

Cepheid Variables and the Cosmic Distance Scale

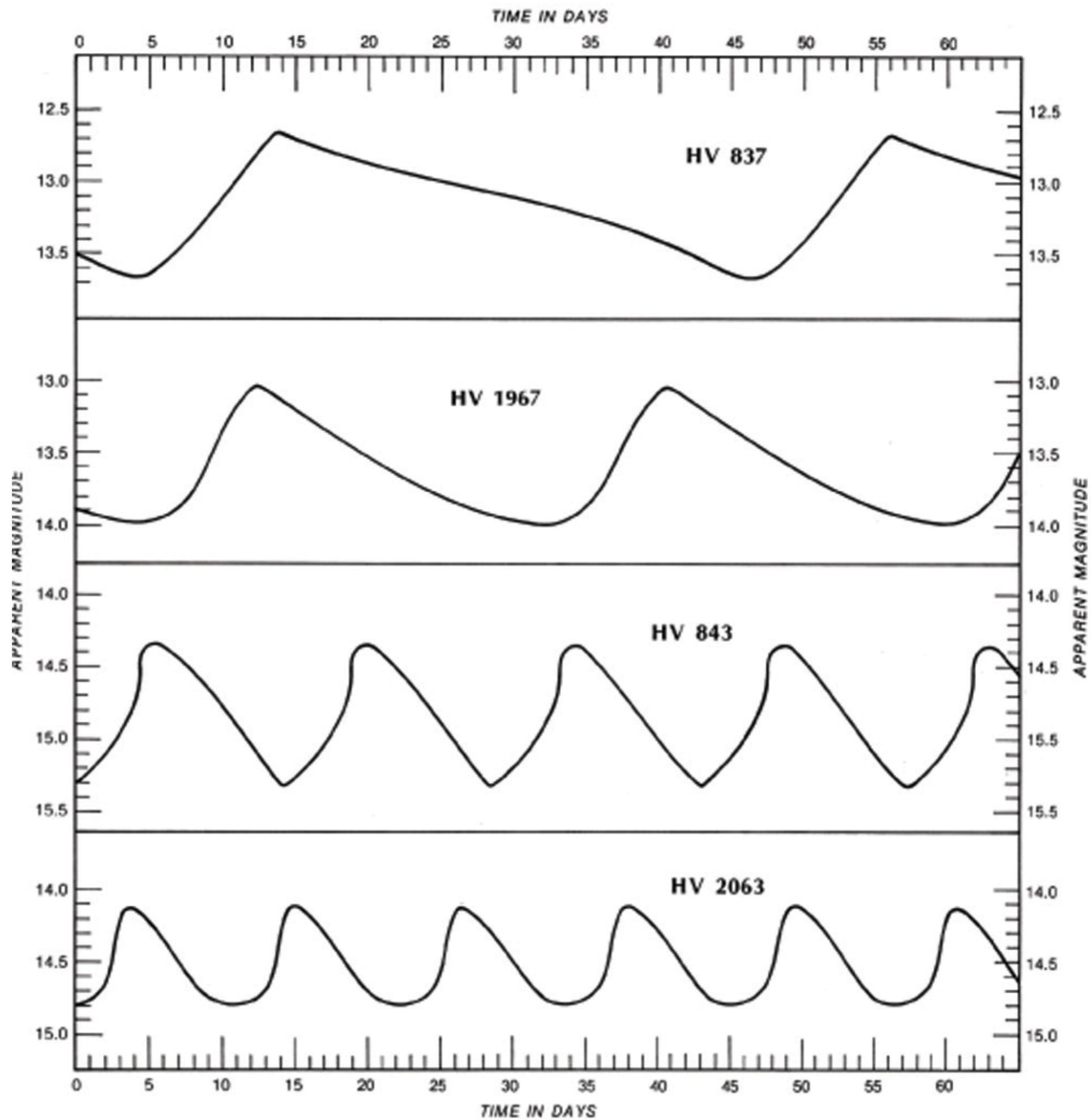
2008/03/13

Distance Measurement

- The most accurate means of determining the distances to the nearest star is [trigonometric parallax](#).
- Every parallax determination has a probable error of about 0.005 second, as a rule.
- However, as the distance increases, the probable error also grows up. At a distance of 200 pc, the error is about as large as the parallax itself.
- Other methods are needed for objects more distant than a few pc. In this exercise, we will use [Cepheid variable stars](#).

Cepheid Variables

- The Periods of Cepheid variable stars are 1-100 days.
- Cepheid variable stars are **supergiant stars** with luminosity much greater than our sun.
- The first known Cepheid was **δ Cephei**, discovered in 1784 by an English amateur astronomer, John Goodricke.
- A. Ritter theorized that the light variations of these stars are due to pulsations, the star alternately expanding and contracting.
- In this exercise, we are not concerned with why the stars pulsate but rather **how they are used as distance indicator**.



