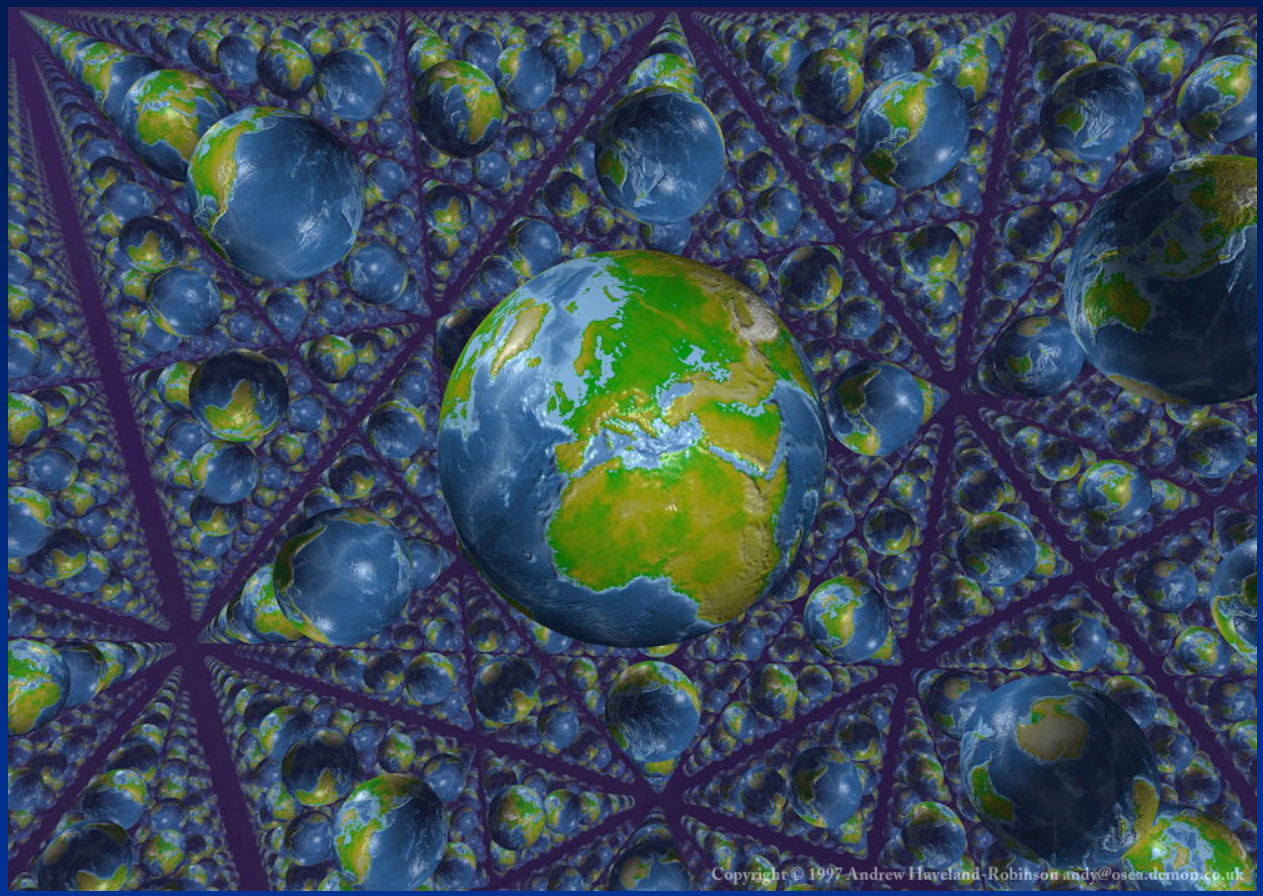
Your place in the cosmos

From Planets to Stars to Galaxies and Beyond



Andrew Friedman & Ryan Hickox

Harvard-Smithsonian Center For Astrophysics

Dudley House Crosstalk: Thursday, December 8th 2005

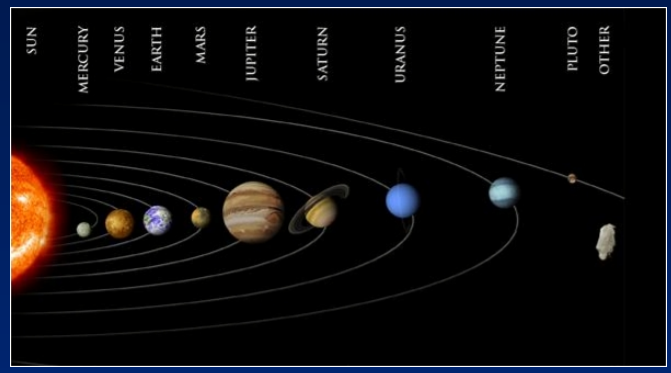
Astrology

"Yeah, m-maybe... by leaving her predictions vague and generalized, there's less of a chance of someone findin' out she's a phoney."

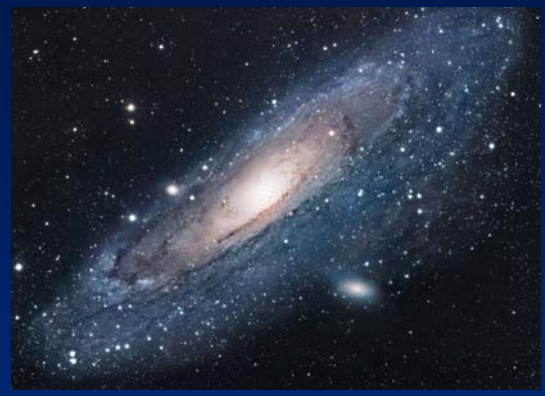
-Bobby Boucher, The Waterboy

The Copernican Principle

People Earth

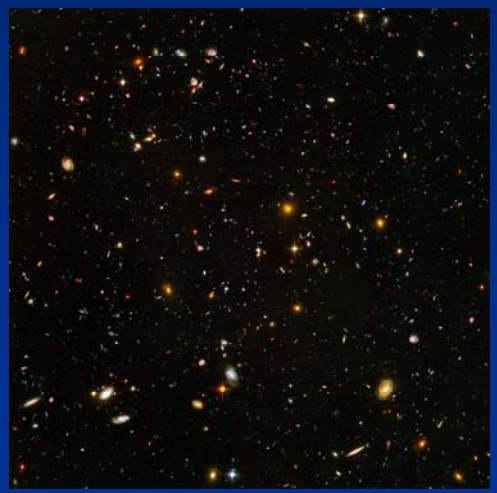


Sun & Solar System



Spiral Galaxy

Galaxy Clusters & Superclusters

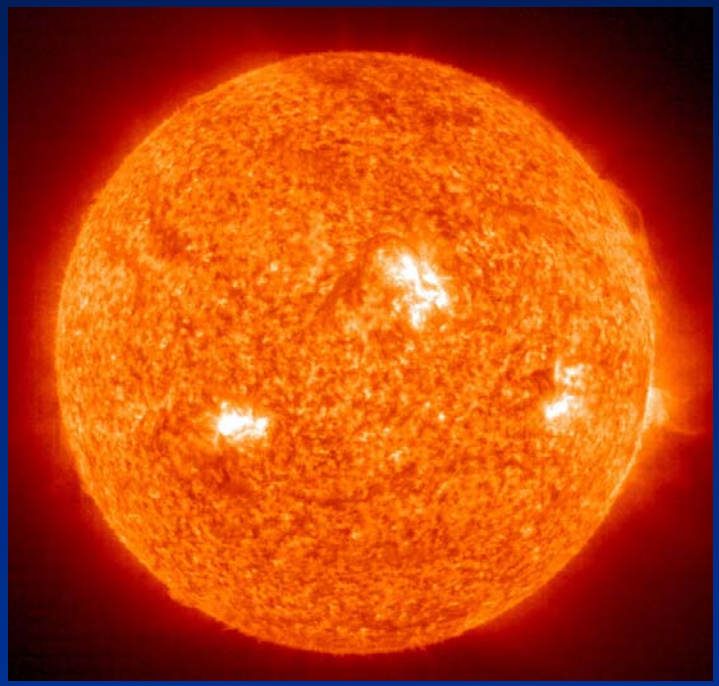


A Small Piece of Our Observable Universe

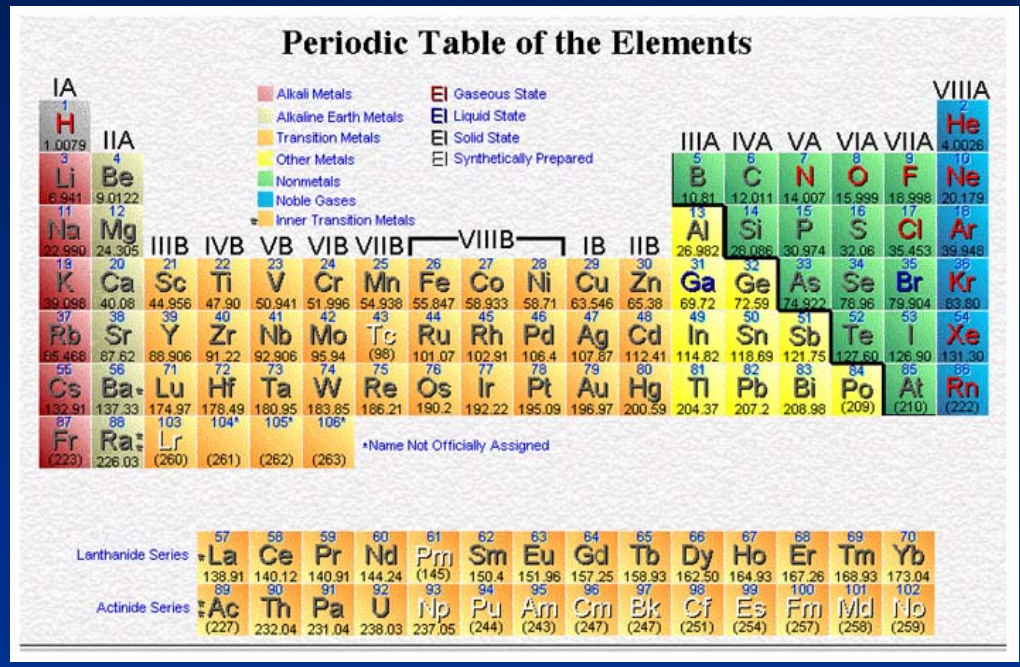
Other Universes?...

Nuclear fusion in stars

Where do heavy elements come from?



