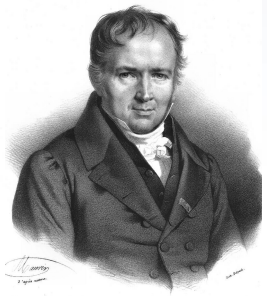
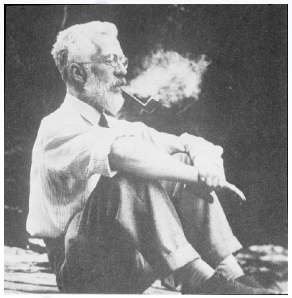
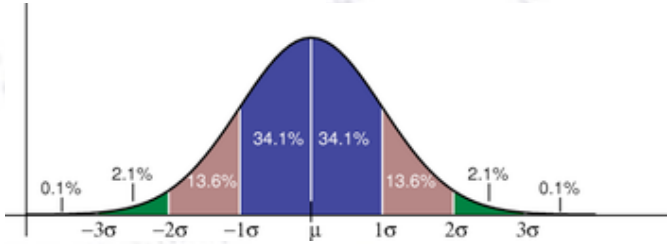
Applied Statistics

Why statistics?




Troels C. Petersen (NBI)



"Statistics is merely a quantisation of common sense"

Why uncertainties?

Errors/Uncertainties

In physics there are various elements of uncertainty:

- Theory is not deterministic
  Examples: Quantum effects & chaos
- Random measurement errors
  Fluctuations are present even without quantum effects!
- Things we could know in principle but don't…
  e.g. from limitations in cost, time, etc.

We can quantify the uncertainty using **PROBABILITY**

Armed with the realisation of limitations, we can make better calculations/experiments and informed conclusions.

Example: Speed of Gravity

Imagine that you measured the speed of gravity, and got the following result:

$$v_{\text{gravity}} = 2.89 \times 10^8 \text{ m/s}$$

That would tell you...

Example: Speed of Gravity

Imagine that you measured the speed of gravity, and got the following result:

$$v_{\text{gravity}} = 2.89 \times 10^{8} \text{ m/s}$$

That would tell you...

Nothing!!!

Because you have no idea of the uncertainty.

Example: Speed of Gravity

Imagine that you measured the speed of gravity, and got the following result:

$$v_{\text{gravity}} = 2.89 \times 10^8 \text{ m/s}$$

Depending on the uncertainty, you might foresee three very different conclusions:

$$v_{\text{gravity}} = (2.89 \pm 9.21) \times 10^8 \text{ m/s}$$ **Could be anything,** even negative!

$$v_{\text{gravity}} = (2.89 \pm 0.09) \times 10^8 \text{ m/s}$$ **Consistent with c,** and not much else!

$$v_{\text{gravity}} = (2.89 \pm 0.01) \times 10^8 \text{ m/s}$$ **Inconsistent with c:** **New Discovery!!!**

(extreme) Conclusion:

Numbers without stated uncertainties are meaningless!

Why precision?

Newton's Law of Gravity

How well do we know Newton's Law of Gravity?

$$F = G\frac{mM}{r^2}$$

Newton's Law of Gravity

How well do we know Newton's Law of Gravity? Well, reasonably well, but...

Force central?

Valid for all masses?

$$F = G\frac{mM}{r^2}$$

Range of validity?

Square Law?

No other dependencies?

Newton's Law of Gravity

How well do we know Newton's Law of Gravity? Well, reasonably well, but...

Force central?

Seemingly...

Valid for all masses?

NO - not large ones!

Why is G so small?

$$F = G\frac{mM}{r^2}$$

Maybe not short ranges

Range of validity?

