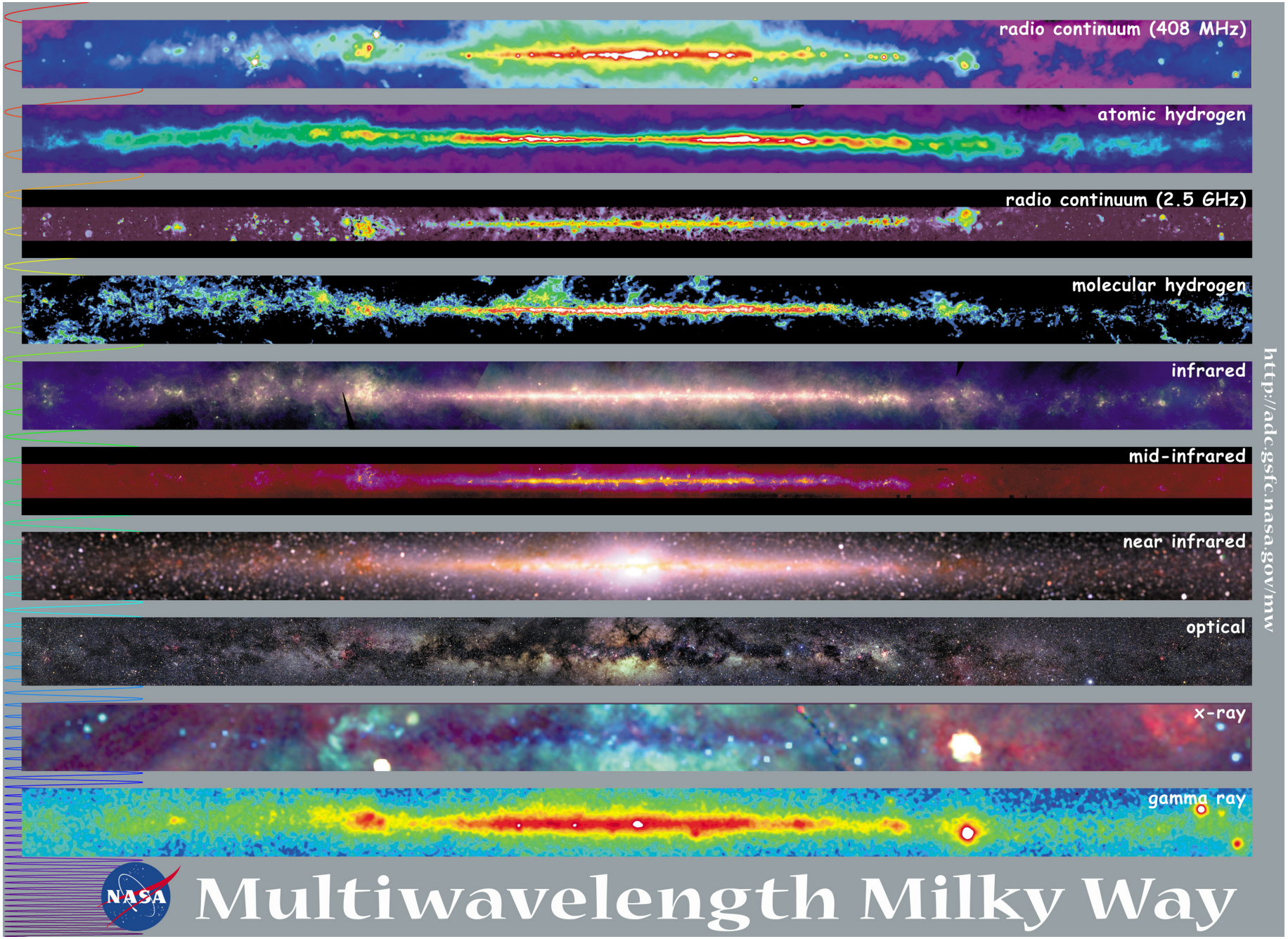
ASTRONOMIA

Relativitat:
Escenaris Astrofísics I: La Galàxia

La Nau Gran

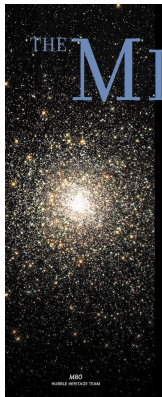
Manel Perucho


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
http://adc.gsfc.nasa.gov/mw
Multiwavelength Milky Way

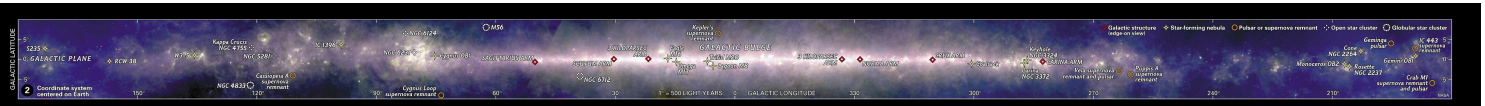
THE MILKY WAY

NATIONAL GEOGRAPHIC

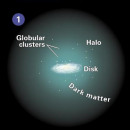
Home galaxy of Earth, the Milky Way is a spiral-shaped system of a few hundred billion stars. Bright regions of recently formed stars highlight its arms, while older stars explode or expel their outer layers as beautiful planetary nebulae, then fade away and die. A thick swarm of orange and red stars marks the galactic bulge, encapsulating the star-packed galactic center. At its core may lie a black hole, a region so dense that not even light can escape its gravitational pull. All objects in the Milky Way orbit the galactic center, much like planets in Earth's solar system revolve around the sun. But the scale is staggering: Light from a star at one edge of the galaxy takes about 100,000 years to reach the opposite side.



M80
HUBLE HERITAGE TEAM



2 Coordinate system centered on Earth

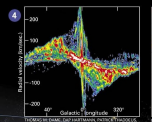


GUIDE TO THE GALAXY

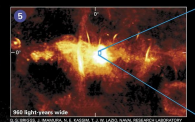
1 Far beyond the galactic disk, yet drawn by its gravity, lone stars and globular clusters wander the galaxy's halo. Regions of dark matter—unseen but felt through its gravitational effects—extend beyond that.

2 Vast clouds of interstellar dust block much of our night sky view of the Milky Way, which from our position in the flat galactic disk appears as a fuzzy band of light. Infrared satellites can see through the dust to reveal the galaxy's structure.

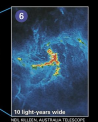
3 Earth's orbit around the sun lies at a severe angle to the galactic plane.



J. L. PEZZIN, J. M. DICKEY, AND J. M. STIL, UNIVERSITY OF MINNESOTA; N. M. MCCLURE-GRIFFITHS, CSIRO DIVISION OF EXPLORATION AND INFORMATION



D. S. MEWES, J. MANGUM, N. S. KASSIM, T. J. W. LAZIO, NRAO, RESEARCH LABORATORY



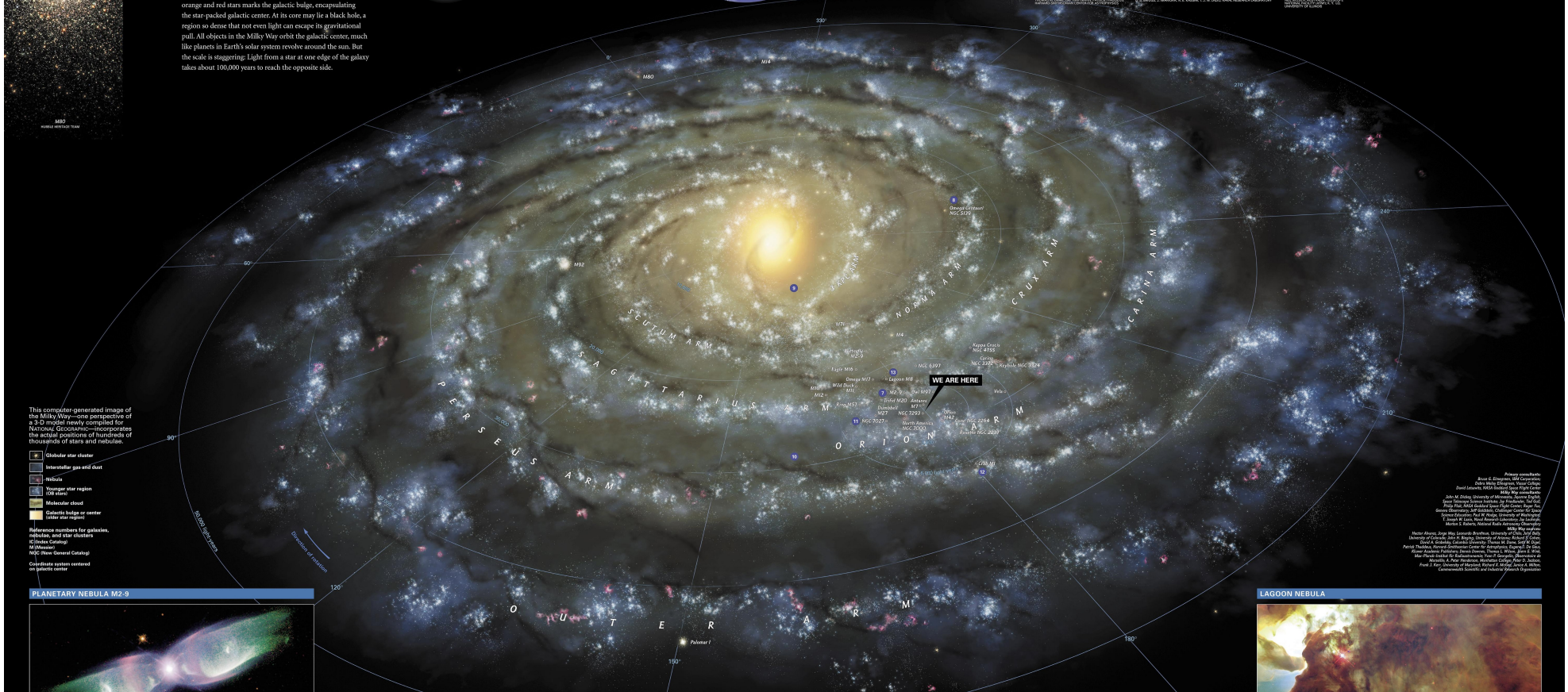
NRL SULLIVAN, AUSTRALIA TELESCOPE NATIONAL FACILITY; DAVID A. G. GRABELSKY, UNIVERSITY OF ILLINOIS

A TURBULENT HEART

4 A graph based on a radio survey reveals the whirlpool motion of molecular gas in the inner part of our galaxy: gas moving away from Earth (top half) and toward Earth (bottom half). The densest gas appears white; least dense, blue.

5 Massive amounts of energy are released near the center of the Milky Way, producing electrons that race along magnetic field lines, illuminating remnants of stellar explosions.

6 Probing even deeper into the core, a radio image details a spiral of hot gas that is falling toward what may be a black hole some 2.6 million times as massive as the sun.



This computer-generated image of the Milky Way—one perspective of a 3-D model newly compiled for NATIONAL GEOGRAPHIC—incorporates the actual positions of hundreds of thousands of stars and nebulae.

- Globular star cluster
- Interstellar gas and dust
- Nebula
- Younger star region (OB stars)
- Molecular cloud
- Galactic bulge or center (older star region)

Reference numbers for galaxies, nebulae, and star clusters
IC (Index Catalog)
M (Messier)
NGC (New General Catalog)

Coordinate system centered on galactic center

Primary consultants:
Bruce G. Elmegreen, IBM Corporation, Dana Mehle Elmegreen, Vassar College, David Leisawitz, NASA Goddard Space Flight Center
Milky Way consultants:
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Milky Way explorers:
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PLANETARY NEBULA M2-9

BRUCE BALICK, UNIVERSITY OF WASHINGTON; VINCENT COX, LEIDEN UNIVERSITY; JARNBJÖRN MELLEMA, STOCKHOLM UNIVERSITY; NASA

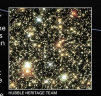
Exotic kaleidoscopes of the Milky Way, colorful nebulae and star clusters are found throughout Earth's galaxy. Even a run-of-the-mill star may eventually produce a nebula of surpassing beauty.

7 Just as our sun will do in its death throes some five billion years from now, a dying star expanded into a red giant and was transformed into the nebula M2-9 (above). At its center shines a small, hot core, which will cool and fade over eons to come. Its stellar wind, streams of charged particles, rushes outward in opposite directions, like exhaust from back-to-back jet engines. This bipolarism, revealed by the Hubble Space Telescope, is common among planetary nebulae. Ultraviolet light from the star heats M2-9's gases and makes them glow.

Other types of nebulae exist in our galaxy, including dark nebulae rich in microscopic dust that blocks our view of stars beyond. When a star adjoins a dark nebula, the dust particles reflect starlight and the black cloud seems to have a silver lining.

8 The million-plus stars packed into a globular cluster such as Omega Centauri (right) are senior citizens of the Milky Way. Unlike human retirees, however, every star in the cluster is about the same age, billions of years older than our 4.6-billion-year-old sun.

PATRICK SEITZER, UNIVERSITY OF MICHIGAN



HUBBLE HERITAGE TEAM

9 Peering between dust clouds toward the central bulge of the Milky Way, the Hubble Space Telescope focused on a rare clear region in the Sagittarius star cloud (above right). These Sagittarius stars formed at different times; most are older than the sun. They sparkle like an assortment of gems on a jeweler's velvet pad.

10 In some dark clouds lurk strange objects like IC2220.B8-1.26, detected by a European Southern Observatory telescope in Chile and mapped in infrared light (right). A star 20 times as massive as the sun and 10,000 times brighter, it sports a disk of circumstellar dust, shown here in false color, about 20,000 times wider than Earth's orbit. Light from the hot star is absorbed by and warms the dust, making it glow.

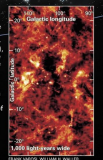
EUROPEAN SOUTHERN OBSERVATORY

11 As stars like the sun die, they become factories for interstellar dust. Celestial soot—the remnants of its red giant stage—surrounds the tiny hot central star of NGC 7027 (above right). Blown outward, the soot would obscure our view of the center of NGC 7027 were it not for this remarkable composite image in infrared and visible light from the Hubble Space Telescope.

WILLIAM J. FIX OF CALIFORNIA INSTITUTE OF TECHNOLOGY, NASA

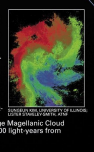
Clouds of interstellar dust (right), strewn over huge regions along the central plane of the Milky Way, are not thick and smooth but seem as frothy as the head on a glass of beer. Supernova shock waves and stellar wind from evolving stars may have shaped this surprising pattern:

When a massive star comes to the end of its nuclear fuel supply, it collapses and then rebounds in a brief, powerful explosion, or supernova. The Chinese called these celestial fireworks guest stars and recorded one such event in the constellation Taurus in July 1054 that was visible in broad daylight.



NASA, NRAO, STELLA SOCIETY, NATIONAL ASTRONOMY OBSERVATORY OF JAPAN, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS, CARLETON DEWEER

12 In that location today astronomers find the fast-expanding Crab Nebula (left), a supernova remnant. At its heart lies a pulsar—a collapsed star—whirling 30 times a second.



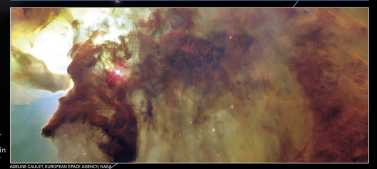
NASA, NRAO, VLA, UNIVERSITY OF ILLINOIS, CARNEGIE-MELLON UNIVERSITY, AND ARIZONA STATE UNIVERSITY, NASA

Satellite galaxies of the Milky Way host equally remarkable celestial phenomena. In the Large Magellanic Cloud (above right), 160,000 light-years from Earth, clumpy, filamentary clouds of hydrogen gas reveal their stately march in a radio map from the Australia Telescope Compact Array. The lower half of the cloud (blue) is rotating toward the Earth while the topside (red) turns away.

13 Glistening along the spiral arms of the galaxy, bright emission nebulae mark regions where new stars are forming. The Lagoon Nebula (above), about 5,000 light-years distant, is easily detected with the naked eye as a fuzzy spot in the southern constellation Sagittarius. Wide-field images show that it covers more of the sky than does the full moon. Where there was once only a vast dark cloud, radiation from the brightest and most massive young star in the nebula, Herschel 36, heats and ionizes the gas across a wide region. Despite the brilliance of the Lagoon Nebula and similar objects like the famous Orion Nebula, such areas are usually little more than hot blisters on the flanks of giant interstellar clouds.

With new tools, astronomers are unraveling the nature of the Milky Way and measuring distances to stars and nebulae with greater accuracy. Still, they ask, how did the Milky Way form in the first place? How and when did the arms form? How many more planets circle nearby stars besides the 102 already discovered? And the biggest question of all: Do any of them harbor life?

LAGOON NEBULA



ADELINE GALLAY, EUROPEAN SPACE AGENCY, NASA

22040

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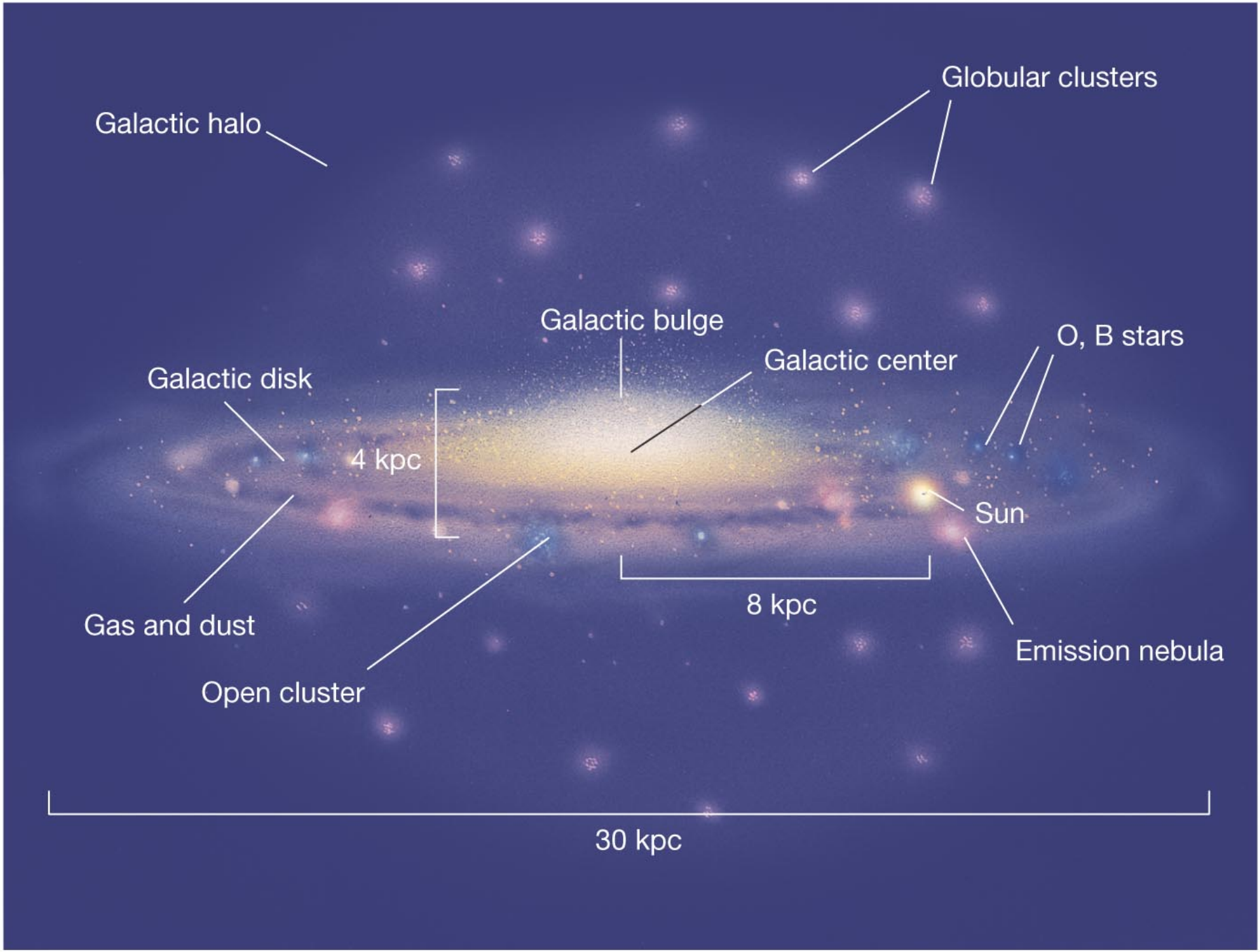
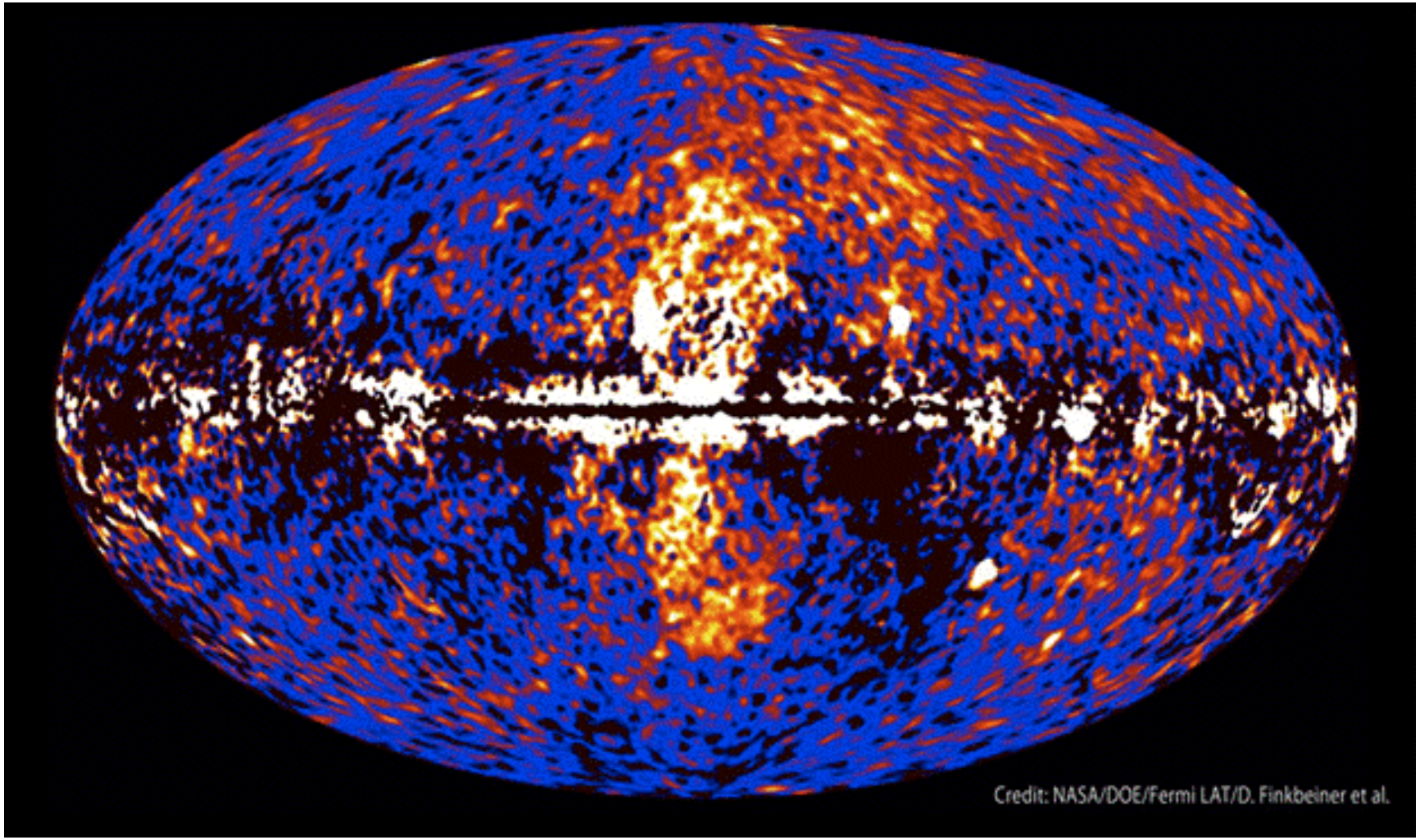
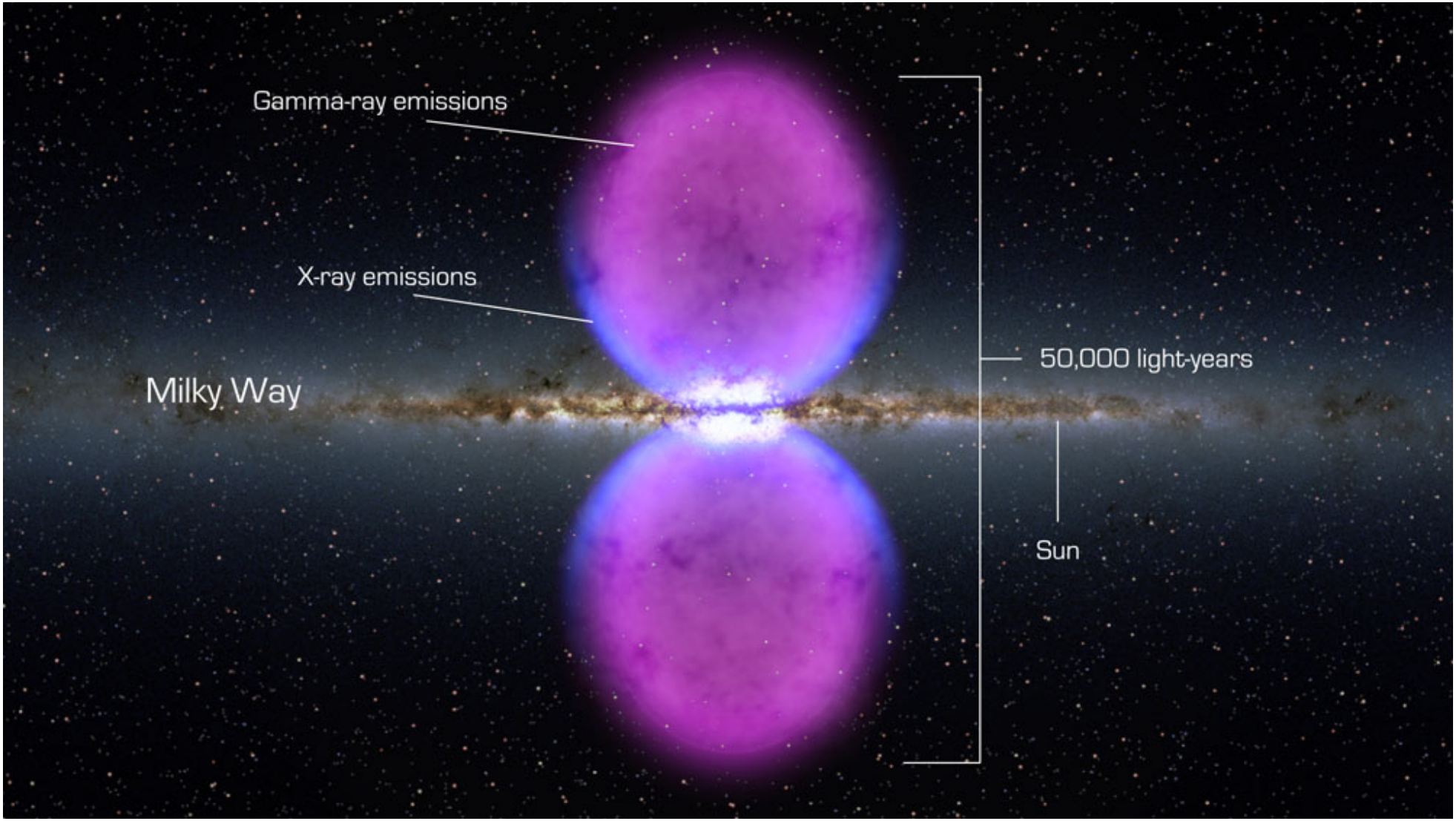


