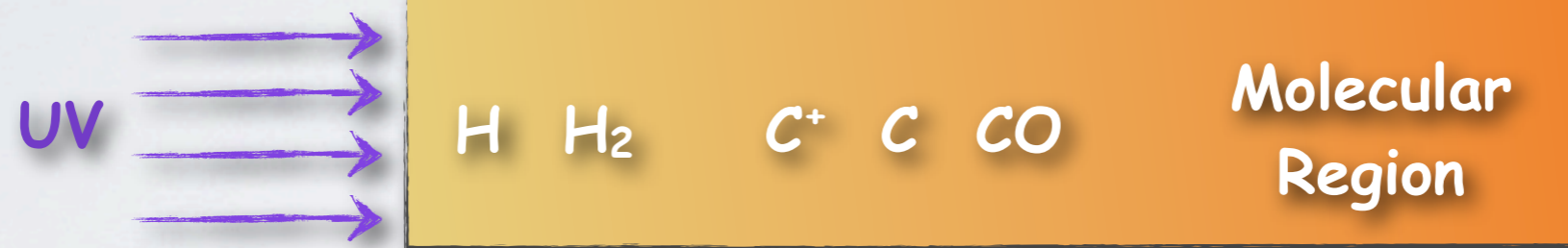


# Platform of Theoretical Services for the Interstellar Medium

## First Application : Meudon PDR code VO services

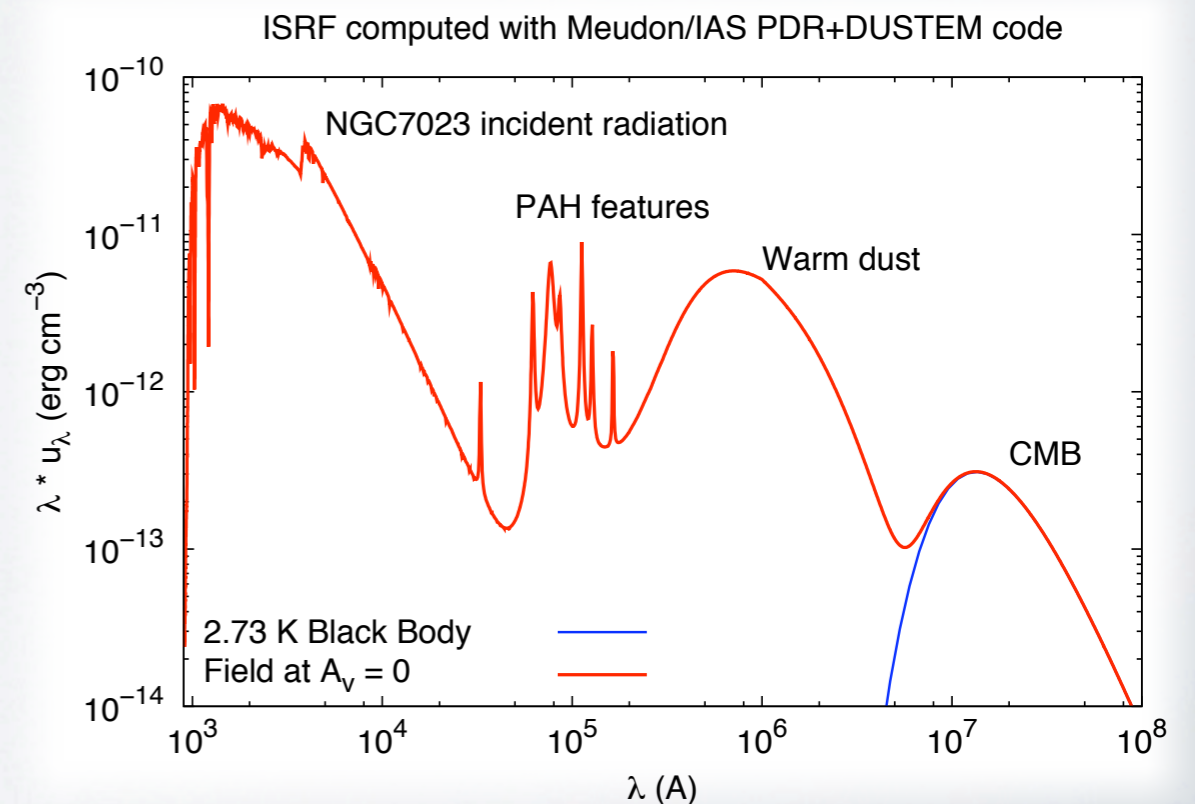
Computes the chemical and thermal structure of interstellar gas

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



- Molecules abundance profiles
- Gas and grains temperature
- Levels excitation
- ...
- Line intensities
- Column densities
- Absorption & emission spectra

Public code : <http://pdr.obspm.fr>



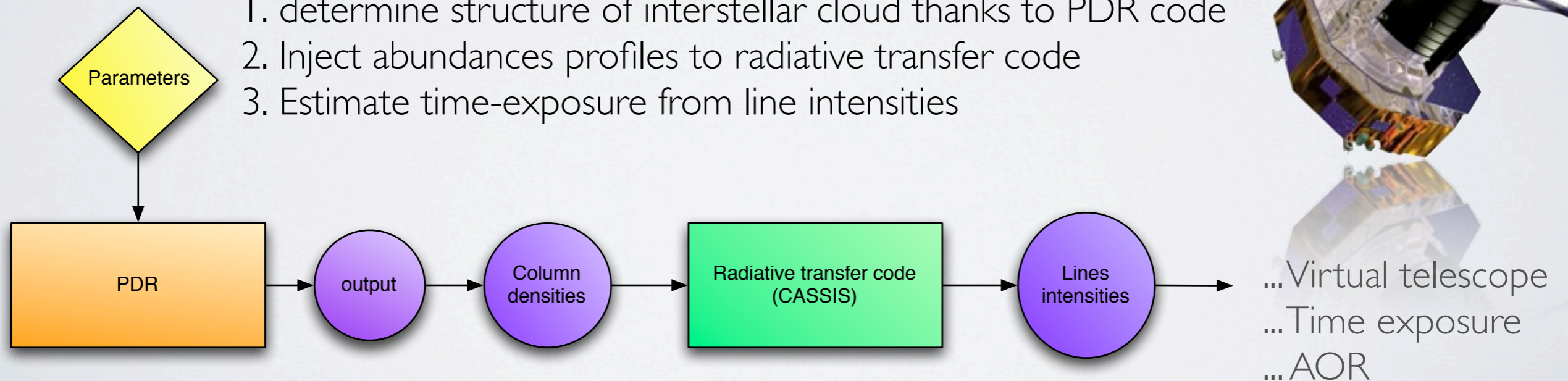
## Objectives via the VO :

