

Virtual Observatory: an Astronomy's answer to Big Data

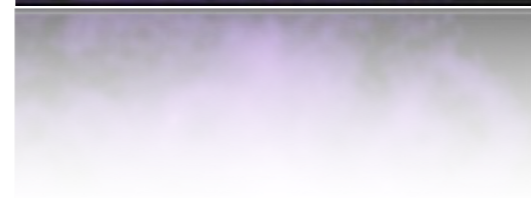
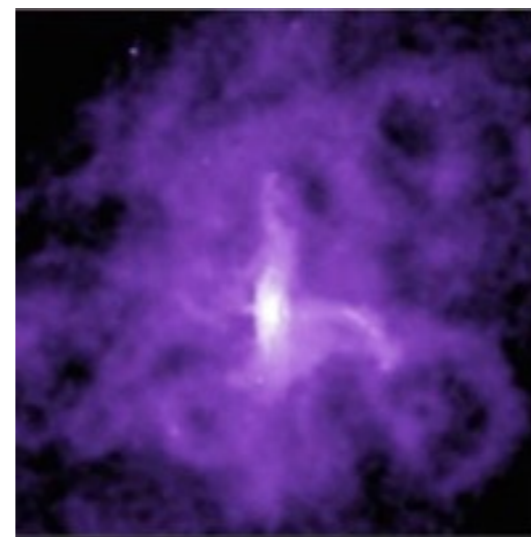
by Paula Coelho, IAG/USP

on behalf of



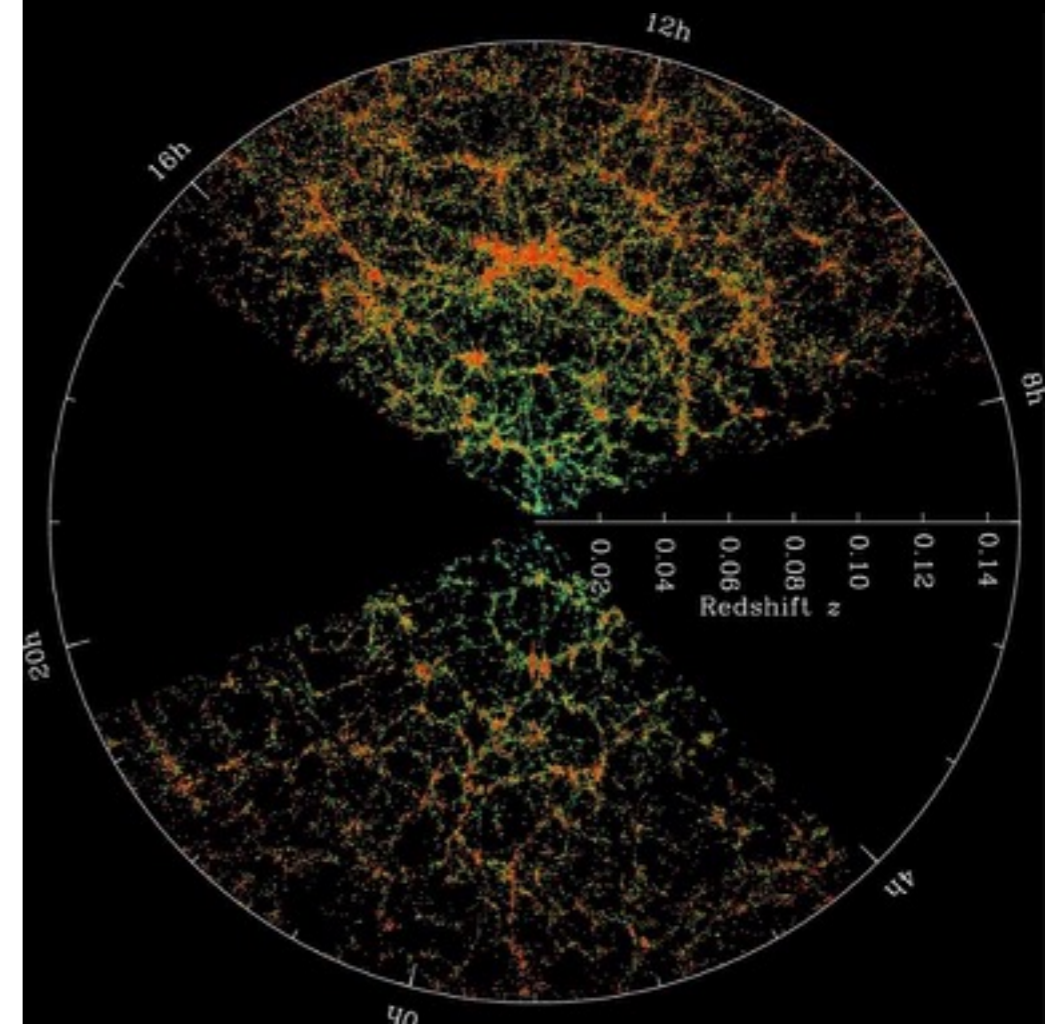
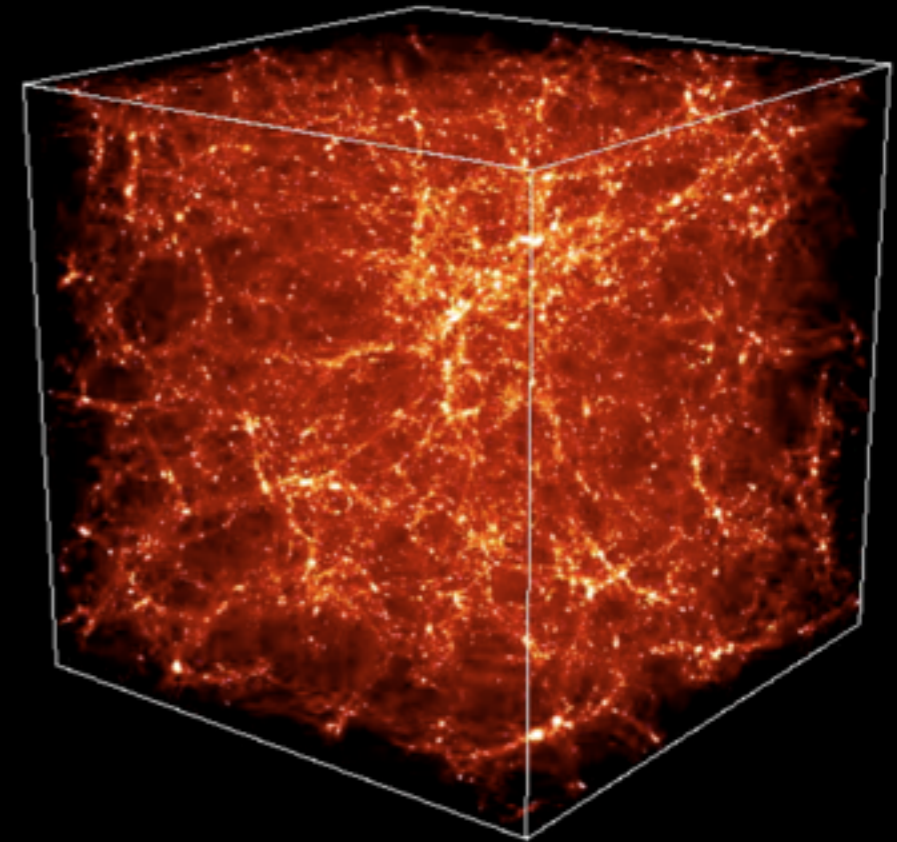
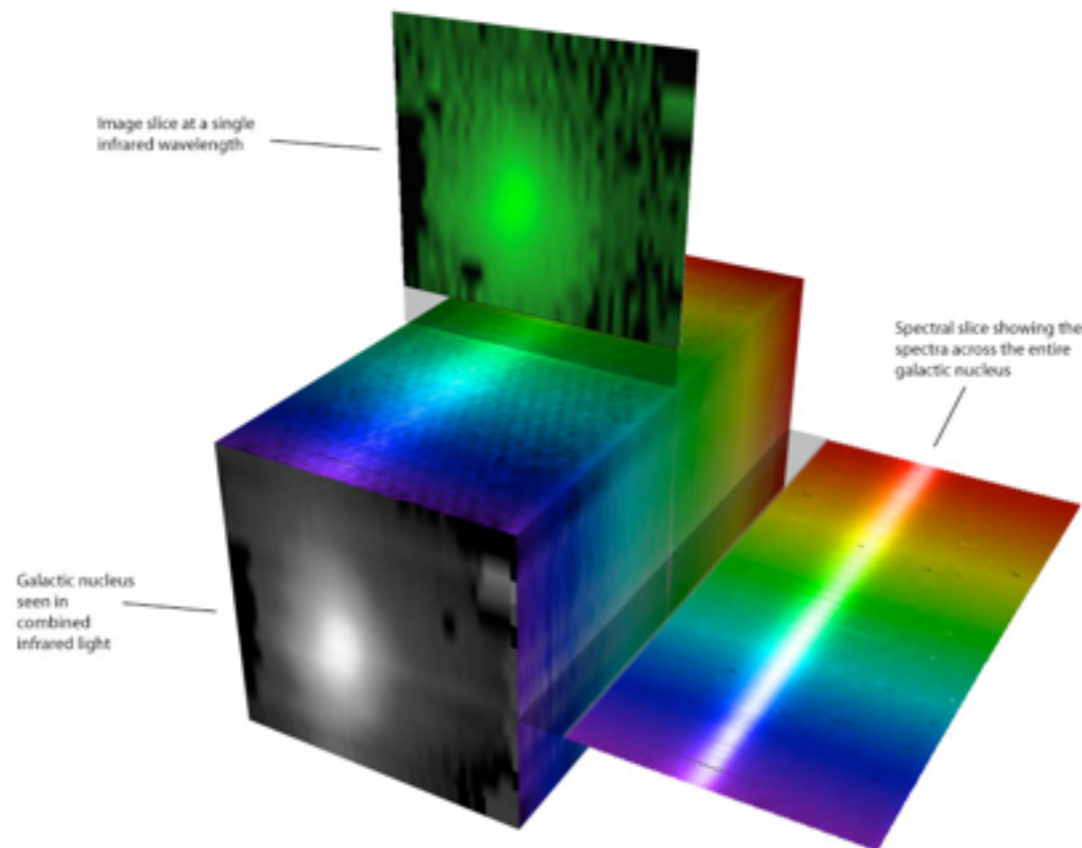
A new era in astronomy

- Past: observations of small, carefully selected samples (often with a priori prejudices) of objects in one or a few wavelength bands



