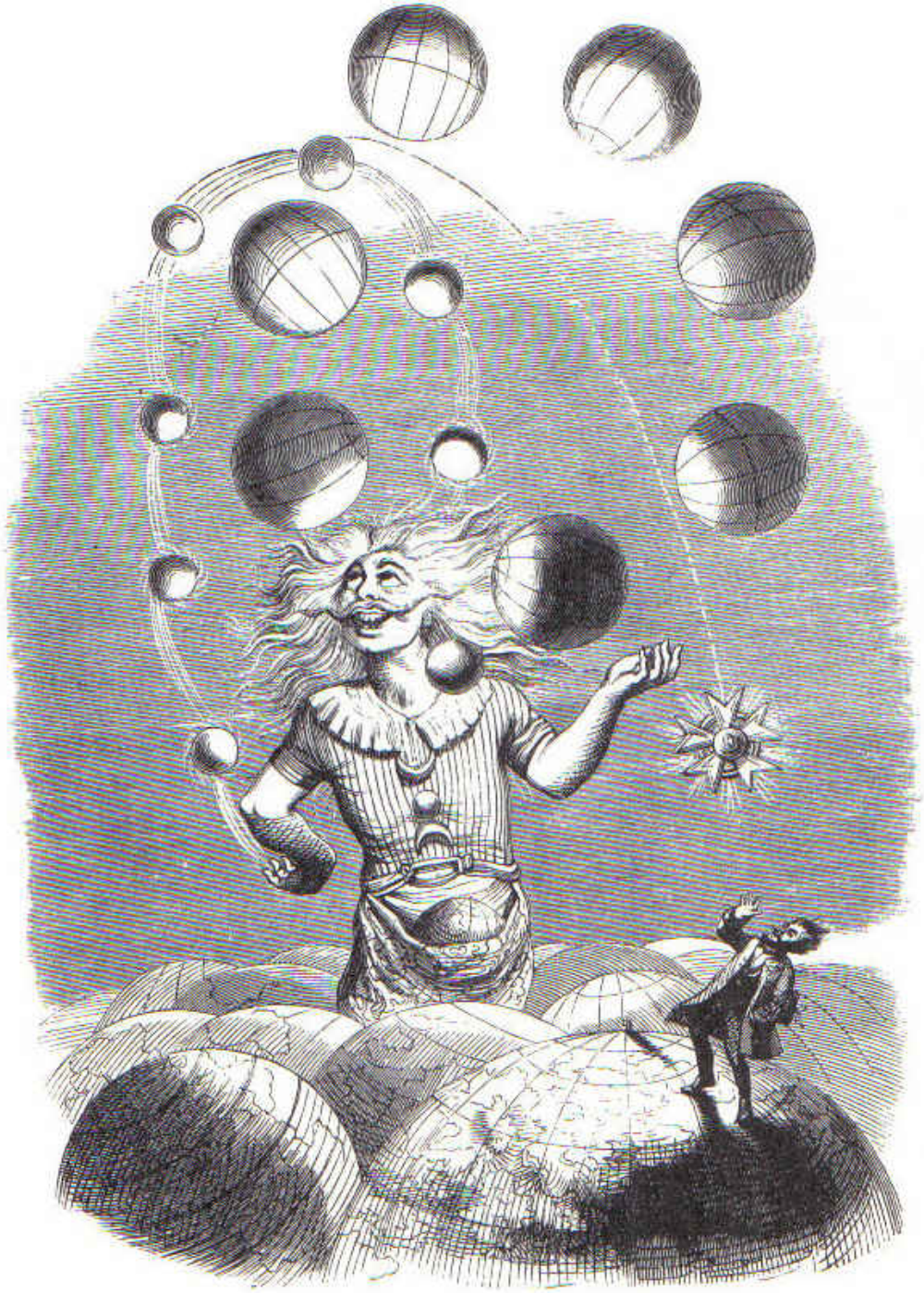
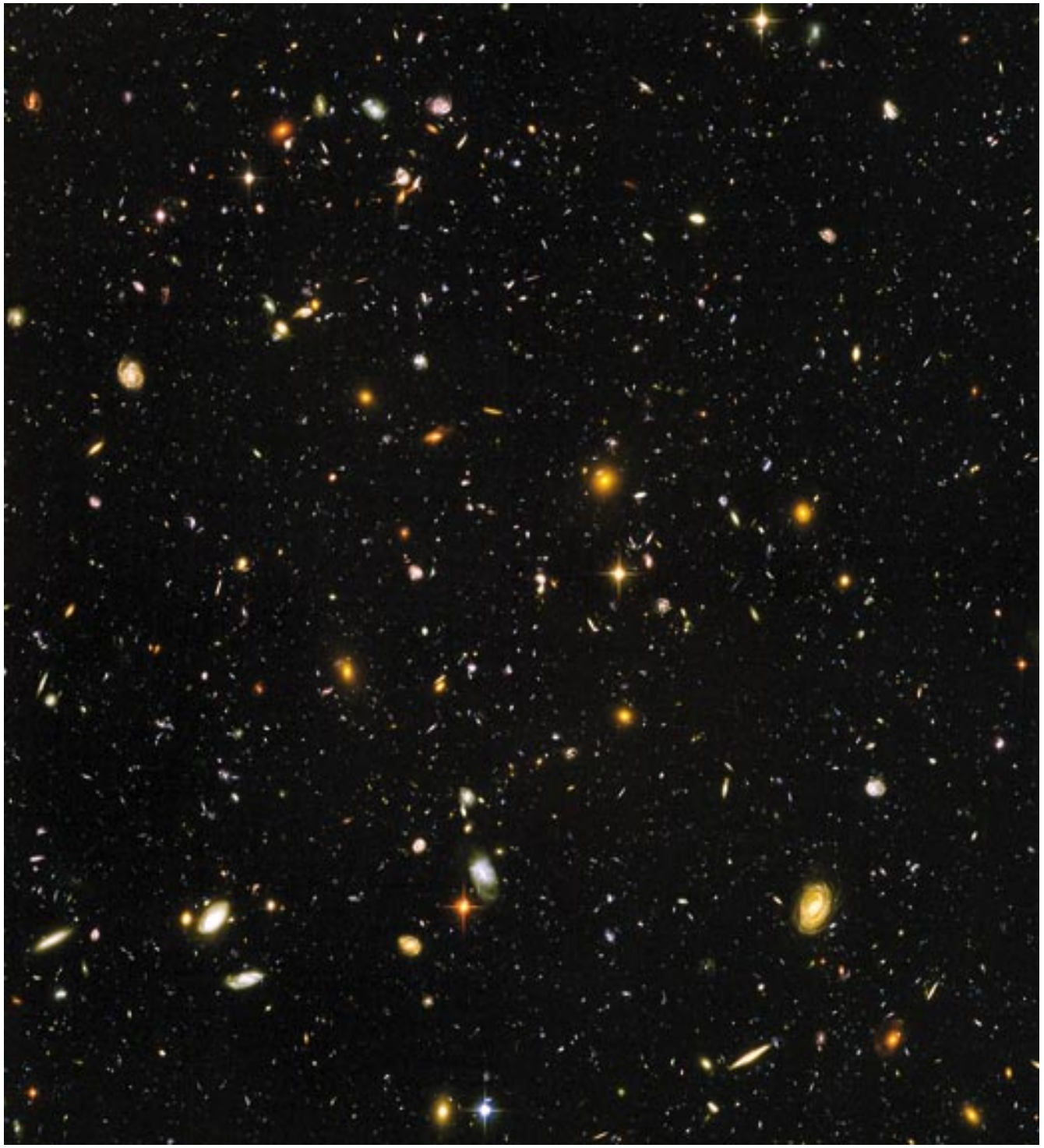

A Tour of the Universe:
Astronomy's Three Kingdoms
STEVEN J. DICK





The New Frontier

The Infinite Ocean

13.7 Billion Years Old

45 Billion Light Years Radius

Hubble Ultra Deep Field, 2004

Space, the final frontier. These are the voyages of the starship *Enterprise*. Its five-year mission: To explore strange new worlds. To seek out new life and new civilizations. To boldly go where no man has gone before ...

Astronomy's Three Kingdoms

Planets

Known since antiquity – "wanderers"

Recognized as possibly Earth-like since Copernicus

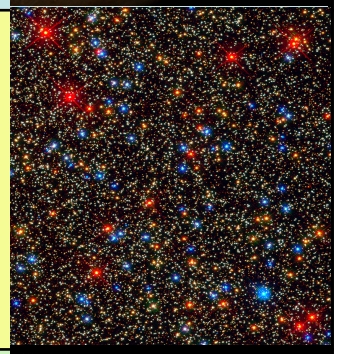
Understood in some detail after telescope

Stars

Known since antiquity – "fixed"

Recognized as possible suns since 16 c (Bruno)

Understood after spectroscopy (19th century)



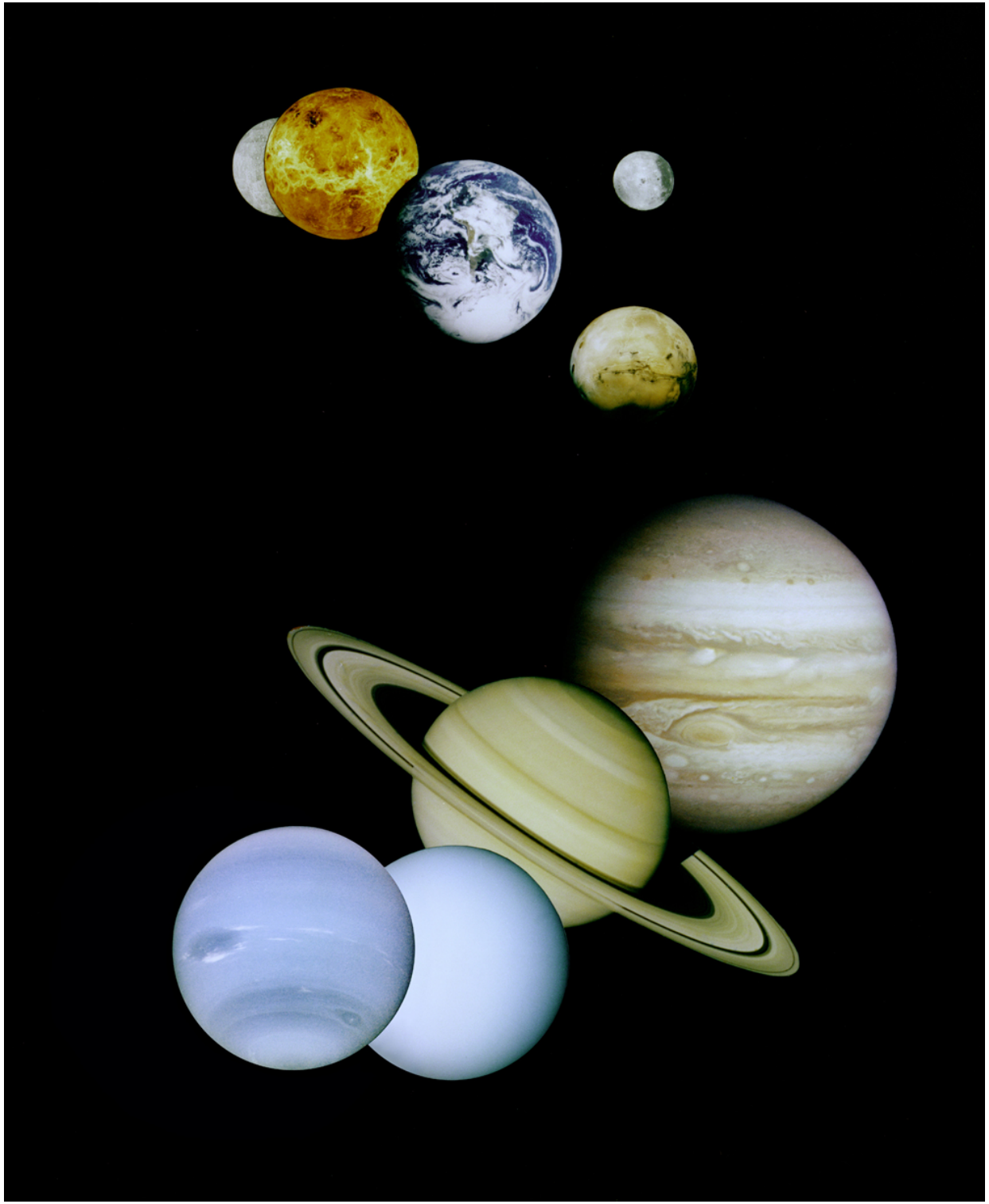
Galaxies

Known since at least 16th c (Magellan)

Recognized as possible 'island universes' in 18th c

Understood since 1920s

These are the main divisions enshrined in all astronomy textbooks since the 1950s

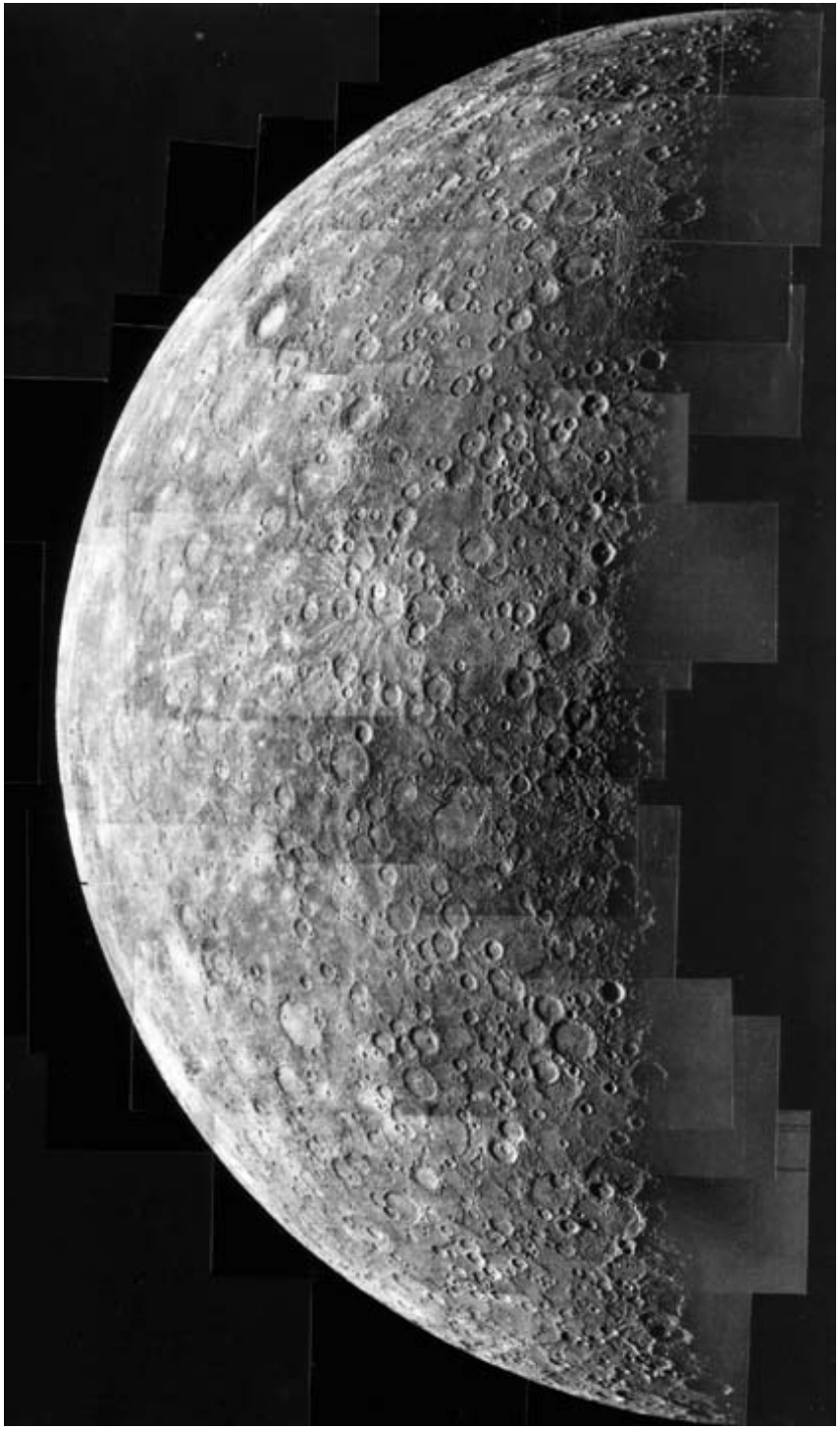


Kingdom Of The Planets

Distance Scale:
Light Minutes to
Light Hours

THE MOON

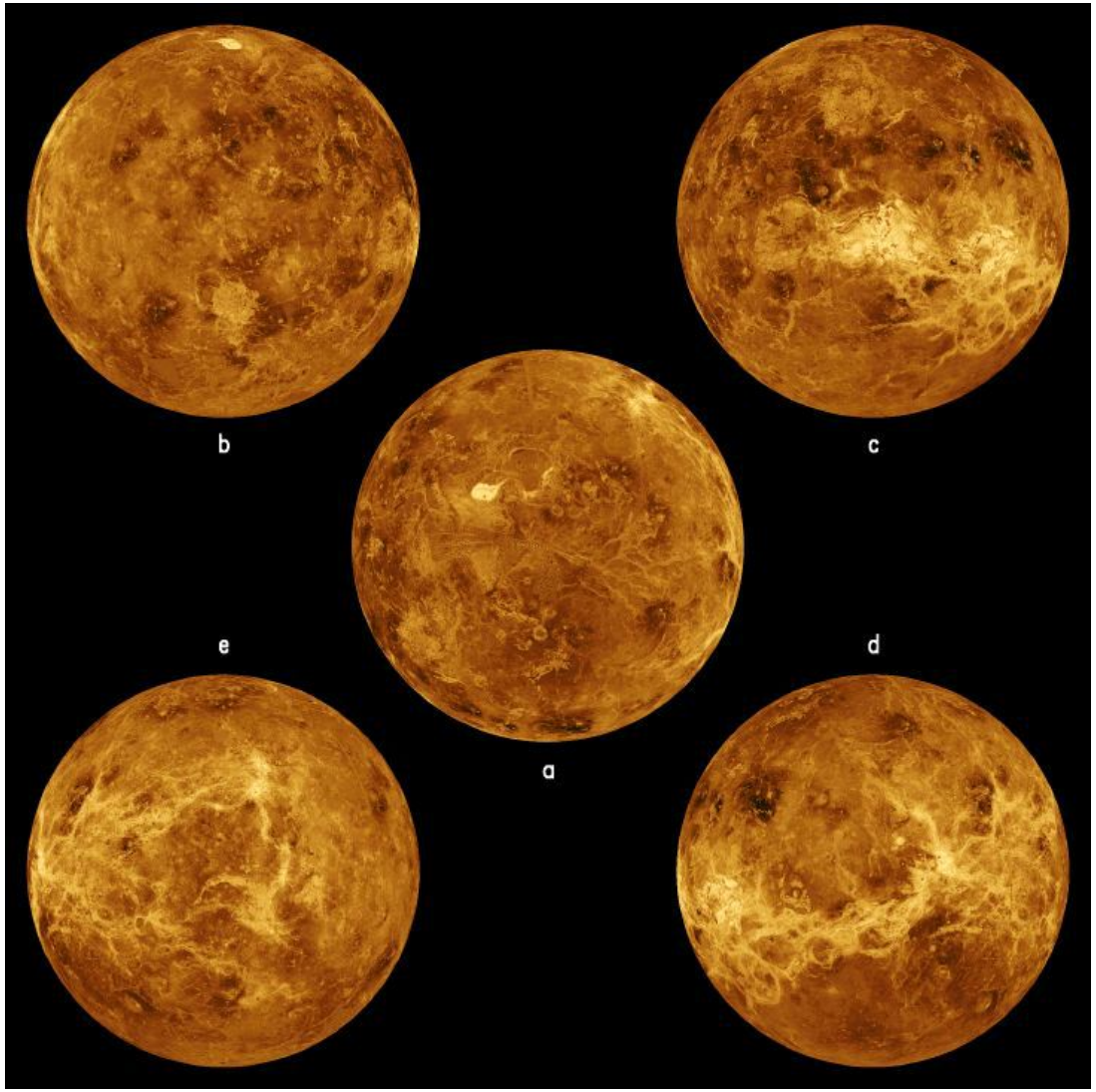
James Irwin at
Hadley Base,
Apollo 15, 1971



Mercury:

- Closest to the Sun
- A Violent History
- Geologically Dead

Mosaic of Mercury taken by the Mariner 10 spacecraft during its approach on 29 March 1974.

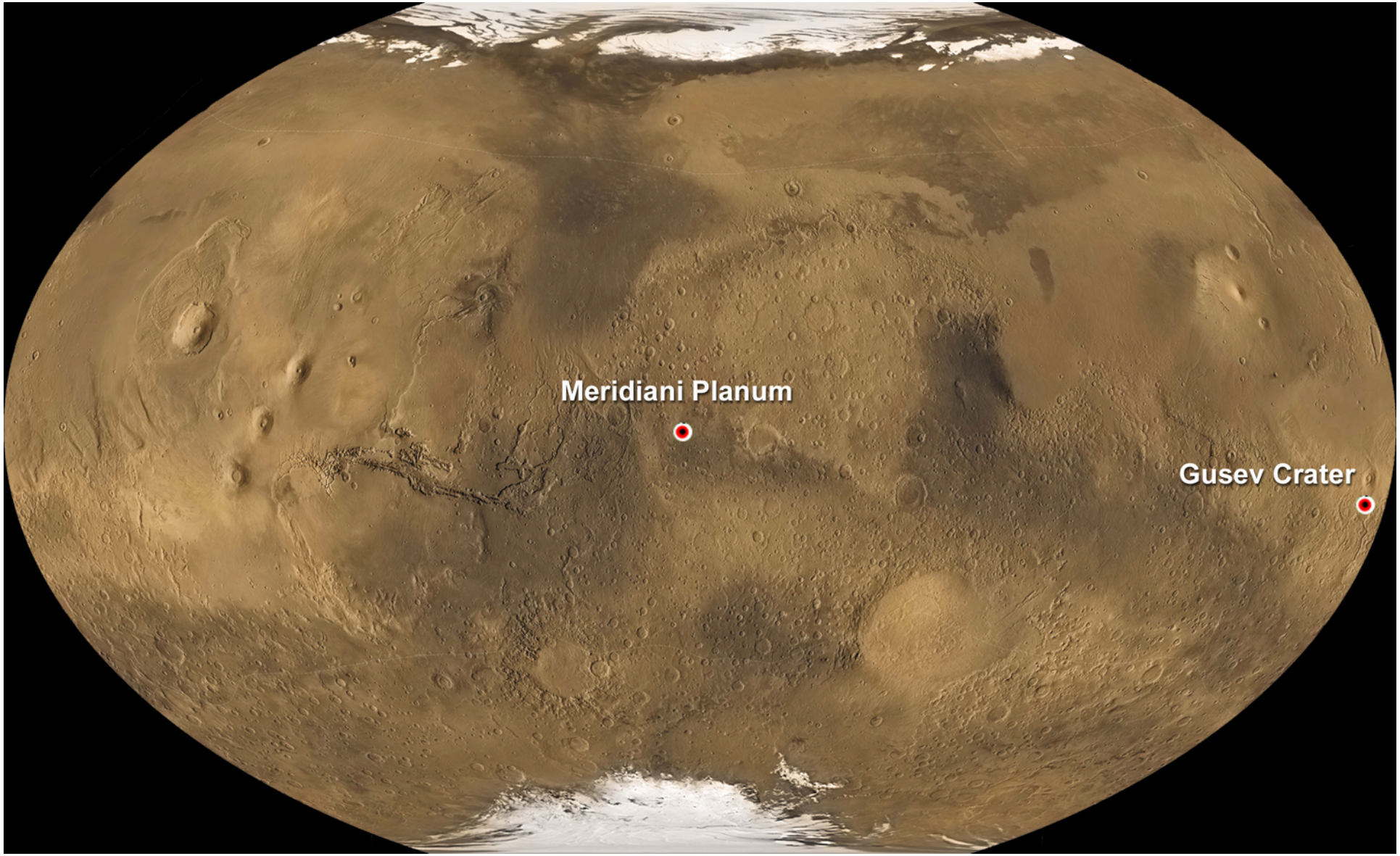


Venus

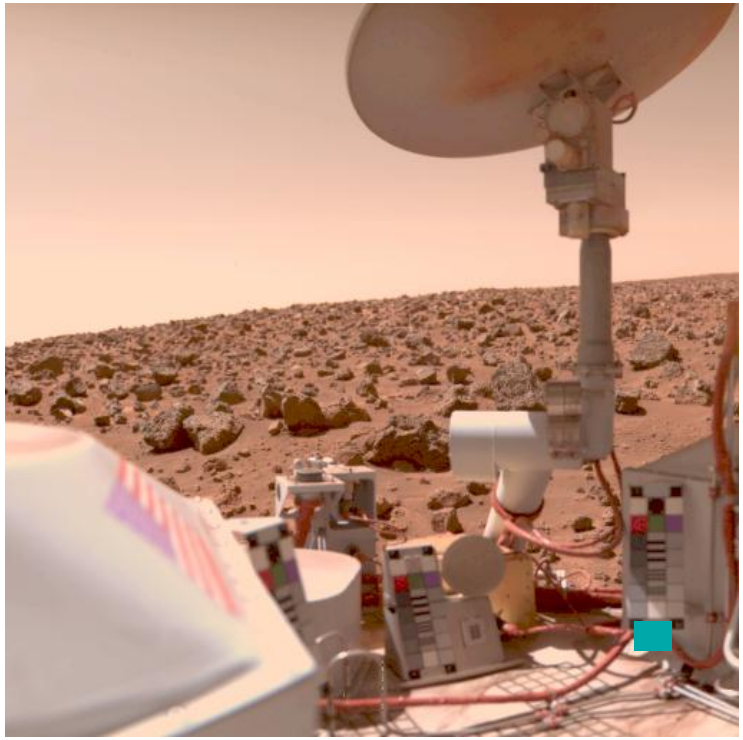
- Similar to Earth Size
- Dense CO2 Atmosphere
- 900 Degrees F
(Greenhouse Effect)
- Sulfuric Acid Clouds
- Geologically Active
(Volcanoes)

Magellan composite radar images. Magellan began mapping the surface of Venus in September, 1990, and ended operations October 12, 1994

Mars

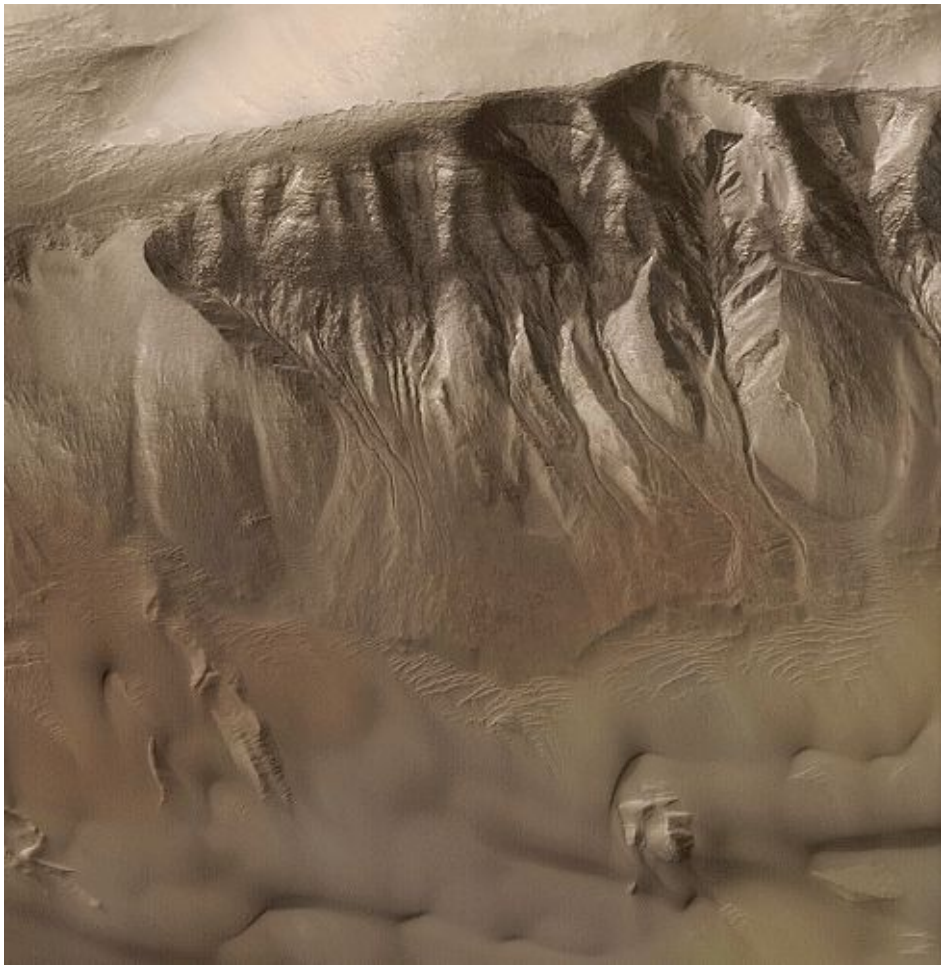


Mars – Evidence of Life?

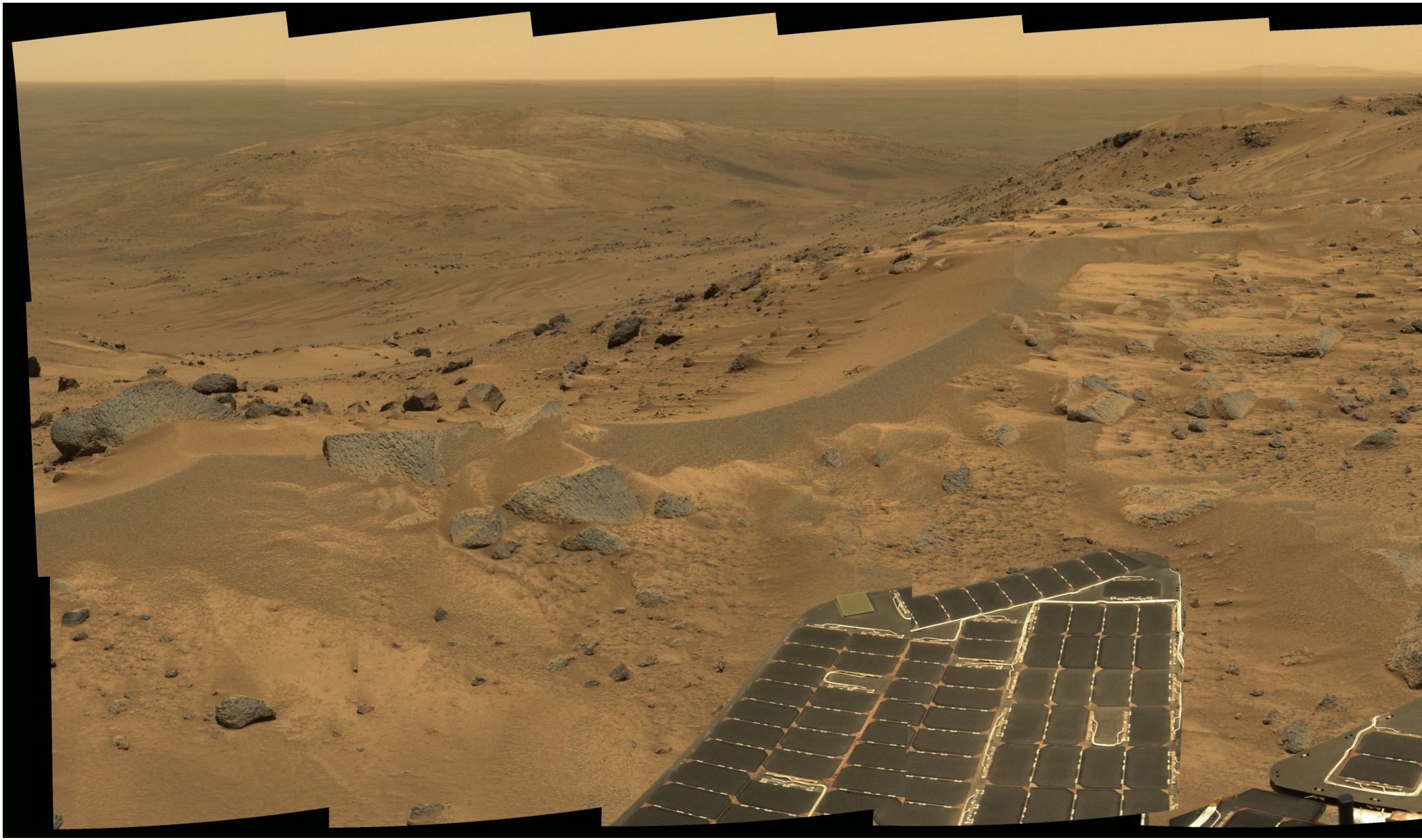


Viking lander, 1976

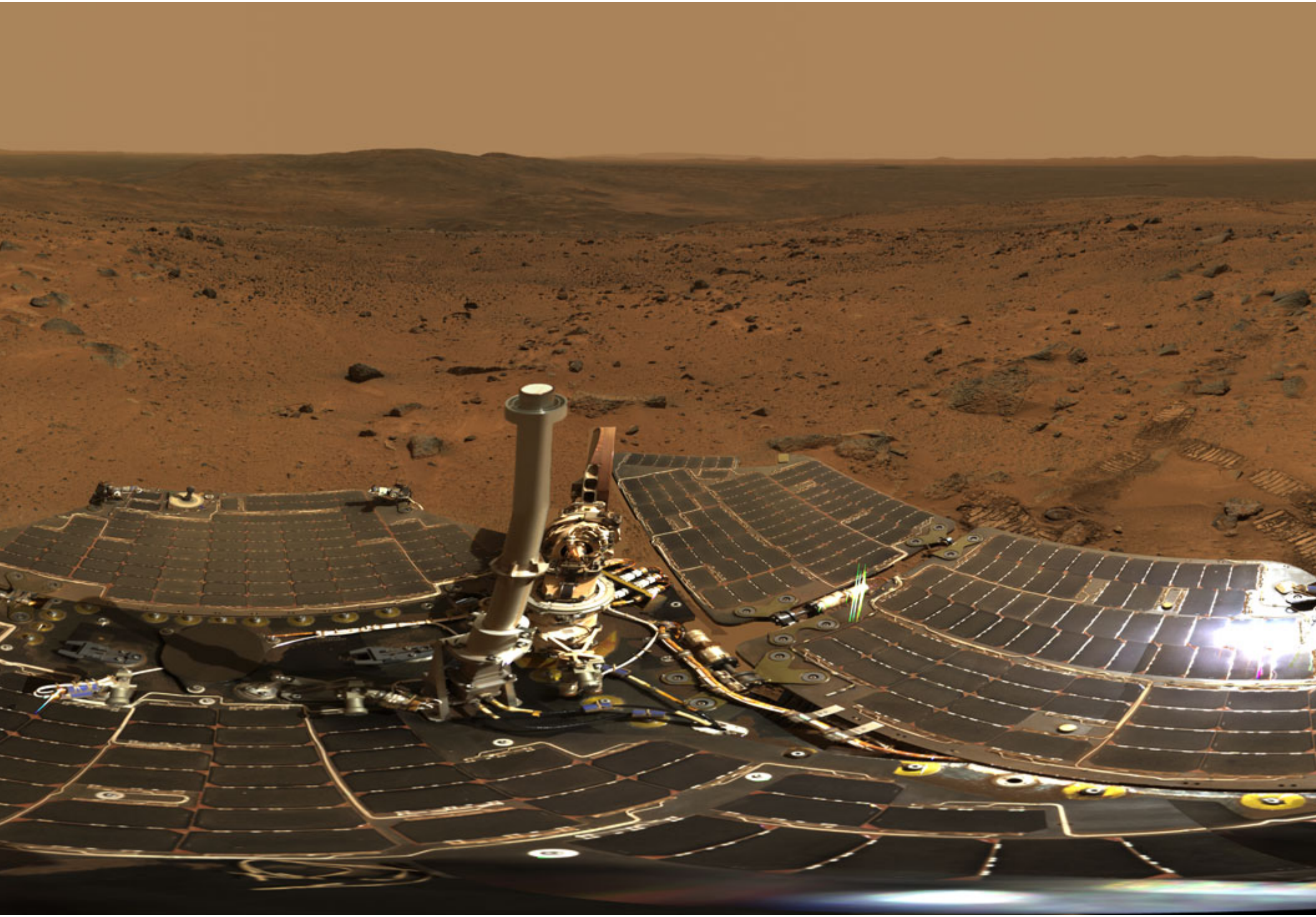
Mars Pathfinder, 1998



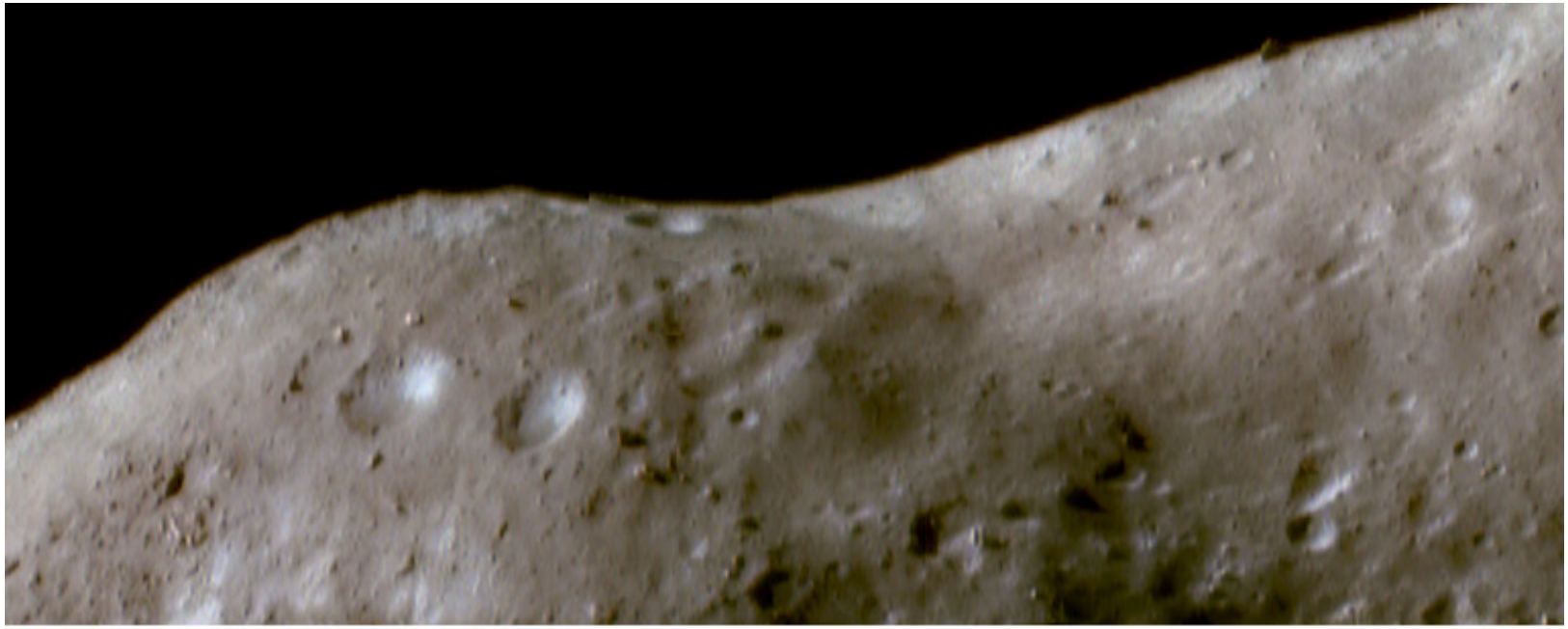
Gullies on Mars, Mars Global Surveyor, 1997



