PDR VO Services

VO-Paris Datacentre

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LUTH / LERMA - Observatoire de Paris

Interstellar Medium

- Data obtained from decades
- multi-wavelength observations
- Many details on objects

Next generation of instruments : Herschel / ALMA

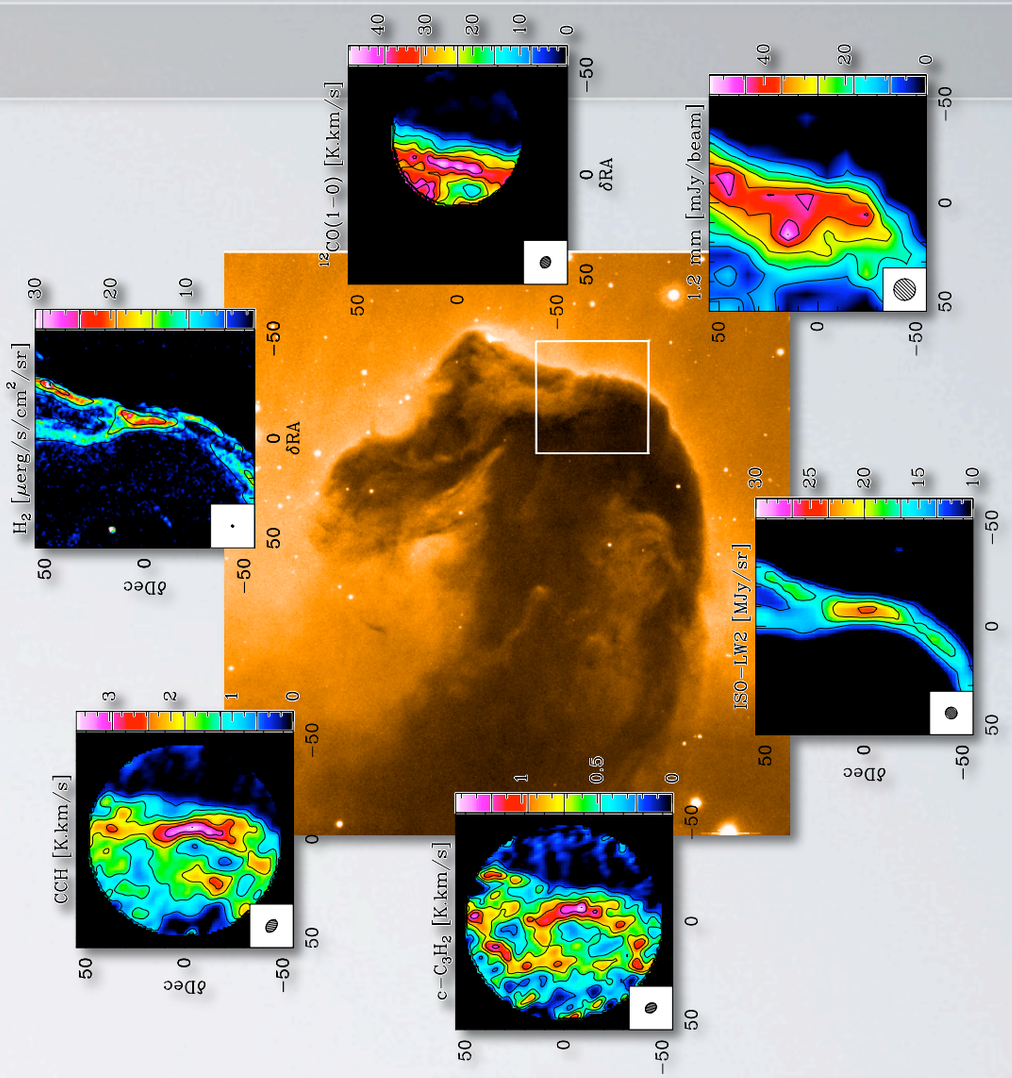
- HIFI : detailed observations of the interstellar medium
- Search for H_2O

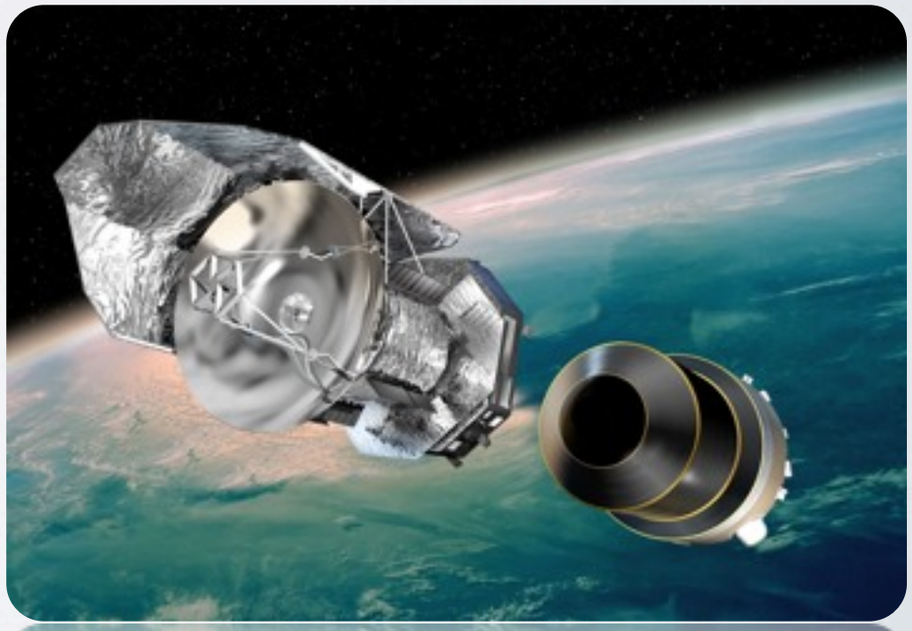
Scientific return of observations requires :

- Effort on theory : detailed codes
- Public codes and services

The efforts in **VO-Theory** are an opportunity to develop theoretical services

- Standard to develop theoretical databases (SimDM / SimDB)
- Access protocol (SimDAP)
- Vocabularies to describe simulations

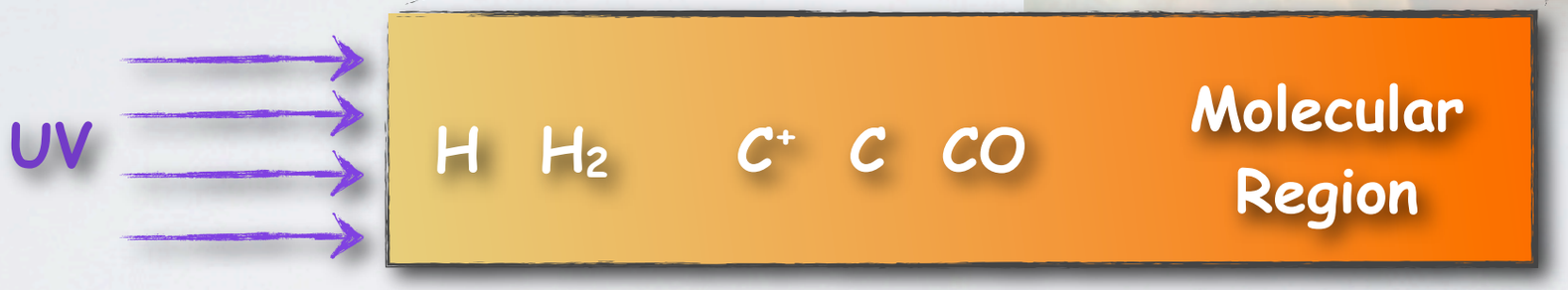


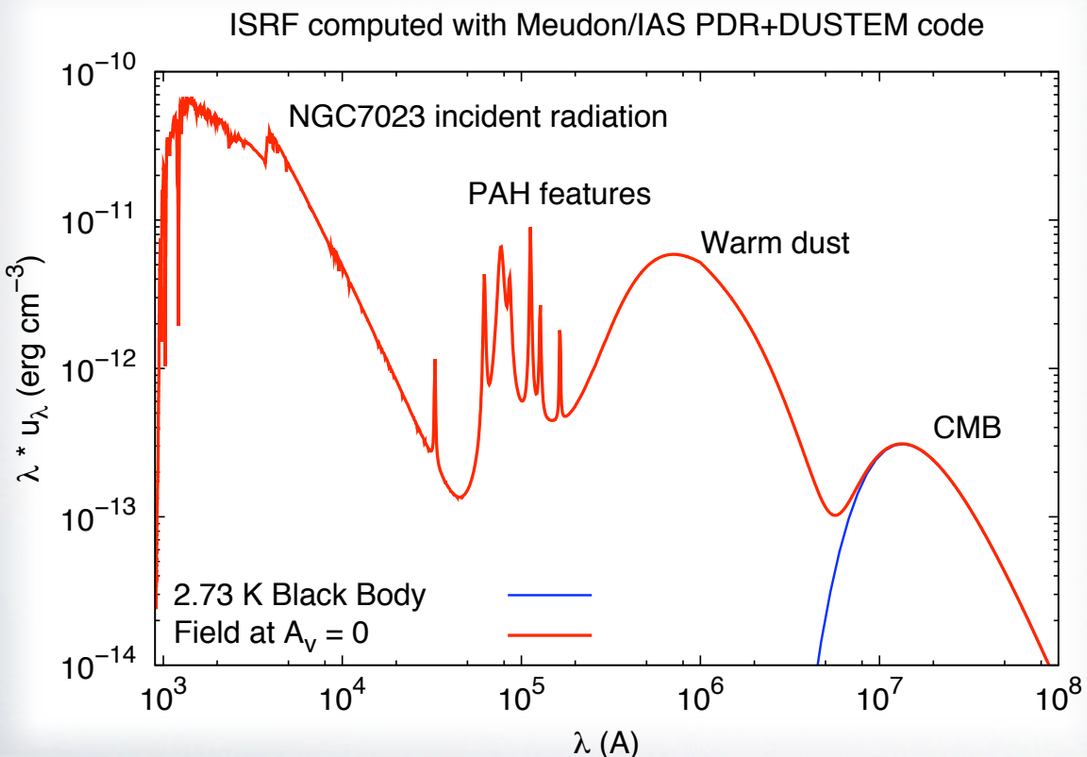


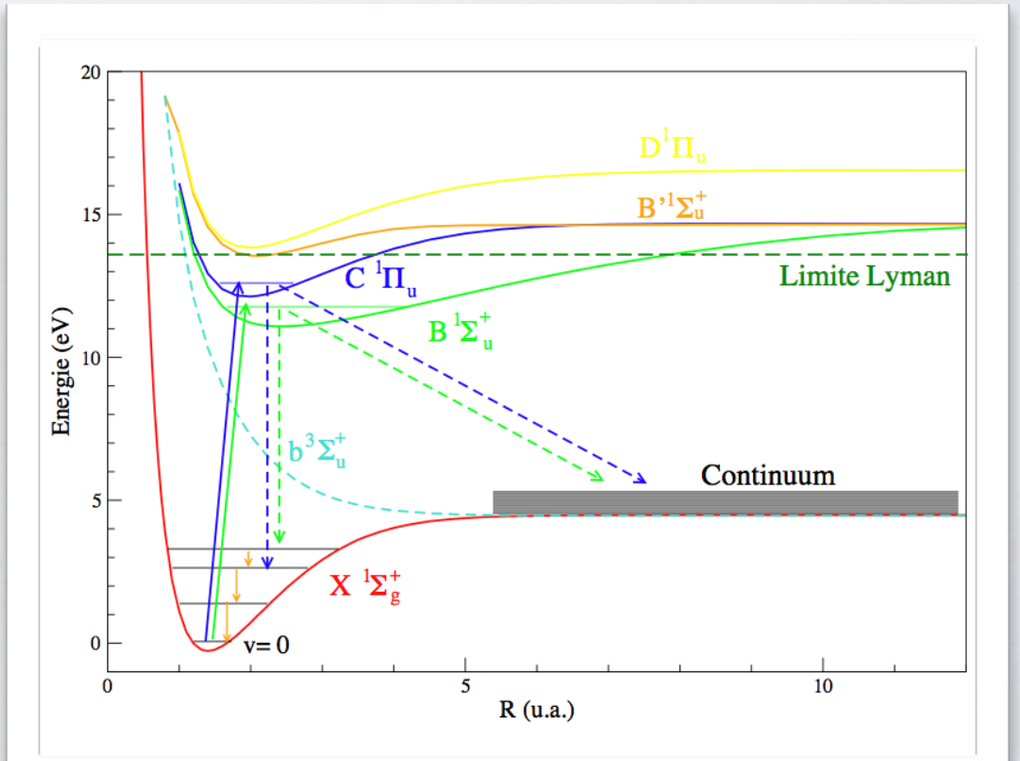
Meudon PDR code

Computes the chemical and thermal structure of interstellar gas

- Radiative transfer (FUV - sub-mm)
- Chemistry
- Thermal processes
- Statistical equilibrium in levels





