Precision, Accuracy and Uncertainty in Data

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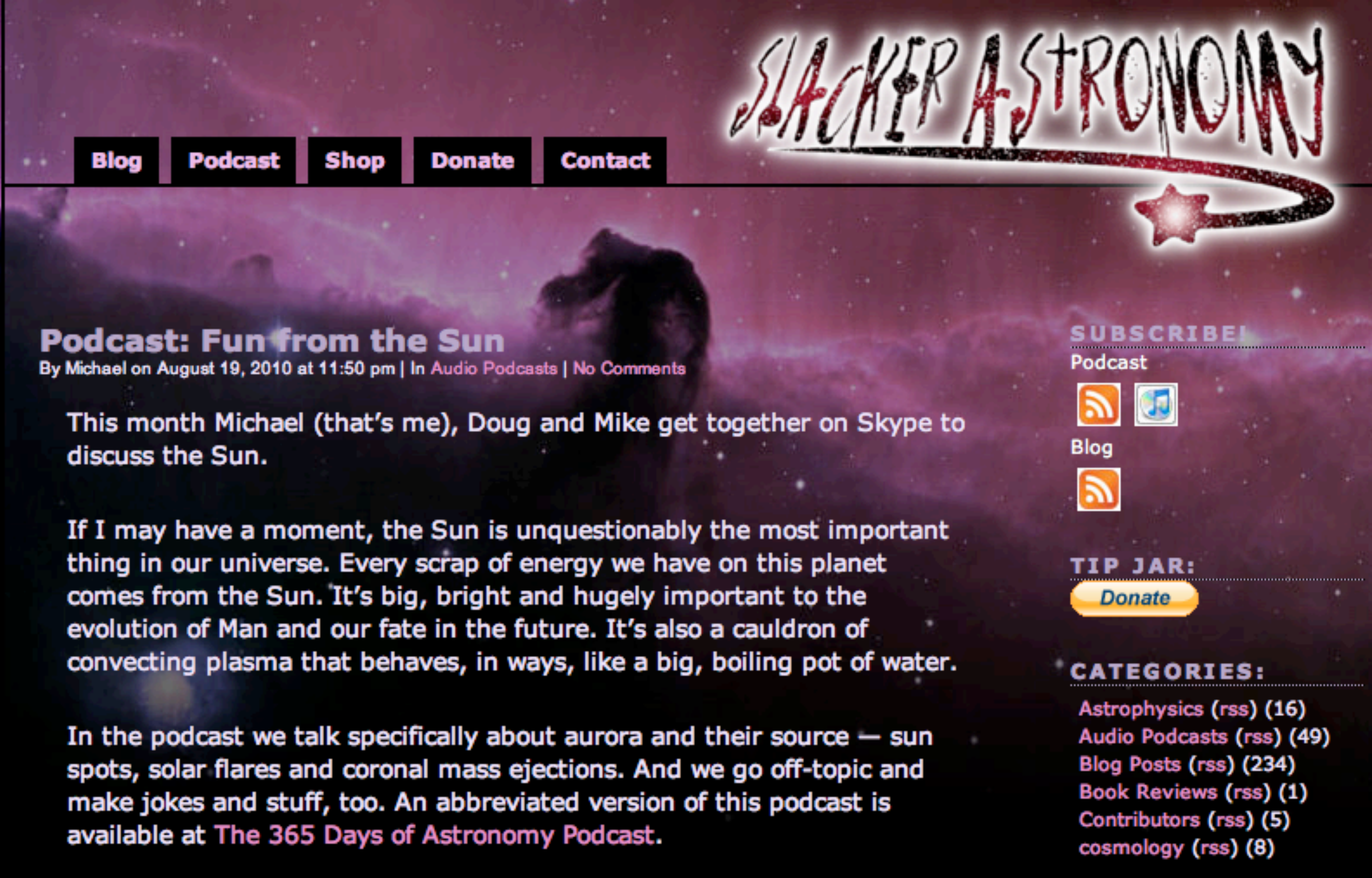
I'm an entrepreneur, astronomer, musician, rocketeer and general tech dork.



http://www.slackerastronomy.org/

Accuracy

Precision

Uncertainty

“data”

- A datum (or plural data) is a measured value.
- It’s a “fact”.
- It’s the output of a sensor, an algorithm or an observation.
- It is <u>always</u> *uncertain* to some extent.

Data is *reduced*

- For example, my CCD detector has 765 x 510 pixels at 16 bits/pixel so a single image is 6,242,400 bits (6.2MB) of data.
- My reported variable star measurement from that single image is approximately 200 bits of data.
- The data in this case was reduced by a factor of *30,000*!

Think about it.

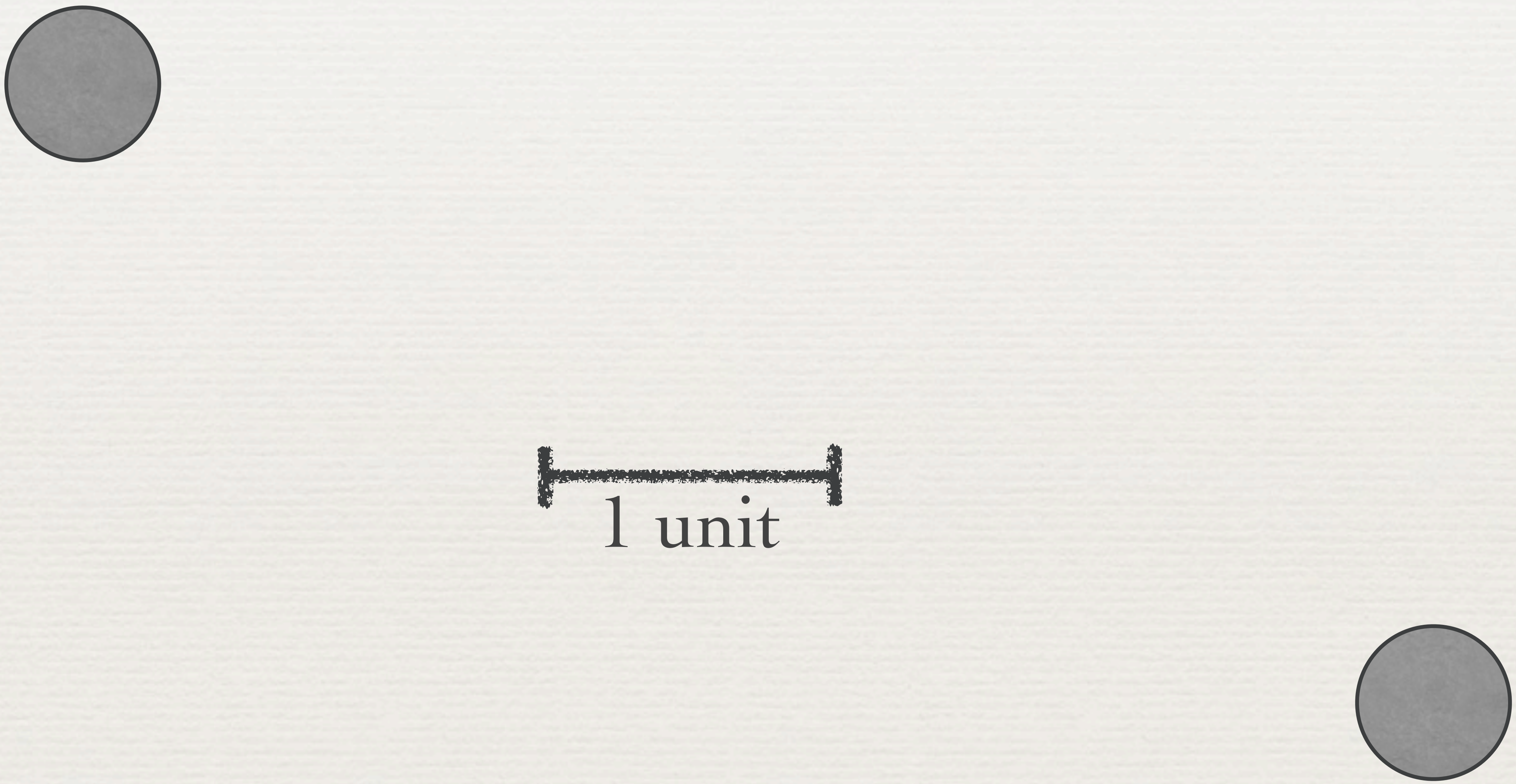
The whole point of science is to reduce data -- to take petabytes of data and turn it into a few key insights.

