Small PIMMS version s2.00 Users' Guide

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1 Introduction

PIMMS (Portable, Interactive, Multi-Mission Simulator) is intended as a versatile simulation tool for X-ray astronomers.

2 PIMMS Terminology

PIMMS uses one command `GO` for actual execution, while other commands are mostly used for setting up various parameters. This approach allows users to repeat similar calculations using a slightly different parameter.

PIMMS uses the following terms:

- Model: spectral model to be used. PIMMS contains a small set of simple spectral models, and others can be imported.
- Instrument: in addition to the instrument for which simulation is to be done, you can specify both **input** and output instruments for count rate calculations. The former is used for calculating normalization of the model; rather than asking for flux in cgs unit, PIMMS can ask for flux in, e.g., Einstein IPC count rate.

3 Simulating spectra

PIMMS does contain a few simple spectral models. However, spectral simulation is not a strength of PIMMS — it does not output spectra as such, and even though modifications can be made to do this, it is unlikely that PIMMS can keep up with the multitude of models that are used for various X-ray emitting objects. We recommend the use of XSPEC for spectral simulation.

4 Sample Sessions

Example 1. Estimating XTE PCA count rates

```
*** Small PIMMS version s2.01 (XTE compatible) ***
    1994 Dec 12 release
    (this version does not simulate images)
    Reading mission directory, please wait
* Current model is BREMSSTRAHLUNG, kT=  10.0000 keV; NH =  1.000E+21
   <--- Use 'MODEL' command to change
* By default, input rate is taken to be
 Flux (  2.000- 10.000 keV) in ergs/cm/cm/s
   <--- Use 'FROM' command to change the default
* Simulation product will be
 Count rate in XTE PCA
   <--- Use 'INSTRUMENT' command to switch to another instrument
pimms > go 1 einstein ipc
* For thermal Bremsstrahlung model with kT= 10.0000 keV; NH =  1.000E+21
  and  1.000E+00 cps in EINSTEIN IPC
  (Model normalization =  5.882E-03)
* PIMMS predicts  3.579E+01 cps with XTE PCA
   (Count rate is for all the detectors)
Results in the 6 canonical XTE PCA bands are:

  Channels Nominal   Source   BGD   5-sigma
           E (keV)   (cps)    (cps) detection (s)
    1- 13  0.0- 3.2      3.1  5.84     23.3
   14- 17  3.2- 4.3      4.9  1.80      6.9
   18- 23  4.3- 5.7      7.7  2.76      4.4
   24- 35  5.7- 8.6     10.4  5.28      3.6
   36- 49  8.6-12.1      5.9  5.29      8.0
   50-249 12.1-60.0      3.8 69.20    128.1
 (5-sigma detection time calculated purely from statistical noise)
pimms > quit
```

In this example, the default spectral model is used to estimate XTE PCA count rate (which is the default). The only place where user did not use the default set-up was to specify conversion from Einstein IPC count rate. PIMMS not only reports the total PCA count rate but also count rates in the 6 standard bins (see XTE NRA for details).

