

ISMDB

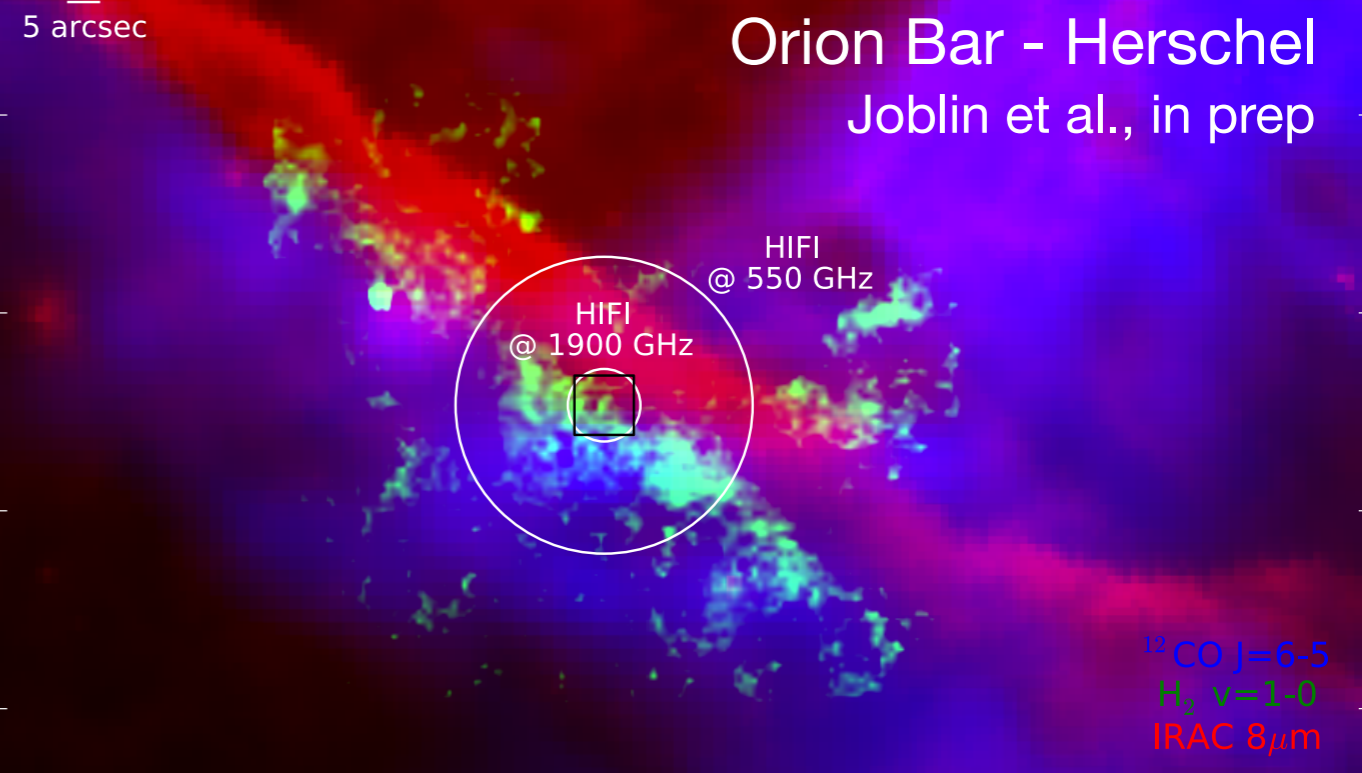
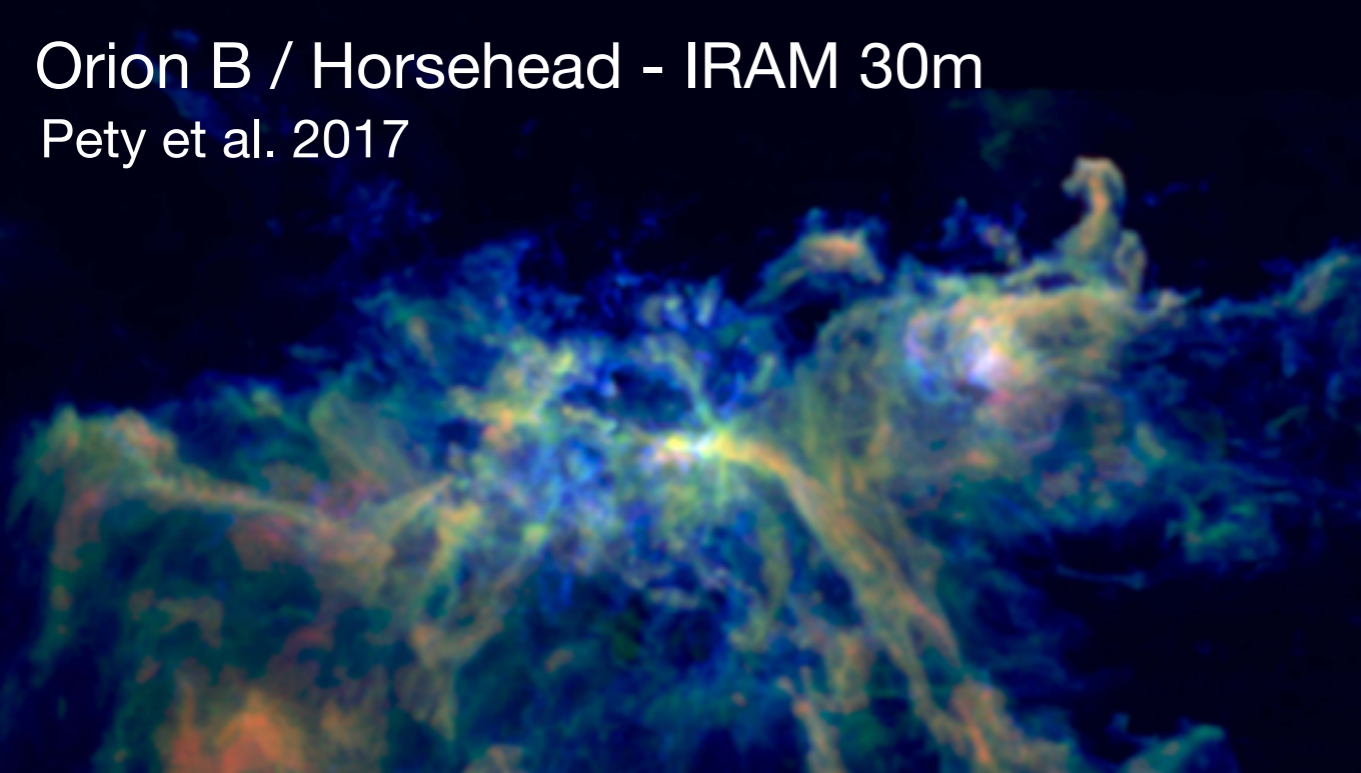
InterStellar Medium DataBase

<http://ism.obspm.fr>

Franck Le Petit
David Languignon
Emeric Bron
Nicolas Moreau

ISMDB: Interstellar Medium DataBase

Goal: Provide numerical tools to interpret observations in the interstellar medium.

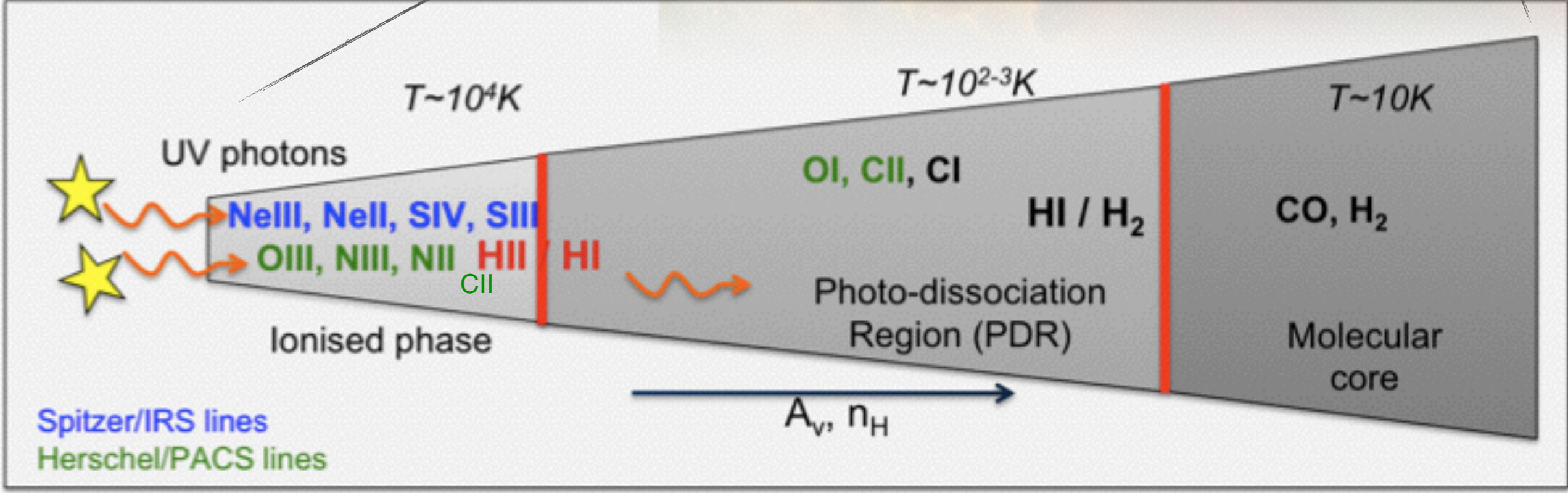


With the new instruments, observations of the ISM are:

- more and more detailed
- more and more difficult to interpret

Schema of the transition atoms / molecules

PDR: Photo-dissociation region
Transitions between H / H₂ regions

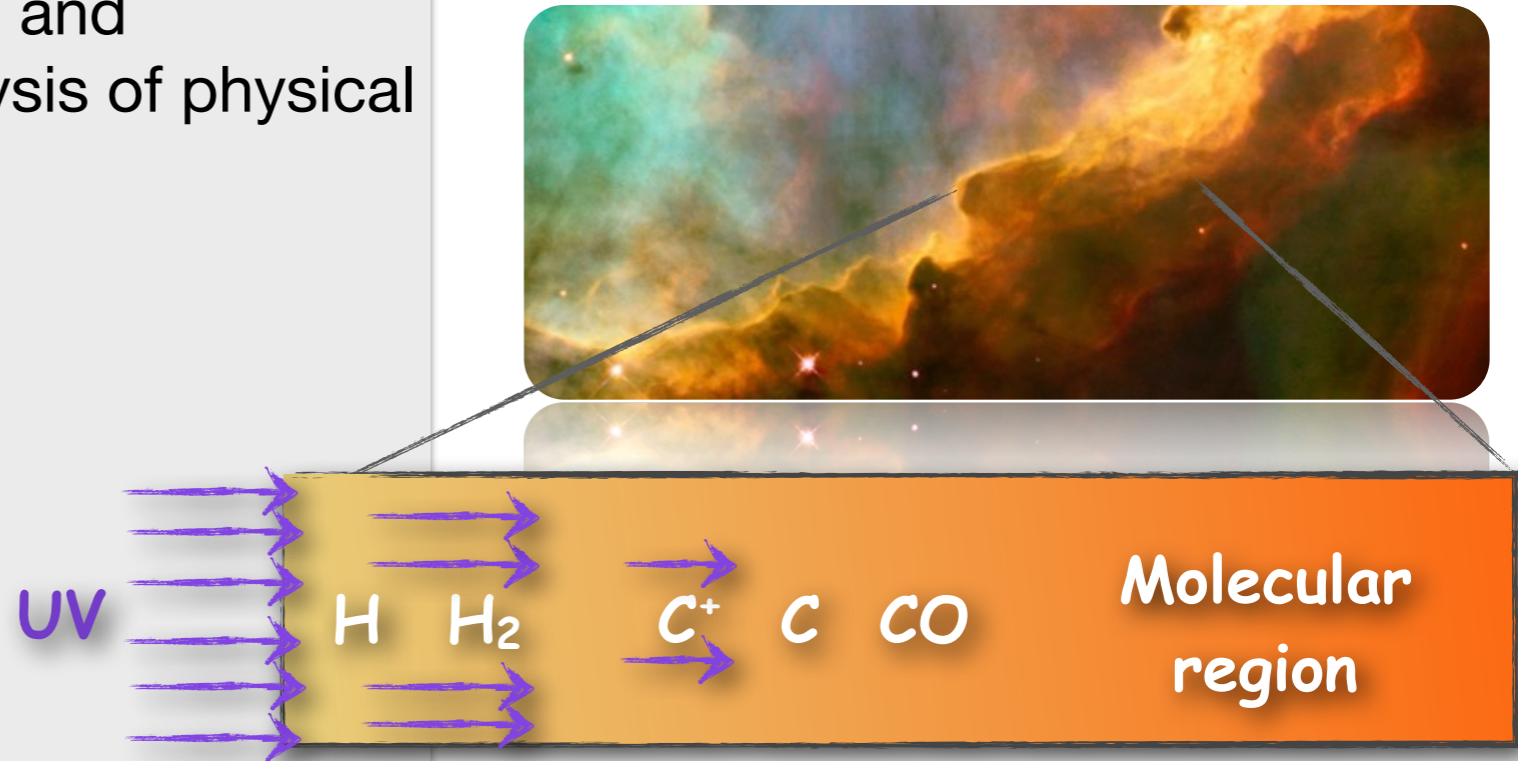


Simulation code: Meudon PDR code

Le Petit et al. (2006), Gonzalez-Garcia et al. (2008), Le Petit et al. (2009), Le Bourlot et al. (2012)

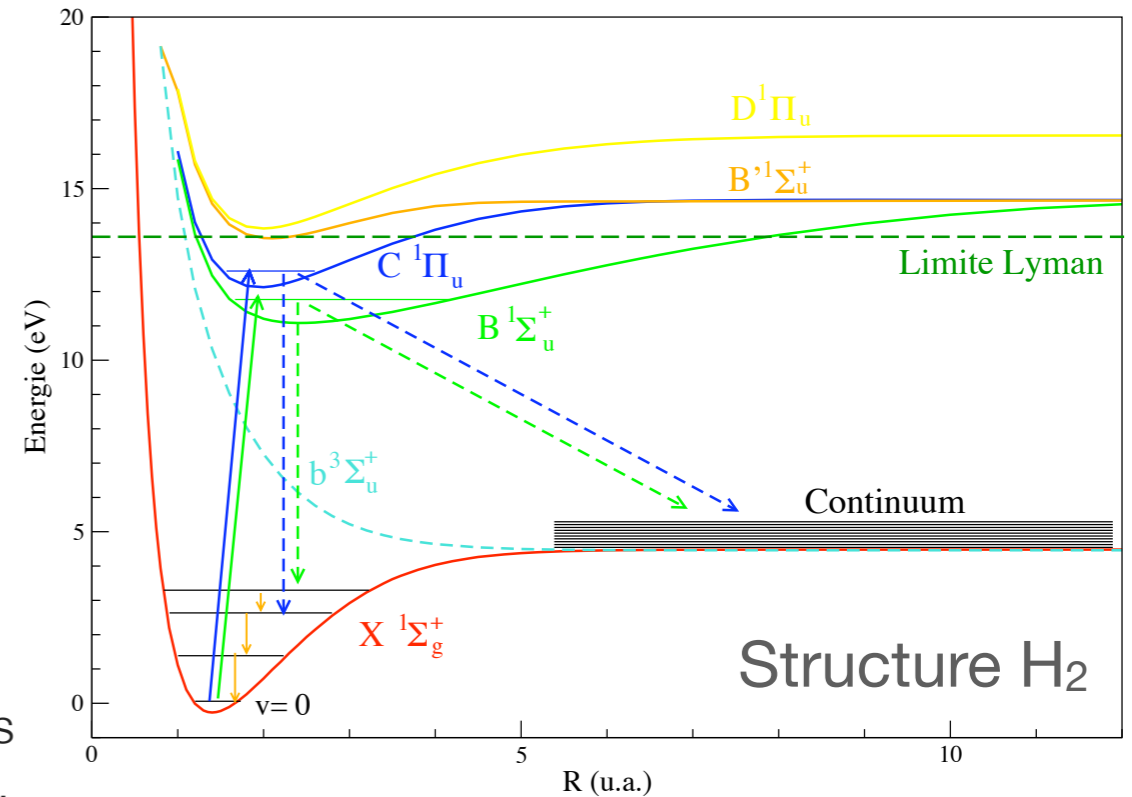
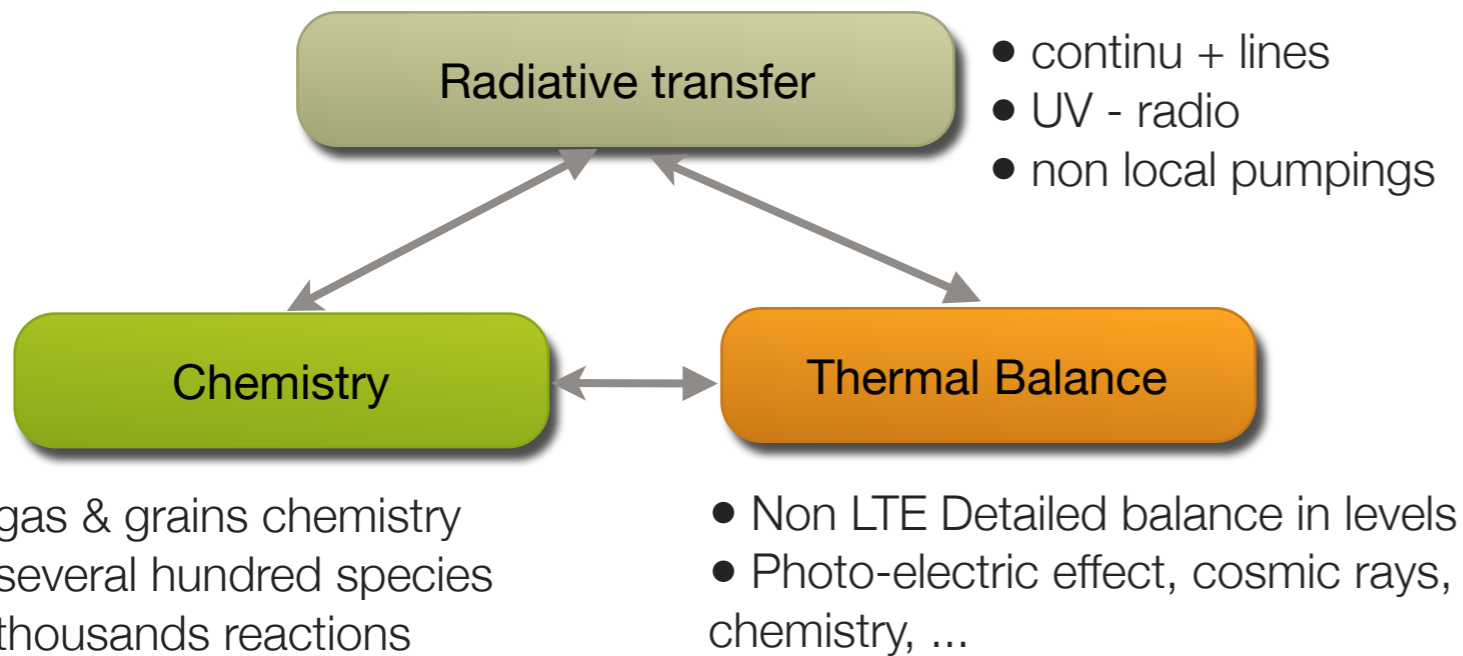
PDR Code : computation of the atomic and molecular structure of clouds and analysis of physical processes

- abundances
- excitation states
- temperatures (gas & grains)
- Intensities (H_2 , CO, H_2O , ...)
- Column densities



Interpretation of large instruments observations

ALMA, SOFIA, IRAM, HERSCHEL, Spitzer, VLT, HST, FUSE, ...



Interpretation of line intensities

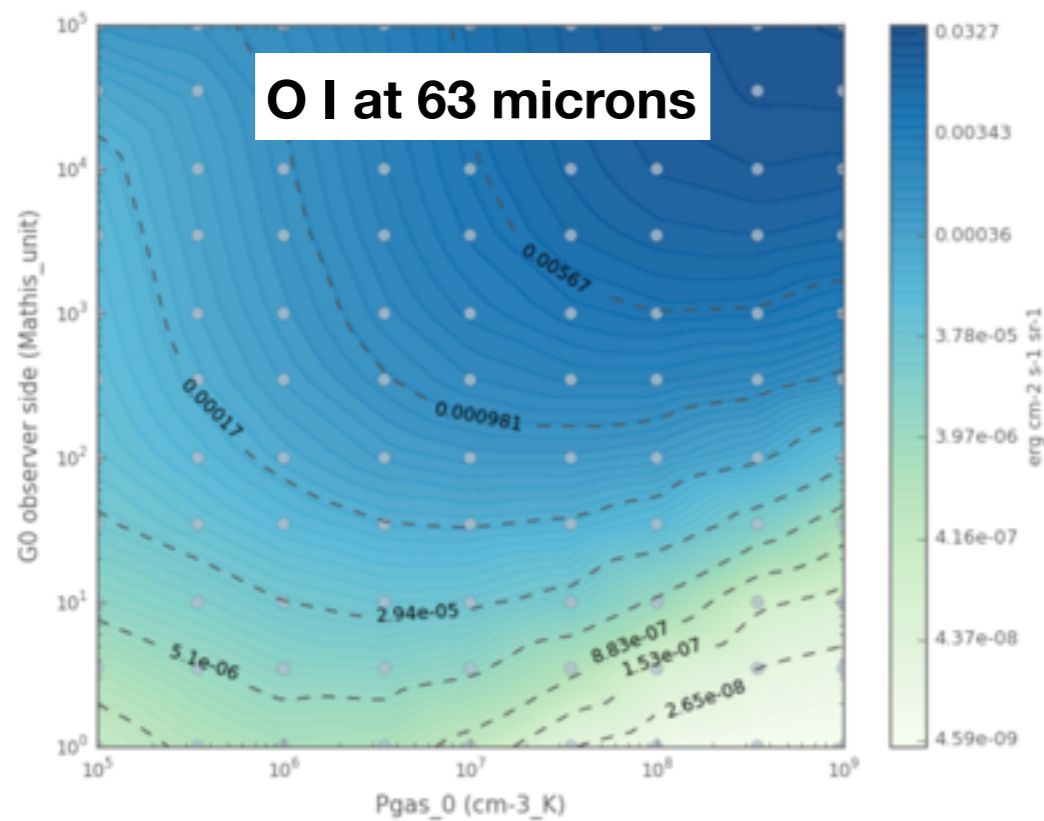
Comparison of observations & grids of models