Statistics, in a sense, is the language of progress.

Thus

Understanding the quality of your data is just as important as understanding the data itself.

A little experiment*



How many units apart are these dots?

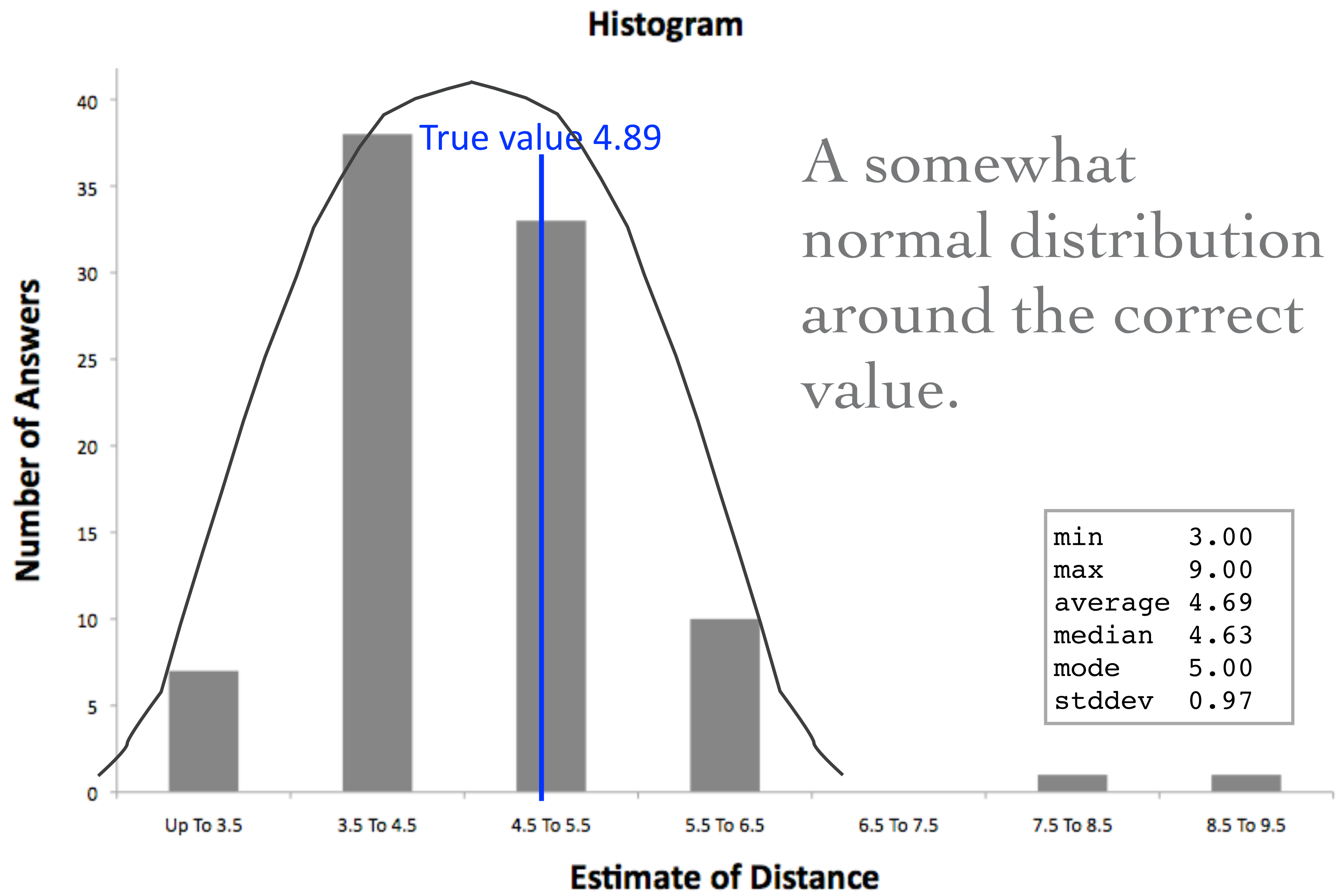
*http://www.lolife.com/experiment1/

What do we expect?

A somewhat normal distribution around the correct value.

Values near the true value should be more frequent than values far from the true value.

What do we get?



A somewhat normal distribution around the correct value.

min	3.00
max	9.00
average	4.69
median	4.63
mode	5.00
stddev	0.97

Accuracy

The degree to which a measured value agrees with the "true value".

Precision

The degree to which repeated measurements agree with each other.

Uncertainty

The range of values that can confidently said to contain the true value of a measurement.

Accuracy vs. Precision

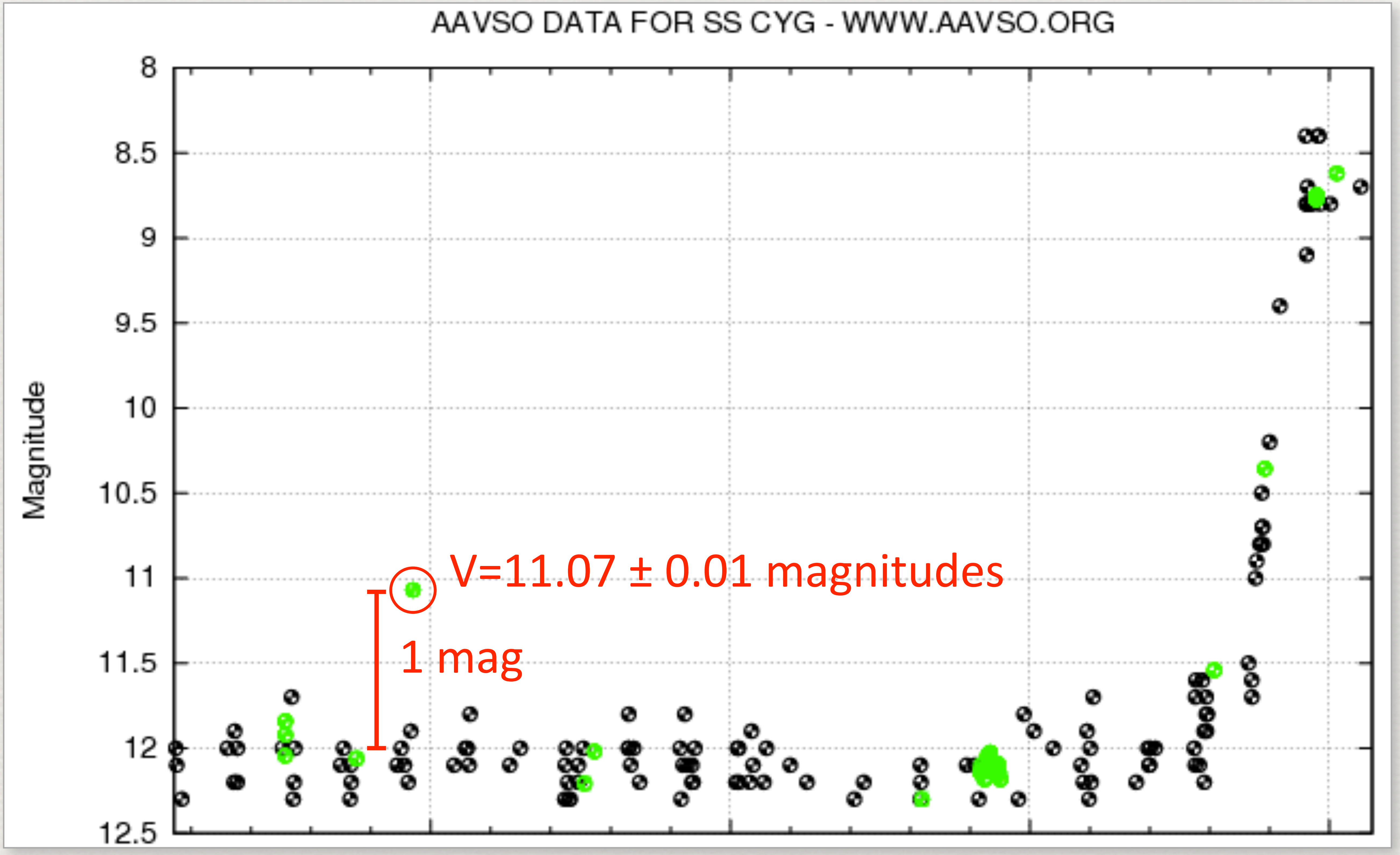
Accuracy is external agreement.

