Cepheid Period-Luminosity Relation:

During the core He burning HR Diagram "loop" the star passes through the "instability strip":

Pulsation is driven by a "feed-back mechanism" in the He envelope where ionization of the He envelope increases the opacity in that region making the He envelope act like a "shutter" which traps the outgoing energy from the core (increasing pressure) causing the star to expand. As the star expands outward the temperature in the He envelope drops allowing the gas to become neutral or "un-ionized" again, releasing the energy (lowering the pressure) and allowing the star to contract. This mechanism "pumps" the star once per pulsation cycle allowing the amplitude of the pulsation to build up until dissipative or frictional forces limit the amplitude.

The "instability strip" is the region in the HR Diagram where the He envelope is at the correct depth in the structure of a He burning star to drive stellar pulsation. For a given luminosity there is a range of surface temperatures where the He envelope is at the correct depth to drive stellar pulsation by the above mechanism, mapped out on the HR Diagram the region is a narrow strip running roughly vertically through the region of the diagram where core He burning is taking place in stars.

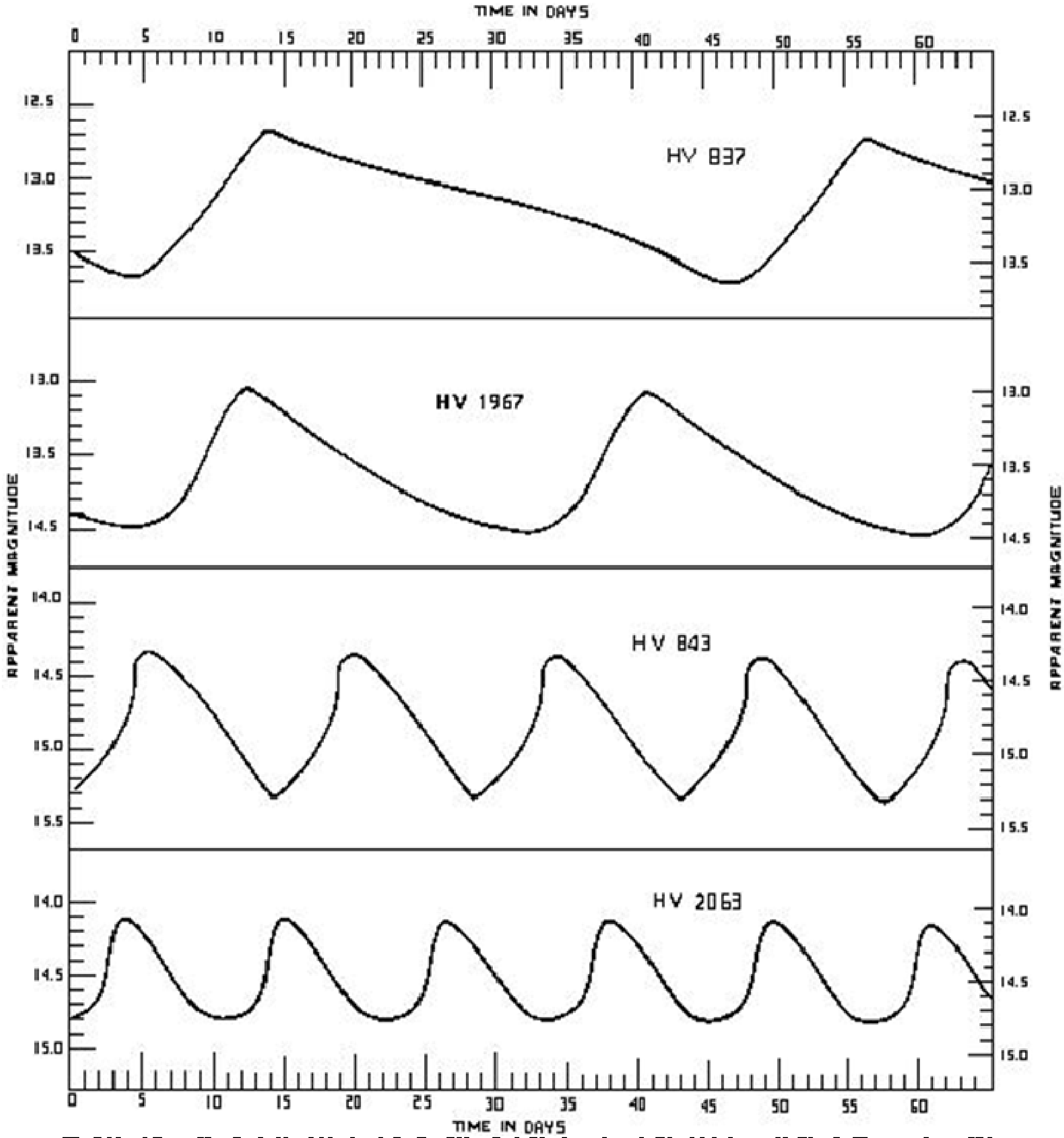
> For low mass stars where the Horizontal Branch runs through the "instability strip" the pulsating stars are called: RR Lyrae stars.
>
> For high mass stars where the Blue Loop runs through the "instability strip" the pulsating stars are called: Cepheid variable stars.