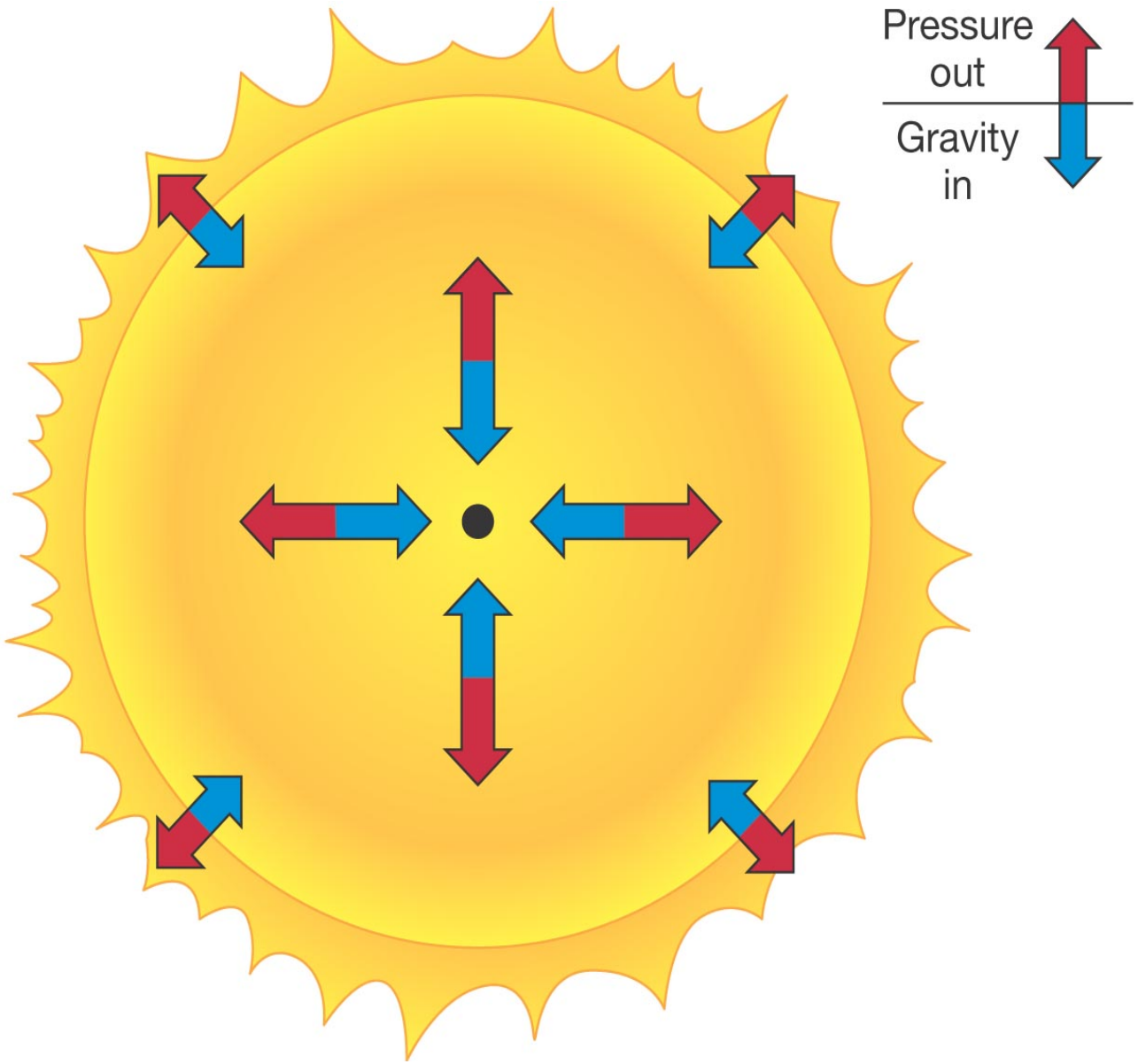
Fermi Bubbles

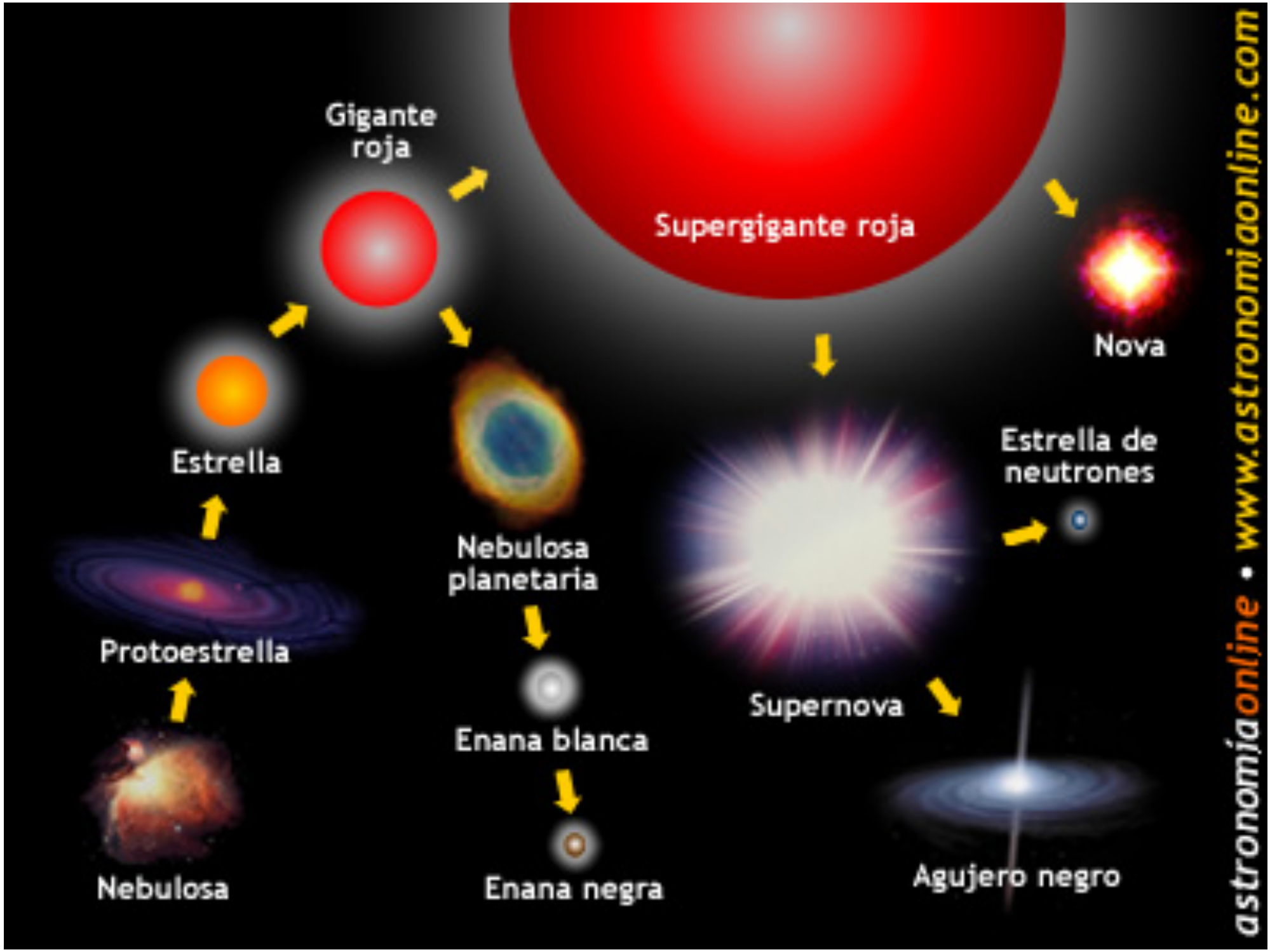


Fermi Bubbles



Forats negres estel·lars




Gigante roja
Supergigante roja
Nova
Estrella
Estrella de neutrones
Nebulosa planetaria
Protoestrella
Supernova
Enana blanca
Nebulosa
Enana negra
Agujero negro
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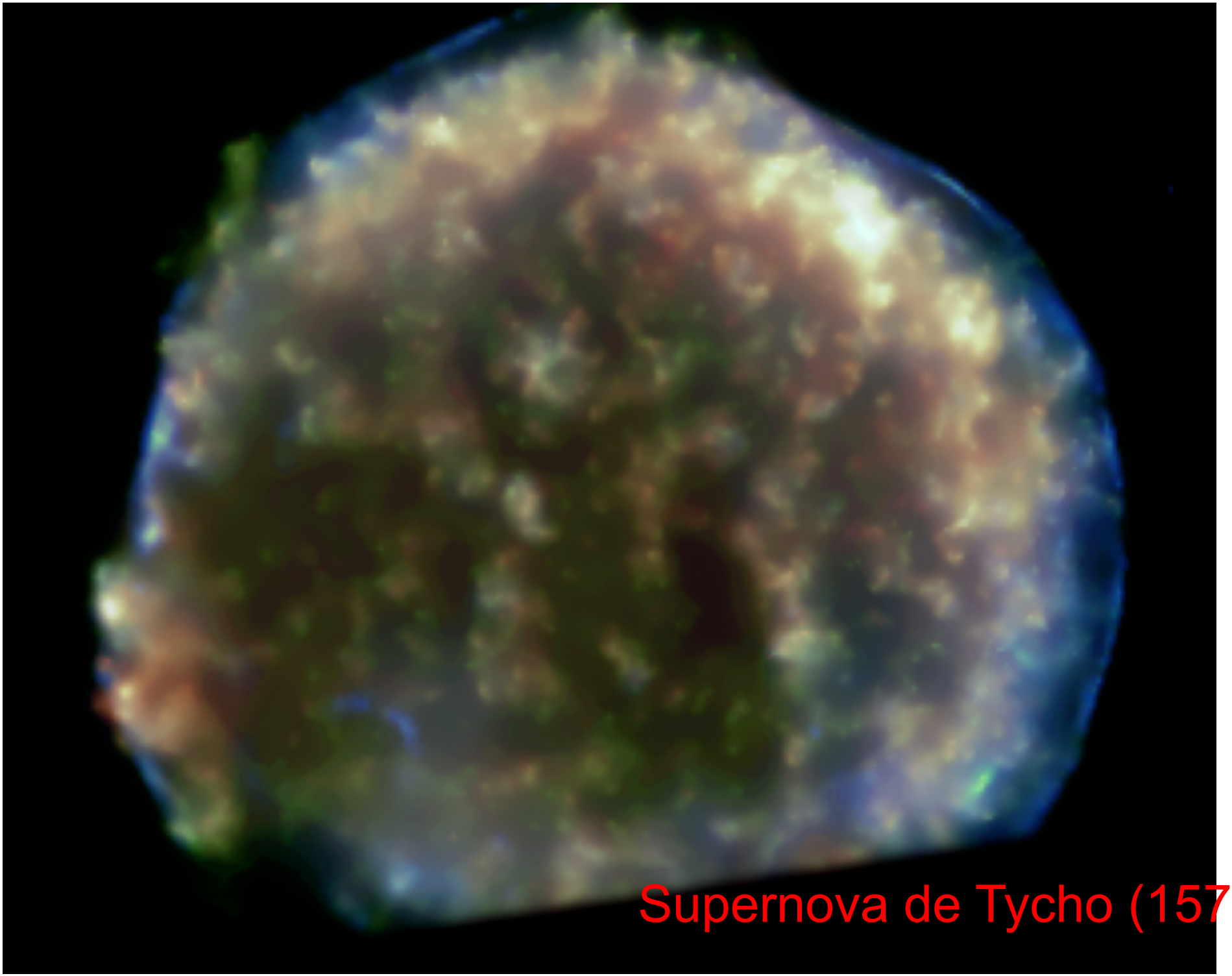
SN1006,
Xina, Japó

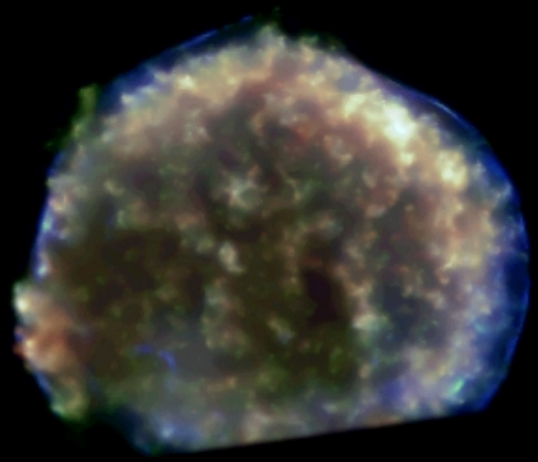
Nebulosa del Cranc
Resto de Supernova (China, 1054)

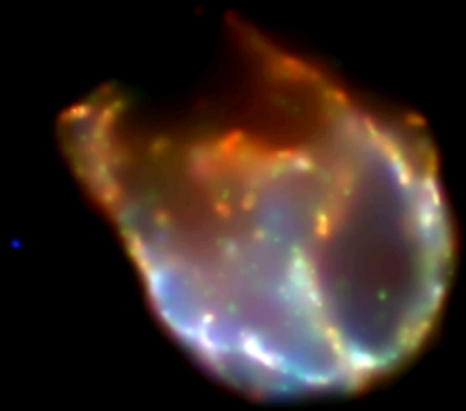

Restes de Supernova en el Núvol Major de Magallanes

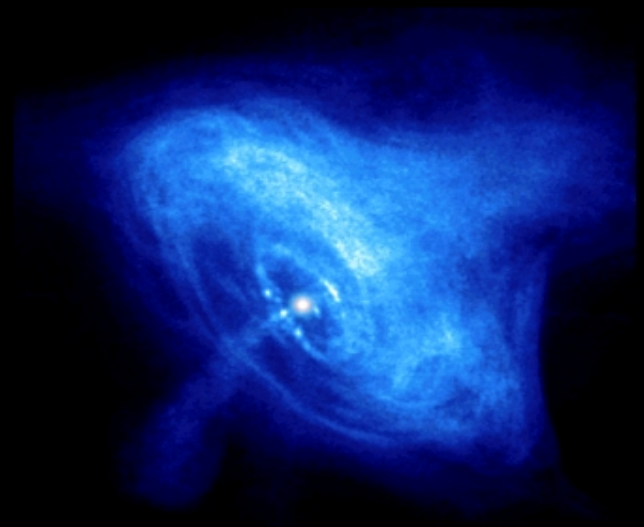


Supernova de Tycho (1572)

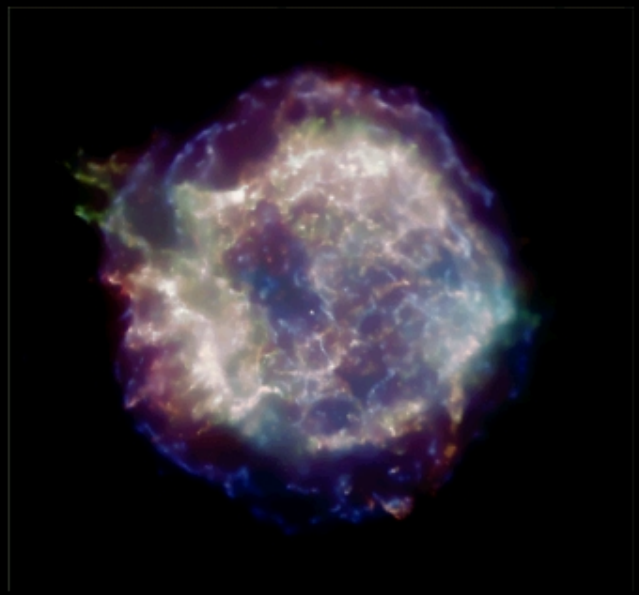

Restes de Supernova en el Núvol Major de Magallanes

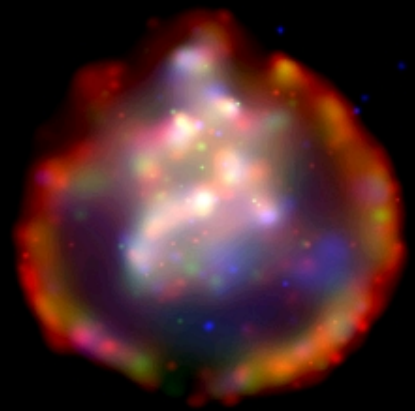




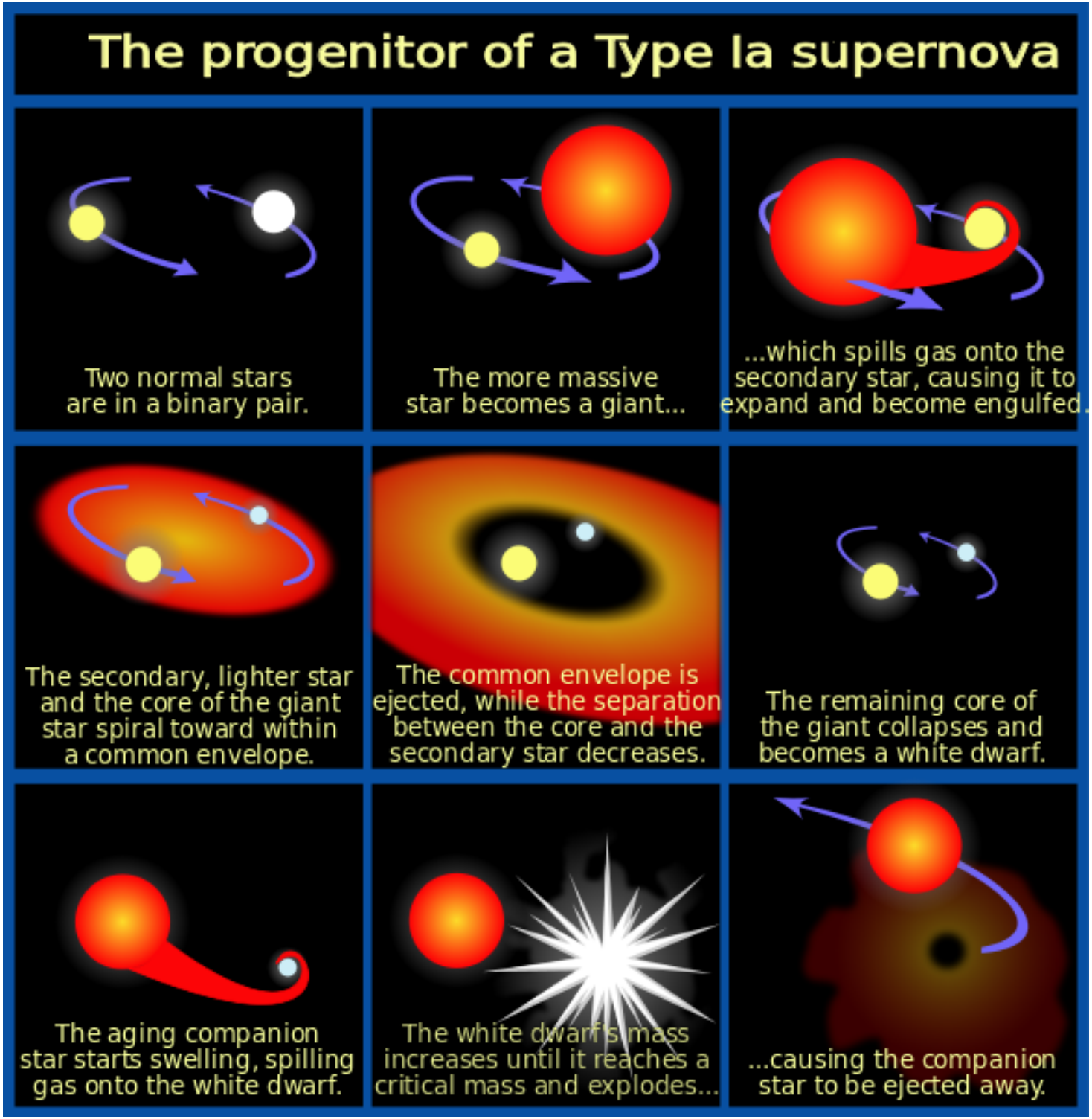


Massive stars explode

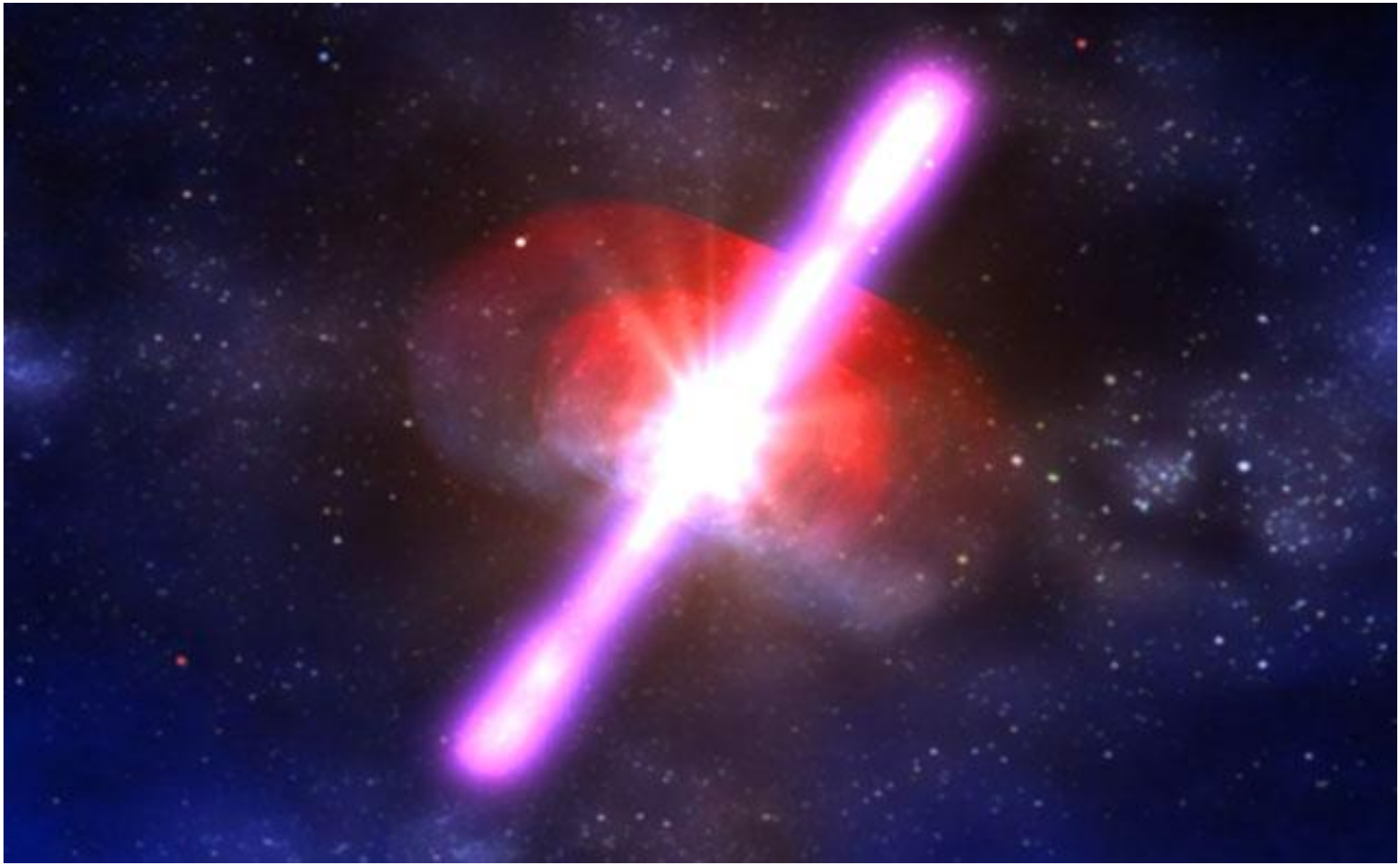


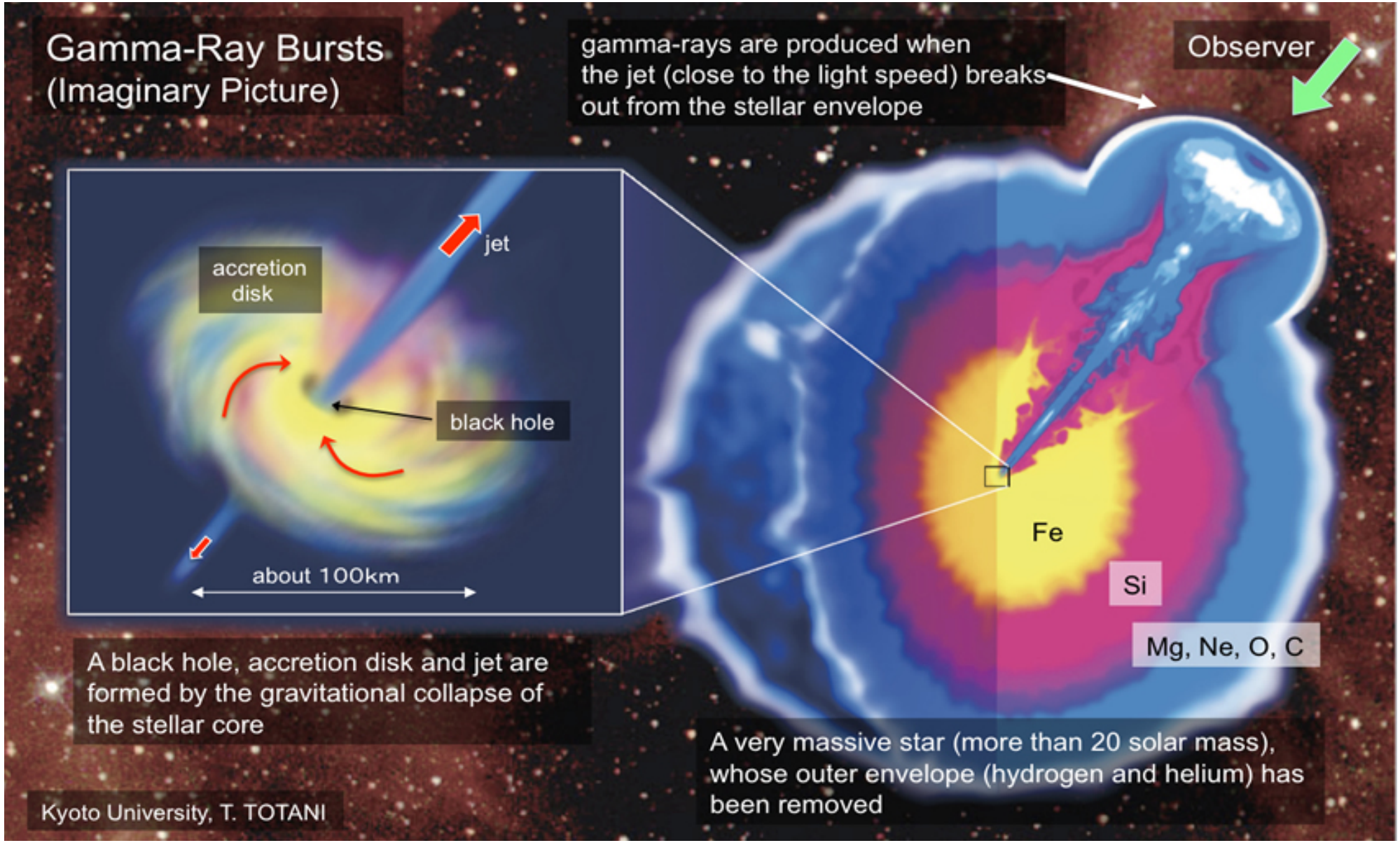


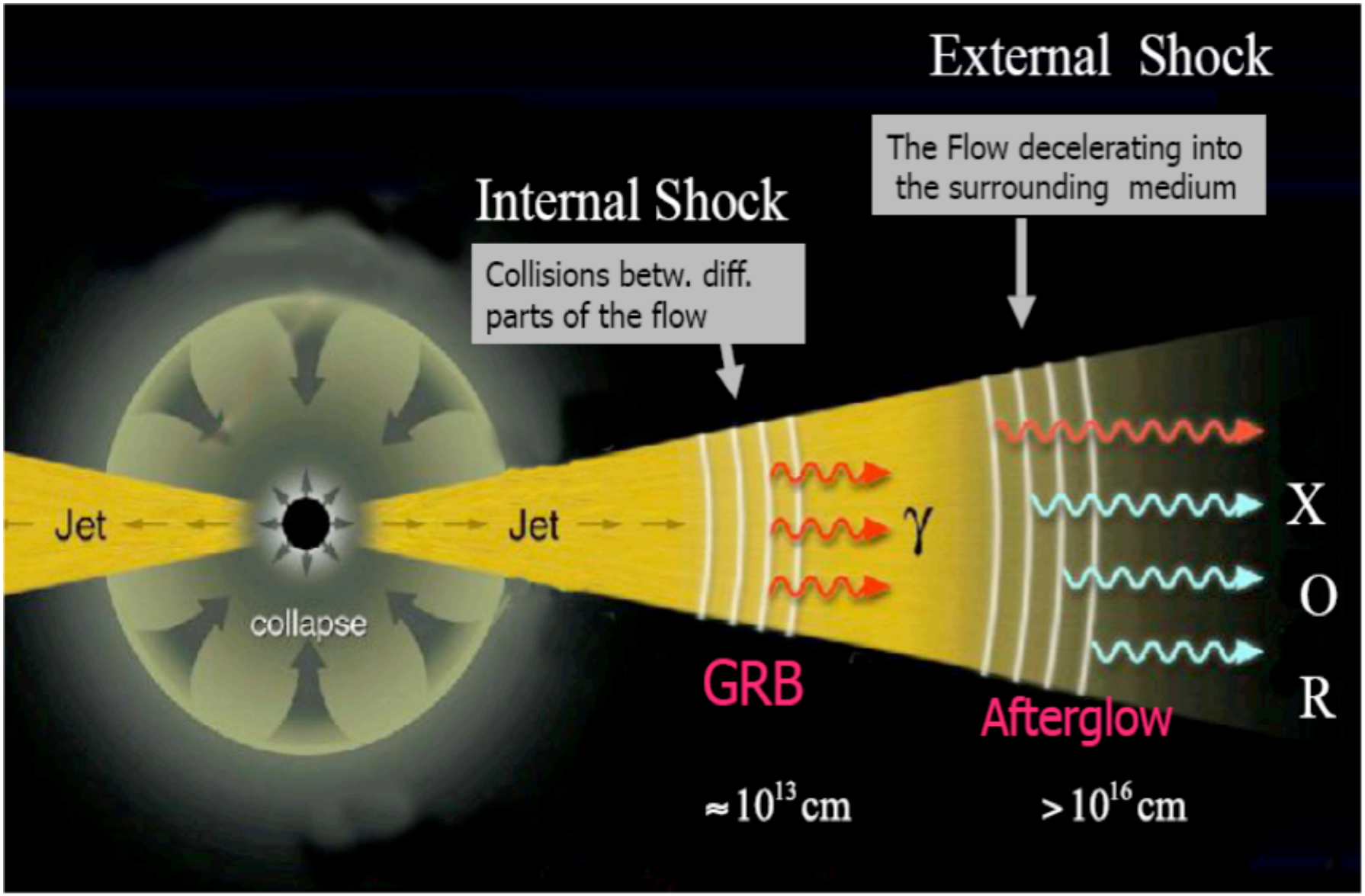
X-ray pictures of supernova remnants from NASA's Chandra Observatory http://chandra.harvard.edu/

