Chanel N°5 (fb\(^{-1}\)):
The Sweet Fragrance of SUSY

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We present compounding evidence of supersymmetry (SUSY) production at the LHC, in the form of correlations between the nominal 5 fb\(^{-1}\) ATLAS and CMS results for the √s = 7 TeV 2011 run and detailed Monte Carlo collider-detector simulation of a concrete supersymmetric model named No-Scale F-SU(5). Restricting analysis to those event selections which yield a signal significance \(S/\sqrt{B+1}\) greater than 2, we find by application of the χ² statistic that strong correlations exist among the individual search strategies and also between the current best fit to the SUSY mass scale and that achieved using historical 1 fb\(^{-1}\) data sets. Coupled with an appropriately large increase in the “depth” of the χ² well with increasing luminosity, we suggest that these features indicate the presence of a non-random structure to the data – a light fragrance perhaps evocative of some fuller coming fruition. Those searches having signal significances below 2 are assembled into a lower exclusion bound on the gaugino mass, which is shown to be consistent with the prior best fit. Assuming the forthcoming delivery of an additional tranche of integrated luminosity at 8 TeV during 2012 that measures on the order 15 fb\(^{-1}\), we project a sufficiency of actionable data to conclusively judge the merits of our proposal.

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I. INTRODUCTION

The quest to identify supersymmetry (SUSY) at the Large Hadron Collider (LHC) is advancing rapidly, where an integrated luminosity of 4.7 fb\(^{-1}\) at √s = 7 TeV was in hand by the close of 2011, and 2012 offers the prospect of an additional 15 fb\(^{-1}\) at the richer collision energy of √s = 8 TeV. The standing prognosis from the ATLAS and CMS Collaborations is that no excess beyond the Standard Model (SM) expectation has been observed. In “Profumo di SUSY” [1] and “...Aroma of Stops and Gluinos” [2], we nevertheless argued that a forthcoming discovery of SUSY might already be actively presaged by the delicate emerging scent of vital excesses in the low statistics collider data. Such a distant early warning, if legitimate, would be distinguishable from stochastic “look elsewhere” styled fluctuations in certain key ways. In particular, the statistical significance of observed signal excesses would scale appropriately with upgrades in luminosity, thus maintaining a consistent window for the extrapolated SUSY mass scale. Additionally, it would be possible (at least in principle) to produce a succinctly described physical model that tightly correlates the observed signal strength in those channels presenting excesses over the expected background while avoiding catastrophic overproduction in those channels that do not.

In the present study we focus on 42 individual event selection channels from five distinct LHC SUSY searches conducted by the ATLAS [3–5] and CMS [6,7] collaborations, each belonging to the nominal 5 fb\(^{-1}\) integrated luminosity class. We partition these searches into two categories, based on the value of the signal significance metric \(S/\sqrt{B+1}\). The significance exceeds a value of 2 for three searches, namely the ATLAS Hadronic SRC Tight and SRE Loose signal regions of Ref. [3], and the 7j80 ATLAS Multijet study in Ref. [4]. We undertake a multi-axis χ² statistical analysis of these searches within the framework of a model named No-Scale F-SU(5) [1, 2, 8–11], and compare the resulting best fit against an earlier study [2] of the corresponding 1.04-1.34 fb\(^{-1}\) ATLAS searches [12, 13]. Remarkably, we find that i) the preferred gaugino mass scale isolated at the χ² minimum has maintained a rock steady correlation across this more than four-fold increase in data, ii) the individual best fits for each of the high significance searches maintain substantial mutual coherence, and iii) the statistical preference for No-Scale F-SU(5) over the null SM limit has indeed increased commensurately with the increase in integrated luminosity. For the remaining 39 searches with \(S/\sqrt{B+1} < 2\), we use a parallel χ² analysis to establish a lower bound on the scale of new physics in F-SU(5), and demonstrate consistency with the best fit extracted from those searches possessing a positive data excess.

We do not consider it incidental that the only three 4.7 fb\(^{-1}\) strategies to transcend a significance limit of 2 are all of the multijet variety [8–11]. As we have vigorously suggested for some time [1, 2, 8–11], multijet events
II. THE NO-SCALE \( F-SU(5) \) MODEL

No-Scale \( F-SU(5) \) (See Refs. [1, 2, 8-11, 14] and all references therein) is defined by the confluence of the \( F \)-lipped \( SU(5) \) grand unified theory (GUT), two pairs of hypothetical TeV scale vector-like supersymmetric multiplets (flippons) of mass \( M_V \) with origins in local \( F \)-theory model building, and the dynamically established boundary conditions of No-Scale Supergravity. This construction inherits all of the most beneficial phenomenology of the flipped \( SU(5) \times U(1)_X \) gauge group structure, as well as all of the theoretical motivation of No-Scale Supergravity. A more expansive theoretical treatment of \( F-SU(5) \) can be found in the cited references, including a comprehensive summary in the Appendix of Ref. [8].

