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Statistics and psychology in science

Quarknet 2017
Spencer Chang

Physics Letters B 716 (2012) 1–29

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Physics Letters B

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Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC ☆

ATLAS Collaboration *

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

ARTICLE INFO

Article history:
Received 31 July 2012
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Editor: W.-D. Schlatter

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Outline

- What constitutes a discovery in particle physics?
- Statistics and psychological effects
- Broader scientific and everyday life impacts

Finding Something New

When trying to find something new (in science), you want to be convinced its broken

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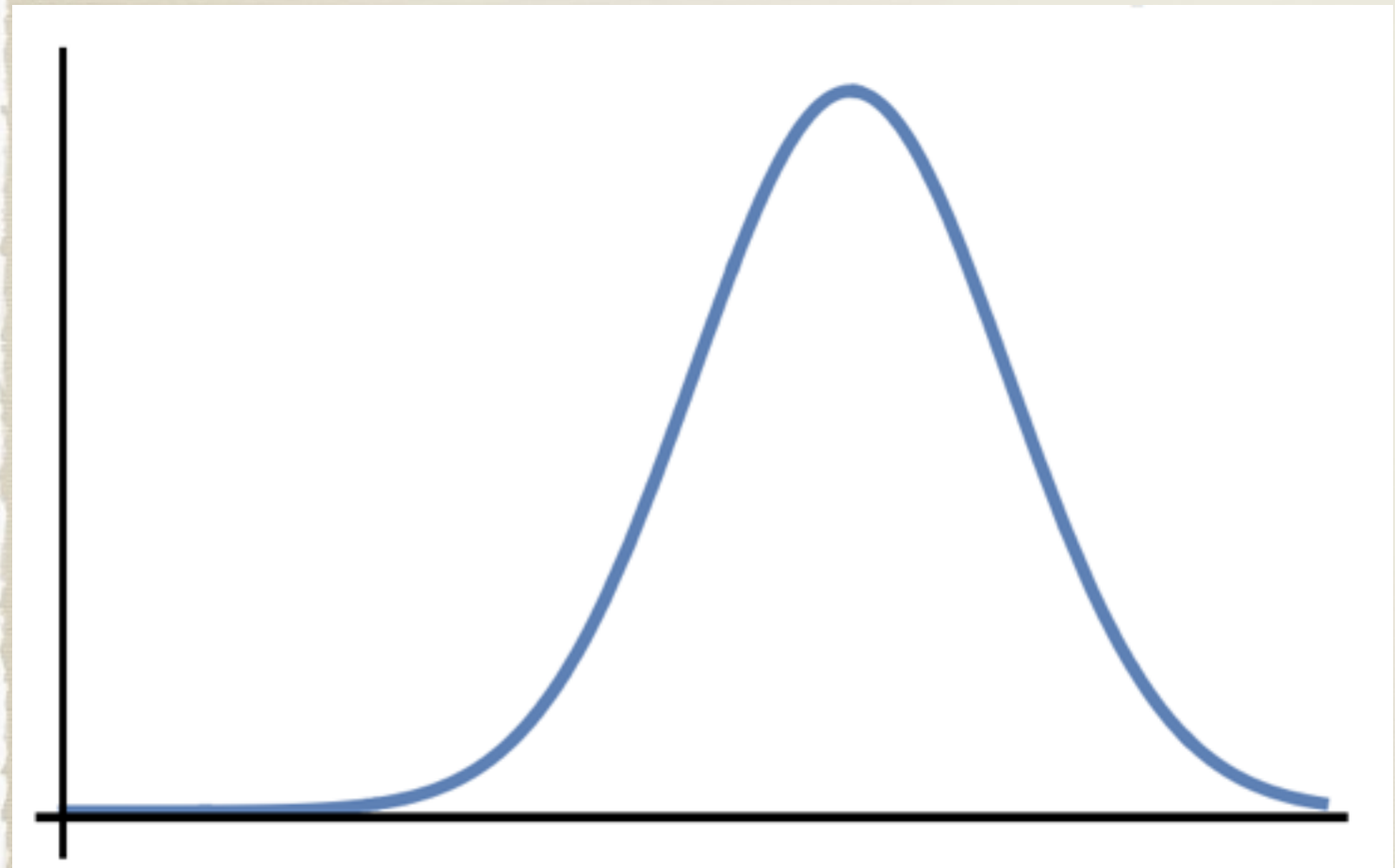

Current theory predicts a distribution for an outcome (e.g. # of events)

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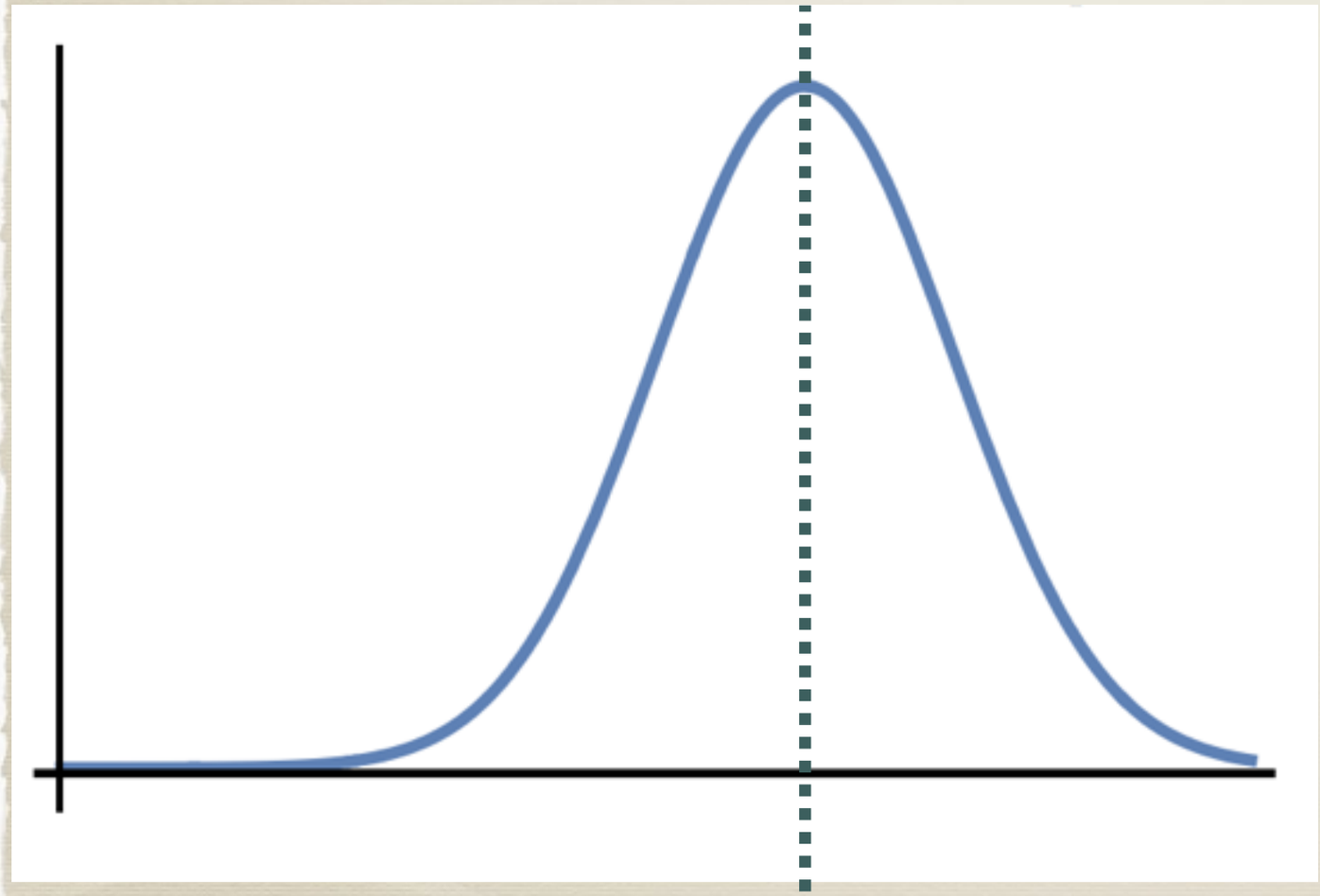

Average

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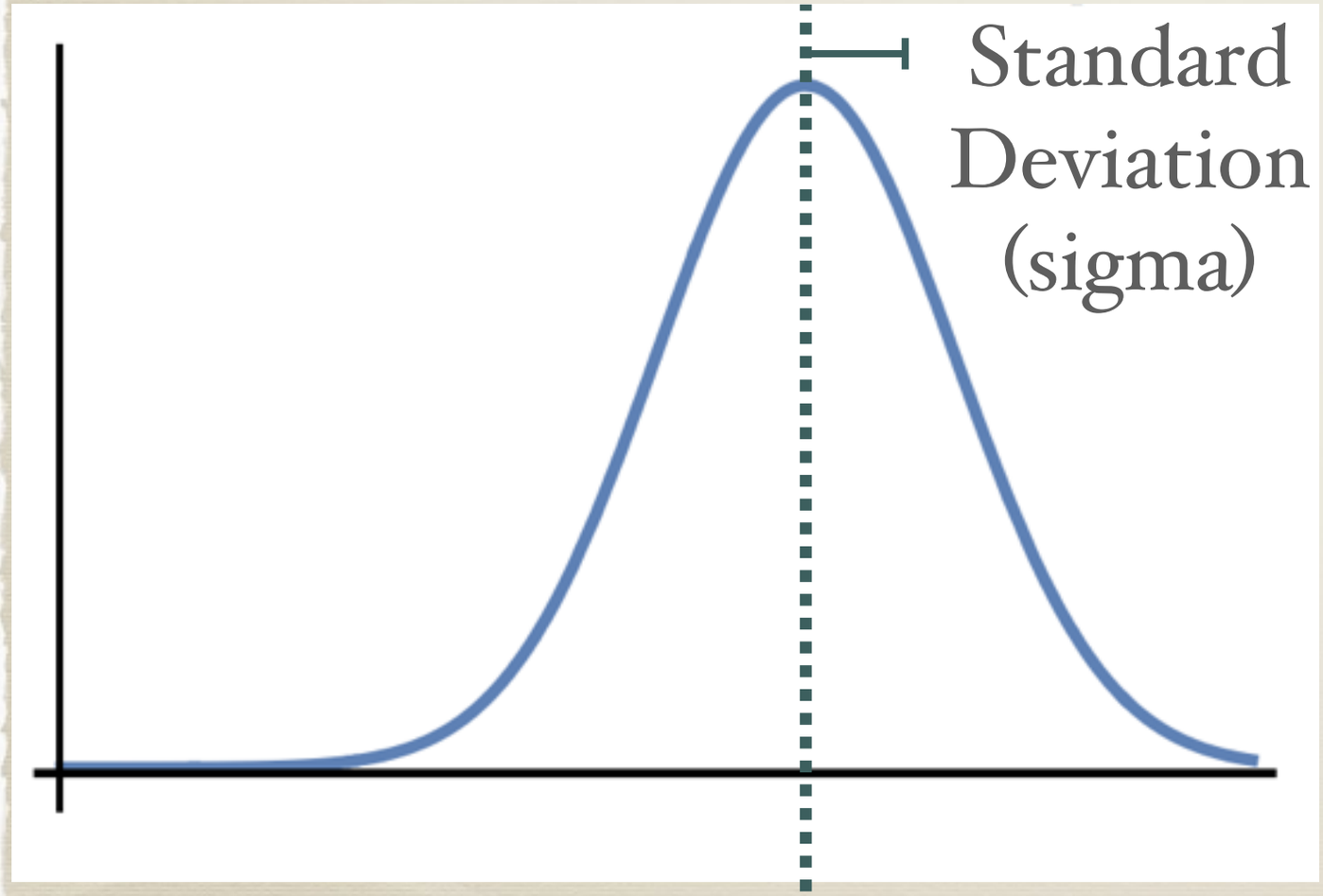

