Virtual Observatory and Relevance to Atomic and Molecular Data

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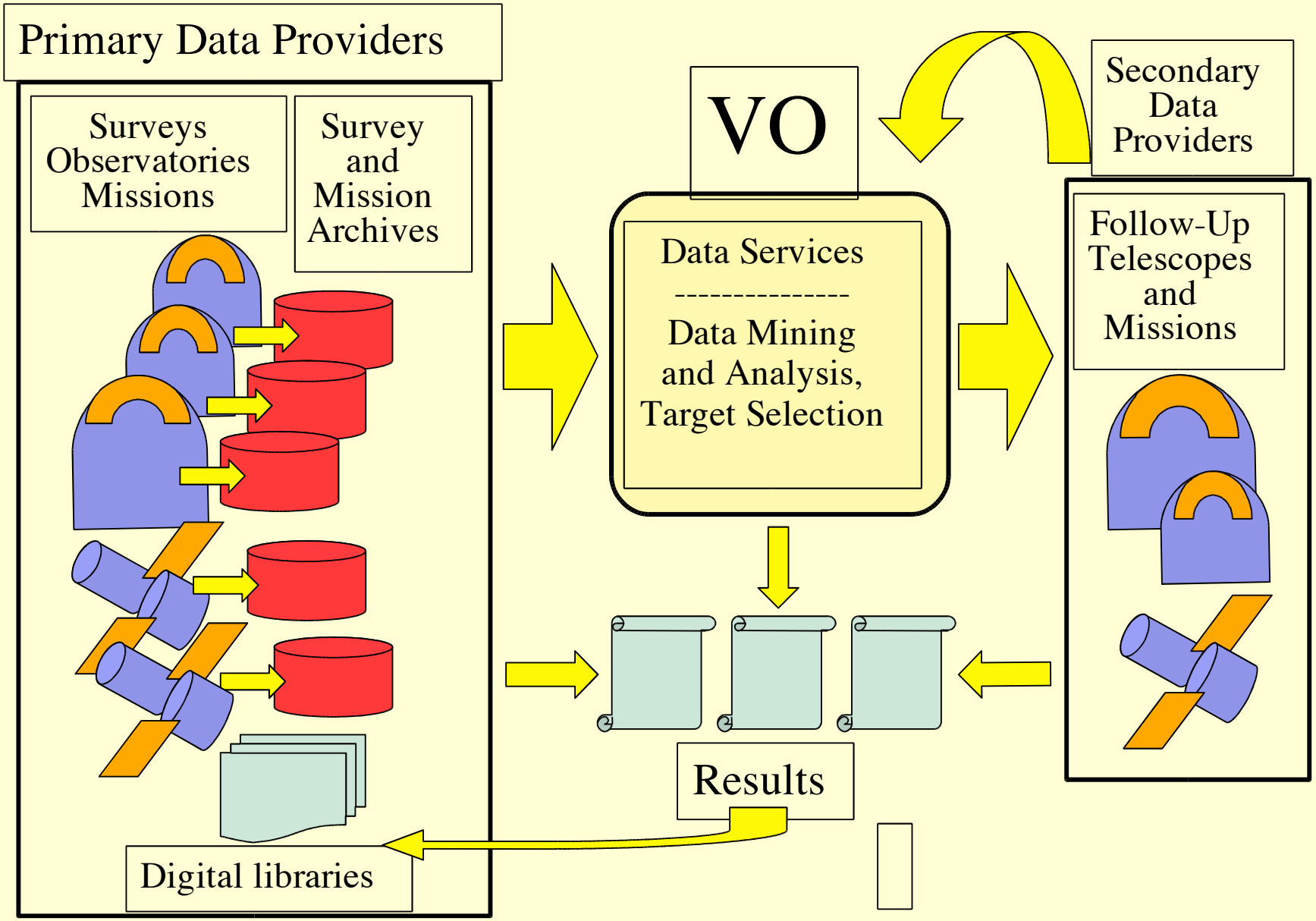
LERMA, Paris Observatory

IVOA (www.ivoa.net)

From observed data to published data including very large survey

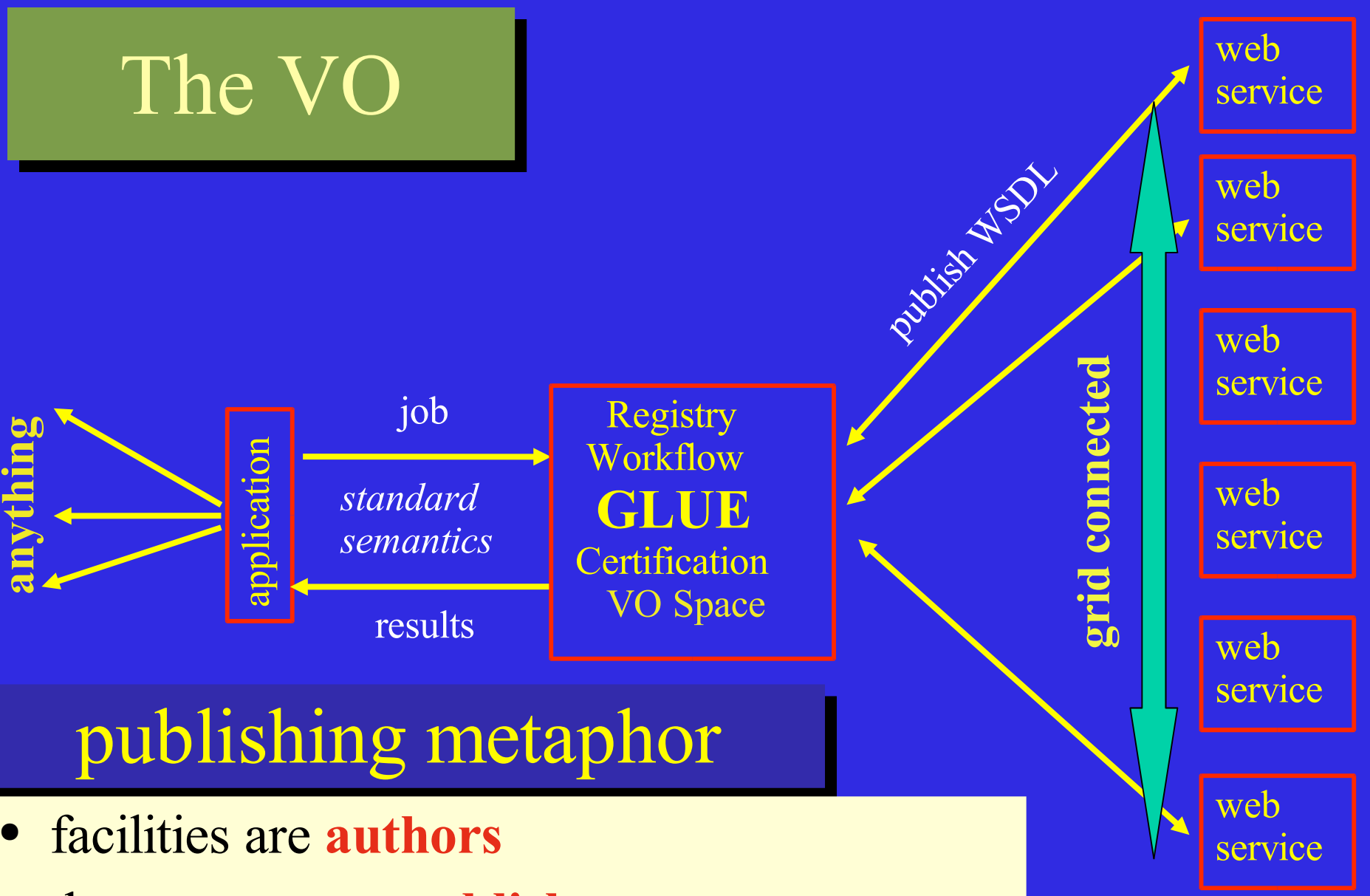
« an enabling and coordinating entity to foster the development of tools, protocols, and collaborations necessary to realize the full scientific potential of astronomical databases in the coming decade »

NVO White Paper, juin 2000


Primary Data Providers
Surveys
Observatories
Missions
Survey
and
Mission
Archives
Digital libraries
VO
Data Services

Data Mining
and Analysis,
Target Selection
Secondary
Data
Providers
Follow-Up
Telescopes
and
Missions
Results

The VO



publishing metaphor

- facilities are **authors**
- data centres are **publishers**
- VO portals are **shops**
- end-users are **readers**
  VO infrastructure is **distribution system**

History

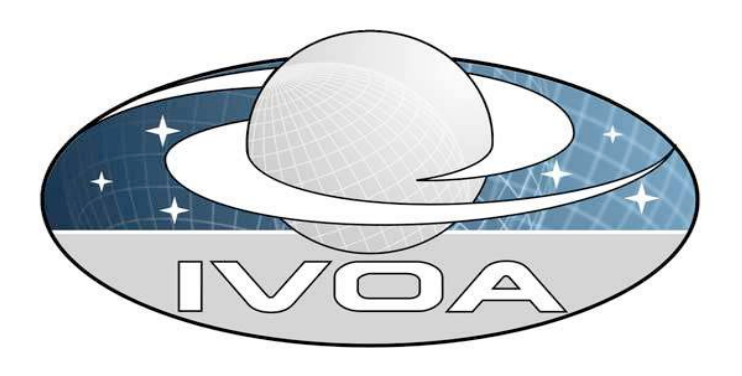
- Launch : "Virtual Observatories of the Future", 13-16 june 2000, Caltech Pasadena
- Since, many national programs : NVO, AstroGrid, GAVO, ... and AVO (Europe)
- Launch of the International Virtual Observatory Alliance in Garching on the 10-14 June 2002

Interoperability Working Groups

- Resource Registry
- Data Modeling
- Content Description
- Data Access Layer
- VOTable
- VO Query Language
- Grid & Web Service
- Standards & Processes

2 Interoperability meetings a year

Next one in China



Standards

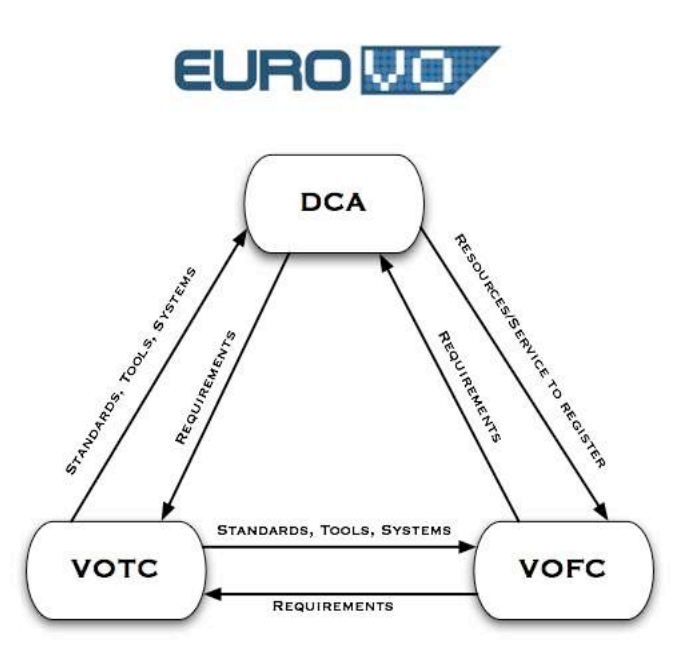
- VOTable: a way to represent a table of data in XML with good metadata about the semantic meaning of the data
- ConeSearch: to find out about sky-located objects such as stars or images: the input is a cone of space with center and radius, the output is a VOTable that has RA and Dec columns
- Simple Image/Spectra Access: protocol that allows publication and query of image sets/spectra

Euro-VO

The EURO-VO project aims at deploying an operational Virtual Observatory in Europe.

Its objectives are

- technology take-up and VO compliant resource provision
- building the technical infrastructure
- support its utilization by the scientific community.



