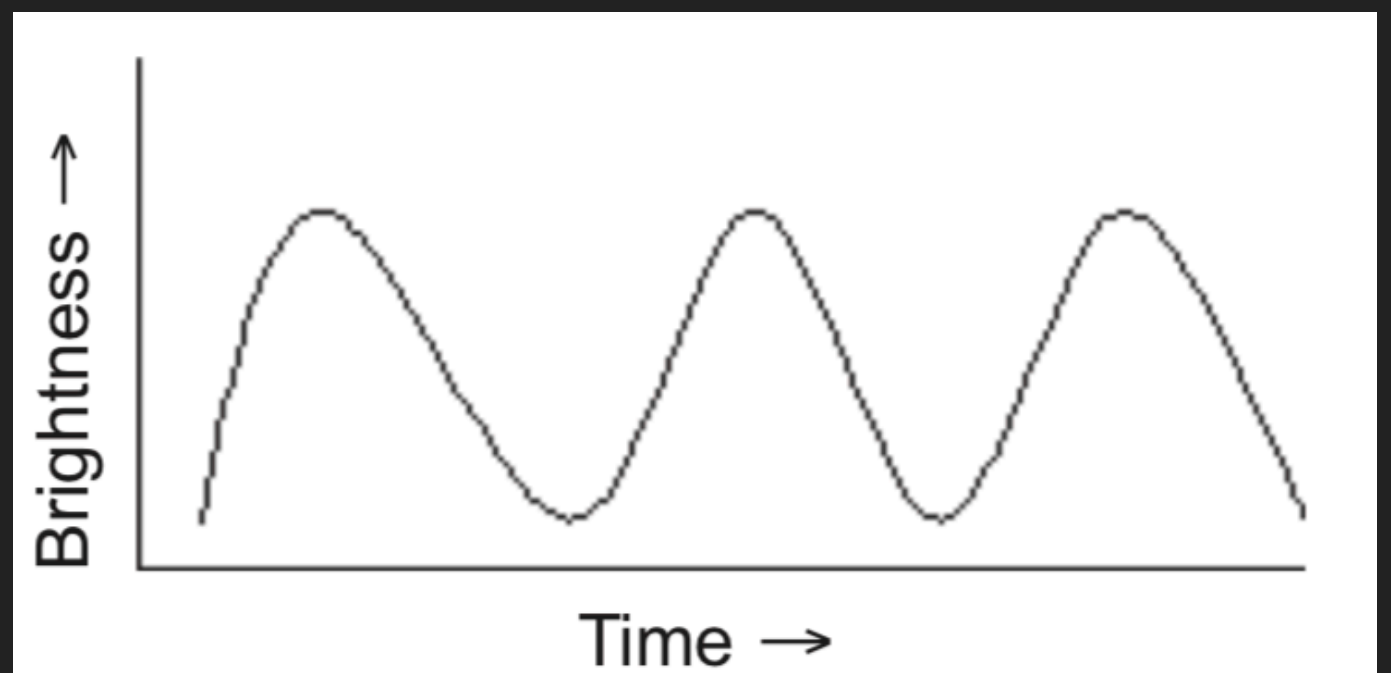
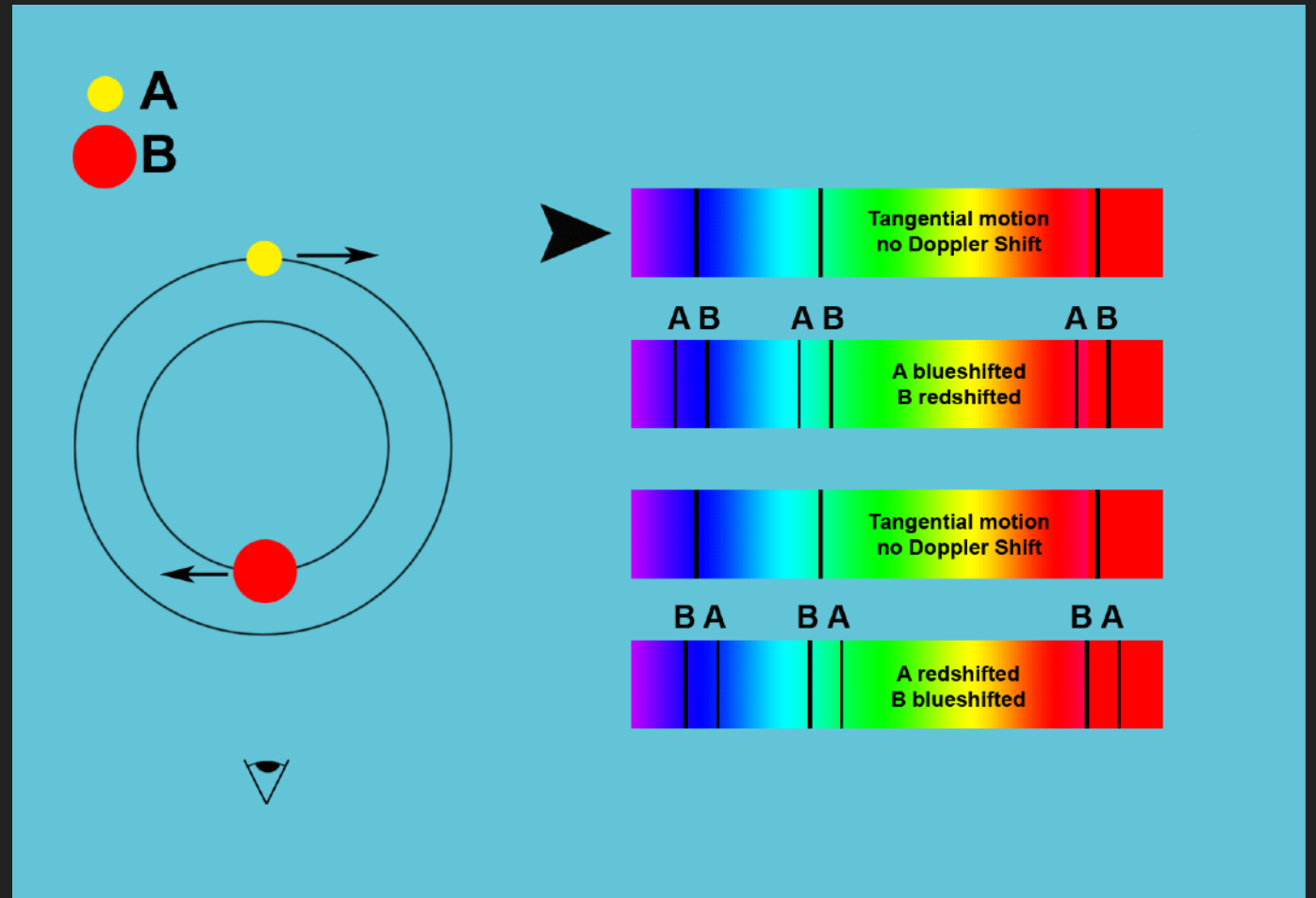


VARIABLE STARS

ASTROPHYSICS

Dr H.T.Sener

REVIEW



VARIABLE STARS

- ▶ Intrinsic: physical changes
 - ▶ Pulsating Stars
 - ▶ Erupting Stars
- ▶ Extrinsic:
 - ▶ Eclipsing binaries
 - ▶ Rotating stars

NAMING VARIABLE STARS

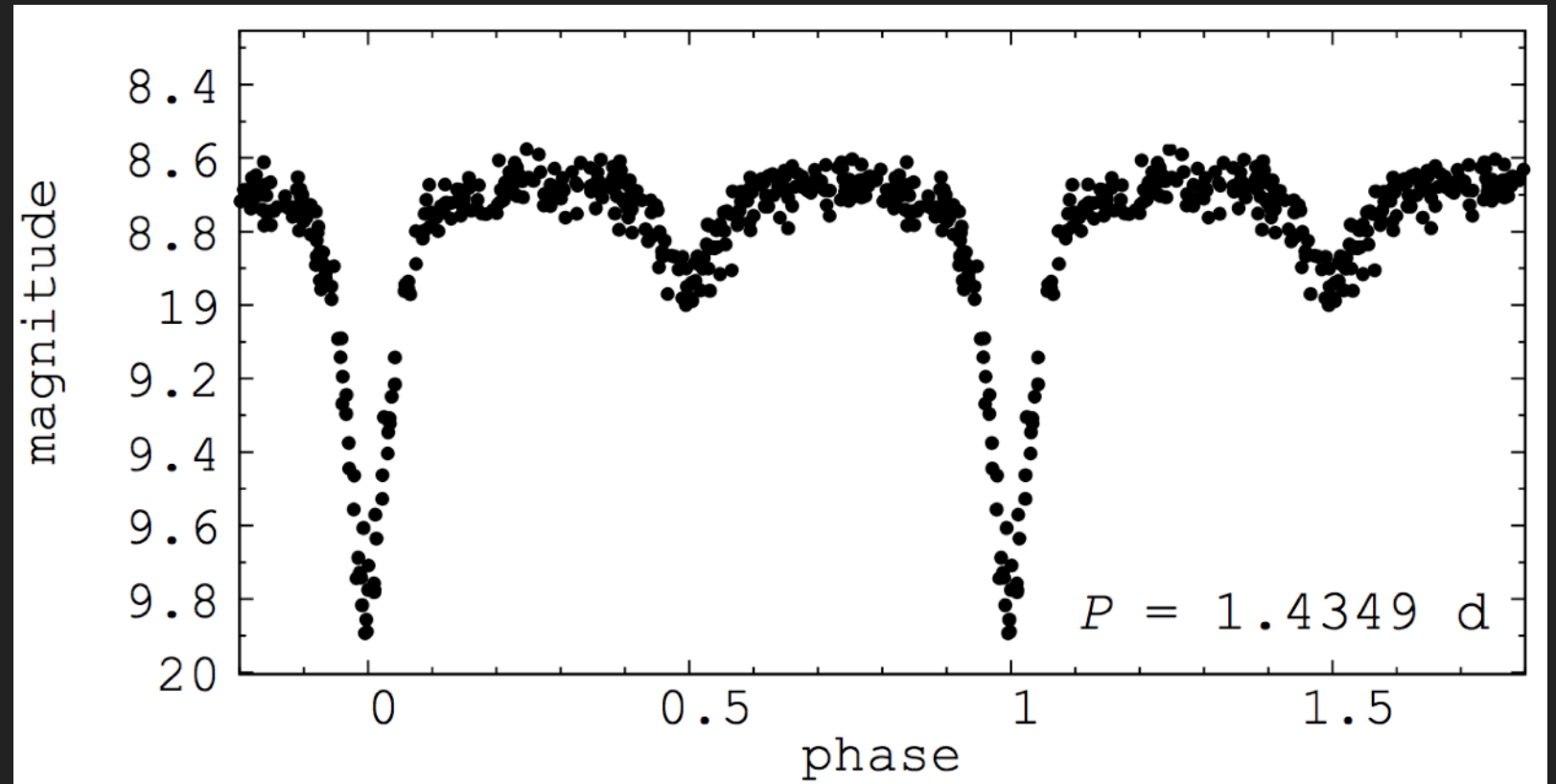
- ▶ Bayer classification ($\alpha, \beta, \gamma, \delta...$) + Constellation
 - ▶ Brightness
- ▶ Argelander classification
 - ▶ start with the letter R ➡ Z.
 - ▶ RR ➡ RZ, and then SS ➡ SZ, TT ➡ TZ and so on until ZZ.
 - ▶ AA ➡ AZ, BB ➡ BZ, CC ➡ CZ and so on until reaching QZ, omitting J in both the first and second positions.
 - ▶ Never: BA, CA, CB, DA or so on.
 - ▶ 334 combinations of letters and numbers
 - ▶ V335, V336, ...

CATALOGUE NAMES

- ▶ M 31
- ▶ NGC 4261
- ▶ PG 1544 + 488
- ▶ SDSS J114635.23+001233.5
- ▶ KIC (Kepler Input Catalogue): KIC #10227020
- ▶ KOI (Kepler Object of Interest): KOI - 730

PHASE DIAGRAMS

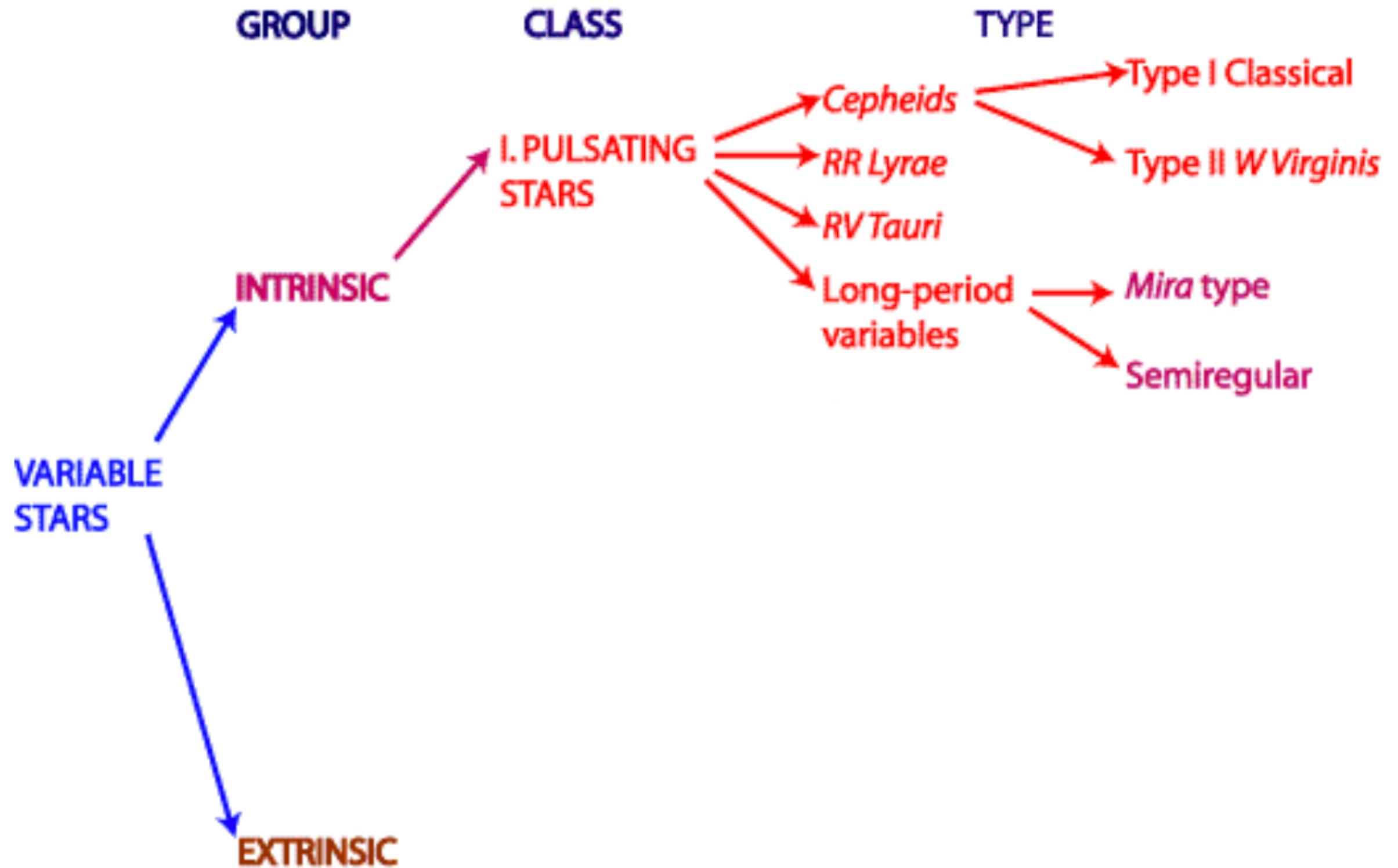
- ▶ Folded light curves
- ▶ Periodic changes