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

Example : Herschel preparation

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

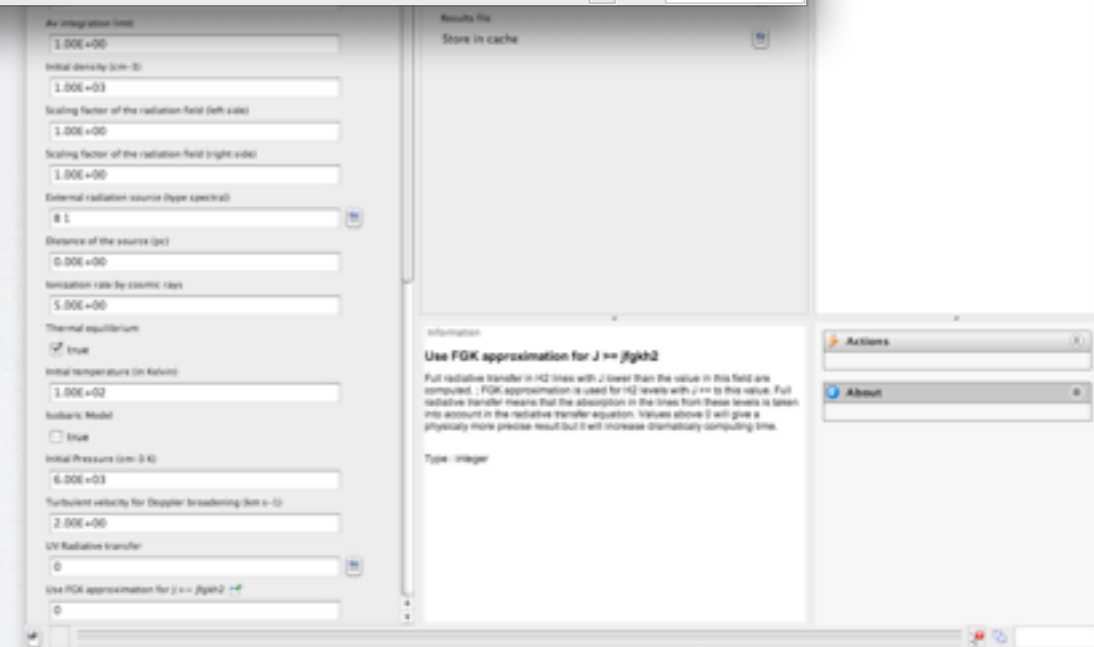
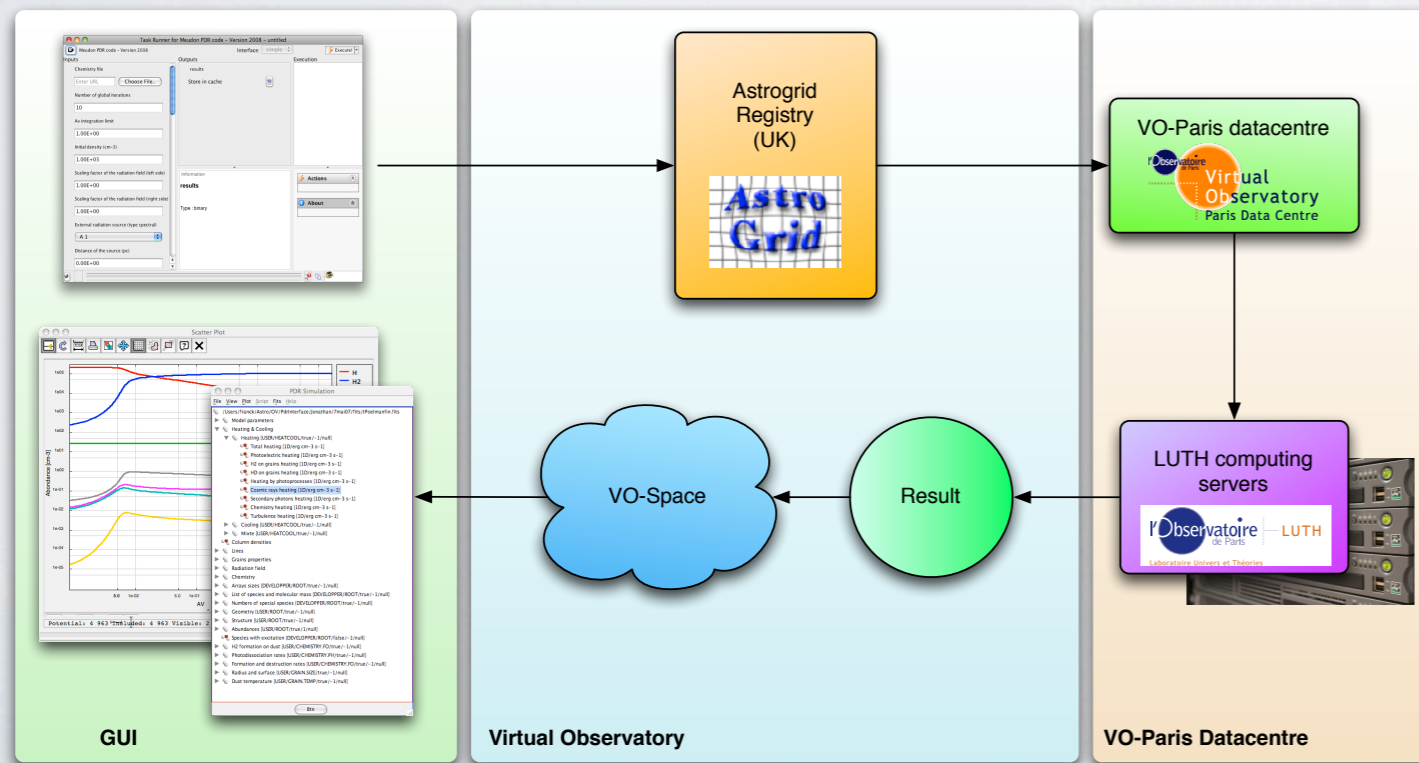
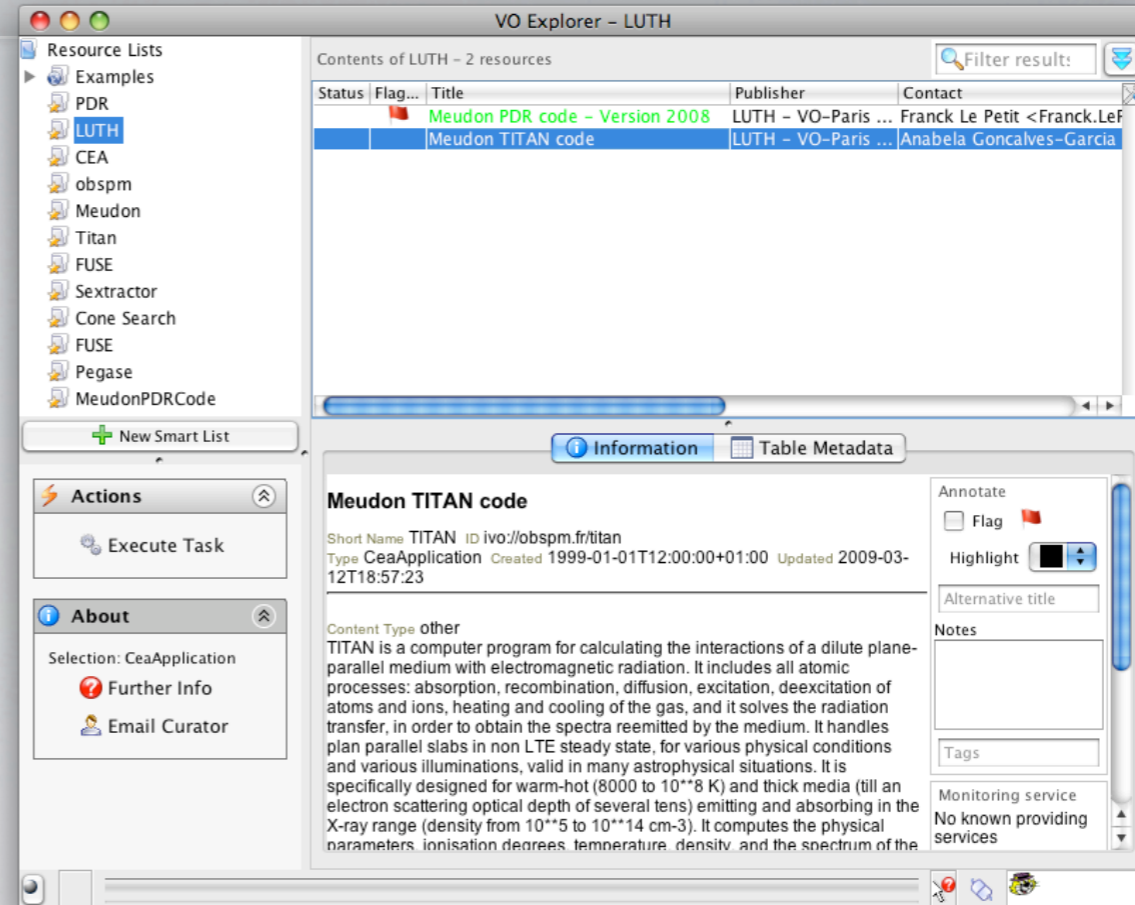


