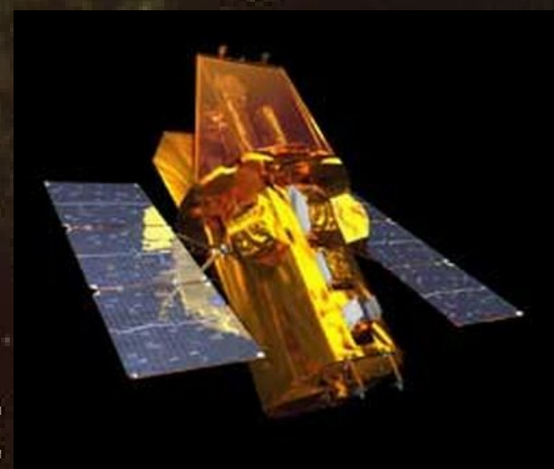
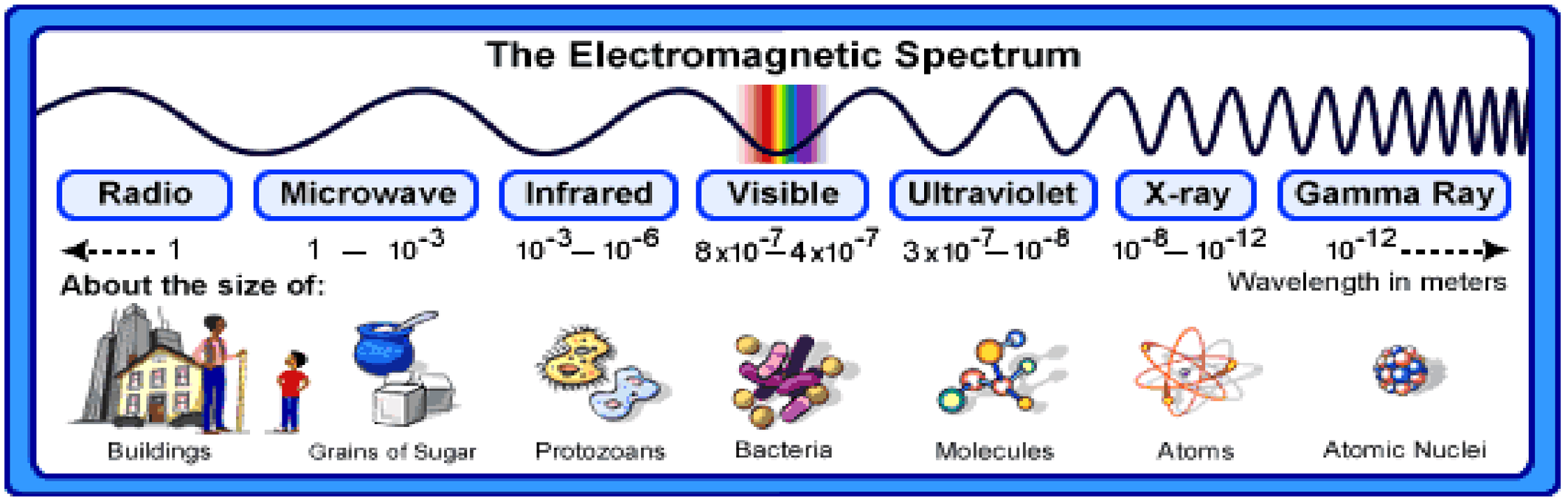
Bad boys nell'Universo:

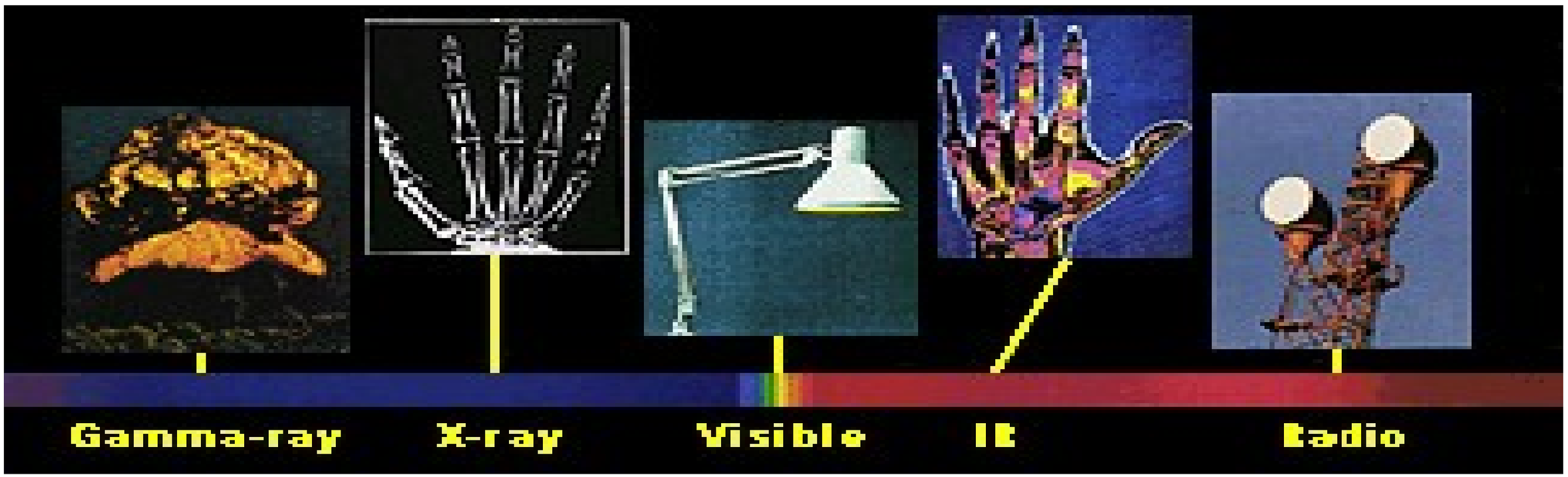
esplosioni stellari e fenomeni estremi

Cristiano Guidorzi
Ferrara, 14/03/2013

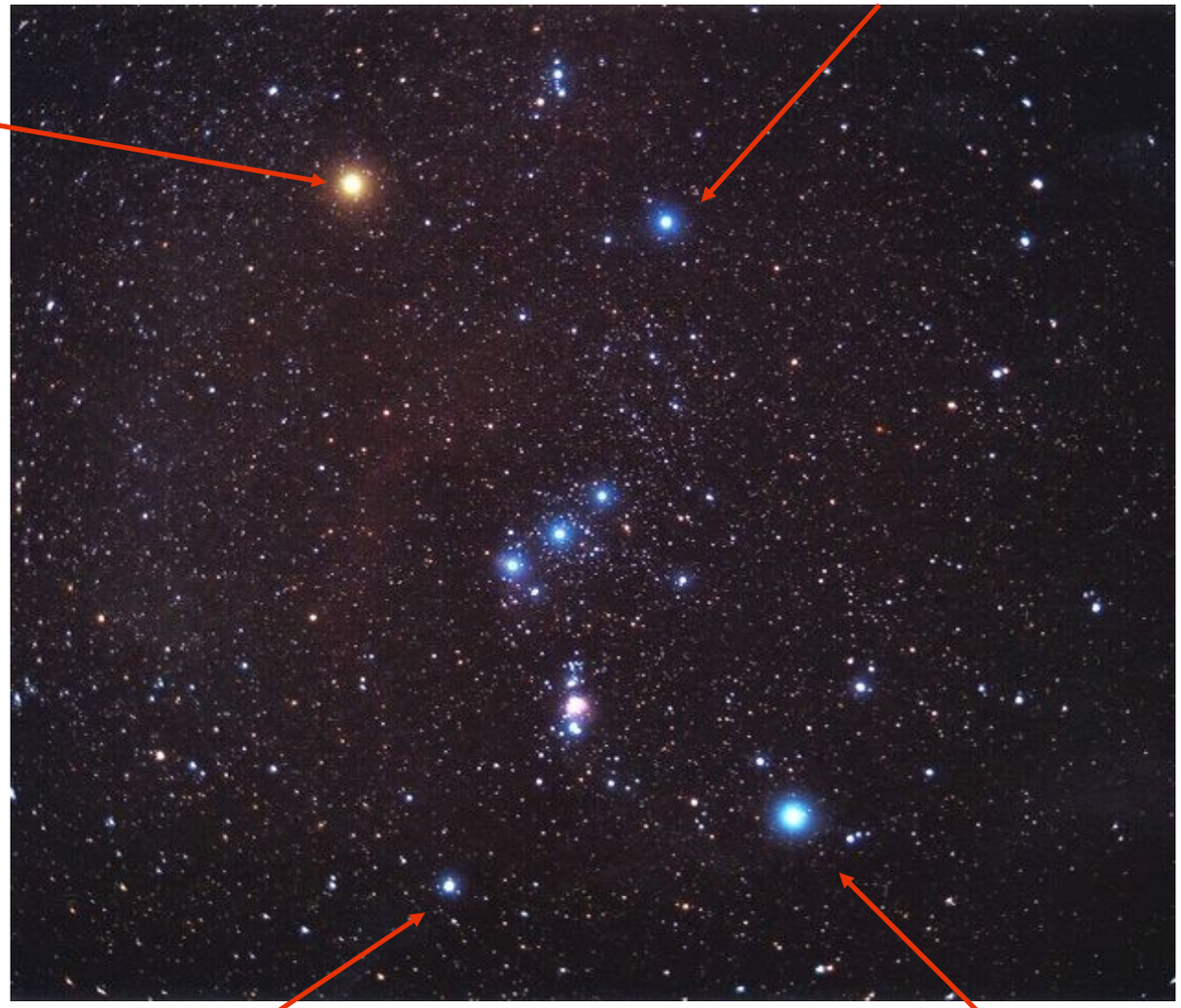


Il messaggero dell'universo: la radiazione elettromagnetica



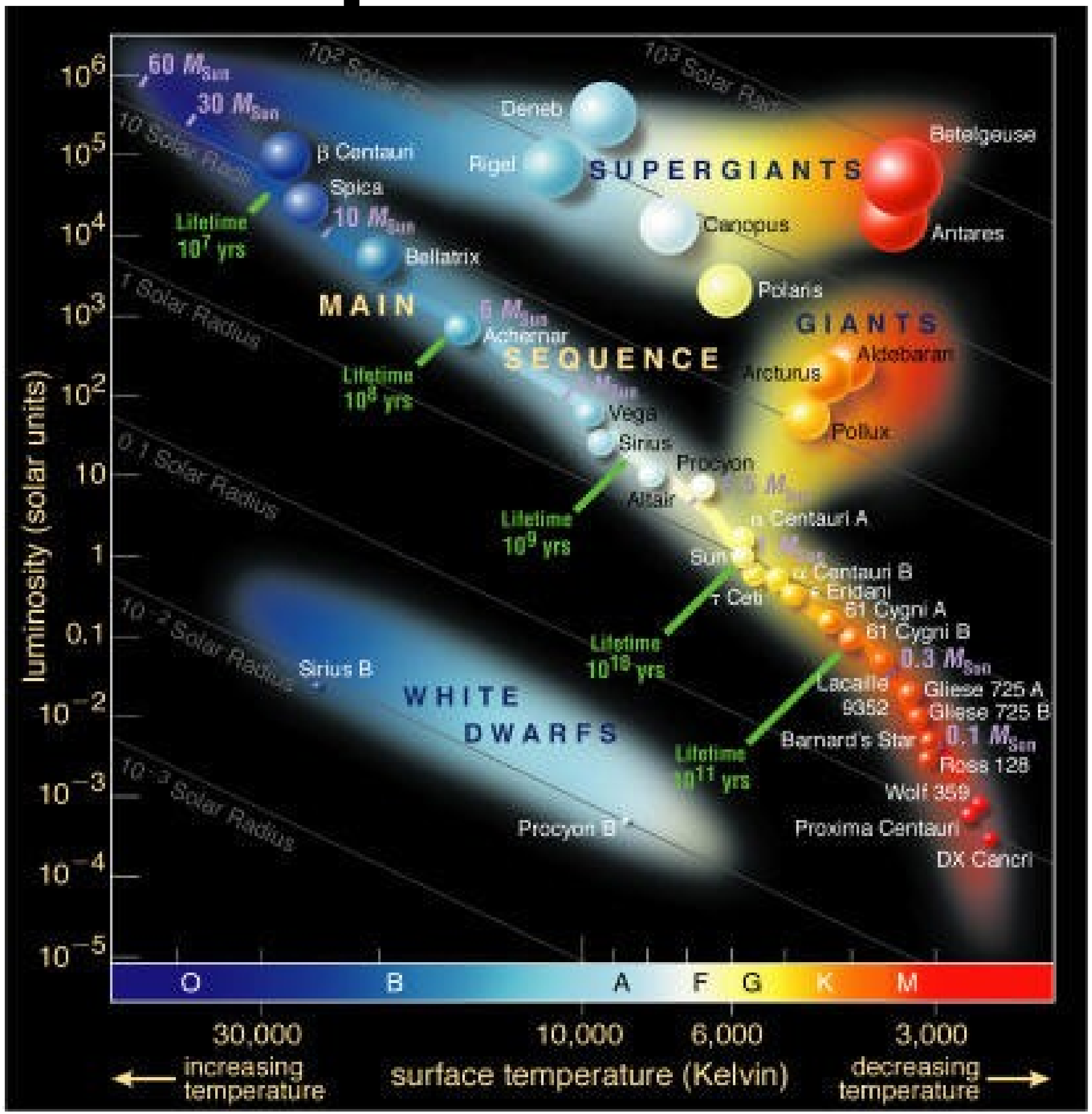


Il cielo che osserviamo

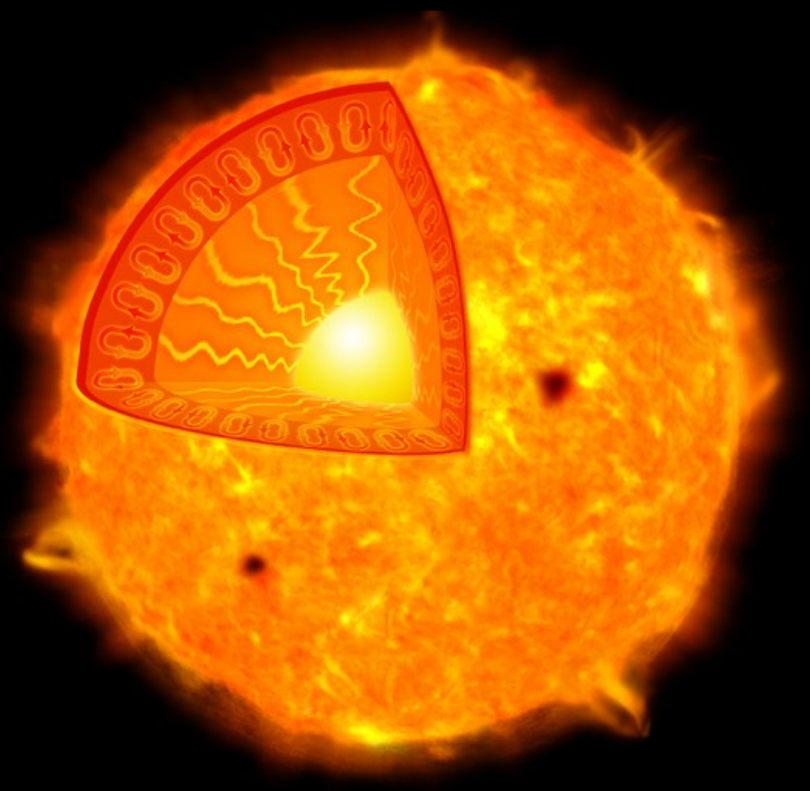


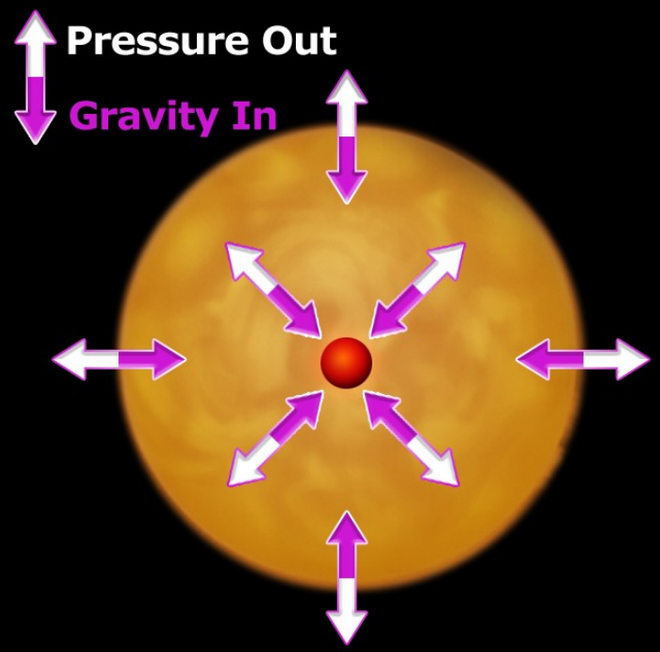
Costellazione
Orione

I diversi tipi di stelle visibili



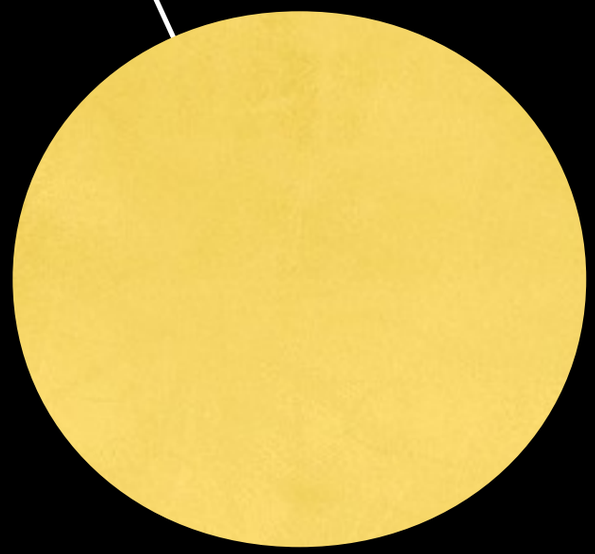
STELLA: sistema in equilibrio





VELOCITÀ DI FUGA

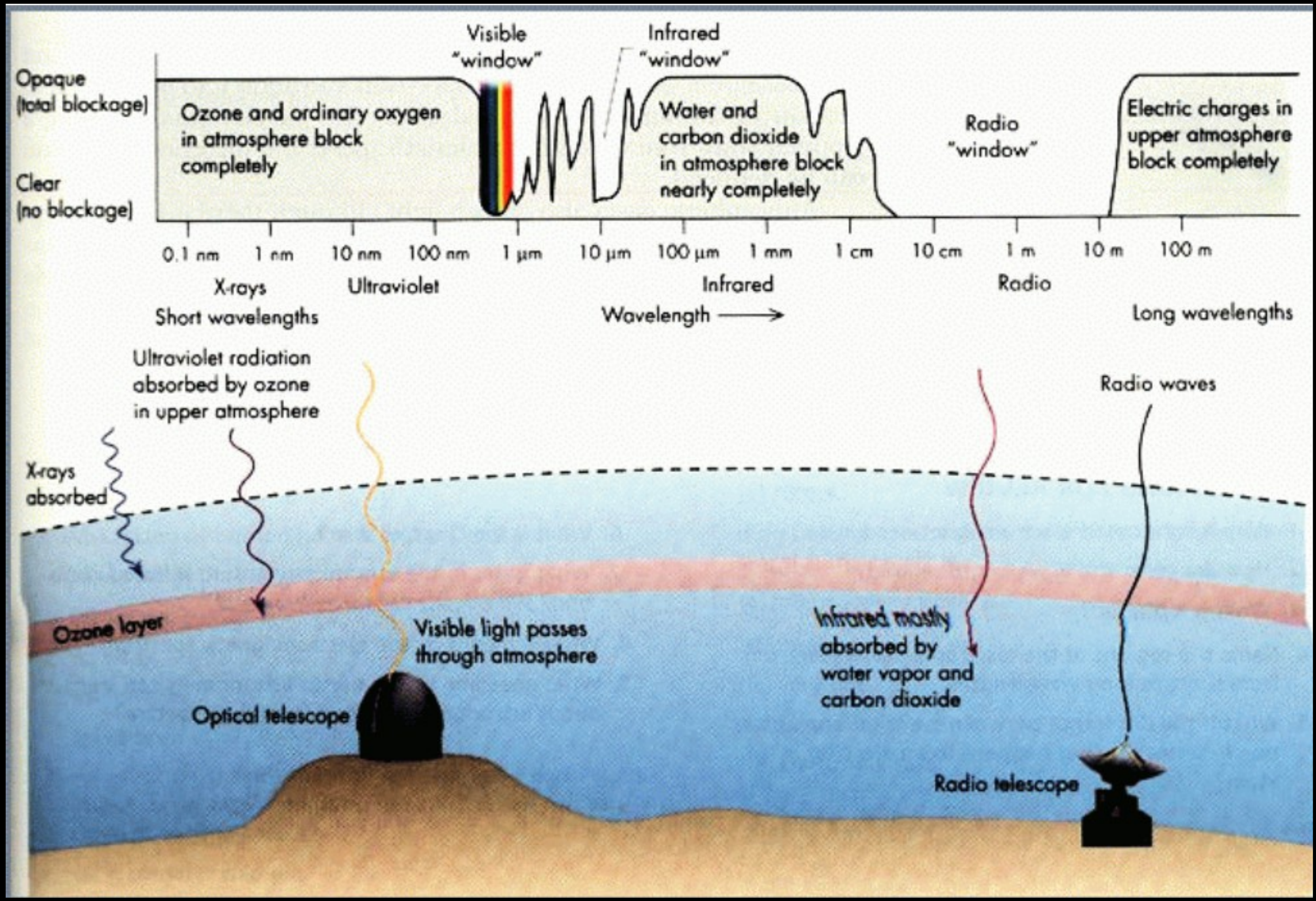
$$V_{\mathrm{FUGA}} = \left(\frac{2GM}{R}\right)^{1/2}$$



