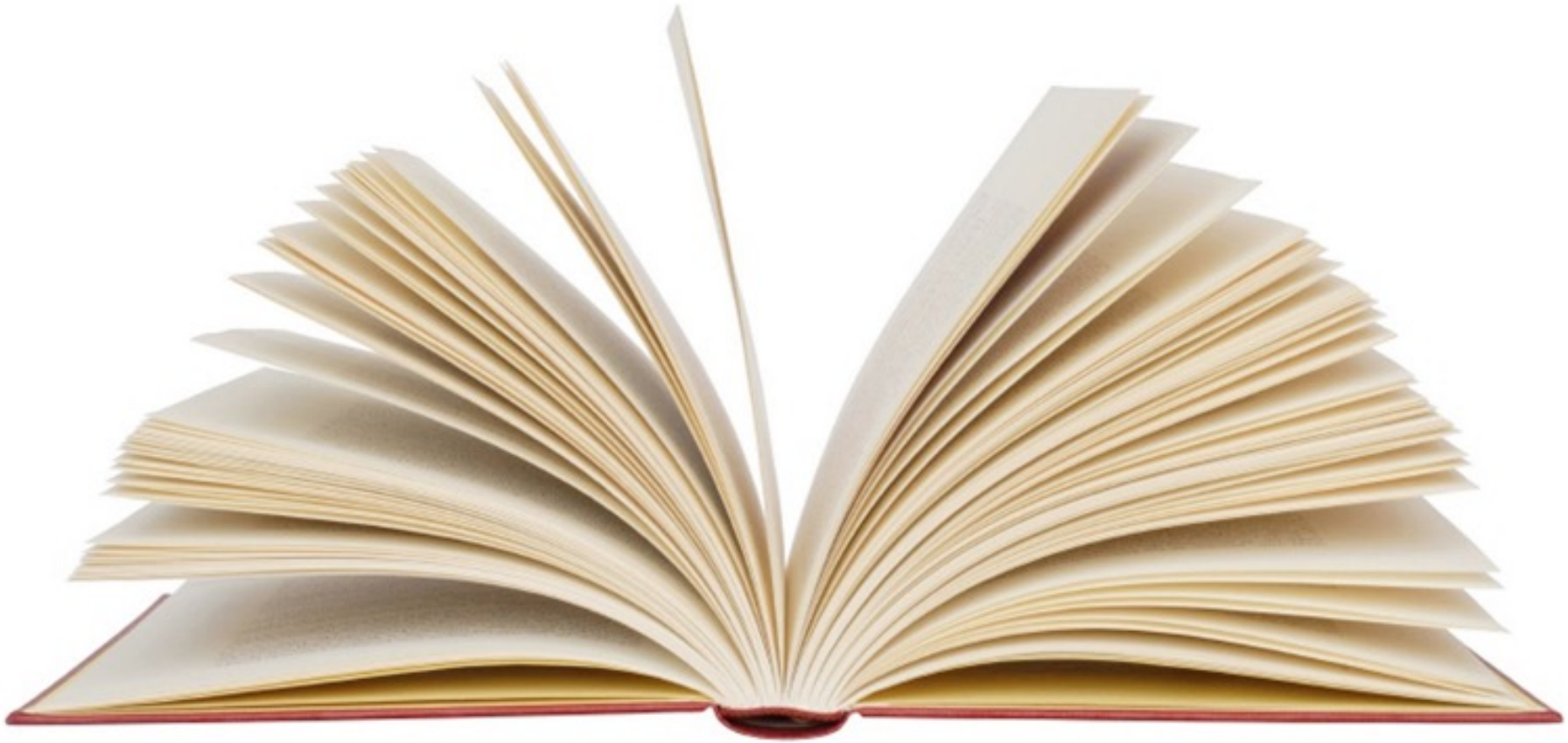
Modello Standard Cosmologico



Calibrazioni

Contare da 1 a 1000 misurando quanto tempo ci mettete.

[credits: A. Balbi]



La velocità della luce

È chiamata c

- è costante

- vale ~3 × 10^8 m/s

- cioè ~1 miliardo di km/h

In un anno ci sono 365g × 24h × 60' × 60 s

~ 3 ×10^7 s = 30 milioni di secondi

In un anno la luce percorre 3 ×10^8 × 3 × 10^7

~ 9 × 10^{15} metri

*Quindi quasi **10 milioni di miliardi di m** all'anno*

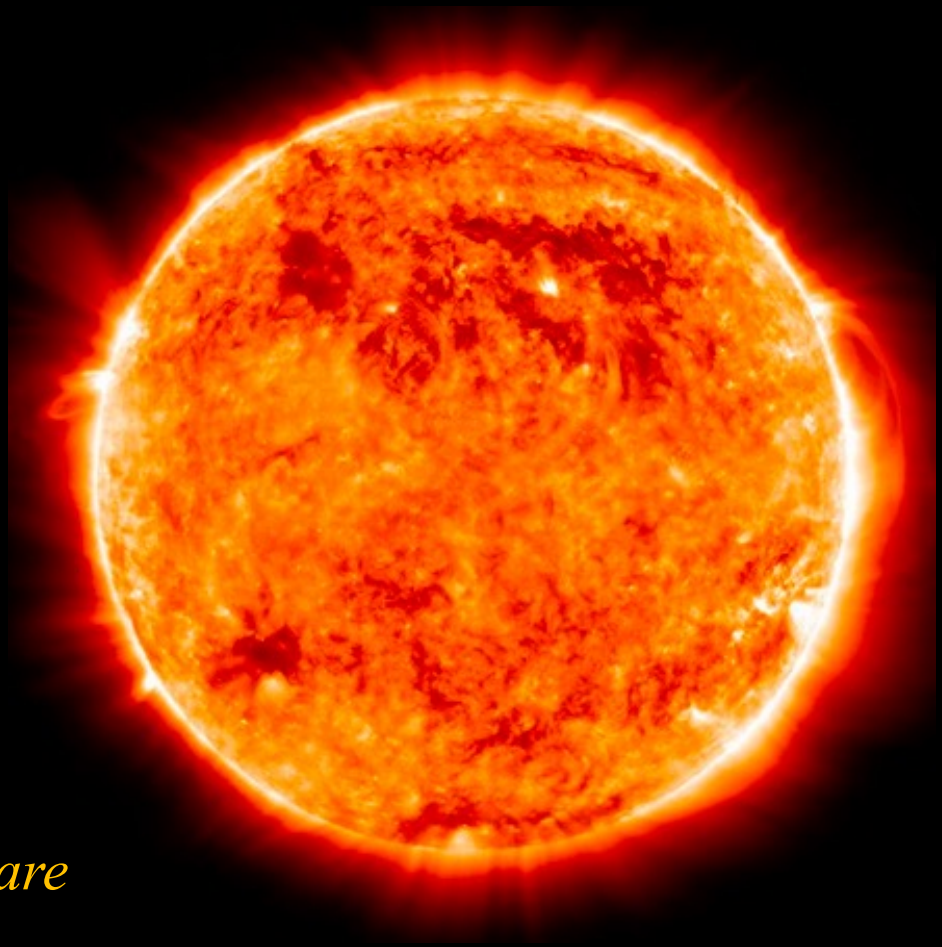
"La velocità della luce diventa una misura di lunghezza"

Tempo o distanza?

Il giro della Terra: 7 volte in un secondo luce

"La velocità della luce diventa una misura di lunghezza"

Tempo o distanza?

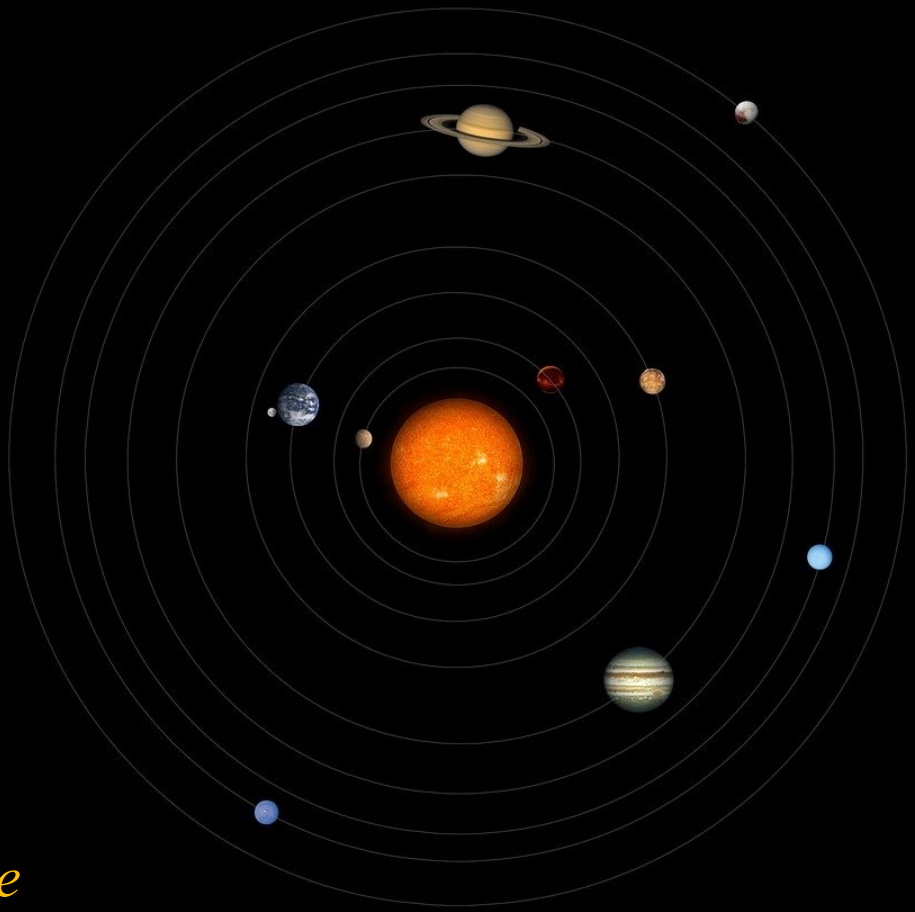


Possiamo "viaggiare nel passato"

Il Sole dista 8 minuti luce

"La velocità della luce diventa una misura di lunghezza"

Tempo o distanza?



Possiamo "viaggiare nel passato"

I confini del sistema solare distano ~ 20 ore luce

Tempo o distanza?

"La velocità della luce diventa una misura di lunghezza"

[ESA/Hubble / CC BY (https://creativecommons.org/licenses/by/4.0)]

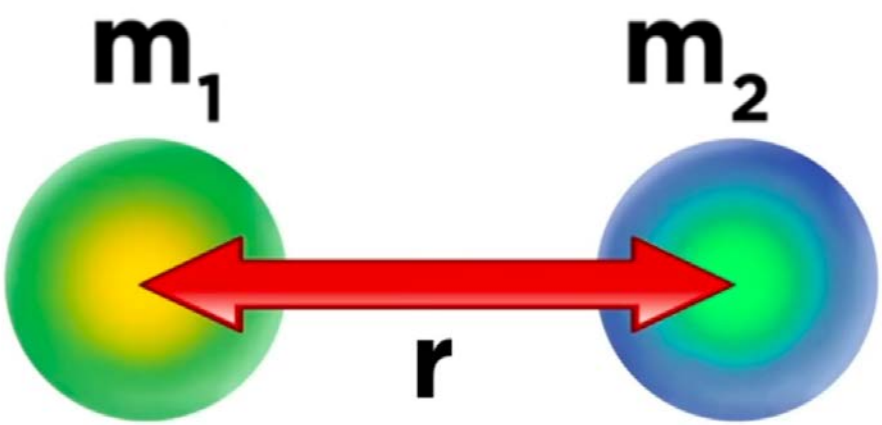
Possiamo "viaggiare nel passato"

La stella più vicina, Proxima Centauri, dista ~4.4 anni luce

Gravità o legge di gravitazione universale

[**G** è un numero costante,
vale 6.67×10^{-11} N m^2/kg^2]

$$F_g = G \frac{m_1 m_2}{r^2}$$



Gravità o legge di gravitazione universale

[**G** è un numero costante,
vale 6.67×10^{-11} N m^2/kg^2]

$$F_g = G \frac{m_1 m_2}{r^2}$$

m_1 = tu
m_2 = la prof.
r = 1 metro
$F \sim 10^{-7}$ N
[N unità della forza]

m_1 = tu
m_2 = la Terra
r = 1 metro
$F \sim 10^{16}$ N
[N unità della forza]

Di oroscopi e di mucche

Problema: data una mucca e un pianeta/stella di distanza e massa noti, ***calcolare la distanza*** *a cui la mucca e il pianeta/stella esercitano su di te la stessa forza. (usare* $m_{MUCCA} = 1000\ Kg$*)*

m_1 = tu
m_2 = pianeta/stella
r = distanza pianeta/stella

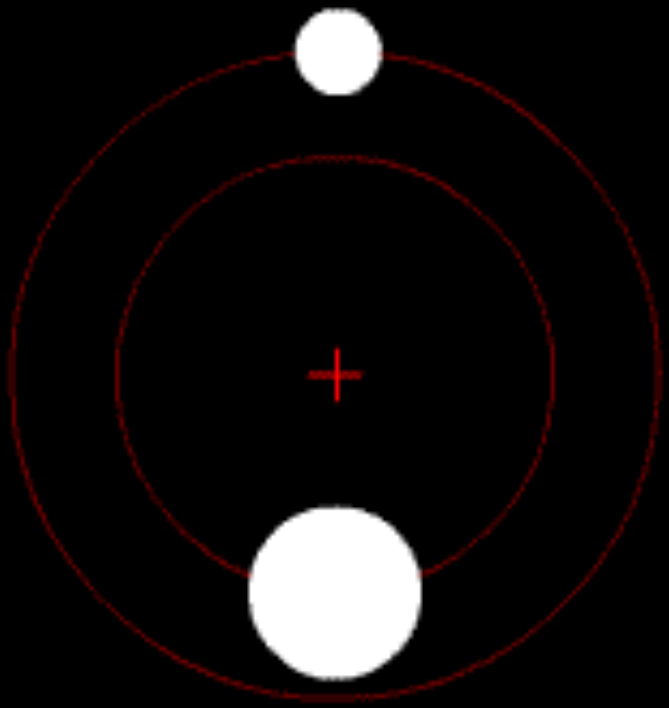
$$F_g = G\frac{m_1 m_2}{r^2}$$

m_1 = tu
m_2 = la mucca
r = ?

Risposte:

Pianeta/stella	Distanza da una mucca
Jupiter	0.57 m
Venus	2.45 m
Mars	10.06 m
Regulus	7.81 km
Alpha Centauri	28.70 km

“Attrarre e girare”



Di User:Zhatt - Opera propria, Pubblico dominio, https://commons.wikimedia.org/w/index.php?curid=280053

[By NASA/JPL - Planetary Photojournal, Public Domain, https://commons.wikimedia.org/w/index.php?curid=38355903]

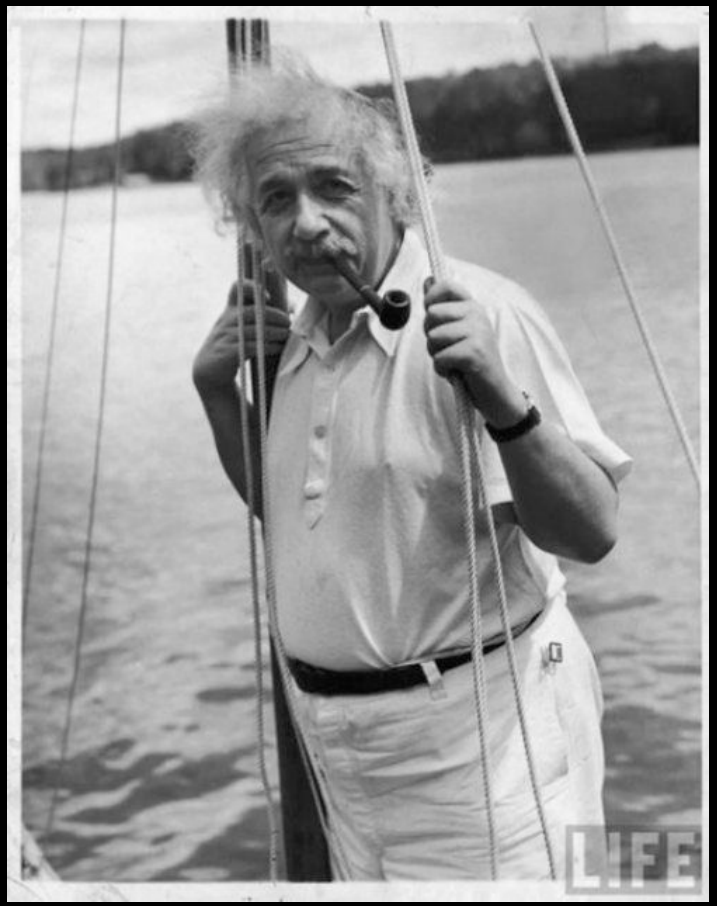
Quanto veloci?

0.5 km/s [giorno/notte]
+ 30 km/s [anno, Sole]
+ 200-220 km/s [Via Lattea]
+ 627 km/s [Gruppo locale]

4GIFs.com

~850 km/s
~ 3 milioni di km/h

Albert Einstein



$$E = mc^2$$

E: energia

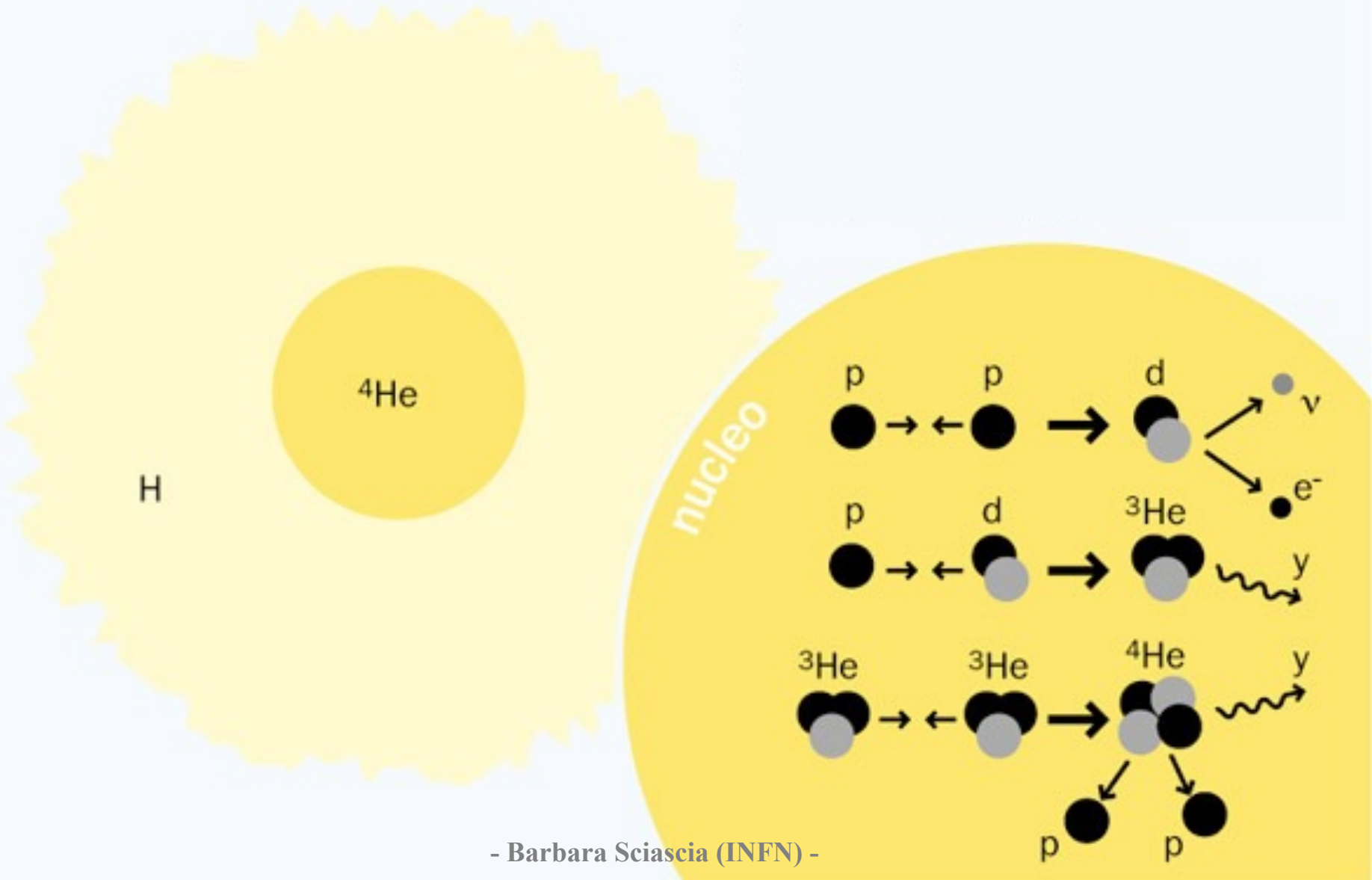
m: massa

c: velocità della luce, è costante
vale 3×10^8 m/s

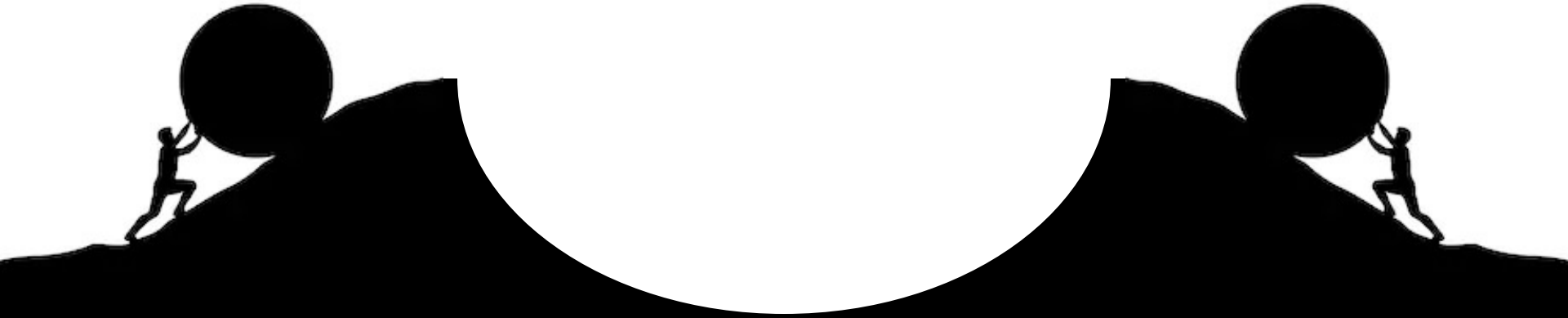
$$m = \frac{E}{c^2}$$

Credits: Asimmetrie

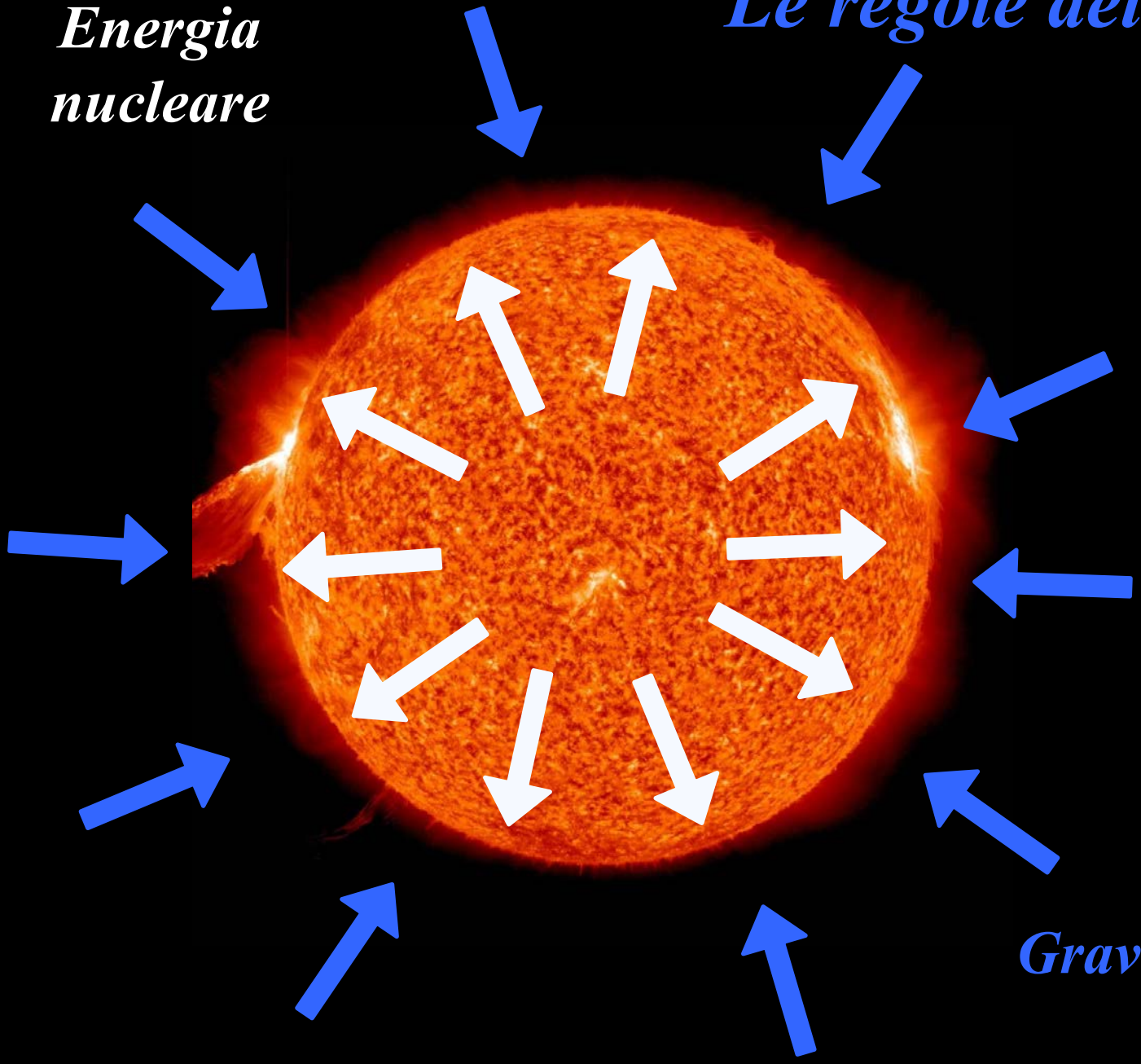
Fusione nucleare



Fusione nucleare



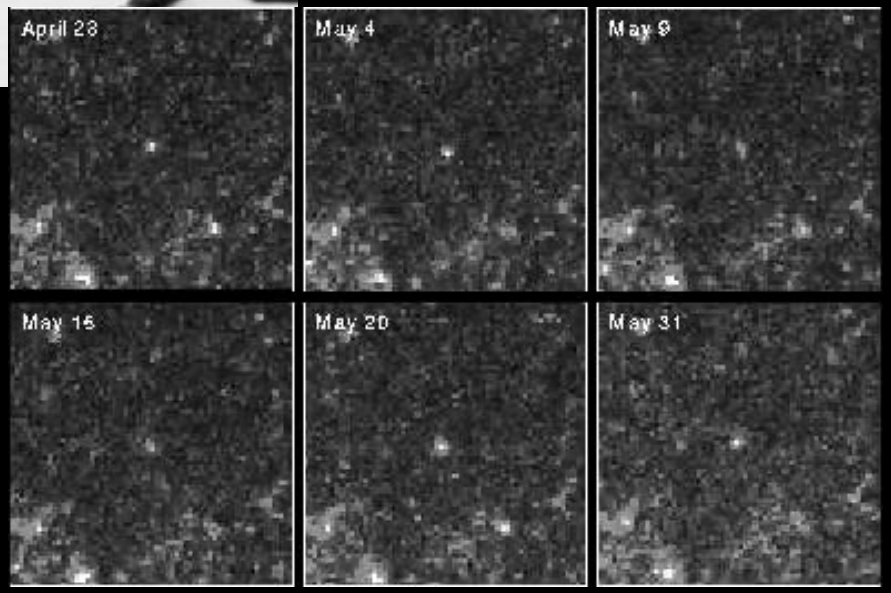
Le regole del gioco



[pikrepo.com, free use]

Henrietta Leavitt

[Public Domain, https://commons.wikimedia.org/w/index.php?curid=23861613]



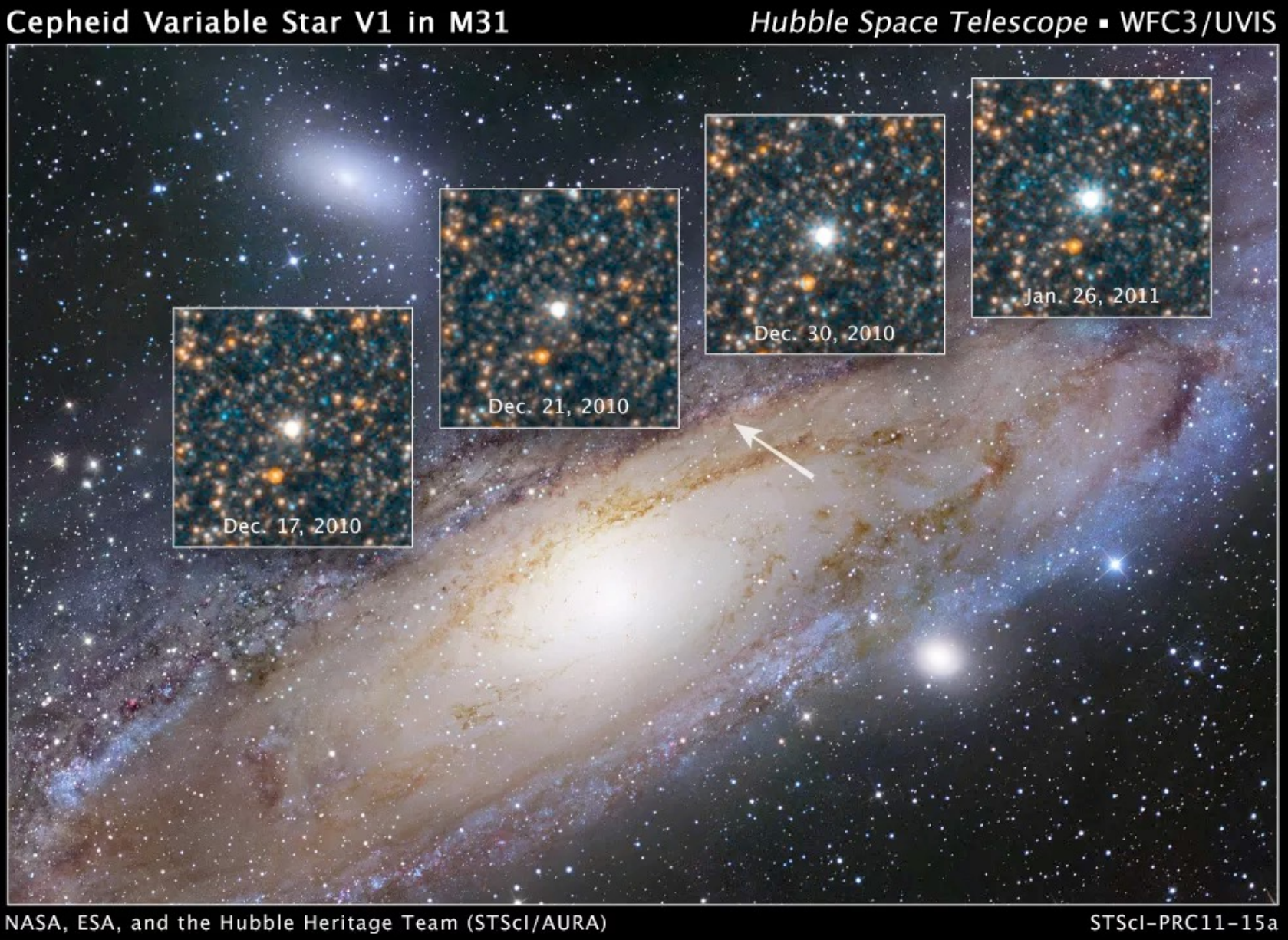
[HST/ESA/NASA]

