ordering of the colors in the colormap). Changing the range will not affect the view until the view window is refreshed. The default range is taken from the Default Settings Window.

- Coding Range Max read-write text field: See the previous entry.

2.7 The Print Window

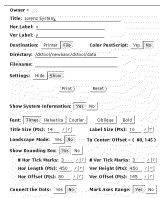

Figure 2.7: The Print Window.

Window title: Print

Function: This window allows the user to output a viewing window to a file or a printing device which understands PostScript.

Description: The Print Window is opened by selecting the Print option on the Options menu button located on a 2-D View Window. The user may then select printing options. When the user hits the Print command button, then the viewing window which last summoned the print panel will be printed. If not pinned, the window disappears after this action. Only a single Print Window may be opened at any one time.

Panel items:

- Owner read-only message: Shows which view window "owns" the print window, i.e., which view window will be printed. On color monitors, this message is followed by a colored glyph. The view window whose panel color matches the color of the glyph is the view window which will be printed. On a monochrome

monitor, the pattern of the glyph matches the pattern of the view window to which it belongs. *Not yet implemented.*

- Title read-write text field: Specifies the string which will appear at the top of the printed image. The default is the title of the dynamical system as it appears on the Models stack setting of the Command Window.
- Hor Label read-write text field: Specifies the string which will appear centered below the horizontal axis of the printed image. The default is the string currently being used to indicate the abscissa.
- Ver Label read-write text field: Specifies the string which will appear centered to the left of the vertical axis of the printed image. The default is the string currently being used to indicate the ordinate.
- Destination exclusive setting: Determines if the output is written to a file or piped to a printer. The default is to print to a file. If File is selected, then the next two text fields on the Print Window are for the directory and filename of this file. If Printer is selected, then the next text field specifies a printer name and the last text field becomes inactive.
- Color PostScript exclusive setting: Allows the user to choose between printing a black and white PostScript image (the default) and a color image. Warning: DsTool does not check to see if the selected printer is a color printer. Printing a color image on a non-color printer will lead to images of poor quality.
- Directory/Printer read-write text field: This field specifies the directory or printer to which images are to be sent. The default directory is the value of the environment variable DSTOOL_DATA_DIR id set, or the user's current working directory if not. The default printer name is specified by the environment variable LPDEST if set, variable PRINTER if LPDEST is not set, or otherwise at the time that DsTool is installed.
- Filename read-write text field: This field specifies the filename of the PostScript file to which data is saved. If the Destination setting is Printer, then this field is inactive. There is no default.
- Settings exclusive setting: This item controls whether or not to display the more specialized customization fields for printing.
- Print command button: Tells DsTool that the user wishes to send PostScript data to the selected file or printer, using the currently displayed settings.
- Reset command button: Resets customization fields to default values.
- Show System Information exclusive setting: If Yes is selected, the upper left portion of the printed image will contain information about the dynamical system being plotted. This information includes the name of the dynamical system, the time that the image (or PostScript file) was generated, the range of the ordinate and abscissa, the initial settings (as seen in the Selected Point Window), and the number of points in the plot. If the dynamical system being plotted is a vector field, then the system information also includes the value for Time Step

as it appears on the Orbits Window. The default value is to show the system information.

