

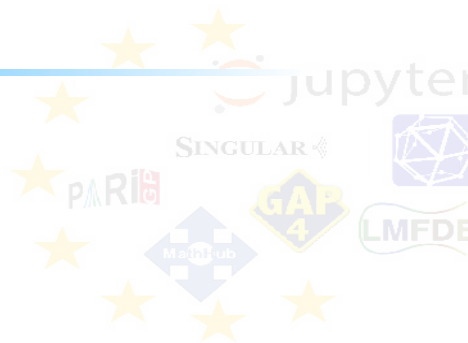


OpenDreamKit: an introduction

Nicolas M. Thiéry

April 25, 2017

Some fundamental trends



Long standing and booming role of computers in pure mathematics

- ▶ **Computer exploration** to discover and check conjectures
- ▶ **Assisted, certified, mechanized proofs:** CoQ, Isabelle, ...
- ▶ **Collaborative work:** Wikipedia, Polymath, ...
- ▶ **Mathematical Knowledge Management**
- ▶ **Education**

Open Science getting momentum

“Open science is the movement to make scientific research, data and dissemination accessible to all levels of an inquiring society, amateur or professional”

- ▶ Open Knowledge (Access, Educational Resources)
- ▶ Open Source or, better, Free Software
- ▶ Open Data
- ▶ Open Peer Review, Methodology, ...

- ▶ At the heart of the scientific method for centuries
no reproducibility without it

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- ▶ At the heart of the scientific method for centuries
no reproducibility without it
- ▶ Finally getting recognition as **viable** and **necessary**,
even by funding agencies!

Emergence of a vibrant ecosystem of free software for pure mathematics

- ▶ **Specialized systems:** LinBox, PARI/GP, MPIR, Singular, ...
- ▶ **General purpose systems:** GAP, SageMath, ...
- ▶ **Online databases:** OEIS, LMFDB, ...
- ▶ **Interactive computing environments:**
Jupyter, SageMathCloud, ...
- ▶ Together with the wider **Scientific Python ecosystem**

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Viable alternatives to Maple, Mathematica, Matlab,...

For research and education (and the industry?)

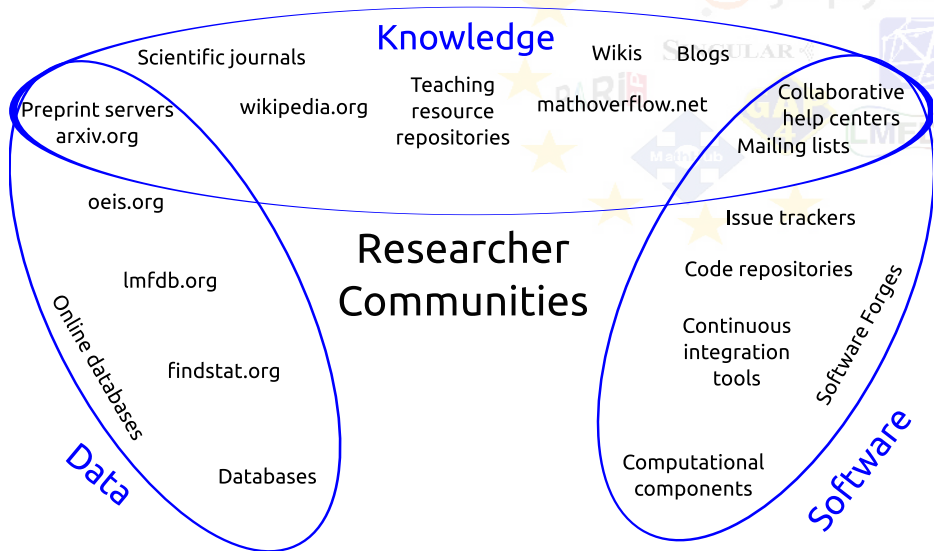
Virtual Research Environments (VRE): the next frontier?

H2020 European Research Infrastructures Work Programme

*“Groups of researchers, typically widely dispersed who are working together through ubiquitous, trusted and easy access to services for scientific data, computing, and networking, in a **collaborative virtual environment** “*

A useful VRE for mathematics?

