DP Scripting

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Introduction

- DP Scripting is based on Python
  - Jython, the Java equivalent of C-based Python
  - HCSS/HIPE includes an implementation of Jython 2.5

- Only a few language features needed to get going
  - Java is not required – use scripting to glue together the provided Java modules from the pipelines, PlotXY, or the Numerics library
  - *It is fine to write "quick-and-dirty", procedural code in Python. Object-oriented code is not required*
  - Many elements are specific to HIPE so advanced Python features aren't needed

- Python resources in the HIPE documentation contain most of what is needed
  - See the Scripting and Data Mining Manual

Outline

- Selected Python features (core language features, usable in Jython or C-based Python)
  - Lists and indexing
  - Tuples and dictionaries
  - Import statements
- Data structures/objects hierarchy (simple to complex)
  - Numeric arrays and methods
  - TableDatasets
- Common pitfalls
  - Assignment of array variables – not the same as a copy
  - Unintended copies of large objects

Variables

- No ‘data-typing’ or declaration needed
- Assignment:

```
a = 1
b = 2
```

- Strings can use single or double quotes:

```
c = “hello world”
e = ‘hi there’
```

More Python basics

- The comment character is the pound sign

```
# this is a comment
```

- The continuation character is the backslash

```
x = a + b + \
       c * d * e
```

- A formatted string uses C-style format characters and the percent sign

```
print "integer = %d, real = %f" %(j,x)
```

- Print to an ascii file

```
fh = open('myoutput.txt','w')
print >> fh, "integer = %d," %j
fh.close()
```

Lists

- Lists are very general and powerful structures
- Easy to define, and the members can be anything:
  `x = [1, 2, 'dog', "cat"]`
- Appending or removing items is easy:
  `x.append(5)`
  `x.remove('dog')`
- Empty list
  `z = []`

Tuples and Dictionaries

- Tuples are just like lists – except they can't be modified:
```
d = ('one', 'two', 'three')
```

- Dictionaries give names to members
```
wavel = {'PSW':250, 'PMW':350,\
        'PLW':500}
```

- Easy to add members
```
wavel['pacsred'] = 160
print wavel['PSW']
```

Conditional Blocks

- Syntax:

```
if condition1:
    block1
elif condition2:
    block2
else:
    block3
```

- Notice that blocks are denoted by *indentation only*
- Example in SPIRE large map pipeline scripts:

```
if pdtTrail != None and \
    pdtTrail.sampleTime[0] > pdt.sampleTime[-1]+3.0:
          pdtTrail=None
          nhktTrail=None
```

For Loops

- Syntax of a for loop:
```
for var in sequence:
  block
```
- The *sequence* can be any list, array, etc.
  Example from pipeline scripts:
```
for bbid in bbids:
    block=level0_5.get(bbid)
    print "processing BBID="+hex(bbid)
```
- The `range` function returns a list of integers. In general `range(start,end,stepsize)` where *start* defaults to 0 and *stepsize* to 1.
```
print range(5)
# [0, 1, 2, 3, 4]
```
- The `range` function can be used to loop for an index:
```
for i in range(20):
```

Indexing and Slicing

- Any *sequence* (list, string, array, etc.) can be indexed
  - zero is the first element
  - negative indices count backwards from the end

```
x=range(4)  # [0, 1, 2, 3]
print x[0] # 0
print x[-1] # 3
```

- A slice consists of *[start:end:stride]* in general. *Start* defaults to 0, *end* to last, *stride* to 1. Examples:

```
print ss[:2] # ['a', 'b']
print ss[::2]  # [‘a’, ‘c’]
print ss[::-1] # [‘d’, ‘c’, ‘b’, ‘a’]
```

Functions

- Functions are defined by *def* statement plus an indented code block:

```
def square(x):
  result=x*x
  return(result)
```

- Optional arguments are given default values in the definition:

```
def myfunc(x,y=1.0,verbose=True):
  z = x*x + y
  if (verbose):
    print "The input is %f %f and"+\
     " the output is %f" %(x,y,z)
  return (x,y,z)
```

- Arguments are passed by value – the names in the *def* statement are local to the body of the function

Import statements

- `import` makes Jython modules or Java packages available to your session or script
- First form uses full names:

```
import herschel.calsdb.util
print herschel.calsdb.util.Coordinate
```

- Second form puts name in your session

```
from herschel.calsdb.util import Coordinate
```

