2 Werkcollege, Sterrenstelsels, Week 2

These are the assignments for the second week of the course *Sterrenstelsels*.
Every week, one of the problems provides credit towards the final exam. If at least 5 of these problems are handed in and approved, one question on the final exam may be skipped. The hand-in assignment for this week is **Problem 2.12** from Sparke & Gallagher.

2.1 Thin and thick disc

According to data from the Sloan Digital Sky Survey, the thin disc has an exponential scale height of 270 pc, the thick disc has a scale height of 1200 pc, and about 4% of the stars near the Sun belong to the thick disc.

Assuming that both the thin and thick disc are symmetric around the Sun in the vertical direction, what fraction of the total surface density of disc stars is due to the thick disc?

2.2 Extinction in magnitudes

Show that, if τ is the optical depth at wavelength λ, then the extinction in magnitudes is

$$A_\lambda = 1.09\,\tau_\lambda$$

2.3 Interstellar absorption

One of the main difficulties which plagued early attempts to determine the dimensions of the Milky Way was *interstellar absorption*. In 1930, Robert Trumpler (at Lick Observatory) studied the relation between apparent diameters and distances of open star clusters. Trumpler determined *photometric distances* from the apparent brightness of stars of known luminosity in the clusters. He could then use the distances to estimate the linear diameters of the clusters. Assuming that all clusters have (on average) the same linear dimensions, the apparent diameter should be inversely proportional to the distance. However, Trumpler instead found a non-linear relation, and correctly concluded that the discrepancy was due to systematic dimming of the light from the more distant clusters, causing the photometric distances to be too large. He was then able to give a quantitative estimate of the average amount of interstellar absorption for the first time. In this assignment we will re-examine some aspects of Trumpler's analysis.

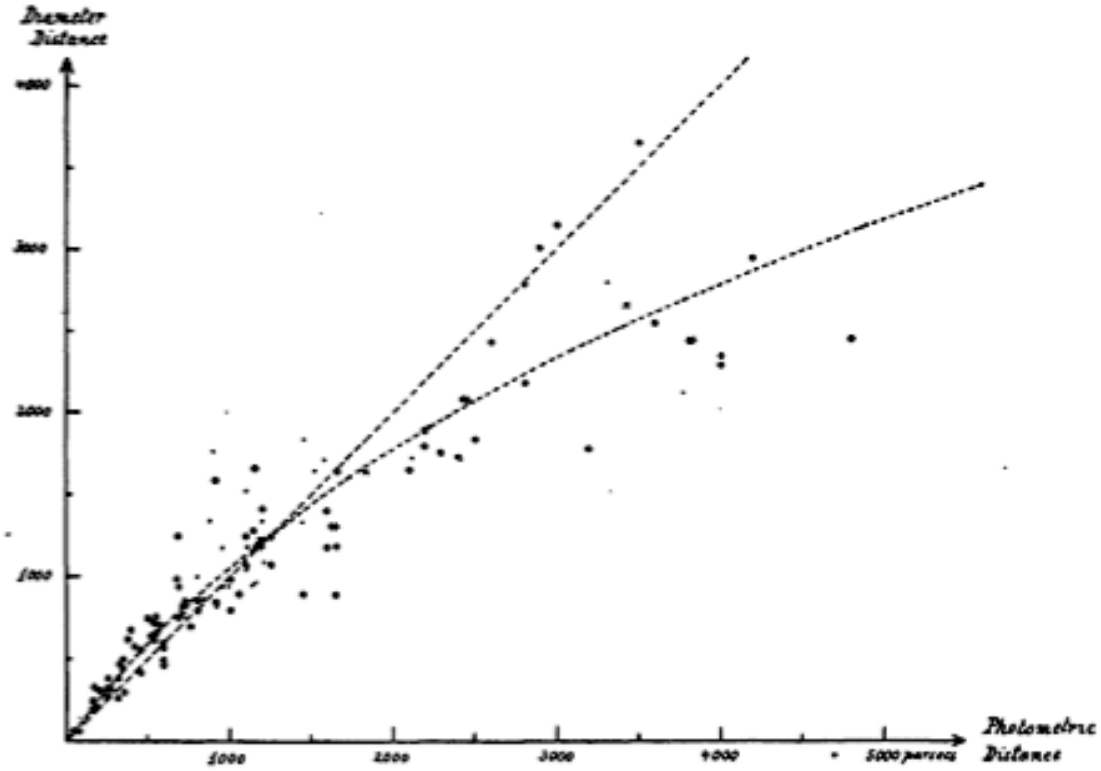

Fig 1: Trumpler's plot of Diameter distance versus Photometric distance (Trumpler 1930, PASP 42, 214). The curved line is Trumpler's estimated relation between the two distance estimates.

1. Show that, in a uniformly distributed absorbing medium, the absorption A, measured in magnitudes, is directly proportional to the distance d: $A = k\,d$.

2. Let us define the photometric distance $d_{\rm phot}$ as the distance one would infer from observations of the apparent brightness of sources with known luminosity, *neglecting extinction*. Further, define $d_{\rm true}$ as the actual distance. Then show that $d_{\rm phot}$ and $d_{\rm true}$ are related as

$$d_{\rm phot} = d_{\rm true} 10^{0.2k\,d_{\rm true}}$$

Fig. 1 shows Trumpler's plot of "Diameter distance" versus "Photometric distance". Note that the two curves *intersect* at $\approx$ 1300 pc. This is because the true linear diameters of the clusters are unknown *a priori* and must be estimated, in the first approximation, by use of the photometric distances. At some mean distance, the photometric and diameter distances will be equal (both greater than the true distance), at even greater distances

the photometric distances are systematically too large, and at smaller distances the photometric distances approach the true distances. Thus, the Diameter distance $d_{\rm diam}$ is *proportional*, but not identical, to the true distance: $d_{\rm diam} = s\, d_{\rm true}$.

3. From Fig. 1, we estimate $d_{\rm diam} = d_{\rm phot}$ at 1300 pc, and $d_{\rm diam} = 2800$ pc at $d_{\rm phot} = 4000$ pc. Using these estimates, what is the average absorption in magnitudes per kpc?

More modern studies suggest that the absorption estimated by Trumpler is too low. For example, Binney & Merrifield give an absorption of $A_V = 1.9$ mag kpc^{-1} for a typical line of sight in the Galactic disk.

4. The brightest individual stars reach absolute magnitudes of $M_V \approx -9$. What would be the apparent magnitude of such a star, located in the Galactic plane, at a distance of 8 kpc?

5. Assuming a distance of 760 kpc and a *total* absorption of $A_V = 0.2$ towards the Andromeda galaxy (M31), what would be the apparent magnitude of a similar star there?

6. Comment on the relative ease / difficulty of studying stars, open star clusters, and globular clusters in our own Galaxy and in M31.

2.4 Sparke & Gallagher, Problem 2.12