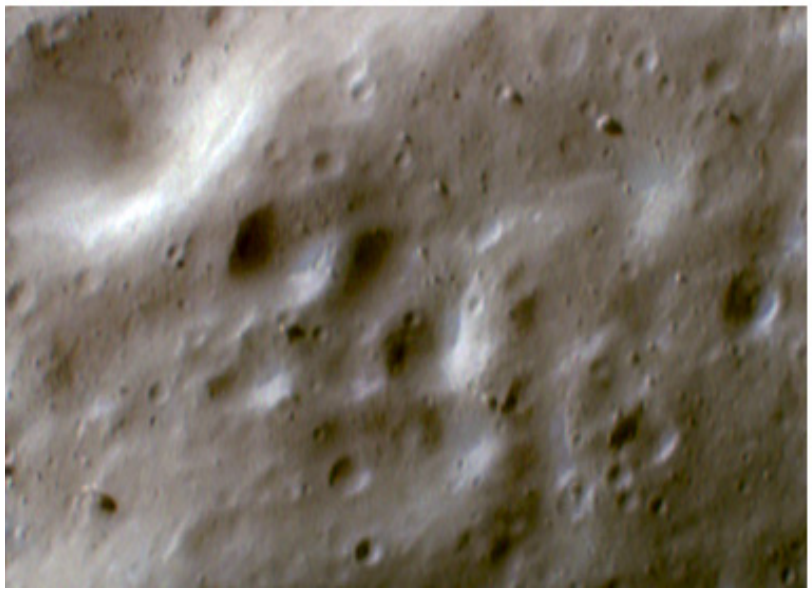
View from Spirit at the top of Husband Hill August 23, 2005

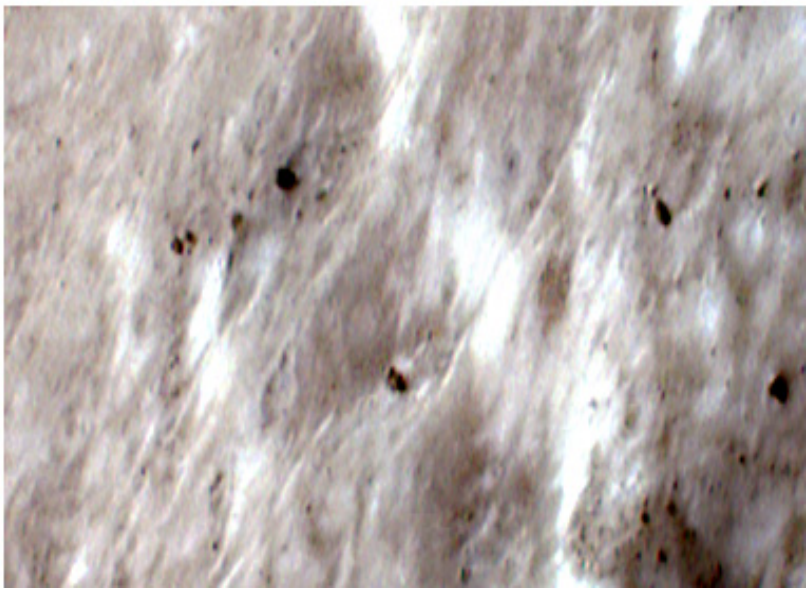


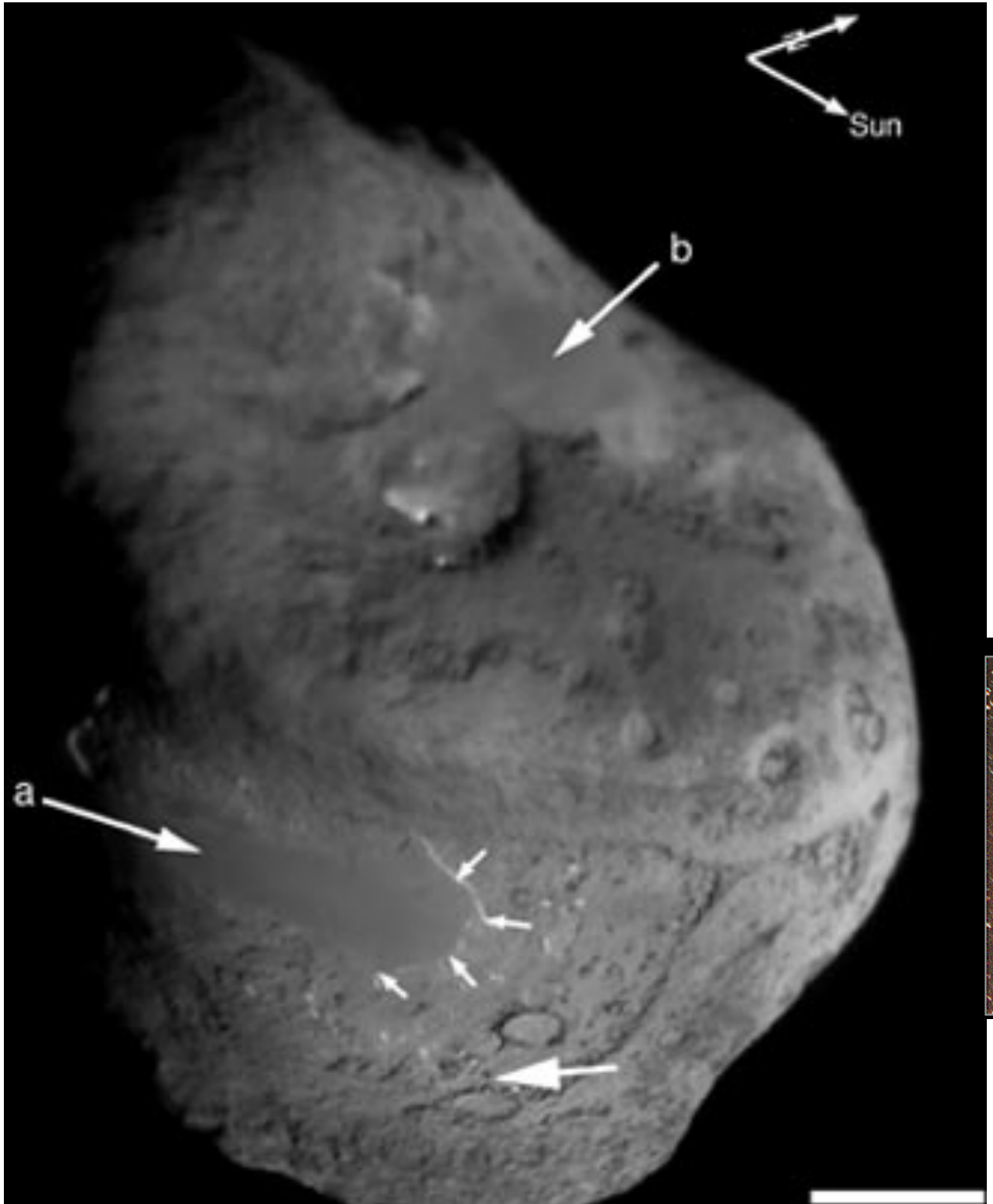
Asteroid Eros from 34 Miles (NEAR-Shoemaker) October 16, 2000



Touchdown
12 Feb 2001





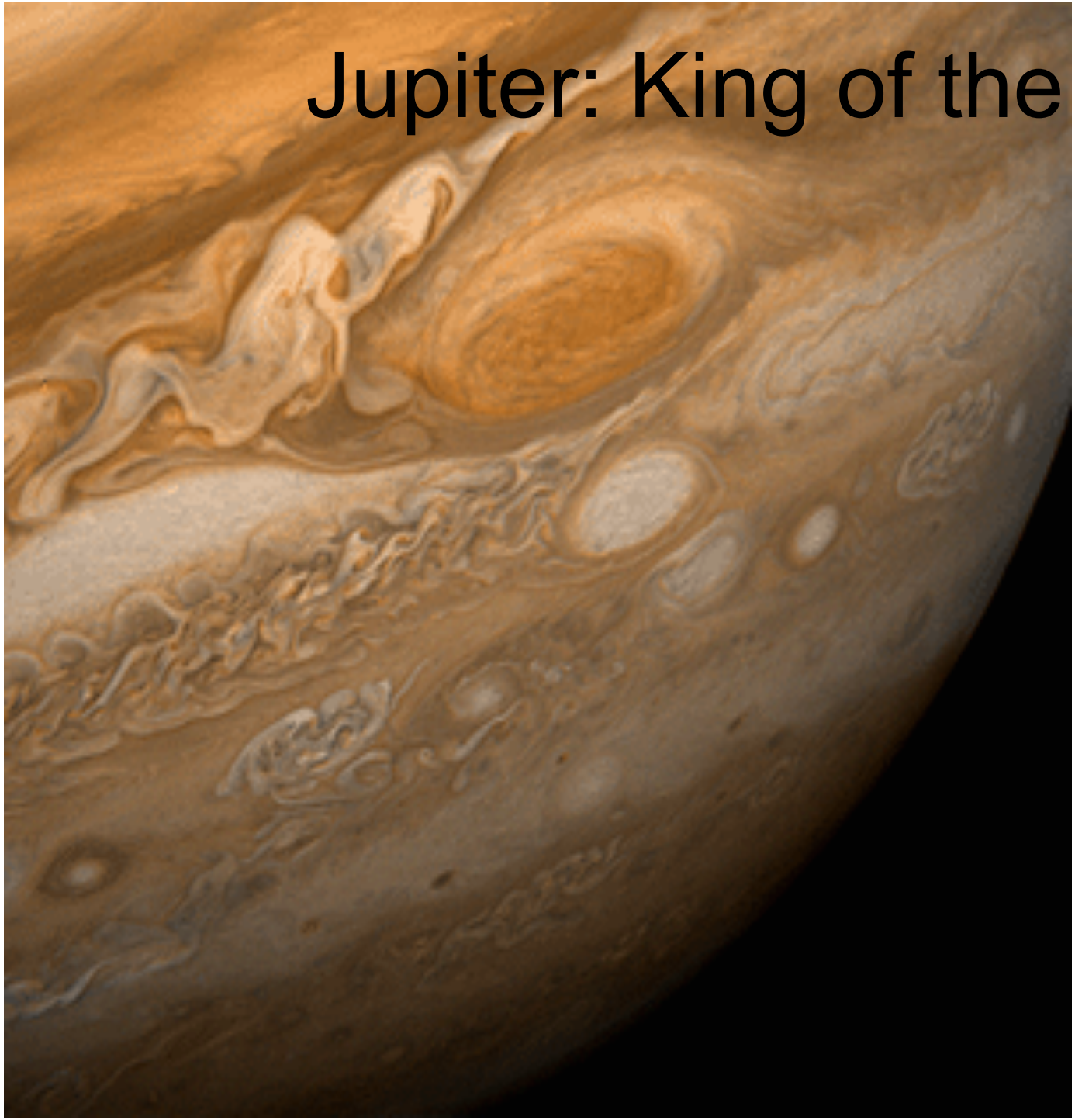


Comet Tempel 1

Viewed by

Deep Impact

Spacecraft



Jupiter: King of the Planets

A Gas Giant

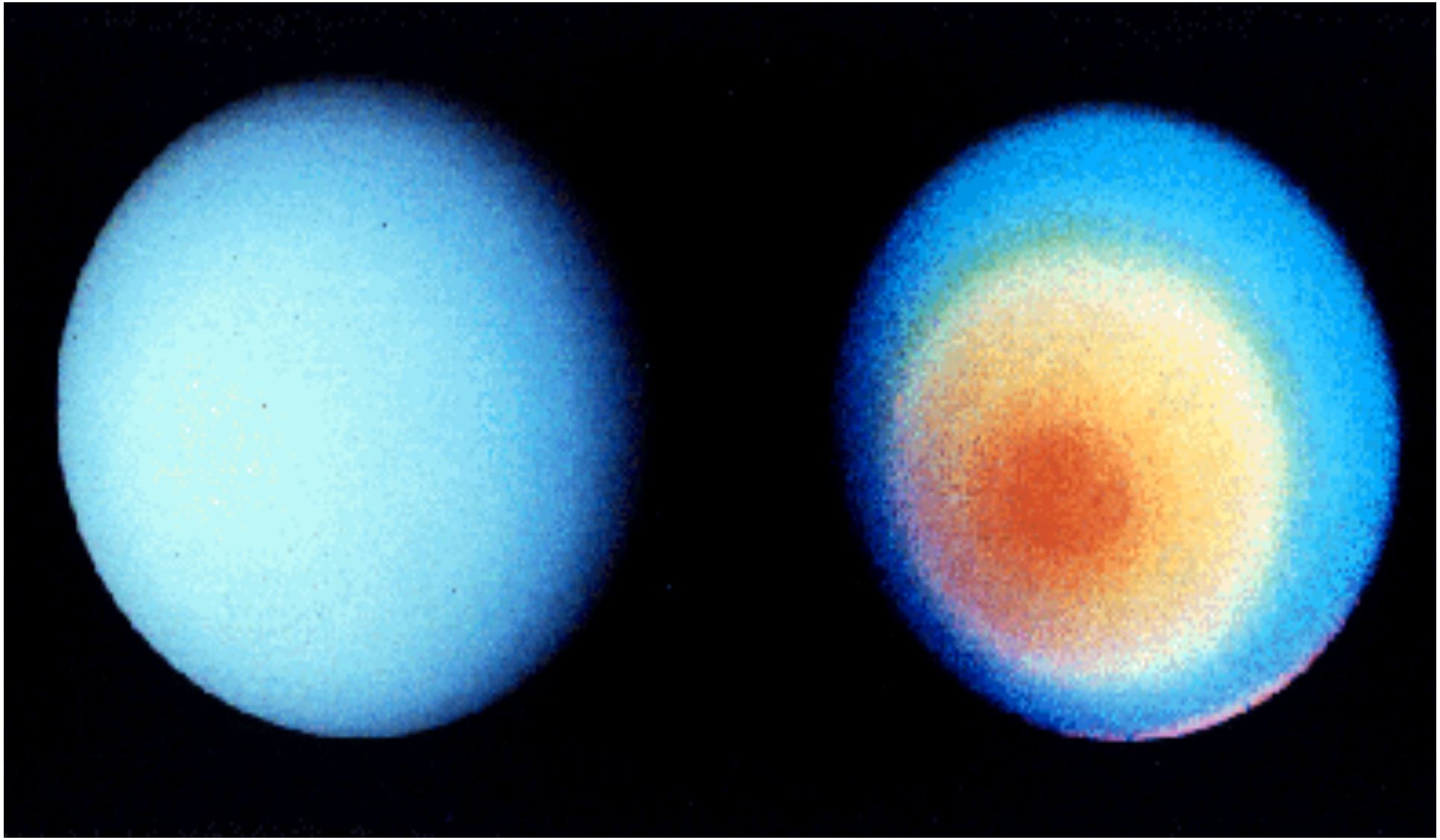
1321 Earths would fit inside Jupiter!

Methane/ Ammonia Clouds

Giant Storms

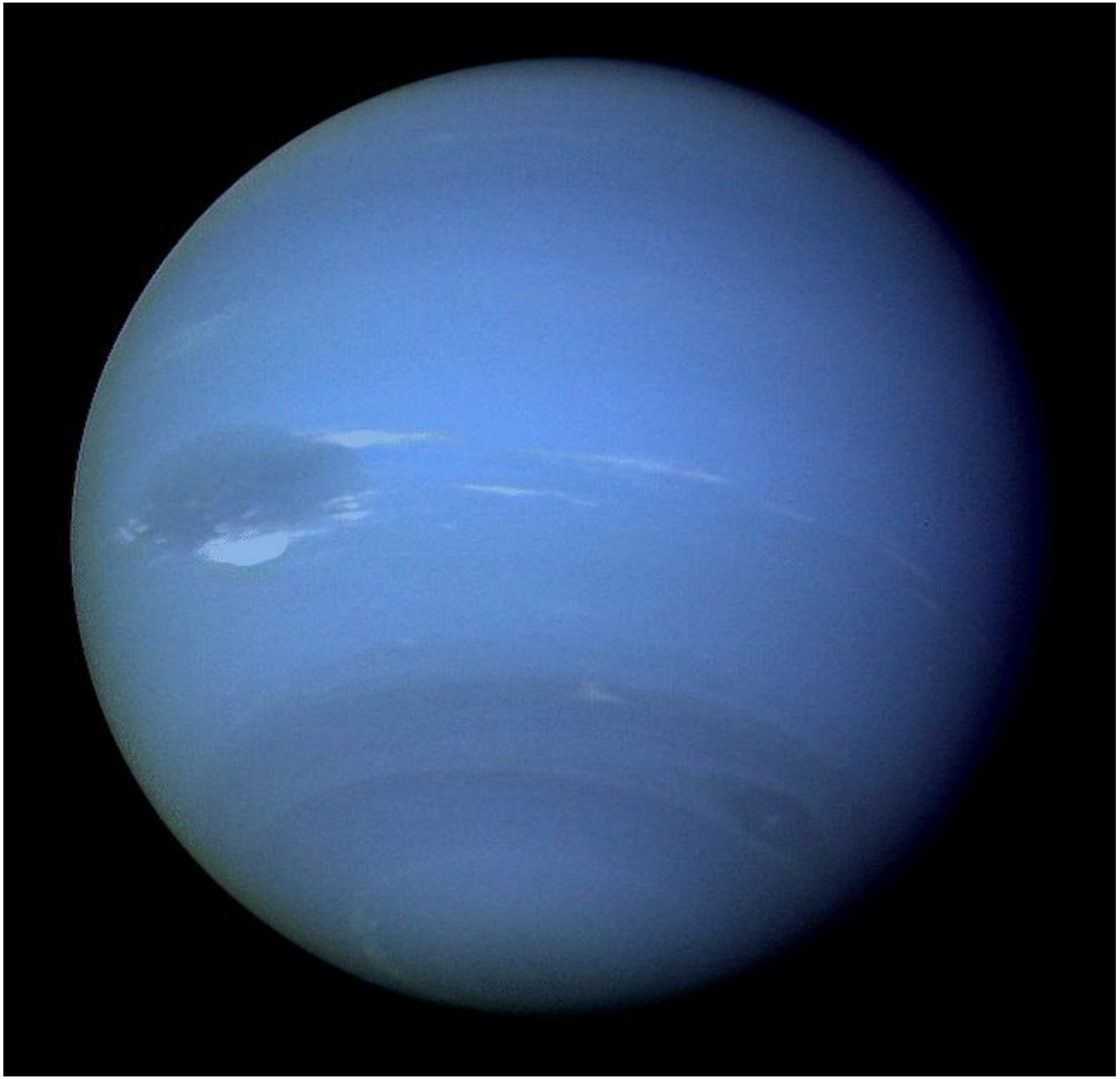
Saturn: Lord of the Rings

Voyager 1 image of Saturn November 6, 1980



Uranus – an Ice Giant. Discovered 1781

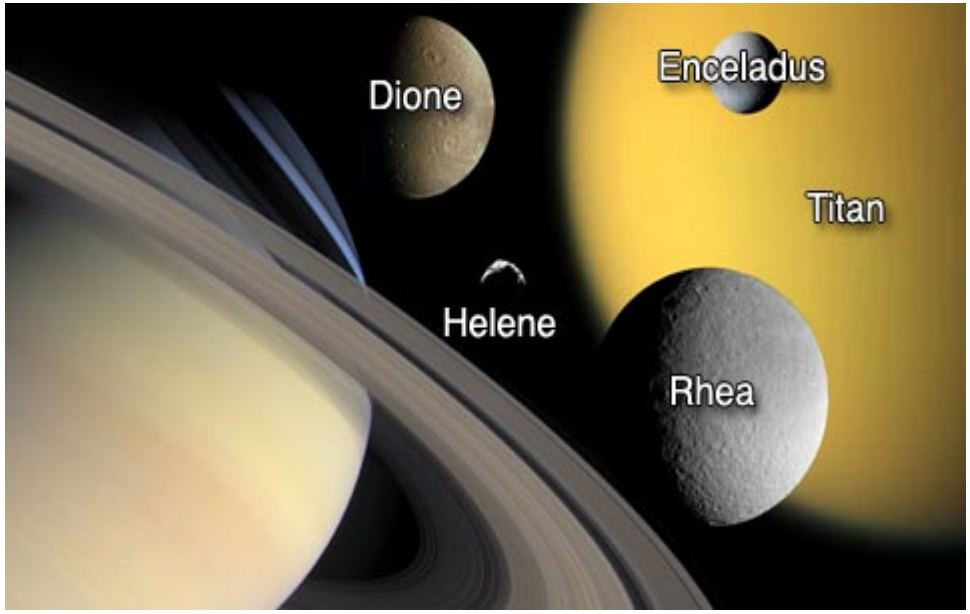
Voyager 2 - January 17, 1986



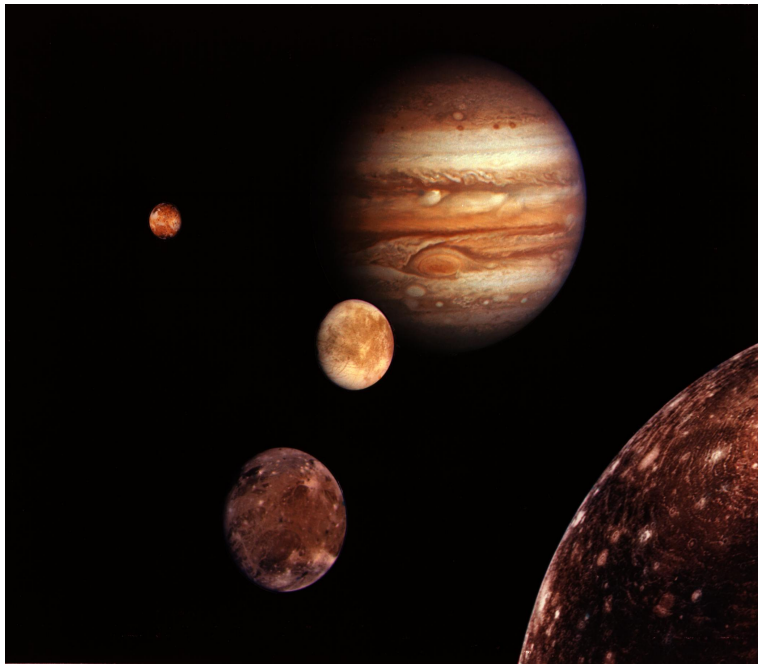
Neptune
An Ice Giant
Discovered 1844

Voyager 2
August, 1989

More Worlds …



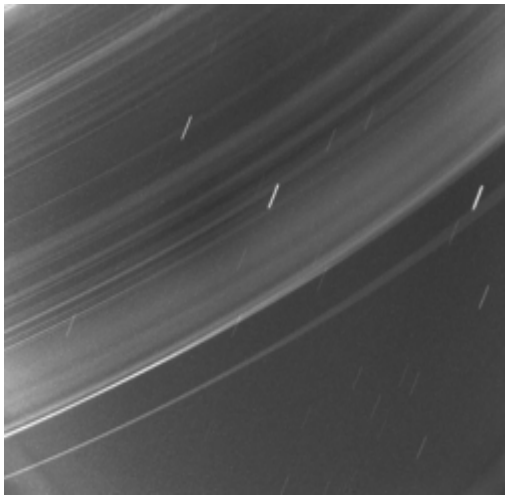
Phobos from Mars Global Surveyor, 1998



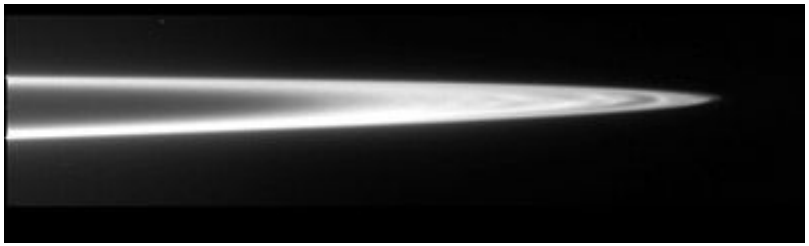
> 130 known satellites in solar system

Planetary Rings

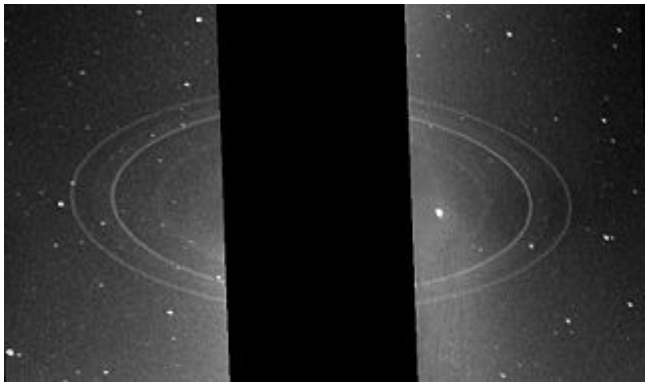
Saturn's rings from Cassini



Uranus rings, Voyager 2

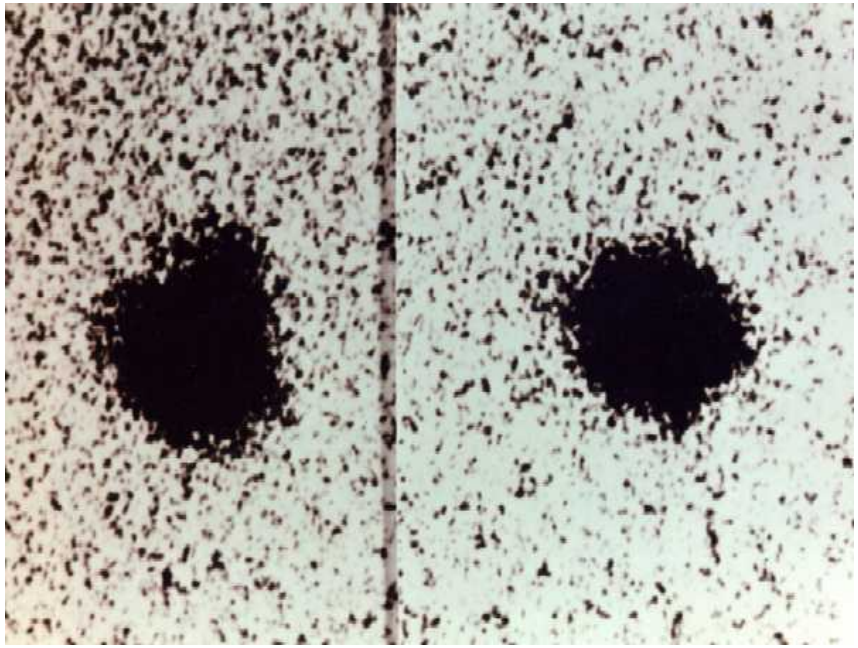


Jupiter's main ring, from Galileo



Neptune rings, Voyager 2

Pluto and its Moon

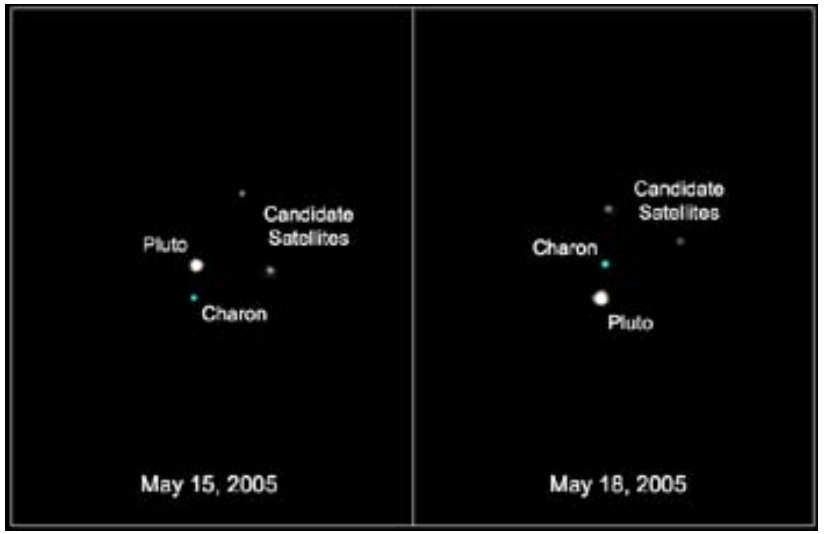


USNO Discovery July 6, 1978

Discovery images of Pluto/Charon, taken with the 1.55-meter (61-inch) Kaj Strand Astrometric Reflector at the USNO Flagstaff Station:
Left: showing elongated image of Pluto, with Charon to the upper right
Right: showing "undistorted" image of Pluto with Charon along line of sight with the planet

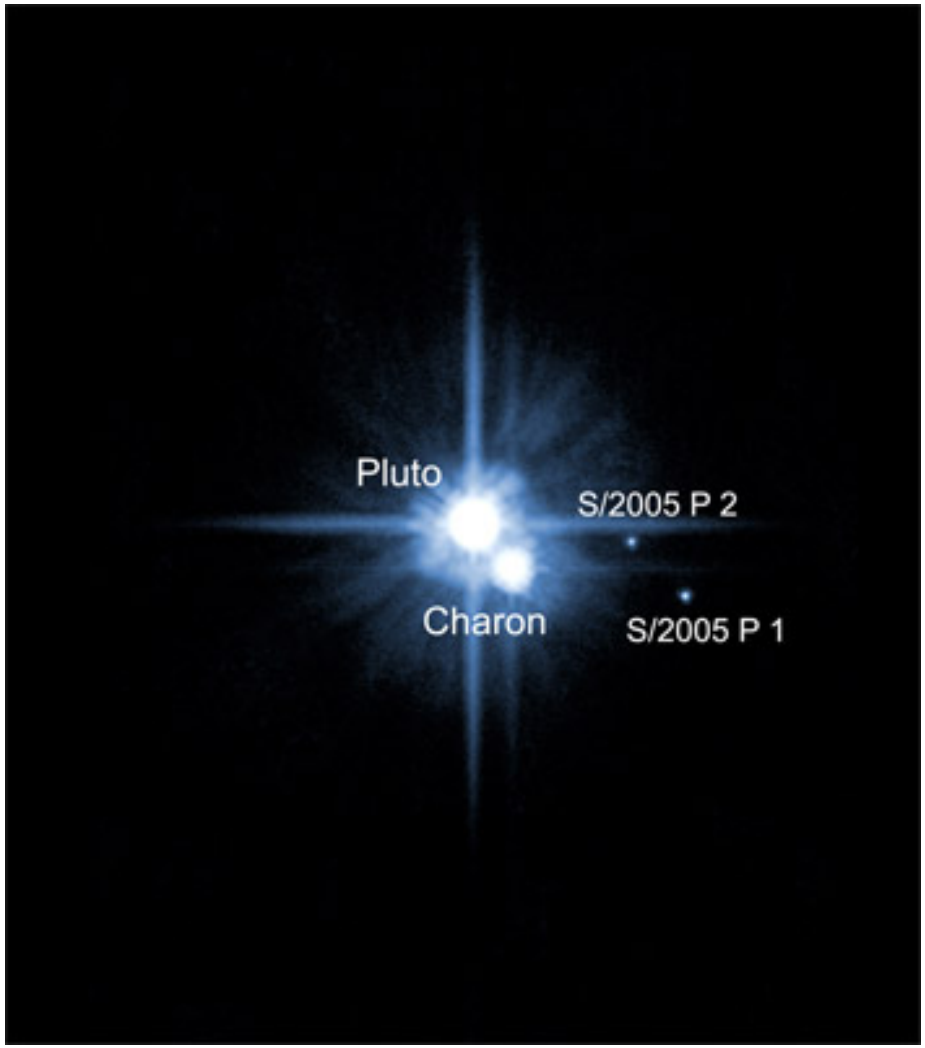
Discovery made June 22, 1978; confirmation image July 6, announcement July 6

