Modelling Photodissociation Regions in Turbulent Clouds

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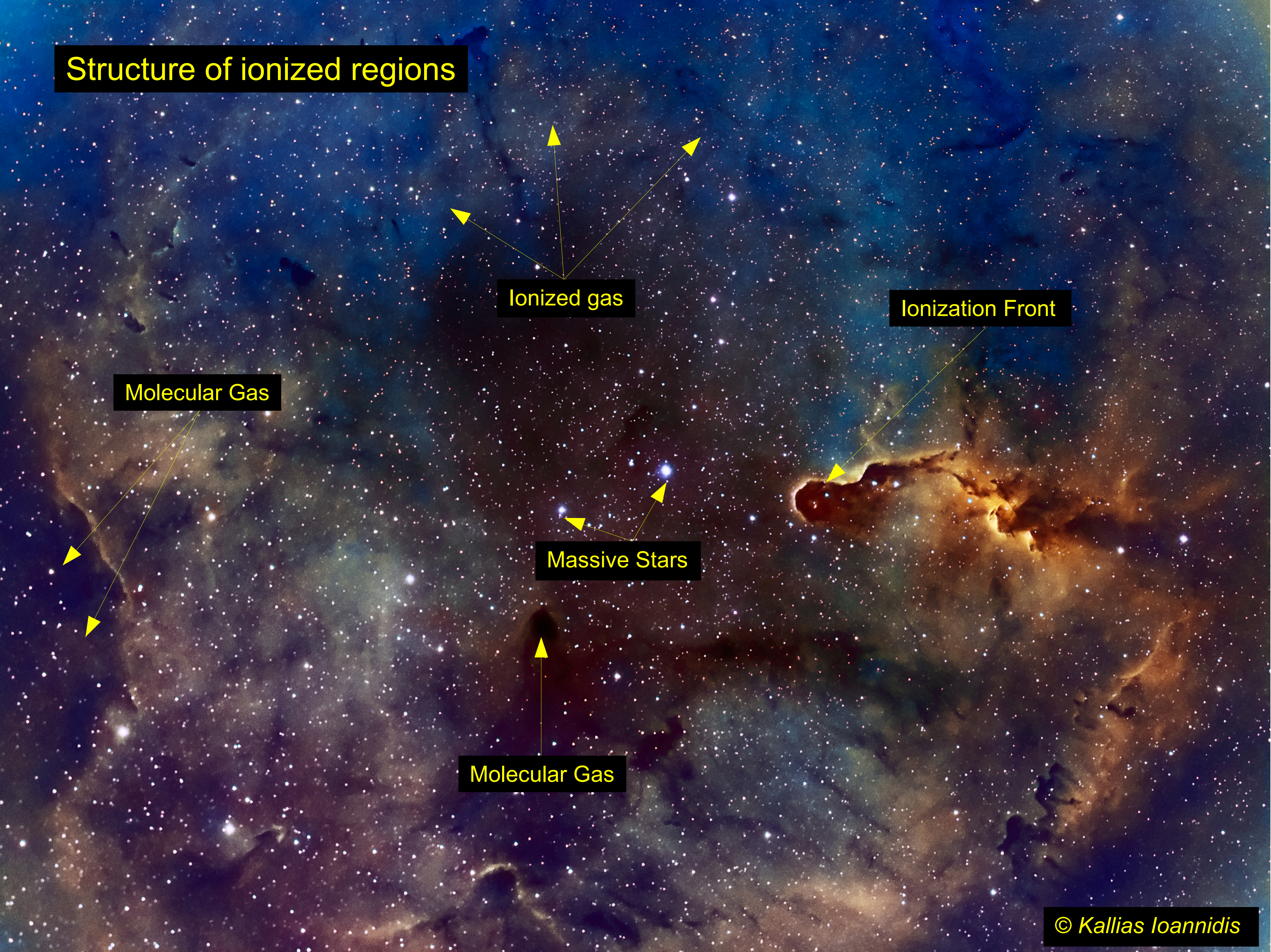

Structure of ionized regions
Ionized gas
Ionization Front
Molecular Gas
Massive Stars
Molecular Gas
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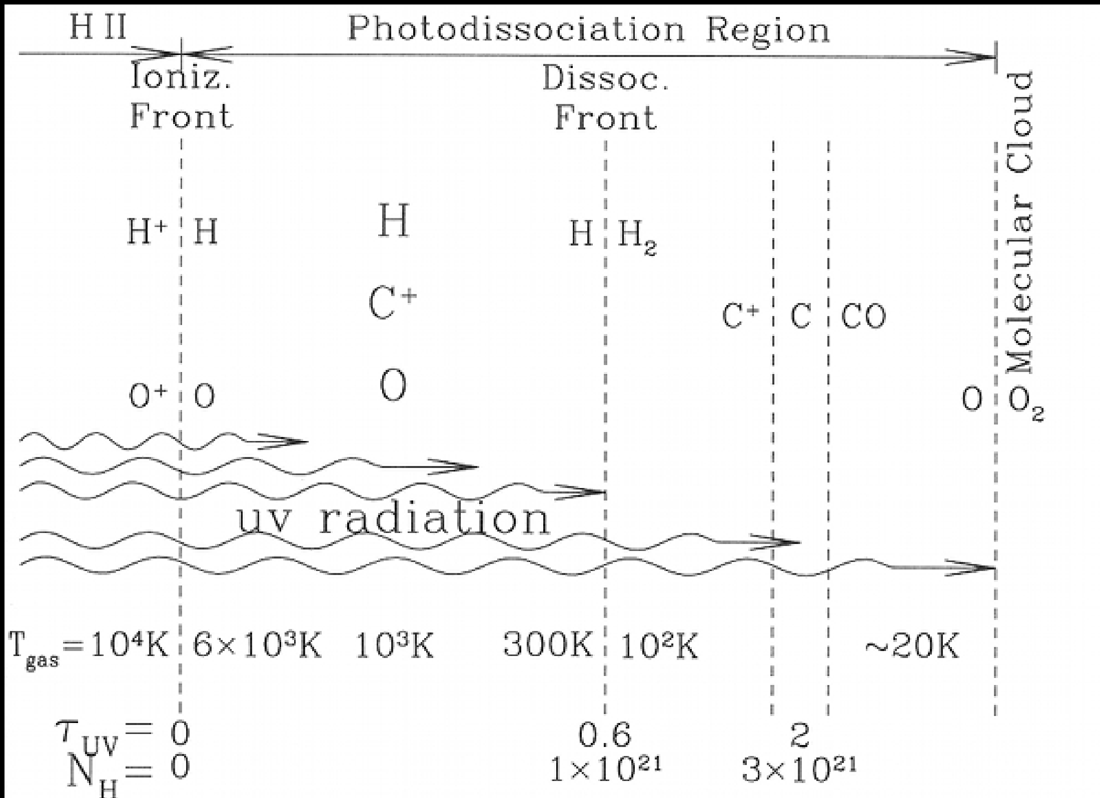
Photodissociation Regions (PDR)



Neutral regions of the interstellar medium in which the FUV photons strongly influence the gas chemistry and act as the most important source of heat.

PDRs occur in any region of the ISM that is dense and cold enough to remain neutral but has too low column density to prevent the penetration of FUV photons.

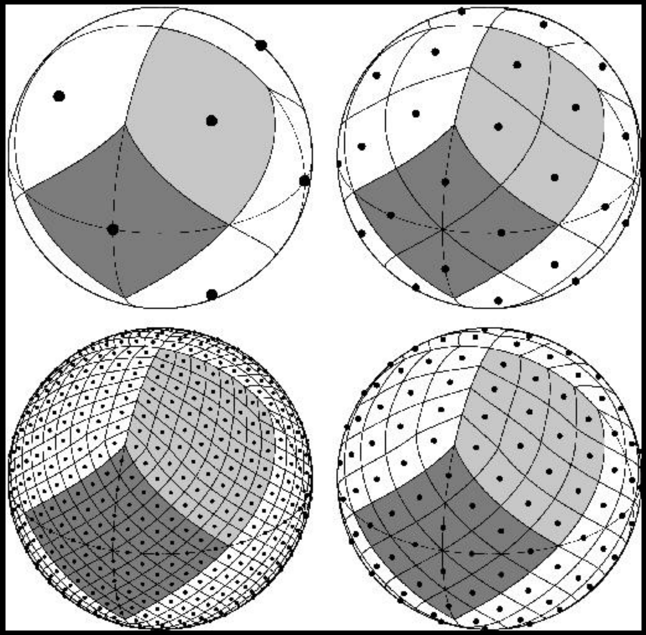
PDRs are located in the edge of the HII regions, where the temperature drops very abruptly from T ~ 10^4 – 10 K.

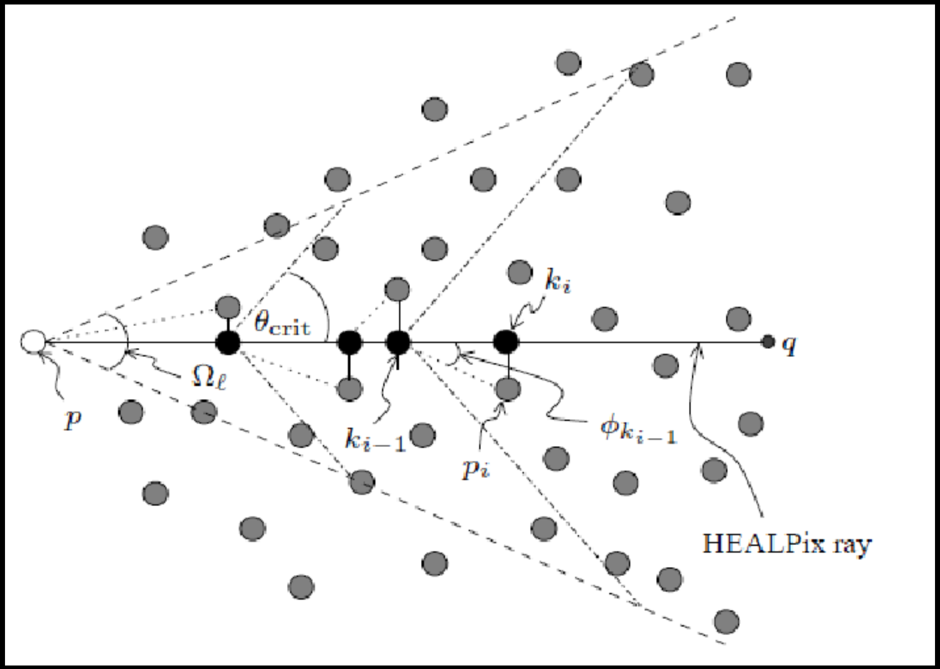
As the binding energy of the H_2 molecule is lower than that of the hydrogen atom, HII regions are enveloped by a region of atomic hydrogen.

In this region UV is great enough to photodissociate H_2 but the recombination rate is high enough to keep the ionized fraction low.

Deeper in the cloud, UV has been sufficiently attenuated, such that most hydrogen is bound to H_2.

Modelling Photodissociation Regions: The 3D-PDR code





$$\mathcal{N}_\ell = 12 \times 4^\ell$$

Rays

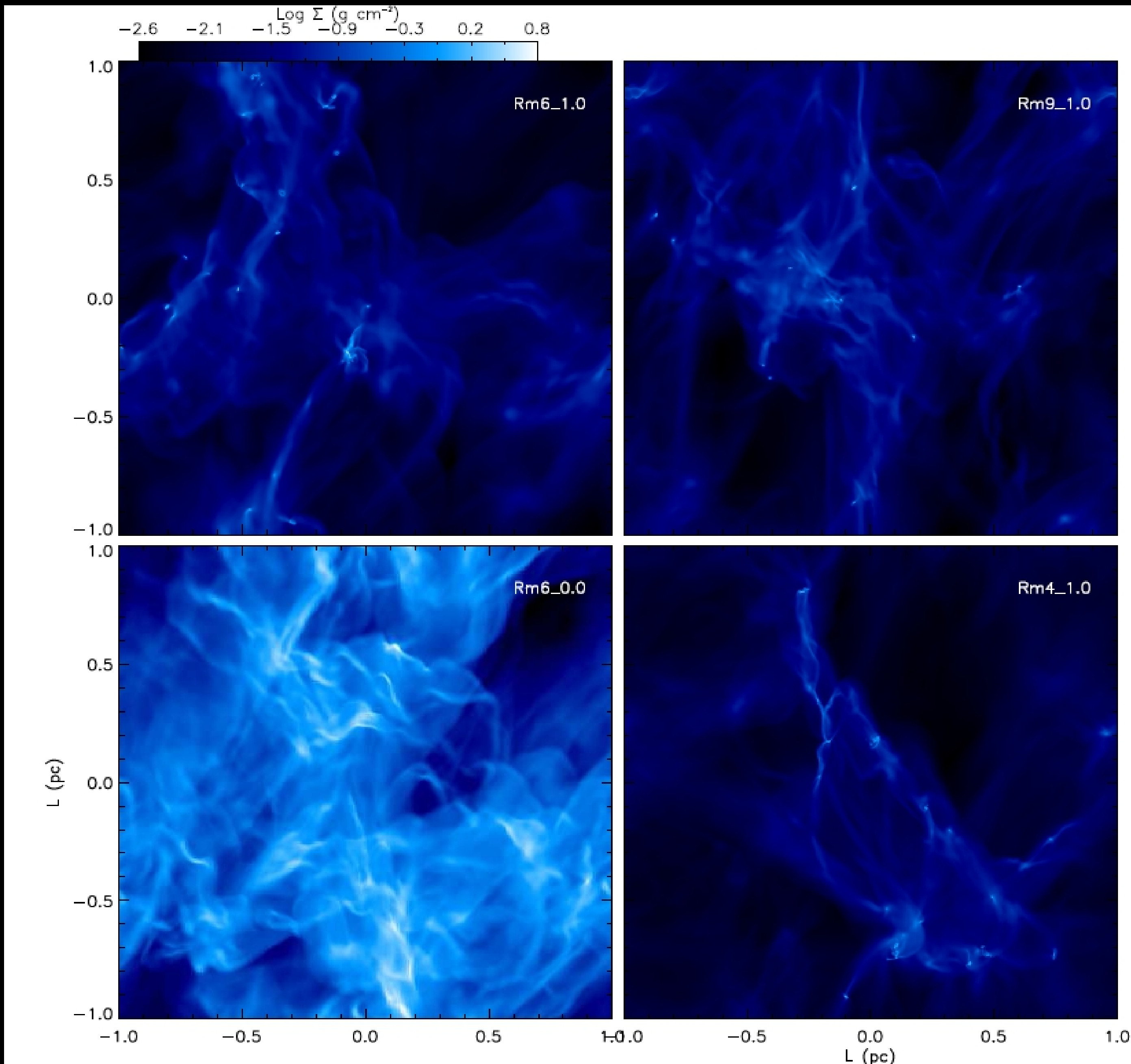
Level of refinement

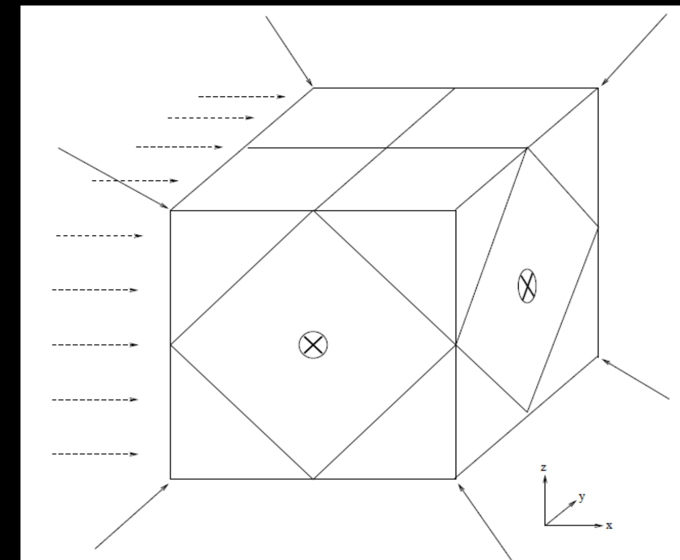
HEALpix (Gorski et al. 2005, **ApJ**, 622, 759)

- Ability to simulate any given 3D density distribution (either Grid or SPH).
- Ray tracing using a HEALPix-based routine
- 3D escape probability routine (Large Velocity Gradient; Sobolev 1960)
- Various heating and cooling mechanisms
- Iterations to obtain thermal balance
- UMIST chemical networks

For full details about 3D-PDR, see: Bisbas et al. 2012, **MNRAS**, 427, 2100

Modelling the Atomic-to-Molecular transition in turbulent star forming clouds



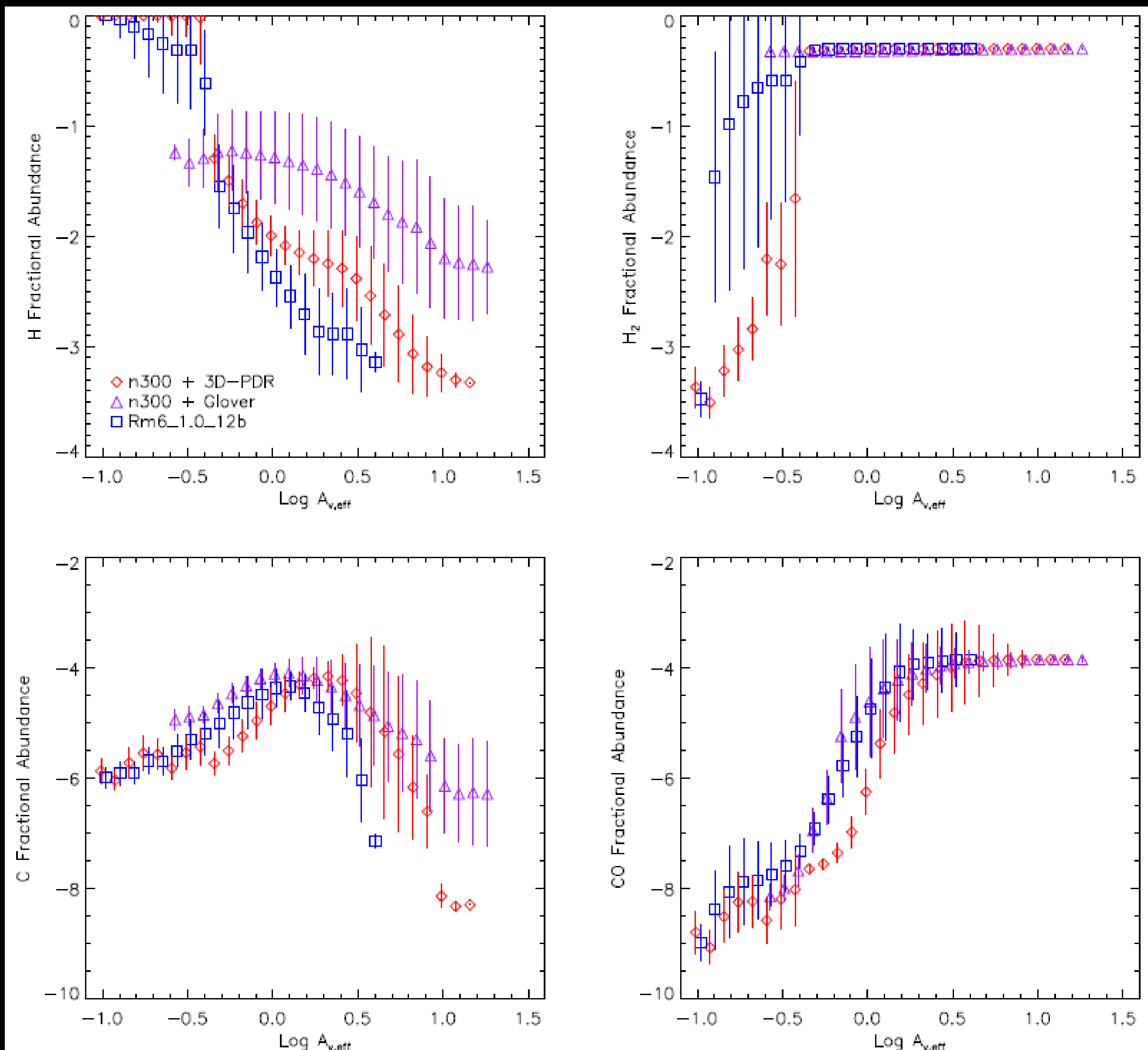


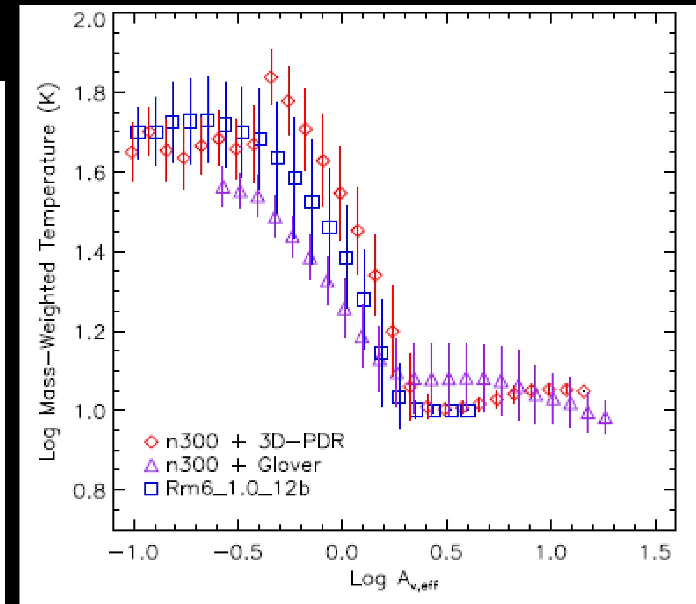
We have post-processed with 3D-PDR four different hydrodynamic simulations of turbulent molecular clouds produced by the ORION adaptive mesh refinement code.

We focus on the transition from atomic to molecular gas with specific attention to the formation and distribution of H, C+, C, H2 and CO.

Offner, Bisbas, et al., 2013, **ApJ**, 770, 49.

Modelling the Atomic-to-Molecular transition in turbulent star forming clouds



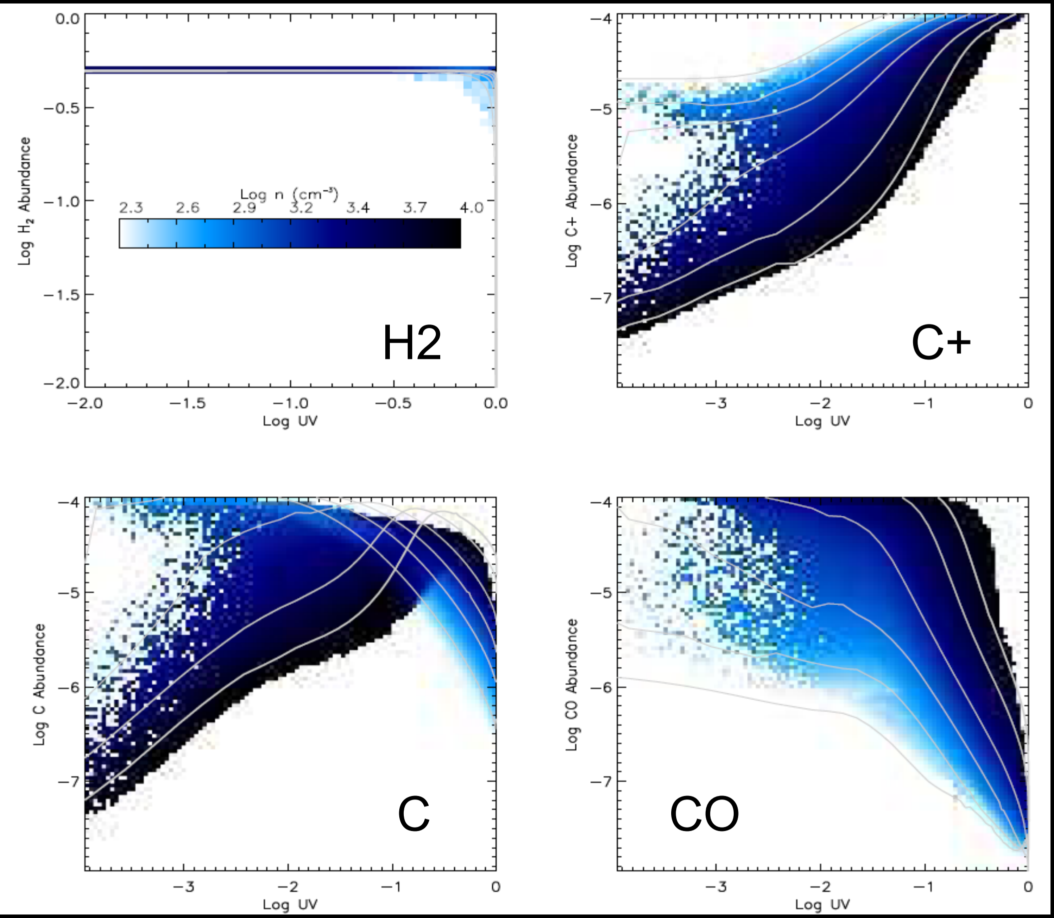


We find that morphological differences due to cloud Mach number and evolutionary time can produce significant differences in the abundance distributions.

It can indirectly impact the properties of the observed molecular emission lines emerging from the cloud.

Offner, Bisbas, et al., 2013, **ApJ**, 770, 49.

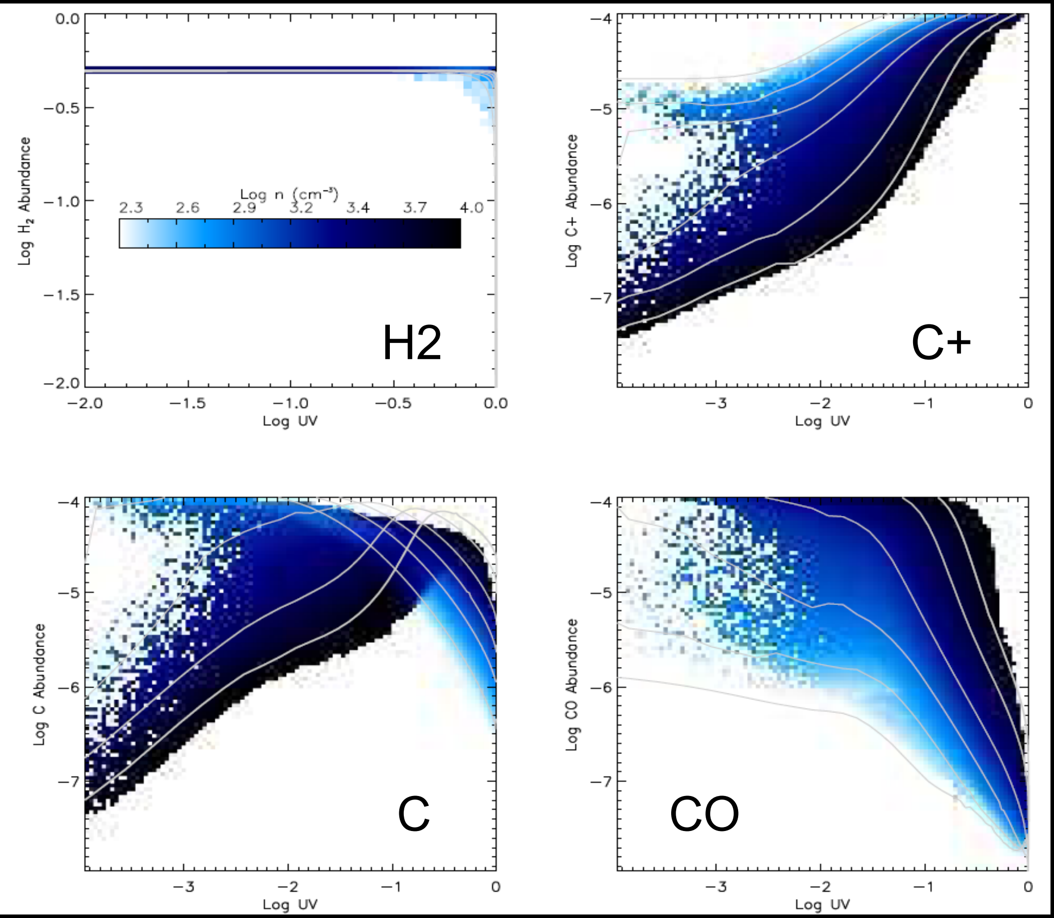
Modelling the Atomic-to-Molecular transition in turbulent star forming clouds



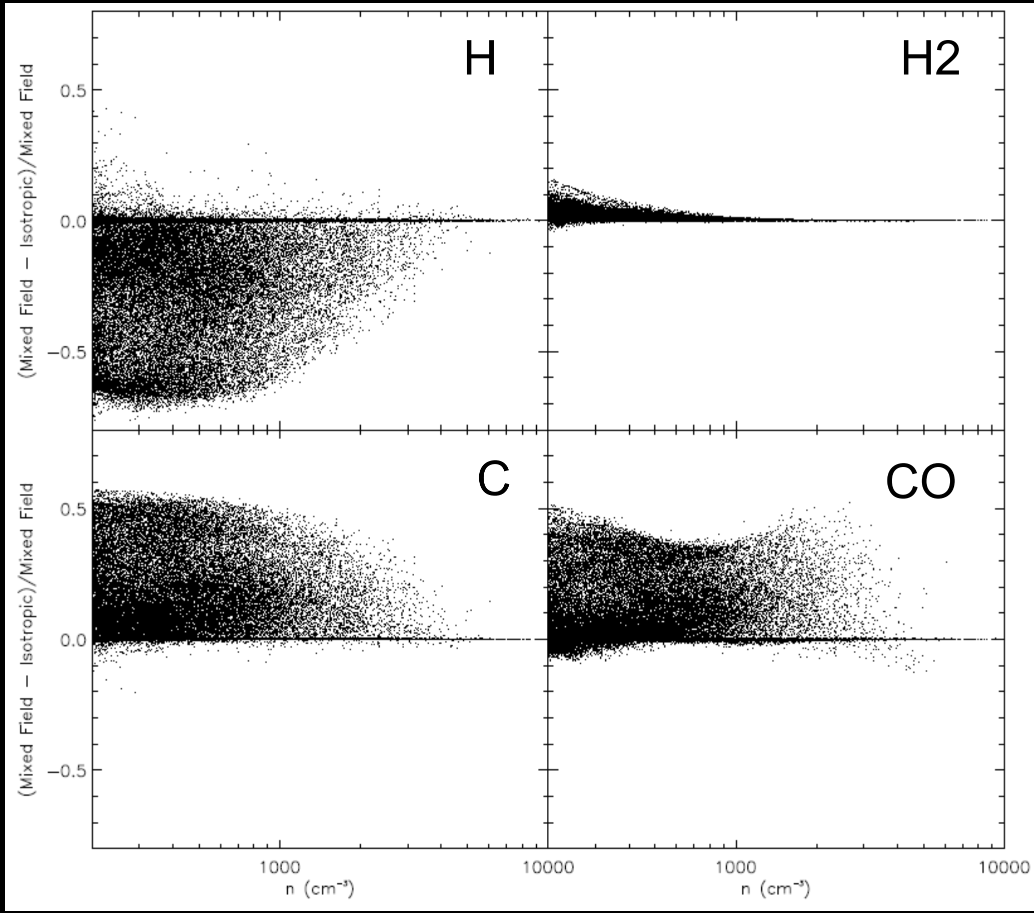
<u>Isotropic radiation involved only</u>

Logarithmic plots of abundances versus UV field.

Modelling the Atomic-to-Molecular transition in turbulent star forming clouds



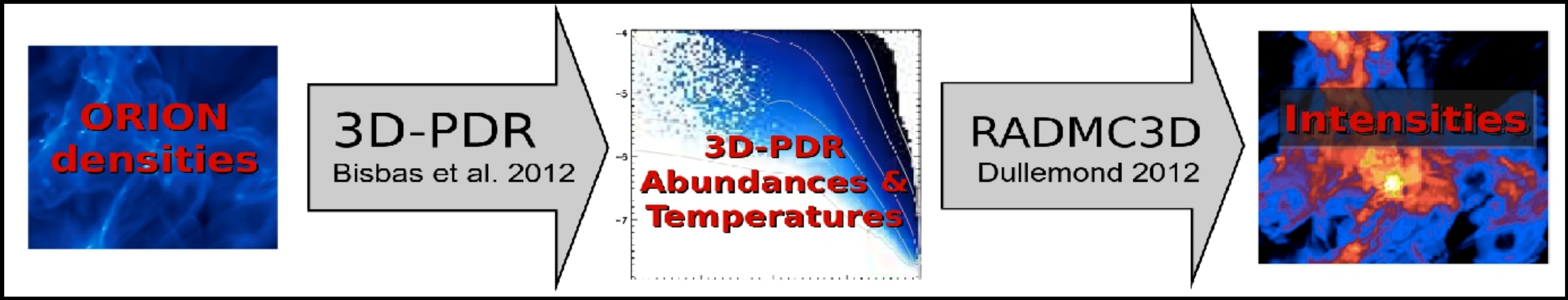
<u>Isotropic radiation involved only</u>
Logarithmic plots of abundances versus UV field.

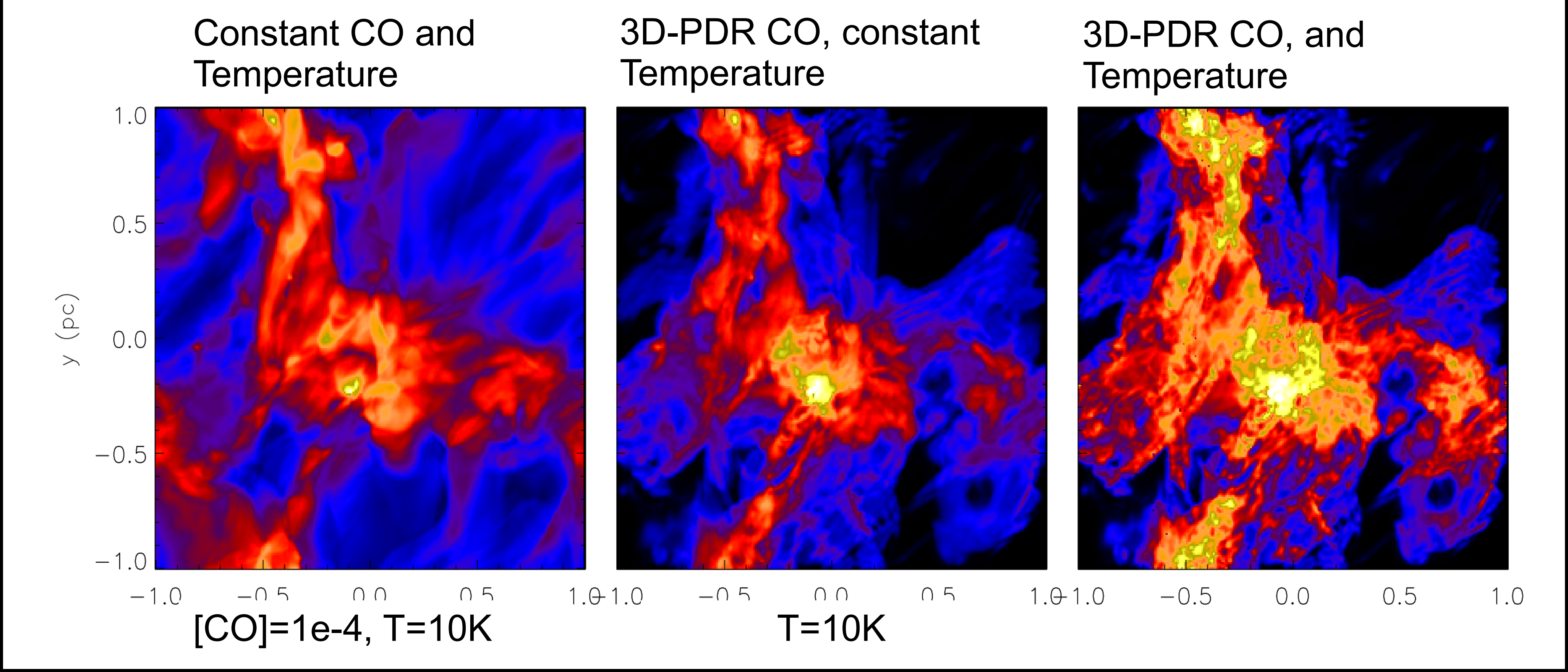


<u>Isotropic and plane-parallel (two component)</u>
Normalized relative differences between the H, H2, C, and CO abundances.

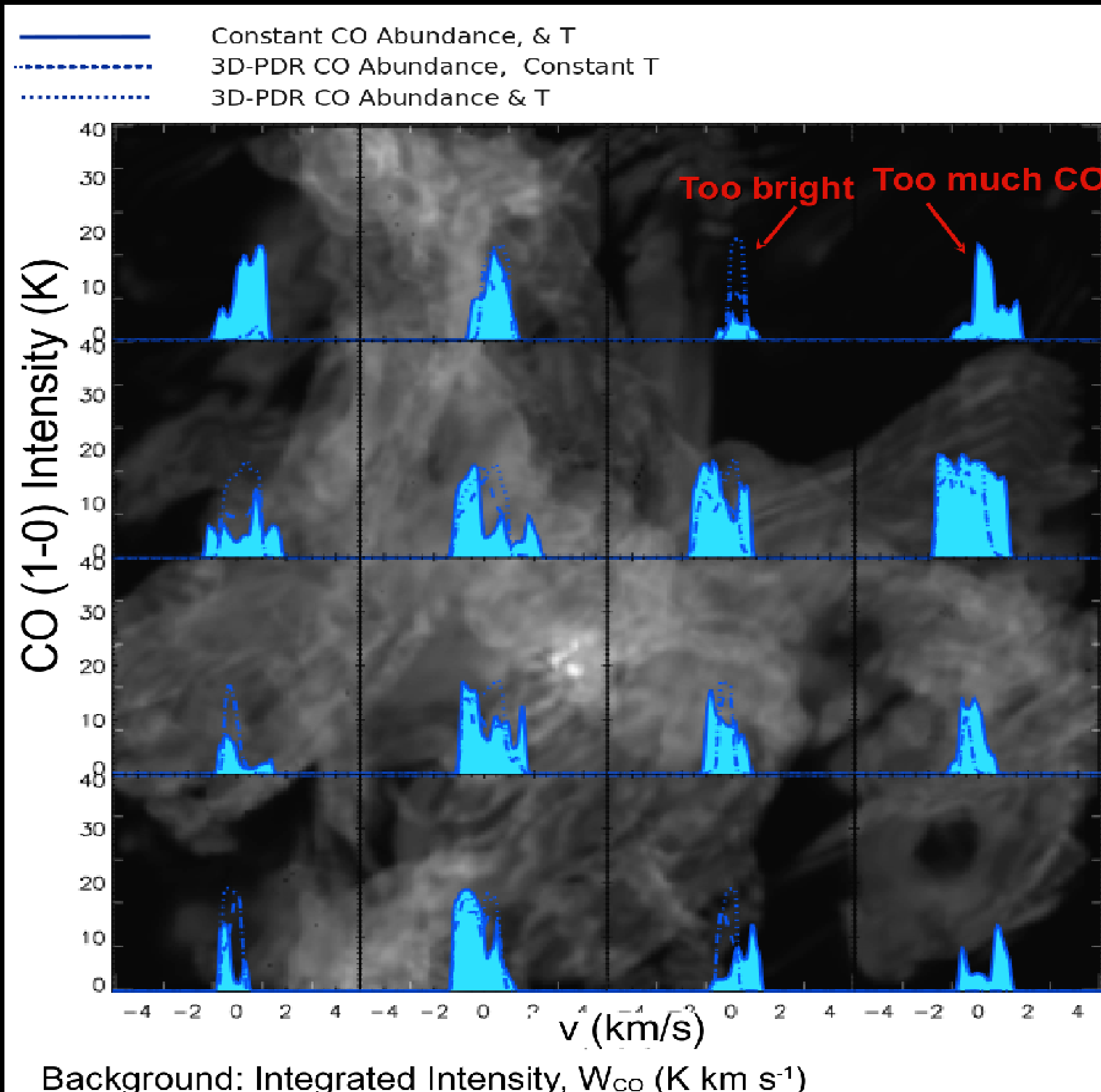
We find that a relatively modest change in the external UV radiation field produces large changes in the chemical abundances. This supports the statement that three-dimensional treatment of PDRs is crucial for complex and non-symmetric problems.

Synthetic observations of turbulent star-forming clouds





Synthetic observations of turbulent star-forming clouds



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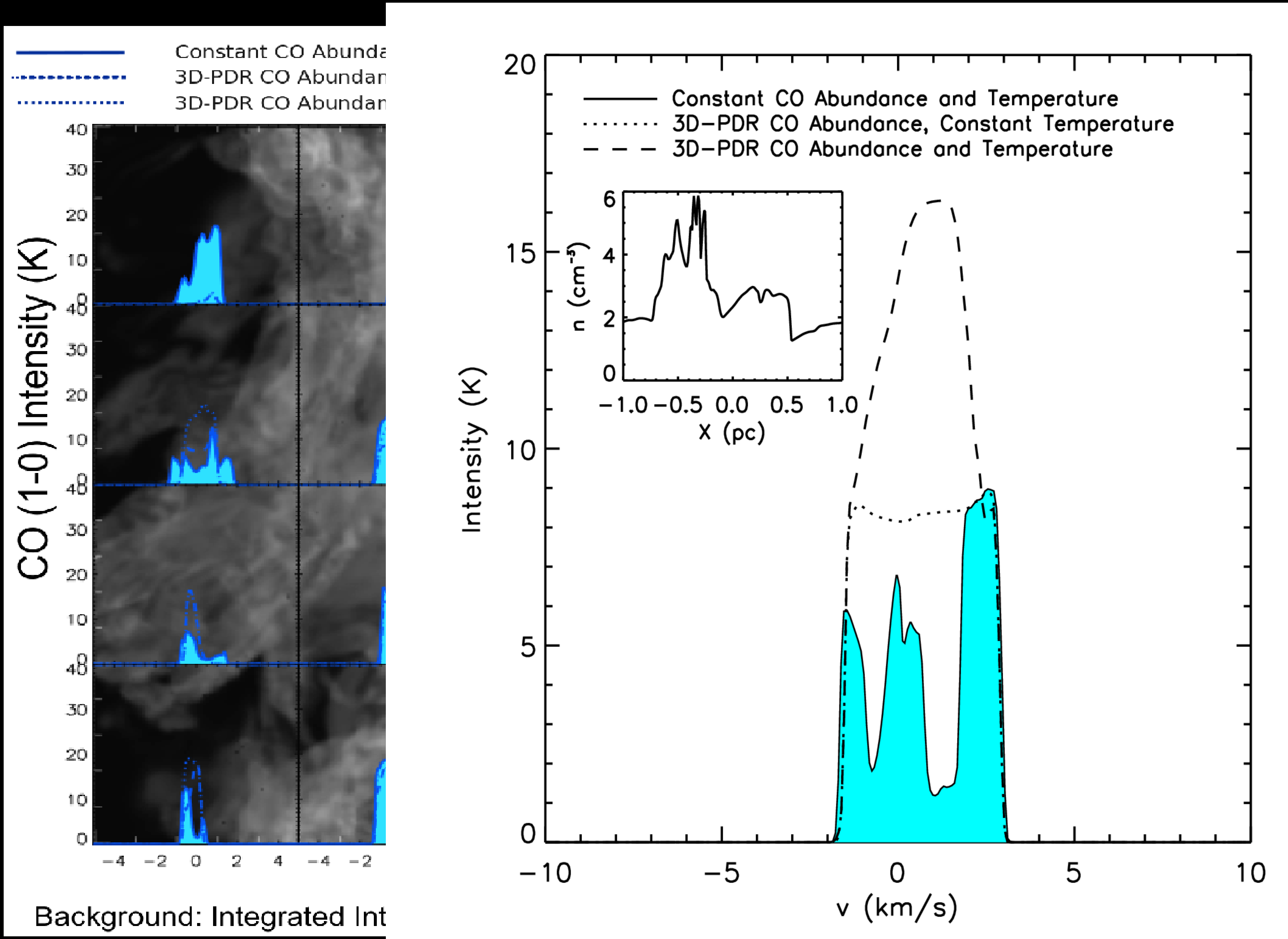

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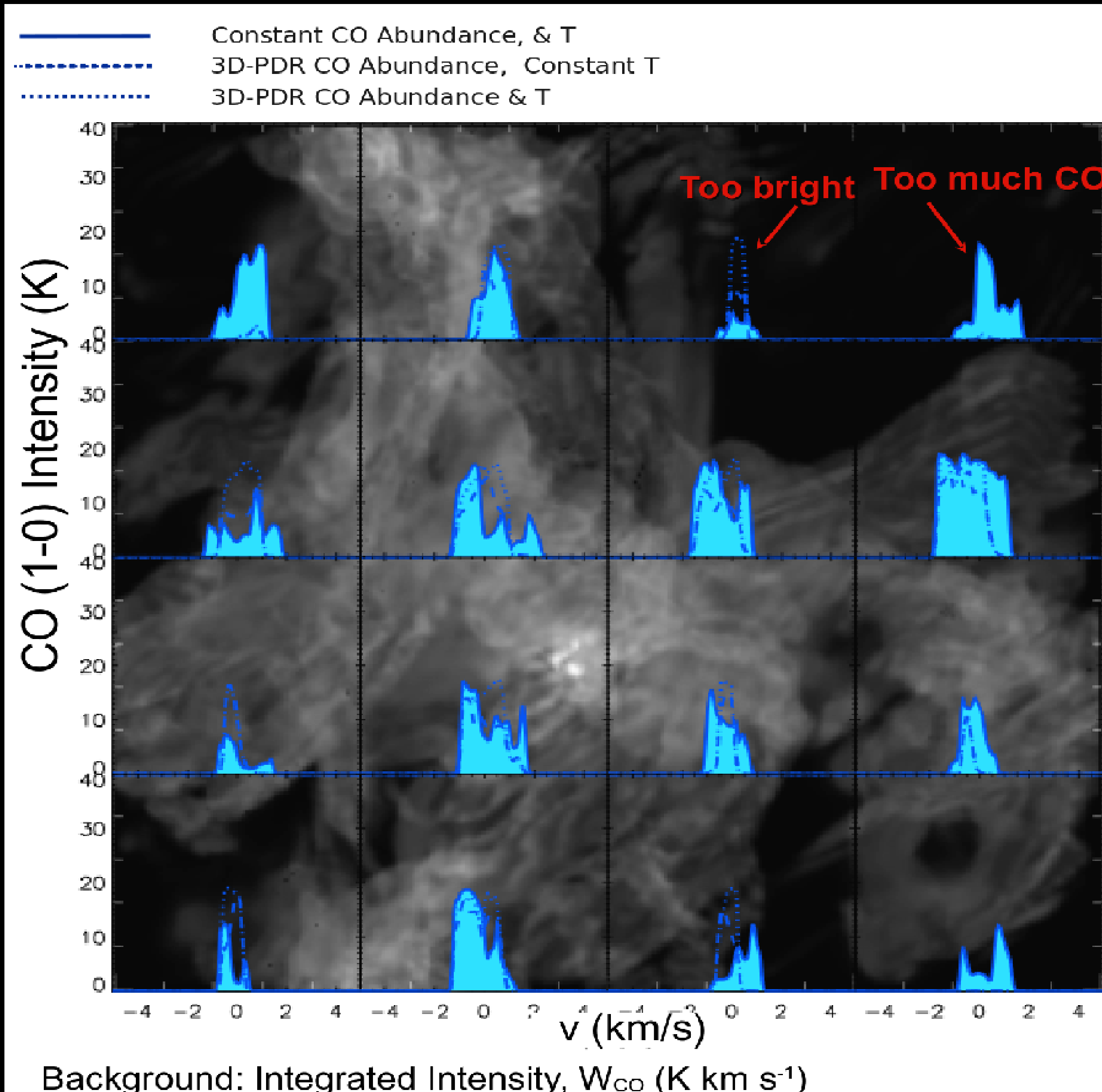

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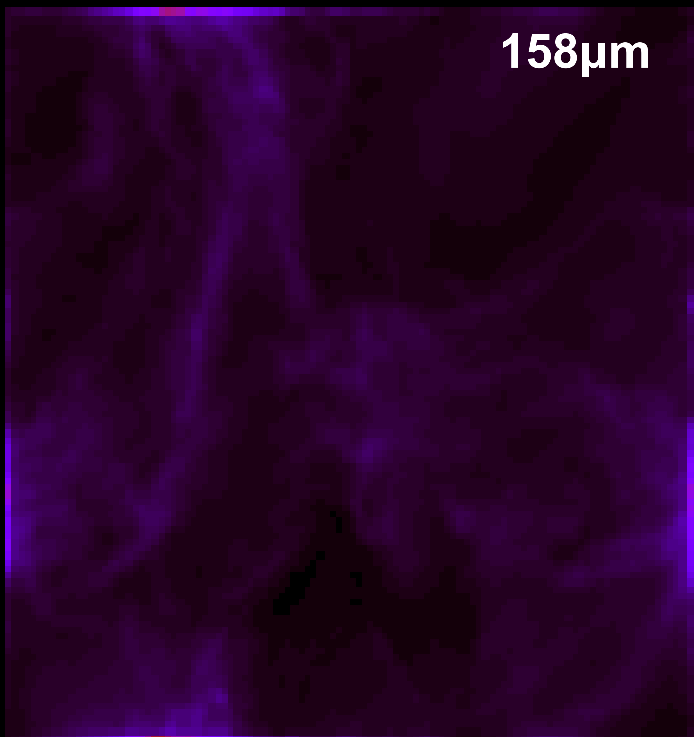
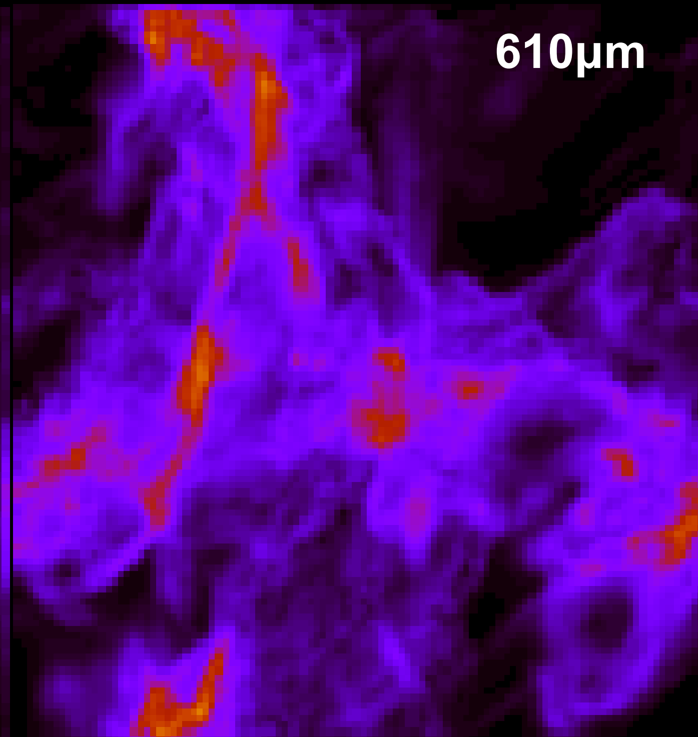
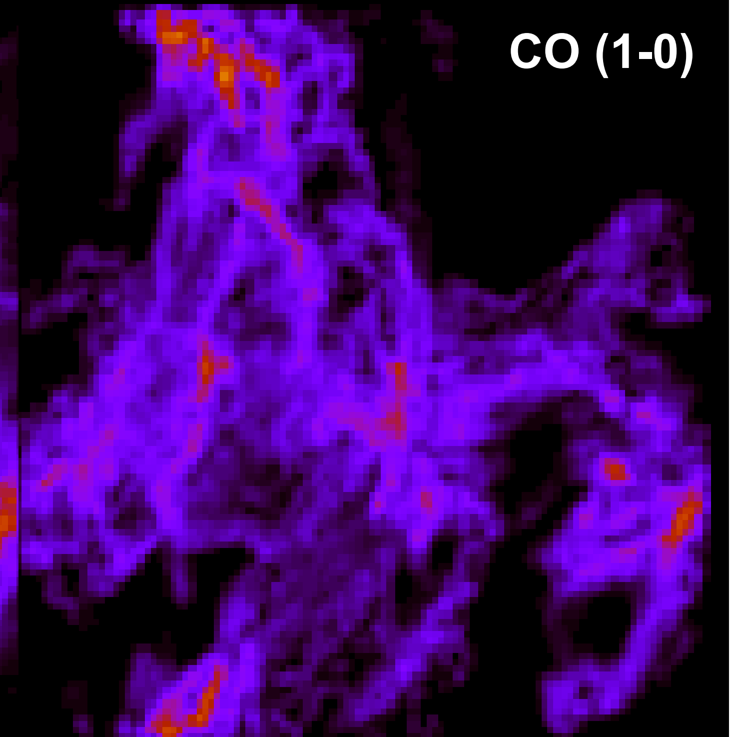
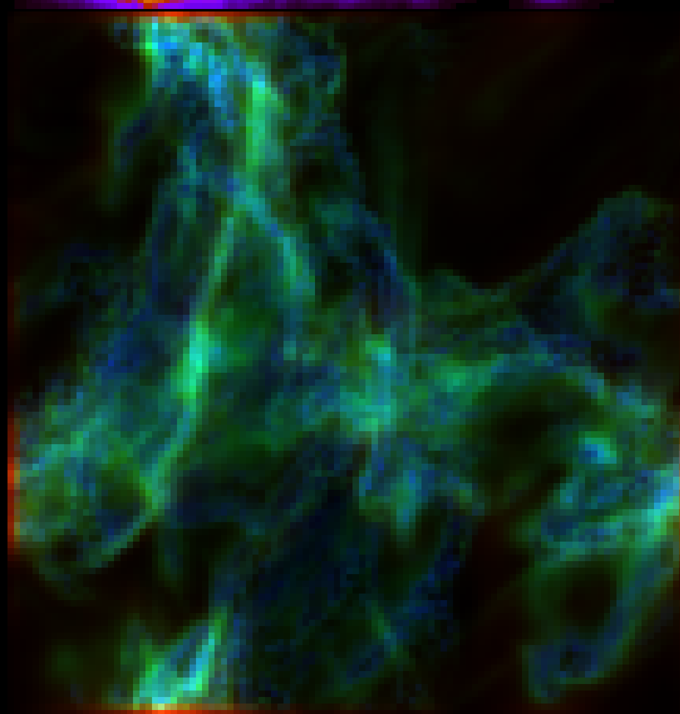






We will use a complicated network of chemical species and reactions and we will account for the molecular region using the specially designed UCL_CHEM code (Viti et al. 2004, **MNRAS**, 354, 1141).



Red: 158μm
Green: 610μm
Blue: CO (1-0)

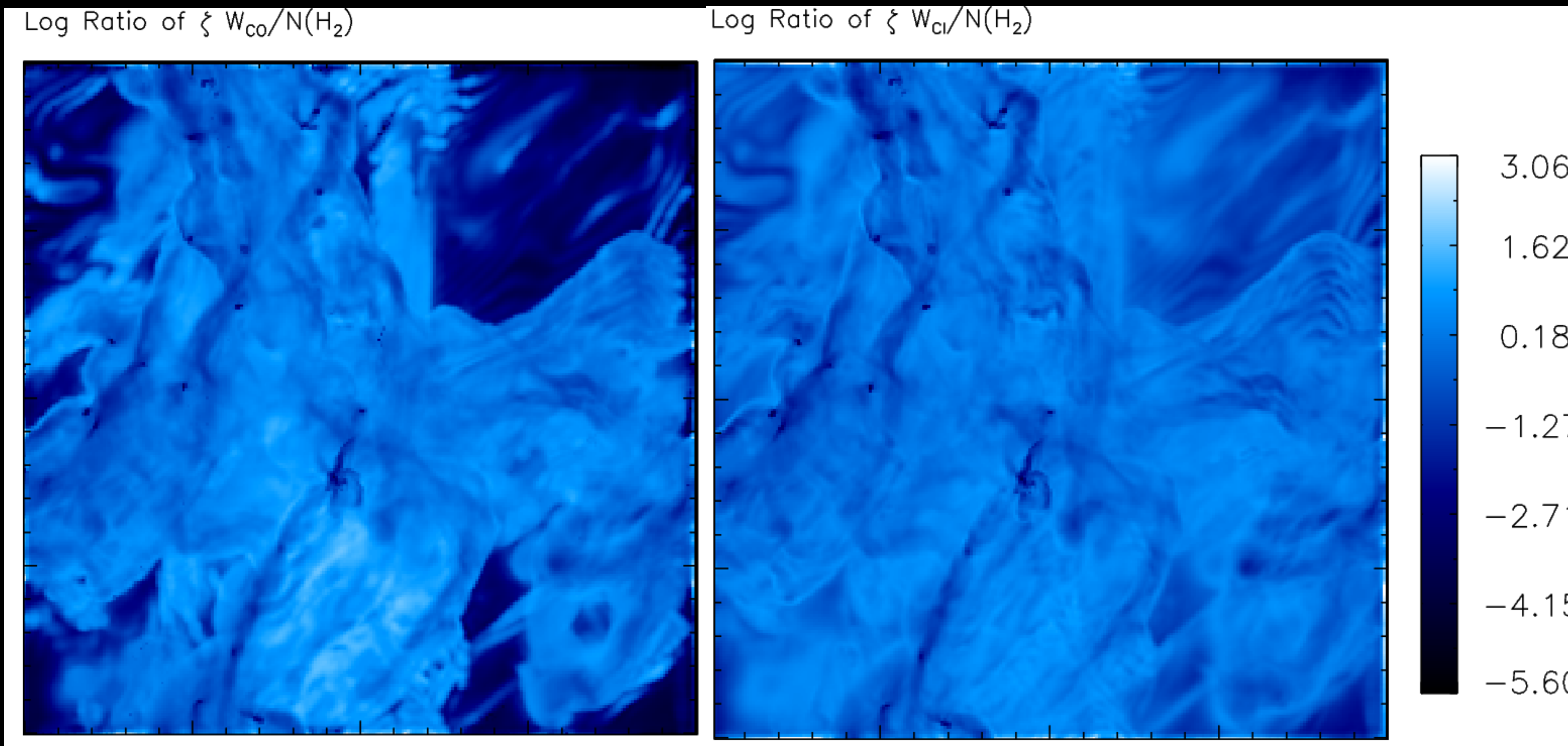
CO vs CI as an H2 tracer

Raster plots. Some preliminary results...

WCO / N(H2)

CO vs CI as an H2 tracer

Raster plots. Some preliminary results...

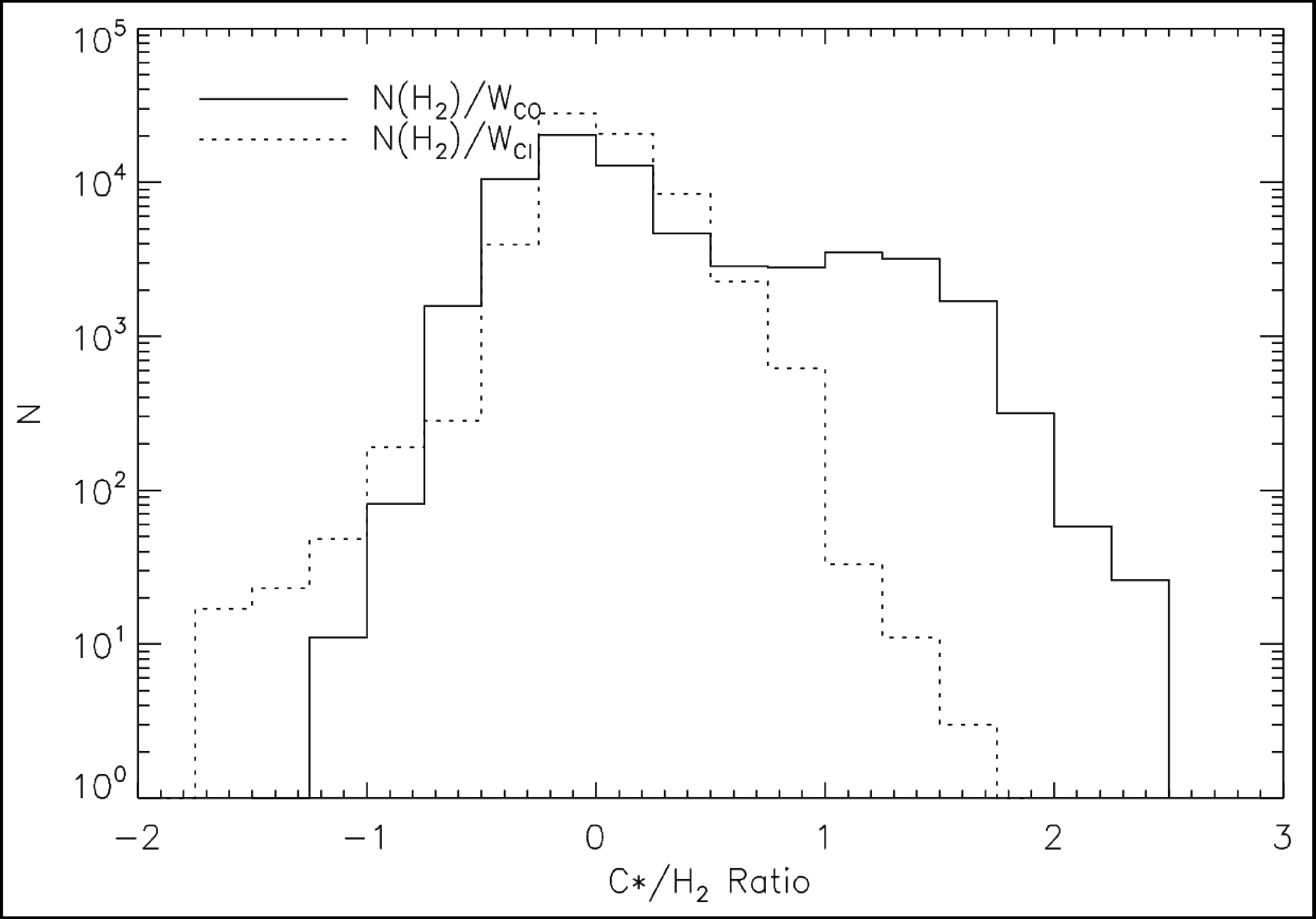


WCO / N(H2)

WCI / N(H2)

It appears that WCI / N(H2) is more flat giving a better `view' of the molecular regions, where UV radiation is almost entirely extinguished.

CO vs CI as an H2 tracer



N(H2)/WCI is more narrow suggesting that CI is a better tracer of N(H2) mass rather than CO.

Conclusions...

- Photodissociation Regions (PDRs) occur in any region of the ISM that is dense and cold enough to remain neutral and interacts with FUV photons.
- We have modelled PDRs in turbulent star forming clouds using 3D-PDR
- We found that the abundances of species depend on the Mach number and evolutionary time.
- It can indirectly impact the properties of the observed molecular emission lines emerging from the cloud.
- We also find that our 3D PDR calculations match with 1D PDR calculations when only one UV field is present and when using the on-the-spot approximation, allowing us to generate tabulated equations of state.
- Intensity maps of synthetic observations of simulations become more narrow (bright regions become brighter and dark regions become darker) when we use more realistic abundances of species and PDR temperatures.
- Finally, we find evidence that CI is better tracer for obtaining the N(H2) mass than CO.