Scripting in HIPE

Miguel Sánchez-Portal

HSC, ESAC

Introduction

- HIPE Scripting is based on Jython
  - Jython is a Java implementation of the Python language.
  - Partial implementation of Jython 2.5 (Python is currently in v3.x)
  - For more information on the Python language, please visit http://www.python.org/doc/

- Only a very basic knowledge is required. For instance:
  - You don't need to write object-oriented code
  - 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 document (HERSCHEL-HSC-DOC-0517) in the Help system.

- *Acknowledgements: this presentation is largely based on material kindly provided by D. Shupe (NHSC)*

Outline

- Some Python basics (core language features, usable in Jython or C-based Python)
  - Variables and other basics (e.g. basic I/O)
  - Lists
  - Blocks, Loops, indexing
- Data structures/objects hierarchy (simple to complex)
  - Numeric arrays and methods
  - TableDatasets
- An example (try it as homework!)

Basic Python concepts – Variables

- No 'data-typing' or declaration needed
- Assignment:

```
a = 1 #this is a comment
# Check the variable class (in this case a PyInteger)
print a.__class__
b = 2.0 # now a PyFloat
```

- Strings can use single or double quotes:

```
c = 'hi there'
e = "I can use 'single quotes' here"
```

Boolean:

```
d = Boolean(0) # Java boolean
```

Numeric variable types

- Jython types:
  - *Integer:* a = 3
  - *Long integer*, denoted by the l or L suffix: a = 3L
  - *Float:* a = 3.0
  - *Complex:* a = (3 + 1j)
- Java numeric types available to Jython:
  - *Byte:* signed 8-bit integer → a=Byte(0).
  - *Short:* signed 16-bit integer → a=Short(0).
  - *Integer:* signed 32-bit integer → a=Integer(0).
  - *Long:* signed 64-bit integer → a=Long(0).
  - *Float:* single-precision 32-bit floating point → a=Float(0).
  - *Double:* double-precision 64-bit floating point → a=Double(0).
  - *Boolean:* either true or false → a=Boolean(0) (or a=Boolean(False))
- Caveat: sometimes, Jython and Java types don't mix well. Check Section *1.4. Type conversions* of the *Scripting manual* for a description

More Python basics

- The comment character is the hash 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()
```

More I/O, and a first example


```
import os #import the Python module "os"

# Open the file
myFile=open("/Users/msanchez/hcss_work/funnytest.txt", "w")

# Print class
print myFile.__class__

# Print available methods
print dir(myFile.__class__)

# Write two lines to the file. Observe the LF character at the end
# of the string
line="%07.2f %07.2f %07.2f %07.2f\n" % (902.42123456, 1044, 920.90, 1043.96)
myFile.write(line)
line="%07.2f %07.2f %07.2f %07.2f\n" % (9999.01, 1050.29, 30.90, 666.66)
myFile.write(line)

# Don't forget to close the file!!
myFile.close()

#This is an example of invoking a "shell" command from your HIPE script…
os.system("cat /Users/msanchez/hcss_work/funnytest.txt")

# Reading the file "HIPE style"
ascii=AsciiTableTool()
ascii.parser=CsvParser(skip=0,delimiter=' ')
ascii.template=TableTemplate(4, \
names=["val1", "val2", "val3", "val4"], \
types=["Double", "Double", "Double", "Double"], \
units=["pixel", "pixel", "pixel","pixel"])
myTable=ascii.load("/Users/msanchez/hcss_work/funnytest.txt")

# But, what's myTable?
print myTable.__class__

# We'll see more about datasets, and specifically about table datasets
# Just as an example, retrieving the values in the first column of our file
print myTable.getColumn("val1").getData()
```

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')
print a.__len__() # length of the array
```
- Listing available methods to a class:
```
print dir(a.__class__)
```
- Empty list
```
z = []
```
- "Java-style" lists: ArrayList: also flexible to store whatever you want:
```
myList=ArrayList()
myList.add(1.0)
myList.add(2.0)
myList.remove(1.0)
```

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):
```

while, break and continue

- while loop syntax:

```
while condition:
   block
```

- The break statement breaks out of the smallest enclosing for or while loop.
- The continue statement continues with the next iteration of the loop.
- The pass statement does nothing. It can be used when a statement is required syntactically but the program requires no action:

