

Del 05 de marzo
al 30 de abril

20
26

CURSO DE ASTRONOMÍA Y ASTROFÍSICA

Del Planetario al Cosmos

Sala de Proyecciones
Planetario de Madrid

"De la Vía Láctea a los confines del universo"

por Jesús Gallego, ASTROFÍSICO, UNIVERSIDAD COMPLUTENSE DE MADRID
(Dpto. Física de la Tierra y Astrofísica)



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DE MADRID

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planetariomadrid

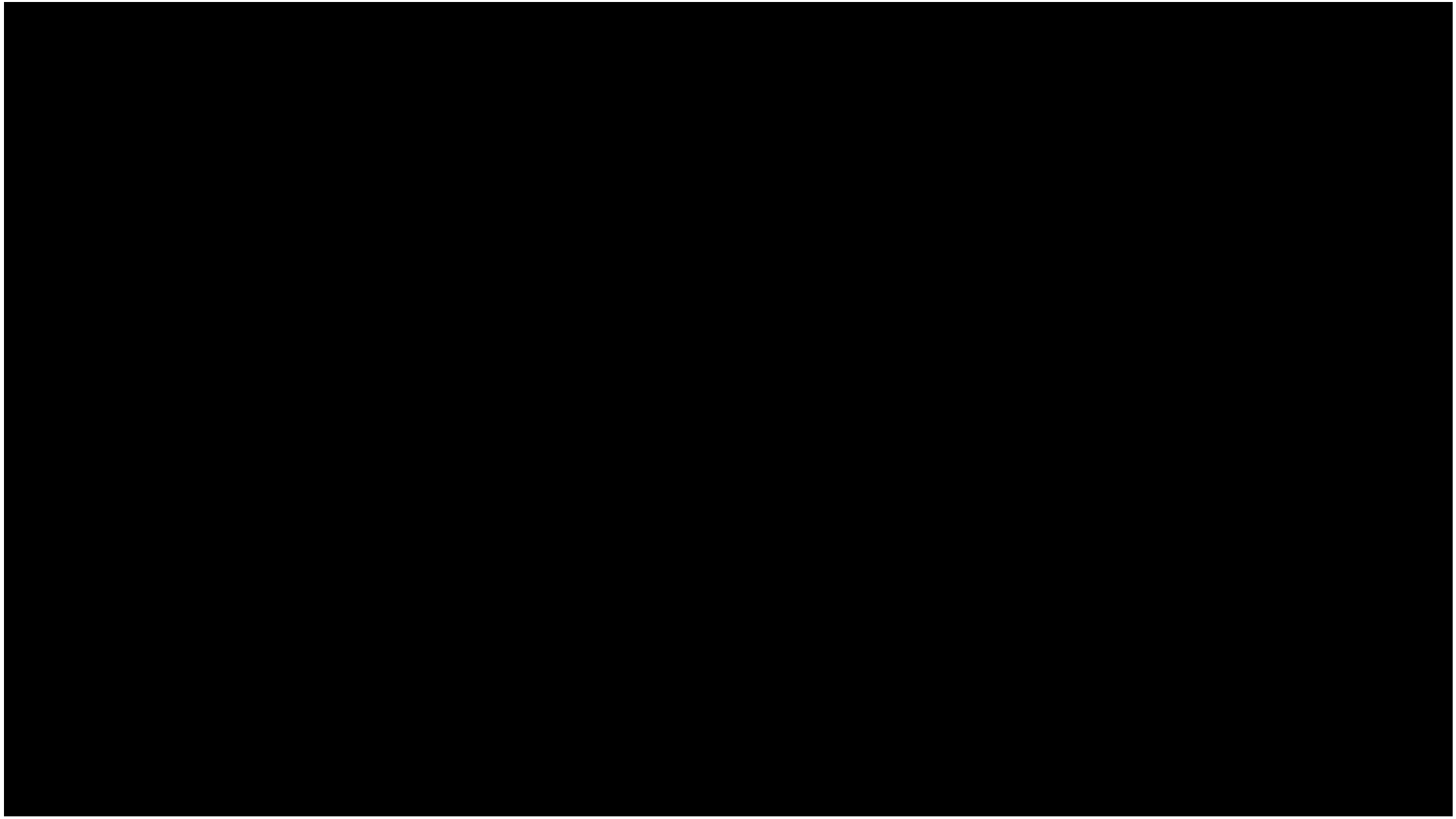


Planetario de Madrid

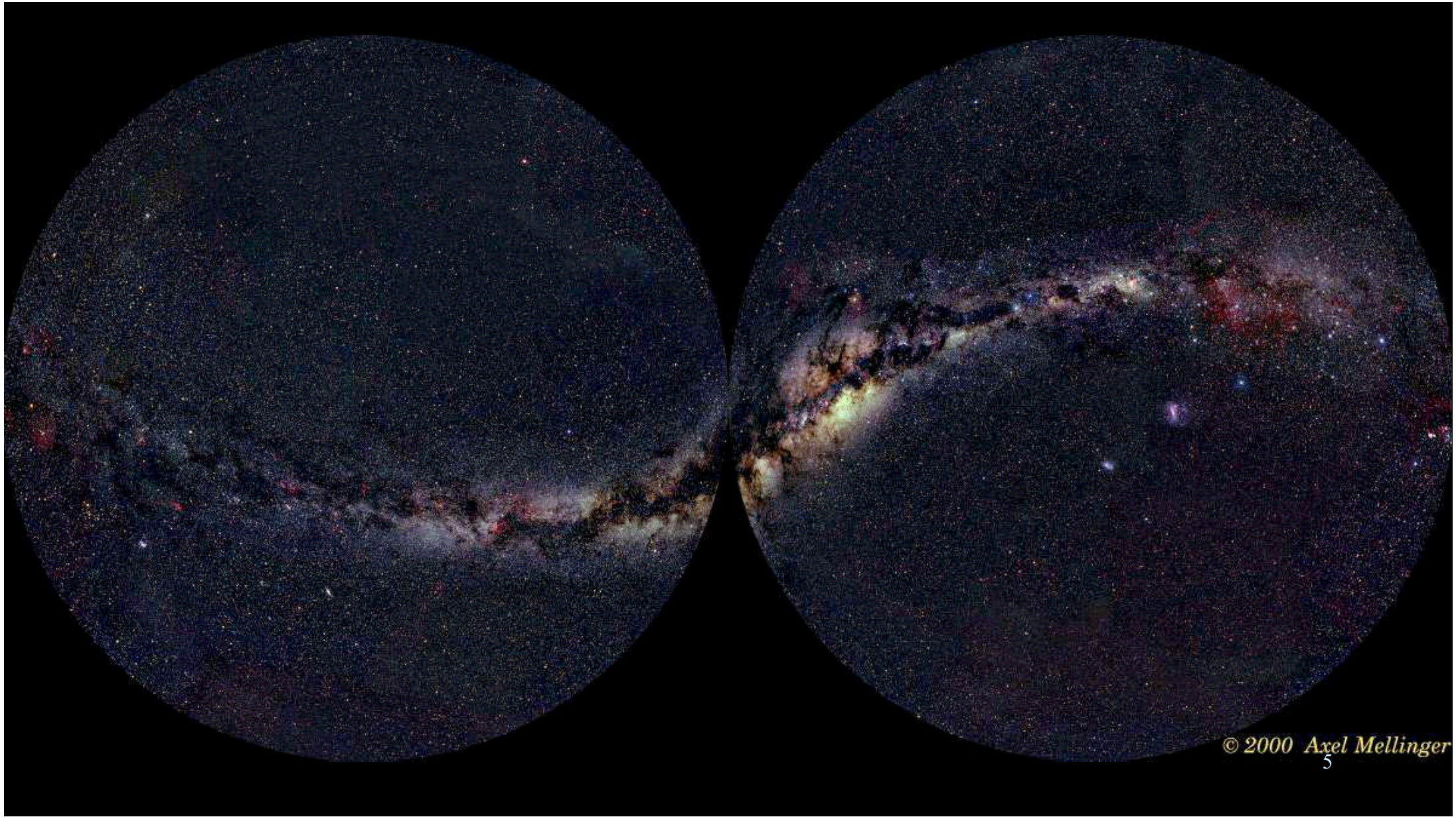
Luces lejanas: De la Vía Láctea a los confines del Universo



Qué nos revelan las galaxias
sobre la naturaleza y la evolución del Universo





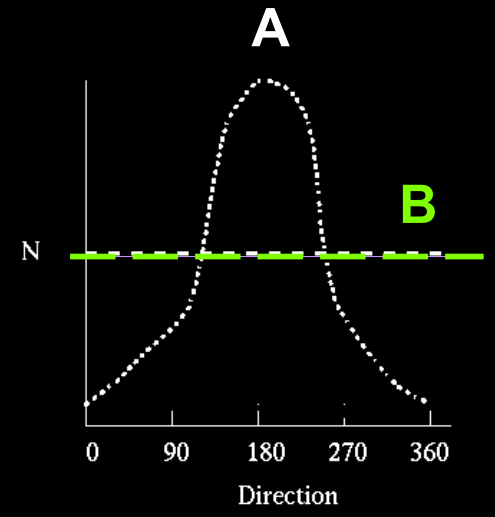
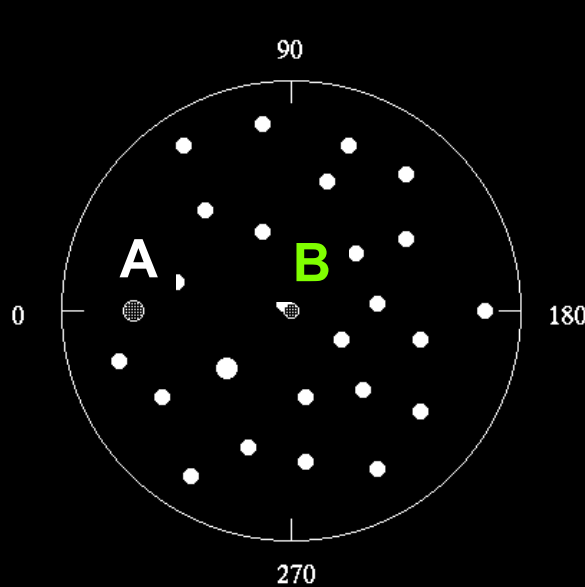
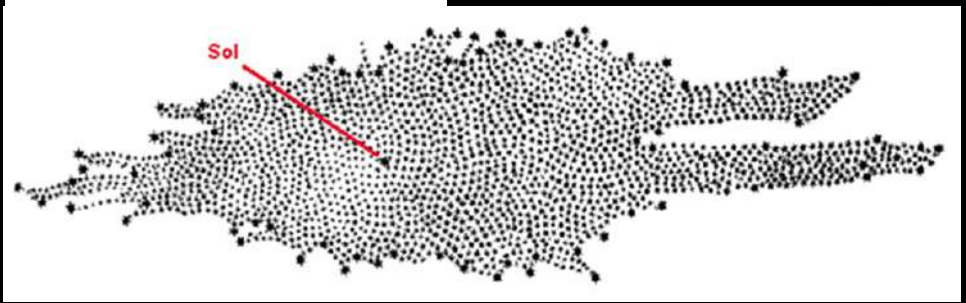


“existen otros universos isla parecidos a la Vía Láctea cuyas estrellas no serían distinguibles y aparecerían como nebulosas...”

Immanuel Kant (1724-1804)

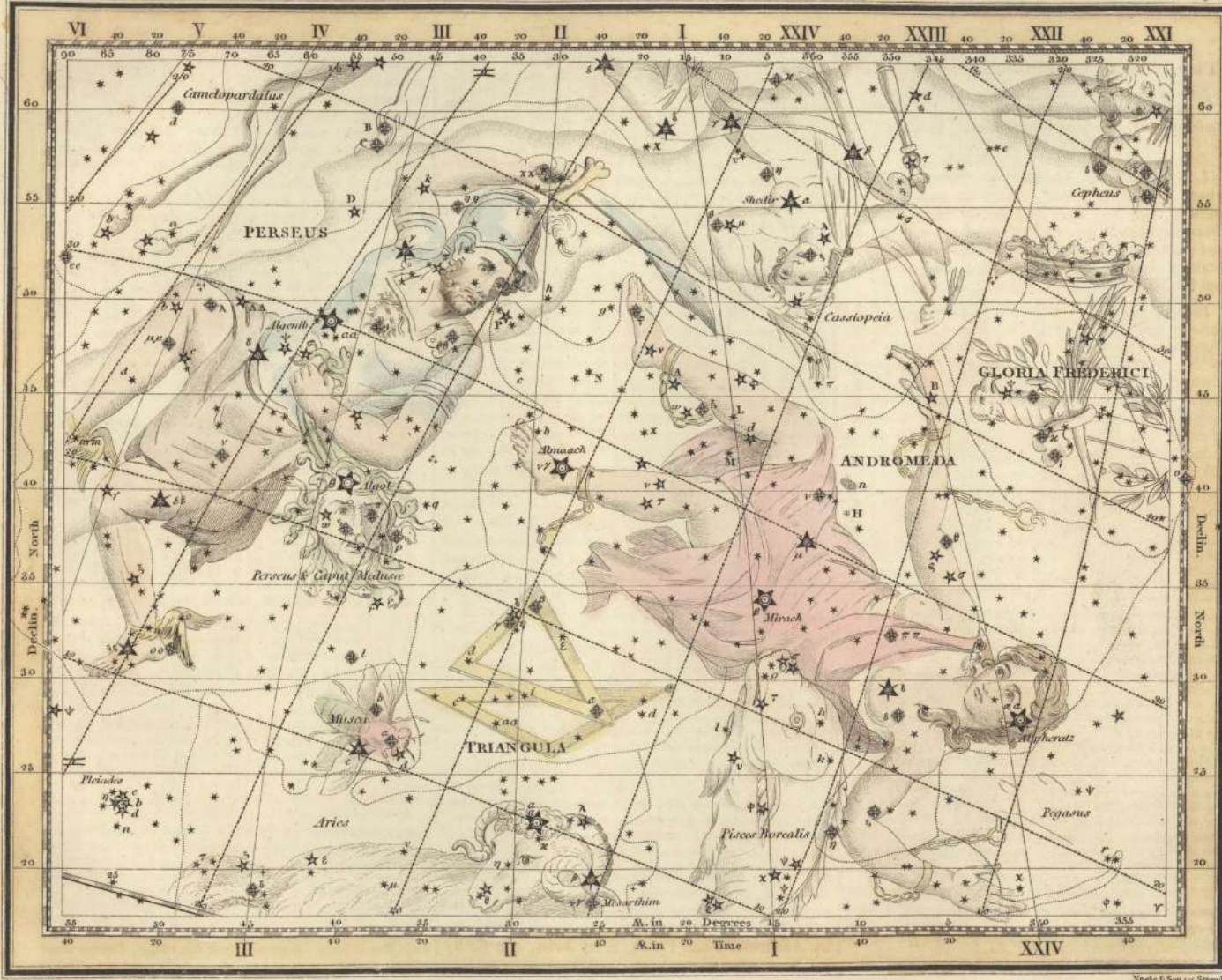


Modelo de Herschel (1785)



“La galaxia es como una rueda de molino con el Sol en el centro...”





1822

Published February 1. 1822 by G. & W. B. Whitcomb, T. Cadell & N. Hails, London.

PHOTOGRAPH OF THE NEBULA. 31 M. ANDROMEDÆ.

AR. $0^{\text{h}}37^{\text{m}}$ D. $40^{\circ}40'$ Exposure 240 minutes. Enlarged 3 times.

ISAAC ROBERTS, F.R.A.S., F.G.S.,
Maghail, 29th Decr 1888.



1888

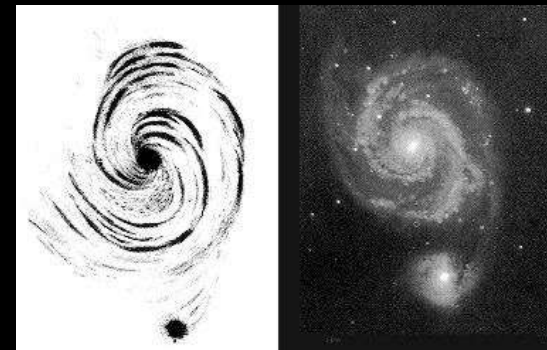
Nebulosas espirales



Fig. 447.



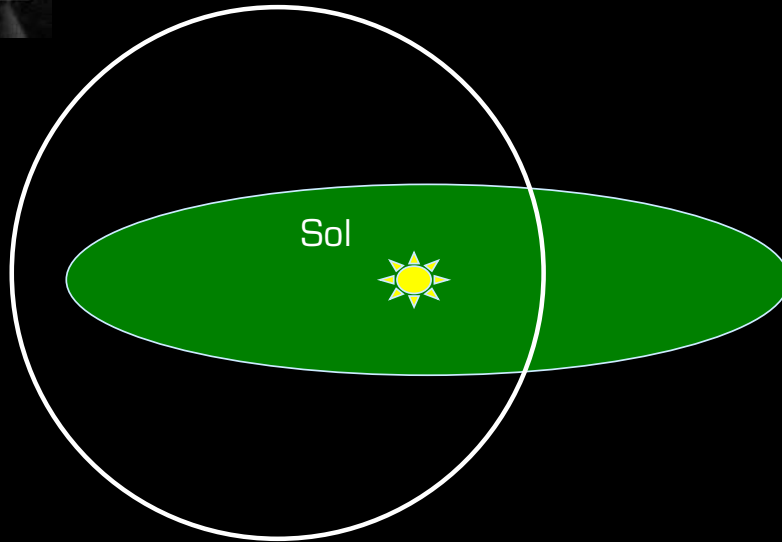
Fig. 449.



El Sol no es el centro de la galaxia (Shapley 1918)



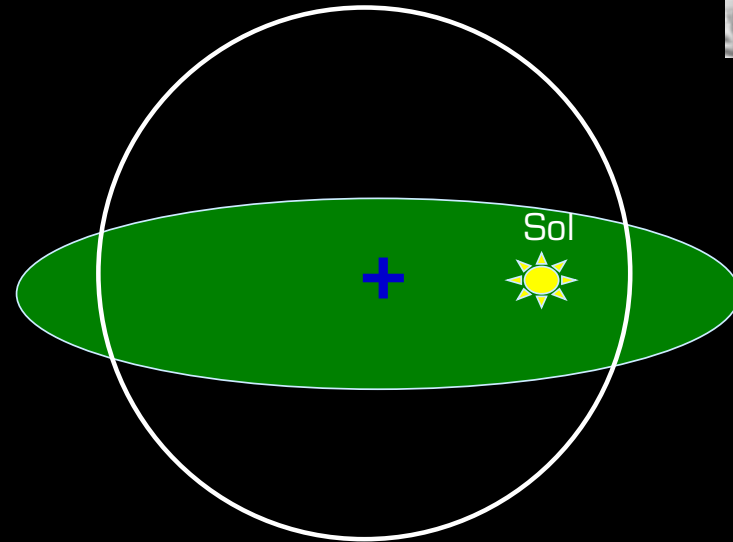
Cúmulos globulares



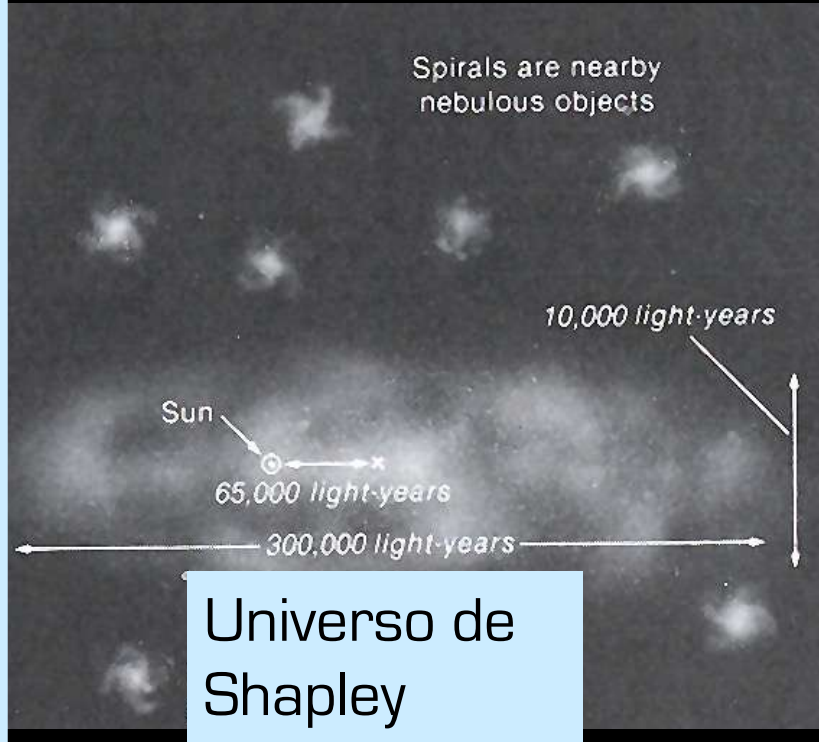
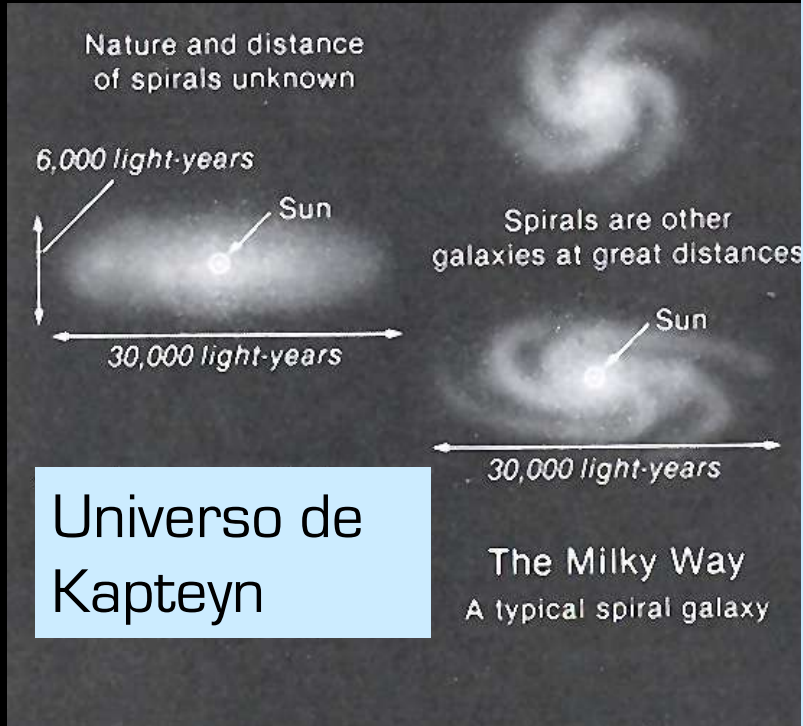
Modelo de Kapteyn (1910)



Cúmulos globulares



Modelo de Shapley (1918)





H. D. Curtiss

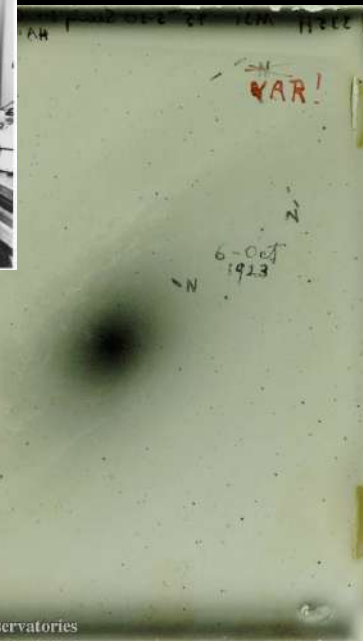
Academia Nacional de Ciencias EE UU

26 Abril 1920



H. Shapley

La solución...



E. Hubble, AAS 30-XII-1924

© Carnegie Observatories

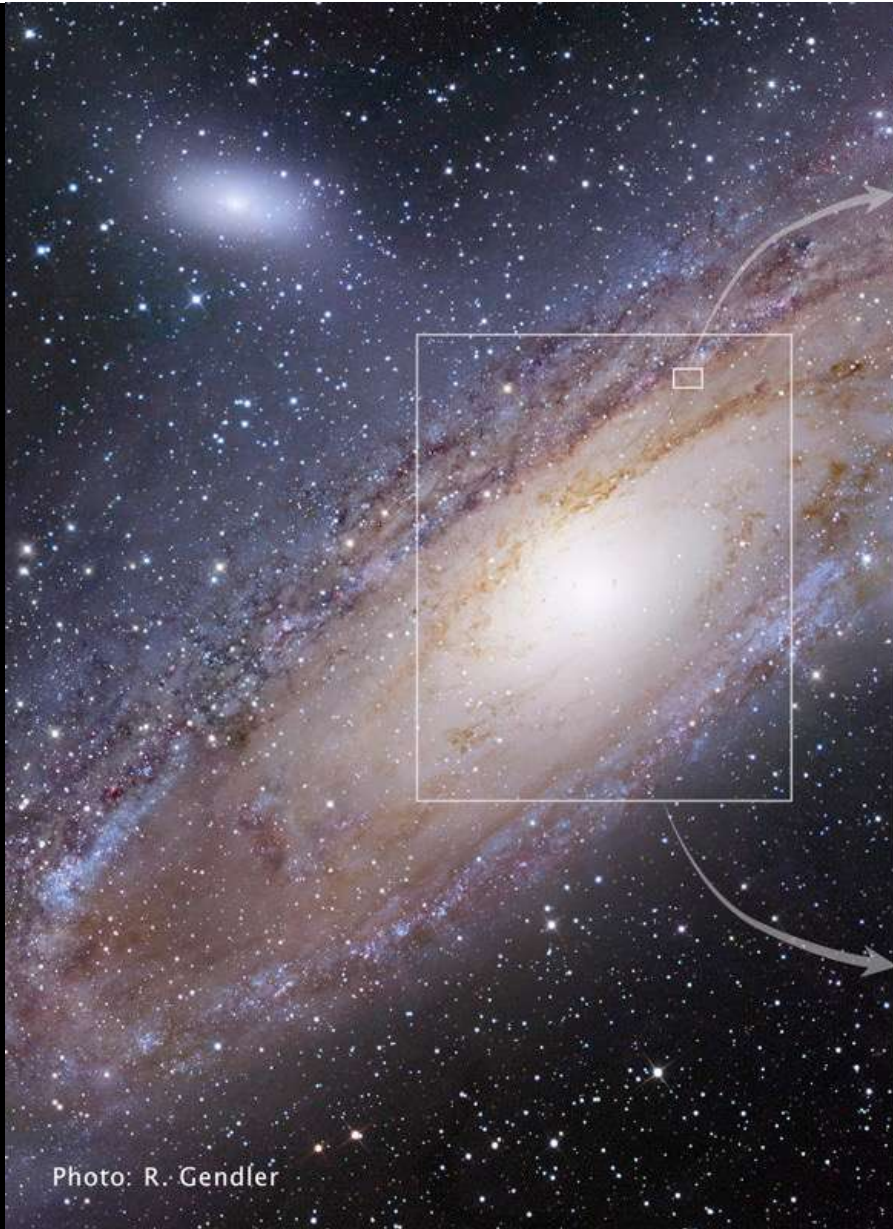
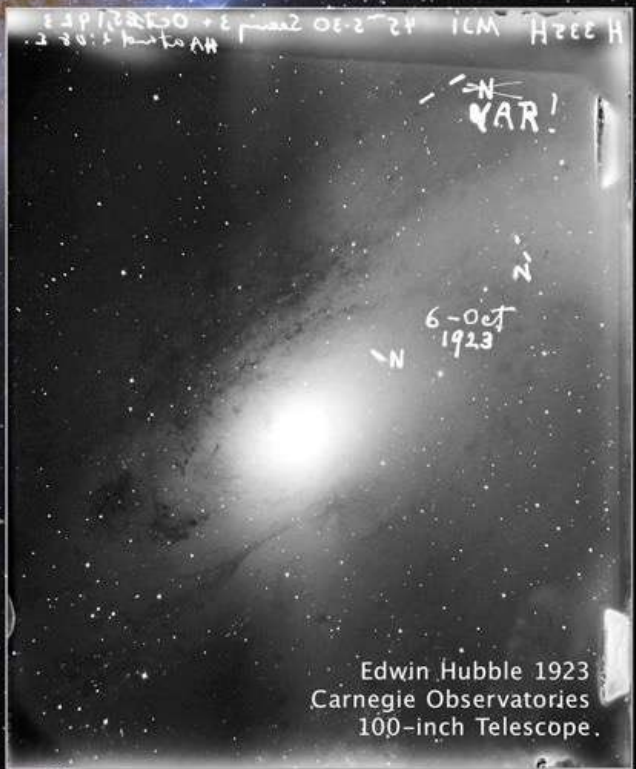


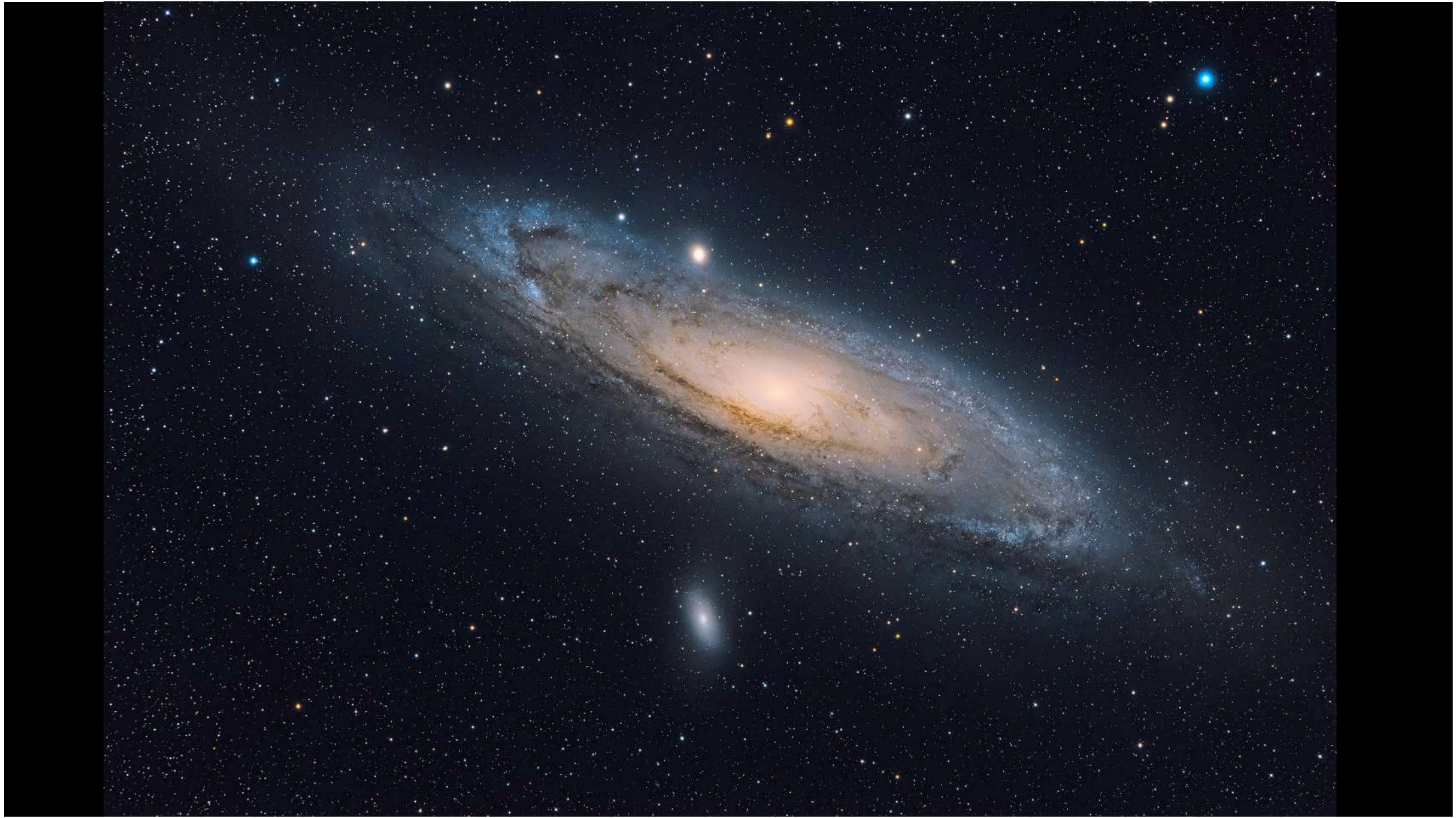
Photo: R. Gendler



Hubble Space Telescope
WFC3/UVIS



Edwin Hubble 1923
Carnegie Observatories
100-inch Telescope.

