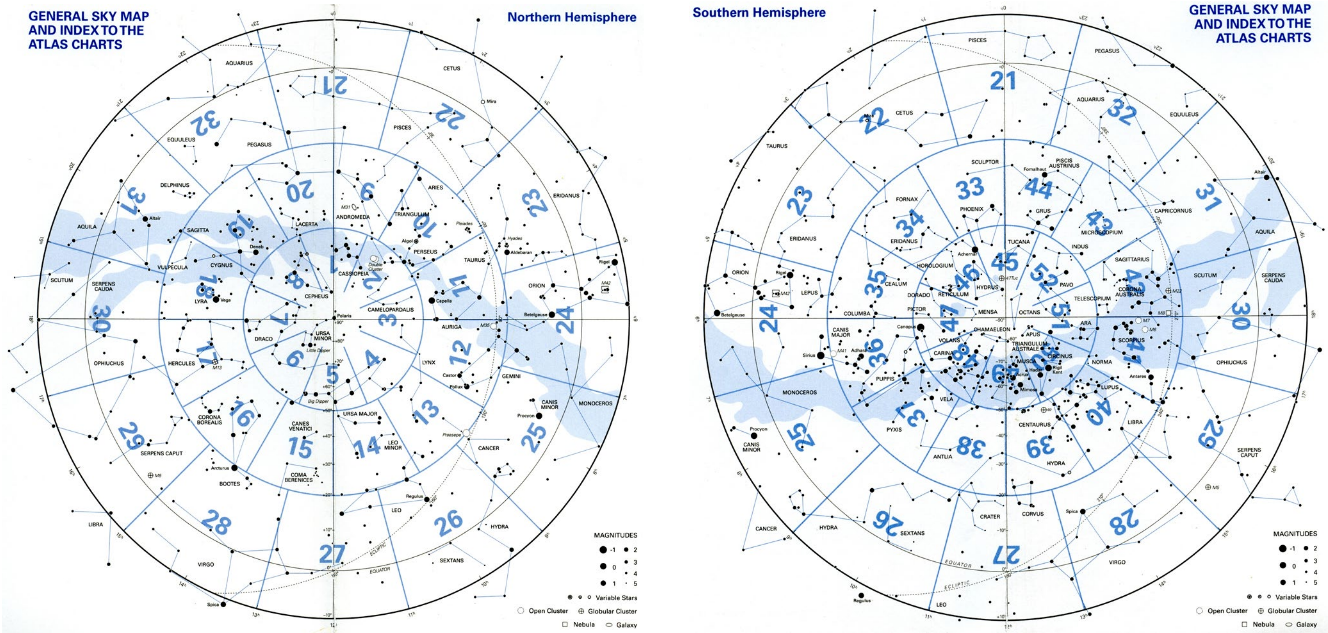
Lab Summary Fall 2024

1. Atlas Charts

Found the Atlas Charts for the Big & Little Dippers using the guide map and read them to learn about the stars in those asterisms and other objects in those areas of the sky.



2. Star Distances and Magnitudes

Used Appendix 2 to look up information about stars in the Summer Triangle and ranked them in order of distance, apparent magnitude (V) and absolute magnitude (M_V). Brighter objects have lower magnitudes … Vega $V_{Vega} = 0.03$ is brighter in the sky than Deneb $V_{Deneb} = 1.25$, but Deneb is intrinsically brighter than Vega: $M_{V,Deneb} = -7.5$ $M_{V,Vega} = 0.6$.

3. Celestial Coordinates

Identified stars on celestial globes using their coordinates and identified coordinates on the atlas chart sky maps.

Right Ascension (Celestial Longitude), 0^h to $23^h59^m59^s$ eastward from ♈

Declination (Celestial Latitude), 0° to ±90° northward & southward from Celestial Equator

4. Changes in Latitude

Wrote down the altitudes of the celestial pole and celestial equator for various latitudes then identified them on horizon diagrams. λ = latitude of the observer.

ALTITUDE OF CELESTIAL POLE = LATITUDE OF THE OBSERVER!

5. Star Trails

Using photographs of the trails of rising stars, we determined the (approximate) latitudes from which each photograph was taken.

