Physics of Universe PHY305A
Exercise Set 2

1. What are the advantages of a reflecting telescope in comparison to a refracting telescope?

2. The annual parallax of Bernard's star is 545.4 ± 0.3 mas (milli arc second). It's proper motion is $10.3''$ per year. Determine it's transverse speed.

3. Consider a star located at an angle θ with respect to the ecliptic pole. The Earth appears to move in an ellipse with respect to the star. Determine the eccentricity of this ellipse.

4. (a) Ignoring proper motion, determine the apparent position of a star as a function of time as observed from Earth, if it is located at (i) the ecliptic pole (ii) the ecliptic plane.
(b) Including proper motion determine the apparent position of a star, located on the ecliptic pole, as a function of time. Take the direction of the proper motion to be your x-axis.

5. Consider the coordinate system (x', y', z') which is related to (x, y, z) by a clockwise rotation of angle θ about the x axis. Explicitly derive the transformation,

$$x' = x$$

$$y' = \cos\theta\, y - \sin\theta\, z$$

$$z' = \sin\theta\, y + \cos\theta\, z$$

between these two coordinates.

6. Determine the inverse transformation from ecliptic to equatorial coordinate system.

7. Determine the rate at which the equatorial coordinates of a source change due to precession. Start by differentiating the equations, obtained in the previous problem, with respect to time. This gives us $d\delta/dt$ and $d\alpha/dt$ in terms of β, λ, $d\lambda/dt$ and the transformation angle $\theta = 23^o26'$. Next eliminate β, λ in terms of δ and α to obtain the final result.

8. Determine the transformation between the equatorial and galactic coordinate systems. The galactic pole is located at $\delta = 27.13^o$ and $\alpha = 192.86^o$. The galactic center is located at $\delta = -28.94^o$ and $\alpha = 266.40^o$.

9. Determine the shift in the angular position of a star due to the aberration effect. You need to use the relativistic velocity addition formula. If not familiar with the special theory of relativity, use the non-relativistic formula.

10. Recall that at the summer solstice, the Sun never sets at latitudes close to the North Pole. (a) Find the range of latitudes for which this is true. (b) At any latitude l there exists a group of stars that always remain either above or below the horizon. These are called circumpolar stars. Find the range of declinations for these stars at latitude l. (c) Determine the names of a few bright circumpolar stars visible at your location. Locate them in the night sky and track their motion by observing them at different times.

11. Let $\vec{\mu}$ represent the proper or angular velocity of a star. We define $\mu_\delta = \dot{\delta} = d\delta/dt$ and $\mu_\alpha = \dot{\alpha} = d\alpha/dt$, where δ and α represent the Dec and RA of the star. Show that the components of the space velocity $\vec{v}$ are given by $v_\delta = r\mu_\delta$ and $v_\alpha = r\cos\delta\mu_\alpha$, where r is the distance of the star.

12. An observer located at the ecliptic plane on Earth is observing a star also located in this plane. Ignore rotation of Earth. Determine the effect of aberration, i.e. the angle θ' due to revolution of Earth. Consider a few cases, such as,
(a) The star is located on the horizon and the observer is approaching the star,
(b) The star is directly overhead (as observed by a stationary observer),
(a) The star is located on the horizon and the observer is receding from the star.

13. In radio interferometry a large number of observations are taken with many baselines oriented in different directions. As the Earth rotates the orientations of the baselines change. Hence observations at different times effectively leads to even larger number of orientations. Consider a baseline of length 1 Km oriented in the east-west direction on the equatorial plane. It is observing a star which also lies in this plane. Ignore the effect of revolution of Earth. When the star is directly overhead, the path difference between the two antennas is zero. Find the path difference one hour later.

14. Two stars with angular separation of 1.2 arcsec are located close to the ecliptic pole as seen by an observer at Earth at some time. Their distances from Earth are 1.5 pc and 2.6 pc respectively. Find the observed angular separation between them six months later if
(a) The displacement vector of the observer is parallel to the line joining the two stars on the celestial sphere.
(b) The displacement vector of the observer is perpendicular to the line joining the two stars on the celestial sphere.

15. A star is seen in the night sky to be directly overhead at 9 PM. After how many solar days will the star have moved by approximately 2 degrees (observed again at 9 PM). Would it move towards east or west?

16. Consider an observer on Earth in orbit around the Sun. The orbital speed of Earth is approximately 30 Km/s. Neglect rotation of Earth. At a particular time the observer notices that a star on the ecliptic plane is located directly overhead (as observed in the

moving frame). Determine the angular position of the star as seen by the observer six months later. At this time the observer is located diametrically opposite to her initial location.