- Third form includes all

```
from herschel.calsdb.util import *
```

Many imports are done for you

- HIPE imports many packages on startup
- "jylaunch" (for batch mode) does too

- When writing modules or plugins, explicitly import everything you need

- No cost for importing a module that was imported previously

Commands can be run in the background

- Use the bg function with your command inside a string

```
bg('scans=baselineRemovalMedian(obs.level1)')
```

- Right-click on a script in Navigator to run in background

```
HIPE> bg('execfile("~/jyscripts/bendoSourceFit_v0_9.py")')
Started: execfile("~/jyscripts/bendoSourceFit_v0_9.py")
Finished: execfile("~/jyscripts/bendoSourceFit_v0_9.py")
```

Hierarchy of data structures (partial list)

- Numeric arrays
- *Array Datasets*
- TableDatasets
- Products (e.g. DetectorTimeline)
- *Context Products – not covered here*

The items lower on this list, are containers of the items one level above

Numeric arrays

- In the `herschel.ia.numeric` package
- Separate classes for data type and dimension
  - Float1d, Float2d….Double1d, Double2d…Int1d, Int2d…,Long1d, Long2d….Bool1d, Bool2d….etc
- Several ways to initialize:

```
z = Double1d(10) # [0.0, …, 0.0]
z = Double1d.range(10)#[0.0,1.0,…9.0]
z = Double1d([1,2,3]) # list
z = Double1d(range(10,20))
```

Numeric functions

- Basic functions are in `herschel.ia.numeric.toolbox.basic`
  - double->double array-to-array functions: **`ABS, ARCCOS, ARCSIN, ARCTAN, CEIL, COS, EXP, FLOOR, LOG, LOG10, SIN, SORT, SQRT, SQUARE, TAN`**
  - Array functions returning a single value **`MIN, MAX, MEAN, MEDIAN, SUM, STDDEV`**
- Advanced functions for filtering, interpolation, convolution, fitting, etc. in other `herschel.ia.numeric.toolbox` packages

Numeric arrays cont'd

- For 1d, slicing/indexing is the same as Python lists
- For 2d+ arrays, dimensions are set off by commas
  - E.g. array3d[k,j,i]
  - The "fastest" index is the last
    - Same ordering as C, C++, Java, other languages
    - opposite ordering as Fortran, IDL
- Tips to improve performance
  - Avoid looping over array indices
  - Take care not to create too many temporary copies of arrays (more on this later)

TableDatasets

- TableDatasets gather Numeric arrays with units

```
x = Double1d.range(100)
tbl = TableDataset(description="test table")
tbl["x"]=Column(data=x,\
 unit=herschel.share.unit.Duration.SECONDS)
tbl["sin"] = Column(data=SIN(x))
```

- Access

```
print tbl["x"].unit
print tbl["x"].data[4] #5th element of data
```

- Easily visualized with TablePlotter

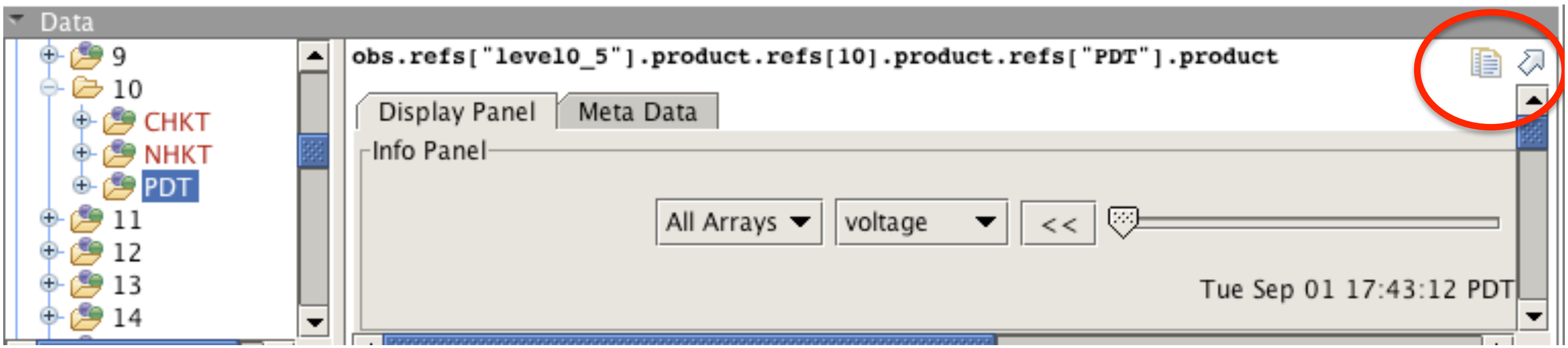
Products

- Products are the containers of Datasets
- Every Product has a 1-to-1 correspondence to a FITS file (but there are caveats on usability)
- Datasets are added and referenced by name:

```
prod = Product()
prod[“signal”] = tbl
print prod[“signal”][“x”].unit
p=PlotXY(pdt[‘voltage’][‘sampleTime’].data,\
     pdt[‘voltage’][‘PSWE4’].data)
```