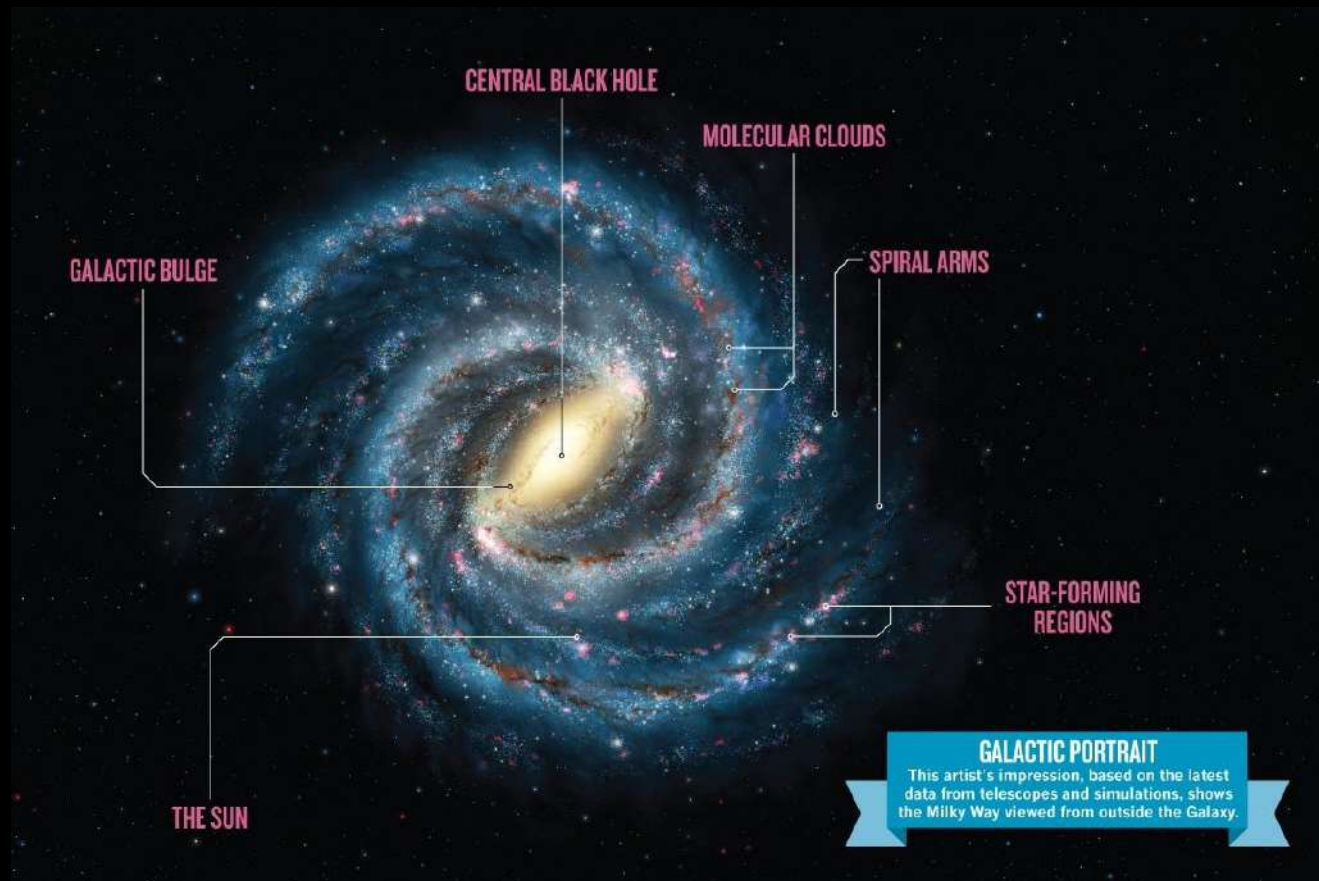




Componentes de la galaxia

Componentes principales:

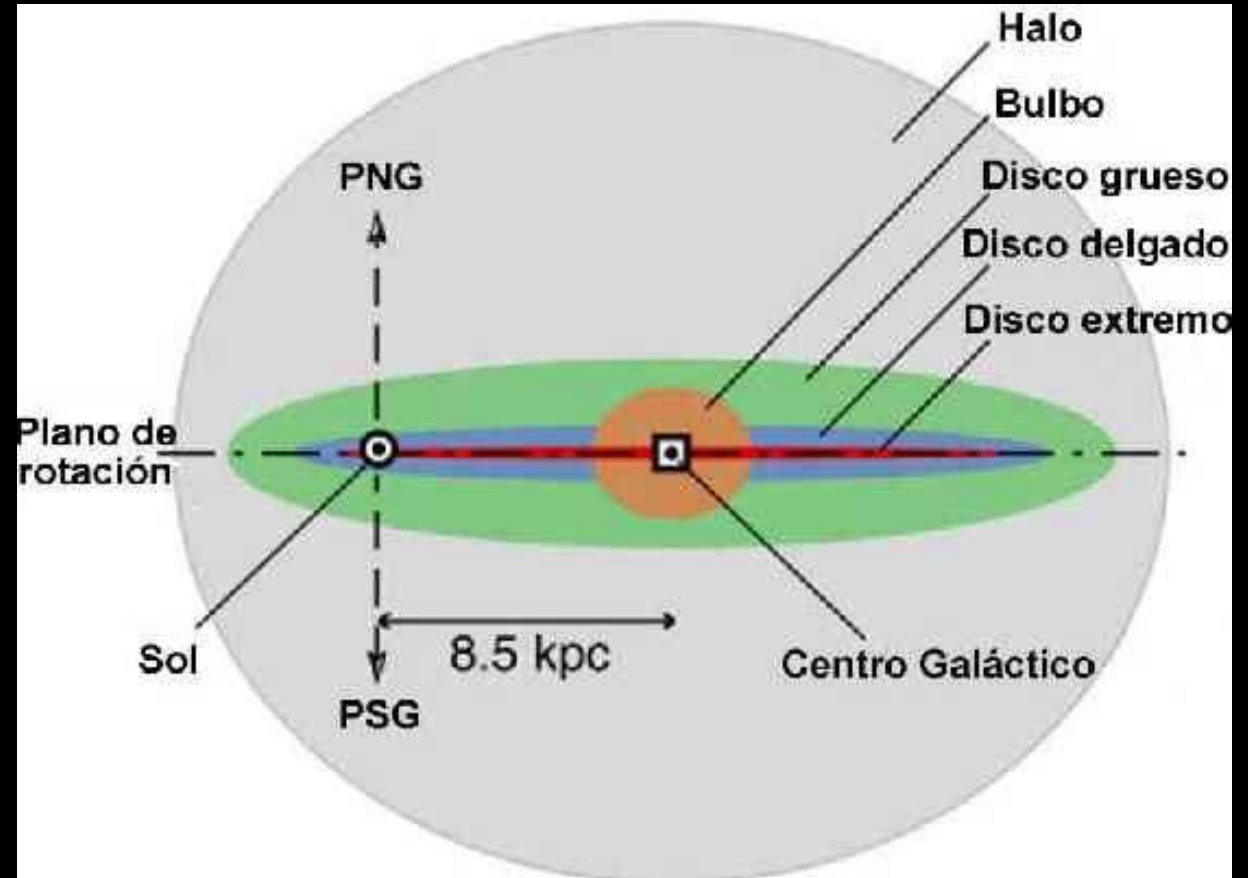
- ◆ Estrellas
- ◆ Gas
- ◆ Polvo
- ◆ Materia oscura

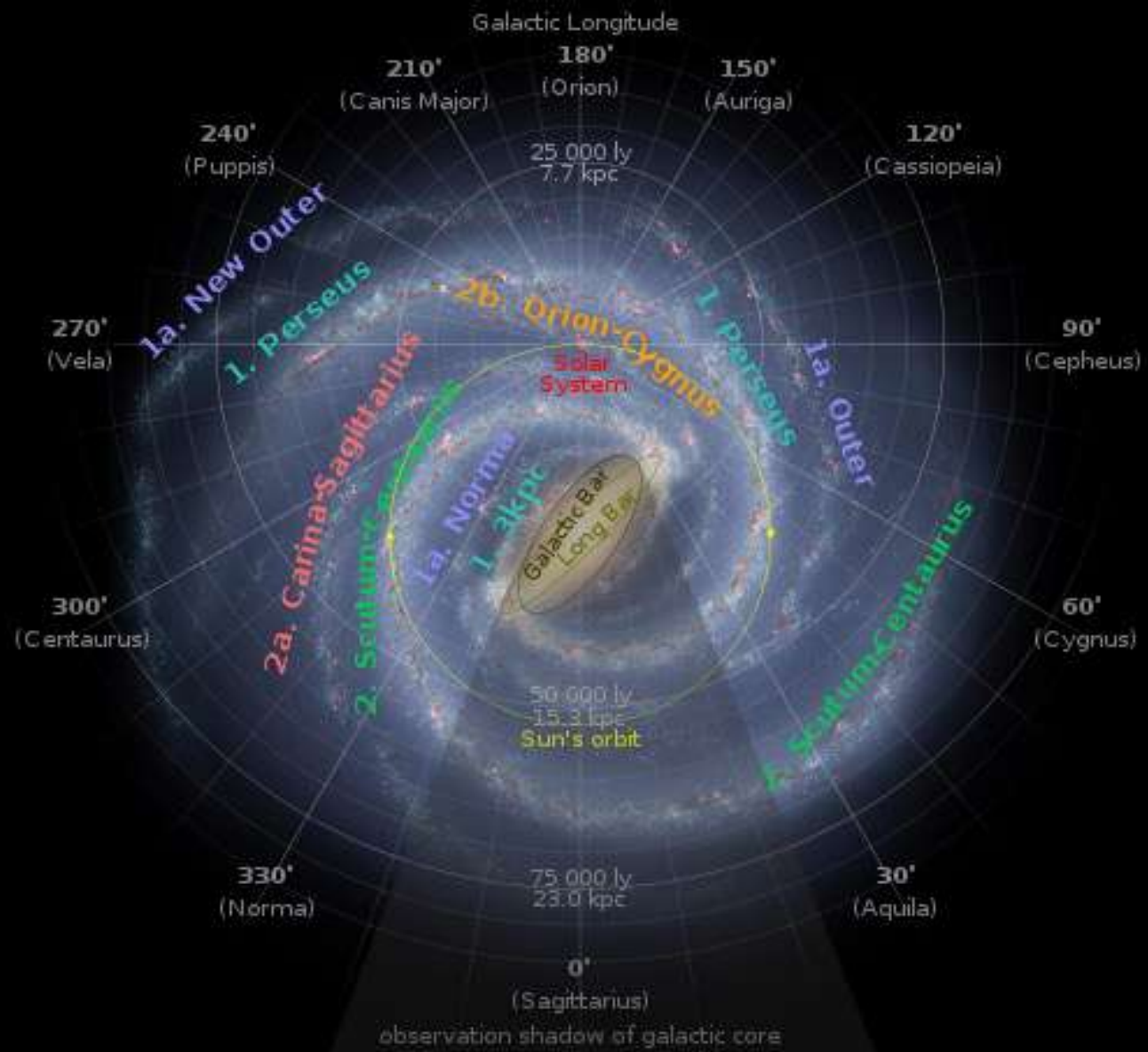


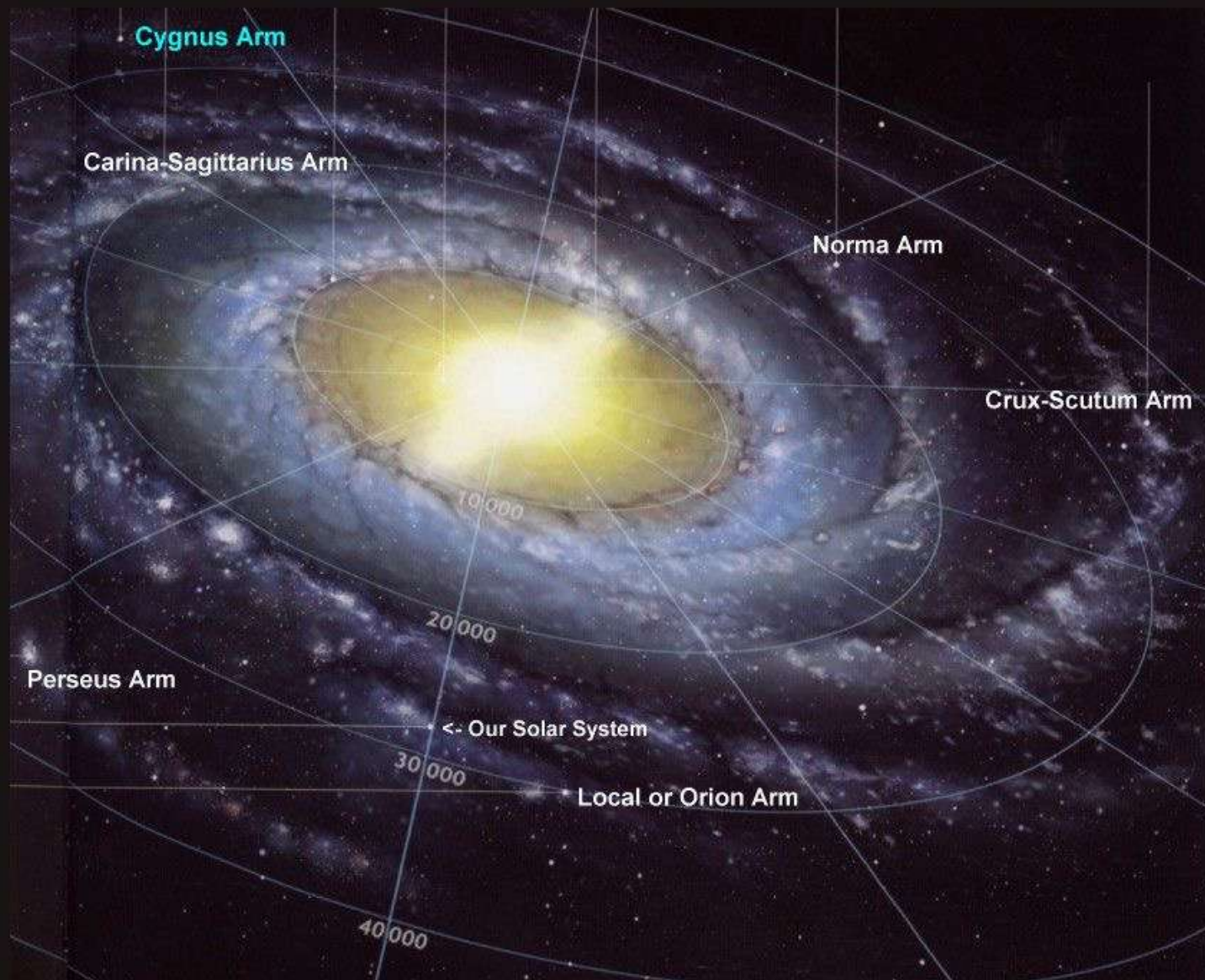
Estructuras de la galaxia

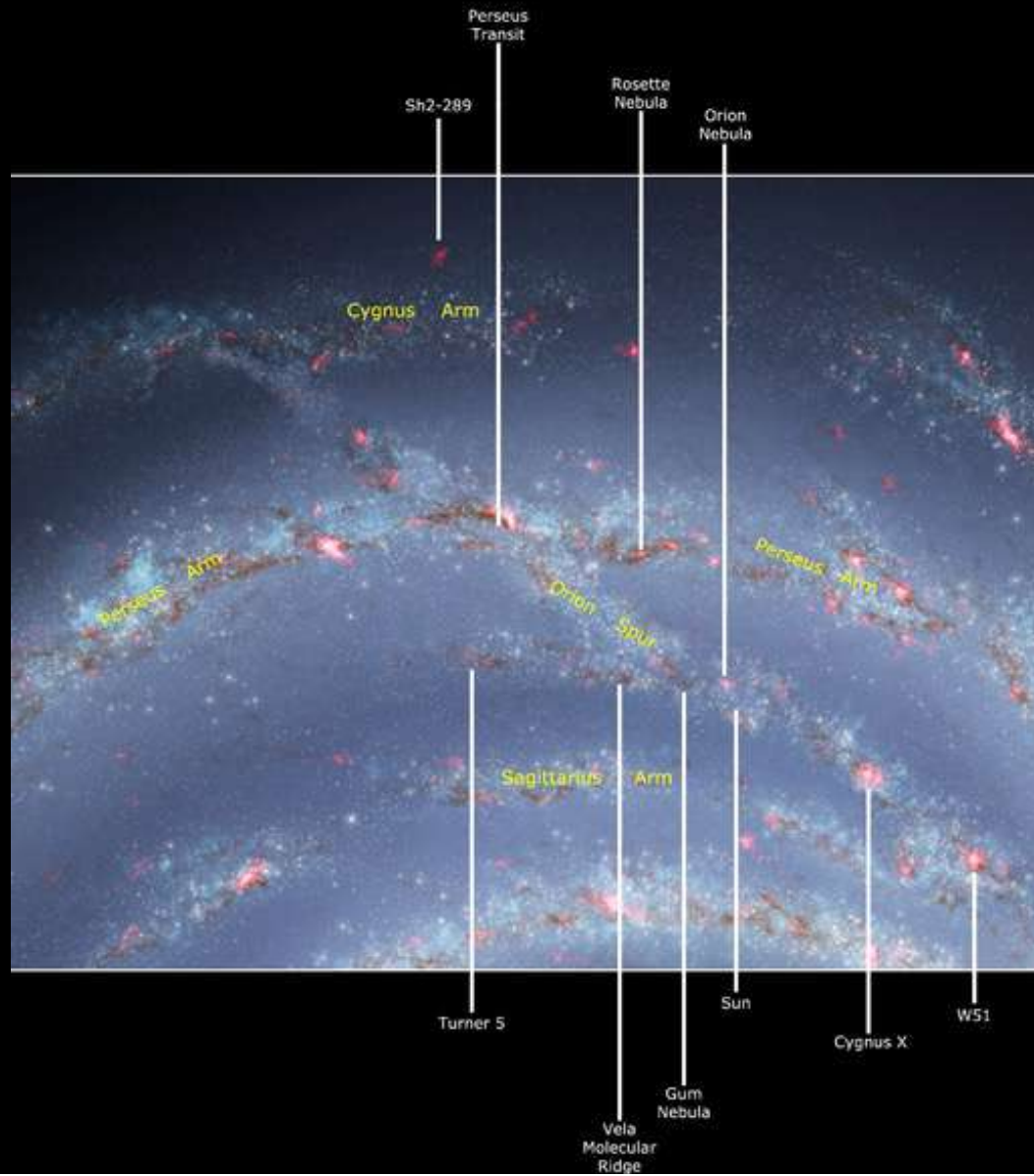
Estructuras principales:

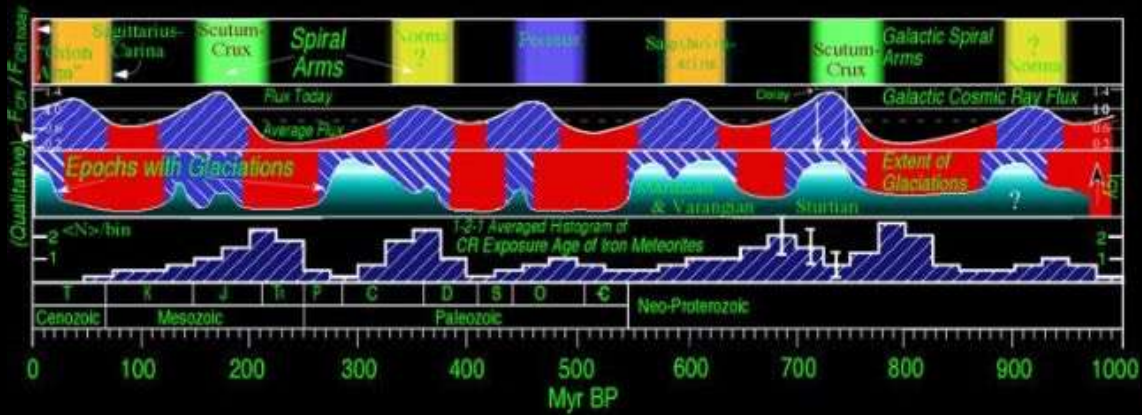
- ◆ Núcleo
- ◆ Bulbo
- ◆ Barra
- ◆ Anillo gas molecular
- ◆ Disco (fino y grueso)
- ◆ Halo (estelar y de materia oscura)

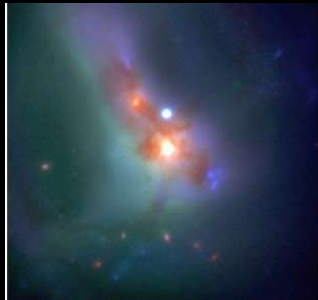
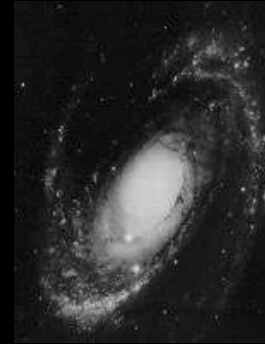








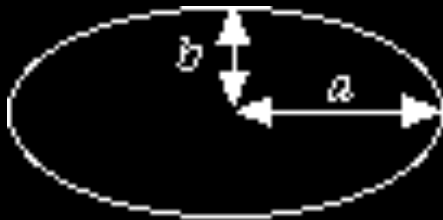




Galaxias Elípticas



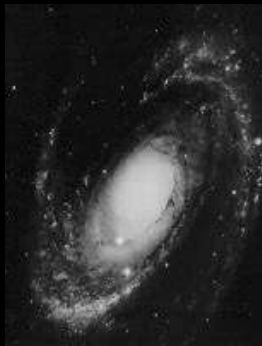
Elipticidad e



$$e = 10 (1 - b / a)$$

- Forma elipsoidal, $e = 0 - 7$
- Estrellas viejas y evolucionadas
- Colores rojizos
- Dominan movimientos aleatorios

Galaxias Espirales



Enrollamiento



Sa, Sb, Sc

- Presentan brazos espirales y/o barras
- Bulbo rojizo con *'s viejas
- disco joven, con *'s jóvenes y gas
- Colores más azulados
- Domina rotación

Galaxias Irregulares



Tipo I
(LMC)



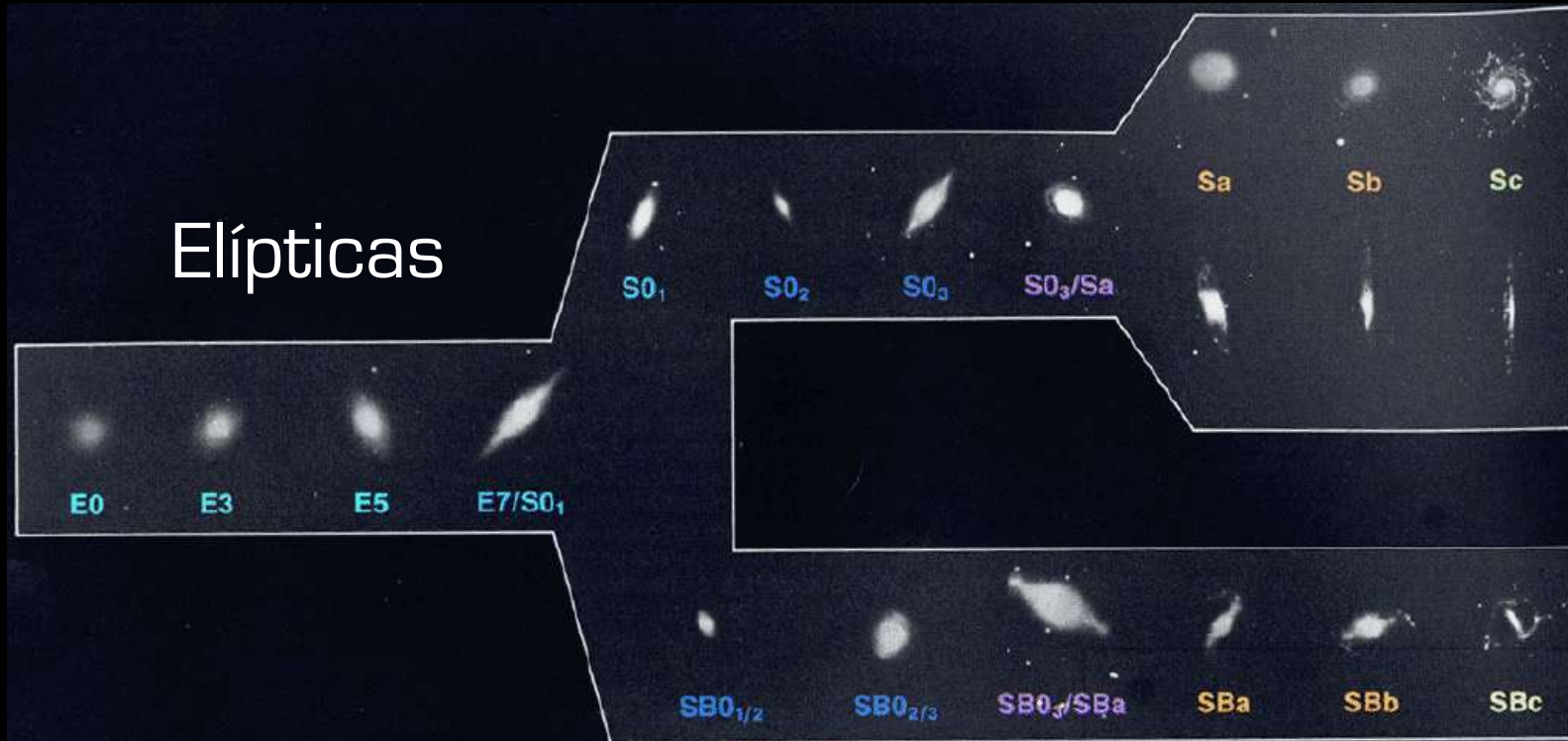
Tipo II



- No presentan estructura simétrica o regular
- Pequeño tamaño
- Ricas en estrellas jóvenes y gas, con formación estelar reciente
- Colores más azulados

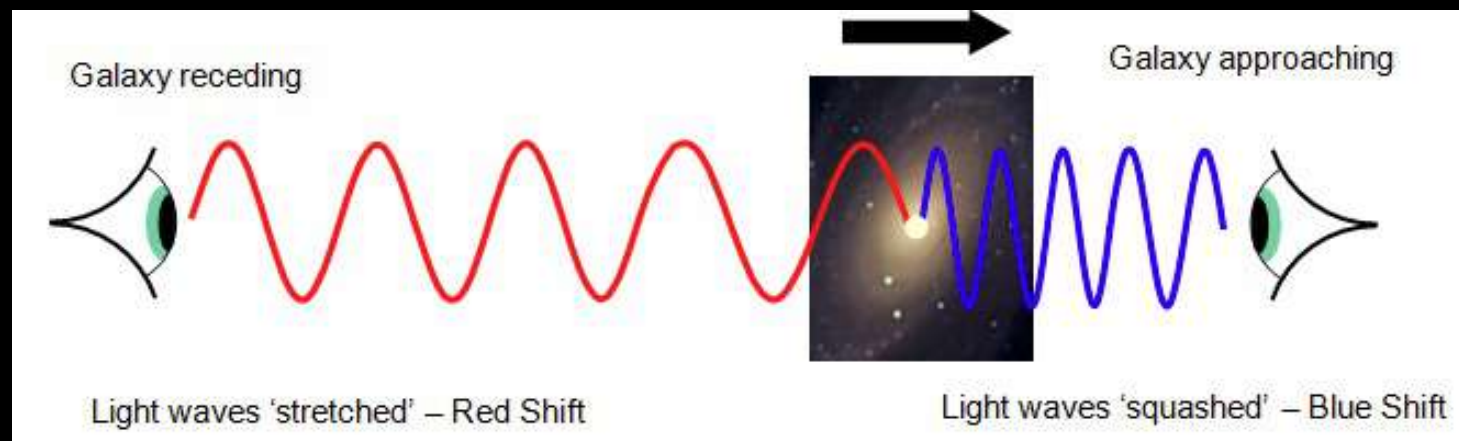
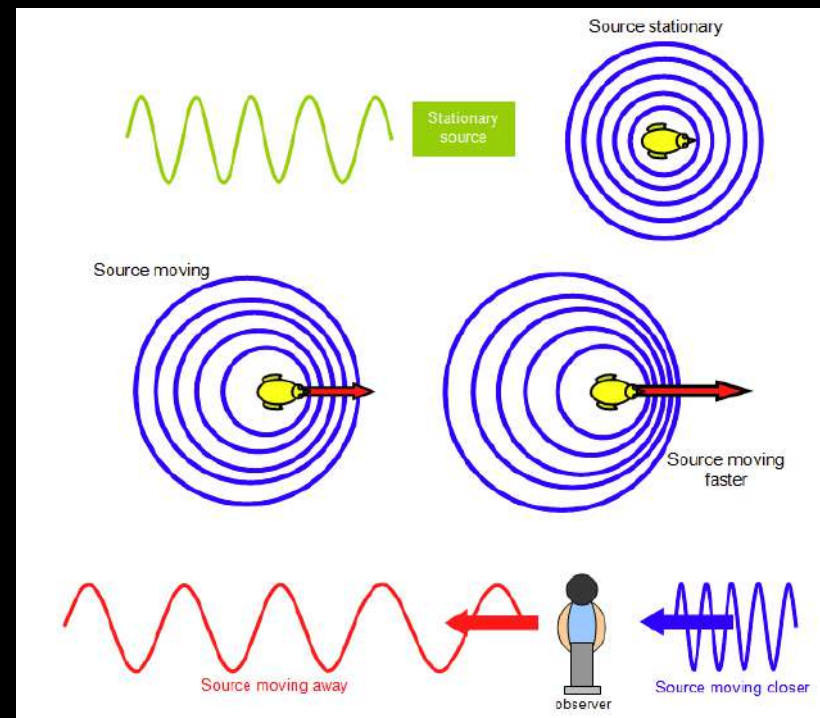
Espirales

Elípticas



Espirales barradas

Efecto Doppler-Fizeau



Galaxy,
Part of
Cluster in:

Estimated Distance
(megaparsecs)

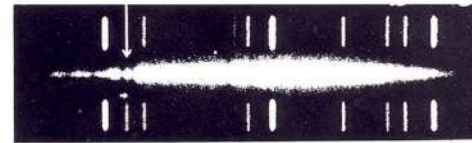
Red Shift



Virgo

15

H + K

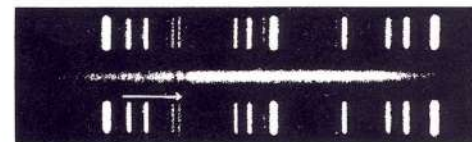


1200 km/s



Ursa Major

190

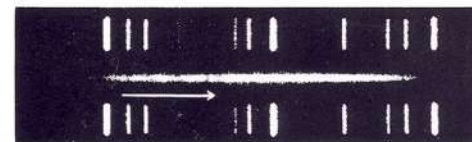


15 400 km/s



Corona Borealis

280

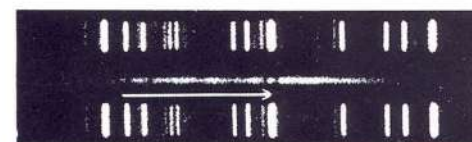


22 000 km/s



Boötes

490

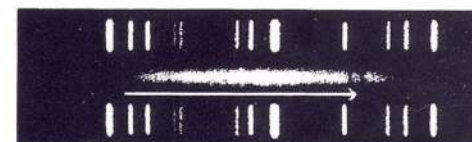


39 400 km/s

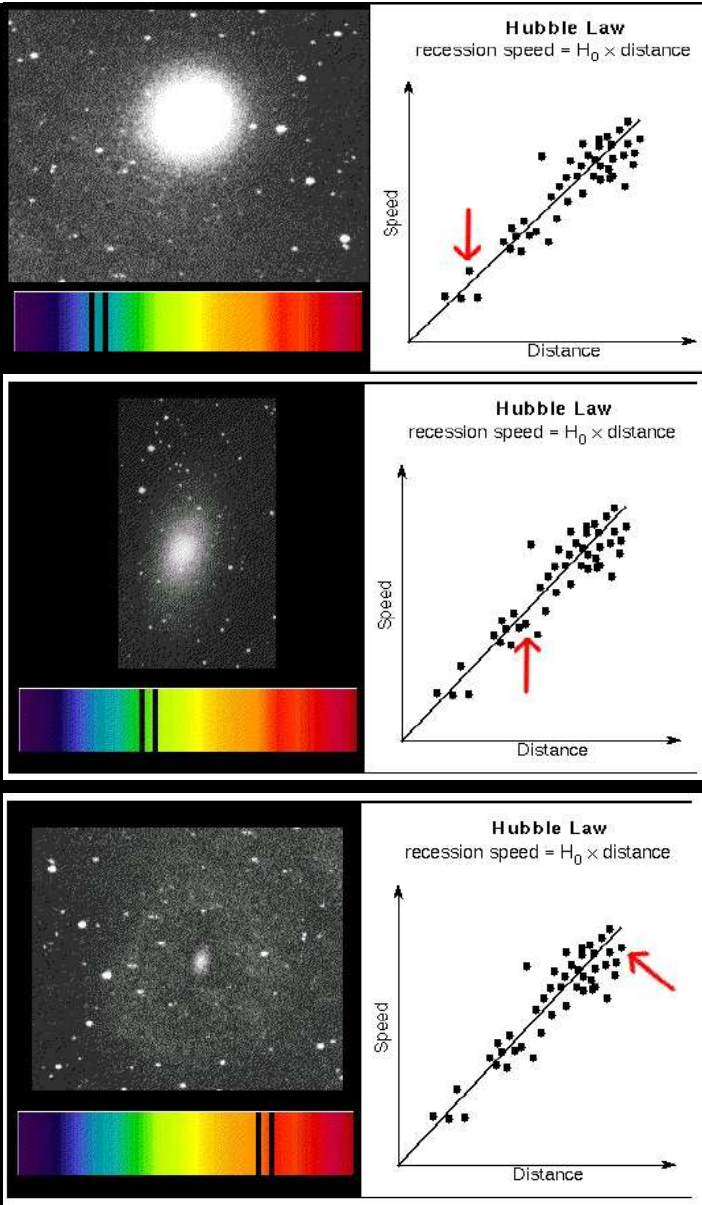


Hydra

760



60 600 km/s



La Ley de Hubble-Lemaitre

La velocidad de recesión de una galaxia es directamente proporcional a su distancia

$$v = c z$$

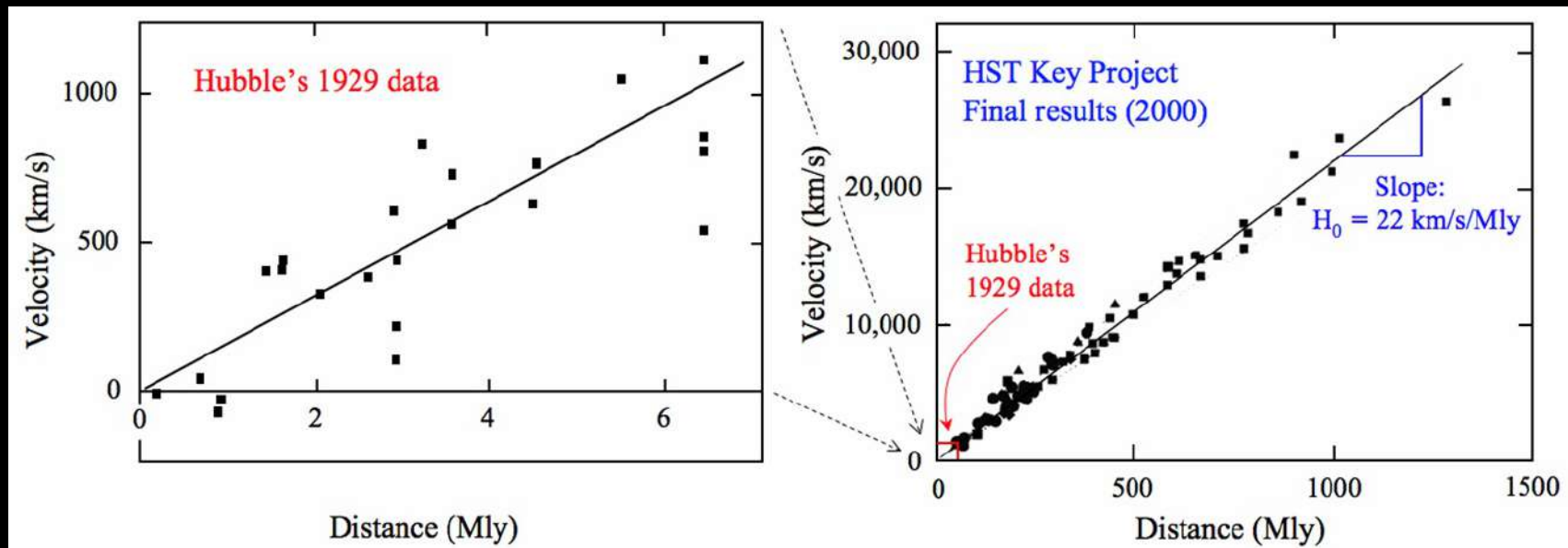
$$v = H_0 \times d$$

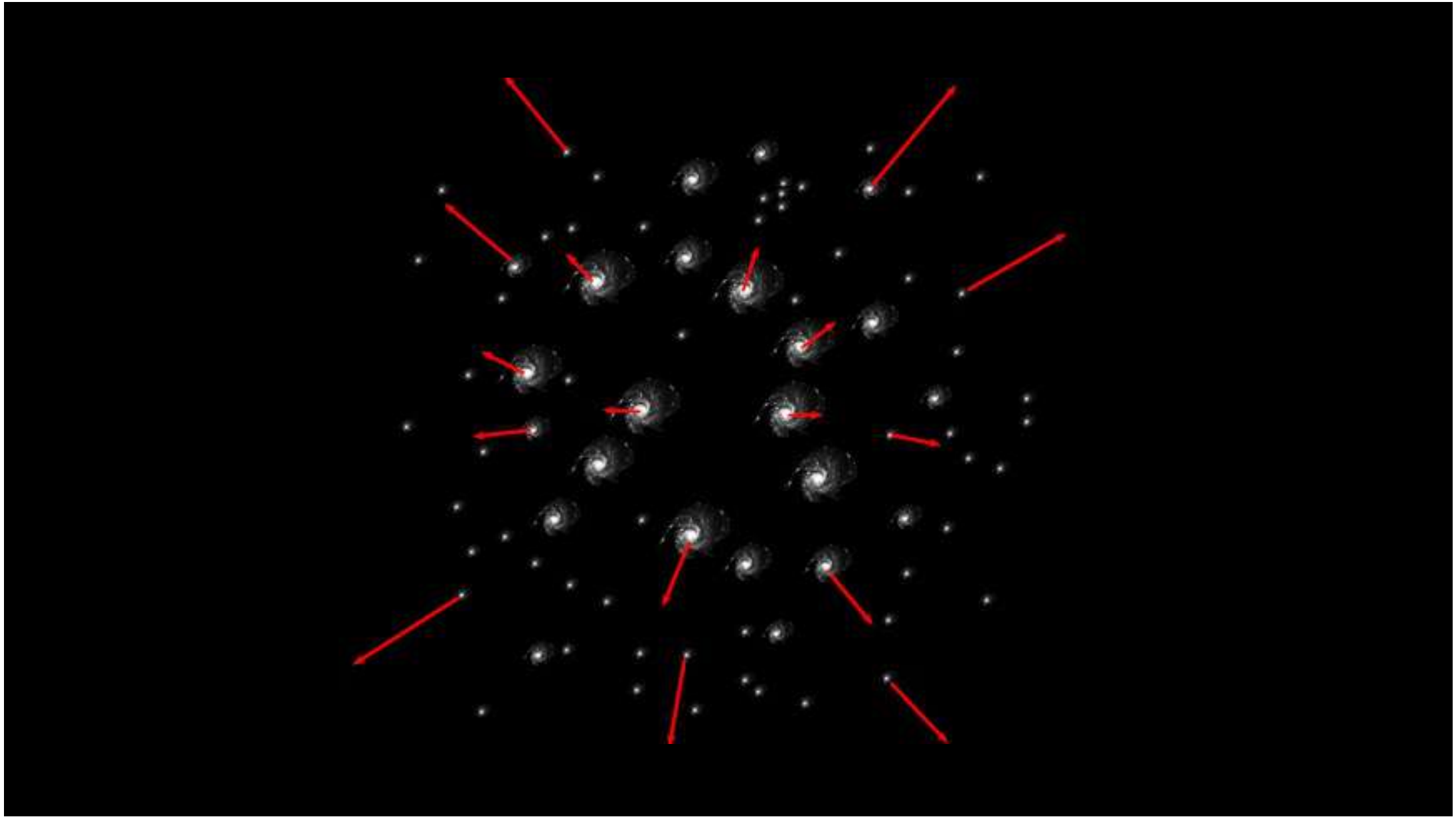
Constante de Hubble

$$H_0 \sim 70 \text{ km/s/Mpc}$$

La Ley de Hubble-Lemaitre

La velocidad de recesión de una galaxia es directamente proporcional a su distancia



