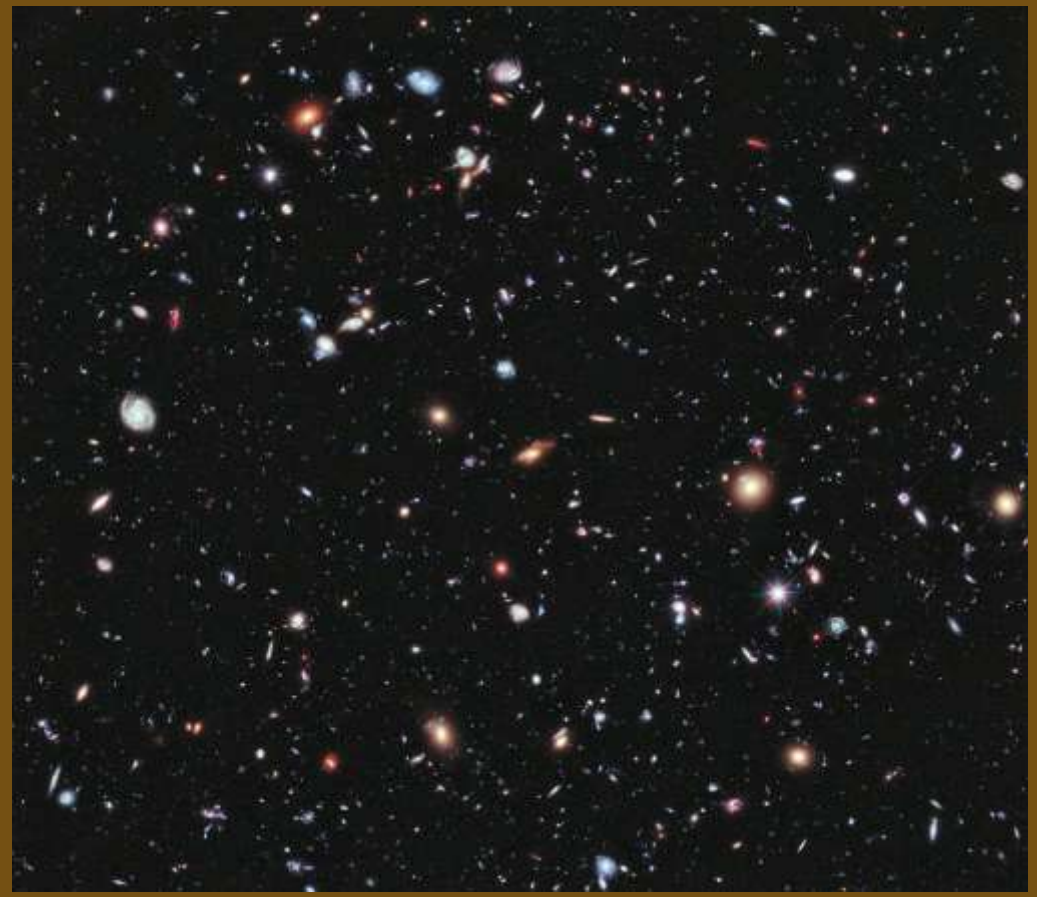
Edwin Hubble and Cosmology



Culpeper Astronomy Club
August 26, 2019

Overview

- Observing Sessions
- Special Topics
- Edwin Hubble
- Constellations
- Observing Session

Observing Sessions

- CAC Observing Session – 9 August
  - Lunar - watched the sunlight progress across Copernicus crater
  - Jupiter (caught the GRS transit) and Saturn
  - Double stars (Albireo, Almach, Izar)
  - Deep sky objects
  - 10-15 Perseid's up to 0200 hrs
- Perseid Meteor Shower Session – 12 August (0100-0500 hrs)
  - Observed 66 meteors, mostly Perseid’s