```
results=browseProduct(ps)
while results.size()==0:
  pass
```

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 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 (use with caution!)**

```
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

Hierarchy of data structures (partial list)

- Numeric arrays
- *Array Datasets*
- TableDatasets
- Products (e.g. DetectorTimeline)
- *Context Products*

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

```
whatsThat=[[1,2,3],[4,5,6],[7,8,9]]
#
print whatsThat.__class__
org.python.core.PyList

myArray=Double2d(whatsThat)
#
print myArray.__class__
herschel.ia.numeric.Double2d
#
print myArray
[
[1.0,2.0,3.0],
[4.0,5.0,6.0],
[7.0,8.0,9.0]
]
# Print "column 0" of the array
print myArray[:,0]
[1.0,4.0,7.0]
# Print "Line 1" of the array
print myArray[1,:]
[4.0,5.0,6.0]
```

Datasets

- Dataset attributes: description+ data (arrays)+metadata
- Array Data set:

```
x = Double1d.range(10)
s = ArrayDataset(data=x,description="range of double values")
```

- 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

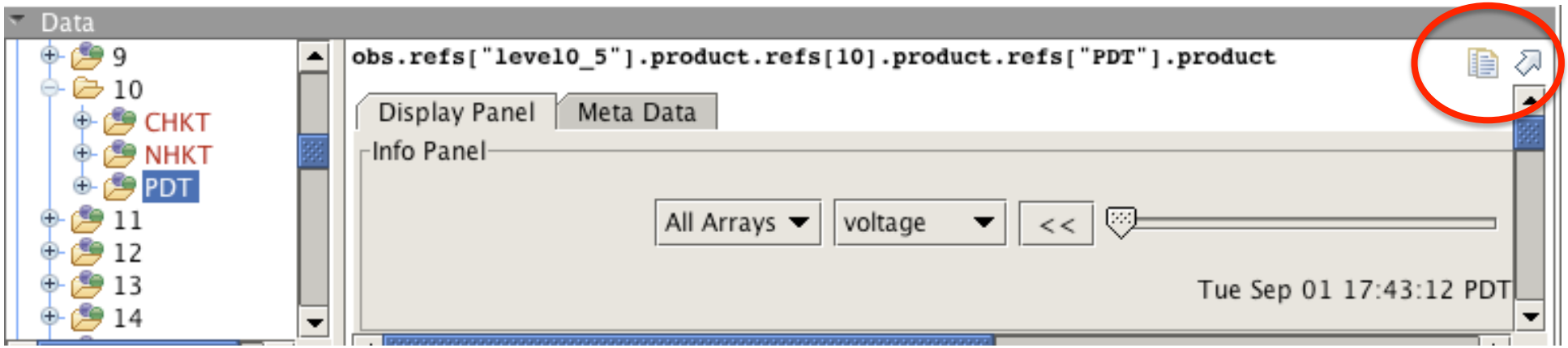
Products

- 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 a compound object in a viewer, copy and paste the expression that accesses the piece you want



Avoiding common pitfalls

Assignment of array is not a copy

- Simple example:

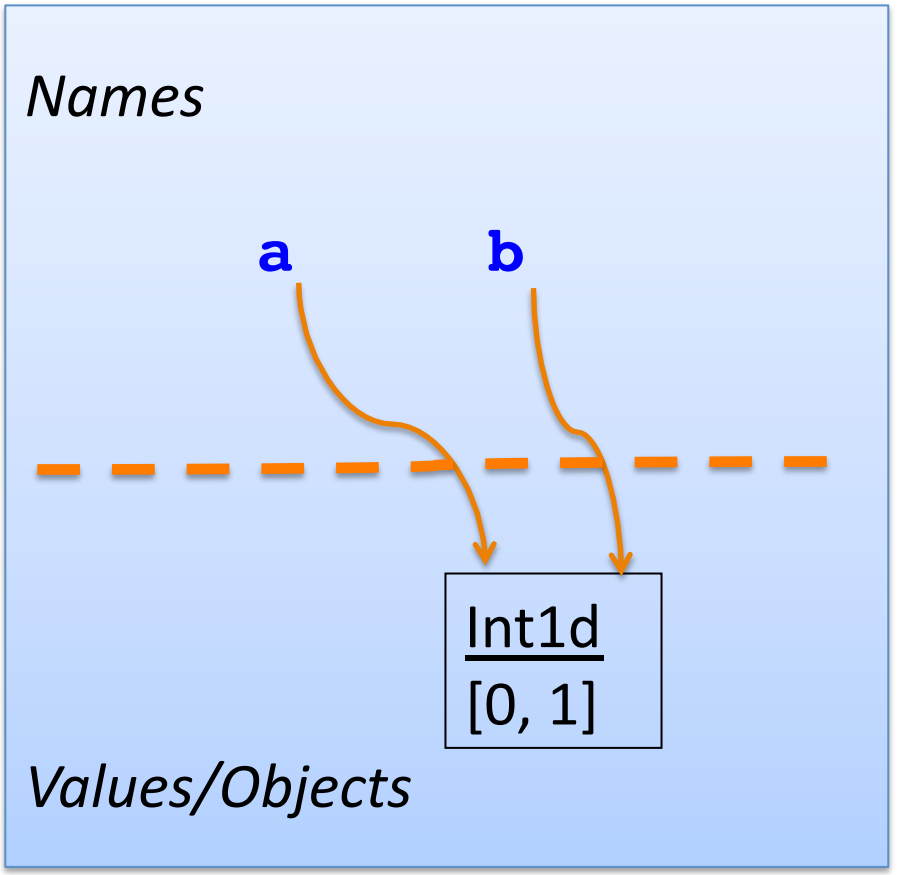
```
a = Int1d.range(2)
print a
# [0, 1]
b = a
b[0] = 5
print b
# [5, 1]
print a
# [5, 1] ????
```

- 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

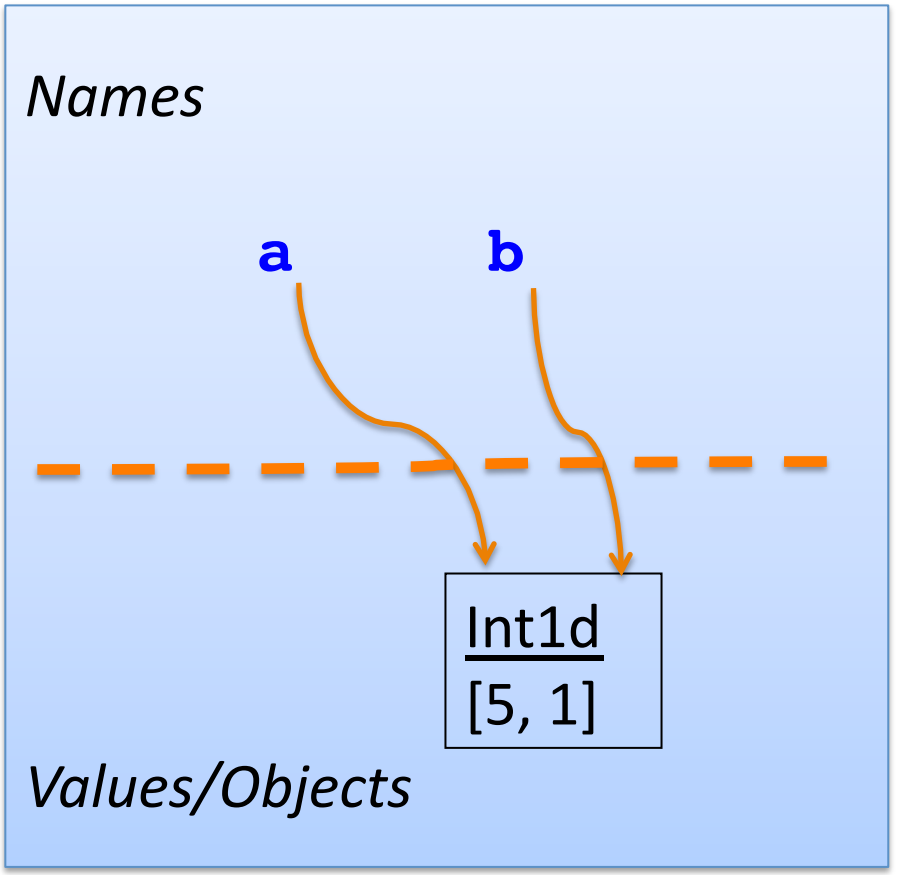
- Do not think of variables as physical locations in memory
- Variables are *names* that are *bound* to *objects*
- The drawing shows the state after:

```
b = a
```



