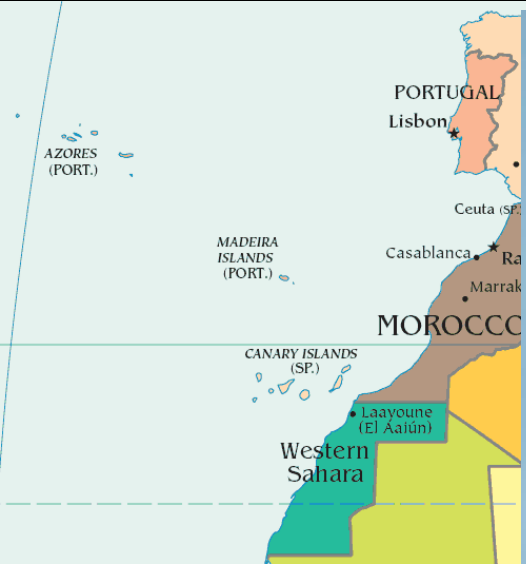
OSSERVATORIO ASTRONOMICO DI BRERA

INAF ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Vedere l'invisibile: l'astronomia X

Stefano Sandrelli

INAF ISTITUTO NAZIONALE DI ASTROFISICA



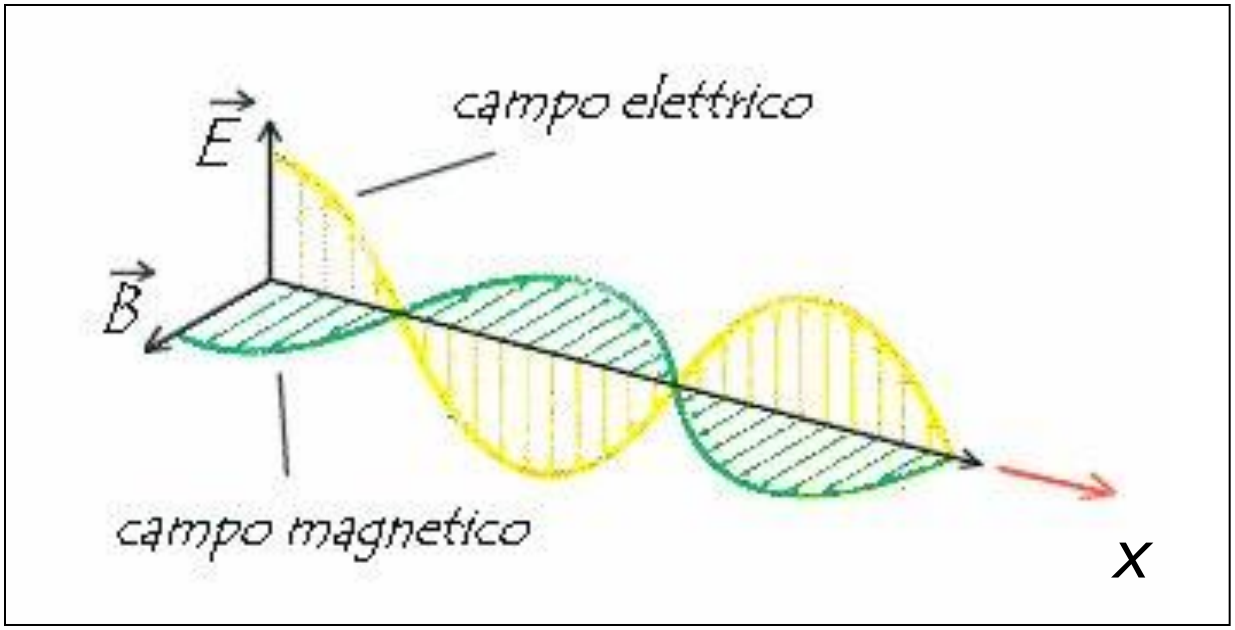

LBT
Ø 2 x 8,4 m
Arizona
Subaru – Giap.
Ø 8,2 m
Hawaii
Keck I & II - CalTech
Ø 10 m
Hobby Eberly
Ø 11 m
Texas
spettroscopia
TNG
Ø 3,5 m
Canarie
VLT - ESO
Ø 4 x 8 m
Paranal Observatory
Atacama
Cile
Magellan
Ø 2 x 6,5 m
Las Campanas


Arizona
Phoenix
st, Arizona, Stati Uniti


05 05 2000


nuvole
arcobaleno

Onde elettromagnetiche

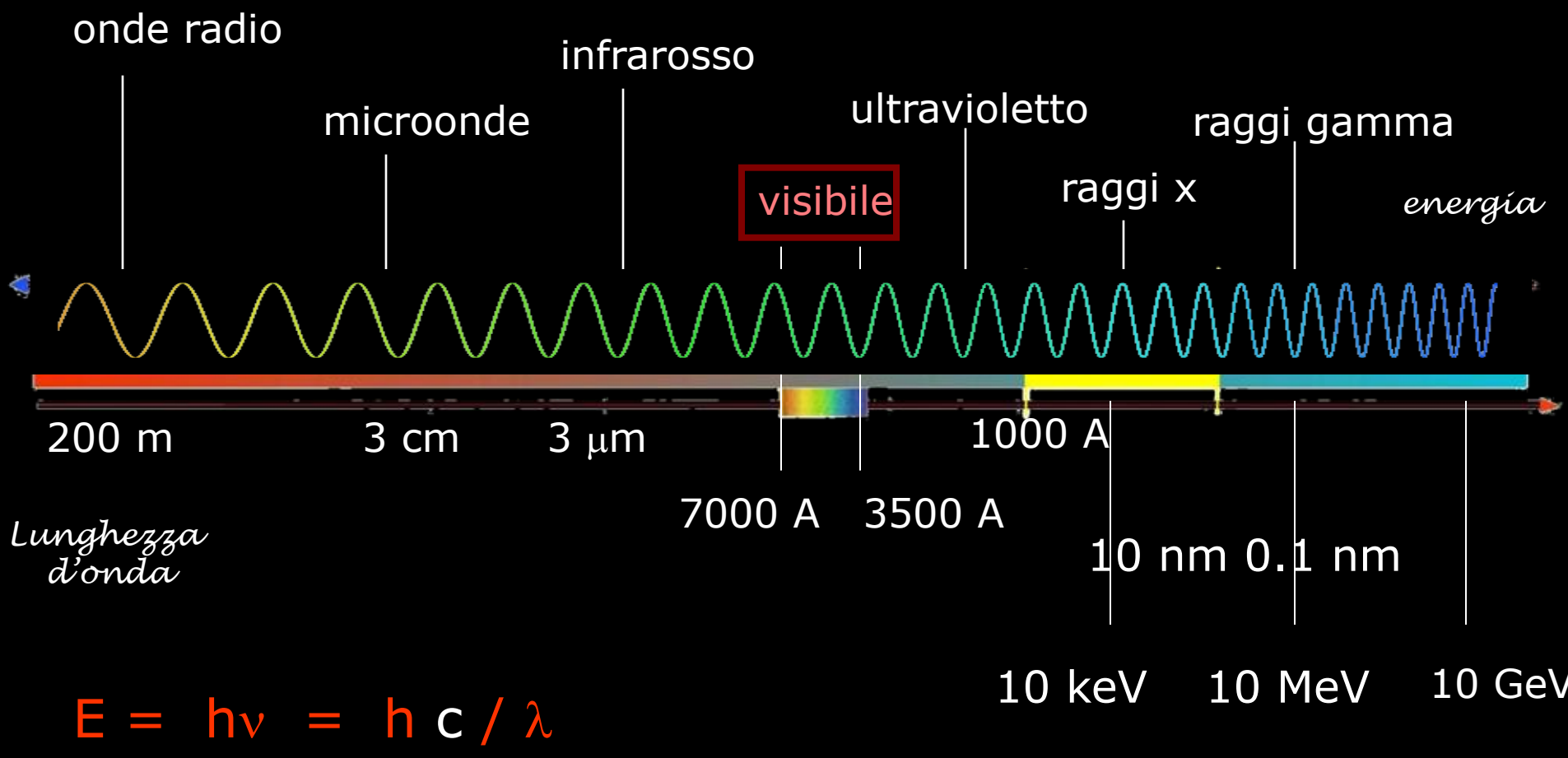


lunghezza d'onda

energia trasportata

velocità della luce

I raggi X sono onde elettromagnetiche

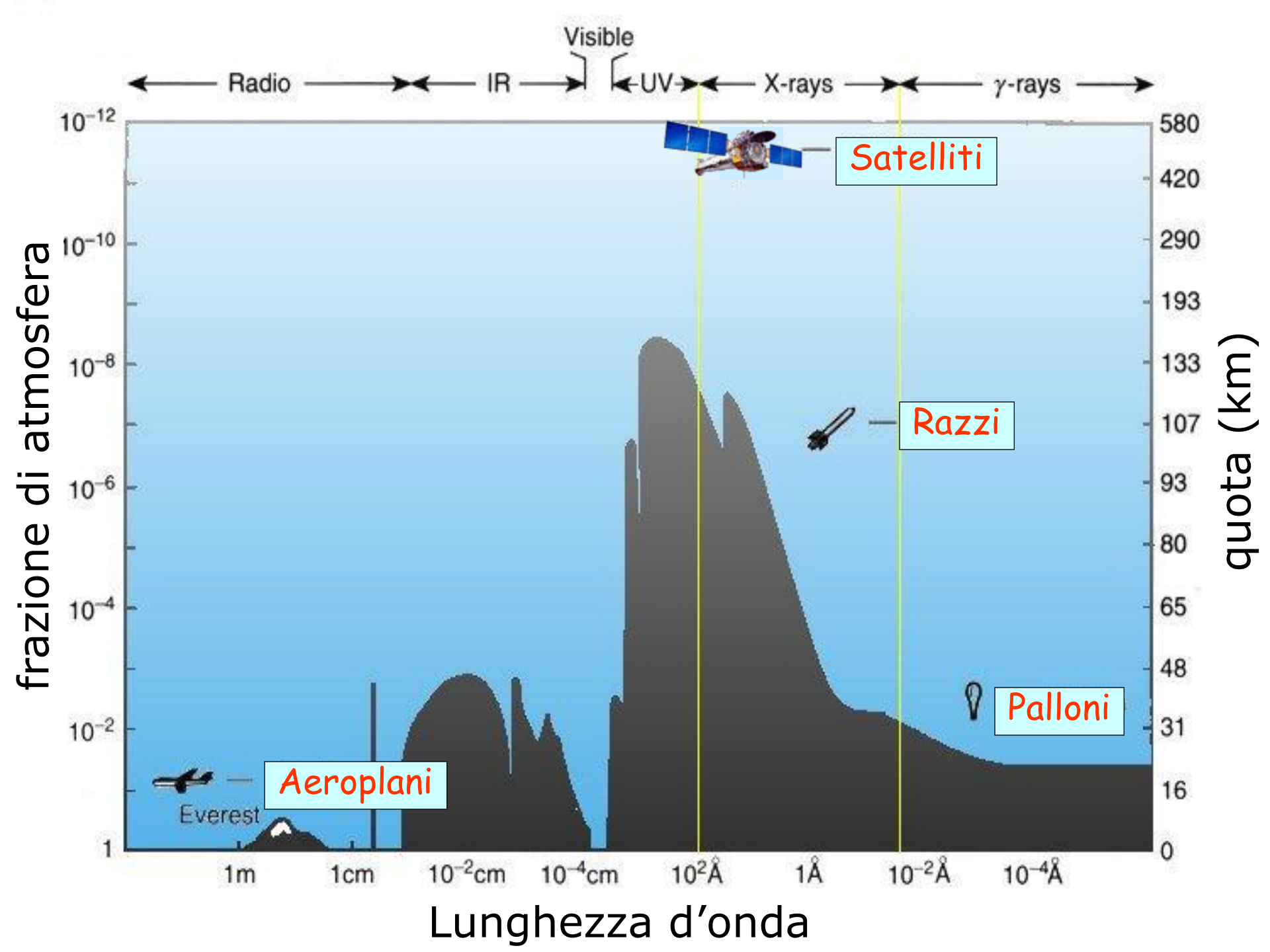


$E = h\nu = h\,c / \lambda$

Che cosa è l'eV ?

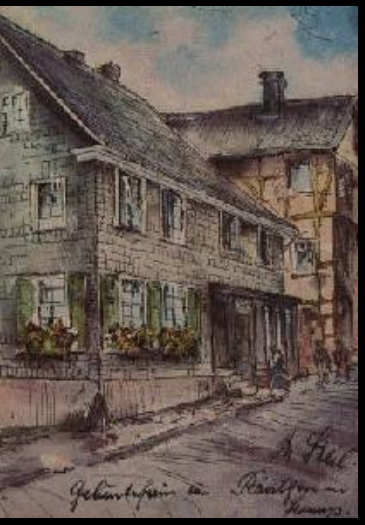
$1\ eV = 1{,}6\ 10^{-19}\ J$

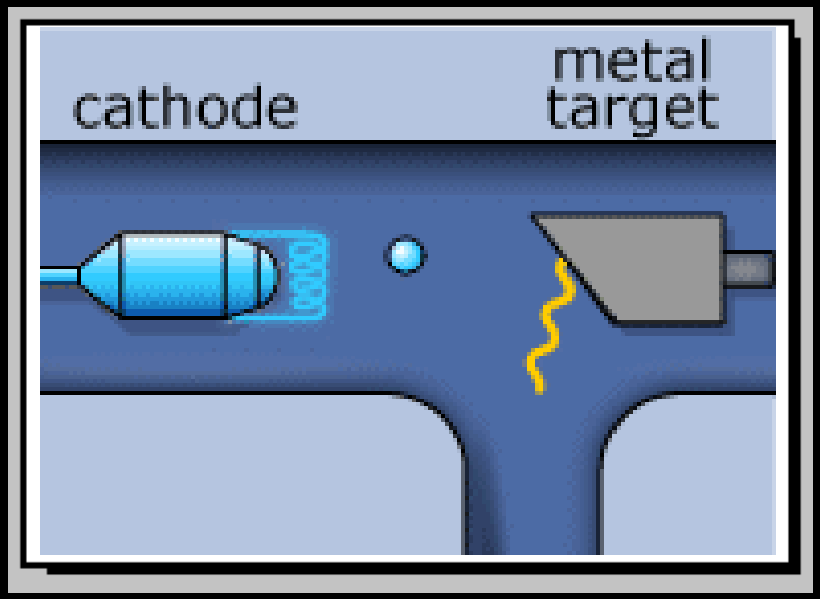
$1\ MeV = 10^{6}\ eV$


Visible
Radio
IR
UV
X-rays
γ-rays
Satelliti
Razzi
Palloni
Aeroplani
Everest
frazione di atmosfera
quota (km)
Lunghezza d'onda
10⁻¹²
10⁻¹⁰
10⁻⁸
10⁻⁶
10⁻⁴
10⁻²
1
580
420
290
193
133
107
93
80
65
48
31
16
0
1m
1cm
10⁻²cm
10⁻⁴cm
10²Å
1Å
10⁻²Å
10⁻⁴Å

