THE PERIOD–LUMINOSITY RELATION

14

OBJECTIVES

After completing this exercise the student will be able to:

1. calculate the absolute magnitude for a cepheid variable with a known distance.
2. plot a period-luminosity diagram for classical cepheids.
3. use the period-luminosity relation to determine the distance to another galaxy.

STUDENT MATERIALS

mm ruler
calculator

LAB MATERIALS

photometric data for several cepheids (optional)

STUDENT REQUIREMENTS

This lab is to be done individually, without lab partners. After completing the exercise, turn in **Table I**, **Fig. 1**, and **Fig. 2**.

INTRODUCTION

In the previous lab the technique of main sequence fitting is used to determine the distance of several star clusters. Thus, if an astronomer can determine the distance to a star cluster which contains one or more cepheid variable stars they also know the distance to these cepheids. From the observed average magnitude of these stars and their known distance it is possible to calculate their absolute magnitudes. If this can be done for several cepheids a plot of absolute magnitude vs. log(**P**) can be made. This graph represents the period-luminosity relation for cepheids. Thus, if astronomers can observe a cepheid's pulsation period they can use this relation to find its absolute magnitude.

Since the apparent magnitude can be observed and the absolute magnitude is determined by observing the star's period, it is possible to determine the distance-modulus (m-M) for cepheids. The distance to any cepheid can be determined using the relation

$$log(\mathbf{D}) = \frac{(\mathbf{m} - \mathbf{M}) + 5}{5}$$

The beauty is that by simply observing a cepheid's average apparent magnitude and period, its distance can be calculated. Because cepheids are giant yellow stars, they are extremely bright and can be observed over large distances. In fact, they are observed in several nearby galaxies. By using the period-luminosity relation the distance to these galaxies can be determined from observations of their cepheid variable stars.

During this exercise you will make a period-luminosity relation for cepheids in our galaxy. From this relation you will estimate the distance to another galaxy.

PROCEDURE

I. Calibration of Period-Luminosity Relation

1. In **Table I** some observations of cepheids in the star cluster χ Persei are listed. The technique of main sequence fitting gives a distance to χ Persei of about 2600 parsecs. Use this distance and the relation **M = m** + 5 – 5 log(**D**) to calculate the absolute magnitude, **M**, for each of these stars. Complete **Table I** with the results.

2. On **Fig. 1** make a plot of the absolute magnitude against the log(**P**) values for the four cepheids in **Table I**.

3. In **Table II** are data on eight additional cepheids which are found in six other star clusters. Their absolute magnitudes have been determined by the same method you just used in part 1, above. Plot their **M**s against their log(**P**)s on **Fig. 1**.

4. In order to best represent the period-luminosity relation, use a ruler to draw a best-fit straight line through the data points plotted on **Fig. 1**. This line should divide the data equally so that you have about the same number of data points above it as below it. Also, notice that the point in the upper right of this figure will help you obtain the proper slope for your line.

II. Distance Determination Using the P-L Relation

Table III gives data obtained for a cepheid in the Large Magellanic Cloud, a nearby irregular galaxy. Column 1 lists the time in fractional days of each observation. The second column gives the apparent magnitude measured at each time.

1. On **Fig. 2**, plot a light curve for the cepheid data in **Table III**. Notice that "maximum" refers to maximum brightness. Thus, the magnitude scale seems to be backwards from most other graphs you have seen.

2. Draw a free-hand best-fit curve that represents the data plotted. Make sure that your curve reaches the same maximum and minimum values for each cycle. From the light curve determine the time for each maximum. The difference in time is the pulsation period, **P**. Record your value of **P** in the space provided in **Fig. 2**.

3. Use a calculator to determine the value of log(**P**), and record the answer in **Fig. 1**. Look up this value of log(**P**) on the x-axis of **Fig. 1**. From the best-fit line determine the cepheid's absolute magnitude. In other words, at your log(**P**) value, go straight up the graph to the best-fit line of the P-L relation and read off the corresponding absolute magnitude on the vertical axis. Record your answer in the space provided in **Fig. 2**.

4. From **Table III** calculate the average apparent magnitude, **m**. Record your results in the space provided in **Fig. 2**.

5. Use the apparent and absolute magnitudes to compute the distance modulus, **m-M**. Record your answer in **Fig. 2**.

6. Use the Distance vs. Distance Modulus graph in **Fig. 3** to determine the distance, **D**, to this cepheid. This is the distance to the Large Magellanic Cloud. Currently, the distance to the LMC is believed to be between 57000 and 65000 parsecs. Record your answer in the space provided in **Fig. 2**.

