
astrodata Tutorial

Release 0.1

Gemini

June 04, 2010

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1 Gemini Astrodata

1.1 Introduction to Astrodata

Astrodata is a module in Python designed to handle sets of astronomical data as a single unit. Currently Astrodata only supports data in Multi-extension FITS files (MEF) coming from the Gemini instruments. The goal is to provide an interface for the non-professional programmer to easily access FITS header values and data in a way that is non instrument dependent.

1.2 Intended Audience

If you have not seen Python you could start with Example 1 for an introductory examples of Astrodata usage.

If you know IDL already, then you could quickly become familiar with Python as the syntax is very similar, with a noticeable exception that Python does not use curly braces nor ‘begin’ or ‘end’ but rather relies on blocks of statements.

1.3 Required software

To use this tutorial you need some modules that are part of the default Python distribution: the Astrodata module is available internally via the Gemini DPD group; the Numpy module is also needed for numerical array calculation and

it might be part of your Python installation.

1.4 Tutorial

1. *Example 1: Python and Astrodata beginners example.*
2. *Example 2: Getting information from list of GEMINI FITS file.*
3. *Example 3: ADUtoElectrons scripts under Astrodata.*
4. *Line by line explanation of Example 3*

1. Example 1: Python and Astrodata beginners example.

This is an interactive Python session with separate commands that give you results right at the terminal.

```
# Starting PYTHON in unix and MacOS.
#
# Astrodata module needs to be visible to Python via the
# unix environment variable PYTHONPATH. Please append a
# pathname to this variable where Astrodata is located in
# your machine.
#
# Example: setenv PYTHONPATH ${PYTHONPATH}:/home/user/soft/astrodata
#
# Now start 'ipython', (a better python shell) and try these commands.

ipython

from astrodata import AstroData          # Load Astrodata module
import numpy as np                       # Load the numpy module and define an alias 'np'

file = 'N20020214S060.fits'             # Define a variable 'file' with a string.

ad = AstroData(file)                    # Open the FITS file using Astrodata
                                         # 'ad' is the Astrodata object. 'ad' is just
                                         # a variable name.
                                         # The default mode is READ_ONLY
                                         # Astrodata support 'new' mode as well

ad.info()                               # Get FITS file information. This notation is python
                                         # syntax stating that one of the function of the object
                                         # 'ad' is info(). For a list of all 'ad' functions i
                                         # please type 'dir ad'.

print ad.info()                         # Same as above. 'print' is optional in most cases using
                                         # the python interpreter.

help ad.info                            # Get help on the 'info' function
help(ad.info)                           # (Same) Get help on the 'info' function
                                         # The parenthesis are mostly optional using the
                                         # python interpreter. If you are using PYRAF,
                                         # these are required.

# Astrodata descriptors

ad.getTypes()                           # Will list the different Astrodata types that this
```

```

# Gemini FITS file has. As the data goes through different
# processing stages, these values will change.

ad.isType('GMOS_IMAGE')      # Boolean function. True is the data file is of type
                             # 'GMOS_IMAGE'

# FITS pixel data with Astrodatab

data = ad[0].data            # Get the first extension pixel data and assign it to
                             # the variable 'data' containing the pixels array.
                             # 'ad' is a Python list pointing to FITS extension
                             # header and data; hence 'ad[0]' points to the first
                             # extension, 'ad[1]' to the second, etc.

dim = np.shape(data)         # Get array dimensionality. Parenthesis are not needed.
                             # Store the values in 'dim'. Here parenthesis are necessary
                             # when you are assigning to a variable.

dim                           # show the values. You can also use 'print dim'

np.median(data)              # Calculates the median of the pixels in the 'data' array.
                             # 'np.median' means 'get the median function from the
                             # numpy (np) module and use it with the data array'

np.median(data[100,:])       # Calculates the median of row 100.
                             # In Python the array order is [y,x] (IDL is [x,y]).
                             # ':' means all the pixels in the row

np.std(data)                 # Get the standard deviation
help np.std                  # see what the help section says about it

maxval = np.amax(data); minval = np.amin(data)  # 2 commands in one line(separator is ';')

dir ad                       # See all the functions available with the
                             # object 'ad' associated to the FITS file.

# FITS HEADER with Astrodatab

hdr = ad[0].header           # Get 1st extension header
hdr.items()                  # list keywords with their values
hdr['crpix1']                # print keyword value (case insensitive)

phu = ad.getPHUHeader()      # Get Primary Header Unit (note the ()); it's a function)
phu.items()                  #
phu['datalab']               #

```

2. Example 2: Getting information from list of GEMINI FITS file

This example is a Python script written into a text file which you can run at the Unix prompt or as a single command in the Python Shell.