Zoom nel profondo cielo visibile

Una galassia come la nostra

L’intero cielo nel visibile


Visible "window"
Infrared "window"
Opaque (total blockage)
Clear (no blockage)
Ozone and ordinary oxygen in atmosphere block completely
Water and carbon dioxide in atmosphere block nearly completely
Radio "window"
Electric charges in upper atmosphere block completely
0.1 nm
1 nm
10 nm
100 nm
1 μm
10 μm
100 μm
1 mm
1 cm
10 cm
1 m
10 m
100 m
X-rays
Ultraviolet
Infrared
Radio
Short wavelengths
Wavelength →
Long wavelengths
Ultraviolet radiation absorbed by ozone in upper atmosphere
X-rays absorbed
Radio waves
Ozone layer
Visible light passes through atmosphere
Infrared mostly absorbed by water vapor and carbon dioxide
Optical telescope
Radio telescope

Telescopi in raggi X nello spazio

Chandra (NASA Great Observatory)

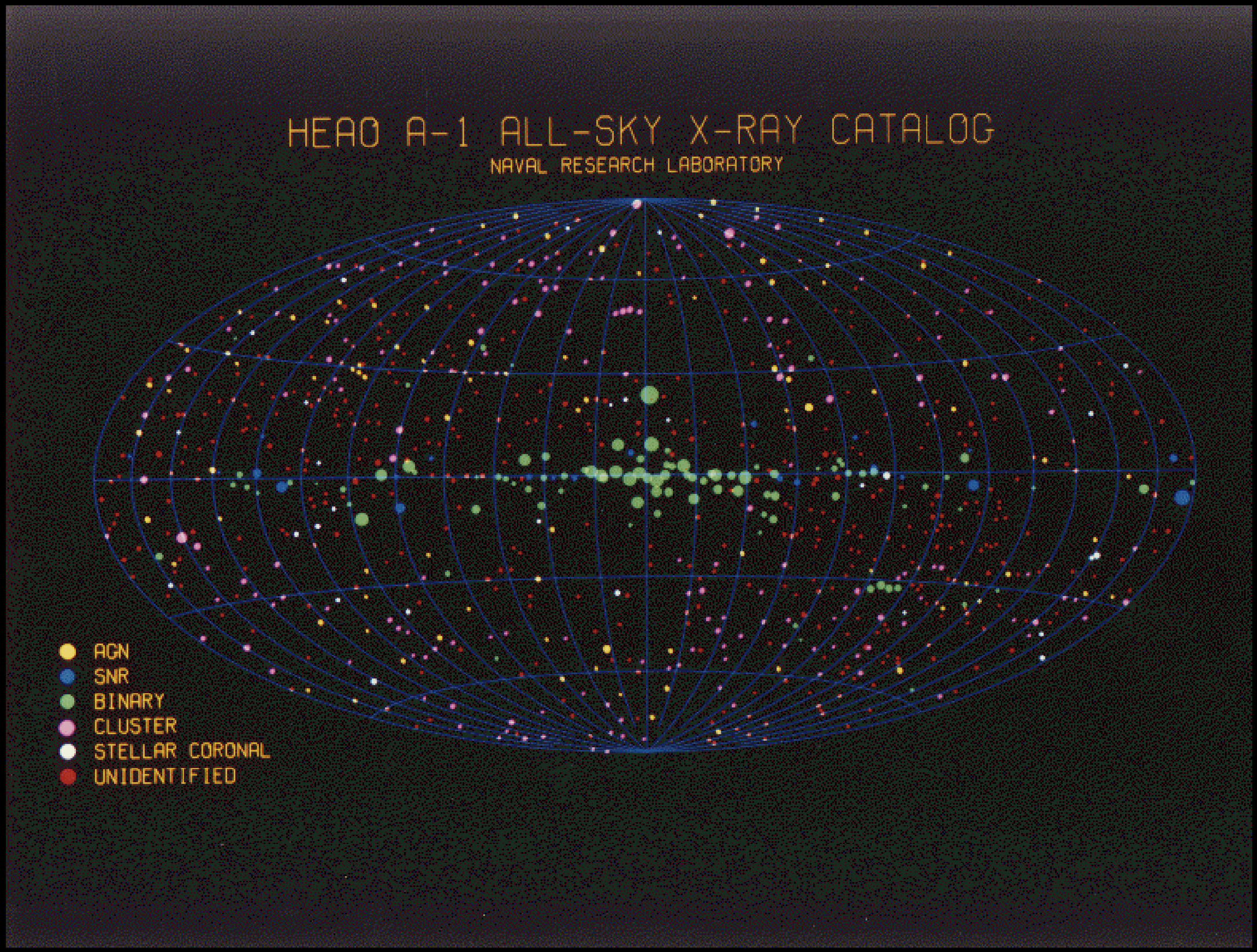
XMM-*Newton* (European Space Agency)

Rossi X-ray Timing Explorer (NASA)

MIRAX (small mission planned by Brazil)

Chandra

Il cielo in raggi X (anni ’80)



Una galassia a spirale “normale” M83

Raggi-X (Chandra)

NUCLEO

GAS CALDO

Ottico & sorgenti X (VLT & Chandra)

BRACCIA A SPIRALE

Sorgenti di raggi X brillanti

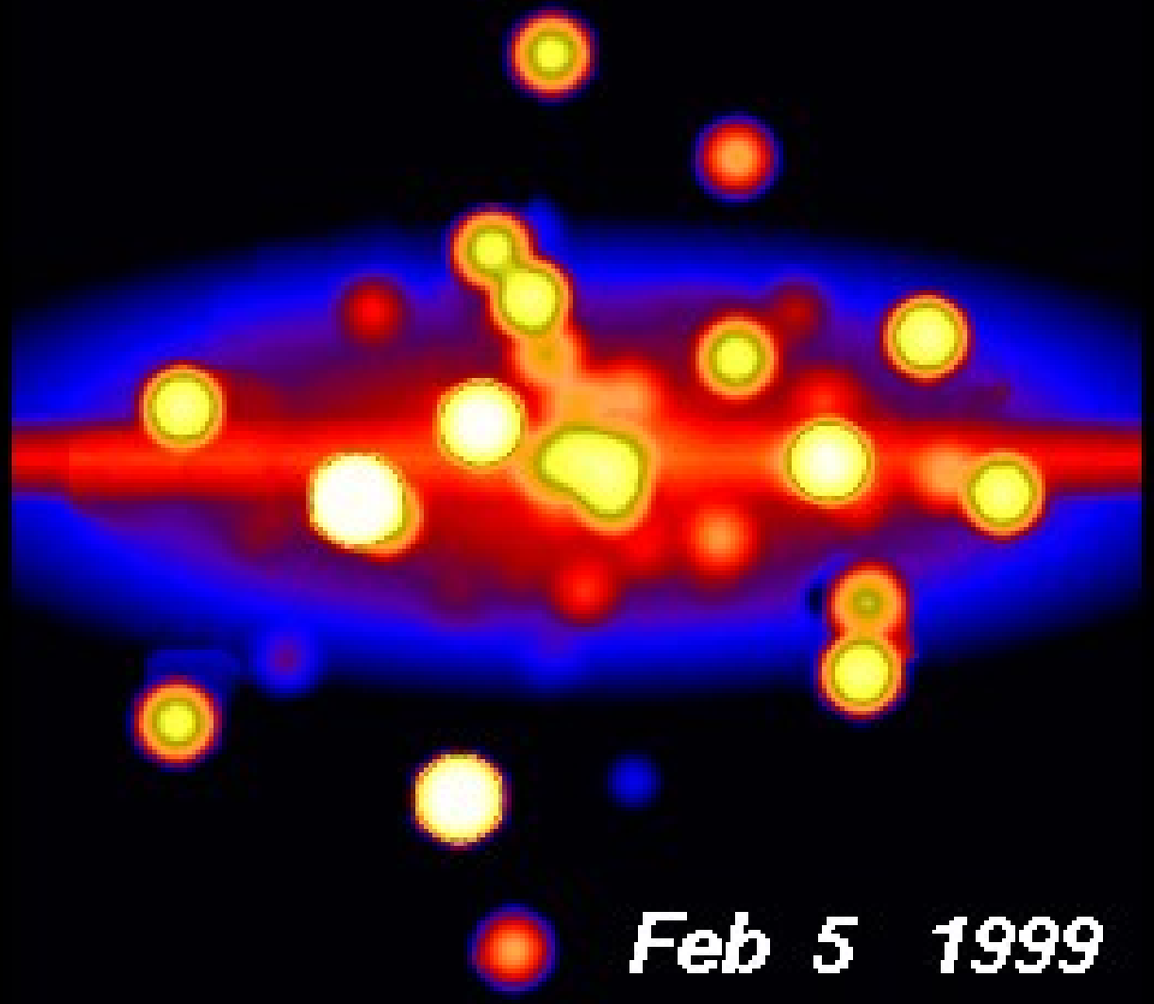
Galassia Sombrero

Raggi X

Ottico

Infrarosso

L’universo violento in raggi X/gamma



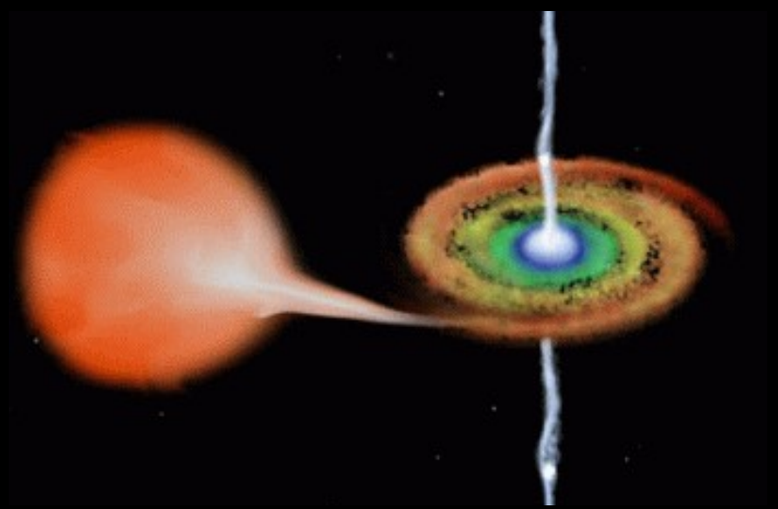
Perchè il cielo in raggi X è così variabile?

Accrescimento di massa

Massa della stella compagna ha momento angolare e non può cadere direttamente sulla compatta

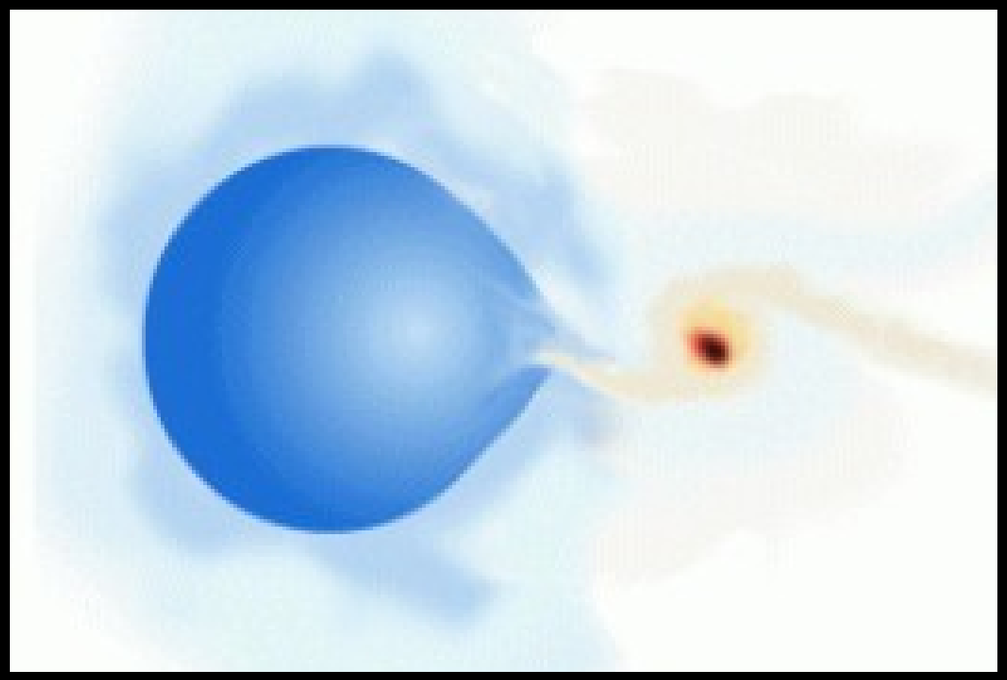
Si scalda per attrito e spiraleggia attraverso un disco di accrescimento

Stelle binarie: oggetti compatti che accrescono massa dalla stella compagna



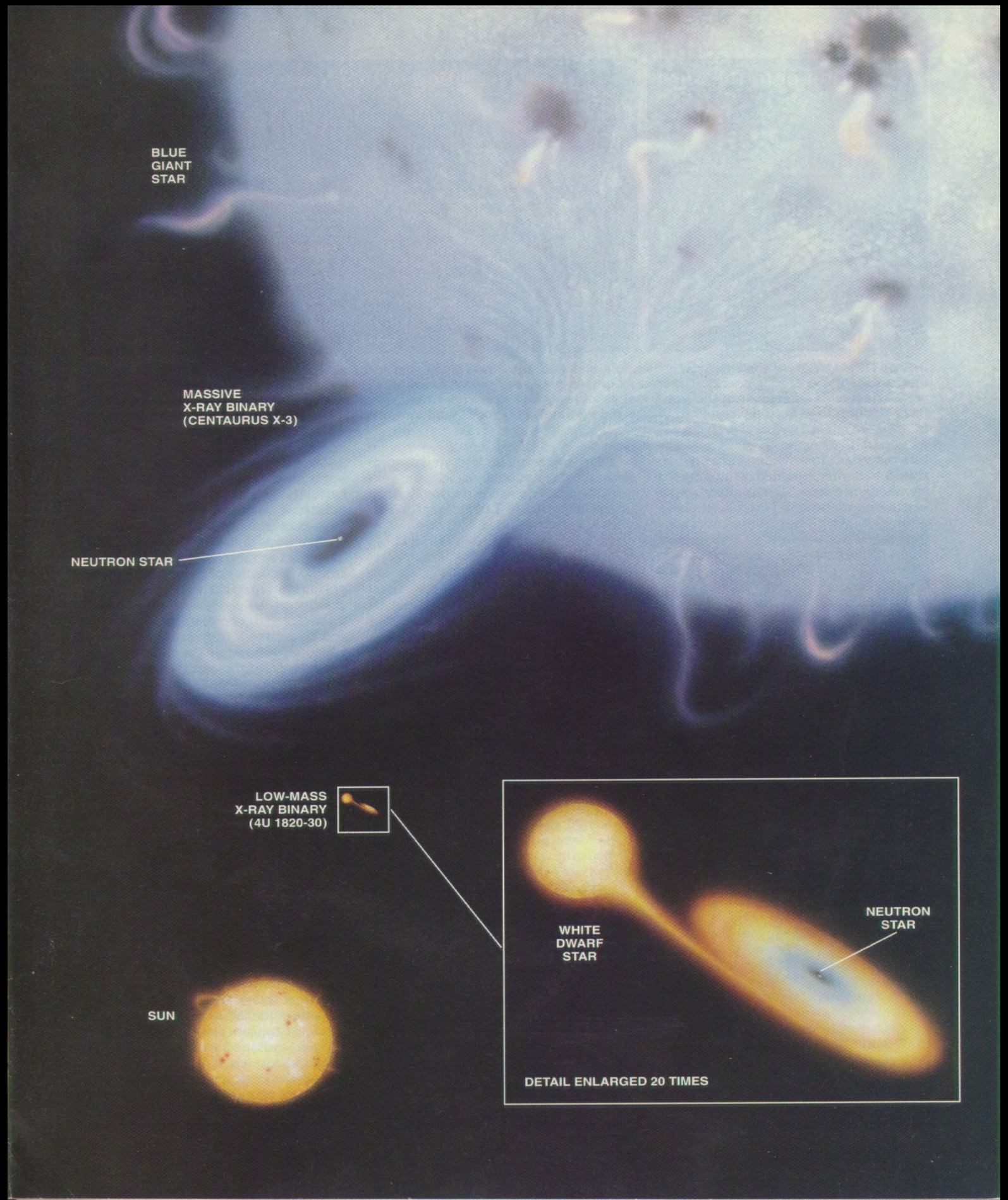
Scenario 1: Roche Lobe overflow
- Stelle + massive muoiono prima
- Distanza tra le due diminuisce nel tempo
  (magnetic braking and/or grav. radiation)

