
Installation Guide

Release 10.4.beta4

The Sage Development Team

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If you are reading this manual at <https://doc.sagemath.org/>, note that it was built at the time the most recent stable release of SageMath was made.

More up-to-date information and details regarding supported platforms may have become available afterwards and can be found in the section “Availability and installation help” of the [release tour](#) for each SageMath release.

Where would you like to run SageMath? Pick one of the following sections.

- **Do you want to do SageMath development?**

- **Yes, development:**

- Obtain the SageMath sources via `git` as described in [The Sage Developer's Guide](#).

- * Then build SageMath from source as described in section [Install from Source Code](#).
 - * Alternatively, follow the instructions in section [Using conda to provide all dependencies for the Sage library](#); these describe an experimental method that gets all required packages, including Python packages, from conda-forge.

- **No development:**

- * Install the [binary build of SageMath](#) from the 3-manifolds project. It is a signed and notarized app, which works for macOS 10.12 and newer. It is completely self-contained and provides the standard Sage distribution together with many optional packages. Additional optional Python packages can be installed with the `%pip` magic command and will go into your `~/ .sage` directory.
 - * Alternatively, install SageMath from the [conda-forge](#) project, as described in section [Install from conda-forge](#).
 - * Alternatively, build SageMath from source as described in section [Install from Source Code](#).

WINDOWS

- **Do you want to do SageMath development?**

- **Yes, development:**

Enable [Windows Subsystem for Linux \(WSL\)](#) and install Ubuntu as follows.

- * Make sure that hardware-assisted virtualization is enabled in the EFI or BIOS of your system. If in doubt, refer to your system's documentation for instructions on how to do this.
- * [Run the WSL install command as administrator](#). This will install Ubuntu Linux.

Note that the basic instructions in the linked article apply to up-to-date installations of Windows 10 and 11, but there are also links to the procedures for older builds of Windows 10.

- * If you had installed WSL previously or installed it using different instructions, [verify that you are running WSL 2](#).
- * [Set up your Linux username and password](#). Do not include any spaces in your username.
- * If your computer has less than 10GB of RAM, [change the WSL settings](#) to make at least 5GB of RAM available to WSL.

Start Ubuntu from the Start menu. Then follow the instructions for development on Linux below.

- **No development:**

Enable [Windows Subsystem for Linux \(WSL\)](#) and install Ubuntu as follows.

- * Make sure that hardware-assisted virtualization is enabled in the EFI or BIOS of your system. If in doubt, refer to your system's documentation for instructions on how to do this.
- * [Run the WSL install command as administrator](#). This will install Ubuntu Linux.

Note that the basic instructions in the linked article apply to up-to-date installations of Windows 10 and 11, but there are also links to the procedures for older builds of Windows 10.

- * If you had installed WSL previously or installed it using different instructions, [verify that you are running WSL 2](#).
- * [Set up your Linux username and password](#). Do not include any spaces in your username.
- * If your computer has less than 8GB of RAM, [change the WSL settings](#) to make at least 4GB of RAM available to WSL.

Start Ubuntu from the Start menu, and type the following commands to install Sage from conda-forge. (The \$ represents the command line prompt, don't type it!) The second step will ask a few questions, and you may need to hit `Enter` to confirm or type `yes` and then hit `Enter`.

```
$ curl -L -O "https://github.com/conda-forge/miniforge/releases/latest/  
↪download/Miniforge3-$(uname) -$(uname -m).sh"  
$ bash Miniforge3-$(uname) -$(uname -m).sh  
$ conda create -n sage sage python=3.11
```

(If there are any installation failures, please report them to the conda-forge maintainers by opening a [GitHub Issue](#) for conda-forge/sage-feedstock.)

You can now start SageMath as follows:

```
$ conda activate sage  
$ sage
```

This way of starting Sage gives you the most basic way of using Sage in the terminal. See [Launching SageMath](#) for recommended next steps, in particular for setting up the Jupyter notebook, which is required if you want to use graphics.

- **Do you want to do SageMath development?**

- **Yes, development:**

- Obtain the SageMath sources via `git` as described in [The Sage Developer's Guide](#).

- * Then build SageMath from source as described in section [Install from Source Code](#).
 - * Alternatively, follow the instructions in section [Using conda to provide all dependencies for the Sage library](#); these describe an experimental method that gets all required packages, including Python packages, from conda-forge.

- No development: **Do you have root access (sudo)?**

- * **Yes, root access:** Then the easiest way to install SageMath is through a Linux distribution that provides it as a package. Some Linux distributions have up-to-date versions of SageMath, see repology.org:sagemath for an overview. See [Linux Package Managers](#) for additional information.

- If you are on an older version of your distribution and a recent version of SageMath is only available on a newer version of the distribution, consider upgrading your distribution. In particular, do not install a version of Sage older than 9.5.

- * **No root access, or on an older distribution:** Install SageMath from the [conda-forge](#) project, as described in section [Install from conda-forge](#).
 - * Alternatively, build SageMath from source as described in section [Install from Source Code](#).

IN THE CLOUD

- [Sage Binder repo](#) provides a Binder badge to launch JupyterLab environment with Sage.
- [Sage Cell Server](#) is a free online service for quick computations with Sage.
- [CoCalc](#) is an online commercial service that provides Sage and many other tools.
- [Docker image sagemathinc/cocalc](#) can be used on any system with Docker to run CoCalc locally.

More information:

4.1 Linux Package Managers

SageMath is available from various distributions and can be installed by package managers.

As of Sage 10.2, we can recommend the following distributions, which provide well-maintained and up-to-date SageMath packages: [Arch Linux](#) and [Void Linux](#).

Gentoo users might want to give a try to [sage-on-gentoo](#).

Do not install a version of Sage older than 9.5. If you are on an older version of your distribution and a recent version of SageMath is only available on a newer version of the distribution, consider upgrading your distribution.

See the [_sagemath dummy package](#) for the names of packages that provide a standard installation of SageMath, including documentation and Jupyter. See also [repology.org: sagemath](http://repology.org:sagemath) for information about versions of SageMath packages in various distributions.

The [GitHub wiki page Distribution](#) collects information regarding packaging and distribution of SageMath.

4.2 Install from Pre-Built Binaries

4.2.1 Linux

SageMath used to provide pre-built binaries for several Linux flavors. This has been discontinued, as most major Linux distributions have up-to-date distribution packages providing SageMath. See [Linux Package Managers](#) for information.

4.2.2 macOS

macOS binaries are available from the [3-manifolds project](#). These have been signed and notarized, eliminating various errors caused by Apple's gatekeeper antimalware protections.

SageMath used to provide pre-built binaries for macOS on its mirrors. This has been discontinued, and the old binaries that are still available there are no longer supported.

4.2.3 Microsoft Windows

SageMath used to provide pre-built binaries for Windows based on Cygwin. This has been discontinued, and the old binaries that can be found are no longer supported. Use Windows Subsystem for Linux instead.

4.3 Install from conda-forge

SageMath can be installed on Linux and macOS via Conda from the [conda-forge](#) conda channel.

Both the `x86_64` (Intel) architecture and the `arm64/aarch64` architectures (including Apple Silicon, M1) are supported.

You will need a working Conda installation: either Miniforge (or Mambaforge), Miniconda or Anaconda. If you don't have one yet, we recommend installing [Miniforge](#) as follows. In a terminal,

```
$ curl -L -O "https://github.com/conda-forge/miniforge/releases/latest/download/
->Miniforge3-$(uname) -$(uname -m).sh"
$ bash Miniforge3-$(uname) -$(uname -m).sh
```

- Miniforge (and Mambaforge) use conda-forge as the default channel.
- If you are using Miniconda or Anaconda, set it up to use conda-forge:
 - Add the conda-forge channel: `conda config --add channels conda-forge`
 - Change channel priority to strict: `conda config --set channel_priority strict`

If you installed Miniforge (or Mambaforge), we recommend to use [mamba](#) in the following, which uses a faster dependency solver than conda.

4.3.1 Installing all of SageMath from conda (not for development)

Create a new conda environment containing SageMath, either with mamba or conda:

```
$ mamba create -n sage sage python=X
```

```
$ conda create -n sage sage python=X
```

where X is version of Python, e.g. 3.9.

To use Sage from there,

- Enter the new environment: `conda activate sage`
- Start SageMath: `sage`

If there are any installation failures, please report them to the conda-forge maintainers by opening a [GitHub Issue](#) for [conda-forge/sage-feedstock](#).

4.3.2 Using conda to provide system packages for the Sage distribution

If Conda is installed (check by typing `conda info`), one can install SageMath from source as follows:

- Create a new conda environment including all standard packages recognized by sage, and activate it:

```
$ conda env create --file environment-3.11-linux.yml --name sage-build
$ conda activate sage-build
```

If you use a different architecture, replace `linux` by `macos`. Alternatively, use `environment-optional-3.11-linux.yml` in place of `environment-3.11-linux.yml` to create an environment with all standard and optional packages recognized by sage.