Learn from the GUI

- Many Views and Tasks execute commands in the Console
  - Copy and paste into scripts when useful
- After opening up a compound object in a viewer, copy and paste the expression that accesses the piece you want



Listing methods with the **`dir`** function

- The dir function lists the methods specific to a given class

```
print dir(variable.__class__)
```

- In HIPE it is reachable from right-click on variable, “Show methods”

Avoiding common pitfalls

Assignment of array is not a copy

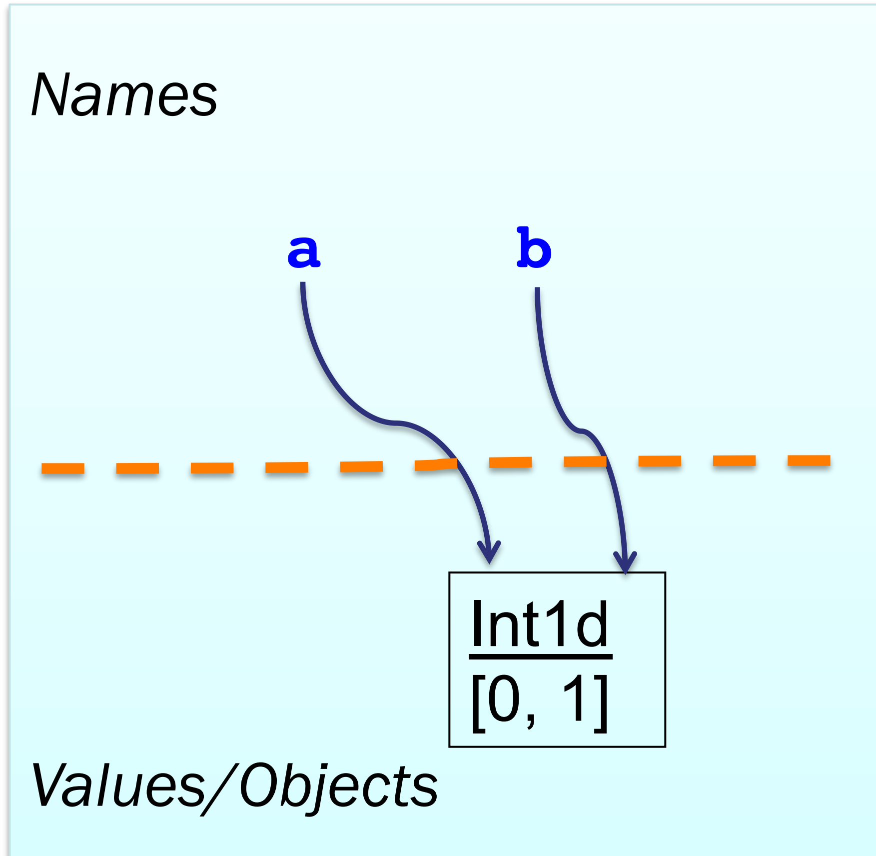
- Simple example:

```
a = Int1d.range(2)
print a
# [0, 1]
b = a
b[0] = 5
print b
# [5, 1]
print a
# [5, 1] ????
```

- What happened? Assignment is "by value". What is the value of **a**? It is an object which is an instance of the Int1d class. Then **b=a** binds the name **b** to the same object to which **a** is bound.