EURO VO TECHNOLOGY CENTRE

http://eurovotech.org/

EURO VO DATA CENTRE ALLIANCE

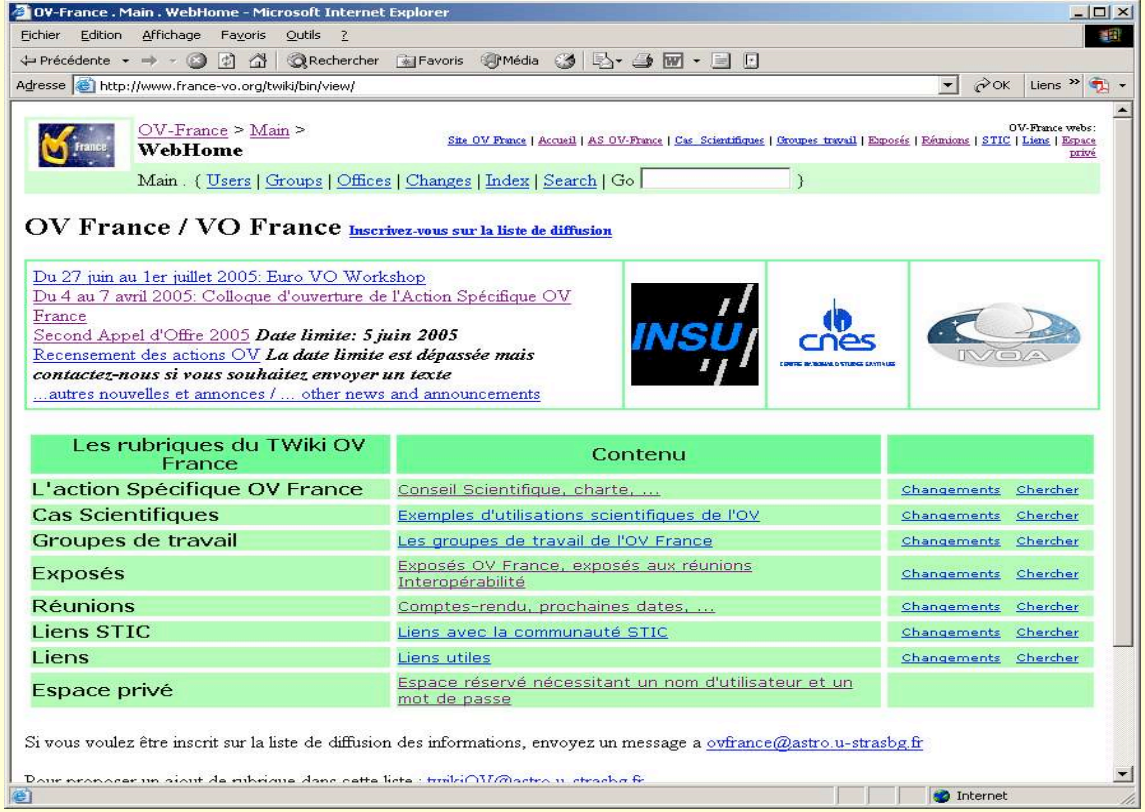
http://cds.u-strasbg.fr/twikiDCA/bin/view/EuroVODCA/WebHome

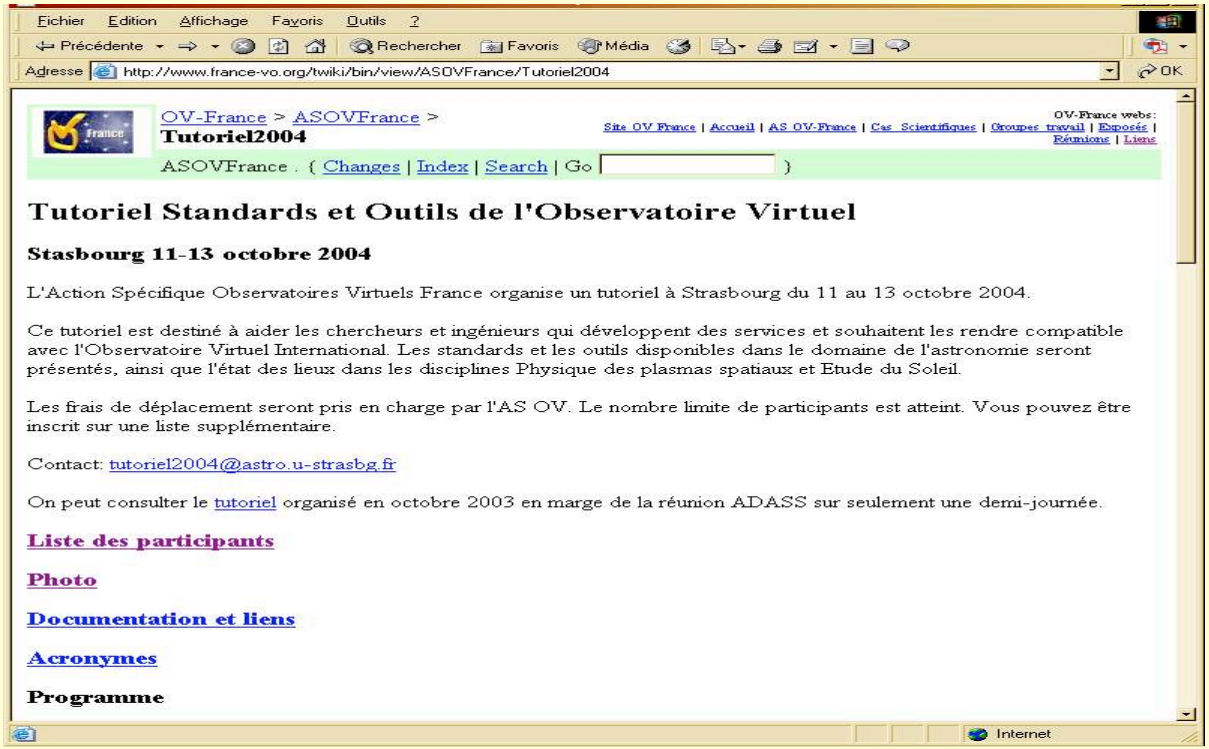
VO-France

www.vo-france.org

Contact:
ovfrance@astro.u-strasbg.fr

Tutorials
Collaborations
Conferences

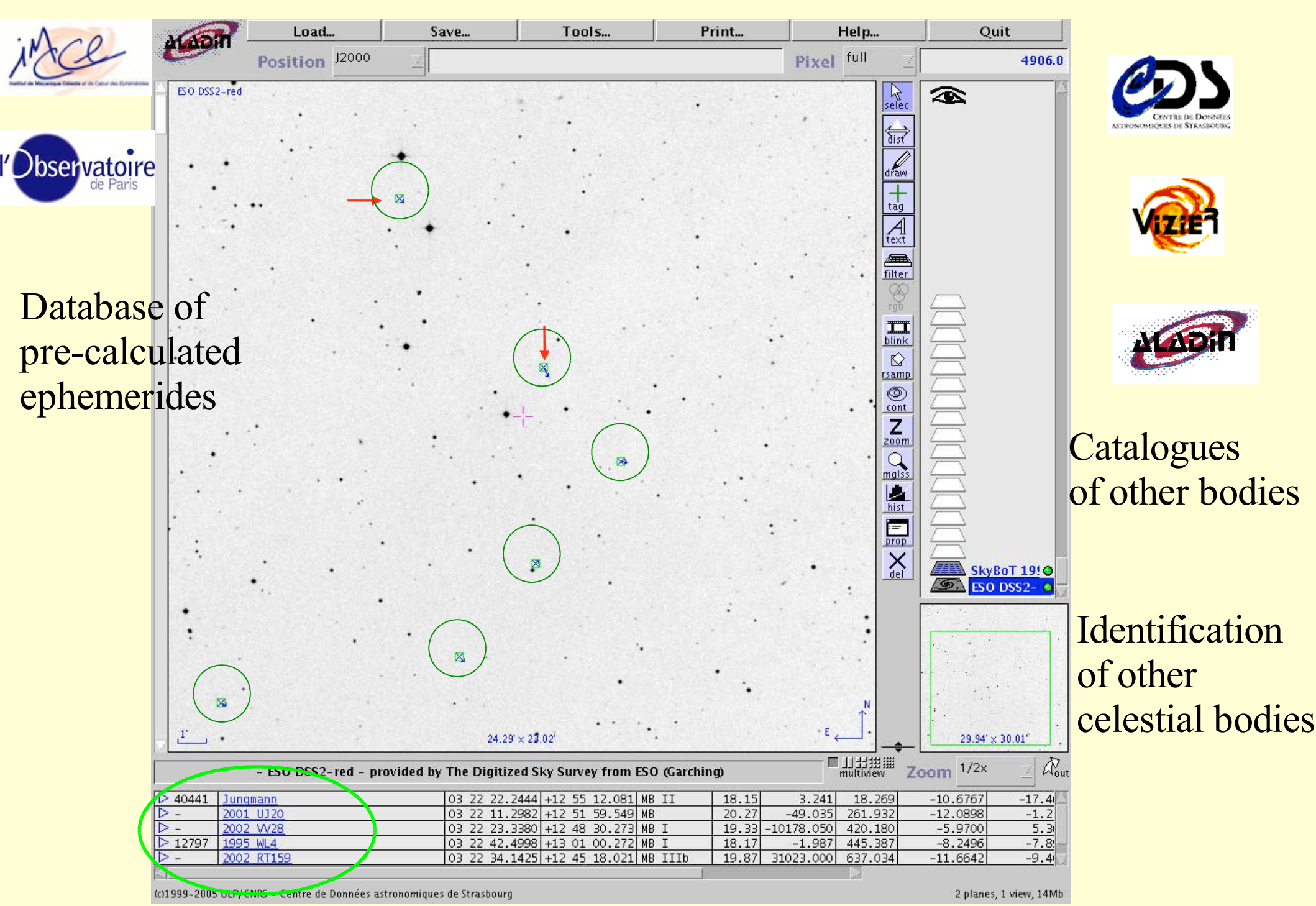




Paris VO Data Center

http://vo.obspm.fr/

- Federation: Paris Observatory, IAP and IPSL
- Very different products
  - Small objects of the solar system, Exoplanets
  - Planetary atmospheres
  - Simulations in the VO
  - Spectra and Images Databases (surveys, instrument archives)
  - Atomic & Molecular Physics
- Implementation of VO Standards
- Tools Development
- Central team of engineers + dedicated R&D in lab



Database of pre-calculated ephemerides

Catalogues of other bodies

Identification of other celestial bodies

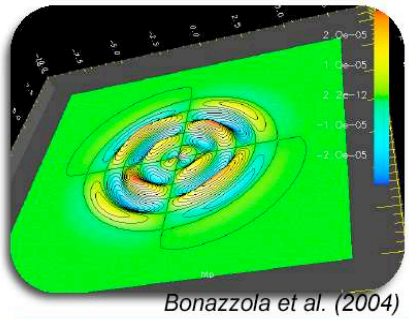
- **Identification of the Solar System bodies**

Some VO Simulation Projects at Paris Observatory

Priority to some « big » codes

Codes

• **Lorene**



Bonazzola et al. (2004)

Relativistic team (LUTH)

- Libraries to solve partial differentials equations
  Multi-domain spectral methods

  Applications : - Compact objects
  - Relativistic jets (Zakaria Meliani)

• **The Meudon PDR code**

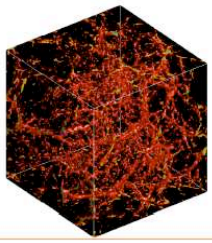
MIS team (LUTH)

Applications :
- Interpretation of observations in molecular regions
  Examples : FUSE, ISO, HST(STIS)
  Herschel, ALMA, …

Courtesy of F. Le Petit
(LUTH, Obs. Paris)

Ongoing projects

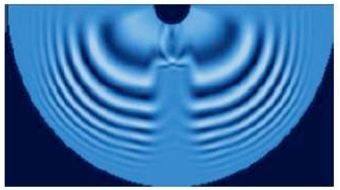
• **Codes de cosmologie**



Jean-Michel Alimi, André Füzfa & collaborators

Applications : Formation of structures / galaxies
- N-body
- Hydrodynamic
- non-equilibrium chemistry

• **code MHD**

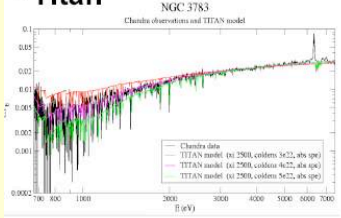


Roland Grappin, Filippo Pantellini (LESIA)