8 novembre 1895

Laboratorio del prof. Roentgen





Raggi catodici fluorescenza

Alta tensione - vuoto spinto

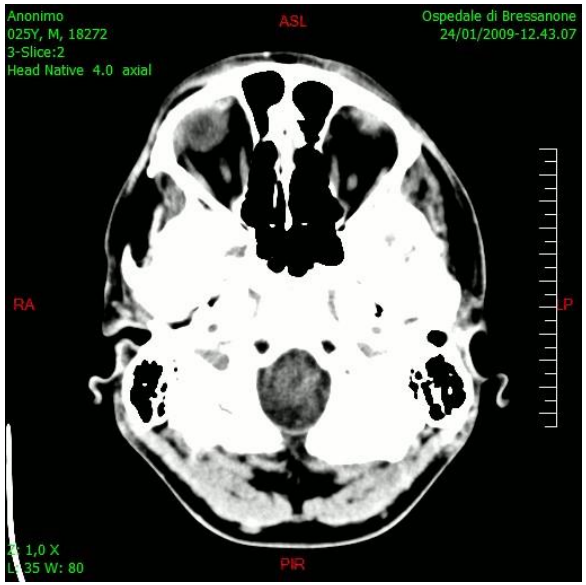
1895

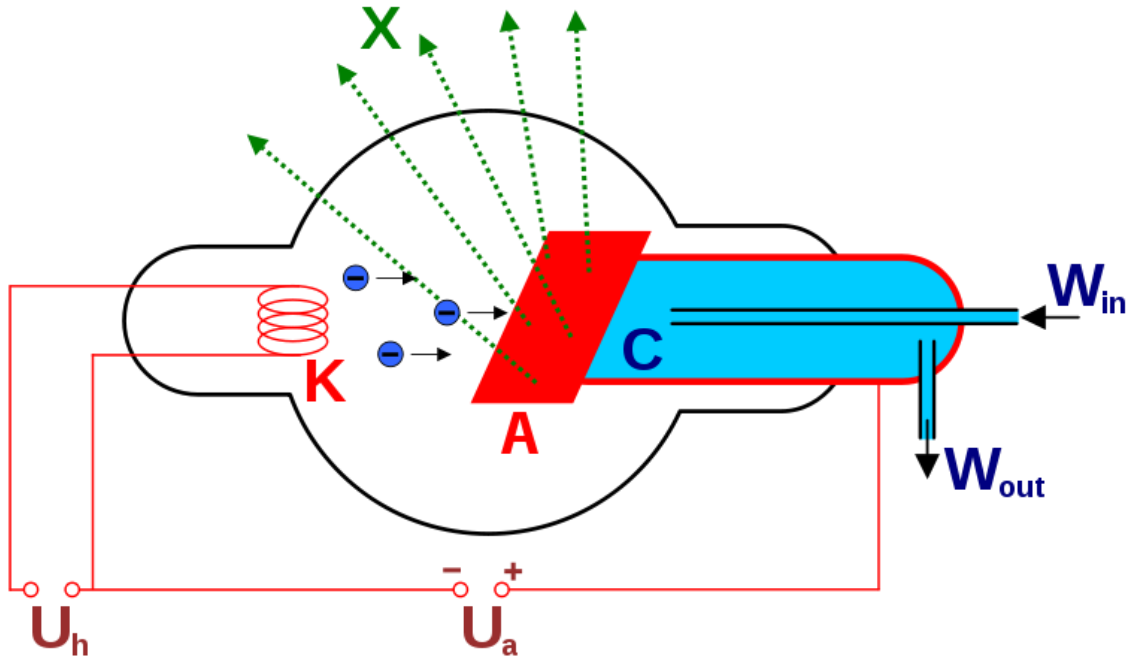
24 dicembre 1895

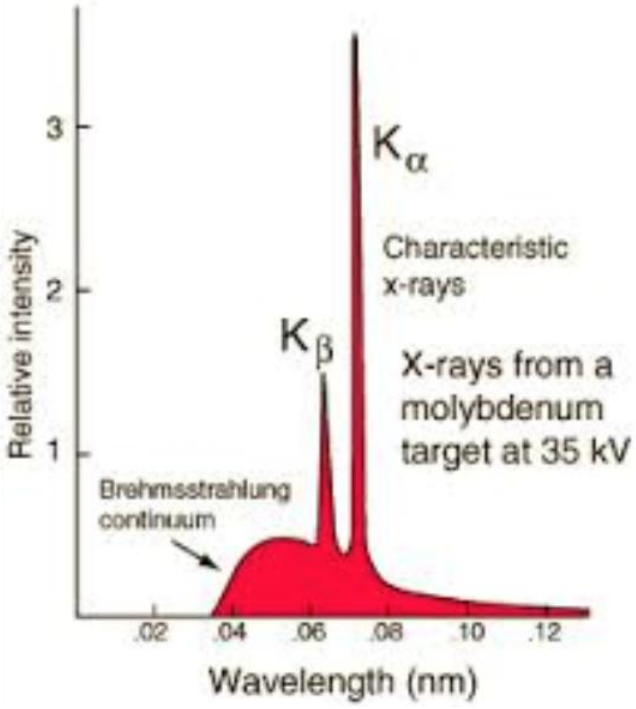
30 minuti di esposizione

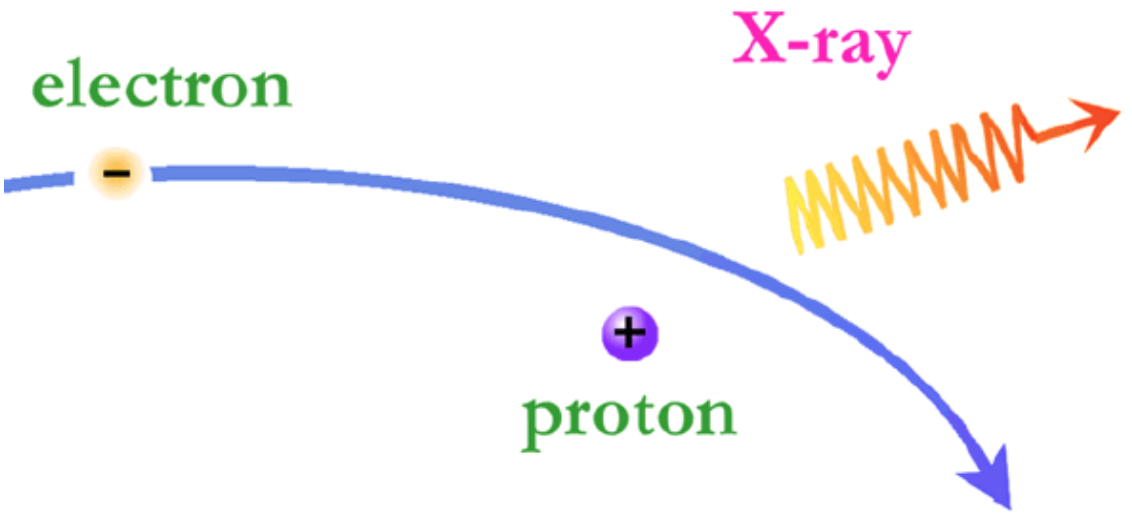
11

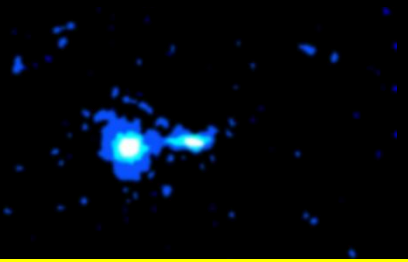
Il tubo radiogeno



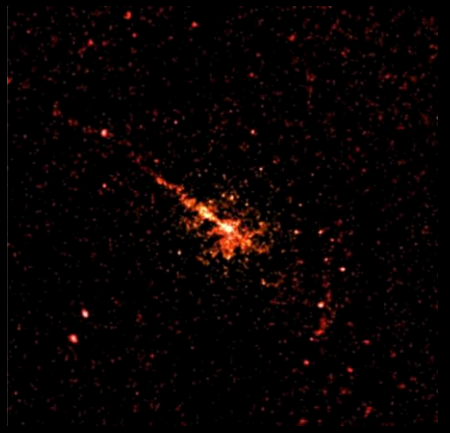


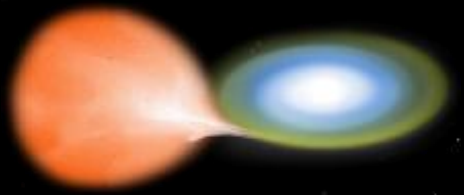


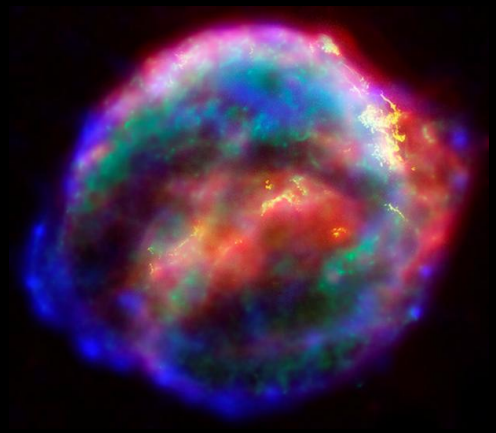




Emissione di raggi X
=
fenomeni
di alta energia








Luce visibile
RAGGI X

Riccardo Giacconi

Premio Nobel per la Fisica

2002

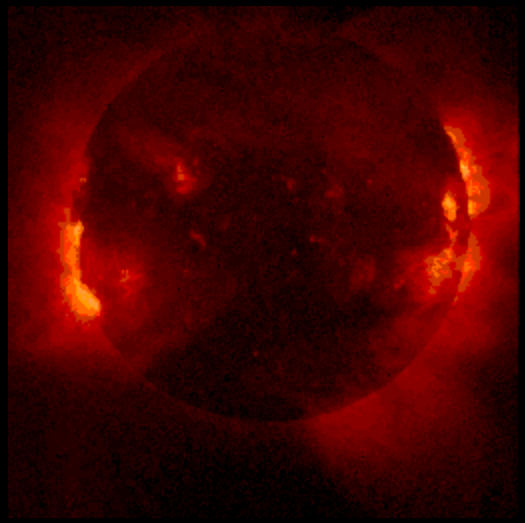
“per aver aperto una nuova finestra sul cosmo”

Bruno Rossi
(13.04.1905 - 21.11.1993)

Giuseppe “Beppo” Occhialini
(5.12.1907 - 30.12.1993)

1962, American Science & Engineering (AS&E)

Riccardo Giacconi, responsabile ricerca in astronomia X

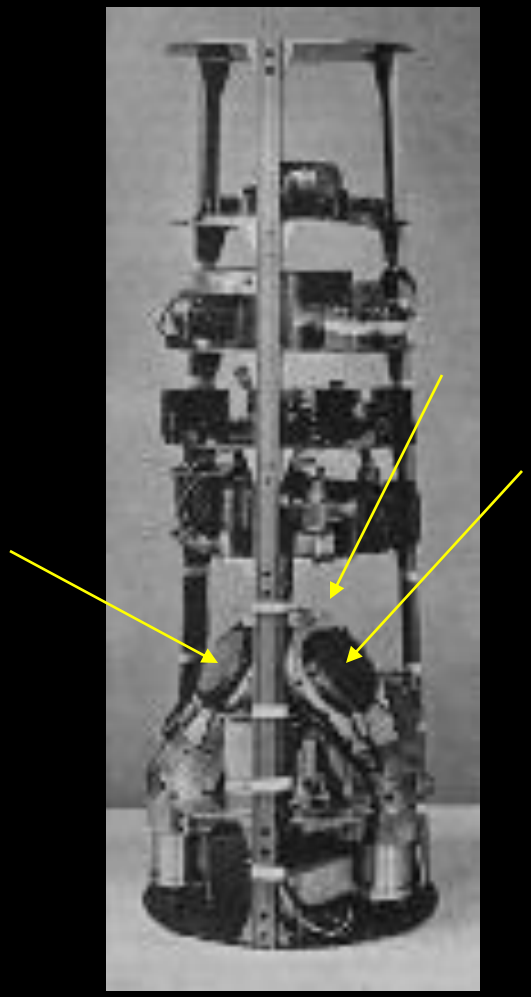


Target

18 giugno 1962

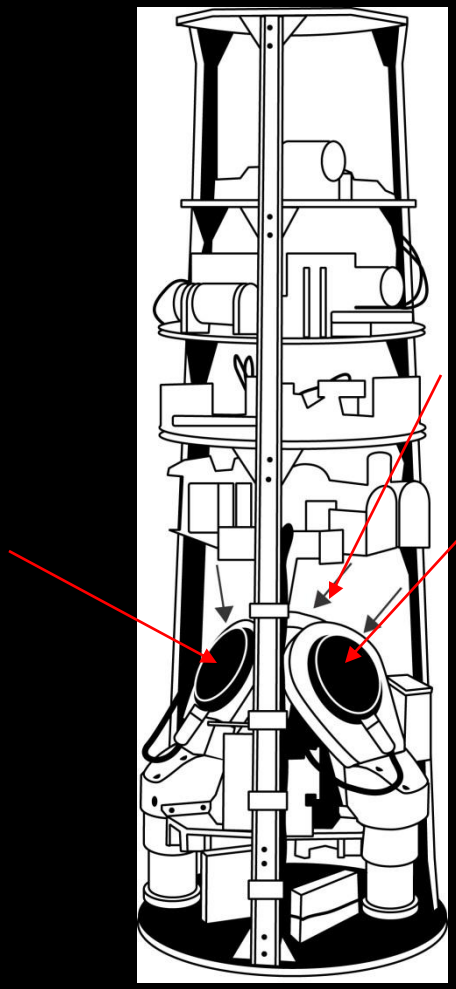
American Science & Engineering, AS&E

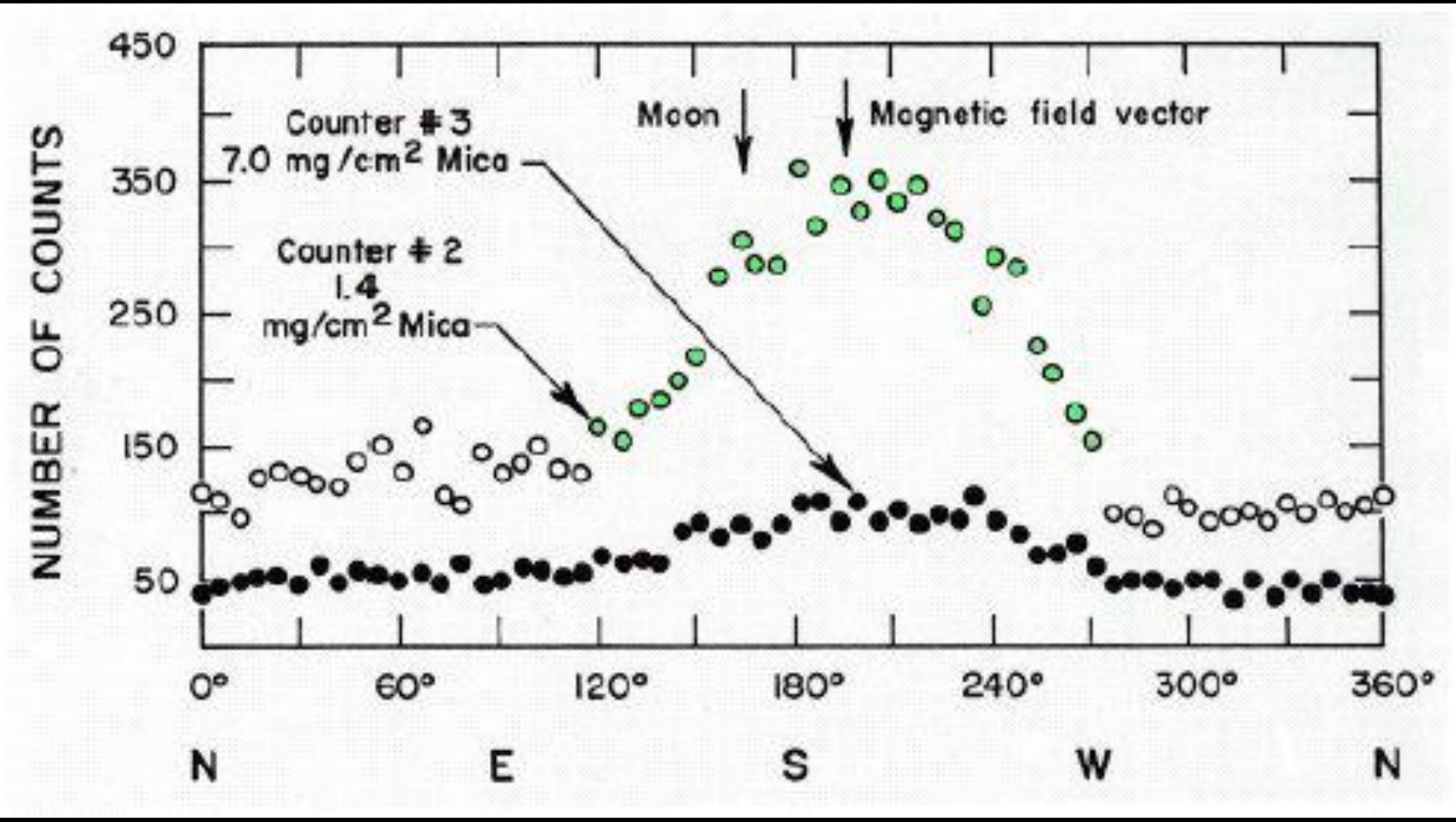
Riccardo Giacconi, Herbert Gursky,
Franck Paolini e Bruno Rossi



3 contatori Geiger

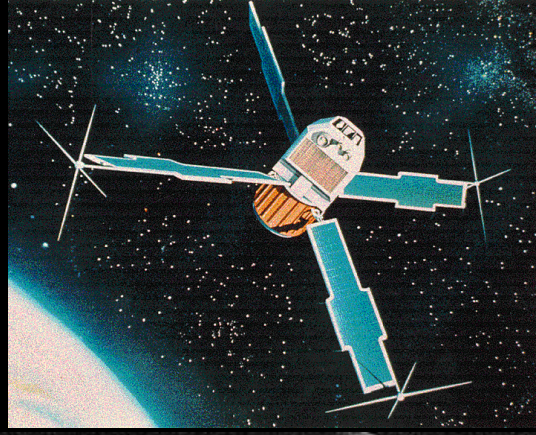
Aerobee Rocket

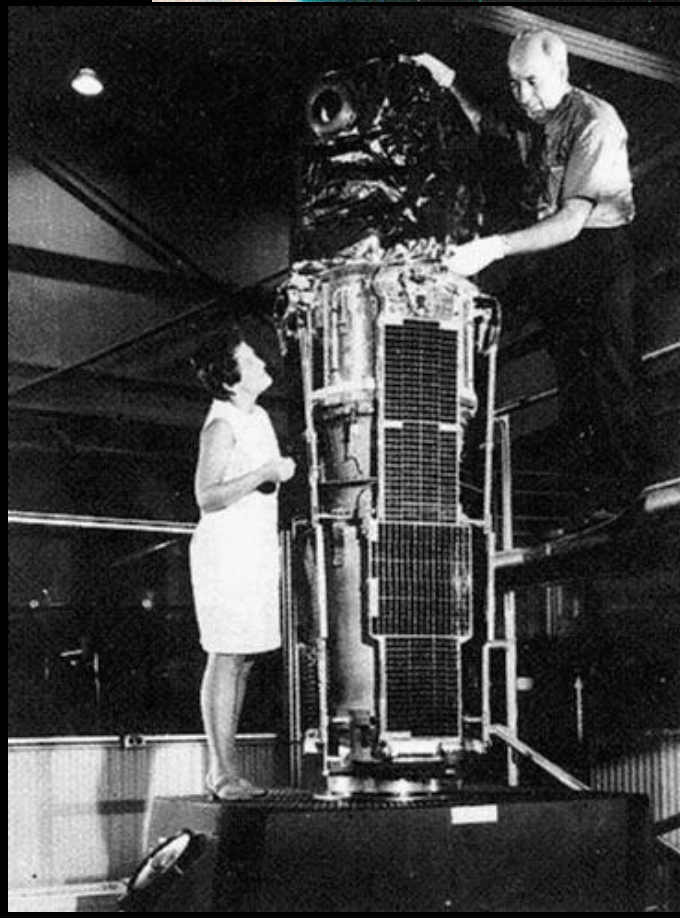


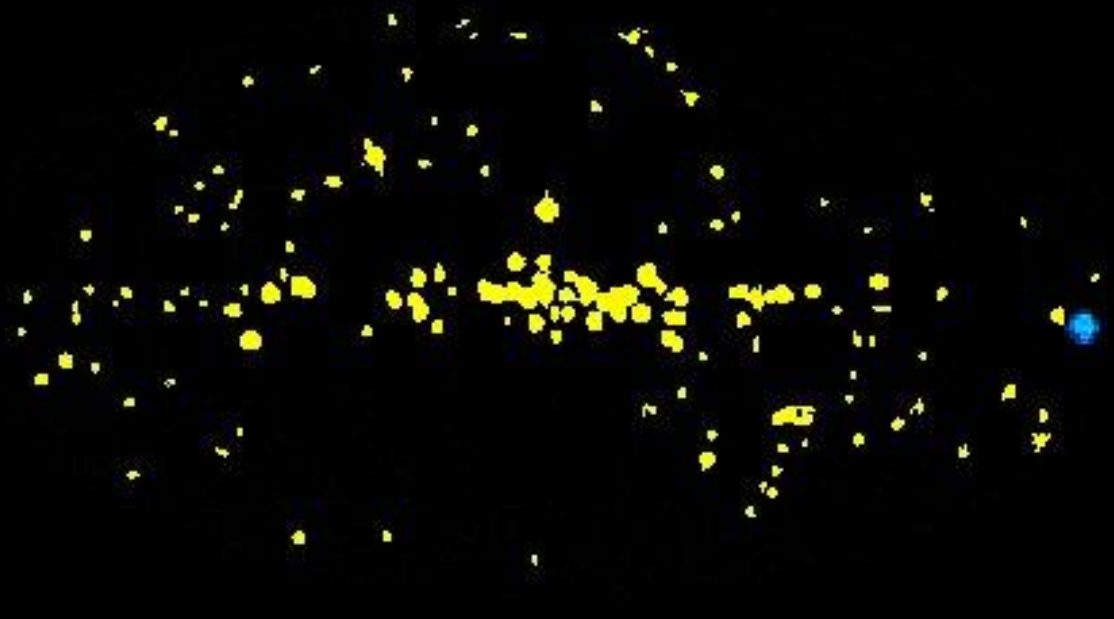

NUMBER OF COUNTS
450
350
250
150
50
Counter #3
7.0 mg/cm² Mica
Counter #2
1.4
mg/cm² Mica
Moon
Magnetic field vector
0°
60°
120°
180°
240°
300°
360°
N
E
S
W
N

Uhuru (1970)