The period of pulsation for a given star is dependent on its mass and the average luminosity of the pulsating star is also dependent on its mass. Therefore, there is a relationship between the luminosity of a pulsating star and its pulsation period. This is call a "Period-Luminosity Relation" and is usually expressed in terms of a star's absolute magnitude as a correlation (or function) of the log (base 10) of its pulsation period in days. This turns out to be modelled well by a linear fit for Cepheid variables. The Period-Luminosity Relation for Cepheids turns out to be one of the most important standard candle methods for determining the cosmic distance scale.

Light Curves:

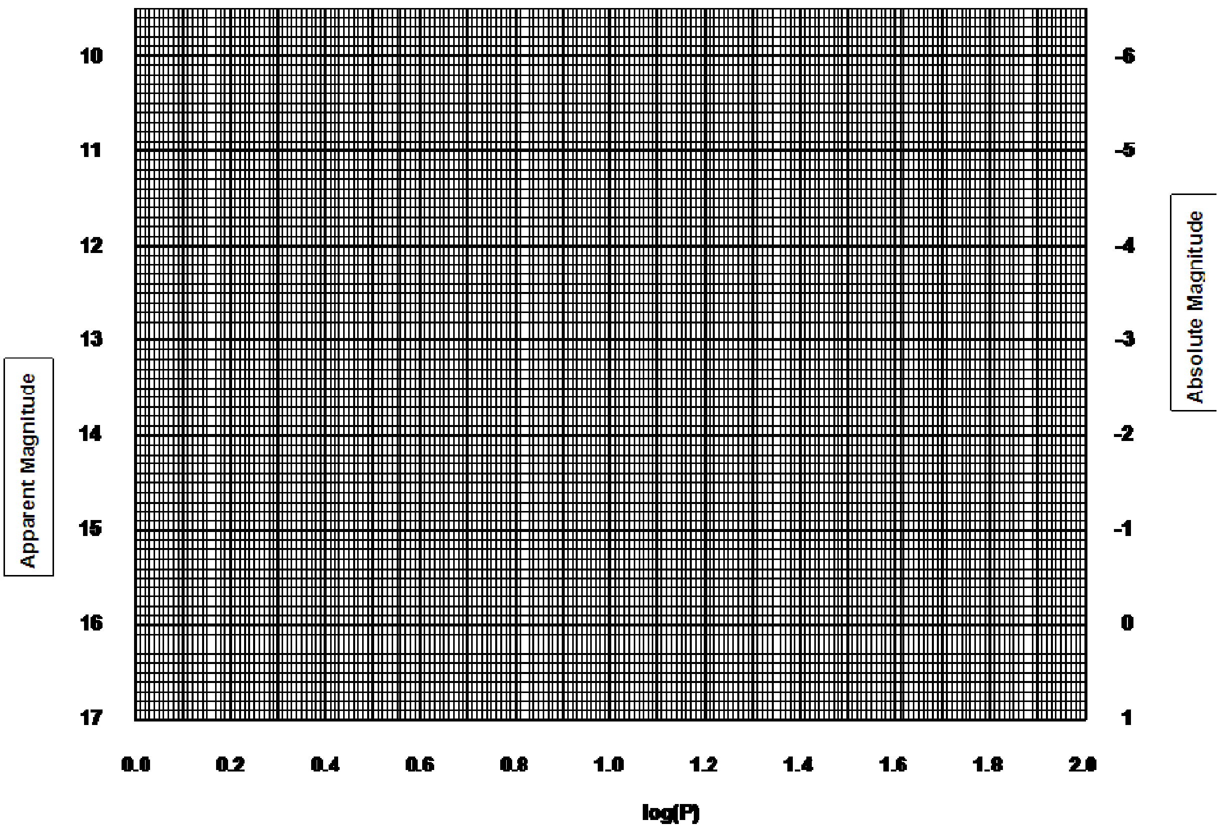
TIME IN DAYS