Resolution of MHD equations 1D/2D/3D
Particularities : open bounds

Applications : - stellar atmospheres, corona, winds
- stellar formation

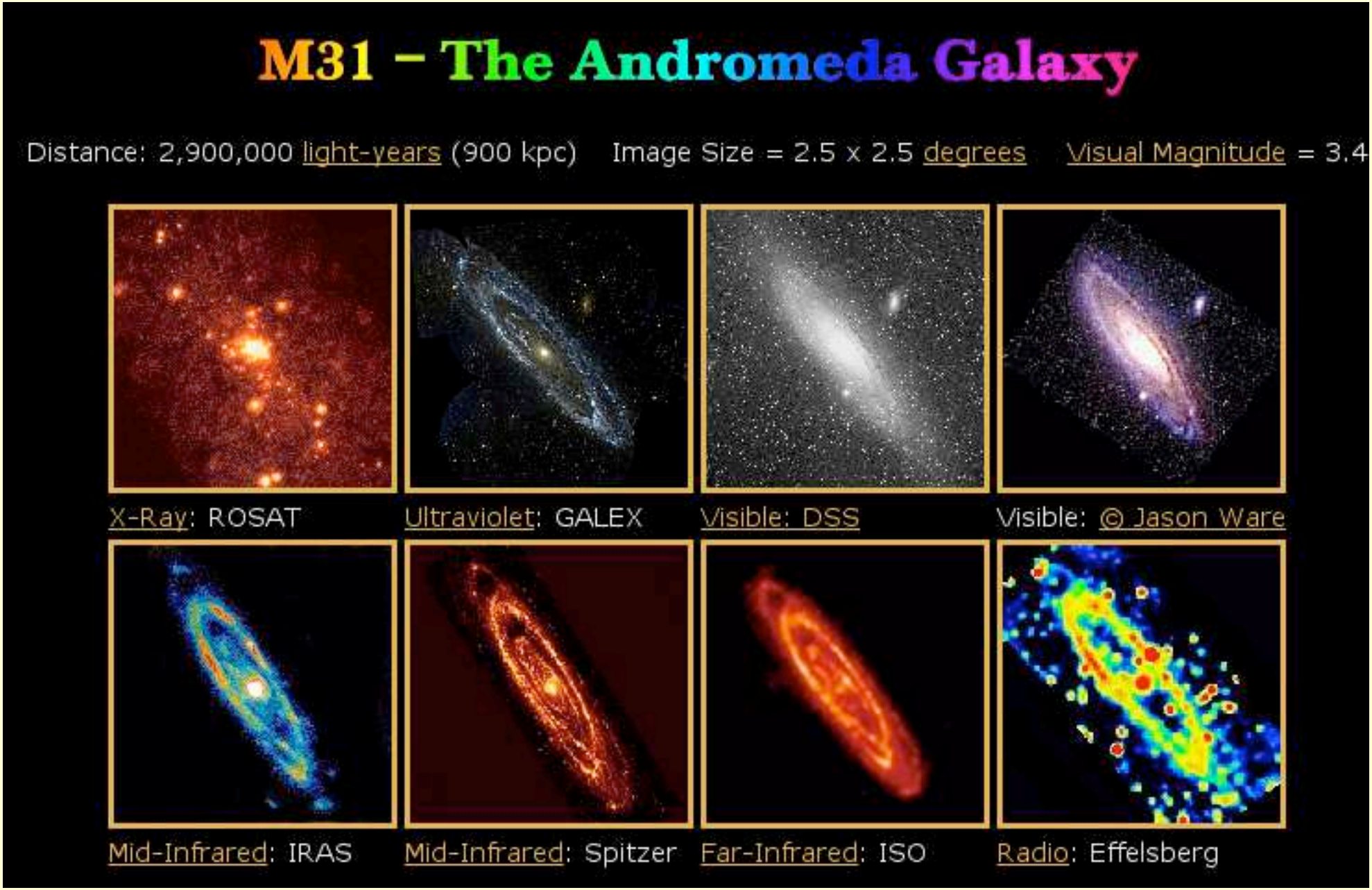
• **Titan**



Anabela Gonçalves, Loïc Chevallier, René Goosman

Radiative transfer in optical thick medium
Applications : Interpretation of X observations
(Chandra, XMM, *XEUS*, …)

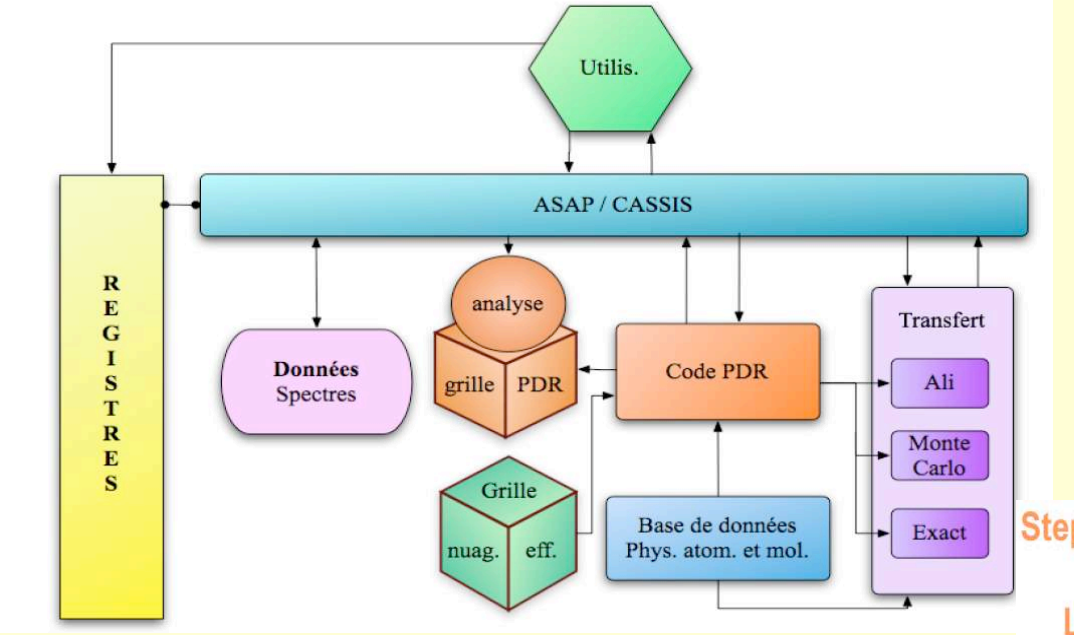
Science: Multi-wavelength Analysis



Science: Comparison Models/Observations

Usecase

Next generation of instruments : huge amount of data
↳ need efficient tools to analyse and interpret the observations



Courtesy of F. Le Petit
(LUTH, Obs. Paris)

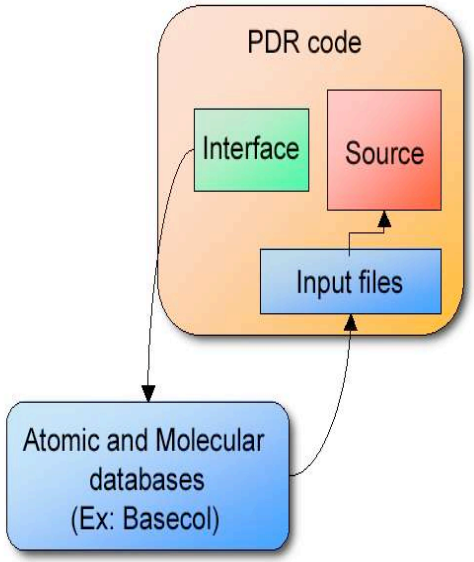
http://aristote.obspm.fr/MIS

Step 1 : Use of the VO :

Link : PDR code / databases (1)

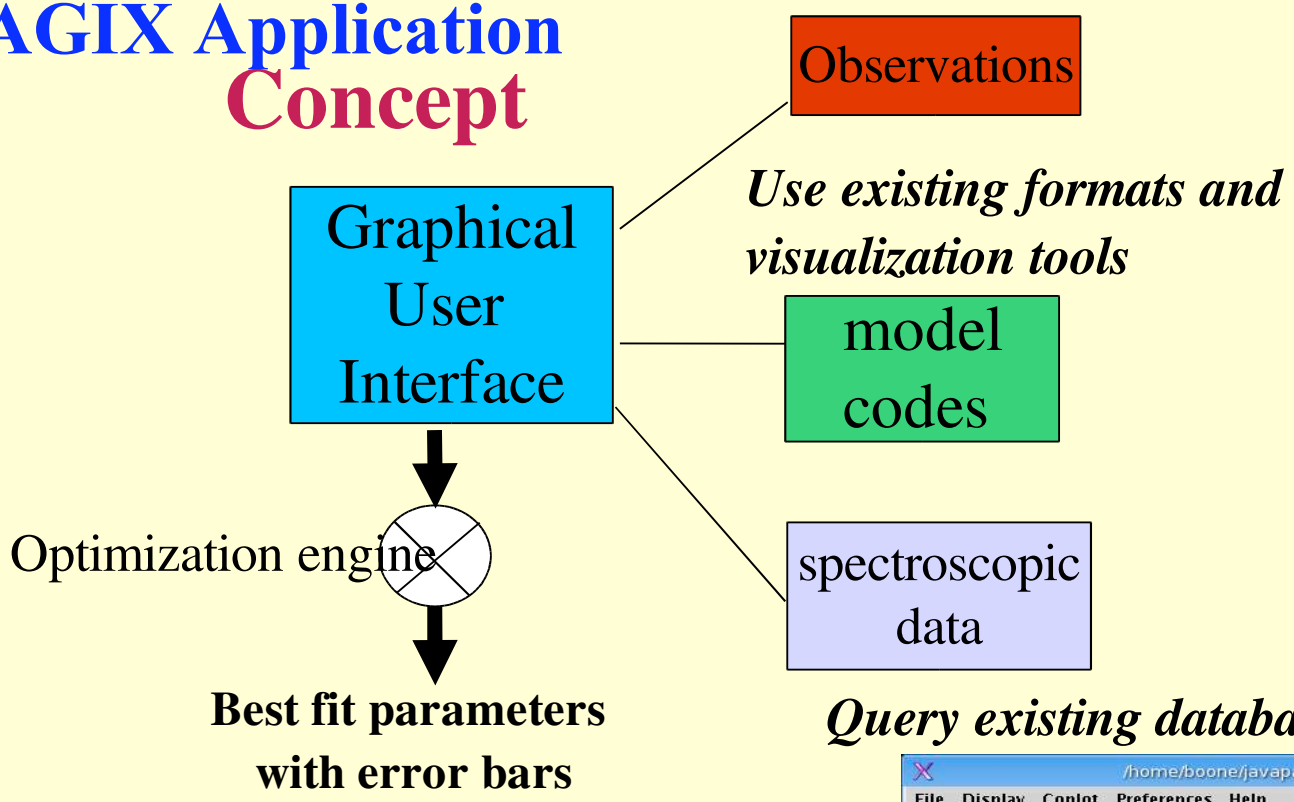
Data used by PDR codes :

- Atomic and molecular properties :
  - Energy levels
  - Einstein coefficients
- Reactions between elements
  - collision rates
  - chemical reaction
    - gas phase reactions
    - surface reactions
    - photo-process cross sections



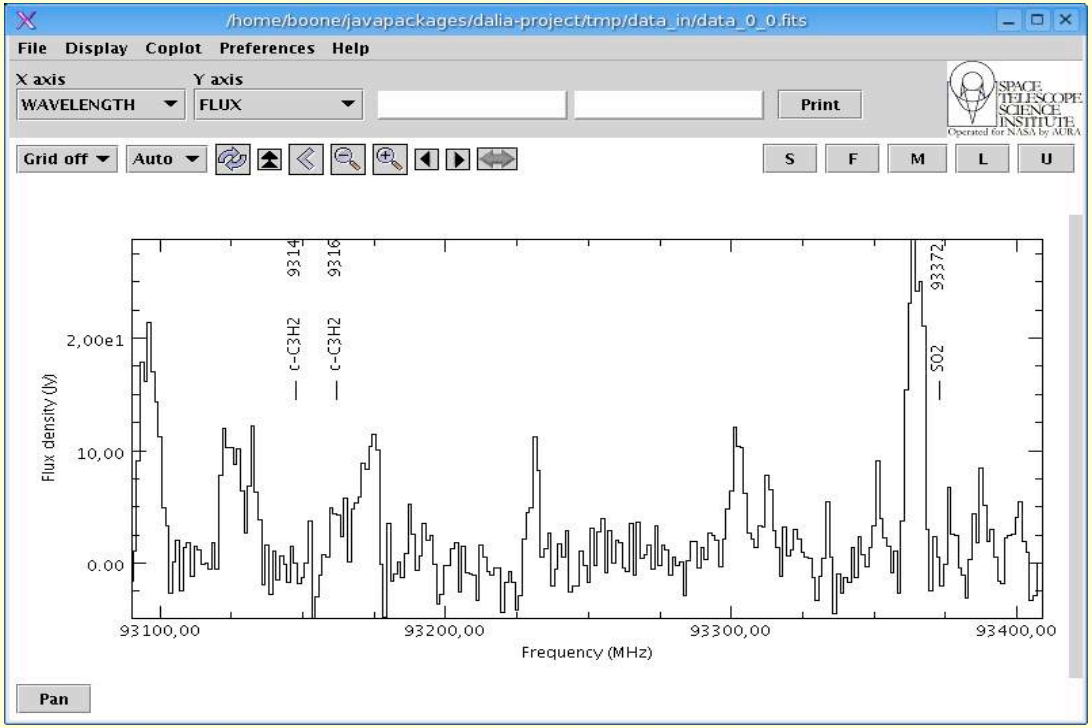
MAGIX Application Concept

Courtesy of F. Boone



Use existing formats and visualization tools

Query existing databases

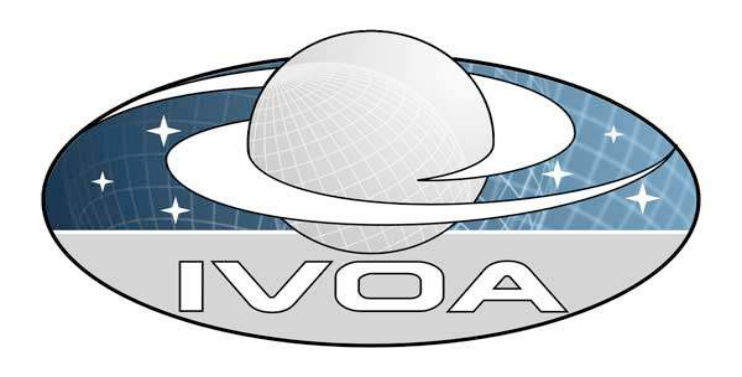


Science Synthetic Spectra

VO: Interoperability of ressources in order to produce science

- Observational Data
  - Archives: well taken care in IVOA, cross correlation (ALMA working group)
- Theoretical/Observed Microphysics Data in Databases
  - Ex : NIST, CDMS/JPL, BASECOL, LOVAS catalogues, UMIST, etc ....
- Numerical Codes
  - Ex : Radiative transfert codes, Modeling codes
- Analysis tools/Visualisation
  - Analysis software (reduction pipeline, optimization algorithms, synthetic spectra): VoSpec, CASSIS, ASAP/MAGIX, etc ....