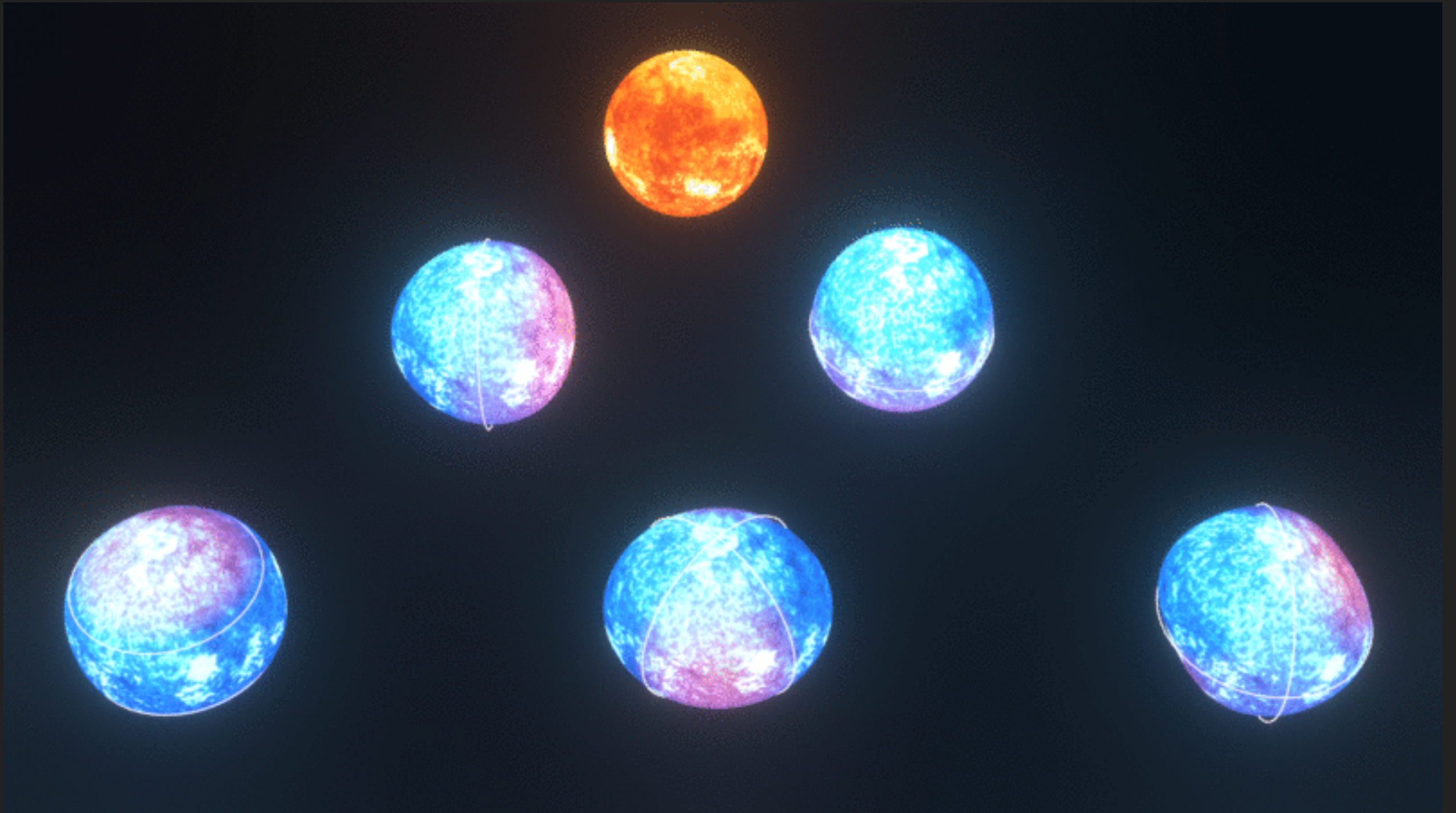
- ▶ T = any observation time
- ▶ T_0 = mid-eclipse time

$$phase = \frac{T - T_0}{Period}$$

VARIABLE STARS

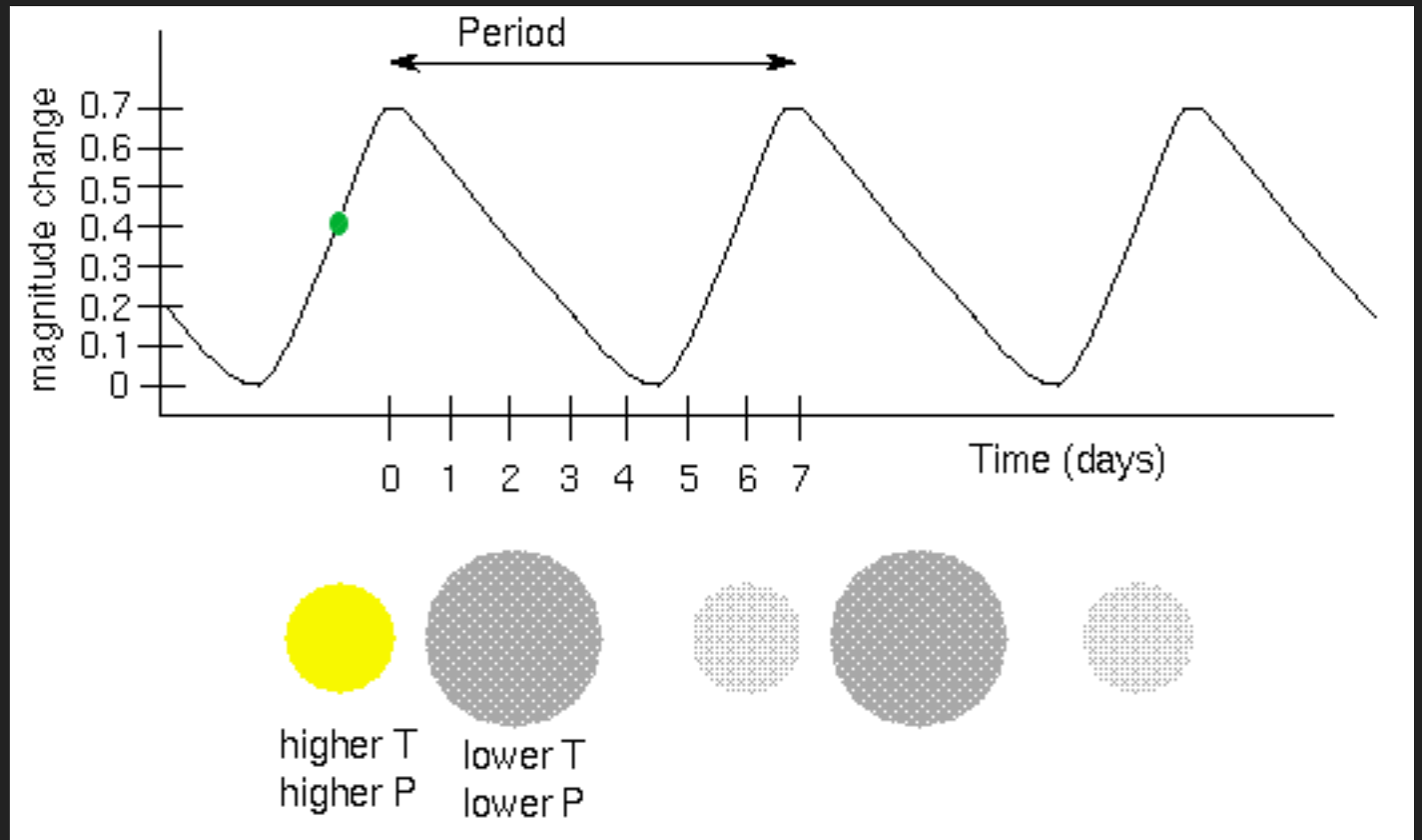


PULSATING VARIABLES

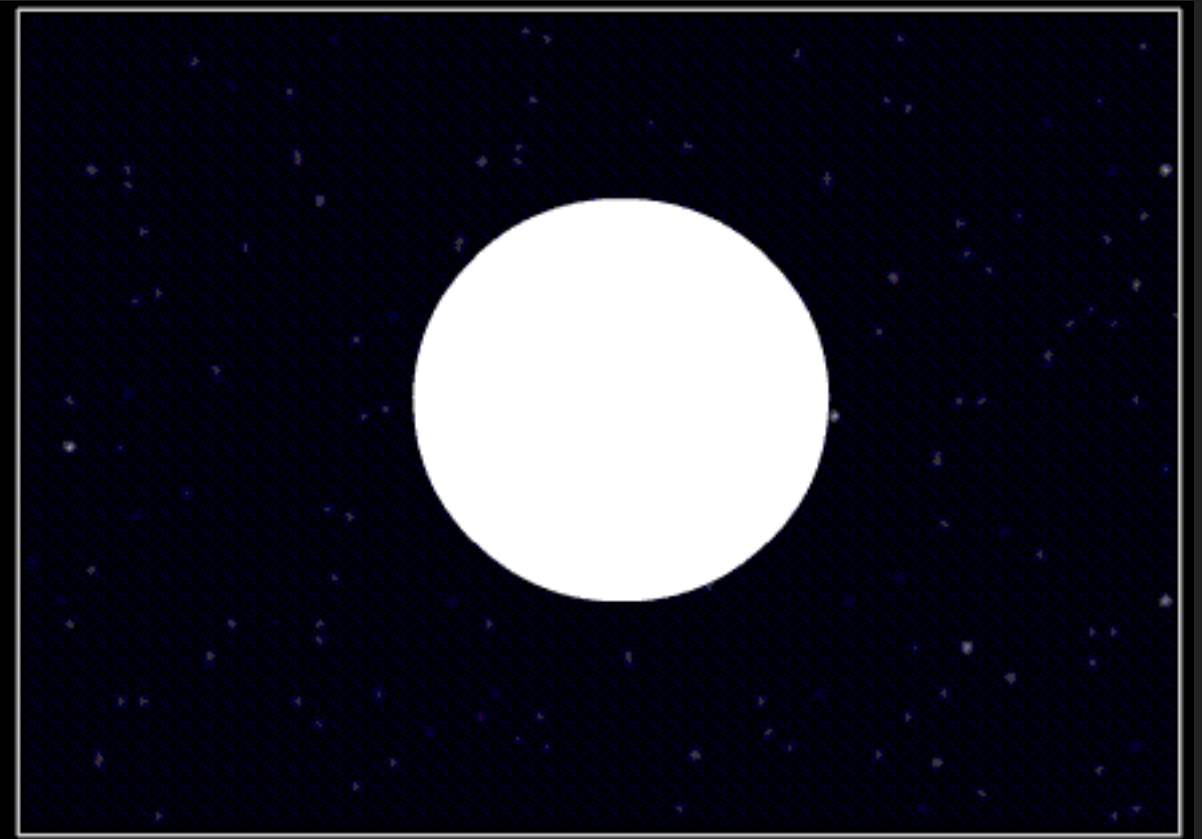
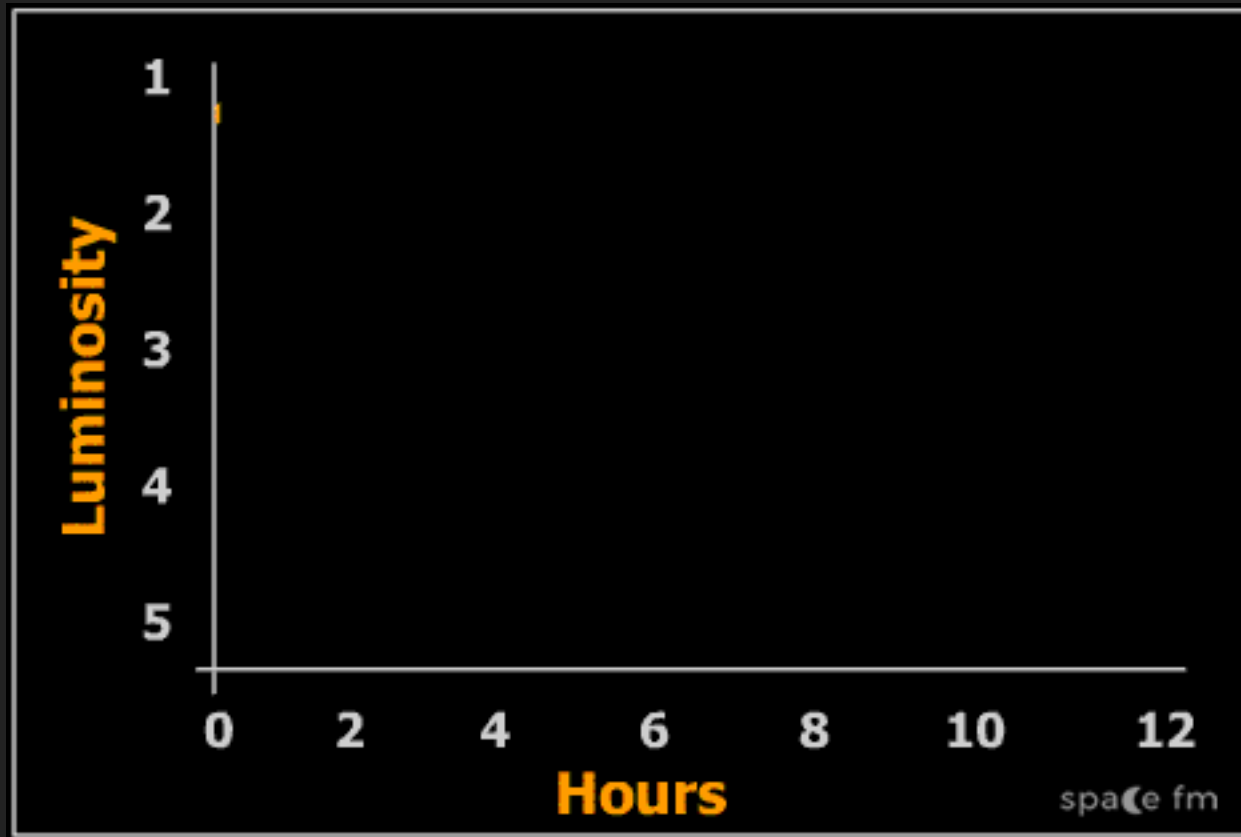


