

Top 5 cosmic

Top 5 cosmic

connections

Martin Hendry
SUPA, School of Physics and Astronomy
University of Glasgow

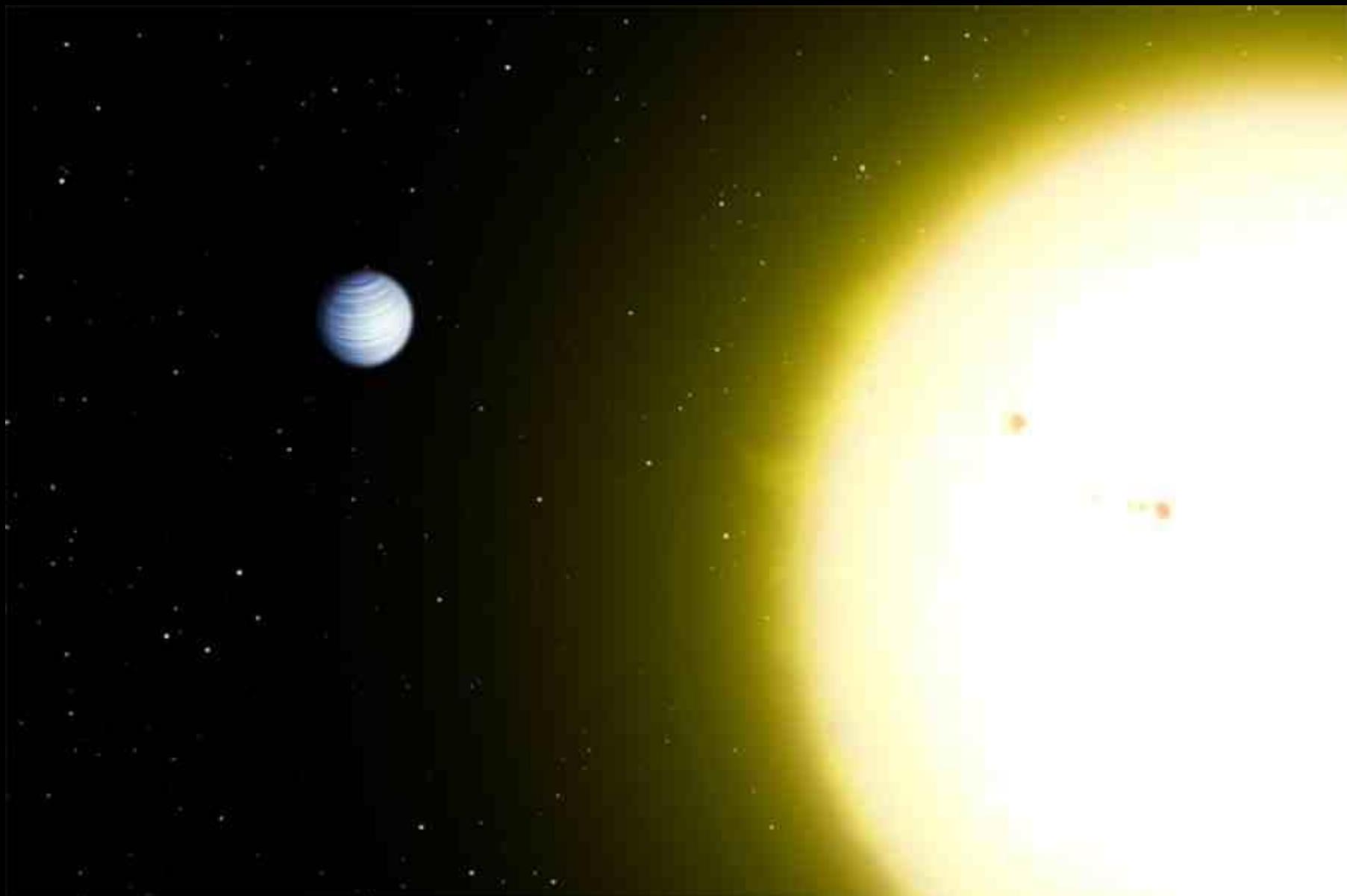


Science & Technology
Facilities Council



University
of Glasgow

1. Extra-solar planets





PLANET QUEST

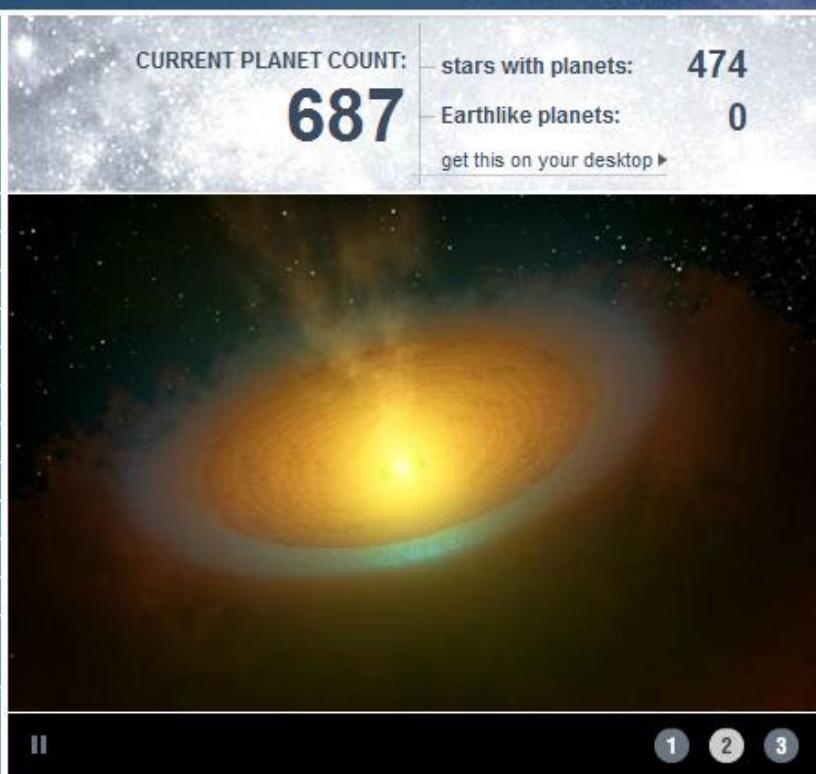
Exoplanet Exploration

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Exoplanet: *n.* a planet that orbits a star outside the solar system.



MULTIMEDIA



Explore the
NEW WORLDS ATLAS
A visual guide to exoplanets ►

MORE STORIES



Ten in transit
CoRoT's latest haul a diverse bunch
07.14.11



Extra(solar) credit
Students build planet-hunting
miniature satellite
05.27.11



Sizzling sibling
New technique validates hot Kepler
discovery.
05.20.11



Orphan orbs
Galaxy teeming with free-floating
planets.
05.18.11

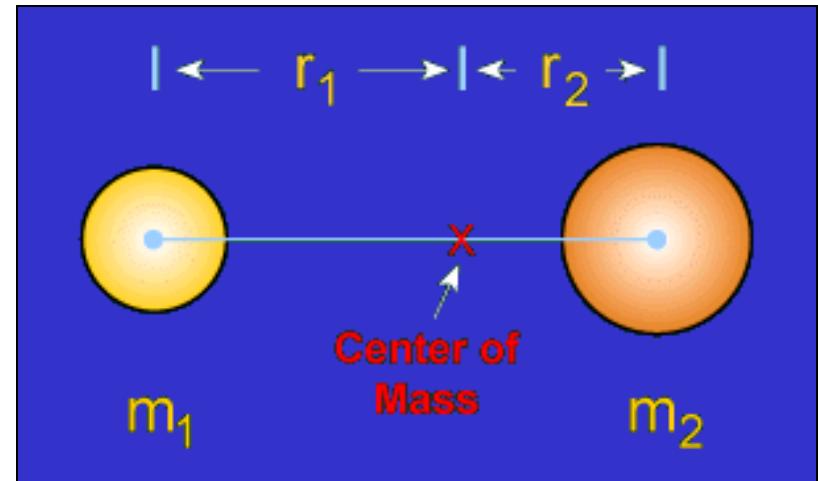
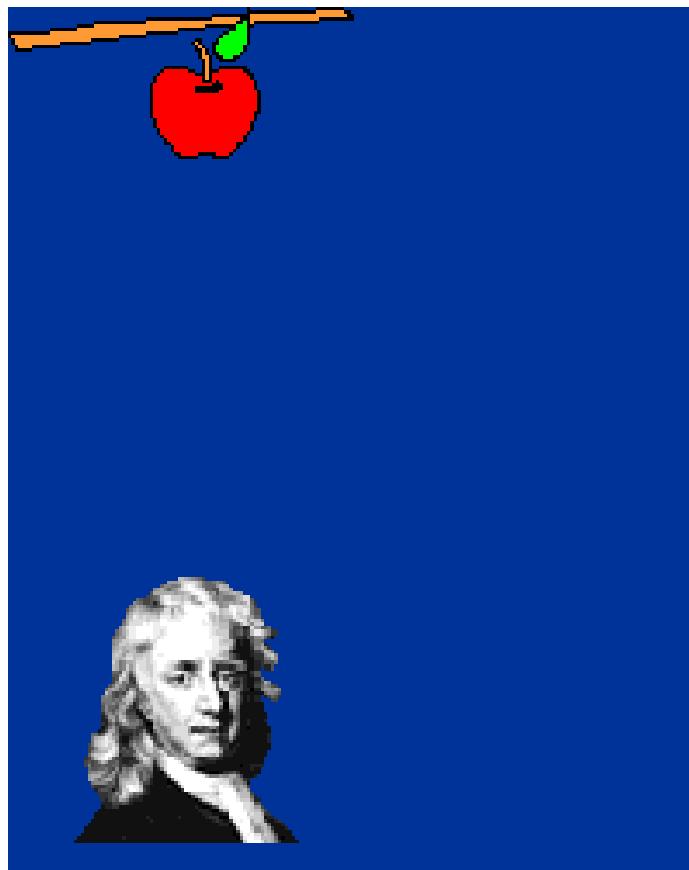
News archive ►



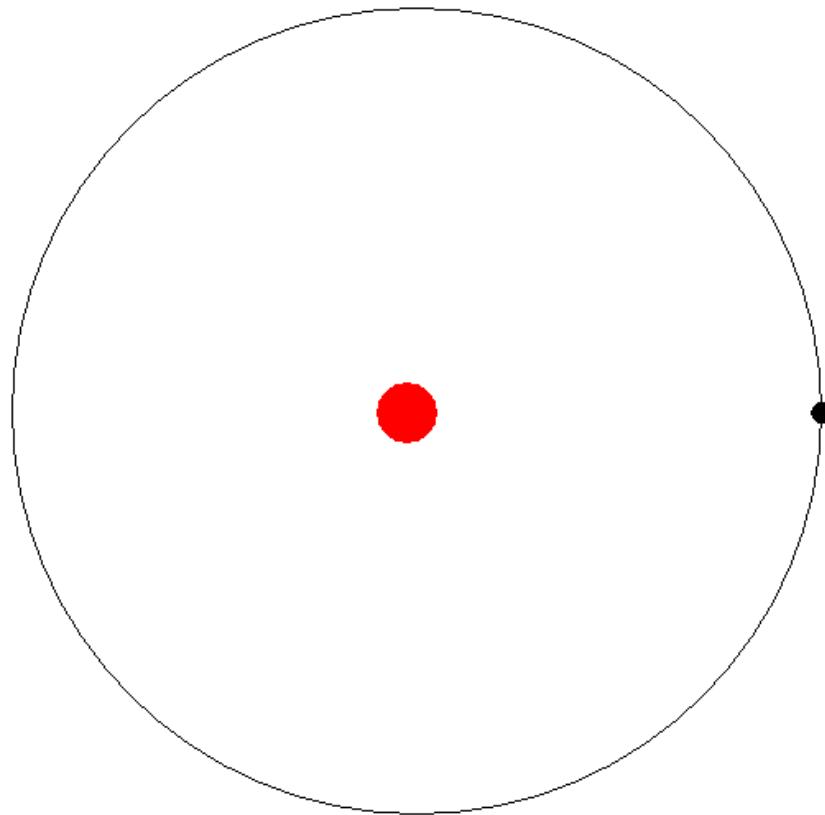
EXTREME

1. How can we detect extra-solar planets?

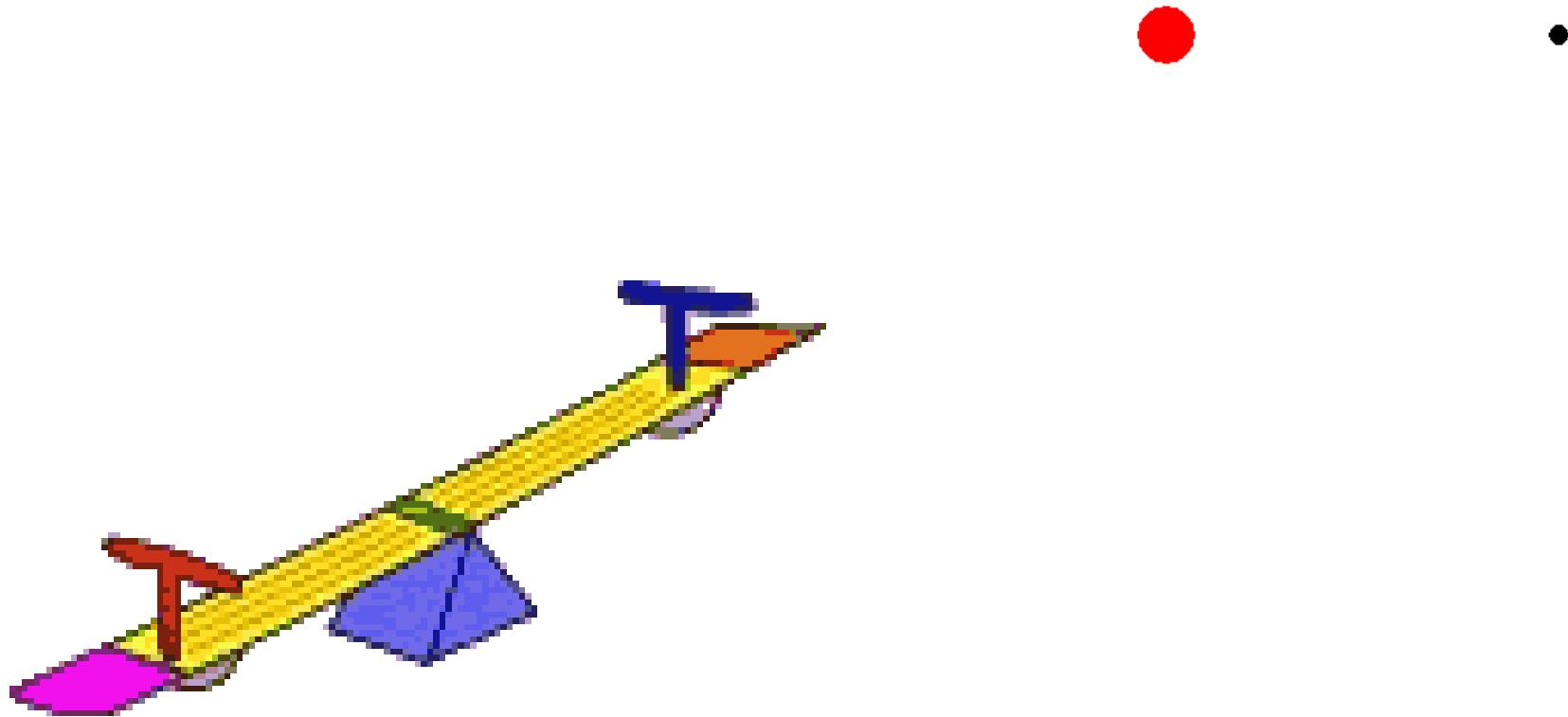
- They cause their parent star to 'wobble', as they orbit their common centre of gravity



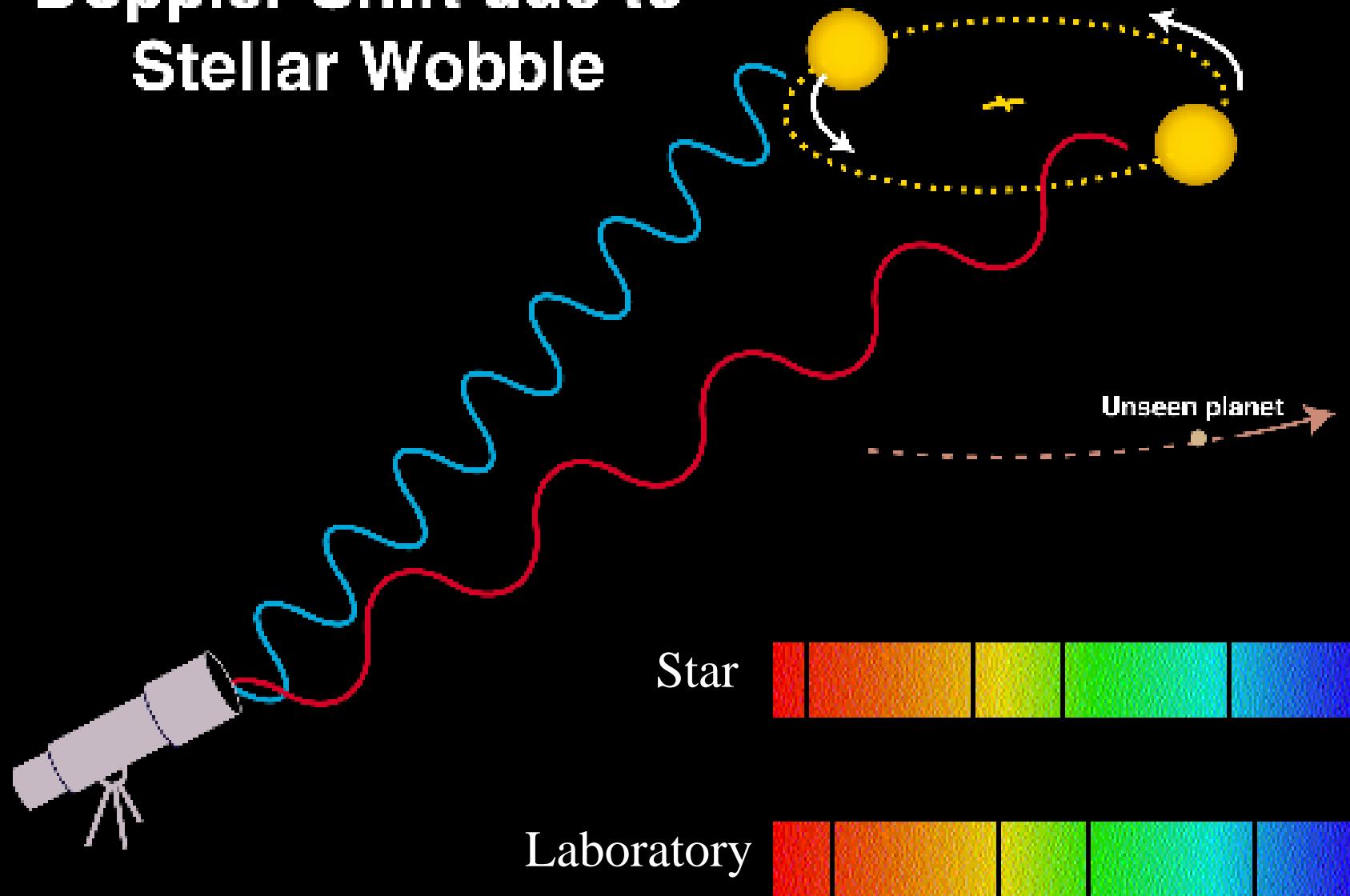
Star + planet in circular
orbit about centre of mass



Star + planet in circular
orbit about centre of mass

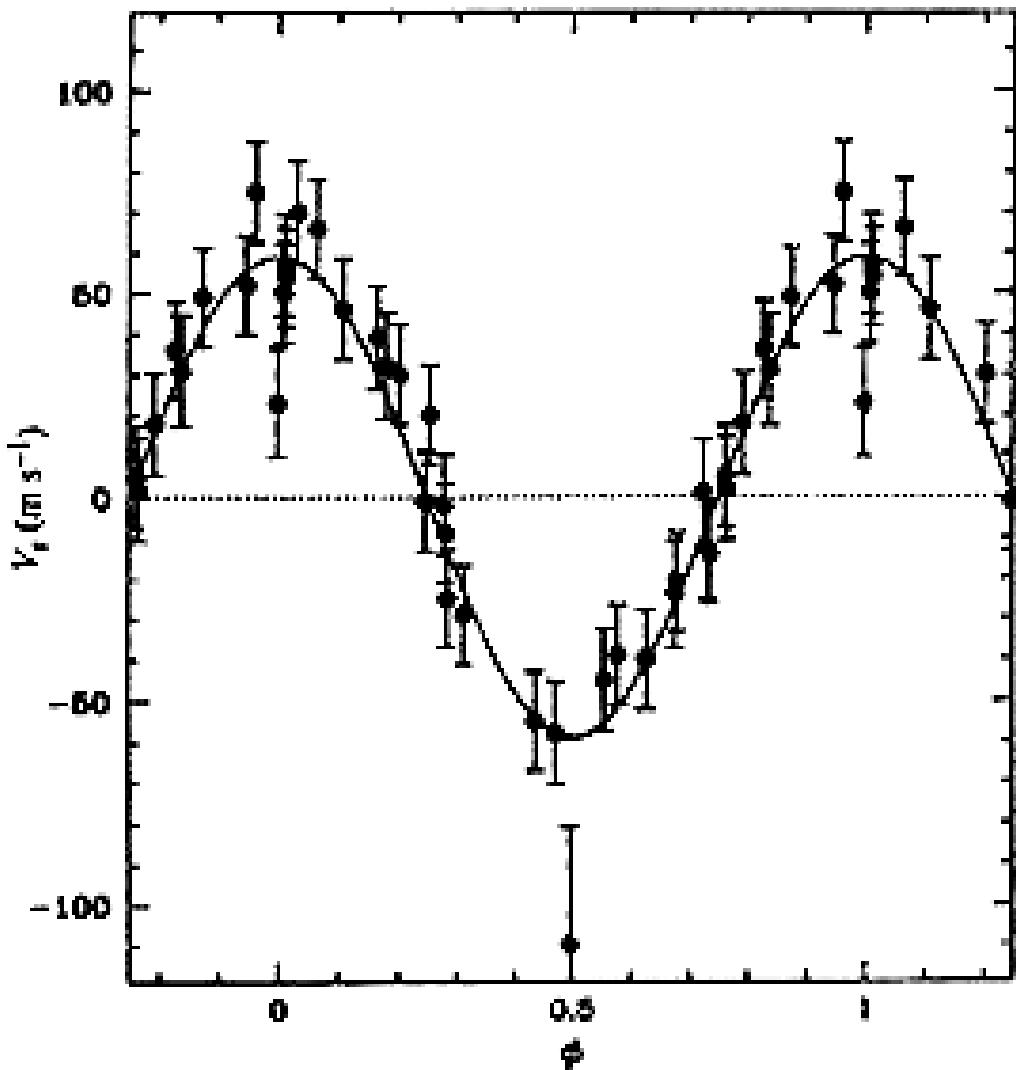


Doppler Shift due to Stellar Wobble



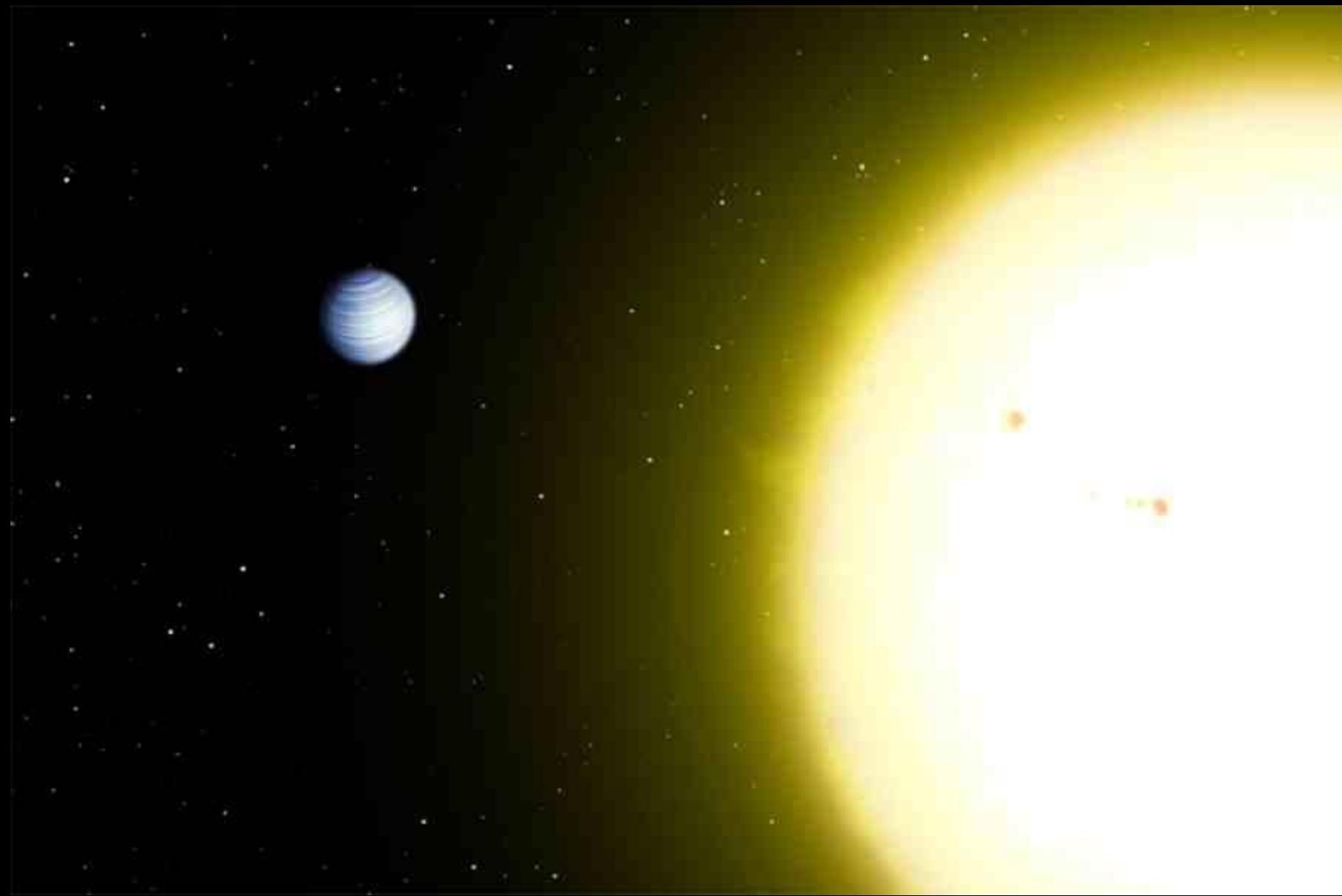
51 Peg – the first new planet

Discovered in 1995



Doppler wobble

$$v = 55 \text{ ms}^{-1}$$



Pegasi 51b



Earth, Lowestoft, 17m

FOV 50.6° 30.7 FPS

2011-07-15 22:00:00

Pegasi 51b

5.1 Peg - HIP 113357

Magnitude: **5.45** (B-V: 0.67)
Absolute Magnitude: 4.52*
RA/DE (J2000): 22h57m28.2s/+20°46'08.7"
RA/DE (of date): 22h58m2s/+20°49'51"
Hour angle/DE: 17h42m19s/+20°49'51"
Az/Alt: +73°37'59"/+13°46'54"
Spectral Type: G5V
Distance: 50.10 Light Years
Parallax: 0.06510".

