

UV SKY MODEL

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1 Introduction

Sky model is a tool to predict the appearance of the sky at any wavelength. It comprises three parts: the zodiacal light background, the diffuse galactic light and the stars. Provision is made for different filters. All programs are written in ANSI C.

2 Contents of the package

2.1 Data files

Inside the folder `data/`

- ***stellar models:*** Castelli and Kurucz Atlas: `stellar_data/castelli/`
- ***Hipparcos Catalogue:*** `stellar_data/hip_main.txt`
- ***Cross-sections from Draine (2003):*** `stellar_data/cross_sec.txt`
- ***Sample filter response files:*** `sample_filters/galex_FUV.txt`, `sample_filters/galex_NUV.txt`, `sample_filters/uvit_FUVBAF2.txt`, `sample_filters/uvit_NUVN2.txt`
- ***Diffuse background spectrum file:*** `diffuse_data/bkgd_spectrum.txt`
- ***GALEX NUV and FUV all sky data:*** `diffuse_data/nuv_allsky.txt`, `diffuse_data/fuv_allsky.txt`
- ***Zodiacal light spectrum file:*** `zodiacal_data/zodiacal_spec.txt`
- ***Zodiacal Data model file (Leinert et al. 1998):*** `zodiacal_data/leinert_dist.txt`

2.2 Source Code

Inside the folder `src/`

- source codes and corresponding header files.

2.3 Other files

- README.txt: *A quick guide to the features, installation and running the software*
- INSTALL.txt: *Generic installation instructions*
- COPYING.txt: *GNU Public License*
- AUTHORS.txt: *Author's name*
- ChangeLog.txt: *Log of versions*

3 Installation

Obtaining the source file.

1. Download the package from the following web page: <http://cads.iiap.res.in/downloads>. Source packages are available as (a) zipped and (b) tar-gzipped files, which contains the sources.
2. Since you are reading this manual, you would have already downloaded the package and extracted the contents.
3. Binary packages are available for a few Redhat-Linux based operating systems.

Installing Pre-requisites.

The following libraries are needed to run this software :

CFITSIO for FITS routines from: <http://heasarc.gsfc.nasa.gov/docs/software/fitsio/fitsio.html>

Libnova to calculate Sun position from: <http://libnova.sourceforge.net/>. If you are compiling the source code, you will have to install the libraries and their respective header files.

4 Compilation

Follow these 4 steps:

1. ‘cd’ to the directory containing the package’s source code and type ‘./configure’ to configure the package for your system. If *CFITSIO* library and header files are not in the standard path, then you may need to pass on the following argument to configure ‘--with-cfitsio=path/to/cfitsio’. The code will search *fitsio* header files in:

- (a) path/to/cfitsio
- (b) path/to/cfitsio/include
- (c) path/to/cfitsio/include/cfitsio

and library (libcfitsio.so or libcfitsio.a) in:

- (a) path/to/cfitsio
- (b) path/to/cfitsio/lib
- (c) path/to/cfitsio/lib64

Similarly, for *libnova* (in case ‘configure’ failed to detect it): ‘--with-libnova=/path/to/libnova’. Running ‘configure’ takes a few seconds. While running, it prints some messages telling which features it is checking for.

If configuration ended without errors, you shall receive the following messages:

```
checking for cfitsio... yes
checking for libnova... yes
configure: creating ./config.status
config.status: creating Makefile
config.status: creating src/Makefile
config.status: creating doc/Makefile
config.status: creating config.h
config.status: config.h is unchanged
config.status: executing depfiles commands
```

```
+-----+
| Configuration complete                                     |
| Type 'make' to compile the software, followed by 'make install' |
|                               All the very best! :-)          |
|                               --CADS Software Team          |
+-----+
```

2. Type ‘make’ to compile the package.
3. Type ‘make install’ to install the programs and any data files and documentation. By default the binary is copied to /usr/local/bin and in that case, you need to run ‘make install’ as root on linux/unix machines. You may change this destination by passing on the following argument to configure: ‘--prefix=/your/chosen/destination’, which would result in the binary in /your/chosen/destination/bin. You may need to ensure that in \$PATH to run the program.
4. You can remove the program binaries and object files from the source code directory by typing ‘make clean’. You may read more about configure script and others in the accompanying file named ‘INSTALL.txt’.