A different Python version can be selected by replacing `3.11` by `3.9` or `3.10` in these commands.

- Then the SageMath distribution will be built using the compilers provided by Conda and using many packages installed by Conda:

```
$ ./bootstrap
$ ./configure --with-python=$CONDA_PREFIX/bin/python \
              --prefix=$CONDA_PREFIX
$ make
```

4.3.3 Using conda to provide all dependencies for the Sage library

You can build and install the Sage library from source, using conda to provide all of its dependencies. This bypasses most of the build system of the Sage distribution and is the fastest way to set up an environment for Sage development.

Here we assume that you are using a git checkout.

- Optionally, set the build parallelism for the Sage library. Use whatever the meaningful value for your machine is - no more than the number of cores:

```
$ export SAGE_NUM_THREADS=24
```

- Create and activate a new conda environment with the dependencies of Sage and a few additional developer tools:

```
.. tab:: mamba

.. code-block:: shell

    $ mamba env create --file src/environment-dev-3.11-linux.yml --name sage-dev
    $ conda activate sage-dev

.. tab:: conda

.. code-block:: shell

    $ conda env create --file src/environment-dev-3.11-linux.yml --name sage-dev
    $ conda activate sage-dev
```

Alternatively, you can use `src/environment-3.11-linux.yml` or `src/environment-optional-3.11-linux.yml`, which will only install standard (and optional) packages without any additional developer tools.

A different Python version can be selected by replacing `3.11` by `3.9` or `3.10` in these commands.

- Bootstrap the source tree and install the build prerequisites and the Sage library:

```
$ ./bootstrap
$ pip install --no-build-isolation --config-settings editable_mode=compat -v -v --
  ↳editable ./src
```

If you encounter any errors, try to install the `sage-conf` package first:

```
$ pip install --no-build-isolation -v -v --editable ./pkgs/sage-conf_conda
```

and then run the last command again.

- Verify that Sage has been installed:

```
$ sage -c 'print(version())'
SageMath version 10.2.beta4, Release Date: 2023-09-24
```

Note that `make` is not used at all. All dependencies (including all Python packages) are provided by `conda`.

Thus, you will get a working version of Sage much faster. However, note that this will invalidate the use of any Sage-the-distribution commands such as `sage -i`. Do not use them.

By using `pip install --editable` in the above steps, the Sage library is installed in editable mode. This means that when you only edit Python files, there is no need to rebuild the library; it suffices to restart Sage.

After editing any Cython files, rebuild the Sage library using:

```
$ pip install --no-build-isolation --config-settings editable_mode=compat -v -v --
  ↳editable src
```

In order to update the conda environment later, you can run:

```
$ mamba env update --file src/environment-dev-3.11-linux.yml --name sage-dev
```

To build the documentation, use:

```
$ pip install --no-build-isolation -v -v --editable ./pkgs/sage-docbuild
$ sage --docbuild all html
```

Note: The switch `--config-settings editable_mode=compat` restores the [legacy `setuptools` implementation of editable installations](#). Adventurous developers may omit this switch to try the modern, PEP-660 implementation of editable installations, see [Issue #34209](#).

Note: You can update the conda lock files by running `.github/workflows/conda-lock-update.py` or by running `conda-lock --platform linux-64 --filename src/environment-dev-3.11-linux.yml --lockfile src/environment-dev-3.11-linux.lock` manually.

4.4 Install from Source Code

Building Sage from the [source code](#) has the major advantage that your install will be optimized for your particular computer and should therefore offer better performance and compatibility than a binary install.

Moreover, it offers you full development capabilities: you can change absolutely any part of Sage or the packages on which it depends, and recompile the modified parts.

See the file [README.md](#) in `SAGE_ROOT` for information on supported platforms and step-by-step instructions.

The following sections provide some additional details. Most users will not need to read them. Some familiarity with the use of the Unix command line may be required to build Sage from the source code.

4.4.1 Prerequisites

Disk space and memory

Your computer comes with at least 6 GB of free disk space. It is recommended to have at least 2 GB of RAM, but you might get away with less (be sure to have some swap space in this case).

Software prerequisites and recommended packages

Sage depends on a [large number of software packages](#). Sage provides its own software distribution providing most of these packages, so you do not have to worry about having to download and install these packages yourself.

If you extracted Sage from a source tarball, the subdirectory `upstream` contains the source distributions for all standard packages on which Sage depends. If cloned from a git repository, the upstream tarballs will be downloaded, verified, and cached as part of the Sage installation process.

However, there are minimal prerequisites for building Sage that already must be installed on your system:

- [Fundamental system packages required for installing from source](#)
- [C/C++ compilers](#)

If you have sufficient privileges (for example, on Linux you can use `sudo` to become the `root` user), then you can install these packages using the commands for your platform indicated in the pages linked above. If you do not have the privileges to do this, ask your system administrator to do this for you.

In addition to these minimal prerequisites, we strongly recommend to use system installations of the following:

- [Fortran compiler](#)
- [Python](#)

Sage developers will also need the [system packages required for bootstrapping](#); they cannot be installed by Sage.

When the `./configure` script runs, it will check for the presence of many packages (including the above) and inform you of any that are missing or have unsuitable versions. **Please read the messages that `./configure` prints:** It will inform you which additional system packages you can install to avoid having to build them from source. This can save a lot of time.

The following sections provide the commands to install a large recommended set of packages on various systems, which will minimize the time it takes to build Sage. This is intended as a convenient shortcut, but of course you can choose to take a more fine-grained approach.

Linux system package installation

We recommend that you install the following packages, depending on your distribution:

```
$ sudo apt-get install bc binutils bzip2 ca-certificates cliquer cmake curl \
ecl eclib-tools fflas-ffpack g++ gap gcc gengetopt gfan gfortran \
glpk-utils gmp-ecm lcalc libatomic-ops-dev libboost-dev \
libbraiding-dev libbrial-dev libbrial-groebner-dev libbz2-dev \
libcdd-dev libcdd-tools libcliquer-dev libcurl4-openssl-dev libec-dev \
libecm-dev libffi-dev libflint-dev libfp111-dev libfreetype-dev \
libgap-dev libgc-dev libgd-dev libgf2x-dev libgiac-dev libgivaro-dev \
libglpk-dev libgmp-dev libgsl-dev libhomfly-dev libiml-dev \
liblfunction-dev liblinbox-dev liblrcalc-dev liblzma-dev libm4ri-dev \
libm4rie-dev libmpc-dev libmpfi-dev libmpfr-dev libncurses5-dev \
libntl-dev libopenblas-dev libpari-dev libplanarity-dev libppl-dev \
libprimecount-dev libprimesieve-dev libpython3-dev libqhull-dev \
libreadline-dev librw-dev libsingular4-dev libsqlite3-dev libssl-dev \
libsuitesparse-dev libsymmetrica2-dev libz-dev libzmq3-dev m4 make \
maxima maxima-sage meson nauty ninja-build openssl palp pari-doc \
pari-elldata pari-galdata pari-galpol pari-gp2c pari-seadata patch \
patchelf perl pkg-config planarity ppl-dev python3 python3-setuptools \
python3-venv qhull-bin singular singular-doc sqlite3 sympow tachyon \
tar texinfo tox xcas xz-utils
```

```
$ sudo yum install --setopt=tsflags=L-function L-function-devel Singular \
Singular-devel binutils boost-devel brial brial-devel bzip2 \
bzip2-devel cddlib cliquer cliquer-devel cmake curl diffutils ecl \
eclib eclib-devel fflas-ffpack-devel findutils flint flint-devel gap \
gap-core gap-devel gap-libs gc gc-devel gcc gcc-c++ gcc-gfortran gd \
gd-devel gengetopt gf2x gf2x-devel gfan giac giac-devel givaro \
givaro-devel glpk glpk-devel glpk-utils gmp gmp-devel gmp-ecm \
gmp-ecm-devel gsl gsl-devel iml iml-devel info libatomic_ops \
libatomic_ops-devel libbraiding-devel libcurl-devel libffi \
libffi-devel libfp111 libfp111-devel libgap libhomfly-devel libmpc \
libmpc-devel linbox-devel lrcalc-devel m4 m4ri-devel m4rie-devel make \
maxima maxima-runtime-ecl meson mpfr-devel nauty ncurses-devel \
ninja-build ntl-devel openblas-devel openssl openssl-devel palp \
pari-devel pari-elldata pari-galdata pari-galpol pari-gp pari-seadata \
patch patchelf perl perl-ExtUtils-MakeMaker perl-IPC-Cmd pkg-config \
planarity planarity-devel ppl ppl-devel primecount primecount-devel \
primesieve primesieve-devel python-setuptools python3 python3-devel \
qhull qhull-devel readline-devel rw-devel sqlite sqlite-devel \
suitesparse suitesparse-devel symmetrica-devel sympow tachyon \
tachyon-devel tar texinfo tox which xz xz-devel zeromq zeromq-devel \
zlib-devel
```

```
$ sudo pacman -S bc binutils boost brial cblas cddlib cliquer cmake ecl \
eclib fflas-ffpack fp111 gap gc gcc gcc-fortran gd gf2x gfan giac glpk \
gsl iml lapack lcalc libatomic_ops libbraiding libgiac libhomfly \
linbox lrcalc m4 m4ri m4rie make maxima-fas meson nauty ninja openblas \
openssl palp pari pari-elldata pari-galdata pari-galpol pari-seadata \
patch perl pkgconf planarity ppl primecount primesieve python \
python-tox qhull rankwidth readline singular sqlite3 suitesparse \
symmetrica sympow tachyon tar which zeromq
```

```
$ sudo zypper install bc binutils boost-devel brial-devel bzip2 \
ca-certificates cddlib-tools cliquer cliquer-devel cmake curl \
```