Stars rise and set parallel to the C. E. at an angle of 90°- $\lambda_{observer}$ to the horizon

6. Star Transit Times

We looked up the transit times for a variety of stars using p. 13 in the *Field Guide* in both standard (EST) and daylight saving time (EDT). Vega's transit times through the summer showed that stars transit 4 minutes earlier every night.

7. Rising, Setting and Time in the Sky

Looked up star names in Appendix 2 using their right ascension. From their declinations, calculated their rising and setting azimuths, maximum altitudes and times above the horizon.

For λ = latitude of the observer and δ = declination of the star, we determined the azimuths of rising and setting, the altitude of the star at transit (the maximum), and the hours the star will be above the horizon using the following equations:

$$A_{rise} = \cos^{-1}\left(\frac{\sin\delta}{\cos\lambda}\right) \text{ degrees} \qquad A_{set} = 360 - A_{rise} \text{ degrees}$$

$$A_{max} = (90-\lambda)+\delta \text{ degrees} \qquad \Delta t = \frac{2}{15}\cos^{-1}(-\tan\lambda\tan\delta) \text{ hours}$$

8. Time Zones

Wrote down the longitudes of the time zone centers in the western hemisphere, converted UT to EDT and EST. For cities at different longitudes, calculated the time of solar noon given the longitude of each city's time zone center.

Earth turns 15°/hour, 1° in 4 minutes, and 15 arcminutes in one minute

$\Rightarrow$ an observer east of the TZ center sees events $(\text{degrees})\times\left(\frac{4 \text{ minutes}}{1 \text{ degree}}\right)$ early.

$\Rightarrow$ an observer west of the TZ center sees events $(\text{degrees})\times\left(\frac{4 \text{ minutes}}{1 \text{ degree}}\right)$ late.

9. Celestial Navigation

We determined an observer's latitude from the altitude of Polaris and longitude from the difference between the observed and expected transit times of Procyon on a particular day.

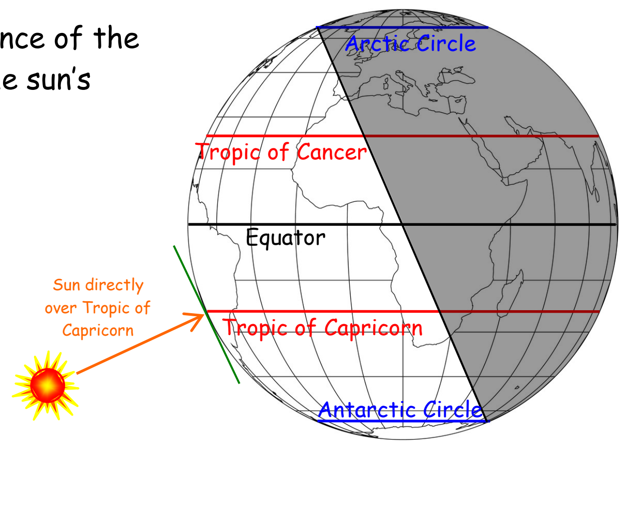
$\Rightarrow$ an observer who sees events early is $(\text{minutes})\times\left(\frac{1 \text{ degree}}{4 \text{ minutes}}\right)$ east of TZ center.

$\Rightarrow$ an observer who sees events late is $(\text{minutes})\times\left(\frac{1 \text{ degree}}{4 \text{ minutes}}\right)$ west of TZ center.

10. Named Latitudes

We determined wrote the geographic significance of the five named latitudes and shaded the Earth to show the sun's position on the solstices and equinoxes.

December Solstice



11. The Ecliptic

We looked up the celestial position of the Sun on Sept. 10 in Leo. Used the Atlas Charts to determine information about the Solstices and Eqinoxes.

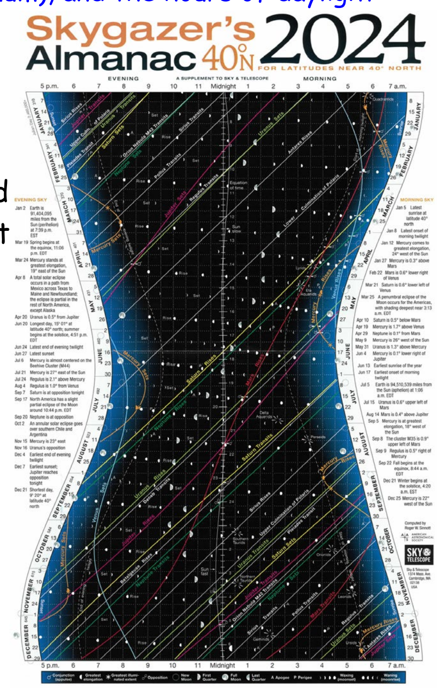
The Ecliptic is the apparent path of the sun across the sky through the year. It is also the Earth's orbital plane.