Example 2. Estimating XTE count rates II

```
*** Small PIMMS version s2.01 (XTE compatible) ***
```

```
    1994 Dec 12 release
    (this version does not simulate images)
    Reading mission directory, please wait
* Current model is BREMSSTRAHLUNG, kT=  10.0000 keV; NH =  1.000E+21
   <--- Use 'MODEL' command to change
* By default, input rate is taken to be
 Flux (  2.000- 10.000 keV) in ergs/cm/cm/s
   <--- Use 'FROM' command to change the default
* Simulation product will be
 Count rate in XTE PCA
   <--- Use 'INSTRUMENT' command to switch to another instrument
pimms > from exosat me
pimms > mo rs 1 5e19
WARNING - PIMMS has a limited grid of Raymond Smith model
           log T of 6.0; kT =  0.086
           log T of 6.2; kT =  0.137
           log T of 6.4; kT =  0.216
           log T of 6.6; kT =  0.343
           log T of 6.8; kT =  0.544
           log T of 7.0; kT =  0.862
           log T of 7.2; kT =  1.366
           log T of 7.4; kT =  2.165
           log T of 7.6; kT =  3.431
           log T of 7.9; kT =  6.845
           log T of 8.2; kT = 13.657
           log T of 8.5; kT = 27.250
          choosing the nearest one, hope that's okay
         New temperature is  0.862 keV (log T is 7.0)
pimms > go 1
* For Raymond Smith model with kT=  0.8617 keV (logT=7.0); NH =  5.000E+19
  and  1.000E+00 cps in EXOSAT ME
  (Model normalization =  1.356E+00)
* PIMMS predicts  2.915E+00 cps with XTE PCA
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
   (Count rate is for all the detectors)
Results in the 6 canonical XTE PCA bands are:

  Channels Nominal   Source   BGD   5-sigma
           E (keV)   (cps)    (cps) detection (s)
    1- 13  0.0- 3.2       1.4  5.84     96.9
   14- 17  3.2- 4.3  9.61E-01  1.80     74.8
   18- 23  4.3- 5.7  4.84E-01  2.76    345.6
   24- 35  5.7- 8.6  1.03E-01  5.28  12634.2
```

```
   36- 49  8.6-12.1  2.87E-03  5.29 1.60E+07
   50-249 12.1-60.0  3.40E-05 69.20 1.50E+12
 (5-sigma detection time calculated purely from statistical noise)
pimms > mo rs 1 1e20
WARNING - PIMMS has a limited grid of Raymond Smith model
           log T of 6.0; kT =  0.086
           log T of 6.2; kT =  0.137
           log T of 6.4; kT =  0.216
           log T of 6.6; kT =  0.343
           log T of 6.8; kT =  0.544
           log T of 7.0; kT =  0.862
           log T of 7.2; kT =  1.366
           log T of 7.4; kT =  2.165
           log T of 7.6; kT =  3.431
           log T of 7.9; kT =  6.845
           log T of 8.2; kT = 13.657
           log T of 8.5; kT = 27.250
          choosing the nearest one, hope that's okay
         New temperature is  0.862 keV (log T is 7.0)
pimms > go 1
* For Raymond Smith model with kT=  0.8617 keV (logT=7.0); NH =  1.000E+20
  and  1.000E+00 cps in EXOSAT ME
  (Model normalization =  1.359E+00)
* PIMMS predicts  2.919E+00 cps with XTE PCA
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
Warning:: integration to energies > calibration data
   (Count rate is for all the detectors)
Results in the 6 canonical XTE PCA bands are:

  Channels Nominal   Source   BGD   5-sigma
           E (keV)   (cps)    (cps) detection (s)
    1- 13  0.0- 3.2       1.4  5.84     96.7
   14- 17  3.2- 4.3  9.62E-01  1.80     74.6
   18- 23  4.3- 5.7  4.85E-01  2.76    344.3
   24- 35  5.7- 8.6  1.03E-01  5.28  12574.8
   36- 49  8.6-12.1  2.88E-03  5.29 1.59E+07
   50-249 12.1-60.0  3.41E-05 69.20 1.49E+12
 (5-sigma detection time calculated purely from statistical noise)
pimms > quit
```

In this example, the user specified conversion from EXOSAT ME count rate and used Raymond-Smith models with two different columns. Since PIMMS has a limited grid of Raymond-Smith models, the temperature of the actual model used does not exactly match the request. In addition, Raymond-Smith models are not calculated up to very high energies (where the flux tends to be low) so warning messages are displayed to that effect.