Setep 1

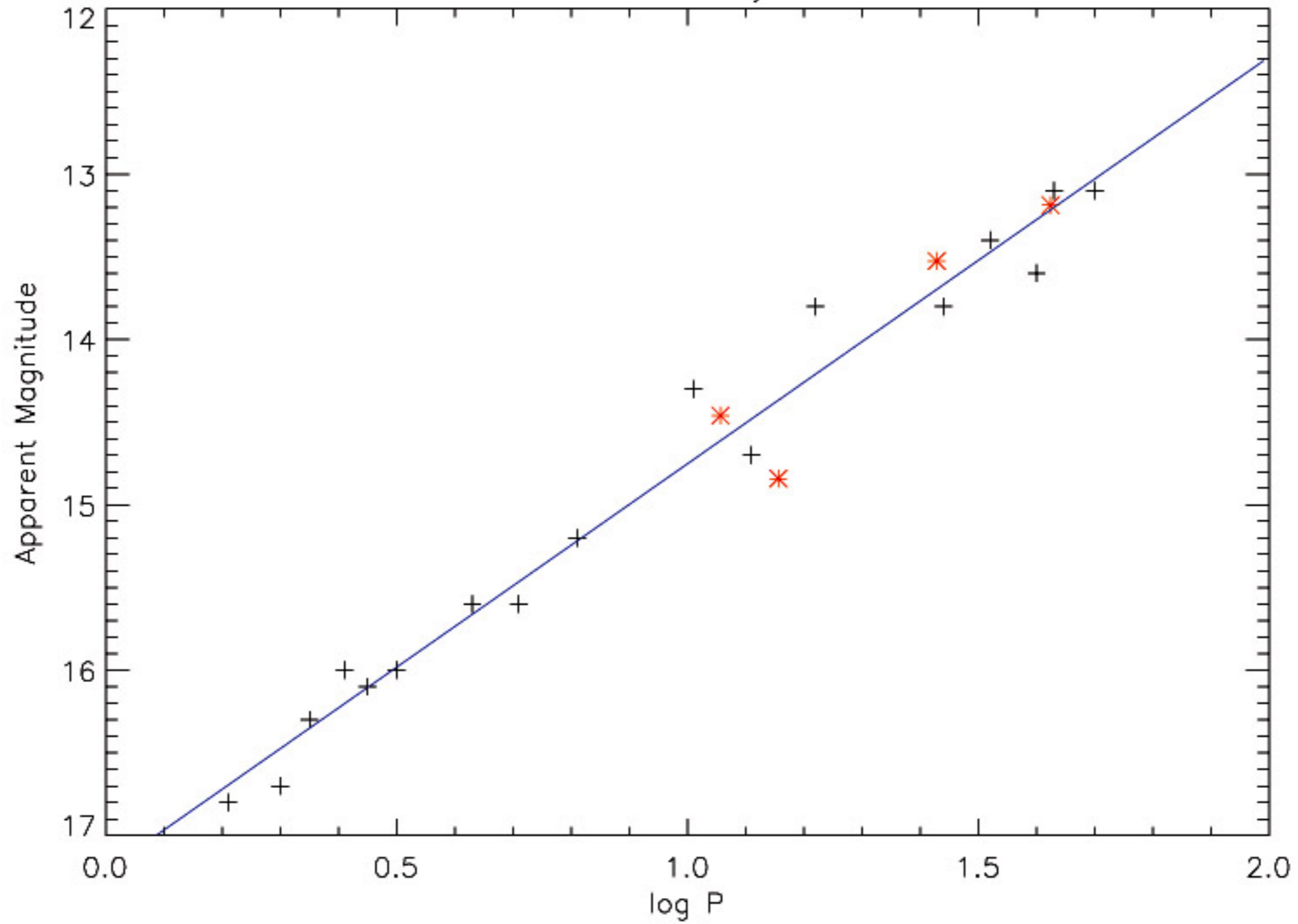
- For each star, read off the apparent magnitudes, and estimate the period.
- Take logarithm of the period.
- Plot each star the mean apparent magnitude as the ordinate against the logarithm of the period. To increase the number of points, plot the data from Table 1, which are also for SMC Cepheid.
- Next, draw a straight line to fit the data points as well as possible.

TABLE I

Cepheids in the Small Cloud

<i>HV</i>	<i>log P</i>	<i>m_v</i>	<i>HV</i>	<i>log P</i>	<i>m_v</i>
2019	0.21	16.8	2060	1.01	14.3
2035	0.30	16.7	1873	1.11	14.7
844	0.35	16.3	1954	1.22	13.8
2046	0.41	16.0	847	1.44	13.8
1809	0.45	16.1	840	1.52	13.4
1987	0.50	16.0	11182	1.60	13.6
1825	0.63	15.6	1837	1.63	13.1
1903	0.71	15.6	1877	1.70	13.1
1945	0.81	15.2			

Period–luminosity relation



$$m = (17.212 \pm 0.025) + (-2.461 \pm 0.022) \times \log P$$

- This plot gives us the relation between apparent magnitude and period for the Cepheids in that galaxy. Since all the stars in SMC are at near the same distance, the plot can be regarded as a **period-luminosity (P-L) relation**.

- The relation between absolute magnitude (M) and apparent magnitude (m) is:

$$M = m + 5 - 5 \log d$$

where d is distance.

