

400 Years of Astronomical Discovery

The Accelerating Understanding
of our Place in the Universe

Lynne Hillenbrand

California Institute of Technology





**Astronomical Society
of the Pacific**

ASTRONOMICAL SOCIETY OF THE PACIFIC

Science Education and Outreach:
Forging a Path to the Future

SEPTEMBER 12-16, 2009 • MILLBRAE, CALIFORNIA

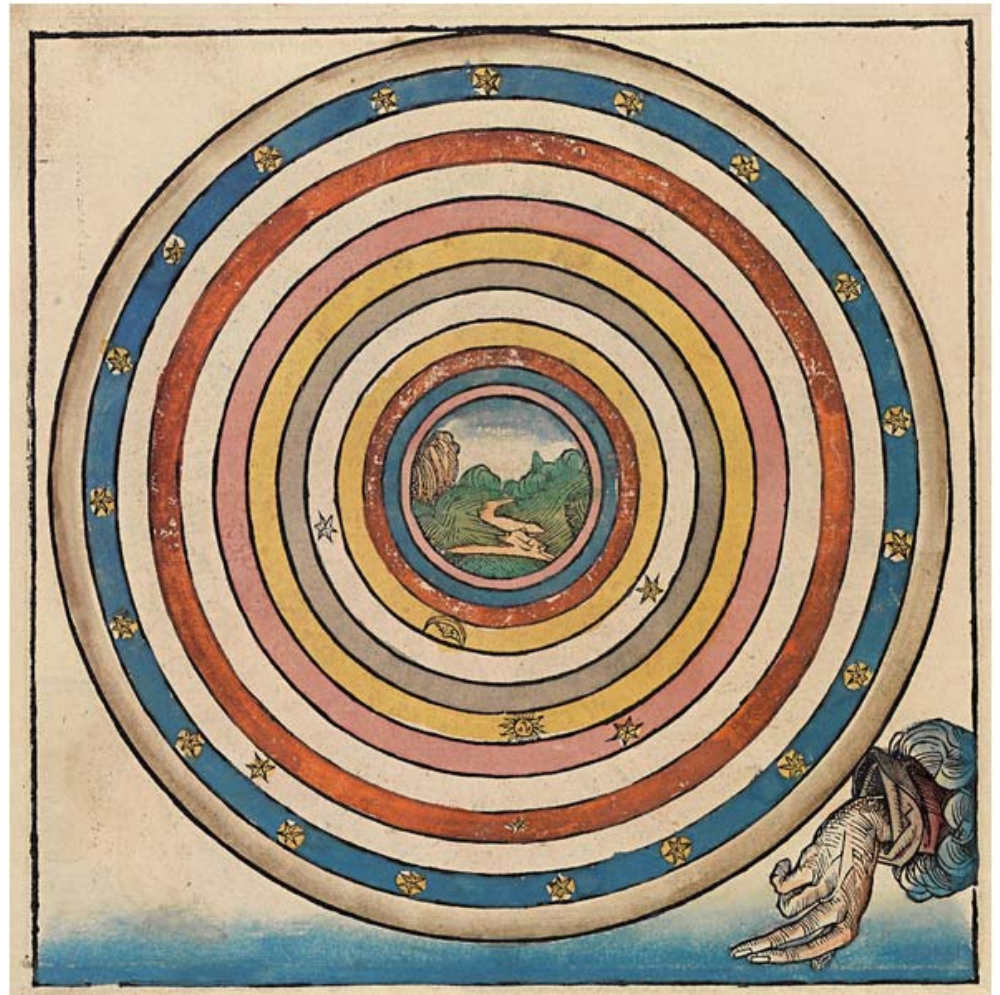
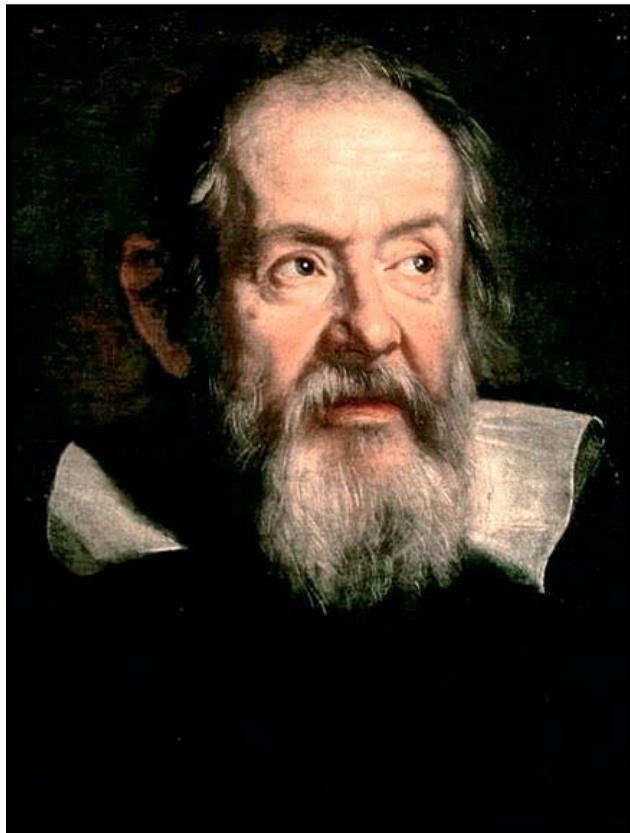


THE UNIVERSE
YOURS TO DISCOVER

INTERNATIONAL YEAR OF
ASTRONOMY
2009

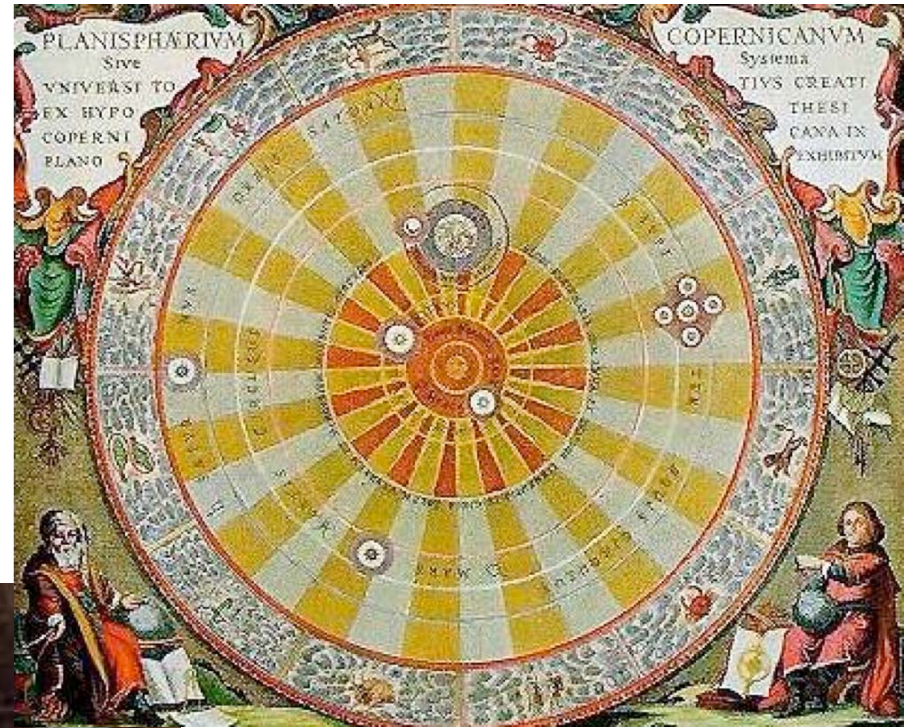
Galileo Galilei

(1564-1642)



Nicolaus Copernicus

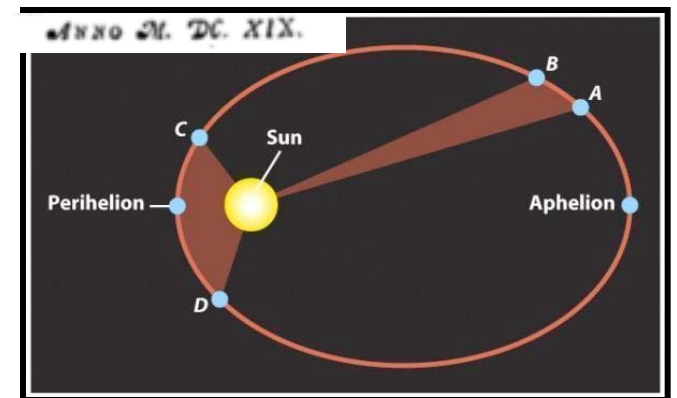
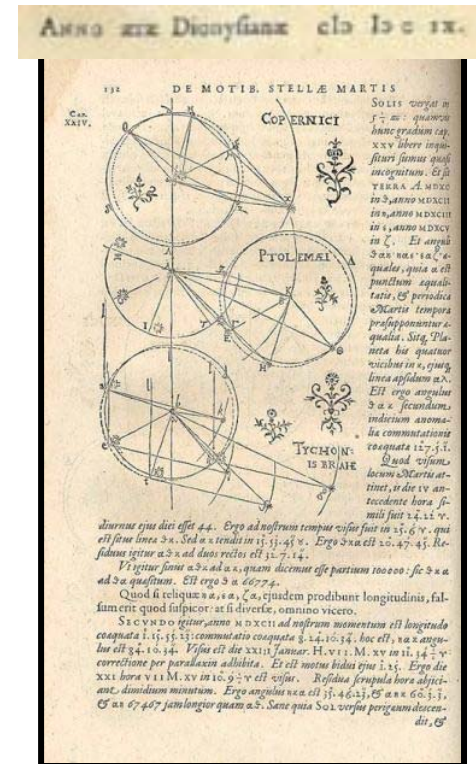
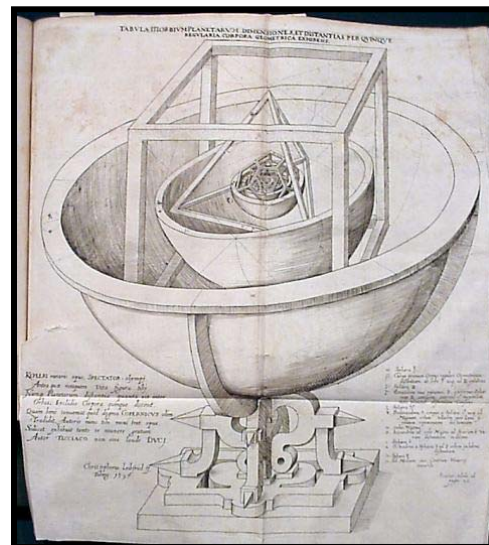
(1473-1543)

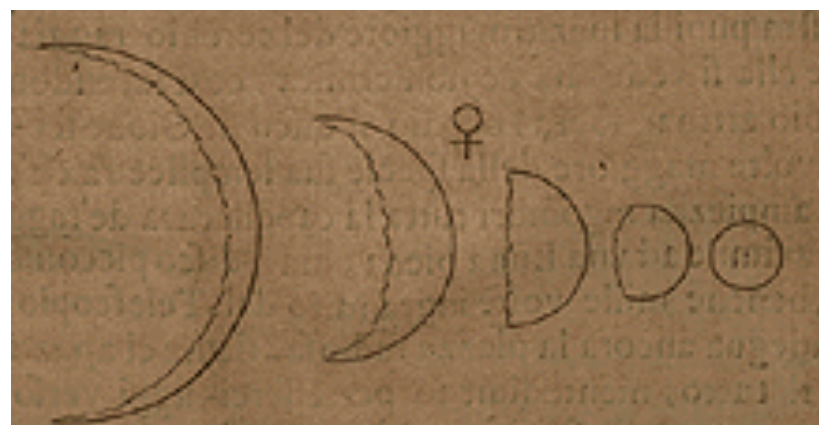
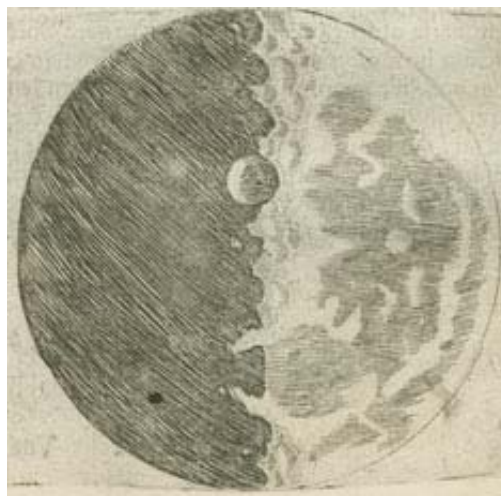
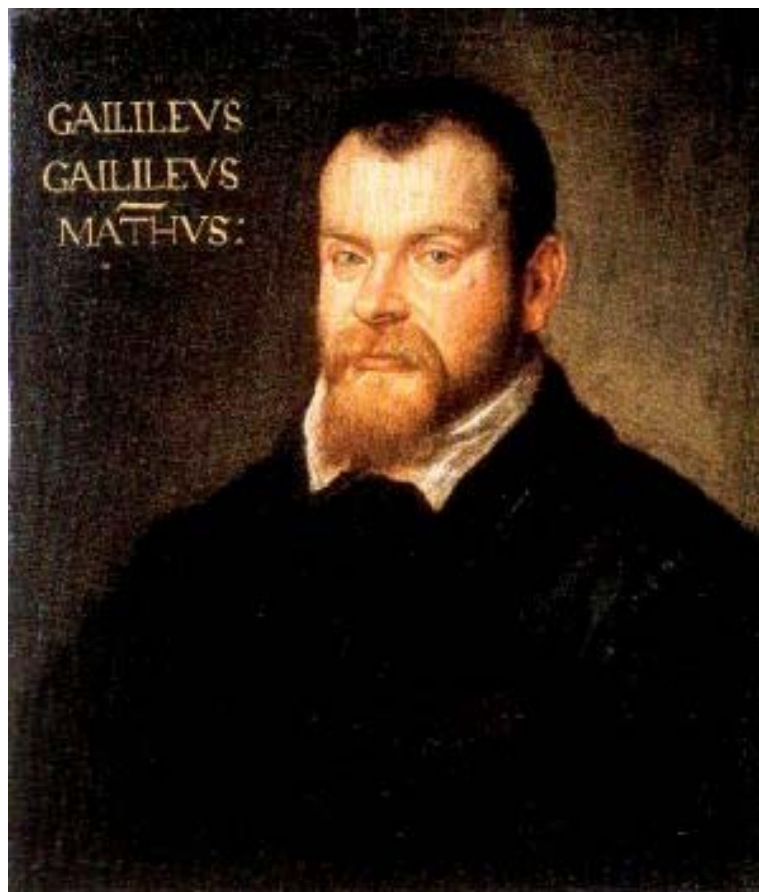