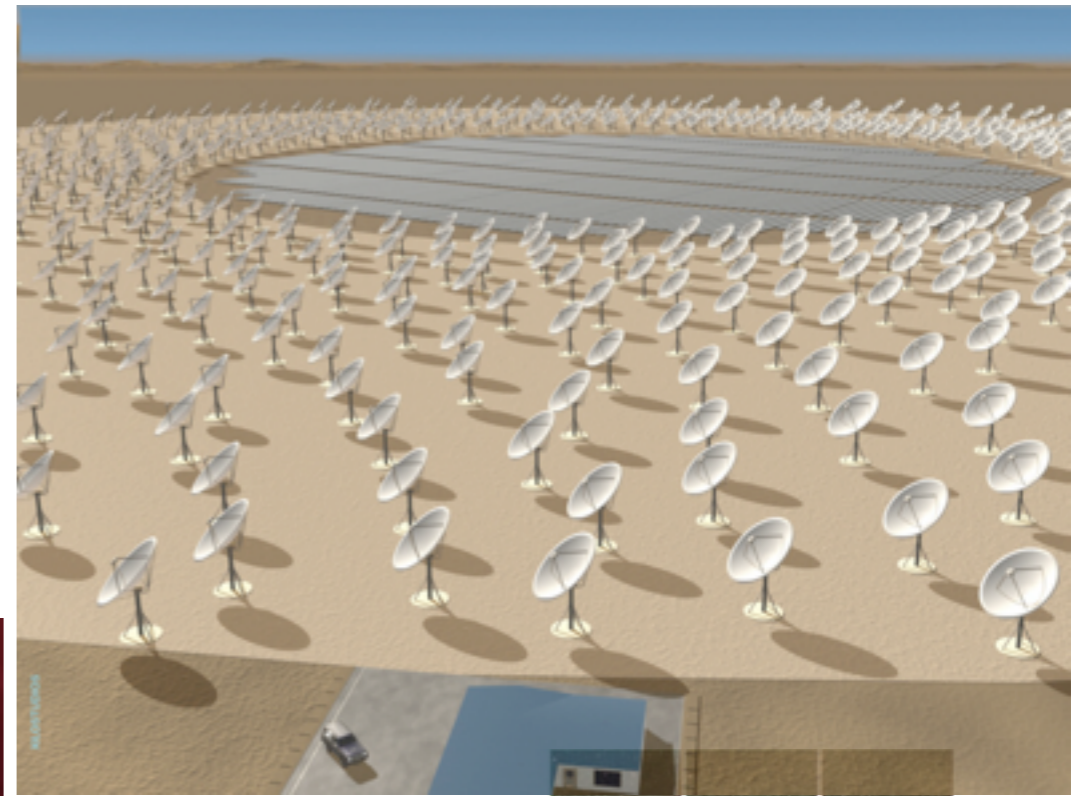
A new era in Astronomy

- Now: multi-wavelength data for millions of objects, allowing us to:
 - **discover** significant patterns from the analysis of statistically rich and unbiased databases
 - **understand** complex astrophysical systems via confrontation between data and sophisticated numerical simulation

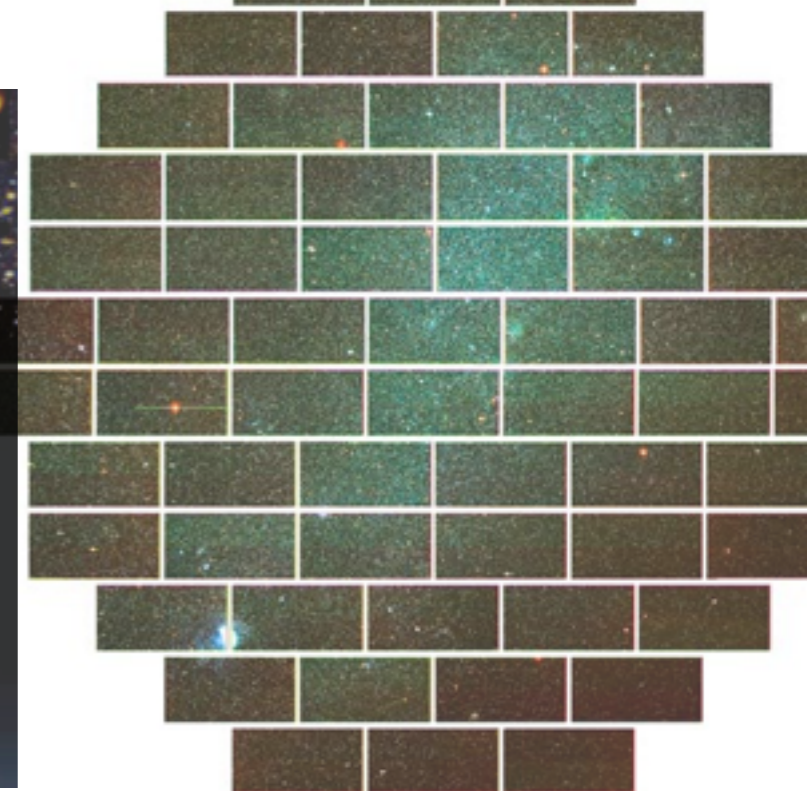
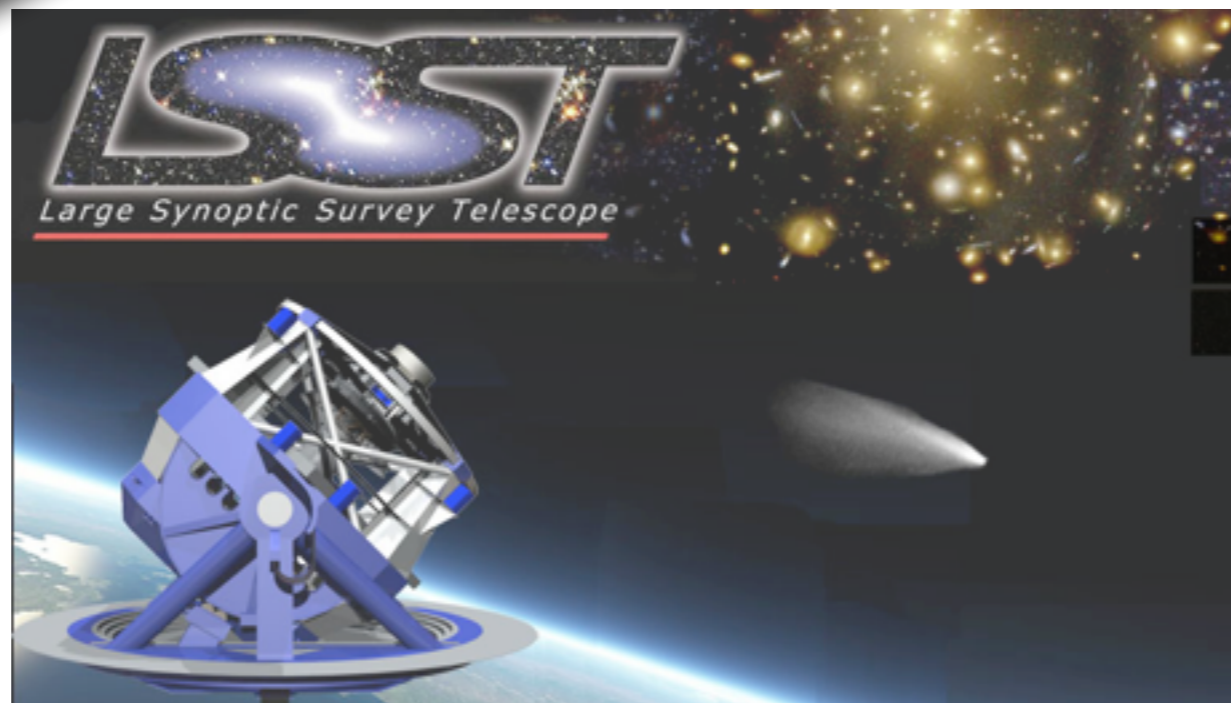


Survey Science: Big Data in Astronomy

SDSS, DES, J-PAS,
LSST, Gaia, SKA...



Exploding Data Rates

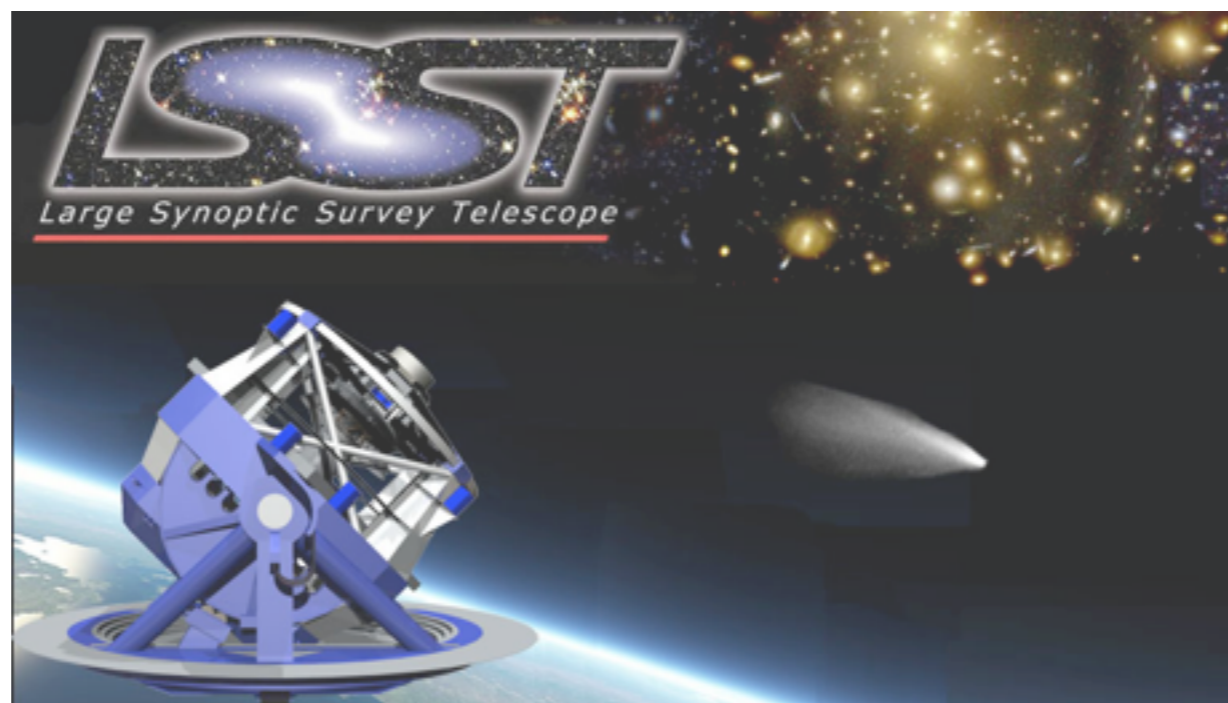


Survey science: Big Data in Astronomy

The Large Synoptic Survey Telescope (LSST) is a planned wide-field survey that will observe the entire available sky every few nights.