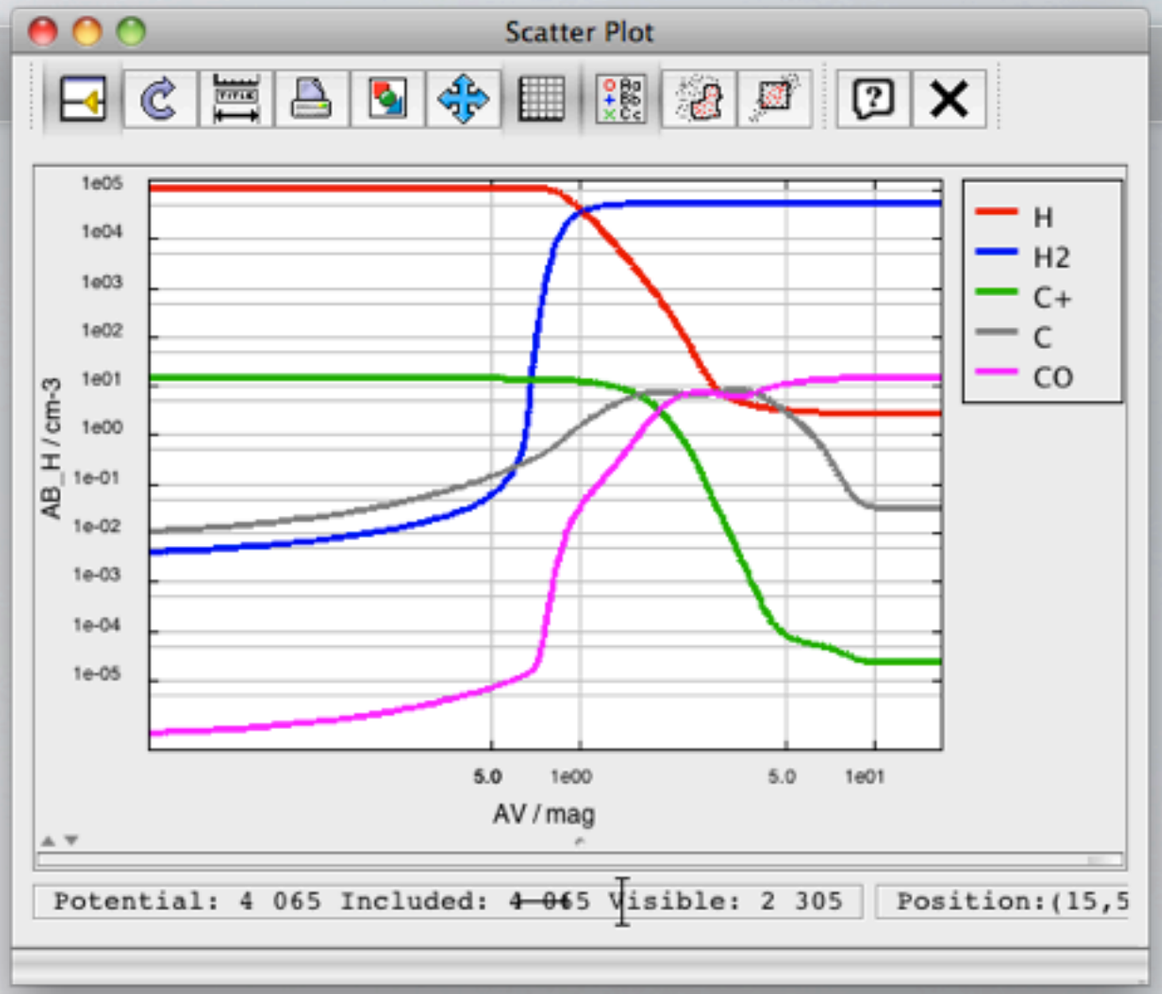


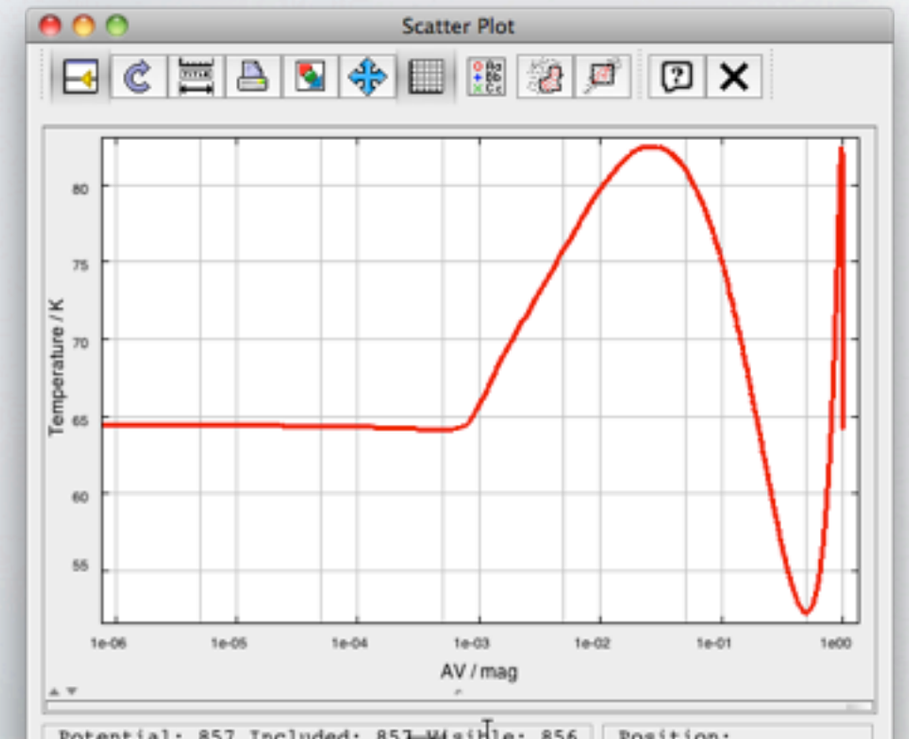
Meudon PDR code

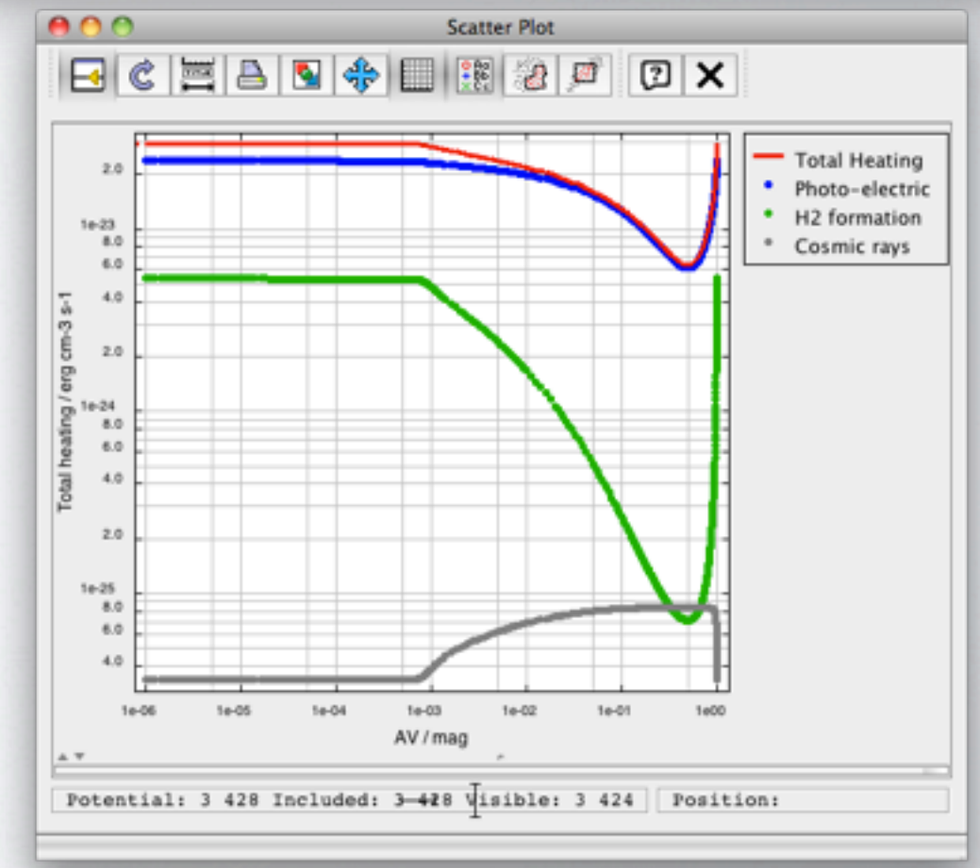
Outputs

- Column densities
- Line intensities

- Profiles (structure as a function of Av)
  - Abundances
  - Level excitation (H_2, CO, C^+, H_2O, ...)
  - Temperature
  - Density
  - Heating and cooling rates
  - Local emissivities