(1546-1601)



(1571-1630)



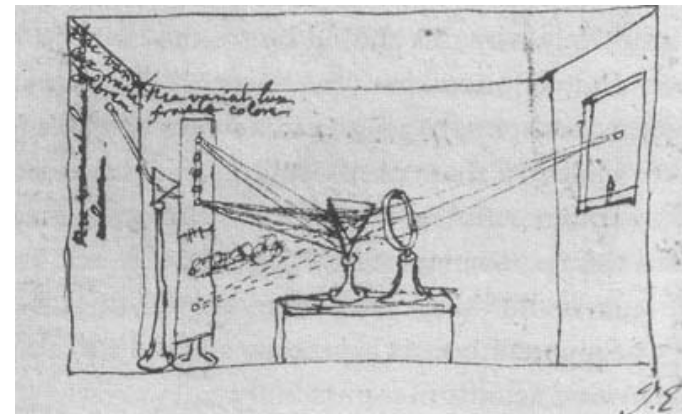
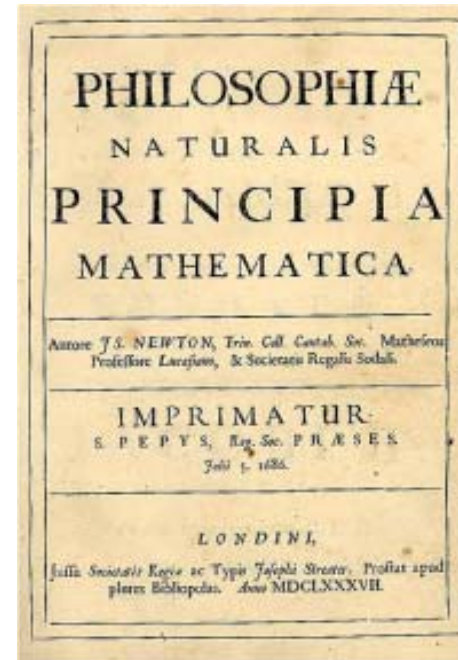


***From the beginning,
astronomy has consisted of
three interacting branches:***

- Invention and Experiment
- Observation and Analysis
- Hypothesis and Theory

Isaac Newton

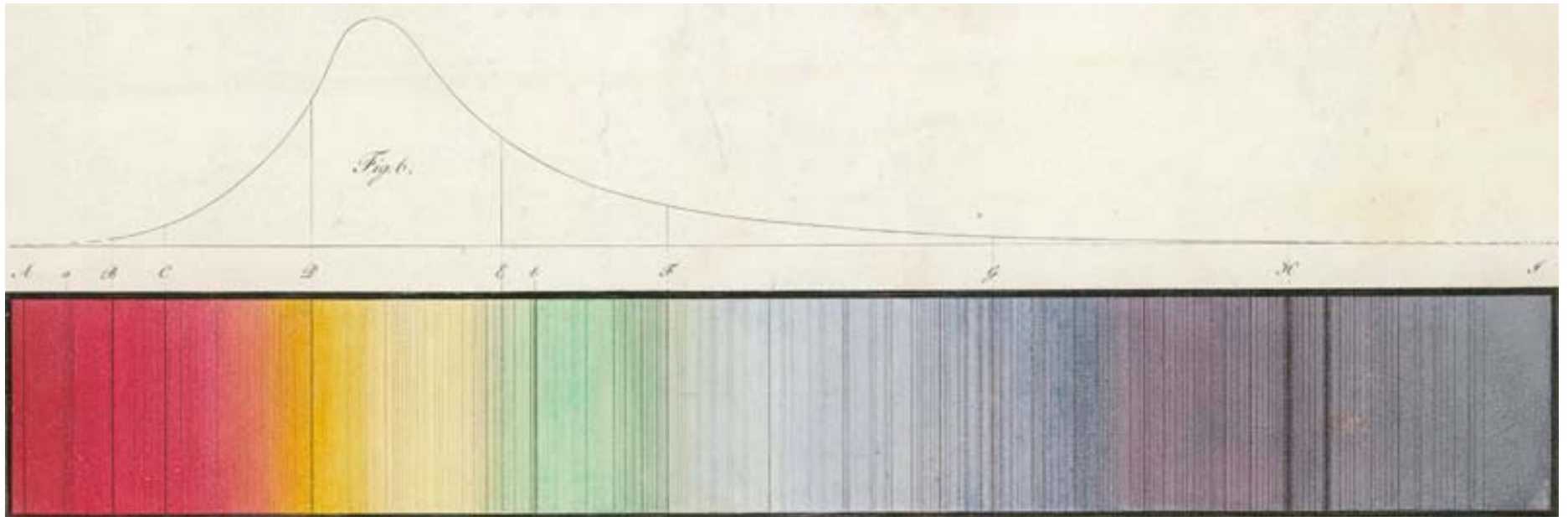
(1642-1727)



"I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Joseph von Fraunhofer

(1787-1826)

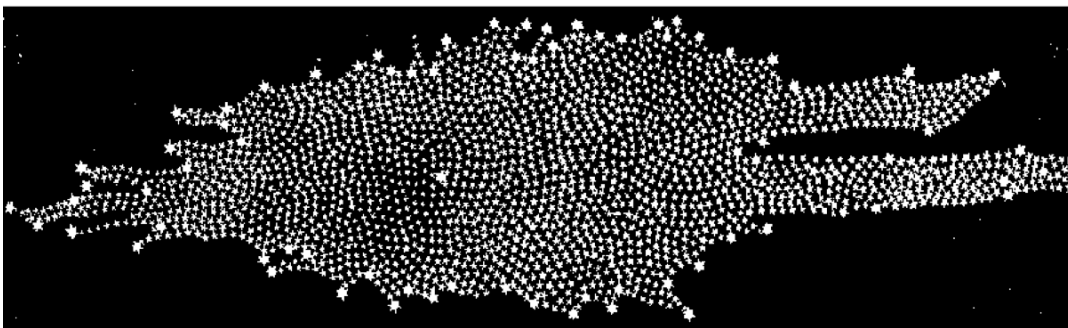
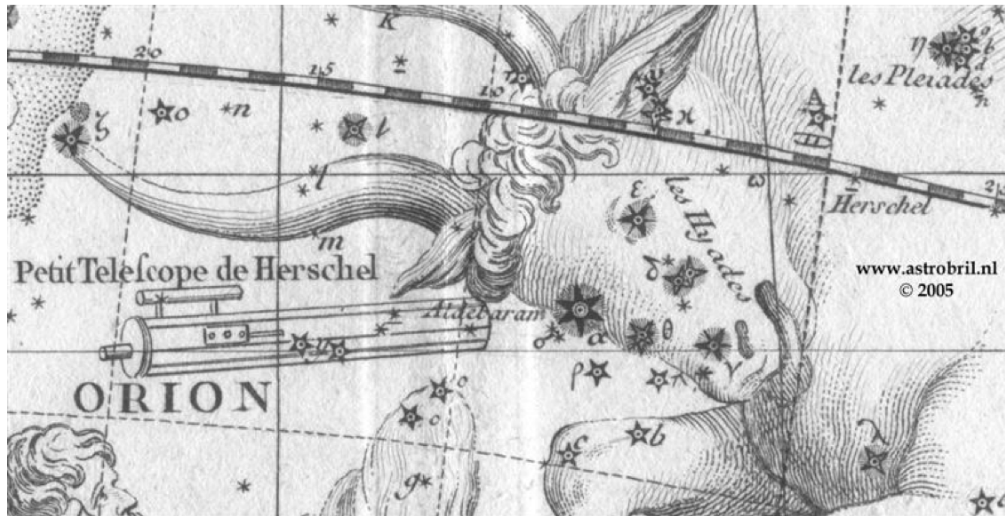


William Herschel

(1738-1822)

Caroline Herschel

(1750-1848)





A. A. Common, 1883

J.C. Kapteyn

(1851-1922)

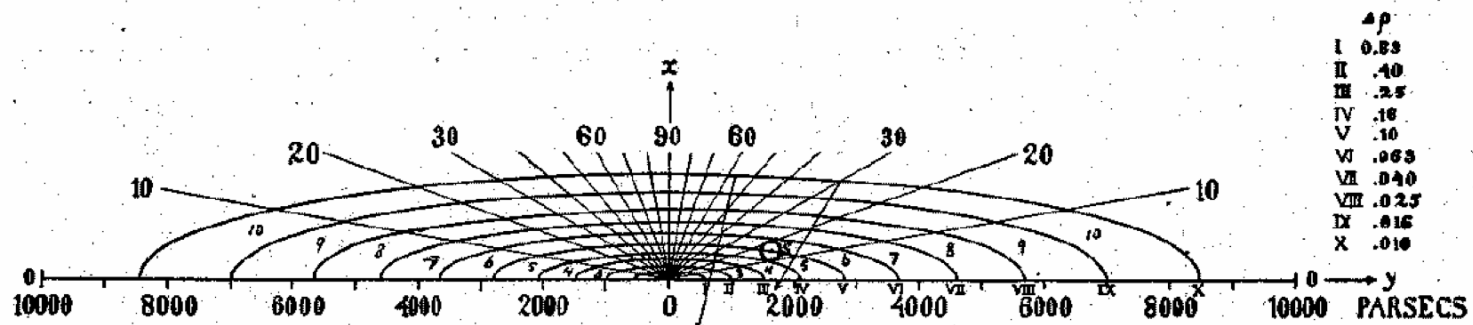
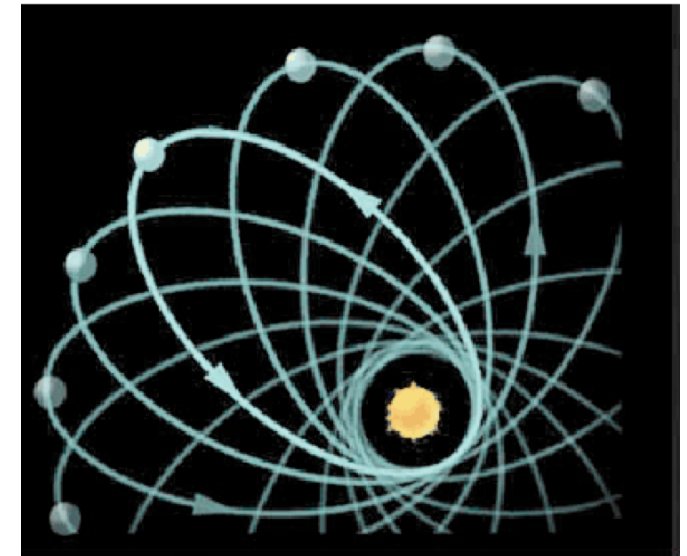
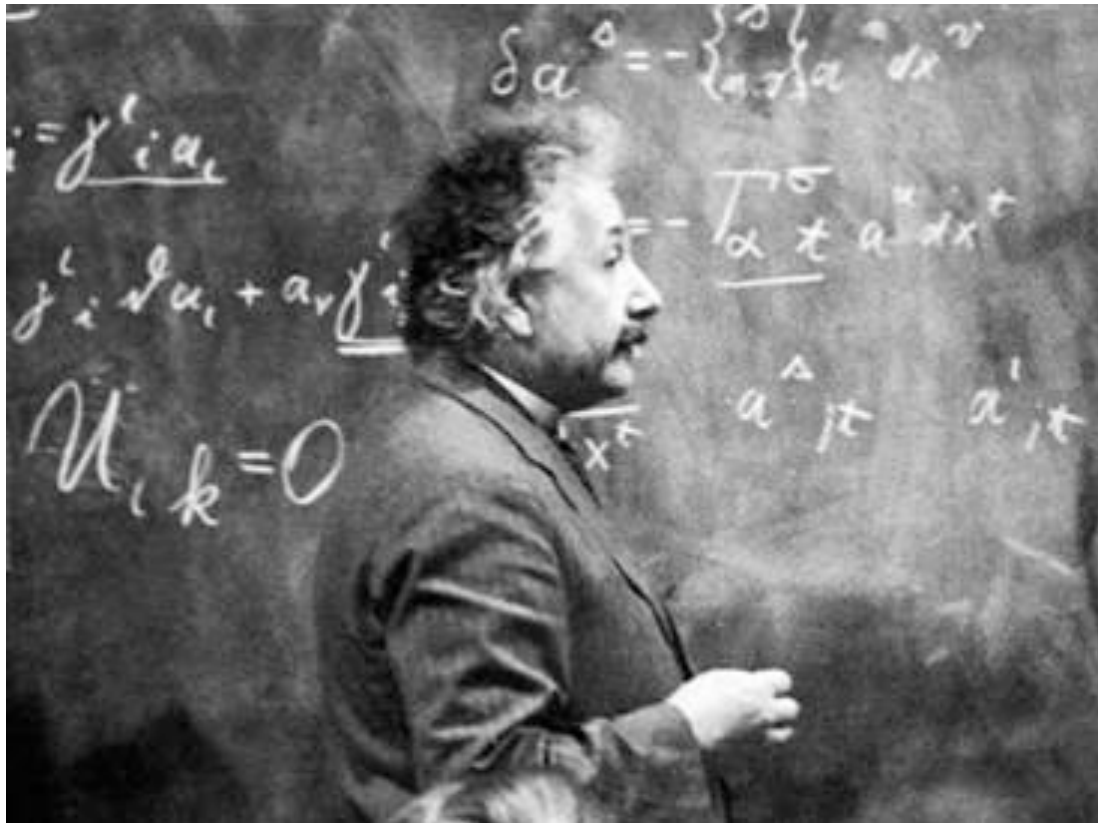


FIG. I

Albert Einstein

(1879-1955)



LIGHTS ALL ASKEW IN THE HEAVENS
ARTIST'S CONCEPTION OF THE HEAVENS
THE NEW YORK TIMES MAGAZINE, 1917

LIGHTS ALL ASKEW IN THE HEAVENS

Men of Science More or Less
Agog Over Results of Eclipse
Observations.

EINSTEIN THEORY TRIUMPHS

Stars Not Where They Seemed
or Were Calculated to be,
but Nobody Need Worry.

