SARAH - A Tool for SUSY Model Builders

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Outline

Basic Idea

SARAH is Mathematica package to get with the minimal amount of information all properties of a $(\mathcal{N}=1)$-SUSY-model

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Input: Gauge Groups, Particle Content, Superpotential
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Lagrangian for Gauge Eigenstates

Basic Idea

SARAH is Mathematica package to get with the minimal amount of information all properties of a ($\mathcal{N} = 1$)-SUSY-model

Input: Gauge Groups, Particle Content, Superpotential

↓

Lagrangian for Gauge Eigenstates

↓

Input: Symmetry Breaking(s) and Rotations

↓

Final Lagrangian, Mass Matrices, Tadpole Equations

What happens automatically:

- Model checked for Gauge Anomalies
- Soft SUSY Breaking terms are added
- Gauge fixing terms can be specified in R_ξ gauge
  $\longrightarrow$ Ghost interactions calculated
- Particles can be integrated out
  $\longrightarrow$ Effective operators up to Dimension 6 calculated

Full Control about the model:

- Properties of all parameter can be defined separetly, e.g. only diagonal, real/complex, relations between parameters
- Arbitrary number of field rotations possible
- Non canonical terms can be added
- Selected Couplings can be manually changed

Model Files

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Model files for CalcHep/CompHep and FenyArts/FormCalc can be generated.

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Features of the model file for CalcHep/CompHep:

- Unitarity and Feynman gauge supported
- Auxiliary fields for splitting vertices with 4 colored particles included
- CP violation possible
- Can be used with MicrOmegas

LaTeX

A model specific LaTeX-file can be created:

- All information about the model (particle content, mass matrices, tadpole equations, vertices)
- Including Feynman diagrams for all vertices using `FeynMP` by Thorsten Ohl
- Own Mathematica functions for better typeset of long formulas

Tests of the Output

Numerical tests of all vertices separetely, complete processes and dark matter calculations have been done.

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	CalcHep	SARAH
Ωh^2	0.191	0.191
Channels	38.72% $\chi_1\chi_1 -> e_3\bar{e}_3$	38.73% $\chi_1\chi_1 -> e_3\bar{e}_3$
	30.40% $\chi_1\chi_1 -> e_2\bar{e}_2$	30.39% $\chi_1\chi_1 -> e_2\bar{e}_2$
	29.23% $\chi_1\chi_1 -> e_1\bar{e}_1$	29.23% $\chi_1\chi_1 -> e_1\bar{e}_1$
	0.31% $\chi_1\chi_1 -> \nu_3\bar{\nu}_3$	0.31% $\chi_1\chi_1 -> \nu_3\bar{\nu}_3$
	0.30% $\chi_1\chi_1 -> \nu_2\bar{\nu}_2$	0.30% $\chi_1\chi_1 -> \nu_2\bar{\nu}_2$
	0.30% $\chi_1\chi_1 -> \nu_1\bar{\nu}_1$	0.30% $\chi_1\chi_1 -> \nu_1\bar{\nu}_1$
	0.24% $\chi_1\chi_1 -> u_2\bar{u}_2$	0.24% $\chi_1\chi_1 -> u_2\bar{u}_2$
	0.23% $\chi_1\chi_1 -> u_1\bar{u}_1$	0.23% $\chi_1\chi_1 -> u_1\bar{u}_1$
	0.10% $\chi_1\chi_1 -> d_3\bar{d}_3$	0.10% $\chi_1\chi_1 -> d_3\bar{d}_3$

From MSSM to NMSSM

- Add singlet superfield

```
Sing[[1]] = {dR, 3, d, 1/3, 0, -1};
Sing[[2]] = {uR, 3, u, -2/3, 0, -1};
Sing[[3]] = {eR, 3, e, 1, 0, 0};
```

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Sing[[2]] = {uR, 3, u, -2/3, 0, -1};
Sing[[3]] = {eR, 3, e, 1, 0, 0};
Sing[[4]] = {Sing, 1, S, 0, 0, 0};
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential

```
TriW = {{q, Hu, u, Yu,1}, {q, Hd, d, Yd, -1},
        {l, Hd, e, Ye, -1}};

BiW = {{Hu,Hd,μ,1}};
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential

```
TriW = {{q, Hu, u, Yu,1}, {q, Hd, d, Yd, -1},
        {l, Hd, e, Ye, -1},
        {Hu, Hd, S, λ,1},{S,S,S,κ,1/3}};
BiW = {};
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential
- Give VEV to scalar singlet

```
{{SHd0, {vd, 1/√2}, {sigmad, I/√2},{phid, 1/√2}},
{SHu0, {vu, 1/√2}, {sigmau, I/√2},{phiu, 1/√2}}};
```

From MSSM to NMSSM

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```
{{SHd0, {vd, 1/√2}, {sigmad, I/√2},{phid, 1/√2}},
{SHu0, {vu, 1/√2}, {sigmau, I/√2},{phiu, 1/√2}},
{SSing, {vS,1/√2},{sigmaS,I/√2},{phiS,1/√2}};
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential
- Give VEV to scalar singlet
- Change particle mixings

```
{{{SdL, SdR}, {Sd, ZD}},
...
{{phiu, phid}, {h, ZH}},
{{sigmau, sigmad}, {Ah, ZA}},
{{fB, fW0, FHd0, FHu0}, {L0, ZN}},
{{{fWm, FHdm}, {fWp, FHup}}, {{Lm,Um}, {Lp,Up}}}}
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential
- Give VEV to scalar singlet
- Change particle mixings

```
{{{SdL, SdR}, {Sd, ZD}},
...
{{phiu, phid,phiS}, {h, ZH}},
{{sigmau, sigmad,sigmaS}, {Ah, ZA}},
{{fB, fW0, FHd0, FHu0,conj[FSing]}, {L0, ZN}},
{{{fWm, FHdm}, {fWp, FHup}}, {{Lm,Um}, {Lp,Up}}}}
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential
- Give VEV to scalar singlet
- Change particle mixings
- Define properties of parameters (optional)

```
{κ,{LaTeX -> "\kappa",
    Real -> True,
    Dependence -> None,
    Value -> None,
    LesHouches -> {EXTPAR,62} }}
```

From MSSM to NMSSM

- Add singlet superfield
- Change superpotential
- Give VEV to scalar singlet
- Change particle mixings
- Define properties of parameters (optional)

That's All!

The new model files are produced within few minutes

Evalution time in seconds (Intel Q8200, 2.33 GHz, 4GB Ram):

Model	Lagrangian	Vertices	FeynArts	CalcHep/CompHep	LaTeX
MSSM	13.3	74.8	0.3	105.7	58.4
NMSSM	39.0	255.0	1.0	210.9	61.9

Outlook

Features under development:

- Support of arbitrary irreducible representations (of $SU(N)$)

  $\rightarrow$ Possibility of GUT theories
- Automatized calculation of 2-Loop Renormalization Group Equations

Summary

- SARAH is a tool for analyzing SUSY models
- Model files for CalcHep/CompHep and FeynArts/FormCalc are created
- The models can be changed in SARAH in an easy and intuitive way