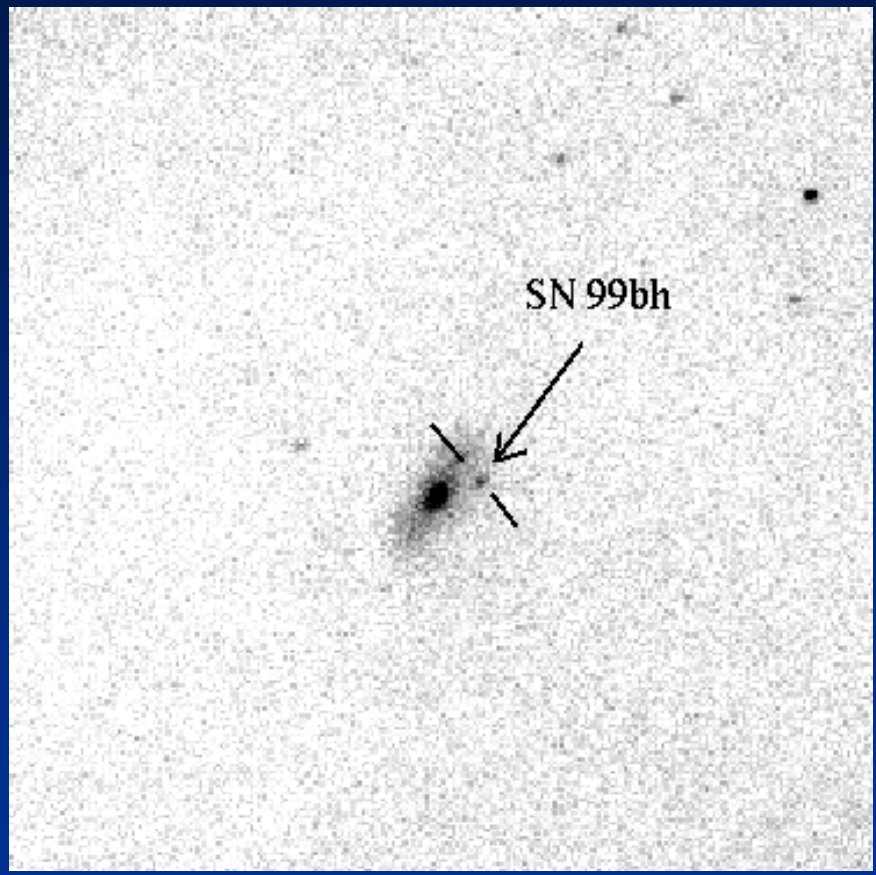
Our Star
The Sun



The Periodic Table

SupernovaE

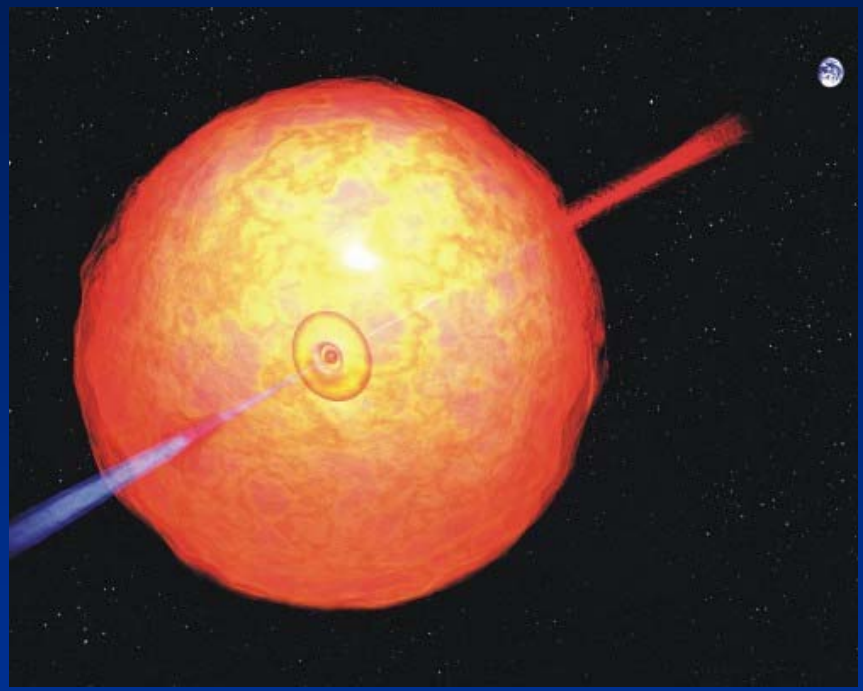
SN 1994d
Hubble Space Telescope



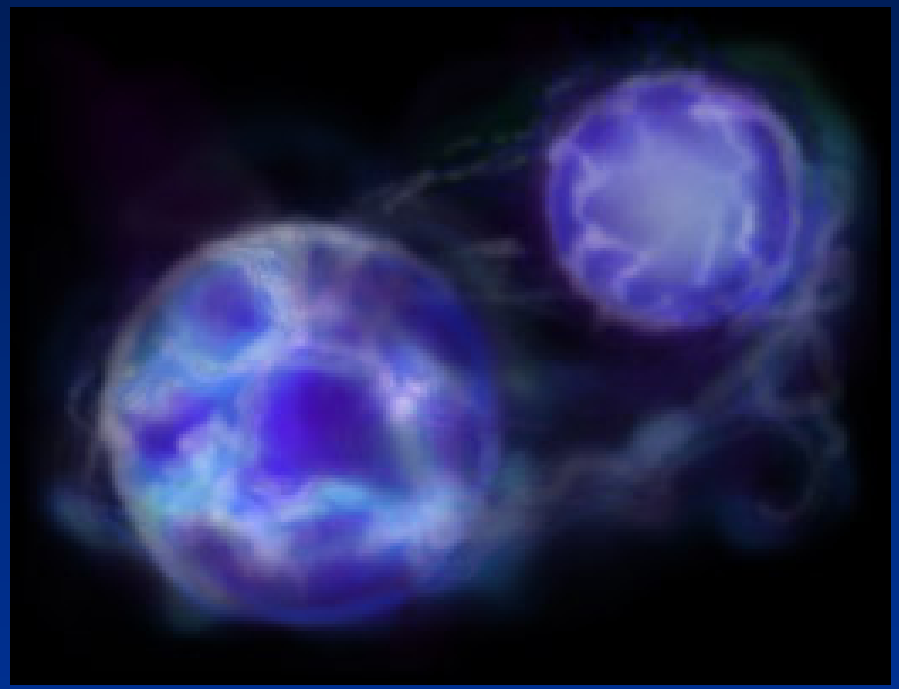
SN 1999bh – Katzmann Automated Imaging Telescope & Andy

Gamma-ray bursts (GRBs)

The Brightest Explosions in the Universe!



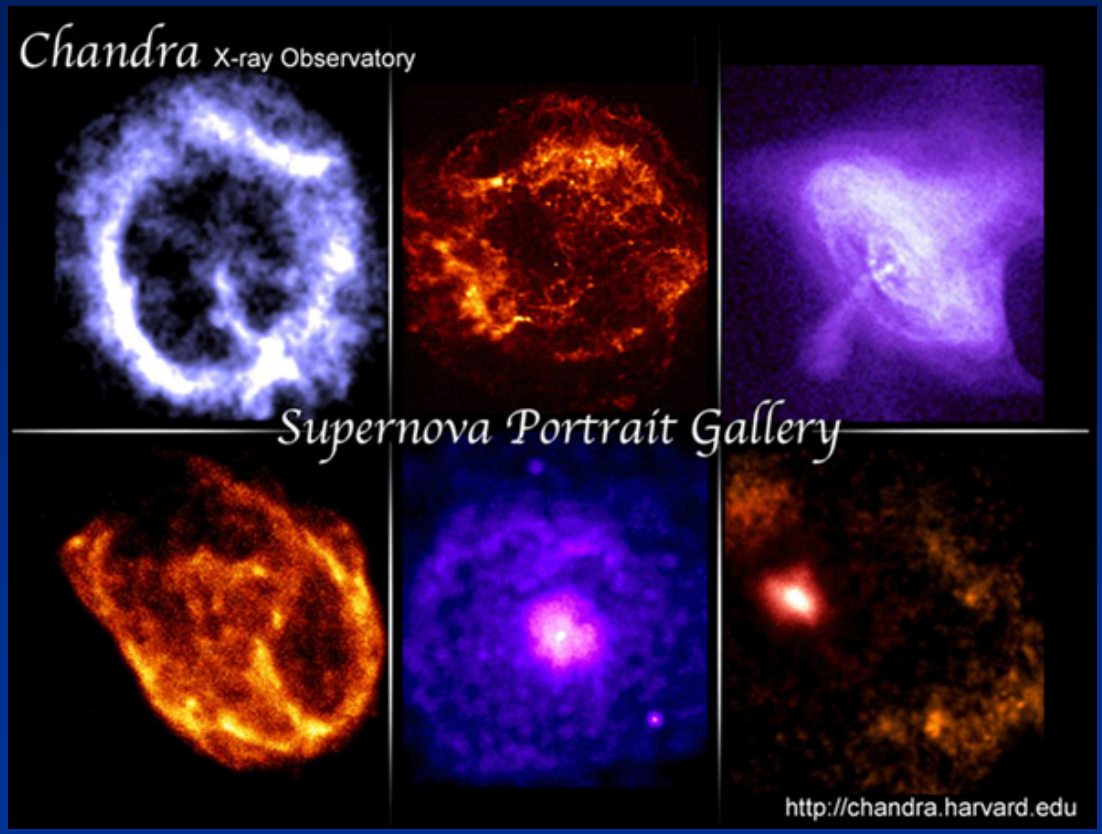
Long Duration GRBs
Occur along with supernovae of some massive stars

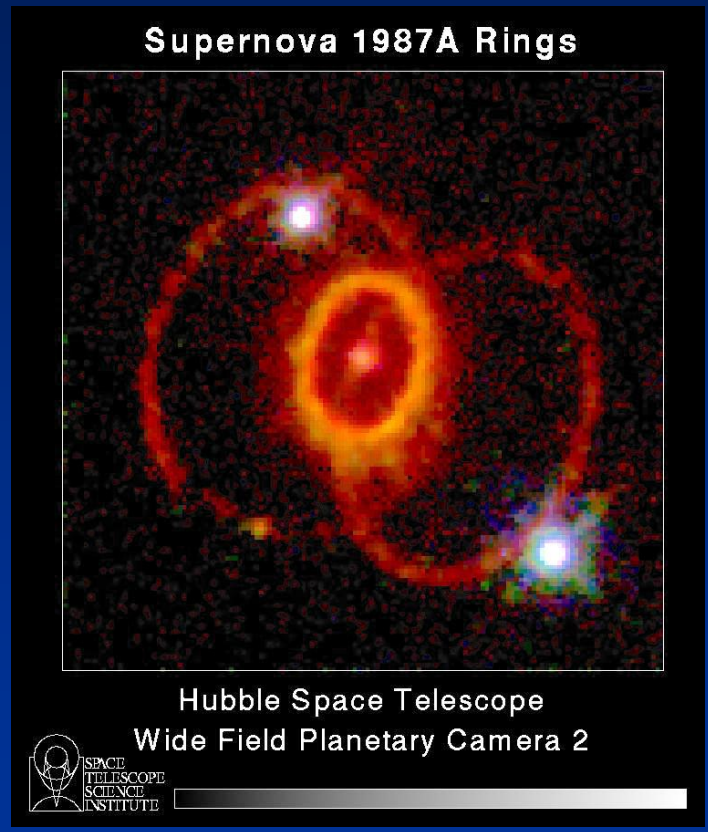


Short Duration GRBs
Probably merging neutron stars

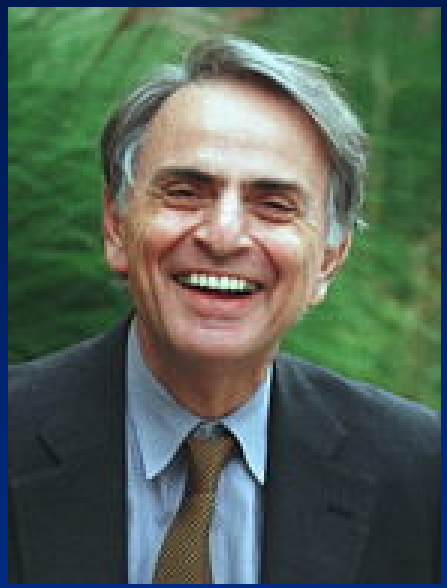
Supernova REMNANTS

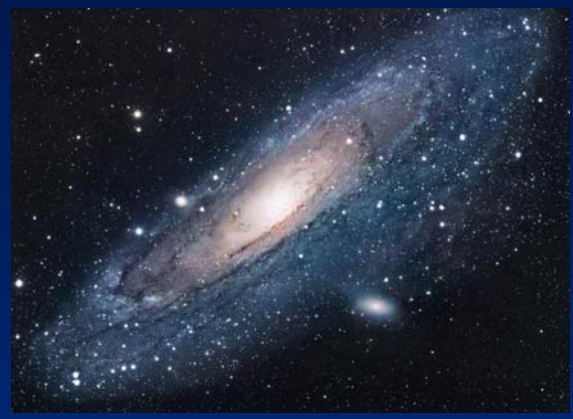
- ***What's left over after the explosion?***