Sheat

Sadalbari

Pegasus

Markab

Homan

Earth, Lowestoft, 17m

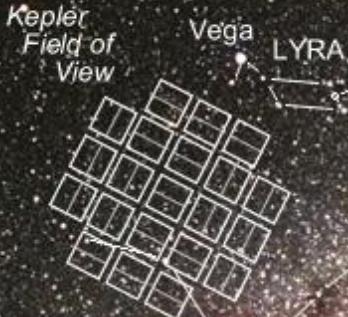
FOV 11.9° 15 FPS

2011-07-15 22:00:00

Kepler spacecraft launched 2009



Kepler
Field of
View



Vega

LYRA

M57

M56

Albireo

M27

M71

AQUILA

Altair

SAGITTA

DELPHINUS

Deneb

CYGNUS

M29

M39

North
American
Nebula

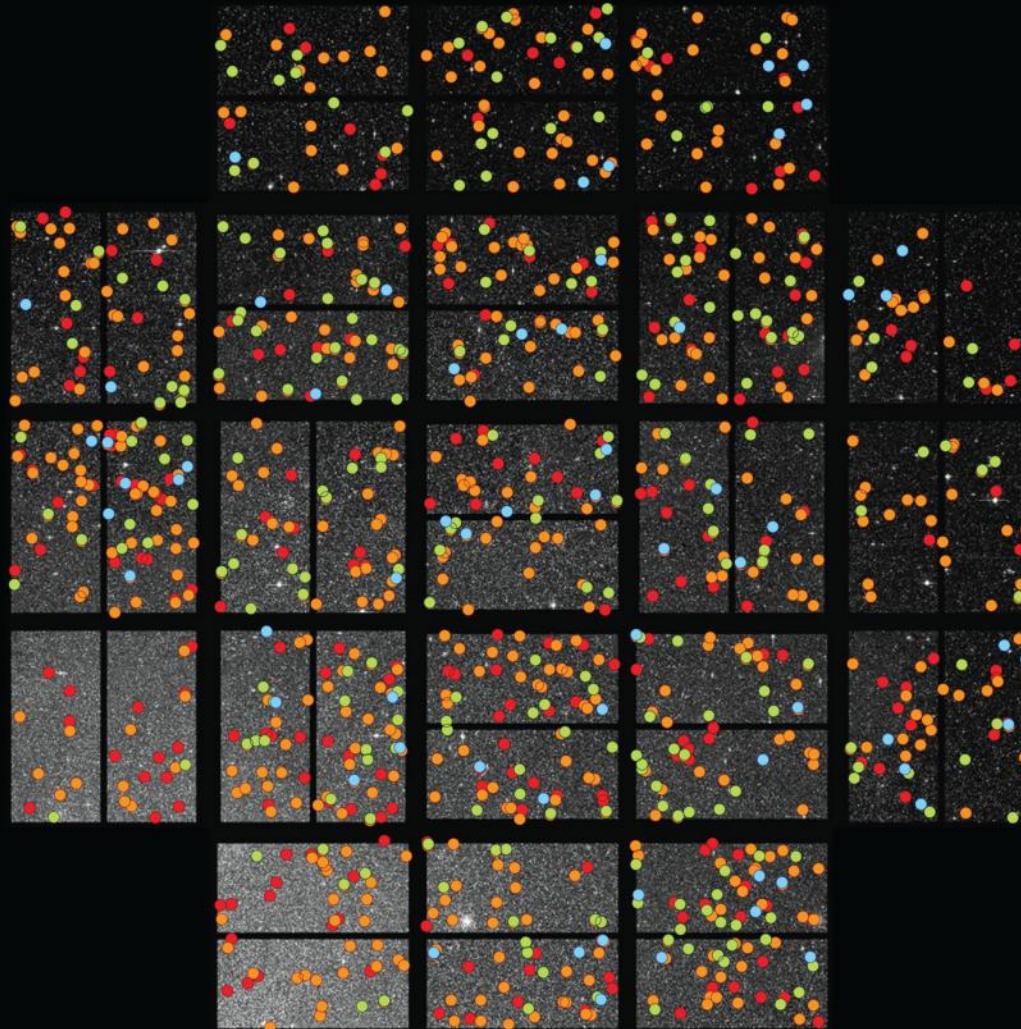
Locations of Kepler Planet Candidates

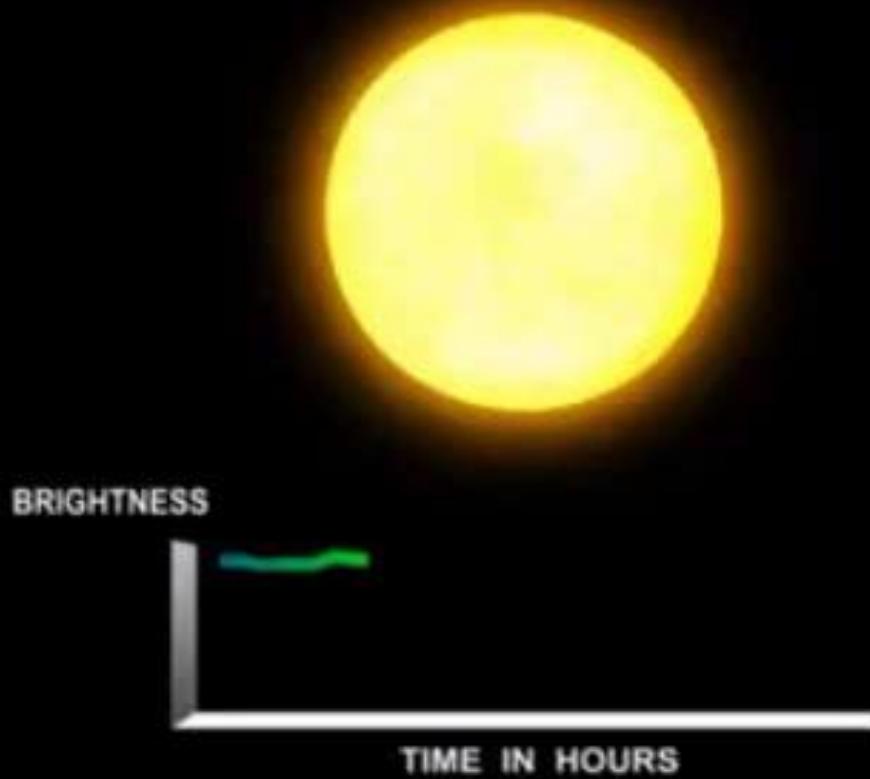
● Earth-size

● Super-Earth size
1.25 - 2.0 Earth-size

● Neptune-size
2.0 - 6.0 Earth-size

● Giant-planet size
6.0 - 22 Earth-size



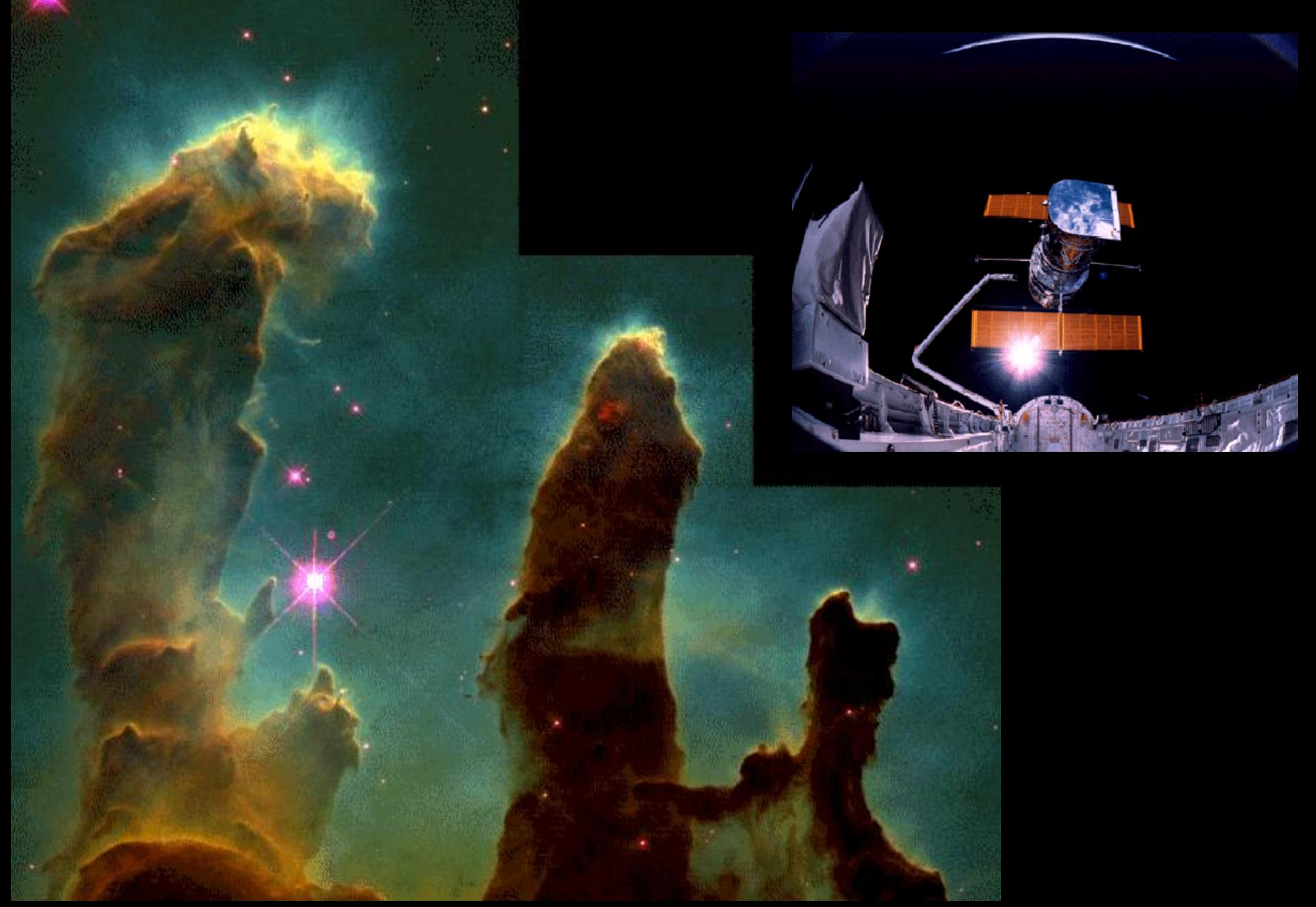


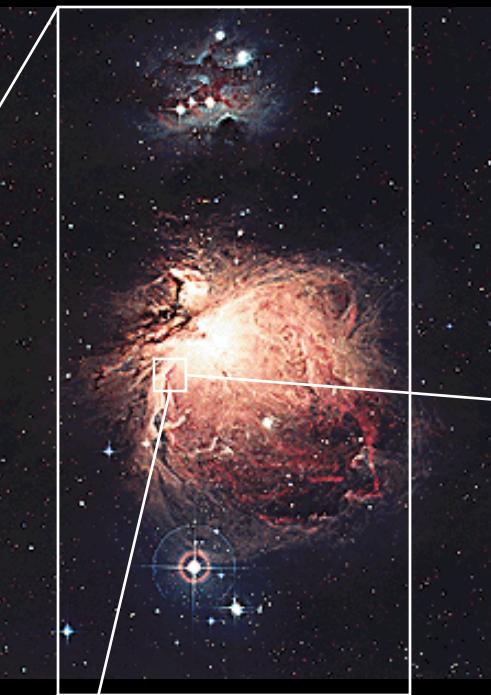




2. Stellar life and death







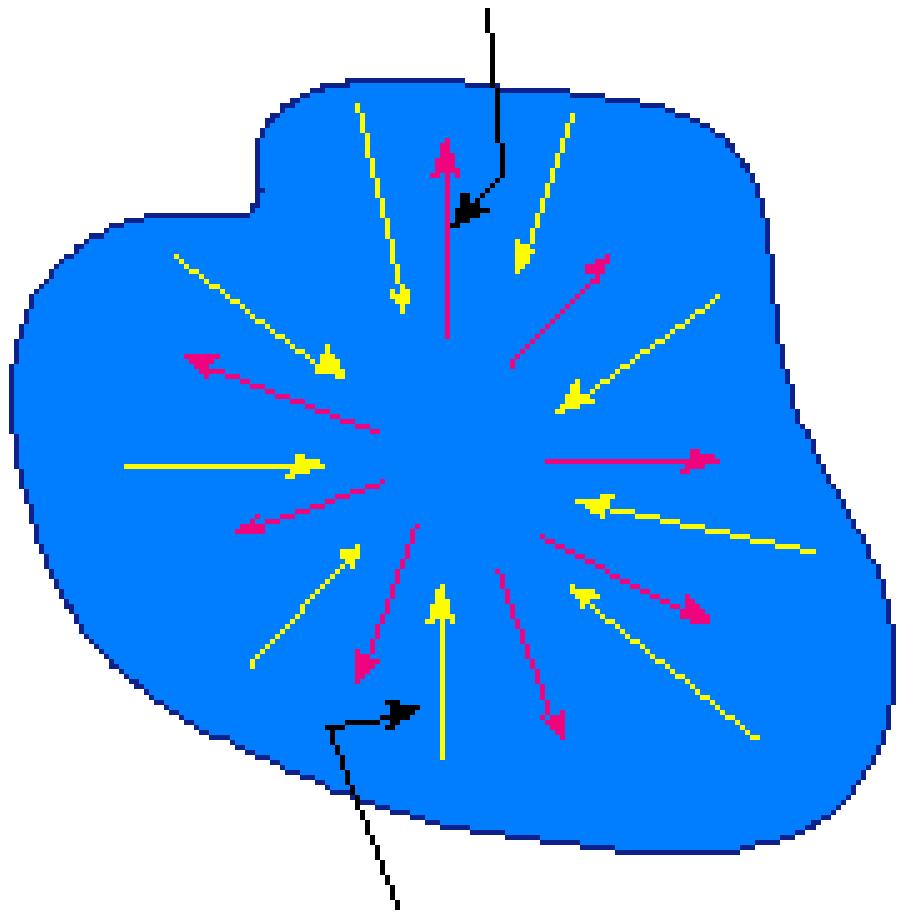
Forming stars

pressure

versus

Gravity

Gas pressure trying
to expand the cloud

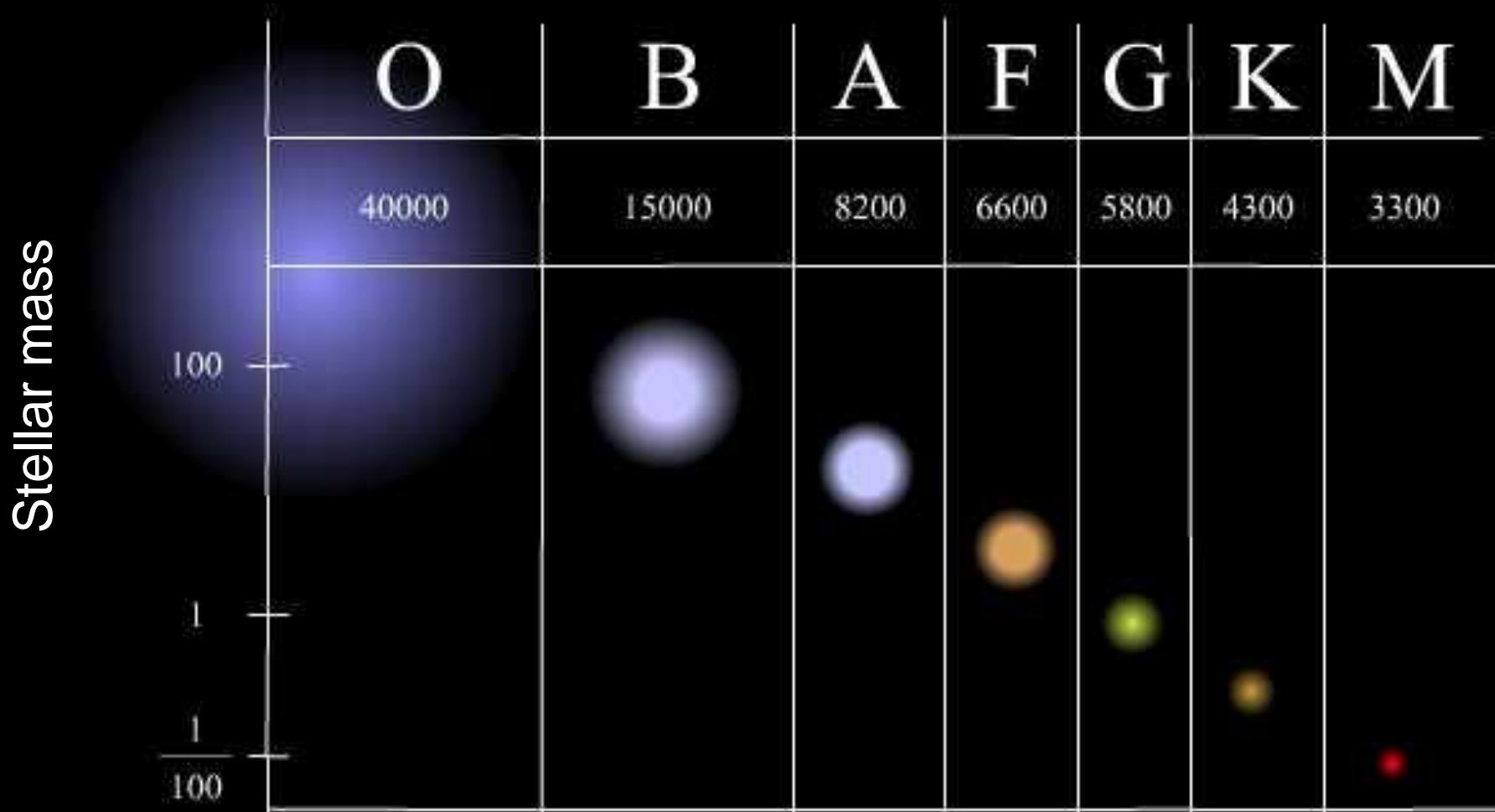


Gravity trying to
collapse the cloud

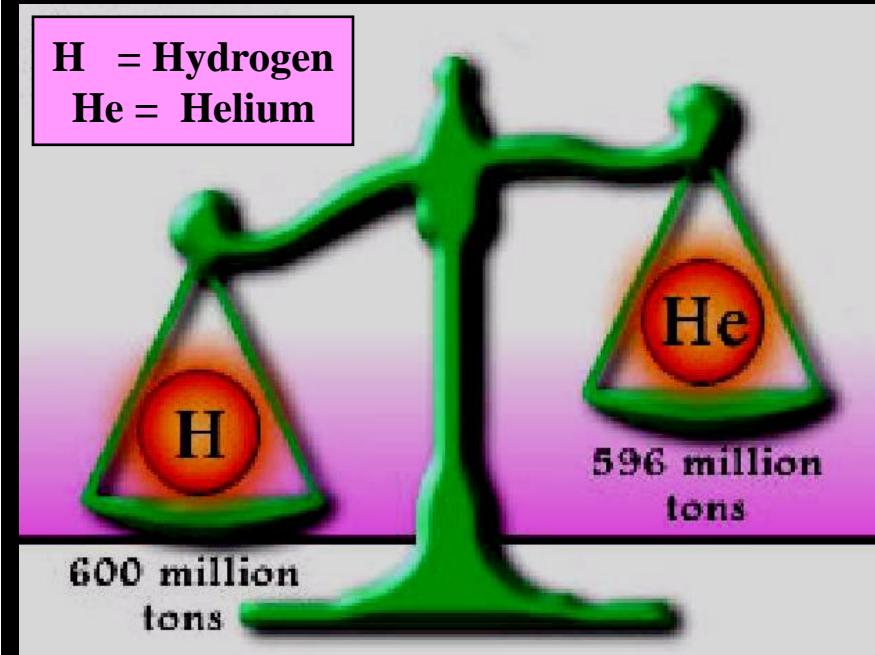
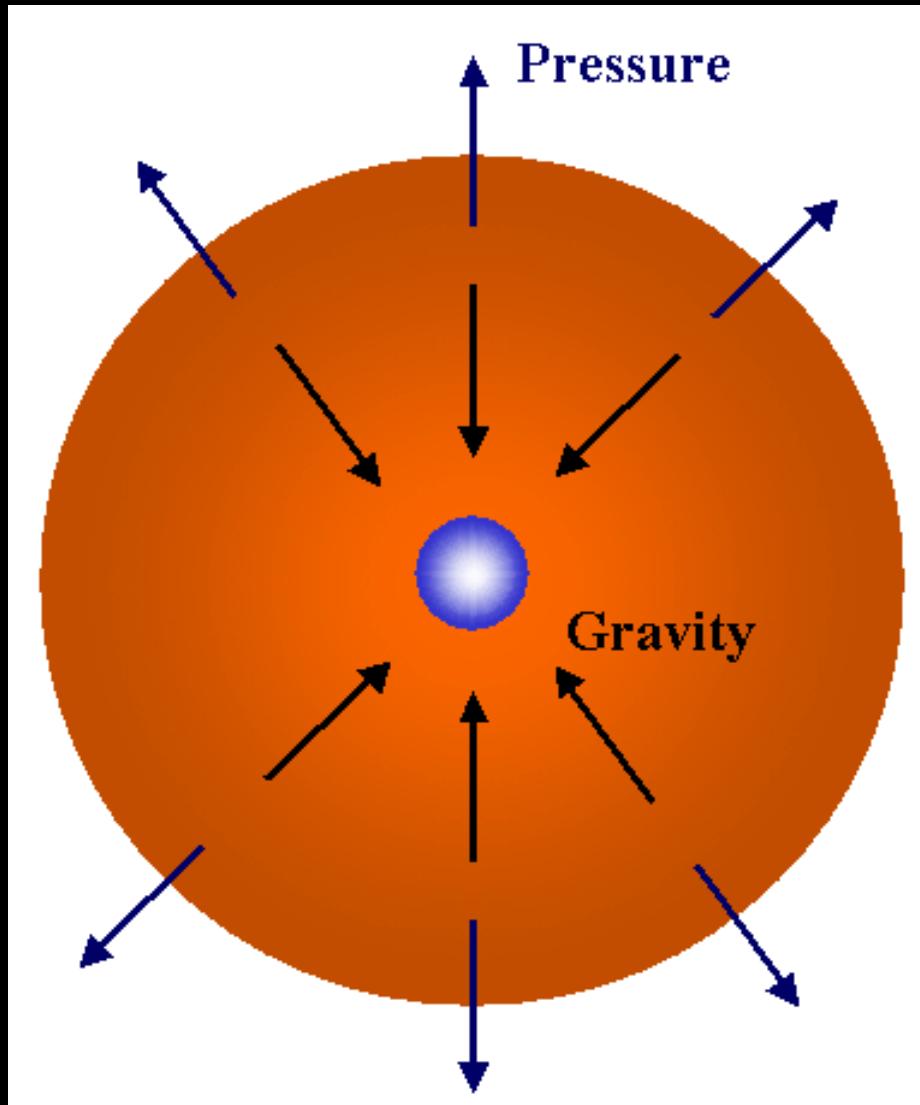
Forming stars