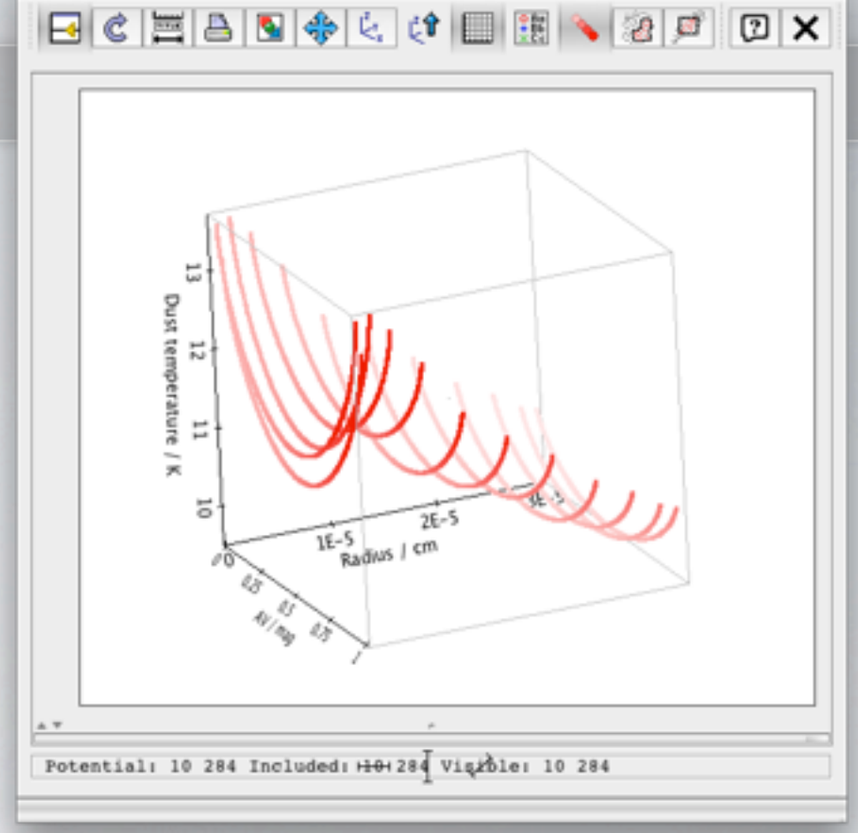




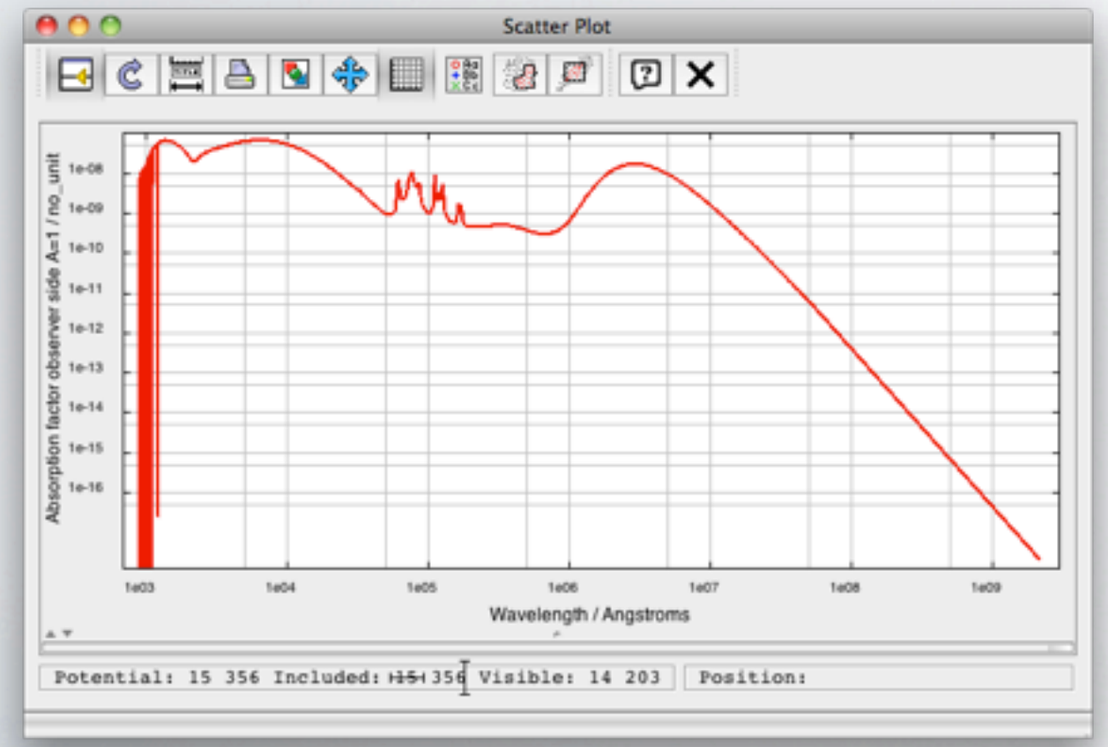


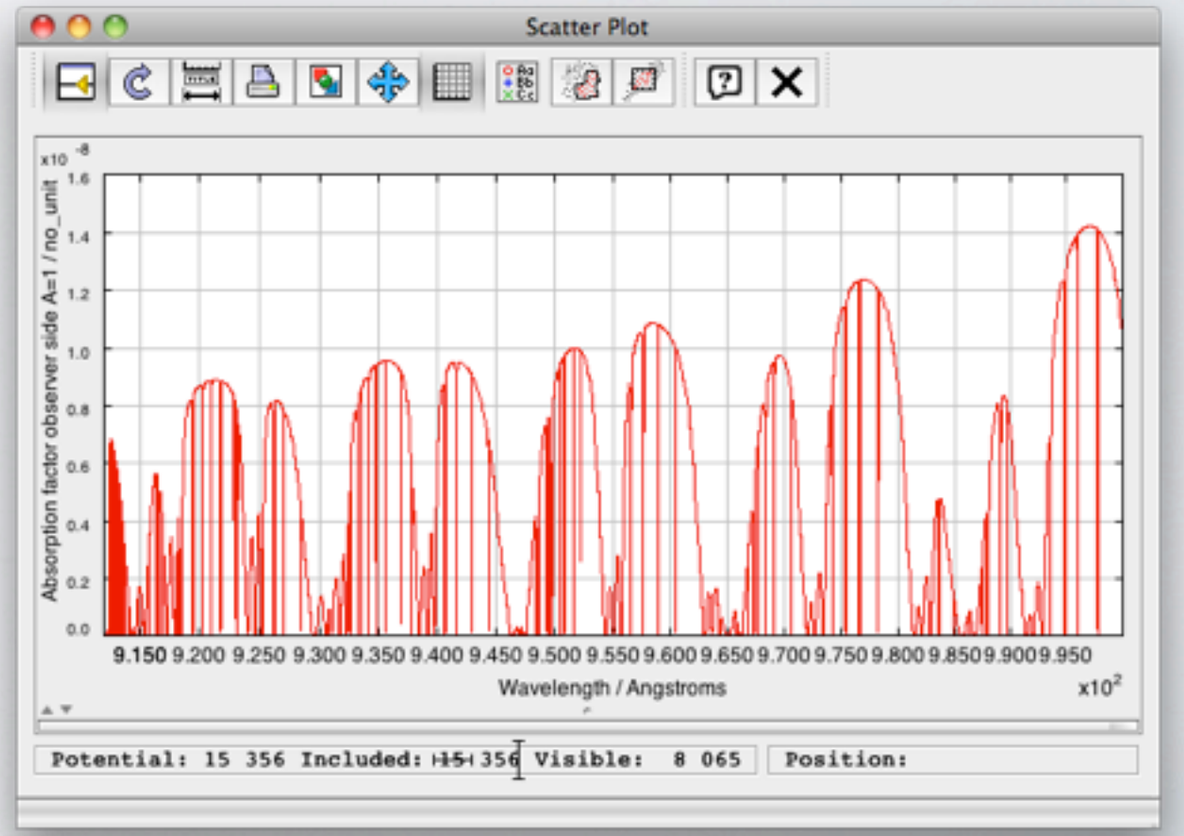
Meudon PDR code

- Grains properties by size of grains
  - temperature
  - charge



- Spectra
  - Far-UV to sub-millimeter
  - Absorption spectra (Ex : comparison with FUSE spectra)

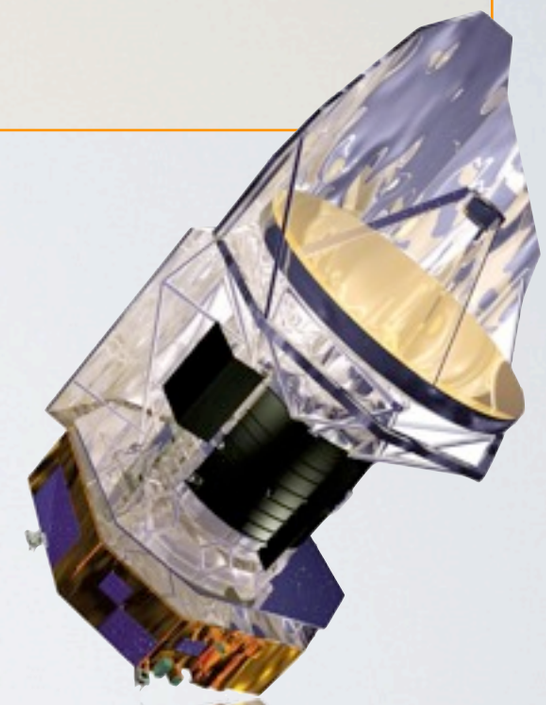




PDR VO Services

Objectives with the VO :

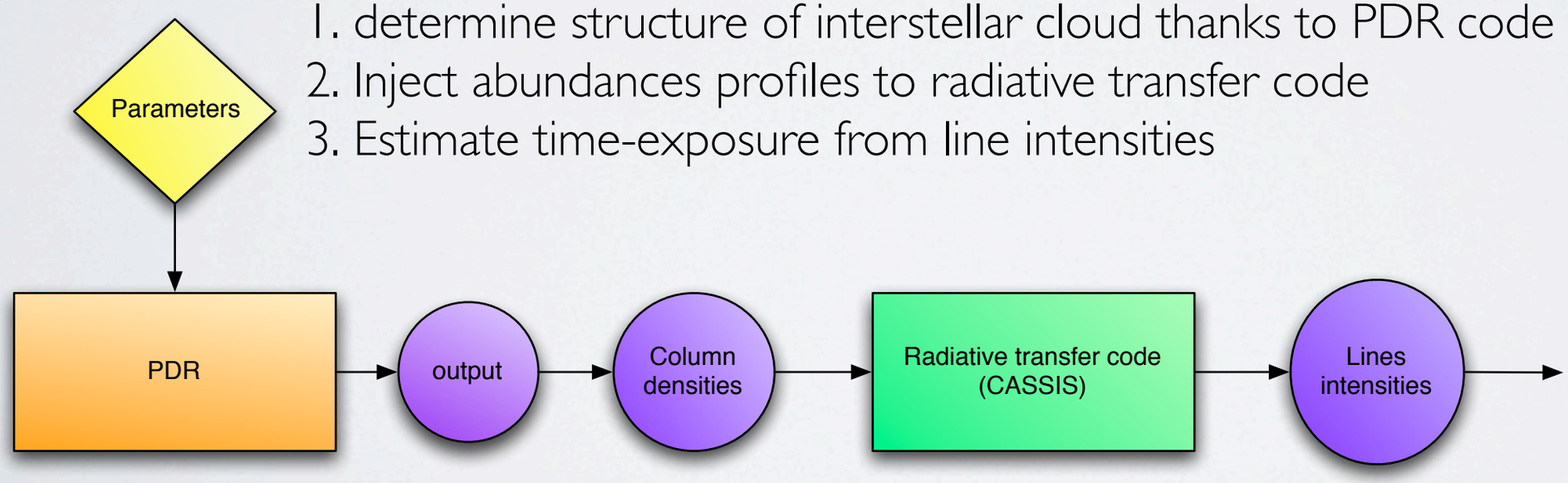
- Online access to online simulation code with computing ressources
- Development of a theoretical database (SimDB / SimDAP)
- Interoperability with other simulation codes / VO services



Example : Preparation of observations

Time-exposure estimation

1. determine structure of interstellar cloud thanks to PDR code
2. Inject abundances profiles to radiative transfer code
3. Estimate time-exposure from line intensities