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```
diffutils edge-addition-planarity-suite \
edge-addition-planarity-suite-devel findutils flint-devel fp111 \
fp111-devel gawk gcc gcc-c++ gcc-fortran gd gfan giac-devel \
glibc-locale-base glpk glpk-devel gmp-devel gzip iml-devel \
libbraiding-devel libhomfly-devel libopenssl-3-devel \
libprimecount-devel m4 make mathjax maxima-exec-clisp meson mpc-devel \
mpfi-devel nauty nauty-devel ninja ntl-devel openblas-devel pari-devel \
pari-galdata pari-gp patch patchelf perl pkgconf \
pkgconfig\atomic_ops\ pkgconfig\bdw-gc\ pkgconfig\bzip2\ \
pkgconfig\cddlib\ pkgconfig\fflas-ffpack\ pkgconfig\fp111\ \
pkgconfig\freetype2\ pkgconfig\gdlb\ pkgconfig\gf2x\ \
pkgconfig\givaro\ pkgconfig\gsl\ pkgconfig\libcurl\ \
pkgconfig\libffi\ pkgconfig\liblzma\ pkgconfig\libpng16\ \
pkgconfig\libzmq\ pkgconfig\linbox\ pkgconfig\m4ri\ \
pkgconfig\m4rie\ pkgconfig\mpfr\ pkgconfig\ncurses\ \
pkgconfig\ncursesw\ pkgconfig\readline\ pkgconfig\sqlite3\ \
pkgconfig\zlib\ ppl-devel primecount primesieve python3 \
python3-devel python3-setuptools qhull-devel readline-devel \
suitesparse-devel sympow tachyon tar texinfo which xz
```

```
$ sudo xbps-install SuiteSparse-devel bash bc binutils boost-devel \
brial-devel bzip2-devel cddlib-devel cliquer-devel cmake curl \
diffutils ecl eclib-devel ecm-devel fflas-ffpack flintlib-devel \
fp111-devel freetype-devel gc-devel gcc gcc-fortran gd-devel gengetopt \
gf2x-devel gfan giac-devel givaro-devel glpk-devel gmp-devel \
gmpxx-devel gsl-devel gzip iml-devel lcalc-devel libatomic_ops-devel \
libbraiding-devel libcurl-devel libffi-devel libgomp-devel \
libhomfly-devel liblzma-devel libmpc-devel libpng-devel libqhull-devel \
libxcrypt-devel linbox-devel lrcalc-devel m4 m4ri-devel m4rie-devel \
make mathjax maxima-ecl mpfi-devel mpfr-devel nauty ncurses-devel \
ninja ntl-devel openblas-devel openssl-devel palp pari pari-devel \
pari-eildata-small pari-galdata pari-galpol-small pari-seadata patch \
patchelf perl pkgconf planarity-devel ppl-devel primecount-devel \
primesieve-devel python3 python3-appdirs python3-devel python3-distlib \
python3-filelock python3-setuptools python3-virtualenv qhull \
rankwidth-devel readline-devel singular sqlite-devel symmetrica-devel \
sympow tachyon tar texinfo tox which xz zeromq-devel zlib-devel
```

If you wish to do Sage development, we recommend that you additionally install the following:

```
$ sudo apt-get install autoconf automake gh git gpgconf libtool \
openssh-client pkg-config
```

```
$ sudo yum install autoconf automake gh git gnupg2 libtool openssh \
pkg-config
```

```
$ sudo pacman -S autoconf automake git github-cli gnupg libtool openssh \
pkgconf
```

```
$ sudo zypper install autoconf automake gh git gpg2 libtool openssh \
pkgconfig
```

```
$ sudo xbps-install autoconf automake git github-cli gnupg2 libtool \
mk-configure openssh pkg-config xtools
```

For all users, we recommend that you install the following system packages, which provide additional functionality and

cannot be installed by Sage. In particular, this includes [LaTeX](#) and related tools. In addition to a base install of [TeX Live](#), our lists of system packages below include everything that is needed for generating the Sage documentation in PDF format. For converting Jupyter notebooks to PDF, also the document converter [pandoc](#) is needed. For making animations, Sage needs to use one of the packages [FFmpeg](#) and [ImageMagick](#).

```
$ sudo apt-get install default-jdk dvipng ffmpeg fonts-freefont-otf \  
imagemagick latexmk libavdevice-dev libjpeg-dev pandoc tex-gyre \  
texlive-fonts-recommended texlive-lang-cyrillic texlive-lang-english \  
texlive-lang-european texlive-lang-french texlive-lang-german \  
texlive-lang-italian texlive-lang-japanese texlive-lang-polish \  
texlive-lang-portuguese texlive-lang-spanish texlive-latex-extra \  
texlive-luatex texlive-xetex xindy
```

```
$ sudo yum install ImageMagick gnu-free-mono-fonts gnu-free-sans-fonts \  
gnu-free-serif-fonts latexmk libjpeg-turbo-devel pandoc texlive \  
texlive-collection-langcyrillic texlive-collection-langeuropean \  
texlive-collection-langfrench texlive-collection-langgerman \  
texlive-collection-langitalian texlive-collection-langjapanese \  
texlive-collection-langpolish texlive-collection-langportuguese \  
texlive-collection-langspanish texlive-collection-latexextra \  
texlive-luatex
```

```
$ sudo pacman -S ffmpeg gnu-free-fonts imagemagick libjpeg-turbo pandoc \  
texlive-collection-luatex texlive-core texlive-langcyrillic \  
texlive-langjapanese texlive-latexextra
```

```
$ sudo zypper install ImageMagick ffmpeg gnu-free-fonts libjpeg-devel pandoc \  
texlive texlive-luatex xindy
```

```
$ sudo xbps-install ImageMagick ffmpeg freefont-ttf libjpeg-turbo-devel \  
pandoc texlive
```

In addition to these, if you don't want Sage to build optional packages that might be available from your OS, cf. the growing list of such packages on [Issue #27330](#), install:

```
$ sudo apt-get install 4ti2 clang coinor-cbc coinor-libcbc-dev fricas \  
graphviz libfile-slurp-perl libgraphviz-dev libigraph-dev libisl-dev \  
libjson-perl libmongodbc-perl libnauty-dev libperl-dev libpolymake-dev \  
libsvg-perl libtbb-dev libterm-readkey-perl libterm-readline-gnu-perl \  
libxml-libxslt-perl libxml-writer-perl libxml2-dev lrslib pari-gp2c \  
pdf2svg polymake r-base-dev r-cran-lattice
```

```
$ sudo yum install 4ti2 R R-devel bliss bliss-devel clang coin-or-Cbc \  
coin-or-Cbc-devel coxeter coxeter-devel coxeter-tools graphviz igraph \  
igraph-devel isl-devel libnauty-devel libxml2-devel lrslib pari-galpol \  
pari-seadata pdf2svg perl-ExtUtils-Embed perl-File-Slurp perl-JSON \  
perl-MongoDB perl-Term-ReadLine-Gnu perl-TermReadKey perl-XML-LibXML \  
perl-XML-LibXSLT perl-XML-Writer polymake tbb-devel
```

```
$ sudo pacman -S 4ti2 bliss clang coin-or-cbc coxeter graphviz igraph \  
intel-oneapi-tbb libxml2 lrs pari-elldata pari-galpol pari-seadata \  
pdf2svg perl-term-readline-gnu polymake r symengine
```

```
$ sudo zypper install 4ti2 4ti2-devel R-base bliss bliss-devel coxeter \  
fricas gp2c graphviz libxml2 llvm lrslib lrslib-devel pari-elldata \  

```

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(continued from previous page)

```

pari-galpol pari-nftables pari-seadata pdf2svg \
perl\(\Term::ReadLine::Gnu\) pkgconfig\(\isl\) \
pkgconfig\(\libsemigroups\) polymake symengine tbb

```