- Font Family exclusive setting: Allows the user to choose between three different fonts for the title and axis labels. The choices are the Times, Helvetica, and Courier families. The default is the Times family.
- Typeface (unlabeled) non-exclusive setting: Allows the user to choose a particular typeface from within a font family. Four choices are available for each family, depending on whether one, both, or no typeface settings are chosen. The Appendix A presents a table of examples for each font typeface. There is no default.
- Title Size (Pts) numeric field: Determines the size (in printer's points; one point is approximately 1/72 inches) of the title. The range is from 4 points to 30 points. The default is 14 points.
- Label Size (Pts) numeric field: Determines the size (in printer's points) of the axis labels. The range is from 4 points to 30 points. The default is 10 points.
- Landscape Mode exclusive choice: Tells DsTool whether to print in landscape mode (rotated by 90 degrees) or not. The default value is no.
- Show Bounding Box exclusive setting: If Yes is chosen, then a bounding box will be printed about the plotted points. The bounding box will contain tick marks as specified in the Number of Tick Marks numeric fields (see below). The default is to show the bounding box.
- Number of Tick Marks (Hor) numeric field: If Show Bounding Box is set to Yes, then this field determines the number of tick marks on the horizontal axis. If Show Bounding Box is set to No, then this field is inactive. The default value is 3.
- Number of Tick Marks (Ver) numeric field: If Show Bounding Box is set to Yes, then this field determines the number of tick marks on the vertical axis. As above, if Show Bounding Box is set to No, then this field is inactive, otherwise the default value is 3.
- Hor Length numeric field: This gives the width in points of the picture. The default value is 450.
- Ver Height numeric field: This gives the height in points of the picture. The default value is 450.
- Hor Offset numeric field: This gives the horizontal indentation in points of the lower left corner of the picture. The default value is 80.
- Ver Offset numeric field: This gives the vertical height from the bottom of the page in points of the lower left corner of the picture. The default value is 145.
- Connect the Dots exclusive setting: This field specifies whether consecutive points in continuous data should be drawn with connecting line segments. A common experience is to attempt to print a PostScript file which is too big to fit

entirely within a printer's buffer. In this case, we recommend attempting to print the file with the unix command `lpr -s` *filename*. We remark in any case that piping data directly to a printer is somewhat riskier than creating a PostScript file and then sending that file to the printer, chiefly because if the pipe fails for any reason, then the image may be lost.

2.8 The Orbits Panel

Figure 2.8: The Orbits Panel.

Window title: Orbits

Function: This panel allows the user to set conditions for orbit propagation, select and control the numerical algorithms used to compute trajectories.

Description: The Orbits Panel is opened by selecting the Orbits option from the Panels menu button located on the Command Window. If unpinned, the panel vanishes when any button is selected.

Panel items:

- Forwards command button: Begins propagation (i.e., integrating a vector field or iterating a map) forward in time using the initial condition given in the Initial column of the Selected Point Window.
- Backwards command button: Begins propagation backwards in time using the initial condition given in the Initial column of the Selected Point Window. If the installed dynamical system is a map, finding inverse images takes on two meanings. If the map has an explicit inverse, the inverse image is computed explicitly. If a map does not have an explicit inverse, Newton's method is used to determine approximate inverse images. The jacobian of the map, the convergence criteria for Newton's method, and other relevant parameters for this numerical procedure may be set by using the Propagation Panel.
- Continue command button: Begins propagation in the current direction, using the final point of the last computed trajectory as the initial condition. If there is no last trajectory, selecting Continue is equivalent to selecting Forwards. The current direction is "forward" if the user selected the Forwards button or the

SELECT mouse button more recently than the user selected the Backwards button or the MENU mouse button. (See Section 2.5 for more information on the effects of mouse buttons.)

- Clear Last command button: Deletes the last computed trajectory segment from memory and updates the number of trajectory data points. Note that the view windows are not automatically refreshed by this command.
- Clear All command button: Deletes stored trajectory data points.
- Start read-write text field: *Not yet implemented.* Setting this text field to a positive integer means that initial transient behavior will not be displayed. Data is plotted and stored after *start* time steps are computed. The default value is 1.
- Stop read-write text field: The default value is 5000. This field has different meanings, depending upon the value of the stack setting entitled Stopping Condition. If the Stopping Condition stack setting is set to Fixed Steps, then Stop is used to compute the total number of time steps taken by the propagation routine (see Plot item below). If the Stopping Condition is set to Event Stopping or Fixed Time, then Stop is used to compute the *maximum* number of time steps which the propagation routine may take. We assume that the trajectory being computed does not propagate to infinity, and also that the propagator does not fail in any way. A failure may occur, for example, when trying to implicitly iterate a map backwards.
- Plot read-write text field: The default value is 1. The ith point calculated will be stored to memory and plotted only if i is greater than *start* and $i - start$ is evenly divisible by *plot*. The exception to this rule is that the initial and final conditions are always stored and plotted. This field is replaced by the Max Steps field when the Poincare Section Stopping Condition is selected.

