CMSSM vs CNMSSM

Which is most natural?

Andrew Fowlie, 23/09/2014

I will talk about...

- My paper, “Is the CNMSSM more credible that the CMSSM?,” arXiv:1407.7534
- Introduce 2 SUSY models: CMSSM & CNMSSM
- Explain why CNMSSM might be most natural
- Measure naturalness with Bayes

CMSSM

- Everyone knows the Constrained Minimal Supersymmetric Standard Model (related to mSUGRA, Nath et al, CMSSM, Kane, Roszkowski et al)
- Minimal field content (2HD), minimal superpotential (no RPV), no specific SUSY breaking mechanism (unless you strictly look at mSUGRA)
- Write all soft-breaking masses, then make life easier…
- Universal scalar, trilinear, and gaugino masses
- 5 parameters m0, m12, a0, tan beta

Two Tuning Problems

1. Higgs is heavy for the model -> heavy stops -> big corrections to EW scale -> little hierarchy problem (LEP paradox, naturalness etc)
2. mu-problem: Why would mu be around the SUSY or EWSB scales? (Magnitude aspect of hierarchy problem. Stability aspect is solved: mu is stable because of SUSY NR theorems)

Is the CMSSM in trouble?

Looks like it.

CNMSSM

- Go beyond minimal! (N = next-to-minimal) Add an extra singlet field, complex scalar
- Extra possible soft-breaking masses and trilinear
- Extra interactions possible in superpotential (-> new F-terms in Higgs potential)
- Also, impose a Z_3 symmetry. This forbids massive terms from superpotential
- In EWSB, singlet field also gets a VEV

CNMSSM parameters

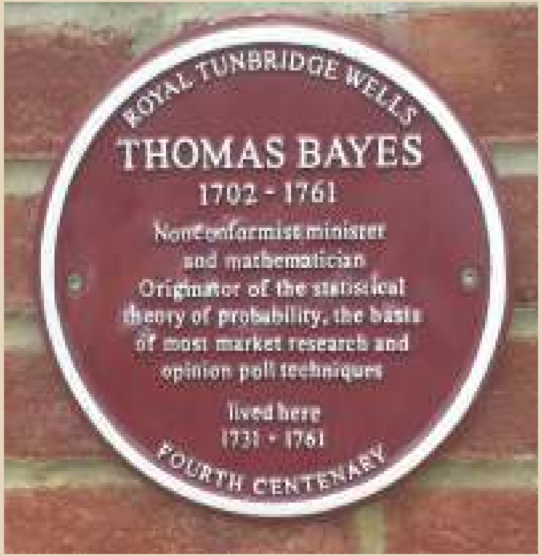
- Because of extra singlet, we gain a few parameters
- But because of Z_3, we lost a few
- We again unify soft-breaking parameters at a high scale
- Net result is 1 extra parameter:
- m0, m12, m_S, tan beta, lambda, A0

CNMSSM: Solving problems?

- mu-problem is solved! EWSB generates a mu-term spontaneously
- mu-term is a function of only soft-breaking masses - magnitude aspect solved
- Extra tree-level contribution to Higgs mass! Stops needn’t be so heavy! Little hierarchy problem solved (!?)/softened
- Maybe CNMSSM is more natural than CMSSM?

How much is that actually going to help?

Bayesian statistics



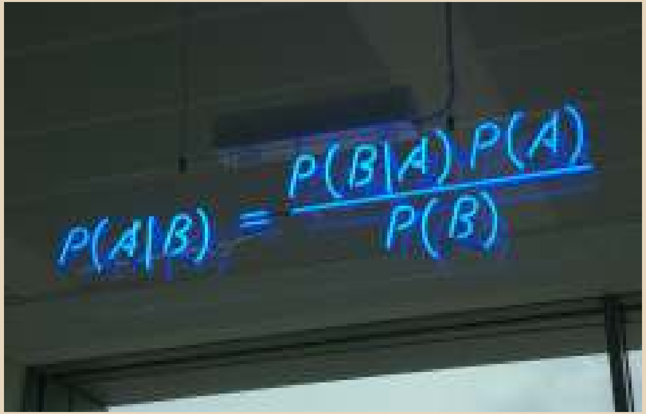
INMHO, that plaque is unbefitting for a giant of probability and statistics. Market research and opinion polls!?

Naturalness & Bayes

- I often hear: “Naturalness is aesthetic”, “cannot be defined”, “let data speak for itself!”
- Is it true?
- NO!
- If a naturalness argument can be formulated with Bayes, it’s well defined and not aesthetic. Trust it. If not, don’t

Bayesian Naturalness

- Trotta, Cabrera, Balazs, et al (and yours truly) argue that naturalness is a Bayesian argument
- We are worried that model is unlikely, because p(MZ, other data | model) is small
- And thus, p(model | data) is small. We calculate these things with Bayes theorem
- I've spoken about this before...