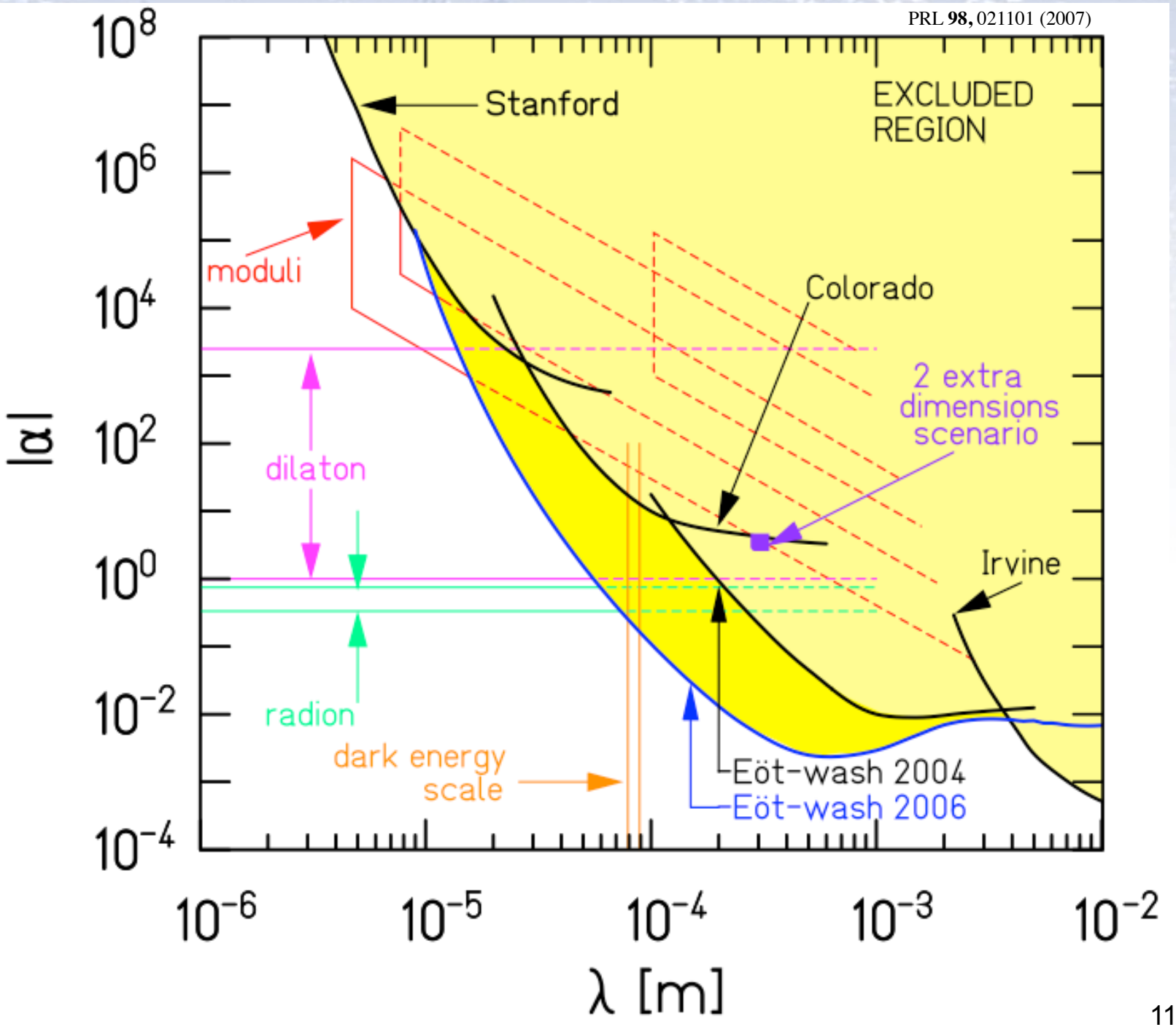
Being tested: Related to search for more dimensions

Square Law?

Yes, from generel relativity

No other dependencies?

Testing Gravity



Why statistics?!?

Why statistics in physics?

Experimental measurements are only **SAMPLES** of the reality, they can never represent the entire set of possibilities, so
→ they are affected by uncertainties
→ results can be expressed as probabilities

Theoretical calculations are mostly **APPROXIMATIONS** limited by finite resources to do the calculations or by imprecise input parameters, so
→ they are also affected by uncertainties
→ predictions can also be expressed in terms of probability

Statistics gives the understanding of uncertainty and probability in relating data and theory!!!

Why statistics in physics?

