

Introduction to Sage

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Observatoire de Paris
November 6th 2013

“You can read Sylow’s Theorem and its proof in Huppert’s book in the library . . . then you can use Sylow’s Theorem for the rest of your life free of charge, but for many computer algebra systems license fees have to be paid regularly . . .

With this situation two of the most basic rules of conduct in mathematics are violated : In mathematics information is passed on free of charge and everything is laid open for checking.”

—J. Neubüser (1993)

(il a fondé GAP en 1986)

Why You Do Not Usually Need to Know about Internals

« You should realize at the outset that while knowing about the internals of Mathematica may be of intellectual interest, it is usually *much less important* in practice than you might at first suppose. [...] For the internals of Mathematica are *quite complicated*, [...], it is usually *extremely difficult* to reach a reliable conclusion about how the detailed implementation of this algorithm will actually behave in particular circumstances. »

—Mathematica Tutorial

`http://reference.wolfram.com/mathematica/tutorial/`

`WhyYouDoNotUsuallyNeedToKnowAboutInternals.html`

*“I think, fundamentally, open source does tend to be more stable software. It’s the right way to do things. I compare it to **science versus witchcraft**.*

In science, the whole system builds on people looking at other people’s results and building on top of them.

In witchcraft, somebody had a small secret and guarded it—but never allowed others to really understand it and build on it.”

—Linus Torvalds

Outline

- 1 History of Sage
- 2 Sage
- 3 Community
- 4 Some functionalities

Plan

- 1 History of Sage
- 2 Sage
- 3 Community
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Before Sage

Existing commercial softwares (general purpose) :

- Maple, Waterloo Maple Inc., Maplesoft, since 1985.
- Mathematica, Wolfram Research, since 1988.
- Magma, University of Sydney, since 1990
- Matlab, MathWorks, since 1989

Free existing softwares (specific purpose) :

- Maxima, W. Schelter et coll., since 1967 : **symbolic operations**
- GAP, GAP Group, since 1986 : **computational group theory**
- Singular, U. of Kaiserslautern, since 1984 : **polynomial comput.**
- PARI/GP, since 1985 : **number theory computations**

Beginning of Sage

- *1999-2005.* William Stein write over 25000 lines of Magma code for its own research, but had some serious concerns :
 - Magma do not allow users to define their own types (or classes)
 - No exception handling
 - No "eval statements"
 - No way for users to write compiled code
 - Magma is closed source
 - Magma is not free

« I sat down on that park bench, and realized what a dangerous path I was taking in giving up so much freedom so early in my career. I resolved at that moment not to do it. At that moment I started designing what would eventually become Sage. »

— William Stein

Mathematical Software and Me : A Very Personal Recollection, 2009

Beginning of Sage

- *Jan. 2005.* William Stein creates Sage.
- *Feb. 2005.* Sage version 0.1 : gathers 5 software : PARI, Maxima, Python, Singular et GAP.
- David Kohel in Australia, David Joyner, in Maryland, joined the project.
- *Dec. 2005.* William receives an email from Magma leader.

Beginning of Sage

Date: Mon, 19 Dec 2005 16:54:09 -0800
From: "John Cannon" <john@maths.usyd.edu.au>
Subject: Magma calculator
William,

This is to formally advise you that your permission to run a general-purpose calculator based on Magma ends on Dec 31, 2005. This was originally set up at your request so students in your courses at Harvard could have easy access to Magma.

Please confirm receipt of this letter.
Wishing you a happy Christmas,
John

Beginning of Sage

« This single email seriously *scared me*. Though I was working on Sage very hard for nearly a year at this point, I honestly didn't then expect Sage to really be able to replace Magma for me. [...] What John made crystal clear to me was that he could destroy my entire longterm plans on a whim. I looked around for other options, and there just weren't any. *Sage had to succeed*. »

— William Stein

Mathematical Software and Me : A Very Personal Recollection, 2009

History of Sage



- *Feb. 2006.* Sage version 1.0 is released ; first "annual" Sage Days are organised : **Sage Days 1.**
- *Dec. 2007.* Sage gets slashdotted :




IT: Open Source 'Sage' Takes Aim at High End Math Software

Posted by [CmdrTaco](#) on Saturday December 08 2007, @12:19PM
from the [that'll-take-awhile](#) dept.

