A Code for Calculating Type II Dynamic Spectra

July 20, 2004

1 A Brief Description

The code *Dynamic_Spectra.f90* calculates the dynamic spectra predicted for a type II radio burst from the solar corona and interplanetary medium. Input values for the coronal, solar wind, and shock parameters are provided by way of the file *Dynamic_Spectra.input* (for details see Subsection 3 below, and the sample input file included as Section **??**). The results of calculations are output as text files, and include such things as a summary of the input parameters and run conditions, plasma and shock parameters as a function of time, plasma and shock parameters as well as fundamental and harmonic emission as a function of location, and dynamic spectra.
The data produced by *Dynamic_Spectra.f90* is placed in a number of different files (for details see Subsection 4 below). These data can then be plotted by means of two IDL scripts called *Dynamic_Spectra.pro* and *Helio_cont.pro*.
The three subsections below summarize: 2 the input file and plotting scripts; 3 the input variables; and 4 the output files related to *Dynamic_Spectra.f90*.

2 Related Files:

`Dynamic_Spectra.input`
Is the parameter input file. The inputs include, but are not limited to, the output directory and file information, initial shock parameters, and the 1 AU and coronal normalizations of plasma and magnetic field parameters. The complete list is described in Subsection 3 below, and an example input file is included as Section **??**.

`Dynamic_Spectra.pro`
Is an IDL script for plotting output from Dynamic_Spectra.f90. It produces three figures: the first is a five panel figure showing UCME, Radial_Height, theta, b, and U; the second is a four panel figure showing Ti, Te, N_e, B1; and the third figure shows the dynamic spectrum for a selected observer. This script is included as Section **??**

`Helio_cont.pro`
Is an IDL script for plotting output from Dynamic_Spectra.f90. It produces a 10 panel figure of the plasma and magnetic field parameters as well as the frequency integrated fundamental and harmonic fluxes as a function of position. This script is included as Section **??**

3 Inputs:

Dynamic_Spectra.f90 gets its input from the file *Dynamic_Spectra.input*. What follows is a list of the input parameters contained in *Dynamic_Spectra.input*. The values listed below as *DEFAULT* are used if the file *Dynamic_Spectra.input* cannot be found.

`Output_dir`
This is the path to the directory to which data will be output. It must already exist, i.e., the program will not create it.
$DEFAULT =$ `'data/spectra/'`

`file_ident`
A distinguishing name to be appended to the end of all of the output files for the current run.
$DEFAULT =$ `'temp.dat'`

`Radial_Height`
The height in solar radii at which the nose of the global shock is positioned at the start of calculations.
($214 \approx 1$ AU)
$DEFAULT =$ `1.1`

`UCME`
The initial radial speed of of the global shock in m s^{-1}. A reasonable range is a few hundred to a couple of thousand km s^{-1}.
$DEFAULT =$ `1500.0e3`

`CME_accel`
The deceleration imposed on the global shock speed in m s^{-2}. A good guide for selecting this number is provided by *Gopalswamy et al.* (2001b).
$DEFAULT =$ `5.9`

`expansion`
A parameter to set the relative flow speed across the global shock front; ranging between 0 and 1 corresponding to no expansion (ie the way ripples are currently done) through to expansion equivalent to its radial speed.
$DEFAULT =$ `0.0`

`scale`
A parameter to set the size of the global shock at 1 AU. A value of 1 gives a shock of 1AU curvature at 1AU, making this number bigger makes the shock smaller at 1AU.
$DEFAULT =$ `1.0`

`scale_exp`
A parameter to define the rate of change of shock size with radial distance (see line 882 of *Dynamic_Spectra.f90*). It should generally be smaller for smaller 1AU shocks so as to give a reasonable size at 1 Solar Radius.
$DEFAULT =$ `0.37`

`exp_min`
$\log_{10}$ Hz of the lowest frequency in the calculated dynamic spectra.
$DEFAULT =$ `4.0`

`exp_range`
$\log_{10}$ Hz of the range of frequencies the dynamic spectra covers.
$DEFAULT =$ `5.0`

`l_val`
A multiplicative coefficient of the dynamic spectra frequency range.
$DEFAULT =$ `1.0`
Lower frequency = l_val$\times 10^{exp_min}$
Upper frequency = l_val$\times 10^{(exp_min+exp_range)}$

`Average_kappa`
Average value of KAPPA parameter of distribution function, 2-5 are reasonable for solar wind.
$DEFAULT =$ `3.0`

`Ne_1AU`
The 1 AU value for the electron number density (m^{-3}). The value at other radial distances is determined using a density model based on the *Saito et al.* (1977), and *Robinson and Cairns* (1998c) models.
$DEFAULT =$ `5.1e6`

`Ne_1Rs`
The 1 solar radius value for the electron number density (m^{-3}). The value at other radial distances is determined using a density model based on the *Saito et al.* (1977), and *Robinson and Cairns* (1998c) models.
$DEFAULT =$ `1.68e14`

`Te_1AU`
The 1 AU value for the electron temperature (K). The value at other radial distances is determined using a power-law electron temperature model from *Robinson and Cairns* (1998c).
$DEFAULT =$ `2.4e5`

`Ti_1AU`
The 1 AU value for the ion temperature (K). The value at other radial distances is determined using the functional form used for T_e, but with an exponent which produces a typical coronal value for a nominal 1 AU value.
$DEFAULT =$ `1.7e5`

`Bo` The magnetic field strength (T) at 1 solar radius. The value at other radial distances is determined using the Parker model for equatorial magnetic field strength, the default value provides typical value at 1 AU)
$DEFAULT =$ `1.89743128e-4`