We are all made of stars

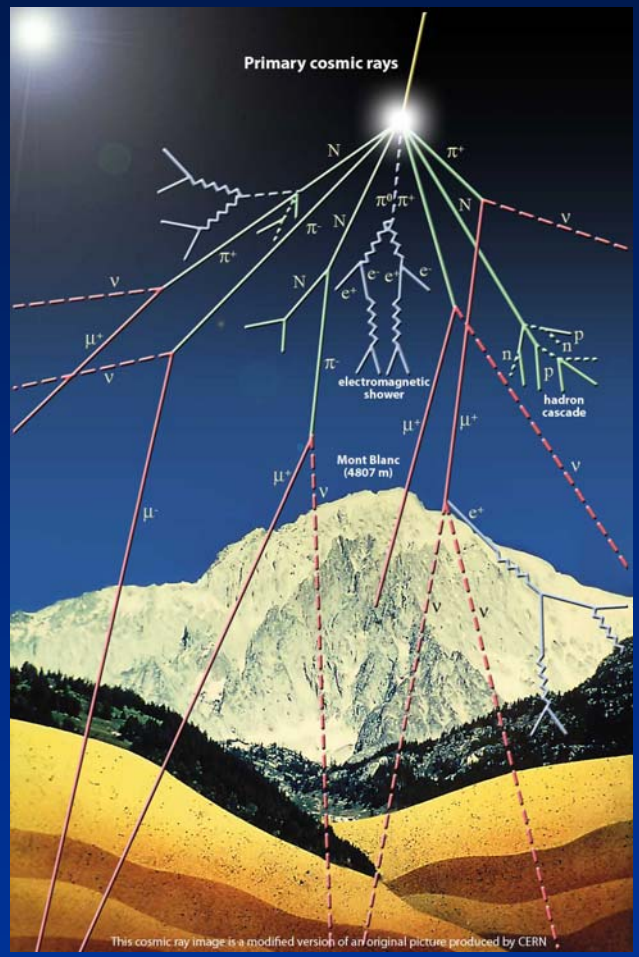




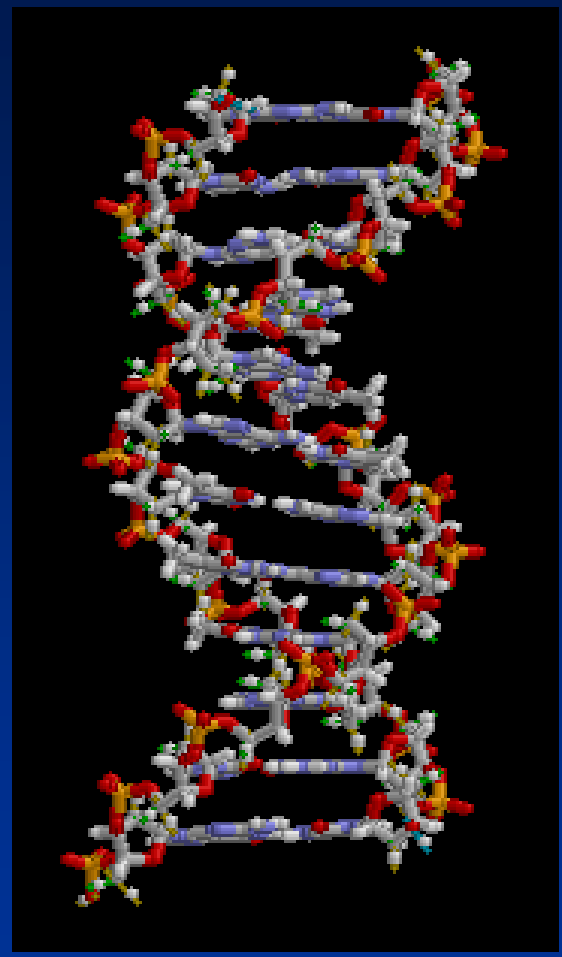
Cosmic Rays

SNe & GRBs Bursts Produce High-Energy Cosmic Rays

Cosmic Rays From Space Set the Background Rate of Genetic Mutation on Earth!