Running from Unix

Notice that this file contains one function called 'list_info' and that the first line is '#! /usr/bin/env python' telling the UNIX system to use the Python interpreter to execute the rest of the script. This happens when you type 'list_FITS_info.py' at the unix prompt.


```

print ad.camera()                # Show the value of the PHU keyword 'CAMERA'

print ad.ad.exposure_time()      # This is the actual EXPTIME*NCOADDS value

print ad.filter_name()           # Filtername is a unique string discribing
                                # the filter for the instrument.

print ad.instrument(), ad.object(), ad.ut_date()    # Header keyword values

if ad.isType('GMOS'):
    if nctxs > 0:
        print "GAIN:", ad.gain(asList=True)        # print a list of gains
        # Based on the value of the PHU keywords MASKTYPE, MASKNAME
        # and GRATING, the followinf values can be inferred:
        # IMAGE, IFU, LONGSLIST or MOS.
        print "OBSMODE:", ad.observation_mode(), '\n'

    if ad.isType('NIRI'):
        print 'NIRI FILTER header keywords:', \
            # this next form is a Python 'list comprehension' syntax. It is
            # a compressed 'for loop'.
            [(ff+'='+ad.getPHUHeader()[ff]) for ff in ad.rePHUKeys('FILTER\w*')]
        print 'From niri.descriptor:', ad.filter_name()
        print 'Non Linear value:', ad.non_linear_level()

if __name__ == "__main__":
    list_info()

```

3. Example 3: ADUtoElectrons scripts under Astrodata.

In order to run this example you need to have:

- Python installed in your machine
- Astrodata module. If you don't, please ask somebody from Kathleen group.
- Some GMOS data

To run the example in your UNIX shell please do:

```

# These are Unix commands
chmod u+x adu2electron.py          # Give execute mode
adu2electron.py gmos1.fits gmos2.fits  # 2 input FITS files

```

Please copy and paste this example into a file 'adu2electron.py'

```

1  #!/usr/bin/env python
2
3  import astrodata as ad
4  from astrodata.AstroData import prepOutput
5  from copy import deepcopy
6
7  def ADUtoElectron(filelist, oprefix):
8      """
9          This is a function to convert the ADU counts to electrons
10         by multiply the pixel values by the gain.
11         """

```

```

12
13     # Loop through the files in filelist
14     for filename in filelist:
15
16         # Open the file as an AstroData object
17         adinput = ad.AstroData(filename, mode='readonly')
18
19         # Verify whether the data has already been converted to electrons
20         if adinput.phuValue('ELECTRON') != None:
21             print "WARNING: File %s has already been converted to electrons" % filename
22             print "      Skipping file."
23             continue
24
25         # Prepare a new output
26         #     Propagate PHU and MDF (if applicable) to output.
27         #     No pixel extensions yet.
28         #     Set output file name.
29         #     No overwrite allowed. (default mode for prepOutput)
30         #
31         # prepOutput copies the adinput PHU and set the name of the new
32         # file represented by adout to outputname.
33
34         outputname = oprefix + filename
35         adout = prepOutput(adinput, outputname)
36
37         # Get the gain values to apply
38         # adinput.gain() returns a list, one value for each science extension.
39
40         gain = adinput.gain(asList=True)
41
42         # Multiply each science extension by the gain.
43         # Append new extension to already prepared output.
44         # Use the deepcopy function to create a true copy and ensure that
45         # the original is not modified.
46
47         adc = deepcopy(adinput)
48         for extension,g,xn in zip(adc, gain, range(len(gain))):
49             extension.data = extension.data * g
50             adout.append(data=extension.data, header=extension.header)
51
52         # Update PHU with timestamps
53         adout.phuSetKeyValue('ELECTRON', fits_utc(), comment='UT Modified with convertToElectrons')
54         adout.phuSetKeyValue('GEM-TLM', fits_utc(), comment='UT Last modification with GEMINI')
55
56         # Write to disk. The filename was specified when prepOutput was called.
57         adout.write()
58
59         # Close files
60         adout.close()
61         adc.close()
62         adinput.close()
63
64     # FITS.UTC -- local function definition
65     import time
66
67     def fits_utc():
68         """
69         Return a UTC string in FITS format: YYYY-MM-DDThh:mm:ss

