Simbad, VizieR & Aladin
The CDS astronomical tool suite

Astronomical Software Lecture at NADC
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Pierre Fernique

CENTRE DE DONNÉES
ASTRONOMIQUES DE STRASBOURG

Observatoire **astronomique**
de Strasbourg | ObAS

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.

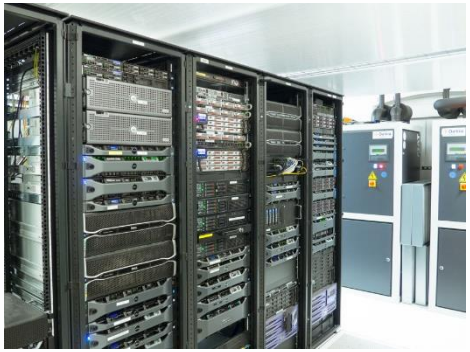
Realized that in the astronomical context – at the Centre de Données astronomiques de Strasbourg - adds a lot to my personal story.

The CDS history

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

CENTRE DE DONNÉES
ASTRONOMIQUES DE STRASBOURG

48 years



"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

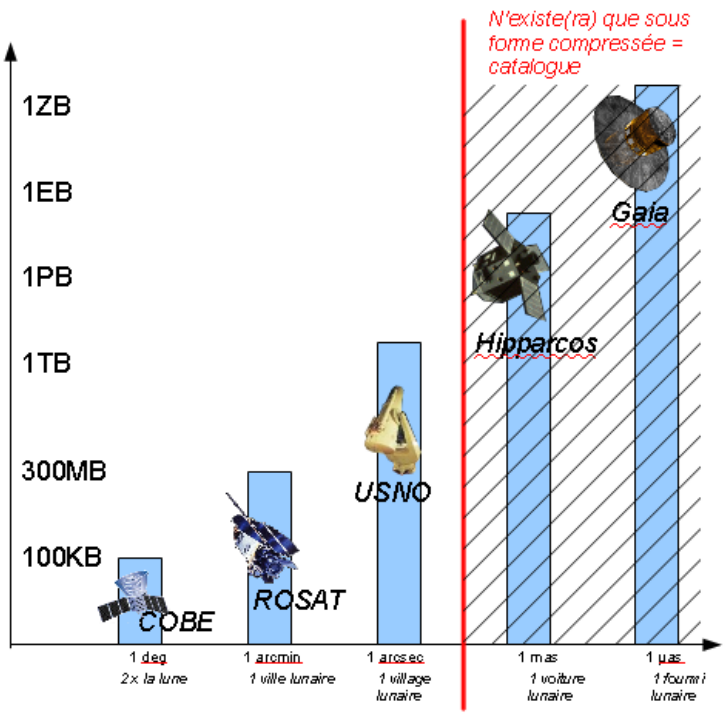
early version of **FAIR**
Findable, **Accessible**, **Interoperable**, **Reusable**

The base of astronomy

Observe the sky as accurately as possible

=> Always at the limit of the technology

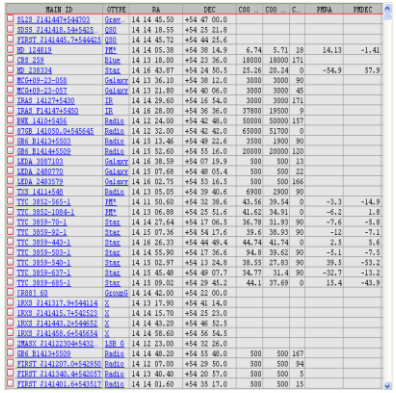
Ie.: Gaia mission a few µ-arcsecond of resolution
(= 1 coin on the moon seen from the earth)
=> An image survey would require 1 ZETAoctets



How to manipulate these observations

Images

catalogs



MAIN_ID	OTYPE	RA	DEC	COO	COO	C.	PMRA	PMDEC
2MASX J14144745+5440703	Gxy	14 14 45.90	+54 47 00.0					
SDSS J141415.54+54582	QSO	14 14 15.55	+54 25 21.8					
2MASX J14144745.7+544403	QSO	14 14 45.72	+54 44 25.6					
HD 124819	PM*	14 14 05.38	+54 38 14.9	6.74	5.71	18	14.13	-1.41
CBS 259	Blue	14 13 10.00	+54 23 36.0	18000	18000	171		
HD 238334	Star	14 16 43.87	+54 24 50.5	25.26	25.24	0	-54.9	57.9
MCG+09-23-058	Galaxy	14 13 36.10	+54 38 12.0	3000	3000	90		
MCG+09-23-057	Galaxy	14 13 21.80	+54 40 06.0	3000	3000	45		
2RAS J1417+5430	IR	14 14 29.60	+54 16 54.0	3000	3000	171		
2RAS J1417+5460	IR	14 16 28.00	+54 36 36.0	37800	19500	9		
NVSS J1410+5456	Radio	14 12 24.00	+54 42 48.0	50000	50000	157		
87GB J141050.0+545648	Radio	14 12 32.00	+54 42 42.0	65000	51700	0		
GB6 B1413+5503	Radio	14 15 13.40	+54 49 22.6	3500	1900	90		
GB6 B1414+5509	Radio	14 15 52.60	+54 55 16.0	20000	20000	120		
LEDA 3087103	Galaxy	14 16 38.59	+54 07 19.9	500	500	13		
LEDA 2480770	Galaxy	14 15 07.68	+54 48 05.4	500	500	22		
LEDA 2483278	Galaxy	14 16 02.75	+54 53 16.5	500	500	166		
2MS J1413+548	Radio	14 13 05.05	+54 39 40.6	6900	2900	90		
TYC 3852-565-1	PM*	14 11 50.60	+54 32 36.6	43.36	39.54	0	-3.3	-14.9
TYC 3852-1058-1	PM*	14 13 06.88	+54 25 51.6	41.62	34.91	0	-6.2	1.8
TYC 3859-70-1	Star	14 14 27.64	+54 17 06.5	36.78	31.93	90	-7.6	-5.8
TYC 3859-92-1	Star	14 15 07.36	+54 54 17.6	39.6	38.93	90	-12	-7.1
TYC 3859-443-1	Star	14 16 26.33	+54 44 49.4	44.74	41.74	0	2.5	5.6
TYC 3859-503-1	Star	14 14 55.90	+54 17 36.6	94.0	39.62	90	-5.1	-7.5
TYC 3859-540-1	Star	14 15 02.97	+54 13 24.8	38.55	27.83	90	39.5	-53.2
TYC 3859-637-1	Star	14 15 45.48	+54 49 07.7	34.77	31.4	90	-32.7	-13.2
TYC 3859-685-1	Star	14 15 09.02	+54 29 45.2	44.1	37.69	0	15.4	-43.9
IRAS 60	Group	14 14 42.00	+54 22 00.0					
IRXS J141317.9+544114	X	14 13 17.90	+54 41 14.0					
IRXS J141415.7+542253	X	14 14 15.70	+54 25 23.0					
IRXS J141443.2+544632	X	14 14 43.20	+54 46 32.5					
IRXS J141458.6+545654	X	14 14 58.60	+54 56 54.5					
2MASX J14122304+5432	LSB G	14 12 23.00	+54 32 26.0					
GB6 B1413+5500	Radio	14 14 40.20	+54 55 40.0	500	500	167		
FIRST J141207.0+542950	Radio	14 12 07.00	+54 29 50.0	500	500	94		
FIRST J141340.4+542057	Radio	14 13 40.40	+54 20 57.0	500	500	5		
FIRST J141401.6+543517	Radio	14 14 01.60	+54 35 17.0	500	500	15		