# Online code

## Use of Astrogrid Infrastructure

F. Roy

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



# ☐ Online code

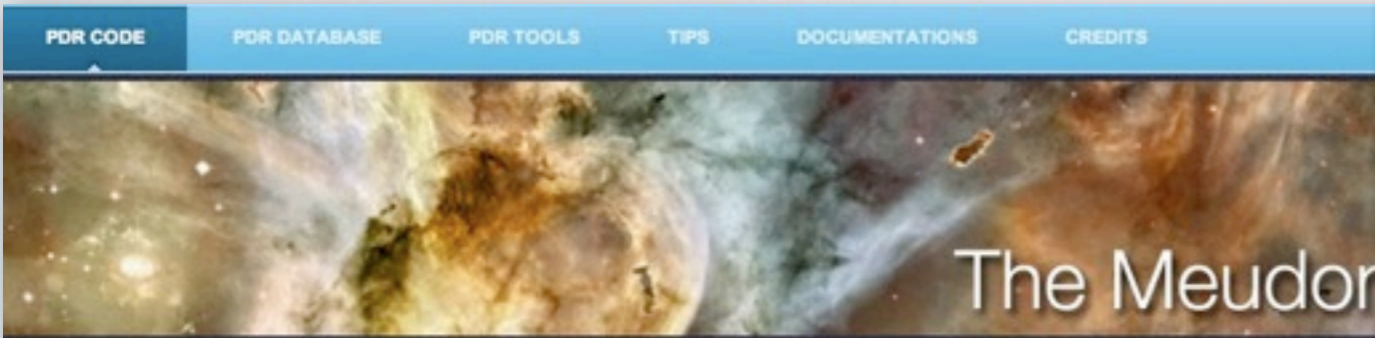
## Specific code interface

F. Roy / N. Moreau

- relationships between parameters
- graphics
- Communicates with Astrogrid

The Meudon PDR code interface includes the following parameters:

- Model name: [ ]
- Chemistry file: [ ] Browse
- Size (Av): 1.0e-5
- Density [cm-3]: 100
- Radiation field (left): 1
- Radiation field (right): 1
- External source
- Spectral type: B 1 V
- User defined source: [ ] Browse
- Distance [pc]: -0.0
- Thermal balance
- Temperature [K]: 100
- Equation of state: Constant density
- Symetrical profile
- Specific density profile: [ ] Browse
- Pressure [cm-3 K]: 6000
- Cosmic rays ionization rate: 2.0
- Turbulent velocity [km/s]: 2.0
- Number of iterations: 2
- Launch button



### Online PDR Code

The Meudon PDR code can be run online on Paris Observatory dedicated cluster.

This makes use of the **Astrogrid** infrastructure. From VO-Desktop or PDR Launcher, select input parameters and execute it. After a few hours (depending on the input parameters), results will be downloadable.

A typical chemistry file is used if none provided. One can select its one chemistry if a chemistry file is previously uploaded in the VO-Space.