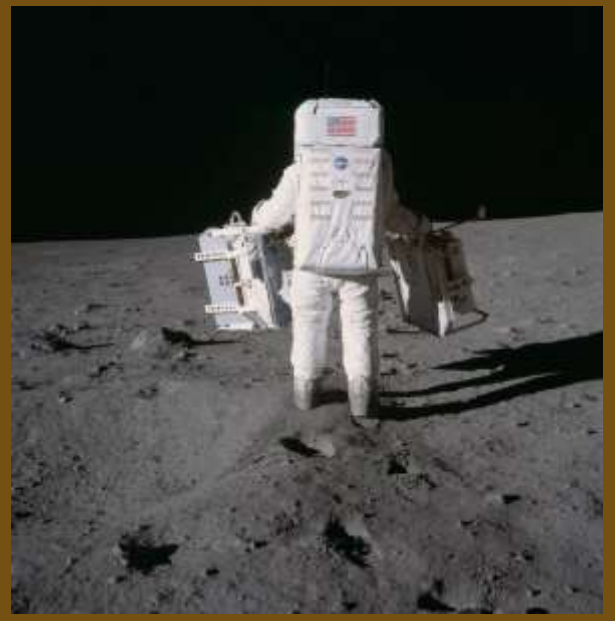
Interesting article…

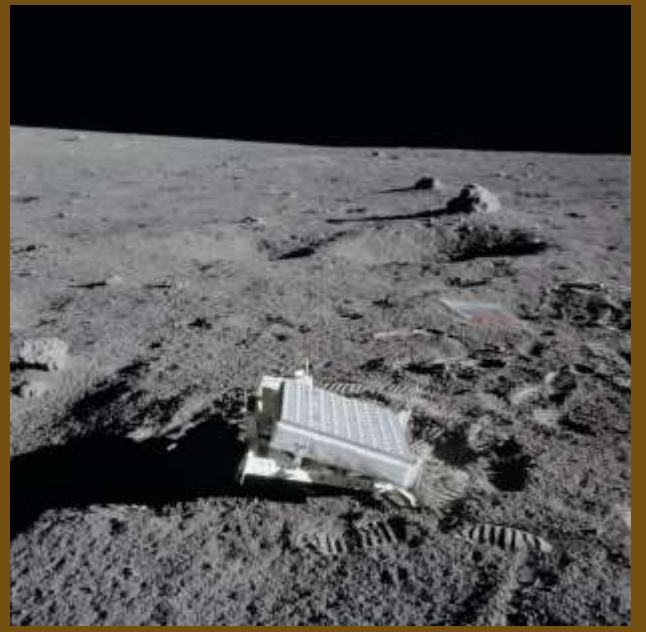
- In a growing technological age, Americans have become increasingly detached from nature
- The lack of engagement with nature is met with a lack of astronomy education, according to research published in the Astronomy education journal
  - According to a study conducted by Northern Illinois University, approximately 94 million Americans don't know that the Earth revolves around the sun and that each revolution takes one year
- According to a survey conducted by Common Sense Media, the average person in the United States spends about 11 hours on technology each day

Special Topics

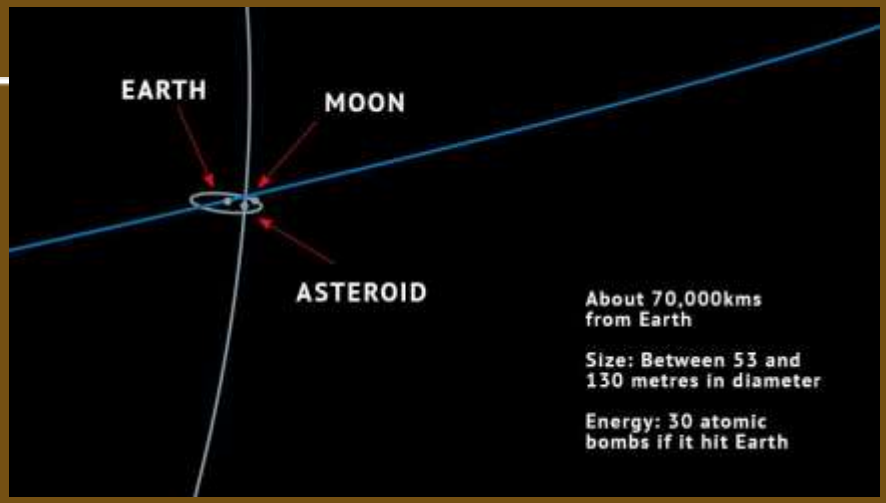
Long Lasting Apollo Experimentation

- One of the experiments left behind continues to return data
  - Consists of arrays of prisms that reflect light
- Along with Apollo 11, Apollo 14 and 15 left arrays behind
  - Apollo 11 and 14 arrays have 100 quartz glass prisms; array of Apollo 15 has 300
- The longevity of the experiment can be attributed to its simplicity; require no power
- The orbit, rotation and orientation of the Moon are accurately determined by lunar laser ranging; data needed by spacecraft that orbit and land on the Moon
- Lunar laser ranging has accurately shown that the distance between the two increases by 1.5 inches a year





Asteroid – Near Miss (25 Jul 2019)

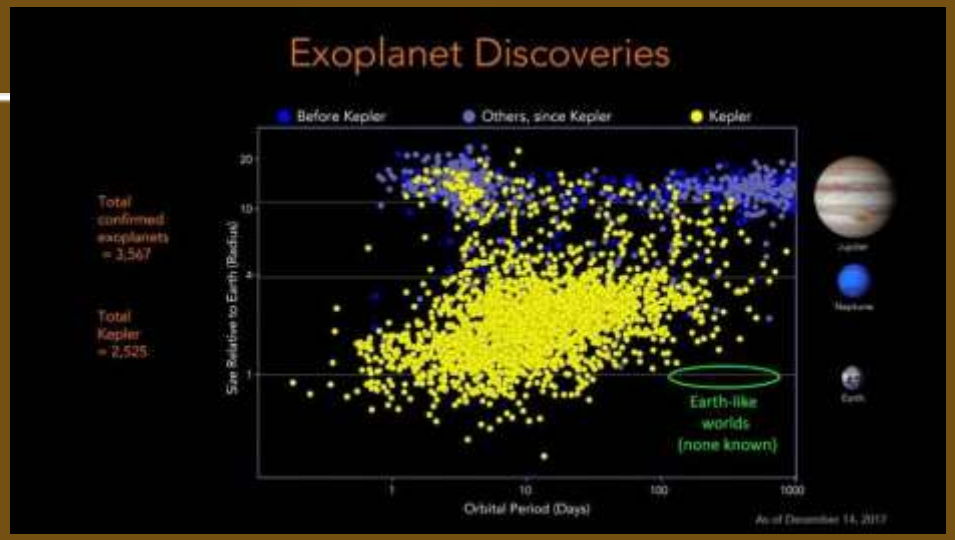


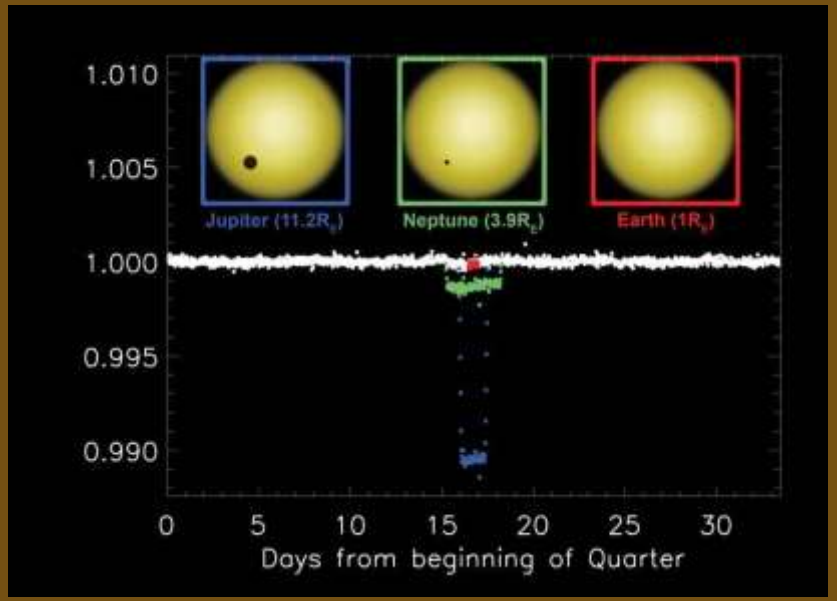
- The rock, called Asteroid 2019 OK, sped by our planet at 11:22 am, Thursday (25 July), passing within about 73,000 kilometers (45,000 miles) – between Earth and Moon
- Due to its trajectory – flying towards us from the direction of the sun – had little warning - less than 24 hours
- Largest object to fly this close to the Earth this year, and possibly for many years
- Estimate its size as between 57 and 130 meters (187 to 427 feet) in diameter