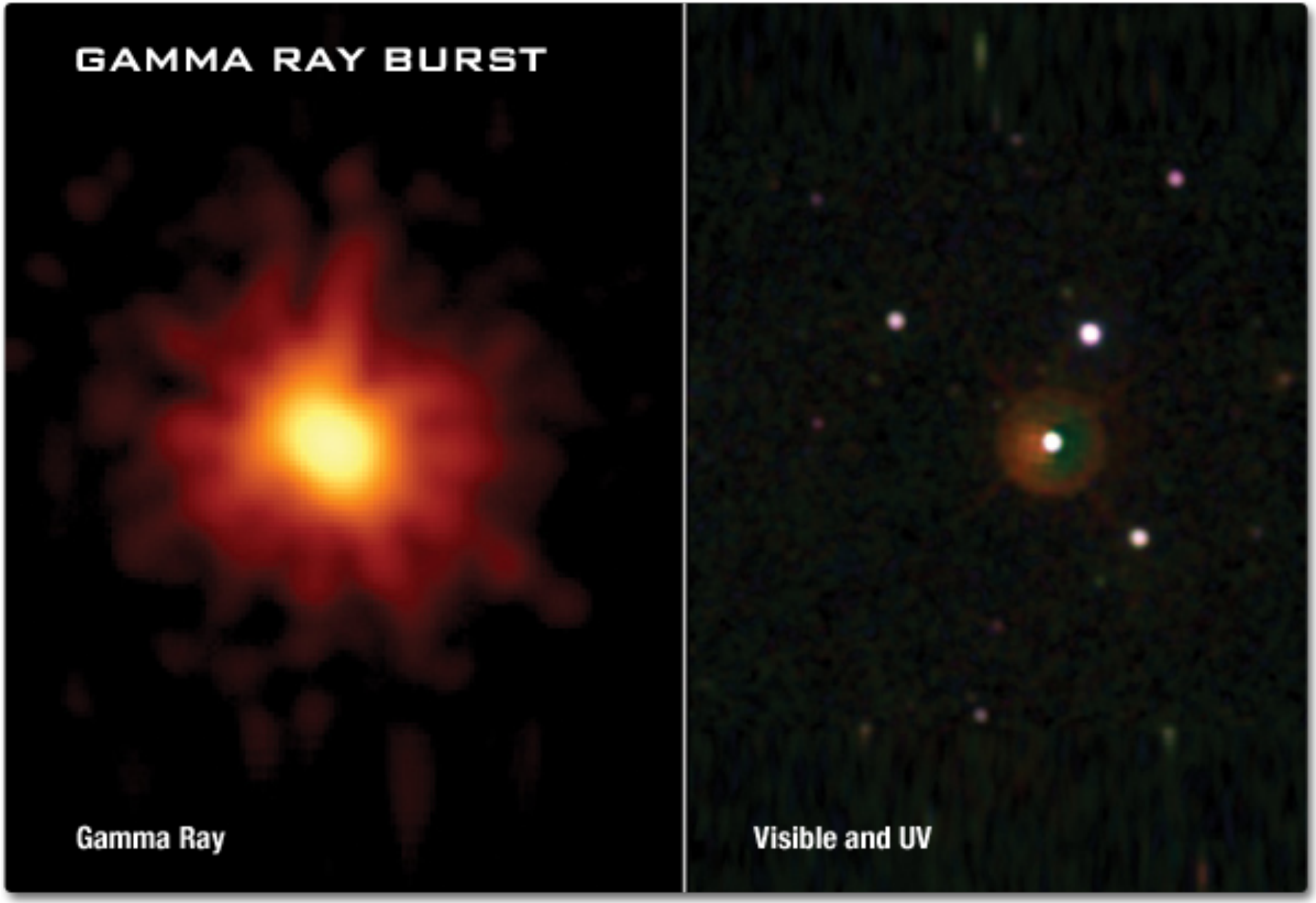


Supernoves tipus I

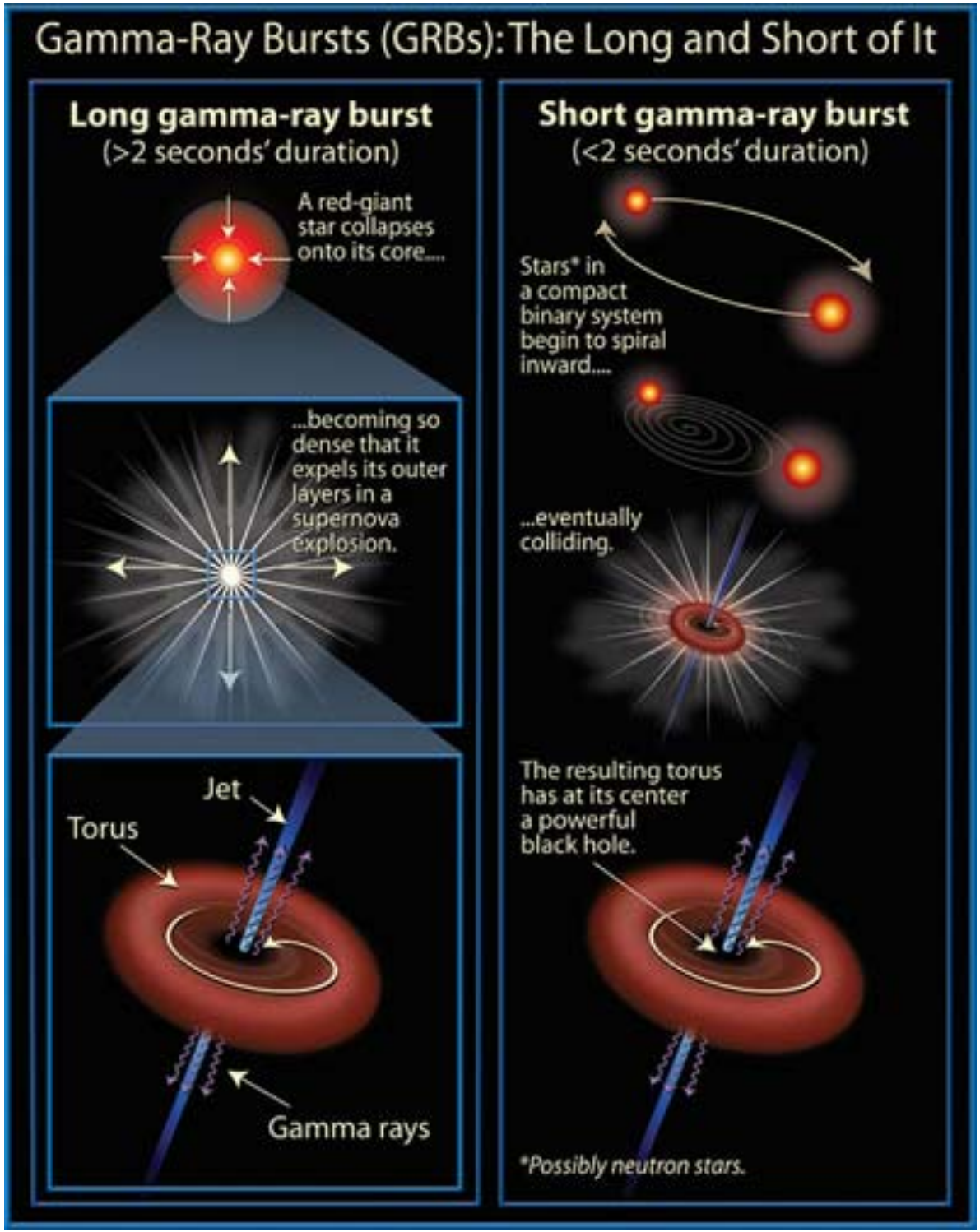



Gamma-Ray Bursts
(Imaginary Picture)
gamma-rays are produced when the jet (close to the light speed) breaks out from the stellar envelope
Observer
jet
accretion disk
black hole
about 100km
Fe
Si
Mg, Ne, O, C
A black hole, accretion disk and jet are formed by the gravitational collapse of the stellar core
A very massive star (more than 20 solar mass), whose outer envelope (hydrogen and helium) has been removed
Kyoto University, T. TOTANI


External Shock
The Flow decelerating into the surrounding medium
Internal Shock
Collisions betw. diff. parts of the flow
Jet
Jet
collapse
γ
X
O
R
GRB
Afterglow
≈10^13 cm
>10^16 cm



12800 milions d’anys llum!!!!

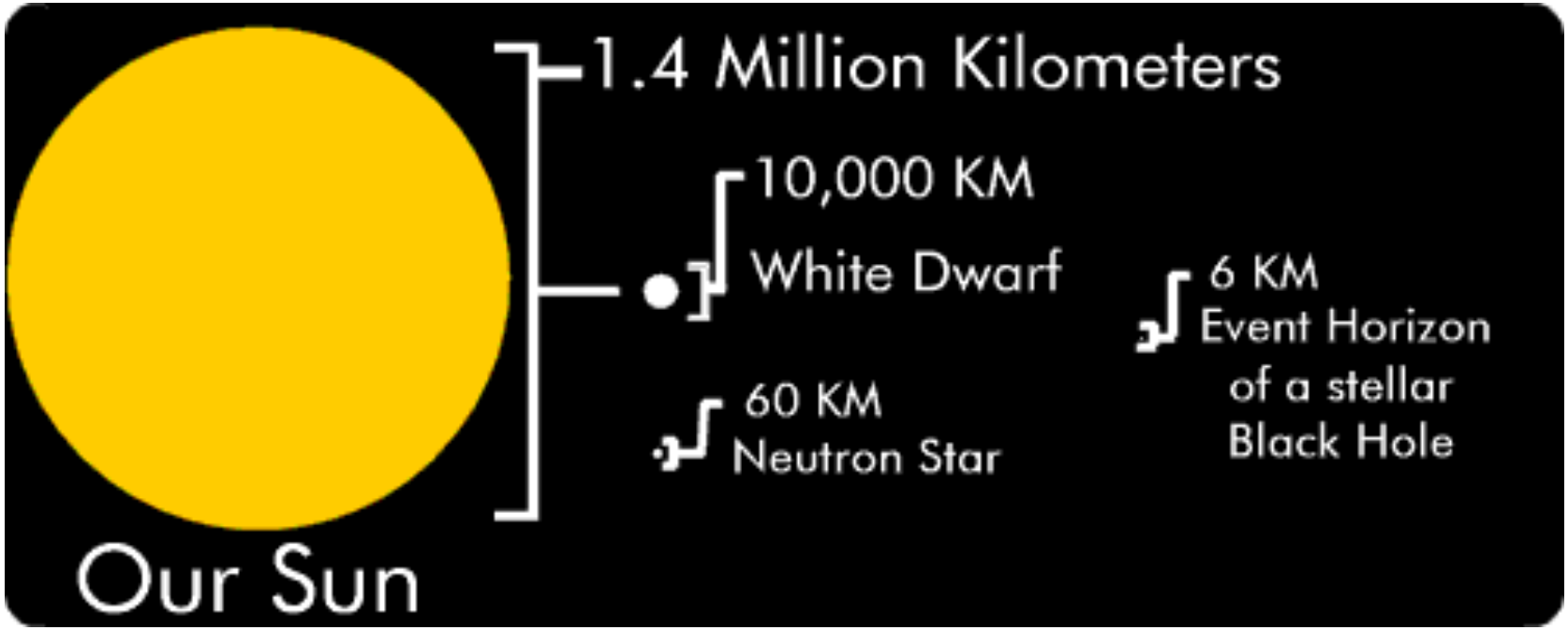


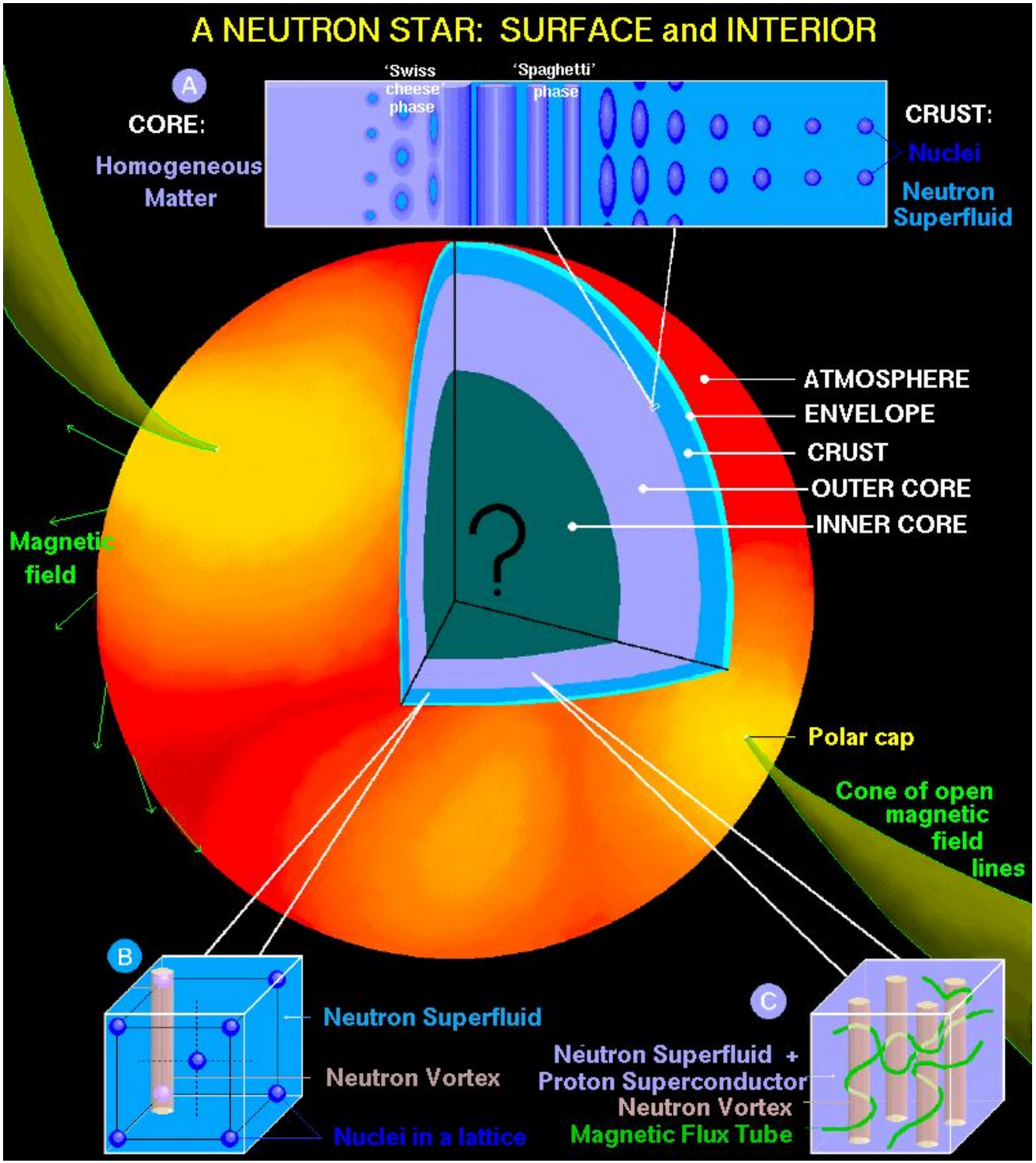
Associats a la formació de forats negres.

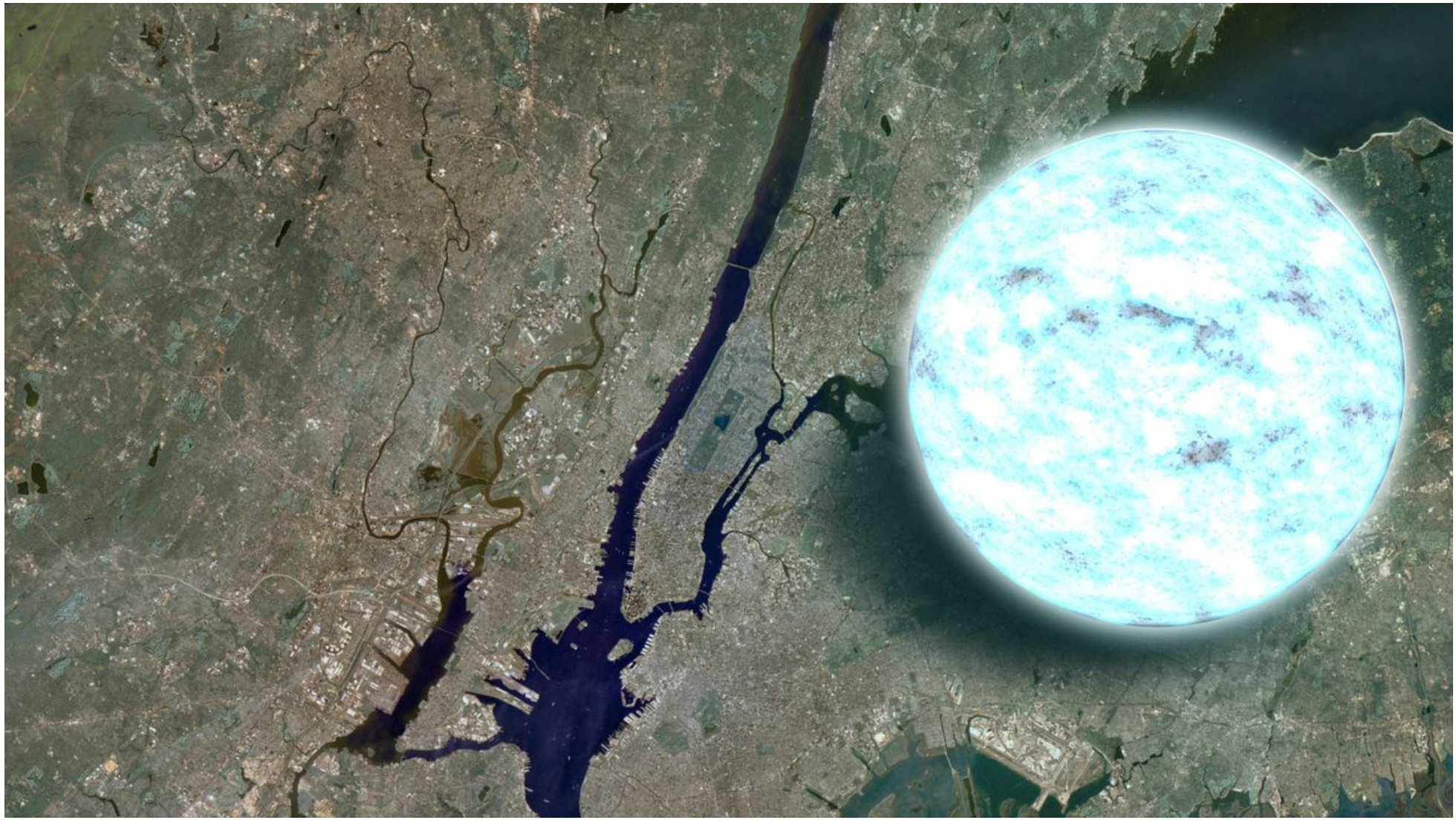
Diferents tipus.

Si el nucli resultant d'una explosió supernova té entre 1.5 i 3 M_{sol}, el resultat és un estel de neutrons.

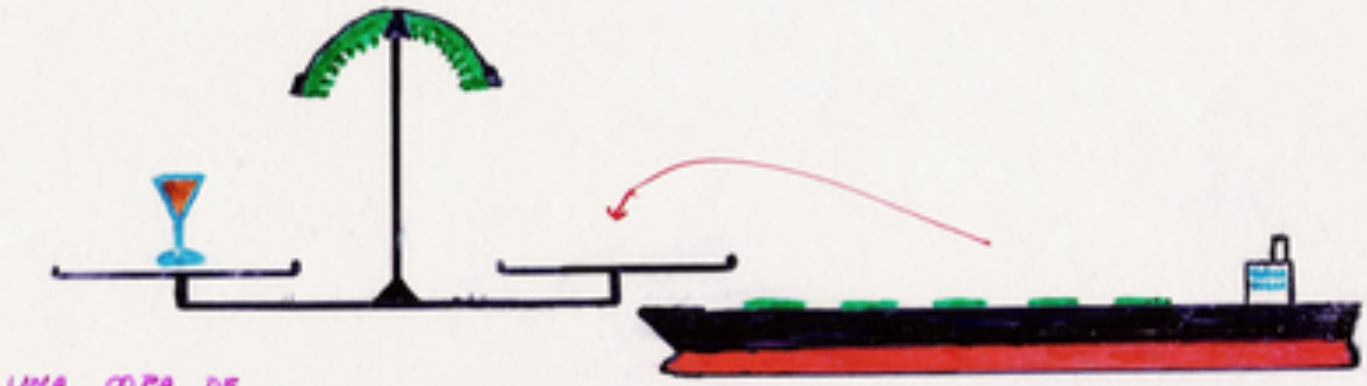
Si el nucli restant té una massa superior a 3 M_{sol}, l'objecte col·lapsa sobre sí mateix i trenca l'espai-temps, formant un forat negre.



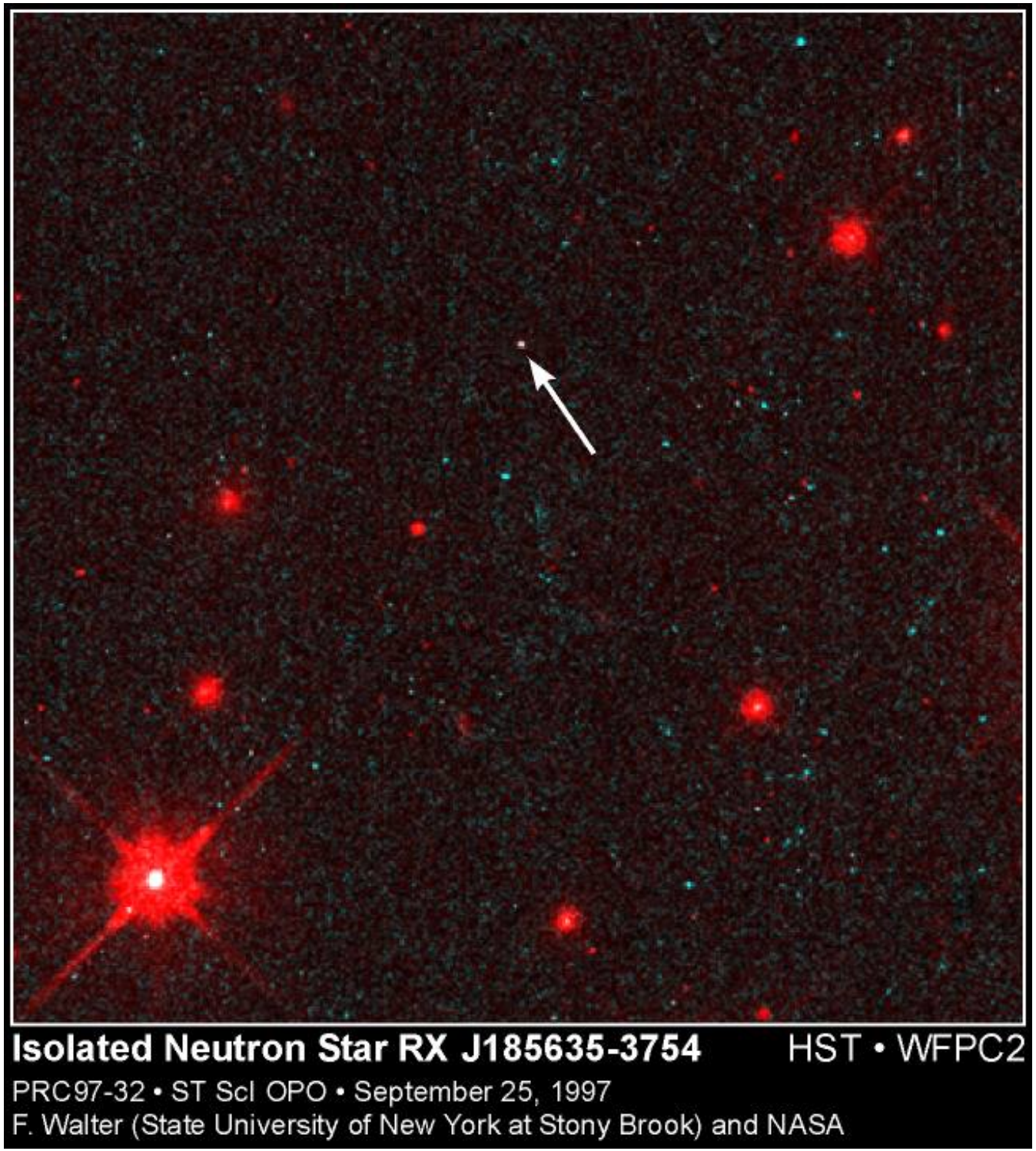

A NEUTRON STAR: SURFACE and INTERIOR
A
CORE:
Homogeneous Matter
'Swiss cheese' phase
'Spaghetti' phase
CRUST:
Nuclei
Neutron Superfluid
ATMOSPHERE
ENVELOPE
CRUST
OUTER CORE
INNER CORE
?
Magnetic field
Polar cap
Cone of open magnetic field lines
B
Neutron Superfluid
Neutron Vortex
Nuclei in a lattice
C
Neutron Superfluid +
Proton Superconductor
Neutron Vortex
Magnetic Flux Tube



ESTRELLA DE NEUTRONES



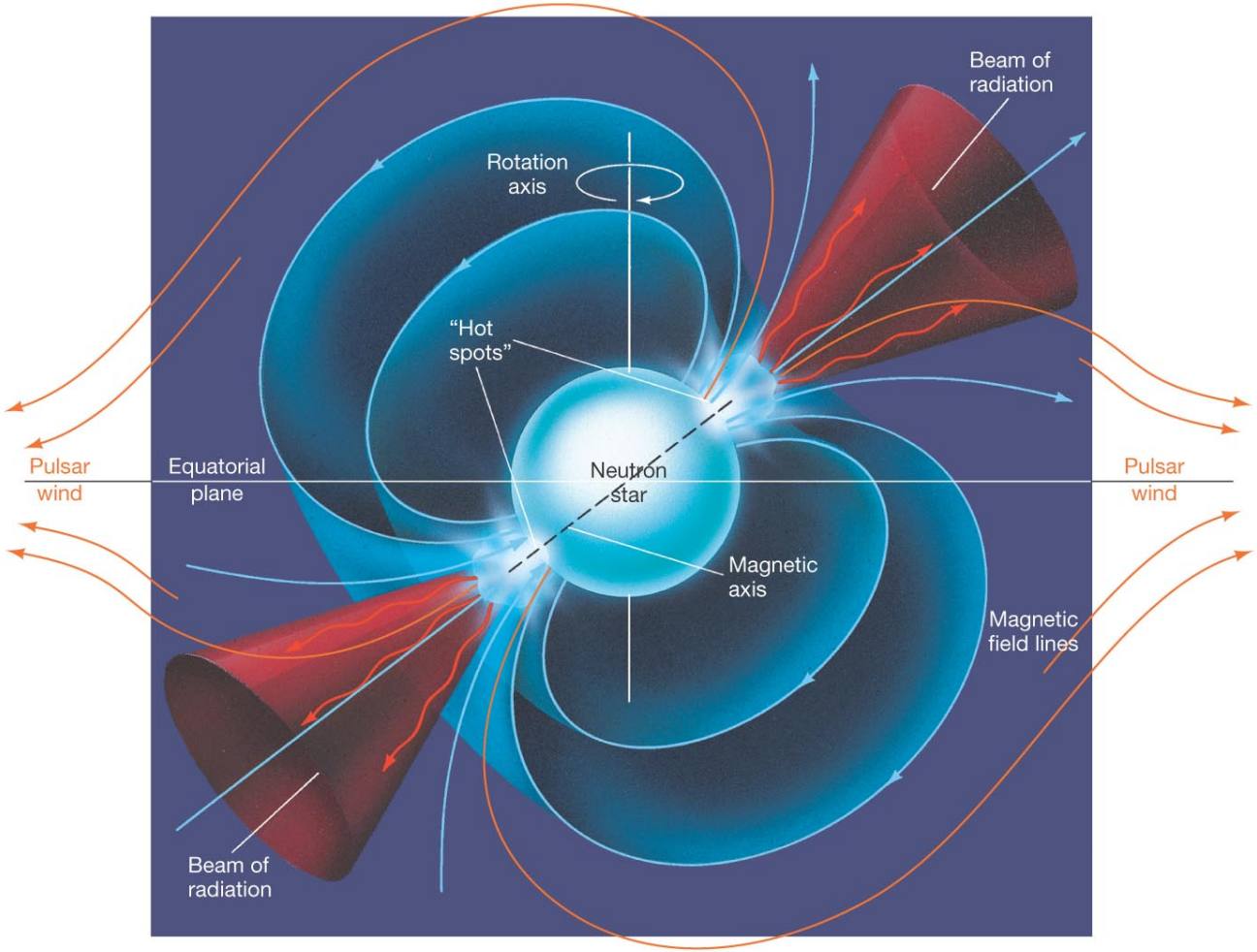
DENSIDAD MEDIA : $\rho \sim 10^{14}\ g/cm^3$

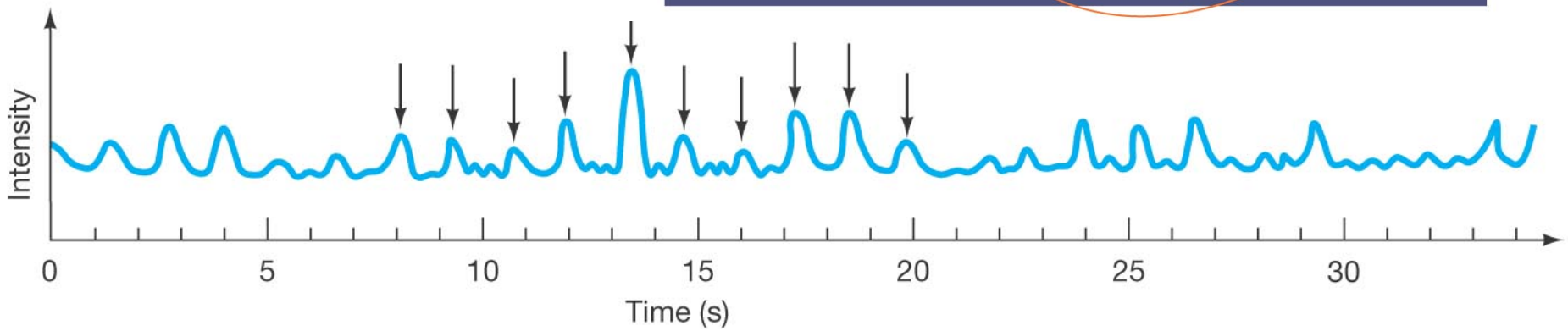


Estels de neutrons

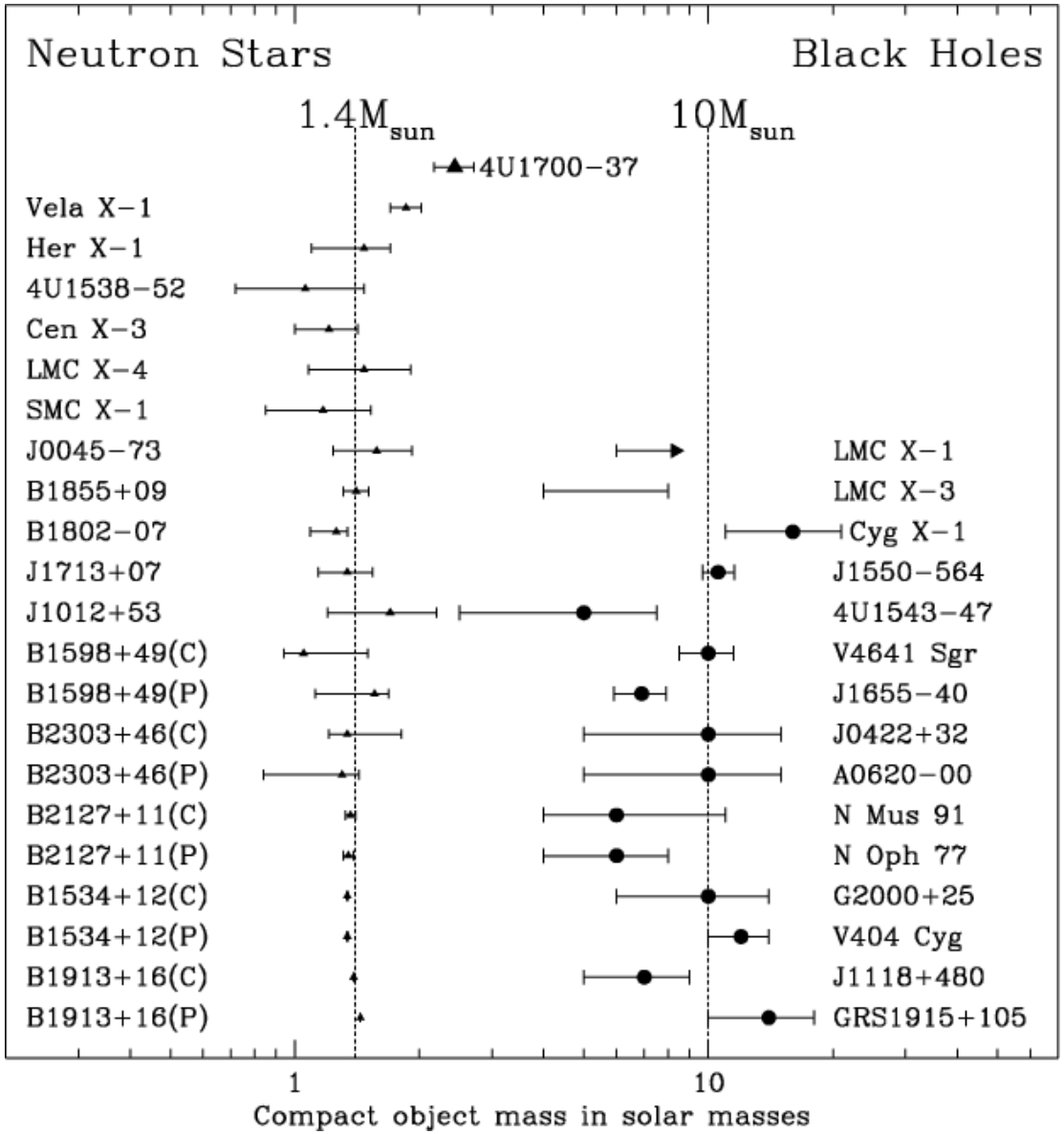

6 Aug 1967

- Púlsars:
  - Estels de neutrons amb alt nivell de magnetització.
  - Descobriment: 1967.