Requirements for Tools Implementation



- Full description of all data
  - Microphysics:
    - references, methods, accuracy
    - Identify measurements/calculations from extrapolation
  - Codes:
    - Identify hypothesis, algorithms, parameters
- Use standardized exchange langage
- Long term maintenance of applications
- Deal with various ressources

Access Atomic/Molecular DB starting with line lists

- Theoretical (measured or calculated) DB
- Observed line lists DB

- **Numerous DB are available**
  - Atomic lines: NIST DBs, Kurucz's CD-ROM, Atomic Line List of P. Van Hoof, TOPbase, Kelly Atomic Line DB, VALD, MCHF/MCDHF Collection, D.R.E.A.M, KAERI AMODS
  - Molecular Lines: JPL Spectroscopic DB, CDMS, HITRAN, GEISA, NIST
  - Other DB: IEAE, NIFS, CHIANTI, UMIST, BASECOL, small compilations
  - Observed databases: ATOMDB, NIST, ...
- **Identification of Pbs**
  - Different DB have similar datasets
    - DB have different levels of update
    - Lengthy to identify origin of datasets, find all relevant description of data
  - Useful data for a single astrophysical application are dispersed in various DB
    - No homogeneous description of data

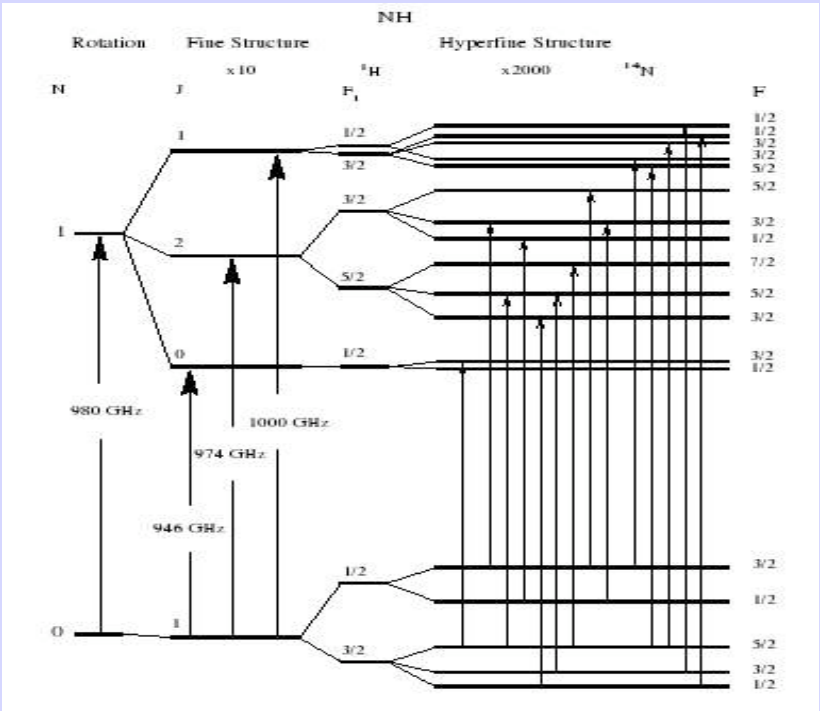
Atomic & Molecular Lines Data Model

Paris Observatory and ESA/ESAC

ML Dubernet, P. Osuna, M. Guanazzi, J. Salgado, E. Roueff

Light – Matter Interaction : bound-bound

A(j) + hv ---> A(j') or A(j') ---> A(j) + hv



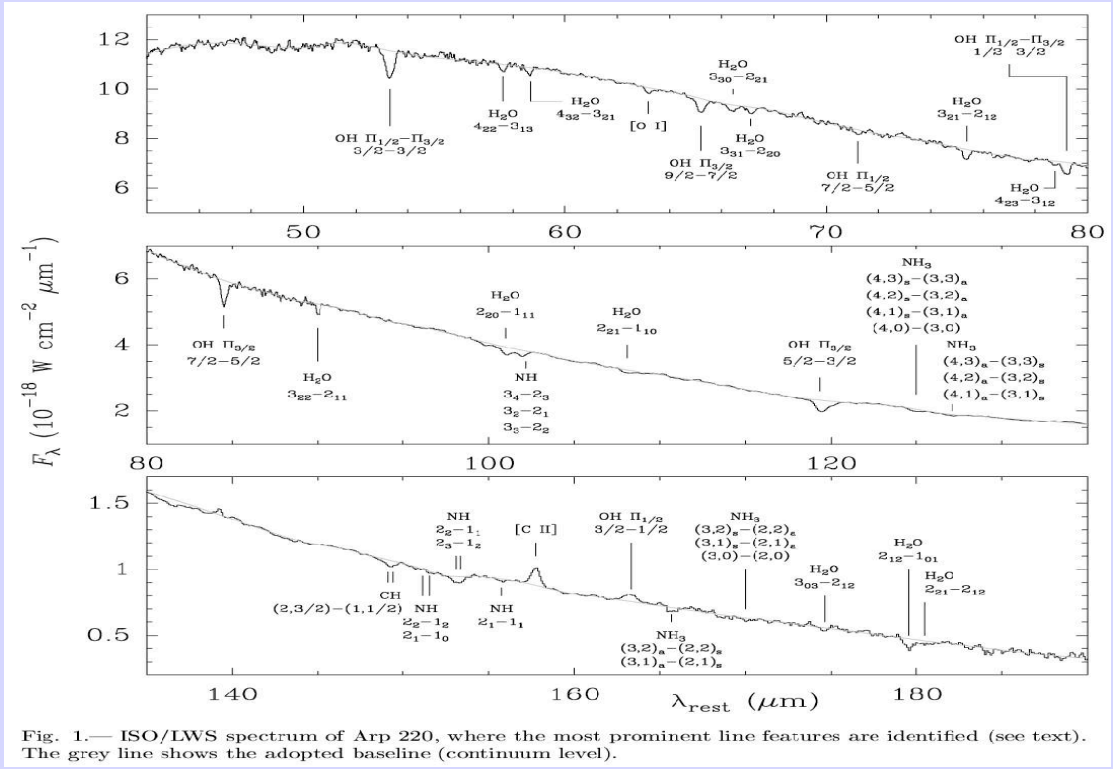


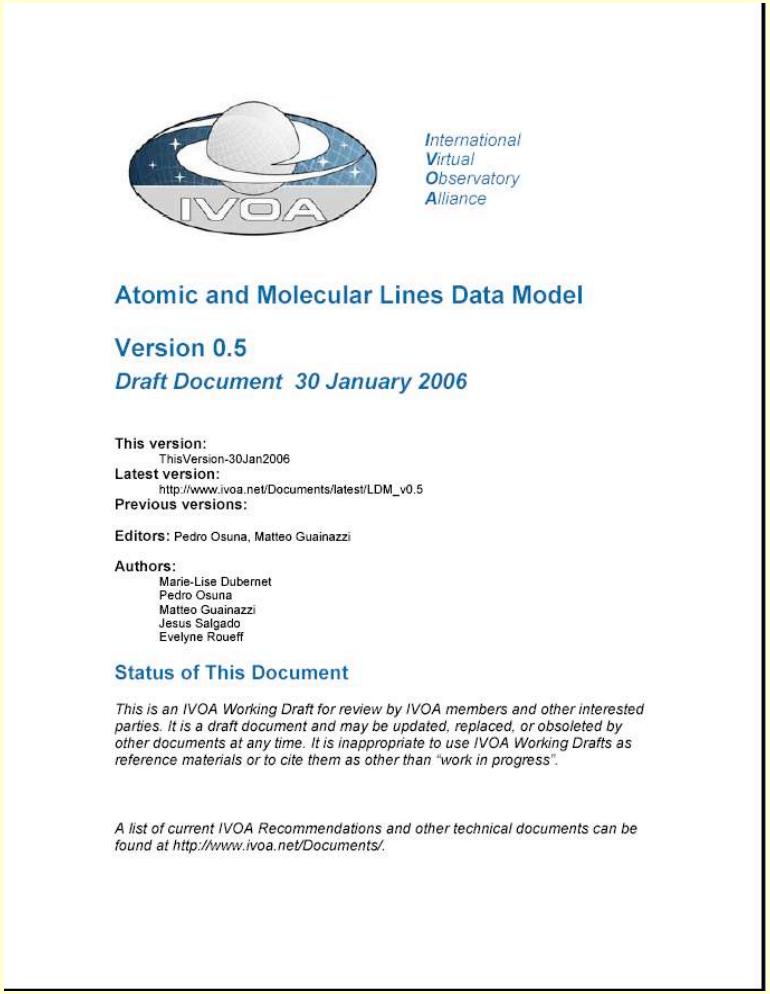
Fig. 1.— ISO/LWS spectrum of Arp 220, where the most prominent line features are identified (see text). The grey line shows the adopted baseline (continuum level).

Radiative recombinaison

(Z, N-1)[level.of.Z(N-1)] + e ---> (Z, N)[level.of.Z(N)] + hv

MLD acknowledges support from VO-France, MDA project (F. Genova), Paris Observatory

Documents status and perspectives



International
Virtual
Observatory
Alliance

Atomic and Molecular Lines Data Model

Version 0.5

Draft Document 30 January 2006

This version:
ThisVersion-30Jan2006
Latest version:
http://www.ivoa.net/Documents/latest/LDM_v0.5
Previous versions:

Editors: Pedro Osuna, Matteo Guainazzi

Authors:
Marie-Lise Dubernet
Pedro Osuna
Matteo Guainazzi
Jesus Salgado
Evelyne Roueff

Status of This Document

This is an IVOA Working Draft for review by IVOA members and other interested parties. It is a draft document and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use IVOA Working Drafts as reference materials or to cite them as other than "work in progress".

A list of current IVOA Recommendations and other technical documents can be found at http://www.ivoa.net/Documents/.

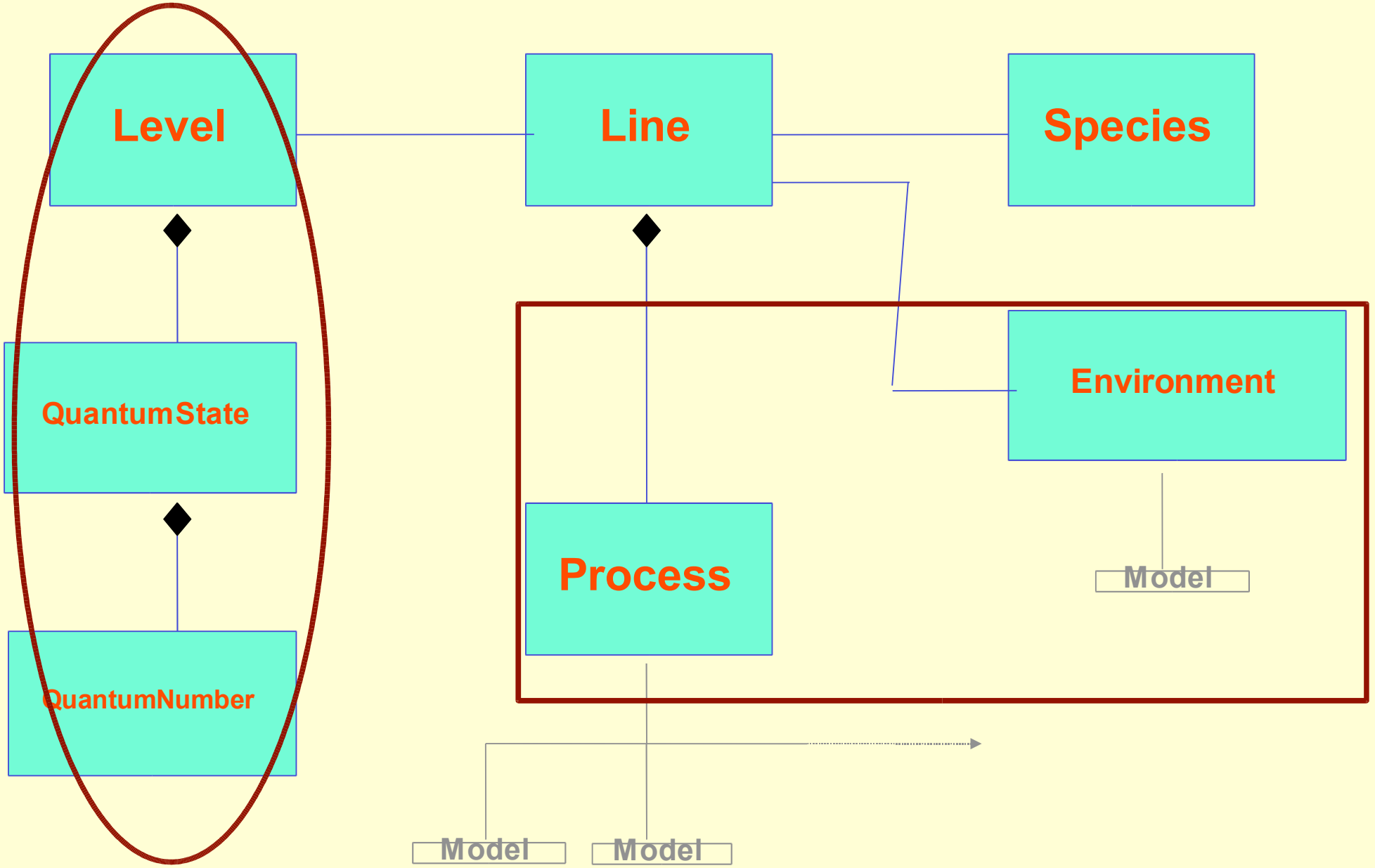
- ***AML DM Current version*: 0.5 (30/1/2006)**
- **circulated to the DM and DAL groups, as well as to atomic and molecular astrophysicists for comments**
- ***Goal:* achieve the status of a *proposed recommendation* in the next 4 months.**
- **Useful for ETL studies and calibration**
- **Requirements: to be implemented by the AM databases communities**