“It would have gone off like a very large nuclear weapon” with enough force to destroy a city. Many megatons, perhaps in the ballpark of 10 megatons of TNT...”

Transiting Exoplanet Survey Satellite (TESS)

- Have discovered 1K's of star systems with planets
- TESS is particularly concerned with finding and characterizing exoplanetary systems around the closest stars to Earth
  - Measures the light coming from a target star (or a set of target stars)
  - Monitor the total light output over relatively long periods of time
  - Search for periodic dips in the overall flux from the star
  - If the dips repeat in frequency and magnitude, extract the radius and orbital distance for a potential candidate planet





Edwin Hubble

“Work, to be pleasant, must be toward some great end, an end so great that dreams of it, anticipation of it, overcomes all aversion to labor. If only I find some principle, for whose sake I could leave everything else and devote my life.”

Letter to his mother, written while at Oxford University

Edwin Hubble – Early Years

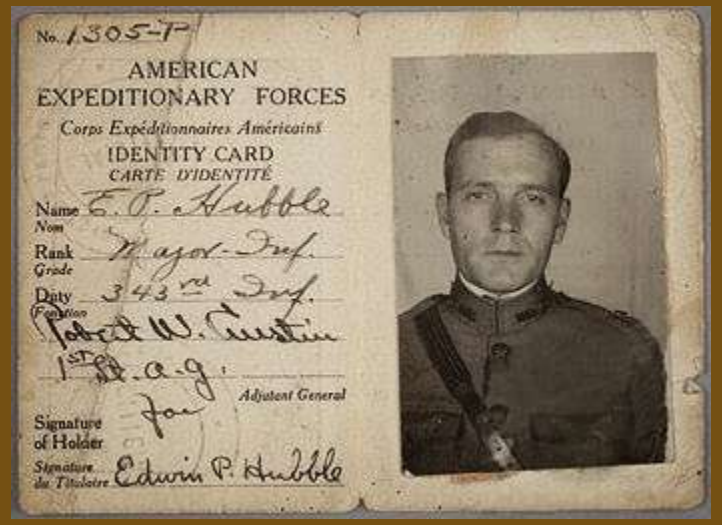
- Edwin Hubble (Edwin Powell Hubble): born November 20, 1889, Marshfield, Missouri, U.S.—died September 28, 1953, San Marino, California
  - American astronomer who played a crucial role in establishing the field of extragalactic astronomy and is generally regarded as the leading observational cosmologist of the 20th century
- Son of John Powell Hubble, a businessman; his mother was a homemaker who ran the household; one of eight children
- Won a scholarship to the University of Chicago (1906), served for a year as a laboratory assistant for physicist Robert Millikan, a future Nobel Prize winner.
  - Graduated in 1910 and was selected as a Rhodes Scholar from Illinois
  - Spent three years at the University of Oxford; awarded a law degree, a subject he had taken at the insistence of his father
  - After his father's death in 1913, the way was open for him to pursue a scientific career

Edwin Hubble - Yerkes

- Upon his return to the United States (1913), Hubble taught high school in Indiana for a year
- He then entered the University of Chicago and embarked on graduate studies in astronomy
- Hubble conducted his observational research at the Yerkes Observatory in Williams Bay, Wisconsin, under the supervision of astronomer Edwin Frost
- By this time Yerkes was no longer on the cutting edge of astronomy, but Hubble did have access to a quite powerful telescope, an innovative 24-inch (61-cm) reflector

Edwin Hubble – Mt Wilson

- Was completing graduate studies just as the director of the Mount Wilson Observatory in California (George Hale), was scouting for new staff
  - The observatory's 100-inch (254-cm) Hooker telescope, the most powerful in the world, was nearing completion.
  - Accepted Hale's job offer, but, before he could take up the position, the US declared war on Germany on April 6, 1917
  - Completed his dissertation on "Photographic Investigations of Faint Nebulae" so he could enlist in the U.S. Army.
  - Hale held the Mount Wilson position open for him until the end of the war; served in France, rising to the rank of major



Edwin Hubble – Research Focus

- Initially studied reflection nebulae within the MW
- Returned to the problem of the so-called spiral nebulae, objects he had investigated for his doctorate
  - The status of the spirals was then unclear
  - Distant star systems comparable to the Milky Way Galaxy, or clouds of gas or sparse star clusters within, or close by, the MW
  - The theory that there are visible galaxies had fallen from favor in the second half of the 19th century
- At the start of the 1920s, astronomers generally agreed insufficient evidence to settle the debate
- Would be up to Hubble to provide that evidence