  Example: If the previous three text fields read Start=500, Stop=1000, and Plot=3, then DsTool will calculate 1000 points along a trajectory but will only store the points indexed by 500, 503, 506,..., 998, and 1000 (the final condition is *always* kept). Setting Plot = $k > 1$ for mappings may be thought of as studying the kth iterate of the map. For vector fields, setting Plot > 1 is useful when it is necessary to choose a small integration step, but we do not want to see every plotted point.
- Max Steps read-write text field: The default value is 5000. This field takes the place of the Plot field when Poincare Section is selected as a stopping condition. This defines the maximum number of integration steps which the propagation routine may take between hitting sections. If a section is not crossed before taking this many steps, then the Propagation routine stops and returns the last plotted point.
- Step Size read-write text field: This field is only active if the dynamical system is a vector field. The default value is 0.01. Like the Stop field, the interpretation

of the value in the Step Size field depends upon the value of the stack setting entitled Stopping Condition and upon the current choice of the integrator.

If the current integrator is a *fixed step* algorithm (e.g., the Euler method or a standard fourth order Runge-Kutta method):

- If the Stopping Condition is Fixed Steps, the size of each integration step is constant and has the value shown in the Step Size field.
- If the Stopping Condition is Event Stopping, the integration step is initially set to the the value shown in the Step Size field, and no step size will ever be larger that this value. The given step size is used by the integration algorithm until an event is detected. The final step (which may be smaller than the value of Step Size) used by the integrator is chosen so that the last point of the trajectory satisfies the given condition even up to some tolerance.
- If the Stopping Condition is Fixed time, a new time step is computed for use by the integration routine. The new step is less than or equal to the value shown in the Step Size field, but is the largest step which divides that flight time by an integral value.

If the current integrator is a *variable step* algorithm (e.g., quality-control algorithms and the Bulirsch-Stoer method), then the value shown in the Step Size field is used as an initial step size.

- Stopping Condition stack setting: Determines the type of event which will terminate a trajectory calculation. There are several options. The exact number depends on whether the current dynamical system is a mapping or a vector field and, if it is a vector field, on the currently installed integrator.

  Fixed Steps: The option Fixed Steps condition means that the propagation algorithms will attempt to propagate the trajectory for the number of time steps specified in the Stop read-write field.

  Event Stopping: The Event Stopping condition means that the propagation algorithms will halt propagation as soon as *any* of the specified events are satisfied. An event is specified by typing in a value for an event field. Any variable or user-defined function may be used to determine an event. For example, if we wish to propagate a trajectory until some scalar function g is zero, then we would type 0.0 into the event field next to the label for g. If we want to propagate until the variable x reaches the value 0.5 *or* until the function g is 1.0, then we would type both of these values into the event fields labeled by x and g. The propagator will stop the first time that *any* of the specified events are true. The parameters controlling the Newton iterations and tolerance for the event are set on the Propagation window.

  Fixed time: This field only exists when the current dynamical system is a vector field. The label for this condition is always Fixed *indep_varb* where *indep_varb* is the name of the independent variable for the current vector field (often "time" is used). When this condition is chosen, the propagation

algorithms will attempt to propagate a trajectory until a final value of the independent variable is satisfied. This is currently implemented by using Newton's method to solve for a final time step so that the last point satisfies the condition to within some error tolerance. The parameters for controlling Newton's method are set in the Propagation Panel.

Poincare Section: This field exists only when the current dynamical system is a vector field. A section or union of sections is setup as stopping events in the same fashion as Event Stopping. The trajectory is flowed from the initial condition until the number of events specified in the Stop field have occurred. Each event starting with the one indicated by the Start field is plotted and saved. Intermediate points are neither plotted nor saved. The Max Steps field specifies the maximum number of propagation steps which the propagation routine is allowed to take between events before stopping.

