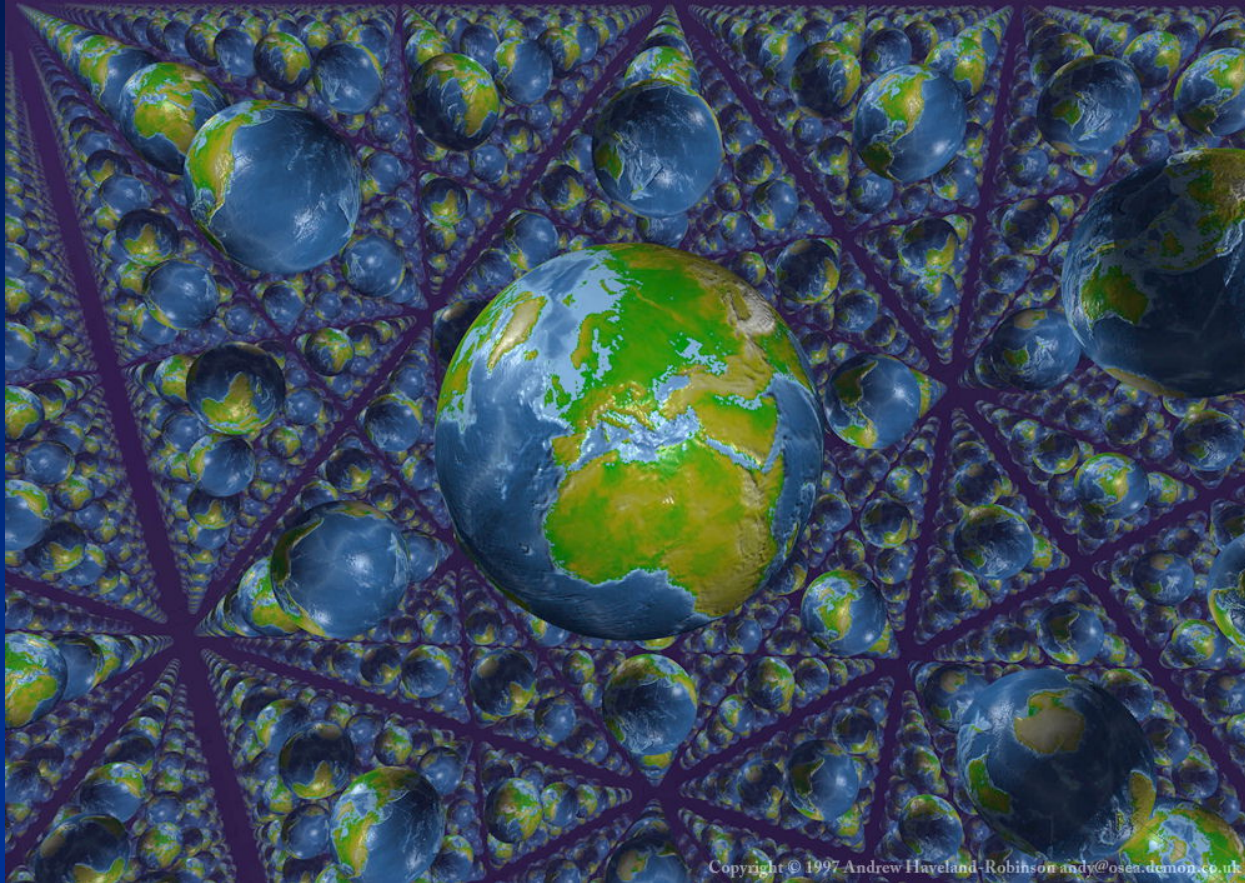


Your place in the cosmos

From Planets to Stars to Galaxies and Beyond



Andrew Friedman & Ryan Hickox

Harvard-Smithsonian Center For Astrophysics

Dudley House Crosstalk: Thursday, December 8th 2005

Astronomy



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

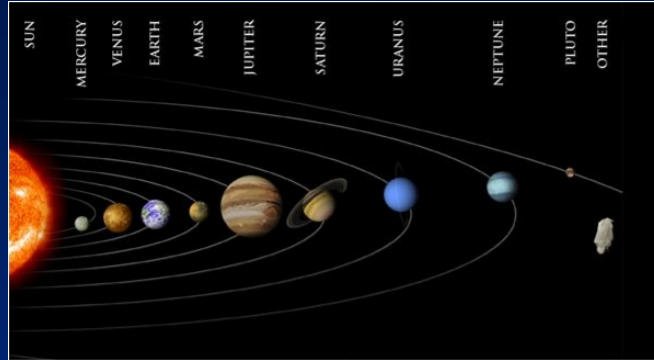
-Bobby Boucher, The Waterboy



The Copernican Principle



People Earth



Sun & Solar System



Spiral Galaxy



**Galaxy Clusters
& Superclusters**



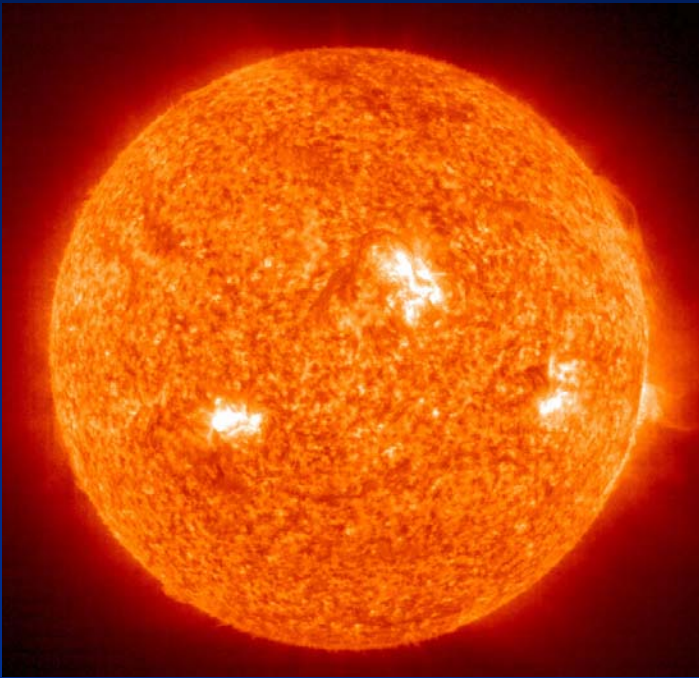
**A Small Piece of
Our Observable
Universe**



**Other
Universes?...**

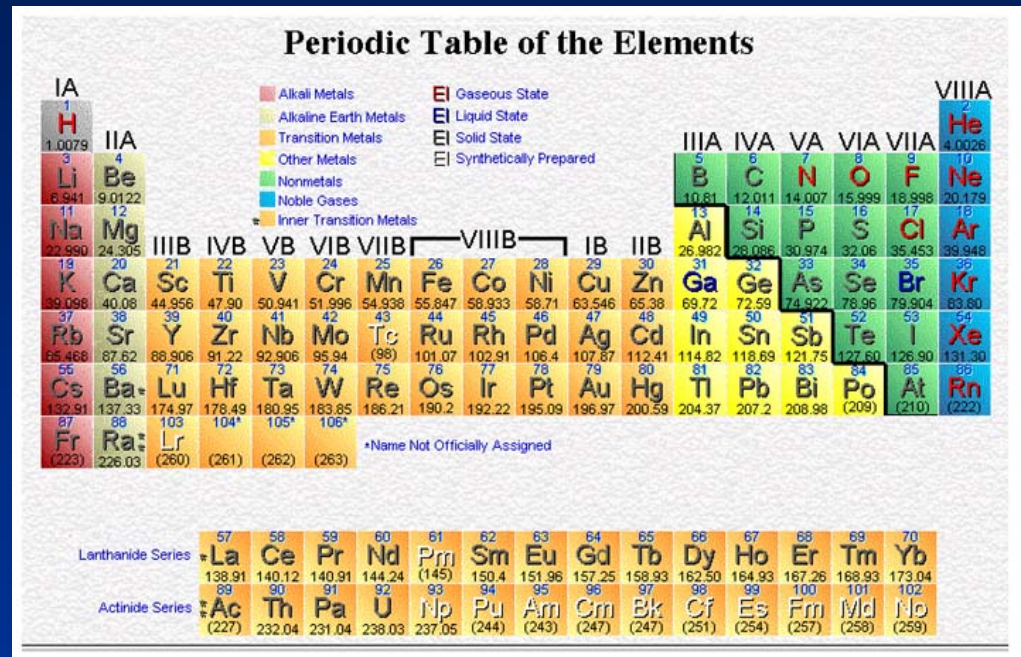
Nuclear fusion in stars

Where do heavy elements come from?



Our Star
The Sun

Periodic Table of the Elements



1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.71	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.33	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Lr (260)	90 Th (232)	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (259)		