Requirements: MUST DESCRIBE

- Laboratory measured & fitted linelists
  - Based on A&M Theoretical Spectroscopy
- Linelists obtained from observed/simulated spectra
  - Environment, Process
- Atomic and Molecular Species
- Precise enough in order to do science
- Unprecise enough in order to cover observational databases

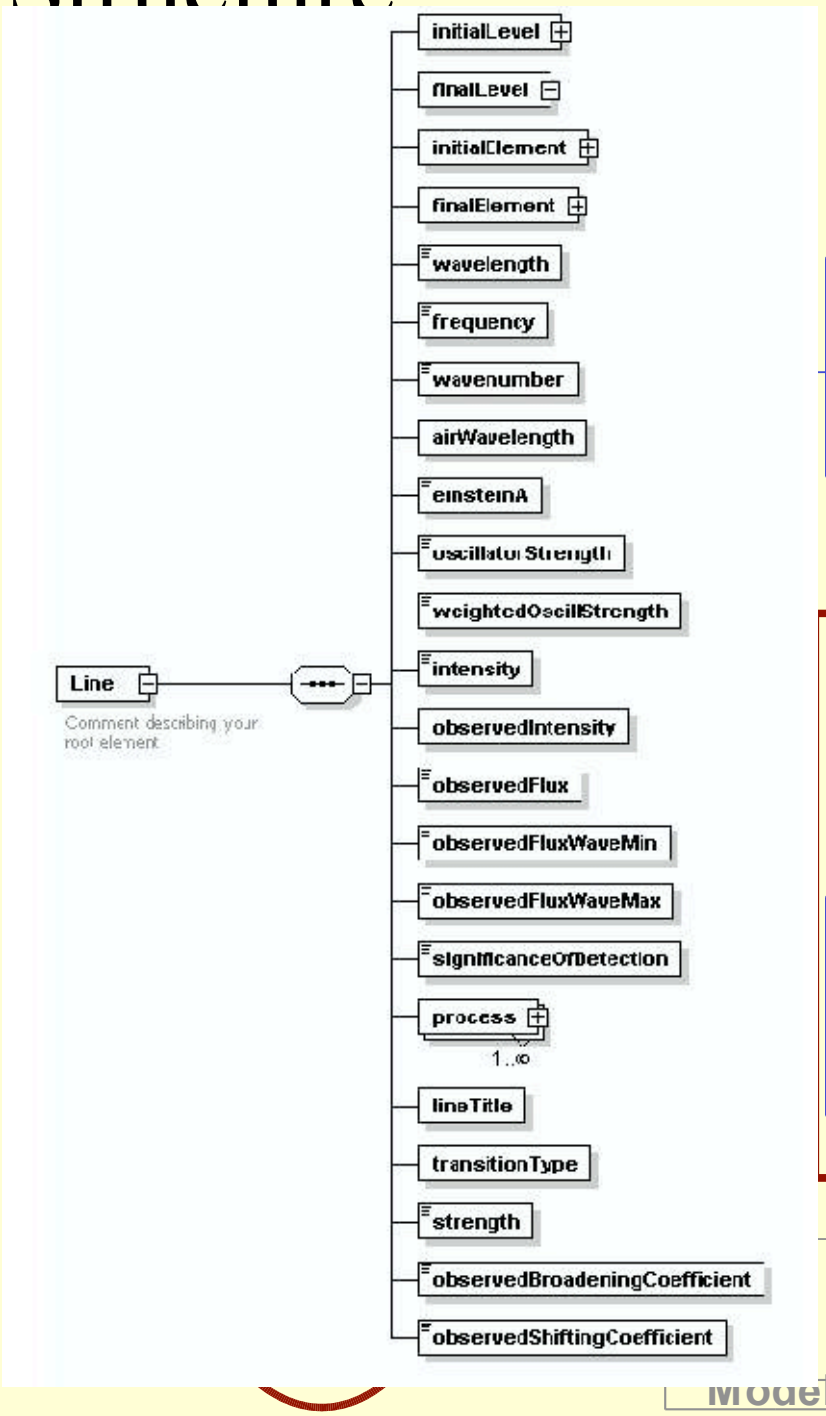
Structure

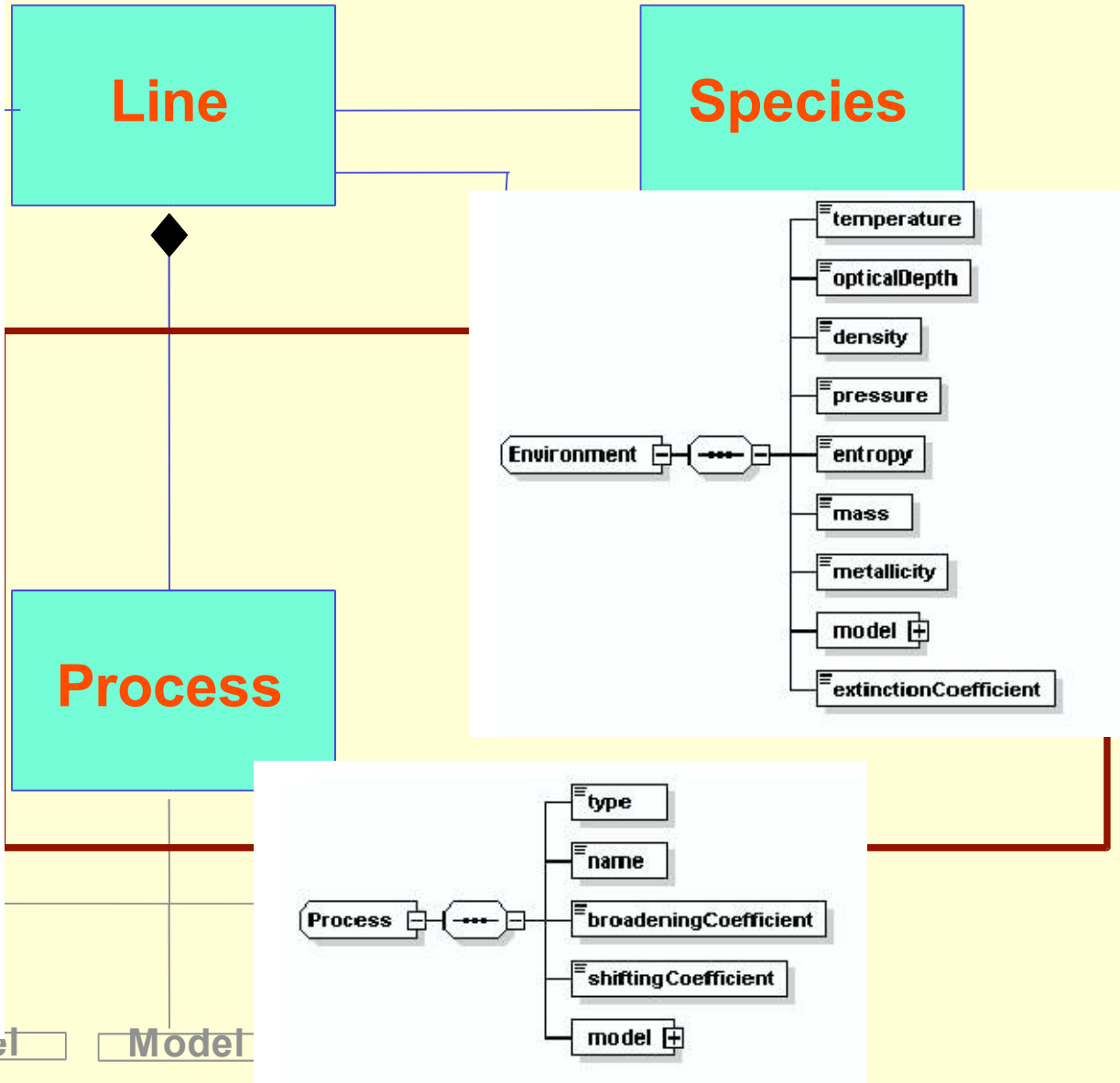
Laboratory & Observed Lines



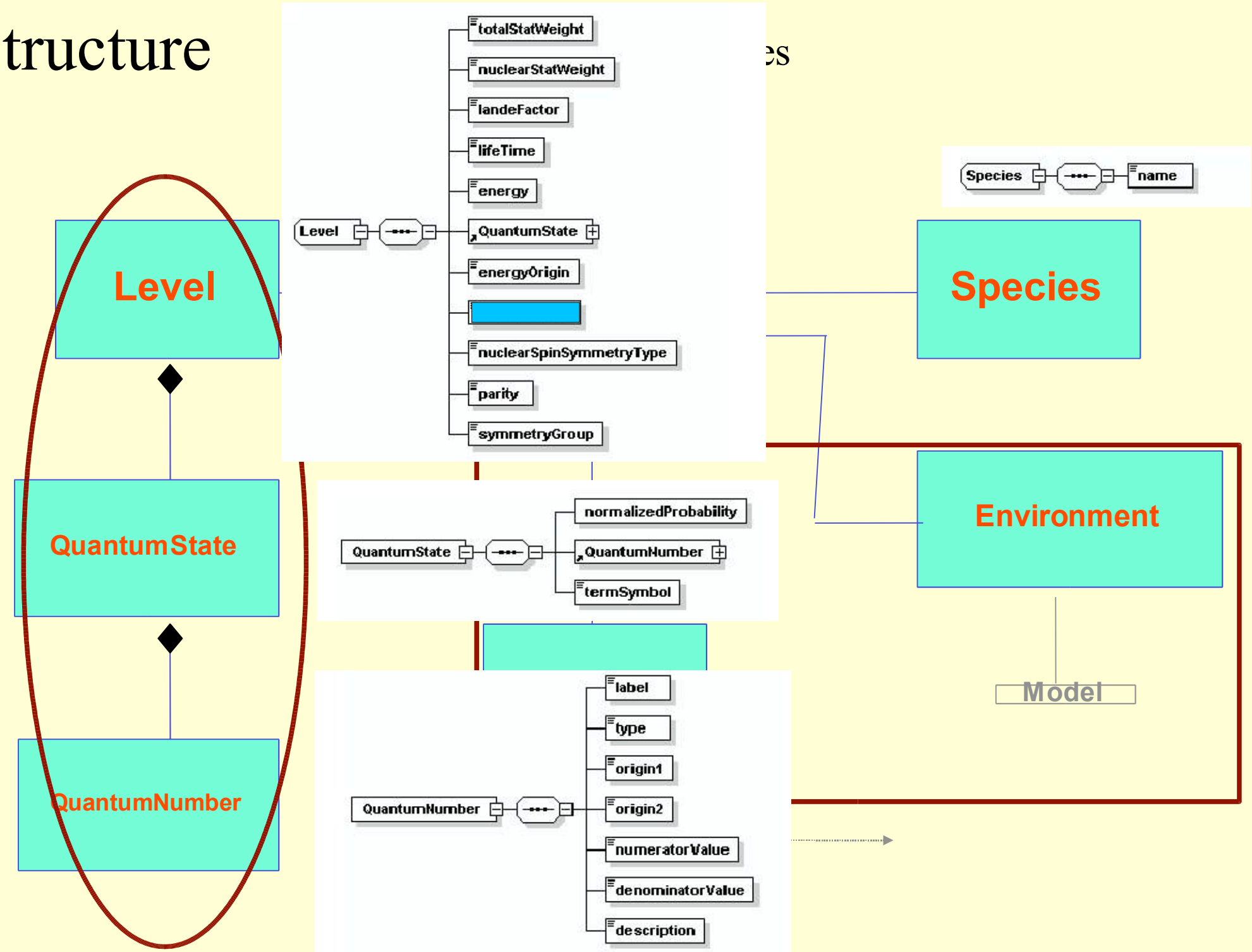
Structure

Laboratory & Observed Lines





Structure


totalStatWeight
nuclearStatWeight
landeFactor
lifeTime
energy
Level
QuantumState
energyOrigin
nuclearSpinSymmetryType
parity
symmetryGroup
Species
name
Level
Species
QuantumState
normalizedProbability
QuantumState
QuantumNumber
termSymbol
Environment
Model
label
type
origin1
QuantumNumber
origin2
numeratorValue
denominatorValue
description
QuantumNumber