```

$ sudo xbps-install CoinMP-devel R clang gp2c graphviz graphviz-devel \
igraph-devel isl-devel libxml2-devel nauty-devel pari-elldata-small \
pari-galpol-small pari-nftables pari-seadata perl-File-Slurp perl-JSON \
perl-SVG perl-Term-ReadKey perl-Term-ReadLine-Gnu perl-XML-LibXML \
perl-XML-LibXSLT perl-XML-Writer tbb-devel

```

macOS prerequisites

On macOS systems, you need a recent version of [Command Line Tools](#). It provides all the above requirements.

Run the command `xcode-select --install` from a Terminal window and click “Install” in the pop-up dialog box.

If you have already installed [Xcode](#) (which at the time of writing is freely available in the Mac App Store, or through <https://developer.apple.com/downloads/> provided you registered for an Apple Developer account), you can install the command line tools from there as well.

If you have not installed [Xcode](#) you can get these tools as a relatively small download, but it does require a registration.

- First, you will need to register as an Apple Developer at <https://developer.apple.com/register/>.
- Having done so, you should be able to download it for free at <https://developer.apple.com/downloads/index.action?command%20line%20tools>
- Alternately, <https://developer.apple.com/opensource/> should have a link to Command Line Tools.

macOS package installation

If you use the [Homebrew package manager](#), you can install the following:

```

$ brew install bdw-gc boost bzip2 cddlib cmake curl ecl flint fplll freetype \
gcc gd gengetopt gfortran glpk gmp gpatch gsl libatomic_ops libffi \
libiconv libmpc libpng maxima meson mpfi mpfr nauty ncurses ninja ntl \
openblas openssl pari pari-elldata pari-galdata pari-galpol \
pari-seadata patchelf pkg-config ppl primesieve \
python-setuptools python3 qhull readline singular sqlite suite-sparse \
texinfo tox xz zeromq zlib

```

Some Homebrew packages are installed “keg-only,” meaning that they are not available in standard paths. To make them accessible when building Sage, run

```

$ source SAGE_ROOT/.homebrew-build-env

```

(replacing `SAGE_ROOT` by Sage’s home directory). You can add a command like this to your shell profile if you want the settings to persist between shell sessions.

If you wish to do Sage development, we recommend that you additionally install the following:

```

$ brew install autoconf automake gh git gnupg libtool pkg-config

```

For all users, we recommend that you install the following system packages, which provide additional functionality and cannot be installed by Sage:

```
$ brew install ffmpeg imagemagick jpeg-turbo pandoc texinfo
```

Some additional optional packages are taken care of by:

```
$ brew install apaffenholz/polymake/polymake cbc graphviz igraph isl libxml2 \
  llvm nauty pdf2svg r symengine tbb
```

WSL prerequisites

Ubuntu on Windows Subsystem for Linux (WSL) prerequisite installation

Refer to *Windows* for installing Ubuntu on Windows Subsystem for Linux (WSL). These instructions describe a fresh install of Ubuntu, the default distribution in WSL, but other distributions or installation methods should work too.

From this point on, follow the instructions in the *Linux system package installation* section. It is strongly recommended to put the Sage source files in the Linux file system, for example, in the `/home/username/sage` directory, and not in the Windows file system (e.g. `/mnt/c/...`).

WSL permission denied error when building packaging package

You may encounter permission errors of the kind `"[Errno 13] Permission denied: 'build/bdist.linux-x86_64/wheel/<package>.dist-info'"` during `make`. This usually comes from a permission conflict between the Windows and Linux file system. To fix it create a temporary build folder in the Linux file system using `mkdir -p ~/tmp/sage` and use it for building by `eval SAGE_BUILD_DIR="~/tmp/sage" make`. Also see the [related Github issue](#) for other workarounds.

WSL post-installation notes

When the installation is complete, you may be interested in *WSL Post-installation steps*.

Other platforms

On Solaris, you would use `pkgadd` and on OpenSolaris `ipf` to install the necessary software.

On other systems, check the documentation for your particular operating system.

Notes on using conda

If you don't want conda to be used by sage, deactivate conda (for the current shell session).

- Type:

```
$ conda deactivate
```

- Repeat the command until `conda info` shows:

```
$ conda info
active environment : None
...
```

Then SageMath will be built either using the compilers provided by the operating system, or its own compilers.

Tcl/Tk (and system's Python)

If you want to use [Tcl/Tk](#) libraries in Sage, and you are going to use your OS's Python3 as Sage's Python, you merely need to install its **Tkinter** module. On Linux systems, it is usually provided by the **python3-tk** or a similarly named (e.g. **python3-tkinter**) package, which can be installed using:

```
$ sudo apt-get install python3-tk
```

or similar commands.

Tcl/Tk (and Sage's own Python)

If you want to use [Tcl/Tk](#) libraries in Sage, and you are going to build Sage's Python from source, you need to install these, and the corresponding headers. On Linux systems, these are usually provided by the **tk** and **tk-dev** (or **tk-devel**) packages which can be installed using:

```
$ sudo apt-get install tk tk-dev
```

or similar commands.

Sage's Python will then automatically recognize your system's install of Tcl/Tk. If you installed Sage first, all is not lost. You just need to rebuild Sage's Python and any part of Sage relying on it:

```
$ sage -f python3 # rebuild Python3
$ make           # rebuild components of Sage depending on Python
```

after installing the Tcl/Tk development libraries as above.

If

```
sage: import _tkinter
sage: import Tkinter
```

does not raise an `ImportError`, then it worked.

4.4.2 Installation steps

1. Follow the procedure in the file [README.md](#) in `SAGE_ROOT`.
2. If you wish to prepare for having to build Sage in an environment without sufficient Internet connectivity:
 - After running `configure`, you can use `make download` to force downloading packages before building. After this, the packages are in the subdirectory `upstream`.
 - Alternatively, instead of cloning the git repository, you can download a self-contained release tarball for any stable release from the Sage project's [GitHub Releases](#). Use the file named `sage-x.y.tar.gz` (1.25 GB as of Sage 10.2) in the Release Assets, which contains a prepopulated subdirectory `upstream`.

After downloading the source tarball `sage-x.y.tar.gz` into a directory `~/sage/`:

```
$ cd ~/sage/
$ tar xf sage-x.y.tar.gz # adapt x.y; takes a while
```

This creates the subdirectory `sage-x.y`. Now change into it:

```
$ cd sage-x.y/ # adapt x.y
```

Note: On Windows, it is crucial that you unpack the source tree from the WSL *bash* using the WSL *tar* utility and not using other Windows tools (including mingw).

This is because the Sage source tree contains symbolic links, and the build will not work if Windows line endings rather than UNIX line endings are used.

- The Sage mirrors also provide such self-contained tarballs for all [stable releases](#) and additionally for all [development releases](#).
3. Additional remarks: You do not need to be logged in as root, since no files are changed outside of the `SAGE_ROOT` directory. In fact, **it is inadvisable to build Sage as root**, as the root account should only be used when absolutely necessary and mistyped commands can have serious consequences if you are logged in as root.

Typing `make` performs the usual steps for each Sage's dependency, but installs all the resulting files into the installation prefix. Depending on the age and the architecture of your system, it can take from a few tens of minutes to several hours to build Sage from source. On really slow hardware, it can even take a few days to build Sage.

Each component of Sage has its own build log, saved in `SAGE_ROOT/logs/pkgs`. If the build of Sage fails, you will see a message mentioning which package(s) failed to build and the location of the log file for each failed package. If this happens, then paste the contents of these log file(s) to the Sage support newsgroup at <https://groups.google.com/group/sage-support>. If the log files are very large (and many are), then don't paste the whole file, but make sure to include any error messages. It would also be helpful to include the type of operating system (Linux, macOS, Solaris, OpenSolaris, or any other system), the version and release date of that operating system and the version of the copy of Sage you are using. (There are no formal requirements for bug reports – just send them; we appreciate everything.)

See [Make targets](#) for some targets for the `make` command and [Environment variables](#) for additional information on useful environment variables used by Sage.

4. To start Sage, you can now simply type from Sage's home directory:

```
$ ./sage
```

You should see the Sage prompt, which will look something like this:

```
$ sage
| SageMath version 8.8, Release Date: 2019-06-26
| Using Python 3.10.4. Type "help()" for help.
sage:
```

Note that Sage should take well under a minute when it starts for the first time, but can take several minutes if the file system is slow or busy. Since Sage opens a lot of files, it is preferable to install Sage on a fast filesystem if possible.

Just starting successfully tests that many of the components built correctly. Note that this should have been already automatically tested during the build process. If the above is not displayed (e.g., if you get a massive traceback), please report the problem, e.g., at <https://groups.google.com/group/sage-support>.

After Sage has started, try a simple command:

```
sage: 2 + 2
4
```


Or something slightly more complicated:

```
sage: factor(2005)
5 * 401
```

5. Optional, but highly recommended: Test the install by typing `./sage --testall`. This runs most examples in the source code and makes sure that they run exactly as claimed. To test all examples, use `./sage --testall --optional=all --long`; this will run examples that take a long time, and those that depend on optional packages and software, e.g., Mathematica or Magma. Some (optional) examples will therefore likely fail.

Alternatively, from within `$SAGE_ROOT`, you can type `make test` (respectively `make ptest`) to run all the standard test code serially (respectively in parallel).

Testing the Sage library can take from half an hour to several hours, depending on your hardware. On slow hardware building and testing Sage can even take several days!

6. Optional: Check the interfaces to any other software that you have available. Note that each interface calls its corresponding program by a particular name: **Mathematica** is invoked by calling `math`, **Maple** by calling `maple`, etc. The easiest way to change this name or perform other customizations is to create a redirection script in `$SAGE_ROOT/local/bin`. Sage inserts this directory at the front of your `PATH`, so your script may need to use an absolute path to avoid calling itself; also, your script should pass along all of its arguments. For example, a `maple` script might look like:

```
#!/bin/sh
exec /etc/maple10.2/maple.tty "$@"
```

7. Optional: There are different possibilities to make using Sage a little easier:

- Make a symbolic link from `/usr/local/bin/sage` (or another directory in your `PATH`) to `SAGE_ROOT/sage`:

```
$ ln -s /path/to/sage_root/sage /usr/local/bin/sage
```

Now simply typing `sage` from any directory should be sufficient to run Sage.

- Copy `SAGE_ROOT/sage` to a location in your `PATH`. If you do this, make sure you edit the line:

```
#SAGE_ROOT=/path/to/sage-version
```

at the beginning of the copied `sage` script according to the direction given there to something like:

```
SAGE_ROOT=<SAGE_ROOT>
```

(note that you have to change `<SAGE_ROOT>` above!). It is best to edit only the copy, not the original.

- For **KDE** users, create a bash script called `sage` containing the lines (note that you have to change `<SAGE_ROOT>` below!):

```
#!/usr/bin/env bash
konsole -T "sage" -e <SAGE_ROOT>/sage
```

make it executable:

```
$ chmod a+x sage
```

and put it somewhere in your `PATH`.

You can also make a KDE desktop icon with this line as the command (under the Application tab of the Properties of the icon, which you get by right clicking the mouse on the icon).

- On Linux and macOS systems, you can make an alias to `SAGE_ROOT/sage`. For example, put something similar to the following line in your `.bashrc` file:

```
alias sage=<SAGE_ROOT>/sage
```

(Note that you have to change `<SAGE_ROOT>` above!) Having done so, quit your terminal emulator and restart it. Now typing `sage` within your terminal emulator should start Sage.

8. Optional: Install optional Sage packages and databases. See [the list of optional packages in the reference manual](#) for detailed information, or type `sage --optional` (this requires an Internet connection).

Then type `sage -i <package-name>` to automatically download and install a given package.

9. Have fun! Discover some amazing conjectures!

4.4.3 Make targets

To build Sage from scratch, you would typically execute `make` in Sage's home directory to build Sage and its [HTML](#) documentation. The `make` command is pretty smart, so if your build of Sage is interrupted, then running `make` again should cause it to pick up where it left off. The `make` command can also be given options, which control what is built and how it is built:

- `make build` builds Sage: it compiles all of the Sage packages. It does not build the documentation.
- `make doc` builds Sage's documentation in HTML format. Note that this requires that Sage be built first, so it will automatically run `make build` first. Thus, running `make doc` is equivalent to running `make`.
- `make doc-pdf` builds Sage's documentation in PDF format. This also requires that Sage be built first, so it will automatically run `make build`.
- `make doc-html-no-plot` builds Sage's documentation in html format but skips the inclusion of graphics auto-generated using the `.. PLOT` markup and the `sphinx_plot` function. This is primarily intended for use when producing certain binary distributions of Sage, to lower the size of the distribution. As of this writing (December 2014, Sage 6.5), there are only a few such plots, adding about 4M to the `local/share/doc/sage/` directory. In the future, this may grow, of course. Note: after using this, if you want to build the documentation and include the pictures, you should run `make doc-uninstall`, because the presence, or lack, of pictures is cached in the documentation output. You can benefit from this no-plot feature with other `make` targets by doing `export SAGE_DOCBUILD_OPTS+=' --no-plot '`
- `make ptest` and `make ptestlong`: these run Sage's test suite. The first version skips tests that need more than a few seconds to complete and those which depend on optional packages or additional software. The second version includes the former, and so it takes longer. The "p" in `ptest` stands for "parallel": tests are run in parallel. If you want to run tests serially, you can use `make test` or `make testlong` instead. If you want to run tests depending on optional packages and additional software, you can use `make testall,make ptestall,make testalllong,ormake ptestalllong`.
- `make doc-uninstall` and `make doc-clean` each remove several directories which are produced when building the documentation.
- `make distclean` restores the Sage directory to its state before doing any building: it is almost equivalent to deleting Sage's entire home directory and unpacking the source tarfile again, the only difference being that the `.git` directory is preserved, so `git` branches are not deleted.

4.4.4 Environment variables

Sage uses several environment variables to control its build process. Most users won't need to set any of these: the build process just works on many platforms. (Note though that setting *MAKE*, as described below, can significantly speed up the process.) Building Sage involves building many packages, each of which has its own compilation instructions.

Standard environment controlling the build process

Here are some of the more commonly used variables affecting the build process:

MAKE

One useful setting for this variable when building Sage is `MAKE='make -jNUM'` to tell the `make` program to run `NUM` jobs in parallel when building. Note that some Sage packages may not support this variable.

Some people advise using more jobs than there are CPU cores, at least if the system is not heavily loaded and has plenty of RAM; for example, a good setting for `NUM` might be between 1 and 1.5 times the number of cores. In addition, the `-l` option sets a load limit: `MAKE='make -j4 -l5.5'`, for example, tells `make` to try to use four jobs, but to not start more than one job if the system load average is above 5.5. See the manual page for GNU `make`: [Command-line options](#) and [Parallel building](#).

V

If set to 0, silence the build. Instead of showing a detailed compilation log, only one line of output is shown at the beginning and at the end of the installation of each Sage package. To see even less output, use:

```
$ make -s V=0
```

(Note that the above uses the syntax of setting a Makefile variable.)

CC

While some programs allow you to use this to specify your C compiler, **not every Sage package recognizes this**. If GCC is installed within Sage, `CC` is ignored and Sage's `gcc` is used instead.

CPP

Similarly, this will set the C preprocessor for some Sage packages, and similarly, using it is likely quite risky. If GCC is installed within Sage, `CPP` is ignored and Sage's `cpp` is used instead.

CXX

Similarly, this will set the C++ compiler for some Sage packages, and similarly, using it is likely quite risky. If GCC is installed within Sage, `CXX` is ignored and Sage's `g++` is used instead.

FC

Similarly, this will set the Fortran compiler. This is supported by all Sage packages which have Fortran code. However, for historical reasons, the value is hardcoded during the initial `make` and subsequent changes to `$FC` might be ignored (in which case, the original value will be used instead). If GCC is installed within Sage, `FC` is ignored and Sage's `gfortran` is used instead.

CFLAGS

CXXFLAGS

FCFLAGS

The flags for the C compiler, the C++ compiler and the Fortran compiler, respectively. The same comments apply to these: setting them may cause problems, because they are not universally respected among the Sage packages. Note also that `export CFLAGS=""` does not have the same effect as `unset CFLAGS`. The latter is preferable.

CPPFLAGS

LDFLAGS

CXXFLAG64

LDFLAG64

LD

Similar comments apply to these compiler and linker flags.

Sage-specific environment variables controlling the build process

SAGE_SERVER

The Sage source tarball already includes the sources for all standard packages, that is, it allows you to build Sage without internet connection. The git repository, however, does not contain the source code for third-party packages. Instead, it will be downloaded as needed (note: you can run `make download` to force downloading packages before building).

If `SAGE_SERVER` is set, the specified Sage mirror is contacted first. Note that Sage will search the directory `SAGE_SERVER/spkg/upstream` for upstream tarballs.

If downloading a file from there fails or `SAGE_SERVER` is not set, files will be attempted to download from release assets of the Sage GitHub repository.

If that fails too, the Sage mirror network is contacted to determine the nearest mirrors.

This sequence of operations is defined by the files in the directory `SAGE_ROOT/upstream.d`.

SAGE_NUM_THREADS

If set to a number, then when rebuilding with `sage -b` or parallel doctesting with `sage -t -p 0`, use at most this many threads.

If this is not set, then determine the number of threads using the value of the `MAKE` (see above) or `MAKEFLAGS` environment variables. If none of these specifies a number of jobs,

- `sage -b` only uses one thread
- `sage -t -p 0` uses a default of the number of CPU cores, with a maximum of 8 and a minimum of 2.

When `sage -t -p` runs under the control of the GNU `make` jobserver, then Sage will request as most this number of job slots.

SAGE_CHECK

If set to `yes`, then during the build process, or when installing packages manually, run the test suite for each package which has one, and stop with an error if tests are failing. If set to `warn`, then only a warning is printed in this case. See also `SAGE_CHECK_PACKAGES`.

SAGE_CHECK_PACKAGES

If `SAGE_CHECK` is set to `yes`, then the default behavior is to run test suites for all spkgs which contain them. If `SAGE_CHECK_PACKAGES` is set, it should be a comma-separated list of strings of the form `package-name` or `!package-name`. An entry `package-name` means to run the test suite for the named package regardless of the setting of `SAGE_CHECK`. An entry `!package-name` means to skip its test suite. So if this is set to `ppl, !python3`, then always run the test suite for PPL, but always skip the test suite for Python 3.

Note: As of Sage 9.1, the test suites for the Python 2 and 3 spkgs fail on most platforms. So when this variable is empty or unset, Sage uses a default of `!python2, !python3`.

SAGE_INSTALL_GCC

Obsolete, do not use, to be removed

SAGE_INSTALL_CCACHE

By default Sage doesn't install `ccache`, however by setting `SAGE_INSTALL_CCACHE=yes` Sage will install `ccache`. Because the Sage distribution is quite large, the maximum cache is set to 4G. This can be changed by running `sage -sh -c "ccache --max-size=SIZE"`, where `SIZE` is specified in gigabytes, megabytes, or kilobytes by appending a "G", "M", or "K".

Sage does not include the sources for `ccache` since it is an optional package. Because of this, it is necessary to have an Internet connection while building `ccache` for Sage, so that Sage can pull down the necessary sources.

SAGE_DEBUG

Controls debugging support. There are three different possible values:

- Not set (or set to anything else than "yes" or "no"): build binaries with debugging symbols, but no special debug builds. This is the default. There is no performance impact, only additional disk space is used.
- `SAGE_DEBUG=no`: no means no debugging symbols (that is, no `gcc -g`), which saves some disk space.
- `SAGE_DEBUG=yes`: build debug versions if possible (in particular, Python is built with additional debugging turned on and Singular is built with a different memory manager). These will be notably slower but, for example, make it much easier to pinpoint memory allocation problems.

Instead of using `SAGE_DEBUG` one can configure with `--enable-debug={no|symbols|yes}`.

SAGE_PROFILE

Controls profiling support. If this is set to `yes`, profiling support is enabled where possible. Note that Python-level profiling is always available; this option enables profiling in Cython modules.

SAGE_BUILD_DIR

The default behavior is to build each `spkg` in a subdirectory of `$SAGE_ROOT/local/var/tmp/sage/build/`; for example, build version 7.27.0 of `ipython` in the directory `$SAGE_ROOT/local/var/tmp/sage/build/ipython-7.27.0/`. If this variable is set, then build in `$SAGE_BUILD_DIR/ipython-7.27.0/` instead. If the directory `$SAGE_BUILD_DIR` does not exist, it is created. As of this writing (Sage 4.8), when building the standard Sage packages, 1.5 gigabytes of free space are required in this directory (or more if `SAGE_KEEP_BUILT_SPKGS=yes` – see below); the exact amount of required space varies from platform to platform. For example, the block size of the file system will affect the amount of space used, since some `spkgs` contain many small files.

Warning: The variable `SAGE_BUILD_DIR` must be set to the full path name of either an existing directory for which the user has write permissions, or to the full path name of a nonexistent directory which the user has permission to create. The path name must contain **no spaces**.

SAGE_KEEP_BUILT_SPKGS

The default behavior is to delete each build directory – the appropriate subdirectory of `$SAGE_ROOT/local/var/tmp/sage/build` or `$SAGE_BUILD_DIR` – after each `spkg` is successfully built, and to keep it if there were errors installing the `spkg`. Set this variable to `yes` to keep the subdirectory regardless. Furthermore, if you install an `spkg` for which there is already a corresponding subdirectory, for example left over from a previous build, then the default behavior is to delete that old subdirectory. If this variable is set to `yes`, then the old subdirectory is moved to `$SAGE_ROOT/local/var/tmp/sage/build/old/` (or `$SAGE_BUILD_DIR/old/`), overwriting any already existing file or directory with the same name.

Note: After a full build of Sage (as of version 4.8), these subdirectories can take up to 6 gigabytes of storage, in total, depending on the platform and the block size of the file system. If you always set this variable to `yes`, it

can take even more space: rebuilding every spkg would use double the amount of space, and any upgrades to spkgs would create still more directories, using still more space.

Note: In an existing Sage installation, running `sage -i -s <package-name>` or `sage -f -s <package-name>` installs the spkg `<package-name>` and keeps the corresponding build directory; thus setting `SAGE_KEEP_BUILT_SPKGS` to `yes` mimics this behavior when building Sage from scratch or when installing individual spkgs. So you can set this variable to `yes` instead of using the `-s` flag for `sage -i` and `sage -f`.

SAGE_FAT_BINARY

To build binaries that will run on the widest range of target CPUs set this variable to `yes` before building Sage or configure with `--enable-fat-binary`. This does not make the binaries relocatable, it only avoids newer CPU instruction set extensions. For relocatable (=can be moved to a different directory) binaries, you must use <https://github.com/sagemath/binary-pkg>

SAGE_SUDO

Set this to `sudo -E` or to any other command prefix that is necessary to write into a installation hierarchy (`SAGE_LOCAL`) owned by root or another user. Note that this command needs to preserve environment variable settings (plain `sudo` does not).

Not all Sage packages currently support `SAGE_SUDO`.

Therefore this environment variable is most useful when a system administrator wishes to install an additional Sage package that supports `SAGE_SUDO`, into a root-owned installation hierarchy (`SAGE_LOCAL`).

Environment variables controlling the documentation build

SAGE_DOCBUILD_OPTS

The value of this variable is passed as an argument to `sage --docbuild all html` or `sage --docbuild all pdf` when you run `make`, `make doc`, or `make doc-pdf`. For example:

- add `--no-plot` to this variable to avoid building the graphics coming from the `.. PLOT` directive within the documentation,
- add `--no-preparsed-examples` to only show the original Sage code of “EXAMPLES” blocks, suppressing the tab with the preparsed, plain Python version, or
- add `--include-tests-blocks` to include all “TESTS” blocks in the reference manual.

Run `sage --docbuild help` to see the full list of options.

SAGE_SPKG_INSTALL_DOCS

If set to `yes`, then install package-specific documentation to `$SAGE_ROOT/local/share/doc/PACKAGE_NAME/` when an spkg is installed. This option may not be supported by all spkgs. Some spkgs might also assume that certain programs are available on the system (for example, `latex` or `pdflatex`).

SAGE_USE_CDNS

If set to `yes`, then build the documentation using CDNs (Content Distribution Networks) for scripts necessary for HTML documentation, such as [MathJax](#).

SAGE_LIVE_DOC

If set to `yes`, then build live Sage documentation. If the `Make live` button on any webpage of the live doc is clicked, every example code gets a [CodeMirror](#) code cell runnable via [Thebe](#). Thebe is responsible in sending

the code to the Sage computing environment built by [Binder](#) and showing the output result. The Sage computing environment can be specified to either a Binder repo or a local Jupyter server. The environment variable `SAGE_JUPYTER_SERVER` is used for this purpose.

SAGE_JUPYTER_SERVER

Set this to either `binder`, `binder:repo` with `repo` specifying a Binder repo or the URL to a local Jupyter server.

- `binder` refers to Sage's official Binder repo. This is assumed if the environment variable `SAGE_JUPYTER_SERVER` is not set.
- `binder:repo` specifies a Binder repo with `repo`, which is a GitHub repository name, optionally added with a branch name with `/` separator.
- To use a local Jupyter server instead of Binder, then set the URL to `SAGE_JUPYTER_SERVER` and the secret token to environment variable `SAGE_JUPYTER_SERVER_TOKEN`, which can be left unset if the default token `secret` is used. If the live doc was built with `SAGE_JUPYTER_SERVER=http://localhost:8889`, run a local Jupyter server by

```
./sage --notebook=jupyterlab \
--ServerApp.token='secret' \
--ServerApp.allow_origin='null' \
--ServerApp.disable_check_xsrf=true \
--ServerApp.port=8889 \
--ServerApp.open_browser=false
```

before opening the Sage documentation webpage.

Environment variables dealing with specific Sage packages

SAGE_MATPLOTLIB_GUI

If set to anything non-empty except `no`, then Sage will attempt to build the graphical backend when it builds the `matplotlib` package.

OPENBLAS_CONFIGURE

Adds additional configuration flags for the OpenBLAS package that gets added to the `make` command. (see [Issue #23272](#))

PARI_CONFIGURE

Use this to pass extra parameters to PARI's `Configure` script, for example to specify graphics support (which is disabled by default). See the file `build/pkgs/pari/spkg-install.in` for more information.

SAGE_TUNE_PARI

If `yes`, enable PARI self-tuning. Note that this can be time-consuming. If you set this variable to "yes", you will also see this: `WARNING: Tuning PARI/GP is unreliable. You may find your build of PARI fails, or PARI/GP does not work properly once built. We recommend to build this package with SAGE_CHECK="yes".`

PARI_MAKEFLAGS

The value of this variable is passed as an argument to the `$MAKE` command when compiling PARI.

Environment variables dealing with doctesting

SAGE_TIMEOUT

Used for Sage's doctesting: the number of seconds to allow a doctest before timing it out. If this isn't set, the default is 300 seconds (5 minutes).

SAGE_TIMEOUT_LONG

Used for Sage's doctesting: the number of seconds to allow a doctest before timing it out, if tests are run using `sage -t --long`. If this isn't set, the default is 1800 seconds (30 minutes).

SAGE_TEST_GLOBAL_ITER

SAGE_TEST_ITER

These can be used instead of passing the flags `--global-iterations` and `--file-iterations`, respectively, to `sage -t`. Indeed, these variables are only used if the flags are unset. Run `sage -t -h` for more information on the effects of these flags (and therefore these variables).

Environment variables set within Sage environments

Sage sets some other environment variables. The most accurate way to see what Sage does is to first run `env` from a shell prompt to see what environment variables you have set. Then run `sage --sh -c env` to see the list after Sage sets its variables. (This runs a separate shell, executes the shell command `env`, and then exits that shell, so after running this, your settings will be restored.) Alternatively, you can peruse the shell script `src/bin/sage-env`.

Sage also has some environment-like settings. Some of these correspond to actual environment variables while others have names like environment variables but are only available while Sage is running. To see a list, execute `sage .env . [TAB]` while running Sage.

4.4.5 Installation in a multiuser environment

This section addresses the question of how a system administrator can install a single copy of Sage in a multi-user computer network.

1. Using `sudo`, create the installation directory, for example, `/opt/sage/sage-x.y`. We refer to it as `SAGE_LOCAL` in the instructions below. Do not try to install into a directory that already contains other software, such as `/usr/local`:

```
$ sudo mkdir -p SAGE_LOCAL
```

2. Make the directory writable for you and readable by everyone:

```
$ sudo chown $(id -un) SAGE_LOCAL
$ sudo chmod 755 SAGE_LOCAL
```

3. Build and install Sage, following the instructions in [README.md](#), using the `configure` option `--prefix=SAGE_LOCAL`.

Do not use `sudo` for this step; building Sage must be done using your normal user account.

4. Optionally, create a symbolic link to the installed `sage` script in a directory that is in the users' `PATH`, for example `/usr/local/bin`:

```
$ sudo ln -s SAGE_LOCAL/bin/sage /usr/local/bin/sage
```

5. Optionally, change permissions to prevent accidental changes to the installation by yourself:


```
$ sudo chown -R root SAGE_LOCAL
```

4.4.6 Upgrading the system and upgrading Sage

Caveats when upgrading system packages

When Sage has been installed from source, it will make use of various system packages; in particular, it will link to shared libraries provided by the system.

The system's package manager does not keep track of the applications that make use of the shared libraries. Therefore indiscriminate upgrades of system packages can break a Sage installation.

This can always be fixed by a full rebuild:

```
$ make distclean && make build
```

But this time-consuming step can often be avoided by just reinstalling a few packages. The command `make -j list-broken-packages` assists with this:

```
$ make -j list-broken-packages
make --no-print-directory auditwheel_or_delocate-no-deps
...
# Checking ../local/var/lib/sage/installed/bliss-0.73+debian-1+sage-2016-08-02.p0
...
Checking shared library file '../local/lib/libumfpack.dylib'
Checking shared library file '../local/var/tmp/sage/build/suitesparse-5.10.1/src/lib/
↳ libsliplu.1.0.2.dylib'
Error during installcheck of 'suitesparse': ../local/var/tmp/sage/build/suitesparse-
↳ 5.10.1/src/lib/libsliplu.1.0.2.dylib
...
Uninstall broken packages by typing:

    make lcalc-SAGE_LOCAL-uninstall;
    make ratpoints-SAGE_LOCAL-uninstall;
    make r-SAGE_LOCAL-uninstall;
    make suitesparse-SAGE_LOCAL-uninstall;
```

After running the suggested commands, run:

```
$ make build
```

Upgrading Sage using a separate git worktree

When you have a working installation of Sage built from source and wish to try out a new version, we strongly recommend to use a separate [git worktree](#), so that you can keep using your existing installation when something goes wrong.

Start from the directory created when you used `git clone`, perhaps `~/sage/sage/`. Let's verify that this is indeed a git repository by looking at the hidden `.git` subdirectory. It will look like this, but the exact contents can vary:

```
[alice@localhost sage]$ ls .git
COMMIT_EDITMSG HEAD          branches          description      gitk.cache
index             logs          packed-refs      FETCH_HEAD      ORIG_HEAD
config           hooks         info             objects          refs
```

Good. Now let's see what worktrees already exist:

```
[alice@localhost sage]$ git worktree list
/home/alice/sage/sage          c0ffeeefe10 [master]
```

We see just one line, the directory created when you used `git clone`. We will call this the “main worktree” from now on. Next to the directory, you can see the abbreviated commit sha and the name of the branch that we’re on (`master`).

To try out a new version of Sage, let’s fetch it first from the main repository:

```
[alice@localhost sage]$ git fetch upstream 10.3.beta8
From https://github.com/sagemath/sage
* tag          10.3.beta8 -> FETCH_HEAD
```

Now let’s create a new worktree. We need a name for it; it should start with `worktree-` but can be anything after that. Experience shows that worktrees are often repurposed later, and because a directory containing a Sage installation cannot be moved without breaking the installation in it, it may be a good idea to choose a memorable name without much meaning:

```
[alice@localhost sage]$ git worktree add worktree-purple FETCH_HEAD
Preparing worktree (detached HEAD 30b3d78fac)
Updating files: 100% (11191/11191), done.
HEAD is now at 30b3d78fac Updated SageMath version to 10.3.beta8
```

We now have a subdirectory `worktree-purple`. This is a “linked worktree”:

```
[alice@localhost sage]$ git worktree list
/home/alice/sage/sage          c0ffeeefe10 [master]
/home/alice/sage/sage/worktree-purple 30b3d78fac (detached HEAD)
[alice@localhost sage]$ cd worktree-purple
[alice@localhost worktree-purple]$ cat VERSION.txt
SageMath version 10.3.beta8, Release Date: 2024-02-13
```

All worktrees created in this way share the same repository, so they have access to all branches:

```
[alice@localhost worktree-purple]$ git --no-pager branch -v
* (no branch) 30b3d78fac Updated SageMath version to 10.3.beta8
+ master      2a9a4267f9 Updated SageMath version to 10.2
```

In fact, `.git` here is not a directory, just a hidden file:

```
[alice@localhost worktree-purple]$ ls -l .git
-rw-r--r-- 1 alice staff 59 Feb 20 18:16 .git
```

In the new worktree, we now build Sage from scratch. This is completely independent of and will not disrupt your existing working installation in the main worktree.

We will refer again to the step-by-step instructions from the file [README.md](#). Our worktree `worktree-purple` is the `SAGE_ROOT` for this purpose.

One thing that we can share between worktrees without worry is the directory `upstream`, where Sage caches downloaded archives of packages. To have the new worktree share it with the main worktree, let’s create a symbolic link. This is an optional step that will avoid re-downloading files that you already have:

```
[alice@localhost worktree-purple]$ ln -s ../upstream/ .
```

Now let’s build Sage, starting with the step:

```
[alice@localhost worktree-purple]$ make configure
```

Refer to the file [README.md](#) for the following steps.

4.5 Launching SageMath

Now we assume that you installed SageMath properly on your system. This section quickly explains how to start the Sage console and the Jupyter Notebook from the command line.

If you did install the Windows version or the macOS application you should have icons available on your desktops or launching menus. Otherwise you are strongly advised to create shortcuts for Sage as indicated in the part 6 of the “Installation steps” Section in *Installation steps*. Assuming that you have this shortcut, running

```
sage
```

in a console starts a Sage session. To quit the session enter `quit` and then press `<Enter>`.

To start a Jupyter Notebook instead of a Sage console, run the command

```
sage -n jupyter
```

instead of just `sage`. To quit the Jupyter Notebook press `<Ctrl> + <c>` twice in the console where you launched the command.

You can pass extra parameters to this command. For example,

```
sage -n jupyter --port 8899
```

will run the Jupyter server on a port different from the default (8888). In particular on WSL, this is very useful because Jupyter may not be able to detect whether the default port is already taken by another instance of Jupyter running in Windows.

4.5.1 Environment variables

Sage uses the following environment variables when it runs:

- `DOT_SAGE` - this is the directory, to which the user has read and write access, where Sage stores a number of files. The default location is `$HOME/.sage/`.
- `SAGE_STARTUP_FILE` - a file including commands to be executed every time Sage starts. The default value is `$DOT_SAGE/init.sage`.
- `BROWSER` - on most platforms, Sage will detect the command to run a web browser, but if this doesn't seem to work on your machine, set this variable to the appropriate command.
- `TMPDIR` - this variable is used by Python, and hence by Sage; it gives the directory in which temporary files should be stored. This includes files used by the notebook. Some browsers have security settings which restrict the locations of files that they will access, and users may need to set this variable to handle this situation.
- See <https://docs.python.org/3/using/cmdline.html#environment-variables> for more variables used by Python (not an exhaustive list). With Python 3.11 or later, a brief summary can also be obtained by running `python3 --help-env`.

4.5.2 Using a Jupyter Notebook remotely

If Sage is installed on a remote machine to which you have `ssh` access, you can launch a Jupyter Notebook using a command such as