Supersymmetry must be broken near the TeV scale since mass degenerate superpartners for the known SM fields are not observed. In the Constrained Minimal Supersymmetric Standard Model (CMSSM) and minimal supergravities (mSUGRA), this first occurs in a hidden sector, and the secondary propagation by gravitational interactions into the observable sector is parameterized by universal SUSY-breaking “soft terms” which include the gaugino mass \( M_{1/2} \), scalar mass \( M_0 \) and the trilinear coupling \( A \). The ratio of the low energy Higgs vacuum expectation values (VEVs) tan \( \beta \), and the sign of the SUSY-preserving Higgs bilinear mass term \( \mu \) remain undetermined, while the magnitude of the \( \mu \) term and its bilinear soft term \( B_\mu \) are determined by the Z-boson mass \( M_Z \) and tan \( \beta \) following electroweak symmetry breaking (EWSB). In the most fundamental No-Scale scenario, \( M_0=A=B_\mu=0 \) at the unification boundary, while the entire array of low energy SUSY breaking soft-terms evolve down with a single non-zero mass parameter \( M_{1/2} \). As a result, the particle spectrum is proportional to \( M_{1/2} \) at leading order, rendering the bulk “internal” physical properties invariant under an overall rescaling. The matching condition between the low-energy value of \( B_\mu \) that is required by EWSB and the high-energy \( B_\mu = 0 \) boundary is extraordinarily difficult to reconcile under the renormalization group equation (RGE) running. The solution at hand relies on modifications to the \( \beta \)-function coefficients that are generated by radiative loops containing the vector-like flippon multiplets. Via couplings to the Higgs boson, the flippons will also have a direct impact on the Higgs boson mass \( m_h \), producing a 3–4 GeV upward shift that naturally facilitates a physical Higgs mass in excellent accord with the central ATLAS, CMS, and CDF/DØ [13, 17] signal at 124–126 GeV [11]. We emphasize that this Higgs mass range is otherwise rather generically difficult to reconcile with a light TeV-scale SUSY spectrum.

The \( F-SU(5) \) model space is adherent to a set of firm “bare-minimal” phenomenological constraints [14], including consistency with the world average top-quark mass \( m_t \), the dynamically established boundary conditions of No-Scale supergravity, radiative electroweak symmetry breaking, the centrally observed WMAP7 CDM relic density [18], and precision LEP constraints on the lightest CP-even Higgs boson \( m_h \) and other light SUSY chargino and neutralino mass content. We have further established a highly constrained subspace, dubbed the \textit{Golden Strip}, that conforms to the phenomenological limits on rare processes established by measurement of the muon anomalous magnetic moment \((g_\mu-2)/2\) and the branching ratios of the flavor-changing neutral current decays \( b \rightarrow s \gamma \) and \( B^0_s \rightarrow \mu^+\mu^- \). A similarly favorable \textit{Silver Strip} slightly eases the constraints imposed by \((g_\mu - 2)\).

III. NO-SCALE \( F-SU(5) \) MULTIJETS

The No-Scale \( F-SU(5) \) model leverages the flippon multiplets to facilitate a flatness in the running of the \( SU(5) \) RGEs (\( \beta \)-coefficient \( b_3 = 0 \)), blocking the standard logarithmic enhancement to the color-charged gaugino mass \( M_3 \) at low energies. This engenders a distinctive mass texture \( M(\tilde{t}_1) < M(\tilde{g}) < M(\tilde{q}) \) featuring a light stop and gluino, both substantially lighter than all other squarks. The stability of this characteristic mass hierarchy is observed across the entire parameter space, a hierarchy that is not, to our knowledge, replicated in any CMSSM/mSUGRA constructions. The same strongness of the Higgs to top quark coupling that provides the primary lifting of the SUSY Higgs mass is utilized in the usual way to generate a hierarchically light partner stop in the SUSY mass-splitting.