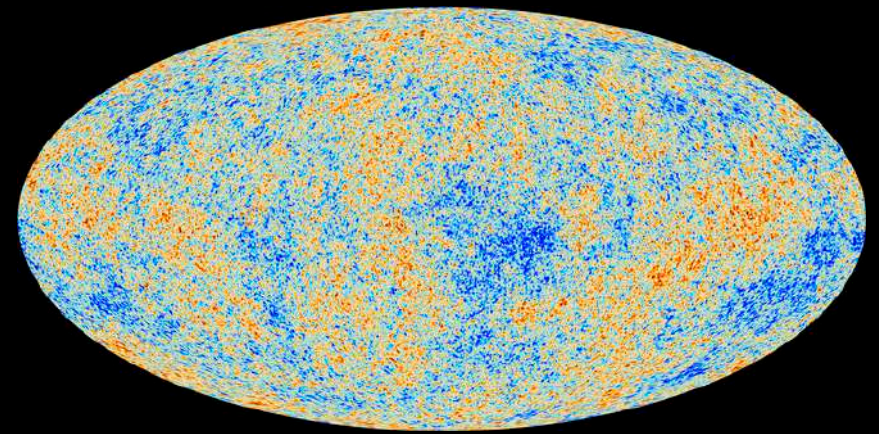


Tensión de Hubble

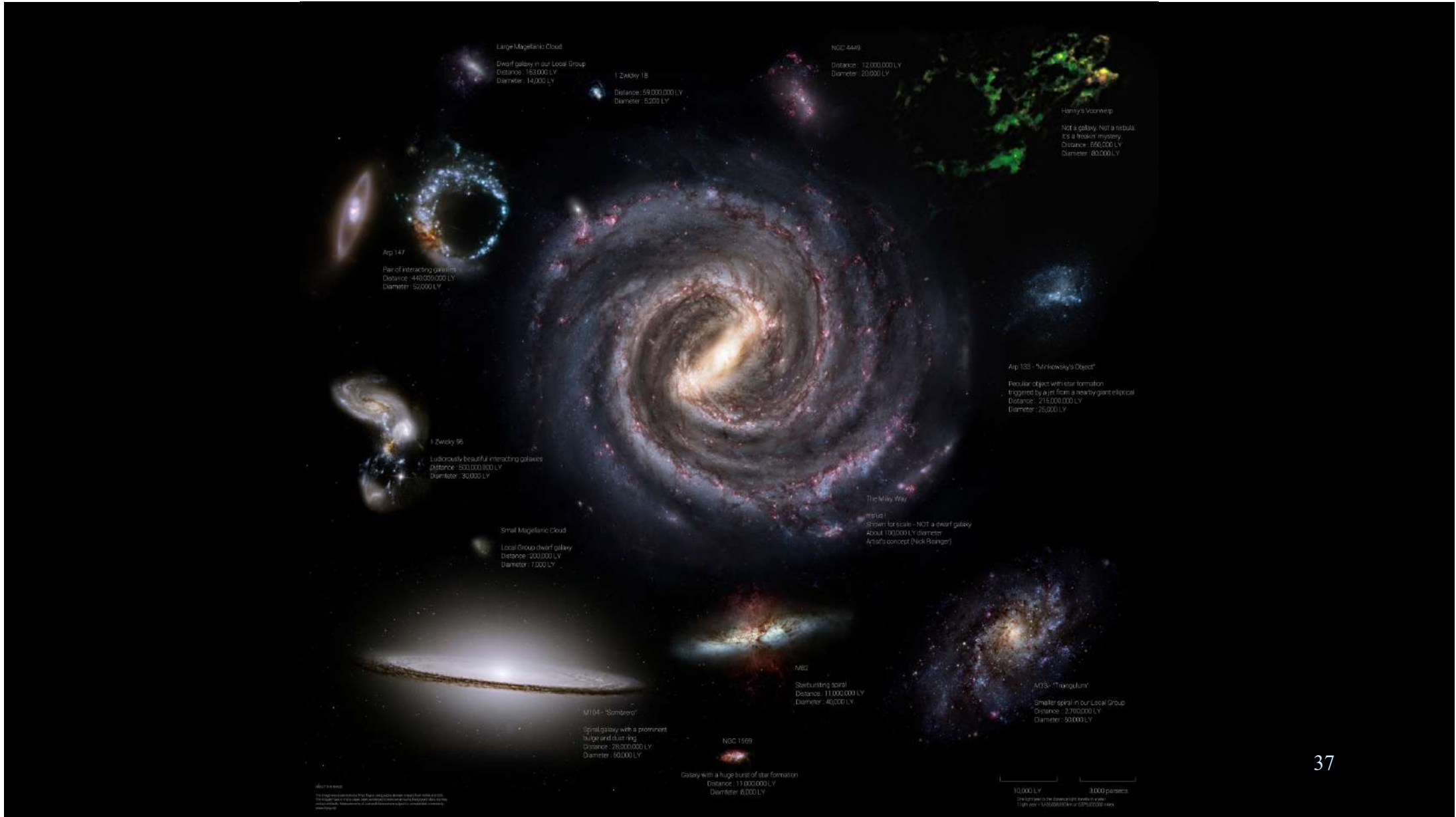
La H medida con cefeidas en la LMC no coincide con la H calculada a partir de la radiación de fondo

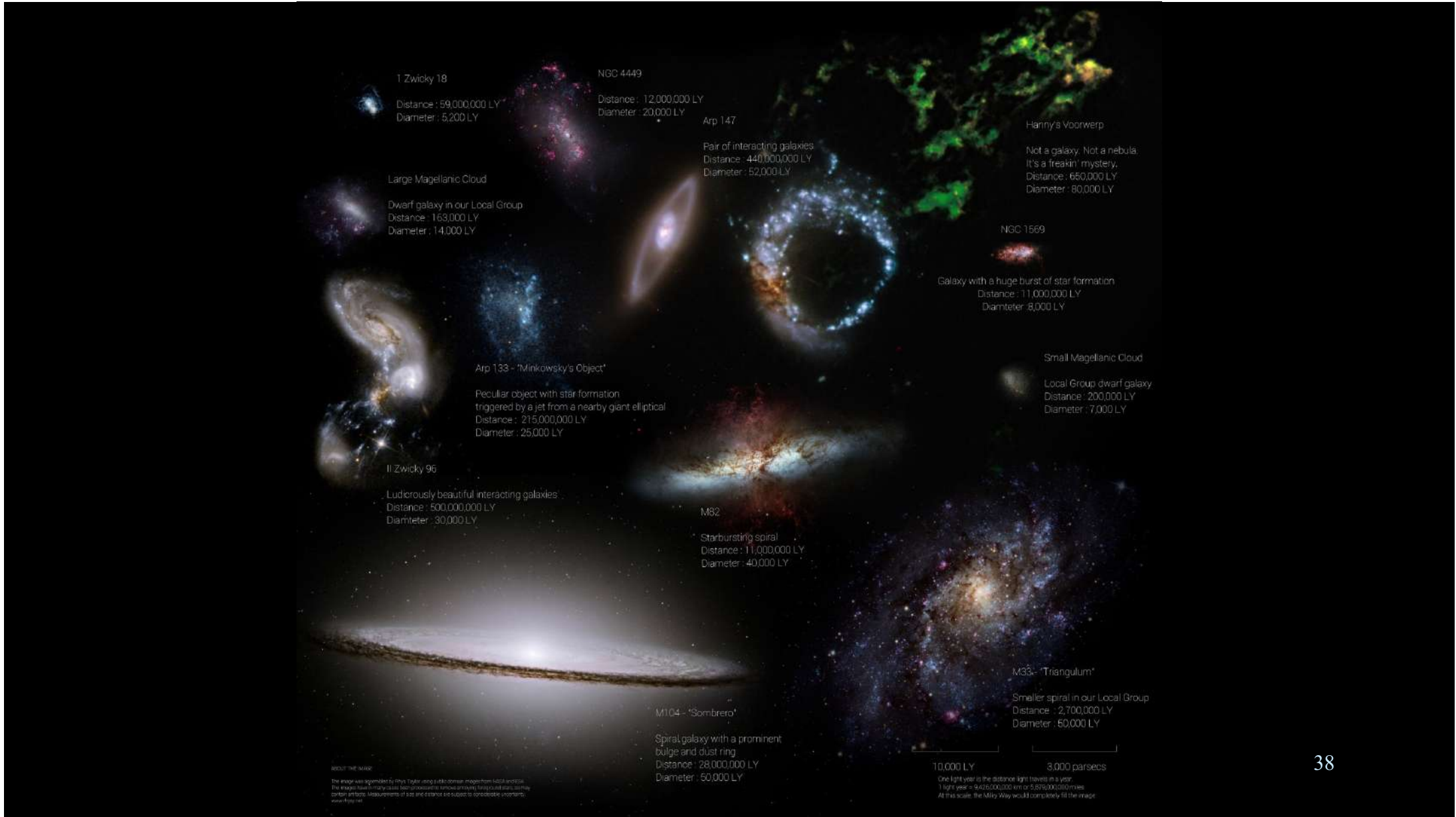


$$H_0 = 73,52 \pm 1,62 \text{ km/s/Mpc}$$



$$H_0 = 67,4 \pm 0,5 \text{ km/s/Mpc}$$





1 Zwicky 18

Distance : 59,000,000 LY
Diameter : 5,200 LY

NGC 4449

Distance : 12,000,000 LY
Diameter : 20,000 LY

Arp 147

Pair of interacting galaxies
Distance : 440,000,000 LY
Diameter : 52,000 LY

Hanny's Voorwerp

Not a galaxy. Not a nebula.
It's a freakin' mystery.
Distance : 650,000 LY
Diameter : 80,000 LY

Large Magellanic Cloud

Dwarf galaxy in our Local Group
Distance : 163,000 LY
Diameter : 14,000 LY

NGC 1569

Galaxy with a huge burst of star formation
Distance : 11,000,000 LY
Diameter : 8,000 LY

Arp 133 - 'Minkowsky's Object'

Peculiar object with star formation
triggered by a jet from a nearby giant elliptical
Distance : 215,000,000 LY
Diameter : 25,000 LY

Small Magellanic Cloud

Local Group dwarf galaxy
Distance : 200,000 LY
Diameter : 7,000 LY

II Zwicky 96

Ludicrously beautiful interacting galaxies
Distance : 500,000,000 LY
Diameter : 30,000 LY

M82

Starbursting spiral
Distance : 11,000,000 LY
Diameter : 40,000 LY

M104 - 'Sombrero'

Spiral galaxy with a prominent
bulge and dust ring
Distance : 28,000,000 LY
Diameter : 50,000 LY

M33 - 'Triangulum'

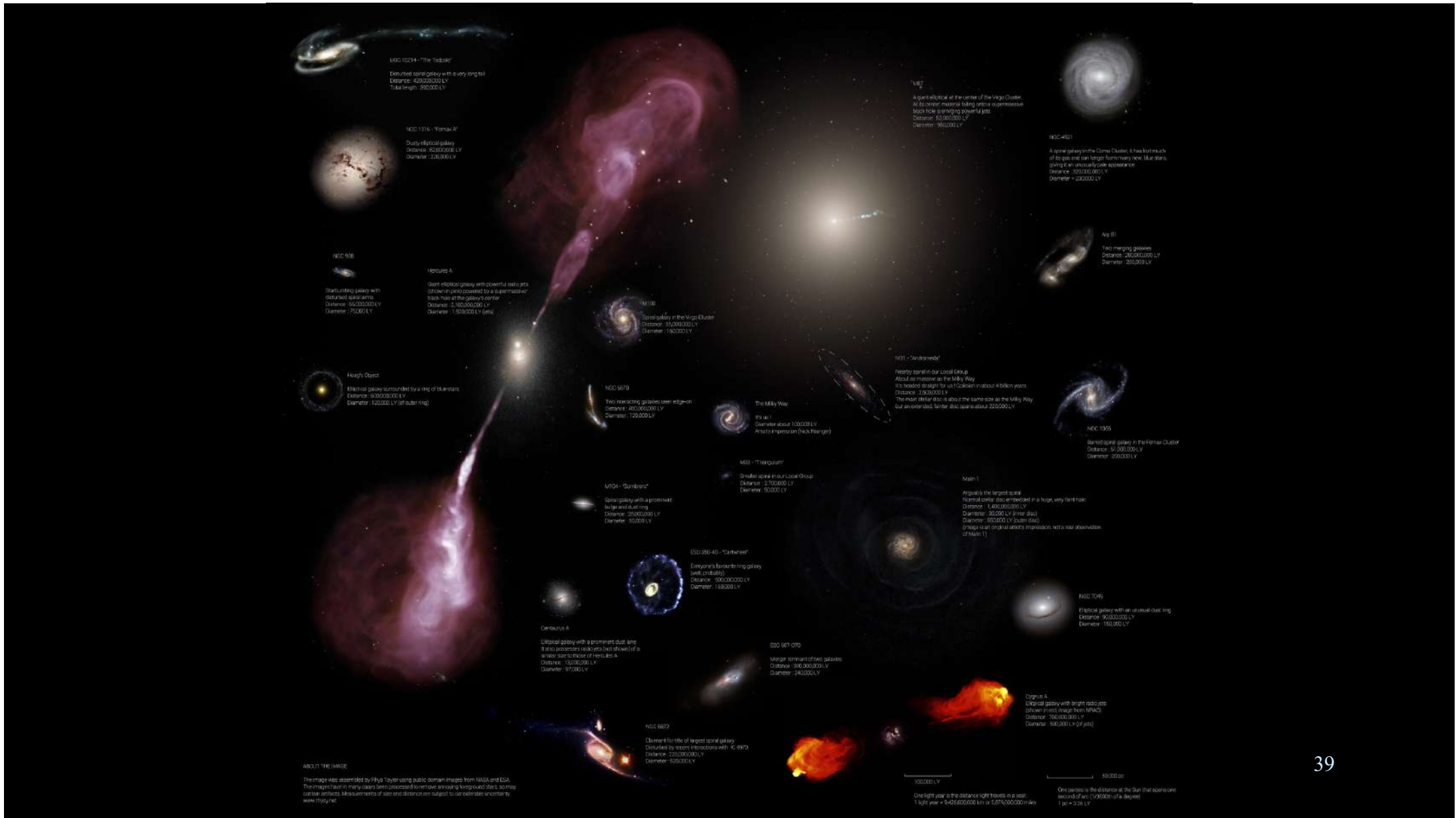
Smaller spiral in our Local Group
Distance : 2,700,000 LY
Diameter : 50,000 LY

ABOUT THE IMAGE

The image was assembled by Chris Taylor using multi-colour images from ESA's Euclid. The images have only been processed to enhance contrast and make them conform in tone. Measurements of size and distance are subject to considerable uncertainty. www.royal.gov.uk

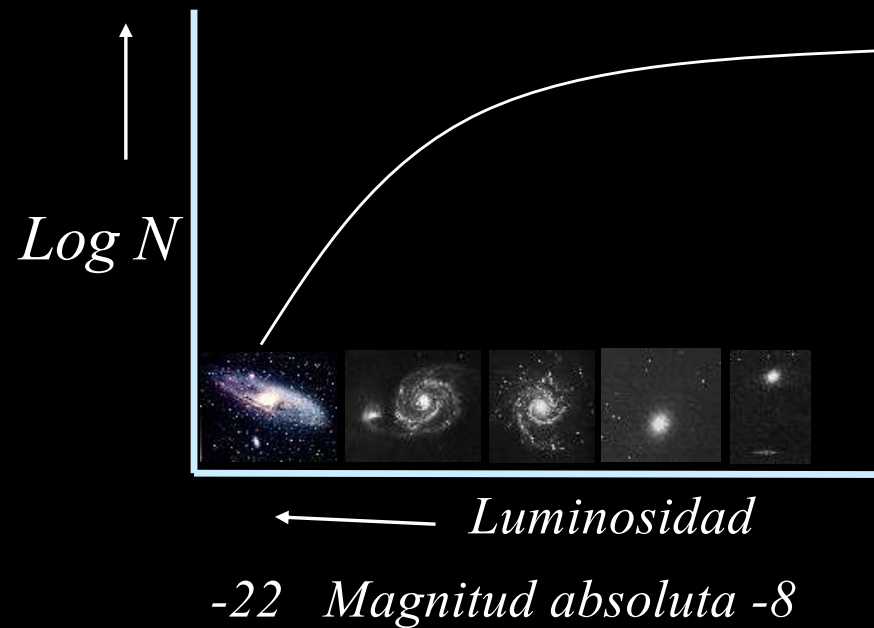
10,000 LY 3,000 parsecs

One light year is the distance light travels in a year.
1 light year = 9,460,000,000 km or 5,879,000,000 miles.
At this scale, the Milky Way would completely fill the image.

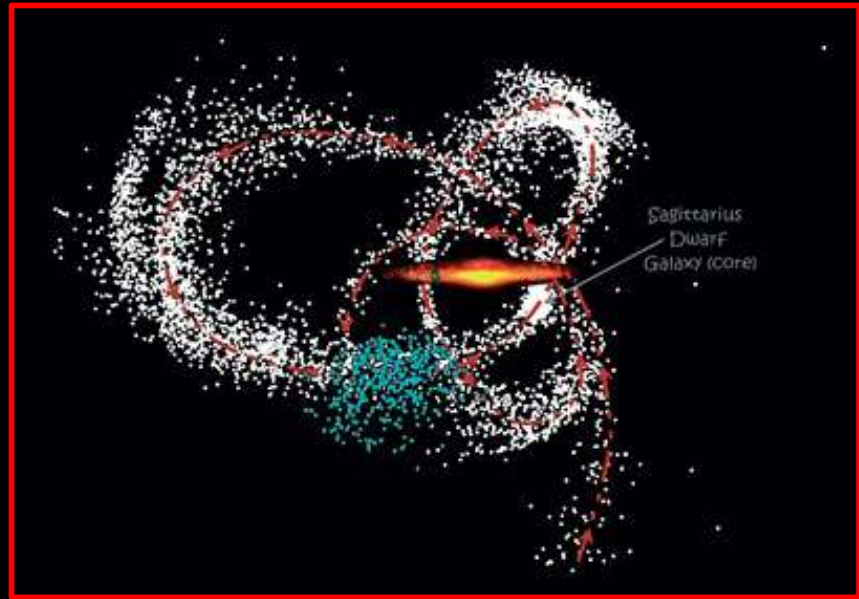


Función de luminosidad

Número de galaxias, por unidad de volumen en el Universo, con una luminosidad dada



Las galaxias poco luminosas son mucho más ($>100x$) numerosas que las muy luminosas