Precision is internal agreement.

Example: photometry

Photometric measurements have uncertainty due to precision (e.g. how many digits after the decimal point on the measurement) and due to accuracy (how well the zero-point of the system matches the standard system).

Example: photometry



Uncertainty

The range of values that can confidently said to contain the true value of a measurement.

Signal-to-Noise Ratio

- aka S/N, SNR
- A statistic of the quality of a measurement.
- A ratio of the data to the uncertainty.

Whence *uncertainty*?

- **Systematic** uncertainty (you unknowingly have a 13-inch ruler).
- **Random** uncertainty: An infinite number of low-amplitude processes and effects that you have no chance of ever physically understanding.

Systematic Uncertainty

"Errors" related to the system, apparatus or analysis specific to your setup.

Bad news: they are your fault.

Good news: they are (usually) fixable.

But you have to identify them first!

Random Uncertainty

- If the noise is dominated by the Poisson noise from the star being measured, the uncertainty is given simply by:

$$\delta q = \sqrt{N}$$

- …where N is the number of electrons (or photons) in the measurement. It is important to note that this does not work for analog-to-digital units (ADUs) – your counts must be in electrons (or photons).

Poisson Statistics

- It is fairly simple to see that this also gives an estimate of the SNR ratio:

$$\frac{S}{N} = \frac{N_*}{\sqrt{N_*}} = \sqrt{N_*}$$

- For example, if the net counts, measured in electrons, for a given star was 64,000 the uncertainty is +/- 253 counts and the SNR is 253. In this case the uncertainty is usually stated as 1/SNR or 0.004 in this example. This is a fractional uncertainty in that it is the noise divided by the signal. Thus, the uncertainty in this example is 0.4%.

Calculating Uncertainty

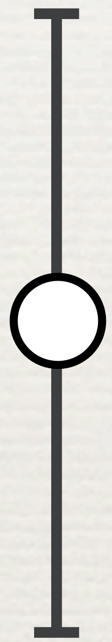
- Two primary methods:
  1. Additive (think of everything and add it up).

$$\frac{S}{N} = \frac{N_*}{\sqrt{N_* + n_{pix}(1 + \frac{n_{pix}}{n_B})(N_S + N_D + N_R^2 + G^2\sigma_f^2)}}$$

  2. Statistics.

$$\sigma_{K-C} = \sqrt{\frac{1}{N-1}\sum(x - \bar{x})^2}$$

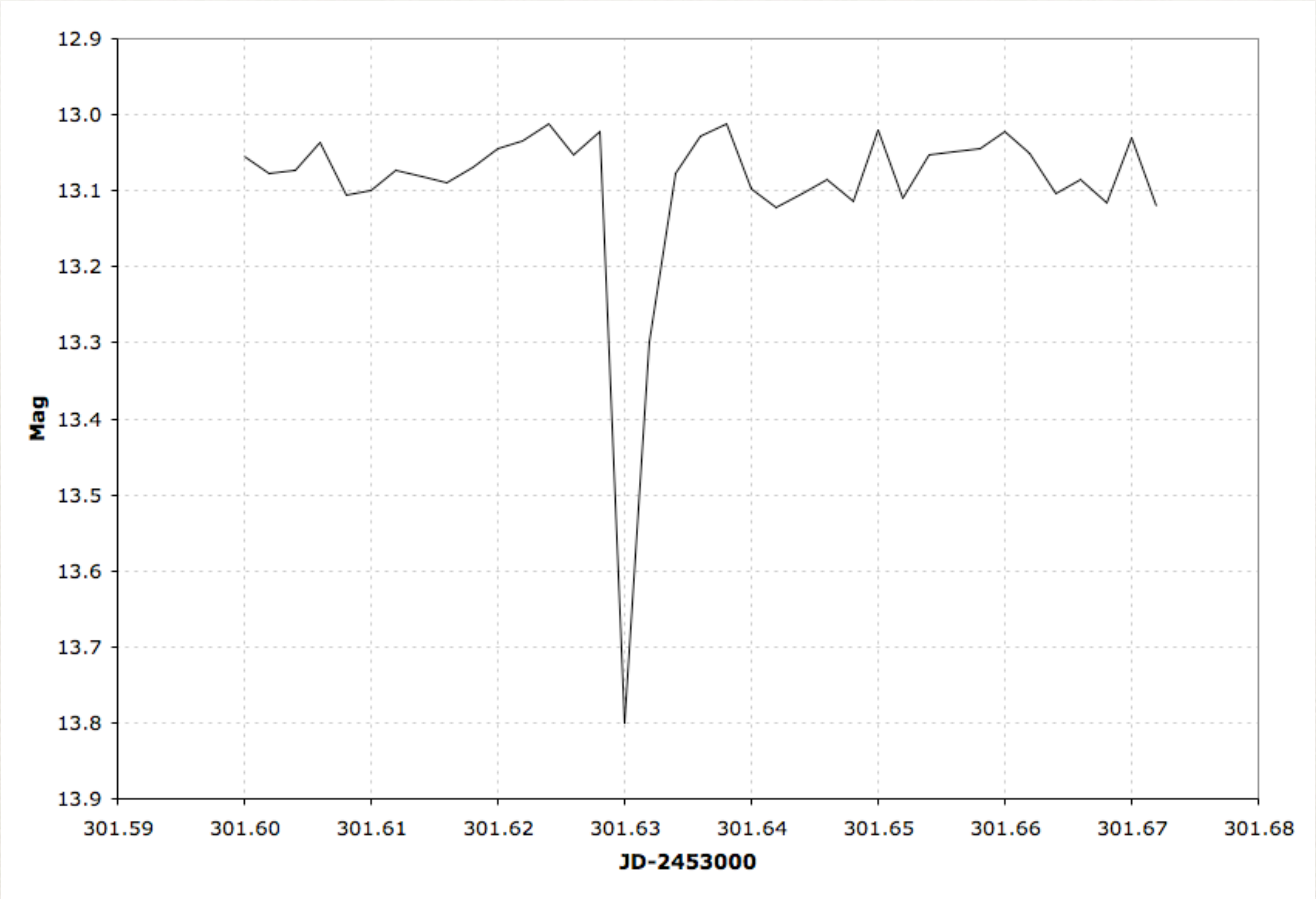
Error Bars



An easy and effective way to report uncertainty.