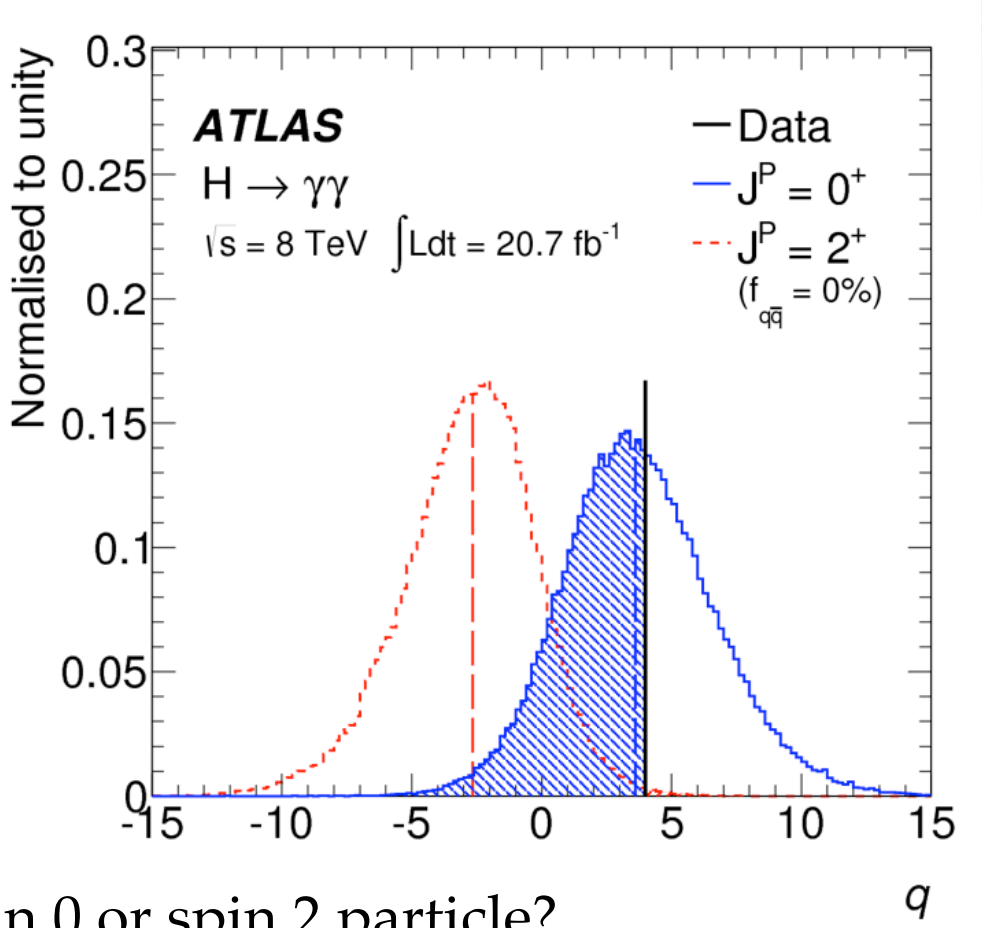
Statistics is about **hypothesis testing**, quantifying the answer to the question

"which theory matches the data best?"

Statistics is about collecting data and logically analysing it, not being fooled by coincidences and chance observations.

Statistics is about fitting trends in data, allowing for projections and predictions.

Statistics is about understanding data, and extracting the essential information from it in the most powerful way.



Is the Higgs a spin 0 or spin 2 particle?

Biases in statistics...

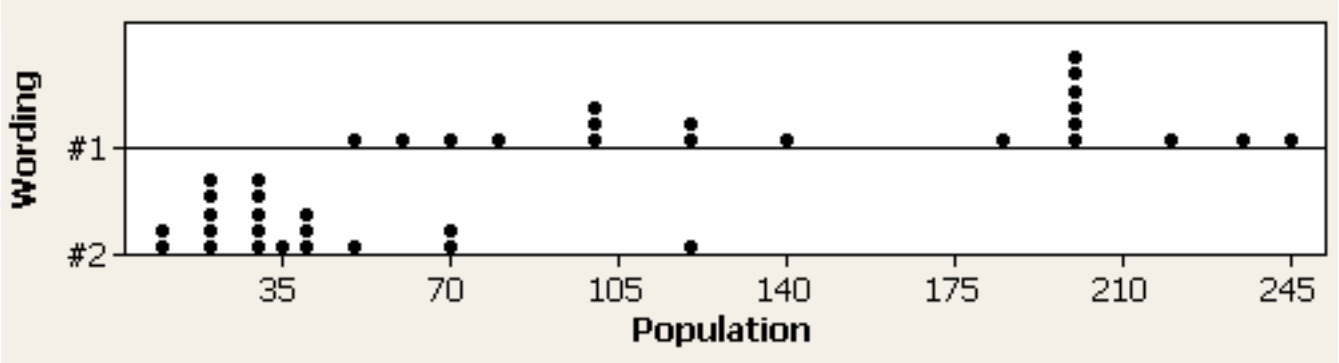
When ASKING people, one may introduce (deliberate?) biases:

- ***Wording 1*:** Pick a color: red or blue?
- ***Wording 2*:** Pick a color: blue or red?