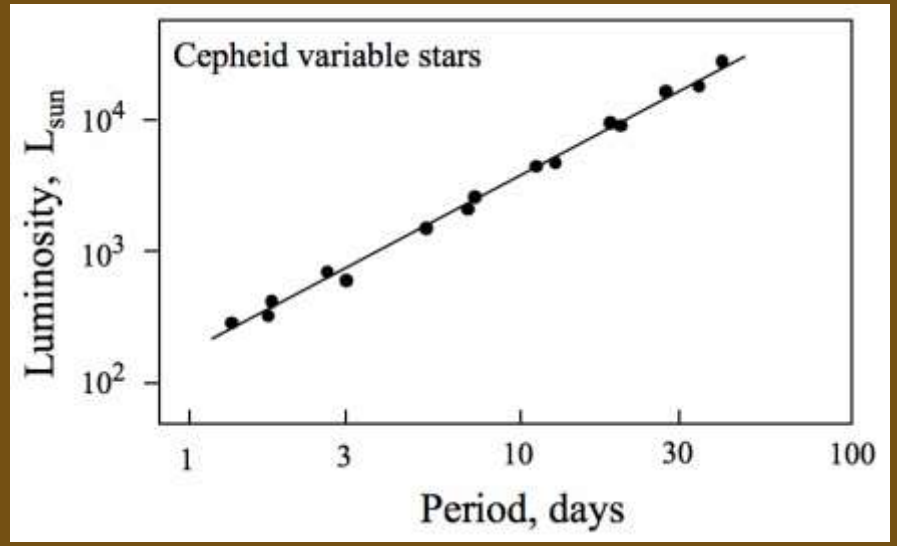
Magnitude (Size) of the Universe

- Dispute over the nature of once termed “spiral nebulae” stands as one of the most significant in the development of astronomy
  - Were we confined to a single, limited stellar system that lay embedded alone in empty space
  - Was our Milky Way Galaxy just one of millions of galaxies that pervaded space, stretching beyond the vast distances
- Long before we knew about the existence galaxies other than ours, astronomers who built larger and larger telescopes discovered that the sky is filled with many nebulous objects
- Confusion over the nature of “spiral nebulae” triggered a great debate between Harlow Shapley and Heber Curtis:
  - Harvard-Smithsonian Museum of Natural History, April 1920
  - The Shapley-Curtis debate could not reach any conclusion

Charcoal drawing of Spiral Nebula (M51), 1845 AD

Cepheid Variables – The Magellanic Clouds

- Henrietta Leavitt studied plates of the Magellanic Clouds; compiled a list of 1,777 periodic variables
- Classified 47 of these in the two clouds as Cepheid variables and noticed that those with longer periods were brighter than the shorter-period ones
  - Inferred that as the stars were in the same distant clouds they were all at much the same relative distance from us
  - Any difference in apparent magnitude was therefore related to a difference in absolute magnitude
  - Her plot showed what is now known as the period-luminosity relationship; Cepheids with longer periods are intrinsically more luminous than those with shorter periods.
- Ejnar Hertzsprung realized the significance of this discovery
  - By measuring the period of a Cepheid from its light curve, the distance to that Cepheid could be determined
  - Used data on nearby Cepheid's to calculate the distance to the Cepheids in the SMC as 37,000 light years away



Cepheid Variables – The P-L Relationship

- The American astronomer Harlow Shapley, noted for his far-reaching work on the size and structure of the Milky Way Galaxy, was one of the first to appreciate the importance of the Magellanic Clouds in terms of the nature of spiral nebulae
- To gauge the distance of the Clouds, he made use of the period-luminosity (P-L) relation discovered by Henrietta Leavitt of the Harvard College Observatory.
  - In 1912 Leavitt had found that there was a close correlation between the periods of pulsation (variations in light) and the luminosities (intrinsic, or absolute, brightness's) of a class of stars called Cepheid variables in the Small Magellanic Cloud.
  - Leavitt's discovery, however, was of little practical value until Shapley worked out a calibration of the absolute brightness's of pulsating stars closely analogous to the Cepheid's, the so-called RR Lyrae variables.
  - With this quantified form of the P-L relation, he was able to calculate the distances to the Magellanic Clouds, determining that they were about 75,000 light-years from Earth.
  - The significance of the Clouds, however, continued to elude scientists of the time. For them, these objects still seemed to be anomalous, irregular patches of the Milky Way Galaxy, farther away than initially thought but not sufficient to settle the question of the nature of the universe.

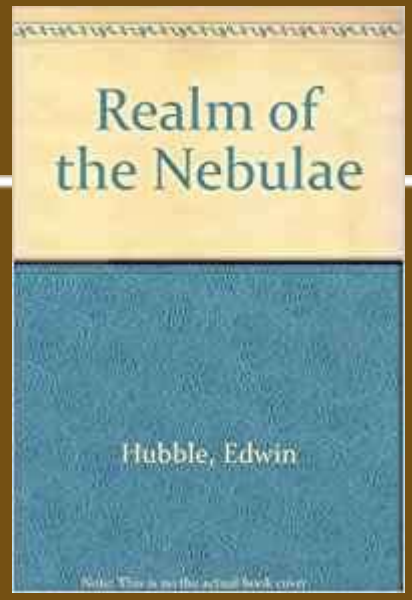
Edwin Hubble – Extra-galactic Galaxies

- In 1923 Hubble found Cepheid variable stars in the Andromeda Nebula, a very well-known spiral
  - Light fluctuations of these stars enabled Hubble to determine the nebula's distance using the relationship between the period of the Cepheid fluctuations and its luminosity
  - Hubble's distance estimate placed the Andromeda Nebula approximately 900,000 light-years away
  - Nebula clearly lay far beyond the borders of the MW Galaxy
  - Andromeda Nebula had to be a galaxy and not a nebulous cloud or sparse star cluster within the Milky Way
- Hubble's finds in the Andromeda Nebula and in other relatively nearby spiral nebulae swiftly convinced the great majority of astronomers that the universe in fact contains a myriad of galaxies (Current distance estimate of the Andromeda Galaxy—is 2.48 million light-years)