Grupo Local

Gran nubé de Magallanes /GNM



Galaxia de Andrómeda



NGC 205



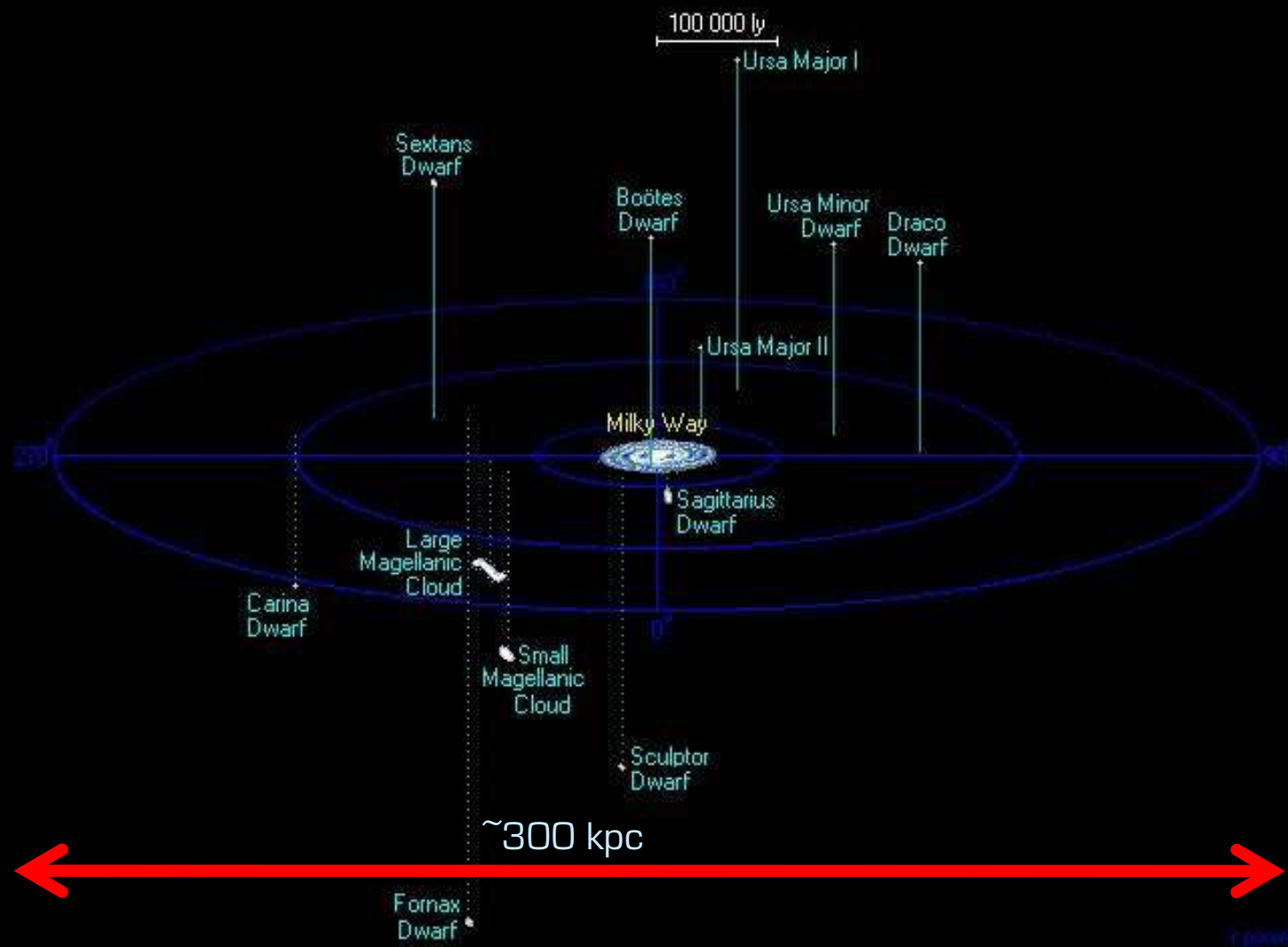
Galaxia NGC 6822

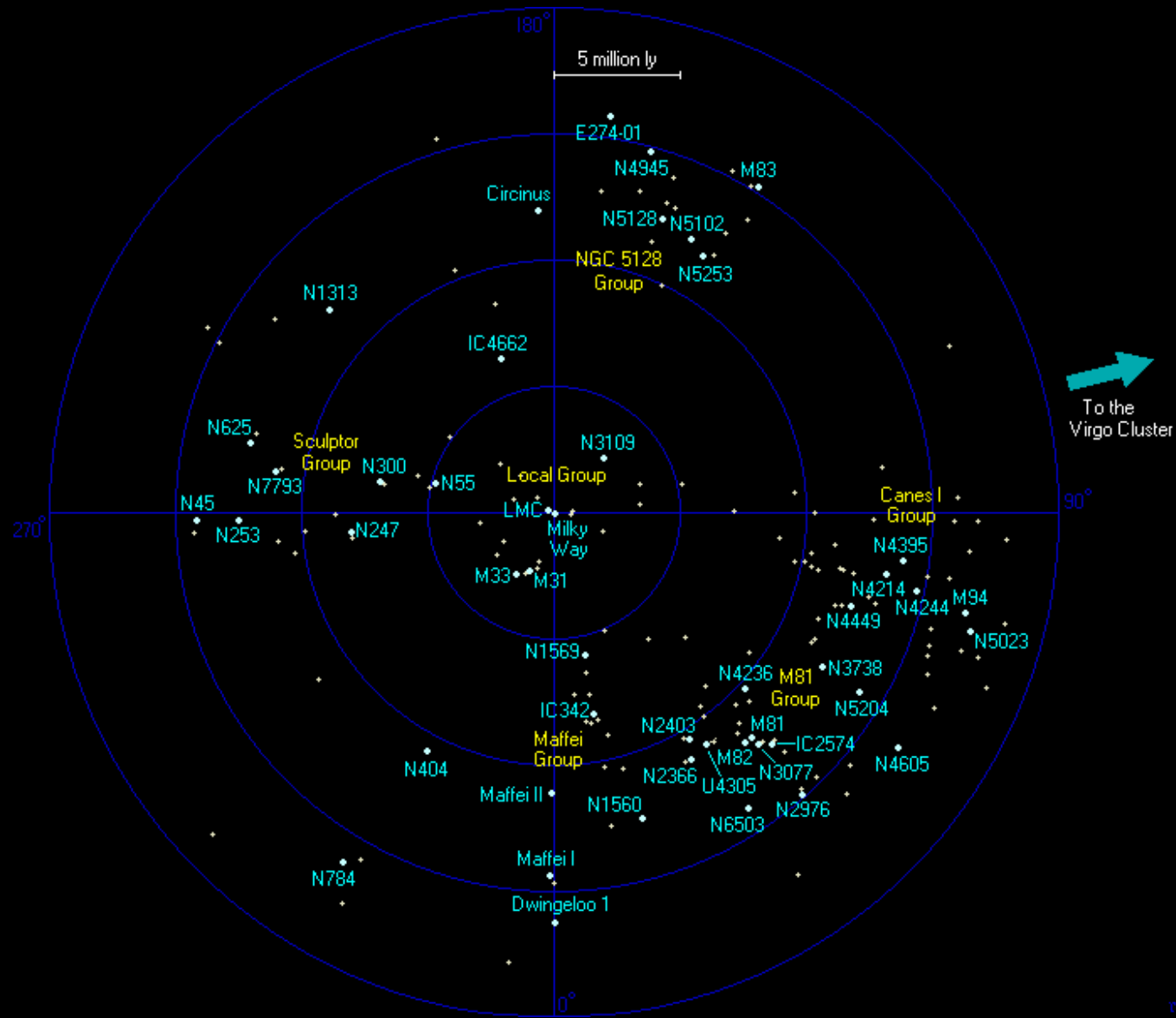
Galaxia NGC 185

Galaxia NGC 147

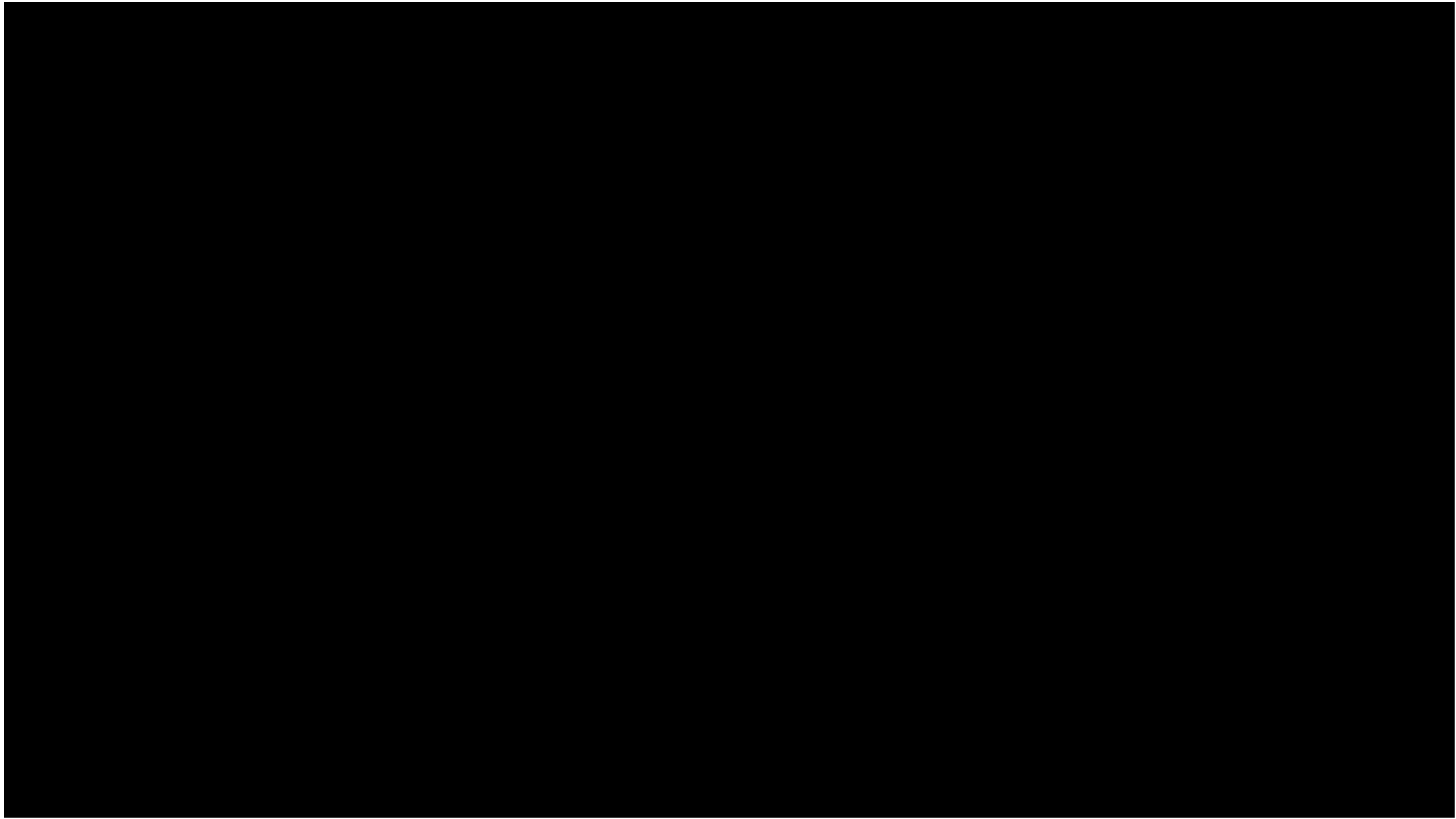


Galaxia M-33

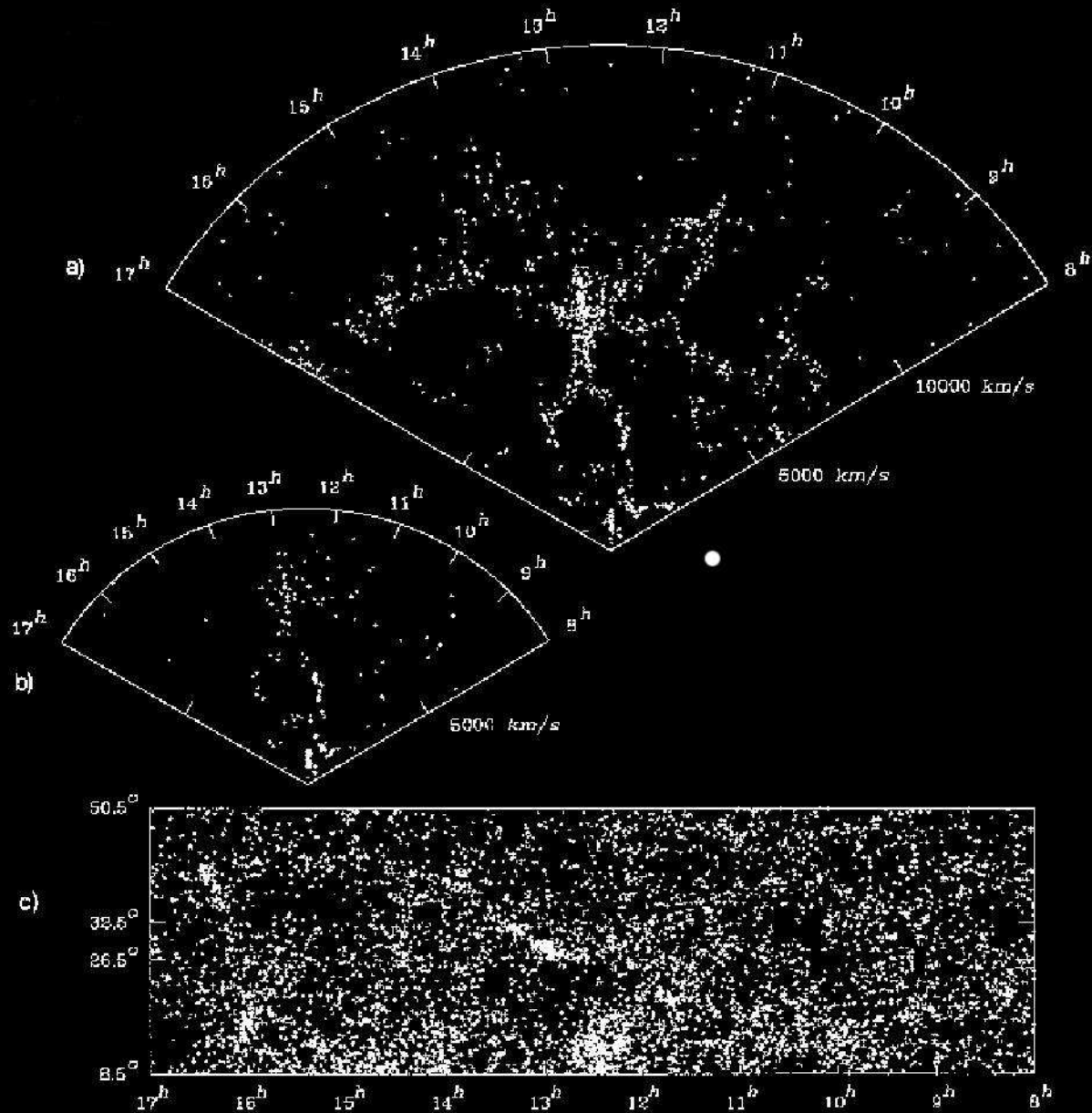


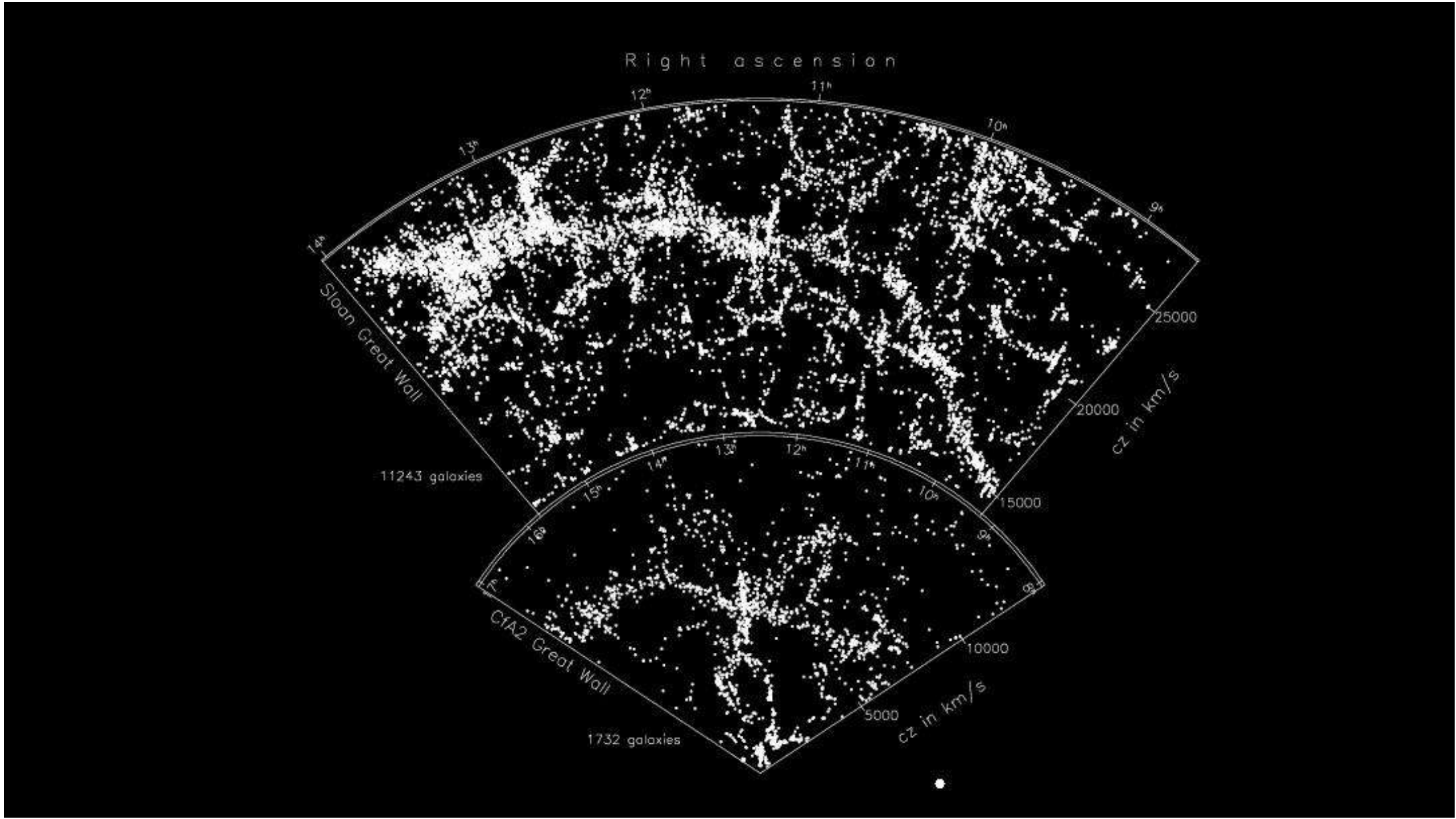


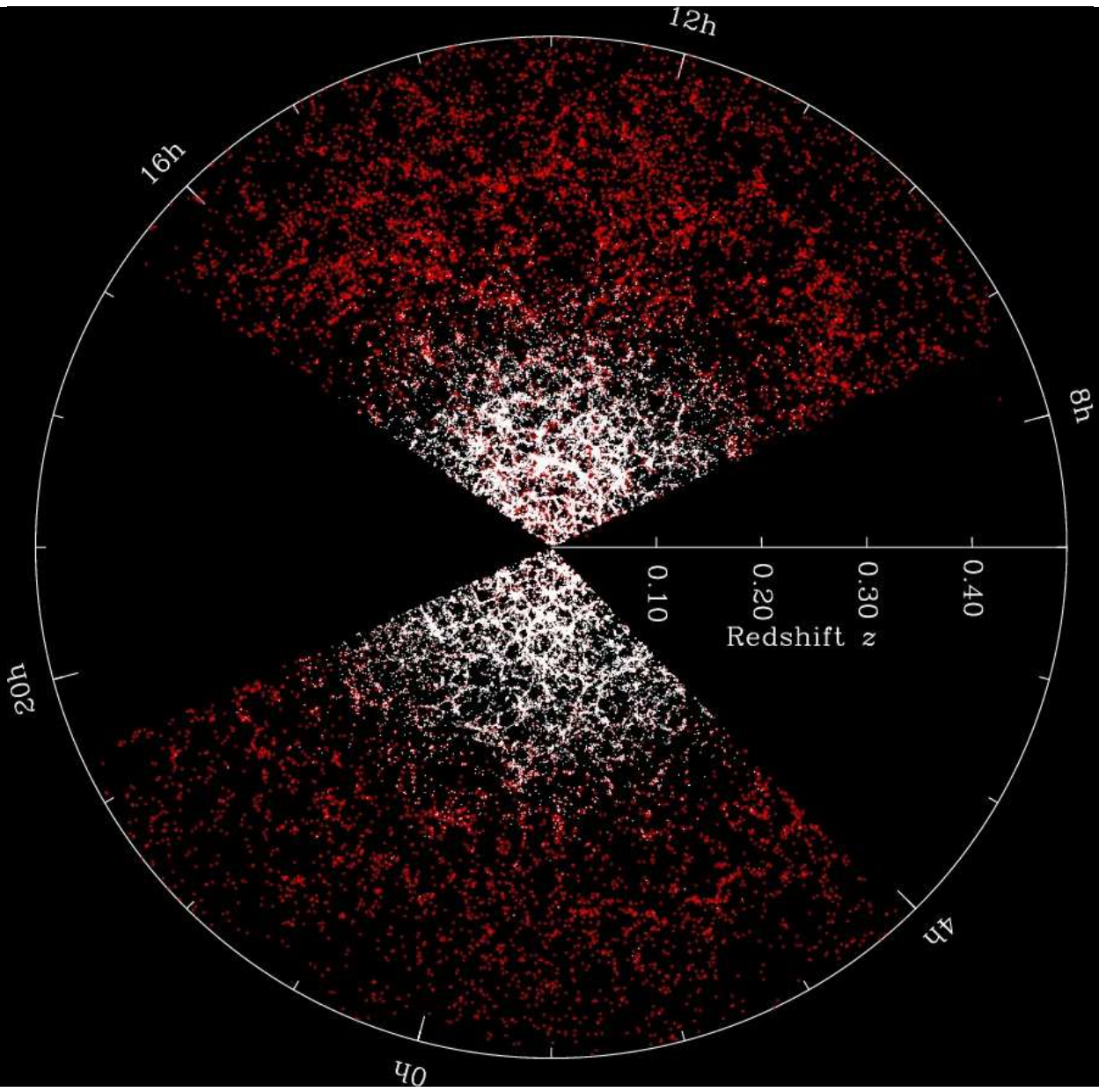
rpowell



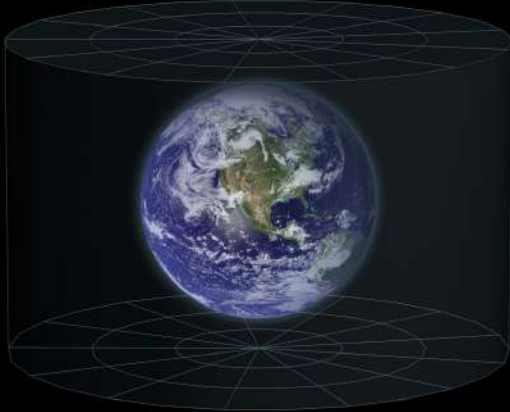
Huchra & Geller 1986



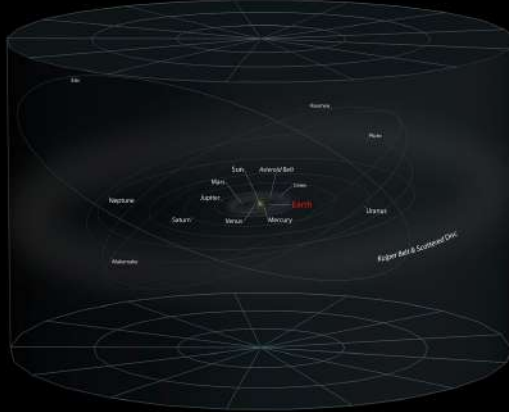




Earth



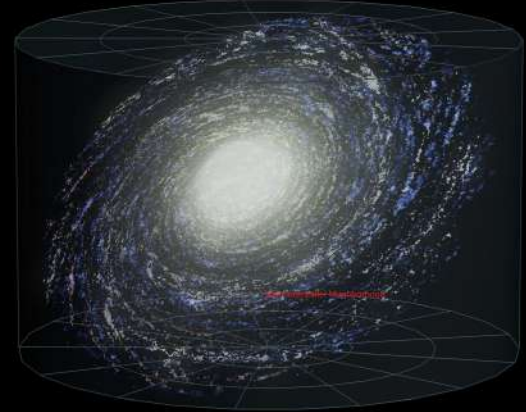
Solar System



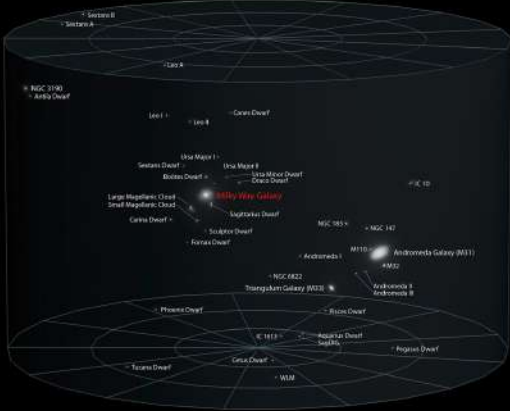
Solar Interstellar Neighborhood



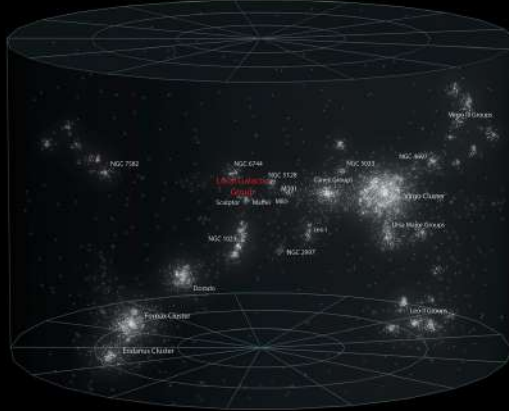
Milky Way Galaxy



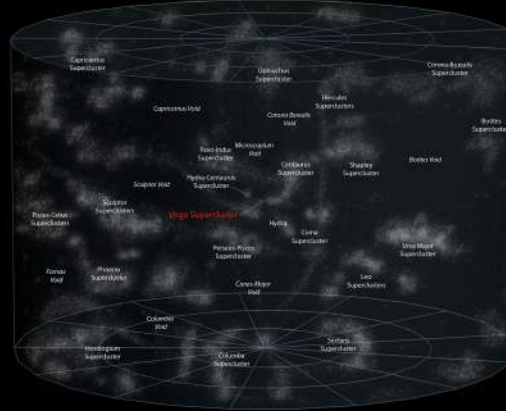
Local Galactic Group



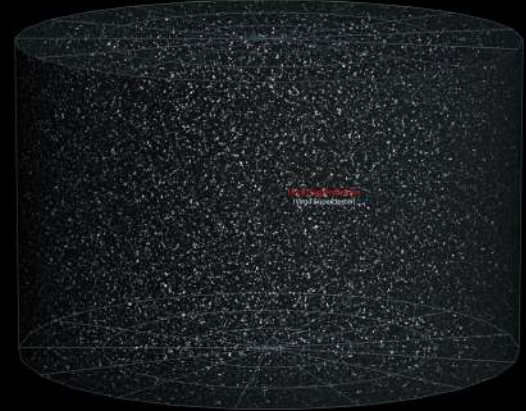
Virgo Supercluster



Local Superclusters



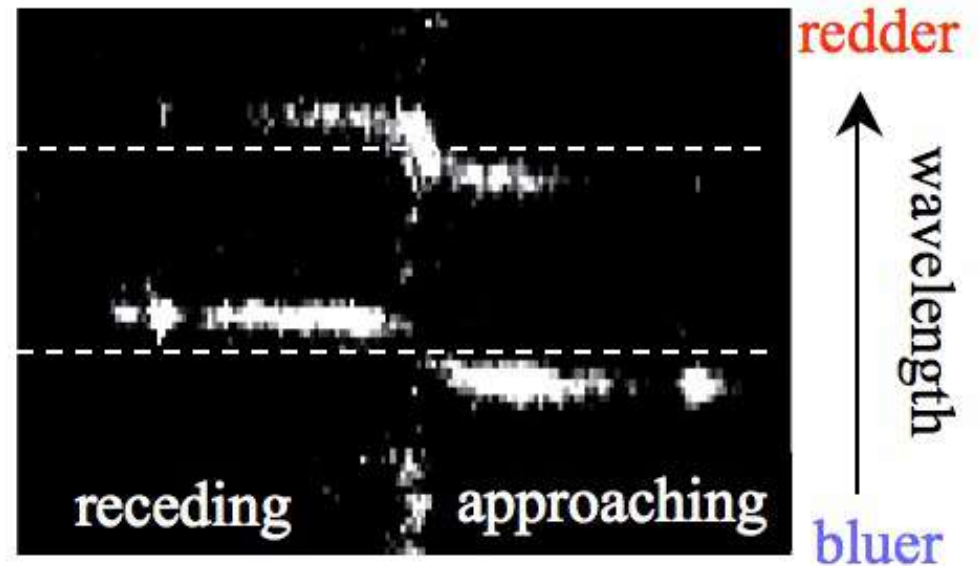
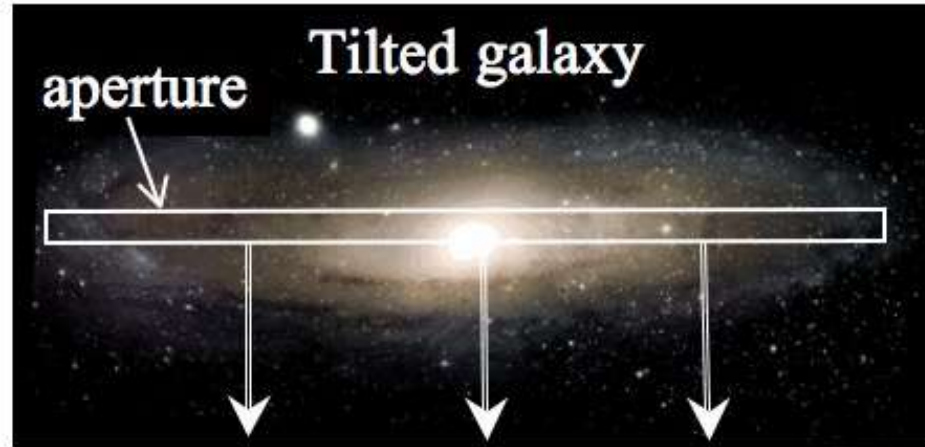
Observable Universe







Vera Rubin measuring galaxy rotation curves (~1970)

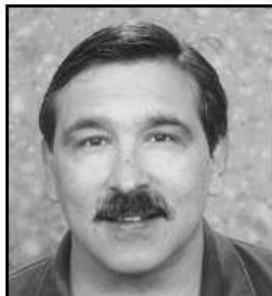


Resulting spectrum of light within aperture

The “NFW” form for dark matter halos



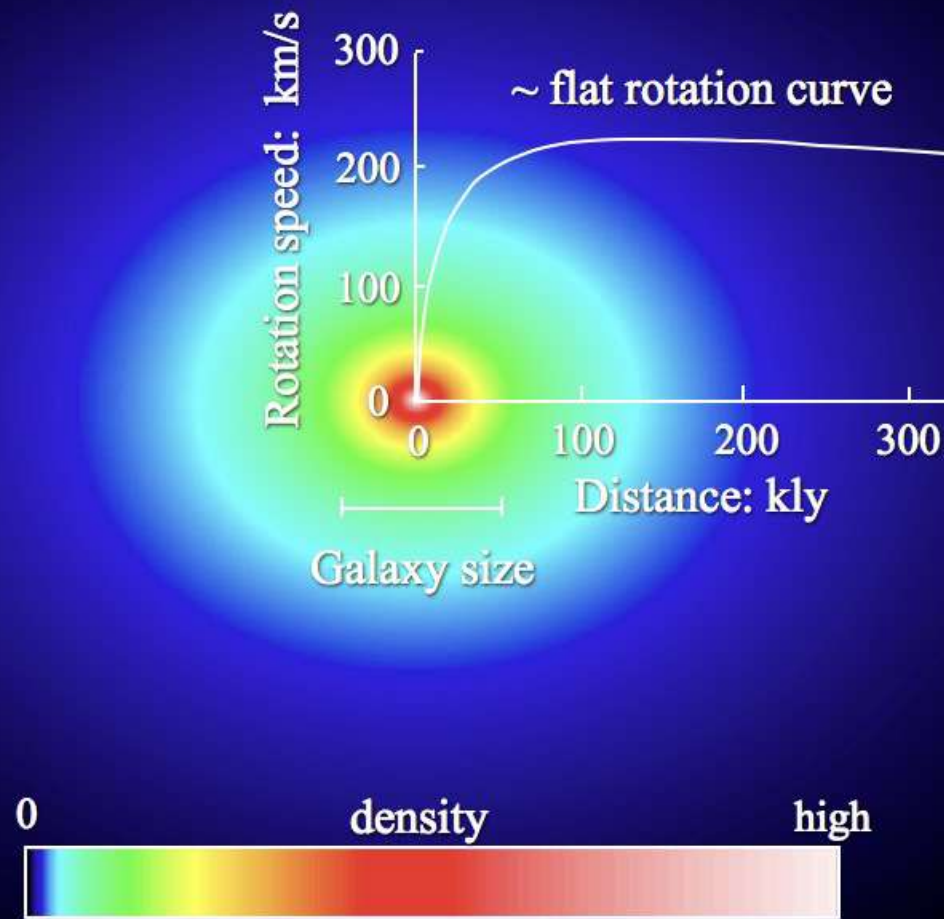
Julio Navarro



Carlos Frenk



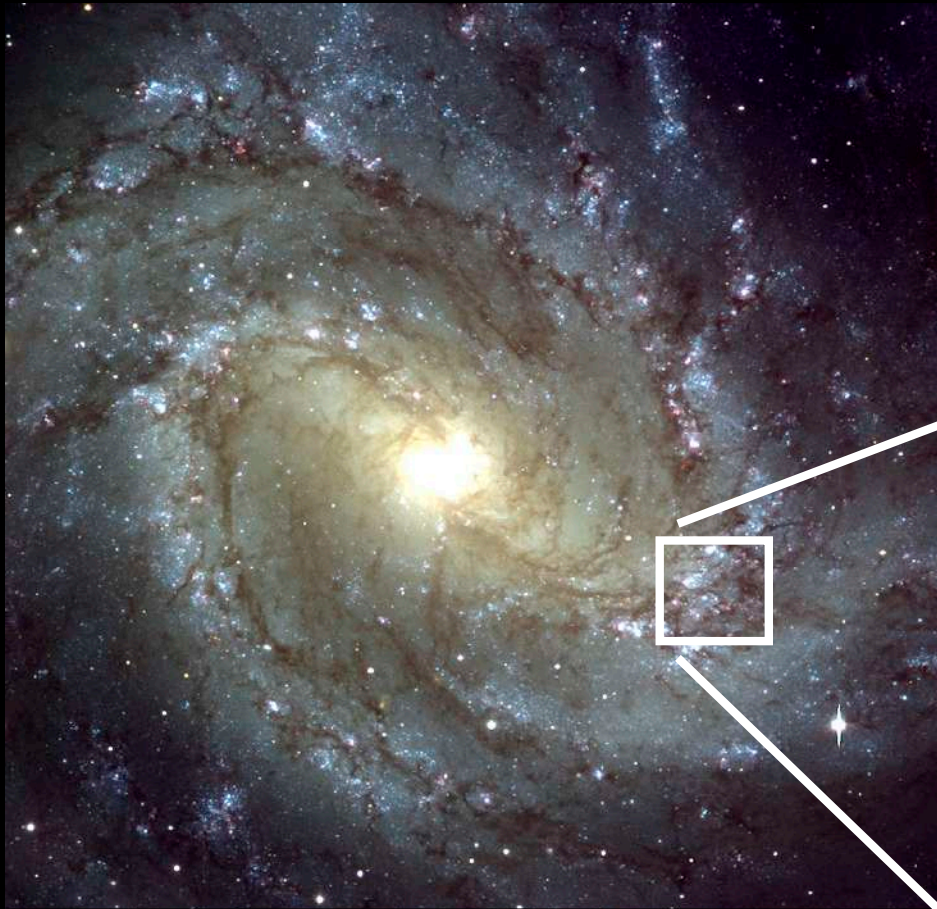
Simon White



Tasa de Formación Estelar (SFR)

Cantidad de gas (masas solares) convertidas en estrellas, por unidad de tiempo

$$\text{SFR} [M_{\odot}/\text{año}] = K * \text{Luminosidad}$$

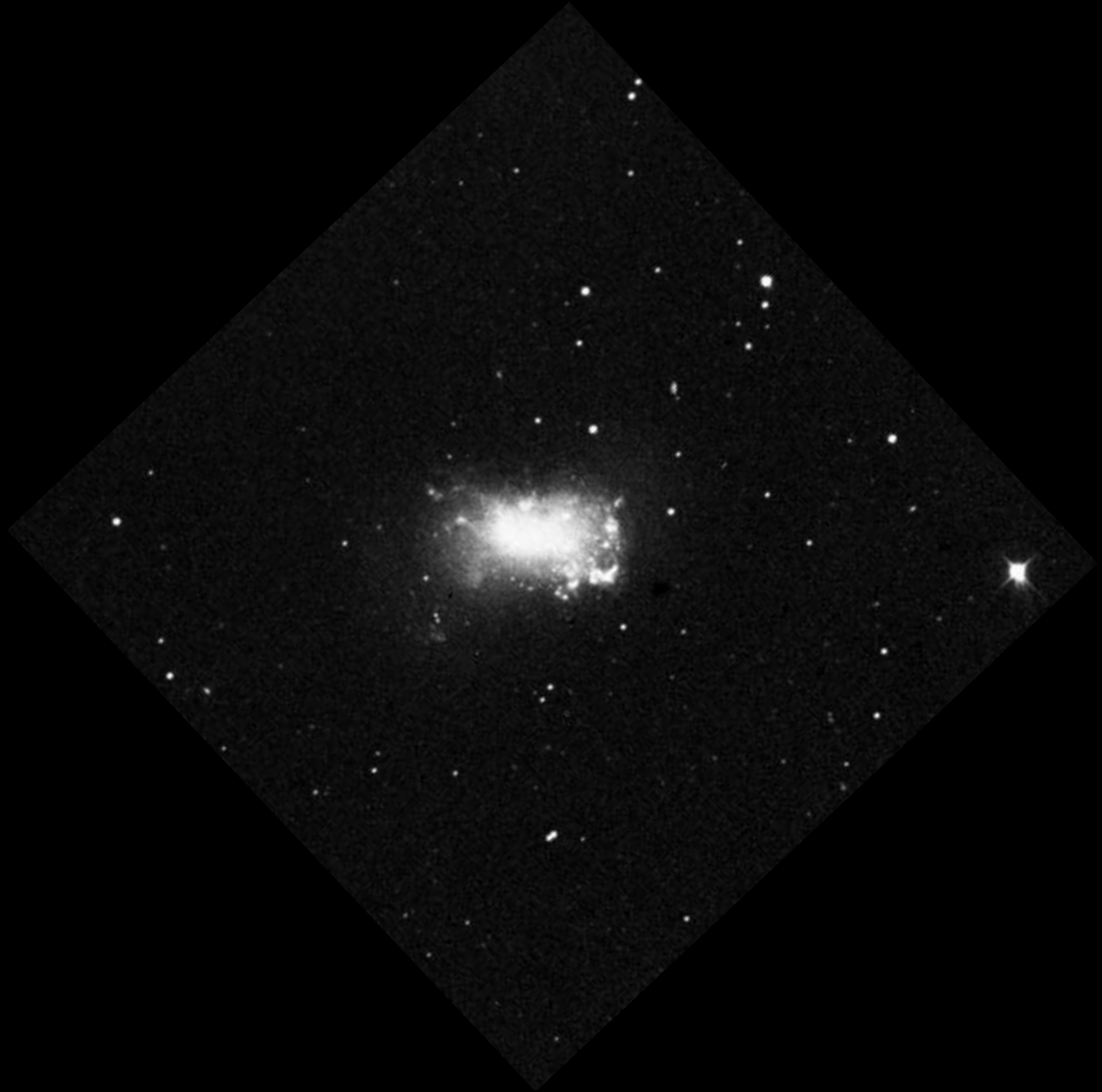


SFR (Vía Láctea) = 1.3 M_{\odot} /año



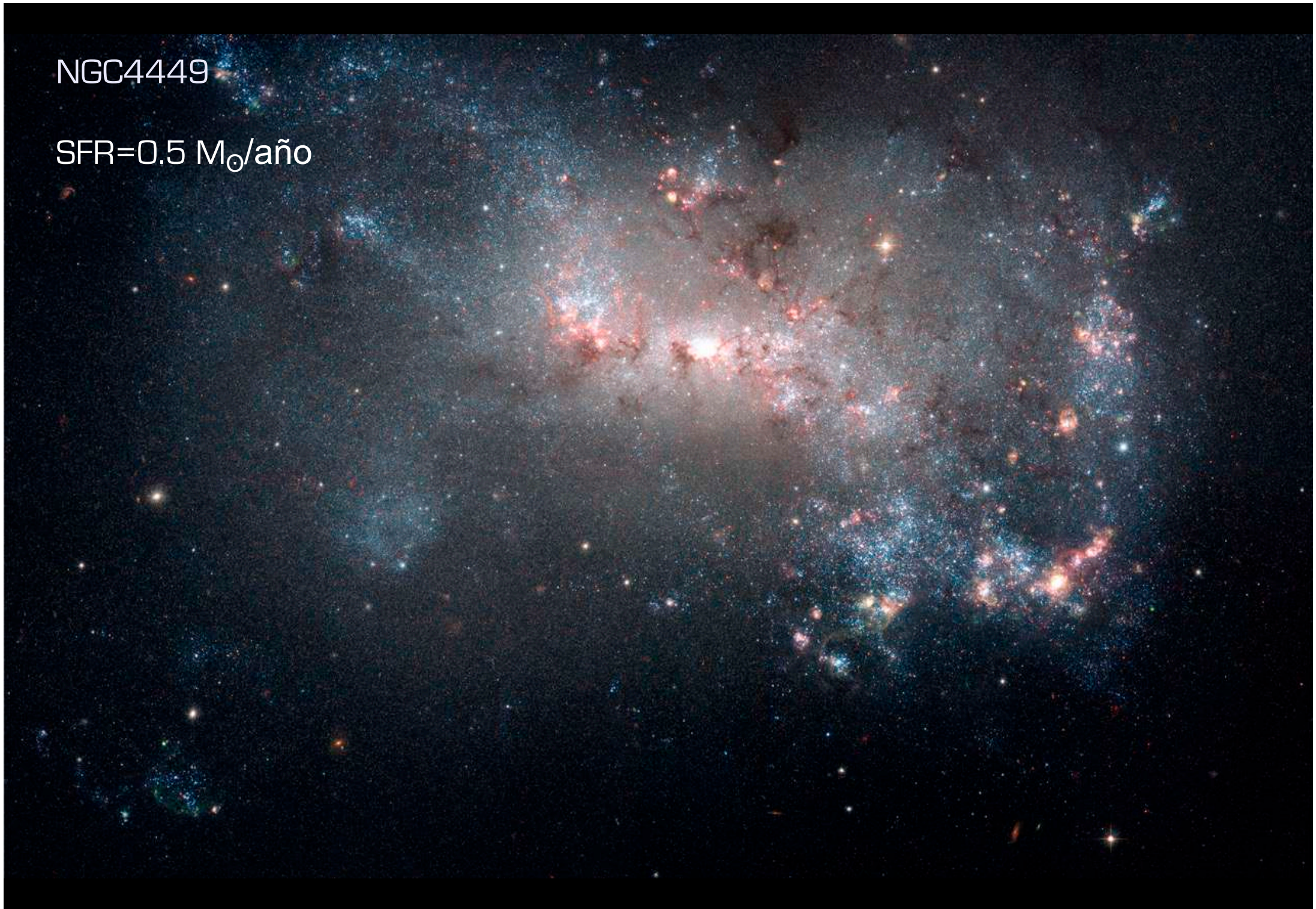
NGC4449

SFR=0.5 M_{\odot} /año



NGC4449

SFR=0.5 M_{\odot} /año



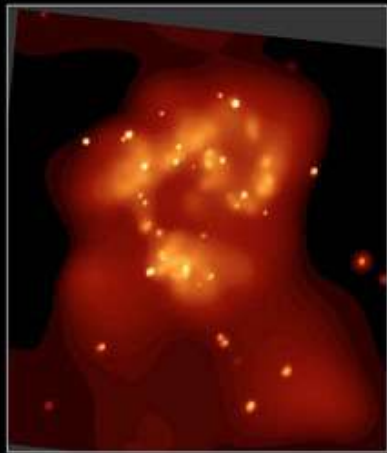
NGC4038 & 4039: la interacción dispara la formación estelar

SFR=300 M_{\odot} /año

SFR específica
SFR/M



Rayos-X



Óptico



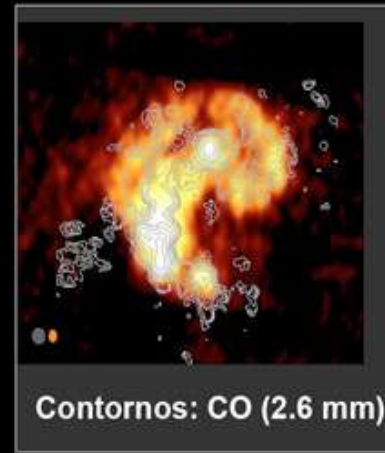
NIR



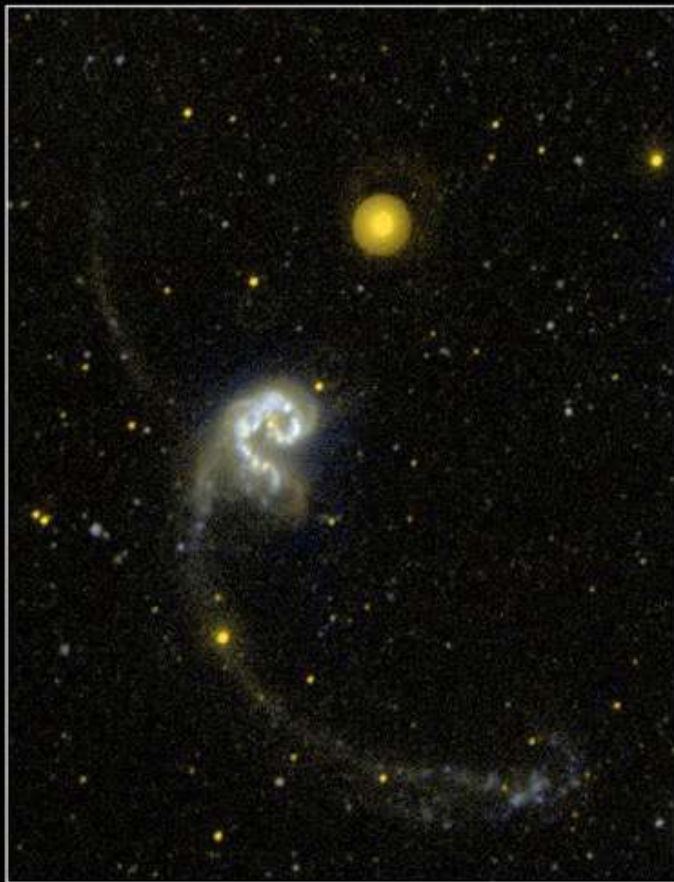
FIR



Radiocontinuo (20 cm)



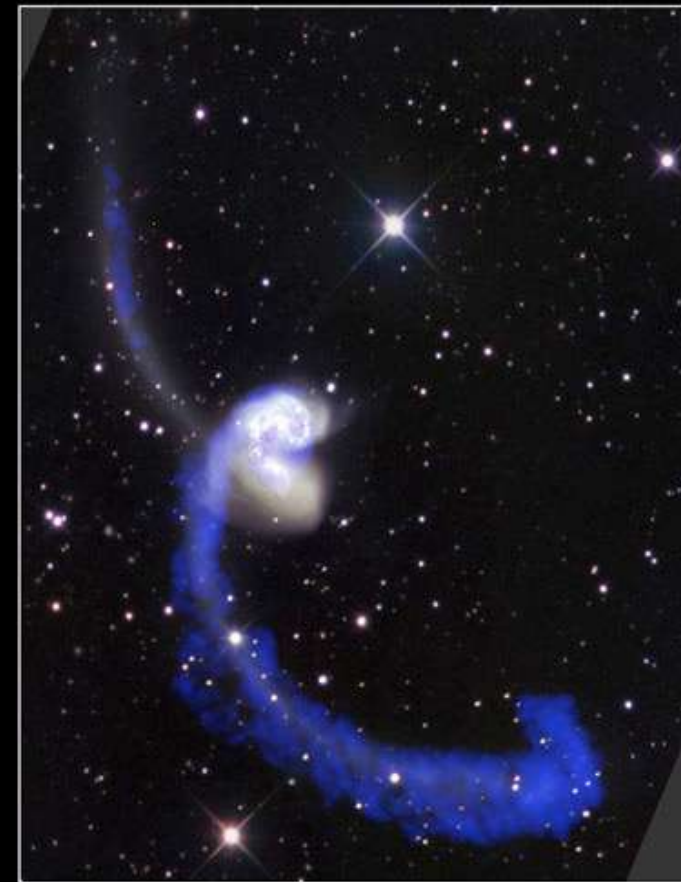
Contornos: CO (2.6 mm)



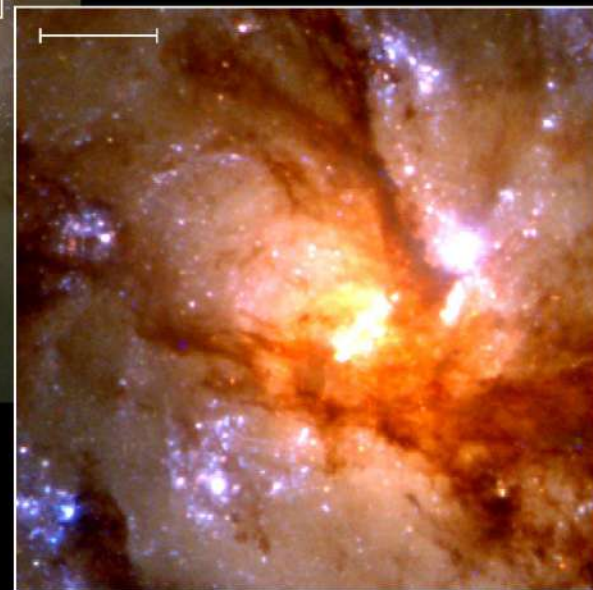
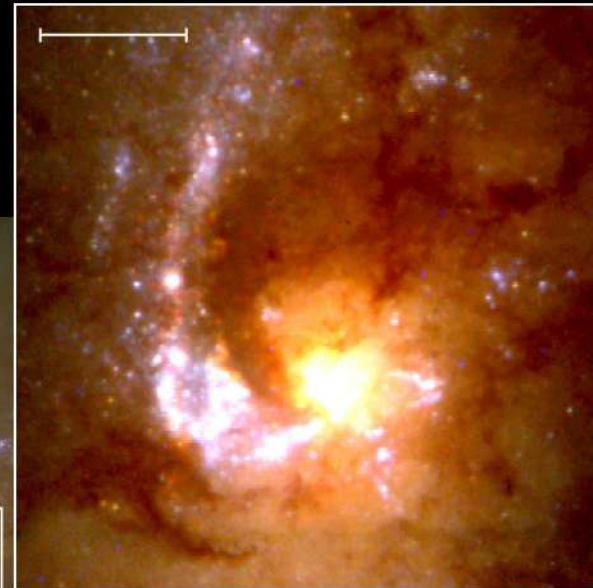
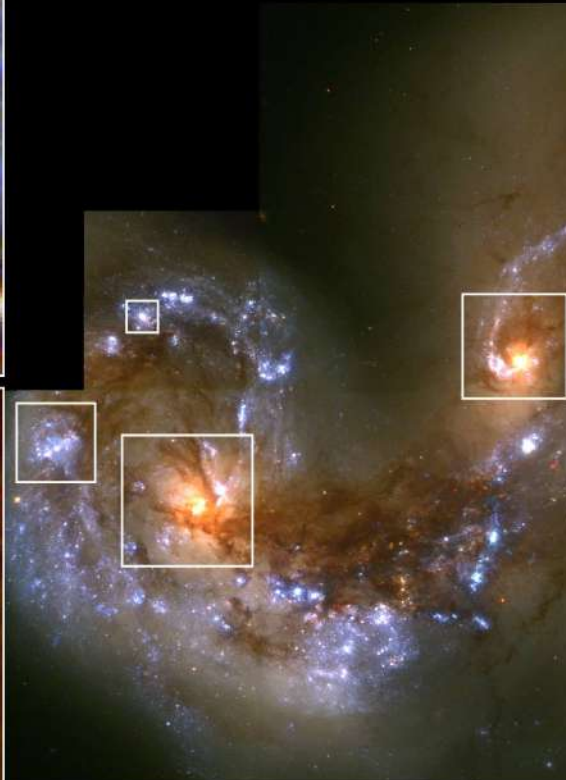
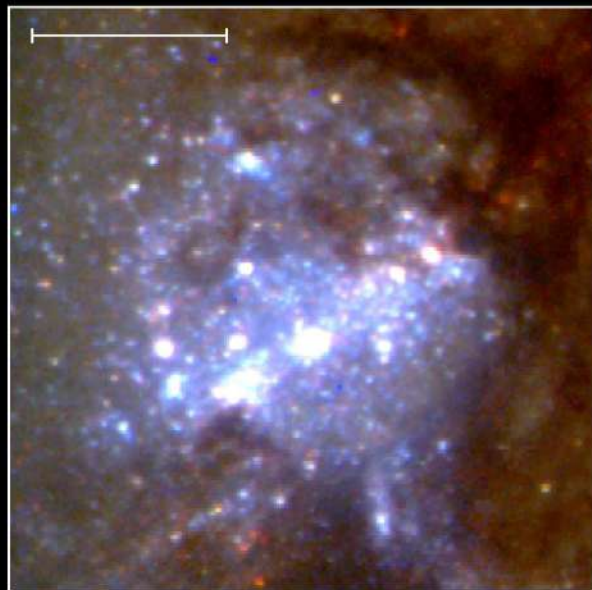
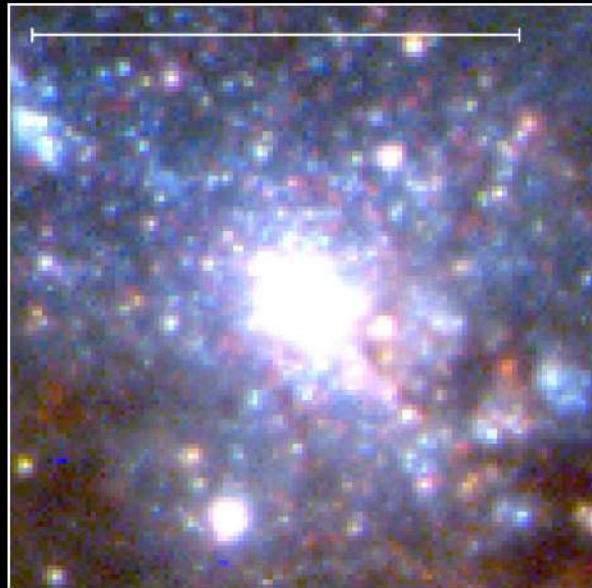
UV



