

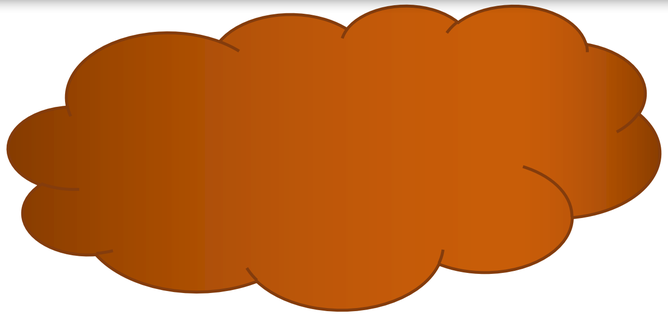
Estimation of the physical conditions in PDRs from IGRINS ro-vibrational H_2 observations

LUX Days

Aurélien PILUSO
MIS/Plasma team

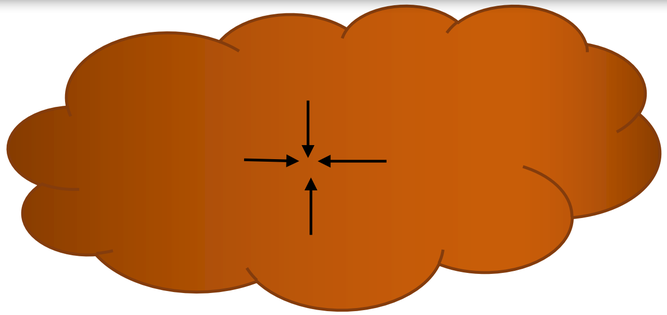
Context : Star formation

Interstellar medium : Molecular gas reservoir for stellar formation



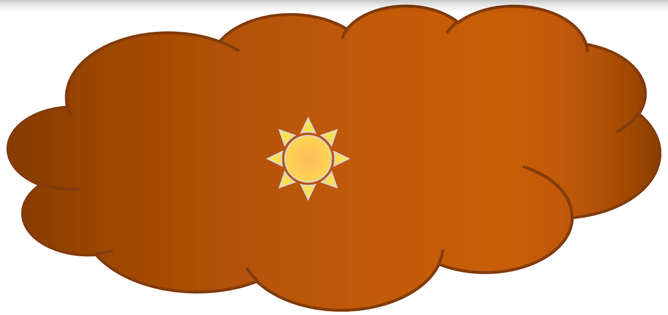
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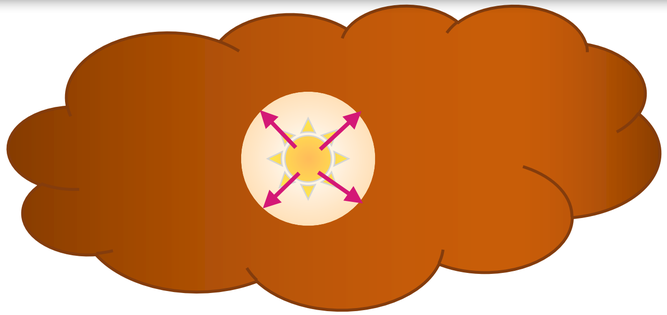
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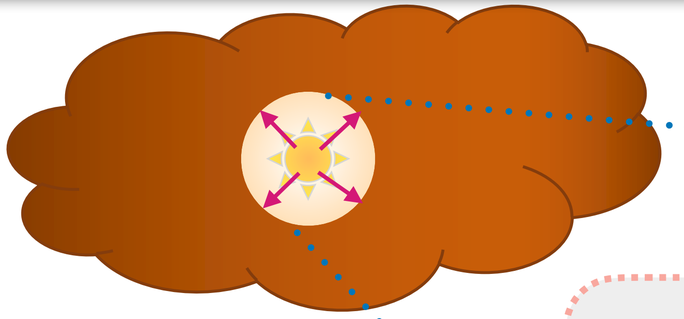
Feedback from forming stars :

✳Mechanical (stellar winds, supernovae)

✳Radiative (UV illumination)

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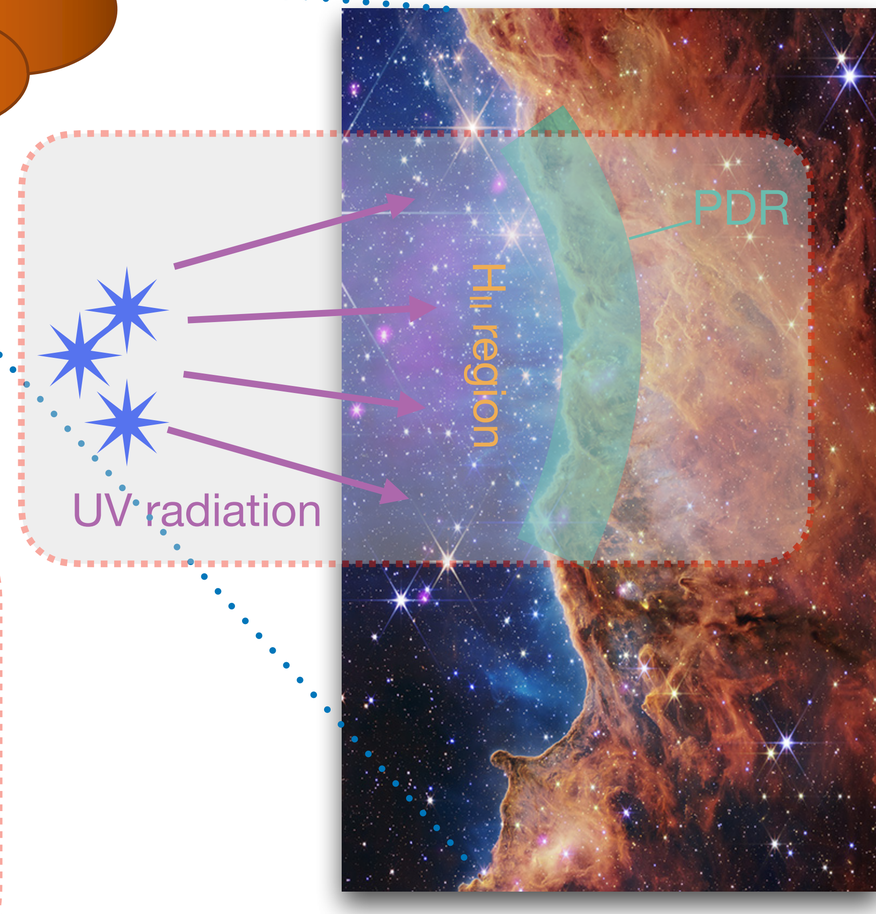
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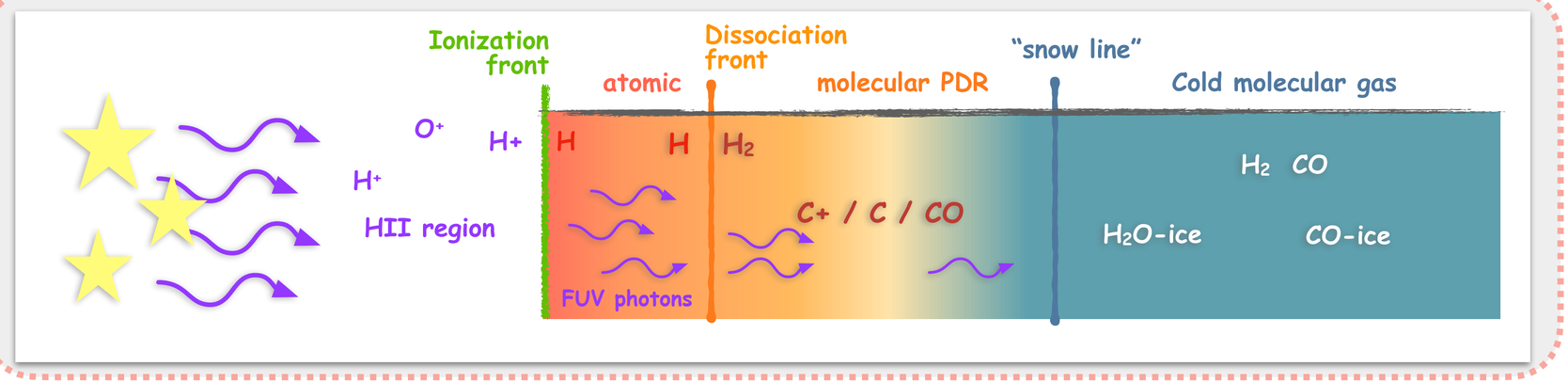
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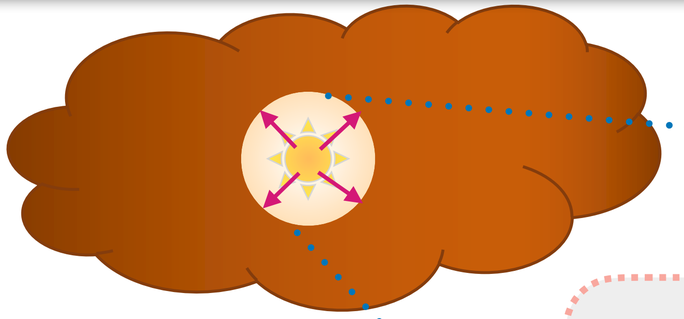
PDR: PhotoDissociation Region

- Radiative feedback of massive stars via UV on the molecular cloud
- UV heats and photodissociates molecules: IR-rich and millimetric emission spectrum
- Excited molecules = Tracker of radiative feedback