```
ssh -L localhost:8888:localhost:8888 -t USER@REMOTE sage -n jupyter --no-browser --  
↪port=8888
```

where `USER@REMOTE` needs to be replaced by the login details to the remote machine. This uses local port forwarding to connect your local machine to the remote one. The command will print a URL to the console which you can copy and paste in a web browser.

Note that this assumes that a firewall which might be present between server and client allows connections on port 8888. See details on port forwarding on the internet, e.g. <https://www.ssh.com/ssh/tunneling/example>.

4.5.3 WSL Post-installation steps

If you've installed SageMath from source on WSL, there are a couple of extra steps you can do to make your life easier:

Create a notebook launch script

If you plan to use JupyterLab, install that first.

Now create a script called `~/sage_nb.sh` containing the following lines, and fill in the correct paths for your desired starting directory and `SAGE_ROOT`

```
#!/bin/bash  
# Switch to desired windows directory  
cd /mnt/c/path/to/desired/starting/directory  
# Start the Jupyter notebook  
SAGE_ROOT/sage --notebook  
# Alternatively you can run JupyterLab - delete the line above, and uncomment the_  
↪line below  
#SAGE_ROOT/sage --notebook jupyterlab
```

Make it executable:

```
chmod ug+x ~/sage_nb.sh
```

Run it to test:

```
cd ~  
./sage_nb.sh
```

The Jupyter(Lab) server should start in the terminal window, and your windows browser should open a page showing the Jupyter or JupyterLab starting page, at the directory you specified.

Create a shortcut

This is a final nicety that lets you start the Jupyter or JupyterLab server in one click:

- Open Windows explorer, and type `%APPDATA%\Microsoft\Windows\Start Menu\Programs` in the address bar and press enter. This is the folder that contains you start menu shortcuts. If you want the sage shortcut somewhere else (like your desktop), open that folder instead.
- Open a separate window and go to `%LOCALAPPDATA%\Microsoft\WindowsApps\`
- Right-click-drag the `ubuntu.exe` icon from the second window into the first, then choose `Create shortcuts here` from the context menu when you drop it.
- To customize this shortcut, right-click on it and choose properties.
 - On the General tab:
 - * Change the name to whatever you want, e.g. “Sage 9.2 JupyterLab”
 - On the Shortcut tab:
 - * Change Target to: `ubuntu.exe run ~/sage_nb.sh`
 - * Change Start in to: `%USERPROFILE%`
 - * Change Run to: Minimised
 - * Change the icon if you want

Now hit the start button or key and type the name you gave it. it should appear in the list, and should load the server and fire up your browser when you click on it.

For further reading you can have a look at the other documents in the SageMath documentation at <http://doc.sagemath.org/>.

4.5.4 Setting up SageMath as a Jupyter kernel in an existing Jupyter notebook or JupyterLab installation

You may already have a global installation of Jupyter. For added convenience, it is possible to link your installation of SageMath into your Jupyter installation, adding it to the list of available kernels that can be selected in the notebook or JupyterLab interface.

Assuming that SageMath can be invoked by typing `sage`, you can use

```
sage -sh -c 'ls -d $SAGE_VENV/share/jupyter/kernels/sagemath'
```

to find the location of the SageMath kernel description.

Now pick a name for the kernel that identifies it clearly and uniquely.

For example, if you install Sage from source tarballs, you could decide to include the version number in the name, such as `sagemath-9.6`. If you build SageMath from a clone of the git repository, it is better to choose a name that identifies the directory, perhaps `sagemath-dev` or `sagemath-teaching` because the version will change.

Now assuming that the Jupyter notebook can be started by typing `jupyter notebook`, the following command will install SageMath as a new kernel named `sagemath-dev`.

```
jupyter kernelspec install --user $(sage -sh -c 'ls -d $SAGE_VENV/share/jupyter/
↪kernels/sagemath') --name sagemath-dev
```

The `jupyter kernelspec` approach by default does lead to about 2Gb of SageMath documentation being copied into your personal jupyter configuration directory. You can avoid that by instead putting a symlink in the relevant spot. and

```
jupyter --paths
```

to find valid data directories for your Jupyter installation. A command along the lines of

```
ln -s $(sage -sh -c 'ls -d $SAGE_VENV/share/jupyter/kernels/sagemath') $HOME/.local/  
↪share/jupyter/kernels/sagemath-dev
```

can then be used to create a symlink to the SageMath kernel description in a location where your own `jupyter` can find it.

If you have installed SageMath from source, the alternative command

```
ln -s $(sage -sh -c 'ls -d $SAGE_ROOT/venv/share/jupyter/kernels/sagemath') $HOME/.  
↪local/share/jupyter/kernels/sagemath-dev
```

creates a symlink that will stay current even if you switch to a different Python version later.

To get the full functionality of the SageMath kernel in your global Jupyter installation, the following Notebook Extension packages also need to be installed (or linked) in the environment from which the Jupyter installation runs.

You can check the presence of some of these packages using the command `jupyter nbextension list`.

- For the Sage interacts, you will need the package `widgetsnbextension` installed in the Python environment of the Jupyter installation. If your Jupyter installation is coming from the system package manager, it is best to install `widgetsnbextension` in the same way. Otherwise, install it using `pip`.

To verify that interacts work correctly, you can evaluate the following code in the notebook:

```
@interact  
def _(k=slider(vmin=-1.0, vmax= 3.0, step_size=0.1, default=0), auto_update=True):  
    plot([lambda u:u^2-1, lambda u:u+k], (-2,2),  
         ymin=-1, ymax=3, fill={1:[0]}, fillalpha=0.5).show()
```

- For 3D graphics using Three.js, by default, internet connectivity is needed, as SageMath's custom build of the Javascript package Three.js is retrieved from a content delivery network.

To verify that online 3D graphics with Three.js works correctly, you can evaluate the following code in the notebook:

```
plot3d(lambda u,v:(u^2+v^2)/4-2, (-2,2), (-2,2)).show()
```

However, it is possible to configure graphics with Three.js for offline use. In this case, the Three.js installation from the Sage distribution needs to be made available in the environment of the Jupyter installation. This can be done by copying or symlinking. The Three.js installation in the environment of the Jupyter installation must exactly match the version that comes from the Sage distribution. It is not supported to use several Jupyter kernels corresponding to different versions of the Sage distribution.

To verify that offline 3D graphics with Three.js works correctly, you can evaluate the following code in the notebook:

```
plot3d(lambda u,v:(u^2+v^2)/4-2, (-2,2), (-2,2), online=False).show()
```

- For 3D graphics using jsmol, you will need the package `jupyter-jsmol` installed in the Python environment of the Jupyter installation. You can install it using `pip`. (Alternatively, you can copy or symlink it.)

To verify that jsmol graphics work correctly, you can evaluate the following code in the notebook:

```
plot3d(lambda u,v:(u^2+v^2)/4-2, (-2,2), (-2,2)).show(viewer="jmol")
```

Using Jupyter notebook through Visual Studio Code (VS Code) in WSL

If you have installed Sage on Windows using Windows Subsystem for Linux (WSL), it is convenient to use Visual Studio Code (VS Code) to interact with Sage.

Here are steps to use SageMath in a Jupyter notebook in VS Code:

- Install and run [VS Code](#) in Windows.
- Click the “Extension” icon on the left (or press `Ctrl + Shift + X`) to open a list of extensions. Install the “Remote - WSL” and “Jupyter” extensions.
- In the command palette (`Ctrl + Shift + P`), enter “Remote-WSL: New Window”, and hit `Enter`.
- In the command palette, enter “Create: New Jupyter Notebook”, and hit `Enter`.
- Click “Select Kernel” on the right (or press `Ctrl + Alt + Enter`), select SageMath, and hit `Enter`.

4.6 Troubleshooting

If no binary version is available for your system, you can fallback to the [Install from Source Code](#) or use one of the alternatives proposed at the end of [Welcome to Sage Installation Guide](#).

If you have any problems building or running Sage, please take a look at the Installation FAQ in the [Sage Release Tour](#) corresponding to the version that you are installing. It may offer version-specific installation help that has become available after the release was made and is therefore not covered by this manual.

Also please do not hesitate to ask for help in the [SageMath forum](#) or the sage-support mailing list at <https://groups.google.com/forum/#!forum/sage-support>.

Also note the following. Each separate component of Sage is contained in an SPKG; these are stored in `build/pkgs/`. As each one is built, a build log is stored in `logs/pkgs/`, so you can browse these to find error messages. If an SPKG fails to build, the whole build process will stop soon after, so check the most recent log files first, or run:

```
grep -li "^Error" logs/pkgs/*
```

from the top-level Sage directory to find log files with error messages in them. Send the file `config.log` as well as the log file(s) of the packages that have failed to build in their entirety to the sage-support mailing list at <https://groups.google.com/group/sage-support>; probably someone there will have some helpful suggestions.

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