**Pressure
versus
Gravity**

Spectral type (temperature)



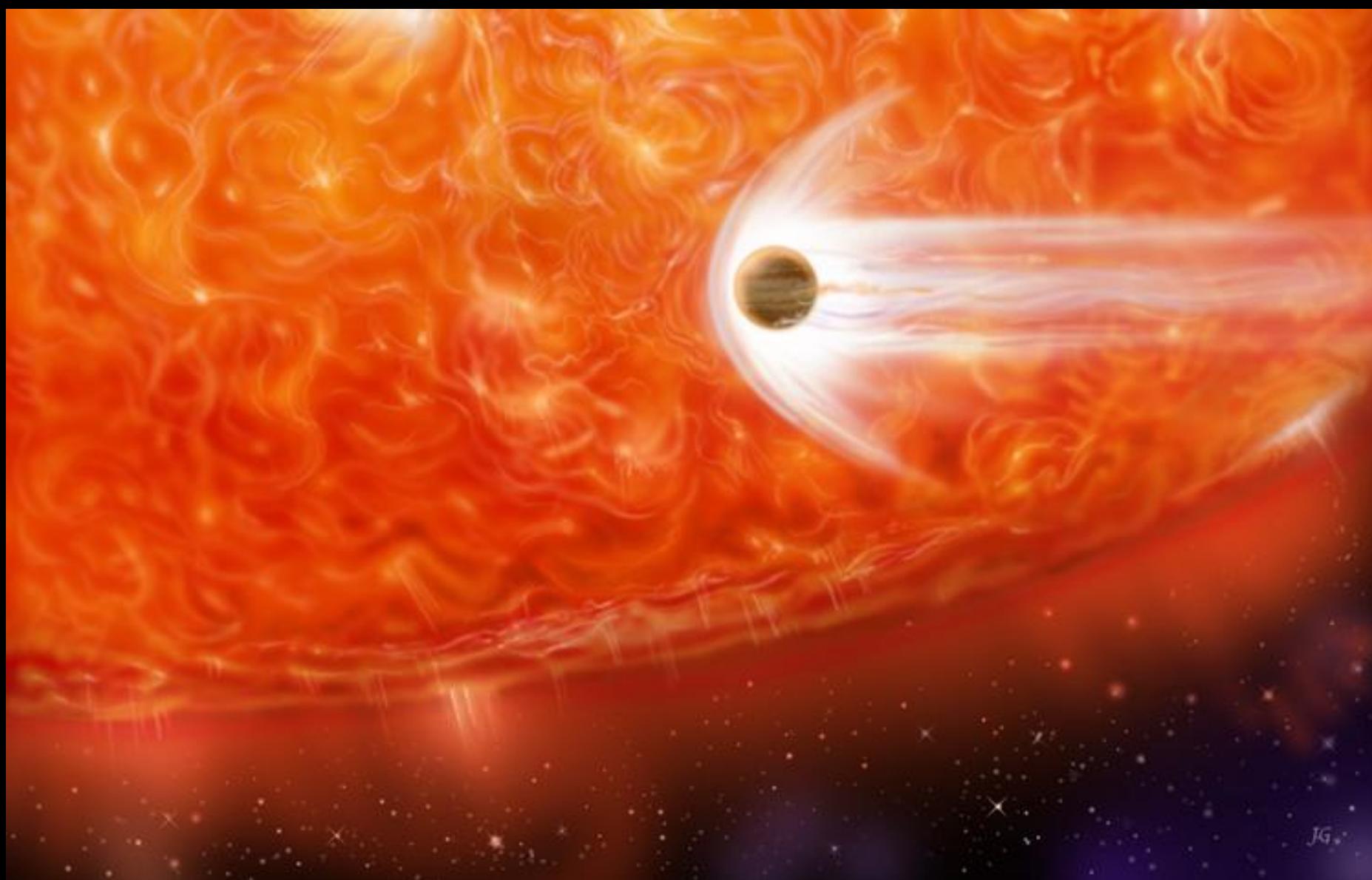
Hydrogen fusion – fuelling a star's nuclear furnace



$$E = mc^2$$

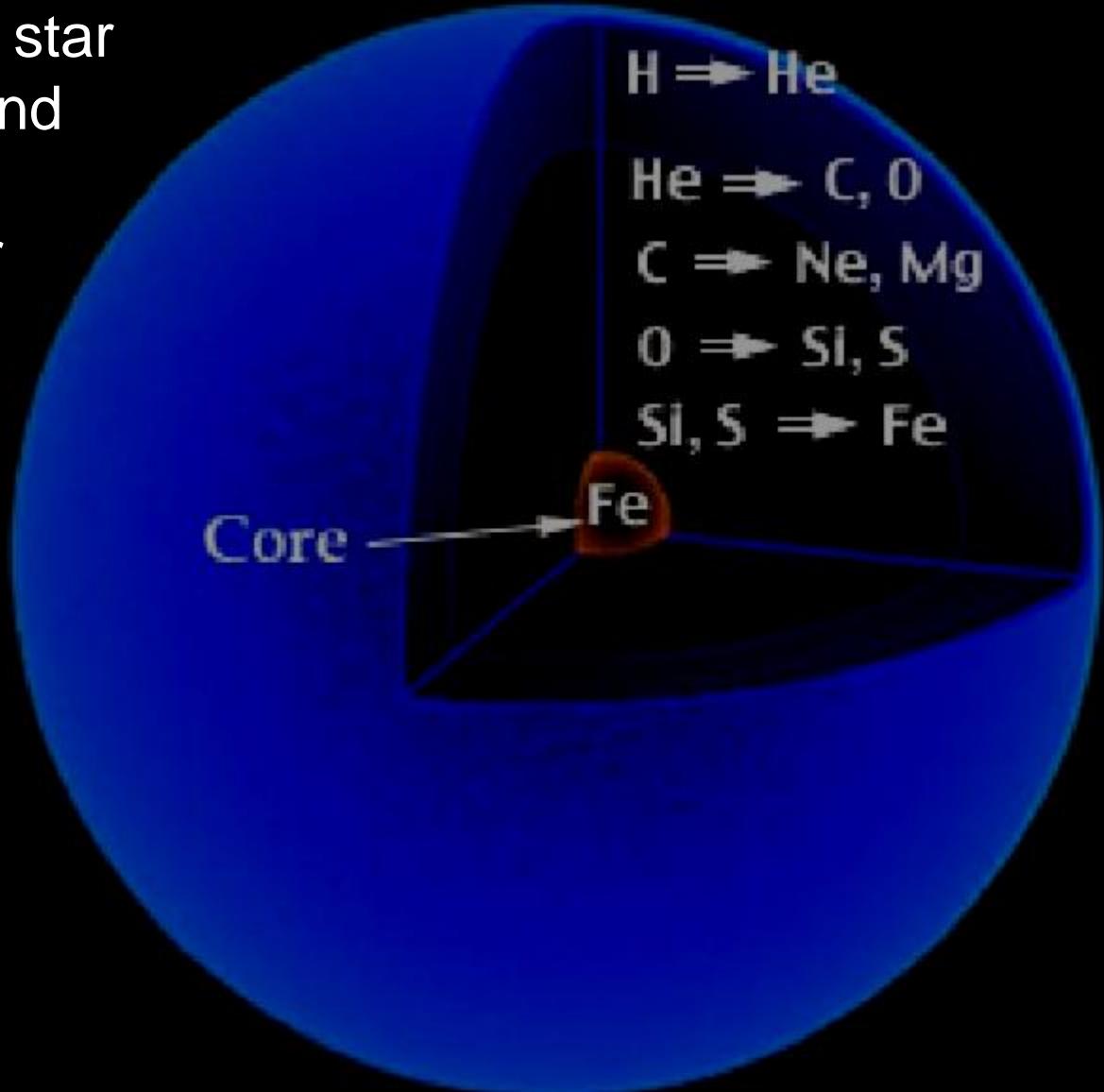
Speed of light



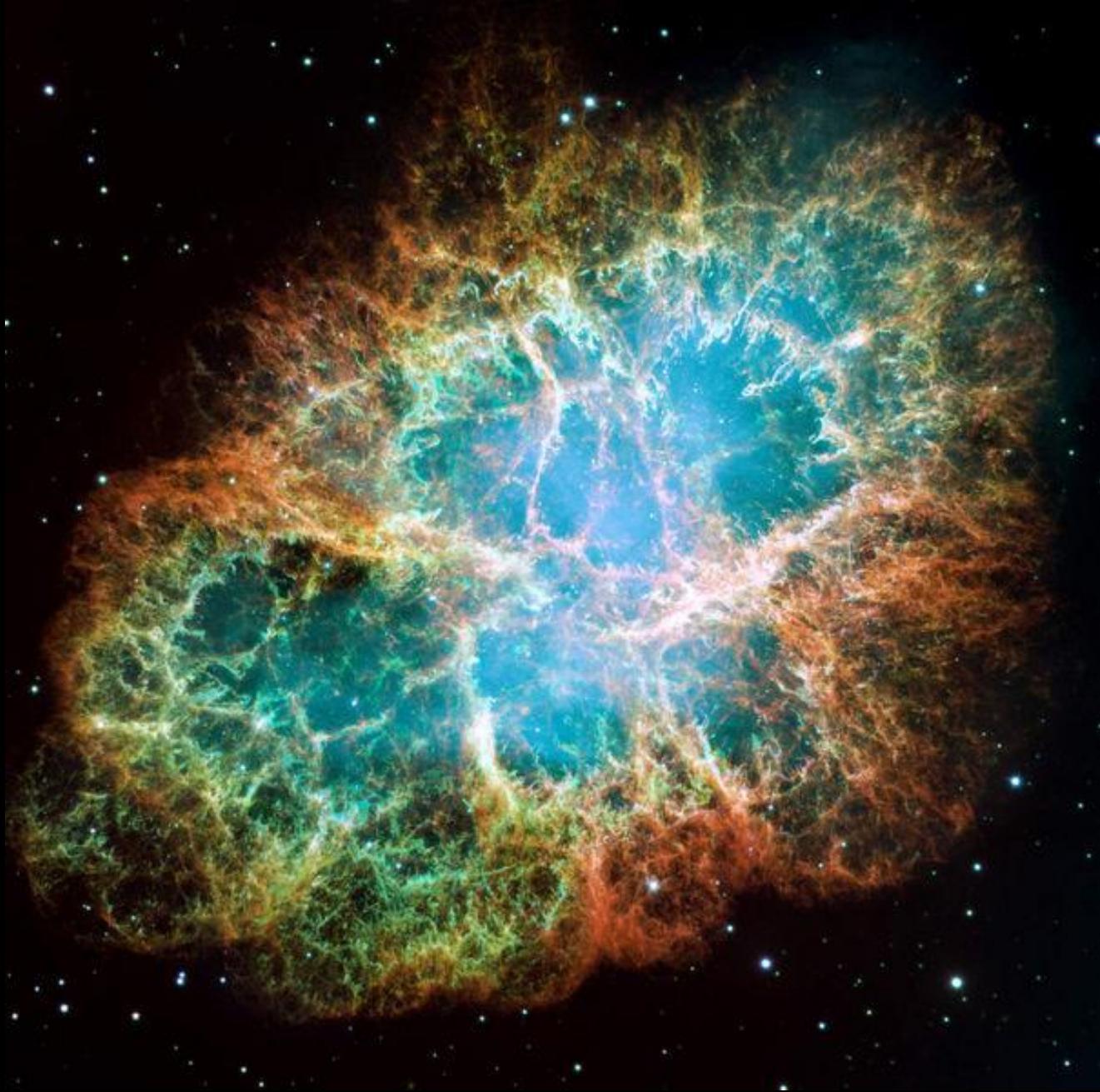


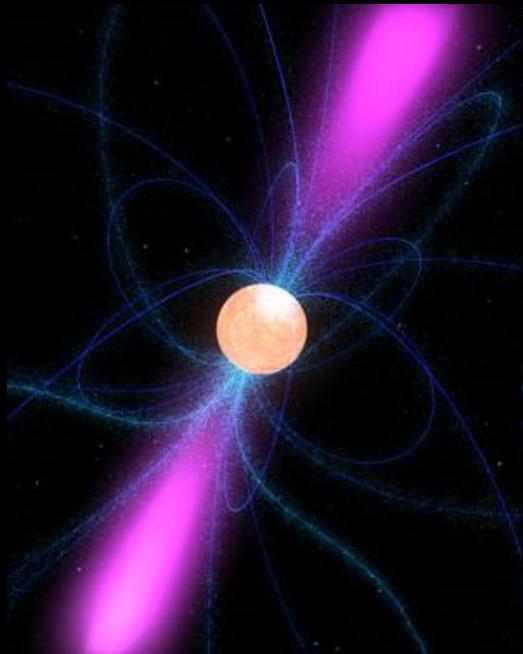


Inside a very massive star
conditions are hot and
dense enough to
fuse even heavier
elements,
all the way up
to **Iron**