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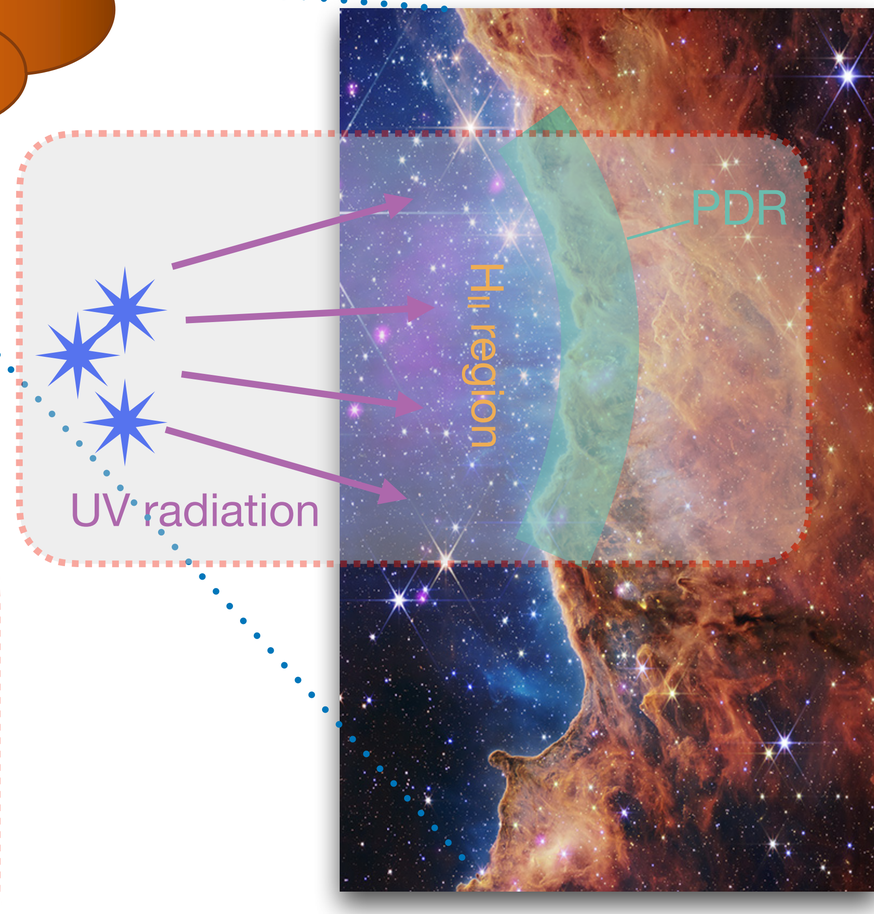
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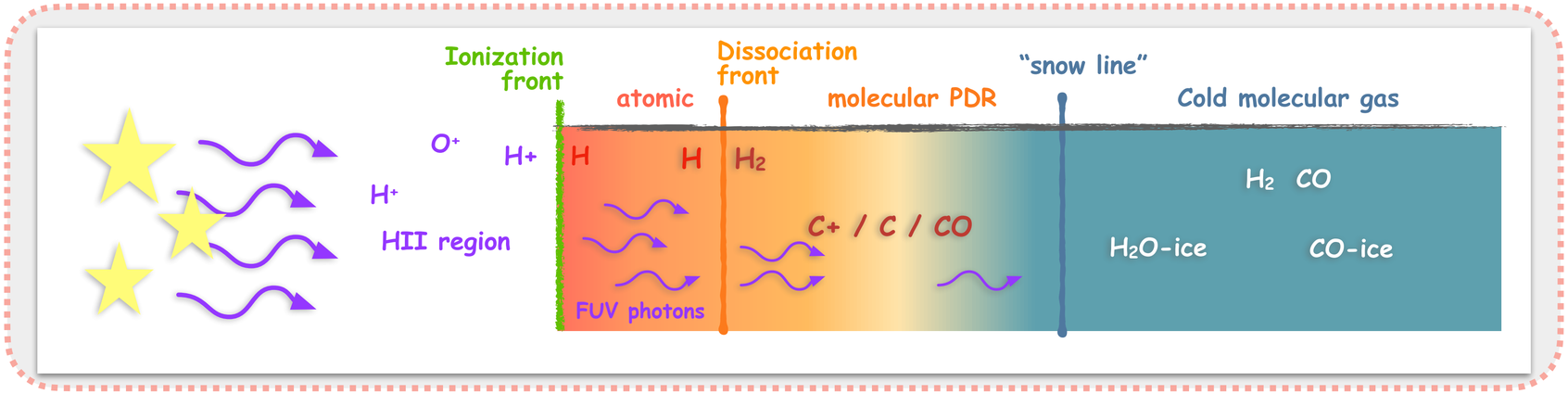
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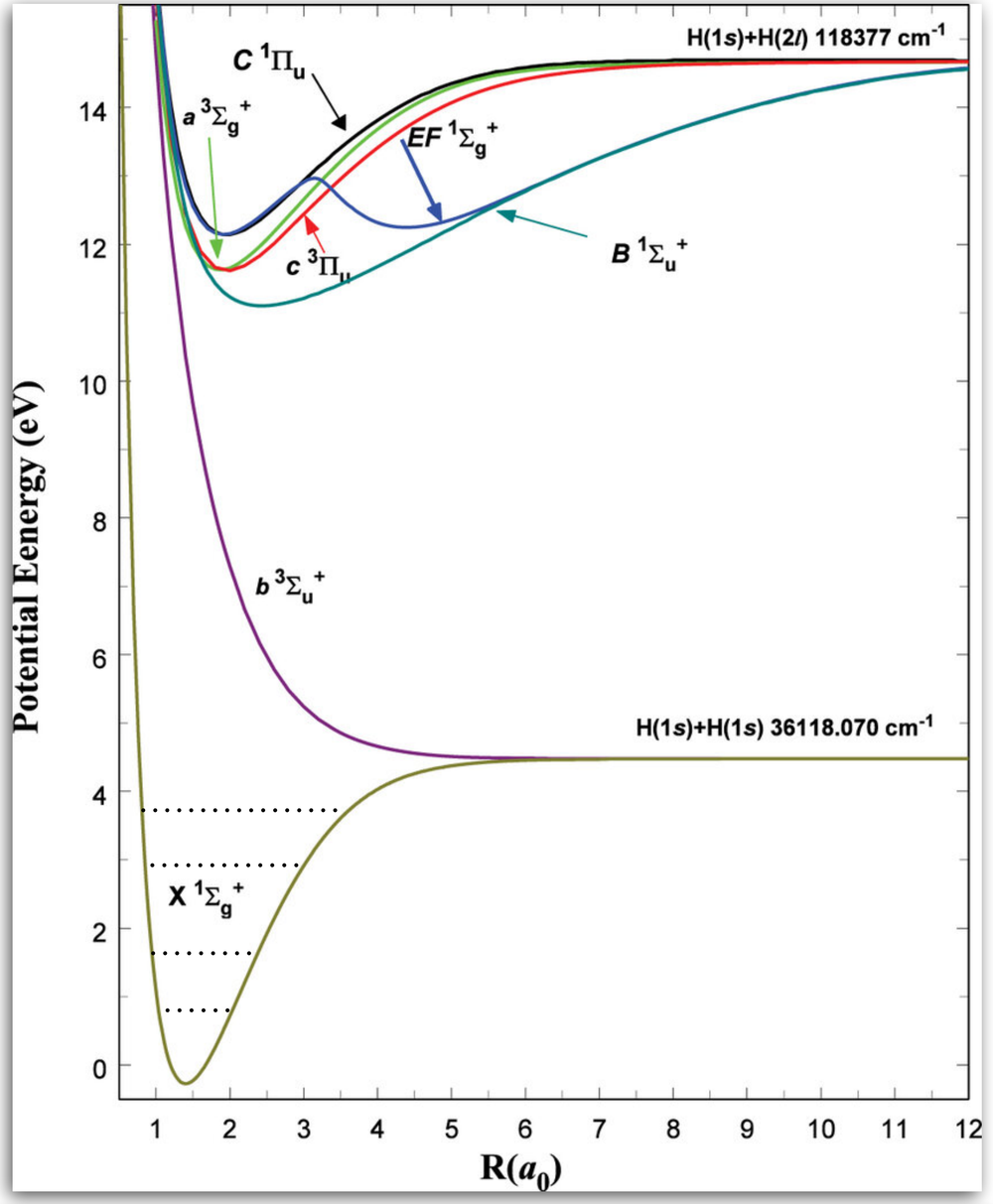


What is the impact of radiative feedback on star formation ?

Observable

H_2 :

- Most abundant molecule in the interstellar medium
- Responsible for a major part of physical and chemical processes occurring in PDRs
- Tracker for UV impact on molecular clouds

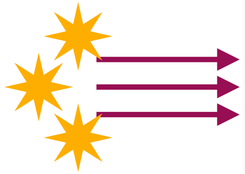


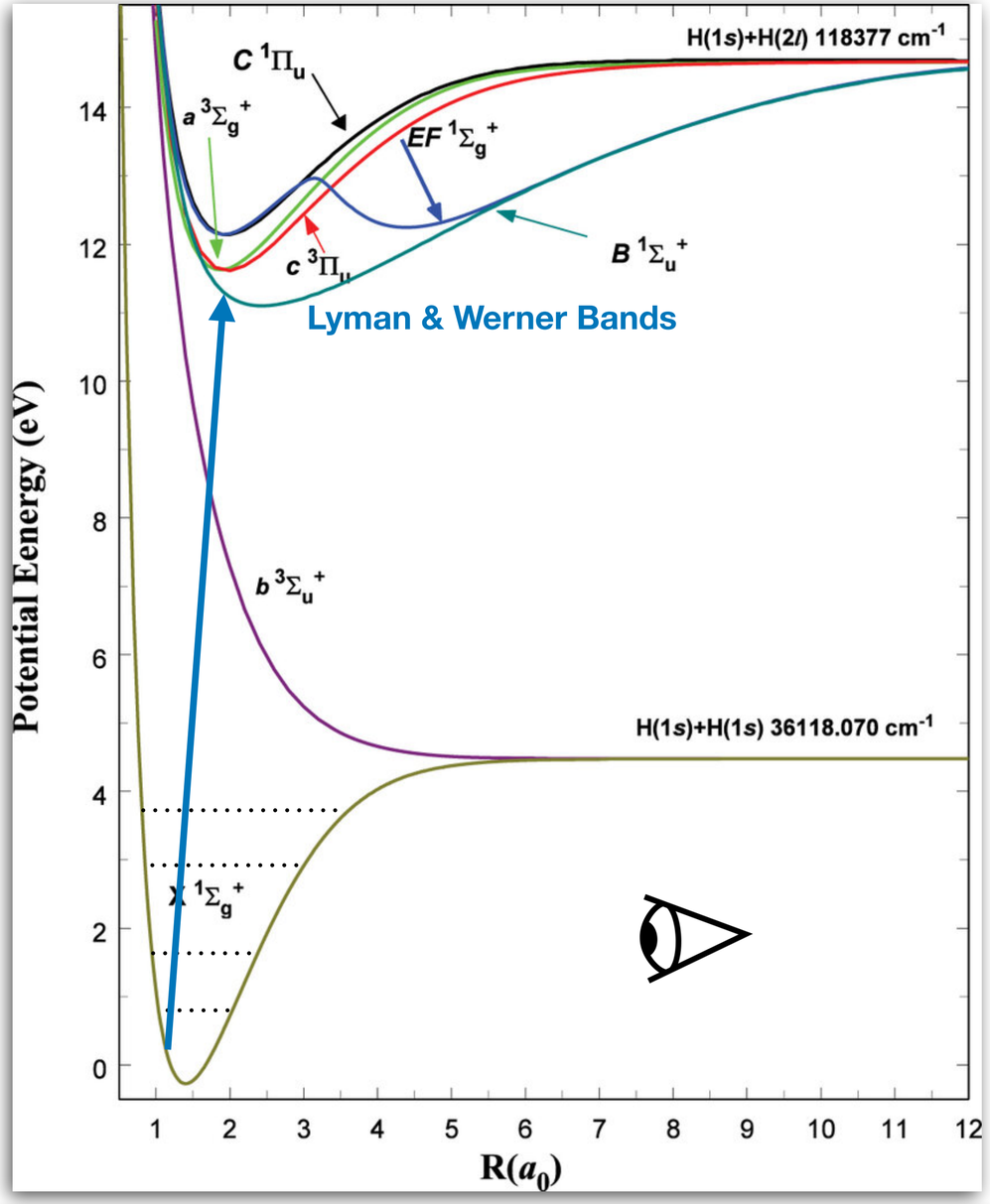
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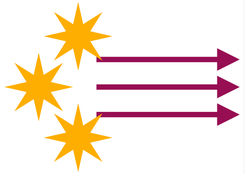


