

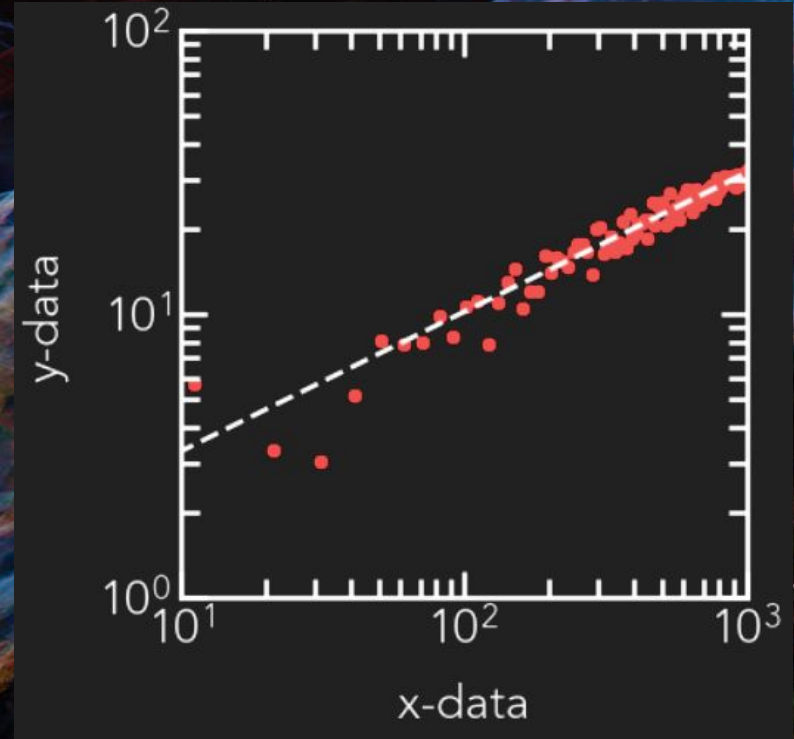
A vibrant, multi-colored image of the cosmic web, showing intricate filaments of gas and dark matter in shades of blue, red, and green against a black background filled with distant stars.

Lecture 11

Statistics and Plotting

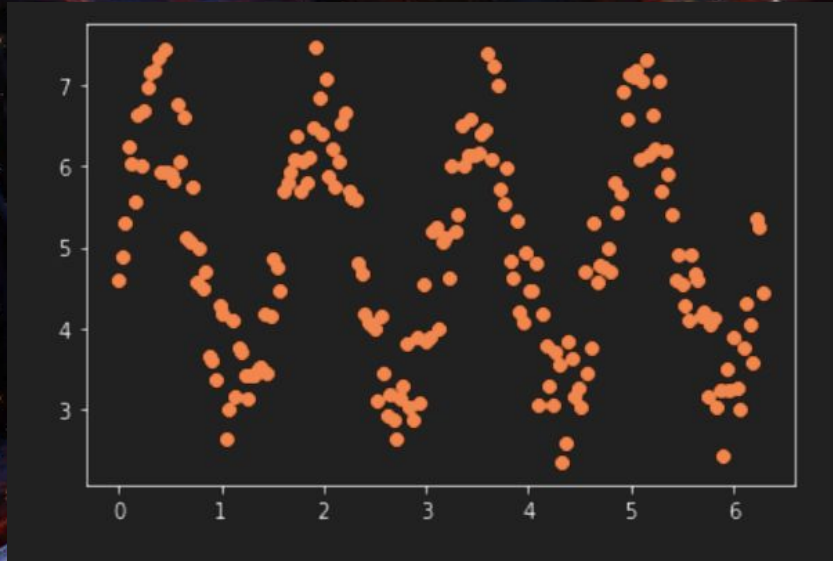
What's better than a plot?

- A plot with statistical significance
- We can do this by fitting our plots with a trend line.
- From this we can make predictions of the data with a known uncertainty



What do we need for fitting?

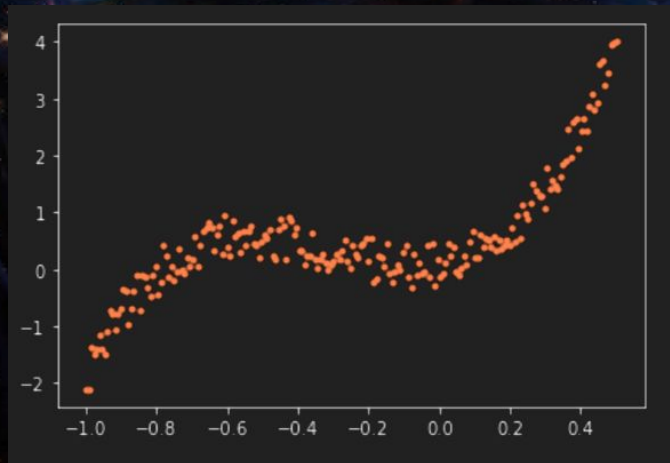
DATA



MODEL

$$y = f(x)$$

First Step: Learning Polynomial Fits



$$y = a_0 + a_1x + a_2x^2 + \dots + a_Px^P = \sum_{i=0}^P a_ix^i$$

Degree of the polynomial
(the highest power P)

`np.polyfit(x, y, deg)`

It outputs an array of coefficients

`[aP, ..., a1, a0]`

A visualization of the cosmic web, showing a vast network of dark matter filaments and galaxy clusters. The filaments are depicted as thin, glowing lines in shades of blue, purple, and red, stretching across a deep black space filled with numerous small, distant stars. The overall structure is complex and interconnected, illustrating the large-scale organization of the universe.