A BOOK FOR 12 WISE MEN

No More in All the World Could
Comprehend It, Said Einstein When
His Daring Publishers Accepted It.

Henry Norris Russell

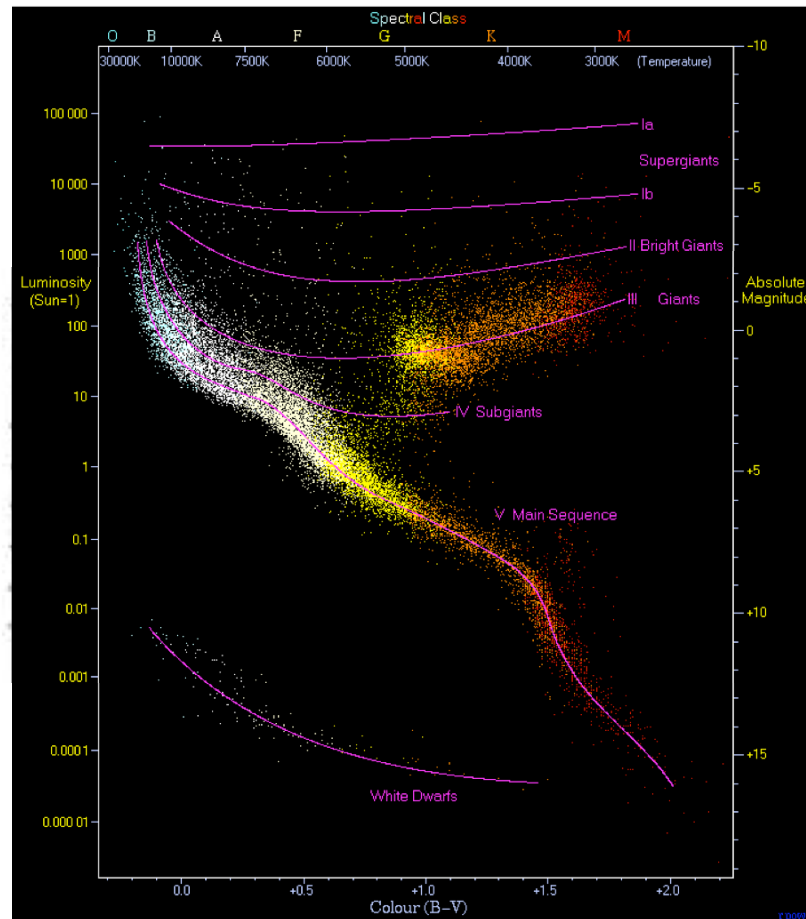
(1877-1957)

Ejnar Hertzsprung

(1873-1967)



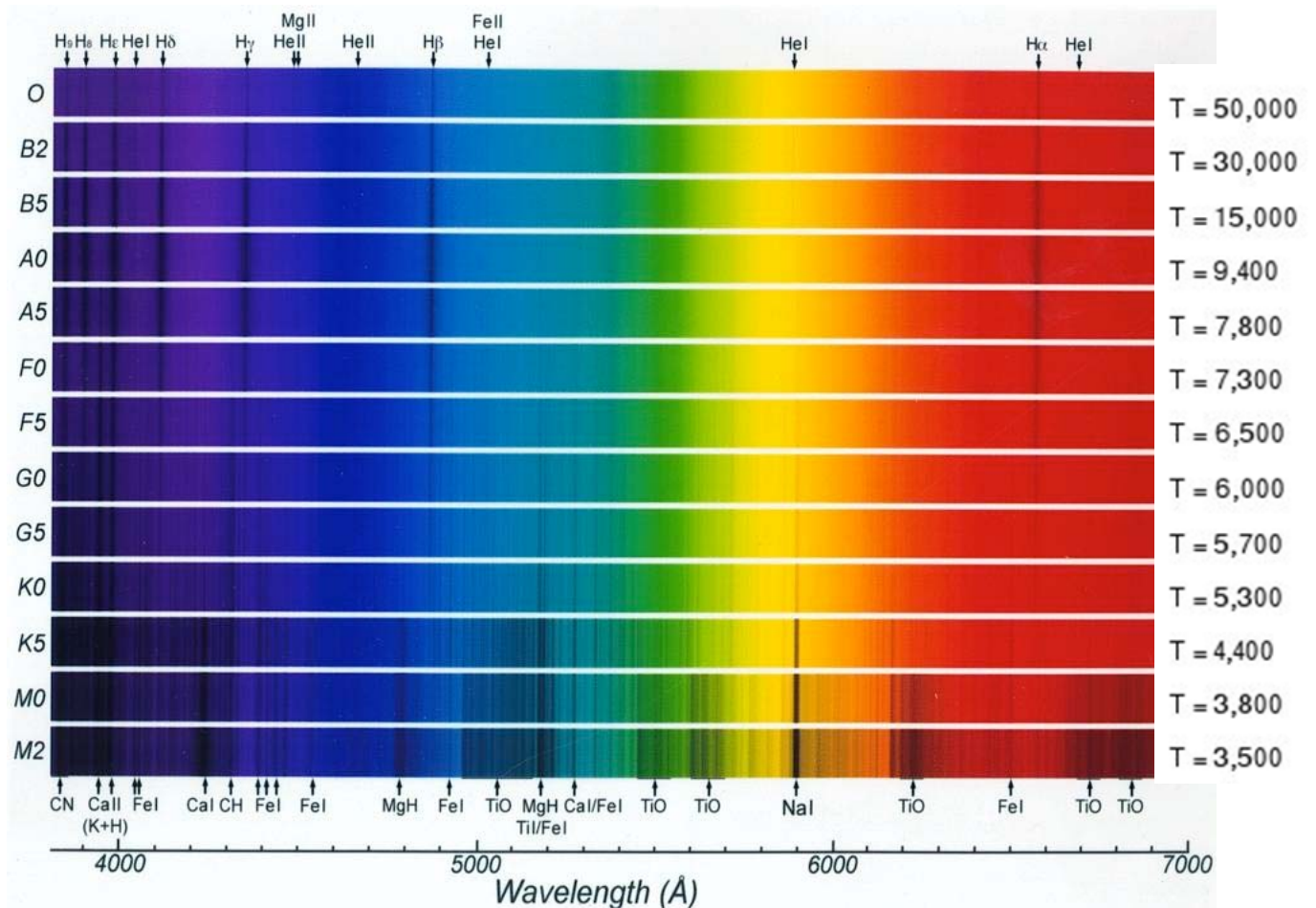
Henry Norris Russell
1877-1957



Ejnar Hertzsprung
1873-1967

(1900-1979)

ever written in astronomy. “ Otto Struve

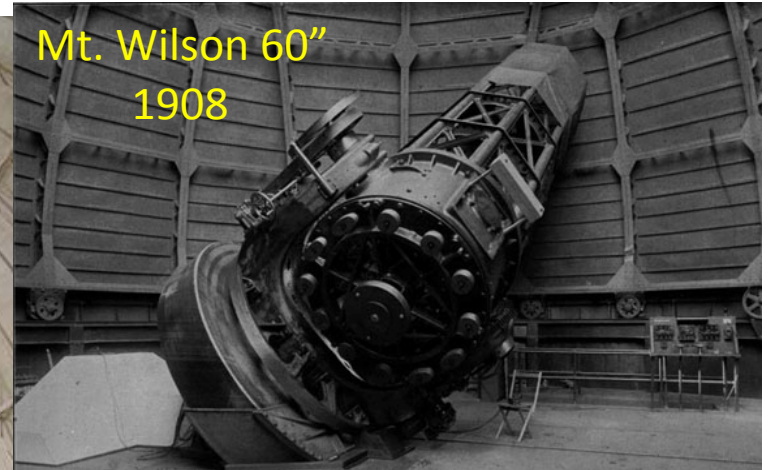


George Ellery Hale

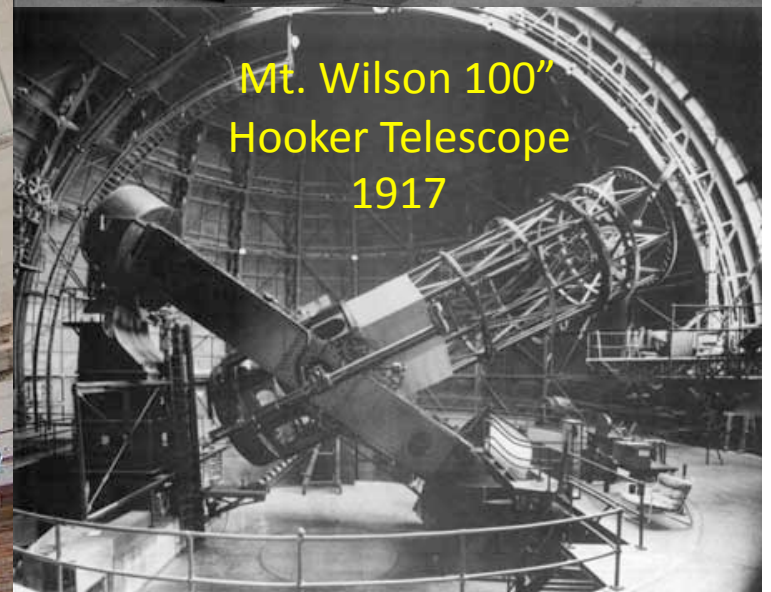
(1868-1938)