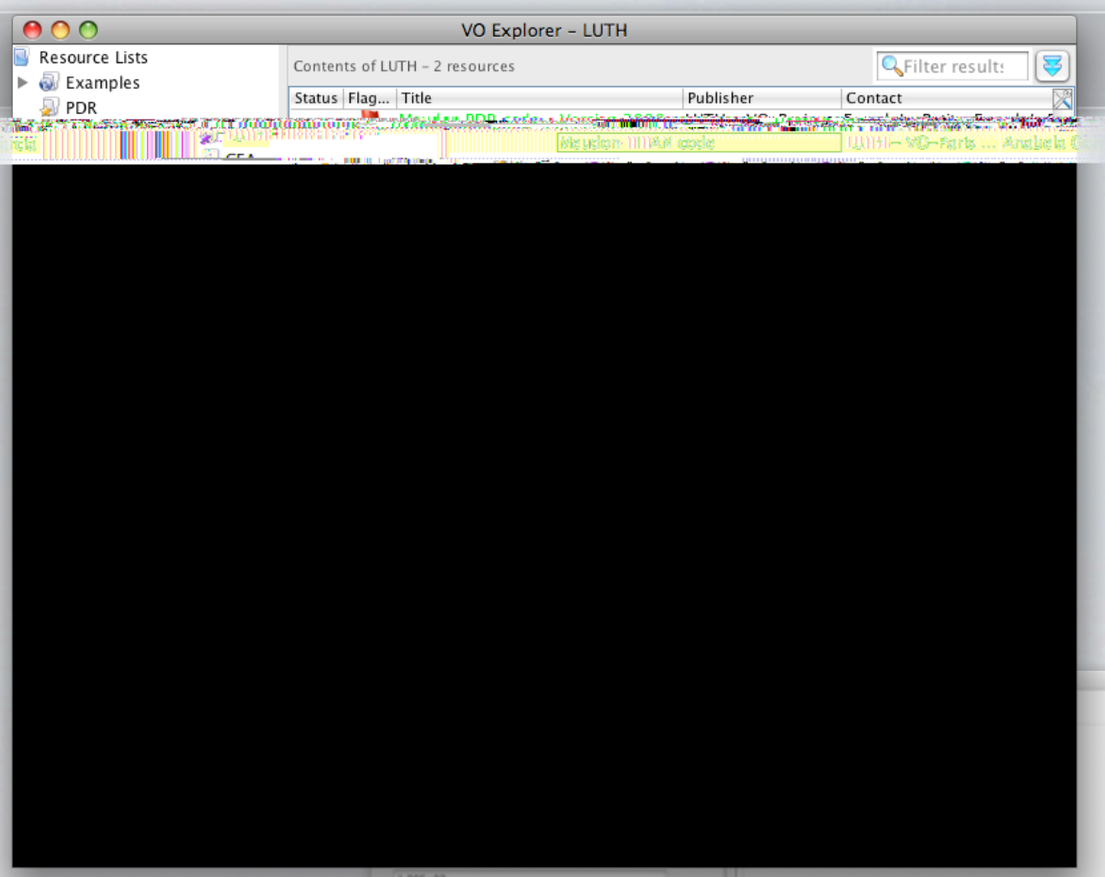
...Virtual telescope
...Time exposure
...AOR

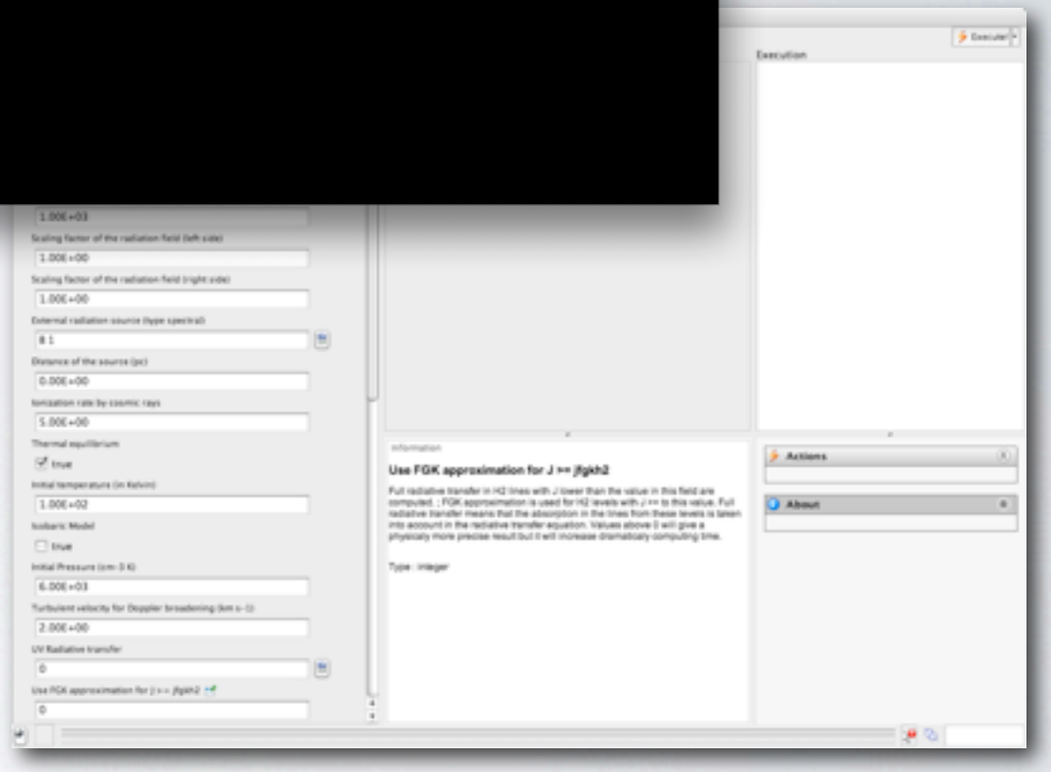
Online code

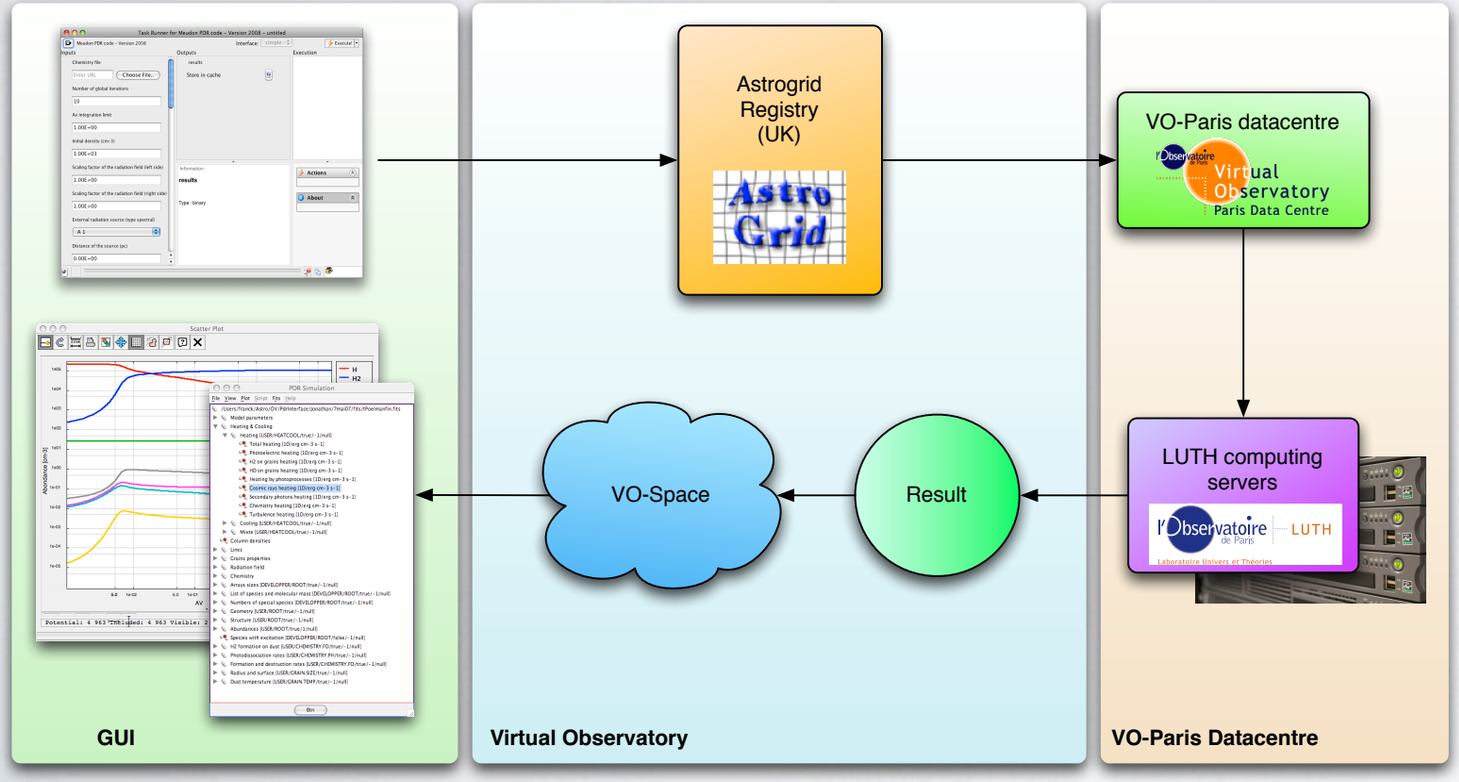
Use of Astrogrid Infrastructure

F. Roy

- Code is registered as a CEA service
- Can be found in the VO-Explorer
- Generic interface







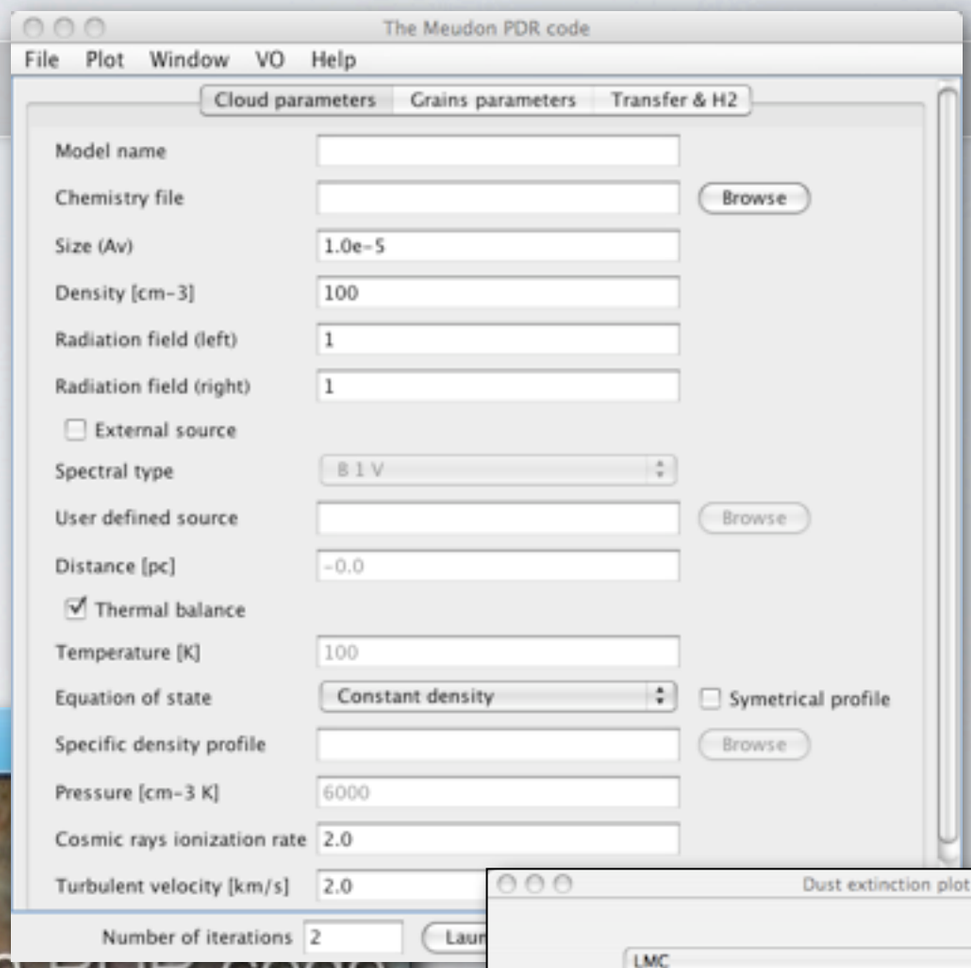
Titan (A.-M. Dumont, S. Collin,) en cours de mise en ligne sur le même modèle par F. Roy