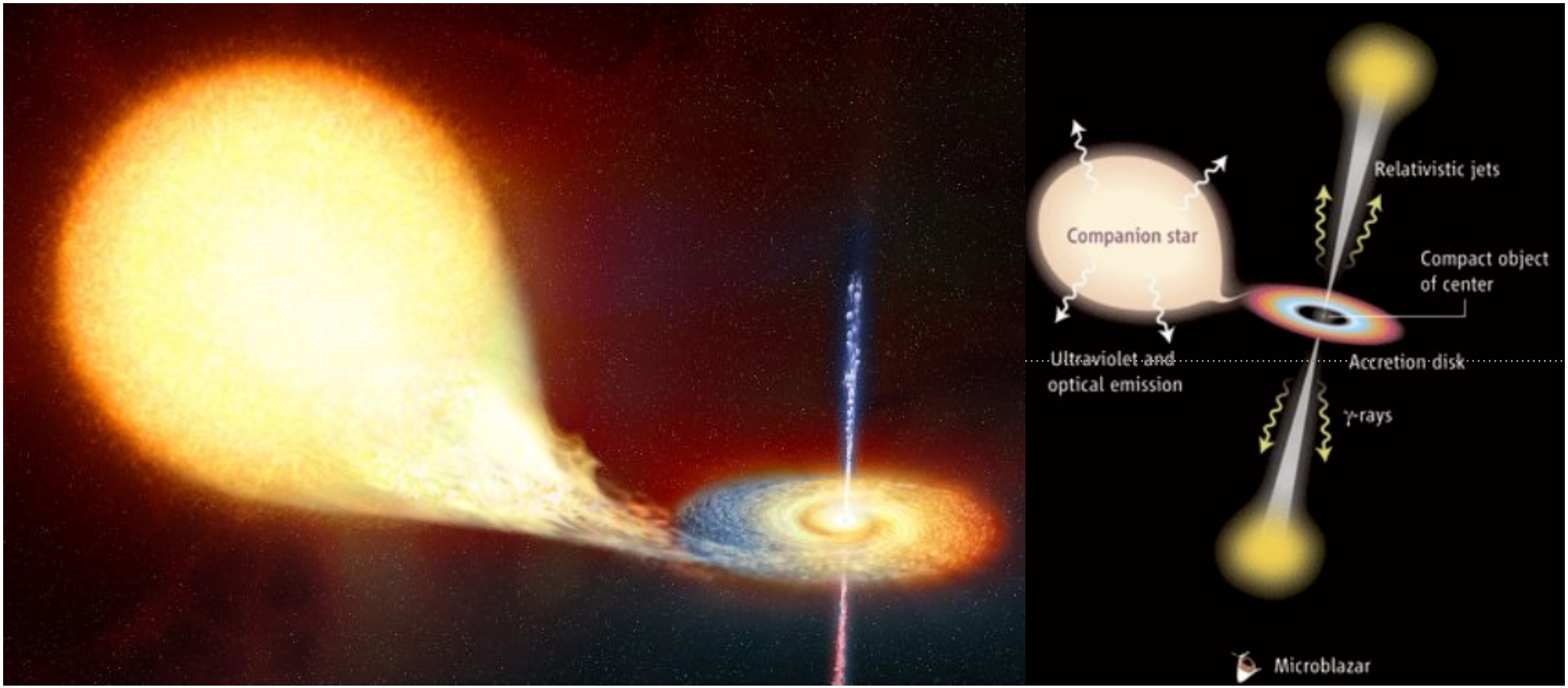
Neutron stars and black holes in our Galaxy

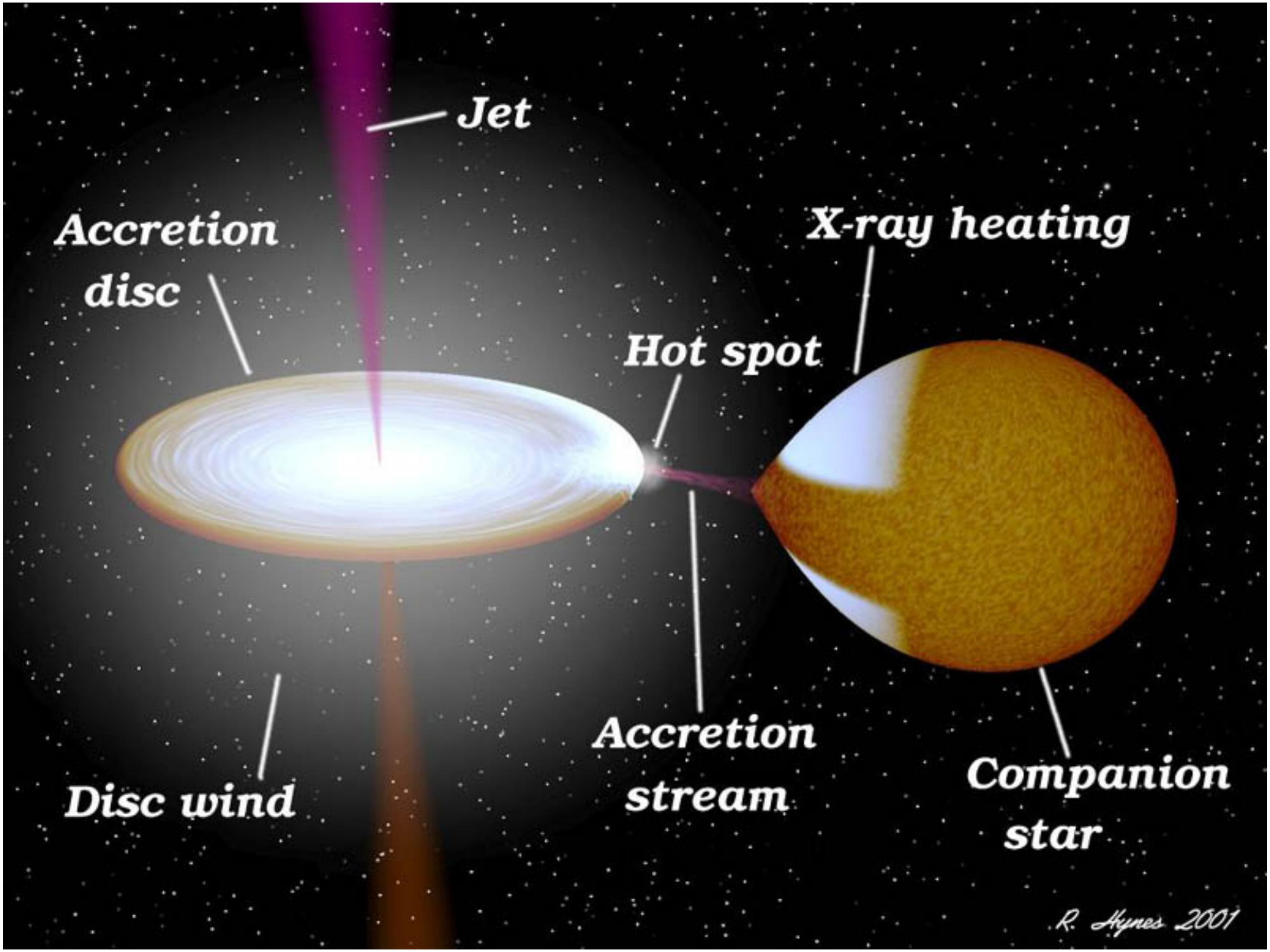


Relativitat General

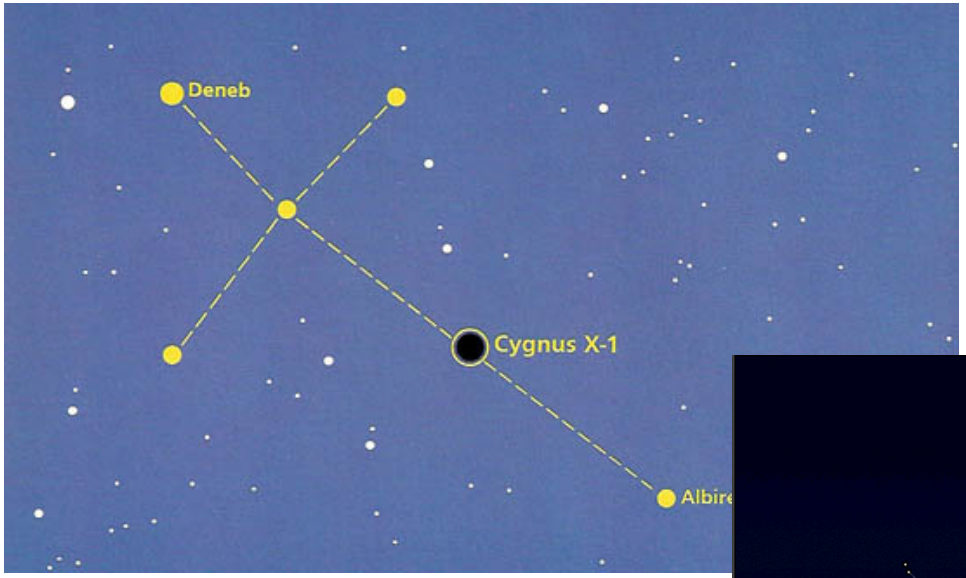
Com detectem forats negres? De manera indirecta.

- Emissió d'alta energia.
- Altres mètodes indirectes relacionats amb l'emissió en l'entorn de l'objecte.
- Estimant el tamany de la regió emissora.

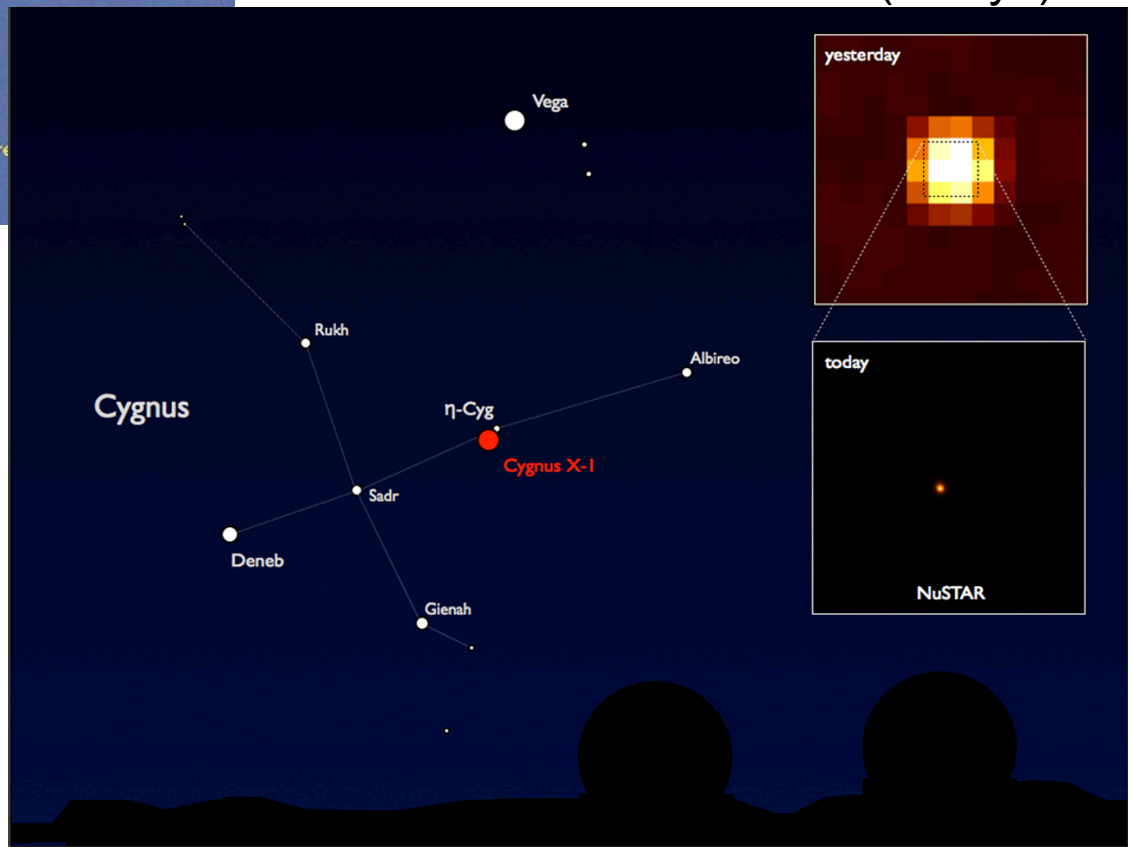



Jet
Accretion disc
X-ray heating
Hot spot
Disc wind
Accretion stream
Companion star
R. Hynes 2001

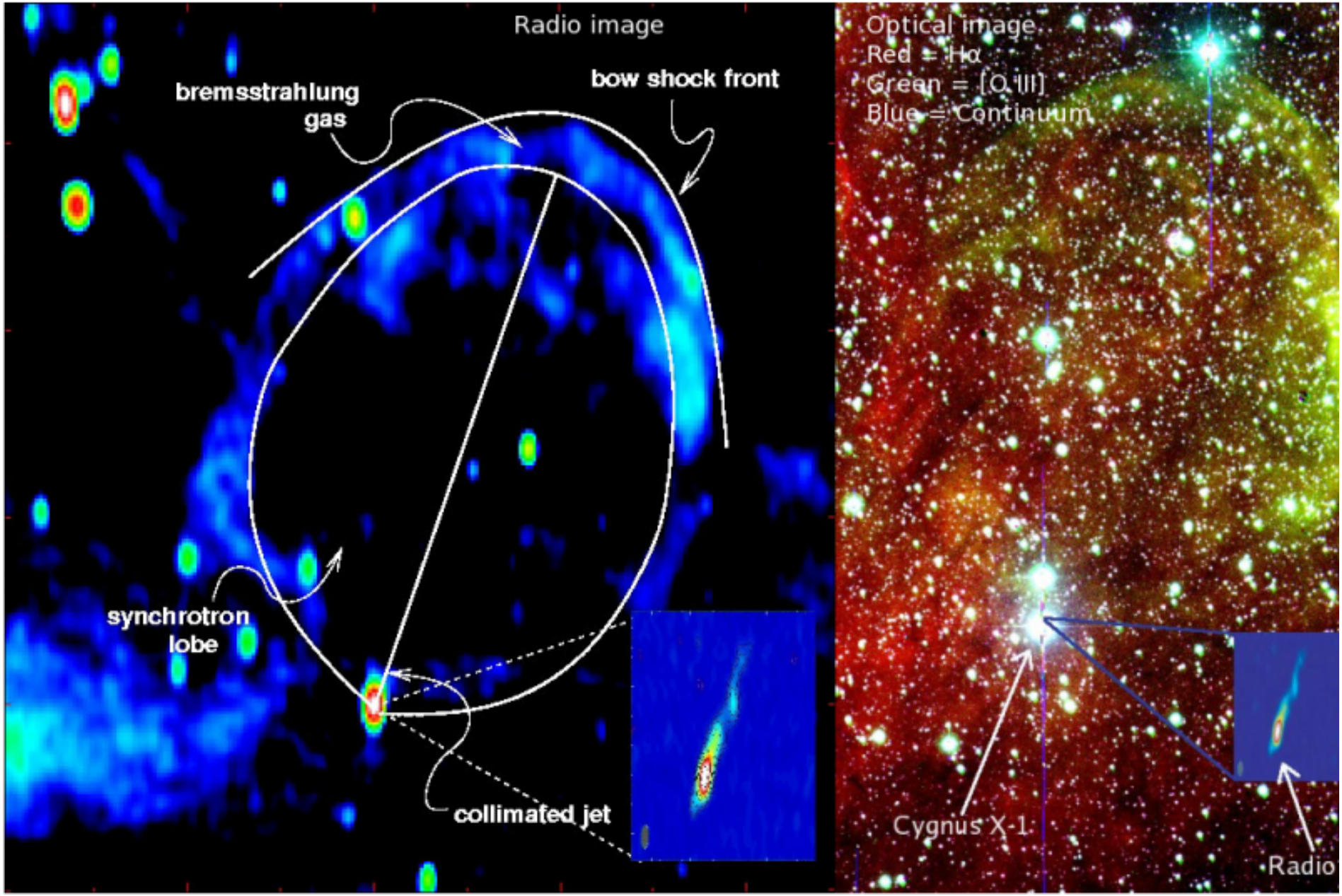
Cygnus X-1 (8000 anys-llum).



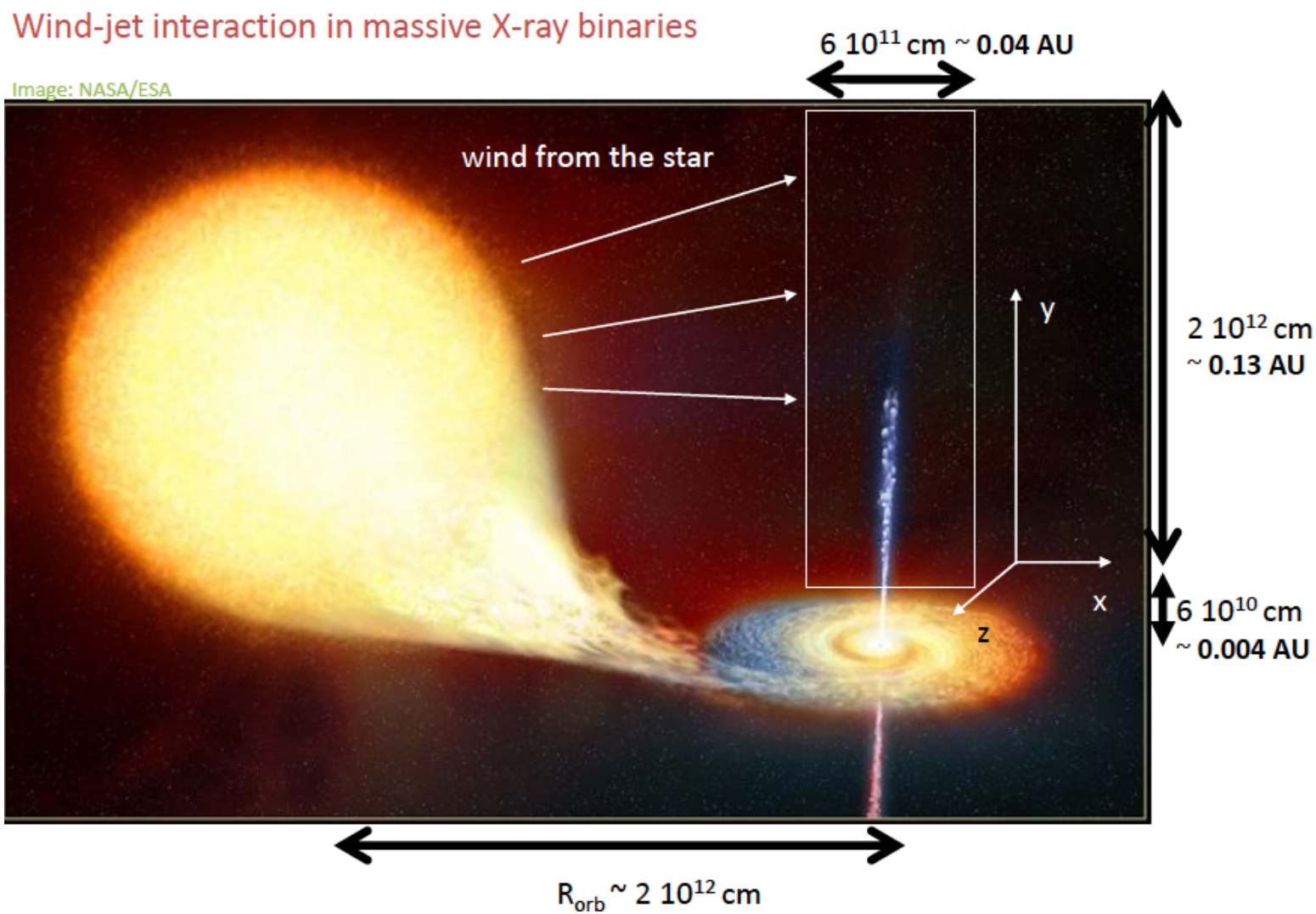
NuSTAR (X-rays)

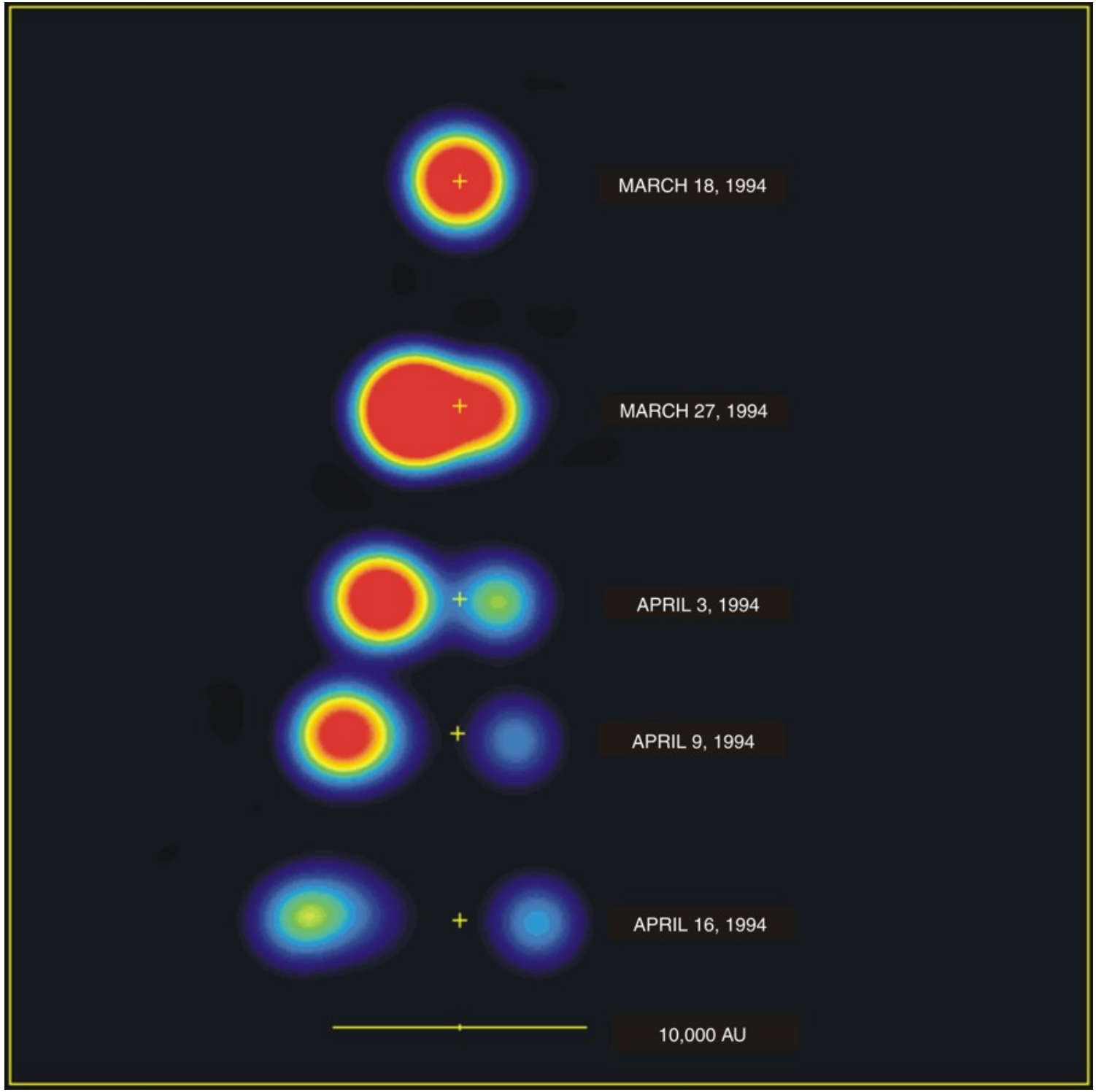


Cygnus X-1: Forat negre de 15 M_{sun} + Supergegant blava



~20 sources with detected jets (microquasars) in the galaxy (Massi ’05, Ribó ’05).