objects

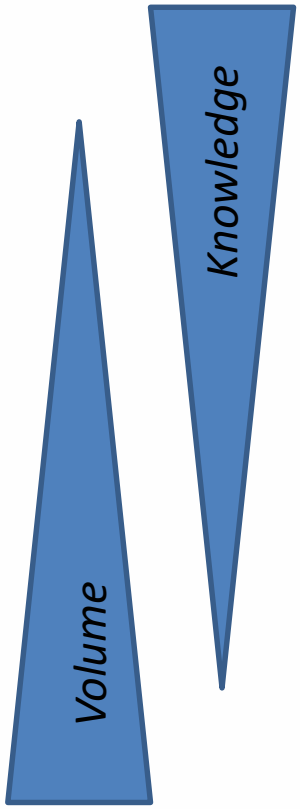
Observation data (J2000 epoch)	
Constellation	Ursa Major
Right ascension	$14^h\ 03^m\ 12.6^s$
Declination	+54° 20′ 57″
Redshift	0.000804
Helio radial velocity	241 ± 2 km/s
Distance	20.9 ± 1.8 Mly (6.4 ± 0.5 Mpc)
Apparent magnitude (V)	7.86
Characteristics	
Type	SAB(rs)cd
Number of stars	1 trillion (10^{12})
Size	~170,000 ly in diameter[1]
Apparent size (V)	28′.8 × 26′.9
Other designations	
Messier 101, M101, NGC 5457, UGC 8981, PGC 50063, Arp 26	
References: [2][3][4][5][6][7]	

Volume

Knowledge

Which data the CDS provided?

The data that we technically can !



1972 — SIMBAD: Data specific to astronomical objects

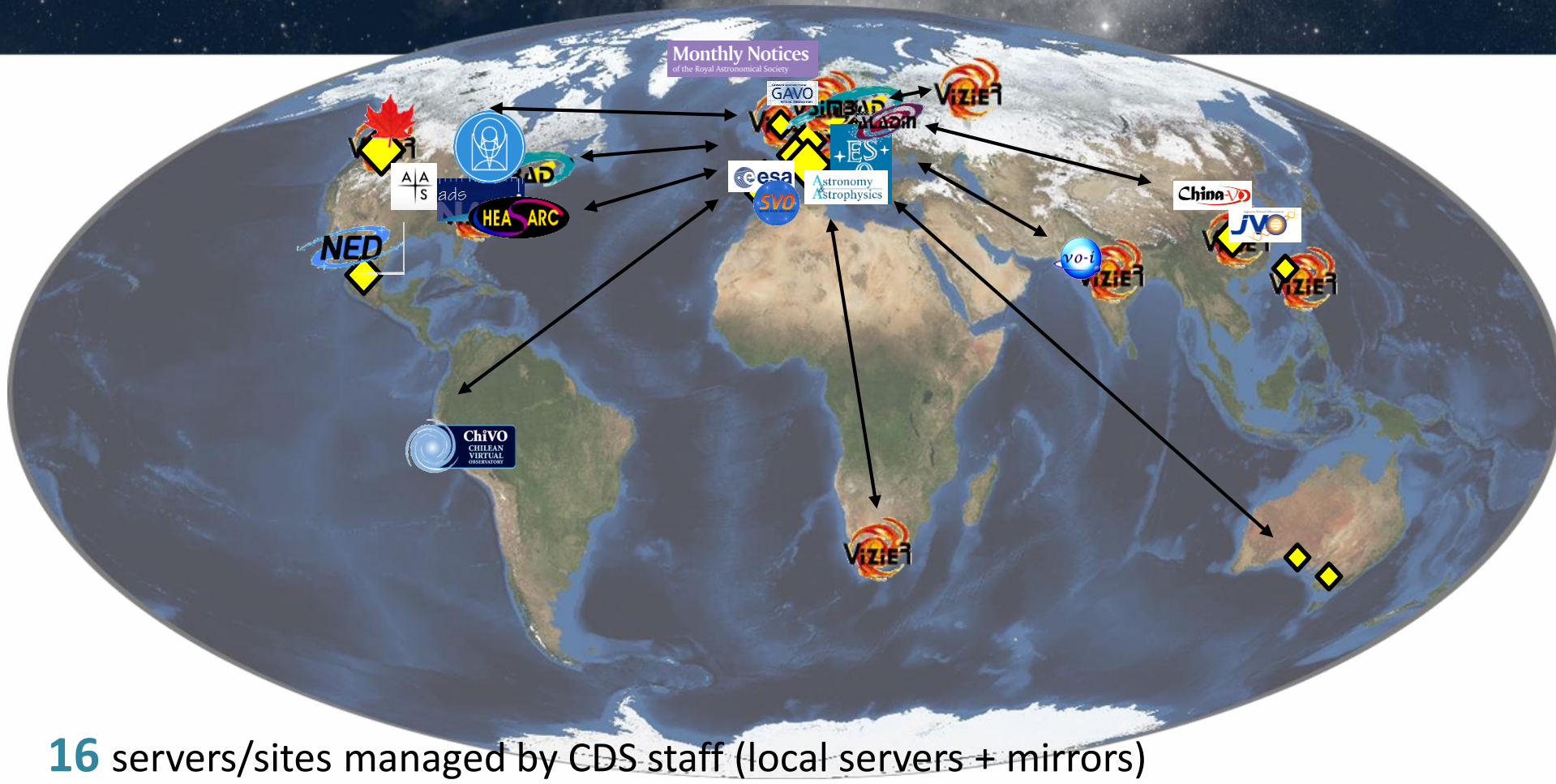
1990
1995 — VizieR: Catalogs & tables

2000
2010 — ALADIN: Images
HiPS (tiled images)

CDS figures: 3-500-16-2E6

- **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

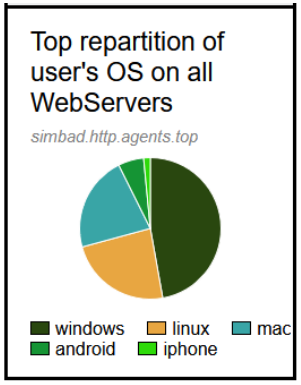
The CDS clients

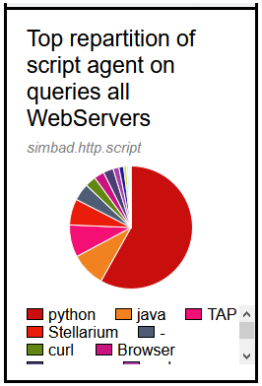
CDS products:

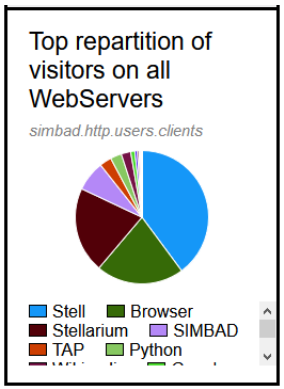
- CDS Web pages
- CDS toolkit
- CDS widgets
- Aladin Lite
- Aladin Desktop
- …

Others:

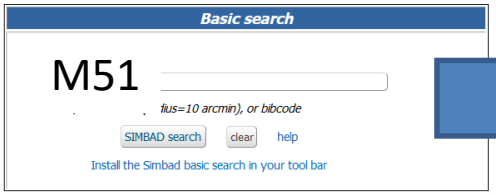
- TAP & other IVOA libs
- Astropy & PyVO python libs
- TOPCAT
- ESASky
- Stellarium
- WWT
- Digistar
- …







http://simbad.u-strasbg.fr



Basic data

M 51 -- Galaxy in Pair of Galaxies

Other object types: rG (), Sy2 (), G (2014AJ,APG,...), Rad (B3,BWE,...), AGN ([VV2000c], [VV2003c],...), X (RX,1RXS,...), IR (IRAS,ISOSS,...), * (BD,PLX), GiP (KPG,[T76]), IG (VV), GiG ([CHM2007])