If everything is correct there should be no error or warning messages during this process.

5 Typical Run

1. Run sky_model to generate the default parameter file by typing the command ‘sky_model’.
2. Edit the default parameter file:

Keyword	Description
Time & date information	
TIME_UT	Time of the day (UT, hours. range: 0.0 – 24.0)
DAY_OF_MONTH	Day of the month (unitless, range: 0 – 31)
MONTH	Month of the year (unitless, range: 1 – 12)
YEAR	Year (unitless, range: 1900 – 2100 for max. accuracy)
List of files	
ZODIAC_MODEL	Zodiacal Data model file
ZODIAC_SPECTRUM	Zodiacal light spectrum file
BKGD_MODEL	GALEX NUV and FUV all sky data
BKGD_SPECTRUM	Diffuse background spectrum file
OUTPUT_FILE	Location and name of output fits file
STELLAR_SPECTRUM	Stellar models
CROSS_SEC	Drain's extinction model
STAR_CAT	Hipparcos Catalogue
FILTER_SPECTRUM	Filter response
WCS parameters for output FITS file	
XREFVAL	Galactic coordinate at the center
YREFVAL	Galactic coordinate at the center
XINC	Pixel size
YINC	Pixel size
ANGSIZE	Angular size
COORDTYPE	Projection type
GAL_COORD	Valid types are: -TAN, -STG, -SIN, -NCP, -ARC, -CAR, -MER, -AIT Flag for galactic coordinates(0=no, 1=yes)
Background parameters	
ANG_LIMIT	The number of degrees to smooth over (default value 3 deg.)
CSC_LAW	Cosecant law constant
Which elements to include	
ZOD_INC	Flag for including zodiacal light (0=no, 1=yes)
GAL_INC	Flag for including diffuse background (0=no, 1=yes)
STAR_INC	Flag for including star catalogue (0=no, 1=yes)

3. Run the code again to generate a desired output.

6 Program Operation

The program is modular and self-documenting. The steps are as follows:

1. **READ_PARAMS**: Read the parameters from the parameter file which has to named **diffuse_initparams.txt**. If this file does not exist, it will be created with a default set of parameters.
2. The output image data, stored in (**data**) array is defined by the WCS parameters as defined in the parameter file. We also define an array to hold the errors (**err**), the predicted galactic background (**diffuse_data**) and the predicted zodiacal light (**zod_data**).
3. The wavelength and spectral arrays for the zodiacal light are defined with **ZOD_SPEC** elements. The default value is 25763 elements for the solar spectrum, defined by Colina et al. (1996).
4. If **gal_inc** = 1 we calculate the diffuse sky background; otherwise the array is filled with zeros.
5. **CALC_BKGD_FLUX**: This module calculates the diffuse sky background. The inputs are the name of the background file (**bkgd_file**), the axes (**naxes**), the WCS parameters (**wcs_in**), the angle within which to include data (**ang_limit**) and k – the factor for the cosecant law (**csc_law**). The output parameters are the calculated backgrounds (**data**) and error (**err**) arrays.
 - (a) Begin by reading data into arrays. The maximum size of the array is set to **MAX_BKGD_ELEM** (100,000 by default).
 - (b) Convert coordinates into cartesian coordinates (x, y, z).
 - (c) Loop through all i and j in the array.
 - (d) Use **fits_pix_to_world** from *CFITSIO* to convert the i, j into galactic coordinates using the WCS.
 - (e) If the point is valid then convert it into cartesian coordinates (x_0, y_0, z_0).
 - (f) Run through all the input background points to find those within **ang_limit**.
 - (g) Add them together weighting by the square of the cosine of the angle.
 - (h) If there is no data nearby, fill the pixel according to the cosecant law:

$$val = \frac{k}{abs(\sin(b))}$$

where b is the galactic latitude and k is the cosecant law factor, specified in the input parameter file. $val = k$ at the poles ($abs(\sin b) = 1$).