**Requirements :**

- Astrogrid account (contact Astrogrid or Franck Le Petit to get one)
- PDR Launcher Webstart

**Use the Meudon PDR code**

The Meudon PDR code can be run in two ways :

- Download and install the code
- Use it online through the Virtual Observatory

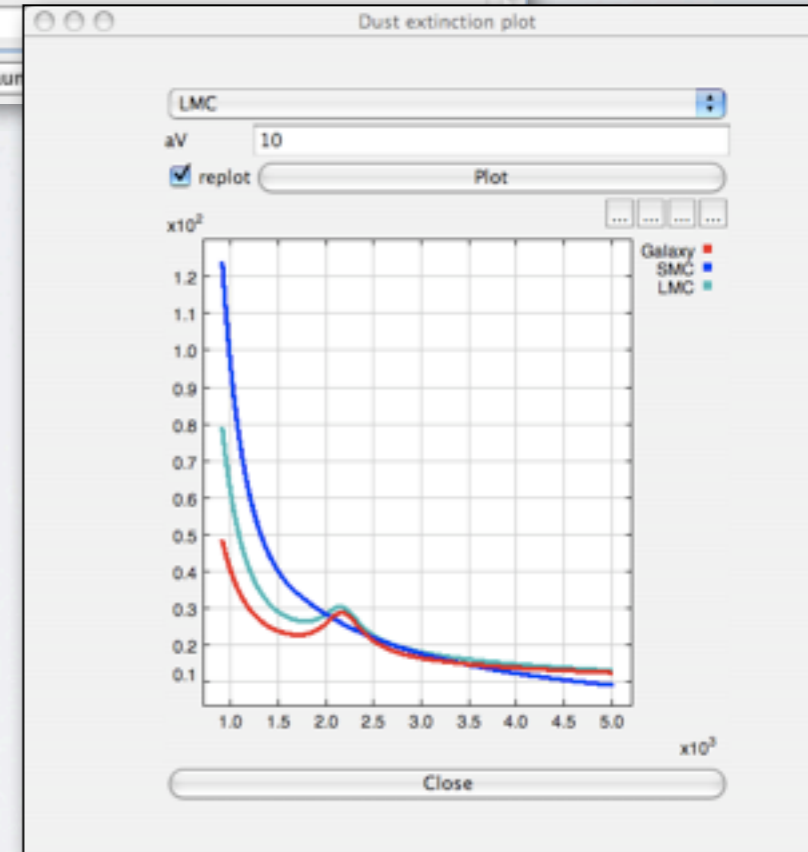
**Chemistry**

- Download chemistry files to run the code

**Atomic and molecular data**

The Meudon PDR code requires atomic and molecular data.

- List of Atomic and Molecular data used



## Output Files

Code produces

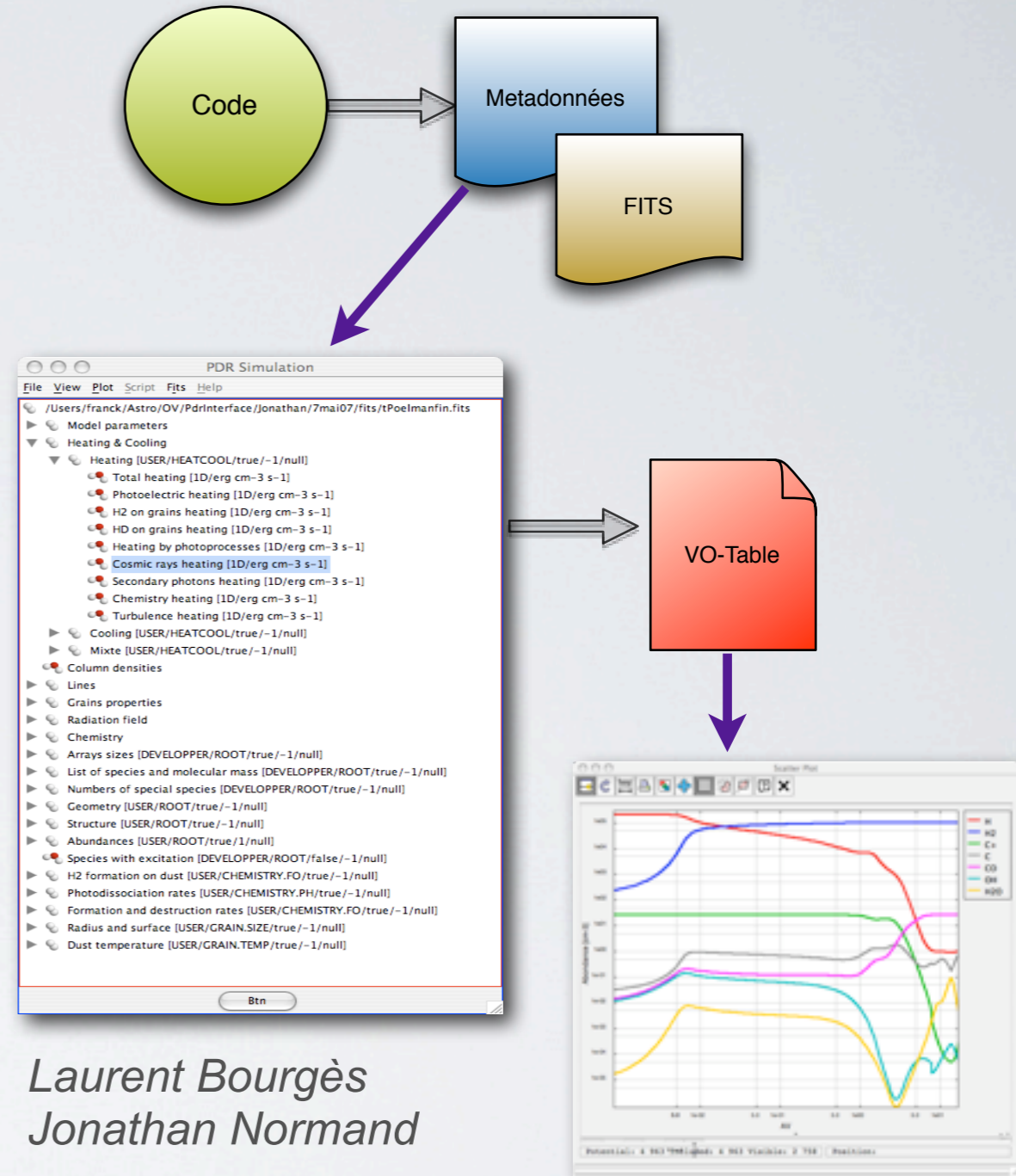
- FITS File : results
- VO-TABLE : meta-data  
(name, description, unities, UCD, ...)

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



Laurent Bourgès  
Jonathan Normand

# PDR Analyser

PDR Simulation

File View Plot Excitation & Lines Spectra Tools Plastic Help

/Users/franck/Astro/OV/PdrInterface/Jonathan/pdr/fits/N7023N

Informations [CNT\_INFODEV]

Species [CNT\_SPECIES]

Model Parameters [CNT\_M...]

Geometry [CNT\_GEOMETRY]

Structure [CNT\_STRUCTURE]

Temperature [DU\_STR...]

Proton density [DU\_STR...]

Pressure [DU\_STRUCTU...]