[By Till Credner - Own work: AlltheSky.com, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20040777]

Andromeda

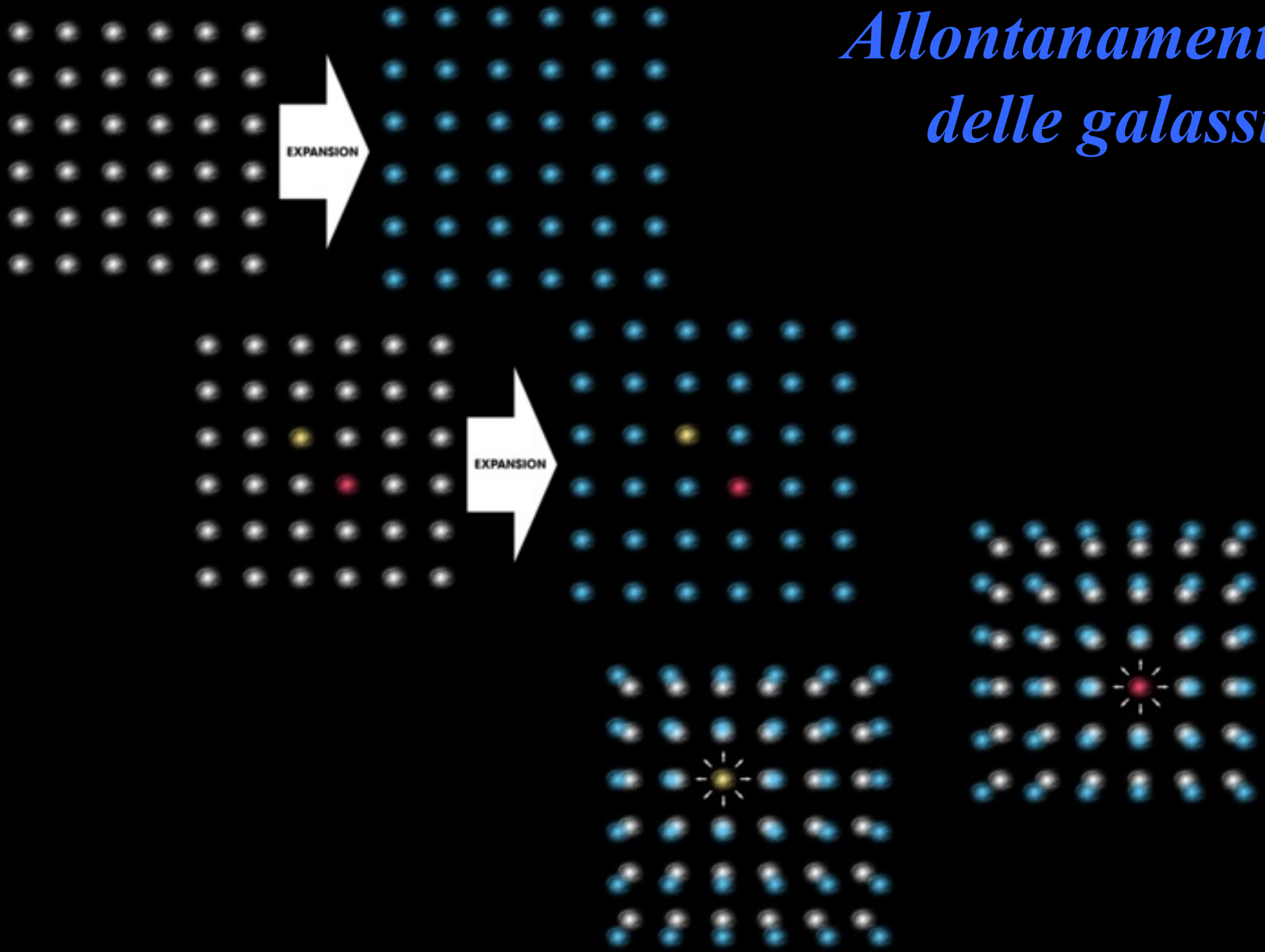
Edwin Hubble

Grande nebulosa di Andromeda o M31



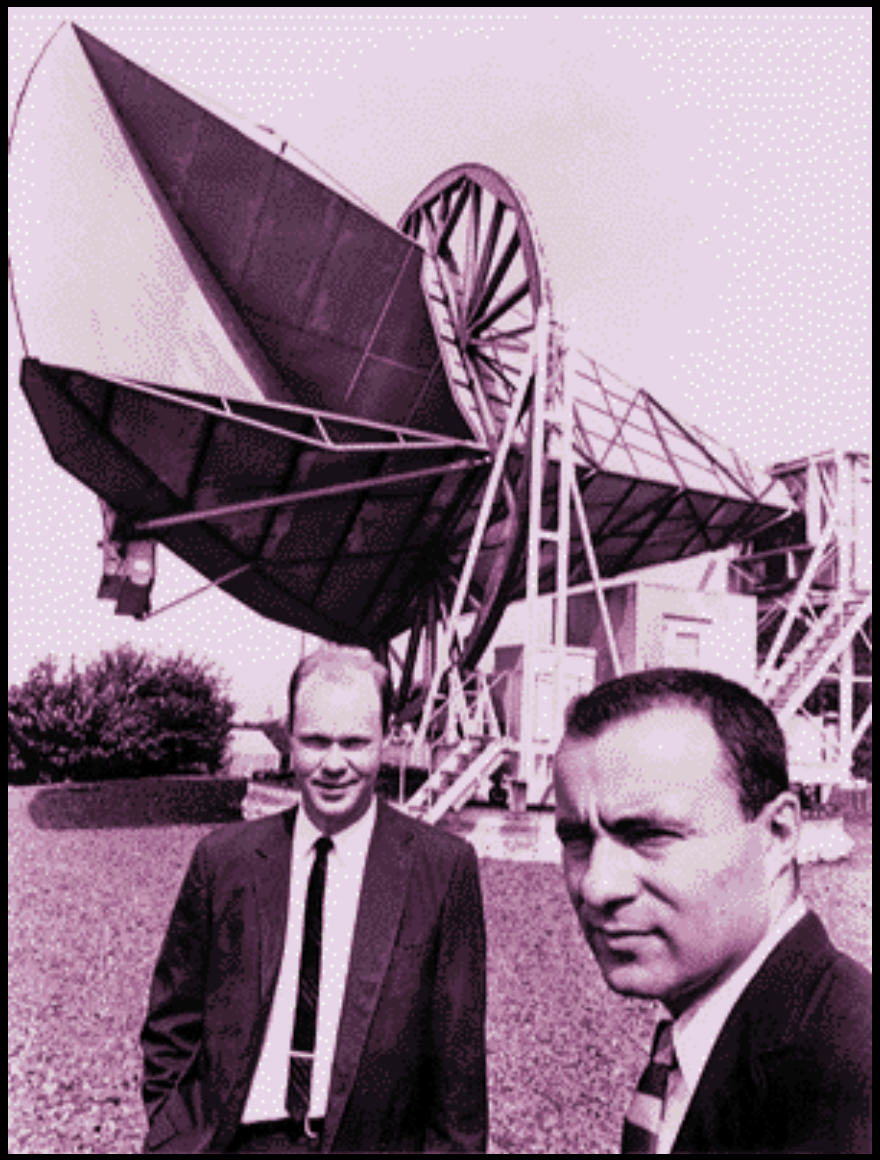
[] By Andrew Z. Colvin - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=71100126

Allontanamento delle galassie

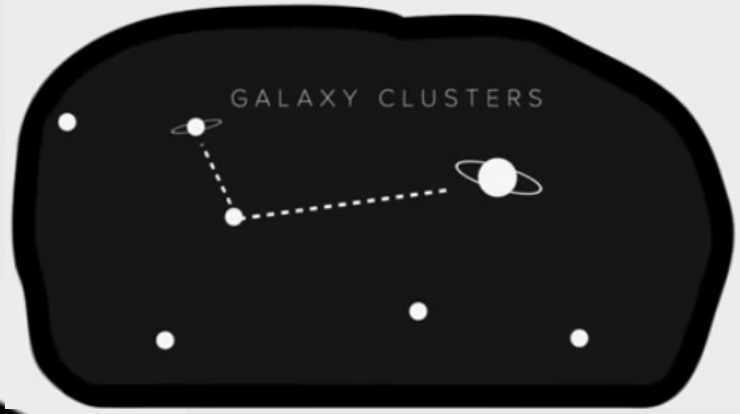


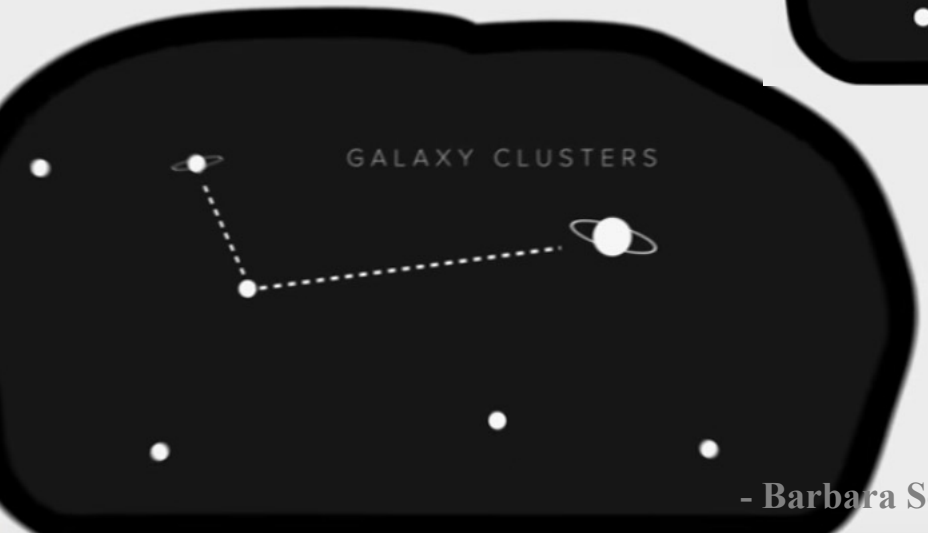
Espansione dell'Universo

Arno Penzias e Robert Wilson

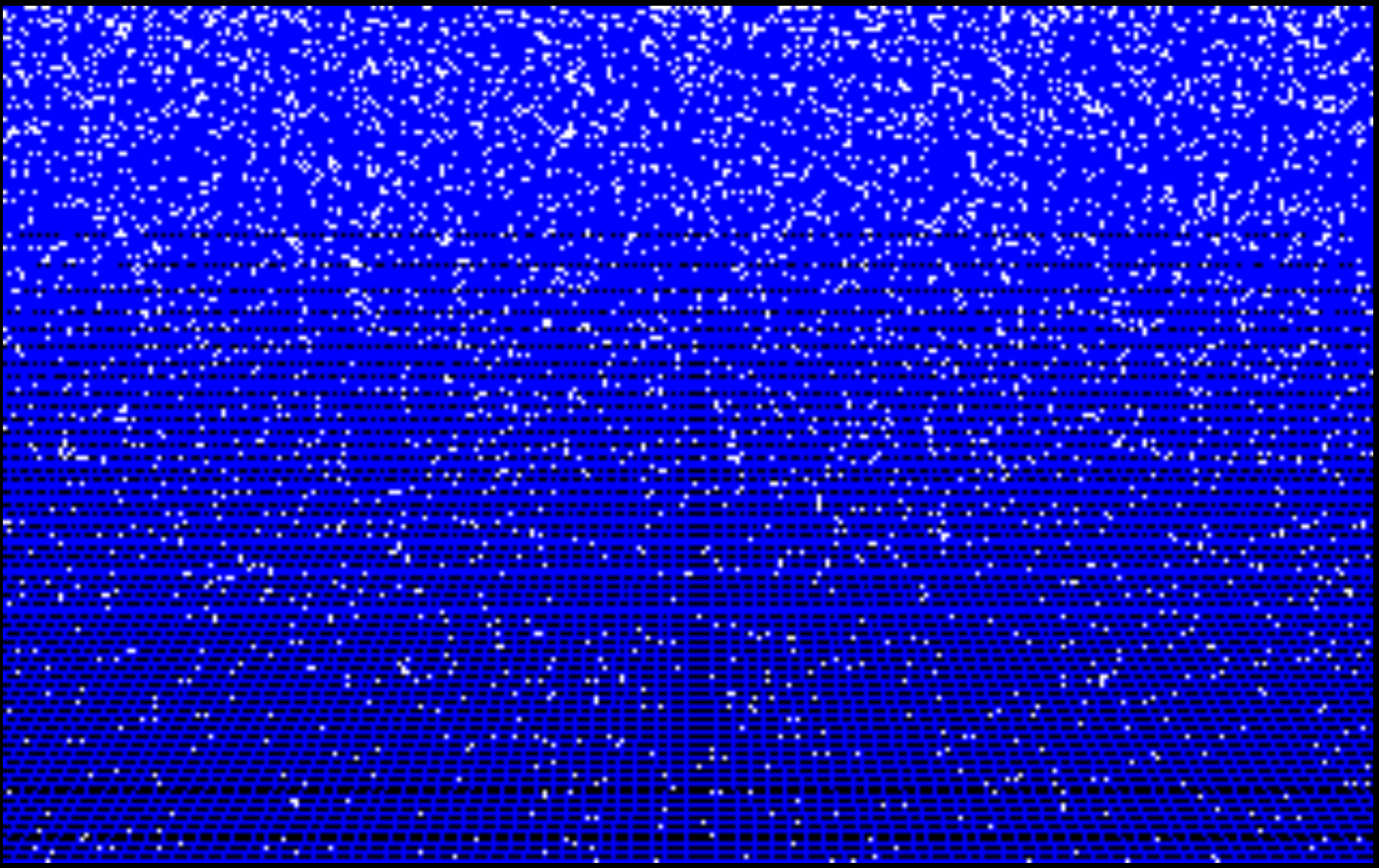


Allontanamento delle galassie





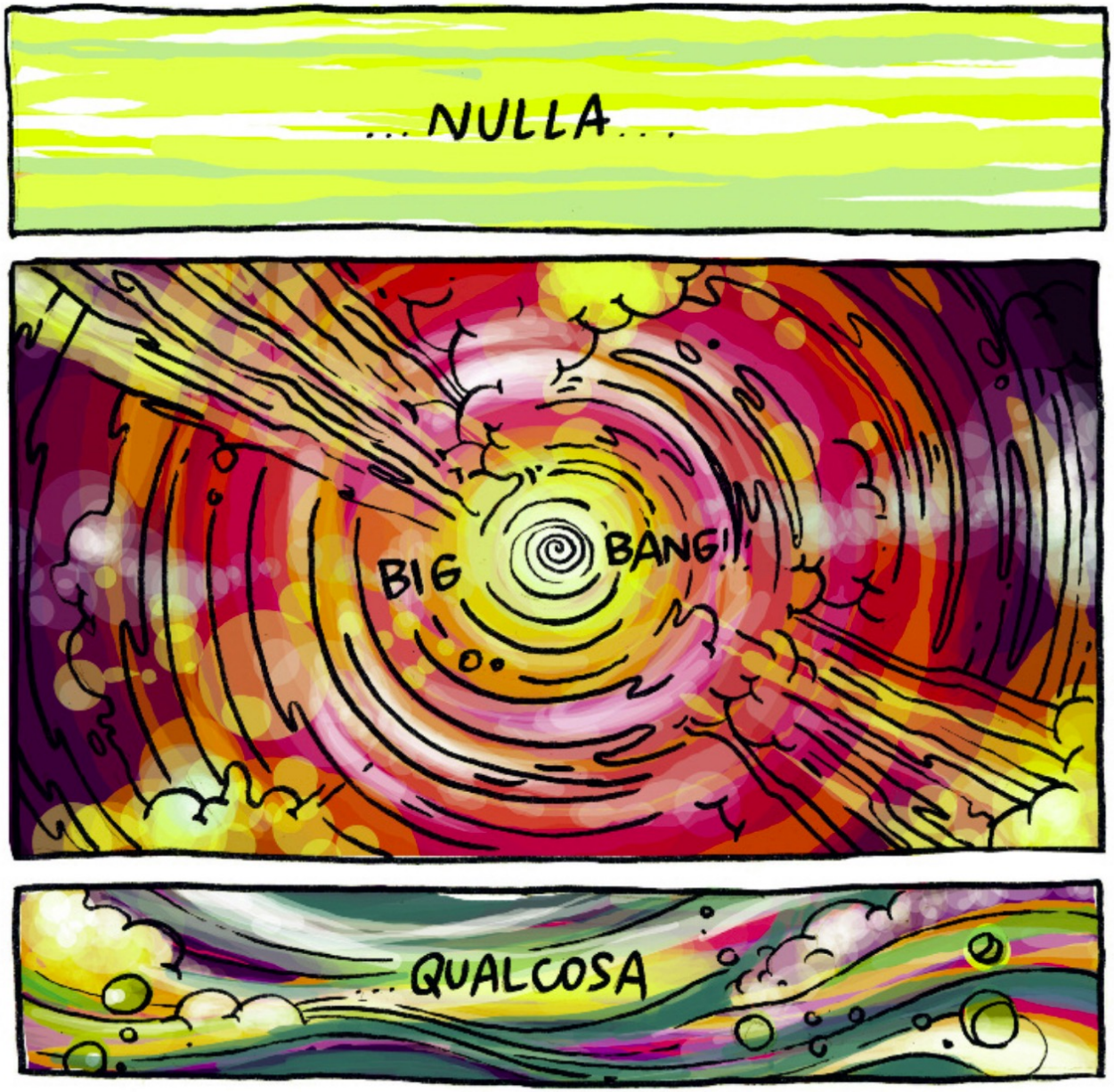
Espansione dell'infinito



Big bang

[tempo]

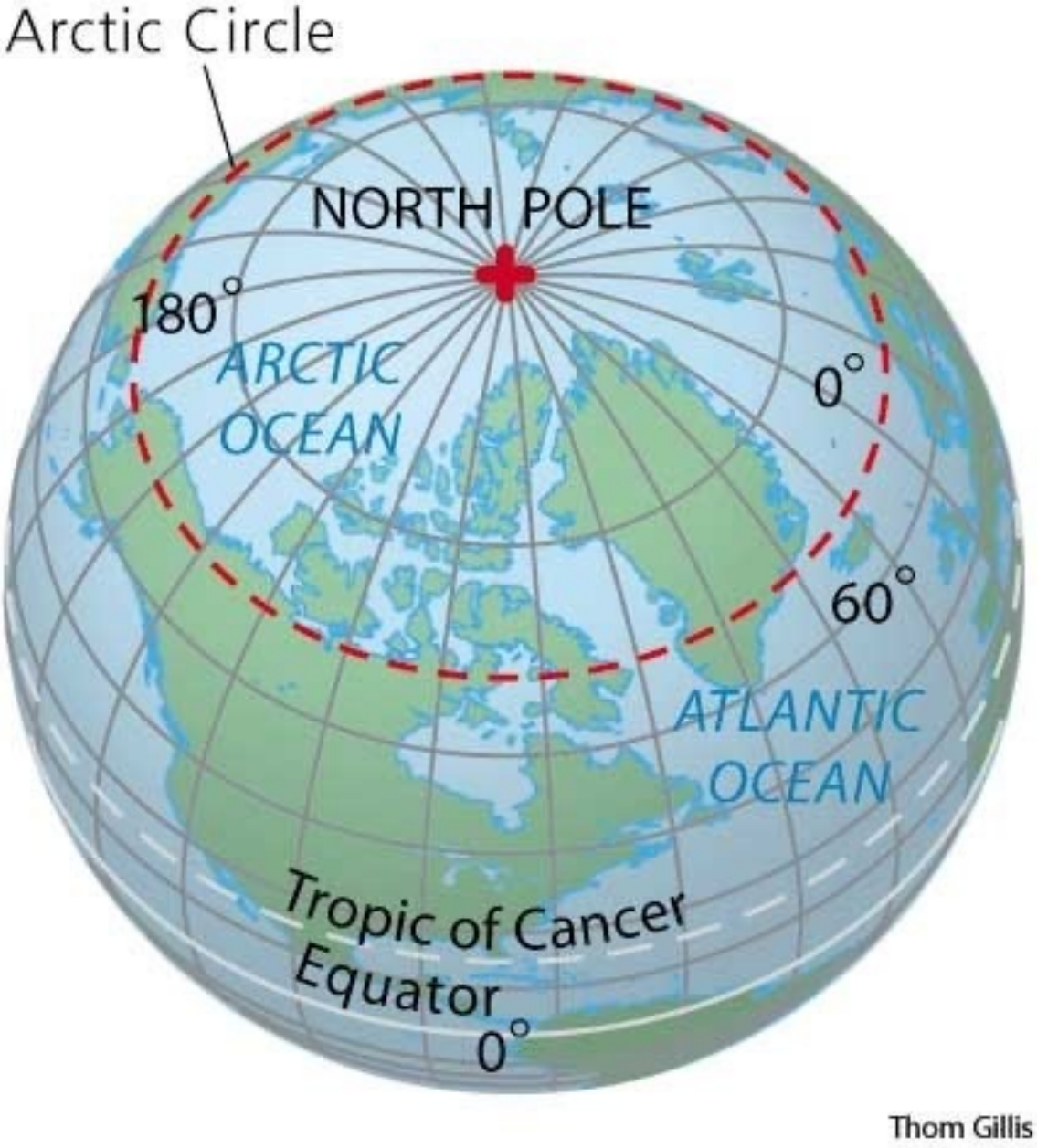
" t = 0"



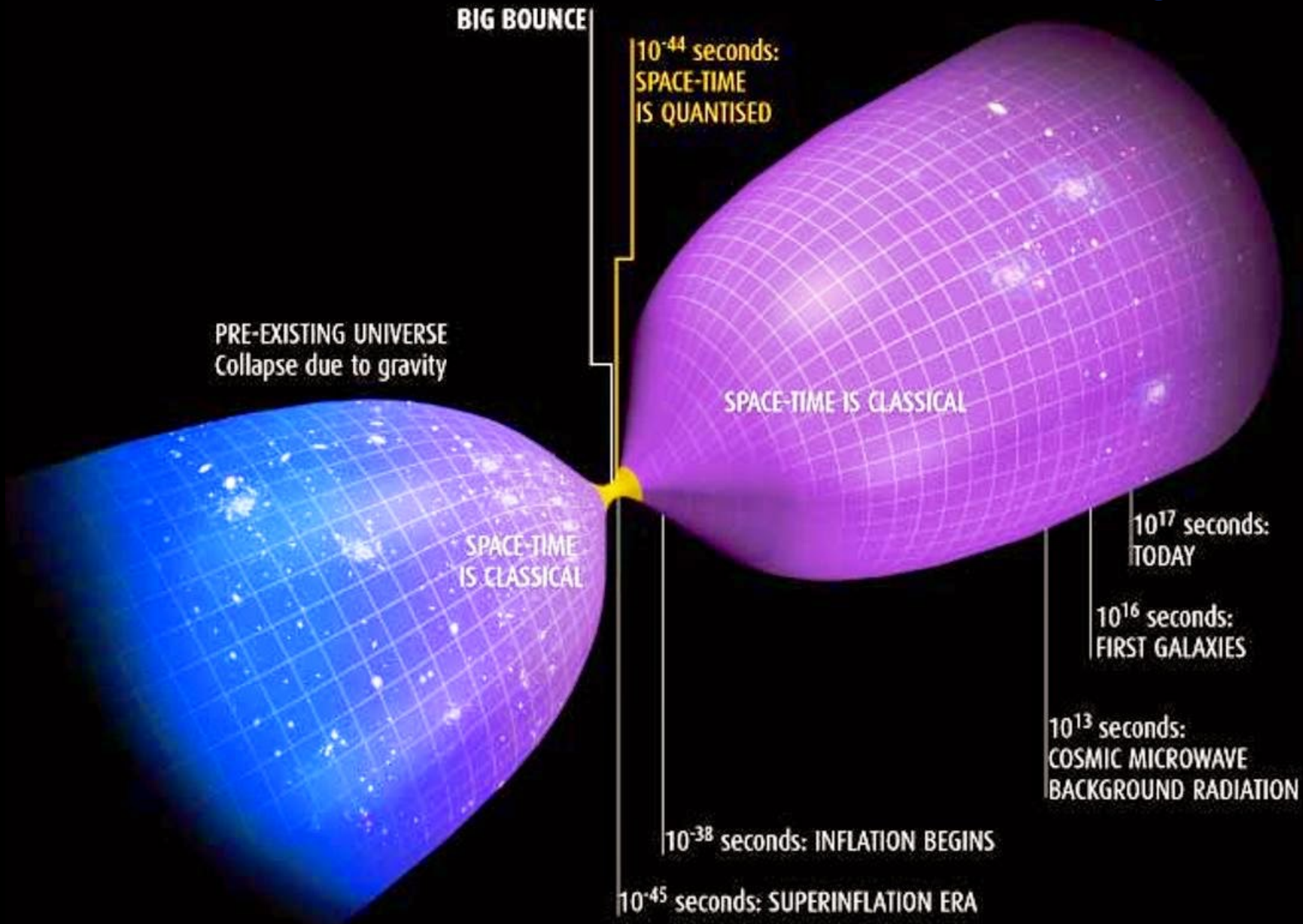
[Illustrazione: A. Iacurci]

Credits: A. Balbi

A Nord del Nord?



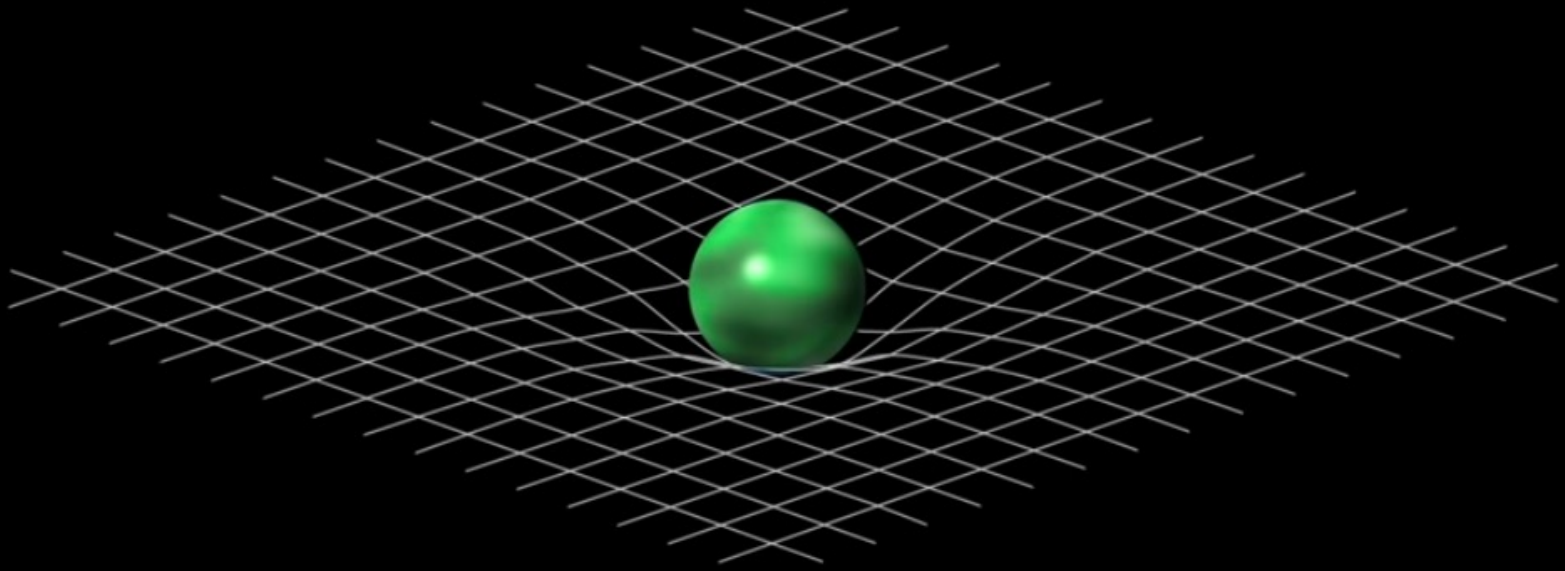
Big Bounce


BIG BOUNCE
10^{-44} seconds:
SPACE-TIME
IS QUANTISED
PRE-EXISTING UNIVERSE
Collapse due to gravity
SPACE-TIME IS CLASSICAL
SPACE-TIME
IS CLASSICAL
10^{17} seconds:
TODAY
10^{16} seconds:
FIRST GALAXIES
10^{13} seconds:
COSMIC MICROWAVE
BACKGROUND RADIATION
10^{-38} seconds: INFLATION BEGINS
10^{-45} seconds: SUPERINFLATION ERA

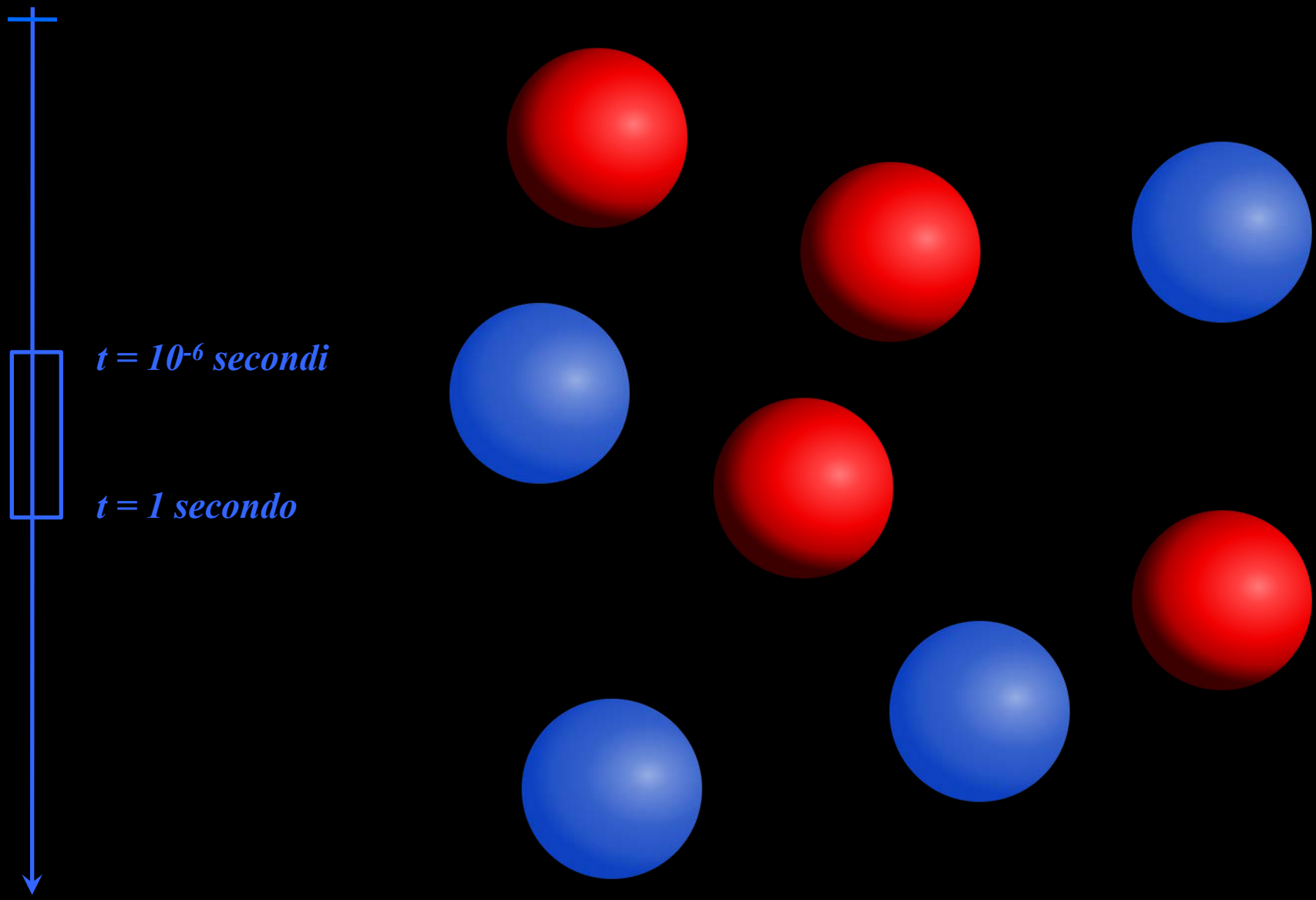
"inizia" la gravità

[tempo]