HST Image, FOC, February 21, 1994



HST Moons announced October 31, 2005

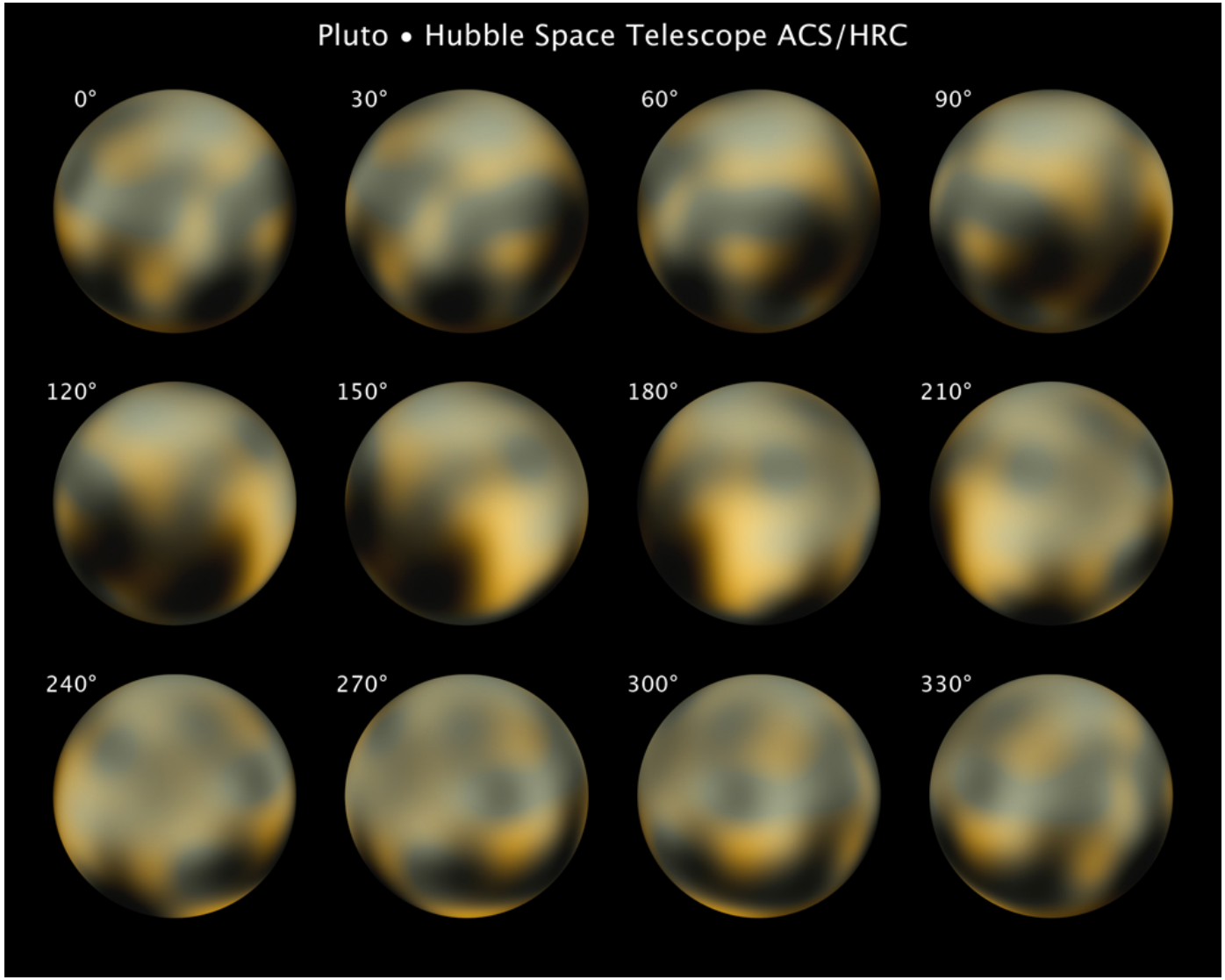
… and a Dwarf Planet



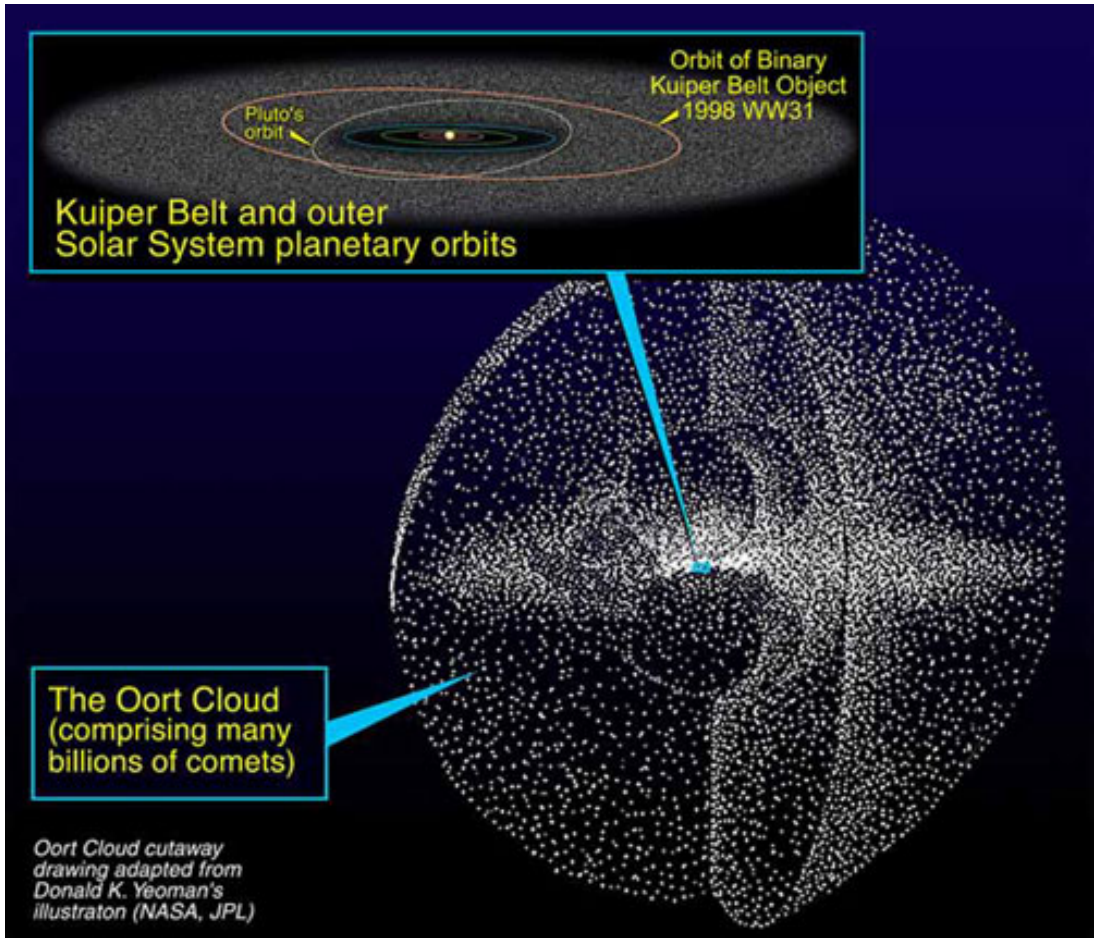
New Horizons
On the way!

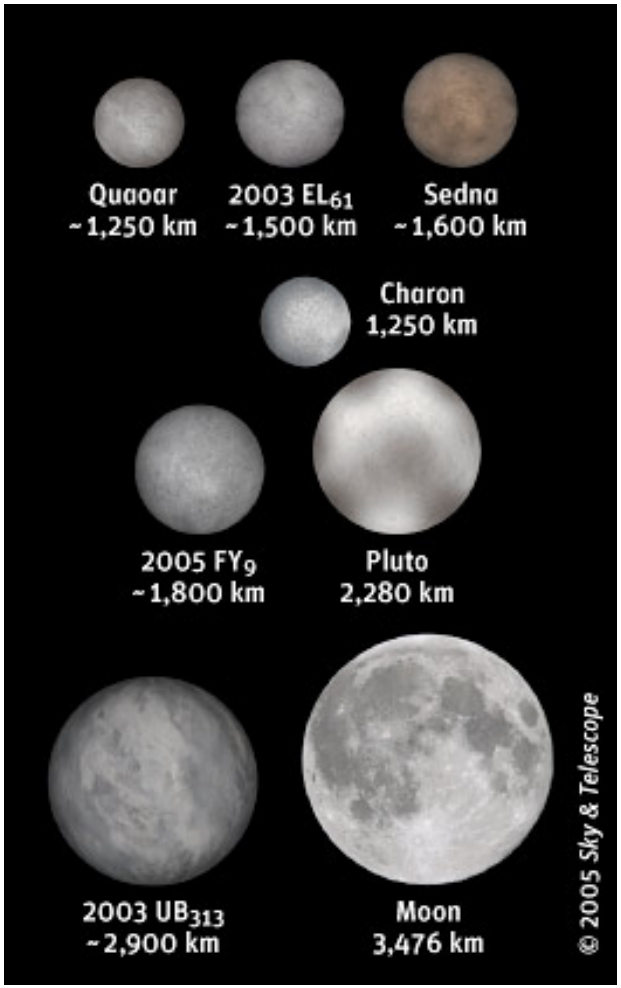
Arrival 2015

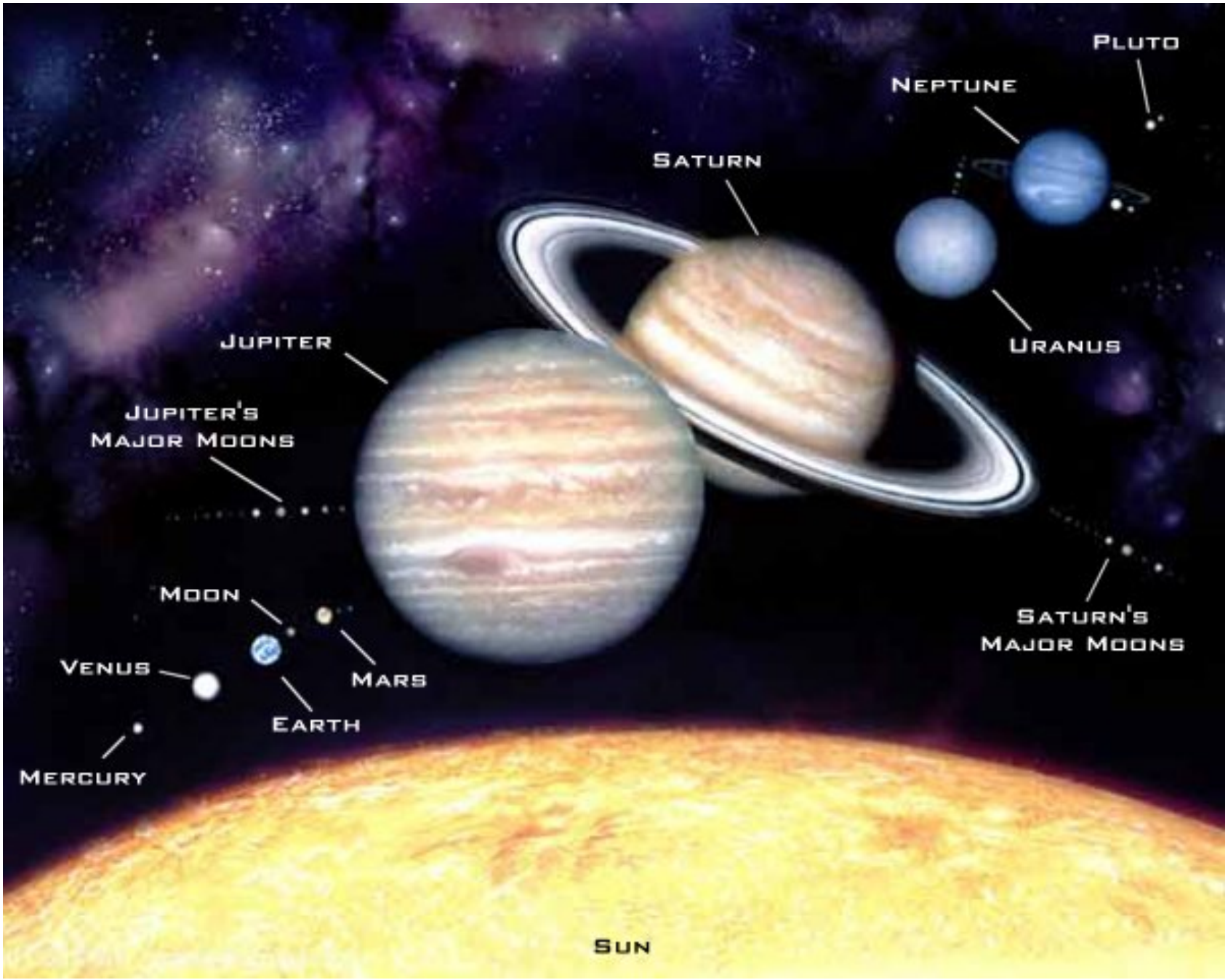
Hubble Space Telescope two new satellites of Pluto announced October 31, 2005


Pluto • Hubble Space Telescope ACS/HRC
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°

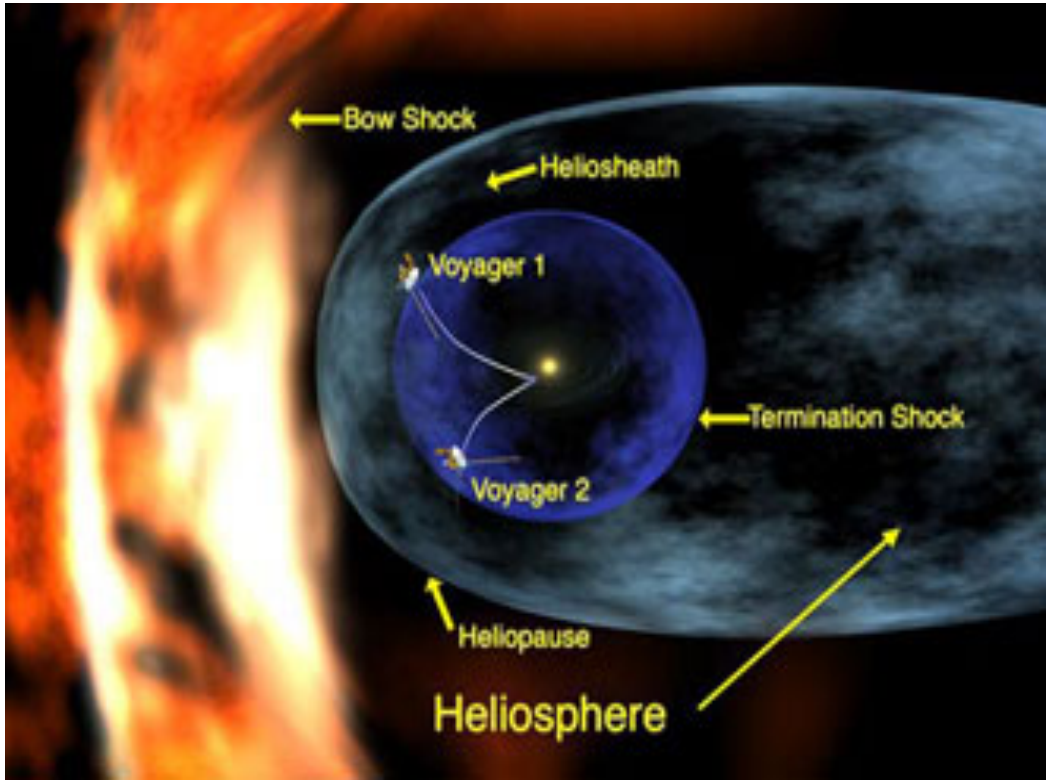
Edgeworth-Kuiper Belt Objects

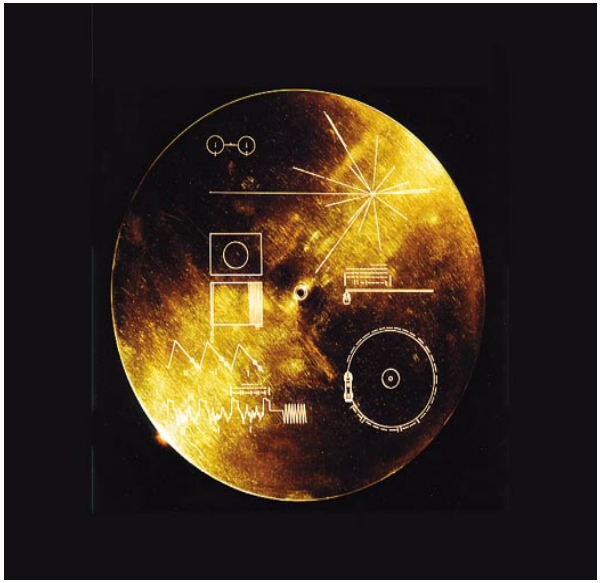





PLUTO
NEPTUNE
SATURN
URANUS
JUPITER
JUPITER'S
MAJOR MOONS
SATURN'S
MAJOR MOONS
MOON
VENUS
MARS
EARTH
MERCURY
SUN

To the edge of the Solar system …





Voyager Record

Voyager Interstellar Mission
On December 16, 2004 Voyager 1 passed
the termination shock at 8.7 billion miles
From the Sun (94 AU)

IBEX Mission, 2008

Yet More New Worlds … Extrasolar Planets

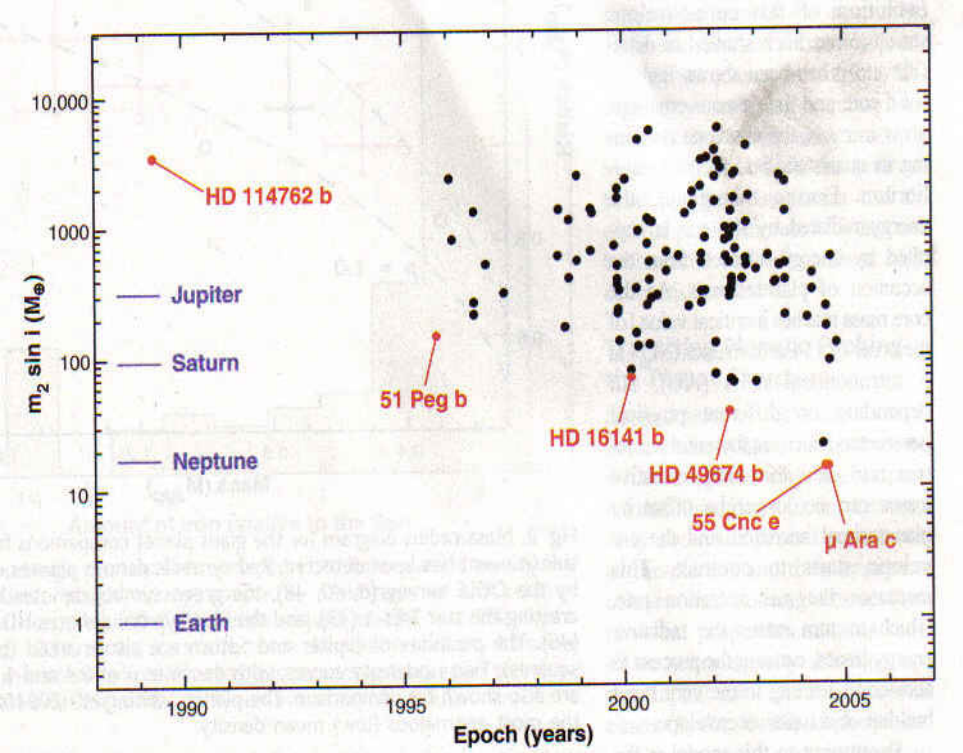
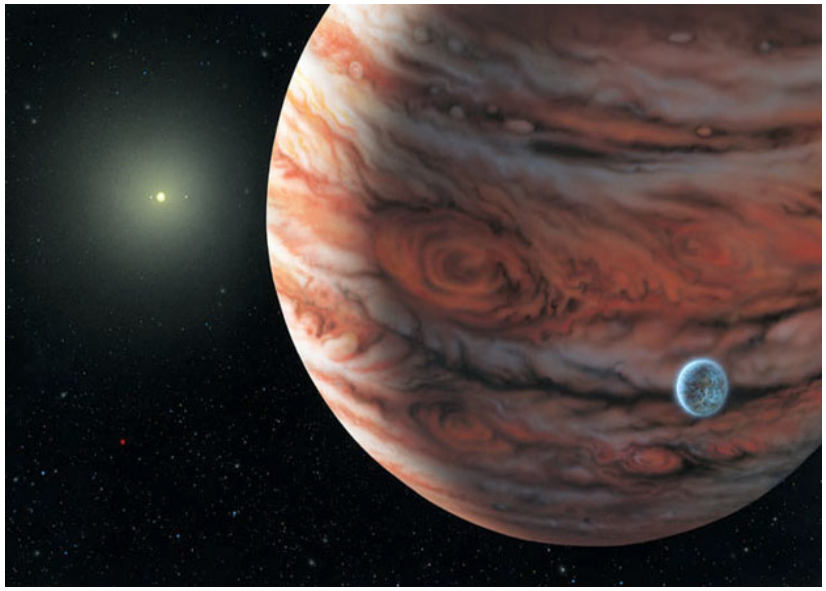
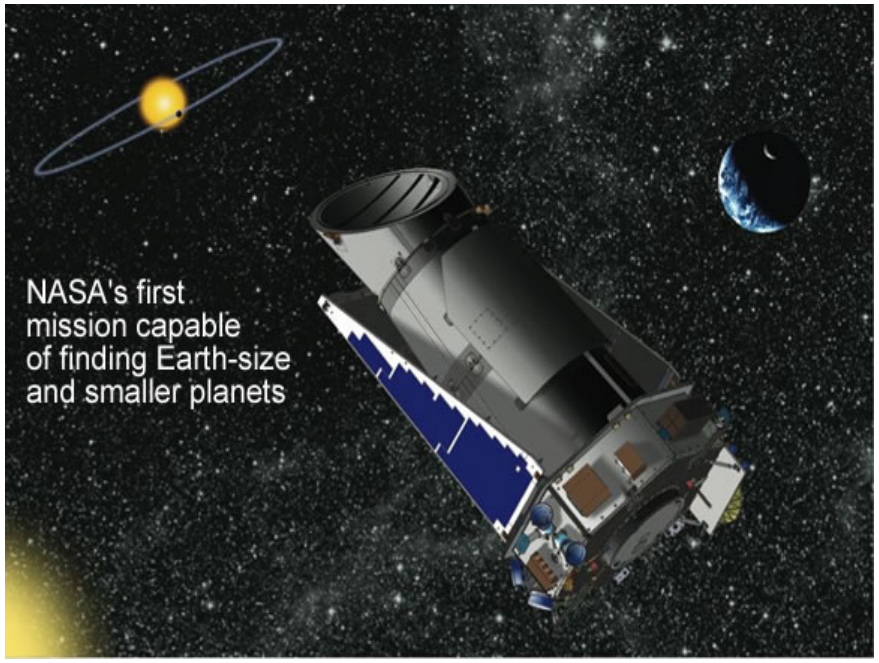
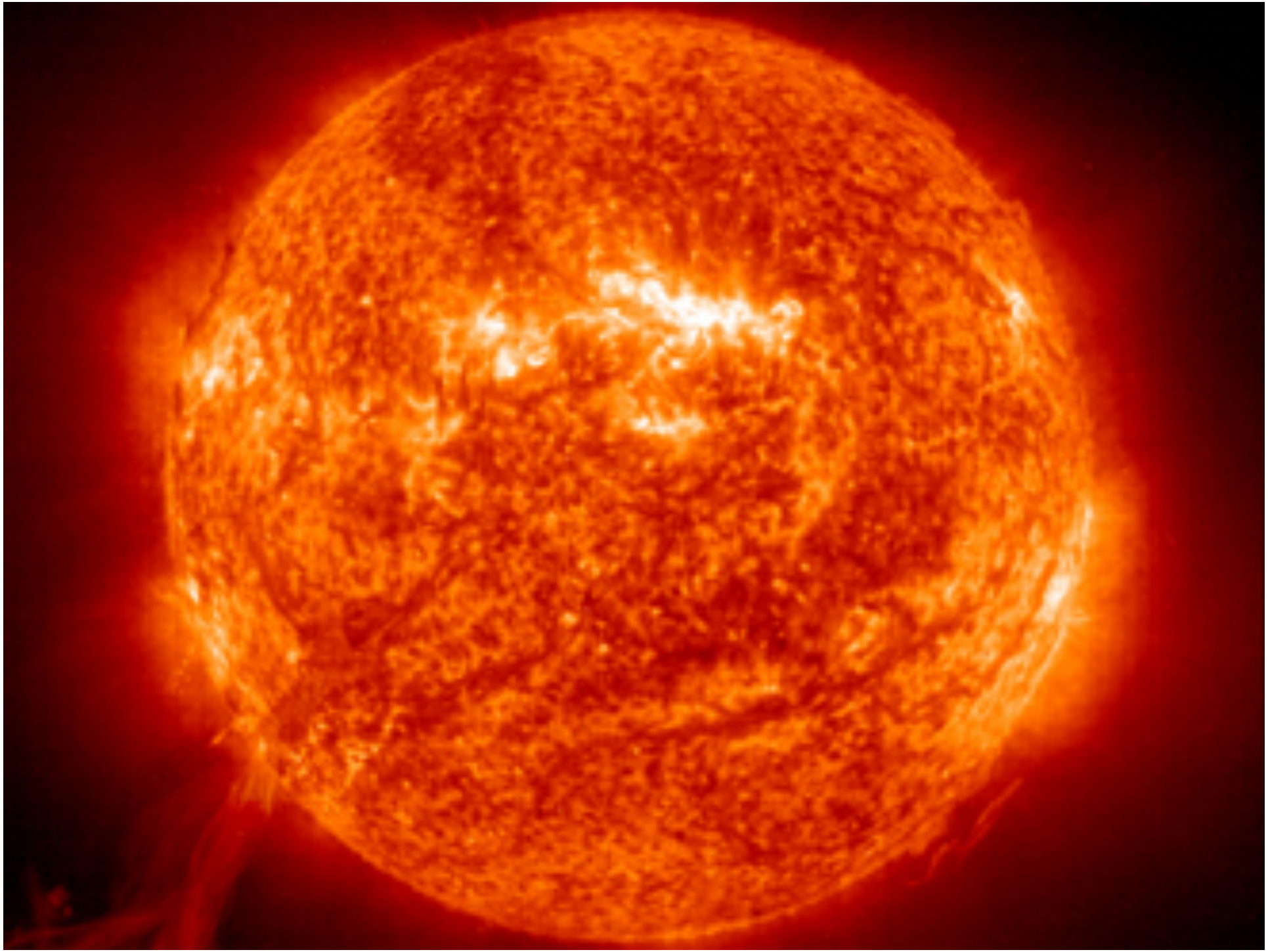


Fig. 1. Minimum mass of the known extrasolar planets orbiting solar-type stars, in Earth masses as a function of the year of the discovery. The masses of Jupiter, Saturn, Neptune, and the Earth are marked for comparison (blue lines). A few benchmark cases (red dots) are labeled: the probable brown-dwarf companion to HD 114762 (*65*), 51 Peg b (*2*), HD 49674 b (*66*), and the record-holders, recently discovered very low mass companions to 55 Cnc and μ Ara (*11*, *12*). Data are as of June 2005.






Kingdom of the Stars
Distance Scale:
A Few Light Years
To 100,000 Light Years
In our Galaxy

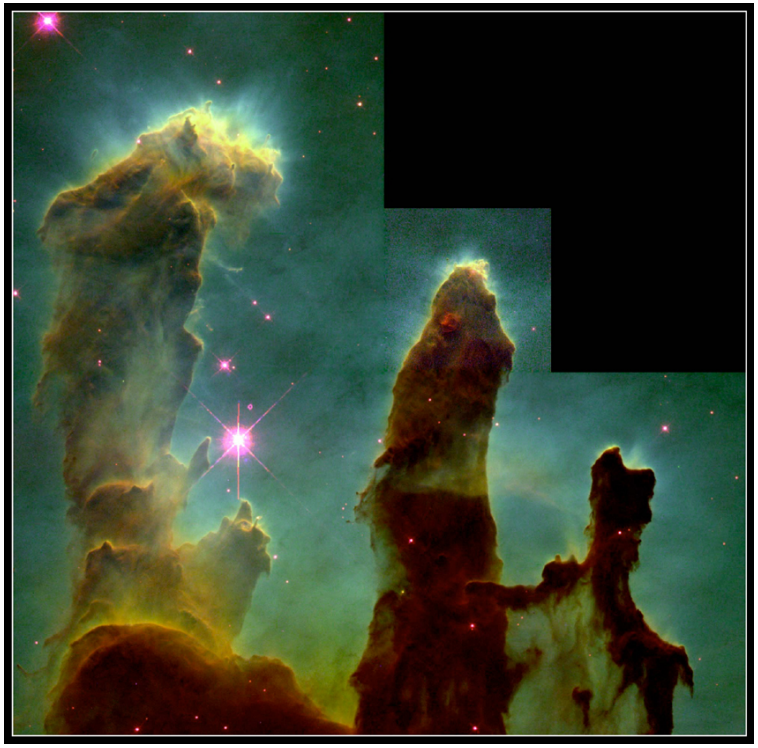


A Star is Born!

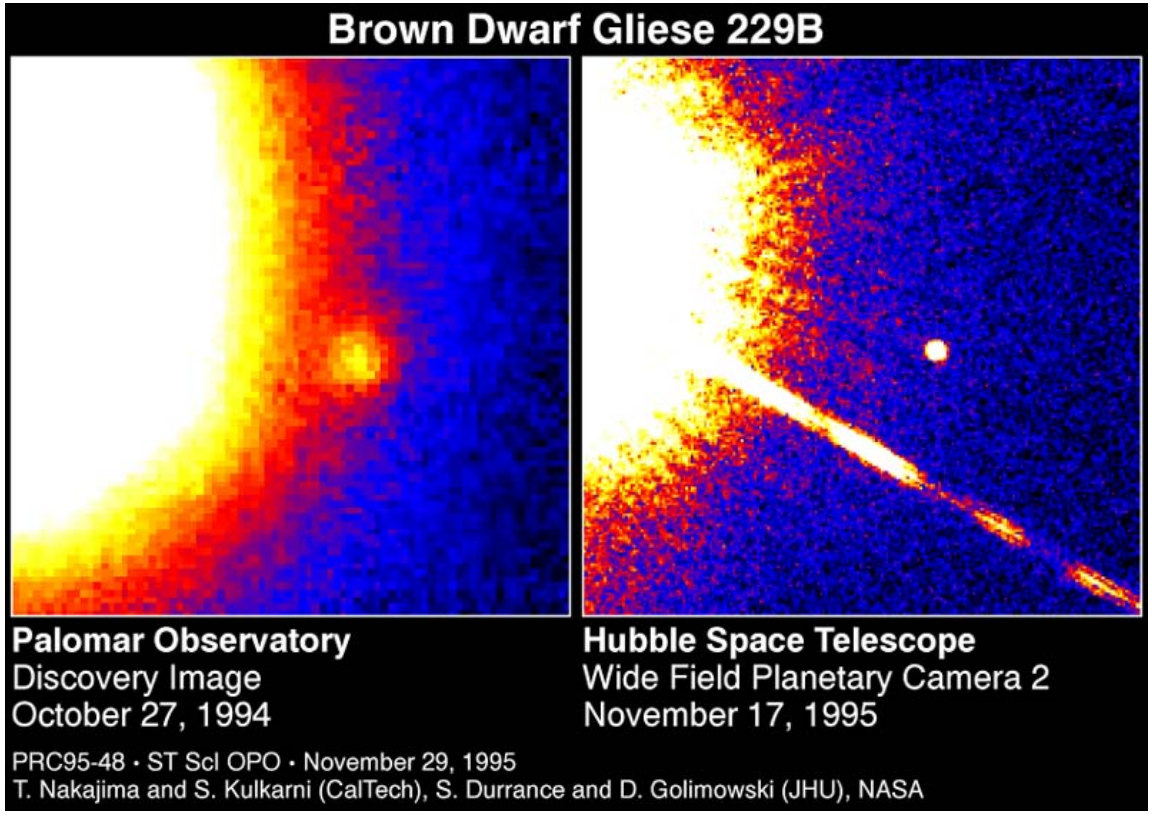
Giant Molecular Clouds

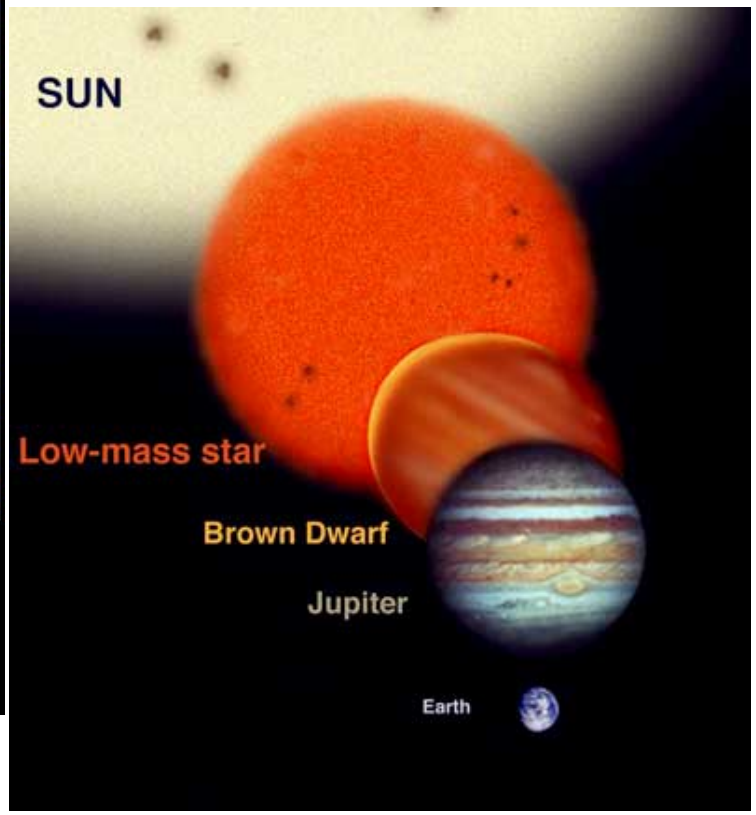
HST and Spitzer
Image of Orion
Nebula

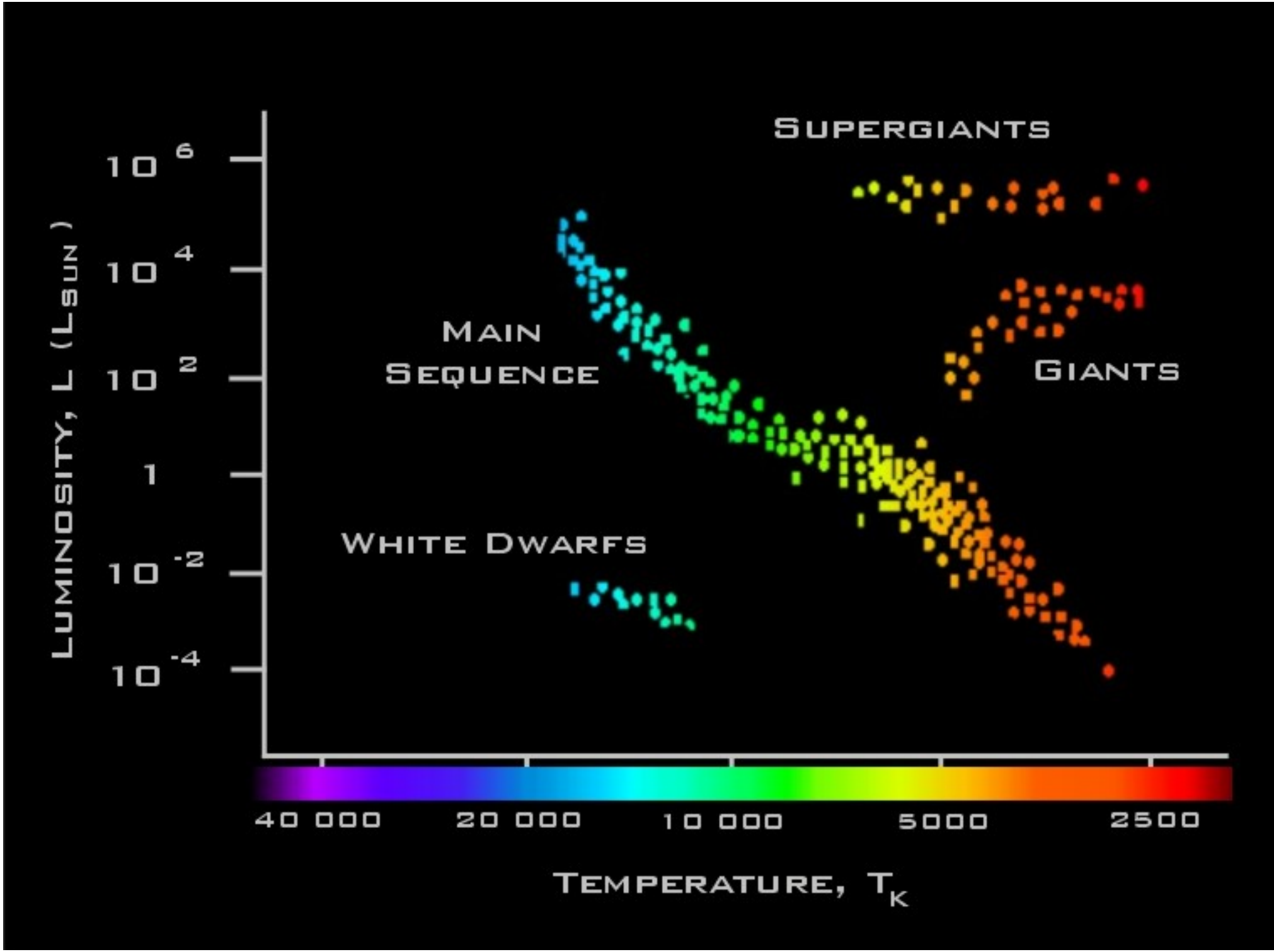
The “Pillars of Creation”
Eagle Nebula,
Hubble Space
Telescope