CEPHEIDS

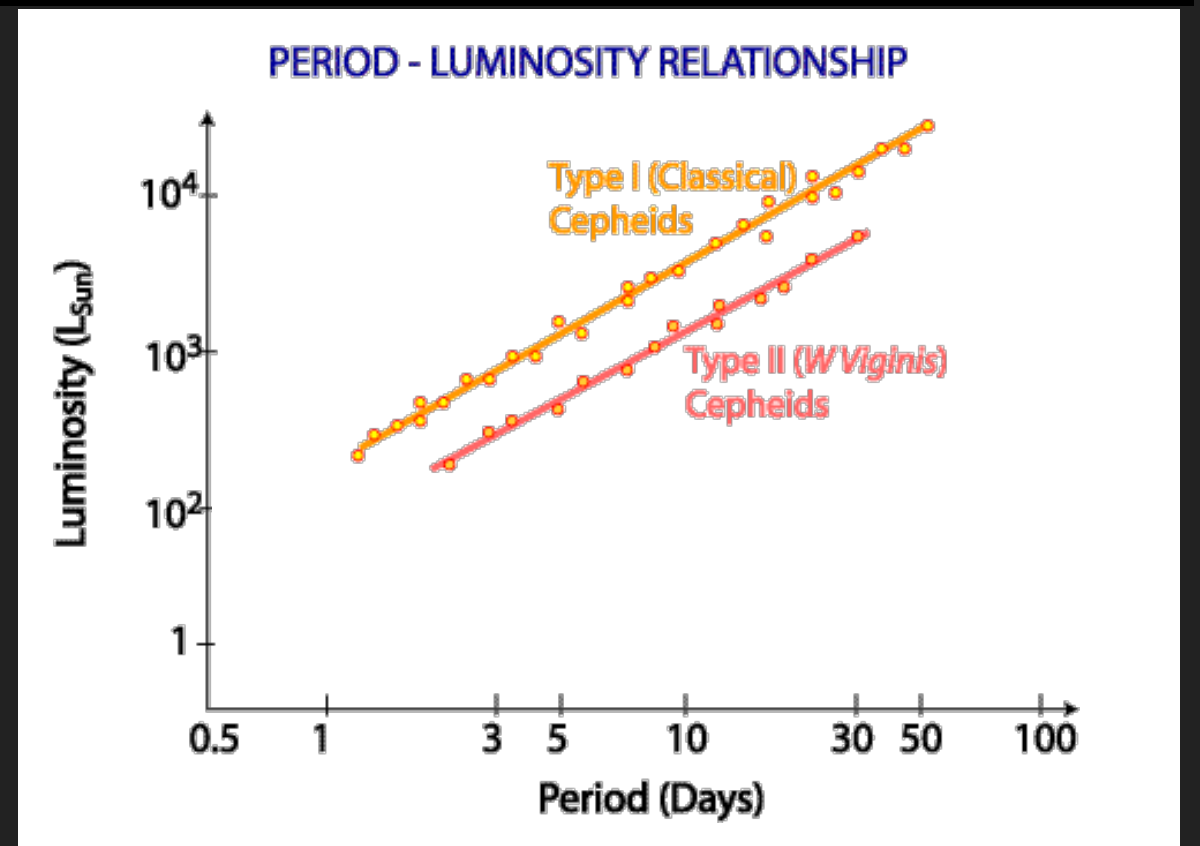
- ▶ Young
- ▶ Massive
- ▶ Pulsating radially
- ▶ $1\text{d} < P < 70\text{d}$
- ▶ Up to 2mag
- ▶ $P \propto L$
- ▶ Distance markers



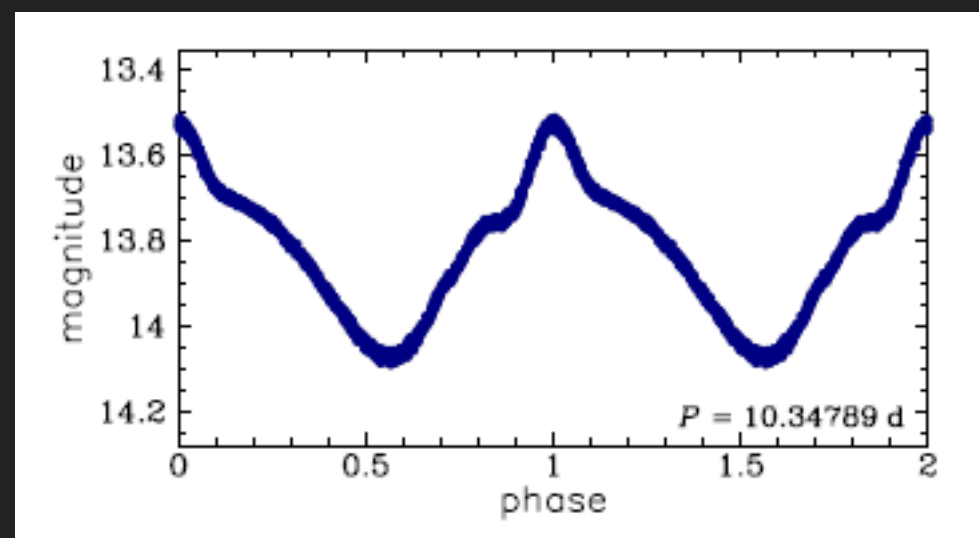
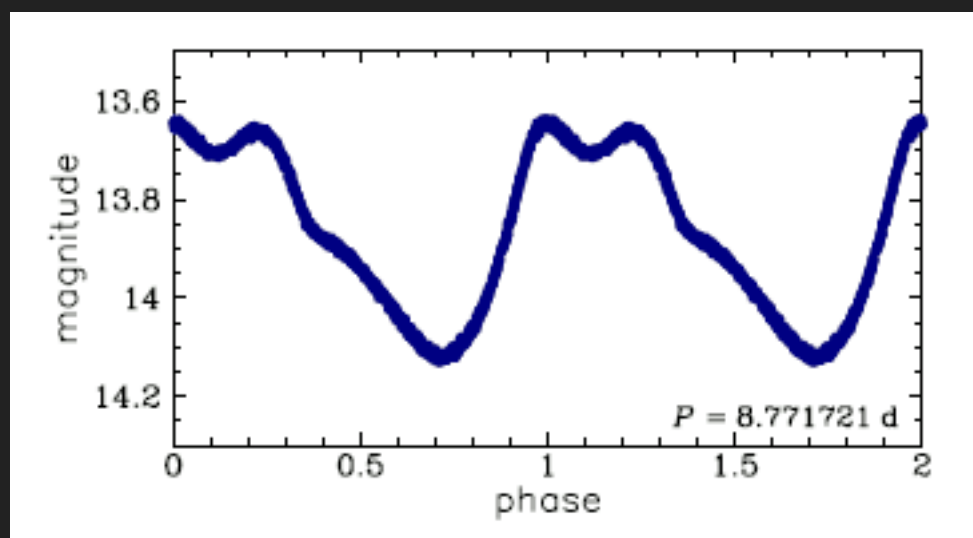
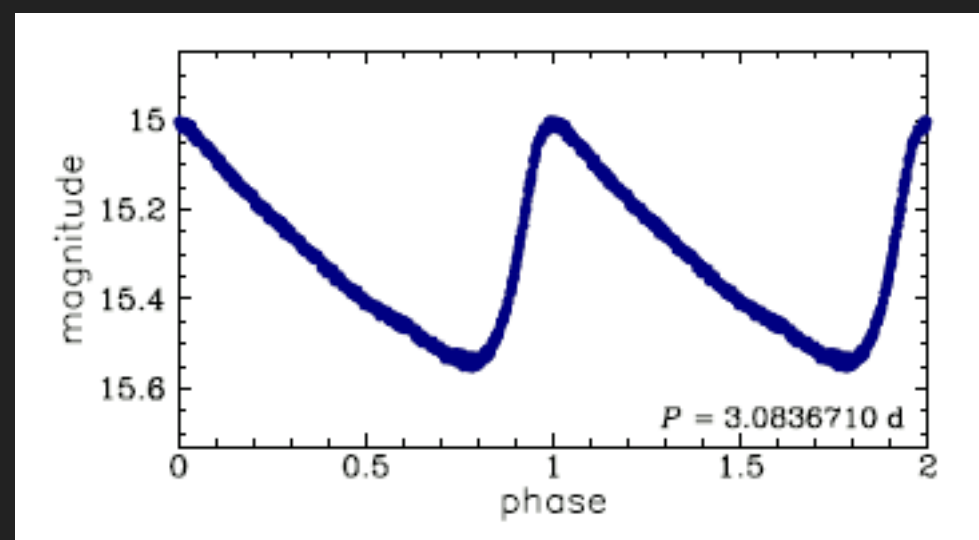
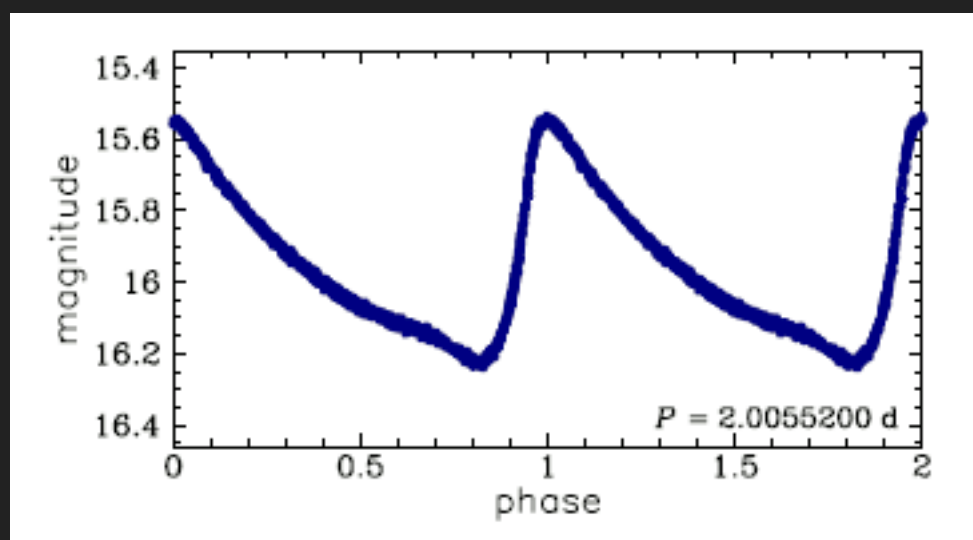
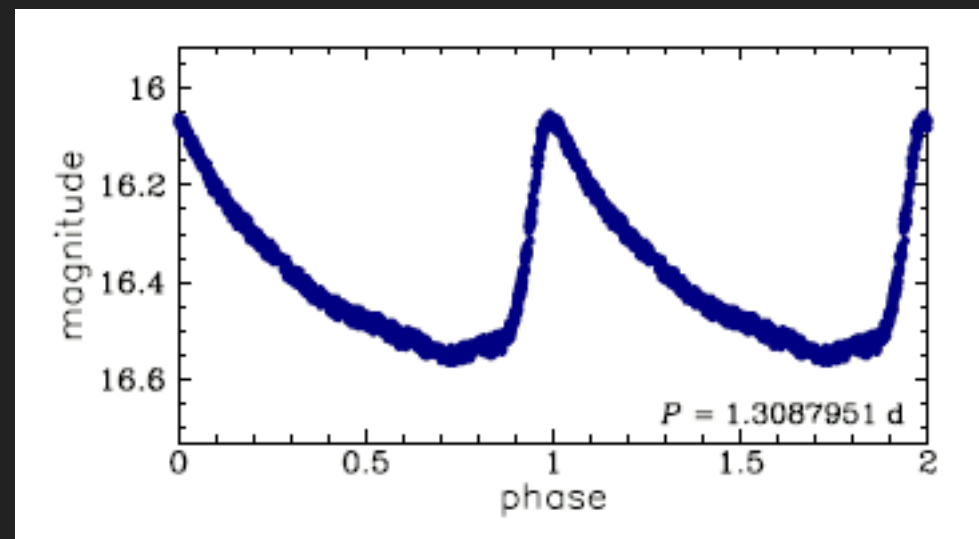
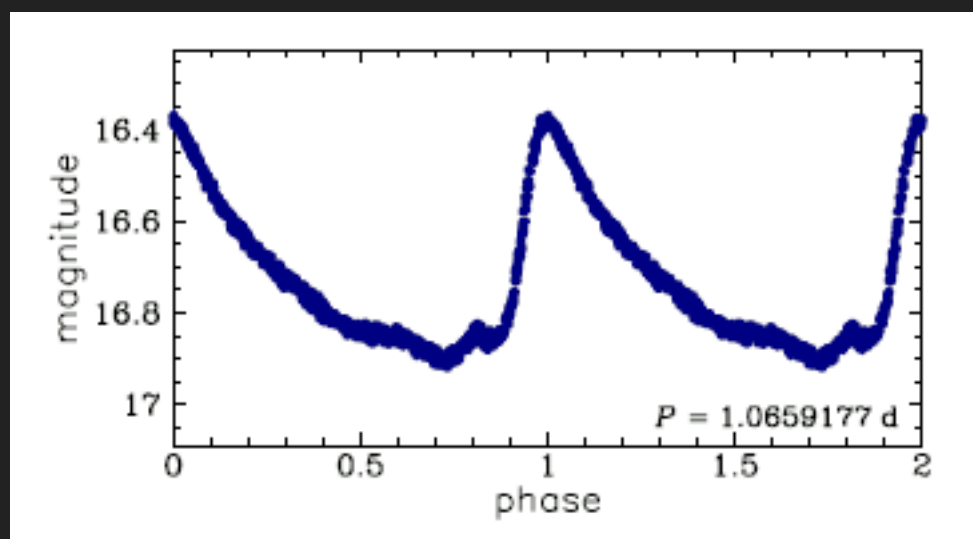
CEPHEIDS



