

CHAPTER 10

Stellar Motions and the Solar Neighborhood

10-1. The Solar Neighborhood

The Solar Neighborhood is the volume of space around the Sun extending to a distance of 100 parsecs. Some properties of the Solar Neighborhood are:

1. The solar neighborhood contains about 500×10^3 stars, most of which are very faint.
2. Stars in the immediate vicinity of the sun are spaced, on the average, about 4 LYs apart.
3. Of the approximate 4500 stars seen by the unaided eye over the entire celestial sphere, 2/3 of these are within 100pc. The other 1/3 are farther than 100 pc, that is, beyond the solar neighborhood. The latter stars must be extraordinarily bright, since the farther a star is, the fainter its apparent brightness.
4. A large fraction of the stars are believed to be binary stars. Estimates range from 50% to 80%, but the exact fraction is not known

Binary Star: A gravitationally bound system, consisting of two stars in orbit around a common center of gravity, or barycenter.

For any two gravitationally interacting bodies, their barycenter is always closer to the more massive object. If the two stars have the same mass, their barycenter is midway between them.

There are also trinary star systems (3 stars) and other multiple star systems in the galaxy.

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Astronomers have now detected hundreds of planetary bodies, called exoplanets, moving in orbit around other stars. Most of these are more massive than any of the Sun's planets. These planetary-like bodies are detected because of their strong gravitational interactions with their stars. However, technology has now been developed to detect small planets like the Earth. The satellite telescope called Kepler is now finding planets by the small dimming they cause in a star's brightness as they transit the surface a star.

In 2011, Kepler found a giant planet like Saturn moving in orbit within a binary star system. It was not known previously that planets could form in a binary star system.

The nearest neighboring star of the Sun is a bright star called Alpha Centauri. This star is a circumpolar star of perpetual occultation for the latitudes of continental US. However it can be seen from regions of Mexico. The system is at a distance of 1.33 pc, or 4.35 LY. Actually, Alpha Centuri is known to be a trinary star system. This system consists of 2 stars similar to the Sun revolving around a common barycenter with a period of about 82 years. The 3rd star is a red dwarf star moving in orbit around the other 2 stars at a distance of 14,400 AU with an orbital period of 1.2 million years.

10-2. Stellar Motions

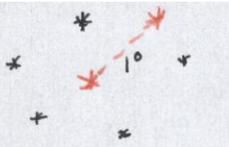
10-2.1. Space Motion or Space Velocity

Stars are moving in orbit around the center of the Galaxy. Near the Sun, there are slight deviations of each star's motion from that of its neighbors. The difference between the Sun's motion and another star's motion is observed to be what is called a star's "space motion" or space velocity. The space motion is the vector sum of what is called the tangential velocity of a star and its radial velocity. The radial velocity may be determined independently of the tangential velocity by measuring the Doppler Effect in a star's spectrum. The tangential velocity may be determined if the distance of the star is known and something called the "proper motion" of the star can be measured.

10-2.2. Proper Motion

Proper motion is the annual angular rate of motion of a star across the line of sight to the star. It is expressed in arcseconds per year. Proper motion is actually the projection of a star's space motion into the plane of the sky. The proper motion may be converted to the tangential velocity of the star, if the distance of the star is determined. Determining the proper motion is complicated by the orbital motion of the Earth around the Sun. Proper motion was suspected by early astronomers (according to Macrobius, AD 400) but proof was provided in 1718 by [Edmund Halley](#), who noticed that [Sirius](#), [Arcturus](#) and [Aldebaran](#) were over half a degree away from the positions charted by the ancient Greek astronomer [Hipparchus](#) roughly 1850 years earlier.

Proper motion is usually represented by the lower case Greek letter mu, μ . For Arcturus, Halley determined it had moved about 1° in approximately 2000 years.



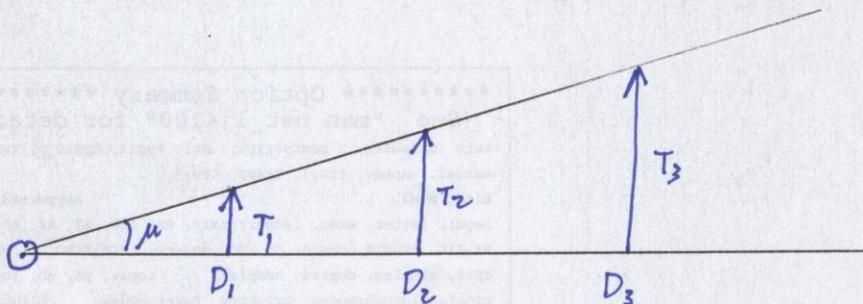
$$\text{Hence } \mu = 3600'' / 2000 = 1.8''/\text{yr.}$$

Proper motion is caused by a star's tangential velocity.

Rule of thumb: closer stars have larger values of μ .

μ causes constellations to change slowly. Changes become noticeable only after $>10^3$ years.