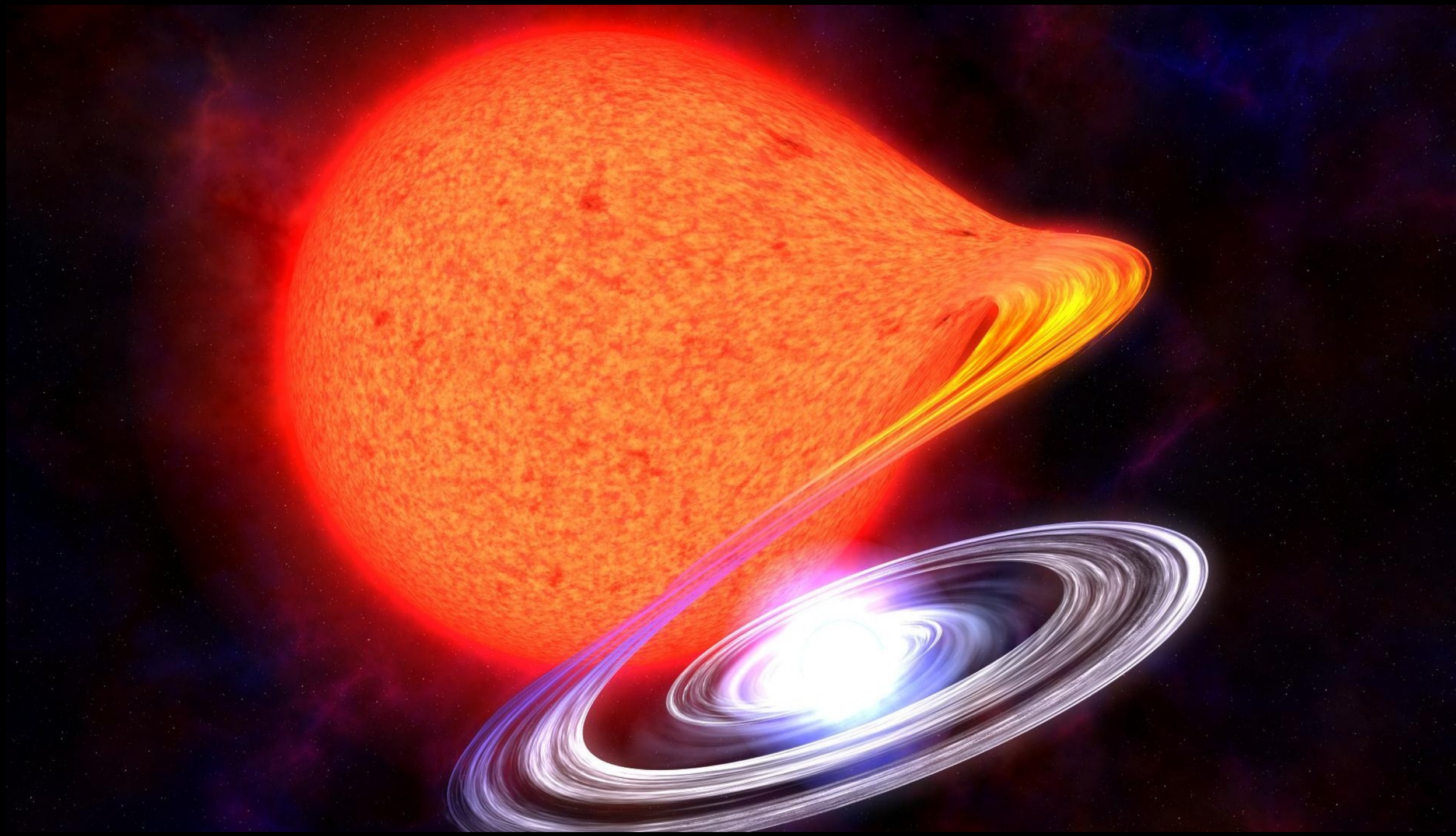
Tipico di binarie a piccola massa (compagna)
Low-Mass X-ray Binary **(LMXB)**



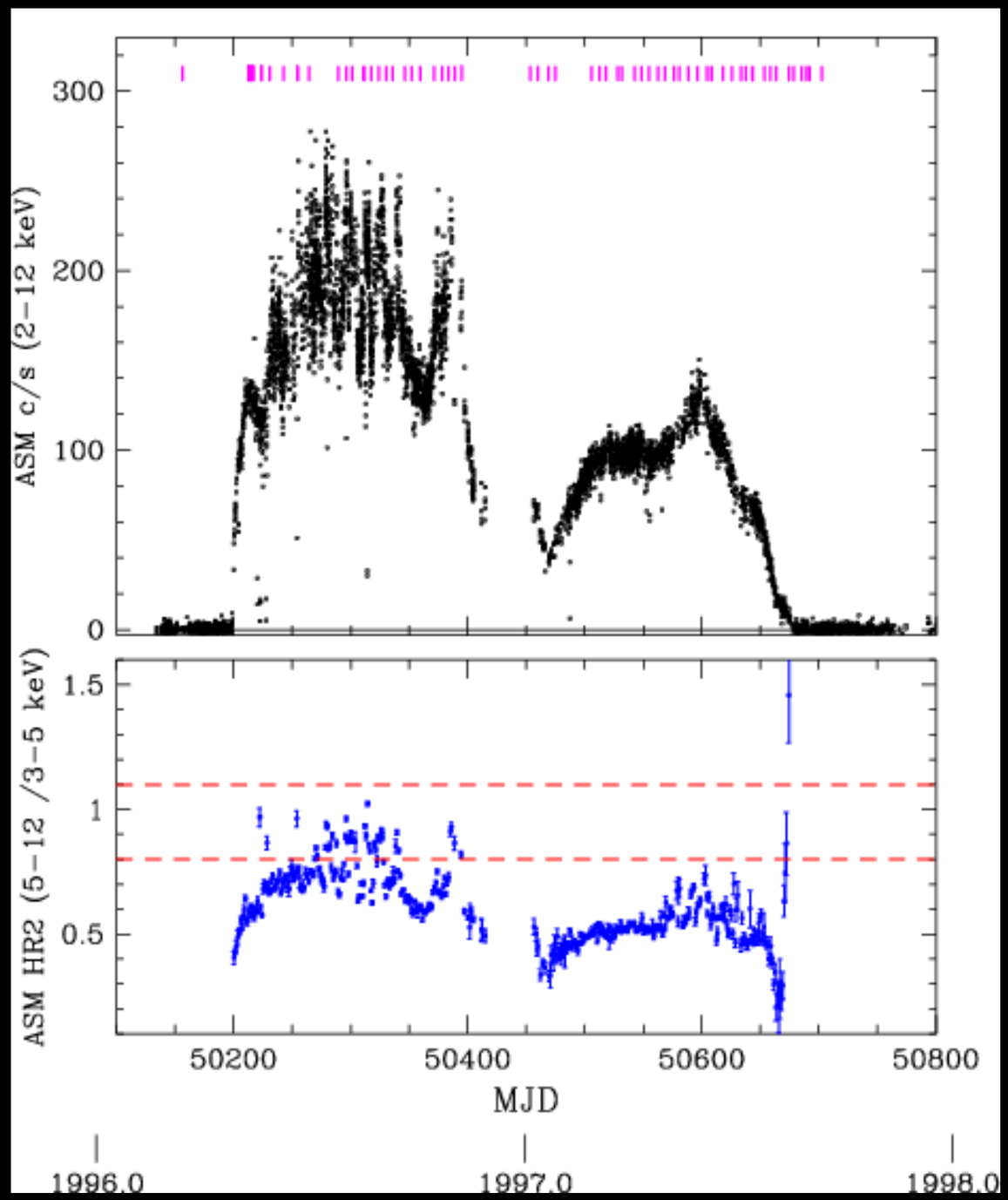
Scenario 2: Vento stellare che accresce
- Stelle + massive muoiono prima
- Massa del vento stellare catturata

Tipico di binarie a grande massa (compagna)
High-Mass X-ray Binary **(HMXB)**


BLUE
GIANT
STAR
MASSIVE
X-RAY BINARY
(CENTAURUS X-3)
NEUTRON STAR
LOW-MASS
X-RAY BINARY
(4U 1820-30)
SUN
WHITE
DWARF
STAR
NEUTRON
STAR
DETAIL ENLARGED 20 TIMES



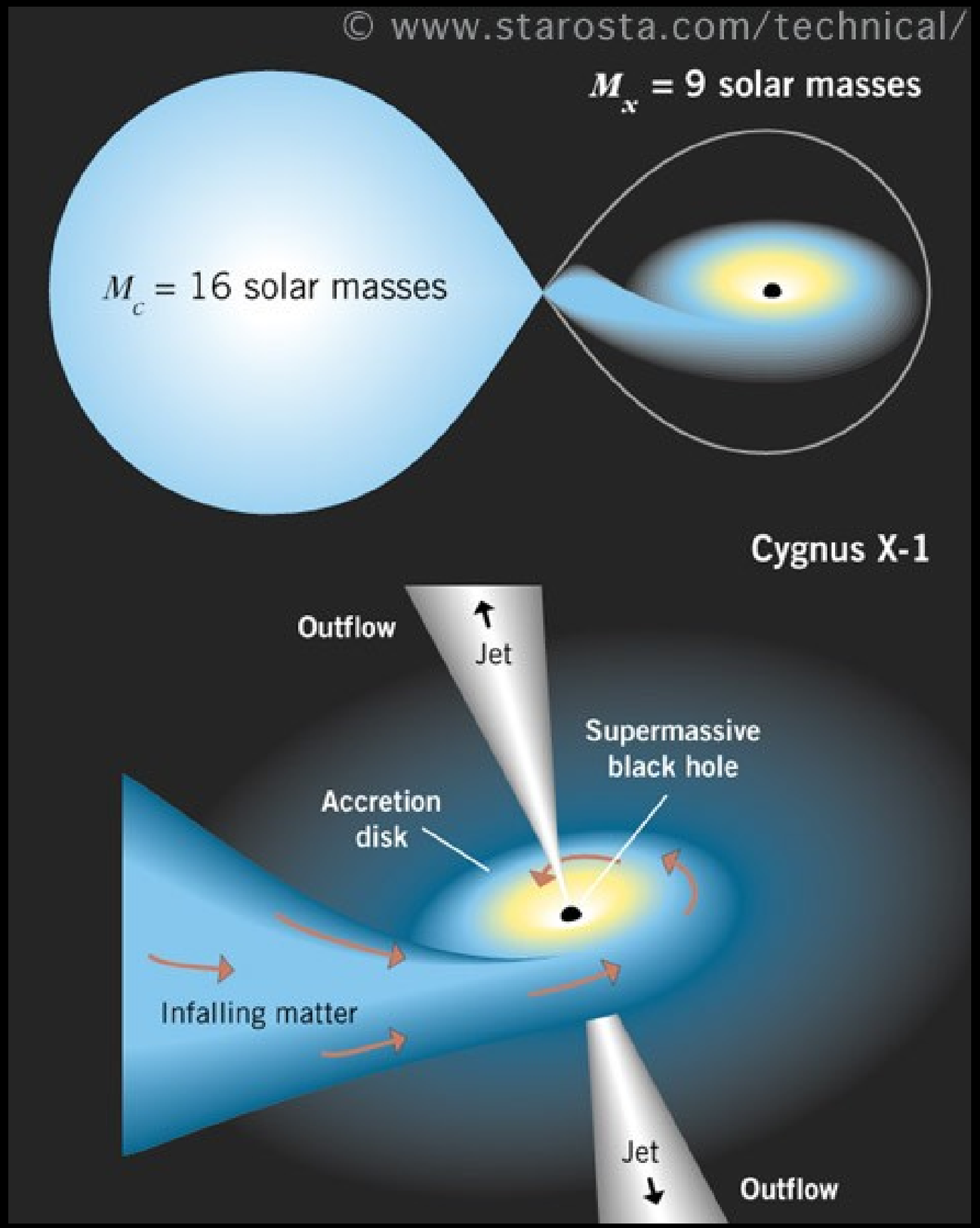
Black Hole X-ray Transient



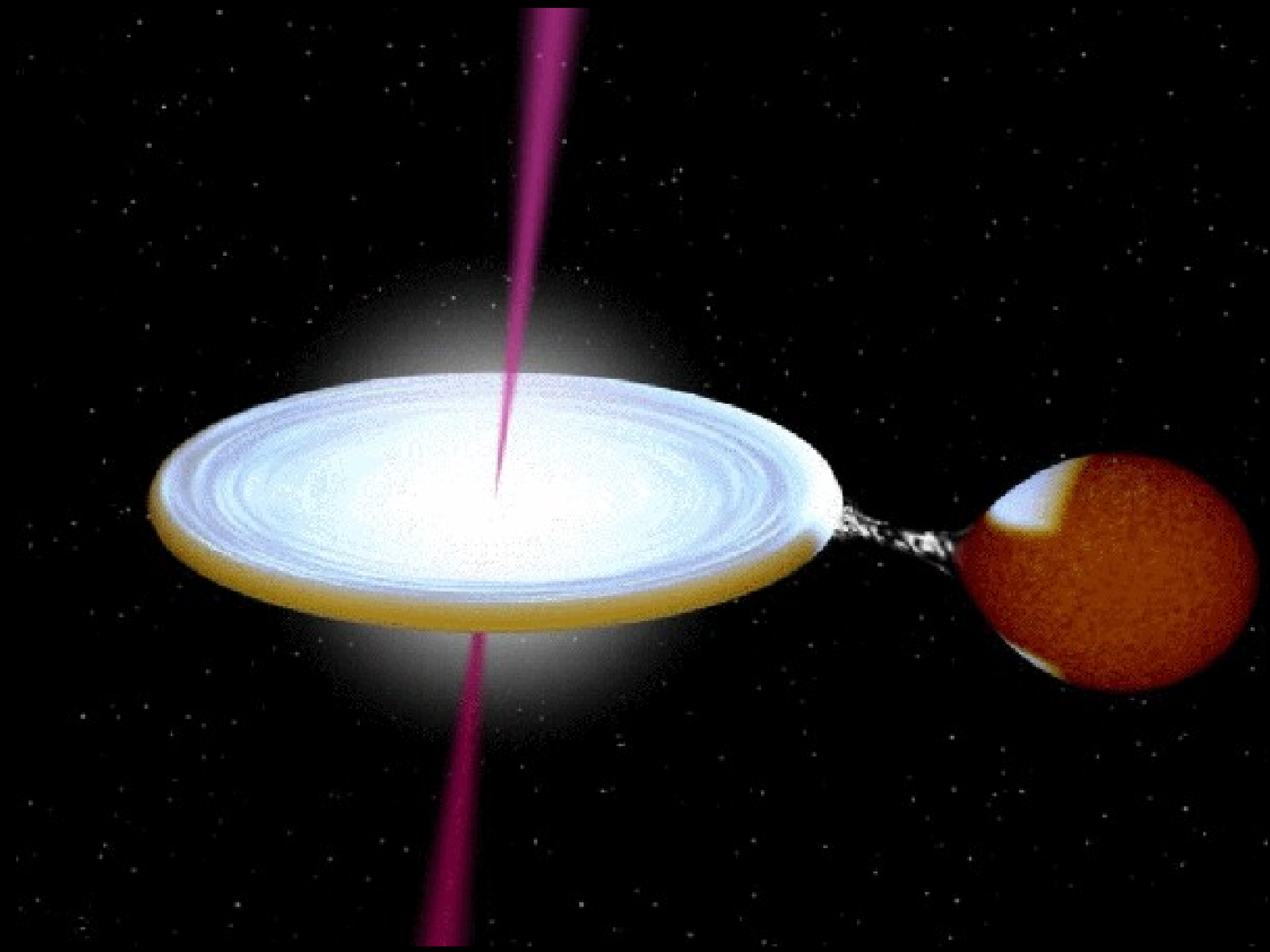
GRO J1655-40

Different X-ray States

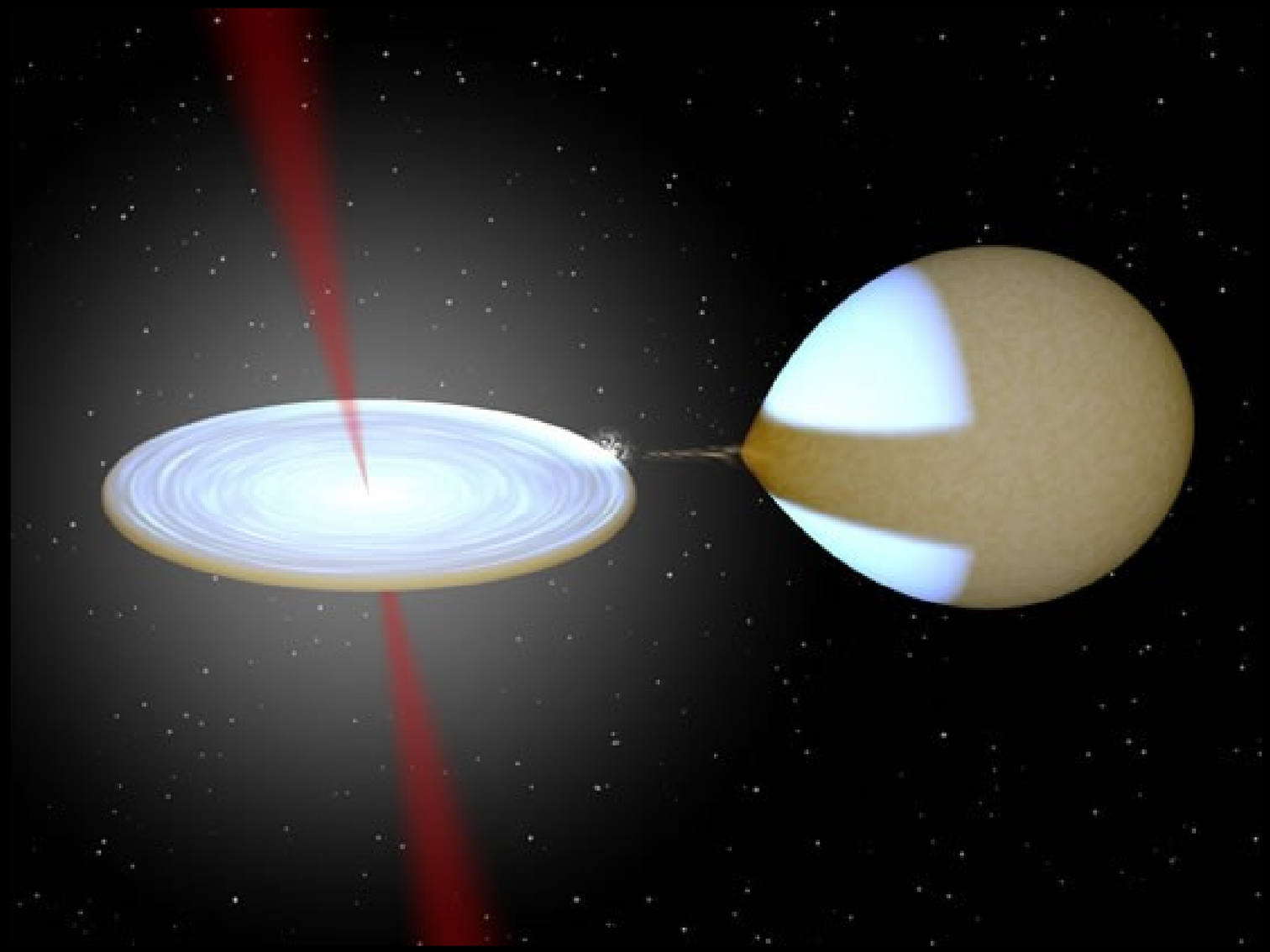
Cygnus X-1


© www.starosta.com/technical/
M_x = 9 solar masses
M_c = 16 solar masses
Cygnus X-1
Outflow
Jet
Supermassive black hole
Accretion disk
Infalling matter
Jet
Outflow