`Vsw_1AU`
The solar wind speed at 1 AU (m s−1). The value at other radial distances is determined using a solar wind flow speed model from *Robinson and Cairns* (1998c).
$DEFAULT =$ `4.0e5`

`Xo1`
The X coordinate (heliocentric) of observer 1 (m).
$DEFAULT =$ `1.49599e11`

`Yo1`
The Y coordinate (heliocentric) of observer 1 (m).
$DEFAULT =$ `1.00e9`

`Xo2`
The X coordinate (heliocentric) of observer 2 (m).
$DEFAULT =$ `1.00e11`

`Yo2`
The Y coordinate (heliocentric) of observer 2 (m).
$DEFAULT =$ `1.00e11`

`Xo3`
The X coordinate (heliocentric) of observer 3 (m).
$DEFAULT =$ `1.00e11`

`Yo3`
The Y coordinate (heliocentric) of observer 3 (m).
$DEFAULT =$ `-1.00e11`

`time_resolution`
The time resolution of dynamic spectra in seconds.
$DEFAULT =$ `10`

`Maxtheta`
The upper range in radians for the array of theta values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `6.283185307`

`Mintheta`
The lower range in radians for the array of theta values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `3.141592654`

`MaxU`
The upper range in m s^{-1} for the array of flow speed values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `100.0e4`

`MinU`
The lower range in m s^{-1} for the array of flow speed values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `0.0e1`

`Maxb`
The upper range in $\log_{10}[\mathrm{m}^{-1}]$ for the array of ripple curvature values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `-7.0`

`Minb`
The lower range in $\log_{10}[\mathrm{m}^{-1}]$ for the array of ripple curvature values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `-10.0`

`MaxB1`
The upper range in $\log_{10}$[T] for the array of magnetic field strength values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `-3.0`

`MinB1`
The lower range in $\log_{10}$[T] for the array of magnetic field strength values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `-9.0`

`MaxNe`
The upper range in $\log_{10}[\mathrm{m}^{-3}]$ for the array of electron number density values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `15.0`

`MinNe`
The lower range in $\log_{10}[\mathrm{m}^{-3}]$ for the array of electron number density values used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `6.0`

`MaxTe`
The upper range in K for the array of electron temperature used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `2.0e6`

`MinTe`
The lower range in K for the array of electron temperature used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `4.0e4`

`MaxTi`
The upper range in K for the array of ion temperature used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `3.0e6`

`MinTi`
The lower range in K for the array of ion temperature used in the calculation of ripples as a function of time – output by the code.
$DEFAULT =$ `4.0e4`

`nos`
The number of plasma structures imposed on the model corona and solar wind. Primary use is so that the code knows how many to try and read in.
$DEFAULT =$ `0`

For examples of structure parameters see Dynamic_Spectra.input and the Structures subroutine in Dynamic_Spectra.f90.

4 Outputs:

The code replaces the $*$ in what follows by file_ident, see page 2.

`Source_Loc_*`
Five numbers output for every ripple calculated, consisting of:
'X' position defined relative to the time step global shock coordinates.
'Y' corresponding to X
'F' Fundamental flux at observer generated by that source.
'H' Harmonic flux at observer generated by that source.
'f_p' The average plasma frequency of the source.

`Source_Num_*`
The number of sources/ripples calculated per time step in order to pack the global shock. Used to work out the the number of sources in a given number of time steps.

`CME_b_*`
The curvature parameter for the global shock at successive time steps.

`DS[1-3][F|H]_*`
An array of the flux in $\log_{10}$ W m^{-2} Hz^{-1} sr^{-1} as a function of frequency and time. [1-3] and [F|H] refer to the six different dynamic spectra for the 3 different observers as separate fundamental and harmonic components, e.g., DS1F_$*$ is the fundamental component of the dynamic spectrum seen by observer 1.

`LOG_*`
General information about a run: Includes start time, array sizes, resolution, input parameter plot ranges, and finish time and reason for finish.

`parameters_*`
Consists of: input parameters followed by the time of time steps in seconds and the corresponding solar wind speed of the last ripple calculation. Can be useful in determining the time in seconds corresponding to a number of time steps.

`scaling_*`
Values used for conversion/stretching of values output on a time step basis into an actual time spread...

`Radial_Height_*`
The height above the Sun of the leading edge of the global shock at successive time steps.

`UCME_*`
The radial speed m s^{-1} of the global shock at successive time steps.

`theta_*`
Ripples at subsequent time steps binned as a function of the angle between the negative of the bulk plasma flow and the upstream magnetic field. (bin ranges are given in LOG_$*$)

`U_*`
Ripples at subsequent time steps binned as a function of the flow speed.

`b_*` Ripples at subsequent time steps binned as a function of the ripple curvature, and thus size.

`B1_*`
Ripples at subsequent time steps binned as a function of the upstream magnetic field strength.

`Ne_*`
Ripples at subsequent time steps binned as a function of the electron number density.

`Te_*`
Ripples at subsequent time steps binned as a function of the electron temperature.

`Ti_*`
Ripples at subsequent time steps binned as a function of the ion temperature.

References

Gopalswamy, N., A. Lara, S. Yashiro, M.L. Kaiser, and R.A. Howard, Predicting the 1-AU arrival times of coronal mass ejections, *Journal of Geophysical Research 106*, 29207, 2001.

Robinson, P.A., and I.H. Cairns, Fundamental and Harmonic Emission in Type III Solar Radio Bursts III. Heliocentric Variations of Interplanetary Beam and Source Parameters, *Solar Physics*, *181*, 429, 1998c.

Saito, Kuniji, Arthur I. Poland, and Richard H. Munro, A Study of the Background Corona Near Solar Minimum, *Solar Physics*, *57*, 121, 1977.