Total density [DU\_STR...]

Ionisation degree [DU...]

Abundances [CNT\_ABUNDA...]

Column densities [CNT\_CO...]

Chemistry [CNT\_CHEMISTR...]

Heating and Cooling [CNT...]

Grains [CNT\_GRAINS]

Radiation field [CNT\_RADFIELD...]

Other [CNT\_OTHER]

Spectra [CNT\_SPECTRA]

Btn

User selection

	AV [mag]	H [cm-3]	H2 [cm-3]	C [cm-3]	CO [cm-3]	O [cm-3]	O2 [cm-3]	OH [cm-3]	H2O [cm-3]	C+ [cm-3]
Structure [CNT_STRUCTURE]	0.000000E00	1.996887E05	1.536761E02	2.650284E-02	1.008693E-02	6.377963E01	1.553816E-05	8.437243E-03	8.104823E-06	2.636310E01
Temperature [DU_STR...]	1.000000E-06	1.996887E05	1.536911E02	2.650409E-02	1.008792E-02	6.377963E01	1.553971E-05	8.438072E-03	8.106518E-06	2.636310E01
Proton density [DU_STR...]	1.122462E-06	1.996886E05	1.536962E02	2.650439E-02	1.008814E-02	6.377963E01	1.554007E-05	8.438250E-03	8.106927E-06	2.636310E01
Pressure [DU_STRUCTU...]	1.259921E-06	1.996886E05	1.537023E02	2.650478E-02	1.008843E-02	6.377963E01	1.554054E-05	8.438485E-03	8.107455E-06	2.636310E01
Total density [DU_STR...]	1.414214E-06	1.996886E05	1.537097E02	2.650524E-02	1.008876E-02	6.377962E01	1.554109E-05	8.438761E-03	8.108077E-06	2.636310E01
Ionisation degree [DU...]	1.587401E-06	1.996886E05	1.537185E02	2.650580E-02	1.008918E-02	6.377962E01	1.554177E-05	8.439104E-03	8.108840E-06	2.636310E01
Abundances [CNT_ABUNDA...]	1.587401E-06	1.996886E05	1.537185E02	2.650580E-02	1.008918E-02	6.377962E01	1.554177E-05	8.439104E-03	8.108840E-06	2.636310E01
Column densities [CNT_CO...]	1.587401E-06	1.996886E05	1.537185E02	2.650580E-02	1.008918E-02	6.377962E01	1.554177E-05	8.439104E-03	8.108840E-06	2.636310E01
Chemistry [CNT_CHEMISTR...]	2.449490E-06	1.996885E05	1.537567E02	2.650831E-02	1.009107E-02	6.377962E01	1.554481E-05	8.440653E-03	8.112253E-06	2.636309E01
Heating and Cooling [CNT...]	2.620741E-06	1.996885E05	1.537755E02	2.650951E-02	1.009196E-02	6.377962E01	1.554625E-05	8.441383E-03	8.113880E-06	2.636309E01
Grains [CNT_GRAINS]	2.803966E-06	1.996885E05	1.537859E02	2.651018E-02	1.009246E-02	6.377962E01	1.554706E-05	8.441790E-03	8.114787E-06	2.636309E01

Line Intensities

H2O Angle (degree): 10

I	J	K	Central wave	E	Information on transitions
1	3	1	2.692722E-...	...	1 1 1 0 0 0 37.1356 cm-1
2	4	2	5.382825E-...	...	1 1 0 1 0 1 18.5768 cm-1
3	5	3	3.034558E-...	...	2 0 2 1 1 1 32.9524 cm-1
4	6	2	1.795260E-...	...	2 1 2 1 0 1 55.6999 cm-1
5	7	5	3.986410E-...	...	2 1 1 2 0 2 25.0842 cm-1
6	8	4	1.080730E-...	...	2 2 1 1 1 0 92.5263 cm-1
7	8	6	1.804876E-...	...	2 2 1 2 1 2 55.4032 cm-1
8	9	3	1.009830E-...	...	2 2 0 1 1 1 99.0225 cm-1
9	9	7	2.439760E-...	...	2 2 0 2 1 1 40.9860 cm-1

Integrated Emissivities

	H2O #1	H2O #2	H2O #3	H2O #4	H2O #5
	2.385918E-07	1.145879E-07	7.293309E-09	9.643572E-07	1.163133E-09

Scatter Plot

External source spectrum

Potential: 1 087 Included: 1 087 Visible: 1 087 Position:

Potential: 4 963 Included: 4 963 Visible: 2 758 Position: (,0053, 127759)

## □ PDR Database

Objectives :