Determine physical conditions:

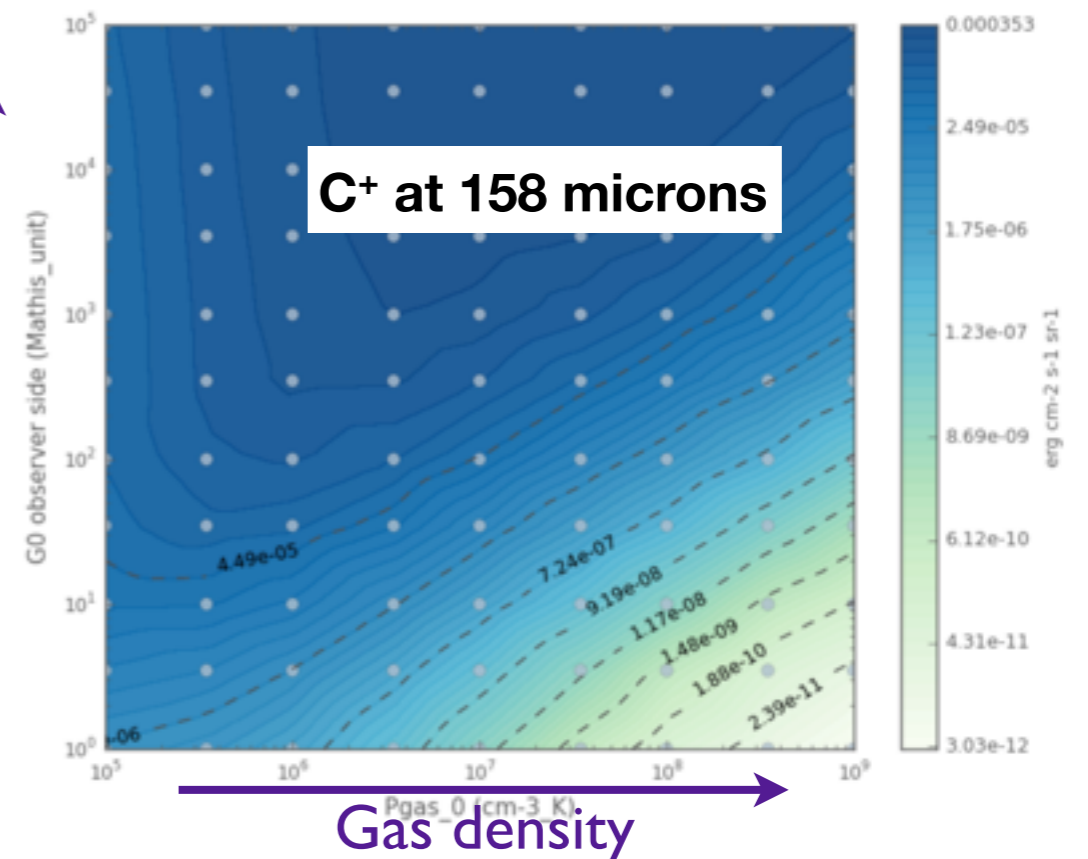
- density / pressure of clouds
- size of clouds
- intensity of radiation field : UV and X-rays
- metallicity
- ...



Grids of models:



UV field intensity



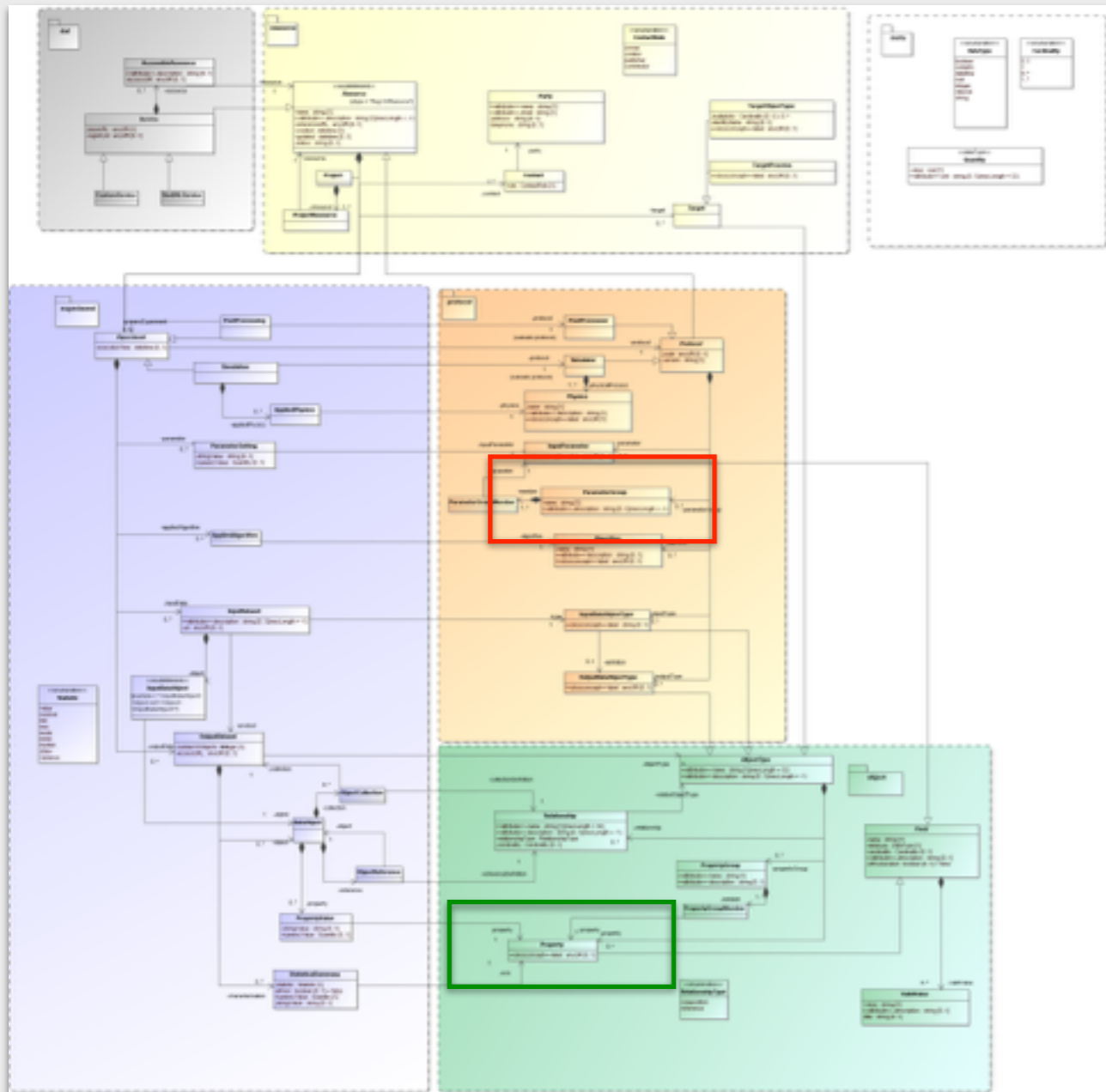
1 model : 6 hours to several days CPU time
Interpretation requires up to thousands models
→ weeks or months of work
How to reduce this work to a few minutes ?

Production of grids of PDR models

- ~ 3000 PDR models in ISMDB for **standard galactic conditions**
- ~ 10 To of data

Cover: **PDR models for Herschel, IRAM/Noema, JWST, ALMA ... observations**

Characterisation of PDR models with the **Simulation DataModel** :



For each model:

InputParameters

- pressure, UV field, ...
- **~ 20 quantities**

Properties / statistics

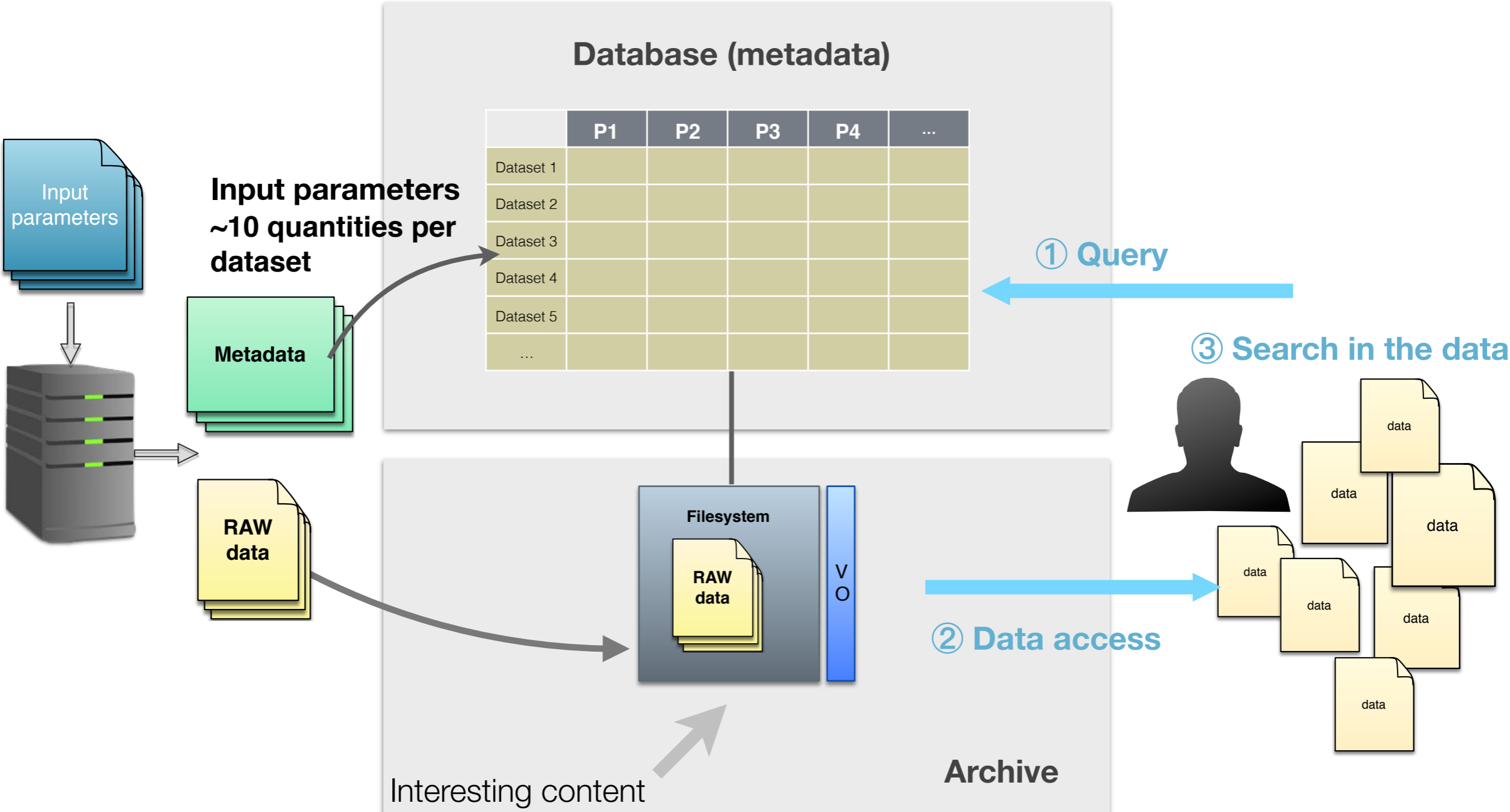
- line intensities: C⁺, C, H₂, CO, H₂O, ...
- **+150 000 metadata**

