Python Course - Class 2:

Scientific Libraries and Data Manipulation

- Why not use basic Python?

Originally Python was not designed for numeric computation in mind. Even now, 30 years after its debut:
"The language comes with a large standard library that covers areas such as string processing (regular expressions, Unicode, calculating differences between files), Internet protocols (HTTP, FTP, SMTP, XML-RPC, POP, IMAP, CGI programming), software engineering (unit testing, logging, profiling, parsing Python code), and operating system interfaces (system calls, filesystems, TCP/IP sockets). Look at the table of contents for The Python Standard Library to get an idea of what's available. A wide variety of third-party extensions are also available. Consult the Python Package Index to find packages of interest to you." (https://docs.python.org/ (https://docs.python.org/))

Thus, even if has built-in ***math*** and ***stats*** libraries, they are not efficient. In this context, several scientific libraries appeared.

Numpy (https://numpy.org/doc/stable/ (https://numpy.org/doc/stable/))

In [1]:
```
import numpy as np
print(np.__doc__[:188])
```

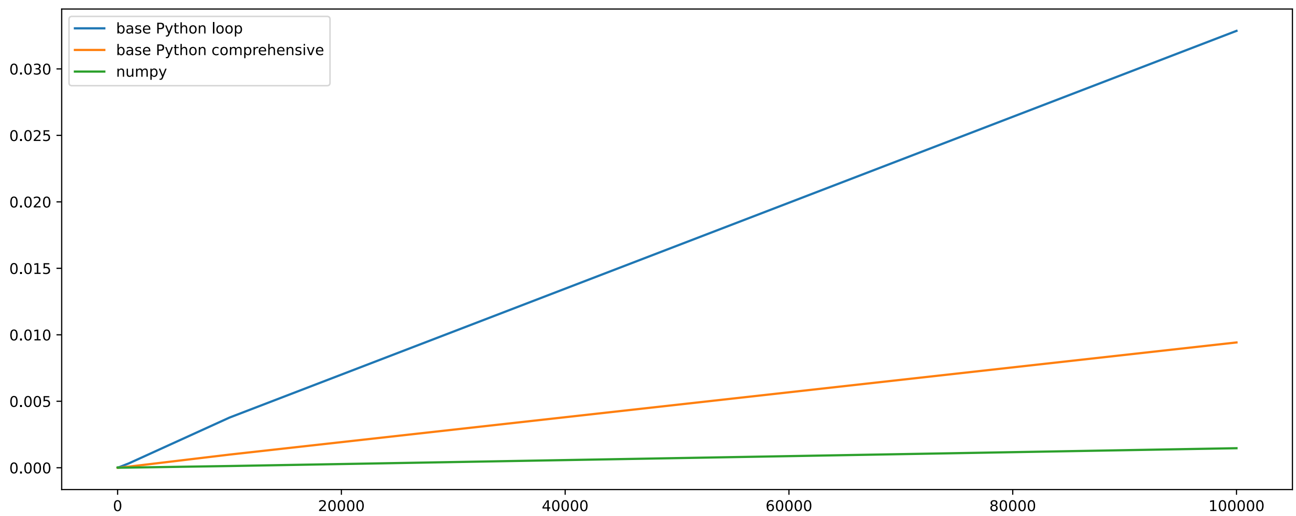
```
NumPy
=====

Provides
  1. An array object of arbitrary homogeneous items
  2. Fast mathematical operations over arrays
  3. Linear Algebra, Fourier Transforms, Random Number Generation
```

- Why Numpy?

"NumPy is the fundamental package for scientific computing in Python. It is a Python library that provides a multidimensional array object, various derived objects (such as masked arrays and matrices), and an assortment of routines for fast operations on arrays, including mathematical, logical, shape manipulation, sorting, selecting, I/O, discrete Fourier transforms, basic linear algebra, basic statistical operations, random simulation and much more." (https://numpy.org/ (https://numpy.org/))

→ Example: Multiplying two lists/arrays

In [2]:
```
from time import process_time       # for timing
import matplotlib.pyplot as mplt    # for plotting

time_py_loop, time_py_comprehensive, time_numpy = [],[],[]
lengths = sorted([10**n for n in range (6)])

# print (lengths)
for lenght in lengths:
    a = range (lenght)
    b = range (lenght)

    # with base Python (looping)
    start_py = process_time()
    c = []
    for i in range(len(a)):
        c.append(a[i]*b[i])
    end_py = process_time()
    time_py_loop.append(end_py - start_py)

    # with base Python (comprehensive)
    start_py = process_time()
    c = [a_i*b_i for a_i,b_i in zip(a,b)]
    end_py = process_time()
    time_py_comprehensive.append(end_py - start_py)


    # with NumPy
    a = np.arange (lenght)
    b = np.arange (lenght)

    start_np = process_time()
    c = a * b
    end_np = process_time()
    time_numpy.append(end_np - start_np)

# plotting code
%config InlineBackend.figure_format = 'svg' # Better quality plots in jupyter noteboo
ks
mplt.figure(figsize = (15,6))
mplt.plot(lengths, time_py_loop, label = 'base Python loop')
mplt.plot(lengths, time_py_comprehensive, label = 'base Python comprehensive')
mplt.plot(lengths, time_numpy, label = 'numpy')
mplt.legend()
mplt.show()
```



NumPy is much faster than base Python!!!

[https://towardsdatascience.com/how-fast-numpy-really-is-e9111df44347 (https://towardsdatascience.com/how-fast-numpy-really-is-e9111df44347)](https://towardsdatascience.com/how-fast-numpy-really-is-e9111df44347)

- The core of NumPy - the ndarray object:

The ***ndarray*** is a multidimensional container of items of the same type and size. It has two main properties:

- *shape* - specifies the dimensions of the array, and can be specified in the form of a tuple or from lists of lists.
- *dtype* - defines the data type of the items in the array (for example, *np.int32*, *np.float64*, etc)

- Some useful NumPy functions:

→ array creation

In [3]:

```
# Create array from list of lists
A = np.array([[1, 2, 3], [4, 5, 6]], np.int32)
print('type = {}, shape = {}\n{}\n'.format(type(A), np.shape(A),A))
```

```
type = <class 'numpy.ndarray'>, shape = (2, 3)
[[1 2 3]
 [4 5 6]]
```

In [4]:

```
# Create empty 4 x 3 array from tuple
B = np.empty((4,3), dtype = np.float64)
print('type = {}, shape = {}\n{}\n'.format(type(B), np.shape(B),B))
```

```
type = <class 'numpy.ndarray'>, shape = (4, 3)
[[ 603. 4863. 1178.]
 [4863. 1178.    0.]
 [ 603.    0.  603.]
 [4863.    0.    0.]]
```

In [5]:

```
# 3 x 8 array, filled with zeroes
C = np.zeros((3,8), dtype = np.float64)
print('type = {}, shape = {}\n{}\n'.format(type(C), np.shape(C),C))
```

```
type = <class 'numpy.ndarray'>, shape = (3, 8)
[[0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0.]]
```

In [6]:

```
# filled with ones, same shape as C
D = np.ones_like(C)
print('type = {}, shape = {}\n{}\n'.format(type(D), np.shape(D),D))
```

```
type = <class 'numpy.ndarray'>, shape = (3, 8)
[[1. 1. 1. 1. 1. 1. 1. 1.]
 [1. 1. 1. 1. 1. 1. 1. 1.]
 [1. 1. 1. 1. 1. 1. 1. 1.]]
```