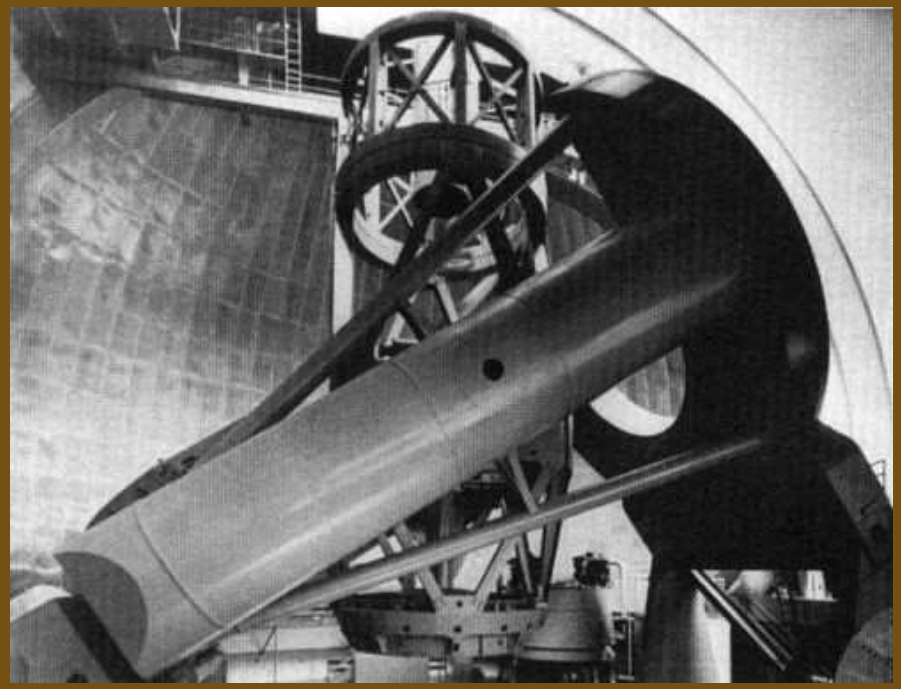
Edwin Hubble – Expanding Universe

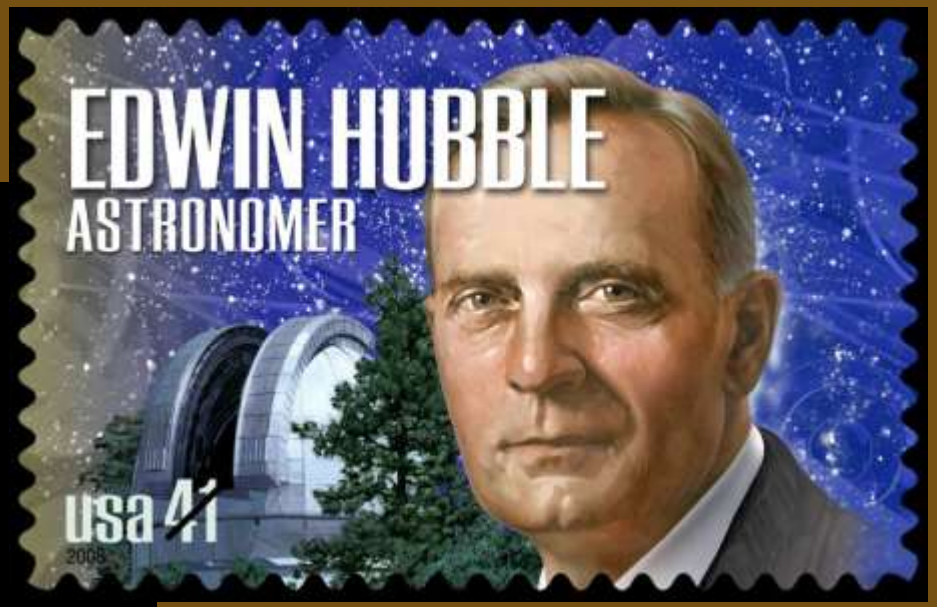
- Within a few years of this path breaking research, Hubble decided to tackle one of the outstanding puzzles about the external galaxies (or extragalactic nebulae, as Hubble always called them):
  - Why did the vast majority seem to be moving away from Earth (if the redshifts in their spectra are interpreted as the result of Doppler shifts)?
  - To this end, Hubble was aided by another Mount Wilson astronomer, Milton Humason. Humason measured the spectral shifts of the galaxies (and in so doing built on the pioneering studies of the Lowell Observatory astronomer Vesto Melvin Slipher), and Hubble focused on determining their distances.
- In 1929 Hubble published his first paper on the relationship between redshift and distance
  - He tentatively concluded that there is a linear redshift-distance relationship; that is, if one galaxy is twice as far away as another, its redshift is twice as large
  - Two years later Hubble and Humason presented what astronomers and cosmologists widely judged to be very convincing evidence that the relationship is indeed linear and hence that a galaxy's redshift is directly proportional to its distance

Edwin Hubble - Legacy



- Hubble published little research after 1936: published his important book “The Realm of the Nebulae”
  - Explained his approaches to extragalactic astronomy and his view of the subject’s history
- He had done much to lay down the methods and techniques that extragalactic astronomers would follow or have to take into account for decades
  - Continued research at Mt Wilson and Palomar Observatory’s (200-inch Hale Telescope that made its first observations in 1949)
- Hubble was the central figure in the establishment of extragalactic astronomy in the 1920s and ’30s




EDWIN HUBBLE
ASTRONOMER
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2008


