Essay

Bayesian Statistics and SUSY

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Abstract

Bayesian rules do not reduce the probability of something existing by as much as you would think if you eliminate a large chunk of the parameter space. Before any experiments started to have their say, I felt that SUSY at the TeV was a well motivated theory, so I might have estimated the probability of it being there as 90%. LEP had eliminated lower mass SUSY just as you might turn over a couple of cups and not find the pea. So, at the start of 2011 before the LHC started to have much to say, I estimated the probability at 75%. You might argue that another two-thirds of the parameter space has been eliminated since then reducing the probability for SUSY at the TeV scale to 50%. For reasons discussed herein, I estimate that the probability for SUSY is now about 70%.

Key Words: Bayesian statistics, parameter space, SUSY, LEP, SUSY.

Here's a puzzle. There are three cups upside down on a table. You friend tells you that a pea is hidden under one of them. Based on past experience you estimate that there is a 90% probability that this is true. You turn over two cups and don't find the pea. What is the probability now that there is a pea underneath? You may want to think about this before reading on.

Naively you might think that two-thirds of the parameter space has been eliminated, so the probability has gone from 90% to 30%, but this is quite wrong. You can use Bayes Theorem to get the correct answer but let me give you a more intuitive frequentist answer. The situation can

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be models by imagining that there are thirty initial possibilities with equal probability. Nine of them have a pea under the first cup, nine more under the second and nine more under the third. The remaining three have no pea under any cup. This distribution models correctly the 90% that a pea is there since 27 out of 30 do. If you now eliminate the cases where the pea is under the first or second cup you are left with nine instances of it under the third cup and three that it not there. So the correct probability is 9 out of 12 or 75%, much better than the naive 30% guess.
I mention this because I saw a comment over at NEW pointing to this paper about applying Bayesian statistics to the probability of finding SUSY at the TeV scale. The puzzle illustrates that Bayesian rules do not reduce the probability of something existing by as much as you would think if you eliminate a large chunk of the parameter space. Before experiments started to have their say I felt that SUSY at the TeV was a well motivated theory and I like the maths of supersymmetry, so I might have estimated the probability of it being there as 90%. By the time that paper was written LEP had eliminated lower mass SUSY just as you might turn over a couple of cups and not find the pea. At the start of 2011 before the LHC started to have much say I estimated the probability at 75%.

You might argue that another two-thirds of the parameter space has been eliminated since then. By the same analysis this would reduce the probability for SUSY at the TeV scale to 50%. However, we also now know that the mass of the Higgs is around 125 GeV with 4 sigma confidence (actually the mass region around 115 GeV - 120 GeV is still wide open so the story is not concluded yet) If the mass had been 115 GeV it would have been a good indicator for SUSY and at 140 GeV it would have been a strong eliminator. At 125 GeV it still "smells" like SUSY but the aroma is not so sweet. This can't be quantified but for me it pushes the probability for SUSY back up to about 70%.

If you are a SUSY sceptic I know what you are thinking. You think that LEP eliminated much more than two-thirds of the parameter space and the LHC eliminated much more than two-thirds of what was left. Is this really the case? All the diagrams from ATLAS and CMS which show large chunks of the parameter space being eaten up are misleading. Firstly there is no uniform measure of probability that can be assigned to the area of the plot. Secondly and more importantly all these plots rely on highly constrained versions of SUSY to reduce the parameter space to two dimensions so that it can be analysed and plotted. If SUSY phenomenologists have made a mistake it was to think that using these simplified models would be a good way to search for SUSY. This was not well motivated and has been shown wrong. If SUSY is to be found she will be seen in direct searches for particles such as the stop or stau. The Higgs is only starting to be seen in the data now so why should we think that heavier particles would already have shown up? The Higgs was in a place where it was not easy to find but this could also be the case for the stop especially if its mass is near the top (see also Stealth Supersymmetry) Higgs searches are relatively straight forward to analyse because if we know its mass we also know its cross-sections and decay rates (assuming the standard model). This is not the case for the stop, tau or gluinos. We have to keep searching until the limits placed on cross-sections are so small that all possibilities are excluded. The LHC is nowhere near that point yet.

As a curious footnote it is amusing to see that my Stop Rumours post is gradually making its way towards being the most read article on this blog. Why so much interest? Looking into it I found

that hit counts on most posts reduce to a trickle after a few days but this post keeps collecting hits at about a hundred a day, even after three months. The stats show that this is because of people searching for the single word "stop" on google. When I do the search myself I find that the post does indeed appear at the bottom of the first page. The "Stop Rumours" title must be enticing enough to lure people to click their way in. I suspect they are a bit baffled by what they find but maybe they will learn something about physics. It is very unusual to get a first page ranking for a single common word like "stop" so why is this happening? A clue is that the Google entry has an attached note saying that "Cliff Harvey shared this". This is a feature of Google plus where Harvey maintains an excellent column commenting on people's blog posts. If I log out of Google plus I no longer see my post in the Google search listing but once logged in I notice that a whole load of my search results are there because Harvey has shared them. Judging by the steady trickle of hits on my post this must be the same for a large number of people. If you are interested in SEO you will find this fact quite interesting and perhaps useful until Google tweak their parameters back to something more sensible.

References

1. http://blog.vixra.org/2012/05/10/bayes-and-susy/