List of Quantum Numbers

- nprincipal
- lElectronicOrbitalAngularMomentum
- sAngularMomentum
- JtotalAngularMomentum
- LmagneticQuantumNumber
- SmagneticQuantumNumber
- nuclearSpinI_I
- totalNuclearSpinI
- totalSpinMomentumS
- totalMagneticQuantumNumberS
- totalMolecularProjectionS
- totalElectronicOrbitalMomentumL
- totalMagneticQuantumNumberL
- totalMolecularProjectionL
- totalAngularMomentumJ
- totalMagneticQuantumNumberJ
- totalMolecularProjectionJ
- totalAngularMomentumF
- totalMagneticQuantumNumberF
- totalAngularMomentumJa
- RotationR , MolecularProjectionR
- asymmetricTau
- asymmetricKa , asymmetricKc
- vibrationNu_i
- vibrationLNu_i
- totalVibrationLNu
- vibronicAngularMomentumK
- VibronicAngularMomentumP
- vibrationSymmetry_i
- HinderedK1, hinderedK2

International
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Simple Line Access Protocol

Version 0.5

Draft Document 17 May 2006

This version:
0.5 17May2006
Latest version:
http://www.ivoa.net/Documents/latest/latest-version-name
Previous version(s):

Editor(s):
Pedro Osuna
Jesus Salgado

Author(s):
Jesus Salgado
Pedro Osuna
Matteo Guainazzi
Isa Barbarisi
Marie-Lise Dubernet
Doug Tody

Abstract

This specification defines a protocol for retrieving spectral lines from different spectral line databases through a uniform interface.

SLAP

Collaboration:
ESA/ESAC
Paris Observatory

Document status

- *Goal*: achieve the status of a *proposed recommendation* in the next 4 months.

Query by Wavelength

Necessary steps before Proposed Recommendation

- Few explanations to modify
- Standardize molecule names
- Quantum State: Symmetry types such as vibronic_Species rovibronic_Species

- Accuracy, Quality, Documentation, Versioning

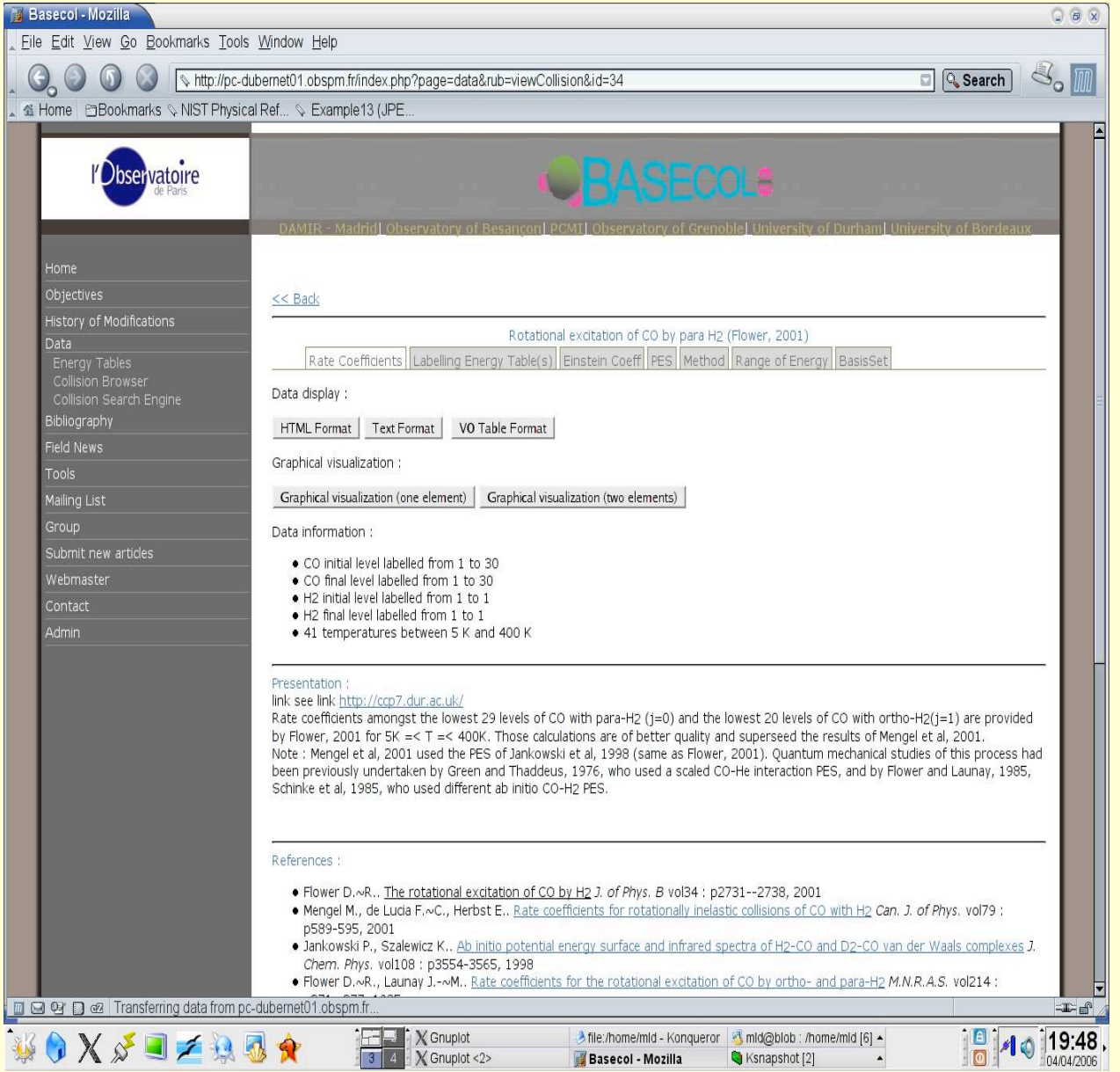
  → Connection to other VO Data Models

Basecol Database (www.obspm.fr/basecol)

Useful for astrophysicists and physicists

Linked to CDMS and JPL

- Published (de)-excitation rate coefficients
  - Rotational (fine, hyperfine)
  - Ro-vibrational, Vibrational
  - Currently: 21 Target molecules
  - Perturbers : He, H, H_2
  - 76 collisional systems
  - Fully documented and referenced (630 ref.)
  - Fitting coefficients, visualisation tools
  - Energy levels, Einstein coefficients, QN



Home
CDMS
What's New
Catalog
General
Entries
Search
partition functions
archive
Molecules in Space
Fitting Spectra
Cologne Spectroscopy Data
Links
Contact

Catalog Directory

See the General part for a description of the content and the home page for citation!

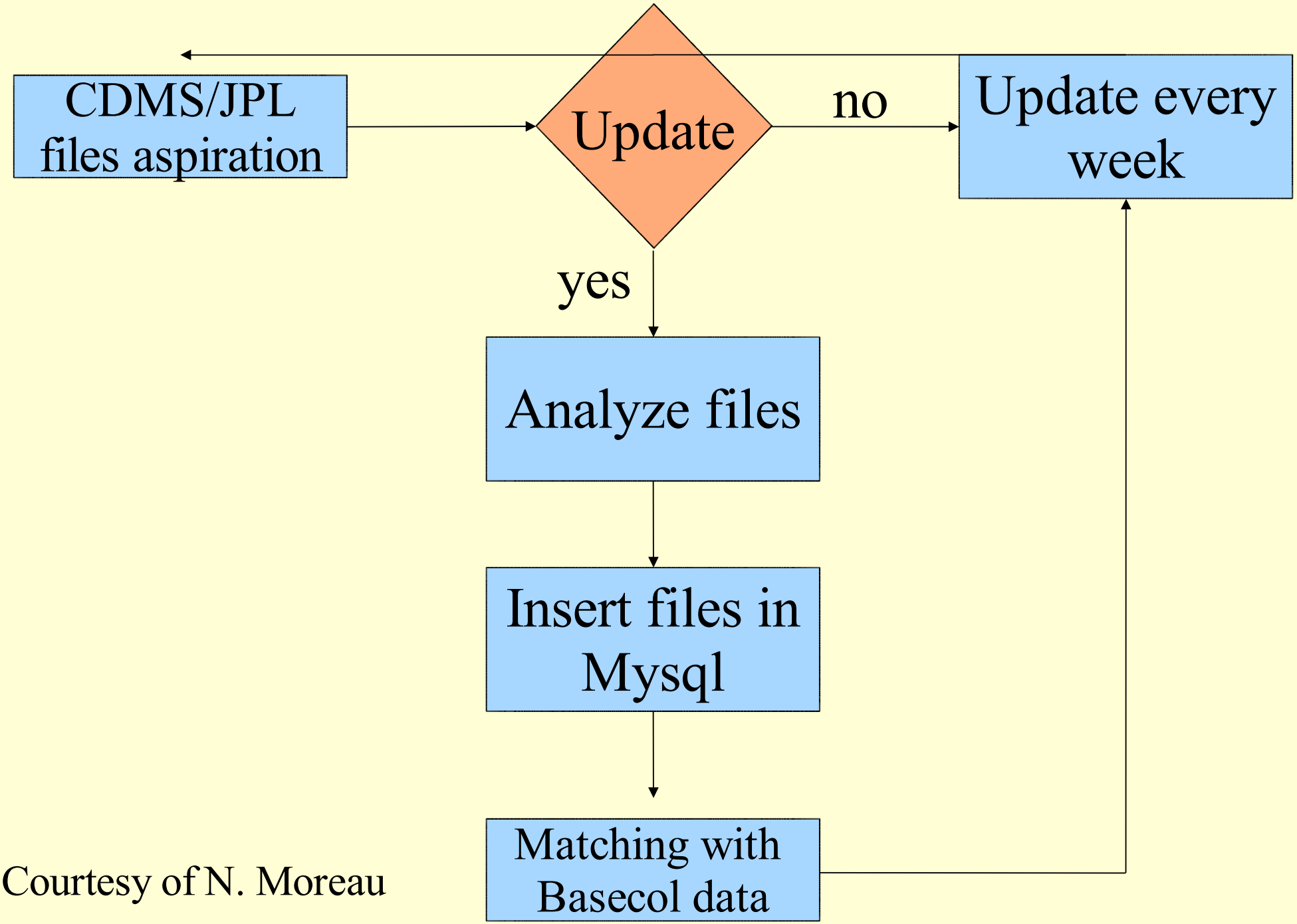
Entries having an asterisk after the version number have been included in the database after acceptance of our new article on the CDMS, *J. Mol. Struct.*, **742** 215–227 (2005), in January, 2005. It can not be ruled out completely that recent entries contain errors.

Note: Entries having an asterisk after the tag state the temperature independent Sμ2 instead of the intensity *I* at 300 K !!

For some entries, where, for example, hyperfine splitting was important for the laboratory data, but is expected to be of minor importance for radioastronomical observations, separate predictions are available. Values of the partition function given in the respective documentation refer to the vibrational ground state only – unless stated otherwise.

Get one list of partition functions for the price of a half.
Currently 387 entries.