THE TABLE YOU FILLED OUT WILL BE ON THE EXAM VERBATIM! KNOW IT!

12. The Day Through the Seasons

Using the Analemma to find solar declinations, we found the azimuths of rising and setting, the maximum altitudes and hours above the horizon for various cities. We also used the Analemma to determine the clock times of solar noon for various dates.

For observer at different latitudes (λ) and different declination of the sun (δ), we determined the azimuths of rising and setting, the altitude of the star at transit (the maximum), and the hours of daylight using the same equations as in lab exercise 7.



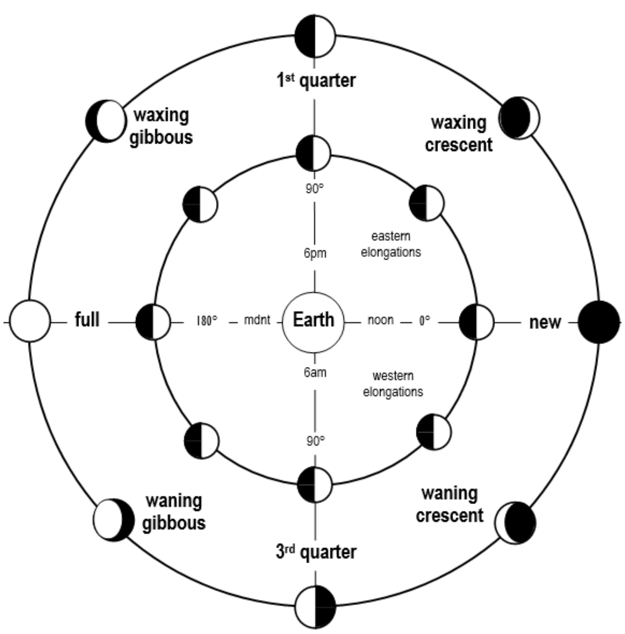
13. Planets in the Sky

Used Appendix 11 to look up planetary longitudes of the sun and (5 naked-eye) planets on a given date. From these we determined the Atlas Charts for the positions of the sun and planets to find what constellation each was in. We then calculated the elongations and plotted their positions for an observer at sunrise and in the solar system.

Planetary Longitude measured east from ♈ to 360° along ecliptic.
Elongation = angle from sun to object.

14. Astronomy and Astrology

Used Starry Night to look at the sky at the moments of our births from the places of our births. Compared the astronomical constellations the sun, moon and planets were in to the astrological "houses" they were in according to our natal charts. Most of the constellations were different showing that astrology is not a scientific representation of the sky.



15. Graphic Timetable: Events of a Single Night

After aswering questions about the the *Sky & Telescope Skygazer's Almanac*, we used it to find all the events that will occur during the night of Sep. 17-18, 2023.

16. Moon Phases

Filled out a table of phases, elongations, rising time, transit time, and setting time for the eight phases from one piece of given information on each.

17. Star Magnitude, Flux and Luminosity

Calculated the distances to four stars in meters, then calculated their luminosities from their absolute magnitudes and used that to calculate their fluxes on Earth.

For M_{Sol} = absolute magnitude of the sun and $M_\star$ = absolute magnitude of a star,

$$L_{\star,sl} = 10^{\left(\frac{M_{Sol}-M_\star}{2.5}\right)} \text{ solar luminosities} \qquad L_{\star,watts} = 10^{\left(\frac{M_{Sol}-M_\star}{2.5}\right)}\left(3.827\times10^{26}\right) \text{ Watts}$$

For a star at $r_{\star,\,ly}$ with 1 light year = 9.48×10^{15} m, the flux at Earth is