ICRS coord. *(ep=J2000)* : 13 29 52.698 +47 11 42.93 (Infrared) [ ] C 2006AJ....131.1163S

FK4 coord. *(ep=B1950 eq=1950)* : 13 27 46.321 +47 27 10.59 [ ]

Gal coord. *(ep=J2000)* : 104.851585 +68.560702 [ ]

Radial velocity / Redshift / cz : V(km/s) 465 [61] / z(~) 0.00155 [0.00020] / cz 465.0 [61.0] D 1999PASP..111..438F

Parallaxes *(mas)*: 7.8 [16.9] E 1995GCTP..C.....0V

Morphological type: SA C 2019MNRAS.488..590B

Angular size *(arcmin)*: 10.00 7.59 163 (Opt) D 2003A&A...412...45P

Fluxes (6) : B (AB) 9.26 [0.03] C 2014MNRAS.445..881C
V 8.36 [0.06] D 2007ApJS..173..185G
R (AB) 8.40 [0.03] C 2014MNRAS.445..881C
J 6.401 [0.019] C 2006AJ....131.1163S
H 5.653 [0.020] C 2006AJ....131.1163S
K 5.496 [0.025] C 2006AJ....131.1163S

Hierarchy

parents : 2 children : 2369 siblings : 136 Display criteria : All

Identifiers

M 51 | IRAS 13277+4727 | 143
APG 85A | ISOSS J13299+4714 | TC 827
APG 85 | KHG 1-C 5 | UGC 8493
B3 1327+474C | KPG 379a | UZC J132952.1+471144
BD+47 2063 | LEDA 47404 | VV 403

Biblio. references

2021AJ....161...29Z [T A S X C ,32]
Astron. J., 161, 29-29 (2021/January-0)
A method to extract spatially resolved polycyclic aromatic hydrocarbon emission
ZHANG L., HO L.C. and XIE Y.

Simbad objects: 1

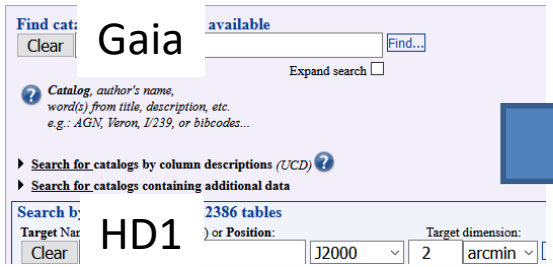
2020A&A...633A..17B [T K A X C D ,43]
Astronomy and Astrophysics, volume 633A, 17-17 (2020/1-1)
Rotation of molecular clouds in M 51.
BRAINE J., HUGHES A., ROSOLOWSKY E., GRATIER P., COLOMBO D., MEIDT S. and SCHINN

Simbad objects: 3

2020A&A...633A.144V [X D ,89]
Astronomy and Astrophysics, volume 633A, 144-144 (2020/1-1)

- 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)