15 TB/night, 7 PB/year, 200 PB total, ~1M transient events/night

(in comparison, SDSS 170 GB/night)



And the scary future... SKA



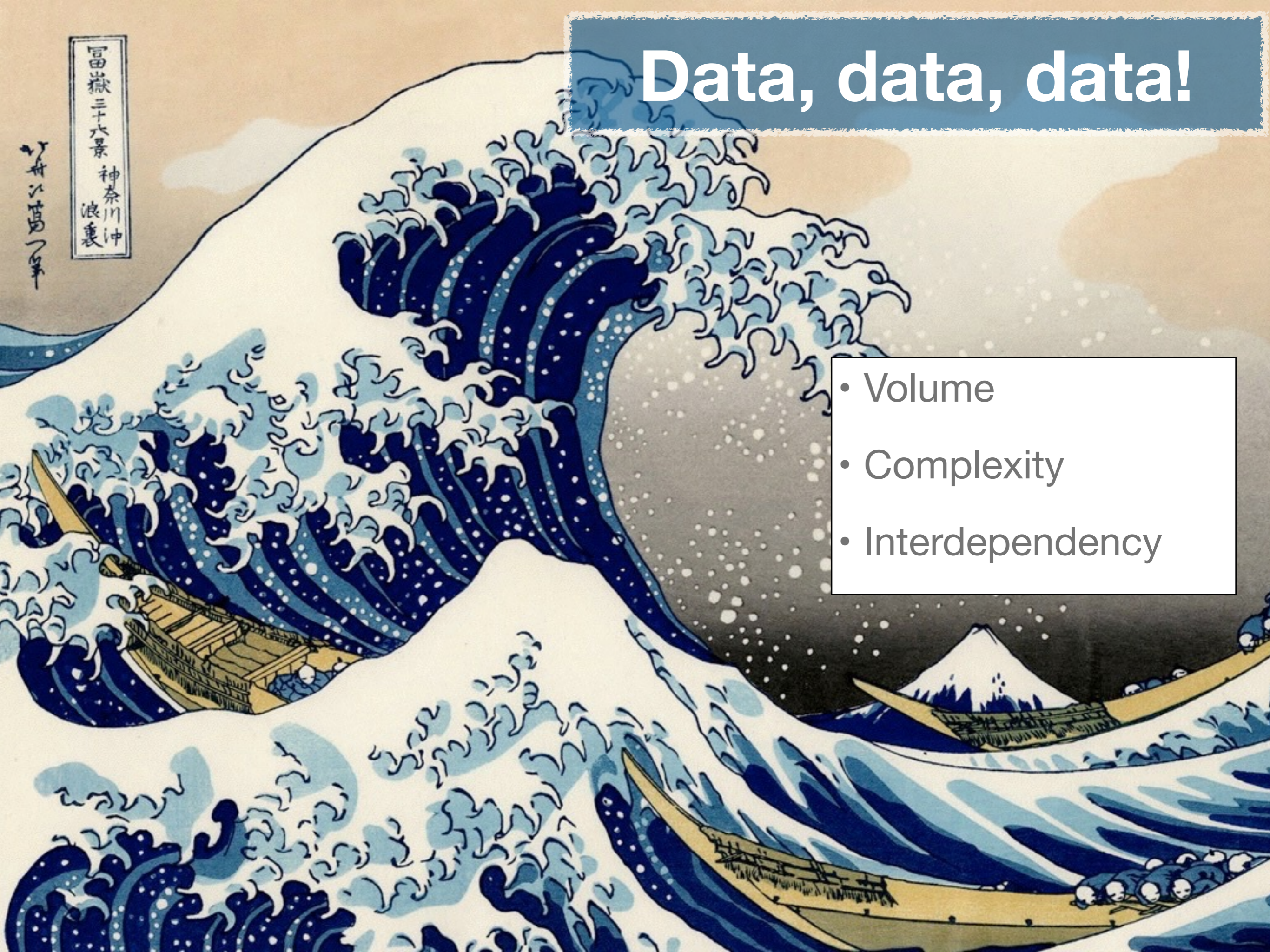
The Square Kilometre Array is a project to build a radio telescope tens of times more sensitive and hundreds of times faster at mapping the sky than today's best radio astronomy facilities.

1 exabyte of raw data in a single day; more than the entire daily Internet traffic!!

What do these projects have in common?

Data, data, data!

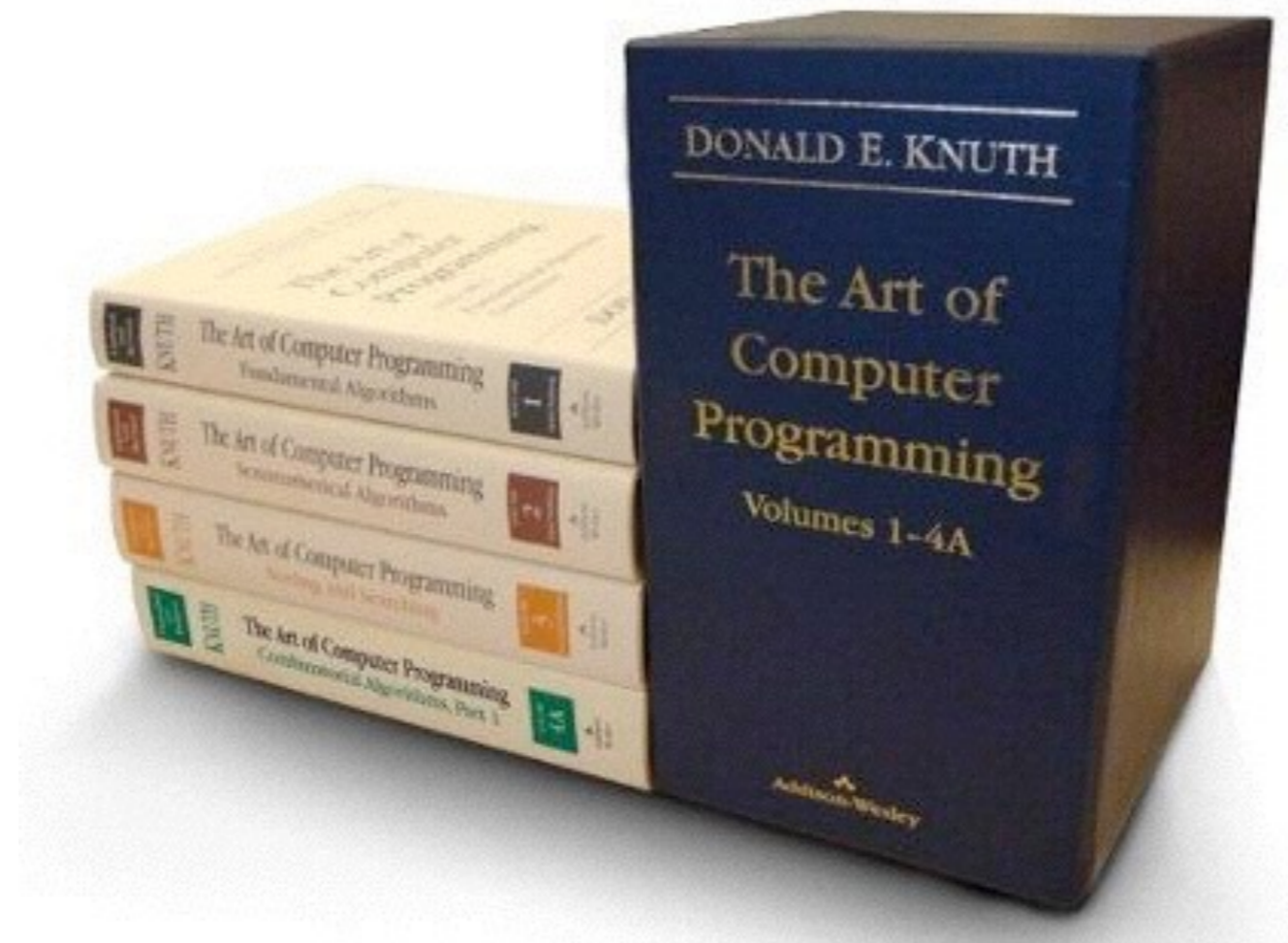
- Volume
- Complexity
- Interdependency



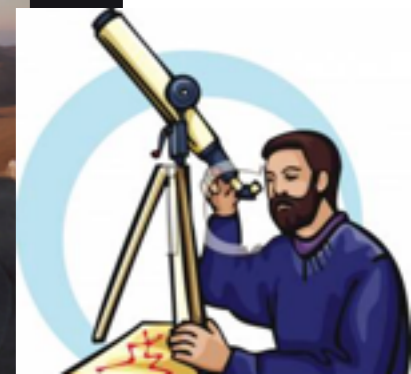
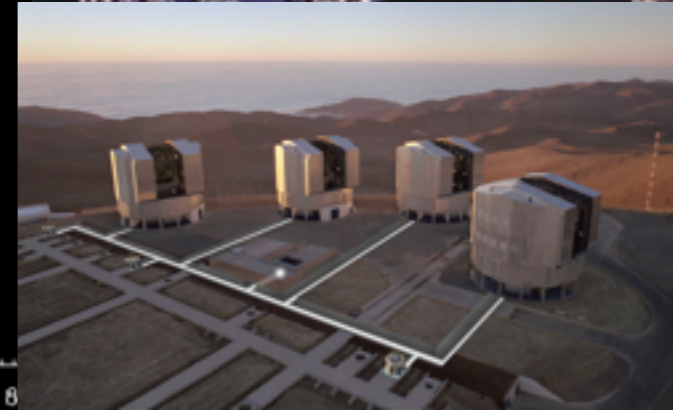
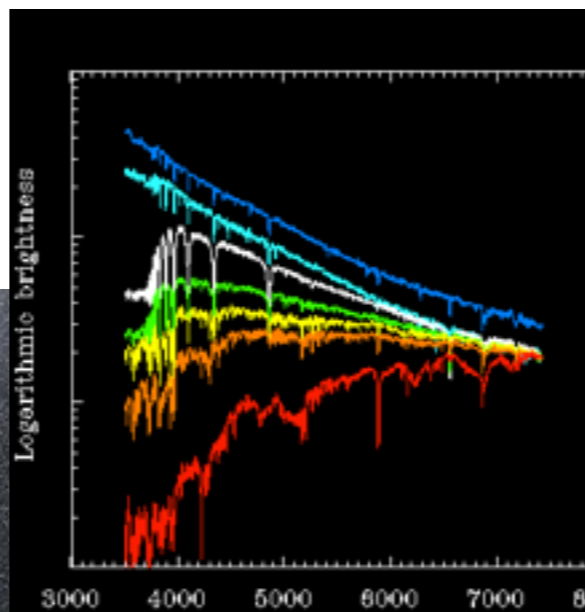
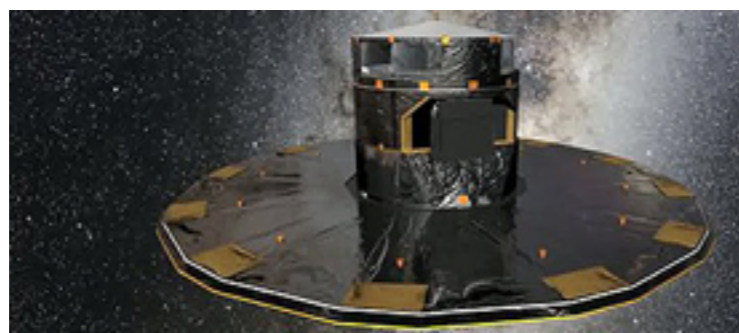
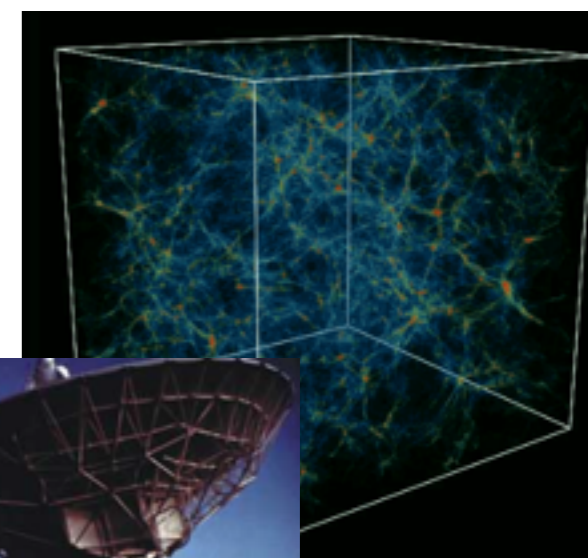
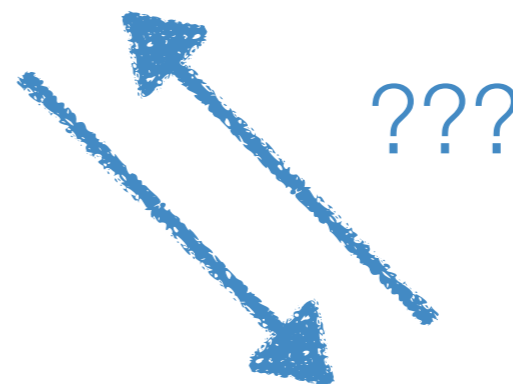
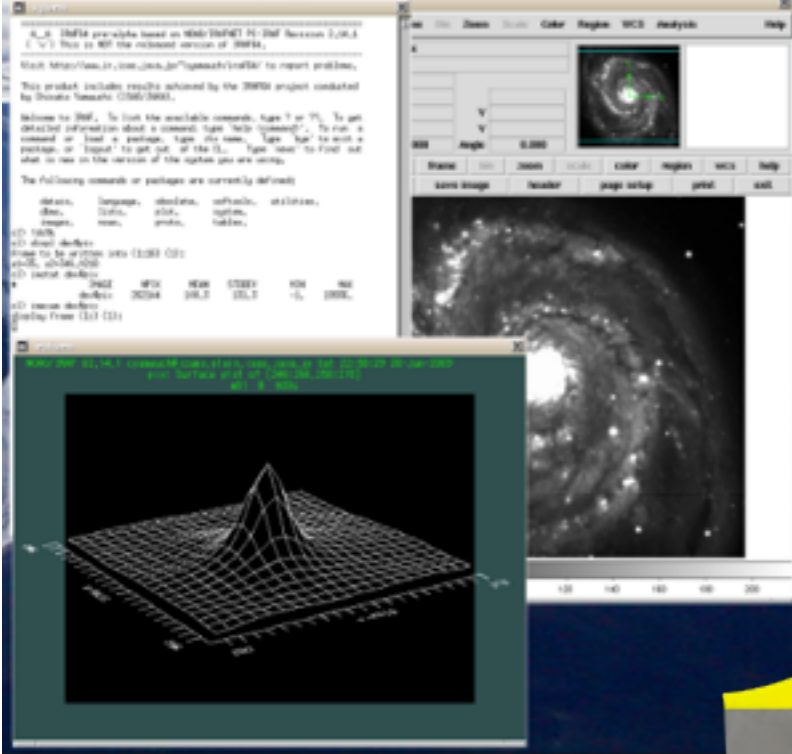
富嶽三十六景 神奈川沖
浪裏