Example Cepheid light curves (from SMC): measure periods & ave. magnitudes from 2 of these light curves and plot on next page.

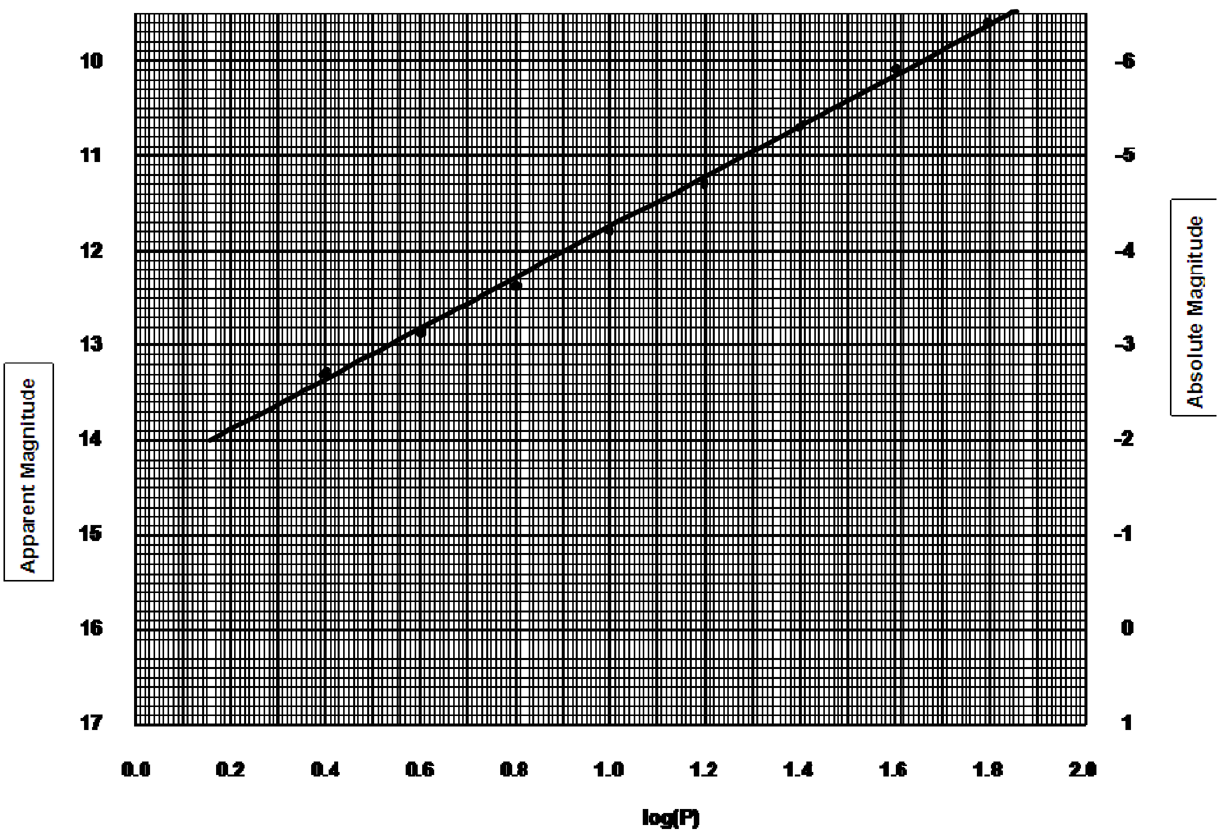


The light variations of four Cepheid variable stars in the Small Magellanic Cloud are shown in this plot, to be used in Step 3 of the procedures of this lab. These curves are based upon photographic observations made in yellow light by Halton G. Arp, using a 46-cm reflector in South Africa. His magnitude scale was calibrated photoelectrically and so is very reliable. The letters HV indicate a variable star discovered by Harvard Observatory astronomers. The great majority of the variables in the Small Cloud were found on photographs taken with Harvard telescopes in Peru and in South Africa. (Sky and Telescope, March 1979)