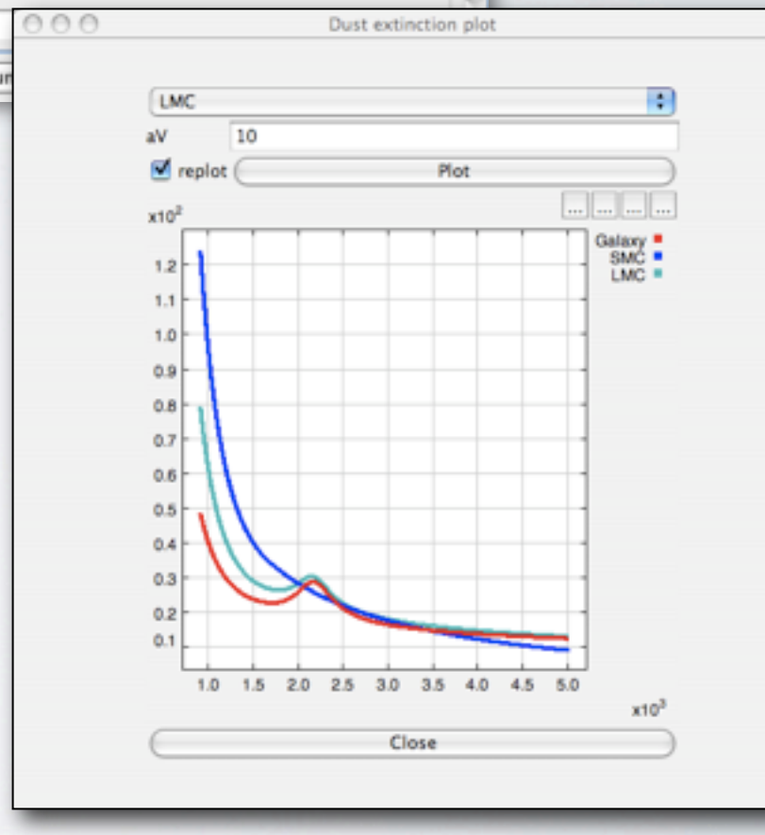
Online code

Specific code interface - Java Webstart

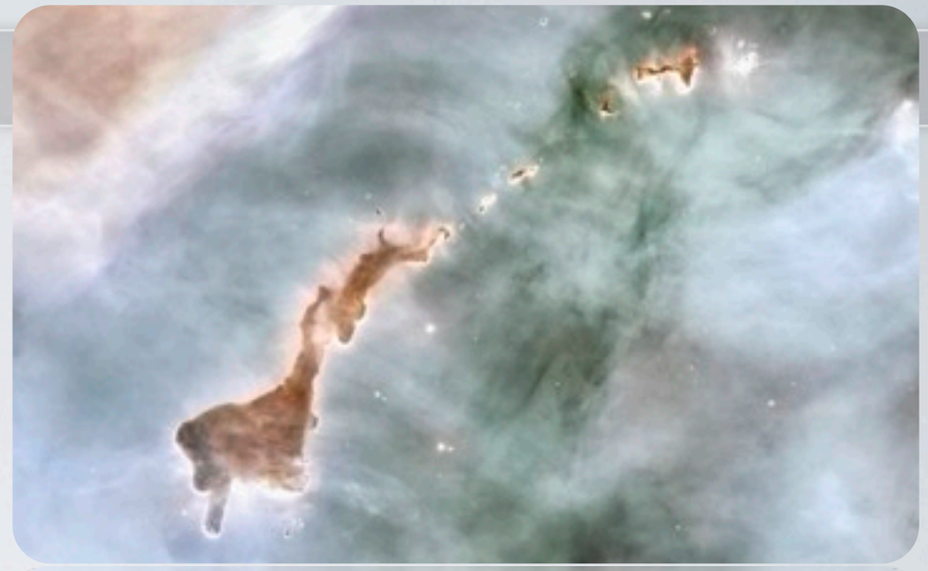
F. Roy / N. Moreau

- relations between parameters
- graphics
- communicates with Astrogrid
- use Astrogrid identification





PDR Database

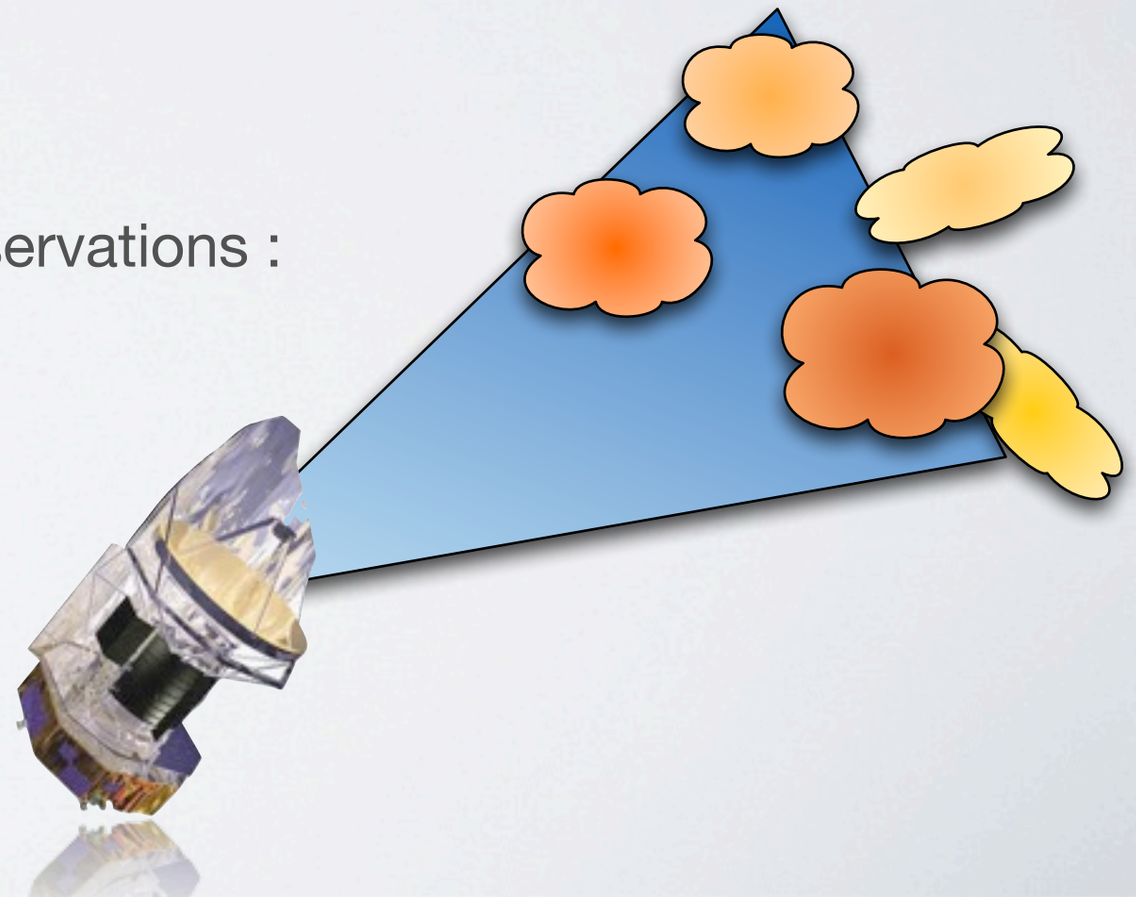


Objectives :
- Publish PDR simulations
- Facilitate inverse problems

Example :
“In which kind of interstellar clouds can we detect H_2O ?”

“Which parameters produce a ratio of line intensity H_2 2-1 S(1) / 1-0 S(0) of 0.56 ?”

Motivated for fast interpretation of HERSCHEL observations :
- Diffuse Interstellar Clouds (PRISMA key prog.)
- Star-Forming regions (WADI key prog.)
- Search for O_2 (O_2 key. prog.)
- Extra-galactic medium
  - non resolved clouds

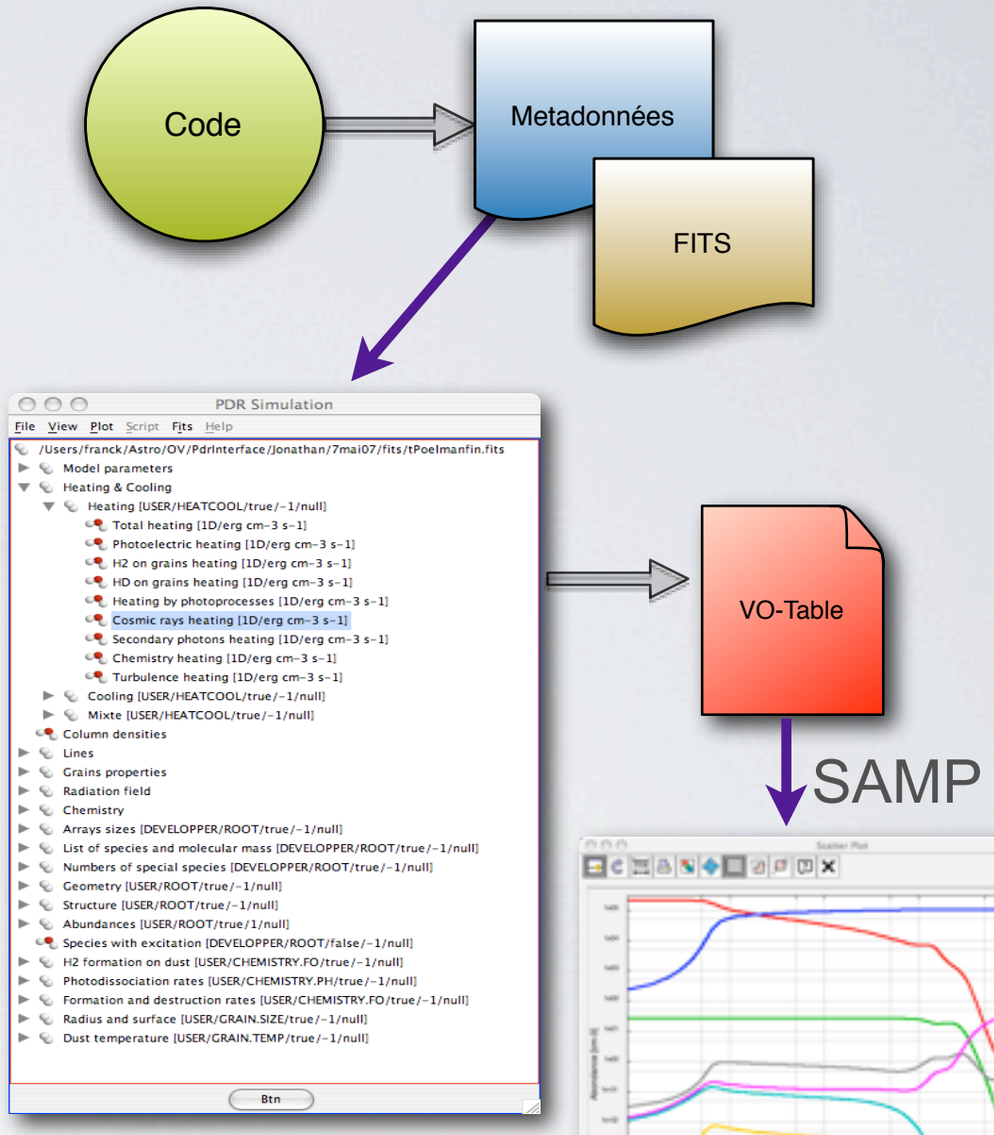


PDR Database

Output Files

Code produces
- raw data : FITS File
- XML / VO-TABLE : meta-data
  (name, description, units, UCD, ...)