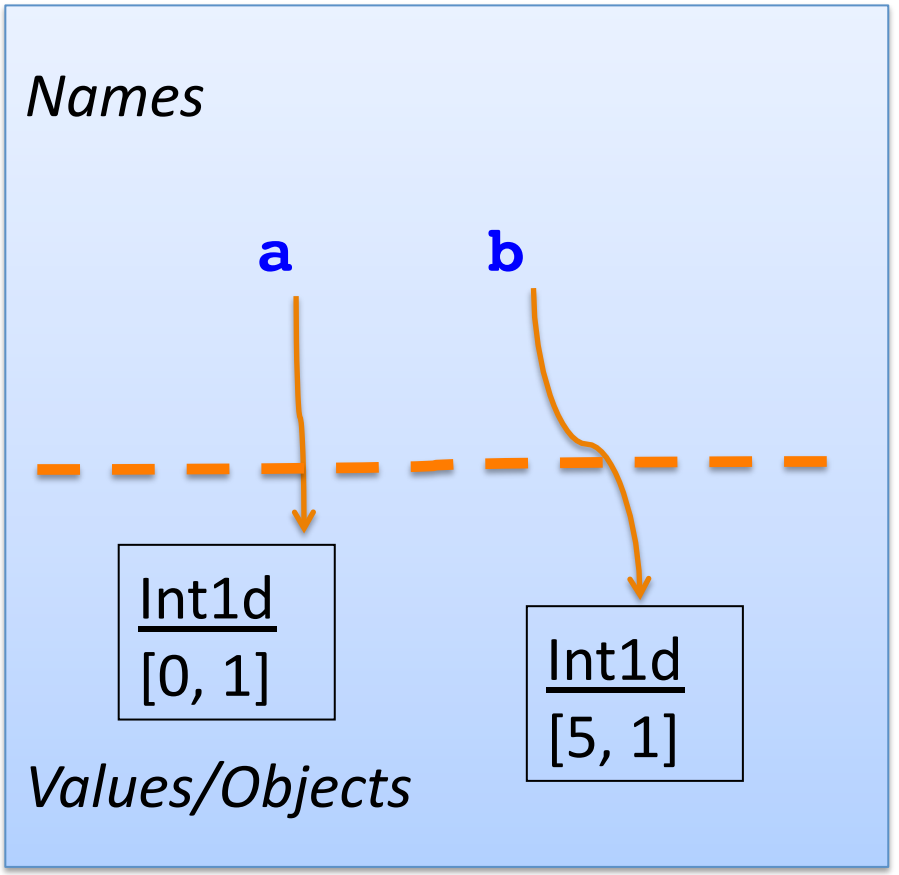
What does `b[0] = 5` really do?