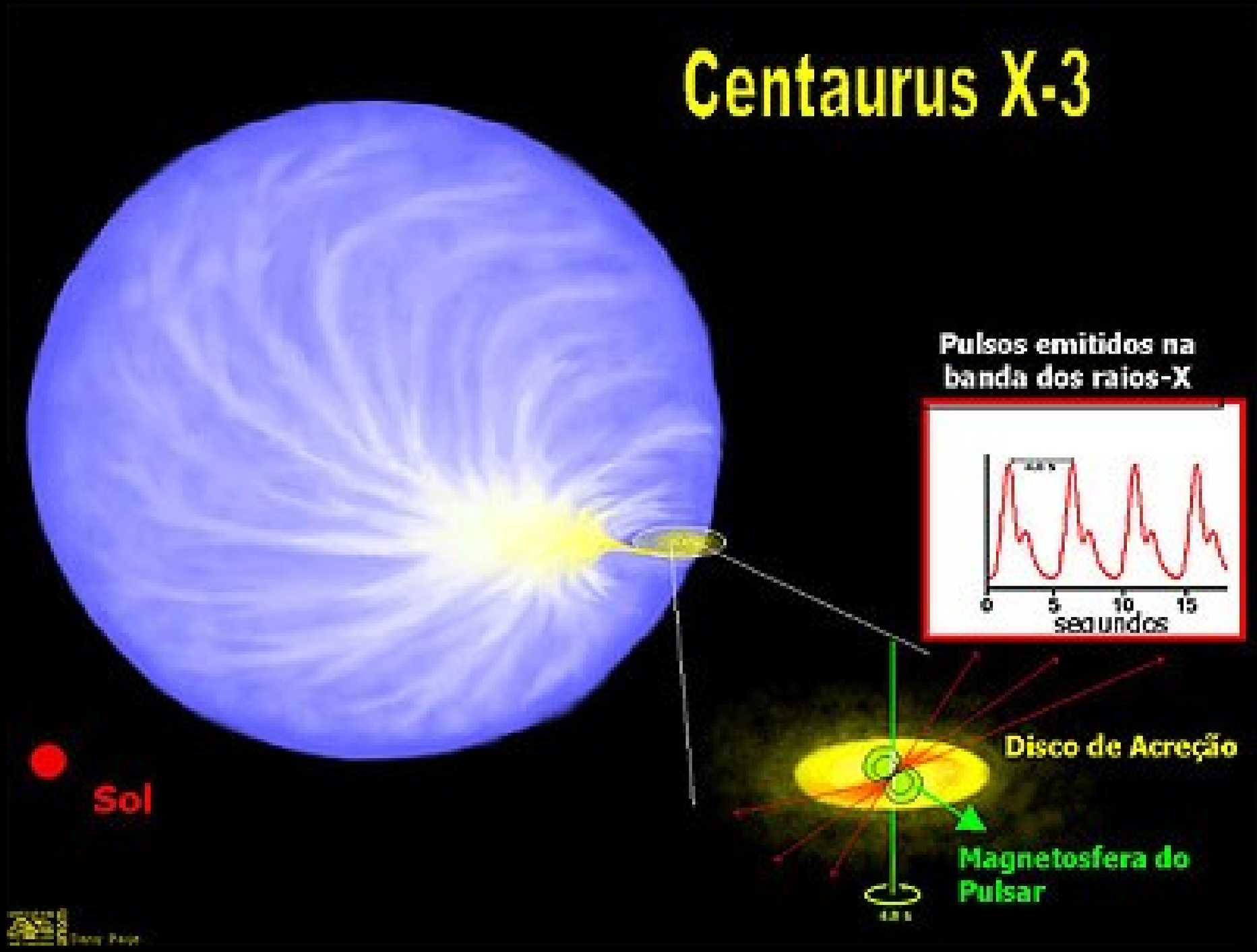
GRS 1915+105



GRO J1655-40



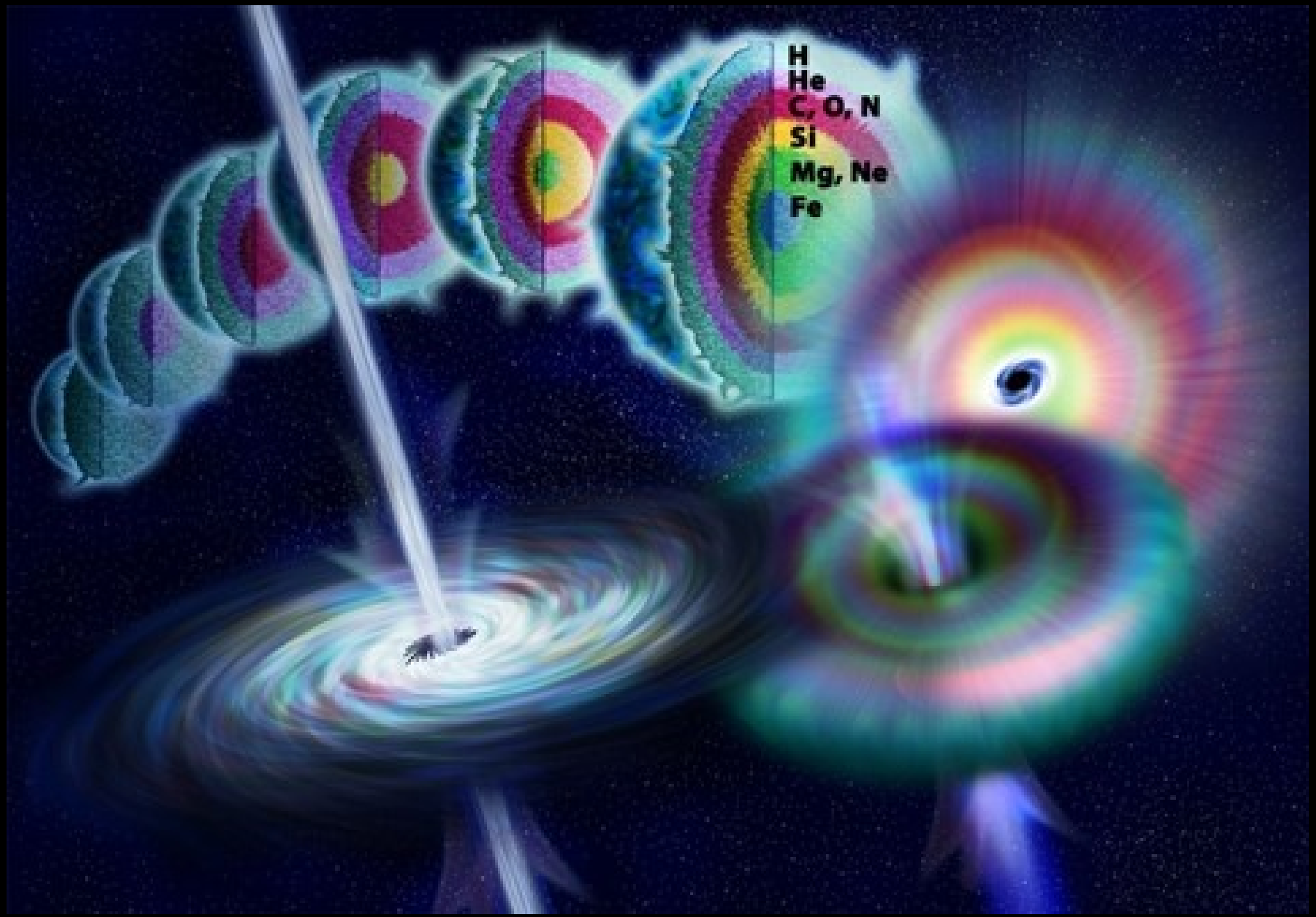
Cen X-3


Centaurus X-3
Pulsos emitidos na banda dos raios-X
0
5
10
15
segundos
Sol
Disco de Acreção
Magnetosfera do Pulsar

Eventi Catastrofici:
Collasso di stella con formazione di un

oggetto compatto

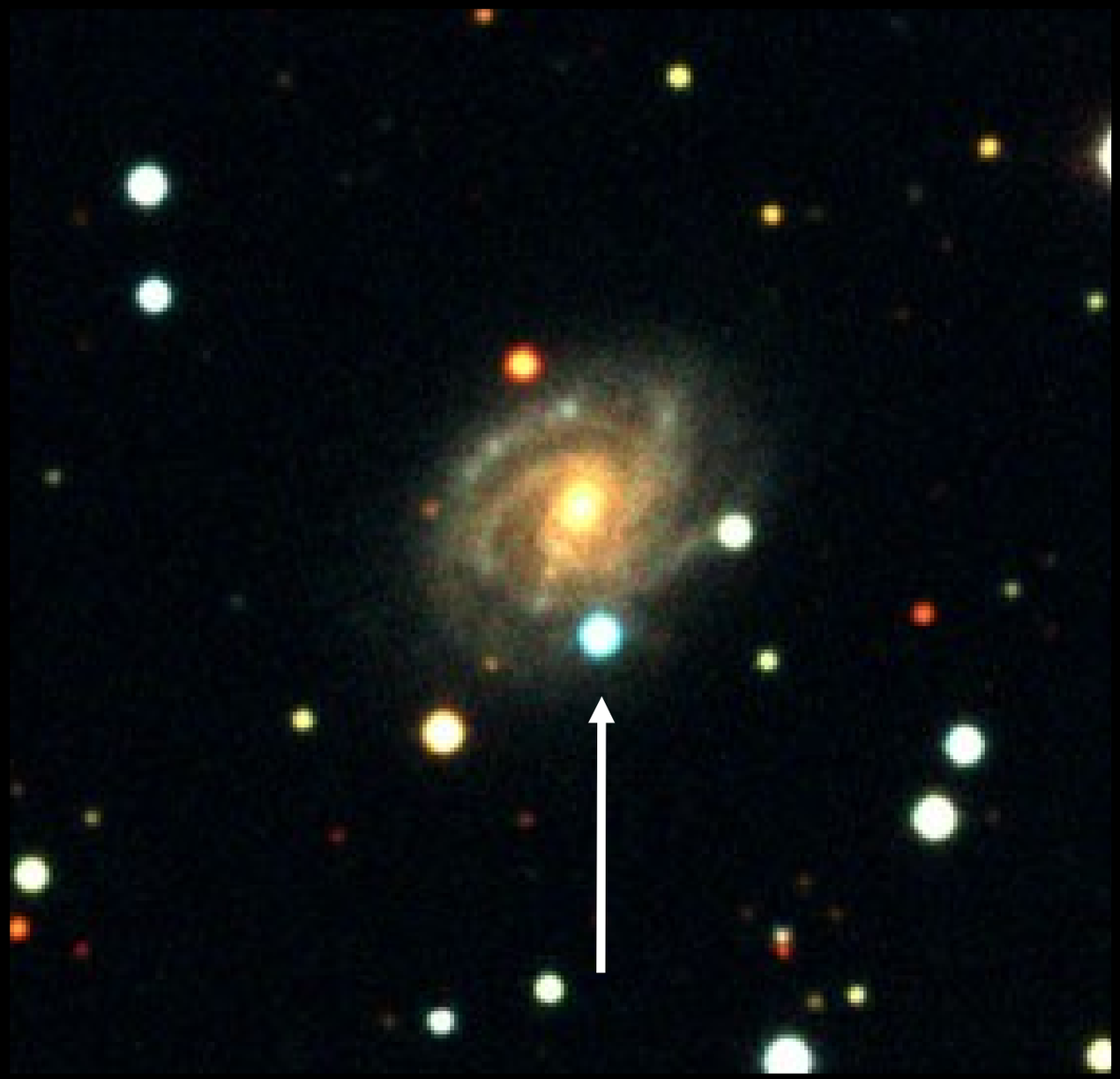
Da stella massiccia a buco nero



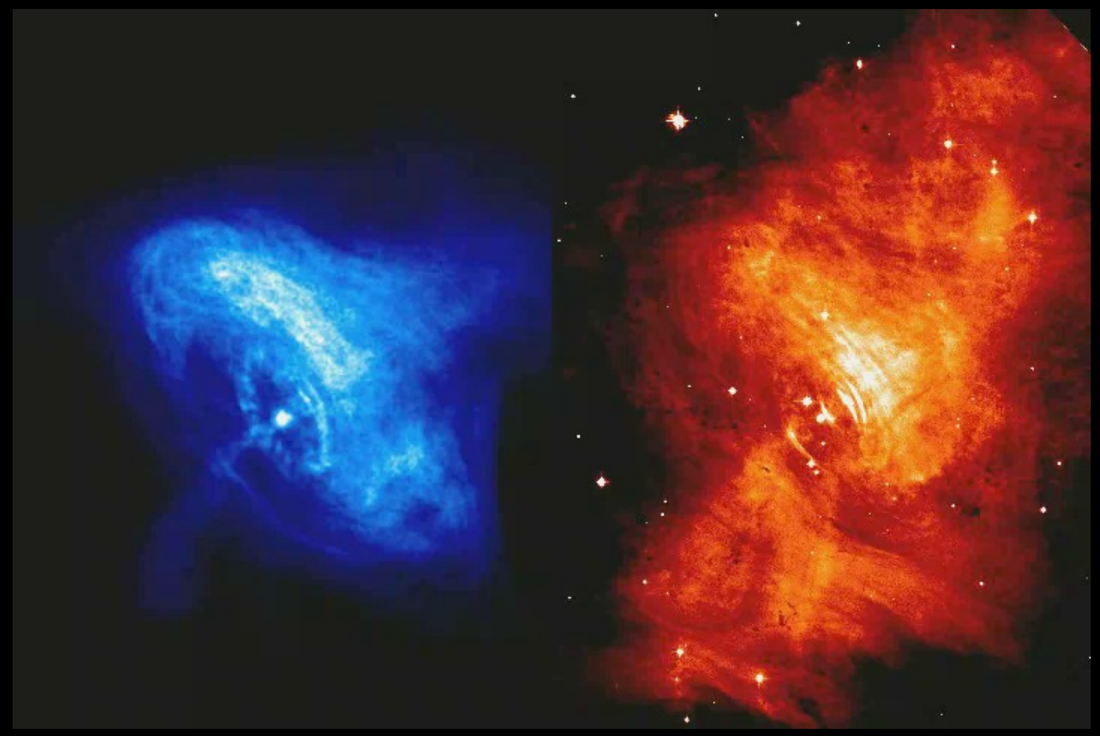
CHADWICK 1932: SCOPERTA DEL NEUTRONE

1933 BAADE & ZWICKY: SUPERNOVAE - STELLE DI NEUTRONI

L'IMPLOSIONE DEL NUCLEO STELLARE ALIMENTA LA SUPERNOVA



Esplosione di supernova

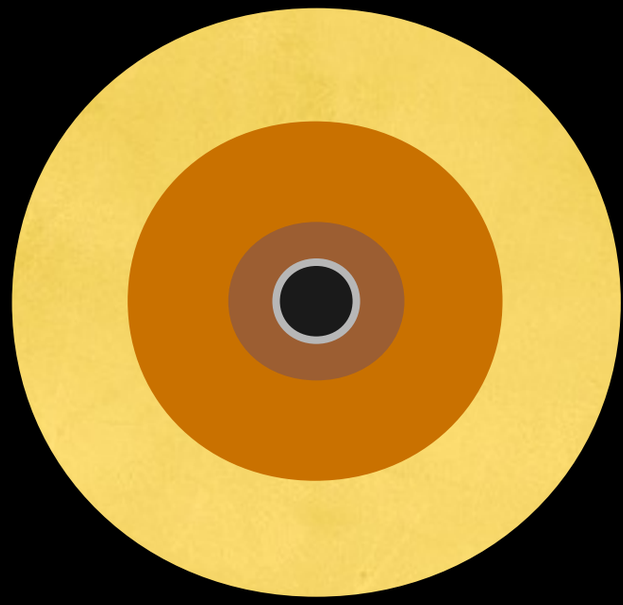


VELOCITÀ DI FUGA

$$V_{FUGA} = \left(\frac{2GM}{R}\right)^{1/2}$$

1783-1795
Michell e
Laplace
“Stella Oscura”

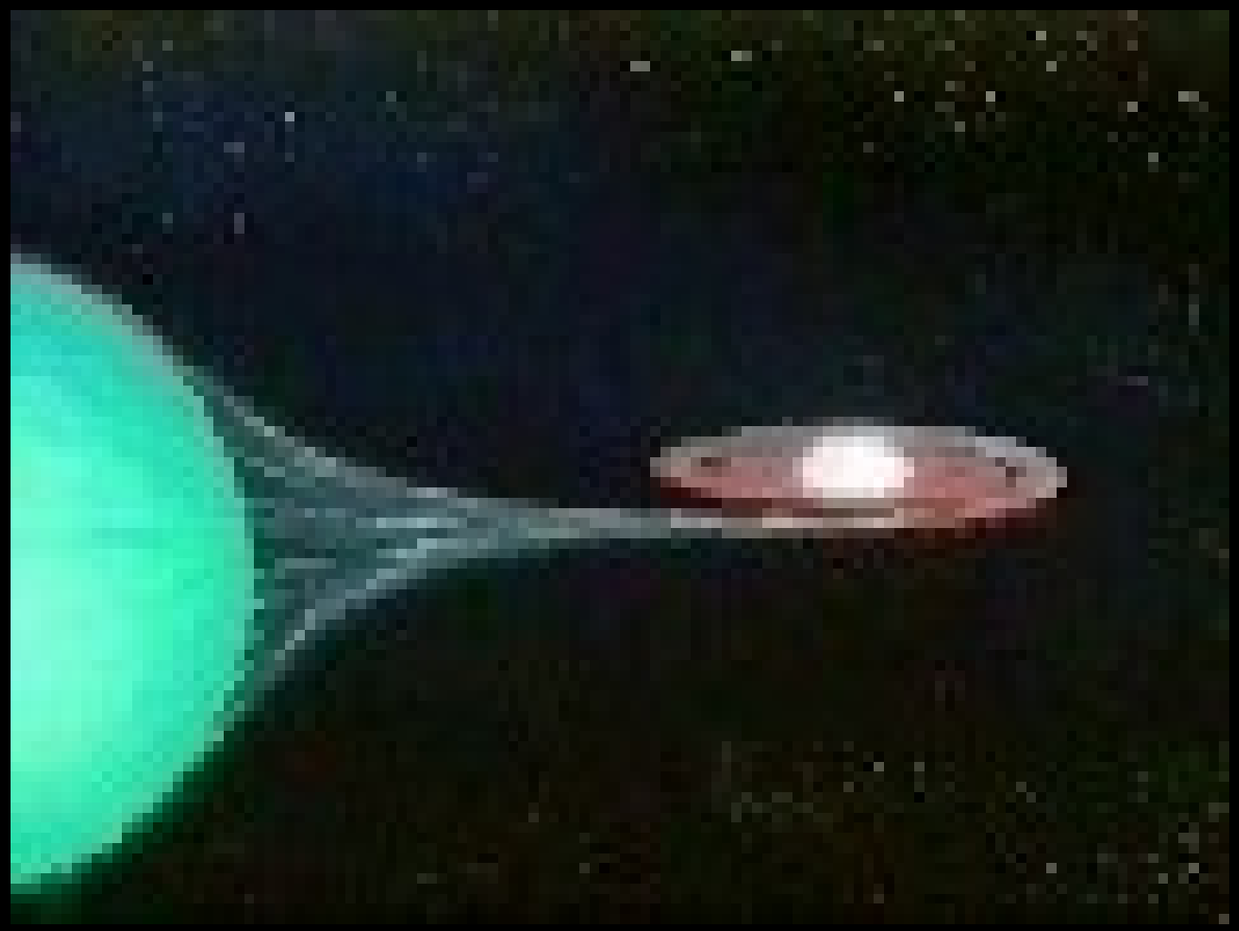
1916
Karl
Schwarzshild
soluzione delle
equazioni di
Einstein
in Relatività
Generale