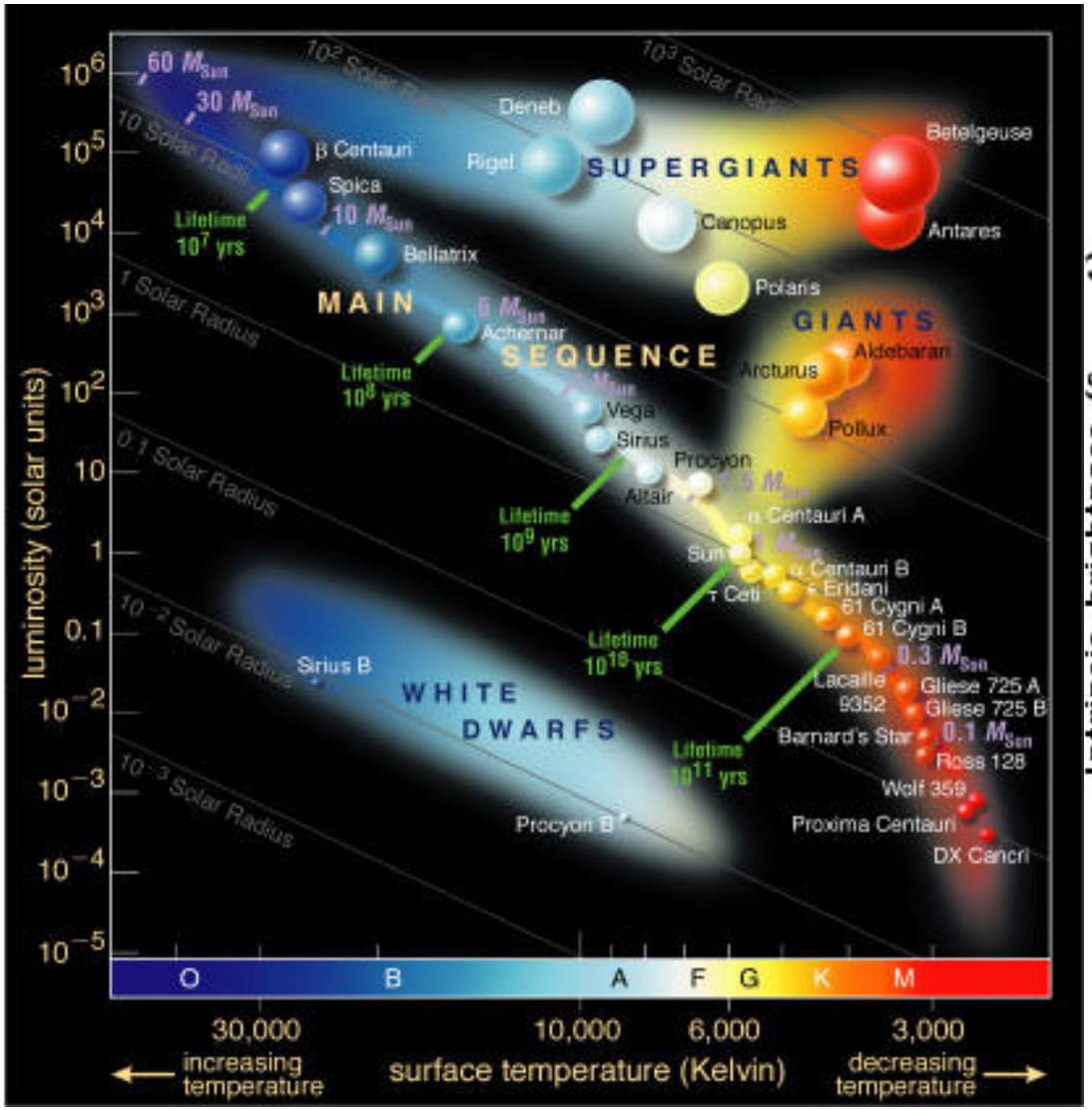


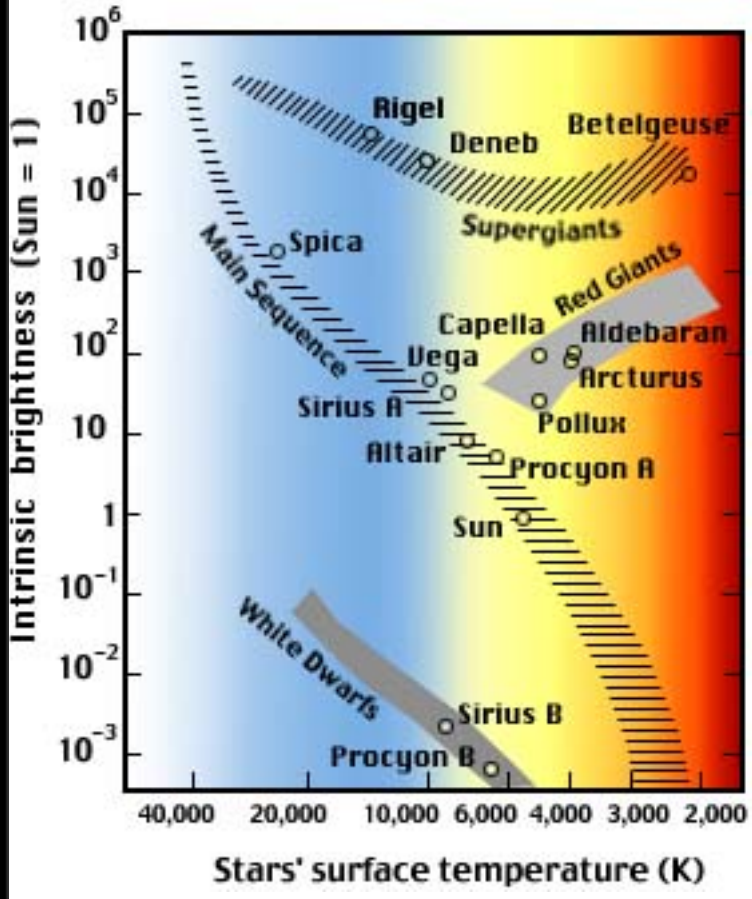
Failed Stars – Brown Dwarfs

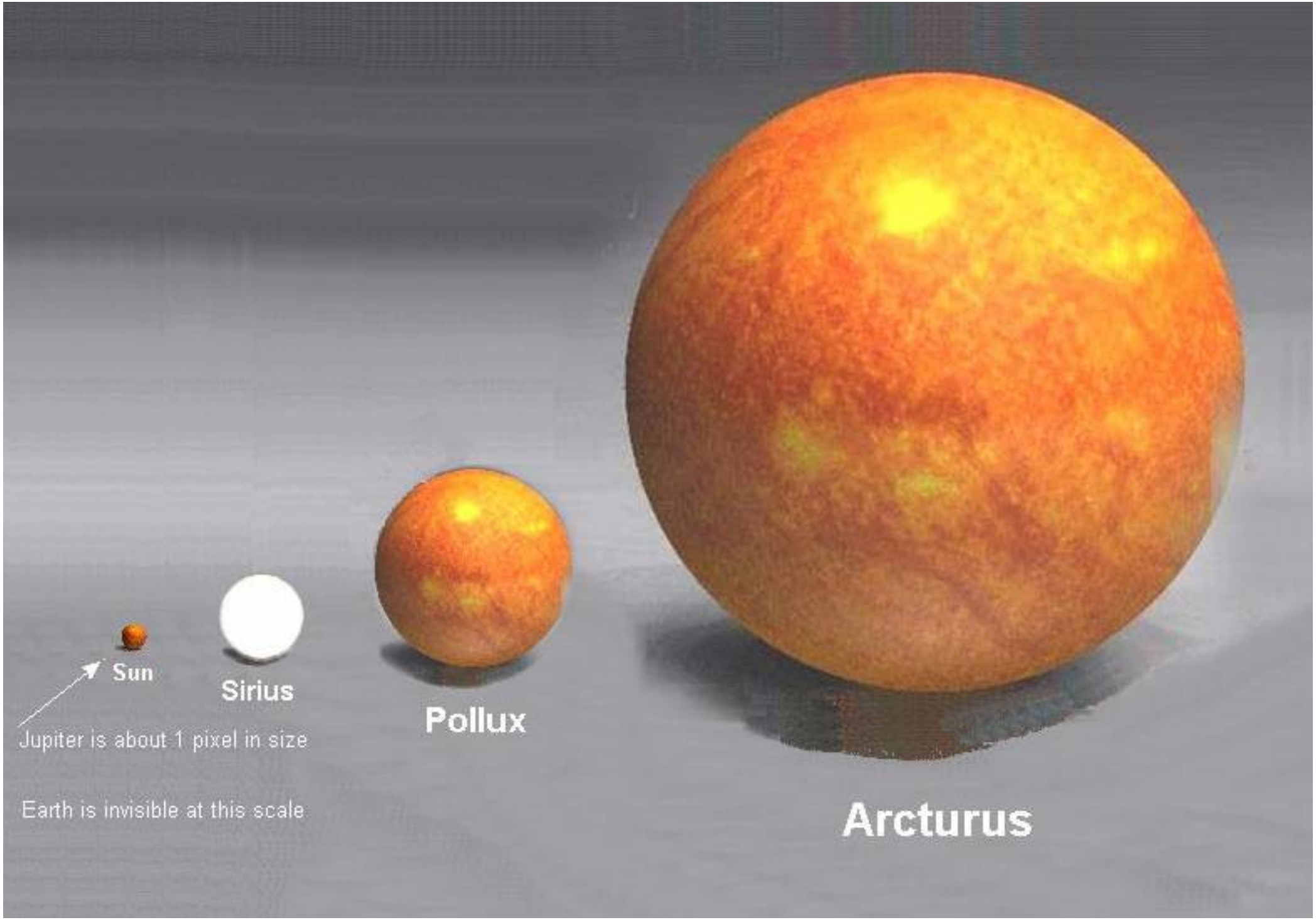


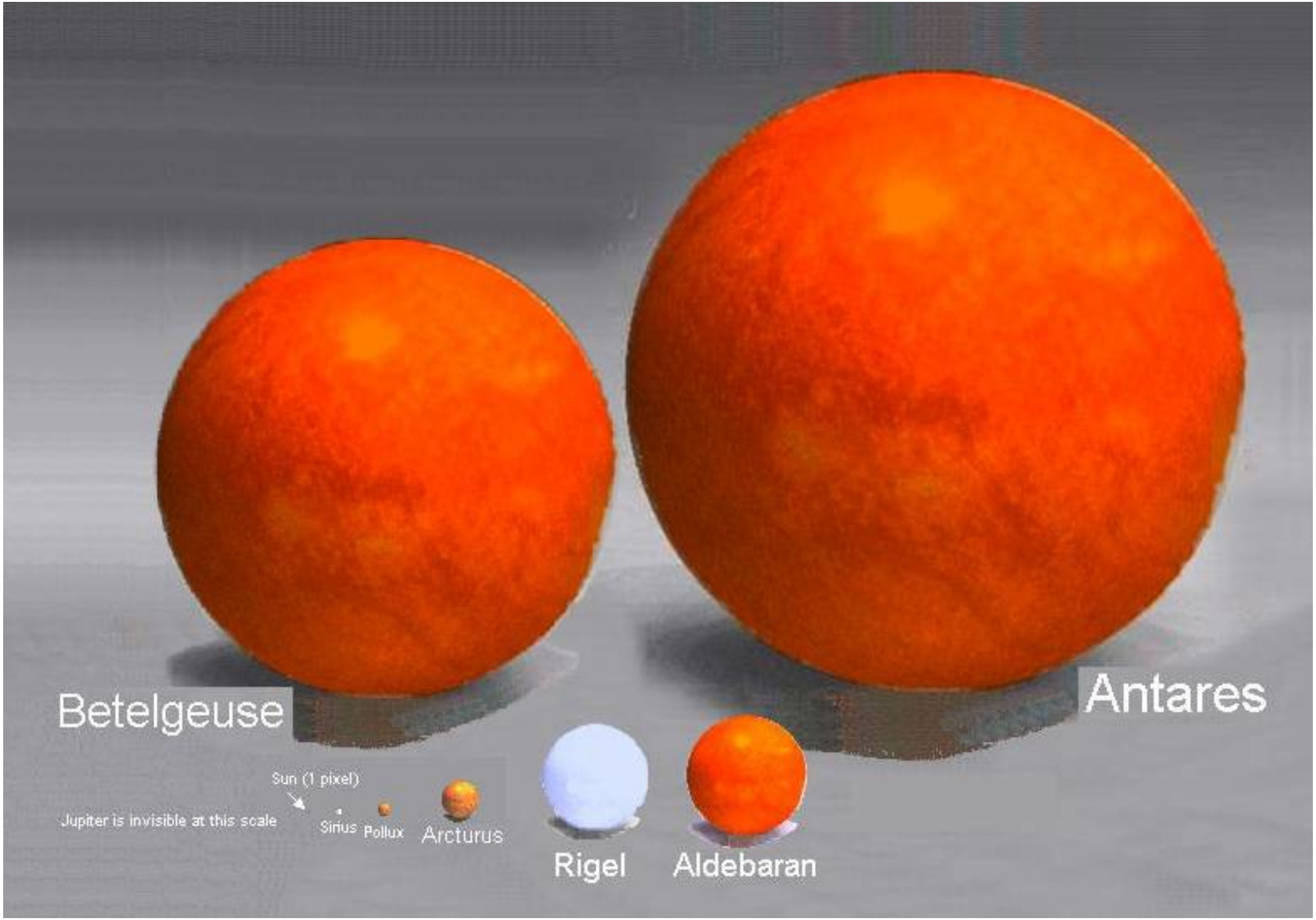



SUPERGIANTS
MAIN SEQUENCE
GIANTS
WHITE DWARFS
LUMINOSITY, L (LSUN)
10 6
10 4
10 2
1
10 -2
10 -4
40 000
20 000
10 000
5000
2500
TEMPERATURE, TK

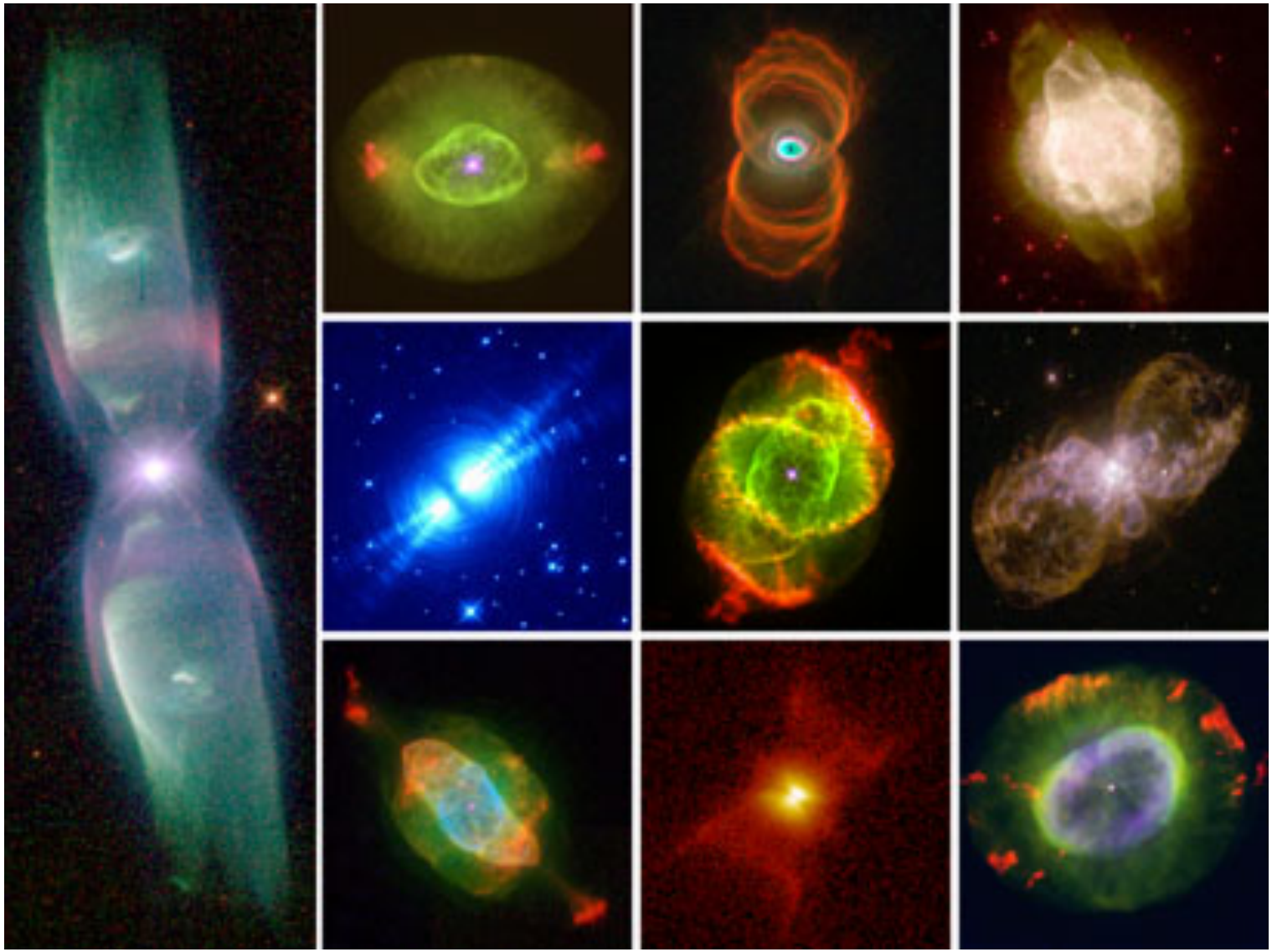

Luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
60 M_{Sun}
30 M_{Sun}
10 M_{Sun}
6 M_{Sun}
1 M_{Sun}
0.3 M_{Sun}
0.1 M_{Sun}
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^{-2} Solar Radius
10^{-3} Solar Radius
Lifetime 10^7 yrs
Lifetime 10^8 yrs
Lifetime 10^9 yrs
Lifetime 10^{10} yrs
Lifetime 10^{11} yrs
Deneb
Rigel
Betelgeuse
β Centauri
Spica
Bellatrix
Canopus
Antares
Polaris
Achernar
Aldebaran
Arcturus
Pollux
Vega
Sirius
Procyon
Altair
α Centauri A
Sun
α Centauri B
ε Eridani
τ Ceti
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B
SUPERGIANTS
MAIN SEQUENCE
GIANTS
WHITE DWARFS
O
B
A
F
G
K
M
30,000
increasing temperature
10,000
6,000
surface temperature (Kelvin)
3,000
decreasing temperature


Intrinsic brightness (Sun = 1)
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
Rigel
Deneb
Betelgeuse
Supergiants
Spica
Main Sequence
Red Giants
Capella
Aldebaran
Vega
Arcturus
Sirius A
Pollux
Altair
Procyon A
Sun
White Dwarfs
Sirius B
Procyon B
40,000
20,000
10,000
6,000
4,000
3,000
2,000
Stars' surface temperature (K)


Sun
Sirius
Pollux
Arcturus
Jupiter is about 1 pixel in size
Earth is invisible at this scale


Betelgeuse
Antares
Sun (1 pixel)
Jupiter is invisible at this scale
Sirius
Pollux
Arcturus
Rigel
Aldebaran