Example 2. Estimating XTE count rates III

```
*** Small PIMMS version s2.01 (XTE compatible) ***
    1994 Dec 12 release
    (this version does not simulate images)
    Reading mission directory, please wait
* Current model is BREMSSTRAHLUNG, kT=  10.0000 keV; NH =  1.000E+21
   <--- Use 'MODEL' command to change
* By default, input rate is taken to be
 Flux (  2.000- 10.000 keV) in ergs/cm/cm/s
   <--- Use 'FROM' command to change the default
* Simulation product will be
 Count rate in XTE PCA
   <--- Use 'INSTRUMENT' command to switch to another instrument
pimms > from ginga lac both
pimms > mo pl 1.5 15 30 1e22
pimms > go 500
* For power-law model with high-energy cut-off with
  Index =  1.50, cutoff 15.00 keV, e-folding energy 30.00 keV; NH =  1.000E+22
  and  5.000E+02 cps in GINGA LAC BOTH
  (Model normalization =  1.493E-01)
* PIMMS predicts  9.376E+02 cps with XTE PCA
   (Count rate is for all the detectors)
Results in the 6 canonical XTE PCA bands are:

  Channels Nominal   Source   BGD   5-sigma
           E (keV)   (cps)    (cps) detection (s)
    1- 13  0.0- 3.2      67.4  5.84 4.03E-01
   14- 17  3.2- 4.3     119.5  1.80 2.12E-01
   18- 23  4.3- 5.7     193.7  2.76 1.31E-01
   24- 35  5.7- 8.6     260.8  5.28 9.78E-02
   36- 49  8.6-12.1     155.6  5.29 1.66E-01
   50-249 12.1-60.0     140.5 69.20 2.66E-01
 (5-sigma detection time calculated purely from statistical noise)
pimms > inst xte hexte
pimms > go 500
* For power-law model with high-energy cut-off with
  Index =  1.50, cutoff 15.00 keV, e-folding energy 30.00 keV; NH =  1.000E+22
  and  5.000E+02 cps in GINGA LAC BOTH
  (Model normalization =  1.493E-01)
* PIMMS predicts  5.405E+01 cps with XTE HEXTE
   (Source-only count rate in 1 cluster; BGD rate is 34.4 per cluster)
```

```
Results in the 4 canonical XTE HEXTE bands are:
             (per HEXTE cluster)

  Channels Nominal   Source   BGD   5-sigma
           E (keV)   (cps)    (cps) detection (s)
   15- 29   15-  30      15.0  4.52      2.7
   30- 61   30-  61       5.0  5.66     17.4
   62-125   61- 125  8.34E-01  7.77    627.9
  126-250  125- 250  2.28E-02 16.40 1.69E+06
 (The default 32-s rocking cycle is assumed for detection time)
pimms > quit
```

In this model, a special version of the power law model (with high energy cut-off) is used, by specifying index, cut-off energy and e-folding energy, as well as Nh, on the command line. User then calculated PCA and HEXTE count rates for a 500 cps Ginga LAC source.

5 Comments on extended sources

PIMMS is written primarily for point sources. To simulate the count rate for an extended source, estimate the total counts/flux within the field of view of the target instrument and use that as the input to the "GO" command.

6 Missions

PIMMS reads the list of missions from a file called "pms_mssn.lst" in the data directory. It then looks, for each mission (i.e., satellite), detector and filter combination, the appropriate calibration files for the effective area, values used for image simulation etc. Since this is a run-time process, the following items may not exactly correspond to what you see. For a listing of what is currently available, use the DIRECTORY command.

6.1 XTE

XTE is the next US X-ray astrophysics satellite, to be launched in Aug 1995. XTE carries the All-Sky Monitor (ASM), large area proportional counter array (PCA) and the high energy X-ray Timing Experiment (HEXTE). The latter two are supported by this version of PIMMS.

PCA is a mechanically-collimated array of five xenon proportional counters with a total effective area of $\sim$7000 cm^2. PIMMS calculates total count rate and the count rates in the 6 canonical PCA channels required on the proposal form and used in RECOMMD. (All count rates are given as the sum over the 5 detectors.)

HEXTE consists of two clusters of detectors, with 4 scintillation detectors in each cluster. Count rates are given per cluster. Values are given for the total count rate, and the count rates in the 4 canonical HEXTE channels required on the proposal form and used in HEXTEmporize.

For faint sources, HEXTE will normally used with one cluster pointed on-source, the other measurinng the background at alternate off-source positions. This is assumed in the count rate and detection time calculations. For bright sources, both clusters can be pointed at the source; in this case, both source and background count rates willdouble but the detection time will also increase relative to what PIMMS gives.

6.2 ASCA

ASCA is the latest Japanese X-ray satellite launched on Feb 20th, 1993, for which US-led collaborations supplied the X-ray mirrors and the CCD detector. It has 4 co-aligned telescopes, each having an effective area of ~250 cm^2 at 1 keV; there are two GIS (imaging gas scintillation proportional counters) and two SIS (Solid-state Imaging Spectrometer, X-ray CCDs) detectors. Count rates are given for a single GIS or a single SIS, as appropriate.

6.3 BBXRT

BBXRT is flown on the Shuttle with the ASTRO payload in December 1990. The effective area curve is that for pixel A0.

6.4 EINSTEIN

Currently PIMMS only have IPC and MPC effective area curves.