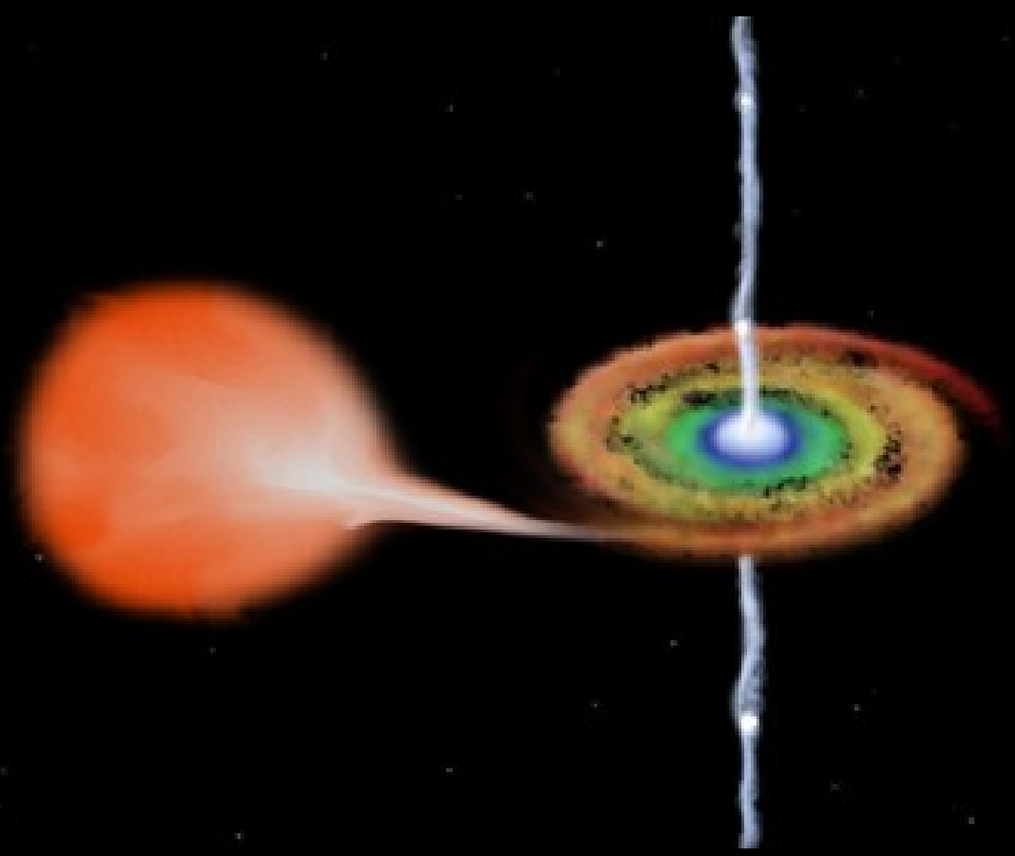


$$V_{FUGA} = c = 300\dot{}000\ km\ s^{-1}$$

BUCO NERO

NS-BH in sistemi binari





Buchi neri che inghiottono stelle

Tidal disruption (distruzione mareale)

28 marzo 2011: stella divorata in diretta

Radio locates Swift J1644+57

Expanded VLA, 22 gigahertz April 16, 2011

Swift XRT position error

Center of EVLA detection

Galaxy's center in Gemini image

1 arcsecond

16,000 light-years

North

East

Gemini North, red filter April 4, 2011

Swift XRT position error

Center of VLBI detection

Galaxy's center

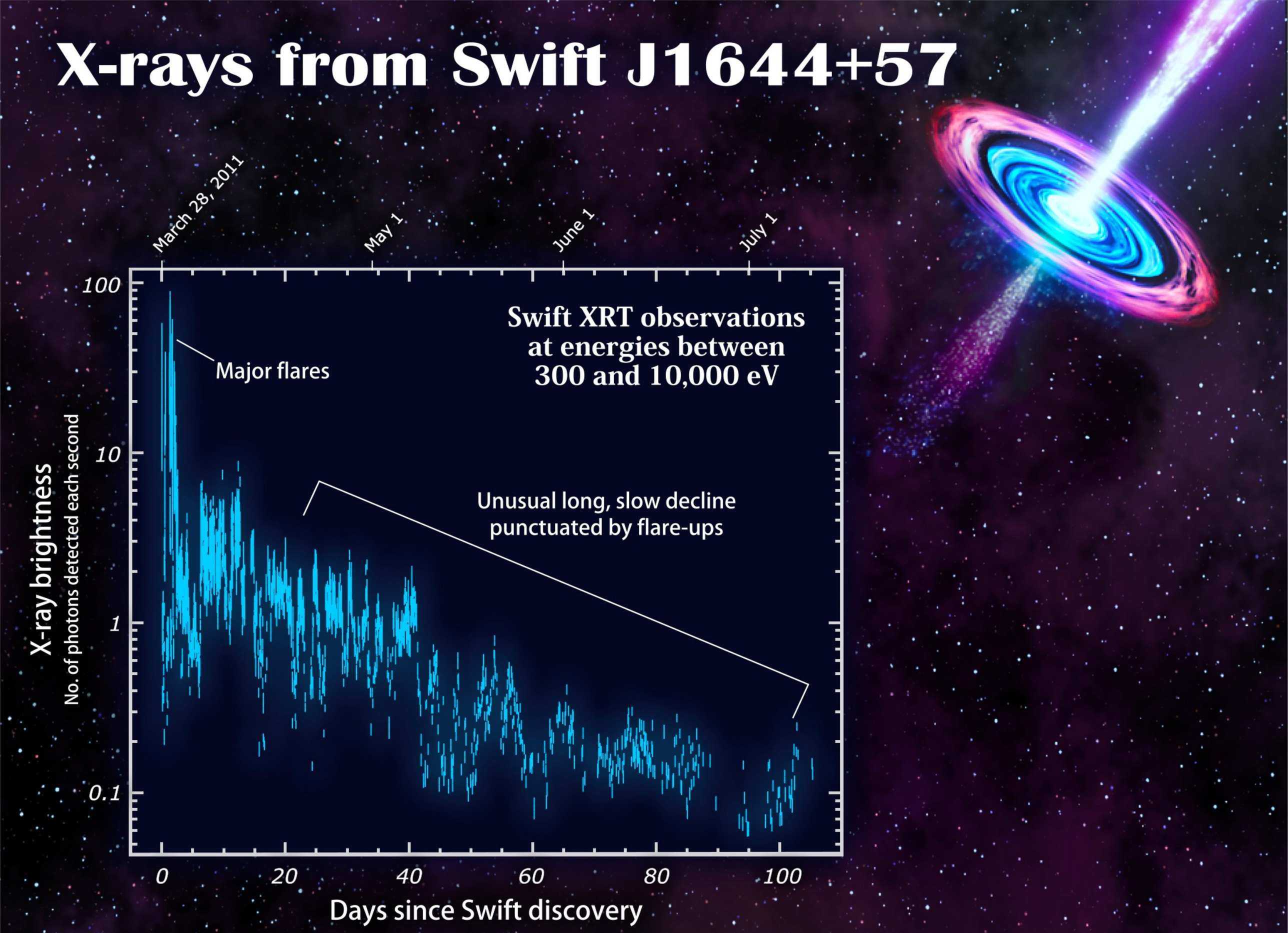
1 arcsecond

16,000 light-years

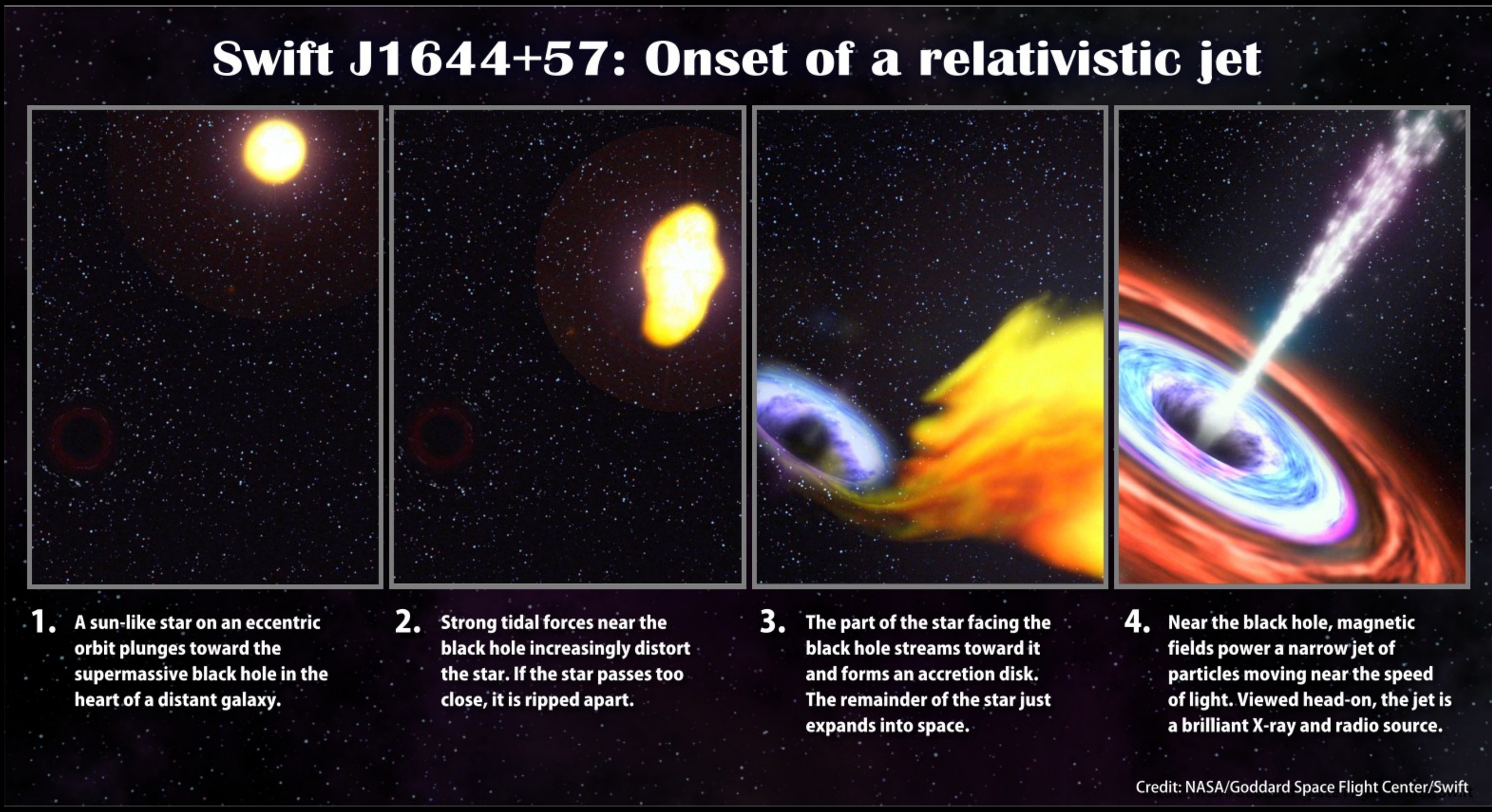
North

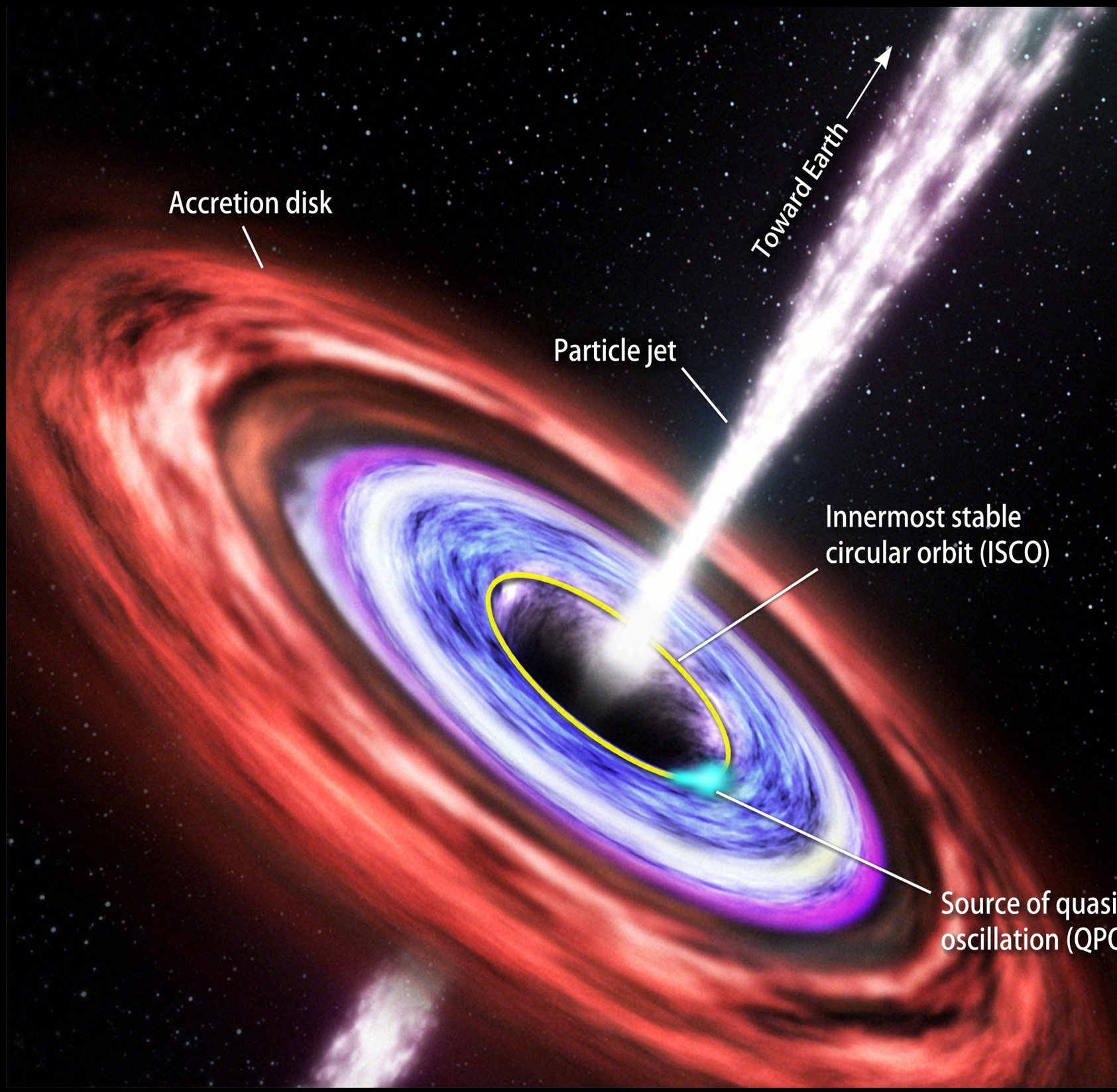
East

X-rays from Swift J1644+57



Formazione di getto relativistico





Stats for Swift J1644+57

Discovery March 28, 2011, by NASA's Swift

Description Supermassive black hole activated by tidal breakup of a passing star

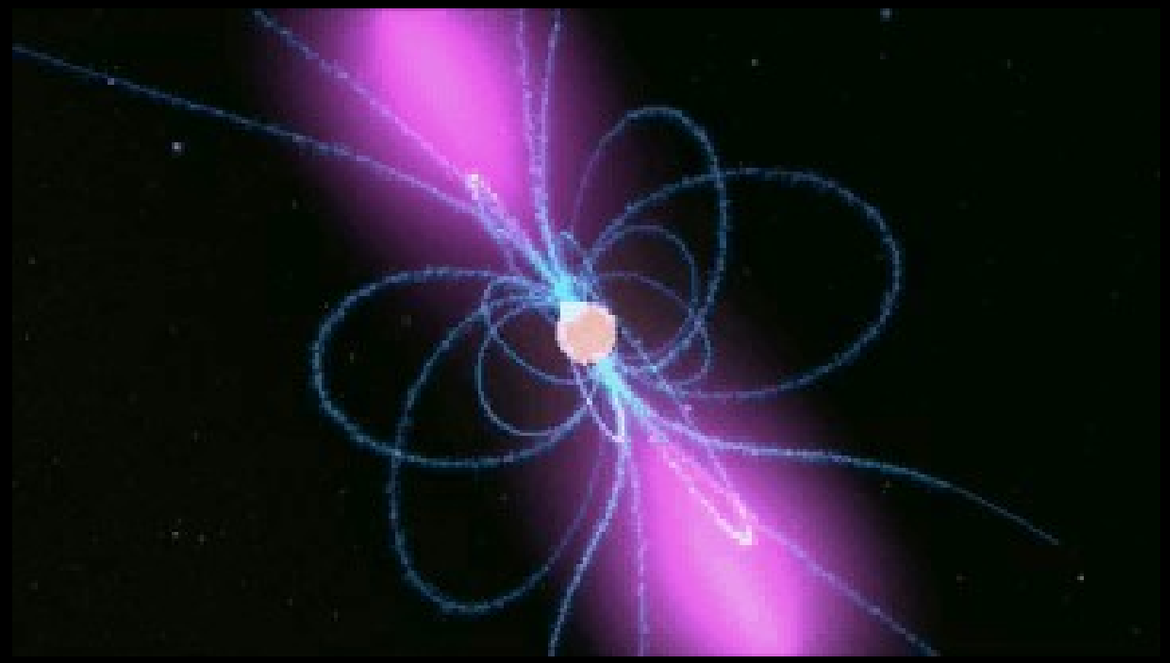
Mass 450,000 to 5 million times the sun's mass

Distance 3.9 billion light-years

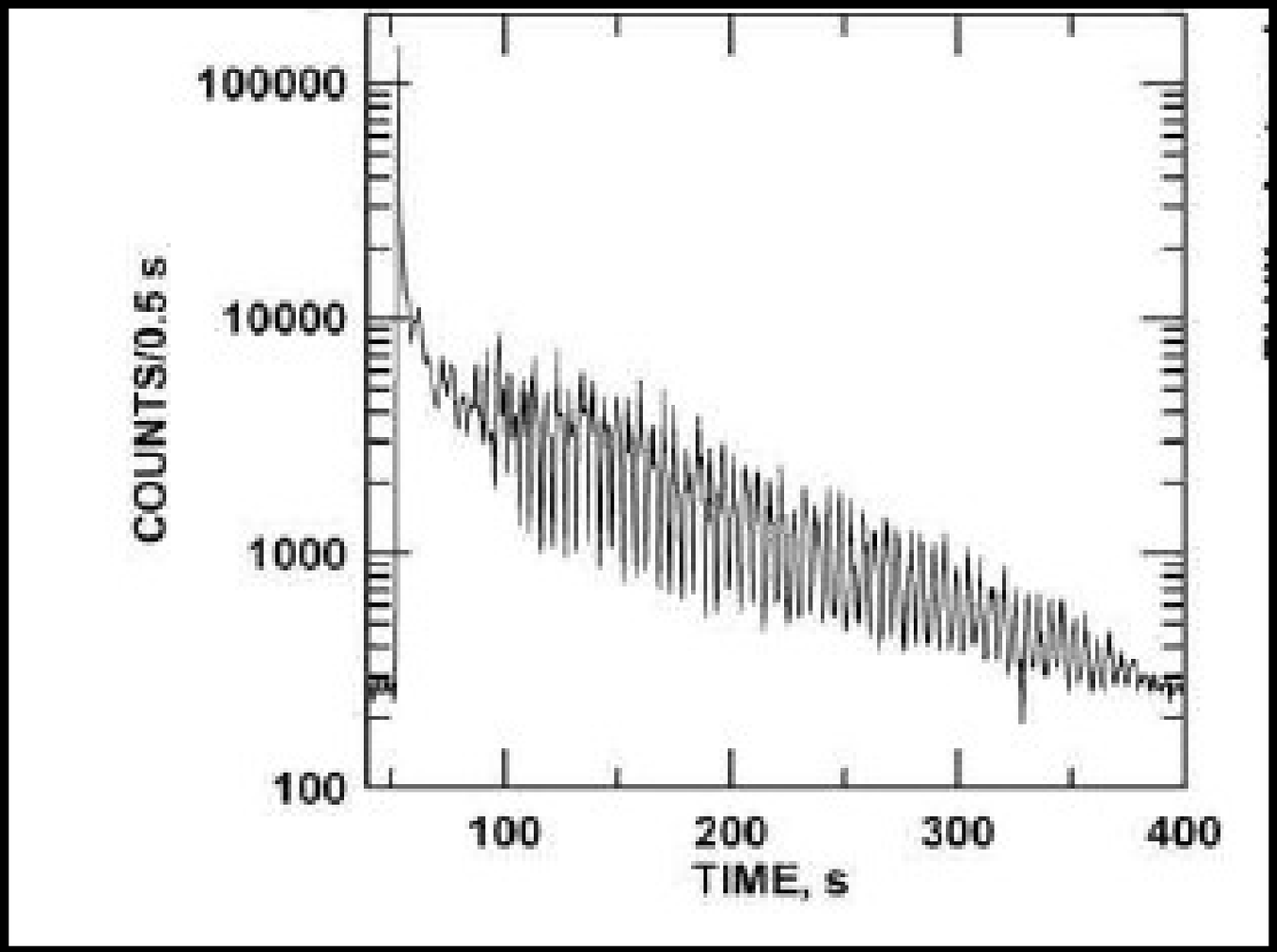
QPO Period of about 3.5 minutes, frequency of 4.8 millihertz. Most distant ever detected.