- 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]
```

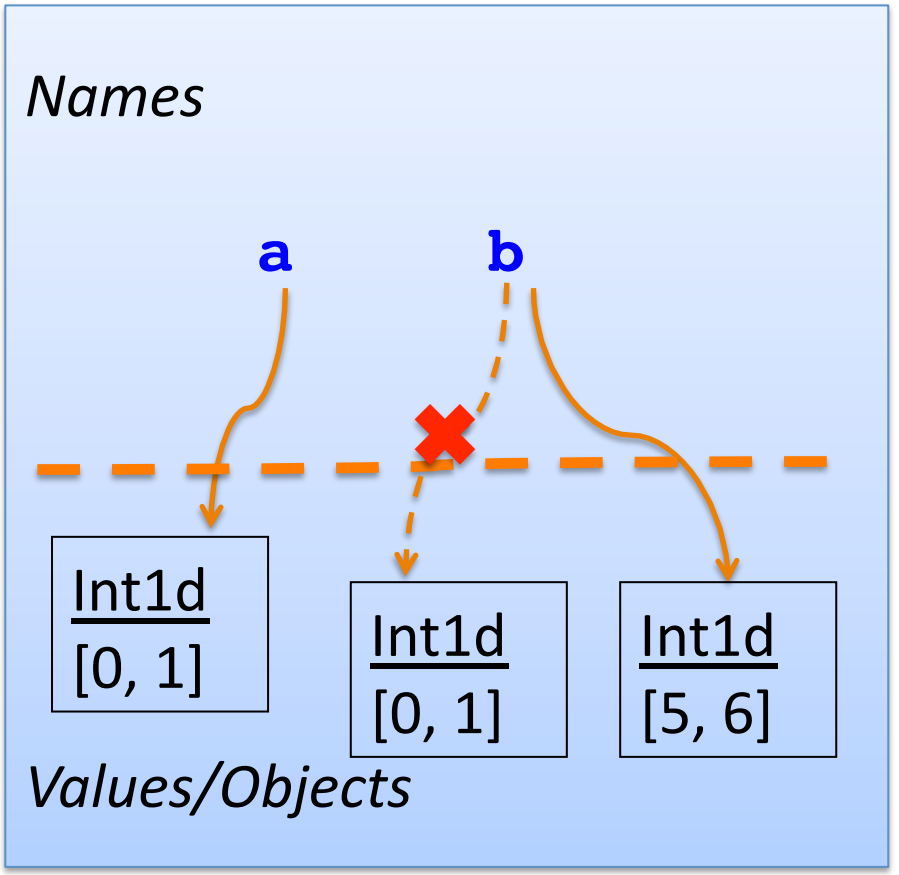
- What happened? At `b += 5` the in-line operator `+=` means that the operation is done in place – no new copy is made of the object to which `a` and `b` are bound.
- Saves memory

Garbage collection

- A related example:

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

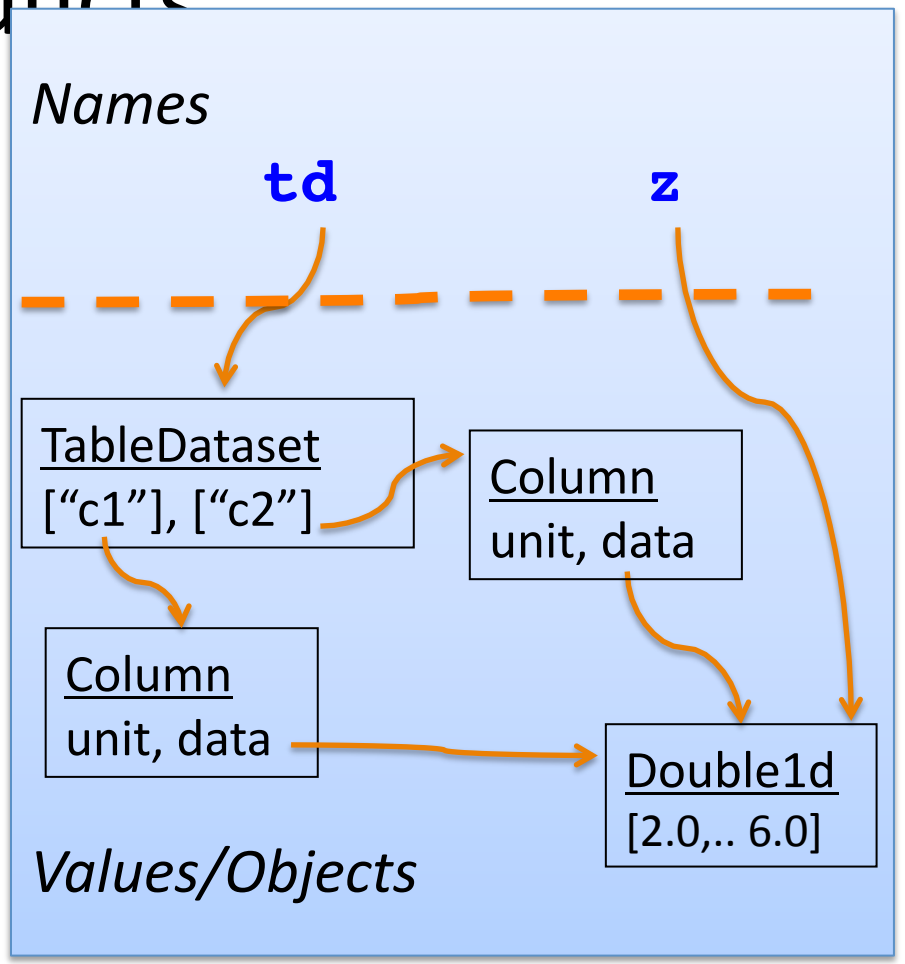
- For a time, three array objects are taking up memory
- What happens to the first copied array? Eventually the *garbage collector* frees up the memory



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)`