NAME: ____________________

SECTION: ____________________

TABLE I

Cepheids in χ Per

Star	Period (days)	log P	m	M
VY Persei	5.37	0.73	8.36	
V Persei	5.53	0.74	7.99	
VX Persei	10.89	1.04	7.56	
SZ Cassiopeiae	13.61	1.13	7.19	

TABLE II

Other Galactic Cepheids

	Period (days)	log P	M
EV Scuti	3.09	0.49	–2.90
CE Cassiopeiae A	5.14	0.71	–3.84
CF Cassiopeiae B	4.48	0.65	–3.78
U Sagittarii	6.73	0.83	–3.63
DL Cassiopeiae	8.00	0.90	–3.62
S Normae	9.75	0.99	–4.27
RS Puppis	41.40	1.62	–6.25

TABLE III

A Cepheid in the LMC

Time (days)	mag
1.28	15.83
1.37	15.95
1.56	15.59
1.84	15.26
2.16	15.20
2.33	15.23
2.67	15.32
3.20	15.41
3.98	15.51
4.17	15.56
4.22	15.63
4.54	15.70
5.20	15.84
5.38	15.84
5.94	15.85
6.04	15.93
6.31	15.61
6.50	15.30
6.92	15.19
7.45	15.33
7.88	15.39
8.65	15.53
8.83	15.56
8.88	15.64
9.21	15.70

Fig.1: P-L relation for cepheids found in star clusters of The Milky Way

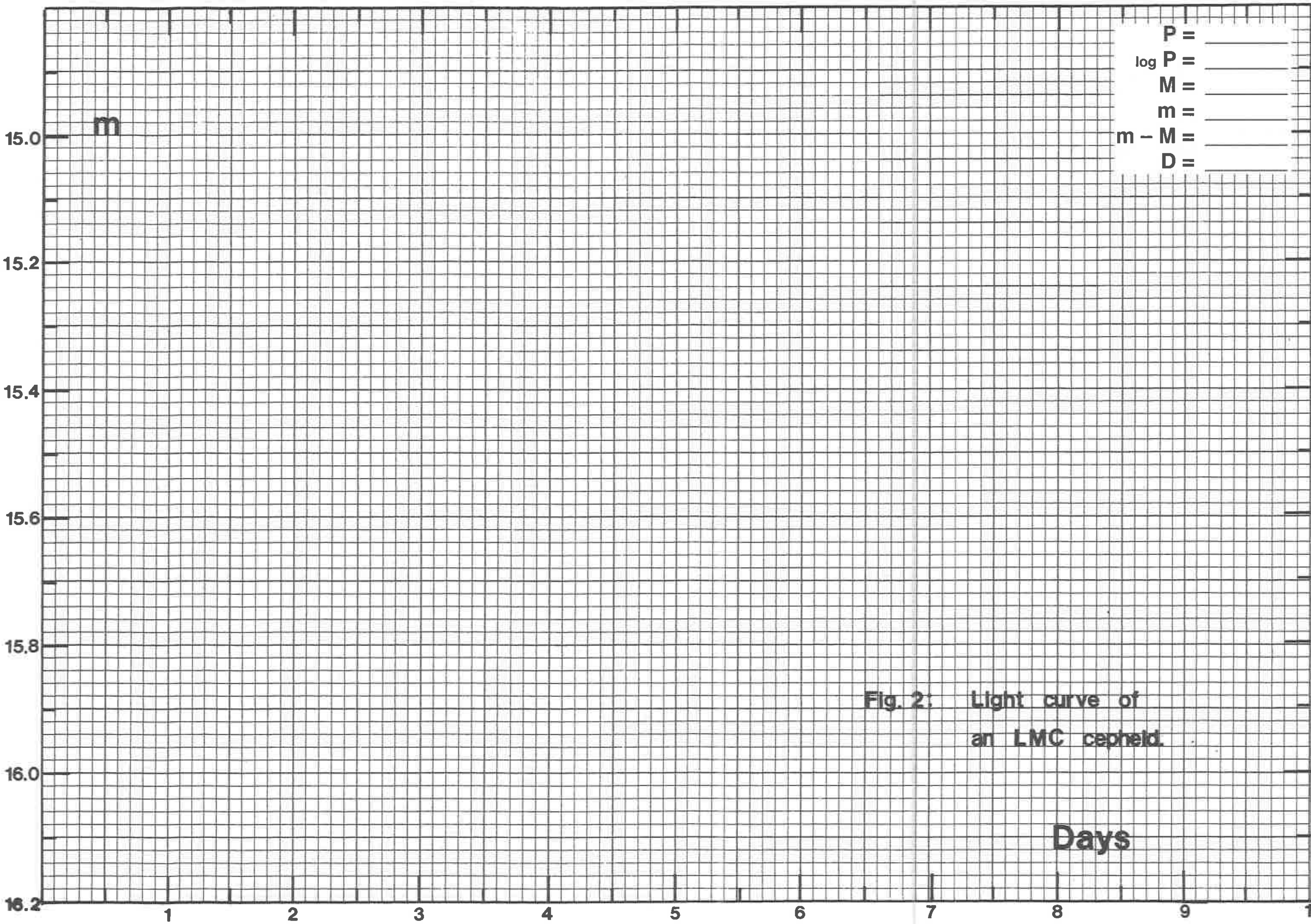

Fig. 2: Light curve of an LMC cepheid.

