# Observational Astronomy - Spring 2014
# Midterm Exam

1. Assume New York has latitude 40°N.

   (a) (5 pts) What is the highest altitude that the Sun ever achieves in New York?

   - The point where the celestial equator crosses the meridian has an altitude equal to $90° - \text{Latitude} = 50°$. If this isn't obvious, remember that the celestial equator will cross the zenith (altitude = 90°) if you are standing on the equator, and be on the horizon (altitude = 0°) if you are standing on the pole. At its highest point, the Sun's declination is +23.5°. This means that it is +23.5° above the equator, so its altitude at the point of transit is $50° + 23.5° = 73.5°$.

   (b) (5 pts) On what date does this occur?

   - On the summer solstice, June 21.

2. ( 10 pts) Will the year 2100 be a leap year? Explain why or why not.

   - The Gregorian calendar which we use is adjusted to match the measured length of the year = 365.2425 days. In this calendar, years divisible by 100 are not leap years unless they are divisible by 400, so 2100 will not be a leap year.

3. As you have seen in the labs, Jupiter is currently a prominent object in the night sky. According to the JPL Horizons ephemeris for today, March 10, 2014, Jupiter is currently at the following equatorial coordinates: $\text{RA} = 6^{\text{h}}44^{\text{m}}43.4^{\text{s}}$, $\text{Dec} = +23°17'19.0''$.

   (a) (5 pts) Convert these sexagesimal coordinates into decimal degrees for both RA and Dec.

   - First, we'll do the RA. Remember that there are $24^{\text{h}}$ and 360° in the circle, so 1 hour of RA is 15°. Of course, there are 60 minutes in an hour, and 60 seconds in a minute, so

   $$\text{RA} = 6^{\text{h}}44^{\text{m}}43.4^{\text{s}} = 15\frac{\text{degrees}}{\text{hour}} \times (6 + \frac{44}{60} + \frac{43.4}{3600})\text{ hours} = 15\frac{\text{degrees}}{\text{hour}} \times (6.745)\text{ hours} = 101.18°$$

   - Next, we'll do the Declination. This is a little easier, since we only need to know that there are 60 minutes in a degree and 60 seconds in a minute, both of which are in the formula sheet.

   $$\text{Dec} = +(23 + \frac{17}{60} + \frac{19}{3600})\text{ degrees} = +23.29°$$

   (b) (5 pts) At about what time will Jupiter transit tonight? ±5 minutes is close enough.

   - Jupiter - $\text{RA} = 6^{\text{h}}44^{\text{m}}$
   - $\text{RA} = 0^{\text{h}}$ transits at noon on Mar 21. Remember that the sun is at RA = 0 on the vernal equinox, and the sun always transits at noon.
   - Number of days between Mar 10 and Mar 21 = 11.
   - Transit time shifts 4 min earlier per day, so in 11 days the transit time shifts 44 min.
   - On Mar 10, $\text{RA} = 0^{\text{h}}$ transits at $12^{\text{h}} + 44^{\text{m}}$ = 12:44 PM.

- RA = $6^h44^m$ transits at $12^h44^m + 6^h44^m = 19^h28^m$ = 7:28 PM.
- Add one hour for daylight savings time (which we just started yesterday!) = 8:28 PM.
- Stellarium gives 8:27 PM.

(c) (5 pts) What will be Jupiter's altitude and azimuth at the time of transit? $\pm 1^\circ$ is close enough.

- The azimuth at time of transit is simple. At transit, the object is crossing the meridian so it's azimuth is $180^\circ$.
- The altitude at time of transit is just like the first problem. The celestial equator has an altitude equal to $90^\circ$ − Latitude = $50^\circ$. Jupiter's declination is $+23^\circ 17'$, so it's altitude at this point is $50^\circ + 23^\circ 17' = 73^\circ 17'$.

(d) (5 pts) What will be Jupiter's Hour Angle at the time of transit?

- An object's hour angle at transit is always zero.

4. While looking through your telescope, you discover a new comet. Observations show that this comet has an elliptical orbit with a perihelion distance of 0.1AU and an aphelion distance of 9.9 AU.

(a) ( 5pts) What is the semi-major axis a of the orbit in AU?

- The major axis is just the sum of $R_P$ and $R_A$, and the semimajor axis is one-half of this, so it is 5.0AU. You can also use the formula sheet to see that $a = (R_A + R_P)/2$.

(b) (5 pts) What is the eccentricity of the orbit e?

- Looking at the equations for $R_P$ and $R_A$:

$$e = \frac{R_A - R_P}{R_P + R_A} = 0.98$$

(c) (5 pts) What is the comet's orbital period T in years?