Death of a Star Like the Sun

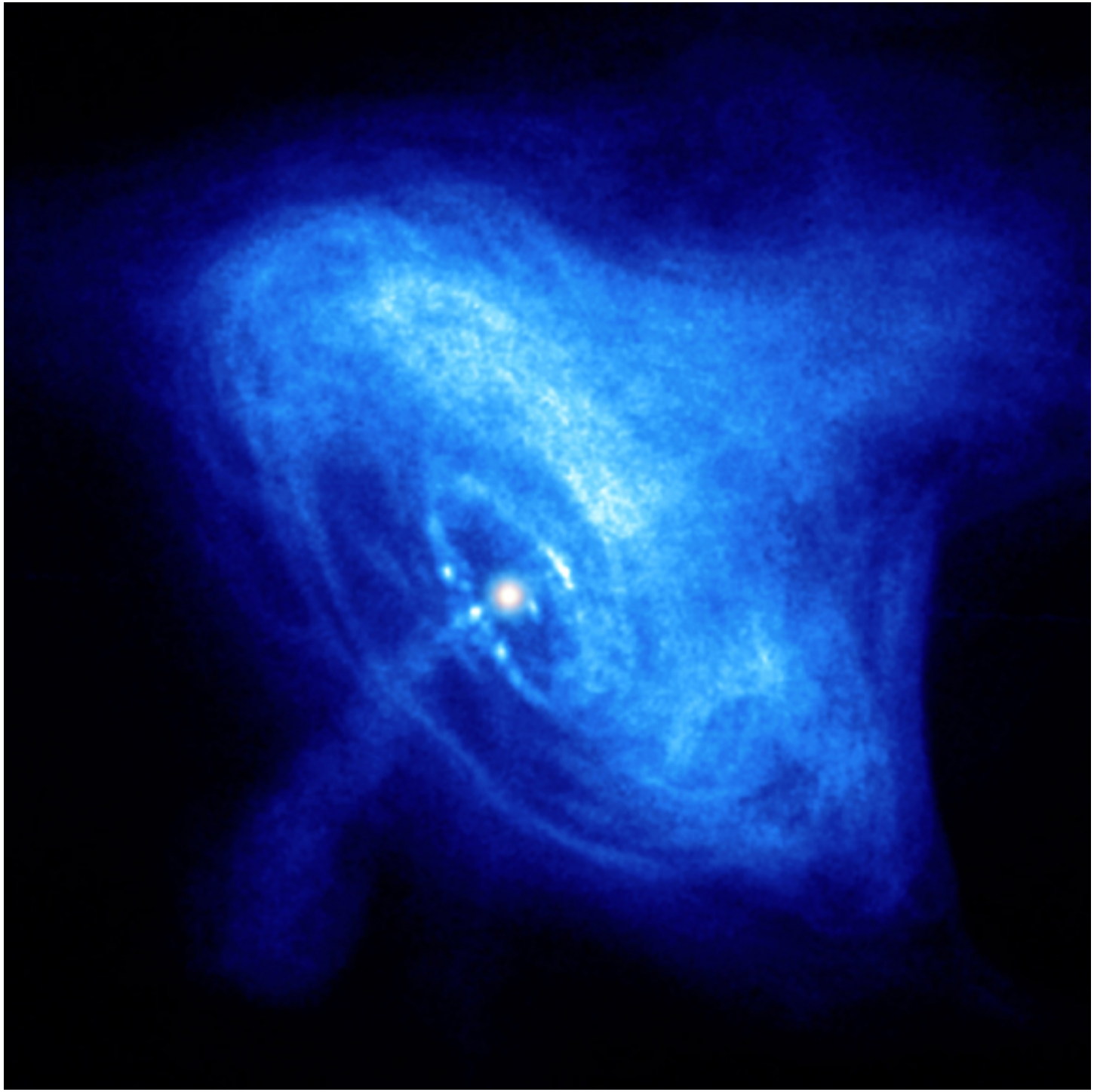


PLANETARY NEBULAE

DEATH OF A MASSIVE STAR

Supernova Remnant – Star Exploded In 1054 AD

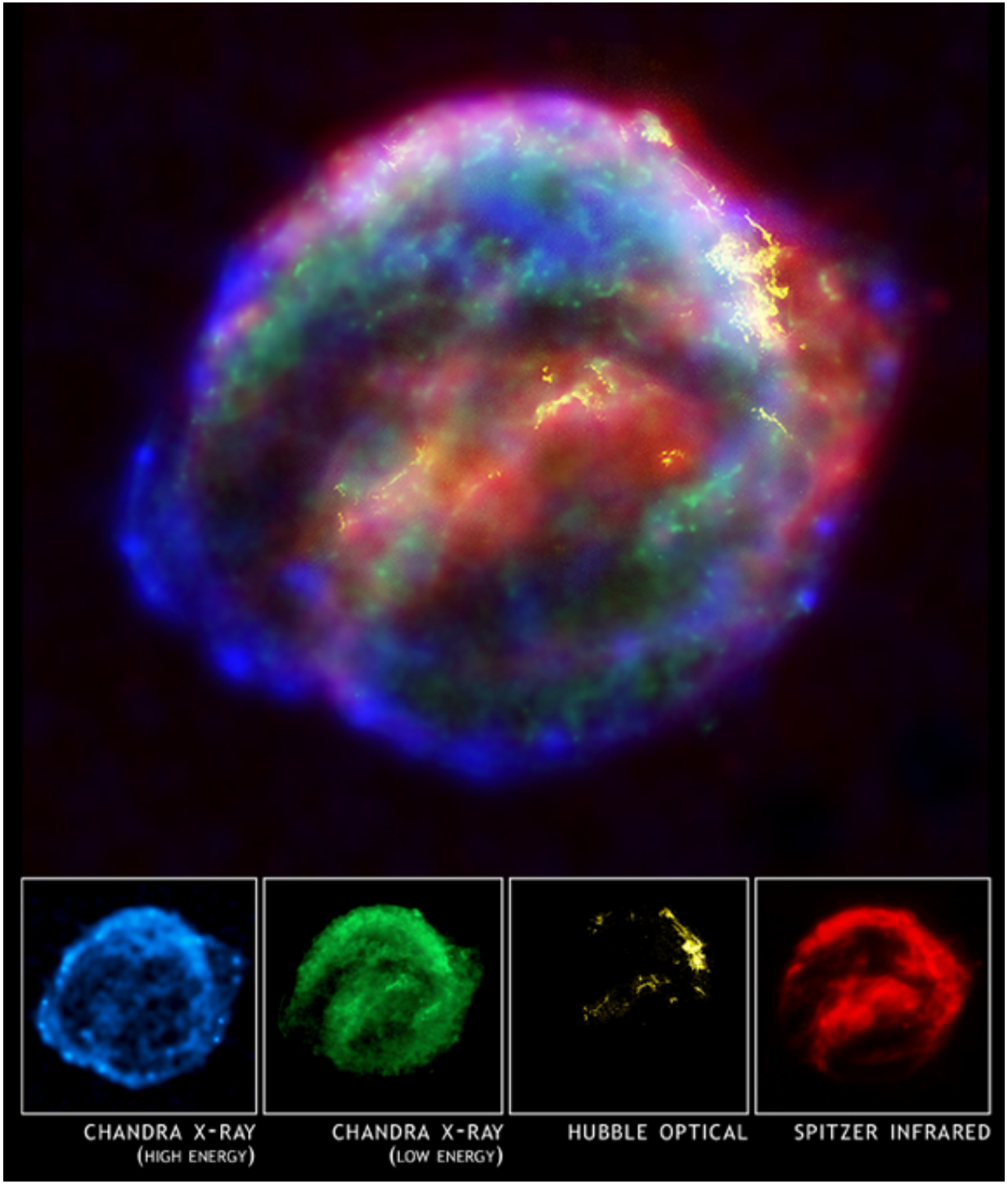
HST mosaic of Crab Nebula



DEATH OF A MASSIVE STAR

Pulsar – A Rapidly Rotating Neutron Star

Chandra X-ray wide field view of Crab Nebula April 6, 2001

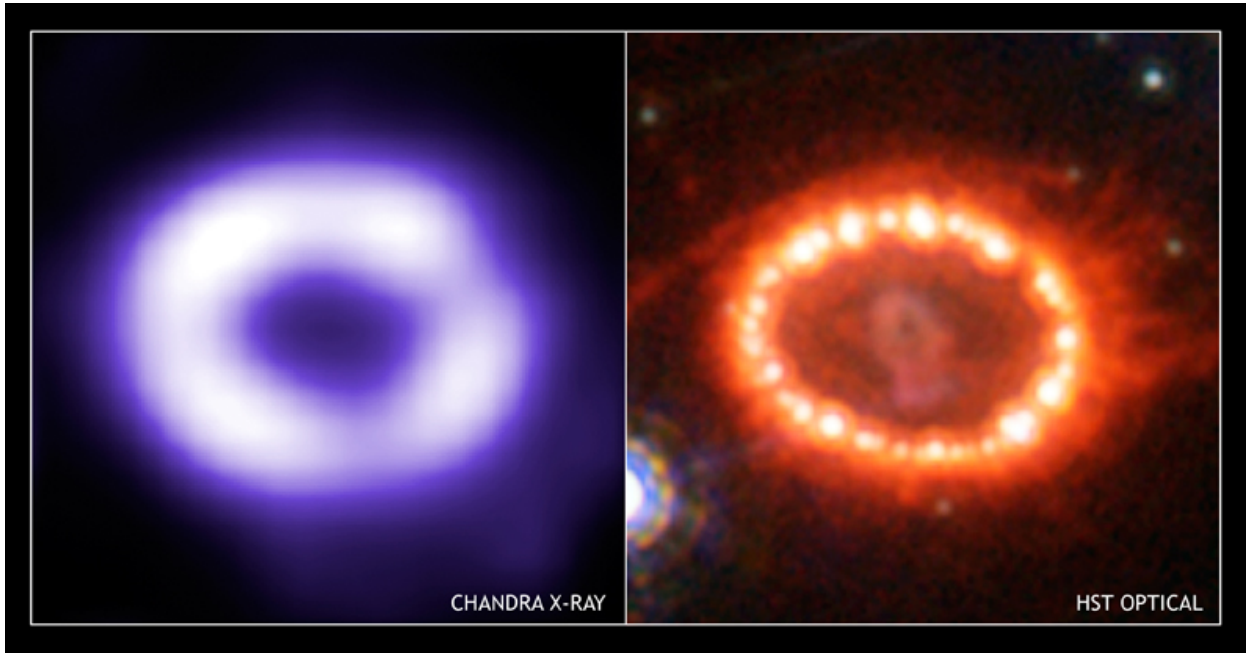


DEATH OF A MASSIVE STAR

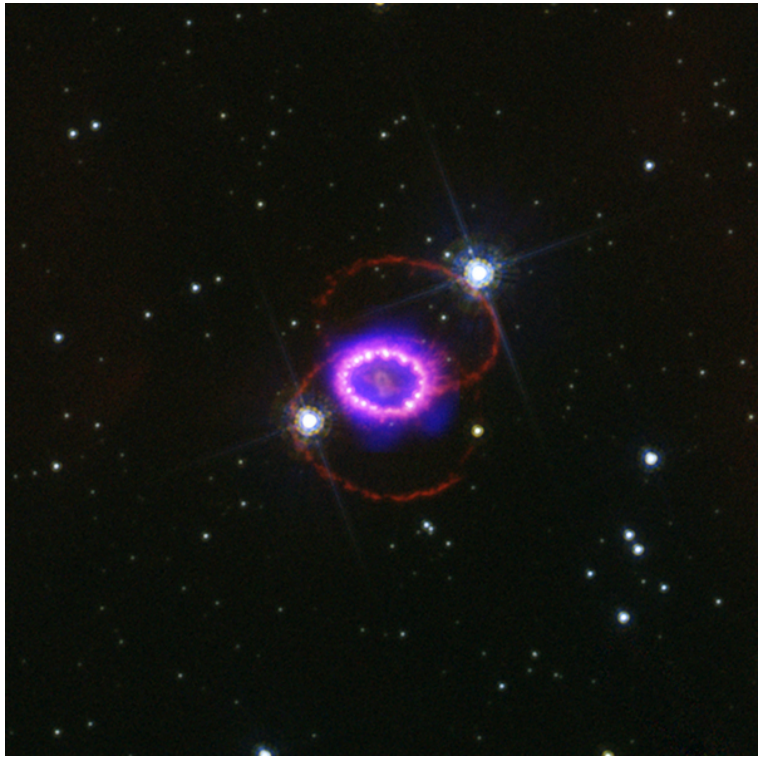
Kepler's Supernova Remnant

Observed 1604

DEATH OF A MASSIVE STAR



1999



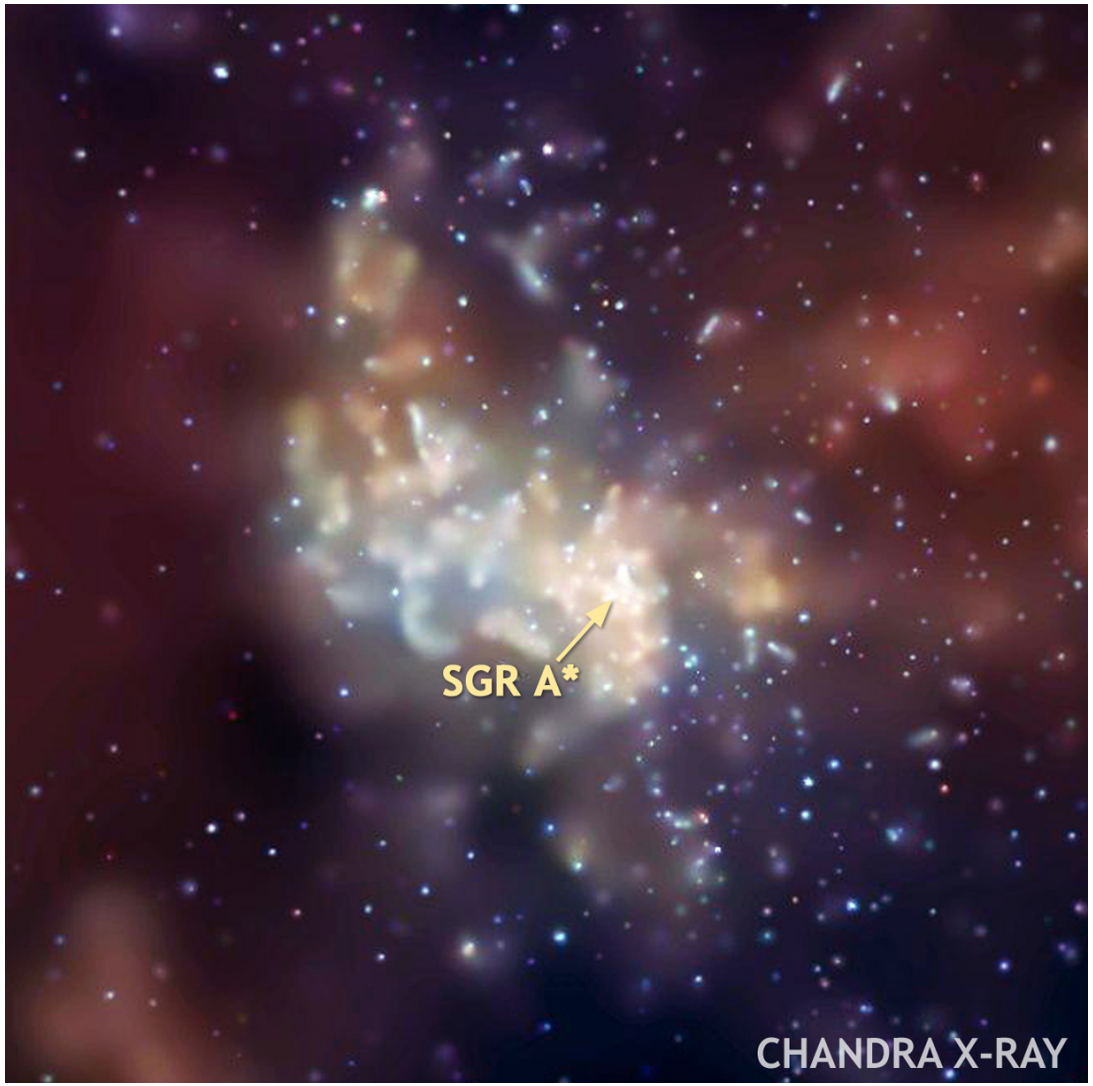
2007

Supernova 1987A
Large Magellanic Cloud

160,000 Light Years Distant

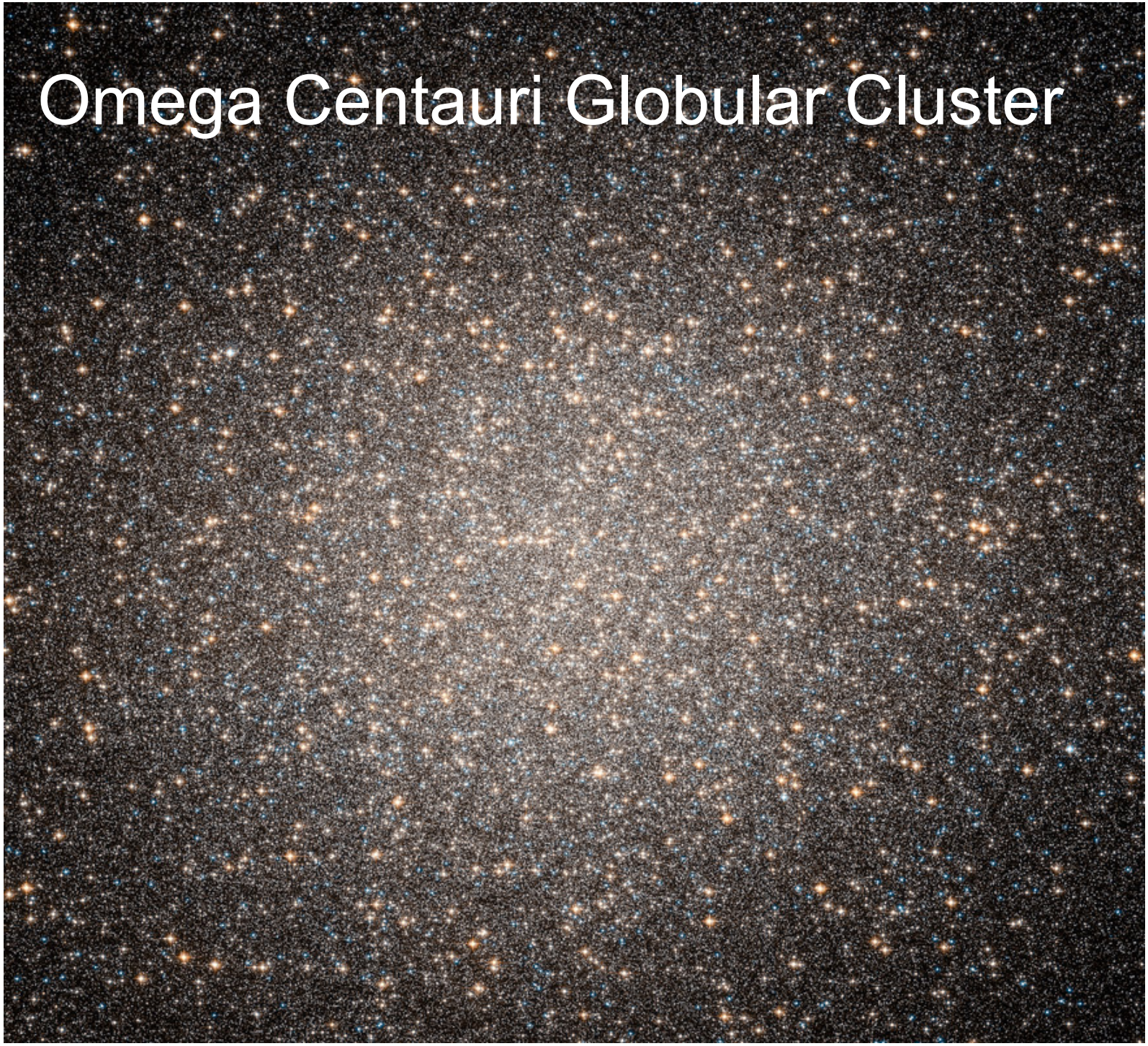
DEATH OF A VERY MASSIVE STAR

4,000,000
SOLAR
MASSES



BLACK HOLE


Pleiades Star Cluster

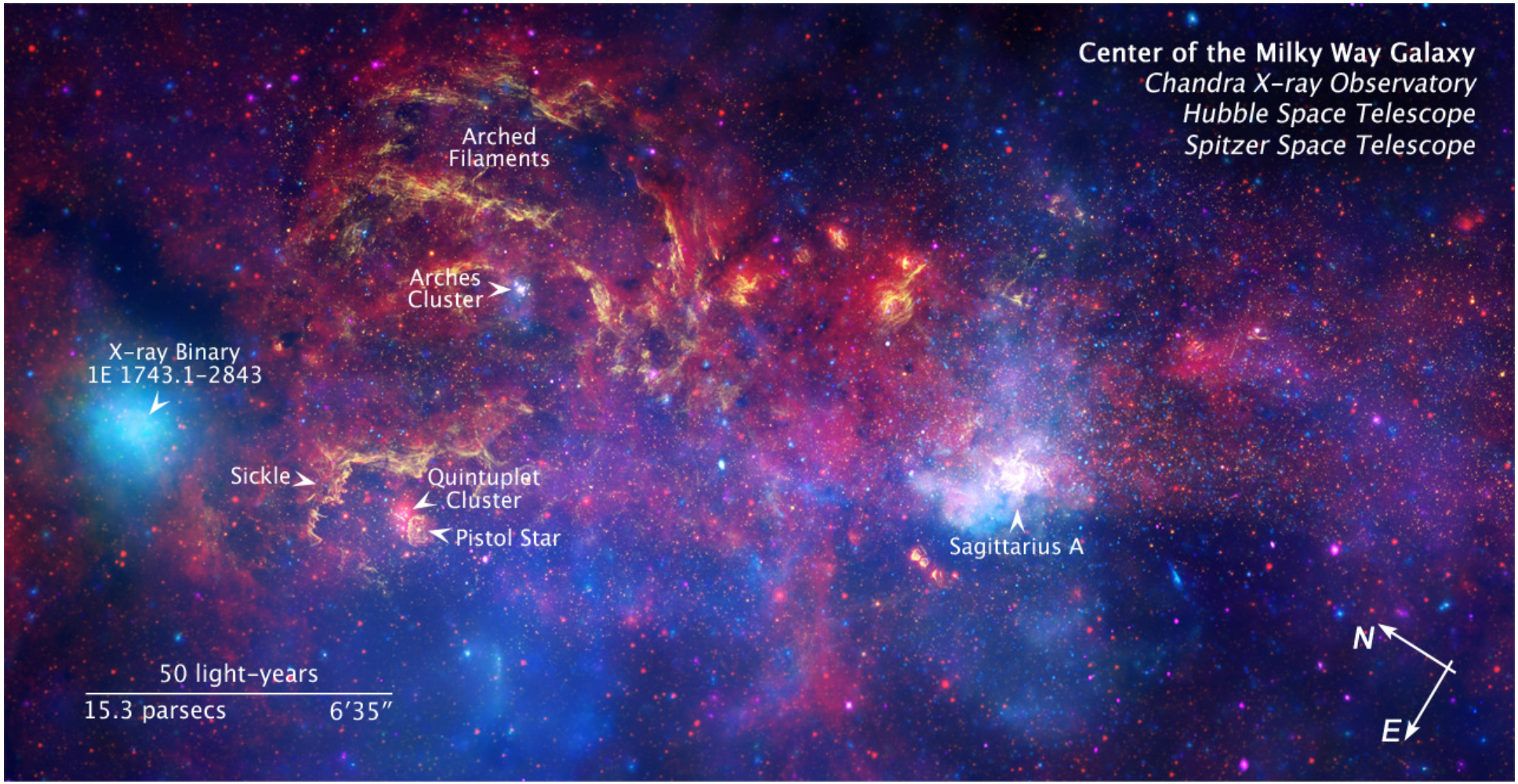

Omega Centauri Globular Cluster

Kingdom of the Galaxies

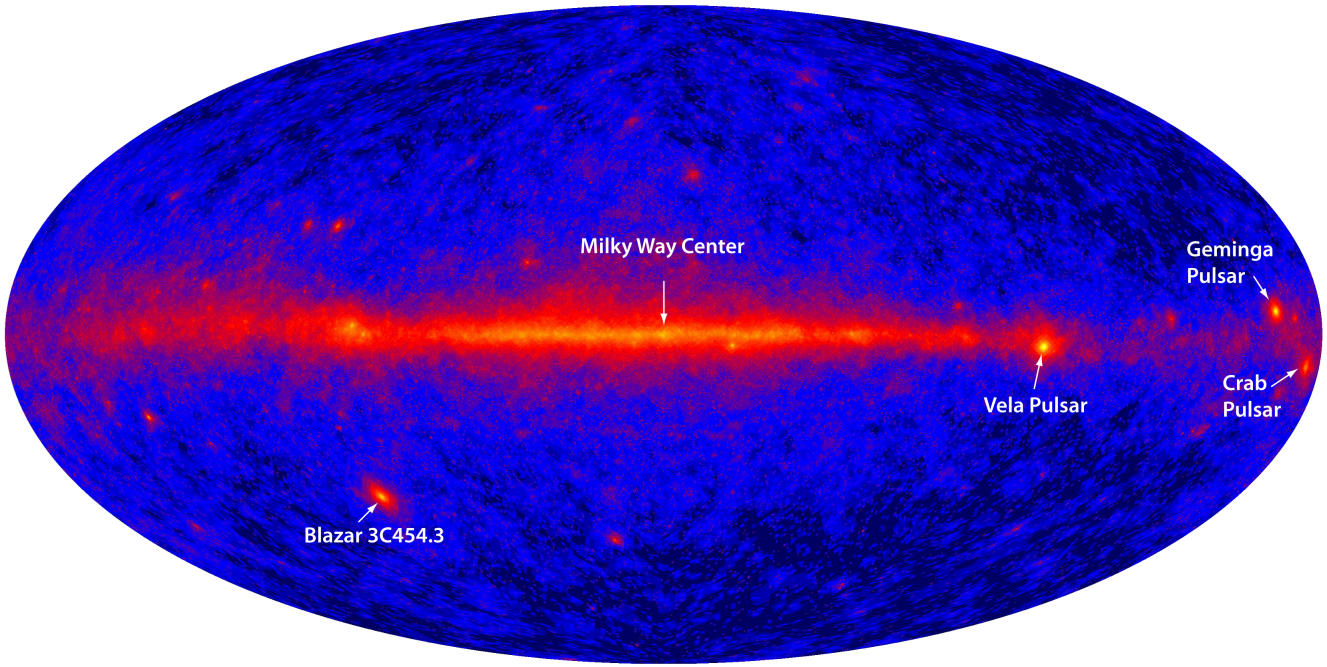
Distance Scale:
Millions to Billions
of Light Years

M 31/ Gendler

CENTER OF MILKY WAY GALAXY

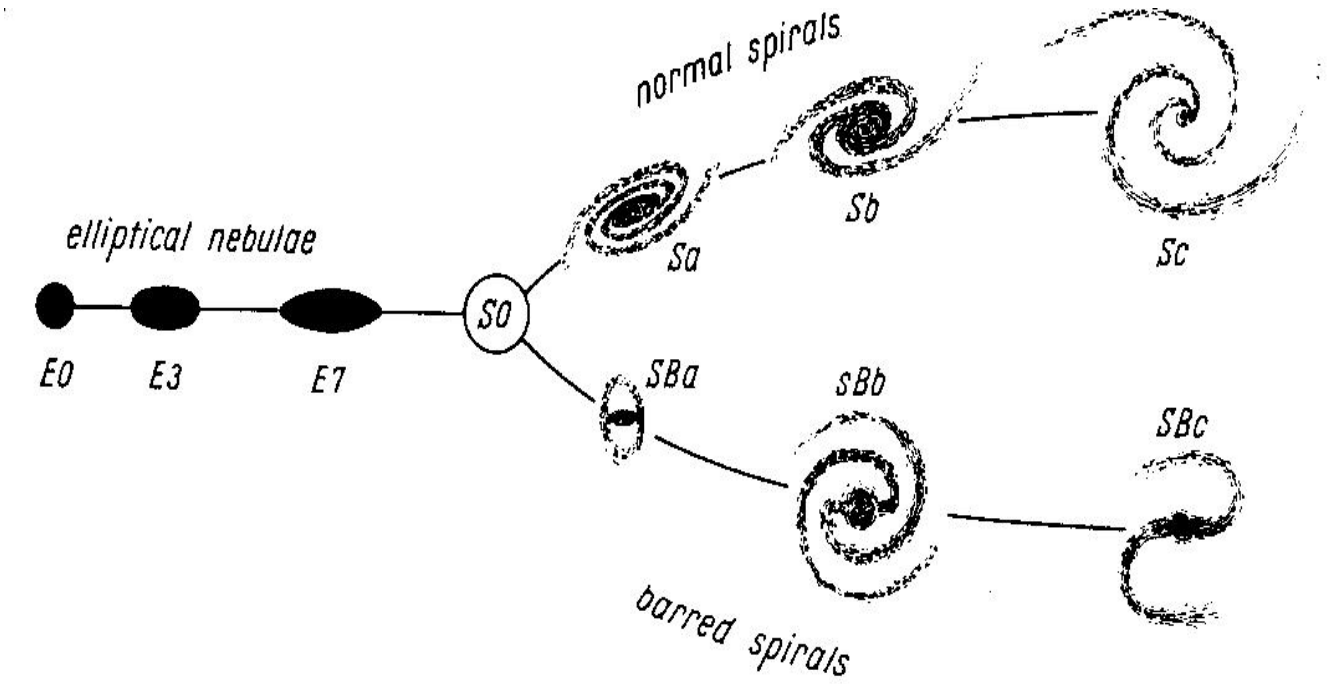


A Gamma-Ray View



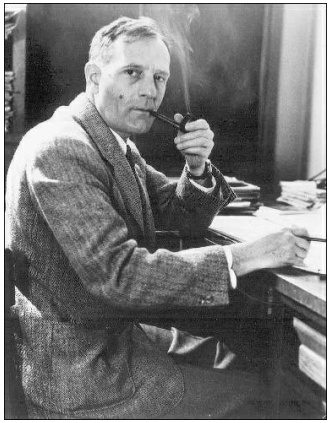
The Fermi Gamma-ray Large Area Space Telescope (GLAST)
All-sky view reveals bright emission in the plane of the Milky Way (center), bright pulsars and super-massive black holes.
Credit: NASA/DOE/International LAT Team

Classification of Galaxies



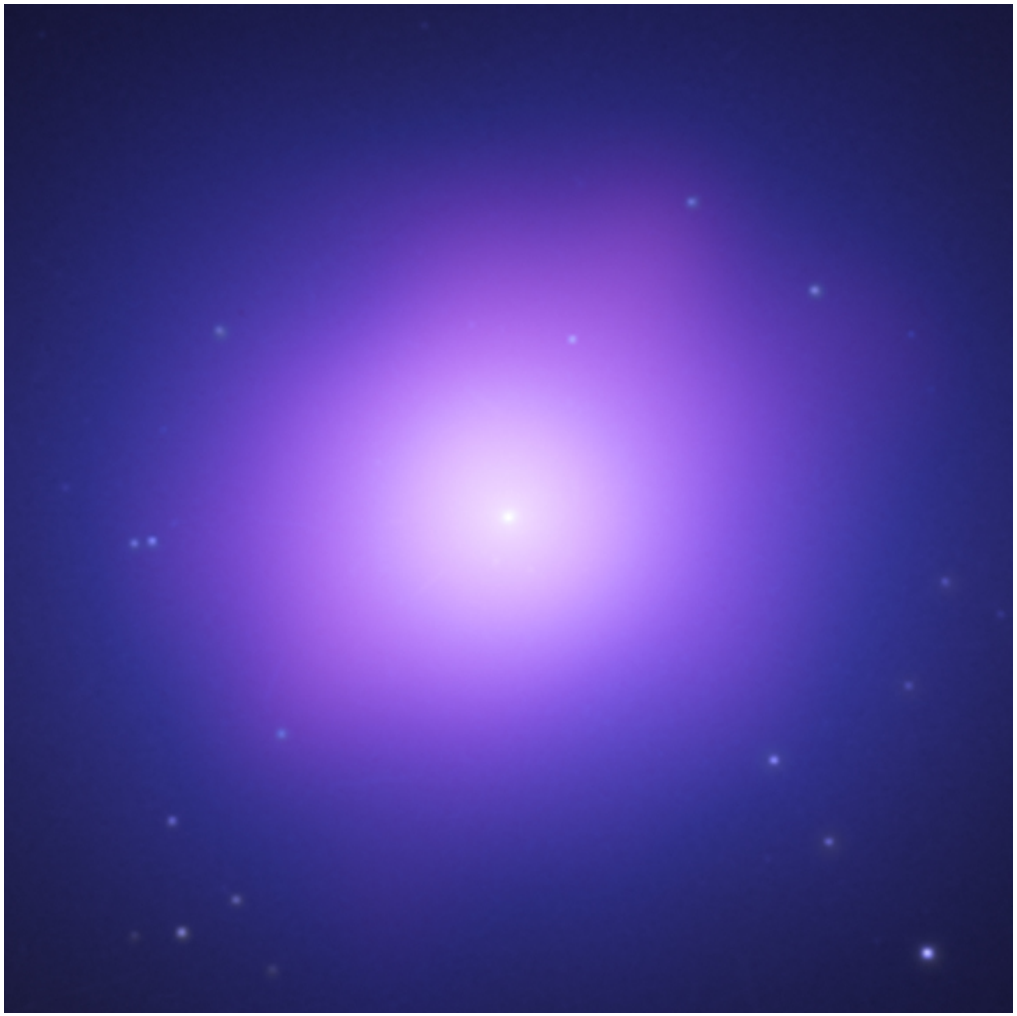
Hubble ‘tuning fork’ classification
From Realm of the Nebulae (1936)