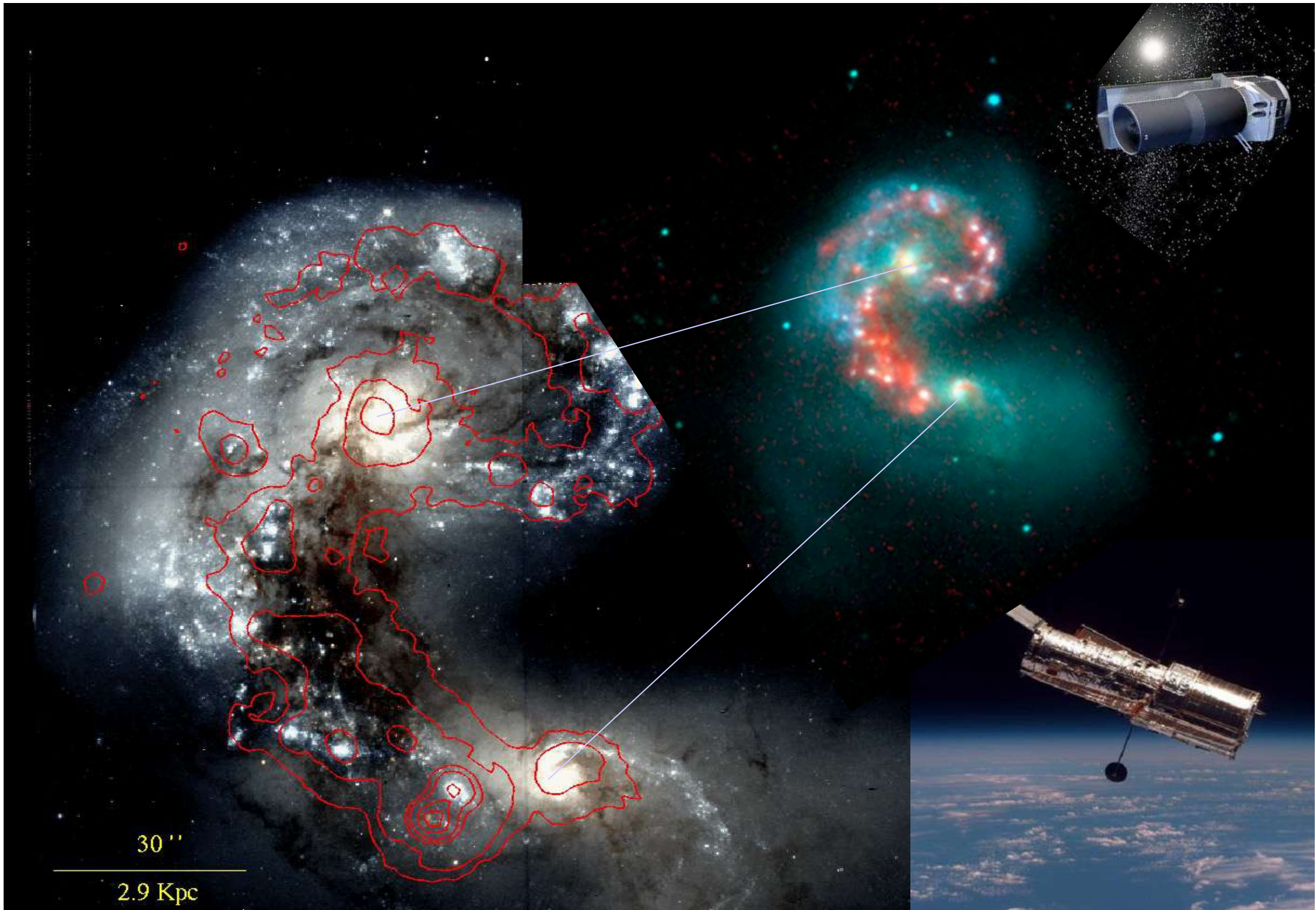
Óptico

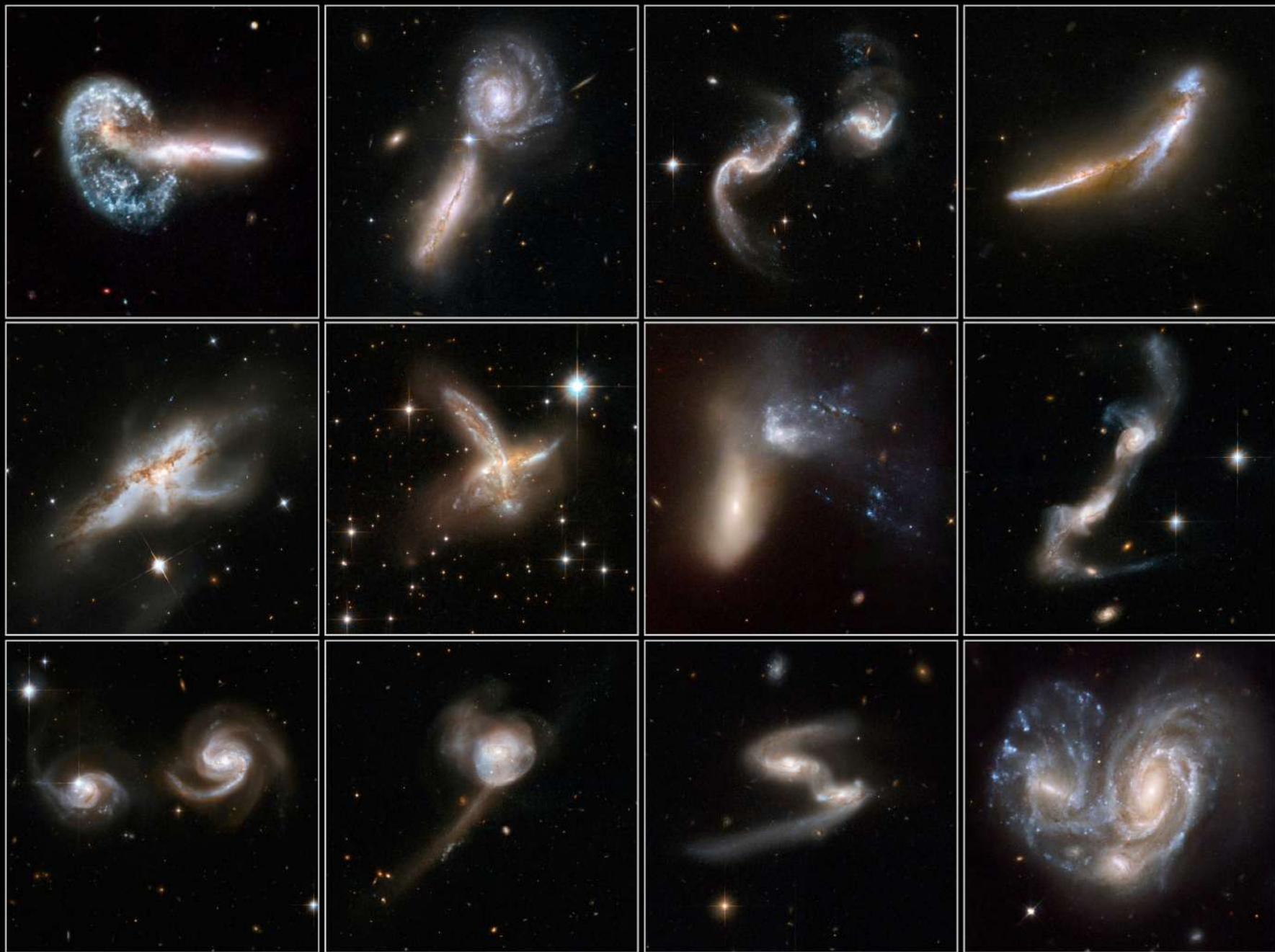


HI (21 cm)

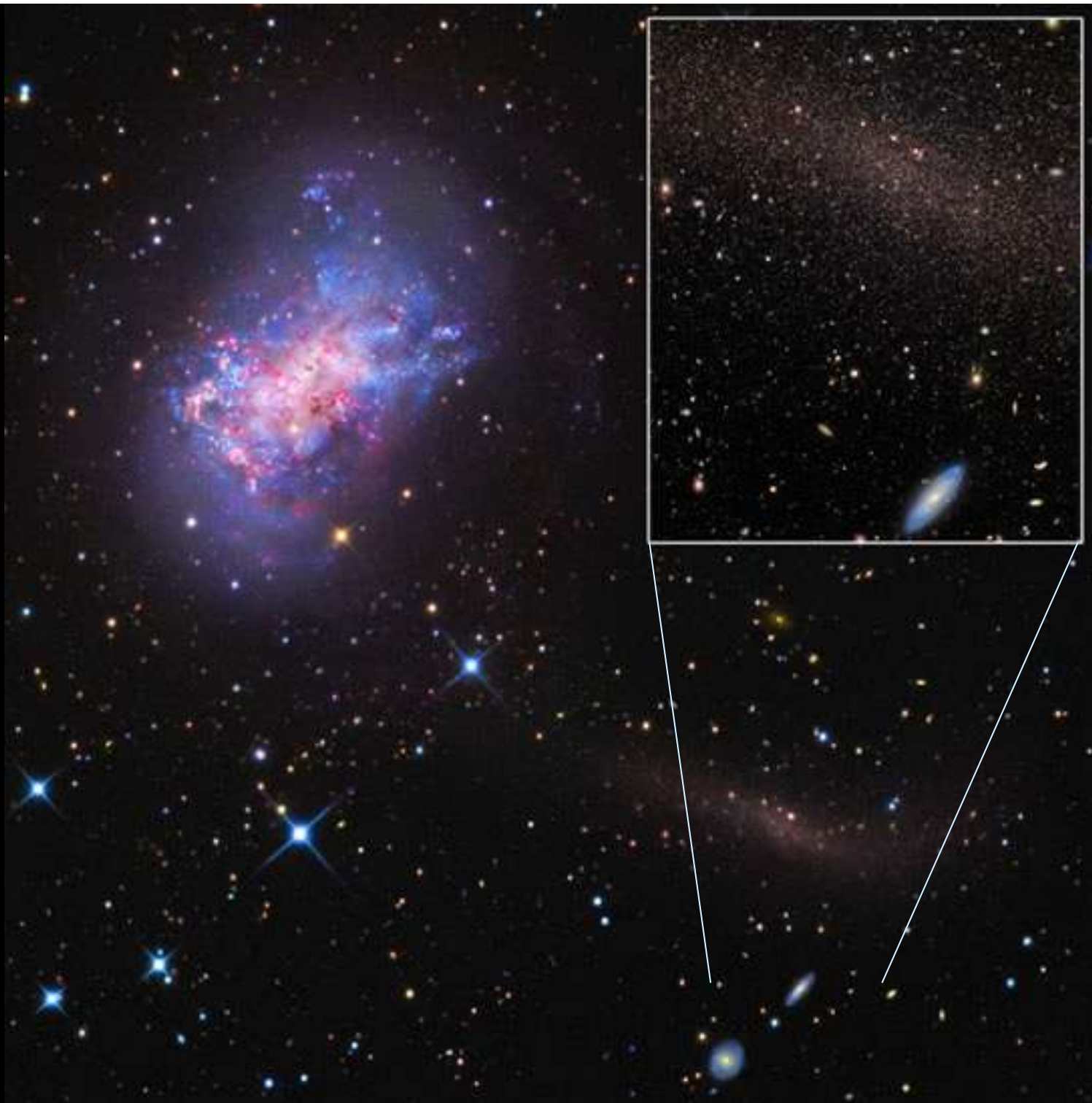


Galaxies NGC 4038 and NGC 4039 • Detail
Hubble Space Telescope • Wide Field Planetary Camera 2



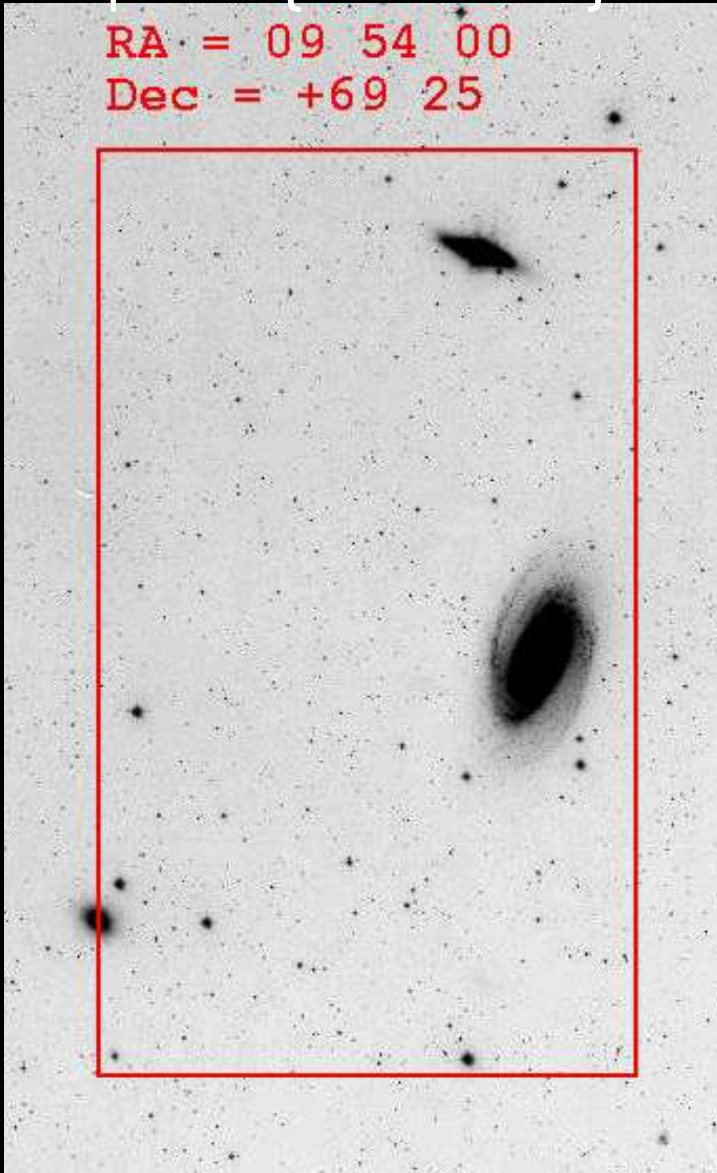


NGC4449 y
NGC4449B

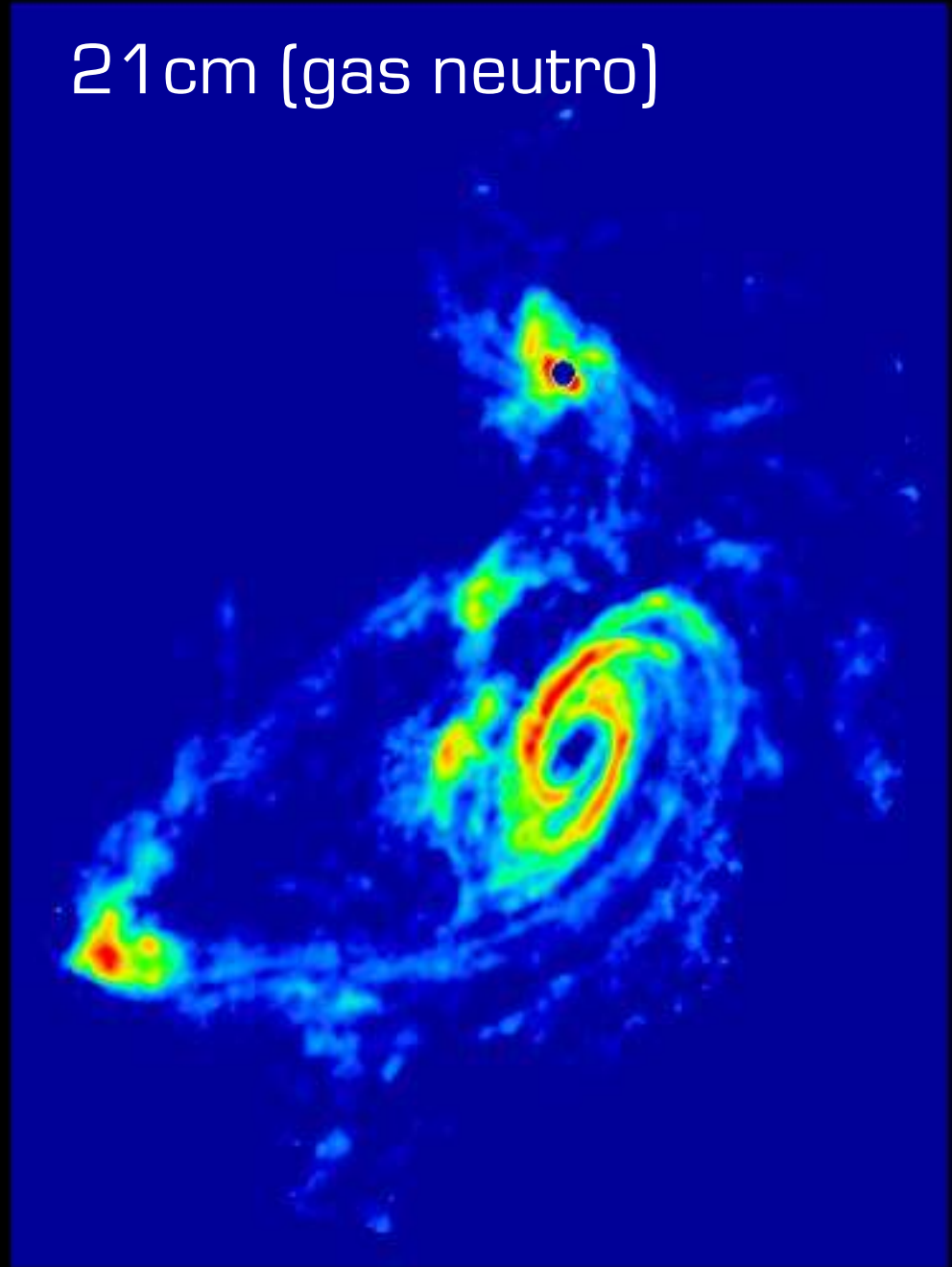


Óptico (estrellas)

RA = 09 54 00
Dec = +69 25



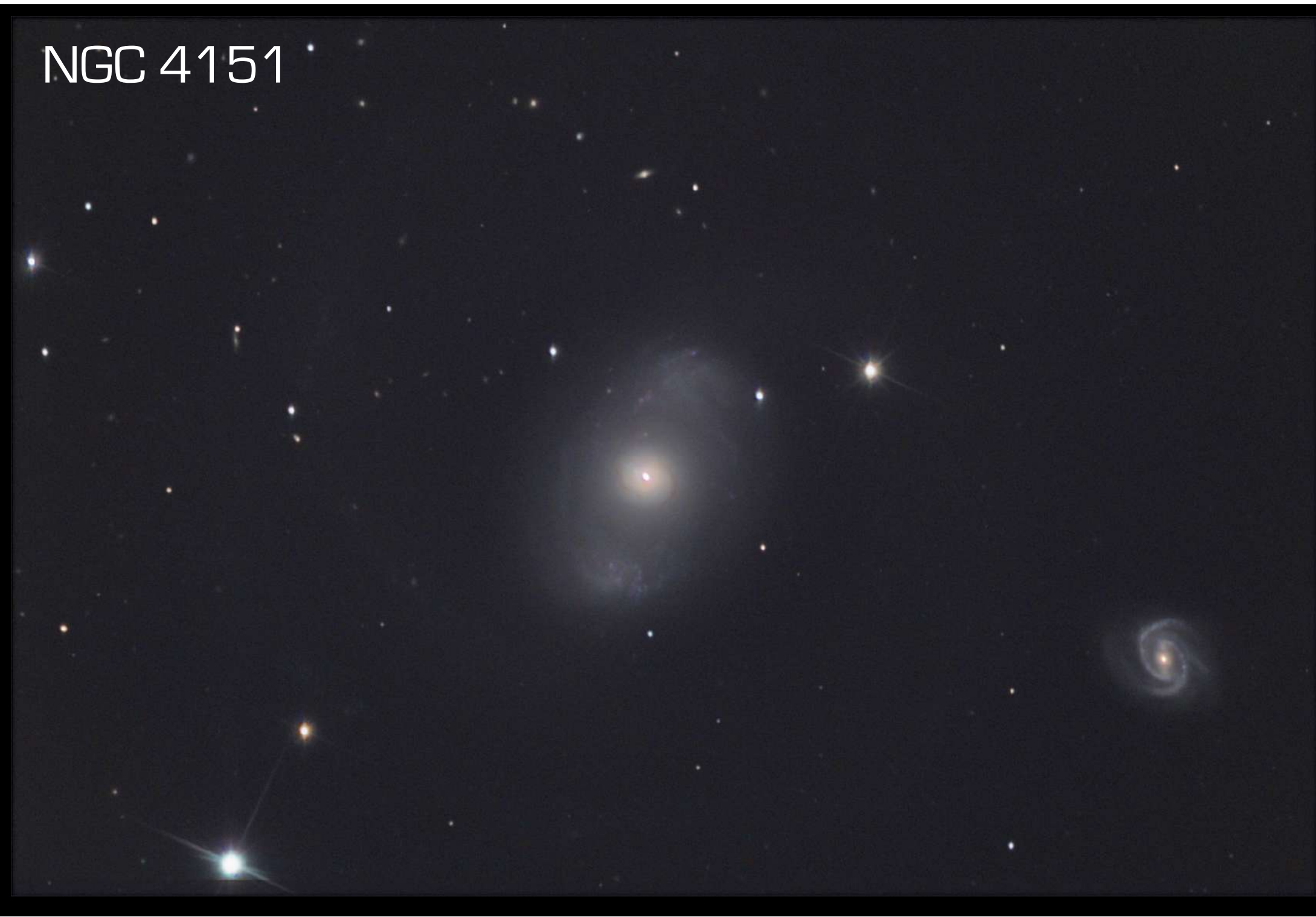
21cm (gas neutro)



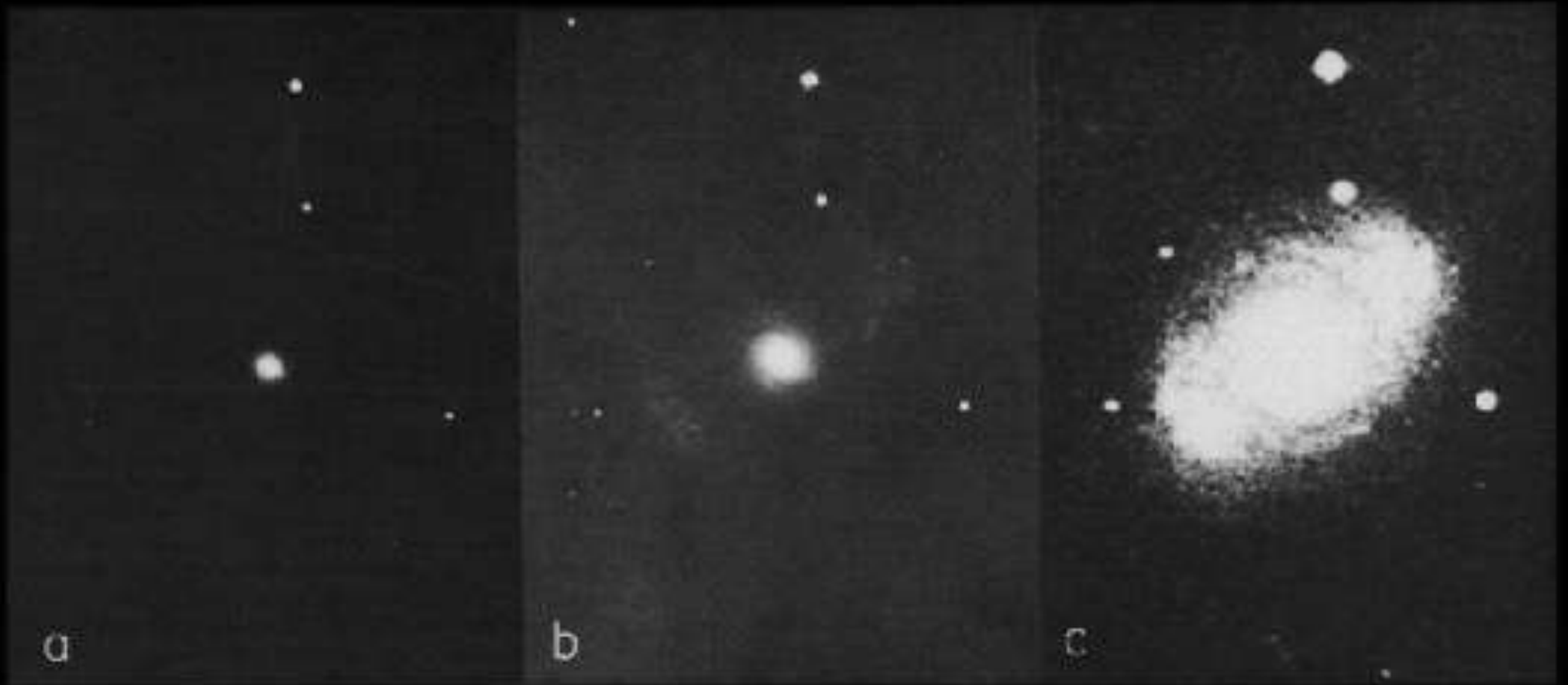




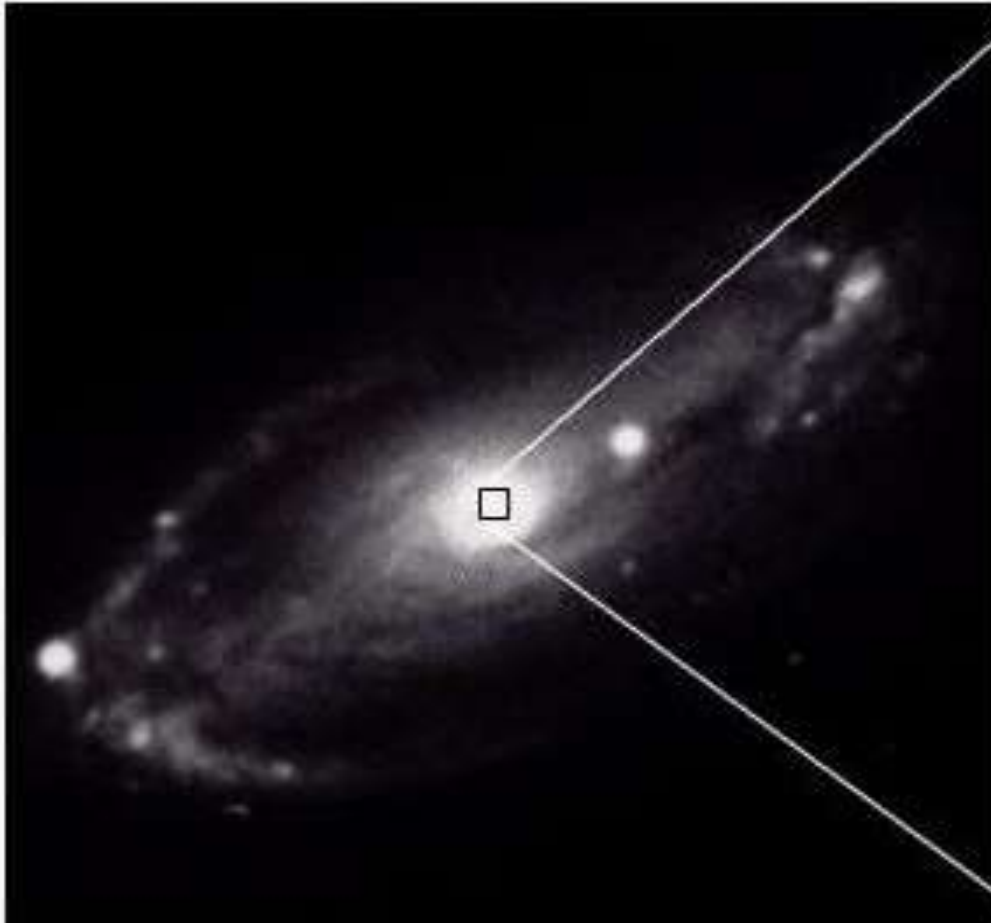
NGC 4151



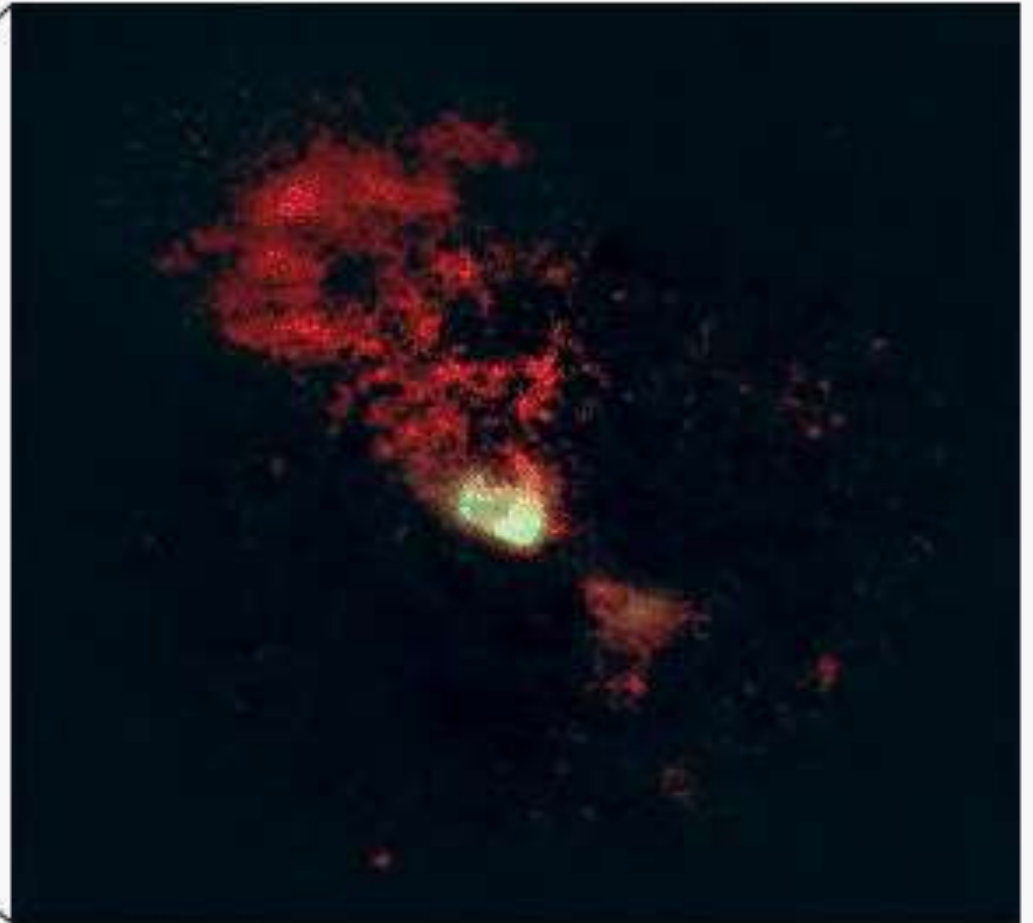
NGC 4151



NGC 5728



Ground View



HST View

M87

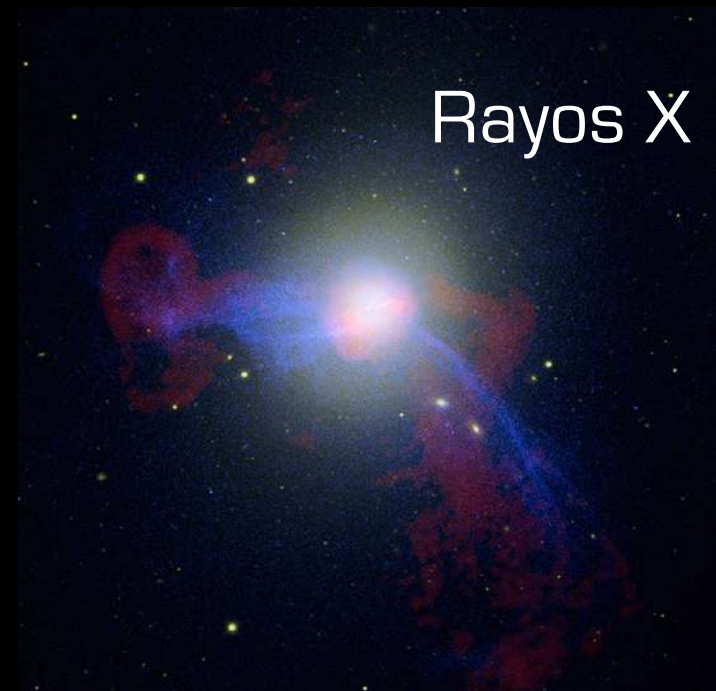
Núcleo activo +
Chorro de gas



Visible



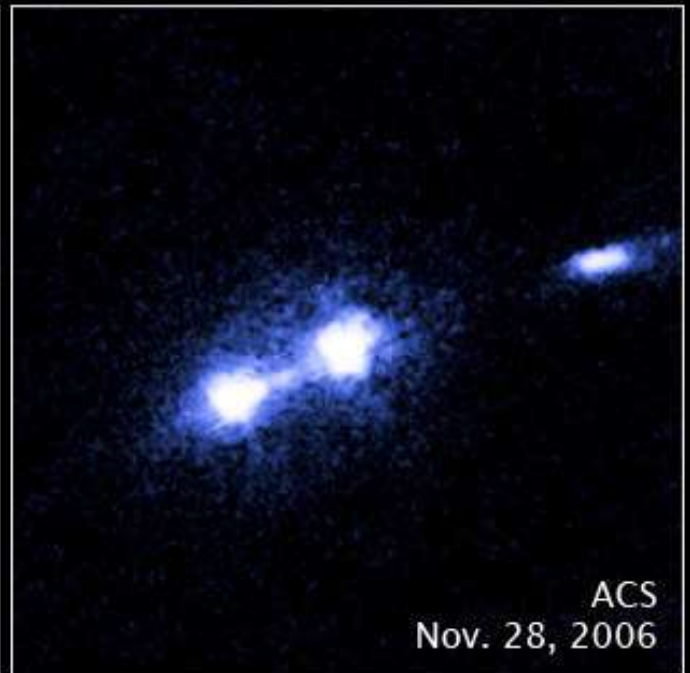
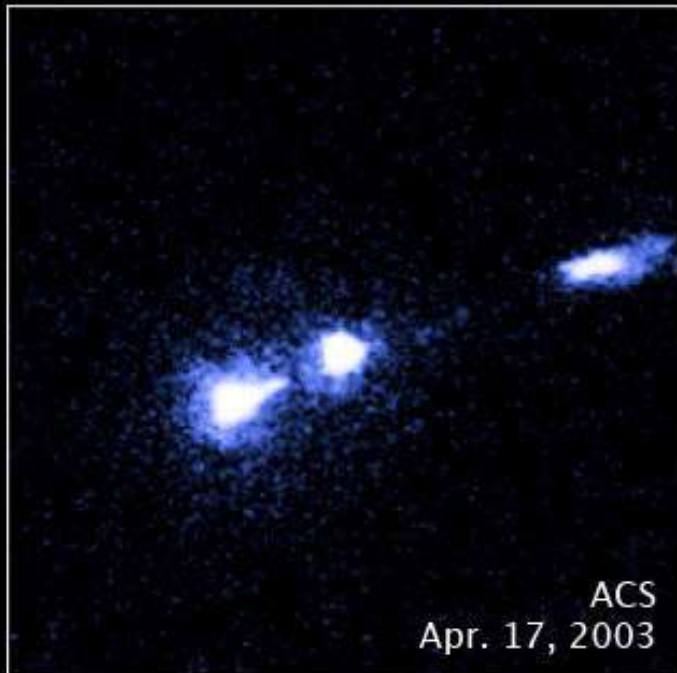
Rayos X