- From Kepler's third law (in the formula sheet), $a^3 \propto T^2$. If we are in AU and years, the proportionality constant is one, so $a^3 = T^2$. Then:

$$T = \sqrt{a^3} = \sqrt{125.0} = 11.2 \text{ years}$$

5. A Type 1A supernova (a type of exploding star) was recently discovered in the nearby galaxy Messier 82. This galaxy is at a distance of 3.5 Mpc (3.5 million parsecs). This supernova is the closest such object to be discovered since 1972, so it has caused a lot of excitement among astronomers. It has reached a peak apparent magnitude m = +10.5.

(a) (5 pts) Calculate its absolute magnitude M.

- From the formula sheet, apparent and absolute magnitude are related by $M = m + 5 - 5\log_{10}(D)$, so:

$$M = 10.5 + 5.0 - 5.0 \times \log_{10}(3.5 \times 10^6) = -17.2$$

(b) (5 pts) The Sun has an absolute magnitude of +4.83. How much brighter is this object than the Sun?

- From the formula sheet, the luminosities are related by:

$$\frac{L_{SN}}{L_{Sun}} = 10^{0.4(4.83-(-17.2))} = 6.5 \times 10^8 = 650 \text{ million times. Wow!}$$

6. The James Webb space telescope will be the successor to the Hubble space telescope, and is expected to launch in 2018. It will have an aperture D = 6.5 meters, so it is several times bigger than the Hubble.

(a) (5 pts) At a wavelength $\lambda = 1.0\ \mu$m (1 millionth of a meter), what will be its angular resolution in seconds of arc?

- $\lambda$ is given as 1.0 $\mu m = 1.0 \times 10^{-6} m$
- D is given as 6.5 m, so, using the formula from the formula sheet, the angular resolution is

$$\theta = 1.22 \frac{1.0 \times 10^{-6}\text{m}}{6.5\text{m}} = 1.88 \times 10^{-7} \text{ radians}$$

$$\theta = 1.88 \times 10^{-7} \text{ radians} \times \frac{360}{2\pi} \times 60 \times 60 = 0.039 \text{ arcseconds}$$

(b) (5 pts) Jupiter has a large storm called the Great Red Spot, which is about 10,000 km across. Suppose Jupiter is at a distance of 5.0 AU. What is the angular size of Jupiter's Great Red Spot in seconds of arc?

- From the formula sheet, an object of size R at a distance d subtends an angle in radians of $\theta = \text{R/d}$, assuming the small angle approximation.

$$\theta = \frac{10000 \text{ km} \times 10^3 \frac{\text{m}}{\text{km}}}{5.0 \text{ AU} \times 1.50 \times 10^{11} \frac{\text{m}}{\text{AU}}} = \frac{1.0 \times 10^7 \text{ m}}{7.5 \times 10^{11} \text{ m}} = 1.33 \times 10^{-5} \text{ radians}$$

$$\theta = 1.33 \times 10^{-5} \text{ radians} \times \frac{360}{2\pi} \times 60 \times 60 = 2.75 \text{ arcseconds}$$

(c) (5 pts) Will the James Webb telescope be able to resolve the Great Red Spot?

- Yes, easily. The Great Red Spot can be seen in even a small telescope.

7. (5 pts) During the course of a year, the Sun follows a specific path relative to the fixed stars. What do we call this path?

   - It is called the ecliptic.

8. (5 pts) What part of the sky is not within any constellation?

   - The 88 constellations cover the entire sky, so no part of the sky is not within any constellation.

9. (10 pts) There are two "windows" in the electromagnetic spectrum, where the atmosphere is transparent so we can observe the universe with ground-based telescopes. What are these two windows?

   - Visible light and radio waves.

## 1 Important Formulae

- Angular size of an object of size R at distance d (small-angle approximation): $\theta = \frac{\mathrm{R}}{\mathrm{d}}$
- Angular resolution of a telescope of aperture D in wavelength $\lambda$: $\theta = 1.22\frac{\lambda}{\mathrm{D}}$
- Relation between apparent magnitude m and absolute magnitude M of an object at distance D in parsecs: $\mathrm{M} = \mathrm{m} + 5 - 5\log_{10}(\mathrm{D})$
- Relation between absolute magnitude M and Luminosity L of two objects: $\frac{\mathrm{L_{obj}}}{\mathrm{L_{ref}}} = 10^{0.4(\mathrm{M_{ref}} - \mathrm{M_{obj}})}$
- Relation between Hour Angle-HA, Right Ascension-RA and Local Sidereal Time-LST: HA = LST - RA
- $360^\circ = 2\pi$ radians
- $1^\circ = 60' = 3600''$
- Kepler's third law: $\mathrm{a}^3 \propto \mathrm{T}^2$
- Perihelion distance: $\mathrm{R_P} = \mathrm{a}(1 - \mathrm{e})$.
- Aphelion distance: $\mathrm{R_A} = \mathrm{a}(1 + \mathrm{e})$.
- 1 AU = $1.50 \times 10^{11}$ m.
- 1 pc = $3.08 \times 10^{16}$ m.