Color Choice	Red	Blue
Wording 1	59%	41%
Wording 2	45%	55%

One may also bias answers by giving (ir-)relevant information:

- ***Wording 1*:** Knowing that the population of the U.S. is 270 million, what is the population of Canada?
- ***Wording 2*:** Knowing that the population of Australia is 15 million, what is the population of Canada?



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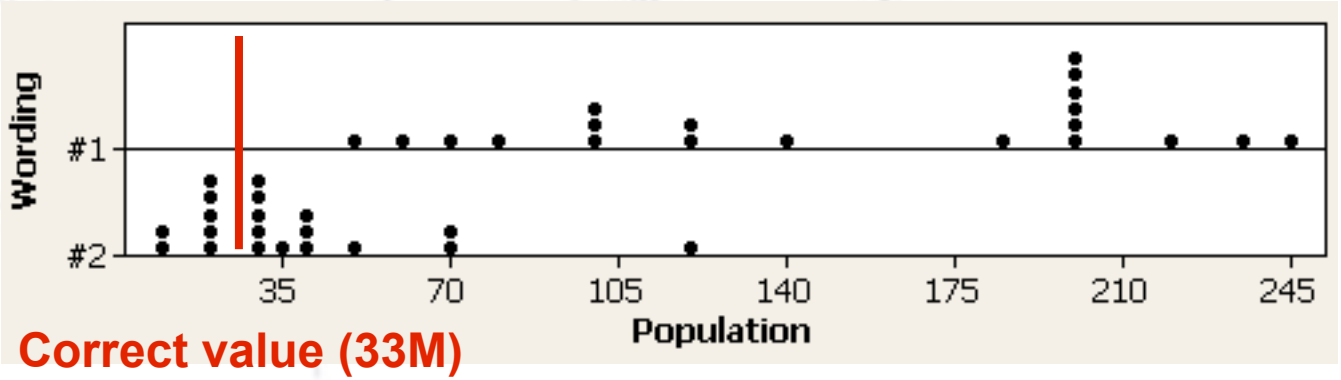


Crisis? Surely, you're joking…

Abstract:

Statistics is experiencing a quality control crisis. There have recently been alarms as to the scientific quality arrangement in several disciplines. The most visible symptom of this possible dysfunction is the so-called **reproducibility crisis**. In the context of the crisis the discipline of statistics has been going through a phase of critique and self-criticism, due to mounting evidence of **poor statistical practice** of which misuse and abuse of the P-test is the most visible sign. Most observers have noted that the crisis has technical as well as ethical and behavioural elements which interact with one another – e.g. the 'publish or perish' obsession has an impact on selection bias – the **tendency to favour positive over negative results**.

Unlike statistics, mathematical modelling is not a discipline, hence the lack of appropriate internal antibodies to fight a possible infection in the form of quality standards, disciplinary fora and journals and recognized leaders. The main issue in existing practices of mathematical modelling is in the **management of uncertainty** in model-based inference. Modelling studies can be seen which tend to overestimate certainty, **pretending to produce crisp numbers precise to the third decimal digits even in situation of pervasive uncertainty or ignorance**. Just as per the case of statistics, no solution is possible without careful appraisal of the social and cultural dimensions of the problem. We suggest that the situation calls an ethics of quantification to be developed, analogous to what is happening in the field of **algorithms and big data**.

Talk given at CERN Colloquium on 7th of June 2018 by Andrea Saltelli (University of Bergen).

PS. The abstract is too long, but I've made an exception in praise here…

Crisis? Surely, you're joking…

A report by the Open Science Collaboration in August 2015 estimated the reproducibility of 100 studies in psychological science from three high-ranking psychology journals [1].

Overall, **36%** of the replications yielded significant findings (p value below 0.05) compared to 97% of the original studies that had significant effects.
The mean effect size in the replications was approximately **half the magnitude** of the effects reported in the original studies.

The problem seems to have been largest in psychology and medicine, but it is certainly also a problem in other fields! Physics?