In [7]:
```
# array that starts at 3, ends at 13, with each item separated by 2
E = np.arange(3,39,2)
print('type = {}, shape = {}\n{}\n'.format(type(E), np.shape(E),E))
```

```
type = <class 'numpy.ndarray'>, shape = (18,)
[ 3  5  7  9 11 13 15 17 19 21 23 25 27 29 31 33 35 37]
```

In [8]:
```
# array with 10 evenly spaced samples, calculated over the interval [-25, 13].
F = np.linspace(-25,13, num = 10)
print('type = {}, shape = {}\n{}\n'.format(type(F), np.shape(F),F))
```

```
type = <class 'numpy.ndarray'>, shape = (10,)
[-25.         -20.77777778 -16.55555556 -12.33333333  -8.11111111
  -3.88888889   0.33333333   4.55555556   8.77777778  13.        ]
```

→ array manipulation:

In [9]:
```
# reshape array E to 3 x 6
E_3x6 = E.reshape(3,6)
print('type = {}, shape = {}'.format(type(E_3x6), np.shape(E_3x6)))
print(E_3x6)
```

```
type = <class 'numpy.ndarray'>, shape = (3, 6)
[[ 3  5  7  9 11 13]
 [15 17 19 21 23 25]
 [27 29 31 33 35 37]]
```

In [10]:
```
# transpose E_3x6
print('type = {}, shape = {}\n{}\n'.format(type(E_3x6.T), np.shape(E_3x6.T),E_3x6.T))
```

```
type = <class 'numpy.ndarray'>, shape = (6, 3)
[[ 3 15 27]
 [ 5 17 29]
 [ 7 19 31]
 [ 9 21 33]
 [11 23 35]
 [13 25 37]]
```

In [11]:
```
# indexing
import random
for i in random.sample(range(np.shape(E_3x6)[0]),2):
    for j in random.sample(range(np.shape(E_3x6)[1]),2):
        print('E_3x6[{},{}]: \t{}'.format(i,j,E_3x6[i,j]))
```

```
E_3x6[1,3]:     21
E_3x6[1,2]:     19
E_3x6[0,3]:     9
E_3x6[0,2]:     7
```

In [12]:
```
# slicing : ARRAY[start:end:step, start:end:step, ...]
# columns 0 and 2 :
label = 'E_3x6[:,0:3:2] ='
print(label, np.array2string(E_3x6[:,0:3:2], prefix='{}        '.format(label)))
```

```
E_3x6[:,0:3:2] = [[ 3  7]
                  [15 19]
                  [27 31]]
```

In [13]:
```
# row 1 :
label = 'E_3x6[1,:] ='
print(label, E_3x6[1,:])
```

```
E_3x6[1,:] = [15 17 19 21 23 25]
```

In [14]:
```
# 2 x 2 array, starting on row 0 and column 3 :
label = 'E_3x6[:2,3:5] ='
print(label, np.array2string(E_3x6[:2,3:5], prefix='{}        '.format(label)))
```

```
E_3x6[:2,3:5] = [[ 9 11]
                 [21 23]]
```

In [15]:
```
# last 3 columns from last two rows :
label = 'E_3x6[-2:,-3:] ='
print(label, np.array2string(E_3x6[-2:,-3:], prefix='{}        '.format(label)))
```

```
E_3x6[-2:,-3:] = [[21 23 25]
                  [33 35 37]]
```

In [16]:
```
# Concatenation
print ( np.concatenate( (A,B) ) )
```

```
[[1.000e+00 2.000e+00 3.000e+00]
 [4.000e+00 5.000e+00 6.000e+00]
 [6.030e+02 4.863e+03 1.178e+03]
 [4.863e+03 1.178e+03 0.000e+00]
 [6.030e+02 0.000e+00 6.030e+02]
 [4.863e+03 0.000e+00 0.000e+00]]
```

In [17]:
```
# stacking
print ( np.stack( (A,B[:2,:]) ) ,'\n')

print ( np.hstack( (A,B[:2,:]) ),'\n' )

print ( np.vstack( (A,B) ) ,'\n')
```

```
[[[1.000e+00 2.000e+00 3.000e+00]
  [4.000e+00 5.000e+00 6.000e+00]]

 [[6.030e+02 4.863e+03 1.178e+03]
  [4.863e+03 1.178e+03 0.000e+00]]]

[[1.000e+00 2.000e+00 3.000e+00 6.030e+02 4.863e+03 1.178e+03]
 [4.000e+00 5.000e+00 6.000e+00 4.863e+03 1.178e+03 0.000e+00]]

[[1.000e+00 2.000e+00 3.000e+00]
 [4.000e+00 5.000e+00 6.000e+00]
 [6.030e+02 4.863e+03 1.178e+03]
 [4.863e+03 1.178e+03 0.000e+00]
 [6.030e+02 0.000e+00 6.030e+02]
 [4.863e+03 0.000e+00 0.000e+00]]
```

→ mathematical operations

Input arrays for performing arithmetic operations such as add(), subtract(), multiply(), and divide() must be either of the same shape or should conform to array broadcasting rules:

- Rule 1: If the two arrays differ in their number of dimensions, the shape of the one with fewer dimensions is padded with ones on its leading (left) side.
- Rule 2: If the shape of the two arrays does not match in any dimension, the array with shape equal to 1 in that dimension is stretched to match the other shape.
- Rule 3: If in any dimension the sizes disagree and neither is equal to 1, an error is raised.

(https://jakevdp.github.io/PythonDataScienceHandbook/02.05-computation-on-arrays-broadcasting.html (https://jakevdp.github.io/PythonDataScienceHandbook/02.05-computation-on-arrays-broadcasting.html))

In [18]:
```
A = np.arange(9, dtype = np.float_)
np.random.shuffle(A)
A = A.reshape(3,3)
B = np.array([5,-7,15])
print(A , '= A', '\n\n',B, '= B')
```

```
[[8. 6. 5.]
 [4. 7. 2.]
 [3. 1. 0.]] = A

 [ 5 -7 15] = B
```

In [19]:
```
# addition/subtraction
print (np.add(A,B),' = A + B\n')
print (np.subtract(A,B),'{} = A - B')
```

```
[[13. -1. 20.]
 [ 9.  0. 17.]
 [ 8. -6. 15.]]  = A + B

[[  3.  13. -10.]
 [ -1.  14. -13.]
 [ -2.   8. -15.]] {} = A - B
```

In [20]:
```
# dot/cross products
print (np.dot(A,B),' = A · B\n')
print (np.dot(B,A),' = B · A\n')

print (np.cross(A,B),' = A × B\n')
print (np.cross(B,A),' = B × A\n')
```

```
[73.  1.  8.]  = A · B

[57. -4. 11.]  = B · A

[[125. -95. -86.]
 [119. -50. -63.]
 [ 15. -45. -26.]]  = A × B

[[-125.   95.   86.]
 [-119.   50.   63.]
 [ -15.   45.   26.]]  = B × A
```

In [21]:
```python
# element-wise multiplication / division
print (np.multiply(A,B),' = [A_i,j · B_i,j]\n')

print (np.divide(A,B),' = [A_i,j / B_i,j]\n')
```

```
[[ 40. -42.  75.]
 [ 20. -49.  30.]
 [ 15.  -7.   0.]]  = [A_i,j · B_i,j]

[[ 1.6         -0.85714286  0.33333333]
 [ 0.8         -1.          0.13333333]
 [ 0.6         -0.14285714  0.        ]]  = [A_i,j / B_i,j]
```

https://www.tutorialspoint.com/numpy/numpy_arithmetic_operations.htm
(https://www.tutorialspoint.com/numpy/numpy_arithmetic_operations.htm)

→ statistics

In [22]:
```python
# median
print('{:17s} = {:>6.3f}'.format('np.median(E_3x6)',np.median(E_3x6)))
# mean
print('{:17s} = {:>6.3f}'.format('np.mean(E_3x6)',np.mean(E_3x6)))
# standart deviation
print('{:17s} = {:>6.3f}'.format('np.std(E_3x6)',np.std(E_3x6)))
# max
print('{:17s} = {:>6.3f}'.format('np.max(E_3x6)',np.max(E_3x6)))
# min
print('{:17s} = {:>6.3f}'.format('np.min(E_3x6)',np.min(E_3x6)))
```

```
np.median(E_3x6)  = 20.000
np.mean(E_3x6)    = 20.000
np.std(E_3x6)     = 10.376
np.max(E_3x6)     = 37.000
np.min(E_3x6)     =  3.000
```

What if array has NaNs?