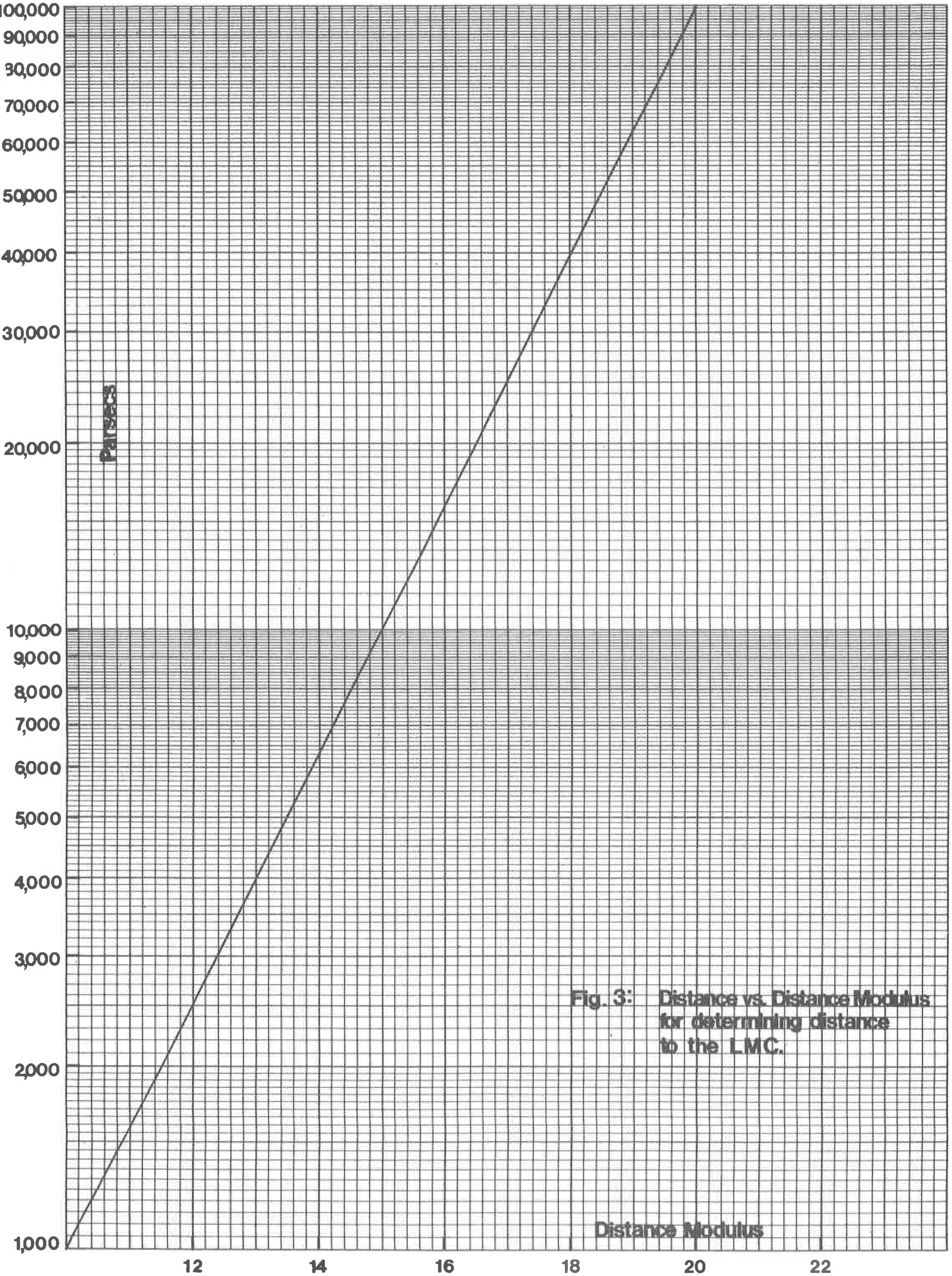

Fig. 3: Distance vs. Distance Modulus for determining distance to the LMC.