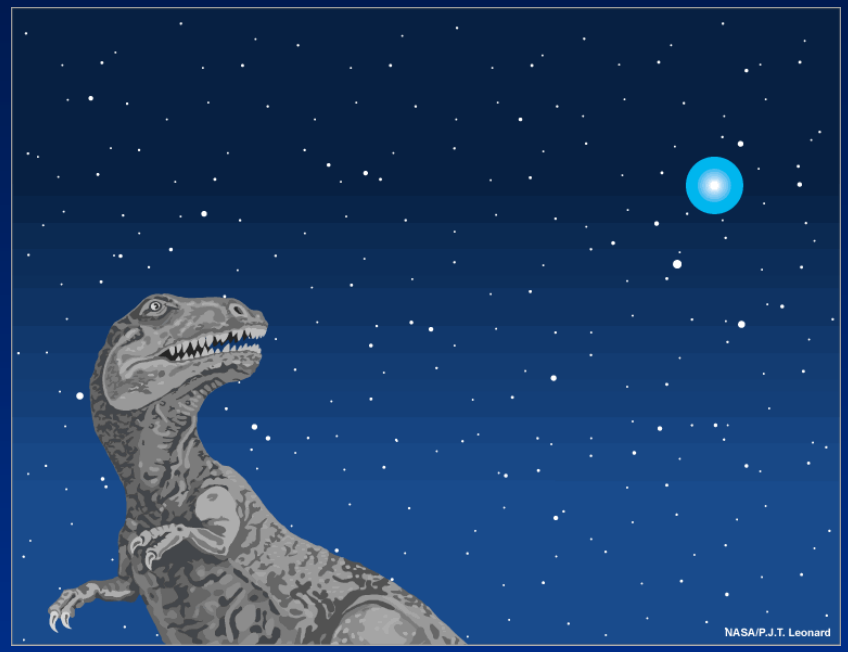


Cosmic Ray Air Shower



DNA Molecule

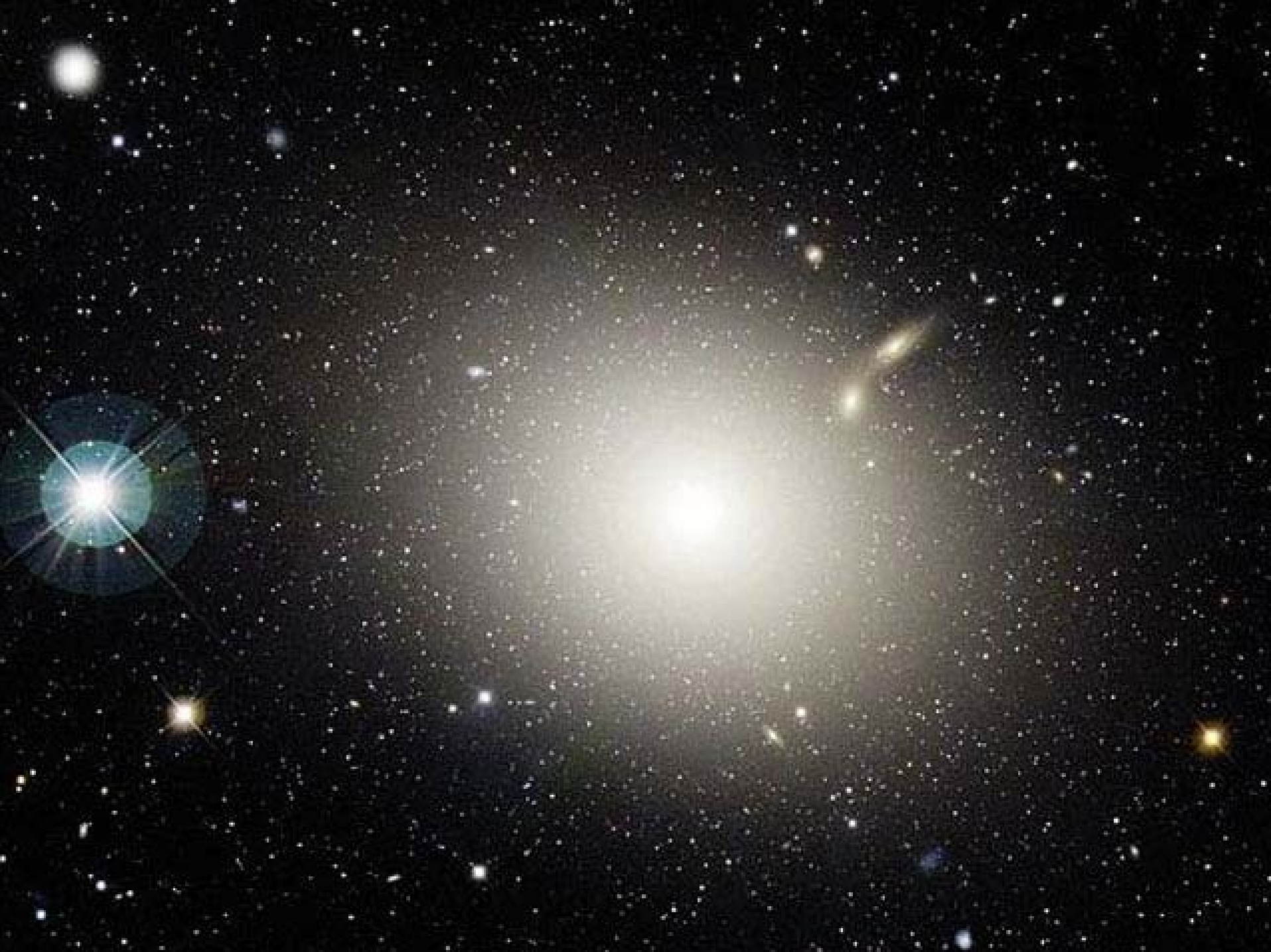
Astrophysical disasters

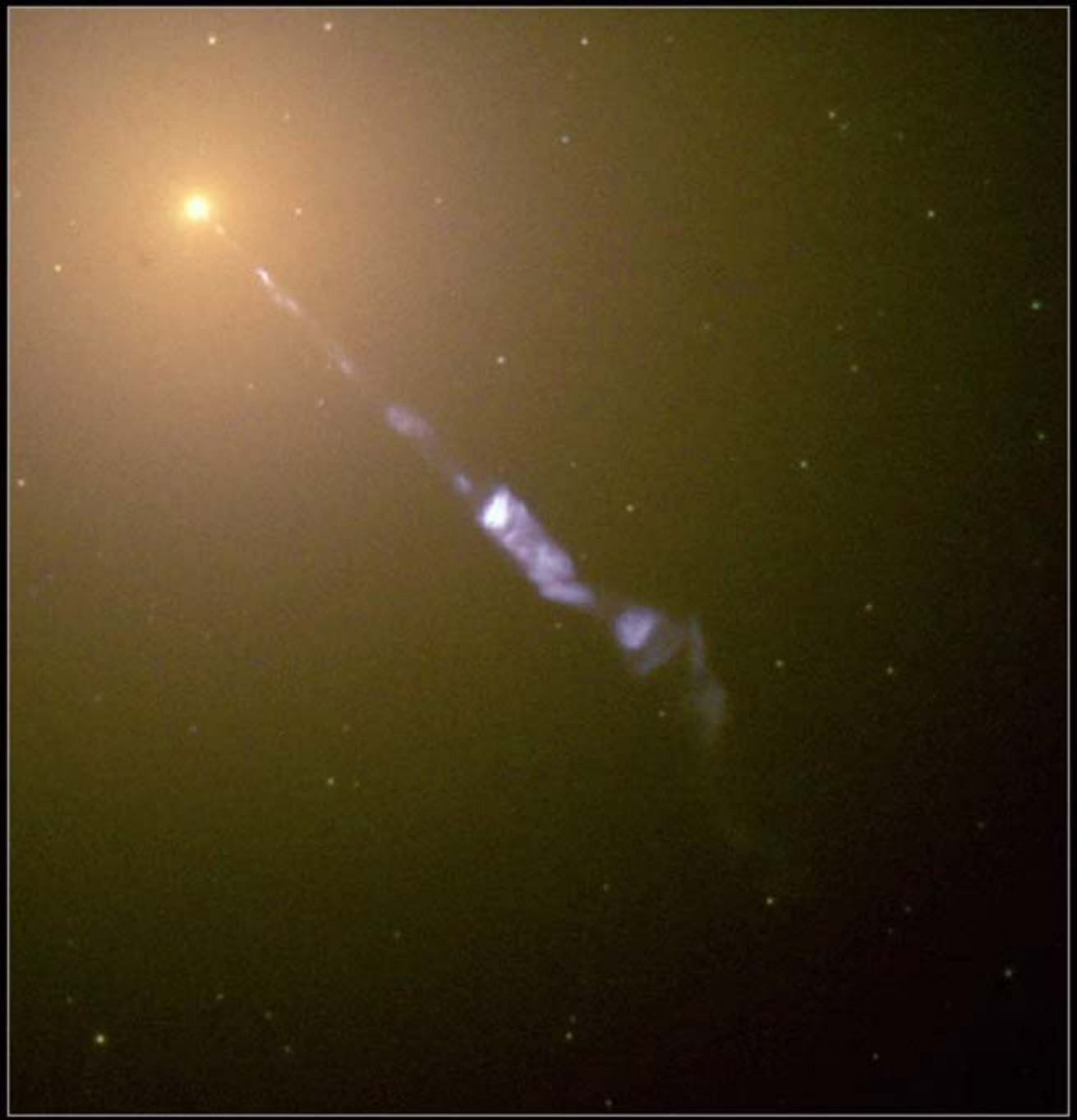


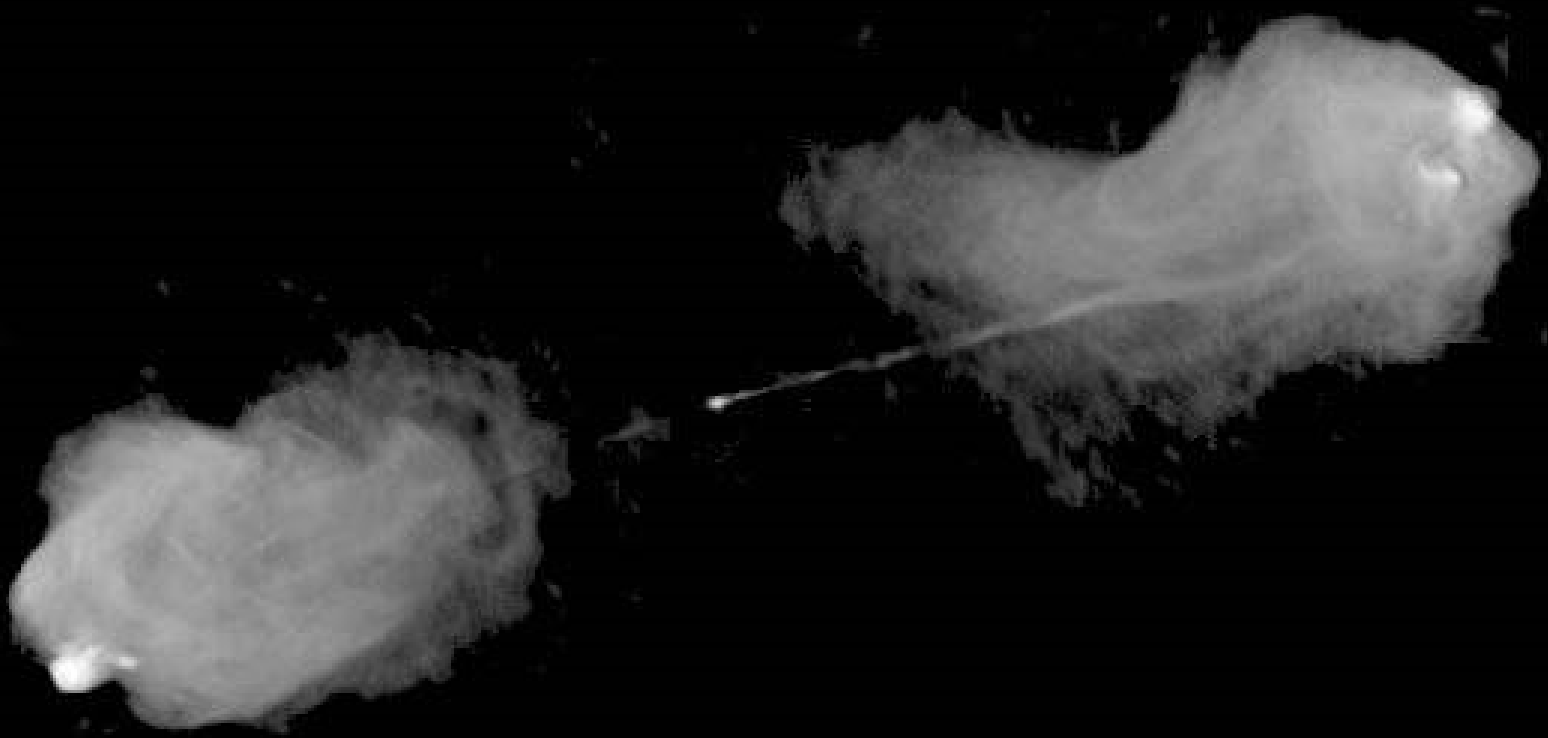
Asteroid Impacts

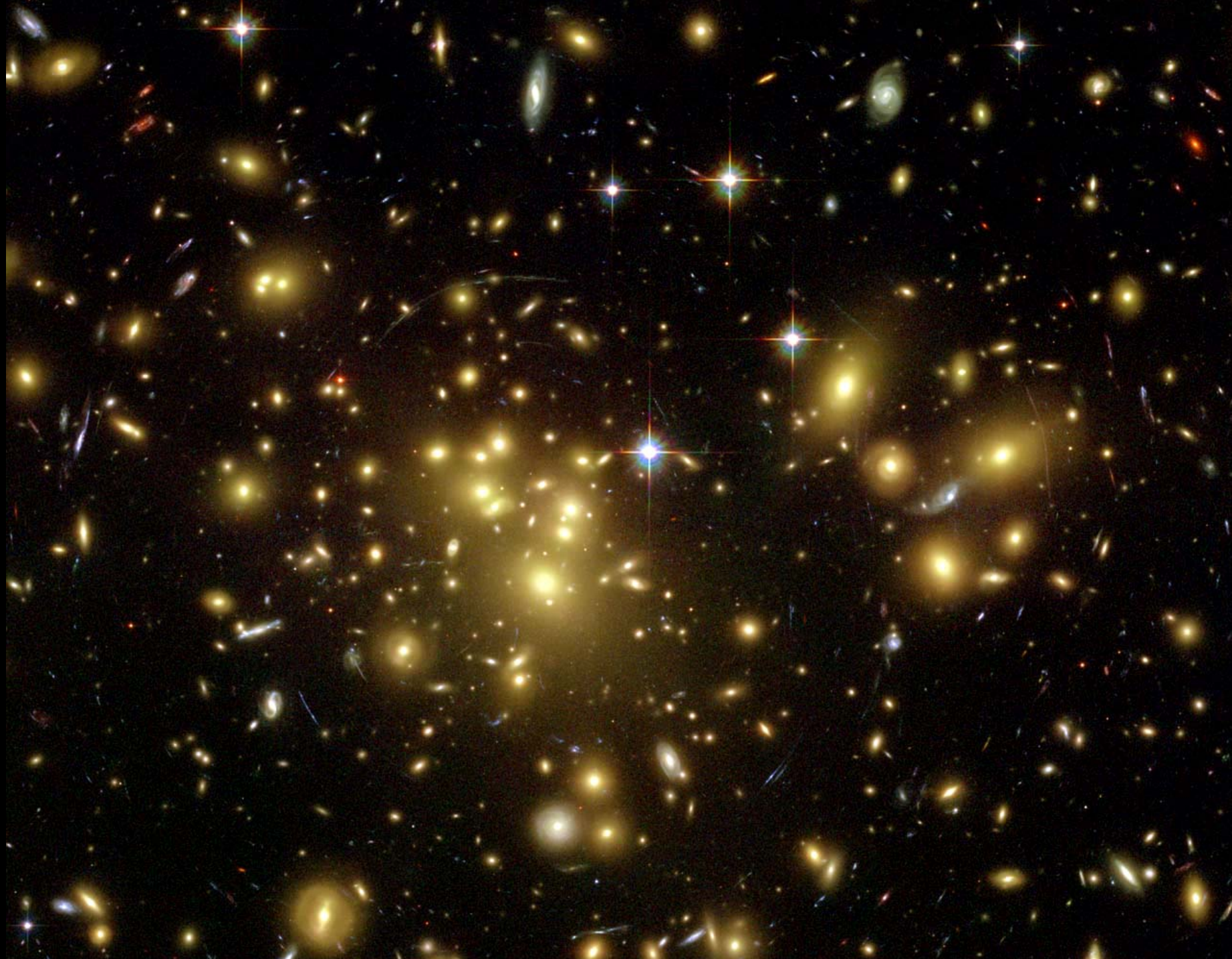
Supernovae in our own Galaxy or Gamma-Ray Bursts even in distant galaxies!