[coondoggie](#) writes

"A [new open source mathematics program](#) is looking to push aside commercial software commonly used in mathematics education, in large government laboratories and in math-intensive research. The program's backers say the software, called Sage, can do anything from mapping a 12-dimensional object to calculating rainfall patterns under global warming."

► [software it sage octave math story](#)

- *2008* Mupad-Combinat group (lead by Nicolas Thiéry et Florent Hivert) switches to Sage : Sage-Combinat

History of Sage

Year	# Sage Days	Releases	Functions	Contributors
2005	0	120		3
2006	2	90		
2007	4	60	17947	
2008	8	23	22034	≈ 100
2009	9	14	23763	
2010	13	16	26592	219
2011	14	5	28462	235
2012	15	9	30508	249
2013	15	6	33772 (5.12)	260

Plan

- 1 History of Sage
- 2 Sage
- 3 Community
- 4 Some functionalities

Mission

The Sage Project aims to create a viable high-quality and open-source alternative to Magma, Maple, Mathematica, Matlab and MuPAD, and to foster a friendly community of users and developers.

Sage is an open source software

Sage is distributed under the terms of the GNU General Public License version 2 (GPLv2) which guarantees four types of freedom :

- The freedom to **use** the software (it is free).
- The freedom to **read the source code**.
- The freedom to **improve the software**.
- The freedom to **redistribute the modified software to anyone**.

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Sharing data in astronomy is not new

*In the case of IUE (International Ultraviolet Explorer) spectra (1978-1996), there are **five times more publications from data retrieved in the archive** than from the selected observing teams (Wamsteker, Griffin, 1995).*

— Françoise Genova, Observatoire de Strasbourg

Sage is . . .

a *distribution* of softwares

Sage is a *distribution* of open source softwares

These softwares are included in Sage :

ATLAS	Automatically Tuned Linear Algebra Software
BLAS	Basic Fortran 77 linear algebra routines
Bzip2	High-quality data compressor
Cddlib	Double Description Method of Motzkin
Common Lisp	Multi-paradigm and general-purpose programming lang.
CVXOPT	Convex optimization, linear programming, least squares
Cython	C-Extensions for Python
F2c	Converts Fortran 77 to C code
Flint	Fast Library for Number Theory
FpLLL	Euclidian lattice reduction
FreeType	A Free, High-Quality, and Portable Font Engine

Sage is a *distribution* of open source softwares

These softwares are included in Sage :

G95	Open source Fortran 95 compiler
GAP	Groups, Algorithms, Programming
GD	Dynamic graphics generation tool
Genus2reduction	Curve data computation
Gfan	Gröbner fans and tropical varieties
Givaro	C++ library for arithmetic and algebra
GMP	GNU Multiple Precision Arithmetic Library
GMP-ECM	Elliptic Curve Method for Integer Factorization
GNU TLS	Secure networking
GSL	Gnu Scientific Library
JsMath	JavaScript implementation of LaTeX

Sage is a *distribution* of open source softwares

These softwares are included in Sage :

IML	Integer Matrix Library
IPython	Interactive Python shell
LAPACK	Fortan 77 linear algebra library
Lcalc	L-functions calculator
Libgcrypt	General purpose cryptographic library
Libgpg-error	Common error values for GnuPG components
Linbox	C++ linear algebra library
Matplotlib	Python plotting library
Maxima	computer algebra system
Mercurial	Revision control system
MoinMoin	Wiki

Sage is a *distribution* of open source softwares

These softwares are included in Sage :