In particular, the light stop \( \tilde{t}_1 \) and gluino \( \tilde{g} \) are lighter than the bottom squarks \( \tilde{b}_1 \) and \( \tilde{b}_2 \), top squark \( \tilde{t}_2 \), and the first and second generation left and right heavy squarks \( \tilde{q}_R \) and \( \tilde{q}_L \). \( F-SU(5) \) thus possesses a uniquely distinctive test signature at the LHC. This spectrum produces a characteristic event topology starting with the pair production of heavy first or second generation squarks \( \tilde{q} \) and/or gluinos \( \tilde{g} \) in the initial hard scattering process, with each heavy squark likely to yield a quark-gluino pair \( \tilde{q} \rightarrow q \tilde{g} \) in the cascade decay. The gluino mediated stops will be off-shell for gaugino masses \( M_{1/2} < 729 \text{ GeV} \). Specifically, for \( 600 < M_{1/2} < 729 \text{ GeV} \), the gluino proceeds off-shell via \( \tilde{g} \rightarrow \tilde{t}_1 \tilde{t} \) at a very high rate of 67-91%.
where the off-shell light stops decay as $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ at 52-78% and as $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ at 13-15%. On the contrary, for gaugino masses $M_{1/2} \geq 729$ GeV, the gluino mediated stops will be on-shell, where here the gluino decay proceeds on-shell via $\tilde{g} \rightarrow \tilde{t}_1 T$ at 100%, where the on-shell light stops decay as $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ at 69-76% and as $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ at 17-22%.

The impact of these final states is critical. Expectations are that each gluino will produce two to six jets, with the gluino-mediated stop channel producing the maximum of six jets. These processes may then consistently result in a net product of four to twelve jets emergent from a single gluino-gluino pair production event, five to thirteen jets emergent from a squark-gluino pair production event, and six to fourteen jets emergent from a squark-squark pair production event. After jet fragmentation following the primary hard scattering events and the sequential cascade decay chain, the final event distribution will contain an unmistakable signal of high multiplicity jets.

IV. ATLAS 4.7 fb$^{-1}$ MULTIJET SEARCHES

The most powerful signal of SUSY will arise where the magnitude of overproduction beyond expectations is highest. This has been recently exhibited in the search for the Higgs boson, where events are distributed from 117.5 GeV to 129 GeV for ATLAS and CMS, and 115 GeV to 135 GeV for CDF/DØ. Yet, the common conviction is that the Higgs boson is more narrowly constrained about 125 GeV, rather than smeared across some average of the various observed signals, since this specific mass range is where the signal is the strongest and where the largest number of events compared to the Standard Model have accumulated. In order to likewise focus our attention on the most potentially active regions of the ongoing SUSY search, we choose to segregate for inclusion in our best-fit comparative study of No-Scale F-SU(5) only those event selection scenarios currently featuring a value of the signal significance metric $S/\sqrt{B+1}$ larger than 2.

Applying this minimum threshold for signal significance to the full compilation of 5 fb$^{-1}$ class studies released to date by ATLAS and CMS, only three individually event selections are found to pass: the 7-jet pT>80 GeV (7j80) case of the ATLAS multijets [4], and the SRC Tight and SRE Loose cases of the ATLAS Hadronic 0-lepton search [3]. The 7j80 case is notable as the extension to higher luminosity of an earlier 1.34 fb$^{-1}$ ATLAS search strategy [12] that was found to be exceptionally favorable in No-Scale F-SU(5) [1, 2, 11]. Positioning an F-SU(5) framework, our full expectations were for 7j80 to likewise be a leading source of excess SUSY event production as integrated luminosity surged higher. The $S/\sqrt{B+1}$ at 1.34 fb$^{-1}$ for 7j80 was measured at 1.12 [12]. Our expectation for 5 fb$^{-1}$ of data for 7j80 was forecast as $S/\sqrt{B+1} = 1.9$ in Ref. [2]. The actual 4.7 fb$^{-1}$ signal significance computed from the ATLAS observations in Ref. [4] lands at $S/\sqrt{B+1} = 2.07$, representing quite an impressive continuation of the burgeoning signal first observed in the much more compact data set.