Bayesian statistics

- Probability here is a degree of belief, credibility in a proposition
- That proposition could be almost anything, not limited to repeatable trials
- Bayesian statistics gives us a “calculus” of beliefs - ways to update our prior beliefs in light of evidence
- We can indeed calculate

$$p(\text{ CMSSM } \mid \text{ data}) \; / \; p(\text{CNMSSM } \mid \text{ data})$$

- And judge claims that CNMSSM is better!

Making the calculation

- There are 2 ingredients:
- Likelihood: contains exp’tal data
- Prior: contains beliefs about parameter space prior to seeing data
- Bayes theorem will update our prior beliefs with the likelihood

Likelihood

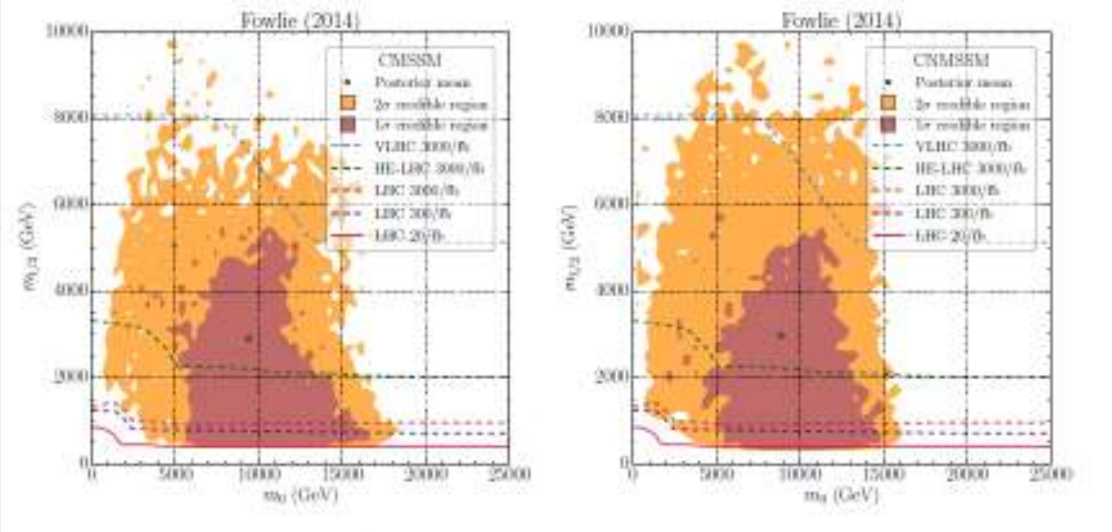
- This ingredient is easy & uncontroversial
- p(data | parameter point)
- Usual a product of Gaussians for experimental data
- My data was EW scale, and other laboratory experiments (b-phys, g-2, Higgs mass etc.), and LHC limits
- EW scale is so well measured that it’s basically a Dirac function

Priors

- (wrongly) controversial
- p(parameter point | model)
- You have to be honest and play fairly - Bayes can only tell you how to update beliefs
- We pick "naturalness" priors - the fairest choice
- Scale invariant priors for Lagrangian parameters

Results - focus points

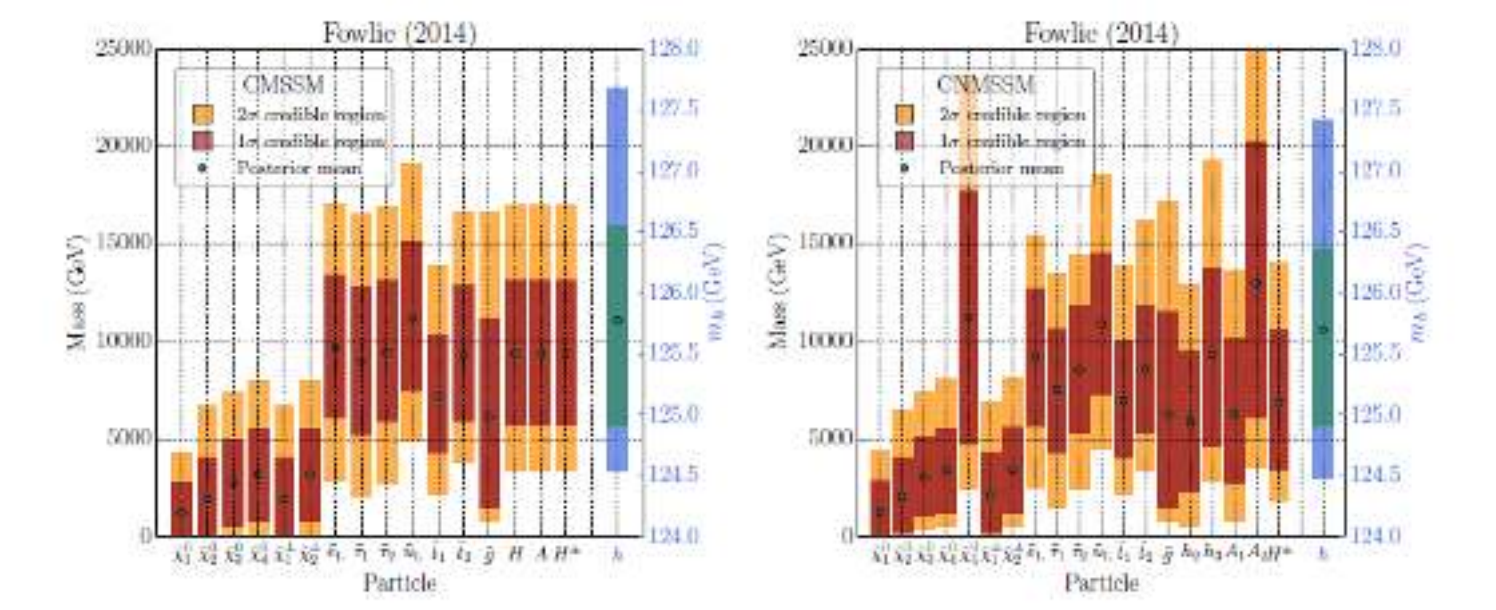
- The best regions of the CMSSM & CNMSSM are similar. Focus points favored