February 9, 1948



SPIRAL GALAXIES

ELLIPTICAL GALAXIES

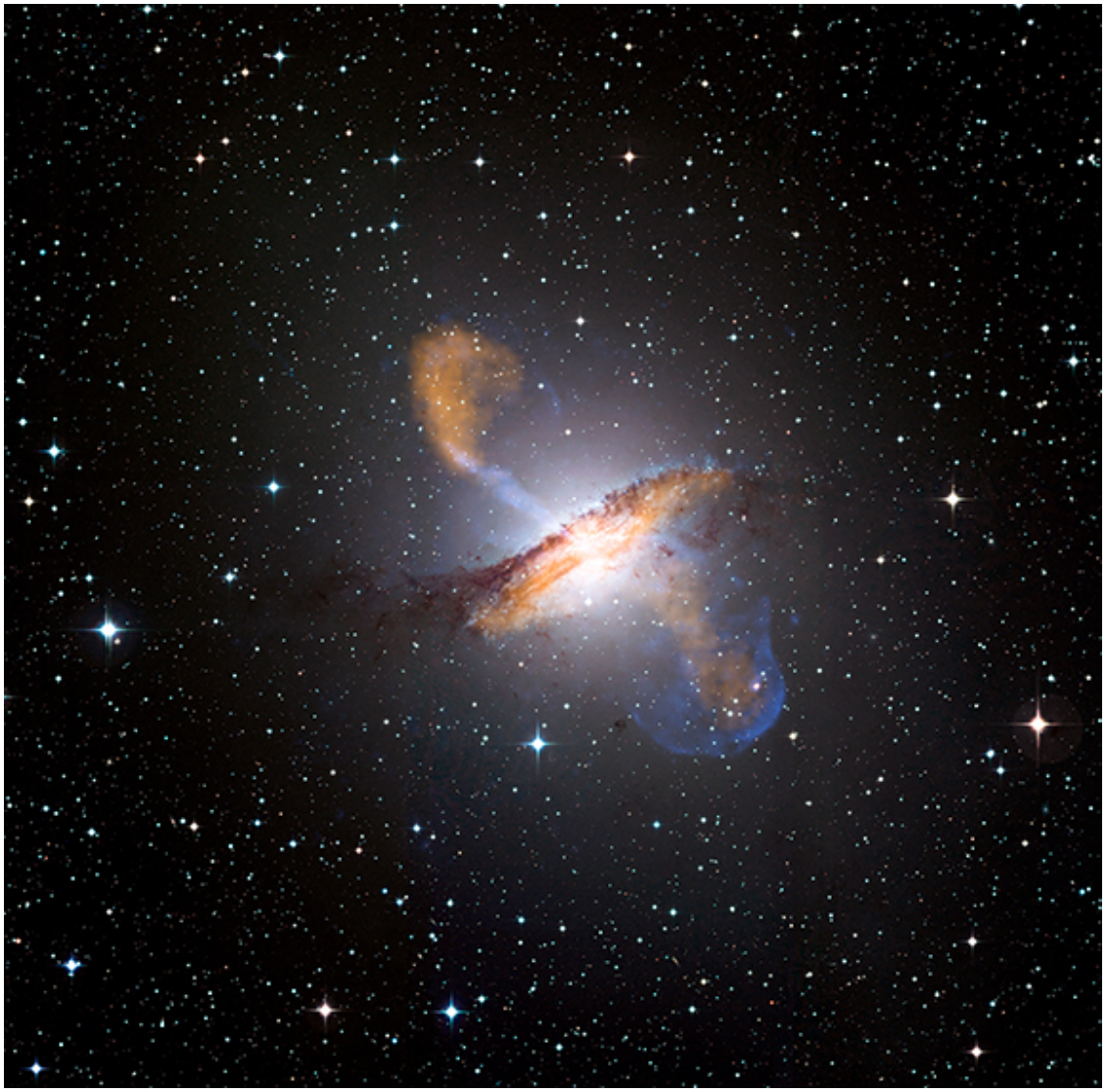


NGC 4649

51 MILLION LIGHT YEARS

FROM EARTH

LENTICULAR GALAXIES



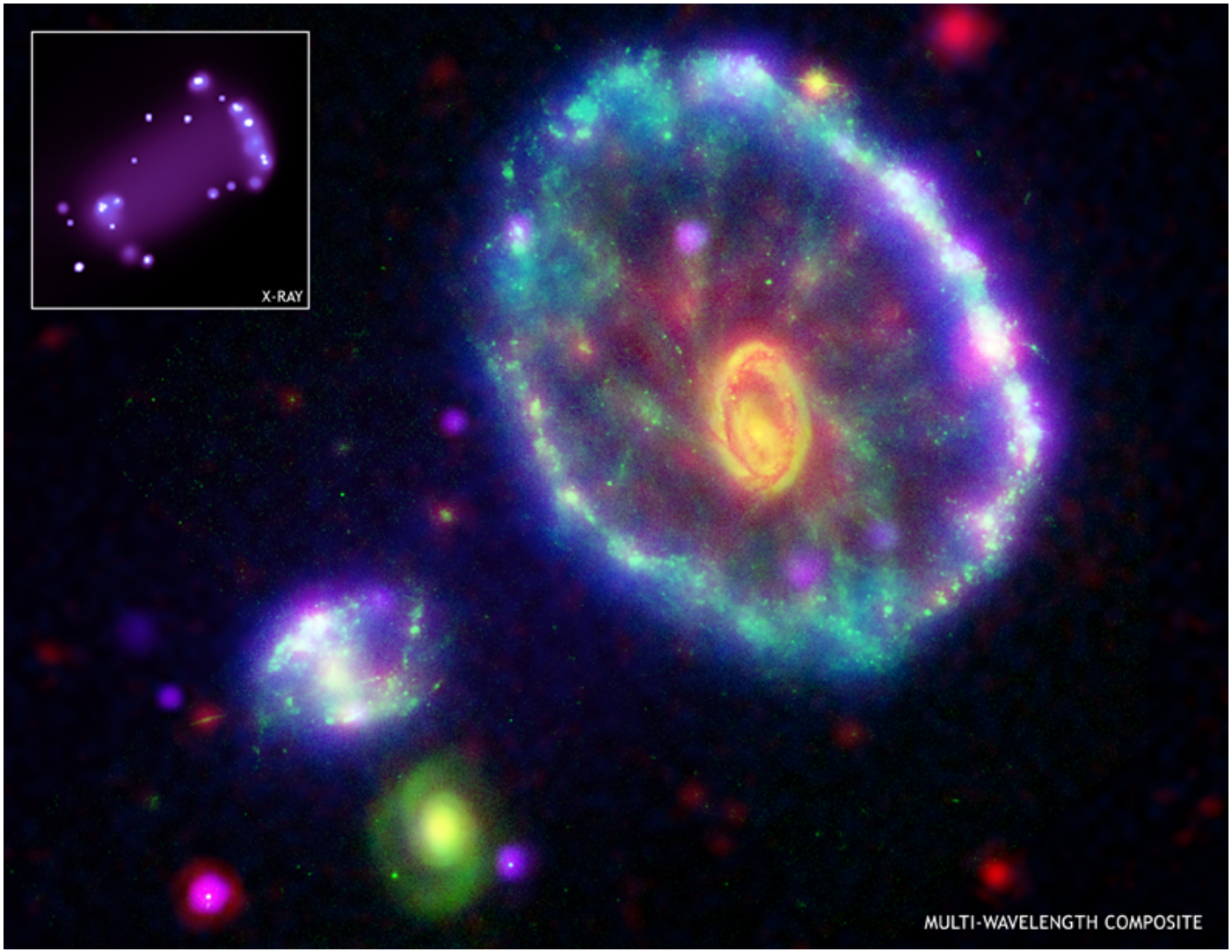
CENTAURUS A

AN ACTIVE GALAXY

10 MILLION LIGHT

YEARS FROM EARTH

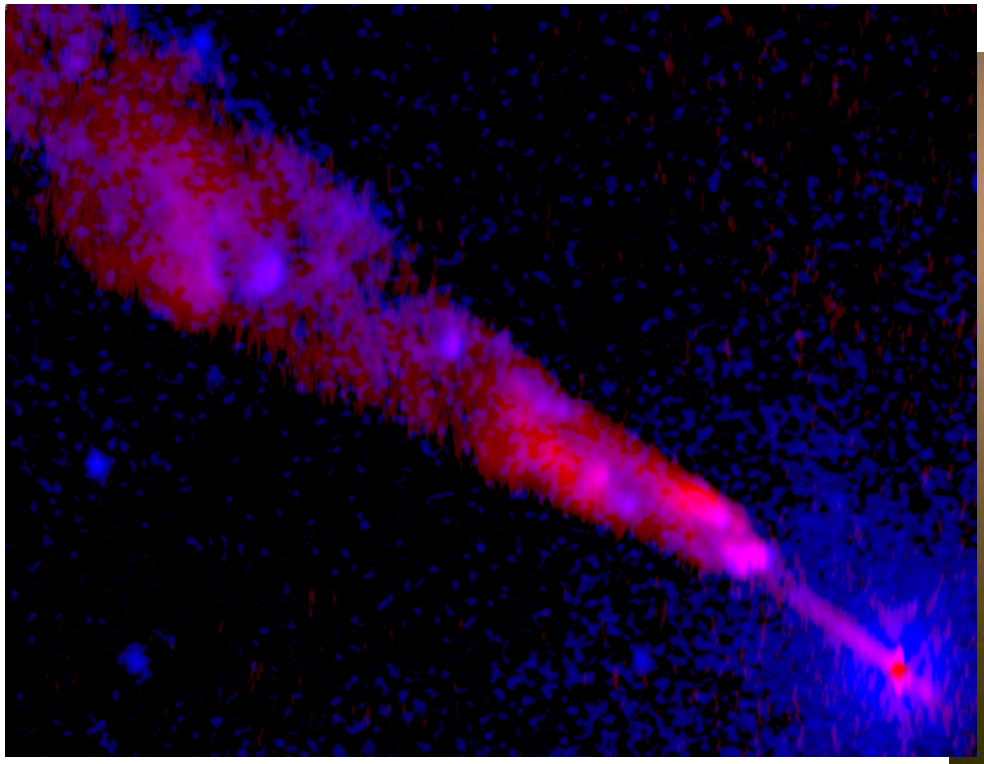
COLLIDING GALAXIES



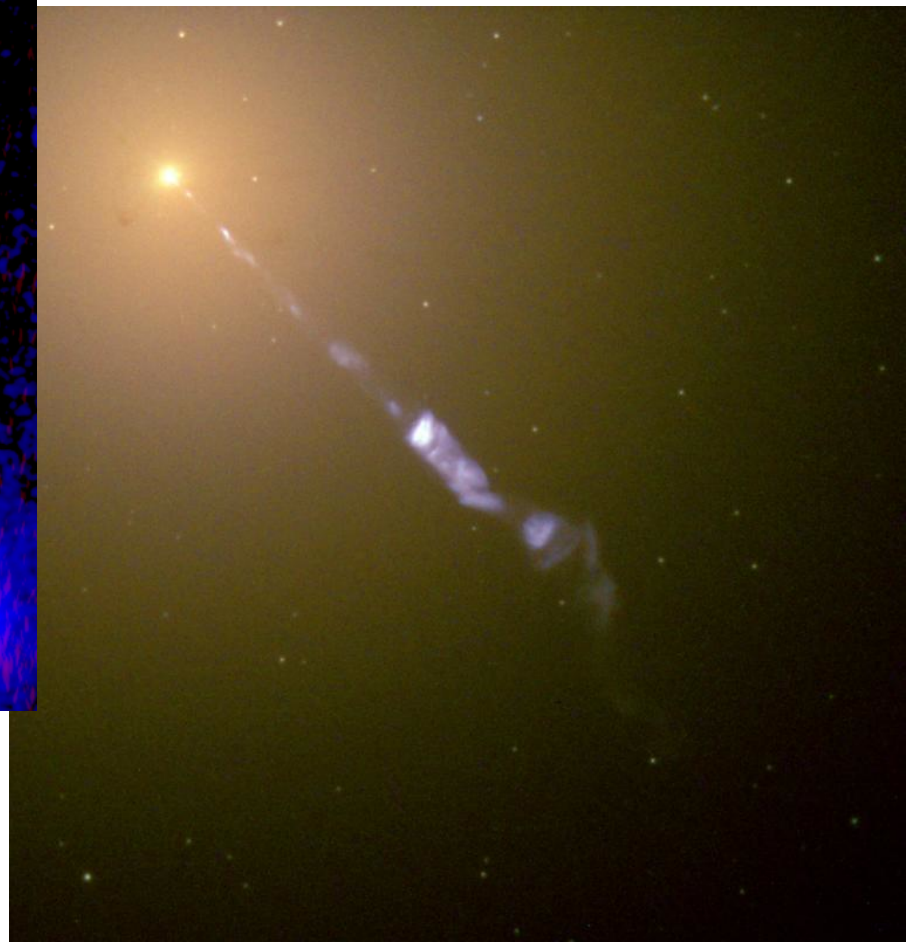
CARTWHEEL GALAXY

400 MILLION LIGHT YEARS FROM EARTH

ACTIVE GALAXIES



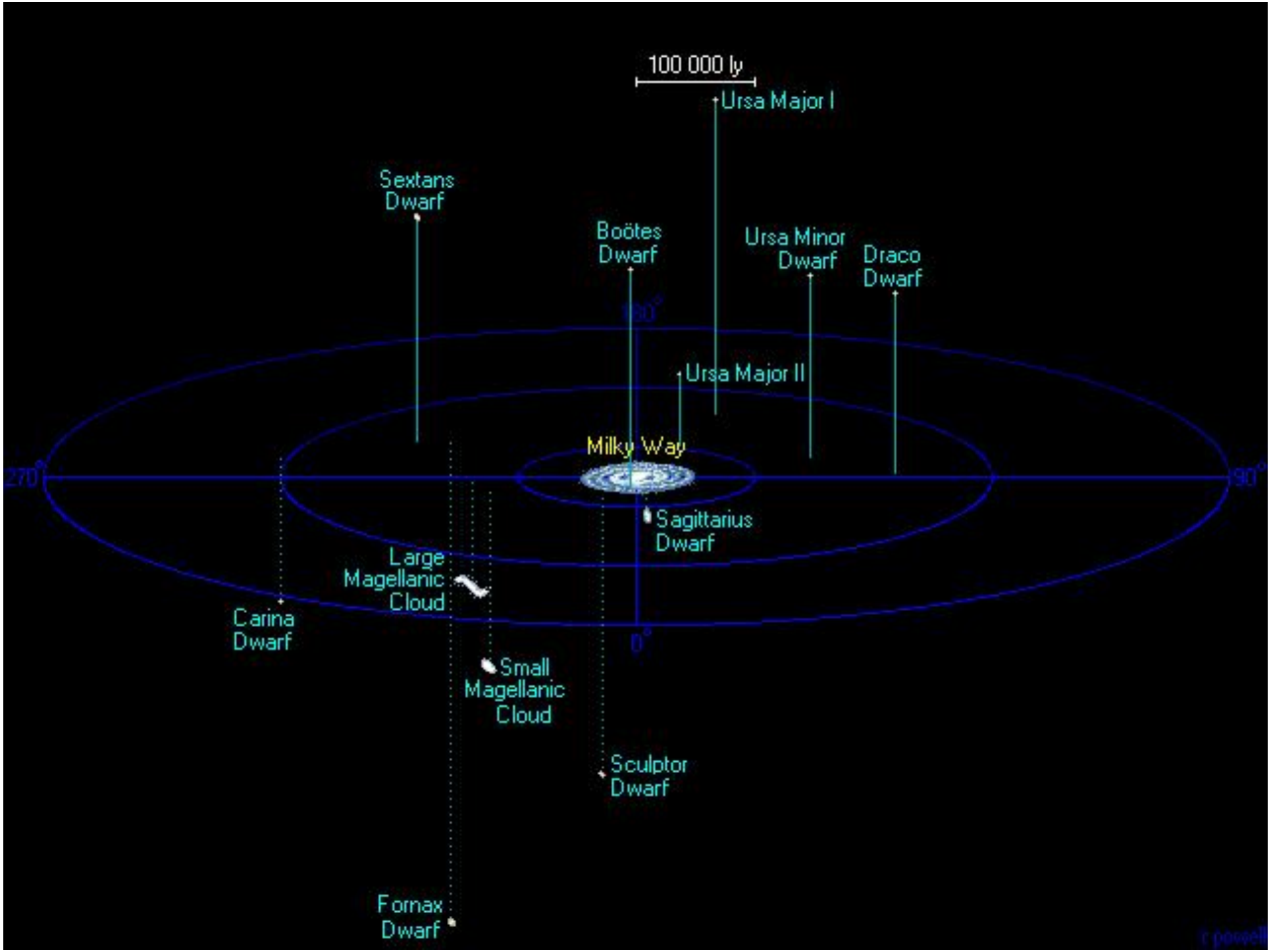
CENTAURUS A

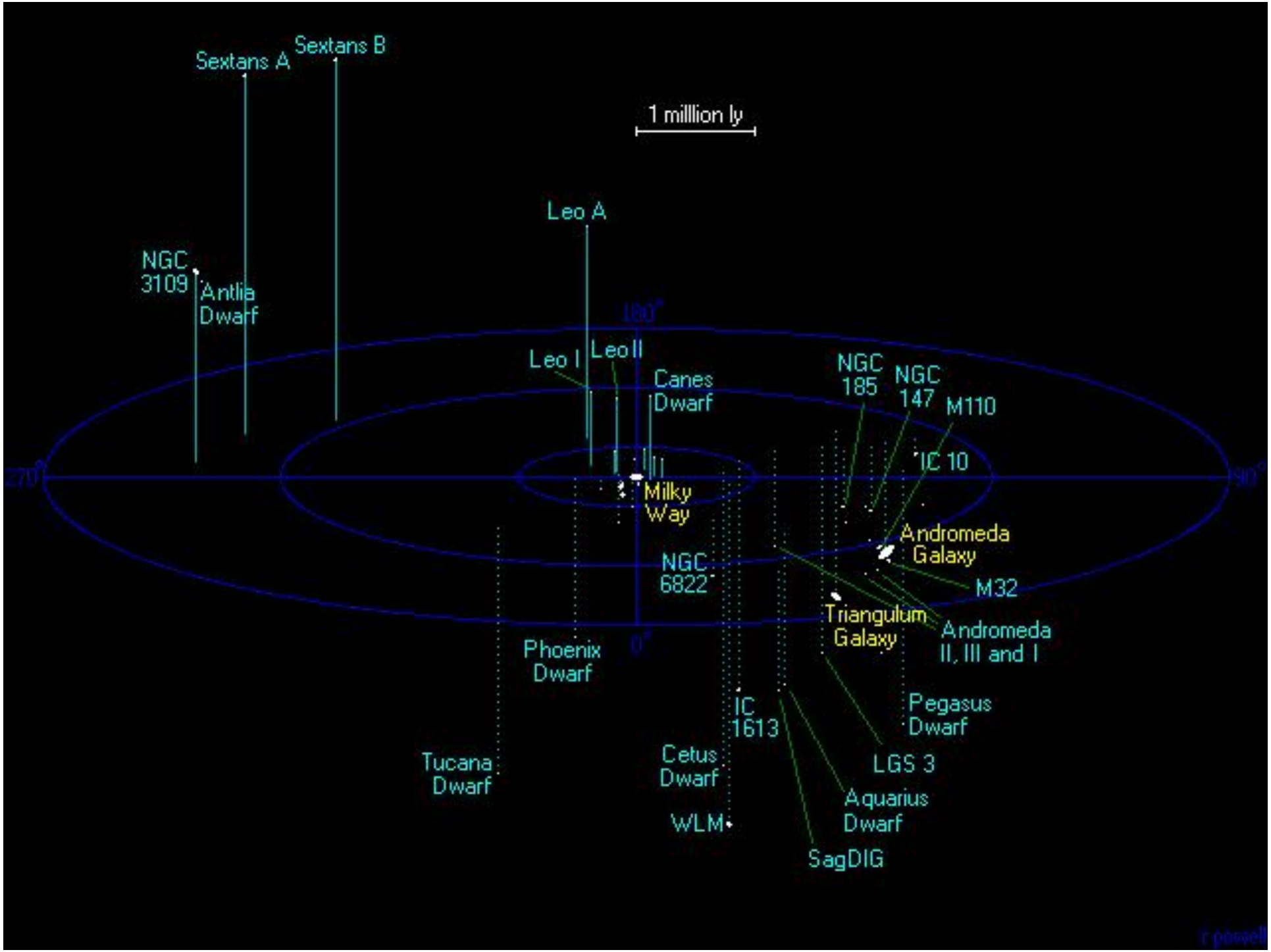


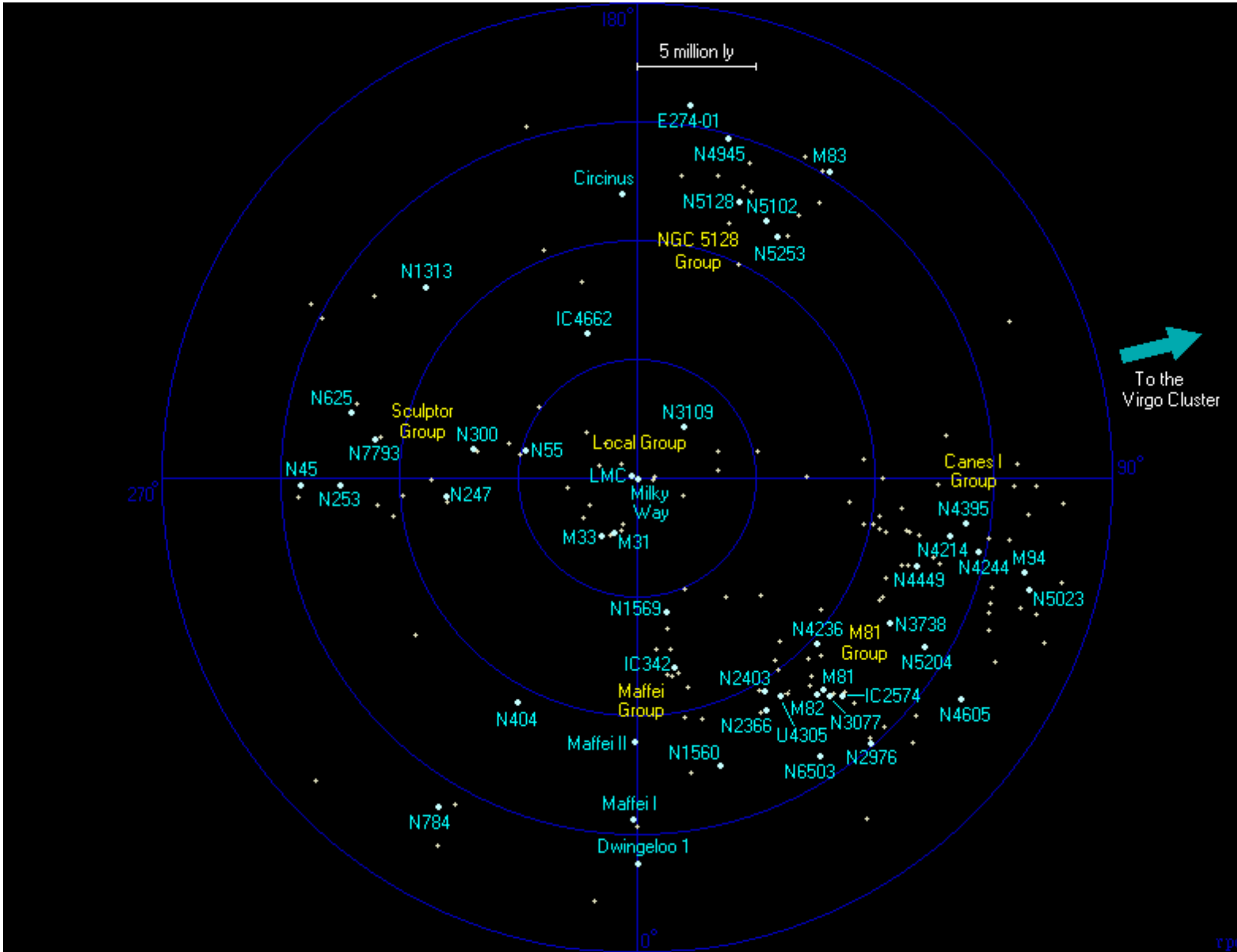
M 87

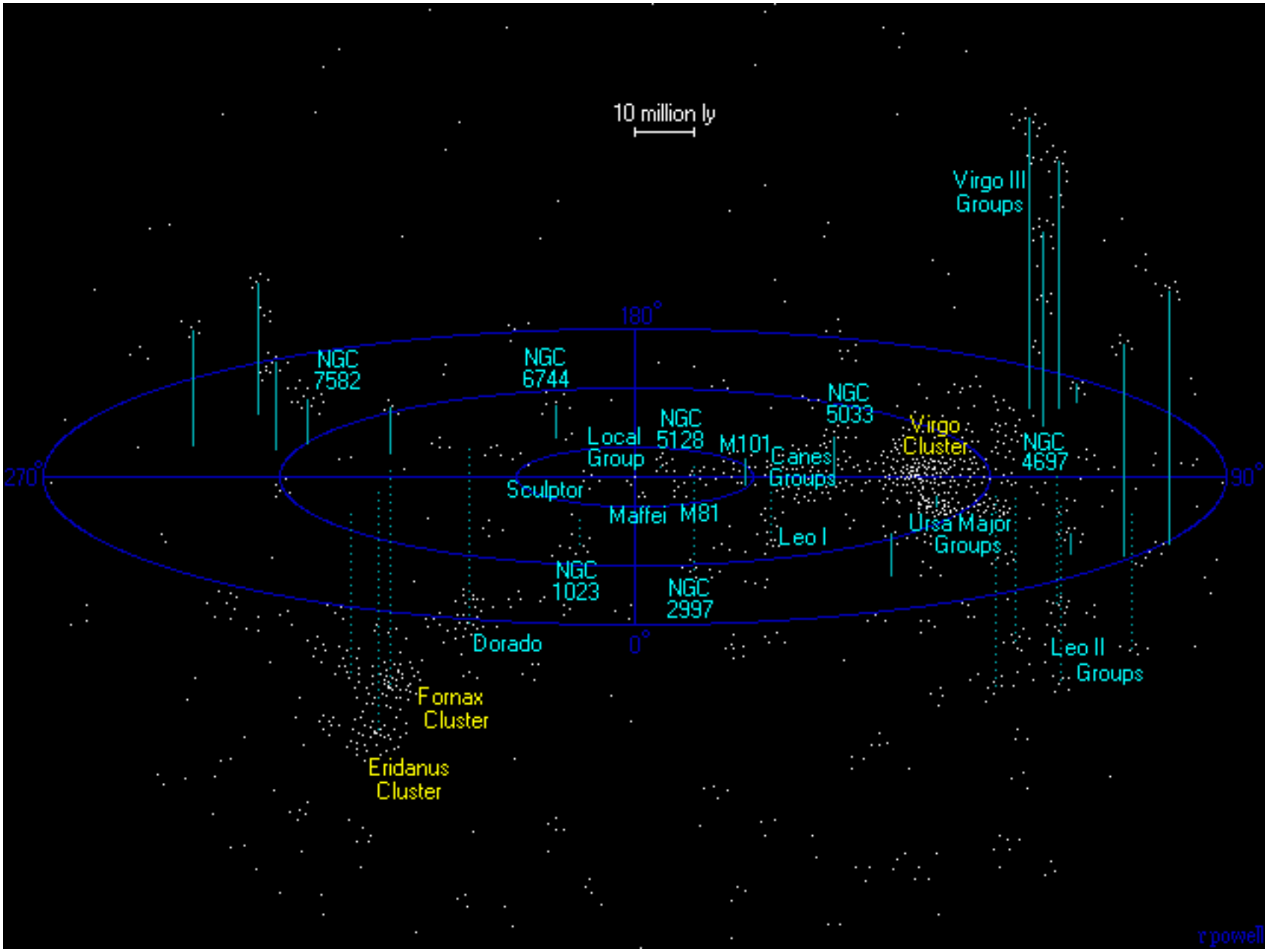
GALAXY GROUPS

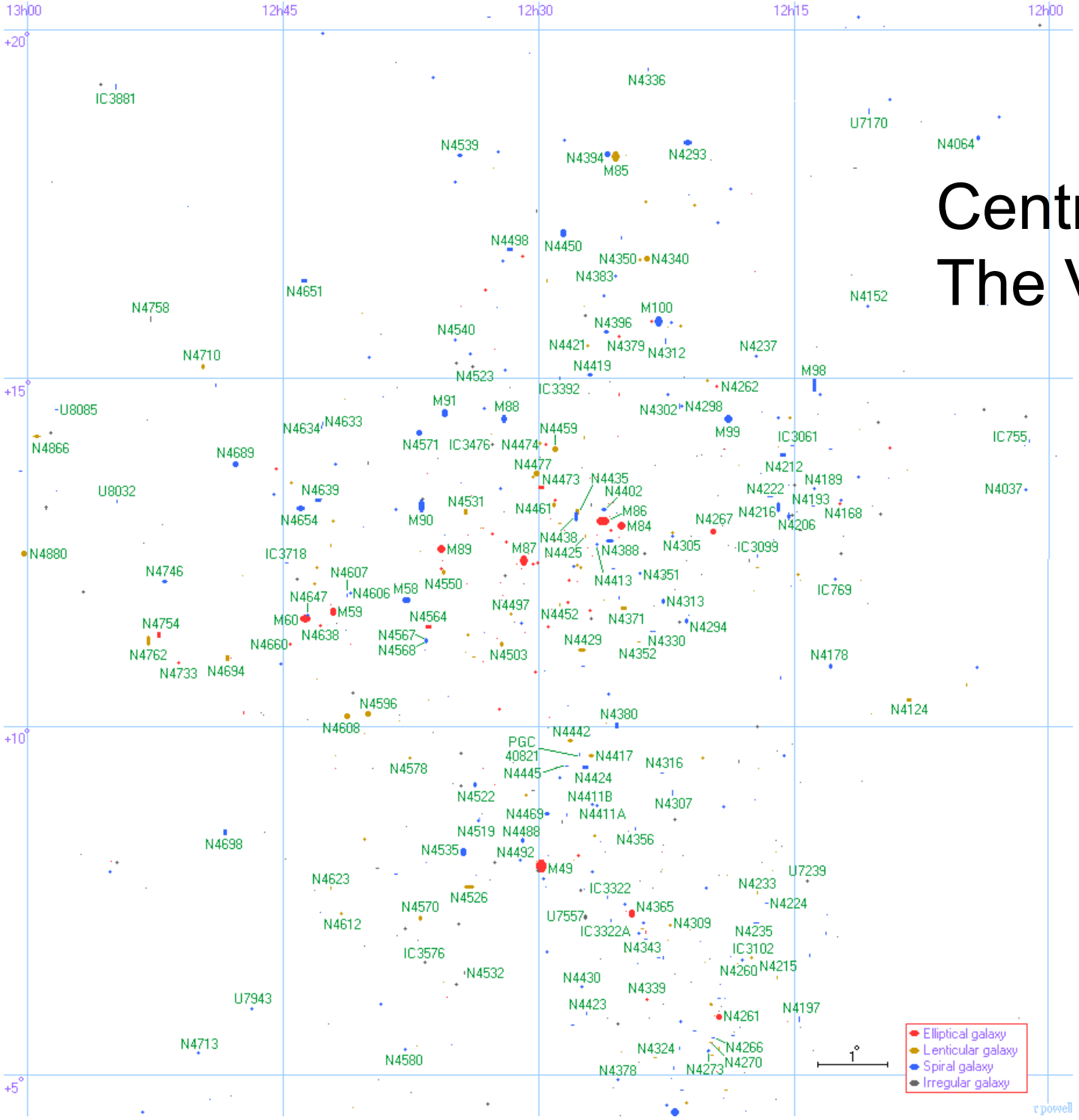
GALAXY CLUSTERS


100 000 ly
Ursa Major I
Sextans Dwarf
Boötes Dwarf
Ursa Minor Dwarf
Draco Dwarf
Ursa Major II
Milky Way
270°
90°
Sagittarius Dwarf
Large Magellanic Cloud
Carina Dwarf
0°
Small Magellanic Cloud
Sculptor Dwarf
Fornax Dwarf

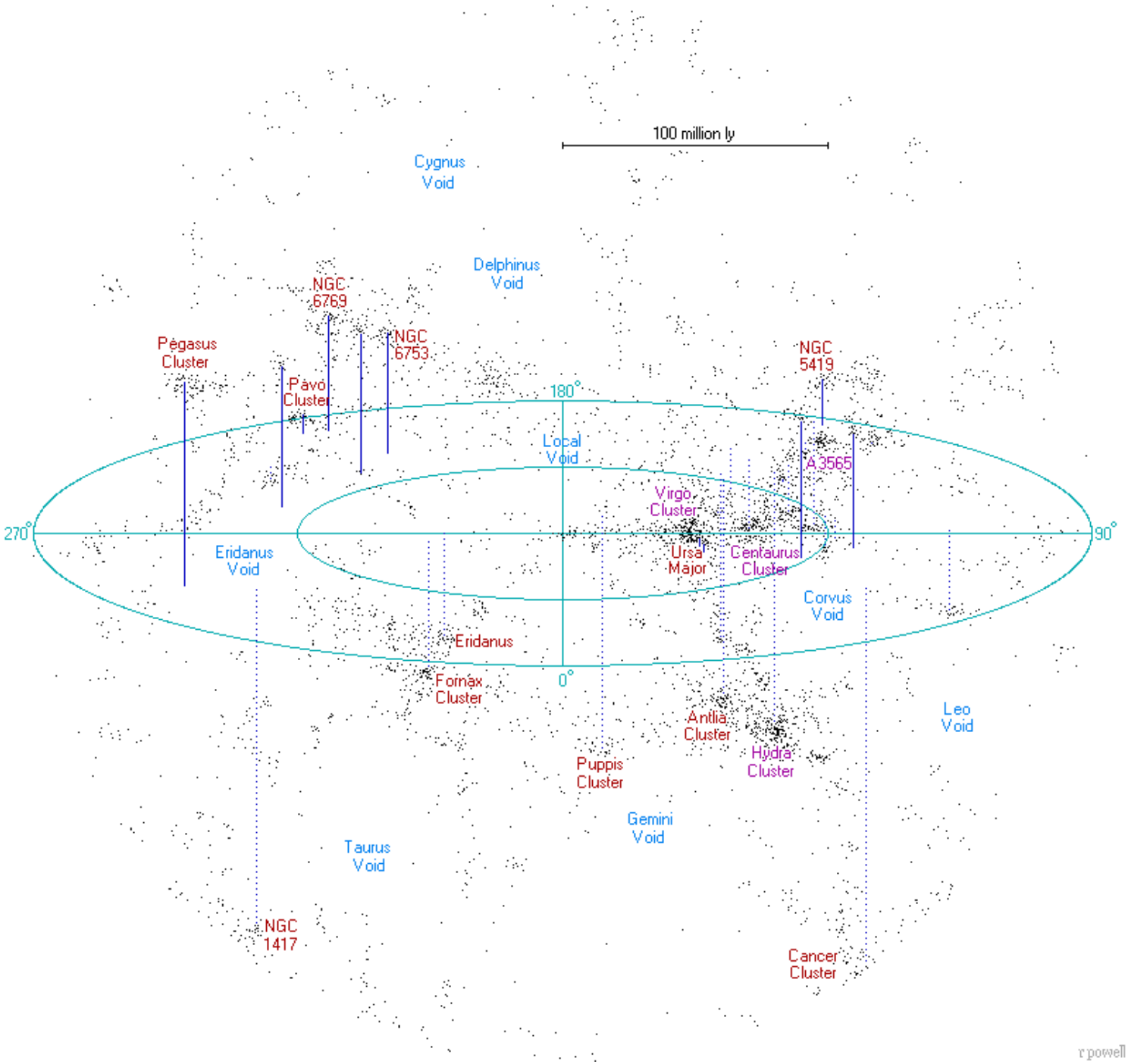

Sextans A
Sextans B
1 milllion ly
Leo A
NGC
3109
Antlia
Dwarf
180°
Leo I
Leo II
Canes
Dwarf
NGC
185
NGC
147
M110
IC 10
270°
90°
Milky
Way
Andromeda
Galaxy
NGC
6822
M32
Triangulum
Galaxy
Andromeda
II, III and I
0°
Phoenix
Dwarf
IC
1613
Pegasus
Dwarf
Tucana
Dwarf
Cetus
Dwarf
LGS 3
Aquarius
Dwarf
WLM
SagDIG

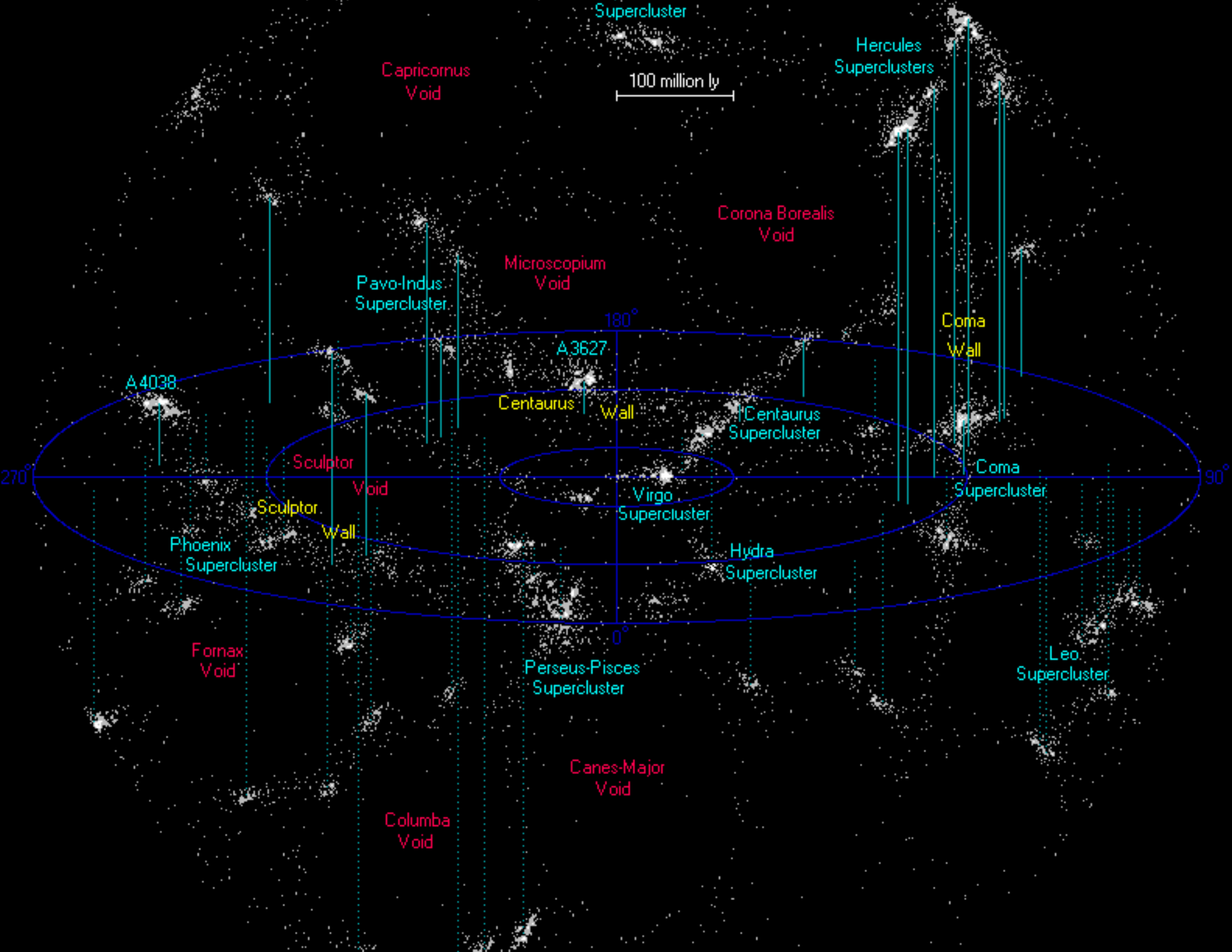

180°
5 million ly
E274-01
N4945
M83
Circinus
N5128
N5102
NGC 5128
Group
N5253
N1313
IC4662
To the
Virgo Cluster
N625
Sculptor
Group
N3109
N300
N55
Local Group
N7793
N45
LMC
90°
Canes I
Group
270°
N253
N247
Milky
Way
N4395
M33
M31
N4214
N4244
M94
N4449
N5023
N1569
N4236
M81
N3738
Group
IC342
N5204
N2403
M81
Maffei
Group
IC2574
M82
N3077
N4605
N404
N2366
U4305
Maffei II
N1560
N2976
N6503
Maffei I
N784
Dwingeloo 1
0°

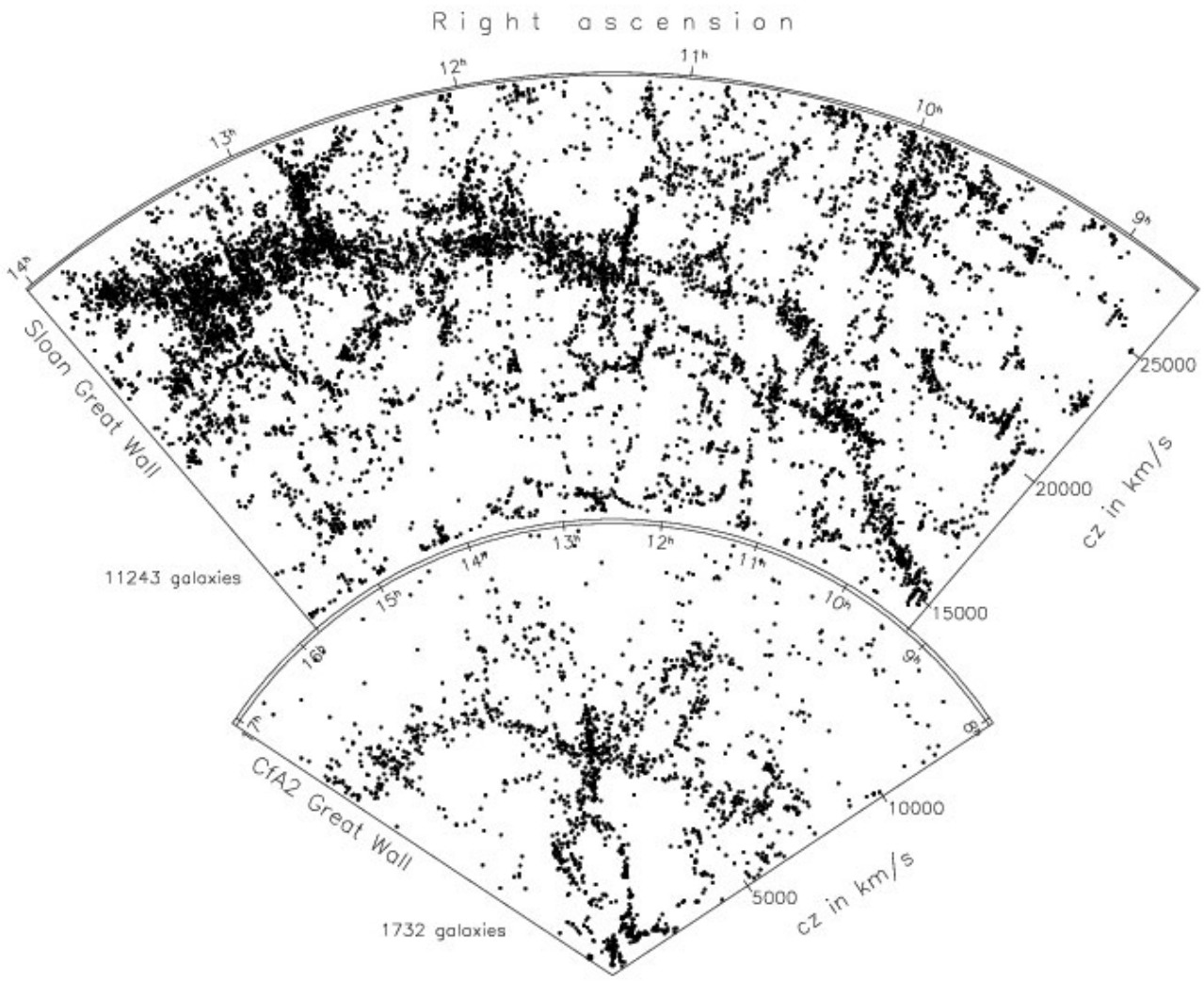

10 million ly
Virgo III
Groups
180°
NGC
7582
NGC
6744
NGC
5033
NGC
5128
Local
Group
M101
Virgo
Cluster
NGC
4697
270°
Canes
Groups
90°
Sculptor
Maffei
M81
Leo I
Ursa Major
Groups
NGC
1023
NGC
2997
0°
Dorado
Leo II
Groups
Fornax
Cluster
Eridanus
Cluster
r powell



Central Portion of The Virgo Cluster

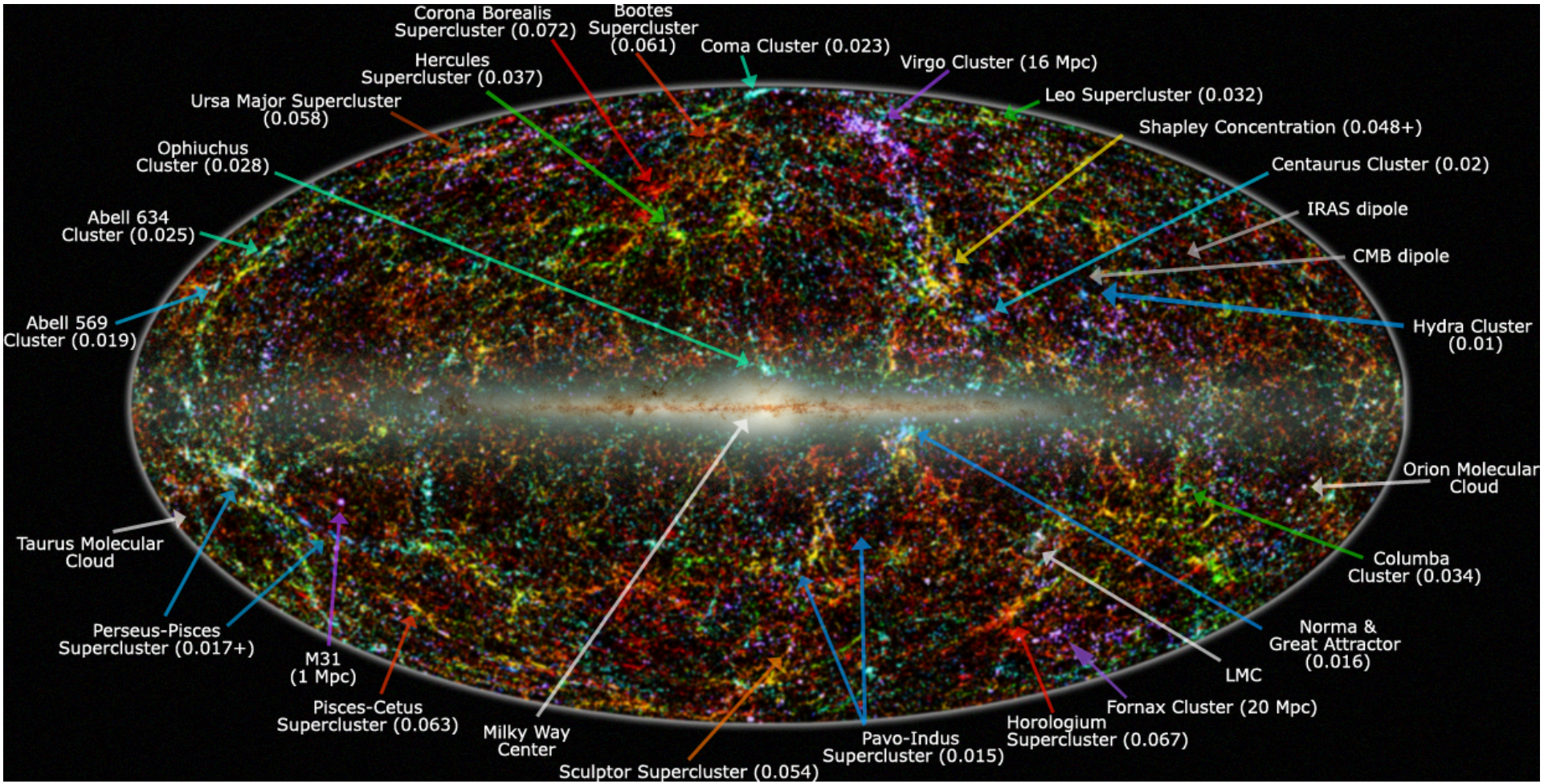

100 million ly
Cygnus Void
Delphinus Void
NGC 6769
NGC 6753
Pegasus Cluster
Pavo Cluster
NGC 5419
180°
Local Void
A3565
Virgo Cluster
270°
90°
Eridanus Void
Ursa Major
Centaurus Cluster
Corvus Void
Eridanus
Fornax Cluster
0°
Antlia Cluster
Leo Void
Hydra Cluster
Puppis Cluster
Gemini Void
Taurus Void
NGC 1417
Cancer Cluster
rpowell


Supercluster
Capricornus
Void
100 million ly
Hercules
Superclusters
Corona Borealis
Void
Microscopium
Void
Pavo-Indus
Supercluster
180°
A3627
Coma
Wall
A4038
Centaurus
Wall
Centaurus
Supercluster
270°
Sculptor
Void
Coma
Supercluster
90°
Virgo
Supercluster
Sculptor
Wall
Phoenix
Supercluster
Hydra
Supercluster
0°
Fornax
Void
Perseus-Pisces
Supercluster
Leo
Supercluster
Canes-Major
Void
Columba
Void