Lanciato dalla base di lancio italiana San Marco, Malindi - Kenya



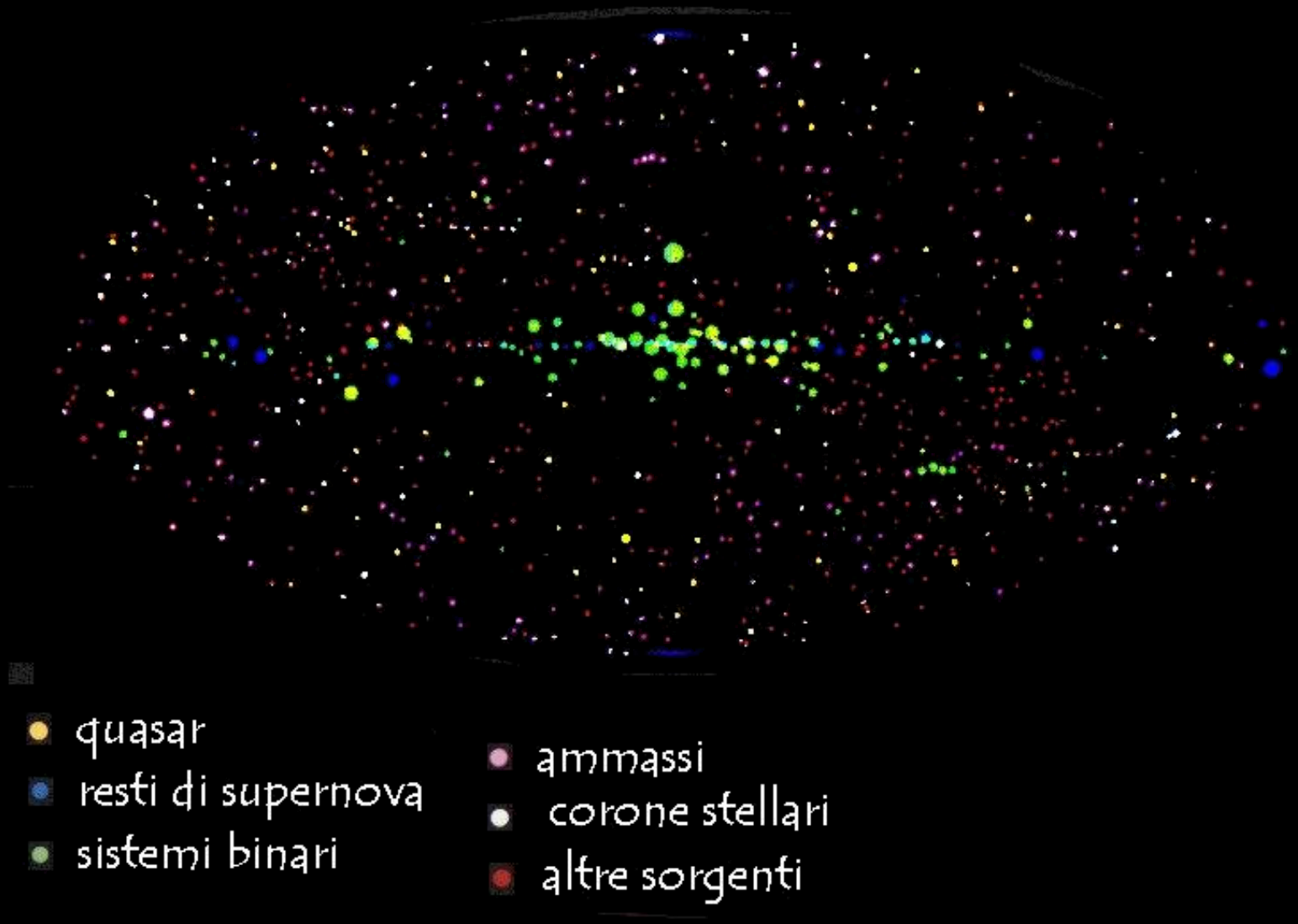




Le sorgenti X scoperte da Uhuru

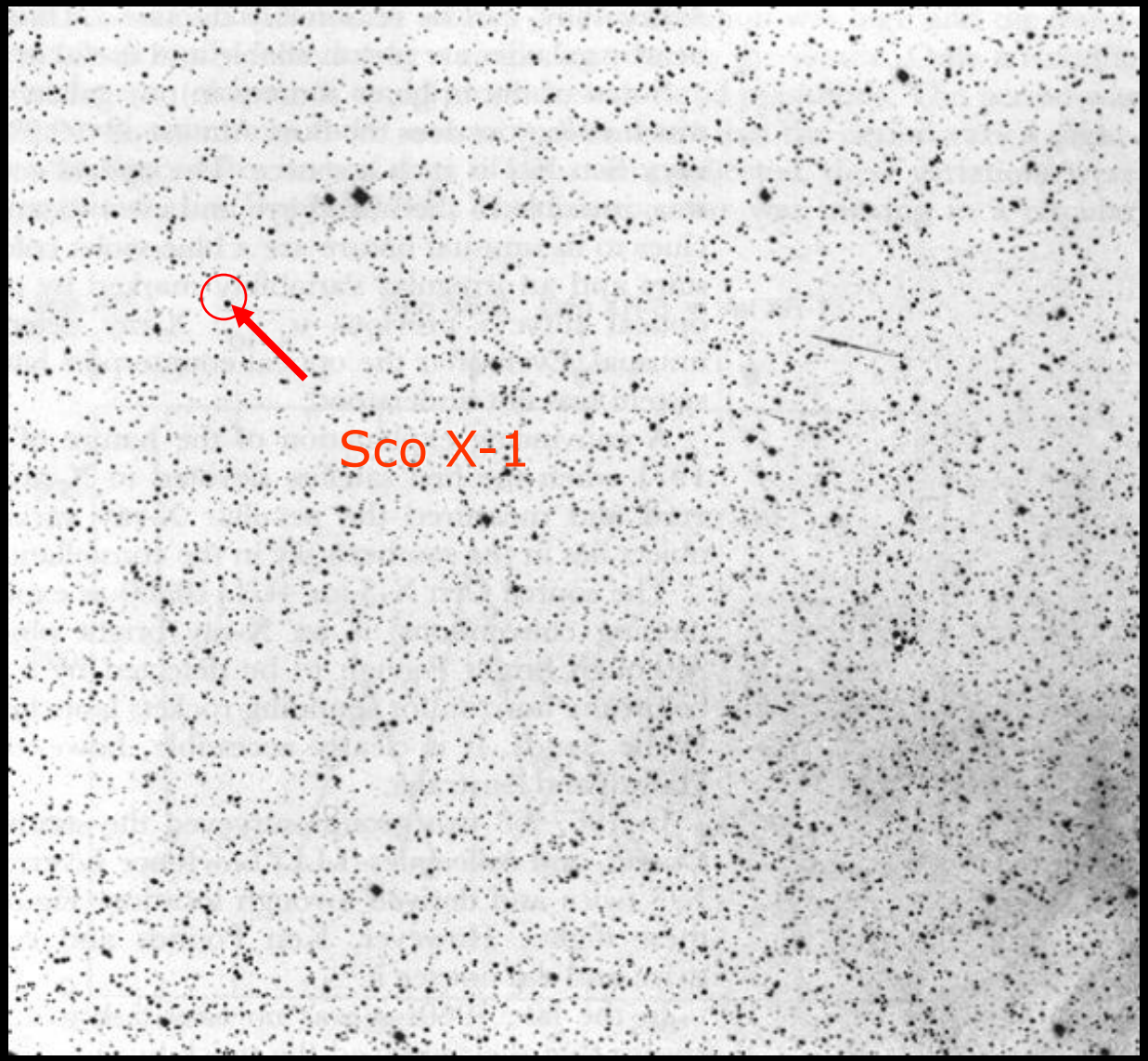
Astro X alla fine degli anni `70

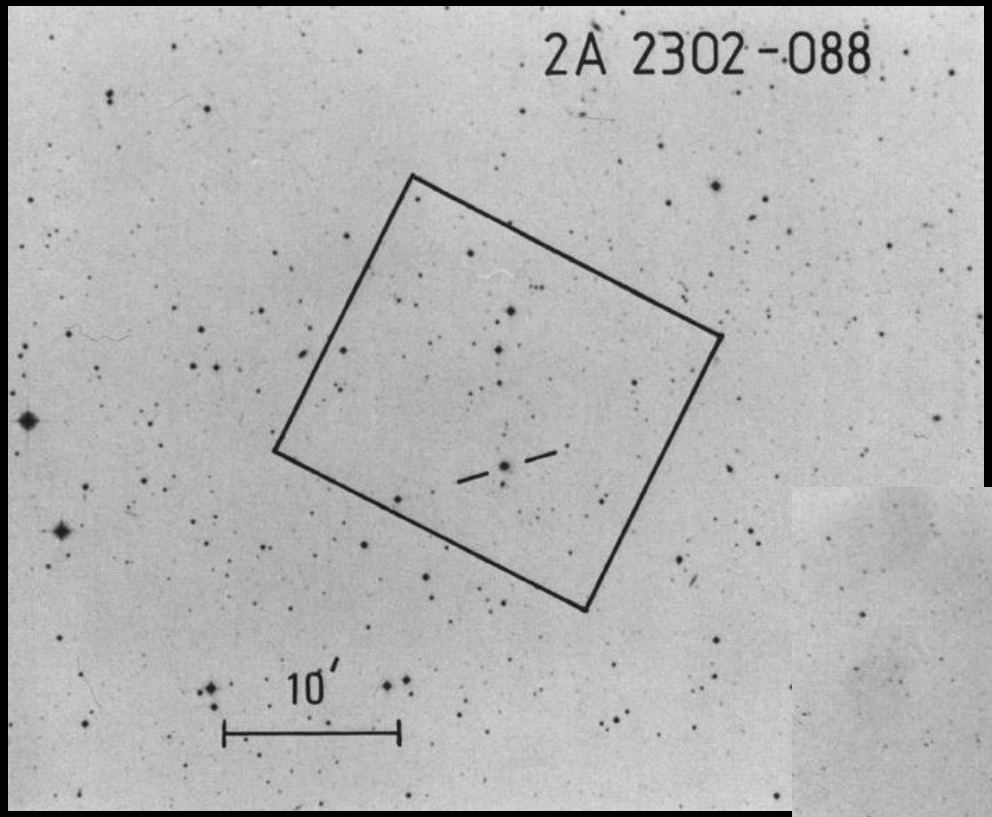
1) qualche centinaio di sorgenti note

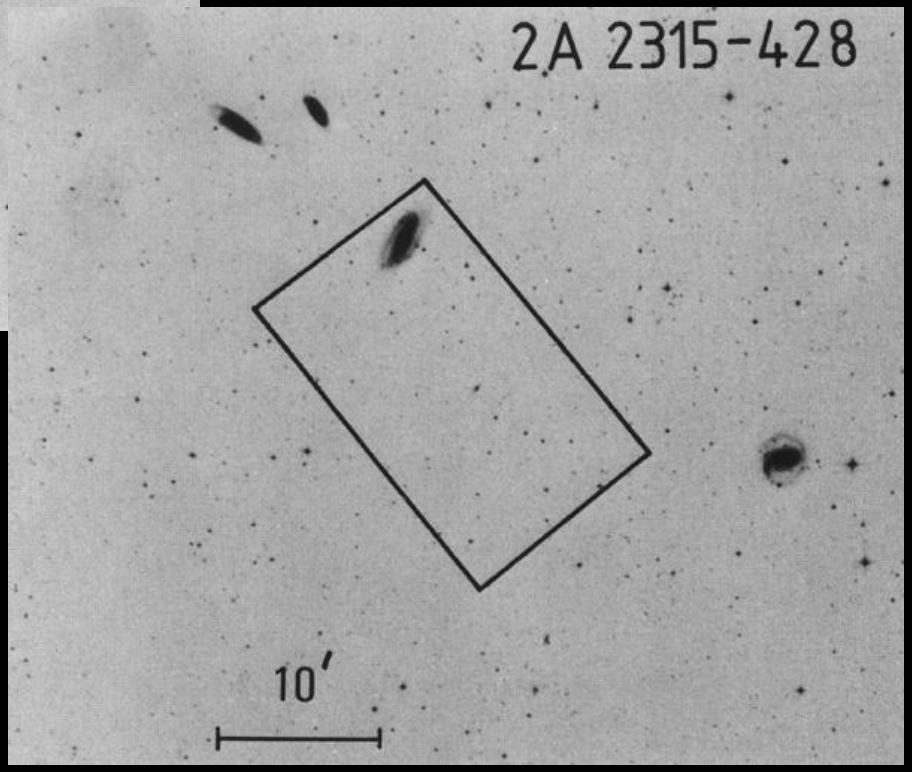


2) solo poche sorgenti identificate otticamente

Immagine ottica della zona di provenienza della radiazione X da Sco X-1




2A 2302-088
10′


2A 2315-428
10′

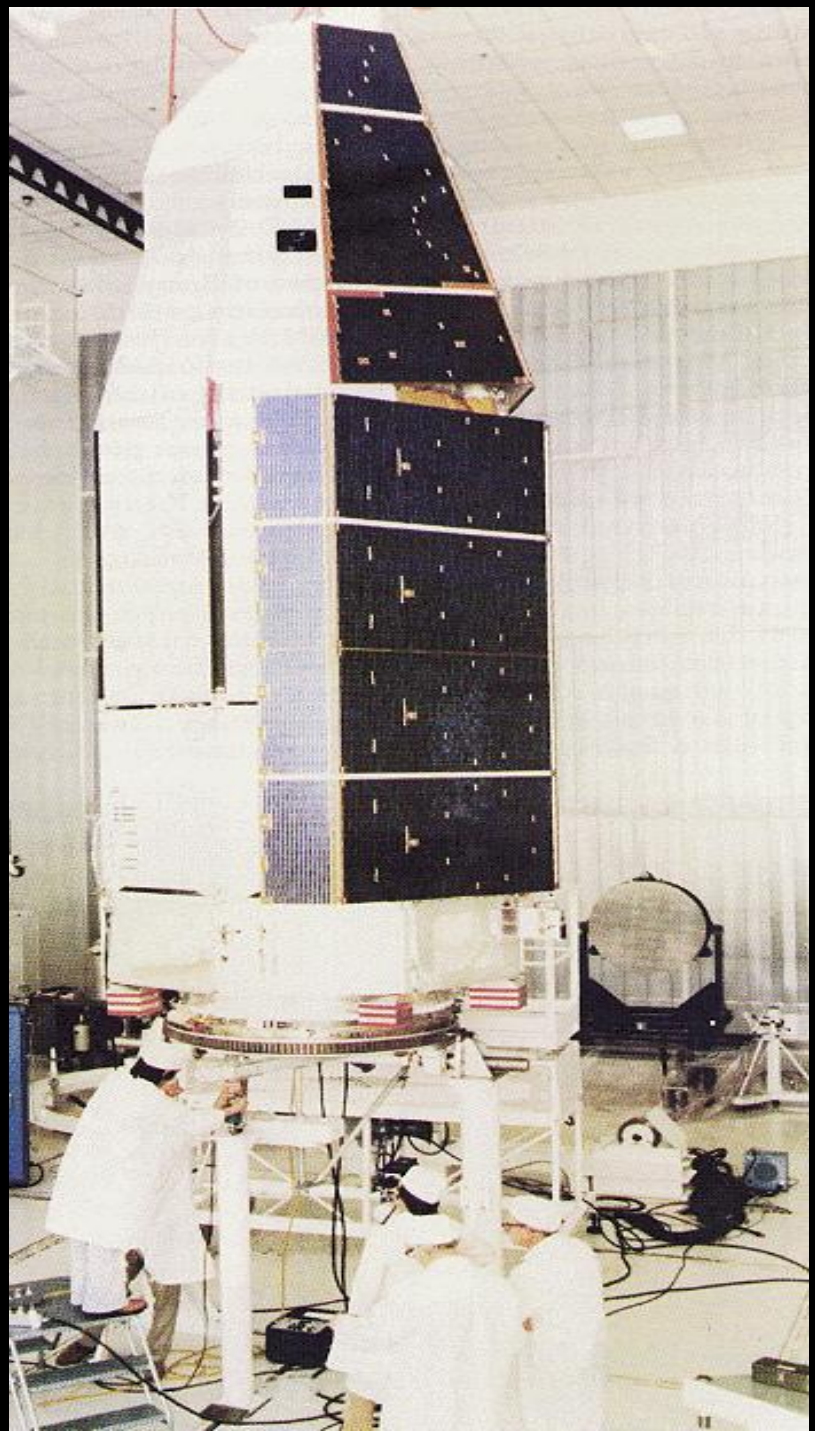
Osservatorio Einstein (1978)

primo grande telescopio

per raggi X

Il primo a usare specchi

a incidenza radente

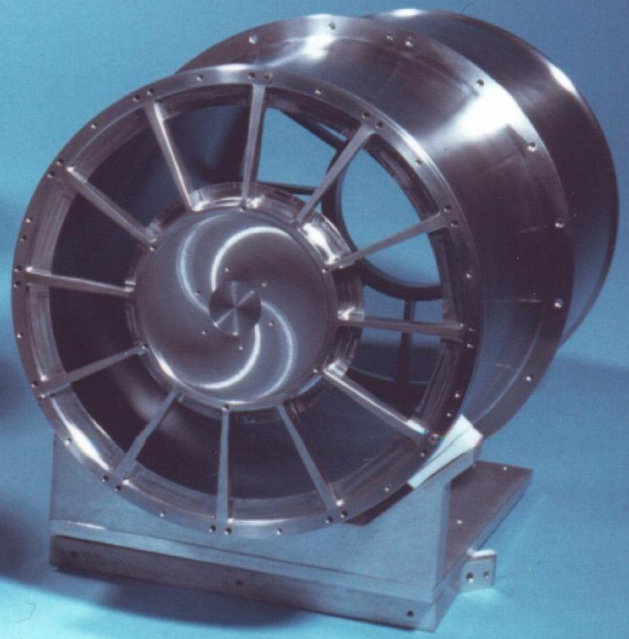


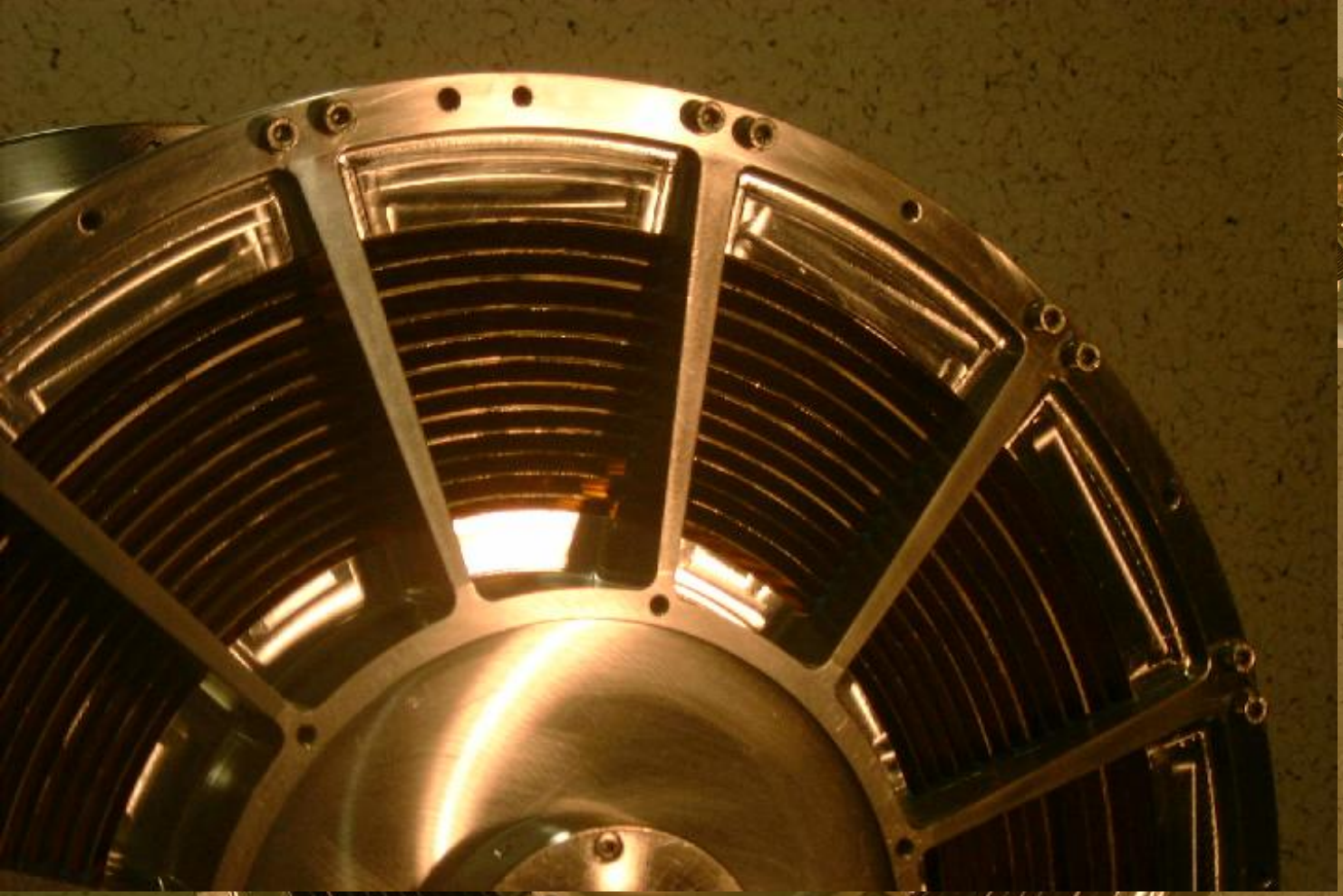
Specchi e telescopi per l'astronomia X

Sistema di specchi concentrici, annidati

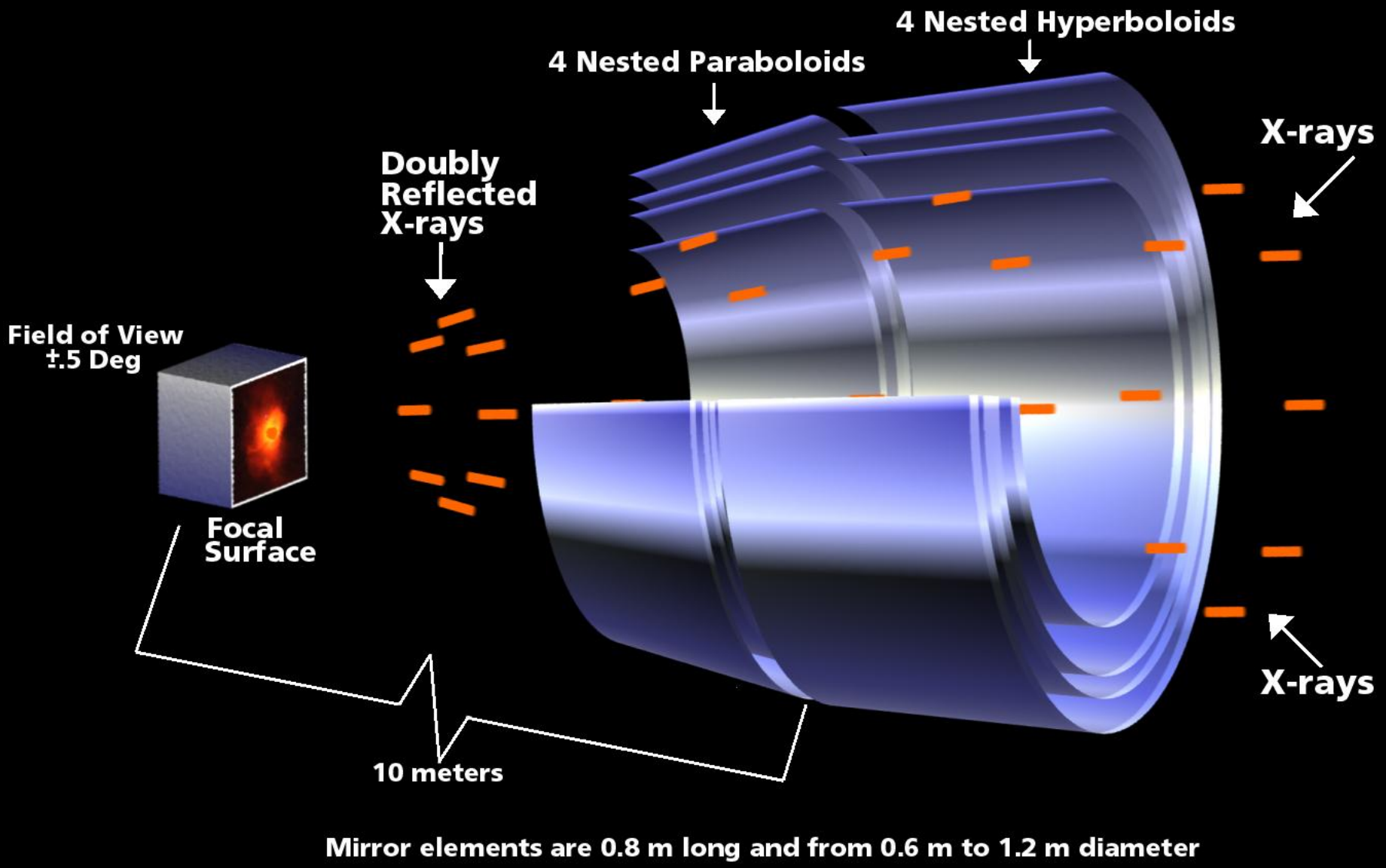
Ciascuno specchio:
un sottilissimo strato d'oro sostenuto da un supporto meccanico di nickel.

Specchi levigati: imperfezioni delle dimensioni di qualche atomo.