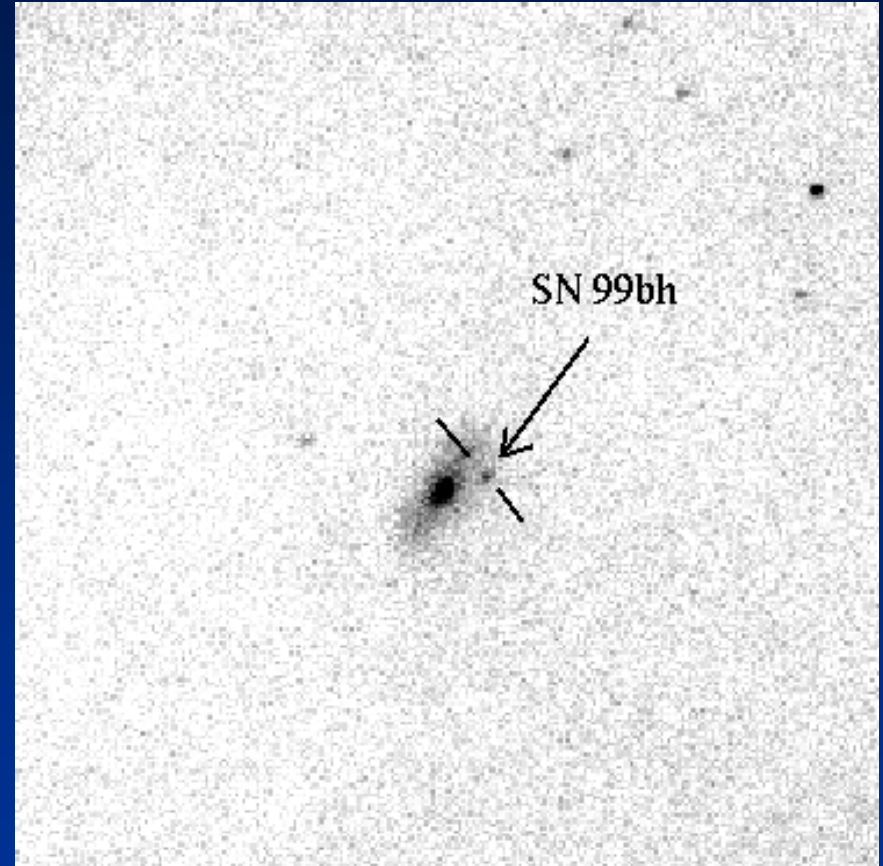
*Name Not Officially Assigned

The Periodic Table

Super novaE



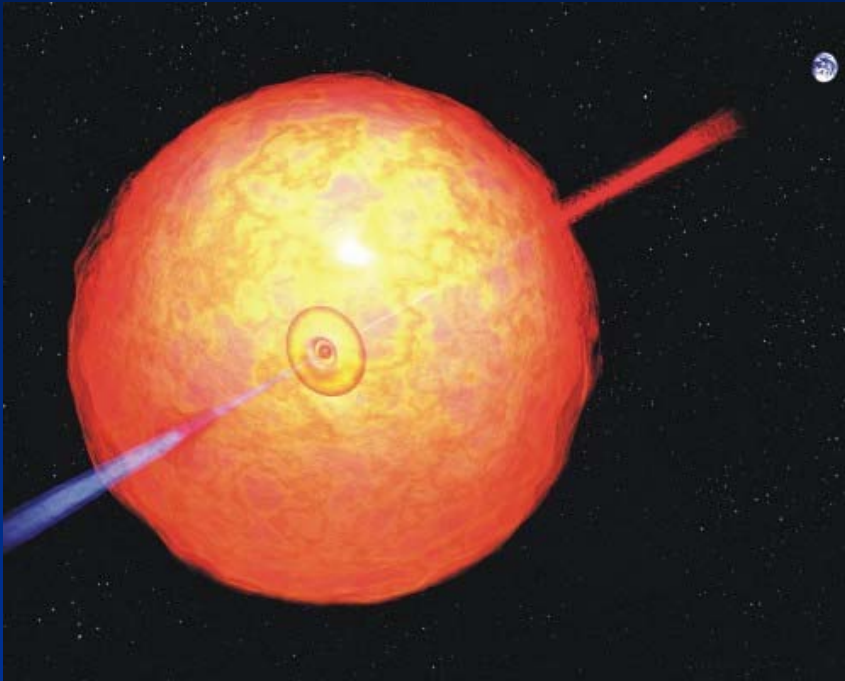
SN 1994d
Hubble Space Telescope



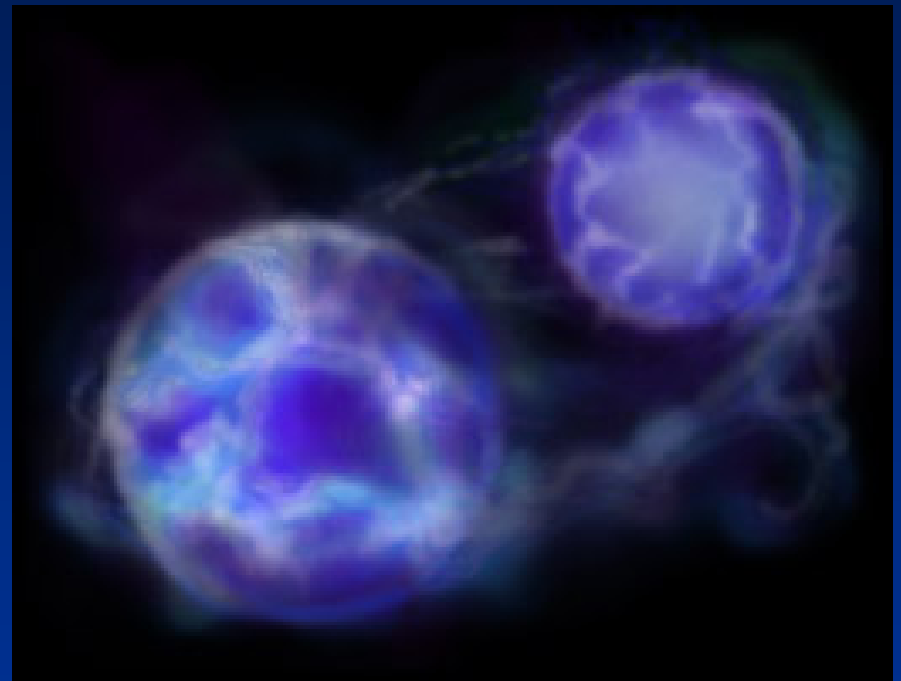
SN 1999bh – Katzmann
Automated Imaging
Telescope & Andy

Gamma-ray bursts (GRBs)

The Brightest Explosions in the Universe!



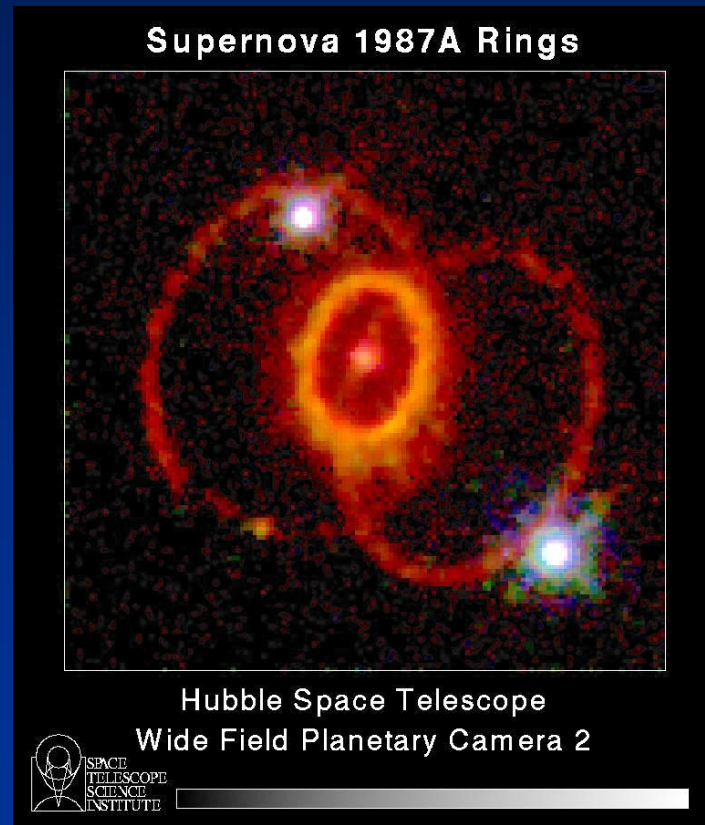
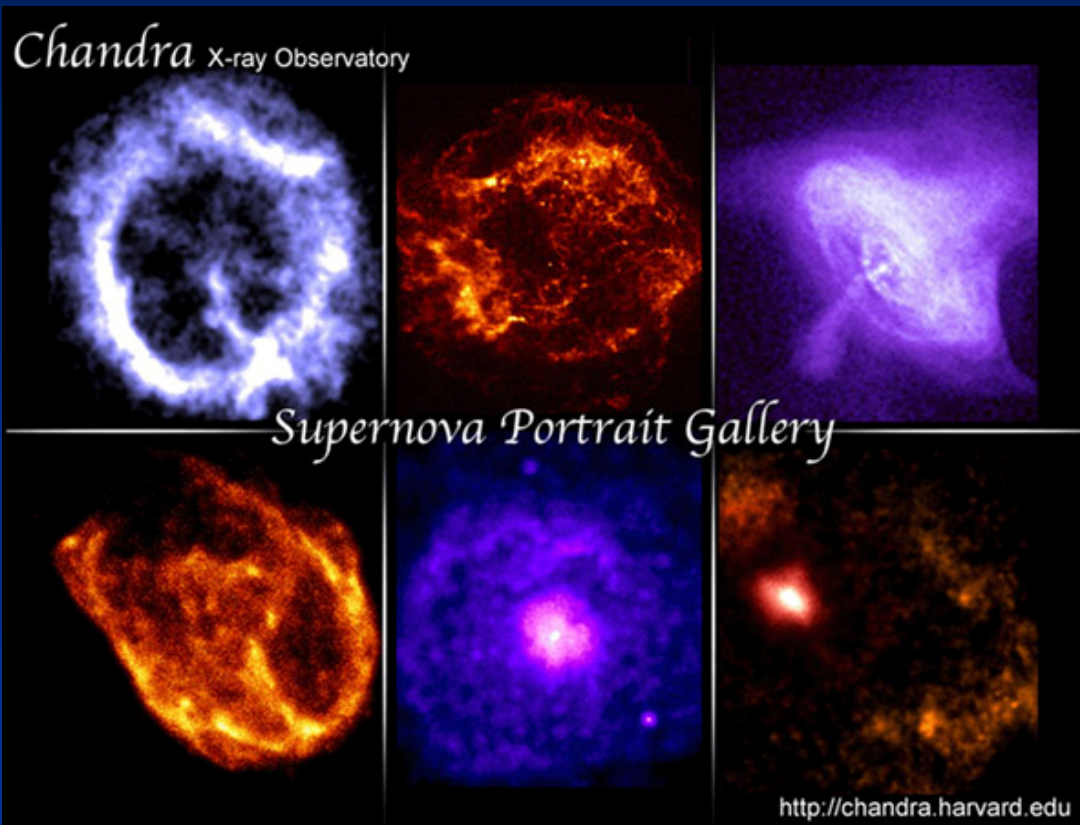
Long Duration GRBs
Occur along with
supernovae of some
massive stars



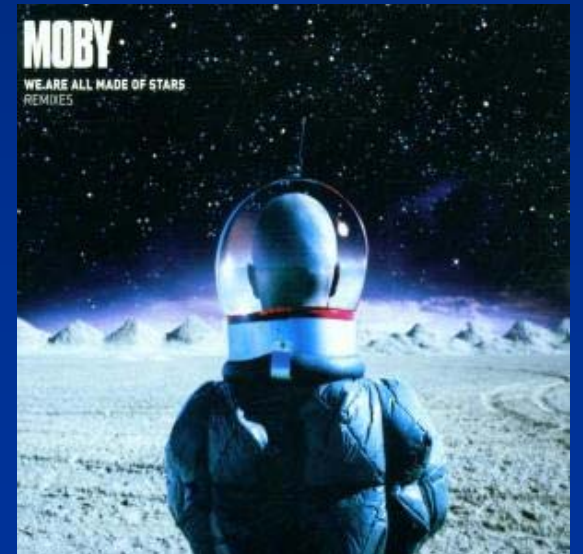
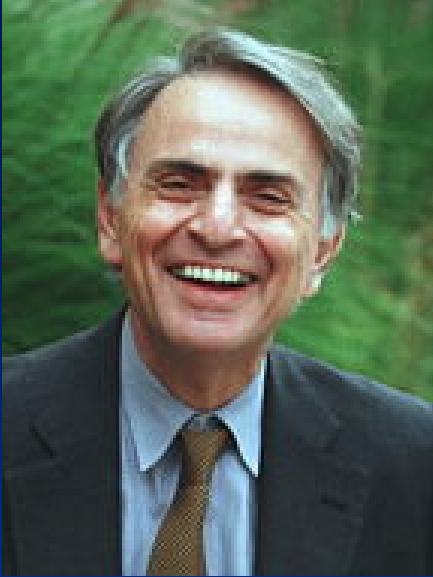
Short Duration GRBs
Probably merging
neutron stars