A Very Real Example

(although it is fabricated)



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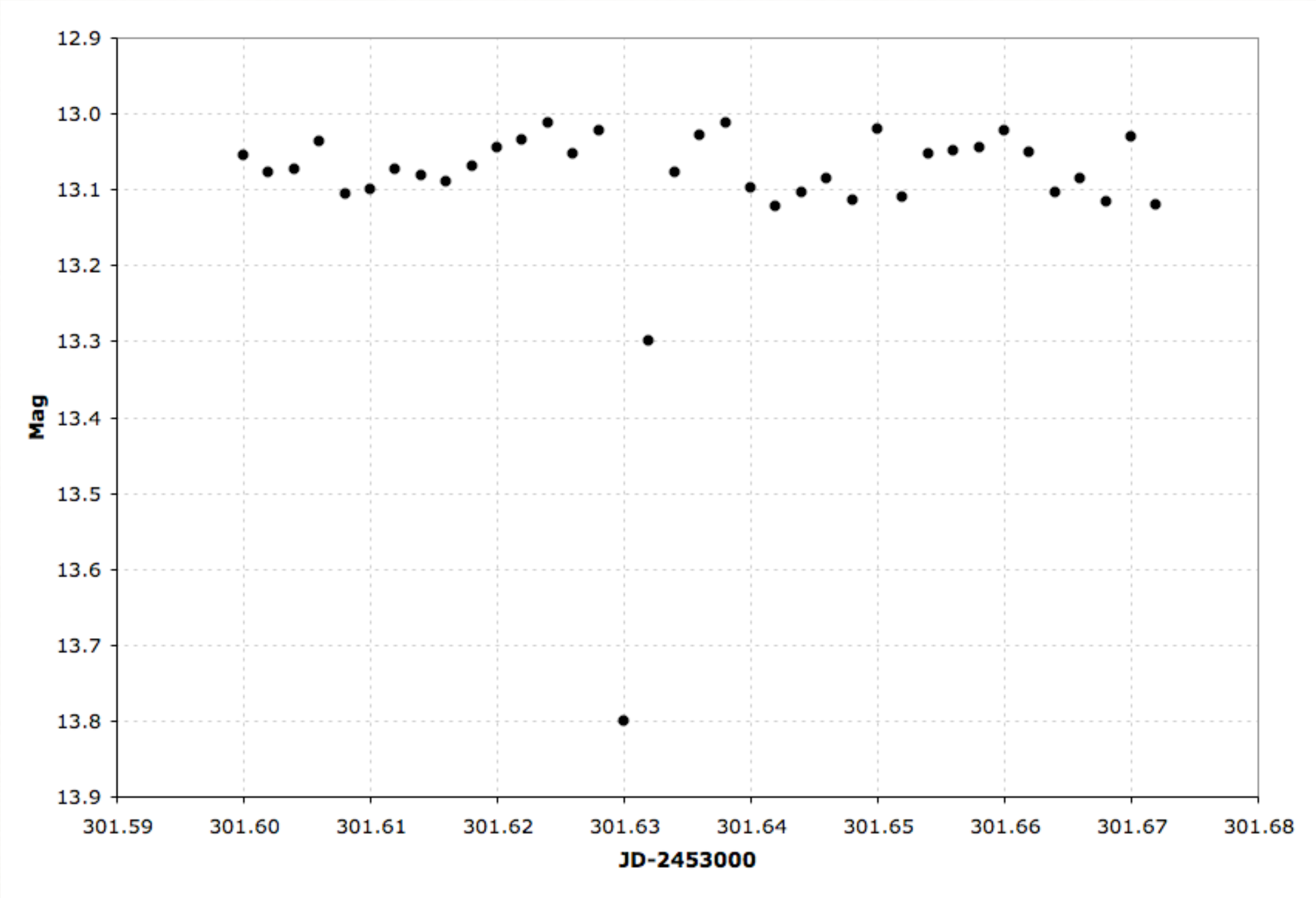

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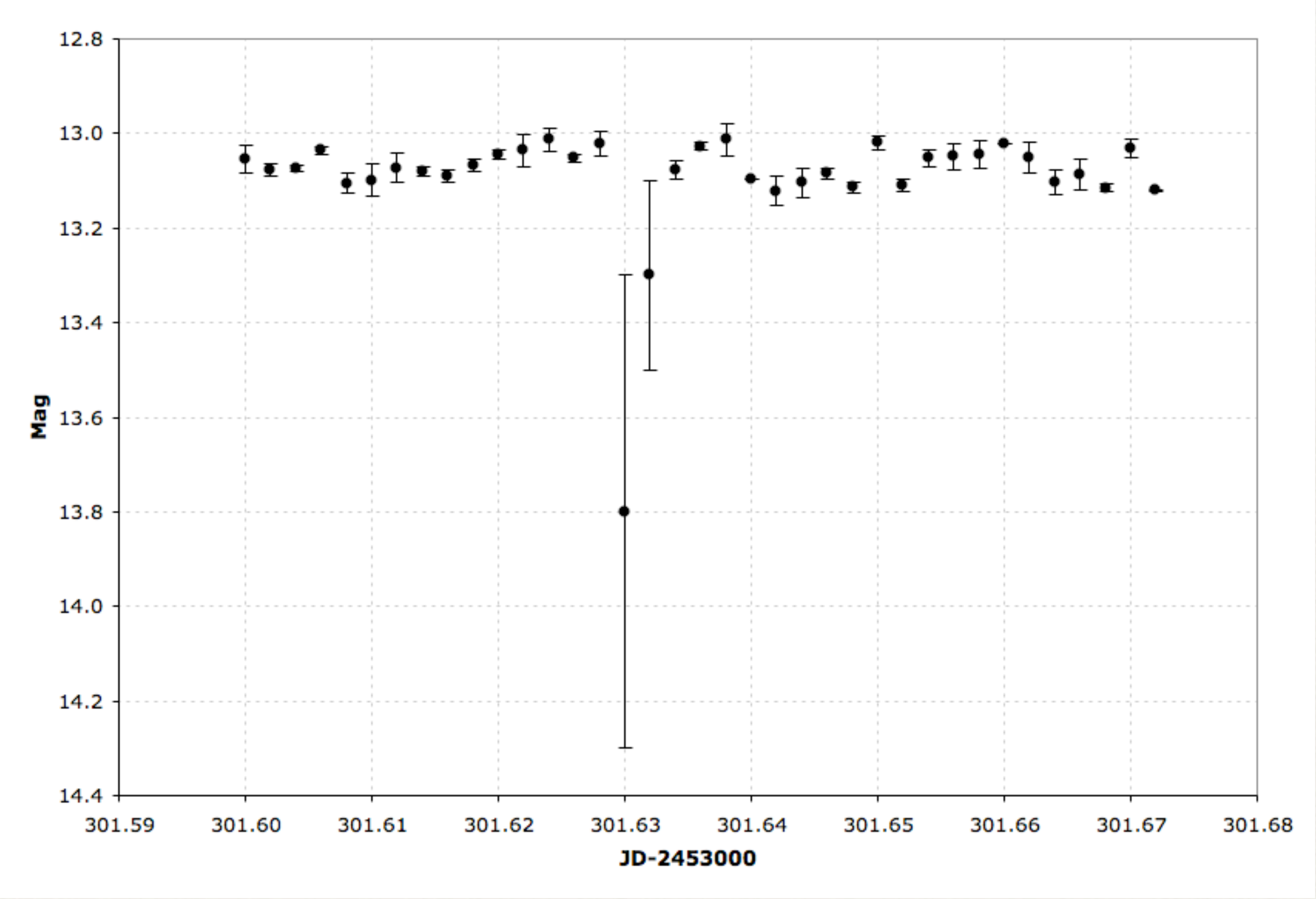
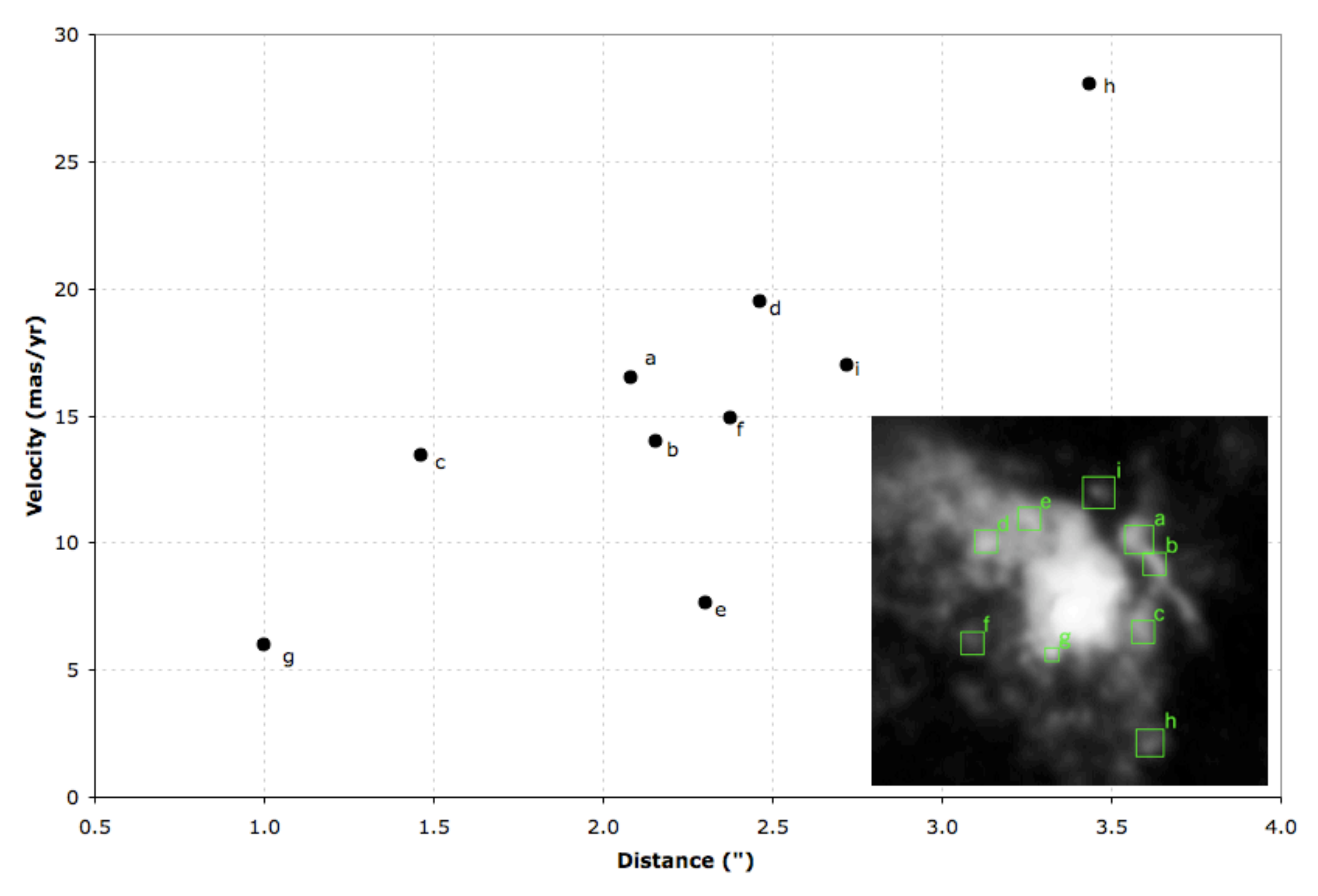