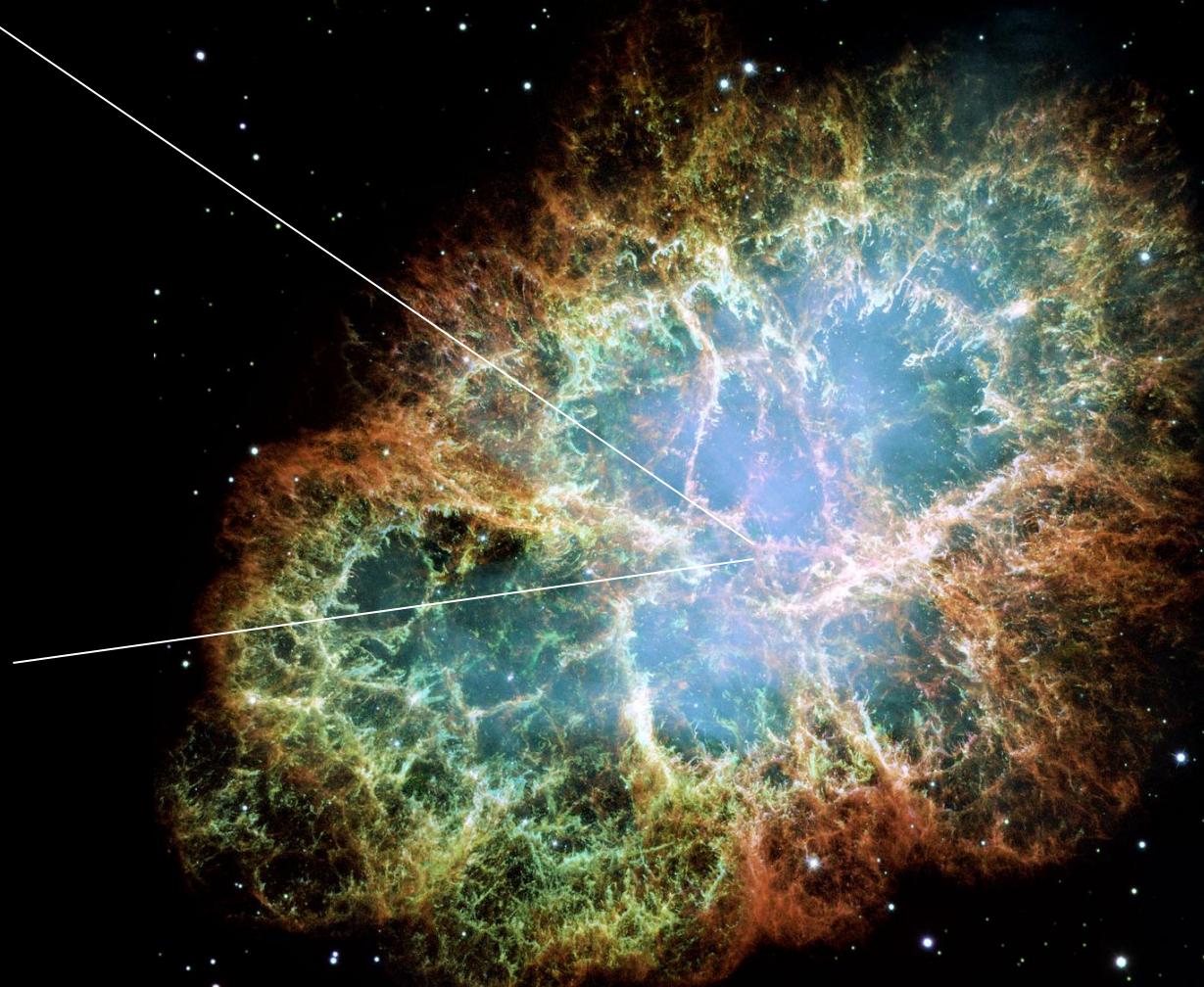




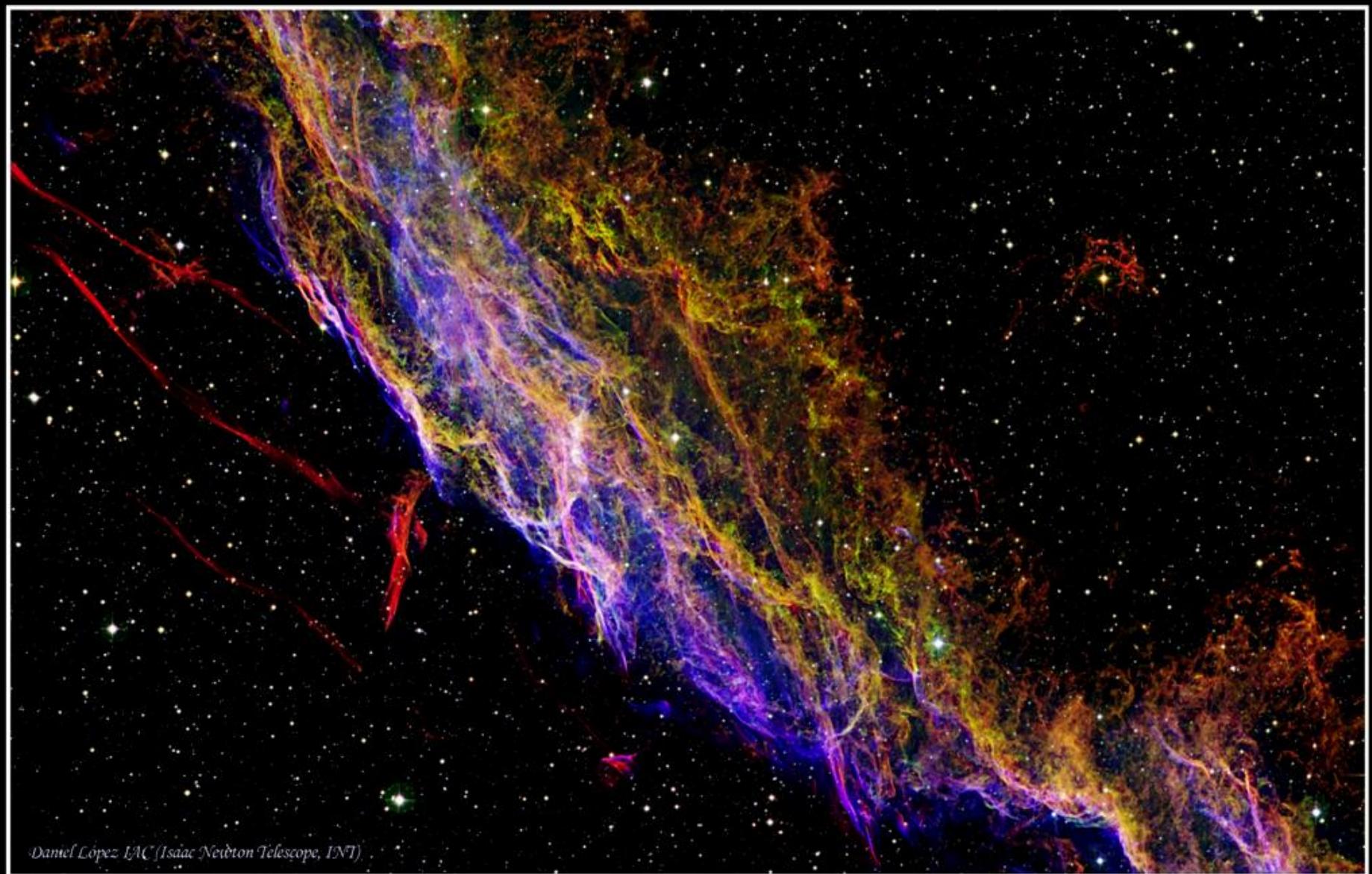




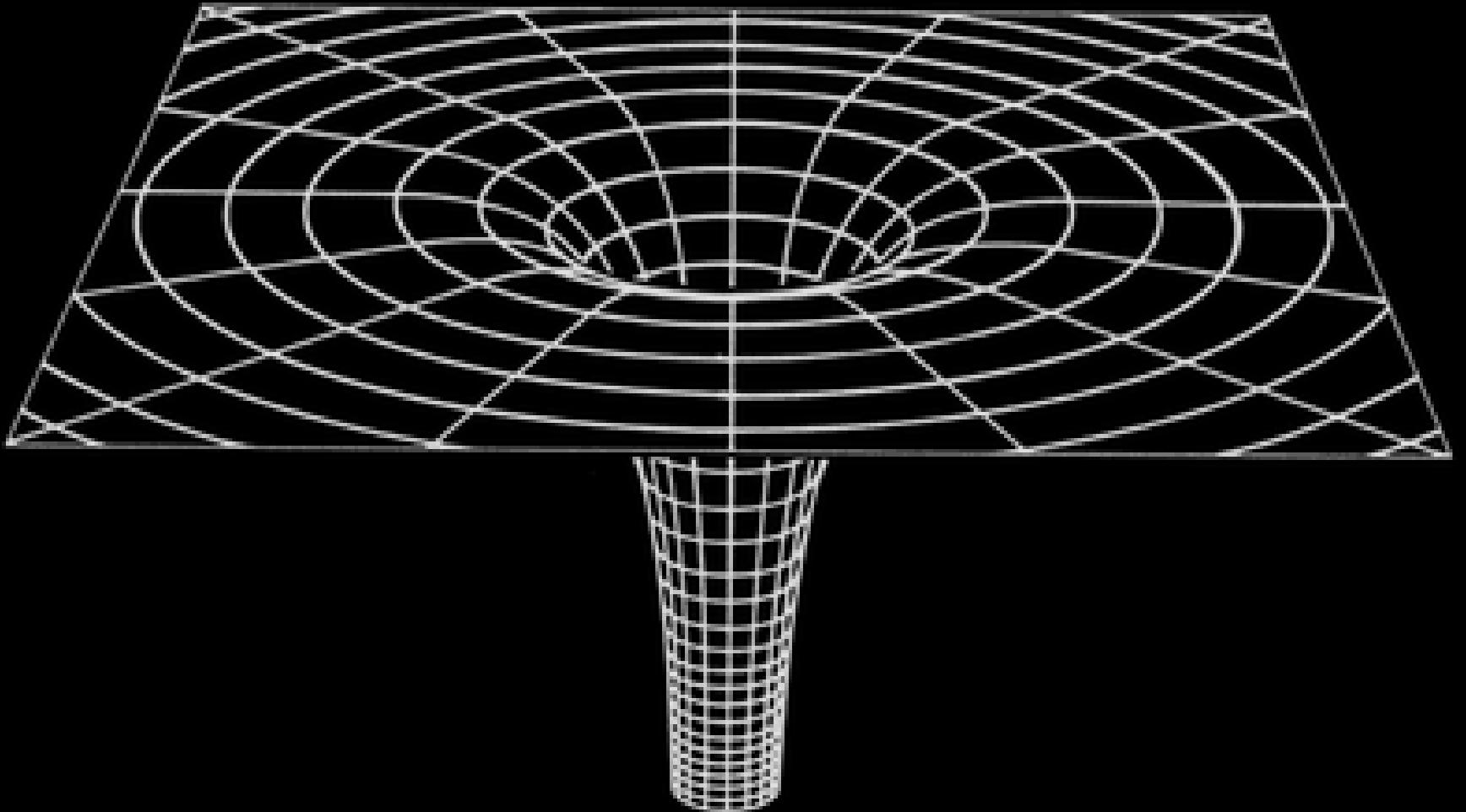
↔
10 km

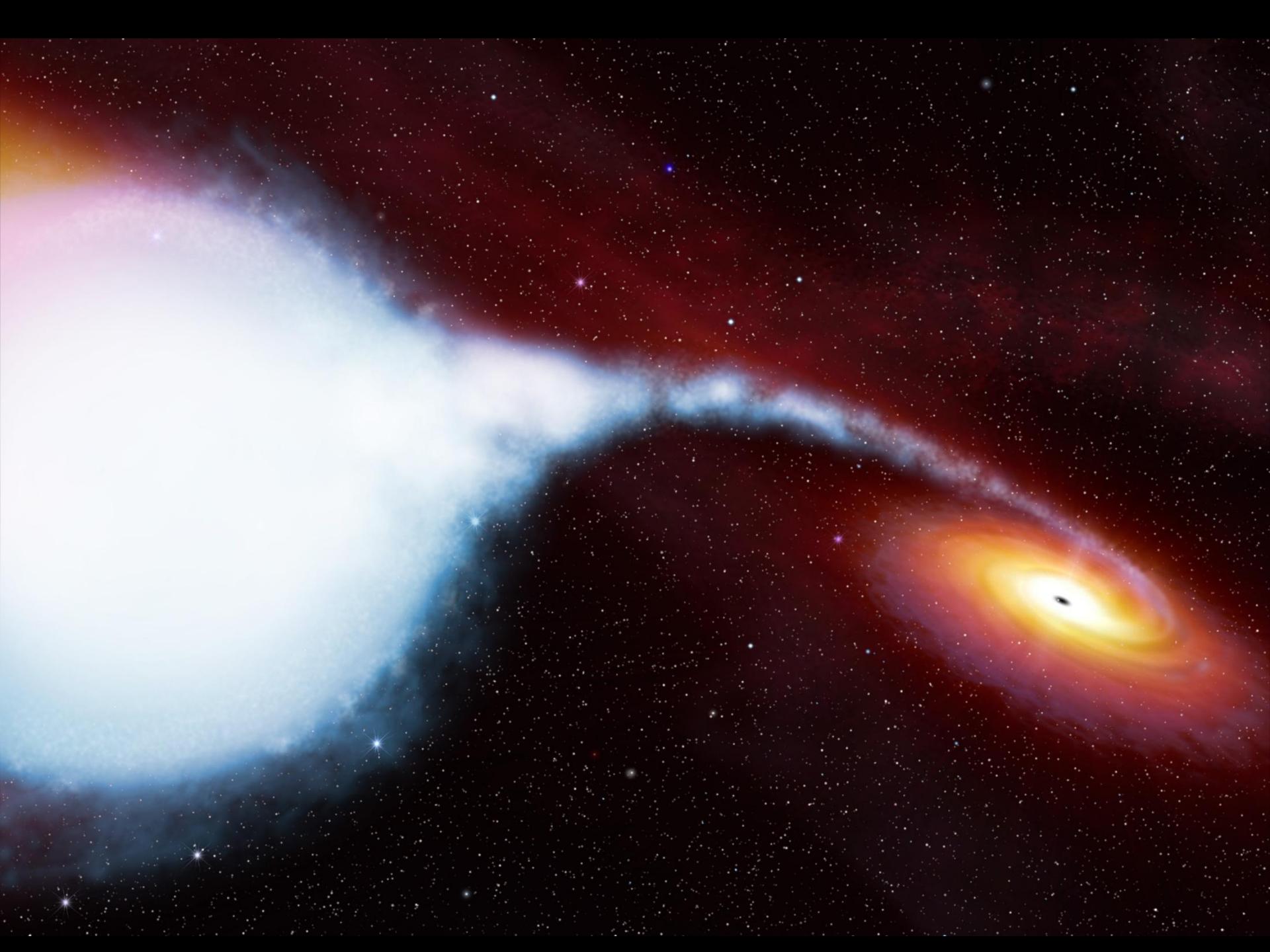


↔
10 light years



Daniel López LAC/Isaac Newton Telescope, INT





Periodic Table of Elements

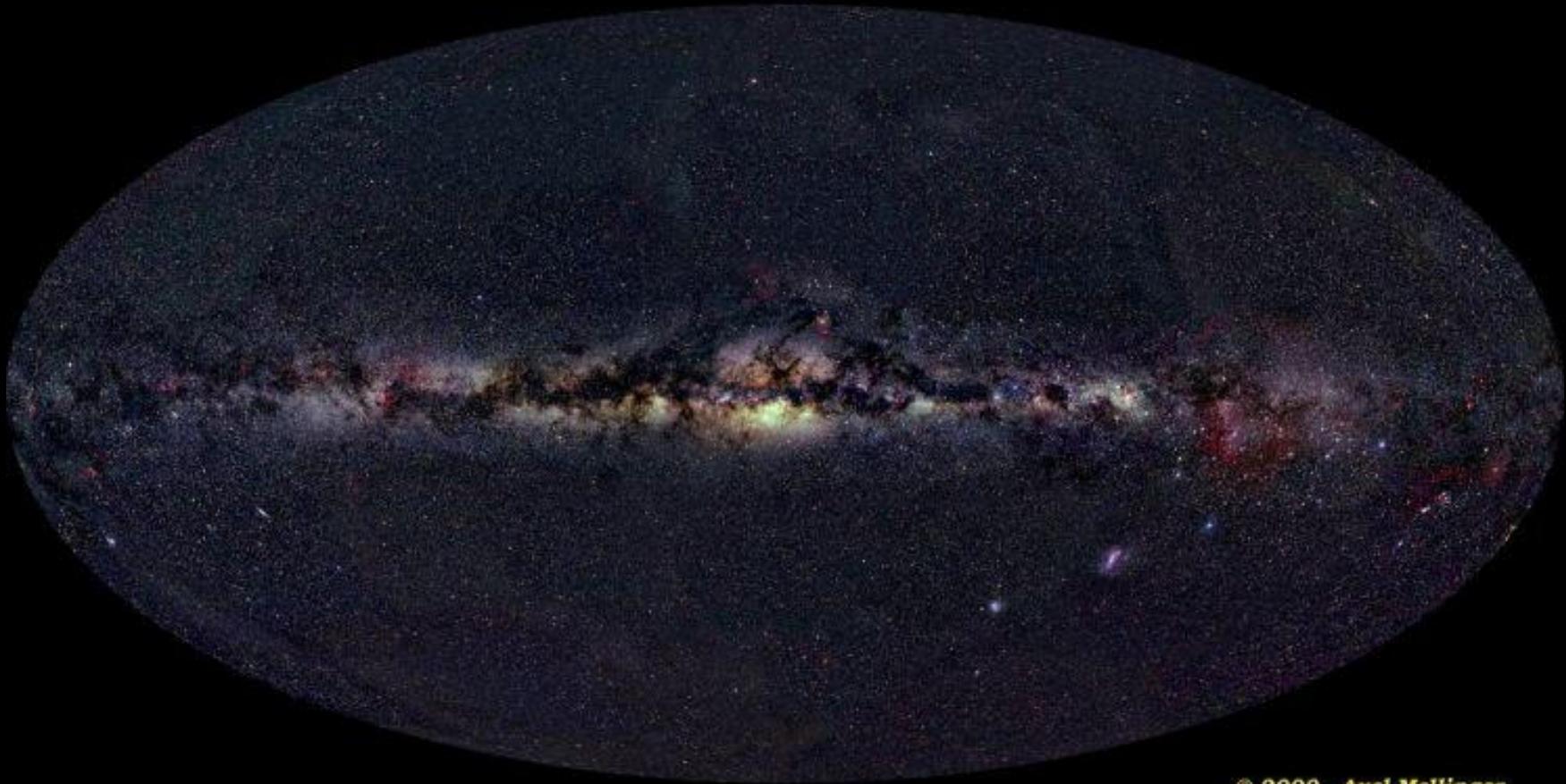
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																											
1 H Hydrogen 1.00794	1 He Helium 4.002602	2 Li Lithium 6.941	3 Be Beryllium 9.012182	4 C Solid	5 Hg Liquid	6 H Gas	7 Rf Unknown	8 Metals	9 Lanthanoids	10 Transition metals	11 Poor metals	12 Nonmetals	13 Other nonmetals	14 Noble gases	15 K Krypton 20.1797	16 Ar Argon 39.948	17 Cl Chlorine 35.453	18 Ne Neon 20.1797																																																																										
11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050	13 Al Aluminum 26.9815388	14 Si Silicon 28.0855	15 P Phosphorus 30.973782	16 S Sulfur 32.0855	17 Cl Chlorine 35.453	18 Ar Argon 39.948	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9981	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.548	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.95	35 Br Bromine 79.904	36 Kr Krypton 83.798	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8882	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Antimony 118.710	51 Sb Stibium 121.750	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293	55 Cs Cesium 132.9054519	56 Ba Barium 137.327	57 Hf Hafnium 178.49	58 Ta Tantalum 180.9788	59 W Tungsten 183.84	60 Re Rhenium 186.207	61 Os Osmium 190.23	62 Ir Iridium 192.217	63 Pt Platinum 195.084	64 Au Gold 196.986569	65 Hg Mercury 200.59	66 Tl Thallium 204.3833	67 Pb Lead 207.2	68 Bi Bismuth 208.98040	69 Po Polonium (208.9871)	70 At Astatine (209.9871)	71 Rn Radon (222.0176)	72 La Lanthanum 138.90547	73 Ce Cerium 140.116	74 Pr Praseodymium 140.90765	75 Nd Neodymium 144.242	76 Pm Promethium 145	77 Sm Samarium 150.35	78 Eu Europium 151.904	79 Gd Gadolinium 157.25	80 Tb Terbium 158.92535	81 Dy Dysprosium 162.500	82 Ho Holmium 164.93032	83 Er Erbium 167.259	84 Tm Thulium 168.93421	85 Yb Ytterbium 173.054	86 Lu Lutetium 174.9668	87 Fr Francium (223)	88 Ra Radium (226)	89 Rf Rutherfordium (261)	90 Db Dubnium (262)	91 Sg Seaborgium (266)	92 Bh Bohrium (264)	93 Hs Hassium (277)	94 Mt Meitnerium (265)	95 Ds Damaskosium (271)	96 Rg Roentgenium (272)	97 Uub Ununbium (285)	98 Uut Ununquadium (284)	99 Uup Ununtrium (285)	100 Uuh Ununhexium (286)	101 Uus Ununseptium (294)	102 No Nobelium (259)	103 Lr Lawrencium (262)
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																																																																																												

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57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium 145	62 Sm Samarium 150.35	63 Eu Europium 151.904	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668	72 Ac Actinium (227)	73 Th Thorium 232.03608	74 Pa Protactinium 231.03588	75 U Uranium 238.02891	76 Np Neptunium (237)	77 Pu Plutonium (244)	78 Am Americium (243)	79 Cm Curium (247)	80 Bk Berkelium (247)	81 Cf Californium (251)	82 Es Einsteinium (252)	83 Fm Fermium (258)	84 Md Mendelevium (259)	85 No Nobelium (259)	86 Lr Lawrencium (262)
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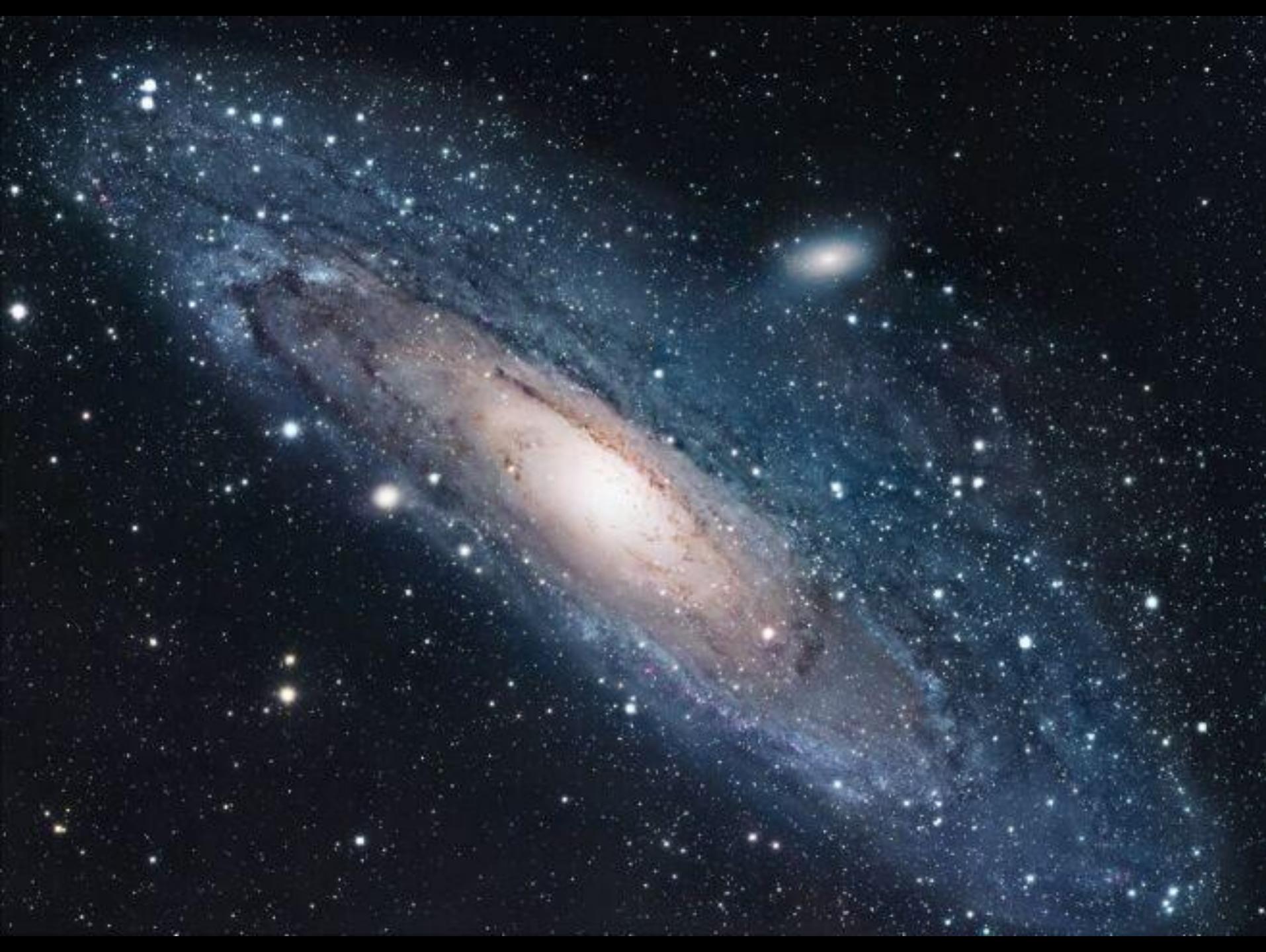
3. The Milky Way and other galaxies



© 2000, Axel Mellinger









Colliding Galaxies NGC 4038 and NGC 4039

PRC97-34a • ST Scl OPO • October 21, 1997 • B, Whitmore (ST Scl) and NASA

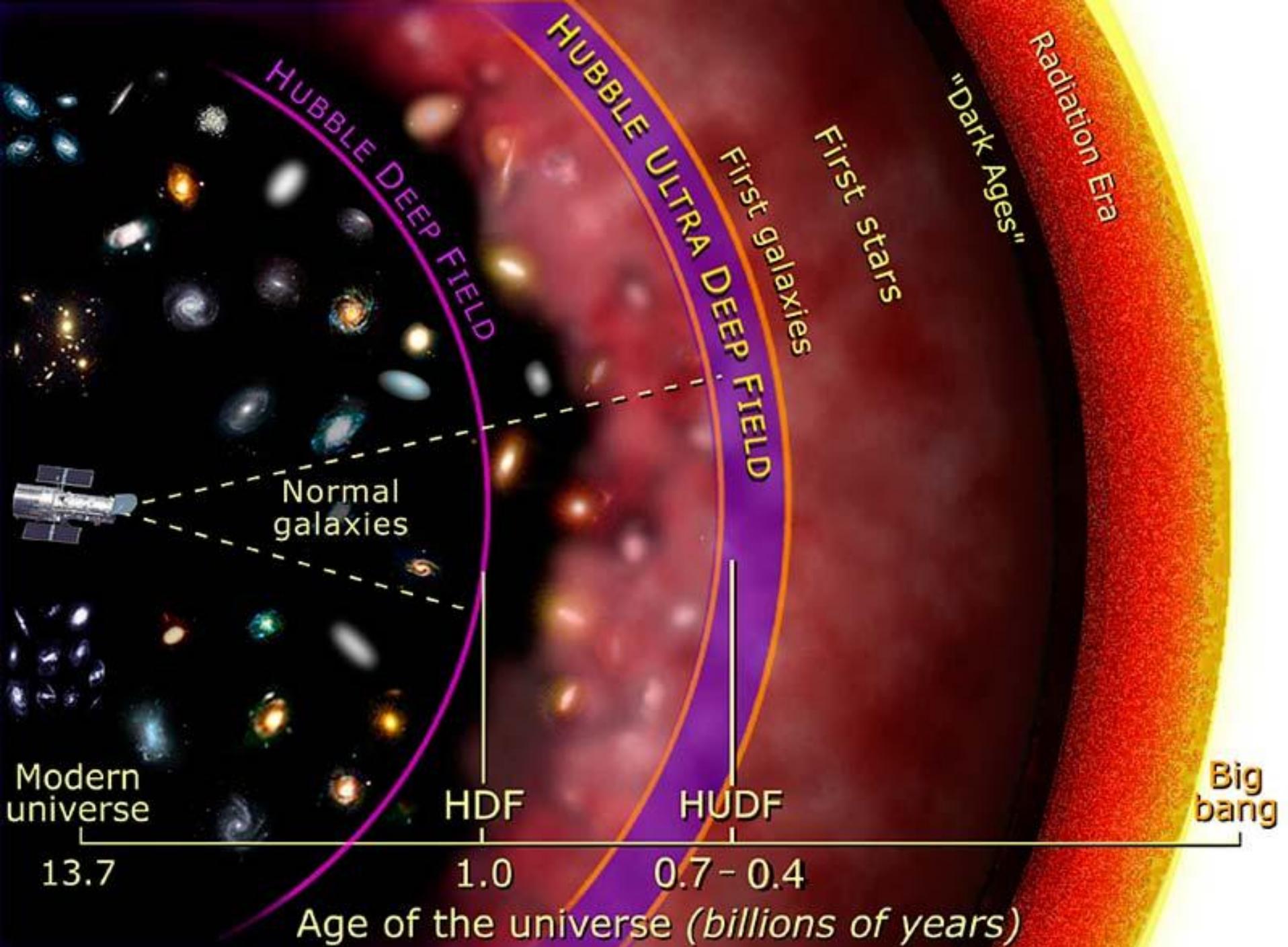
HST • WFPC2

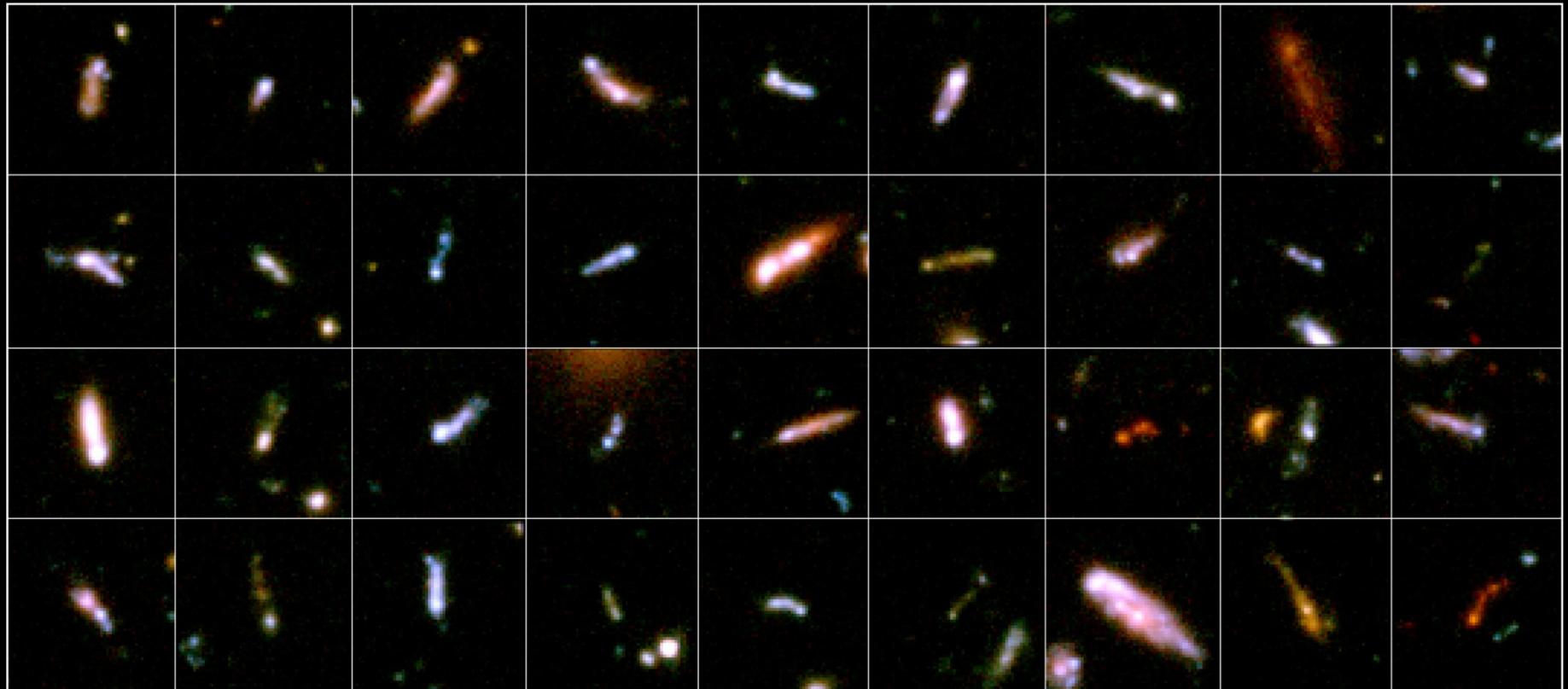
Galaxies NGC 2207 and IC 2163



Hubble
Heritage

A long time ago,
in a galaxy far, far away...