Mathematicians are already immersed in many VREs

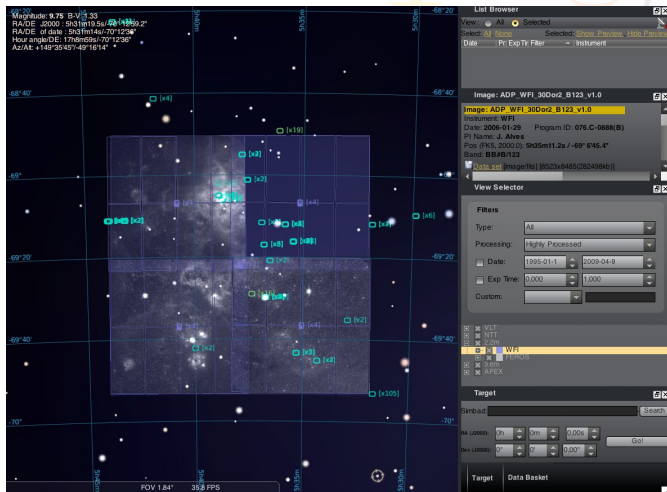


A workflow based VRE?

The screenshot displays a Virtual Reality Environment (VRE) for astronomy. The main view shows a star field with a grid overlay. The grid is labeled with coordinates: RA (Right Ascension) and Dec (Declination). The RA values are 30h35m, 30h36m, 30h37m, and 30h38m. The Dec values are 68° 40', 68° 42', 68° 44', 68° 46', 68° 48', 68° 50', 69° 00', 69° 02', 69° 04', 69° 06', 69° 08', 69° 10', 69° 12', 69° 14', 69° 16', 69° 18', 69° 20', 69° 22', 69° 24', 69° 26', 69° 28', 69° 30', 69° 32', 69° 34', 69° 36', 69° 38', 69° 40'. The FOV (Field of View) is 1.84° and the FPS (Frames Per Second) is 35.8. The image is titled "ADP: WFI_30Dor2_B123_v1.0". The control panel on the right includes a "List Browser" with a "View" dropdown set to "All" and "Selected". The "Image" section shows "Image: ADP: WFI_30Dor2_B123_v1.0" and "Instruments: WFI". The "View Selector" section has "Filters" and "Processing" dropdowns. The "Target" section has a "Search" button and "RA (J2000): 3h 35m 00.00s" and "Dec (J2000): 69° 07' 00.00\"

The Virtual Observatory: a VRE for astronomy

A workflow based VRE?



The Virtual Observatory: a VRE for astronomy

Could cover only a fragment of mathematics

Our requirements

- ▶ Support a large area of **pure mathematics**

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- ▶ Support a large area of **pure mathematics**
- ▶ Support a large range of users



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- ▶ Support a large range of scales:
 - ▶ A single person installation on a laptop
 - ▶ A collaborative VRE between three researchers, running on their lab's server
 - ▶ A university wide VRE for teaching
 - ▶ A service provided by a grid infrastructure

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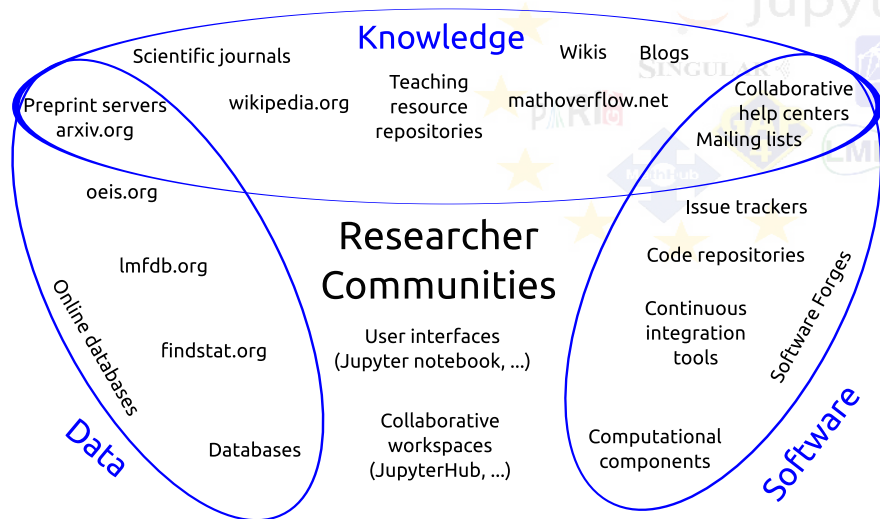
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Just a dream?