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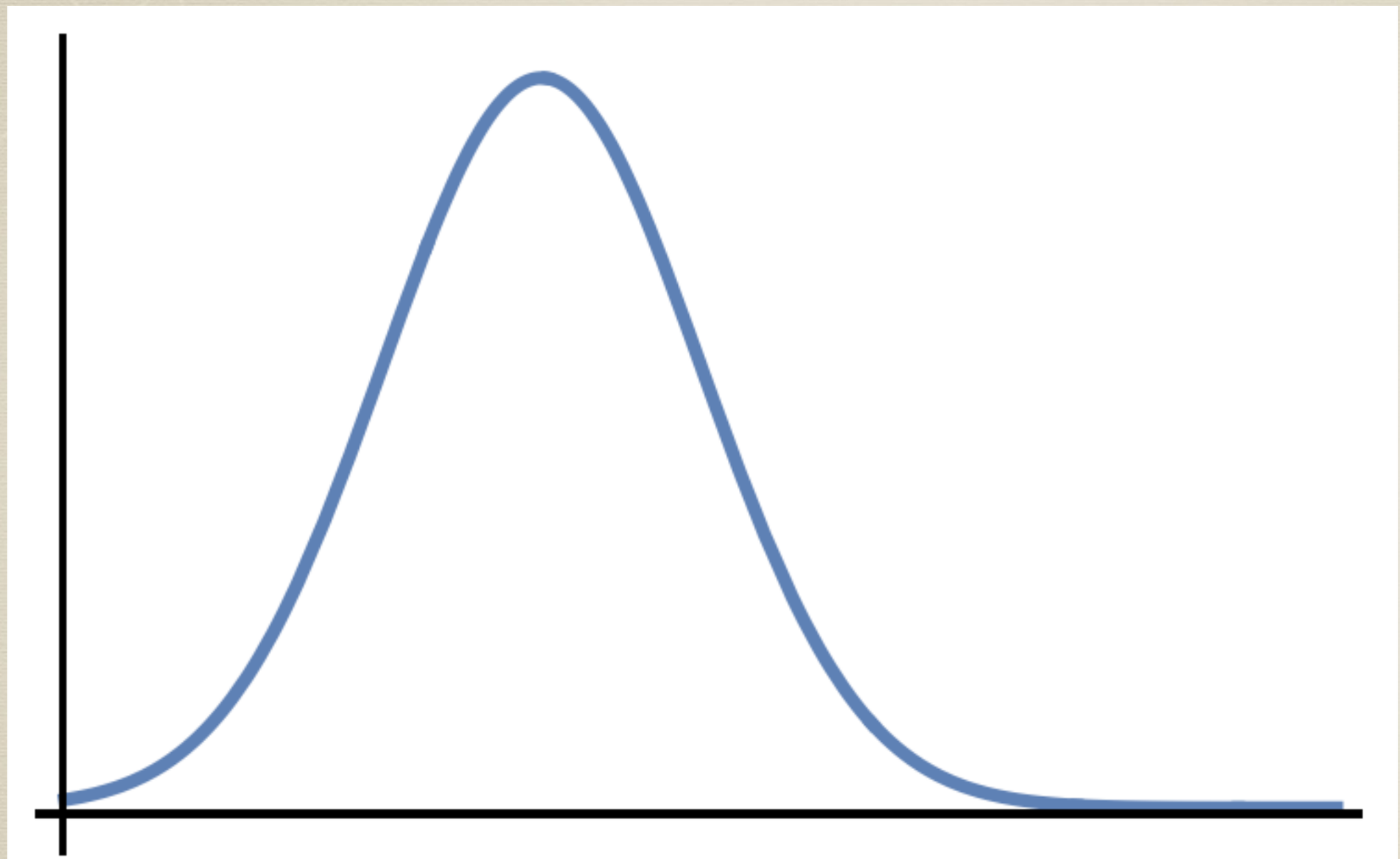
The Breaking Point



# of events

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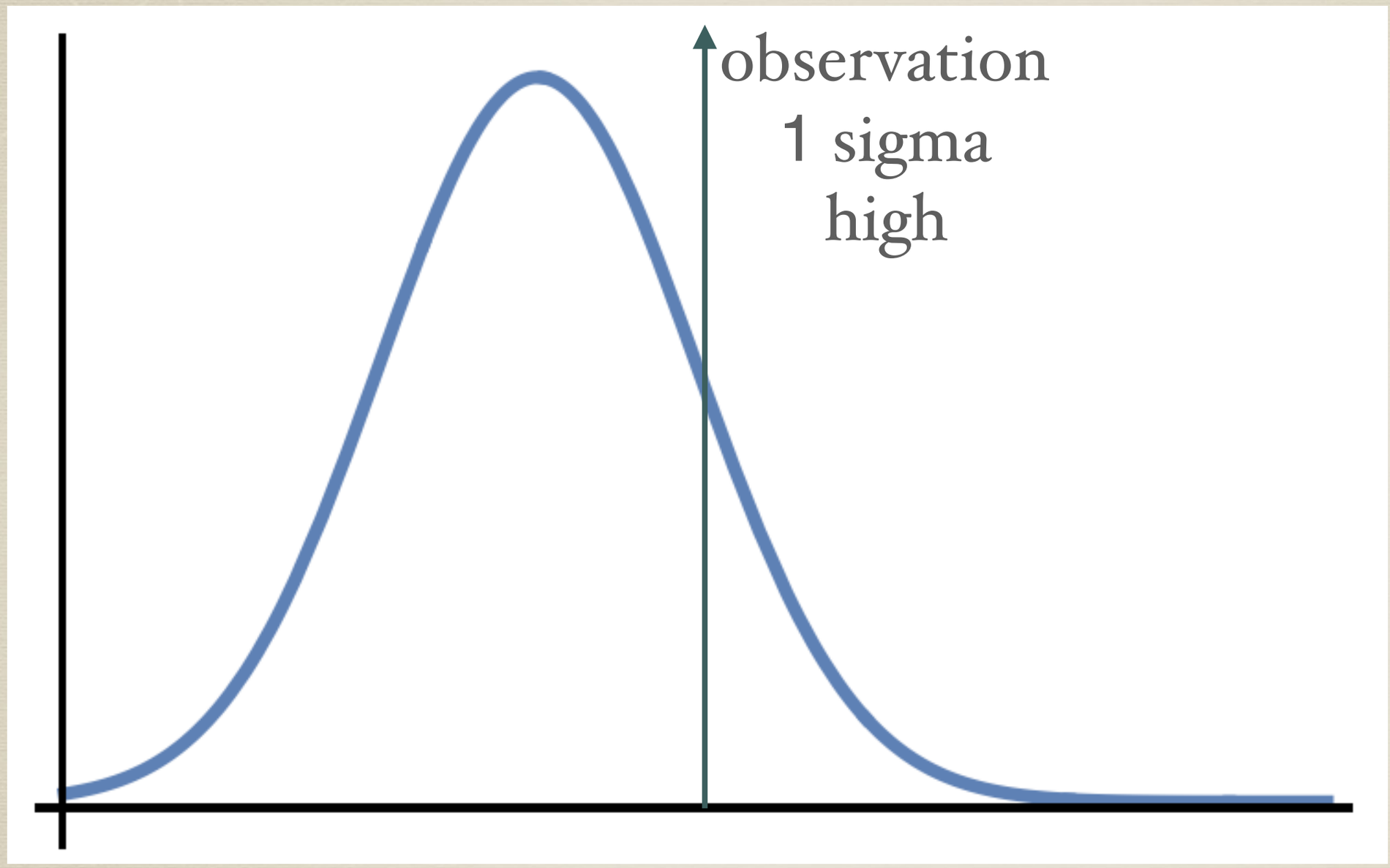