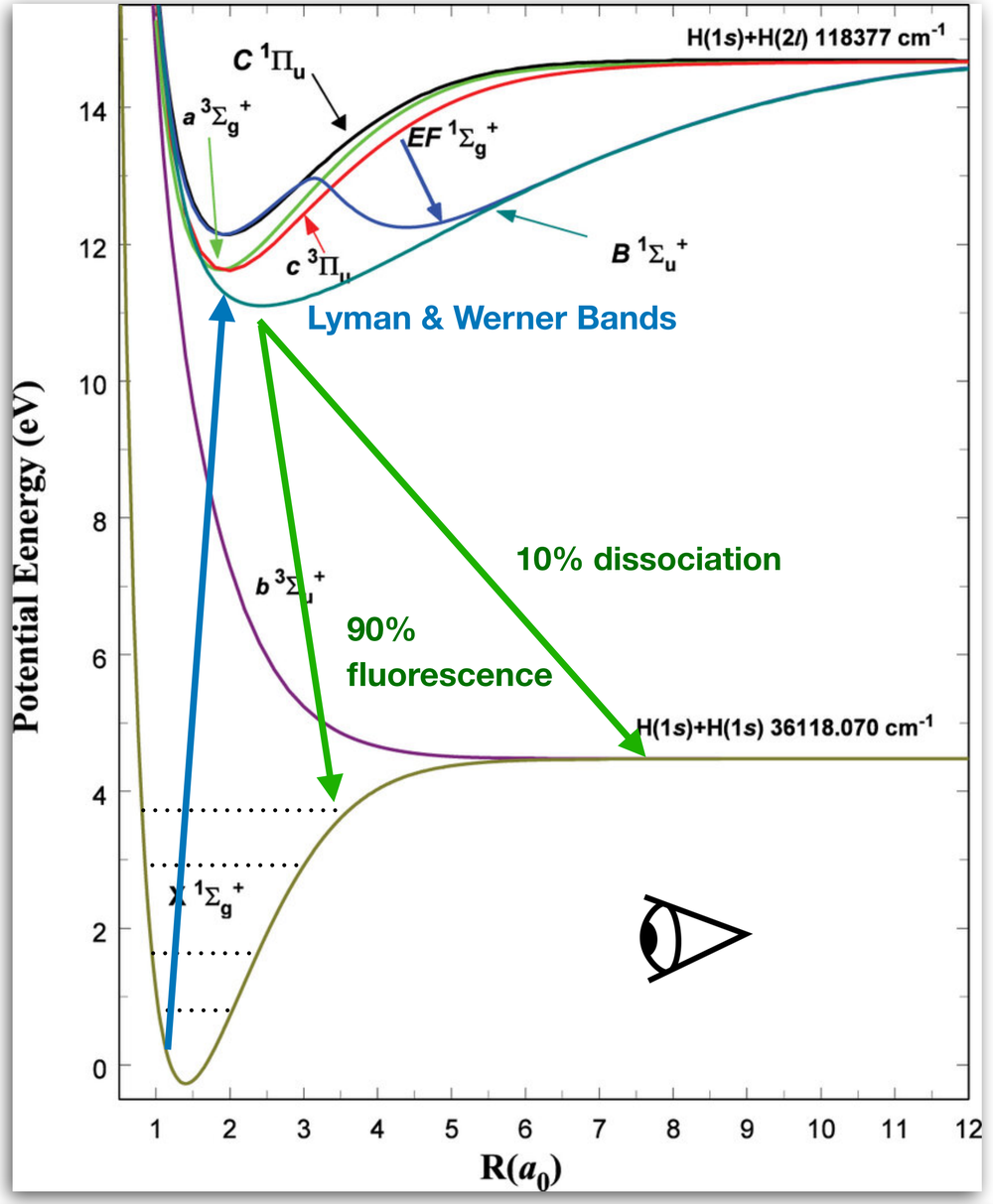
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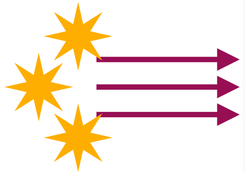


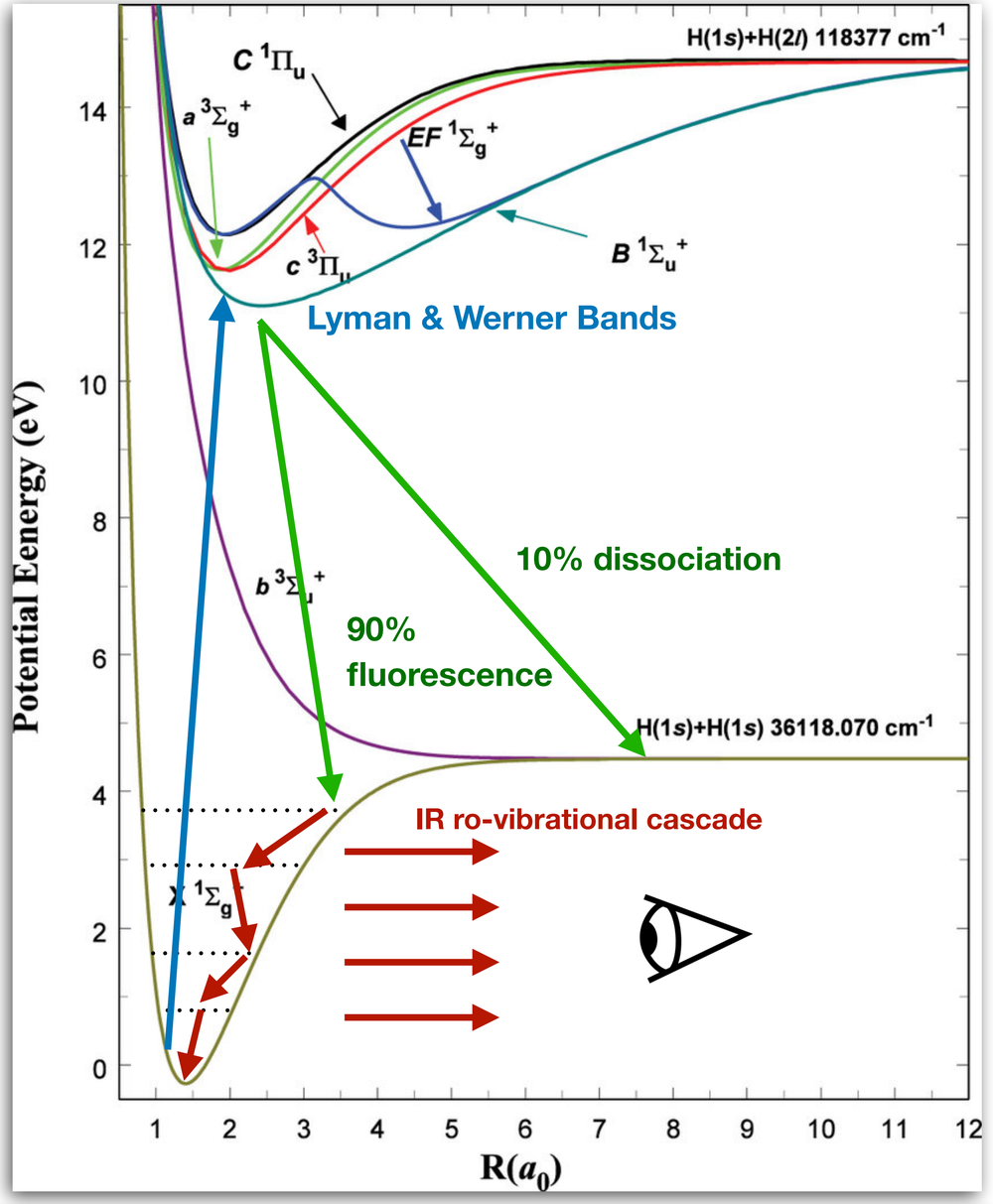
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3. ***Rovibrational cascade (IR emission)***





2. Instrument

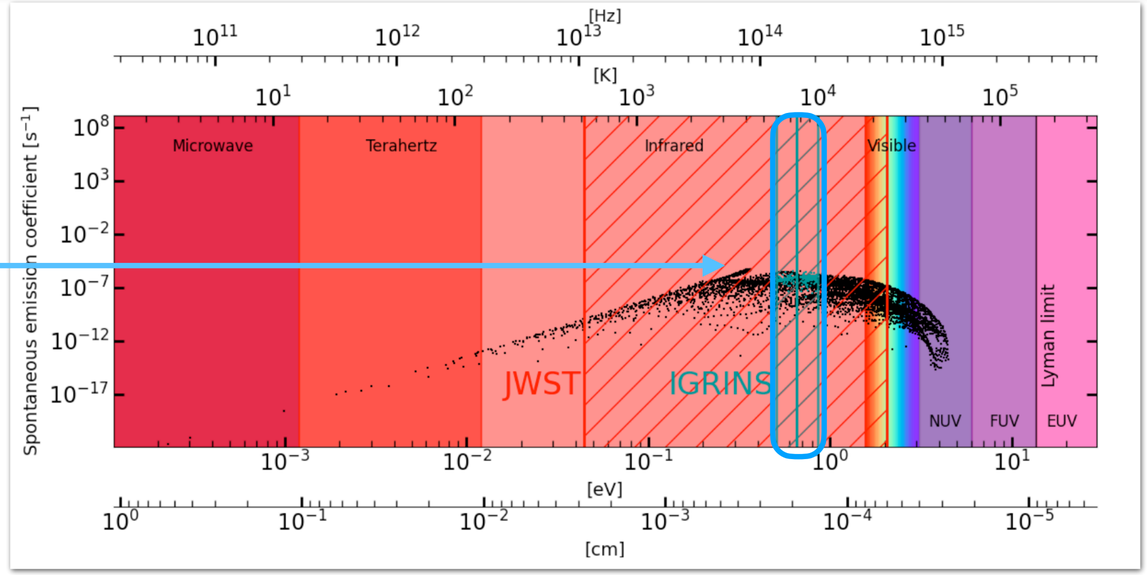
Instrument : ***IGRINS*** : **I**mmersion **GR**ating **IN**frared **S**pectrometer

- Covering H and K band (**1.45 and 2.45 μm**)
- Spectral resolution of **45,000**