Cepheid Period-Luminosity standard candle distance method:

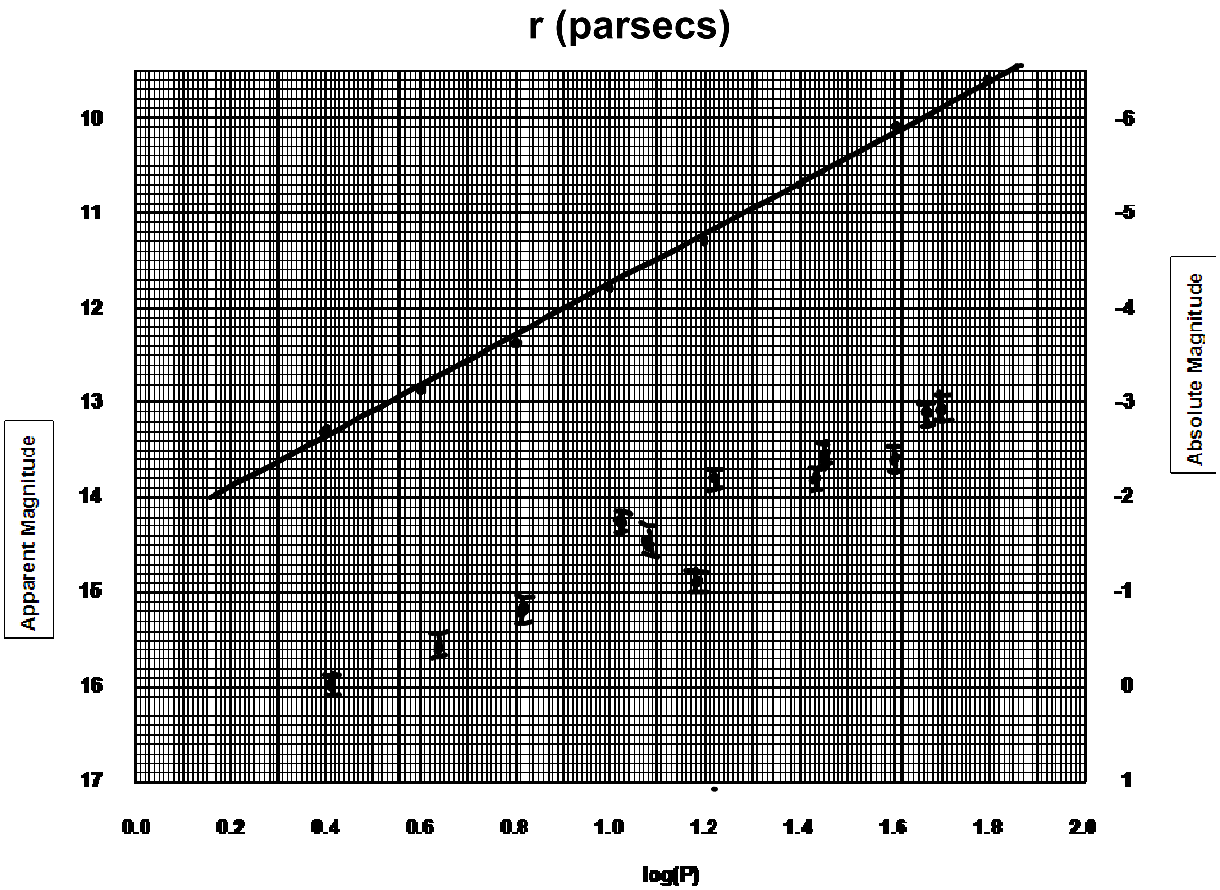


Calibrated Period-Luminosity Relation: Originally calibrated by finding the distance to a Cepheid variable using cluster MS-fitting method. Now with the Hubble and other space-based telescopes, we have directly determined (by parallax method) distances to Cepheid variable stars.