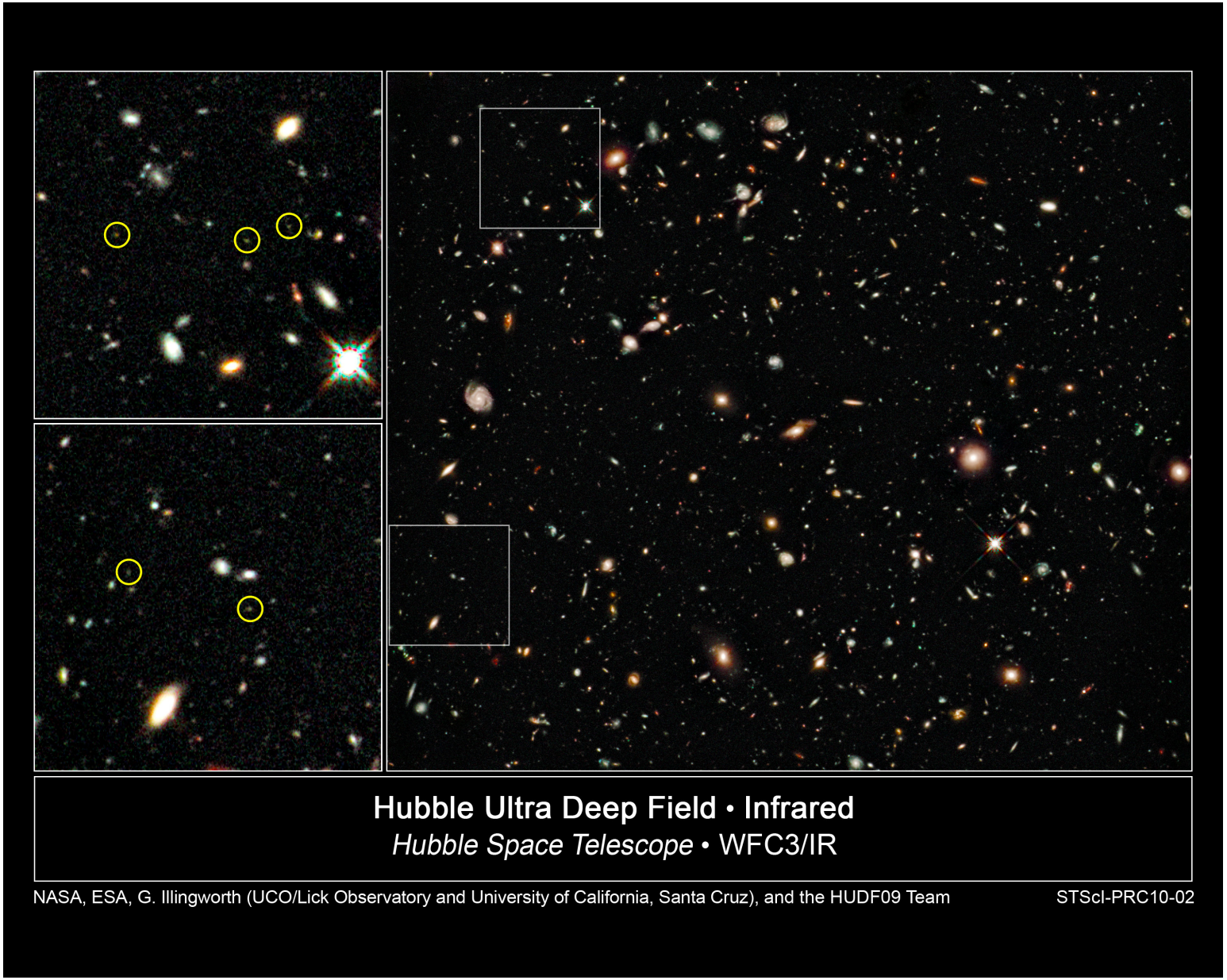

Right ascension
12h
11h
13h
10h
14h
9h
Sloan Great Wall
11243 galaxies
25000
20000
cz in km/s
15000
13h
12h
14h
11h
15h
10h
16h
9h
CfA2 Great Wall
1732 galaxies
10000
5000
cz in km/s

Distribution of Galaxies

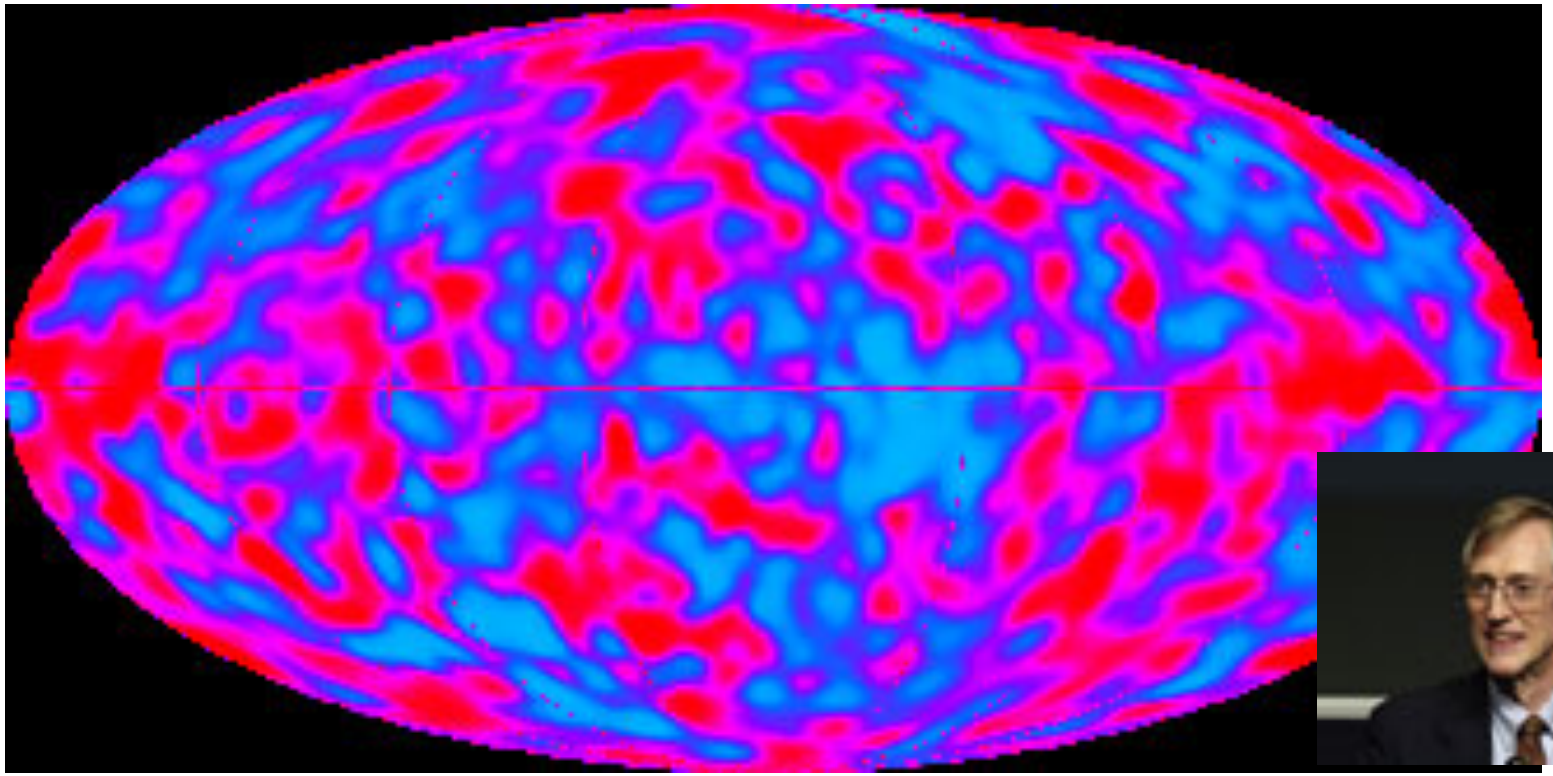
(2-MASS)



Billions of Light Years Distant



To the Beginning of Time

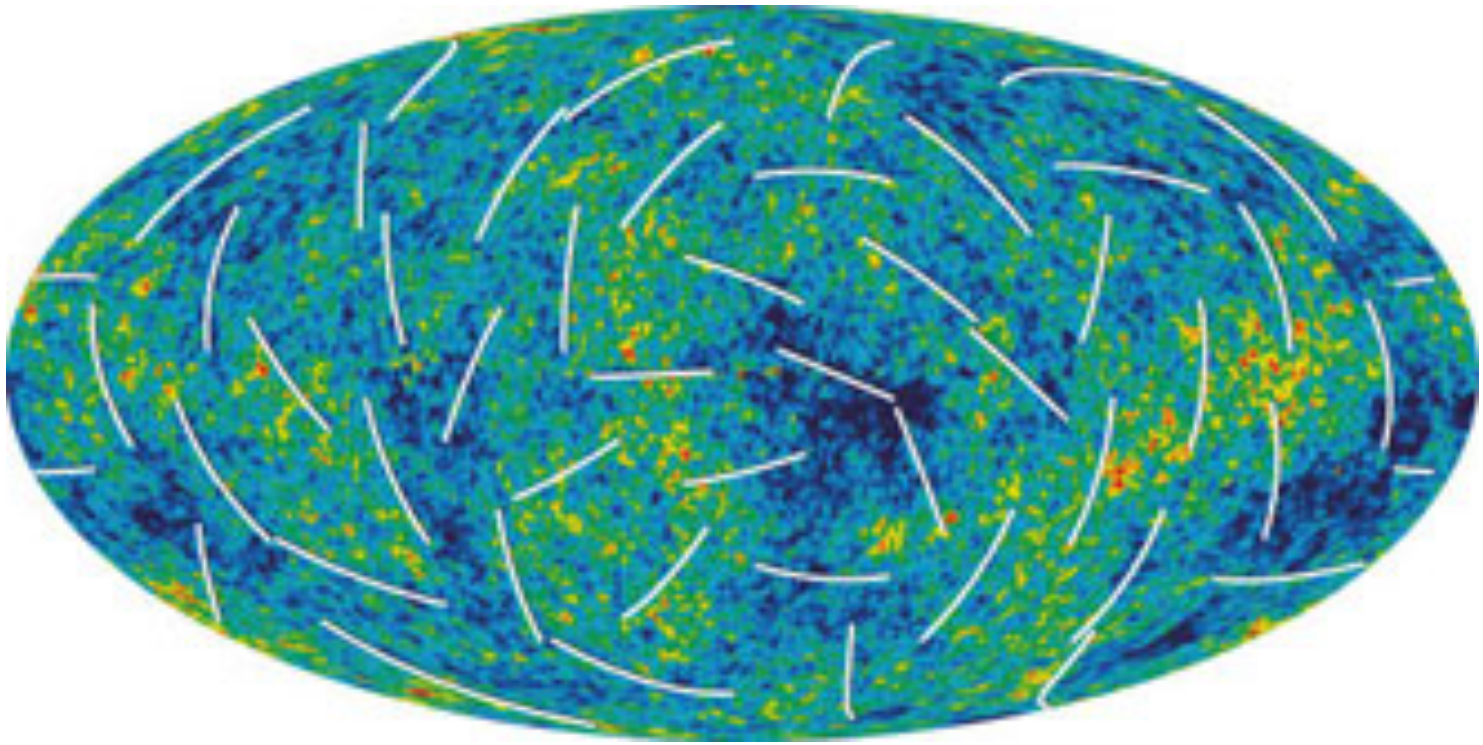


John Mather
NASA 2006 Nobelist

Cosmic Background Radiation data from COBE Satellite, 1992

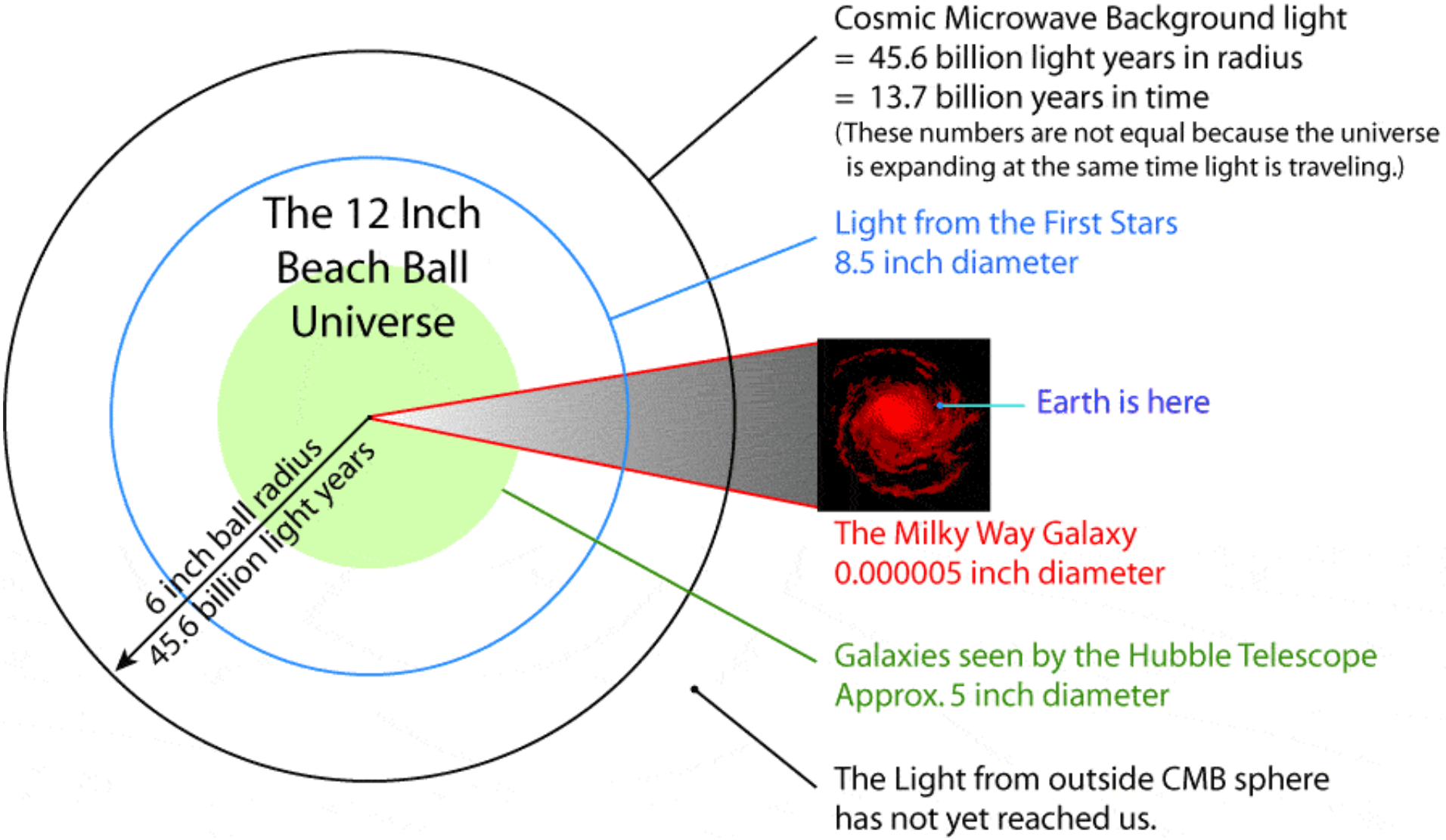
The cosmic microwave background fluctuations are extremely faint (red is hotter), only one part in 100,000 compared to the 2.73 degree Kelvin average temperature of the radiation field.

… and with even greater resolution



Where COBE measured temperature variations to one part in 100,000, WMAP measures those variations to less than one part in 1,000,000. Colors indicate warmer (red) and cooler (blue).
2006 Data from the Wilkinson Mapping Anisotropy Probe

The Universe in a Beach Ball



RETURN TO EARTH!

Astronomy's Three Kingdoms

Planets

Known since antiquity – "wanderers"

Recognized as possibly Earth-like since Copernicus

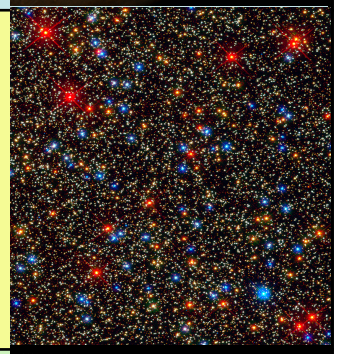
Understood in some detail after telescope

Stars

Known since antiquity – "fixed"

Recognized as possible suns since 16 c (Bruno)

Understood after spectroscopy (19th century)



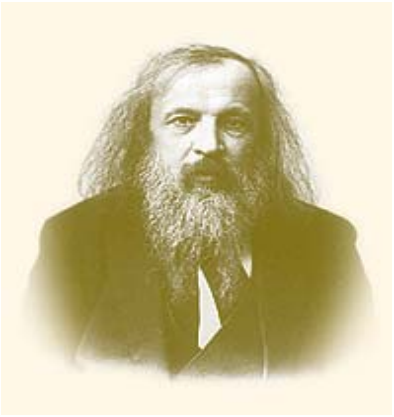
Galaxies

Known since at least 16th c (Magellan)

Recognized as possible 'island universes' in 18th c

Understood since 1920s

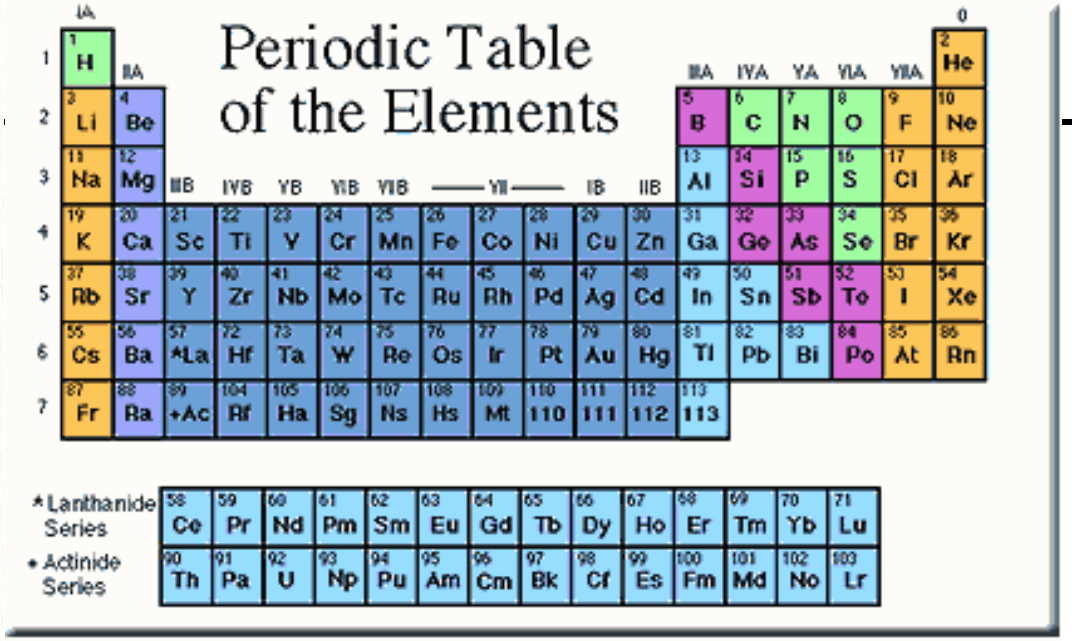
These are the main divisions enshrined in all astronomy textbooks since the 1950s



Chemistry – Periodic Table of Elements

			Ti = 50	Zr = 90	? = 180.	
			V = 51	Nb = 94	Ta = 182.	
			Cr = 52	Mo = 96	W = 186.	
			Mn = 55	Rh = 104,4	Pt = 197,4	
			Fe = 56	Ru = 104,4	Ir = 198.	
			Ni = Co = 59	Pl = 106,6	Os = 199.	
H = 1			Cu = 63,4	Ag = 108	Hg = 200.	
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112		
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?	
	C = 12	Si = 28	? = 70	Sn = 118		
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?	
	O = 16	S = 32	Se = 79,4	Te = 128?		
	F = 19	Cl = 35,5	Br = 80	J = 127		
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.	
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.	
		? = 45	Ce = 92			
		? Er = 56	La = 94			
		? Yt = 60	Di = 95			
		? In = 75,6	Th = 118?			

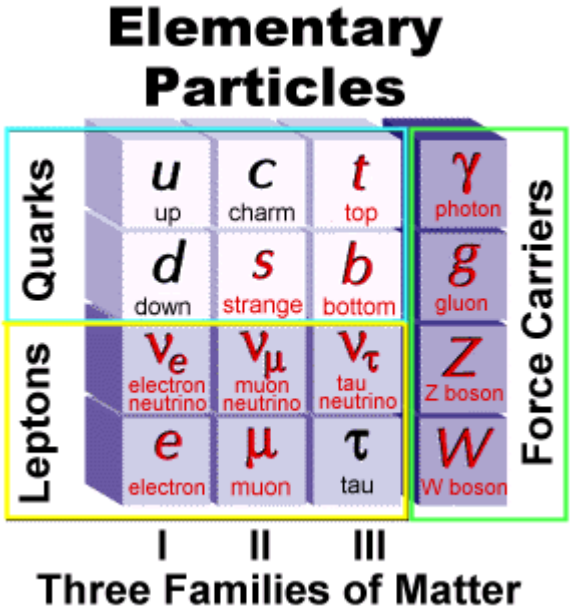
FIGURE 2.1 The first published form of Mendeleev's periodic system, dated 17 February 1869 and entitled "An Attempt at a System of Elements, Based on Their Atomic Weight and Chemical Affinity." Mendeleev had 50 of these images printed up under a French title and 150 under a Russian one, which he mailed to various chemists. In order to transform this image into a modern periodic system, it must first be rotated clockwise 90°, reflected, and then the halogens (the row beginning with F = 19) need to be placed at the opposite extreme from the alkali metals (the row beginning with Li = 7). Notice that spaces are left with question marks for elements that Mendeleev suspected existed. Source: Mendeleev, *Periodicheskii zakon. Klassiki nauki,* 9.

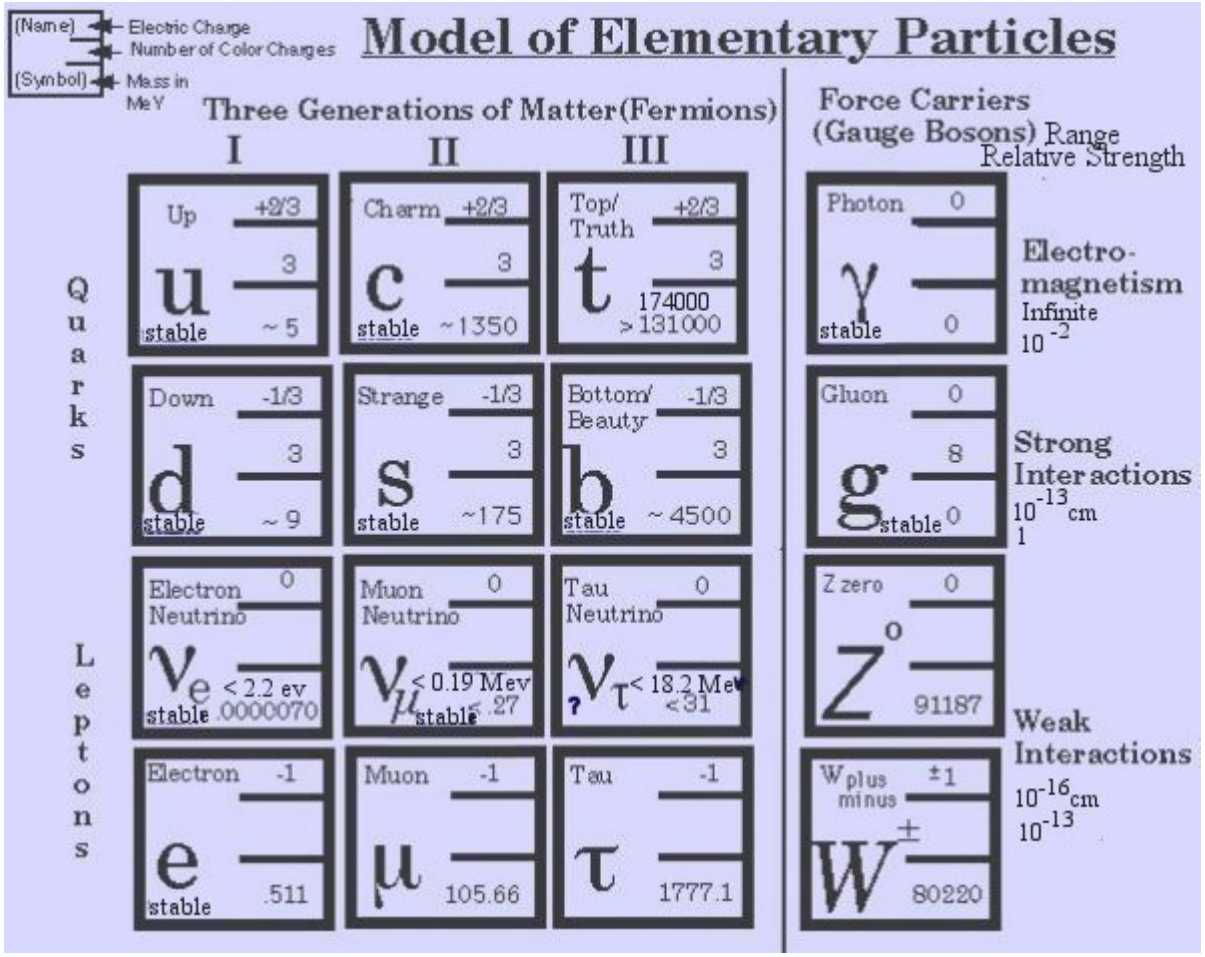


From Michael D. Gordon,
A Well-Ordered Thing: Dmitrii Mendeleev
And the Shadow of the Periodic Table (2004)

The Standard Model of Particle Physics

Murray Gellman – 1969 Nobel Prize
For classification and interaction of Elementary particles

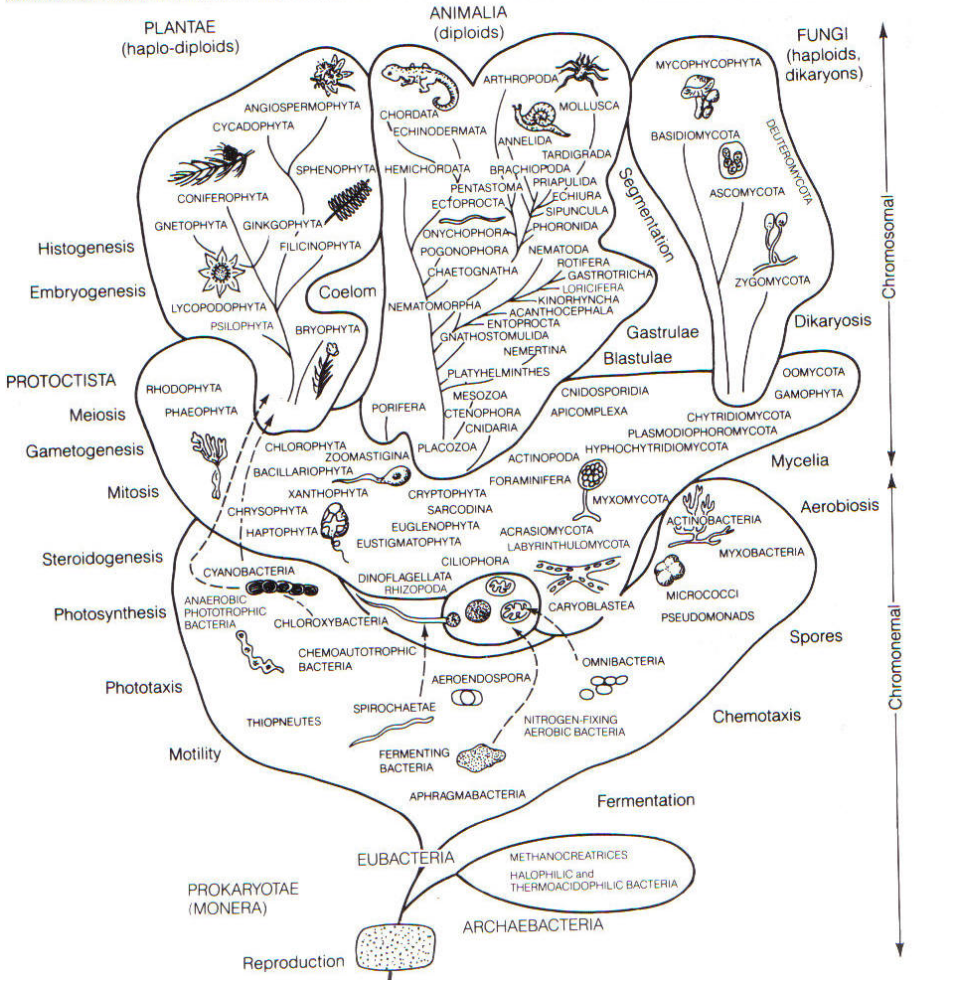




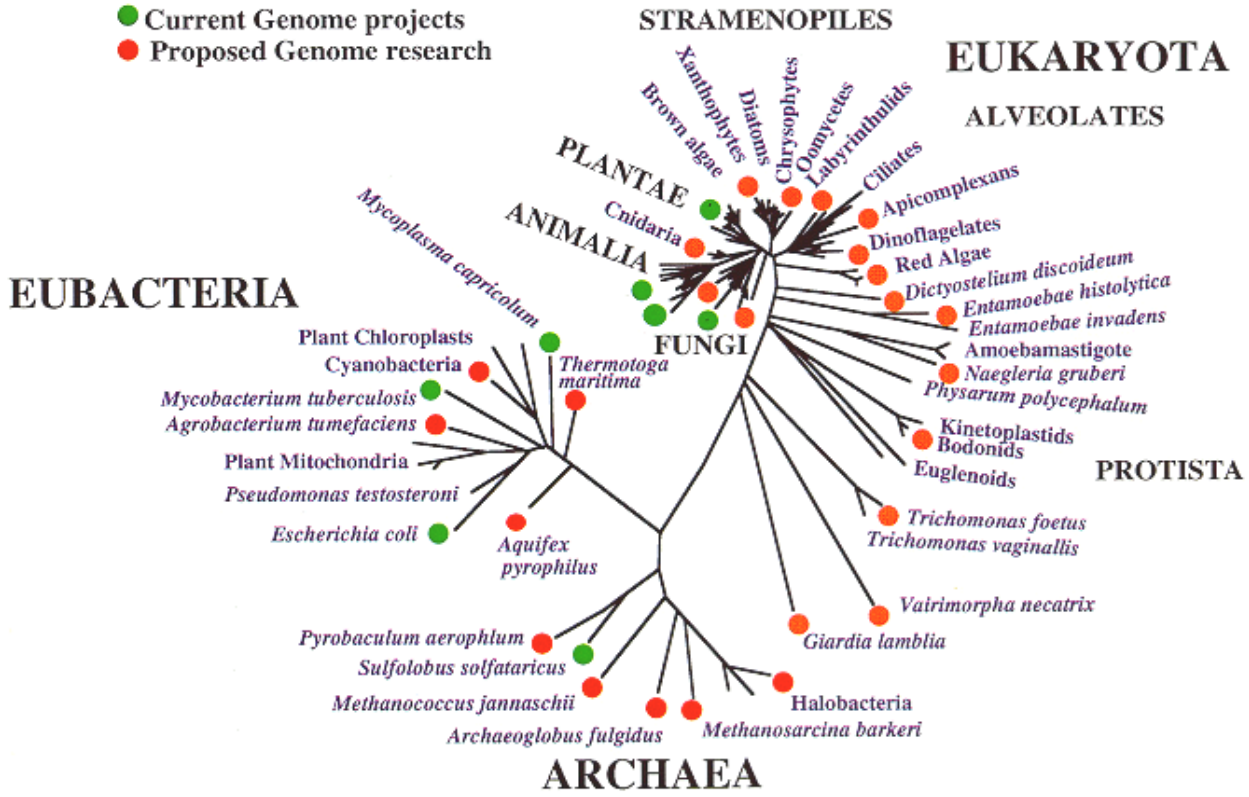
Sometimes called the “periodic table” of elementary particles

Classification in Biology
Five Kingdoms

A phylogeny of life on Earth based on the Whittaker five-kingdom system and the symbiotic theory of the origin of eukaryotic cells.



Classification in Biology
Three Domains

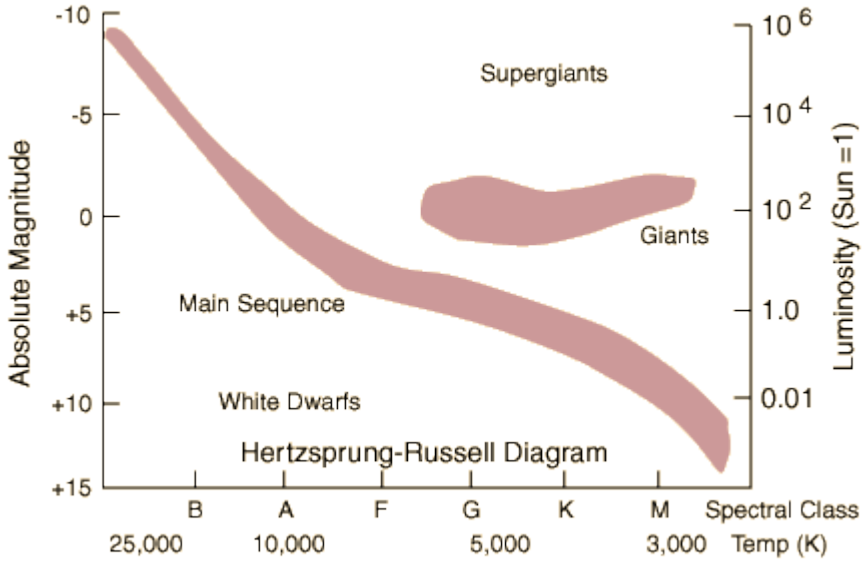


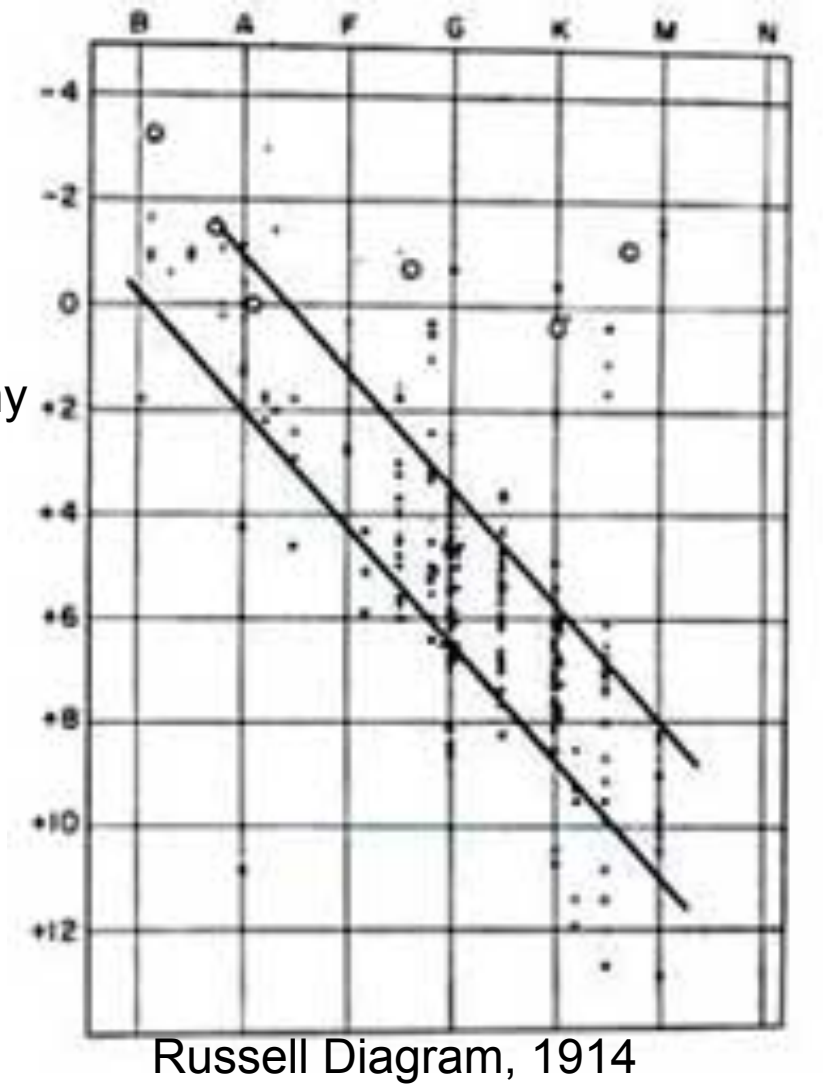
Molecular biology had led to 3-domain classification system, based on comparing sequences of ribosomal RNA (Woese)

Classification of Stars: The H-R Diagram

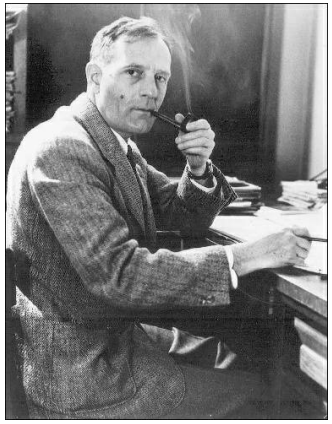
Not just a classification scheme –

An evolutionary sequence – phylogeny

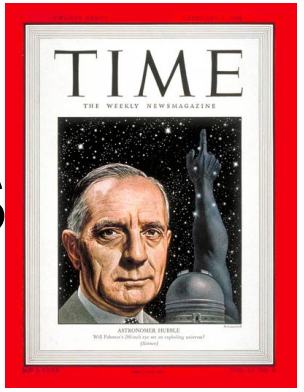




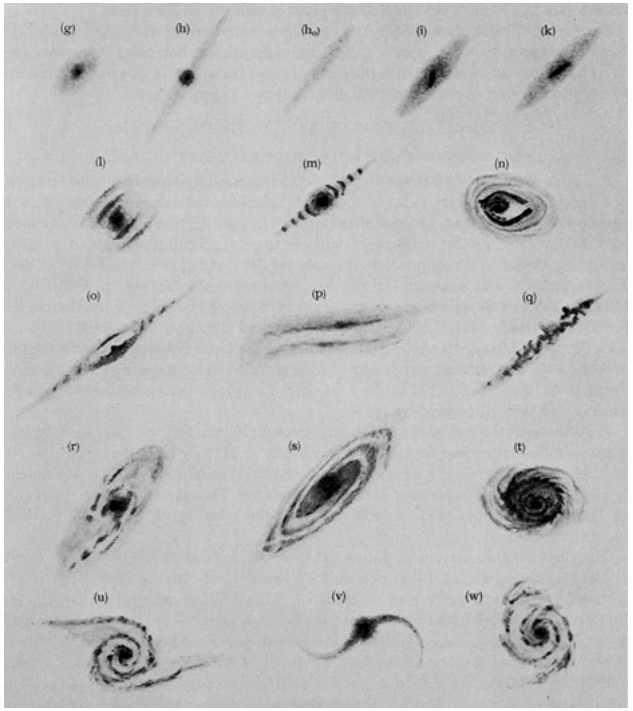
Russell Diagram, 1914



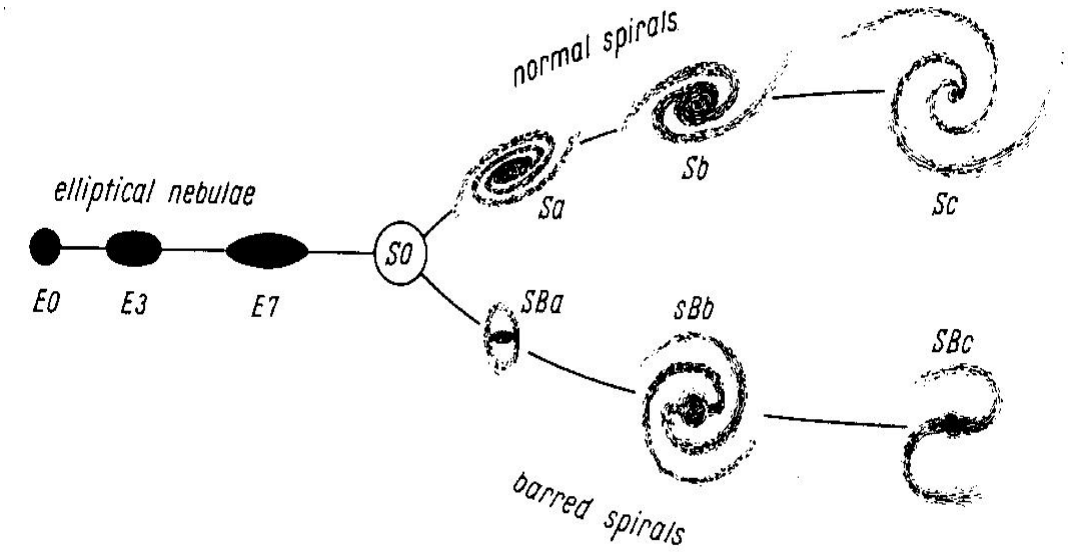
Classification of Galaxies



February 9, 1948

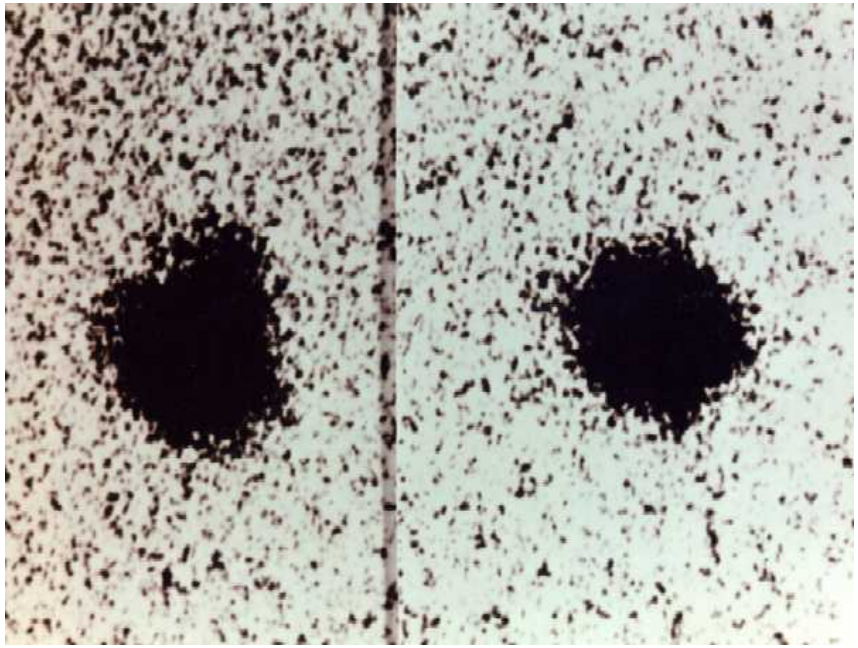


Wolf's system, 1908



Hubble 'tuning fork' classification
From Realm of the Nebulae (1936)

Pluto and its Moon

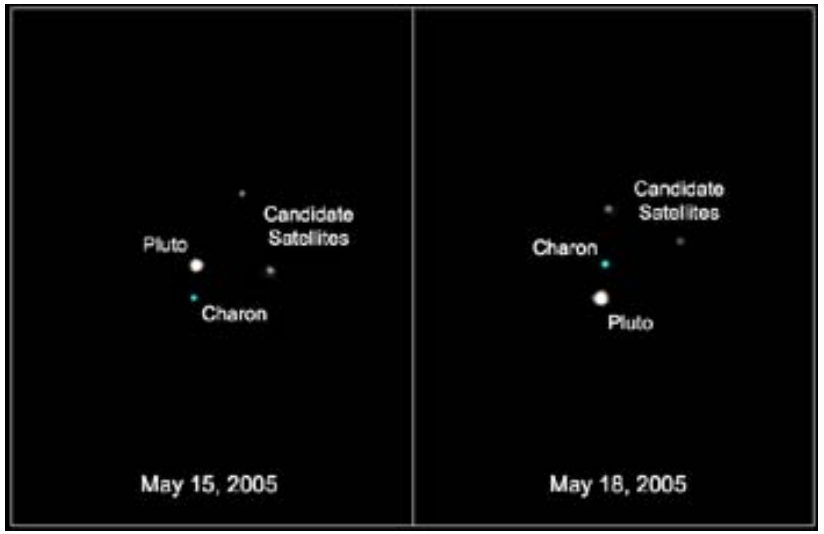


USNO Discovery July 6, 1978

Discovery images of Pluto/Charon, taken with the 1.55-meter (61-inch) Kaj Strand Astrometric Reflector at the USNO Flagstaff Station:
Left: showing elongated image of Pluto, with Charon to the upper right
Right: showing "undistorted" image of Pluto with Charon along line of sight with the planet

Discovery made June 22, 1978; confirmation image July 6, announcement July 6

HST Image, FOC, February 21, 1994



HST Moons announced October 31, 2005

Taxonomic Levels in Biology

Kingdom	Animalia
Phylum/Division	Chordata
Subphylum	Vertebrata
Class	Mammalia
Order	Primates
Family	Hominoidea
Genus	Homo
Species	Sapiens

Taxonomic Levels in Astronomy

Taxa	Example
Kingdom	Stellar
Family	Star
Division	Post-Main Sequence
Class	Giant, Luminosity Class III
Type	F, G, K, M spectral type
Subtype	RR Lyrae

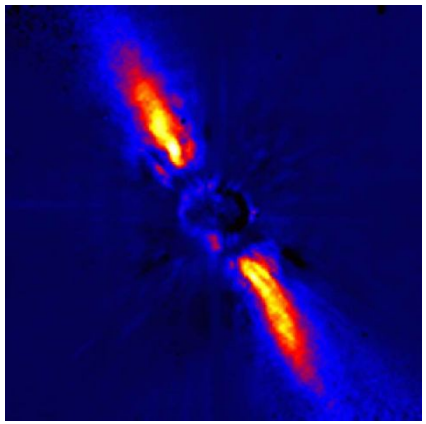
Astronomy's 18 Families

Protoplanetary	Protostellar	Protogalactic
Planet	Star	Galaxy
Circumplanetary	Circumstellar	Circumgalactic
Subplanetary	Substellar	Subgalactic
Interplanetary Medium	Interstellar Medium	Intergalactic Medium
Planetary Systems	Stellar Systems	Galactic Systems

Gravity is the basis for defining Families

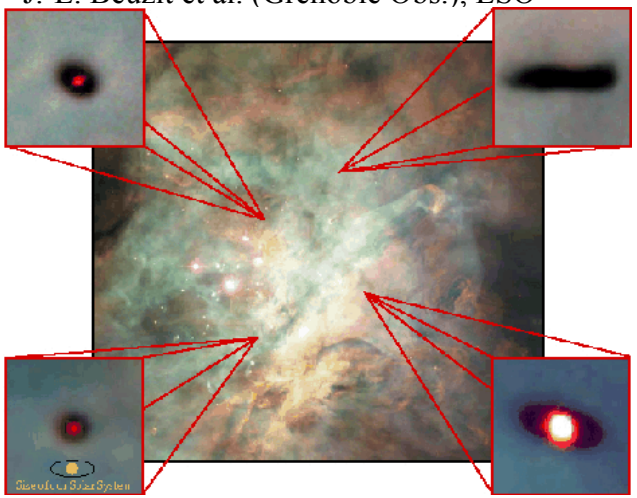
The Proto-Family

Protoplanetary



Beta Pictoris

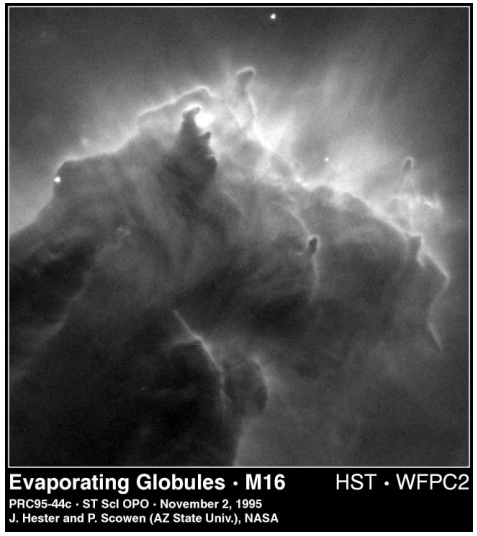
J.-L. Beuzit et al. (Grenoble Obs.), ESO



Planetary formation in Orion

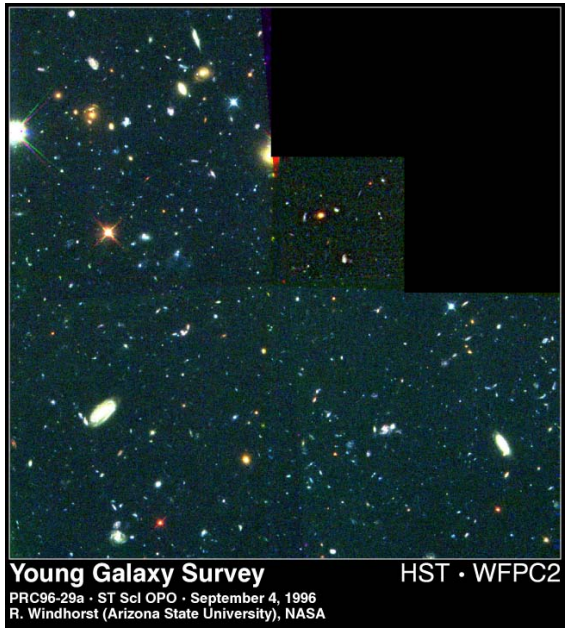
C. R. O'Dell and S. K. Wong, Rice U., WFPC2, HST, NASA

Protostellar



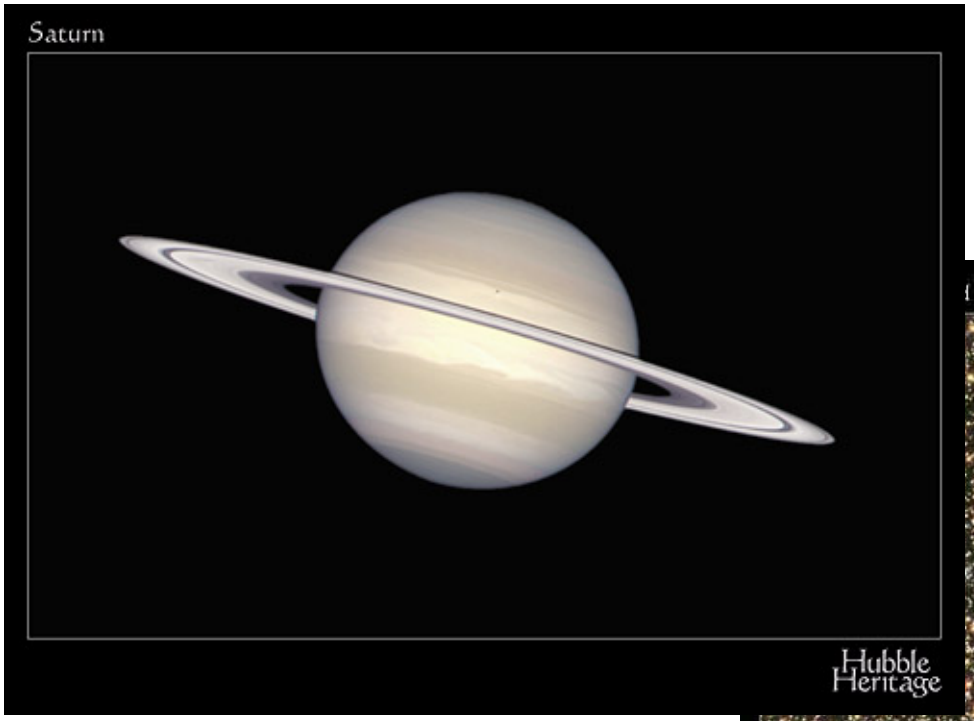
Evaporating Gaseous Globules (EGGs) in M 16

Protogalactic

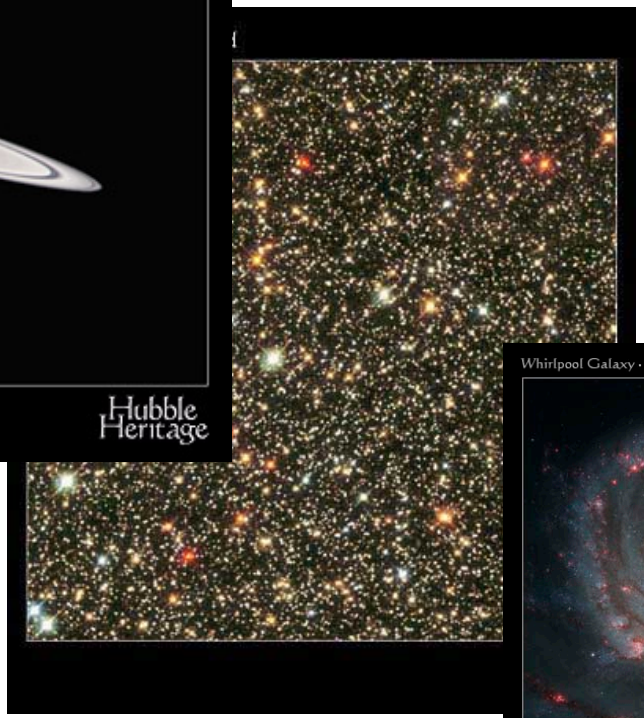


18 galactic building Blocks that may Merge to form a single Galaxy, 11 billion LY away

The Central Family



Planets

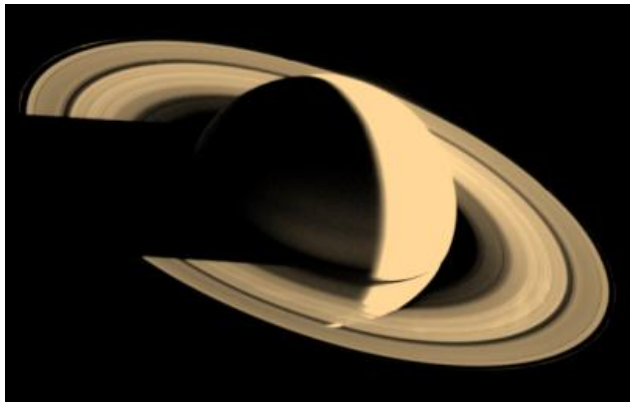


Stars

Galaxies

The Circum-Family

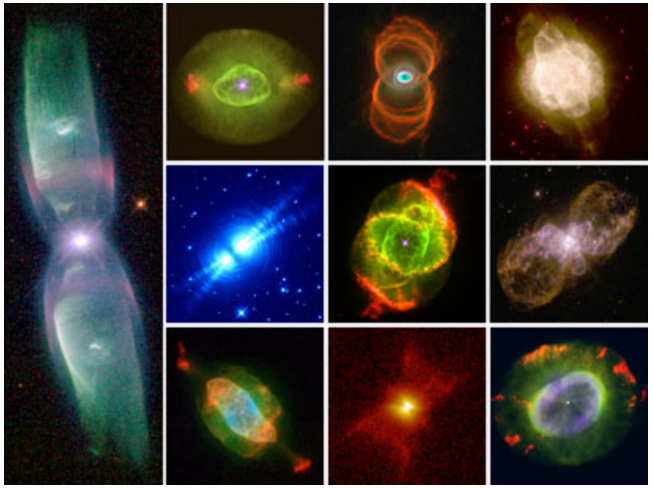
Circumplanetary



Rings – Voyager 1

Moons – Voyager 1

Circumstellar



Planetary Nebulae

HH1/HH2: Star Jets

Credit J. Hester (ASU), WFPC2 Team, NASA

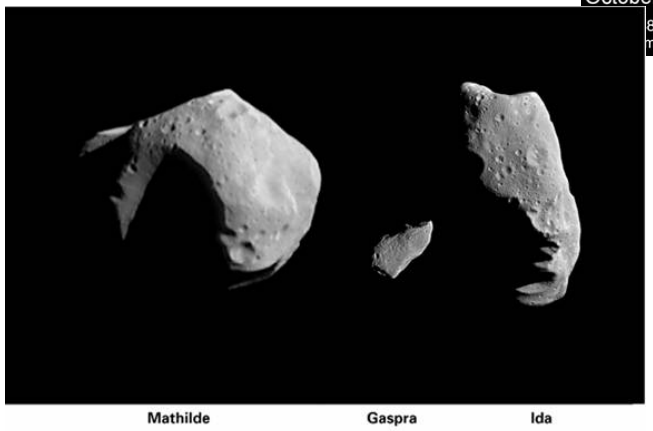
Circumgalactic

Globular Cluster
HST

The Sub-Family

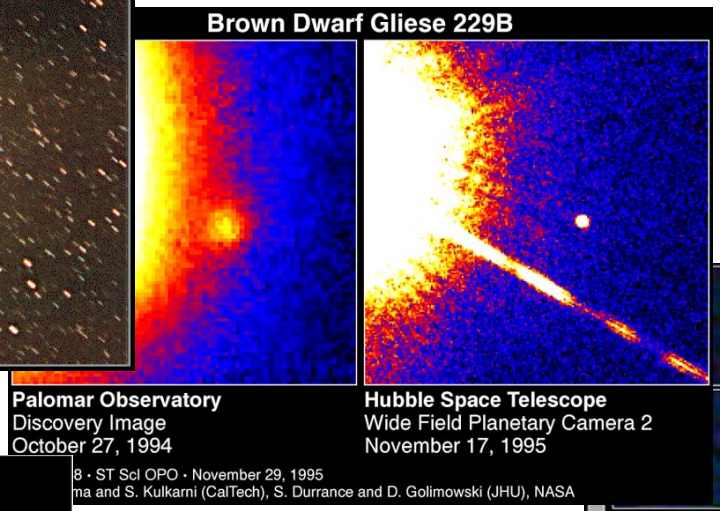
Subplanetary

Comets



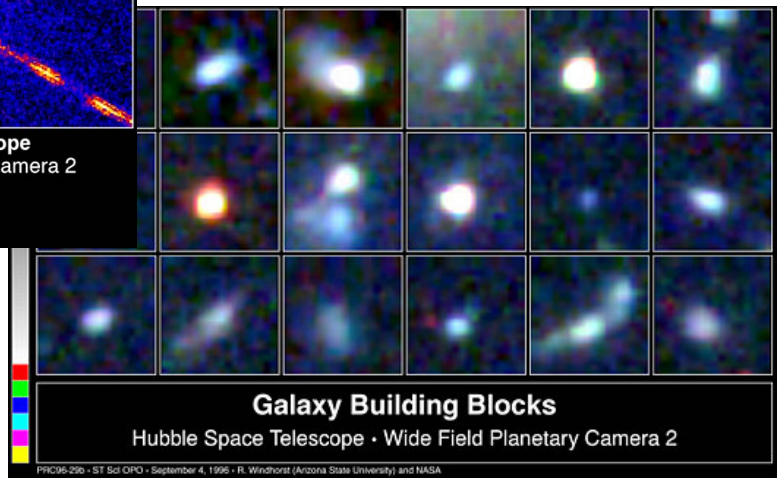
Asteroids

Substellar



Brown Dwarfs

Subgalactic



Galaxy Building Blocks

The Inter-Family

Interplanetary

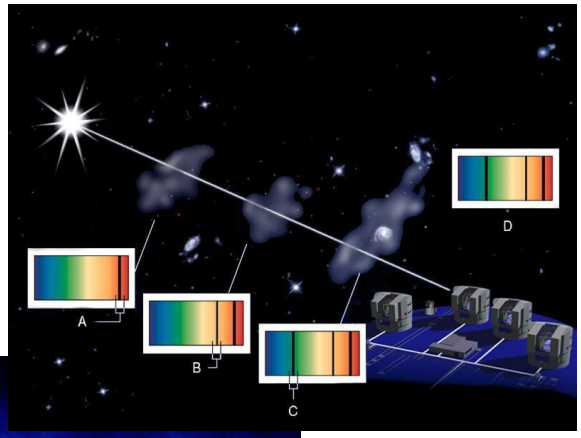
Zodiacal Light – reflected from Interplanetary dust particles
D. Malin

Interstellar

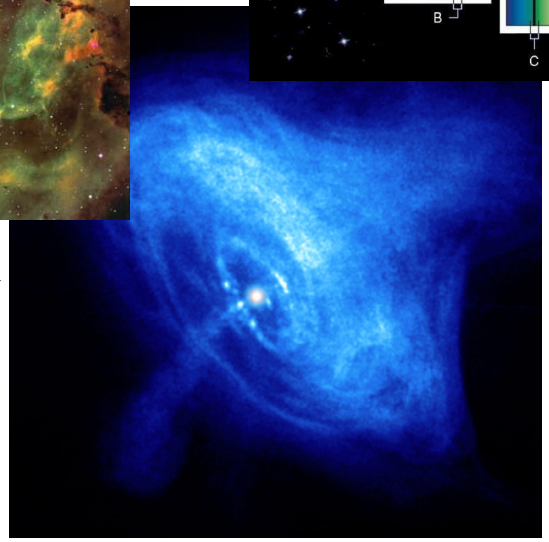
Rosette Emission Nebula

Credit: T. A. Rector, B. Wolpa, M. Hanna (AURA/NOAO/NSF)

Intergalactic



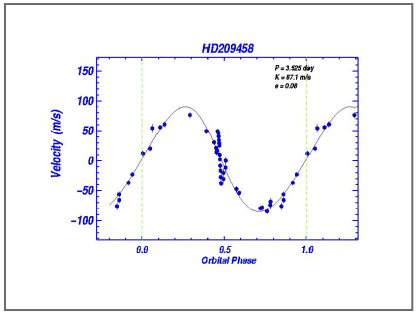
Absorption spectra
Due to intergalactic Gas - Ed Janssen, ESO

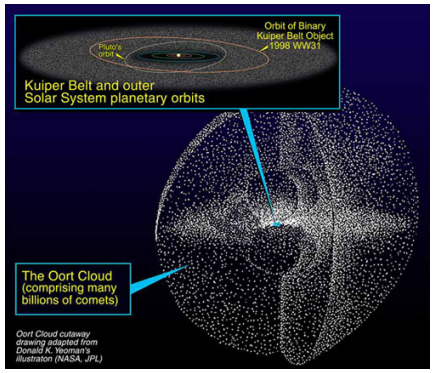


Crab Nebula – SN Remnant
Chandra X-ray wide field view
April 6, 2001

The Systems Family

Planetary systems





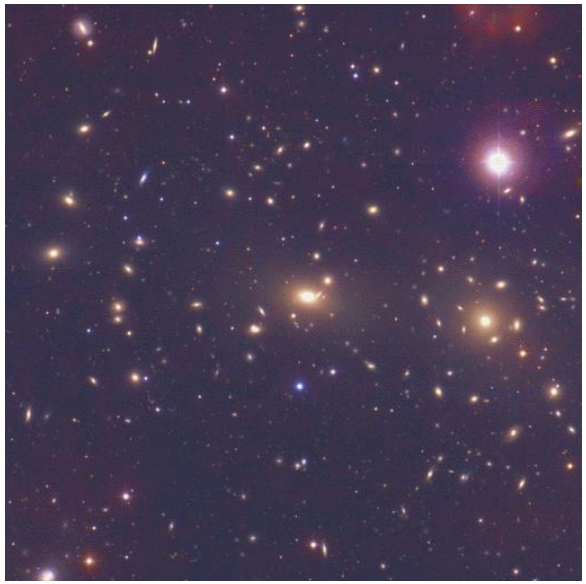
Cometary systems

Stellar systems

Pleiades Open Cluster
Credit & Copyright: David Malin

AAO, AATB, ROE, UKS Telescope

Galactic systems



Coma Cluster of Galaxies
Credit & Copyright:

O. Lopez-Cruz (INAOEP) et al., AURA, NOAO, NSF

Kingdom of the Planets

Family: Protoplanetary

Class P 1: Proplyd

Family: Planet

Class P 2: Terrestrial (rocky)

Class P 3: Gas Giant

Class P 4: Ice Giant

Class P 5: Pulsar Planet

Family: Circumplanetary

Class P 6: Planetary Satellite

Class P 7: Planetary Ring

Class P 8: Radiation Belt

Family: Subplanetary

Class P 9: Dwarf Planet

Class P 10: Meteoroid

Subfamily: Small Bodies Solar System

Class P 11: Minor Planet/ Asteroid

Class P 12: Comet

Class P 13: Trans-Neptunian Objects

Family: Interplanetary Medium

Class P 14: Gas

Class P 15: Dust

Subfamily: Energetic Particles

Class P 16: Solar Wind

Class P 17: Anomalous Cosmic Ray

Kingdom of the Stars

Family: Protostellar

Class S 1: Protostar

Family: Star

Subfamily: Pre-Main Sequence

Class S 2: T-Tauri

Class S 3: Herbig Ae/Be

Subfamily: Main Sequence (H burning - Lum Class V)

Class S 4: Upper Main Sequence

Class S 5: Lower Main Sequence

Class S 6: Subdwarf

Subfamily: Post-Main Sequence (He burning and higher elements)

Class S 7: Subgiant (Lum Class IV)

Class S 8: Giant (Lum Class III)

Class S 9 : Bright Giant (Lum Class II)

Class S 10 Supergiant (Lum. Class I)

Subfamily: Evolutionary Endpoints

Class S 11 Supernova

Class S 12 White Dwarf

Class S 13 Neutron Star

Class S 14 Black Hole

Family: Circumstellar

Class S 15: Debris disk

Class S 16: Shell (dying stars)

Class S 17: Planetary Nebula

Class S 18: Nova Remnant

Class S 19: Core Collapse Supernova Remnant

Class S 20: Stellar Jet

Class S 21: Herbig-Haro Object

[See also Planetary System, P 18]

Kingdom of the Galaxies

Family: Protogalactic

Class G 1: Protogalactic Cloud

Family: Galaxy

Subfamily: Normal

Class G 2 Elliptical

Class G 3 Lenticular

Class G 4 Spiral

Class G 5 Irregular

Subfamily: Active

Class G 6 Seyfert

Class G 7 Radio Galaxy

Class G 8 Quasar

Class G 9 Blazar

Family: Circumgalactic

Class G 10 Galactic Ring

Class G 11 Galactic Jet

Class G 12 Galactic Halo

Family: Subgalactic

Class G 13 Failed Galaxies

Family: Intergalactic Medium

Subfamily: Gas

Class G 14 Gas

Class G 15 Lyman alpha blobs

Subfamily: Dust

Class G 16 Dust

Subfamily: Energetic Particles

Class G 17 Galactic Wind

Class G 18 Extragalactic Cosmic Rays

Astronomy's 83 Classes (cont.) Preliminary

Family: Systems
- Class P 18: Planetary System
- Class P 19: Asteroid Groups
- Class P 20: Meteor streams

Subfamily: Trans-Neptunian Systems
- Class P 21: Edgeworth/ Kuiper Belt
- Class P 22: Scattered Disk
- Class P 23: Oort Cloud

Family: Substellar
- Class S 22: brown dwarf

Family: Interstellar Medium

Subfamily: Gas (99%]
- Class S 23: Cool Atomic Cloud (H I)
- Class S 24: Hot Ionized Cloud (H II)
- Class S 25: Molecular Cloud (H2)
- Class S 26: White Dwarf Supernova Remnant

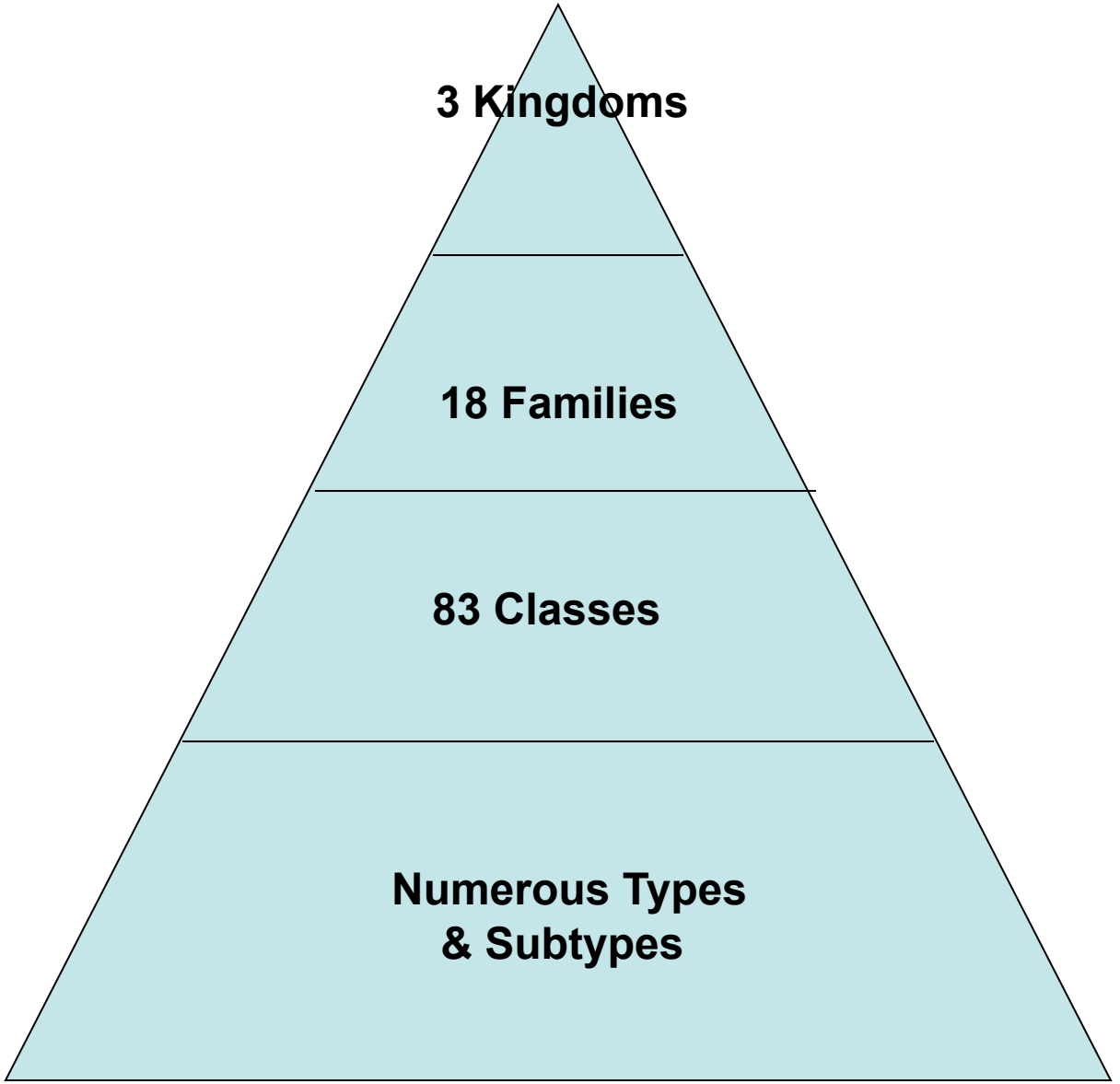
Subfamily: Dust (1%)
- Class S 27: Dark Nebulae
- Class S 28: Reflection Nebulae

Subfamily: Energetic Particles
- Class S 29: Stellar Wind
- Class S 30: Galactic Cosmic Rays

Family: Systems
- Class S 31: Binary
- Class S 32: Multiple Star
- Class S 33: Association (OB)
- Class S 34: Open Cluster
- Class S 35: Globular Cluster
- Class S 36: Population

Family: Systems
- Class G 19 Binary
- Class G 20 Interacting
- Class G 21 Group
- Class G 22 Cluster
- Class G 23 Supercluster
- Class G 24 Filaments & Voids

The Three Kingdom System




THANK YOU!