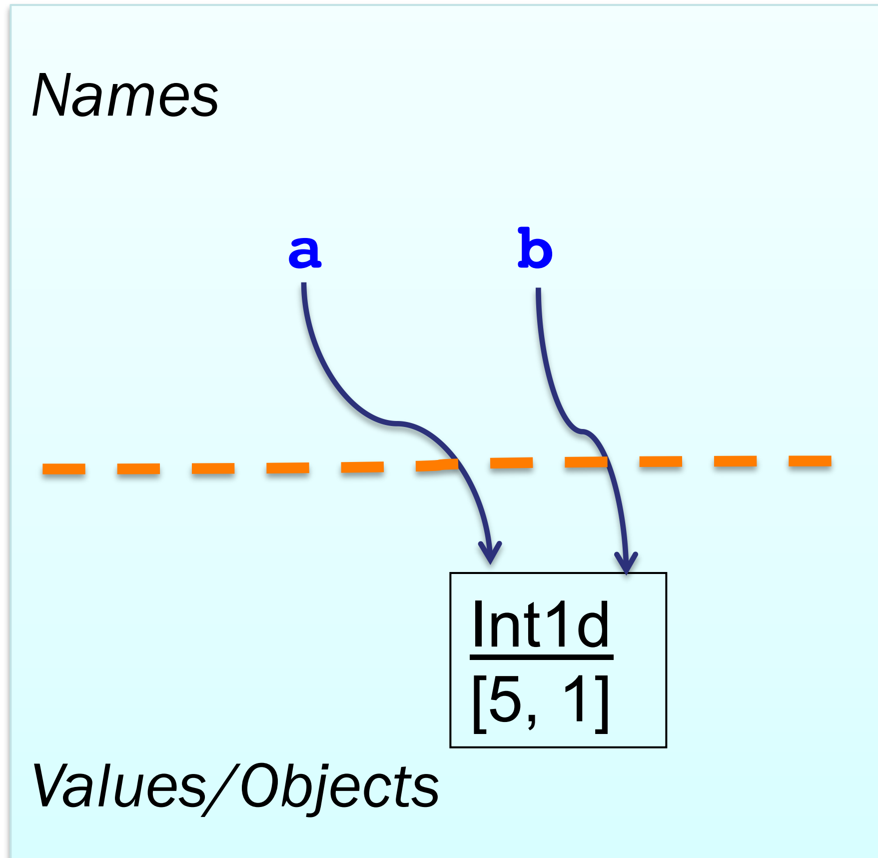
A useful visualization

- Do not think of variables as physical locations in memory
- Variables are *names* that are *bound* to *objects*
- The drawing shows the state after:
  `b = a`



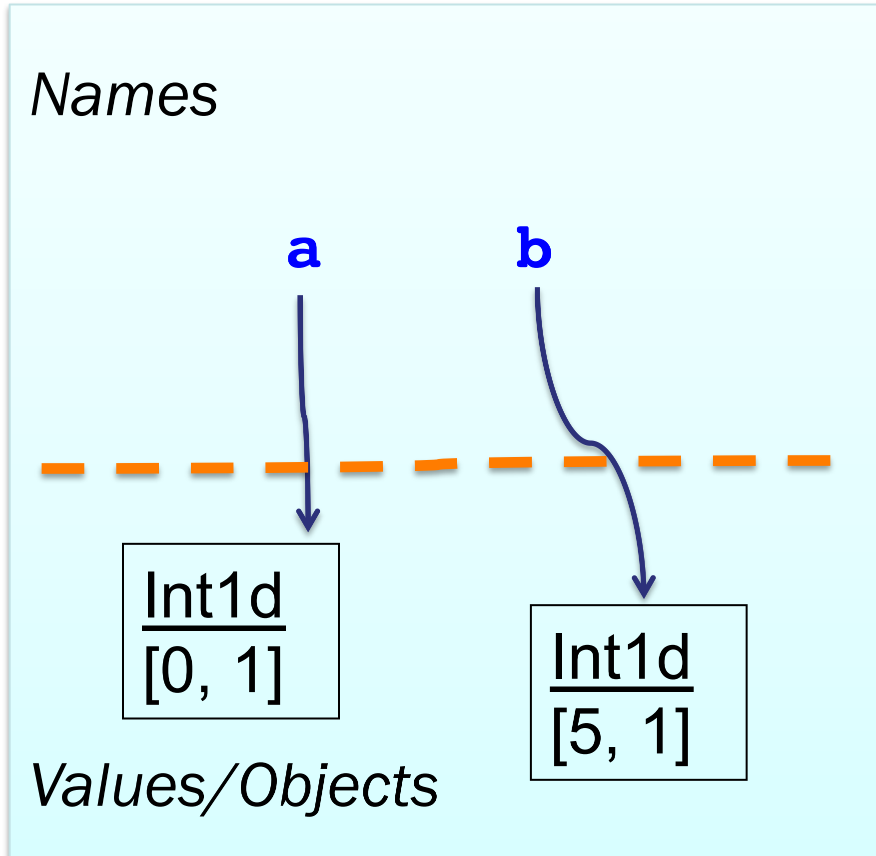
What does `b[0] = 5` really do?