In [23]:
```python
E_3x6_NaNs = E_3x6.astype(np.float64)

for i in random.sample(range(np.shape(E_3x6)[0]),2):
    for j in random.sample(range(np.shape(E_3x6)[1]),2):
        E_3x6_NaNs[i,j] = np.nan
```

In [24]:
```
# median
print('{:21s} = {:>6.3f}'.format('np.median(E_3x6_NaNs)',np.median(E_3x6_NaNs)))
# mean
print('{:21s} = {:>6.3f}'.format('np.mean(E_3x6_NaNs)',np.mean(E_3x6_NaNs)))
# standart deviation
print('{:21s} = {:>6.3f}'.format('np.std(E_3x6_NaNs)',np.std(E_3x6_NaNs)))
# max
print('{:21s} = {:>6.3f}'.format('np.max(E_3x6_NaNs)',np.max(E_3x6_NaNs)))
# min
print('{:21s} = {:>6.3f}'.format('np.min(E_3x6_NaNs)',np.min(E_3x6_NaNs)))
```

```
np.median(E_3x6_NaNs) =    nan
np.mean(E_3x6_NaNs)   =    nan
np.std(E_3x6_NaNs)    =    nan
np.max(E_3x6_NaNs)    =    nan
np.min(E_3x6_NaNs)    =    nan
```

In [25]:
```
# median
print('{:24s} = {:>6.3f}'.format('np.nanmedian(E_3x6_NaNs)',np.nanmedian(E_3x6_NaNs
)))
# mean
print('{:24s} = {:>6.3f}'.format('np.nanmean(E_3x6_NaNs)',np.nanmean(E_3x6_NaNs)))
# standart deviation
print('{:24s} = {:>6.3f}'.format('np.nanstd(E_3x6_NaNs)',np.nanstd(E_3x6_NaNs)))
# max
print('{:24s} = {:>6.3f}'.format('np.nanmax(E_3x6_NaNs)',np.nanmax(E_3x6_NaNs)))
# min
print('{:24s} = {:>6.3f}'.format('np.nanmin(E_3x6_NaNs)',np.nanmin(E_3x6_NaNs)))
```

```
np.nanmedian(E_3x6_NaNs) = 16.000
np.nanmean(E_3x6_NaNs)   = 18.429
np.nanstd(E_3x6_NaNs)    = 11.095
np.nanmax(E_3x6_NaNs)    = 37.000
np.nanmin(E_3x6_NaNs)    =  3.000
```

→ file manipulation

In [26]:

```python
# save array to txt file
np.savetxt('E_3x6_NaNs.txt',E_3x6_NaNs, fmt='%s,%.0f,%s,%s,%s,%s', delimiter=",")
print('E_3x6_NaNs.txt contents:')
with open('E_3x6_NaNs.txt', 'r') as f:
    print(f.read())
# load array from txt file with loadtxt
E_3x6_NaNs_loadtxt = np.loadtxt('E_3x6_NaNs.txt', dtype = 'float', delimiter=",")

print('\nnp.loadtxt')
print(E_3x6_NaNs_loadtxt,'\n')

# load array from txt file with genfromtxt: many more options!!
E_3x6_NaNs_genfromtxt = np.genfromtxt('E_3x6_NaNs.txt',dtype = (float,int,complex,boo
l,np.float64,float), delimiter=",")

print('np.genfromtxt')
print(E_3x6_NaNs_genfromtxt)
```

```
E_3x6_NaNs.txt contents:
3.0,5,7.0,9.0,11.0,13.0
15.0,17,19.0,nan,nan,25.0
nan,29,nan,33.0,35.0,37.0


np.loadtxt
[[ 3.   5.   7.   9.  11.  13.]
 [15.  17.  19.  nan nan 25.]
 [nan 29.  nan 33.  35.  37.]]

np.genfromtxt
[( 3.,  5,  7.+0.j, False, 11., 13.) (15., 17, 19.+0.j, False, nan, 25.)
 (nan, 29, nan+0.j, False, 35., 37.)]
```

More file formats:
https://numpy.org/doc/stable/reference/routines.io.html (https://numpy.org/doc/stable/reference/routines.io.html)

- Numpy cheat sheet:

https://www.dataquest.io/blog/numpy-cheat-sheet/ (https://www.dataquest.io/blog/numpy-cheat-sheet/)

Scipy (https://www.scipy.org/ (https://www.scipy.org/))

In [27]:
```python
import scipy as sp
print(sp.__doc__)
```

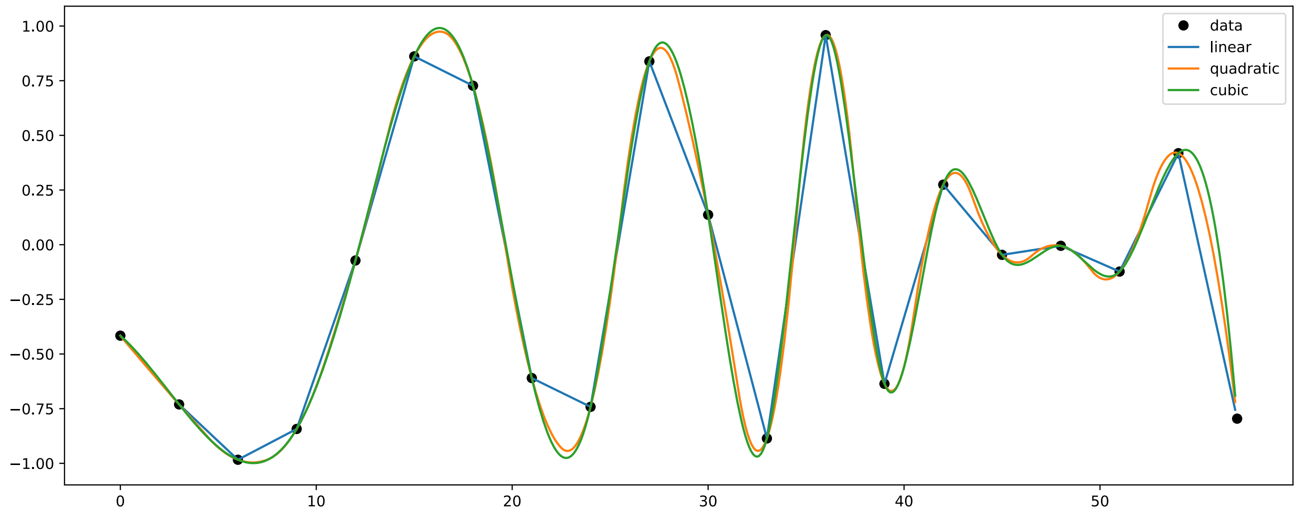
```
SciPy: A scientific computing package for Python
================================================

Documentation is available in the docstrings and
online at https://docs.scipy.org.

Contents
--------
SciPy imports all the functions from the NumPy namespace, and in
addition provides:

Subpackages
-----------
Using any of these subpackages requires an explicit import. For example,
``import scipy.cluster``.

::

 cluster                      --- Vector Quantization / Kmeans
 fft                          --- Discrete Fourier transforms
 fftpack                      --- Legacy discrete Fourier transforms
 integrate                    --- Integration routines
 interpolate                  --- Interpolation Tools
 io                           --- Data input and output
 linalg                       --- Linear algebra routines
 linalg.blas                  --- Wrappers to BLAS library
 linalg.lapack                --- Wrappers to LAPACK library
 misc                         --- Various utilities that don't have
                                  another home.
 ndimage                      --- N-D image package
 odr                          --- Orthogonal Distance Regression
 optimize                     --- Optimization Tools
 signal                       --- Signal Processing Tools
 signal.windows               --- Window functions
 sparse                       --- Sparse Matrices
 sparse.linalg                --- Sparse Linear Algebra
 sparse.linalg.dsolve         --- Linear Solvers
 sparse.linalg.dsolve.umfpack --- :Interface to the UMFPACK library:
                                  Conjugate Gradient Method (LOBPCG)
 sparse.linalg.eigen          --- Sparse Eigenvalue Solvers
 sparse.linalg.eigen.lobpcg   --- Locally Optimal Block Preconditioned
                                  Conjugate Gradient Method (LOBPCG)
 spatial                      --- Spatial data structures and algorithms
 special                      --- Special functions
 stats                        --- Statistical Functions

Utility tools
-------------
::

 test              --- Run scipy unittests
 show_config       --- Show scipy build configuration
 show_numpy_config --- Show numpy build configuration
 __version__       --- SciPy version string
 __numpy_version__ --- Numpy version string
```