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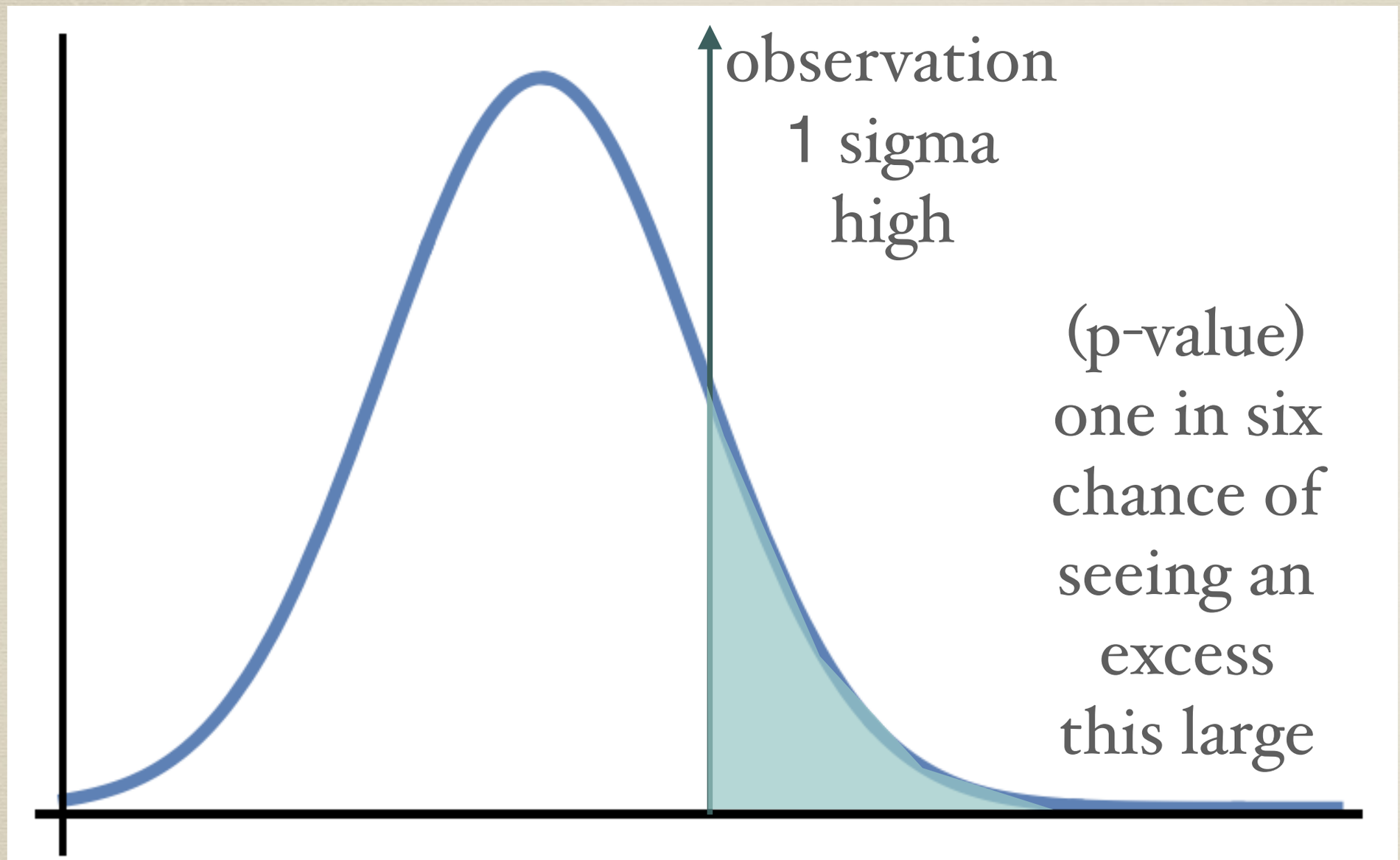

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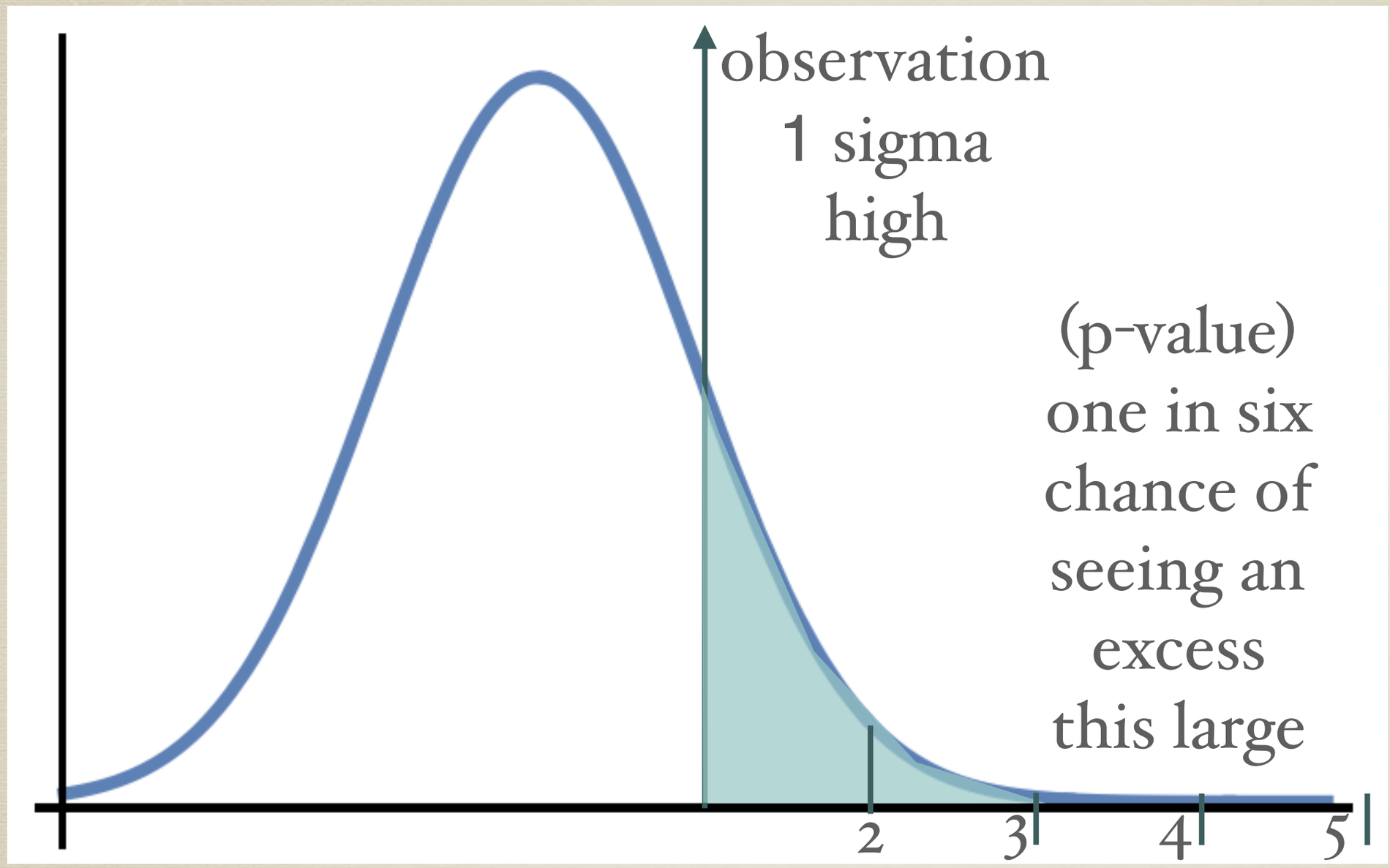

As one increases the deviation, chance drops

2 sigma = one in 40, 3 sigma - 1 in 740, 4 sigma =1 in 30k

5 sigma = 1 in 30 million

Particle Physics Discovery Convention

Convention for when a theory breaks and you see a new effect is **field** dependent

In particle physics, it is convention for five sigma,
i.e. only in a one in 30 million chance of making a mistake
and there is no new effect

In other fields, two sigma is standard (e.g. psychology),
only a chance of one in 40 that it is wrong

Why this standard?

- Historical: 3 sigma effects go away
- Look elsewhere effect
- p-hacking

Many examples of 3 sigma effects (only one in 1000) going away

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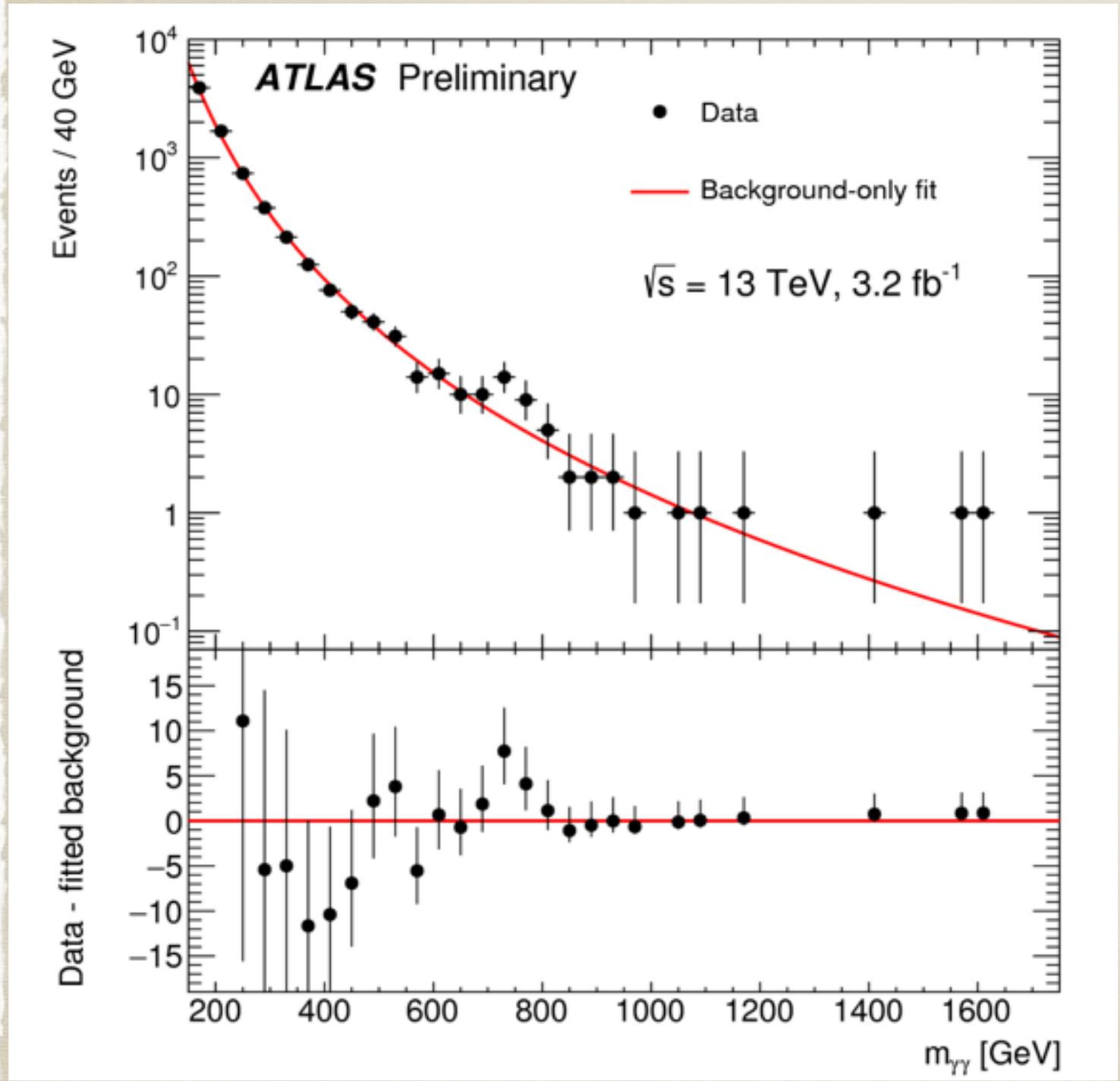