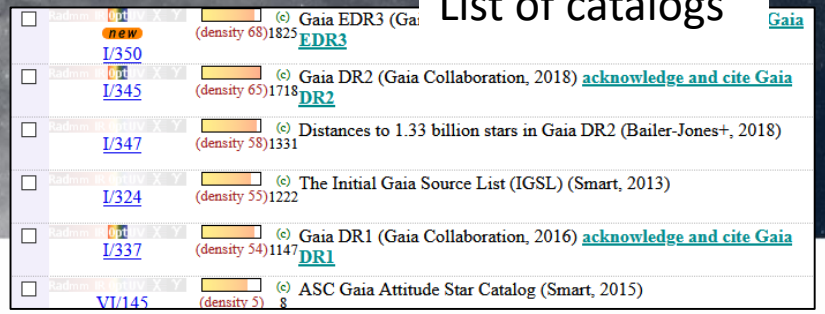
https://vizier.u-strasbg.fr



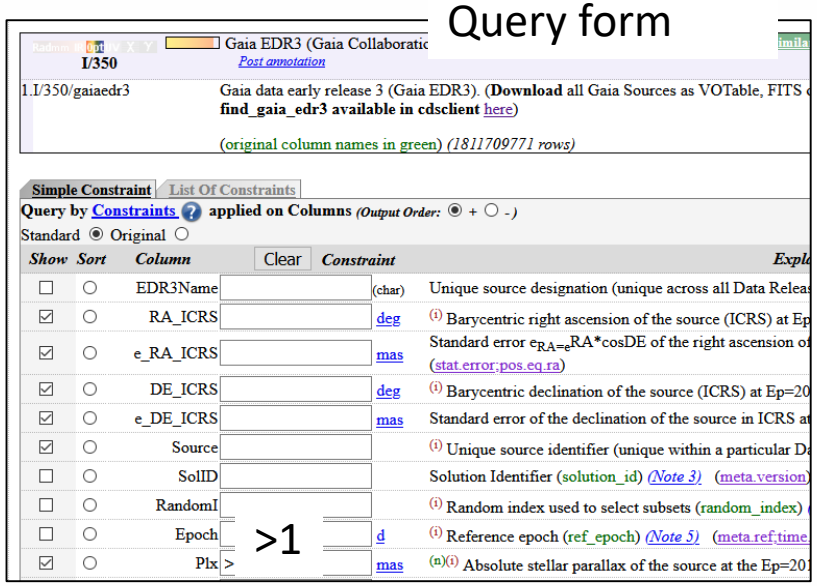
Gaia

HD1

List of catalogs

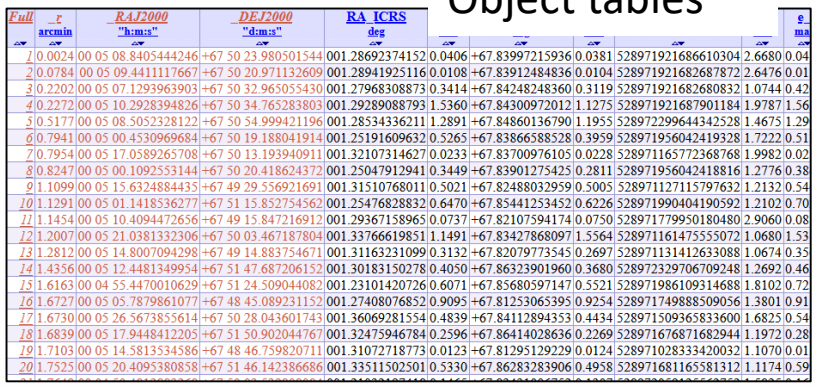


Query form



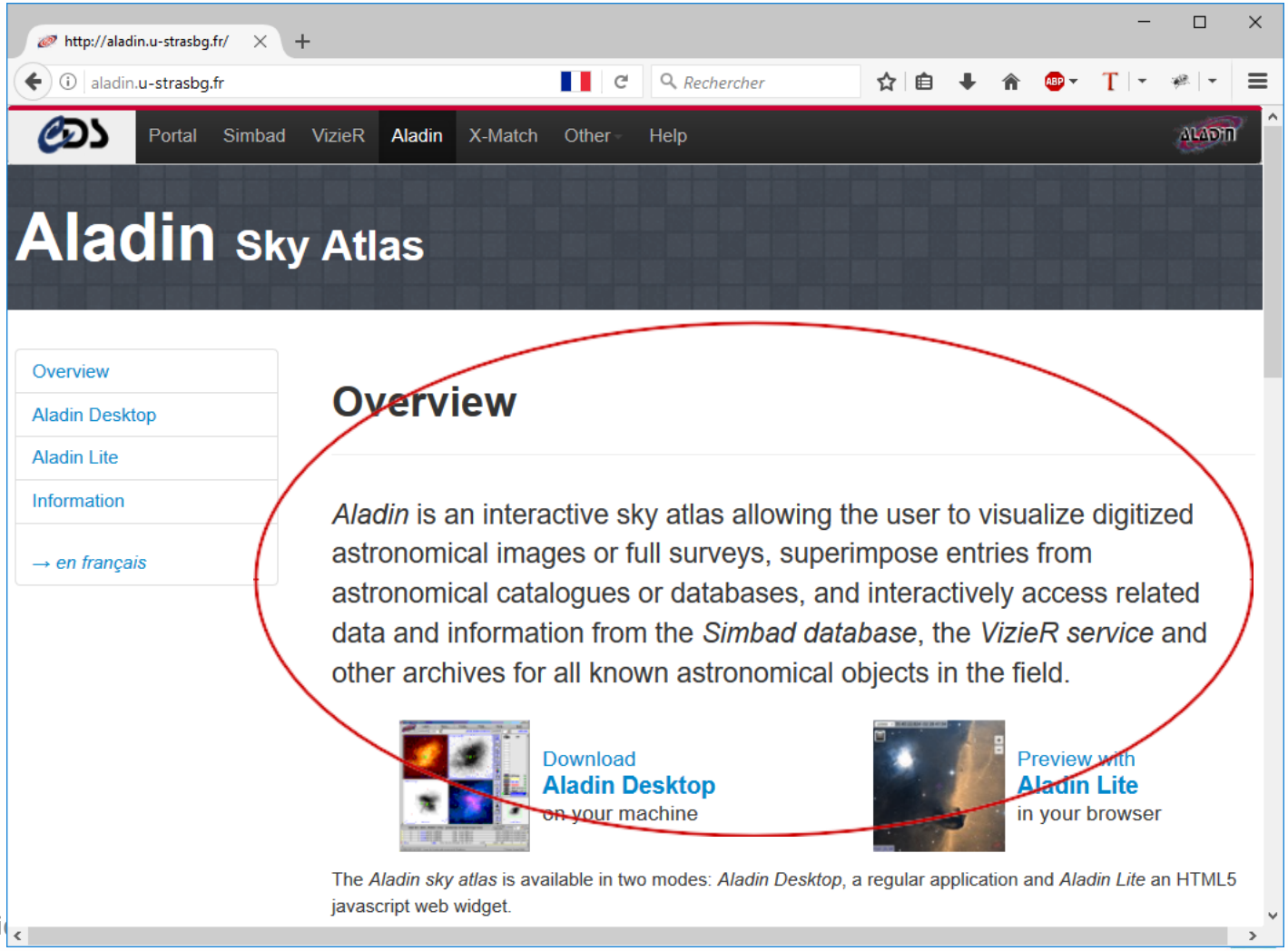
>1

Object tables

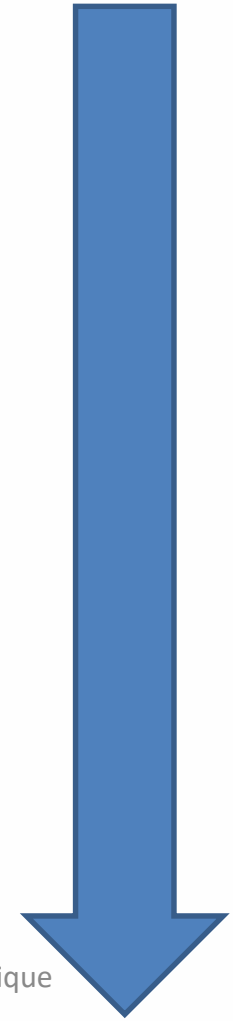


- The VizieR service contains 20,500 catalogues, published tables,and observation logs
- Daily updated by CDS documentarists & astronomers from astronomical literature & mission catalogs
- C + Java + Postgres DB
- 2 main developers (*F.Ochsenbein*, G.Landais)
- Linked to CDS Xmatch tool (FX.Pineau)

https://aladin.u-strasbg.fr

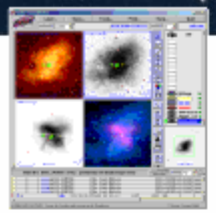


Aladin technology evolution



1995	Proto XWindows (C++)
2000	Applet (java)
2003	Standalone/Applet (java)
2013	Aladin Lite (javascript) **Aladin Desktop** (java)
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)