Supernova REMNANTS

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



We are all made of stars

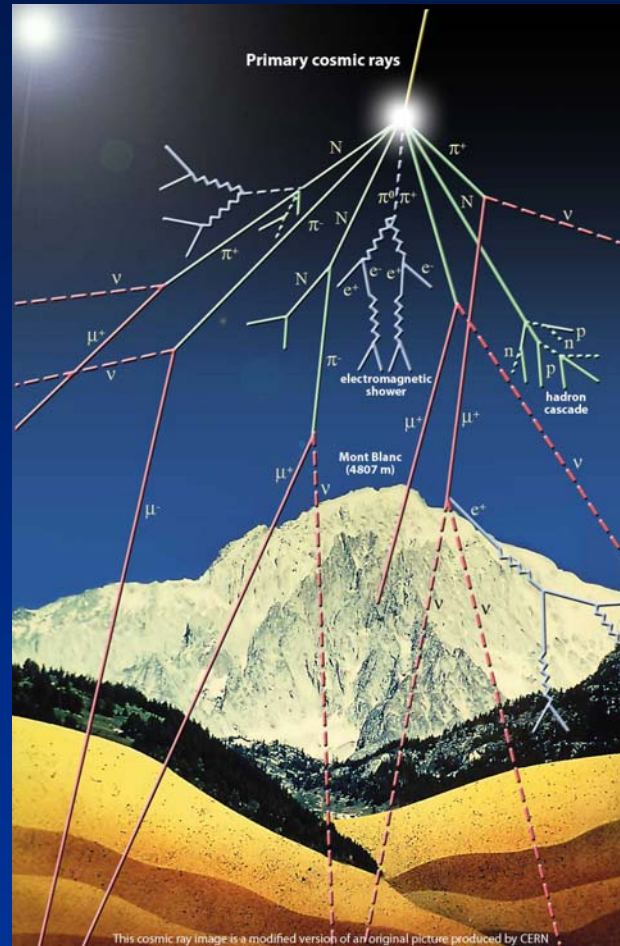


Cosmic Rays

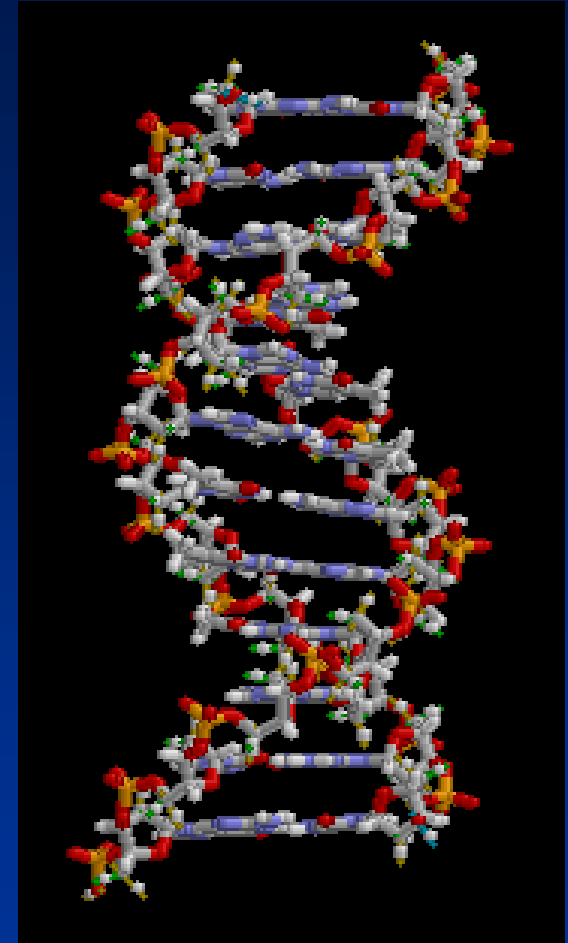


SNe & GRBs
Bursts Produce
High-Energy
Cosmic Rays

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



Cosmic Ray
Air Shower