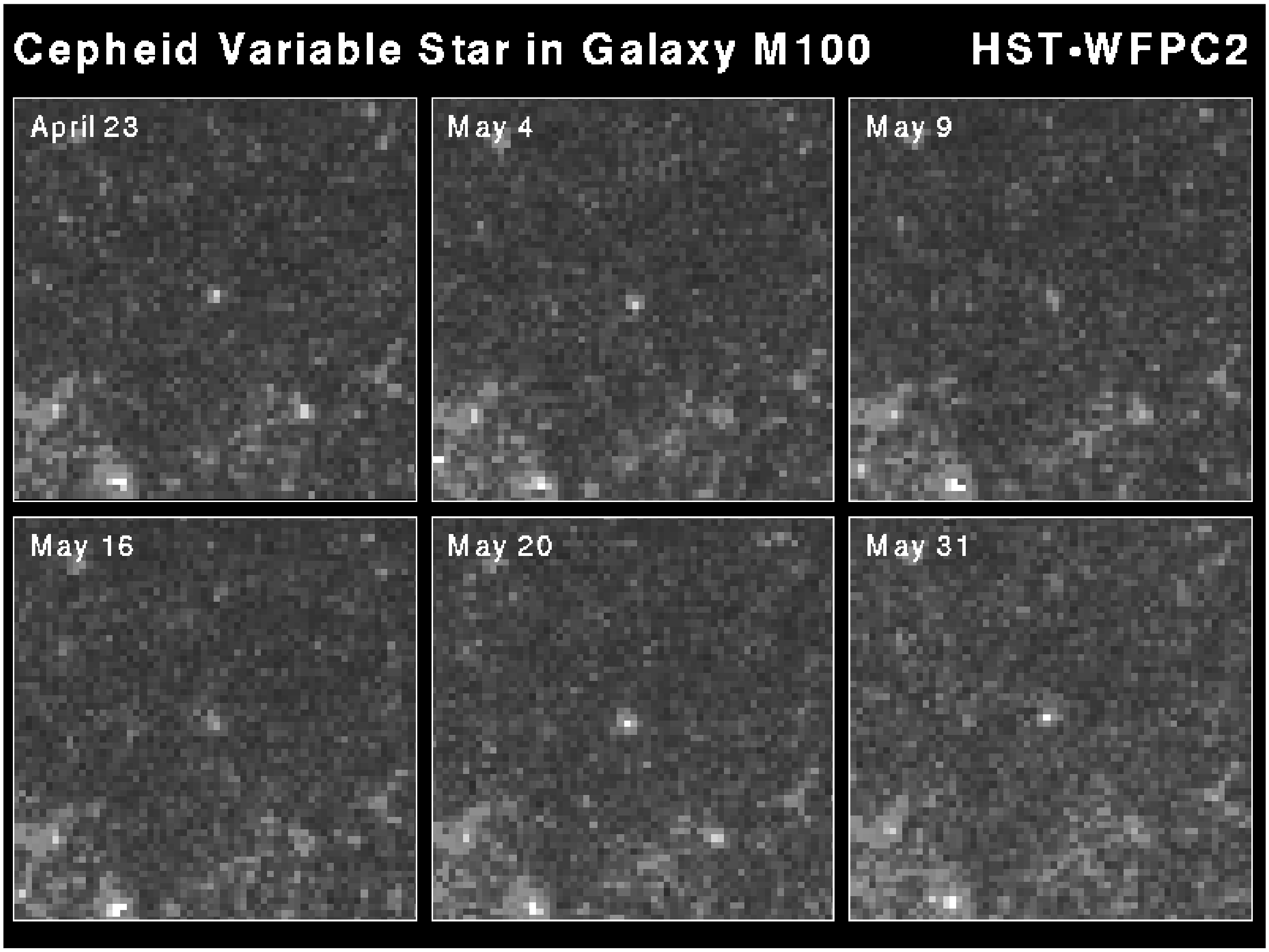


$$r = 10^{[0.2(V-M_V)+1]}$$

SMC: r = 66,000 pc



Fit the P-L relation on the apparent magnitude relation from the SMC to determine the distance modulus of the SMC.



Current status of cosmic distance scale determination:

Hubble telescope can observe Cepheids in several "near-by" galaxy clusters, thereby establishing accurate distances to these galaxy clusters.

The SN Ia type supernova standard candle method can be calibrated using these distances. The SN Ia supernova standard candle method can be used to extend the cosmic distance scale out to the very edge of the observable Universe.