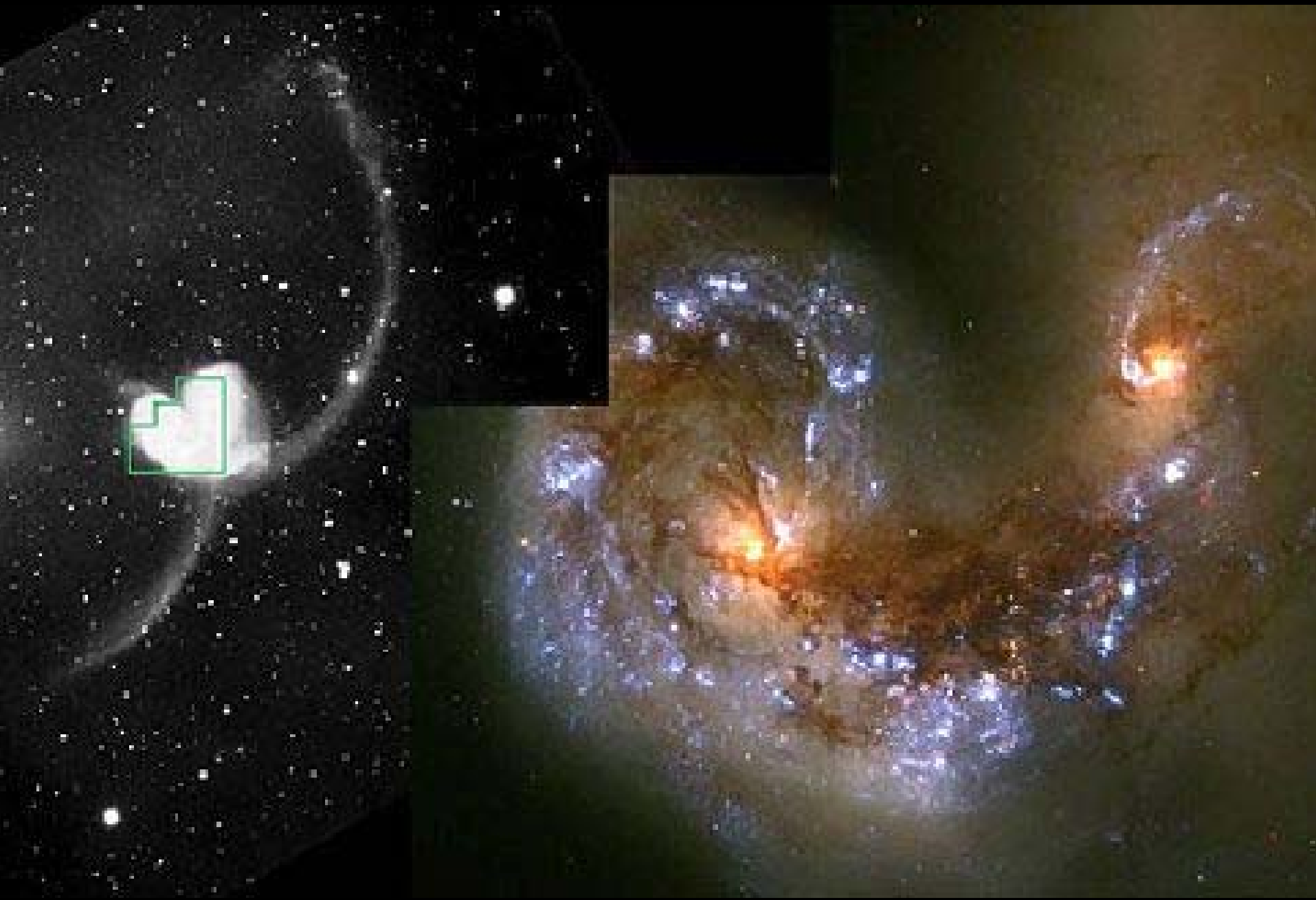
conclusions

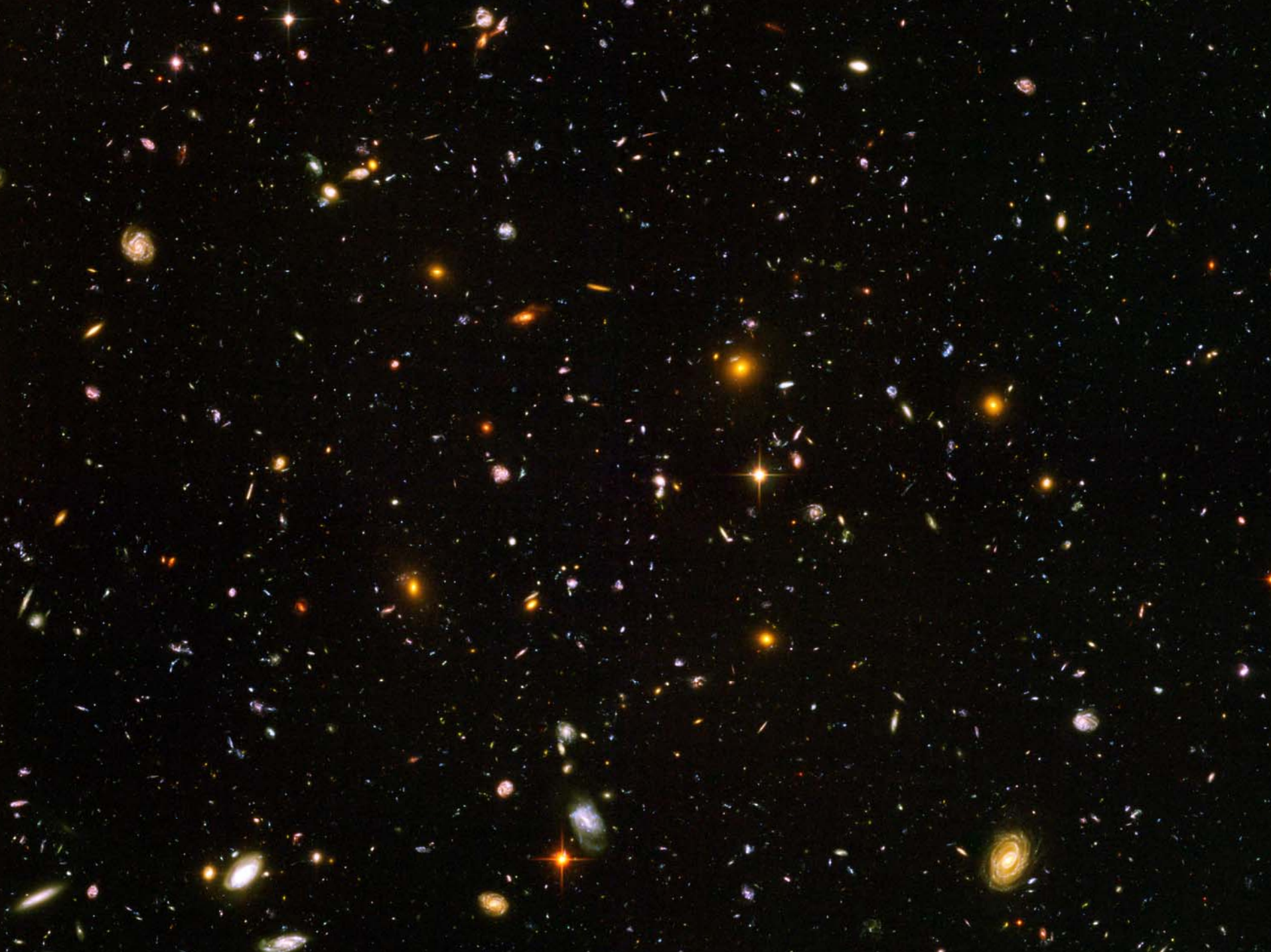


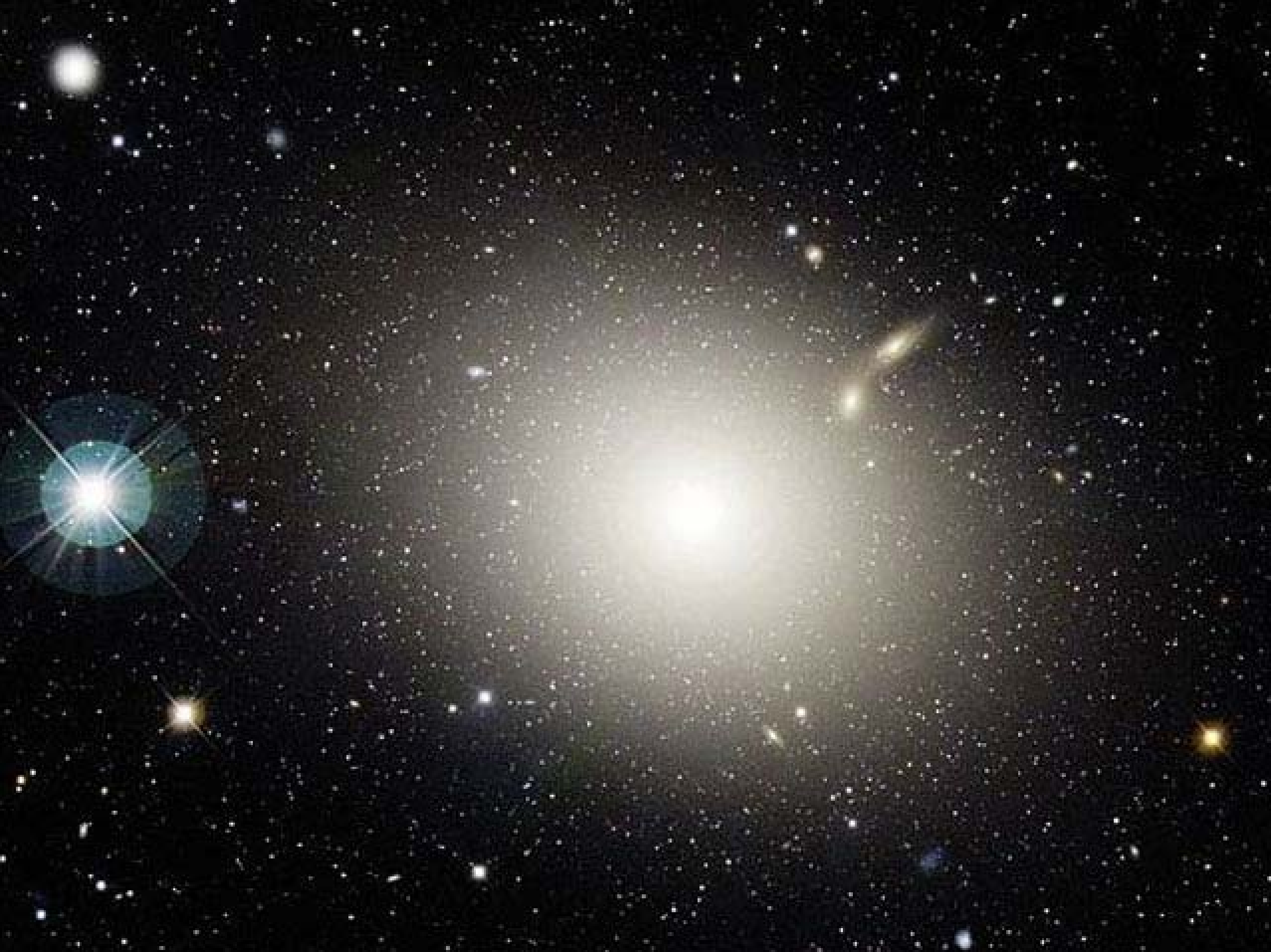


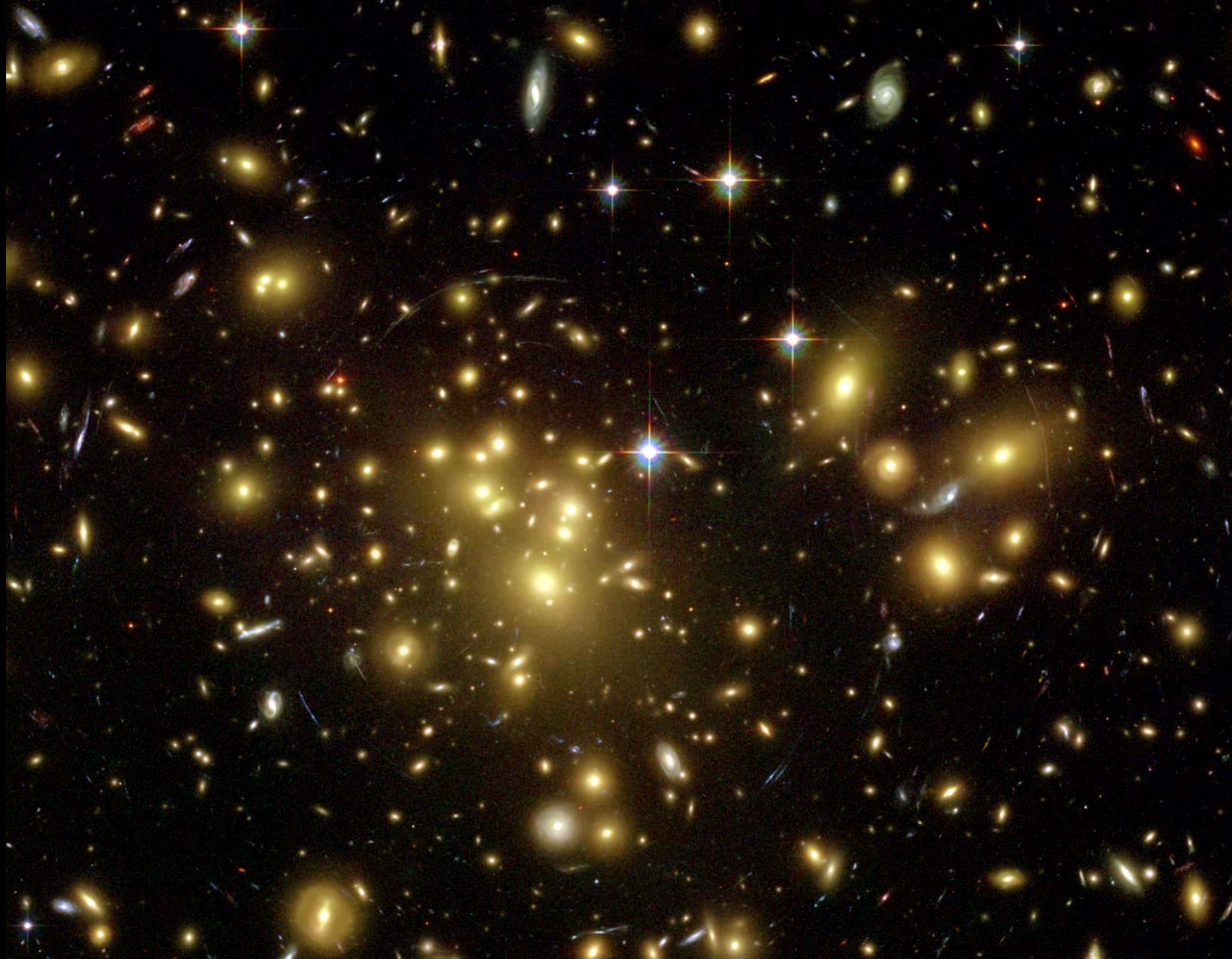