A Very Real Example

(that is actually real)



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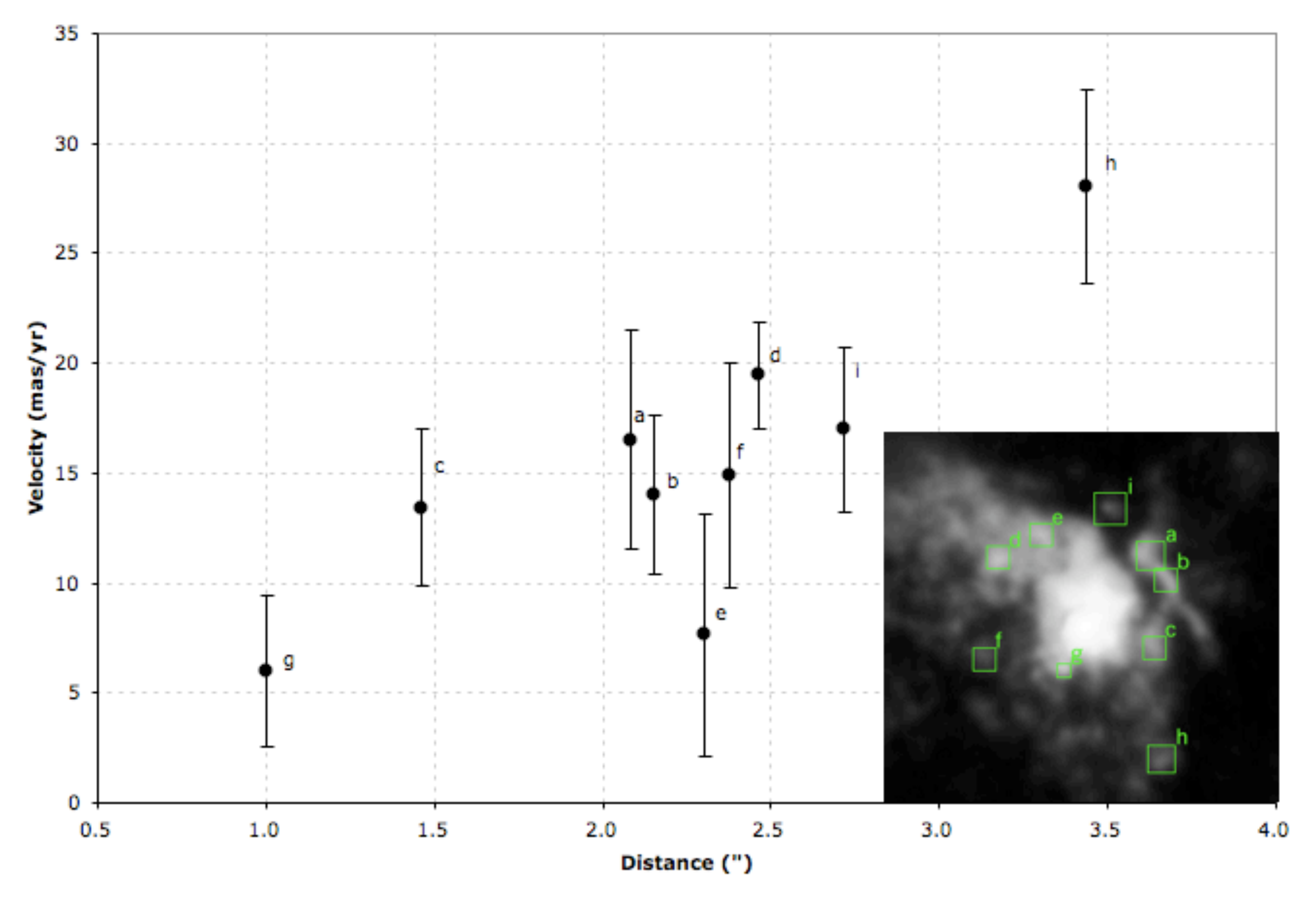
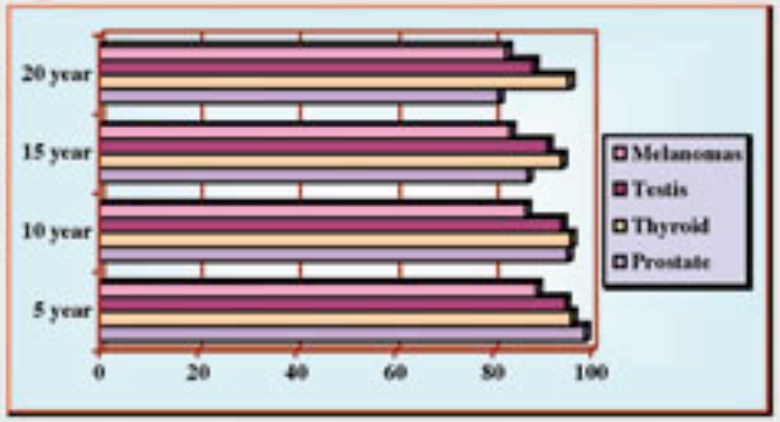
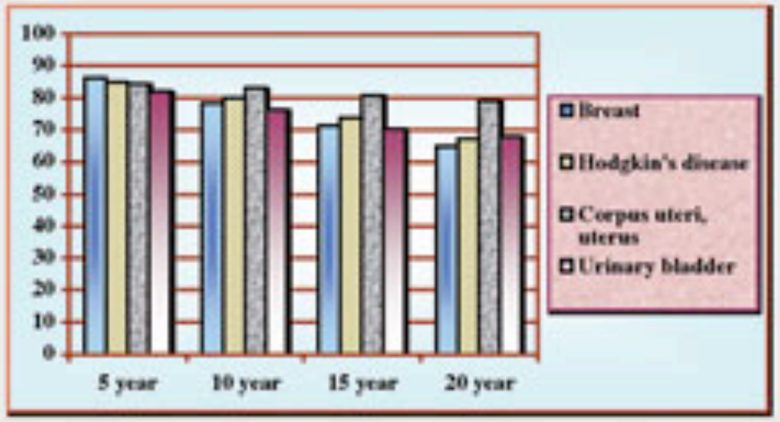