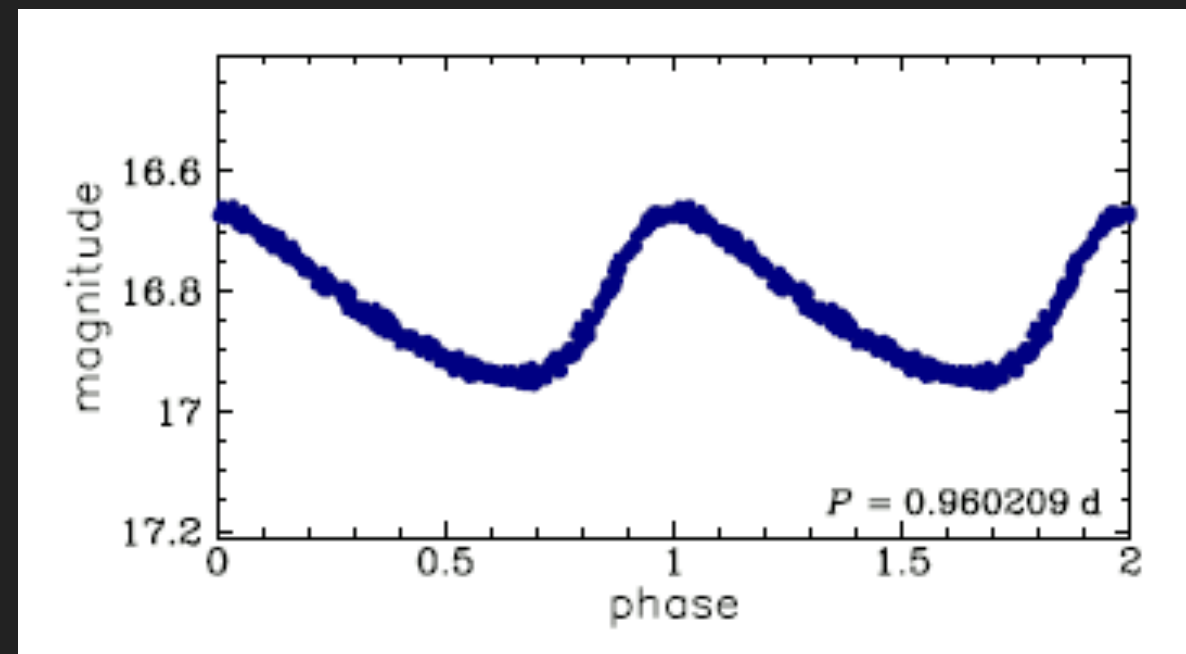
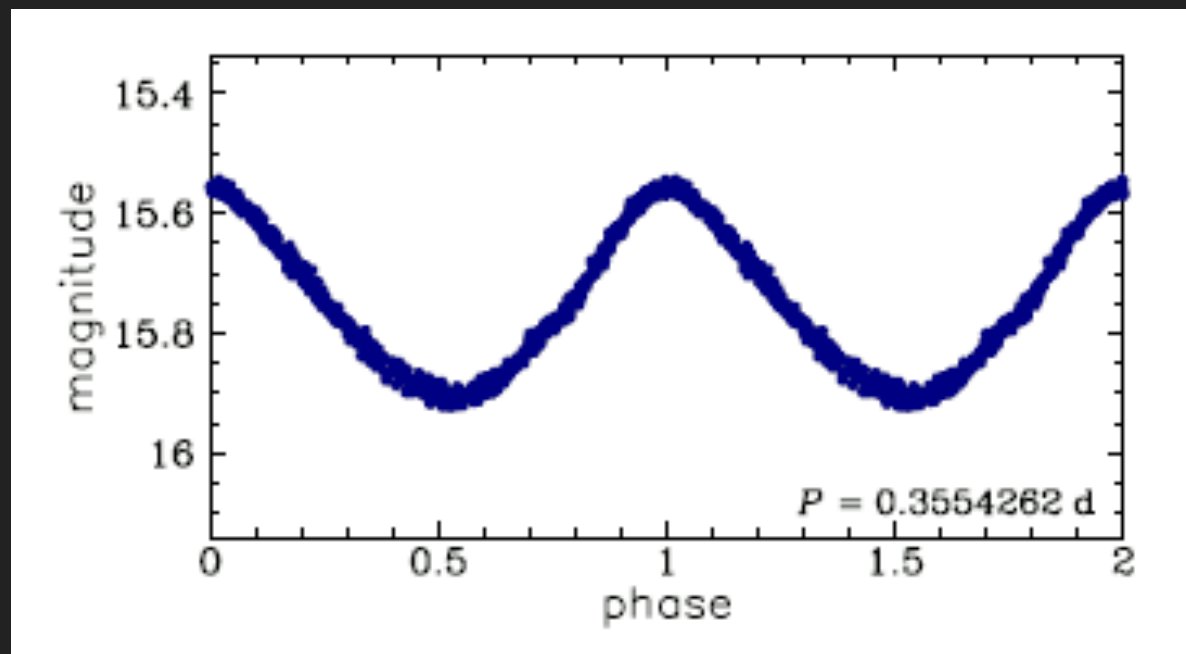
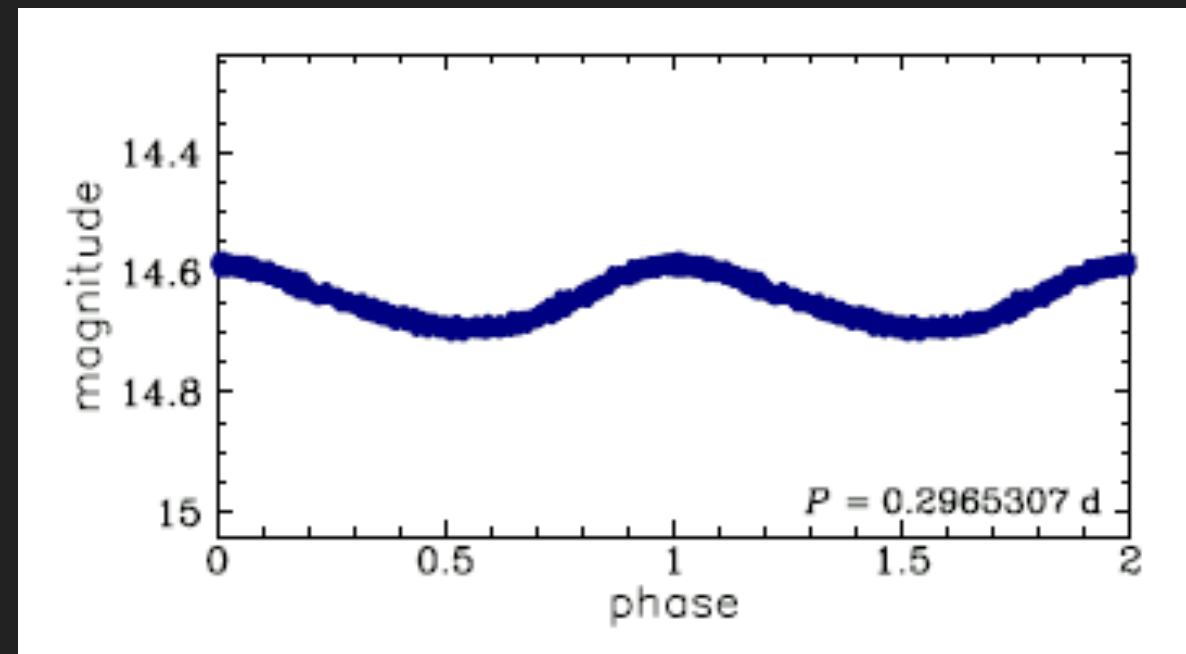
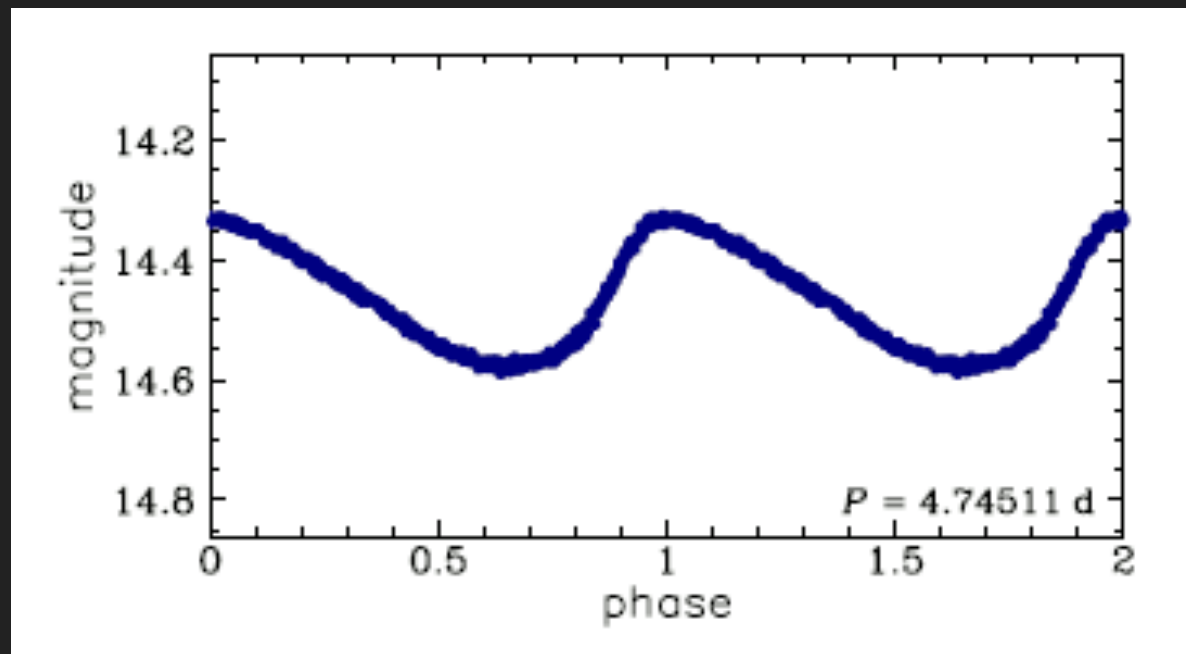
- ▶ Type I
 - ▶ $P = \text{a few days} - \text{weeks}$
 - ▶ $\Delta m = 0.1 - 2 \text{ mag}$
- ▶ Type II (BL Her, W Vir, RV Tau)
 - ▶ Low mass
 - ▶ $P = 1 - 50 \text{ days}$



CEPHEIDS – OGLE

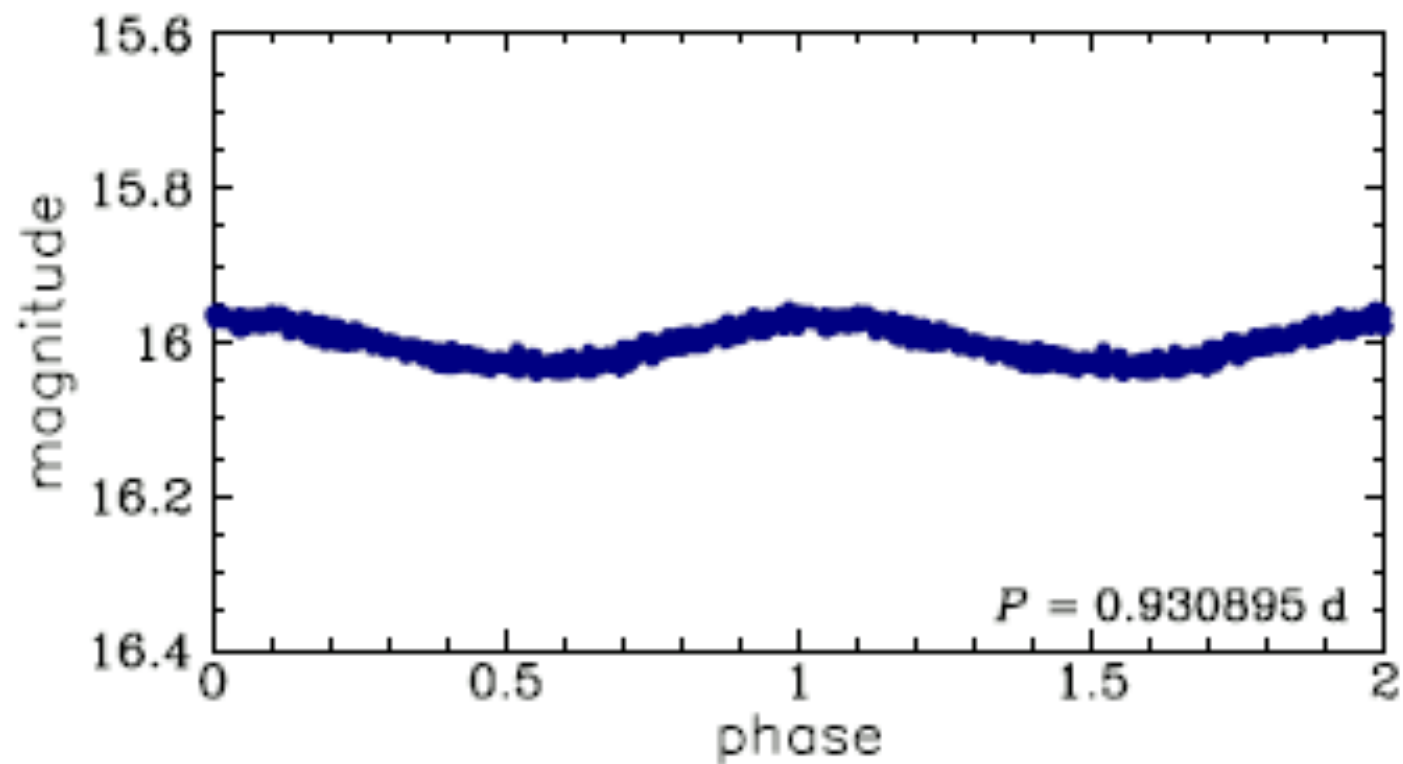
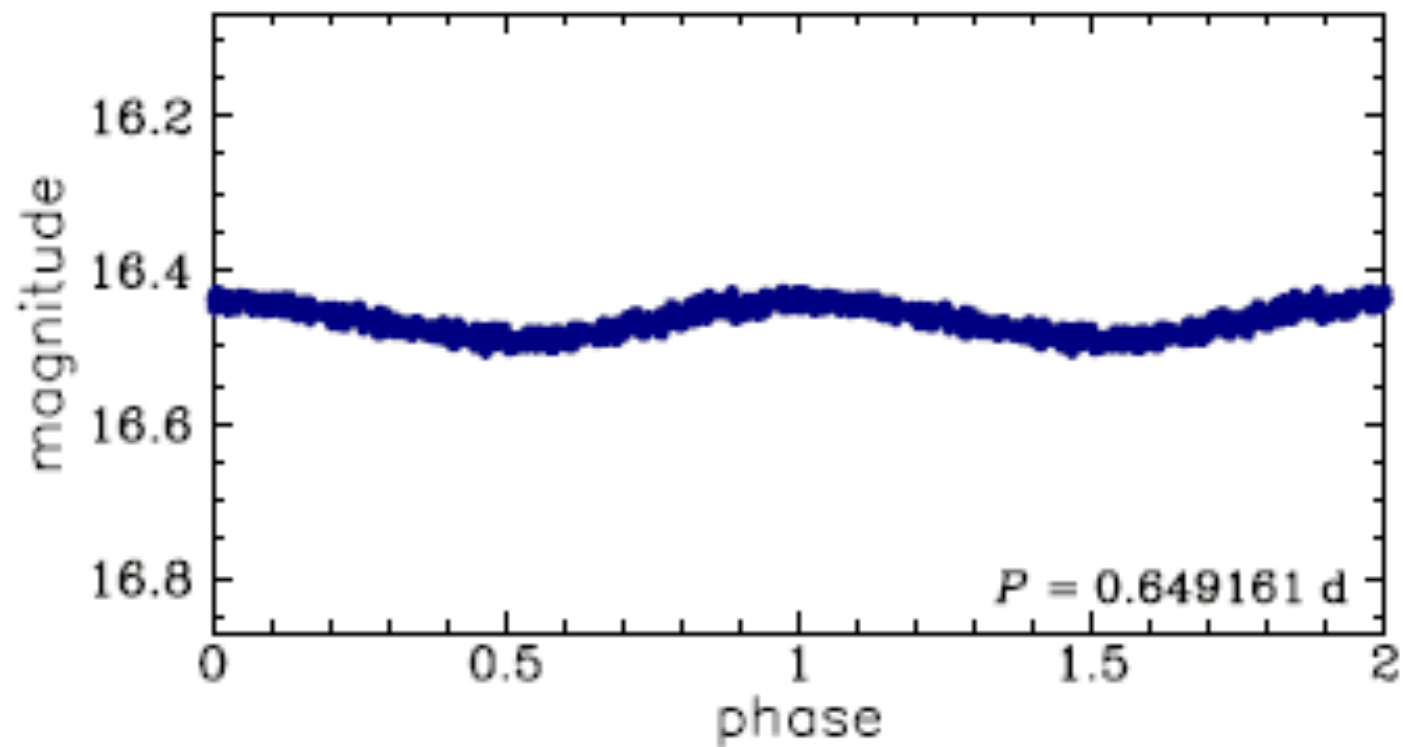


FIRST-OVERTONE PULSATORS

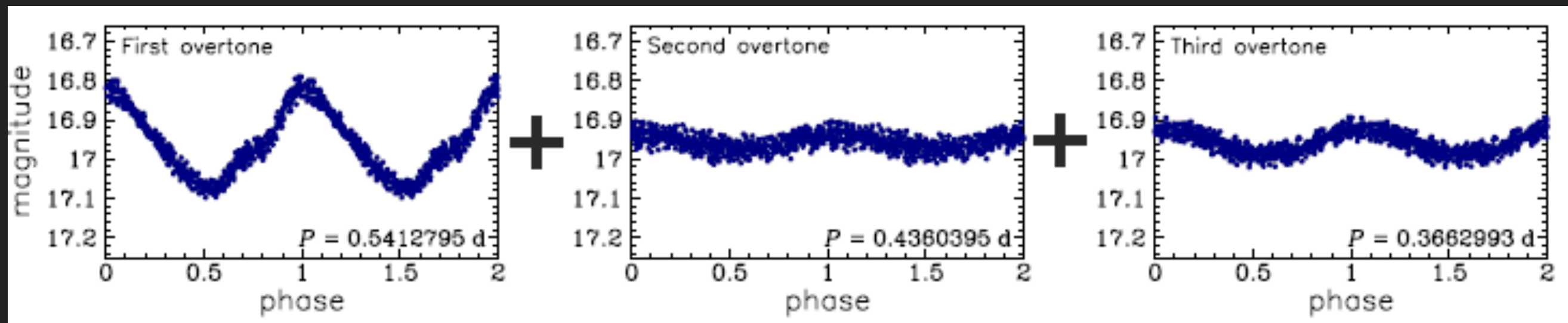
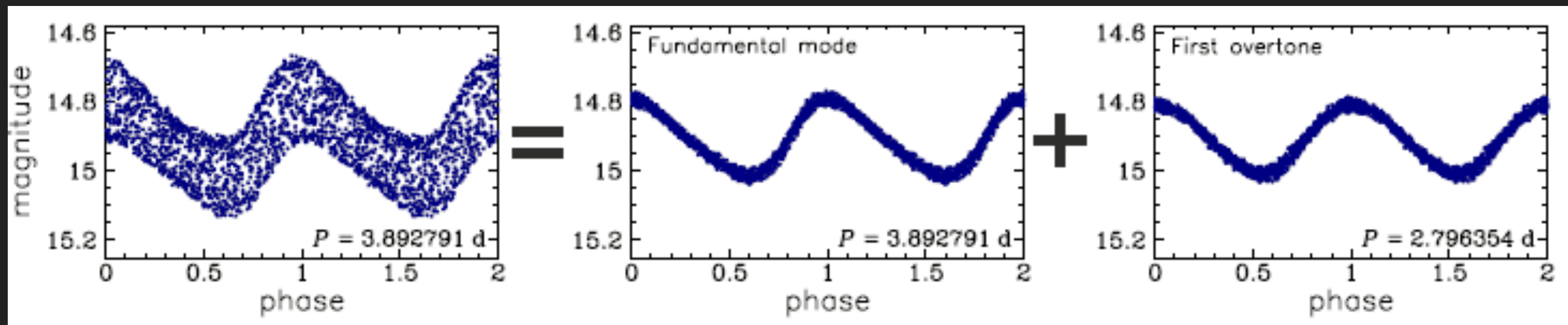


