

**HOMEWORK #3**  
**Due date: Sep 12, 2016**

1. Globular cluster M13 is one of the most impressive clusters in the northern sky. We can find it in the Hercules constellation, its coordinates are  $\alpha = 16^{\text{h}}41^{\text{m}}42^{\text{s}}$  and  $\delta = 36^{\circ}27'37''$ . On what day in 2016 should we observe it if we want to catch it around 10pm local time as it crosses the local meridian? How high above the horizon will it be? How long will it still be observable? We are observing from Villanova ( $\varphi = 40^{\circ}02'14''$  N,  $\lambda = 75^{\circ}20'57''$  W). Use the ephemerides from the Nautical Almanac.
2. On September 7, 2016, we set out to observe the Cygnus constellation from Villanova ( $\varphi = 40^{\circ}02'14''$  N,  $\lambda = 75^{\circ}20'57''$  W). The brightest stars in that constellation are Deneb ( $\alpha = 20^{\text{h}}41^{\text{m}}26^{\text{s}}$ ,  $\delta = 45^{\circ}16'49''$ ) and Albireo ( $\alpha = 19^{\text{h}}30^{\text{m}}43^{\text{s}}$ ,  $\delta = 27^{\circ}57'35''$ ). They plan to start observing at the time of Albireo culminating. When is that? At what altitude and what azimuth will we see Deneb at Albireo's culmination? How long will the two stars both be visible? Sidereal time at 0<sup>h</sup> UT is 23<sup>h</sup>06<sup>m</sup>00<sup>s</sup>.
3. Where on Earth do we need to be to catch the Geminid meteor shower radiant (Dec 14, 2016 at 10<sup>h</sup> UT;  $\alpha \sim 4^{\text{h}}$ ,  $\delta \sim 40^{\circ}$ ) at zenith? What will be the local time there? Estimate sidereal time instead of looking it up in the Almanac.
4. We got tired of Earth and decide to move to Mars! (You've seen The Martian, right?) There we build a neat little cottage on the 20° parallel and we're trying to figure out how long will we be able to sunbathe. If one day on Mars is 24<sup>h</sup>37<sup>m</sup>23<sup>s</sup>, how long will the Sun be above the horizon on the first day of summer? The obliquity of Mars is 25.19°. Assume that Mars orbits the Sun in the ecliptic (in reality its orbit is tilted 1.85°).
5. We want to figure out when to plan on harvesting the crops. Ancient Egyptians used an astronomical event to figure it out: when Sirius rises with the Sun, that is when they started their harvest. The coordinates of Cairo are  $\varphi = 30^{\circ}03'00''$  and  $\lambda = 31^{\circ}14'00''$ . Hint: derive an expression for equatorial coordinates of the Sun ( $\alpha_{\odot}$ ,  $\delta_{\odot}$ ) as a function of time.
6. *Extra credit:* A fun one to wrap up: using spherical trig, derive the expressions for ecliptic latitude  $\beta$  and longitude  $\lambda$  from known equatorial coordinates  $\alpha$  and  $\delta$ . Googling for these transformations is cheating. Trust in yourselves and do it yourselves. Yes, it'll take a while, so better start soon. The calculations are straight-forward, but drawing a bunch of spherical triangles (till you figure out the useful one) takes time. Hint: don't give up.