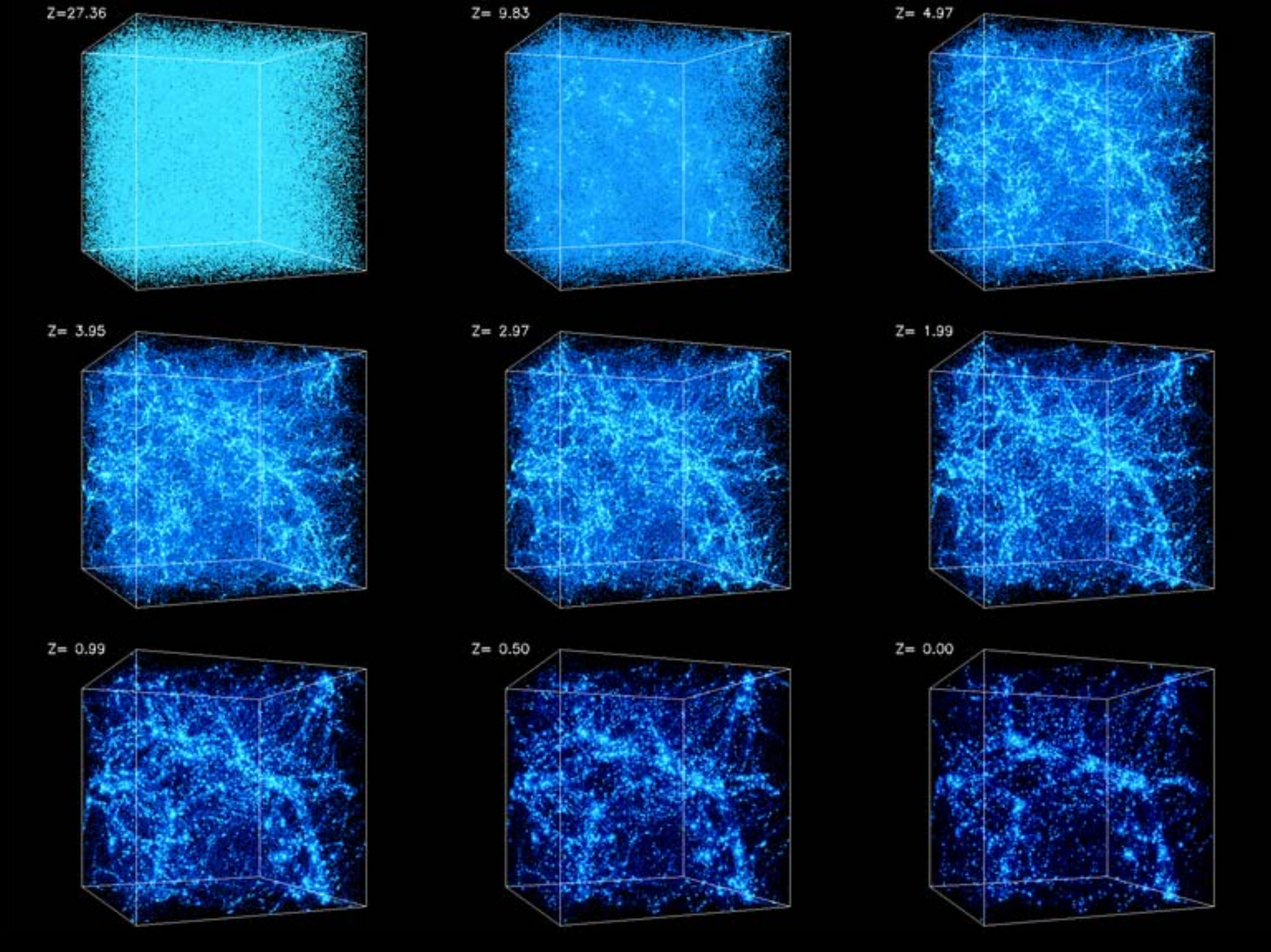








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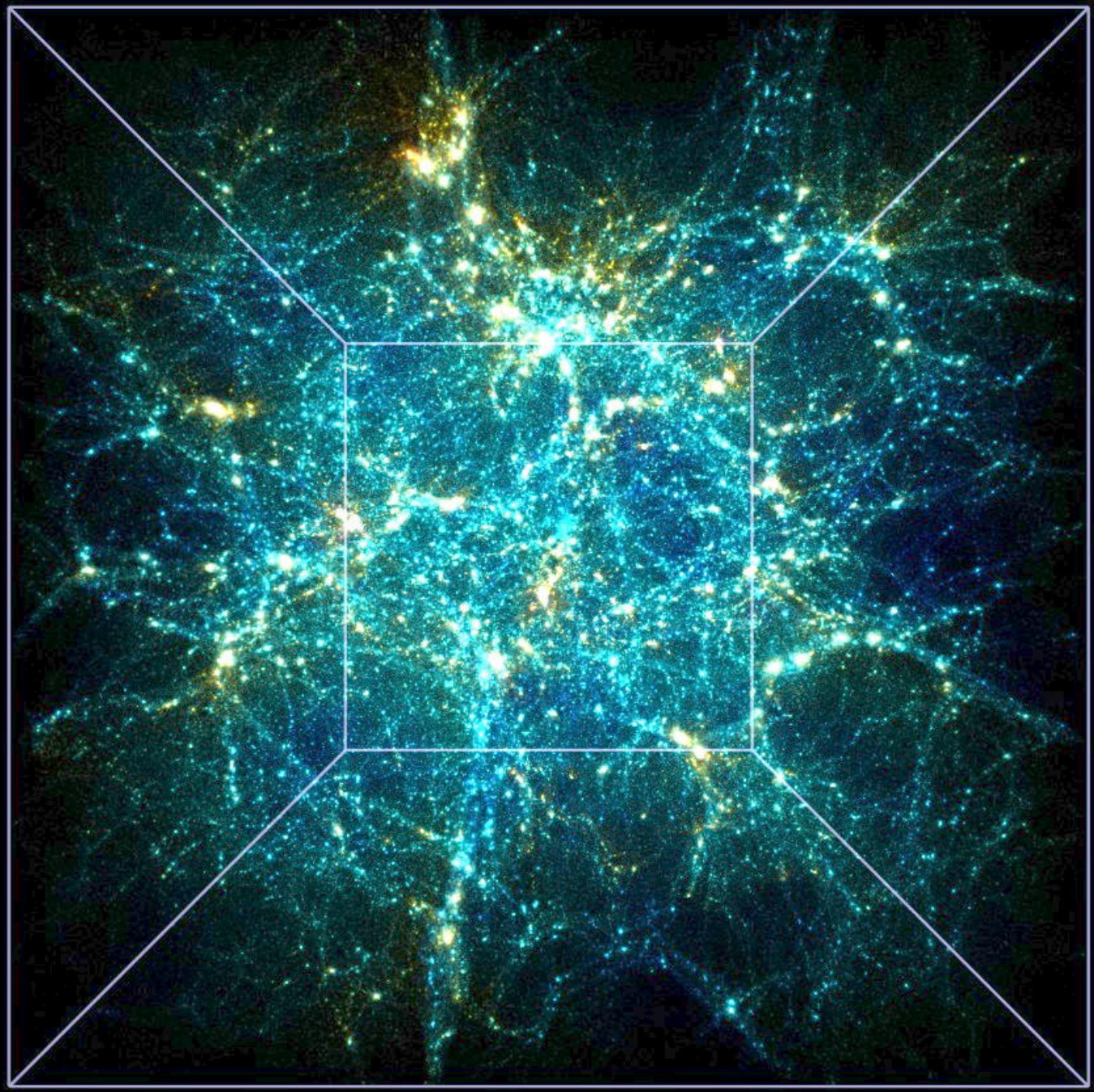
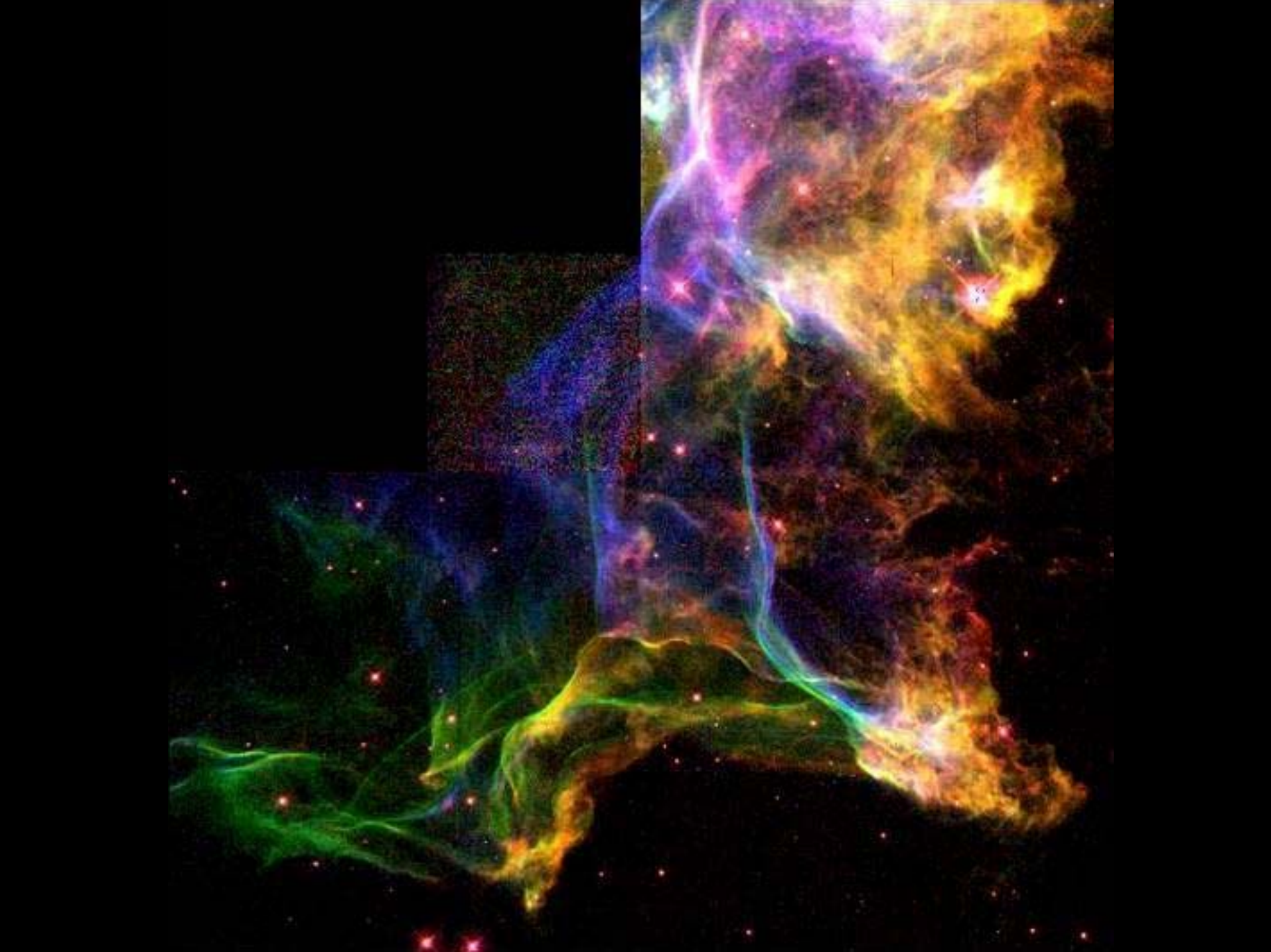
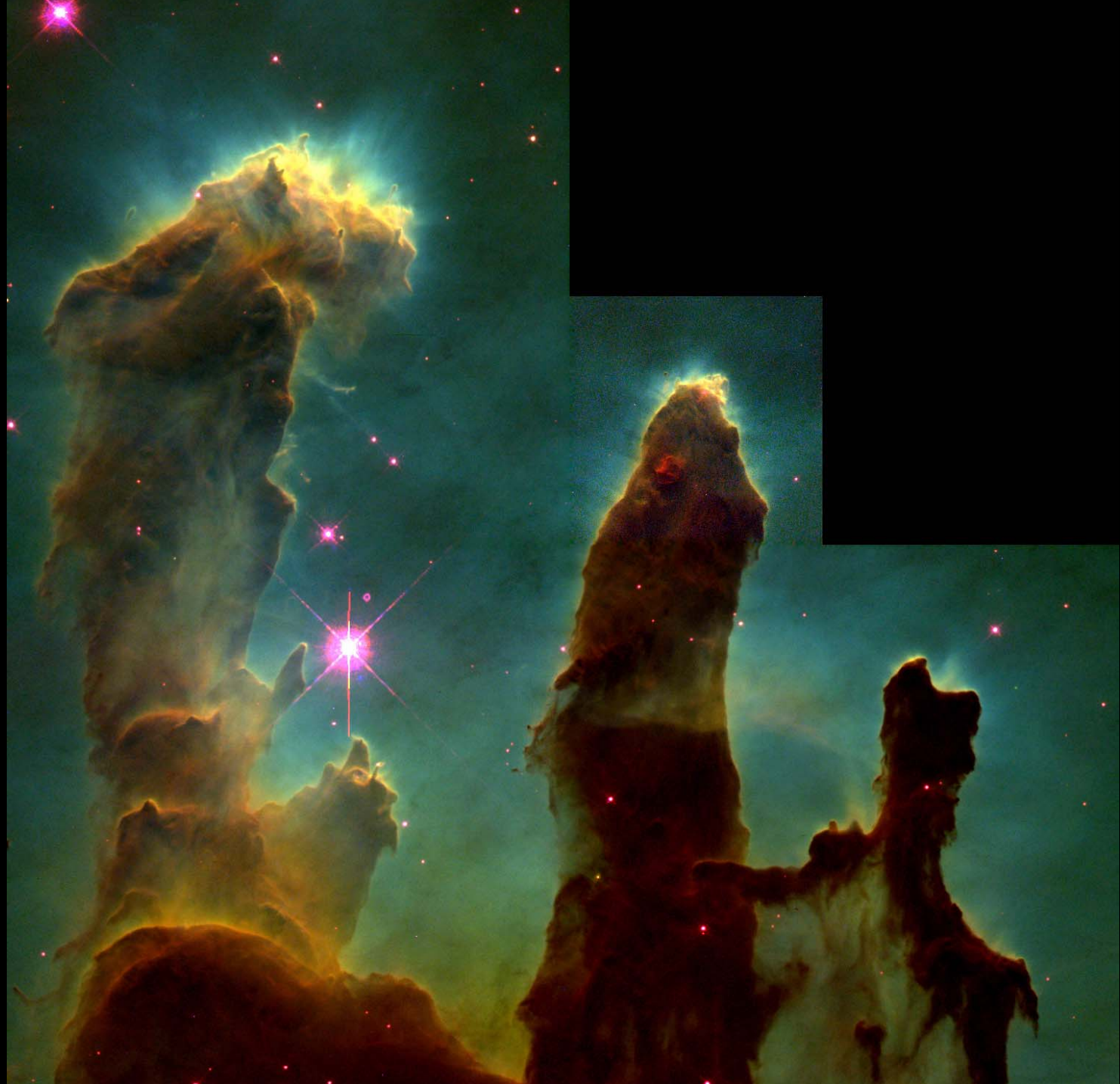