[1] Collaboration, Open Science (2015-08-28). "Estimating the reproducibility of psychological science". Science. 349 (6251): aac4716. doi:10.1126/science.aac4716. ISSN 0036-8075. PMID 26315443.

Crisis? Surely, you're joking…

Ending of "Surely, you're joking Mr. Feynman"

They run a million rats no, it's people this time they do a lot of things and get a certain statistical effect. Next time they try it they don't get it any more. And now you find a man saying that it is an irrelevant demand to expect a repeatable experiment. This is science?

This man also speaks about a new institution, in a talk in which he was resigning as Director of the Institute of Parapsychology. And, in telling people what to do next, he says that one of the things they have to do is be sure they only train students who have shown their ability to get PSI results to an acceptable extent not to waste their time on those ambitious and interested students who get only chance results. It is very dangerous to have such a policy in teaching to teach students only how to get certain results, rather than how to do an experiment with scientific integrity.

So I have just one wish for you the good luck to be somewhere where you are free to maintain the kind of integrity I have described, and where you do not feel forced by a need to maintain your position in the organisation or financial support, or so on, to lose your integrity.

May you have that freedom.

Crisis? Surely, you're joking…

In a work published in 2015 Glenn Begley and John Ioannidis offer five bullets as to summarize the present predicaments [2]:

- Generation of new data/ publications at an unprecedented rate.
- Compelling evidence that the majority of these discoveries will not stand the test of time.
- Causes: failure to adhere to good scientific practice & the desperation to publish or perish.
- This is a multifaceted, multistakeholder problem.
- No single party is solely responsible, and no single solution will suffice.

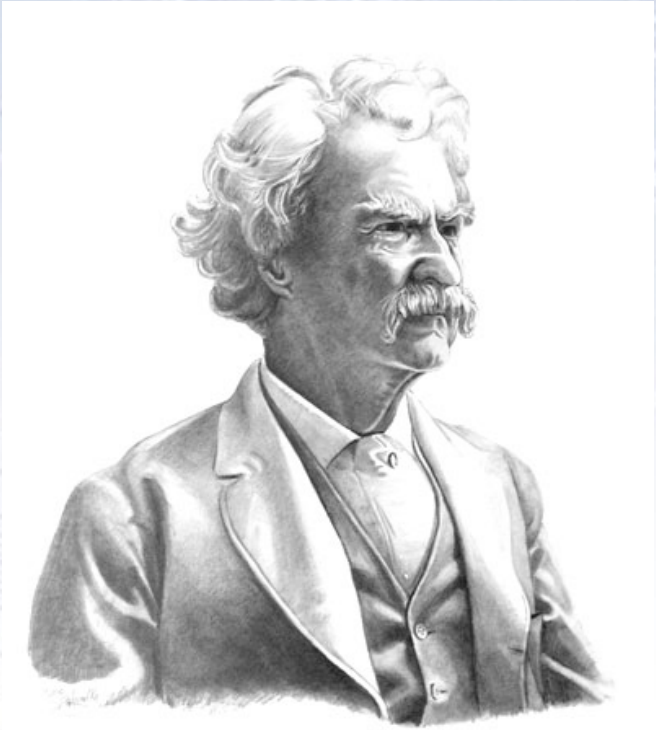
Remember ALWAYS to ask yourself, if what you're doing is reproducible!
Go back and reproduce it. Have someone else also do it. Question everything!

[2] Begley, C. G. & Ioannidis, J. P. (2015). "Reproducibility in Science: Improving the Standard for Basic and Preclinical Research". Circulation Research. 116 (1): 116–126. doi:10.1161/CIRCRESAHA.114.303819. PMID 25552691.

Mark Twain:

"There are three kinds of lies:

lies, damned lies, and statistics."



My opinion:

"The only way to convey accurate

information is by statistics."

THE WALL STREET JOURNAL.

Big Data's High-Priests of Algorithms

'Data Scientists' Meld Statistics and Software for Find Lucrative High-Tech Jobs

8th of August 2014

While a six-figure starting salary might be common for someone coming straight out of a doctoral program, data scientists with just two years' experience can earn between $200,000 and $300,000 a year, according to recruiters.

“Fysik er et brødløst studium”.

[Studenterhåndbogen AU, 1954]

“I keep saying the sexy job in the next ten years will be statisticians.”

[Hal Varian in 2009, Chief economist of Google, Berkeley professor]