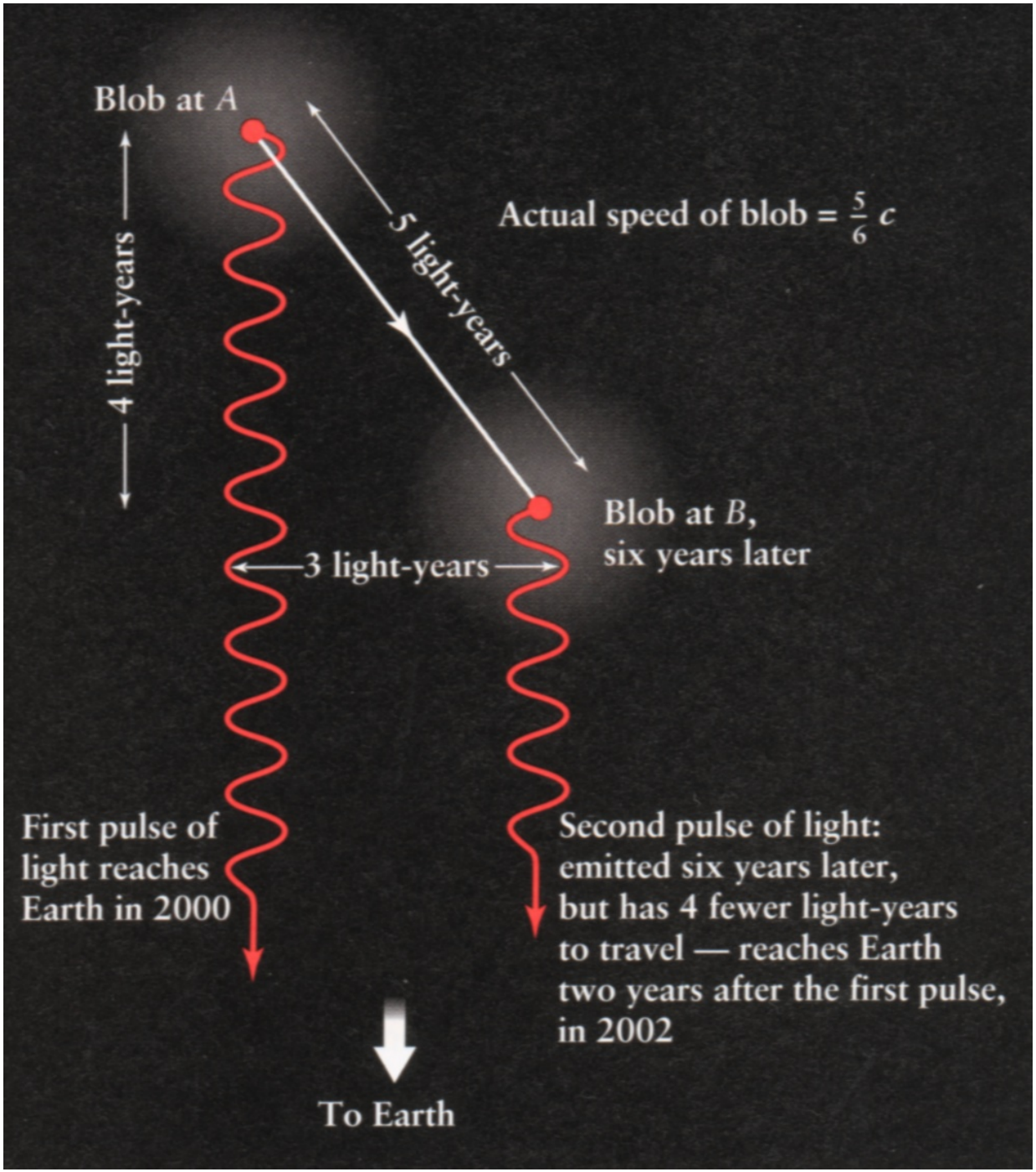
Estels binaris

Microquasars

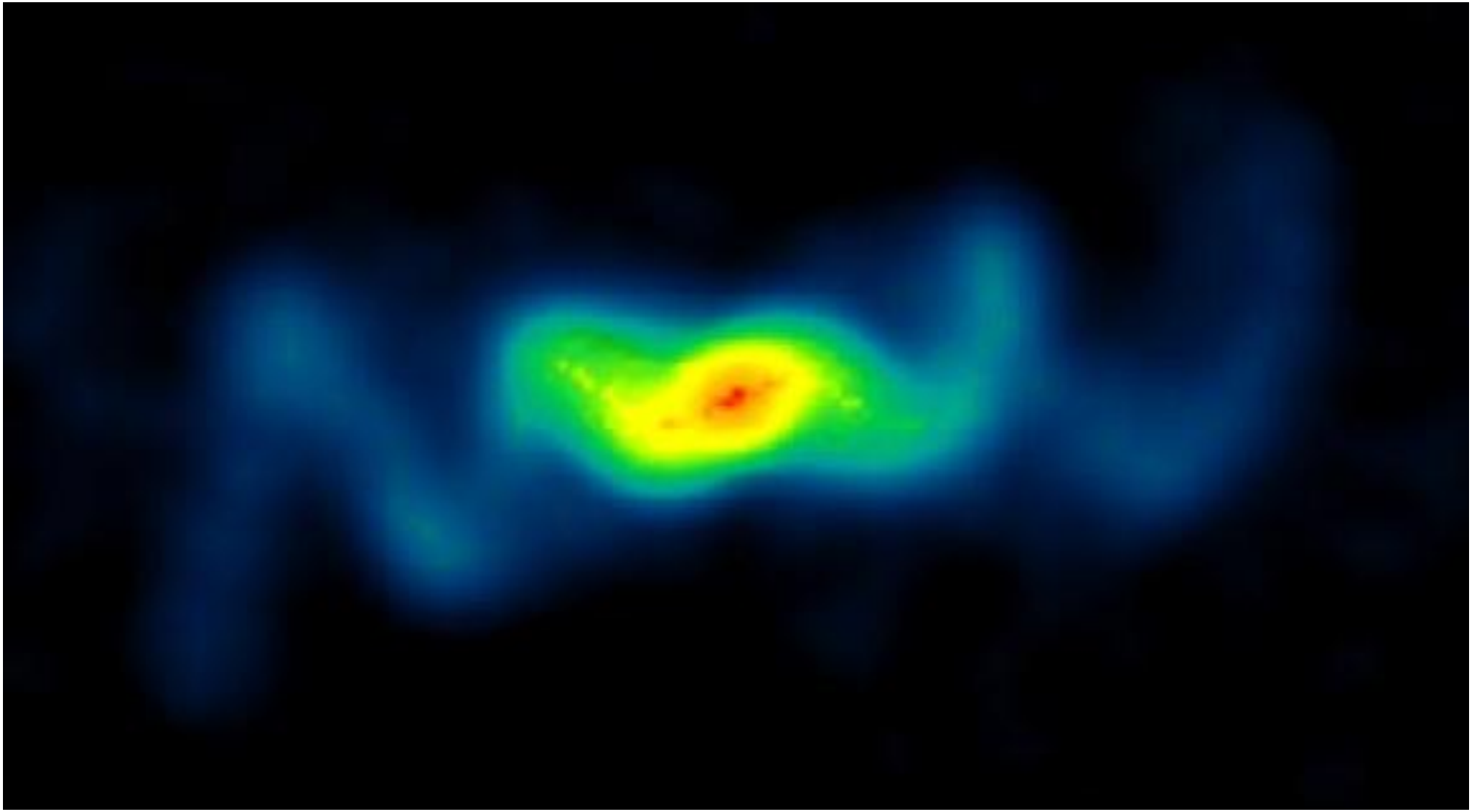
GRS 1915+105

VLA

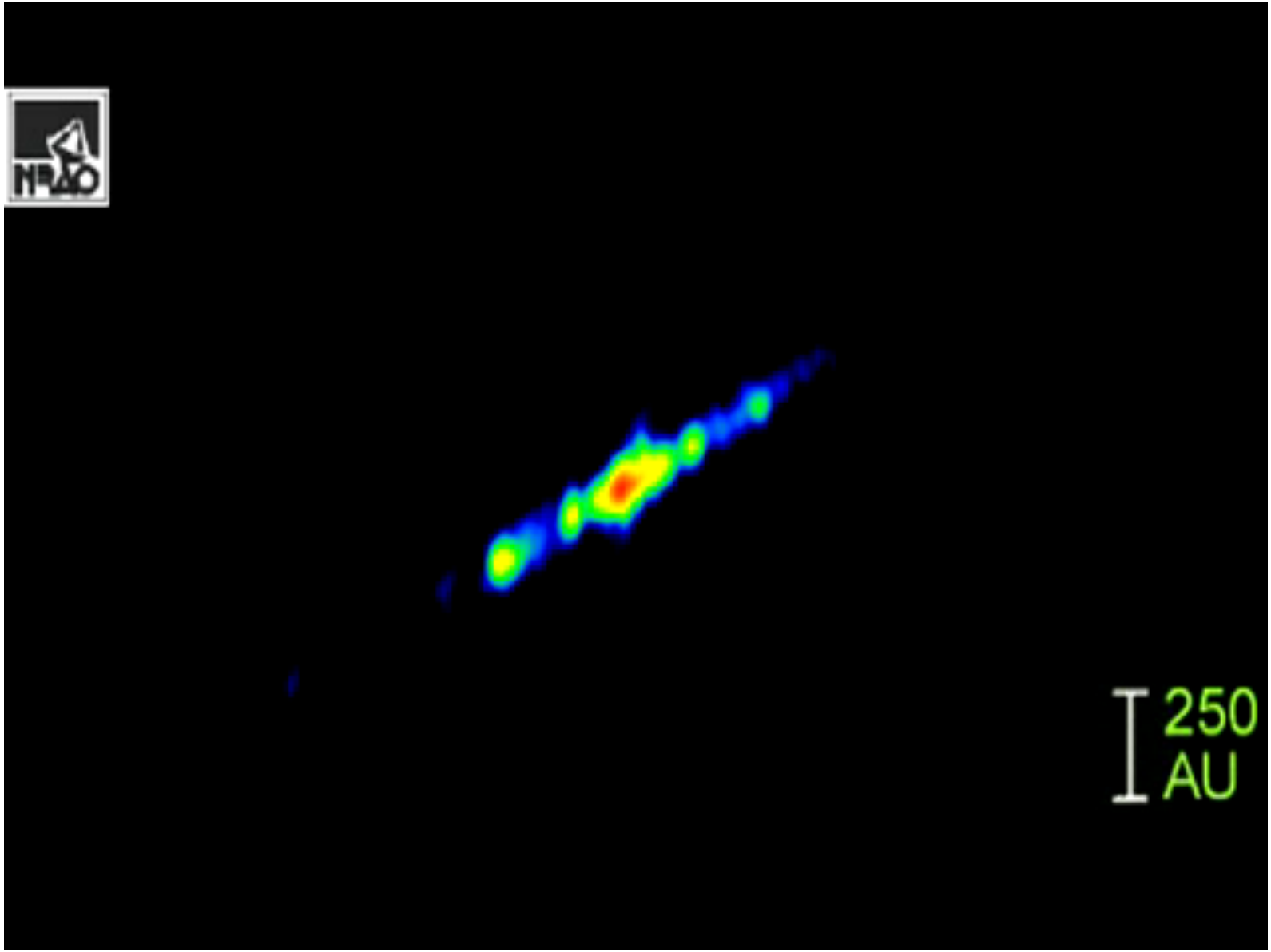
Forat negre de 10-18 M_{sun}


Blob at A
4 light-years
5 light-years
Actual speed of blob = $\frac{5}{6}c$
Blob at B,
six years later
3 light-years
First pulse of
light reaches
Earth in 2000
Second pulse of light:
emitted six years later,
but has 4 fewer light-years
to travel — reaches Earth
two years after the first pulse,
in 2002
To Earth

SS433: Objecte compacte + estel.

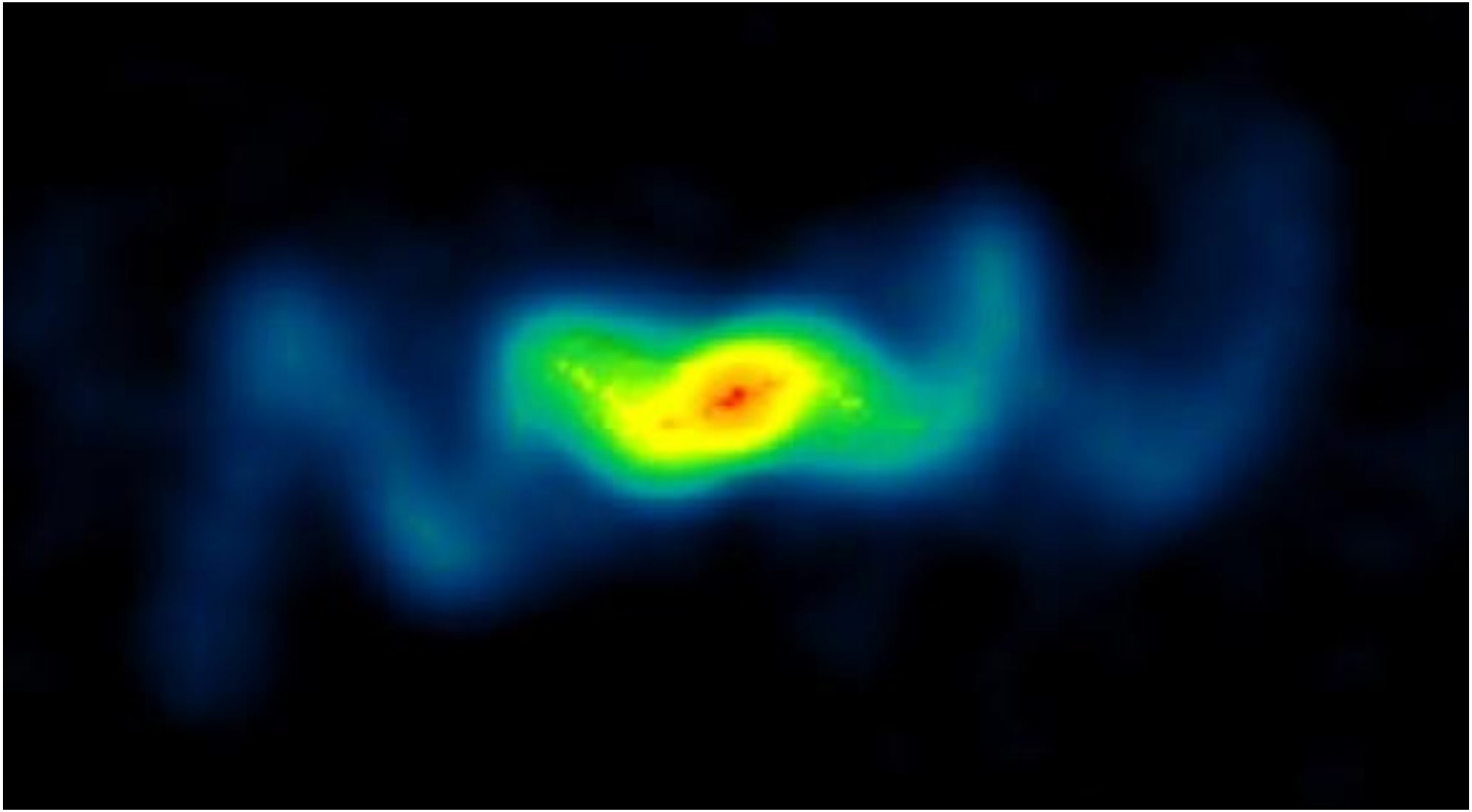


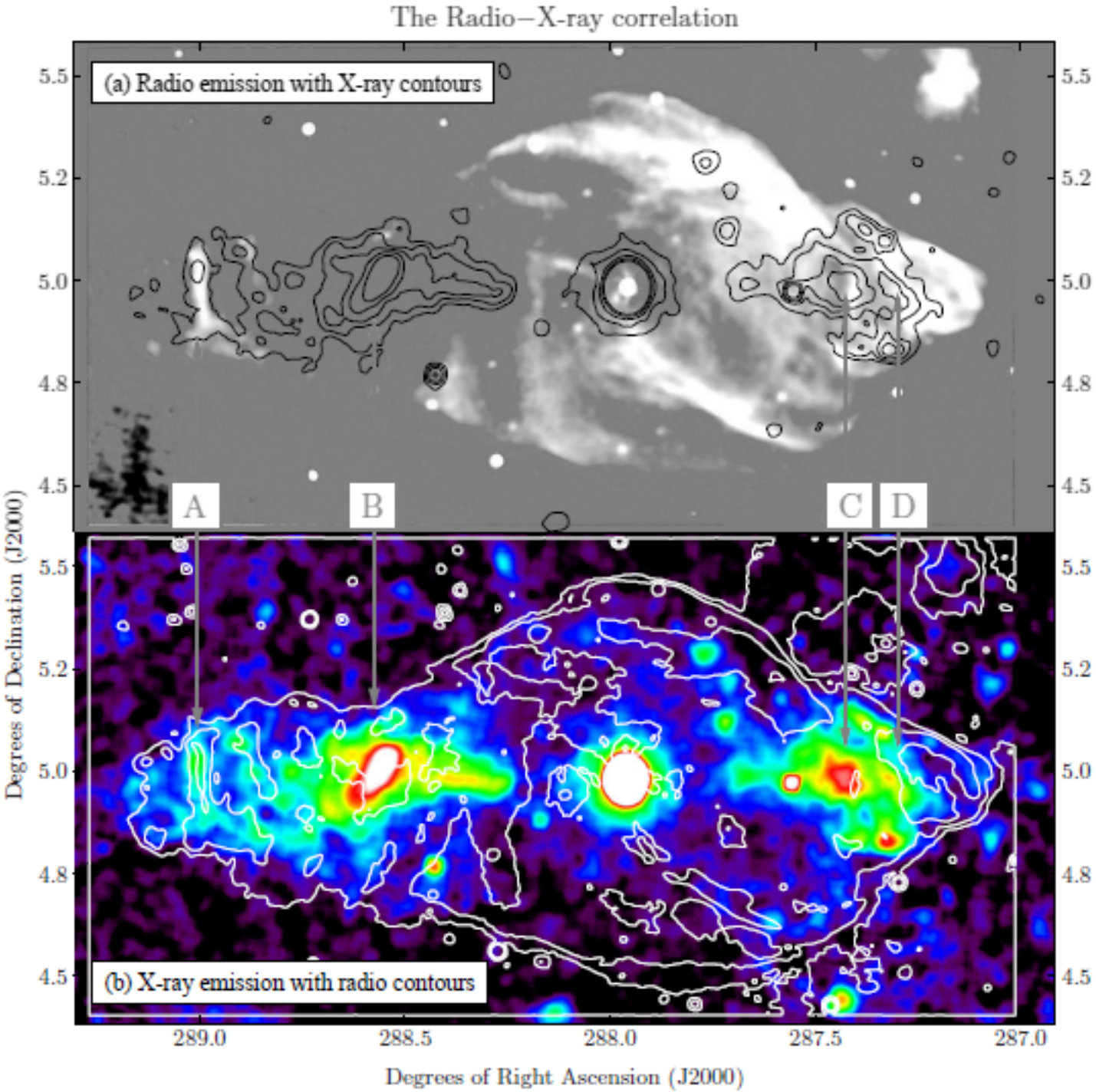
SS433: Objecte compacte + estel.



42 dies d’observacions (2003)

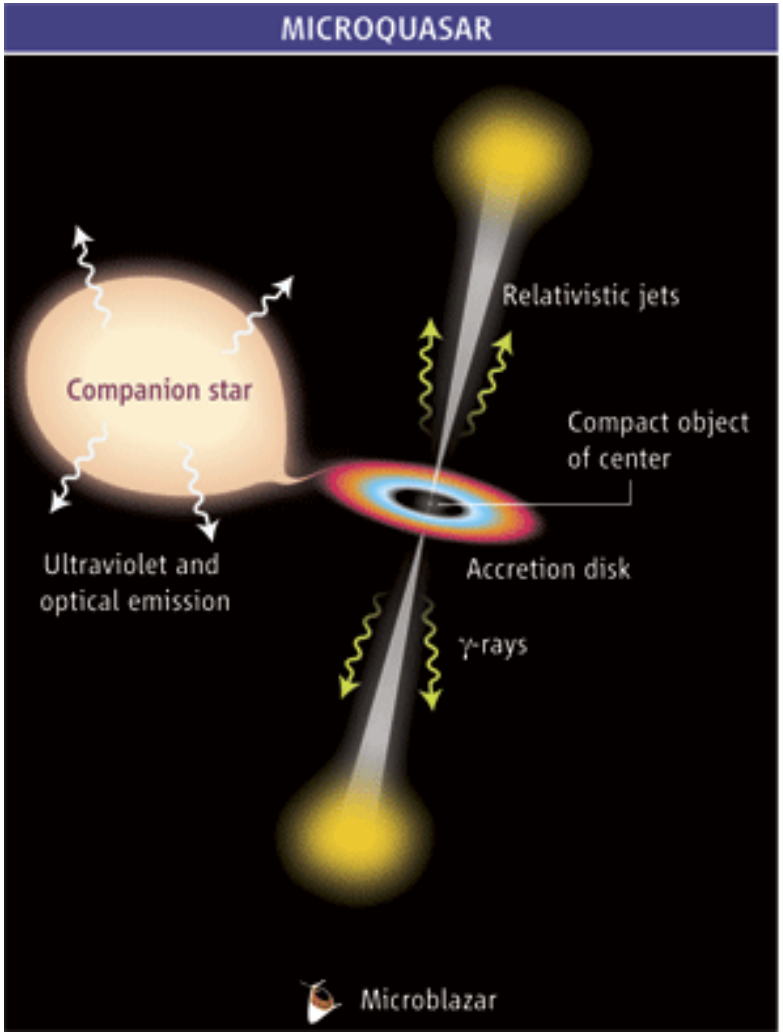
SS433: Objecte compacte + estel.

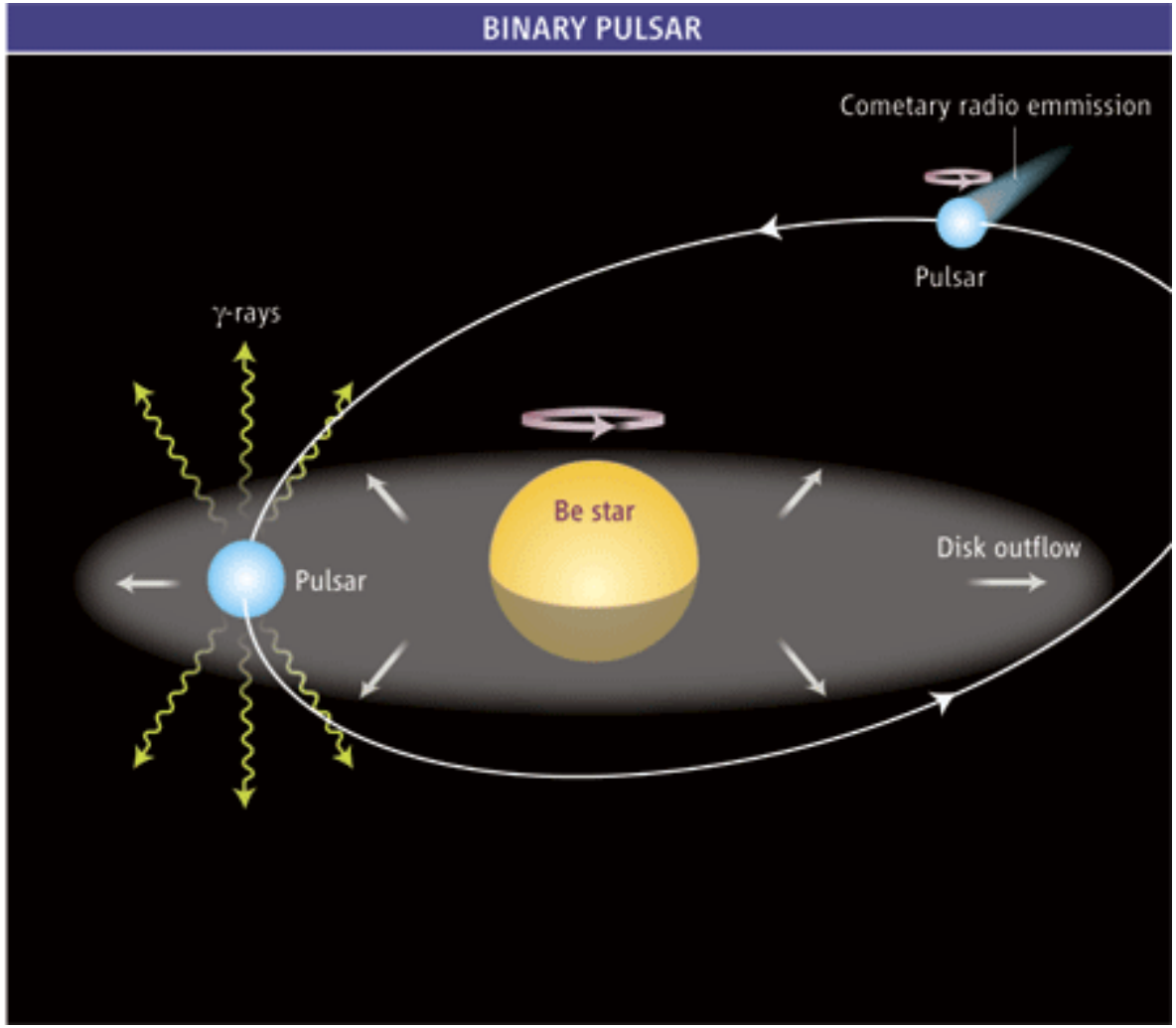



The Radio−X-ray correlation
(a) Radio emission with X-ray contours
(b) X-ray emission with radio contours
A
B
C
D
5.5
5.2
5.0
4.8
4.5
289.0
288.5
288.0
287.5
287.0
Degrees of Declination (J2000)
Degrees of Right Ascension (J2000)

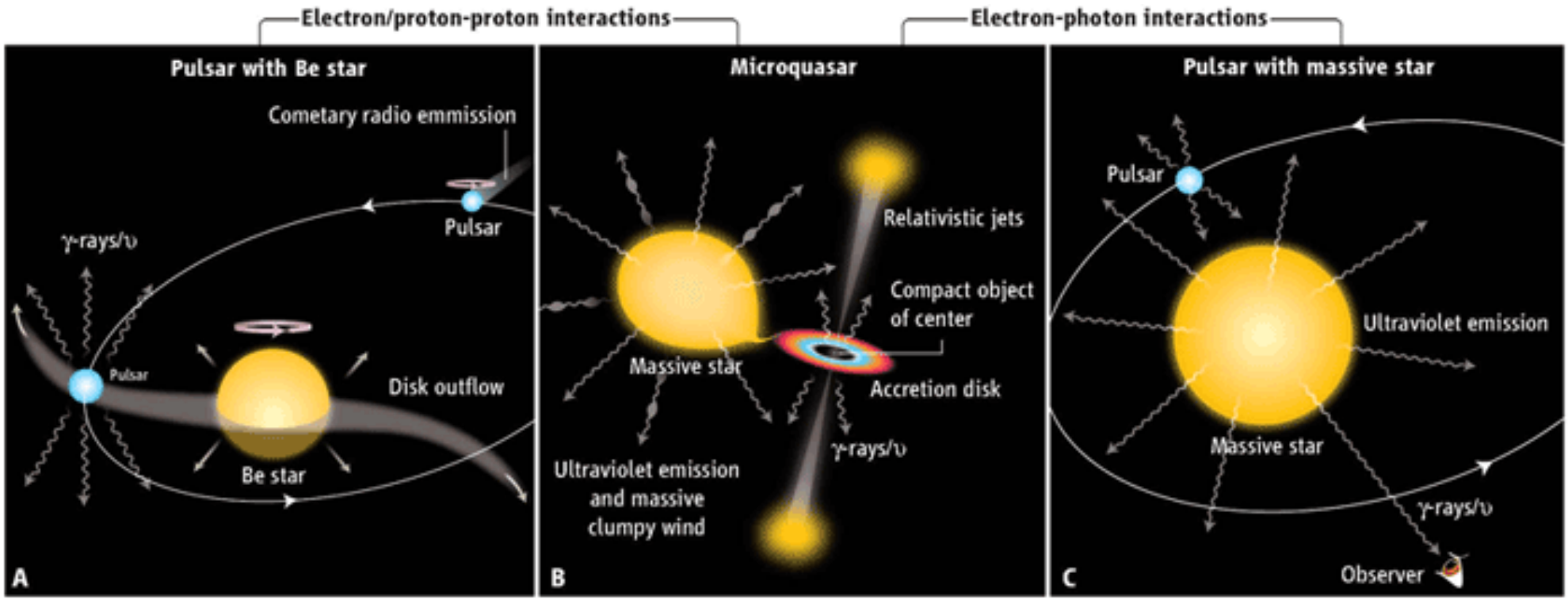
SS433

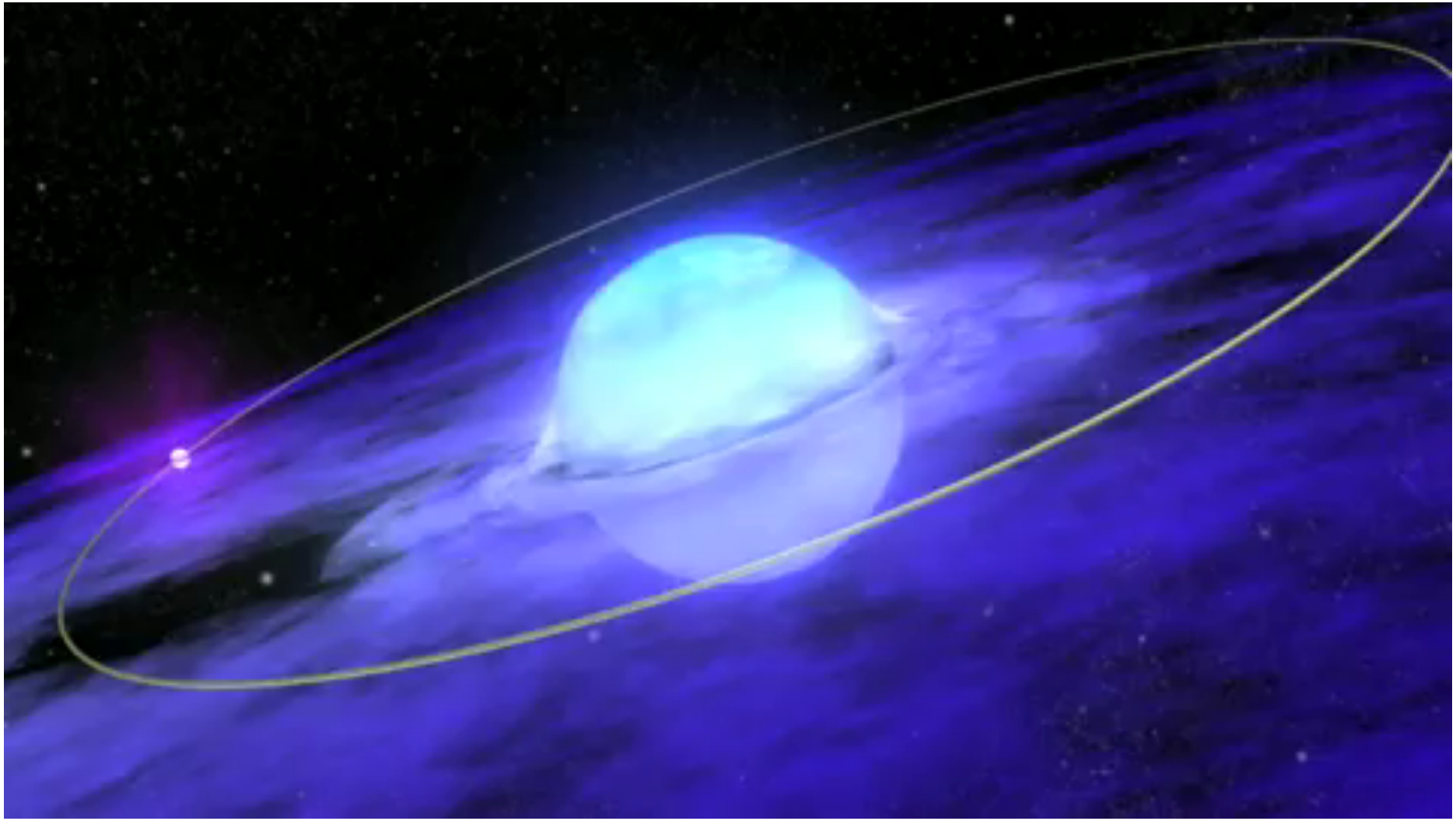
Mecanismes de producció de radiació de molt alta energia