Yerkes 40"
1895



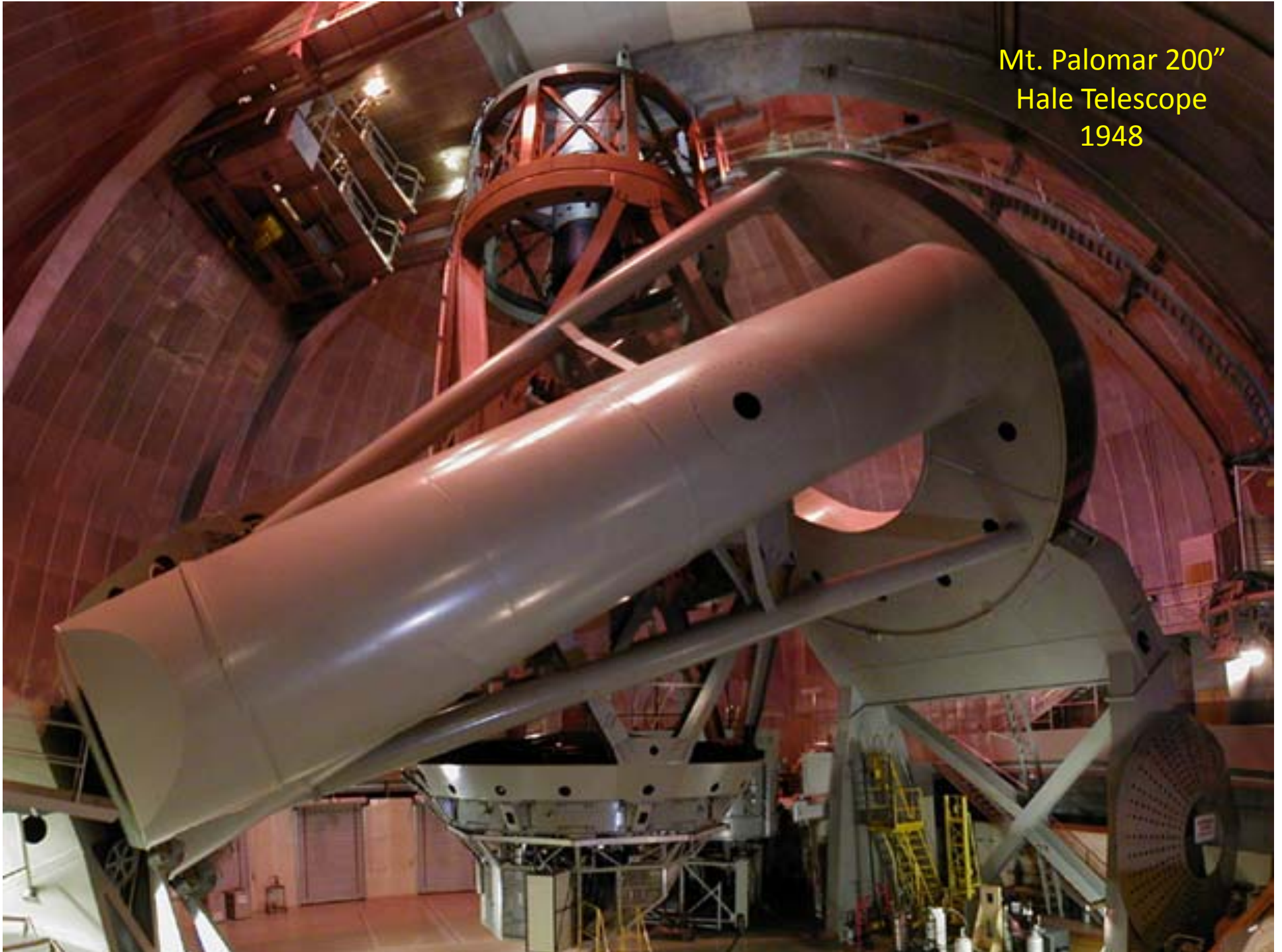
Mt. Wilson 60"
1908



Mt. Wilson 100"
Hooker Telescope
1917

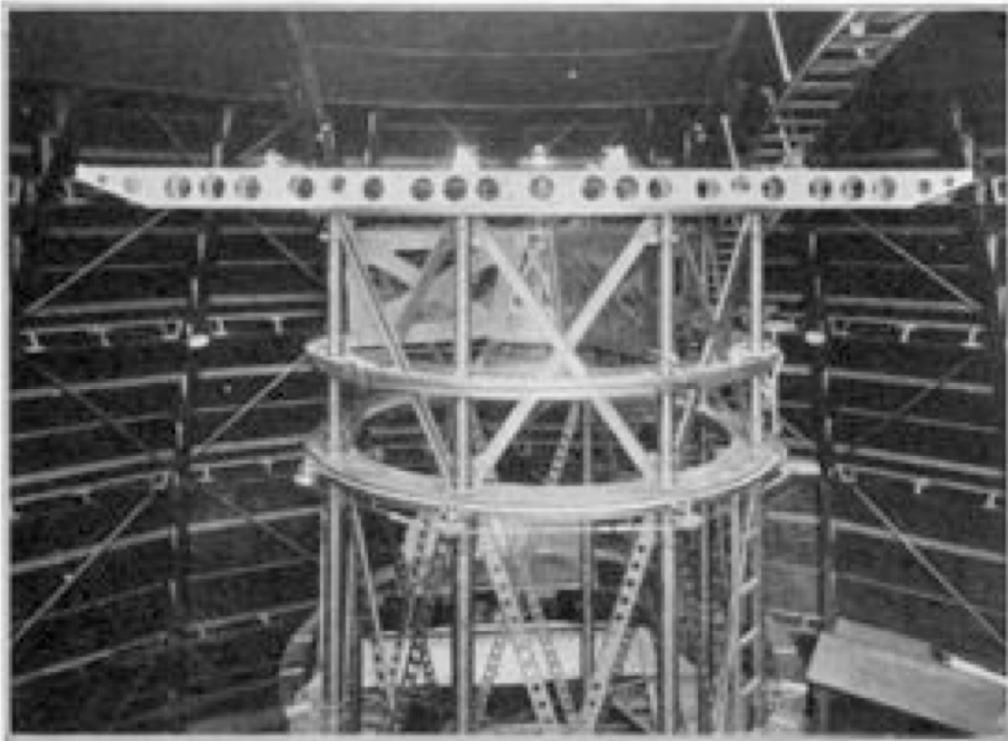
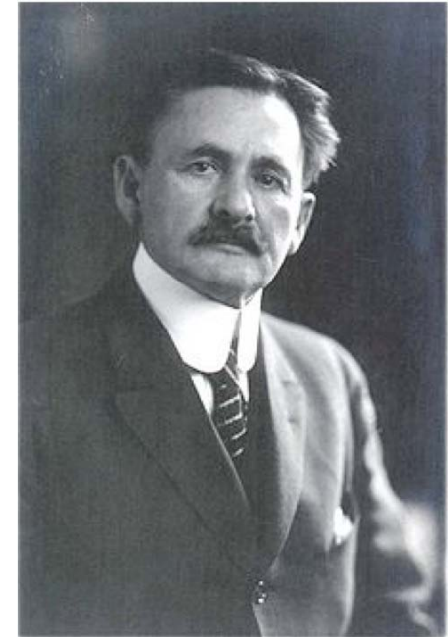


Mt. Palomar 200"
Hale Telescope
1948

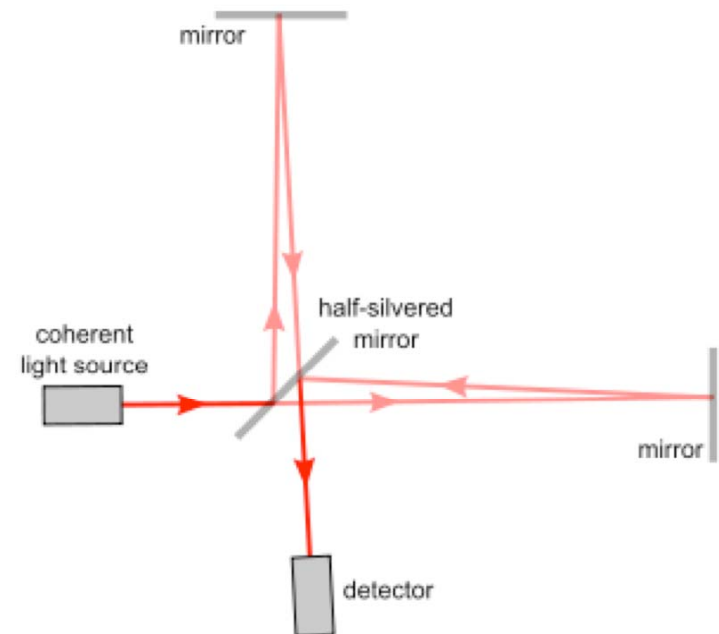


Albert A. Michelson

(1852-1931)



Mean result
Correction for temp. (20°) 299728
Velocity of light in air + 12
* Correction for vacuum 299740
Velocity of light in vacuum + 88
299828 Miles
meters per second.



Henrietta Leavitt

(1868-1921)

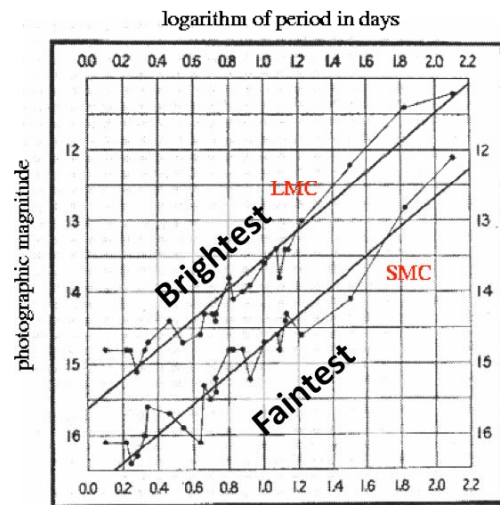
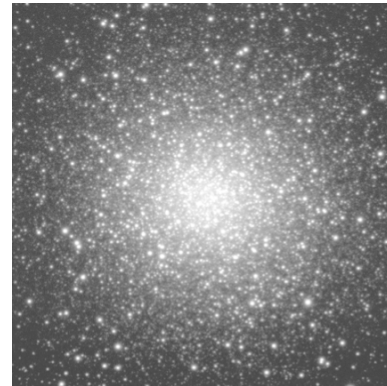


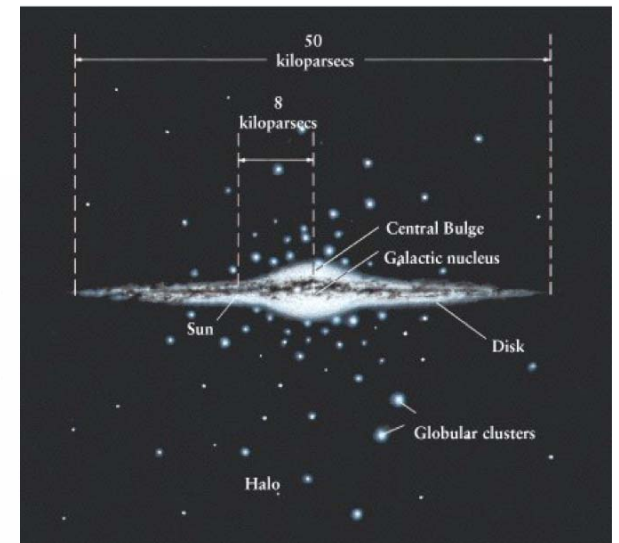
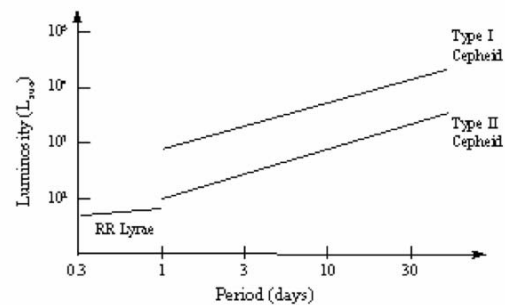
FIG. 2.

Harlow Shapley

(1885-1972)

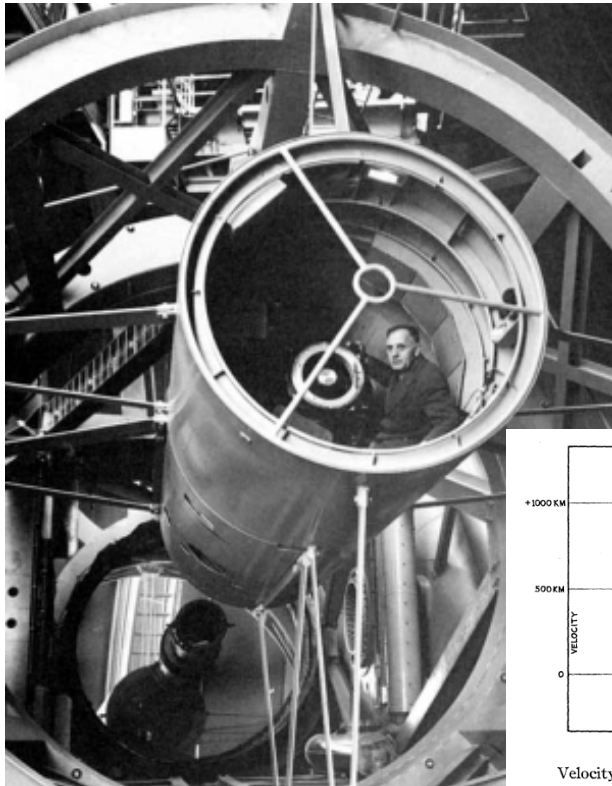


Period-Luminosity Relationship



Edwin Hubble

(1889-1953)



ANOTHER UNIVERSE SEEN BY ASTRONOMER

*Dr. Hubble Describes Mass of
Celestial Bodies 700,000 Light
Years Away.*

CHICAGO, Jan. 21 (P).—For years astronomers have speculated as to whether various nebulous formations in the heavens belongs to this universe or were "island" universes of their own, immeasurable distances away.

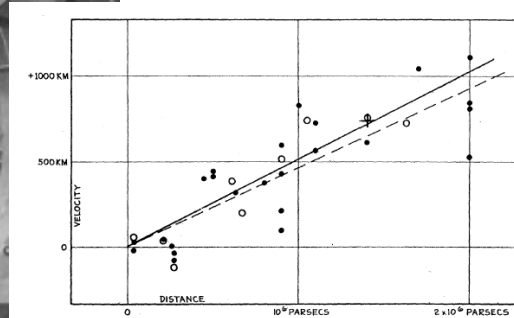
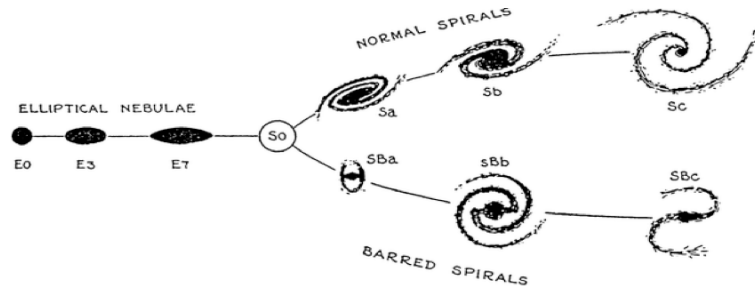


FIGURE 1
Velocity-Distance Relation among Extra-Galactic Nebulae.



Walter Baade

(1893-1960)



Karl Jansky

(1906-1950)



Copyright, 1933, by The New
NEW YORK, FRIDAY

NEW RADIO WAVES TRACED TO CENTRE OF THE MILKY WAY

Mysterious Static, Reported
by K. G. Jansky, Held to
Differ From Cosmic Ray.

DIRECTION IS UNCHANGING

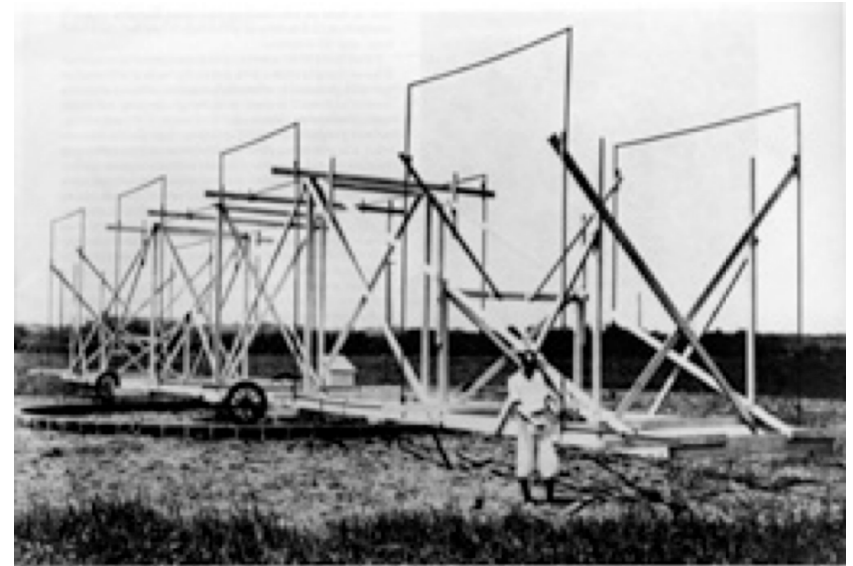
Recorded and Tested for More
Than Year to Identify It as
From Earth's Galaxy.

ITS INTENSITY IS LOW

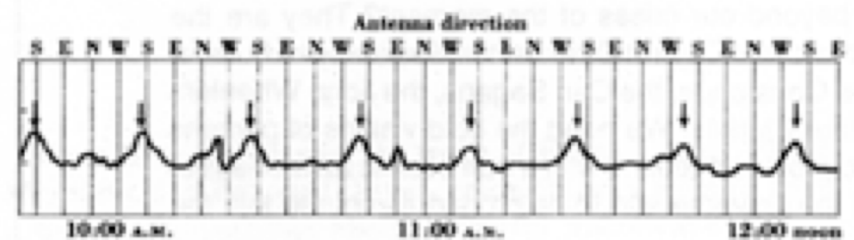
Only Delicate Receiver is Able to
Register—No Evidence of
Interstellar Signaling.

Discovery of mysterious radio waves which appear to come from the centre of the Milky Way galaxy was announced yesterday by the Bell Telephone Laboratories. The discovery was made during research studies on static by Karl G. Jansky of the radio research department at Holmdel, N. J., and was described by him in a paper delivered before the International Scientific Radio Union in Washington.

The galactic radio waves, Mr. Jansky said, differ from the cosmic rays and also from the phenomenon



"About March 1929, Karl Jansky began the design of a 14.6 meter rotatable, directional antenna system and the development of the associated receiving apparatus. By the fall of 1930 (the system) was complete and in good working order."