Data: OGLE

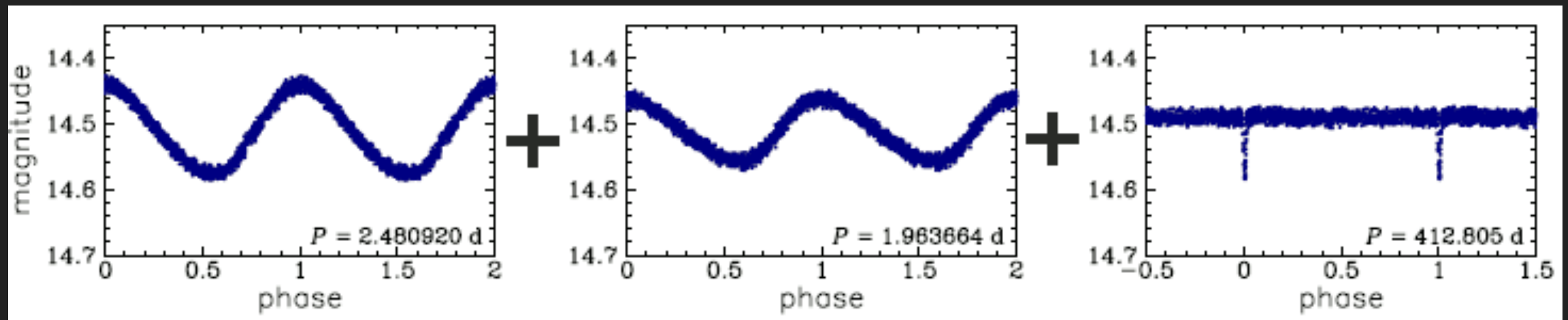
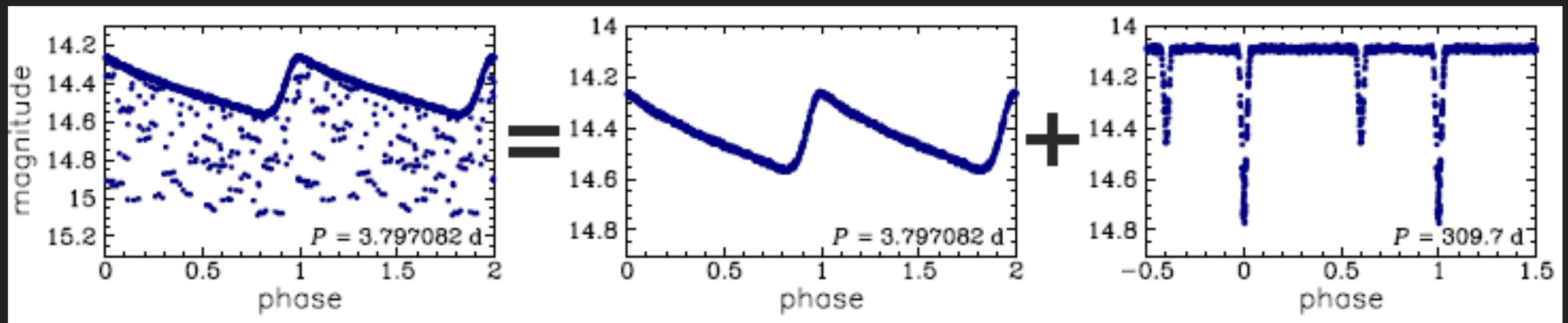
SECOND-OVERTONE PULSATORS



MULTI-MODE PULSATORS

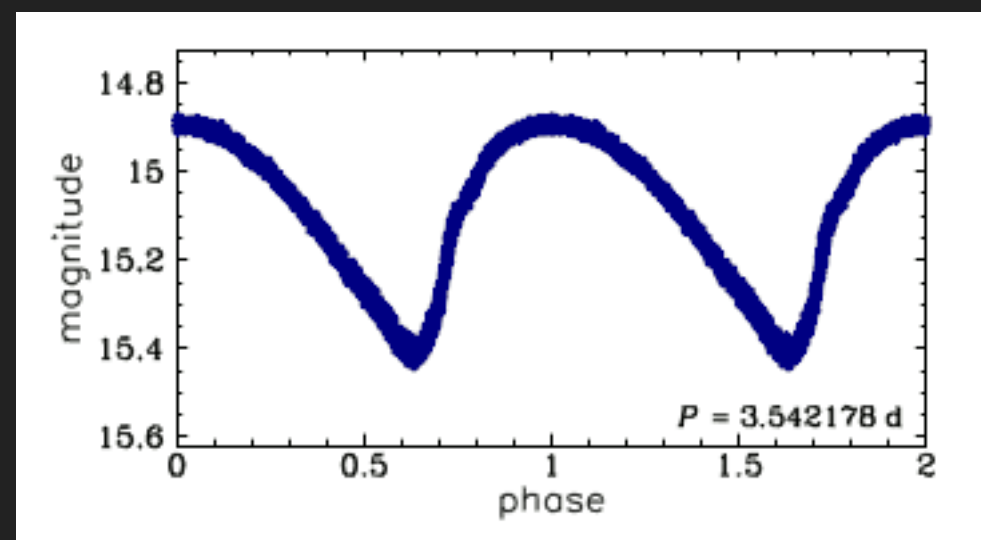
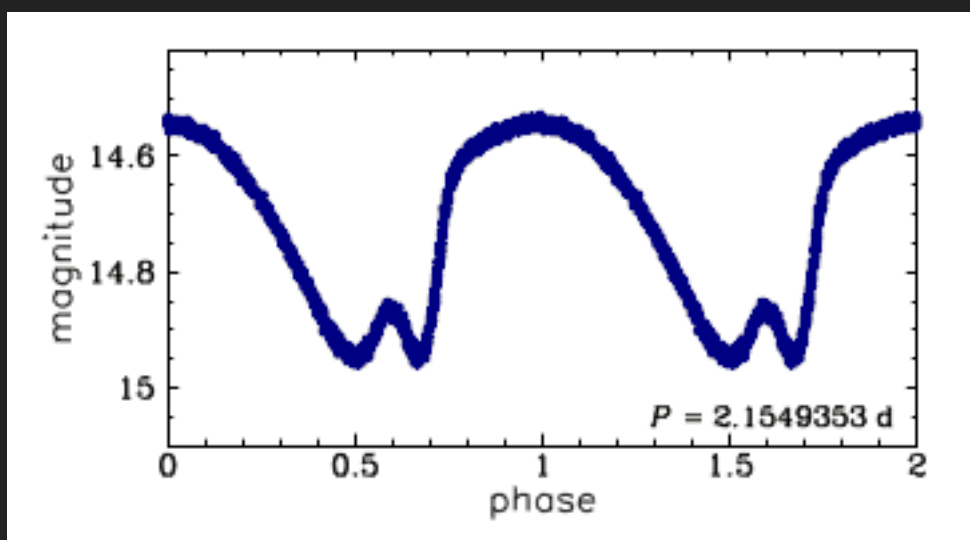
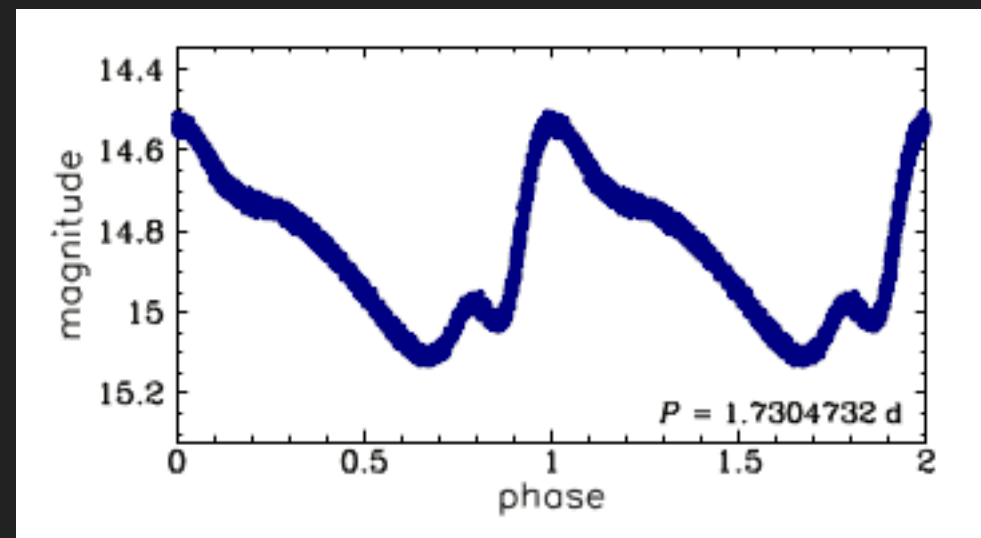
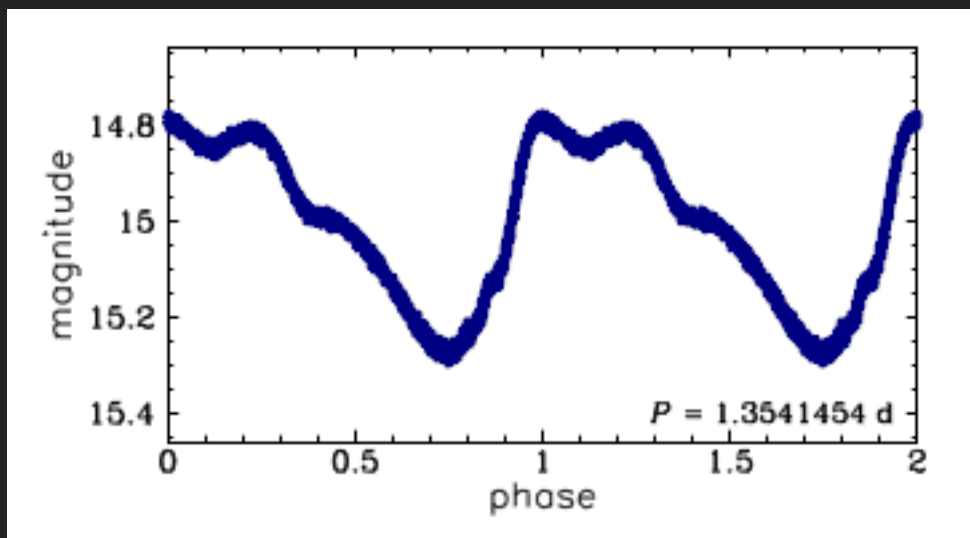


CEPHEIDS IN BINARIES



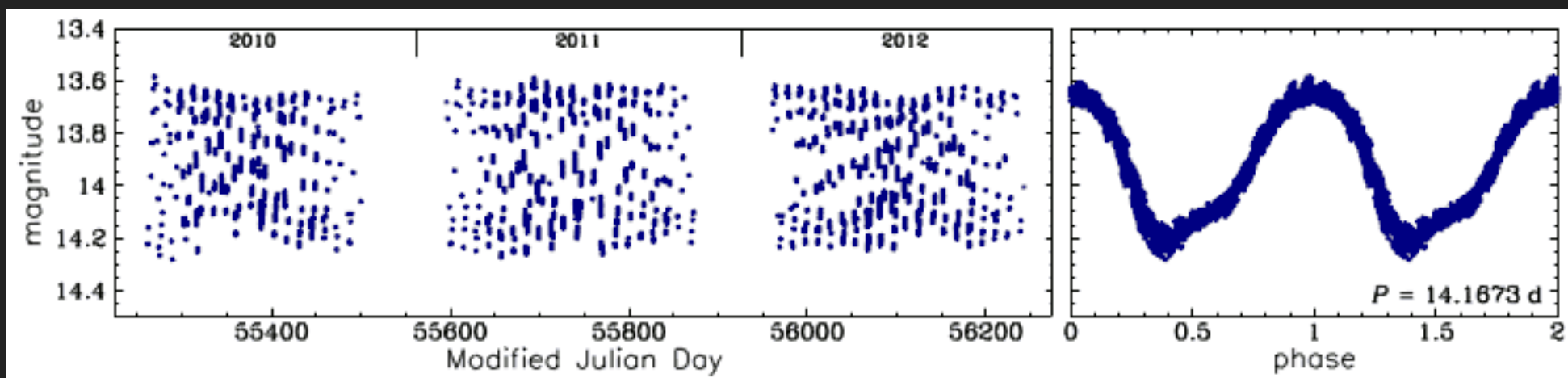
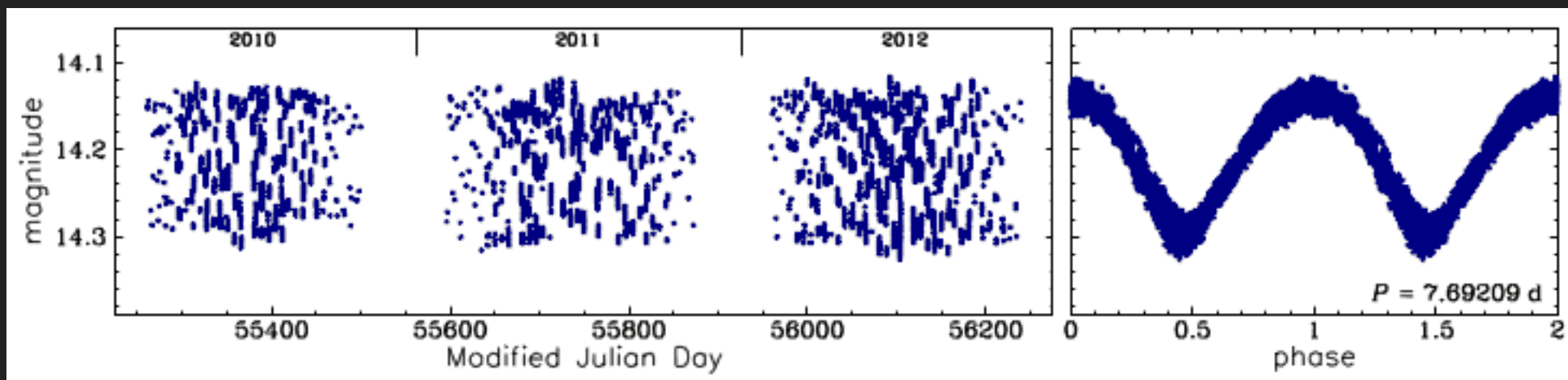
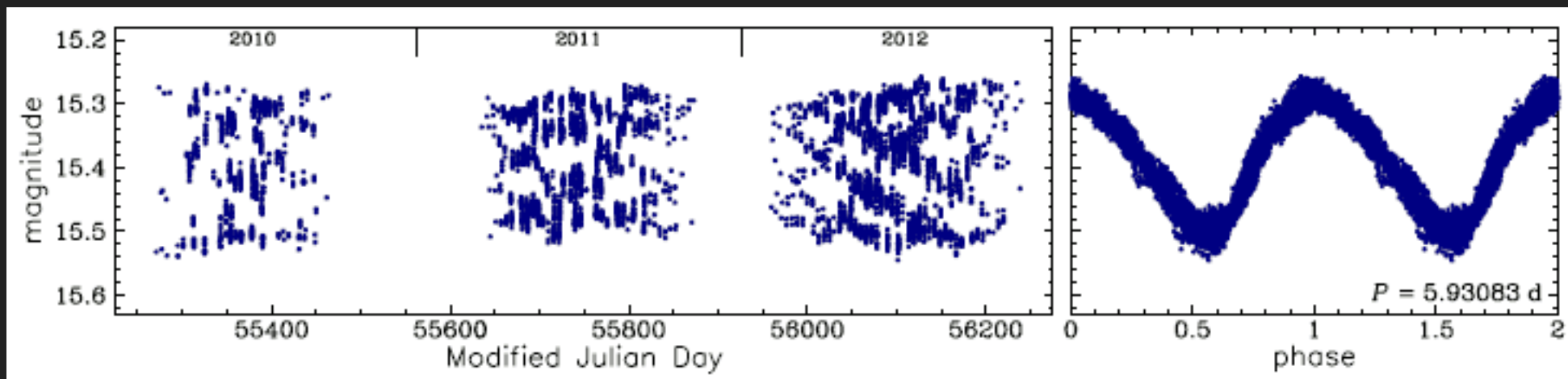
BL HER