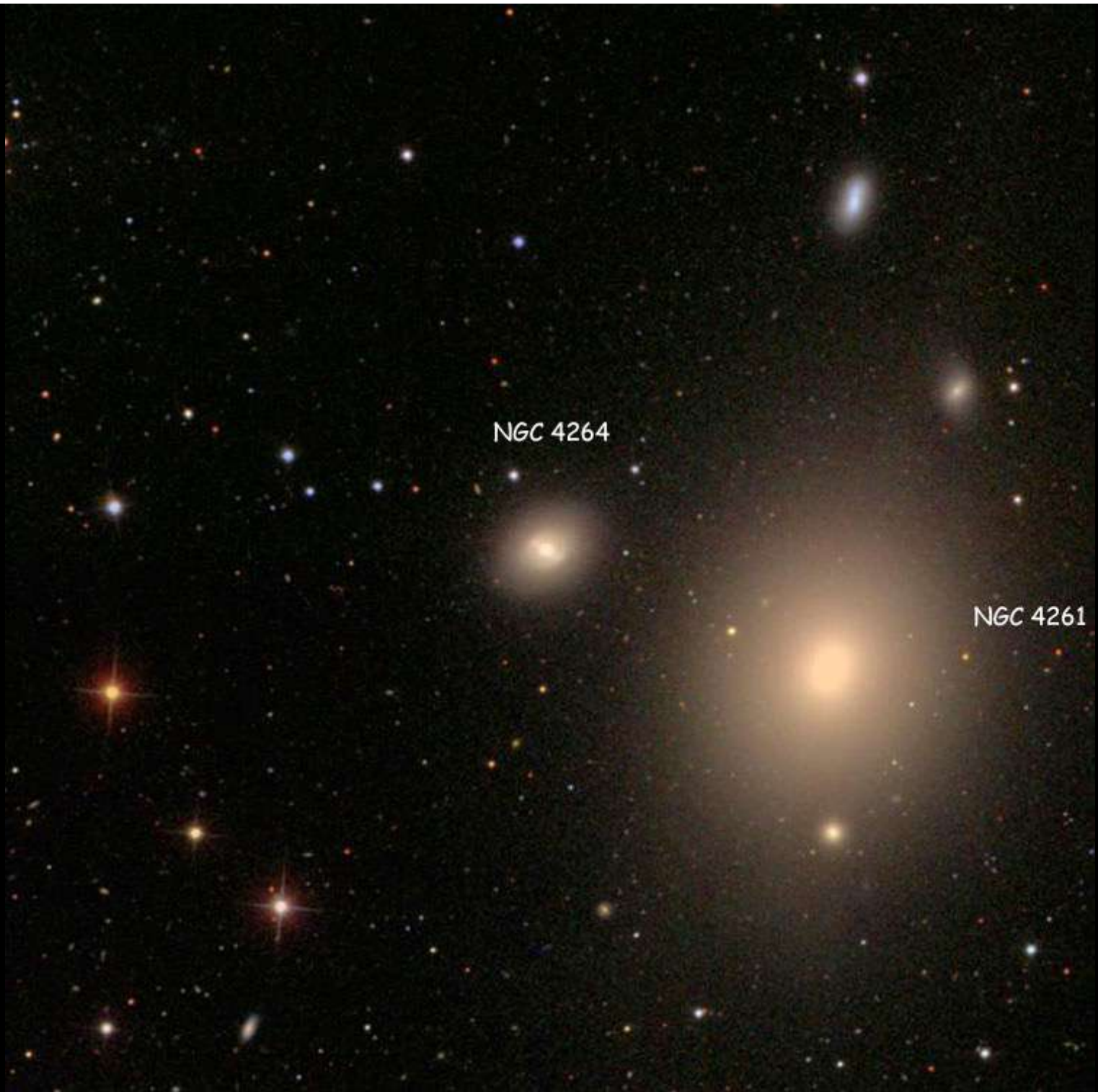


Radio

M87 Nucleus and Bright Knot in Extragalactic Jet

HST • STIS/MAMA • ACS/HRC





NGC 4264

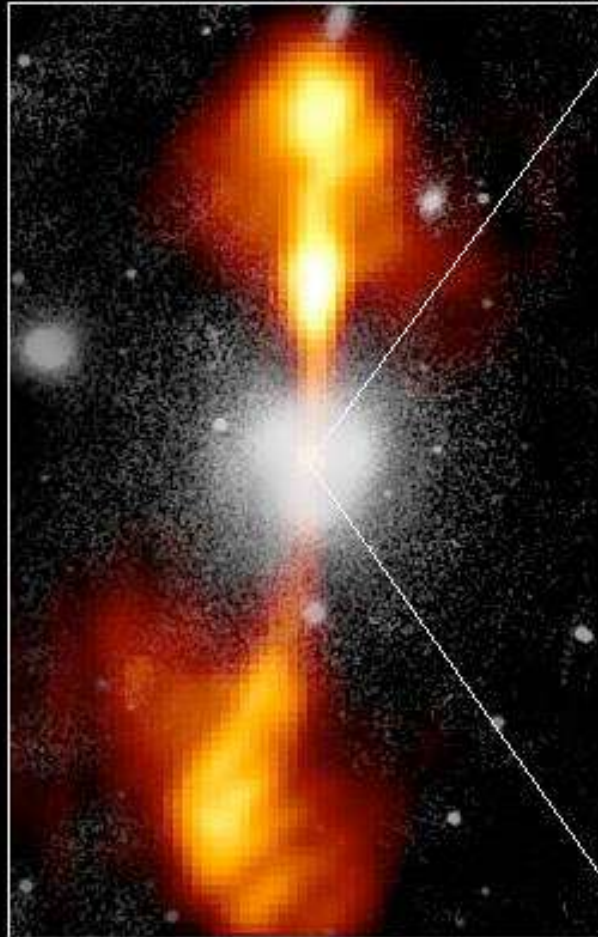
NGC 4261

Core of Galaxy NGC 4261

Hubble Space Telescope

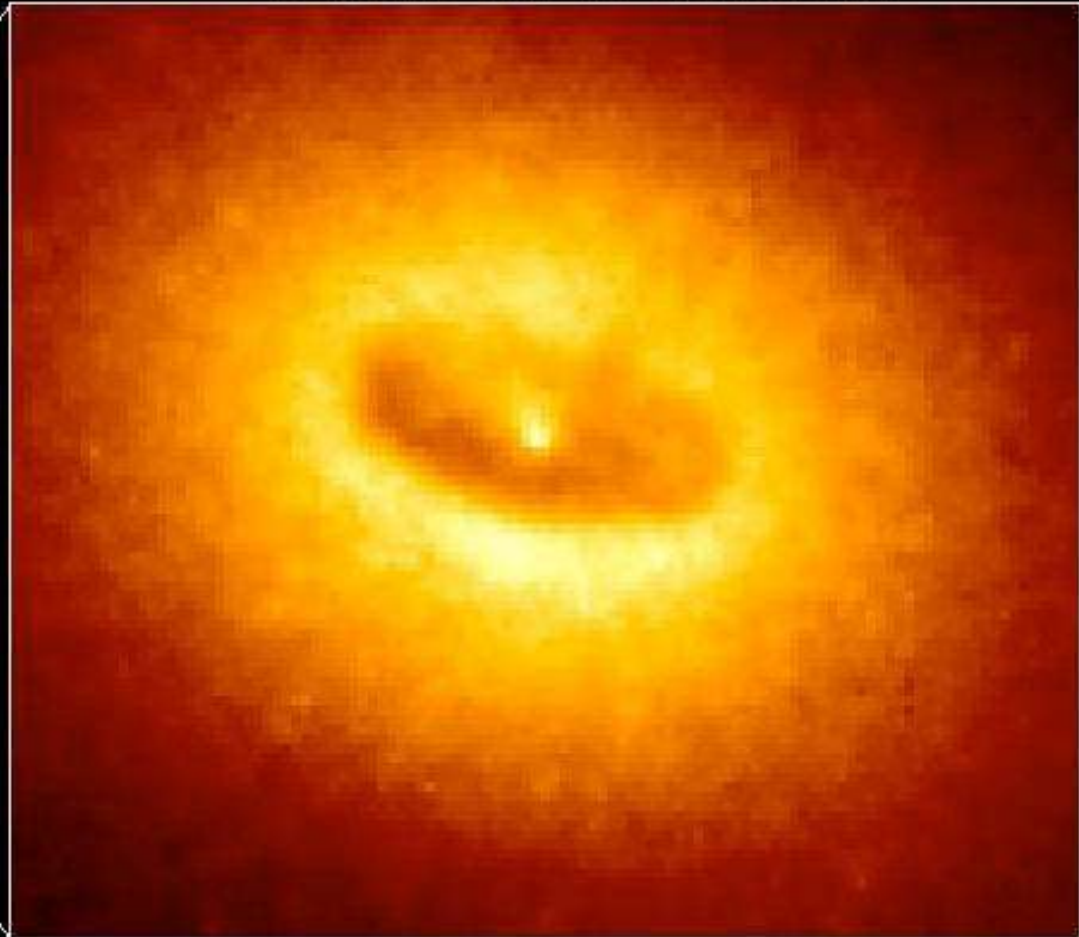
Wide Field / Planetary Camera

Ground-Based Optical/Radio Image



380 Arc Seconds
88,000 LIGHTYEARS

HST Image of a Gas and Dust Disk



17 Arc Seconds
400 LIGHTYEARS

Centaurus A



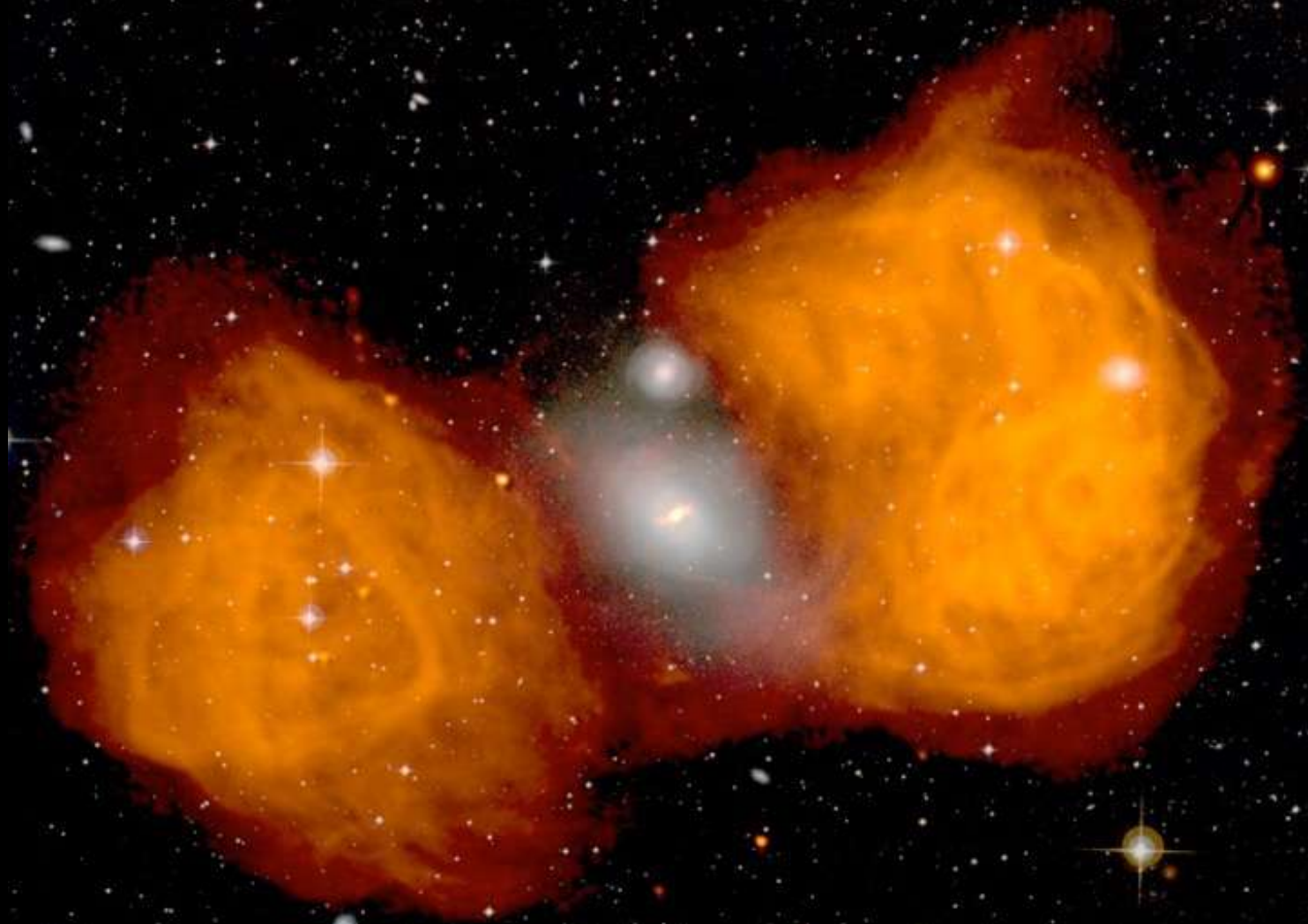
X-RAY

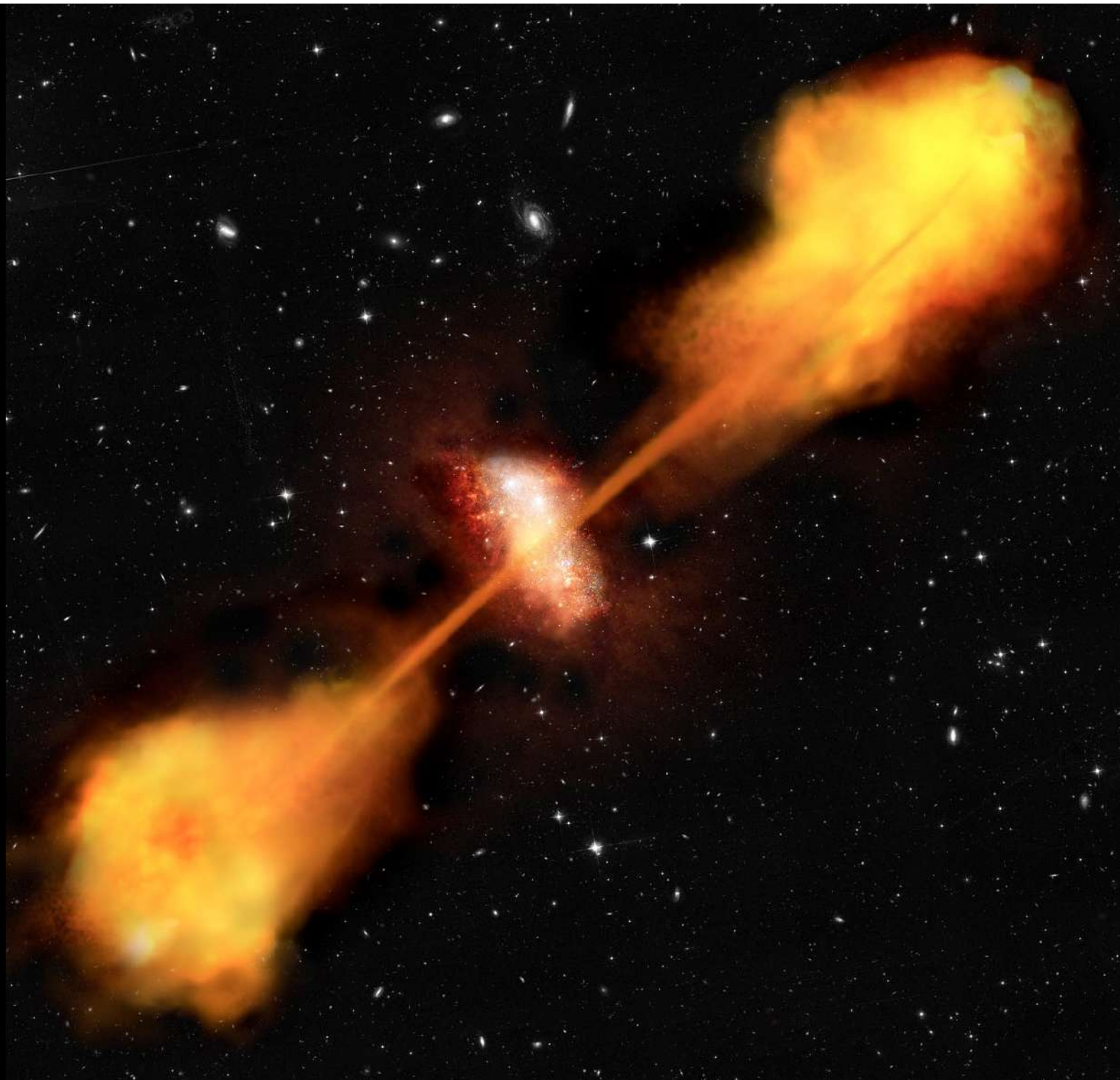
RADIO

OPTICAL

COMPOSITE

FORNAX- A



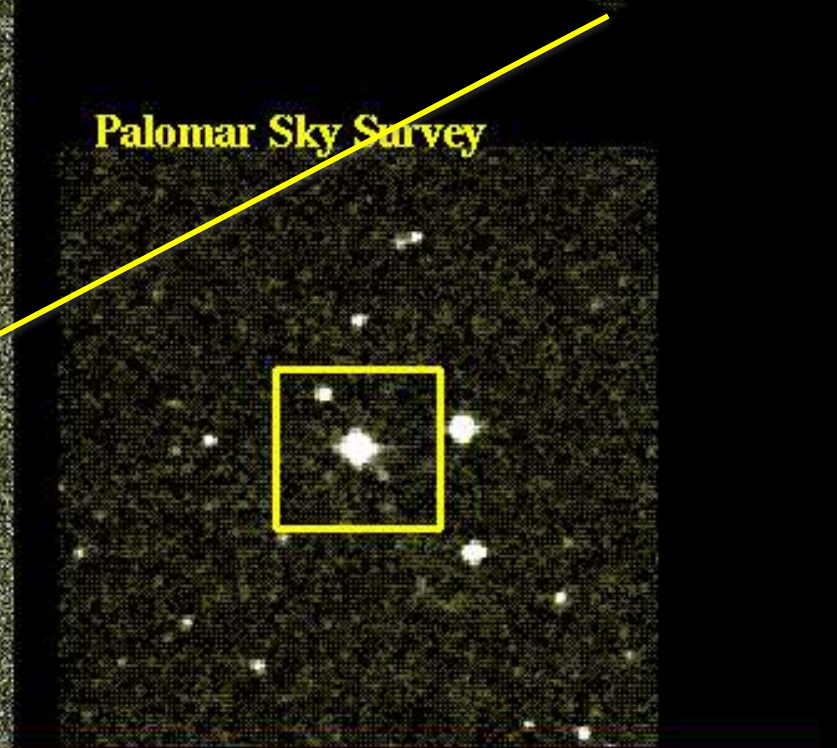
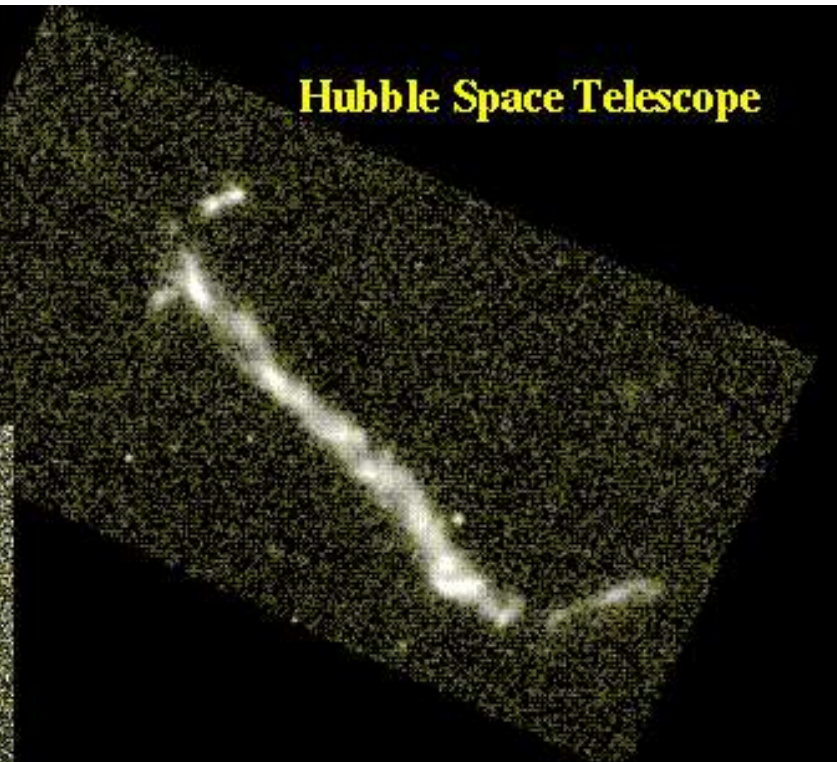
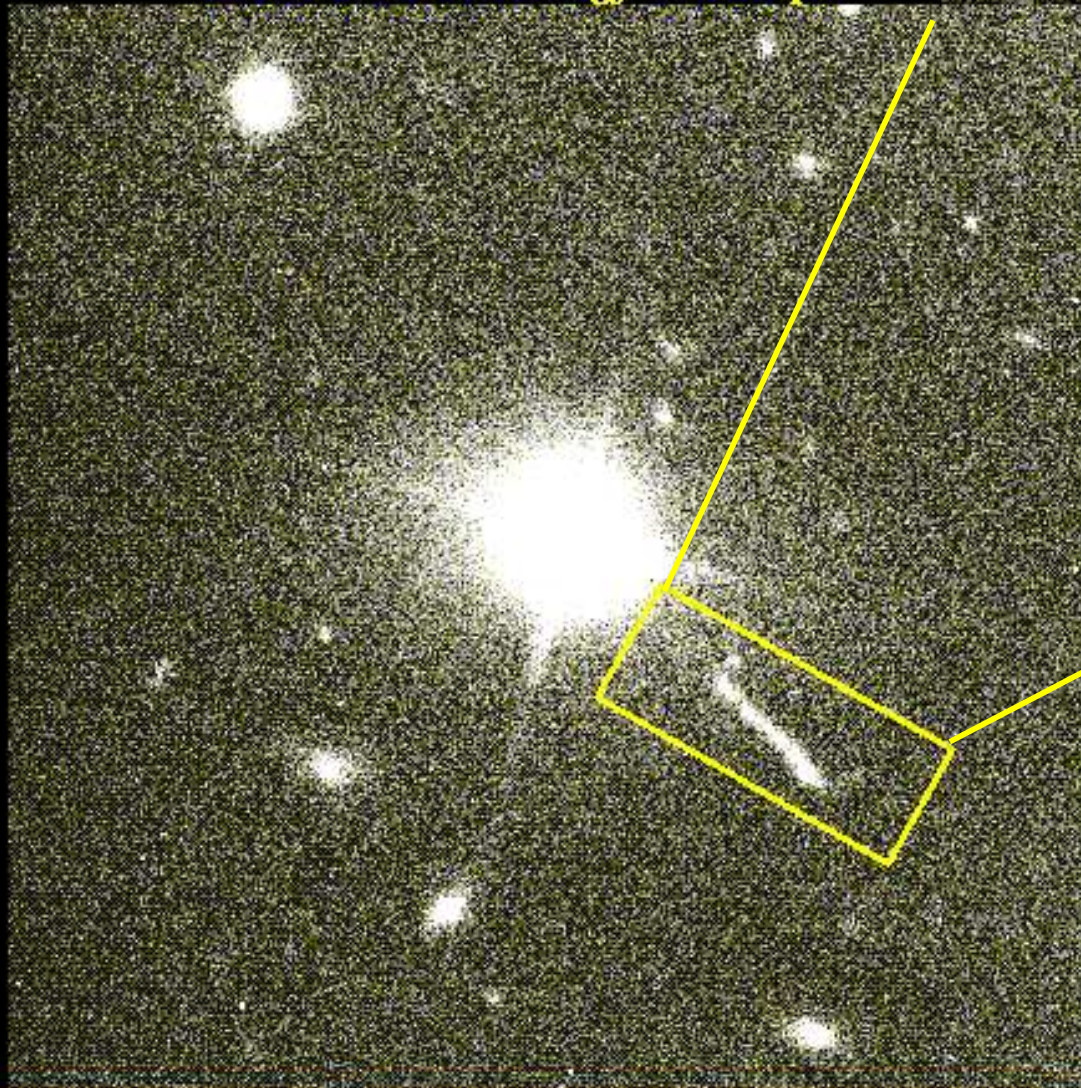


3C 273 y su chorro

Hubble Space Telescope

ESO New Technology Telescope

Palomar Sky Survey



Cuáasar 3C 273

Objeto
"casi"
estelar

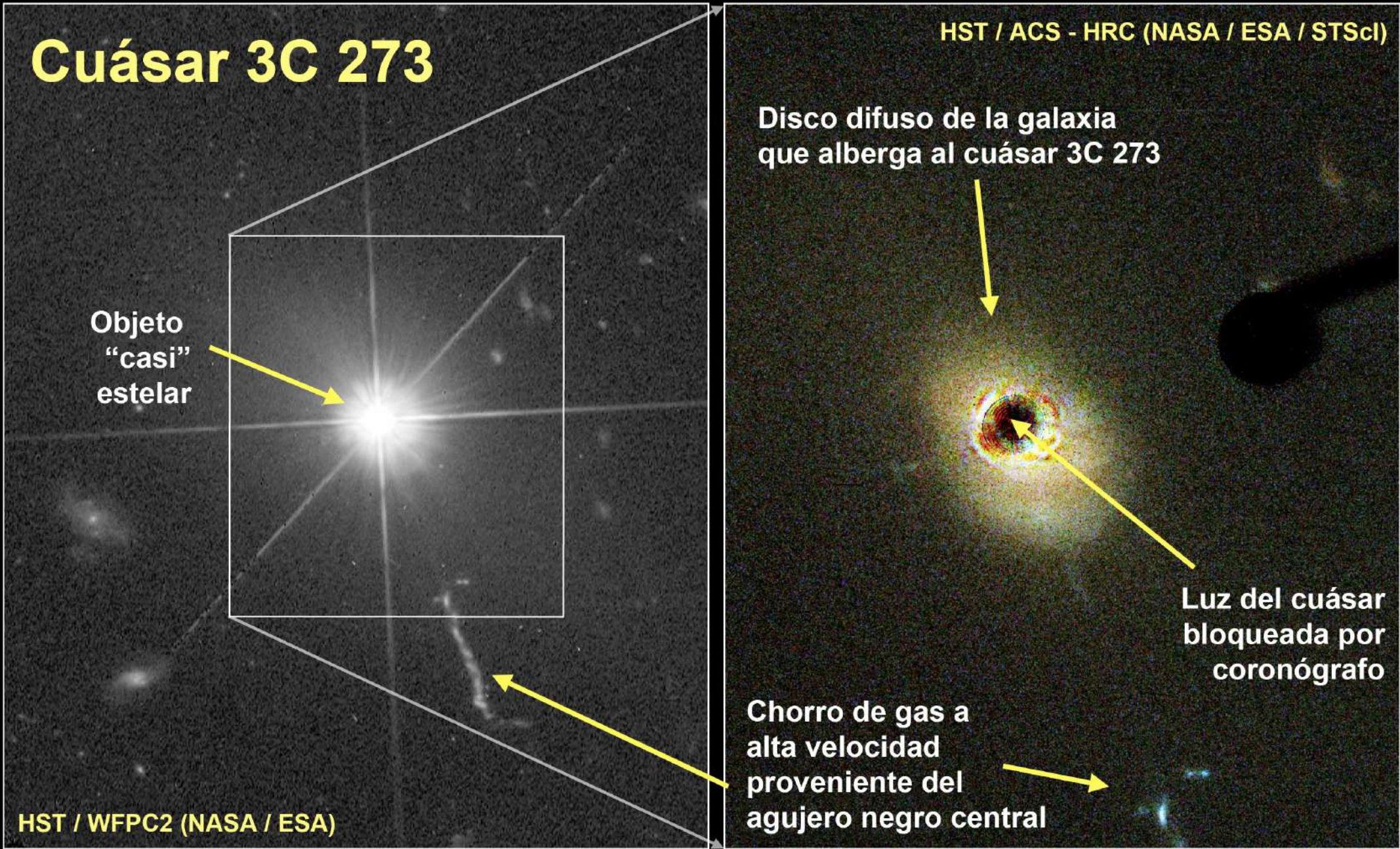
HST / WFPC2 (NASA / ESA)

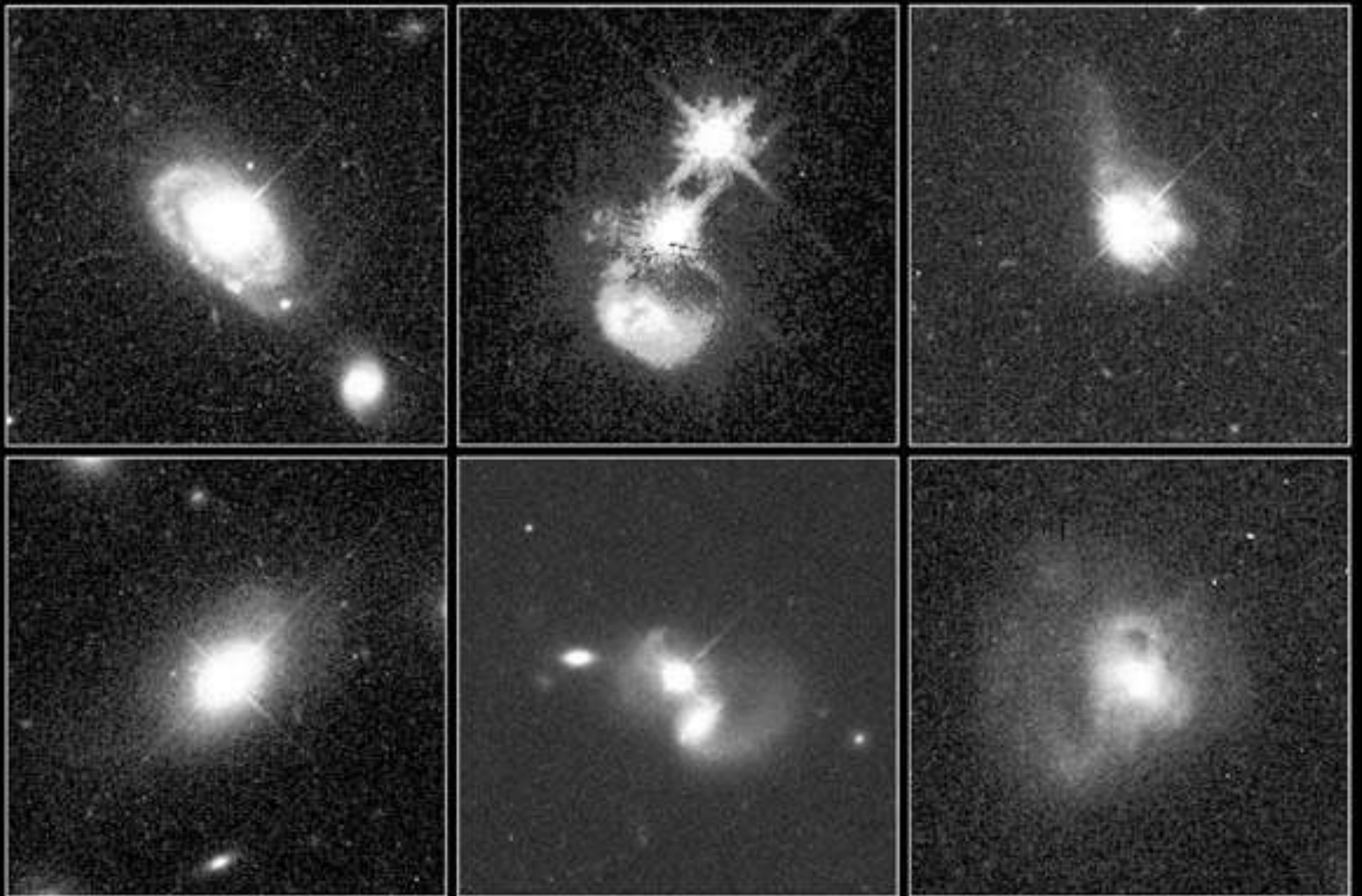
HST / ACS - HRC (NASA / ESA / STScI)

Disco difuso de la galaxia
que alberga al cuáasar 3C 273

Luz del cuáasar
bloqueada por
coronógrafo

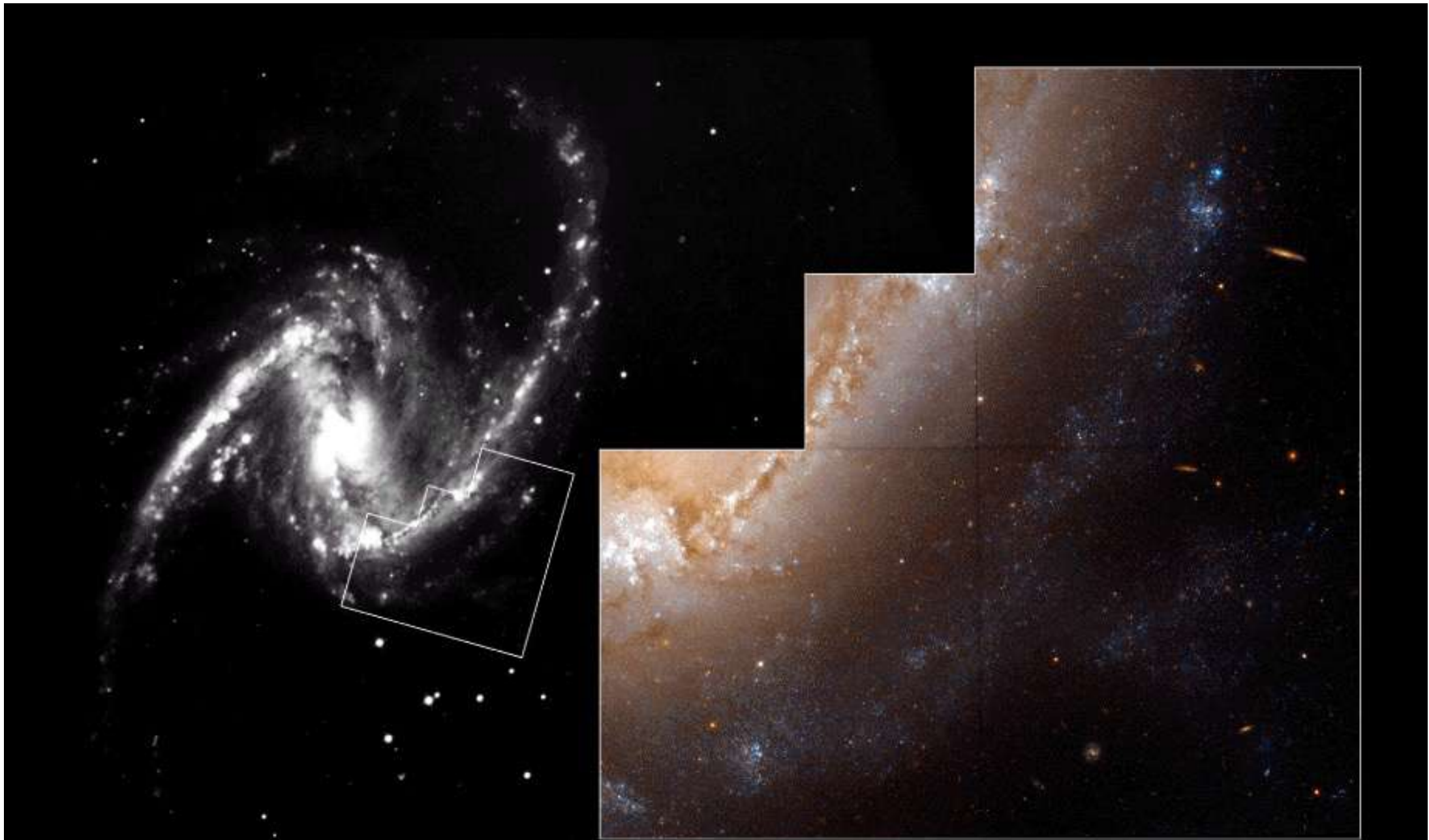
Chorro de gas a
alta velocidad
proveniente del
agujero negro central





Quasar Host Galaxies

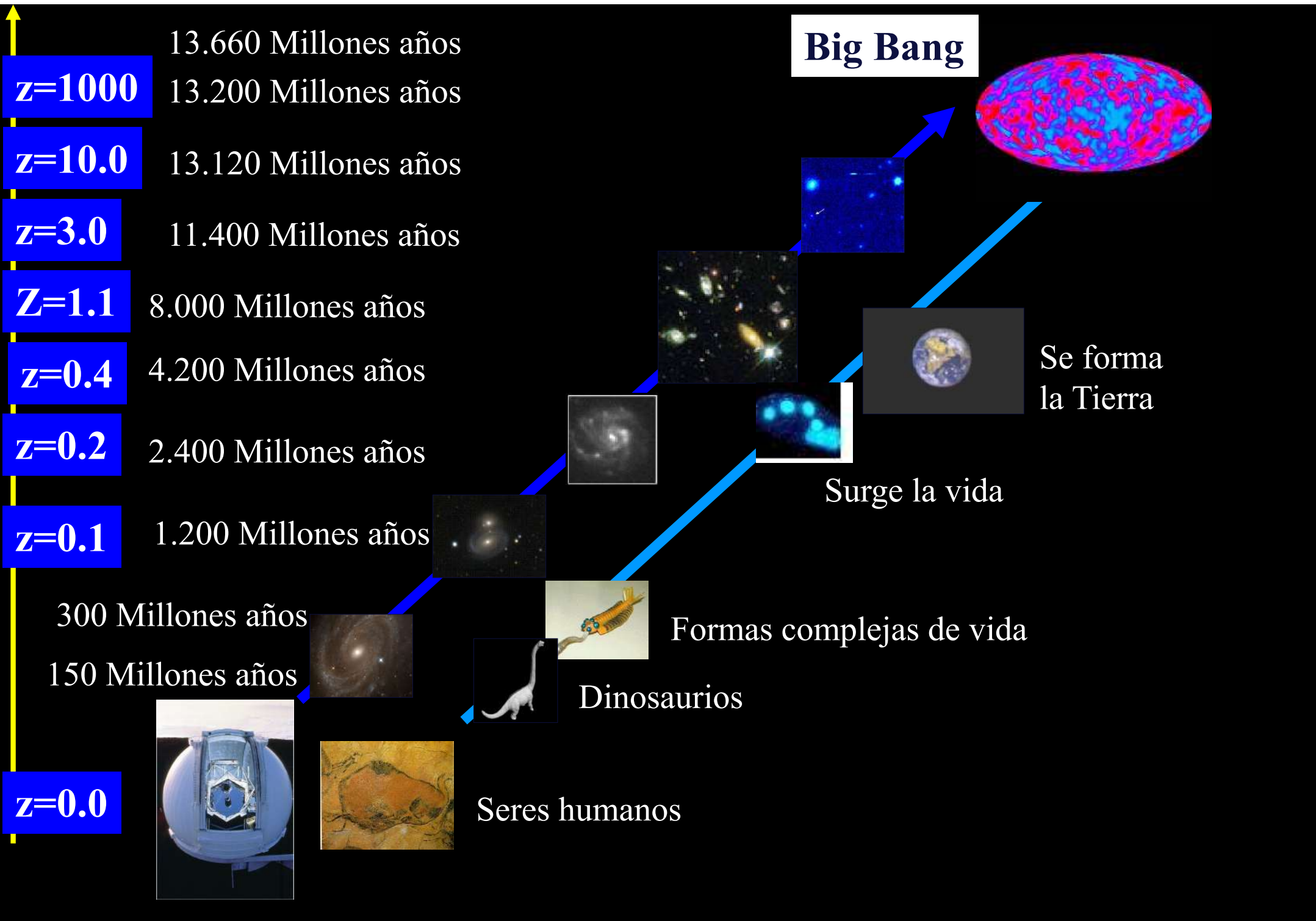
Hubble Space Telescope · Wide Field Planetary Camera 2



Galaxy NGC1365

HST · WFPC2

PRC96-21a · ST ScI OPO · May 9, 1996 · W. Freedman (Carnegie Insitution of Washington) and NASA