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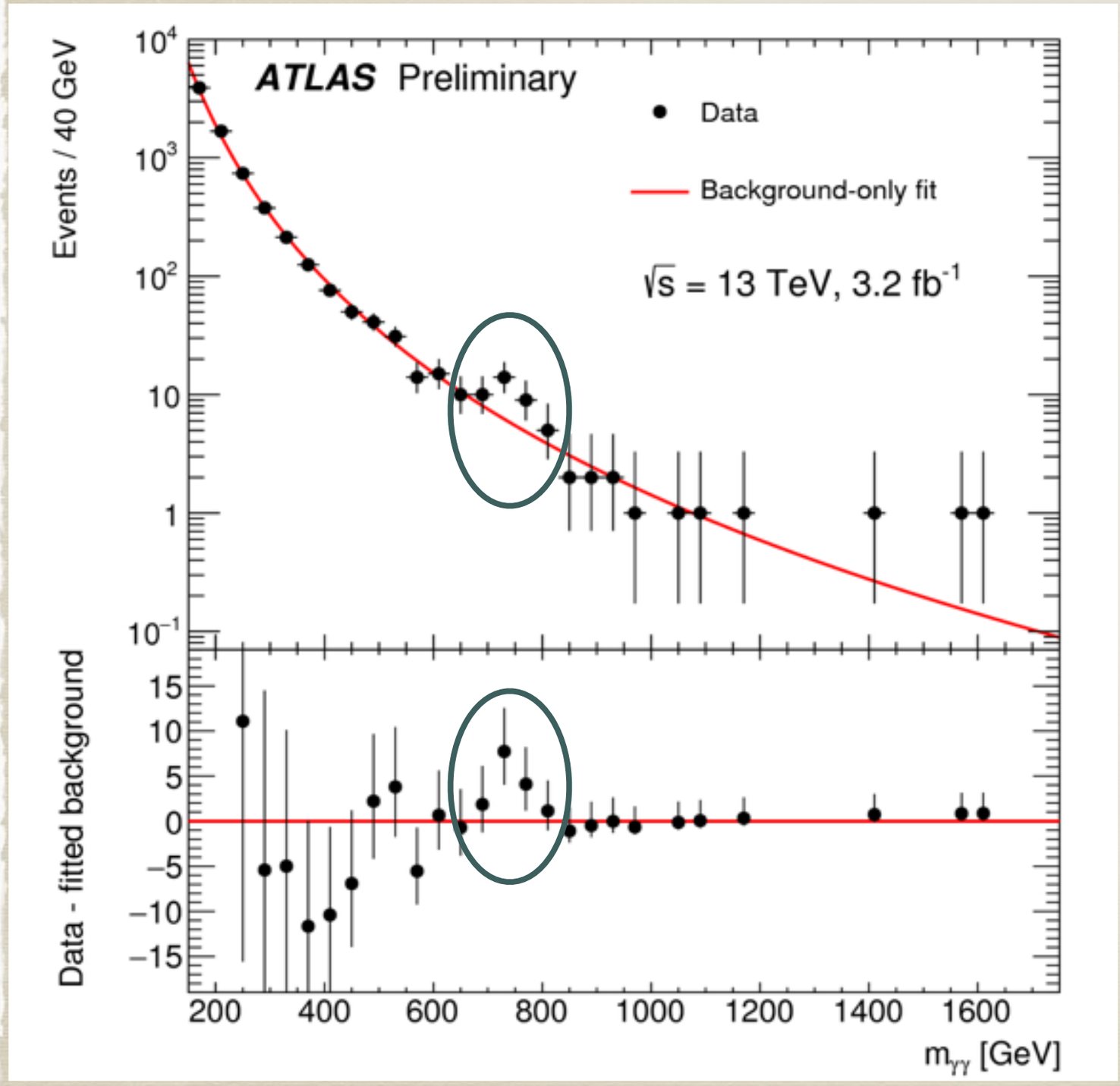

Dec. 2015 ATLAS and CMS saw a nearly 4 sigma excess (one in 10000)

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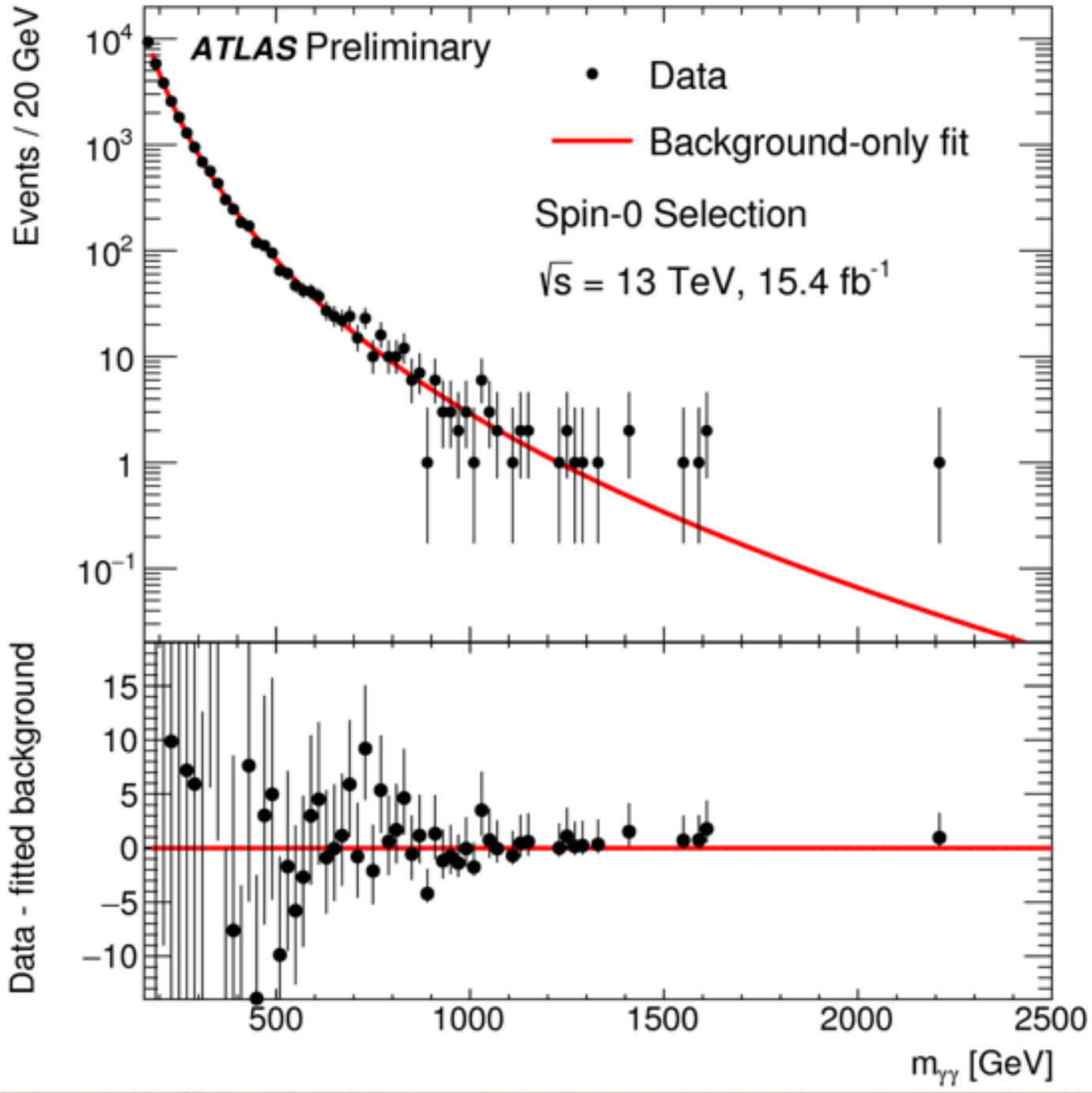

Dec. 2015 ATLAS and CMS saw a nearly 4 sigma excess (one in 10000)

With more data the excess has gone away

This was more extreme, but shows why 2, 3 sigmas are only interesting, but nothing concrete

How does this happen?

Look Elsewhere Effect

Rare events are less rare if you are looking in several places

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Example: It is rare to win the lottery, but you know somebody who's won the lottery, how rare is that?