DNA Molecule

Astronomical disasters



Asteroid Impacts

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

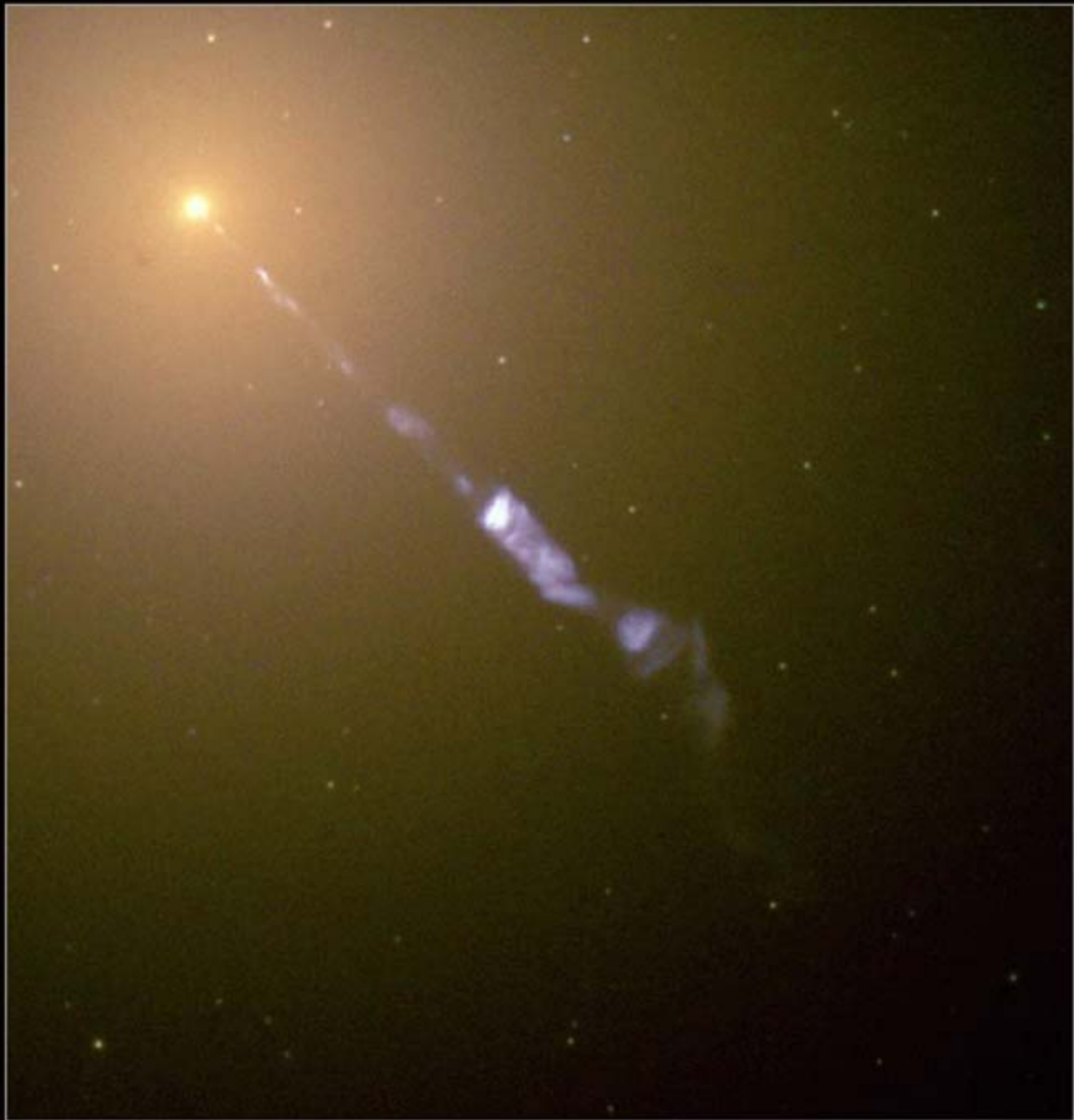
concl usions

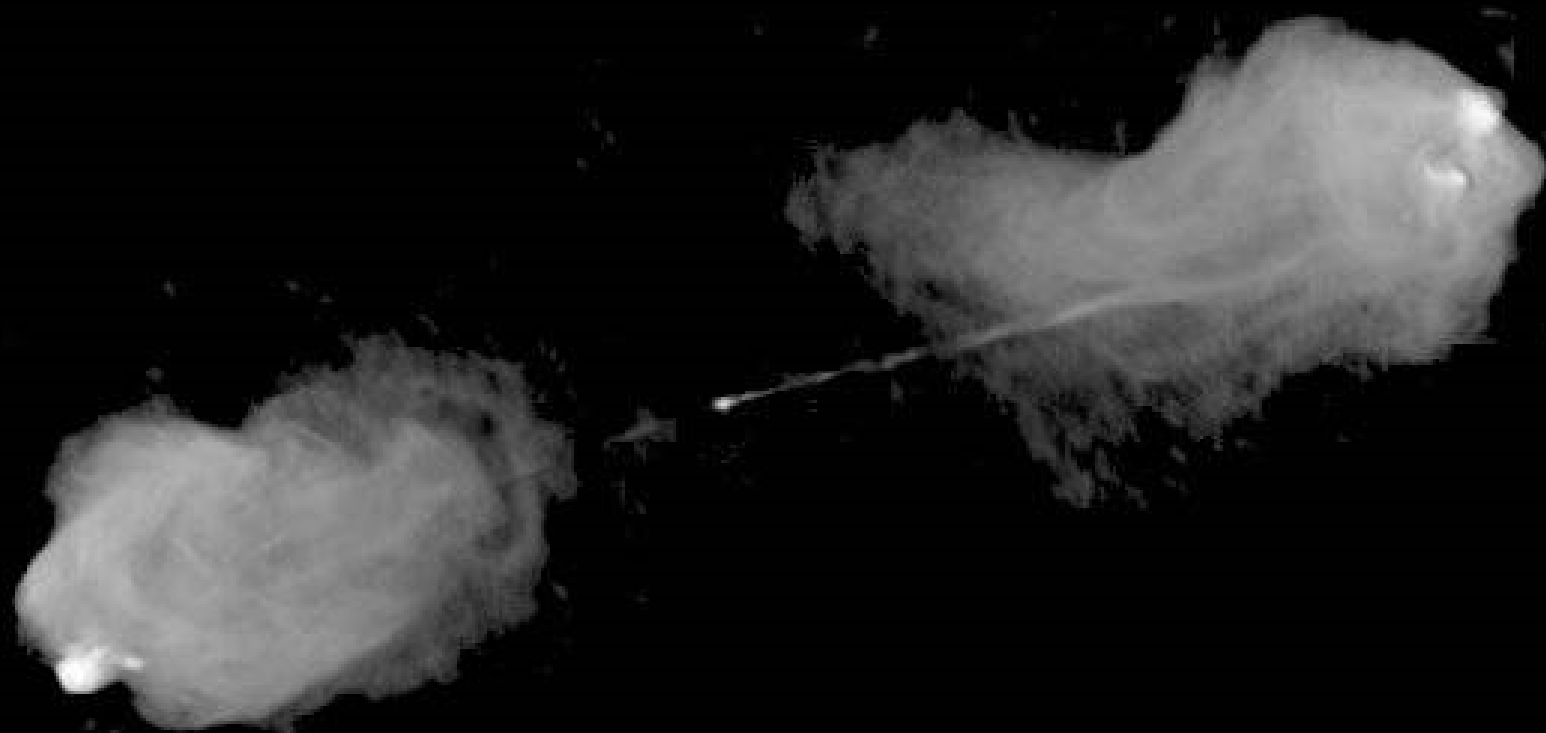


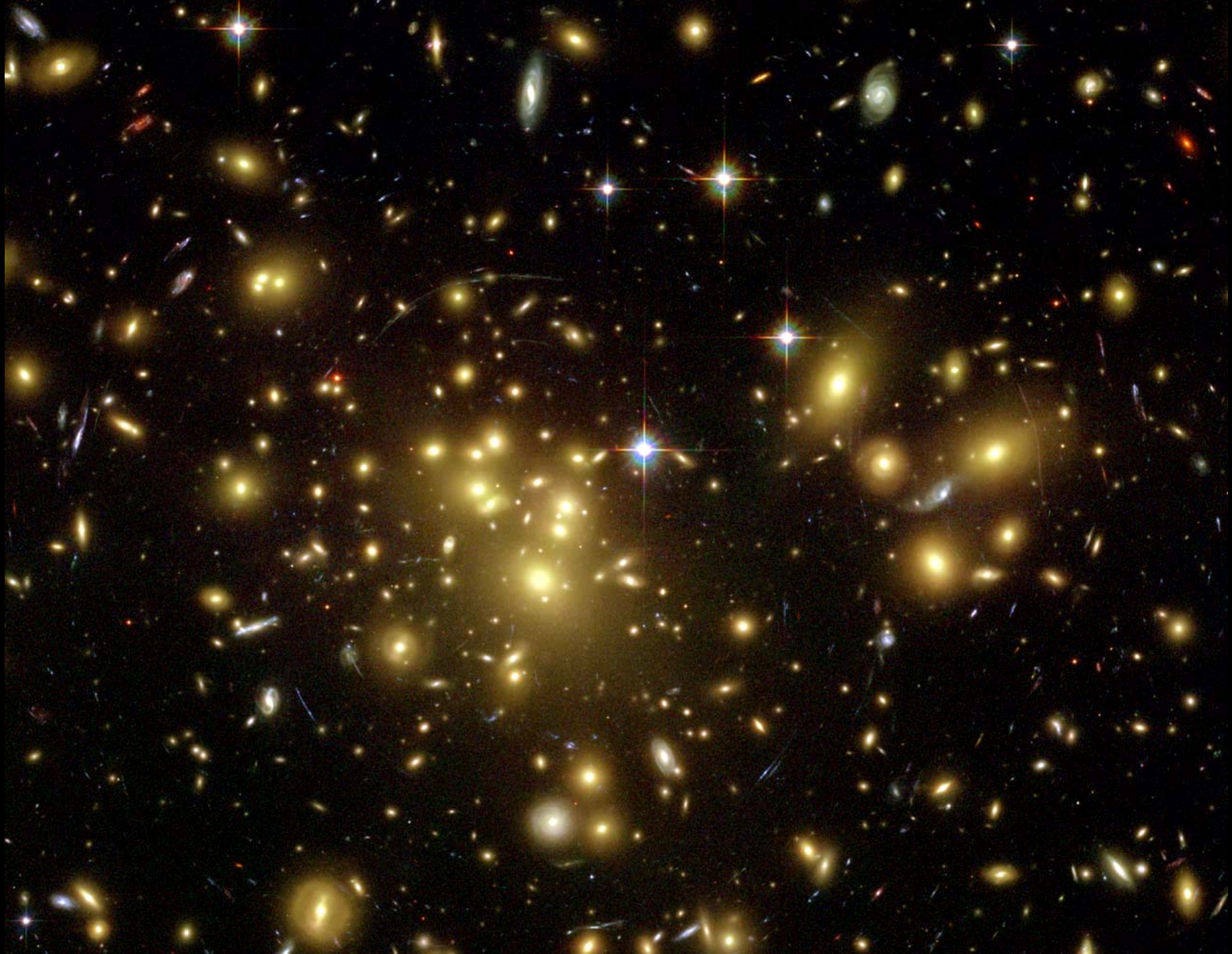


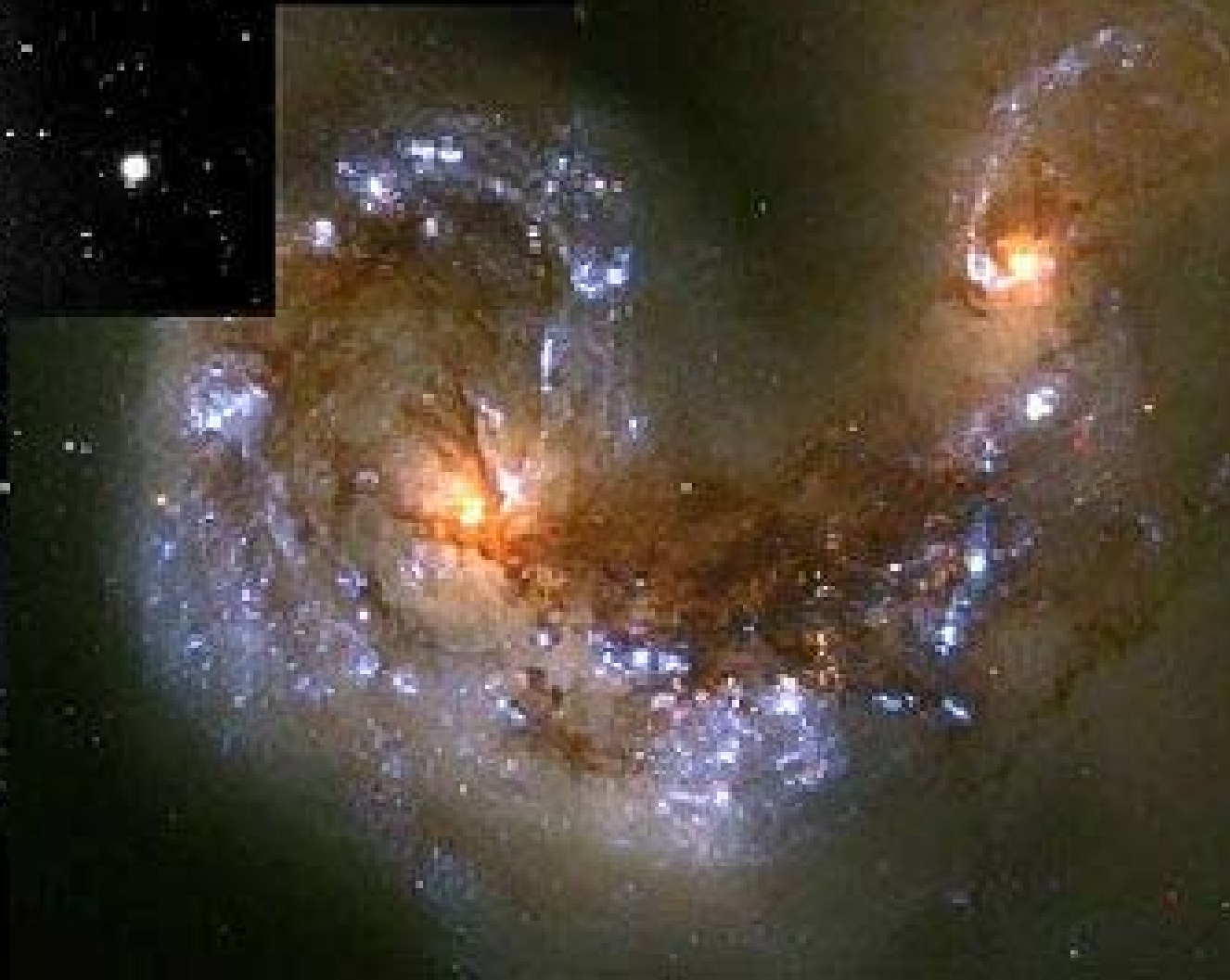
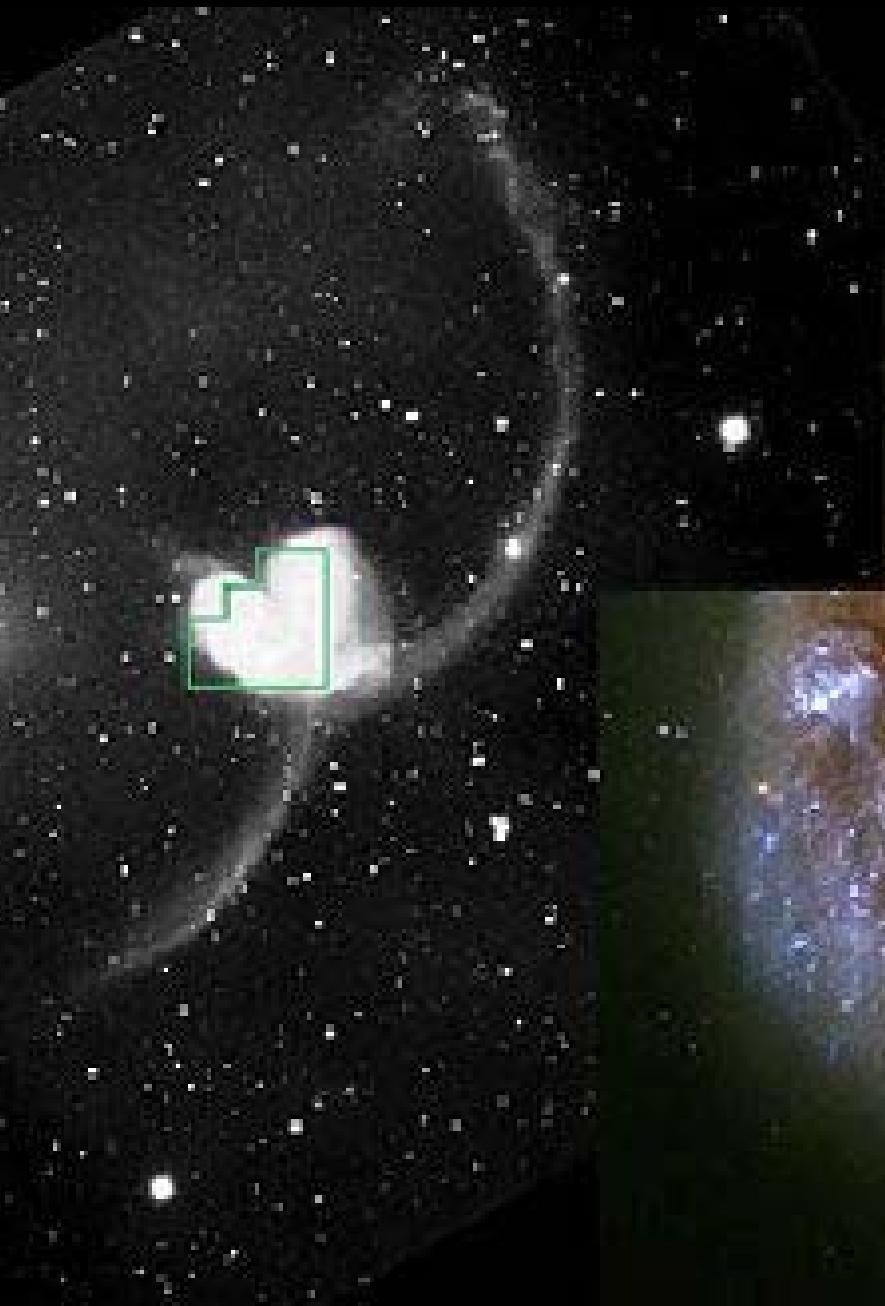