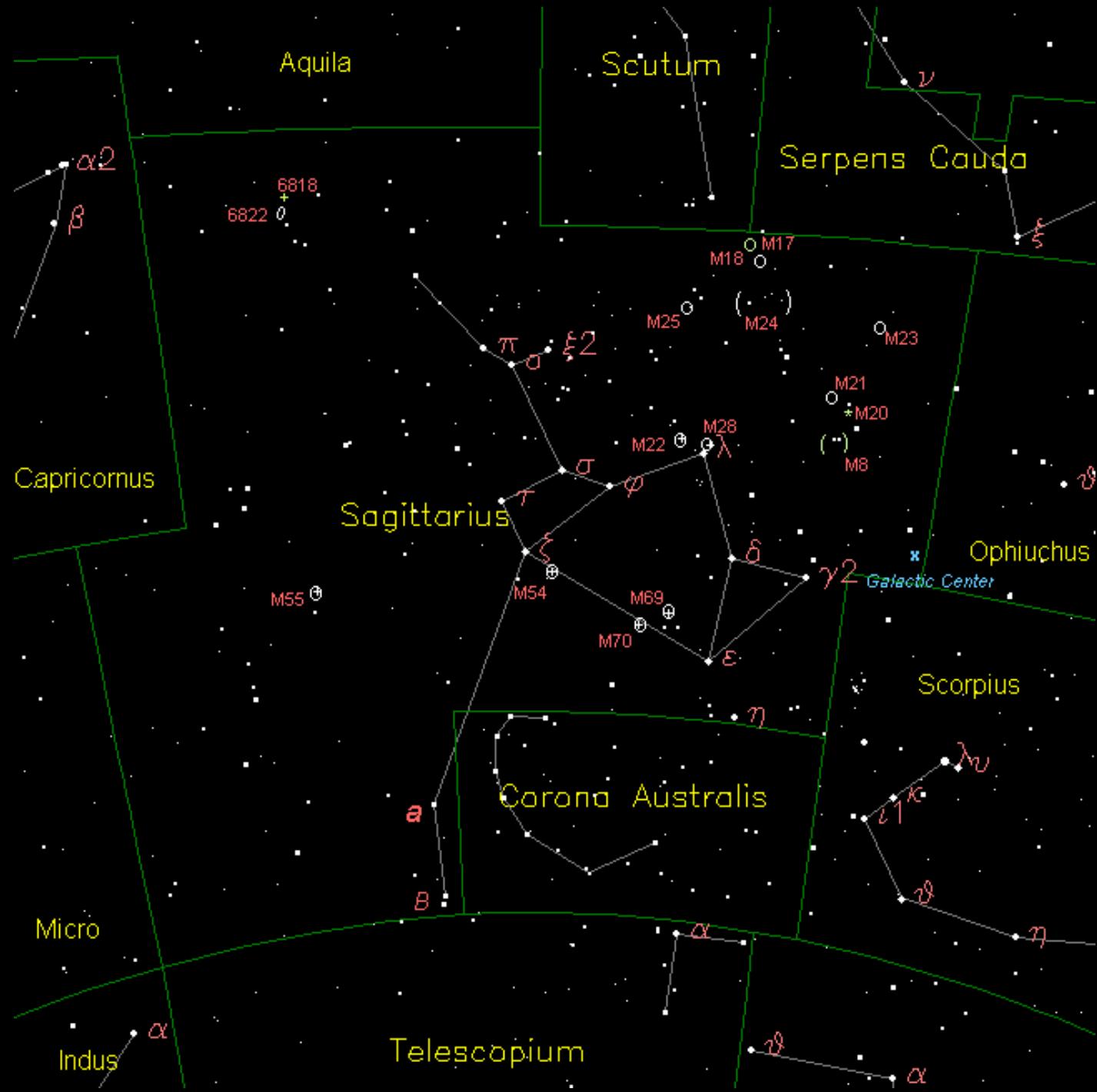


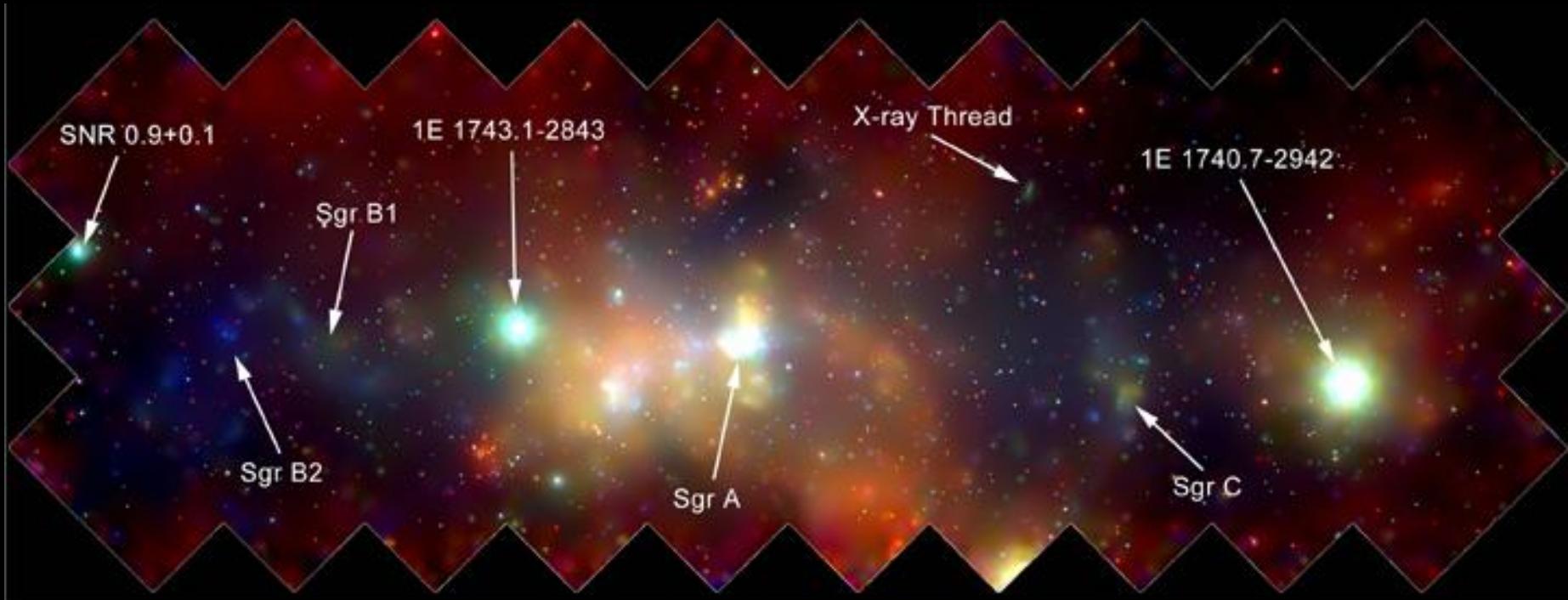
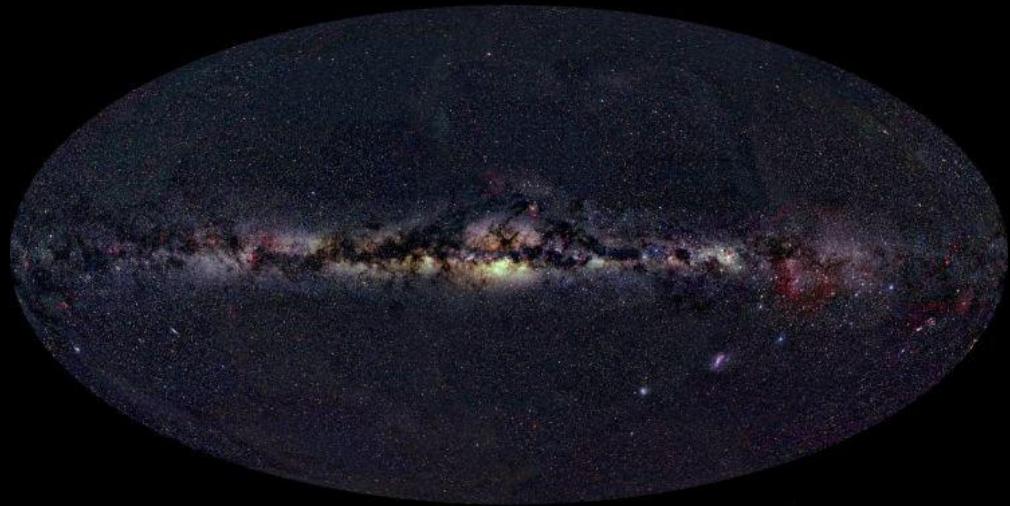


“Tadpole” Galaxies in the Hubble Ultra Deep Field
Hubble Space Telescope ■ ACS/WFC

NASA, ESA, A. Straughn, S. Cohen and R. Windhorst (Arizona State University), and the HUDF team (STScI)

STScI-PRC06-04





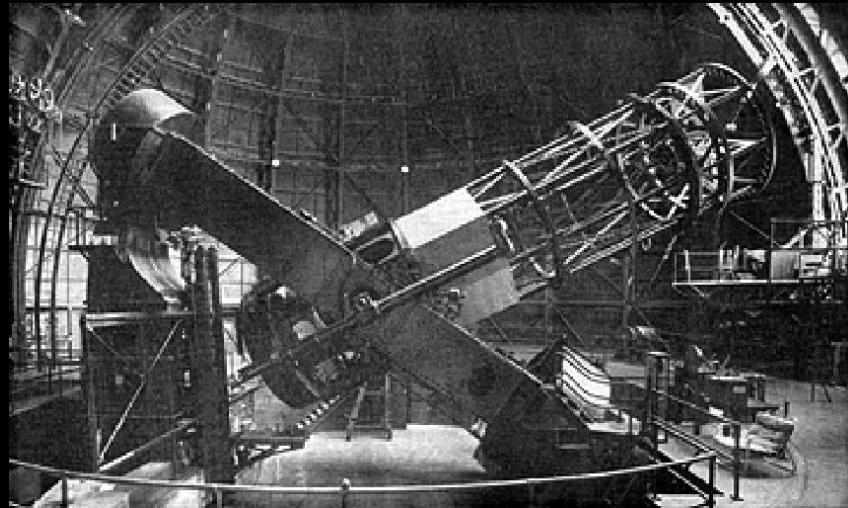




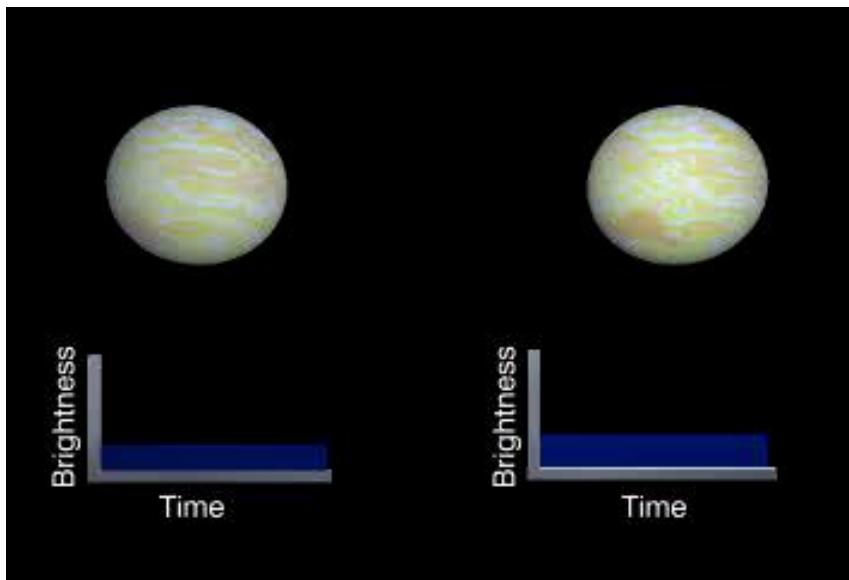
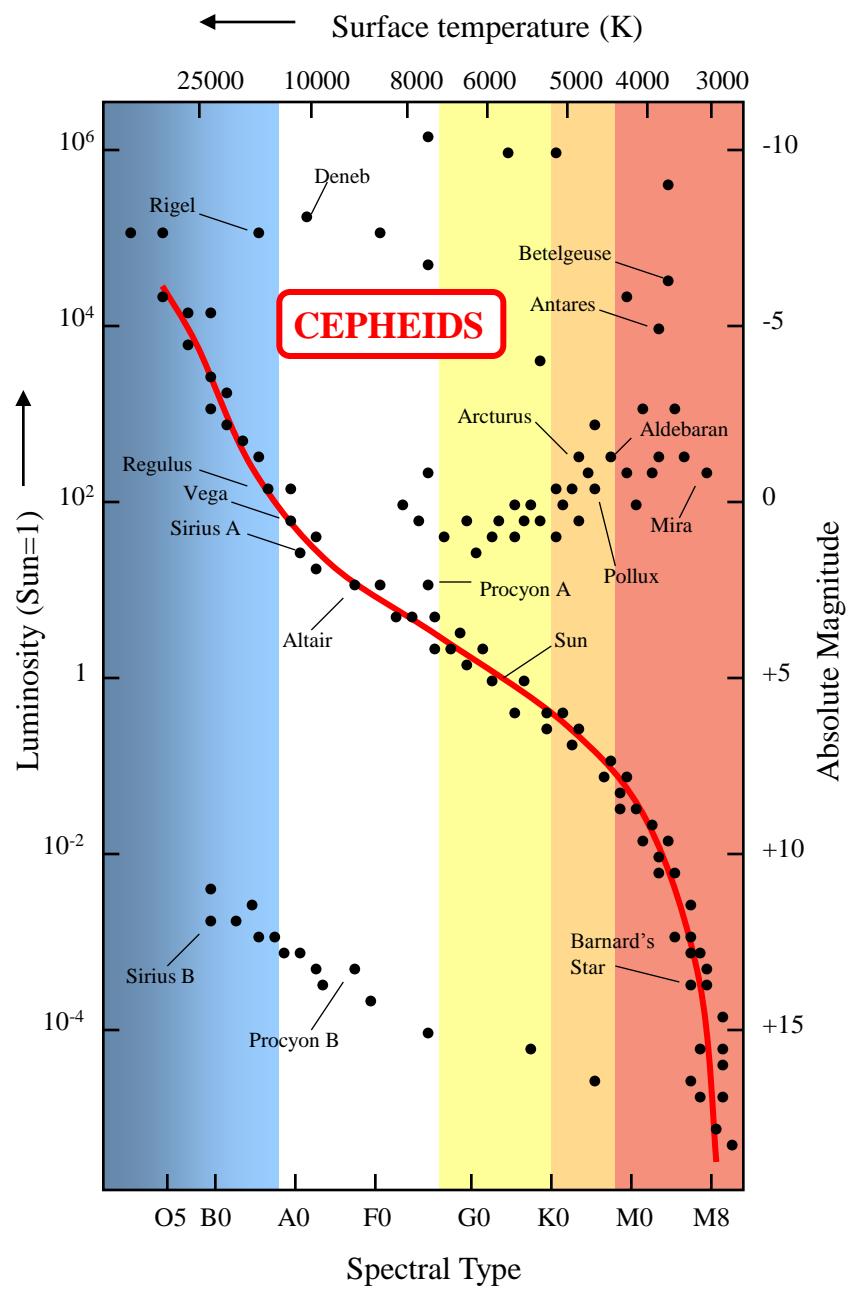


4. The runaway Universe







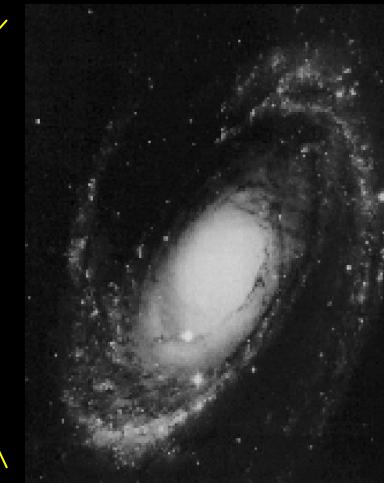
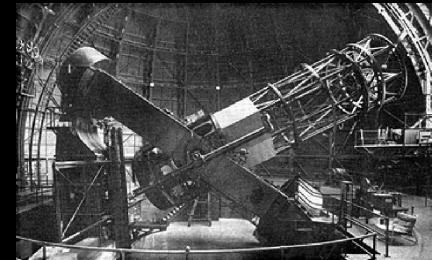




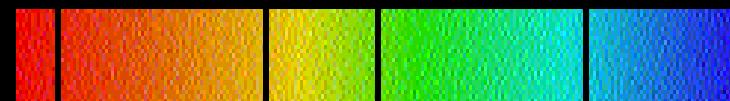




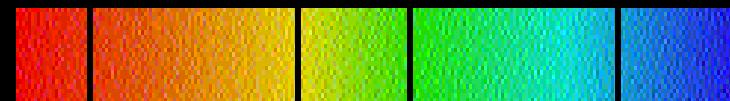
Hubble also measured
a shift in **colour** of
the light from
distant galaxies.



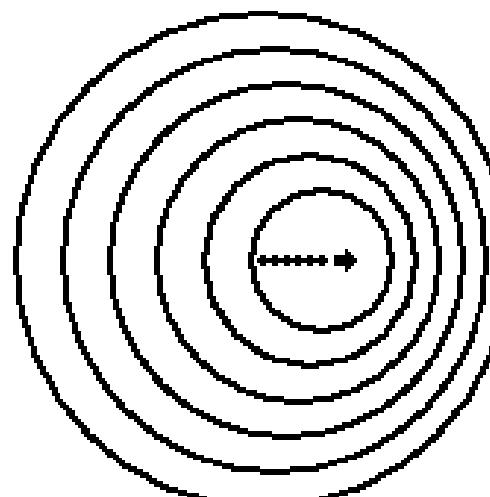
Galaxy



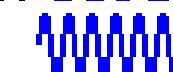
Laboratory



OBJECT RECEDING:
LONG **RED** WAVES



OBJECT APPROACHING:
SHORT **BLUE** WAVES



Hubble's Law

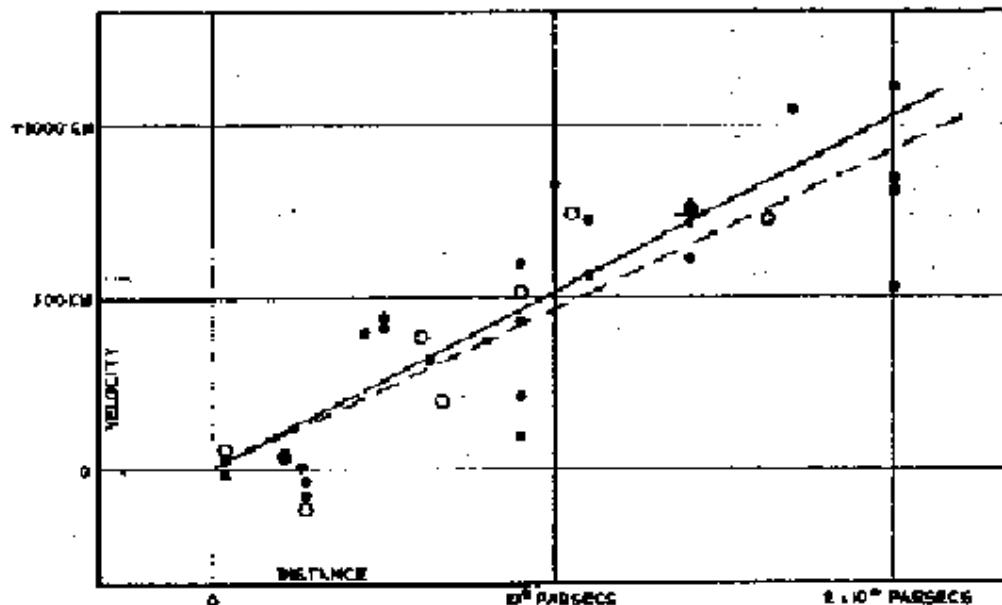
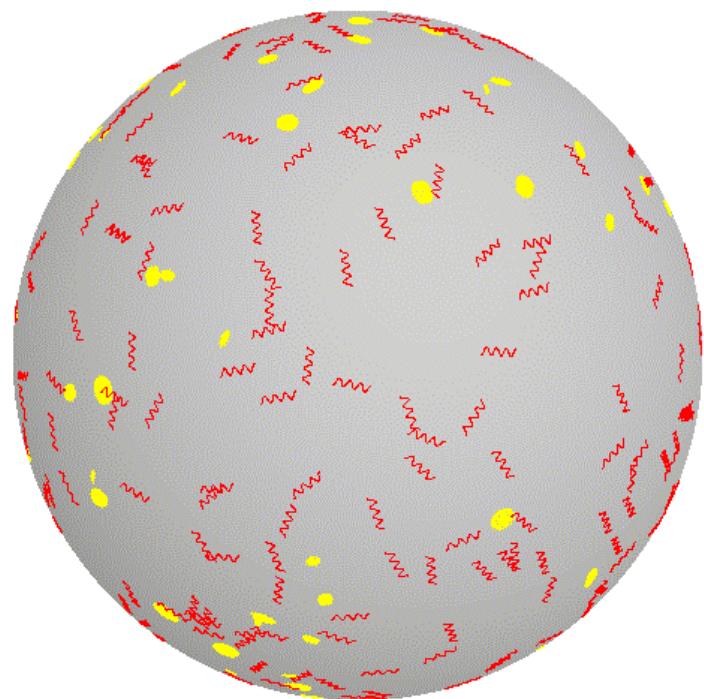
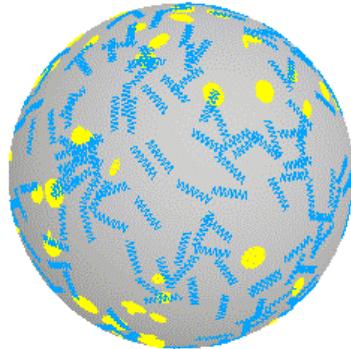
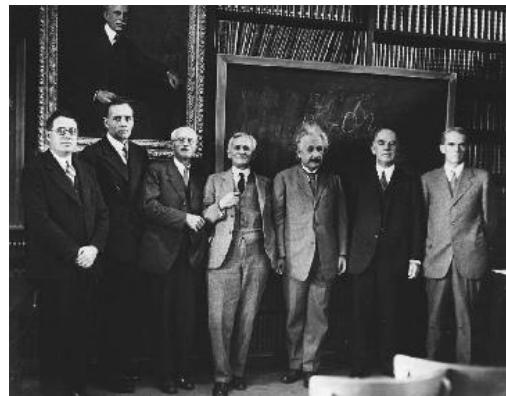


FIGURE 1

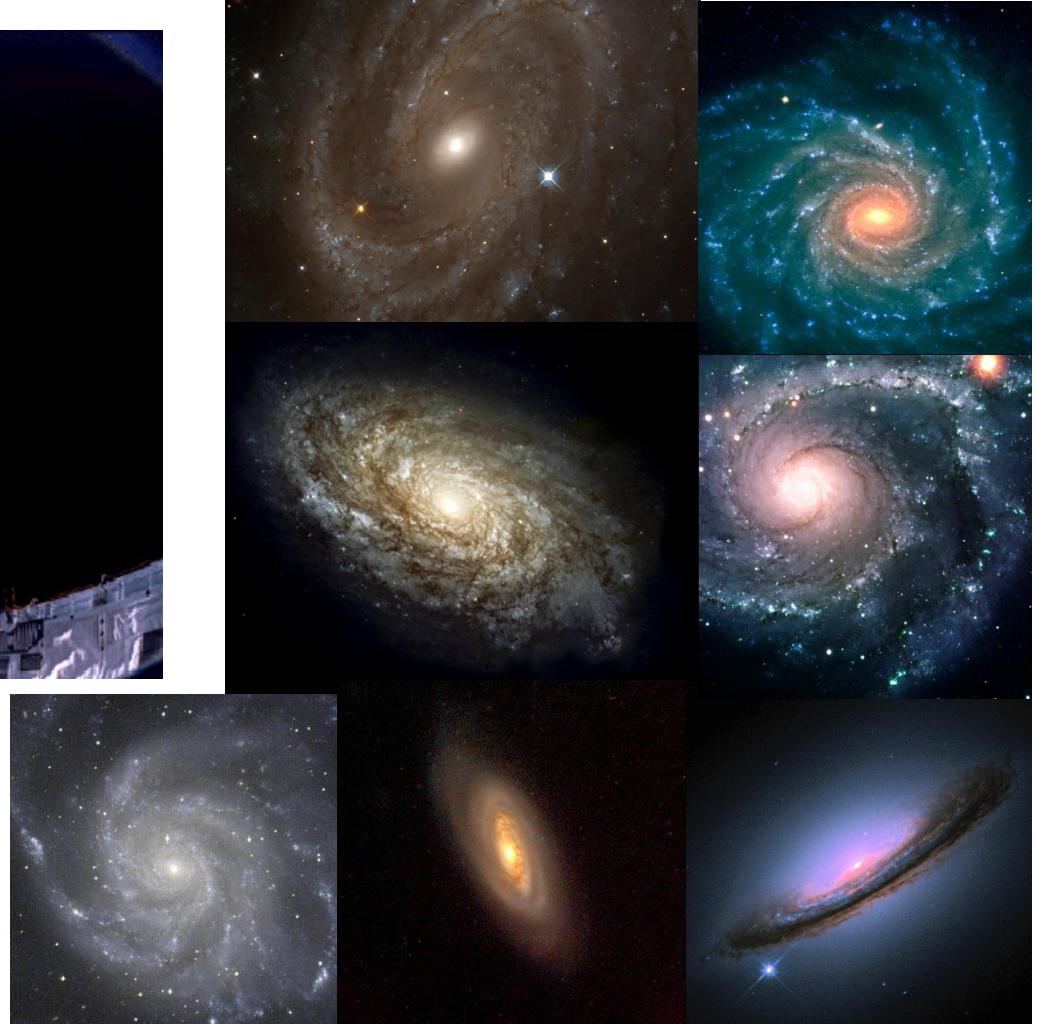


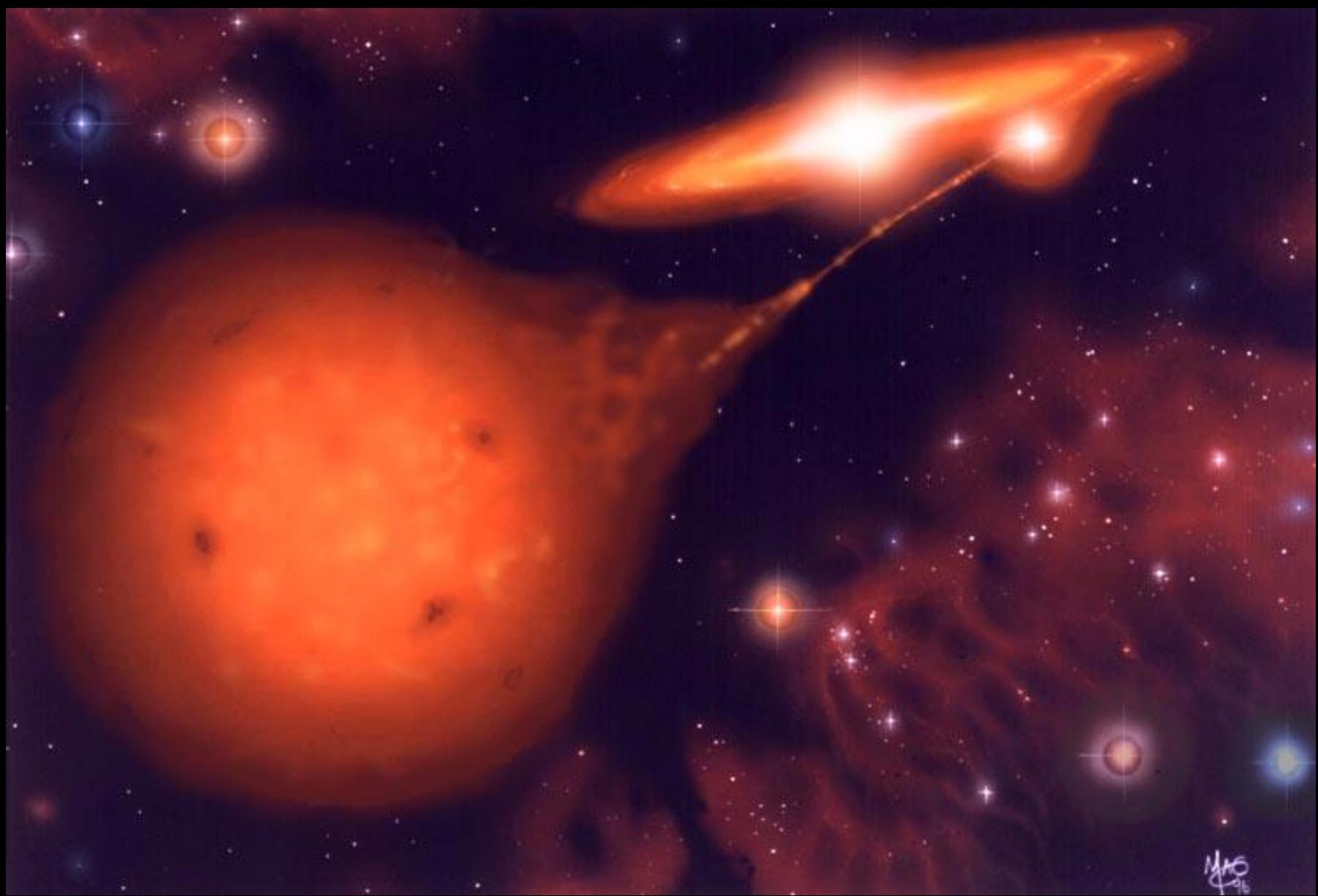
How fast is the Universe expanding?