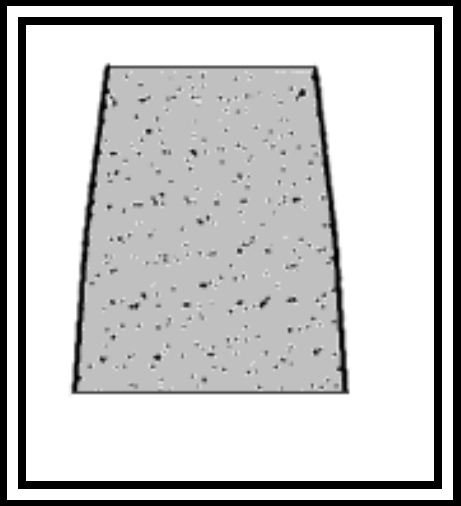
Specchi di Chandra, 1999



Tecnica di produzione: la replica per elettroformatura

processo messo a punto dalla Soc. Media Lario (Bosisio Parini, LC) con la collaborazione dell'INAF-Osservatorio Astronomico di Brera

a) Il mandrino superpulito

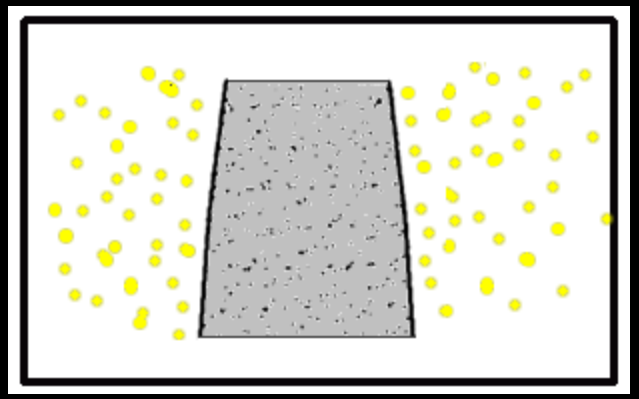


Un mandrino di alluminio è rivestito di uno strato di un decimo di millimetro di nichel, depositato attraverso un processo chimico (©Kanigen).

Il mandrino così preparato viene sagomato fino a ottenere il profilo parabolico-iperbolico desiderato.

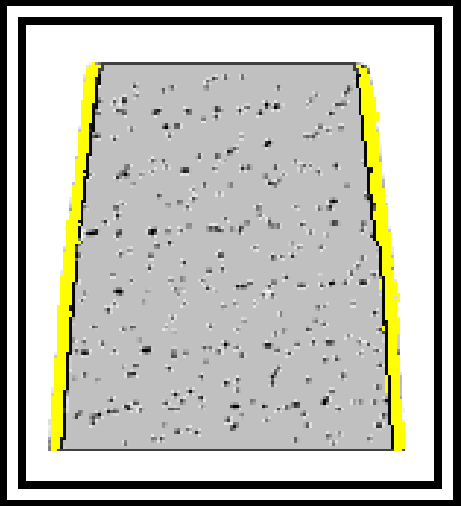
Quindi è sottoposto a un processo di superpulitura per raggiungere una rugosità superficiale minore di 0,5 miliardesimi di metro.

b) Una pioggia d'oro



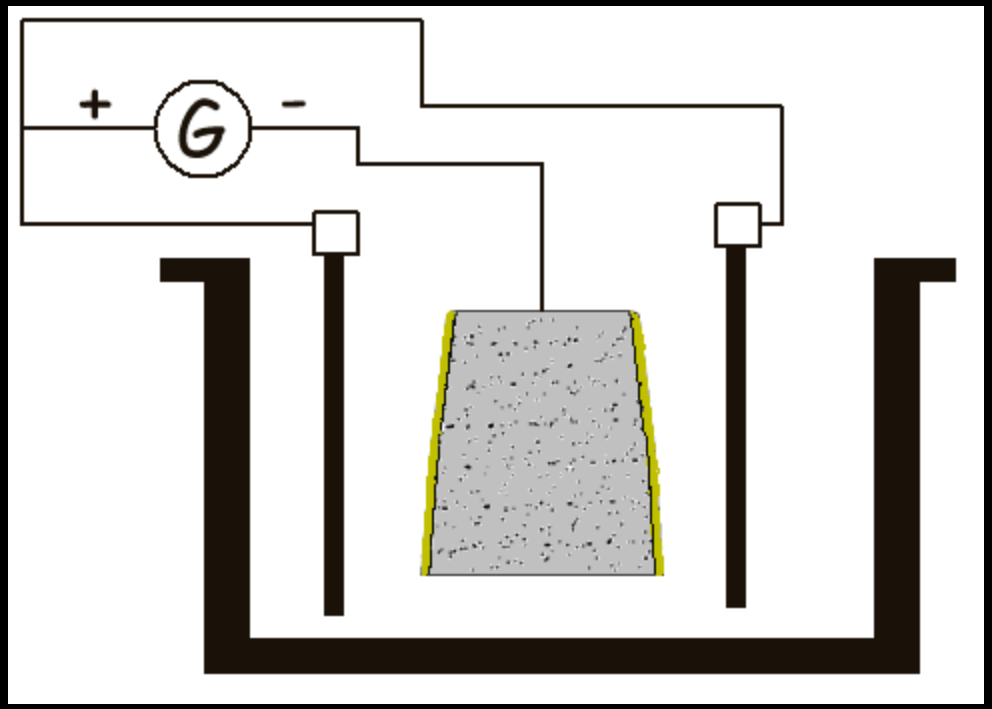
Il mandrino superpulito viene inserito in un crogiuolo dove viene depositato l'oro da far evaporare. L'oro viene riscaldato con un bombardamento di elettroni, fino a ottenerne l'evaporazione.

Gli atomi d'oro si depositano sulla superficie del mandrino, fino a formare un sottile strato di circa 100 miliardesimi di metro.



c) Il rivestimento di nichel

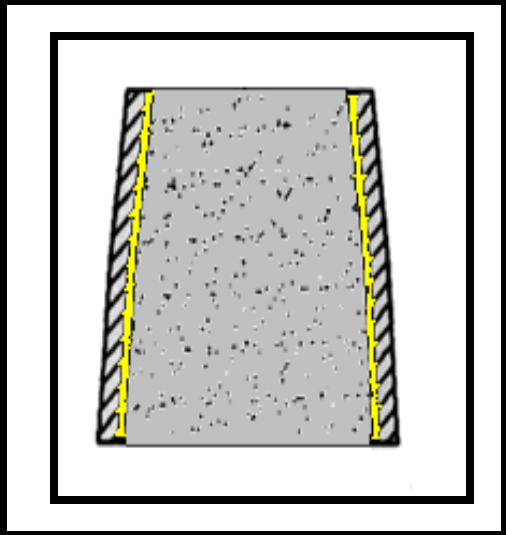
Lo strato di oro è rivestito di un ulteriore strato di nichel attraverso un bagno elettrolitico fino al raggiungimento dello spessore desiderato (0,1 – 1,0 mm).



d) Lo specchio sul mandrino

È lo strato d'oro rinforzato da quello di nichel che costituisce lo specchio.

La superficie d'oro ha la funzione di riflettere i raggi X.



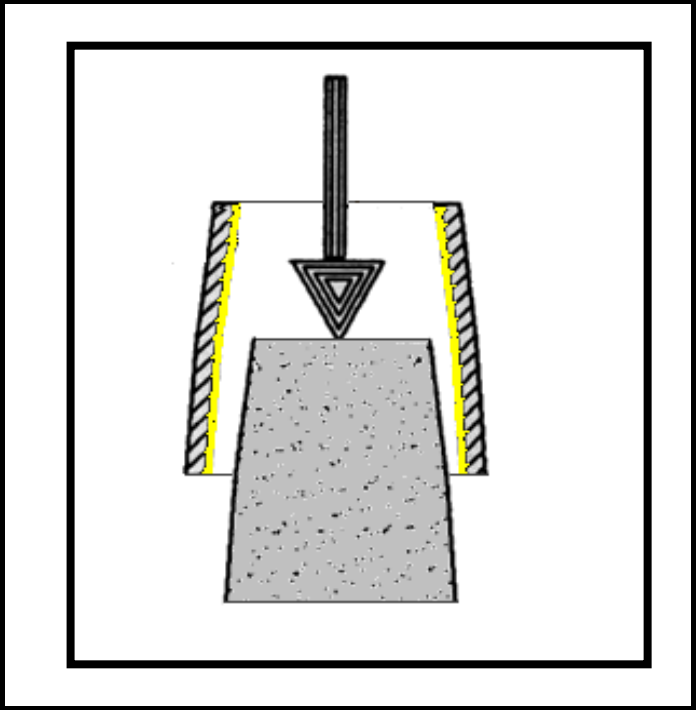
Il rivestimento di nichel depositato attraverso il bagno elettrolitico serve a dare consistenza meccanica al sottile strato di metallo prezioso.

e) Lo separazione dello specchio

La separazione è ottenuta raffreddando il mandrino: il coefficiente di espansione termica dell'alluminio è circa il doppio di quello del nichel.

Con il raffreddamento si crea una piccola intercapedine che consente la separazione dello specchio.

Il mandrino si può riutilizzare per uno specchio identico.

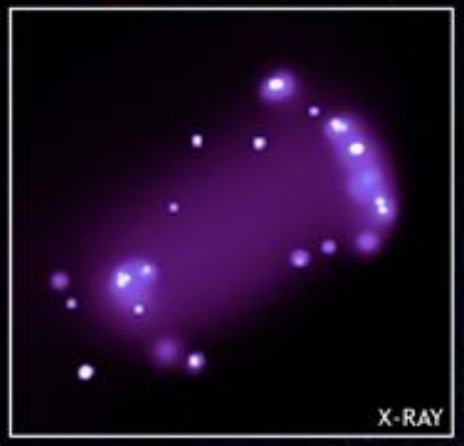


Perché gli specchi sono d'oro?

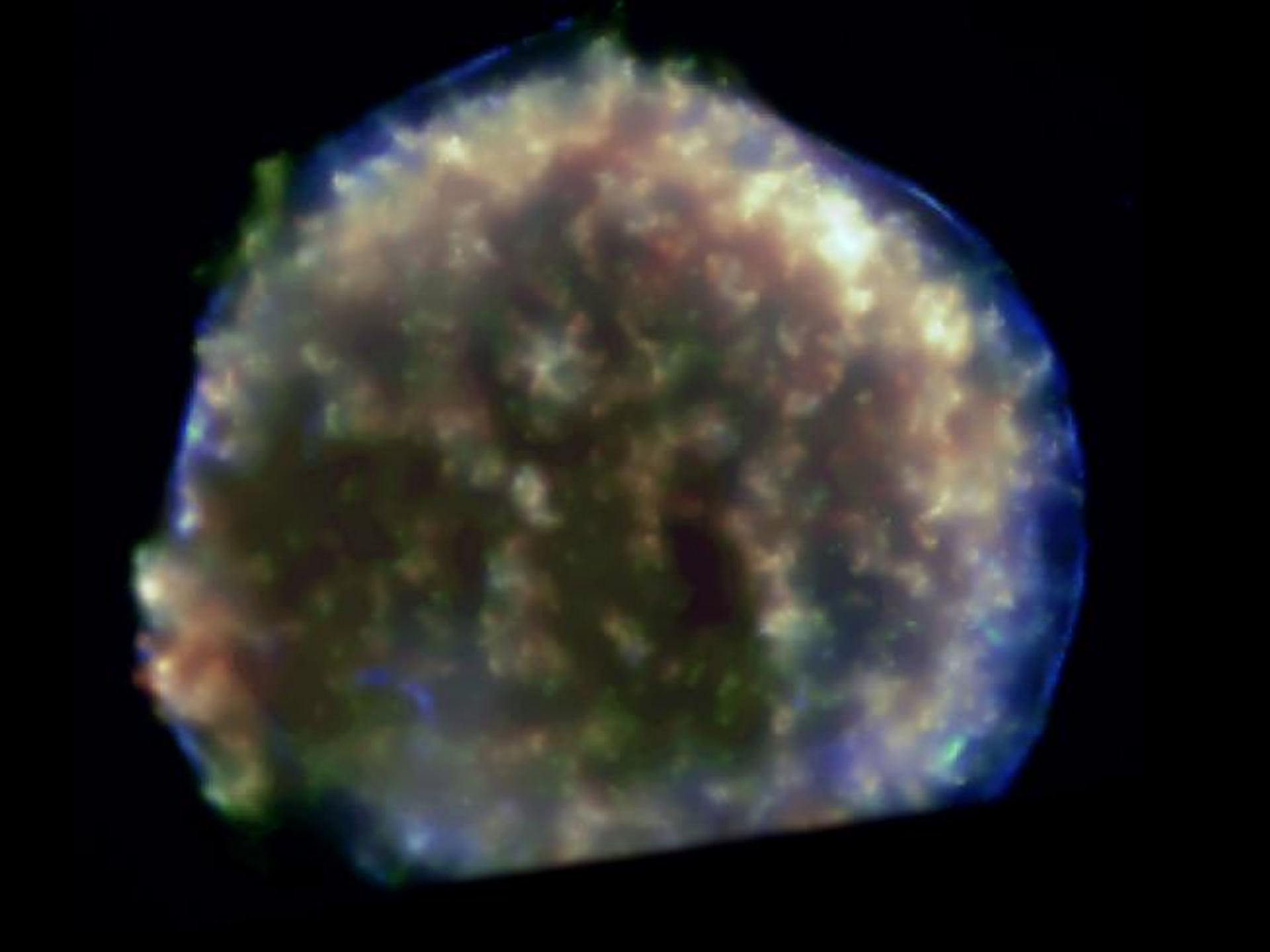
L'oro viene usato per due motivi principali:

1) L'oro ha densità molto elevata e questo permette la riflessione dei raggi x anche di energia relativamente alta. Gli specchi realizzati sono così in grado di raccogliere informazioni su fenomeni astronomici molto diversi fra loro (osservazioni a "banda larga").

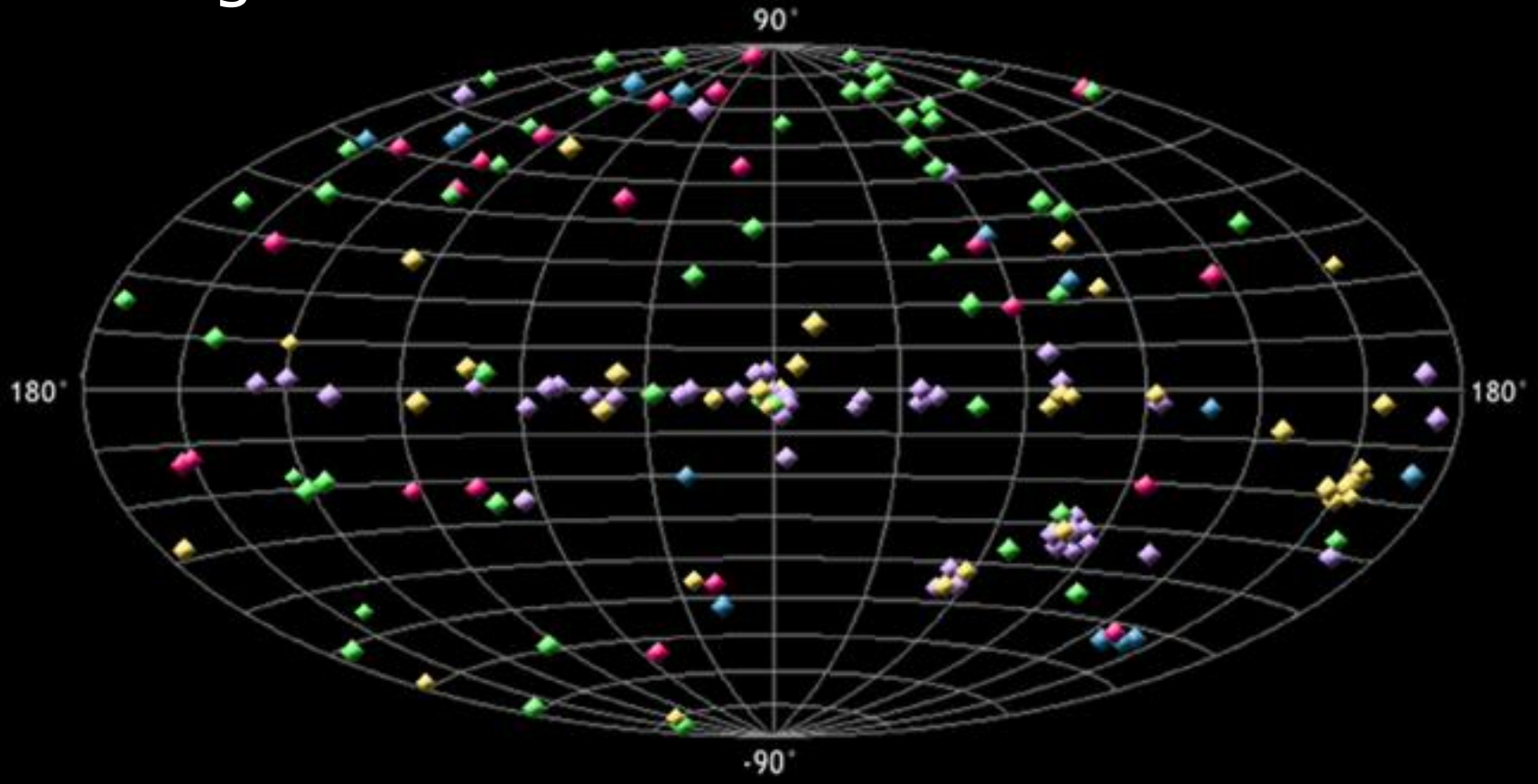
2) L'aderenza dell'oro al mandrino è bassa: l'oro funziona come agente di separazione tra specchio e mandrino.



MULTI-WAVELENGTH COMPOSITE



Le sorgenti



Stelle "vive"

