

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Physics Department

Earth, Atmospheric, and Planetary Sciences Department

Astronomy 8.282J-12.402J

March 22, 2006

Problem Set 7

Due: Wednesday, April 5 (in lecture)

Reading: Zeilik & Gregory: Chapters 14 and 15.

Problem 1

“Spectroscopic Parallax”

In the accompanying figure we reproduce a color-absolute magnitude plot for stars whose distance can be directly measured (from a paper by Johnson and Morgan). The main sequence can be clearly identified. Also given on the same page is a table of measured parameters for stars in the Pleiades cluster, including the apparent visual magnitude, V , the $B-V$ color, and in some cases a spectral type (column labeled Sp).

- Plot at least ten of the Pleiades stars on Johnson and Morgan’s figure. Use the $B-V$ axis to plot values of $B-V$, and the M_V axis for values of V . (Don’t be overly concerned, but be aware of the fact that M_V of the original plot refers to *absolute* magnitudes, while you will be plotting *apparent* magnitudes, V , on the same axis.) Try to choose stars that span as wide a range in $B-V$ as possible. Avoid stars that are off the main sequence, i.e., those labeled with luminosity classes III or IV.
- Draw a smooth curve through your plotted data points; you should make the assumption that the shape of your curve will mimic the shape of the main sequence already displayed in the figure.
- Measure the average separation, in units of magnitudes, between your curve and the main sequence shown in the figure.
- Use the result of part (c) to find the distance to the Pleiades.

Problem 2

“Orbiting Globular Cluster”

Zeilik & Gregory, Chapter 14, Problem 5, page 282.

[Part a: Assume that the mass of the galaxy is concentrated at a point. Recall that the maximum separation in an eccentric orbit is $(1 + e) \times a$.]

[Part b: In a Keplerian orbit the average kinetic energy equals minus one half the average potential energy. “Escape” implies a total energy > 0 . By how much must the speed be increased to have a total energy of zero?]

Problem 3

“Spherical, Uniform–Density Model of the Galaxy”

Zeilik & Gregory, Chapter 14, Problem 6, page 282.

Problem 4

“Model Galactic Rotation Curve”

This is essentially a more realistic version of Problem 6 in Chapter 6 of Zeilik & Gregory, page 282.

Construct a theoretical rotation curve, $v(r)$, for a galaxy that is modeled by the uniform spherical mass distribution described in Problem 3 above. Let $R = 4$ kpc and $M = 10^{11}M_{\odot}$. Use the results of Problem 3 to find $v(r)$ for values of $r < R$. For larger distances, you may (rigorously) take all the mass to be effectively concentrated at a point at the center. There obviously must be mass in the form of stars at distances > 4 kpc in order to have a visible galaxy; however, we are assuming that these stars do not contribute much to the total gravitational force.

Plot v (in km/sec) versus the radial distance over a range $r = 0$ to $r = 20$ kpc.

Problem 5

“Absorption in the Galactic Plane”

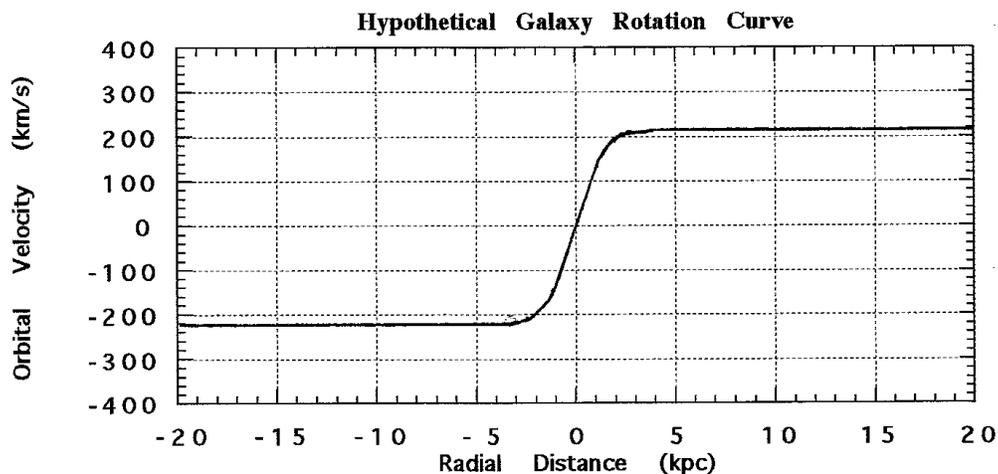
Zeilik & Gregory, Chapter 14, Problem 7, page 282.

[Assume a visual absorption of 1 magnitude per kpc everywhere within the model galactic disk whose thickness is 500 pc. Instead of declaring that $b < 10^{\circ}$ is the “zone of avoidance”, it is more instructive to make a rough plot of total absorption vs. galactic latitude b .]

Problem 6

“Rotation Curve”

Spectroscopic measurements along the axis of an edge-on spiral galaxy yield the rotation curve shown below.



It has been suggested that a dark, spherically symmetric halo of matter provides an explanation for these observations.