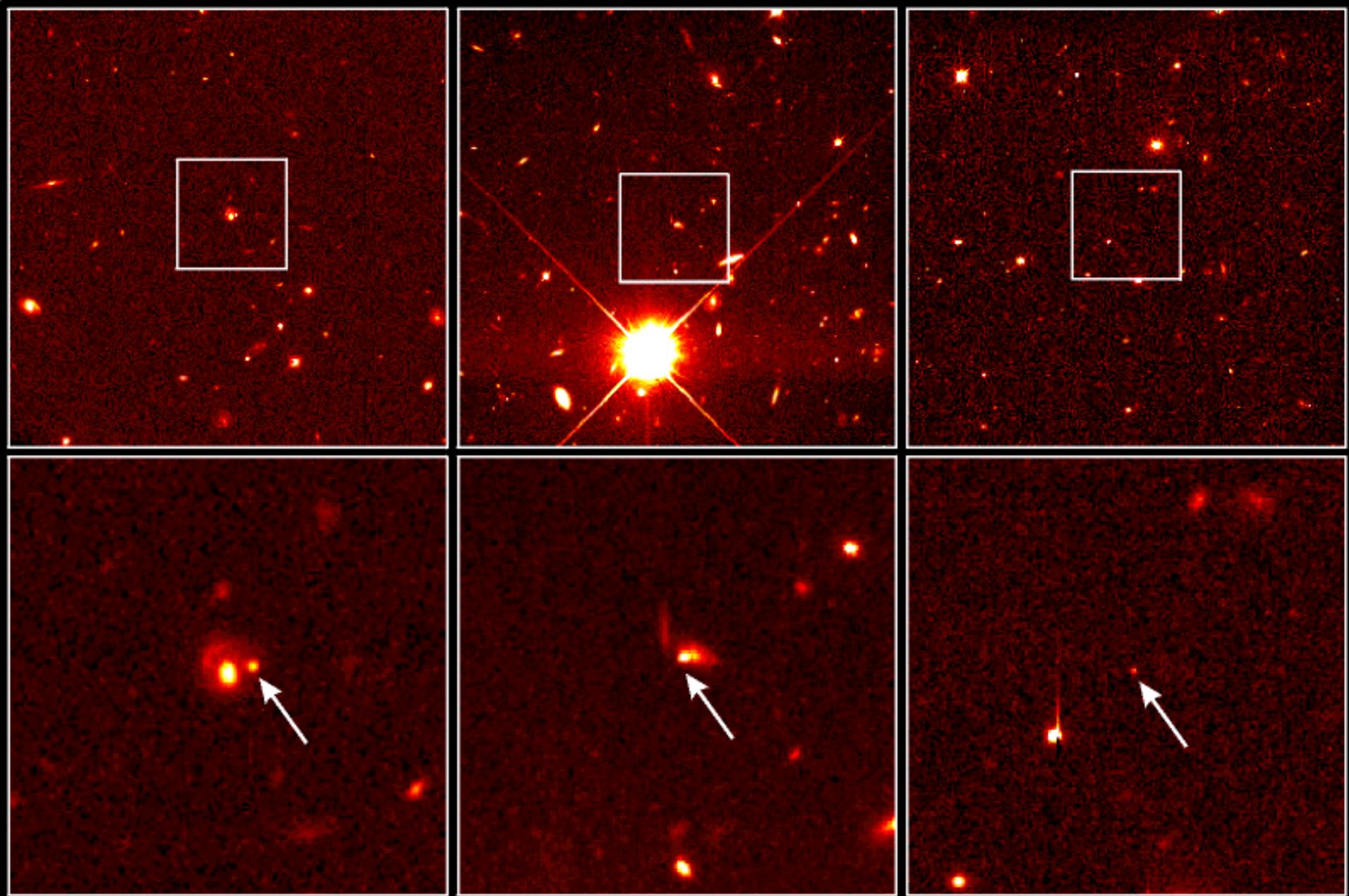


Hubble space Telescope
Key Project: 1990-2000

Cepheid distances to ~30 galaxies, linking to other
standard candles





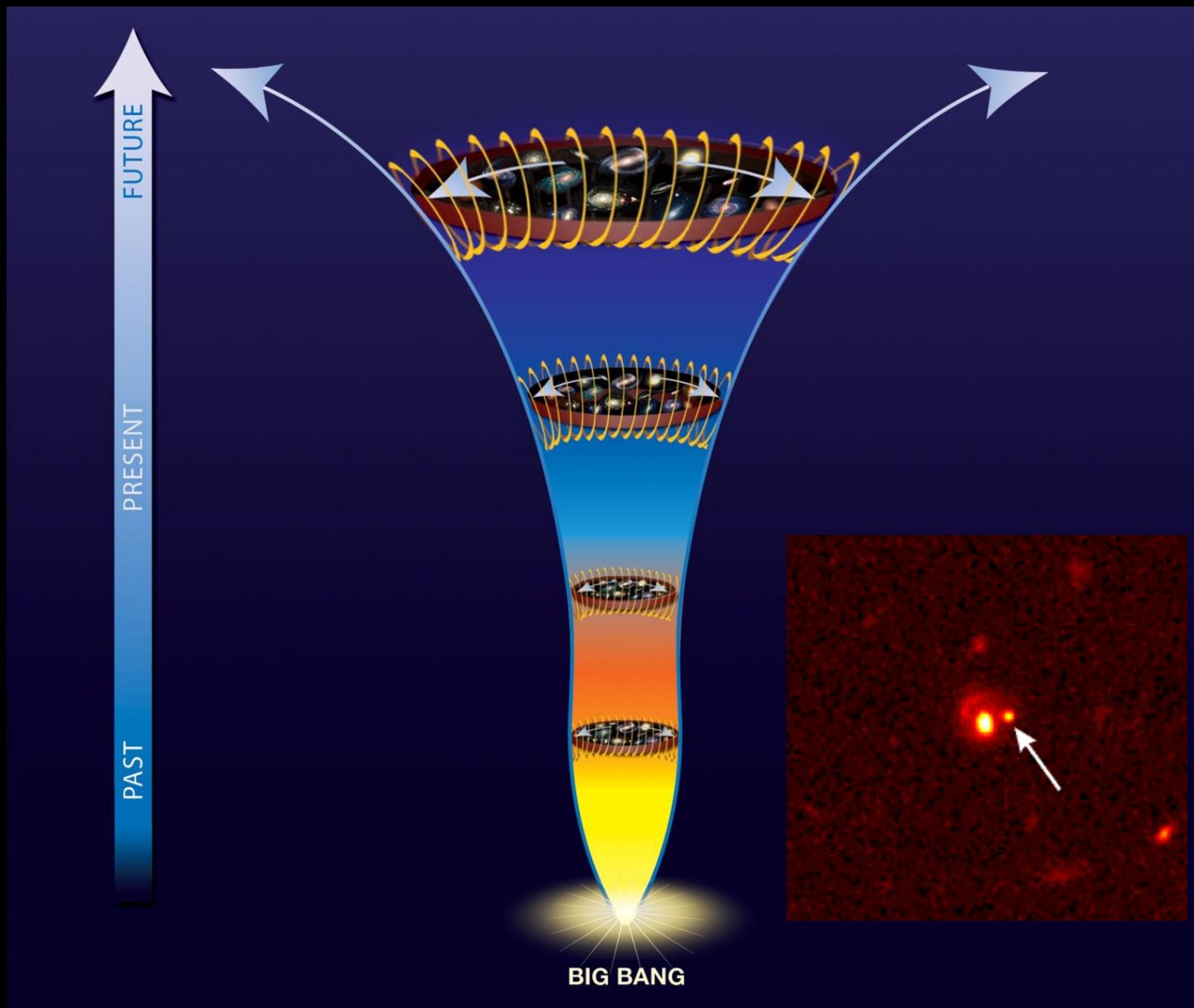


Distant Supernovae

PRC98-02 • January 8, 1998 • ST Scl OPO

P. Garnavich (Harvard-Smithsonian Center for Astrophysics) and NASA

HST • WFPC2



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4 October 2011 Last updated at 11:02

391 Share

Nobel physics prize honours accelerating Universe find

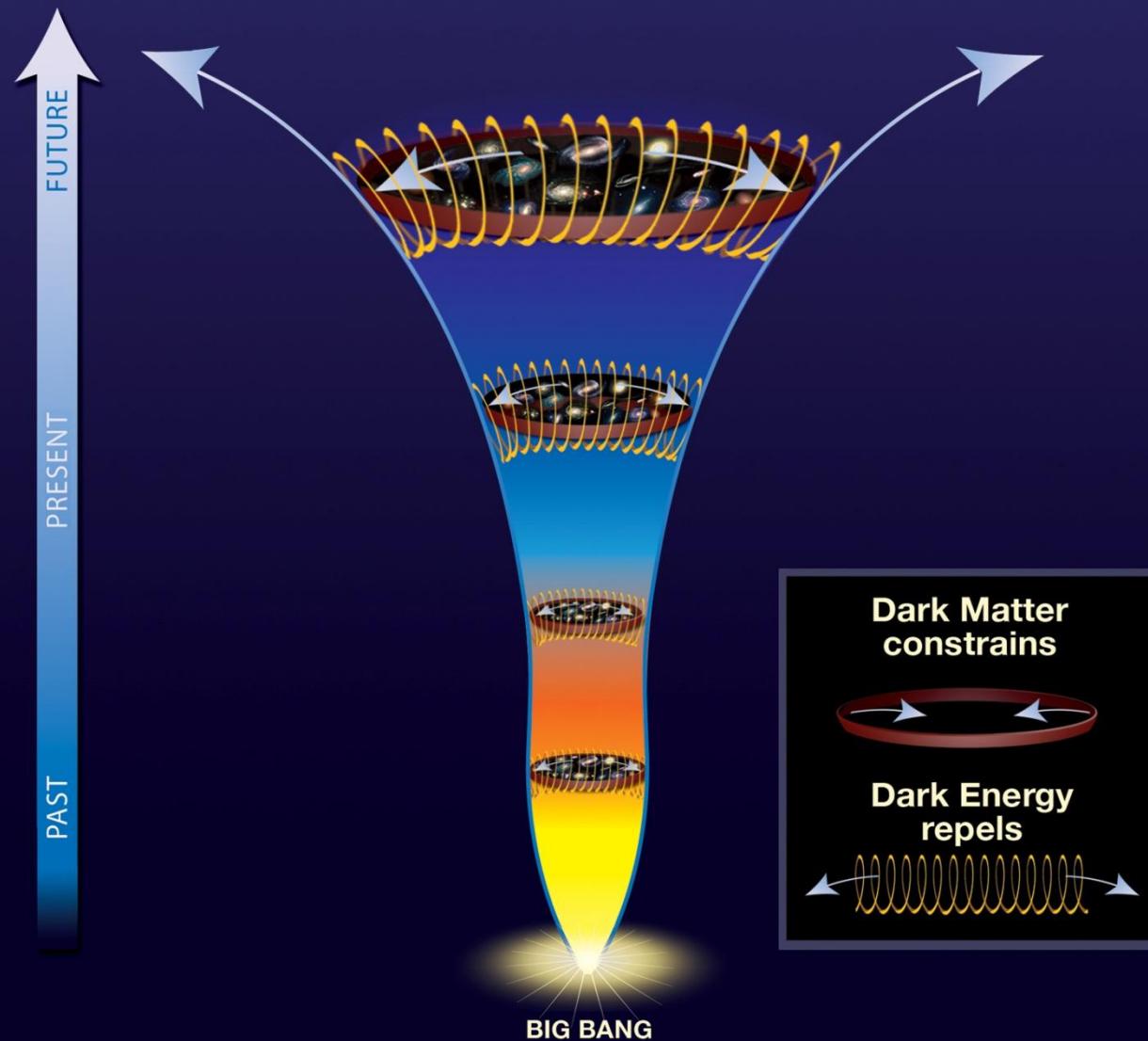


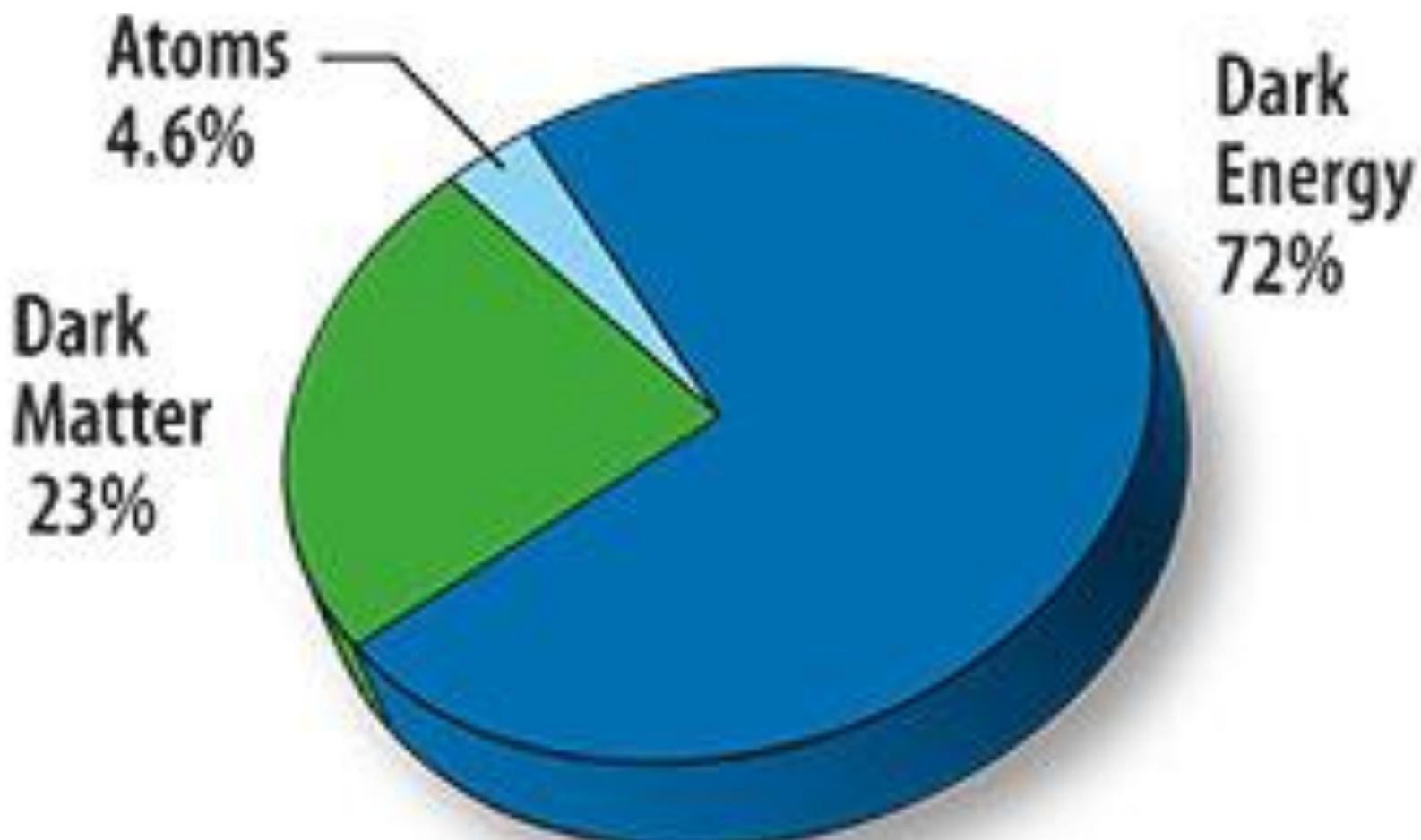
The three researchers' work has led to an expanding knowledge of our Universe



Cosmic tug of war

The force of dark energy surpasses that of dark matter as time progresses.







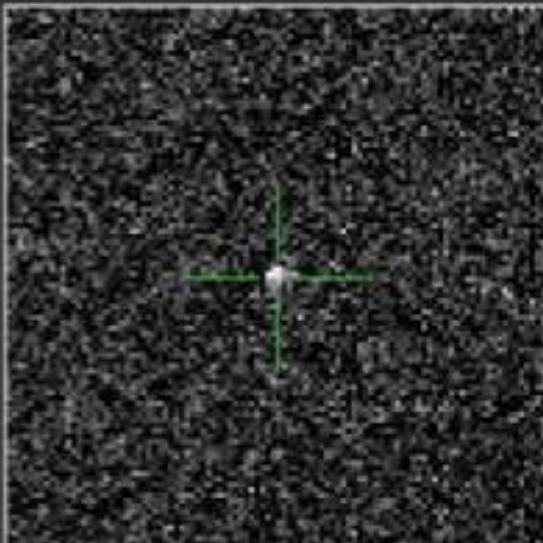
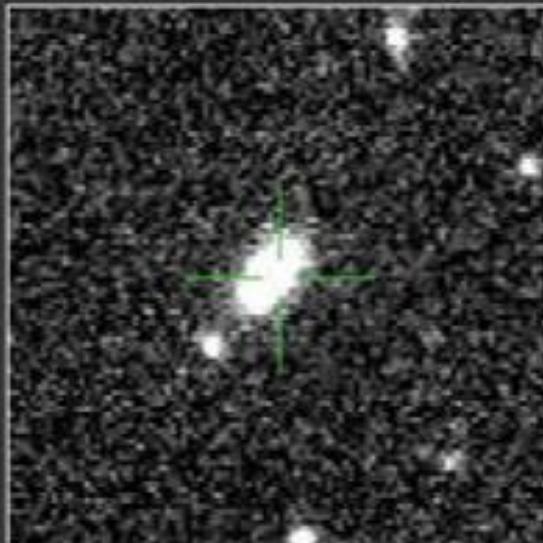
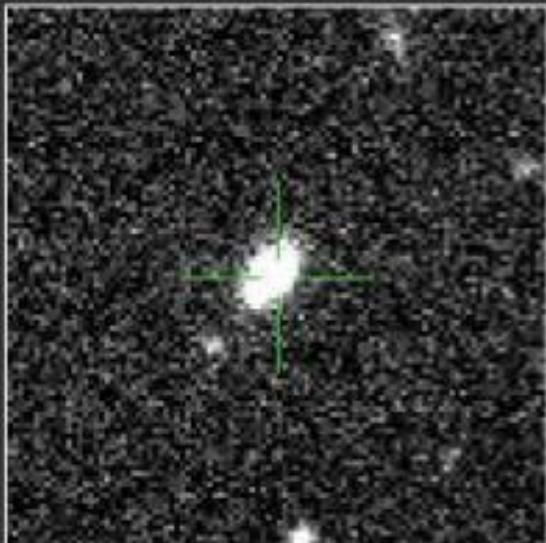
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Supernovae Discoveries

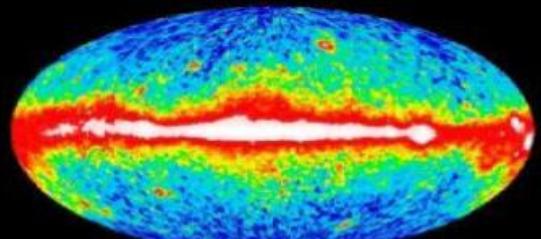
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Candidate ID

PTF ID: 10aarz (uploaded 2010-11-08 17:50:37 UTC)



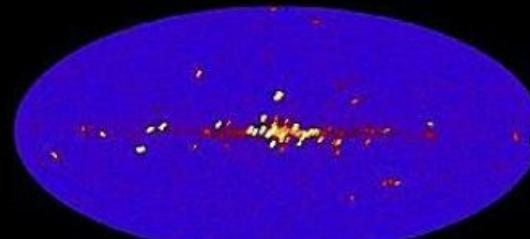
5. Multimessenger Astronomy



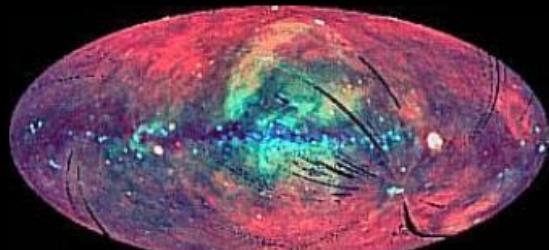
Gamma-Ray >100MeV (CGRO, NASA)



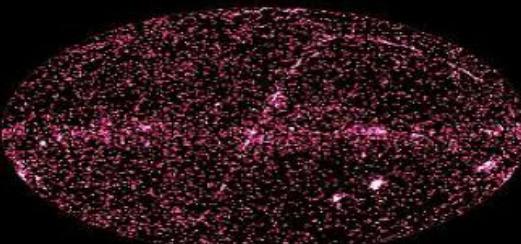
Gamma-Ray (N. Gehrels et.al. GSFC, EGRET, NASA)



X-Ray 2-10keV (HEAO-1, NASA)



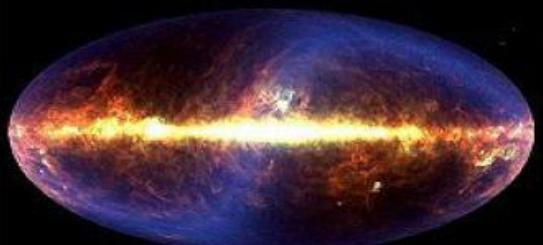
X-Ray 0.25, 0.75, 1.5 keV (S. Digel et al. GSFC, ROSAT, NASA)



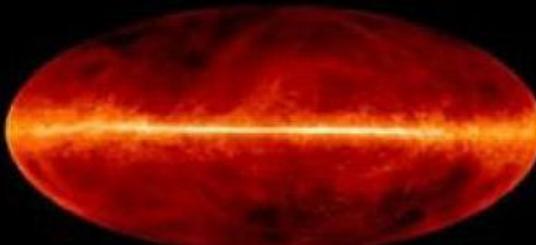
Ultraviolet (J. Bonnell et.al.(GSFC), NASA)



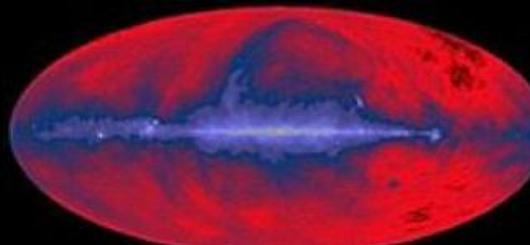
Visible (Axel Mellinger)



Infrared (DIRBE Team, COBE, NASA)