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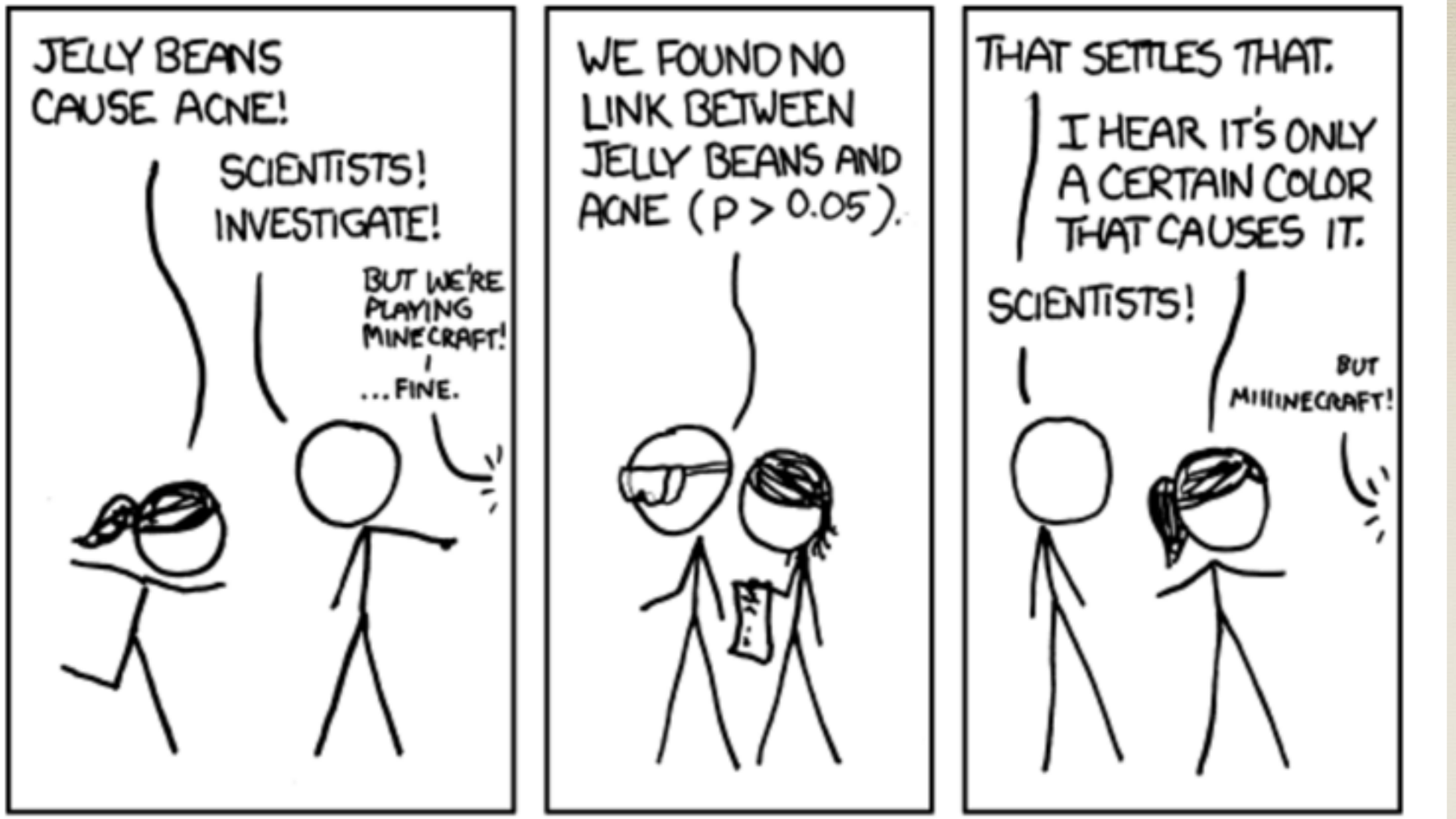
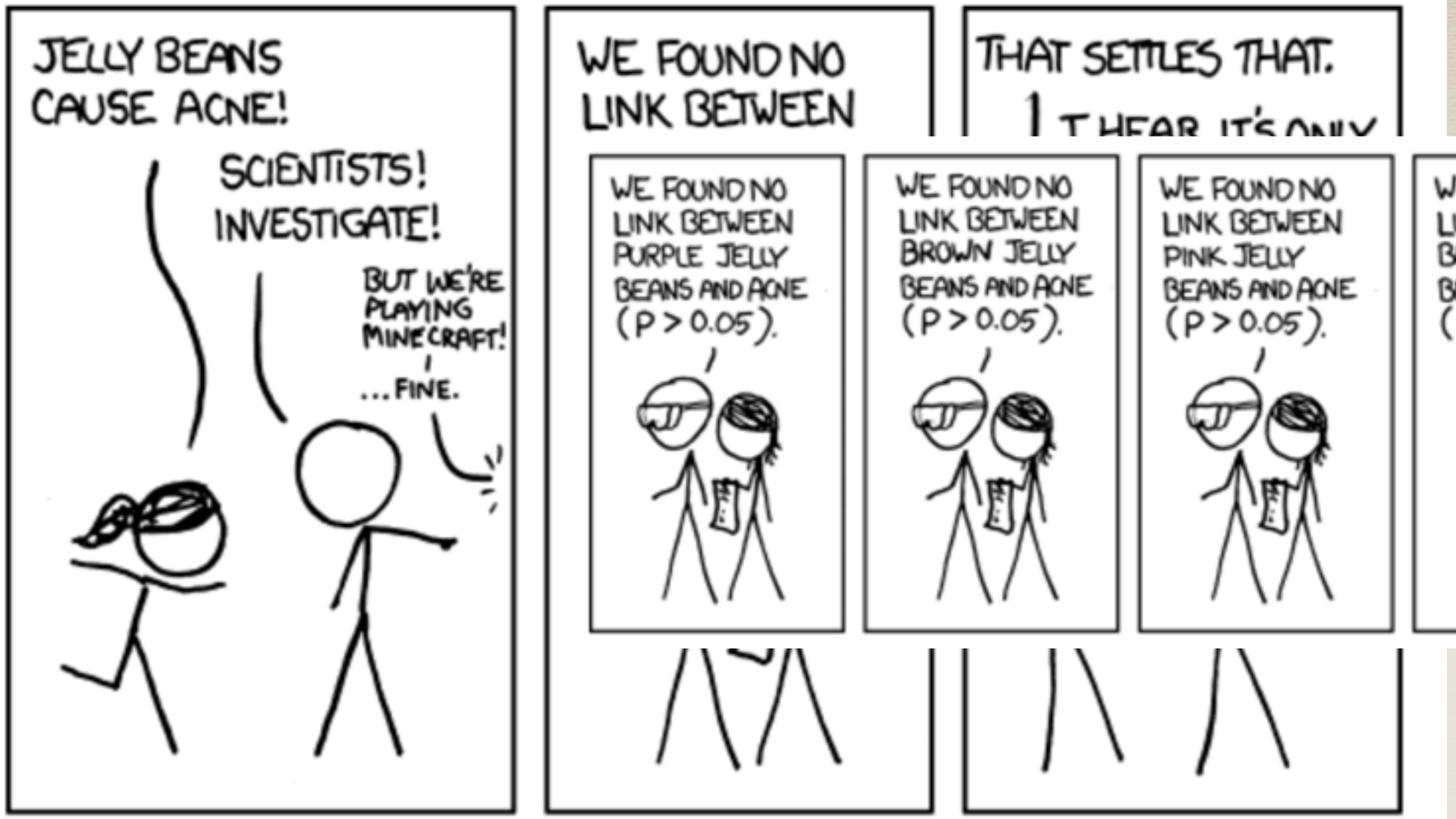
It might be more common because you know many people also you might have been also surprised if somebody you knew won a Nobel prize, was in the NBA, a rock star, etc....



Credit: xkcd.com



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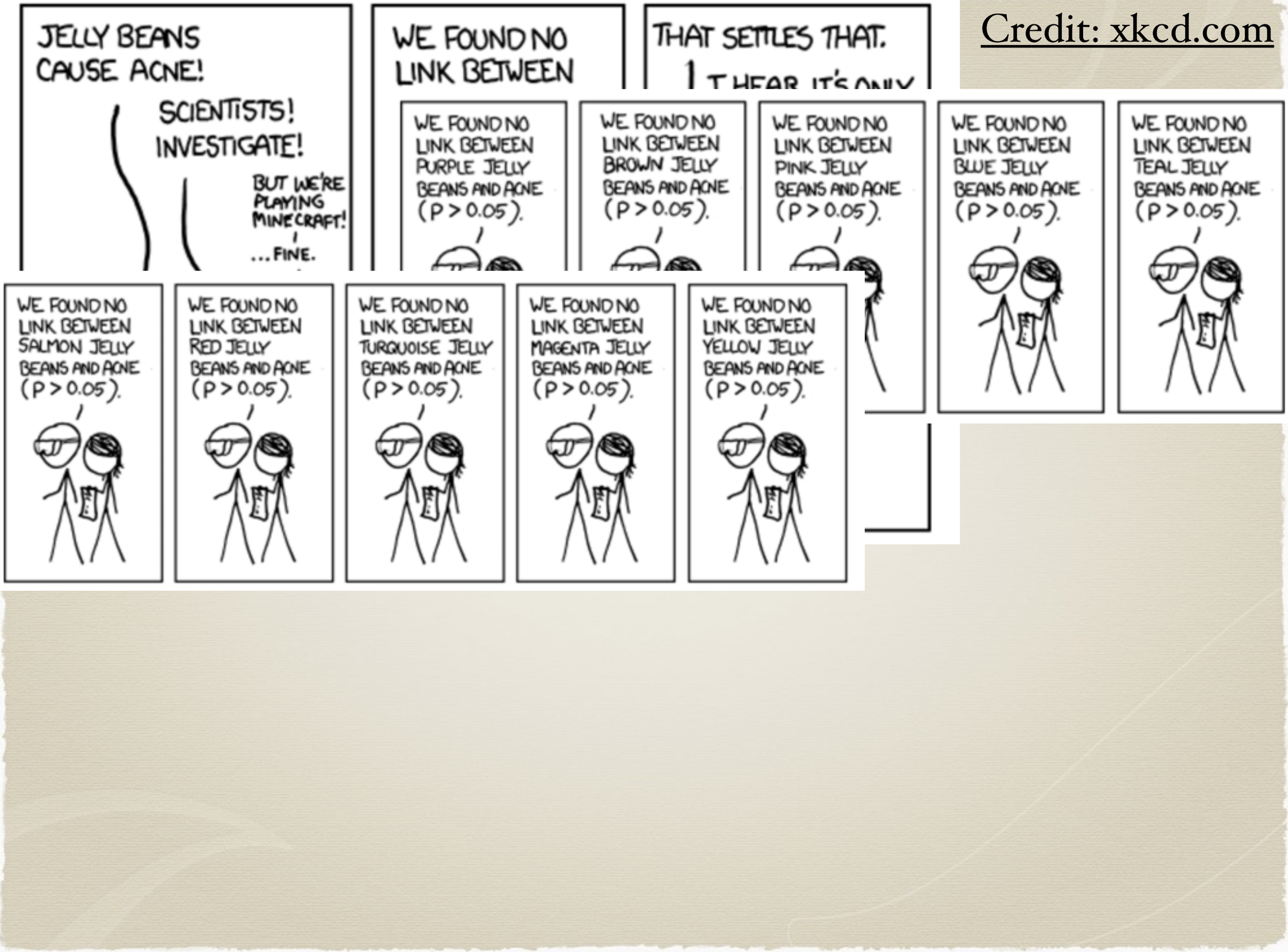