Provide all quantities computed by the code
- observables
- theoretical quantities



PDR Analyser
- browse the computed quantities
- extraction (ASCII, VO-Table)
- SAMP
- Download data from VO-Space
- Scriptable

Nicolas Moreau
Laurent Bourgès
Jonathan Normand

PDR Database - N. Moreau & B. Ooghe

PDR Database is developped as a **SimDB** service

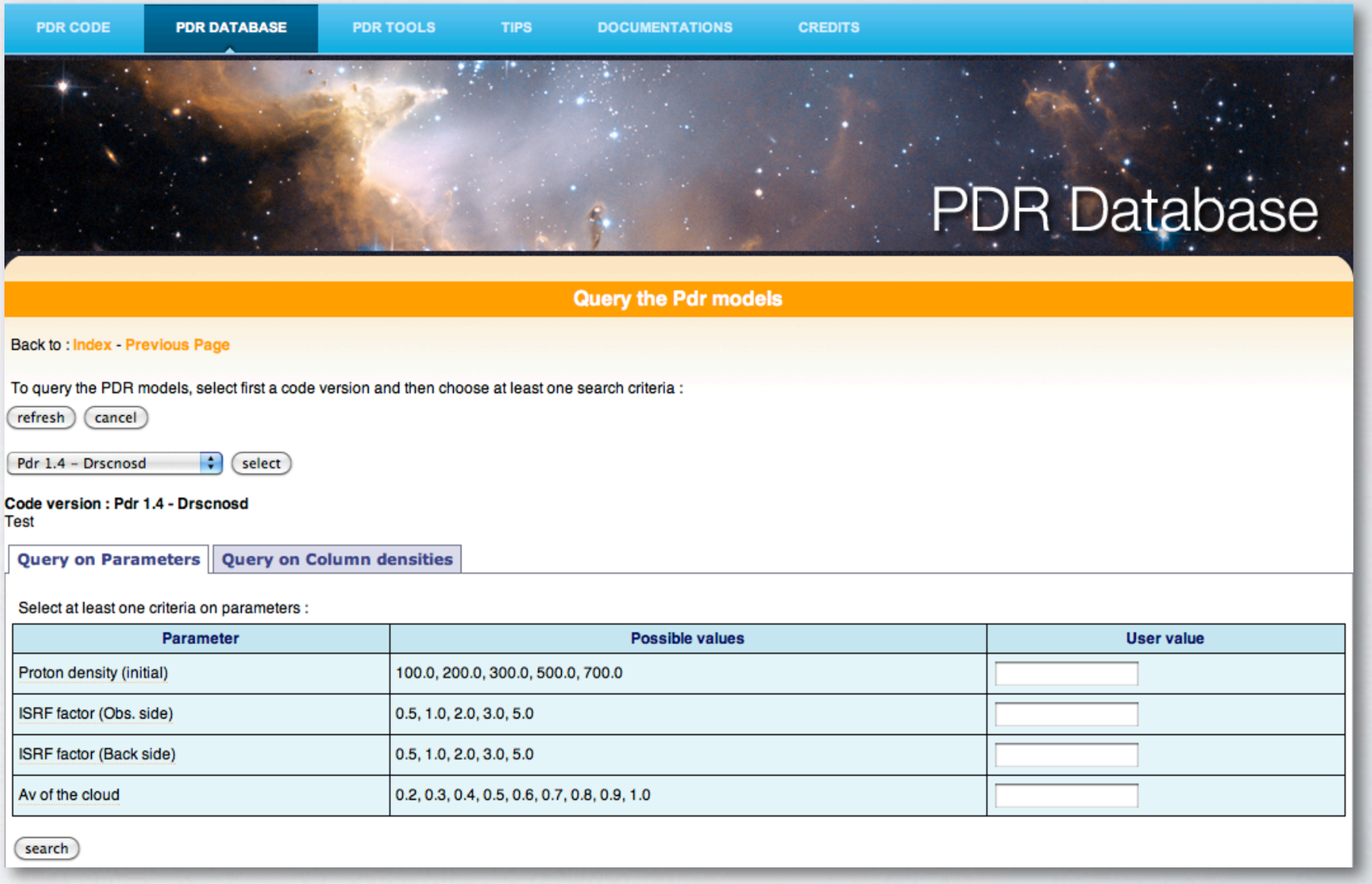
SimDB : Standard developped by the **VO-Theory interest group** at IVOA
Laurent Bourgès (LAOG - Euro-VO / LUTH) & Gerard Lemson (MPe)

Project : Diffuse clouds
225 models (700 days CPU)

Parameters space :
- Density 100 to 700 cm-3
- Radiation field 0.5 - 5 ISRF
- Size 0.2 to 1 mag

Next set of models :
- PDRs
- Extra-galactic medium
- ...

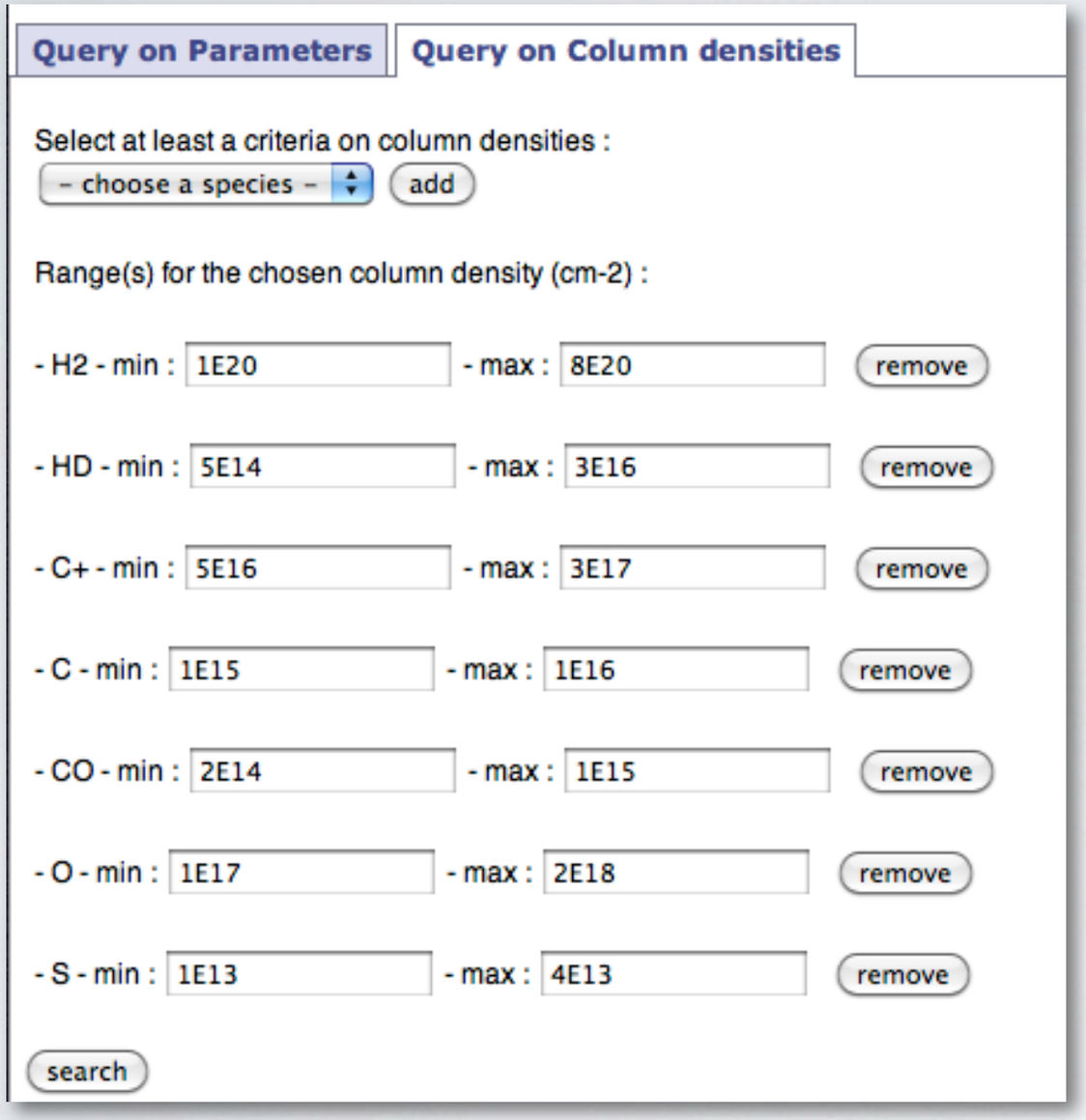
Queries on input parameters



PDR Database

SimDM permits queries on some outputs

Queries on column densities



Queries on column densities : functionnal
Queries on line intensities : to come

Species	min	max
H	5.7 (20)	7.1 (20)
H_2	3.2 (20)	7.1 (20)
HD	2.0 (15)	1.1 (16)
C^+	1.8 (17)	
C	2.9 (15)	3.6 (15)
CO	5.4 (14)	
CH	1.9 (13)	2.0 (13)
CH+	3.5 (12)	
C2	1.6 (13)	2.2 (13)
C3	1.0 (12)	
CN	2.7 (12)	3.3 (12)
NH	9.0 (11)	
O	0.2 (18)	1.0 (18)
OH	4.0 (13)	
H3+	8.0 (13)	
S+	1.7 (16)	2.3 (16)
S	1.5 (13)	2.2 (13)
Si+	2.8 (16)	6.6 (16)
H2 (J=0)	2.2 (20)	4.8 (20)
H2 (J=1)	1.0 (20)	2.3 (20)
H2 (J=2)	1.1 (18)	2.4 (18)
H2 (J=3)	2.0 (16)	9.6 (16)
H2 (J=4)	1.1 (15)	2.0 (15)
H2 (J=5)	2.3 (14)	2.8 (14)

Column densities [cm^{-2}] towards Zeta Perseus

PDR Database

Results :

Input parameters
- description of all parameters

PDR CODE | PDR DATABASE | PDR TOOLS | TIPS | DOCUMENTATIONS | CREDITS

PDR Database

Model : n1e2r5m1r5m1J4A9m1_10

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Model : n1e2r5m1r5m1J4A9m1_10
Description :
Test
Download full simulation for the PDR analyzer

Model | Structure | Plot | Column densities | Line intensities

Cloud parameters	
Proton density (initial)	1.000E02 cm-3
Flag : 1 or 2 side(s) model	0
ISRF factor (Obs. side)	5.000E-01
ISRF factor (Back side)	5.000E-01
Distance of the point UV source	0 pc
External source name	
Flag : Thermal balance	1
Gas temperature (initial)	7.000E01 K
Flag: State equation	0
Gas pressure	7.000E03 cm-3 K
Density-Temperature profile file name	
Flux of cosmic rays	5.000E00 1E-17 s-1
Micro-turbulent velocity	2.000E05 cm s-1

Line of sight parameters	
Line of sight dust extinction curve	Galaxy
C = NH / E(B-V)	5.800E21 cm-2 mag-1
Rv	3.100E00

Algorithm parameters	
Number of global iterations	10
Flag: Algorithm for line self-shielding	2
J limit for H2 exact self-shielding	4
Code version	10VII08_JLB_and_Co

Grains parameters	
Mass grain / Mass of gas	1.000E-02
Grains minimal radius	3.000E-07 cm
Grains maximum radius	3.000E-05 cm
Grains albedo	4.200E-01
Grains anisotropy factor	6.000E-01
Grains volumic mass	2.590E00 g cm-3
Index of grains size distribution	3.500E00

Chemistry parameters	
He / H	1.666E-01
C / H	1.326E-04
N / H	7.566E-05
O / H	3.196E-04
D / H	1.566E-05
C13 / H	0
N15 / H	0
O18 / H	0
PAH / H	0
F / H	0
Na / H	2.100E-07
Mg / H	0
Al / H	0
Si / H	8.200E-07
P / H	9.000E-10
S / H	1.860E-05
Cl / H	0
Ca / H	0
Fe / H	1.500E-08
H2 excitation model after formation on grains	0
Model for H + H2 collision rates	2
Model for atoms sticking on dust	4

Information	
ISRF factor (Obs. side) - edge of the cloud	3.083E-01
ISRF factor (back side) - edge of the cloud	3.083E-01
ISRF scaling factor (Obs. side) in Habing units	3.871E-01
ISRF scaling factor (back side) in Habing units	3.871E-01 phot cm-2 s-1
Flux of secondary photons	5.000E03 s-1
Relative abundance of grains	1.777E-09
Mean number of adsorption sites per grain	1.338E-05
Mean grains cross section	2.261E-21 cm2
Distance between adsorption sites	2.600E-08 cm
Total grain surface	9.046E-21