ISMDB

ISMDB: InterStellar Medium DataBase

- not only a classical database to find pre-computed models
- but **also a tool that can interpret observations**

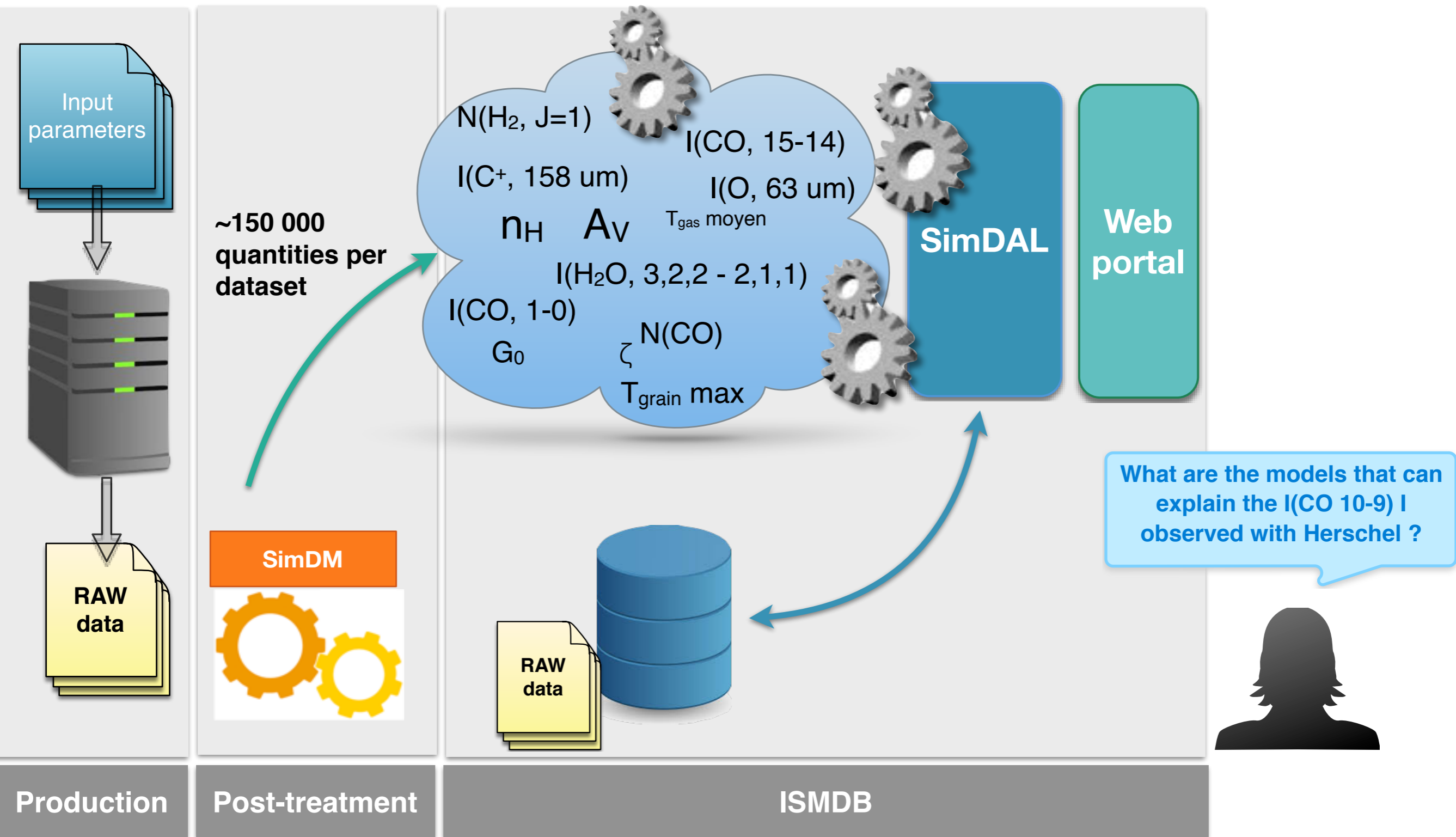
Standard databases:



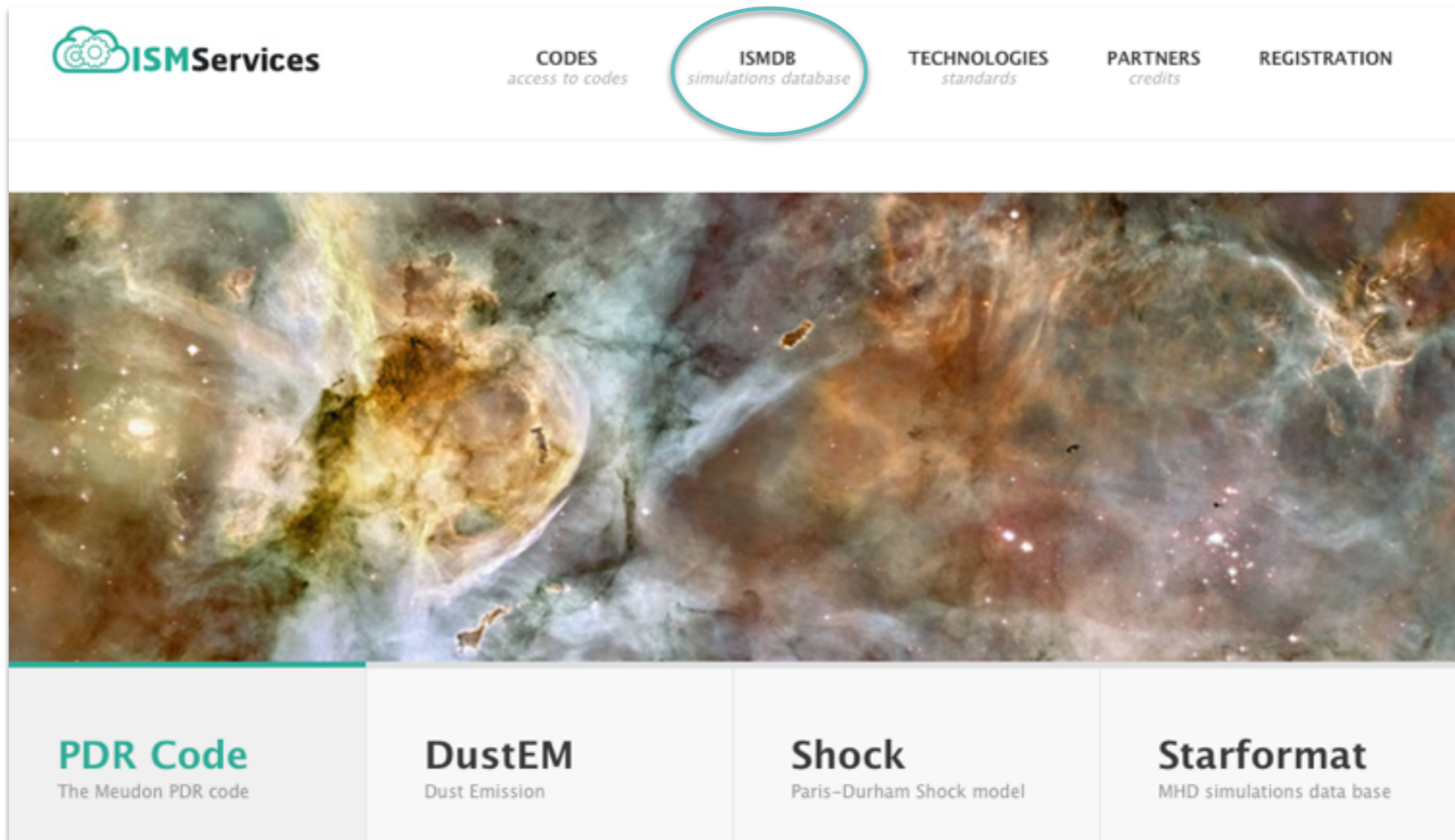
ISMDB

- not only a classical database to find pre-computed models
- but **also a tool that can *interpret* observations**

High dimensionnality
=> specific technologies required



<http://ism.obspm.fr>



ISMServices

CODES
access to codes

ISMDB
simulations database

TECHNOLOGIES
standards

PARTNERS
credits

REGISTRATION

PDR Code
The Meudon PDR code

DustEM
Dust Emission

Shock
Paris-Durham Shock model

Starformat
MHD simulations data base

- Source codes & specific developments
- Online codes
- Tools to analyze results
 - Extractor & Chemistry Analyzer
- ISMDB

ISMServices CODES ISMDB PARTNERS REGISTRATION

Help Contact

ISM DataBase – Inverse Search service Beta

Grid of isobaric PDR 1.5.2 models
2016.12.03

1 – search among two parameters

x (cm-3_K) log scale

y (Mathis_unit) log scale

2 – fix all the other parameters

(mag)

3 – observational constraints

"I(CO v=0J=1->v=0J=0 angle 00 deg)" > 1.8E-7
 "I(CO v=0J=1->v=0J=0 angle 00 deg)" < 2.4E-7
 "I(H2 v=0J=2->v=0J=0 angle 60 deg)" > 1E-8
 "I(H2 v=0J=2->v=0J=0 angle 60 deg)" < 5E-7

① Select the searched input parameters

Example of a search:

- gas pressure
- UV intensity

② Fix the other input parameters

Example: size of the cloud

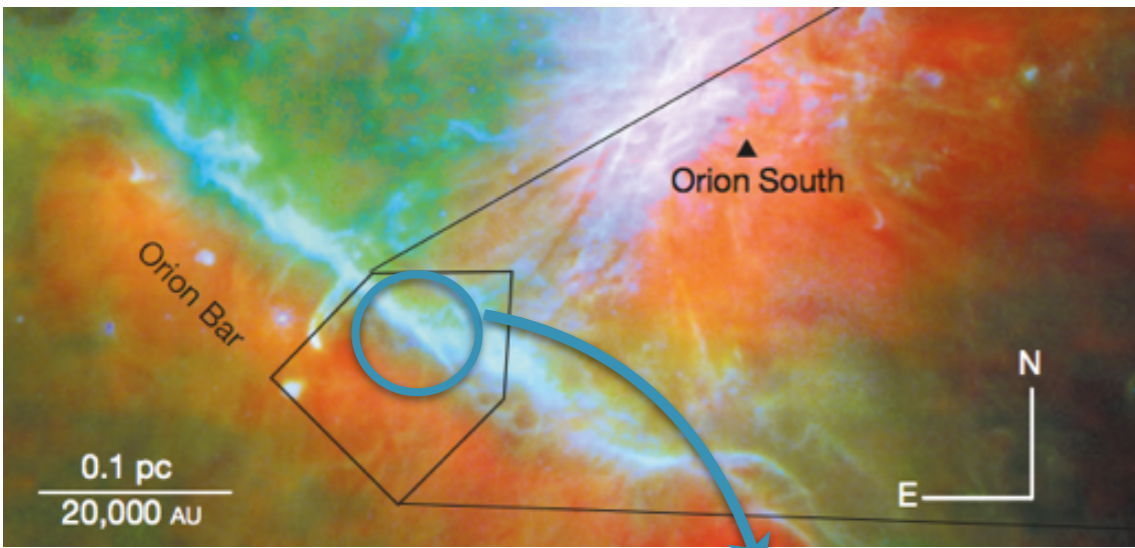
③ Enter the observations

Example: observations CO and H₂ intensities

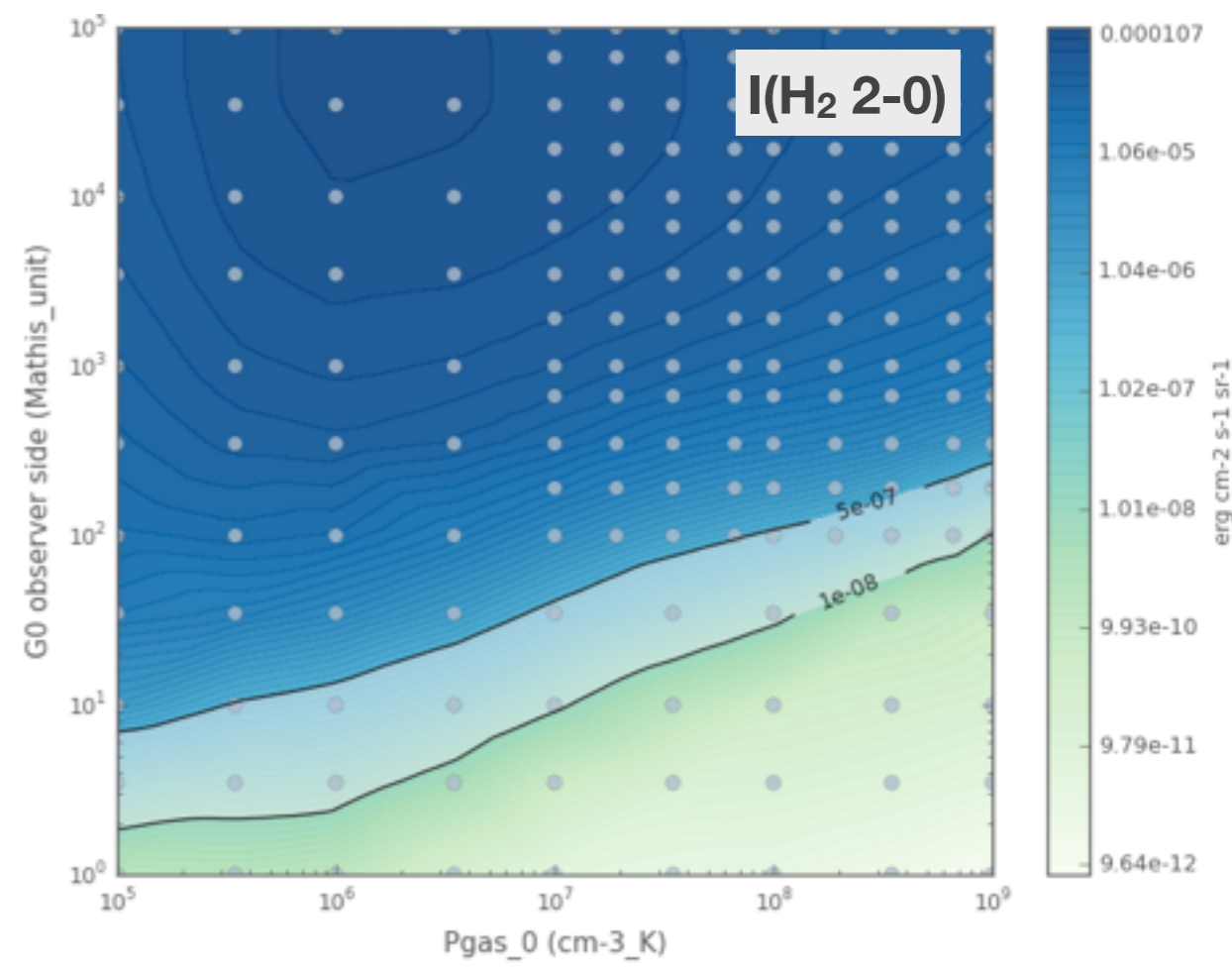
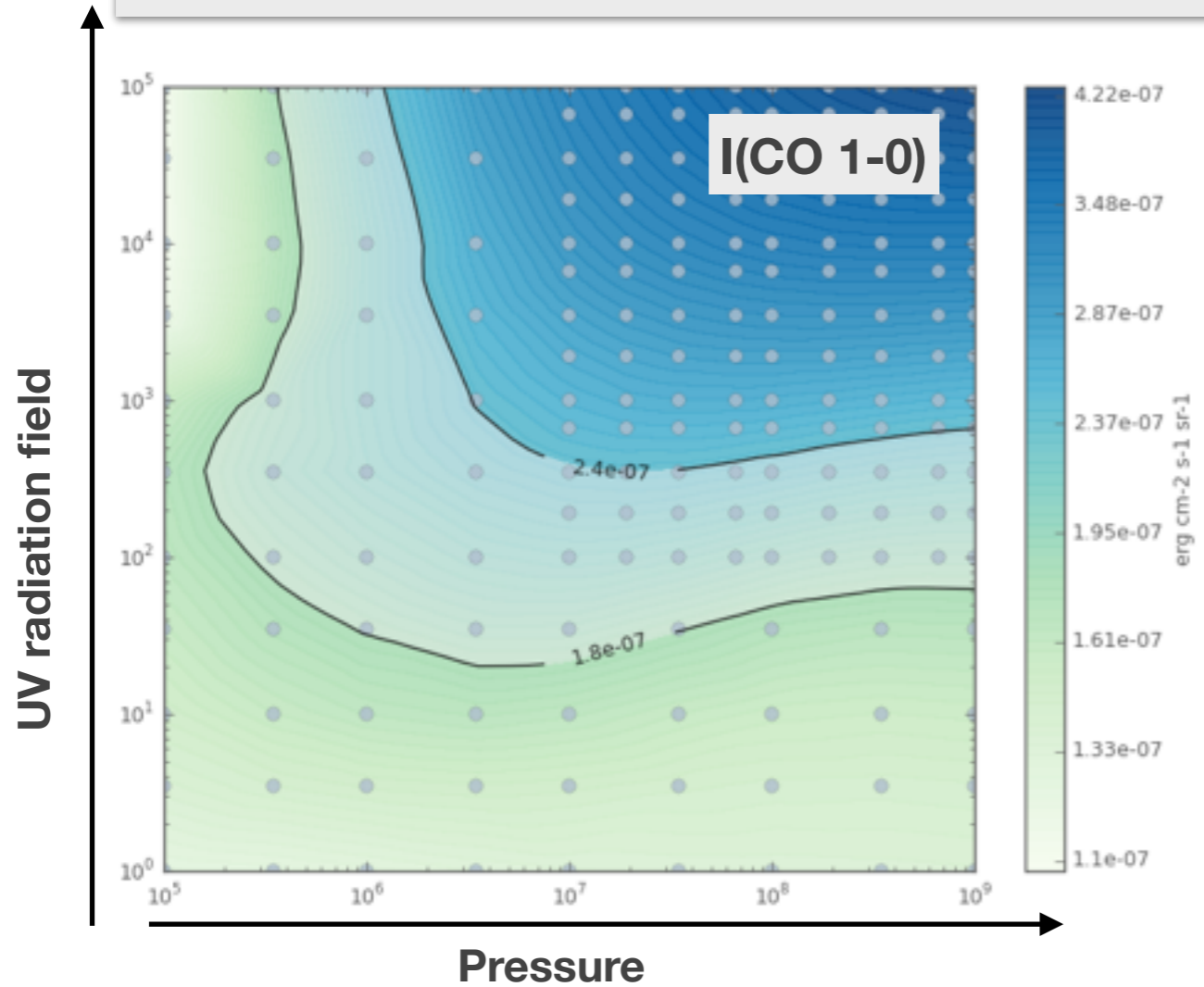
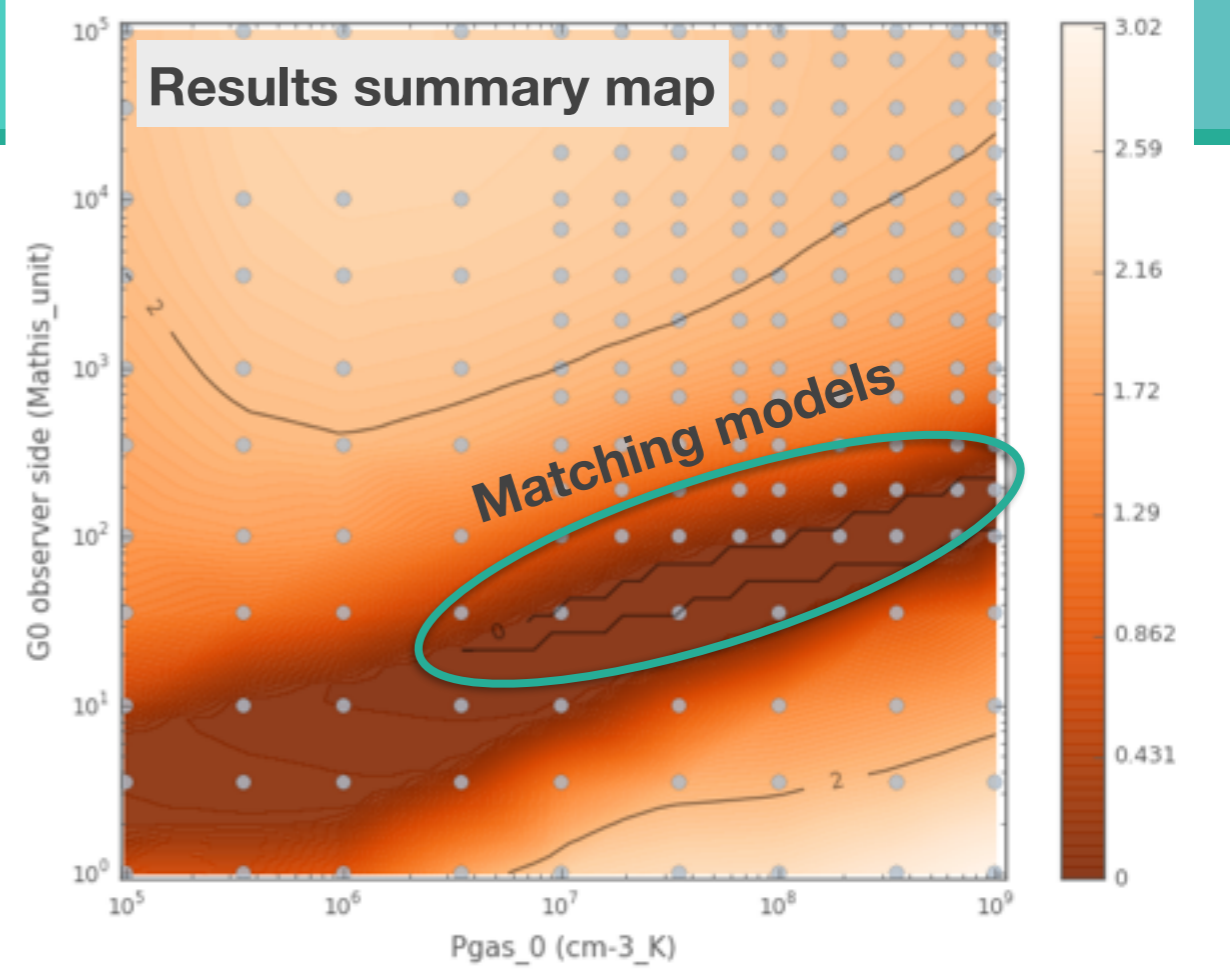
$$1.8 \cdot 10^{-7} < I(\text{CO } 1-0) < 2.4 \cdot 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$$

$$1.0 \cdot 10^{-8} < I(\text{H}_2 \text{ } 2-0) < 5.0 \cdot 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$$