MPFI	Multiple Precision Floating-point Interval library
MPFR	C library for multiple-precision floating-point computations
ECLib	Cremona's Programs for Elliptic curves
NetworkX	Graph theory
NTL	Number theory C++ library
Numpy	Numerical linear algebra
OpenCDK	Open Crypto Development Kit
PALP	A Package for Analyzing Lattice Polytopes
PARI/GP	Number theory calculator
Pexpect	Pseudo-tty control for Python
PNG	Bitmap image support

Sage is a *distribution* of open source softwares

These softwares are included in Sage :

PolyBoRi	Polynomials Over Boolean Rings
PyCrypto	Python Cryptography Toolkit
Python	Interpreted language
Qd	Quad-double/Double-double Computation Package
R	Statistical Computing
Readline	Line-editing
Rpy	Python interface to R
Scipy	Python library for scientific computation
Singular	fast commutative and noncommutative algebra
Scons	Software construction tool
SQLite	Relation database

Sage is a *distribution* of open source softwares

These softwares are included in Sage :

Sympow	L-function calculator
Symmetrica	Representation theory
Sympy	Python library for symbolic computation
Tachyon	lightweight 3d ray tracer
Termcap	for writing portable text mode applications
Twisted	Python networking library
Weave	Tools for including C/C++ code within Python
Zlib	Data compression library
ZODB	Object-oriented database

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...and more !

◀ ◻ ▶ ◀ ◻ ▶ ◀ ≡ ▶ ◀ ≡ ▶ ≡

```
> sage -singular
```

```

                SINGULAR                               /  Development
A Computer Algebra System for Polynomial Computations /  version 3-1-0
                                                    0<
    by: G.-M. Greuel, G. Pfister, H. Schoenemann      \  Mar 2009
FB Mathematik der Universitaet, D-67653 Kaiserslautern \
>
```

```
> sage -maxima
```

```
Maxima 5.16.3 http://maxima.sourceforge.net
```

```
Using Lisp ECL 9.4.1
```

```
Distributed under the GNU Public License. See the file COPYING.
```

```
Dedicated to the memory of William Schelter.
```

```
The function bug_report() provides bug reporting information.
```

```
(%i1)
```



```
> sage -gp
```

```
GP/PARI CALCULATOR Version 2.3.3 (released)
amd64 running linux (x86-64/GMP-4.2.1 kernel) 64-bit version
compiled: Jul 10 2009, gcc-4.3.2 (Ubuntu 4.3.2-1ubuntu12)
(readline v5.2 enabled, extended help available)
```

```
Copyright (C) 2000-2006 The PARI Group
```

```
PARI/GP is free software, covered by the GNU General Public License, and
comes WITHOUT ANY WARRANTY WHATSOEVER.
```

```
Type ? for help, \q to quit.
```

```
Type ?12 for how to get moral (and possibly technical) support.
```

```
parisize = 8000000, primelimit = 500000
```

```
?
```

```
> sage -R
```

R version 2.6.1 (2007-11-26)

Copyright (C) 2007 The R Foundation for Statistical Computing

ISBN 3-900051-07-0

R is free software and comes with ABSOLUTELY NO WARRANTY.

You are welcome to redistribute it under certain conditions.

Type 'license()' or 'licence()' for distribution details.

Natural language support but running in an English locale

R is a collaborative project with many contributors.

Type 'contributors()' for more information and

'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or

'help.start()' for an HTML browser interface to help.

Type 'q()' to quit R.

```
>
```

Sage *combines* software.