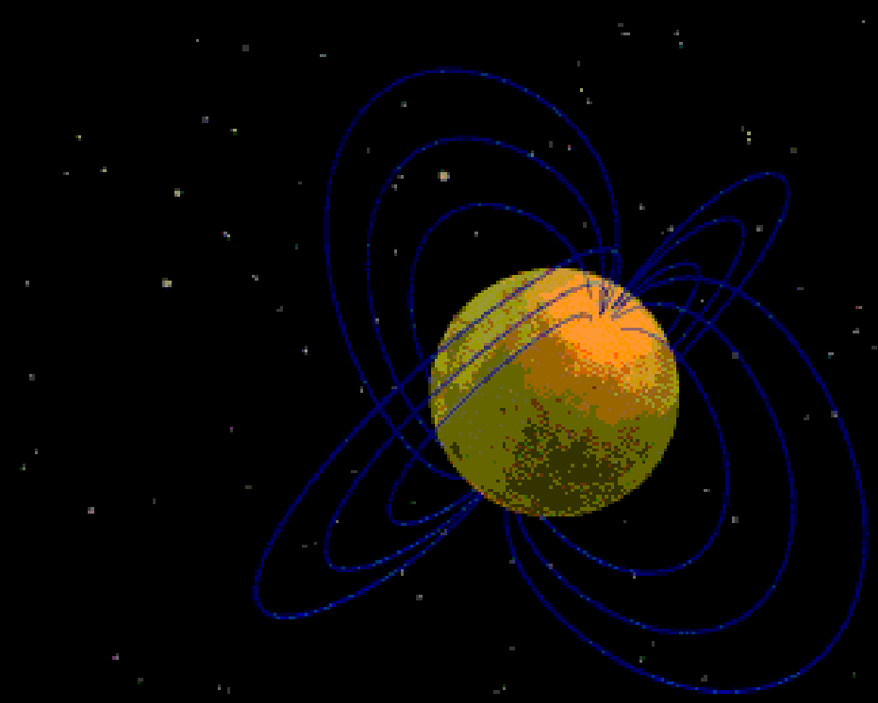
ISCO 2.5 to 5.8 million miles (4 to 9.3 million km) from the center of the black hole. This range is roughly 3 to 6 times the sun's diameter.

Magnetar: stella di neutroni “super” magnetica



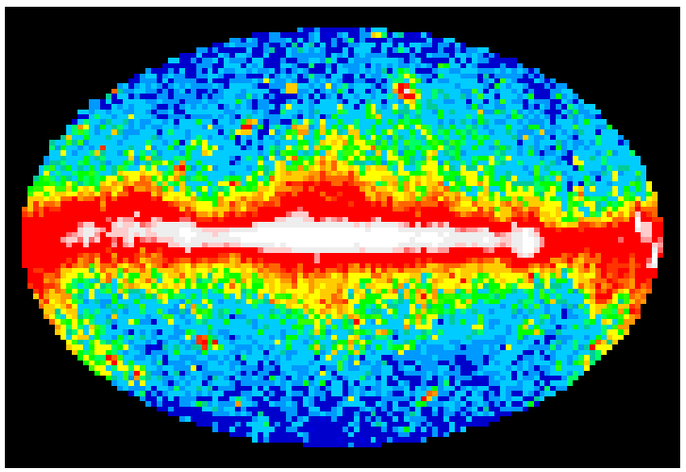
Esplosioni di raggi X da una magnetar

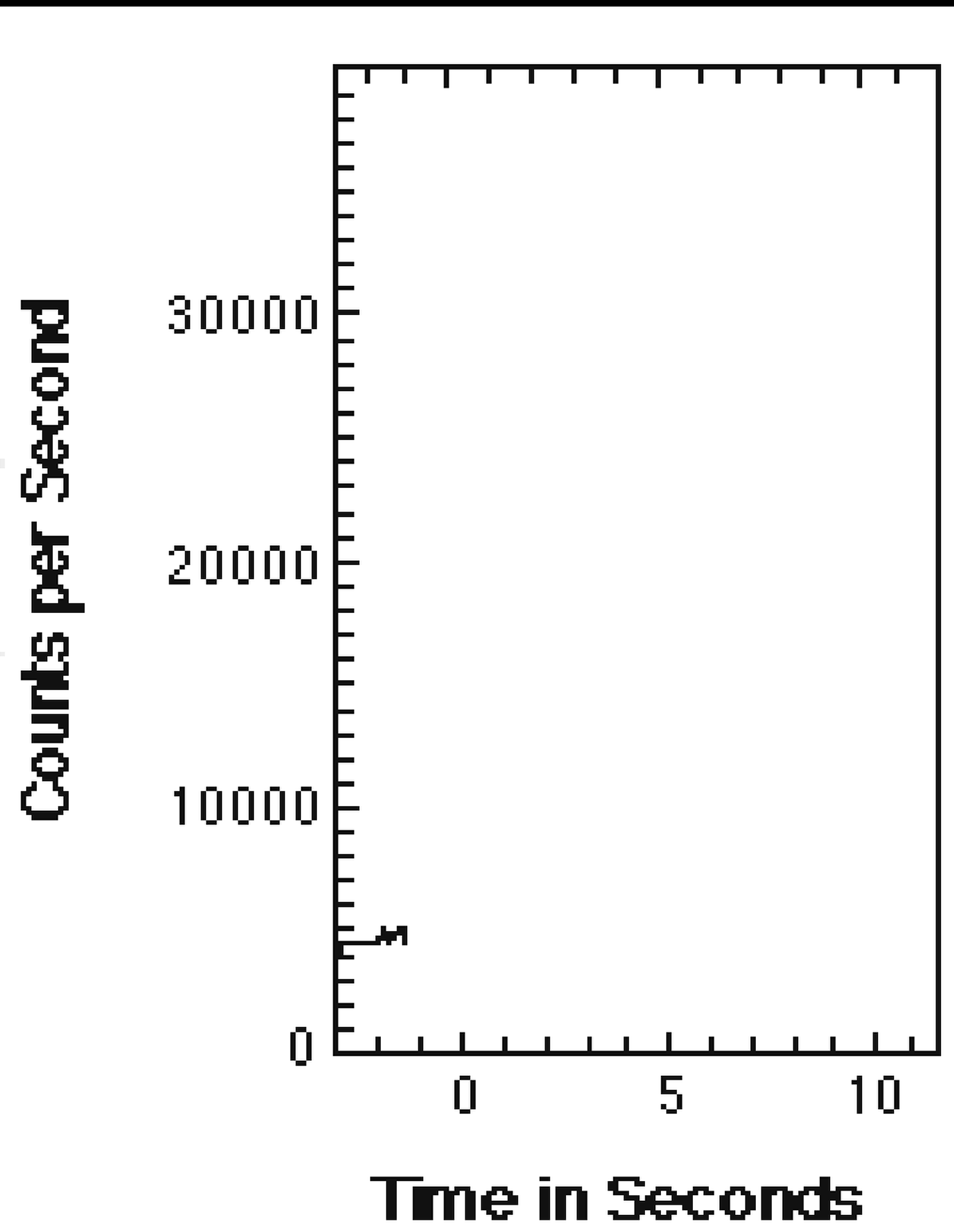




Lampi di raggi gamma

GRBs (inglese: gamma-ray bursts)

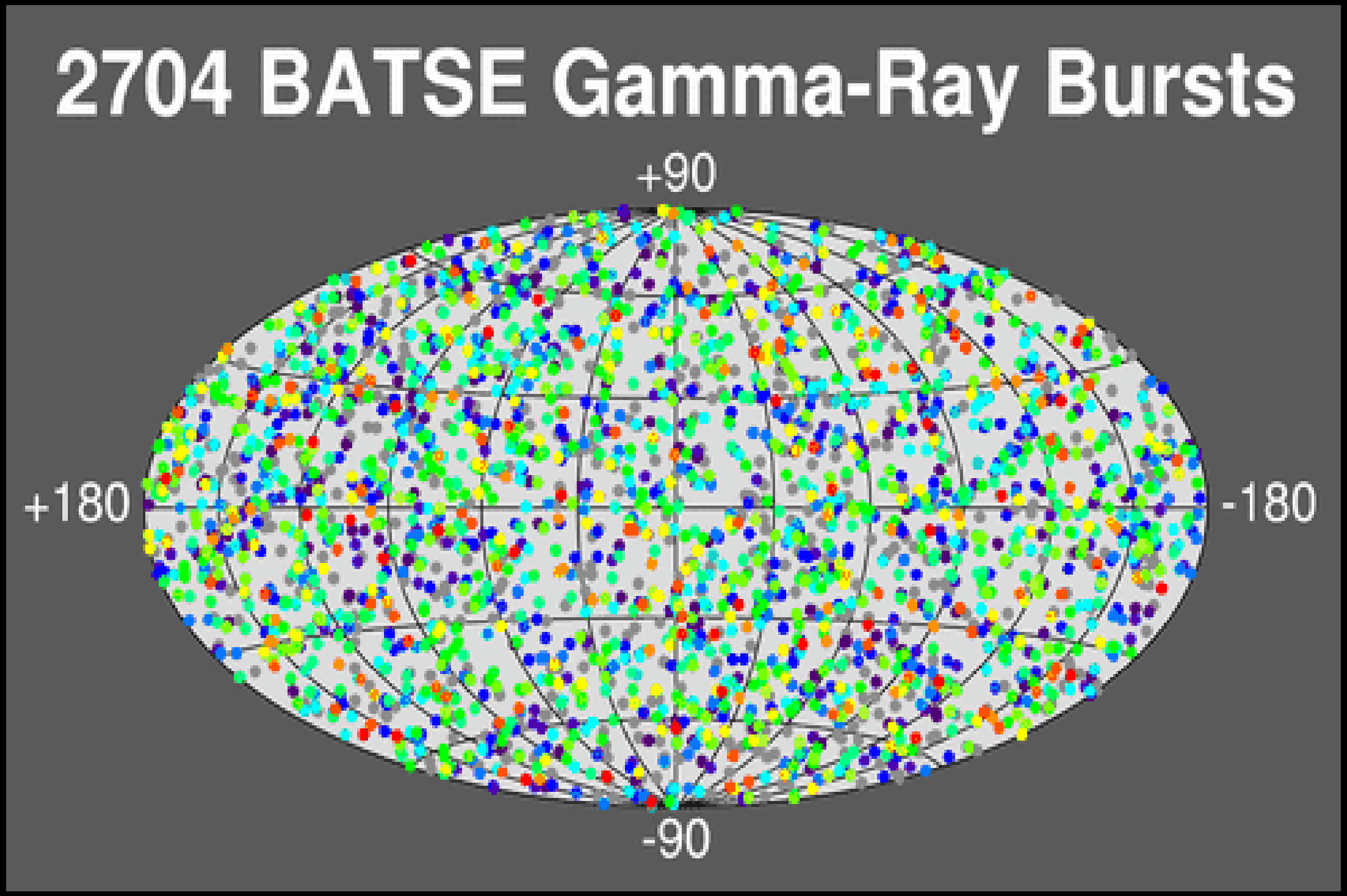




Gamma-Ray X-Ray Visible Infrared Microwave & Radio

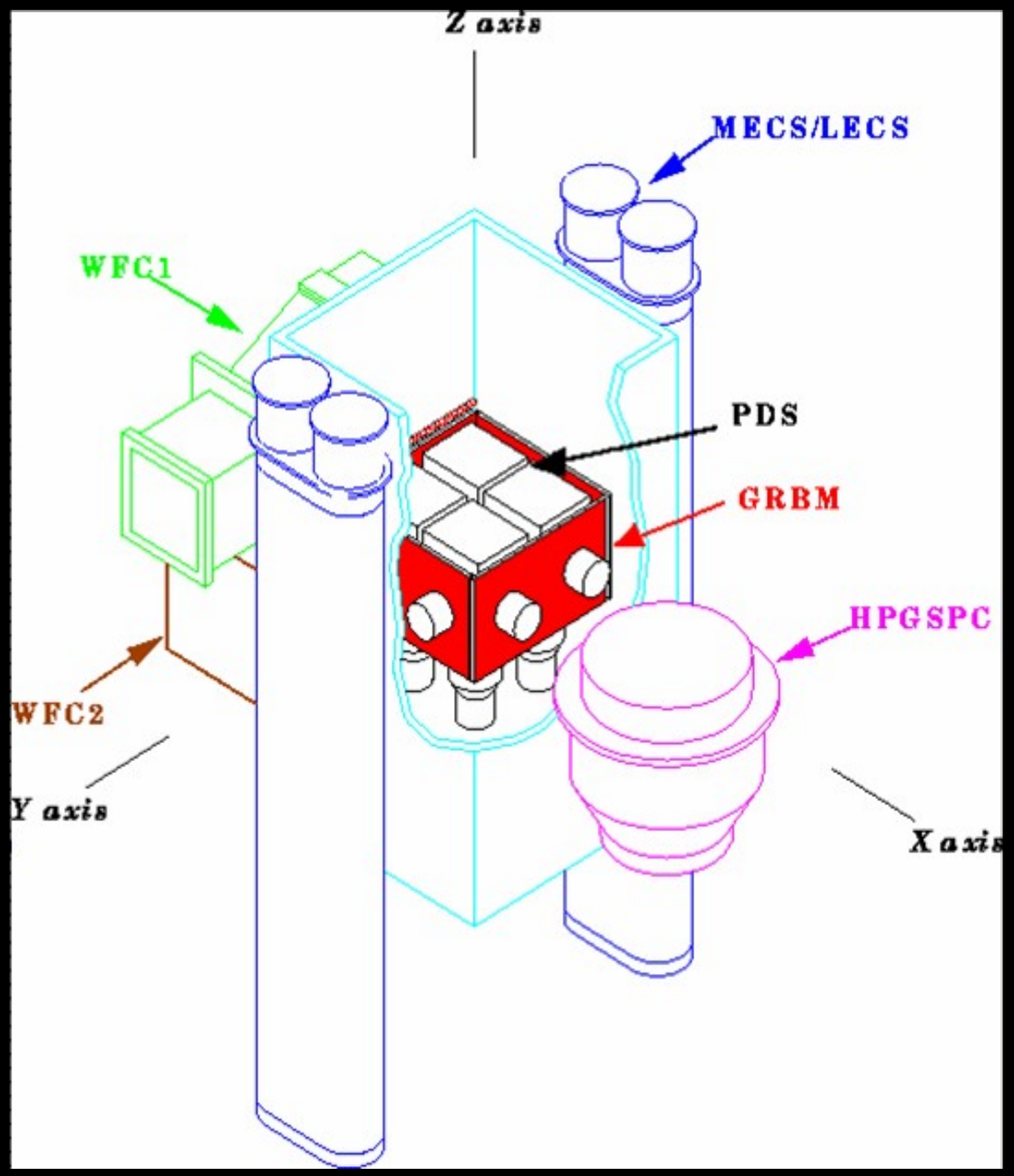
SATELLITI “VELA”
anni ’60

Il mistero dell’origine dei lampi gamma

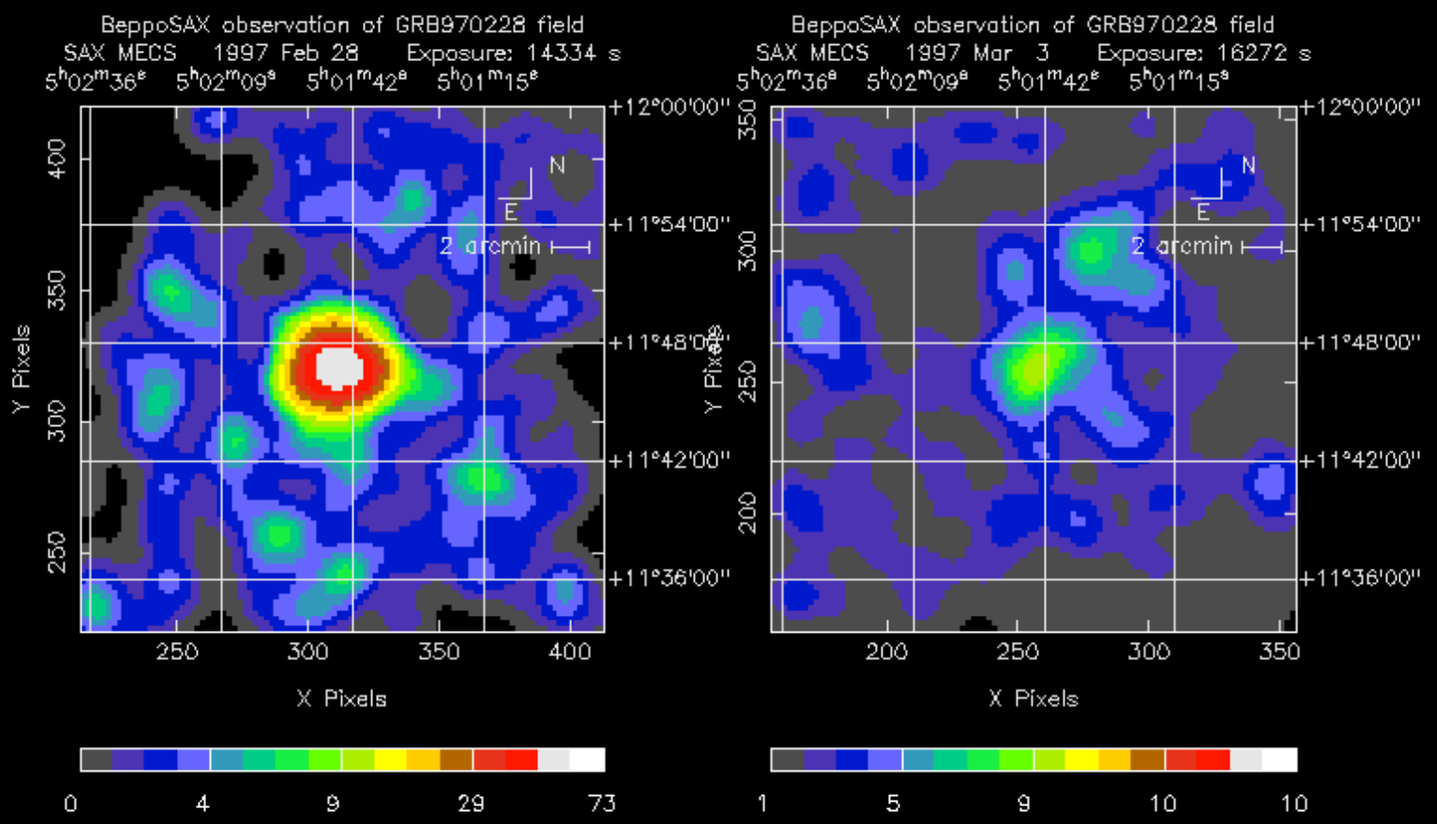


Origine rimasta misteriosa per 30 anni.