Interpretation of observations



$1.8 \cdot 10^{-7} < I(\text{CO } 1-0) < 2.4 \cdot 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$
 $1.0 \cdot 10^{-8} < I(\text{H}_2 \text{ } 2-0) < 5.0 \cdot 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$



VO Integration

Metadata definition & organization

Data Access

Raw data (extractor tool)

Simulation Data Model (SimDM)

Simulation Data Access Layer (SimDAL)

VOTable
SAMP connector

Extractor Tool

SAMP

PDR Extractor

n(CO) Confirm Remove All

DM54NoPAH_A1e1p6p7e7r1e4_s_20.hdf5

- Integrated quantities
- Local quantities
 - Auxiliary
 - Excitation
 - H2 chemistry
 - Ice layers
 - Molecular fraction
 - Photo reactions
 - Radiation
 - Thermal balance
 - Densities
 - Column densities
 - Densities
 - Dust
 - Gas state
 - Positions
 - AV
 - Distance
 - tauV
 - Parameters

Export as Text Export as VOTable Send Table

TOPCAT

Table List

1: PDR Extractor table 1

Current Table Properties

Label: PDR Extractor table 1

Location: PDR Extractor:PDR Extractor table 1

Name: PDR Extractor table 1

Rows: 760

Columns: 6

Sort Order: ↑

Row Subset: All

Activation Action: (no action) Broadcast Row

SAMP

Messages: 0 Clients: 0

10	1,41421E-5	36682,	0,502178	4,84237	8,67592E-5	1,05931E-7
11	2,00000E-5	36683,	0,50224	4,84246	8,67717E-5	1,05952E-7
12	3,00000E-5	36653,	0,501271	4,83854	8,65837E-5	1,05723E-7
13	3,87298E-5	36681,	0,502296			
14	5,00000E-5	36682,	0,502387			
15	7,00000E-5	36651,	0,501473			
16	1,00000E-4	36678,	0,50262			
17	0,000141	36648,	0,501867			
18	0,0002	36673,	0,503188			
19	0,0003	36670,	0,503839			
20	0,000387	36665,	0,504349			
21	0,0005	36659,	0,505011			
22	0,0007	36648,	0,506189			
23	0,001	36632,	0,507966			
24	0,001414	36610,	0,510433			
25	0,002	36579,	0,51394			
26	0,003	36526,	0,519966			
27	0,003873	36482,	0,52531			
28	0,005	36426,	0,532248			
29	0,007	36328,	0,544744			
30	0,01	36190,	0,564053			
31	0,014142	36014,	0,591946			
32	0,02	35789,	0,634301			
33	0,025	35597,	0,672784			
34	0,03	35442,	0,715947			
35	0,034365	35318,	0,757359			
36	0,03873	35204,	0,802962			
37	0,04365	35080,	0,849565			

56 / 3641 M

n(H) / cm⁻³

AV / mag

Interpretation of observations

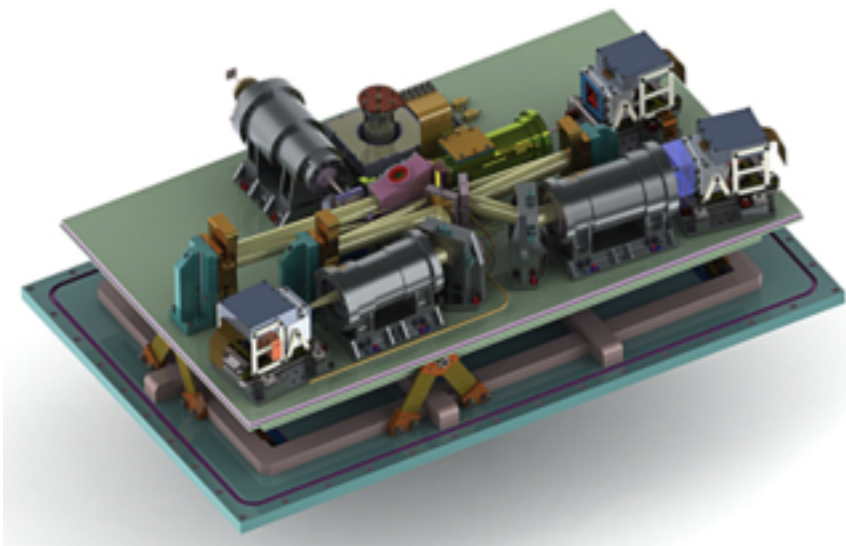
IGRINS observations

Instrument - Univ. Texas, Austin

Mc Donald observatory

Bands: H et K (1.5 to 2.5 microns)

$R = 45\,000$

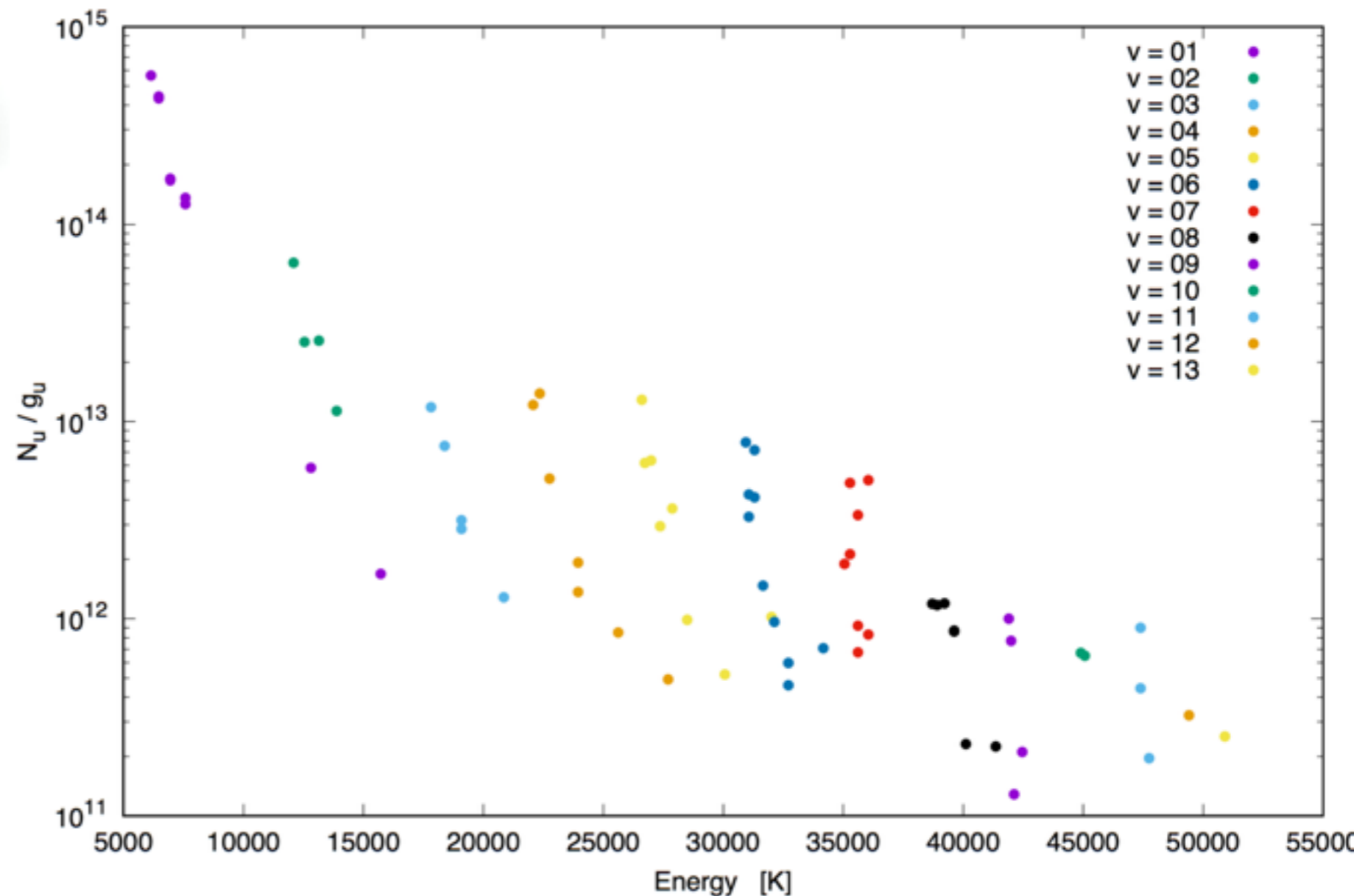


Observations of NGC 7023

(Le et al. - 2016 / ArXiv)