Sage combines software

[This examples are from a presentation of William Stein]

Sage combines software

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Construct an elliptic curve using *John Cremona's table* :

```
sage: E = EllipticCurve('389a')
```

Sage combines software

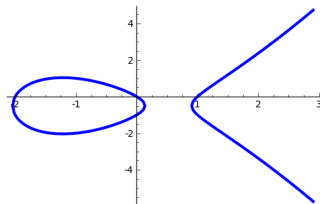
[This examples are from a presentation of William Stein]

Construct an elliptic curve using *John Cremona's table* :

```
sage: E = EllipticCurve('389a')
```

Use *matplotlib* to plot it :

```
sage: plot(E,thickness=3)
```



Sage combines software

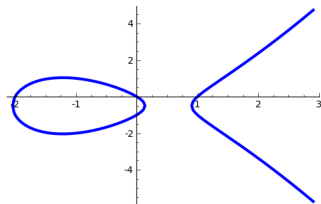
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```

Use *matplotlib* to plot it :

```
sage: plot(E,thickness=3)
```



mwrnk to do a 2-descent :

```
sage: E.mwrnk()
```

```
Curve [0,1,1,-2,0] : Rank = 2
```

Sage combines software

PARI to compute Fourier coefficients a_n :

```
sage: E.anlist(15)
```

```
[0, 1, -2, -2, 2, -3, 4, -5, 0, 1, 6, -4, -4, -3, 10, 6]
```


Sage combines software

PARI to compute Fourier coefficients a_n :

```
sage: E.anlist(15)  
[0, 1, -2, -2, 2, -3, 4, -5, 0, 1, 6, -4, -4, -3, 10, 6]
```

lcalc to compute zeros in the critical strip of the L-series :

```
sage: E.lseries().zeros(5)  
[0.000000000, 0.000000000, 2.87609907, 4.41689608, 5.79
```

Sage combines software

PARI to compute Fourier coefficients a_n :

```
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```

sympow to compute the modular degree :

```
sage: E.modular_degree()
40
```

Sage combines software

PARI to compute Fourier coefficients a_n :

```
sage: E.anlist(15)
[0, 1, -2, -2, 2, -3, 4, -5, 0, 1, 6, -4, -4, -3, 10, 6]
```

lcalc to compute zeros in the critical strip of the L-series :

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[0.000000000, 0.000000000, 2.87609907, 4.41689608, 5.79
```

sympow to compute the modular degree :

```
sage: E.modular_degree()
40
```

Magma to compute the rank of the 3-selmer group :

```
sage: magma(E).ThreeSelmerGroup()
Abelian Group isomorphic to Z/3 + Z/3
Defined on 2 generators
```

Sage combines software

Let's integrate $\int \cos(x^2)dx$:

```
sage: integrate(cos(x^2), x)
-1/8*((I + 1)*sqrt(2)*erf((1/2*I - 1/2)*sqrt(2)*x) +
(I - 1)*sqrt(2)*erf((1/2*I + 1/2)*sqrt(2)*x))*sqrt(pi)
```

Software **used** for this computation :

```
sage: from sage.misc.citation import get_systems
sage: get_systems("integrate(cos(x^2), x)")
['MPFI', 'ginac', 'GMP', 'Maxima']
```

Sage combines software

*“We implement all **conversion routines**, instead of expecting upstream to do it : **we make them communicate with Sage**, whether they want to or not. Resistance is futile.”*

*—William Stein
(started Sage)*

Sage Optional Packages (spkg)

<http://www.sagemath.org/packages/optional/>

Fokko Ducloux's Coxeter 3 C++ library

```
sage -i coxeter3-1.1.spkg
```

Gnuplot.py is a Python package that interfaces to gnuplot

```
sage -i gnuplotpy-1.8.spkg
```

Ore Polynomials in Sage

http://www.risc.jku.at/research/combinat/software/ore_algebra/

```
sage -i ore_algebra-0.1.spkg
sage: from ore_algebra import *
```

SageManifolds : Differential geometry and tensor calculus

<http://sagemanifolds.obspm.fr/>

```
sage -i http://sagemanifolds.obspm.fr/spkg/manifolds-0.2.spkg
sage: from manifolds.all import *
```

Sage Important Philosophy : Elements have parent

```
sage: m = matrix(ZZ, 3, [2,3,4,2,4,6,8,8,5])
```

```
sage: m.parent()
```

Full MatrixSpace of 3 by 3 dense matrices over Integer Ring

```
sage: m.echelon_form()
```

```
[2 0 1]
```

```
[0 1 2]
```

```
[0 0 3]
```

```
sage: m = matrix(QQ, 3, [2,3,4,2,4,6,8,8,5])
```

```
sage: m.parent()
```

Full MatrixSpace of 3 by 3 dense matrices over Rational Field

```
sage: m.echelon_form()
```

```
[1 0 0]
```

```
[0 1 0]
```

```
[0 0 1]
```

Sage uses Python
as its programming language.