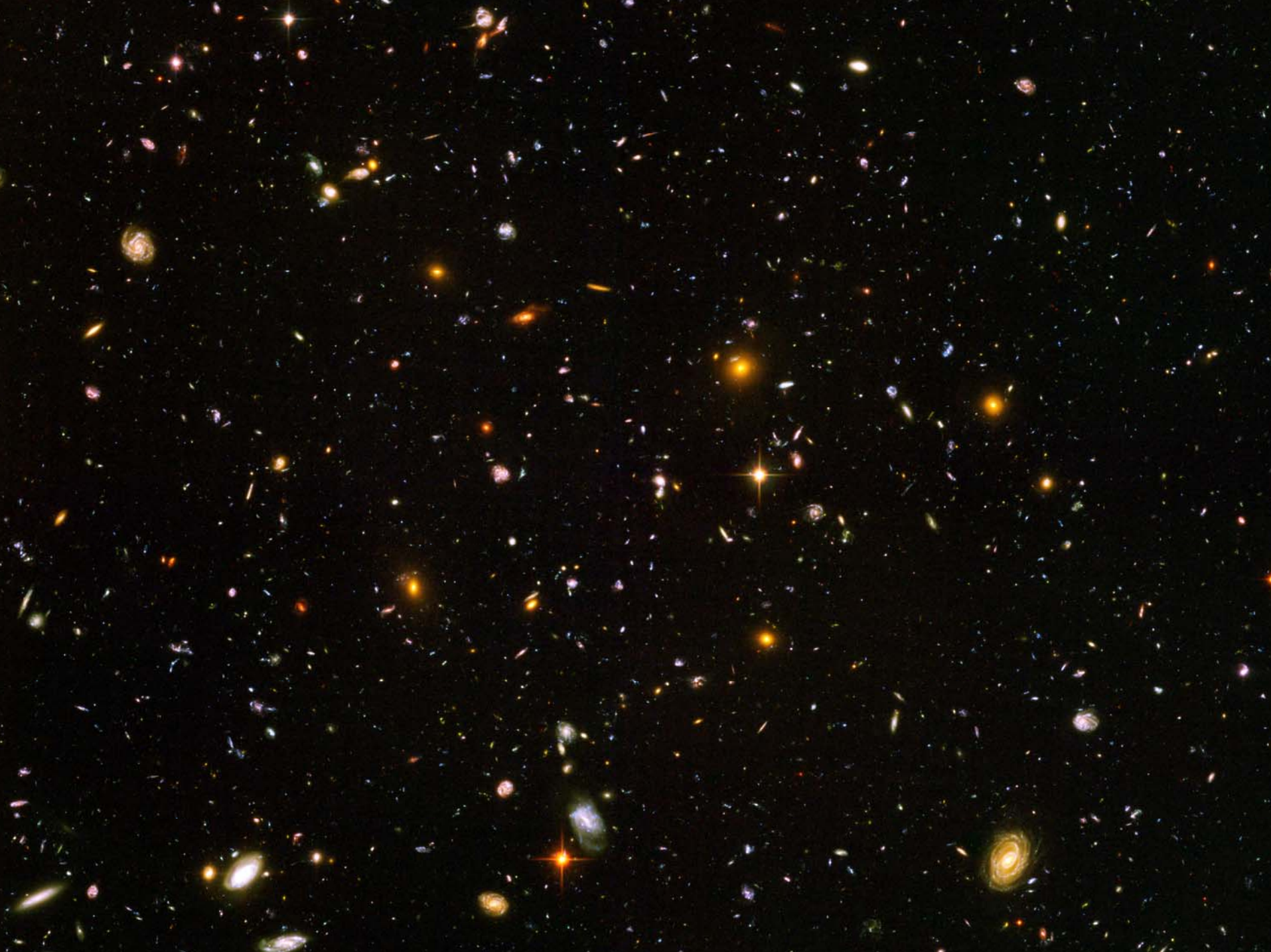




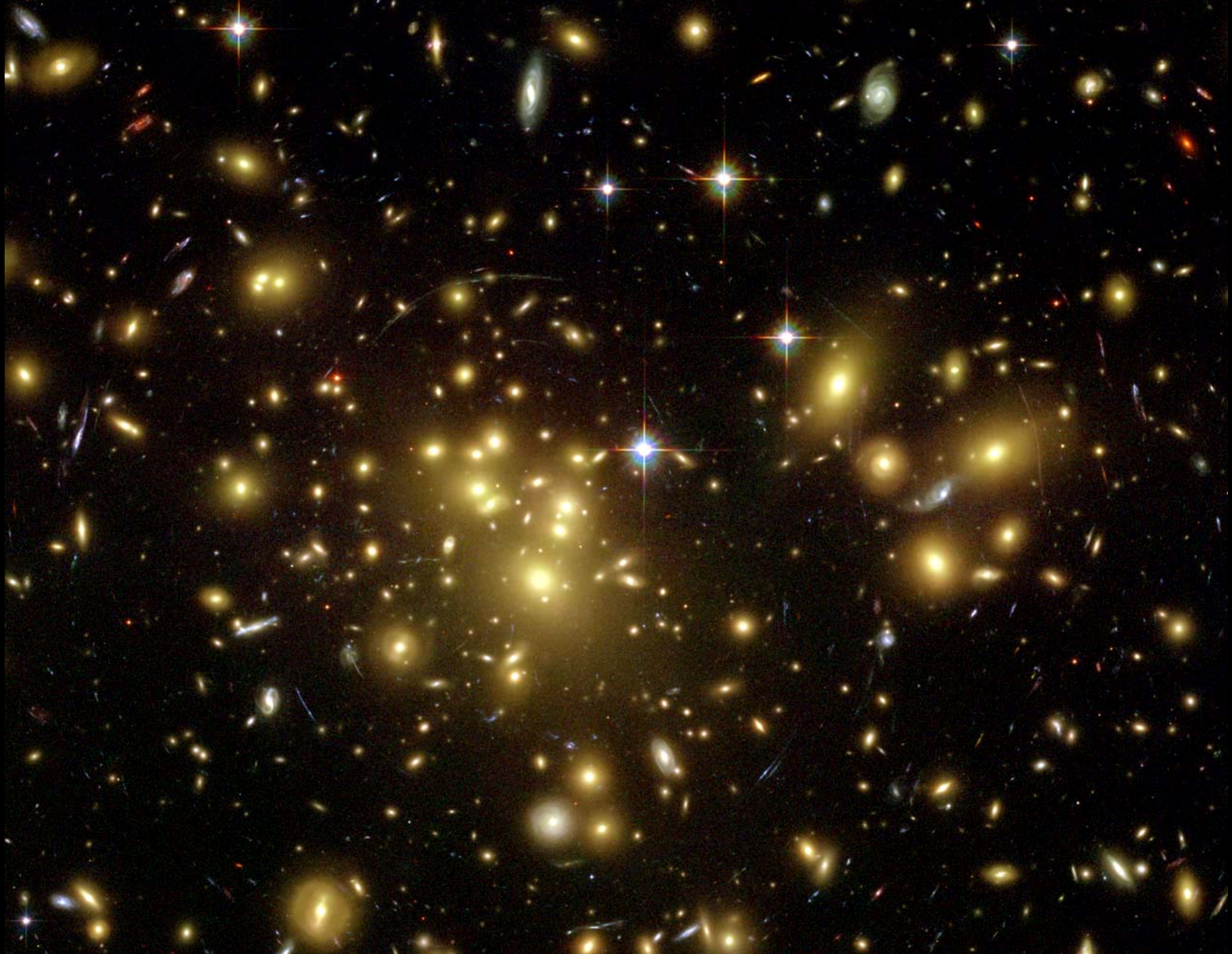




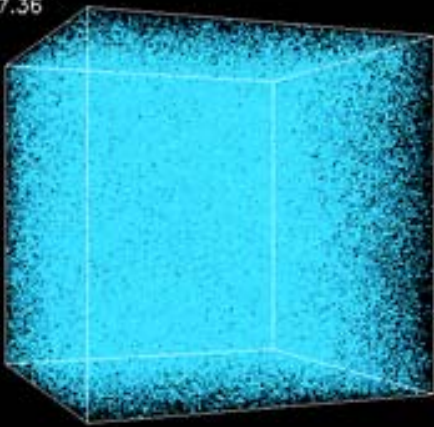




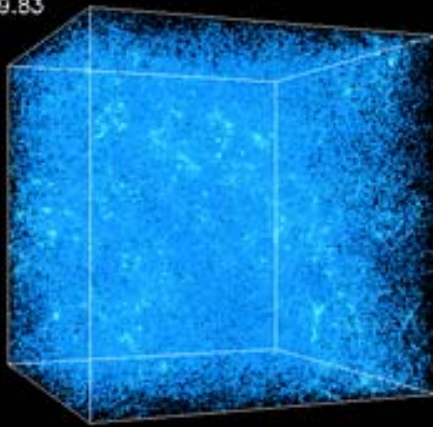




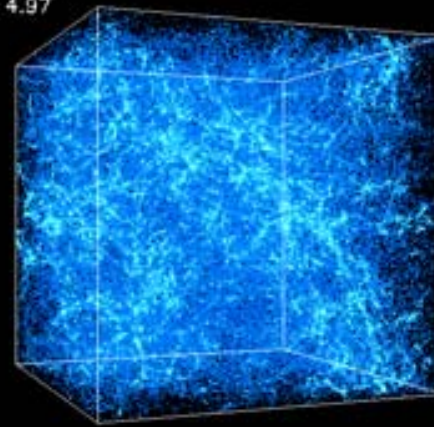
Z=27.36



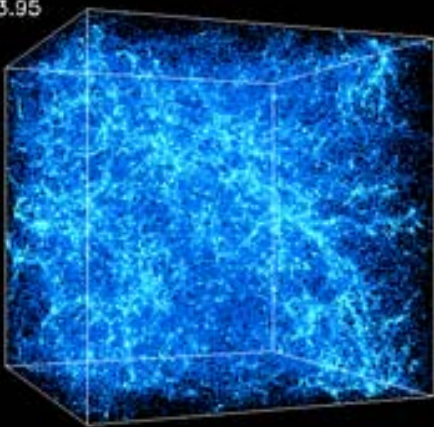
Z= 9.83



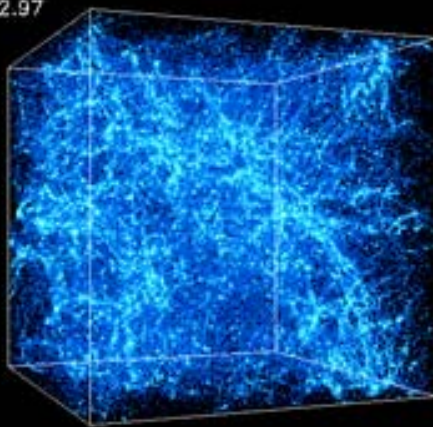
Z= 4.97



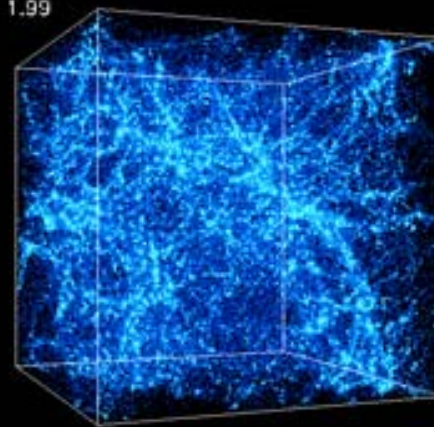
Z= 3.95



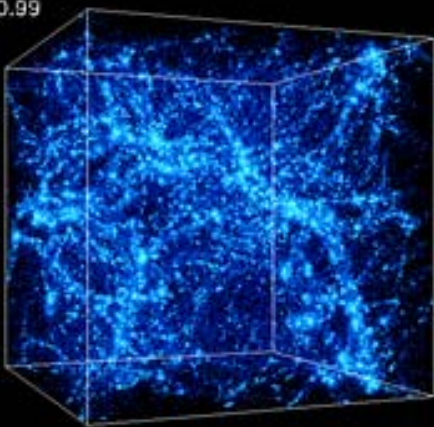
Z= 2.97



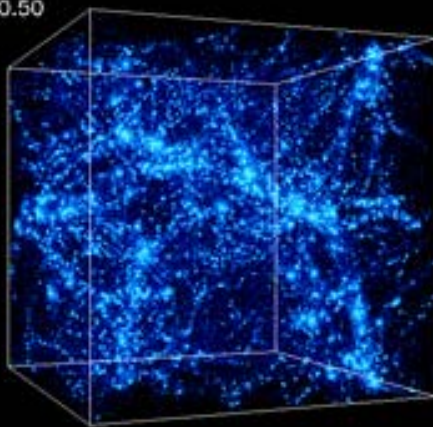
Z= 1.99