The remaining two 4.7 fb$^{-1}$ searches exceeding two standard deviations emerge from ATLAS Ref. [3], applying 4-jet (SRC Tight) and 6-jet (SRE Loose) cutting strategies, while concurrently requiring zero leptons. This is intended to isolate the $q\bar{q}, qg, \bar{q}g$ channels via $\tilde{q} \rightarrow q\bar{g}$ and $\tilde{g} \rightarrow q\bar{q}$. The lepton exclusion here is very important, such that there will typically be no other productive lepton-free channels capable of generating 4, 5, or 6 jets from the expected pair produced gluinos and/or heavy squarks. These studies likewise extend an earlier ATLAS study at lower luminosity (1.04 fb$^{-1}$) that had previously attracted our attention. In this case, we had forecast a value of $S/\sqrt{B+1} = 3.0$ in Ref. [2] for the “High Mass” search of Ref. [12], along with a 24 event excess. In the prior 1.04 fb$^{-1}$ ATLAS 0-lepton analysis of Ref. [13], the region of large effective mass was essentially consolidated into a single test case, identified as “High Mass”, with a cut of $\geq 4$ jets and $M_{eff} > 1100$ GeV. The signal significance of the “High Mass” 1.04 fb$^{-1}$ search was $S/\sqrt{B+1} = 1.3$. In the 4.7 fb$^{-1}$ ATLAS 0-lepton results, ATLAS has in essence separated the “High Mass” search of Ref. [13] into the more targeted 4-jet, 5-jet, and 6-jet searches of Ref. [3]. We must therefore analyze the separate 4.7 fb$^{-1}$ searches in Ref. [3] to permit a direct comparison to the 1 fb$^{-1}$ total $\geq 4$ jet “High Mass” result. In this manner, SRC Tight shows $S/\sqrt{B+1} = 3.22$ with an 8.3 event excess, whereas SRE Loose gives $S/\sqrt{B+1} = 2.65$ with a 29 event excess. The remainder of the Ref. [3] searches are of a very small signal significance, and therefore can be neglected in this comparison. Hence, we again find the projections for signal significances and event excesses to be in very good agreement with the actual data observations of SRC Tight and SRE Loose.

Taking pause to reflect upon this correlation for a moment, one would not expect random fluctuations to produce such an interrelation between these two disparate searches. Both strategies isolate multijet events of 4 jets, 6 jets, and 7 or more jets, the dominant signal region of F-SU(5), with varying cuts on jet $p_T$. Mutual improvement of signal strength from 1 fb$^{-1}$ to 4.7 fb$^{-1}$ such as these that correspond to predictions from F-SU(5) simulations hints of a possible underlying structure, with the accidental intersection of random background fluctuations across a more than four-fold increase in data being highly improbable. The targeted enhancement in signal significance for those channels in which a No-Scale F-SU(5) signal is expected to be prevalent is moreover highly suggestive. If indeed the framework of our Universe is described by the F-SU(5) model, then such a correlated growth in signal strength in all productive channels, multijets in particular, would surely be observed.
FIG. 1: We depict the $\chi^2$ analyses of the ATLAS 4.7 fb$^{-1}$ 7j80, SRC Tight, and SRE Loose Multijet search strategies from Refs. [3, 4] (upper pane), and the corresponding historical studies (“High Mass” and 7j80 cases of Refs. [12, 13]) at 1.04 and 1.34 fb$^{-1}$ (lower pane). The thin dotted blue lines correspond to the individual $\chi^2$ curves for each event selection, which are summed into the thick green cumulative multi-axis $\chi^2$ curves. These searches are selected for the exhibition of a signal significance $S/\sqrt{B+1}$ greater than 2 for the 5 fb$^{-1}$ class studies. A direct visual inspection of the growth of the signal strength and the fluctuation of the $\chi^2$ minimum with increasing luminosity is thus facilitated. Remarkably, we observe extreme stability in the favored mass scale, despite more than a four-fold increase in the integrated luminosity. The individual curves also display a very tight correlation amongst themselves. Together with an appropriately large increase in the “depth” of the $\chi^2$ well, we suggest that these features indicate the presence of a non-random structure.
V. CHI-SQUARE ANALYSIS

We apply the $\chi^2$ test statistic to probe for specific correlations between various ATLAS \[3, 5, 12, 13\] and CMS \[8, 7\] observations and the No-Scale $F$-$SU(5)$ model. For the error width of each search we combine a statistical factor $\sqrt{S + B + 1}$ accounting for Poisson fluctuations in the net observed event counting in quadrature with the quoted collaboration estimates of the background uncertainty. Searches exhibiting an anomalous under-production with respect to the expected background are zeroed out to allow the full error width for post-SM physics. Each relevant SUSY search is then compared against the full portion of the $F$-$SU(5)$ model space that remains simultaneously consistent with all the latest experimental constraints, including a 124-126 GeV Higgs boson mass, but excluding the ATLAS and CMS SUSY constraints that are the objective of this exercise. The narrow strip of otherwise viable parameterizations ranging from $400 \leq M_{1/2} \leq 900$ GeV is liberally sampled at 22 representative benchmark combinations of $M_{1/2}, \overline{M}_t, m_t$ and $\tan \beta$.

