Introduction to Astronomy
Summary Questions Week 11

16 December 2019

1. What are the three types of star clusters and how do you distinguish them?

> **Solution:** The first type are the *associations*. These are very *loose* collections of *very few stars* (~ 10), found *in the spiral arms* of the Galactic disk.
>
> Secondly, there are *open clusters*. These contain *slighly more stars (up to a few hundred)* and are also found *in the Galactic disk*.
>
> Finally, the *globular clusters* are the most massive star clusters, with *many, old, stars (thousands to about a million)*. They are found *in the Galactic halo* as well as *in the disk near the Galactic centre*.

2. Explain how the moving cluster method can be used to determine this distance to a star cluster.

> **Solution:** (For clarity, Figure 16.4 on page 342 of the handbook should be copied, at least the right-hand part of it.) Assume all stars move in the same direction, away or towards the observer (alternatively a common tangential velocity component can be subtracted). This will cause the tangential velocities v_t to all point towards a single point on the sky (the "convergence point"). Measurement of the radial velocities ($v_\mathrm{r} = v\cos\theta$) through the Doppler shift of spectral lines and the tangential velocity ($v_\mathrm{t} = v\sin\theta$) through proper motion ($\mu = v_\mathrm{t}/D$, i.e. the change in position on the sky over time), allows us to determine the distance based on the angular distance (θ) of the stars from their convergence point: $D = v_\mathrm{t}/\mu = v\sin\theta/\mu = v_\mathrm{r}\tan(\theta/)/\mu$.

3. What do we know about the mass function of open clusters and what does that suggest about the cluster's evolution?

> **Solution:**
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> According to the mass function of open clusters, there are *relatively more heavy stars in open clusters than in the Galactic disk*. There are three possible reasons for this:
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> 1. low-mass stars are *fainter* and therefore harder to detect
> 2. low-mass stars are *easiest to "kick out"* of the cluster (i.e. for an equal amount of kinetic energy they have a higher velocity, so they reach the escape velocity more quickly)
> 3. because the high-mass stars have shorter lives, most of these *high-mass stars will already have died by the time the cluster dissipates* into the disk, leaving mostly low-mass stars behind.
>
> This seems to indicate that it is *possible that the disk stars come from clusters*. In other words: *clusters lose their low-mass stars over time*; and *eventually they may simply dissipate altogether*, feeding the Galactic disk with low-mass stars and dense compact objects (which are mostly unobservable).

4. What can we learn from the Hertzsprung-Russell diagram of open clusters?

Solution: The HR diagram for open clusters has a *very narrow main sequence*. This suggests that all stars in the cluster have an identical metallicity (which can be and is confirmed observationally). This in turn implies that all the stars in the cluster have been *born at essentially the same time*.

Because of this uniformity in age, we can see a very clear *turnoff of the main sequence towards the sub-giant branch*. This turnoff – and specifically the spectral type (i.e. mass) at which it occurs – can be translated into a *cluster age* following stellar evolution models.

5. What are blue stragglers?

Solution:

Blue stragglers are stars that are found in the HR diagram of a stellar cluster, *beyond the turnoff point of the main sequence* of that cluster. They are expected to be formed either through *the merger of two lower-mass stars*, or through *accretion of a substantial amount of matter, in a close binary system.*

6. What is the Virial theorem and what can it be used for?

Solution:

The virial theorem *analyses the stability of a multi-body, gravitational system.* It states that a system in which the time-averaged kinetic energy is half the time-averaged potential energy, is stable and will neither disperse nor collapse.

The Virial theorem can be used to a) *analyse the stability of open clusters*[1] and b) *estimate the mass of globular clusters*[2].

7. What is mass segragation in globular clusters?

Solution: Mass segragation is the effect where *high-mass stars are more likely to be found near the centre of the cluster*, as a consequence of the uniform distribution of kinetic energy. If kinetic energy gets distributed evently, then the low-mass objects will necessarily have higher velocities and will therefore inhabit wider orbits around the cluster's centre of mass.