6.5 EUVE

PIMMS currently has the effective area curves for the three channels of the spectrometer, which is used by GOs for pointed observations. Detectors are SW (70–190Å), MW (140–480Å) and LW (280–750Å)

6.6 EXOSAT

For the Low Energy telescopes, only the LE1/CMA effective area data are kept within PIMMS. Specify filter OPEN, LX3, LX4, ALP, or BRN. The ME effective area is for a half-array; GSPC area is also available.

6.7 ROSAT

For the German XRT, effective area curve with PSPC (filter OPEN or BRN) and HRI are available. For the British WFC, filters S1, S2, P1 and P2 effective area curves are available; these are appropriate for the time of launch. Note the S1 and S2 sensitivity dropped to $\sim$75% of initial value by the end of the survey, followed by a steeper decline to 15–20% of the original value after The Tumble. Non-survey (P1 and P2) filters have suffered much smaller degradation.

6.8 Ginga

Ginga is the 3rd Japanese X-ray astronomy satellite, which carried the LAC (Large Area Counter) array with an effective area of $\sim$4000 cm^2. Count rate can be calculated for TOP layer of the detector only or BOTH.

6.9 Flux

PIMMS can also calculate conversion to/from flux values not folded through any instrument responses can also be used. To use flux, the unit must be specified: "ERGS" for ergs $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ or "PHOTONS" for photons $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Also necessary is the energy range of interest, to be specified in the form "2.5–10" (for 2.5 to 10 keV). Optional keyword "UNABSORBED" following the range will make PIMMS calculate flux with Nh set to 0.0; this is useful in relating the flux to the total bolometric luminosity of the X-ray source before interstellar absorption.

7 User interface

7.1 Command interpreter

Commands can be abbreviated (as long as it is unique), numerical and character string parameters can be passed onto the commands. Parameters are interpreted according to their positions within the command line (first string is input file name, second file name is output file name etc., although this does not happen in PIMMS). Some parameters are compulsory — PIMMS will prompt you for them if they are not given on the command line; others are optional (default values will be used unless the user specifies them on the command line). Commands can be stringed together by using a semicolon.

Note that future versions of PIMMS may use a different interface.

7.2 On-line help

PIMMS contains a VMS-style help facility, within which information is stored in a hierarchical structure. On the top level, there are two types of topics. Those listed in ALL CAPITAL LETTERS are PIMMS command names, containing the usage of these commands. Others are of more general nature, not linked with specific commands. HELP items are arranged in many levels, so that you start with a general introduction and pick up as many specific details as you like by going down several levels.

This help is case-insensitive (i.e., it accepts both lower-case and capital letters). If you type n characters, it will be matched against the first n characters of the topic names at that level. No wild card is allowed in specifying item names.

If the topic name string supplied by the user can be matched to (parts of) two more more topic names, then information on all the matching topics will be displayed.

Type "?" to repeat the current level.

Type <RETURN> as the topic name to go up one level.

To exit HELP, type the EOF character (Ẑ on VAX/VMS, D̂ on UNIX machines).

7.3 Spawn

Enter a dollar sign "$" followed by a command to be spawned. Note that some operating system may not pass aliases, environment variables, logicals etc.

Appendix A. PIMMS commands

MODEL

Command syntax: MODEL <name> <par> <nh>
or MODEL <filename> [<nh>]
or MODEL ?
Minimum abbreviation: M
Examples: "MO PL 1.7 3e21" "MO mymodel.dat"
Model specifies the spectral shape to be folded with the effective area curve of the instrument. Currently three simple, one-parameter models are recognized with a fixed absorption model (due to Morrison & McCammon). In particular, it does not allow for the possibility of partial absorption, interstellar plus intrinsic (potentially warm and/or red-shifted) absorption etc. N_H, the equivalent neutral hydrogen column density, is to be specified in full with the appropriate exponent (e.g., 2.5E21); however, Nh values smaller than 30.0 will be interpreted as $\log10(N_H)$. If the string parameter does not match the names of the models, PIMMS interprets it as a file name.

MODEL — ?

MODEL command with a question mark (or no parameters) will return a short listing of available models.

MODEL — Blackbody

Can be abbreviated to "BL.." or "BB". Parameter is temperature in keV.

MODEL — Bremsstrahlung

Can be abbreviated to "BR.." or "TB" (short for Thermal Bremsstrahlung); the model include the Gaunt factor. Parameter is temperature in keV.