舟の島の一景

But with data...



should come the software!



Data – Software

DATA

**The language in which
we register Nature
(even if simulated!)**

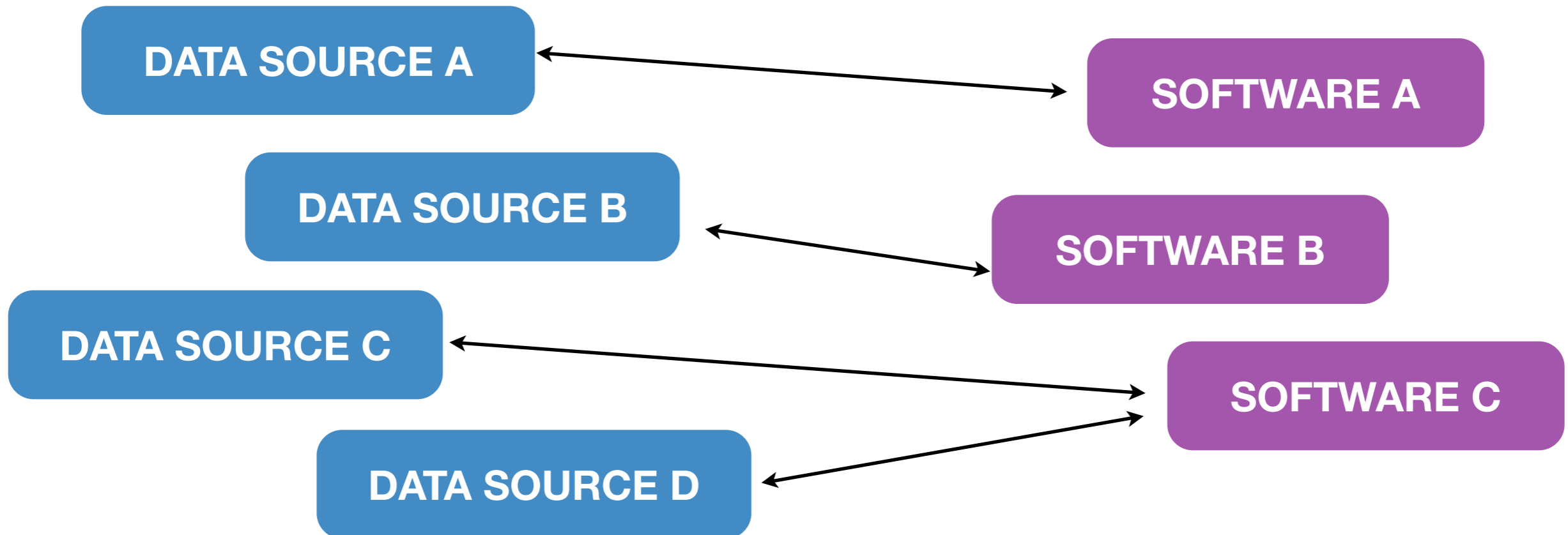
SOFTWARE

**The language in which
we interpret Nature
(even if simulated!)**

Data – Software

DATA
The language in which
we register Nature
(even if simulated!)

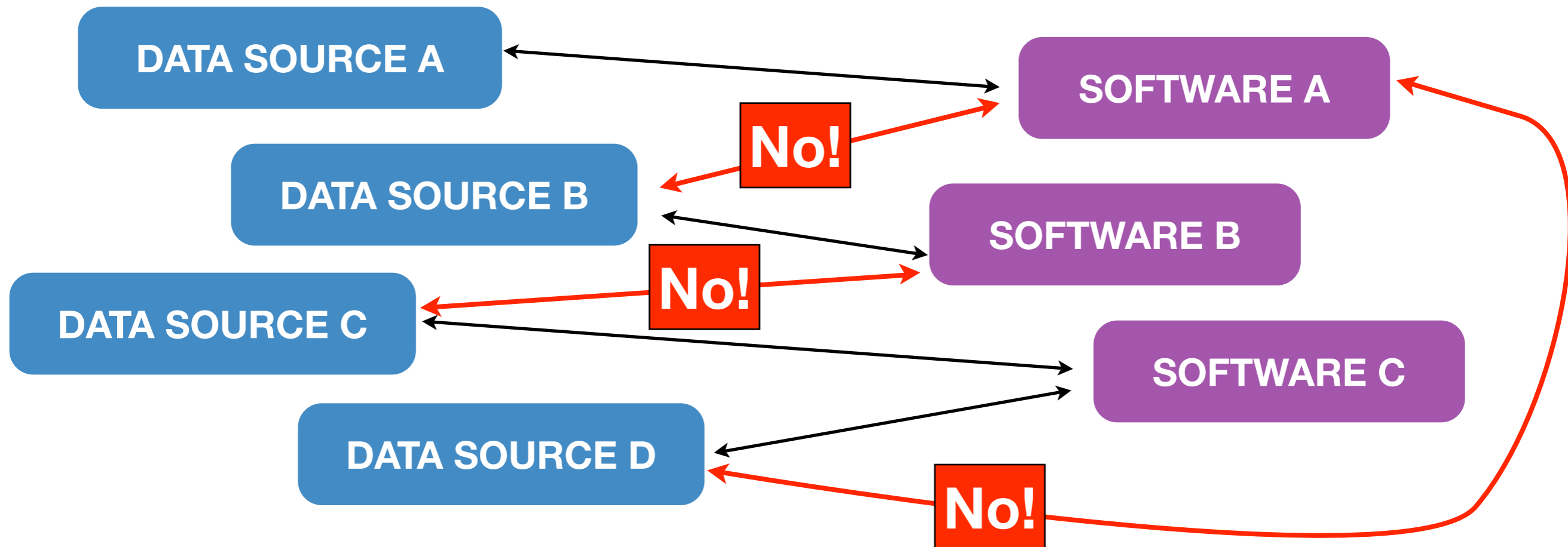
SOFTWARE
The language in which
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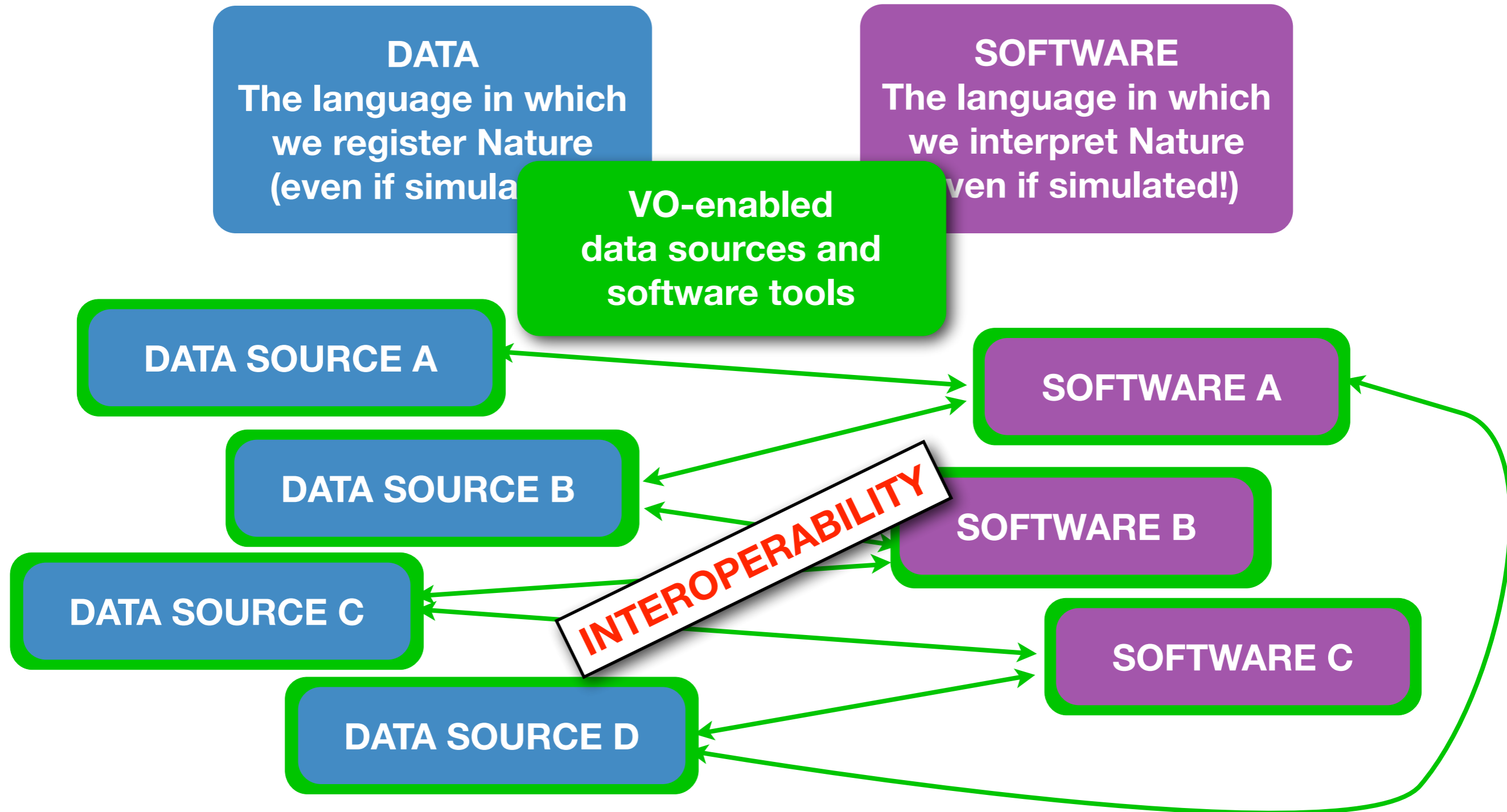
Data – Software