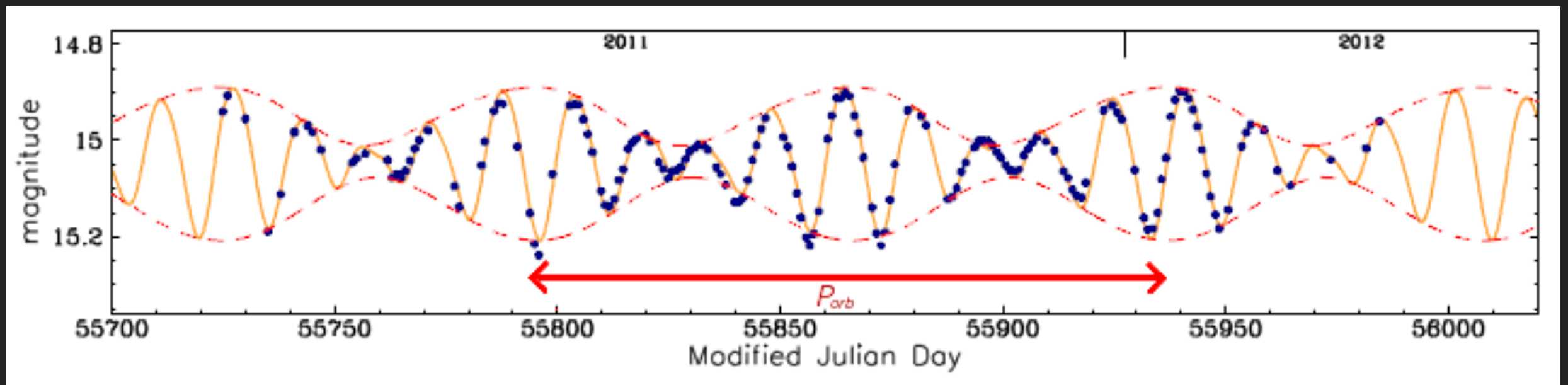
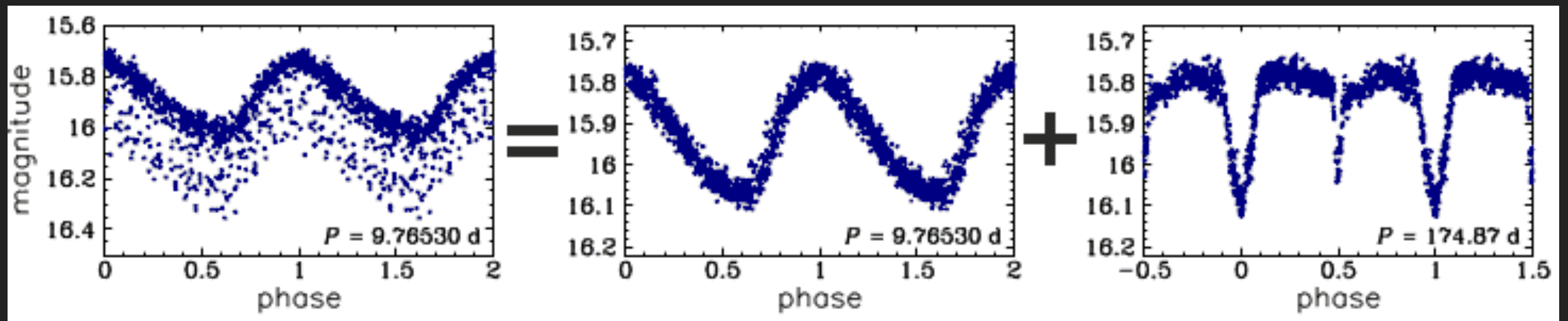
- ▶ Shortest pulsation periods: 1 - 5 days
- ▶ See the secondary bump



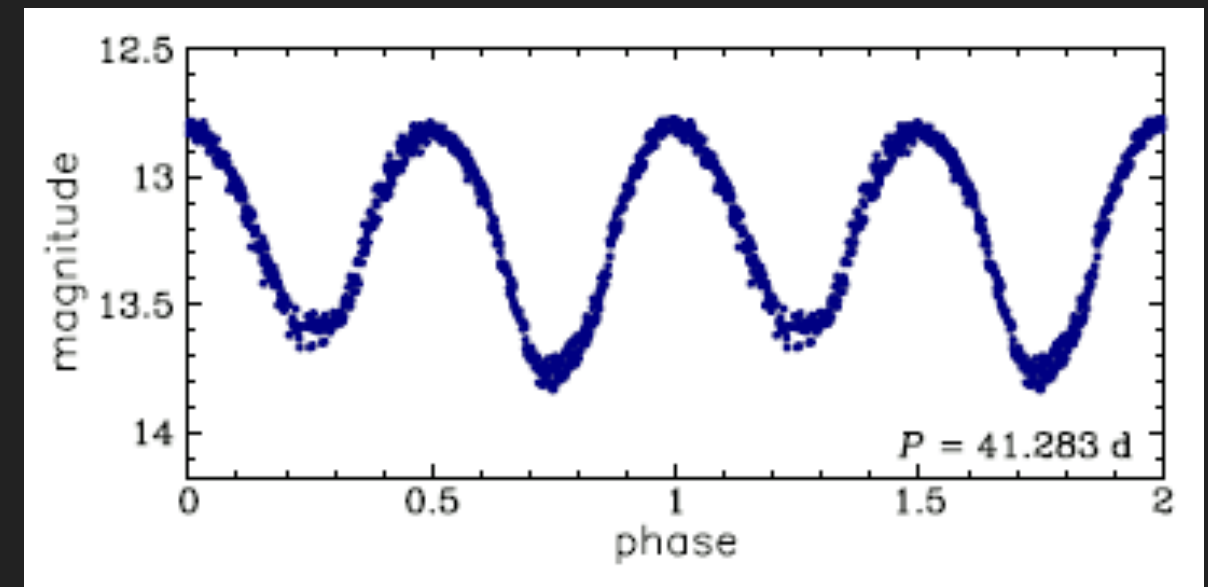
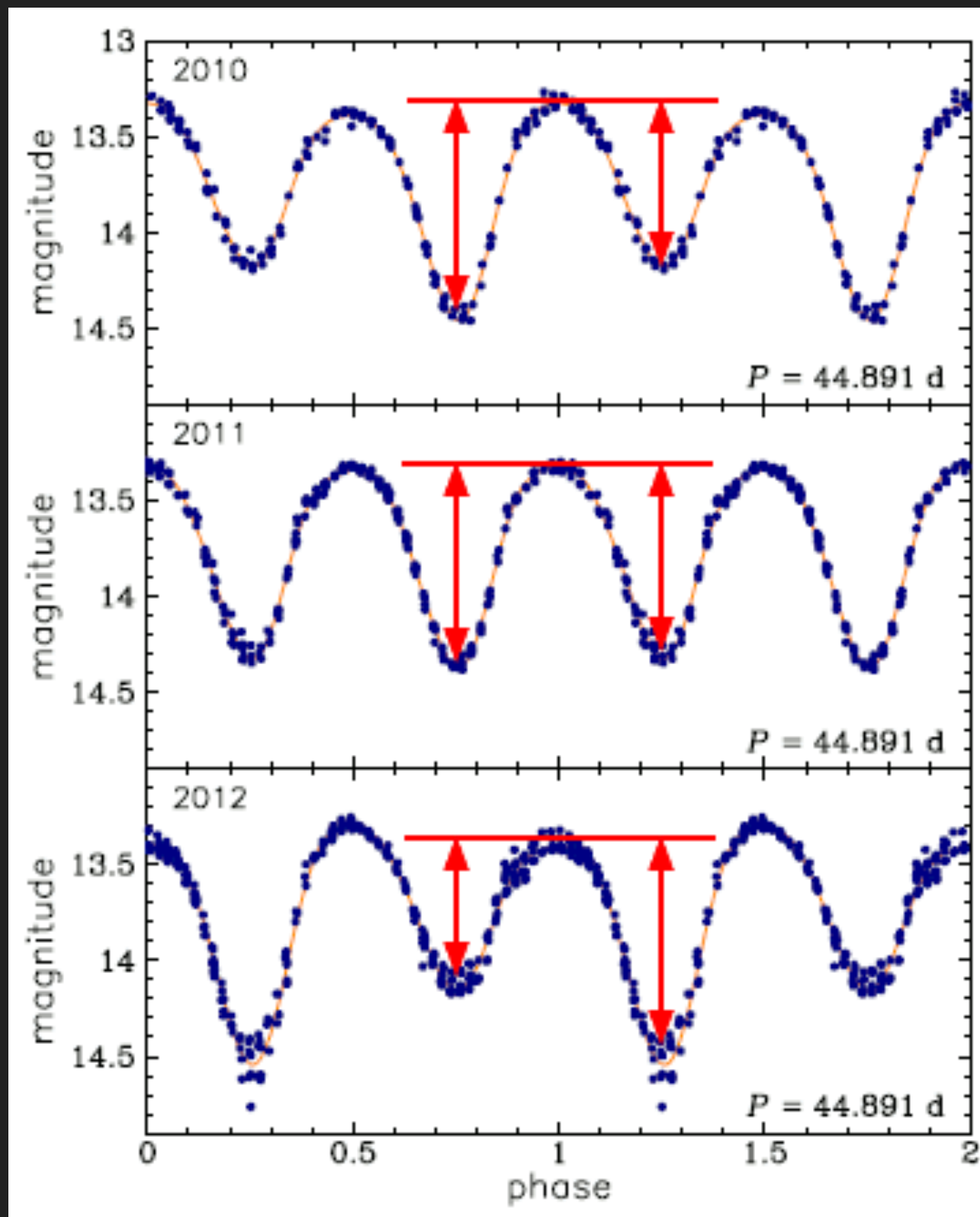
► $P = 5 - 20$ days

► Irregular





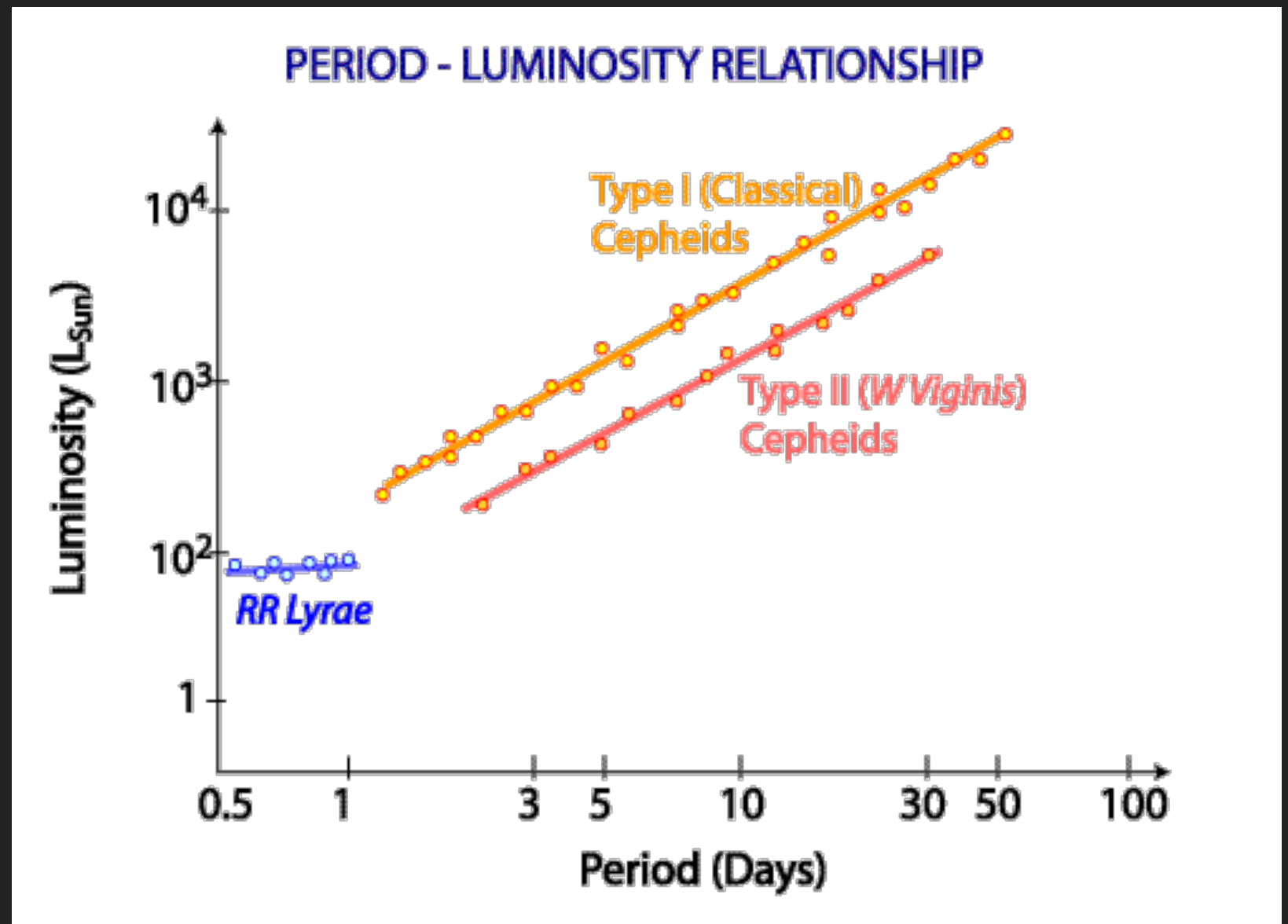
RV TAU



- ▶ Yellow supergiant (G-K)
- ▶ Alternating deep and shallow minima
- ▶ $P = 40 - 100$ days

RR LYRAE

- ▶ Old stars
- ▶ @ Globular clusters
- ▶ $\Delta m = 0.3 - 2$ mag
- ▶ Short periods: ~ 1.5 hr - day
- ▶ $d =$ up to 200 npc