PDR Database

Column densities

PDR CODE | PDR DATABASE | PDR TOOLS | TIPS | DOCUMENTATIONS | CREDITS

Model : n1e2r5m1r5m1J4A9m1_10

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Model : n1e2r5m1r5m1J4A9m1_10
Description :
Test
Download full simulation for the PDR analyzer

Model | Structure | Plot | Column densities | Line intensities

Column densities of chemical species in cm-2

Species	Column density [cm-2]
H+	1.830E16
D+	2.048E10
H2+	3.818E11
HD+	1.067E07
H3+	1.412E13
H2D+	4.158E09
He+	5.085E14
C+	2.180E17
CH+	2.380E10
CD+	1.999E06
CH2+	1.642E11
CHD+	3.949E06
CH3+	2.490E11
CH2D+	3.492E07
CH4+	8.791E04
CH3D+	6.285E00
CH5+	7.010E06
CH4D+	5.152E02
O+	6.183E10
O2+	1.194E08
OH+	7.958E10
OD+	8.441E05
H2O+	7.409E10
HDO+	3.618E05

Species	Column density [cm-2]
H	6.415E19
D	3.994E15
H2	8.099E20
HD	2.126E16
He	1.684E20
C	4.156E15
CH	6.373E12
CD	7.537E08
CH2	6.621E12
CHD	6.402E08
CH3	9.846E07
CH2D	1.341E04
CH4	4.863E07
CH3D	8.961E03
O	5.370E17
O2	7.956E10
OH	1.160E13
OD	3.657E09
H2O	2.111E12
HDO	4.521E06
CO	1.075E14
CO2	8.887E04
C2	3.433E11
C2H	3.184E11

Line intensities

- Main lines
- Face-on cloud

Model : n1e2r5m1r5m1J4A9m1_10

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Model : n1e2r5m1r5m1J4A9m1_10
Description :
Test
Download full simulation for the PDR analyzer

Model | Structure | Plot | Column densities | Line intensities

Line intensities for a face-on cloud *To get line intensities for other angles or other lines, download the simulation in PDR Analyzer*

[C I] Line intensities	
3P_J=1, 3P_J=0, 609.75 micron	1.235E-08
3P_J=2, 3P_J=1, 370.37 micron	1.120E-08

[O I] Line intensities	
3P_J=0, 3P_J=1, 145.53 micron	2.242E-09
3P_J=1, 3P_J=2, 63.19 micron	7.793E-08

[C II] Line intensities	
2P_J=3/2, 2P_J=1/2, 157.68 micron	2.106E-06

H2 Line intensities	
1 2 0 0 1- 0 S(0), 2.2232 micrometres	4.904E-09
1 3 0 1 1- 0 S(1), 2.1217 micrometres	3.867E-09
1 4 0 2 1- 0 S(2), 2.0337 micrometres	3.659E-09
1 5 0 3 1- 0 S(3), 1.9575 micrometres	1.460E-09
2 4 1 2 2- 1 S(2), 2.1541 micrometres	1.747E-09
2 5 1 3 2- 1 S(3), 2.0734 micrometres	6.484E-10

CO Line intensities	
1 0 115.268 GHz	6.666E-11
2 1 230.537 GHz	1.571E-10
3 2 345.805 GHz	8.186E-11
6 5 691.485 GHz	2.517E-13
15 14 1726.587 GHz	2.859E-14

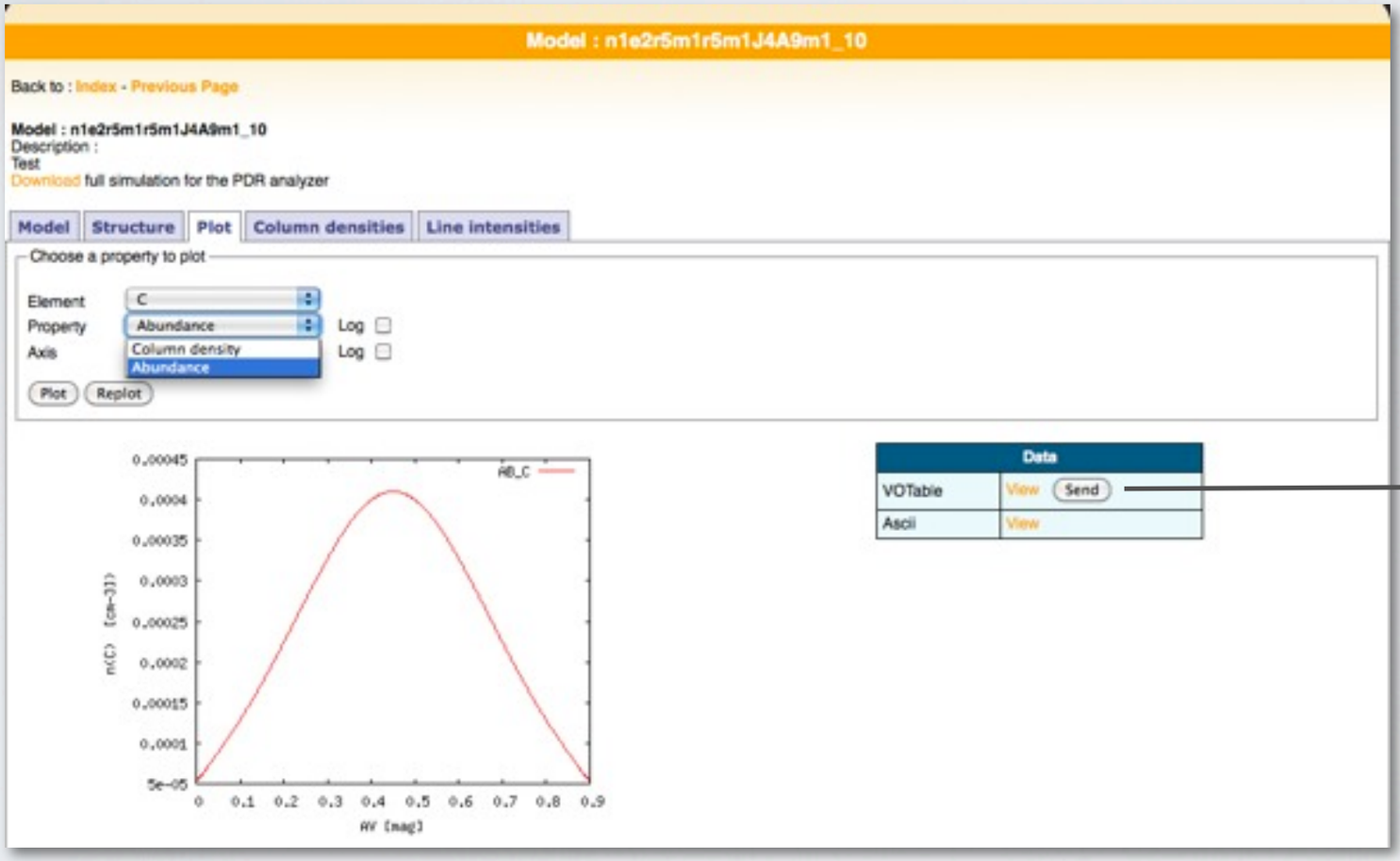
HD Line intensities	
0 1 0 0 0- 0 R(0), 112.0707 micrometres	7.009E-09
0 2 0 1 0- 0 R(1), 56.2283 micrometres	3.708E-11

H2O Line intensities	
2 2 1 1 1 0 92.5263 cm-1	5.619E-14
3 0 3 2 1 2 57.2630 cm-1	9.813E-14
2 1 2 1 0 1 55.6999 cm-1	6.952E-13
2 2 1 2 1 2 55.4032 cm-1	3.107E-14
1 1 0 1 0 1 18.5768 cm-1	1.286E-13
3 1 2 2 2 1 38.4624 cm-1	1.546E-14
3 1 2 3 0 3 36.6025 cm-1	1.981E-14
2 2 0 1 1 1 99.0225 cm-1	2.389E-14
1 1 1 0 0 0 37.1356 cm-1	4.811E-13
2 0 2 1 1 1 32.9524 cm-1	1.260E-13
2 1 1 2 0 2 25.0842 cm-1	-1.524E-14

PDR Database

Exportation :

- **Extraction** from web interface
  - ASCII / VO-Table
  - SAMP towards VO-Tools



- **Download** the full result
  - Usable in PDR Analyser
  - Restart new model with small changed in input parameters

PDR Services

Feedbacks of the observers :

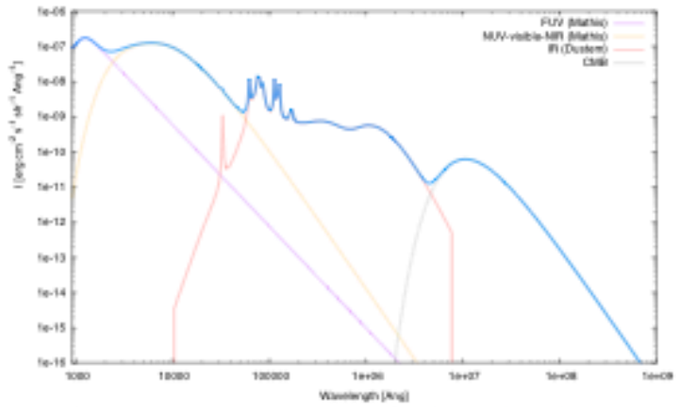
- Theoretical services difficult to use
- Need :
  - Documentations
  - User friendly interfaces
  - Help desk

Semi-infinite cloud : to model a semi-infinite cloud, no radiation field should be added on the back side of the cloud (i.e. set radp to 0 and d_sour <= 0).

Interstellar Standard Radiation Field (ISRF)

The ISRF used in the Meudon PDR code goes from Far-UV to submillimeter. It is the sum of 4 components :

- Far-UV to Near-UV
- Near-UV - Visible - Near IR
- Dust emission (IR)
- CMB



Specific intensity in erg cm^{-2} s^{-1} Ang^{-1} str^{-1} used in the Meudon PDR code.

Far UV to Near UV

The expression of the UV radiation field based on Mathis et al. 1983 and Black 1994 and fitted by Jacques Le Bourlot is :

$$\lambda \leq 8000\mathring{A}, \quad I(\lambda) = \left[tanh(4.07 \cdot 10^{-3} * \lambda - 4.5991) + 1.0\right] * 107.192 * \lambda^{-2.89}$$
$$\lambda > 8000\mathring{A}, \quad I(\lambda) = 2 * 107.192 * \lambda^{-2.89}$$

In this expression, the wavelength is in Angstroms and the specific intensity in erg cm^{-2} s^{-1} Ang^{-1} str^{-1}.

The intensity of this component can be scaled by the radm and radp parameters in the input data file.

Near UV to near IR

The expression of the radiation field form near UV to near IR is the sum of 3 black bodies. Data comes from Mathis et al. (1983) and Black (1994). They have been fitted by Jacques Le Bourlot.