For each benchmark sample, we execute an in-depth Monte Carlo collider-detector simulation of all 2-body SUSY processes based on the MadGraph \[14, 20\] program suite, including the MadEvent \[21\], PYTHIA \[22\] and PGS4 \[23\] chain. The input SUSY particle masses are computed with MicrOMEGAs 2.1 \[24\], using a proprietary modification of the SuSpect 2.34 \[25\] codebase to run the flipon-enhanced RGEs. We use a modified version of the default ATLAS and CMS detector specification cards provided with PGS4 that calls on the newly available anti-kt jet clustering algorithm, indicating an angular scale parameter of $\Delta R = 0.4$ and $\Delta R = 0.5$, respectively. The resulting event files are filtered according to a precise replication of the selection cuts specified by the collaborations, employing a script CutLHCO 2.0 of our own design \[26\]. Finally, the sampled event counts are used to extrapolate a continuous functional dependence on the gaugino mass $M_{1/2}$ that is suitable for the generation of a $\chi^2$ fitting of the $F$-$SU(5)$ event production against the experimental data.

In order to make a meaningful comparison between our Monte Carlo collider-detector simulation and the experimental results, it is necessary to establish a consistent cross-calibration. A convenient language for accomplishing the requisite normalization is the mutual analysis of a common mSUGRA benchmark. In most cases, ATLAS and CMS provide precisely such benchmark data, which is in turn carefully internally calibrated against their own experimental results. We find consistent structural correlation against the major collaboration analyses, affirming the intrinsic soundness of our quantitative procedure. However, we do observe a small systematic suppression in our absolute event counts relative to the reference data. The mean value of the required calibration factor for the four out of five search methodologies providing a suitable mSUGRA benchmark is 1.84. When provided dual mSUGRA points, we have favored the more conservative adjustment. The reader who wishes to compare our current results against prior publications should be aware that the enhancement in the event production rate garnered by this normalization must presently be countered by a corresponding suppression, to be achieved via moderate elevation of the mass scale $M_{1/2}$. In conjunction, we remark again that the No-Scale $F$-$SU(5)$ SUSY spectrum possesses the rather unique textural characteristic of leading order en masse proportionality to just that single dimensionful parameter. In this sense, the internal physics of the model are largely invariant under a numerical relabeling of the horizontal $M_{1/2}$ axis.

The chi-square analyses presented in Figure Set 11 are focused on the isolation of a best fit to the No-Scale $F$-$SU(5)$ mass parameter $M_{1/2}$ against a subset of selection strategies exhibiting various degrees of activity beyond the SM expectation. The contemporary searches that we consider to hold data excesses include the 4.7 fb$^{-1}$ Tj80 search of Ref. \[4\] along with the 4.7 fb$^{-1}$ SRC Tight and SRE Loose cases of Ref. \[3\]. The best fit obtained by this analysis (upper pane) is compared to that obtained from the corresponding historical (lower pane) 1.04 fb$^{-1}$ and 1.34 fb$^{-1}$ studies \[12, 13\]. We will expound upon the remarkable correlation that is exhibited across these dramatically different luminosities in the next section. Since the best $F$-$SU(5)$ fit in these cases may, in principle, be either better or worse than the null production scenario embodied in the SM limit, we adopt a two-sided presentation of the cumulative distribution function. Each event selection strategy contributing to the net $\chi^2$ statistic is individually labeled, and individually calibrated against reference data provided by the ATLAS collaboration.

In the analysis presented in Figure 2, we are instead intent on establishing a global lower bound on $M_{1/2}$ by consideration of those studies without compelling hints of new physics. Specifically, we include the 39 signal regions from the 5 fb$^{-1}$ class references under analysis \[8, 7\] that possess a data significance $S/\sqrt{B + 1}$ of less than 2. As such, we adopt a single-sided cumulative distribution function for this case, and are interested in the values of $M_{1/2}$ at the median, $+1\sigma$ and $+2\sigma$ intersections of the $\chi^2$ statistic. Specific correlations exhibited against the best fit $\chi^2$ analysis are likewise a topic for discussion in the following section. Expecting that parallel event selections within a single SUSY search strategy may be strongly inter-dependent, we condense each of the five searches under consideration into a single unit-strength composite degree of freedom, collectively representing the complete set of 39 individual event selection channels. Each composite is calibrated according to a mean of factors sampled from its constituent channels, when available. Since no mSUGRA benchmark sample is provided for the CMS Jets and Dilepton study \[6\], the mean of means is applied in this case.
VI. THE CORRELATION OF NO-SCALE F-SU(5) WITH LHC OBSERVATIONS

