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`Vscape V1.1.0`. An interactive tool for metastable vacua ☆

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Abstract

`Vscape` is an interactive tool for studying the one-loop effective potential of an ungauged supersymmetric model of chiral multiplets. The program allows the user to define a supersymmetric model by specifying the superpotential. The F-terms and the scalar and fermionic mass matrices are calculated symbolically. The program then allows you to search numerically for (meta)stable minima of the one-loop effective potential. Additional commands enable you to further study specific minima, by, e.g., computing the mass spectrum for those vacua. `Vscape` combines the flexibility of symbolic software, with the speed of a numerical package.

Program summary

Program title: `Vscape 1.1.1`
Catalogue identifier: ADZW_v1_0
Program summary URL: http://cpc.cs.qub.ac.uk/summaries/ADZW_v1_0.html
Program obtainable from: CPC Program Library, Queen's University, Belfast, N. Ireland
Licensing provisions: Standard CPC licence, http://cpc.cs.qub.ac.uk/licence/licence.html
No. of lines in distributed program, including test data, etc.: 80 507
No. of bytes in distributed program, including test data, etc.: 6 708 938
Distribution format: tar.gz
Programming language: C++
Computer: Pentium 4 PC Computers: need (GNU) C++ compiler, Linux standard GNU installation (./configure; make; make install). A precompiled Windows XP version is included in the distribution package
Operating system: Linux, Windows XP using cygwin
RAM: 10 MB
Word size: 32 bits
Classification: 11.6
External routines: GSL (http://www.gnu.org/software/gsl/), CLN (http://www.ginac.de/CLN/), GiNaC (http://directory.fsf.org/GiNaC.html)
Nature of problem: `Vscape` is an interactive tool for studying the one-loop effective potential of an ungauged supersymmetric model of chiral multiplets. The program allows the user to define a supersymmetric model by specifying the superpotential. The F-terms and the scalar and fermionic mass matrices are calculated symbolically. The program then allows you to search numerically for (meta)stable minima of the one-loop effective potential. Additional commands enable you to further study specific minima, by, e.g., computing the mass spectrum for those vacua. `Vscape` combines the flexibility of symbolic software with the speed of a numerical package.
Solution method: Coleman–Weinberg potential is computed using numerical matrix diagonalization. Minima of the one-loop effective potential are found using the Nelder and Mead simplex algorithm. The one-loop effective potential can be studied using numerical differentiation. Symbolic users interface implemented using flex and bison.
Restrictions: $N = 1$ supersymmetric chiral models only
Unusual features: GiNaC (+CLN), GSL, ReadLib (not essential)

☆ This paper and its associated computer program are available via the Computer Physics Communications homepage on ScienceDirect (http://www.sciencedirect.com/science/journal/00104655).

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Running time: Interactive users interface. Most commands execute in a few ms. Computationally intensive commands execute in order of minutes, depending on the complexity of the user defined model.

PACS: 11.30.Pb; 11.30.Qc; 12.60.Jv

Keywords: Metastable supersymmetry breaking; Elementary particle physics; Phenomenological model; Beyond standard model; Coleman–Weinberg effective potential

1. Introduction

The requirement that supersymmetry is broken at the global minima in field theories with dynamical supersymmetry breaking [1] puts tight constraints on model building. Recently, dynamical supersymmetry breaking in metastable vacua has attracted attention as a promising phenomenological possibility. This greatly simplifies the model building problems. The metastable states are viable candidates to describe our world, when the tunneling probability to the supersymmetric ground state is highly suppressed. As argued in [2], metastable vacua might be quite generic in supersymmetric theories [3,4]. With some mild assumptions, low energy supersymmetry breaking even requires our world as we know it to be a long lived metastable state [5]. From the string theory point of view, non-supersymmetric flux compactifications might also be rather generic in the landscape of vacua [6].

An important role in studying the moduli space of supersymmetric theories is played by the one-loop effective potential of the field theory. The classical (pseudo)moduli space can contain flat directions. The one-loop corrections often lift those pseudomoduli directions of the classical theory, thus creating isolated (meta)stable vacuum. Generically, several fields will have vacuum expectation values (vevs) at those local minima. The important phenomenological objective is then to create models that communicate this dynamical breaking of supersymmetry to the supersymmetric standard model such that one gets attractive superpartner spectra [7].

The computation of the Coleman–Weinberg potential [8] in realistic models often becomes rather involved as the mass matrices become large and one can expect several fields to gain vevs. Even for symbolic software package, multiple diagonalization of large mass matrices is rather time consuming, while numerical packages usually do not provide the flexibility of working with symbolic formulas. `Vscape` aims to bridge this gap between symbolic and numerical packages. The flexibility of the `Vscape` users interface gives the user the freedom to define the physics of the model symbolically, while the computationally intensive evaluations of the Coleman–Weinberg potential rely on fast numerical C++ routines.

In addition `Vscape` provides the necessary tools to analyse a metastable vacuum once one is found. Commands are provided to compute the mass spectrum at the local minimum. Those results can then be used as input data for a spectrum generator such as `SOFTSUSY` [9]. `Vscape` has a command implemented with allows for the creation of files formatted according the Model Input File standard described in the Les Houches Accord 1.0 to supply the high energy input to the spectrum generator.

The code for `Vscape` was written in object-oriented C++ since this language compiles to speed efficient programs, allowing for fast diagonalization of large matrices for the Coleman–Weinberg potential. Using C++ also has the advantage that an extensive collection very powerful, mathematical libraries are freely available. `Vscape` makes use of the recent libraries GSL [10], GiNaC and CLN [11]. `Vscape` also has Tab-completion build in, if one has the readline library installed. The program can freely be downloaded and installed from either:

http://www.physics.rutgers.edu/korneel/vscape/vscape.html

or

http://projects.hepforge.org/vscape/

Detailed installation instruction (Linux and Windows) can also be found there. Updates and fixes of possible errors will also appear on those websites.

In Section 2, we briefly introduce the physics behind the commands of `Vscape`. We then give a short account on how the program is structured in Section 3. Section 4 lists several possibilities for further extensions of the program. Appendices A and B contain the detailed syntax and functionality of all the commands understood by `Vscape`. Section B.8 discusses the precision of the numerical computations, while Section B.9 lists the commands to change the control parameters of the program to influence the algorithms underlying the program.

2. Physics overview

2.1. The supersymmetric model of chiral fields

The current version of `Vscape` allows one to study various $\mathcal{N} = 1$ supersymmetric models with chiral fields [12]. The user defines the model by specifying the parameters and chiral fields ϕ_i of the model. In addition, one has to specify the subset of fields