- The line
  `b[0] = 5`
  is equivalent to
  `b.__setitem__(0,5)`
  which is a *method* of our object, that modifies a single element
- Our two variables are still bound to the same object



How do I get a new array object?

- For a new copy of the array object, do
  `b = a.copy()`
- This also works:
  `b = Int1d(a)`
- The diagram at right shows the state after
  `b[0] = 5`



Automatic creation of arrays

- Another example:

```
a = Int1d.range(2)
print a
# [0, 1]
b = a
b = b + 5
print b
# [5, 6]
print a
# [0, 1]
```

- What happened? At `b + 5` a new array was automatically created to hold the sum of **b** and 5. Then the name **b** was bound to this new array object. **a** was left unchanged.

In-line operations

- A changed example:

```
a = Int1d.range(2)
print a
# [0, 1]
b = a
b += 5
print b
# [5, 6]
print a
# [5, 6]
```

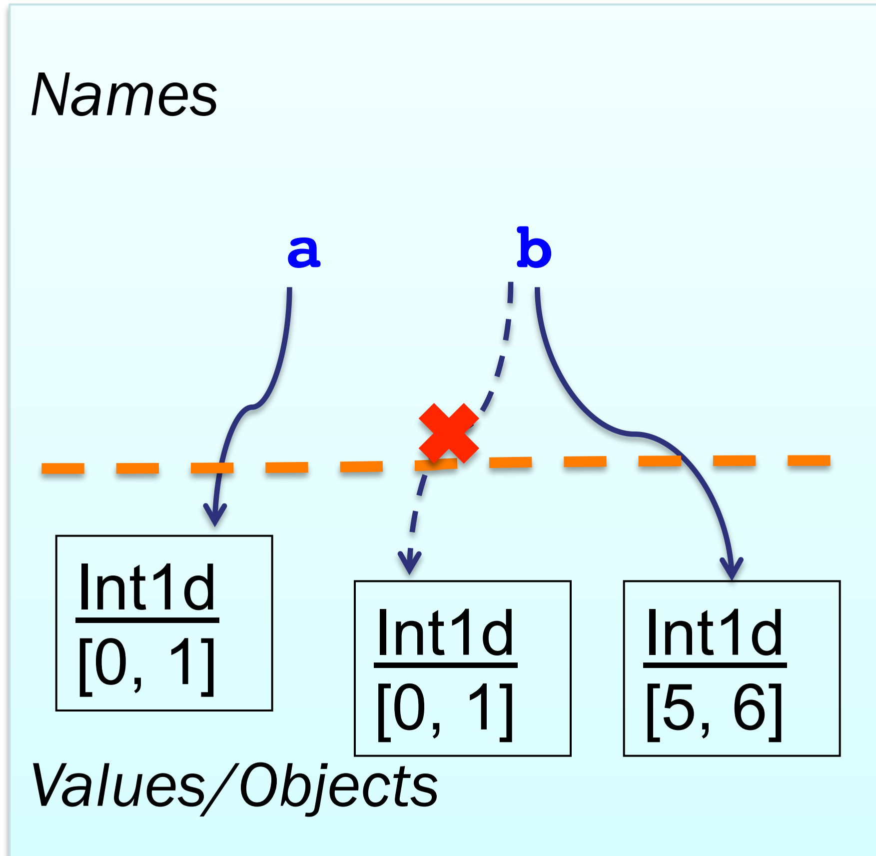
- What happened? At **`b += 5`** the in-line operator **`+=`** means that the operation is done in place – no new copy is made of the object to which **`a`** and **`b`** are bound.
- Saves memory