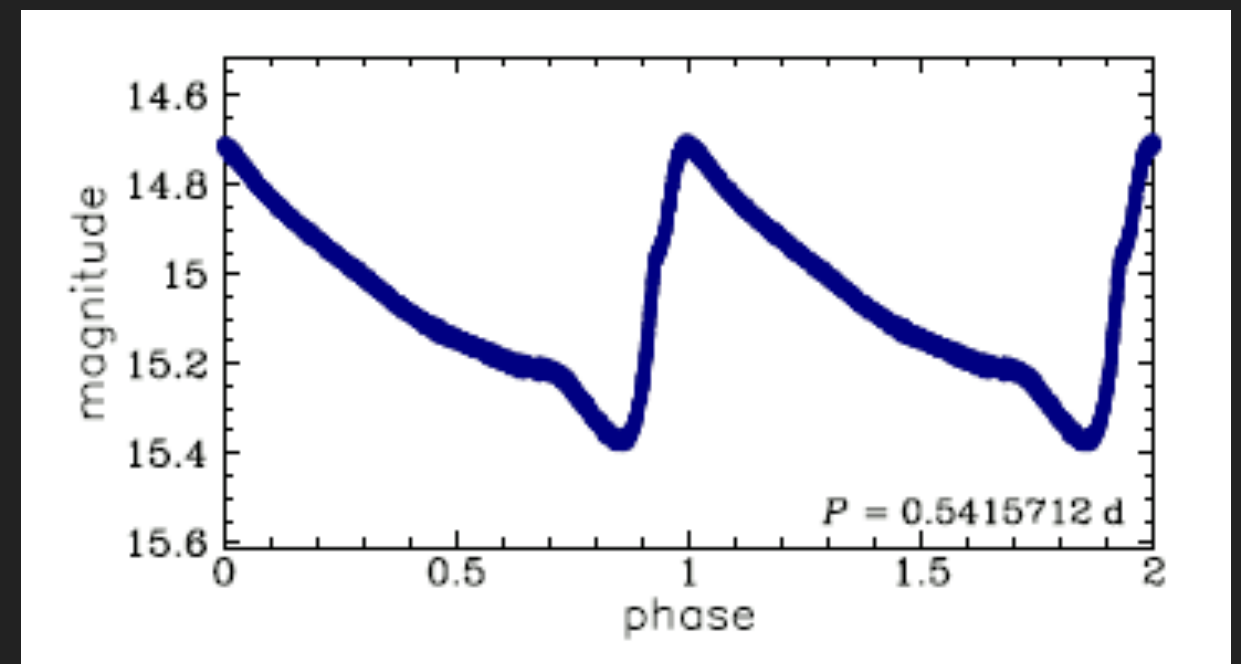
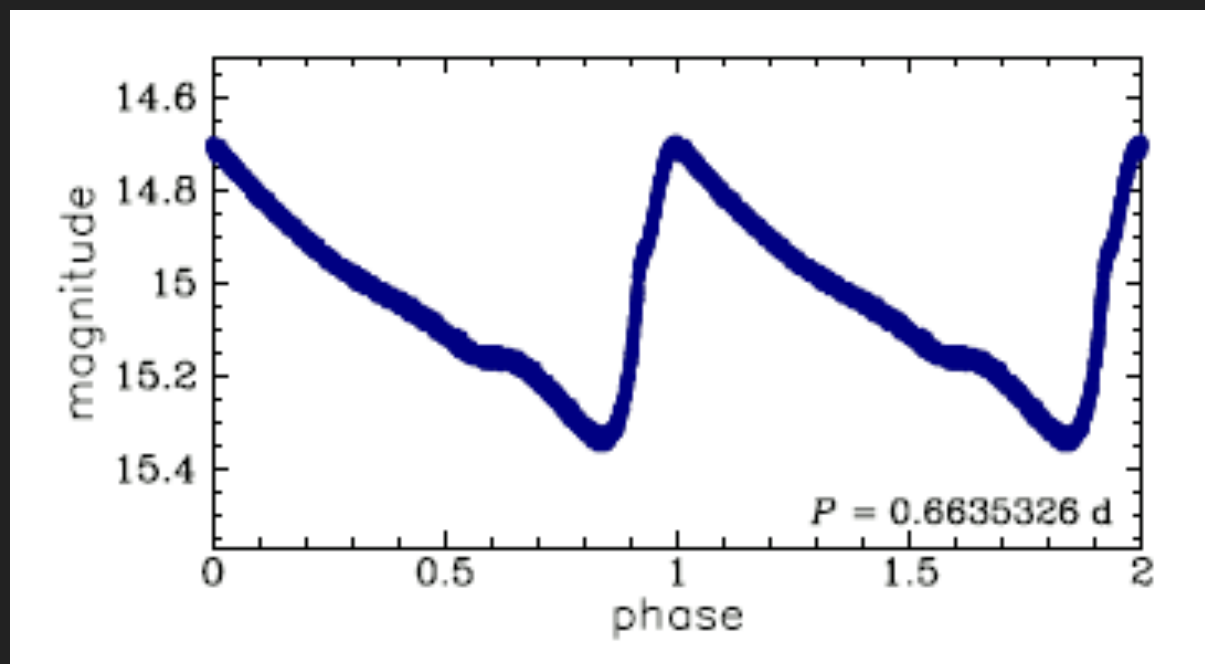
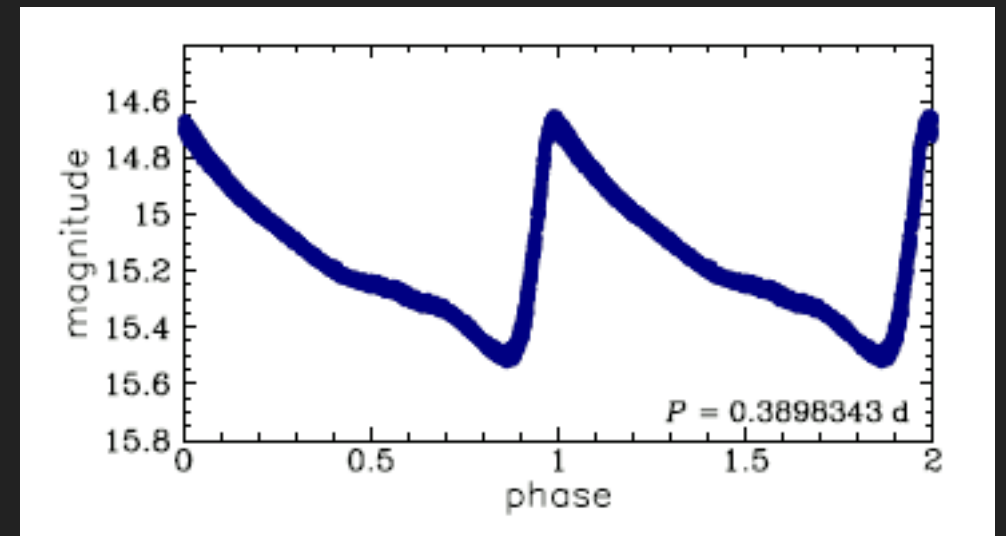


RR LYRAE

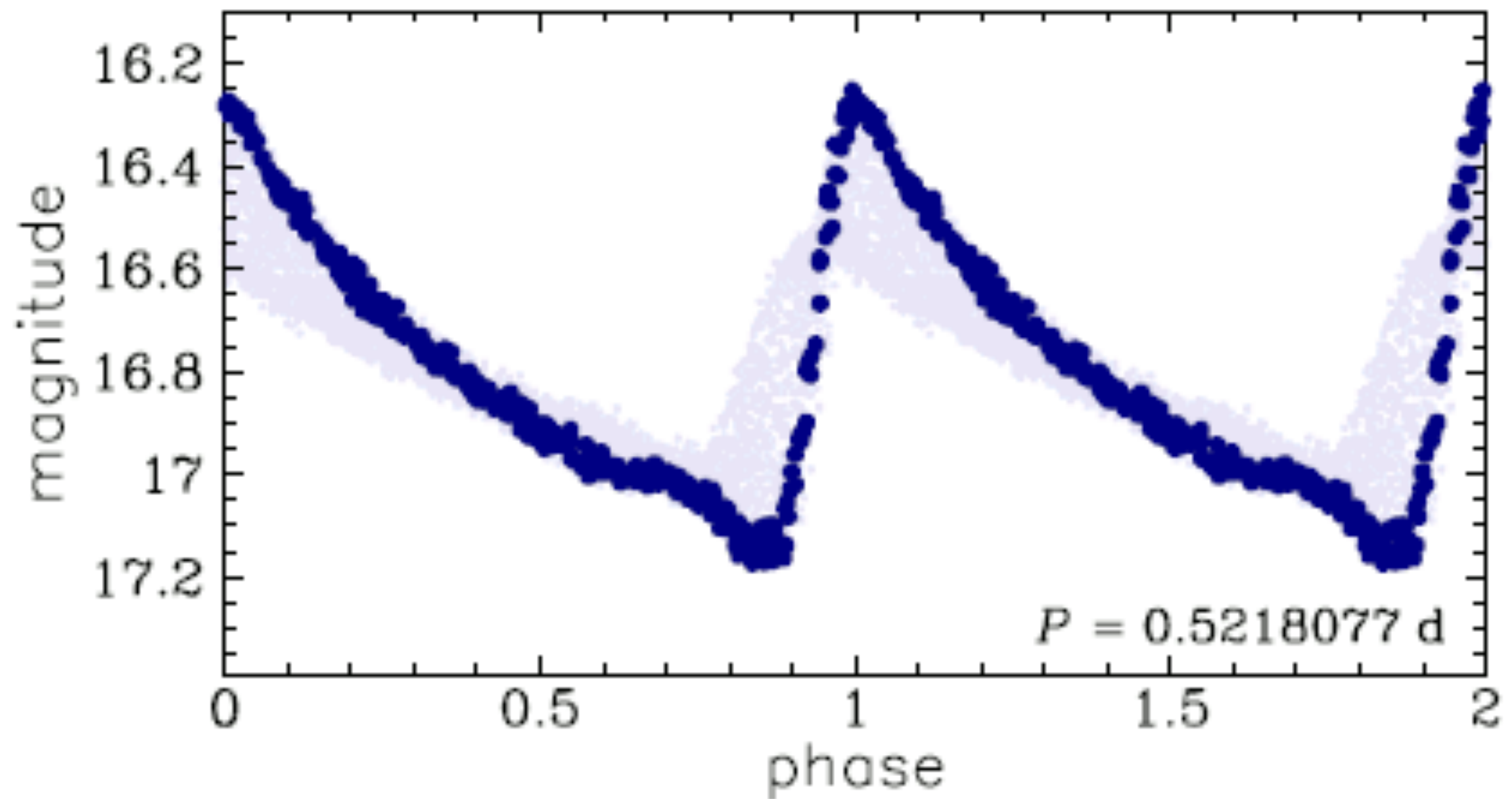
- ▶ Old
- ▶ Low-mass
- ▶ Radially pulsating
- ▶ $P = 0.2 - 1$ day
- ▶ Distance measures
- ▶ Amplitude & skewness
 - ▶ R Rab
 - ▶ RRc
 - ▶ RRd

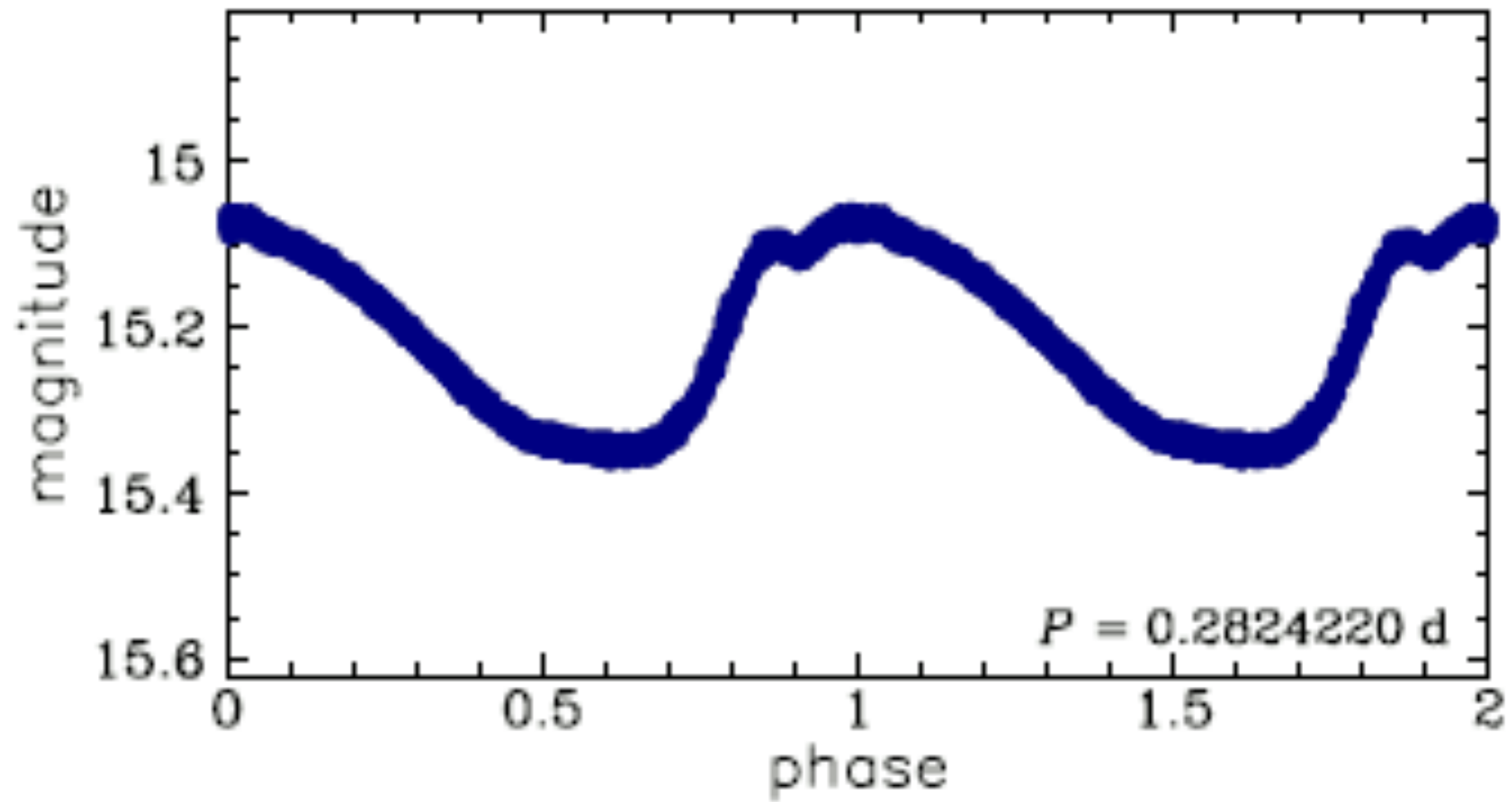
RR AB

- ▶ $P = 0.3 - 1$ day
- ▶ ↑ Pulsation Period \Rightarrow Metal-poor ↑
- ▶ Shortest period \Rightarrow Largest amplitude
- ▶ Longer period \Rightarrow Shorter amplitude