Tag	Name	# lines	Ver.	Catalog	Documentation	Date of entry	Entry in cm−1
003501	HD, *v* = 0, 1	21	1*	HTML | ASCII	e003501.cat	Sep. 2005	w003501.cat
004501	H_2D^+	137	1*	HTML | ASCII	e004501.cat	Aug. 2005	w004501.cat
005501	HD_2^+	163	1*	HTML | ASCII	e005501.cat	Aug. 2005	w005501.cat
012501	C	2	1*	HTML | ASCII	e012501.cat	Sep. 2005	w012501.cat
013501	^{13}C	7	1*	HTML | ASCII	e013501.cat	Sep. 2005	w013501.cat
013502	CH	385	2*	HTML | ASCII	e013502.cat	Sep. 2006	w013502.cat
014501	CH_2	1400	1*	HTML | ASCII	e014501.cat	Sep. 2005	w014501.cat
015501	NH	1948	1	HTML | ASCII	e015501.cat	May 2004	w015501.cat
016501	NH_2	18513	2	HTML | ASCII	e016501.cat	Oct. 2001	w016501.cat
016502	ND	2020	1	HTML | ASCII	e016502.cat	Feb. 2004	w016502.cat
016503	CH_2D^+	222	1	HTML | ASCII	e016503.cat	July 2004	w016503.cat
017501	OH^+	209	1	HTML | ASCII	e017501.cat	Apr. 2003	w017501.cat
018501	NH_2D	3343	1	HTML | ASCII	e018501.cat	May 2004	w018501.cat
019501	NHD_2	4442	1	HTML | ASCII	e019501.cat	Aug. 2004	w019501.cat
020501	ND_3	698	1	HTML | ASCII	e020501.cat	June 2002	w020501.cat
024501	NaH	172	1	HTML | ASCII	e024501.cat	Jan. 2001	w024501.cat
025501	CCH, *v* = 0	109	1	HTML | ASCII	e025501.cat	Apr. 2004	
025502	MgH	96	1	HTML | ASCII	e025502.cat	May 2001	w025502.cat
025503	CCH, *v*2 = 1	374	1	HTML | ASCII	e025503.cat	Apr. 2004	
026501	CCD	198	1	HTML | ASCII	e026501.cat	Apr. 2000	
026502	^{13}CCH	232	1	HTML | ASCII	e026502.cat	May 2000	
026503	$C^{13}CH$	223	1	HTML | ASCII	e026503.cat	May 2000	
026504	CN, *v* = 0, 1	646	1*	HTML | ASCII	e026504.cat	May. 2005	



Courtesy of N. Moreau

Service for MAGIX

- Query Parameters
  - Frequency_min (instead of wavelength_min)
  - Frequency_max (instead of wavelength_max)
  - *Chemical_element (SLAP non compulsory parameter)*
  - *Chemical_element_symmetry (specific to this service)*
- Return list of transitions with:

```
- <VOTABLE version="1.1" xsi:schemaLocation="http://www.ivoa.net/xml/VOTable/v1.1 http://www.ivoa.net/xml/VOTable/v1.1">
  - <RESOURCE type="results">
      <INFO name="QUERY_STATUS" value="OK"/>
    - <TABLE>
        <FIELD name="frequency" ucd="em.freq" utype="ldm:Line.frequency" datatype="int"/>
        <FIELD name="chemicalelement_name" ucd="phys.atmol.element" utype="ldm:Line.initialElement.name" datatype="char" arraysize="*"/>
        <FIELD name="chemicalelement_symmetry" ucd="phys.atmol.element" datatype="char" arraysize="*"/>
        <FIELD name="final_level_energy" ucd="phys.energy;phys.atmol.final;phys.atmol.level" utype="ldm:Level.energy" datatype="double"/>
        <FIELD name="einstein_coefficient" ucd="phys.atmol.transProb" utype="ldm:Line.einsteinA" datatype="double"/>
        <FIELD name="statistical_weight" ucd="" datatype="double"/>
        <FIELD name="quantum_number_tag" ucd="meta.id" datatype="int"/>
        <FIELD name="id_chemical_element" ucd="meta.id" datatype="int"/>
        <FIELD name="data_source" ucd="meta.table" datatype="char" arraysize="*"/>
        <FIELD name="creation_date" ucd="" datatype="char" arraysize="*"/>
        <FIELD name="quantum_numbers_link" ucd="meta.ref.url" datatype="char" arraysize="*"/>
        <FIELD name="partition_function_link" ucd="meta.ref.url" datatype="char" arraysize="*"/>
      - <DATA>
        + <TABLEDATA></TABLEDATA>
        </DATA>
      </TABLE>
    </RESOURCE>
  </VOTABLE>
```

SLAP Server choice

Other servers :
- NIST
- ESA

Result of a simple request

Spectral lines Dialog

File Request Display Server

Filters

Minimum frequency value (in MHz) :	45000	Maximum frequency value (in MHz) :	45100
Minimum energy value (in cm-1) :	none	Maximum energy value (in cm-1) :	none
Minimum A value :	none	Maximum A value :	none

Lines

Molecule name	Transition quantum numbers (l,F)	Wavelength	Frequency	Initial energy	Final energy	Einstein coefficients	Source DB
34SO2; symmetry : none; date of import : 2006-09-12							
34SO2	[N=19.0 Ka=2.0 Kc=18.0][N=18.0 Ka=3.0 Kc=15.0]		0.00665027919453		45079.67999998945		
41KCl, v = 0, 1; symmetry : none; date of import : 2006-09-12							
41KCl, v = 0, 1	[N=6.0 v1=30.0][N=5.0 v1=30.0]		0.00665185496346		45069.00099999494		
aa-(C2H5)2O; symmetry : none; date of import : 2006-09-12							
aa-(C2H5)2O	[N=8.0 Ka=2.0 Kc=6.0][N=8.0 Ka=1.0 Kc=7.0]		0.0066608678184		45008.01789998782		
aa-(C2H5)2O	[N=79.0 Ka=13.0 Kc=67.0][N=80.0 Ka=12.0 Kc=68.0]		0.0066578546256		45028.387499972334		
aa-(C2H5)2O	[N=79.0 Ka=13.0 Kc=66.0][N=80.0 Ka=12.0 Kc=69.0]		0.00665785456645		45028.387900015485		
aa-(C2H5)2O	[N=14.0 Ka=4.0 Kc=11.0][N=15.0 Ka=3.0 Kc=12.0]		0.006651433554		45071.856399995544		
c-C2H4O; symmetry : ortho; date of import : 2006-09-12							
c-C2H4O	[N=18.0 Ka=3.0 Kc=15.0][N=19.0 Ka=2.0 Kc=18.0]		0.00665008997246		45080.96269998296		
c-C2H4O; symmetry : para; date of import : 2006-09-12							
c-C2H4O	[N=18.0 Ka=4.0 Kc=15.0][N=19.0 Ka=1.0 Kc=18.0]		0.00665008997246		45080.96269998296		
c-C6H4; symmetry : para; date of import : 2006-09-12							
c-C6H4	[N=4.0 Ka=3.0 Kc=2.0][N=3.0 Ka=2.0 Kc=1.0]		0.0066578322546		45028.53879997784		
c-C6H4	[N=21.0 Ka=12.0 Kc=9.0][N=21.0 Ka=11.0 Kc=10.0]		0.00665725755037		45032.42600000326		
c-HCOOH; symmetry : none; date of import : 2006-09-12							
c-HCOOH	[N=30.0 Ka=2.0 Kc=29.0][N=29.0 Ka=3.0 Kc=26.0]		0.00666061444936		45009.73000003119		
c-SiC3; symmetry : none; date of import : 2006-09-12							
c-SiC3	[N=22.0 Ka=4.0 Kc=18.0][N=23.0 Ka=2.0 Kc=21.0]		0.00665048909655		45078.2571999885		
C5N; symmetry : none; date of import : 2006-09-12							

OK Apply filters

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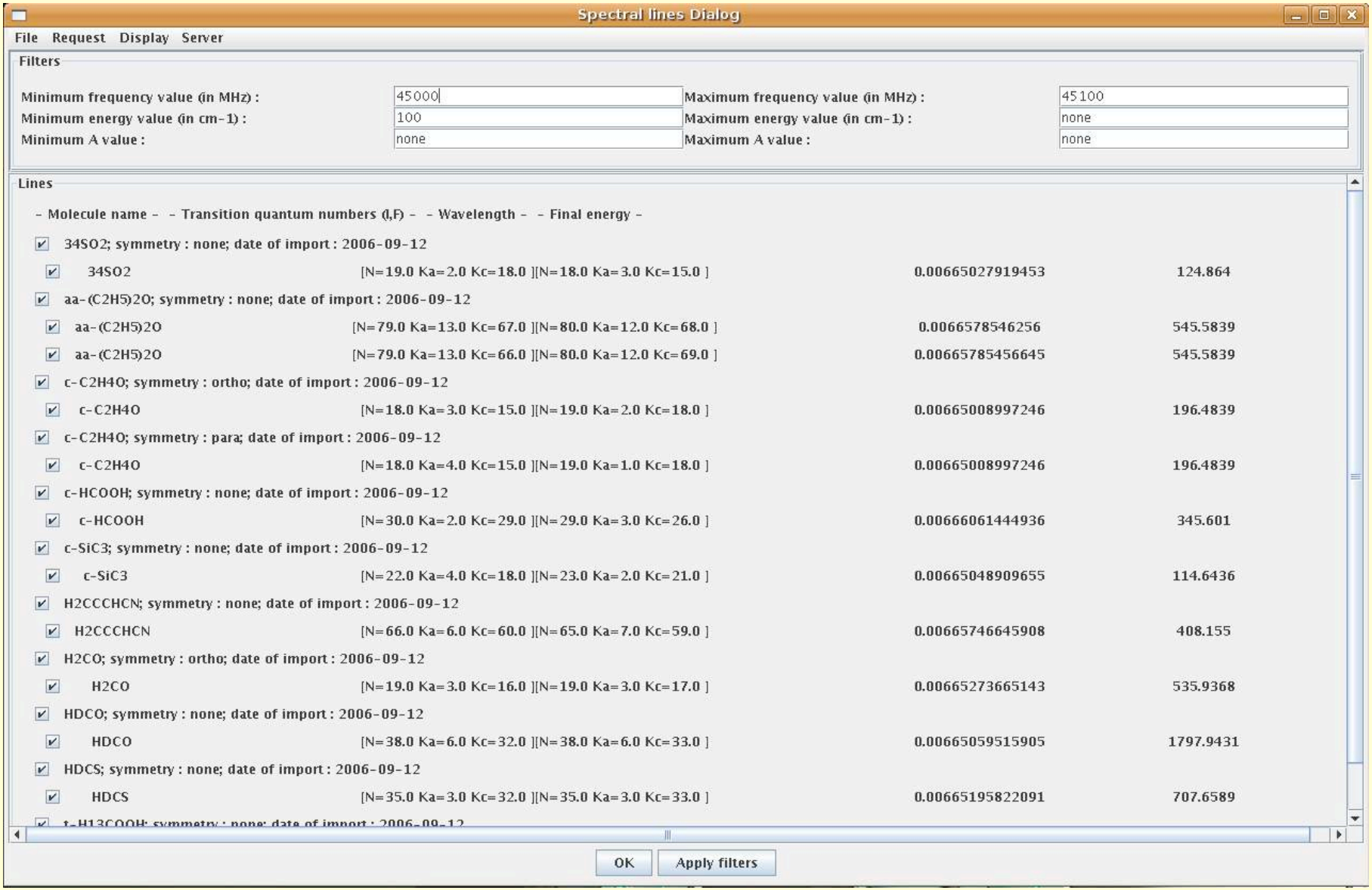
Filtered request result



minimum energy value = 100

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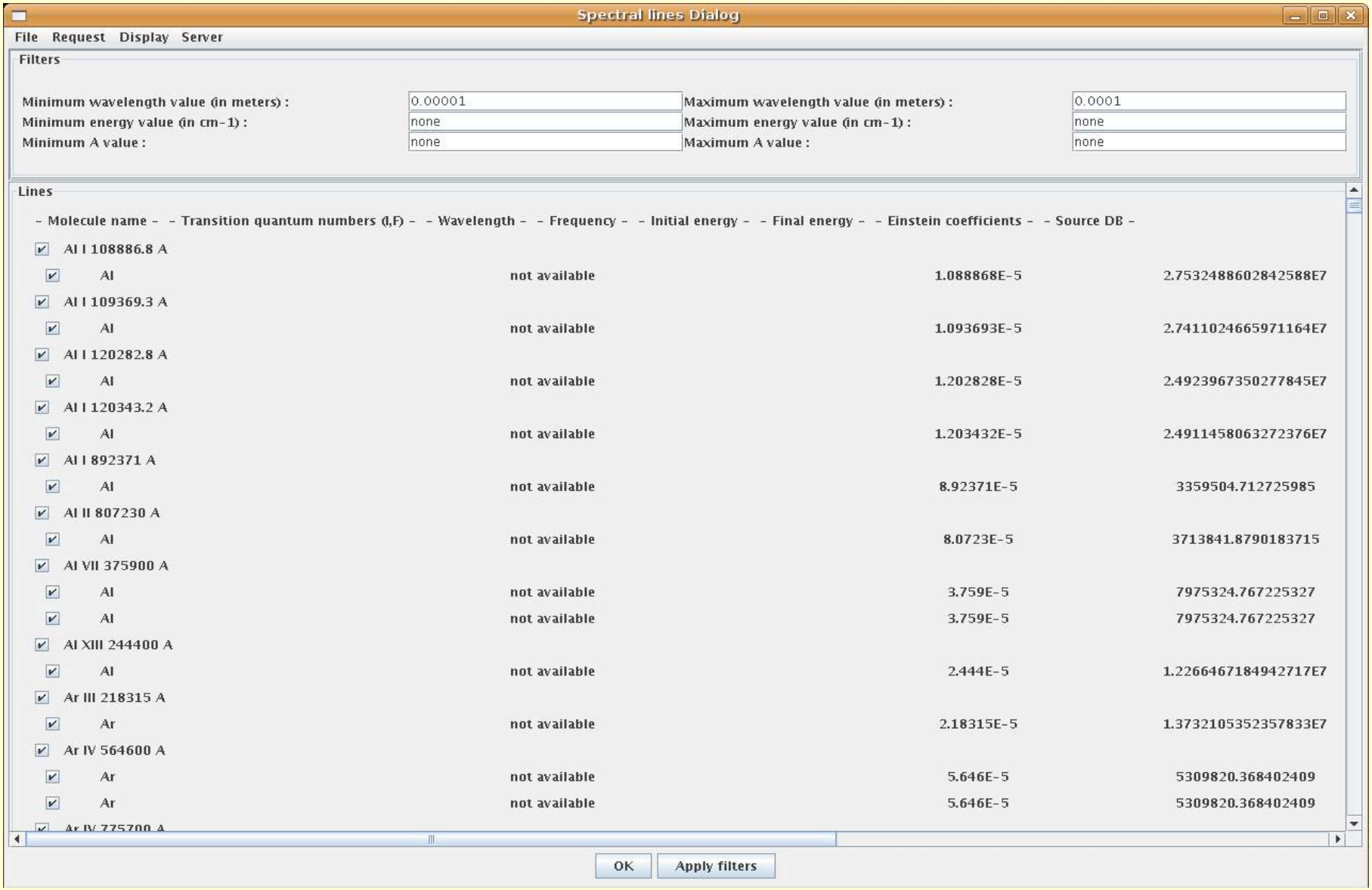
SLAP request to NIST server



