Simbad, VizieR & Aladin
The CDS astronomical tool suite

Astronomical Software Lecture at NADC
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Who am I?

I'm mostly a person who loves to develop software. Programming is a real pleasure, a challenge.

Discovering the Internet in its infancy in 1990, until using it day-after-day in the context of my work has been a chance for me.

Realized that in the astronomical context – at the Centre de Données astronomiques de Strasbourg - adds a lot to my personal story.
The CDS history

« Centre de Données astronomiques de Strasbourg »
created by The French Ministry of Education and Research in 1972

“Collect "useful" data on astronomical objects, in electronic form;
Improve them by critically evaluating them and combining them;
Distribute the results to the international community...”

CDS charter

eyearly version of FAIR
Findable, Accessible, Interoperable, Reusable
The base of astronomy

Observe the sky as accurately as possible

=> Always at the limit of the technology

I.e.: Gaia mission a few \( \mu \)-arcsecond of resolution (\( \approx 1 \) coin on the moon seen from the earth)

=> An image survey would require \( 1 \) ZETAoctets

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How to manipulate these observations

Images → catalogs → objects

Volume → Knowledge

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Which data the CDS provided?

The data that we technically can!

- **1972**: Data specific to astronomical objects
- **1990**: Catalogs & tables
- **1995**:
- **2000**: Images
- **2010**: HiPS (tiled images)

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CDS figures: 3-500-16-2^{E6}

- **3** services: Simbad, VizieR & Aladin
- **500** TB of data
- **16** operational sites/servers on 5 continents (7 local servers + 9 mirrors)
- **Around 2 million** requests per day
The CDS implementation

16 servers/sites managed by CDS staff (local servers + mirrors)

+ **Dozens of collaborative institutes/data centers/publishers**... (especially 18 HiPS nodes) which abound their own service with CDS data, and **reciprocally**

+ **Thousands of clients**
The CDS clients

**CDS products:**
- CDS Web pages
- CDS toolkit
- CDS widgets
- Aladin Lite
- Aladin Desktop
- ...

**Others:**
- TAP & other IVOA libs
- Astropy & PyVO python libs
- TOPCAT
- ESASky
- Stellarium
- WWT
- Digistar
- ...

![Top repartition of user's OS on all WebServers](image1)

![Top repartition of script agent on queries all WebServers](image2)

![Top repartition of visitors on all WebServers](image3)
The Simbad database contains information around 11,500,000 astronomical objects.

Daily updated by CDS documentarists & astronomers from astronomical literature & mission catalogs.

Java + Postgres DB

3 main developers

(M.Wenger, A.Oberto, G.Mantelet)
The VizieR service contains 20,500 catalogues, published tables, and observation logs.

Daily updated by CDS documentarists and astronomers from astronomical literature & mission catalogs.

- C + Java + Postgres DB
- 2 main developers (F.Ochsenbein, G.Landais)
- Linked to CDS Xmatch tool (FX.Pineau)
Aladin is an interactive sky atlas allowing the user to visualize digitized astronomical images or full surveys, superimpose entries from astronomical catalogues or databases, and interactively access related data and information from the Simbad database, the VizieR service and other archives for all known astronomical objects in the field.

The Aladin sky atlas is available in two modes: Aladin Desktop, a regular application and Aladin Lite an HTML5 javascript web widget.
Aladin technology evolution

- **1995**: Proto XWindows (C++)
- **2000**: Applet (java)
- **2003**: Standalone/Applet (java)
- **2013**: Aladin Lite (javascript)
- **2020**: Aladin Lite v3 (typescript+webgl)
Aladin Sky Atlas, one in two!

**Aladin Desktop**
- high level features **desktop**
- access images, catalogs, footprints
- **full range of functionalities**
- interoperable with VO tools
  - Aladin is a VO portal
  - used to validate most standards
- Used for observation preparation tools (APT, GuideCam)
- going all hierarchical now! (HiPS)

**Aladin Lite**
- **Web** HiPS visualizer
- preview mode
- embed in any webpage
- **easy appropriation**
- **highly used in wide range of sites/services**
- basic functions… but more and more!
Key figures on Aladin Desktop

1. **Started in 1999**

2. **Code:** **5MB** jar, 250k source lines, 500 classes
   - only based on CDS & JDK regular libraries
   - 5 main developers (P. Fernique, T. Boch, Chaitra, A. Oberto, F. Bonnarel)
   + dozen of contributors

3. **Usage:** **1k sessions per day** for 180k http queries (HiPS tiles queries included)

4. **Language:** **86% en**, 8% fr, 3% jp, 1% es, 0.5% cn ..

5. **Java:** **64% 1.8**, 18% 11.0, 12% 1.7, 2% 10.0, ...

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Aladin Desktop – 22 years old

Aladin v0 - 1999

Aladin v11 - 2020
The basis of Aladin

Demo2 with comments
New context – new feature

2009 - The HiPS (r)evolution
Browsing the sky...

