

WWW-Based Fourier coefficient database – A status report

Siobahn M. Morgan

Department of Earth Science, University of Northern Iowa, Cedar Falls, IA 50614-0335, USA

Abstract. The status of the WWW-based Fourier Coefficient web site is presented. Currently the database has coefficients for not only galactic field variables, but also those found in globular clusters and other galaxies, including the Magellanic Clouds. The database can be used to show various correlations between physical characteristics of the stars and the coefficients, as well as inter-relationships between the coefficients themselves. The database is accessible at <http://nitro9.earth.uni.edu/fourier/>.

1. Introduction

Fourier series have long been used to investigate the properties of variable stars, particularly in how the various Fourier coefficients are related to physical parameters. The most common form of the Fourier function used today is that given by Simon & Lee (1981), which for V measurements would be defined by

$$V(t) = A_0 + \sum_{i=1}^n A_i \cos(i\omega t + \phi_i) \quad (1)$$

where $\omega = 2\pi/\text{period}$, n is the order of the fit and t is a time or time interval measured from a certain epoch. The Fourier coefficients are comprised of the amplitude values, A_i , and the phase values, ϕ_i . The amplitude and phase coefficients are frequently combined to produce the following terms,

$$R_{ij} = A_i/A_j$$
$$\phi_{ij} = \phi_i - i\phi_j$$

where the value of j is often set to 1. The format of Eq. 1 can vary quite a bit, and could be defined with a series of sine functions, negative amplitude or negative phase values. The R_{ij} and ϕ_{ij} values vary in a manner that can be related to various physical quantities. Jurscik & Kovács (1996) have shown that the metallicities of RR Lyr ab-types are related to the coefficients, while Kovács & Walker (2001) have related the luminosities of RR Lyr ab-types to the coefficients. Often the Fourier coefficients can help distinguish between the different pulsation modes (overtone and fundamental) for both Cepheids and RR Lyr stars. They can also indicate the presence of resonances between different pulsation modes (Antonello & Mantegazza 1984; Antonello & Morelli 1996; Antonello 1998; Kienzle et al. 1999).

After accumulating Fourier coefficient data for several years, it was thought that a web site with published Fourier coefficients would be of use to other researchers, and such a database has been created. Included at the web site are values for galactic, globular cluster and extragalactic variables. SX Phe, δ Sct, RR Lyr stars and Cepheids are included. There are also several interactive tools available at the web site to assist users in finding the coefficients that would be of interest to them. A description of the database content and resources is provided here. The web-based archive is located at the site <http://nitro9.earth.uni.edu/fourier/>.

2. Database content

The Fourier coefficient database was established to place all currently available data into a central location as well as providing bibliographical references and interactive search tools for researchers. As the results of large-scale surveys of the sky become available, the vast amount of data that is released by them makes the need for an easily accessible database both appealing and practical. The literature was searched for every instance where Fourier coefficients were derived and published for intrinsic variable stars, from the present day and going all the way back to Edward Pickering (1881). All of the data were collected and formatted to a uniform standard (i.e., fit according to Eq. 1). In those cases where an alternate form of the Fourier series is used, such as the use of a sine function or negative amplitudes, the ϕ_i terms are adjusted by adding or subtracting $\pi/2$ or π . Every effort is made to limit the range of the ϕ_i values to be between 0 and 2π .

The Fourier coefficient database for galactic variables includes data concerning intrinsic variables such as Cepheids, RR Lyr, SX Phe, and δ Sct stars. Radial velocity data are also provided, but are based upon the use of a sine function in Eq. 1. The database provides the following for each galactic variable star:

- general Catalog of Variable Stars (*GCVS*, Kholopov et al. 1985-8) values for period, variable type, right ascension and declination;
- magnitude based coefficient data, including full bibliographic reference, system of measurement, degree of fit, period used in the fit and the coefficients A_0 , $R_{21} - R_{41}$, $\phi_{21} - \phi_{41}$;
- radial velocity and color coefficients, when available, presented in the same format as the magnitude based coefficients;
- access to all of the Fourier coefficients for a star, where available, including error values and individual amplitude (A_i) and phase (ϕ_i) terms;
- a JAVA graphing utility to display the light curves based upon the coefficients from all sources, when possible.