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Automatic script to get data from Basecol

Script in Python, Use the SLAP service
Store the data in VOTable or in ascii files
Get all the collisions available in Basecol

Example of a query result :

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File listing all downloaded collisions

```
List of available tables of collision rates. After five header lines,
each entry consists of three lines: name of the file containing the table,.
description of the data and a separator line


H2O-ortho_He_rotation.kij
Rotational excitation of ortho-H$_2$O by He (Green & al., 1993)
   ********************


CS_H2-para_rotation.kij
Rotational excitation of CS by para-H$_2$, 20K < T < 300K, lowest 21 levels (Turner & al, 1992)
   ********************


HCO+_H2-para_rotation.kij
Rotational excitation of HCO$^+$ by para-H$_2$, 10K < T < 400K (Flower, 1999)
   ********************


OCS_He_rotation.kij
Rotational excitation of OCS by He (Flower, 2001)
   ********************


HCl_He_hyperfine.kij
Excitation of the hyperfine levels of HCl by He (Neufeld & al. 1994)
   ********************


HF_He_rotation.kij
 Rotational excitation of HF(v=0) by He (Reese et al, 2005)
   ********************


H2CO-para_He_rotation.kij
Rotational Excitation of para-H$_2$CO by He (Green, 1991)
   ********************


H2CO-ortho_He_rotation.kij
Rotational Excitation of ortho-H$_2$CO by He (Green, 1991)
   ********************
```

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Einstein coefficients

Einstein coefficients A_ij for c-C3H2
Reference : JPL

i	j	A_ij....
2	1	4.2263065752e-07
3	1	2.55334550477e-05
4	2	7.46365079557e-05
4	3	3.80296644732e-06
5	3	7.67030052301e-05
6	4	7.44204214473e-05
6	5	1.0907409924e-05
7	3	6.49147849116e-05
7	6	3.51497796146e-06
8	5	0.0001800850413
9	4	0.000281274770668
9	5	4.09019577389e-07
9	7	1.07159096204e-06
10	6	0.000239338358103
10	8	2.46408072369e-05
10	9	3.8977132555e-07
11	8	0.000346901479579
12	5	8.90722201873e-05
12	7	0.000342485688259
12	10	1.67297462027e-05
13	6	0.000130700524776
13	8	1.45695026515e-07
13	9	0.000799273098548
13	12	7.57505463427e-06
14	10	0.000442683072
14	11	4.3505634887e-05
14	13	7.18729155496e-09
15	11	0.000593376026698
16	8	0.000125491181256
16	12	0.000457272678169
16	14	3.66887521178e-05
16	15	4.89008576098e-10
17	10	0.0002941249067
17	11	1.86320242591e-07
17	13	0.000177015839039
17	16	1.540606331156e-05
18	8	9.11569309474e-07
18	12	0.000661124626506
18	14	1.05257205244e-06
18	17	4.07161990011e-06
19	14	0.000742320443638

Energy table

Rotational Excitation of ortho-cyclopropendyle by He (Chandra & al., 2000)
Reference : JPL

N	g	Energy in cm^{-1}	Level details....
1	9	1.6332	Ka=0 Kc=1 N=1 epsilon=-1 tau=-1
2	15	1.6332	Ka=1 Kc=0 N=1 epsilon=1 tau=1
3	15	2.2451	Ka=1 Kc=2 N=2 epsilon=-1 tau=-1
4	15	4.4798	Ka=2 Kc=1 N=2 epsilon=1 tau=1
5	21	4.4798	Ka=0 Kc=3 N=3 epsilon=-1 tau=-3
6	21	6.3153	Ka=1 Kc=2 N=3 epsilon=1 tau=-1
7	21	8.3875	Ka=2 Kc=1 N=3 epsilon=-1 tau=1
8	21	4.4798	Ka=1 Kc=4 N=4 epsilon=-1 tau=-3
9	21	11.155	Ka=3 Kc=0 N=3 epsilon=1 tau=3
10	27	8.3875	Ka=2 Kc=3 N=4 epsilon=1 tau=-1
11	21	6.3153	Ka=0 Kc=5 N=5 epsilon=-1 tau=-5
12	21	8.3875	Ka=3 Kc=2 N=4 epsilon=-1 tau=1
13	21	12.6262	Ka=4 Kc=1 N=4 epsilon=1 tau=3
14	27	11.155	Ka=1 Kc=4 N=5 epsilon=1 tau=-3
15	27	13.4194	Ka=1 Kc=6 N=6 epsilon=-1 tau=-5
16	27	13.5296	Ka=2 Kc=3 N=5 epsilon=-1 tau=-1
17	33	13.4194	Ka=3 Kc=2 N=5 epsilon=1 tau=1
18	27	8.3875	Ka=4 Kc=1 N=5 epsilon=-1 tau=3
19	27	12.6262	Ka=2 Kc=5 N=6 epsilon=1 tau=-3
20	27	17.3465	Ka=5 Kc=0 N=5 epsilon=1 tau=5
21	27	11.155	Ka=0 Kc=7 N=7 epsilon=-1 tau=-7
22	27	13.4194	Ka=3 Kc=4 N=6 epsilon=-1 tau=-1
23	27	13.5296	Ka=4 Kc=3 N=6 epsilon=1 tau=1
24	27	20.2037	Ka=1 Kc=6 N=7 epsilon=1 tau=-5
25	33	17.3465	Ka=1 Kc=8 N=8 epsilon=-1 tau=-7
26	33	19.5679	Ka=5 Kc=2 N=6 epsilon=-1 tau=3
27	33	22.3944	Ka=6 Kc=1 N=6 epsilon=1 tau=5
28	39	19.5679	Ka=2 Kc=5 N=7 epsilon=-1 tau=-3
29	33	13.4194	Ka=2 Kc=7 N=8 epsilon=1 tau=-5
30	33	20.2037	Ka=3 Kc=4 N=7 epsilon=1 tau=-1
31	33	24.6162	Ka=0 Kc=9 N=9 epsilon=-1 tau=-9
32	33	26.8337	Ka=4 Kc=3 N=7 epsilon=-1 tau=1
33	33	17.3465	Ka=5 Kc=2 N=7 epsilon=1 tau=3
34	33	19.5679	Ka=3 Kc=6 N=8 epsilon=-1 tau=-3
35	33	22.3944	Ka=6 Kc=1 N=7 epsilon=-1 tau=5
36	33	28.5113	Ka=7 Kc=0 N=7 epsilon=1 tau=7
37	33	13.4194	Ka=1 Kc=8 N=9 epsilon=1 tau=-7
38	33	20.2037	Ka=4 Kc=5 N=8 epsilon=1 tau=-1
39	33	24.6162	Ka=1 Kc=10 N=10 epsilon=-1 tau=-9
40	33	31.083	Ka=5 Kc=4 N=8 epsilon=-1 tau=1
41	39	24.6162	Ka=2 Kc=7 N=9 epsilon=-1 tau=-5
42	39	26.8337	Ka=6 Kc=3 N=8 epsilon=1 tau=3
43	39	31.083	Ka=2 Kc=9 N=10 epsilon=1 tau=-7
44	33	17.3465	Ka=7 Kc=2 N=8 epsilon=-1 tau=5
45	33	22.3944	Ka=0 Kc=11 N=11 epsilon=-1 tau=-11
46	33	28.5113	Ka=3 Kc=6 N=9 epsilon=1 tau=-3

Collision rates

Rotational Excitation of ortho-cyclopropendyle by He (Chandra & al., 2000)

Number of temperature columns : 4

I	J	Temperature (K).... 30	60	90	120
2	1	8.032e-12	8.321e-12	8.281e-12	8.16e-12
3	1	2.091e-11	2.096e-11	2.091e-11	2.098e-11
3	2	1.609e-12	1.895e-12	2.102e-12	2.17e-12
4	1	1.251e-11	1.33e-11	1.454e-11	1.581e-11
4	2	8.336e-12	8.54e-12	8.632e-12	8.6e-12
4	3	1.329e-11	1.33e-11	1.341e-11	1.357e-11
5	1	2.067e-12	2.334e-12	2.485e-12	2.526e-12
5	2	2.55e-11	2.346e-11	2.287e-11	2.284e-11
5	3	8.323e-12	8.103e-12	7.968e-12	7.822e-12
5	4	2.784e-12	3.241e-12	3.485e-12	3.607e-12
6	1	4.456e-12	3.715e-12	3.559e-12	3.529e-12
6	2	1.497e-12	1.363e-12	1.357e-12	1.331e-12
6	3	1.348e-11	1.381e-11	1.477e-11	1.582e-11
6	4	2.135e-11	2.109e-11	2.097e-11	2.098e-11
6	5	6.256e-12	6.754e-12	6.977e-12	7.066e-12
7	1	7.275e-12	6.789e-12	7.051e-12	7.442e-12
7	2	5.075e-13	5.046e-13	5.221e-13	5.291e-13
7	3	1.23e-11	1.193e-11	1.189e-11	1.19e-11
7	4	5.586e-12	6.061e-12	6.513e-12	6.91e-12
7	5	1.763e-12	2.053e-12	2.257e-12	2.382e-12
7	6	1.572e-11	1.647e-11	1.68e-11	1.708e-11
8	1	1.858e-11	1.498e-11	1.399e-11	1.366e-11
8	2	2.586e-12	2.673e-12	2.715e-12	2.728e-12
8	3	7.54e-12	7.841e-12	8.159e-12	8.324e-12
8	4	1.614e-11	1.449e-11	1.4e-11	1.388e-11
8	5	9.92e-12	1.011e-11	1.027e-11	1.029e-11
8	6	4.762e-12	5.756e-12	6.291e-12	6.593e-12
8	7	8.483e-12	9.172e-12	9.5e-12	9.776e-12
9	1	3.956e-12	3.846e-12	3.935e-12	3.955e-12
9	2	1.534e-11	1.415e-11	1.46e-11	1.537e-11
9	3	4.222e-12	3.74e-12	3.731e-12	3.798e-12
9	4	6.05e-12	5.493e-12	5.381e-12	5.346e-12
9	5	1.79e-11	1.727e-11	1.715e-11	1.724e-11
9	6	2.746e-12	3.175e-12	3.526e-12	3.756e-12
9	7	9.252e-12	1.015e-11	1.049e-11	1.061e-11
9	8	2.024e-12	2.84e-12	3.246e-12	3.466e-12
10	1	1.417e-12	1.121e-12	1.052e-12	1.024e-12
10	2	1.466e-11	1.13e-11	1.041e-11	1.008e-11
10	3	3.25e-12	2.951e-12	2.934e-12	2.92e-12
10	4	2.139e-12	2.311e-12	2.457e-12	2.51e-12
10	5	2.012e-11	2.018e-11	2.134e-11	2.264e-11
10	6	7.822e-12	7.294e-12	7.128e-12	7.024e-12
10	7	3.14e-12	3.551e-12	3.793e-12	3.904e-12

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Future

- Homogenisation of output for all molecular data
- Currently AMDML for Fusion Physics: NIST, IAEA, Oakridge (see Y. Ralchenko's talk at 15:30 + following Discussion Panel)
- More general approach to AMDML with inclusion molecular physics
  - New Collaboration with Paris Observatory
  - Link to IVOA for astrophysical application

Do not confuse AMDML and AMLDM !!! :-)

VO Collaborations

- LERMA: N. Moreau (PI for engineering), F. Boone (PI of the MAGIX project)
- LUTH: E. Roueff (DM), F. Le Petit (PI of PDR code in the VO)
- M. Elitzur (Kentucky Univ.): MOLPOP code
- ESAC-VO Team (spain): P. Osuna & coll. (IVOA collaboration for AMLDM, SLAP)
- CDMS: H. Mueller
- HITRAN: L. Rothman

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- Paris VO Data Center
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