The purpose of a plot is to *assist thinking*.

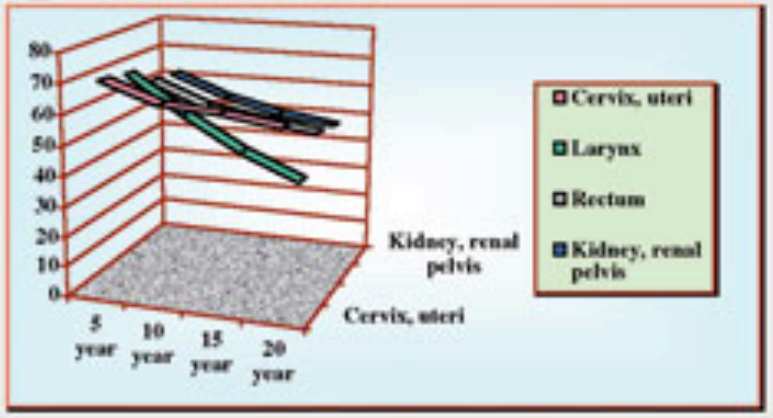
I. Cancer Survival Rates



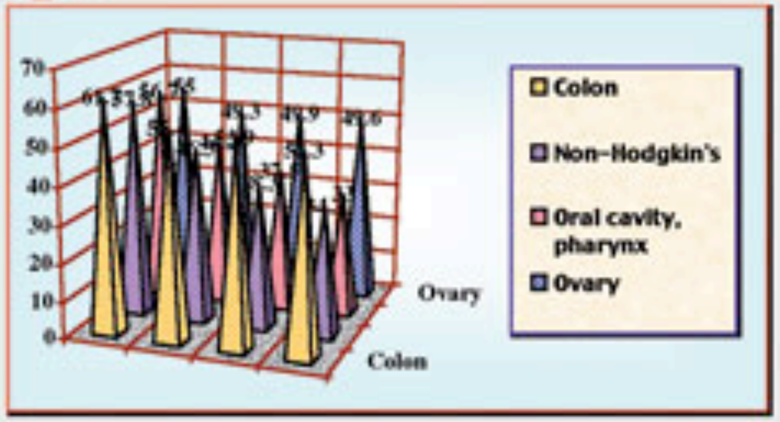
II. Cancer Survival Rates



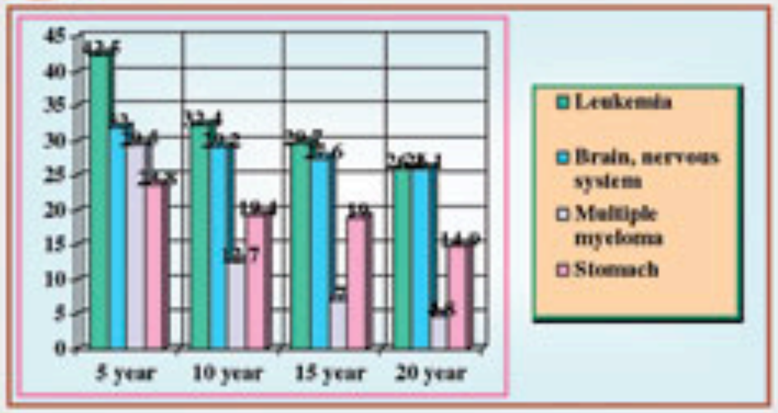
III. Cancer Survival Rates



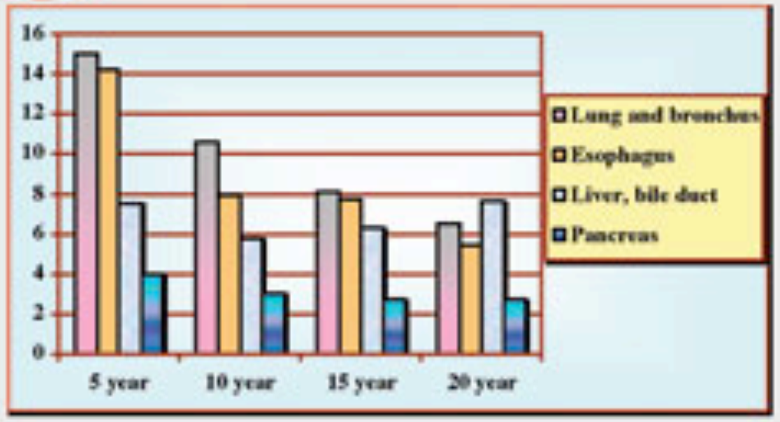
IV. Cancer Survival Rates



V. Cancer Survival Rates

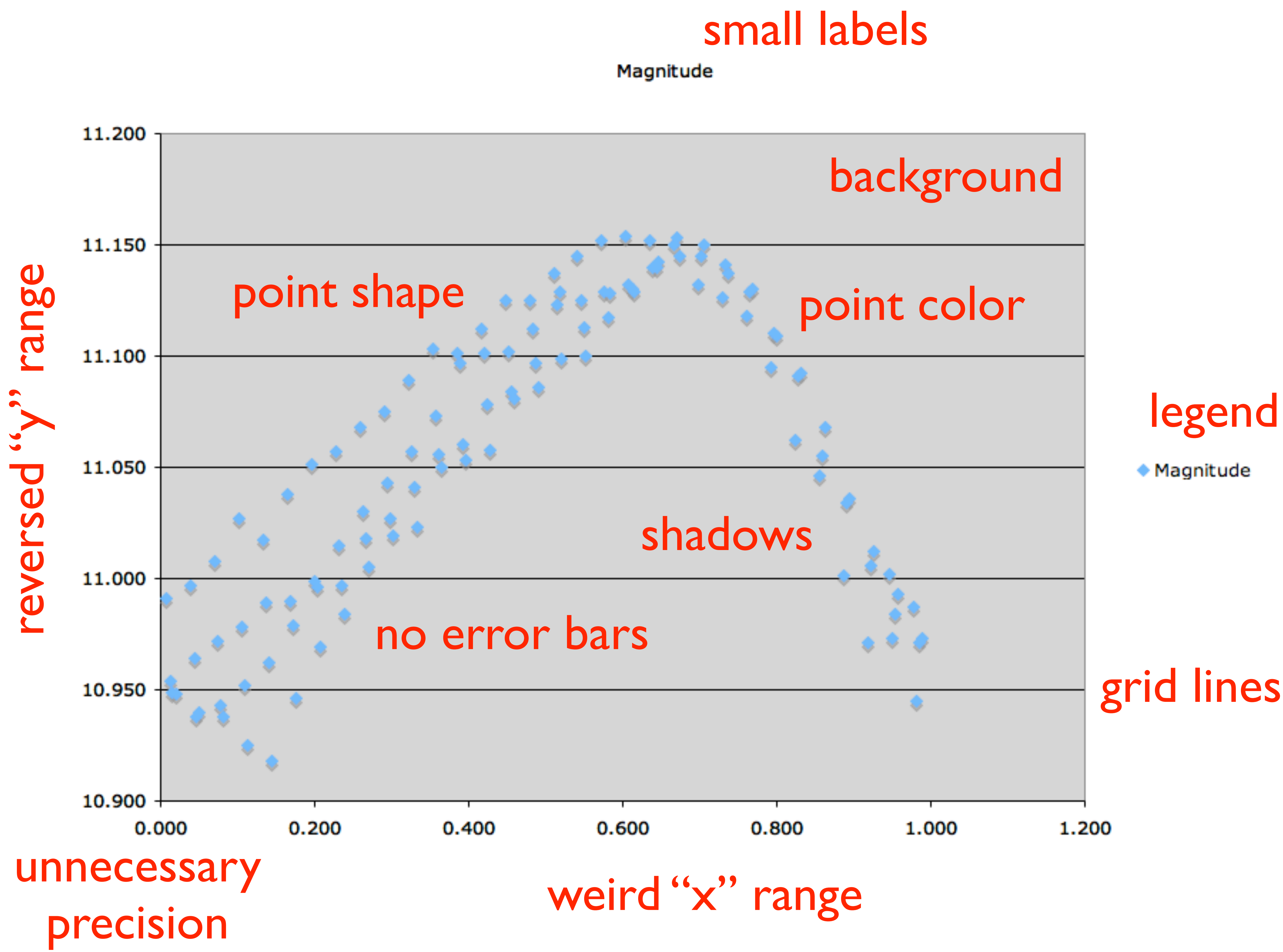


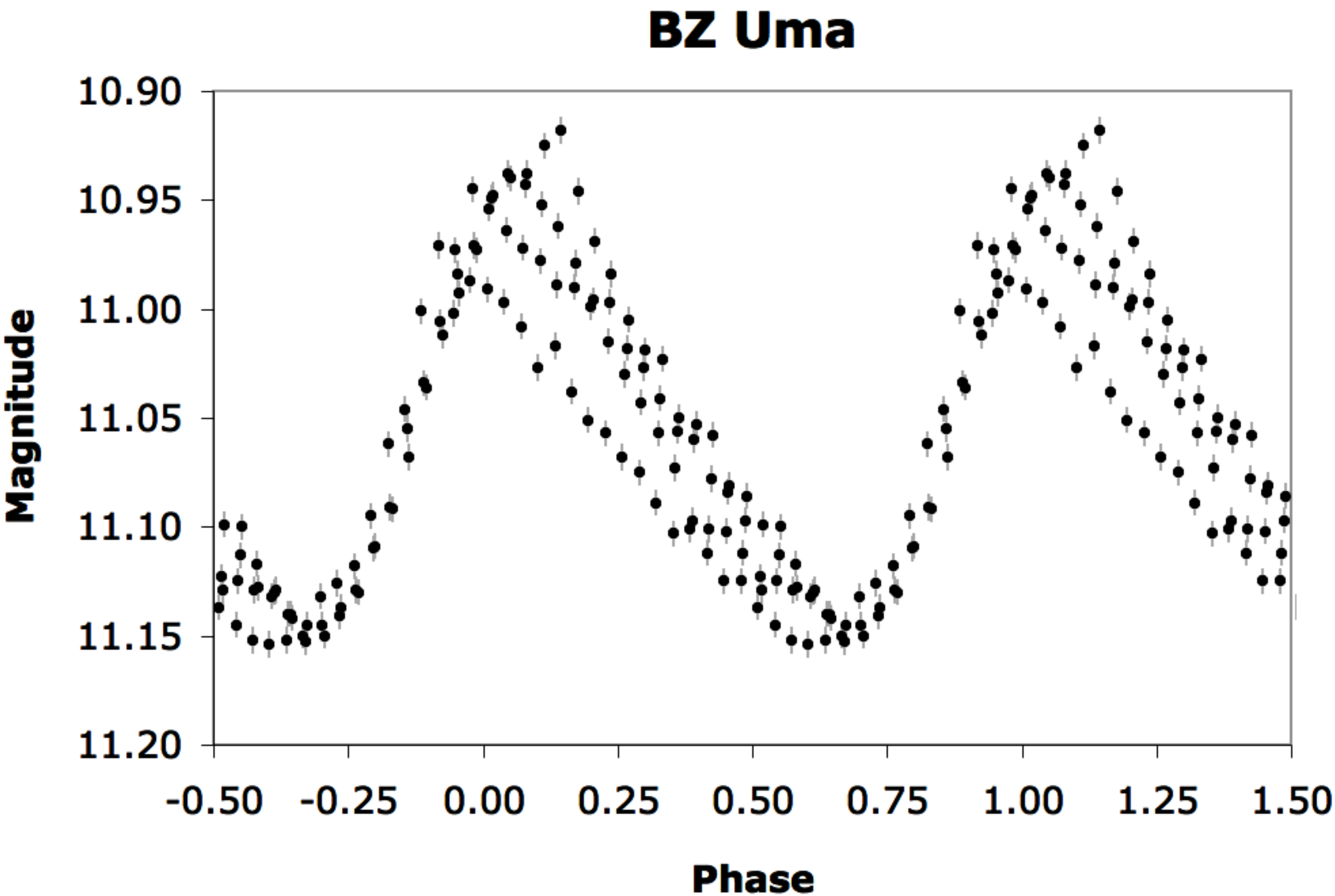
VI. Cancer Survival Rates



Estimates of % survival rates

	5 year	10 year	15 year	20 year
Prostate	99	95	87	81
Thyroid	96	96	94	95
Testis	95	94	91	88
Melanomas	89	87	84	83
Breast	86	78	71	65
Hodgkin's disease	85	80	74	67
Corpus uteri, uterus	84	83	81	79
Urinary, bladder	82	76	70	68
Cervix, uteri	71	64	63	60
Larynx	69	57	46	38
Rectum	63	55	52	49
Kidney, renal pelvis	62	54	50	47
Colon	62	55	54	52
Non-Hodgkin's	58	46	38	34
Oral cavity, pharynx	57	44	38	33
Ovary	55	49	50	50
Leukemia	43	32	30	26
Brain, nervous system	32	29	28	26
Multiple myeloma	30	13	7	5
Stomach	24	19	19	15
Lung and bronchus	15	[illegible]		