Galactic variables are sorted according to constellation and variable type, which is generally defined by the classification given in the *GCVS*. There are instances where this classification is in error (usually for stars listed as eclipsing variables

in the *GCVS*). In such cases a correction is made. For those stars that have uncertain type, most often short period δ Sct stars, RR Lyr c-types or SX Phe stars, the *GCVS* type is usually used, though it is possible that some have subsequently been identified as a different type. In the case of galactic variables discovered by a large scale survey, the original survey name and designation is provided, along with a constellation identifier. For example, *EROS II* survey variable J132412 – 623424 is listed as EROS2J132412 – 623424.cen in the database, since it is located in Centaurus. Once a name for such a variable is designated in the format of the *GCVS*, that name will be used in the database.

Globular cluster variables are sorted by cluster name, and their data are accessible on the individual cluster web pages. Data for variable stars within each cluster are ordered according to the listing from the on-line database of Clement (1997) for the *Helen Sawyer Hogg Catalogue of Variable Stars in Globular Clusters*. Only magnitude and color coefficients have been published for globular cluster variables. Extragalactic data are sorted by host galaxy and then ordered by increasing period for the variables. Extragalactic variables that are identified by the original authors as overtone mode Cepheids are noted as such. This designation scheme is *not* used for galactic Cepheids however, since the pulsation mode for many of these is still debatable. At the present time there are data on over 1000 galactic variables, more than 1100 globular cluster variables (in 35 different clusters) and over 12 000 extragalactic variables. The current number of data sets for Cepheids and RR Lyr stars for each database, as well as the Magellanic Clouds, is provided in Table 1 along with the total number of data sets. The number of sets of data is not the number of variables contained in the database, since many stars have multiple sets of Fourier coefficients.

Table 1. Current WWW Fourier Database Content

Database	Cepheids	RR Lyr	Total
Galactic	1908	987	3386
Globular Cluster	39	2786	2866
Extragalactic	5783	9035	19814
Large Magellanic Cloud	2240	7864	10830
Small Magellanic Cloud	3465	581	4276

All coefficient data are accessible by a variety of search engines. A user can do a simple search of the database, by selecting stars according to several criteria including database (galactic, globular cluster, or extragalactic), period range, type of variable, or type of measurement. There is also a more advanced database interface, that can search according to author designation, R_{21} value range, ϕ_{21} value range, method of measurement (U , B , radial velocity etc.), as well as period range and variable type. Output of the search results can also be limited so that only amplitude or phase values are displayed by a search or the values $R_{21} - R_{41}$ and $\phi_{21} - \phi_{41}$. Where ever a value is missing in the database, such as an error value for a coefficient, a value of 99.99 is used. This allows users to create a uniform output of data for use in graphs or spreadsheets.

Another search method is through “clickable” R_{21} and ϕ_{21} graphs that will produce a list of variables close to the location of the users mouse click. Since the

distribution and quantity of R_{21} and ϕ_{21} values from the three databases varies significantly, there are separate “clickable” graphs for each database. Users may also download current graphs of the photometric values showing how the R_{21} , R_{31} , and R_{41} values vary with $\log P$ as well as the $\log P$ distribution of the ϕ_{21} , ϕ_{31} , and ϕ_{41} values. Graphs are available in encapsulated postscript, PDF and JPG formats and variable type is designated by color coding.

3. Summary and future work

The on-line database of Fourier coefficients can be a useful tool in the investigation of variable star properties, particularly for those stars that are found in different environments. The physical characteristics of the variables, such as the luminosities or metallicities of RR Lyr stars, can be discerned using the coefficients in a relatively simple manner. The accumulation of this large pool of data has provided the author the opportunity to investigate aspects of Fourier Coefficients observed in the Milky Way and the Magellanic Clouds. One feature that has come to light is how the period of the resonance features varies for both overtone and fundamental mode Cepheids in the Milky Way and the Magellanic Clouds. This variation will be discussed in greater detail in a forthcoming paper (Morgan 2004). While the amount of information in the database is currently quite large, there is always room for additional sets of data. Authors are encouraged to submit their unpublished or soon to be published data for inclusion in the database by contacting the author.

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