- Publish PDR simulations
- Facilitate solving of inverse problems

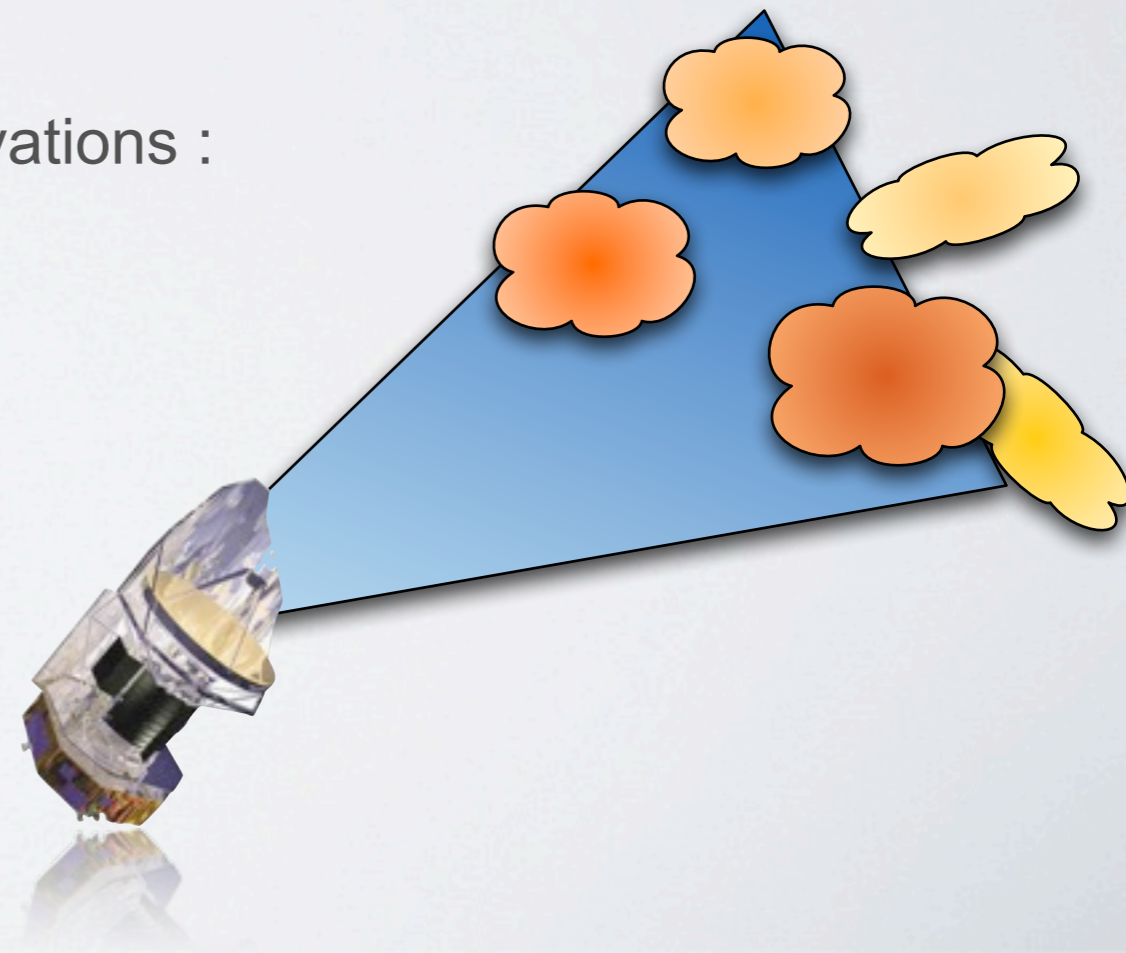
**Example :**

“In which kind of interstellar clouds can we detect H<sub>2</sub>O ?”

“Which parameters produce a ratio of line intensity H<sub>2</sub> 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<sub>2</sub> (O<sub>2</sub> key. prog.)
- Extra-galactic medium





SimDB prototype : Laurent Bourgès (Euro-VO DCA - Aïda / LUTH)

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



## PDR Database

**Query the Pdr models :**

[previous page](#)

To query the PDR models, select first a code version and then choose at least a search criteria :

**Code version : Pdr1.2\_chimie08**  
Description du code + fichiers input (chimie\_08)

Select at least one criteria on parameters :

Parameter	Possible values	User value
<a href="#">nH_init</a>	100.0, 500.0, 1000.0, 3.000E03, 7.000E03, 1.000E04, 3.000E04, 7.000E04, 1.000E05, 3.000E05, 7.000E05, 1.000E06, 3.000E06, 7.000E06	<input type="text"/>
<a href="#">radm_ini</a>	1.0, 5.0, 10.0, 1000.0, 3.000E03, 7.000E03, 1.000E04, 3.000E04, 7.000E04, 1.000E05, 3.000E05, 7.000E05, 1.000E06, 3.000E06, 7.000E06, 1.000E07	<input type="text"/>
<a href="#">radp_ini</a>	0.0, 1.0, 5.0	<input type="text"/>
<a href="#">Av_max</a>	1.0, 20.0	<input type="text"/>

SimDB permits queries on :

- input parameters : density, flux of cosmic rays, ...
- characterisation of properties : column densities, line intensities

Model : n1e3r3e4r0A2e1\_10 :

previous page

Model : n1e3r3e4r0A2e1\_10  
Description : One face simulations of bright and dense PDRs with visual extinction of  $A_v = 20$ . Proton density ranges from  $1E3$  to  $7E6$   $cm^{-3}$  and Rad from  $1E3$  to  $1E7$  (Draine's unit). - Galactic values for grain properties and elementary abundances - Standard UV transfer  
[Download full simulation for the PDR analyzer](#)

Model Structure Column densities Line intensities

Cloud parameters		Chemistry parameters	
Av_max	2.000E01 mag	Chemistry file name	chime08.chi
nH_init	1.000E03 $cm^{-3}$	He/H	1.000E-01
isoneside	1	C/H	1.320E-04
radm_ini	3.000E04	N/H	7.500E-05
radp_ini	0	O/H	3.190E-04
d_sour	0 pc	D/H	0
External source name		C13/H	0
ifeqth	1	N15/H	0
tg_init	1.000E02 K	O18/H	0
ifisob	0	PAH/H	0
presse	6.000E03 $cm^{-3}$ K	F/H	0
nH - Temp profile file name		Na/H	0
fmrc	5.000E00 $1E-17$ s-1	Mg/H	0
vturb	2.000E05 $cm$ s-1	Al/H	0
		Si/H	0
		P/H	0
		S/H	1.860E-05
		Cl/H	0
		Ca/H	0
		Fe/H	1.500E-08
		iforh2	0
		ichh2	2
		istic	4
Line of sight parameters		Information	
Line of sight	Galaxy	radm	1.475E04
cdunit	5.800E21 $cm^{-2}$ mag-1	radp	0
Rv	3.100E00	G0m	1.852E04
		G0p	0 phot $cm^{-2}$ s-1
		fphsec	5.000E03 s-1
		xngr	1.777E-09
		bsitgr	1.338E-05
		signgr	2.261E-21 $cm^2$
		dsite	2.600E-08 $cm$
		s_gr_1	9.046E-21
Algorithm parameters		Grains parameters	
ifafm	10	gratio	1.000E-02
itrfer	0	rmin	3.000E-07 $cm$
ifgkh2	0	rmax	3.000E-05 $cm$
Code version	3111108_JLB_and_Co	albedo	4.200E-01
		gg	6.000E-01
		rhoqr	2.590E00 $g$ $cm^{-3}$
		alpqr	3.500E00

Model : n1e3r3e4r0A2e1\_10 :

previous page

Model : n1e3r3e4r0A2e1\_10  
Description : One face simulations of bright and dense PDRs with visual extinction of  $A_v = 20$ . Proton density ranges from  $1E3$  to  $7E6$   $cm^{-3}$  and Rad from  $1E3$  to  $1E7$  (Draine's unit). - Galactic values for grain properties and elementary abundances - Standard UV transfer  
[Download full simulation for the PDR analyzer](#)

Model Structure Column densities Line intensities

Gas characterisation :

	Temperature (K)	Proton density ( $cm^{-3}$ )	Ionization degree
min	6.196E00	1.000E03	1.983E-05
moy	1.093E02	1.000E03	9.685E-05
max	3.849E02	1.000E03	2.038E-04

Gas temperature [K]

Temperature (K) vs AV (mag)

