

Introduzione all'Astrofisica

Corso terzo anno Fisica

30 settembre 2019 - 17 gennaio 2020

(6 CFU, 56 ore)

Docenti: Sandra Savaglio & Sergio Servidio

Dipartimento di Fisica, Università della Calabria

Prova intermedia:

- Scritta con domande (20) e risposte multiple (4) su prima parte del corso
- A scelta, valida per risultato finale dell'esame
- Prova superata se almeno 14 risposte sono giuste

Il Prova intermedia a fine corso:

- Stessa modalità sulla seconda parte del corso
- A scelta, valida per esonero dallo scritto

Esame finale:

- Scritto con 40 domande con risposte multiple (4)
- Prova superata se almeno 28 risposte sono giuste
- Orale

Libri di testo

- **An introduction to the Sun and stars**

Simon F. Green and Mark H. Jones (2004, Cambridge University Press)
ISBN 0521546222

- **An introduction to galaxies and cosmology**

M. H. Jones & R.J.A. Lambourne (2004, Cambridge University Press)
ISBN: 0521546230

- **Observational cosmology**

Stephen Serjeant (2010, Cambridge University Press)

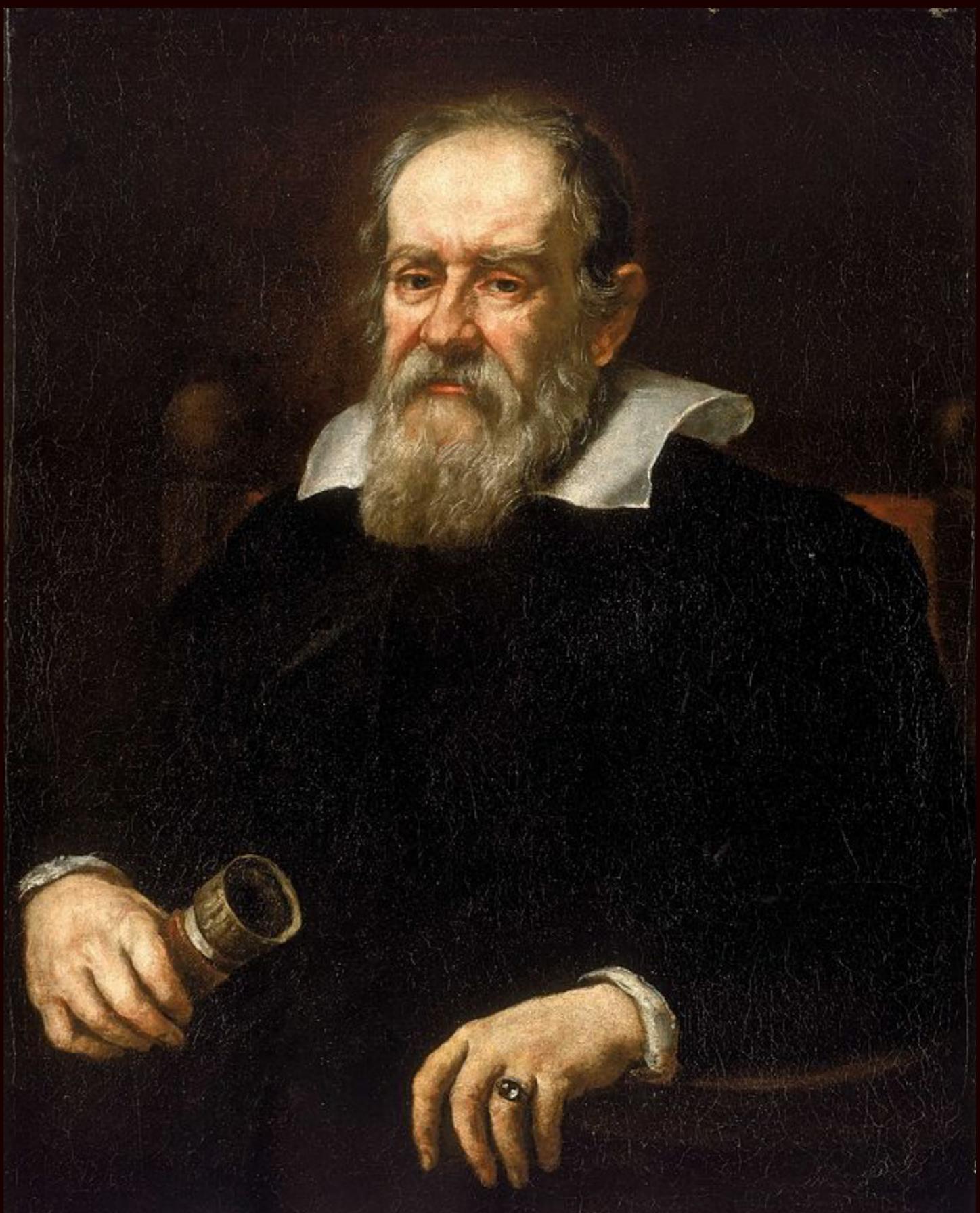
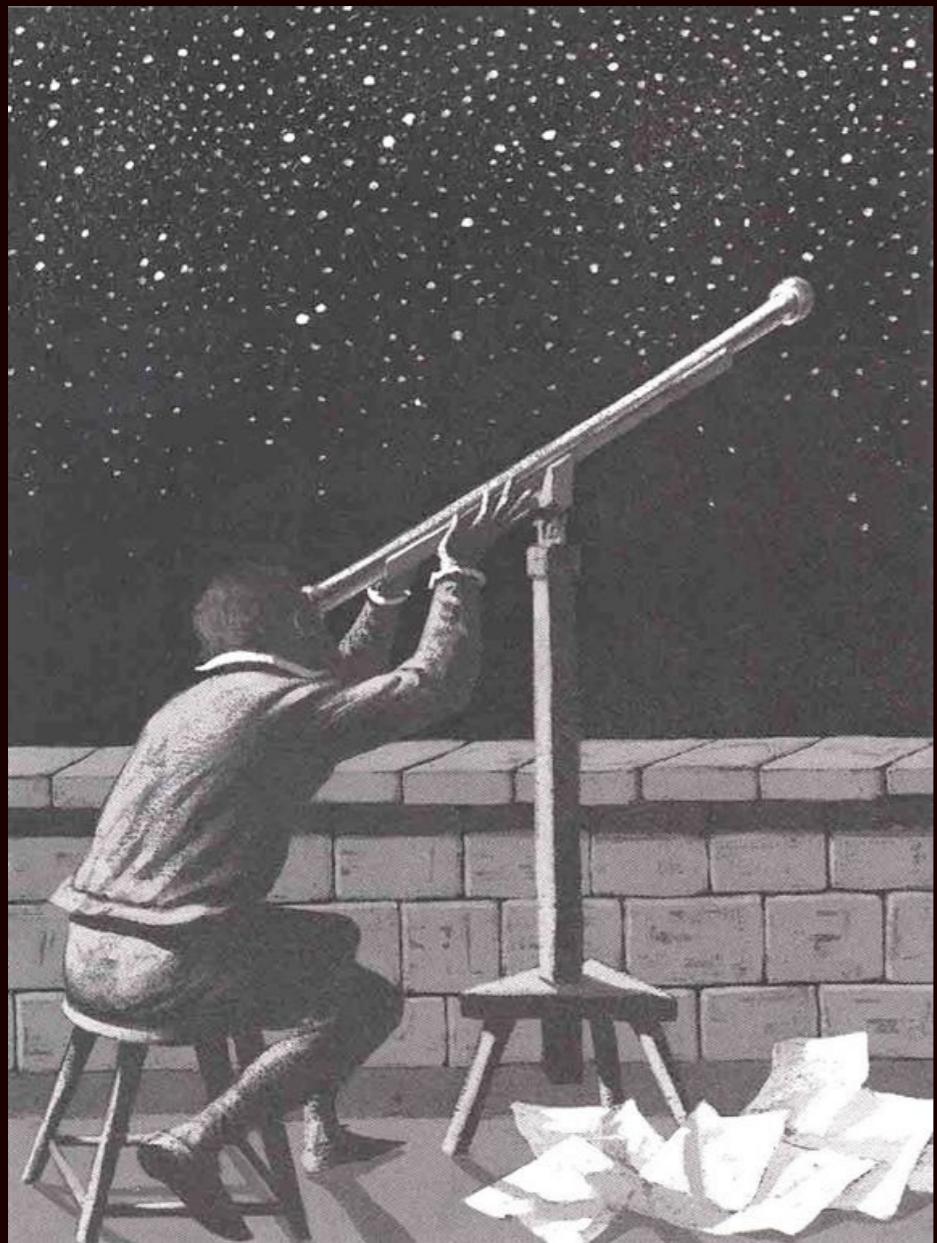
Materiale delle lezioni:

<https://sandrasavaglio.info/course-stars-galaxies-cosmology/>

Contenuto del corso

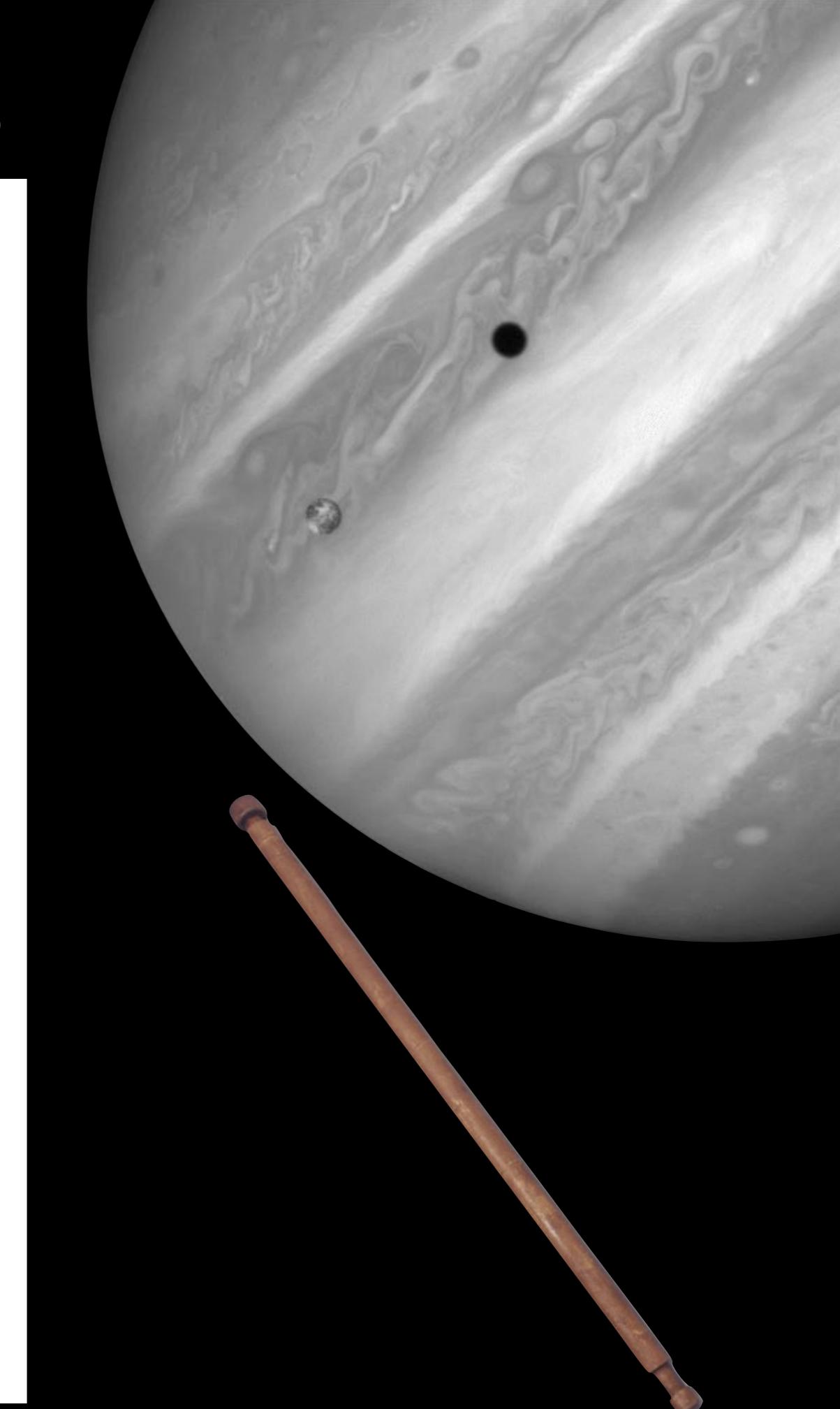
Firenze, anno 1609: La nascita dell'astrofisica moderna

Galileo Galilei
(Pisa 1564 - Arcetri 1642)

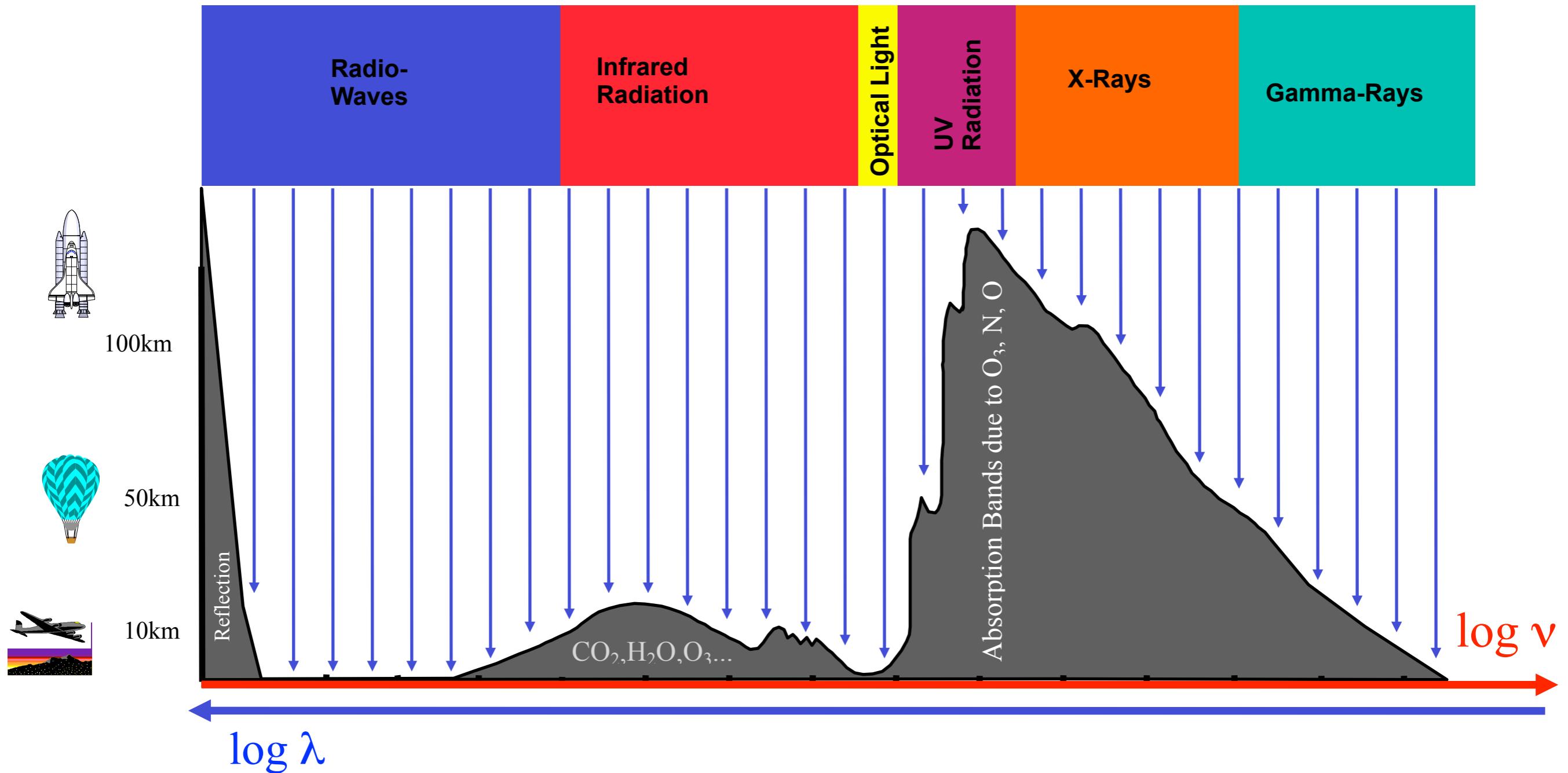


Nel 1609 il telescopio viene usato per la prima volta per guardare il cielo da Galileo

Observations January 1610			
2. S. 9 th 1610.	mark H. 12	O **	
3. 10 th		** O *	
2. 11 th		O ** *	
3. 12 th		O * *	
3. H. 13 th		* O *	
4. 14 th		* O **	
6. 15 th	mark	** O *	
8. 16 th H. 13.		* * * O	
10. 17 th	mark.	* * * O *	
11.		* * O *	
12. H. 18 th		* O *	
13. 19 th		* ** O *	
14. 20 th		* * * O *	