- Propagation window button: Selecting this button opens and brings to the foreground the Propagation Panel.
- *function_name* Event read-write text fields: If the Stopping Condition choice is Fixed Steps, then none of these fields are active and trajectories will propagate as described above under the description of Start, Stop, and Plot. If the choice is Event Stopping or Poincare Section then all dependent variables and auxiliiary functions are active. If the choice is Fixed Time then only the independent variable is active.

2.9 T

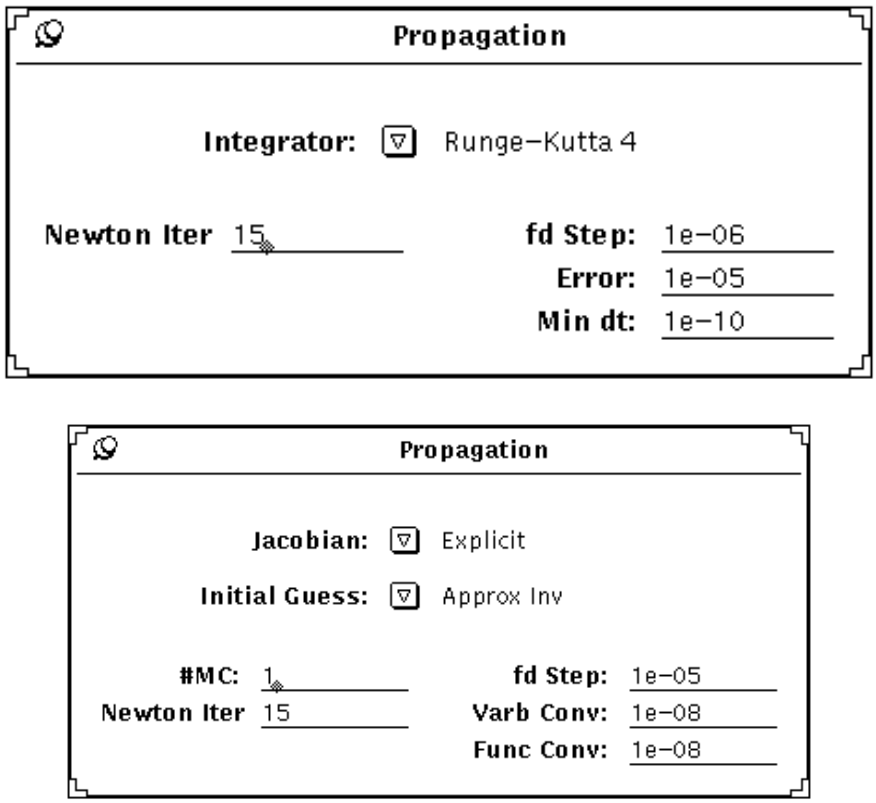

Figure 2.10: A Propagation Panel for mappings.

Window title: Propagation

Function: The Propagation Panel allows the user to select and control the algorithms to use to compute trajectories.

Description: The Propagation Panel is opened by selecting the Propagation window button located on the Orbits Panel. The Propagation Panel contains information necessary to control the forward and backward propagation of trajectories. When the Orbits Panel is dismissed, the Propagation Panel also vanishes. *Not yet implemented.*

Panel items: The panel items on the Propagation Panel will depend on the method of propagation chosen. The top portion of the panel consists of $k \geq 1$ stack settings from which the user may select algorithms used by the propagator. The lower left section of the panel consists of $i \geq 0$ integer fields which are used to control integer parameters of the algorithms chosen. The maximum number of Newton iterations used in estimating an inverse image for a diffeomorphism is one example of an integer parameter. The lower right section of the panel contains a list of $j \geq 0$ double precision fields which are used to control floating point parameters of the chosen numerical algorithms. These fields may be used, for example, to set the minimum step size allowable for variable-step integrators, or to establish convergence criteria for Newton's method.