DATA
The language in which we register Nature (even if simulated!)

SOFTWARE
The language in which we interpret Nature (even if simulated!)



Data – Software



The Virtual Observatory (VO) is ...

- **the vision** that astronomical datasets and other resources should work as a seamless whole (IVOA)
- **a collection of interoperating data archives and software tools** which utilize the internet to form an environment in which astronomical research projects can be conducted (Wiki)
- a data discovery, access, and integration **facility** (B. Hanisch)

The Virtual Observatory (VO)

It provides a **common language** (standards, protocols, data models etc.) for communicating and exchanging data within Astronomy, and indicate where the data is stored!

Goal: To enable science! **Transparent and distributed access to data available worldwide**, allowing scientists to discover, access, analyze, and combine nature and lab data from **heterogeneous data collections** in a **user-friendly** manner.

An ambitious goal and no pre-existing model to follow...

IVOA



Global interoperability means world-wide agreement

Many projects and data centres worldwide are working towards this goal since 2002.

The **I**VOA is a standards body created by the VO projects to develop and agree the vital interoperability standards upon which the VO implementations are constructed.

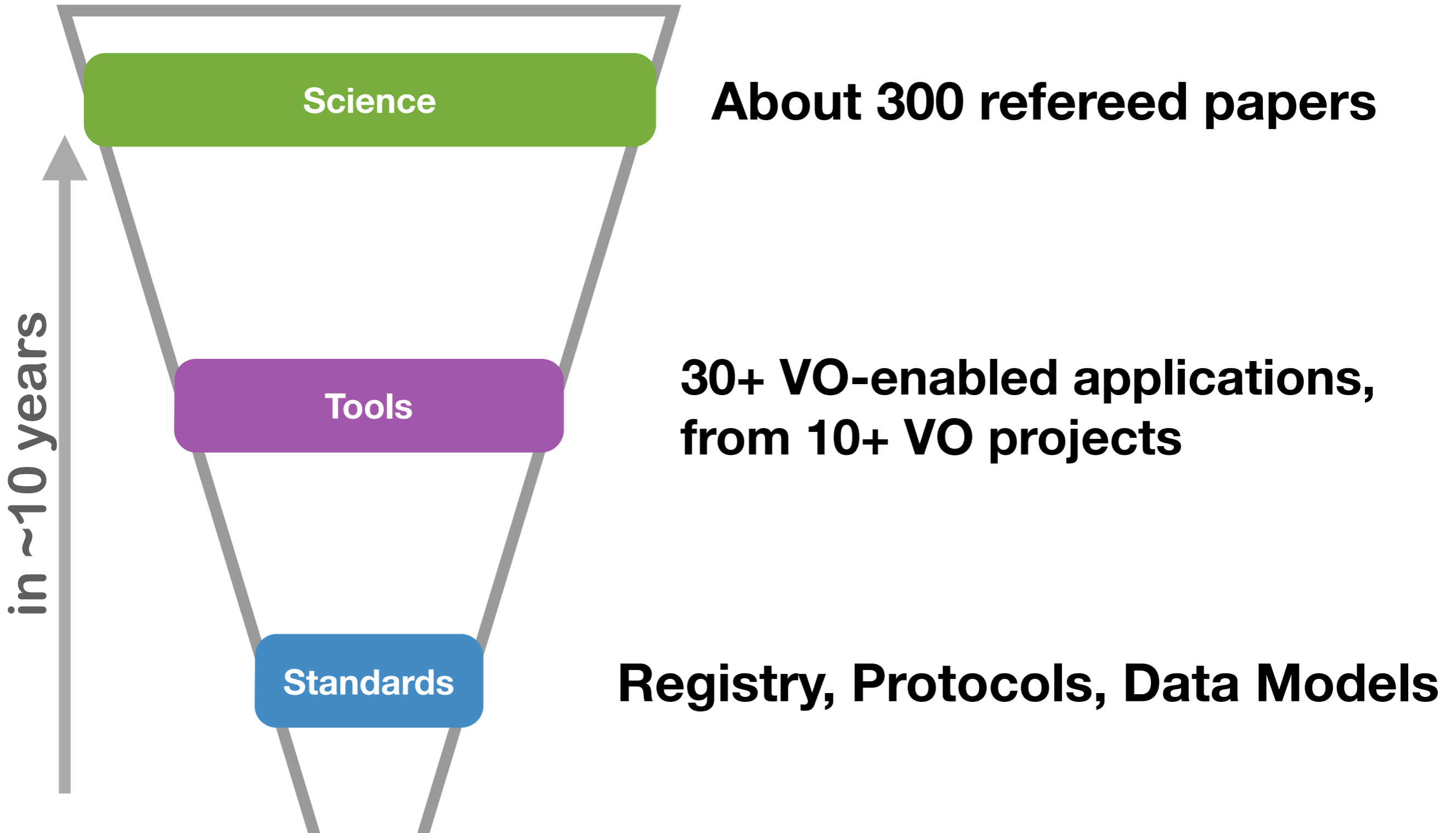


International **V**irtual **O**bservatory **A**lliance

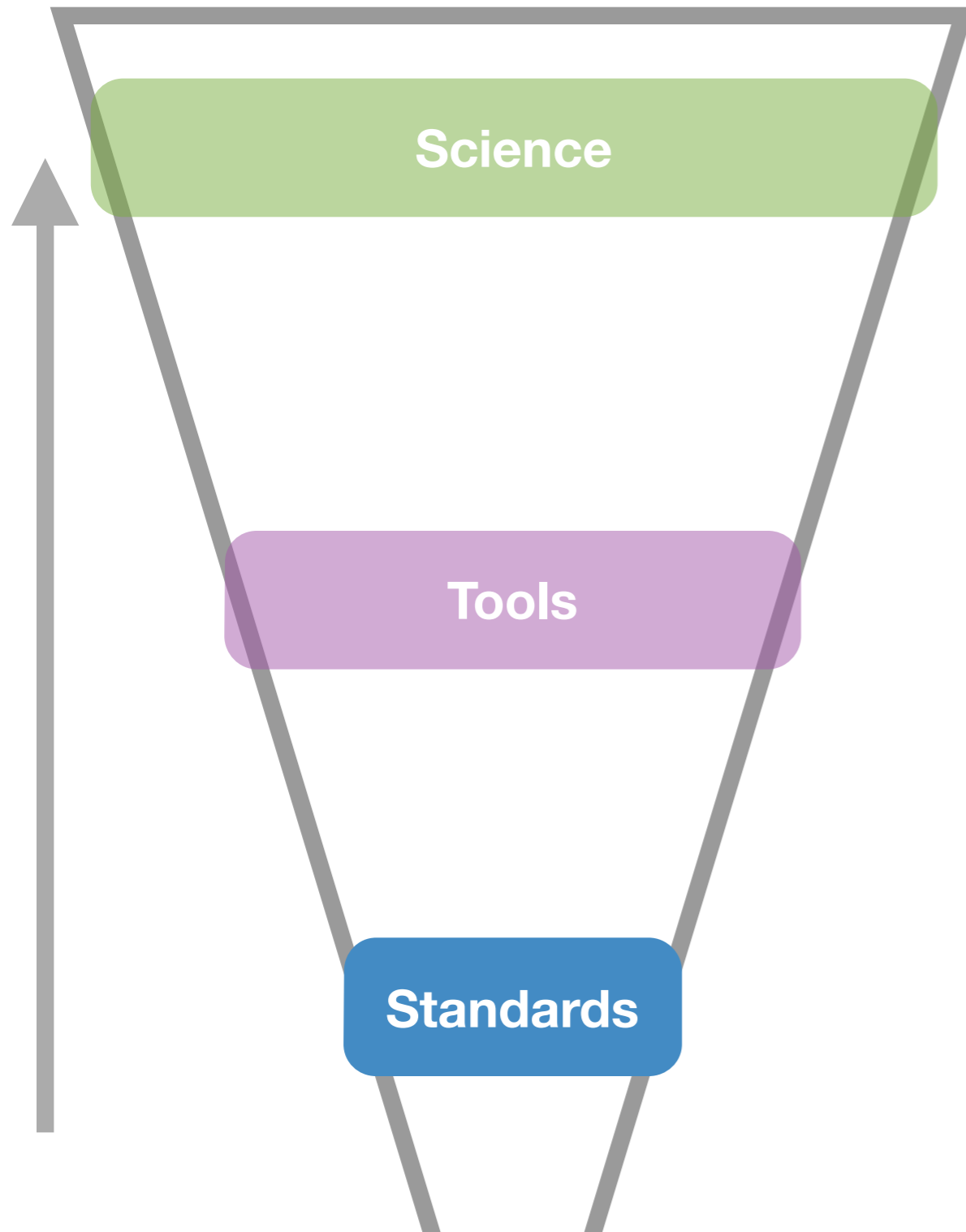
<http://www.ivoa.net>

17 country members + 2 institutions

VO: bottom-up approach



VO: bottom up approach

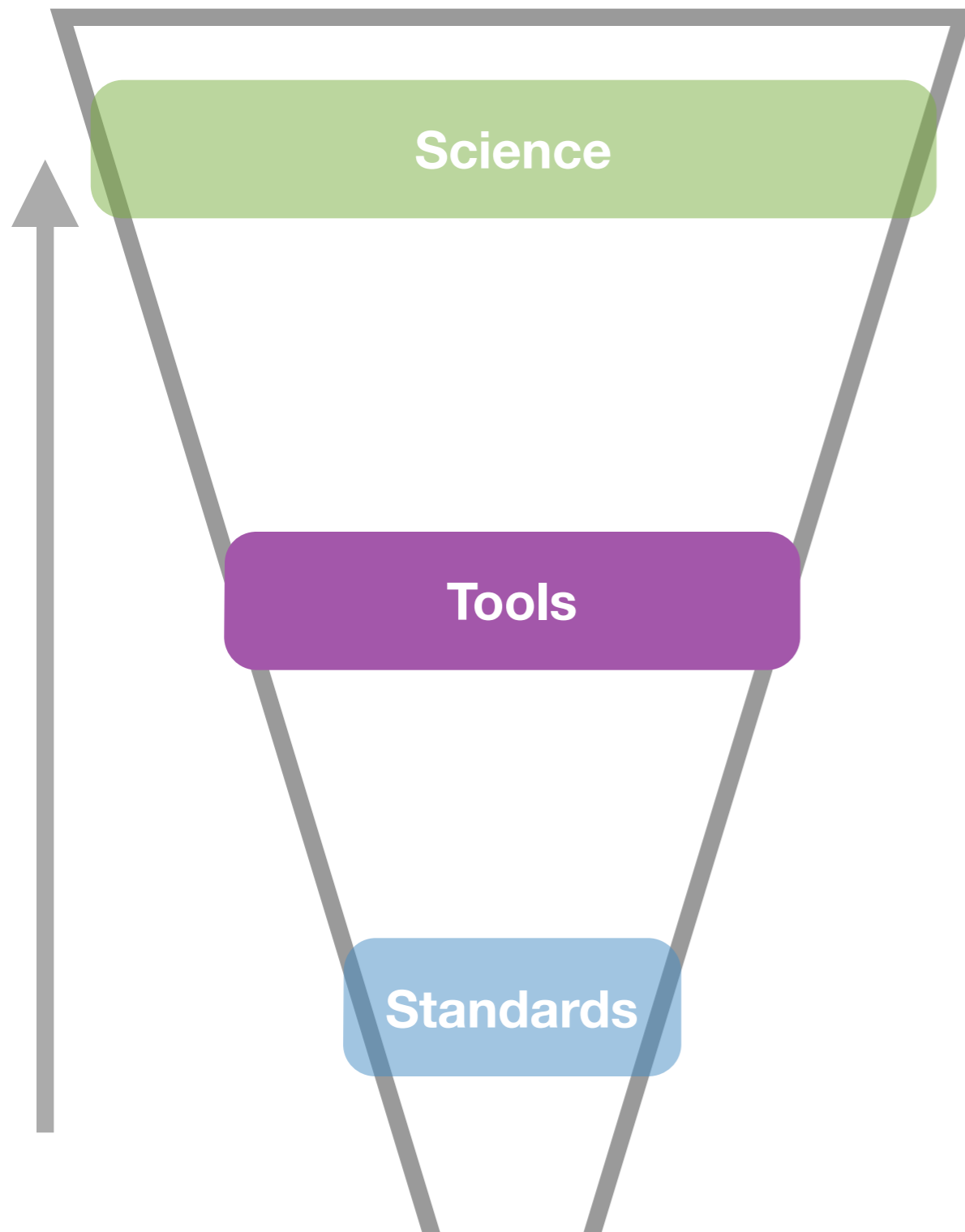


**Registry, Protocols
and Data Models**

**Core standards
established**

**Priorities now on
multi-dimensional data
and time domain
astronomy**

VO: bottom up approach



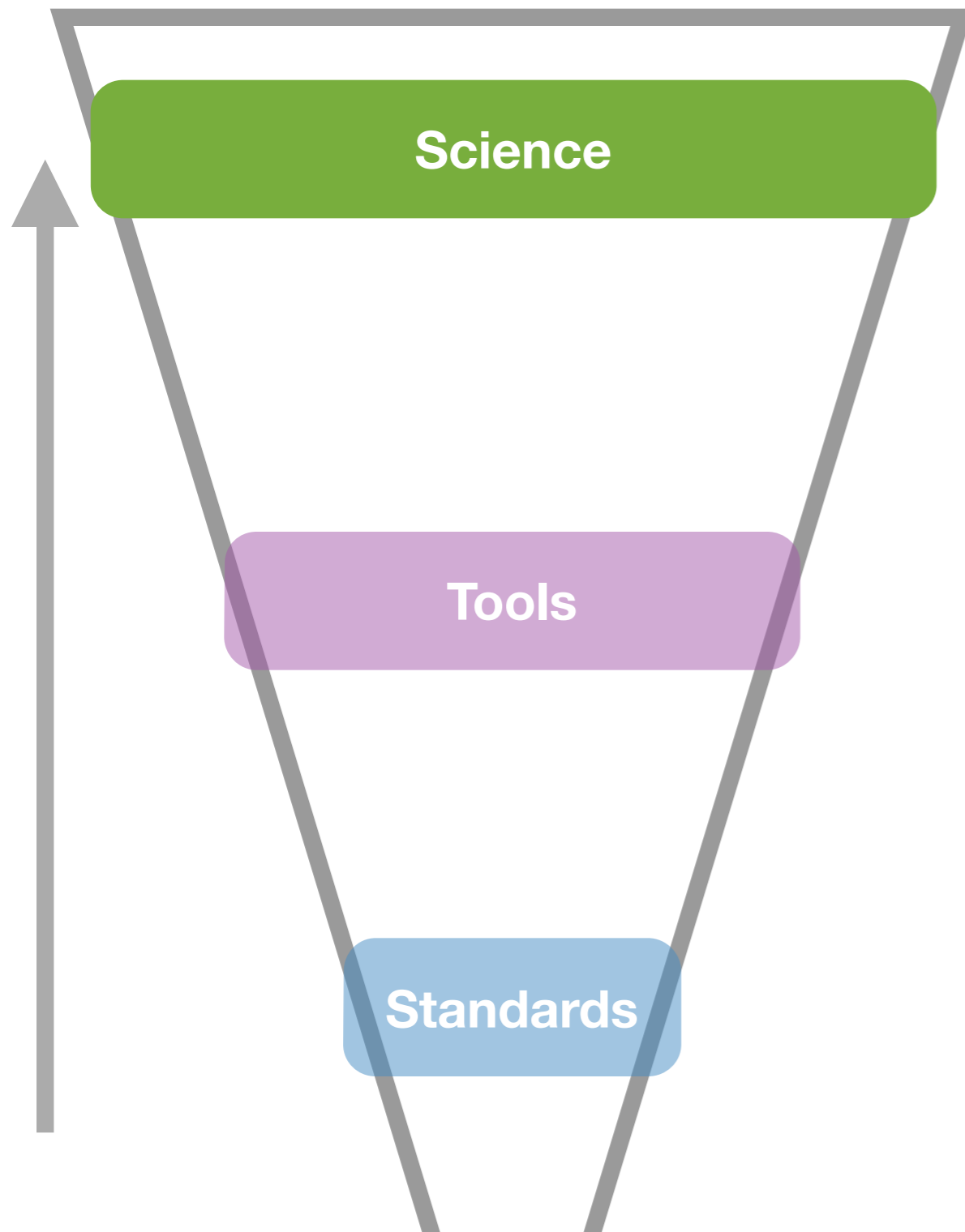
30+ VO-enabled applications, from 10+ VO projects

Many with hundreds of downloads

Web apps used frequently

Many users are unaware that data requests are being handled by VO services

VO: bottom up approach



About 300 refereed papers, several of them with innovative ways

Part of Astronomer's everyday tool kit

'VO' not well cited, but tools are!

Really is just the beginning...

scolps.esa.int

Research & Science Home | ESA Public Web Site | Sci-Tech Portal

Research Science Portal

Astrophysics Missions | Planetary Exploration Missions | Solar Terrestrial Science Missions | Fundamental Physics Missions

Science Archives Team

- ESA Science Archives
- People

9-April-2015 23:35:04

odsweb.u-strasbg.fr

Portal | Simbad | VizieR | Aladin | X-Match | Other | Help

Centre de Données astronomiques de Strasbourg
Strasbourg astronomical Data Center

Entry point to all services | Object database | Catalogue database | Interactive sky atlas

Object/position | Obj/position/bibcode | Keywords, target, ... | Object/position

Other services

- X-match
- Dictionary
- Sesame
- SimPlay

