Teaching Physics with Python

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Outline

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1. Context
2. Why Python?
3. Challenges
4. The courses
5. More challenges (and successes)
6. The future

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7. Conclusions

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- 2013-2014: Introduction of brand new Python course for first year "Practical physics 1A" module
- 2014-2015: Introduction of follow-on Python course for second year "Practical physics 2B" module
- Now integrating computing into other parts of the curriculum

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However...

Modern languages like Python make computation much more accessible to the non-specialist.

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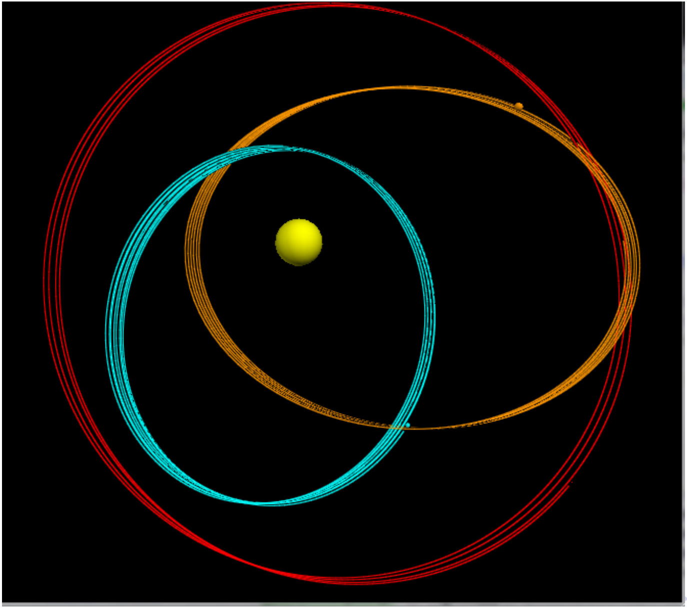
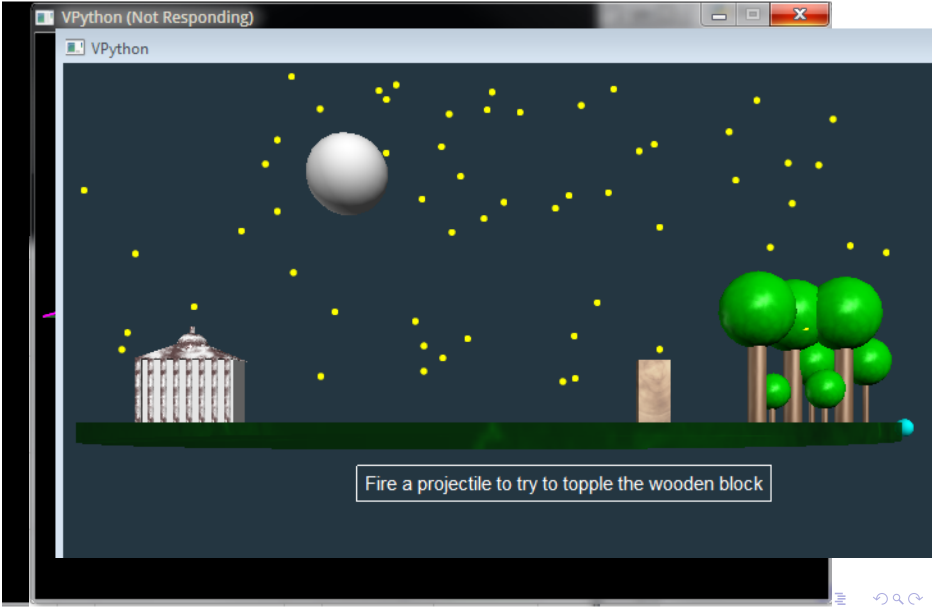
Vpython



Vpython


VPython (Not Responding)
Target at
x = 5.75 m
You hit the target, but failed to topple it!

Vpython


VPython (Not Responding)
VPython
Fire a projectile to try to topple the wooden block

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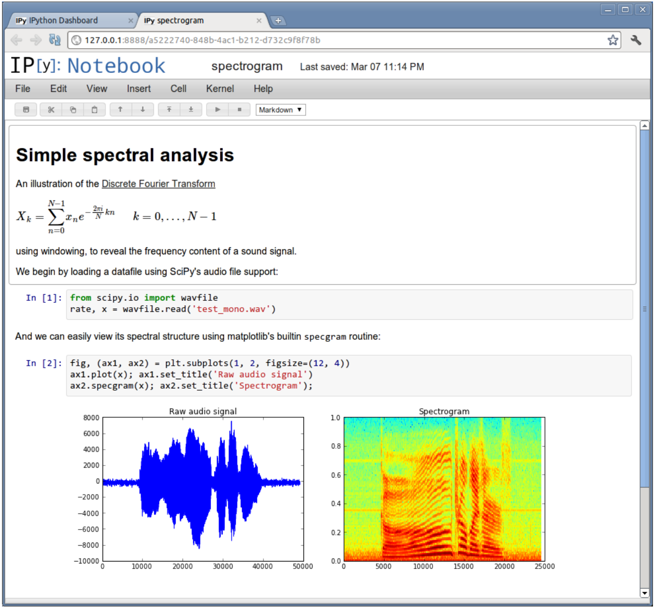
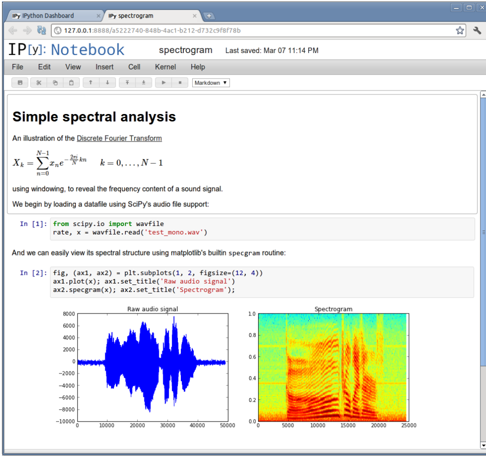
The IPython Notebook