Upon review of Figure Set 1, several features immediately jump out. Firstly, the overall \( \chi^2 \) best fit for the 4.7 fb\(^{-1} \) \( S/\sqrt{B+1} \geq 2 \) searches at \( M_{1/2} = 708 \) GeV is in fine accord with the overall \( \chi^2 \) best fit at \( M_{1/2} = 705 \) GeV for the 1 fb\(^{-1} \) incarnations of the same searches. Table I gives a benchmark SUSY spectrum for this 4.7 fb\(^{-1} \) cumulative \( \chi^2 \) best fit of \( M_{1/2} = 708 \) GeV. Incidentally, the more broadly based \( \chi^2 \) analysis of Ref. 2 for seven 1–2 fb\(^{-1} \) studies has a calibrated best fit of \( M_{1/2} = 689 \) GeV, which is likewise in excellent agreement with the newer 5 fb\(^{-1} \) results. Secondly, there is also steady coherence amongst the individual \( \chi^2 \) best fits, with the most productive 4.7 fb\(^{-1} \) studies (those with \( S/\sqrt{B+1} > 2 \)) in particular exhibiting no substantial outliers to the global best fit. Thirdly, the “depth” of the \( \chi^2 \) well is substantially enhanced in the larger luminosity study. By way of comparison, the 1 fb\(^{-1} \) best fit occurs at \( \chi^2 = 0.15 \) (out of two degrees of freedom), with a cumulative distribution percentage (CDP) of 7.0%, while the 4.7 fb\(^{-1} \) best fit occurs at \( \chi^2 = 0.10 \) (out of three degrees of freedom), with a CDP of 0.8%. Similarly, the null SM limit at 1 fb\(^{-1} \) occurs at \( \chi^2 = 1.44 \) with a CDP of 51.3%, while the same limit for 4.7 fb\(^{-1} \) corresponds to \( \chi^2 = 5.85 \) with a CDP of 88.1%. It seems that the gulf separating new physics from the SM alternative is indeed widening with accumulating statistics, exactly as it must if legitimate SUSY production is indeed at the root of the observed overproduction. Should this trend continue, it may not be long until the prospect of a satisfactory SM limit has been methodically laid to rest.

Turning attention to Figure 2, it is incumbent upon us to verify that the best fit established in the prior figure is not undone by a fundamental inconsistency with exclusion limits on \( M_{1/2} \) from the studies without any dramatic post-SM production. At a 2\( \sigma \) (95% confidence) level, it seems that we may exclude gaugino masses \( M_{1/2} \) below 673 GeV. This is comfortably consistent with the best fit for \( M_{1/2} \) that is established by a parallel \( \chi^2 \) analysis of those searches exhibiting post-SM physics at a signal significance greater than 2, as depicted in Figure Set 1.
intersection boundaries of the median fit for the upper pane of Figure Set (11) at 663–790 GeV. Of course, indefinitely large values of $M_{1/2}$ are no worse a fit to the data represented by this figure than the SM limit itself.

We cannot help but entertain optimism for an imminent SUSY discovery in the tranche of data to be released in 2012. With another 15 fb$^{-1}$ at $\sqrt{s} = 8$ TeV expected to be delivered over the running season, the debate of whether we live in a supersymmetric universe could reach a climactic resolution soon. Assuming the next release of LHC data in Summer 2012 is 5 fb$^{-1}$ at 8 TeV, for an interim total of 10 fb$^{-1}$, a quick “back of the envelope” projection suggest that discovery might already be within sight, even at that intermediate point. Specifically, our simulations of the key signal space at 8 TeV suggest that the increased beam energy may yield a multiplicative signal efficiency advantage of around 3.66. Naïvely extrapolating this same advantage onto the 6.4 events observed over a background of 8.6 events in the ATLAS 7j80 search of Ref. [4], we might reasonably expect that discovery might already be within sight, even at that intermediate point. Specifically, our simulations of the key signal space at 8 TeV suggest that the increased beam energy may yield a multiplicative signal efficiency advantage of around 3.66. Naïvely extrapolating this same advantage onto the 6.4 events observed over a background of 8.6 events in the ATLAS 7j80 search of Ref. [4], we might reasonably expect a signal significance for this channel on the order of $4.66 \times 6.4/\sqrt{4.66 \times 8.6 + 1} \sim 4.7$ with 5 fb$^{-1}$ each of 7 TeV and 8 TeV data. Likewise, for the 0-lepton search, we find a multiplicative signal advantage of about 3.1 for 10 fb$^{-1}$, yielding an $S/\sqrt{B + 1}$ signal significance near 7.0 for SRC-Tight and 5.4 for SRE-Loose. In light of this, we eagerly await the first 8 TeV data release by the ATLAS collaboration, and particularly so for these sets of event selection cuts.