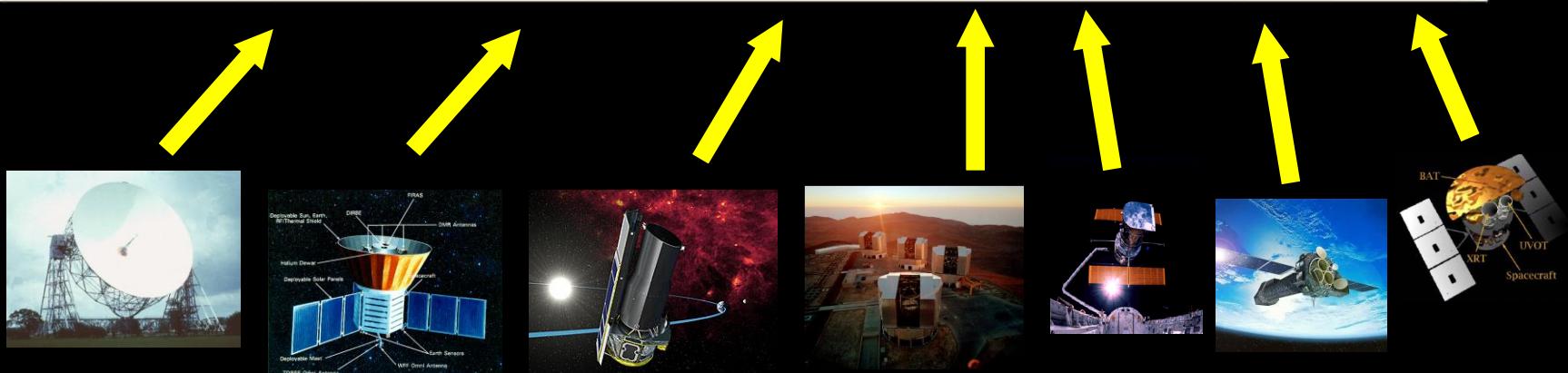
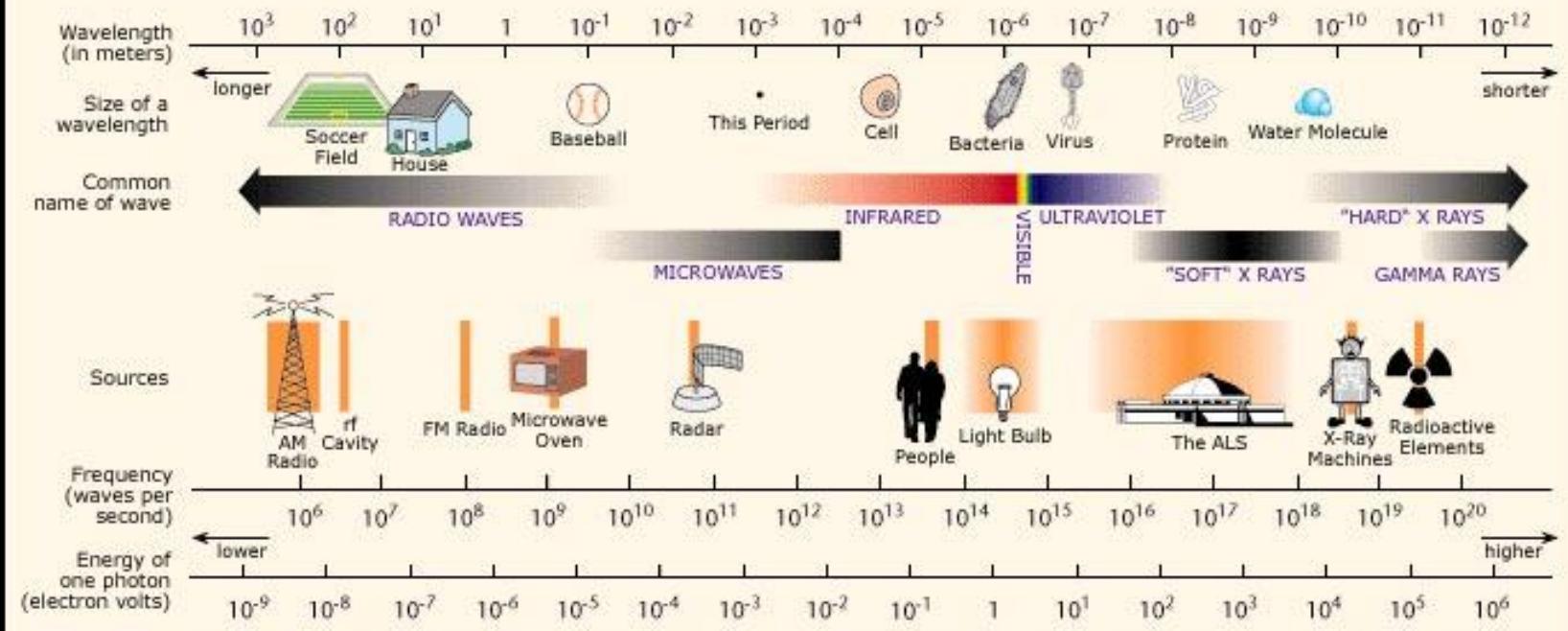


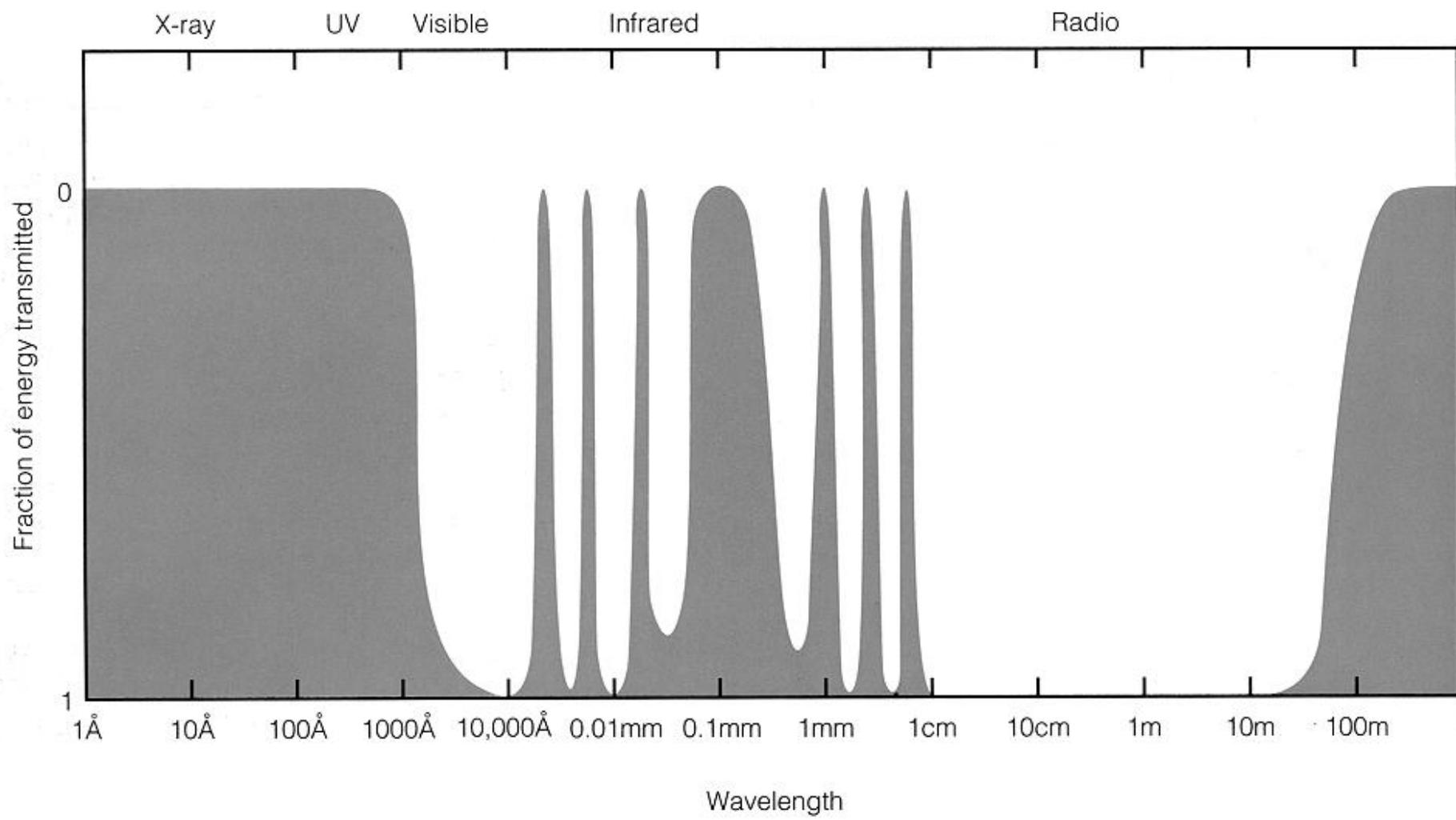
Radio 1420MHz (J. Dickey et.al. UMin. NRAO SkyView)

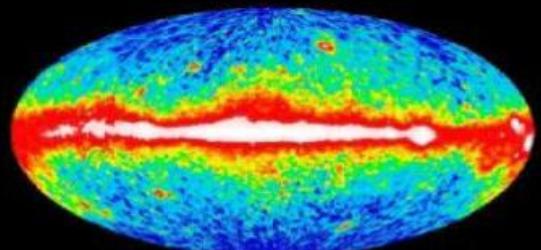


Radio 408MHz (C. Haslam et al., MPIfR, SkyView)

THE ELECTROMAGNETIC SPECTRUM



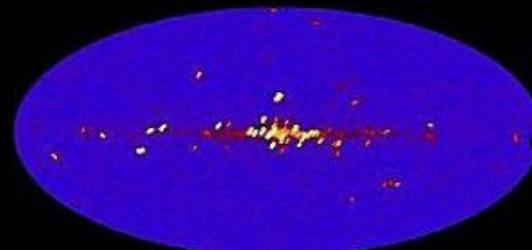




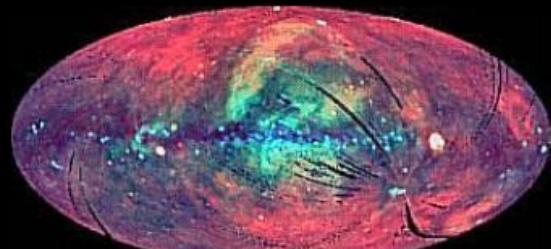
Gamma-Ray >100MeV (CGRO, NASA)



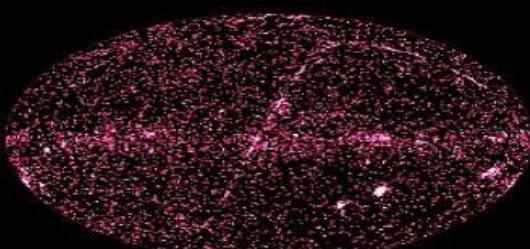
Gamma-Ray (N. Gehrels et.al. GSFC, EGRET, NASA)



X-Ray 2-10keV (HEAO-1, NASA)



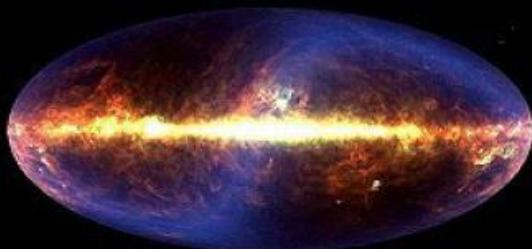
X-Ray 0.25, 0.75, 1.5 keV (S. Digel et. al. GSFC, ROSAT, NASA)



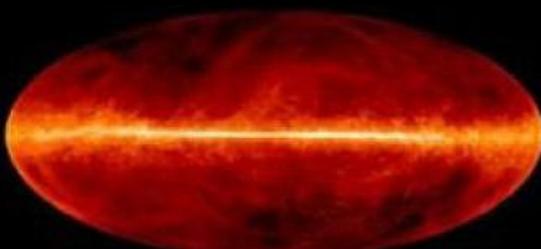
Ultraviolet (J. Bonnell et.al.(GSFC), NASA)



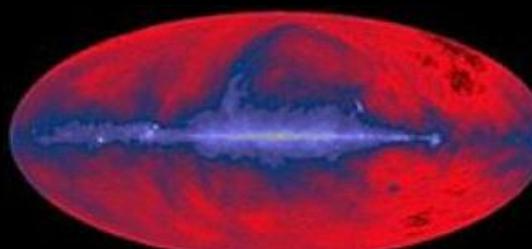
Visible (Axel Mellinger)



Infrared (DIRBE Team, COBE, NASA)



Radio 1420MHz (J. Dickey et.al. UMn. NRAO SkyView)



Radio 408MHz (C. Haslam et al., MPIfR, SkyView)

M1 - The Crab Nebula

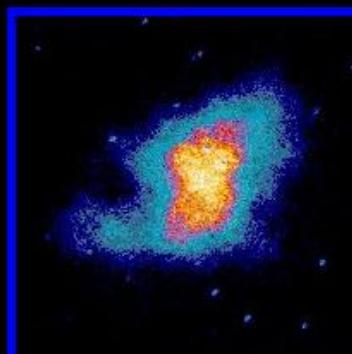
Distance: 6300 light-years (1.9 kpc)

Image Size = 6.5 x 6.5 arcmin

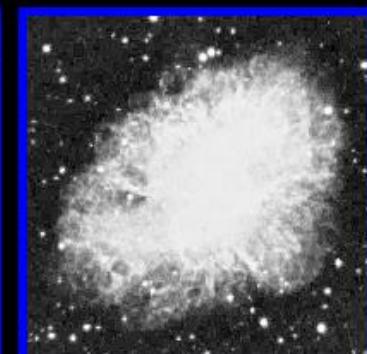
Visual Magnitude = 8.4



X-Ray: Chandra



Ultraviolet: ASTRO-1



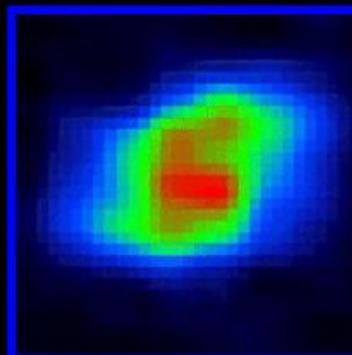
Visible: DSS



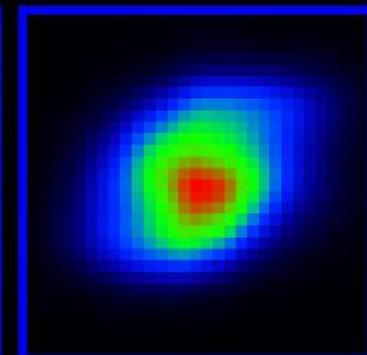
Visible: Color VLT



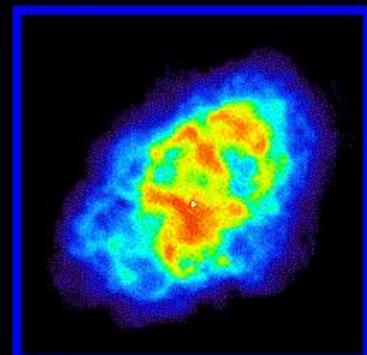
Near-Infrared: 2MASS



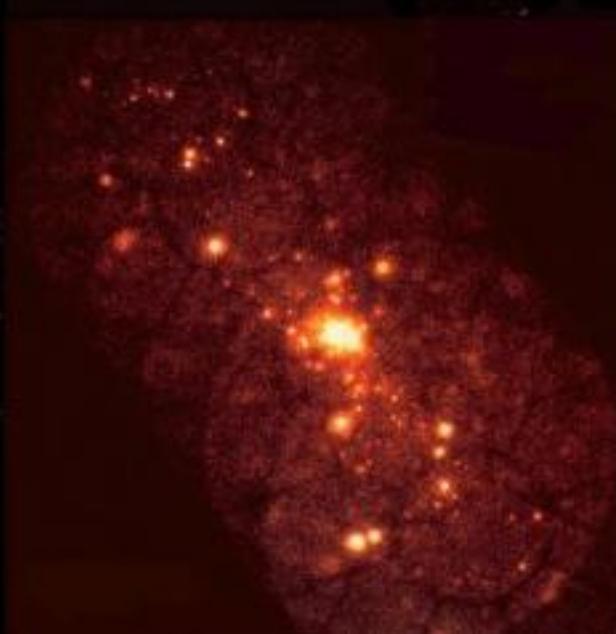
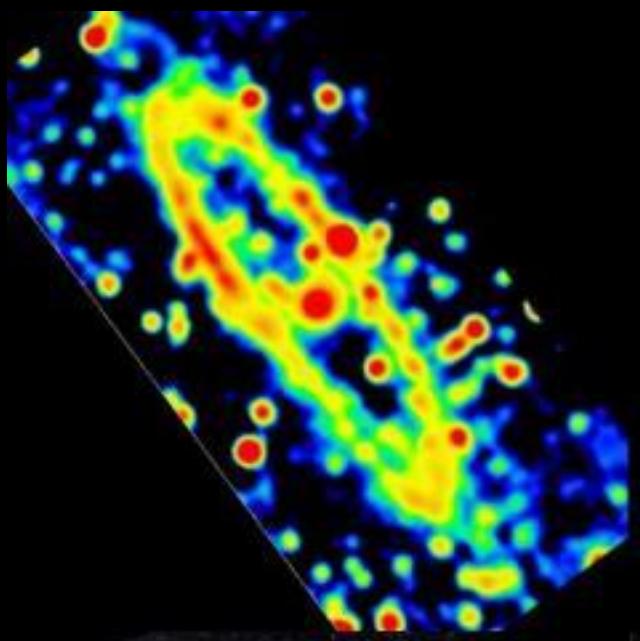
Mid-Infrared: IRAS

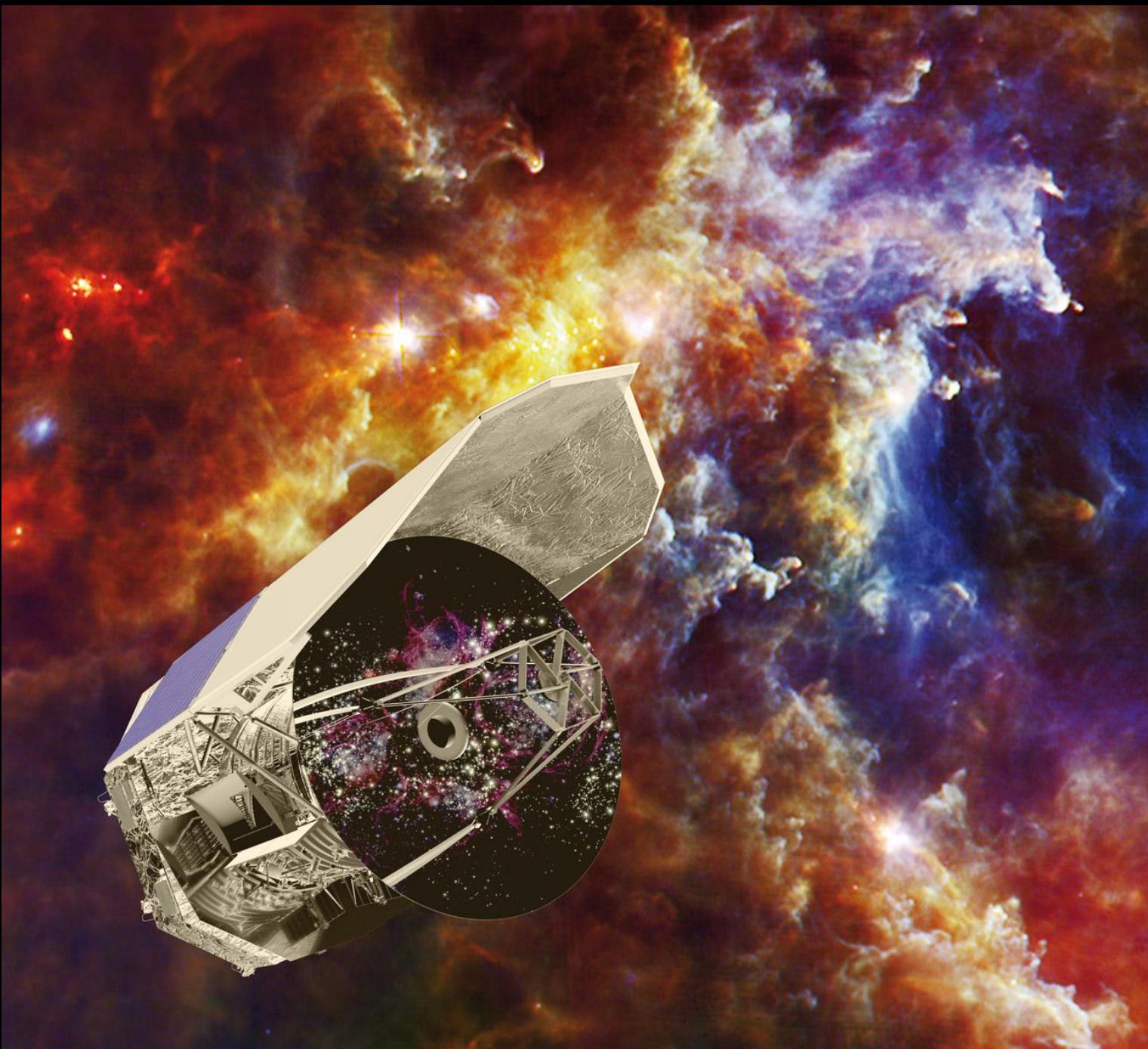


Far-Infrared: IRAS



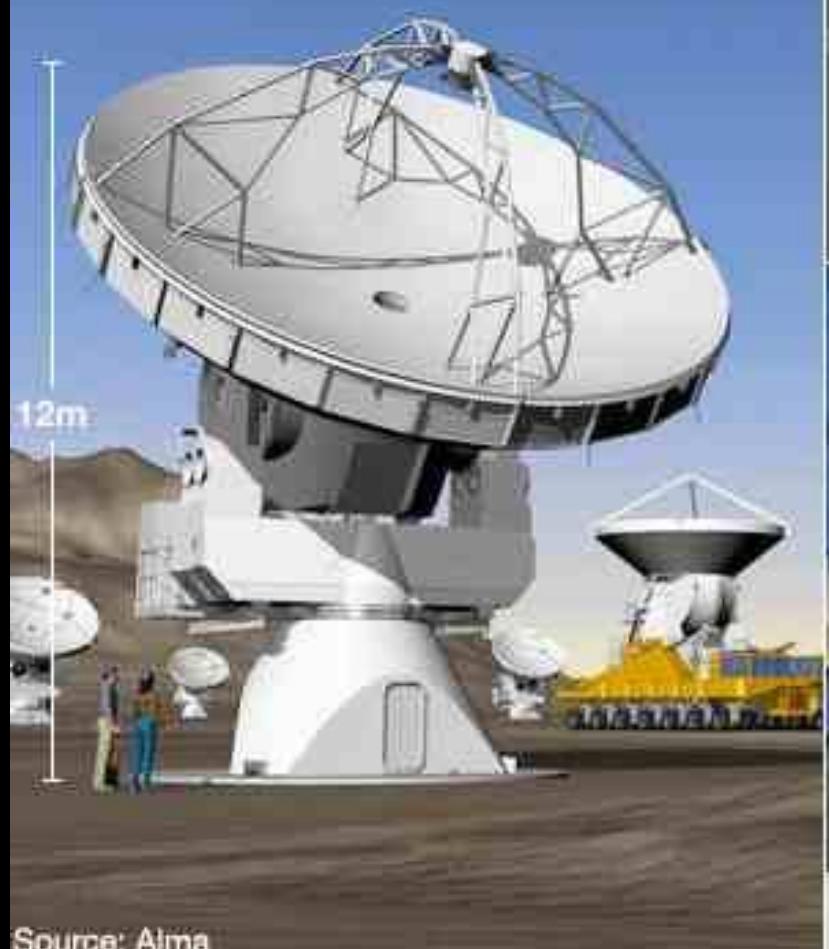
Radio: NRAO





Alma Observatory at high altitude in Atacama desert

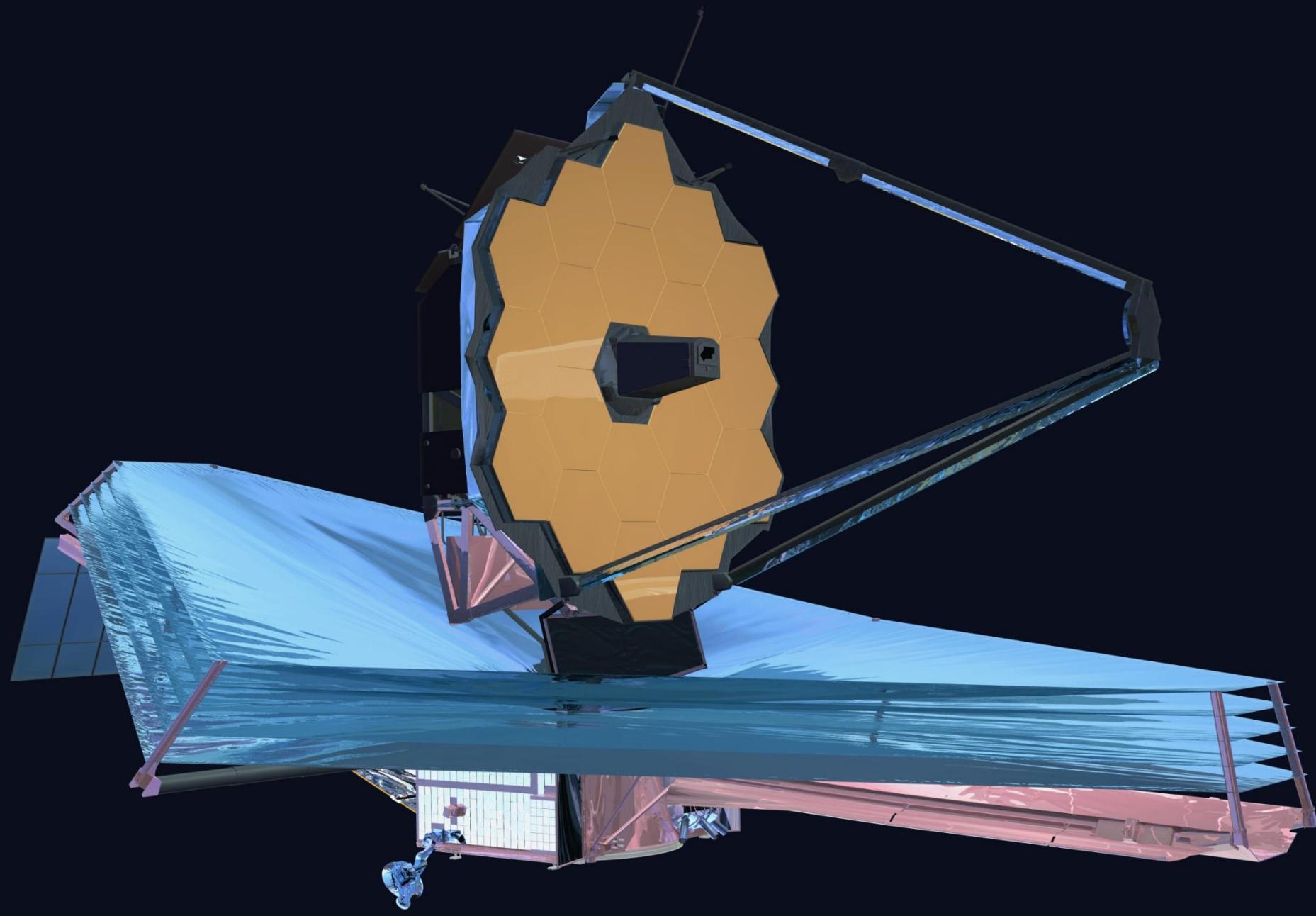
Capacity: 66 antennas
Area: 7,240 sq m
Altitude: 5,000m