- **2001**: Virtual Sky  [http://www.virtualsky.org](http://www.virtualsky.org)
- **2006**: Wikisky/sky-map  [http://sky-map.org](http://sky-map.org)
- **2006**: World wind  [http://worldwind.arc.nasa.gov](http://worldwind.arc.nasa.gov)
- **2007**: Google sky  [http://earth.google.com](http://earth.google.com)
- **2008**: WWT  [http://www.worldwidetelescope.org](http://www.worldwidetelescope.org)
- **2008**: VIRGO  [http://archive.eso.org](http://archive.eso.org)
- **2009**: Aladin  [http://aladin.u-strasbg.fr](http://aladin.u-strasbg.fr)

=> *21st century tools*
The 4 main issues

1. The size of data (server-side, via internet, client-side)
2. The client display performances
3. The data base structure (storage and retrieval)
4. The sky projection/distorsion
1) Data size...

• DSS2: 1 arcsec/pixel resolution survey
  – => 500 billions pixels = 1 TB in 16 bits/pixel
  – => 70 GB in JPEG

• Resampling whole DSS2 takes a few days of elapsed time for computation on a basic machine

• A few MB in a second via internet

“Traditional” surveys not so big today!
2) Client display performances...

- Current graphics cards require <1ms for projecting 1 million pixels (bilinear method)
  
  => 10 ms for redrawing an all sky view with one thousand (64x64) mosaic images

=> You can drag & drop the sky with the mouse

=> Thanks to computer games
3 & 4) How to « divide » the sky?

- Server database => get a good spatial index
- Client => get an efficient display (poles ?, pixel value ?...)

Aladin choice
Hierarchical Progressive Survey

- "The more you zoom in on a particular area, the more details show up"
- Multi-resolution HEALPix data structure for Images, Catalogues, 3-dimensional data cubes, ...
- Conserves scientific data properties alongside visualisation considerations
- No databases or dedicated servers are required, just HTTP
HiPS principles

- A global resample of a survey in HEALpix grid at various resolutions
- Resulting pixels packaged as tiles in regular files (jpeg, png, fits)
- Tiles stored in a basic file system
- Distributed by a classical HTTP server (ie. Apache)
HiPS time line


IVOA HiPS 1.0
IVOA standardization
HiPS network
ESAsky, JUD02, ...
A&A article

CDS Aladin lite
Mizar/CNES client
Proto in CDS Aladin Desktop
ADASS talk

Start of the story at CDS
by A. Oberto, P. Fernique, T. Boch & Al.
HiPS 2021

1. An IVOA standard
2. A collaborative HiPS networks
3. Dozens of HiPS clients

HiPS – Hierarchical Progressive Survey

Version 1.0
IVOA Recommendation
10th May 2017

This version:
1.0 Recommendation 2017-05-18

Previous versions:
2.0 Proposed Recommendation 2017-04-05
1.2 Proposed Recommendation 2017-03-23
1.1 Proposed Recommendation 2017-03-03
1.0 Proposed Recommendation 2016-11-22
1.0 Working Draft 2016-06-12

Interresting Working Group:
Applications (http://www.ivoa.net/documents/ive/ivoa/ImsApplications.html)

HiPS nodes

• 20 HiPS nodes (stable compared to last year)
  CFA, WFAU, CASDA, PACD, IPAC, ANU, LEIDEN, IRAP, SSC, CDS, AMIGA, SVO, IAS, ESAC, JAXA, CADC, HEASARC, China-VO...
  www.sternwarte.uni-erlangen.de
  www.eoo.hawaii.edu
  www.atnf.csiro.au
  mill.astro.puc.cl
  lofar.strw.leidenuniv.nl
  gtc.sdc.inta-csic.es
  erosita.mpempg.de
  elenchically.net
  databib.noao.edu
  darts.isas.jaxa.jp
  archive-new.nrao.edu
  ada.physics.usyd.edu.au:8021
  ada.physics.usyd.edu.au:8020
  192.168.56.1:80
  192.168.56.200:80
  192.168.2.45

+ dozens of undeclared HiPS nodes (private, project oriented...)

Dozens of HiPS clients covering various niches

• Available
  • Aladin Desktop (CDS/ivo)
  • MIZAR (IS/WEBGL)
  • Aladin Lite (CDS/ivo)
  • ESAsk, ESOnportal, JURO2, ++ (Aladin Lite based tools)
  • HsMap (Subaru project/WEBGL)
  • Stellarium Desktop (C++)
  • Stellarium Web (C++/Web assembly)
  • Stellarium mobile (C++)
  • Kstar (C++)
  • Firefly (J2E/Javajava backend)

• Proto
  • WWT China-VO (China-VO/C)

• In preparation
  • Aladin Lite WebGL (CDS/JS/WebGL/RUST)
  • Digistar (C++)
4. And a lot of HiPS surveys

http://aladin.u-strasbg.fr/hips/list

- **1034** HiPS
- **2483** instances (masters + mirrors)
- **370TB** of HiPS
- around **800K** tile queries per day
HiPS manipulation with Aladin

Demo1 with comments
My conclusion

- Always Data first
- Hurry up “slowly" on new technology
- Let be surprised by young people's ideas
Questions ?