```

```

70     """
71
72     gmt = time.gmtime()
73     fitsT = '%d-%02d-%02dT%02d:%02d:%02d' % gmt[:6]
74
75     return fitsT
76
77 if __name__ == "__main__":
78
79     import optparse
80     VERSION = '1.0'
81
82     # Parse input arguments
83     usage = 'usage: %prog [options] file1 .. fileN'
84     p = optparse.OptionParser(usage=usage, version='v'+VERSION)
85     p.add_option('--oprefix', '-p', action='store', dest='oprefix', default='elec_',
86                 help='Prefix for the output files')
87
88     (options, args) = p.parse_args()
89
90     ADUToElectron(args, options.oprefix)

```

4. Line by line explanation of Example 3

Line 1: `#!/usr/bin/env python`

If you want to run the Python script as a Unix command, this statement tells the UNIX shell that indeed is a Python program and loads the interpreter.

Line 3: `import astrodata as ad`

```
from astrodata.AstroData import prepOutput
```

Python modules that are not part of the default installation need to be loaded using some of these constructions. `'import astrodata as ad'`: Will look at the directory 'astrodata' and executes the file `'__init__.py'` creating a shorter name 'ad' as an alias. `'from astrodata.AstroData import prepOutput'` will load the module 'AstroData.py' and loads the function 'prepOutput' The pathname to this directory needs to be accessible via the environment variable PYTHONPATH.

Line 7: `def ADUToElectron(filelist, outprefix, verbose)`

This is the function definition, its name is 'ADUToElectron'. When calling it you must give the one or more filenames in a list and the output prefix for the output files as a string, verbose is a True/ False argument.

Line 14: `for filename in filelist:`

The first line is a DO loop statement. It will take each element of 'filelist' and put the value in 'filename'.

Line 17: `adinput = ad.AstroData(file, mode='readonly')`

We use the function 'AstroData()' from the module 'AstroData.py' that was loaded when we imported in Line 3. This is the starting point of the 'astrodata' usage. We are opening a file and returning a list of Astrodata (iterable) and functions. To see a list of these functions please type 'dir adinput' in your Python shell. For help on any: 'help adinput.phuValue'

Line 20: `if adinput.phuValue('ELECTRON') != None:`

This function looks for the value of the PHU (primary header unit) keyword 'ELECTRON'; if there is no such keyword, it returns the value 'None'.

Line 35: `adout = prepOutput(adinput, outputname)`

This function returns an AstroData object with the PHU of the input file. The output filename will be 'outputname'.

Line 40: `gain = ad.gain(asList=True)`

The fits file opened has gain information in each of the EHUs (extension header unit). This command returns a python list with those values. It assumes that the keyword name is 'GAIN'.

Line 47: `adc = deepcopy(adinput)`

Make a new copy of the input Astrodata object; we do not want to change the input data in memory.

Line 48: `for extension,g,xn in zip(adinput, gain, range(len(gain))):`

This is a compound Do loop statement of the form 'for VARS in LIST'. The 'zip' function takes as arguments one or more Python lists and returns a list of tuples, with one element at a time. For example: `zip([1,2],['a','b'])`, returns [(1, 'a'), (2, 'b')]. The function 'range(n)' takes an integer and expands it into an increasing sequence from 0..n-1.

The VARS will then contain one set of tuples at a time.

Line 49: `extension.data = extension.data * g`

'extension' is a python object containing the pixel area data among other things. we just replace those values with the new ones. This is a memory operation and does not affect the input file.

Line 50: `adout.append(data=extension.data, header=extension.header)`

We now append a new FITS extension to the output file with its data and header.

**Line 53: `adout.phuSetKeyValue('ELECTRON', fits_utc(), \`
`comment='UT Modified with convertToElectrons')`**

Appends the indicated keyword to the PHU; its value is the value of the function 'fits_utc()' defined at the end of the Example. Notice that Python allows for a statement to be broken in different lines; mostly a comma is a good line separator.

Line 57: `adout.write()`

Writes to disk the updated output AstroData object. The filename was already defined in 'prepOutput()'