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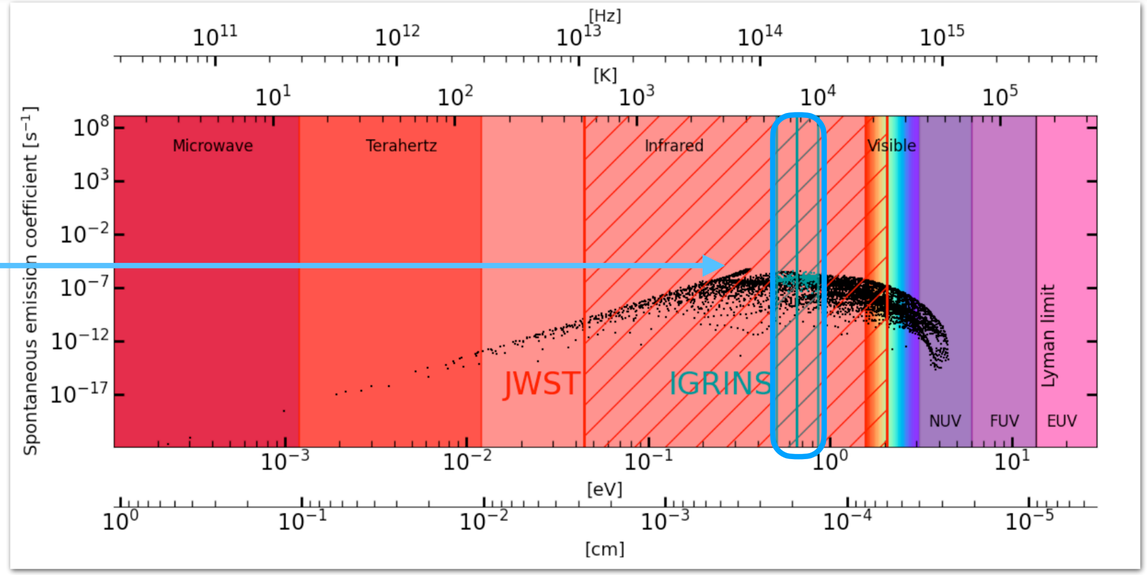




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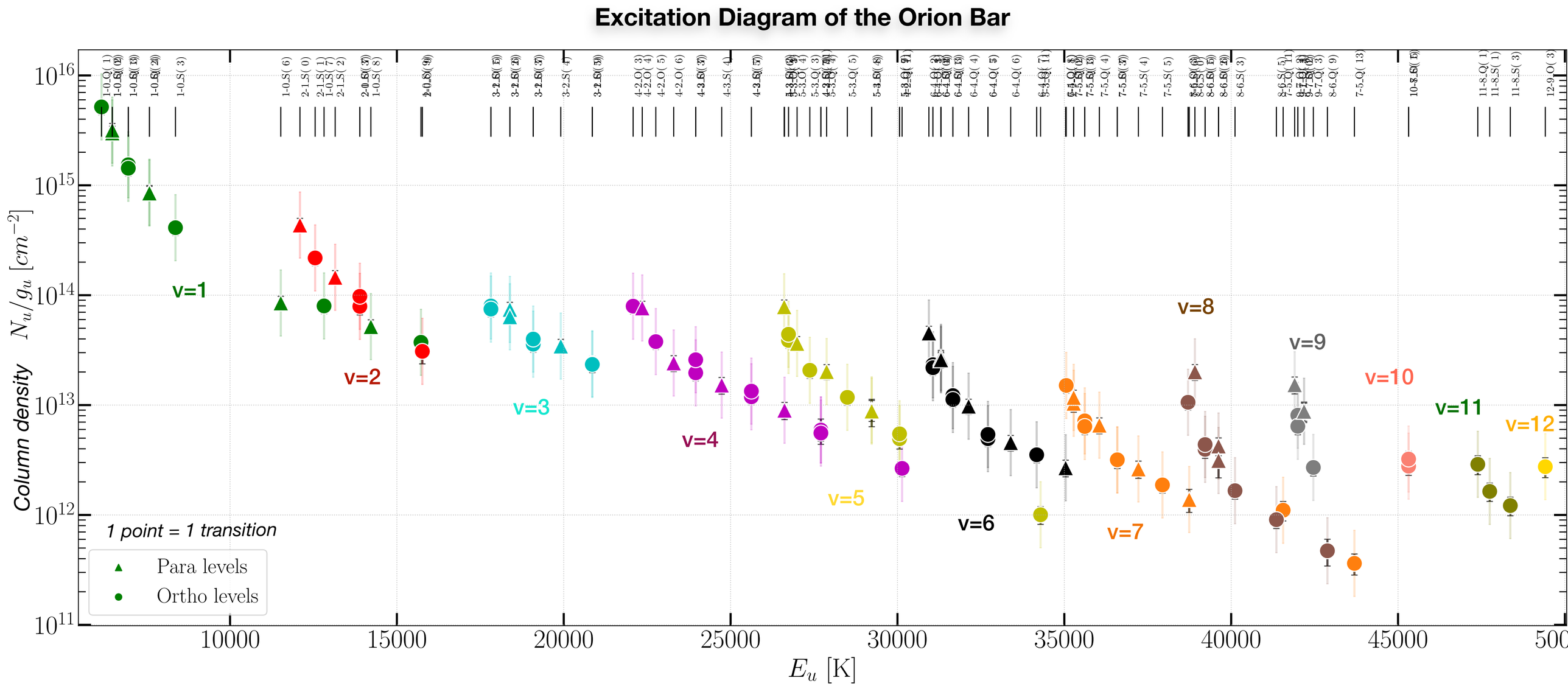


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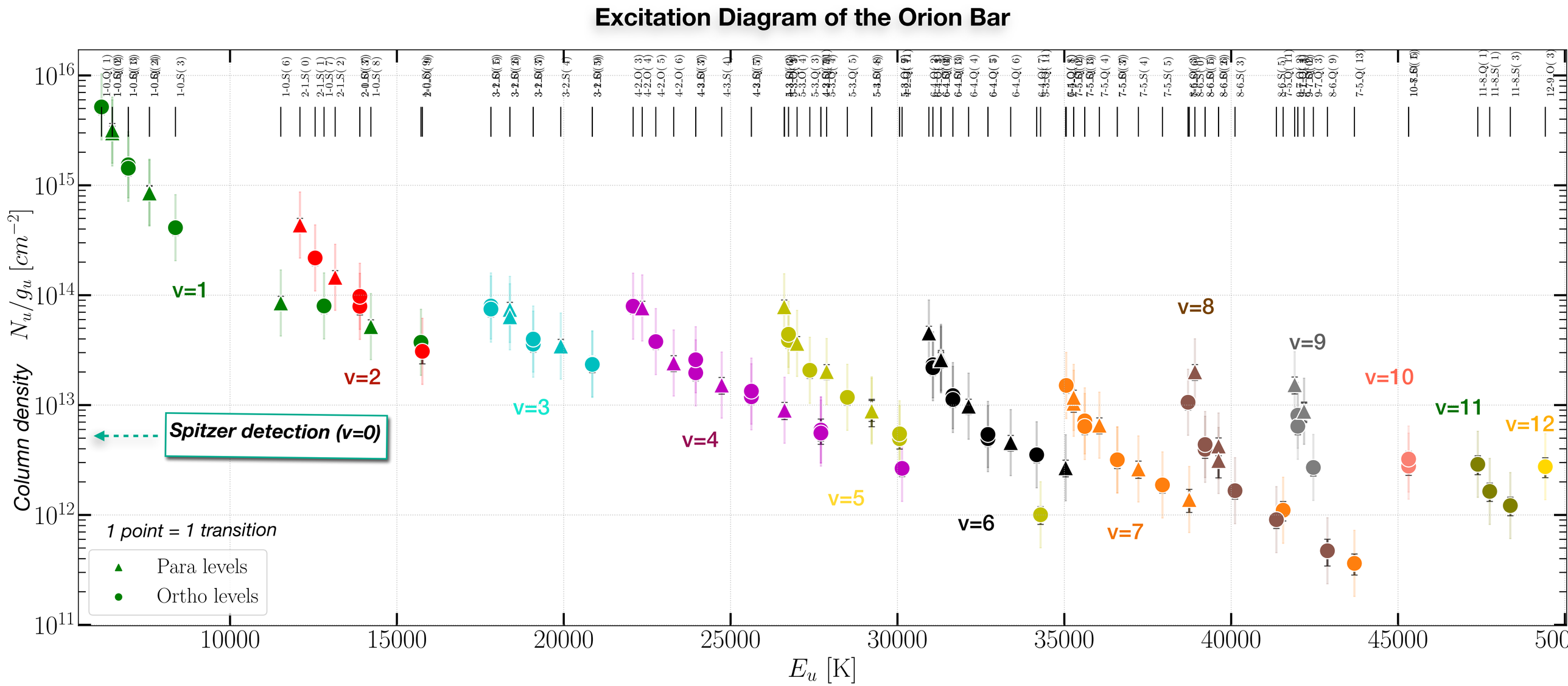
- **5 PDRs :** *Horsehead Nebula, Orion Bar, NGC2023, S140, IC63*
- **>120 ro-vibrational lines of H_2 per PDR**