- Interpolation Tools (scipy.interpolate)

→ 1-D interpolation (interp1d)

In [28]:
```
from scipy.interpolate import interp1d

# create data
x = np.arange(0, 60, 3)
y = np.cos ( x / 10 + 2 + (x / 10 )**2 )

# define plot
mplt.figure(figsize = (15,6))
mplt.plot(x,y,'ko',label = 'data')

# create interpolation functions
interps= ['linear','quadratic','cubic']
funcs = {interp:interp1d(x, y, kind=interp,fill_value=np.nanmedian(y)) for interp in
interps}

# define new x array
x_new = np.arange(0, 57, 0.1)

for interp in interps:
    mplt.plot(x_new,funcs[interp](x_new),label = interp)

mplt.legend()
```

Out[28]: <matplotlib.legend.Legend at 0x7f2382cd1f40>



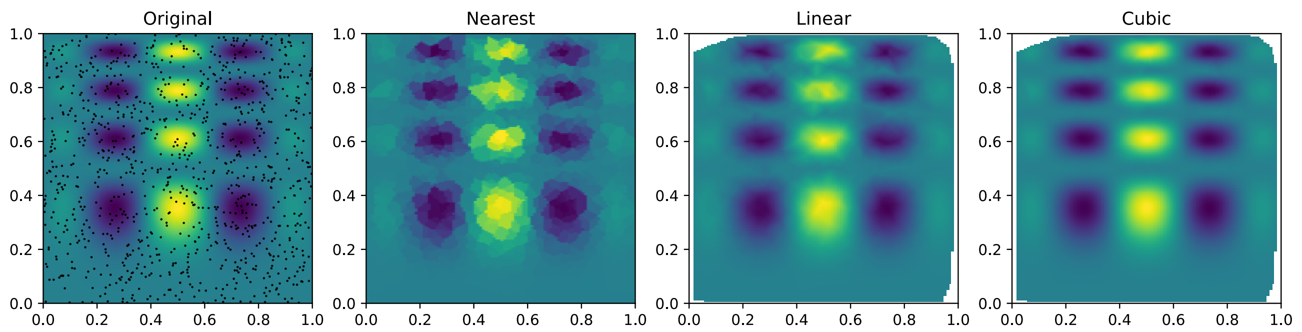
→ 2-D interpolation (griddata)

`griddata(points, values, xi[, method, …])` - Interpolate unstructured 2-D data.

In [91]:
```
# Generate 2-D data grid
grid_x, grid_y = np.mgrid[0:1:100j, 0:1:200j]

# model function
def func(x, y):
    return x*(1-x)*np.cos(4*np.pi*x) * np.sin(4*np.pi*y**2)**2

# data points
points = np.random.rand(1000, 2)
values = func(points[:,0], points[:,1])
```

In [92]:
```
from scipy.interpolate import griddata
# Fit data with different methods
grid_z0 = griddata(points, values, (grid_x, grid_y), method='nearest')
grid_z1 = griddata(points, values, (grid_x, grid_y), method='linear')
grid_z2 = griddata(points, values, (grid_x, grid_y), method='cubic')
```

In [103]:
```
# Plots
import matplotlib.pyplot as plt
mplt.figure(figsize=(15,6))
mplt.subplot(141)
mplt.imshow(func(grid_x, grid_y).T, extent=(0,1,0,1), origin='lower')
mplt.plot(points[:,0], points[:,1], 'k.', ms=1)
mplt.title('Original')
mplt.subplot(142)
mplt.imshow(grid_z0.T, extent=(0,1,0,1), origin='lower')
mplt.title('Nearest')
mplt.subplot(143)
mplt.imshow(grid_z1.T, extent=(0,1,0,1), origin='lower')
mplt.title('Linear')
mplt.subplot(144)
mplt.imshow(grid_z2.T, extent=(0,1,0,1), origin='lower')
mplt.title('Cubic')

mplt.show()
```



→ Spline interpolation

...

[https://docs.scipy.org/doc/scipy-1.6.2/reference/tutorial/interpolate.html (https://docs.scipy.org/doc/scipy-1.6.2/reference/tutorial/interpolate.html)](https://docs.scipy.org/doc/scipy-1.6.2/reference/tutorial/interpolate.html)

- Optimization tools (scipy.optimize)

In [30]:
```
# Generating some data to fit

x = np.random.uniform(-5, 5., 100)
y_params = [2.,3.,-5.]
y = y_params[0] + y_params[1] * x + y_params[2] * x**2 + np.random.normal(0, 10., 100
)
e = np.random.normal(1., 5., 100) # error

# model that defines the data
def poly2(x, a, b,c):
    return a  + b * x + c * x**2
```