Sage uses Python

- Sage \approx Python + a huge Python library
- Sage may be the first successful math software system **to not invent its own new language** just for mathematics.
- Tens of thousands of **third party Python packages** are immediately available for use with Sage!
- Easy to **write and read** :

math : $\left\{ 17x \mid x \in \{0, 1, \dots, 9\} \text{ et } x \text{ est impair} \right\}$
python : `[17*x for x in range(10) if x % 2 == 1]`

Sage uses Python

« Google has made no secret of the fact they use Python a lot for a number of internal projects. Even knowing that, once I was an employee, I was amazed at how much Python code there actually is in the Google source code system. »

— Guido van Rossum

(Python creator)

Sage follows *Best practices for Scientific Computing*

Aruliah, D. A., C. Titus Brown, Neil P. Chue Hong, Matt Davis, Richard T. Guy, Steven H. D. Haddock, Katy Huff, et al.

Best Practices for Scientific Computing.

September 30, 2012

<http://arxiv.org/abs/1210.0530>.

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Community

You are not alone !

Working together with internet

Development :

- <http://groups.google.com/group/sage-devel>
- http://trac.sagemath.org/sage_trac/
- <http://wiki.sagemath.org/>

Support :

- <http://groups.google.com/group/sage-support>
- <http://ask.sagemath.org/questions/>
- <http://wiki.sagemath.org/>

Other Google Group include : [sage-combinat-devel](#),
[sage-release](#) and [sage-edu](#).

[irc-channel](#)

#sage-devel on freenode.net

Developer Map



There are currently $244 + 1 + 4 + 11$ contributors
in $165 + 1 + 2 + 9$ different places from all around the world.

Sage Days

Sage Days are workshops aiming at

- fix bugs and develop new functionalities
- attract new users and developers

Dozen of workshops are organized every year all around the world.

Sage Days in 2010

- Sage Days 19 : Seattle, USA (January 2010)
- Sage Days 20 : Marseille, France (February 2010)
- Sage Days 20.25 : Montreal, Canada (March 2010)
- Sage Days 20.5 : Toronto, Canada (May 2010)
- Sage Days 21 : Seattle, USA (June 2010)
- Sage-Combinat/Chevie : France (June 2010)
- Sage Days 22 : Berkeley, USA (July 2010)
- Sage Days 23 : Leiden, Netherlands (July 2010)
- Sage Days 23.5 : Kaiserslautern, Germany (July 2010)
- Sage Days 24 : Linz, Austria (July 2010)
- Sage Days 25 : Mumbai, India (August 2010)
- Sage Days 25.5 : Montreal, Canada (September 2010)
- Sage Days 26 : Seattle, USA (December 2010)

Sage Days in 2011

- Sage Days 27 : Seattle, USA (January 2011)
- Sage Days 28 : Orsay, France (January 2011)
- Sage Days 29 : Seattle, USA (March 21-25, 2011)
- Sage Days 30 : Halifax, Canada (May 2-6, 2011)
- Sage Days 31 : Seattle, USA (June 11-18, 2011)
- Sage Education Days 3 : Seattle, USA (June 16-18, 2011)
- Sage Days 32 : Seattle, USA (August 21-25, 2011)
- Sage Days 33 : Women in Sage, Seattle (September 2011)
- Sage Days 34 : Kaiserslautern, Germany (Sept. 2011)
- Sage Days 34.5 : Bobo Dioulasso, Burkina Faso (Nov. 2011)
- Sage Days 35 : Warwick UK (December 2011)