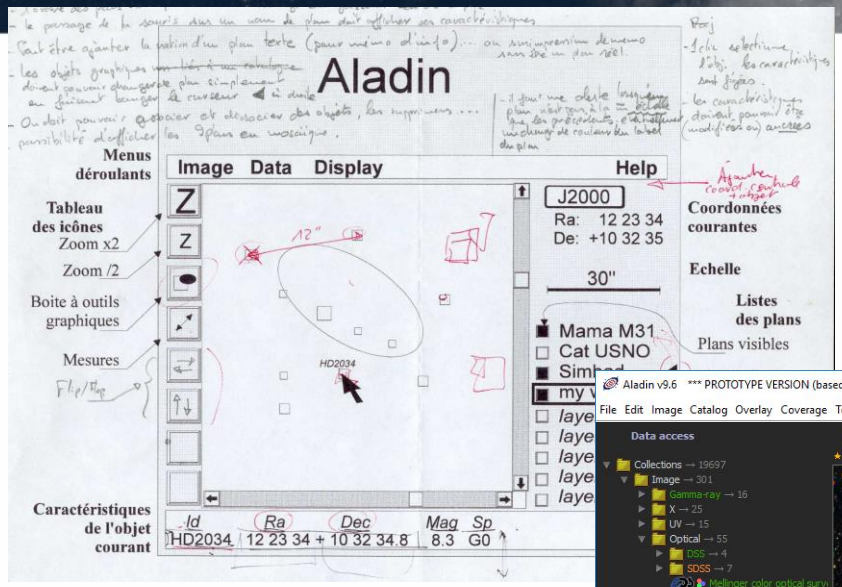
Aladin Lite

- **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

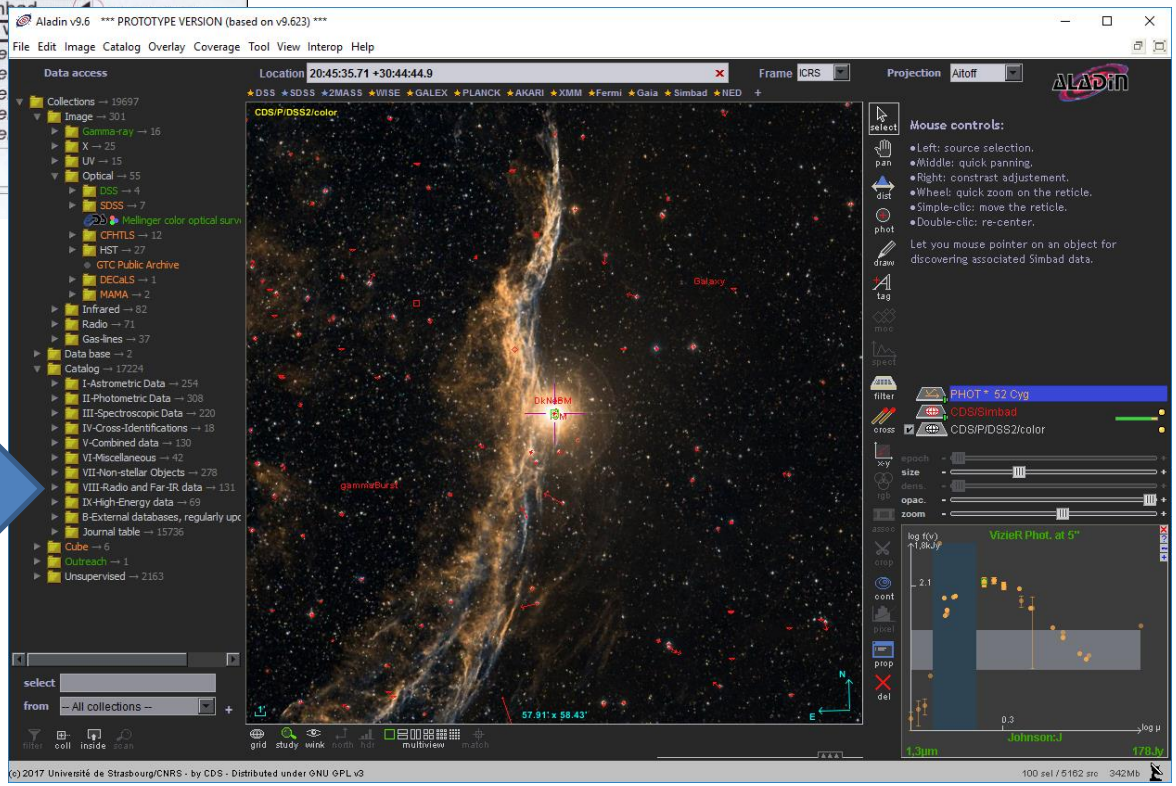
1. **Started in 1999**
2. **Code**: **5MB jar**, 250k source lines, 500 classes
   - only based on CDS & JDK regular libraries
   - 5 main developers (P. Fernique, T. Boch, Chaitra, A. Oberto, F. Bonnarel)
     + dozen of contributors
3. **Usage**: **1k sessions per day** for 180k http queries (HiPS 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, ...

Aladin Desktop – 22 years old

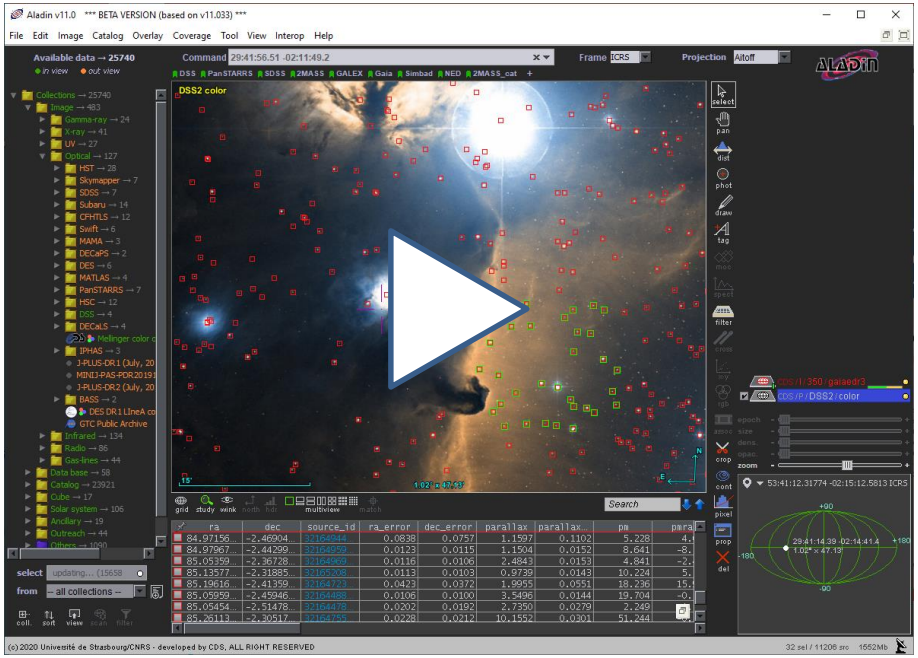


Aladin v0 - 1999

Aladin v11 - 2020



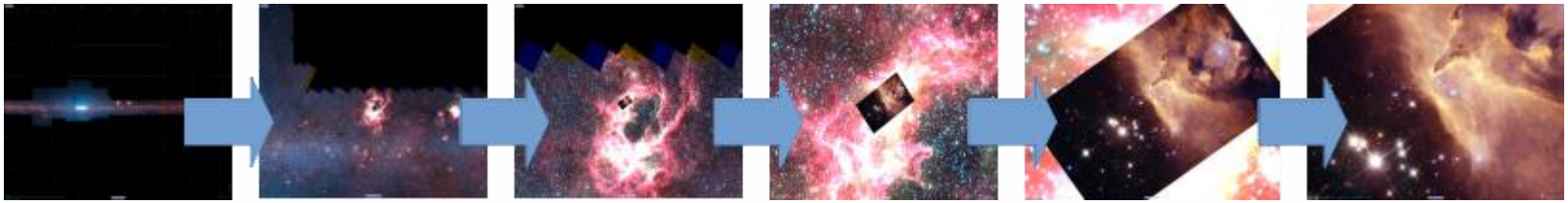
The basis of Aladin



Demo2 with comments

New context – new feature

2009 - The HiPS (r)evolution



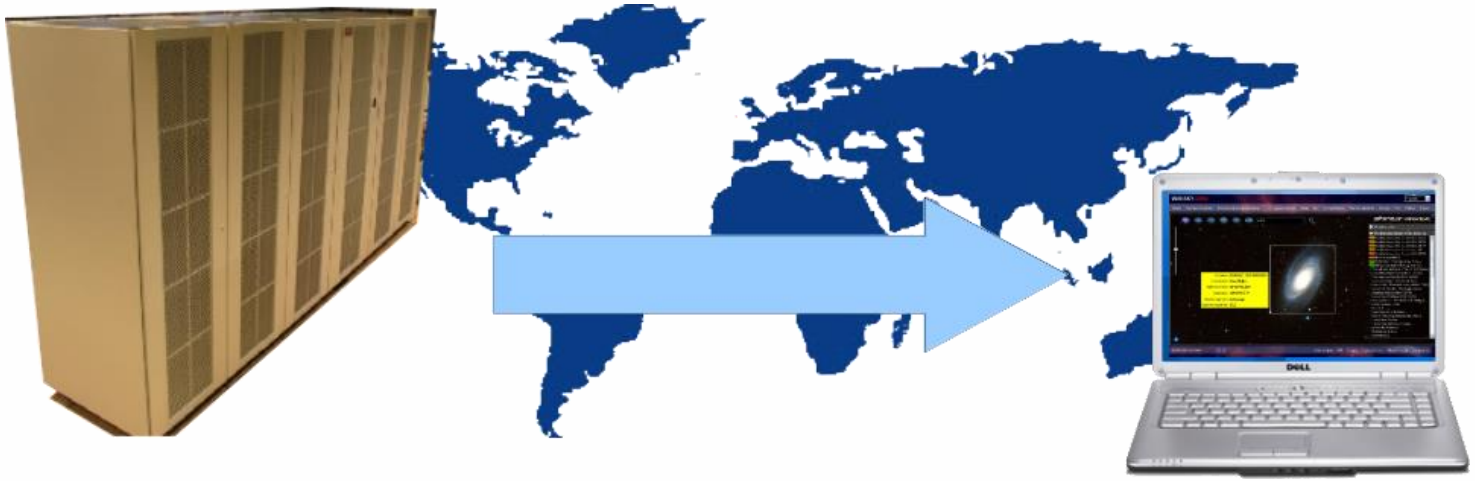
Browsing the sky...