OpenDreamKit's proposal



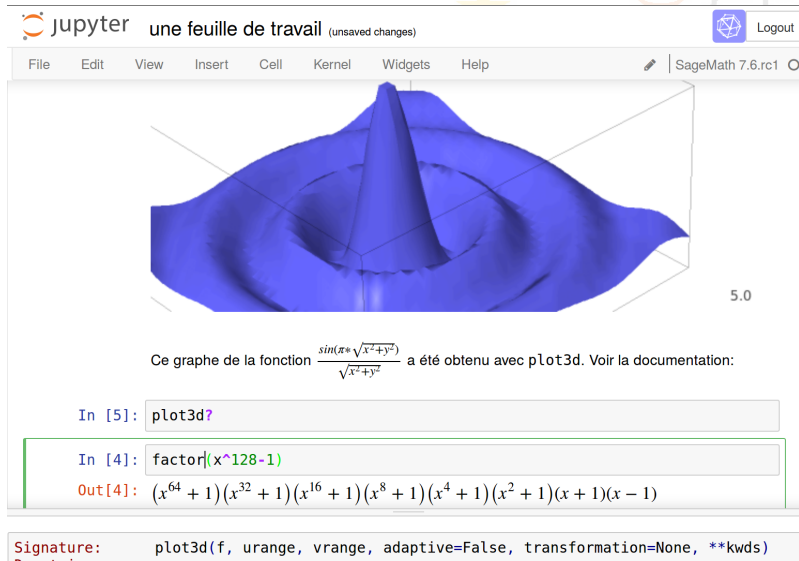
Storage resources
(local, shared folder, cloud)

Computational resources
(local, super computer, cloud)

OpenDreamKit's proposal

- ▶ Deliver a **VRE Toolkit for Mathematics**
- ▶ From the ecosystem of open source software for mathematics
- ▶ And the Jupyter interactive computing environment

The Jupyter interactive computing environment



The screenshot shows the JupyterLab interface. At the top, the Jupyter logo is on the left, followed by the text "une feuille de travail (unsaved changes)". On the right, there is a "Logout" button. Below this is a menu bar with "File", "Edit", "View", "Insert", "Cell", "Kernel", "Widgets", and "Help". To the right of the menu bar, there is a "SageMath 7.6.rc1" indicator. The main area displays a 3D plot of a blue surface with a central peak, resembling a bell curve. The plot is labeled "5.0" in the bottom right corner. Below the plot, there is a text block: "Ce graphe de la fonction $\frac{\sin(\pi \sqrt{x^2+y^2})}{\sqrt{x^2+y^2}}$ a été obtenu avec plot3d. Voir la documentation:". Below this text are three code input boxes. The first box contains "In [5]: plot3d?". The second box contains "In [4]: factor(x^128-1)". The third box contains "Out[4]: (x^64 + 1)(x^32 + 1)(x^16 + 1)(x^8 + 1)(x^4 + 1)(x^2 + 1)(x + 1)(x - 1)". At the bottom, there is a "Signature:" label followed by the code "plot3d(f, urange, vrange, adaptive=False, transformation=None, **kwargs)".

Jupyter une feuille de travail (unsaved changes) Logout

File Edit View Insert Cell Kernel Widgets Help SageMath 7.6.rc1

5.0

Ce graphe de la fonction $\frac{\sin(\pi \sqrt{x^2+y^2})}{\sqrt{x^2+y^2}}$ a été obtenu avec plot3d. Voir la documentation:

In [5]: plot3d?

In [4]: factor(x^128-1)

Out[4]: (x⁶⁴ + 1)(x³² + 1)(x¹⁶ + 1)(x⁸ + 1)(x⁴ + 1)(x² + 1)(x + 1)(x - 1)

Signature: plot3d(f, urange, vrange, adaptive=False, transformation=None, **kwargs)

Proof of concepts VREs built from the same ecosystem

SageMathCloud

- ▶ A web service launched in 2013
- ▶ Widely adopted
- ▶ For teaching, for research



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Simulagora, tmpnb, mybinder, ...