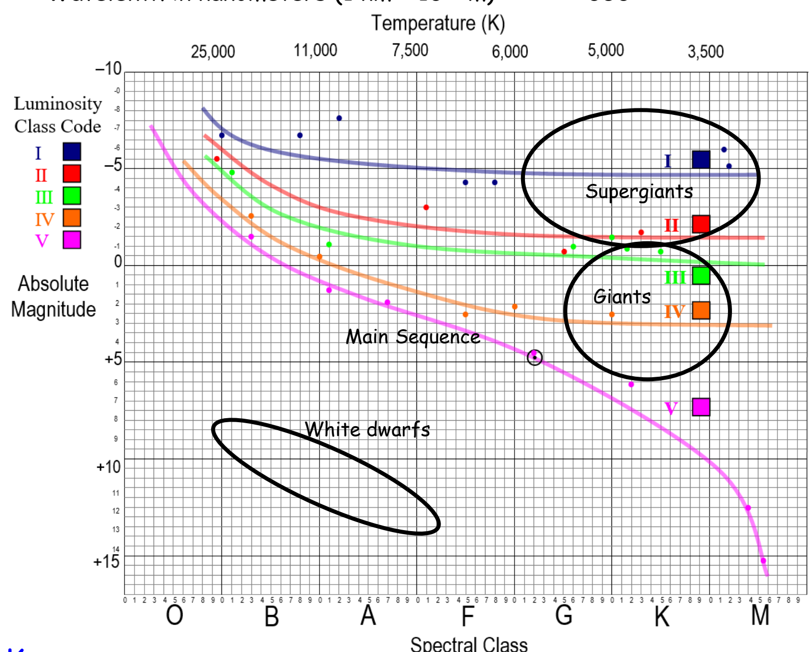
$$F_\oplus = \frac{L_{\star,\,watts}}{4\pi\left(r^2_{\star,meters}\right)}\ \frac{\text{watts}}{\text{m}^2}$$

18. Hydrogen Spectrum

Using gas tubes and spectroscopes, we measured the wavelengths of the β and γ Balmer Hydrogen lines from that of the α line. We also calculated the energies of the transitions in hydrogen that give rise to them.

19. HR Diagram

Plotted stars on the HR Diagram with colors corresponding to their luminosity class and used the plot to draw smooth lines representing the five luminosity classes.



20. Star Temperature and Size

Calculated the temperatures, luminosities and sizes of stars from the data in Appendix 2.

The temperature is found using the star's spectral class that spans temperatures T_{min} to T_{max}.

$$T_\star = T_{max} - \left\{(\text{subclass}) \times \frac{T_{max} - T_{min}}{10}\right\} \text{ K}$$

Then the star's radius is found using the Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$

$$R_\star = \sqrt{\frac{L_{\star,Watts}}{4\pi\sigma T^4}} \text{ m}$$

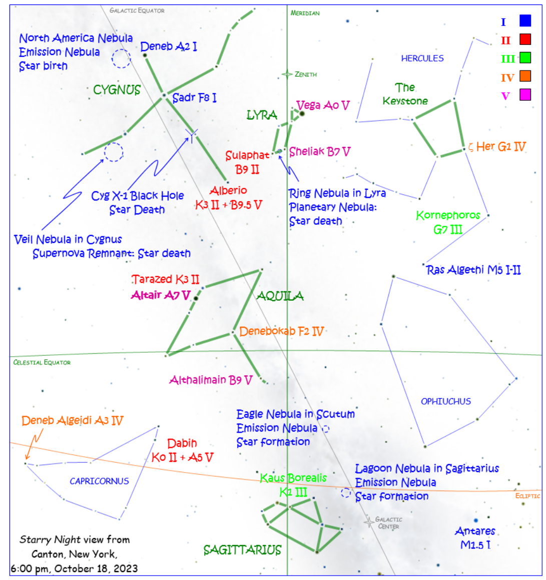
21. Power from Fusion

Using data from fusion and the Sun, we calculated the amount of hydrogen that would suppy the annual electric power for NY residences through fusion. We then calculated the mass of hydrogen fused each second by the Sun and how much mass is converted completely to energy.

$$E = mc^2 \begin{cases} E = \text{energy released by H fusing to He} \\ m = \text{mass lost in fusion}\left(m_{He} - 4m_H\right)\text{that turns into energy} \\ c = \text{speed of light} = 2.998\times10^8 \text{ m/s} \end{cases}$$

22. Stellar Evolution in the Sky

Labeled an image of the sky with star names with colors corresponding to their luminosity classes and some objects (mostly nebulae) with their names, types and stages of stellar evolution.