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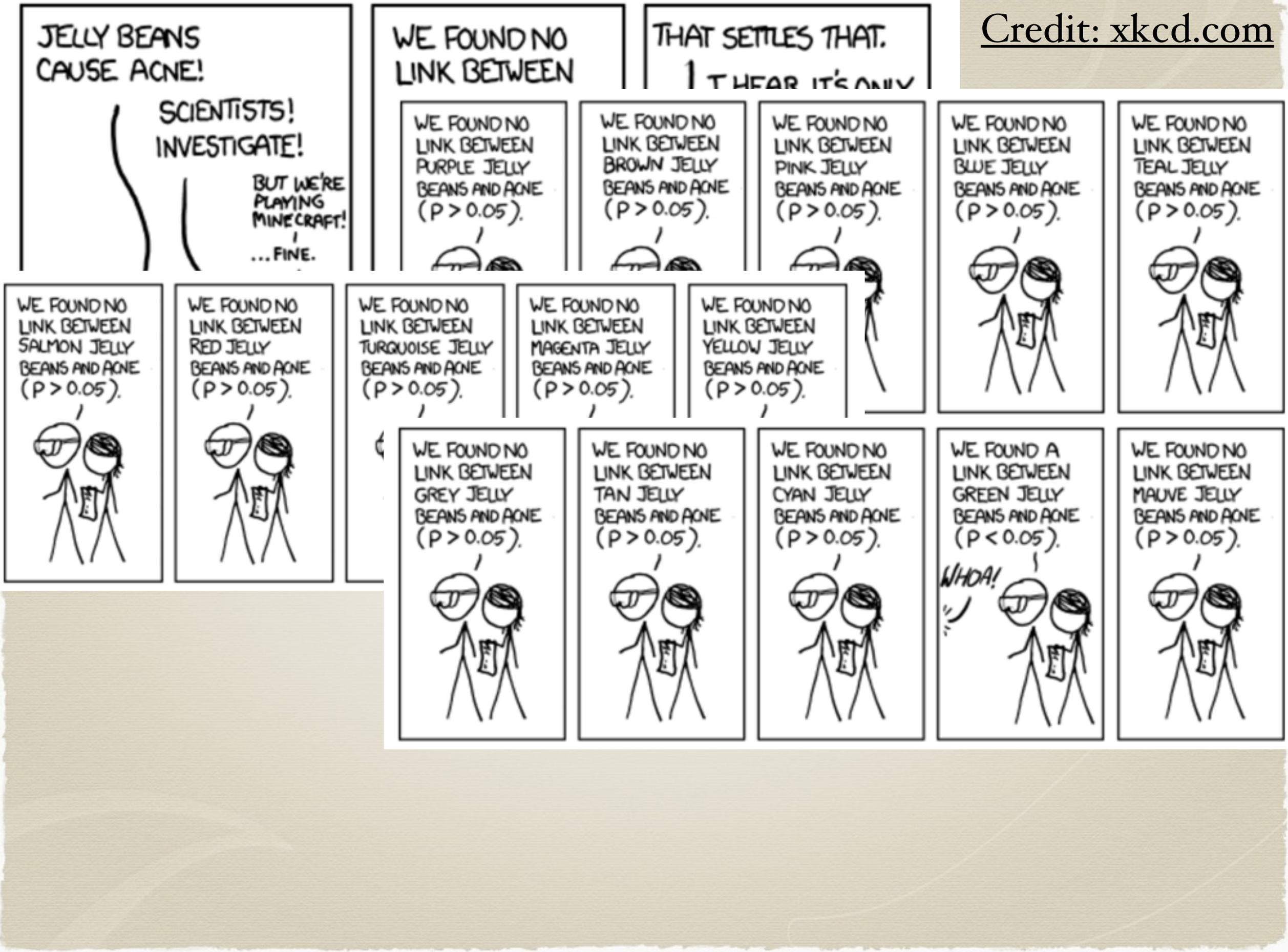

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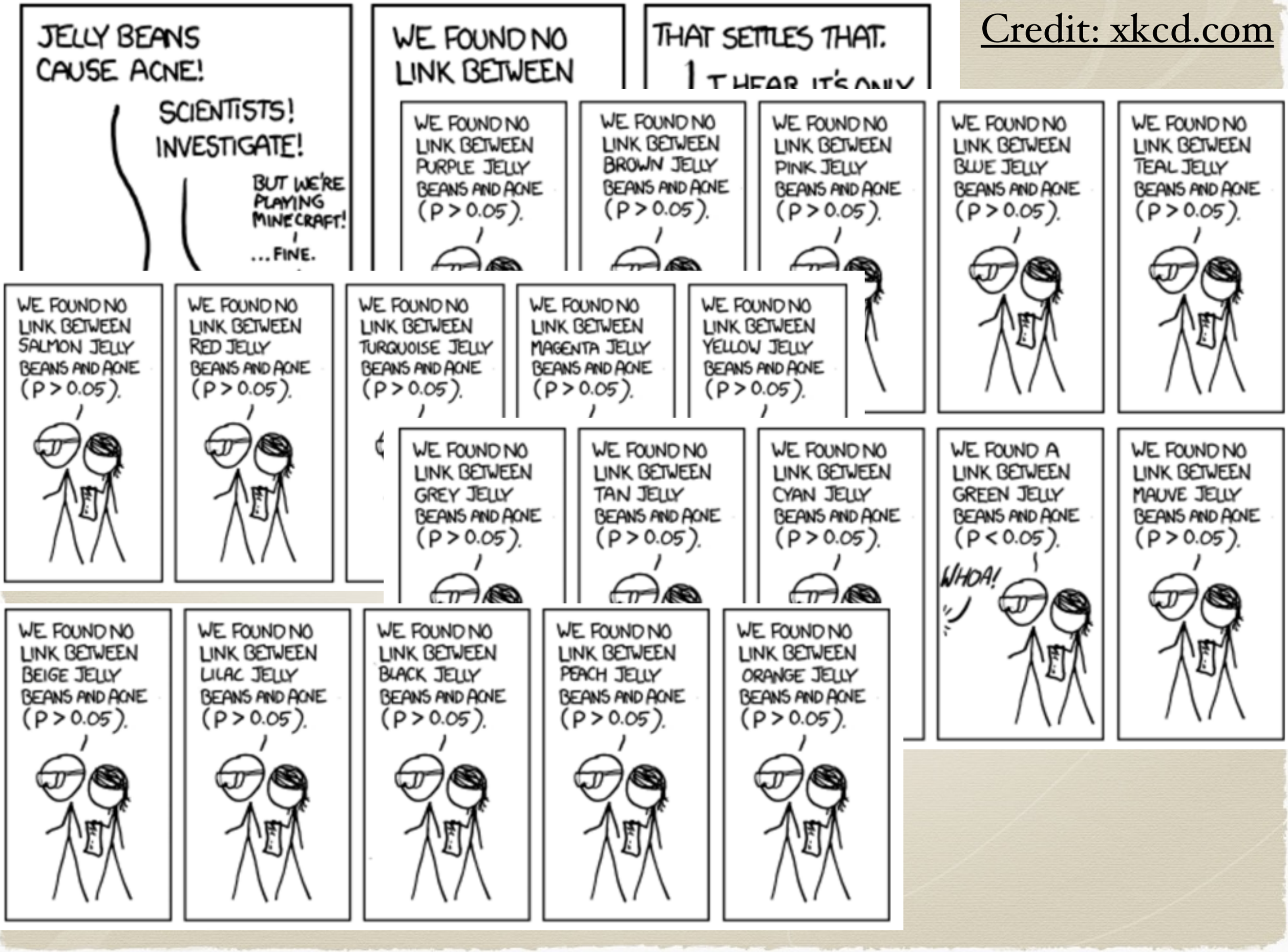

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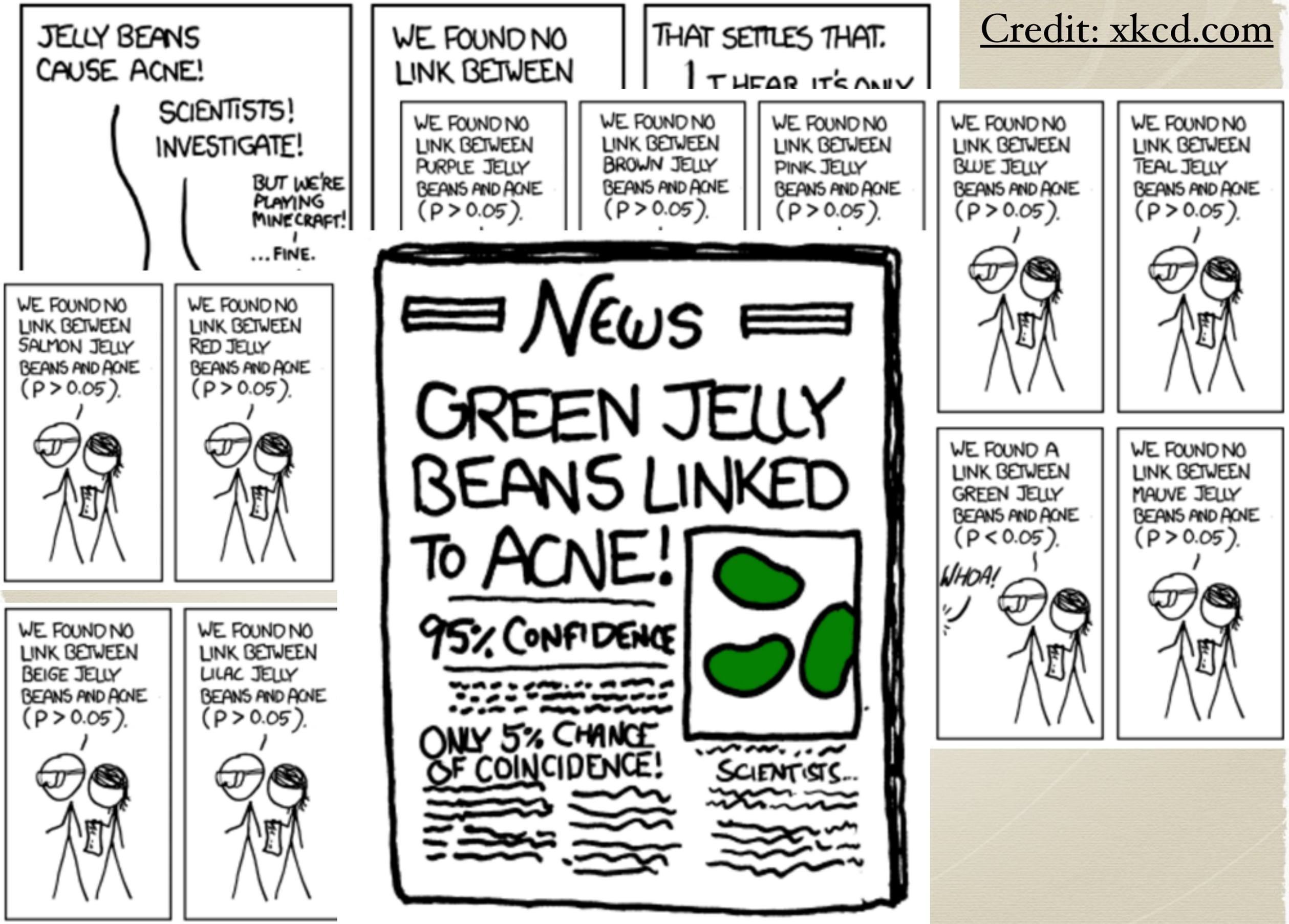