Observational windows of electromagnetic radiation



Very Large Telescope

Four telescopes

Mirrors: 8 meter size

Cerro Paranal (Chile) at 2600 meters altitude



Hubble Space Telescope

UV / optical / near infrared telescope

Launched in 1990

Altitude: 547 km

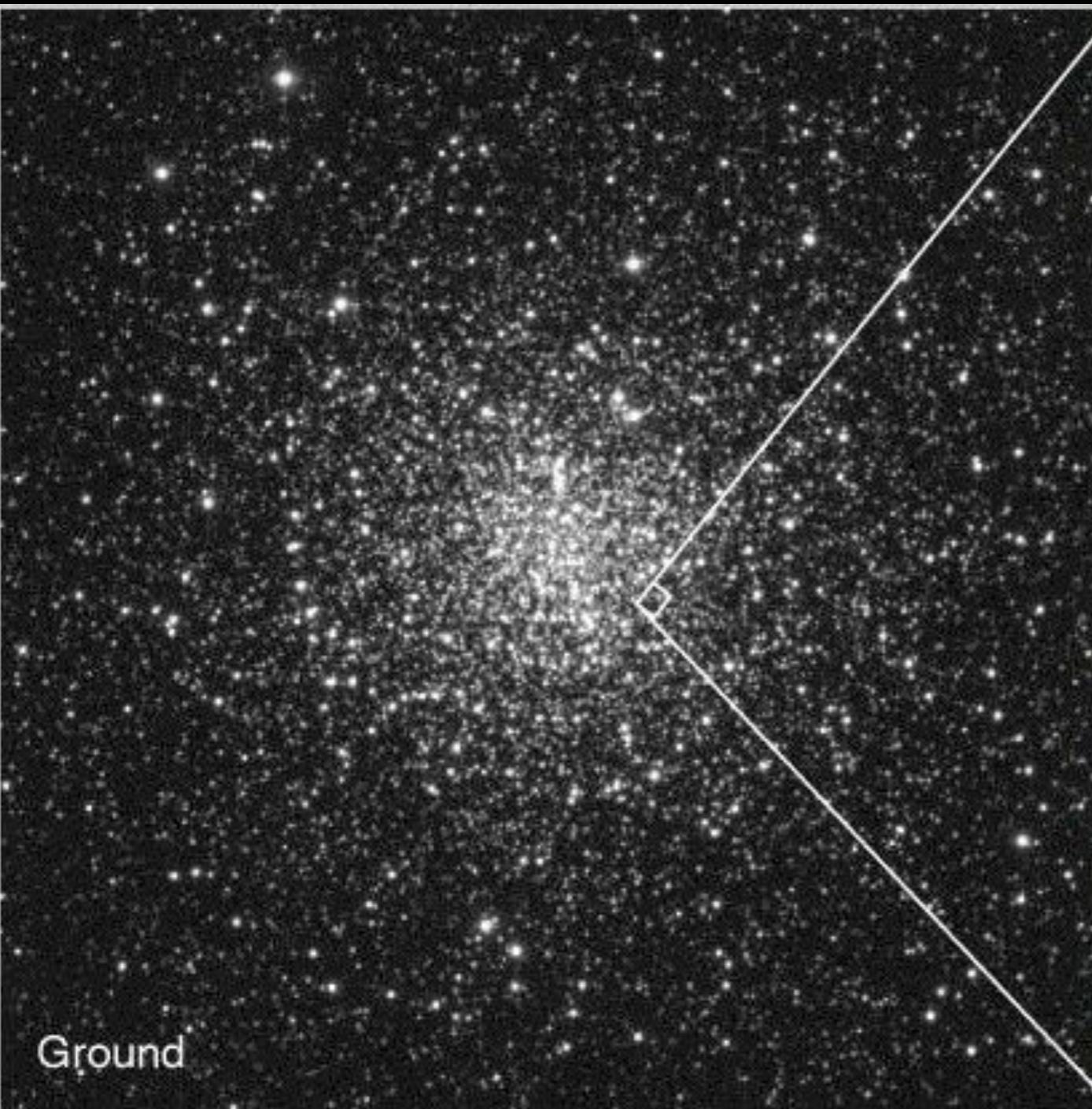
Time to complete one orbit: ~ 95 minutes