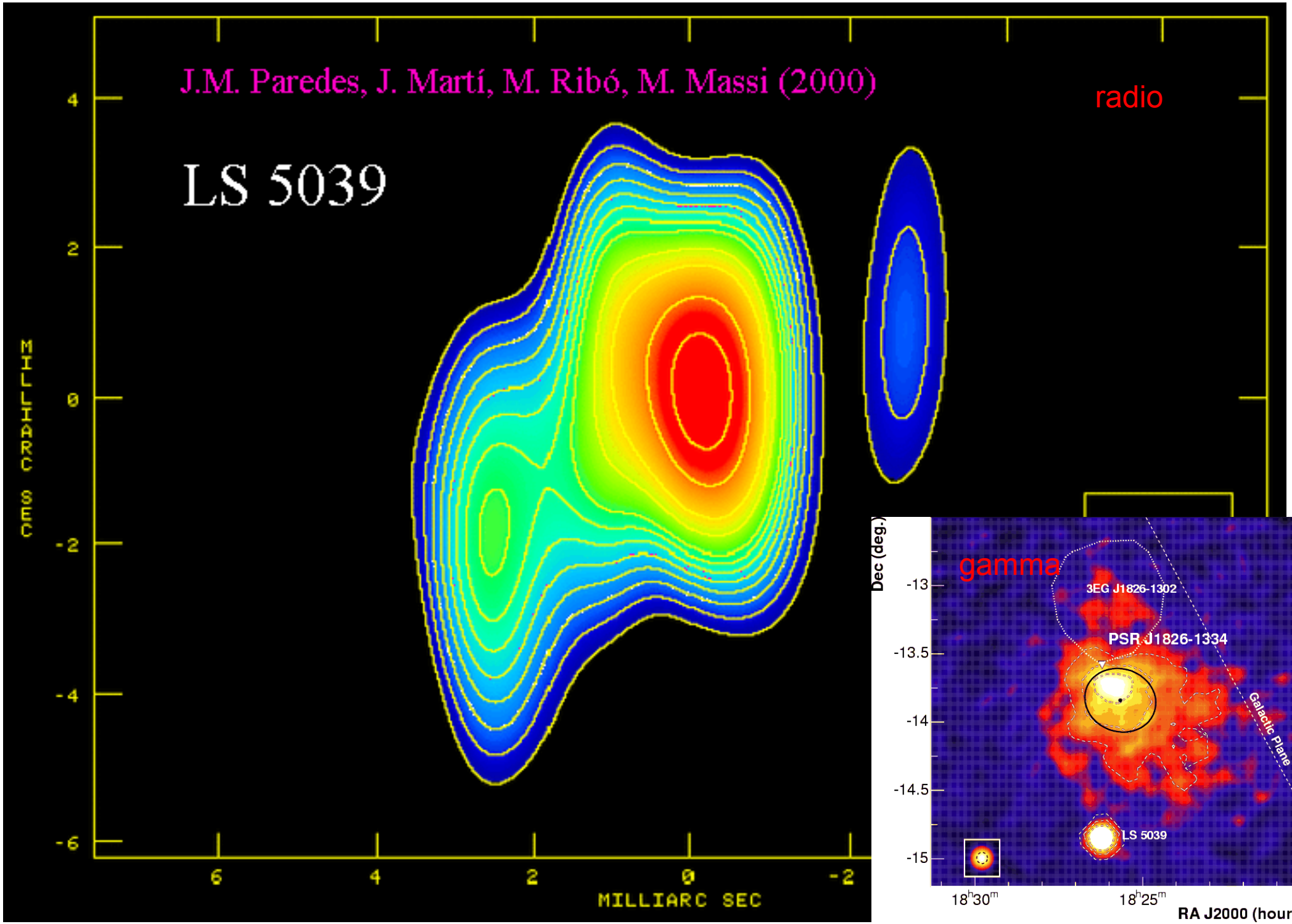


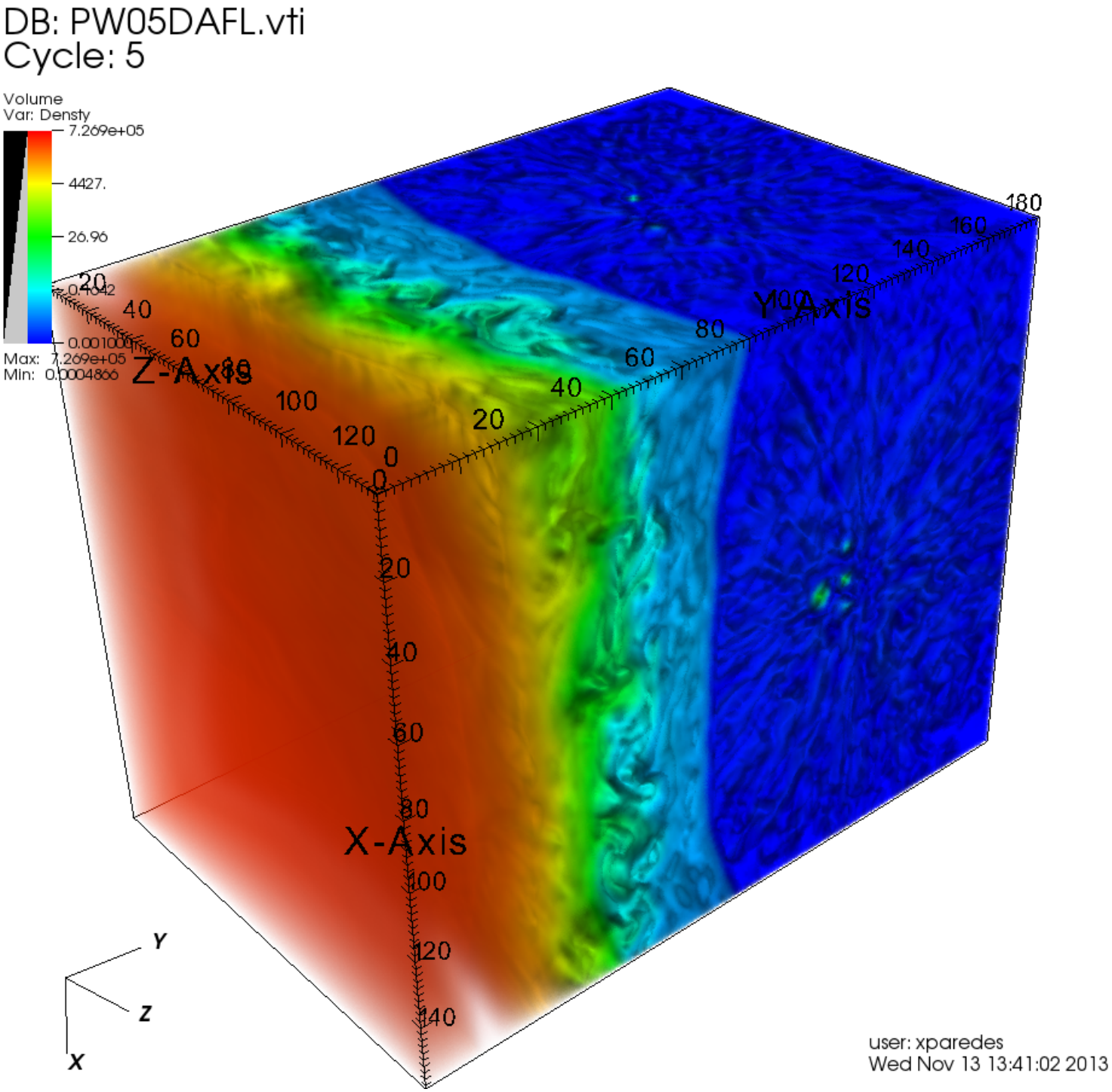


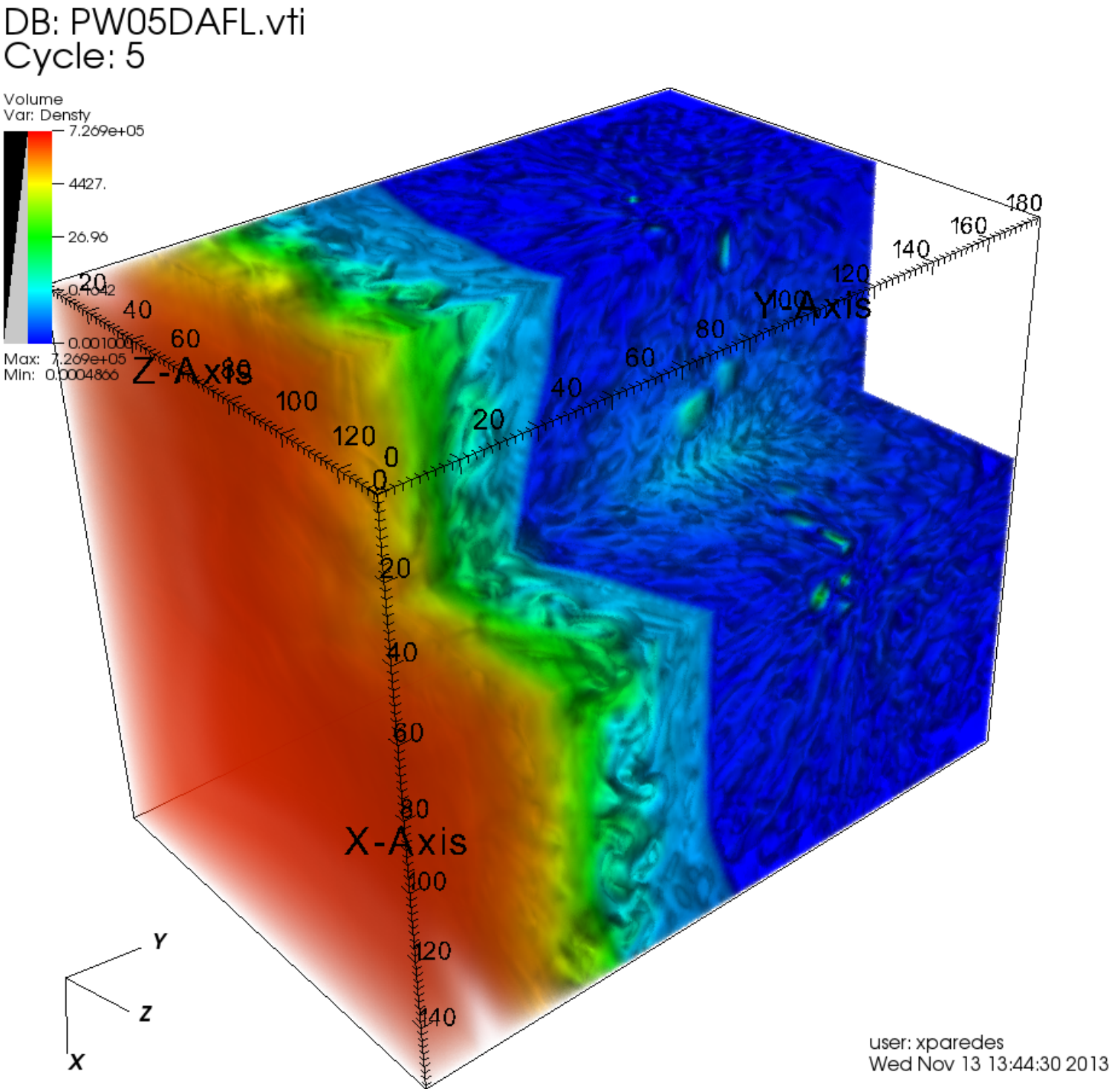
Mecanismes de producció de radiació de molt alta energia

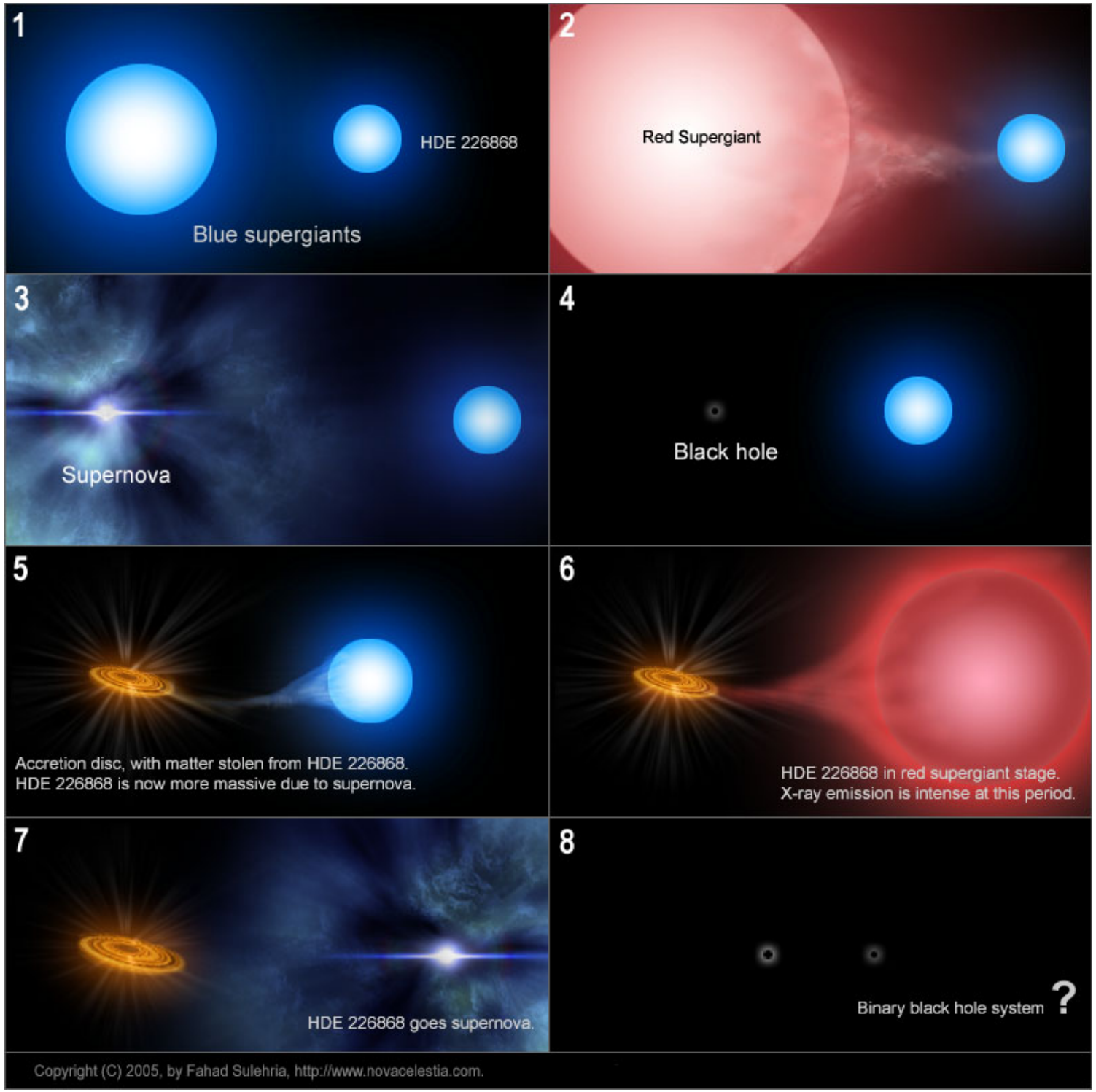





J.M. Paredes, J. Martí, M. Ribó, M. Massi (2000)
radio
LS 5039
MILLIARC SEC
MILLIARC SEC
gamma
3EG J1826-1302
PSR J1826-1334
Galactic Plane
LS 5039
Dec (deg.)
RA J2000 (hours)

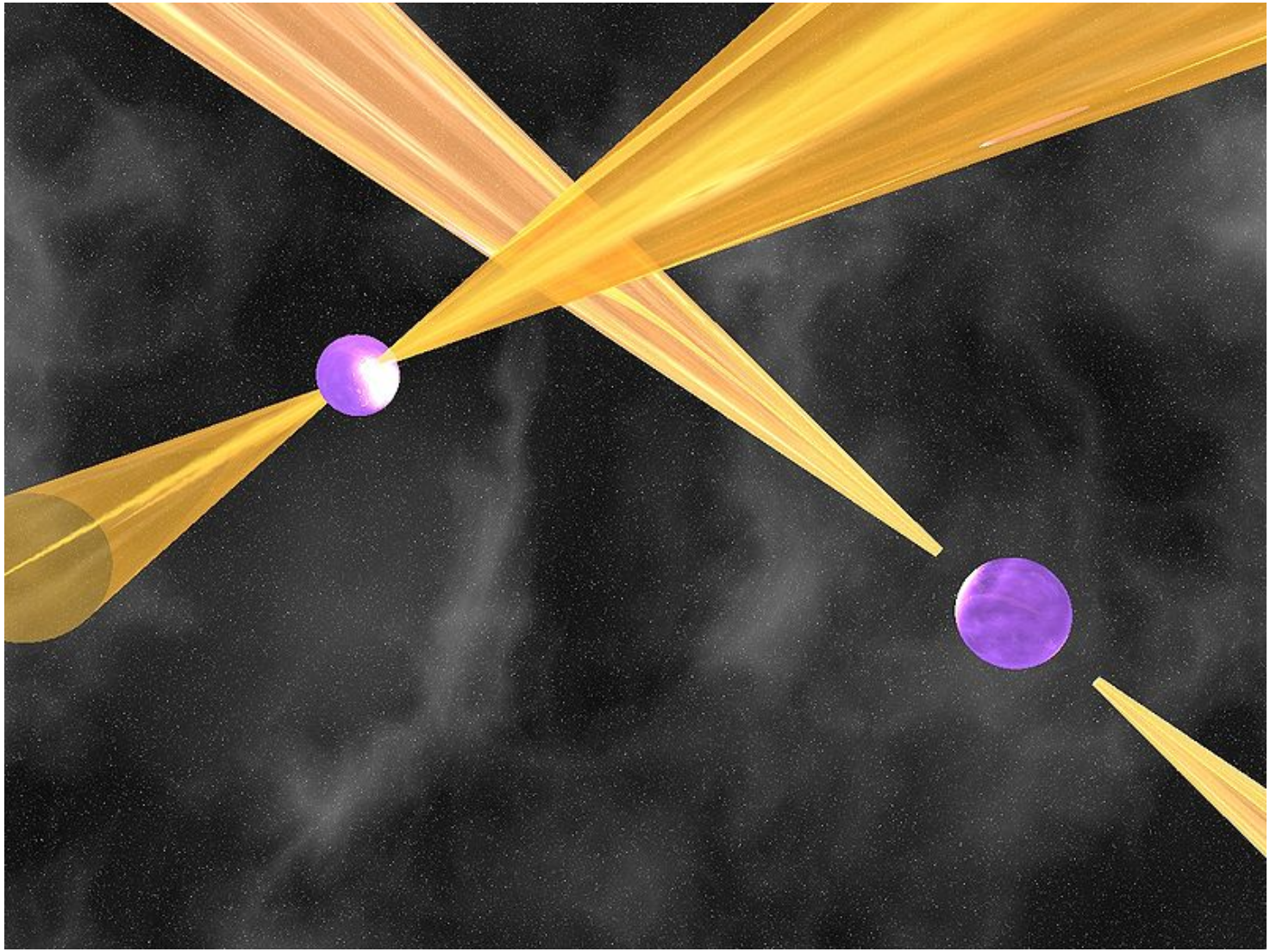

DB: PW05DAFL.vti
Cycle: 5
Volume
Var: Densty
7.269e+05
4427.
26.96
0.4542
0.001000
Max: 7.269e+05
Min: 0.0004866
Z-Axis
Y-Axis
X-Axis
Y
Z
X
user: xparedes
Wed Nov 13 13:41:02 2013


DB: PW05DAFL.vti
Cycle: 5
Volume
Var: Densty
7.269e+05
4427.
26.96
0.4642
0.001000
Max: 7.269e+05
Min: 0.0004866
Z-Axis
Y-Axis
X-Axis
Y
Z
X
user: xparedes
Wed Nov 13 13:44:30 2013


1
HDE 226868
Blue supergiants
2
Red Supergiant
3
Supernova
4
Black hole
5
Accretion disc, with matter stolen from HDE 226868.
HDE 226868 is now more massive due to supernova.
6
HDE 226868 in red supergiant stage.
X-ray emission is intense at this period.
7
HDE 226868 goes supernova.
8
Binary black hole system ?
Copyright (C) 2005, by Fahad Sulehria, http://www.novacelestia.com.

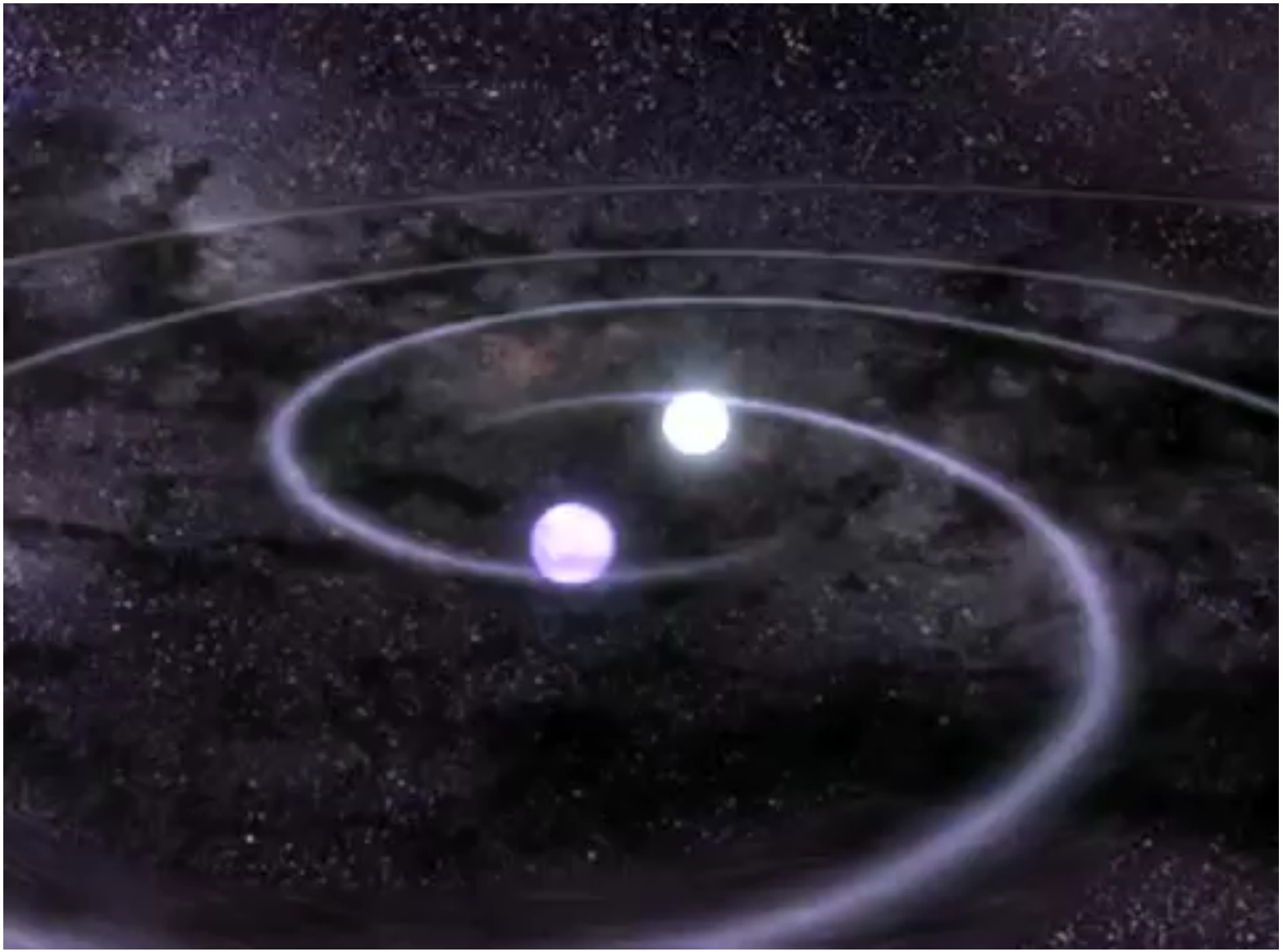
Binary pulsar – gravitational waves

Hulse-Taylor pulsar. Nobel prize 1993.

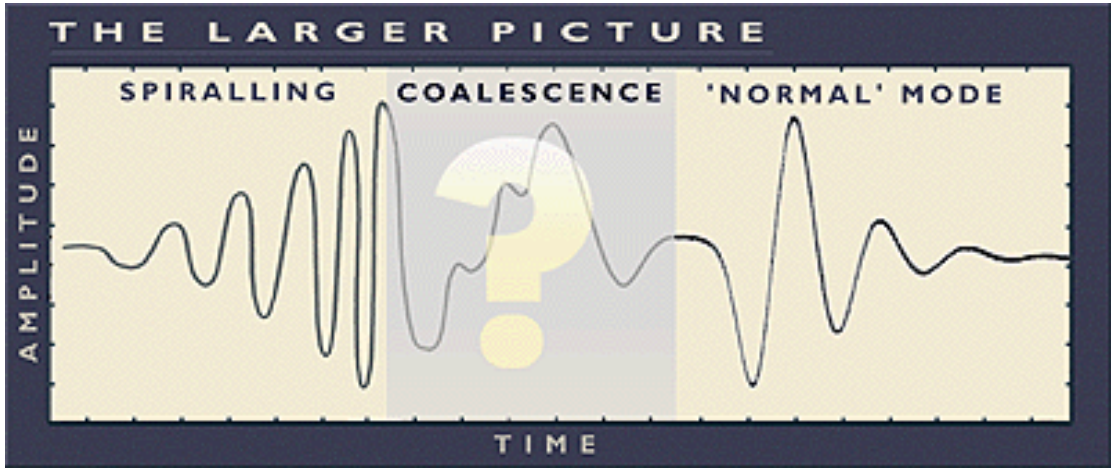


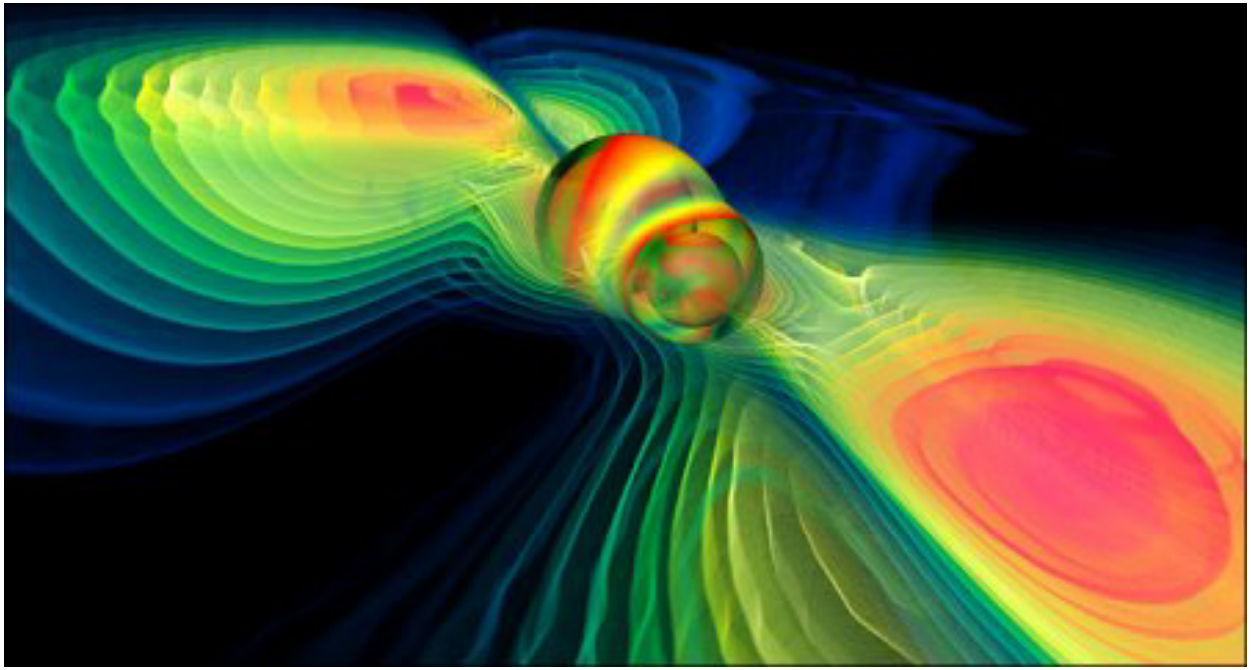
El periode dels pulsos es fa més llarg quan els objectes s’apropen: efecte relativista.