Images from the
Hubble Space Telescope
named in honor of
distinguished
American astronomer
EDWIN POWELL HUBBLE
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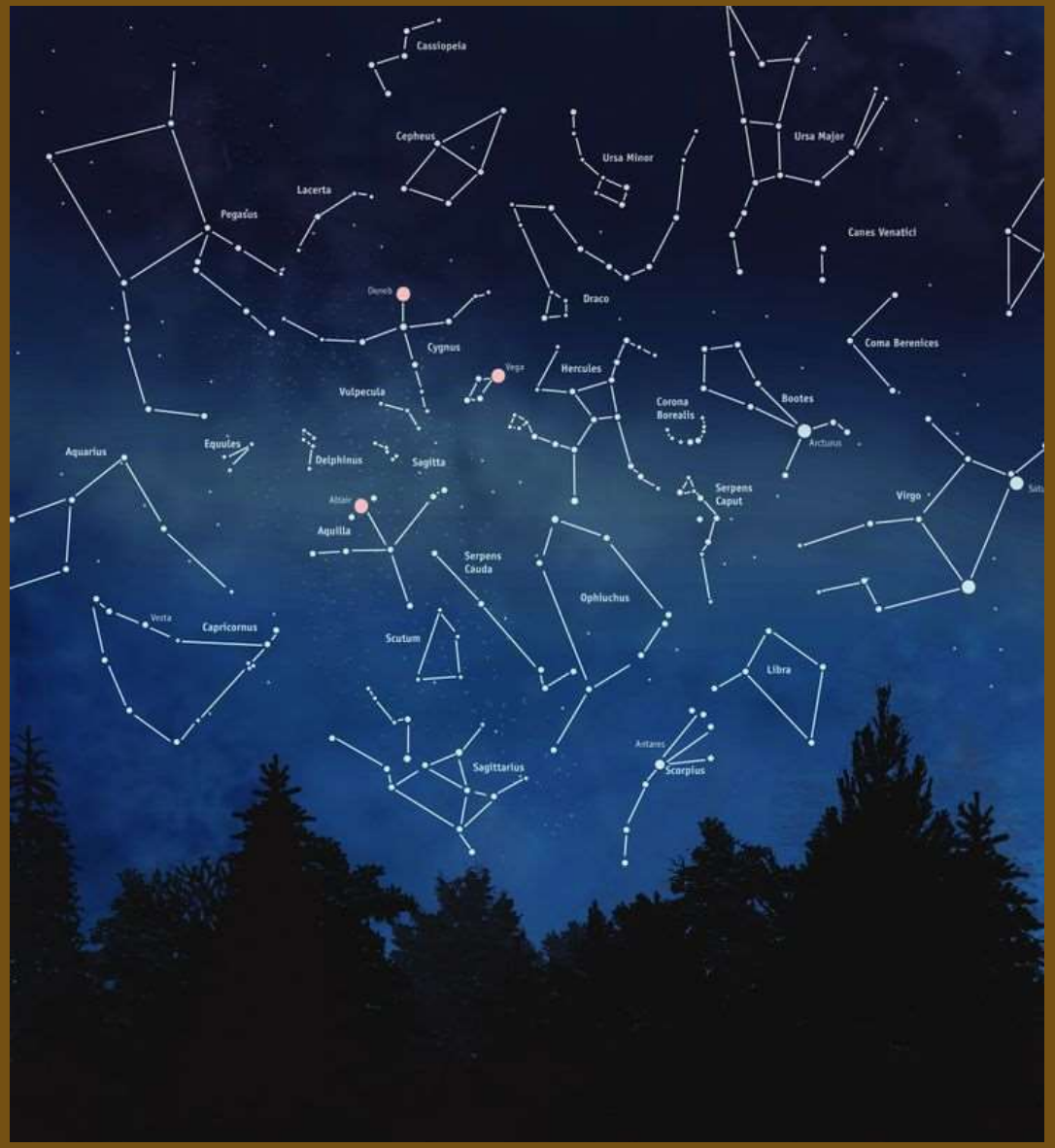
Constellations

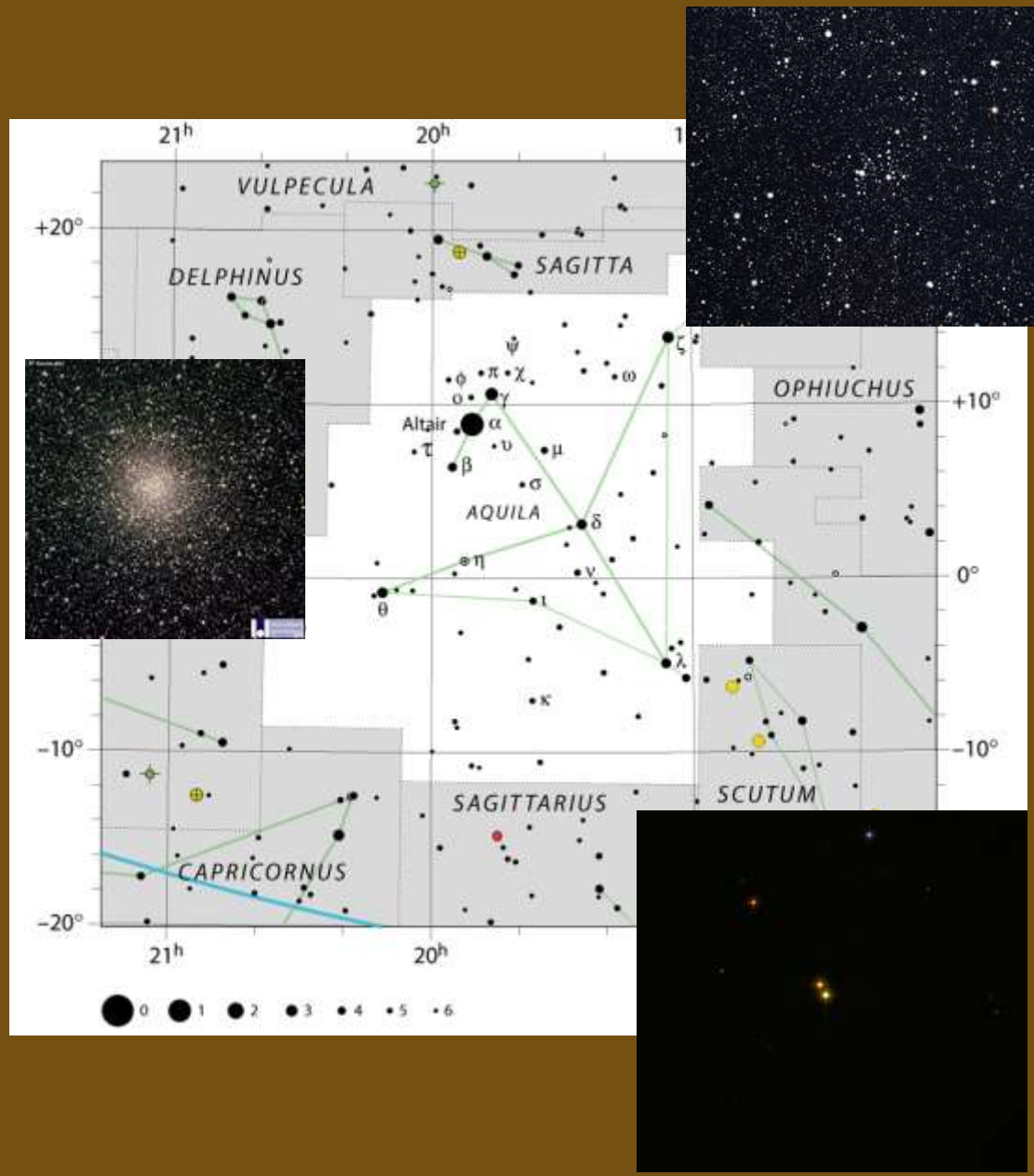
- Aquila: “The Eagle”
- Delphinus: “The Dolphin”
- Scutum - “The Shield”