Home | About CDS | People | Support | myCDS | Virtual Observatory projects | Authorities | Strasbourg

Science Archives at ESAC

Click on a satellite to visit the mission archive homepage.

- ESA Hubble Science Archive
- EXOSAT Science Archive
- Herschel Science Archive
- ISO Data Archive
- Planck Legacy Archive
- Planetary Science Archive
- SOHO Science Archive
- Ulysses Archive

European Space Astronomy Centre (ESAC) hosts most of ESA astronomy and planetary missions' archives. This currently includes:

- Cluster Science Archive → Cluster Mission
- ESA Hubble Science Archive → HST Mission
- EXOSAT Science Archive → EXOSAT Mission
- Herschel Science Archive → Herschel Mission
- ISO Data Archive → ISO Mission
- Planck Legacy Archive → Planck Mission
- ESA's Planetary Science Archive → (regrouping data from Rosetta, Mars Express, Venus Express, Huygens, Smart-1 and Giotto for the time being)

www3.cadc-coda.hia-ihh.nrc-cnrc.gc.ca

Government of Canada | Gouvernement du Canada

Canada.gc.ca | Services | Departments | Français

Canadian Astronomy Data Centre

Telescope Data Products | Advanced Data Products | Services | Advanced Search | Login

CADC Home

Search for data by target [Search]

[Advanced Search](#)

Telescope Data Products

- Gemini
- CFHT
- JCMT
- HST
- BLAST
- MOST

Advanced Data Products

- MegaPipe
- HLA
- IRIS
- CGPS

Services

- Meetings
- Community
- SSOIS
- CAN FAR
- CANFAR

And future surveys, such as J-PAS and Gaia

The VO concept elsewhere

- Space Science
 - Virtual Heliophysics Observatory (HELIO)
 - Virtual Radiation Belt Observatory (ViRBO)
 - Virtual Space Physics Observatory (VSPO)
 - Virtual Magnetospheric Observatory (VMO)
 - Virtual Ionosphere Thermosphere Mesosphere Observatory (VITMO)
 - Virtual Solar-Terrestrial Observatory (VSTO)
 - Virtual Sun/Earth Observatory (VSEO)
- Virtual Solar Observatory
- Planetary Science Virtual Observatory
- Deep Carbon Virtual Observatory

And currently this model is being exported to the National Institute of Standards and Technology (NIST) and to Neurosciences



BRAVO

- BRazilian Astrophysical Virtual Observatory
- 2006: BRAVO is born as a collaboration between **Divisão de Astrofísica** and **Laboratório de Computação @ INPE**
- 2009: BRAVO becomes IVOA partner and associate with INCT-A
- 2015: team 6 integrants and 5 collaborators <http://bravo.iag.usp.br>

**Would you like to join us?
Let me know!**

Mission

- To **stimulate** and to **encourage** the **projects** of the different local groups, facilitating the necessary coordination and collaboration for the **development and deployment** of the tools, systems, and organizational structures;
- To **organize workshops and schools** aiming at the dissemination of the VO concepts and the qualification of people capable to use and to work on the development of new VO services and tools;
- To **act as a partner of the IVOA** and as an intermediate between the IVOA and the various Brazilian groups working with VO.