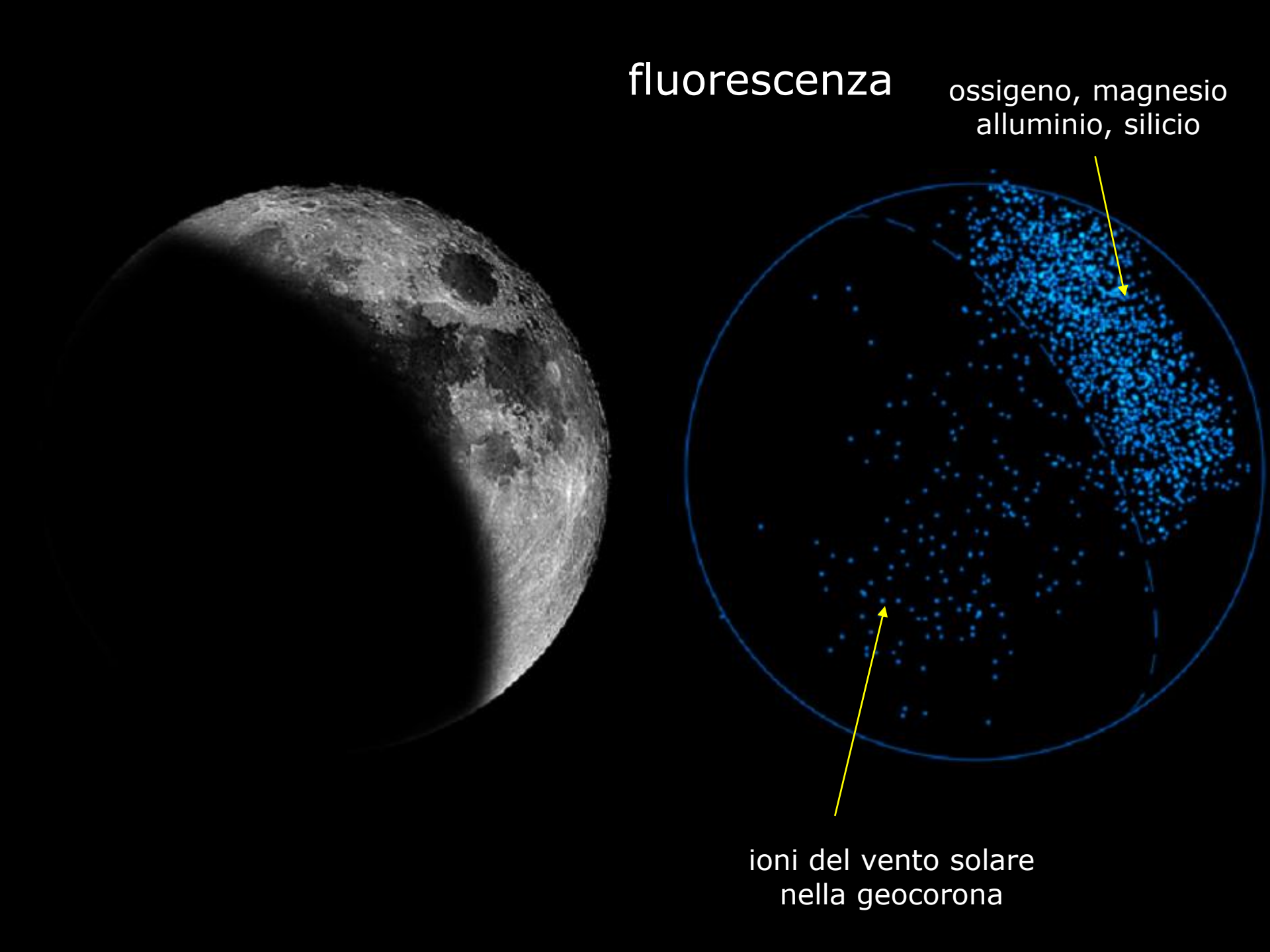
Resti di stelle

Galassie

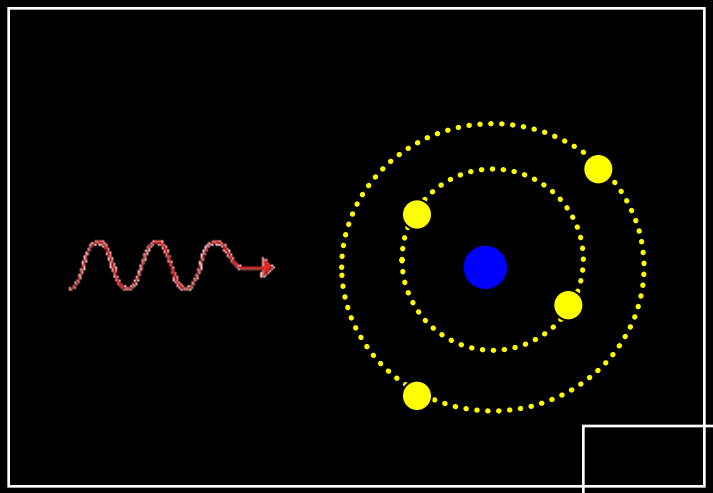
Ammassi di galassie

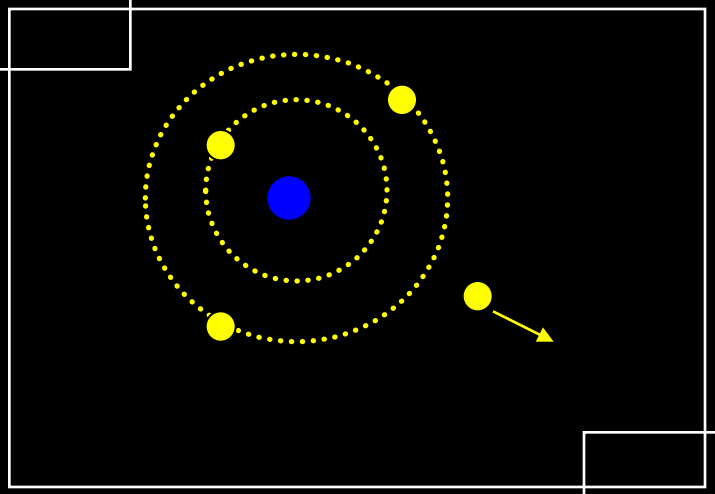
altri

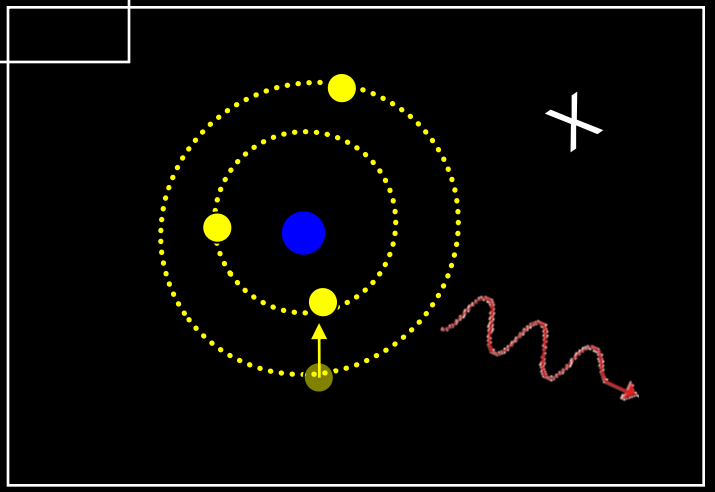
fluorescenza

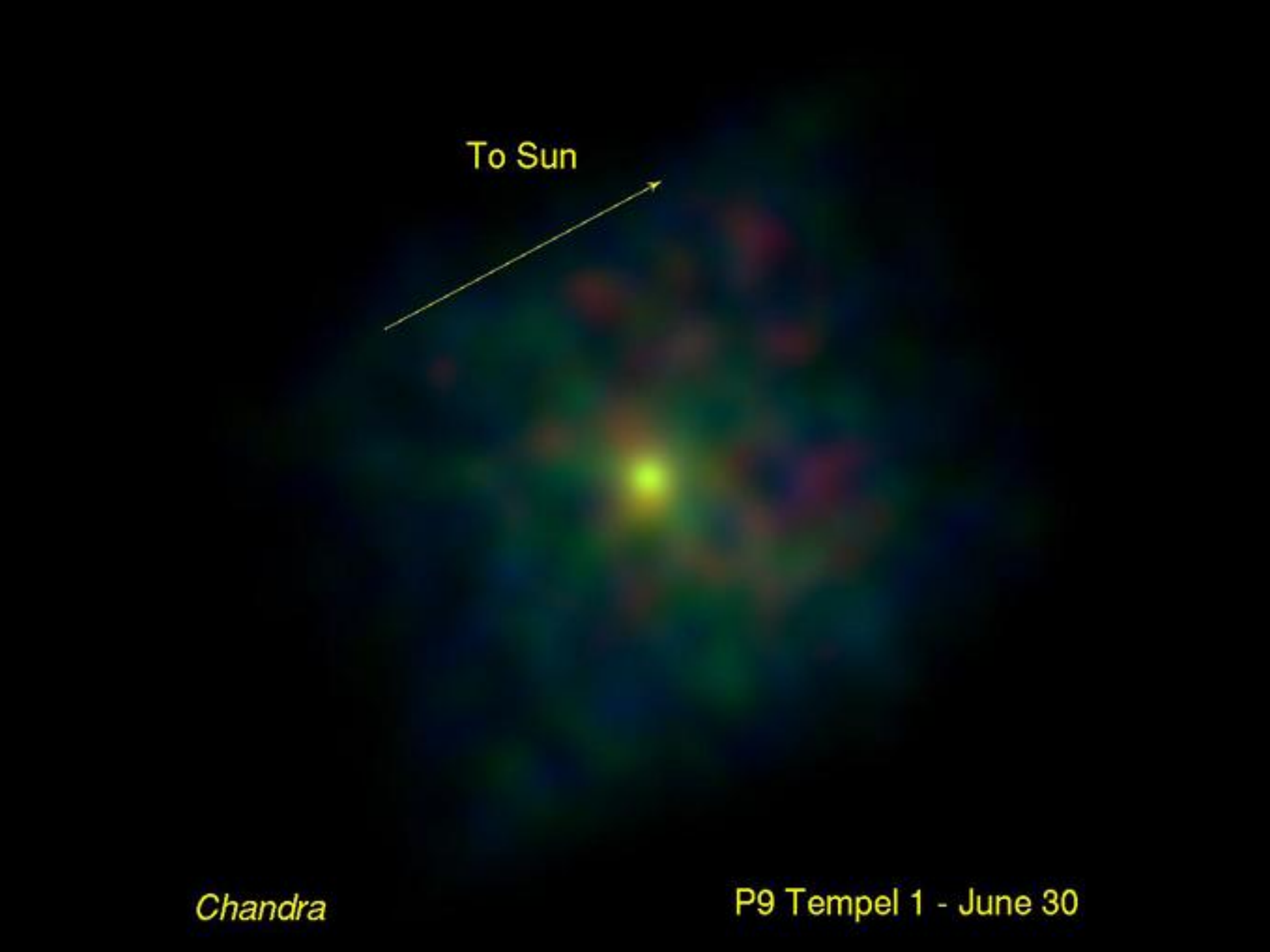


La fluorescenza

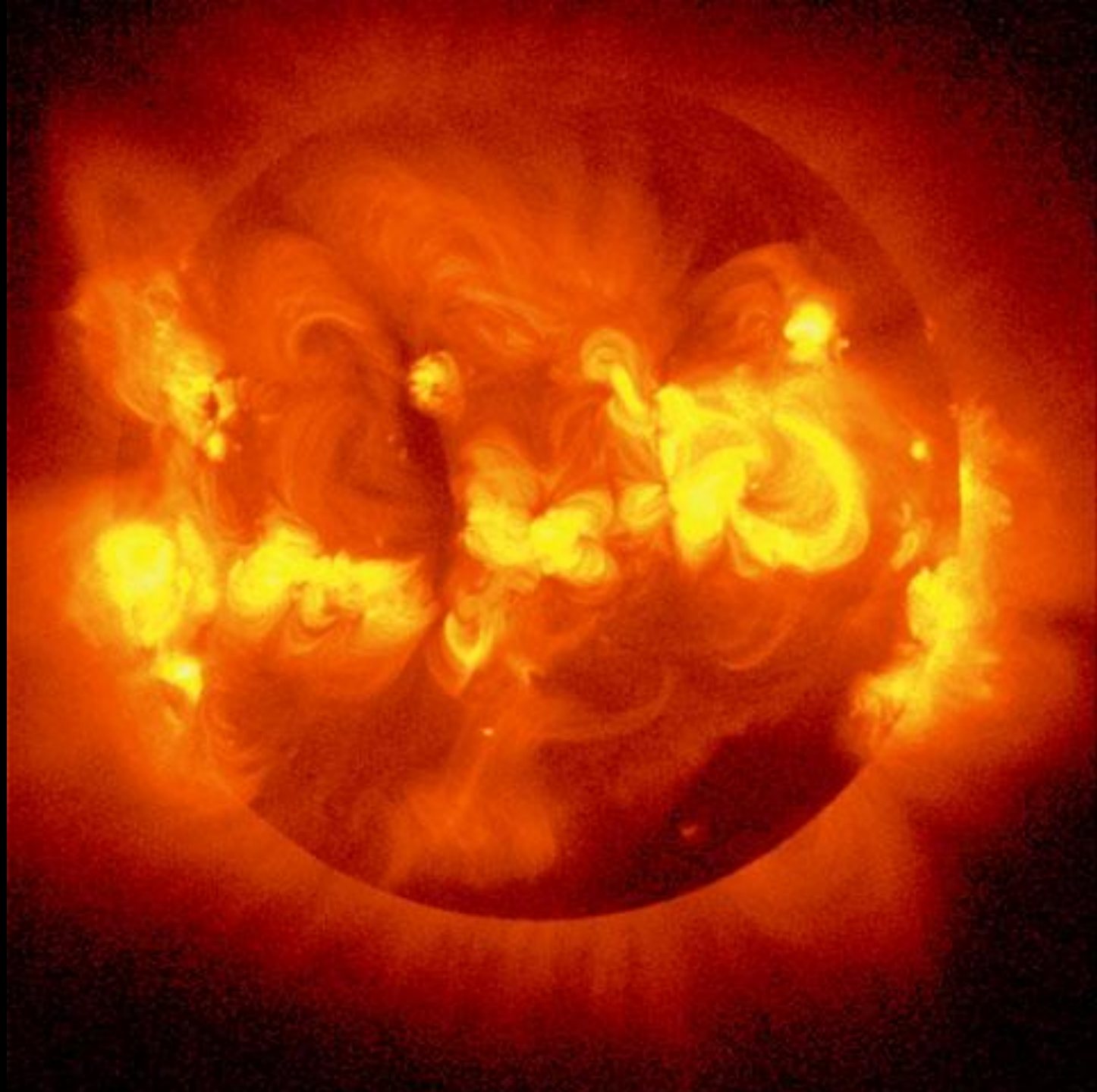






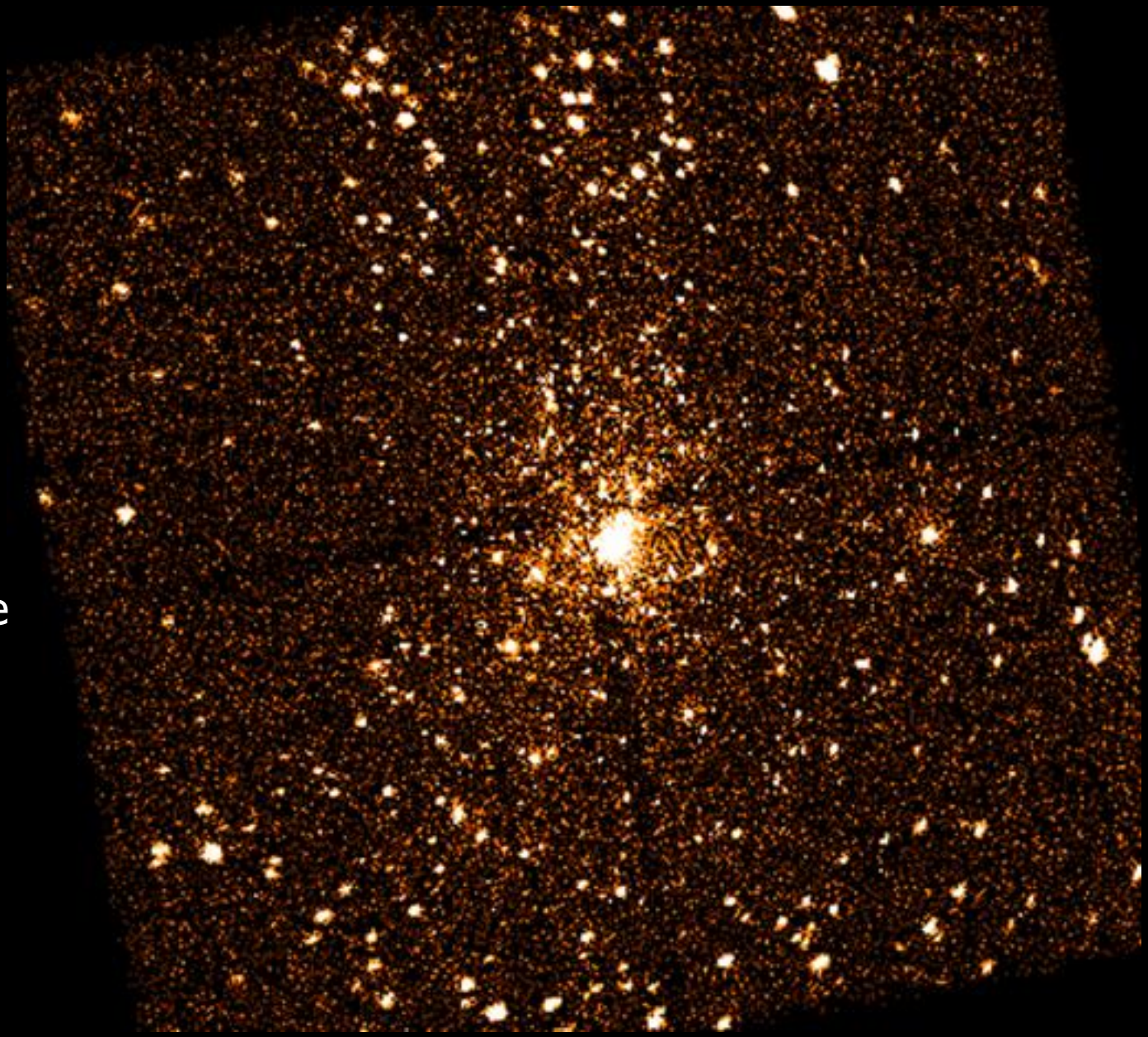

To Sun
Chandra
P9 Tempel 1 - June 30

Il sole

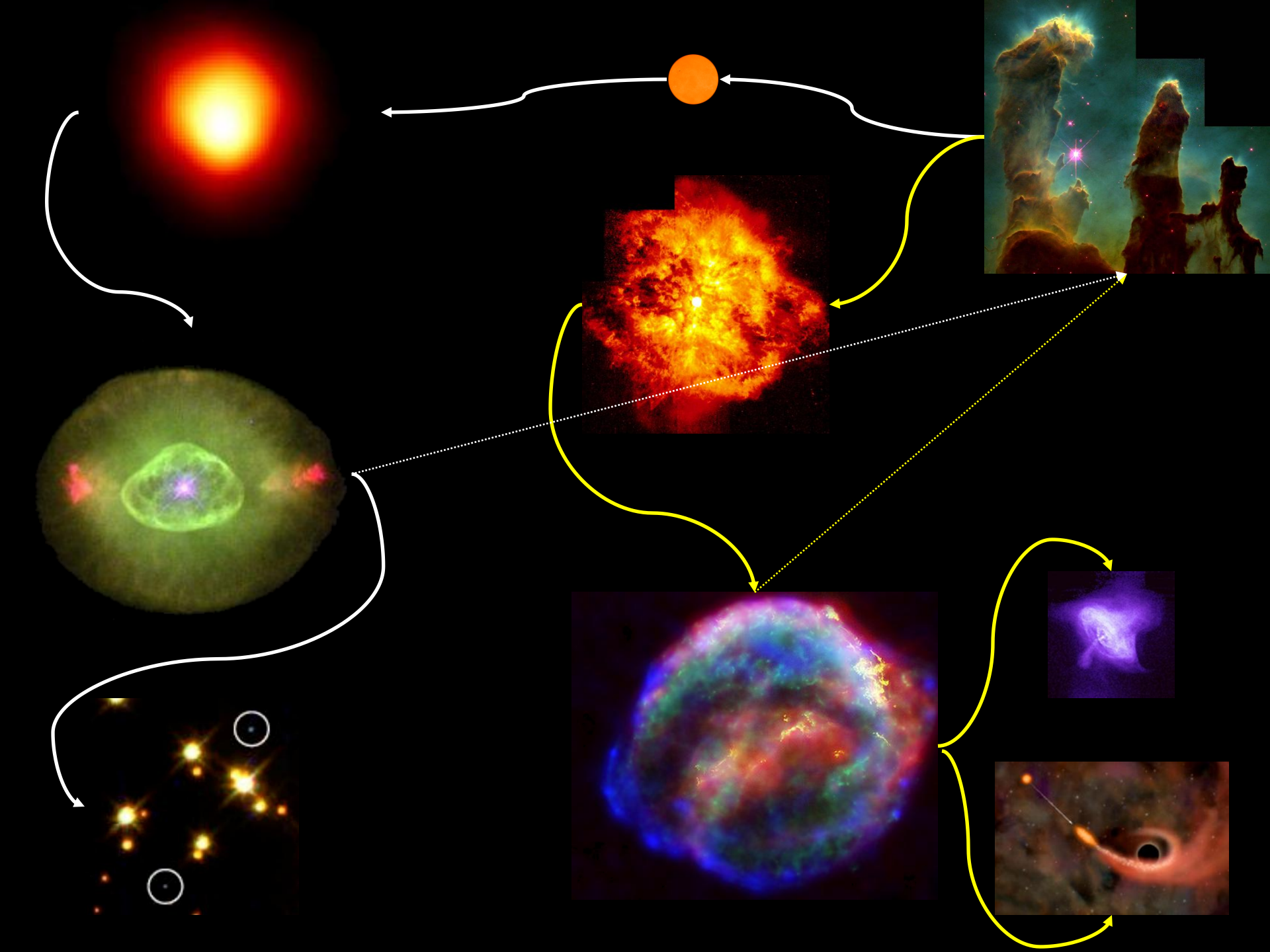


Nebulosa
di
Orione