MODEL — Power Law

Can be abbreviated to "P.." or "PL". Parameter is photon index (flux in photons $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ is $E^{-(index)}$. Currently, entering a negative number as the index will PIMMS calculating $E^{(value-as-entered)}$, one whereby flux increases with increasing energy will never be calculated by PIMMS.

A power law with high energy cutoff $E^{-index}\exp[(E_{cut}-E)/E_{efold}]$ can be specified by typing "model pl 1.5 13.5 20.0 1e22" for example — this will result in an index of 1.5, cut-off energy of 13.5 and e-folding energy of 20 keV, with an N_H of 1E22.

MODEL — Raymond & Smith

Can be abbreviated to "R.." or "RS". At the moment, PIMMS cannot compute an arbitrary RS model but merely uses one of 12 pre-calculated models, for log T of 6.0, 6.2, 6.4, 6.6, 6.8, 7.0, 7.2., 7.4, 7.6, 7.9, 8.2 an 8.5. Plasma temperature can be specified either as logt (in which case type, e.g., "model rs logt 6.6 3e19") or as keV ("model rs 2.5 1e20"). Solar abundance is assumed.

MODEL — External Models

Other, perhaps more complex, models can be imported in the form of an Ascii file containing energy (keV) vs. flux (photons $\mathrm{cm^{-2}\,s^{-1}\,keV^{-1}}$ pairs. N_H correction is optional (i.e., interstellar absorption can be included when producing the file or done within PIMMS). If the full directory/file name is not specified, user's current default directory is assumed first, and if not the models directory is searched.

MODEL — Models directory

Some external models (see help item under that name) may be kept under the MODELS subdirectory. If the file names and a short description is also included in the MODEL.IDX file, then PIMMS users will be able to see what is available. Currently, a series of 0.25 Solar abundance Raymond-Smith models are available from MODELS directory.

MODEL — Importing from XSPEC

To import a model from XSPEC, start XSPEC and read, e.g., a template ASCA SIS pha file (which specifies the SIS response matrix which specifies the PHA channel boundary etc.). Create your model. Then use IPLOT MODEL command to plot the model, then from within plot use the WD <filename> command to output the model into an Ascii file. The program XSING within the MODELS directory should be used to convert the XSPEC output into a form readable by PIMMS.

FROM

Command syntax: FROM <mission> [<det> [<filt>]] [<lo>-<hi>]
FROM FLUX <unit> <lo>-<hi> [UNABSORBED]
Minimum abbreviation: F

Examples: “FROM EINSTEIN IPC” “‘FROM FLUX PHOTONS 0.5-10”
This command specifies the default “instrument” that the conversion is to take place from. This default will be used in GO (in count rate simulation mode) or POINT (in image simulation mode) command if not explicitly specified. See Missions for details of the available instruments, or try DIRECTORY. Initially the default is 2.0–10.0 flux in ergs $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

INSTRUMENT

Command syntax: INSTRUMENT <mssn> [<det> [<filt>]] [<lo>-<hi>]
or INSTRUMENT FLUX <unit> <lo>-<hi> [UNABSORBED]
Minimum abbreviation: I
Examples: “INST EXOSAT LE LX3” “INST FLUX ERGS 1-10 U”
This command specifies the “instrument” that the conversion is to take place to. See Missions for details of the available instruments, or try DIRECTORY. Initially default is ASCA SIS.

GO

Minimum abbreviation: G
Command syntax: GO <input_rate> [<mission> [<det> [<filt>]]] [<lo>-<hi>]
or GO <input_rate> [FLUX <unit> <lo>-<hi> [UNABSORBED]]
Examples: “G 1.0” “GO 3.4 EINSTEIN IPC”
This command actually tells PIMMS to execute the simulation.

Given a source spectrum in the form specified with MODEL, which produces an input rate (count rate in the specified instruments or flux) of <input_rate> it GO predicts what the rate would be for the instrument specified with the INSTRUMENT command. Unit of input rate can be specified here, or else the default is used (see FROM).

SHOW

Command syntax: SHOW
Minimum abbreviation: SH
Presents a summary of the current defaults on the screen.

DIRECTORY

Command syntax: DIRECTORY [<mission> [<detector>]]
Minimum abbreviation: D
Examples: “DIR” “DIRE EXOSAT”

This command prints, on your screen, the full listing of missions that PIMMS recognizes. For explanations and comments, see “Missions” in this help.