One of Karl Jansky's records taken with his rotating antenna in February, 1932, with peaks (indicated

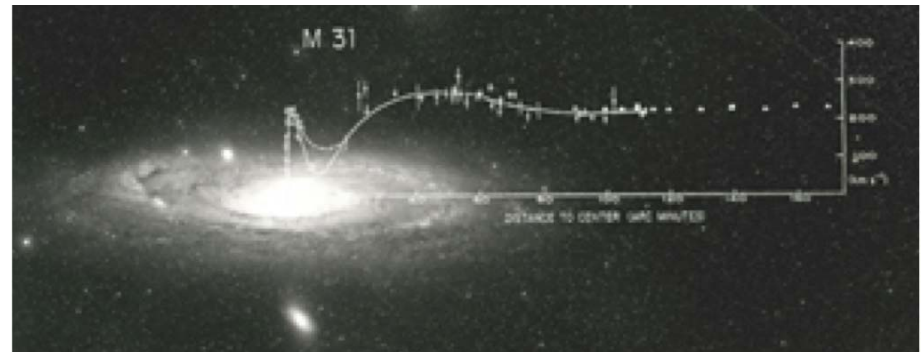
Fritz Zwicky

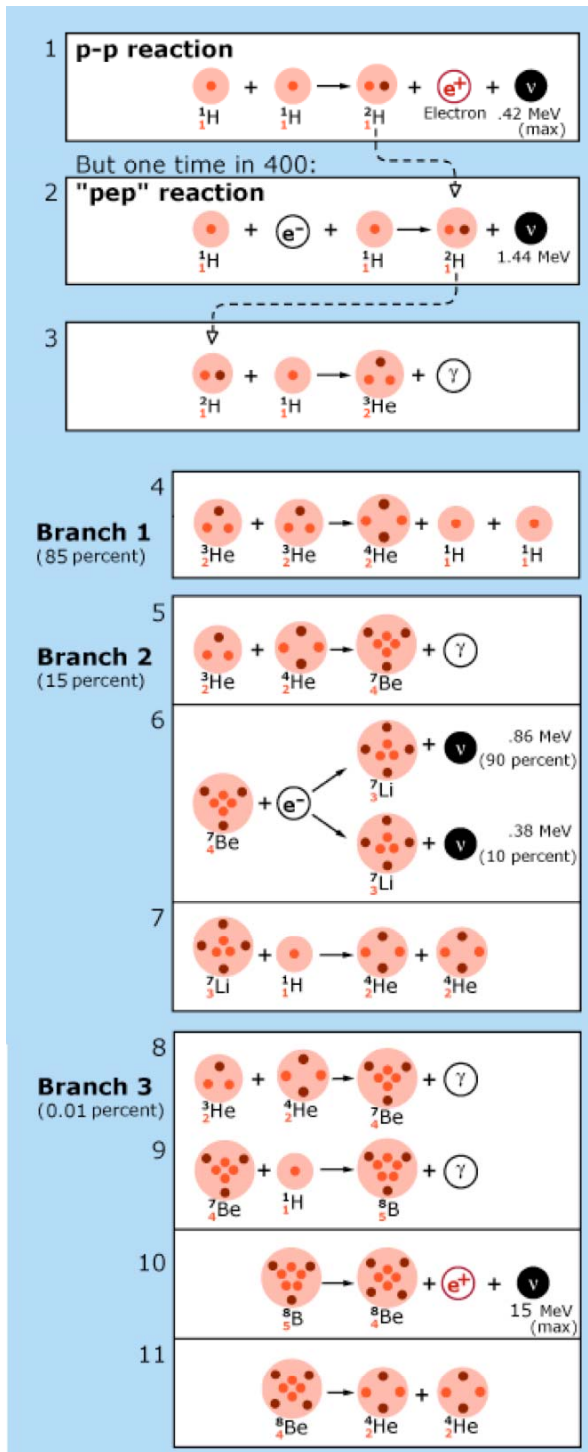
(1898-1974)



Vera Rubin

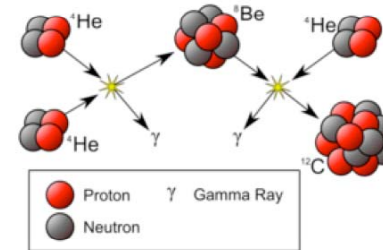
(1928-)





Hans Bethe

(1906-2005)



Edwin Salpeter

(1924-2008)

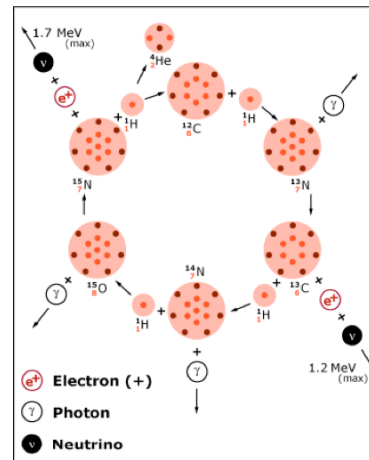


A.G.W. Cameron

(1925-2005)

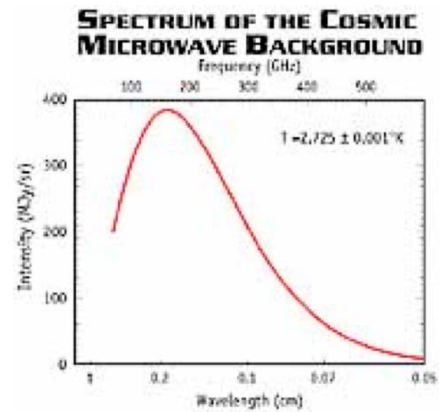
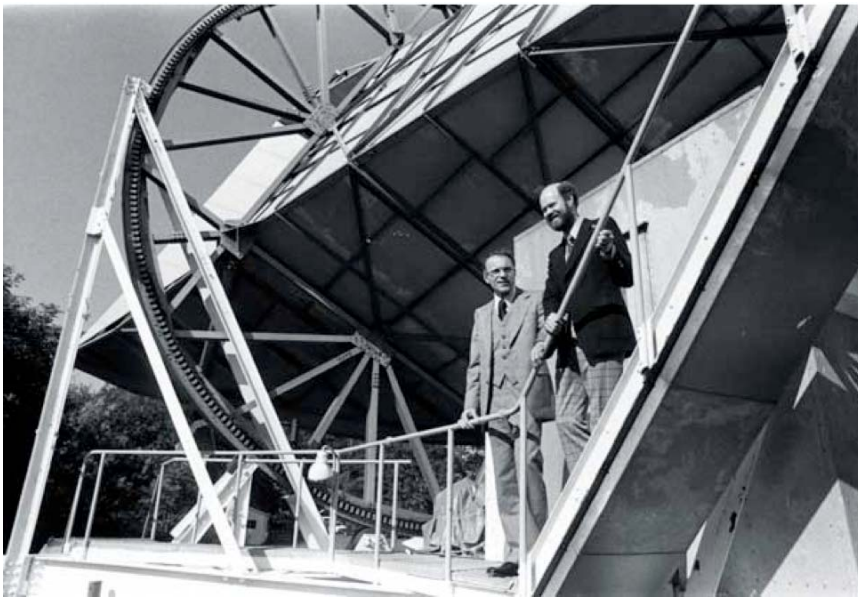


M. Burbidge, G. Burbidge, W. Fowler, & F. Hoyle

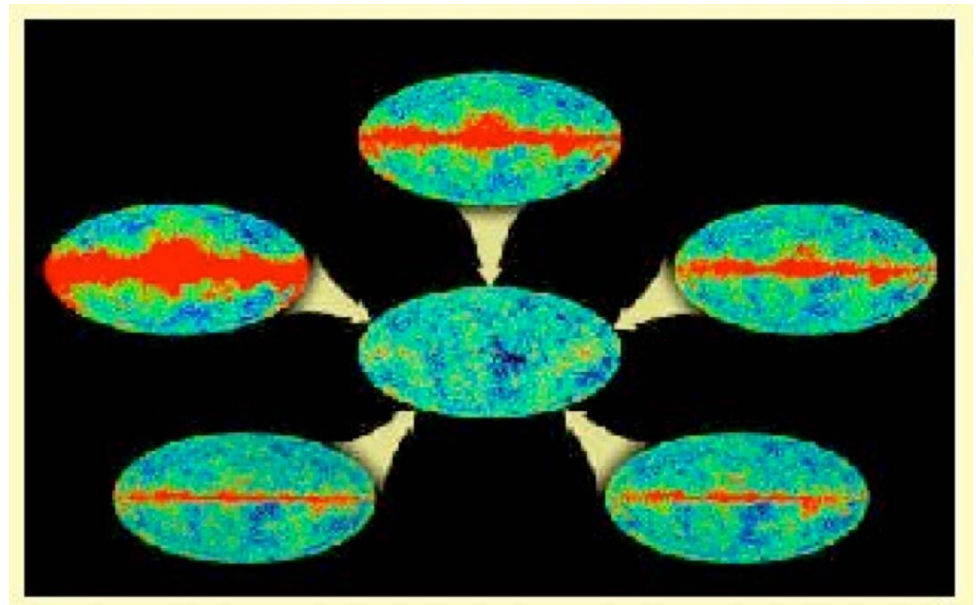
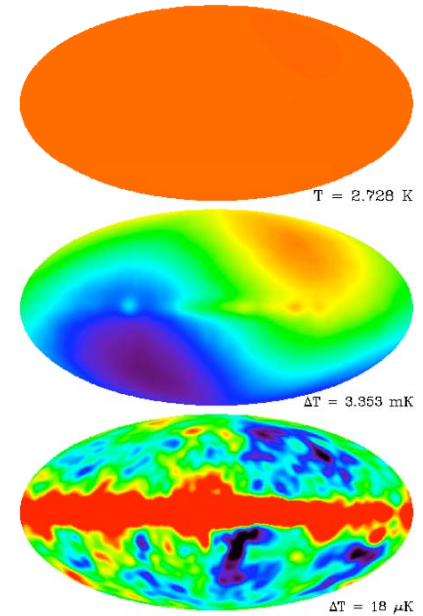


Penzias & Wilson

(1933- and -1936-)



ISOTROPY OF THE COSMIC MICROWAVE BACKGROUND



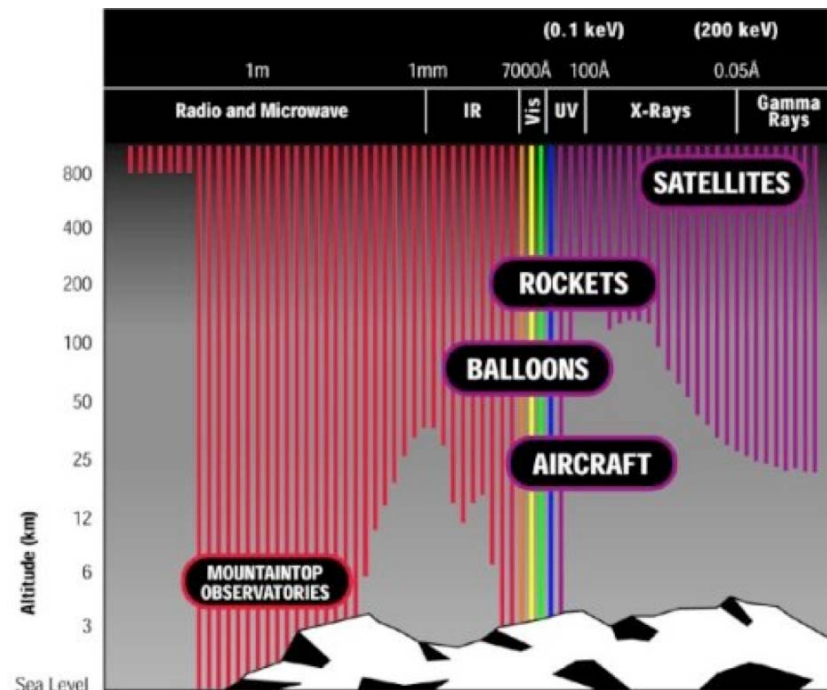
Infrared & X-ray Pioneers



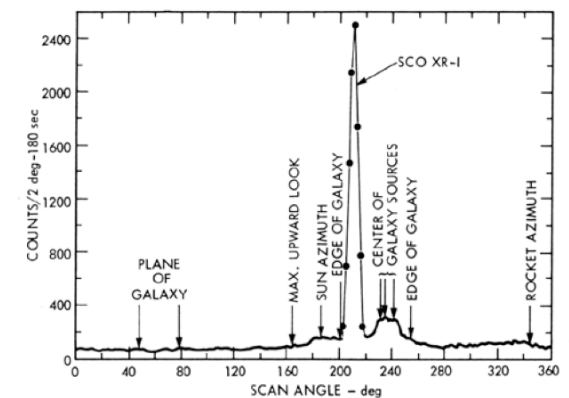
Robert Leighton
Gerry Neugebauer



Harold Johnson
Frank Low



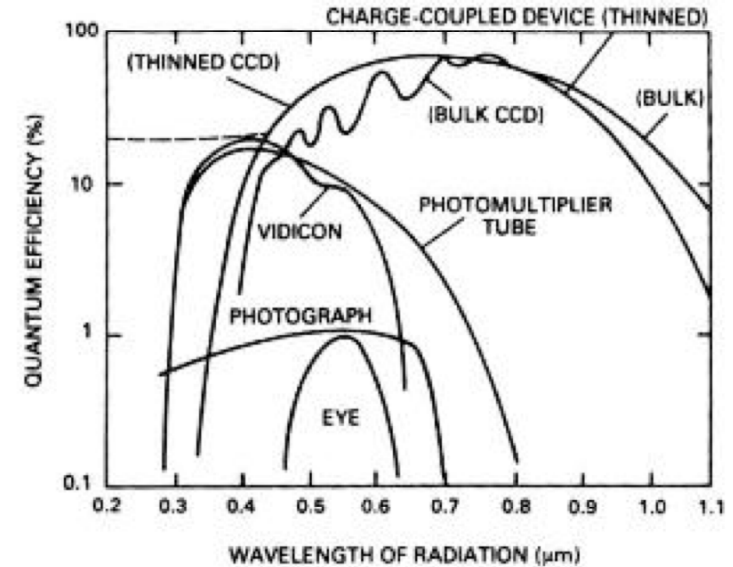
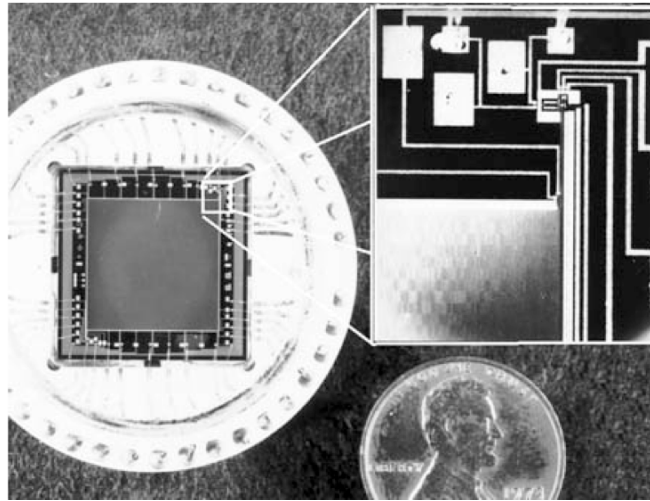
Riccardo Giacconi