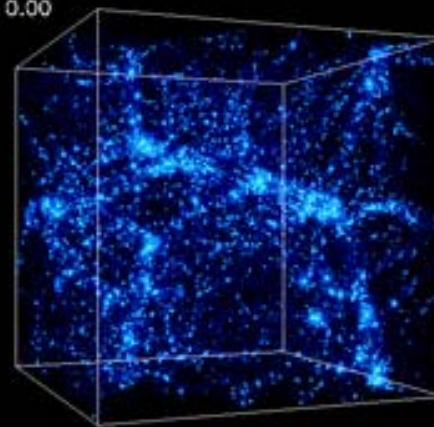
Z= 0.99

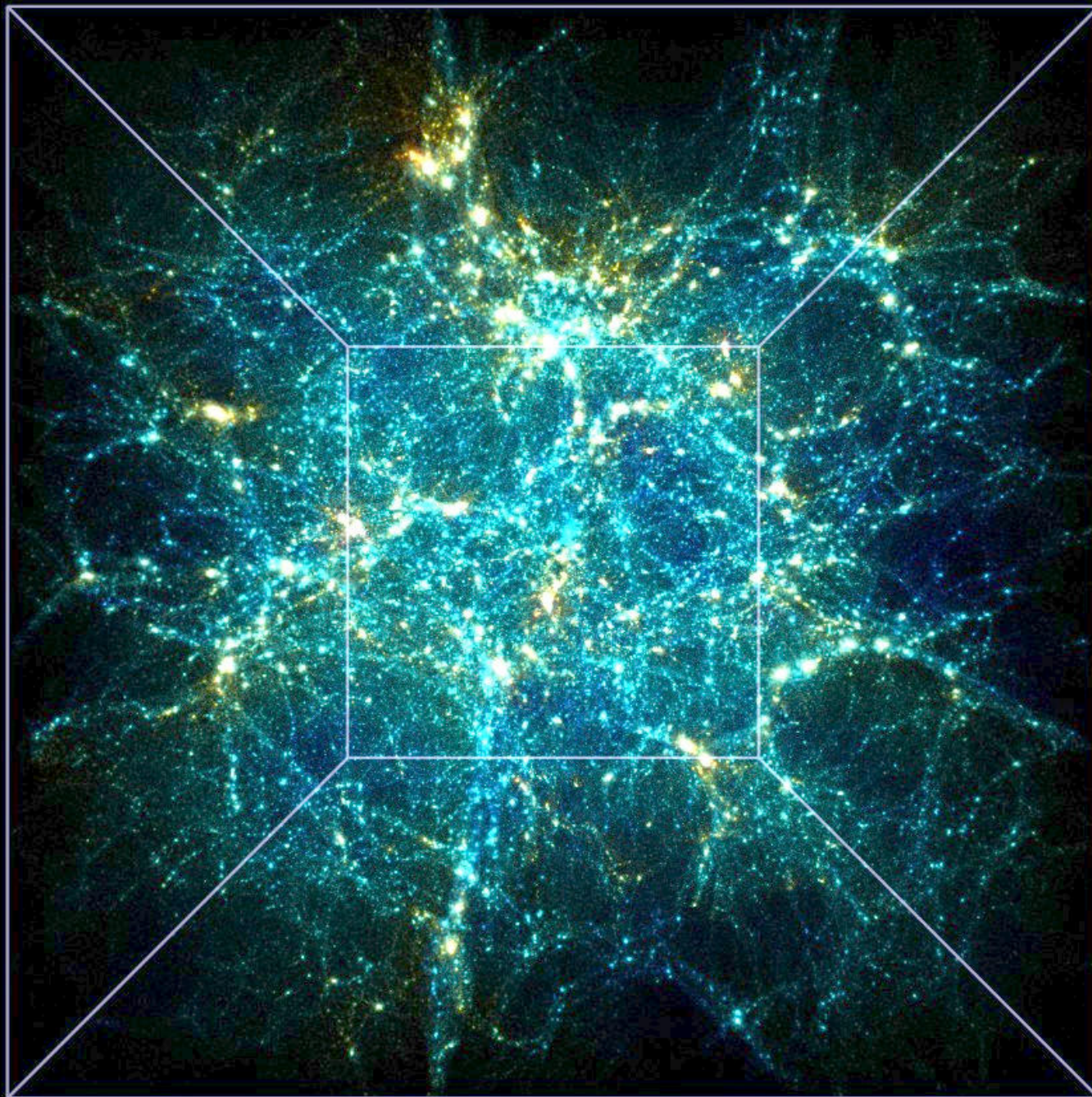


Z= 0.50

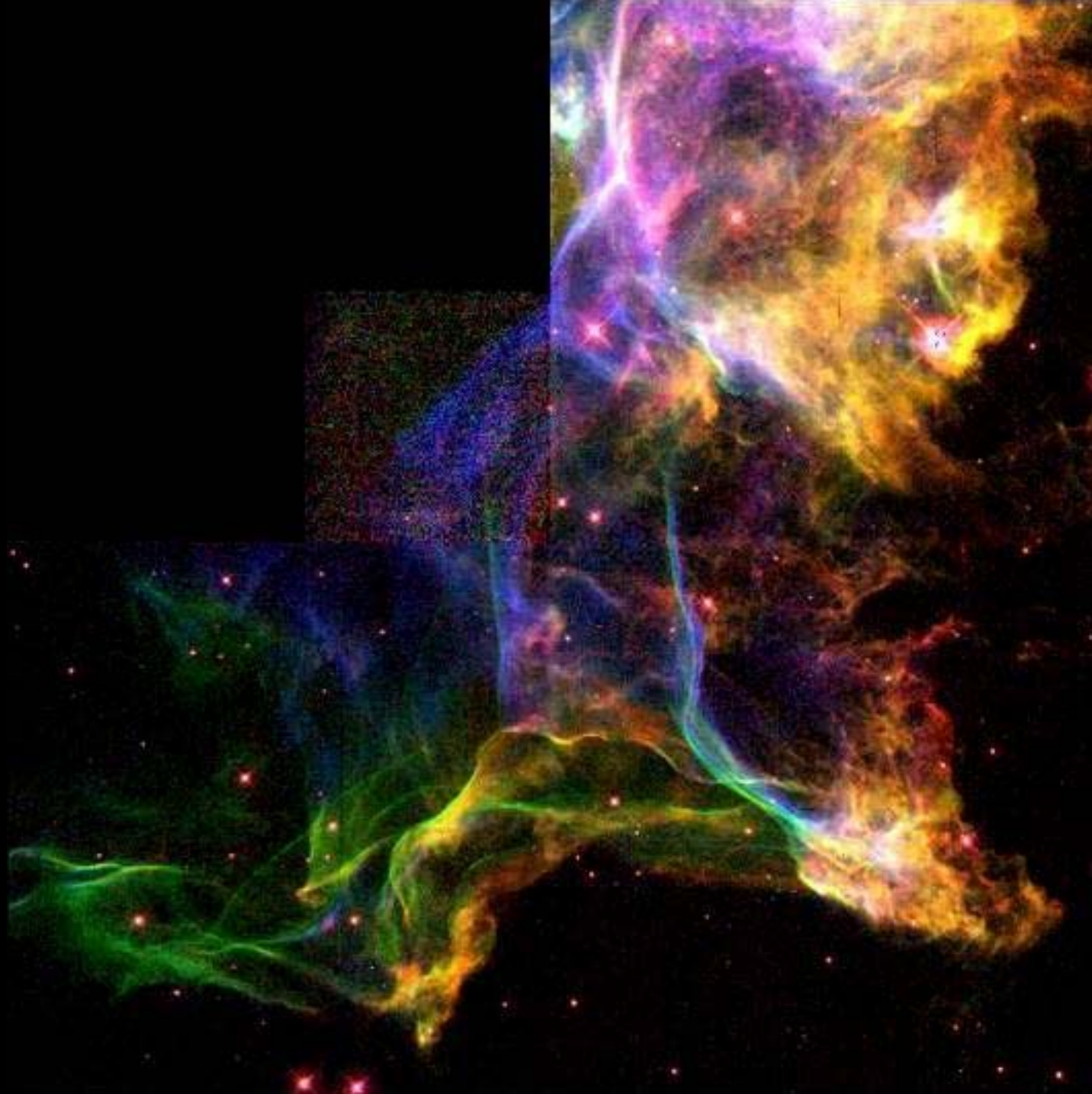


Z= 0.00

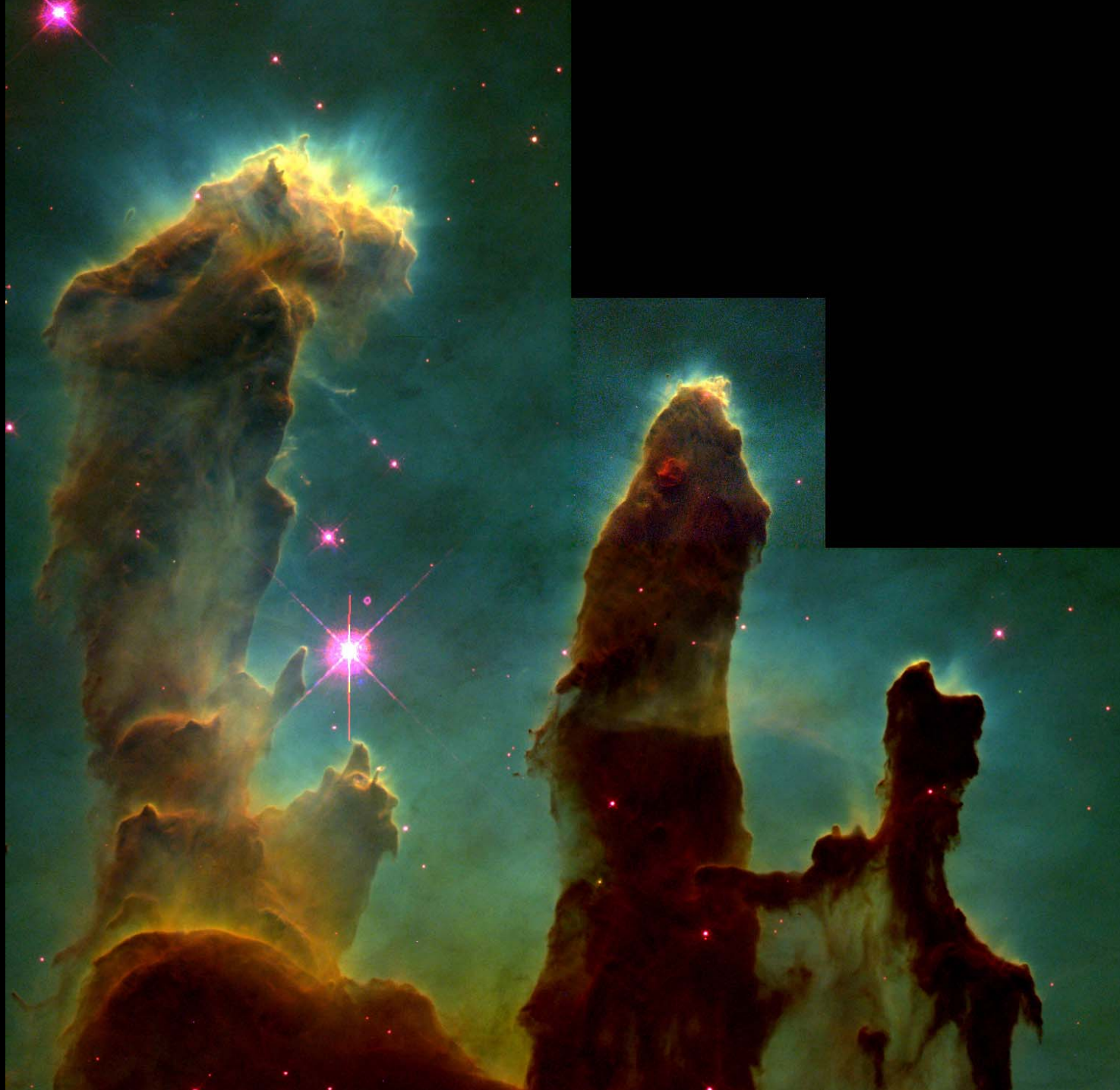










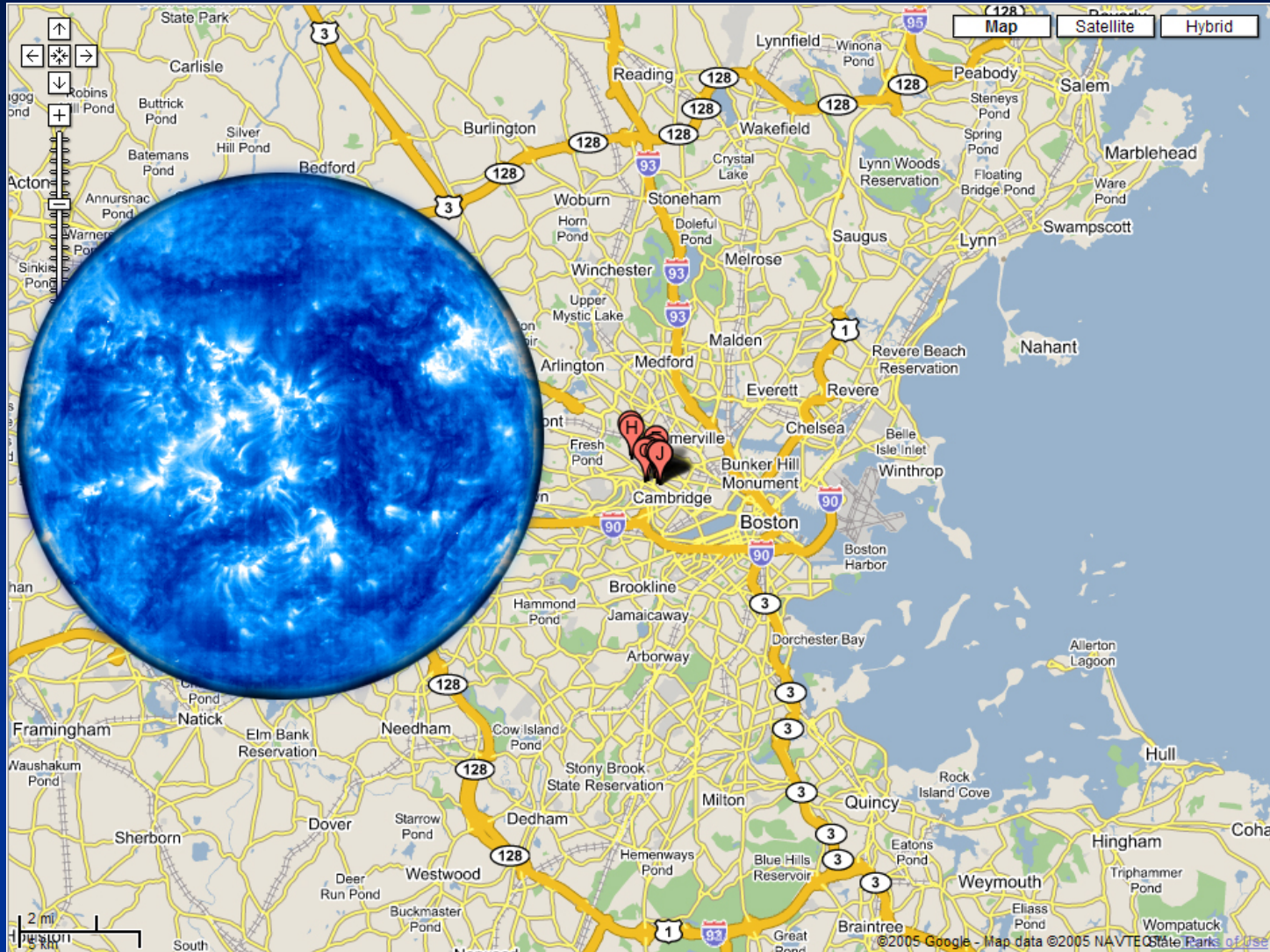


HISTORICAL SUPERNOVAE

Supernovae in our galaxy (or a nearby galaxy)

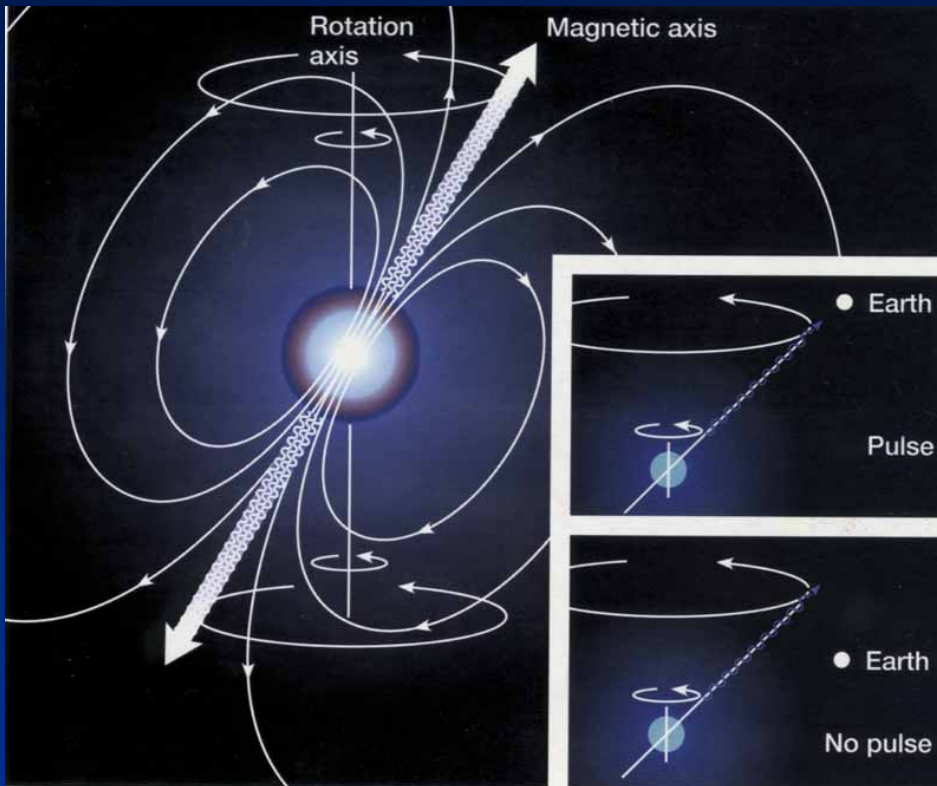
<u>Year</u>	<u>Report</u>	<u>Supernove Remnant</u>
1006	China, Japan, Korea, Arab lands, Europe	Identified with radio SNR
1054	China, Japan	Crab Nebula