$t = 10^{-43}$ *secondi*

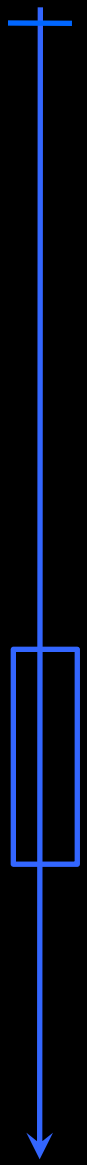


Protoni e neutroni



Nuclei atomici

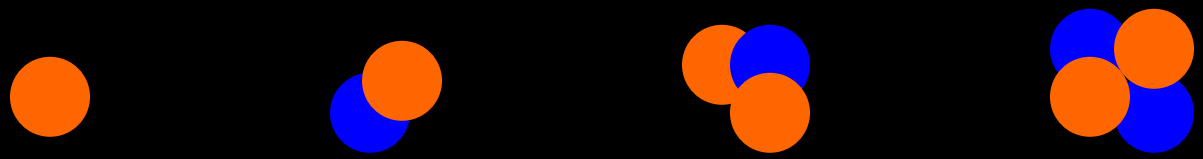
[tempo]



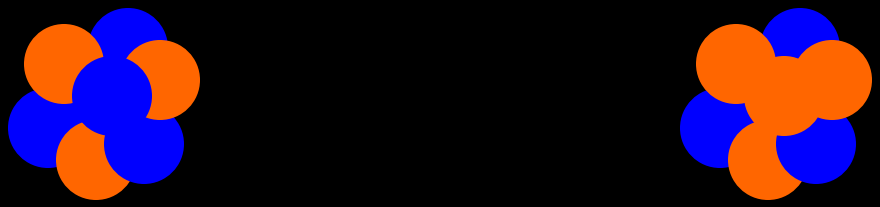
t = 10 secondi

t = 17 minuti

^{1}H ^{2}H ^{3}He ^{4}He



(tracce di) ^{7}Li ^{7}Be *(instabile)*



Nucleosintesi primordiale

Universo: 600 anni luce

[tempo]

"nubi"

[https://pngimg.com/download/55245, Creative Commons 4.0 BY-NCC]

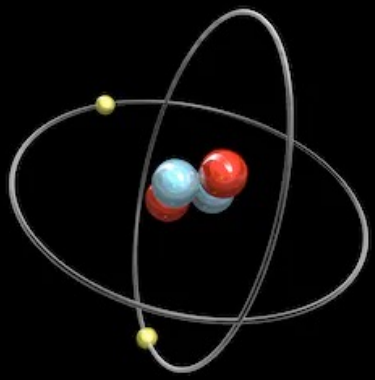
t = 17 minuti

t = 377000 anni

[elettroni, protoni, neutroni]

Formazione di atomi

[tempo]

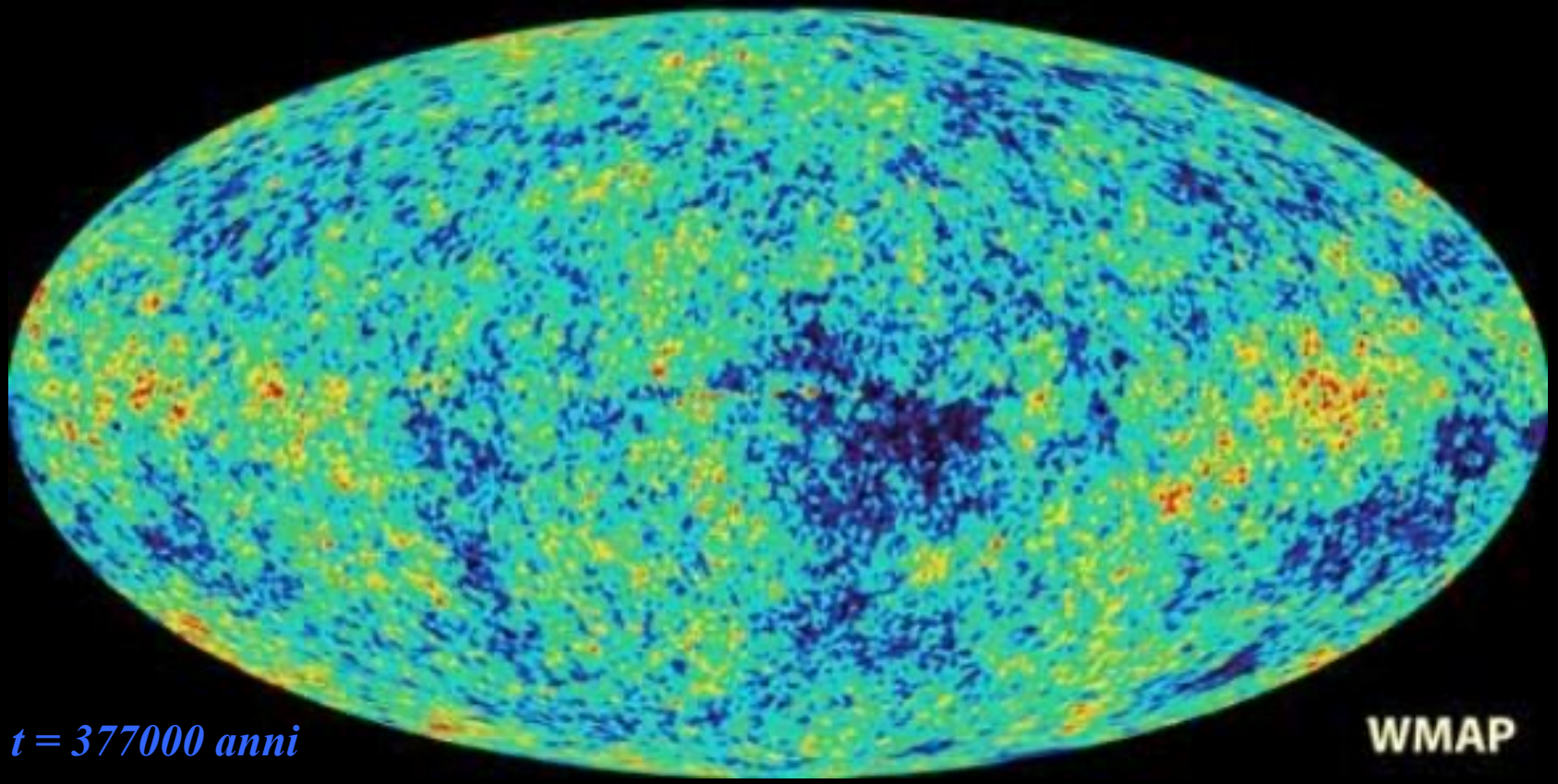


t = 17 minuti

t = 377000 anni

[tempo]

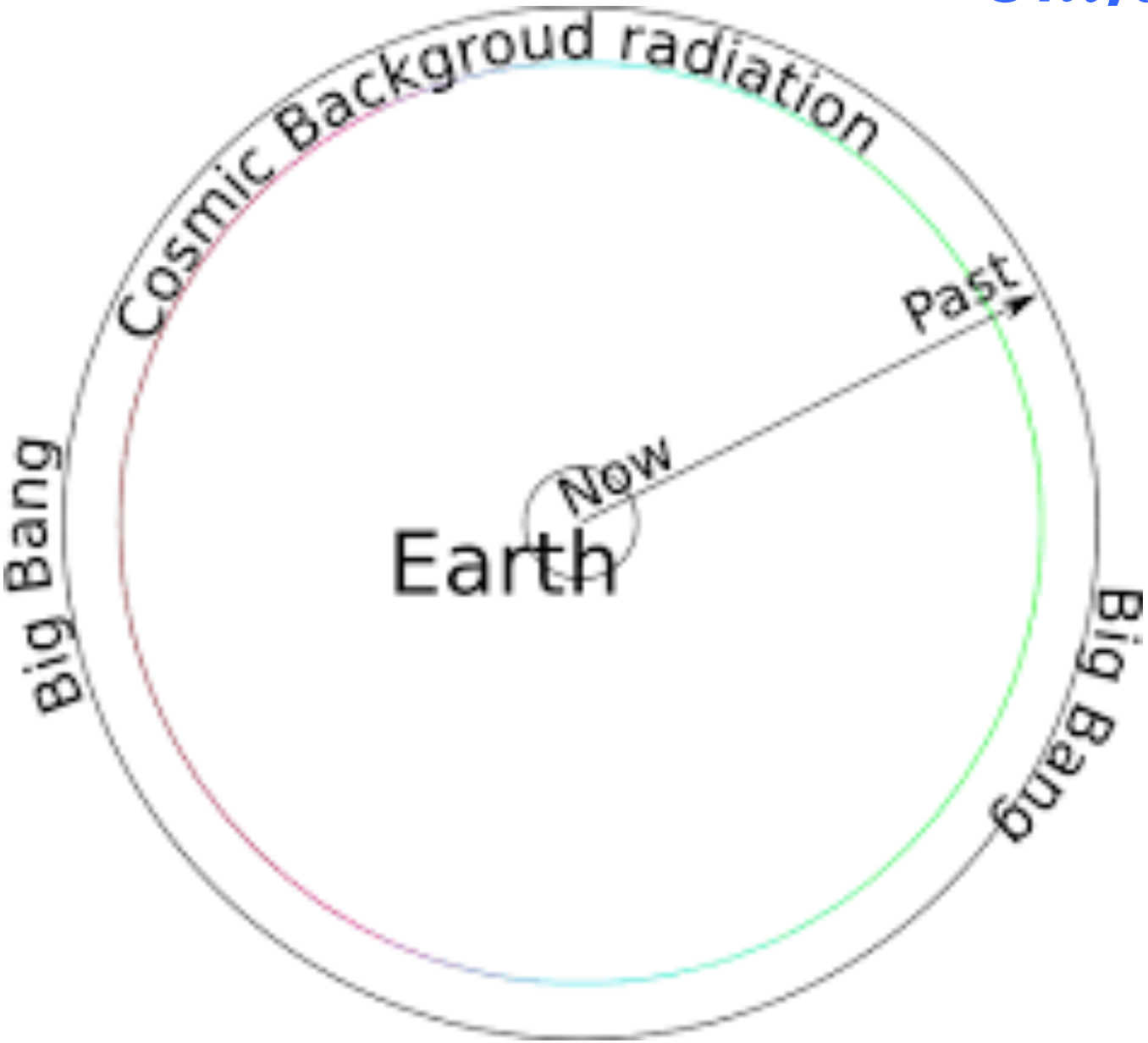
L'Universo diventa trasparente



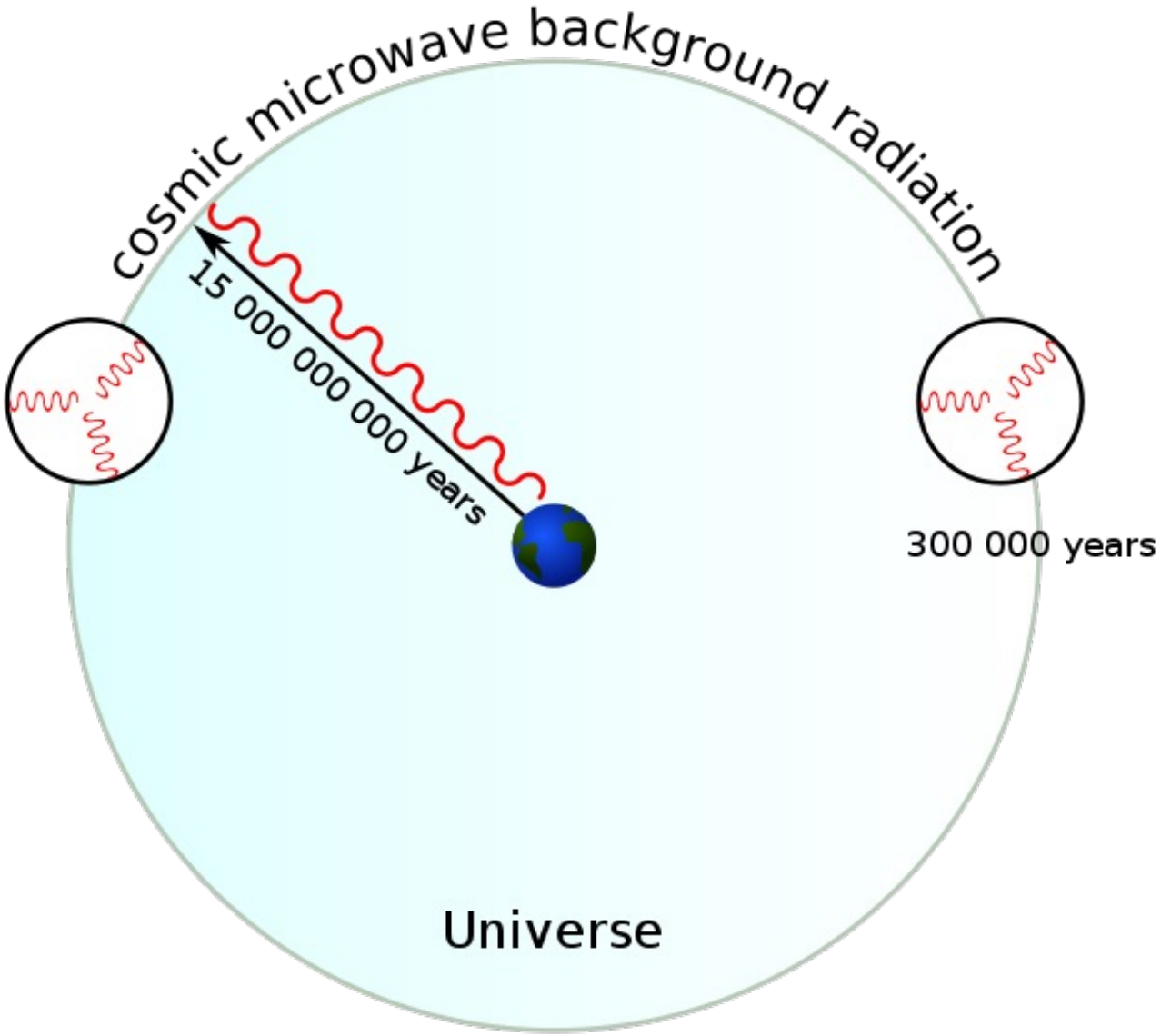
t = 377000 anni

Universo: 100 milioni di anni luce

Uniformità

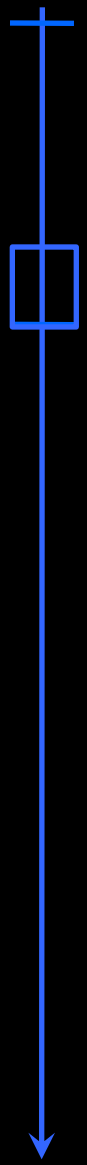

Cosmic Backgroud radiation
Past
Now
Earth
Big Bang
Big Bang

Uniformità


cosmic microwave background radiation
15 000 000 000 years
300 000 years
Universe

Uniformità

[tempo]



$t = 10^{-36}$ secondi

$t = 10^{-32}$ secondi

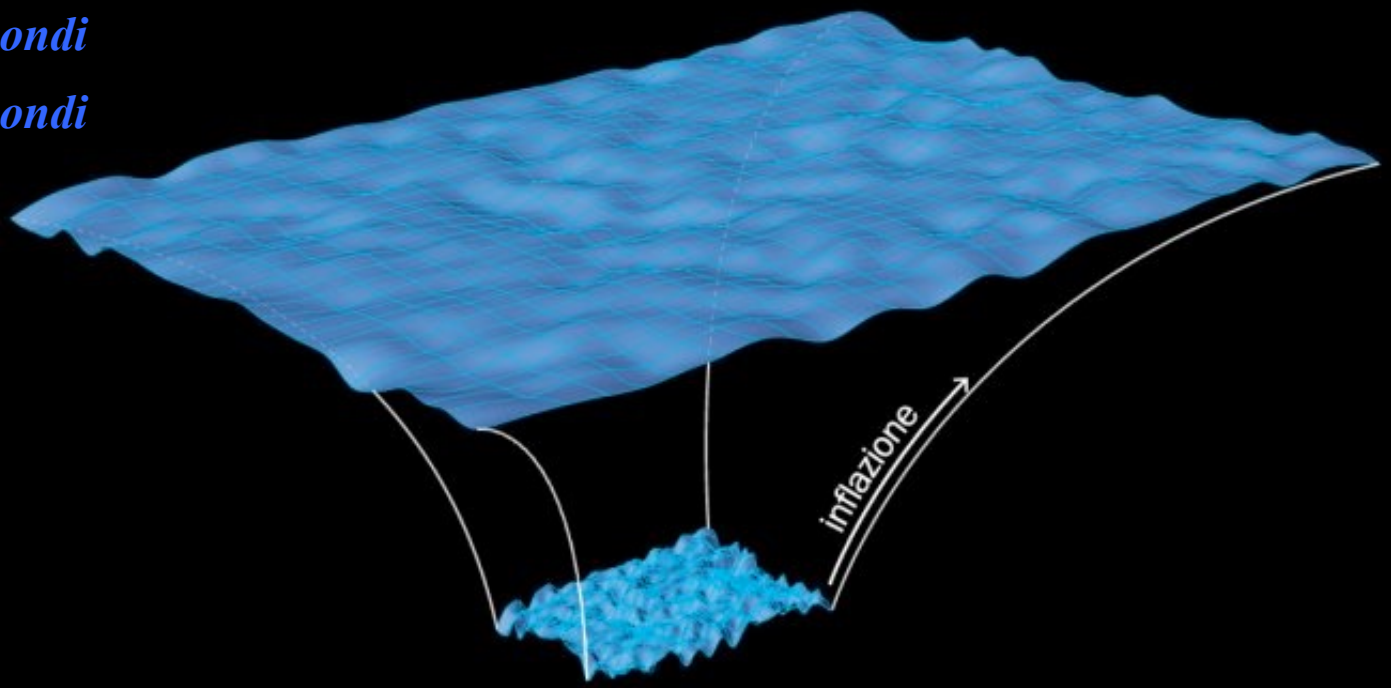
Credits: A. Balbi

Inflazione

[tempo]

t = 10^{-36} secondi

t = 10^{-32} secondi

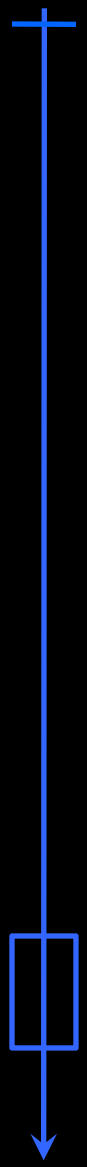


[Credits: Asimmetrie]

Da distanze delle dimensioni di una molecola [un decimo di miliardesimo di metro] a distanze di 10 anni luce [100 milioni di miliardi di metri]

[tempo]

nubi invisibili?



Dark age

t = 377000 anni

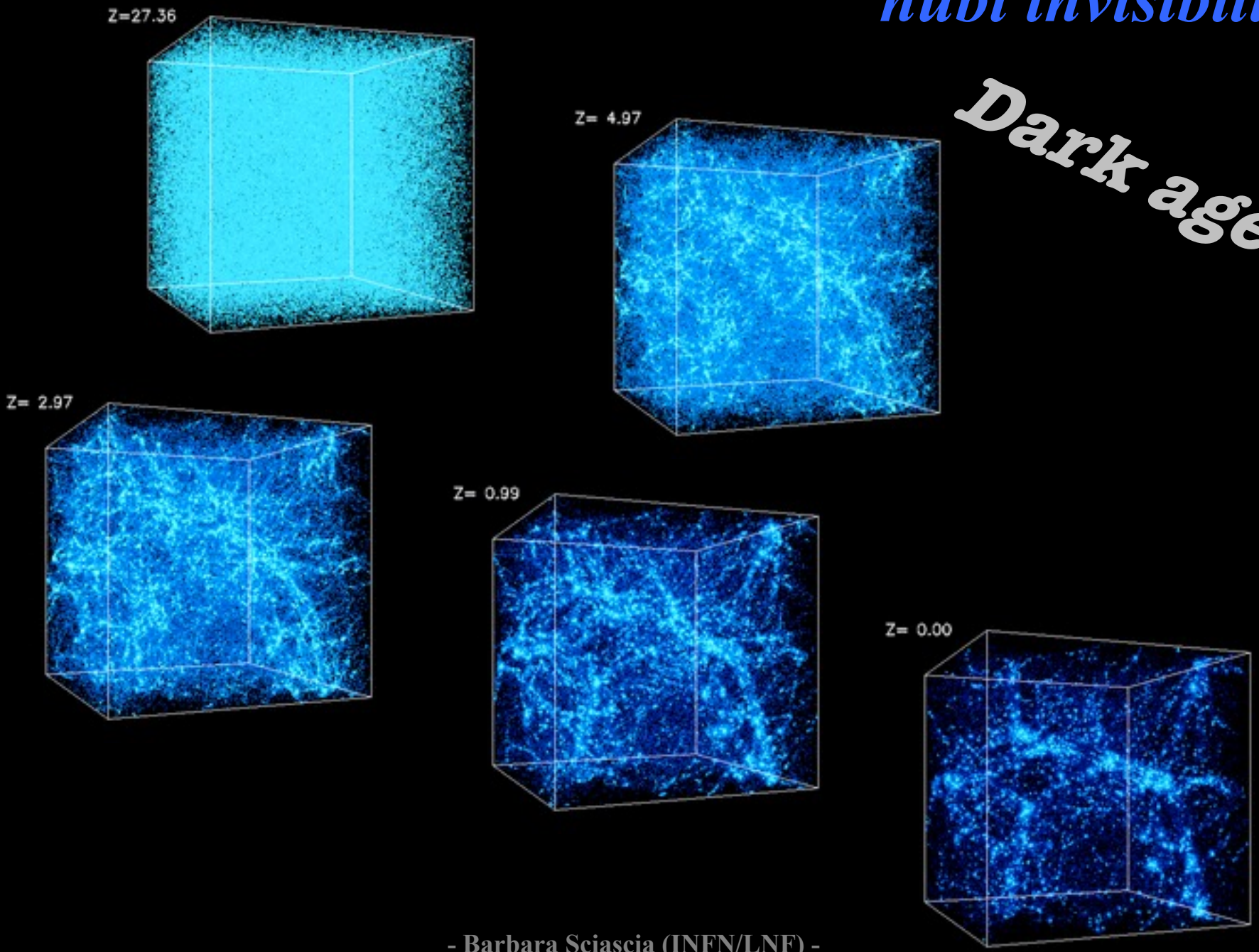
t = 150 milioni di anni

[atomi di idrogeno e di elio]

http://cosmicweb.uchicago.edu/filaments.html

nubi invisibili?

Dark age



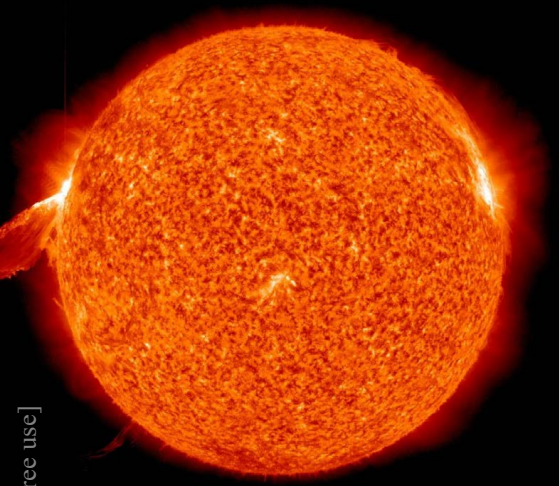
[tempo]

Stelle!

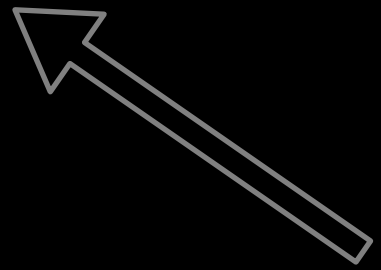
t = 150 milioni di anni

t = 1 miliardo di anni

Il processo base



[pikrepo.com, free use]



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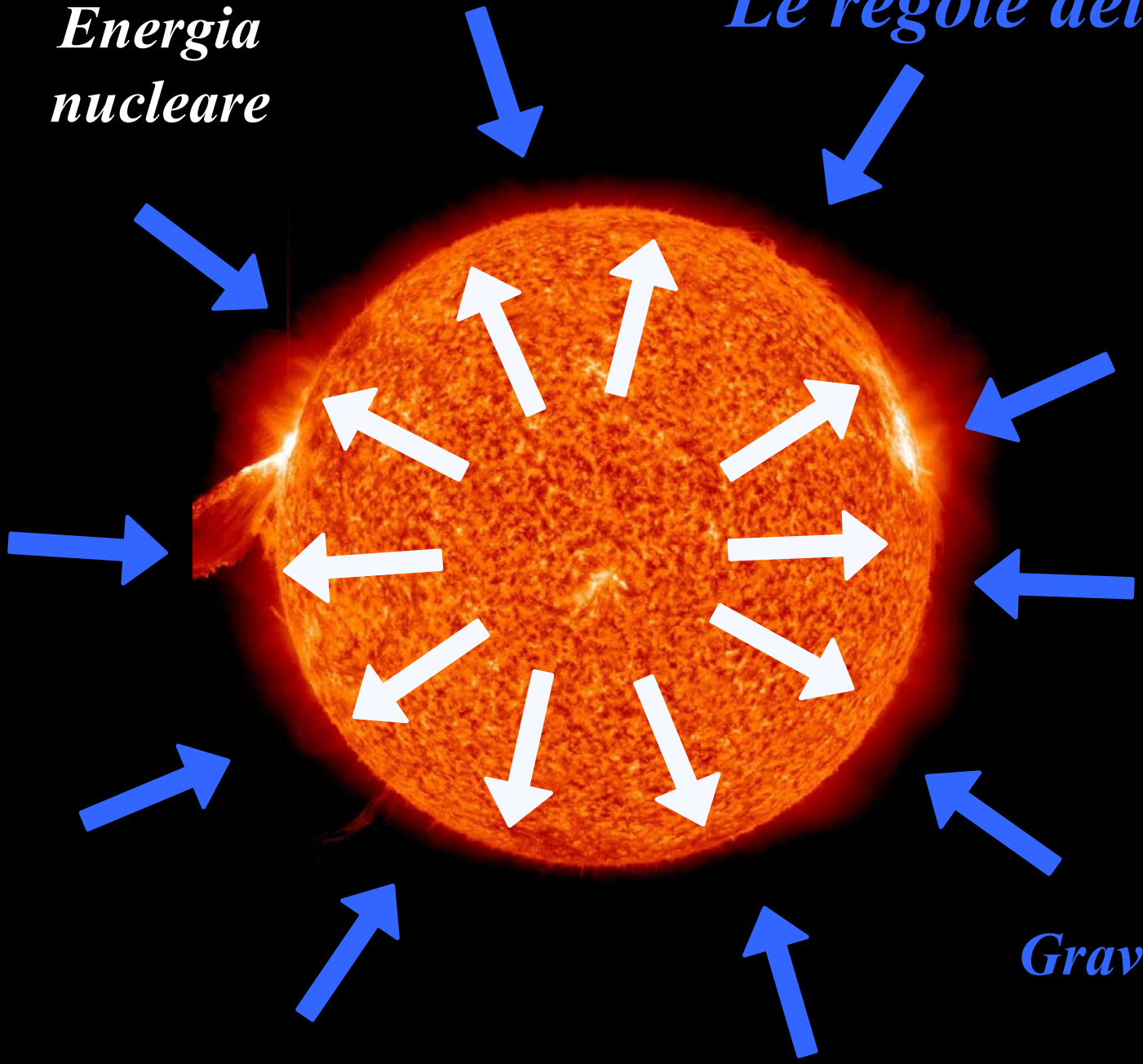
[atomi di Idrogeno ed Elio]

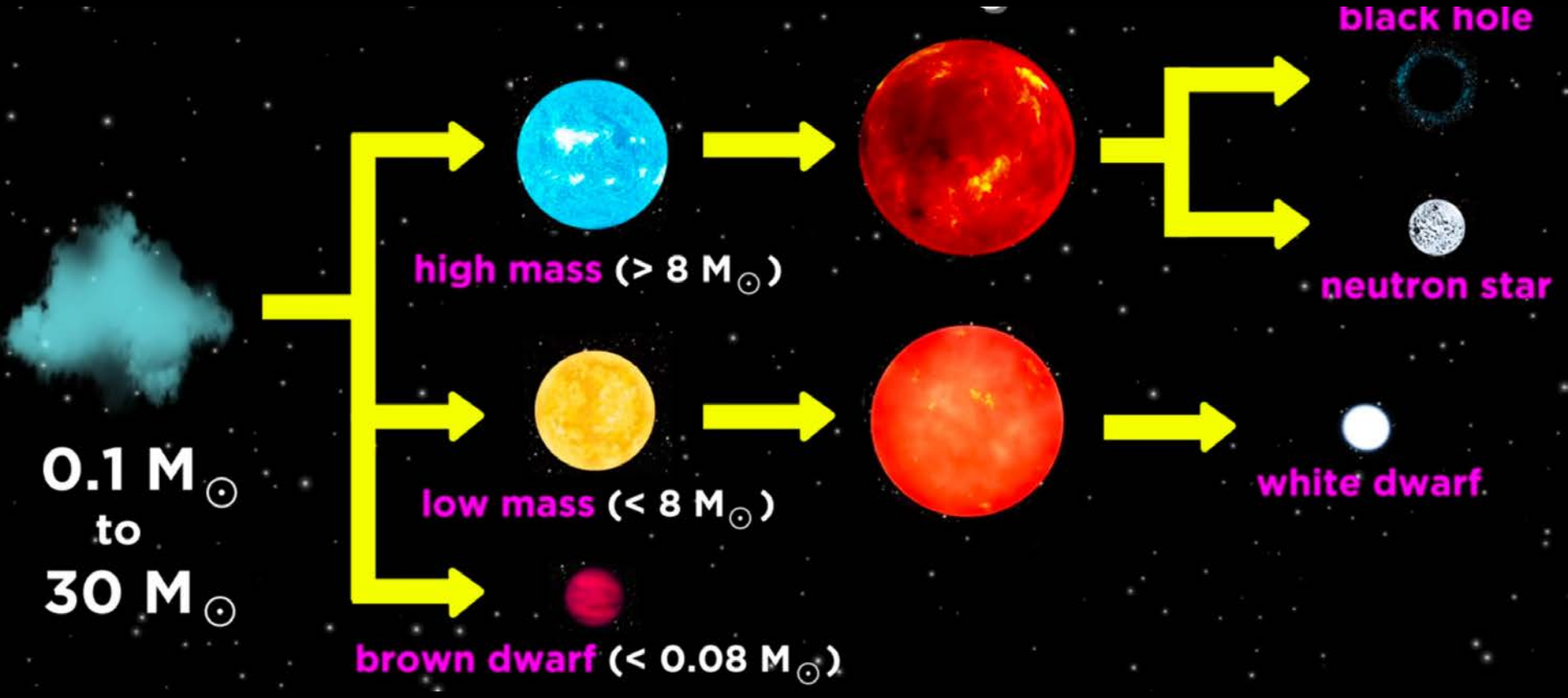
Le regole del gioco



[pikrepo.com, free use]