(a) The rotation speed is independent of radius. Assume the total mass distribution is spherically symmetric, and that the density is $\rho(r) = kr^{-n}$ where k is a constant and n is an integer. Assume that the stars execute circular orbits in the galactic plane. Use Newton's laws and the kinematics of circular orbits to find k and n .

(b) If $v_0 = 220$ km/s, what is the density at a radius equal to that of the Sun in our Galaxy ($r = 8.5$ kpc)? Express your answer in solar masses per cubic parsec.

(c) Is the density you calculated in part (b) larger or smaller than the density of visible matter in the solar neighborhood?

THE PLEIADES

| Hertzsprung No. | V | B-V | U-B | Sp |
|--------------------|-------|--------|-------|----------|
| 28 | 8.24 | +0.235 | +0.14 | ..... |
| 43 | 8.05 | +0.197 | +0.15 | ..... |
| 88 | 9.08 | +0.458 | +0.10 | ..... |
| 92 | 8.16 | +0.285 | +0.09 | ..... |
| 108 | 9.32 | +0.537 | +0.05 | ..... |
| 117 | 5.45 | -0.046 | -0.35 | B7 IV |
| 126 | 5.69 | -0.107 | -0.41 | B6 III |
| 135 | 10.37 | +0.827 | +0.13 | ..... |
| 146 | 8.57 | +0.331 | +0.16 | ..... |
| 150 | 5.34 | -0.075 | -0.35 | B8 V |
| 156 | 4.29 | -0.106 | -0.46 | B6 V |
| 169 | 8.93 | +0.439 | +0.08 | ..... |
| 187 | 8.02 | +0.216 | +0.19 | ..... |
| 206 | 8.58 | +0.352 | +0.11 | ..... |
| 213 | 10.12 | +0.802 | +0.13 | ..... |
| 216 | 7.16 | +0.159 | +0.08 | ..... |
| 219 | 9.70 | +0.548 | +0.05 | ..... |
| 227 | 9.45 | +0.523 | +0.11 | ..... |
| 242 | 5.86 | -0.088 | -0.43 | B7 III |
| 251 | 7.34 | +0.192 | +0.16 | ..... |
| 255 | 5.75 | -0.044 | -0.23 | B8 V |
| 265 | 6.41 | -0.028 | -0.15 | B9 V: |
| 523 | 4.18 | -0.056 | -0.43 | B6 IV mn |
| 529 | 10.42 | +0.840 | +0.15 | ..... |
| 541 | 7.34 | +0.097 | +0.12 | ..... |
| 571 | 8.09 | +0.355 | +0.28 | A0: |
| 585 | 10.20 | +0.724 | +0.31 | ..... |
| 588 | 9.28 | +0.457 | +0.05 | ..... |
| 423 | 10.52 | +0.338 | +0.16 | ..... |
| 456 | 6.80 | +0.025 | -0.07 | B9 V: |
| 457 | 8.38 | +0.294 | +0.08 | ..... |
| 468 | 9.44 | +0.468 | +0.02 | ..... |
| 510 | 6.98 | +0.050 | +0.05 | ..... |
| 513 | 7.84 | +0.206 | +0.12 | ..... |
| 520 | 7.28 | +0.035 | +0.05 | ..... |
| 554 | 7.76 | +0.155 | +0.12 | ..... |
| 540 | 8.30 | +0.085 | +0.02 | ..... |
| 542 | 2.86 | -0.090 | -0.35 | B7 III |
| 569 | 7.88 | +1.24 | +1.10 | ..... |
| 597 | 8.77 | +1.17 | +0.81 | ..... |
| 620 | 9.88 | +0.540 | +0.11 | ..... |
| 569 | 8.45 | +1.702 | +2.00 | ..... |
| 681 | 9.24 | +0.548 | +0.12 | ..... |
| 693 | 8.25 | +0.361 | +0.11 | ..... |
| 695 | 9.12 | +0.470 | +0.07 | ..... |
| 708 | 10.09 | +0.558 | +0.07 | ..... |
| 722 | 5.44 | -0.072 | -0.32 | B8 V |
| 736 | 10.02 | +0.556 | +0.09 | ..... |
| 742 | 6.94 | +0.125 | +0.09 | ..... |
| 760 | 10.34 | +0.514 | +0.13 | ..... |
| 792 | 8.36 | +0.284 | +0.15 | ..... |
| 970 | 3.32 | -0.085 | -0.58 | B8 III |
| 378 | 5.05 | -0.079 | -0.29 | Pec |
| 885 | 8.11 | +0.22 | +0.15 | ..... |
| 991 | 7.51 | +0.097 | +0.11 | ..... |
| 910 | 6.59 | -0.028 | -0.12 | A0 V: |
| 924 | 7.36 | +0.175 | +0.13 | ..... |
| 943 | 9.03 | +0.434 | +0.02 | ..... |
| 977 | 6.16 | -0.062 | -0.19 | B9 V |
| 995 | 9.14 | +0.162 | +0.15 | ..... |
| 996 | 7.53 | +0.077 | +0.08 | ..... |
| 1069 | 7.41 | +0.154 | +0.12 | ..... |
| 1129 | 6.92 | +0.086 | +0.05 | ..... |
| 1184 | 8.81 | +0.584 | +0.05 | ..... |