Sage Days in 2012

- Sage Days 35.5 : Wenham, MA (January 2012)
- Sage-Combinat Days 35.75 : France (February 2012)
- Sage Days 36 : UC San Diego, (February 2012)
- Review Days 2 : March 17-22, Seattle WA.
- Sage Days 36.5 : April 17-22, Seattle WA.
- Sage Days 37 : 28 April 2012, Seoul, South Korea.
- **Sage Days 38 : May 7-11 2012, Montréal, Canada.**
- Bug Days 19 : May 24-29, Seattle WA.
- Sage Days 39 : May 26-27 2012, Fukuoka, Japan.
- Sage Days 41 : June 11-15, 2012, Seattle.
- Sage Edu Days 4 : June 13-15, 2012, Seattle.
- SAGE-Combinat Days 40 : July 9-13, Minneapolis, MN.
- Sage Days 42 : July 15-19, 2012, Seattle, WA.

Sage à Paris

<http://wiki.sagemath.org/GroupeUtilisateursParis>
(meetings since November 2011)

Montly meetings for *new users*, *users* and *developers*
Goal : Learn from each other

Locations :

- Orsay
- Jussieu
- Chevaleret
- IRILL
- Télécom ParisTech

Plan

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Some functionalities

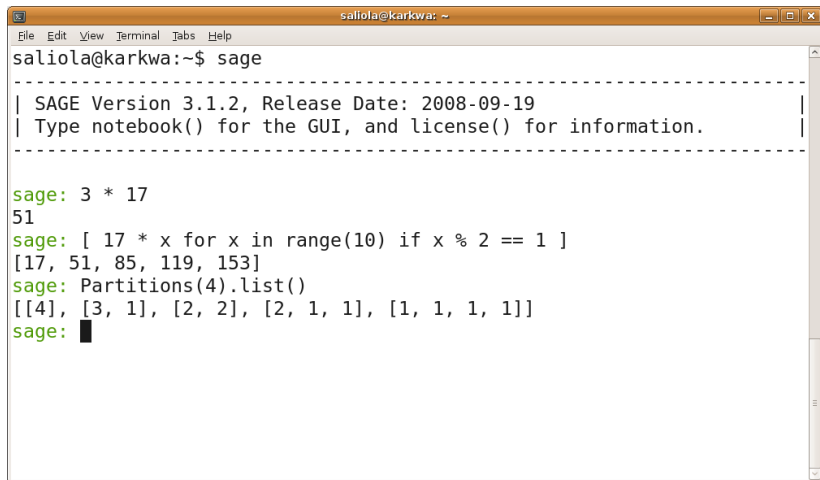
Interfaces :

- Command line
- Sage Notebook (local)
- Sage Notebook (internet)
- **New** : Sage in a web page (by Jason Grout, USA)

Interesting features :

- Sagetex (Dan Drake, Corée du Sud)
- Graph Editor (Radoslav Kirov, États-Unis)
- Interact and animations
- **Cython** : translates Python code \mapsto C code.

Command line interface



The screenshot shows a terminal window titled "saliola@karkwa: ~". The window has a menu bar with "File", "Edit", "View", "Terminal", "Tabs", and "Help". The prompt is "saliola@karkwa:~\$". The user has entered "sage", which has triggered a welcome message from SAGE Version 3.1.2, released on 2008-09-19. The message suggests using "notebook()" for the GUI and "license()" for information. After the message, the user enters "sage: 3 * 17", which returns "51". Then, the user enters "sage: [17 * x for x in range(10) if x % 2 == 1]", which returns "[17, 51, 85, 119, 153]". Next, the user enters "sage: Partitions(4).list()", which returns "[[4], [3, 1], [2, 2], [2, 1, 1], [1, 1, 1, 1]]". Finally, the user enters "sage:" followed by a cursor, and the prompt returns.

```
saliola@karkwa:~$ sage
-----
| SAGE Version 3.1.2, Release Date: 2008-09-19                |
| Type notebook() for the GUI, and license() for information.  |
-----

sage: 3 * 17
51
sage: [ 17 * x for x in range(10) if x % 2 == 1 ]
[17, 51, 85, 119, 153]
sage: Partitions(4).list()
[[4], [3, 1], [2, 2], [2, 1, 1], [1, 1, 1, 1]]
sage: █
```