Vita da stelle

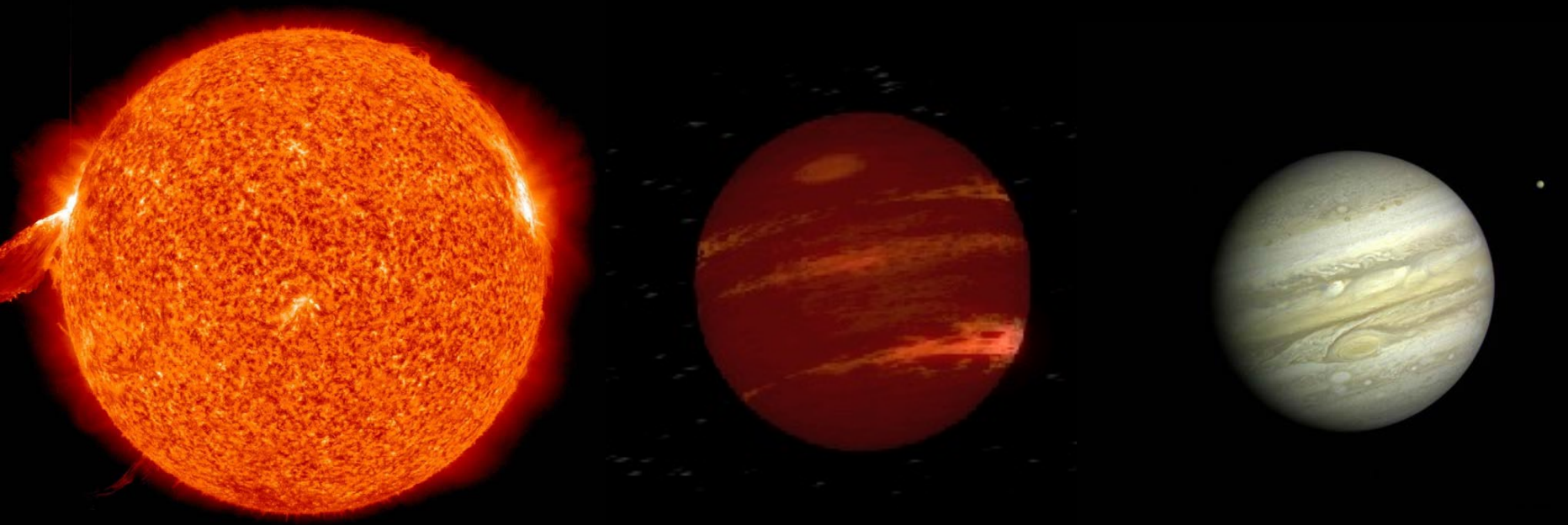
$M_\odot$: massa del Sole



Credits: https://www.youtube.com/channel/UC0cd_-e49hZpWLH3UIwoWRA

Nane brune

[NASA/JPL]

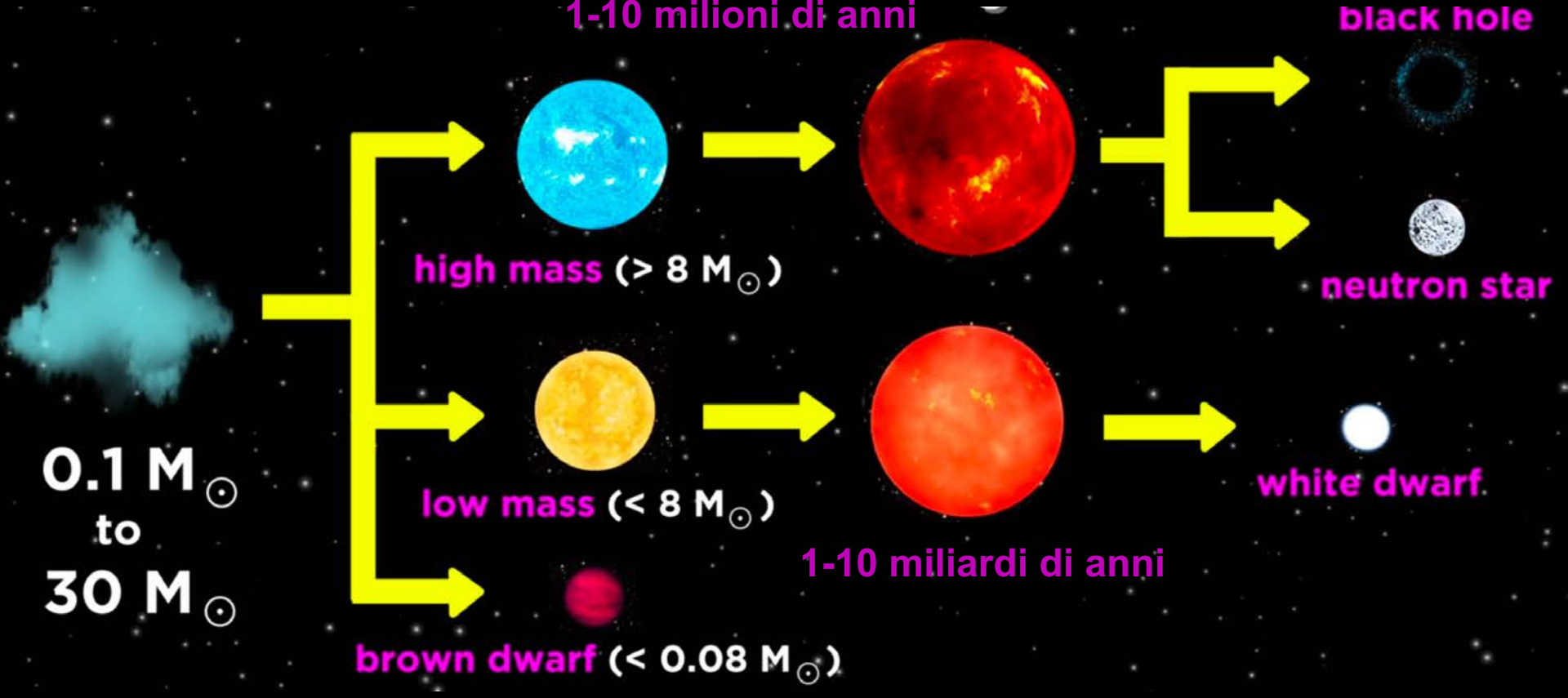


Stella (Sole)

Pianeta gassoso (Giove)

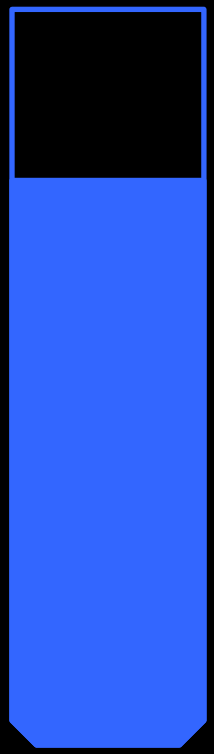
Vita da stelle

$M_\odot$: massa del Sole



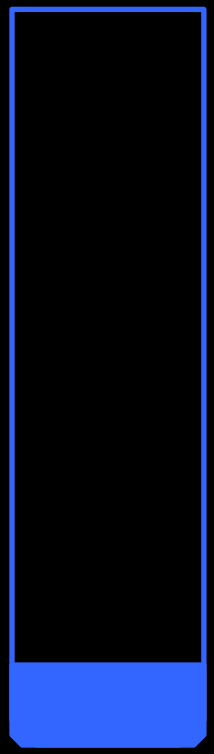
[Credits: https://www.youtube.com/channel/UC0cd_-e49hZpWLH3UIwoWRA]

Fornaci stellari

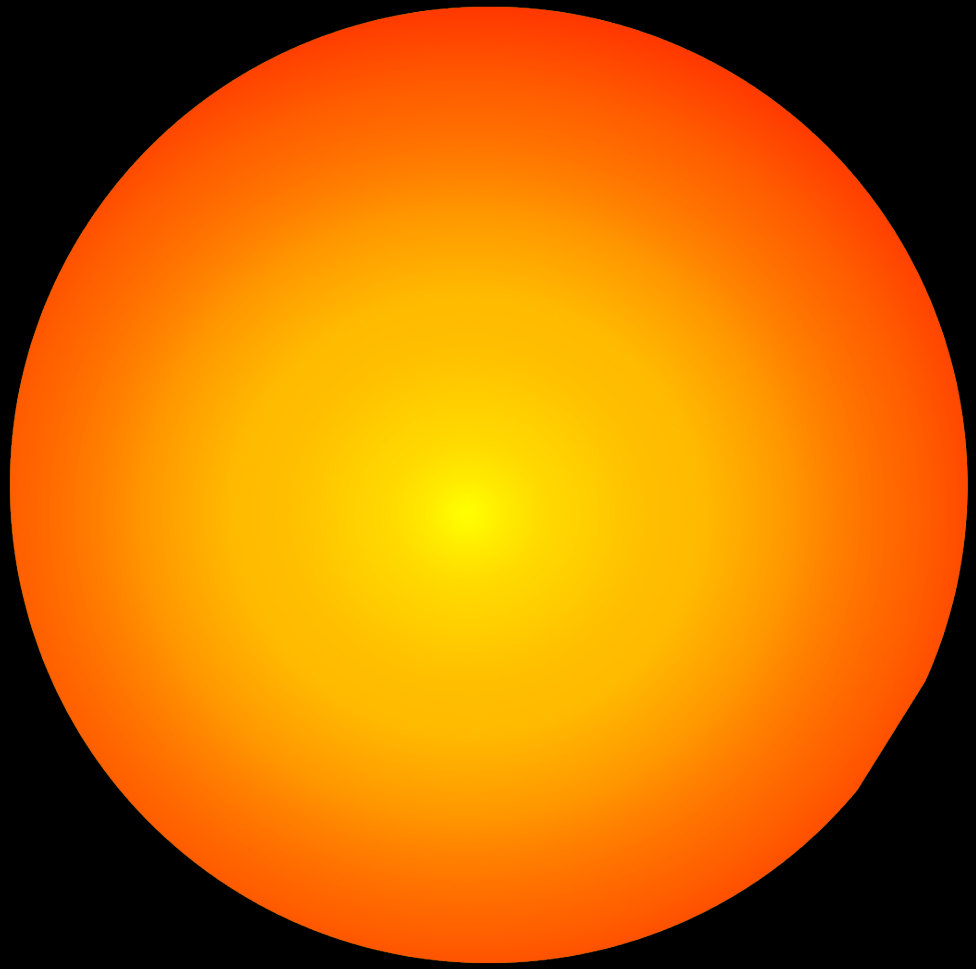


H
(idrogeno)

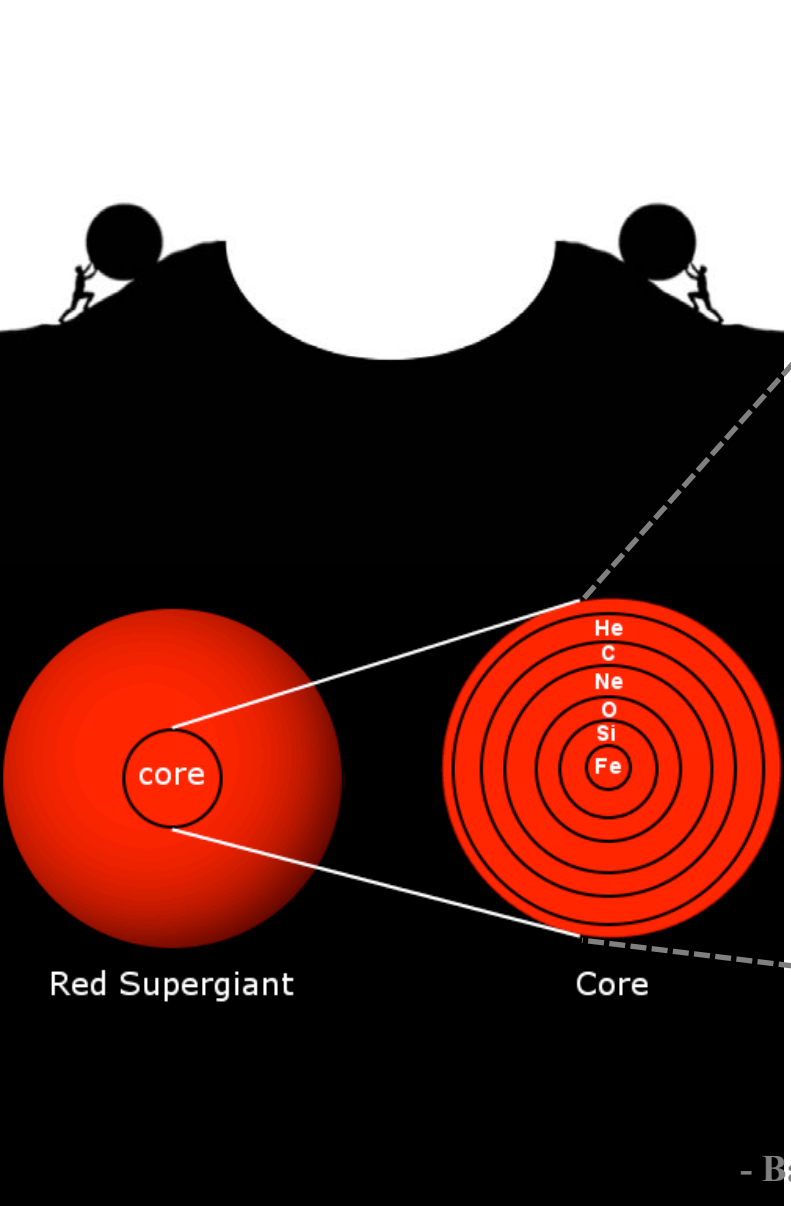
Fornaci stellari

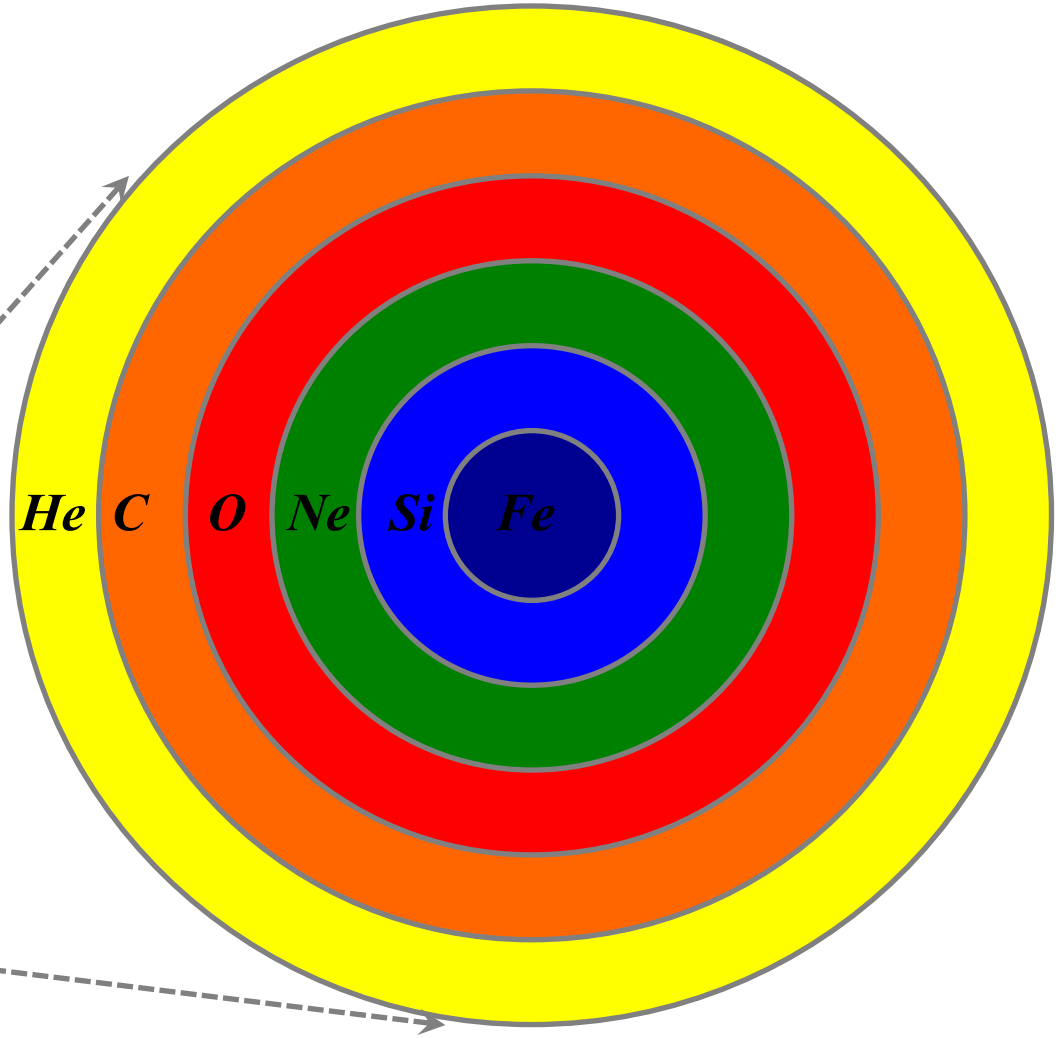


H
(idrogeno)

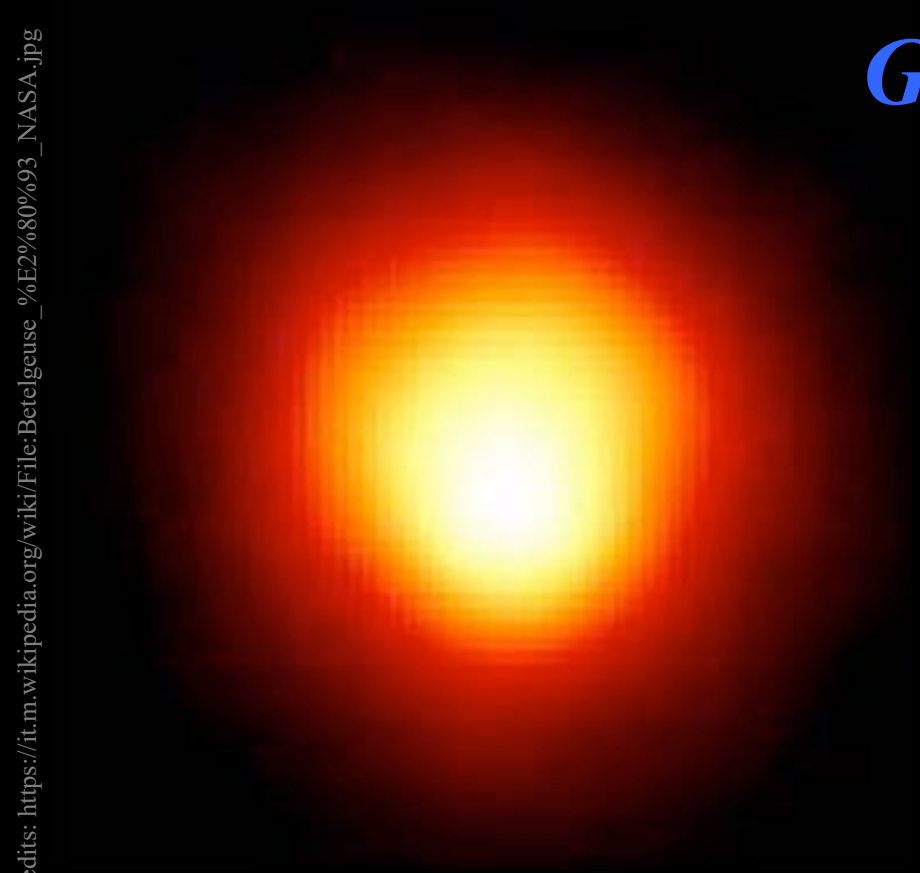


Nucleosintesi stellare





Giganti rosse (Betelgeuse)



Credits: https://it.m.wikipedia.org/wiki/File:Betelgeuse_%E2%80%93_NASA.jpg

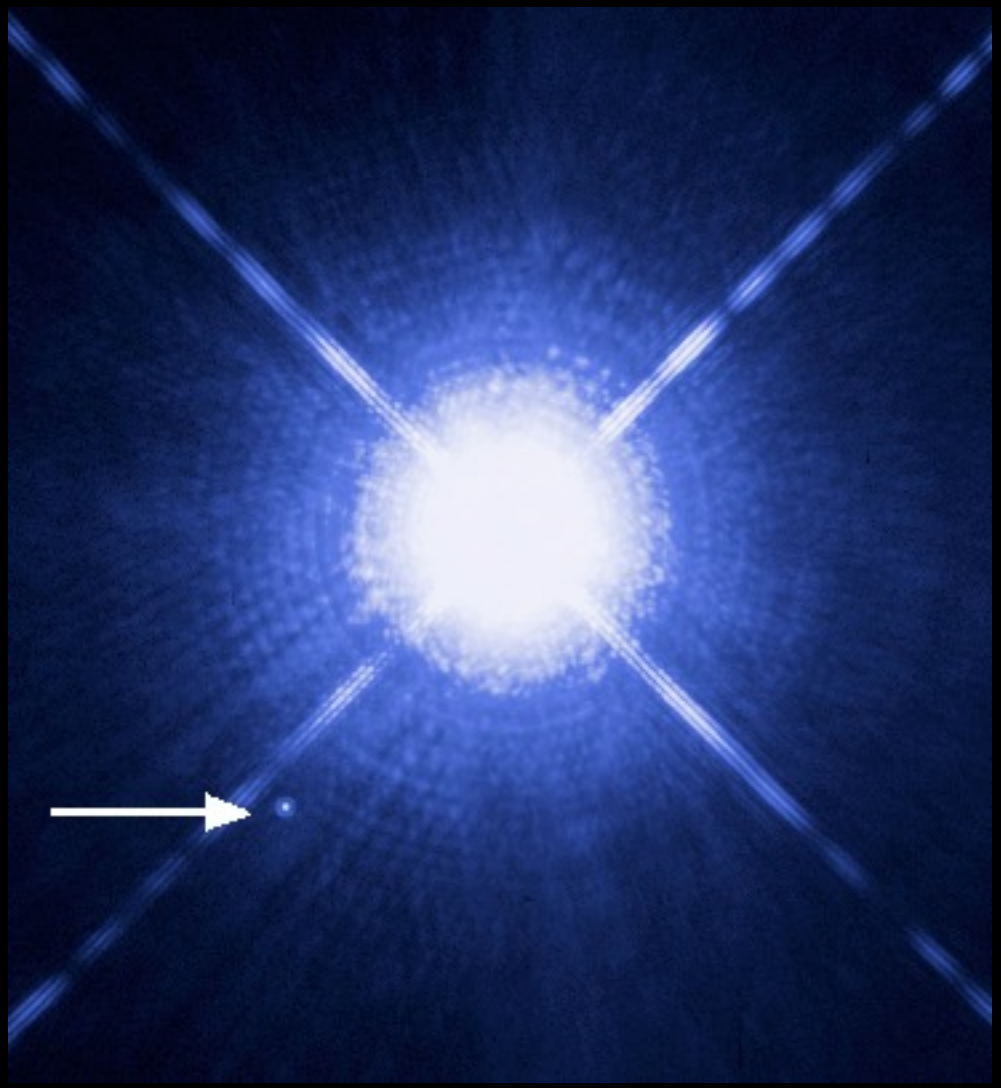
Nebulosa planetaria [NGC7293]

Credits: The HST data , https://commons.wikimedia.org/w/index.php?curid=1721117

Nebulosa planetaria [NGC6326]

Credits:Di ESA/Hubble, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=10758494

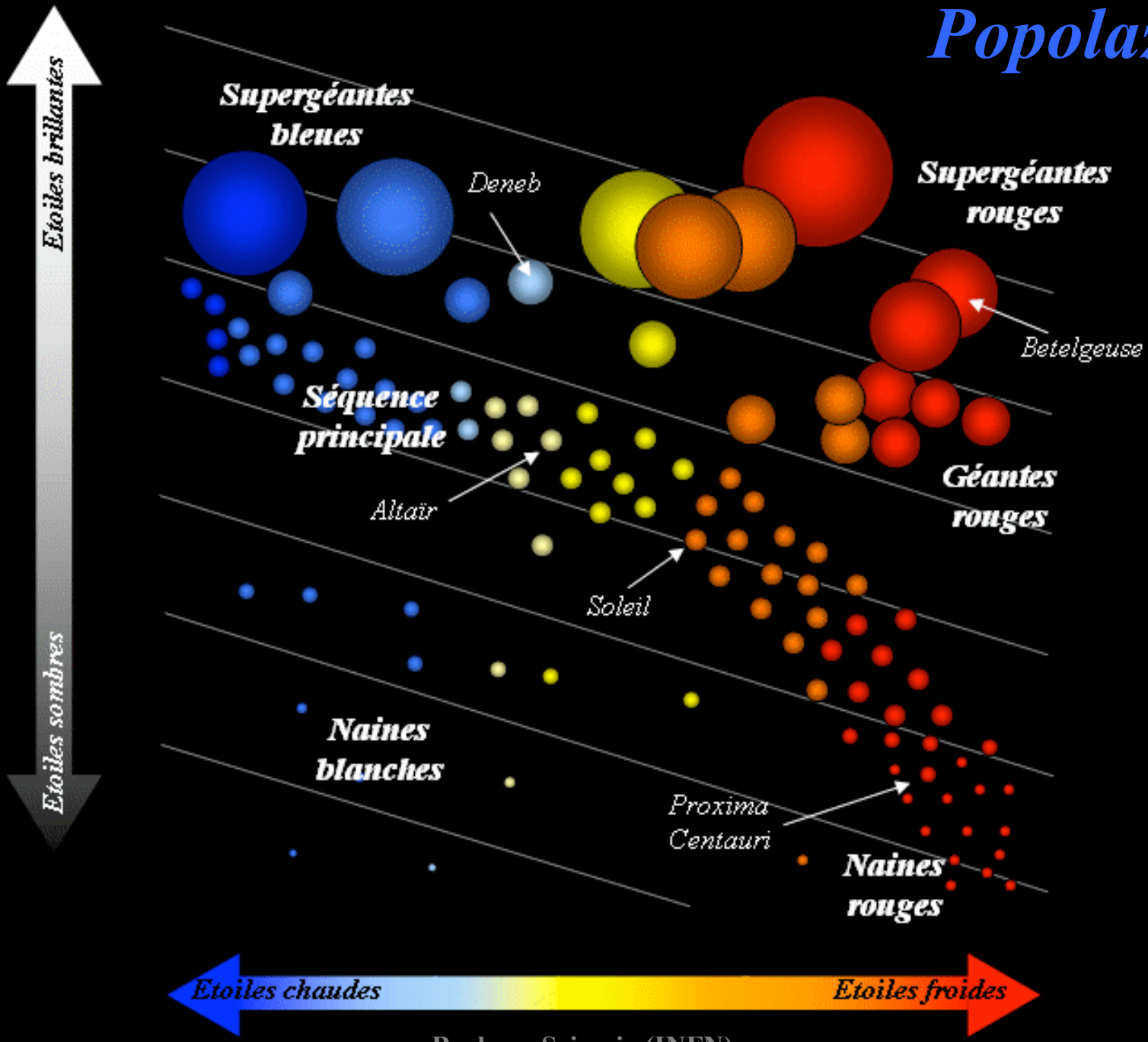
Nana bianca (Sirius B)



[Public Domain, https://commons.wikimedia.org/w/index.php?curid=1271789]

Popolazione

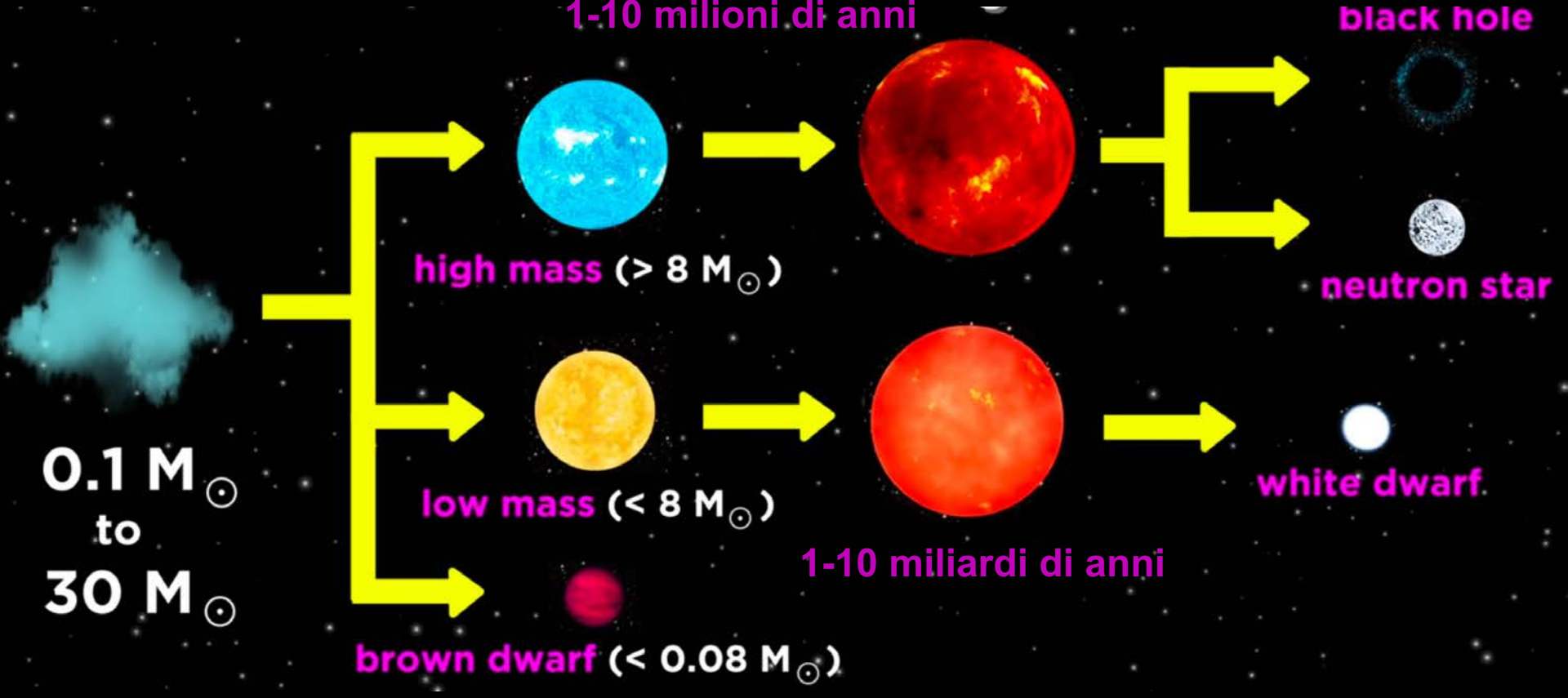
Popolazione



Credits: http://cepheides.fr/2018/03/de-l-astronomie-le-soleil-une-etoile-ordinaire.html