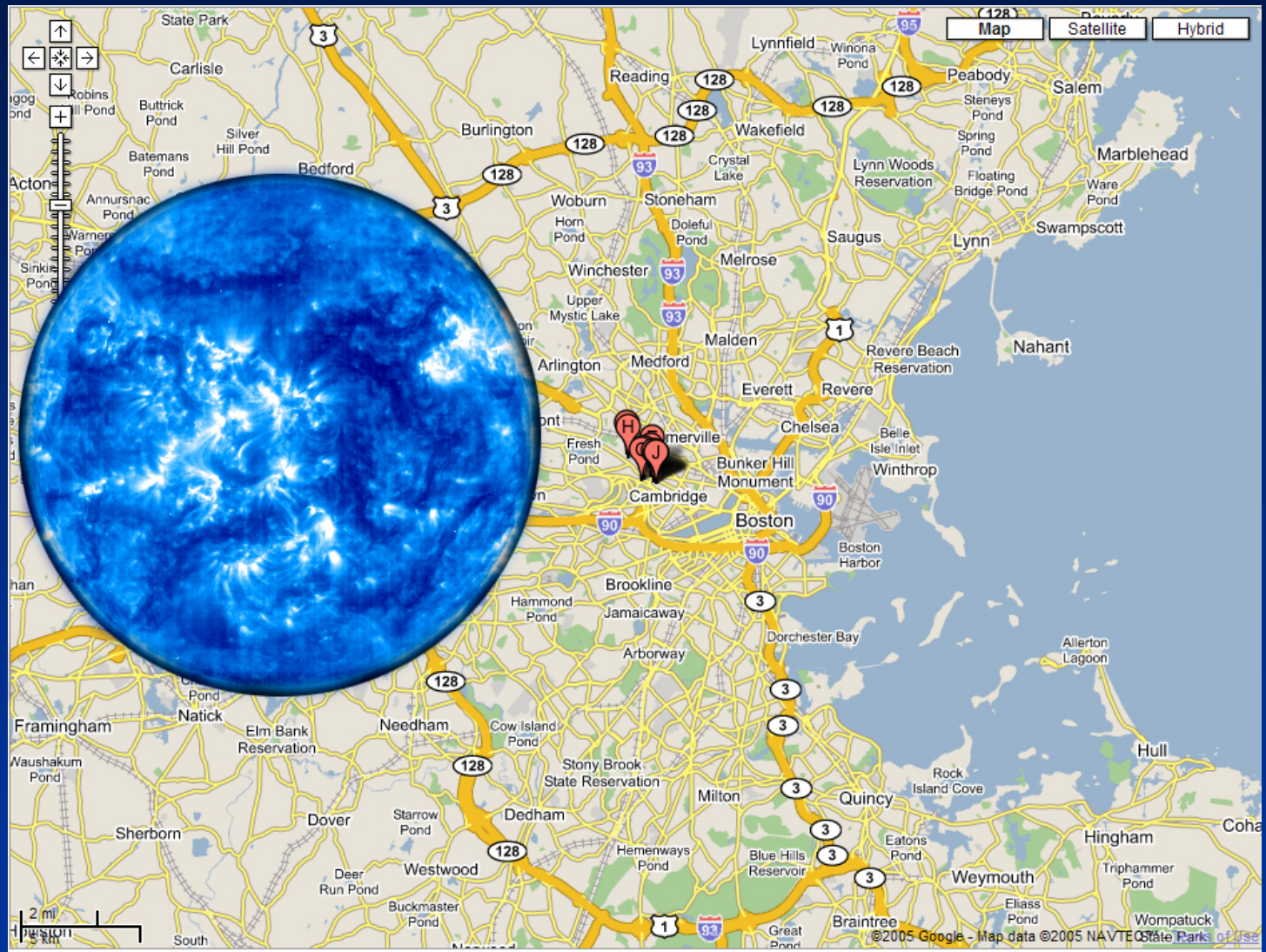


HISTORICAL SUPERNOVAE

Supernovae in our galaxy (or a nearby galaxy)

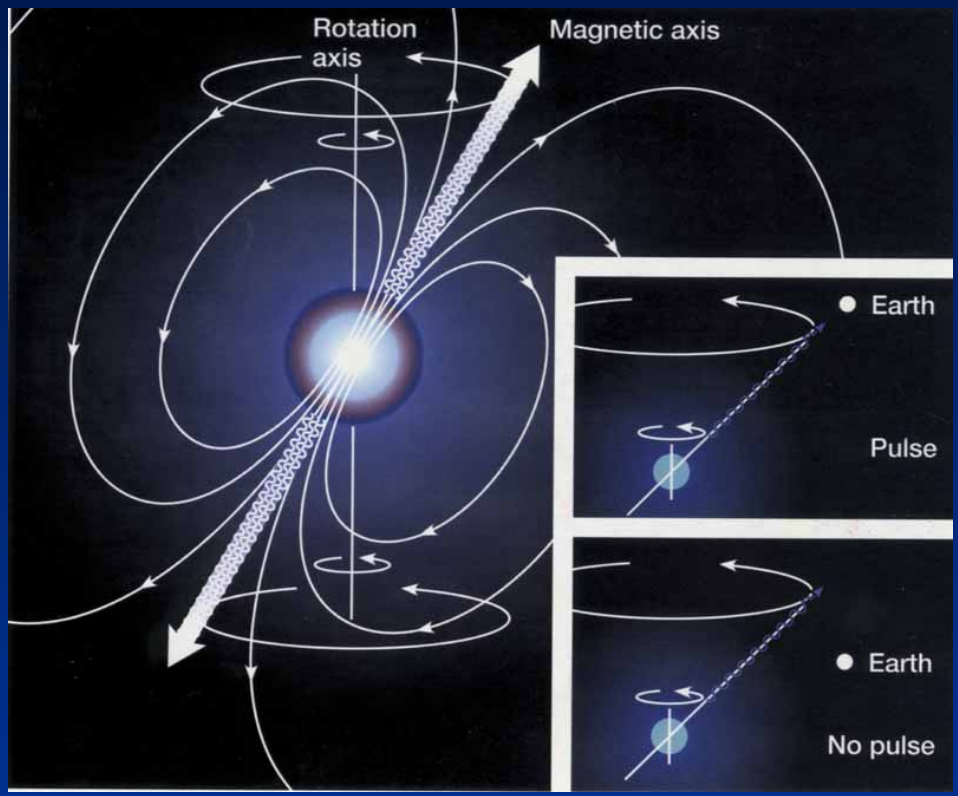
Year	Report	Supernove Remnant
1006	China, Japan, Korea, Arab lands, Europe	Identified with radio SNR
1054	**China, Japan**	**Crab Nebula**
1181	China, Japan	Possible identification with radio SNR 3C58
1572	Europe (Tycho Brahe), China, Japan	Tycho's remnant
1604	Europe (Kepler), China, Japan, Korea	Kepler's remnant
1987	***SN 1987A – Large Magellanic Cloud***	***Remnant still observable***

Neutron stars



Neutron Star to Attend Harvard

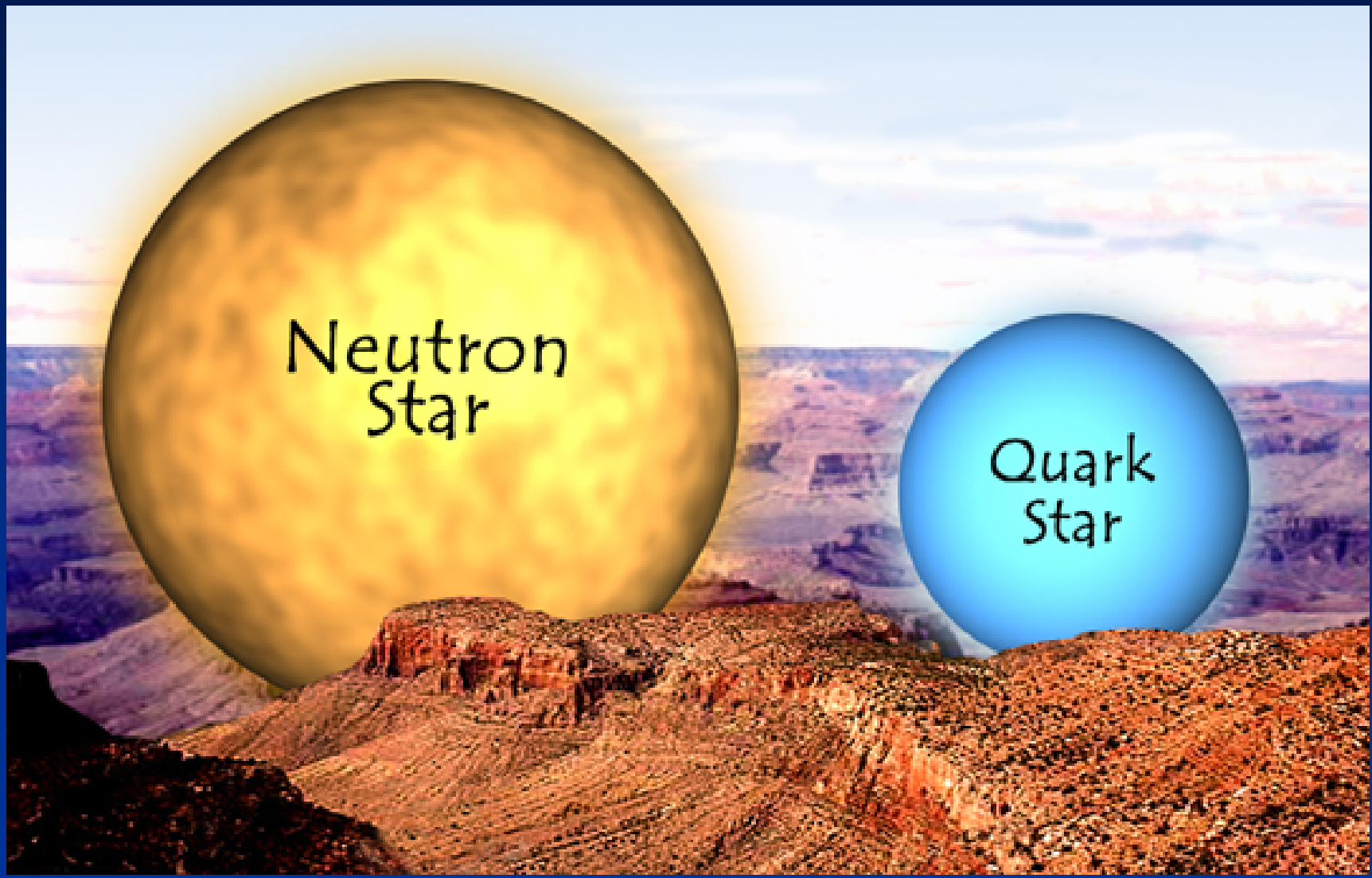
PULsars



Crab Nebula Pulsar Movie

- Pulsars are rapidly rotating neutron stars with radio or X-ray beams like lighthouses
- Pulsars rotate with precise regularity that beats our best atomic clocks.

Quark stars



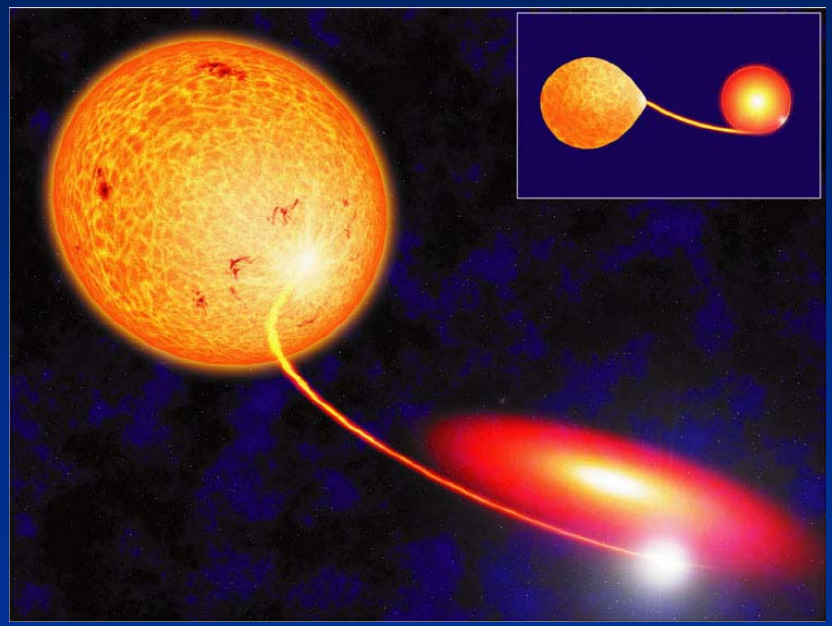
Star wars

Astrophysical Object	Force Fighting Gravity
People	Electromagnetism
Planets	Electromagnetism
Protostars	Thermal Pressure (gravitational contraction)
Main Sequence Stars	Thermal Pressure (nuclear fusion)
White Dwarfs	electron degeneracy pressure
Neutron Stars	neutron degeneracy pressure
Quark Stars	quark pressure?
Black Holes	NOTHING!