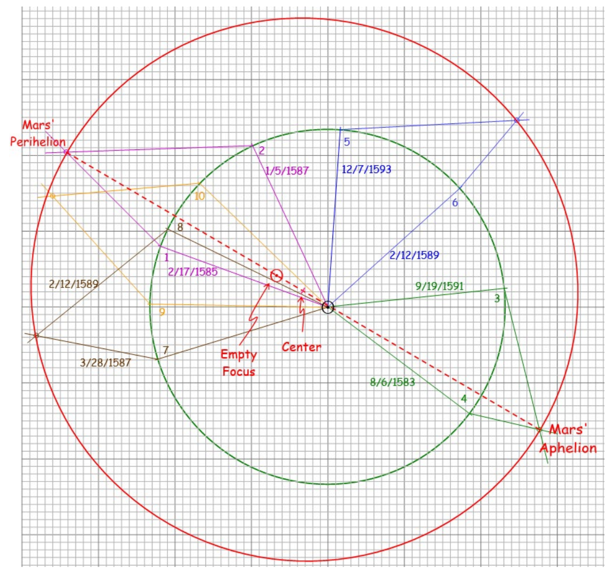


23. Scaled Solar System

Taking a large beach ball as the sun, we scaled the solar system to discover that the Earth on that scale is the size of a small bluberry, 0.7 cm in diameter and it's 46 yards (41.3 m) away from Sol.

24. S&T, The Orbit of Mars

Using data from Johannes Kepler's *Astronomia Nova*, based on measurements of Mars' position made by Tycho Brahe, we plotted pairs of Earth positions and the associated observed positions of Mars when it was in the same orbital position (observations one Martian year apart). Using these, we were able to plot the orbit of Mars.

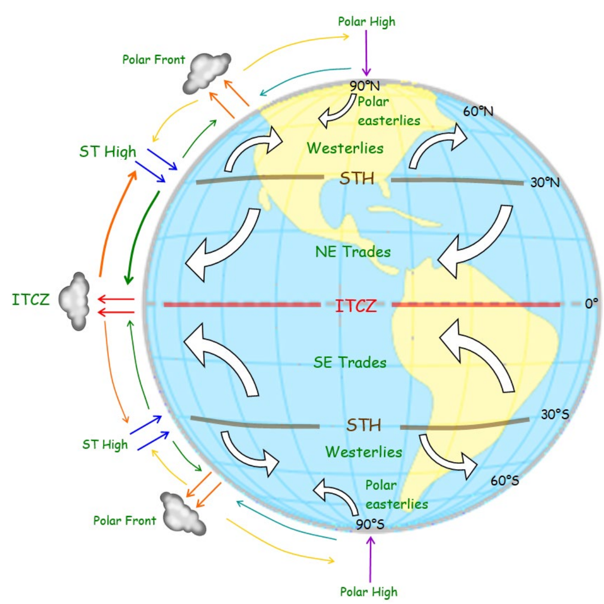


25. Plugged in to CO_2

We measured the power used by small electrical appliances (lamps, clocks, hairdryers) and calculated the amount of CO_2 the use of the appliance releases into the atmosphere over the course of a year.

26. Atmospheric Cirulation Model

We modeled the atmospheric circulation first discussed by Hadley and Ferrel driven by the insolation at the sub-solar latitude and the intense cold aloft at the poles.



27. Stone Soup and Fire & Ice

Using a Lab Pro temperature sensor and Logger Pro software, in Stone Soup, we measured the temperature rise once a hot rock was dropped into cold water to explore the high heat capacity of water. We measured the final temperature of the mix and compared it to the measured final temperature. In Fire & Ice, we did the same for an ice cube dropped into hot water. In this case we calculated the final temperature for water at the ice's temperature.