→ Curve fitting

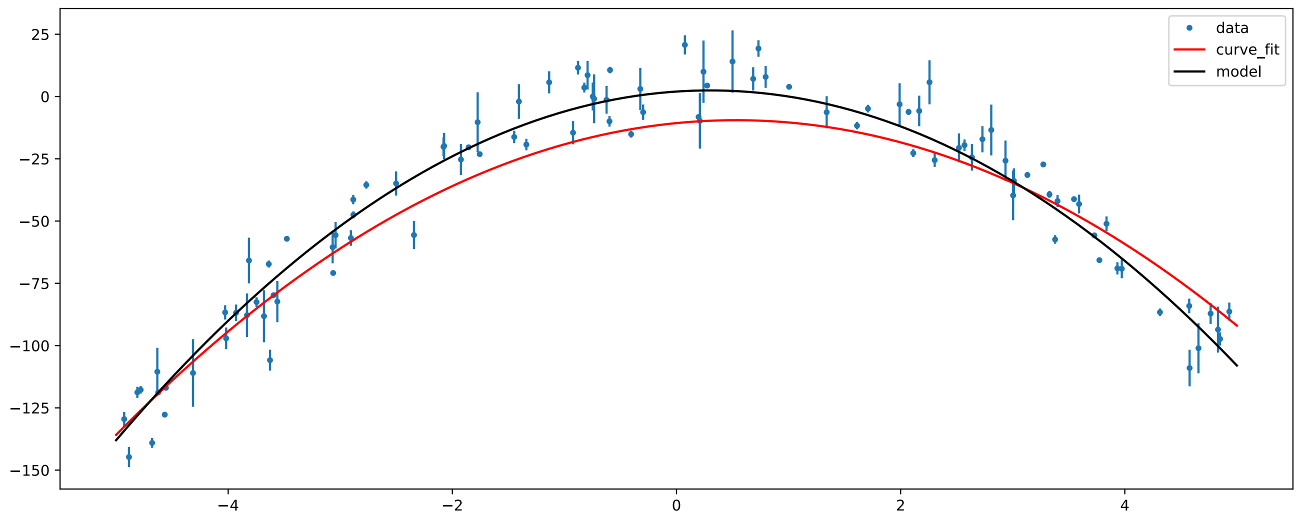
`scipy.optimize.curve_fit(f, xdata, ydata[, p0, sigma, …])` - Use non-linear least squares to fit a function, f, to data.

In [31]:
```
from scipy.optimize import curve_fit


# fit results
popt, pcov = curve_fit(poly2, x, y, sigma=e)
print("a =", popt[0])
print("b =", popt[1])
print("c =", popt[2])
```

```
a = -10.66696801741625
b = 4.386028008397757
c = -4.129935397746482
```

In [32]:
```
# plots
mplt.figure(figsize = (15,6))
mplt.plot(x, y, '.',label='data')
mplt.errorbar(x, y, yerr=e, fmt="none")
xfine = np.linspace(-5, 5., 100)
mplt.plot(xfine, poly2(xfine, popt[0], popt[1], popt[2]), 'r-',label='curve_fit')
mplt.plot(xfine, poly2(xfine, y_params[0], y_params[1], y_params[2]), 'k-',label='mod
el')
mplt.legend()
```

Out[32]:
```
<matplotlib.legend.Legend at 0x7f237debbc40>
```



→ nonlinear least-squares fitting

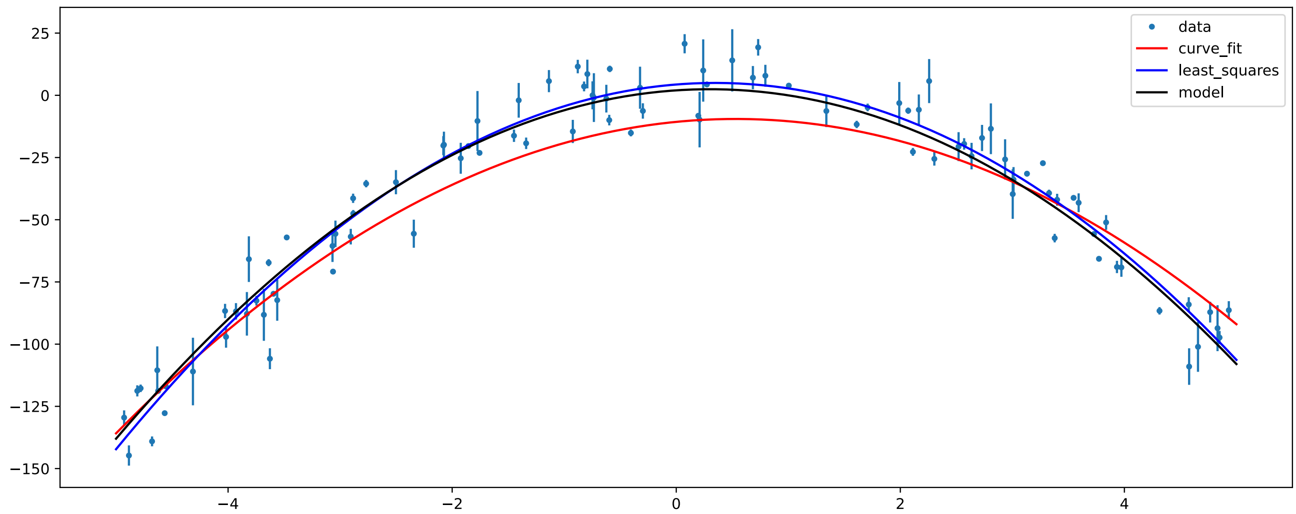
`scipy.optimize.least_squares(fun, x0[, jac, bounds, …])` - Solve a nonlinear least-squares problem with bounds on the variables.

In [33]:
```
from scipy.optimize import least_squares
# minimizing function
def fun(params):
    return poly2(x,params[0],params[1],params[2]) - y

# initial parameters
params_ini = [1,2,3]

# fit results
params_fit = least_squares(fun, params_ini)
print("a =", params_fit['x'][0])
print("b =", params_fit['x'][1])
print("c =", params_fit['x'][2])
```

```
a = 4.3521555288735865
b = 3.591181866952384
c = -5.144784922883848
```

In [34]:
```
# plots
mplt.figure(figsize = (15,6))
mplt.plot(x, y, '.',label='data')
mplt.errorbar(x, y, yerr=e, fmt="none")
xfine = np.linspace(-5, 5., 100)
mplt.plot(xfine, poly2(xfine, popt[0], popt[1], popt[2]), 'r-',label='curve_fit')
mplt.plot(xfine, poly2(xfine, params_fit['x'][0], params_fit['x'][1], params_fit['x']
[2]), 'b-',label = 'least_squares')
mplt.plot(xfine, poly2(xfine, y_params[0], y_params[1], y_params[2]), 'k-',label='mod
el')
mplt.legend()
```

Out[34]: `<matplotlib.legend.Legend at 0x7f237ddb07f0>`



...

https://docs.scipy.org/doc/scipy-1.6.2/reference/tutorial/optimize.html (https://docs.scipy.org/doc/scipy-1.6.2/reference/tutorial/optimize.html)

- and much more...

https://docs.scipy.org/doc/scipy-1.6.2/reference/ (https://docs.scipy.org/doc/scipy-1.6.2/reference/)

Astropy

In [35]:
```
import astropy as astro
print(astro.__doc__)
```

```
Astropy is a package intended to contain core functionality and some
common tools needed for performing astronomy and astrophysics research with
Python. It also provides an index for other astronomy packages and tools for
managing them.
```

- Exploring fits data files

→ Handling fits files

In [36]:
```
from astropy.io import fits
fits_image_filename = '../data/spectra.fits'
# open fits file as HDU list (Header Data Unit list)
hdul = fits.open(fits_image_filename)

# print fits file information
hdul.info()

# close HDU list
hdul.close()
```

```
Filename: ../data/spectra.fits
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU       5   (0,)      
  1  WAVE          1 ImageHDU         8   (4096, 72)   float64   
  2  TEMP          1 ImageHDU         8   (4096, 72)   float64   
```

In [37]:
```python
# same as before, but within a context manager
with fits.open(fits_image_filename) as hdul:
    hdul.info()
```

```
Filename: ../data/spectra.fits
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU       5   (0,)
  1  WAVE          1 ImageHDU         8   (4096, 72)   float64
  2  TEMP          1 ImageHDU         8   (4096, 72)   float64
```

In [38]:
```python
# write data to file
hdul = fits.open(fits_image_filename)
hdul.writeto('../data/spectra_new.fits', overwrite=True)

# close HDU list
hdul.close()
```