6. Calculate the total background flux in the field.
7. If **zod_inc** = 1 we calculate the zodiacal light.
8. **ZOD_SPECT_READ** reads in the spectral dependence of the zodiacal light. The input is the name of the file and the outputs are the wavelength and spectrum.

9. **CALC_ZOD_FLUX**: This module calculates the zodiacal light with inputs of the name of the zodiacal distribution (**zod_file**), the time (**hour, day, month, year**), the axis definition (**naxes**) and the WCS parameters (**wcs_in**). All of these parameters are defined in the parameter file.
 - (a) Begin by reading the zodiacal light into an array. This is done using **ZOD_DIST_READ** which reads the distribution of the zodiacal light (**zod_dist**) and the ecliptic coordinate axes (**table_ecl, table_beta**) from the distribution file (**zod_file**).
 - (b) Calculate the position of the Sun from the observation date and time t_{UT} (UT). The Julian date is calculated from the time using the formula:
 if (month \leq 2) month=month+12; year=year-1;

$$JD = \text{Int}(365.25 \times \text{year}) + \text{Int}(30.6001 \times (\text{month}+1)) - 15 + 1720996.5 + \text{day} + \frac{t_{UT}}{24.0},$$
 where Int means the integer of the value.
 - (c) Equatorial coordinates of the Sun is calculated using the *libnova* routines.
 - (d) In the same manner as the galactic background, we step through all pixels (ix, iy)
 - (e) Use **fits_pix_to_world** to convert into galactic coordinates.
 - (f) If the point is valid, convert the galactic coordinates into ecliptic coordinates.
 - (g) Convert the ecliptic coordinates into helioecliptic coordinates (angle from Sun).
 - (h) Get the values for the zodiacal light from the table. Note that this is the scale value at 5000 Å.
10. Find the subscript for the observation value in the zodiacal light spectrum. This multiplied by the zodiacal light distribution will give the zodiacal light in photon units because the spectrum is scaled.
11. Calculate the total zodiacal light in the field.
12. If star_inc = 1 we add stars.
13. Read stellar data.
 - (a) The spectral type from the Hipparcos file is converted into a temperature T and surface gravity g as recommended in the STScI page¹. We assume that all the stars are main sequence with flux scaled to the observed magnitude.
 - (b) Read cross-sections from cross-section file.
 - (c) Read Hipparcos data.
 - (d) Convert spectral type into a Castelli model.

¹http://www.stsci.edu/hst/observatory/cdbs/castelli_kurucz_atlas.html

- (e) Scale the model flux to the magnitude at the Earth and correct for extinction by the function **CALC_FLUX**.

$$\text{scale} = 3.64 \times 10^{-9} \frac{10^{-0.4(V_{\text{mag}} - 3.2ebv)}}{vflux},$$

where ebv is $E(B - V)$.

- (f) Complete for all Hipparcos stars so that they are all read into memory.
 - (g) Begin reading locations from location file and process each location individually.
 - (h) Calculate x, y, z of position and find distance from star. The stellar flux is scaled by the square of the distance. Assume that the flux is extinguished by the distance times the average density.
 - (i) Loop over all the Hipparcos stars.
14. Calculate the total contribution of stars in the filed.
 15. Add together the zodiacal light and the galactic background.
 16. Write out the result as a FITS file.

7 References

- Draine, B. T. “Interstellar Dust Grains”, 2003, Ann. Rev. Astr. Astrophys., 41, 241-289
- Leinert, C., Bowyer, S., Haikala, L. K., 1998, Astron. Astrophys. Suppl., 127, 1
- Colina, L., Bohlin, R. C., & Castelli, F., “The 0.12-2.5 micron Absolute Flux Distribution of the Sun for Comparison With Solar Analog Stars”, 1996, AJ, 112, 307