small labels
Magnitude
background
point shape
point color
legend
Magnitude
shadows
no error bars
grid lines
reversed "y" range
11.200
11.150
11.100
11.050
11.000
10.950
10.900
0.000
0.200
0.400
0.600
0.800
1.000
1.200
unnecessary precision
weird "x" range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11.00
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11.20
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-0.25
0.00
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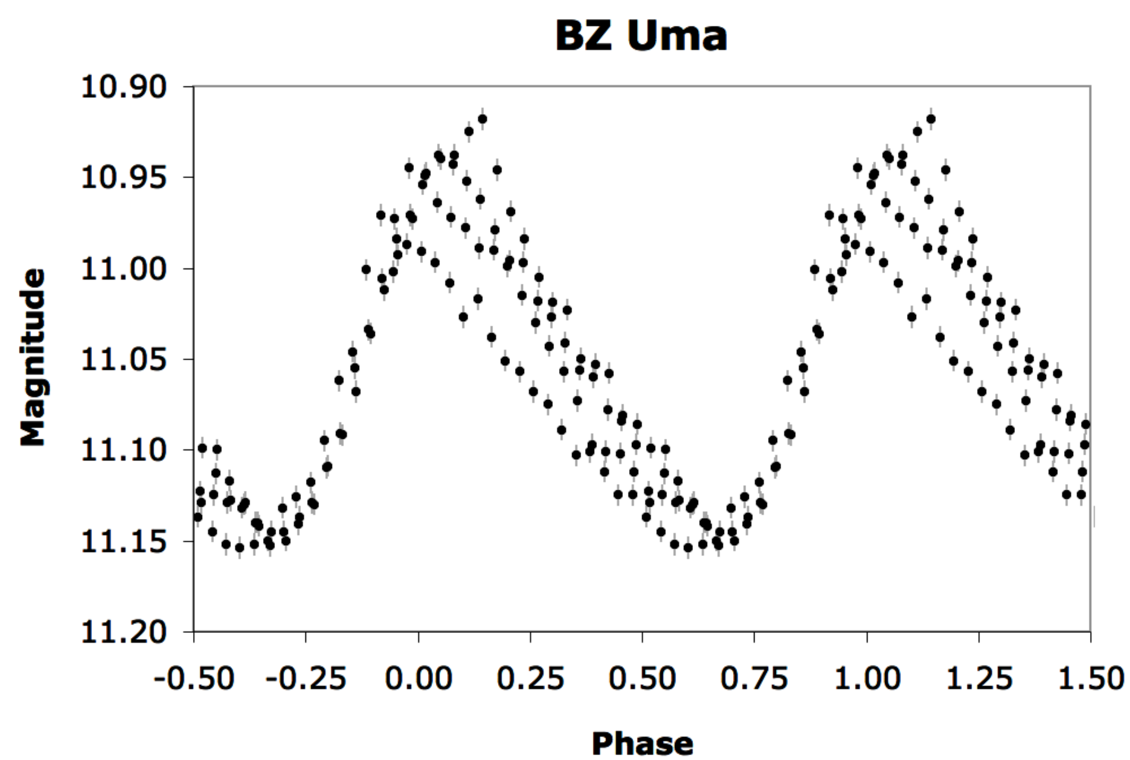
0.75
1.00
1.25
1.50
Phase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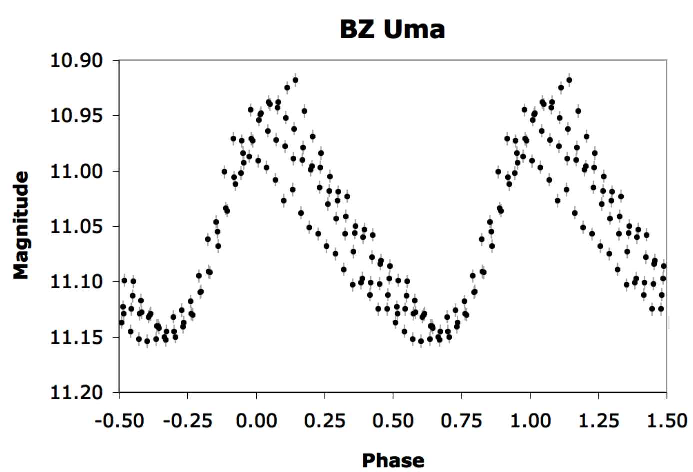
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
Phase



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Phase
10.90
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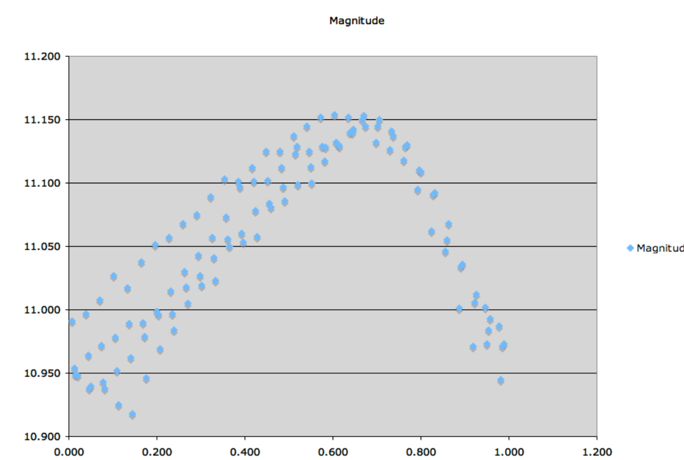

Magnitude
11.200
11.150
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11.000
10.950
10.900
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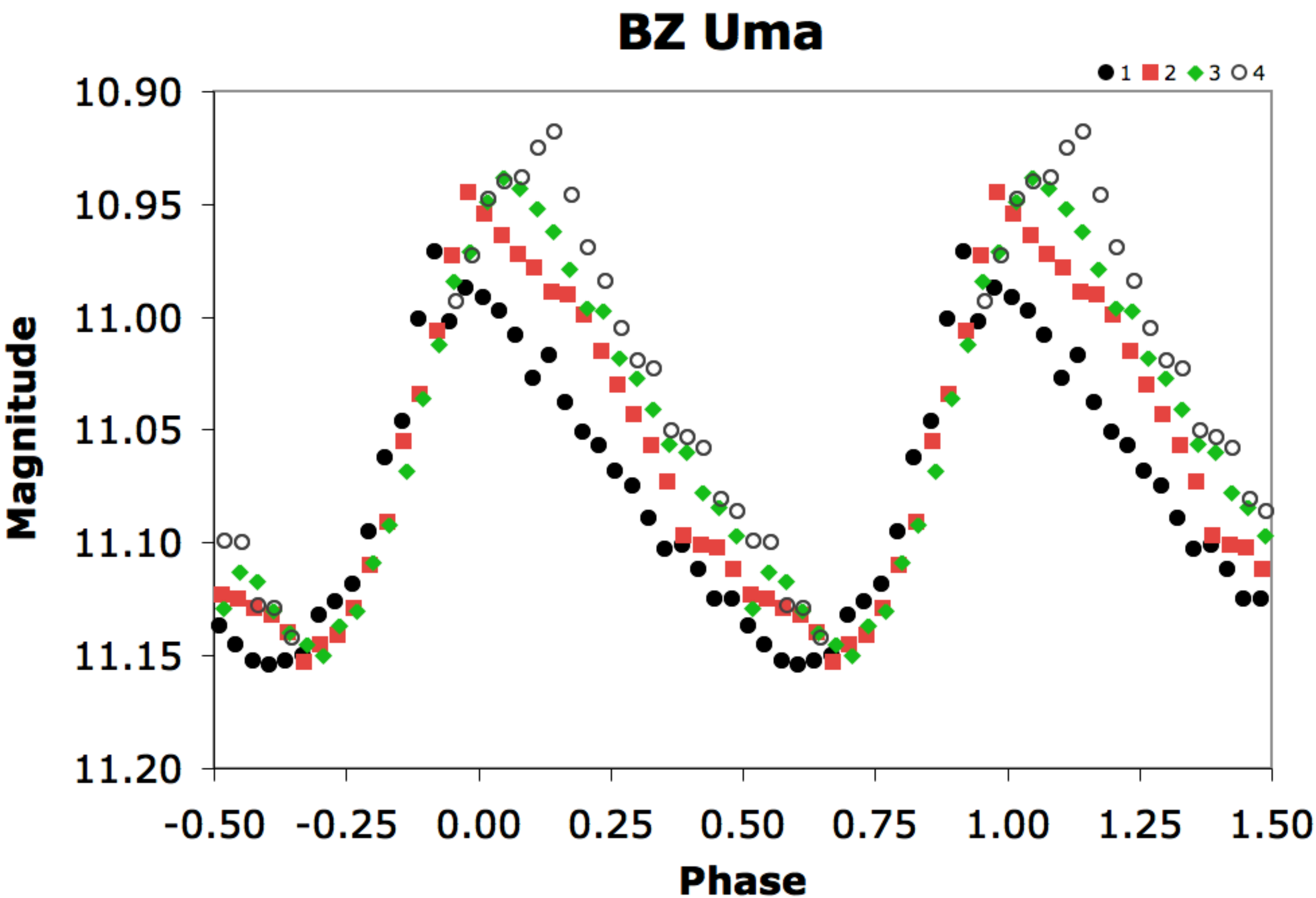
0.200
0.400
0.600
0.800
1.000
1.200
Magnitude


BZ Uma
1 2 3 4
Magnitude
10.90
10.95
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Thank You!

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