- Detection of **70 H₂ lines in NGC 7023**
- Conclude to a clumpy medium

H₂ excitation diagram at position A



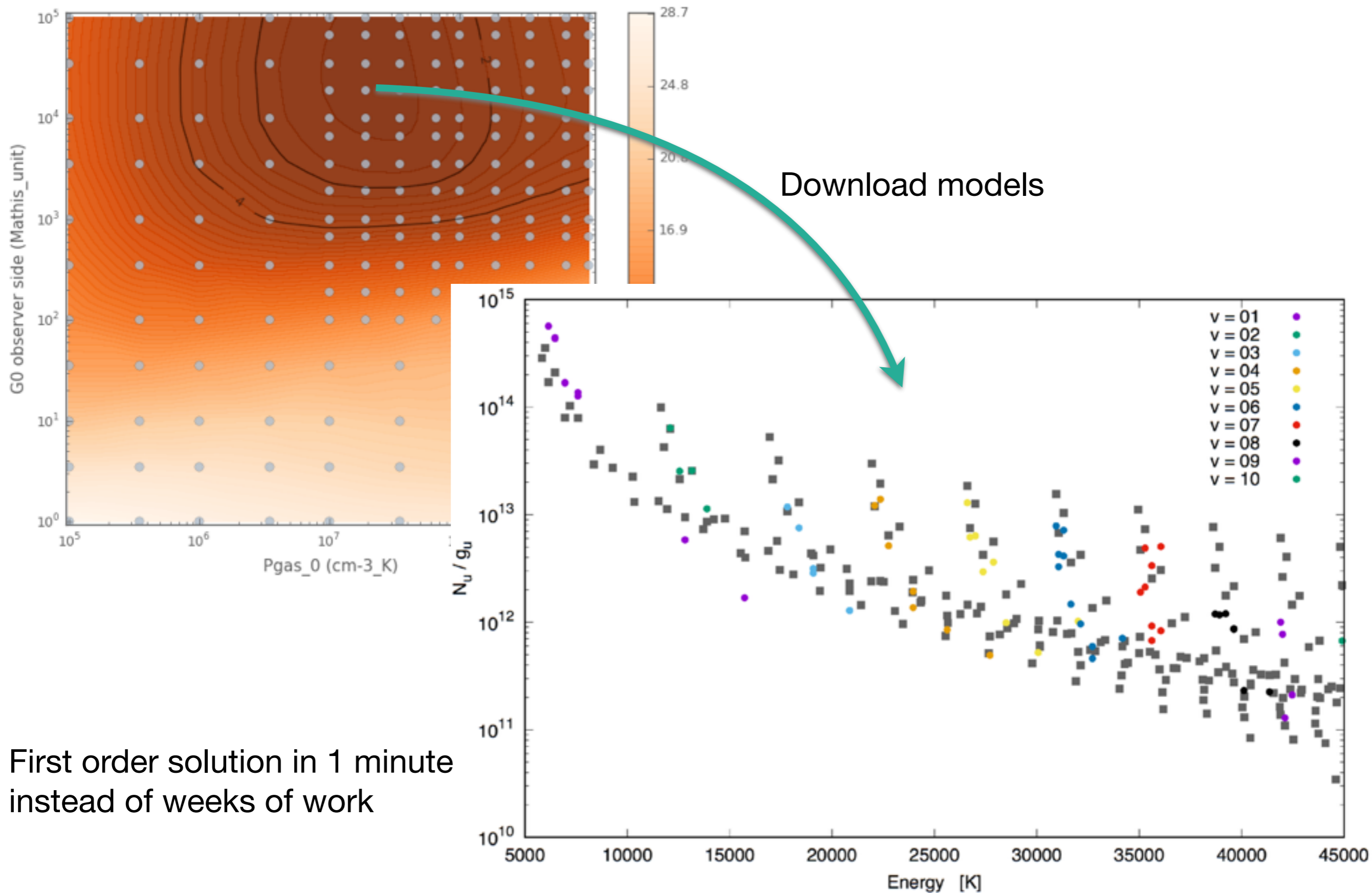
Interpretation of observations

Build the query for the 70 H₂ lines (140 constraints)

```
"I(H2 v=4,J=9->v=2,J=9 angle 60 deg)" < 5.408e-06
"I(H2 v=4,J=9->v=2,J=9 angle 60 deg)" > 2.912e-06
"I(H2 v=4,J=1->v=2,J=3 angle 60 deg)" < 2.665e-05
"I(H2 v=4,J=1->v=2,J=3 angle 60 deg)" > 1.435e-05
"I(H2 v=5,J=4->v=3,J=4 angle 60 deg)" < 9.659e-06
"I(H2 v=5,J=4->v=3,J=4 angle 60 deg)" > 5.201e-06
"I(H2 v=3,J=3->v=1,J=5 angle 60 deg)" < 1.2532e-05
"I(H2 v=3,J=3->v=1,J=5 angle 60 deg)" > 6.748e-06
"I(H2 v=5,J=5->v=3,J=5 angle 60 deg)" < 9.607e-06
"I(H2 v=5,J=5->v=3,J=5 angle 60 deg)" > 5.173e-06
"I(H2 v=6,J=2->v=4,J=0 angle 60 deg)" < 7.67e-06
"I(H2 v=6,J=2->v=4,J=0 angle 60 deg)" > 4.13e-06
"I(H2 v=10,J=1->v=7,J=3 angle 60 deg)" < 4.121e-06
"I(H2 v=10,J=1->v=7,J=3 angle 60 deg)" > 2.219e-06
"I(H2 v=5,J=0->v=3,J=2 angle 60 deg)" < 1.118e-05
"I(H2 v=5,J=0->v=3,J=2 angle 60 deg)" > 6.02e-06
"I(H2 v=5,J=7->v=3,J=7 angle 60 deg)" < 6.955e-06
"I(H2 v=5,J=7->v=3,J=7 angle 60 deg)" > 3.745e-06
"I(H2 v=4,J=2->v=2,J=4 angle 60 deg)" < 1.1531e-05
"I(H2 v=4,J=2->v=2,J=4 angle 60 deg)" > 6.209e-06
"I(H2 v=7,J=4->v=5,J=2 angle 60 deg)" < 5.109e-06
"I(H2 v=7,J=4->v=5,J=2 angle 60 deg)" > 2.751e-06
"I(H2 v=6,J=1->v=4,J=1 angle 60 deg)" < 1.846e-05
"I(H2 v=6,J=1->v=4,J=1 angle 60 deg)" > 9.94e-06
"I(H2 v=6,J=2->v=4,J=2 angle 60 deg)" < 1.599e-05
"I(H2 v=6,J=2->v=4,J=2 angle 60 deg)" > 8.61e-06
"I(H2 v=5,J=9->v=3,J=9 angle 60 deg)" < 1.729e-05
"I(H2 v=5,J=9->v=3,J=9 angle 60 deg)" > 9.31e-06
"I(H2 v=5,J=1->v=3,J=3 angle 60 deg)" < 2.379e-05
"I(H2 v=5,J=1->v=3,J=3 angle 60 deg)" > 1.281e-05
"I(H2 v=13,J=1->v=9,J=1 angle 60 deg)" < 9.334e-07
"I(H2 v=13,J=1->v=9,J=1 angle 60 deg)" > 5.026e-07
"I(H2 v=6,J=3->v=4,J=3 angle 60 deg)" < 1.287e-05
"I(H2 v=6,J=3->v=4,J=3 angle 60 deg)" > 6.93e-06
```

```
I(H2 v=7,J=3->v=5,J=1 angle 60 deg)" < 1.1531e-05
"I(H2 v=7,J=3->v=5,J=1 angle 60 deg)" > 6.209e-06
"I(H2 v=4,J=3->v=2,J=5 angle 60 deg)" < 1.2961e-05
"I(H2 v=4,J=3->v=2,J=5 angle 60 deg)" > 6.979e-06
"I(H2 v=6,J=4->v=4,J=4 angle 60 deg)" < 3.523e-06
"I(H2 v=6,J=4->v=4,J=4 angle 60 deg)" > 1.897e-06
"I(H2 v=6,J=5->v=4,J=5 angle 60 deg)" < 7.878e-06
"I(H2 v=6,J=5->v=4,J=5 angle 60 deg)" > 4.242e-06
"I(H2 v=3,J=5->v=1,J=7 angle 60 deg)" < 2.457e-06
"I(H2 v=3,J=5->v=1,J=7 angle 60 deg)" > 1.323e-06
"I(H2 v=11,J=1->v=8,J=1 angle 60 deg)" < 2.899e-06
"I(H2 v=11,J=1->v=8,J=1 angle 60 deg)" > 1.561e-06
"I(H2 v=7,J=2->v=5,J=0 angle 60 deg)" < 4.628e-06
"I(H2 v=7,J=2->v=5,J=0 angle 60 deg)" > 2.492e-06
"I(H2 v=8,J=7->v=6,J=5 angle 60 deg)" < 5.824e-06
"I(H2 v=8,J=7->v=6,J=5 angle 60 deg)" > 3.136e-06
"I(H2 v=5,J=2->v=3,J=4 angle 60 deg)" < 9.425e-06
"I(H2 v=5,J=2->v=3,J=4 angle 60 deg)" > 5.075e-06
"I(H2 v=6,J=0->v=4,J=2 angle 60 deg)" < 9.776e-06
"I(H2 v=6,J=0->v=4,J=2 angle 60 deg)" > 5.264e-06
"I(H2 v=6,J=7->v=4,J=7 angle 60 deg)" < 1.2532e-05
"I(H2 v=6,J=7->v=4,J=7 angle 60 deg)" > 6.748e-06
"I(H2 v=11,J=3->v=8,J=3 angle 60 deg)" < 1.924e-06
"I(H2 v=11,J=3->v=8,J=3 angle 60 deg)" > 1.036e-06
"I(H2 v=1,J=11->v=0,J=9 angle 60 deg)" < 4.407e-06
"I(H2 v=1,J=11->v=0,J=9 angle 60 deg)" > 2.373e-06
"I(H2 v=8,J=5->v=6,J=3 angle 60 deg)" < 5.122e-06
"I(H2 v=8,J=5->v=6,J=3 angle 60 deg)" > 2.758e-06
"I(H2 v=7,J=1->v=5,J=1 angle 60 deg)" < 1.2922e-05
"I(H2 v=7,J=1->v=5,J=1 angle 60 deg)" > 6.958e-06
"I(H2 v=8,J=4->v=6,J=2 angle 60 deg)" < 5.109e-06
"I(H2 v=8,J=4->v=6,J=2 angle 60 deg)" > 2.751e-06
"I(H2 v=6,J=1->v=4,J=3 angle 60 deg)" < 2.405e-05
...
...
...
...
```

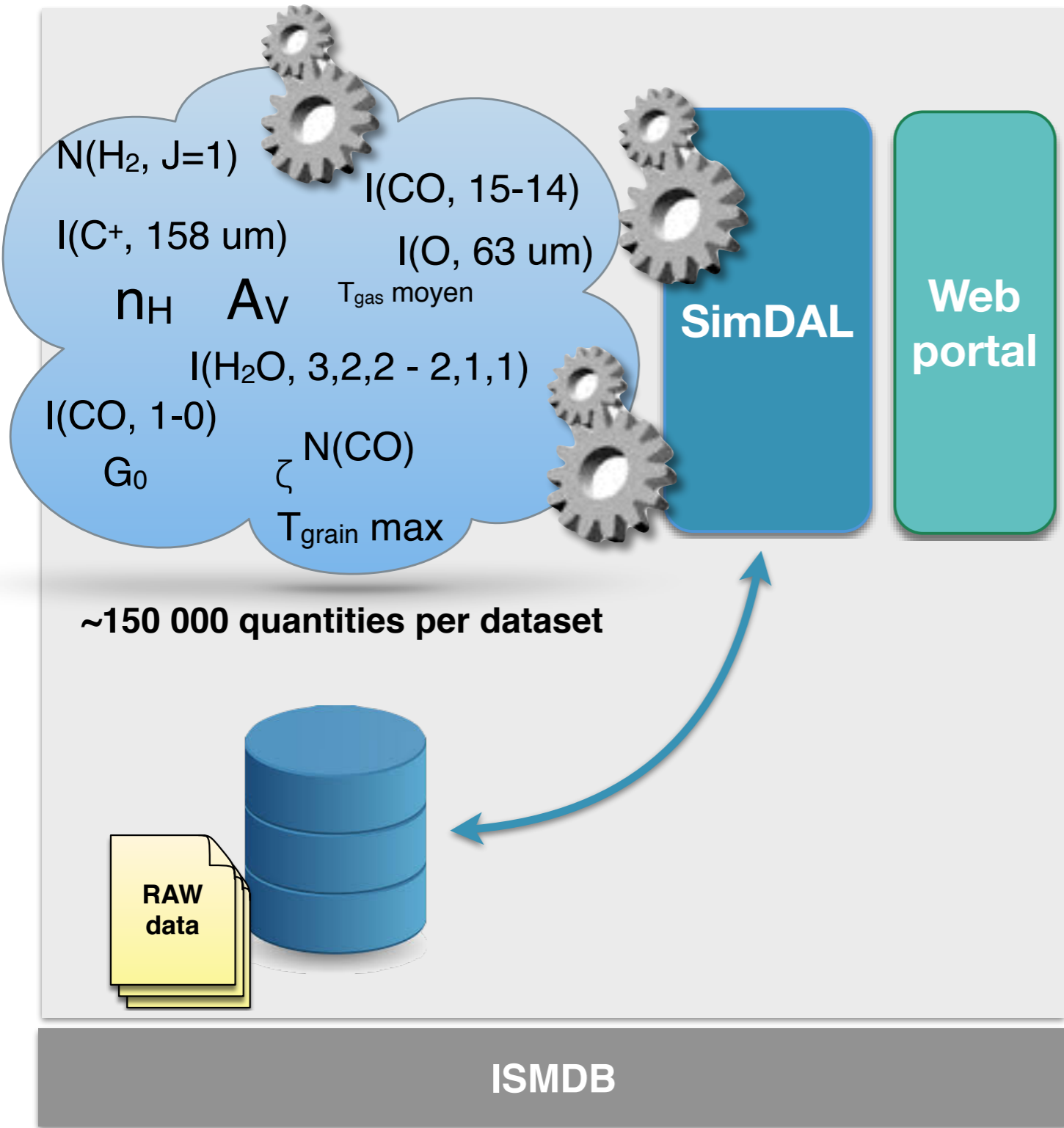

Interpretation of observations



First order solution in 1 minute instead of weeks of work

Semantics

Interaction between a human and the system



What are the models that can explain the $I(\text{CO } 10-9)$ I observed with Herschel ?



