Thinking Like a Physicist, For Non-Physicists

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Note:

- Will be talking about skills physicists have, tools physicists use. So,

I'll be talking about things you already know.

- But, we can do more to communicate them to the public! So, want to bring them to your attention.

- Physicists are good at quantifying uncertainty.

Or,

Really good at knowing how wrong something can (typically) be.

↙ ↘

Reporting experimental results, quantifying the uncertainty.

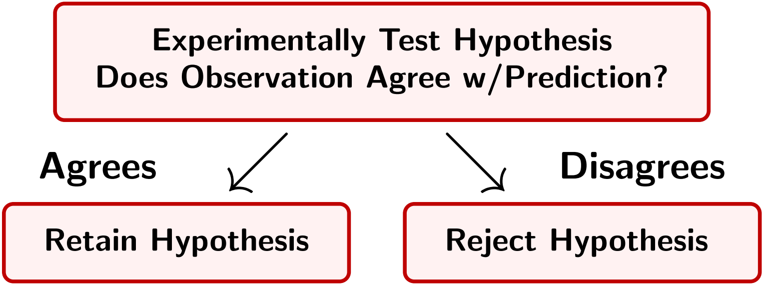
Making simplified models, knowing how good they are.

Reporting results, quantifying uncertainty:

Introduction

Reporting results, quantifying uncertainty:

- Physics is an experimental science.
- We make hypotheses and experimentally test them.
- Simplified view of how we use an experimental result:



- Does not capture full picture.

Introduction

Reporting results, quantifying uncertainty:

- Actually compare predicted and measured values of physical quantities:

Measured results (with their error bars)

Predictions (with their error bars)

Somehow reach conclusion anyway.

- Not just say agrees or disagrees; quantify agreement/ disagreement.

Reporting results, quantifying uncertainty:

- Or, say we are model-building.
- We have a model (like the SM!) that has passed a series of experimental tests, to certain precisions.
- Want to consider NP effects that could be added in on top of this.
- Need to know how well our old model (SM) has been tested to know how much wiggle room we have for possible NP effects.

Making simplified models, knowing how good they are:

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- Solving hard problems:
  Choose simplified models to obtain (approximate) answers to hard problems. Add complications back in, if needed.
- Applications: Choose simplified models appropriate to situation. (Don't need QM in everyday life!)
- Must know how good simplified model/approximation is. (In what regime is it good enough?)

Specific skills:

- Quantifying:
    - Uncertainties in measured and predicted quantities,
    - Agreement/disagreement of measured, predicted values,
    - How good an approximation/model is in regimes of interest.
- Tools/Concepts: gaussian errors, statistical significance, *p*-values, look-elsewhere effect, confidence intervals, Bayes' theorem, Poisson statistics.

Introduction

- These skills are integral to what we do as physicists, but the public barely hears about them.
- Press does not report these details well.
- Goal: convince you this part of the story is valuable and we should be including it.
- Seeking discussion!

Why We Should Do This

Why should we do this?

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(Useful: p-values, error bars, statistical significance....)

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Picture that too often gets lost:

- Current understanding of Nature is approximation to reality, limited by error bars and the regimes under which our ideas have been tested.
- Over time, error bars shrink, ideas tested in increasingly larger regimes.
- Old hypotheses fall out of agreement with data, new ones must be formulated.
- Approximation to reality gets better with time.

Concept of uncertainty is central to this picture!

We should do this if we want people to understand our work.

Why We Should Do This

Non-science reasons:

Non-science reasons:

- Skills not just useful to scientists; also useful in real world.
- Taking into account the uncertainties, regimes of validity of real-life statements.
- Evaluating claims: e.g., health claims and claims from non-scientific sources. (Is this product's claim statistically significant?)

(Imagine! In the age of misinformation....)

What I'm Doing

So far:

- Current efforts mostly consist of a moderately successful ($\sim$ 4K subs) youtube channel.
- Classes of topics:
  - (Particle) physics & methods (w/emphasis on statistical methods)
  - Statistics
  - Real-life applications
- Target audience: general public.

What I'm Doing

- Not much known about actual audience: Some physics students, some data science students, some armchair scientists.
- Not surprising: videos on high-profile physics results ($(g-2)_\mu$!) popular.
- Current most popular video on comparison of frequentist and Bayesian statistics.
- Communicating these concepts neither easy nor impossible.

What I'm Doing

Next: Trying to create online mini-course.

Rough outline ($\sim$ 20 5-10 min lectures):

- Introduction/Motivation
  - Current understanding is approximation to reality
  - Measurement errors, theory errors, how they arise
  - Error bars determine which hypotheses we keep, discard
  - Why physicists have useful skills for dealing with this
  - Why this is useful to everybody
- Gaussian errors
  - Starting with random walk
  - Emphasis on intuition from simulations, not calculation
  - When they approximately apply, when they don't
- Applications
  - Interpreting scientific measurements
  - Progress of science
  - Spherical-cow models

What I'm Doing

- Goal of mini-course is to present the most important tools for the general public to interpret scientific results.
- But, plenty more!
- Longer term: More full-fledged course.
  - p-values, Bayes' theorem, hypothesis testing, Poisson distribution, confidence intervals, look-elsewhere effect.....
  - More mathematical treatment: binomial, Poisson, Gaussian distributions, with derivations

Conclusions

Questions/comments welcome!