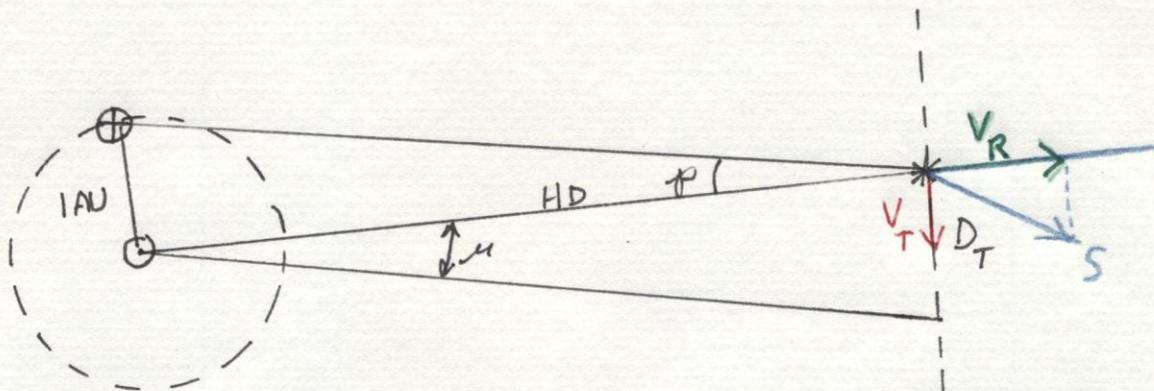
μ does not indicate dist. of star.



For the same value of μ , T is greater for more distant stars.

10-3. Relation Between Tangential Velocity and Proper Motion.

Relation between T and μ



$D_T = \text{dist. moved in 1 yr due to Tangential Velocity, } V_T.$

$$D_T = HD \tan \mu = \text{AU/yr} \quad \tan \mu = \frac{D_T}{HD} \quad \tan \phi = \frac{1 \text{ AU}}{HD}$$

If μ in $" / \text{yr}$ $\tan \mu \approx \mu$ $\tan \phi \approx \phi \Rightarrow \frac{\mu}{\phi} = \left(\frac{D_T}{HD} \right) \left(\frac{HD}{1 \text{ AU}} \right)$

So, $D_T = \left(\frac{\mu}{\phi} \right) 1 \text{ AU}$ in AU/yr

Now $\frac{1 \text{ AU}}{\text{yr}} = \frac{149,450,000 \text{ km}}{\pi \times 10^7 \text{ sec}} = 4.74 \text{ km/sec}$

So $T (\text{km/sec}) = 4.74 \frac{\mu ("/\text{yr})}{\phi (")}$

Example: Barnard's star has $\mu = 10.25"/\text{yr}$ and $\phi = 0.54"$

So $T = (4.74) \left(\frac{10.25}{0.54} \right) = 4.74 (18.98) = 89.97 \text{ km/sec}$

10-4. Peculiar Velocity and Standard Apex of the Sun's Way

PECULIAR Velocity is a star's velocity after the Sun's velocity is subtracted. It is the result of differential galactic rotation.

STANDARD APEX OF SUN'S WAY:

Determined separately from proper motions and radial velocities of other stars.

Assume random velocities for stars near Sun. Then:

At apex, ave. R_v at maximum for approach velocities.

At antapex, ave R_v for stars there is a max. for velocities of recession.

At right angles to Sun's Space velocity, the proper motions for stars will be at a maximum for stars moving opposite Sun.

RESULT: Apex of Sun is in Hercules, 10° from Vega
It is ~ 19 km/sec.

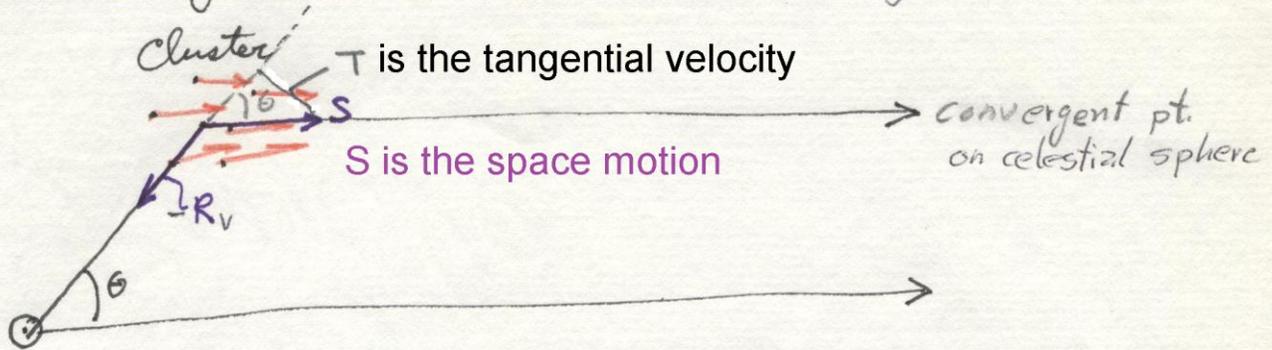
Most stars in Solar neighborhood have same peculiar vel.
"High velocity stars": ~ 160 km/sec; Older stars; interlopers from halo of galaxy into the disk.
The sun is a disk star

10-6. Statistical Methods of Distance Determination (Skipped)

10-7. The Components of Stellar Motion (Skipped)

10-8.

Moving cluster Method for Determining Distance



$$\vec{R}_v = S \cos \theta \quad T = S \sin \theta$$

$$\text{Now } T = \frac{4.74 \mu}{p} \Rightarrow p = \frac{4.74 \mu}{T}$$

$$p = \frac{4.74 \mu}{S \sin \theta}$$

$$\text{But } S = R / \cos \theta$$

$$\text{So } p = \frac{4.74 \mu}{\frac{R}{\cos \theta} \sin \theta} = \frac{4.74 \mu \cos \theta}{R \sin \theta} =$$

$$p = \frac{4.74 \mu}{R \tan \theta}$$

μ & R are measured for stars in the cluster.