ones gravitatòries



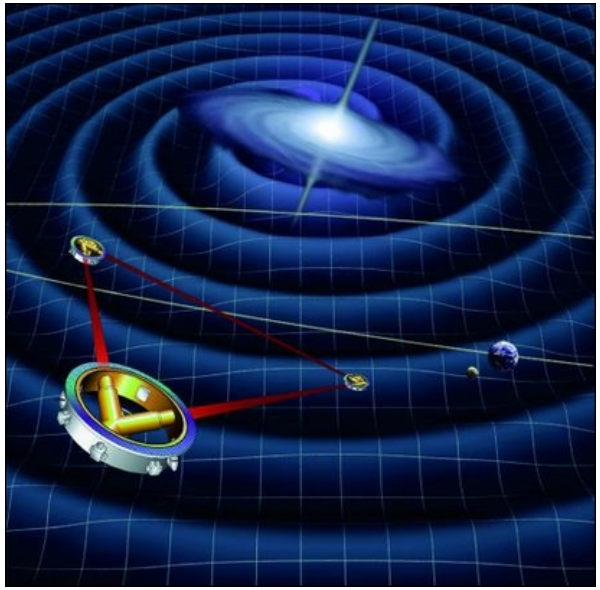
ones gravitatòries





ones gravitatòries

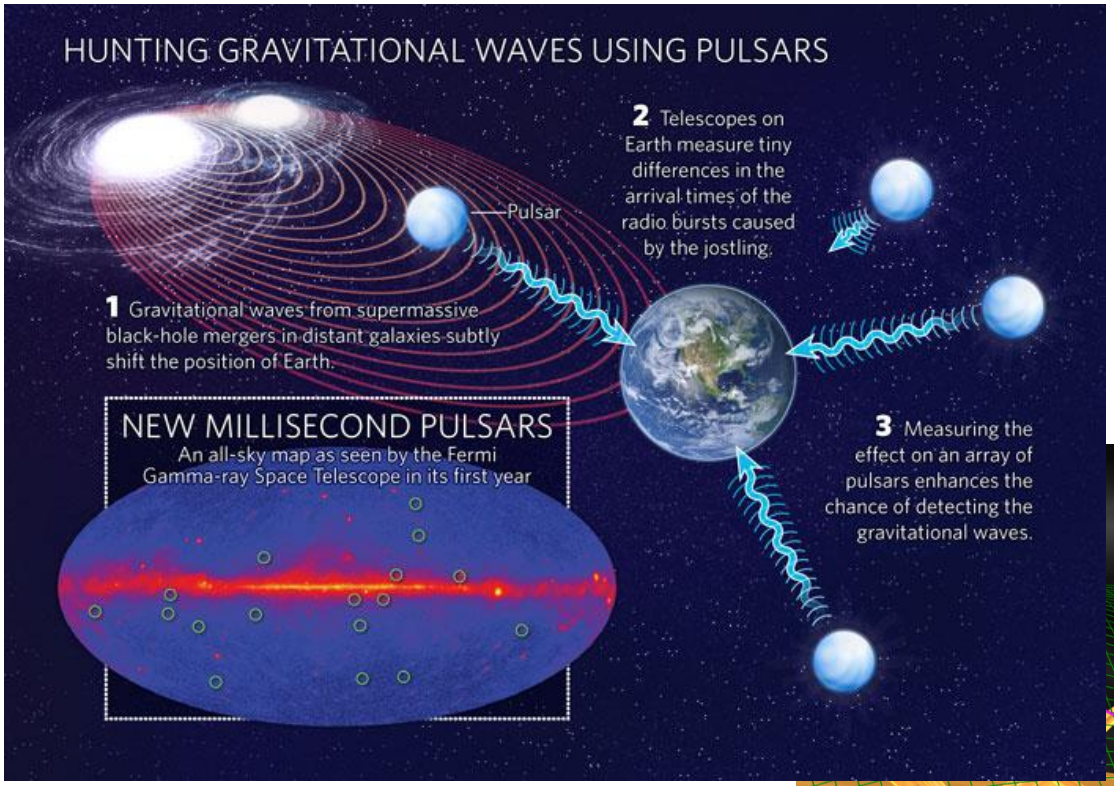
LIGO (USA)

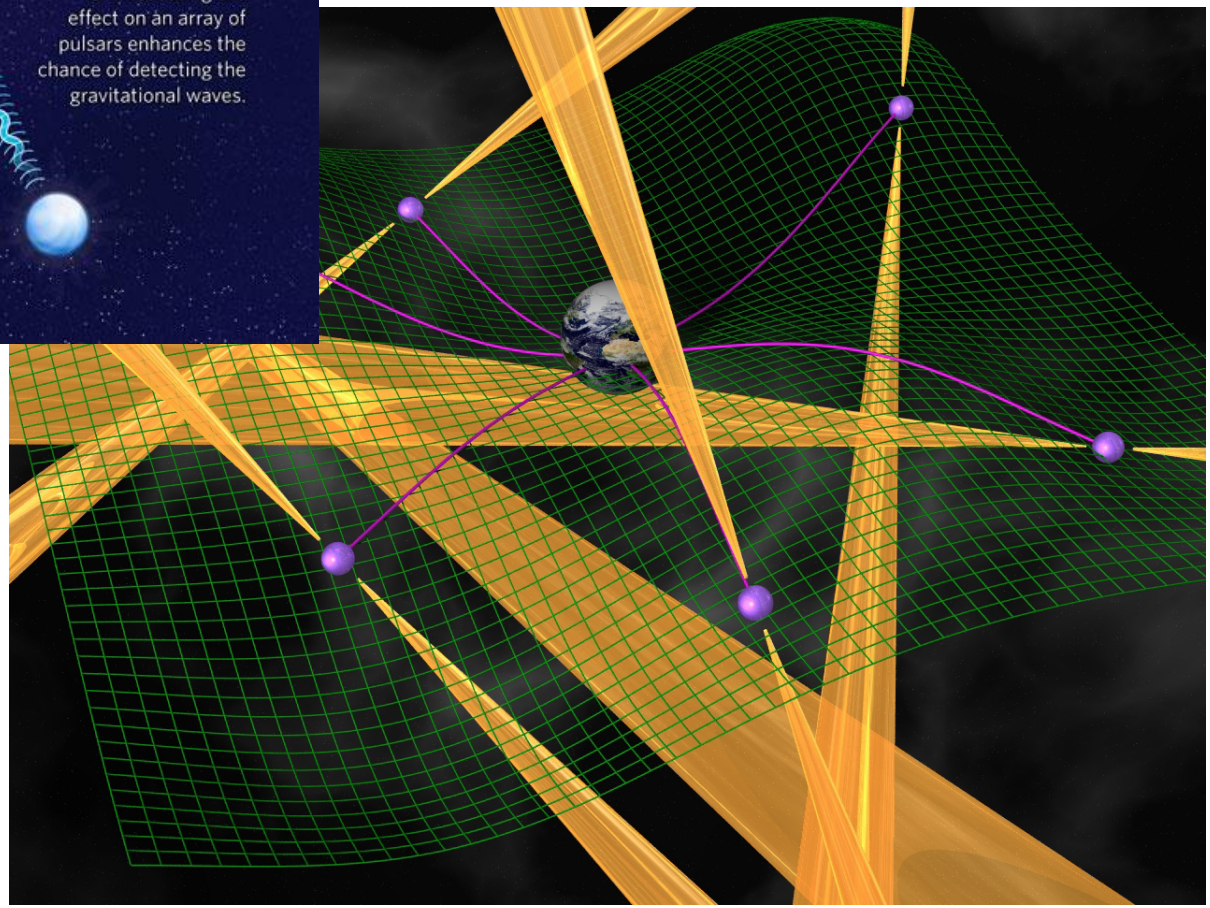


LISA
(delayed)

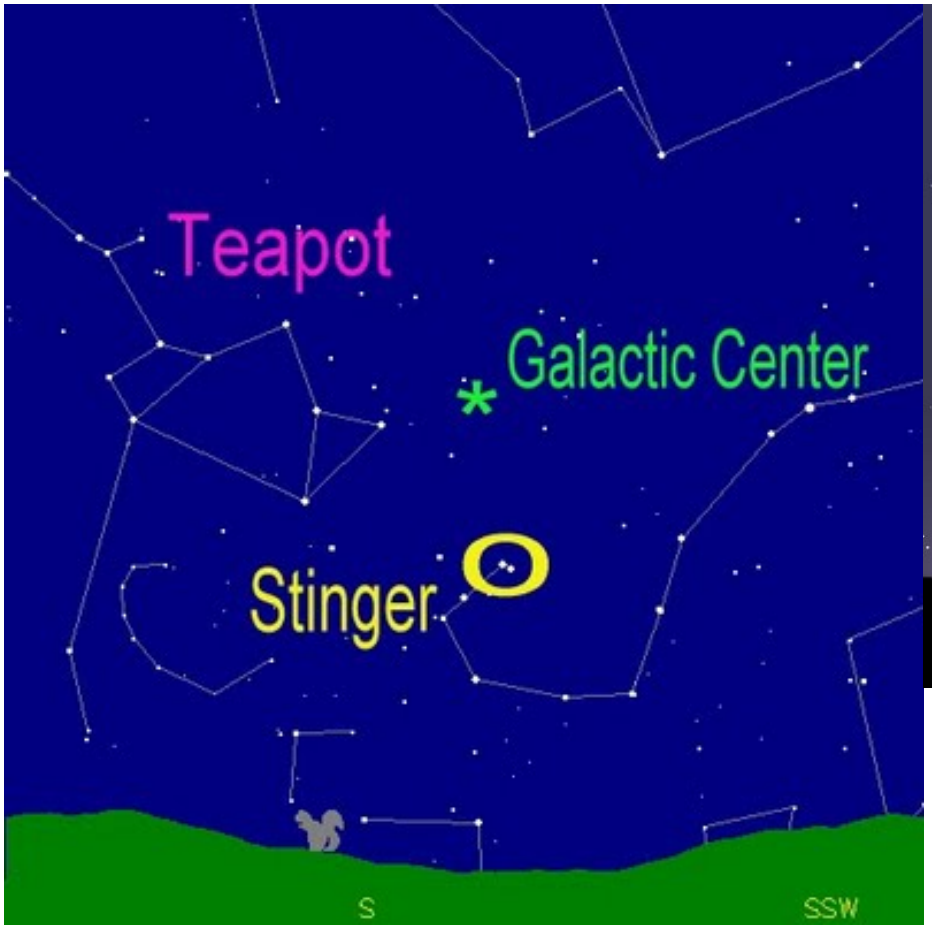
VIRGO (Italia)

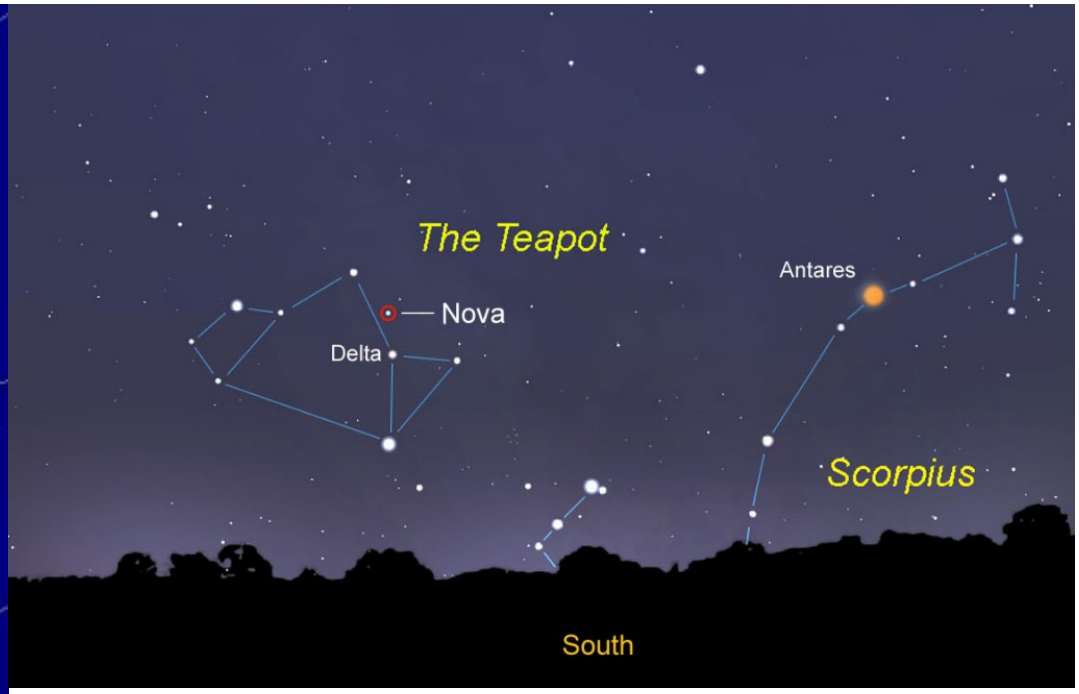
ones gravitatòries





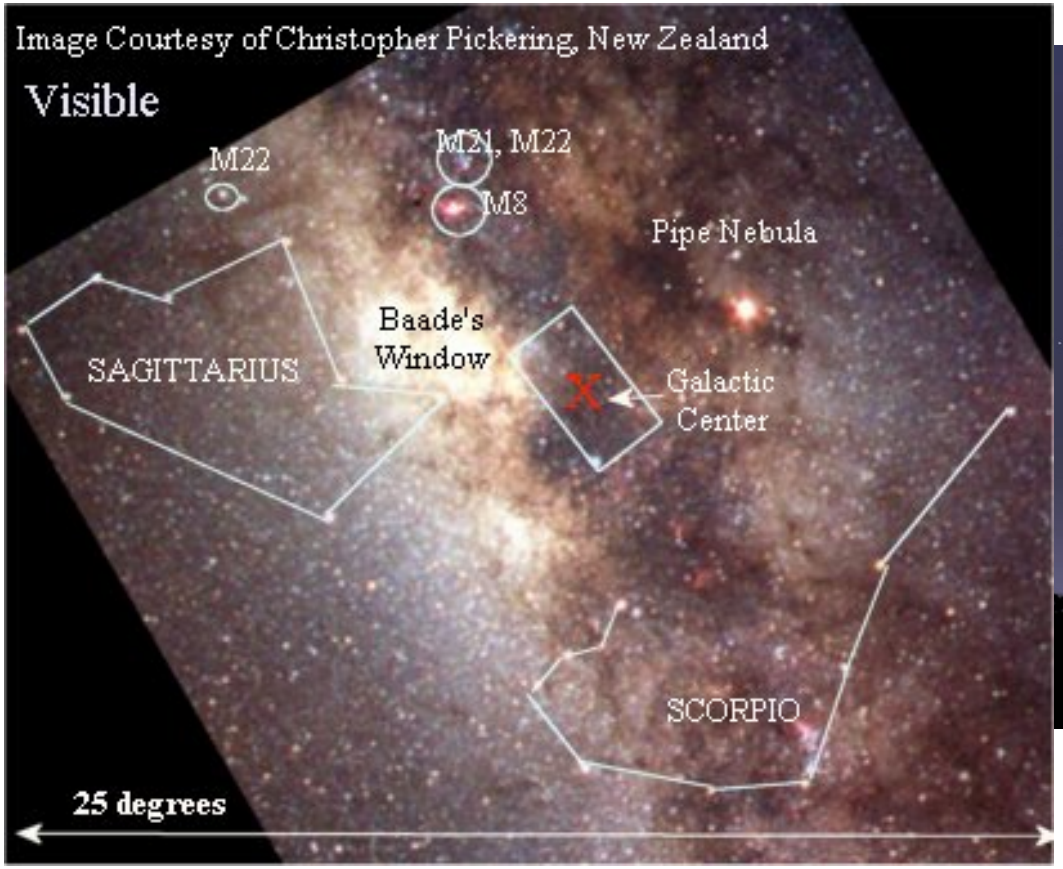
El centre de la Galàxia

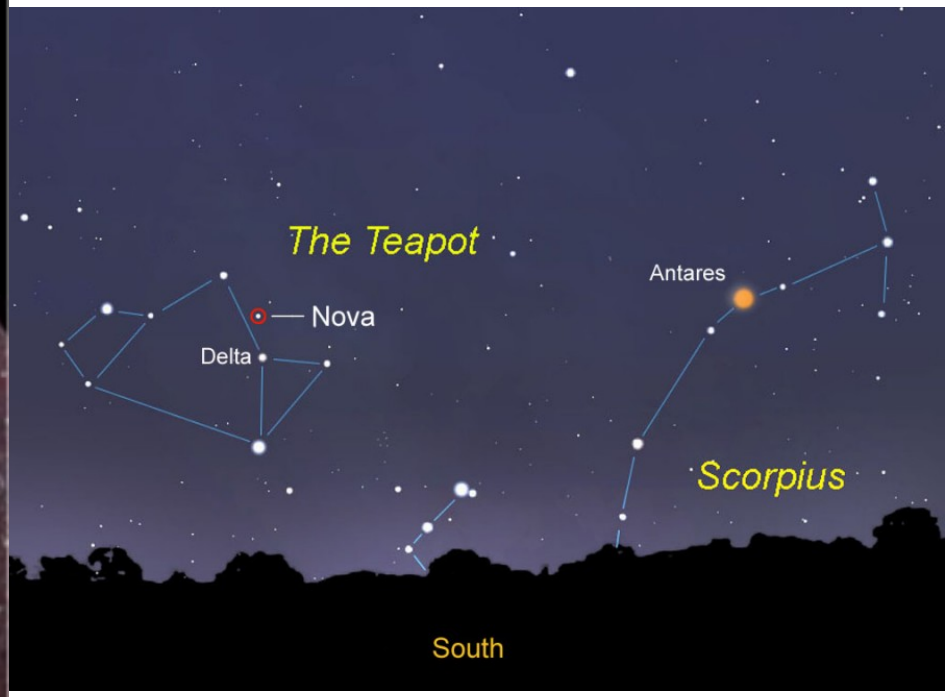




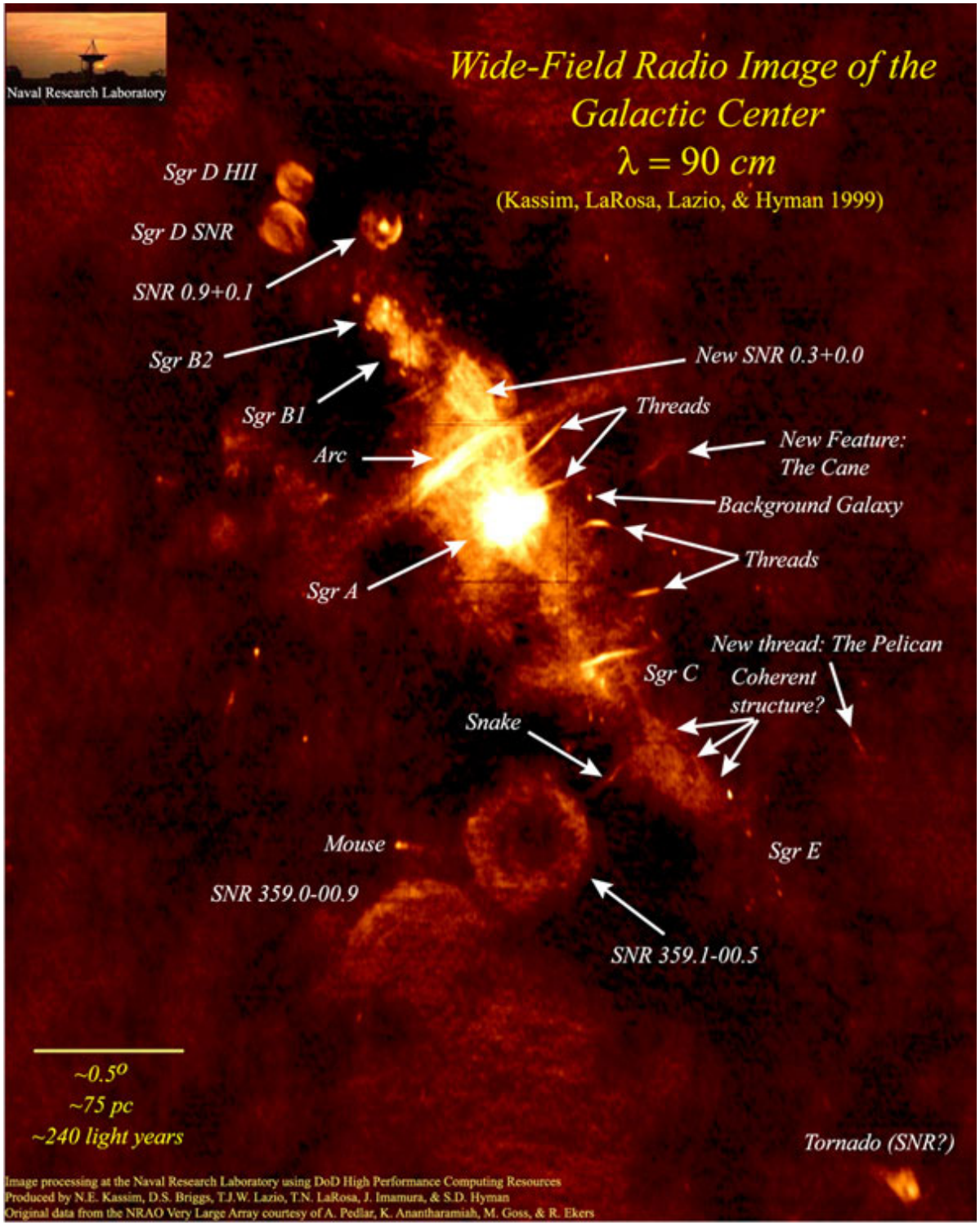
Mirant al Sud, a la constel·lació de Sagitari.

El centre de la Galàxia



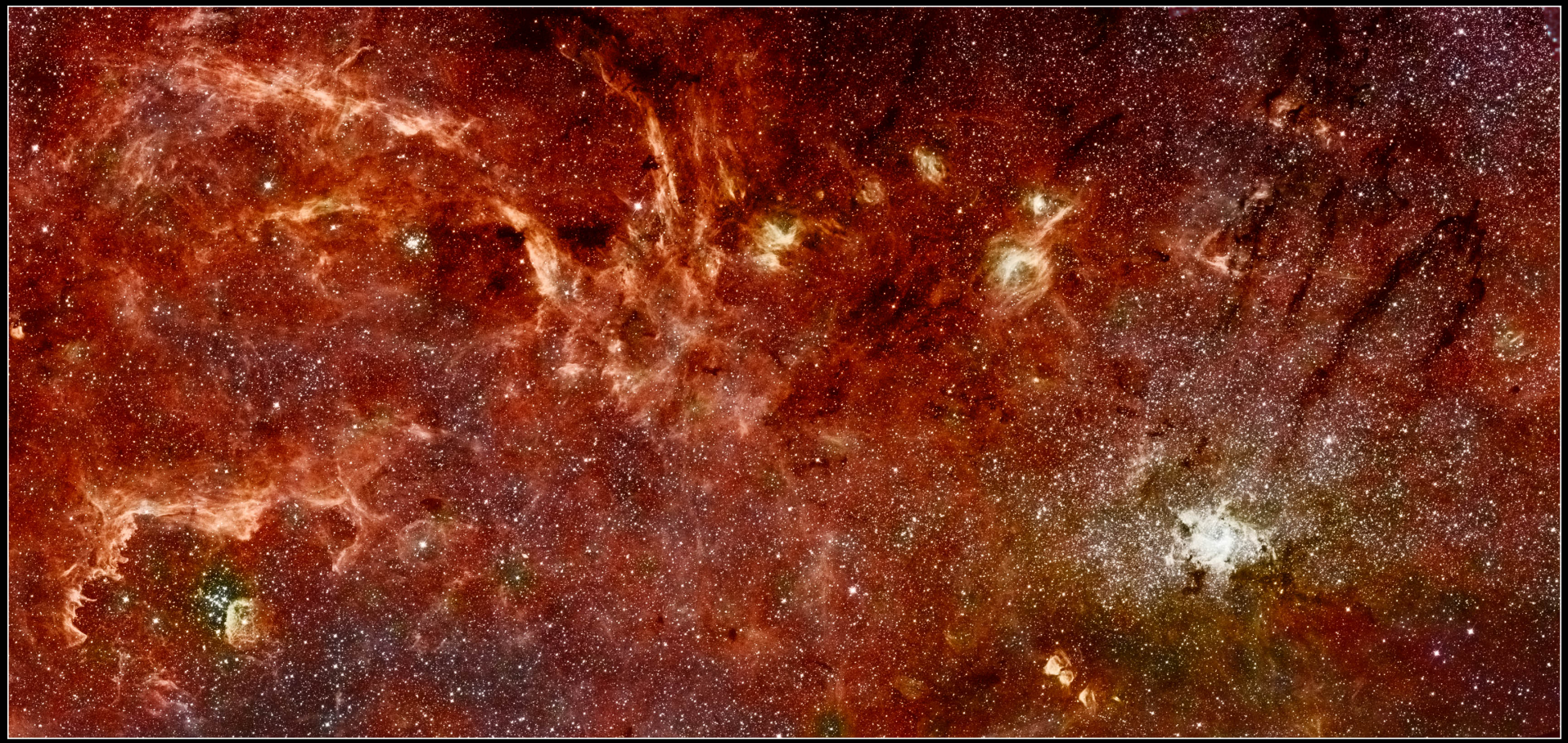


Mirant al Sud, a la constel·lació de Sagitari.



El centre de la Galàxia en radio freqüències.

Infraroig

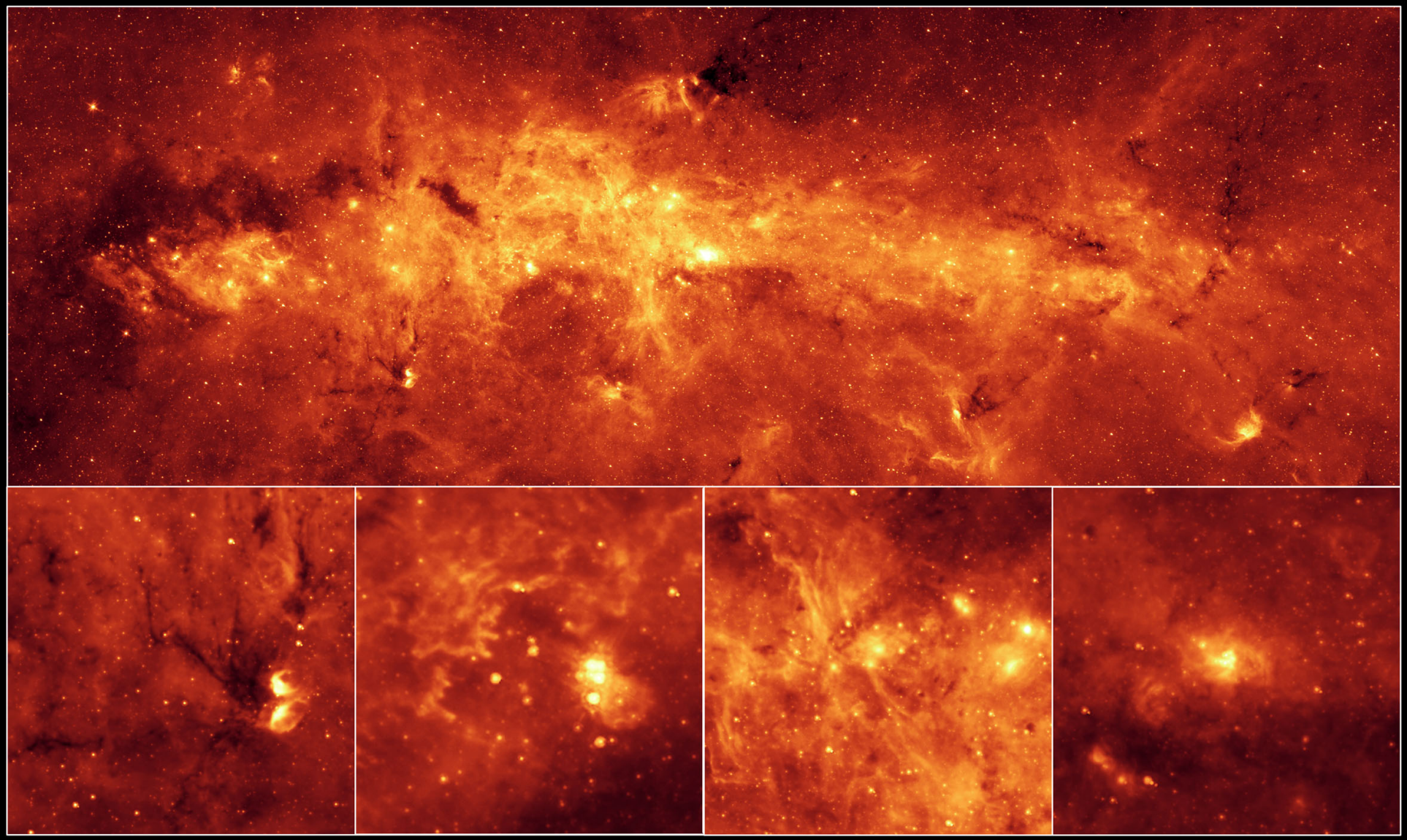


Galactic Center Survey

Hubble Space Telescope NICMOS • *Spitzer Space Telescope* IRAC

NASA, ESA, Q.D. Wang (University of Massachusetts, Amherst), and S. Stolovy (Caltech)