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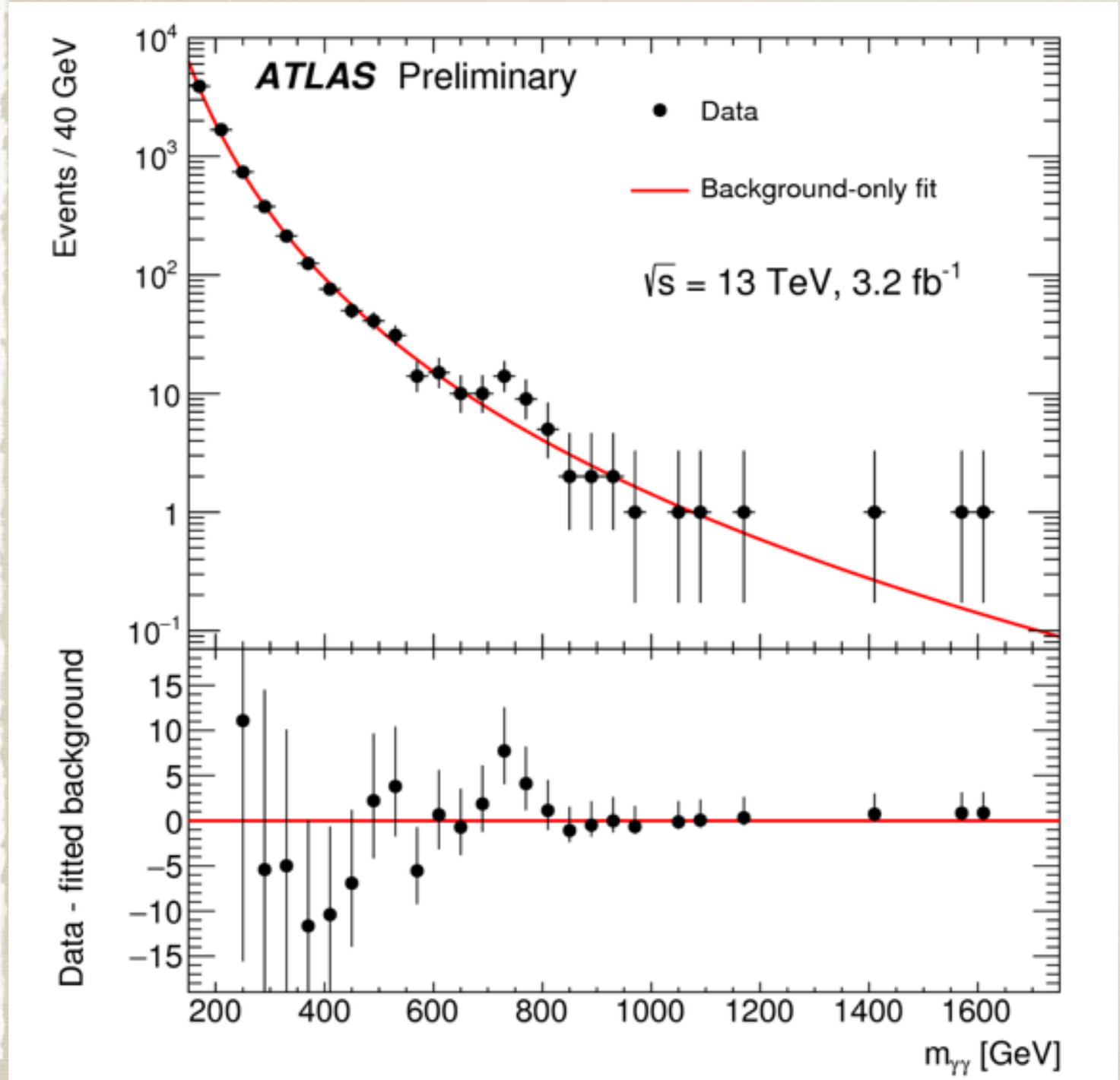

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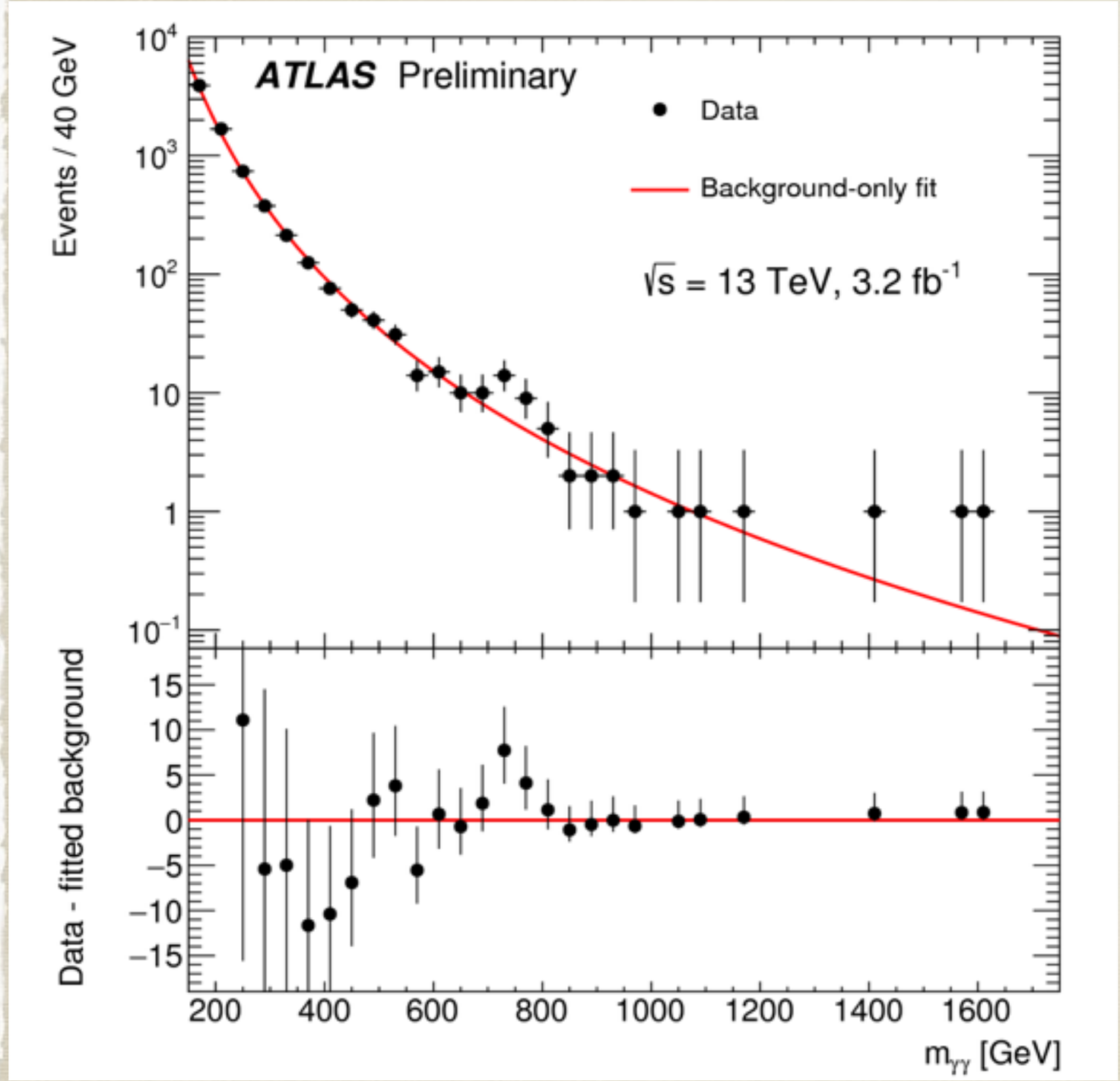

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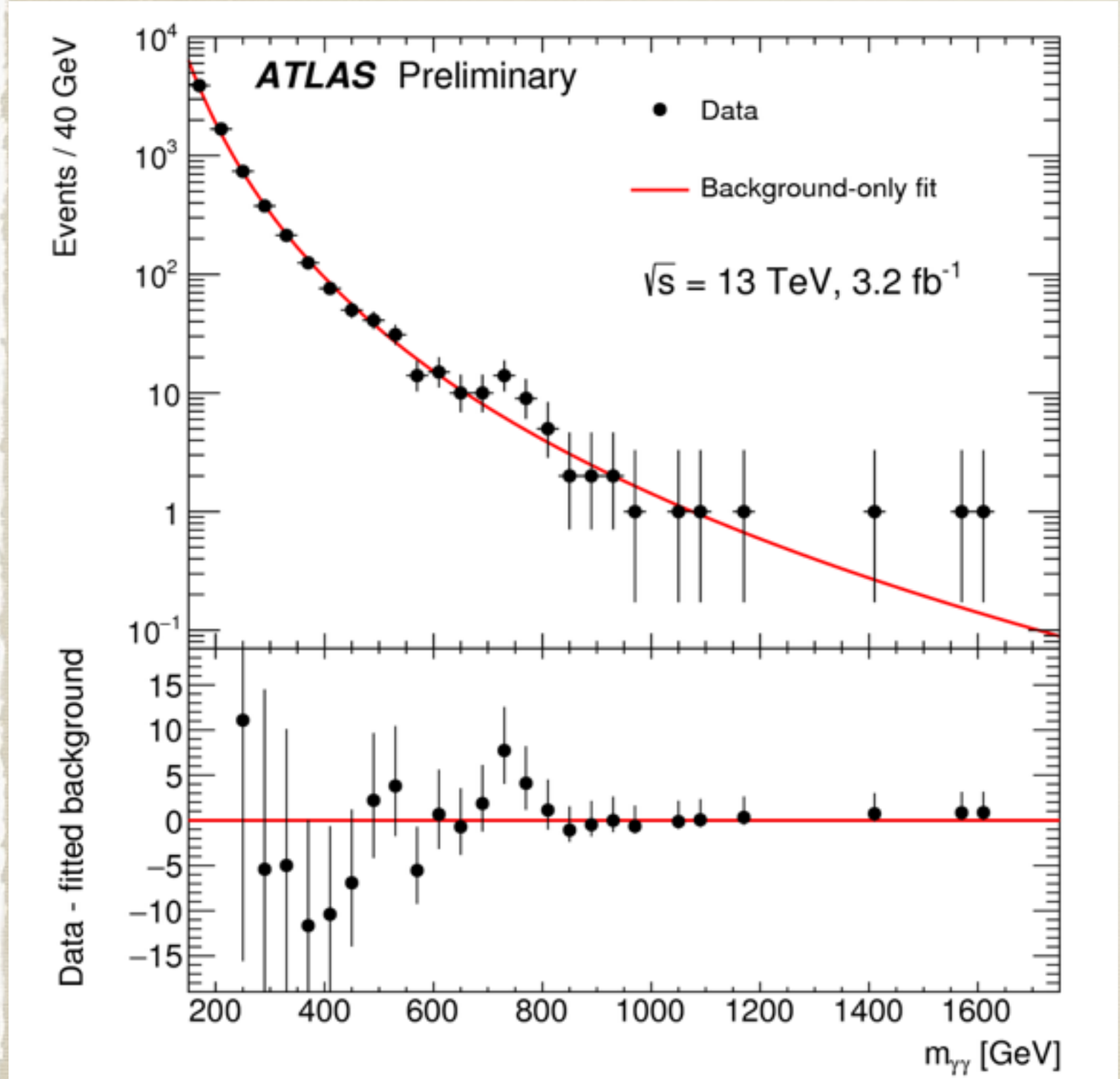

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So in a given search, there is also a "global" p-value, taking into look elsewhere

However, there are many searches, so 5 sigma is a conservative standard to be extra sure

P-hacking

Another potential worry is p-hacking, continuing to look for significant effects until one finds one
(e.g. testing a new color of jelly bean until one finds a statistically significant result)

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Now, experimental analyses are often blinded, with analysis procedure set before "opening" the box

The New York Times | https://nyti.ms/1JoE6N6

SCIENCE

Many Psychology Findings Not as Strong as Claimed, Study Says

By BENEDICT CAREY AUG. 27, 2015

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nymag.com

BAD SCIENCE

A Popular Diet-Science Lab Has Been Publishing Really Shoddy Research

By **Jesse Singal**

The Food and Brand Lab at Cornell University publishes a huge amount of research about how people perceive, consume, and think about food. The lab covers subjects ranging from seasonal trends in weight gain to how happy music influences employees, and its director, the marketing and consumer behavior expert Brian Wansink, regularly touts his lab's research during his frequent media appearances, focusing particularly on the behavioral science underlying people's consumption habits.