Speed: ~ 7.6 km/s

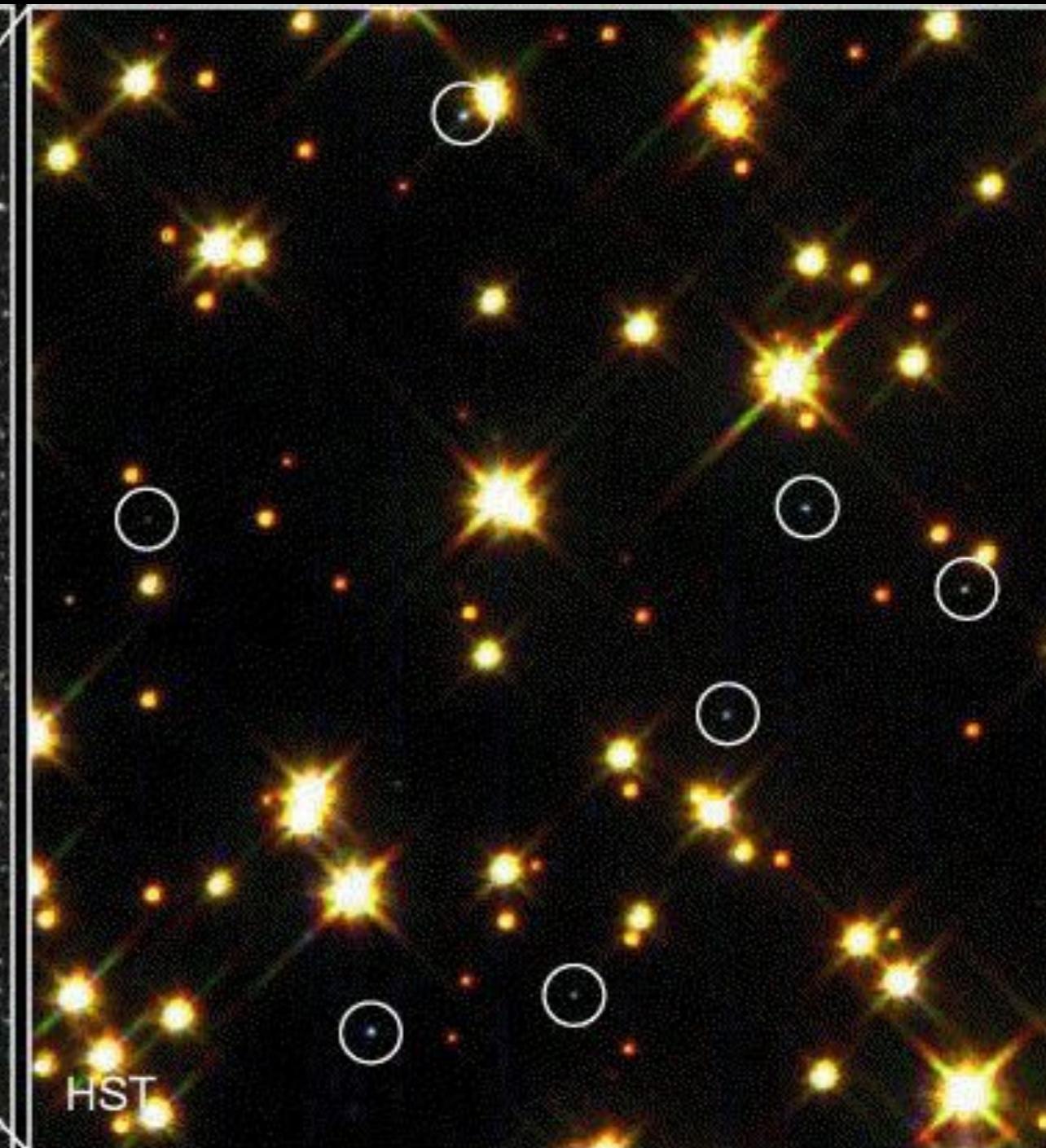


Ammasso Globulare Messier 4

Ground observations



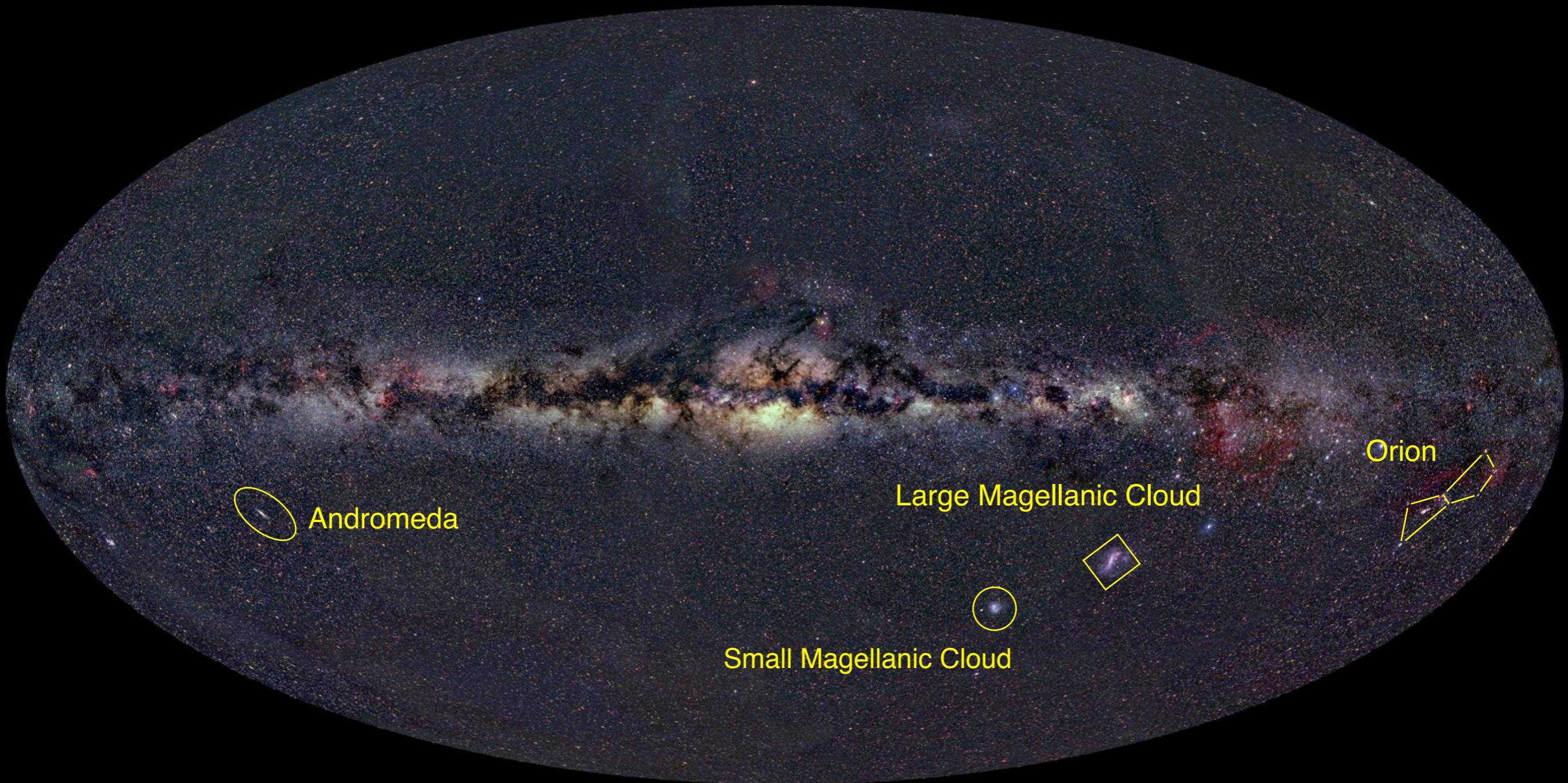
Hubble Space Telescope image



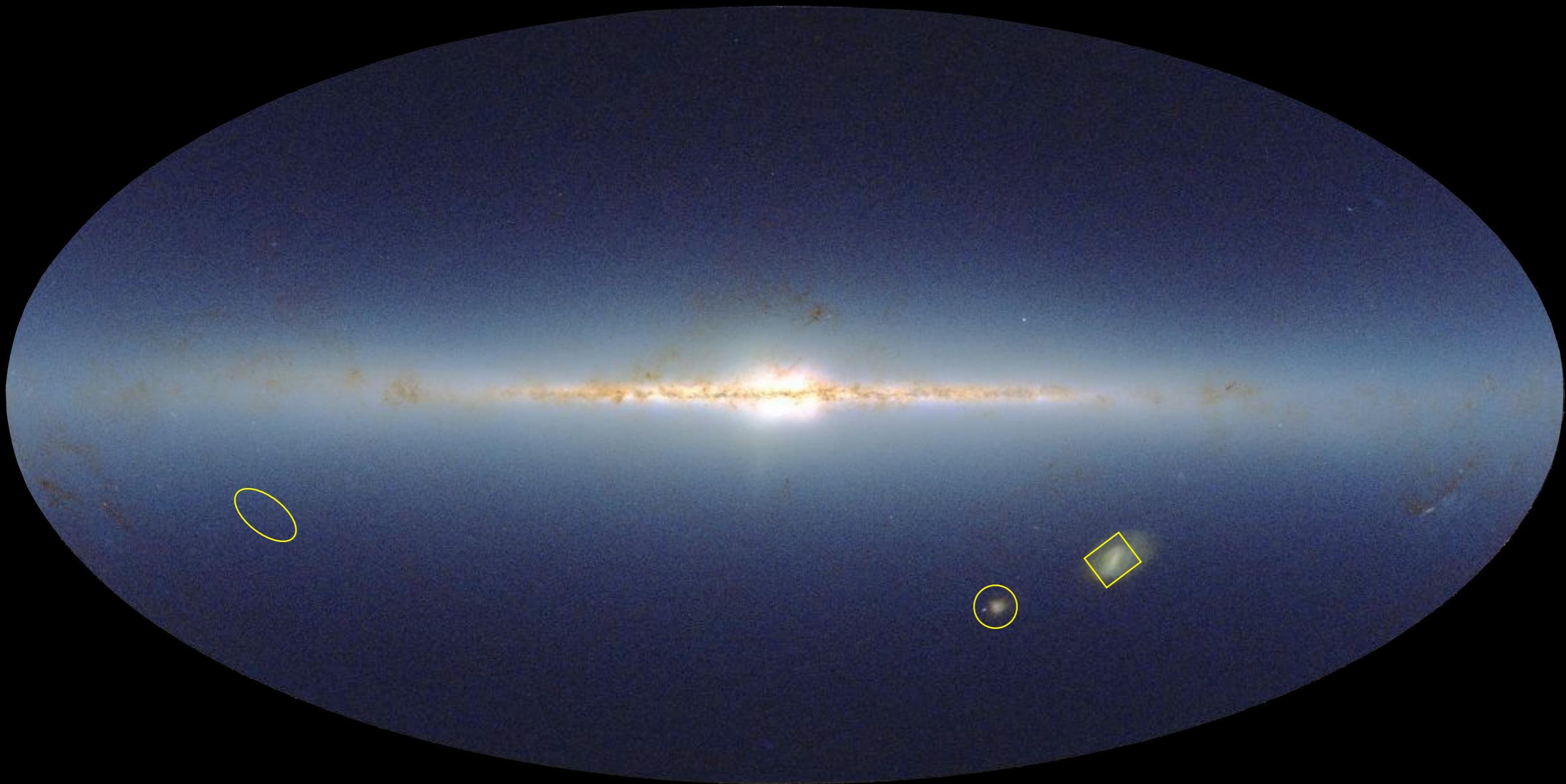
Our Galaxy: the Milky Way



Our Galaxy: the Milky Way

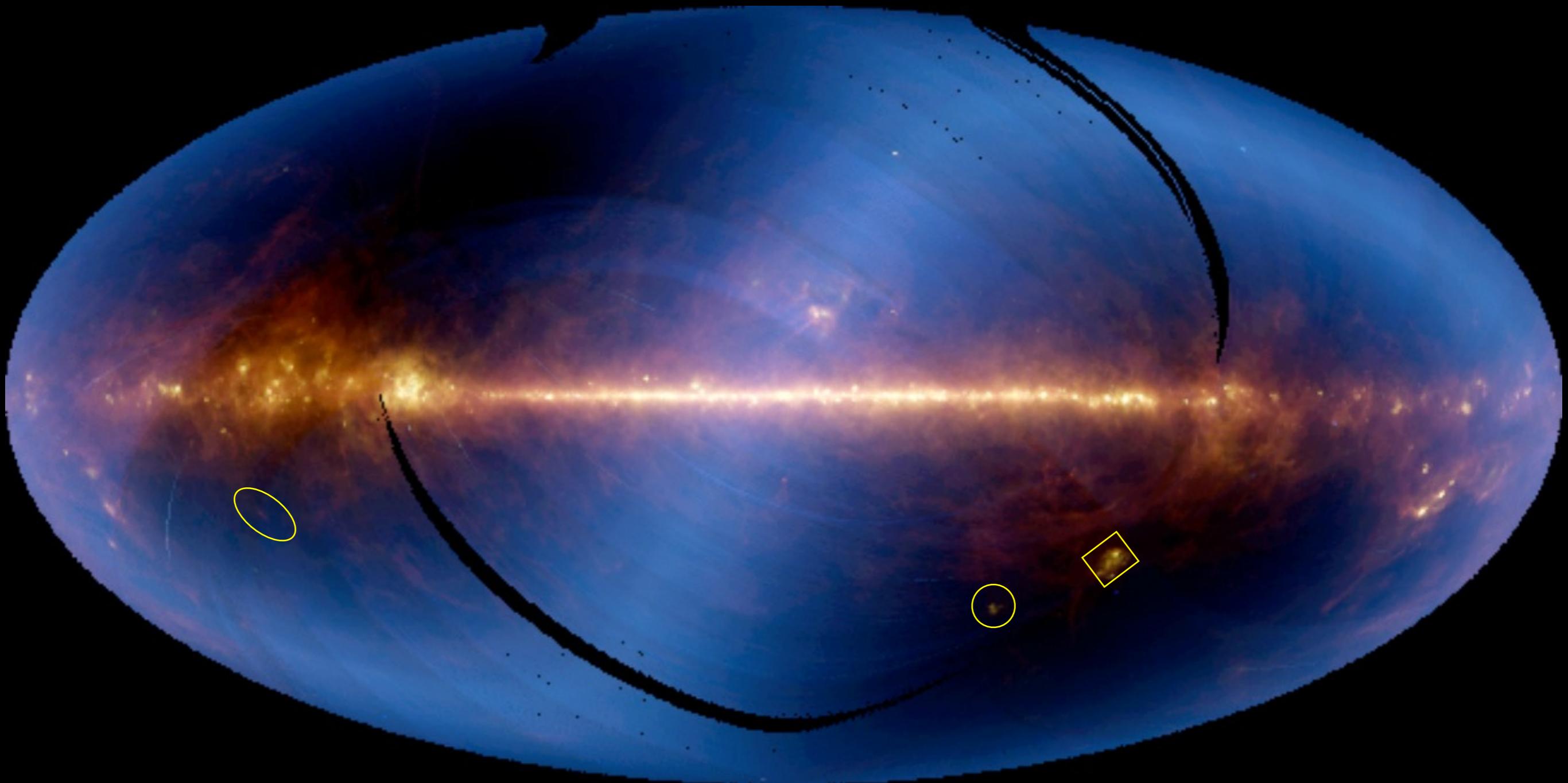


Our Galaxy: the Milky Way



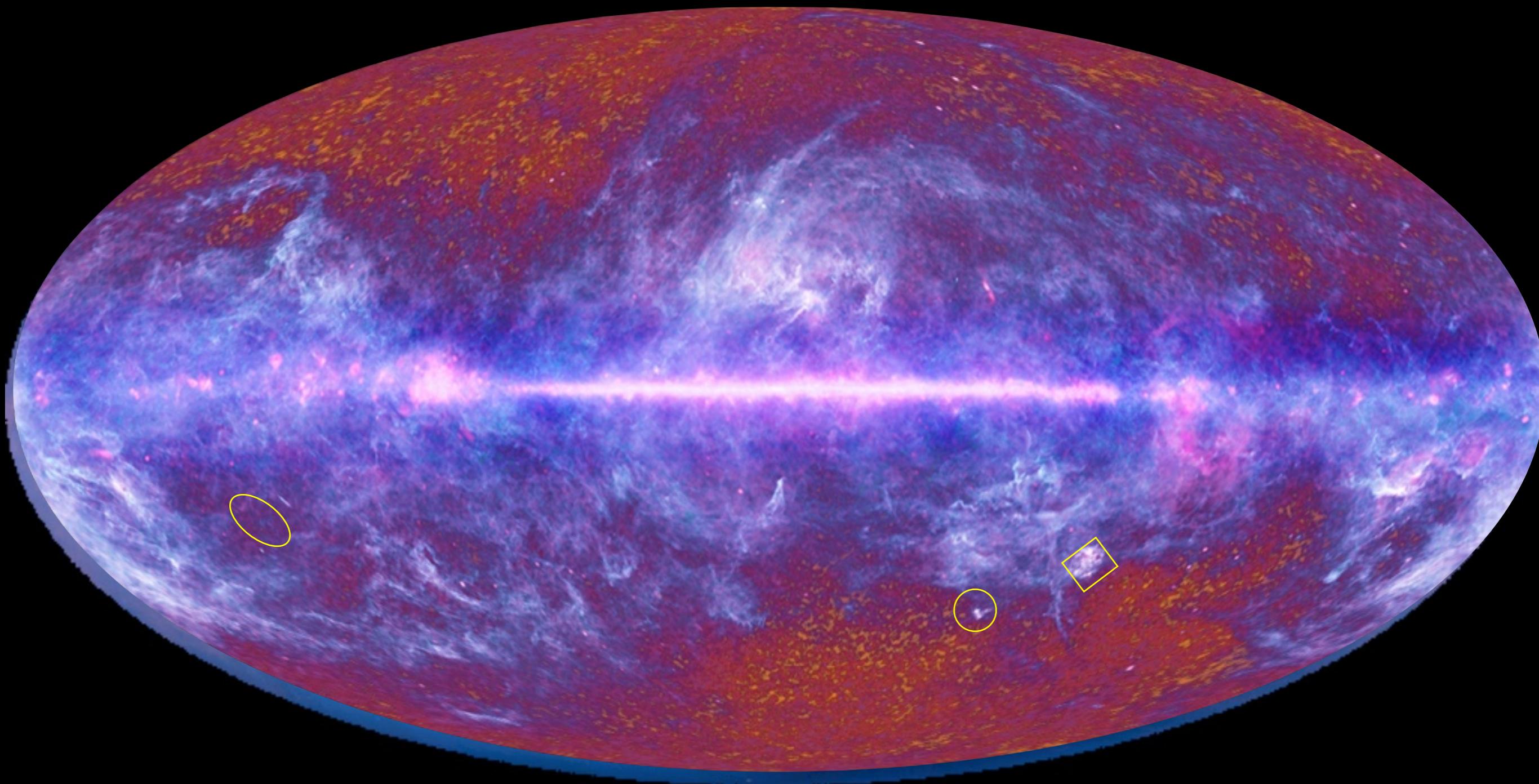
Near IR

Our Galaxy: the Milky Way



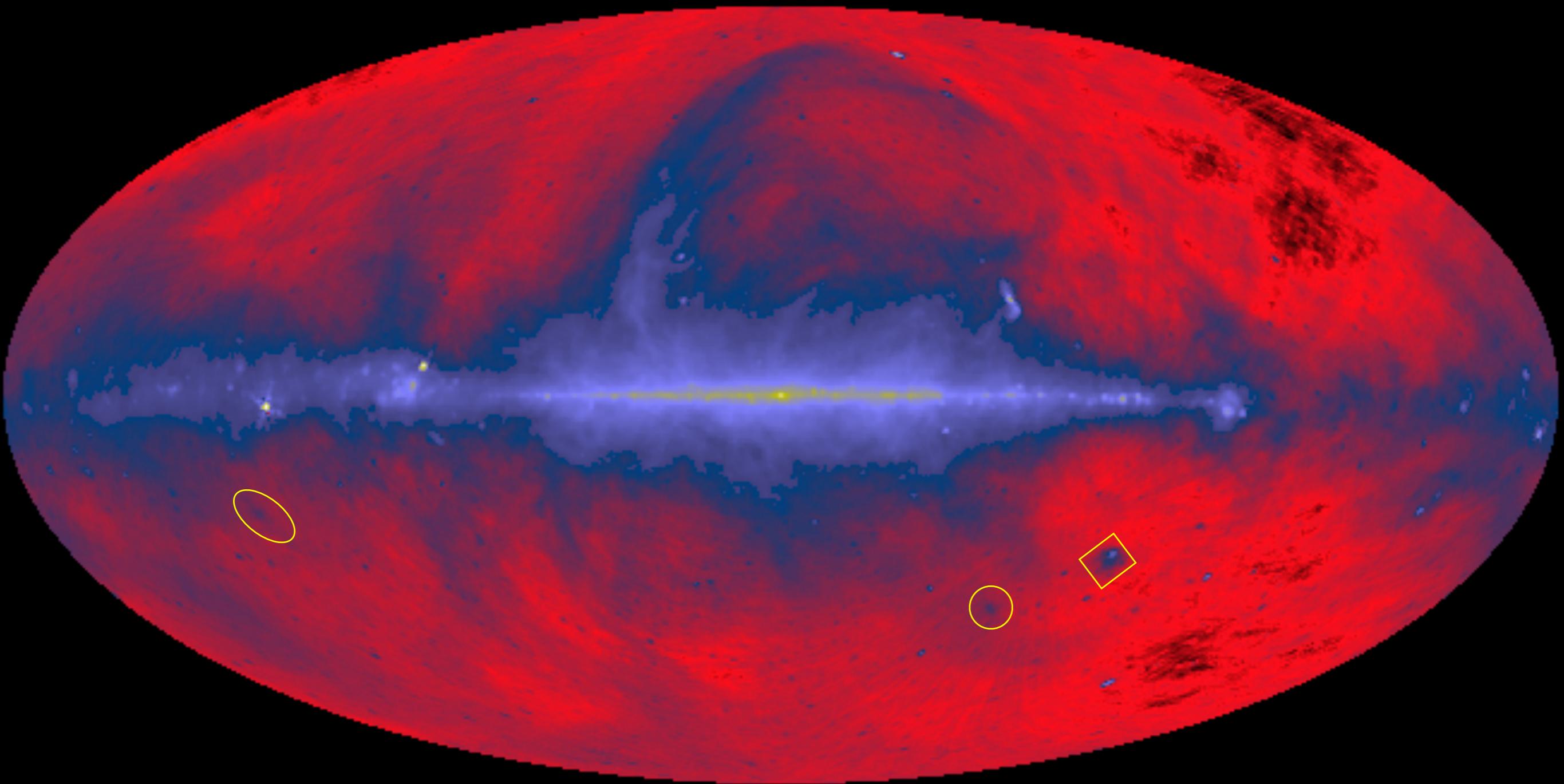
Far IR

Our Galaxy: the Milky Way



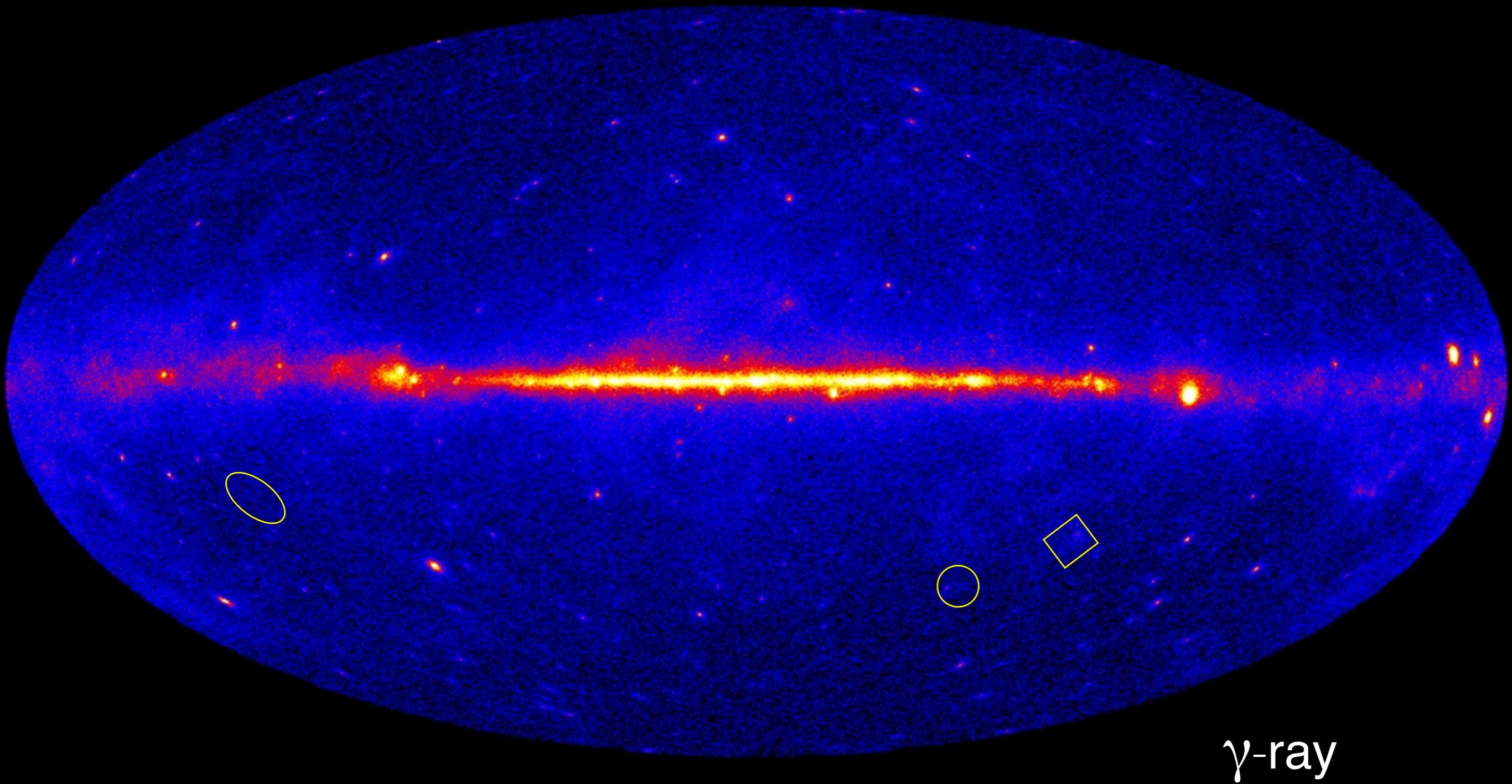
Microwave

Our Galaxy: the Milky Way



Radio

Our Galaxy: the Milky Way



Distance scale:

1 parallasse secondo = 1 parsec (pc) = 3.26 light years

Light year: $9\ 460\ 000\ 000\ 000\ \text{km} = 9.46 \times 10^{12}\ \text{km}$

Earth - Sun: $1.5 \times 10^8\ \text{km} = 8.3\ \text{light minutes}$

Closest star (Proxima Centauri): 4.25 light years

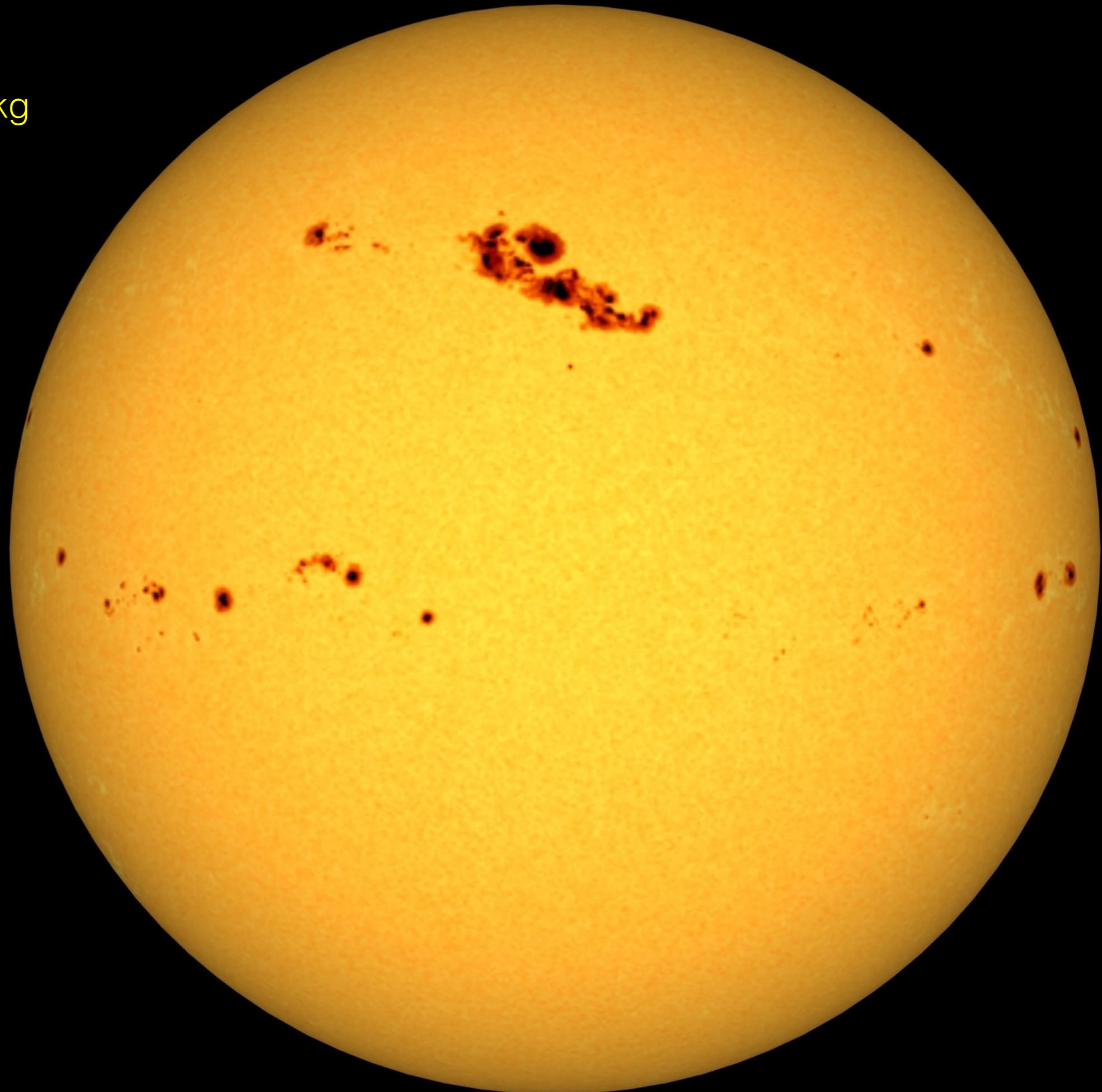
Diameter of our galaxy (Miky Way): 100 000 light years = 30 kpc