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

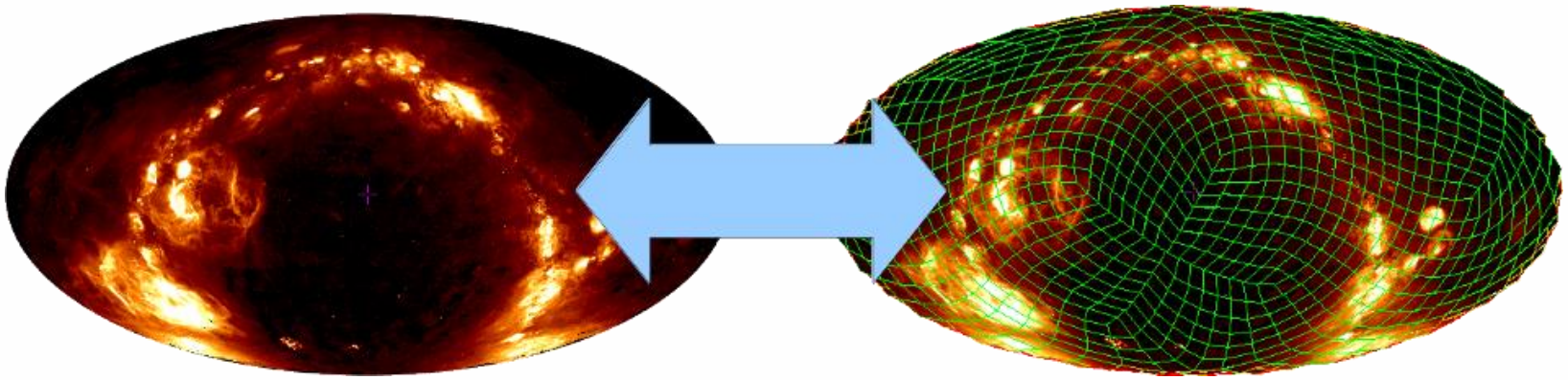
- DSS2: 1 arcsec/pixel resolution survey
  - => 500 billions pixels = 1 TB in 16 bits/pixel
  - => 70 GB in JPEG
- Resampling whole DSS2 takes a few days of elapsed time for computation on a basic machine
- A few MB in a second via internet

"Traditional" surveys not so big today !

2) Client display performances...

- Current graphics cards require <1ms for projecting 1million pixels (bilinear method)

  => 10 ms for redrawing an all sky view with one thousand (64x64) mosaic images

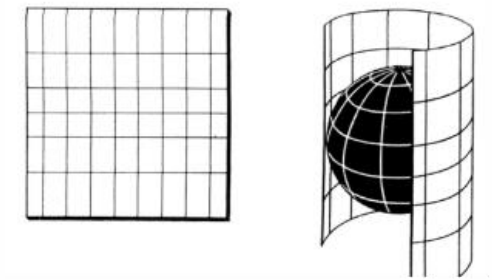


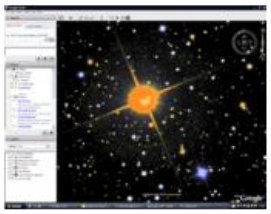
=>You can drag&drop the sky with the mouse

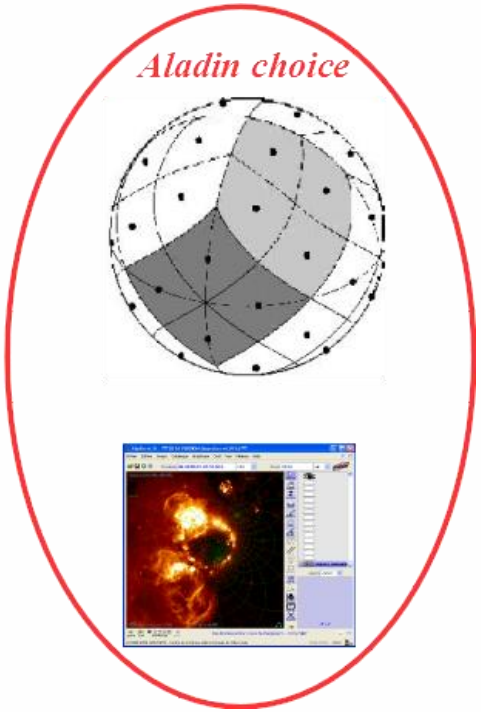
=> Thanks to computer games

3 & 4) How to « divide » the sky ?

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



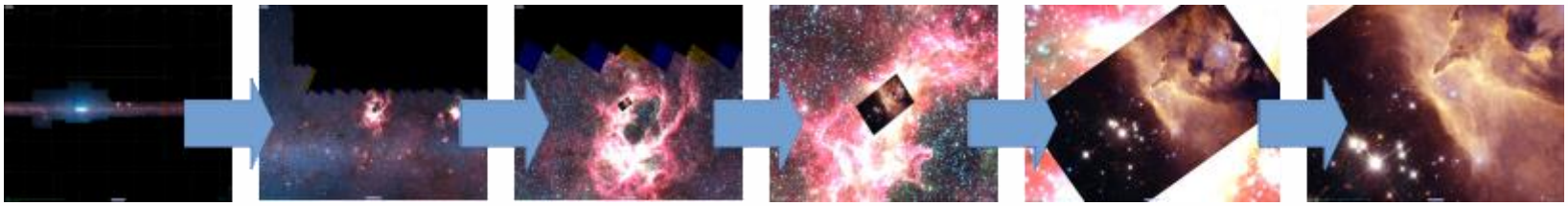




HiPS – What is it ?