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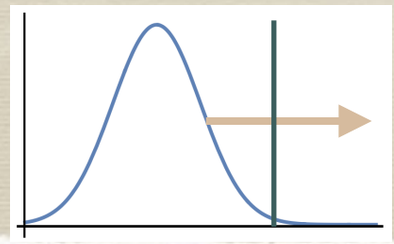

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Updated online: 23 September 2011

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Geoff Brumfiel

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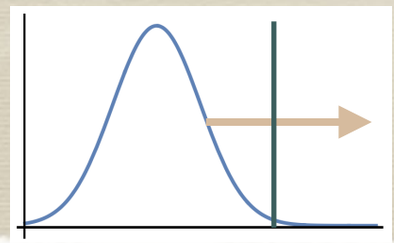

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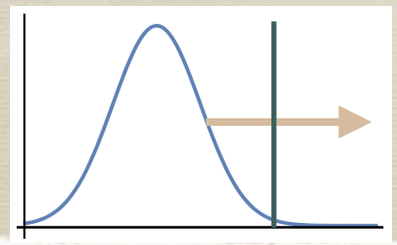

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Geoff Brumfiel

A cable was not tightened

Other Psychological Effects

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Confirmation Bias

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Texas Sharpshooter's Falacy

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For many more, see You Are Not So Smart Podcast

Science Media Literacy

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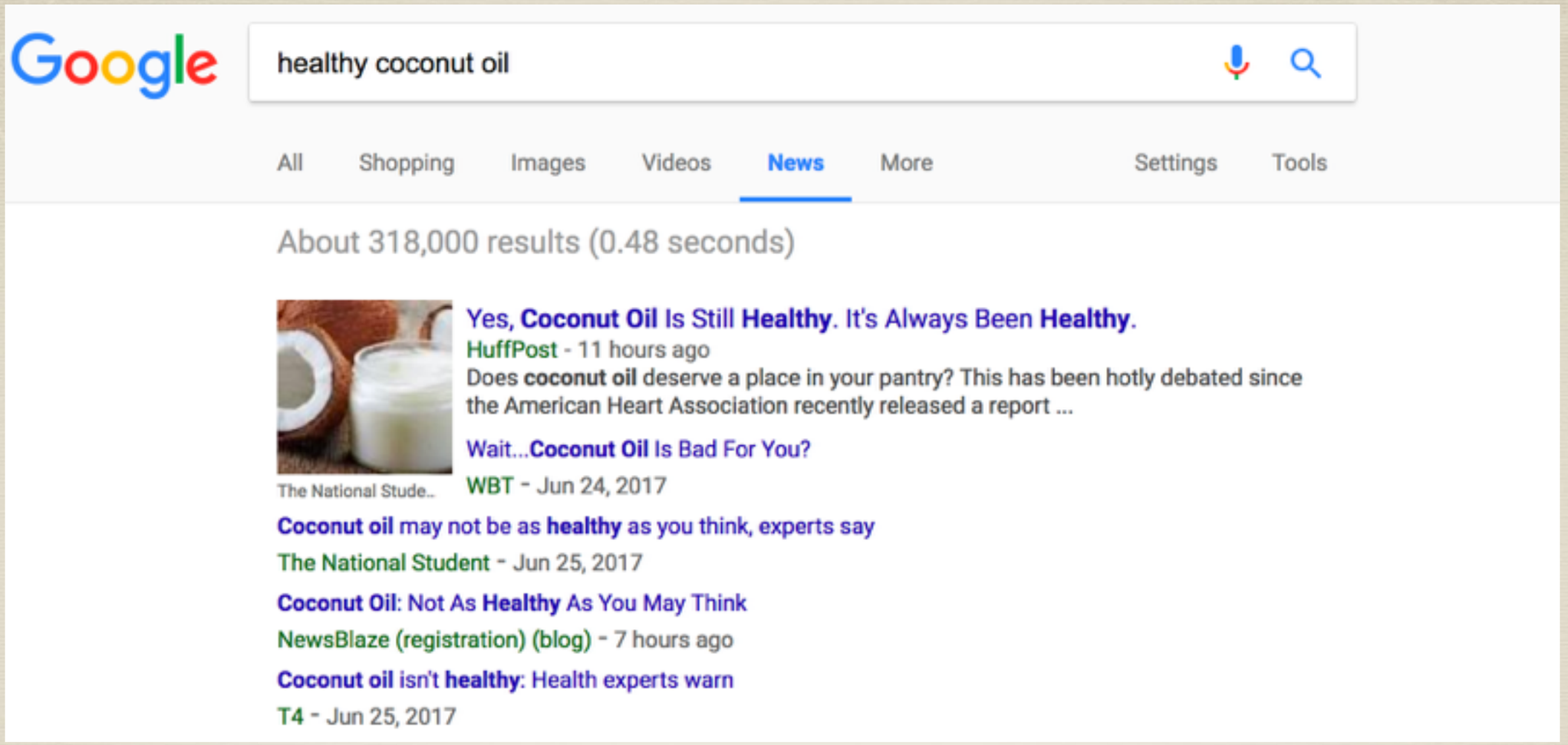

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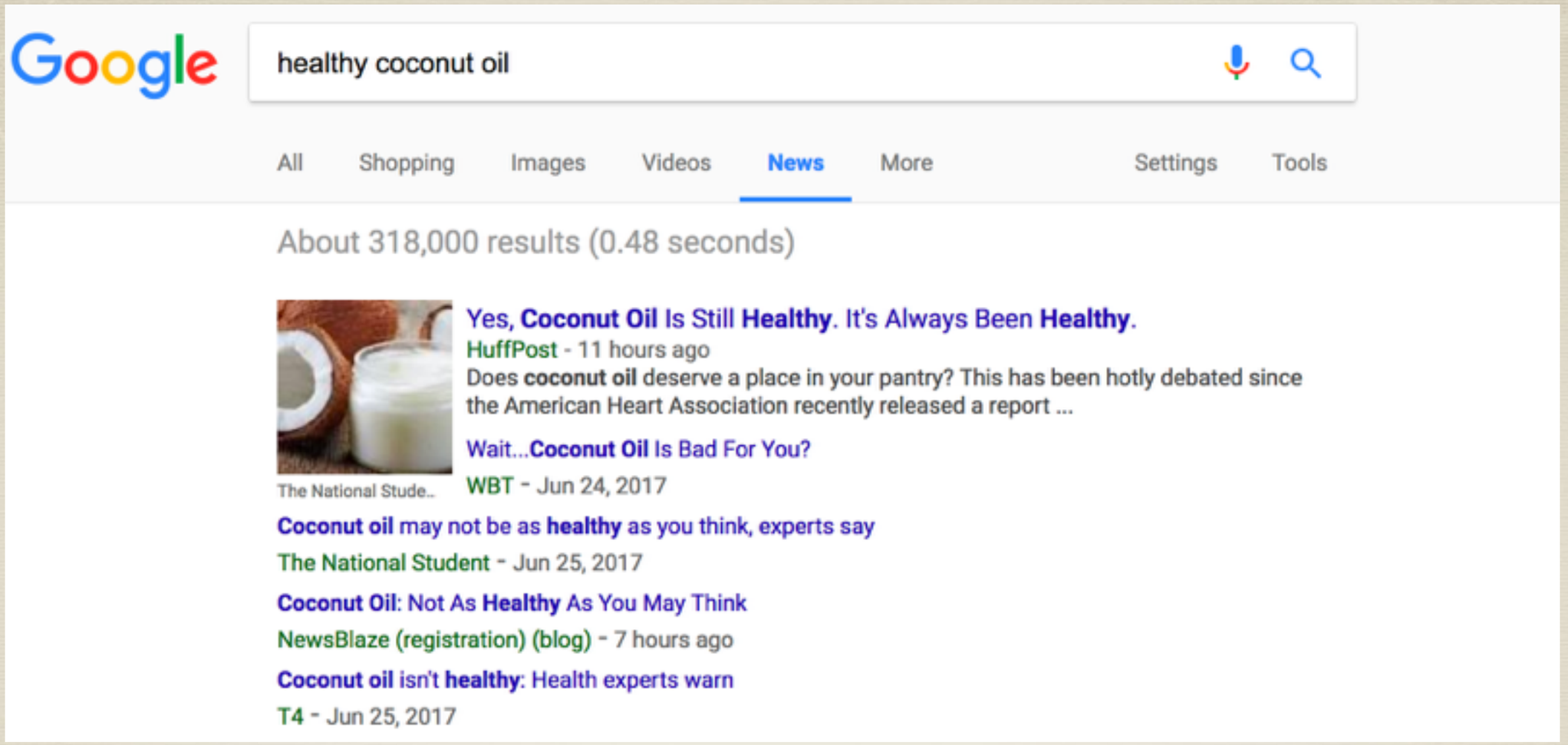

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Everybody has to be wary of their own psychological biases, critically evaluate study/report, and remain skeptical

Science as Evolving Story

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Unfortunately, we can't be experts on everything, so we have to evaluate and find trusted sources

Conclusions

- 5 sigma discovery standard
- Look elsewhere effect
- Replication crisis and past wrong results
- Science Media Literacy and Science as an Evolving Story

Thanks for your time!