To organize workshops and schools aiming at the dissemination of the VO concepts

2011

I Workshop de Computação Científica em Astronomia

2 A 5 DE JUNHO DE 2011
NÚCLEO DE ASTROFÍSICA TEÓRICA
UNIVERSIDADE CRUZEIRO DO SUL
(SAO PAULO - SP)

PROGRAMA MINICURSOS

- SIMULAÇÕES NUMÉRICAS PARA ASTRONOMIA (Diego Falco-Goncalves (EACH))
- INTRODUÇÃO A COMPUTAÇÃO ESTATÍSTICA EM ASTRONOMIA (Hektor Monteiro (UNFIC))
- PROGRAMAÇÃO PARA GPU (Ricardo Farias (COPPE UFRJ))
- INTRODUÇÃO A VETORIZAÇÃO, MPI E OPENMP (Paulo Penteado (IAS))

PALESTRAS CONVIDADAS

- VISUALIZAÇÃO AVANÇADA DE DADOS (Gregorz Kowal (IAG))
- TÓPICOS E DESAFIOS EM COSMOLOGIA COMPUTACIONAL (Reinaldo Rosa (LAC - INPE))
- PROCESSAMENTO DE IMAGENS (Daniel Nicolato (IN))
- RESTAURAÇÃO DE IMAGENS SOB BAIXA CONTAGEM DE FOTONS (Nelson Mascarenhas (UFSCar))
- PCA EM ASTRONOMIA (João Steiner (IAS))
- INTRODUÇÃO A GRID / CLOUD COMPUTING (Alberto Krone-Martins (IAG))
- BANCOS DE DADOS EM ASTRONOMIA (William Schoenel (UFSC))
- OBSERVATORIO VIRTUAL: UMA VISÃO GERAL (Hugo Capelato (INPE))
- PYTHON PARA ASTRONOMOS (Daniel Moser (IAS))

COMITÊ ORGANIZADOR:
LUCIMARA MARTINS (NAT)
PAULA COELHO (NAT)
ALEX CARCIOLI (IAS)
REINALDO ROSA (LAC)

COMITÊ CIENTÍFICO:
Alex Cavaliéri Carcioli (IAG e BRAVO) - Co-chair
Alberto Krone-Martins (Universidade de Lisboa) - Co-chair
Claudia Bauzer Medeiros (IC/UNICAMP)
Lucimara Pires Martins (NAT/UJS) - Chair
Paula Rodrigues Teixeira Coelho (IAG e BRAVO) - Co-chair
Paulo Penteado (Northern Arizona University)
Reinaldo Roberto Rosa (LAC/INPE)
Fábio Porto (LNCC)

APÓIO E FINANCIAMENTO: INAT, Universidade Cruzeiro do Sul, BRAVO, LAC, inct, CNPq, FAPESP

2014

II Workshop de Computação Científica em Astronomia

3 - 6 de junho de 2014
Núcleo de Astrofísica Teórica
Universidade Cruzeiro do Sul
(São Paulo - SP)
Campus Liberdade

COMITÊ CIENTÍFICO

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• NAT/LAC/BRAVO/IAG initiative

To organize workshops and schools aiming at the dissemination of the VO concepts

2012

Workshop de eScience na Astronomia Brasileira

- One day meeting aiming at

- To **stimulate** the **approximation** between **Astronomy and Computing** (CS and Eng.) research **communities**.

- Open a communication channel between these societies.

- Result: The **creation** of the **Astronomy Track** at the **Brazilian Computer Society** annual meeting!



To organize workshops and schools aiming at the dissemination of the VO concepts

2012



DESAFIO BRAVO

O QUE É?
O BRAVO, a Microsoft Research e a AMD te desafiam a desenvolver um sistema para disponibilizar imagens do telescópio SOAR no Wide World Telescope, por meio de protocolos do Observatório Virtual.

QUEM?
Podem participar graduandos, mestrandos e doutorandos da área de exatas. Pós-doutorandos se estiverem com muita vontade. Preferencialmente em pares!

QUANDO?
As inscrições estarão abertas de 11 de junho até 12 de agosto e os trabalhos devem ser entregues até 17 de agosto de 2012. A premiação será feita em Outubro durante o encontro IVOA Interop e os estágios da equipe vencedora serão realizados em 2013.

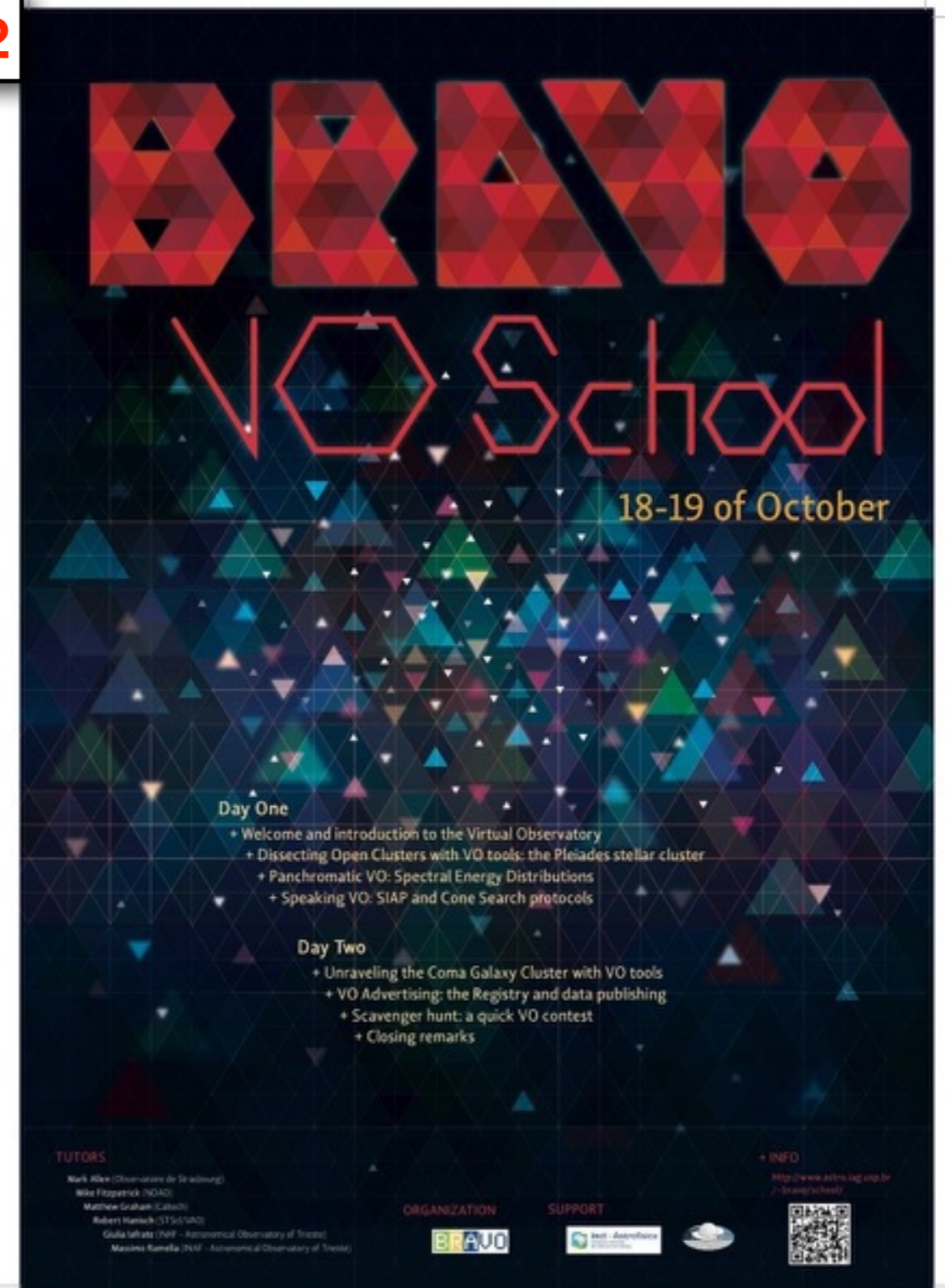
PRÊMIO?
Um mês de estágio na Microsoft Research (Redmond, Estados Unidos) e/ou um mês no Instituto CALTECH (Califórnia, Estados Unidos), além de dois notebooks.

MAIS INFORMAÇÕES
www.astro.iag.usp.br/~bravo/desafio/

ORGANIZAÇÃO
BRAVO

PATROCÍNIOS
Microsoft Research, Inct - Astrofísica, AMD

APOIOS
Laboratório Nacional de Computação Científica, SOAR, sgi, Laboratório Nacional de Computação Científica, Laboratório Nacional de Computação Científica



BRAVO VO School

18-19 of October

Day One

- + Welcome and introduction to the Virtual Observatory
- + Dissecting Open Clusters with VO tools: the Pleiades stellar cluster
- + Panchromatic VO: Spectral Energy Distributions
- + Speaking VO: SIAP and Cone Search protocols

Day Two

- + Unraveling the Coma Galaxy Cluster with VO tools
- + VO Advertising: the Registry and data publishing
- + Scavenger hunt: a quick VO contest
- + Closing remarks

TUTORS
Mark Allen (Observatoire de Strasbourg), Mike Fitzpatrick (NOAO), Matthew Graham (Caltech), Robert Hainack (STScI/VOA), Giulia Iaffaità (INAF - Astronomical Observatory of Trieste), Massimo Ramella (INAF - Astronomical Observatory of Trieste)