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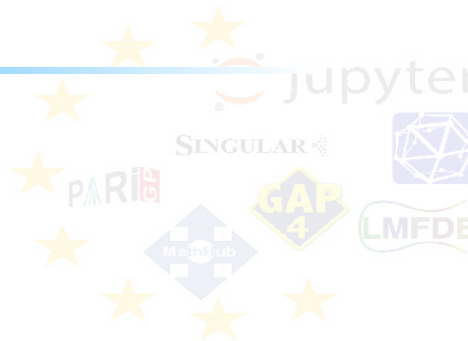
Prove that

- ▶ The ecosystem is mature
- ▶ This kind of VRE fulfills a strong need



Added values of our approach

- ▶ **Modular**



Added values of our approach

- ▶ **Modular**
- ▶ Joining forces with the wider scientific computing community

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- ▶ **Sustainable**



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- ▶ **Sustainable**
- ▶ Lowers the software barrier between pure and applied maths

Added values of our approach

- ▶ **Modular**
- ▶ Joining forces with the wider scientific computing community
- ▶ **Sustainable**
- ▶ Lowers the software barrier between pure and applied maths
- ▶ Impact way beyond pure maths

Open Digital Research Environment Toolkit for the Advancement of Mathematics

- ▶ OpenDreamKit.org
- ▶ H2020 European Research Infrastructures Work Programme
Call: Virtual Research Environments
- ▶ Budget: 7.6M€
- ▶ 18 sites, 50 participants
- ▶ In close collaboration with the international community!

A user-driven consortium

European **power users** and **core developers** of the ecosystem of open source software for Mathematics:

- ▶ GAP (St Andrews, Oxford)
- ▶ Linbox (Grenoble)
- ▶ PARI/GP (Bordeaux, Versailles)
- ▶ SageMath (Bordeaux, Grenoble, Paris Sud, Oxford, Versailles)
- ▶ Singular (Kaiserslautern)
- ▶ LMFDB (Warwick, Zürich)
- ▶ MathHub, MMT/OpenMath (Bremen)
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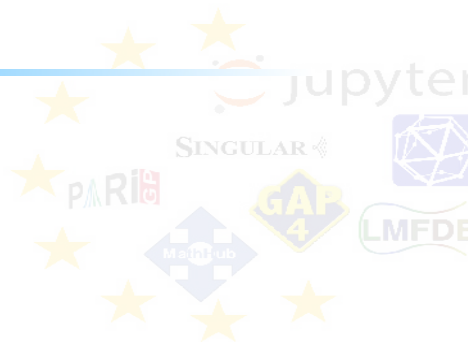
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- ▶ Jupyter (Simula)
- ▶ Scientific Python (SouthHampton, Sheffield, Silesia)

Supported by:

- ▶ Research Software Engineers
- ▶ An open source based company (Logilab)

Open from the ground up

- ▶ Free software
- ▶ Open data
- ▶ Open source publications



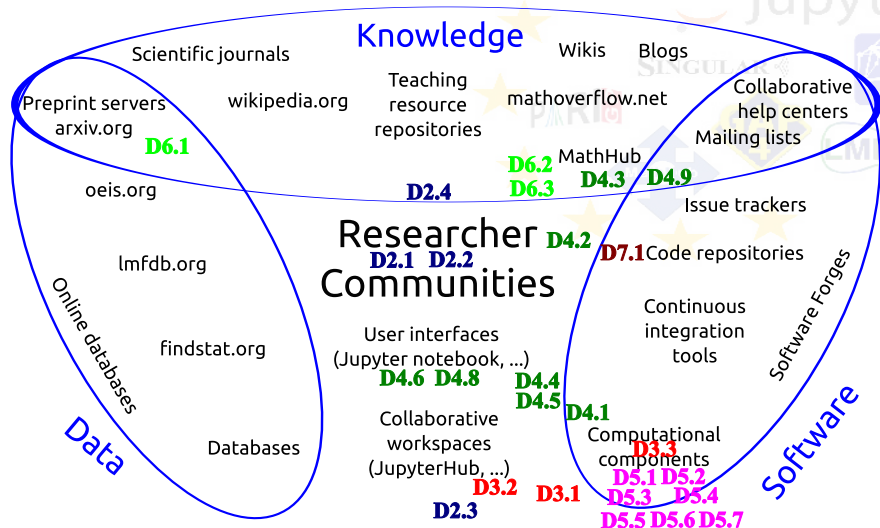
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- ▶ Open source publications
- ▶ **Open proposal!**



- ▶ Improve the productivity of researchers in pure mathematics and applications by further promoting collaborations on **Data, Knowledge, and Software**
- ▶ Make it easy for teams of researchers of any size to set up custom, collaborative **Virtual Research Environments** tailored to their specific needs, resources and workflows
- ▶ Support the entire life-cycle of computational work in mathematical research, from **initial exploration** to **publication, teaching, and outreach**

How to get there?



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