Big Bang

z=1000

13.660 Millones años

z=10.0

13.200 Millones años

z=3.0

11.400 Millones años

z=1.1

8.000 Millones años

z=0.4

4.200 Millones años

z=0.2

2.400 Millones años

z=0.1

1.200 Millones años

300 Millones años

150 Millones años

z=0.0

Se forma la Tierra

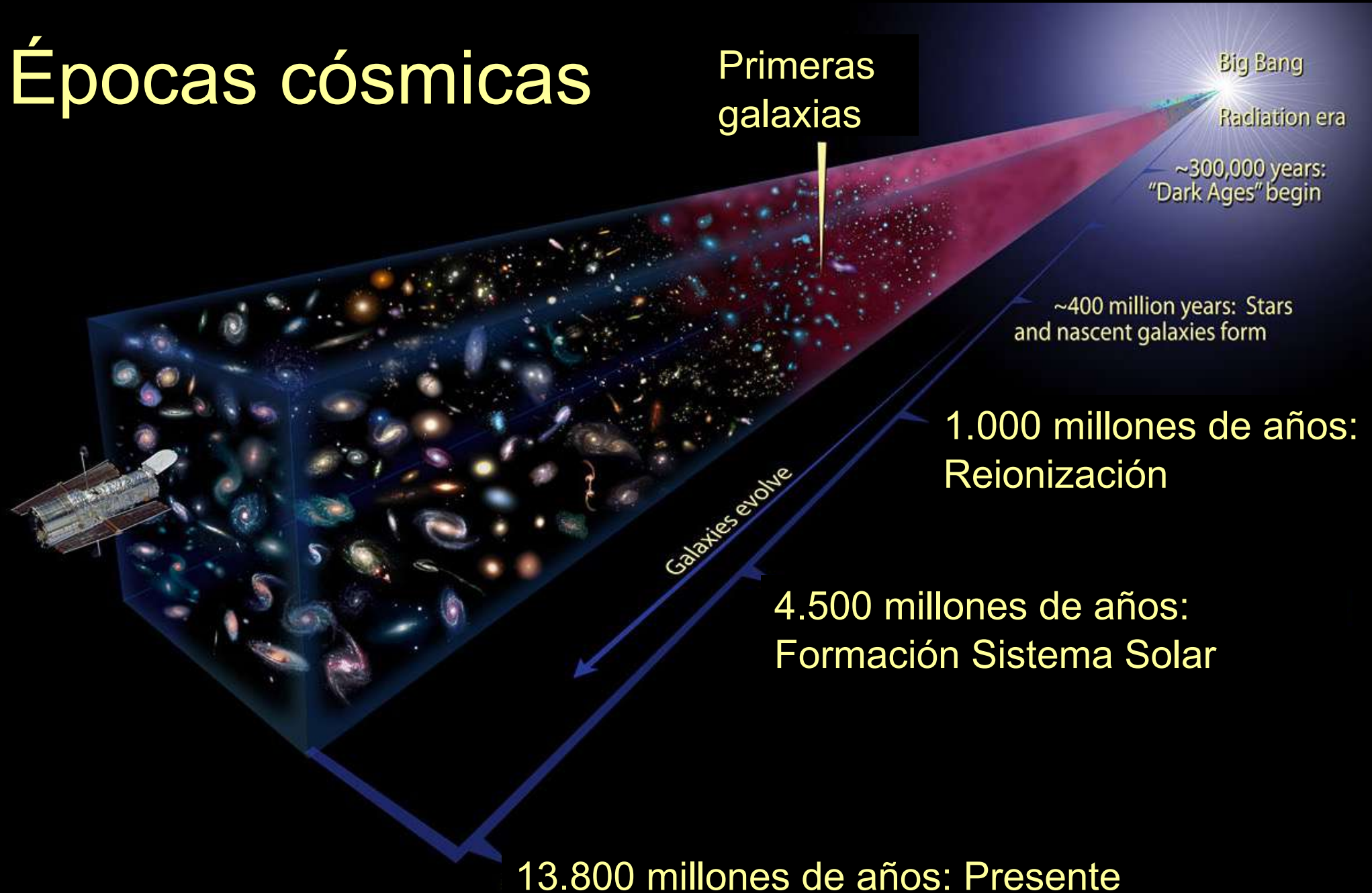
Surge la vida

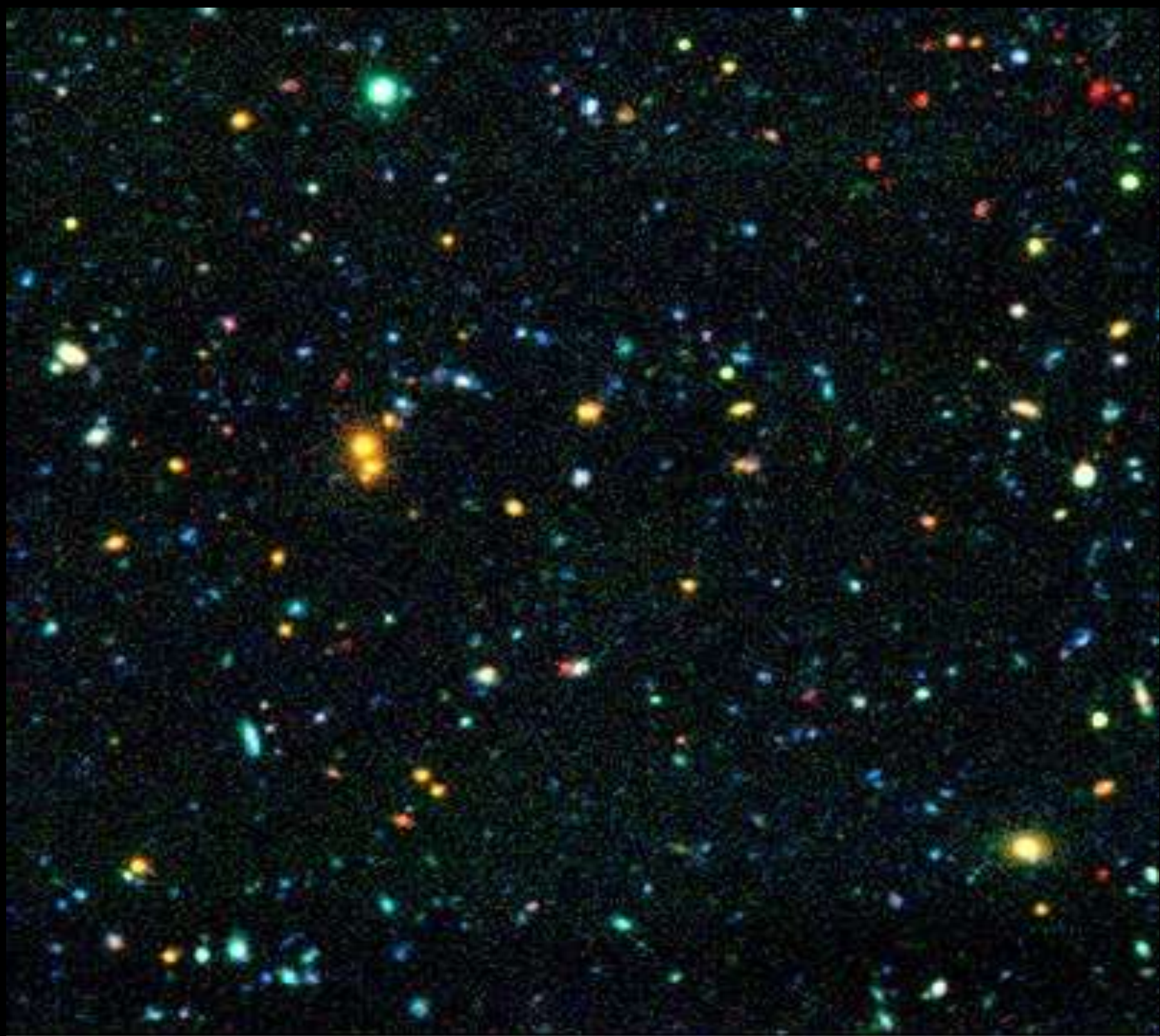
Formas complejas de vida

Dinosaurios

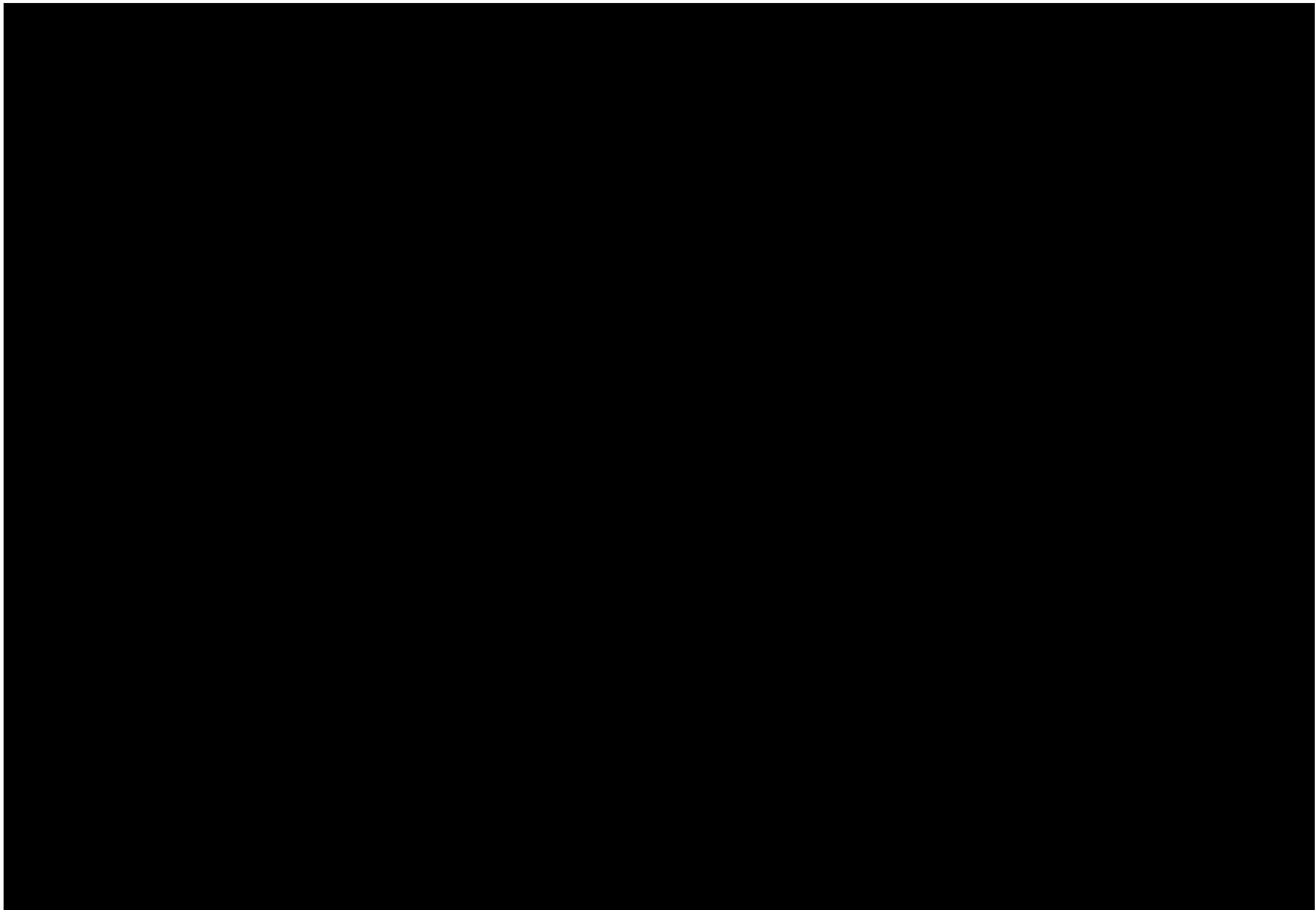
Seres humanos

Épocas cósmicas



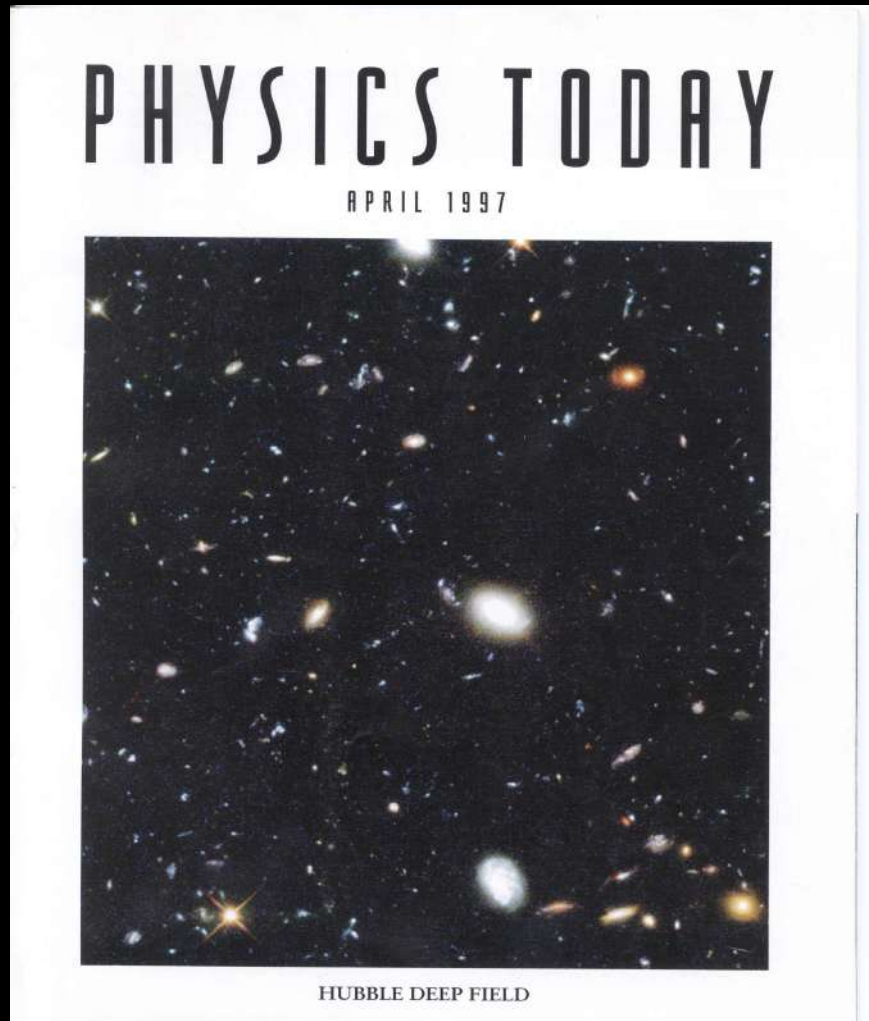








El Hubble Deep Field N



- Imagen de Hubble Space Telescope
- 10 días de observación (Nov 1995)
- 140 horas en cuatro colores U, B, V, I
- 144 segundos de arco de diámetro

- 3.000 galaxias de hasta magnitud 29
- < 20 estrellas
- ~ 2 supernovas

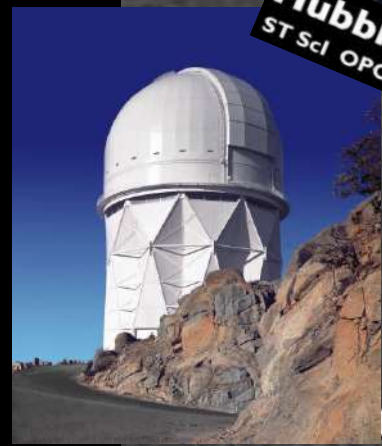
0014 0018 0020 0022
0024 0026 0028 0030 0032 0034 0036 0038 0040 0042 0044 0046 0048 0050 0052 0054 0056 0058 0100

11
12

Hubble Deep Field

ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

HST
WFPC2



el Ultra Deep Field

- Imagen de HST/ACS
- Centrado en CDF-S
- 412 órbitas
- Release, 9 marzo 2004
- 1.5 mag más que el HDF

y...

El eXtreme Deep Field

- Imagen de ACS/WFC3
- Centrado en HUDF
- 23 días exposición
- Release, 25-IX-2012
- 5,500 galaxias más