How the user can know the name of the available quantities ?

Semantics

ISMServices CODES ISMDB

ISM DataBase – Inverse Search service Beta

Grid of isobaric PDR 1.5.2 models
2016.12.03

1 – search among two parameters

x (cm-3_K) log scale

y (Mathis_unit) log scale

2 – fix all the other parameters

(mag)

3 – observational constraints

"I(CO v=0J=1->v=0J=0 angle 00 deg)" > 1.8E-7
"I(CO v=0J=1->v=0J=0 angle 00 deg)" < 2.4E-7
"I(H2 v=0J=2->v=0J=0 angle 60 deg)" > 1E-8
"I(H2 v=0J=2->v=0J=0 angle 60 deg)" < 5E-7

More than 150 000 queryable quantities in the database

- users do not know all the available list
- users do not know how these quantities are named

Example:

- H₂ line at 12 microns
- H₂ 0-0 S(2)
- H₂ v=0, J=4 -> v=0, J=2

3 – observational constraints



Semantics interpreter

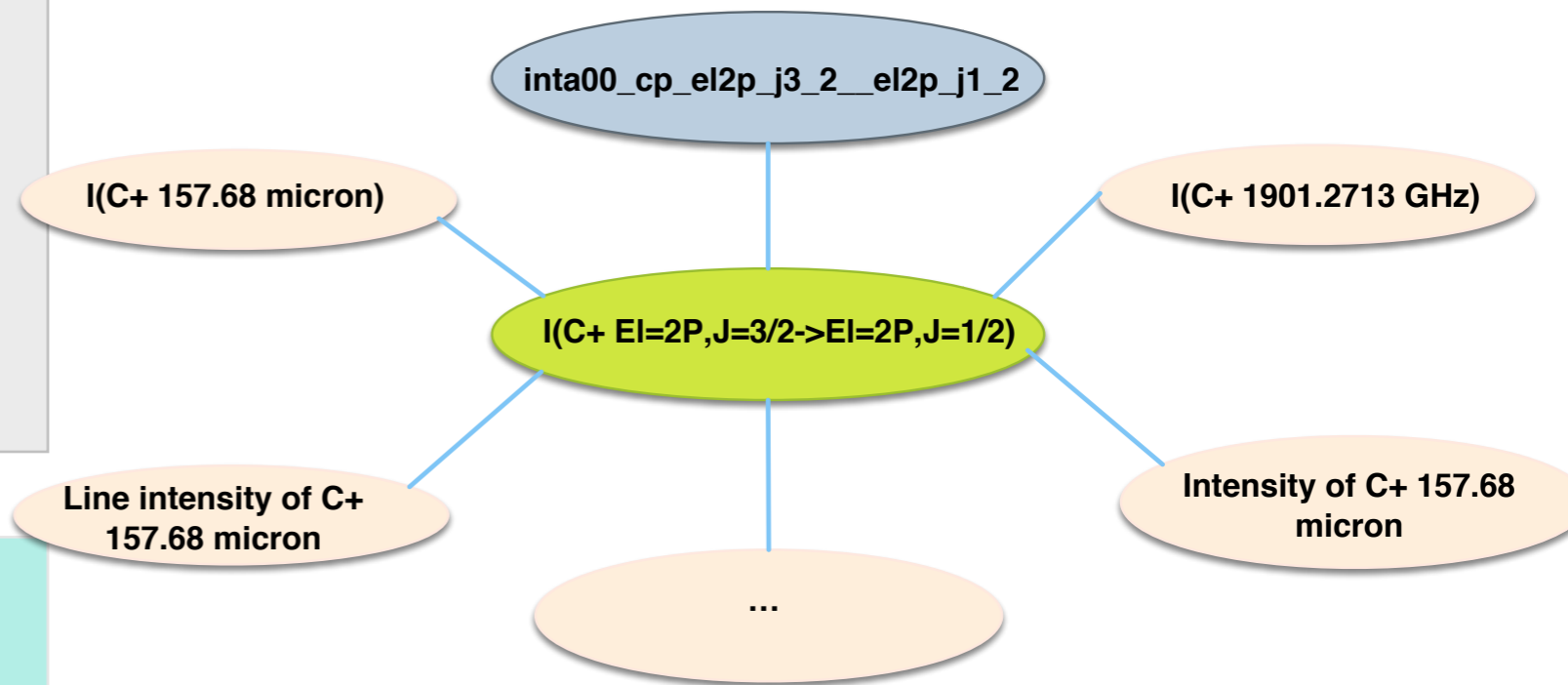
Semantics : SKOS vocabularies

Each metadata is tagged by:

- ID
- name
- unit
- utype
- description
- **label (UCD / SKOS)**
- ...

Simulation
DataModel

Example of the 157.7 micron C+ line intensity



SKOS vocabulary

For each quantity several synonyms
(name, units, ...)

~ 300 000 terms for the PDR code

- ID:** inta00_cp_el2p_j3_2__el2p_j1_2
- PREF:** I(C+ El=2P,J=3/2->El=2P,J=1/2)
- ALT:** I(C+ El=2P,J=3/2->El=2P,J=1/2) face on
- ALT:** I(C+ 157.68 micron) face on
- ALT:** Intensity of C+ 157.68 micron face on
- ALT:** Line intensity of C+ 157.68 micron face on
- ALT:** I(C+ 1901.2713 GHz) face on
- ALT:** Intensity of C+ 1901.2713 GHz face on
- ALT:** Line intensity of C+ 1901.2713 GHz face on
- ...

3 - observational constraints

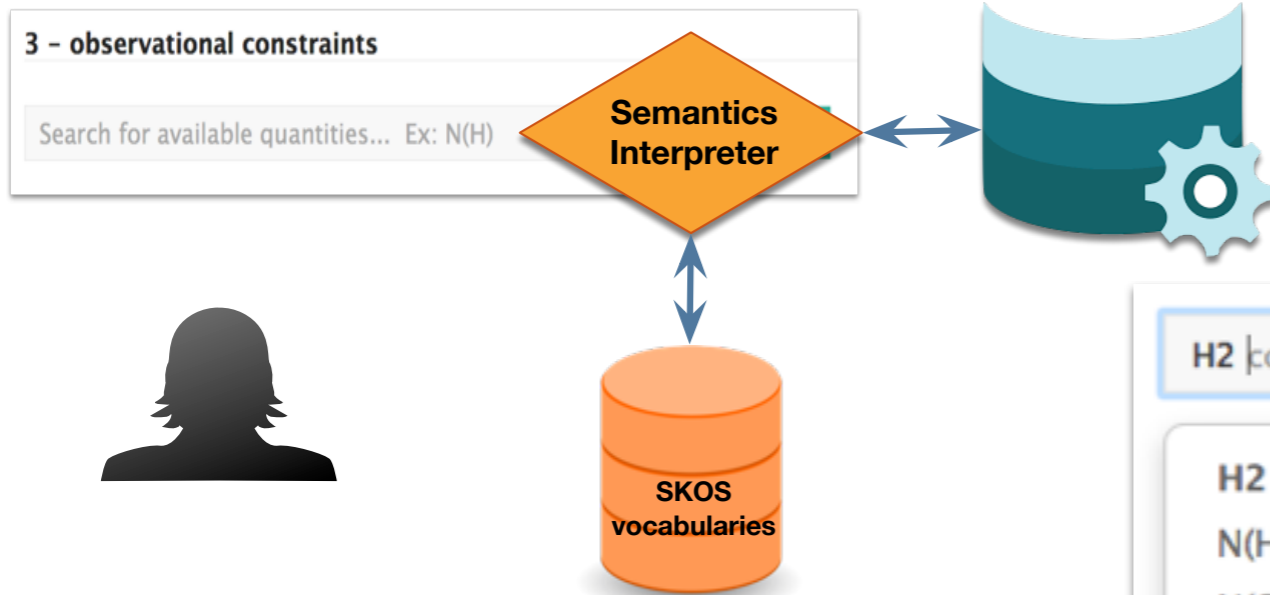
Search for available quantities... Ex: N(H)

Semantics
Interpreter



SKOS
vocabularies

Semantics : SKOS vocabularies



Semantics Interpreter

Semantics

SKOS: PREF + ALT
→ synonyms

+

Ranking system

(learn from users)

The screenshot shows the interface of the Semantics Interpreter. It displays search results for two queries. The first query is 'H2 column density', and the second is 'I(H2 0-0 S(0)) angle 00 degrees'. Each query has a 'Use' button on the right. The results are listed in a scrollable area.

H2 column density Use

- H2 column density
- N(H2)
- N(C2H2)
- N(c-C3H2)
- N(C_13CH2)
- N(C_13CH2+)
- C2H2 column density
- Column density of H2

I(H2 0-0 S(0)) angle 00 degrees Use

- I(H2 0-0 S(0)) angle 00 degrees
- I(H2 10-10 S(0)) angle 00 degrees
- I(H2 9.6645 micrometres) angle 00 degrees
- I(H2 28.2196 micrometres) angle 00 degrees
- I(H2 156.4883 micrometres) angle 00 degrees
- I(H2 v=0,J=2->v=0,J=0) angle 00 degrees
- I(H2O 6.1140 cm⁻¹) angle 00 degrees
- I(H2O J=1,ka=1,kc=1->J=0,ka=0,kc=0) angle 00 degrees

The screenshot shows the ISM Services website. At the top, there are navigation links: ISM Services, CODES (access to codes), ISMDB (simulations database), TECHNOLOGIES (standards), PARTNERS (credits), and REGISTRATION. Below this is a large image of a nebula. Underneath the image are four buttons: PDR Code (The Meudon PDR code), DustEM (Dust Emission), Shock (Paris-Durham Shock model), and Starformat (MHD simulations data base). There are also 'Help' and 'Contact' buttons. The main section is titled 'ISM DataBase - Inverse Search service Beta' with a 'Beta' badge. Below this, it says 'Grid of isobaric PDR 1.5.2 models' and '2016.12.03'. The interface is divided into three steps: 1 - search among two parameters (with input fields for 'Pgas_0' and 'G0 observer side'), 2 - fix all the other parameters (with an input field for 'AVmax'), and 3 - observational constraints (with a search bar and a 'Use' button). A yellow box contains instructions: 'Type quantities to plot in the input below, with optional constraints. (click Search to view the result of the example query below)'. Below this, there is a text area with example queries: '"I(CO v=0,J=1->v=0,J=0 angle 00 deg)" > 2.4e-9', '"I(CO v=0,J=1->v=0,J=0 angle 00 deg)" < 7.2e-8', and '"NH2"'. A 'Search' button is at the bottom.

Status

- Available at <http://ism.obspm.fr>
- Grids of PDR models

Starts to be used:

- Individual teams: ALMA, IRAM, NOEMA, ...
- Projects as SPICA, GUSTO (NASA/CNES)
- JWST ERS

Plans - short term

- Grids of shocks models
- Operations on quantities

Plans - medium term

- Quickviews on models
- Interpretation of images (pixels)

Plans - long term

- Search in N-dimension space
- Machine Learning technics
- Suggestions of observations