1181	China, Japan	Possible identification with radio SNR 3C58
1572	Europe (Tycho Brahe), China, Japan	Tycho's remnant
1604	Europe (Kepler), China, Japan,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

Neutron stars



Neutron Star to Attend Harvard

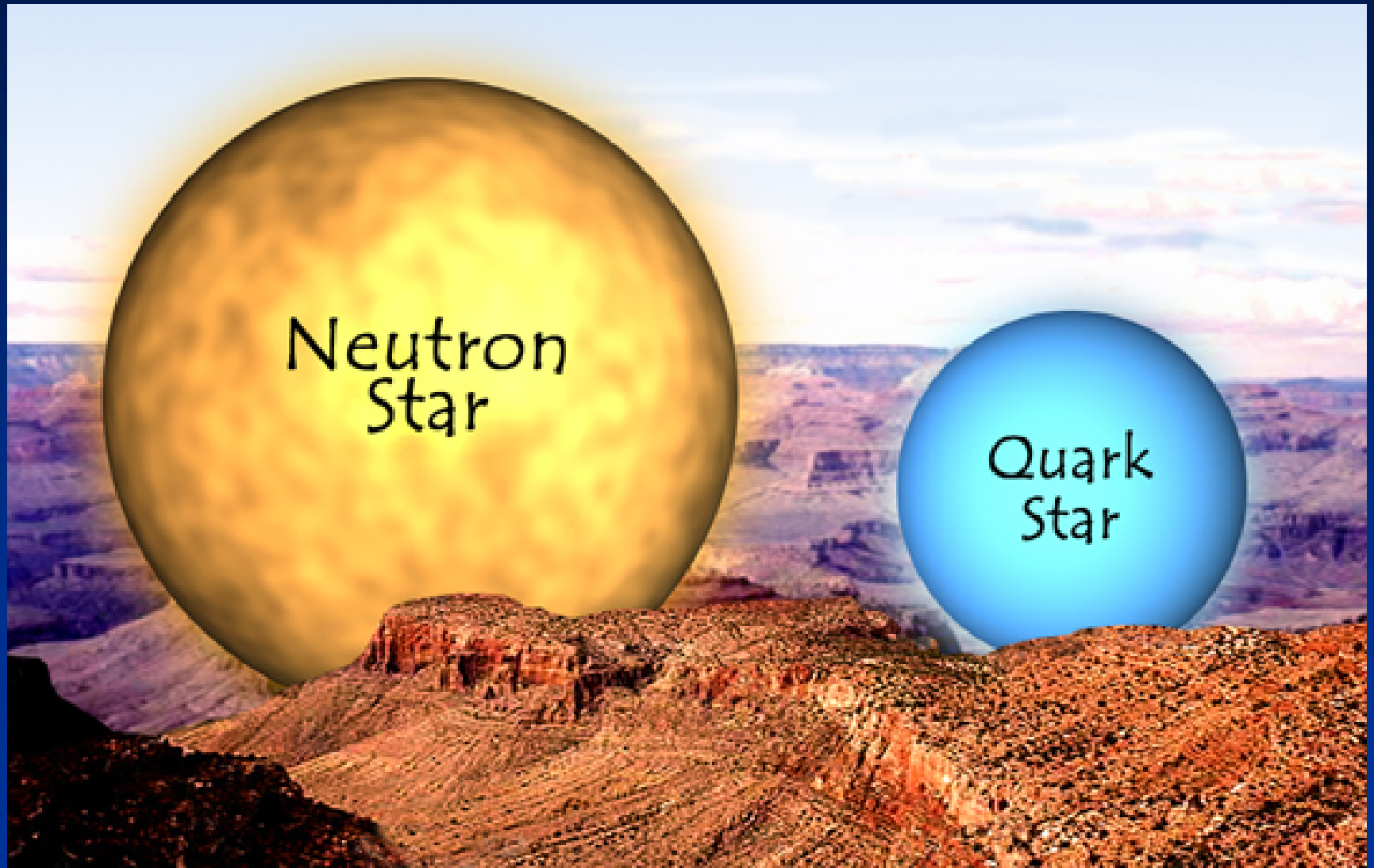
PULSARs



[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?

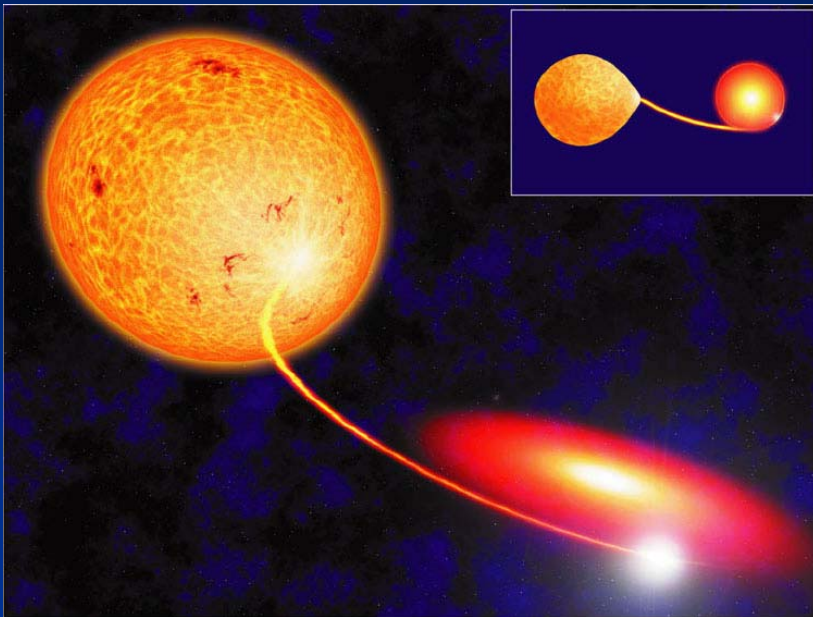
Black Holes

NOTHING!

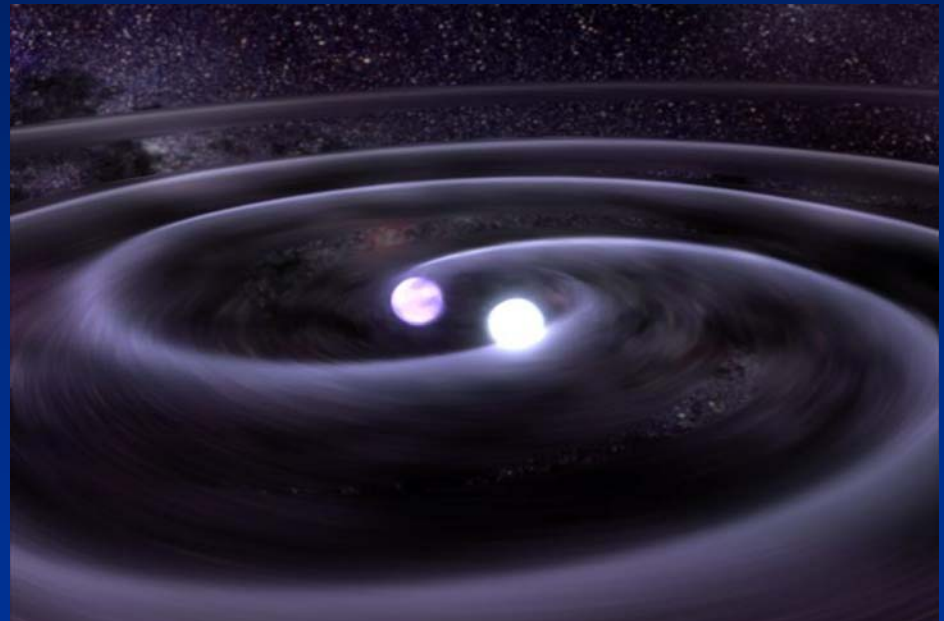
Type Ia Supernovae

Thermonuclear Bombs in Space!