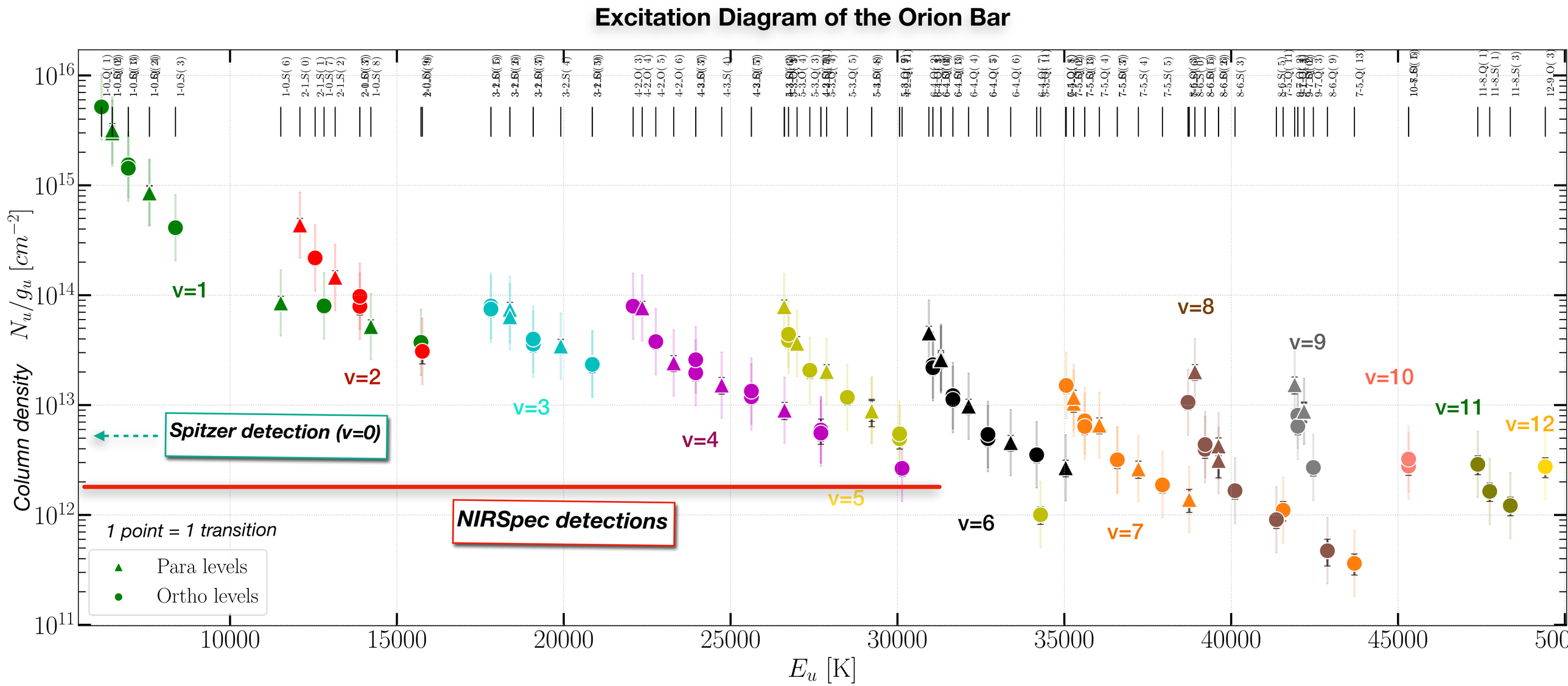
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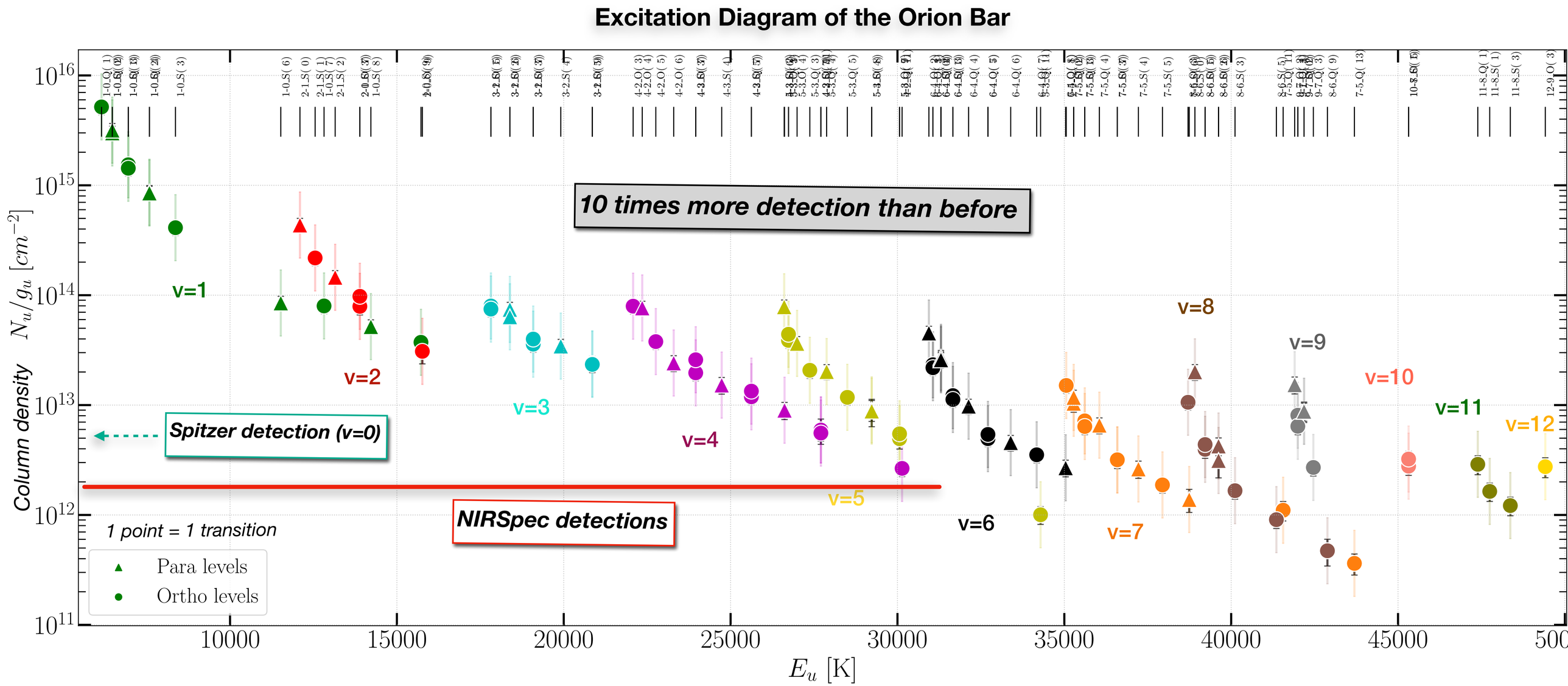
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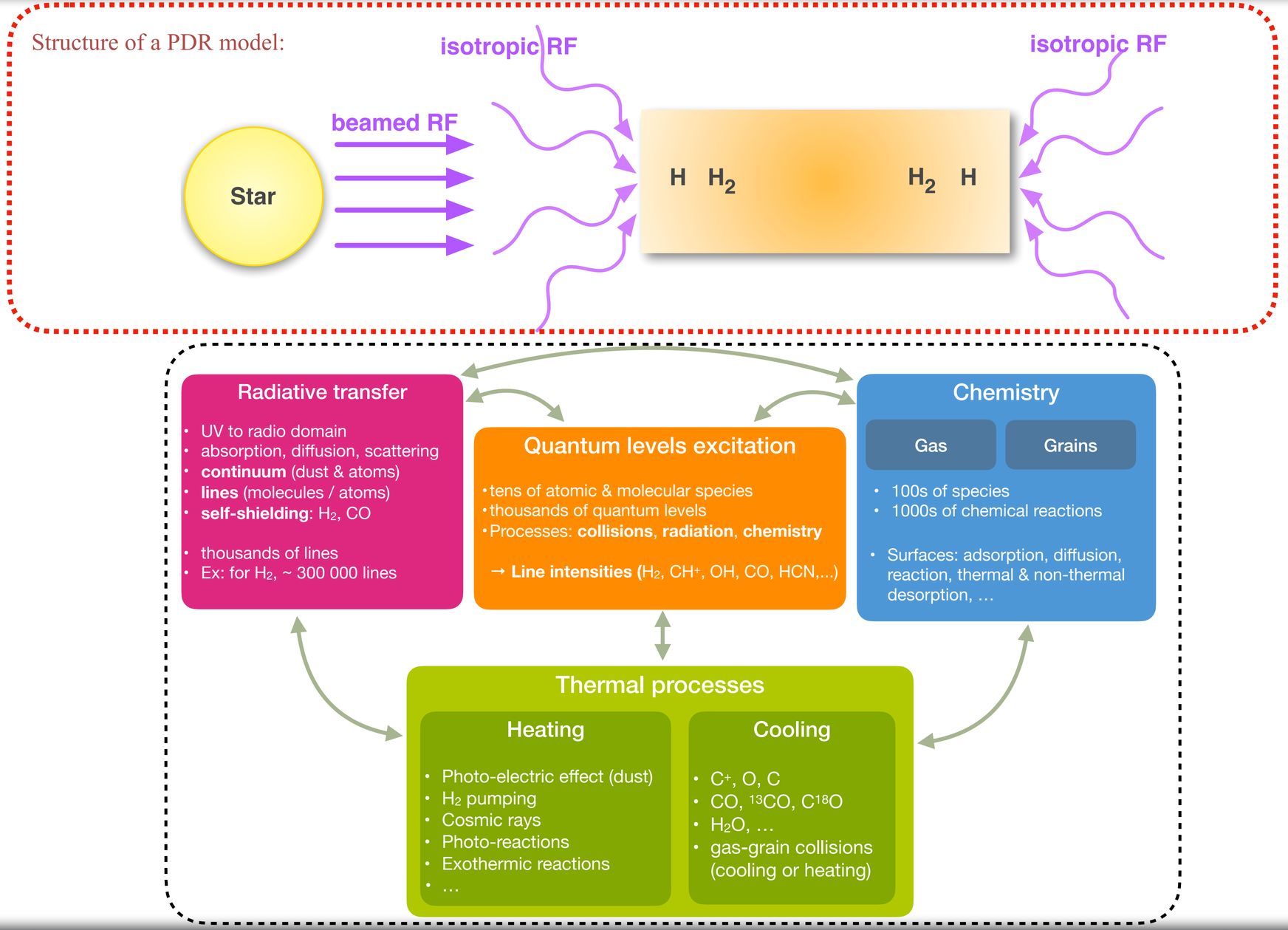
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3. Meudon PDR Code

Meudon PDR Code :

- State of the art
- 1D model
- Stationary model
- Isobaric/isocore model



3. Meudon PDR Code

Varying parameters :

- **Thermal pressure** P_{th} between $5 \times 10^5 - 5 \times 10^9\ Kcm^{-3}$
- **UV field intensity** normalized in Habing G_0 between $10 - 10^5$

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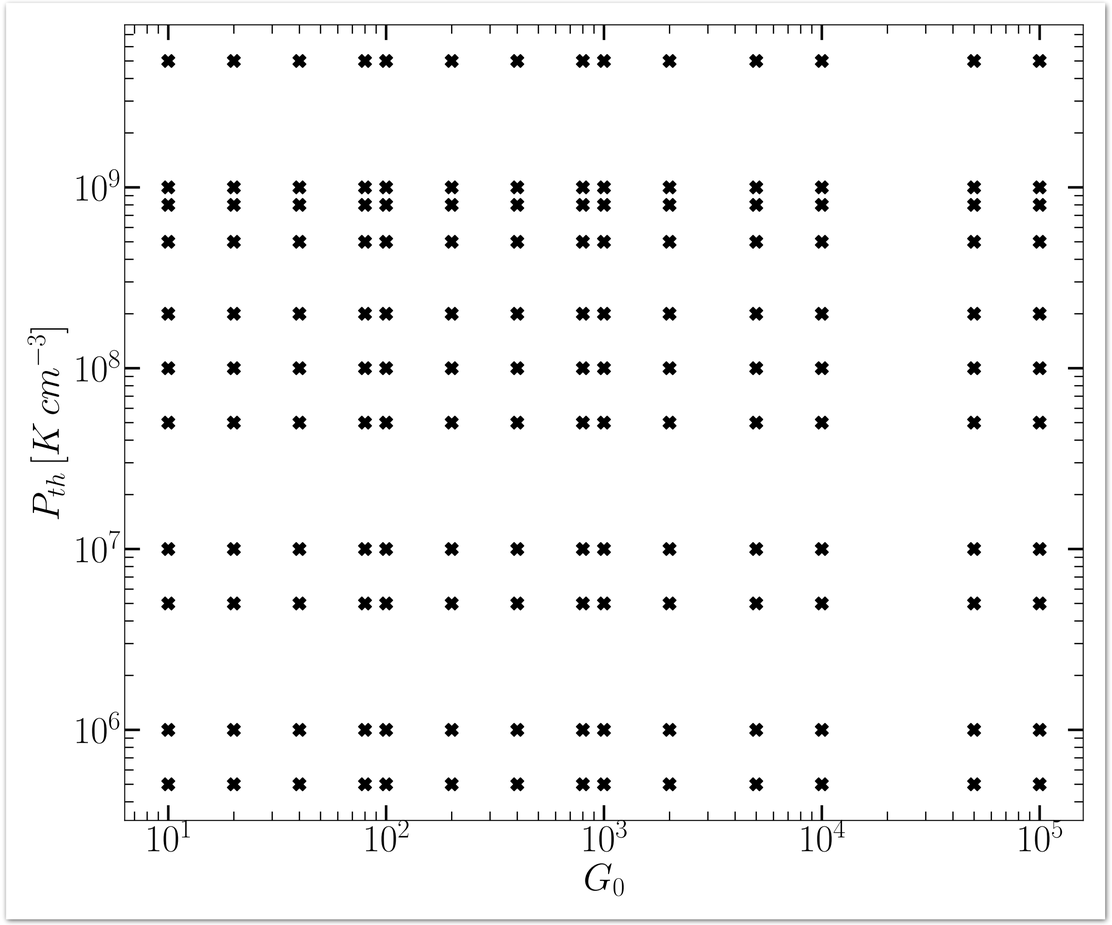
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- Creating a grid of 200 models