La scoperta dell’origine dei GRB con BeppoSAX



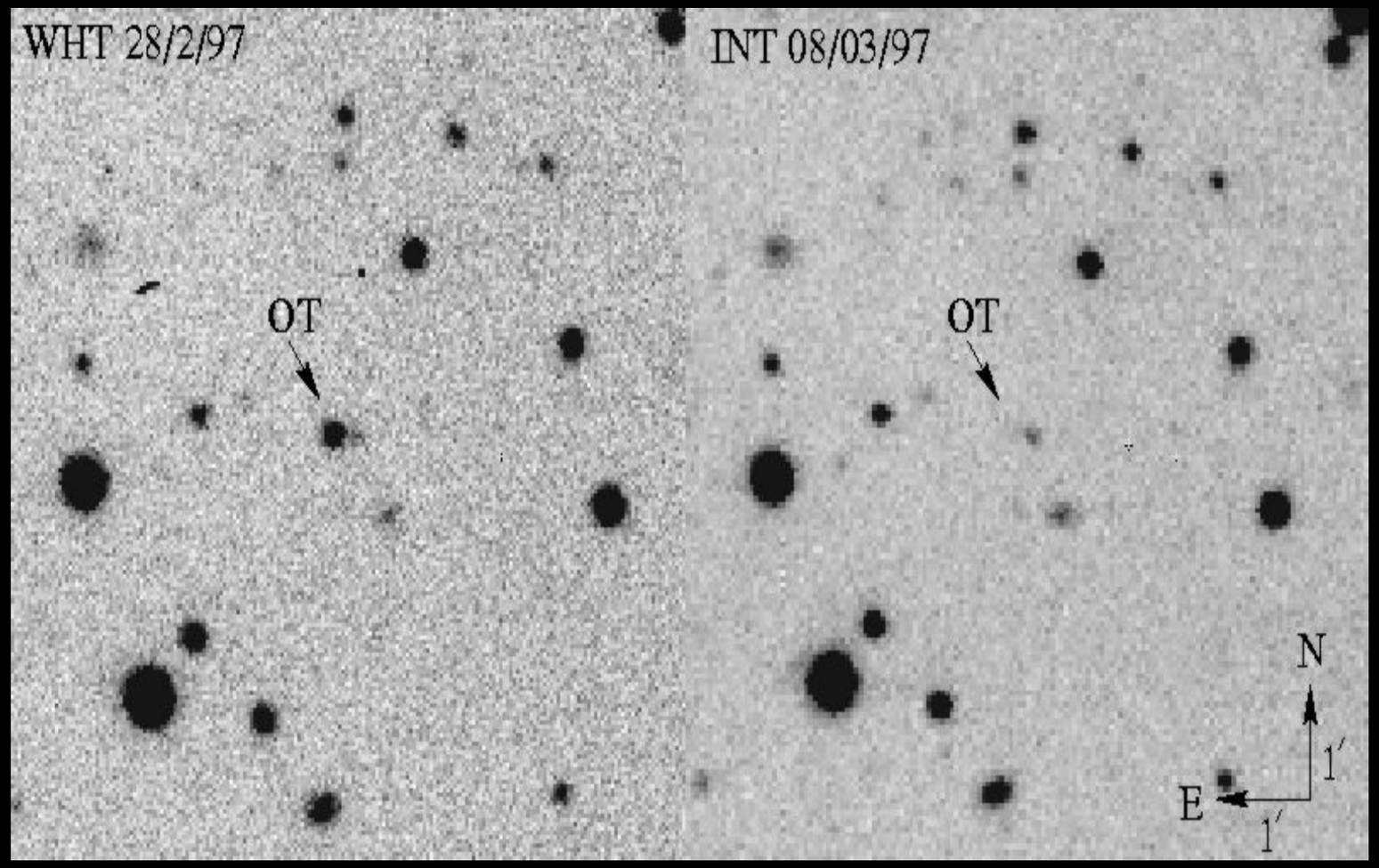
La rivoluzione BeppoSAX (1/5)



- **Il 28 febbraio 1997 il primo lampo viene individuato con GRBM e subito localizzato con WFC;**
- **I telescopi a campo stretto vengono puntati rapidamente in direzione del lampo;**
- **Una sorgente X in rapido spegnimento (post-luminescenza X) viene scoperta.**

La rivoluzione BeppoSAX (2/5)

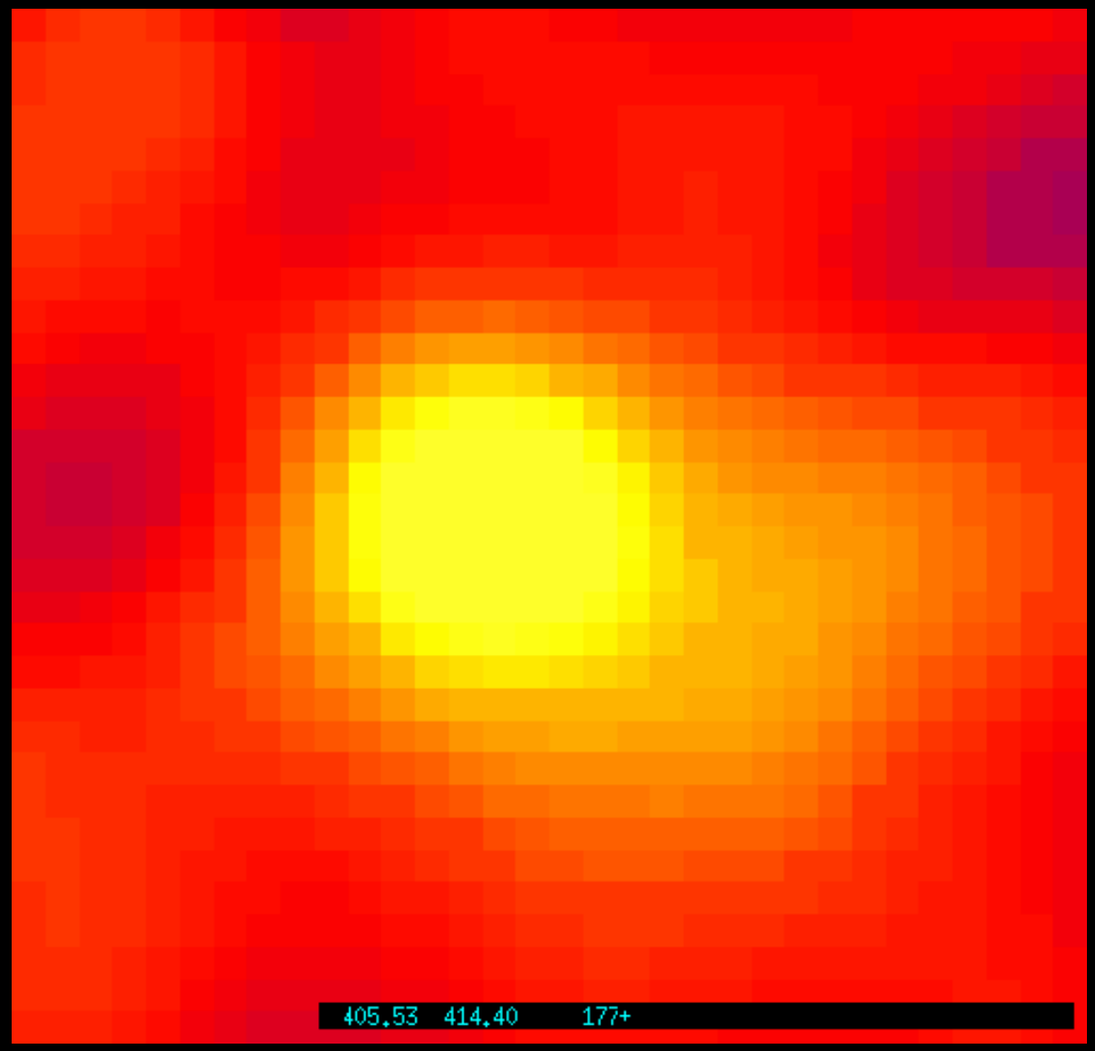
- **Le coordinate del lampo vengono subito trasmesse a telescopi ottici.**
- **Il telescopio W. Hershel (Canarie)** è il primo a scoprire la controparte ottica della sorgente X, anch'essa in rapido spegnimento.



Dove si è verificato il lampo? (3/5)

- **Il telescopio spaziale Hubble mostra che il lampo è occorso all'interno di una nebulosità, probabilmente in una galassia lontana.**
- Ma la **risposta definitiva** si ha **due mesi dopo** …

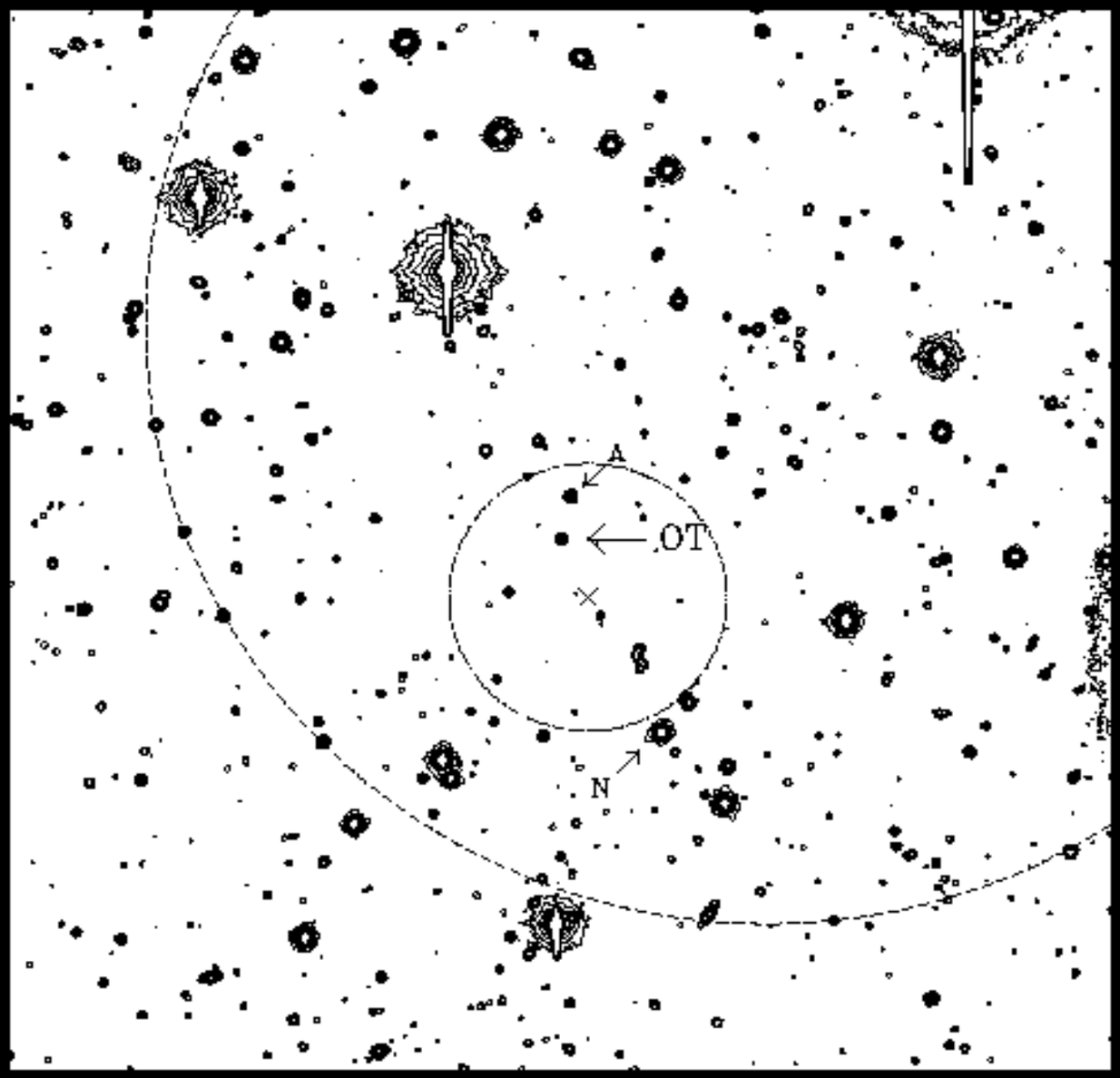
GRB970228



HST image

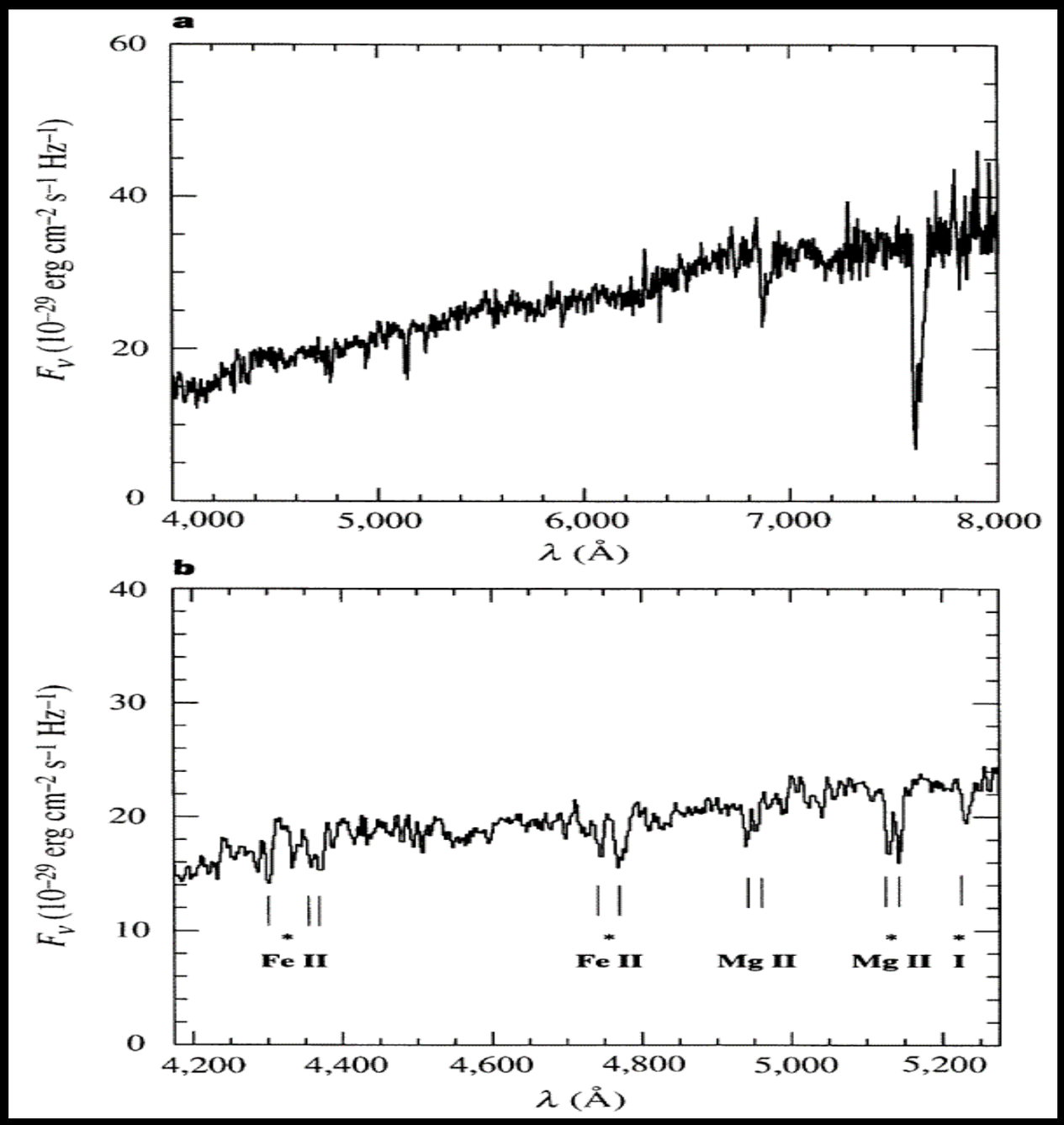
La rivoluzione BeppoSAX (4/5)

- **L’8 maggio 1997** un **altro lampo** viene individuato e localizzato con BeppoSAX.
- Anche la **luce ottica viene vista,** che fortunatamente è molto più intensa.