Demo Time....

The background of the slide is a deep space image featuring vibrant, multi-colored nebulae in shades of blue, red, and green, set against a dark field filled with numerous stars of varying brightness.

Something slightly more useful...

```
from scipy.optimize import curve_fit
```

Importing the function this way will allow you to directly use the **curve_fit** function without typing everything else.

This command basically picks out the function from **scipy.optimize** package.

The `curve_fit` function

```
fit_params = curve_fit(model, xdata, ydata,  
                        Initial guess, [...] is an array p0=[...],  
                        Uncertainty on ydata, [...] is an array of length len(ydata) sigma=[...],  
                        Fixes range for your fitted parameter bounds=( [...], [...]))
```

A note on defining the model function:

```
def model(x, a1, a2, a3):  
    return a1*np.sin(x)**a2 + a3
```

Fitted parameters can be obtained by calling `fit_params[0]`

What is a good fit?

Minimise chi-squared

$$\chi^2 = \sum_i \left(\frac{y_i - f(x_i)}{\sigma_i} \right)^2$$

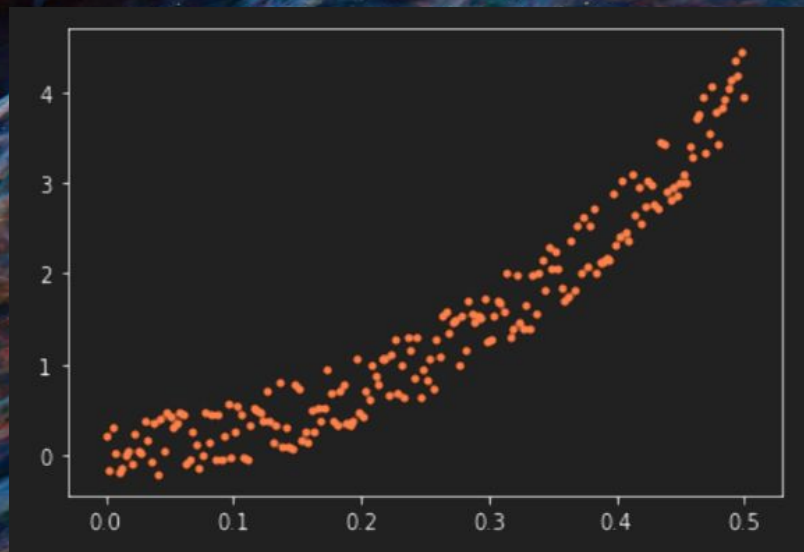
Fitted model

uncertainty

Be aware of overfitting

- Number of data points should be larger than the number of fitted parameters
- I can guarantee once you start taking lab classes they will ask for the chi-squared value

What function could be the model?



A visualization of the cosmic web, showing a vast network of filaments and clusters of galaxies. The filaments are depicted as thin, glowing lines of blue, red, and green, stretching across a dark, star-filled background. The overall structure is complex and interconnected, representing the large-scale distribution of matter in the universe.

Demo Time Part 2...

Root Finding

$$\sqrt{1 - x^2} = \sin(x)$$

- There are equations we simply cannot solve analytically by hand

```
from scipy.optimize import root
```

```
sol = root(func, x0)
```

```
def func(x):  
    return np.sqrt(1-x**2)-np.sin(x)
```

The equation you want
to find roots of

Initial guess
(can be found by plotting)

Solution can be obtained by calling `sol.x`

Root Finding

- We can also use the function from `scipy.optimize`:

```
from scipy.optimize import fsolve
```

```
fsolve(func, x0, args=())
```

- What if you are given this function for the first time? Go to breakout rooms and discuss with others and come back with the explanation for the highlighted variables!

Root Finding

```
fsolve(func, x0, args=())
```

- **func**: a callable function that takes in at least one arguments and returns output of the same length.
- **x0**: The starting estimate of the roots of $\text{func}(x)=0$
- **args**: any other arguments that goes to func that you have defined.
- Outputs an ndarray that contains the solution.

A visualization of the cosmic web, showing a vast network of filaments and clusters of galaxies. The filaments are colored in vibrant shades of blue, red, and green, set against a dark background filled with numerous stars.

Demo Time 3...