A short introduction to SageMath

Éric Gourgoulhon

Laboratoire Univers et Théories (LUTH)
CNRS / Observatoire de Paris / Université Paris Diderot
Université Paris Sciences et Lettres
92190 Meudon, France

https://luth.obspm.fr/~luthier/gourgoulhon/

Black Hole Perturbation Toolkit Workshop
University College Dublin
19-21 March 2019

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures
  - Jupyter: graphical interface (notebook)

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures
  - Jupyter: graphical interface (notebook)

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures
  - Jupyter: graphical interface (notebook)

  SageMath provides a **uniform interface** to them but it also contains a significant part of **original code** (Python, Cython)
- William Stein (Univ. of Washington) created SageMath in 2005; since then, $\sim$**100 developers** (mostly mathematicians) have joined the SageMath team

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures
  - Jupyter: graphical interface (notebook)

  SageMath provides a **uniform interface** to them but it also contains a significant part of **original code** (Python, Cython)
- William Stein (Univ. of Washington) created SageMath in 2005; since then, $\sim$**100 developers** (mostly mathematicians) have joined the SageMath team
- SageMath is supported by European Union via the open-math project OpenDreamKit (2015-2019, within the *Horizon 2020* program)

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures
  - Jupyter: graphical interface (notebook)

  SageMath provides a **uniform interface** to them but it also contains a significant part of **original code** (Python, Cython)
- William Stein (Univ. of Washington) created SageMath in 2005; since then, $\sim$**100 developers** (mostly mathematicians) have joined the SageMath team
- SageMath is supported by European Union via the open-math project OpenDreamKit (2015-2019, within the *Horizon 2020* program)

SageMath in a few words

- SageMath (*nickname:* Sage) is a **free open-source** mathematics software system
- It is based on the Python programming language
- It makes use of **many pre-existing open-sources packages**, among which
  - Pynac, Maxima, SymPy: symbolic calculations
  - GAP: group theory
  - PARI/GP: number theory
  - Singular: polynomial computations
  - matplotlib: high quality figures
  - Jupyter: graphical interface (notebook)

  SageMath provides a **uniform interface** to them but it also contains a significant part of **original code** (Python, Cython)
- William Stein (Univ. of Washington) created SageMath in 2005; since then, $\sim$**100 developers** (mostly mathematicians) have joined the SageMath team
- SageMath is supported by European Union via the open-math project OpenDreamKit (2015-2019, within the *Horizon 2020* program)

The mission: *create a viable free open source alternative to Magma, Maple, Mathematica and Matlab.*

Some advantages of SageMath

SageMath is free (GPL v2)

Freedom means

1. everybody can use it, by downloading the software from http://sagemath.org
2. everybody can examine the source code and improve it

Some advantages of SageMath

SageMath is free (GPL v2)

Freedom means

1. everybody can use it, by downloading the software from `http://sagemath.org`
2. everybody can examine the source code and improve it

SageMath is based on Python

- no need to learn any specific syntax to use it
- easy access for students
- Python is a very powerful *object oriented language*, with a neat syntax
- SageMath benefits from all the Python ecosystem (e.g. `numpy`, `Jupyter`, `pip`, etc.)

Some advantages of SageMath

SageMath is free (GPL v2)

Freedom means

1. everybody can use it, by downloading the software from `http://sagemath.org`
2. everybody can examine the source code and improve it

SageMath is based on Python

- no need to learn any specific syntax to use it
- easy access for students
- Python is a very powerful *object oriented language*, with a neat syntax
- SageMath benefits from all the Python ecosystem (e.g. `numpy`, `Jupyter`, `pip`, etc.)

SageMath is developing and spreading fast (at least in Mathematics...)