The IPython Notebook

- Text commentary encourages students to think clearly about what they are doing and *why*...
- ...from a coding and from a physics point of view.



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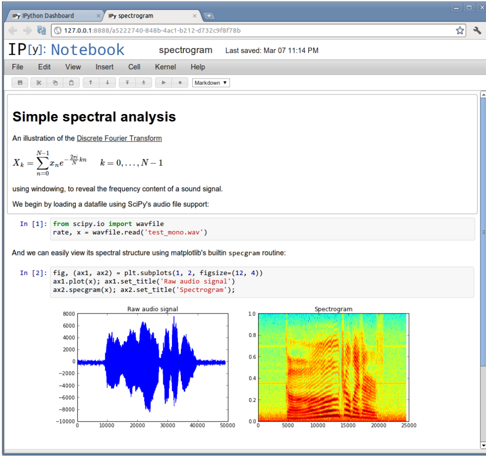

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In [5]:
```
guess = [75,10,3.5,18] # list of initial guess parameters

type(guess) # what type of object does the variable "guess" represent?
```
Out[5]:
```
list
```

Now we can retry the fit:

In [6]:
```
popt,pcov = curve_fit(gaussian,xdata,ydata,p0=guess)
print "popt :\n", popt
print "pcov :\n", pcov
```
```
popt :
[ 72.50930905    3.01525268    3.85742572   13.40680376]
pcov :
[[  2.02507205e-03  -3.77758184e-10   4.14321753e-12   1.66043777e-09]
 [ -3.77758184e-10   2.22561784e-03  -6.30519920e-04  -4.05620885e-03]
 [  4.14321753e-12  -6.30519920e-04   1.98236679e-03  -1.40174499e-03]
 [  1.66043777e-09  -4.05620885e-03  -1.40174499e-03   3.10175058e-02]]
```

This has worked (or it should have done)! We can use the information from the matrix of covariance to calculate the error on each parameter, just as we did in the previous session for the polynomial coefficients. Remember, the errors on the parameters are given by the *square roots* of the diagonal elements of the matrix of covariance.

In the cell below, you should:

- calculate the errors on the parameters
- output each parameter with its error and an appropriate text string
- plot the original data and the fitted line on a single, appropriately labelled graph

In [7]:
```
### STUDENT COMPLETED CELL ###
```

If you've done this correctly, you should obtain a good fit to the data.

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- At the beginning they don't know much physics or maths either...
- Computing notoriously hard to teach, and to assess (see work of Mark Guzdial, https://computinged.wordpress.com/

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  - ...mostly based on classical mechanics

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- ...Compare and contrast with inbuilt (numpy) FFT libraries

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  - Students considerably more anxious about marks than understanding the concepts
- IPython Notebooks and Vpython don't work well together, frustratingly!

Successes

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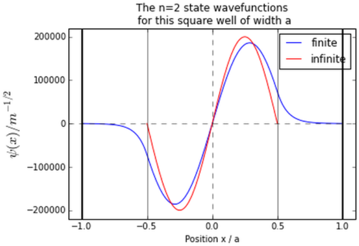
```
plt.xlim(-1.1,1.1)
plt.ylim(min(iwf)*1.1, max(iwf)*1.1)
plt.legend(loc='best')
plt.title("The n=2 state wavefunctions \n for this square well of width a")
```

[72]: <matplotlib.text.Text at 0x17002dd8>



Same observations as in the $n = 1$ state can be seen here, which include the sinusoidal wave form similar to the $n = 2$ 'infinite' wave inside the finite walls, and the decay to zero outside. Differences between the two above waves are due to their different energies and boundary conditions. These points are also exhibited in all higher energy states. Take $n = 3$ state for example, with which we'll, firstly, calculated the energy level E_3:

[73]:
```
# Define the initial conditions
E1 = Eisw[2]*0.3 # guess 1 of n=2 state energy (J)
E2 = Eisw[2]*0.6 # guess 2 of n=2 state energy (J)

# solve for the first and second guesses
psi1 = RungeKutta2d3(xpoints,E1)[N]
psi2 = RungeKutta2d3(xpoints,E2)[N]

### now for the secant method to converge on the right answer
```

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    - Partial solution: run "catch-up" conversion workshop from Matlab to Python

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- Early stages of planning new lecture course where the physics will be entirely assessed by IPython Notebook computation rather than written exam.

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- Extending this to fully embed computational physics within the curriculum

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