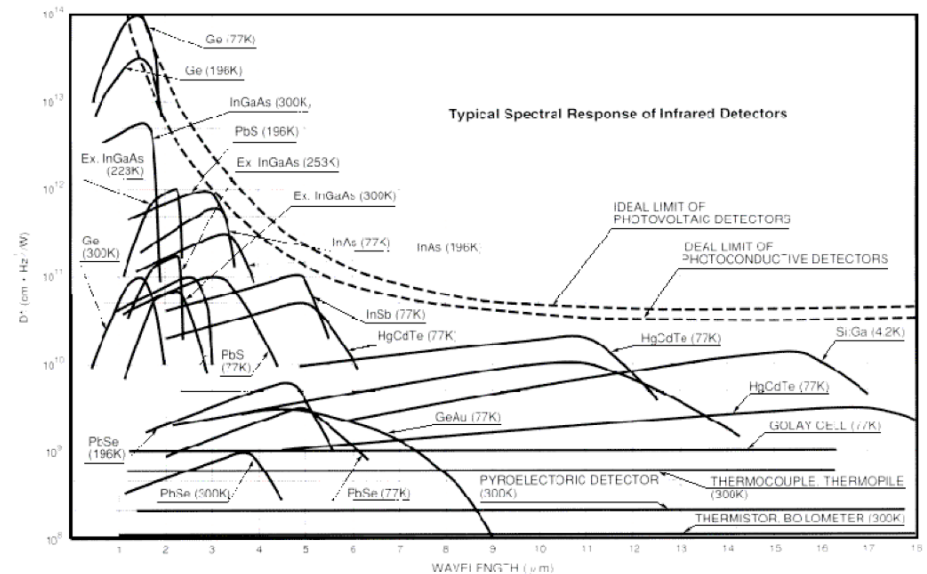
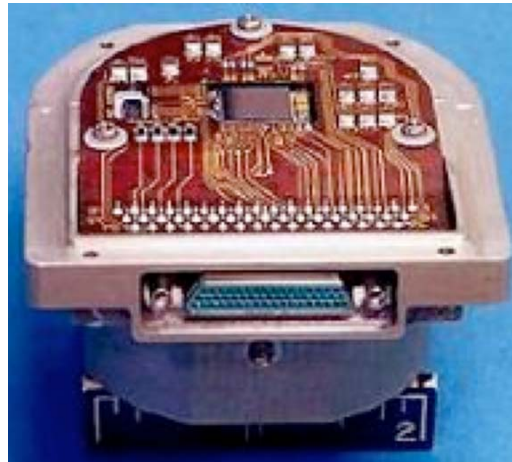
Efficient Light Detection



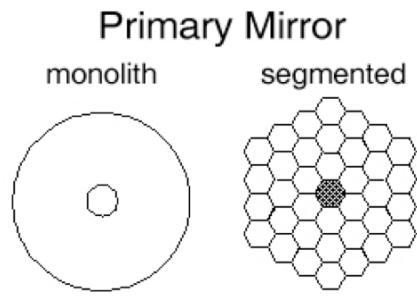
James Westphal



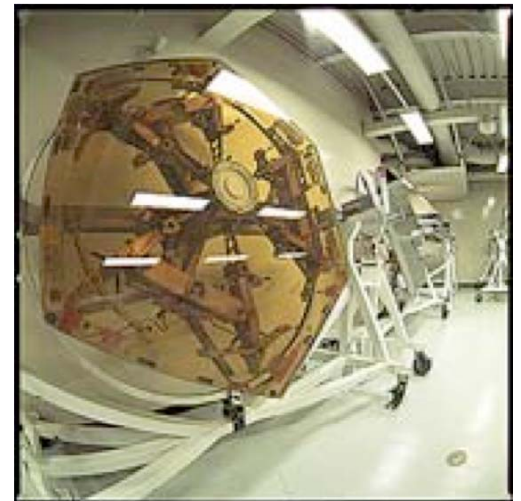
Judith Pipher

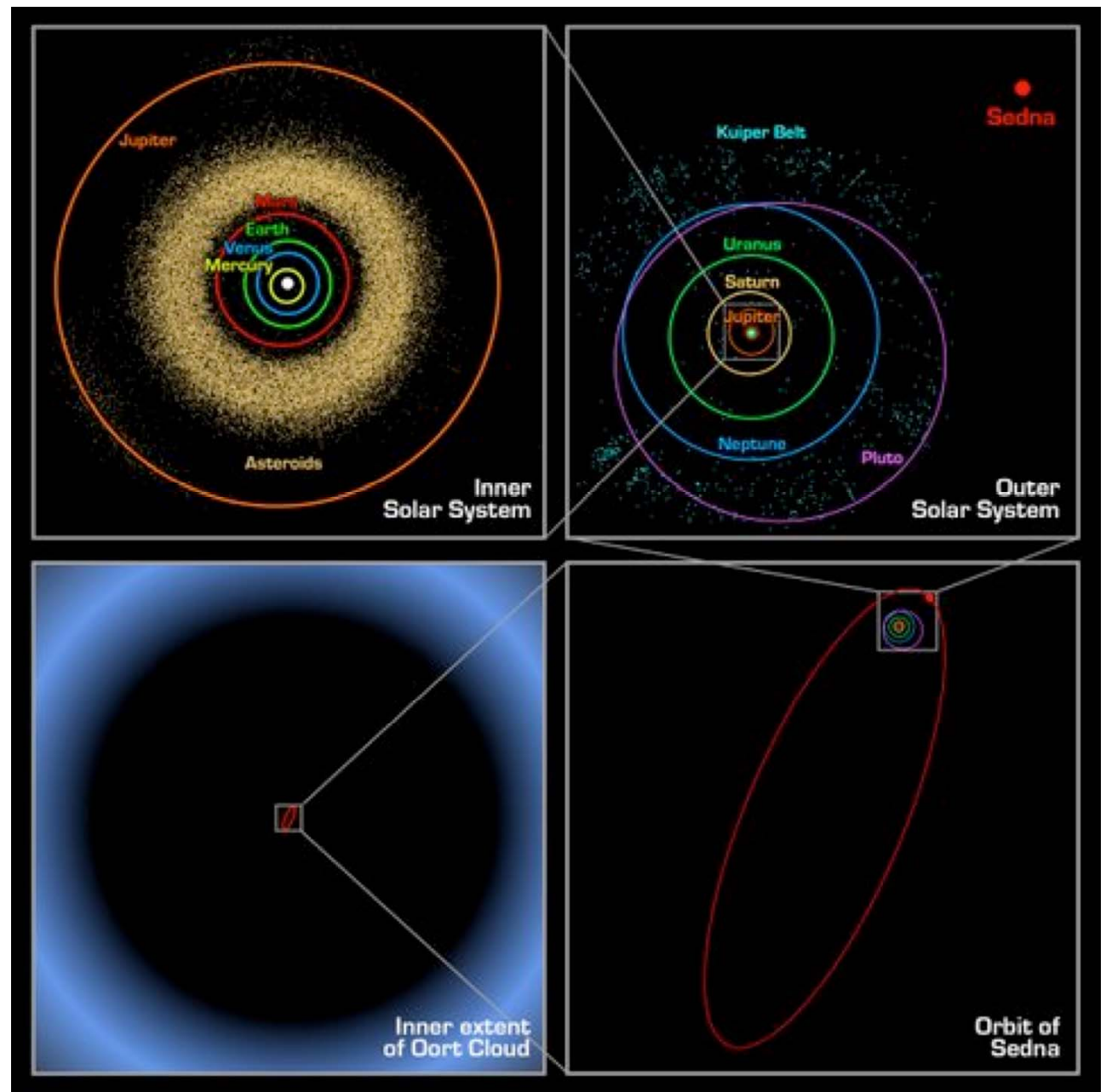
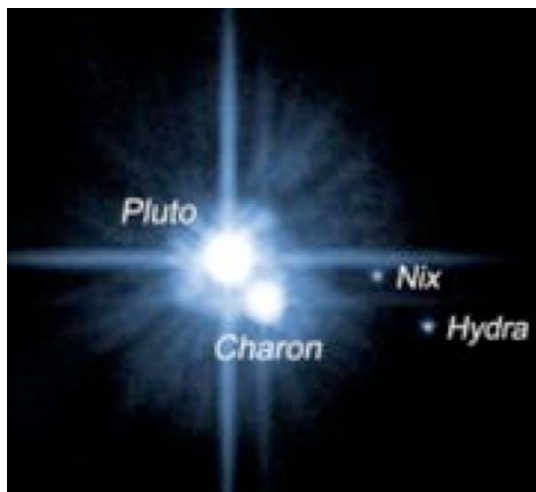
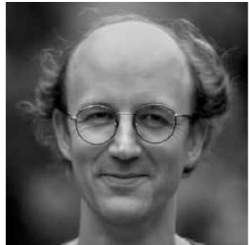


Roger Angel

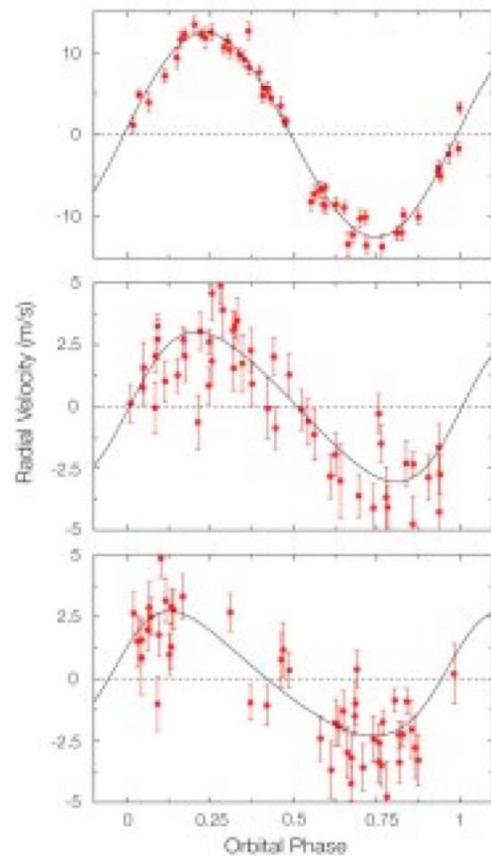
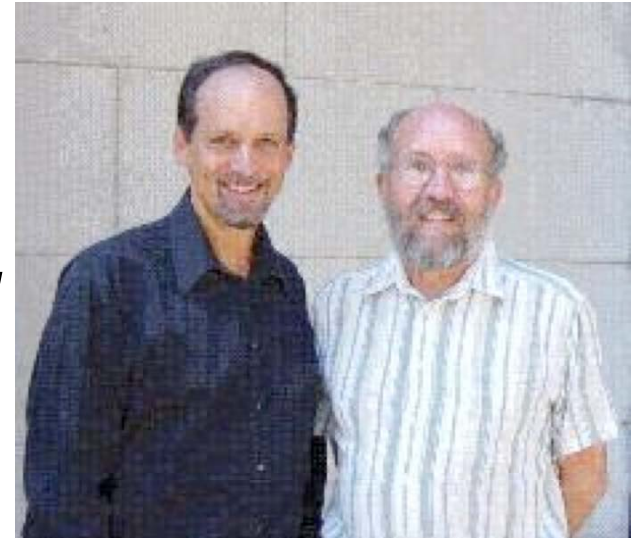