Grid of models for this study



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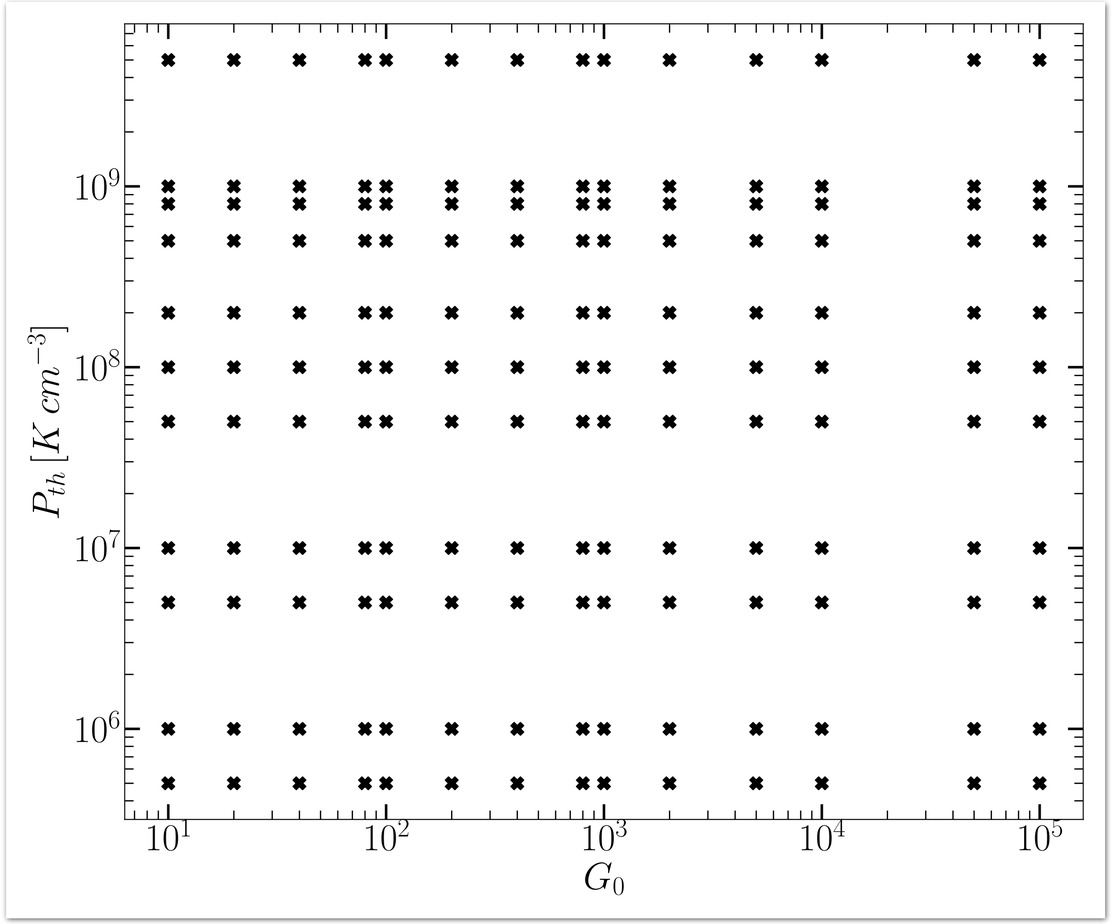
Approaches to quantify the relevance of the model

- χ^2 minimisation $\chi^2 = \frac{1}{N} \sum \frac{(I_{obs} - \Omega \times I_{mod}(P_{th}, G_0))^2}{\sigma^2}$
- Bayesian inversion and posterior exploration (*beetroots*)

Interpolation within model grid :

- Nonlinear interpolation (*log RBF*)
- Neural Network learning of the grid : *nnbma*

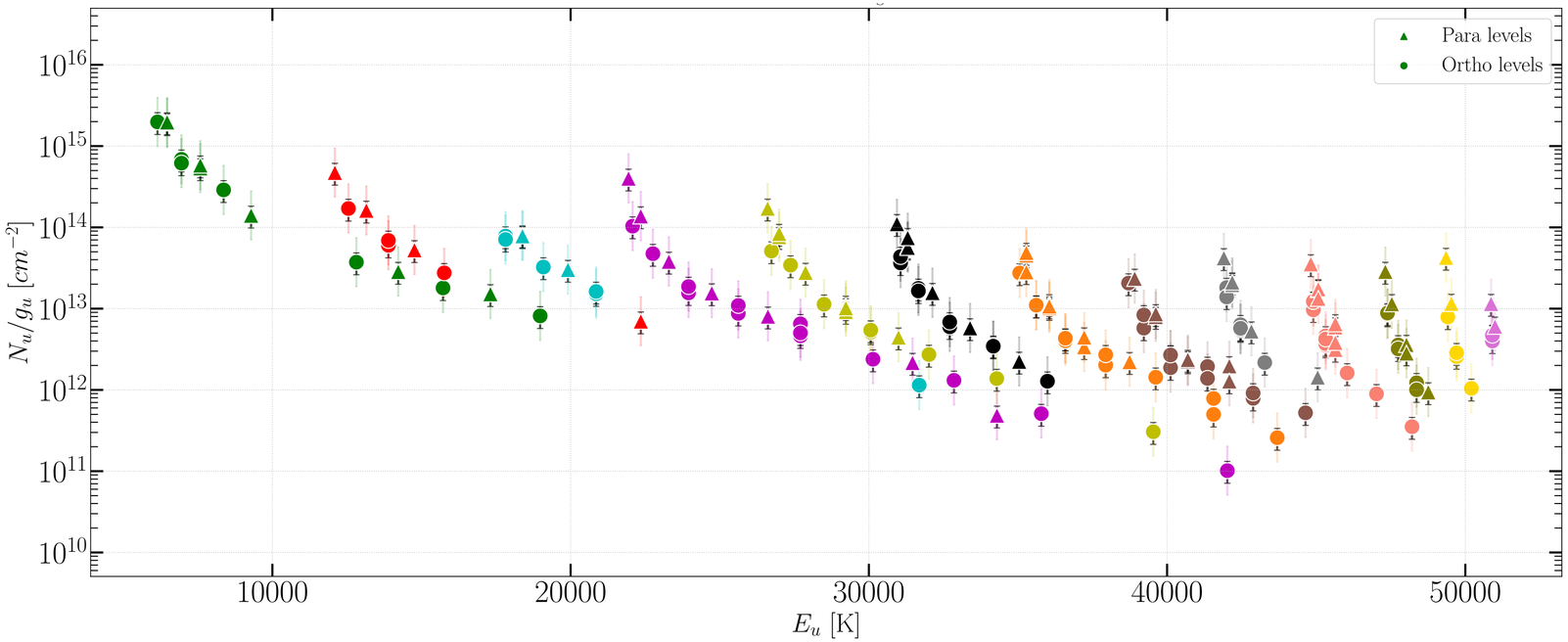
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4. Results