...sustained by an enthusiastic community of developers

Various ways to install/access SageMath 8.6

- Install on your computer: 2 options:

Various ways to install/access SageMath 8.6

- Install on your computer: 2 options:
  - install a compiled binary version for Linux, MacOS X or Windows from `http://www.sagemath.org/download.html`

Various ways to install/access SageMath 8.6

- Install on your computer: 2 options:
  - install a compiled binary version for Linux, MacOS X or Windows from http://www.sagemath.org/download.html
  - compile from source (Linux, MacOS X): check the prerequisites (see here for Ubuntu) and run

```
git clone git://github.com/sagemath/sage.git
cd sage
MAKE='make -j8' make
```

Various ways to install/access SageMath 8.6

- Install on your computer: 2 options:
  - install a compiled binary version for Linux, MacOS X or Windows from http://www.sagemath.org/download.html
  - compile from source (Linux, MacOS X): check the prerequisites (see here for Ubuntu) and run

```
git clone git://github.com/sagemath/sage.git
cd sage
MAKE='make -j8' make
```

- Run on your computer without installation: **Sage Debian Live**
  https://sagedebianlive.metelu.net/
  Bootable USB flash drive with SageMath (boosted with octave, scilab), Geogebra, LaTeX, gimp, vlc, LibreOffice,...

Various ways to install/access SageMath 8.6

- Install on your computer: 2 options:
  - install a compiled binary version for Linux, MacOS X or Windows from http://www.sagemath.org/download.html
  - compile from source (Linux, MacOS X): check the prerequisites (see here for Ubuntu) and run

```
git clone git://github.com/sagemath/sage.git
cd sage
MAKE='make -j8' make
```

- Run on your computer without installation: **Sage Debian Live**
  https://sagedebianlive.metelu.net/
  Bootable USB flash drive with SageMath (boosted with octave, scilab), Geogebra, LaTeX, gimp, vlc, LibreOffice,...
- Open a (free) account on **CoCalc** (*Collaborative Calculations in the Cloud*)
  https://cocalc.com/

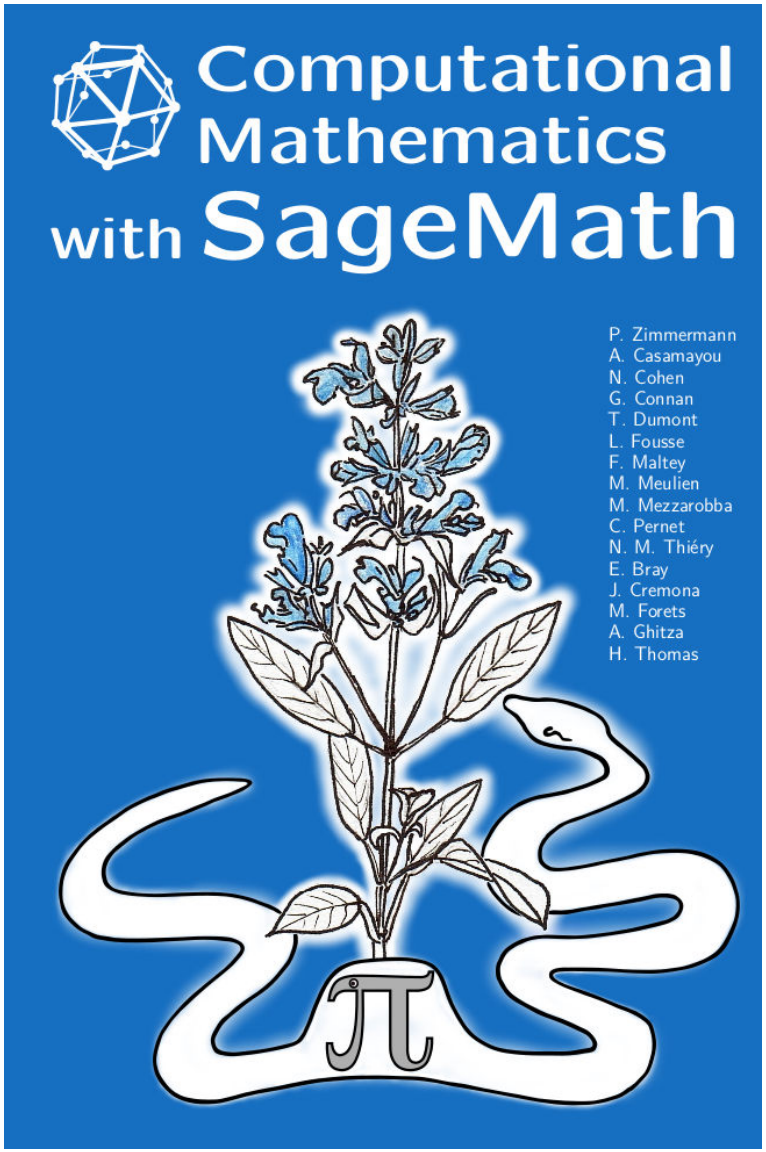
Various ways to install/access SageMath 8.6