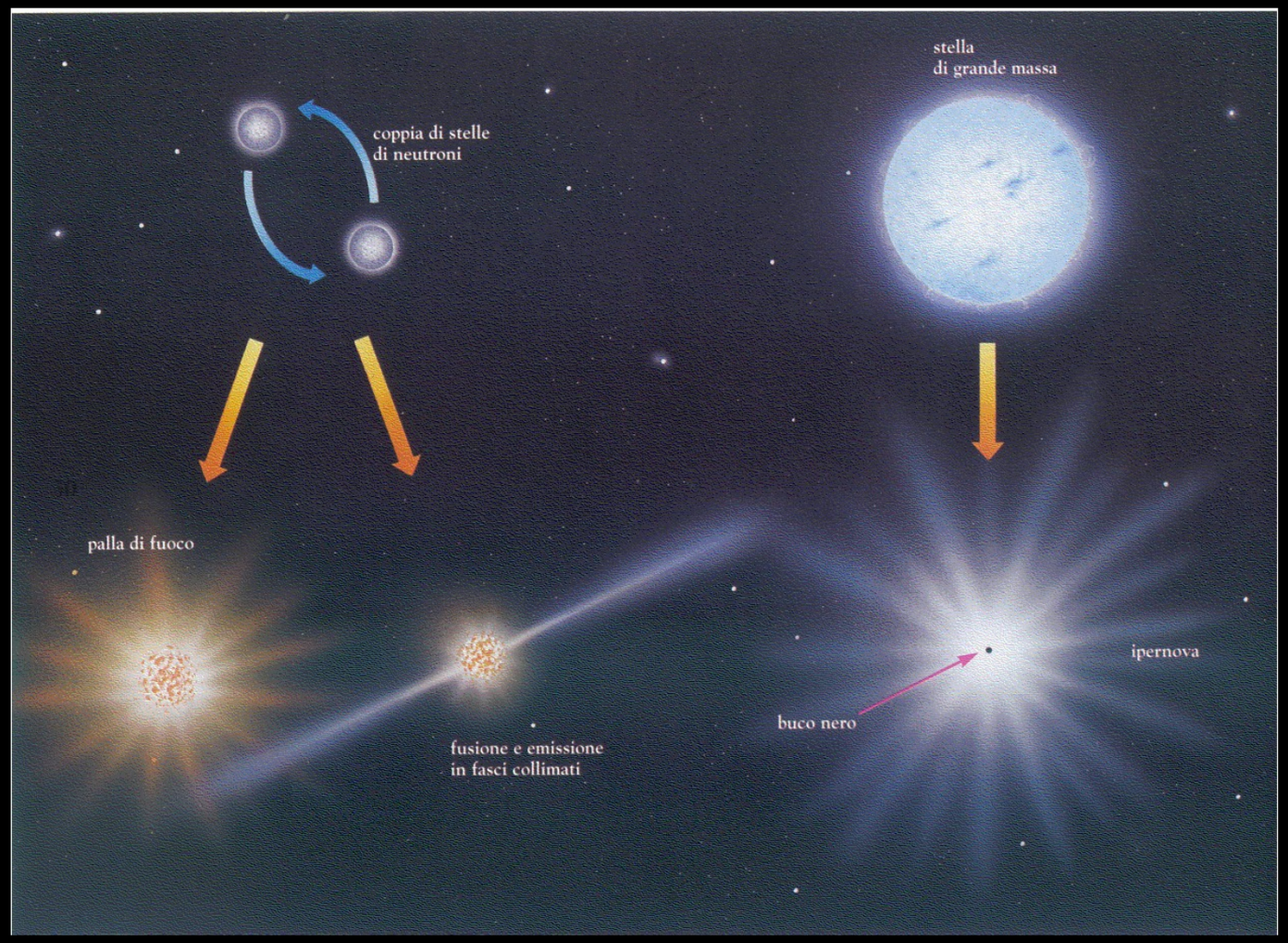
GRB 970508

- **Col grande telescopio Keck** da 8 m (Hawai), è possibile misurare lo **spettro della luce**.
- Esso mostra **righe di assorbimento spostate verso il rosso per** effetto dell**'espansione cosmologica** dell'Universo.
- Viene così **misurata la distanza**: **miliardi di anni luce.**
- Il **mistero della distanza** dei GRB viene finalmente **risolto** dopo circa 30 anni



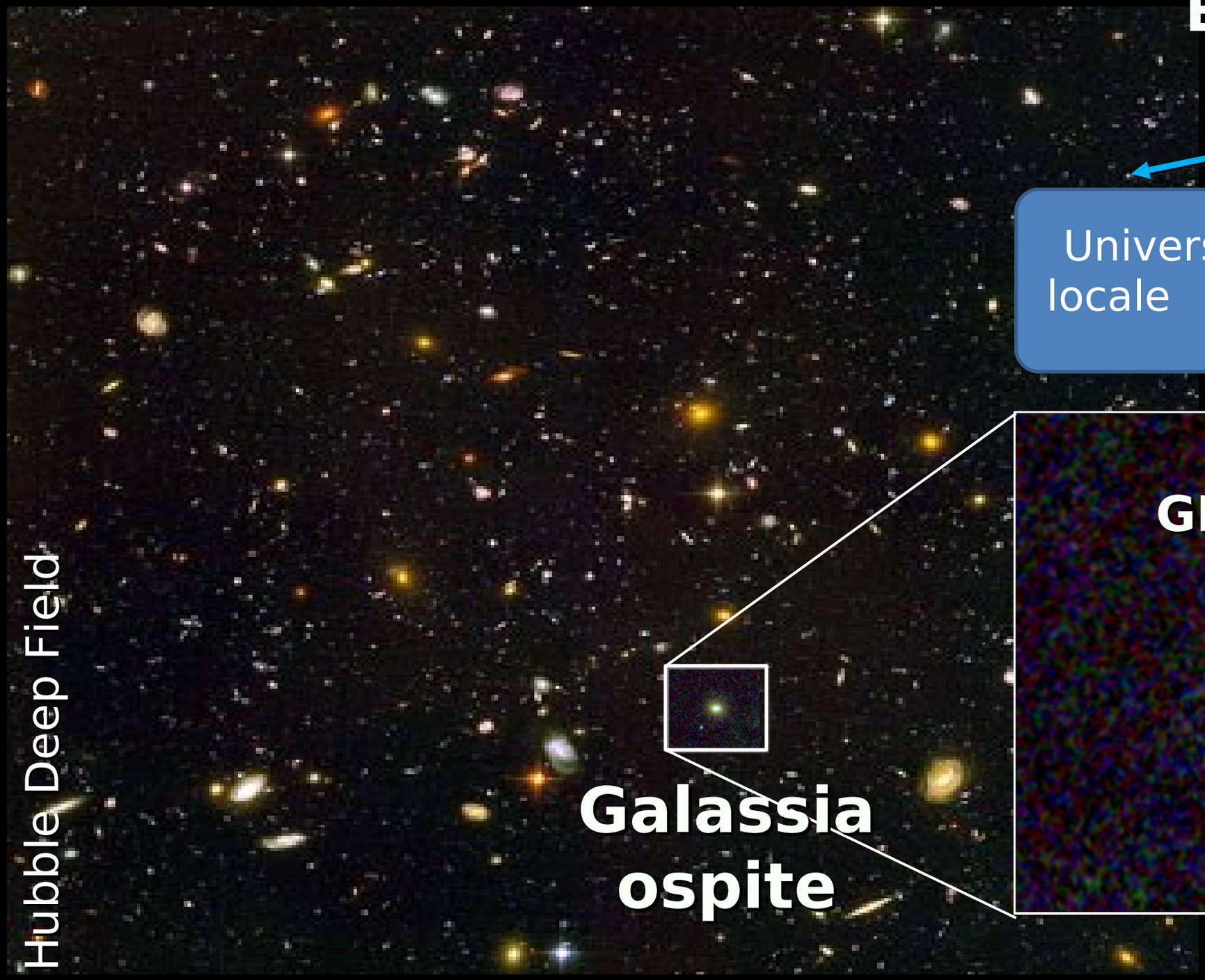
La rivoluzione BeppoSAX (5/5)

- Da distanza e flusso si può misurare **l'energia liberata nell'evento.**
- **Essa è risultata enorme (~10^{52} erg), seconda solo all'energia liberata nel BIG BANG.**
- Morte catastrofica di stelle massive
- **Una scoperta di grande importanza per l'astrofisica e la cosmologia.**



Gamma Ray Bursts: Lampi a raggi gamma

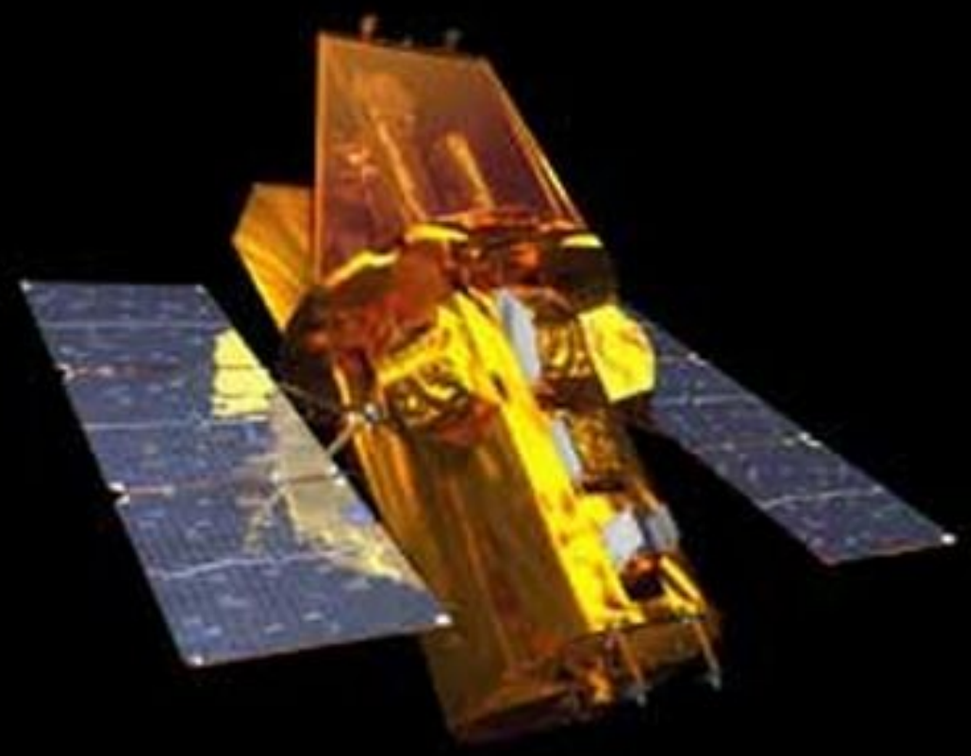
Cataclismi dai confini dell'Universo



Eventi Extra-galattici

- Universo locale
- A distanze cosmologiche

Swift (2004): il successore di BeppoSAX



Swift

Ulysses

Integral

HETE

XTE

GCN

TeV site

radio site

radio site

optical site

optical sit

Liverpool Telescope

LIVERPOOL TELESCOPE

ASTROPHYSICS RESEARCH INSTITUTE

JMU

Grandi Telescopi Robotici

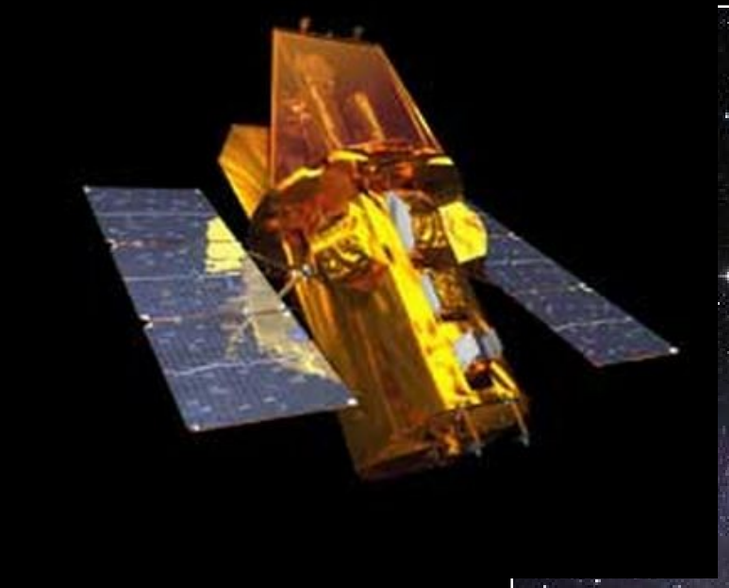
Liverpool and Faulkes Telescopes: world's largest (2-m) fully robotic optical telescopes (http://telescope.livjm.ac.uk)

Observations coordinates with other facilities, both ground-based and from space

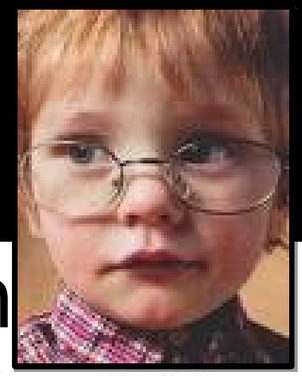
Intelligent dispatch scheduler

Liverpool Telescope is *not* in Liverpool

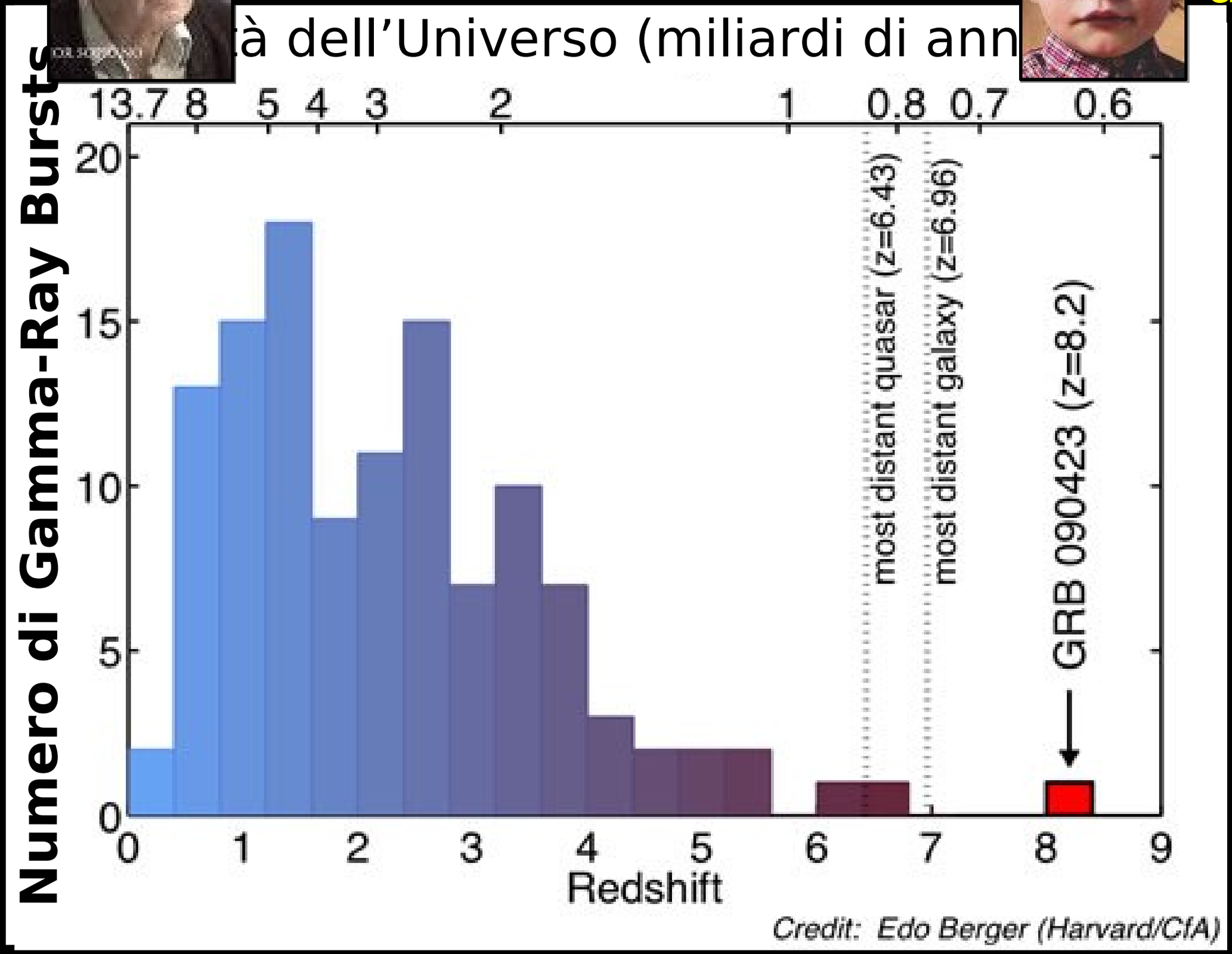
L’esplosione più lontana mai osservata



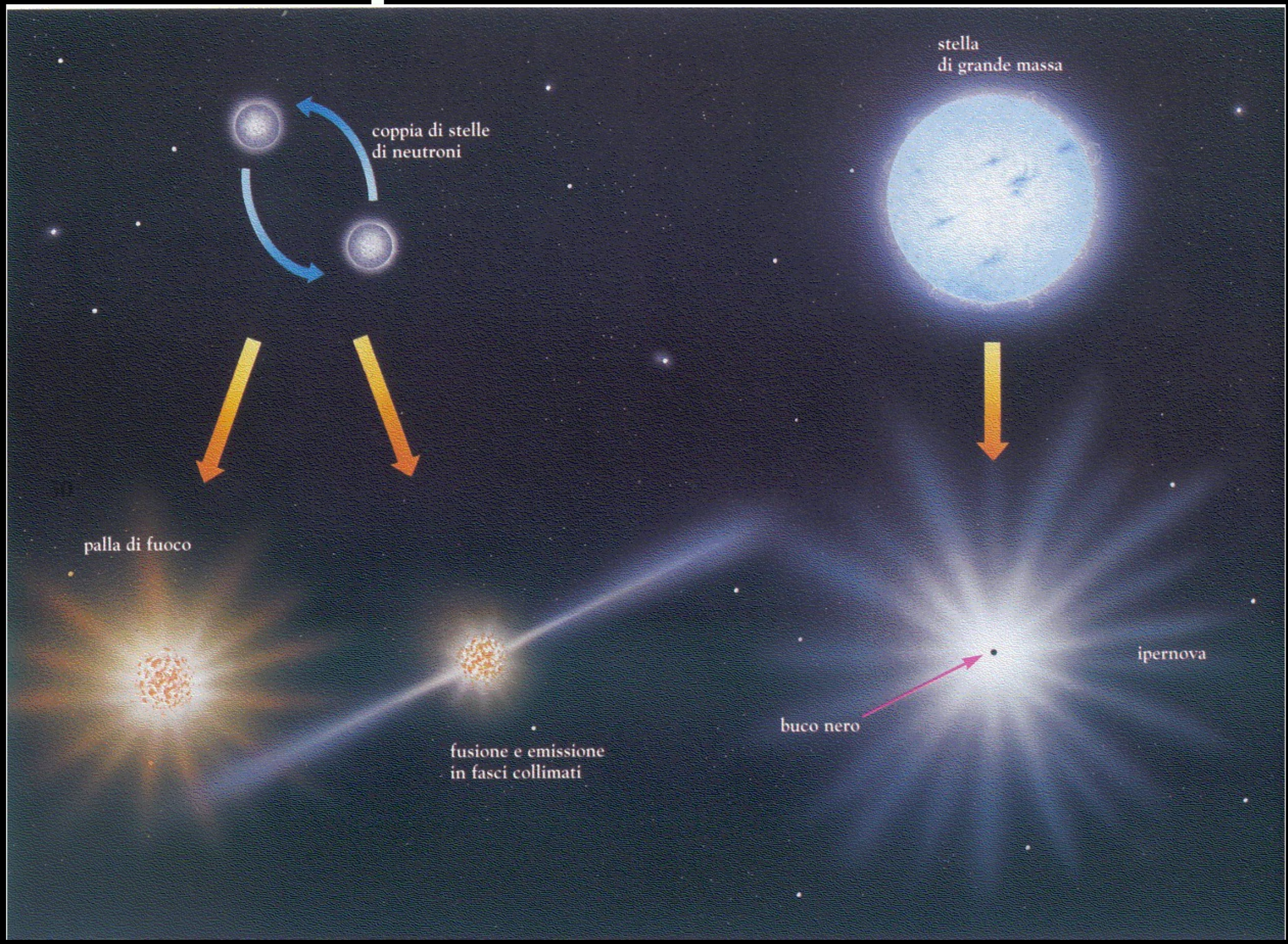
80 anni



3.5 anni



Interpretazione dei GRB



Conclusioni

- Gli oggetti stellari compatti (stelle di neutroni, buchi neri) sono il residuo della morte di stelle massive
- In sistemi binari, strappano massa alla stella compagna e “accrescono” producendo raggi X e gamma
- I raggi X e gamma sono il prodotto di processi energetici estremi con temperature di milioni di gradi.
- Tra i processi più energetici mai osservati sono i Lampi di Raggi Gamma (GRB), immense esplosioni visibili ai confini dell’Universo.


The End