Vita da stelle

$M_\odot$: massa del Sole

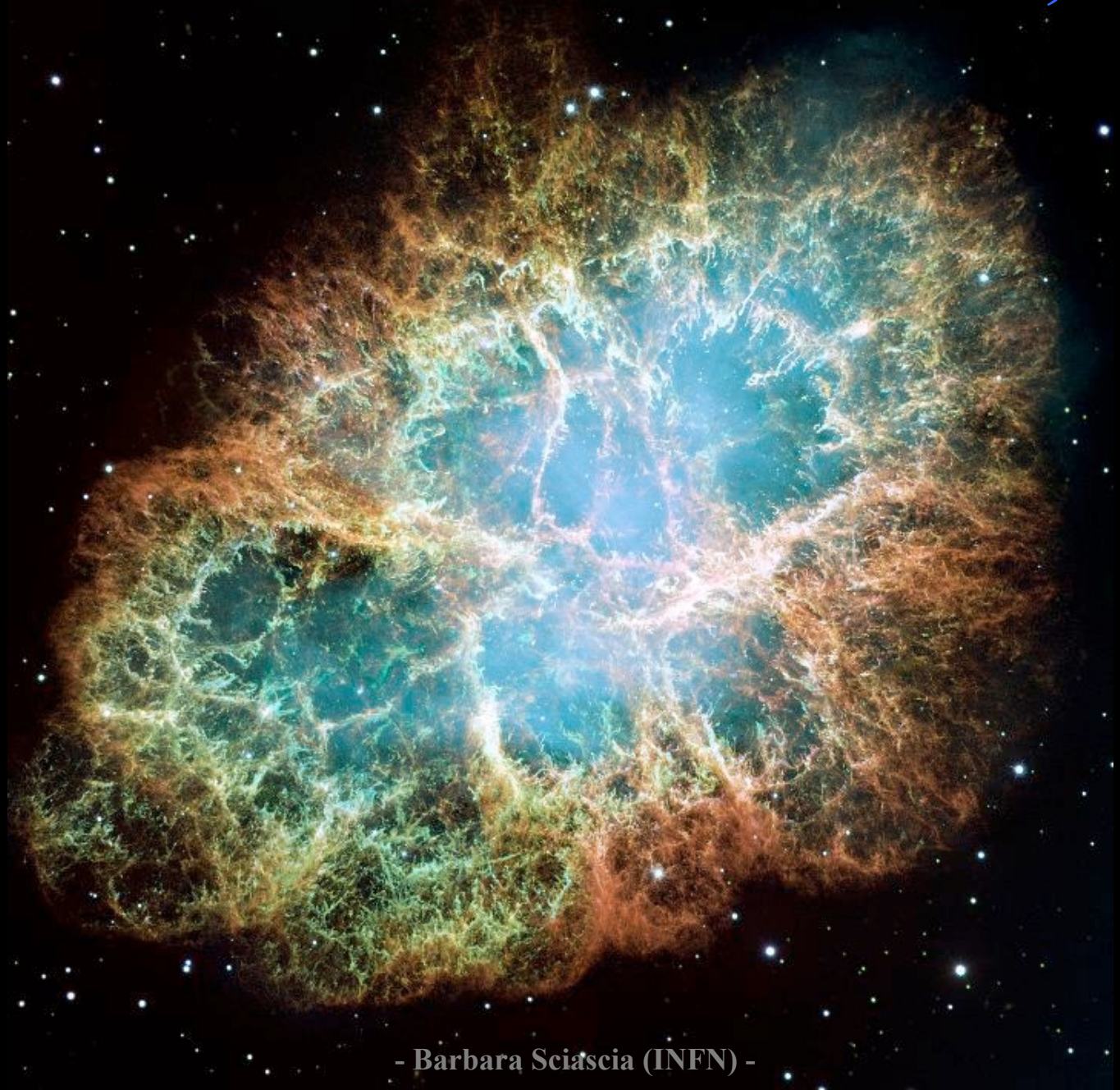


[Credits: https://www.youtube.com/channel/UC0cd_-e49hZpWLH3UIwoWRA]

Supernova [SN1994D]

By NASA/ESA, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=407520

Nebulosa del Granchio, SN1054



Credits: Di NASA, ESA, J. Hester and A. Loll (Arizona State University) - HubbleSite: gallery, release., Pubblico dominio, https://commons.wikimedia.org/w/index.php?curid=516106

Nebulosa del Granchio e Betelgeuse

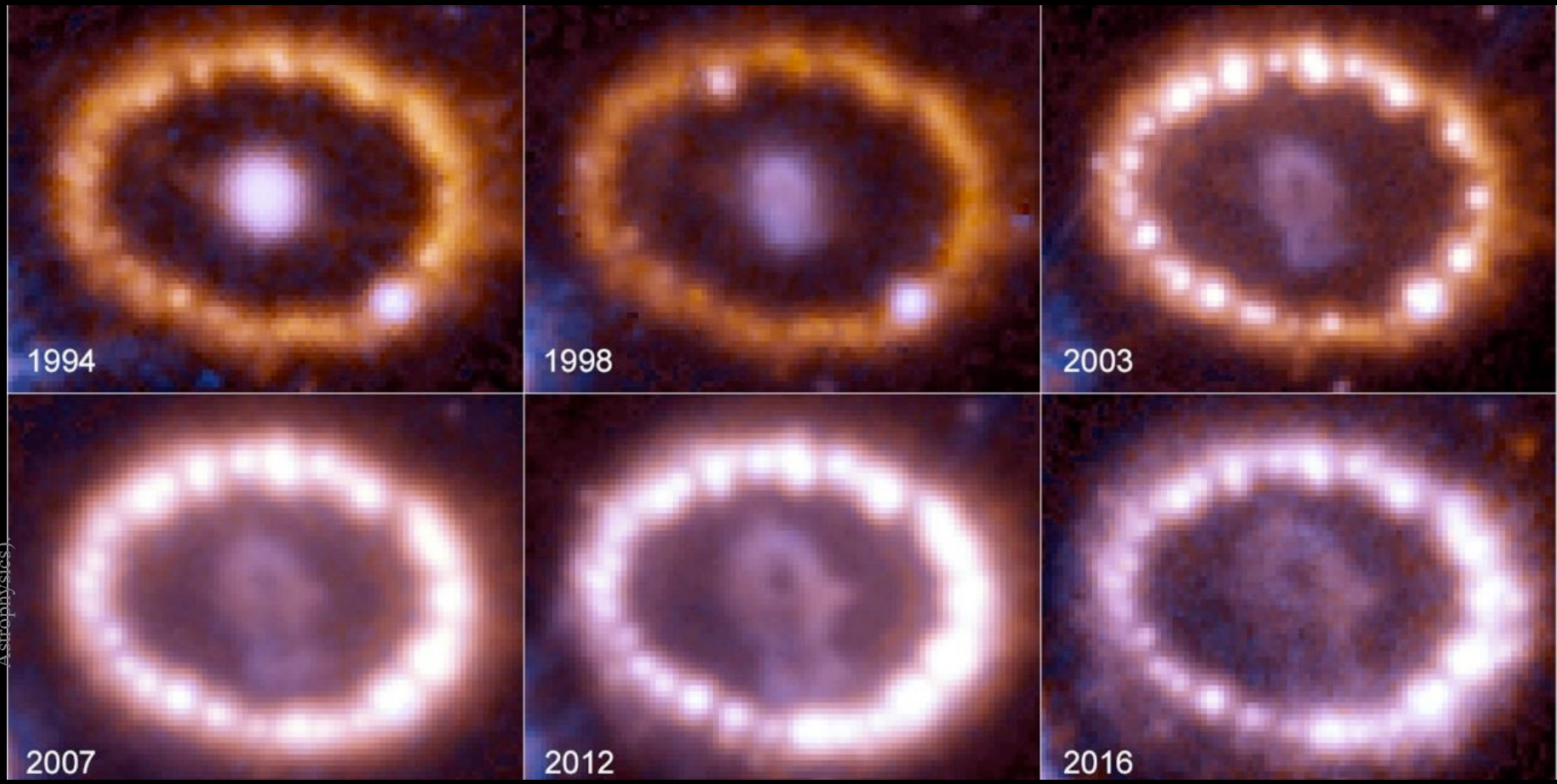
Credits: https://stellarium.org/

SN 1987 A [Sanduleak]

Fonte: Serge Brunier, "Majestic Universe: Views from Here to Infinity", 1998

SN 1987 A [Sanduleak]
Fonte: Serge Brunier, "Majestic Universe: Views from Here to Infinity", 1998

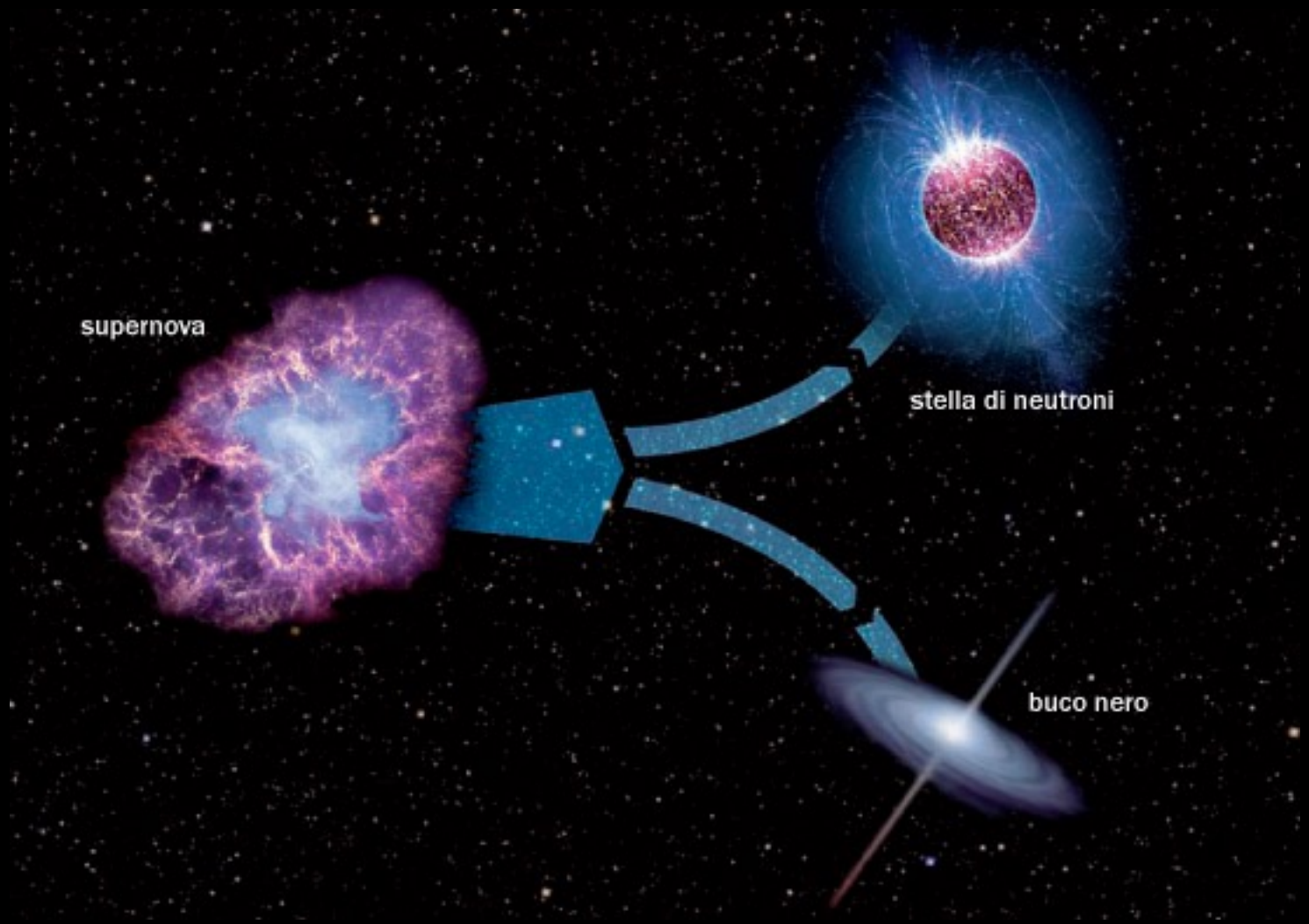
SN 1987 A + stella di neutroni



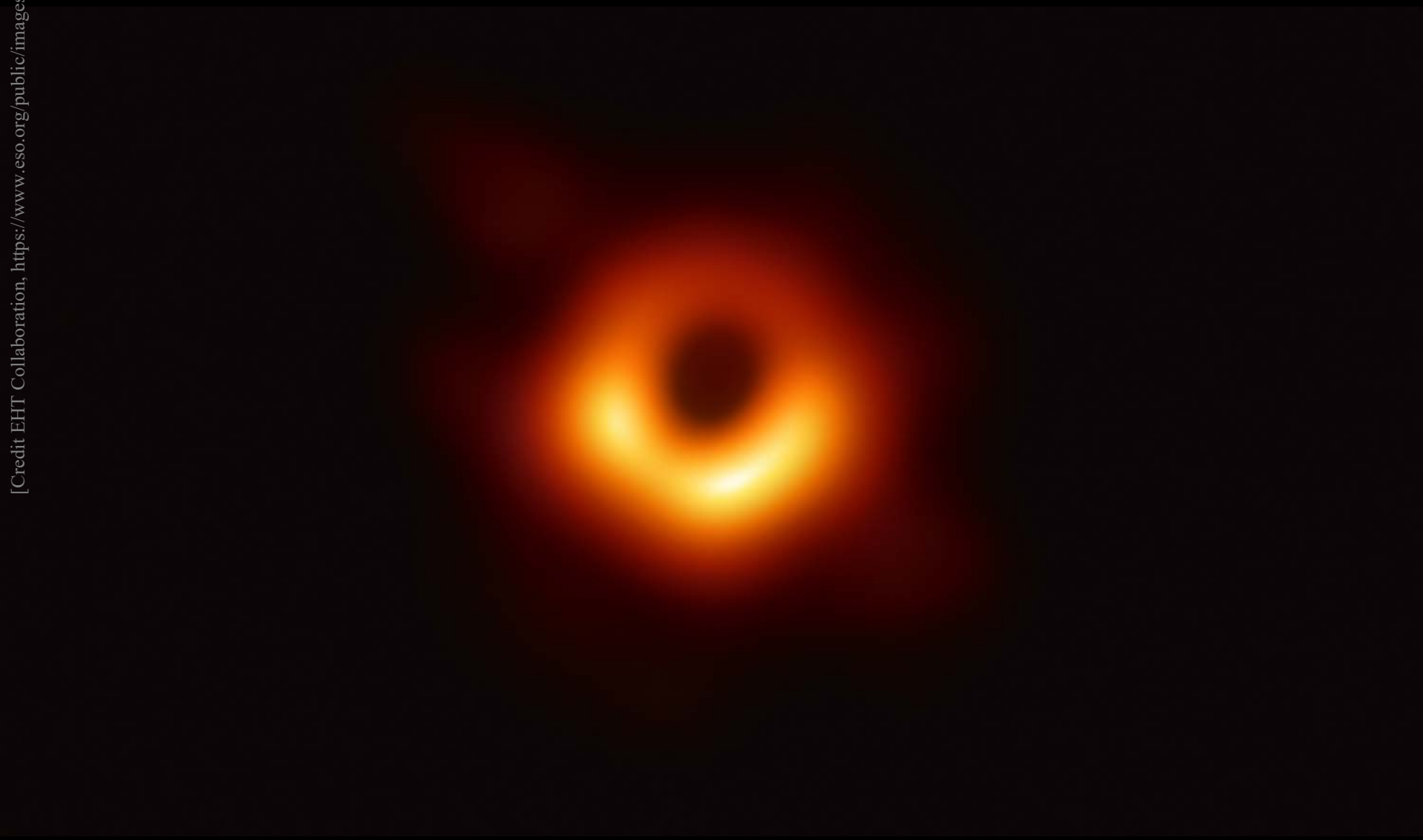
Credits: NASA, ESA, and R. Kirshner (Harvard-Smithsonian Center for Astrophysics and Gordon and Betty Moore Foundation), and P. Challis (Harvard-Smithsonian Center for Astrophysics)

Credits: Asimmetrie

Quel che resta



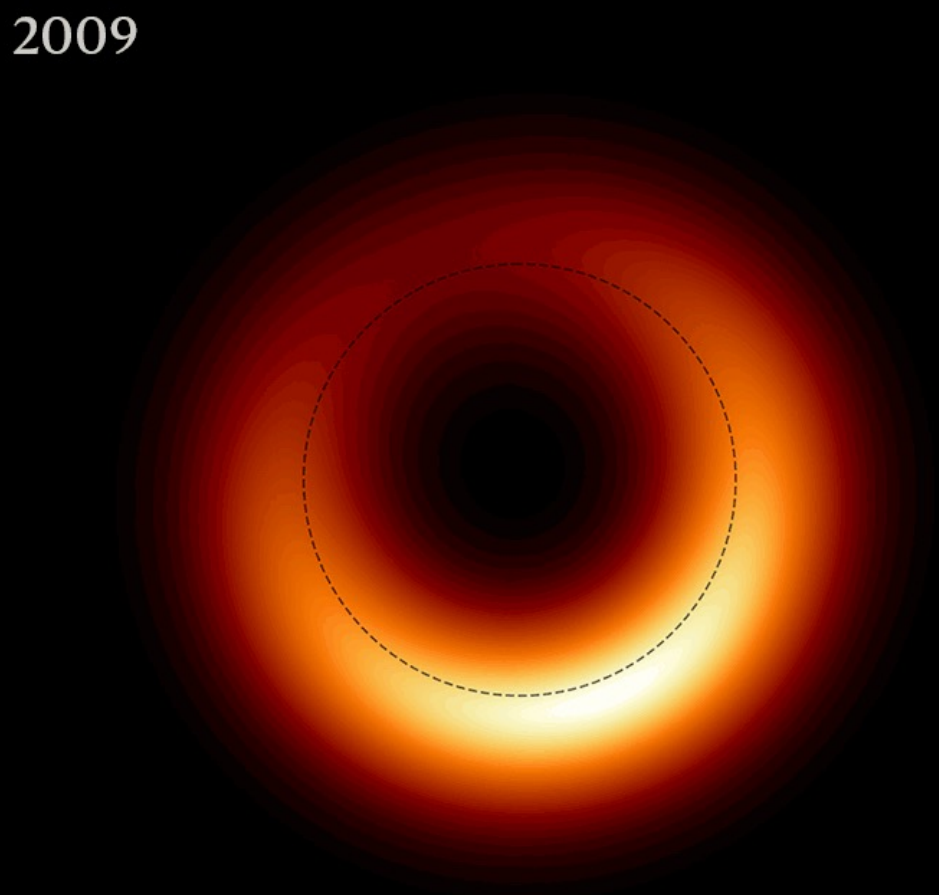
M87 – visto da Event Horizon Telescope



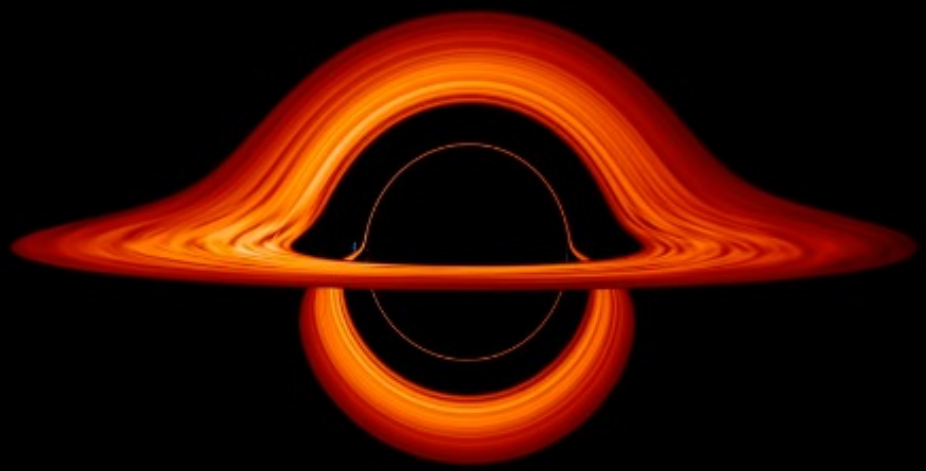
[Credit EHT Collaboration, https://www.eso.org/public/images/eso1907a/]

M87 – visto da Event Horizon Telescope

Credits: nature, 2021

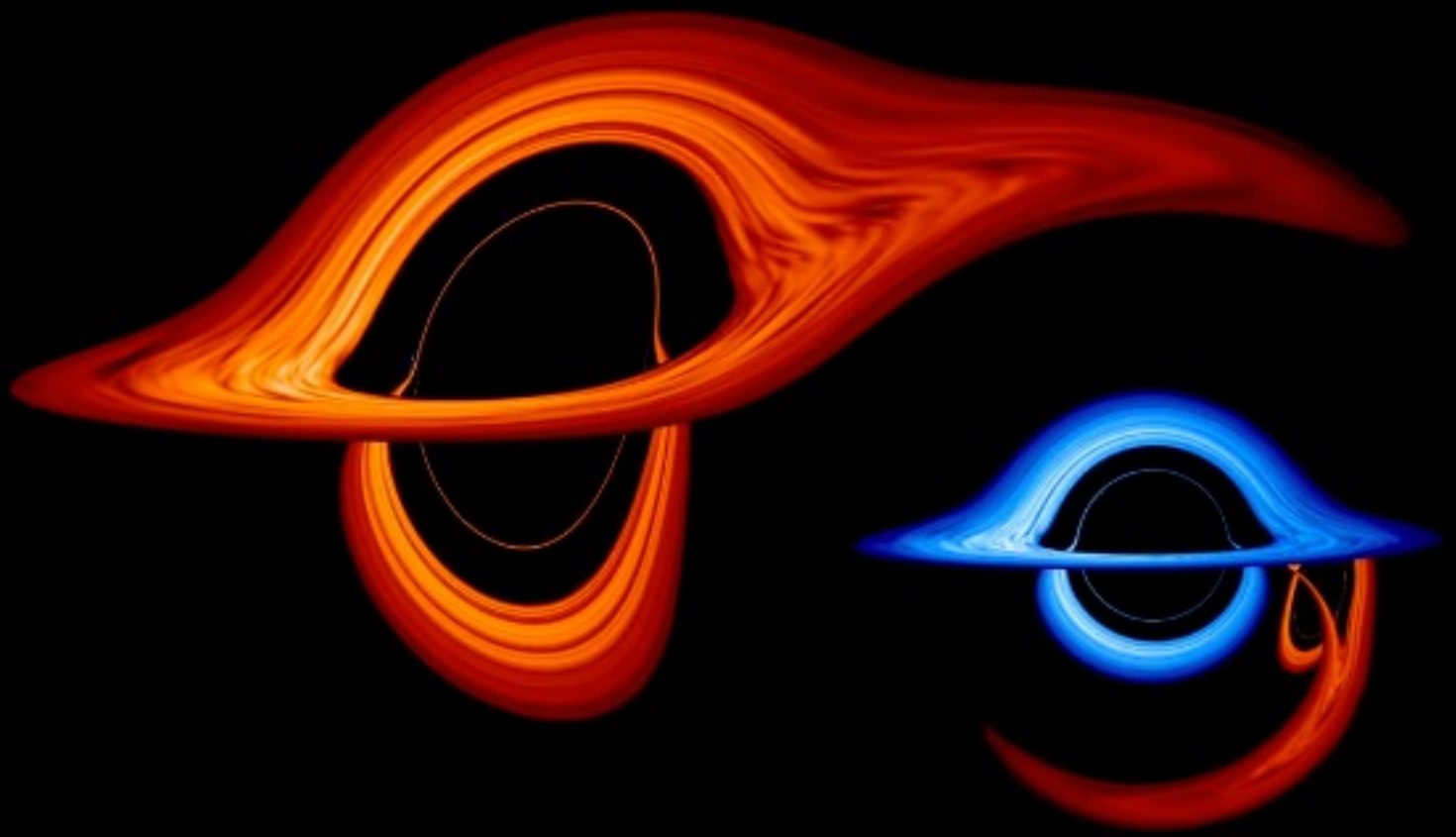


Buchi neri – simulazione NASA



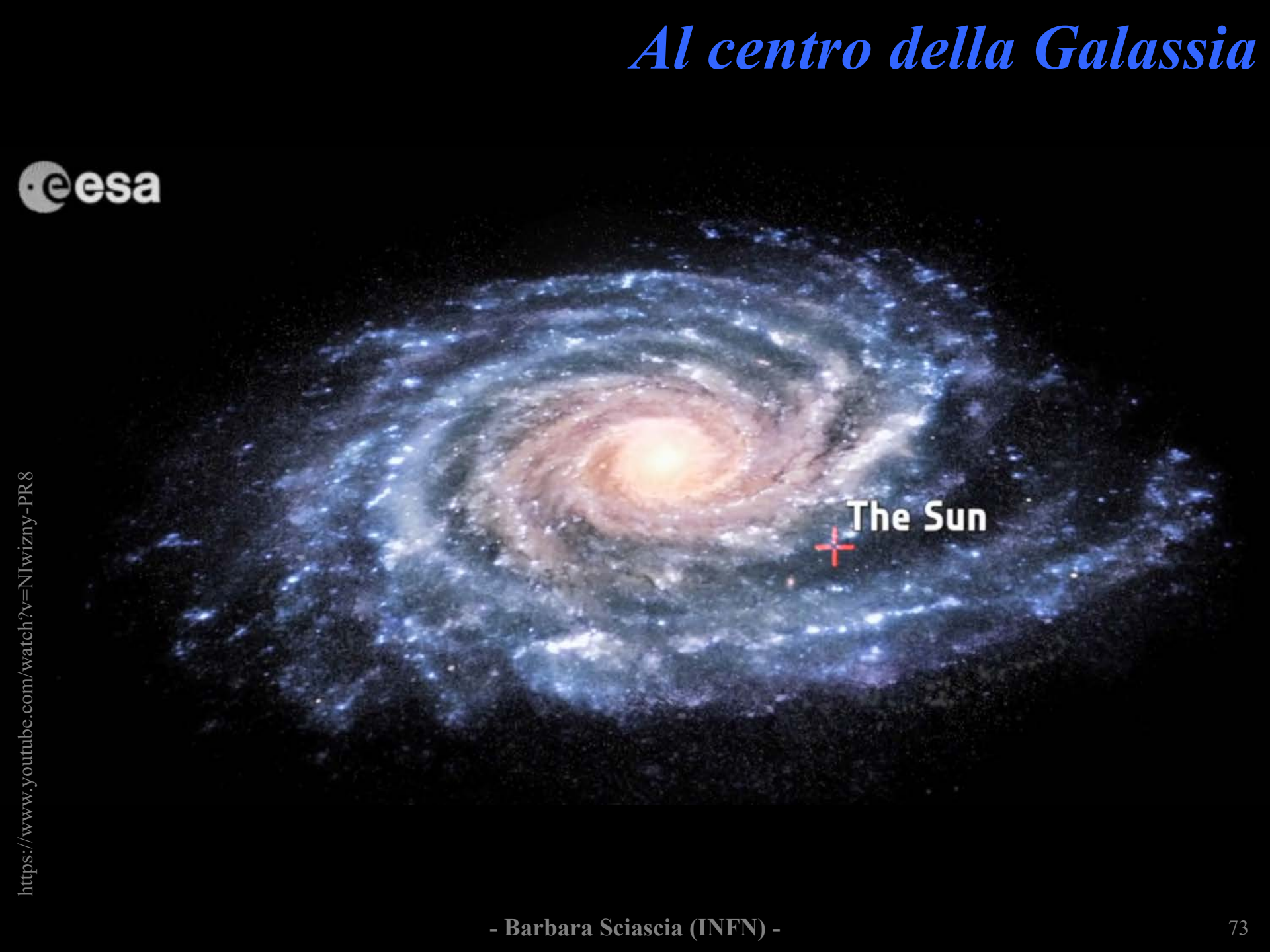
https://www.youtube.com/watch?v=rQcKIN9vj3U

Buchi neri – simulazione NASA



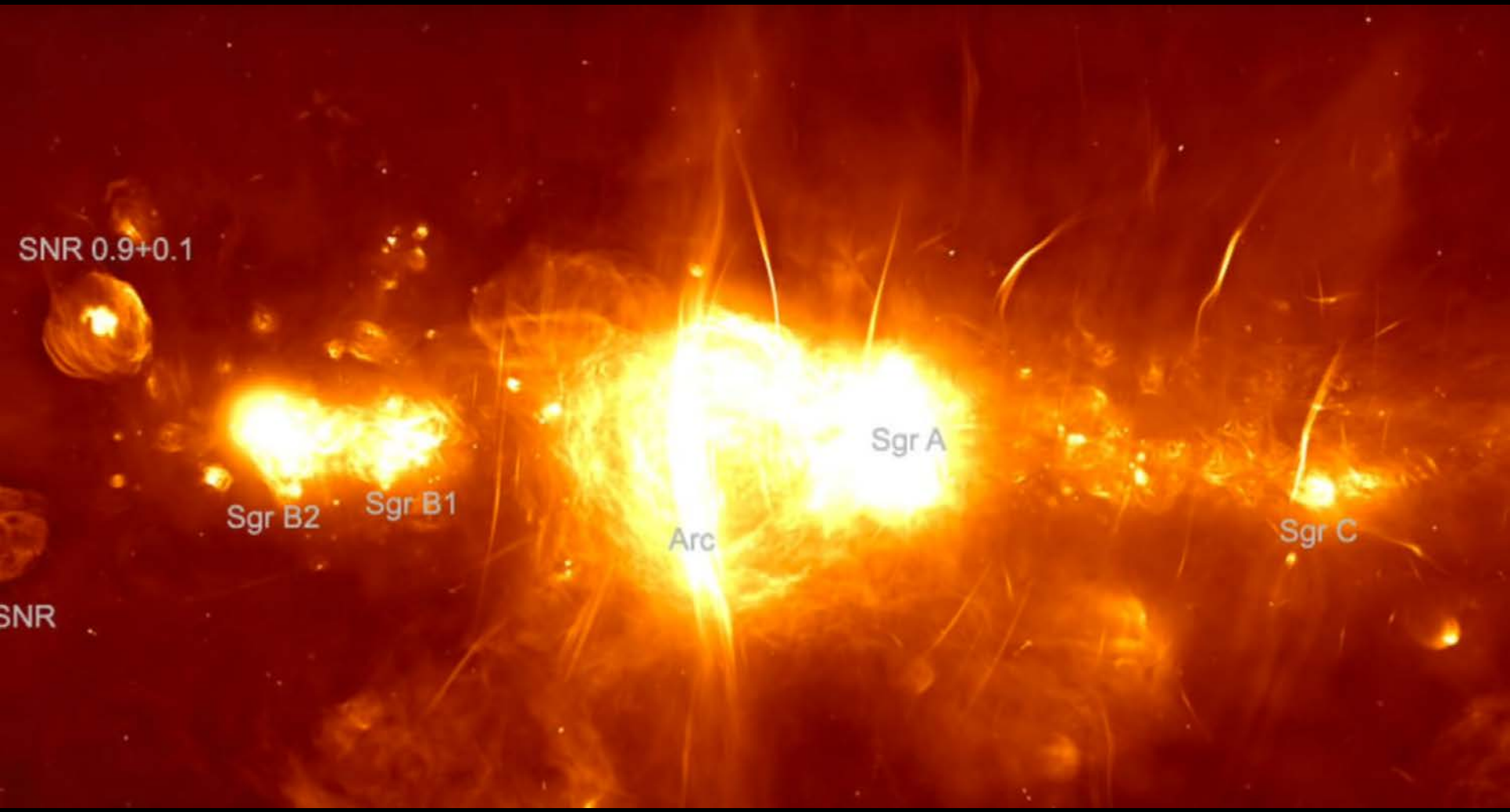
https://www.youtube.com/watch?v=rQcKIN9vj3U