Jerry Nelson

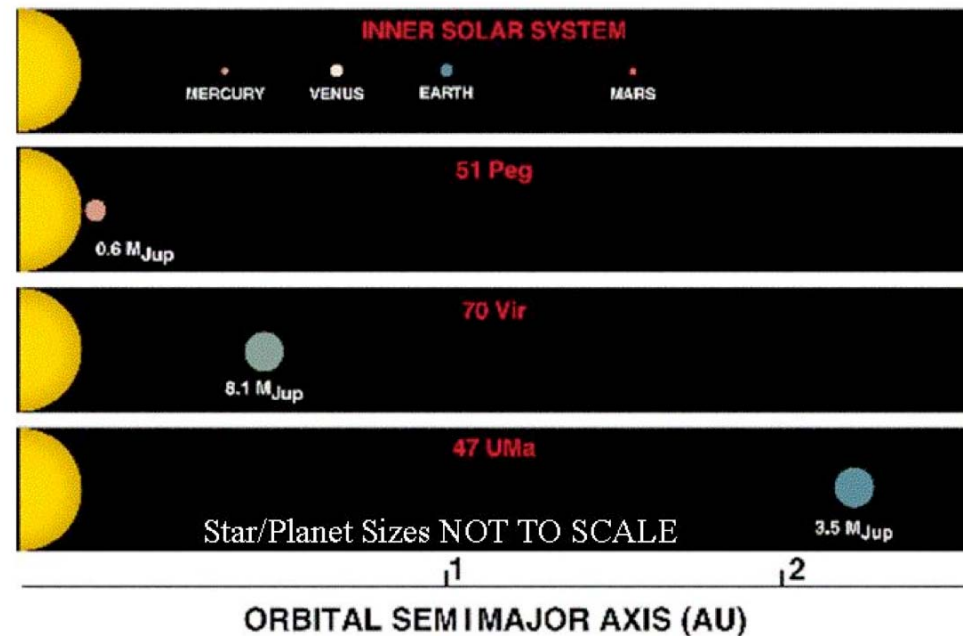




“California Planet Search” and “Geneva Extrasolar Planet” Teams

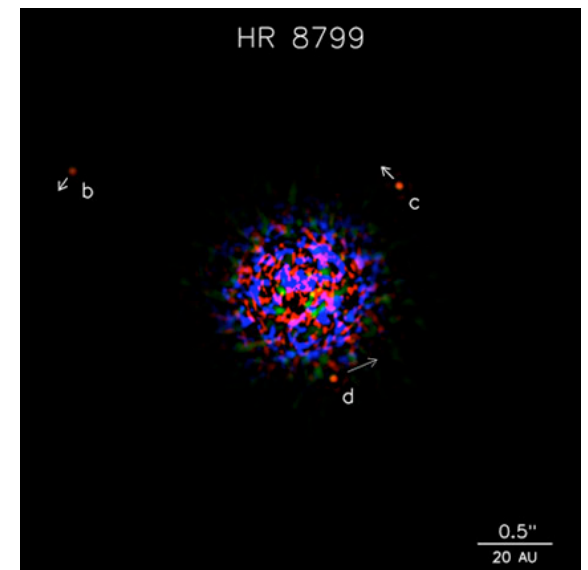
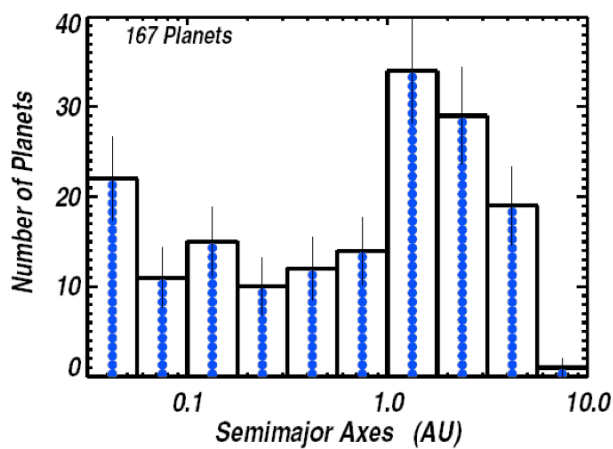
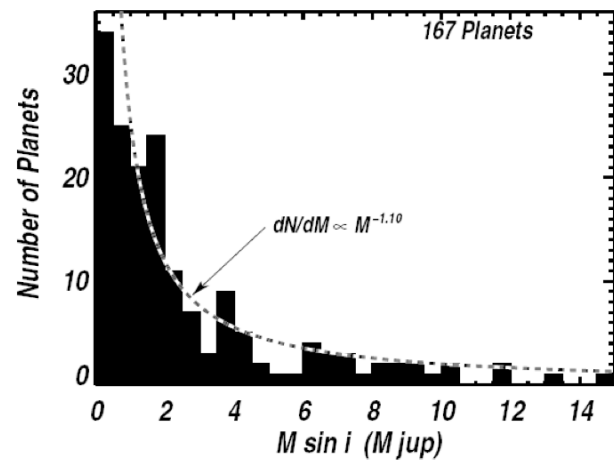
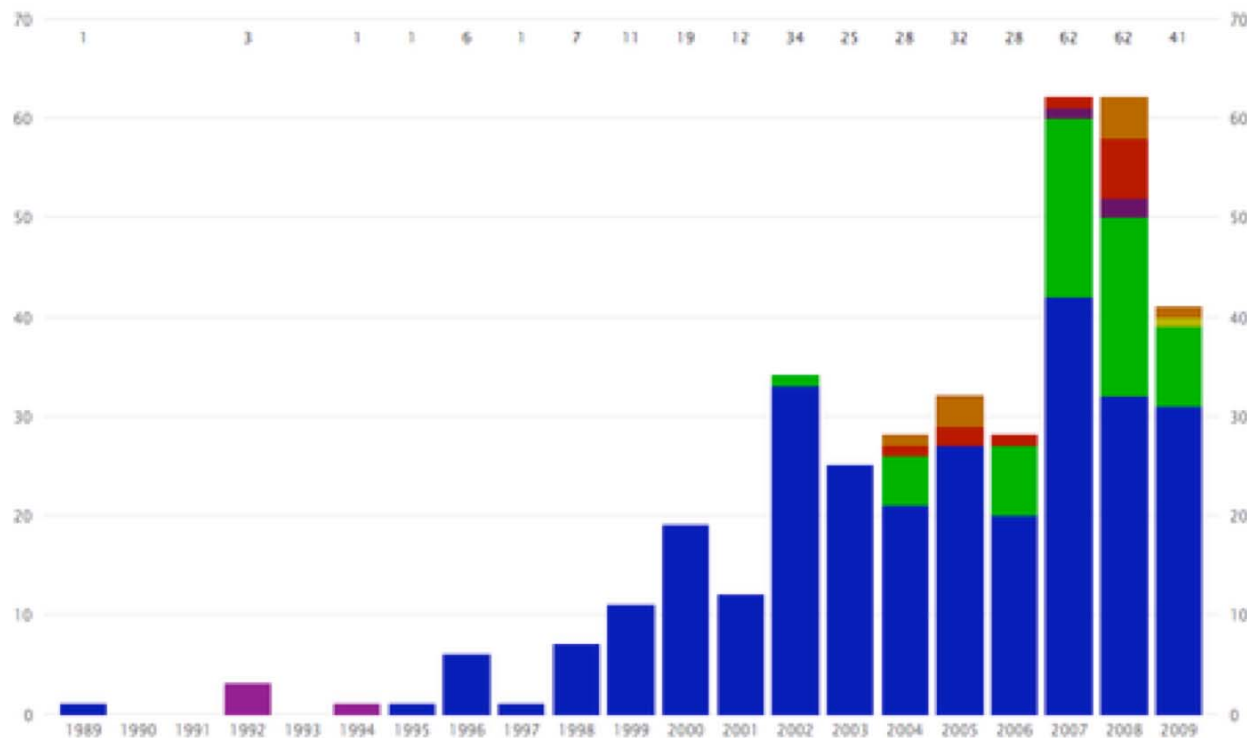


PLANETS AROUND NORMAL STARS

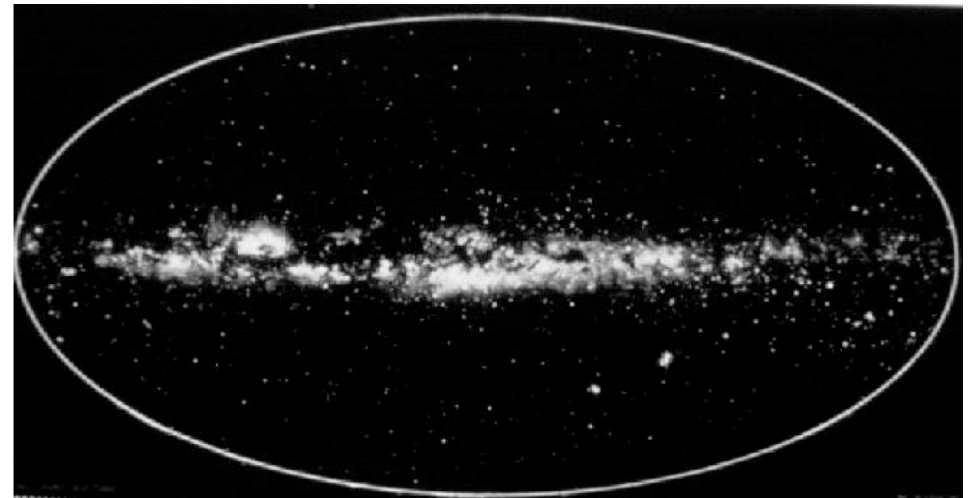
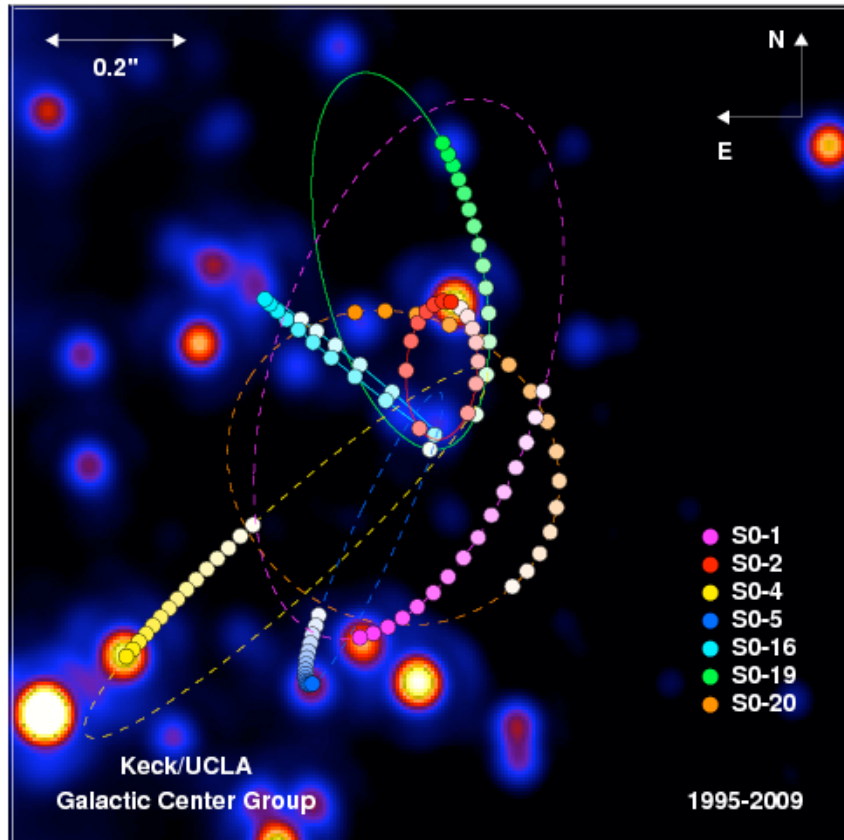


Picture Credit: E. Williams, G. Marcy, and L.-A. McConnaughey, (UC Berkeley), (SFSU)

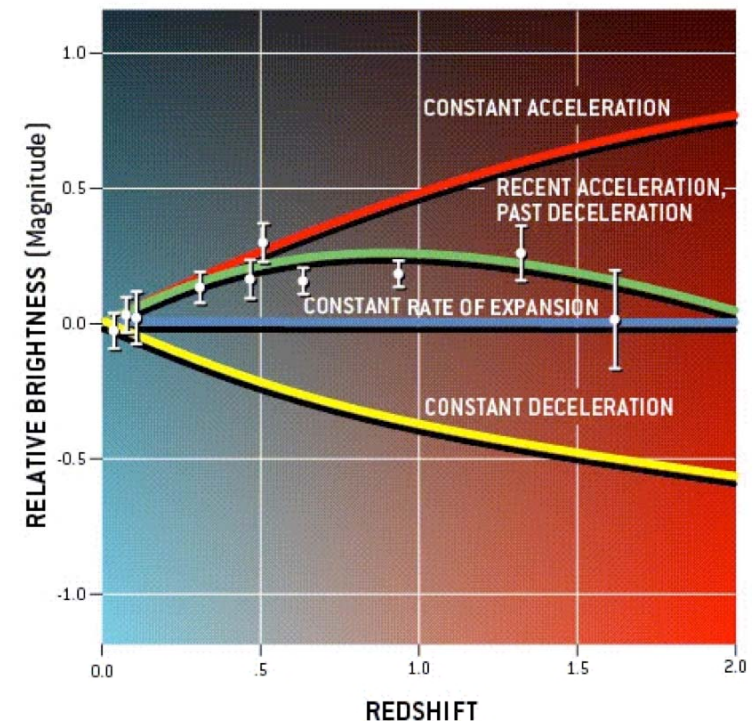
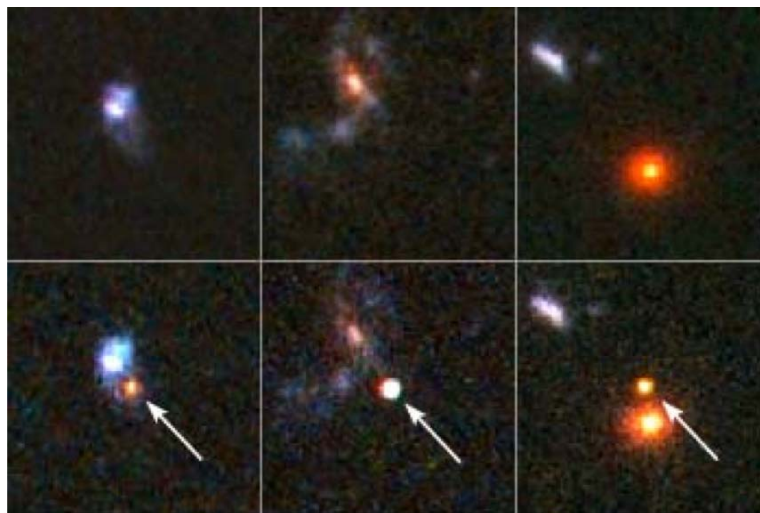
>350 known “exo-planets”



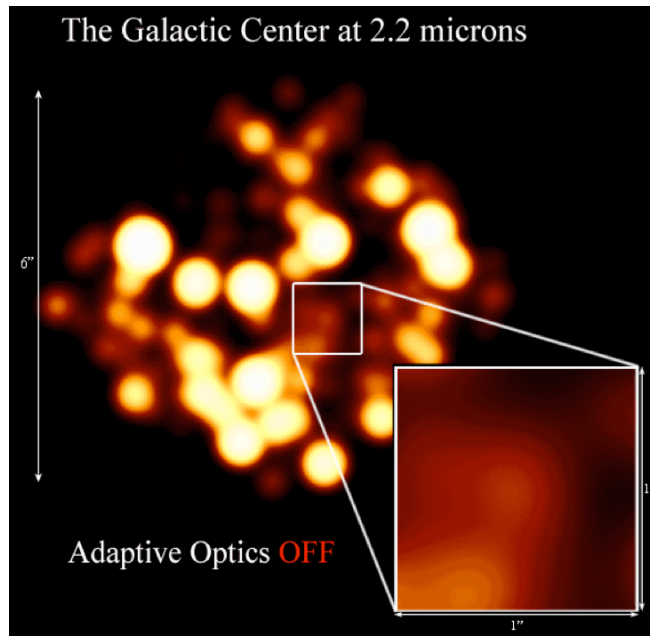
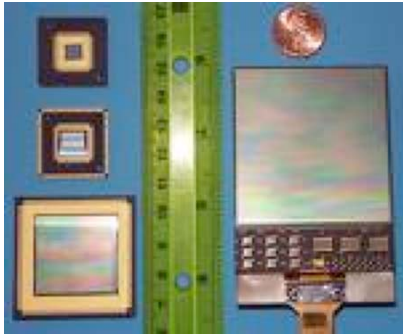
“UCLA Galactic Center” and “Max Planck Institut IR/Submm” Teams