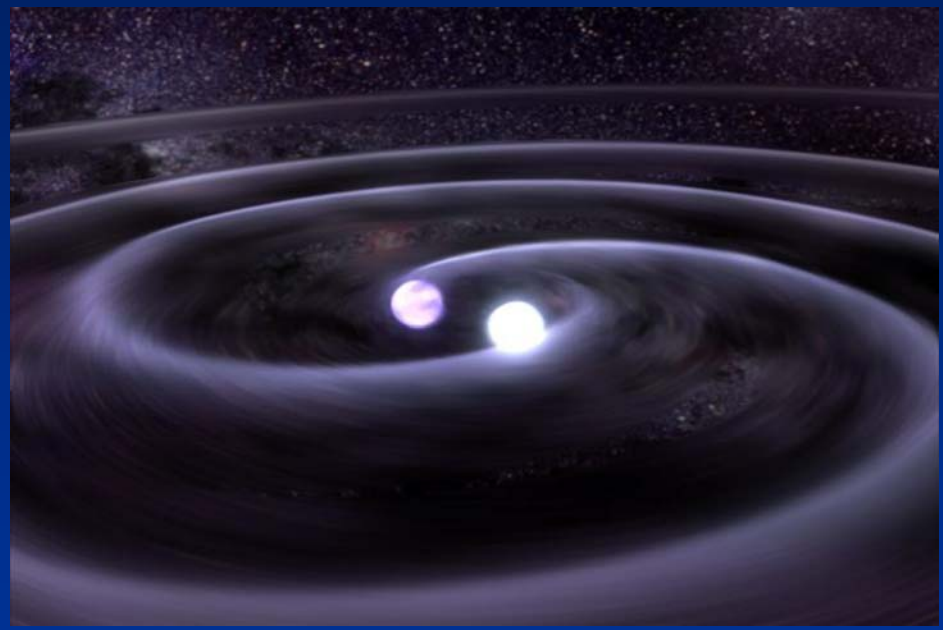
Type Ia SupernovaE

Thermonuclear Bombs in Space!

Explosions of White Dwarfs in Binary Systems



WD Accretion From Main Sequence Companion

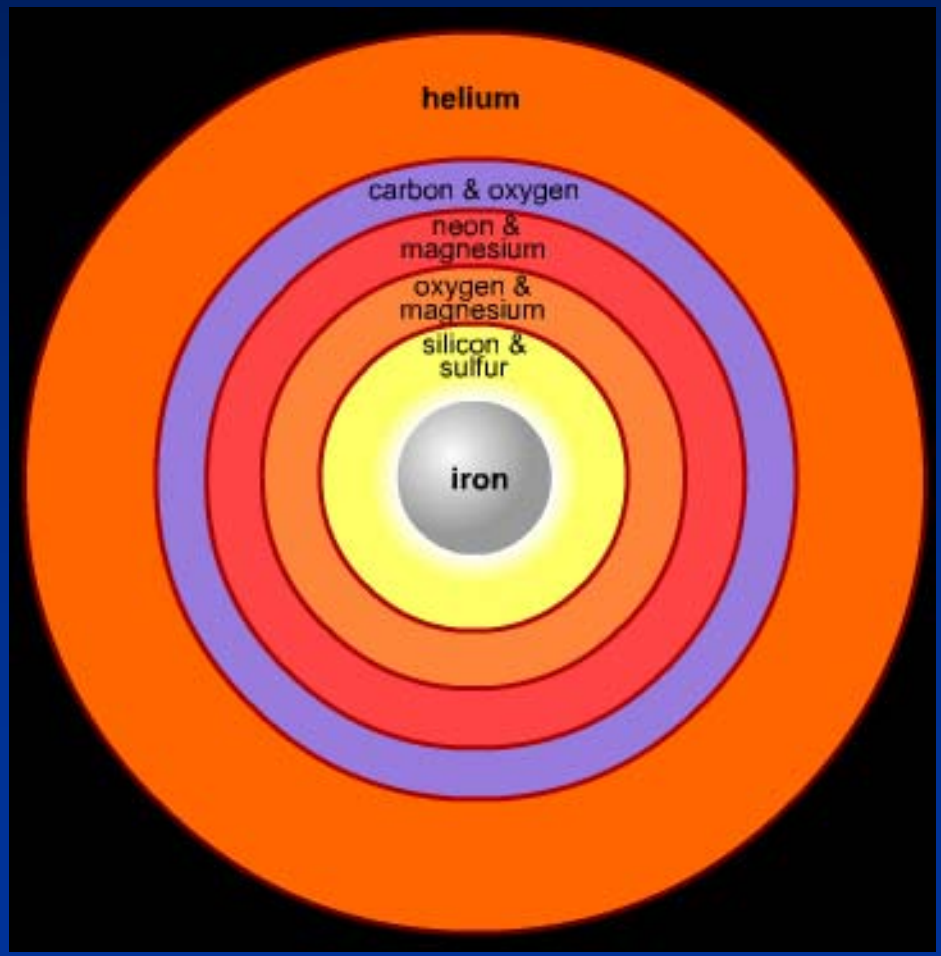


Merger of 2 White Dwarfs

Type Ii Supernovae

Gravity Bombs!

Gravitational Core Collapse of Massive Stars



Star with M > 8 M_{sun}

The Sun

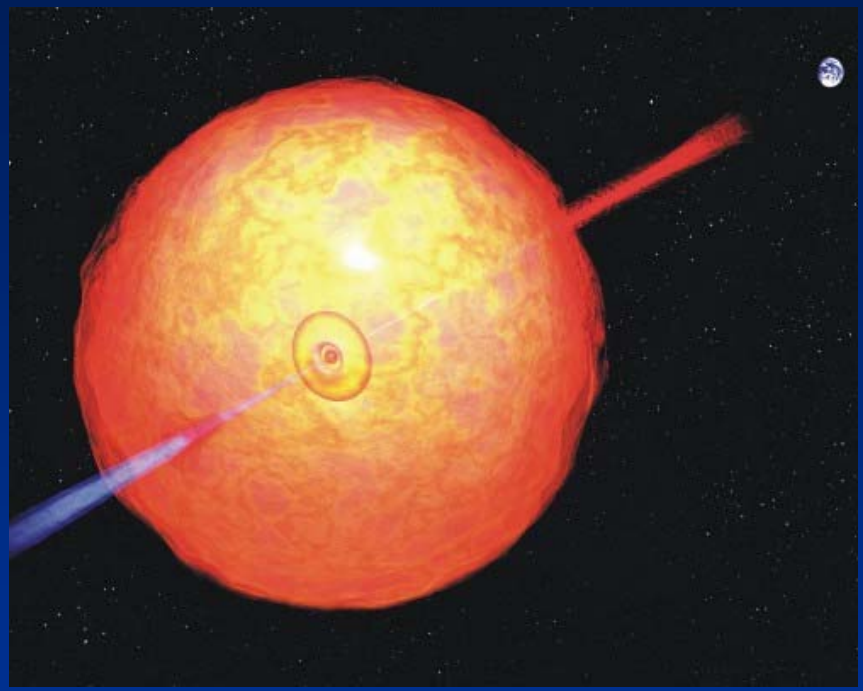
Stellar Explosion MOVIEs

Core Collapse

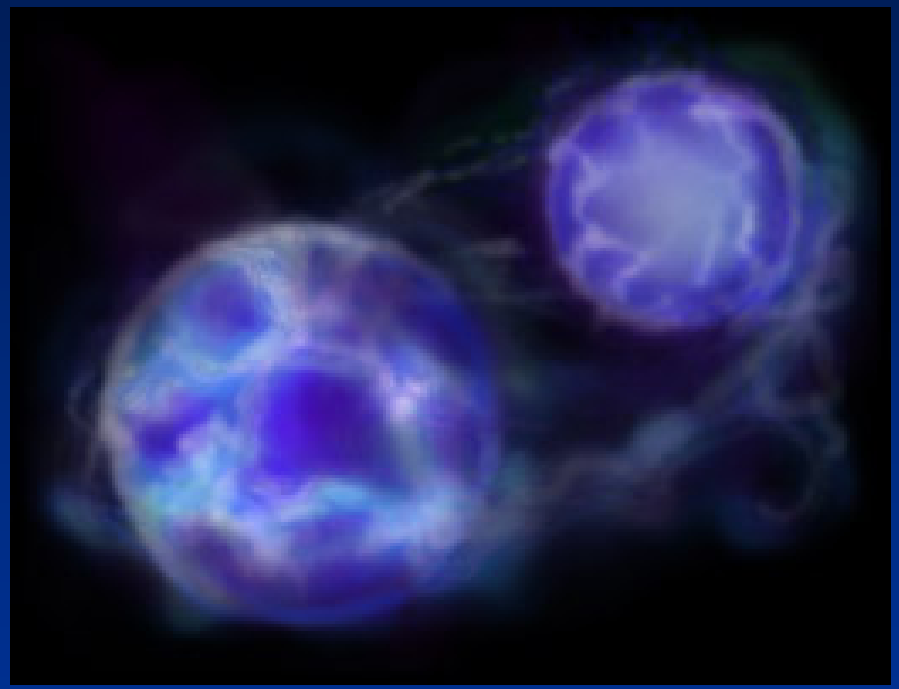
Supernova Movie

Gamma-ray bursts (GRBs)

The Brightest Explosions in the Universe!



Long Duration GRBs
Occur along with core collapse supernovae of some massive stars



Short Duration GRBs
Probably merging neutron stars

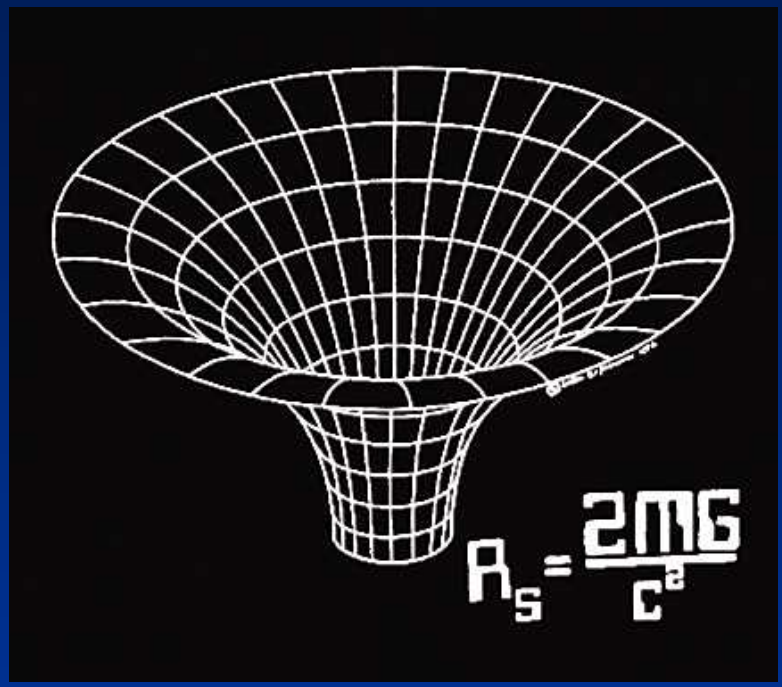
Stellar Explosion MOVIEs

Gamma Ray Burst Movie

Leftover COMpact objects

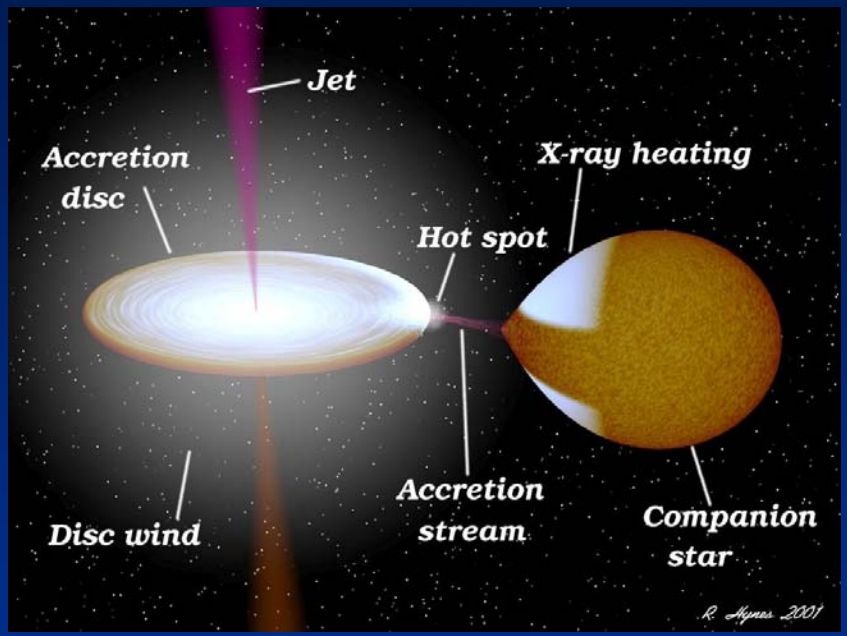
Type of Stellar Explosion	**Compact Remnant**
Type Ia	NOTHING!
Failed Type Ia	*NEUTRON STAR?*
Type II	NEUTRON STAR
	BLACK HOLE
Gamma-Ray Burst	BLACK HOLE

Black holes



The Schwarzchild Radius

Evidence for Black holes



Stellar Mass Black Holes

M ~ 3 – 20 M_{sun}

Supermassive Black Holes

M ~ 10^6 – 10^9 M_{sun}