Al centro della Galassia

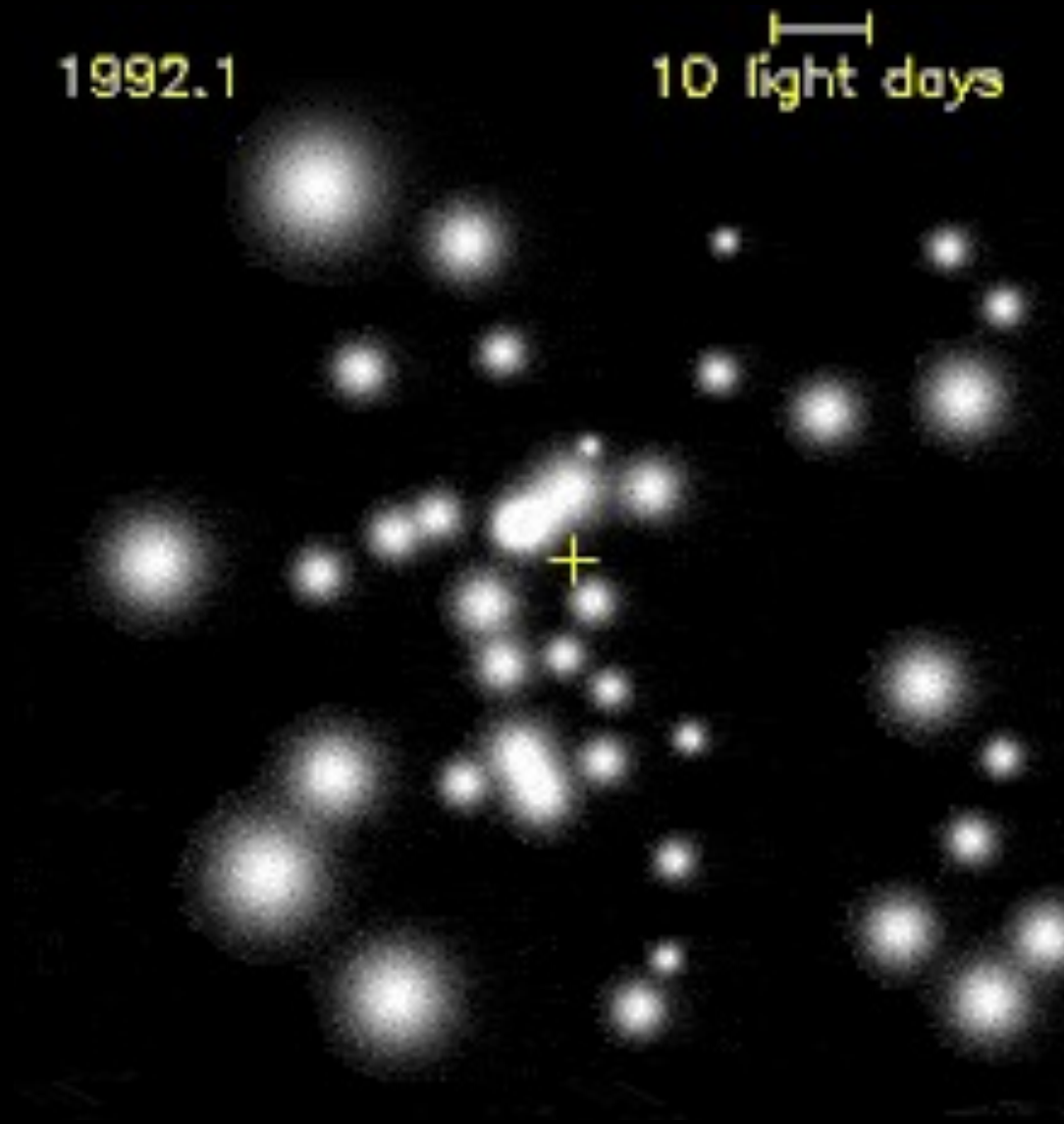


https://www.youtube.com/watch?v=NIwizny-PR8

Al centro della Galassia

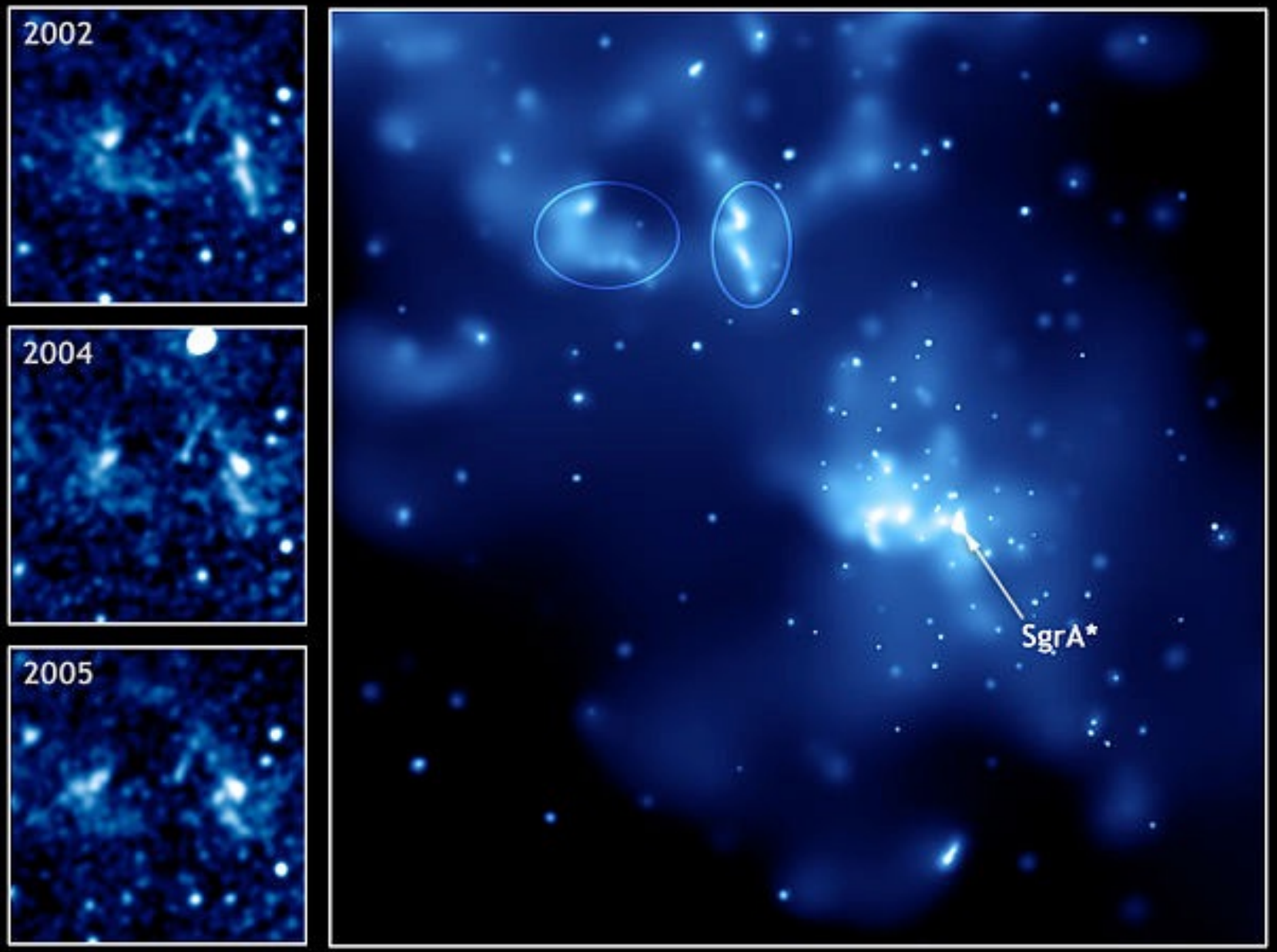


Al centro della Galassia



Credit: A. Eckart (U. Koeln) & R. Genzel (MPE-Garching), SHARP I, NTT, La Silla Obs., ESO

*Sagittarius A**



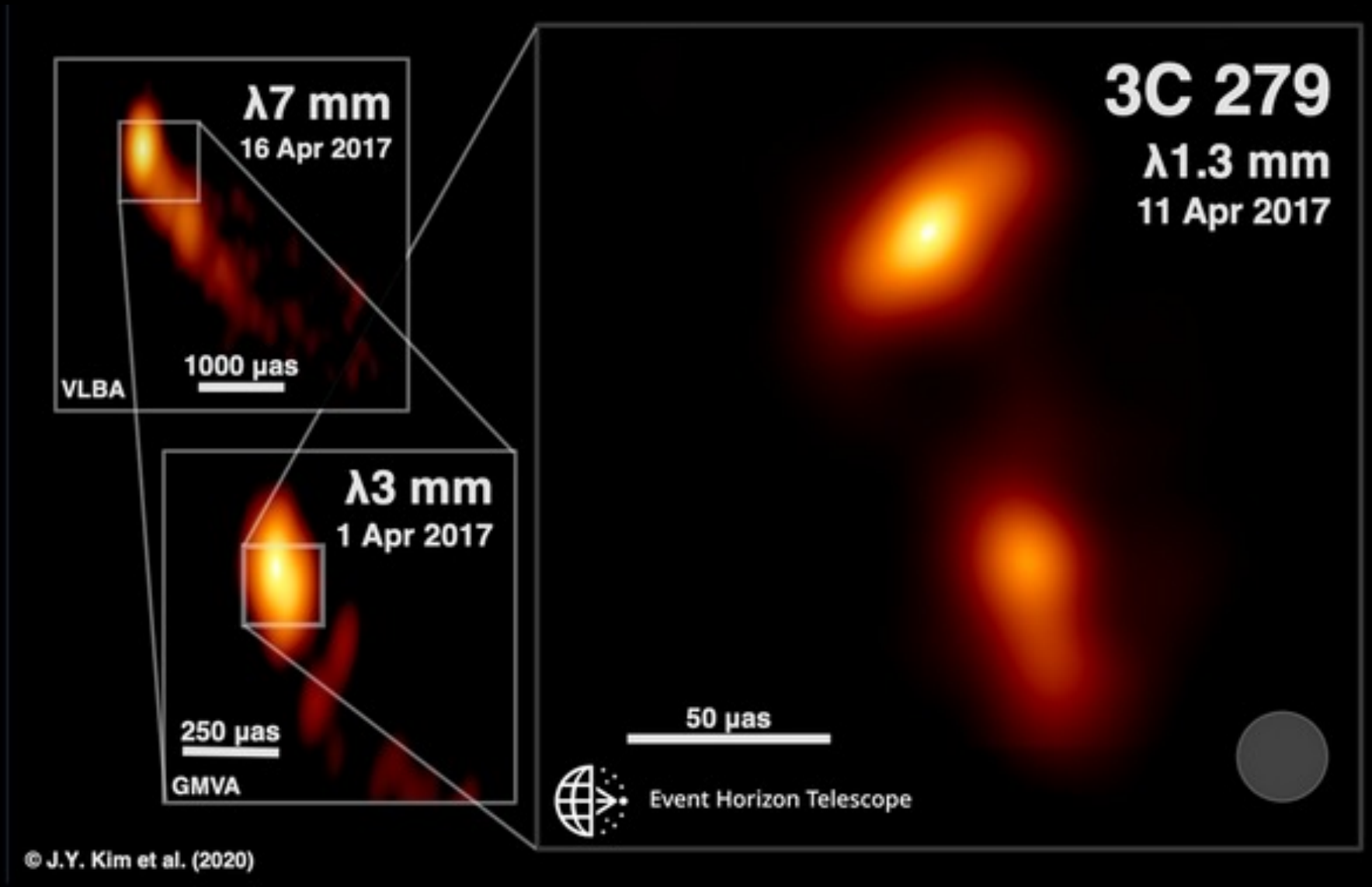
Credit: NASA/CXC/Caltech/M.Muno et al.

Quasar Host Galaxies HST • WFPC2

PRC96-35a • ST ScI OPO • November 19, 1996

J. Bahcall (Institute for Advanced Study), M. Disney (University of Wales) and NASA

Quasar 3C 279 – visto da EHT



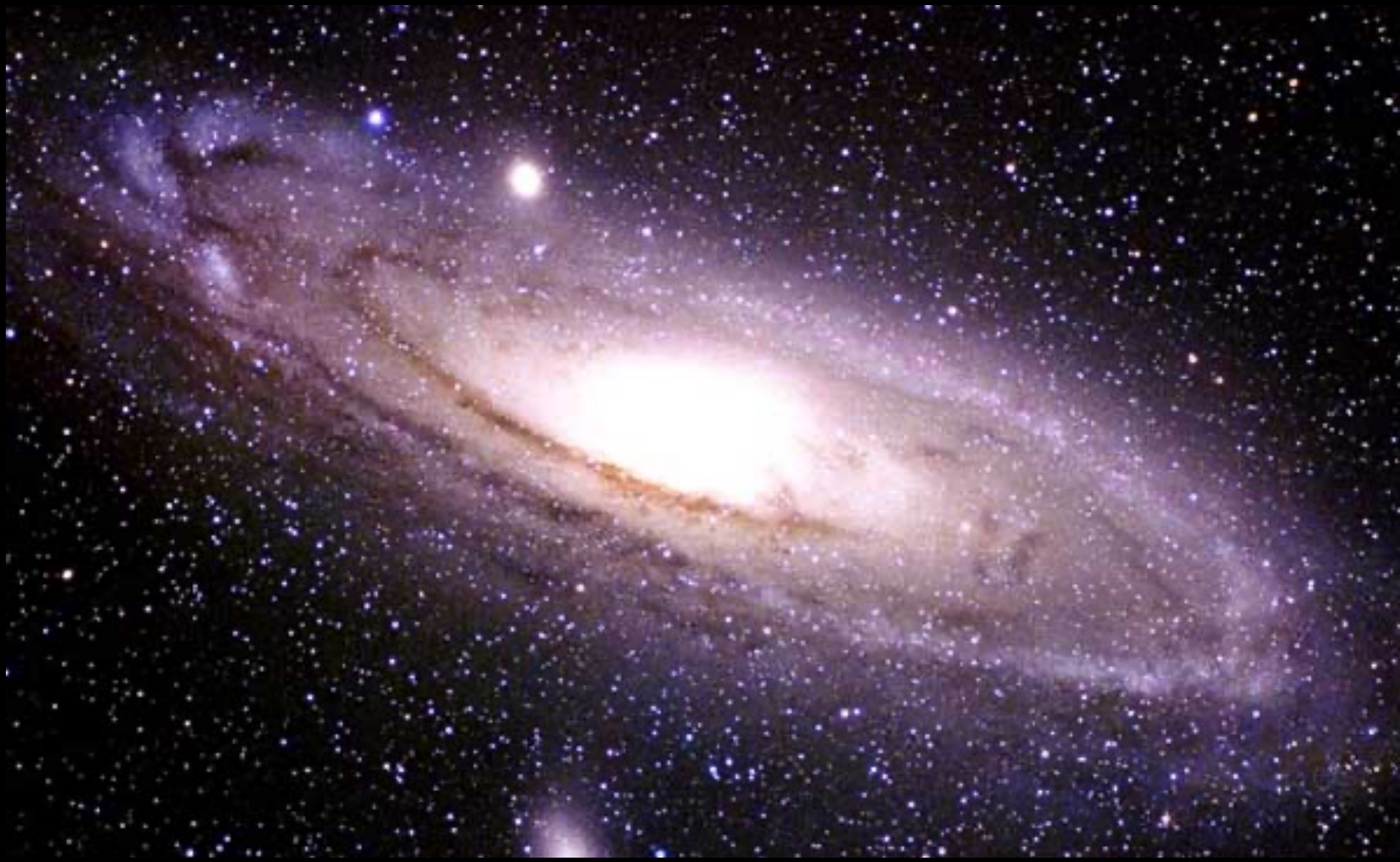
https://www.aanda.org/articles/aa/full_html/2020/08/aa37493-20/aa37493-20-fig3.pdf

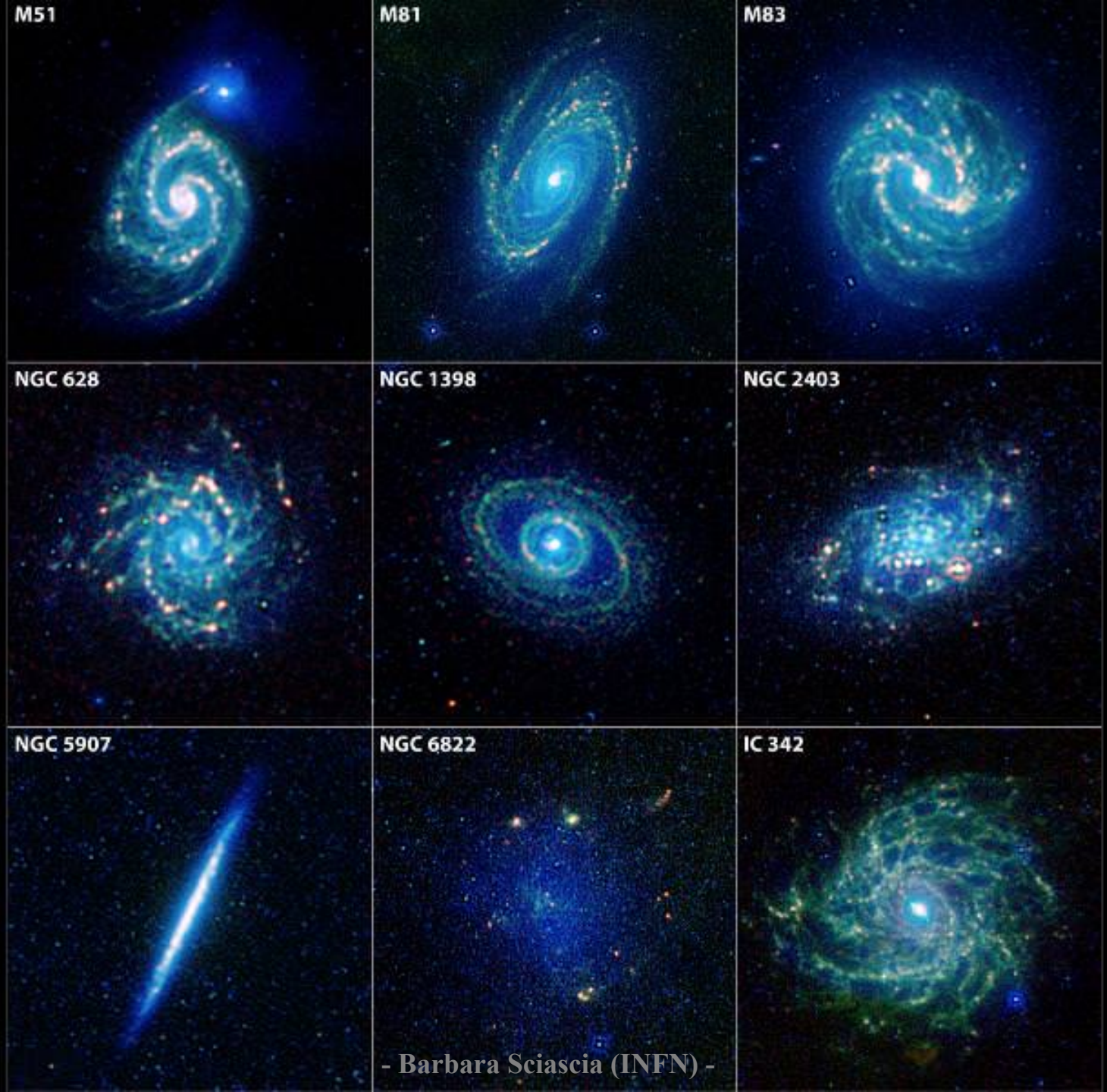
Formazione di galassie

https://www.flickr.com/photos/26365906@N08/15239953423

Formazione di galassie

[https://svs.gsfc.nasa.gov/11534]




M51
M81
M83
NGC 628
NGC 1398
NGC 2403
NGC 5907
NGC 6822
IC 342

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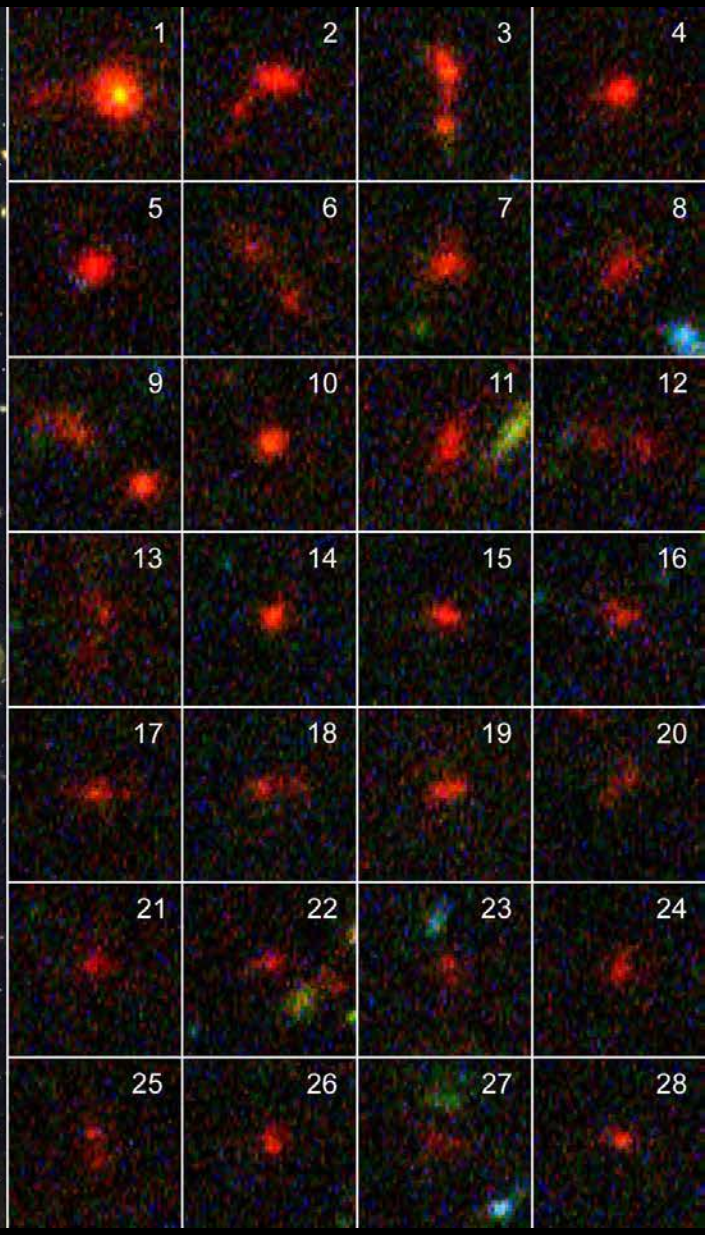
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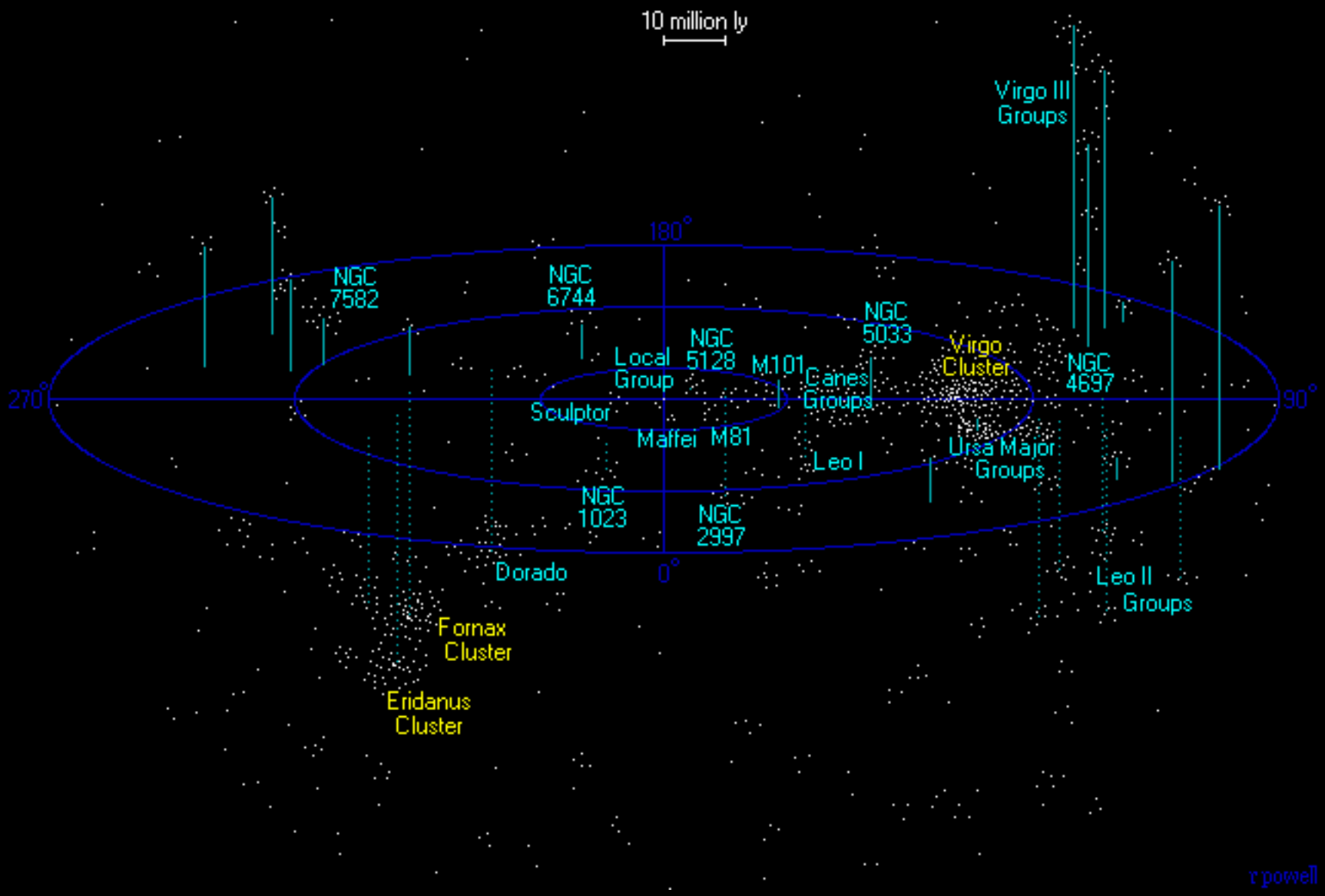
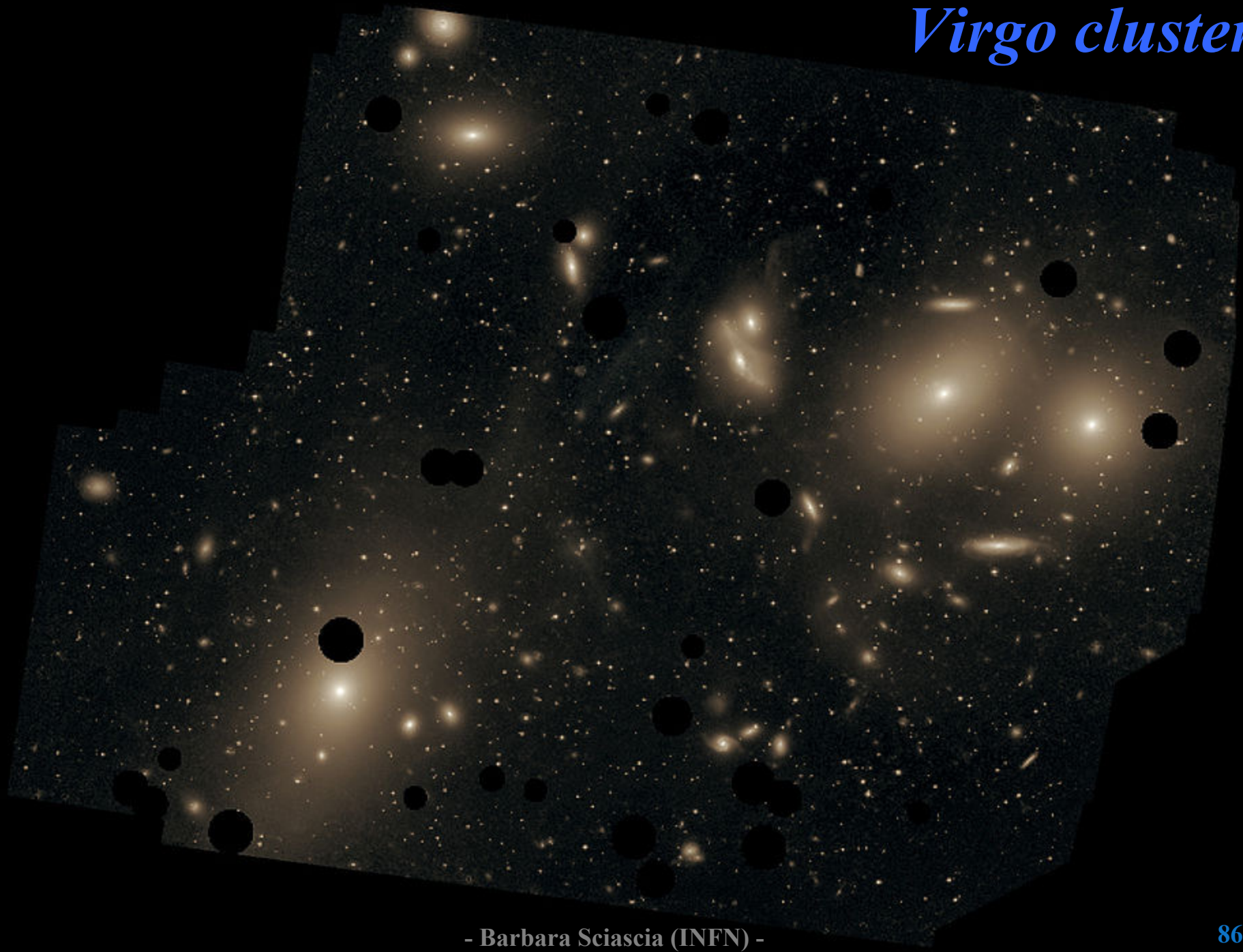
James Webb Space Telescope (JWST)

Virgo supercluster



By Richard Powell , CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=4873071

Virgo cluster



By Chris Mihos (Case Western Reserve University)/ESO - http://www.eso.org/public/images/eso0919a/

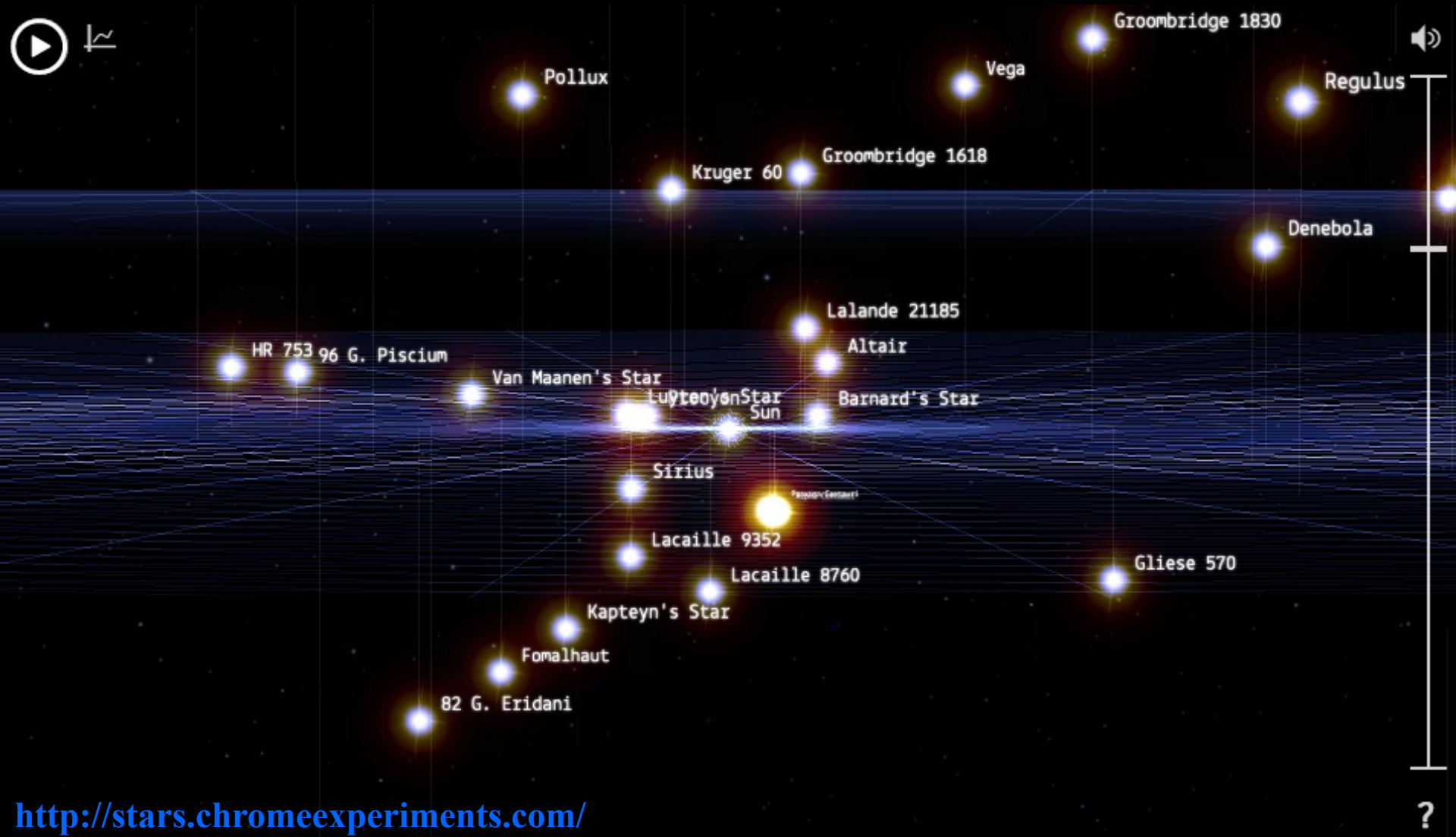
Gruppo locale

https://it.wikipedia.org/wiki/Gruppo_Locale

La "Via Lattea" (UGC12158)