→ Working with headers

In [39]:
```python
# loading fits header
hdul = fits.open(fits_image_filename)
hdr0 = hdul[0].header
hdr1 = hdul['WAVE'].header
hdr2 = hdul[2].header
```

In [40]:
```python
# viewing extension 0 header contents
hdr0
```

Out[40]:
```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                  -64 / array data type
NAXIS   =                    1 / number of array dimensions
NAXIS1  =                    0
EXTEND  =                    T
```

In [41]:
```python
# viewing extension 1 header contents
hdr1
```

Out[41]:
```
XTENSION= 'IMAGE   '           / Image extension
BITPIX  =                  -64 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                 4096
NAXIS2  =                   72
PCOUNT  =                    0 / number of parameters
GCOUNT  =                    1 / number of groups
EXTNAME = 'WAVE    '           / extension name
```

In [42]:
```python
# view header key list
list(hdr2.keys())
```

Out[42]:
```
['XTENSION',
 'BITPIX',
 'NAXIS',
 'NAXIS1',
 'NAXIS2',
 'PCOUNT',
 'GCOUNT',
 'EXTNAME']
```

In [43]:
```
# showing individual values
print(hdr1[4])
hdr0['EXTEND']
```

```
72
```

Out[43]:
```
True
```

In [44]:
```
# adding/updating key/value in header
hdr2['banana'] = 'rama'
print('hdr2[{}] : {}'.format('banana',hdr2['banana']))

hdr2.set('poison', 'Alice Cooper')

print('hdr2[{}] : {}'.format('poison',hdr2['poison']))
```

```
hdr2[banana] : rama
hdr2[poison] : Alice Cooper
```

In [45]:
```
# adding key/value/comment in header
hdr2['doctor'] = ('who','T.A.R.D.I.S')
print('hdr2[{}] : {} / {}'.format('doctor',hdr2['doctor'],hdr2.comments['doctor']))

# updating key/value/comment in header
hdr2.set('doctor', 'who','Time And Relative Dimensions In Space')

print('hdr2[{}] : {} / {}'.format('doctor',hdr2['doctor'],hdr2.comments['doctor']))
```

```
hdr2[doctor] : who / T.A.R.D.I.S
hdr2[doctor] : who / Time And Relative Dimensions In Space
```

In [46]:
```
# Change values
hdr2
```

Out[46]:
```
XTENSION= 'IMAGE   '           / Image extension
BITPIX  =                  -64 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                 4096
NAXIS2  =                   72
PCOUNT  =                    0 / number of parameters
GCOUNT  =                    1 / number of groups
EXTNAME = 'TEMP    '           / extension name
BANANA  = 'rama    '
POISON  = 'Alice Cooper'
DOCTOR  = 'who     '           / Time And Relative Dimensions In Space
```

→ Working with data

In [47]:
```
# loading fits data
data0 = hdul[0].data
data1 = hdul['WAVE'].data
data2 = hdul[2].data
```

In [48]:
```
# print data properties (numpy array properties)
print(data0.dtype.name)
data1.shape
```

```
float64
```

Out[48]:
```
(72, 4096)
```

In [49]:
```python
# print data
data2[:10,-5:-2]
```

Out[49]:
```
array([[ 0.        ,  0.        ,  0.        ],
       [ 6.0504756 ,  4.54973412, -5.09431505],
       [14.49281502, 22.94881058,  2.9430759 ],
       [ 8.55088997, 10.27470875, 17.77082825],
       [24.26220703, 24.10009766, 38.36051178],
       [ 8.0759182 , 23.01345062, 13.49031162],
       [12.69156647, 50.55630493, 29.20264053],
       [30.02444267,  2.91292548, 52.68100357],
       [18.66321182, 12.92525005, 30.41882515],
       [34.14628601, 43.53718948, 57.77914429]])
```

In [50]:
```python
# modify data values
data2[3:6,-3:-1] = np.nan
data2[1,-3] = -999
data2[:10,-4:]
```

Out[50]:
```
array([[   0.        ,    0.        ,    0.        ,    0.        ],
       [   4.54973412, -999.        ,   47.63366318,   18.29163742],
       [  22.94881058,    2.9430759 ,    6.63907337,   28.18529701],
       [  10.27470875,           nan,           nan,   21.1298008 ],
       [  24.10009766,           nan,           nan,  -18.69415092],
       [  23.01345062,           nan,           nan,   16.28915405],
       [  50.55630493,   29.20264053,    7.26905489,   32.25184631],
       [   2.91292548,   52.68100357,   47.24837112,   41.05011749],
       [  12.92525005,   30.41882515,   10.67175961,   29.30817795],
       [  43.53718948,   57.77914429,   61.58086395,   51.68750381]])
```

https://docs.astropy.org/en/stable/io/fits/index.html (https://docs.astropy.org/en/stable/io/fits/index.html)

- Units and Quantities (astropy.units)

- Astronomical Coordinate Systems (astropy.coordinates)

- Time and Dates (astropy.time)

...

https://docs.astropy.org/en/stable/ (https://docs.astropy.org/en/stable/)

In [51]:
```python
from astropy import units as u
```

Astroquery

In [52]:
```
import astroquery as query
print(query.__doc__)
```

```
Accessing Online Astronomical Data.

Astroquery is an astropy affiliated package that contains a collection of tools
to access online Astronomical data. Each web service has its own sub-package.
```

Some examples:

→ ESO Archive (http://archive.eso.org/cms.html (http://archive.eso.org/cms.html))

In [53]:
```
from astroquery.eso import Eso

# note that this requires a keyring backend to store the passwords
# see https://pypi.org/project/keyring/ for details
# setup login
eso = Eso()
eso.login("jhumberto", store_password=True)
```

```
INFO: Authenticating jhumberto on www.eso.org... [astroquery.eso.core]
INFO: Authentication successful! [astroquery.eso.core]
```

In [54]:
```
# get availble instruments list
eso.list_instruments()
```

Out[54]:
```
['fors1',
 'fors2',
 'sphere',
 'vimos',
 'omegacam',
 'hawki',
 'isaac',
 'naco',
 'visir',
 'vircam',
 'apex',
 'giraffe',
 'uves',
 'xshooter',
 'espresso',
 'muse',
 'crires',
 'kmos',
 'sinfoni',
 'amber',
 'gravity',
 'matisse',
 'midi',
 'pionier',
 'wlgsu']
```