Distance of Andromeda galaxy: 2.54 million light years = 0.779 Mpc

The Universe is 4D, where time is the fourth dimension

The Sun

Mass (M_\odot): 2×10^{30} kg



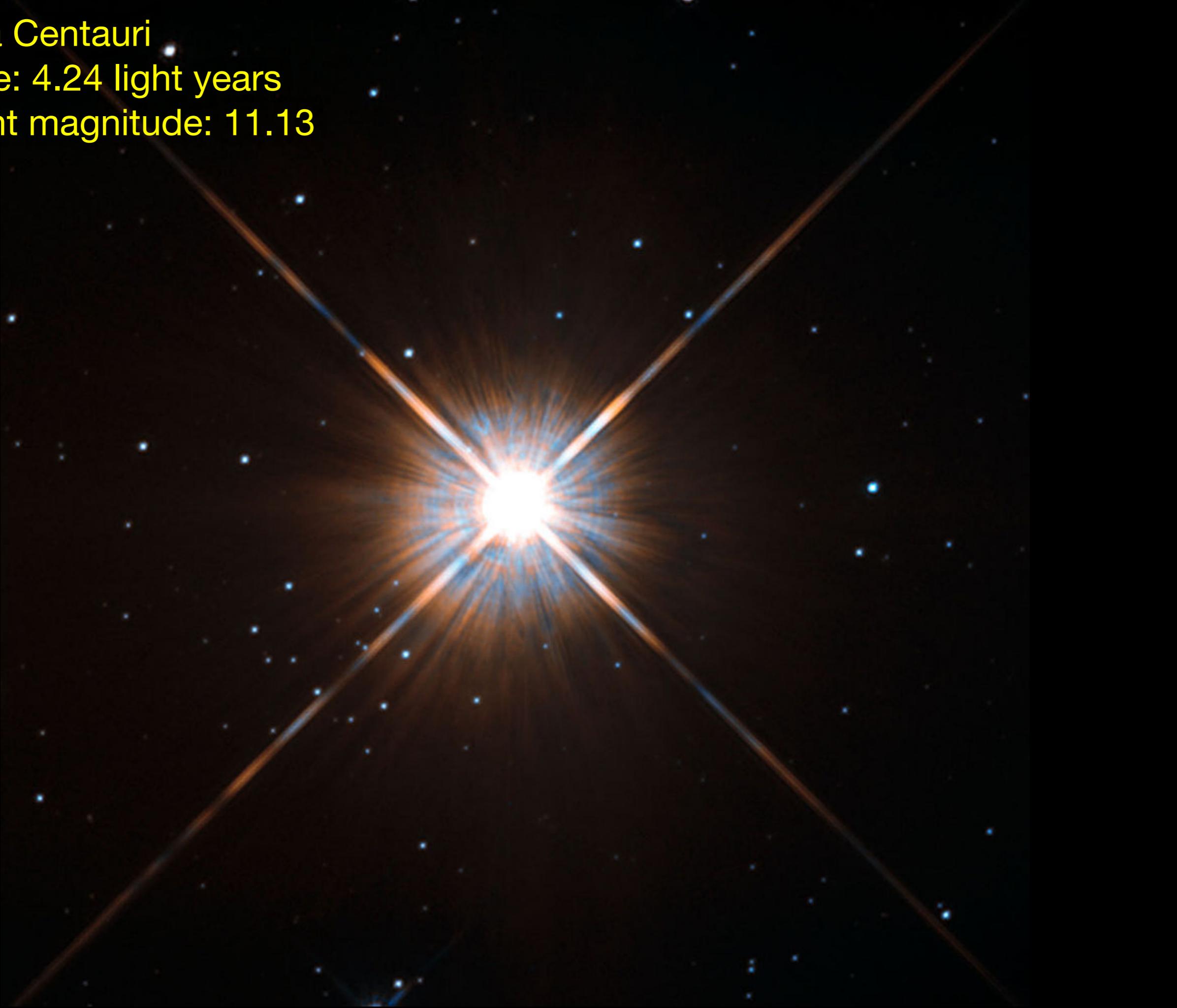


Flares

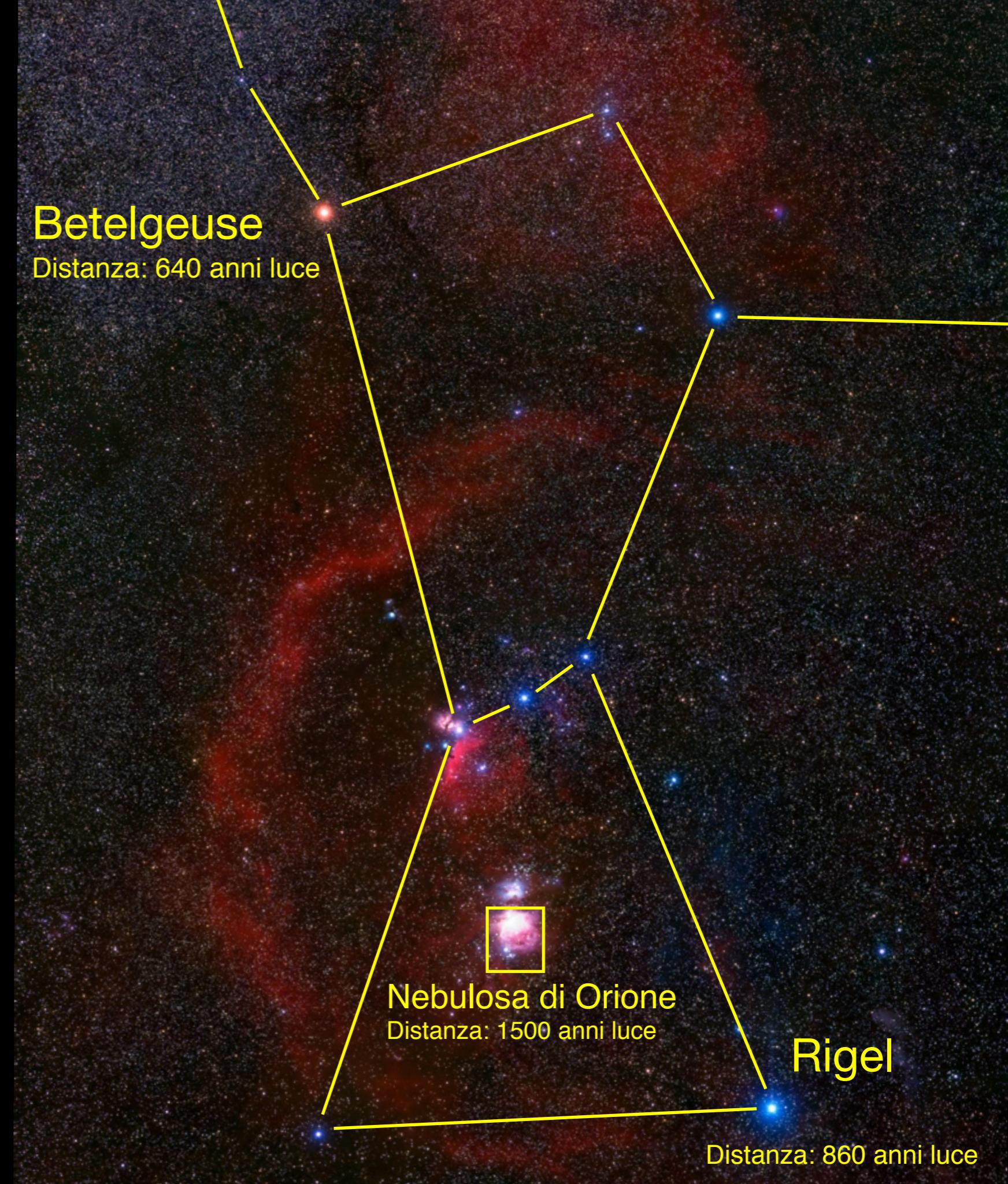
Proxima Centauri

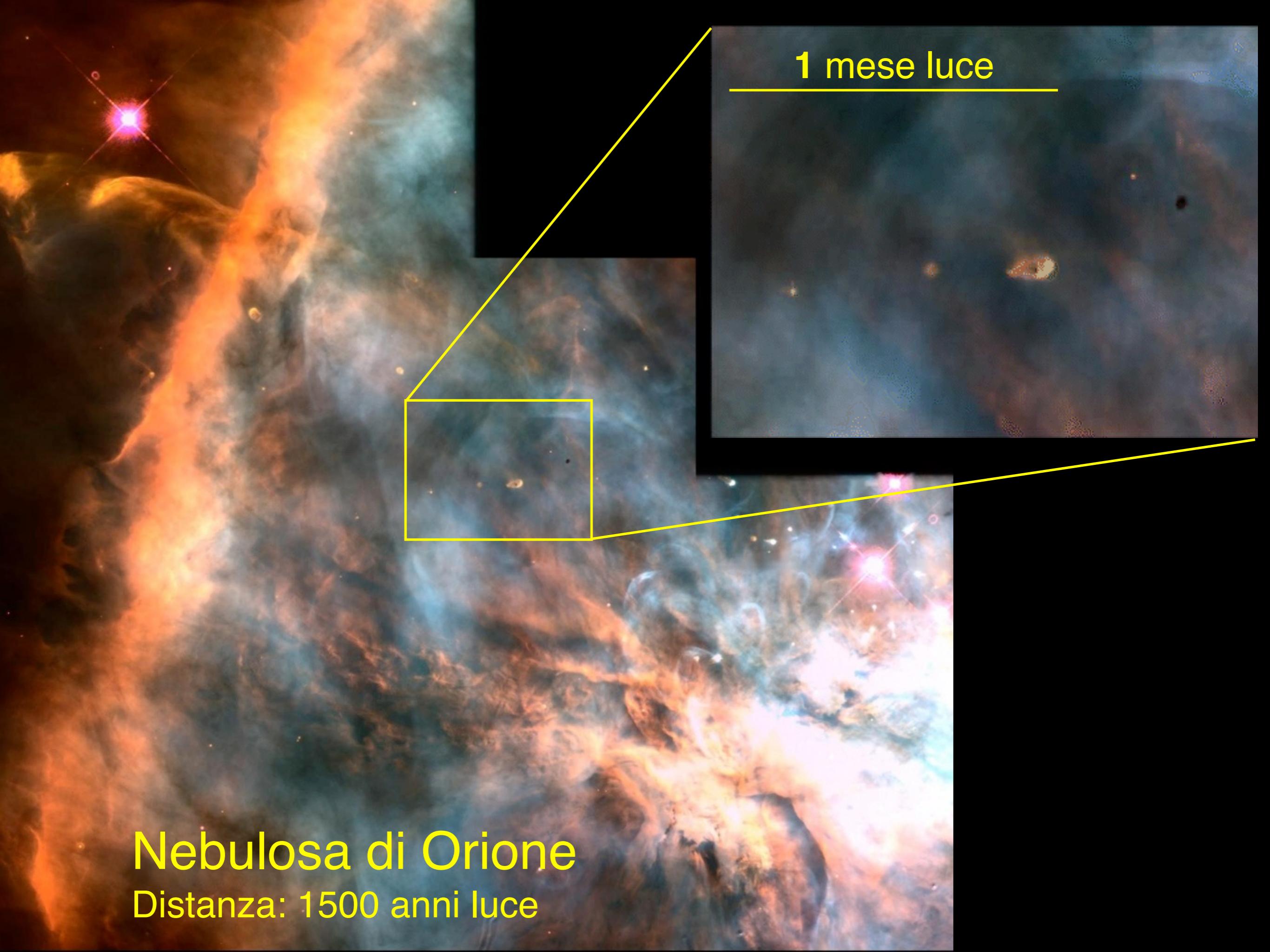
Distance: 4.24 light years

Apparent magnitude: 11.13



Costellazione di Orione





Nebulosa di Orione
Distanza: 1500 anni luce

1995: discovered the first planet outside the solar system

Star: 51 Pegasi

Apparent magnitude: $m = 5.49$

Distance: $d = 15.6$ pc (50.9 l.y)

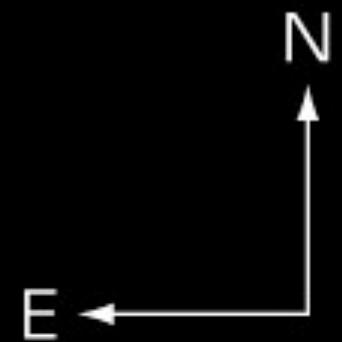


Extrasolar planets: planets around other stars

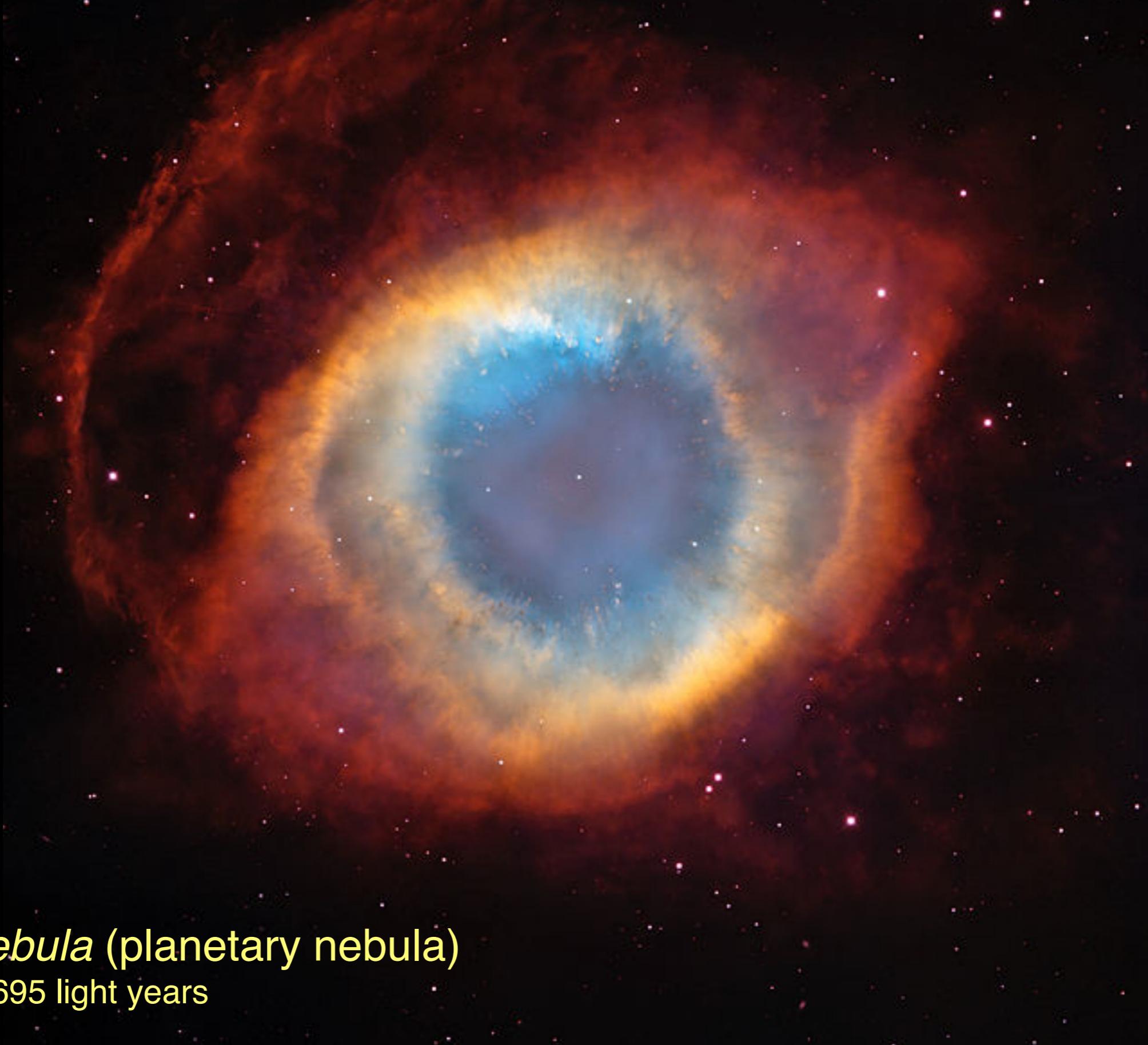


778 mas
55 AU at 70 pc

Extrasolar planet: M1207b
Distance: 170 light years



End of life of stars of like the Sun

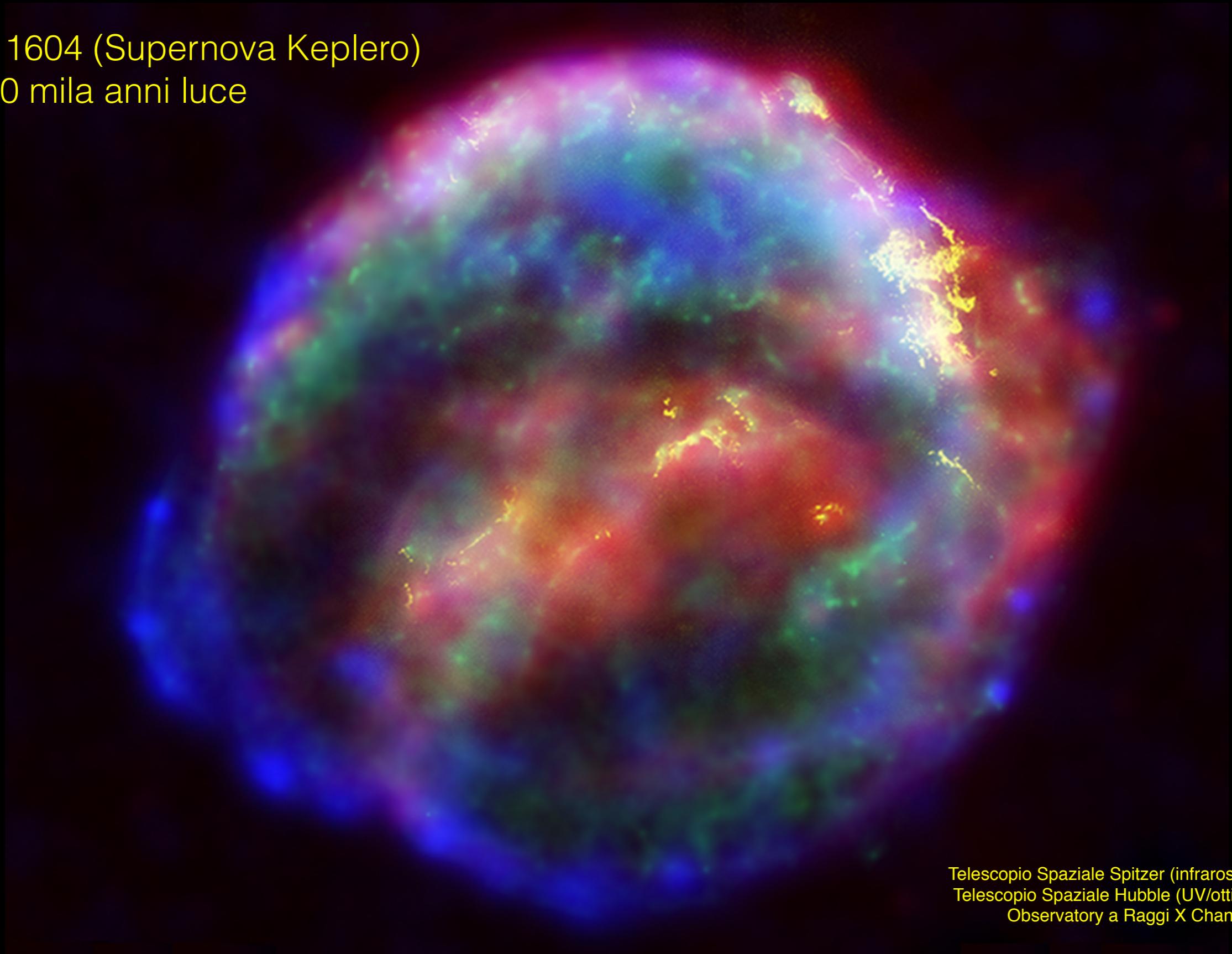


Helix Nebula (planetary nebula)

Distance: 695 light years

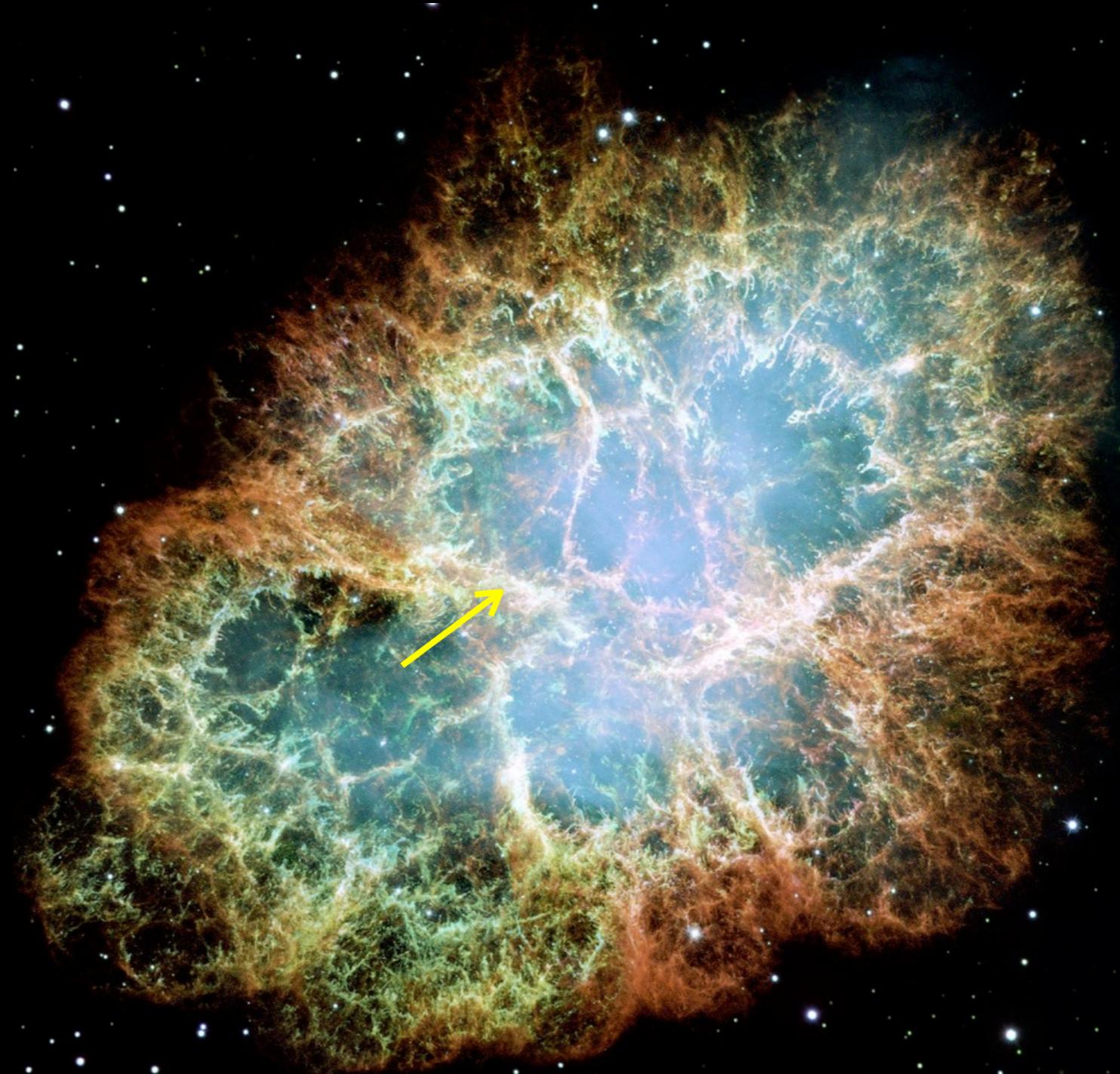
Esplosioni di stelle di grande massa (supernove) e loro resti

Supernova 1604 (Supernova Keplero)
Distanza: 20 mila anni luce



Telescopio Spaziale Spitzer (infrarosso)
Telescopio Spaziale Hubble (UV/ottico)
Observatory a Raggi X Chandra

Stelle di neutroni e pulsar come resti di esplosioni stellari



Resto di supernova: *Nebulosa del Granchio*

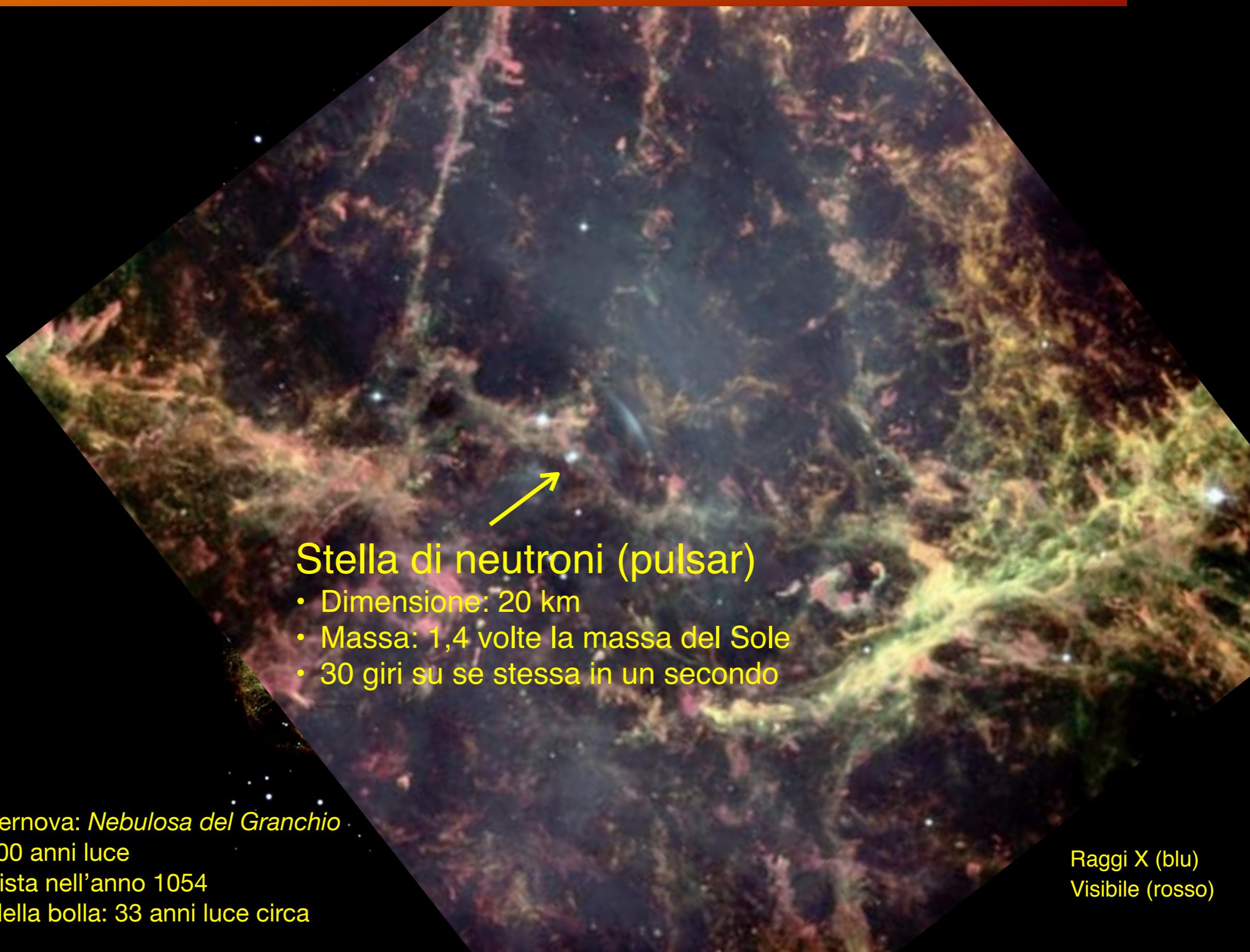
Distanza: 6500 anni luce

Esplosione vista nell'anno 1054

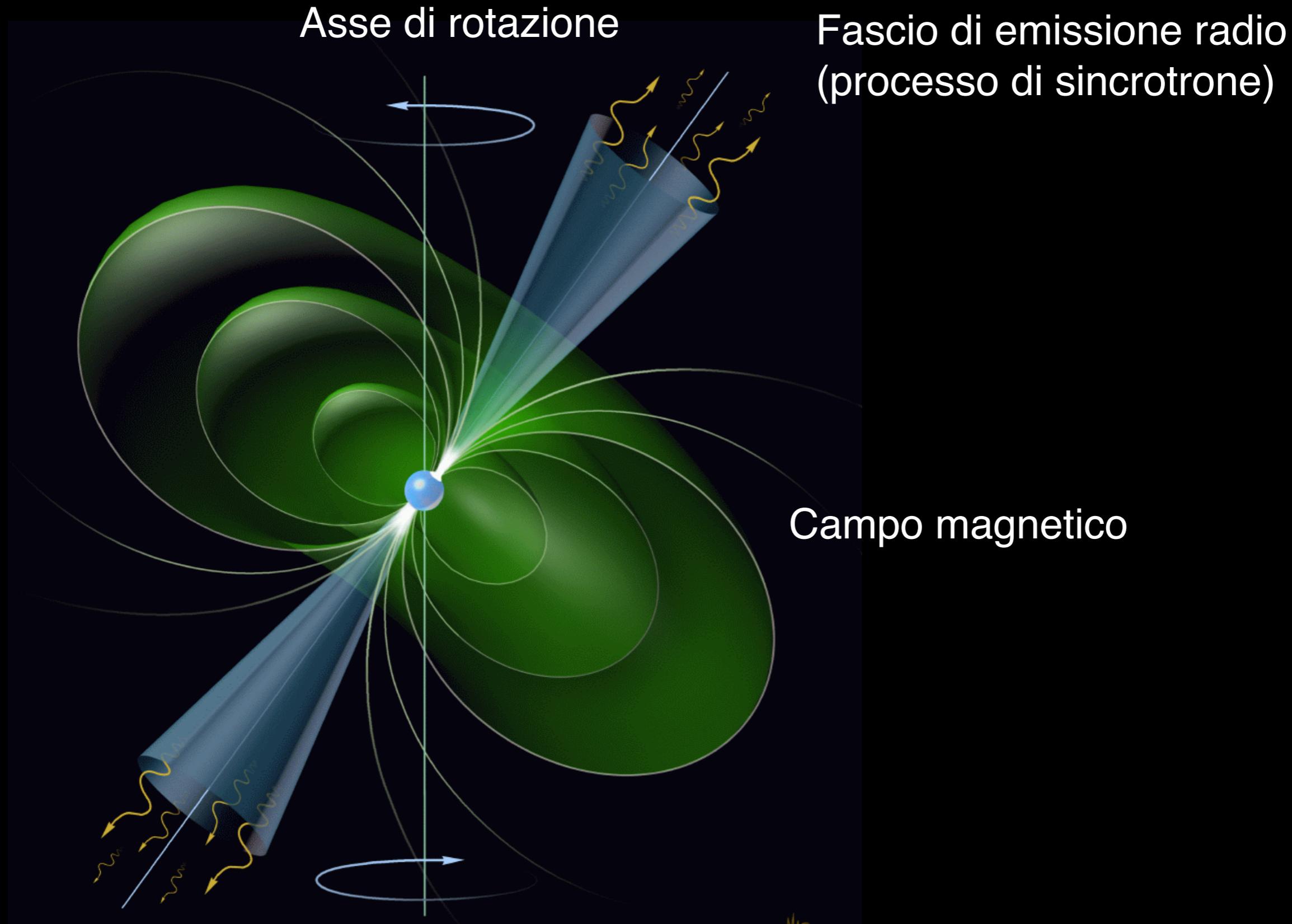
Dimensioni della bolla: 33 anni luce circa

Raggi X (blu)
Visibile (rosso)

Stelle di neutroni e pulsar come resti di esplosioni stellari



Pulsar: stelle di neutroni con forte rotazione e campo magnetico



Esplosioni più energetiche nell'universo: gamma-ray burst

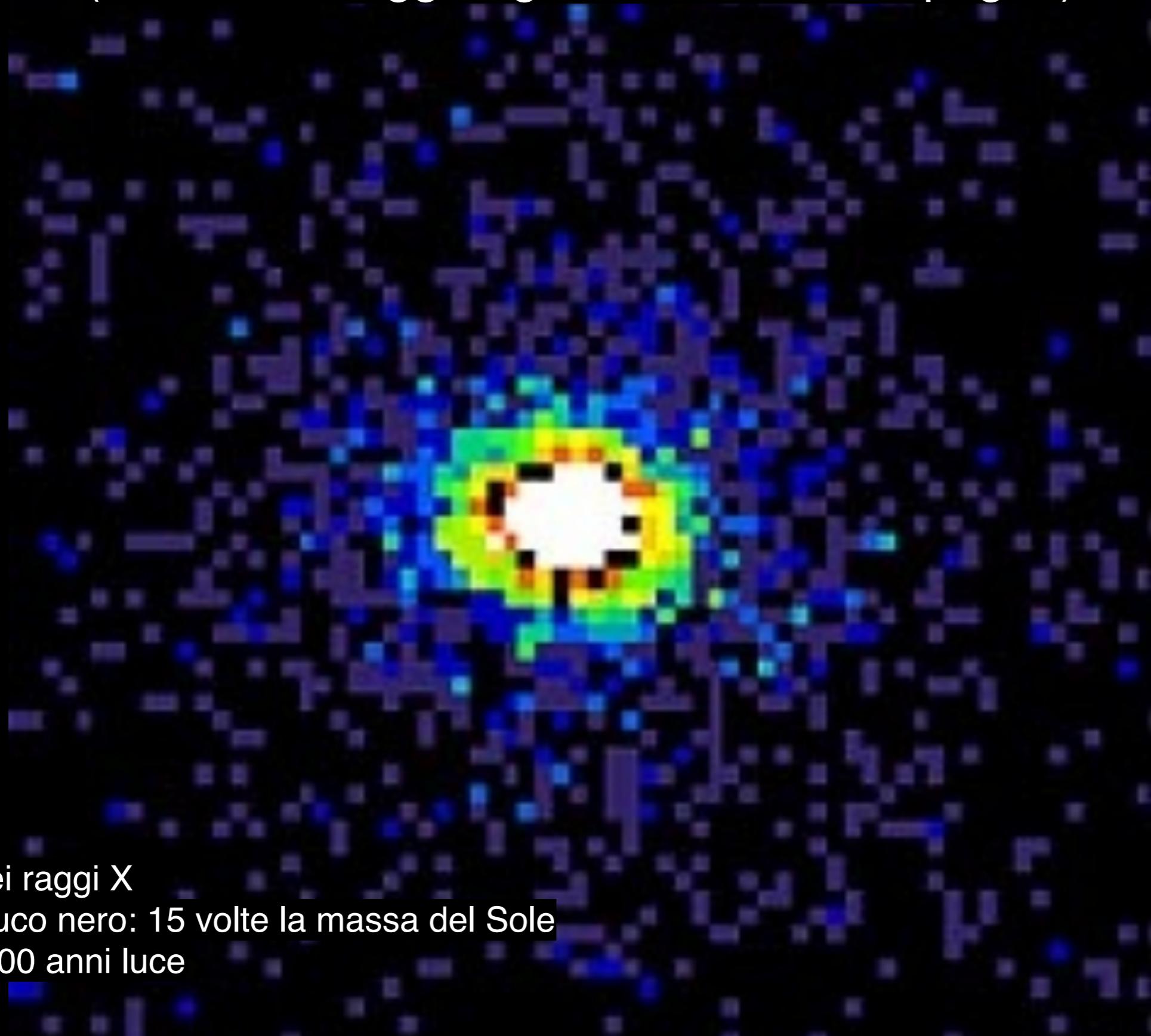


Lampo gamma: GRB 011121

Rivelato il 21 novembre 2001

Esplosione avvenuta 4 miliardi di anni fa

Buchi neri di origine stellare come resti di esplosioni stellari
(visibile nei raggi X grazie a stella compagna)



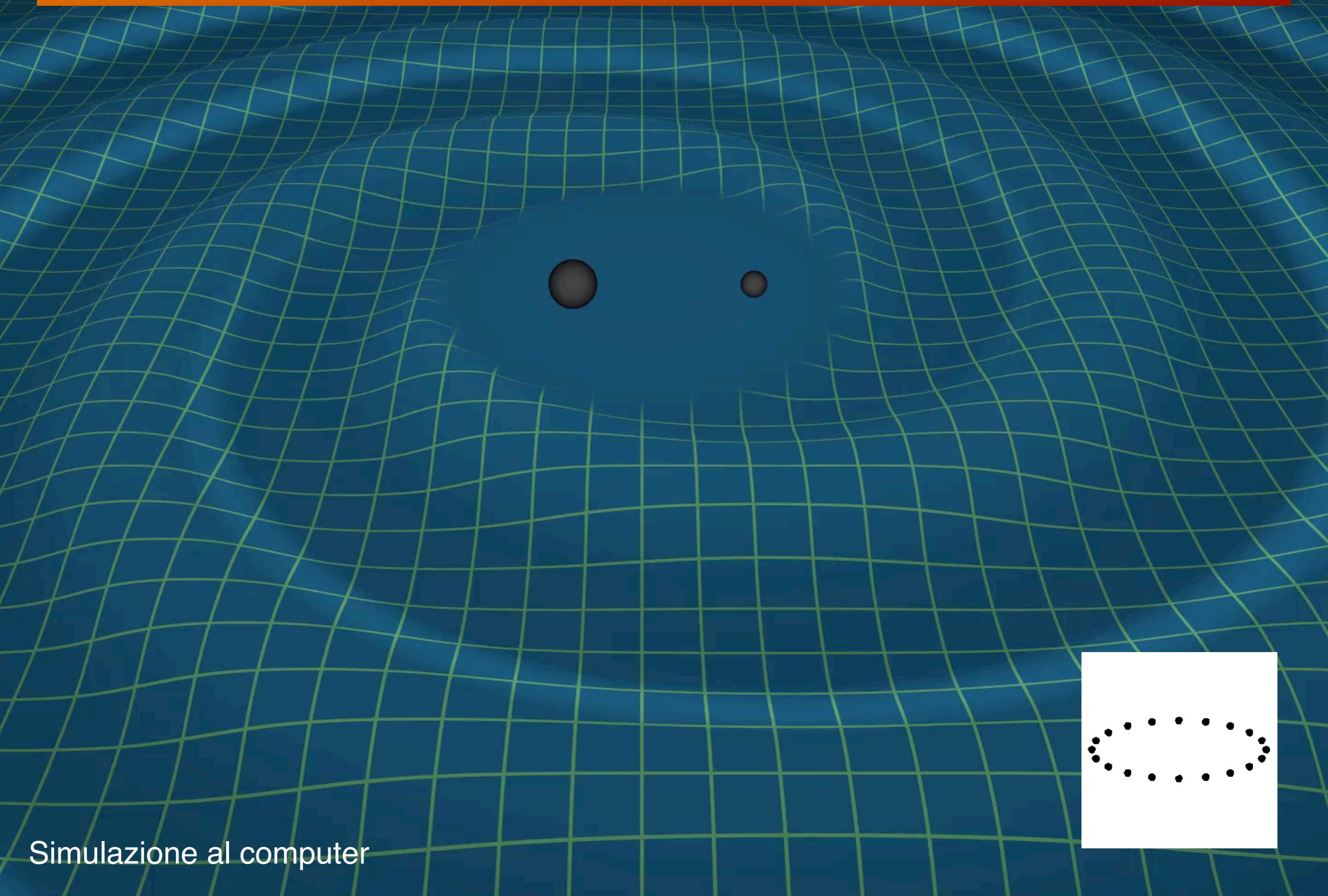
Cigno X-1

Immagine nei raggi X

Massa del buco nero: 15 volte la massa del Sole

Distanza: 5900 anni luce

Fusione di buchi neri: forte sorgente di onde gravitazionali



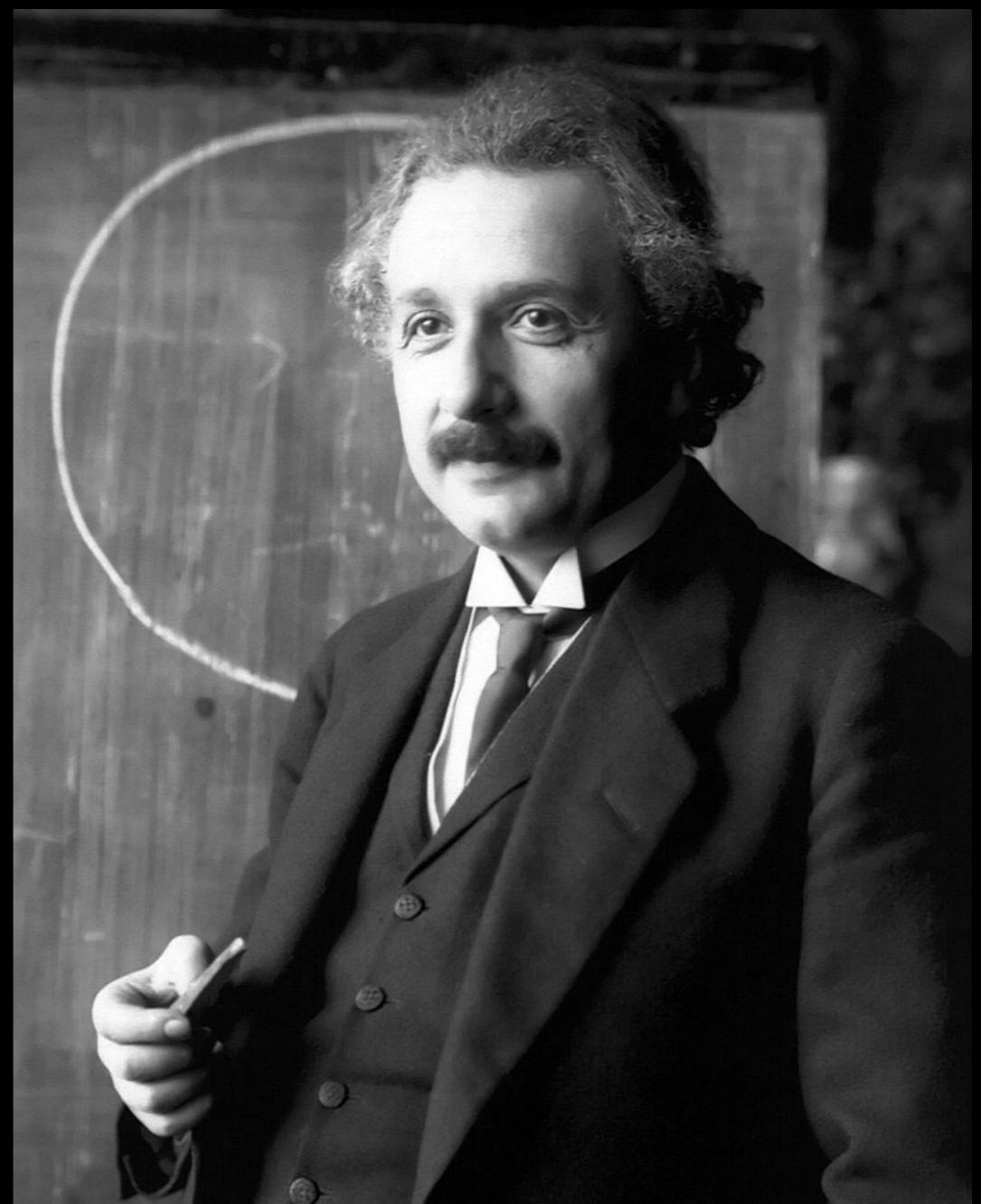
Simulazione al computer

Le onde gravitazionali

1915: Albert Einstein pubblica la teoria della Relatività Generale

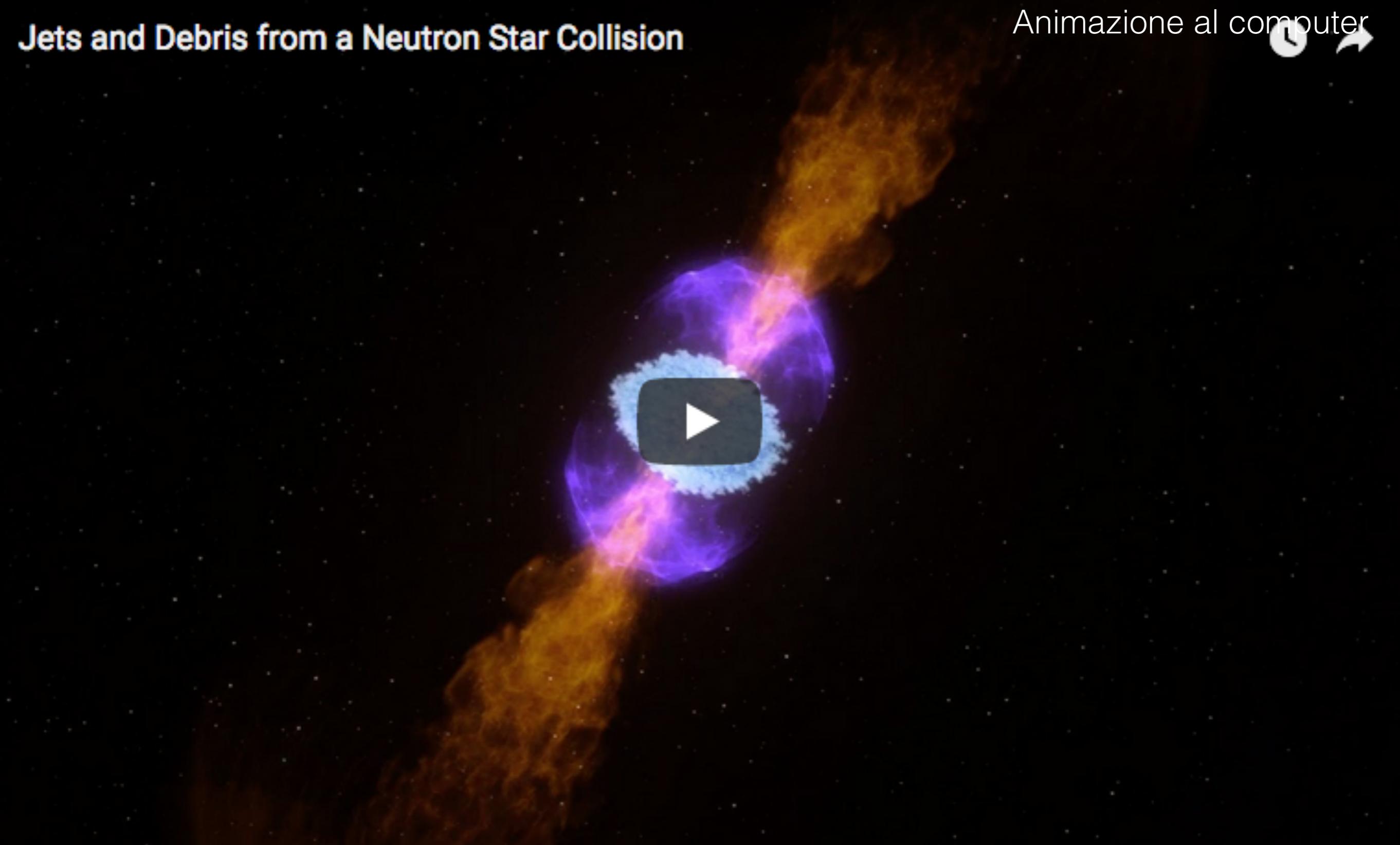
1916: la Relatività Generale prevede l'esistenza delle onde gravitazionali

Definizione: oggetti con massa e in moto generano cambiamenti della curvatura dello spazio-tempo che si propagano alla velocità della luce in modo ondulatorio



Jets and Debris from a Neutron Star Collision

Animazione al computer



La Via Lattea nel cielo notturno

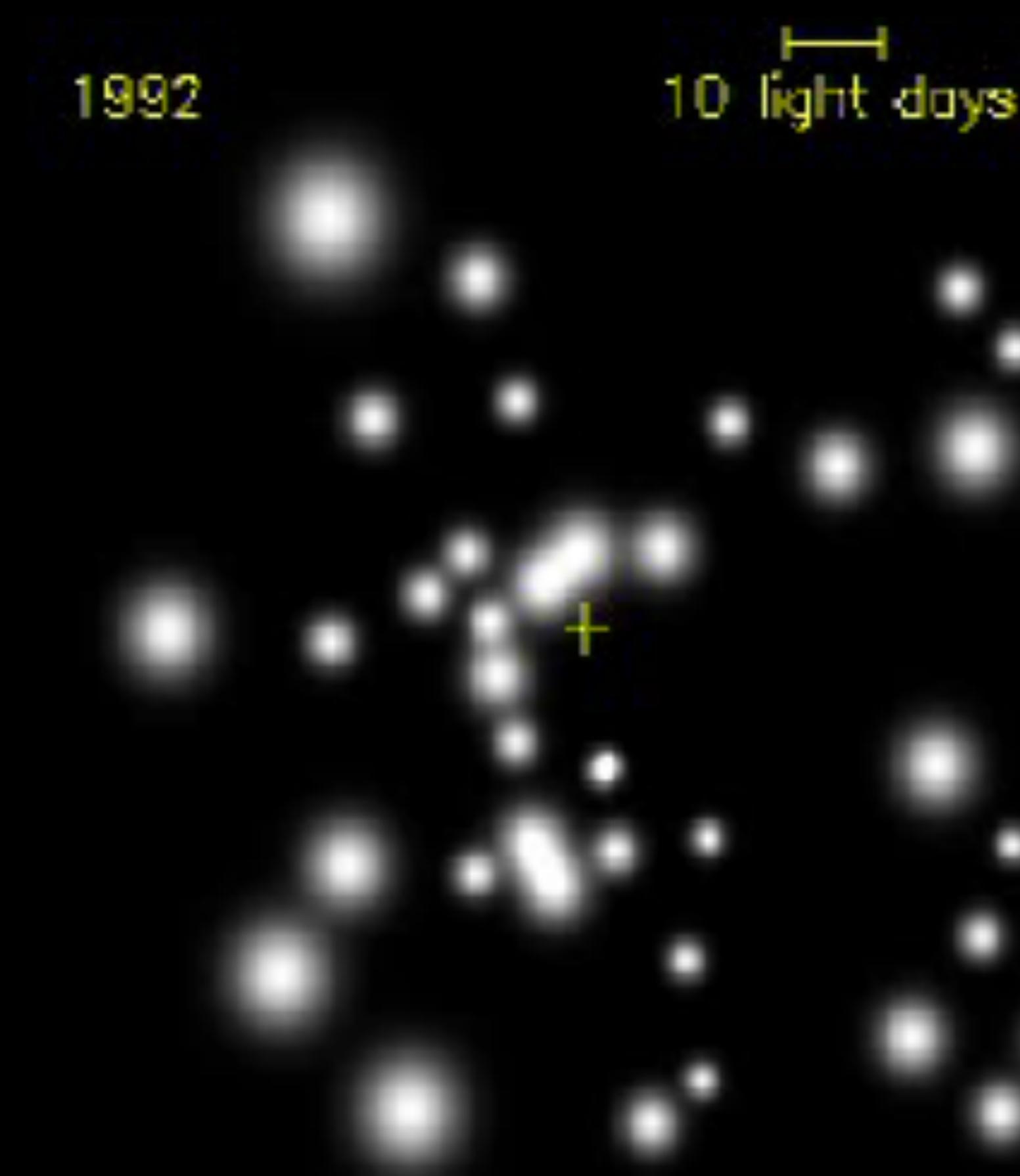
Centro della nostra Galassia



Una gemella della nostra Galassia



Black hole at the center of the Milky Way



Spiral galaxies

Edge on spiral galaxy



NGC 891

Face on spiral galaxy



NGC 6744

Irregular galaxies



Dwarf elliptical galaxies

Leo I
(distance 250 kpc)

Galassie interagenti



Galassie Antenne

Distanza: 63 milioni di anni luce

Galaxies with very luminous center (*Active Galactic Nuclei*)

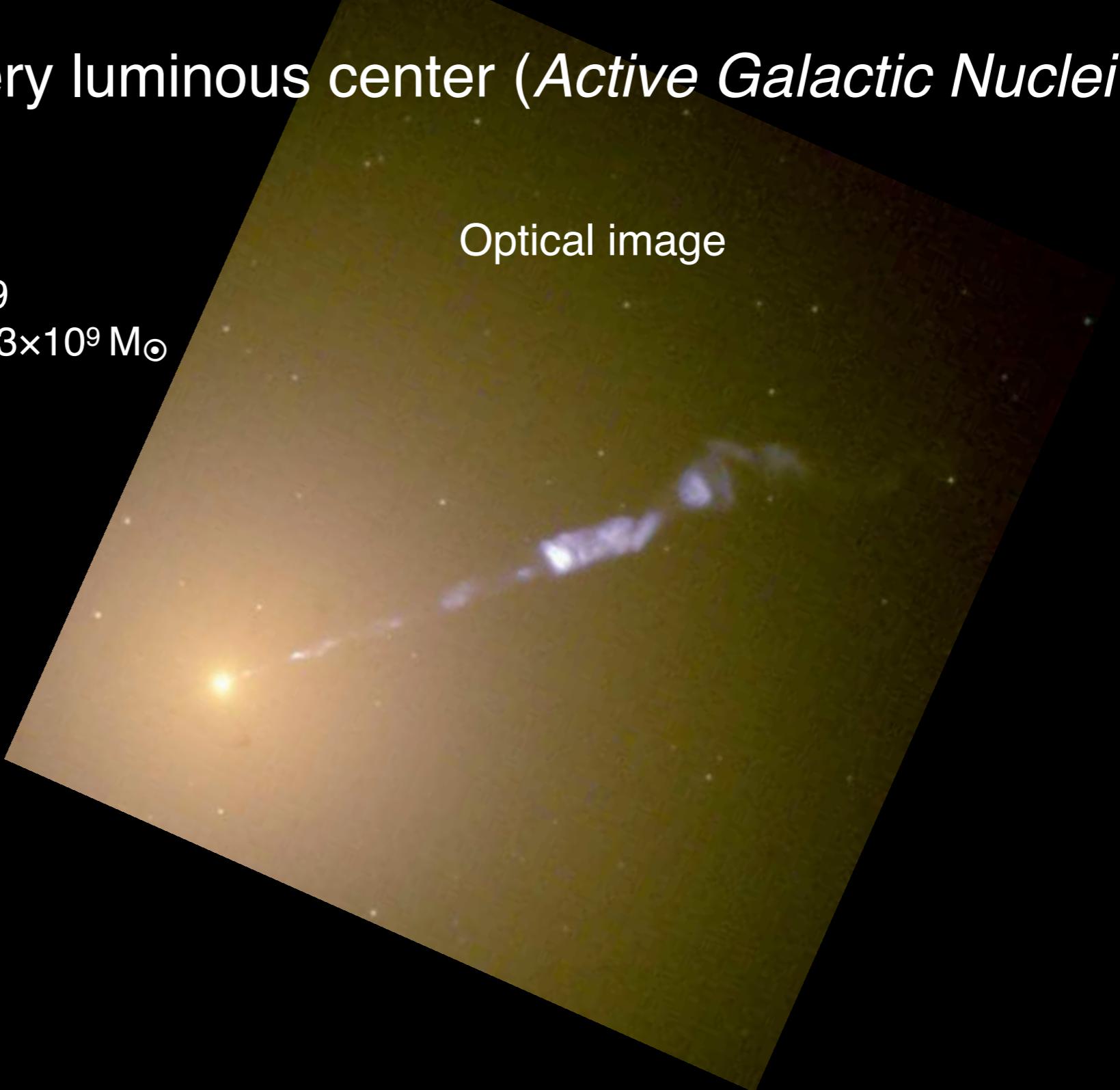
Radio galaxy **Messier 87**

Distance: 16.40 ± 0.50 Mpc

Apparent magnitude: $mV = 9.59$

Mass central black hole: $M_{\text{BH}} = 3 \times 10^9 M_{\odot}$

Optical image



Galaxies with very luminous center (*Active Galactic Nuclei*)

Radio galaxy **Messier 87**

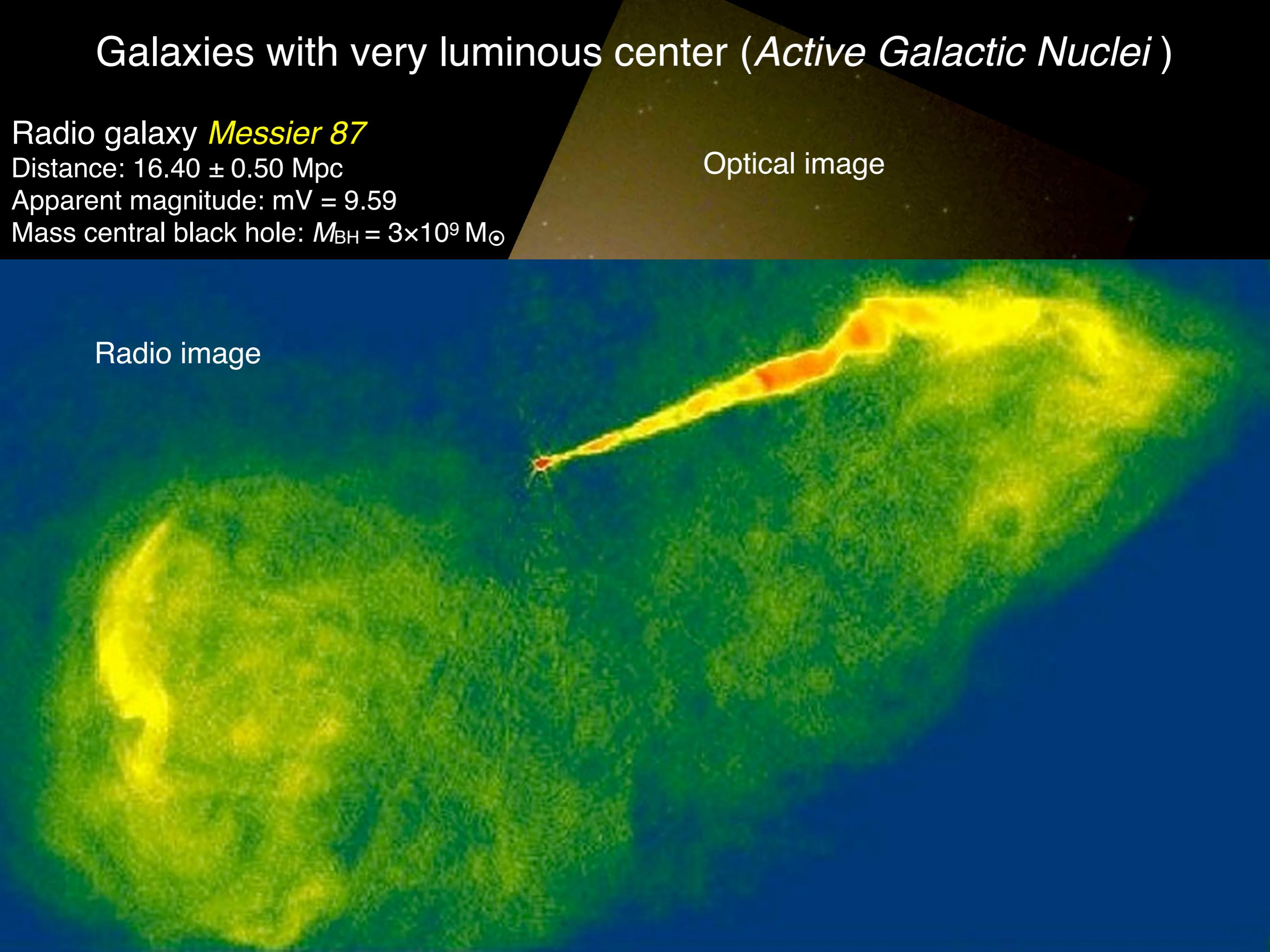
Distance: 16.40 ± 0.50 Mpc

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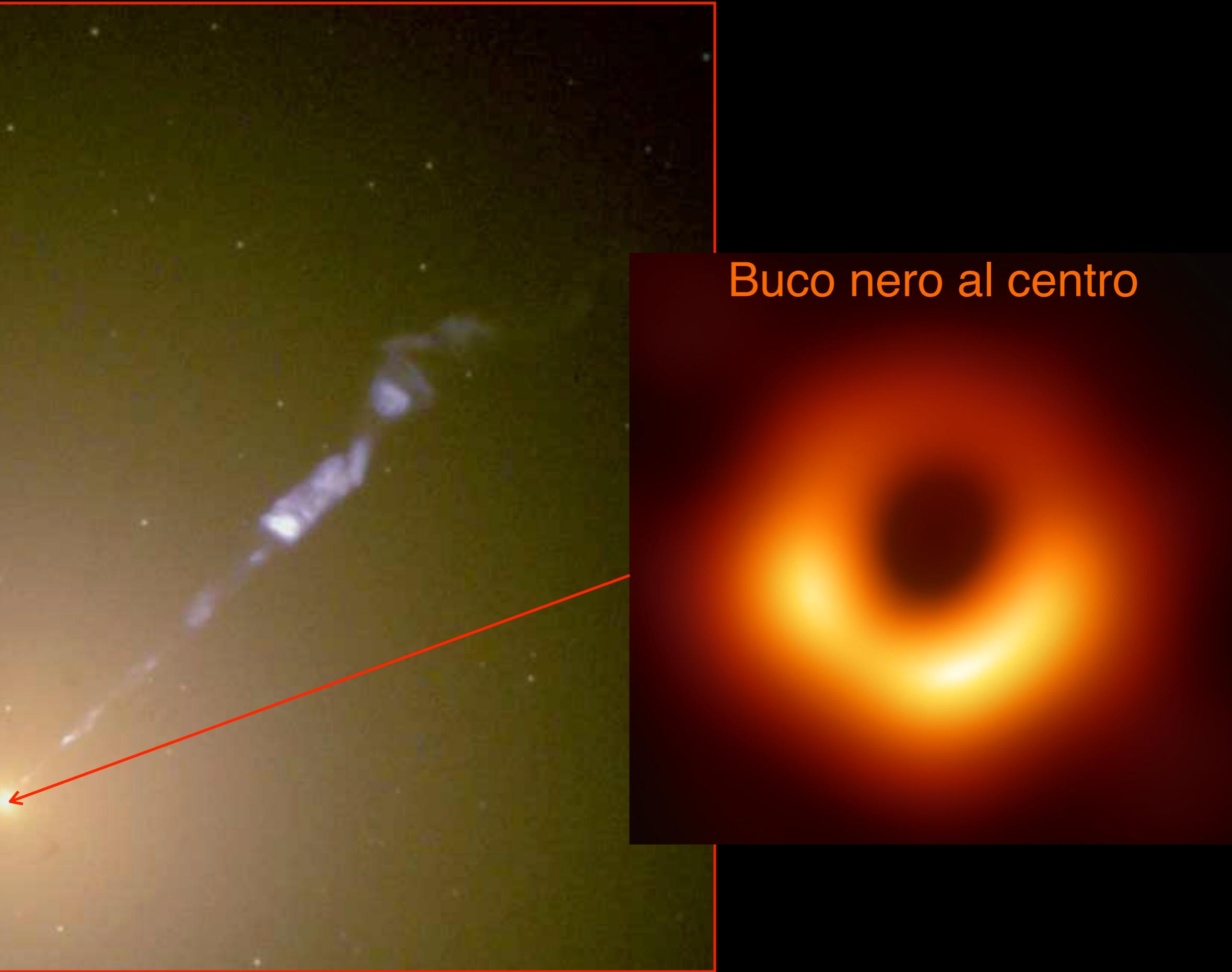
Mass central black hole: $M_{\text{BH}} = 3 \times 10^9 M_{\odot}$

Optical image

Radio image



Messier 87: una delle galassie più grandi dell'universo



L'ammasso di galassie più vicino alla Via Lattea

Ammasso della Vergine

1500 galassie circa



Messier 87: una delle galassie più grandi dell'universo

Presenza di materia oscura negli ammassi di galassie

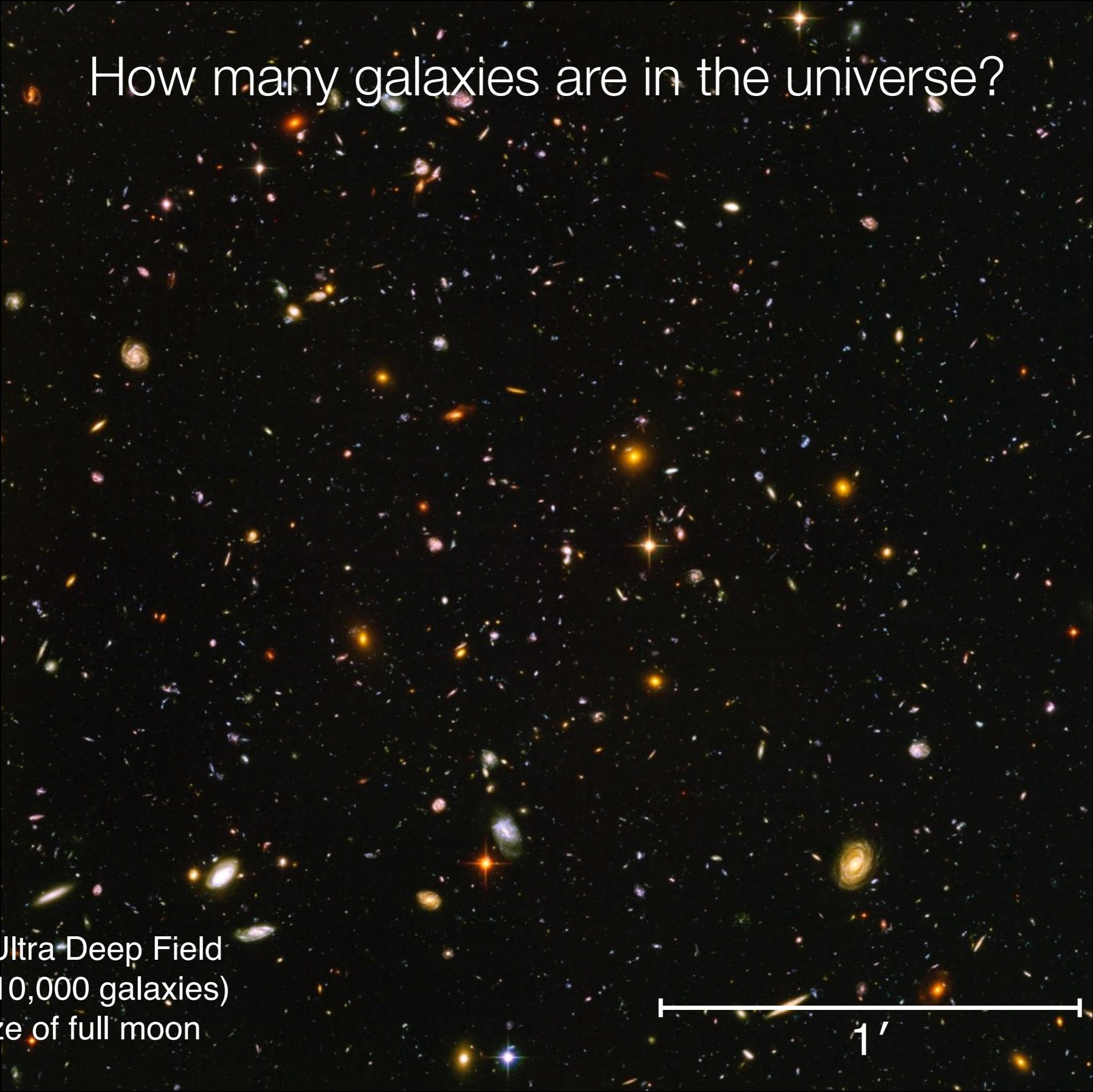


Coma Galaxy Cluster
Distance: 102 Mpc

Effetto di lente gravitazionale negli ammassi di galassie



How many galaxies are in the universe?