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	
Line	Intensity [erg $cm^{-2}$ s $^{-1}$ ]
3P_J=1, 3P_J=0, 609.75 micron	4.320E-06
3P_J=2, 3P_J=1, 370.37 micron	6.605E-06

[O I] Line Intensities	
Line	Intensity [erg $cm^{-2}$ s $^{-1}$ ]
3P_J=0, 3P_J=1, 145.53 micron	3.824E-05
3P_J=1, 3P_J=2, 63.19 micron	8.420E-04

[C II] Line Intensities	
Line	Intensity [erg $cm^{-2}$ s $^{-1}$ ]
2P_J=3/2, 2P_J=1/2, 157.68 micron	6.571E-04

H2 Line intensities	
Line	Intensity [erg $cm^{-2}$ s $^{-1}$ ]
1 2 0 1-0 S(0), 2.2232 micrometres	1.401E-09
1 3 0 1-0 S(1), 2.1217 micrometres	1.346E-09
1 4 0 2-1-0 S(2), 2.0337 micrometres	1.288E-09
1 5 0 3-1-0 S(3), 1.9575 micrometres	6.064E-10
2 4 1 2-2-1 S(2), 2.1541 micrometres	6.279E-10
2 5 1 3-2-1 S(3), 2.0734 micrometres	2.768E-10

Next step : Add access protocol TAP / SimDAP

## PDR Services

Online PDR code in the VO

SimDB PDR service

Documentations

- Scientists using the services
- Developpers & scientists wishing to develop VO services

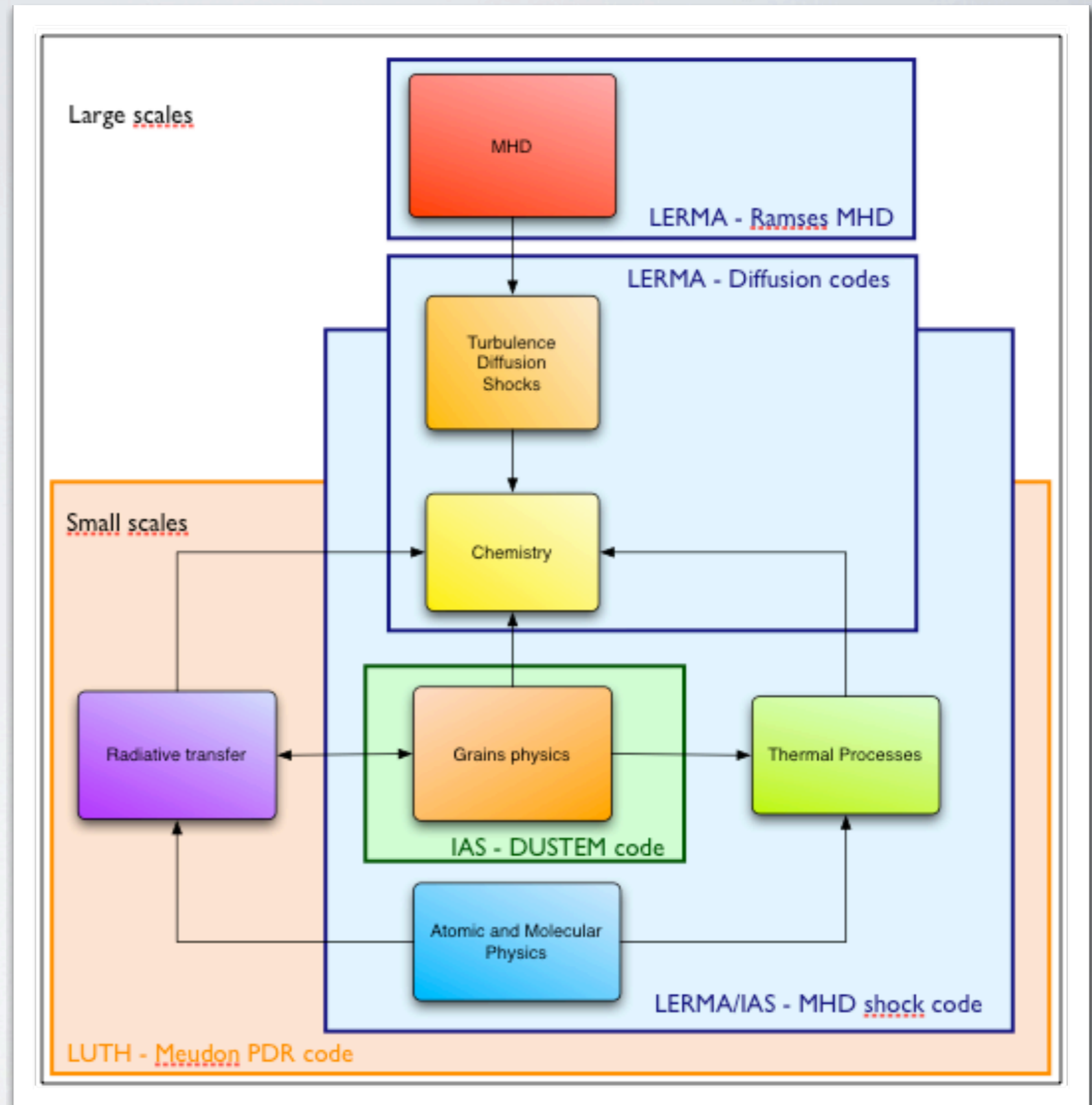
This work motivated scientists to build theoretical services

- among them those working on simulations of the ISM in Paris

# VO Plateform for simulation of ISM

## LERMA - LUTH - IAS

Franck Le Petit  
Patrick Hennebelle  
Fabrice Roy  
Evelyne Roueff  
Jacques Le Bourlot  
Edith Falgarone  
Nicolas Moreau  
Benjamin Ooghe  
Sylvie Cabrit  
Pierre Lesaffre  
François Lévrier  
Laurent Pagani  
François Boulanger  
Laurent Verstraete  
Guillaume Pineau des Forêts

