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The Binary Star Observables Programs – Start-up Instructions for the 2015 Version

This file provides instructions for getting off square one in accessing and running the accompanying binary star programs. It will be appreciated if anyone who downloads these files sends a brief message to `rewilson@astro.ufl.edu`, stating that the files have been copied. That will help in keeping track of how many copies have gone out. Reprints of work that uses the programs are also appreciated. Please cite relevant features of the model/program via the following papers:

- Wilson R. E. & Devinney E. J. 1971, ApJ, 166, 605 (initial paper)
- Wilson R. E. 1979, ApJ, 234, 1054 (simultaneous light/RV solutions and several generalizations)
- Wilson R. E. 1990, ApJ, 356, 613 (improved reflection effect)
- Van Hamme W. & Wilson R. E. 2007, ApJ, 661, 1129 (3rd body light time effect)
- Wilson R. E. 2008, ApJ, 672, 575 (Direct Distance Estimation [DDE] logic)
- Wilson R. E., Van Hamme W. & Terrell D. 2010, ApJ, 723, 1469 (flux calibrations for DDE implementation)
- Wilson R. E. 2012, AJ, 144, 73 (precision starspot algorithm)
- Wilson R. E. & Van Hamme W. 2014, ApJ, 780, 151 (unified solutions of light curves, RV curves, and eclipse timings)

Please cite these papers, or the ones more pertinent to your application, rather than only saying that the program was used.

The 2015 version is back-compatible with previous versions (it can do anything the earlier versions can do, except that band-integrated fluxes have *replaced* the "effective wavelength fluxes" of 1998 and earlier). It has the precision starspot algorithm cited above, time/phase smearing by Gaussian quadrature to simulate long integrations (as in the Kepler mission's long cadence observations), optional automatic iterative weight computation (so personal intervention to compute standard deviations is no longer necessary except for rough initial values), and unified solutions of light curves, RV curves, and eclipse timings.

The programs have been tested to a reasonable degree, but may still have bugs (please write about any that are found). The documentation in files ebdoc.13july2015.ps or ebdoc.13july2015.pdf should answer most questions.

The main FORTRAN program and subroutines for computing light, velocity, line profiles, conjunction times, etc., are in file lc14june2015flop.f. The program is called LC. Data files atmcof.dat, atmcofplanck.dat and effwvl.dat need to be in the subdirectory from which the programs are run, or there should be a link to their sub-directory. If (local) limb darkening coefficients are to be generated within the LC and DC programs (with the law-specifying integers LD1 or LD2 being negative), rather than adopted from input lines, a path to the Van Hamme (1993, AJ, 106, 2096) bandpass-specific limb darkening tables must be set, or the limb darkening files must reside in the same sub-directory as the program. Limb darkening tables are in data files named limcof_bp_*.dat and limcof_bp_preamble_*.dat, with the asterisk to be replaced by a chemical composition label, and can also be found on the website http://faculty.fiu.edu/~vanhamme/.

Examples of LC and DC input data files in the FTP download directory

1. The file lcin.examples has input for two light curves (Johnson V and B bands), one set of star 1 and star 2 radial velocity curves, three star 1 and one star 2 line profiles, one set of star radii vs. orbit phase for an eccentric binary, system images for six phases, and conjunction times along with predicted timing residuals (with input of observed timings to allow computation of the timing residuals). In previous years, individual 'lcin' example files for the several kinds of output were provided, but this time there is just one file that gives light curve, RV curve, etc. output corresponding to MPAGE = 1, 2, 3, 4, 5, and 6. Of course the six examples can easily be separated for particular cases. A postscript file, lcout.mpage5.26june2015.ps, shows system images at six phases for an eccentric EB.

2. dcin.example has input for simultaneous solution of two RV curves (star 1 and star 2), four light curves, and a collection of eclipse timings. It does one subset solution in addition to the base set. This file has three data points per line (input integer NPPL=3), although NPPL can be 1, 2, 3, 4, or 5. You may find that having only one point per line is simpler in terms of data manipulations.

These files provide examples of correct format, so the idea is to copy the relevant part of lcin.examples if you are computing light curves for example, and just change the integer and floating point numbers to your binary of interest. Then the LC input file that you have just altered must be copied into file lcin.active, which is accessed via an OPEN statement within the LC main program. LC input should be in the `lcin.active` file unless the OPEN statement has been commented out and you want to use the UNIX/LINUX feature of input/output via $<$ and $>$ symbols. Otherwise output is through a file named `lcout.active` that will be overwritten each time the program runs. So copy `lcout.active` under another name if you want to save its contents. Input/output with the DC program is done the same way, with the analogous file names being `dcin.active` and `dcout.active`.

The differential corrections (DC) solution program is in file `dc22may2015flop.f` (main program plus subroutines).

Note that the programs run MUCH faster for circular than for eccentric orbits.

You can run LC and DC just as they are on almost any modern computer, as they contain no machine-dependent statements. All that is needed is a compiler for FORTRAN 77 or FORTRAN 90.

Do not expect the sample input files to be at all instructive about astrophysics or binary stars. They are intended only as samples of correct formatting, with parameters that will not cause blow-ups in execution. You will need to think about every number that you enter.

Versions of 2003 and later incorporate stellar atmosphere approximation functions by Van Hamme & Wilson (2003, ASP Conf. Ser. 298, 323). The functions are based on model stellar atmospheres by R. L. Kurucz that are described in *Light Curve Modeling of Eclipsing Binary Stars*, ed. E. F. Milone (New York: Springer-Verlag), p. 93. The radiative atmosphere implementation is in terms of photometric bands, with 93 bands now accomodated, as listed in Table 2 of the documentation file `ebdoc.13july2015.pdf`. Input for the radiative treatment includes $\log g$ and chemical composition in addition to effective temperature. Influences of T_{eff} and $\log g$ on radiative output can be applied *locally* on all surface elements (not merely with one result for the entire star). See Van Hamme & Wilson (2003) for information about smooth transitions from atmosphere to black body treatment at the limits of the atmosphere tables and for other specifics of the radiative atmosphere application. Older references that are relevant to the history of the model and programs are listed in the documentation.

For persons who want to work with a somewhat simpler program, without some of the 2015 capabilities, older versions are in subdirectories `pub/wilson/lcdc2010` and `pub/wilson/lcdc2013` but will no longer be maintained. For those who want to work in terms of effective wavelength, the 1998 version can be accessed on ftp subdirectory `pub/wilson/lcdcprog/`, but it will no longer be maintained.

You should read through the documentation at least superficially at the start, to have a rough idea of what the programs will do. From this point, just follow the instructions at the beginning of the documentation. A common error is to try running LC or DC with an input file from an old version. Be sure not to do that as formatting differs among versions.

It is not practical to notify users of corrected bugs in any thoroughgoing way, although there may be occasional such notices. Therefore you may want to check this site from time to time for updates.