Notebook interface (local)

The screenshot displays the Sage Notebook (local) interface in a web browser. The browser address bar shows `localhost:8000/home/admin/3/`. The page header includes the Sage logo, version 4.5.3, and navigation links: [admin](#), [Toggle](#), [Home](#), [Published](#), [Log](#), [Settings](#), [Help](#), [Report a Problem](#), and [Sign out](#).

The main content area is titled "The Sage Notebook" and shows the last edit on November 27, 2010 01:03 PM by admin. Below this is a toolbar with buttons: [File...](#), [Action](#), [Data...](#), [sage](#), [Typeset](#), [Print](#), [Worksheet](#), [Edit](#), [Text](#), [Undo](#), [Share](#), and [Publish](#). There are also buttons for [Save](#), [Save & quit](#), and [Discard & quit](#).

The code editor contains the following code:

```
plot(sin(x^2)+cos(x), -pi, pi, hue=0.8, thickness=4).show(figsize=[8,2])
```

Below the code editor is a plot of the function $\sin(x^2) + \cos(x)$ over the interval $[-\pi, \pi]$. The plot is a thick magenta line on a coordinate system with x-axis from -3 to 3 and y-axis from -1.5 to 1.5.

On the left side, there is an "evaluate" button and a text input field.

A modal window titled "plot" is open, showing examples of plotting the sine function:

EXAMPLES: We plot the sin function:

```
sage: P = plot(sin, (0,10)); print P
Graphics object consisting of 1 graphics primitive
sage: len(P) # number of graphics primitives
1
sage: len(P[0]) # how many points were computed (random)
225
sage: P # render
```

```
sage: P = plot(sin, (0,10), plot_points=10); print P
Graphics object consisting of 1 graphics primitive
sage: len(P[0]) # random output
32
sage: P # render
```

At the bottom of the modal window, there is a note: "We plot with `randomize=False`, which makes the initial sample points evenly spaced (hence always the same). Adaptive plotting might insert other points, however, unless

Notebook interface (internet)

`http://sagenb.org/`



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Single Cell Server

`http://www.liafa.univ-paris-diderot.fr/~labbe/
blogue-index/`

`http://www.sagemath.org/eval.html`




v4.8 (2012-01-20) ·  Like 1.4k  +1 459    

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Sage Cell Server

This web page contains an interactive Sage widget and a collection of 26 examples. You can edit it however you want. Interacts, graphics and plotting, etc., should all work.

Topic	Subtopic	Examples
Algebra	Basics	Funny Plot
Calculus	Multivariate	ODE Plot
Geometry	ODE	Simple Plot
Graph Theory	Plot	
Graphics		
Libs		

Calculus>Plot
Funny Plot: this is just a funny plot

```

1 plot(sin(x) / (2+cos(pi*x)), (-2*pi, 6*pi))

```

\LaTeX

In this \LaTeX file, I write

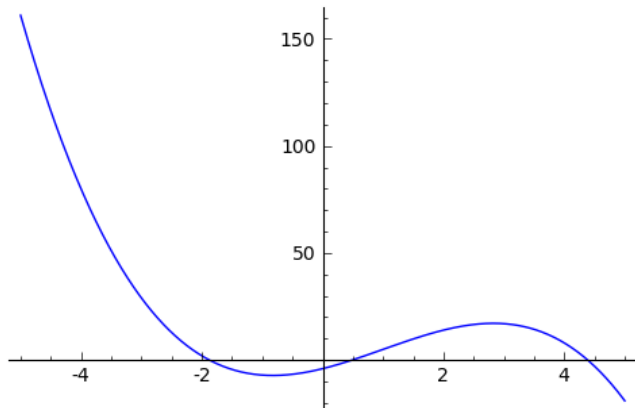
```
\sageplot{plot(-x^3+3*x^2+7*x-4,-5,5)}
```