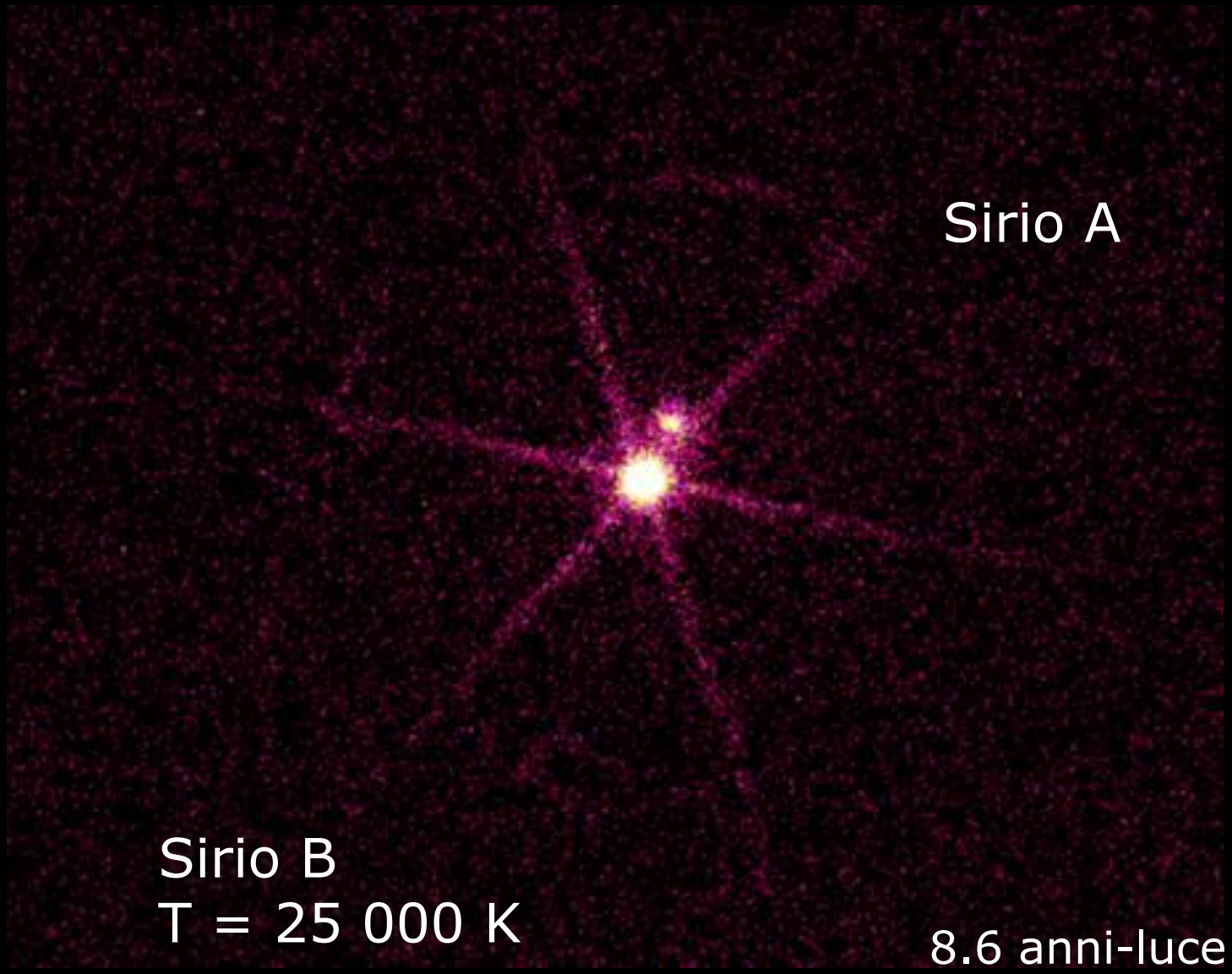
Distanza:
1800 anni-luce

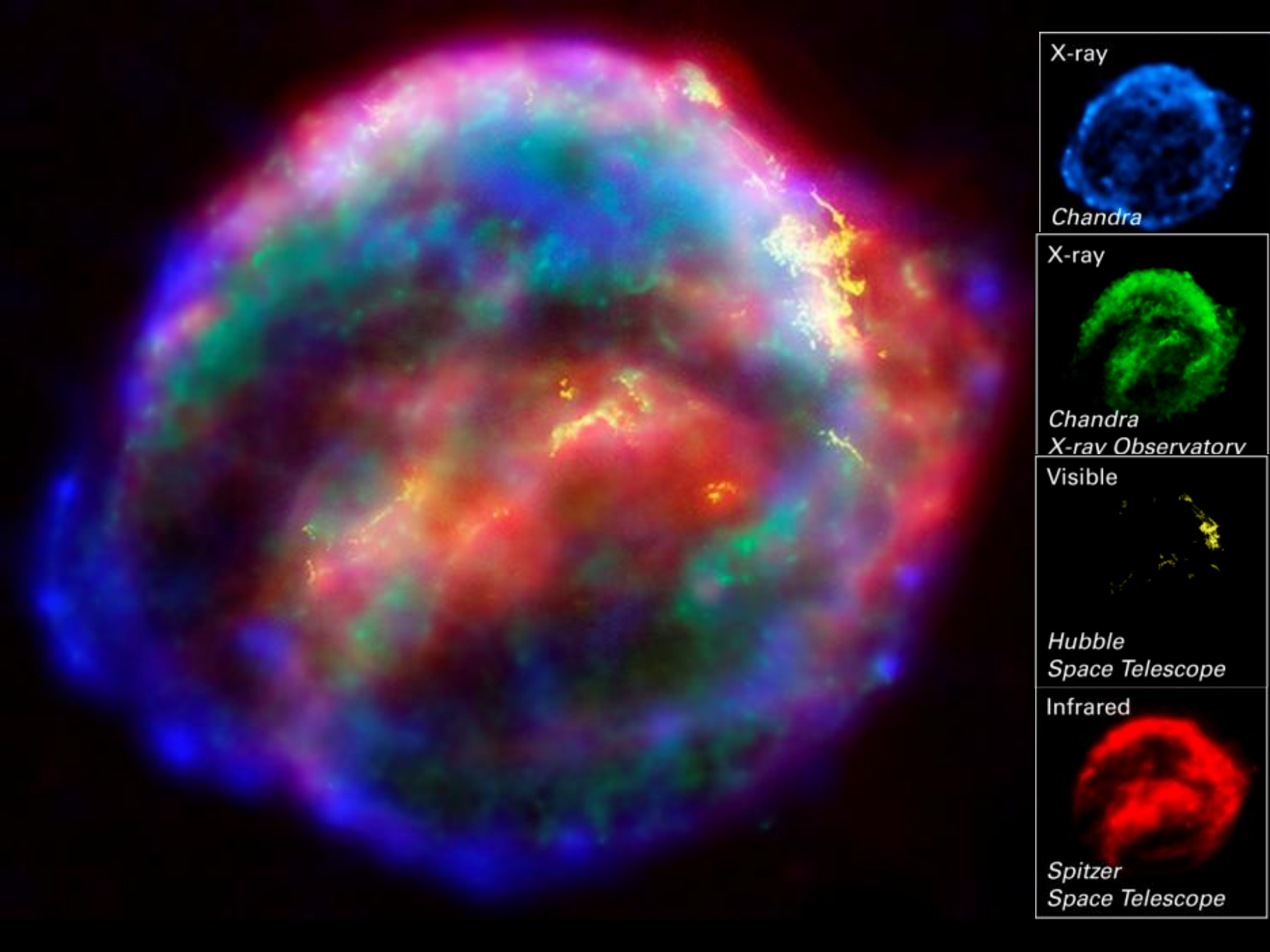


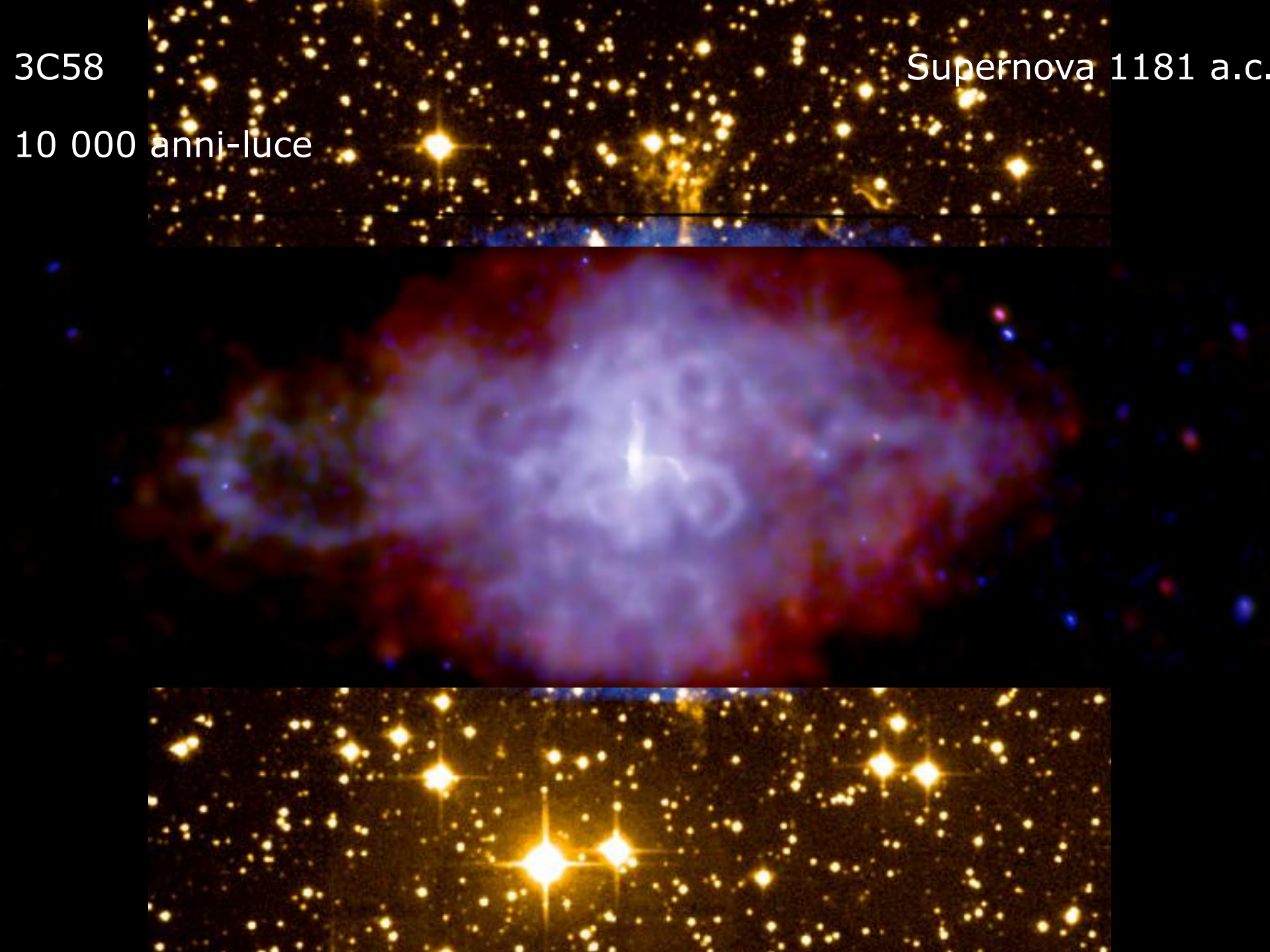
10 anni-luce



Nana bianca

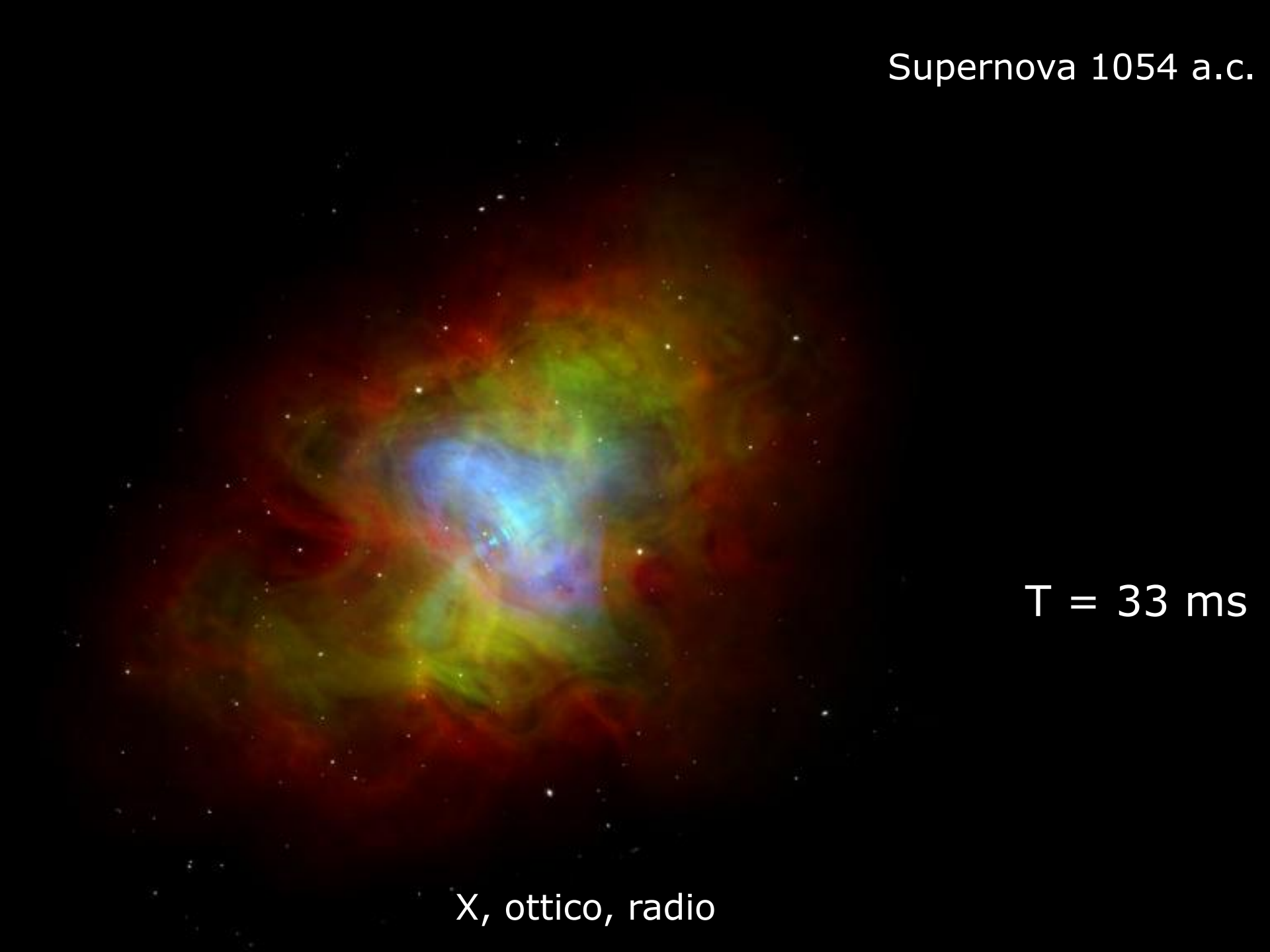



X-ray
Chandra
X-ray
Chandra
X-ray Observatory
Visible
Hubble
Space Telescope
Infrared
Spitzer
Space Telescope


3C58
10 000 anni-luce
Supernova 1181 a.c.


Nebulosa del Granchio
Supernova 1054 a.c.
Luce visibile

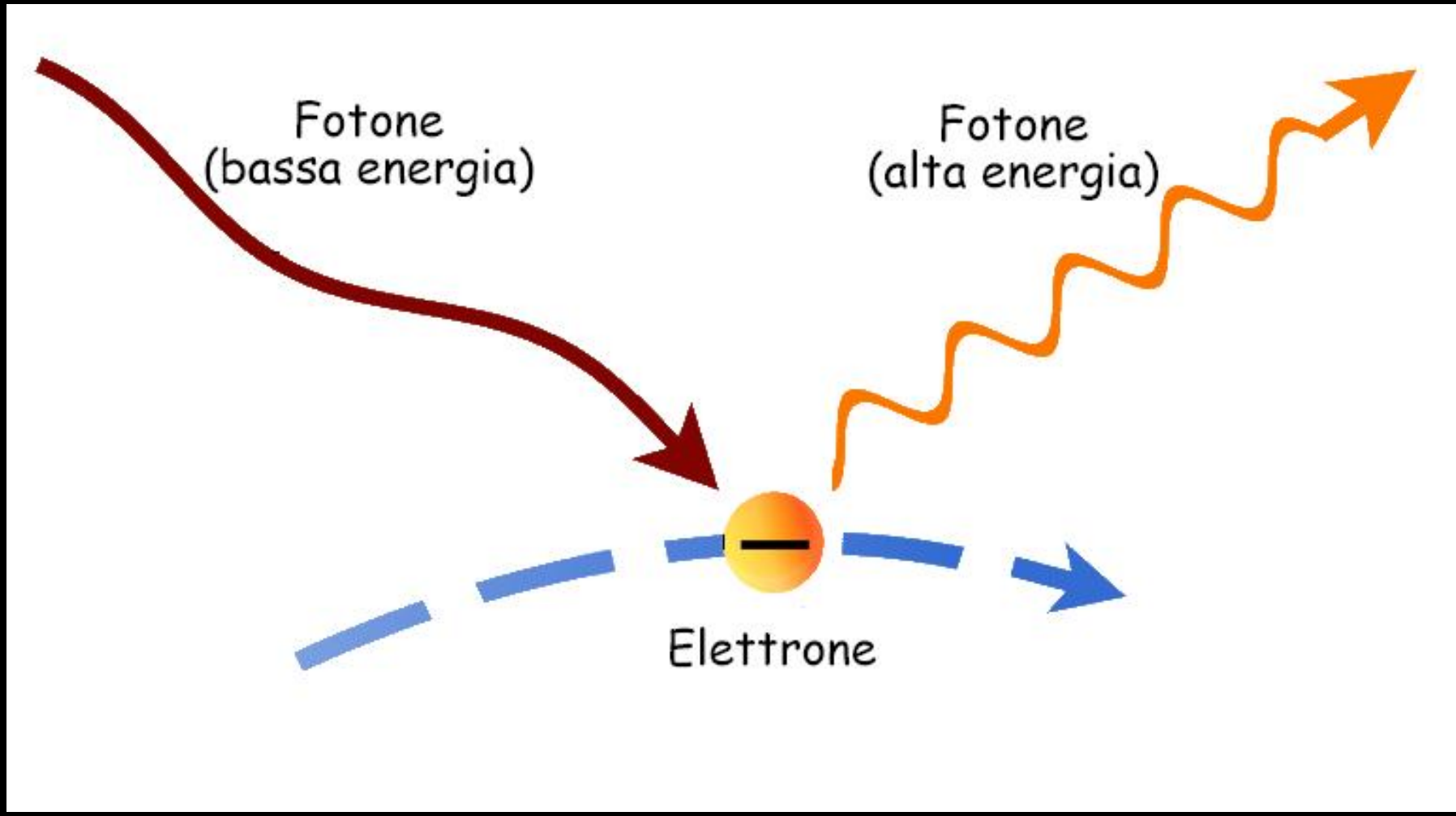
Supernova 1054 a.c.