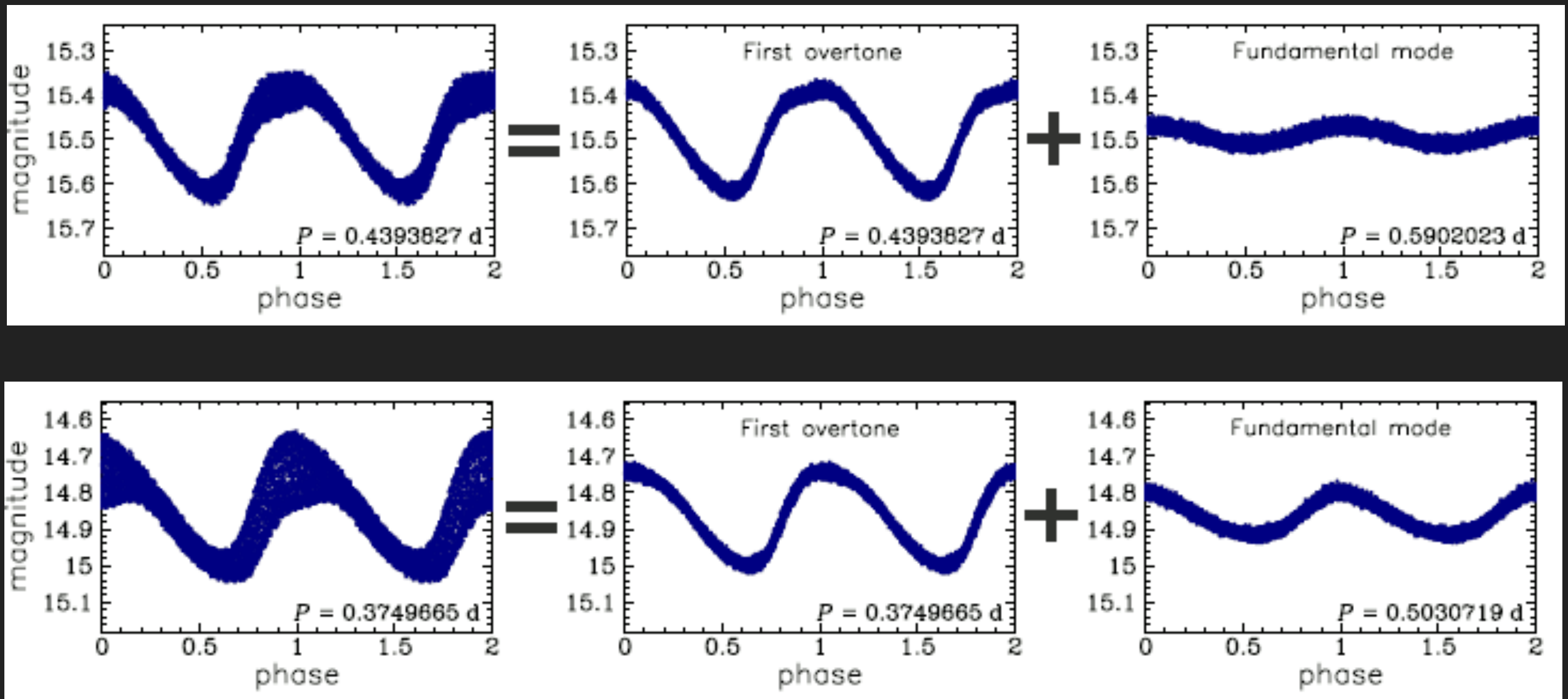


RR LYR – BLAZHKO EFFECT

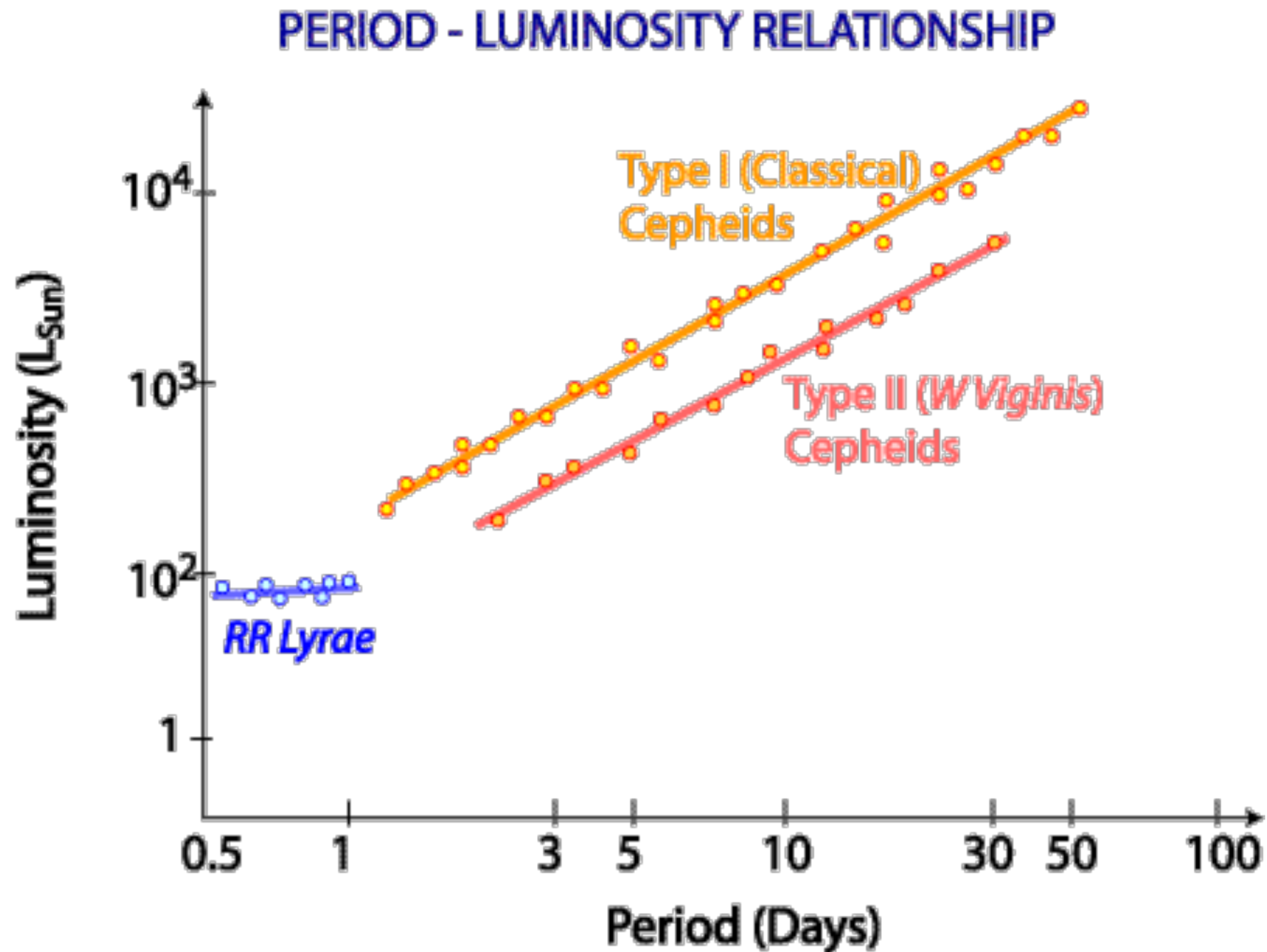




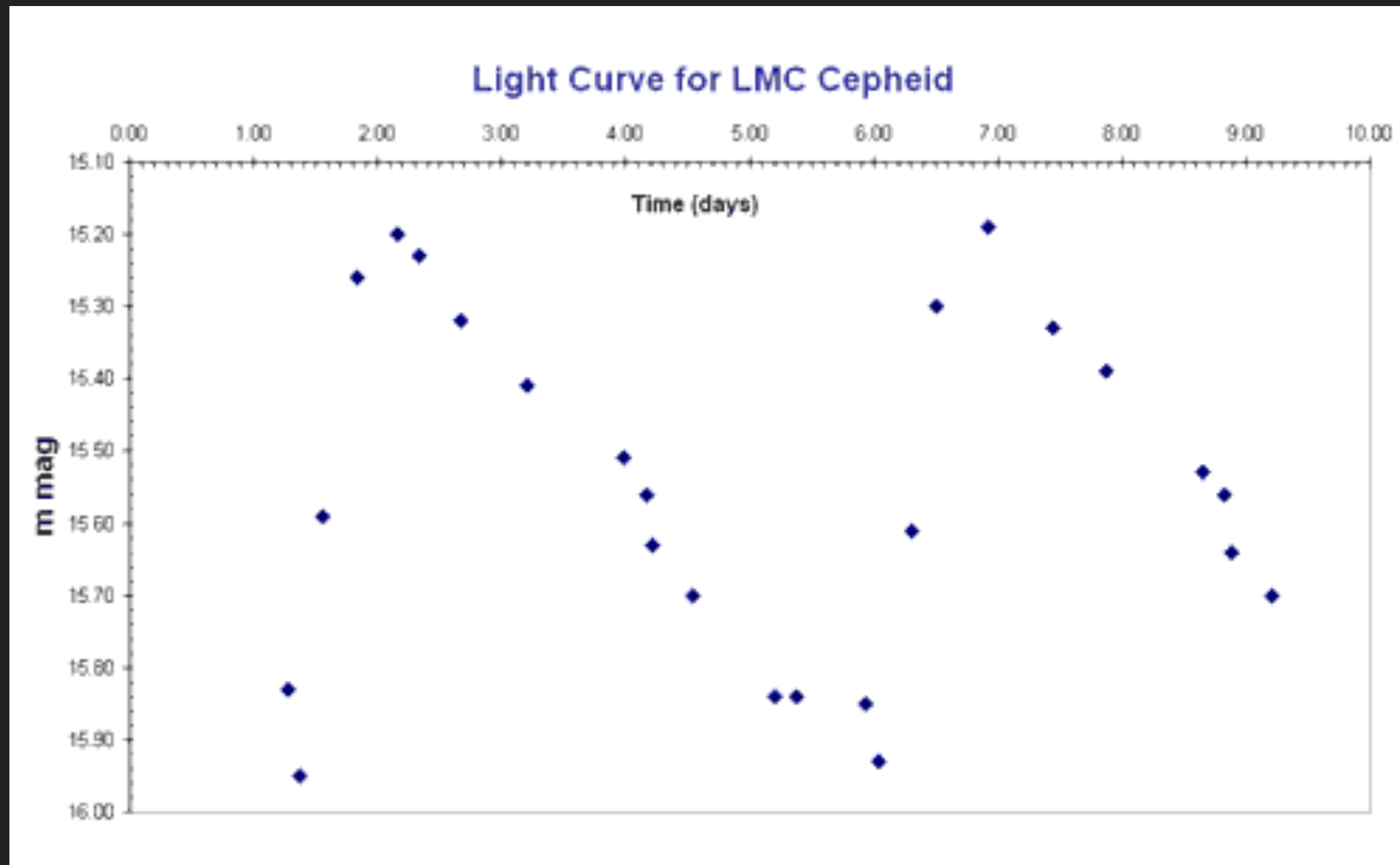
- ▶ @metal-poor regions
- ▶ Two pulsation periods



DISTANCE CALCULATION



DISTANCE CALCULATION



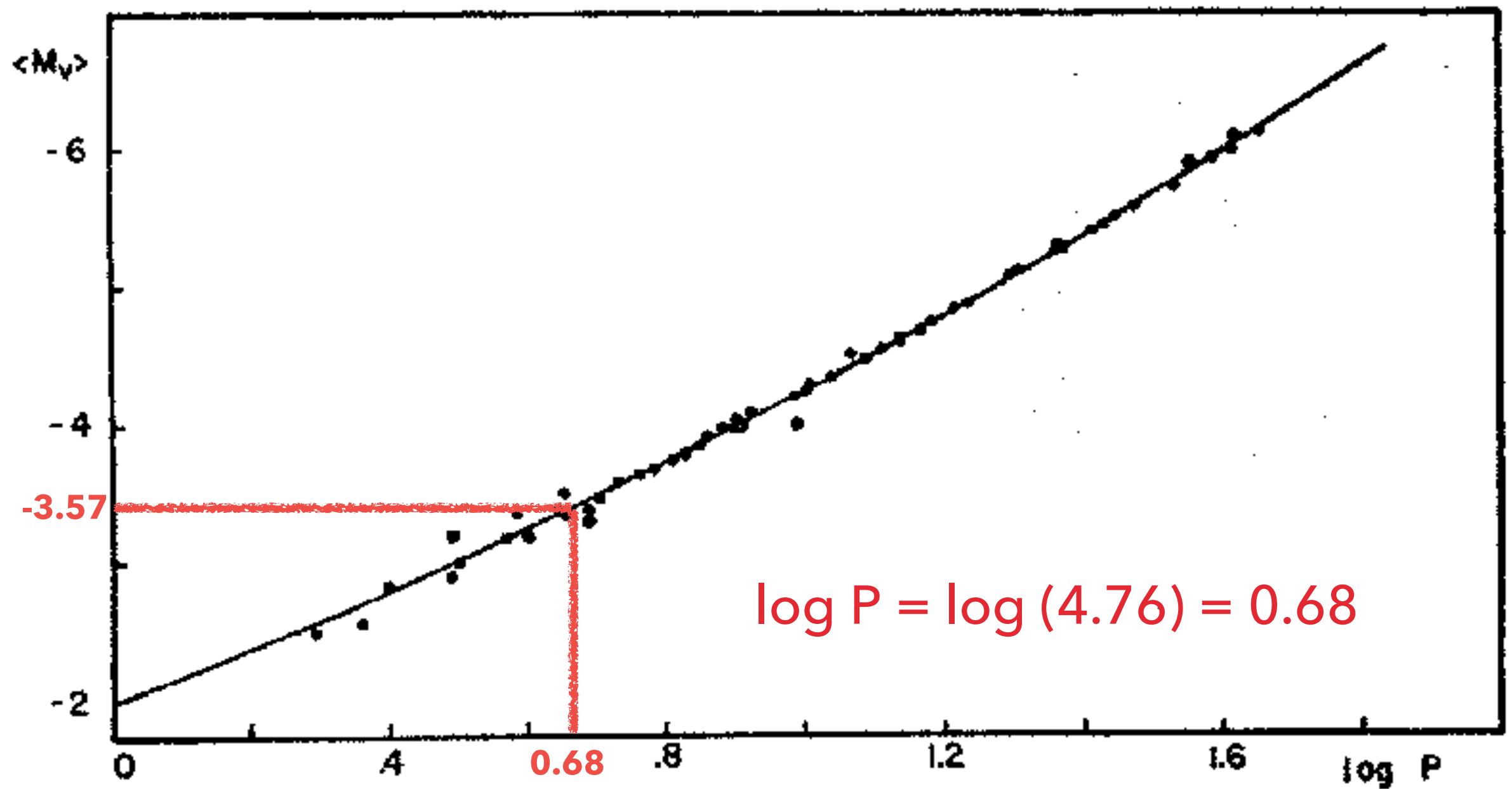
► Light curve \Rightarrow apparent magnitude & Period

$m \approx 15.5$

$P \approx 4.76$

DISTANCE CALCULATION

PERIOD \propto LUMINOSITY



DISTANCE CALCULATION

▶ $P \approx 4.76$ days

▶ $m \approx 15.56$

▶ $M \approx -3.6$

$$m - M = 5 \log \frac{d}{10}$$

$d \approx 68$ kpc

REFERENCES

- ▶ AAVSO Manual for Visual Observing of Variable Stars
- ▶ <http://www.astrouw.edu.pl/~jskowron/ogle/PR/galactic-cepheids-p9idWz/>
- ▶ <https://www.space.fm/astronomy/starsgalaxies/cepheidlightcurves.html>
- ▶ <https://towardsdatascience.com/exploring-pulsating-variable-stars-with-gaussian-process-regression-418fab1d3d04>
- ▶ https://www.atnf.csiro.au/outreach/education/senior/astrophysics/variable_types.html
- ▶ https://www.atnf.csiro.au/outreach/education/senior/astrophysics/variable_pulsating.html
- ▶ <http://www.astro.sunysb.edu/fwalter/PHY515/cepheidpl.html>