Explosions of White Dwarfs in Binary Systems



**WD Accretion From Main
Sequence Companion**

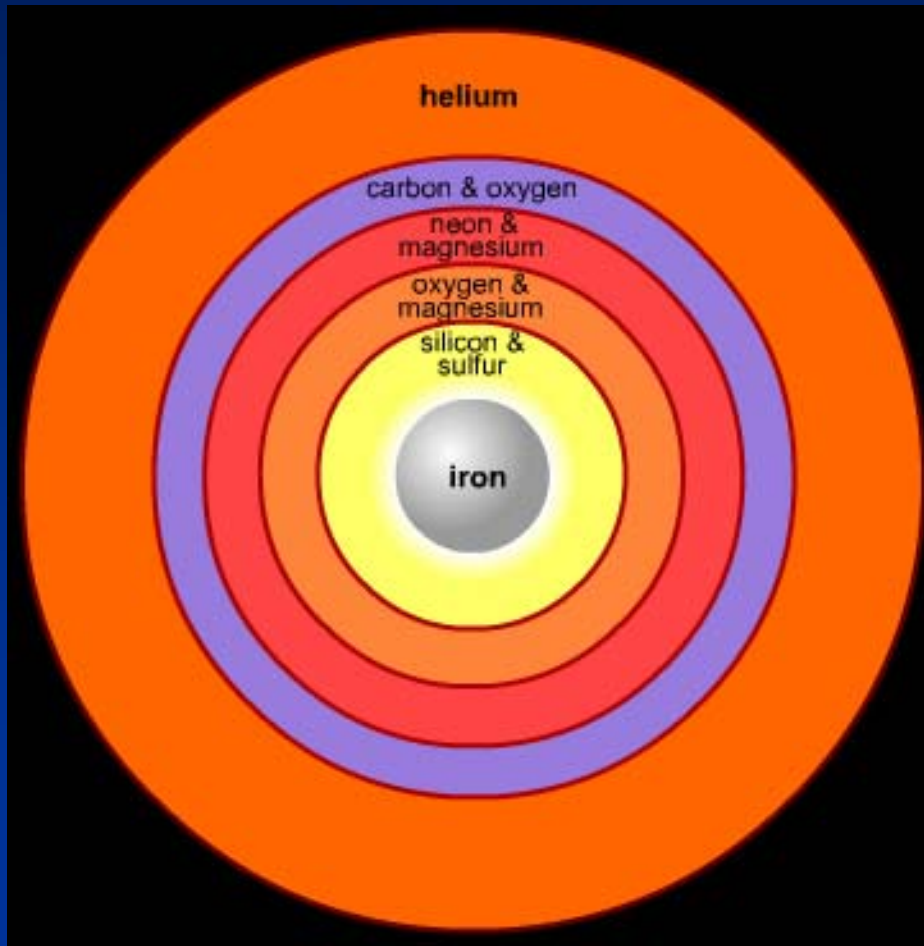


Merger of 2 White Dwarfs

Type I i Supernovae

Gravity Bombs!

Gravitational Core Collapse of Massive Stars



Star with $M > 8 M_{\text{sun}}$

The Sun

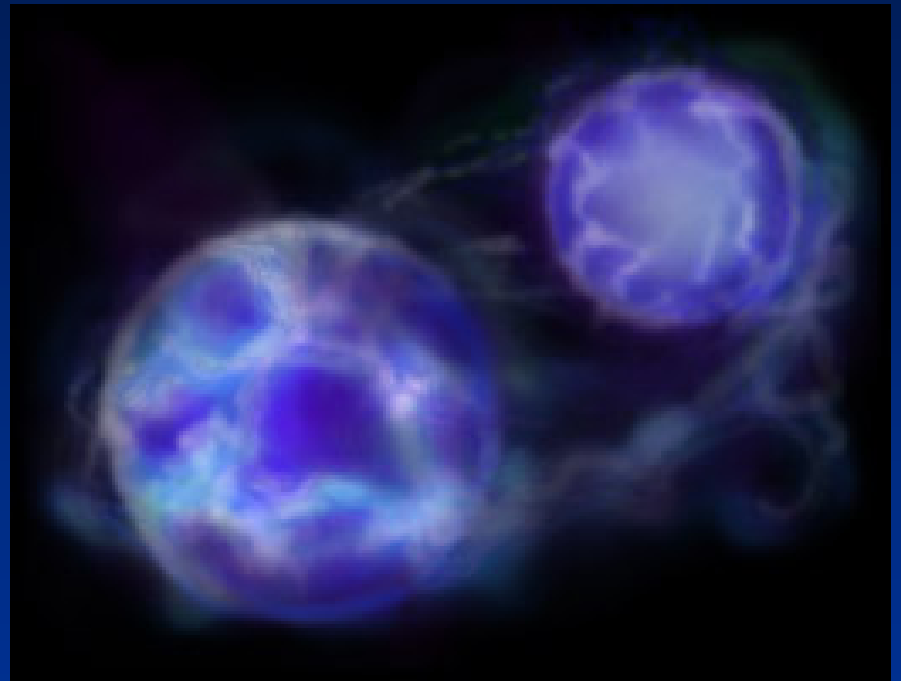
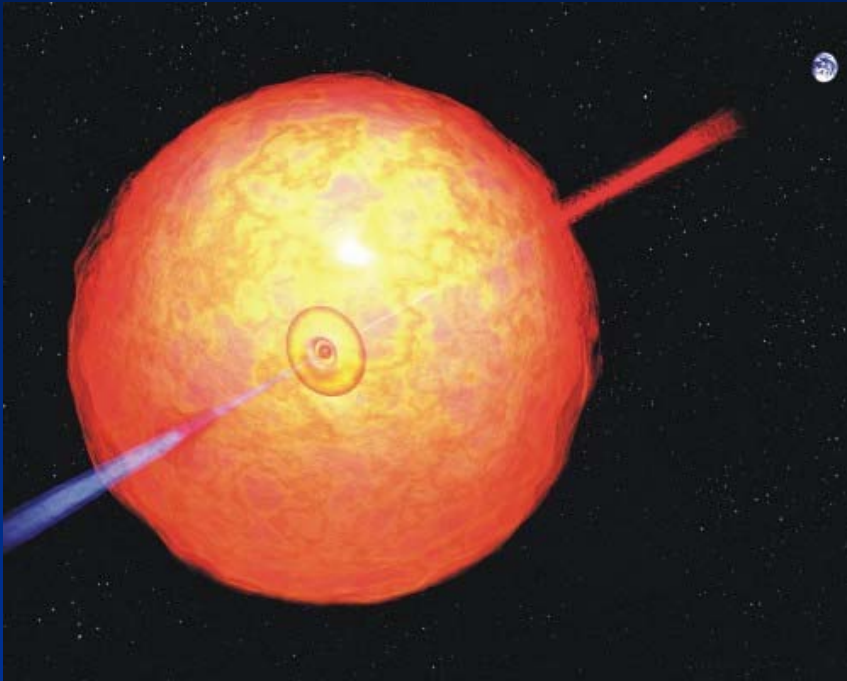


Stel I ar Expl osion MOVIEs

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

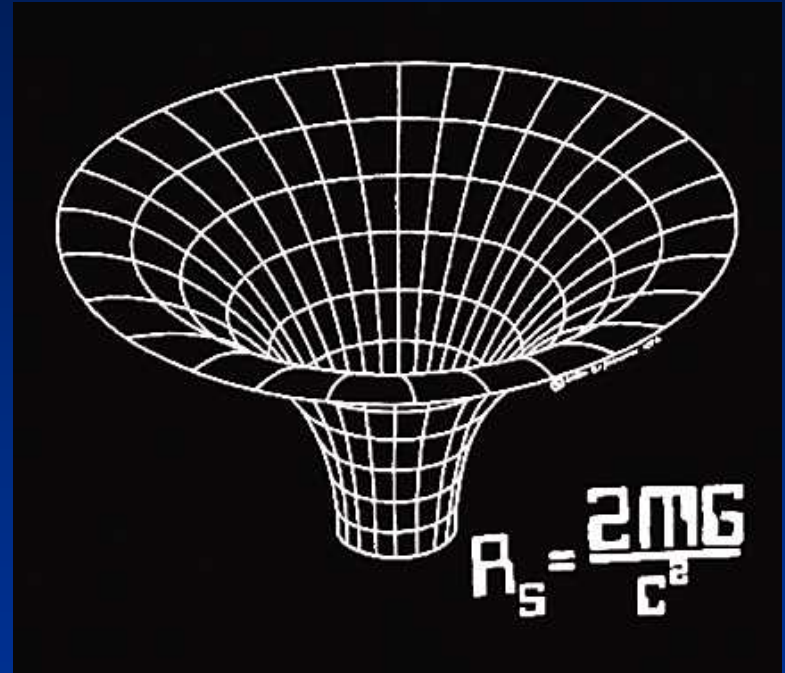
Stellar Explosion MOVIES

Gamma Ray Burst Movie

Leftover COMpact objects

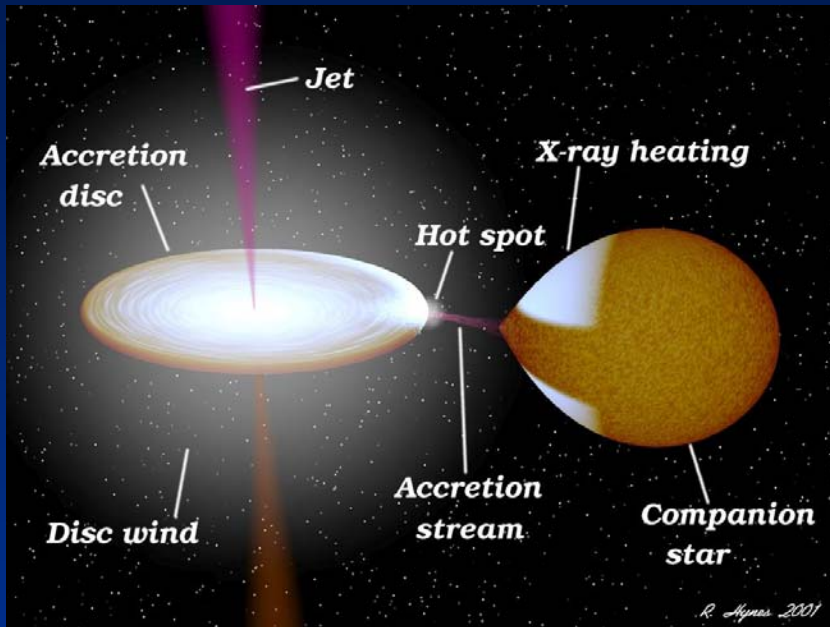
<u>Type of Stellar Explosion</u>	<u>Compact Remnant</u>
Type Ia	NOTHING!
<i>Failed Type Ia</i>	<i>NEUTRON STAR?</i>
Type II	NEUTRON STAR
	BLACK HOLE
Gamma-Ray Burst	BLACK HOLE

Black holes



The Schwarzschild
Radius

Evidence for Black holes



Stellar Mass Black Holes

$$M \sim 3 - 20 M_{\text{sun}}$$

Supermassive Black Holes

$$M \sim 10^6 - 10^9 M_{\text{sun}}$$