In closing, we wish to briefly highlight the 4.7 fb$^{-1}$ cumulative $\chi^2$ best fit lightest supersymmetric particle (LSP) mass of $m_{\tilde{\chi}^0} = 143.4$ GeV. While the greater than 99% bino composition of the $F$-$SU(5)$ LSP generates a much smaller photon-photon annihilation cross-section and gamma-ray flux (when using the typical Einasto halo profile assumptions) than the FERMI-LAT reported fluxes of Refs. [27, 28], we do nonetheless find the tentative measurement of a 130 GeV monochromatic gamma-ray line at over $4\sigma$ quite interesting. Adding even further intrigue is the more recent result [29] that due to energy loss from final state radiation in the $\gamma\gamma$ final state, the $\chi^2$ best fit to the 130 GeV monochromatic gamma-ray line is in fact $M_{DM} = 145$ GeV.

VII. CONCLUSIONS

The overarching message that the reader should take from the analysis presented in this work is the existence of a beautiful correlation between the ATLAS 1 fb$^{-1}$ to 4.7 fb$^{-1}$ multijet observations, and the intrinsic consistency with which certain event selection channels are currently exhibiting overproduction at the LHC. We partitioned the 5 fb$^{-1}$ class searches into two categories based on the signal significance metric $S/\sqrt{B + 1}$. Those searches with a value greater than 2, all corresponding to ATLAS Multijet studies (4 jets, 6 jets, and $\geq7$ jets), were used to establish a $\chi^2$ best fit to the SUSY mass scale in the context of the No-Scale $F$-$SU(5)$ model. The revealing aspect of these three searches is that they all reside in the heart of the $F$-$SU(5)$ signal region, which lays claim to multijets as an atypically dominant signature. We discovered that in the realm of an $F$-$SU(5)$ framework, a splendid correlation exists between the best fits of the 1 fb$^{-1}$ and 4.7 fb$^{-1} \chi^2$ studies, and all high significance searches moreover possess an individual best fit in close proximity to the overall best fit. Such intricate natural correlations hint of an underlying structure, and not unpredictable randomly delivered fluctuations of the background. Our proposed benchmark has a Higgs boson mass $m_h = 124.4$ GeV, and a best fit SUSY spectrum featuring an LSP mass $m_{\tilde{\chi}^0} = 143.4$ GeV, light stop mass $m_{\tilde{t}_L} = 786$ GeV, gluino mass $m_{\tilde{g}} = 952$ GeV, and $u_L$ heavy squark mass $m_{\tilde{u}_L} = 1490$ GeV.

The grand finale of this longstanding debate over the reality of supersymmetry in our Universe could arrive rather soon, materializing well before most high-energy physicists imagined, particularly pessimistic critics hardened by the early demise of the most popular SUSY constructions. Notably, we suggest that if current signal strengths hold up, the next release of LHC data, assumed to be 5 fb$^{-1}$ at 8 TeV, could yield signal significances very close to 5 for certain individual highly favored production channels. Such an eventuality would dramatically expose the already plausible possibility that supersymmetry is in fact quite alive and well at the LHC, robustly amassing statistics as the integrated luminosity surges steadily upward. As we await this ever important next assemblage of data, we again accentuate the point that the validation of an $F$-$SU(5)$ framework underlying the LHC collisions would necessarily also carry with it implications more profound than even just the realization of supersymmetry, touching also on the stringy origins of our Universe, the landscape of string vacua, and even perhaps the No-Scale foundations of the Multiverse. But those are stories for another day; the day after the conclusive discovery of supersymmetry.

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[1] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “Profumo di SUSY: Suggestive Correlations in the ATLAS and CMS High Jet Multiplicity Data,” (2011), 1111.4204.

[2] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “A Multi-Axis Best Fit to the Collider Supersymmetry Search: The Aroma of Stops and Gluinos at the $\sqrt{s} = 7$ TeV LHC,” (2012), 1203.1918.

[3] “Search for squarks and gluinos with the ATLAS detector using final states with jets and missing transverse momentum and 4.7 fb$^{-1}$ of $\sqrt{s} = 7$ TeV proton-proton collision data,” (2012), ATLAS-CONF-2012-033, URL http://cdsweb.cern.ch

[4] “Hunt for new phenomena using large jet multiplicities and missing transverse momentum with ATLAS in $\mathcal{L} = 4.7$ fb$^{-1}$ of $\sqrt{s} = 7$ TeV proton-proton collisions,” (2012), ATLAS-CONF-2012-037, URL http://cdsweb.cern.ch

[5] ATLAS, “Further search for supersymmetry at $\sqrt{s} = 7$ TeV in final states with jets, missing transverse momentum and one isolated lepton,” (2012), ATLAS-CONF-2012-041, URL https://atlas.web.cern.ch/

[6] “Search for new physics in events with same-sign dileptons, b-tagged jets and missing energy,” (2012), CMS PAS SUS-11-020, URL http://cdsweb.cern.ch

[7] S. Chaturvedyan et al. (CMS Collaboration), “Search for physics beyond the standard model in events with a Z boson, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV,” (2012), 1204.3774.