- As the relation between absolute magnitude and apparent magnitude, the P-L relation can be calibrated in terms of absolute magnitude, then we can know the **Cepheid's distance**.
- In 1918, Harlow Shapley provided a calibration. Table 2 shows Shapley's P-L relation with absolute visual magnitudes.

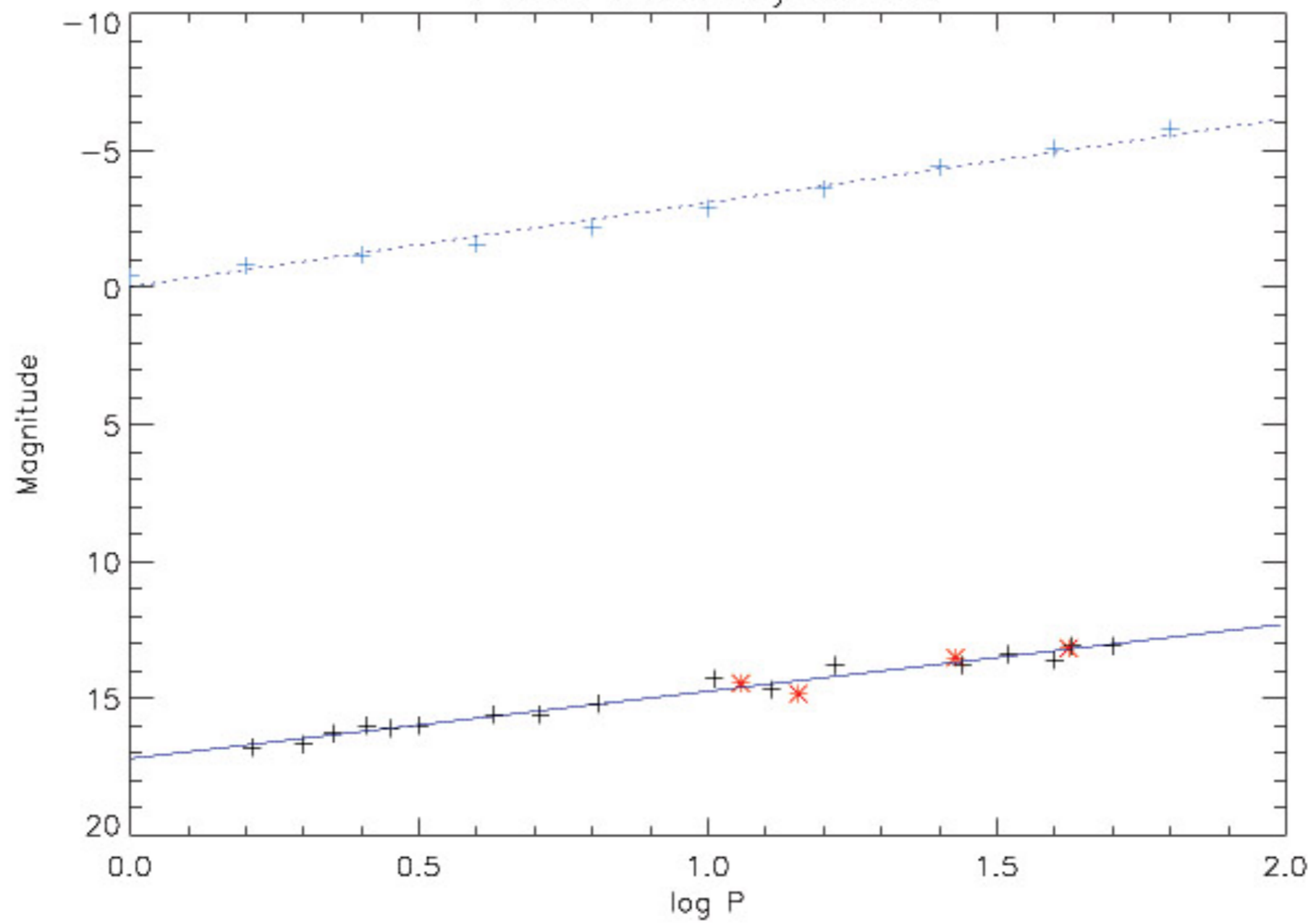
TABLE II
Shapley's Period-Luminosity Curve

<i>log P</i>	<i>M_v</i>	<i>log P</i>	<i>M_v</i>	<i>log P</i>	<i>M_v</i>
0.0	- 0.4	+ 0.8	- 2.2	+ 1.4	- 4.4
+ 0.2	- 0.8	+ 1.0	- 2.9	+ 1.6	- 5.1
+ 0.4	- 1.2	+ 1.2	- 3.6	+ 1.8	- 5.8
+ 0.6	- 1.6				

Step 2

- Plot Shapley's data on the same graph, but using the right-hand scale on the ordinate (y) axis, this time in terms of absolute magnitude M .
- Draw a straight line to fit the points. This is the **calibrated P-L relation** that for many years was used in determining the distance to objects containing Cepheids.
- Determine the Vertical difference ($m - M$) between two lines. Use $M = m + 5 - 5 \log d$, you can calculate the distance to the SMC.

Period–luminosity relation



Baade's calibration and Kraft's calibration