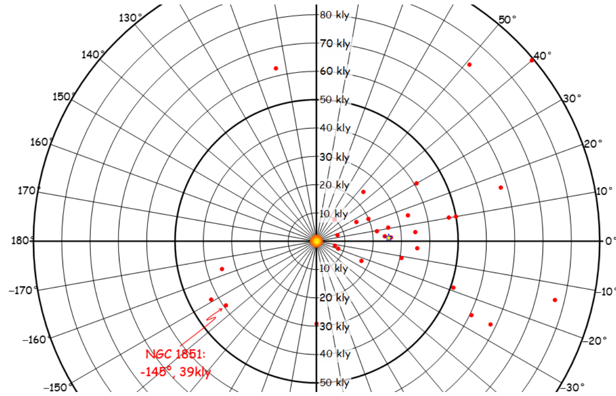
The final temperature after a hot rock is dropped into cold water is given by the top equation to the right. In lab, this was 16°C for a 150 g rock at 100°C and 150 g of water at 0°C due to the specific heat of water being 4,186 J/K/kg and that of granite is 804 J/K/kg. So the water's temperature changes much less than the rock's. The final temperature of a mixture of ice and hot water is given by the lower equation. In lab, this was 69°C for 150 g of ice at -2°C and 150 g of water at 100°C due to the fact that it takes energy to melt the ice. If 150 g of water at -2°C were added to the hot water, the final temperature would have been 77°C. So it takes about 10°C worth of energy to just melt the ice!

$$T_{final} = \frac{m_{water} c_{water} T_{water} + m_{rock} c_{rock} T_{rock}}{\left(m_{water} c_{water} + m_{rock} c_{rock}\right)}$$

$$T_{final} = \frac{\left(m_{ice} T_{ice} + m_{water} T_{water}\right) c_{water} + m_{ice} L_{fusion}}{\left(m_{ice} + m_{water}\right) c_{water}}$$

28. Globular Clusters

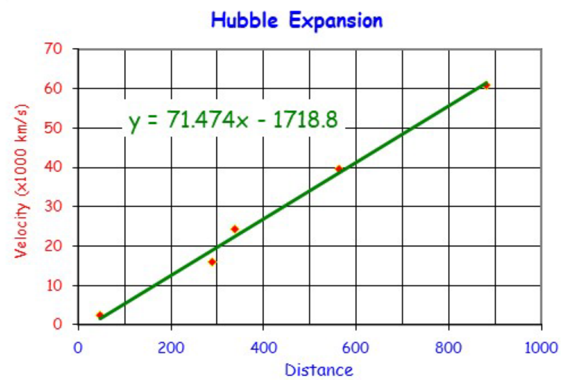
Following Shapley's 1918 paper, we plotted the positions and distances of globular clusters relative to the Sun to find the center of the Milky Way galaxy. Excel's average of the positions gave the Sun's distance to be 26,700 ly, close to the currently accepted 8 kpc = 26,000 ly.



29. Teach and Reflect

30. The Hubble Law

Using an exercise from Sky and Telescope Magazine, we measured galaxy redshifts and sizes on images and plotted their speeds against their distances to repeat Hubble's 1929 paper. Careful measurements of the galaxies gave H_0 = 71.5 km/s/Mpc, which inverts to an age of the universe of 13.7 billion years.



31. History of the Universe

We filled in a table of the occurance times of important events in the history of the universe.

Time	Era	Event or Contents
t = 0		Time Begins ... the beginning of the universe
	Planck	Quantum Foam, nature unknown (also in black holes)
t ≈ 10^{-43} sec.		Gravity separates from the other three forces
	GUT	Elementary particles of matter and antimatter (leptons & quarks) forming out of energy
t ≈ 10^{-38} sec.		The strong force separates from electroweak
	Inflation	Universe undergoes HUGE, RAPID expansion (due to separation of strong force from electroweak
	Electroweak	Elementary particle (leptons & quarks) soup
t ≈ 10^{-10} sec.		Electromagnetic & weak forces separate
	Particle	Quarks bind into protons & neutrons (1 no for each 7 p+). Ends with matter/antimatter annihilation ... only matter left
t ≈ 10^{-3} sec.		Last matter-antimatter annihilation
	Nucleosynthesis	Nuclei of H, He (+ some others) formed by fusion
t ≈ 3 min.		Fusion ends ... matter is 75% H nuclei, 25% He nuclei
	Nuclei	Plasma of H and He nuclei and electrons.
t ≈ 500,000 yr.		The universe begins to becomes transparent
	Atoms	Nuclei capture electrons to form atoms and the universe becomes transparent.
t ≈ 1,000,000 yr.		First galaxies form
	Galaxies	Stars, galaxies, puppies, kittens and us!