Aquila- “The Eagle”

- Aquila is identified as the eagle that carried Zeus’ thunderbolts
  - Altair: “flying eagle” or “vulture”; one of the three stars that form the Summer Triangle
  -
- Double Stars:
  - 15 Aquilae: binary star; 5 mag yellow star and 7 mag companion

- Deep Sky Objects:
  - NGC 6709: Open Star Cluster; stars are loosely arranged into a diamond-like shape
  - NGC 6760: Globular Cluster

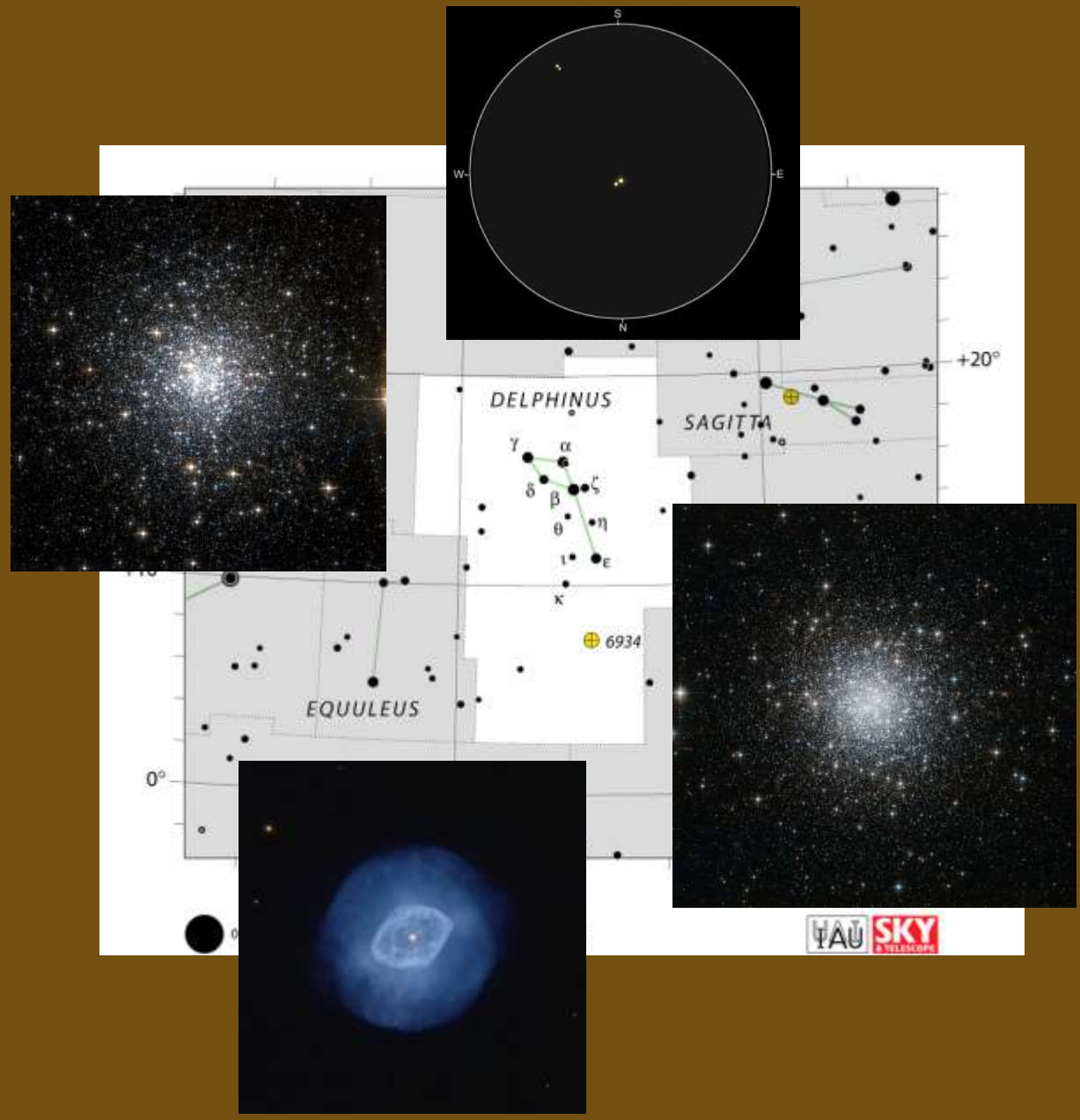


Delphinus - “The Dolphin”