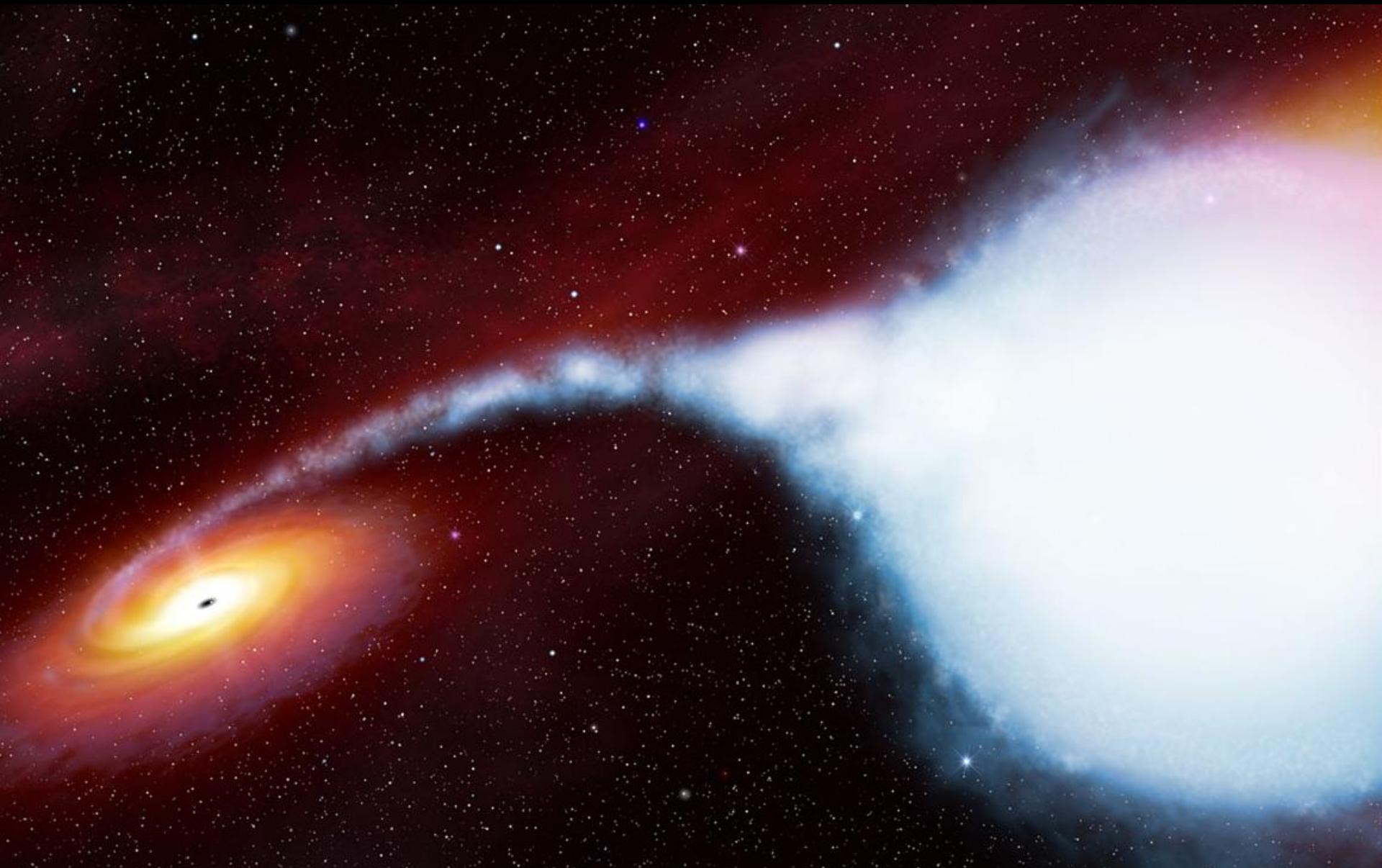
T = 33 ms

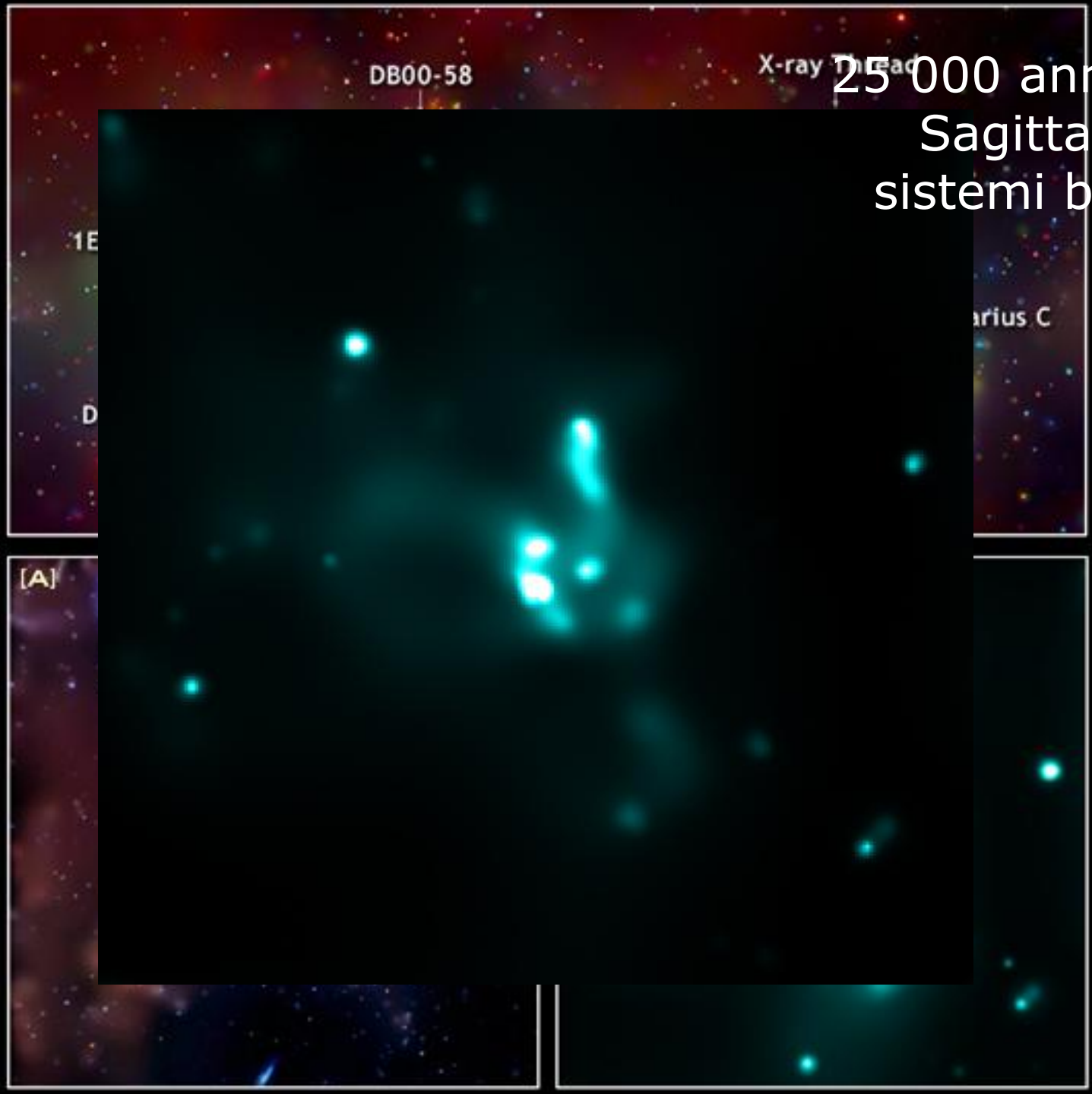
X, ottico, radio

Radiazione per effetto Compton inverso



Cygnus X-1: supergigante blu & buco nero





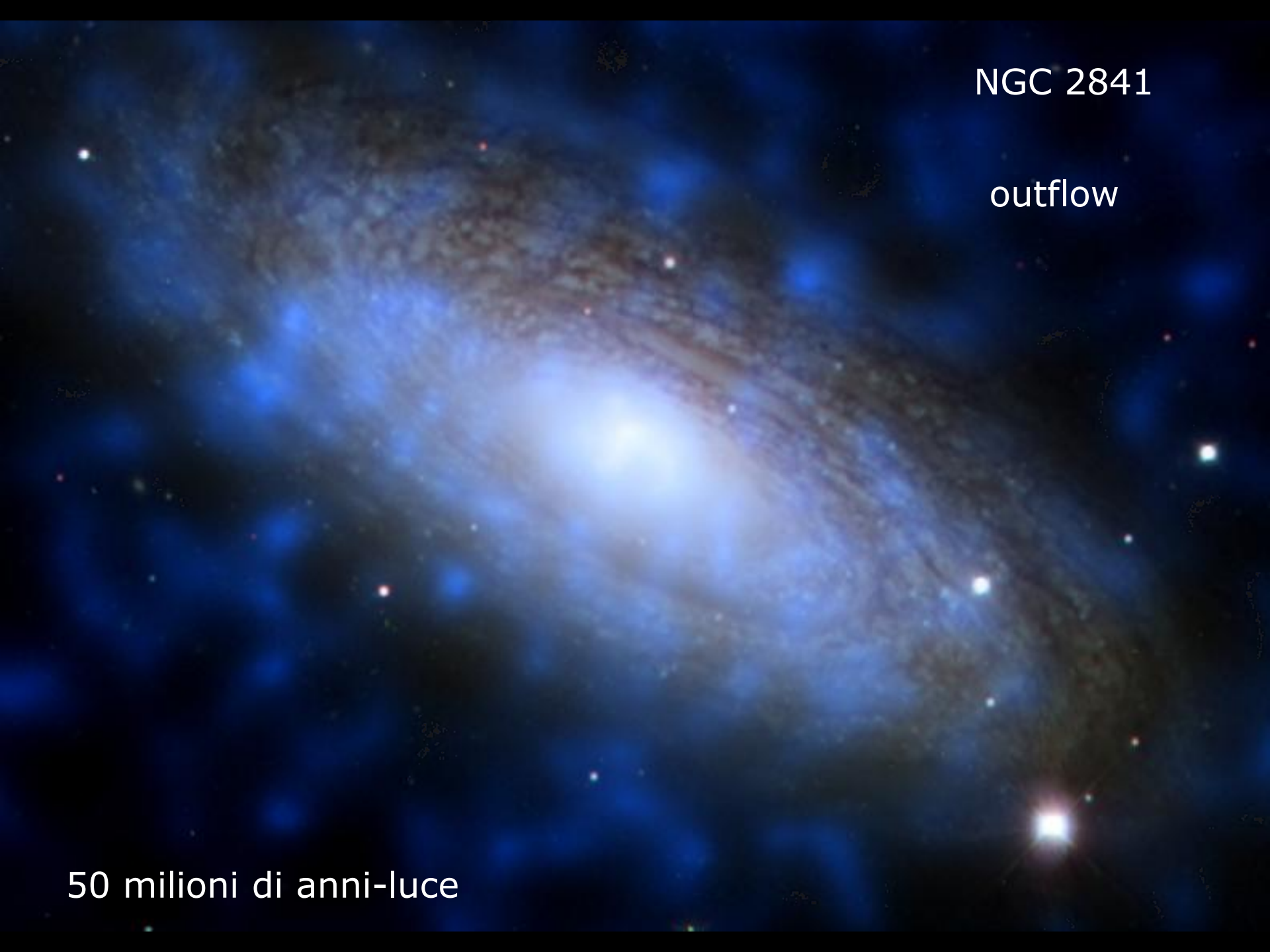
25 000 anni-luce
Sagittario
sistemi binari