Moderate PDRs : NGC 2023 Case

Similar results for Horsehead Nebula, S140, IC63

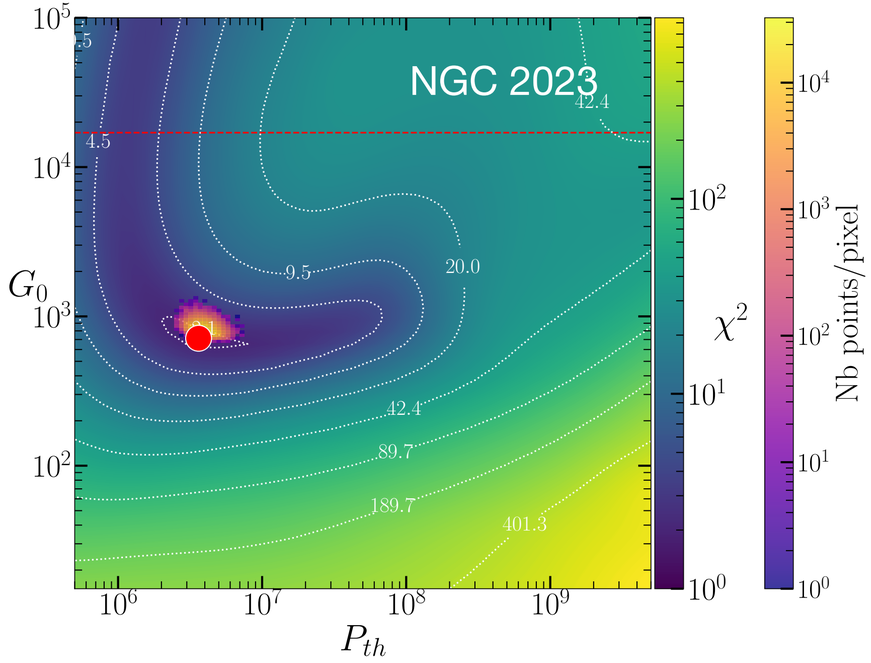


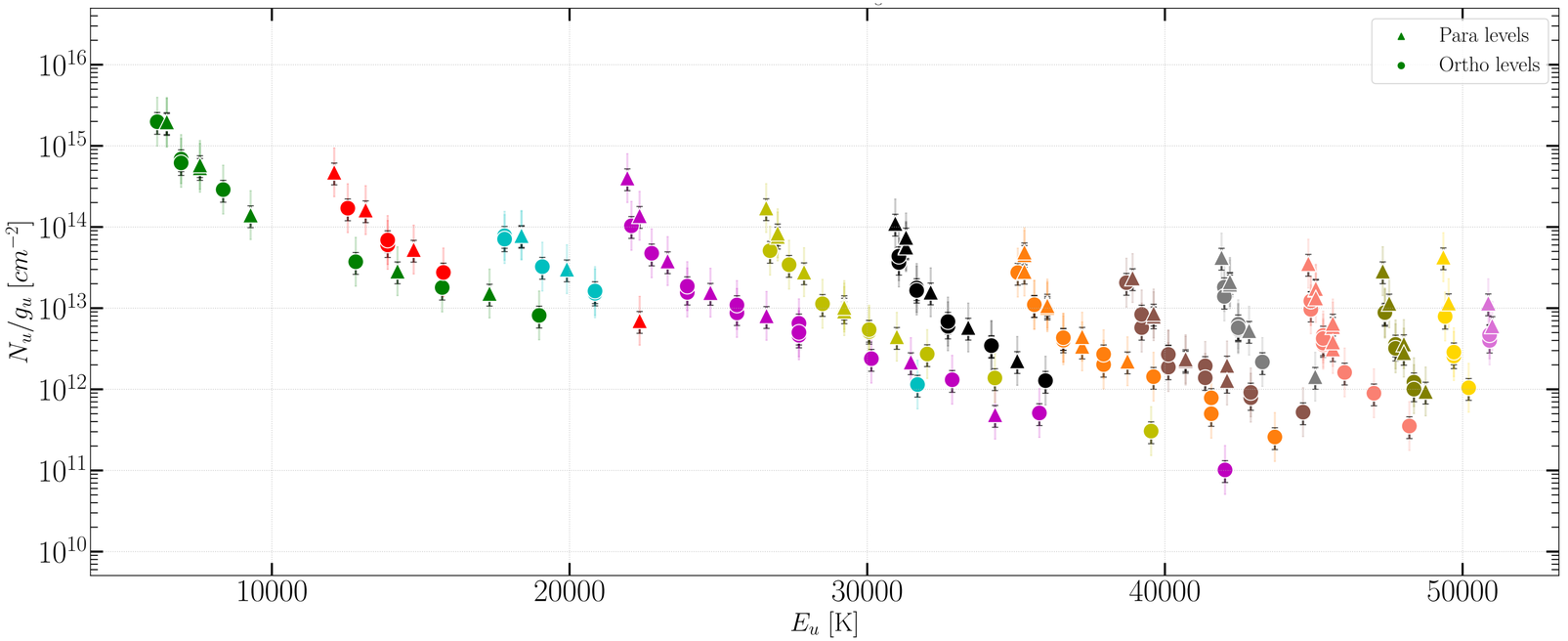
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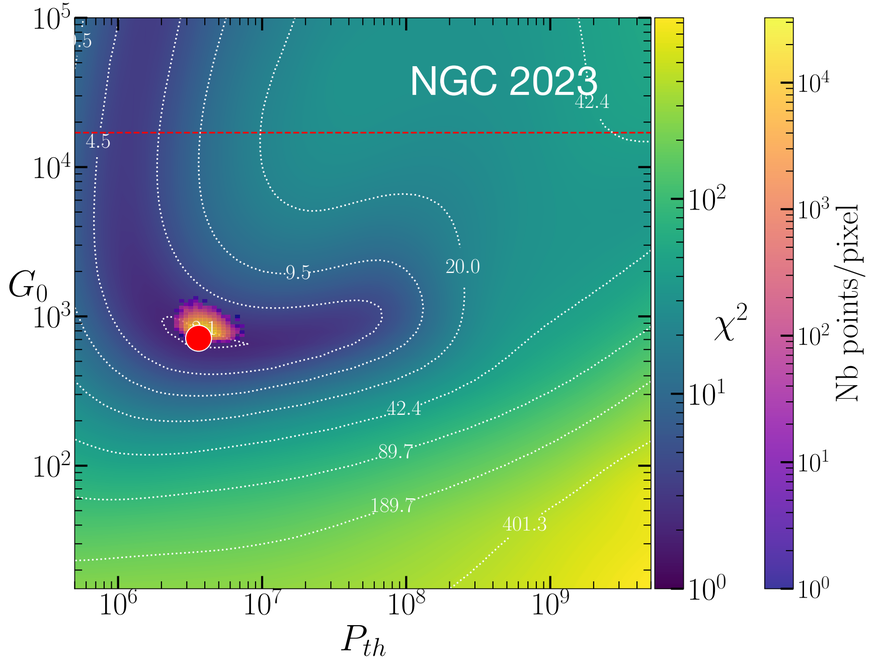
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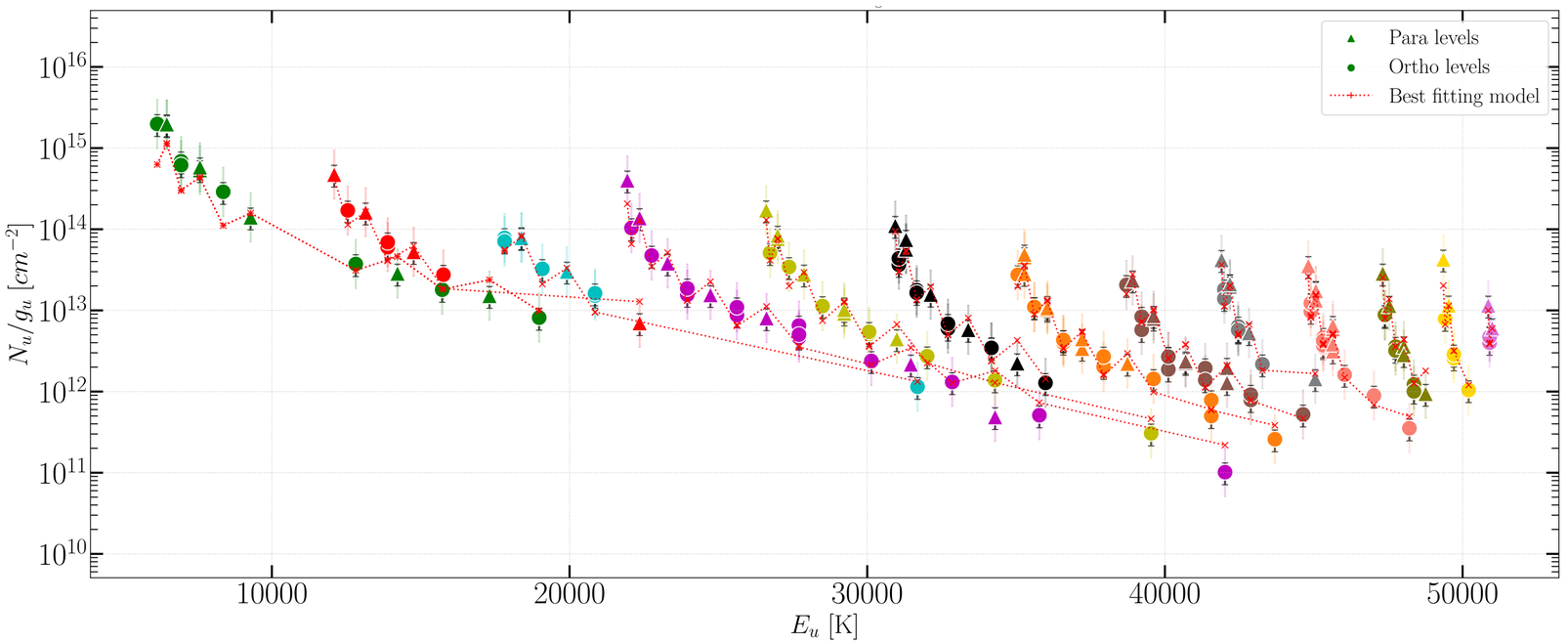
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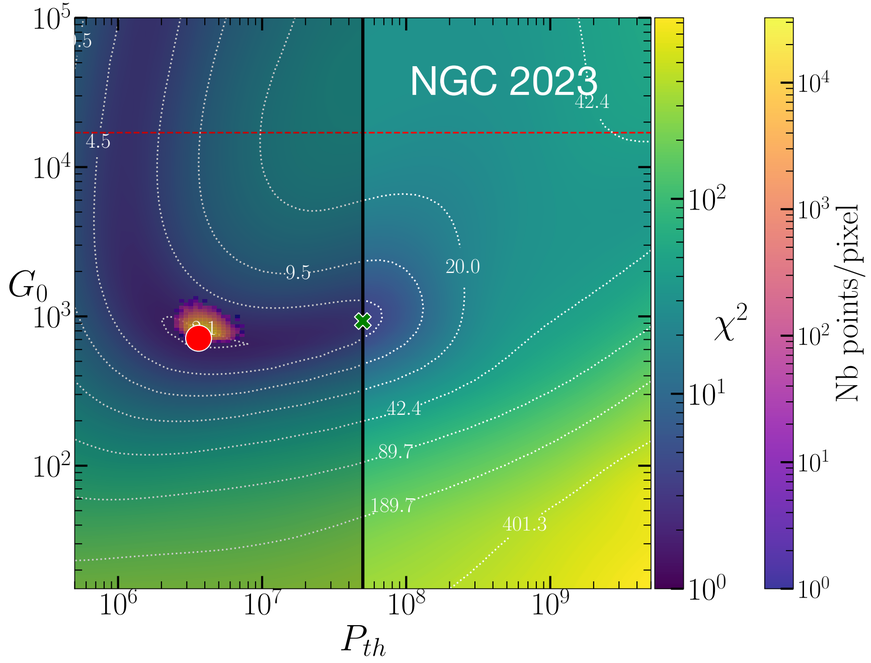
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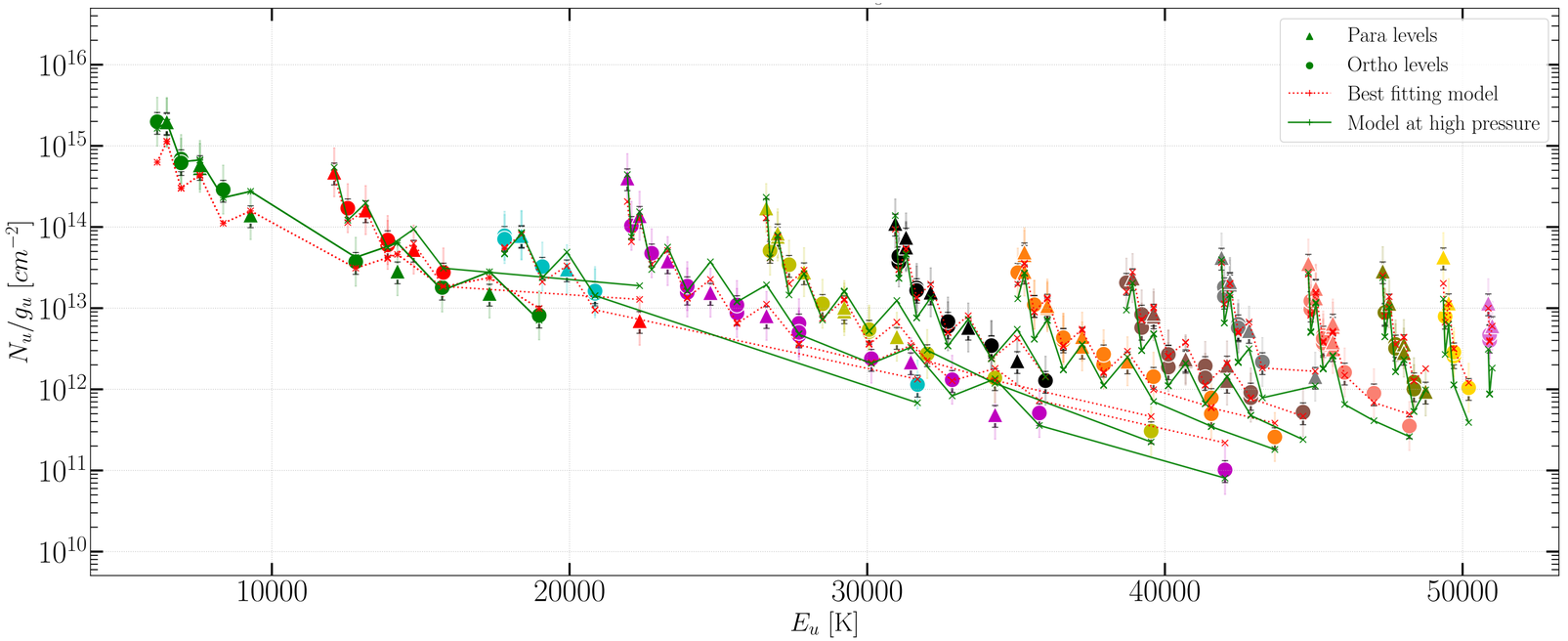
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✓ Parameter space exploration -> **Estimation of uncertainties**