- One of the smallest constellations; represents the dolphin sent by Poseidon to find Amphitrite, his future wife

- Gamma Delphini - binary star; 101 light years distant; yellow-white dwarf and an orange subgiant; mag of 5.14 and 4.27; 9” Sep

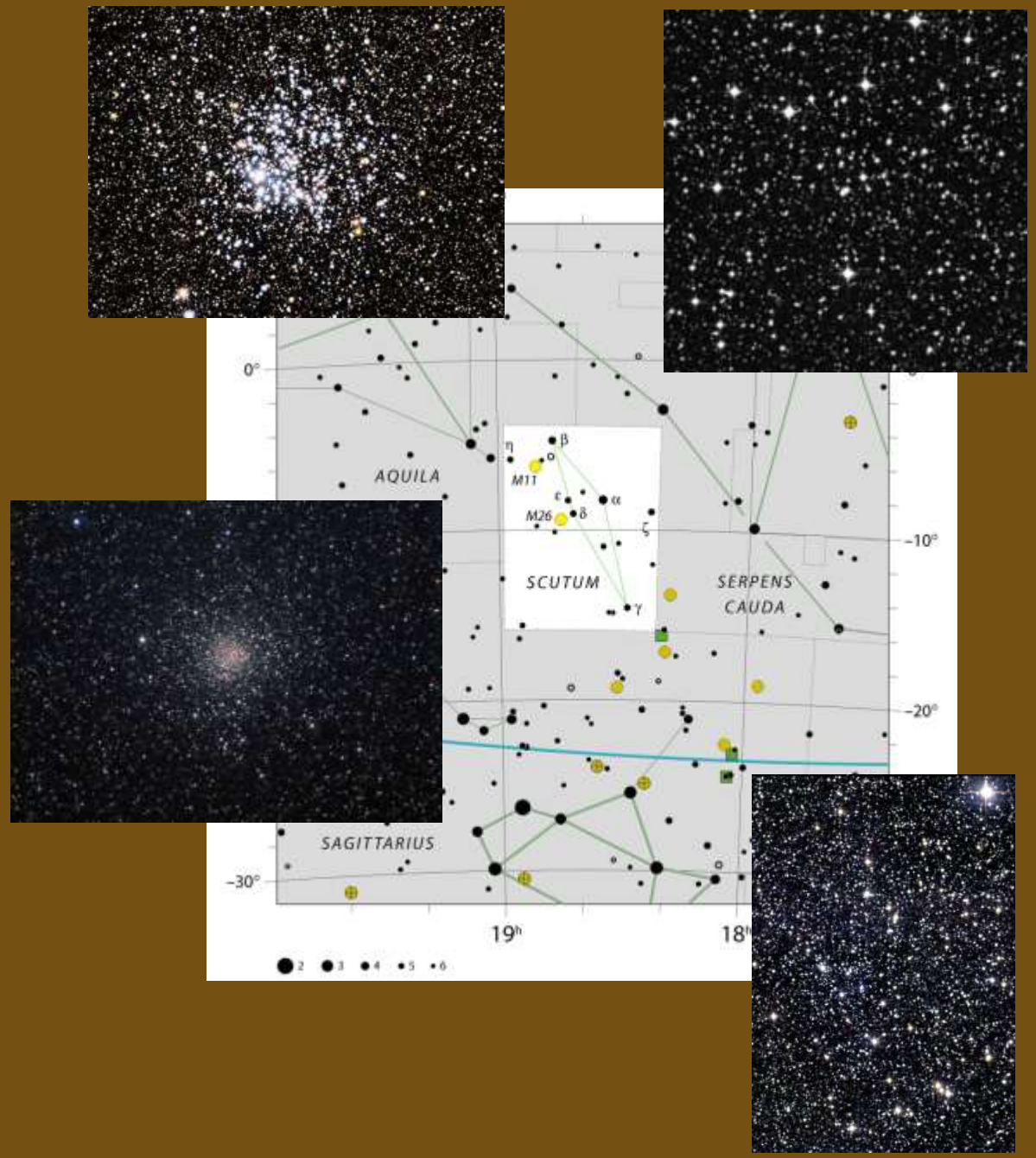
- Deep Sky Objects:
  - NGC 6934 - large globular cluster near Epsilon Delphini; 50K LY distant; 8.83 mag
  - NGC 6891 - small planetary nebula located near the star Rho Aquilae; 7.2K LY distant
  - NGC 7006 - globular star cluster located 137K LY distant; The cluster has a visual magnitude of 10.6; located close to Gamma Delphini



Scutum - “The Shield”

- Hevelius named it Scutum Sobiescianum, Shield of Sobieski
  - In honor of the Polish King Jan Sobieski
  - Had been victorious in the Battle of Vienna in 1683

- The most famous deep sky objects in Scutum:
  - Messier 11, Wild Duck Open Star Cluster, 5.8 mag, 6.1K LYs distant
  - NGC 6664, Open Cluster, E of Alpha, 7.8 mag, 3.8K LYs distant
  - Messier 26, Open Star Cluster, 8th mag, 3.8K LYs distant
  - NGC 6712, Globular Cluster, ENE of M26, 8th mag, 22.5K LYs distant



Meteor Showers

- Some of the best are listed below along with dates when the most meteors are visible
  - Quadrantids, January 3-4 (Comet 2003 EH1)
  - Lyrids, April 22-23 (Comet Thatcher)
  - Perseids, August 12-13 (Comet Swift-Tuttle)
  - Orionids, October 20-21 (Halley's Comet)
  - Leonids, November 17-18 (Comet Tempel-Tuttle)
  - Geminids, December 13-14 (Asteroid 3200 Phaethon)
  - Ursids, December 23-24 (Comet 8P/Tuttle)
- The name of each shower refers to the constellation to which the meteors trace their apparent paths

Upcoming Events

- Next Meeting: September 23, 7-8:30 p.m.
  - Topic: Fall Constellations
    - Great Courses: “Our Night Sky”