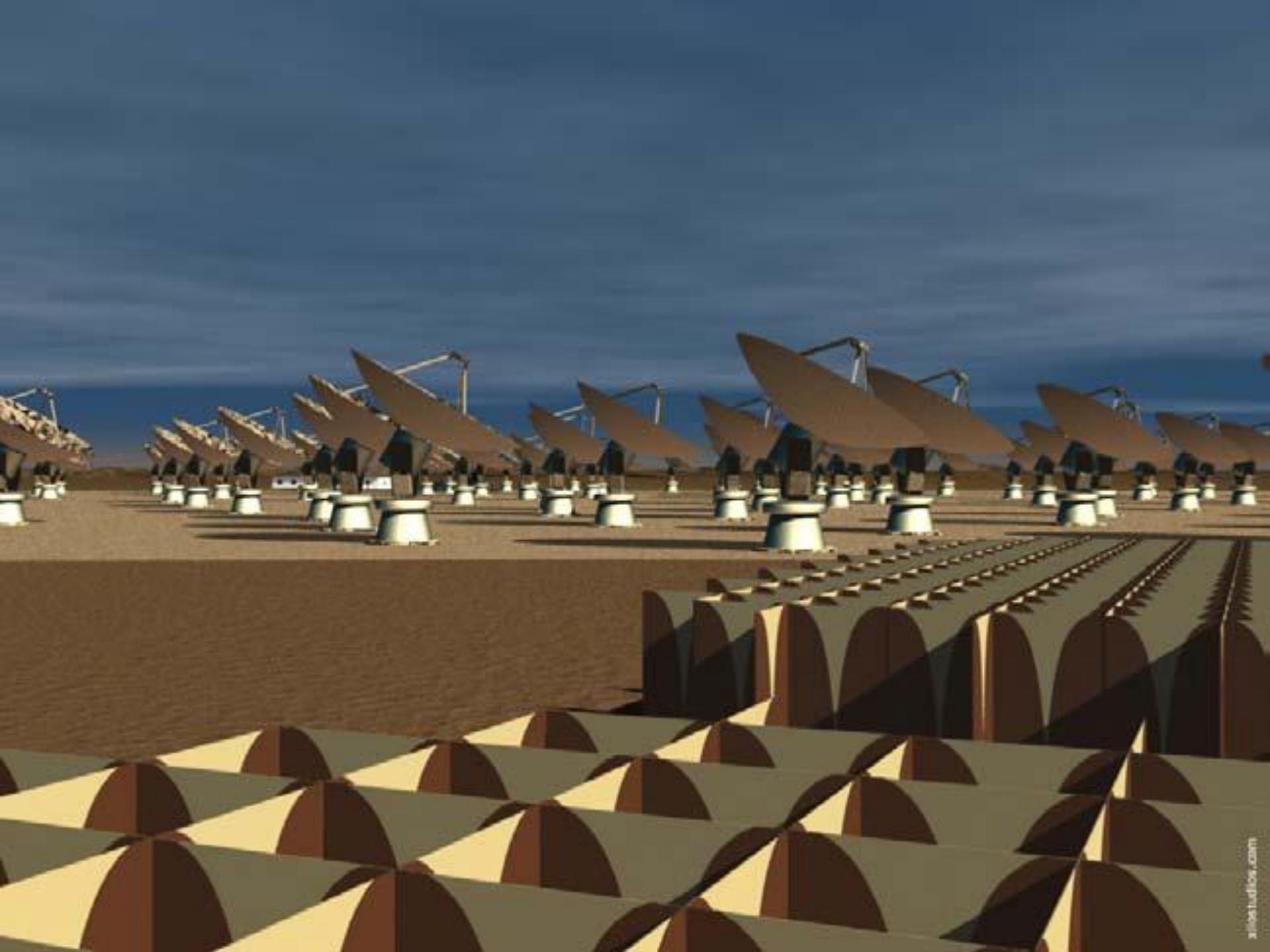


Source: Alma

50km

Google

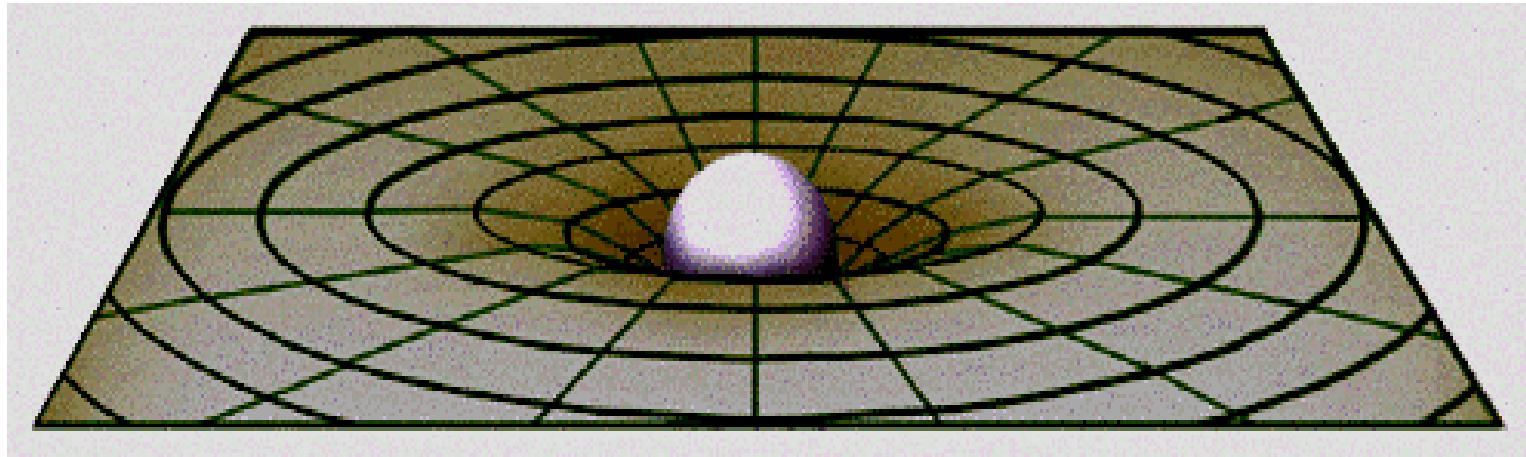




Gravity in Einstein's Universe



“Space tells matter how to move, and matter tells space how to curve”

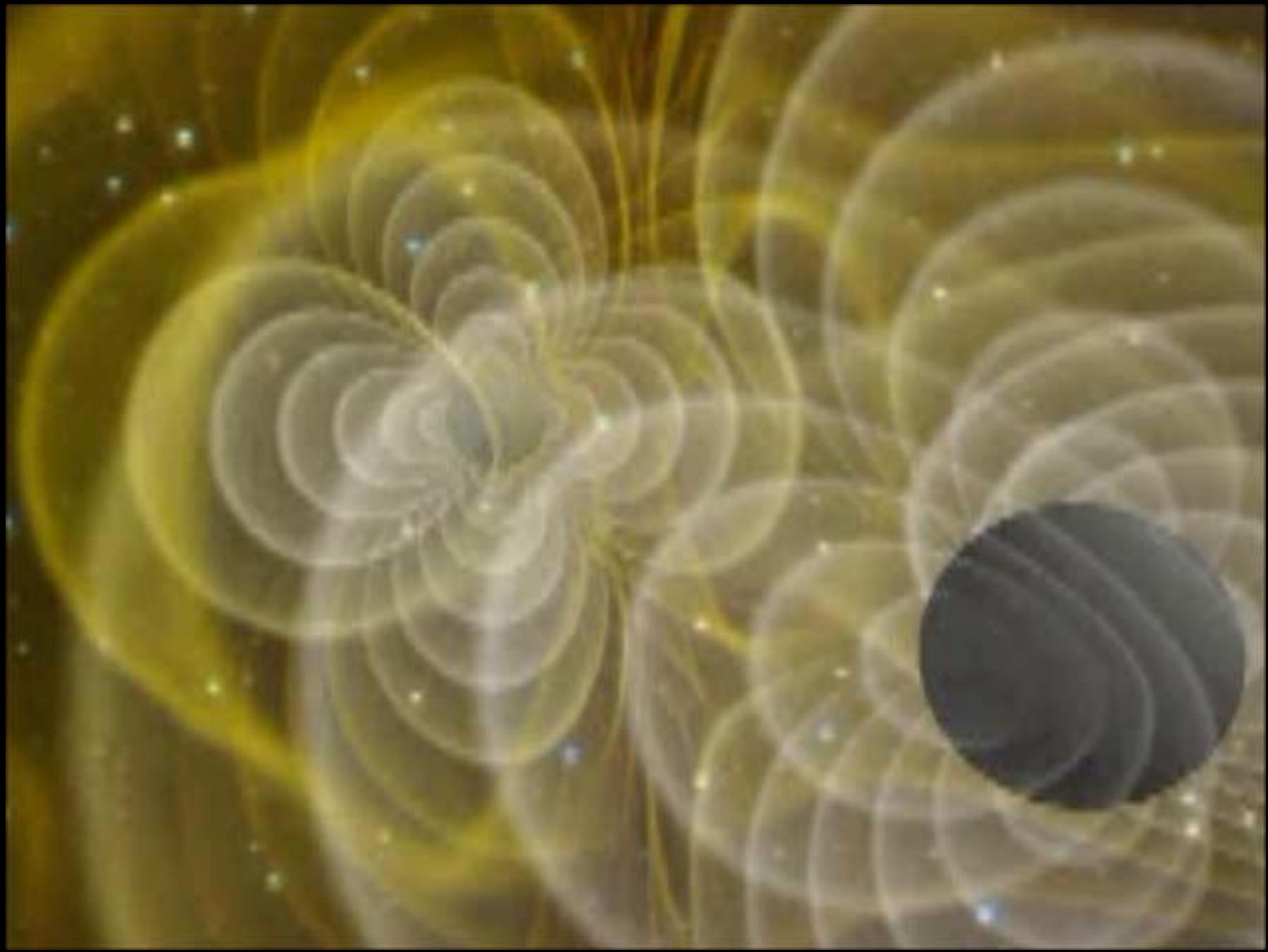


Gravity in Einstein's Universe

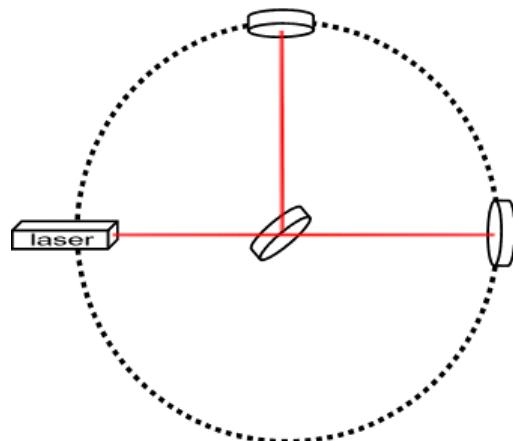




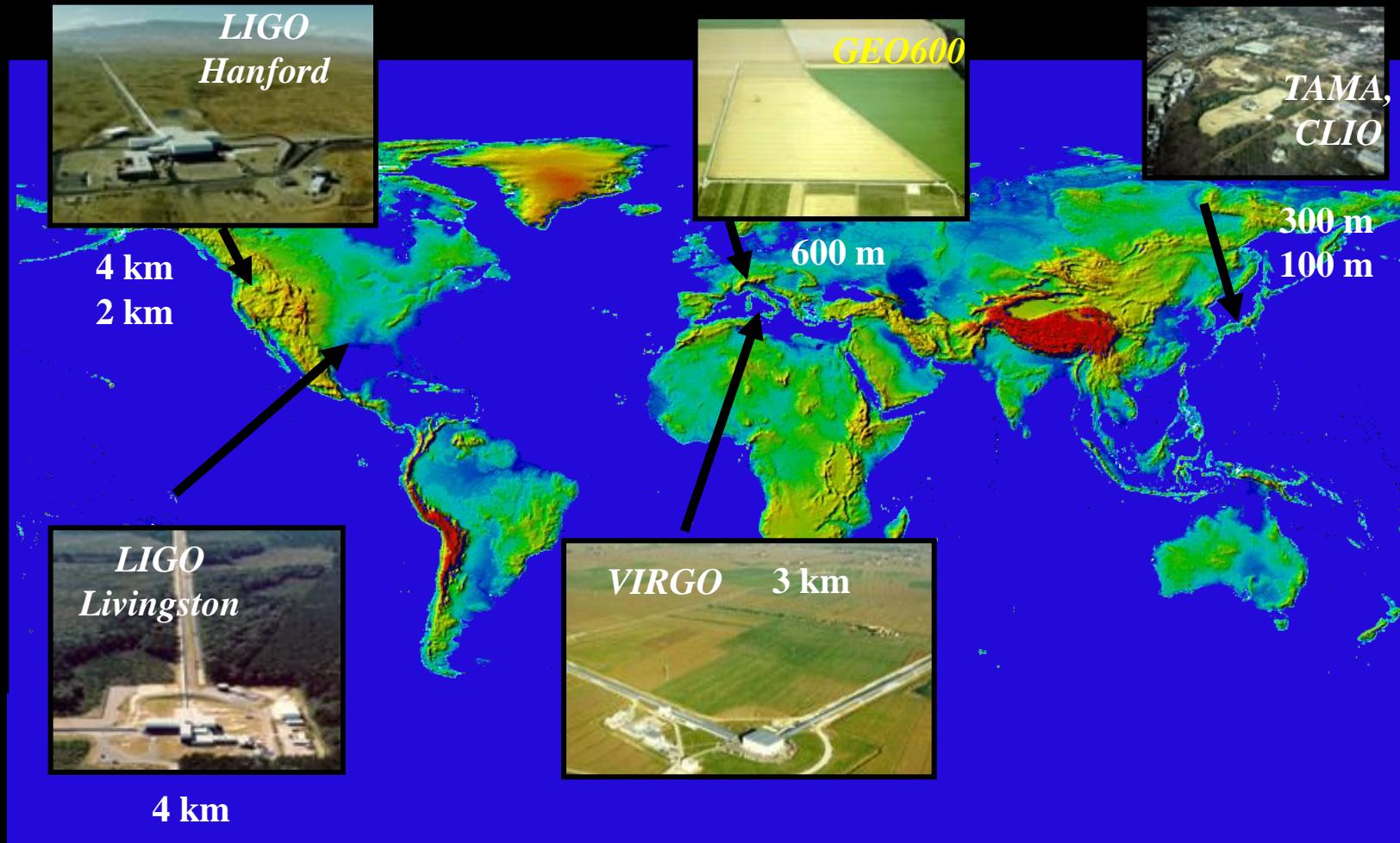
Mei Photography



Detecting gravitational waves with laser interferometers



Ground-based network of detectors



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Advanced LIGO: The Next Step

Test weld, glass fiber suspensions, University of Glasgow, Scotland

Gravity: Making Waves

NEWS

- 09.20.10 [LSC-Virgo Meeting in Cracow, Poland](#)
04.27.10 [LSC paper chosen by Reports on Progress in Physics as one of Highlights of 2009](#)
06.30.09 [Classical and Quantum Gravity picks LIGO-GEO 600 paper among its 2009 highlights](#)

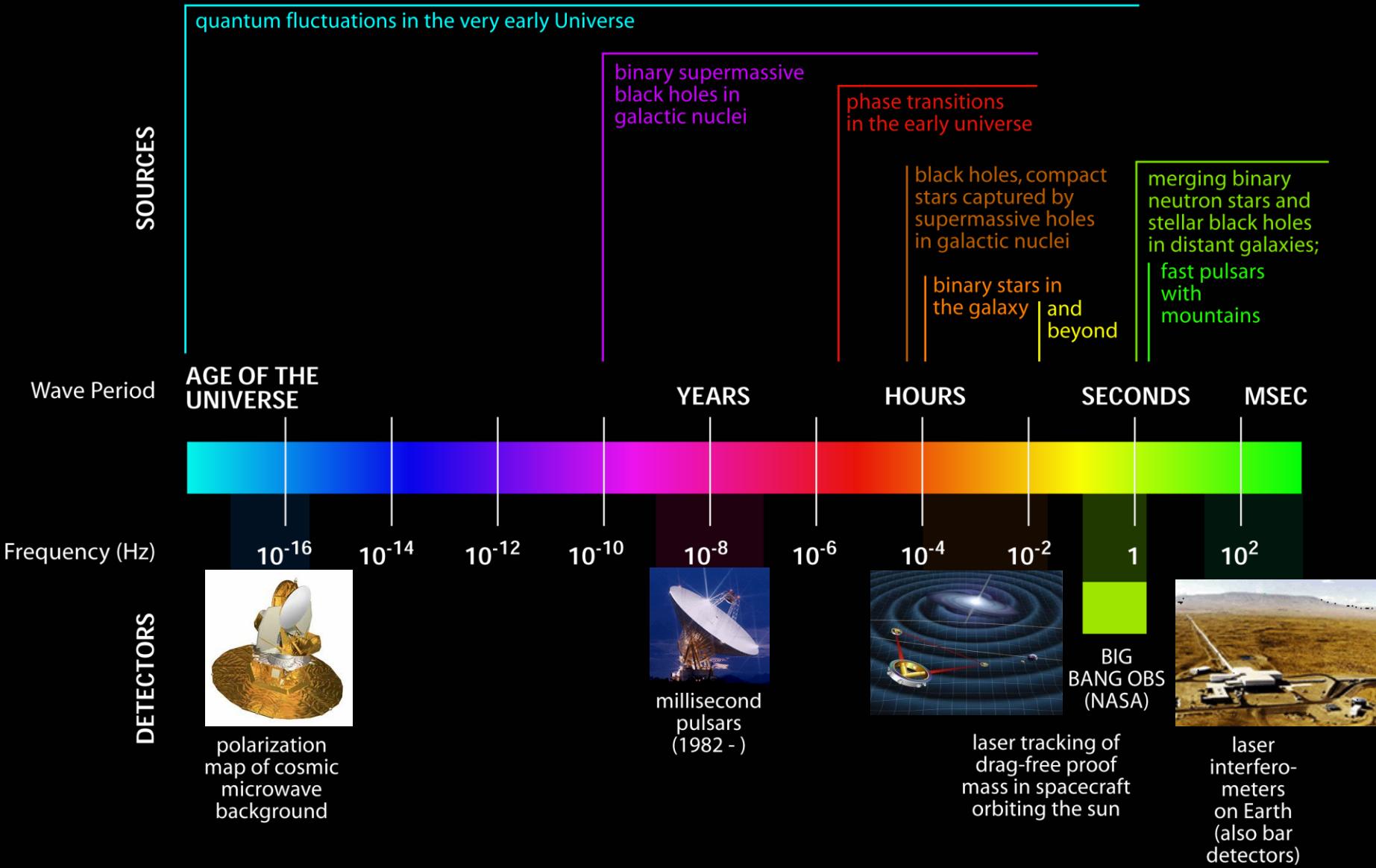
PRESS RELEASES

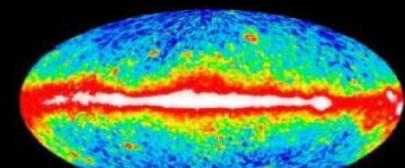
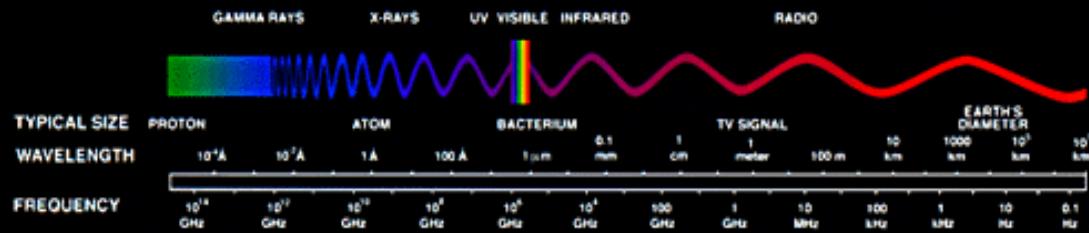
- 05.24.10 ['Astronomy's New Messengers' Arrive in Manhattan \(2010 World Science Festival\)](#)
08.19.09 [LIGO Listens for Gravitational Echoes of the Birth of the Universe](#)
06.02.08 [LIGO Observations Probe the Dynamics of the Crab Pulsar](#)
01.04.08 [Advanced LIGO Project Funded by](#)

The LIGO Scientific Collaboration (LSC) is a dynamic group of approximately 760 scientists worldwide who have joined together in the search for gravitational waves from the most violent events in the universe. Learn more about gravitational waves and the LSC [here!](#)

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THE GRAVITATIONAL WAVE SPECTRUM

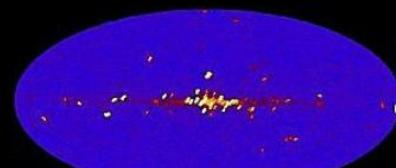




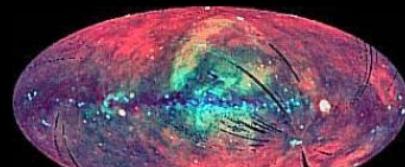
Gamma-Ray >100MeV (CGRO, NASA)



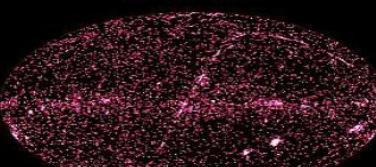
Gamma-Ray (N. Gehrels et.al. GSFC, EGRET, NASA)



X-Ray 2-10keV (HEAO-1, NASA)



X-Ray 0.25, 0.75, 1.5 keV (S. Digel et al. GSFC, ROSAT, NASA)



Ultraviolet (J. Bonnell et.al.(GSFC), NASA)



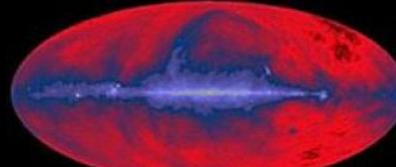
Visible (Axel Mellinger)



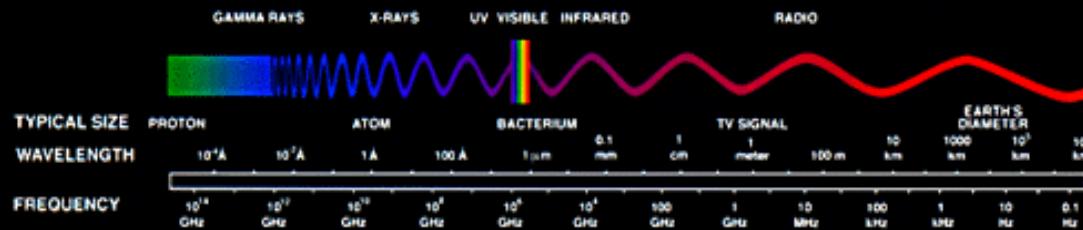
Infrared (DIRBE Team, COBE, NASA)



Radio 1420MHz (J. Dickey et.al. UMinn, NRAO SkyView)



Radio 408MHz (C. Haslam et al., MPIfR, SkyView)



Gravitational Waves ????

Infrared (DIRBE Team, COBE, NASA)

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NRAO SkyView)

Radio 408MHz (C. Haslam et al., MPIfR,
SkyView)