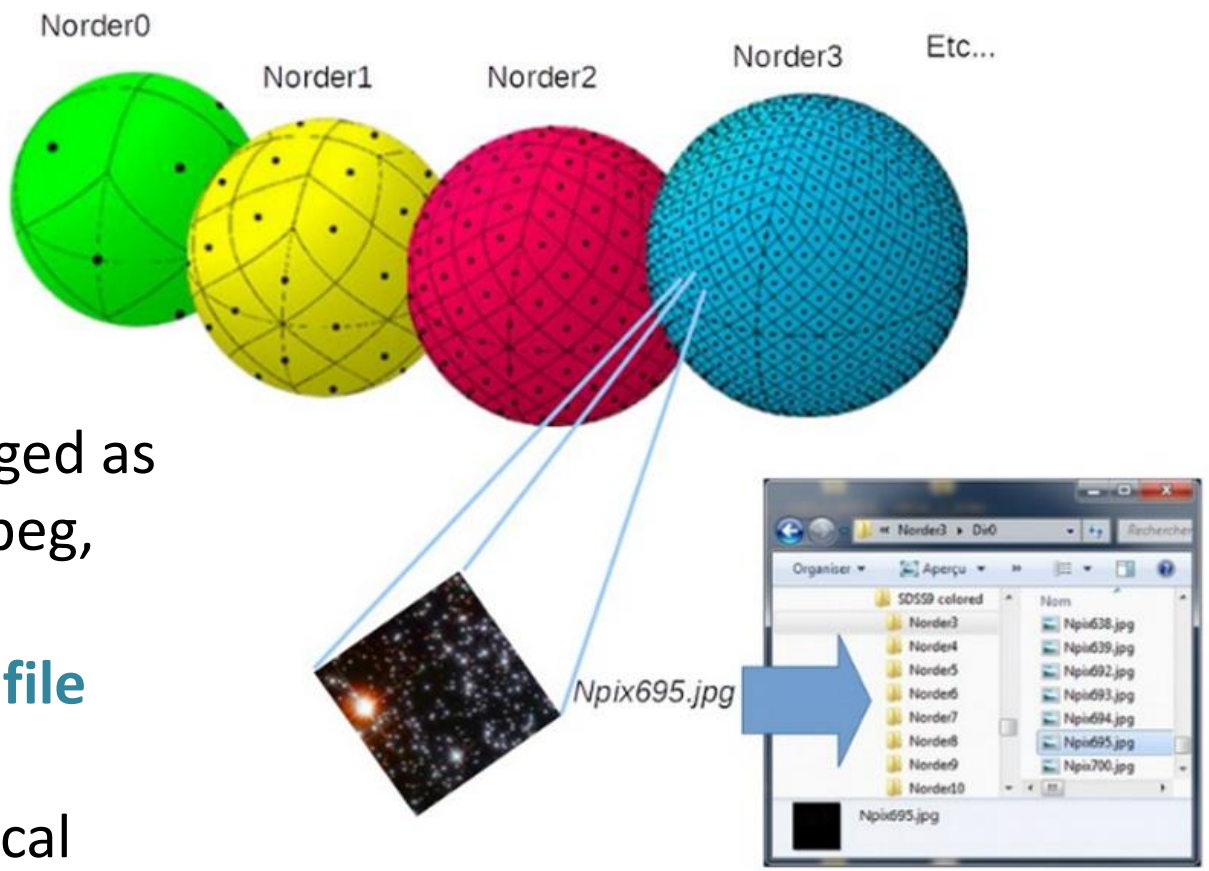
Hierachical Progressive Survey

- "*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



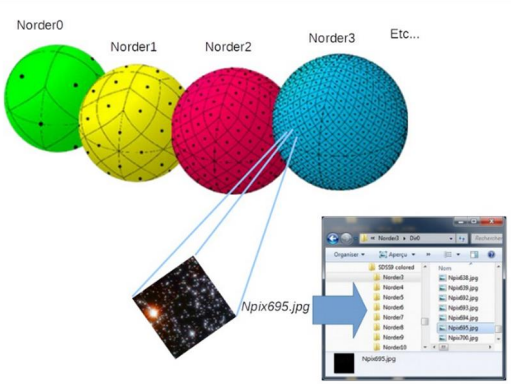
HiPS principles

- 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

2009 2010 2011 2012 2013 2014 2015 2016 2017



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

Proto in CDS Aladin Desktop
ADASS talk

Mizar/CNES client

CDS Aladin lite

ADASS talk
HiPS cube, cat, ...

A&A article

ESAsky,JUDO2,...

HiPS network

IVOA standardization

IVOA HiPS 1.0

HiPS 2021

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

HiPS nodes

- **20** HiPS nodes (stable compared to last year)
  CFA, WFAU, CASDA, PADC, IPAC, ANU, LEIDEN, IRAP, SSC, CDS , AMIGA, SVO, IAS, ESAC, JAXA, CADC, HEASARC, China-VO…

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

www.sternwarte.uni-erlangen.de
www.eaobservatory.org
www.eao.hawaii.edu
www.atnf.csiro.au
mill.astro.puc.cl
lofar.strw.leidenuniv.nl
gtc.sdc.cab.inta-csic.es
erosita.mpe.mpg.de
elenchically.net
datalab.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
192.168.56.100:80
192.168.2.45

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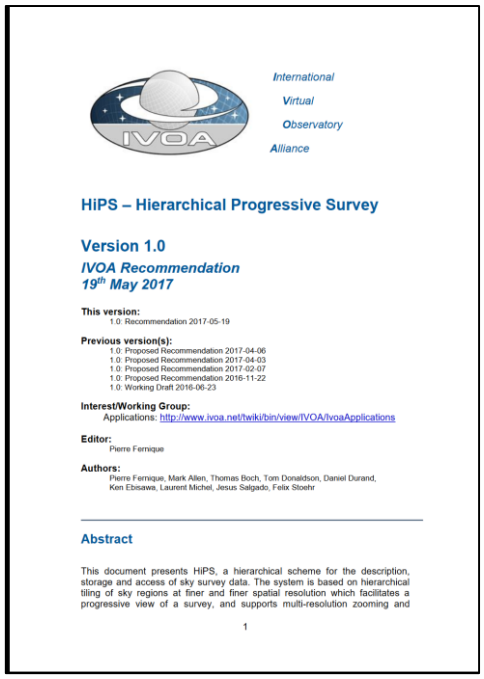

International Virtual Observatory Alliance

HiPS – Hierarchical Progressive Survey

Version 1.0

IVOA Recommendation
19th May 2017

This version:
1.0: Recommendation 2017-05-19

Previous version(s):
1.0: Proposed Recommendation 2017-04-06
1.0: Proposed Recommendation 2017-04-03
1.0: Proposed Recommendation 2017-02-07
1.0: Proposed Recommendation 2016-11-22
1.0: Working Draft 2016-06-23

Interest/Working Group:
Applications: http://www.ivoa.net/twiki/bin/view/IVOA/IvoaApplications

Editor:
Pierre Fernique

Authors:
Pierre Fernique, Mark Allen, Thomas Boch, Tom Donaldson, Daniel Durand, Ken Ebisawa, Laurent Michel, Jesus Salgado, Felix Stoehr

Abstract

This document presents HiPS, a hierarchical scheme for the description, storage and access of sky survey data. The system is based on hierarchical tiling of sky regions at finer and finer spatial resolution which facilitates a progressive view of a survey, and supports multi-resolution zooming and

1

Dozens of HiPS clients covering various niches

- *Available*
  - Aladin Desktop (CDS/Java)
  - MIZAR (JS/WebGL)
  - Aladin Lite (CDS/JS)
  - ESAsky, ESOportal, JUDO2, ++ (Aladin Lite based tools)
  - HscMap (Subaru project/WebGL)
  - Stellarium Desktop (C)
  - Stellarium Web (C -> Web assembly)
  - Stellarium mobile (?)
  - Kstar (C++)
  - Firefly (IPAC/JS+java backend)
- *Proto*
  - WWT China-VO (China-VO/C#)
- *In preparation*
  - Aladin Lite WebGL (CDS/JS/WebGL/RUST)
  - Digistar (?)

Scientifical purpose
Planetarium control
Amateurs
Public

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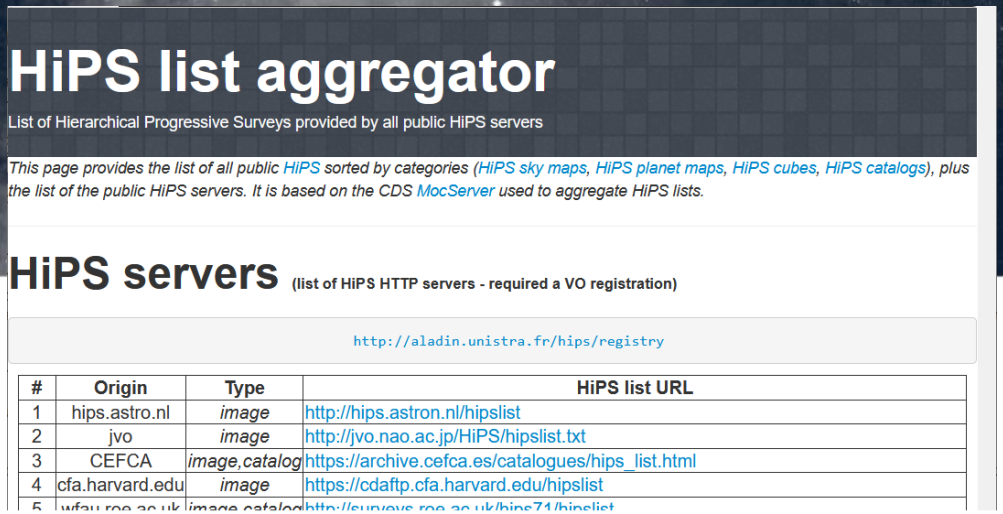
4. And a **lot of HiPS surveys**



HiPS list aggregator

List of Hierarchical Progressive Surveys provided by all public HiPS servers

This page provides the list of all public HiPS sorted by categories (HiPS sky maps, HiPS planet maps, HiPS cubes, HiPS catalogs), plus the list of the public HiPS servers. It is based on the CDS MocServer used to aggregate HiPS lists.

