ASP 5203, Estrellas Variables

2019-1

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Tarea 1

04/04/2019

Fecha de entrega: 17/04/2019[1]

Problem 1. The *General Catalog of Variable Stars* (*GCVS*) and *International Variable Star Index* (*VSX*) are compilations of variability data that have appeared in the literature. They can be accessed from the following URLs, respectively: http://www.sai.msu.su/gcvs/, https://www.aavso.org/vsx/.

a. Select at least one subclass of variable star among each of the eclipsing, pulsating, rotating, eruptive and cataclysmic subclasses, and provide an ***updated*** estimate of the corresponding number of variables in these subclasses that are contained in each of these catalogs, indicating the date/version of the database that you used in your work.

b. What is the constellation with (currently) the largest number of variable stars in the GCVS? What is the constellation with the smallest number of variable stars in the same catalog?

c. For the constellations cited in the previous item, how do the stars distribute into the various variability classes? Please comment.

[1] This assignment should be turned in electronically, in the form of a single pdf file. To gain familiarity with paper-writing, it is strongly recommended (but *not* mandatory!) that you use LaTeX, along with the style files corresponding to a journal of your choice – you may want to check, for instance, AASTeX, EmulateApJ (my personal favorite), MNRAS, A&A, etc.

In the next problem, you will be asked to compute periods of variability on the basis of empirically derived data. Some useful standalone tools that you can use to compute these periods include Period04 and Peranso. Some popular python packages, such as astropy and astroML, also contain useful modules for time series analysis. Sect. 2.3 in the book contains some references about period-finding algorithms; you can also check Templeton (2004), Graham et al. (2013), and Vanderplas (2018) for useful reviews on the subject.

Problem 2. In the course's web page you will find two files (star1.dat and star2.dat) with visual photometry for two field variable stars. In these files, the first column gives the Julian Date, while the second column shows the apparent magnitude in *V*.

a. Make a plot of magnitude vs. time for both stars.

b. Compute the variability period for each star, using two different techniques of your choice. Pay attention to the number of significant digits used! (You may want to refine your answer after working on item d below.)

c. Plot the corresponding phased light curves (also frequently called folded light curves or phase diagrams), in the range of phases between 0 and 2. Make sure you place either the maxima or main minima at phase 0. (The former is typically used in the case of pulsating stars, and the latter for eclipsing binaries.)

d. Estimate the corresponding precision in the derived periods. One simple (not very formal, but still useful) way to do this is to iteratively change your derived period by very tiny amounts, always keeping track of the visual appearance of the folded light curve, until you notice that this folded light curve starts to become dispersed. (More sophisticated methods are implemented, say, in Period04 and Peranso.)

e. To which variability classes do you think these stars may correspond? Explain the criteria that you used in arriving at your answer.

Problem 3. In class, we saw how the times when the light curve of a periodic star will reach maximum light can be predicted, if its period is known. Thus, for a star with initial period P_0, given an initial maximum T_0, the time of maximum corresponding to epoch E will be given by ("linear ephemeris case")

$$T_E = T_0 + PE.$$

However, this expression assumes that the period P is constant. In reality, the periods of many stars are seen to change over time, even if very slowly, for reasons that include the long-term evolution of the star.

a. Demonstrate that, if a star's period changes linearly with time, the time of maximum at epoch E will be given by

$$T_E = T_0 + P_0 E + \frac{1}{2}\frac{dP}{dt}\langle P\rangle E^2,$$

where $\langle P\rangle$ is the mean period over the whole time interval covered by the data. This implies that, if one incorrectly assumes the period to be constant, systematic offsets between the actual observed (O) times of maxima will differ from those computed (C) assuming a constant period. This constitutes the basis of the *O-C* technique (for a review, see e.g., Sterken 2005).

b. On the course's web page you will find historical data (file times-of-maxima.dat) with times of maxima for an RR Lyrae star from the GEOS database (http://rr-lyr.irap.omp.eu/dbrr/index.php). Compute $O - C$ values assuming linear ephemeris based on the star's GCVS period, namely 0.41986 d. For T_0, assume HJD 2442582.4060.

c. What is the earliest and latest time of maximum available in this dataset, in terms of UT? Express your results in the usual format for time, i.e., hh:mm:ss, dd/mm/year.

d. Using these data, obtain an estimate of the period change rate of the star, in units of days/Myr. Estimate the error in this value.

e. ***Bonus problem***: what objective criterion would you use to establish if a constant period, a linear period change, or a higher-order (say, quadratic) period change is most suitable to describe the data? Apply your criterion to the data at hand.