- Install on your computer: 2 options:
  - install a compiled binary version for Linux, MacOS X or Windows from http://www.sagemath.org/download.html
  - compile from source (Linux, MacOS X): check the prerequisites (see here for Ubuntu) and run

```
git clone git://github.com/sagemath/sage.git
cd sage
MAKE='make -j8' make
```

- Run on your computer without installation: **Sage Debian Live**
  https://sagedebianlive.metelu.net/
  Bootable USB flash drive with SageMath (boosted with octave, scilab), Geogebra, LaTeX, gimp, vlc, LibreOffice,...
- Open a (free) account on **CoCalc** (*Collaborative Calculations in the Cloud*)
  https://cocalc.com/
- Run in **SageMathCell**
  Single cell mode: https://sagecell.sagemath.org/

The Sage book



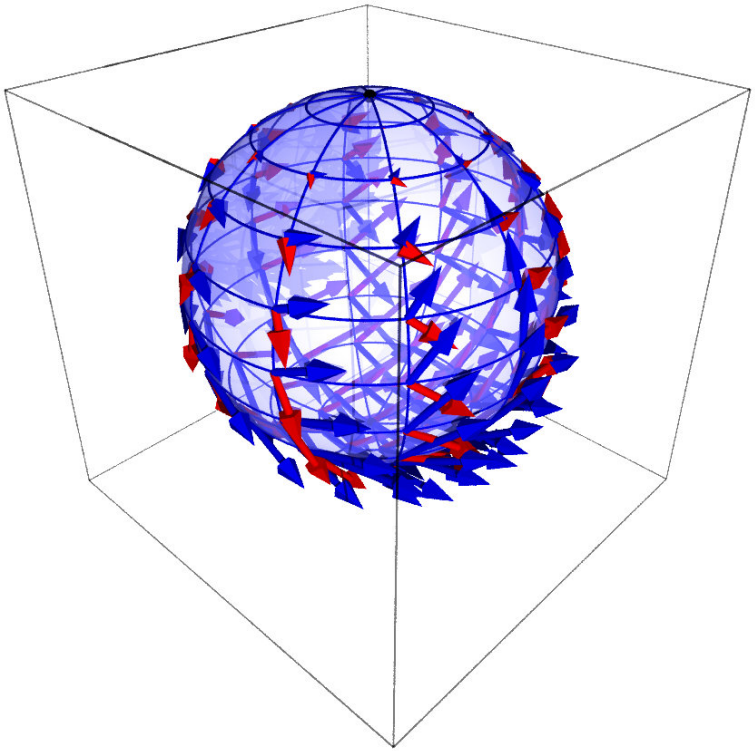
by P. Zimmermann, A. Casamayou, N. Cohen, G. Connan, T. Dumont, L. Fousse, F. Maltey, M. Meulien, M. Mezzarobba, C. Pernet, N.M. Thiéry, E. Bray, J. Cremona, M. Forets, A. Ghitza & H. Thomas (2018)

Released under *Creative Commons* license

Freely downloadable from
http://sagebook.gforge.inria.fr/english.html

Tensor calculus with SageMath

SageManifolds project: extends SageMath towards **differential geometry** and **tensor calculus**



Stereographic-coordinates frame on $\mathbb{S}^2$

- https://sagemanifolds.obspm.fr
- fully included in SageMath (through a review process, see the Trac page)
- a dozen of contributors (developers and reviewers)
  cf. http://sagemanifolds.obspm.fr/authors.html
- want to stay tuned: subscribe to the mailing list
- help: https://ask.sagemath.org

Everybody is very welcome to contribute:
visit https://sagemanifolds.obspm.fr/contrib.html

Short demos

- Schwarzschild spacetime:
  https://nbviewer.jupyter.org/github/egourgoulhon/SageMathTour/blob/master/Notebooks/demo_Schwarzschild.ipynb
- More general relativity examples at
  https://luth.obspm.fr/~luthier/gourgoulhon/leshouches18/sage.html
  and https://sagemanifolds.obspm.fr/examples.html
- Generic introductory demos about SageMath (elementary calculus, 2D and 3D plots, solving equations):
  https://github.com/egourgoulhon/SageMathTour/blob/master/README.md