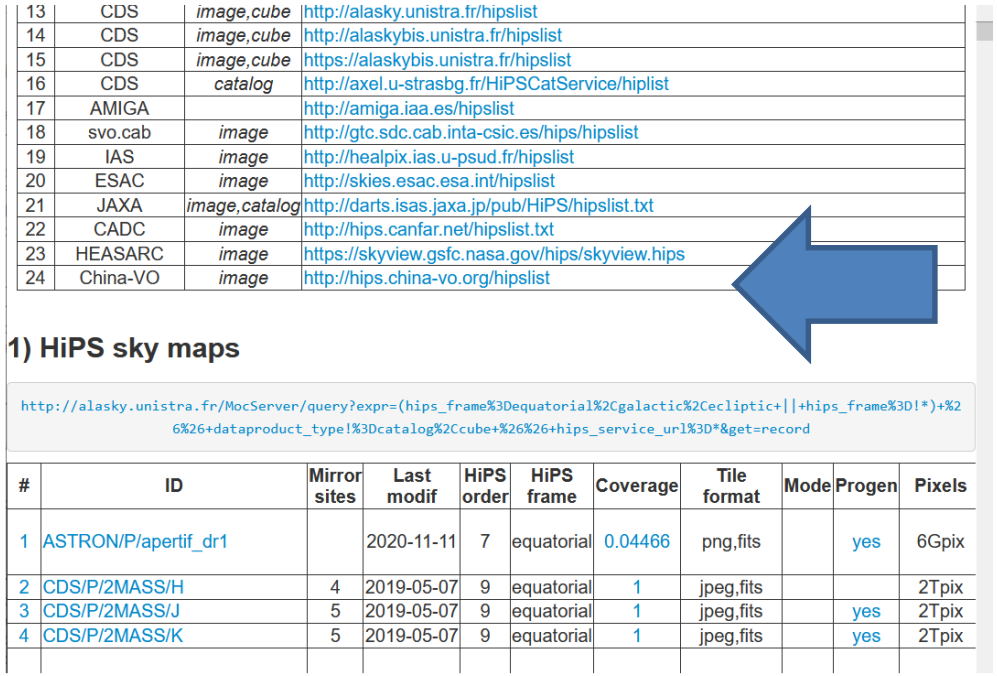
HiPS servers (list of HiPS HTTP servers - required a VO registration)

http://aladin.unistra.fr/hips/registry

#	Origin	Type	HiPS list URL
1	hips.astro.nl	*image*	http://hips.astron.nl/hipslist
2	jvo	*image*	http://jvo.nao.ac.jp/HiPS/hipslist.txt
3	CEFCA	*image,catalog*	https://archive.cefca.es/catalogues/hips_list.html
4	cfa.harvard.edu	*image*	https://cdaftp.cfa.harvard.edu/hipslist

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

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



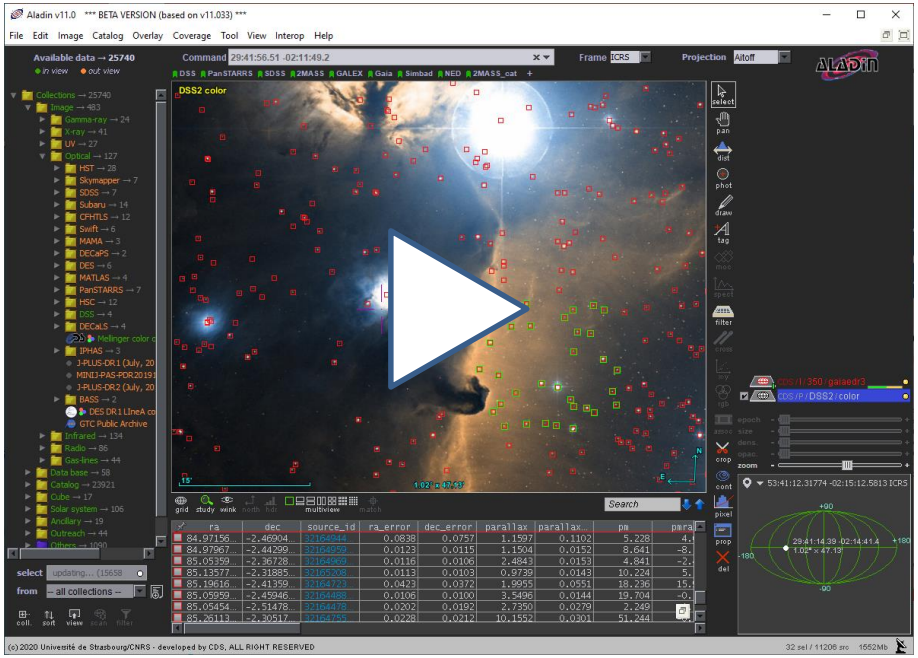
13	CDS	*image,cube*	http://alasky.unistra.fr/hipslist
14	CDS	*image,cube*	http://alaskybis.unistra.fr/hipslist
15	CDS	*image,cube*	https://alaskybis.unistra.fr/hipslist
16	CDS	*catalog*	http://axel.u-strasbg.fr/HiPSCatService/hiplist
17	AMIGA		http://amiga.iaa.es/hipslist
18	svo.cab	*image*	http://gtc.sdc.cab.inta-csic.es/hips/hipslist
19	IAS	*image*	http://healpix.ias.u-psud.fr/hipslist
20	ESAC	*image*	http://skies.esac.esa.int/hipslist
21	JAXA	*image,catalog*	http://darts.isas.jaxa.jp/pub/HiPS/hipslist.txt
22	CADC	*image*	http://hips.canfar.net/hipslist.txt
23	HEASARC	*image*	https://skyview.gsfc.nasa.gov/hips/skyview.hips
24	China-VO	*image*	http://hips.china-vo.org/hipslist

1) HiPS sky maps

http://alasky.unistra.fr/MocServer/query?expr=(hips_frame%3Dequatorial%2Cgalactic%2Cecliptic+||+hips_frame%3D!*)+%26%26+dataproduct_type!%3Dcatalog%2Ccube+%26%26+hips_service_url%3D*&get=record

#	ID	Mirror sites	Last modif	HiPS order	HiPS frame	Coverage	Tile format	Mode	Progen	Pixels
1	ASTRON/P/apertif_dr1		2020-11-11	7	equatorial	0.04466	png,fits		yes	6Gpix
2	CDS/P/2MASS/H	4	2019-05-07	9	equatorial	1	jpeg,fits			2Tpix
3	CDS/P/2MASS/J	5	2019-05-07	9	equatorial	1	jpeg,fits		yes	2Tpix
4	CDS/P/2MASS/K	5	2019-05-07	9	equatorial	1	jpeg,fits		yes	2Tpix

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 ?