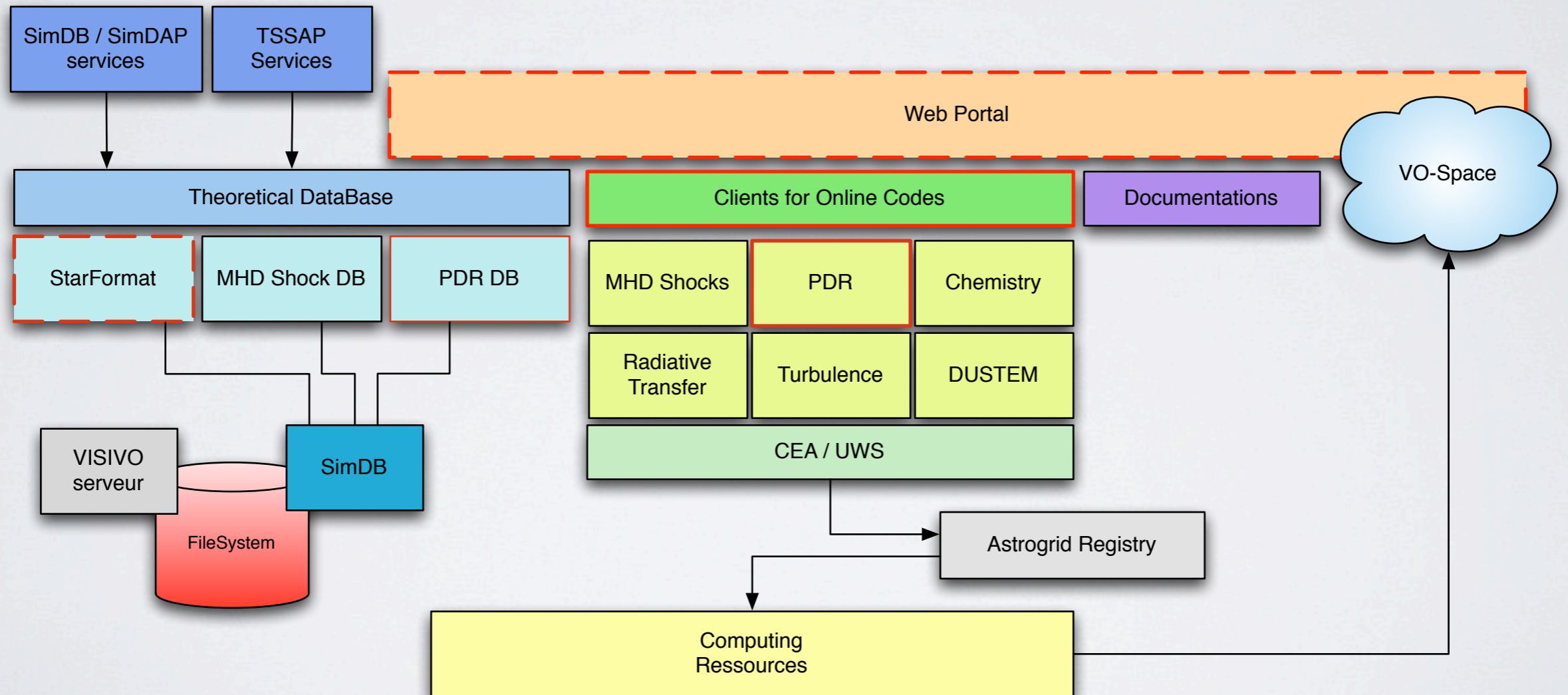


# ☐ Interstellar Medium Platform

Bring together expertise in modeling / simulation of the ISM

Provide theoretical services about ISM

## Codes - Databases - Tools & services



# ASTRONET : Project STARFORMAT



First part of the project funded by ASTRONET  
(P. Hennebelle et al.)

French & German teams

Development of services for MHD simulations  
SimDB

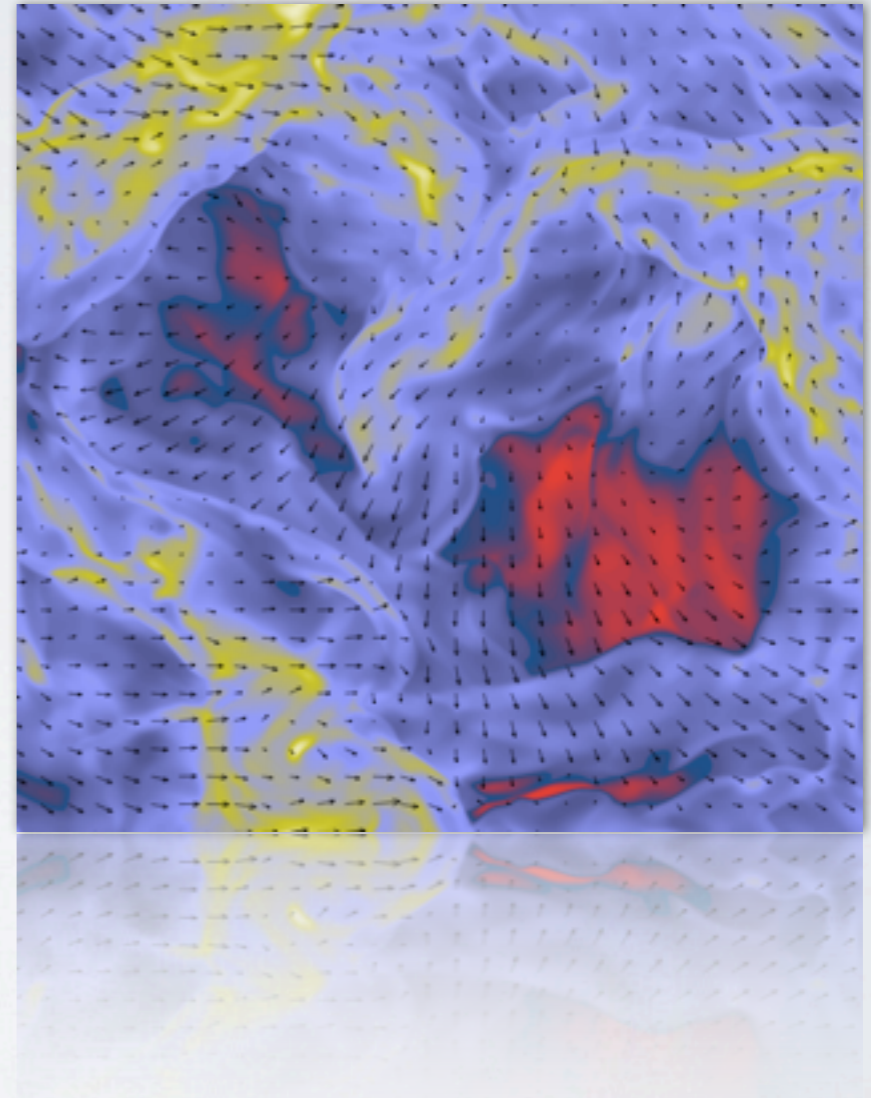
Codes : Ramses / FLASH

**Catalogs of dense cores properties**

**services (SimDAP):**

Extraction of cores

Extraction of density profiles on a line of sight



# Interstellar Medium Platform

## Interoperability between codes & services