RX J0806.3+1527 - sistema binario di nane bianche

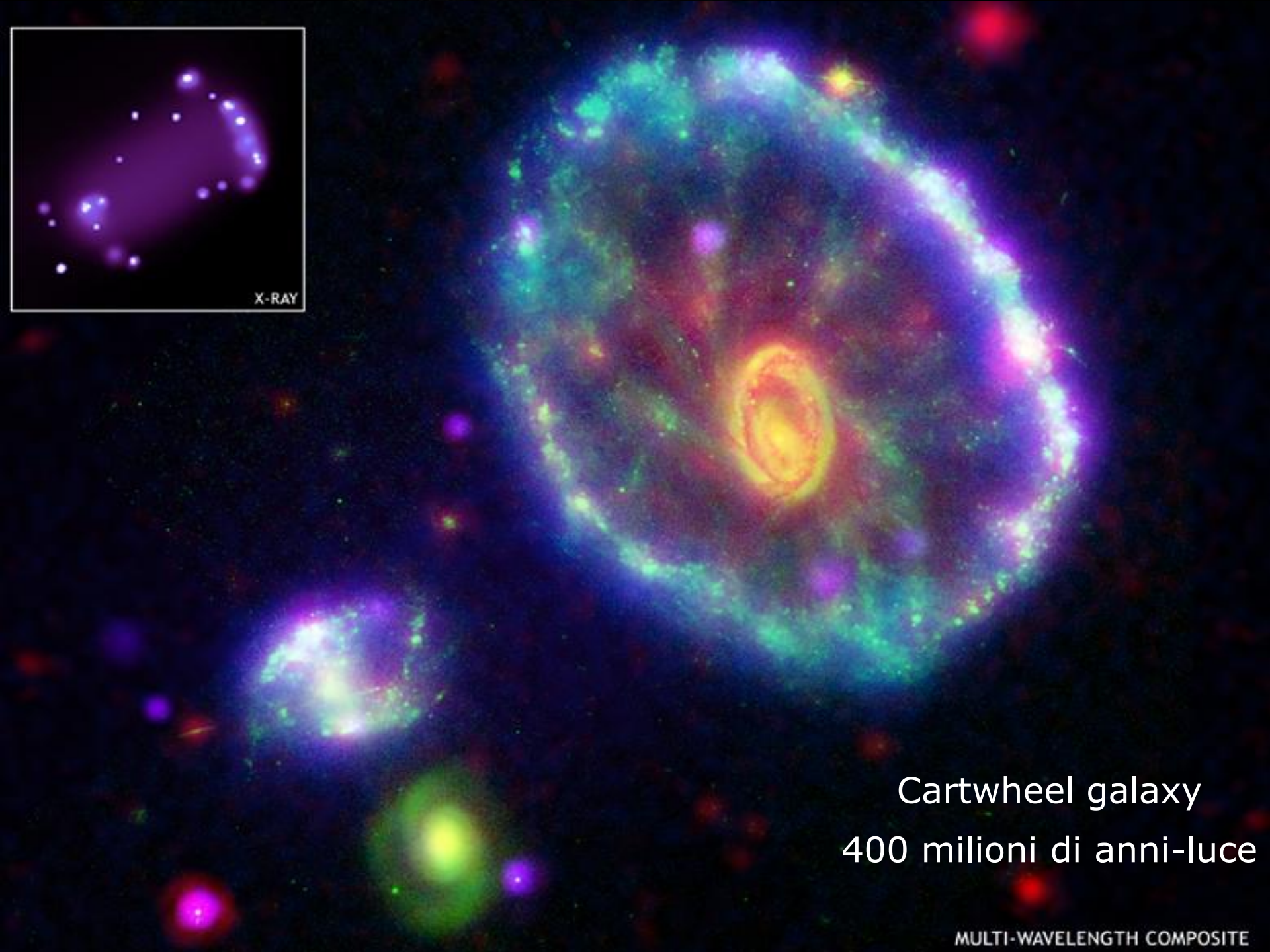
1 600 anni-luce

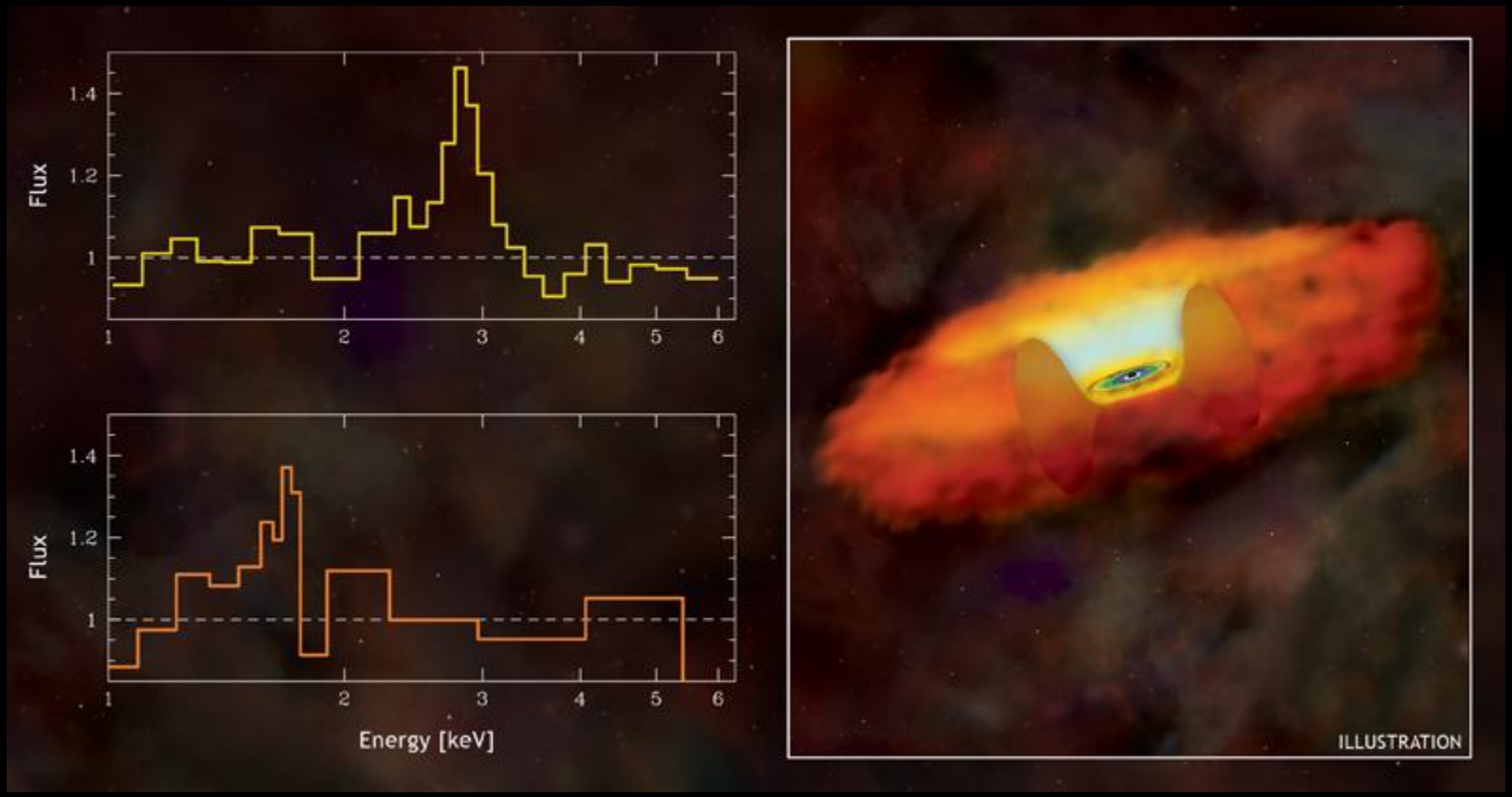
70 mila kilometri

Distanza diminuisce di 60 cm al giorno

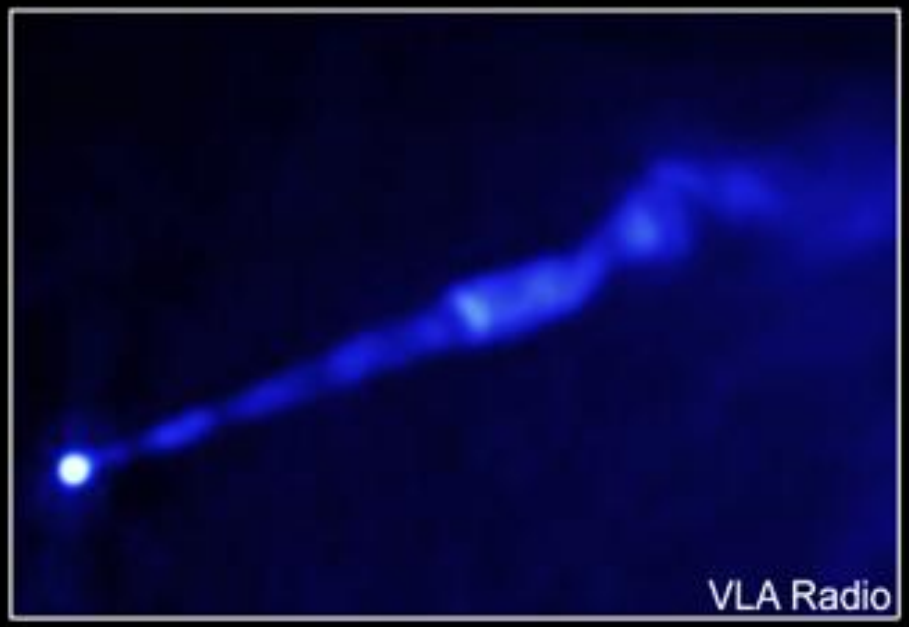

NGC 2841
outflow
50 milioni di anni-luce

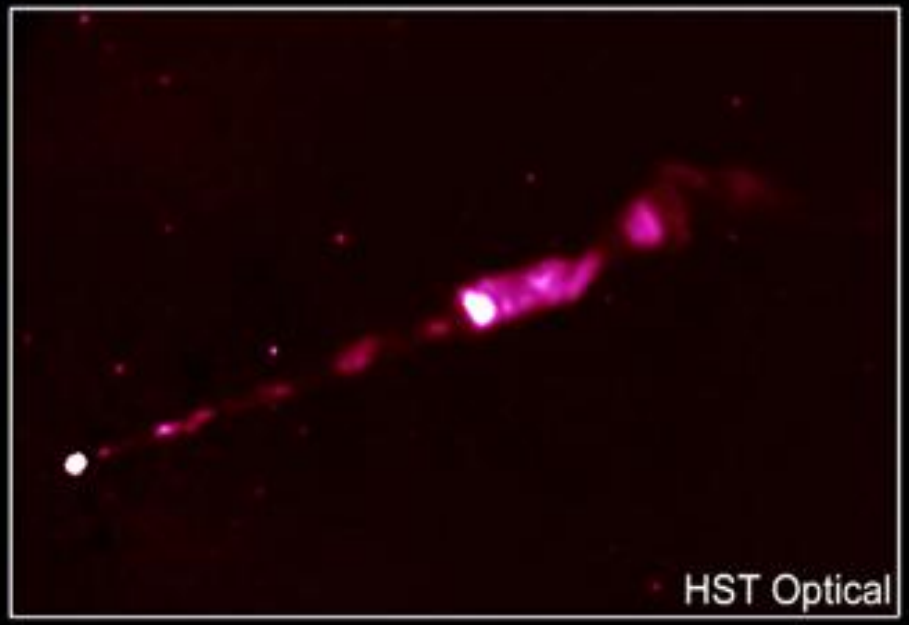

NGC 5746
inflow
100 milioni di anni-luce


X-RAY
Cartwheel galaxy
400 milioni di anni-luce
MULTI-WAVELENGTH COMPOSITE


Flux
1.4
1.2
1
1
2
3
4
5
6
Flux
1.4
1.2
1
1
2
3
4
5
6
Energy [keV]
ILLUSTRATION

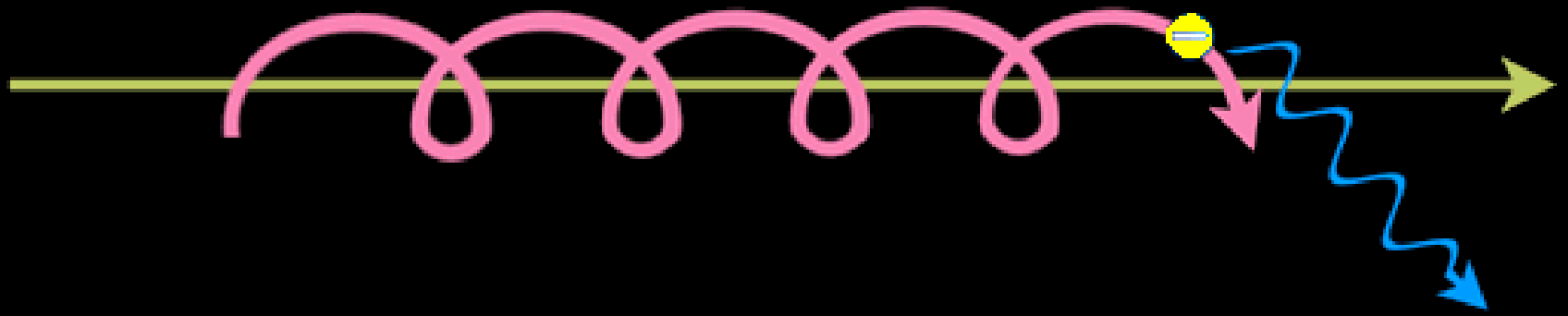
M 87
Virgo A

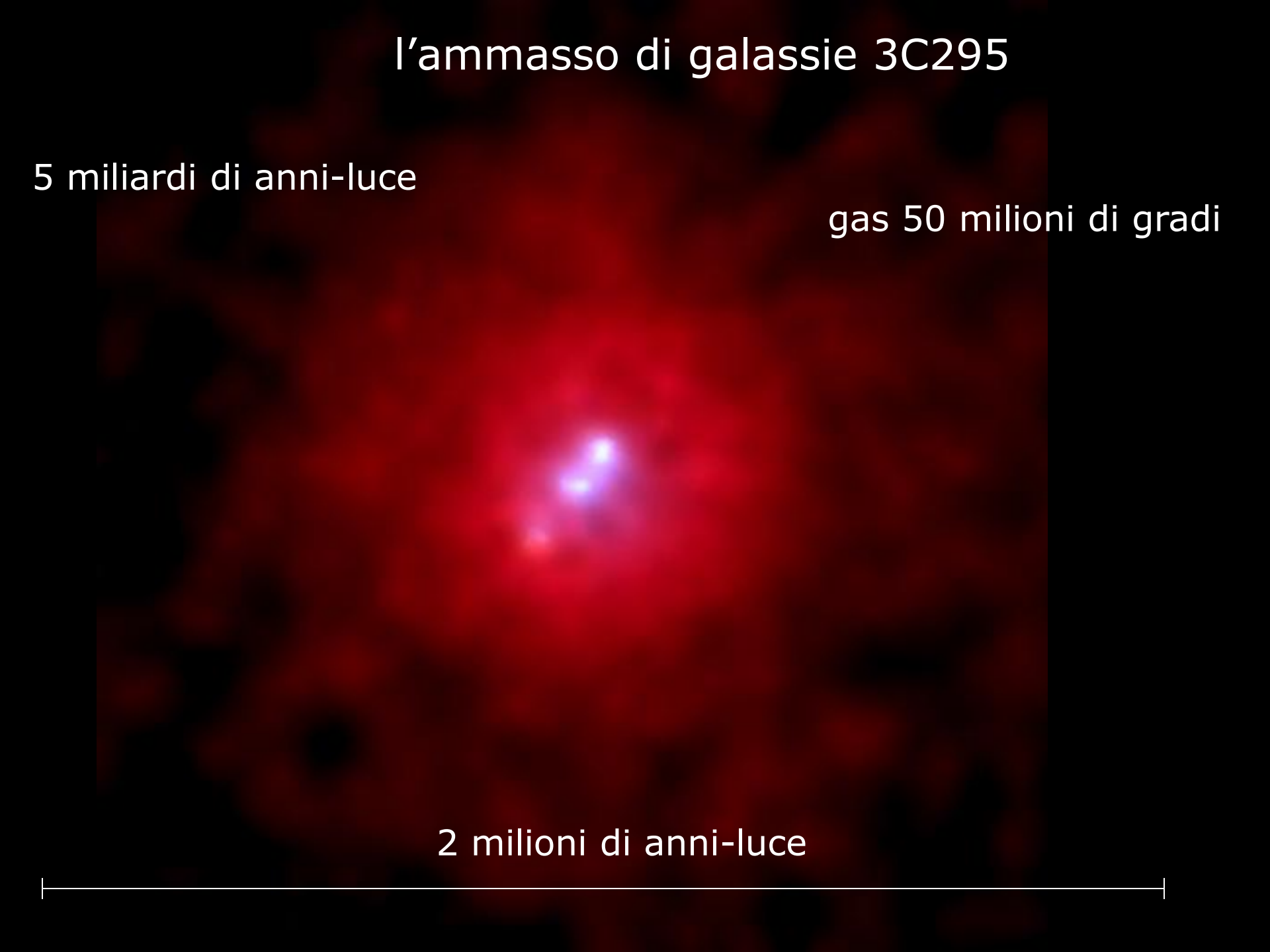




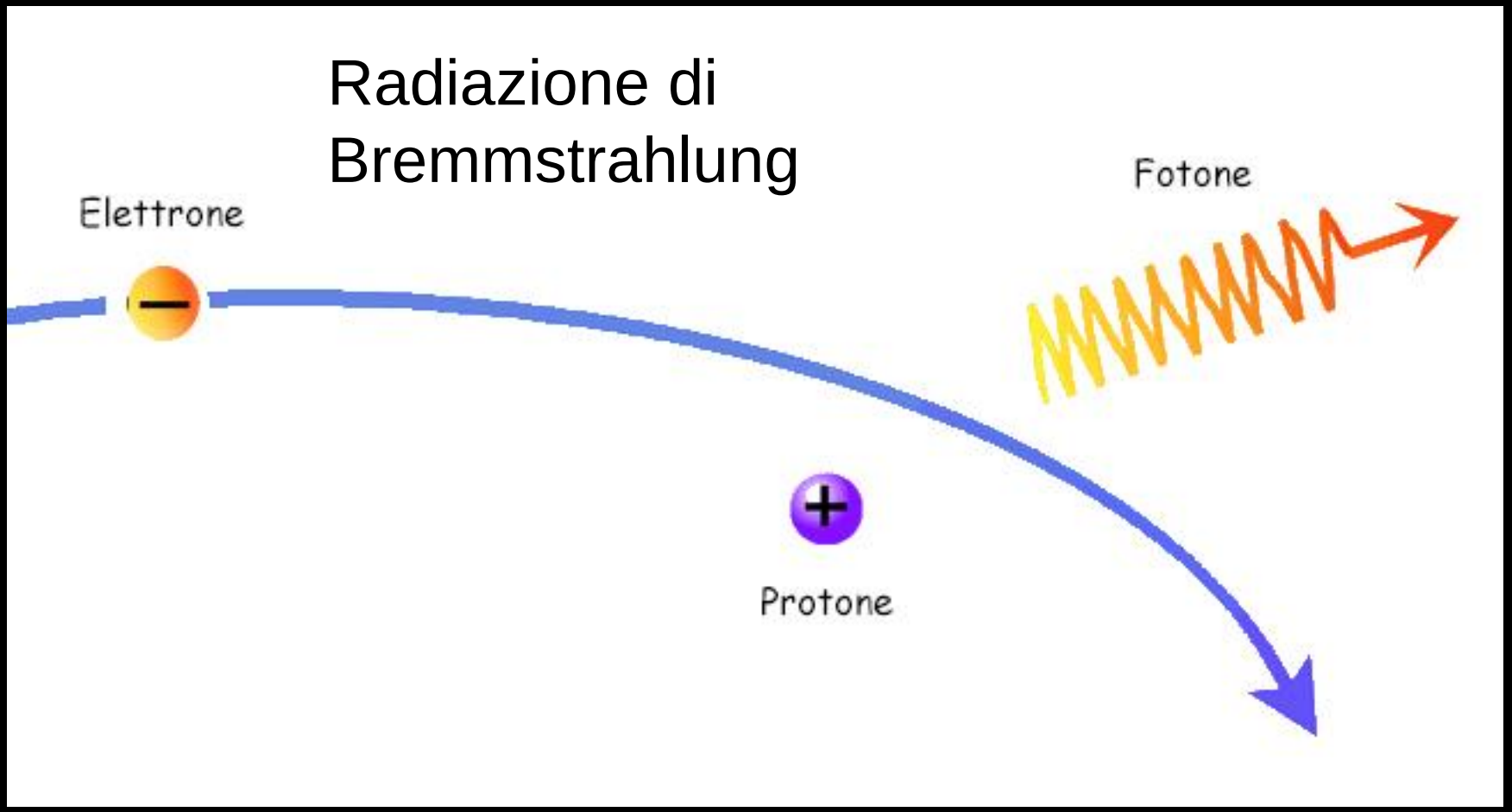
50 milioni di anni-luce

radiazione di
sincrotone




l’ammasso di galassie 3C295
5 miliardi di anni-luce
gas 50 milioni di gradi
2 milioni di anni-luce

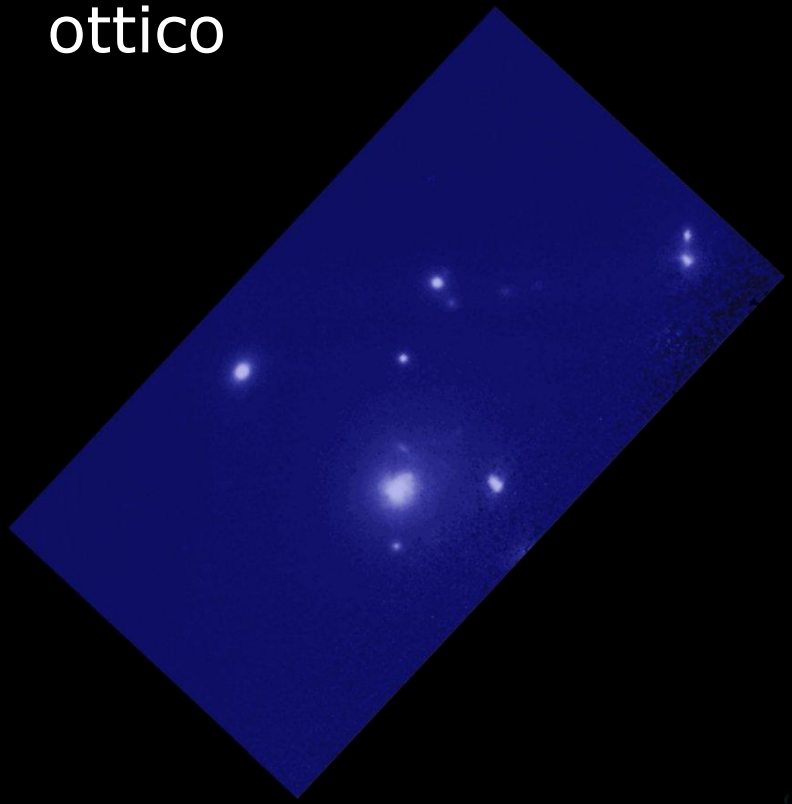
Radiazione di Bremmstrahlung



Frenamento di elettroni di alta T ad opera di protoni in un gas caldo.

corone stellari
resti di supernova
ammassi di galassie

l’ammasso di galassie 3C295

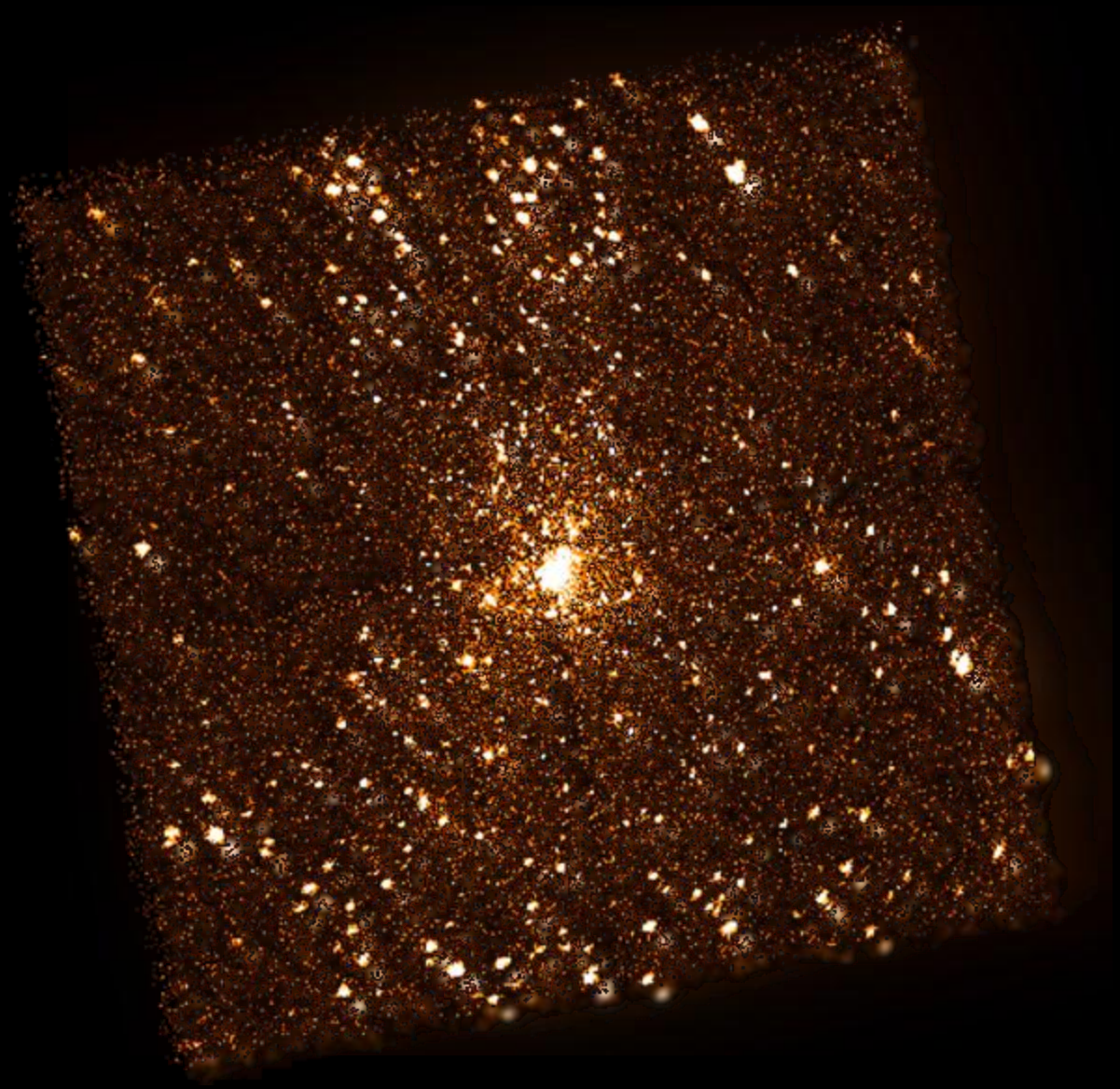


ottico

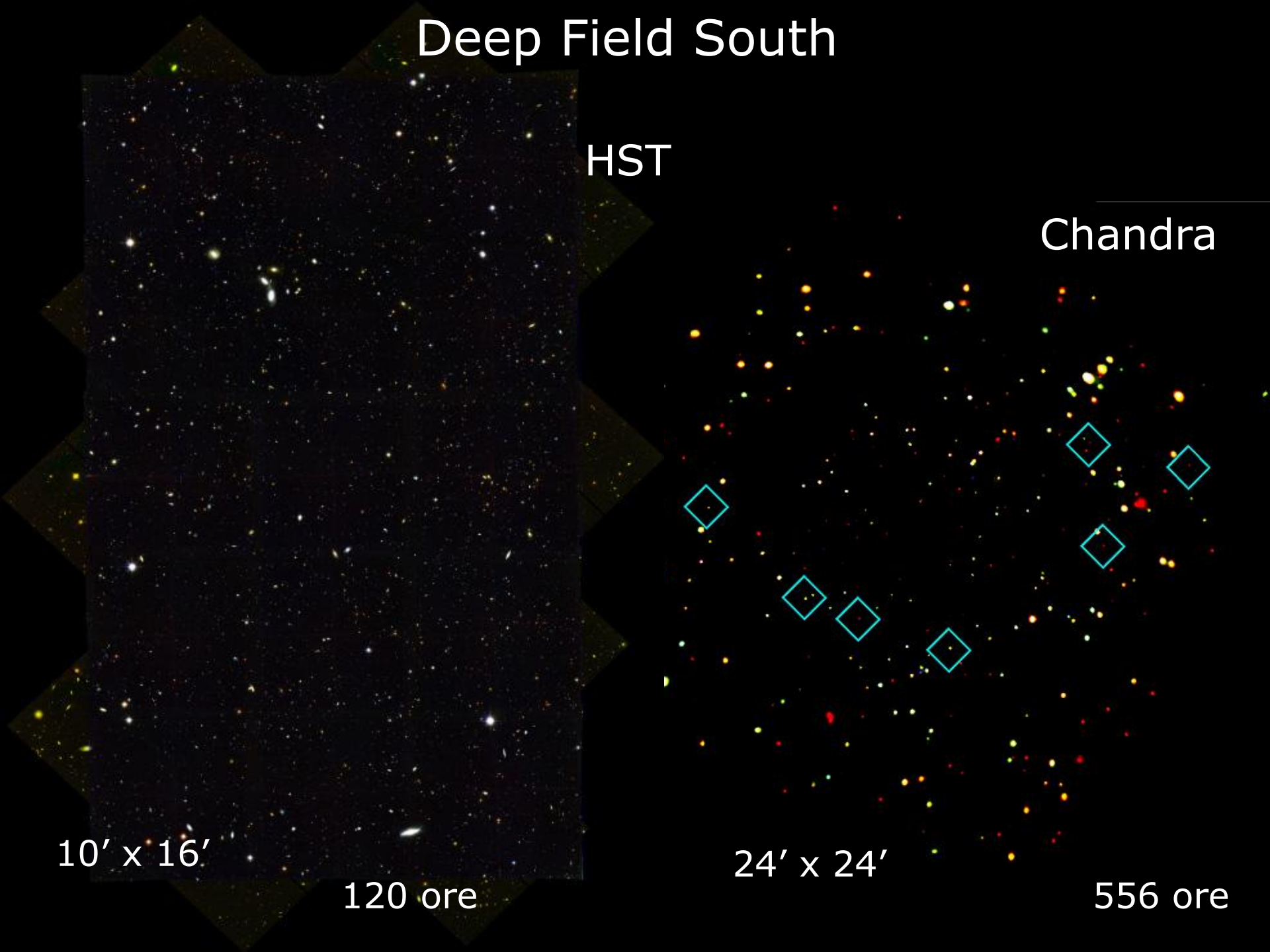
X

radio

Il fondo X



Deep Field South




Supernova 1054 a.c.

INAF-Osservatorio Astronomico di Brera:
http://www.brera.inaf.it

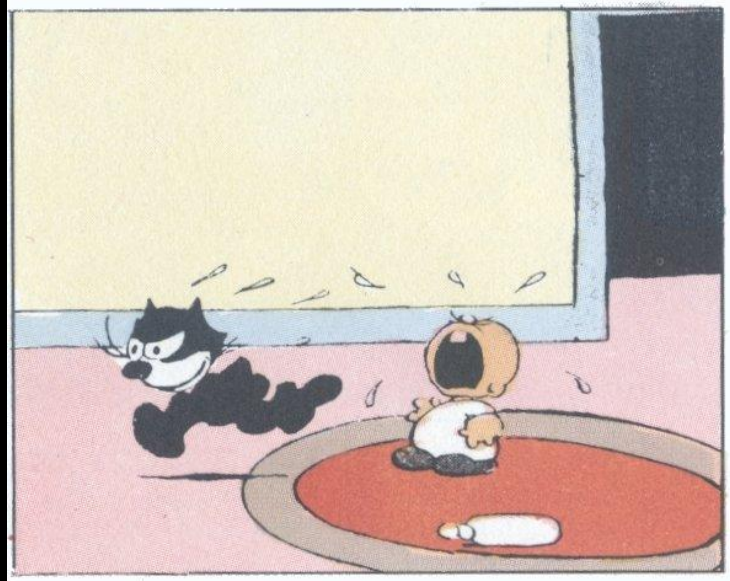
Chandra (NASA): http://chandra.harvard.edu

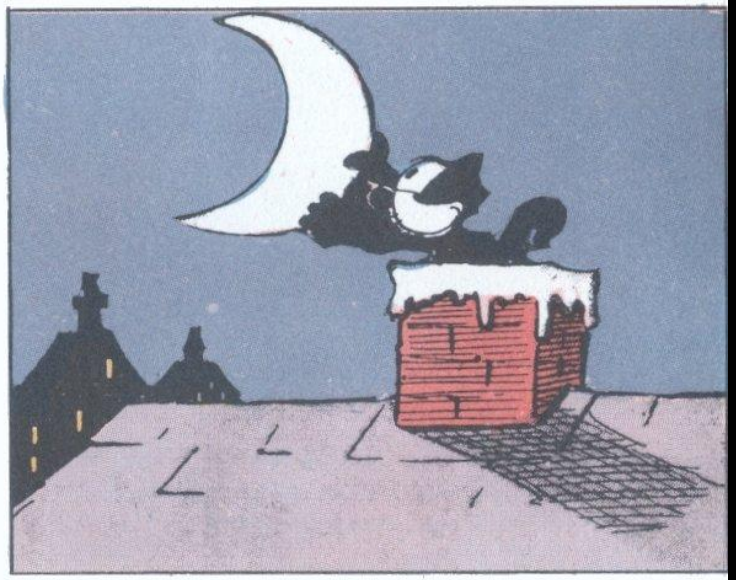
HST (NASA/ESA): http://hubblesite.org

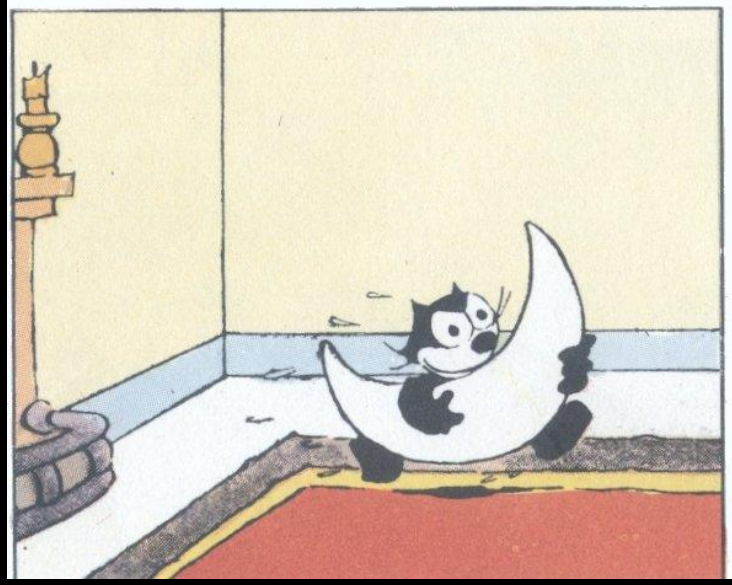
ESA: http://www.esa.int

Nobel Prize: http://nobelprize.org

Un’idea di Felix







Meccanismi di produzione di raggi X

- Meccanismi termici
  - Bremmsstrahlung
  - Accrescimento
  - Corpo nero
- Meccanismi non termici
  - Compton inverso
  - Sincrotrone