\LaTeX

In this \LaTeX file, I write

```
\sageplot{plot(-x^3+3*x^2+7*x-4,-5,5)}
```

and this is replaced by :



L^AT_EX

In this L^AT_EXfile :

```
\begin{sagesilent}
  sigma = Permutation([7,3,1,5,2,6,8,4])
  P, Q = sigma.robinson_schensted()
\end{sagesilent}
```

Let $\sigma = \text{sage}\{\sigma\}$. The Robinson-Schensted-Knuth algorithm produces the tableaux:

```
\[\text{sage}\{P\} \quad \text{sage}\{Q\}\]
```

L^AT_EX

It got replaced with :

Let $\sigma = [7, 3, 1, 5, 2, 6, 8, 4]$. The Robinson-Schensted-Knuth algorithm produces the tableaux :

1	2	4	8
3	5	6	
7			

1	4	6	7
2	5	8	
3			

L^AT_EX

It got replaced with :

Let $\sigma = [7, 3, 1, 5, 2, 6, 8, 4]$. The Robinson-Schensted-Knuth algorithm produces the tableaux :

1	2	4	8
3	5	6	
7			

1	4	6	7
2	5	8	
3			

This is done with the **sagetex** package for L^AT_EX, written by Dan Drake. Of course, the package is included with Sage.

For more informations

<http://sagemath.org>



The screenshot shows the SageMath website homepage. At the top, there is a navigation bar with the Sage logo (a geometric polyhedron) and the word "sage" in a stylized font. To the right of the logo, it says "v4.7.1 (2011-08-11)" and includes social media links for Facebook, Twitter, and YouTube, along with a "Like" button and a count of "177". Below this, there are links for "RSS", "Blog", "Trac", "Report Bugs", "Wiki", "Ask", "Feedback", and "Search". A search bar is also present. The main content area has a navigation menu with links for "Home", "Tour", "Support", "Library", "Download", "Development", and "Links". The central text describes Sage as a free open-source mathematics software system licensed under the GPL, combining the power of many existing open-source packages into a common Python-based interface. It also states the mission: "Creating a viable free open source alternative to Magma, Maple, Mathematica and Matlab." Below this, there are six main sections, each with an icon and a title: "Try Sage Online" (with a sub-note "other: KAIST testing: alpha, Solaris SPARC"), "Download 4.7.1" (with a sub-note "Changelog · Source 4.7.1 · Packages"), "Help/Documentation" (with a sub-note "Video · Lists · Tutorial · FAQ · Ask"), "Feature Tour" (with a sub-note "Quickstart · Research · Graphics"), "Library" (with a sub-note "Testimonials · Books · Publications · Press Kit"), and "Search" (with a search input field). At the bottom, there is a "Random Link: Publications citing Sage" section. On the right side of the page, there is a vertical sidebar with a "Follow us" button and a list of social media links.

Sage is a free [open-source](#) mathematics software system licensed under the GPL. It [combines the power](#) of many existing [open-source packages](#) into a common Python-based interface.

Mission: *Creating a viable free open source alternative to Magma, Maple, Mathematica and Matlab.*

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For more information

- <http://sagemath.org>
- <http://sagemath.org/doc>
- <http://sagemath.org/help.html>
- <http://wiki.sagemath.org>

Ressources in **French** :

- <http://sagemath.org/fr>
- <http://sagemath.org/fr/html/tutorial>

Le livre **Calcul mathématique avec Sage** :

- <http://sagebook.gforge.inria.fr/>

Let's start !
Commençons !