Garbage collection

- A related example:

```
a = Int1d.range(2)
b = a.copy()
b = b + 5
```

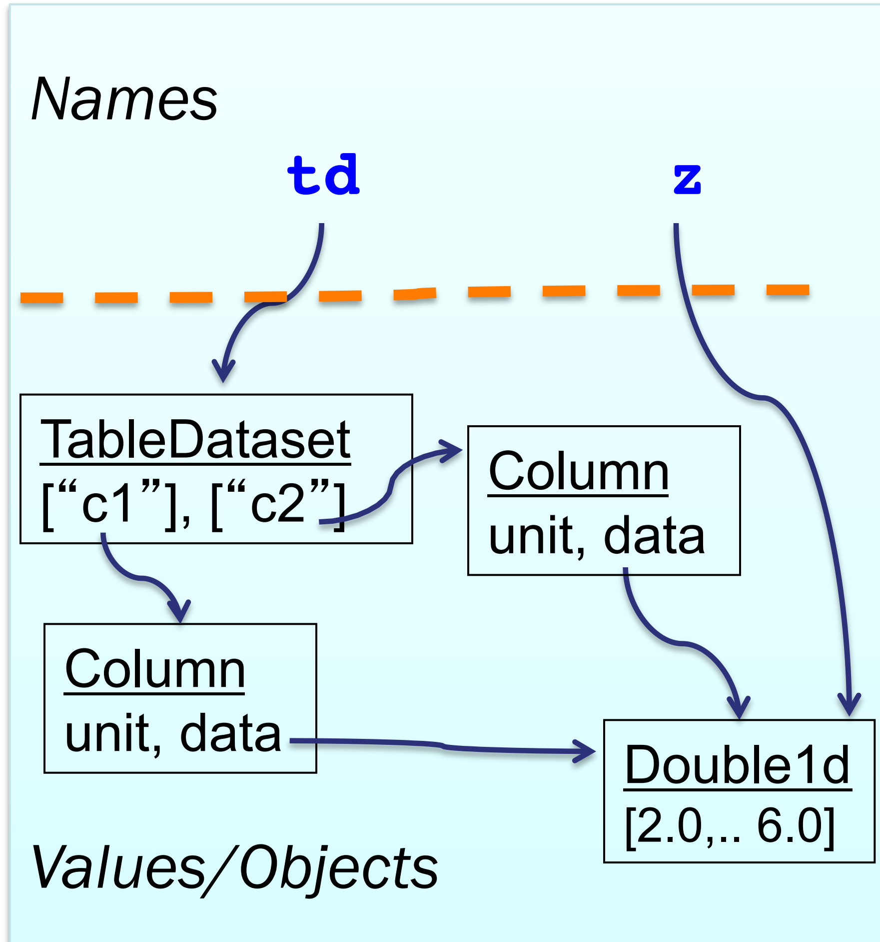
- For a time, three array objects are taking up memory
- What happens to the first copied array? Eventually the *garbage collector* frees up the memory



Changes inside higher-level products

- Another example:

```
z=Double1d.range(5)
td=TableDataset()
td["c1"]=\
  Column(data=z)
print td["c1"].data
#[0.0,1.0,2.0,3.0,4.0]
z += 2
td["c2"]=\
  Column(data=z)
print td["c1"].data
#[2.0,3.0,4.0,5.0,6.0]
```



Avoiding temporary copies of arrays

- Assume we have three large arrays named
  `x, y, c`
  and we want to compute
  `y = (x + SIN(y))/c`
- As typed above, some temporary arrays are made, then discarded
- Can greatly increase memory usage

- Here's a way to do it with in-line operations, making no array copies.

```
y.perform(SIN)
y += x
y /= c
```

- The **`y.perform`** does an in-place operation. **`y.apply(SIN)`** makes a copy, like **`SIN(y)`**

Reference slides

Advanced topics....

List comprehensions

- List comprehensions are a shorthand for writing a loop that appends to a list

```
print [x*x for x in range(10)]
# [0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

- The above is short for:

```
list = []
for x in range(10):
  list.append(x*x)
print list
```

- Handy for converting any sequence into a list
- For numerical calculations, it is more efficient to use the Numeric functions

Context Products

- Context Products are the containers of Products
  - More precisely, contains references to products
  - Not understandable outside HIPE/HCSS
- Two flavors of Context Product:
  - Map Context – maps keys/names to product refs

```
mc = MapContext()
mc.refs["prod1"] = ProductRef(prod))
p = mc.refs["prod1"].product
```

  - List Context – ordered list of Products

```
lc = ListContext()
lc.refs.add(ProductRef(prod))
p = mc.refs[0].product
```

Building up complex products

- Array => TableDataset => Product => Context:

```
x = Double1d.range(100)
table = TableDataset()
table["col1"] = Column(data=x)
prod = Product()
prod["error"] = table
mcontext = MapContext()
mcontext.refs["unc"] = \
     ProductRef(prod))
```