By ESA/Hubble & NASA - http://www.spacetelescope.org/images/potw1035a/

«Giocare» con la Via Lattea



http://stars.chromeexperiments.com/

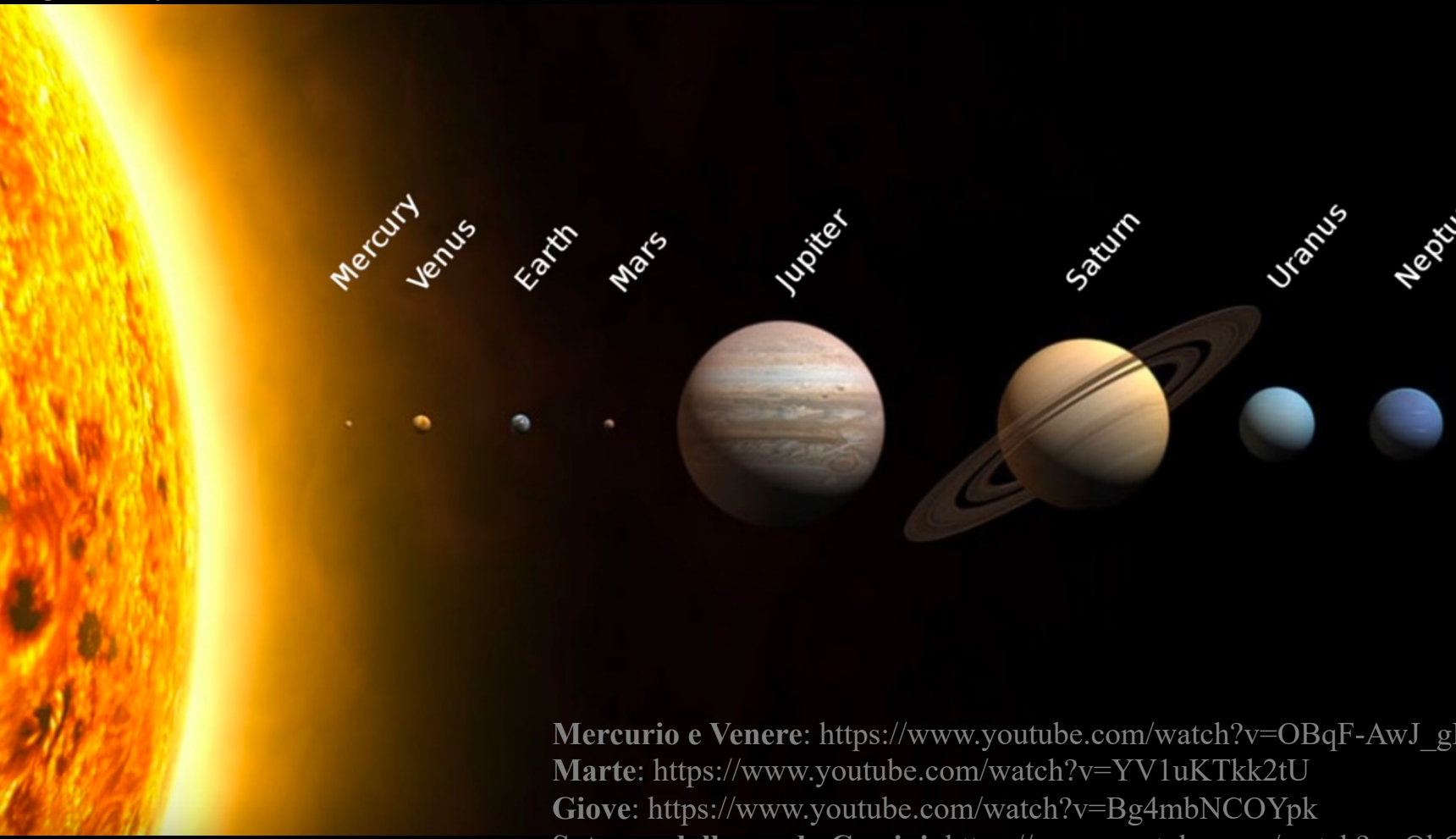
Sole

Disco protoplanetario [HL Tauri]

By ALMA, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=36643860

Pianeti del sistema solare

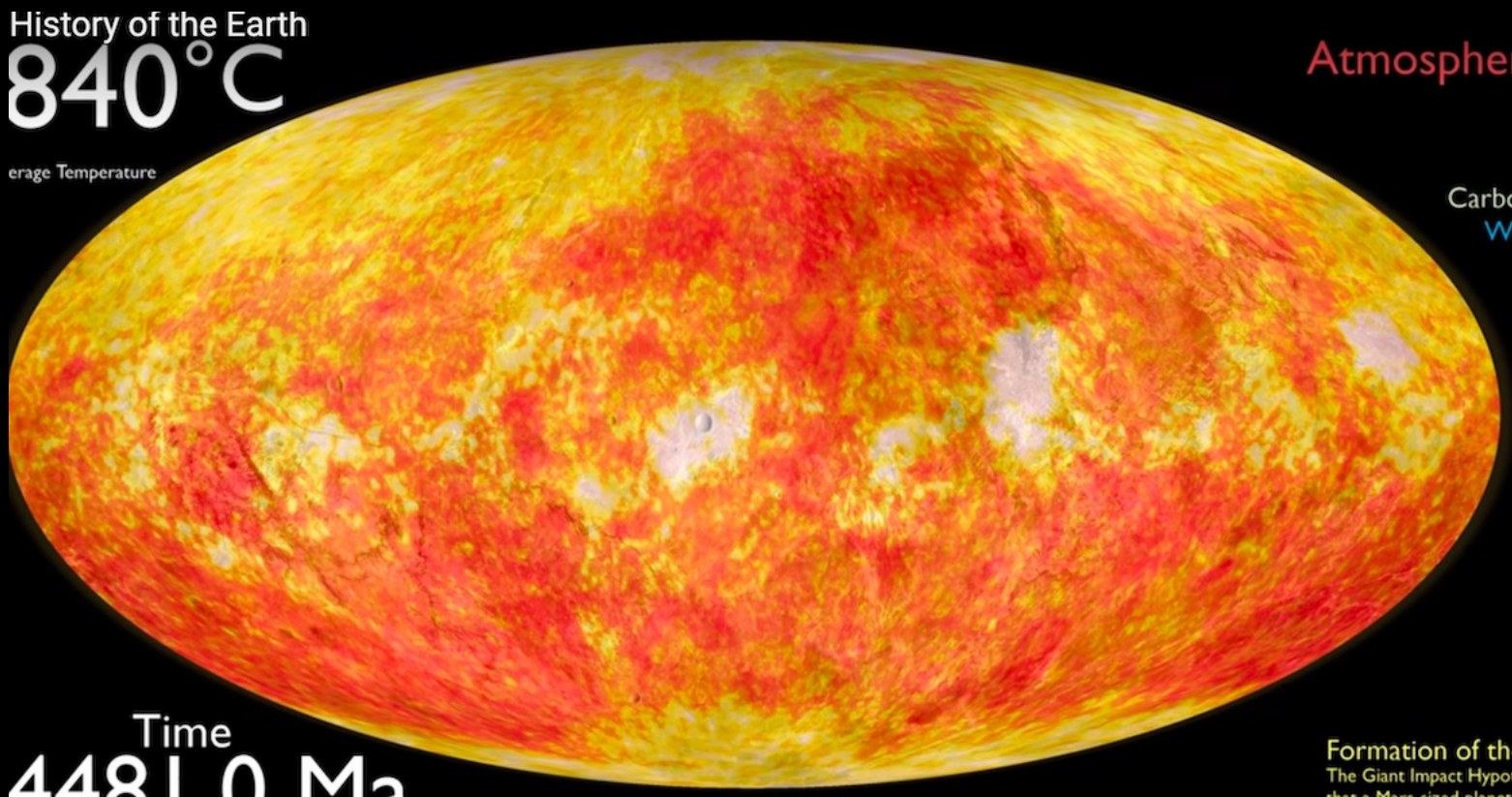
https://www.youtube.com/watch?v=MD7Zt2cGXRc



Mercurio e Venere: https://www.youtube.com/watch?v=OBqF-AwJ_gM
Marte: https://www.youtube.com/watch?v=YV1uKTkk2tU
Giove: https://www.youtube.com/watch?v=Bg4mbNCOYpk
Saturno dalla sonda Cassini: https://www.youtube.com/watch?v=QbQM7-1ylU0
Pianeti gioviani: https://www.youtube.com/watch?v=cpipS1xAGPw
Urano e Nettuno: https://www.youtube.com/watch?v=pO-kubG95hc

https://www.youtube.com/watch?v=Q1OreyX0-fw [11'35"]

Storia della Terra da 4.5 miliardi di anni fa a oggi



Equazione di Drake (1961)

$$N = R^{*} \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

[https://www.youtube.com/watch?v=cl_YuKk9mzg]

Equazione di Drake (1961)

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Stelle nuove / anno

Con pianeti

Pianeti che potrebbero ospitare la vita

Pianeti dove si è sviluppata la vita

Pianeti con vita intelligente

Comunicazioni

Durata della civiltà

+ paradosso di Fermi

[https://www.youtube.com/watch?v=cl_YuKk9mzg]

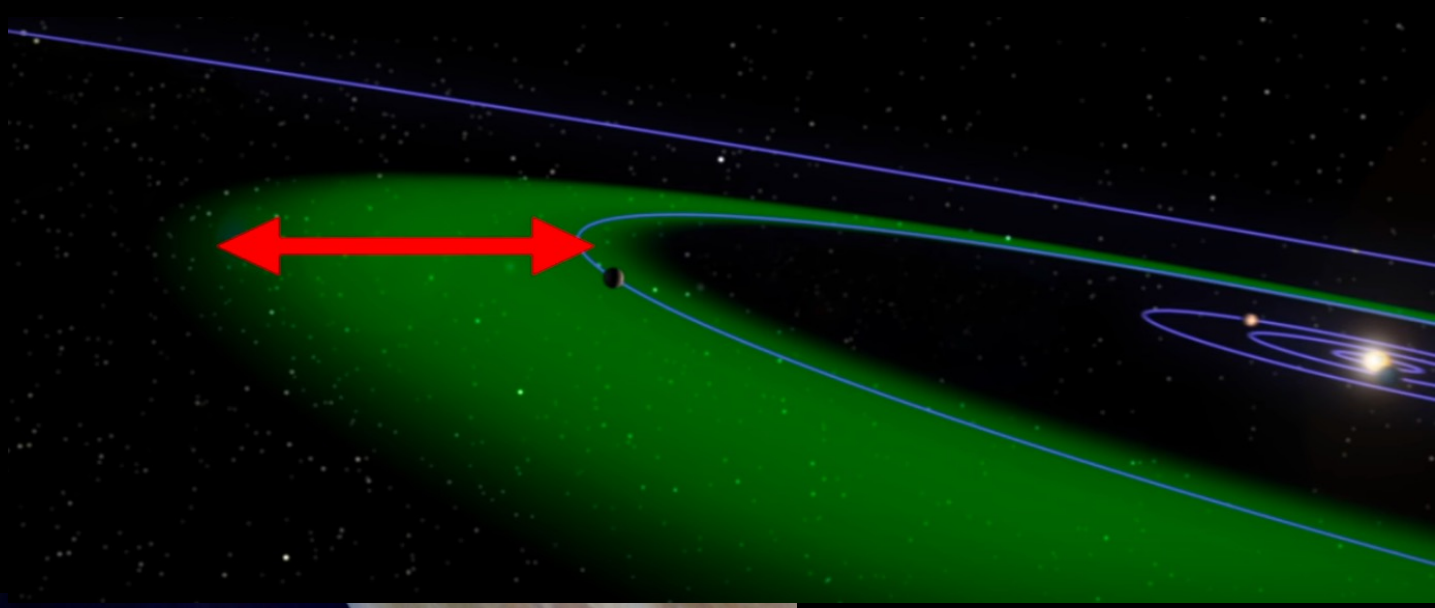
Astrobiologia

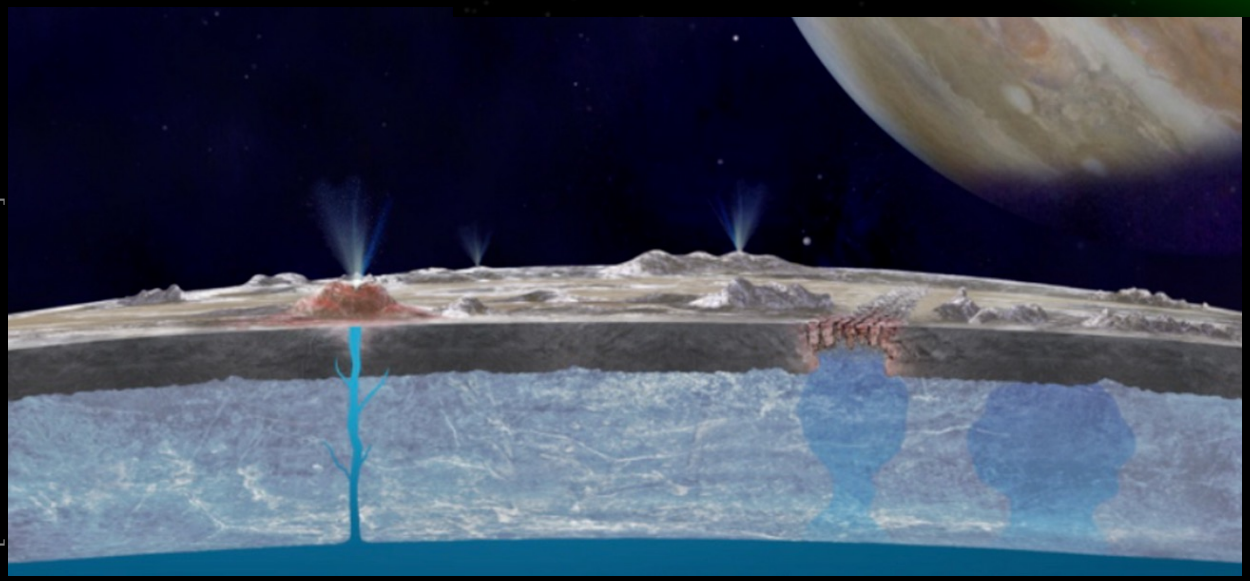
Condizioni per la vita:

- acqua liquida?

- ammoniaca?

- polveri?



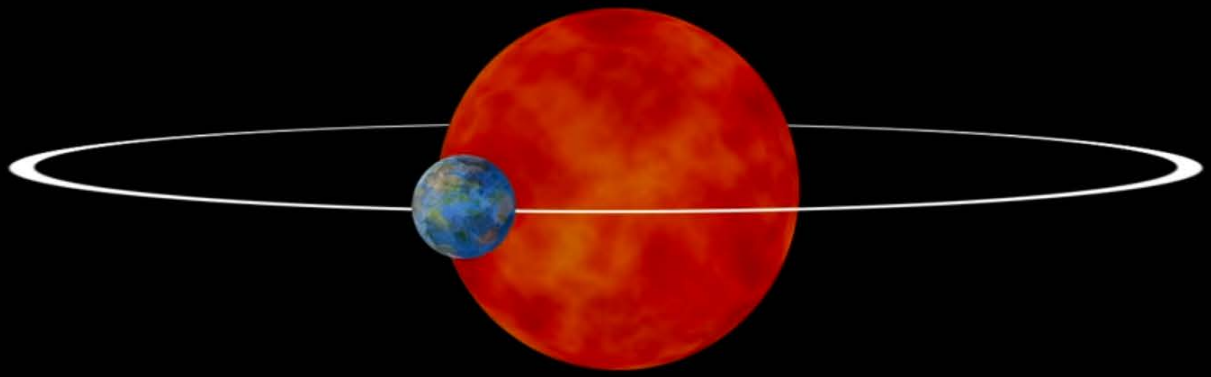


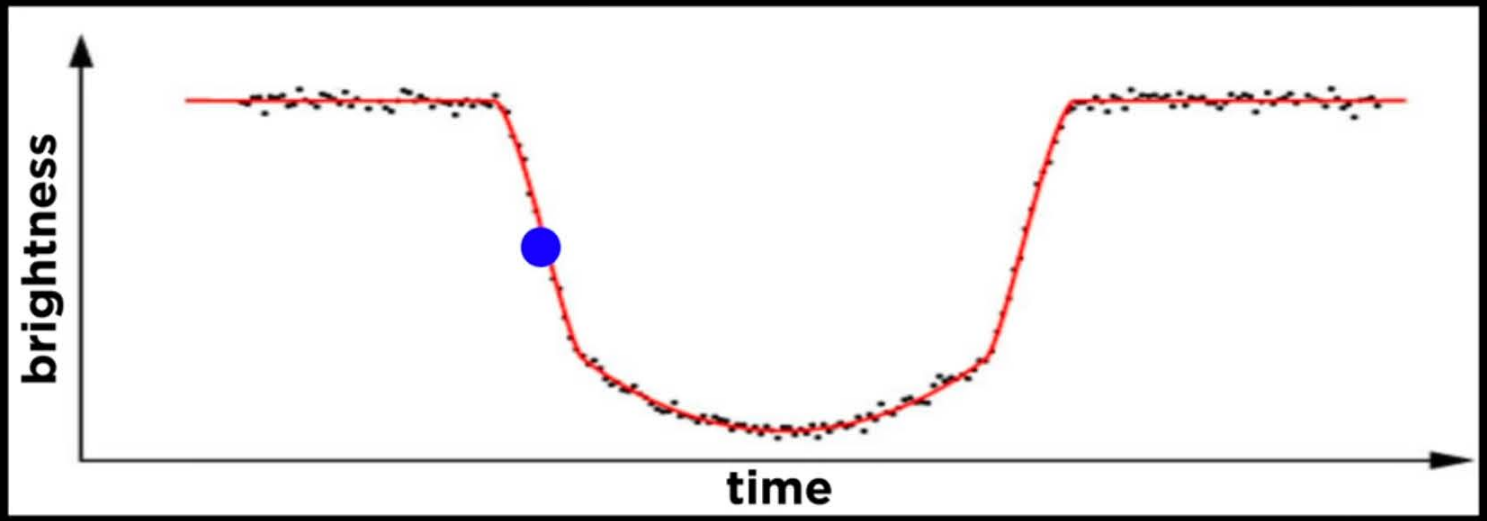
[Credits: NASA/JPL-Caltech]

Encelado (Saturno) o
Europa (Giove)?

Esopianeti

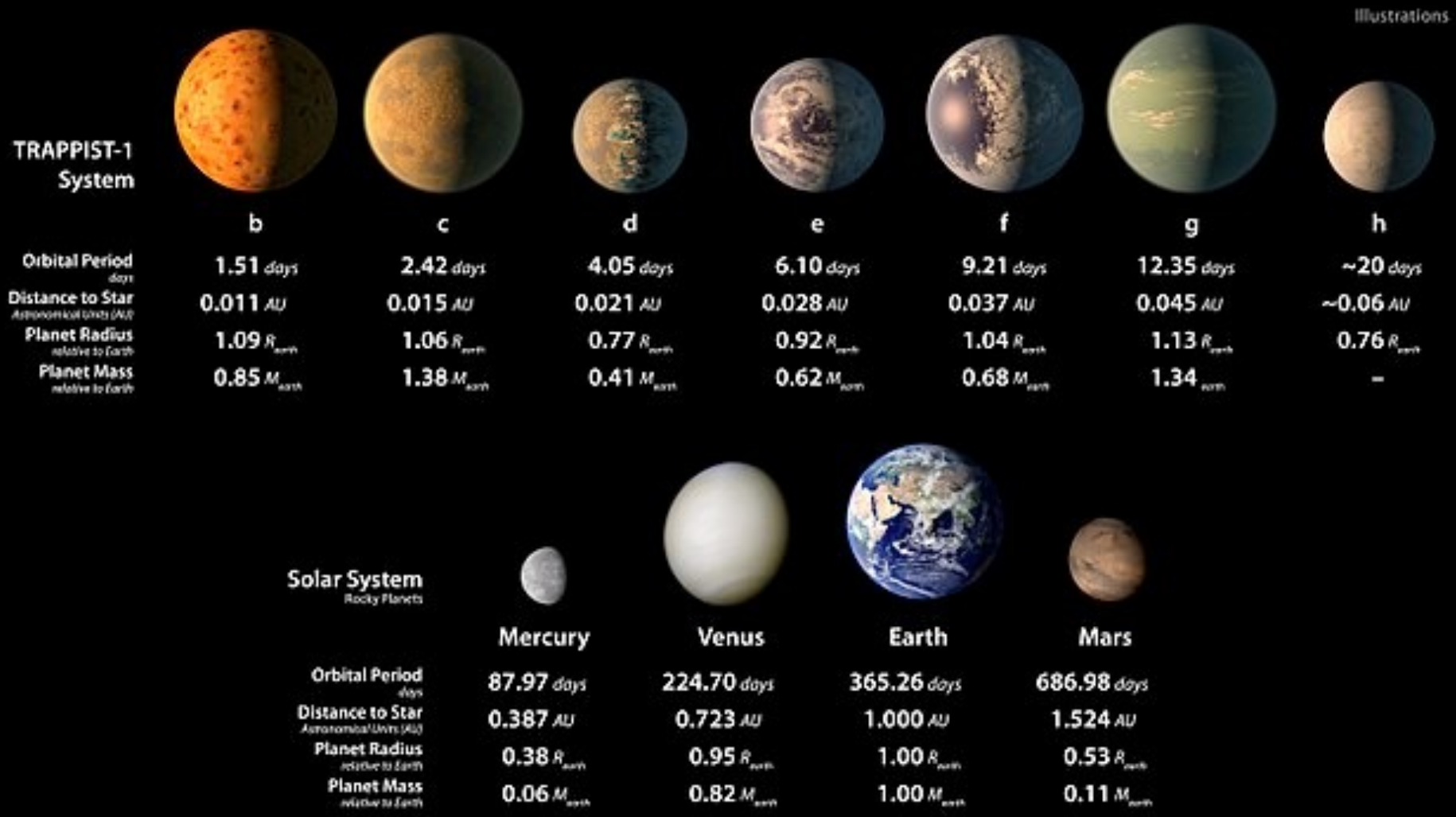
Il primo nel 1988
Oggi ~4000 in ~3000 sistemi stellari





Esopianeti: Trappist-1

39.5 anni luce



Di NASA/JPL-Caltech - Catalog page · Full-res (JPEG · TIFF),

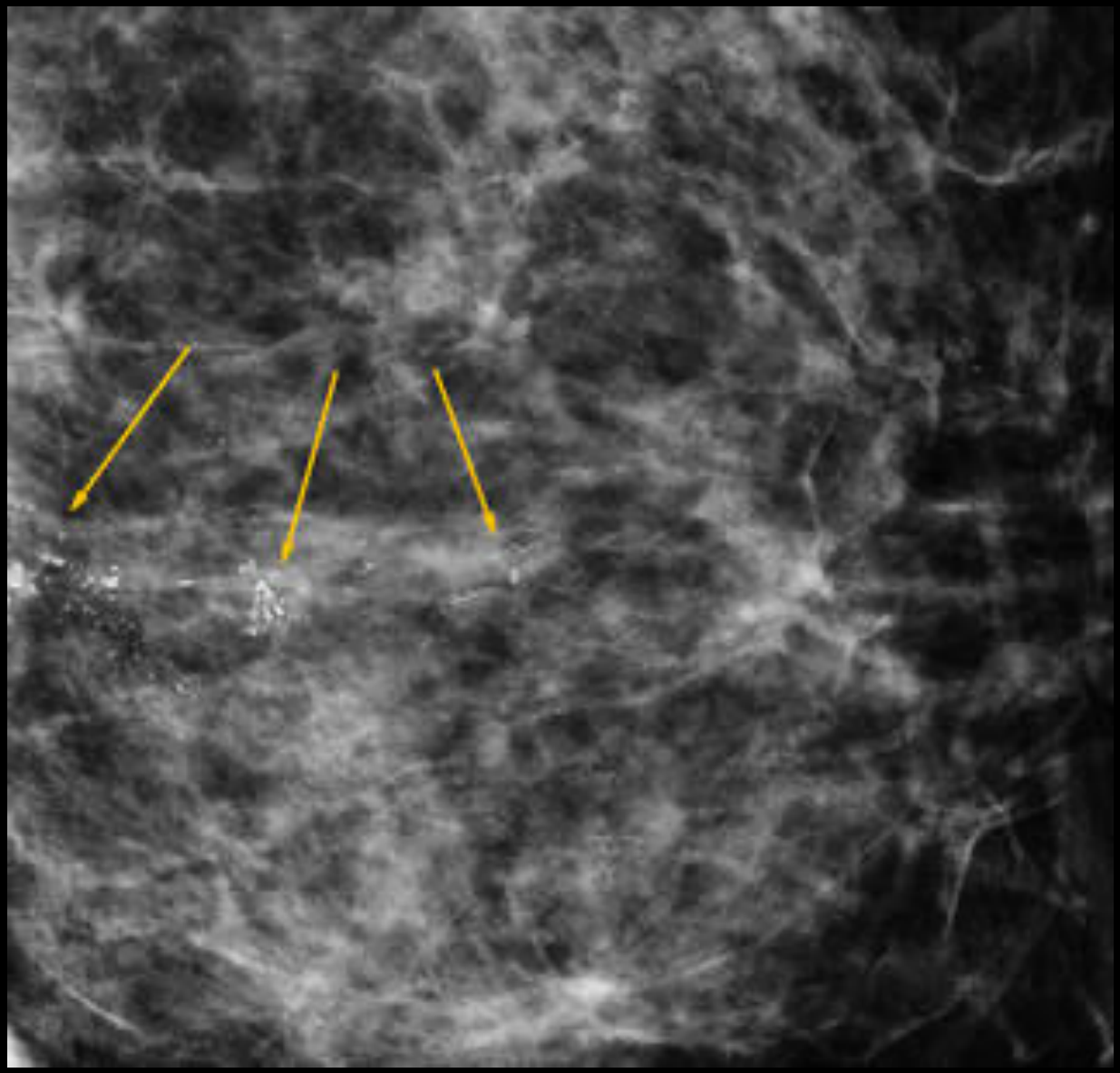
SETI INSTITUTE

(Search for Extra-Terrestrial Intelligence)