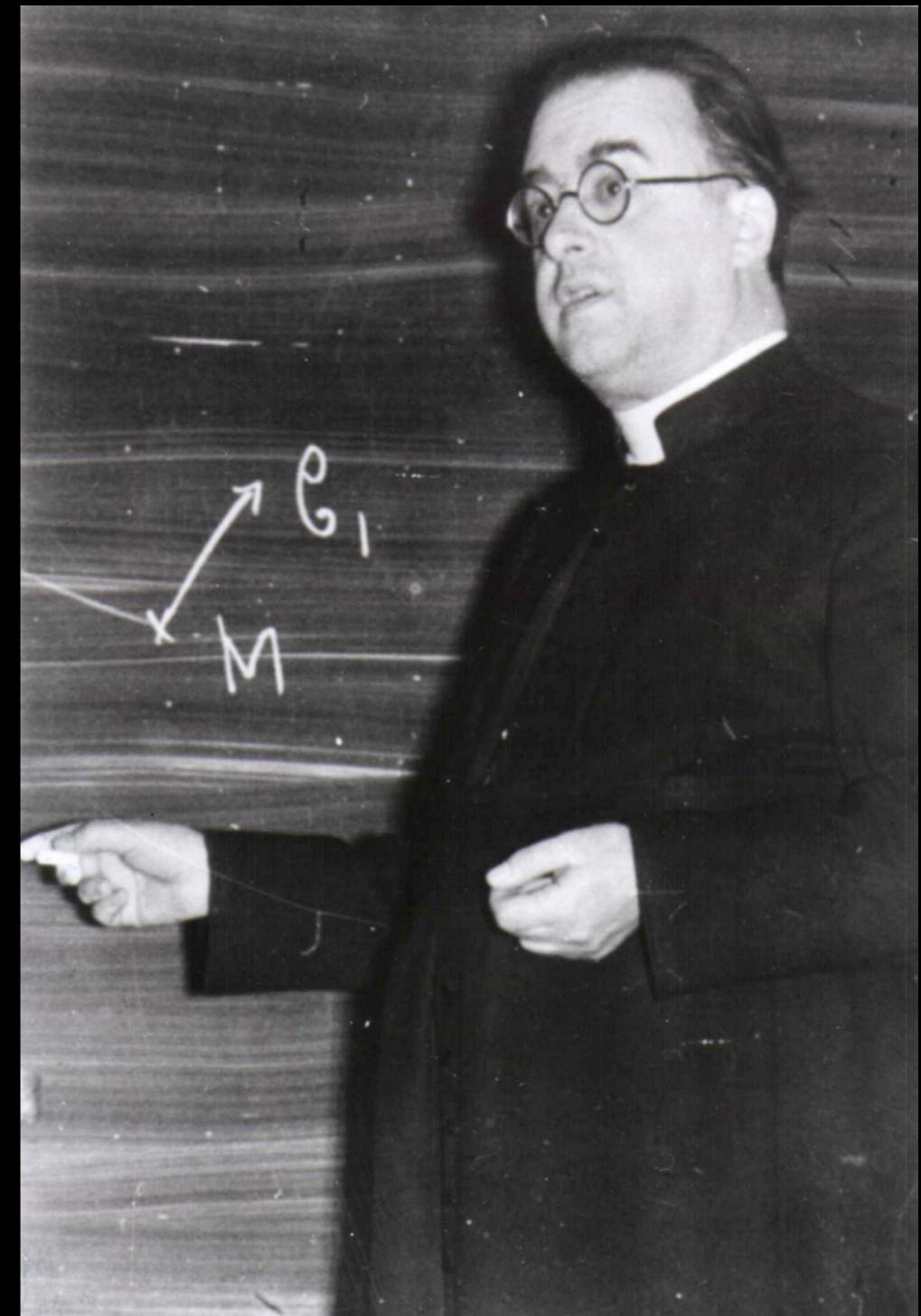
Hubble Ultra Deep Field
(almost 10,000 galaxies)
1/122 size of full moon

1'

1915: A. Einstein formulates the Theory of General Relativity



1927: Monsignor Georges Lemaître introduces the *Big Bang* & expansion of the Universe

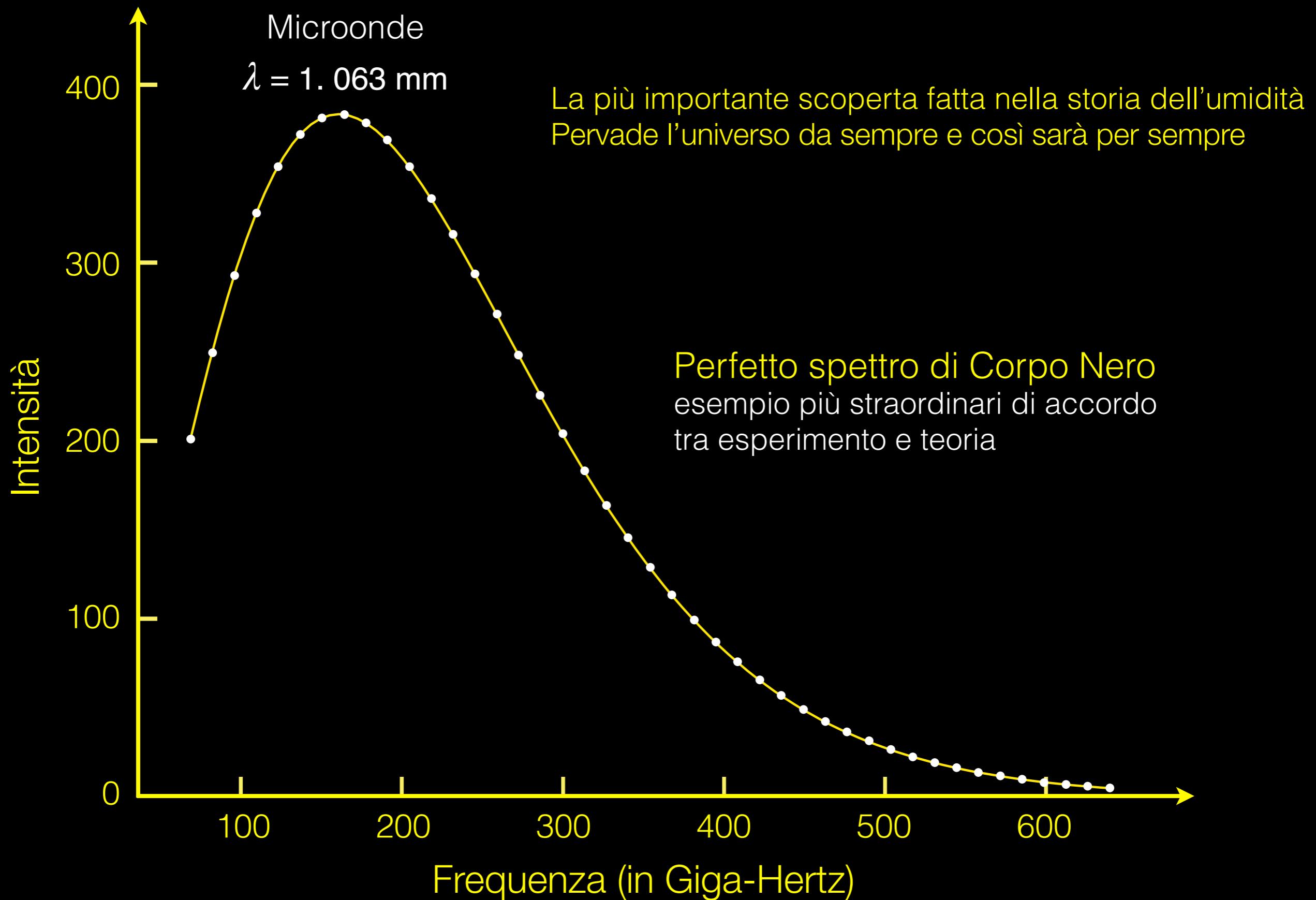


Fotografia del passato dell'universo e conferma del Big Bang ($t = 380$ mila anni dopo)

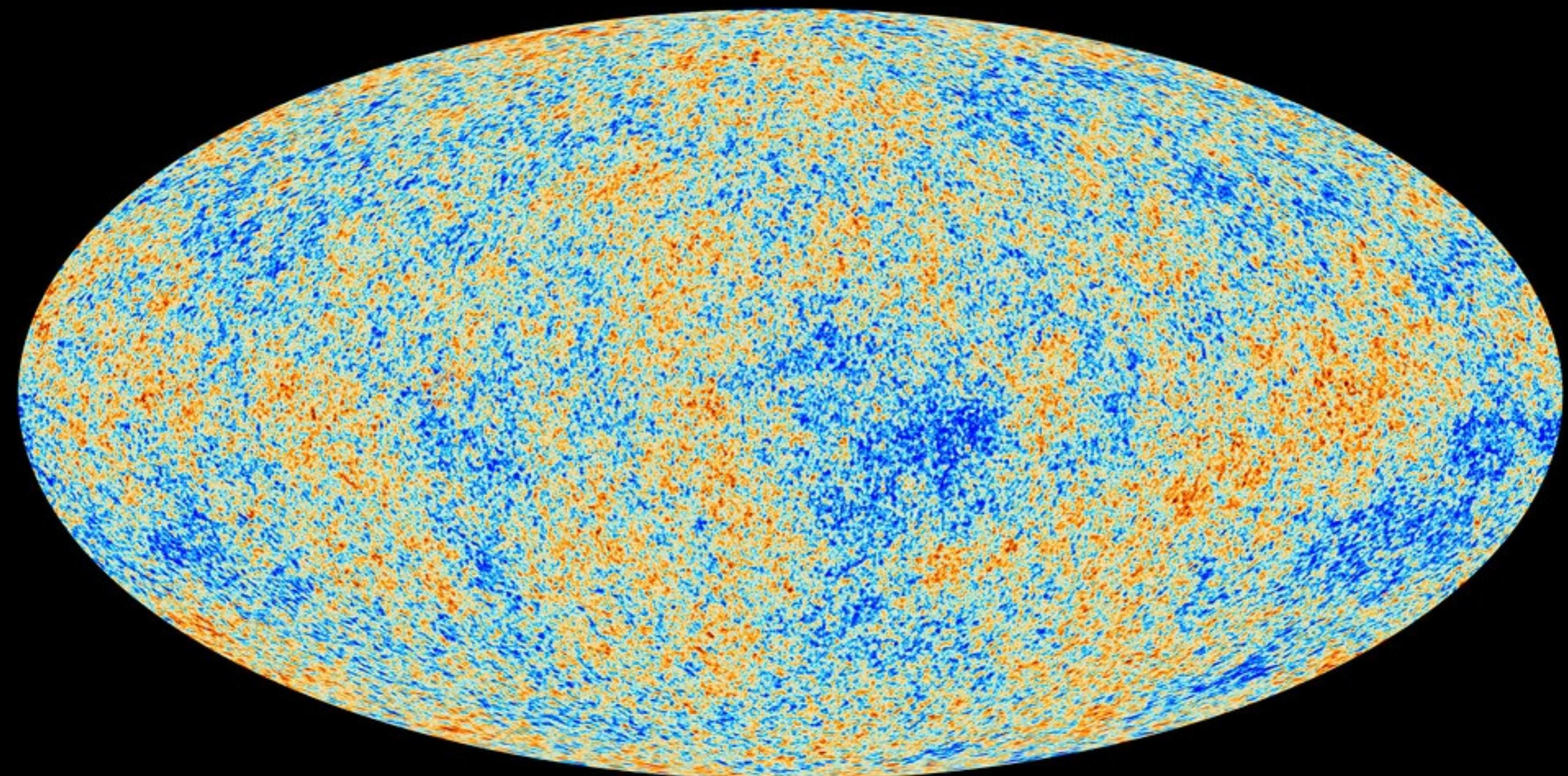
Radiazione cosmica di fondo è uguale in ogni punto (isotropia)
Temperatura: $T = 2.72548 \pm 0.00057$ K

0  3.64 K

Radiazione cosmica di fondo

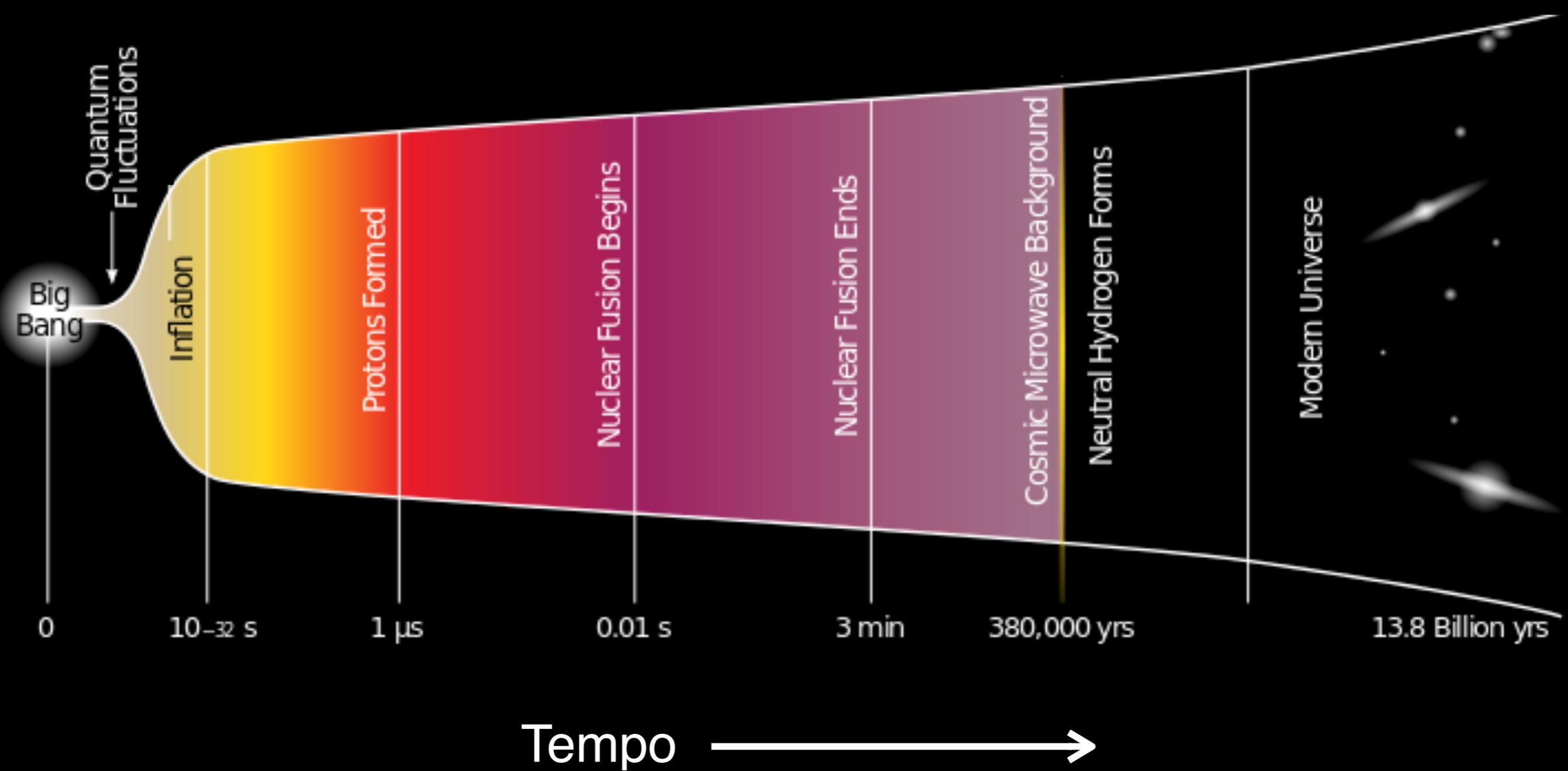


Anisotropies of Cosmic Microwave Background

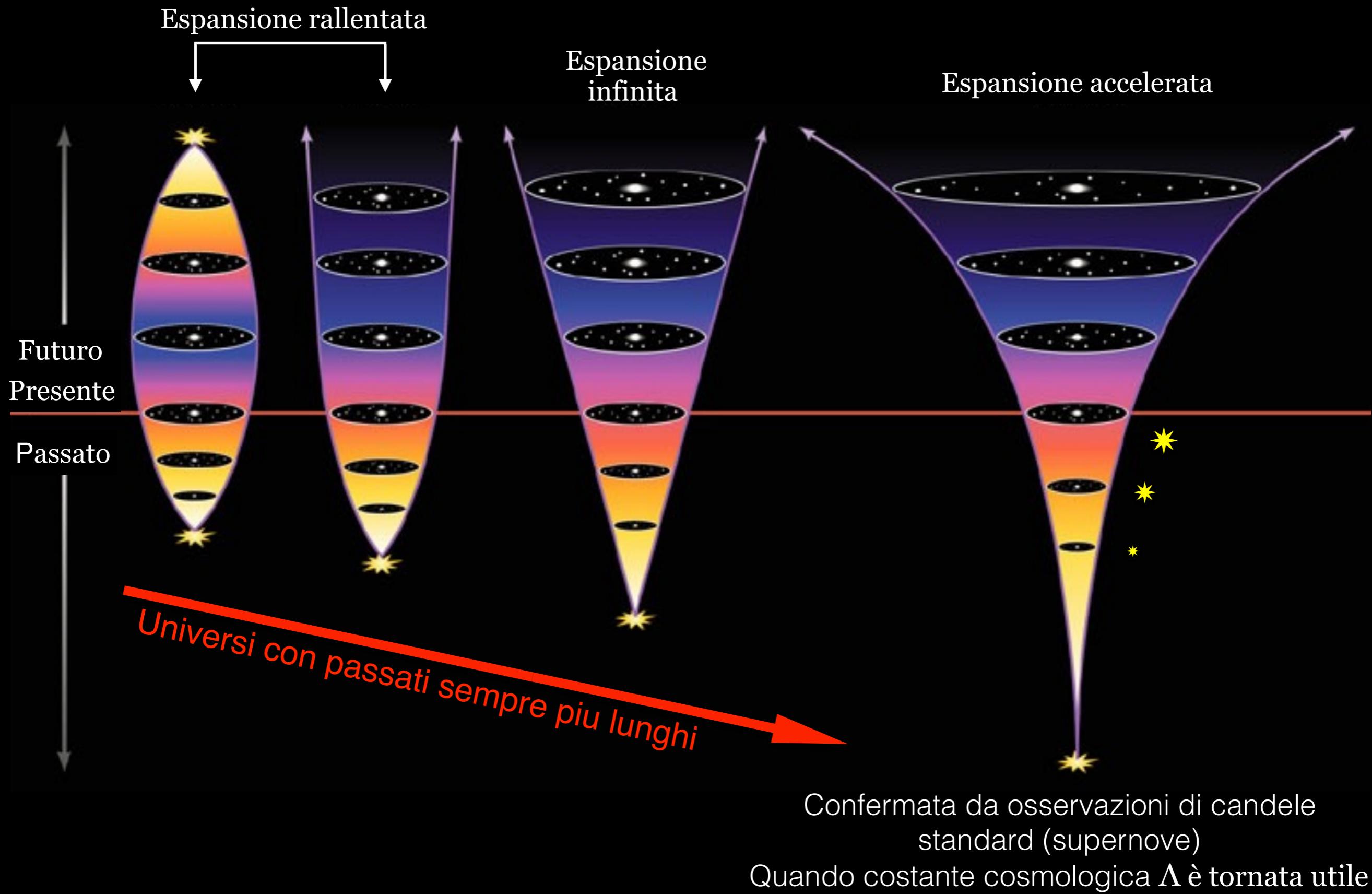


All-sky surveys from ESA's Planck space telescope

Storia dell'Universo da $t = 0$ ad oggi



Possibili modelli di espansione dell'universo



Di cosa è fatto l'universo oggi