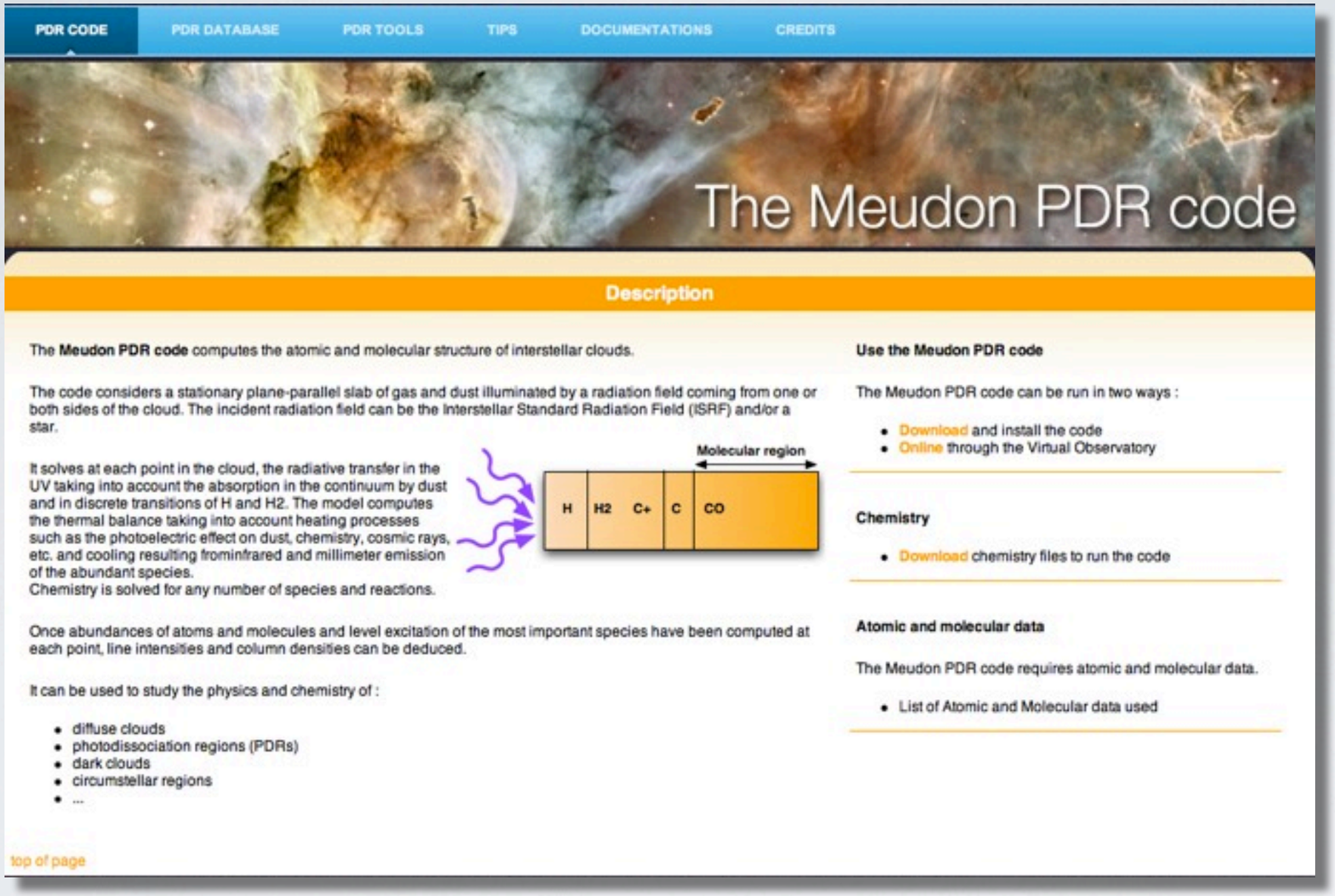
$$\begin{aligned} I(\lambda) &= 1.05 \cdot 10^{-14} \times \frac{2 \times h \times c^2 \times 1 \cdot 10^{32}}{\lambda^5 \times e^{\frac{hc10^8}{k\lambda 7127}}} \\ &+ 1.25 \cdot 10^{-13} \times \frac{2 \times h \times c^2 \times 1 \cdot 10^{32}}{\lambda^5 \times e^{\frac{hc10^8}{k\lambda 4043}}} \\ &+ 3.30 \cdot 10^{-13} \times \frac{2 \times h \times c^2 \times 1 \cdot 10^{32}}{\lambda^5 \times e^{\frac{hc10^8}{k\lambda 2930}}} \end{aligned}$$

Dust emission (IR)

The I.R. component produced by dust has been estimated by the code DUSTEM. The resulting specific intensity is the sum of the emission by PAHs, very small grains and big grains. Data are provided in the file : data/Astrodata/IR_field_dustem.dat.

PDR Services

Services open at the end of 2009 : **http://pdr.obspm.fr**



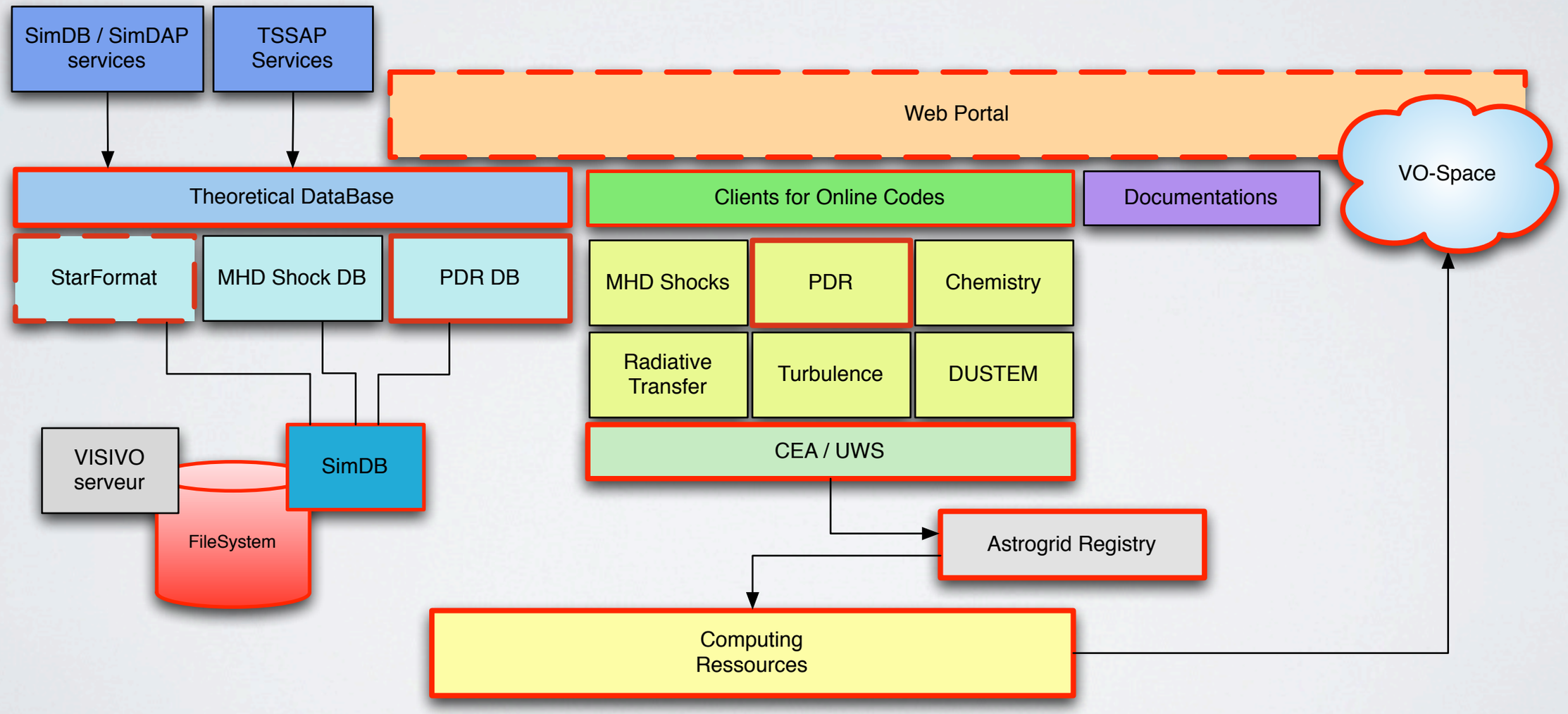
Next steps : services & interoperability between VO services

Interstellar Medium Platform

Bring together expertise in modeling / simulation of the ISM

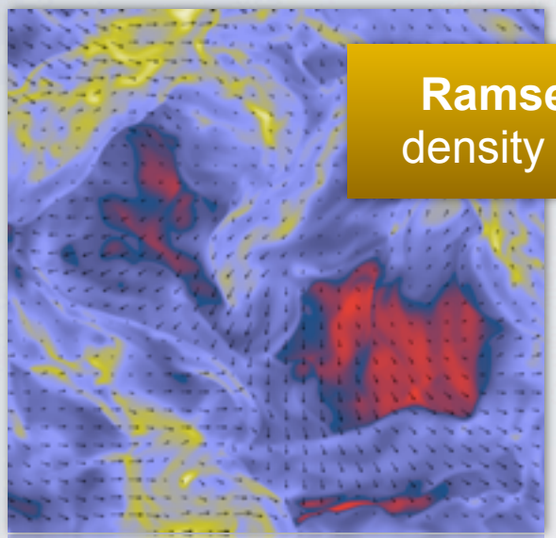
Provide theoretical services about ISM

Codes - Databases - Tools & services



Interstellar Medium Platform

STARFORMAT project (PI: P. Hennebelle)



Ramses-MHD database
density & velocity structure

SimDAP

Meudon PDR code
Chemical & thermal structure

SimDAP

Radiative transfer code
Molecules excitations

Line intensity

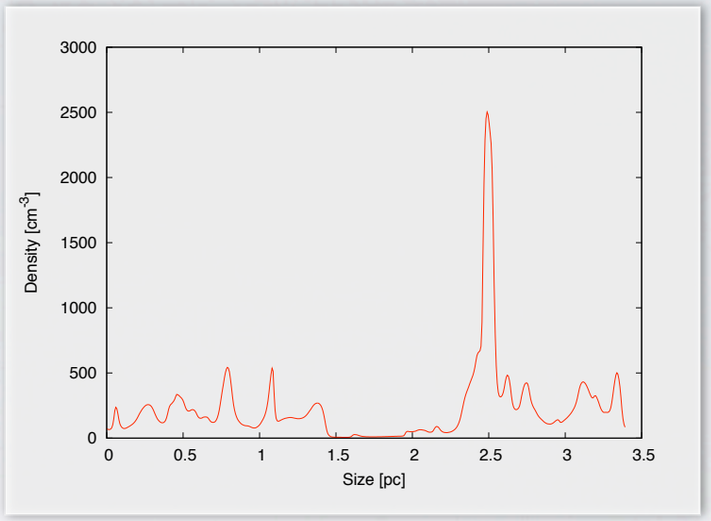
DUSTEM
Grains emission / temperature

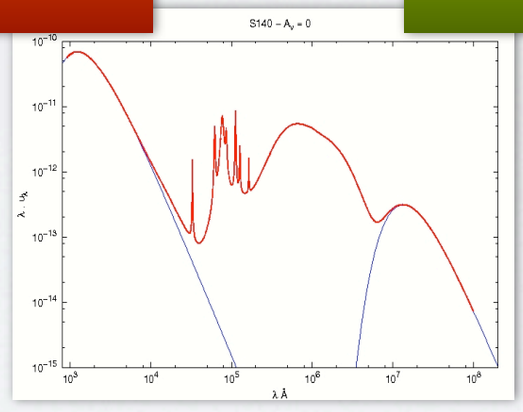
SLAP

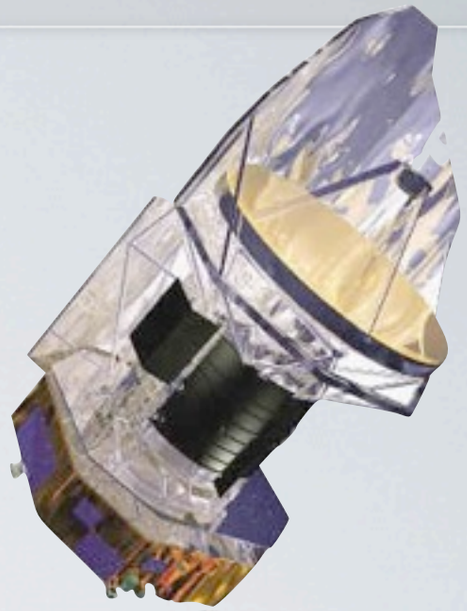
SLAP

Atomic & Molecular Databases (VAMDC)

Density profile on a line of sight (3.5 pc)







l'Observatoire de Paris

l'Observatoire de Paris – LUTH
Laboratoire Univers et Théories

l'Observatoire de Paris – LERMA
Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique

IAS

EURO VO
DATA CENTRE ALLIANCE