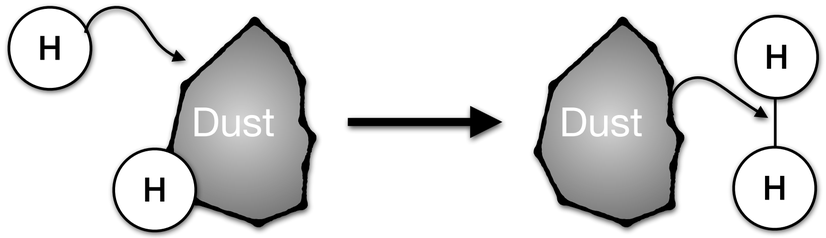




4. Results : Microphysical processes

Microphysical process : Distribution at formation for Intermediate PDRs

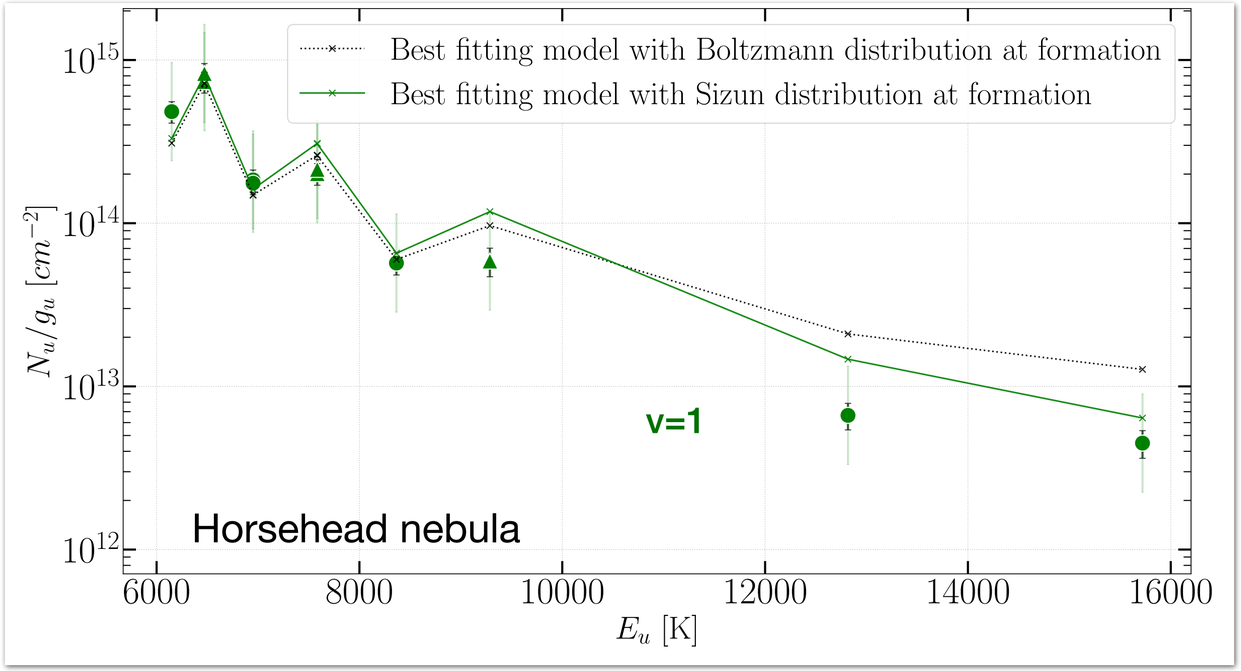
Until now, the observations could not allow to constrain distribution at formation



Comparison between :

A. Boltzmann Distribution

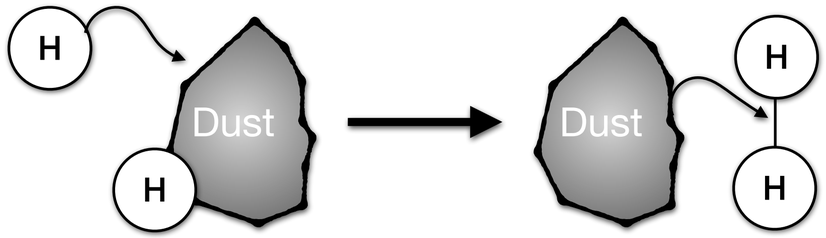
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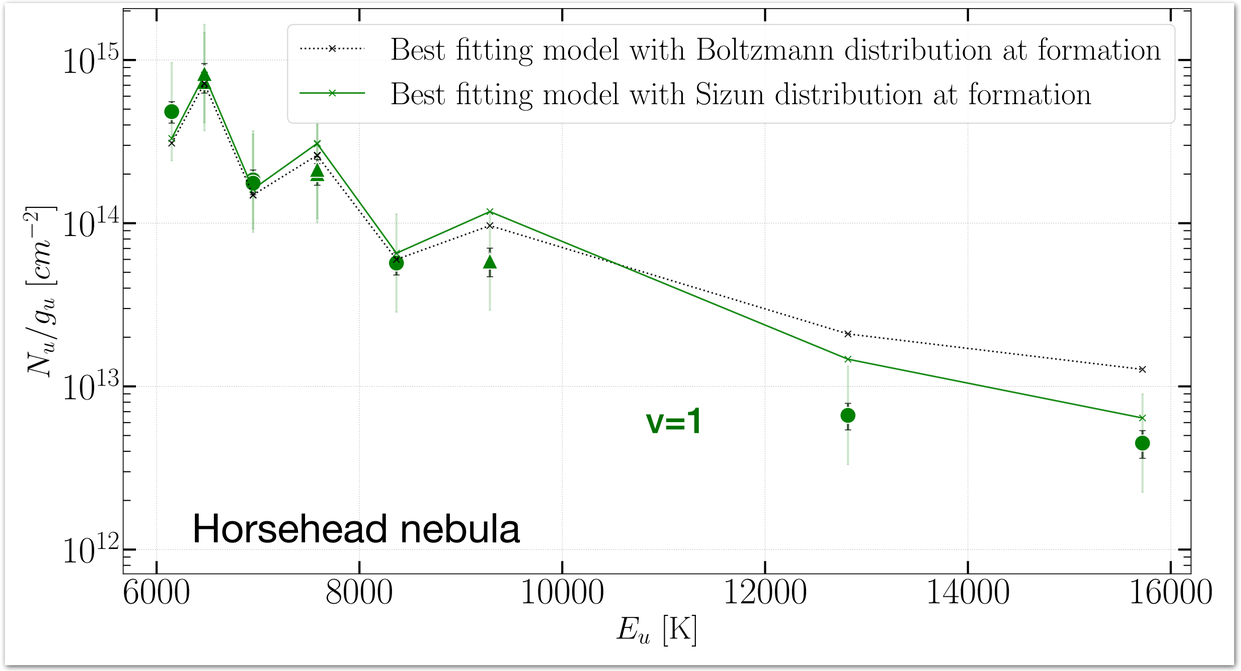


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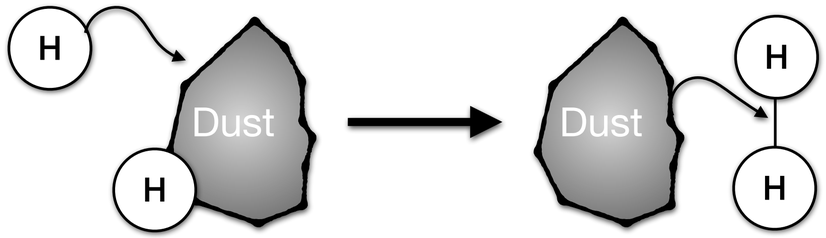
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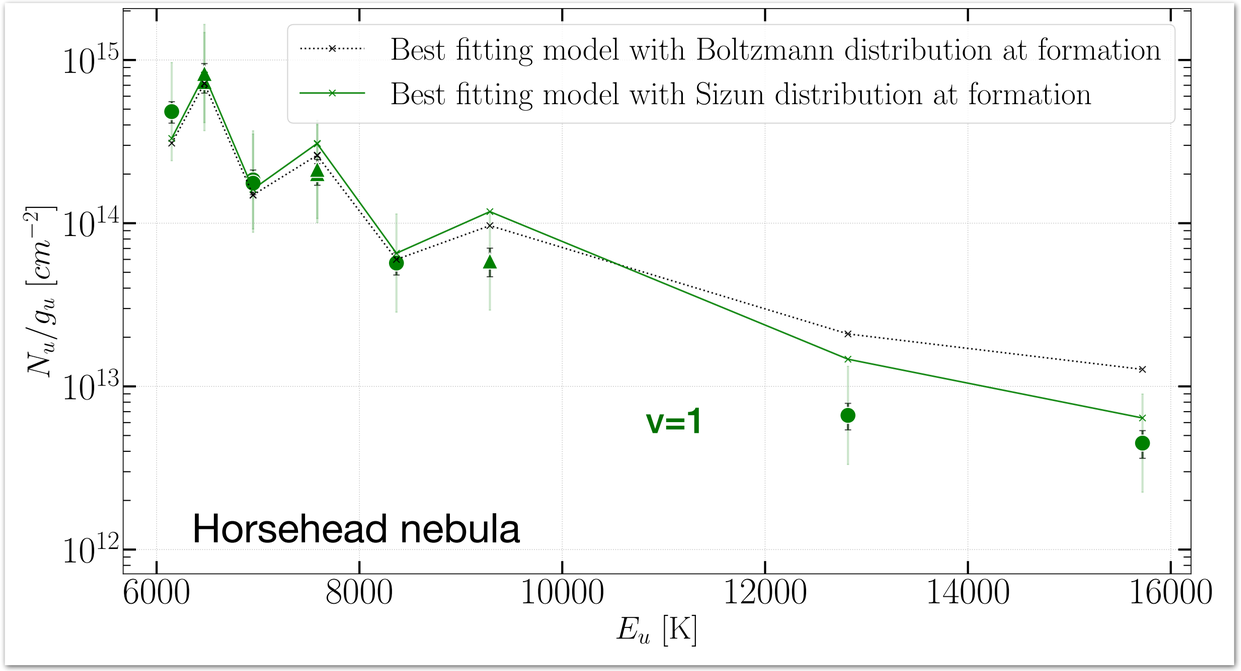
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➡ **H_2 forms preferably vibrating than rotating**



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- v=1 highly rotational emission lines provide information of **excitation at formation for the first time**
- Need of considering **collision rate for high energy levels** to model accurately PDRs


Thank you for your listening
Do you have some questions ?