[8] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “The Ultrahigh jet multiplicity signal of stringy no-scale $F$-SU(5) at the $\sqrt{s} = 7$ TeV LHC,” Phys.Rev. D84, 076003 (2011), 1103.4160.

[9] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “Prospects for Discovery of Supersymmetric No-Scale F-SU(5) at The Once and Future LHC,” Nucl.Phys. B859, 96 (2012), 1107.3825.

[10] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “Has SUSY Gone Undetected in 9-jet Events? A Ten-Fold Enhancement in the LHC Signal Efficiency,” (2011), 1108.5169.

[11] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “A Higgs Mass Shift to 125 GeV and A Multi-Jet Supersymmetry Signal: Miracle of the Flippons at the $\sqrt{s} = 7$ TeV LHC,” Phys.Lett. B710, 207 (2012), 1112.3024.

[12] G. Aad et al. (Atlas Collaboration), “Search for new phenomena in final states with large jet multiplicities and missing transverse momentum using $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector,” JHEP 1111, 099 (2011), 1110.2299.

[13] G. Aad et al. (ATLAS Collaboration), “Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions,” (2011), 1109.6572.

[14] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “The Unification of Dynamical Determination and Bare Minimal Phenomenological Constraints in No-Scale F-SU(5),” Phys.Rev. D85, 056007 (2012), 1105.3988.

[15] CMS, “Combined results of searches for the standard model Higgs boson in pp collisions at $\sqrt{s} = 7$ TeV,” (2012), 1202.1488.

[16] ATLAS, “Combined search for the Standard Model Higgs boson using up to 4.9 fb$^{-1}$ of pp collision data at $\sqrt{s} = 7$ TeV with the ATLAS detector at the LHC,” (2012), 1202.1408.

[17] “Combined CDF and D0 Search for Standard Model Higgs Boson Production with up to 10.0 fb$^{-1}$ of Data,” (2012), preliminary results prepared for the Winter 2012 Conferences, 1203.3774.

[18] E. Komatsu et al. (WMAP), “Seven-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Cosmological Interpretation,” Astrophys.J.Suppl. 192, 18 (2010), 1001.4538.

[19] T. Stelzer and W. F. Long, “Automatic generation of tree level helicity amplitudes,” Comput. Phys. Commun. 81, 357 (1994), hep-ph/9401258.

[20] J. Alwall et al., “MadGraph/MadEvent Collider Event Simulation Suite,” (2011), URL http://madgraph.hep.uiuc.edu/

[21] J. Alwall et al., “MadGraph/MadEvent v4: The New Wave Generator,” JHEP 09, 028 (2007), 0706.2334.

[22] T. Sjostrand, S. Mrenna, and P. Z. Skands, “PYTHIA 6.4 Physics and Manual,” JHEP 05, 026 (2006), hep-ph/0603175.

[23] J. Conway et al., “PGS4: Pretty Good Simulation,” (2009), URL http://www.physics.ucdavis.edu/~conway/research/

[24] G. Belanger, F. Boudjema, A. Pukhov, and A. Semenov, “Dark matter direct detection rate in a generic model with micrOMEGAs2.1,” Comput. Phys. Commun. 180, 747 (2009), 0803.2360.

[25] A. Djouadi, J.-L. Kneur, and G. Moulata, “Suspect: A Fortran code for the supersymmetric and Higgs particle spectrum in the MSSM,” Comput. Phys. Commun. 176, 426 (2007), hep-ph/0211331.

[26] T. Li, J. A. Maxin, D. V. Nanopoulos, and J. W. Walker, “CutLHCO: A Tool for Detector Selection Cuts,” (2011), URL http://www.joelwalker.net/code/cut_lhco.tar.gz.

[27] T. Bringmann, X. Huang, A. Ibarra, S. Vogl, and C. Weniger, “Fermi LAT Search for Internal Bremsstrahlung Signatures from Dark Matter Annihilation,” (2012), 1203.1312.

[28] C. Weniger, “A Tentative Gamma-Ray Line from Dark Matter Annihilation at the Fermi Large Area Telescope,” (2012), 1204.2797.

[29] E. Tempel, A. Hektor, and M. Raidal, “Fermi 130 GeV gamma-ray excess and dark matter annihilation in sub-haloes and in the Galactic centre,” (2012), 1205.1045.