Film: Contact

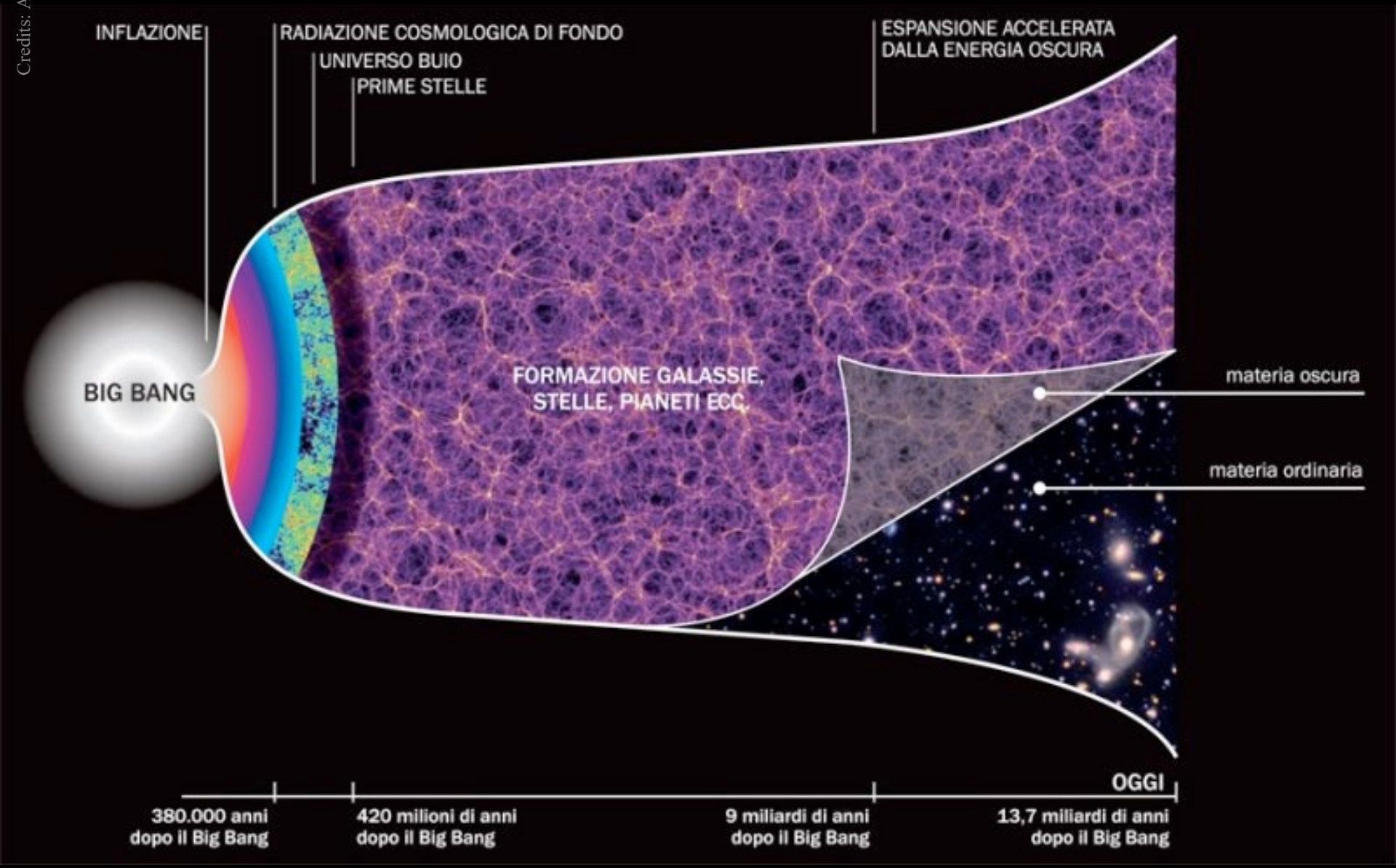
Hubble Space Telescope, 1994

Mammografia, 2018



Credits: Avice O'Connell, University of Rochester Medical Center

Modello Standard Cosmologico

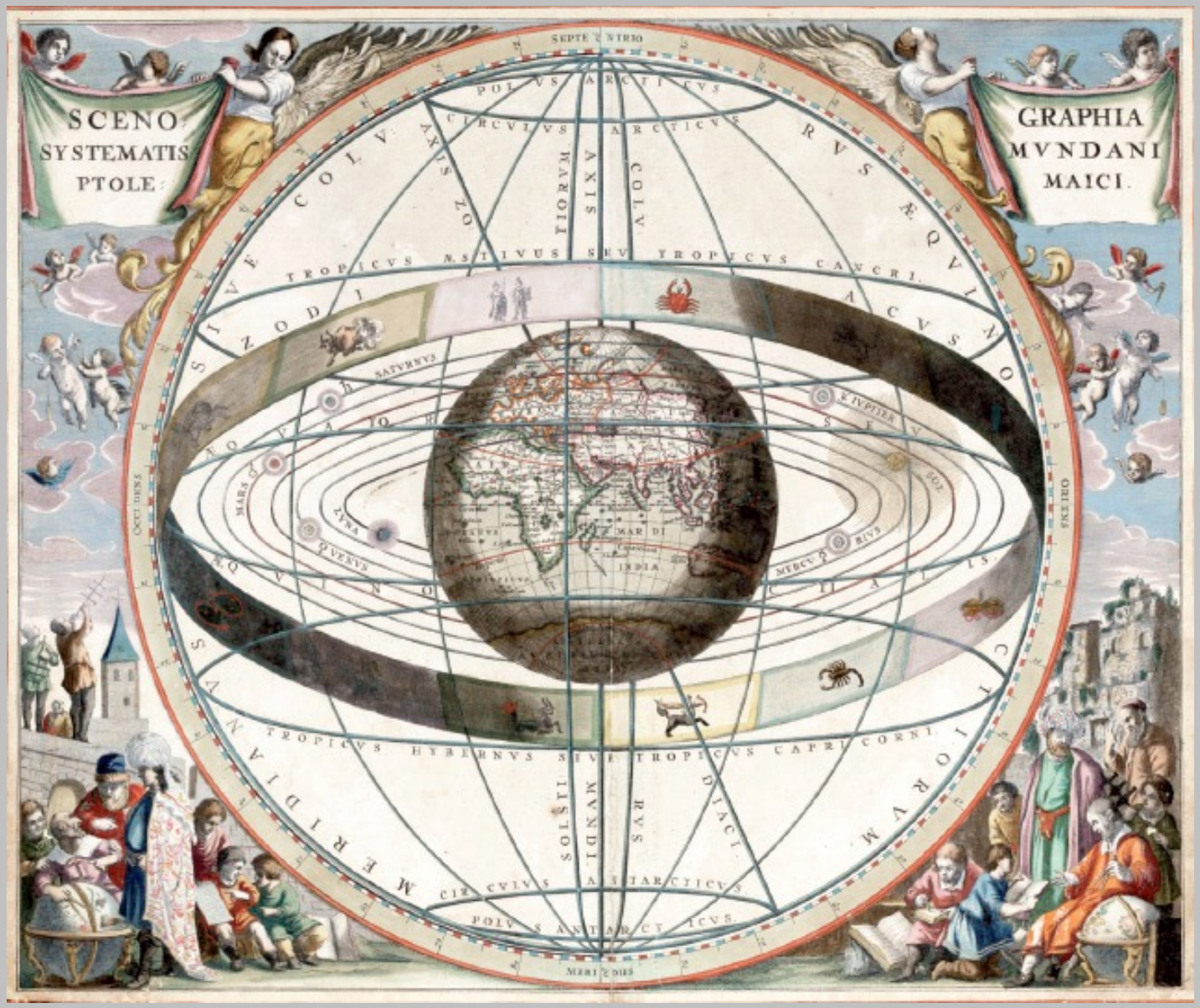


Energia oscura

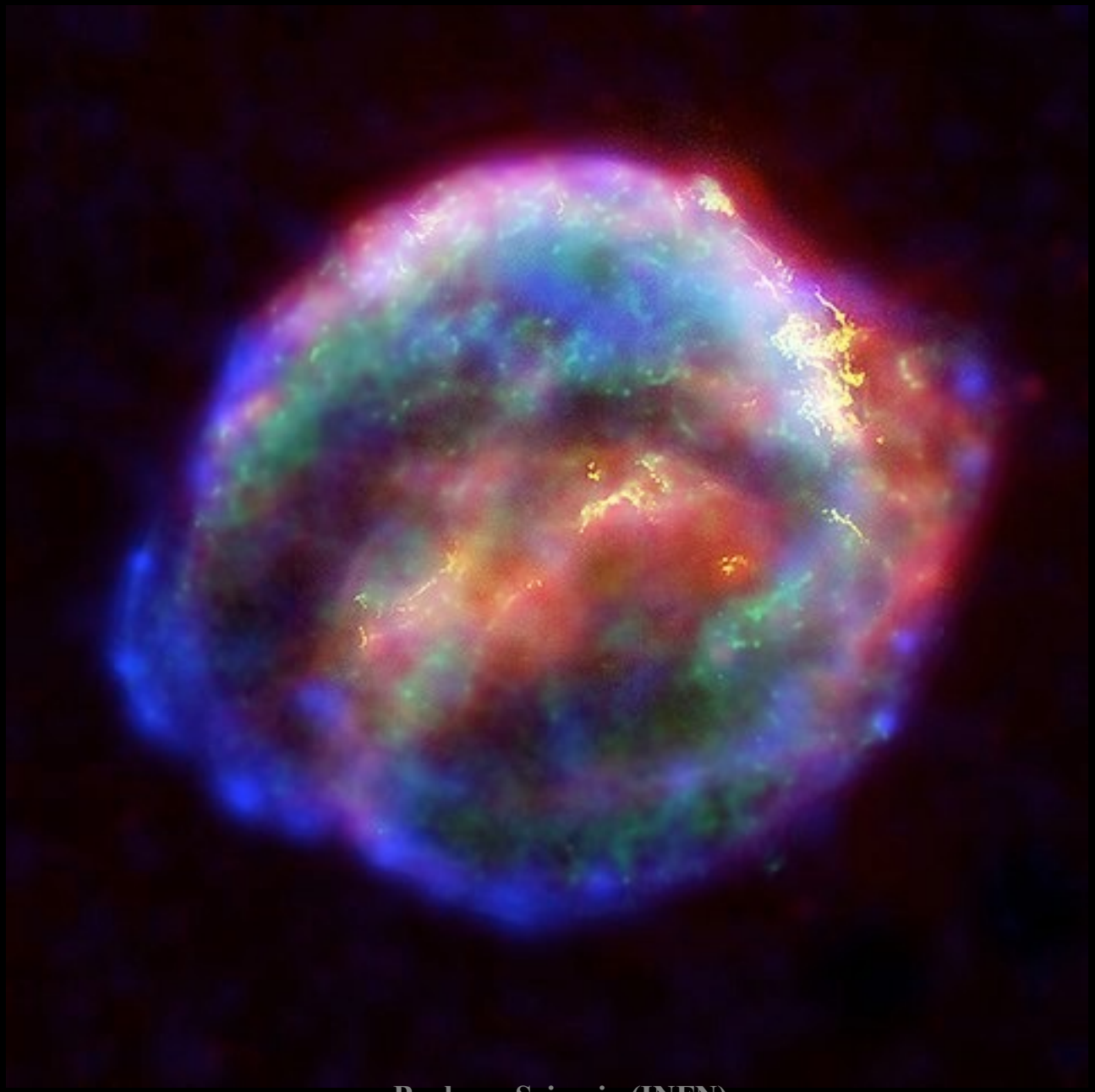
By Lin Mei - File:Astérix & Obélix Bruxelles rue de la Buanderie (cropped).jpg. Original posted to Flickr as New without information, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=74111516

Credidts: Asimmetrie

L'Universo immobile



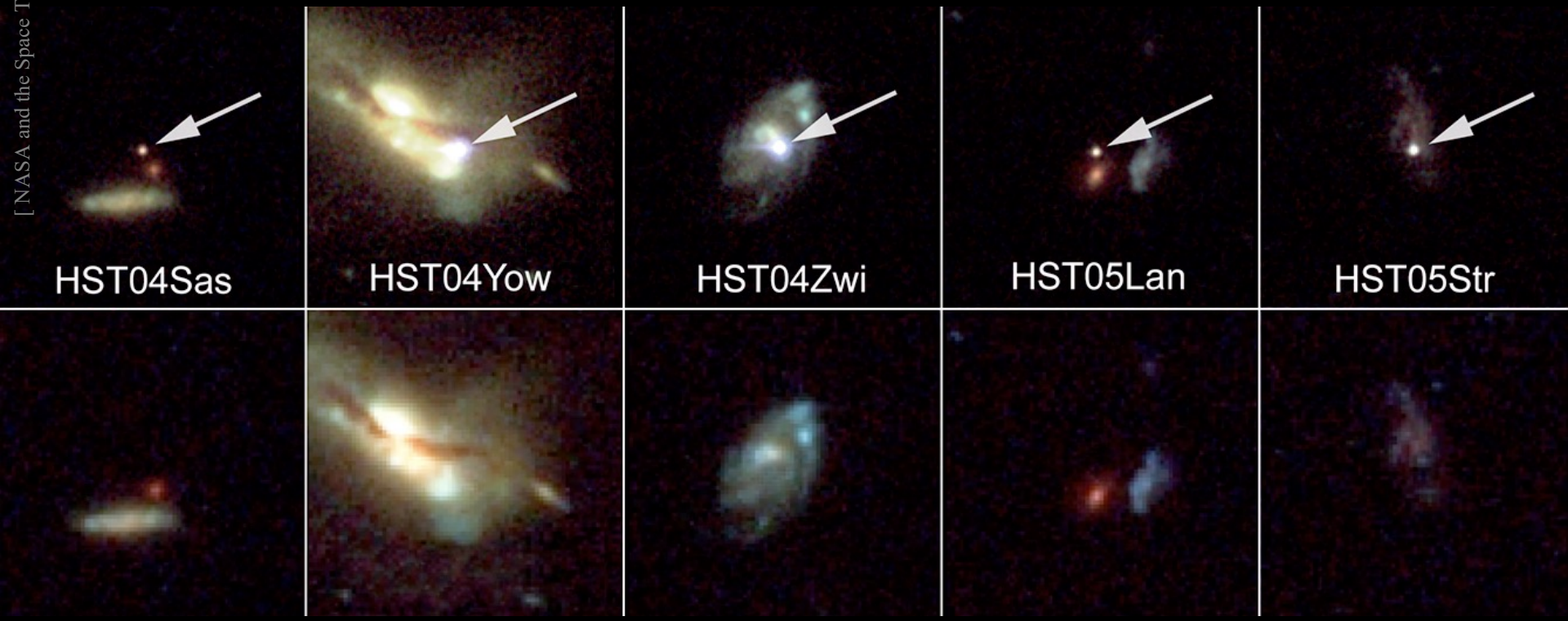
SN 1604 o stella di Keplero



[NASA/ESA/JHU/R.Sankrit & W.Blair]

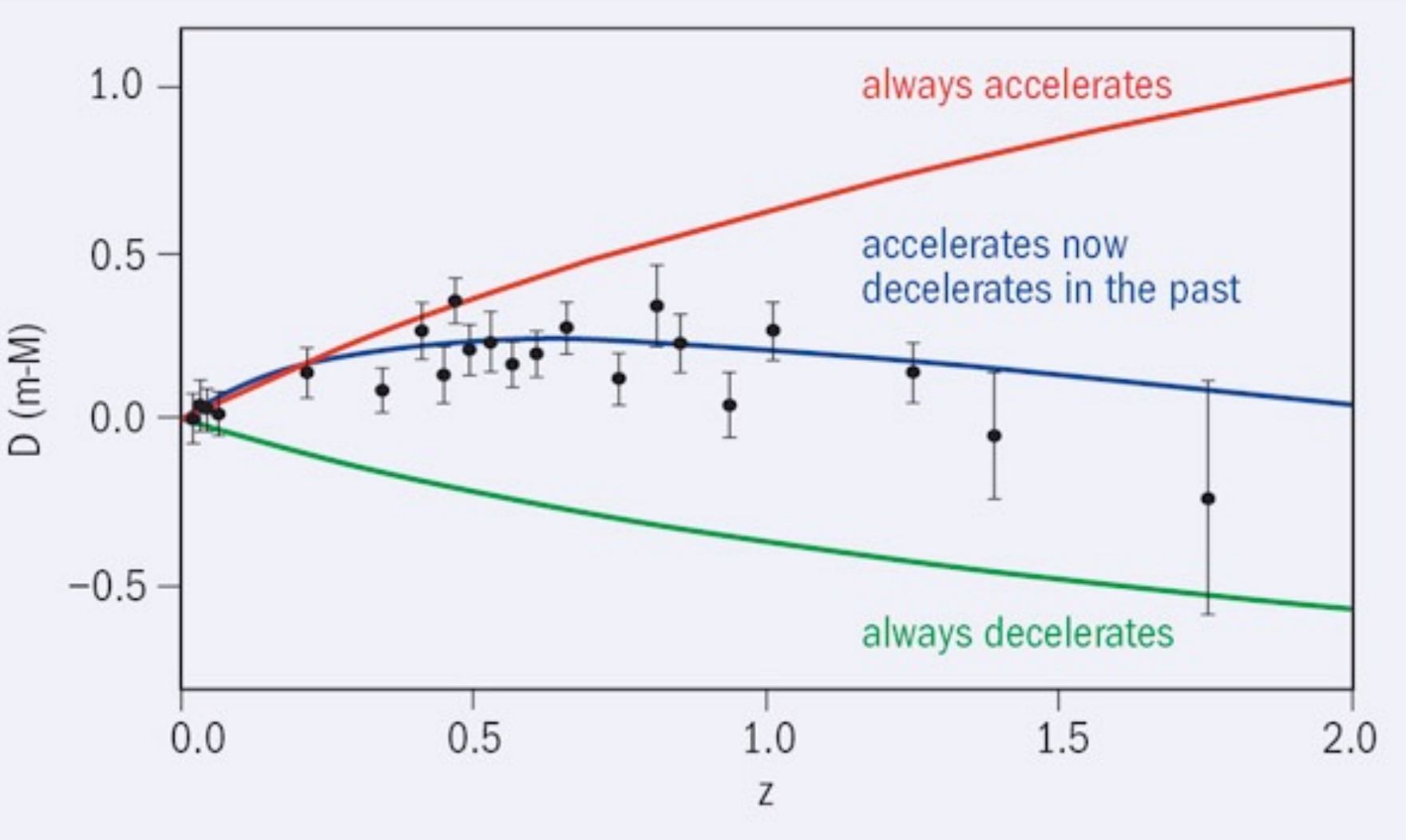
1998: Perlmutter, Schmidt e Riess

[NASA and the Space Telescope Science Institute (STScI)]

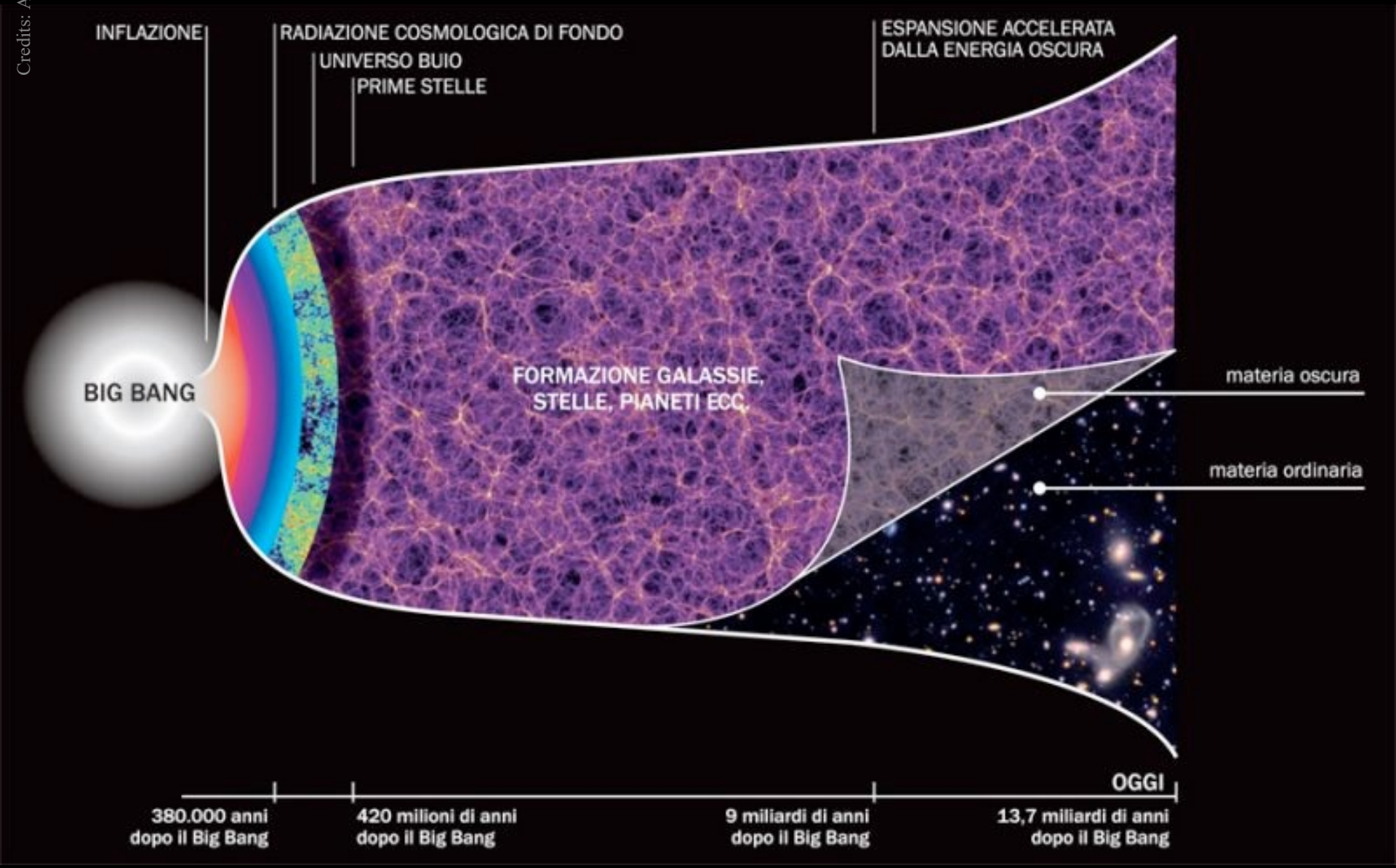


[CERN Courier]

Espansione accelerata



Modello Standard Cosmologico



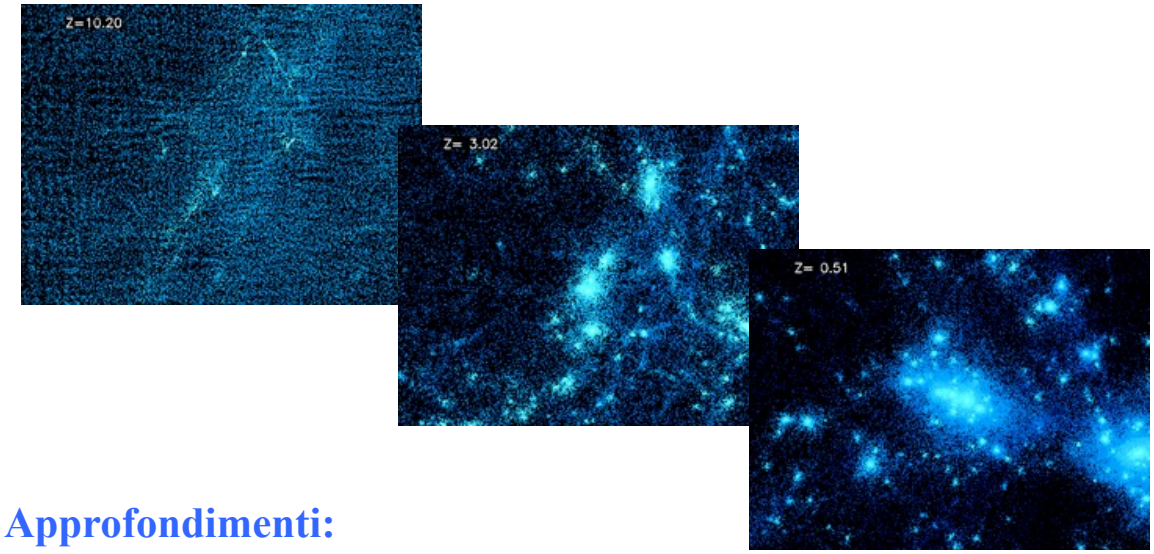
https://it.wikipedia.org/wiki/Voyager_1

The pale blue dot

«Da questo distante punto di osservazione, la Terra può non sembrare di particolare interesse. Ma per noi, è diverso. Guardate ancora quel puntino. È qui. È casa. È noi. Su di esso, tutti coloro che amate, tutti coloro che conoscete, tutti coloro di cui avete mai sentito parlare, ogni essere umano che sia mai esistito, hanno vissuto la propria vita. L'insieme delle nostre gioie e dolori, migliaia di religioni, ideologie e dottrine economiche, così sicure di sé, ogni cacciatore e raccoglitore, ogni eroe e codardo, ogni creatore e distruttore di civiltà, ogni re e plebeo, ogni giovane coppia innamorata, ogni madre e padre, figlio speranzoso, inventore ed esploratore, ogni predicatore di moralità, ogni politico corrotto, ogni "superstar", ogni "comandante supremo", ogni santo e peccatore nella storia della nostra specie è vissuto lì, su un minuscolo granello di polvere sospeso in un raggio di sole. La Terra è un piccolissimo palco in una vasta arena cosmica.
Pensate ai fiumi di sangue versati da tutti quei generali e imperatori affinché, nella gloria e nel trionfo, potessero diventare per un momento padroni di una frazione di un puntino. Pensate alle crudeltà senza fine inflitte dagli abitanti di un angolo di questo pixel agli abitanti scarsamente distinguibili di qualche altro angolo, quanto frequenti le incomprensioni, quanto smaniosi di uccidersi a vicenda, quanto fervente il loro odio. Le nostre ostentazioni, la nostra immaginaria autostima, l'illusione che noi abbiamo una qualche posizione privilegiata nell'Universo, sono messe in discussione da questo punto di luce pallida. Il nostro pianeta è un granellino solitario nel grande, avvolgente buio cosmico. Nella nostra oscurità, in tutta questa vastità, non c'è alcuna indicazione che possa giungere aiuto da qualche altra parte per salvarci da noi stessi.
La Terra è l'unico mondo conosciuto che possa ospitare la vita. Non c'è altro posto, per lo meno nel futuro prossimo, dove la nostra specie possa migrare. Visitare, sì. Colonizzare, non ancora. Che ci piaccia o meno, per il momento la Terra è dove ci giochiamo le nostre carte.
È stato detto che l'astronomia è un'esperienza di umiltà e che forma il carattere. Non c'è forse migliore dimostrazione della follia delle vanità umane che questa distante immagine del nostro minuscolo mondo. Per me, sottolinea la nostra responsabilità di occuparci più gentilmente l'uno dell'altro, e di preservare e proteggere il pallido punto blu, l'unica casa che abbiamo mai conosciuto.»

- Carl Sagan, 1990

Conclusione: Big Bang



Approfondimenti:

Newton e la forza di gravità [4’56s, descrittivo] https://www.youtube.com/watch?v=5IuaXIHg85E
Leggi di Keplero [12’21s, esplicativo] https://www.youtube.com/watch?v=cR85ike9gZc
Scale of the Universe [interattivo] http://htwins.net/scale2/
The known Universe [6’30s] https://www.youtube.com/watch?v=17jymDn0W6U
Forza di gravità nel vuoto [4’41s, in inglese, facile] https://www.youtube.com/watch?v=E43-CfukEgs
Forza di gravità nel vuoto [2’35s, in inglese, facile] https://www.youtube.com/watch?v=s9Zb3xAgIoY
Volare in assenza di gravità [12’0s, facile] https://www.youtube.com/watch?v=_bQAMjYmwhI

Conclusione: Big Bang e poi?

Approfondimenti:

Come si forma una galassia [5’41s, descrittivo, IT] https://www.youtube.com/watch?v=ubT73CFiwik
Viaggio tra 5 galassie [7’38, poche scritte EN] https://www.youtube.com/watch?v=HhctqhISJL8
Una notte Australiana in time lapse [3’34”] https://www.youtube.com/watch?v=j4yxBwmLxms
Galaxy Zoo: https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/

Conclusione: stelle e galassie

Approfondimenti:

Canale YouTube di Amedeo Balbi [impegnativo ma chiaro]
https://www.youtube.com/channel/UCvG_mqHj_wmFZiM1SkoZccw
Cosmologia: https://www.youtube.com/playlist?list=PLhhIH8RzamP5IxgpR_V-OaojFYFu5PjgK
Buchi neri: https://www.youtube.com/playlist?list=PLhhIH8RzamP6x_aw_eaxdz-obPBDR5N-p

Costellazioni [facile, 9'59''] https://www.youtube.com/watch?v=beNEP-2ZDl0&t=1s

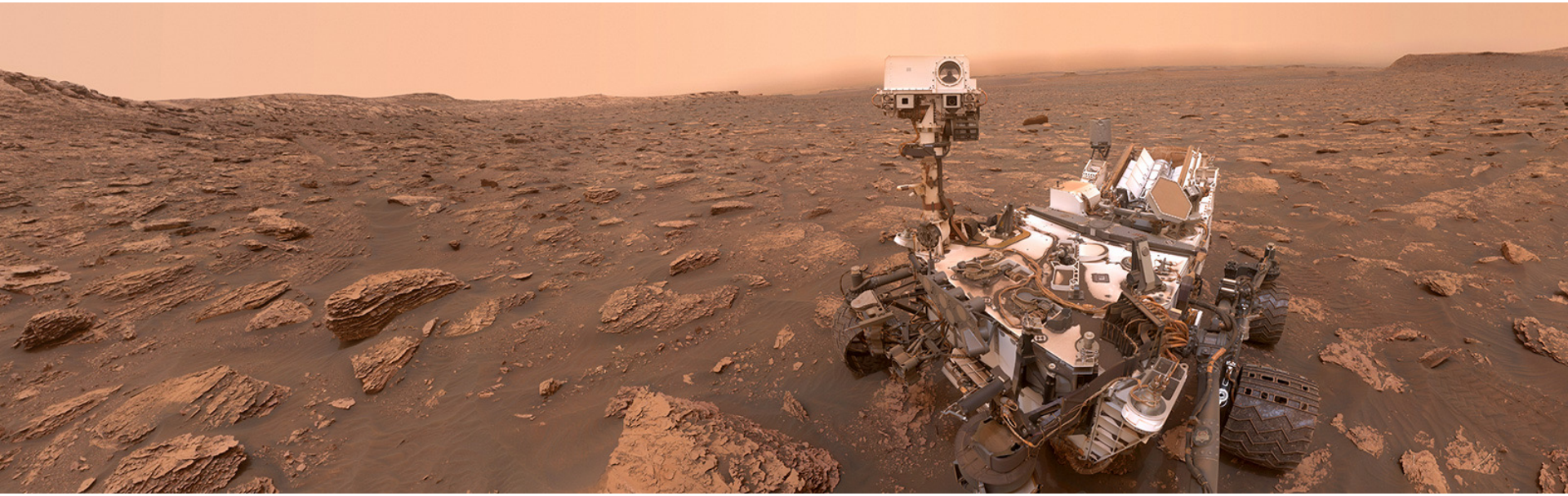
Buchi neri – simulazione NASA: https://www.youtube.com/watch?v=rQcKIN9vj3U

Montage by Ghislain Bonneau
http://www.gbphotodidactical.ca

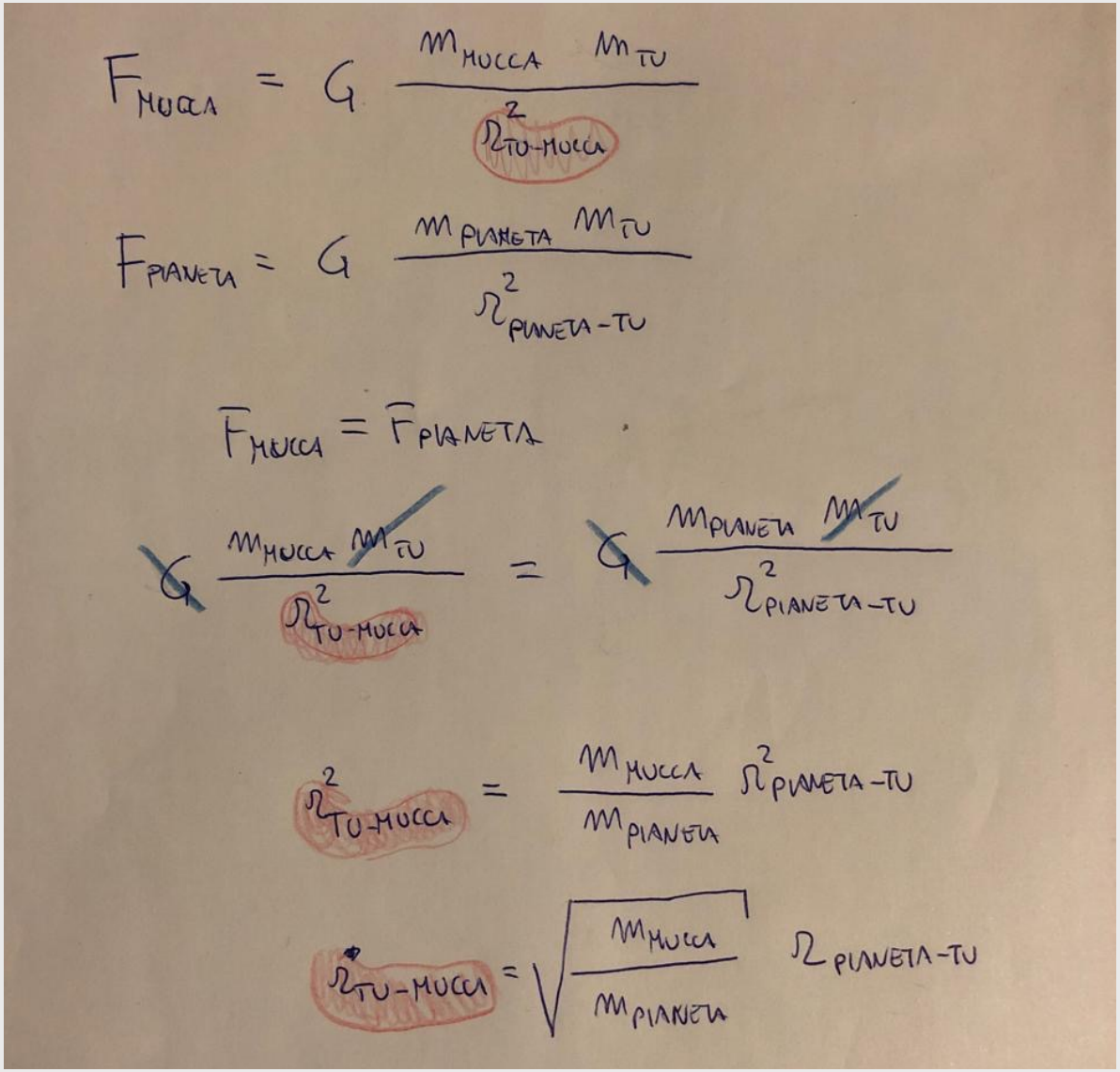
Conclusioni: Sole

Film:

- Apollo 13
- Sopravvissuto – The Martian
- Contact
- Il diritto di contare - Hidden figures



Approfondimenti:

Cosmo4kids.com [sito in inglese ma molto utile] http://www.cosmos4kids.com/map.html
e http://www.cosmos4kids.com/misctopics.html
Libro di Amedeo Balbi https://www.keplero.org/2016/05/dove-sono-tutti-quanti-un-viaggio-tra.html
Astrobiology [in inglese]: https://www.youtube.com/watch?v=cl_YuKk9mzg

Di oroscopi e di mucche: svolgimento