STScI-PRC09-02a

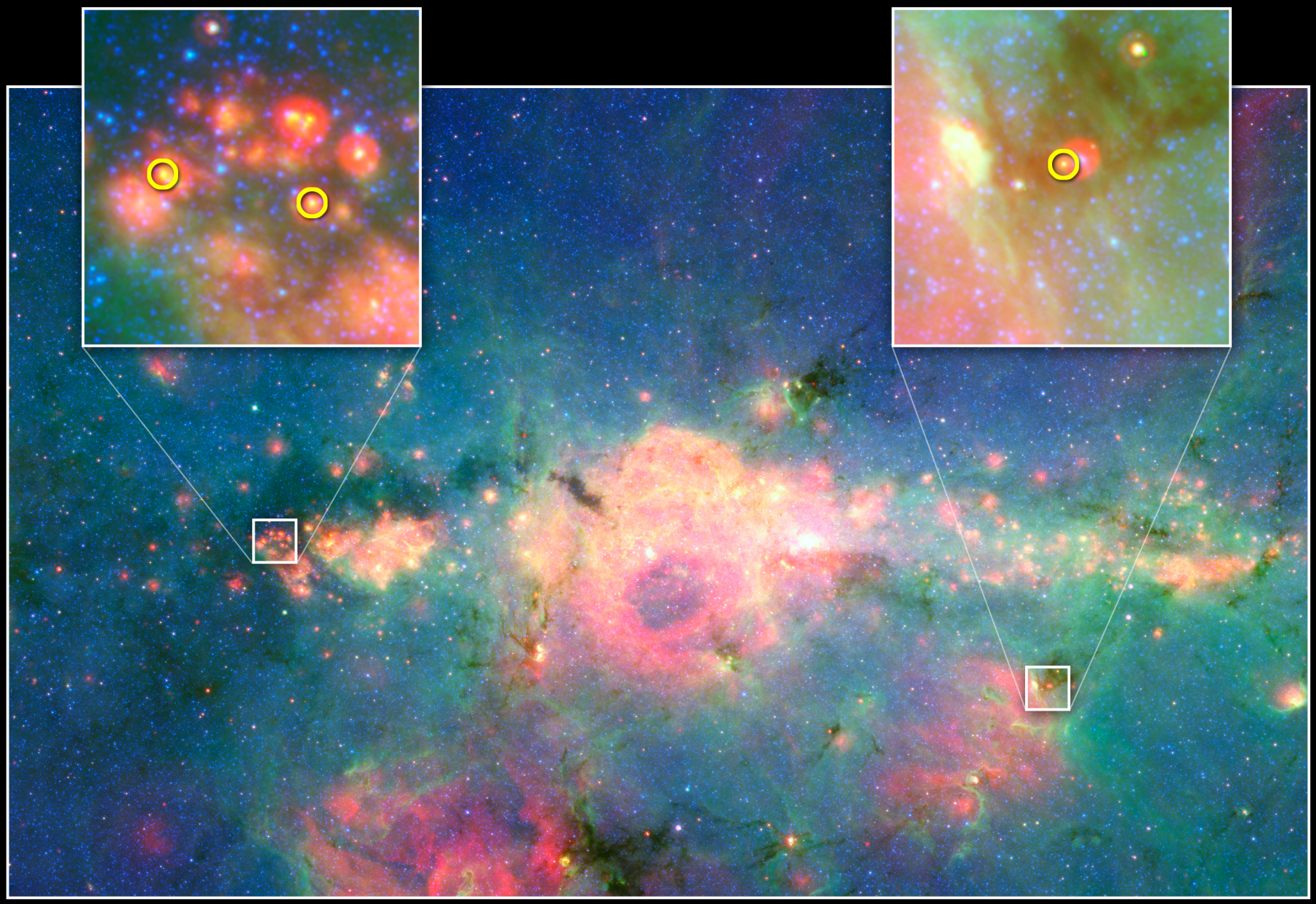


Dust in the Center of the Milky Way Galaxy

NASA / JPL-Caltech / S. Stolovy (Spitzer Science Center/Caltech)

Spitzer Space Telescope • IRAC

ssc2006-02b

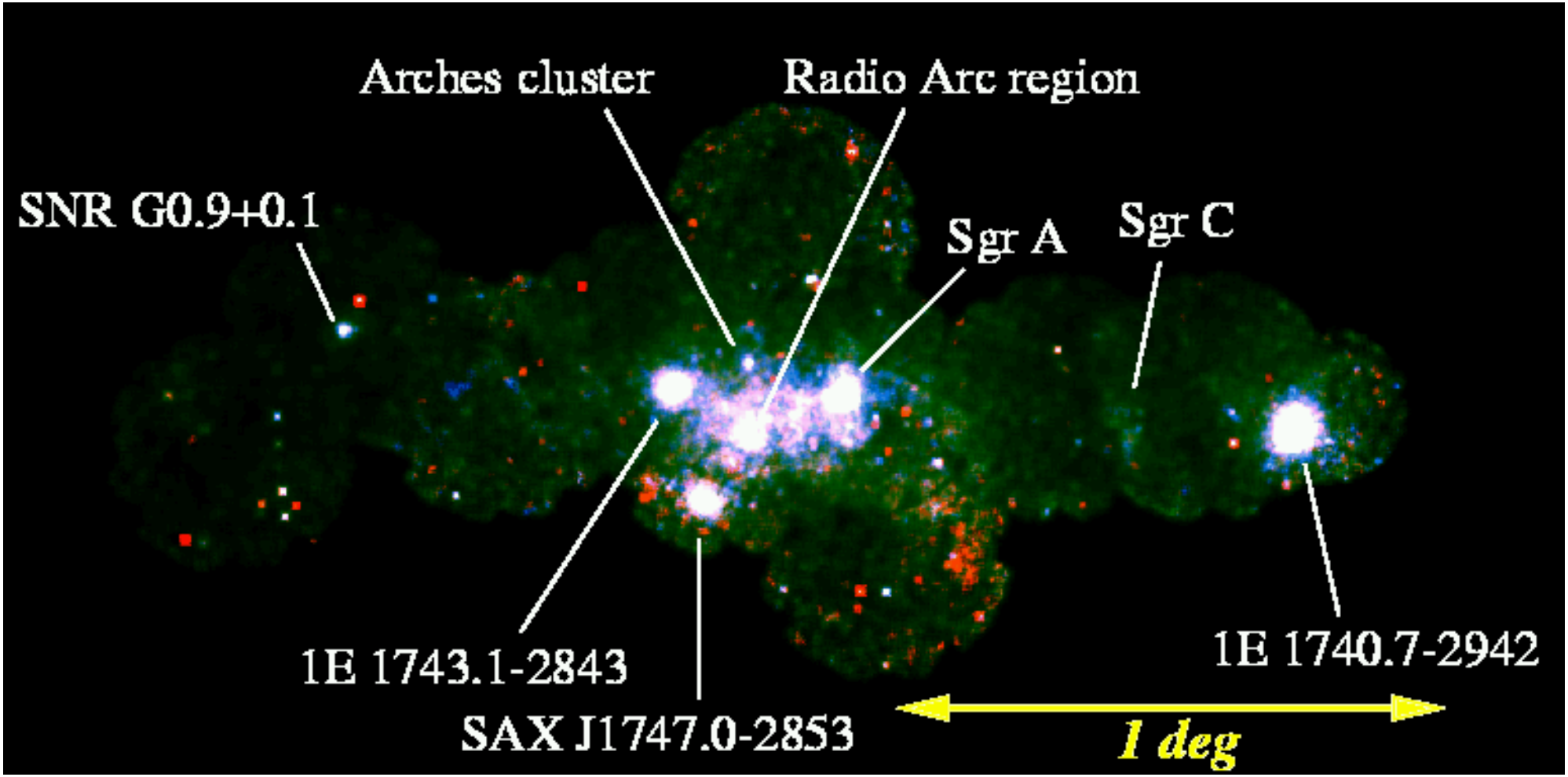


Young Stars Forming in the Galactic Center

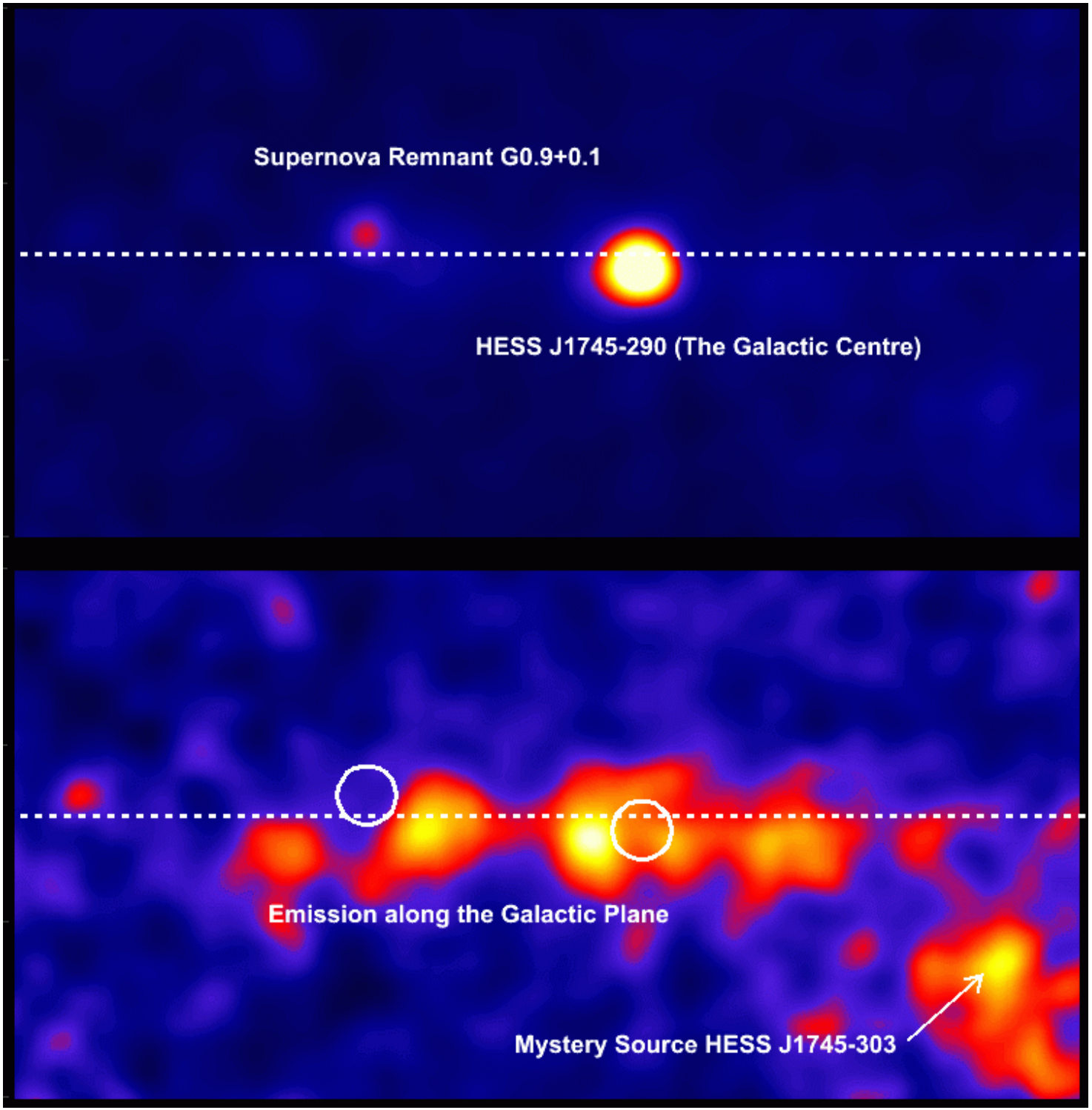
Spitzer Space Telescope • IRAC • MIPS • IRS

NASA / JPL-Caltech / S. V. Ramírez (NExScI/Caltech)

ssc2009-13a

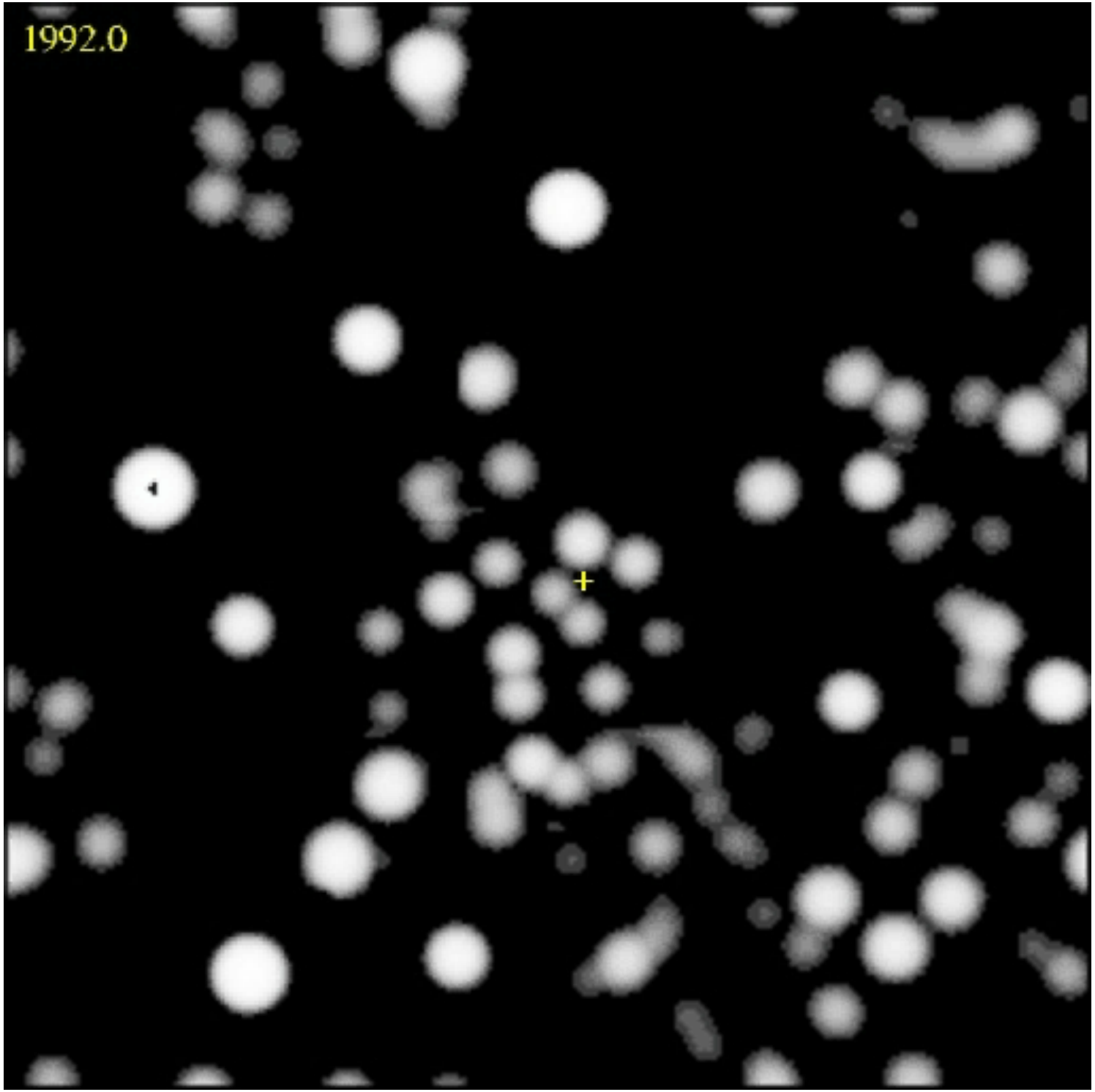

Arches cluster
Radio Arc region
SNR G0.9+0.1
Sgr A
Sgr C
1E 1743.1-2843
SAX J1747.0-2853
1E 1740.7-2942
1 deg

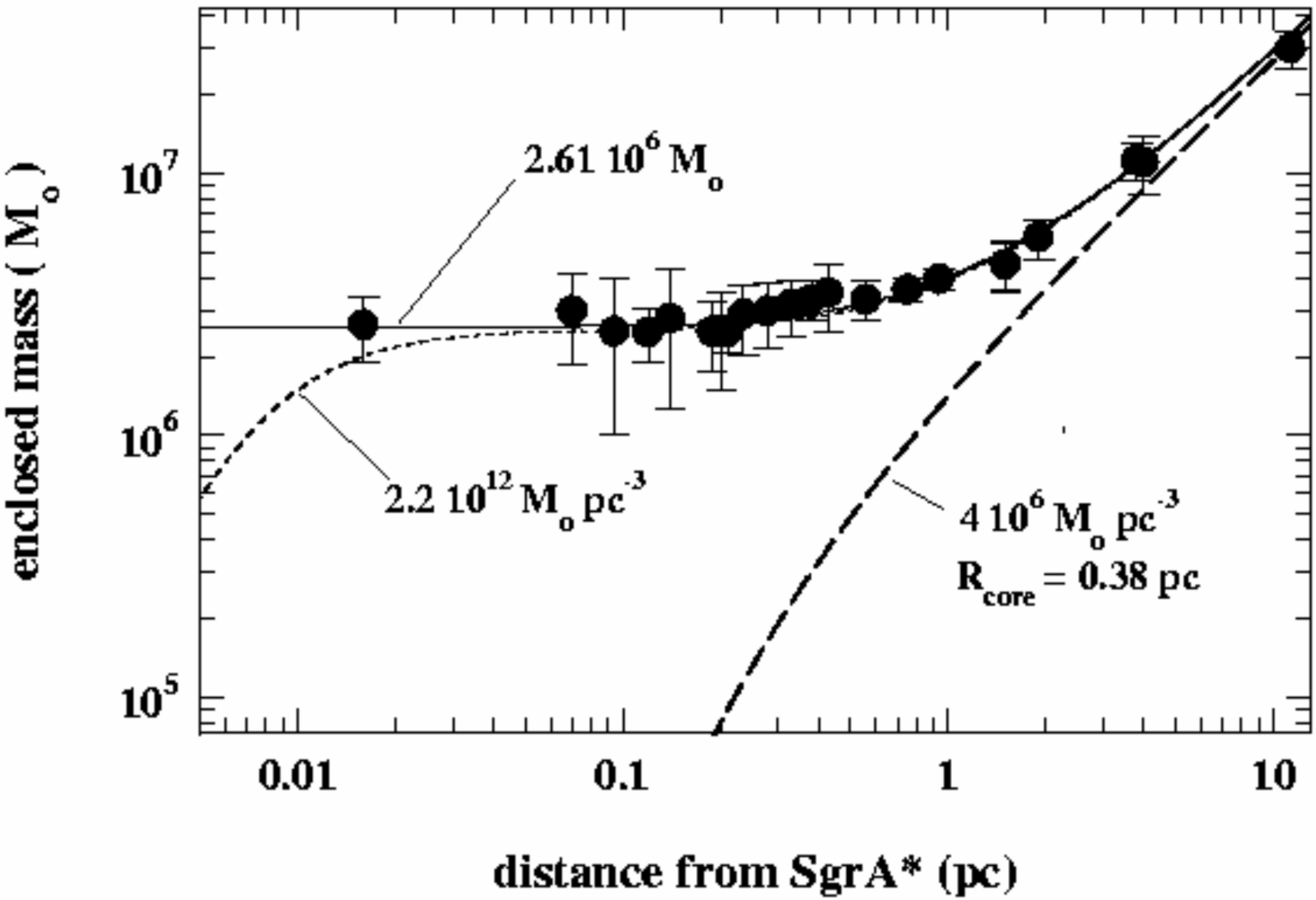
Raigs X - XMM

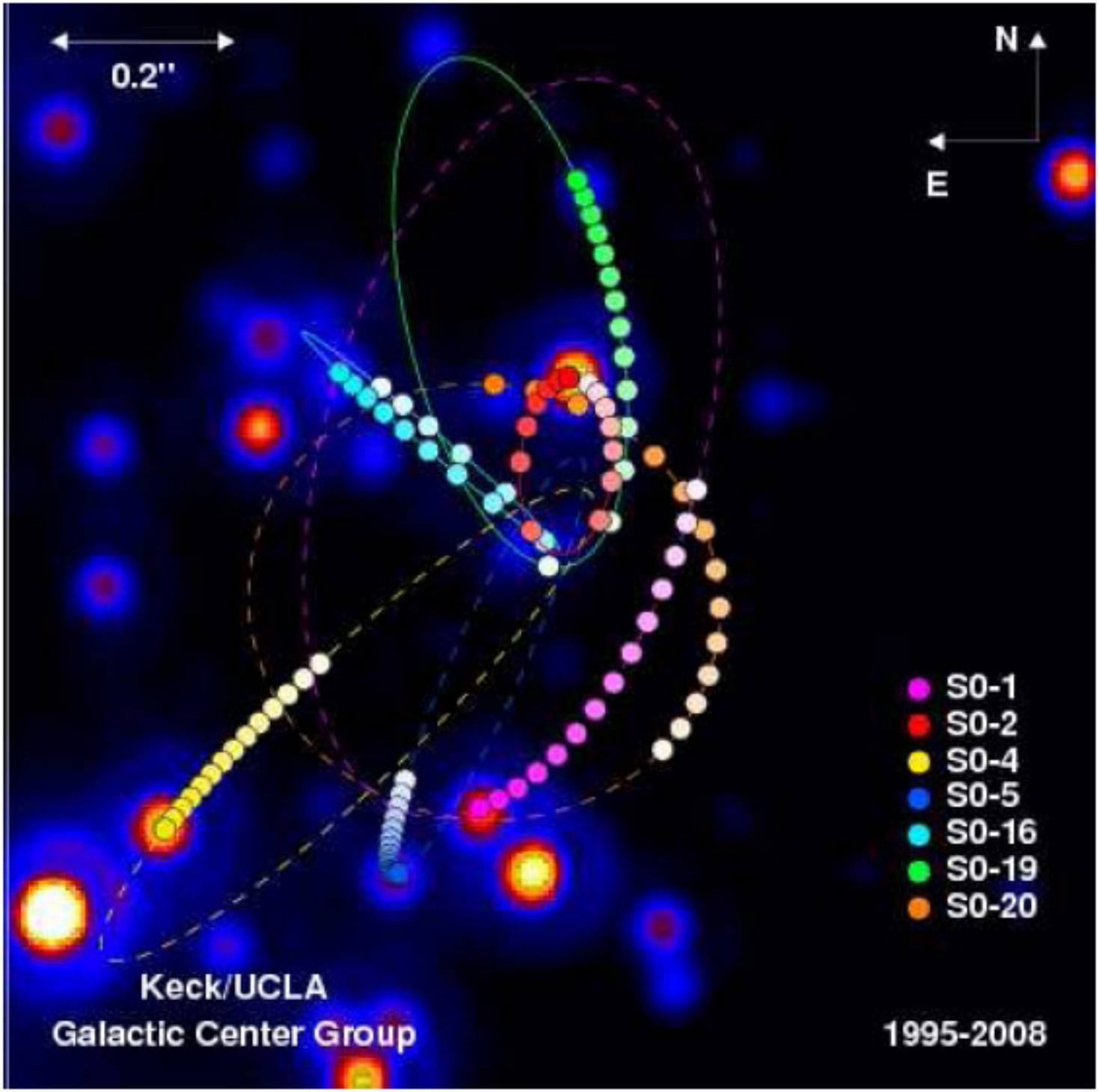


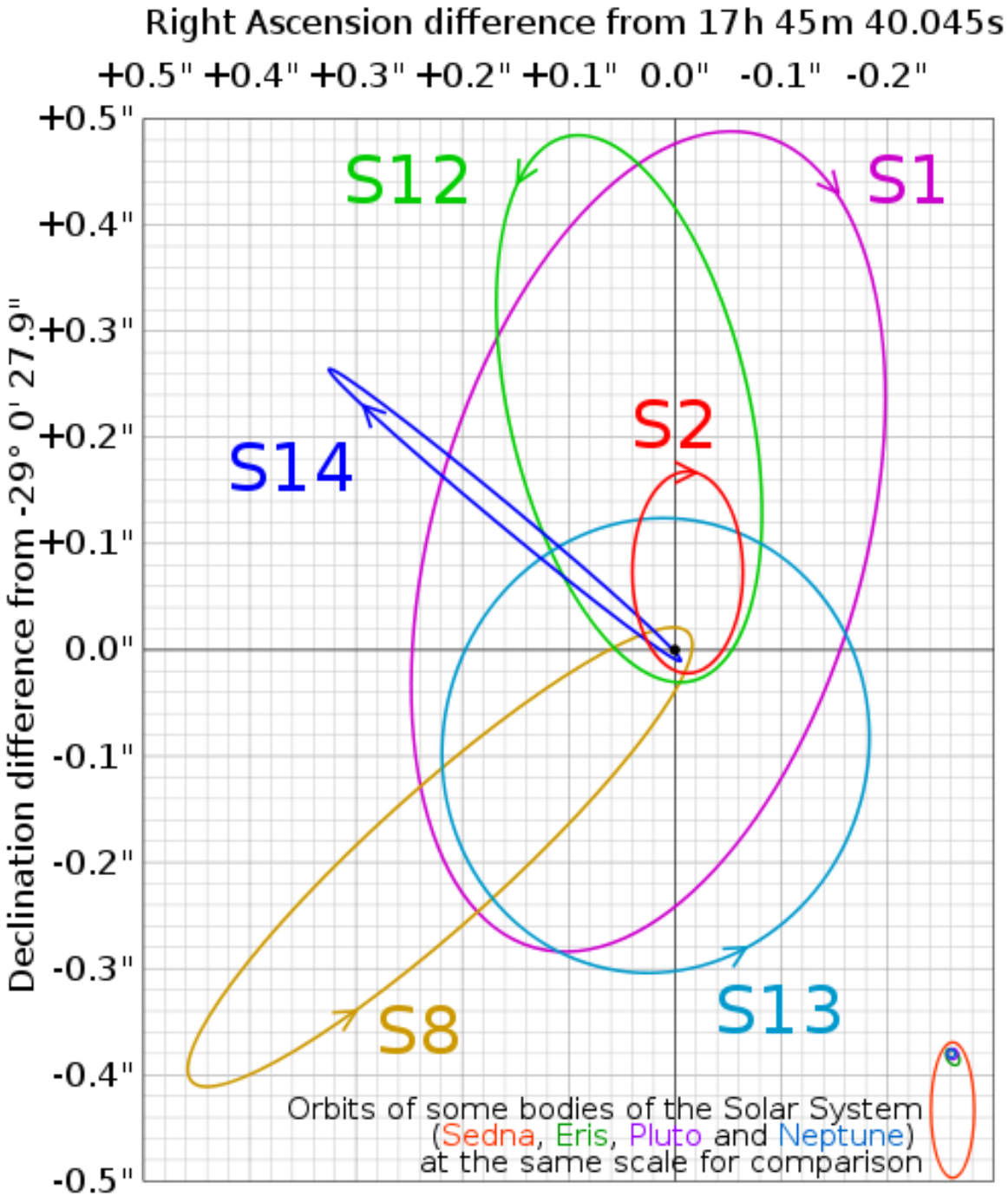
Raigs gamma

HESS

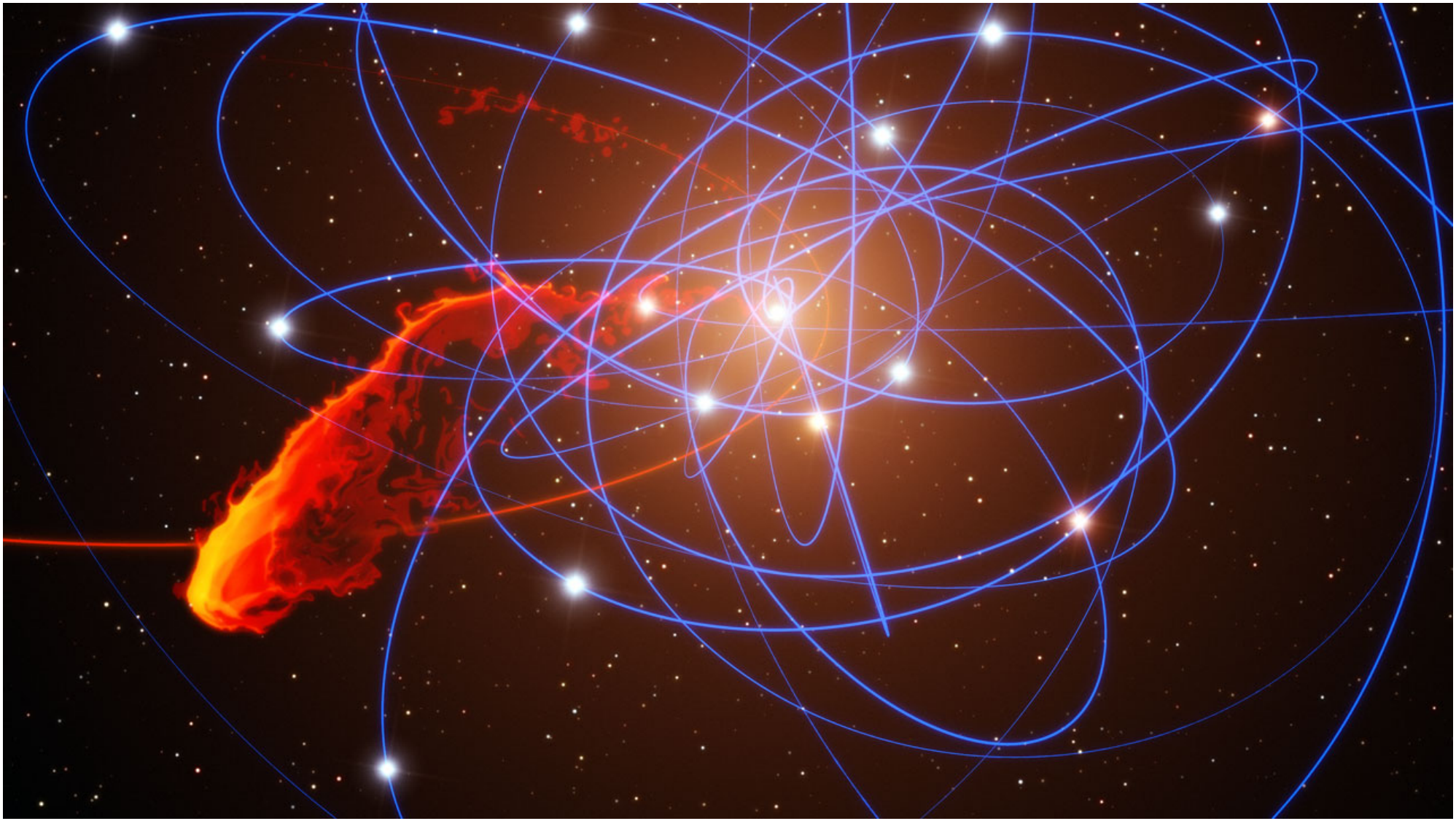

1992.0


2.61 10^6 M_o
2.2 10^12 M_o pc^-3
4 10^6 M_o pc^-3
R_core = 0.38 pc
10^7
10^6
10^5
0.01
0.1
1
10
enclosed mass (M_o)
distance from SgrA* (pc)


0.2''
N
E
S0-1
S0-2
S0-4
S0-5
S0-16
S0-19
S0-20
Keck/UCLA
Galactic Center Group
1995-2008


Right Ascension difference from 17h 45m 40.045s
+0.5" +0.4" +0.3" +0.2" +0.1" 0.0" -0.1" -0.2"
Declination difference from -29° 0' 27.9"
+0.5"
+0.4"
+0.3"
+0.2"
+0.1"
0.0"
-0.1"
-0.2"
-0.3"
-0.4"
-0.5"
S12
S1
S2
S14
S13
S8
Orbits of some bodies of the Solar System
(Sedna, Eris, Pluto and Neptune)
at the same scale for comparison

Relativitat General



El centre de la galàxia

Fermi Bubbles