ORGANIZATION
BRAVO

SUPPORT
Inct - Astrofísica

INFO
<http://www.astro.iag.usp.br/~bravo/school/>

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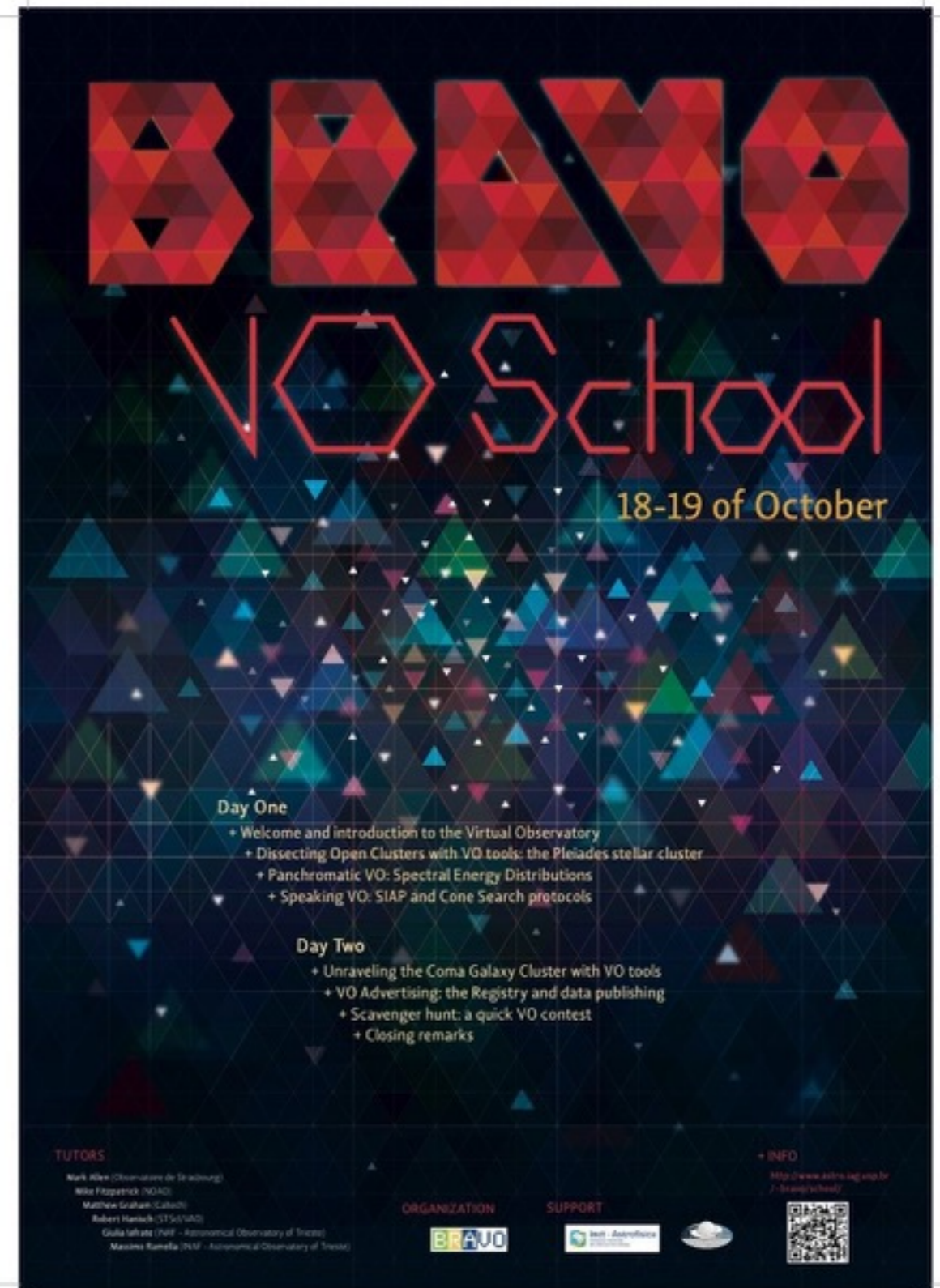
MAIS INFORMAÇÕES
www.astro.iag.usp.br/~bravo/desafio/

ORGANIZAÇÃO: BRAVO
PATROCÍNIOS: Microsoft Research, Inct - Astrofísica, AMD
APOIOS: SOAR, sgi, Laboratório Nacional de Computação Científica

- To develop a minimal **SIAP** service from scratch and to demonstrate that this works integrated with Microsoft's **World Wide Telescope**;
- **21 teams**
- **To the winners:** Internship stage at Microsoft Research and/or Caltech and Two AMD notebooks;
- **winner team were 2 undergrad students at UFRJ!**

To organize workshops and schools aiming at the dissemination of the VO concepts

- **Aim:** To begin a gradual empowering of the community
- Very good answer from the community. **Over-subscribed!**
- ~35 participants
- **Tutors:** Mark Allen, Mike Fitzgerald, Mathew Graham, Bob Hanisch, Giulia Iafrate, Massimo Ramela



The poster features the word "BRAVO" in large, red, geometric letters at the top. Below it, "VO School" is written in a red, outlined font, with "18-19 of October" in yellow text to the right. The background is a dark space filled with colorful triangles and stars. The event details are listed in two columns:

Day One

- + Welcome and introduction to the Virtual Observatory
- + Dissecting Open Clusters with VO tools: the Pleiades stellar cluster
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Massimo Ramela (INAF - Astronomical Observatory of Trieste)

ORGANIZATION


BRAVO

SUPPORT

INAF - Astronomical Observatory of Trieste

+ INFO

<http://www.asim.rdg.spa.br/vo-school/>



To act as a partner of the IVOA and as an intermediate between the IVOA and the Brazilian groups working with VO

S A B

XXXVII

Reunião Anual da
Sociedade Astronômica
Brasileira

14 a 18 de outubro de 2012
Águas de Lindóia - SP
Hotel Majestic

2012

IVOA Interop

21 26 | 10 | 2012

São Paulo

BRAVO

To act as a partner of the IVOA and as an intermediate between the IVOA and the Brazilian groups working with VO

VO-DAY

- *The International Virtual Observatory Alliance*
Mark Allen

- *The Research Tools of the Virtual Astronomical Observatory*
Robert Hanisch

- *What the VO can do for you?*
Massimo Ramela

- *An introduction to VO-IRAF*
Mark Fitzpatrick



- *The transient sky and the Virtual Observatory*
Mathew Graham
- *The VO in the classroom*
Giulia Iafrate

To act as a partner of the IVOA and as an intermediate between the IVOA and the Brazilian groups working with VO

- IVOA centered discussions
- VO-driven presentations.
- Brazilian talks about:
 - J-PAS and S-MAPS
 - DES Brazil
 - South-Pol
 - ... and BRAVO.

IVOA Interop 21 26 10 | 2012

São Paulo



To stimulate and to encourage the projects, facilitating the development and deployment of the tools, systems, and organizational structures



We negotiated community access to the IAG/NAT's Alphacrucis cluster, together with the emergent groups

A promotional poster for GINA (GPU for INCT-A). The poster has a blue background on the left and a purple background on the right. A green vertical bar in the center contains the text 'GPUs para o INCT-A'. The text is in Portuguese. A red '2011' sticker is in the top right corner.

GINA

O uso de GPUs (Graphical Processing Units) tem aberto novas possibilidades para computação astronômica, provendo paralelização em grande escala.

GINA (GPUs para o Instituto Nacional de Ciência e Tecnologia de Astrofísica) é um cluster experimental, com o objetivo de ser um ambiente de desenvolvimento e testes de aplicativos que fazem uso de GPUs na área de Astronomia.

Está aberto para o uso de toda a comunidade astronômica brasileira

BRAVO
BRASILIAN REGIONAL ASTRONOMICAL OBSERVATORY

O computador GINA possui atualmente 2 nós, cada um com:

- 2 GPUs NVIDIA Tesla C2050 (448 núcleos cada)
- 2 CPUs Intel Xeon X5650 (6 núcleos cada)
- 48 GB de RAM

Os softwares já disponíveis incluem:

- CUDA C
- CUDA Fortran
- IDL (com GPULib)
- R (com R+GPU)
- Python (com PyCUDA)
- MPI, OpenMP, TORQUE

Veja mais em:

<http://www.astro.iag.usp.br/~gina>

To stimulate and to encourage the projects, facilitating the development and deployment of the tools, systems, and organizational structures

2011 - 2015?

Quanto tempo de sua pesquisa precisa ser dedicado para tarefas de Tecnologia da Informação para as quais, como astrônomo, você não possui conhecimento ou vocação?

Caso você tenha respondido "muito", e caso seu projeto faça uso de Observatório Virtual, o BRAVO pode ajudá-lo por meio de um novo mecanismo chamado:

CASO DE USUÁRIO



Um Caso de Usuário é um projeto simples, curto e facilmente testável, voltado à implementação ou uso de serviços de Observatório Virtual.

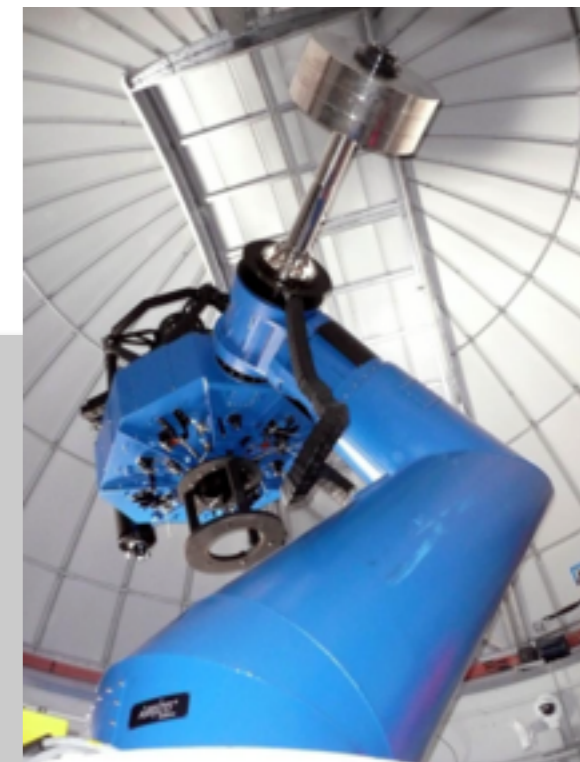
Aliás, mesmo que você tenha uma idéia para um projeto de Observatório Virtual nas condições acima, mas não possua o *know-how* para elaborar um Caso de Usuário completo, o BRAVO poderá auxiliá-lo.

Veja mais em:

<http://www.astro.iag.usp.br/~bravo/cdu>

- A Database for the SOUTH POL survey
- Photometric Redshifts Portal
- Grid of Synthetic Spectra (3x)

- A-Plus (S-Plus + J-Plus), ~40TB/year



To stimulate and to encourage the projects, facilitating the development and deployment of the tools, systems, and organizational structures

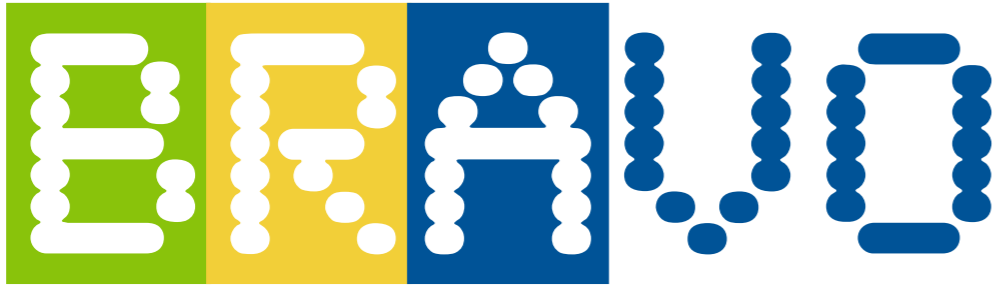
2015



- First BRAVO's **dedicated servers** !
- To host several VO compliant archives and services (catalogues, images and theoretical spectra) **Currently being deployed**
- Software architecture being designed, **advisors:** SVO (Spain), CADC (Canada), NOAO (US), NOVA (Argentine)

BRAVO nowadays

- **Synergy with J-PAS and A-Plus surveys**
 - 3 telescopes, 2 surveys, 17000 square degrees. A consortium of Spanish and Brazilian institutions, funding agencies and universities. The team of scientists and engineers includes more than 100 people from Brazil, Spain, the U.S.A. and other countries.
- **Archiving and publishing of T80S data (S-Plus), and negotiating mirror of T80N data (J-Plus)**
- Strong support from VO communities abroad, with special thanks to Spanish teams at CEFCA and Spanish VO



We are an alliance of people in Brazil who believes in worldwide, interoperable and distributed access to astronomical data and software.

Would you like to join us? Let us know!

Obrigada!

bravo@iag.usp.br