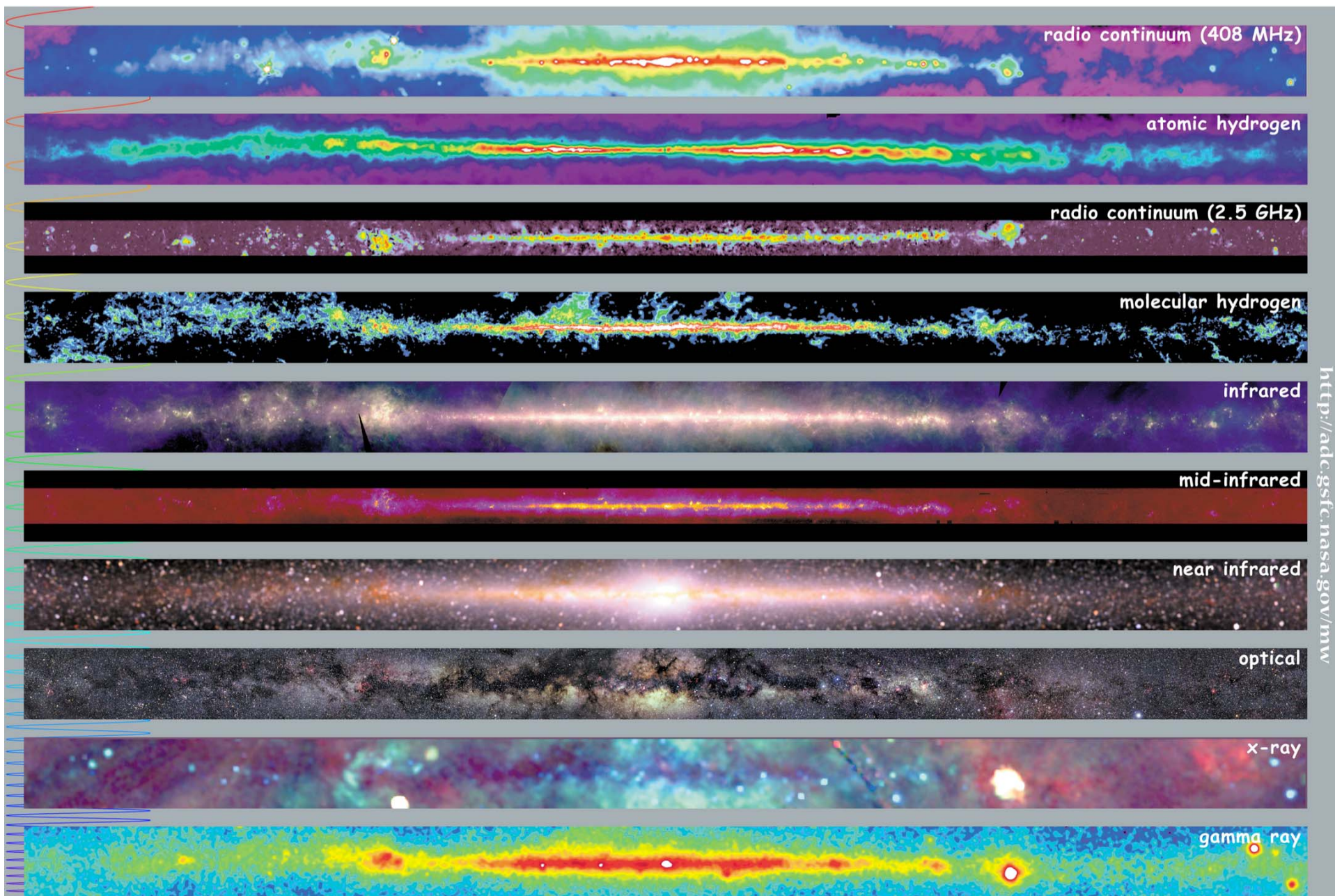
“High-z Supernova Search” and “Supernova Cosmology Project” Teams



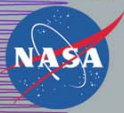
Massive Multiplexing



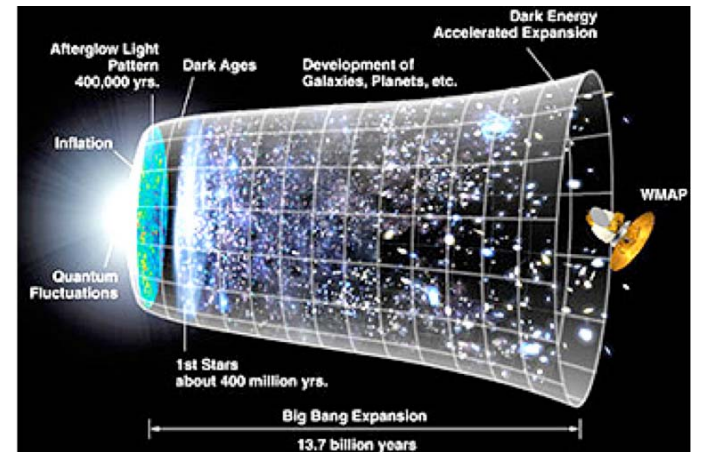
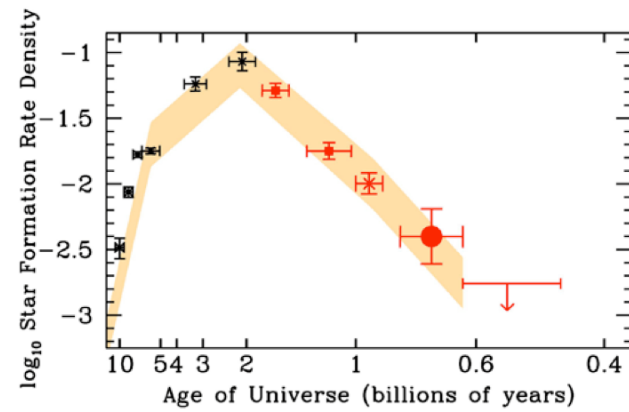
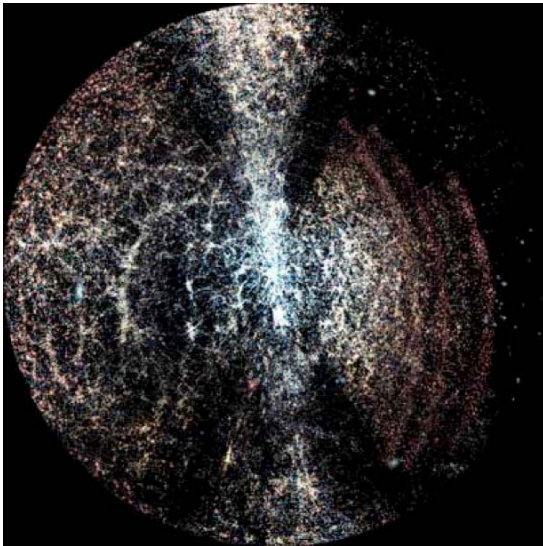
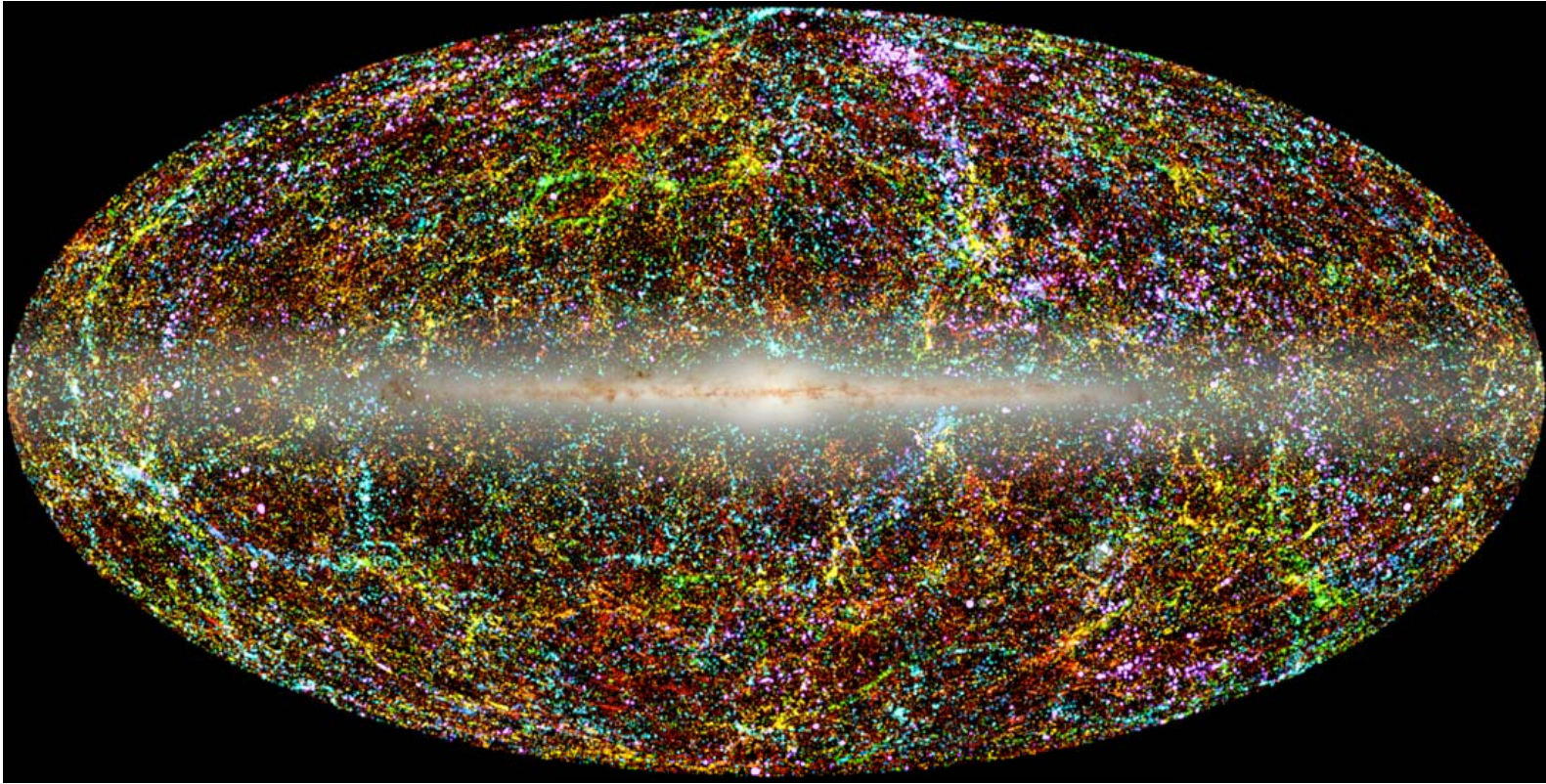
Adaptive Optics

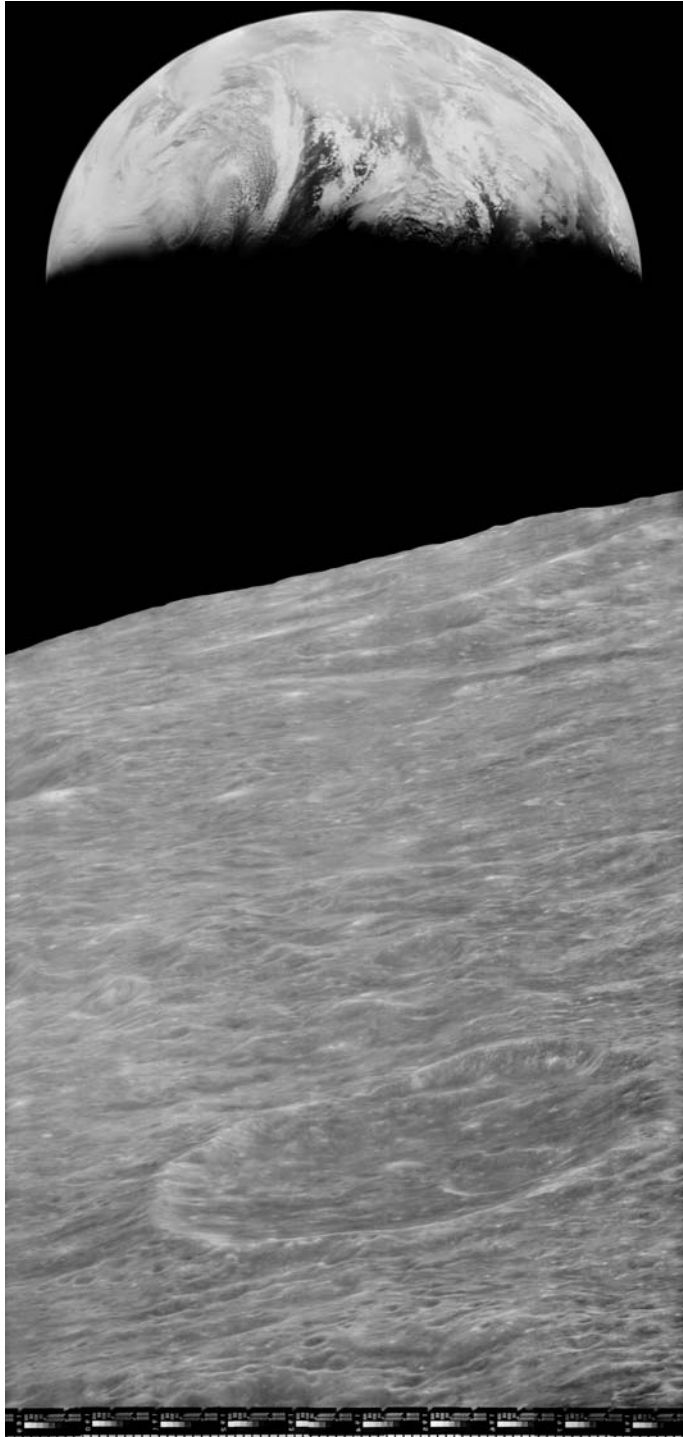


<http://adc.gsfc.nasa.gov/mw>



Multiwavelength Milky Way





Common Themes:

- Inspiration
- Cataloging the sky
- Deciphering physical nature of objects
- Establishing empirical relations / patterns
- Appreciating our place in the universe – location and relative size, evolution, whether we are common/unique.
- Cleverness in our pursuit of the unknown
- The pace of astronomical discovery shows no signs of slowing down!

From Galileo to Today to the Future:

- Technology and instrumentation
- Data collection and analysis
- Interpretation → more questions