(a) *CMSSM.* (b) *CNMSSM.*

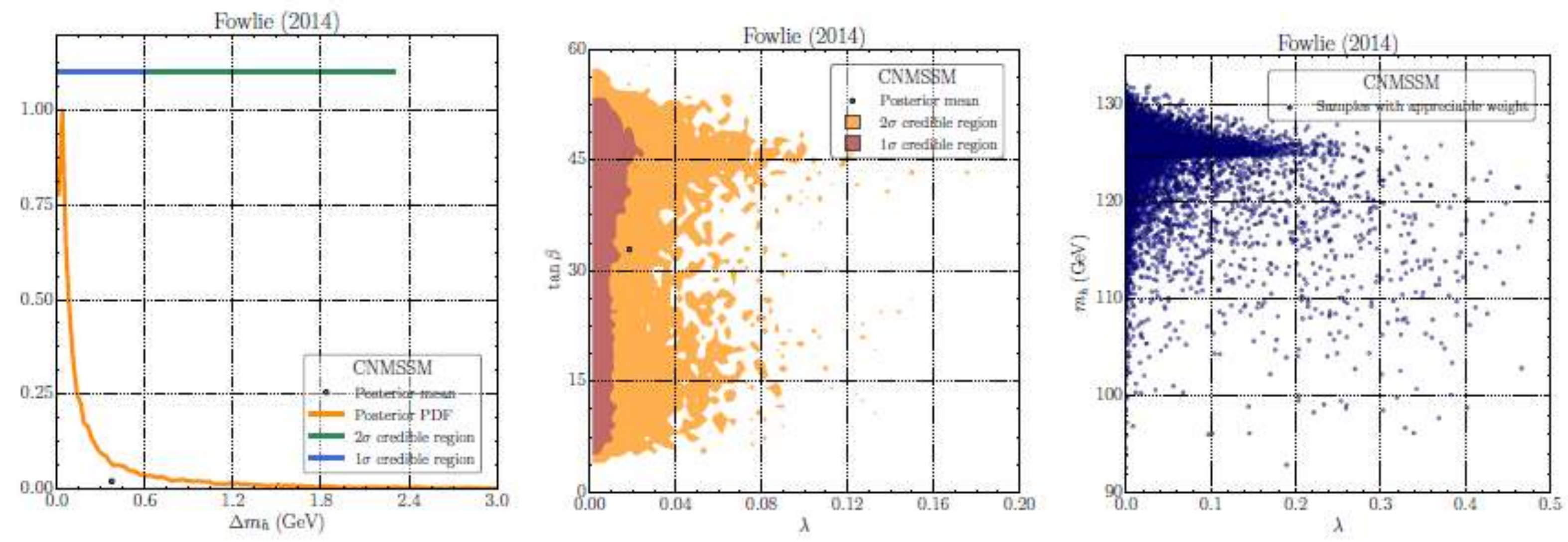
Sparticle masses

- Same story for here - very similar



(a) *CMSSM.* (b) *CNMSSM.*

Extra Higgs mass in CNMSSM?



(a) *Additional tree-level contribution to Higgs mass.*

(b) $(\lambda, \tan\beta)$ *plane.*

(c) (λ, m_h) *plane.*

Extra Higgs mass in CNMSSM?

- What happened? Why is it so small?
- The lambda parameter is tiny - the extra mass is negligible
- Why? This isn’t that clear, but it’s been previously found in the literature
- Large lambda suffers from lots of physicality problems
- CNMSSM corrections can make Higgs mass smaller (by negative loop corrections)

Finally, those probabilities

$$B\left(\mathrm{CNMSSM}/\mathrm{CMSSM}\right) = 10^{+100}_{-5}$$

- This is “positive” to “strong” evidence in favor of the CNMSSM…
- Unfortunately, there are big uncertainties in my result, but it’s the first time it’s been calculated. That can be reduced in the future

What about the mu-problem…?

- A factor of about 5 comes from solving the mu-problem
- Without that, evidence is “barely worth a mention” to “strong”
- The extra contributions to the Higgs mass along aren’t that important