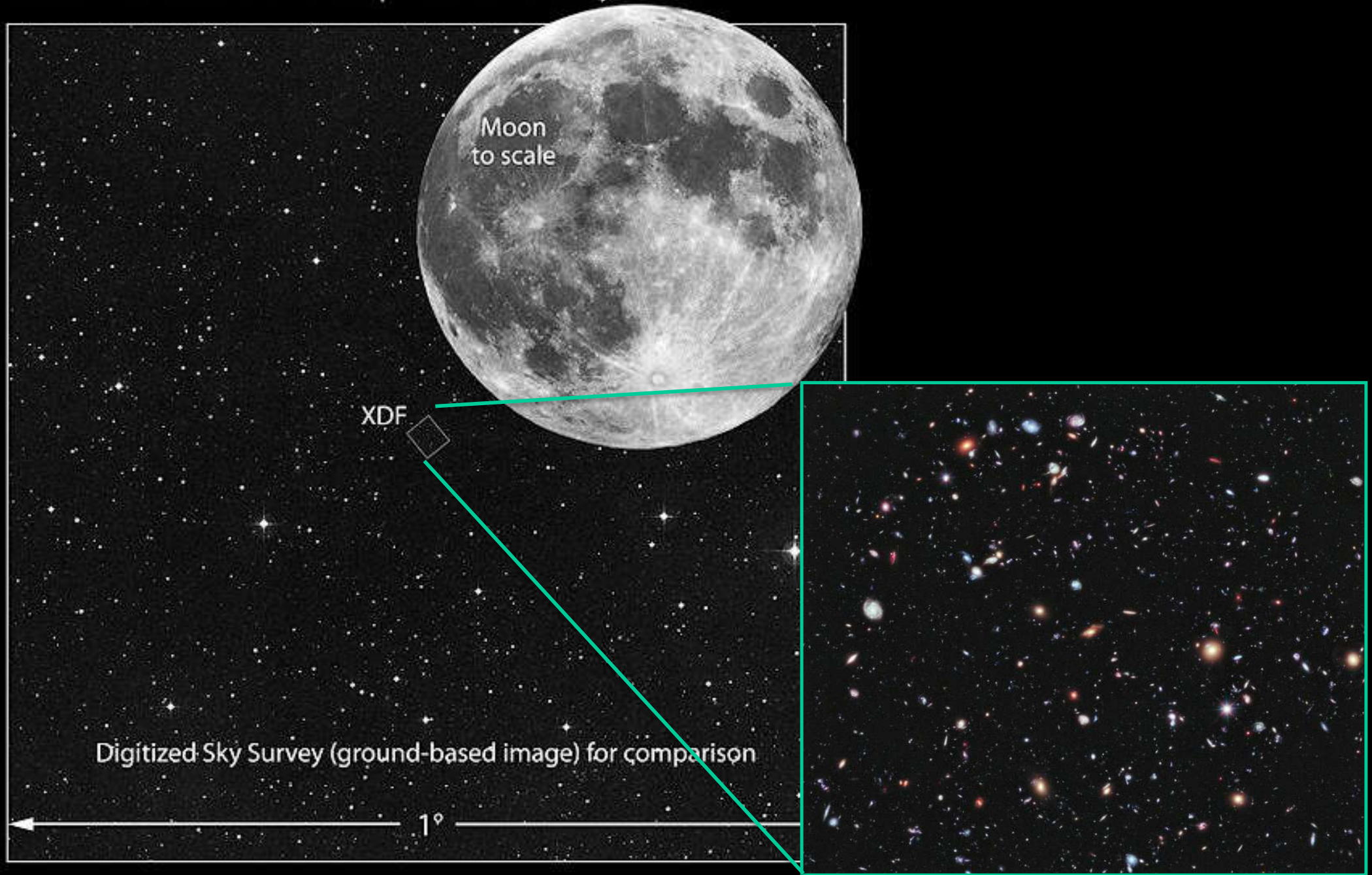
El Hubble Deep Field N



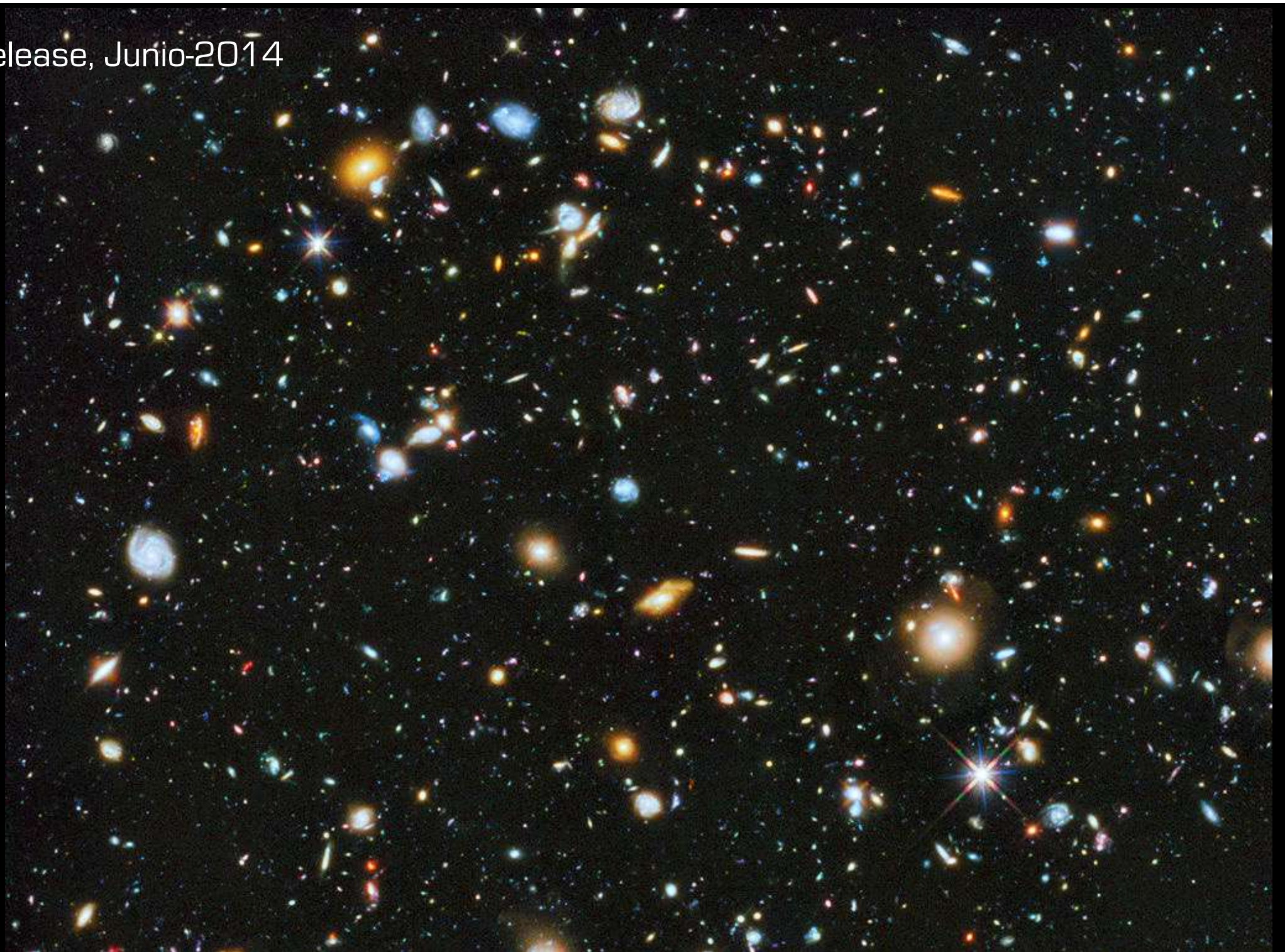
100m distancia

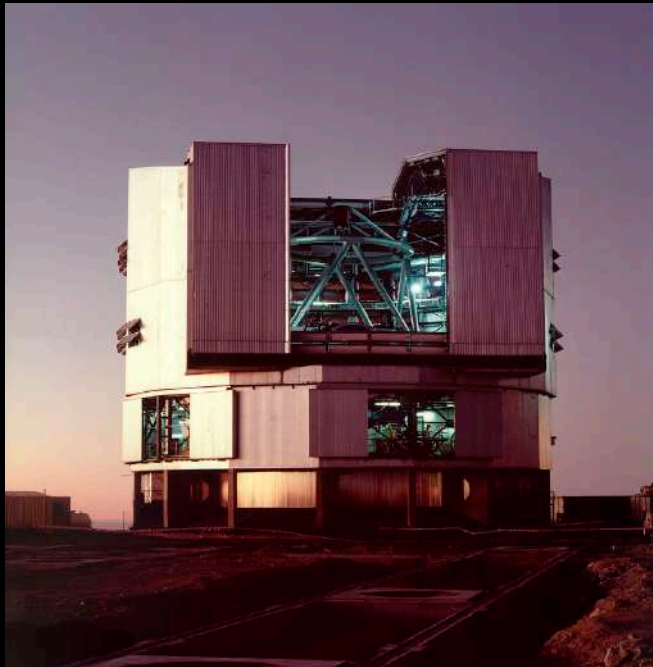


Size of Hubble eXtreme Deep Field on the Sky

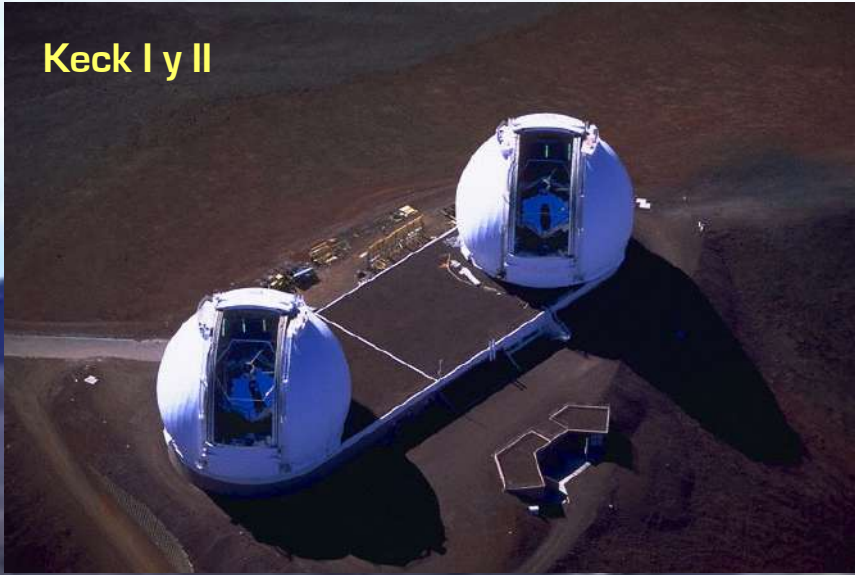


Release, Junio-2014

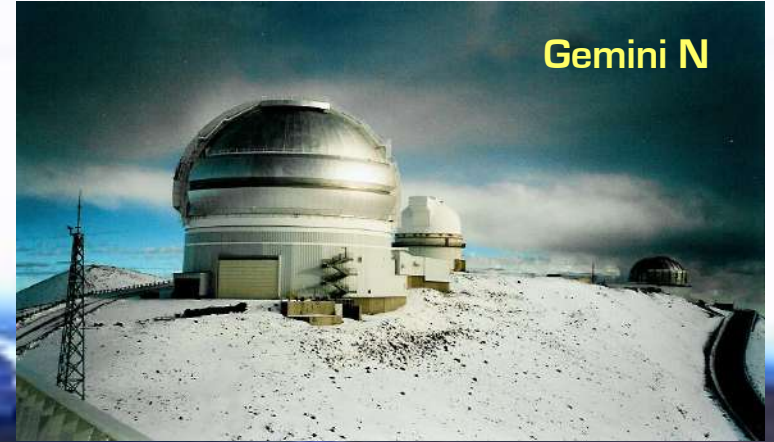




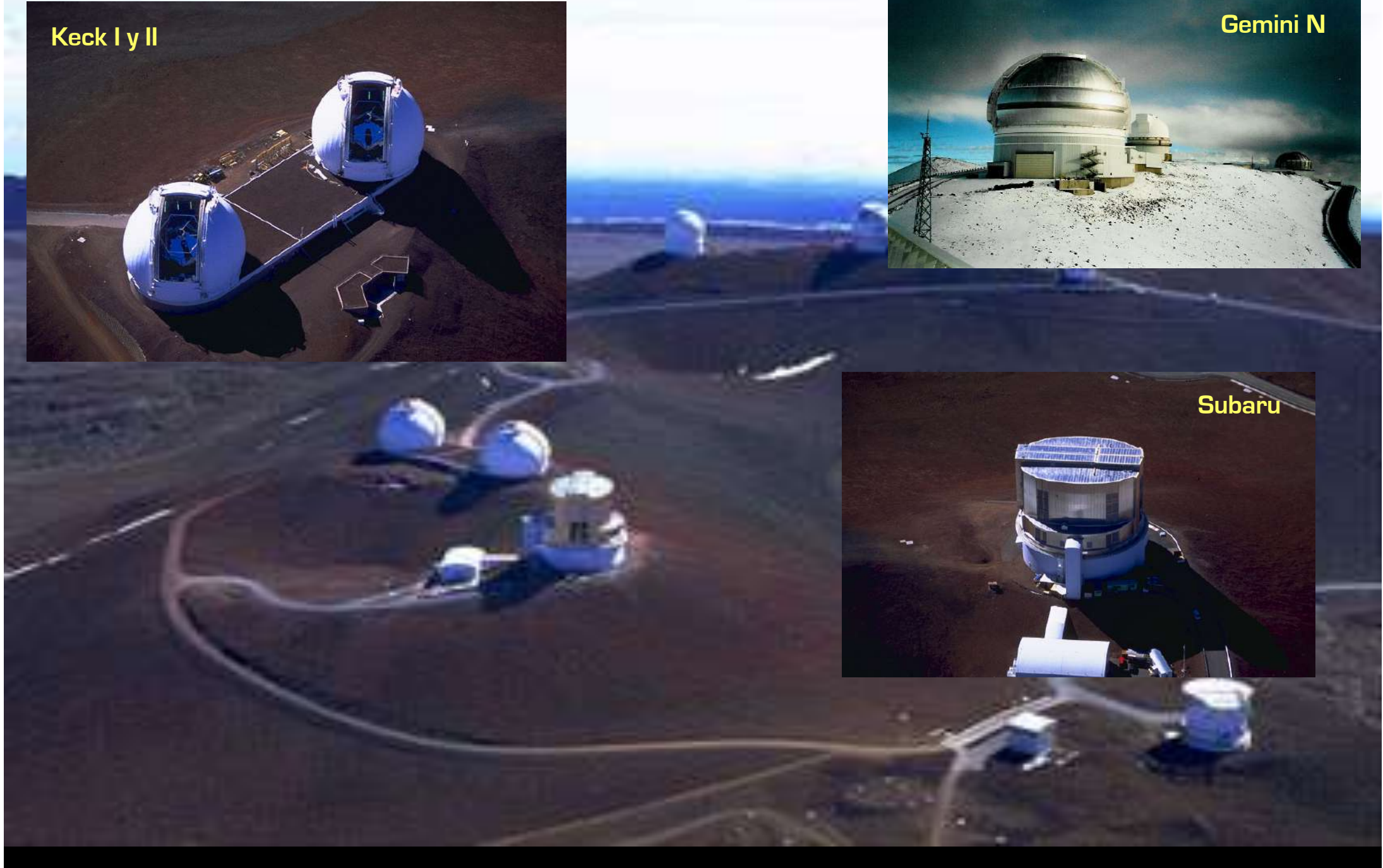
Keck I y II



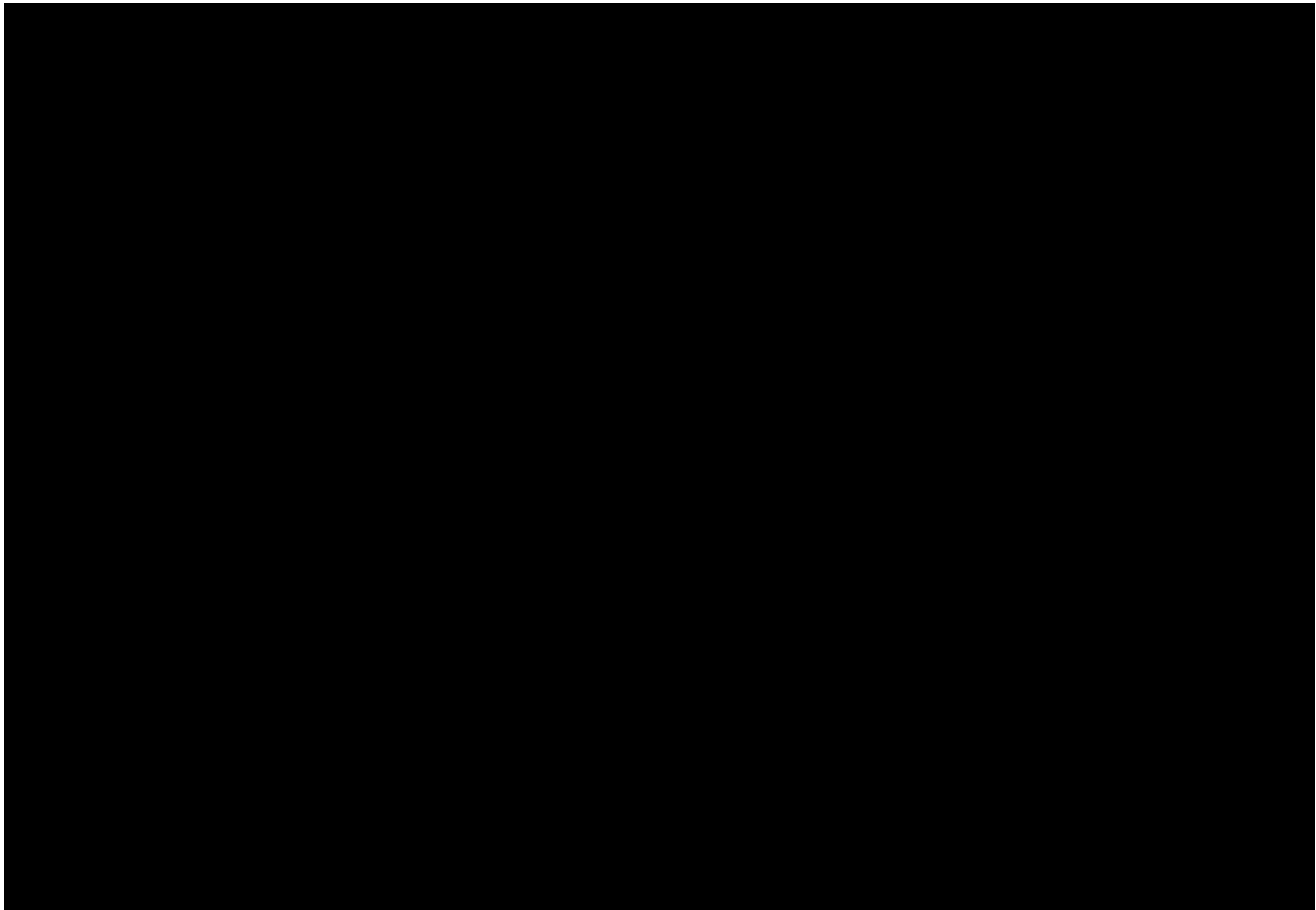
Gemini N

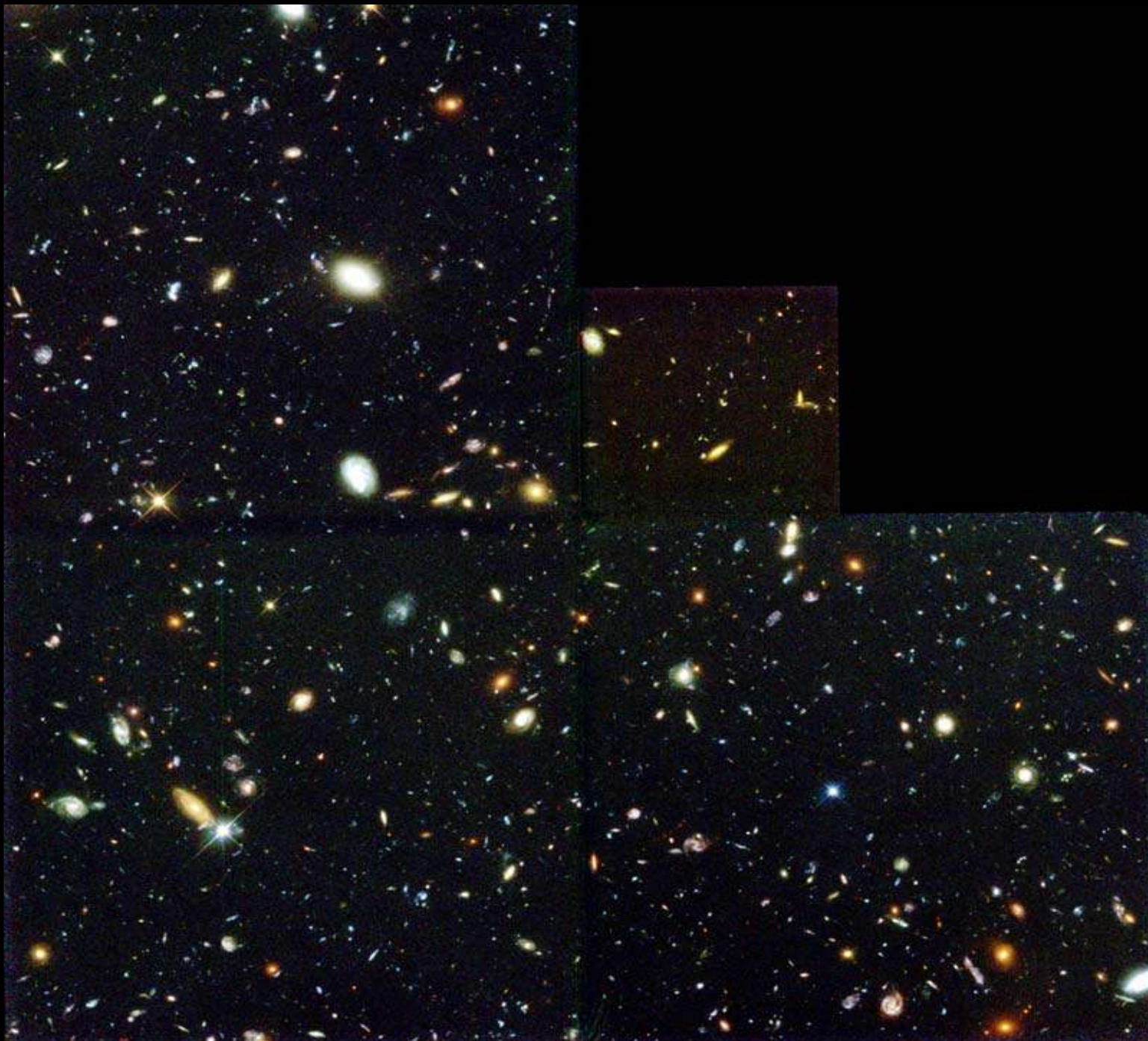


Subaru









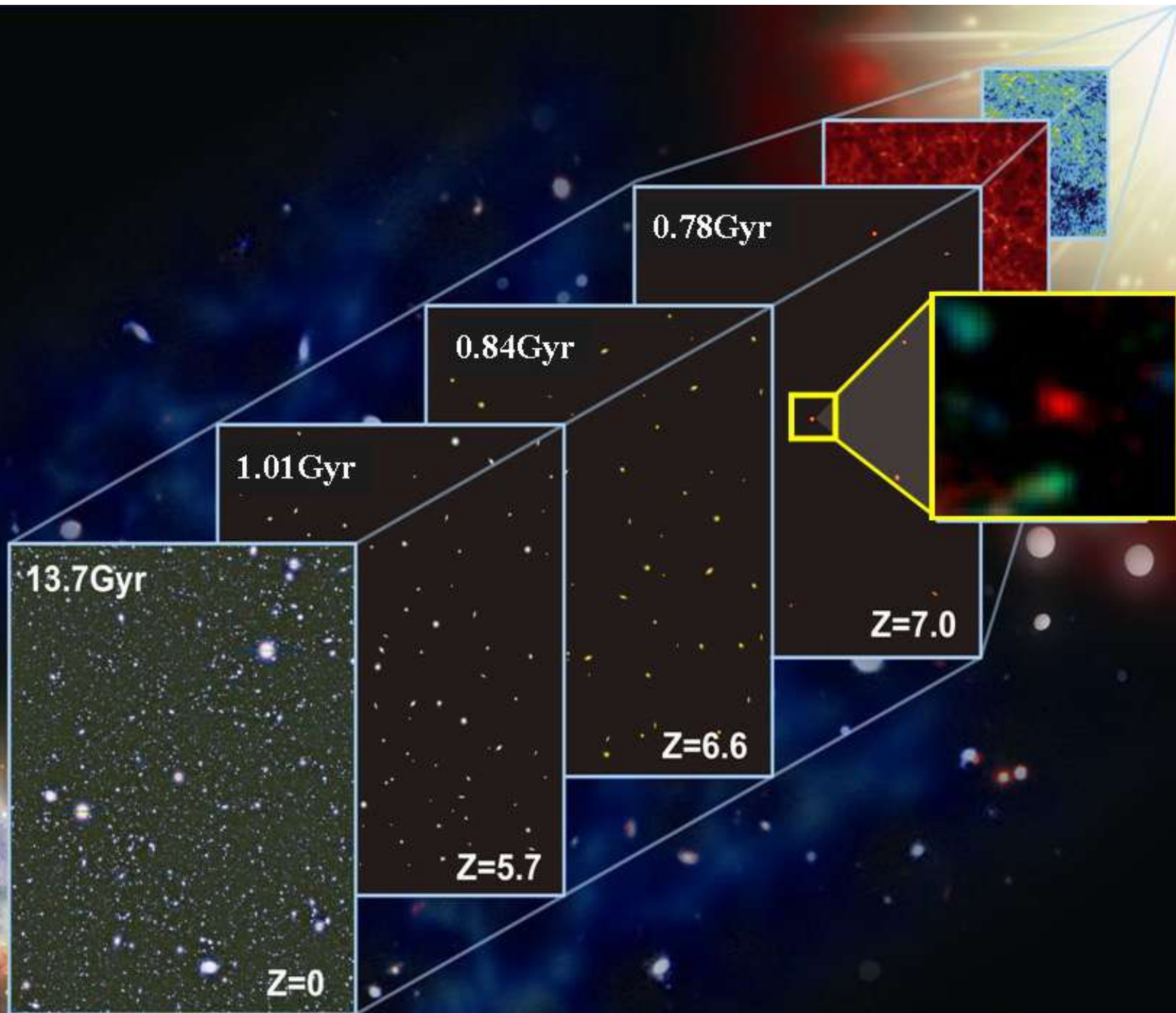
Hubble Deep Field

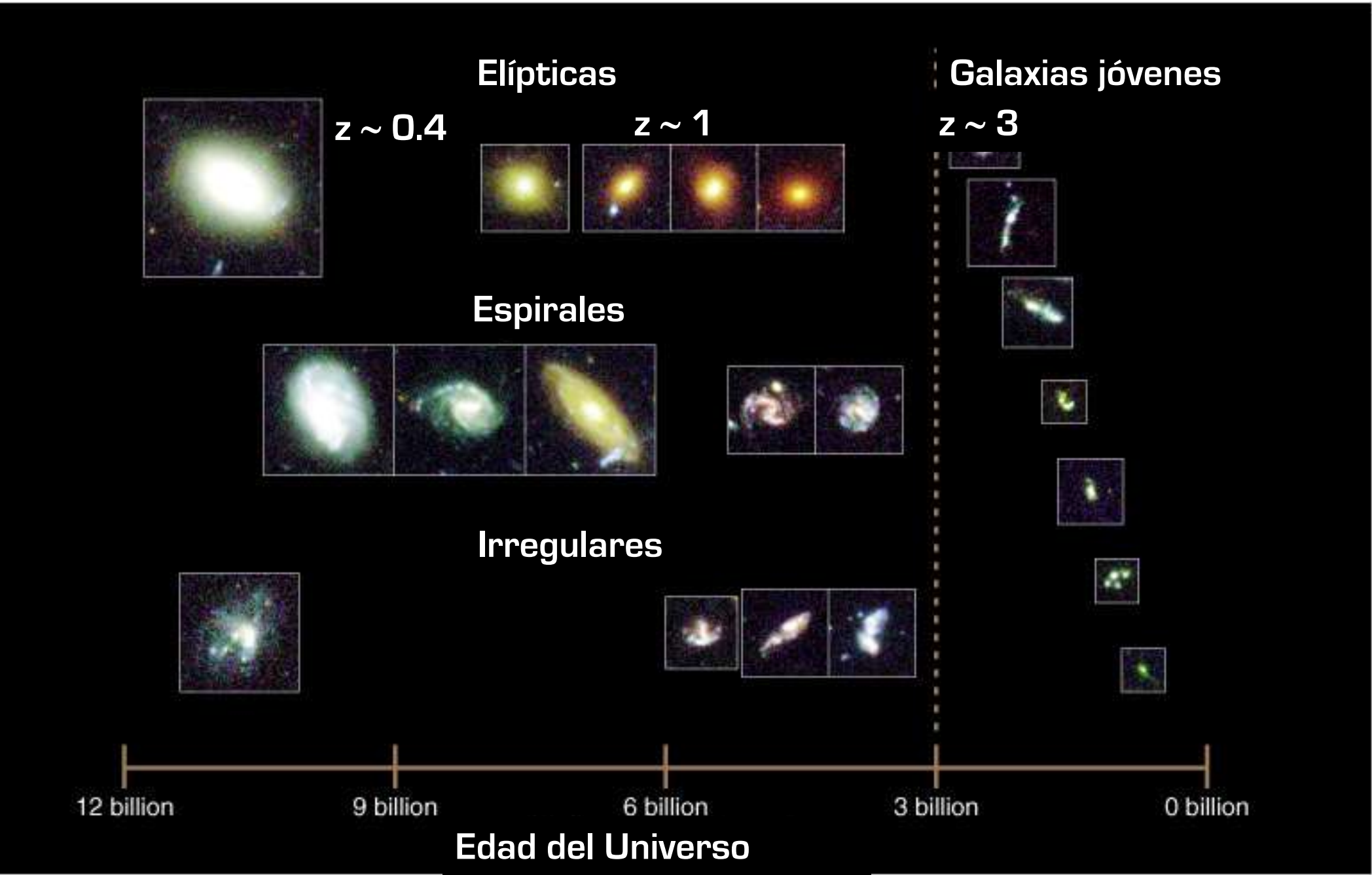
HST WFPC2

ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

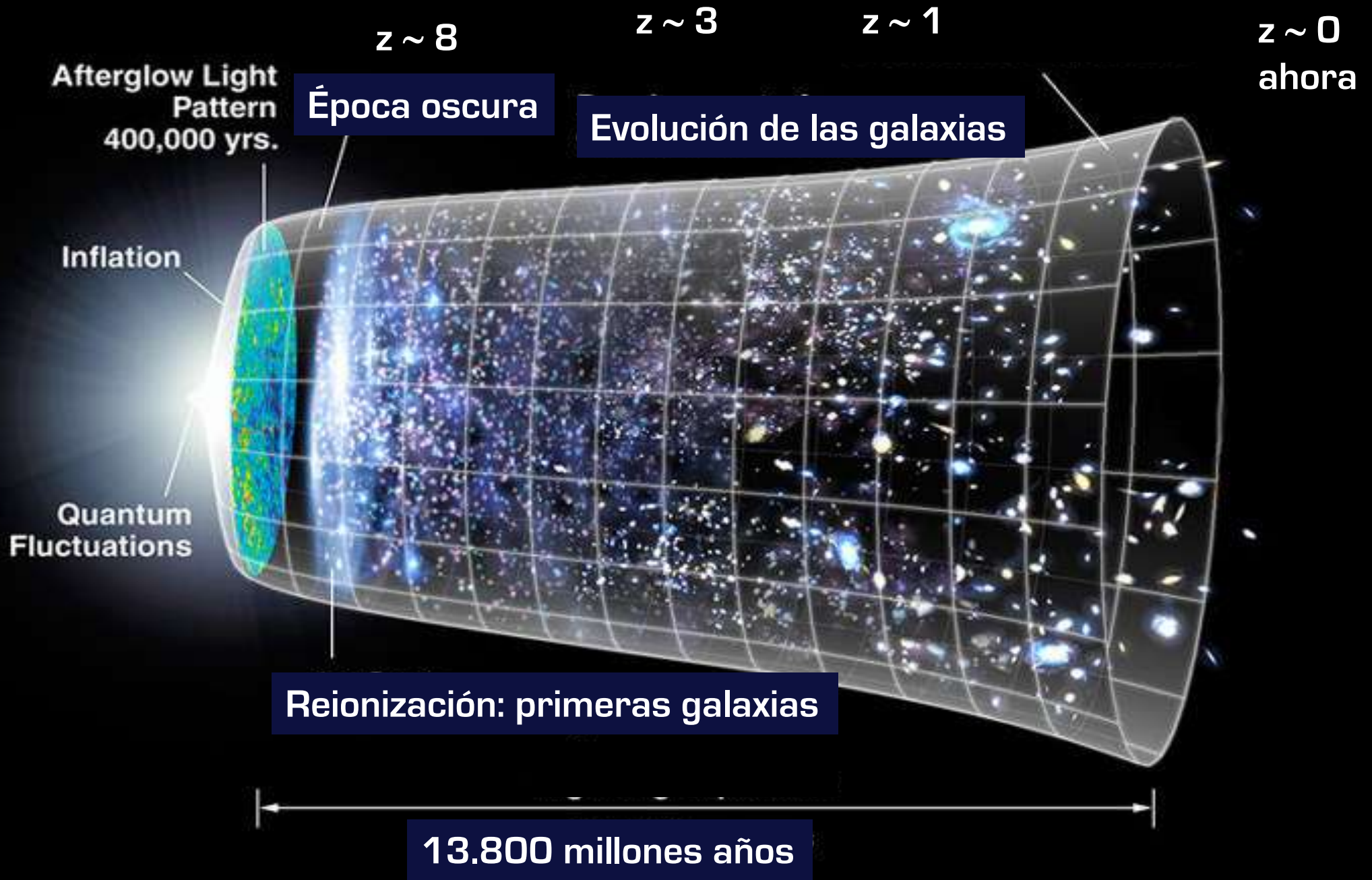
$z=0$







Las grandes épocas



Modelo monolítico

0.5 Gaños

A large, diffuse, bright blue circular glow centered in a dark blue square, representing a monolithic model with 0.5 years of development.

1 Gaños

A smaller, more concentrated blue circular glow centered in a dark blue square, representing a monolithic model with 1 year of development.

2 Gaños

A very small, tightly focused blue circular glow centered in a dark blue square, representing a monolithic model with 2 years of development.

4 Gaños

A blue circular glow centered in a dark blue square, appearing slightly more concentrated than the 2-year model, representing a monolithic model with 4 years of development.

13 Gaños

A red circular glow centered in a dark blue square, appearing as a distinct, concentrated spot, representing a monolithic model with 13 years of development.

Modelo jerárquico



0.5 Gaños



1 Gaño



2 Gaños



4 Gaños

Grupos de CDM colapsan en halos virializados.

El gas se enfría y agrega en esos halos para formar discos rotantes. Son los bloques formadores de las futuras galaxias.

Modelo jerárquico

4 Gaños

13 Gaños

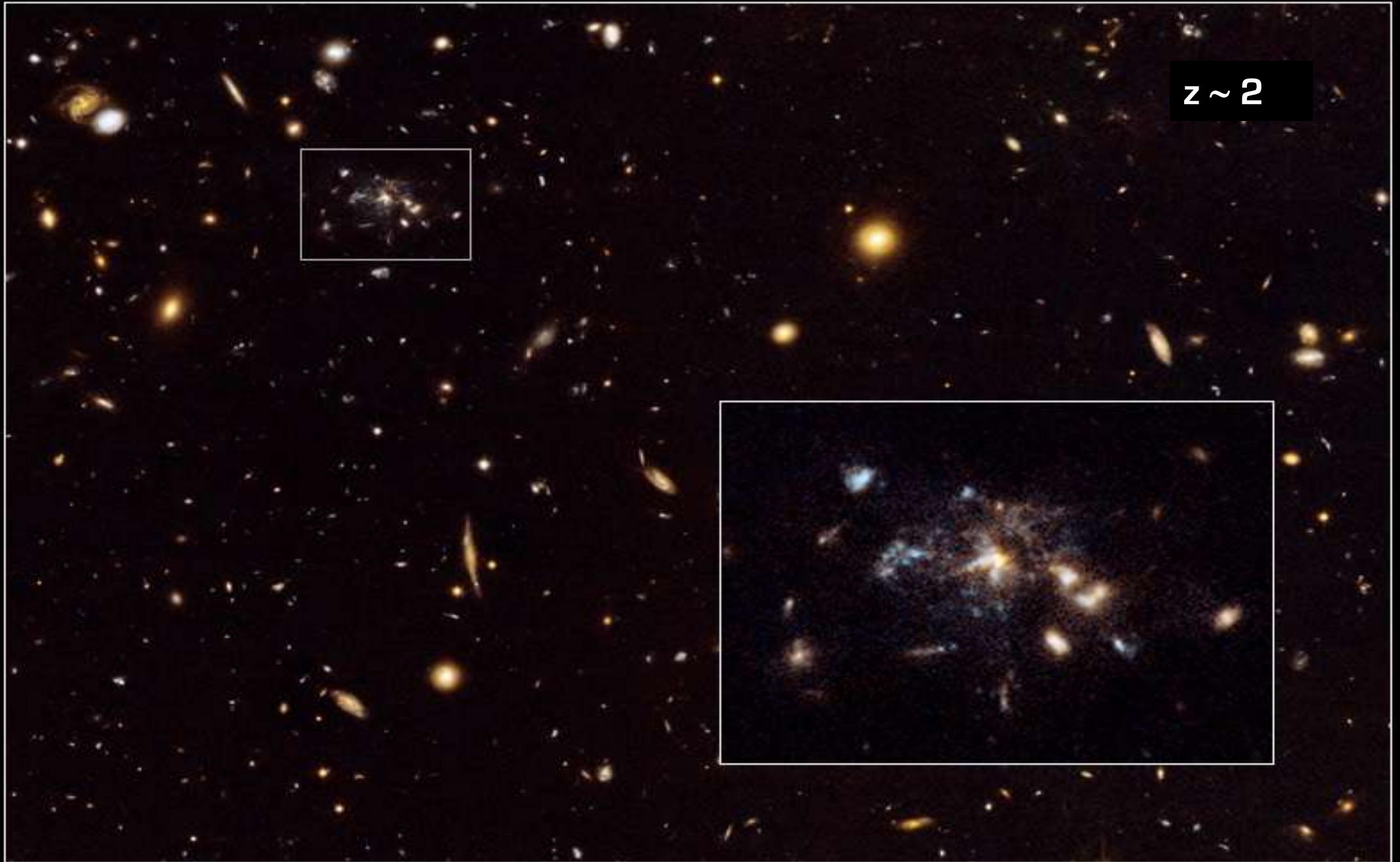
¿“Nature” o “Nurture”?

Las galaxias crecen y evolucionan (se ensamblan) mediante varios mecanismos:

- Mergers mayores y menores
- La acreción de gas frío mediante filamentos (más importante a $z > 2$)
- Los procesos seculares internos, que redistribuyen el material

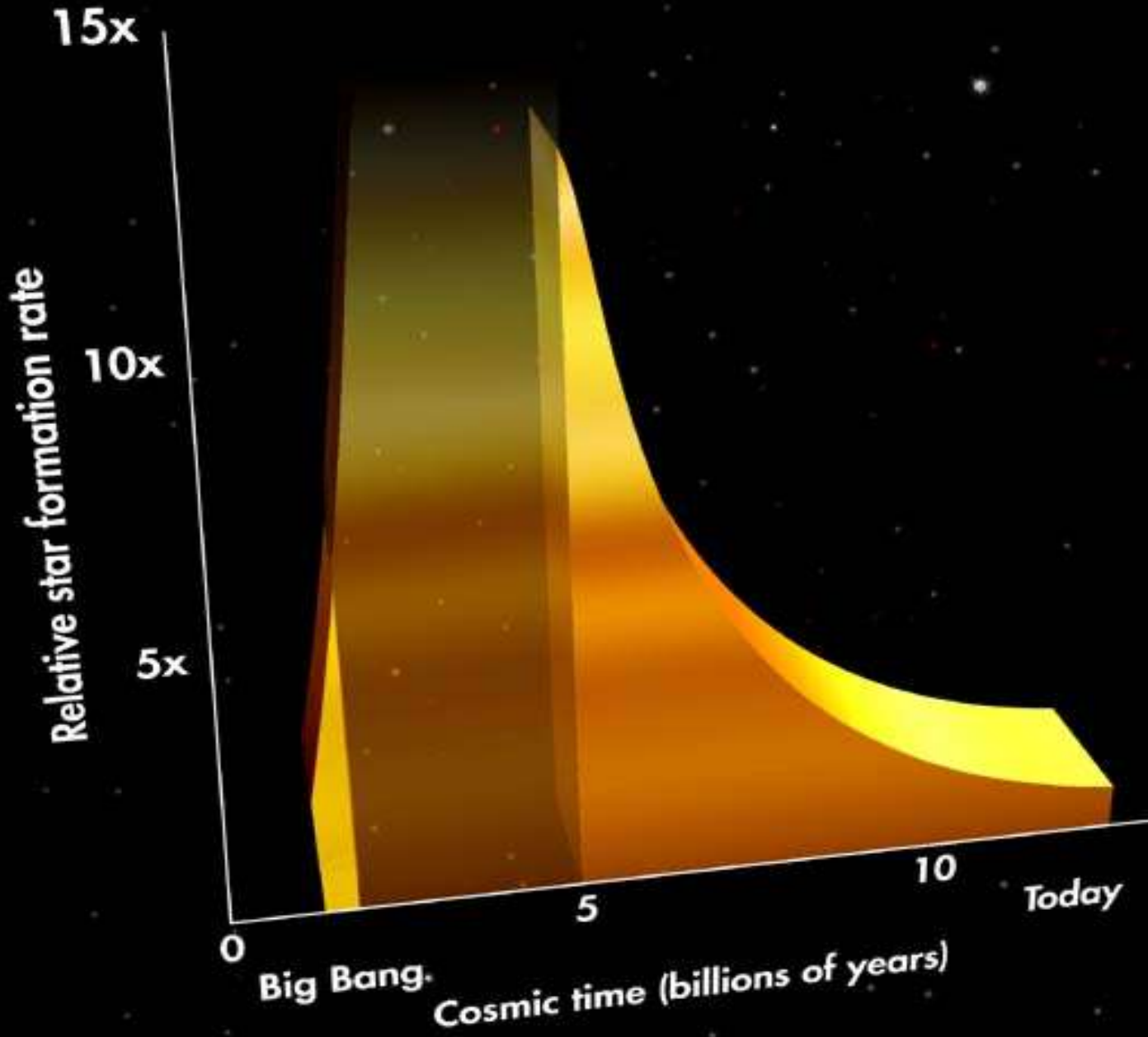
El entorno juega también un papel importante en la evolución.

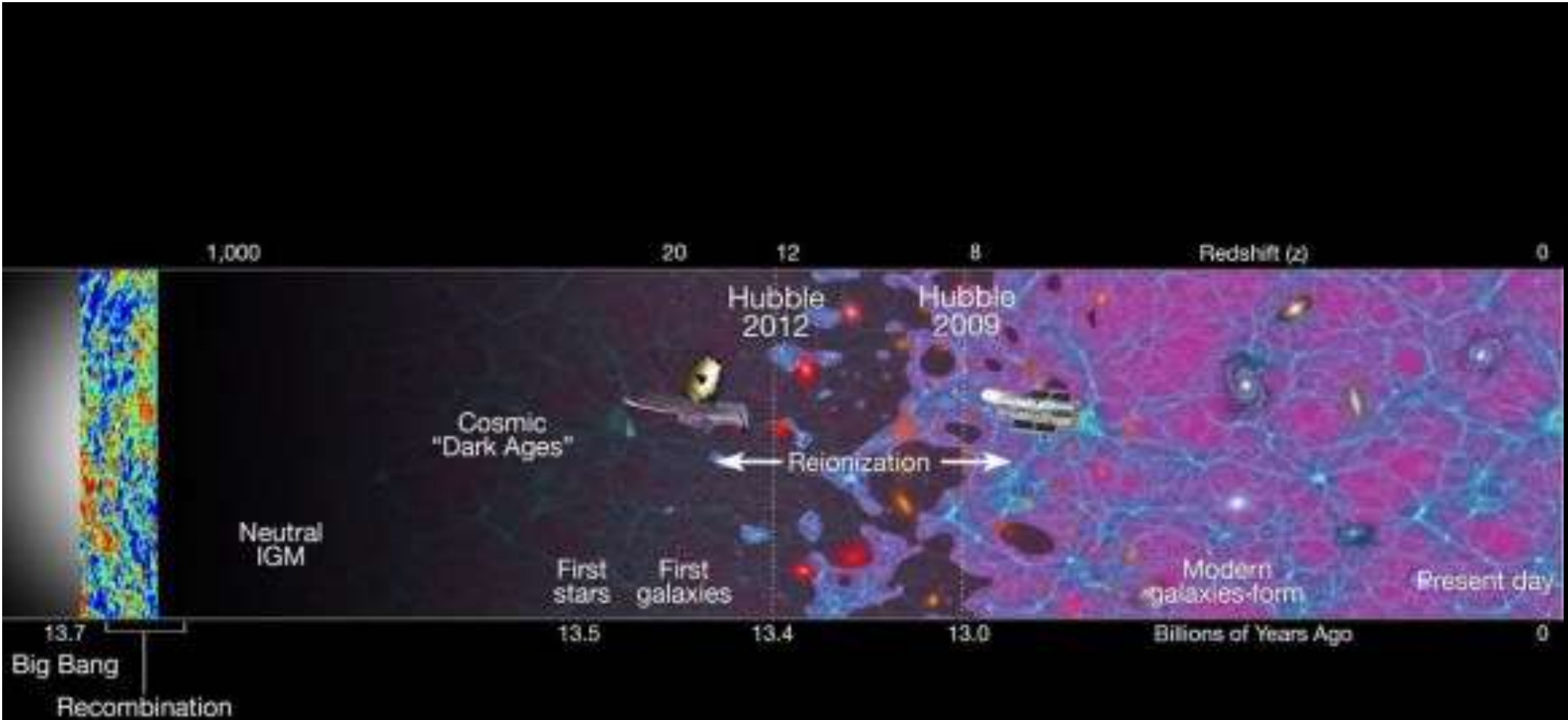
- Galaxias de campo con densidades 0.1-1.0 galaxias / Mpc³
- Galaxias en cúmulos ricos, con 1,000 galaxias / Mpc³



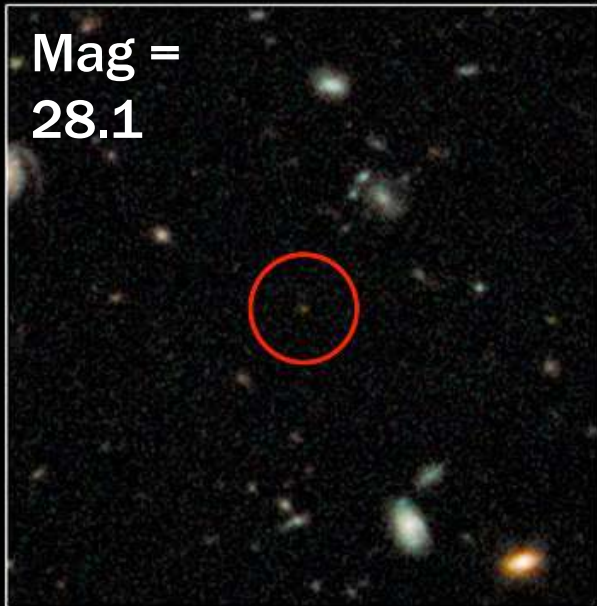
$z \sim 2$

Densidad cósmica de SFR

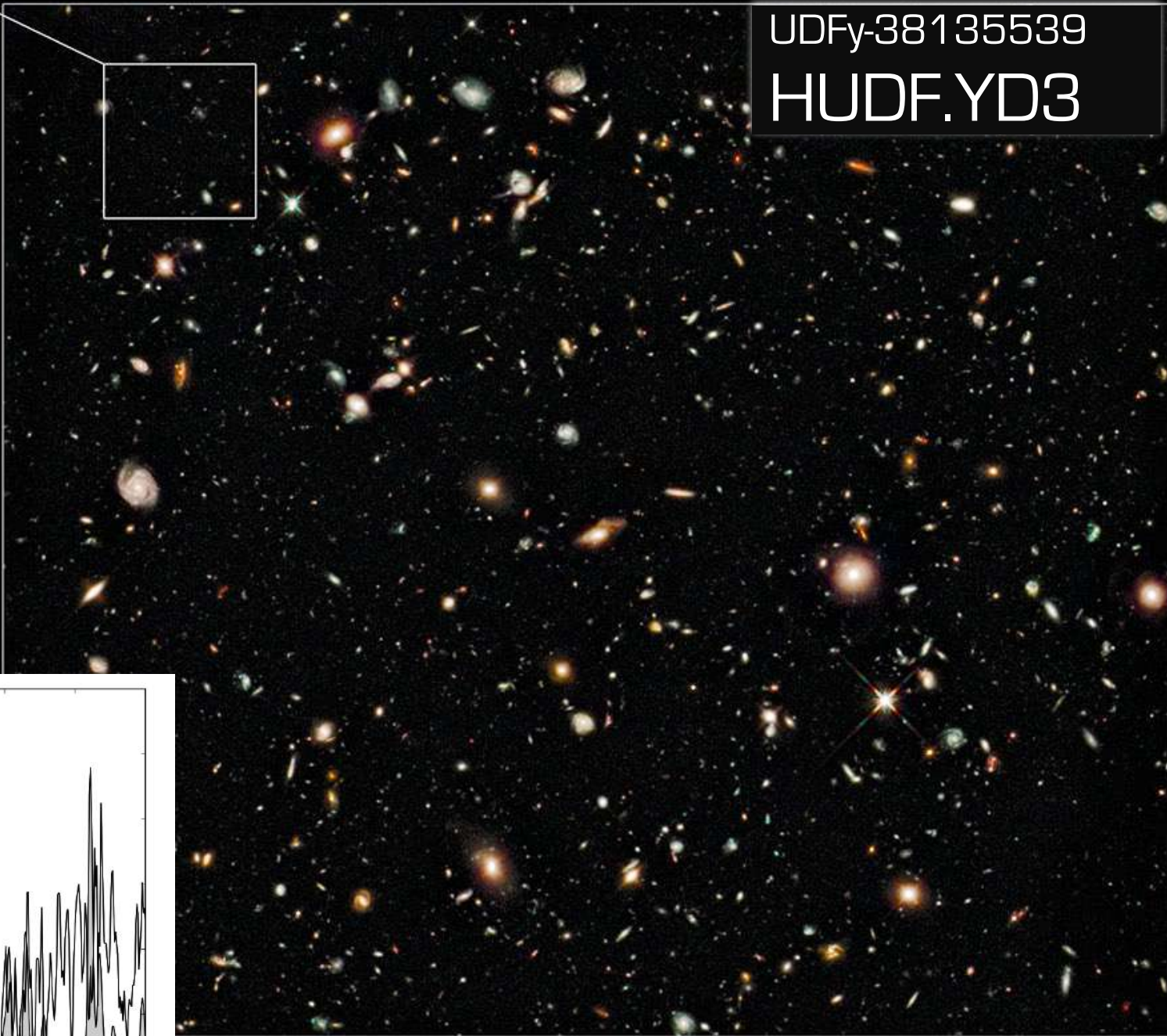




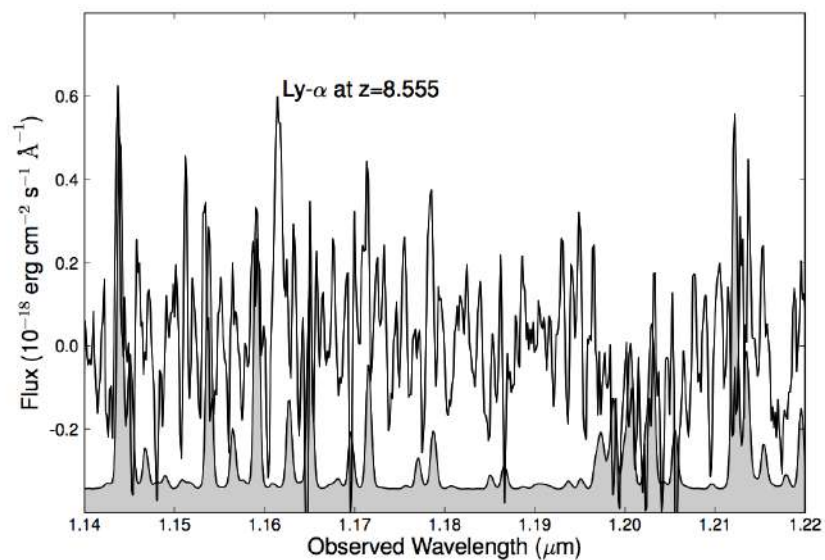
Mag =
28.1



UDFy-38135539
HUDF.YD3



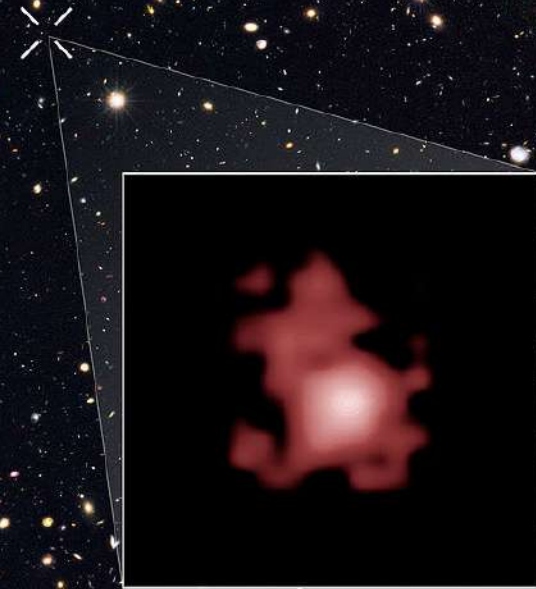
**z=8.6 (oct 2010)
confirmado VLT**



Mag = J Dropout

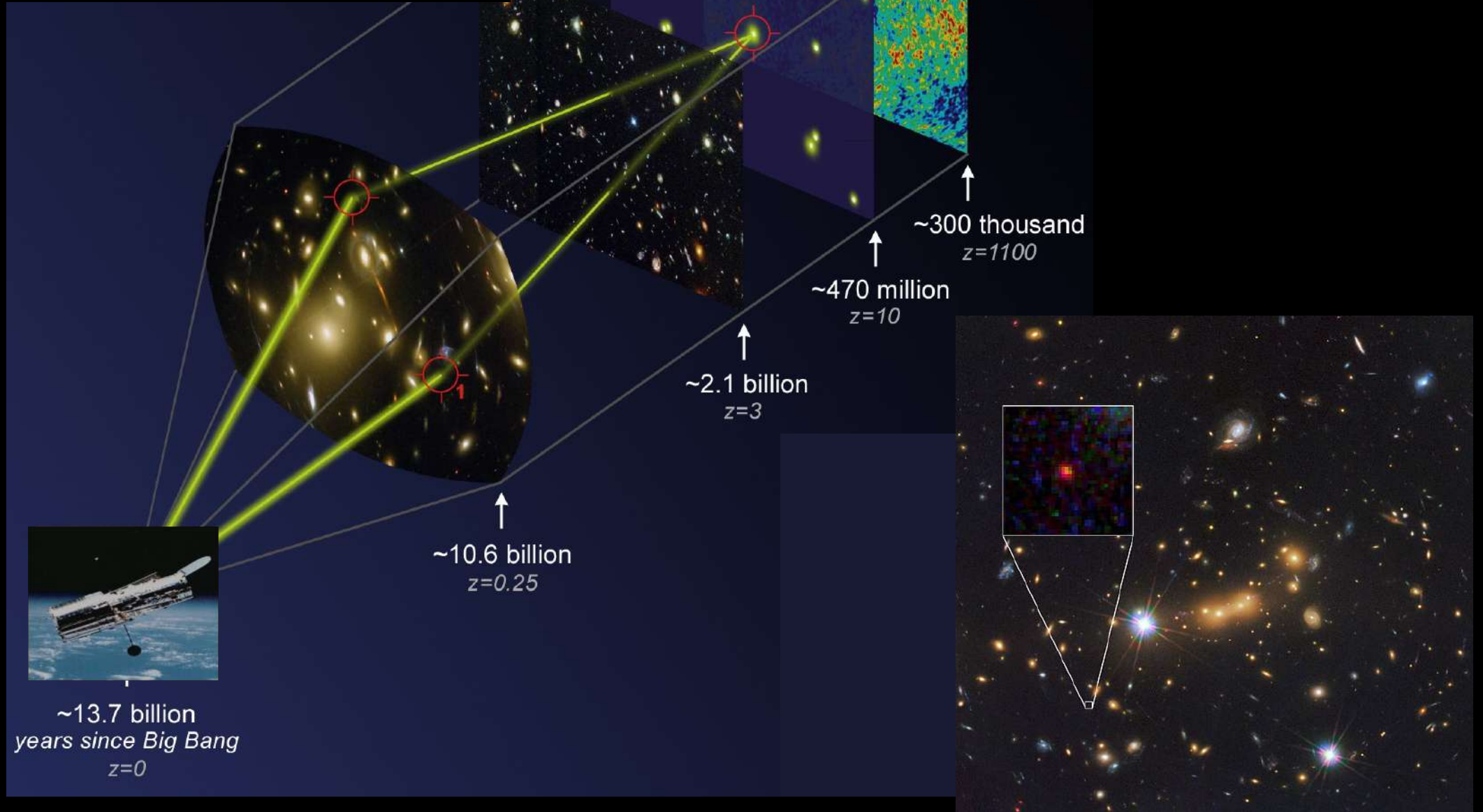
GN-z11

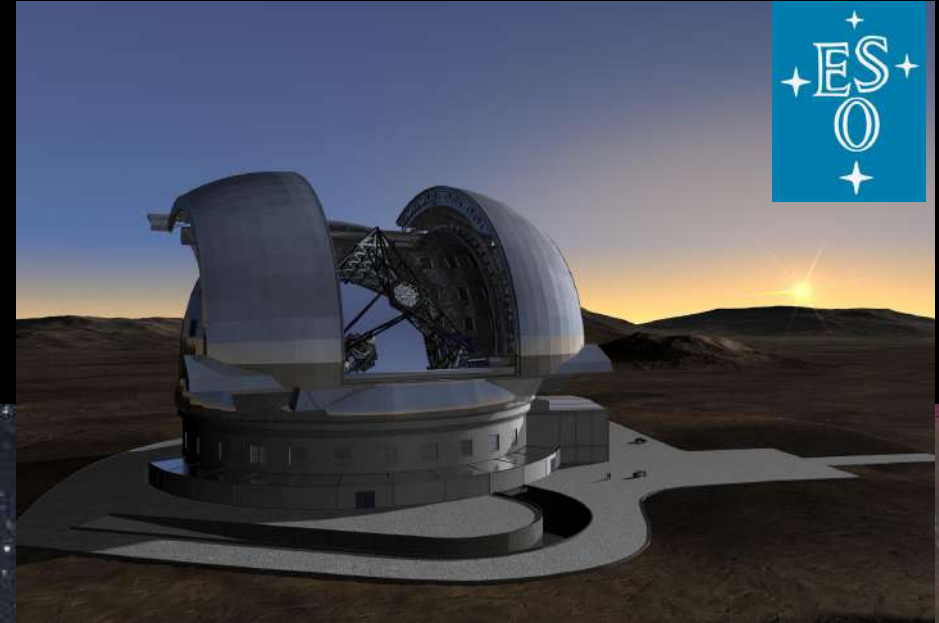
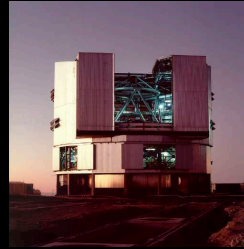
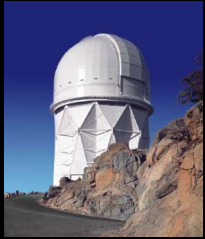
$z=11.09$ (marzo
2016) GOODS-N
confirmado



MACS0647-JD

$z \sim 10.7$ (nov 2012)



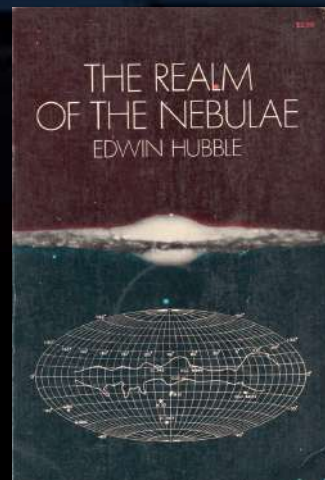


4m KPNO
0.04", 600 s

HST
0.02",
1600 s

VLT-I
0.006", 160 s

E-ELT
0.0005"
1 segundo



Nuestro conocimiento del Universo disminuye rápidamente según nos alejamos de nuestra Tierra.

Trabajamos en el límite de nuestros telescopios, y la búsqueda continuará.

E. Hubble, Realm of the Nebulae, 1936