In [55]:

```python
# Check accepted instrument query parameters
eso.query_instrument('espresso', help=True)
```

```
INFO: List of accepted column_filters parameters. [astroquery.eso.core]
INFO: The presence of a column in the result table can be controlled if prefixed wit
h a [ ] checkbox. [astroquery.eso.core]
INFO: The default columns in the result table are shown as already ticked: [x]. [ast
roquery.eso.core]

Target Information
------------------
    target:
    resolver: simbad (SIMBAD name), ned (NED name), none (OBJECT as specified by the
observer)
    coord_sys: eq (Equatorial (FK5)), gal (Galactic)
    coord1:
    coord2:
    box:
    format: sexagesimal (Sexagesimal), decimal (Decimal)
[x] wdb_input_file:

Observation and proposal parameters
-----------------------------------
[ ] night:
    stime:
    starttime: 00 (00 hrs [UT]), 01 (01 hrs [UT]), 02 (02 hrs [UT]), 03 (03 hrs [U
T]), 04 (04 hrs [UT]), 05 (05 hrs [UT]), 06 (06 hrs [UT]), 07 (07 hrs [UT]), 08 (08
hrs [UT]), 09 (09 hrs [UT]), 10 (10 hrs [UT]), 11 (11 hrs [UT]), 12 (12 hrs [UT]), 1
3 (13 hrs [UT]), 14 (14 hrs [UT]), 15 (15 hrs [UT]), 16 (16 hrs [UT]), 17 (17 hrs [U
T]), 18 (18 hrs [UT]), 19 (19 hrs [UT]), 20 (20 hrs [UT]), 21 (21 hrs [UT]), 22 (22
hrs [UT]), 23 (23 hrs [UT]), 24 (24 hrs [UT])
    etime:
    endtime: 00 (00 hrs [UT]), 01 (01 hrs [UT]), 02 (02 hrs [UT]), 03 (03 hrs [UT]),
04 (04 hrs [UT]), 05 (05 hrs [UT]), 06 (06 hrs [UT]), 07 (07 hrs [UT]), 08 (08 hrs
[UT]), 09 (09 hrs [UT]), 10 (10 hrs [UT]), 11 (11 hrs [UT]), 12 (12 hrs [UT]), 13 (1
3 hrs [UT]), 14 (14 hrs [UT]), 15 (15 hrs [UT]), 16 (16 hrs [UT]), 17 (17 hrs [UT]),
18 (18 hrs [UT]), 19 (19 hrs [UT]), 20 (20 hrs [UT]), 21 (21 hrs [UT]), 22 (22 hrs
[UT]), 23 (23 hrs [UT]), 24 (24 hrs [UT])
[x] prog_id:
[ ] prog_type: % (Any), 0 (Normal), 1 (GTO), 2 (DDT), 3 (ToO), 4 (Large), 5 (Short),
6 (Calibration)
[ ] obs_mode: % (All modes), s (Service), v (Visitor)
[ ] pi_coi:
    pi_coi_name: PI_only (as PI only), none (as PI or CoI)
[ ] prog_title:

Generic File Information
------------------------
[x] dp_id:
[x] ob_id:
[x] obs_targ_name:
[x] exptime:
[x] dp_cat: % (Any), CALIB (CALIB), SCIENCE (SCIENCE)
[x] dp_type: % (Any), BIAS (BIAS), CONTAM,OFF,FP (CONTAM,OFF,FP), DARK (DARK), EFF,S
KY,SKY (EFF,SKY,SKY), FLAT%  (---  Any FLAT ---), FLAT,LAMP,OFF% (FLAT,LAMP,OFF), FL
AT,OFF,LAMP% (FLAT,OFF,LAMP), FLUX,STD,SKY (FLUX,STD,SKY), LED% (LED), OBJECT% (---
Any OBJECT ---), OBJECT,FP (OBJECT,FP), OBJECT,LFC (OBJECT,LFC), OBJECT,SKY (OBJECT,
SKY), OBJECT,THAR (OBJECT,THAR), ORDERDEF% (ORDERDEF), WAVE% (--- Any WAVE ---), WAV
E,FP,FP (WAVE,FP,FP), WAVE,FP,LFC (WAVE,FP,LFC), WAVE,FP,THAR (WAVE,FP,THAR), WAVE,L
FC,FP (WAVE,LFC,FP), WAVE,LFC,LFC (WAVE,LFC,LFC), WAVE,LFC,THAR (WAVE,LFC,THAR), WAV
E,THAR,FP (WAVE,THAR,FP), WAVE,THAR,LFC (WAVE,THAR,LFC), WAVE,THAR,THAR (WAVE,THAR,T
HAR)
    dp_type_user:
[x] dp_tech: % (Any), ECHELLE% (ECHELLE), IMAGE% (IMAGE)
[ ] tpl_name:
[ ] tpl_nexp:
[x] tpl_start:
```

```
Instrument Specific Information
-------------------------------
[x] ins_mode: % (Any), MULTIMR (MULTI Medium Resolution), SINGLEHR (SINGLE High Reso
lution), SINGLEUHR (SINGLE Ultra High-Resolution)
[x] det_binx: % (Any), 1 (1), 2 (2), 4 (4), 8 (8)
[x] det_biny: % (Any), 1 (1), 2 (2), 4 (4)
[x] det_read_curname: % (Any), 1: SCI 100kpix% (1: SCI 100kpix), 2: FAST 500kpix%
(2: FAST 500kpix), 8: SCI DI 100kpi% (8: SCI DI 100kpix), 9: FAST DI 500kp% (9: FAST
DI 500kpix), Fast (Fast), Slow (Slow)
[x] tel_id: % (Any), ESO-VLT-U1 (ESO-VLT-U1), ESO-VLT-U2 (ESO-VLT-U2), ESO-VLT-U3 (E
SO-VLT-U3), ESO-VLT-U4 (ESO-VLT-U4), ESO-VLT-U1234 (ESO-VLT-U1234)
[x] ins5_lsela_name: % (Any), DARK (DARK), FPCS (FPCS), LDLS (LDLS), LFC (LFC), TAL1
(TAL1), TAL2 (TAL2)
[x] ins5_lselb_name: % (Any), DARK (DARK), FPCS (FPCS), LDLS (LDLS), LFC (LFC), TAL1
(TAL1), TAL2 (TAL2)

Ambient Parameters
------------------
[x] fwhm_avg:
[ ] airmass_range:
[ ] night_flag: % (Any), 0 (Night), 1 (Twilight), 2 (Daytime)
[ ] moon_illu:

Result set
----------
    order:  (nothing (faster)), dp_id (Observation Time), dp_cat (DPR.CATG), dp_tech
(DPR.TECH), tpl_start (TPL.START), ob_id asc (OB.ID (ascending)), ob_id desc (OB.ID
(descending)), period asc,prog_id asc (Period and Run ID (earliest first)), period d
esc,prog_id desc (Period and Run ID (latest first))
```

In [56]:

```python
# Query the archive for ESPRESSO science data on 2019-08-29
results = eso.query_instrument('espresso', column_filters={'night':'2019-08-29','dp_c
at':'SCIENCE'}, columns=['target','prog_type'])
results.pprint(max_width=150)
```

```
Release Date  Object     RA         DEC          Target Ra Dec       ... DET READ CURNA
ME TELESCOPE  INS5 LSELA NAME INS5 LSELB NAME DIMM Seeing-avg
------------ ------- ---------- --------- ----------------------- ... --------------
-- ---------- --------------- --------------- ---------------
  2020-08-30   K2-23 331.202603 -12.01786 22:04:48.62 -12:01:04.3 ...             Sl
ow ESO-VLT-U3            DARK            DARK      1.58 [1.00]
  2020-08-30   K2-23  331.20261 -12.01784 22:04:48.63 -12:01:04.2 ...             Sl
ow ESO-VLT-U3            DARK            DARK      1.44 [0.85]
  2020-08-30   K2-23 331.202637 -12.01782 22:04:48.63 -12:01:04.2 ...             Sl
ow ESO-VLT-U3            DARK            DARK      2.24 [1.72]
  2020-08-30 LHS1140  11.248446 -15.27439 00:44:59.63 -15:16:27.8 ...             Sl
ow ESO-VLT-U3            DARK            FPCS      1.20 [0.53]
```

In [57]:

```python
# Query the archive for ESPRESSO science data on 2019-08-29, and return only the targ
et name, ra, dec and release date
results = eso.query_instrument('espresso', column_filters={'night':'2019-08-29','dp_c
at':'SCIENCE'}, columns=['target','prog_type'])['Object','RA','DEC','Release Date']
results.pprint(max_width=100)
```

```
 Object      RA         DEC     Release Date
------- ---------- --------- ------------
  K2-23 331.202603 -12.01786   2020-08-30
  K2-23  331.20261 -12.01784   2020-08-30
  K2-23 331.202637 -12.01782   2020-08-30
LHS1140  11.248446 -15.27439   2020-08-30
```

→ **SIMBAD ([http://simbad.u-strasbg.fr/simbad/ (http://simbad.u-strasbg.fr/simbad/)](http://simbad.u-strasbg.fr/simbad/))**

In [58]:
```python
from astroquery.simbad import Simbad

# query for HD 209458
results_table = Simbad.query_object("HD 209458")
print(results_table)
```

```
 MAIN_ID        RA           DEC      ... COO_WAVELENGTH     COO_BIBCODE
             "h:m:s"       "d:m:s"    ...
--------- ------------- ------------- ... -------------- -------------------
HD 209458 22 03 10.7729 +18 53 03.548 ...              O 2018yCat.1345....0G
```

In [59]:
```python
# returning the ra, dec, main ID of Helvetios
results_table = Simbad.query_object("Helvetios")
print(results_table['MAIN_ID','RA','DEC'])
```

```
 MAIN_ID        RA           DEC
             "h:m:s"       "d:m:s"
--------- ------------- -------------
*  51 Peg 22 57 27.9804 +20 46 07.782
```

In [60]:
```python
# query for all WASP targets
results_table = Simbad.query_object("WASP-*", wildcard=True)
print (results_table['MAIN_ID','RA','DEC'])
```

```
  MAIN_ID          RA           DEC
                "h:m:s"       "d:m:s"
------------ ------------- -------------
      WASP-1 00 20 40.0746 +31 59 23.953
     WASP-1b 00 20 40.0746 +31 59 23.953
      WASP-2 20 30 54.1279 +06 25 46.338
** DAE   10B  20 30 54.179  +06 25 46.18
     WASP-2b 20 30 54.1279 +06 25 46.338
 BD+35  3293 18 34 31.6255 +35 39 41.489
BD+35  3293b 18 34 31.6255 +35 39 41.489
      WASP-4 23 34 15.0858 -42 03 41.049
     WASP-4b 23 34 15.0858 -42 03 41.049
      WASP-5 23 57 23.7565 -41 16 37.745
         ...           ...           ...
   WASP-181b 01 47 10.3796 +03 07 58.897
   WASP-182b 20 46 41.5598 -41 49 15.202
   WASP-183b 10 55 09.3535 -00 44 13.811
   WASP-184b 13 58 04.0876 -30 20 53.271
   WASP-185b 14 16 14.3136 -19 32 32.208
 TOI-1494.01 01 15 58.8508 +21 37 01.006
 TOI-1493.01 01 09 53.9653 +25 40 54.103
   WASP-189b 15 02 44.8679 -03 01 52.986
   WASP-190b 00 30 50.2350 -40 34 24.319
   WASP-192b 14 54 38.0915 -38 44 40.344
Length = 394 rows
```

In [61]:
```python
# list all possible wildcards
Simbad.list_wildcards()
```

```
* : Any string of characters (including an empty one)

? : Any character (exactly one character)

[abc] : Exactly one character taken in the list. Can also be defined by a range of c
haracters: [A-Z]

[^0-9] : Any (one) character not in the list.
```

In [62]:
```
# query a article/bibcode
results_table = Simbad.query_bibcode('1995Natur.378..355M')

print (results_table)
```

```
                                                                References
-------------------------------------------------------------------------------------
--------------------------------------------------------
1995Natur.378..355M = DOI 10.1038/378355a0
Nature, 378, 355-359 (1995)
MAYOR M. and QUELOZ D.
A Jupiter-mass companion to a solar-type star.
```

In [63]:
```
# query for all objects related to an article/bibcode
results_table = Simbad.query_bibobj('1995Natur.378..355M')
print(results_table['MAIN_ID','RA','DEC'])
```

```
  MAIN_ID          RA            DEC
                "h:m:s"       "d:m:s"
------------ ------------- -------------
PSR B1257+12 13 00 03.1075 +12 40 55.155
 *   51 Peg b 22 57 27.9804 +20 46 07.782
   *   51 Peg 22 57 27.9804 +20 46 07.782
```

In [ ]:

What services are available in Astroquery?

[https://astroquery.readthedocs.io/en/latest/#available-services (https://astroquery.readthedocs.io/en/latest/#available-services)](https://astroquery.readthedocs.io/en/latest/#available-services)

Pandas

In [64]:
```python
import pandas as pd
print(pd.__doc__)
```

```
pandas - a powerful data analysis and manipulation library for Python
=====================================================================

**pandas** is a Python package providing fast, flexible, and expressive data
structures designed to make working with "relational" or "labeled" data both
easy and intuitive. It aims to be the fundamental high-level building block for
doing practical, **real world** data analysis in Python. Additionally, it has
the broader goal of becoming **the most powerful and flexible open source data
analysis / manipulation tool available in any language**. It is already well on
its way toward this goal.

Main Features
-------------
Here are just a few of the things that pandas does well:

  - Easy handling of missing data in floating point as well as non-floating
    point data.
  - Size mutability: columns can be inserted and deleted from DataFrame and
    higher dimensional objects
  - Automatic and explicit data alignment: objects can be explicitly aligned
    to a set of labels, or the user can simply ignore the labels and let
    `Series`, `DataFrame`, etc. automatically align the data for you in
    computations.
  - Powerful, flexible group by functionality to perform split-apply-combine
    operations on data sets, for both aggregating and transforming data.
  - Make it easy to convert ragged, differently-indexed data in other Python
    and NumPy data structures into DataFrame objects.
  - Intelligent label-based slicing, fancy indexing, and subsetting of large
    data sets.
  - Intuitive merging and joining data sets.
  - Flexible reshaping and pivoting of data sets.
  - Hierarchical labeling of axes (possible to have multiple labels per tick).
  - Robust IO tools for loading data from flat files (CSV and delimited),
    Excel files, databases, and saving/loading data from the ultrafast HDF5
    format.
  - Time series-specific functionality: date range generation and frequency
    conversion, moving window statistics, date shifting and lagging.
```

img align="left" width="500" src="./know_more_banner.png">

[https://pandas.pydata.org/docs/ (https://pandas.pydata.org/docs/)](https://pandas.pydata.org/docs/)

Astroconda

AstroConda is a free Conda channel maintained by the Space Telescope Science Institute (STScI) in Baltimore, Maryland. This channel provides tools and utilities required to process and analyze data from the Hubble Space Telescope (HST), James Webb Space Telescope (JWST), and others.

At this moment, it is the best (only?) way to install IRAF on more recent machines.

https://astroconda.readthedocs.io/en/latest/ (https://astroconda.readthedocs.io/en/latest/)

python-cpl

"The Common Pipeline Library (CPL) consists of a set of C libraries, which have been developed to standardise the way VLT instrument pipelines are built, to shorten their development cycle and to ease their maintenance. The Common Pipeline Library was not designed as a general purpose image processing library, but rather to address two primary requirements. The first of these was to provide an interface to the VLT pipeline runtime- environment. The second was to provide a software kit of medium-level tools, which allows astronomical data-reduction tasks to be built rapidly." (http://www.eso.org/sci/software/cpl/introduction.html (http://www.eso.org/sci/software/cpl/introduction.html))

The `python-cpl` library is a non-official python module to access and run CPL recipes.

https://python-cpl.readthedocs.io/en/latest/ (https://python-cpl.readthedocs.io/en/latest/)

email us at Jorge.Martins@astro.up.pt (mailto:Jorge.Martins@astro.up.pt) or Andre.Silva@astro.up.pt (mailto:Andre.Silva@astro.up.pt)

In [ ]: