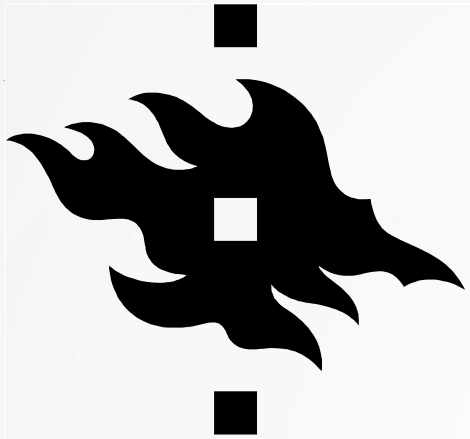


EFFECT OF MEDIUM INHOMOGENEITES ON INFRARED OBSERVATIONS OF PHOTON DOMINATED REGIONS

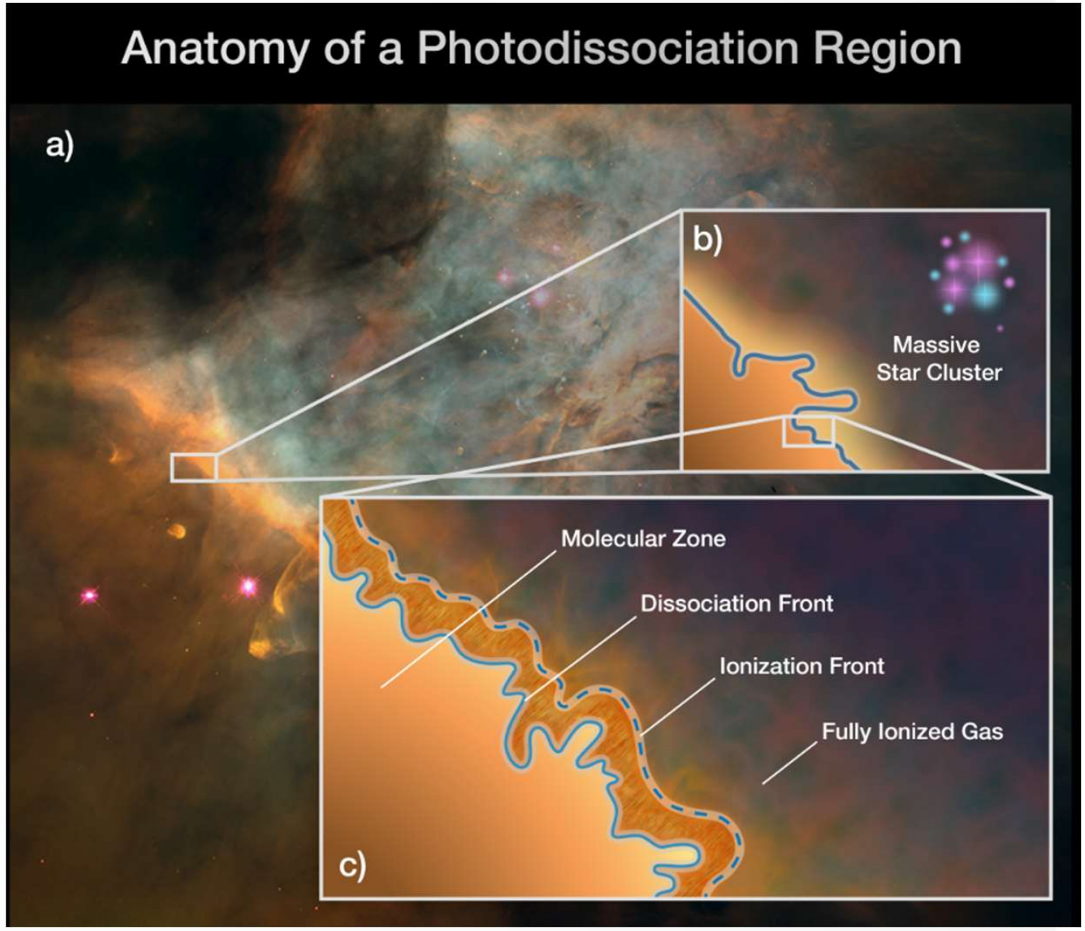
Jouni Rissanen

OUTLINE

- Introduction
- Recent observations and studies
- Methods and tools
- Modelling and analysis
- Summary

INTRODUCTION_PDR

- PDRs are regions of the interstellar medium at the boundaries of molecular clouds, in which far-ultraviolet (FUV) photons influence the chemistry, thermal balance, and structure of the gas and dust.
- FUV radiation originates in close by high-mass stars (≥8M⊙).
- PDRs consist of ionization front, atomic zone, dissociation front and molecular zone.



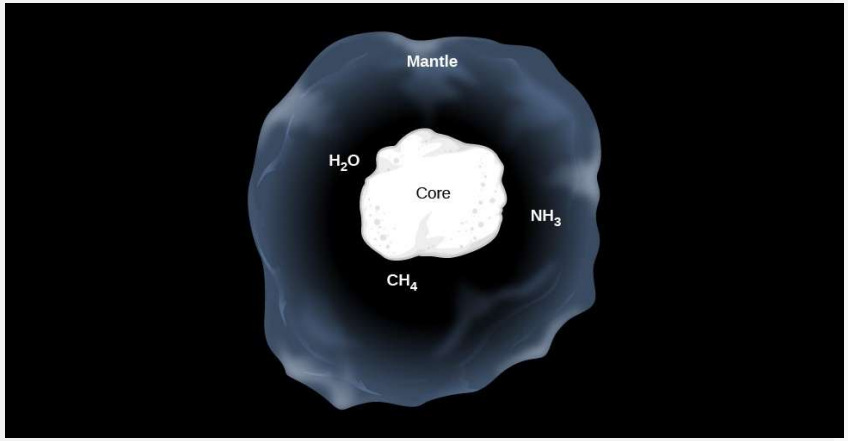
NASA, ESA, CSA, Jason Champion (CNRS), Pam Jeffries (STScI), PDRs4ALL ERS Team

INTRODUCTION: DUST

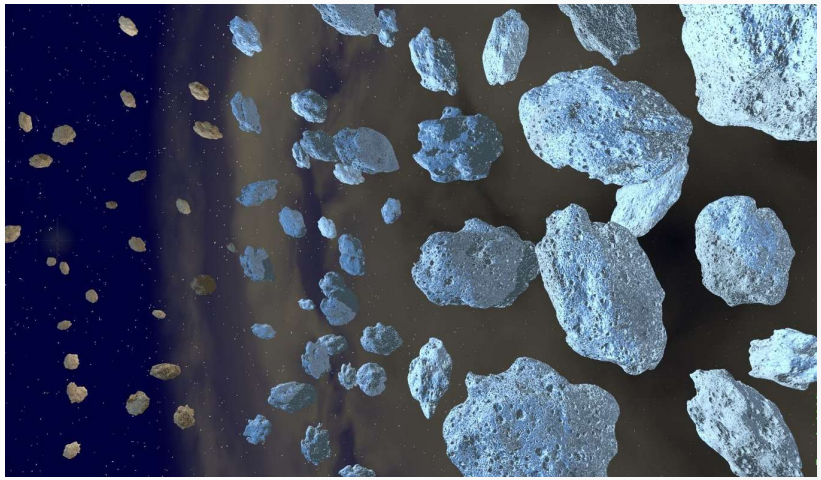
- Chemical composition
  - carbonaceous, silicates
- Structure
  - core, mantels, ice mantels
- Grain sizes

  ~ 0.0005– 5 μm
- Mass

  ~1% of the mass of the gas



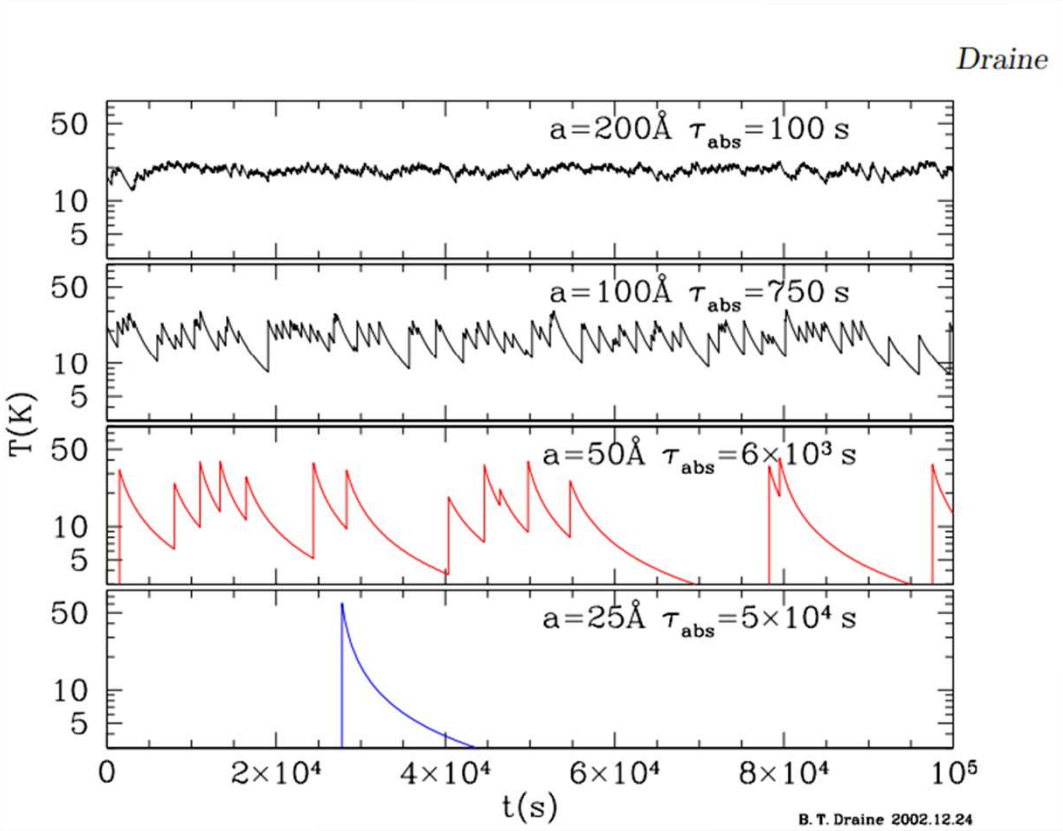
Astronomy. Copyright by OpenStax



Dartois et al. 2024

INTRODUCTION: DUST

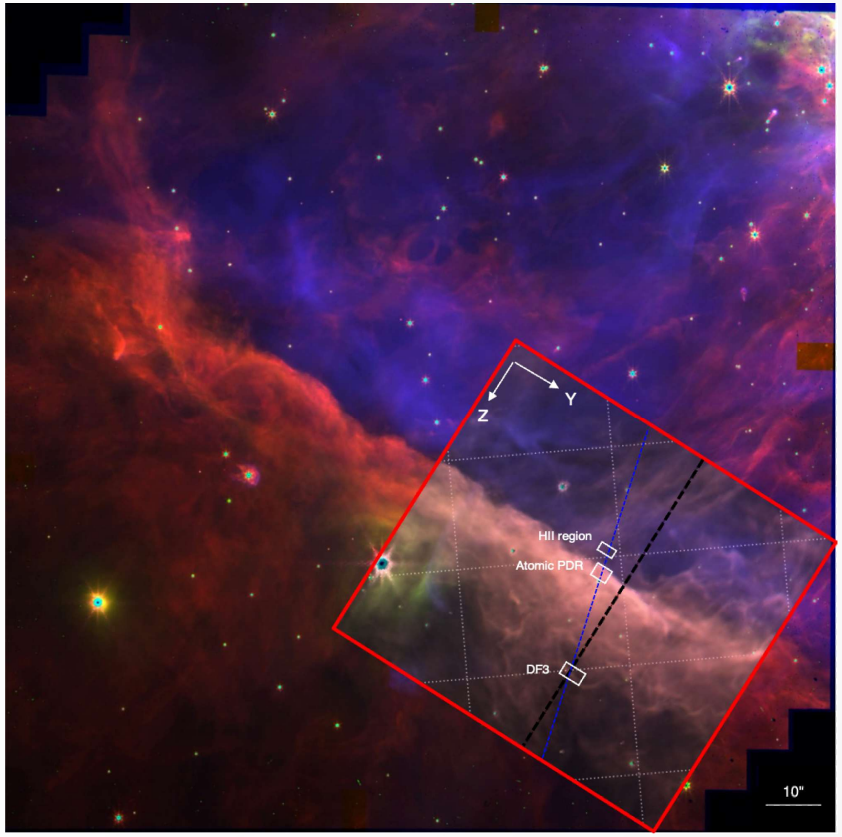
- Larger grains at equilibrium temperature emit at far-infrared (FIR) wavelengths (50 – 500 μm).
- Smaller grains experience stochastic heating, and emit at mid-infrared (MIR) wavelengths (5-30 μm).



A day in the life of 4 carbonaceous grains heated by local interstellar radiation field.

PDRS4All: GOALS

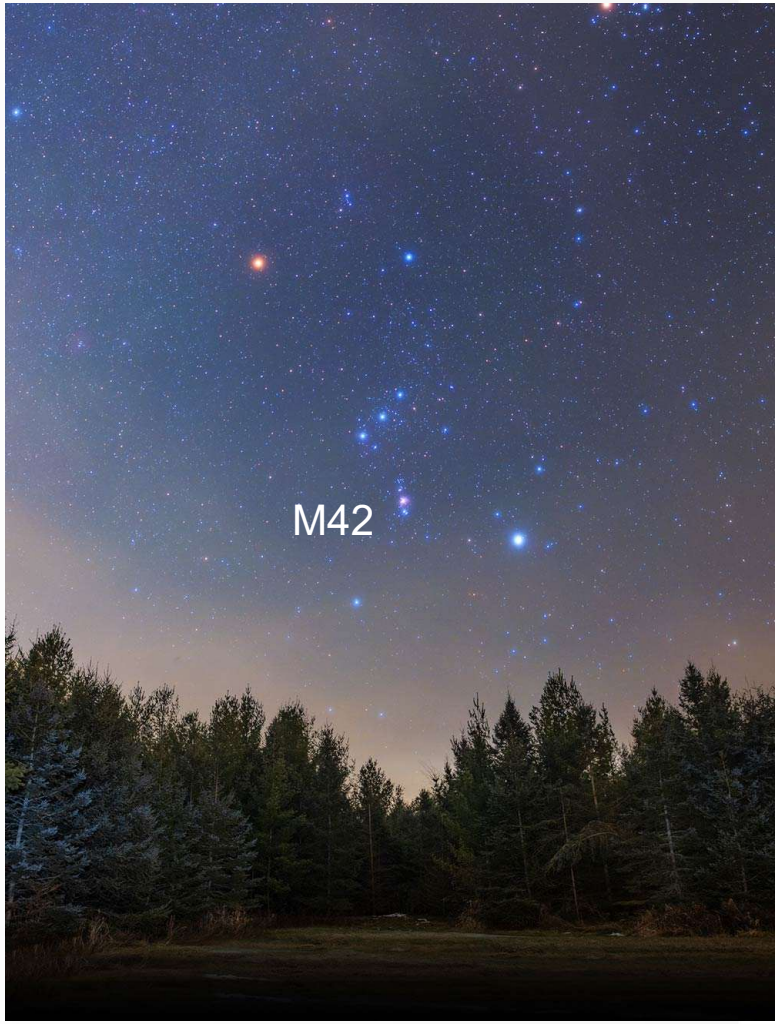
- Early Release Science program PDRs4All:
  - The program aims to obtain the first spatially resolved, high spectral resolution observations of a PDR and provide it to the community
  - Observations obtained with the James Webb Space Telescope (JWST)



The Orion Bar PDR
Habart et al. (2024)

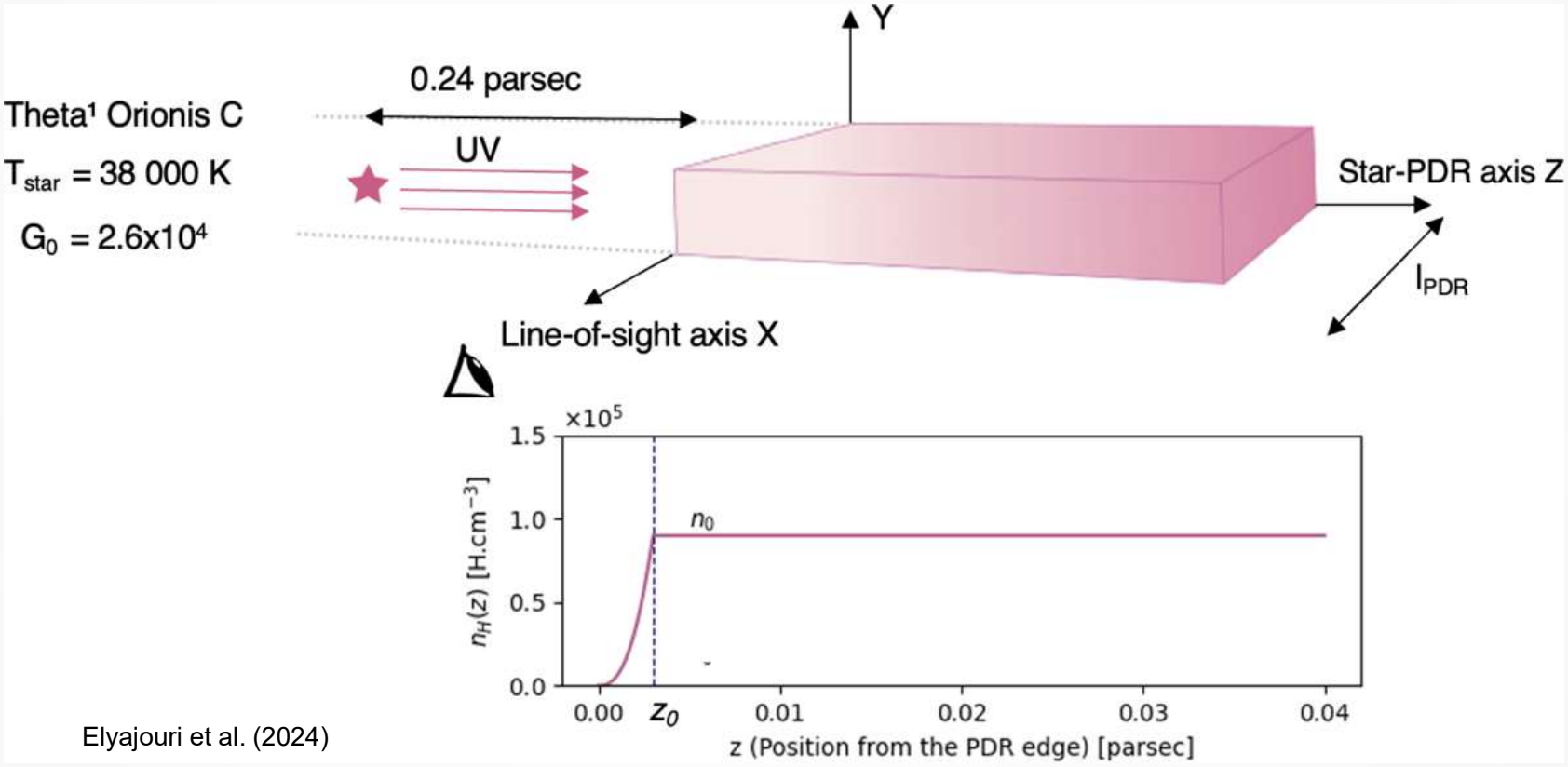
PDRS4AII: THE ORION BAR

- Location: M42 in the Constellation of Orion, the closest site of ongoing massive star formation
- Distance: 414 pc
- With a nearly edge-on geometry→ convenient to study



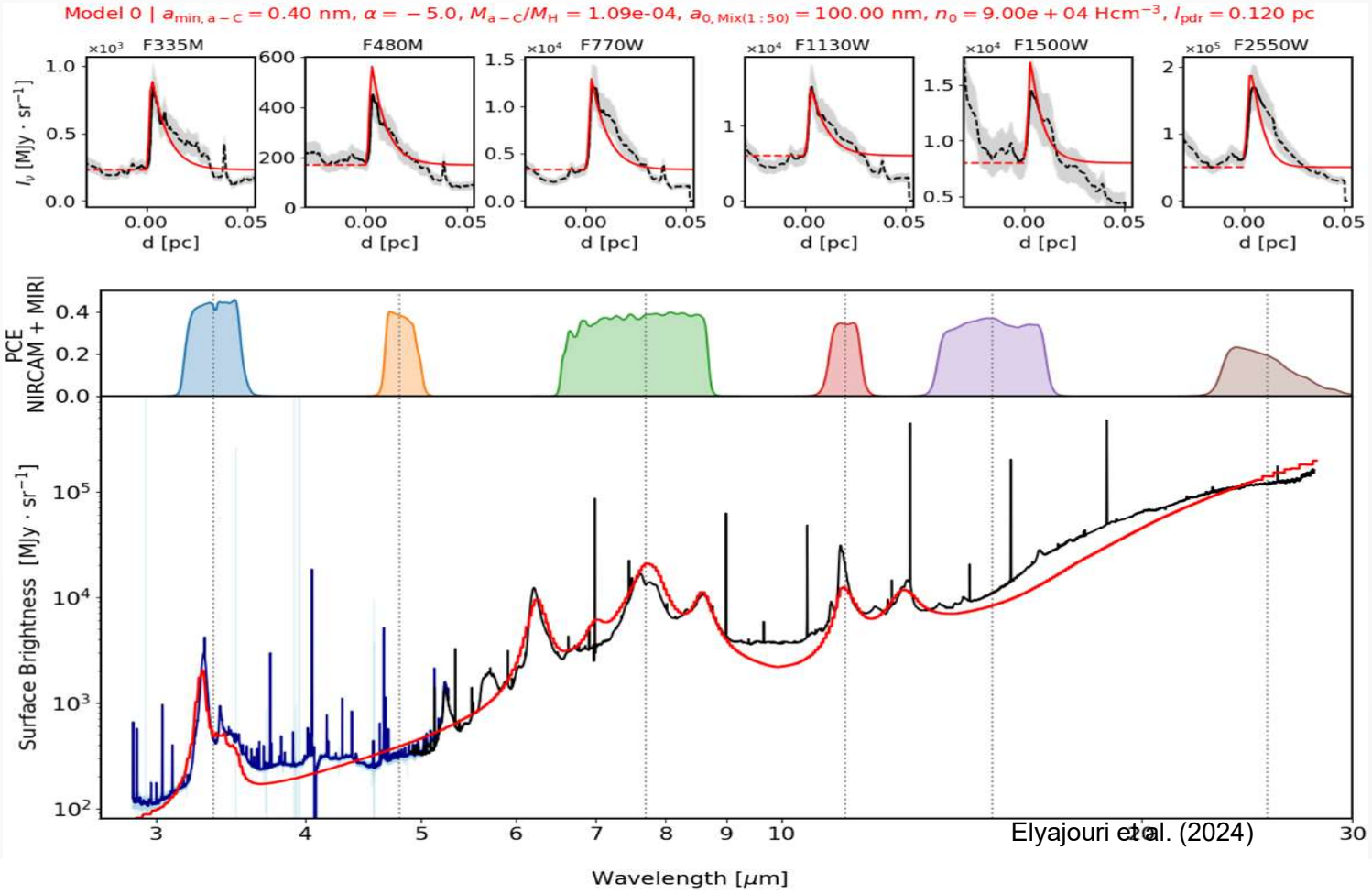
AstroBackyard / Trevor Jones

PDRS4AII: SCHEMATIC ILLUSTRATION OF THE PDR ILLUMINATED BY A RADIATION FIELD



Elyajouri et al. (2024)

PDRS4All: Comparison of the observational data with the results of the model simulations



Elyajouri et al. (2024)

METHODS AND TOOLS

- THEMIS

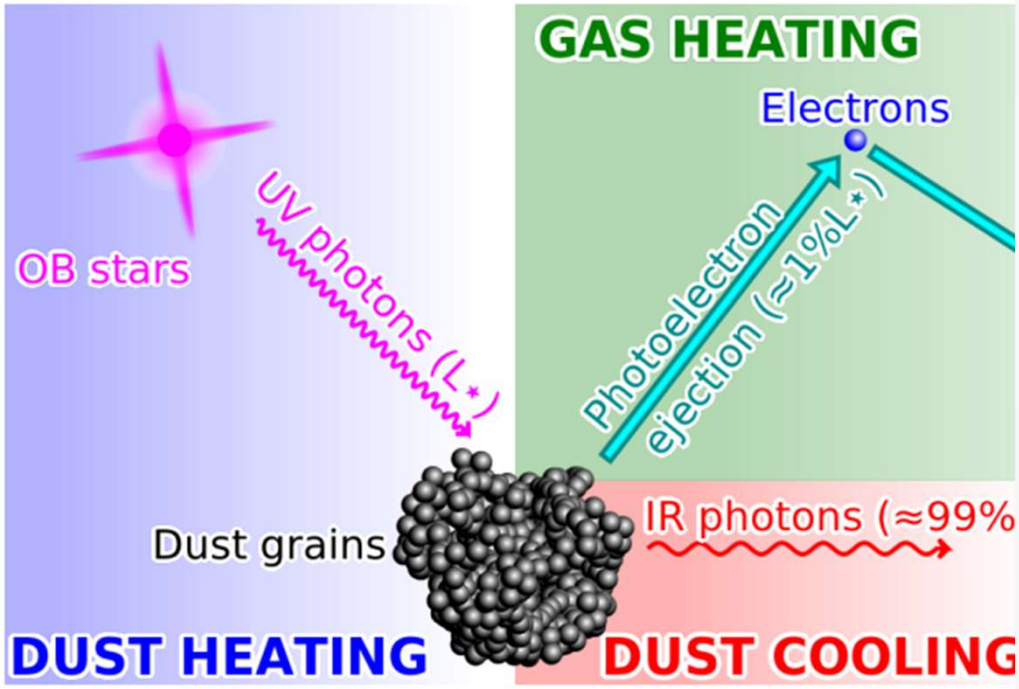
Is a cosmic dust modelling framework within which the dust structure, composition and evolution are determined by the local physical conditions, i.e., density, radiation field, etc.

- DustEM

Predicts the emission and extinction of dust grains based on their size distribution and their optical and thermal properties.

- SOC

The continuum radiative transfer program based on the Monte Carlo method.

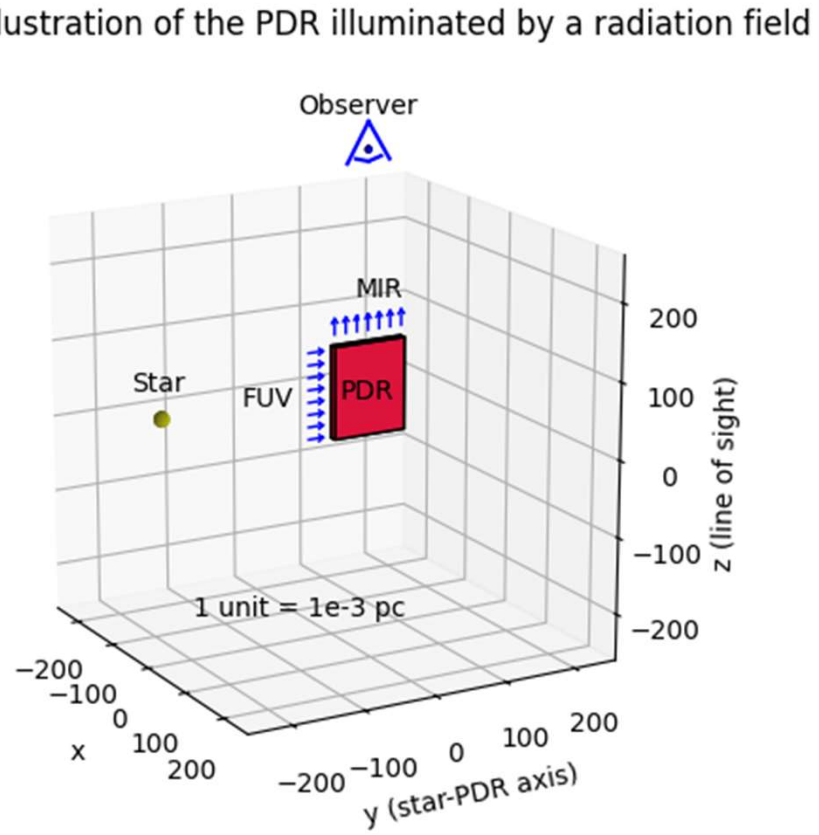


Galliano / CC BY-SA 4.0

THE MODEL

- PDR:
  - The size is X, Y, Z = 20, 100, 200
  - Consists of cube shaped cells

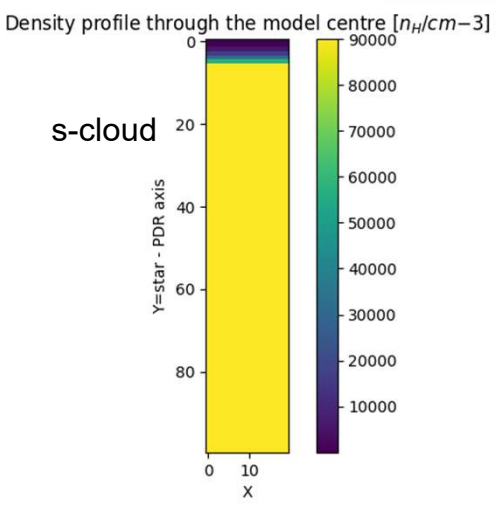
- Star:
  - T=38000 K
  - Star-PDR distance 0.24 pc



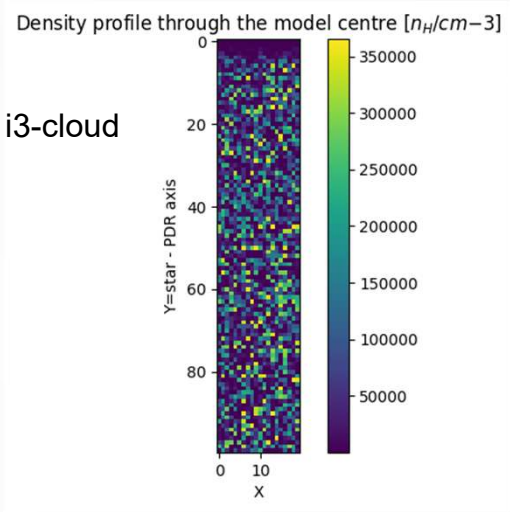
THE MODEL

- Gas models:
  - $n_{H,\,avg}$ = 90 000/cm^3
  - Homogeneous /Smooth (s-cloud)
  - Random inhomogeneous (i-cloud)
  - Power spectrum inhomogeneous (f-cloud)

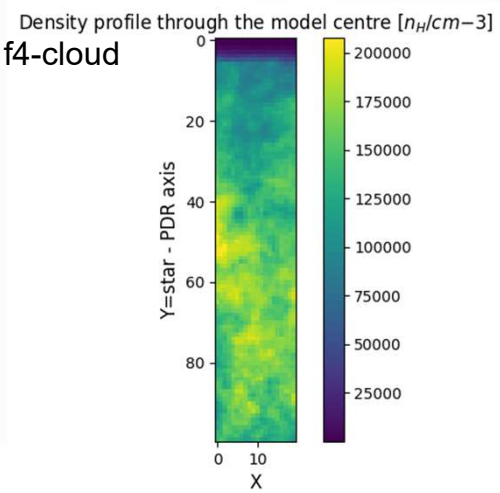
s-cloud



i3-cloud



f4-cloud

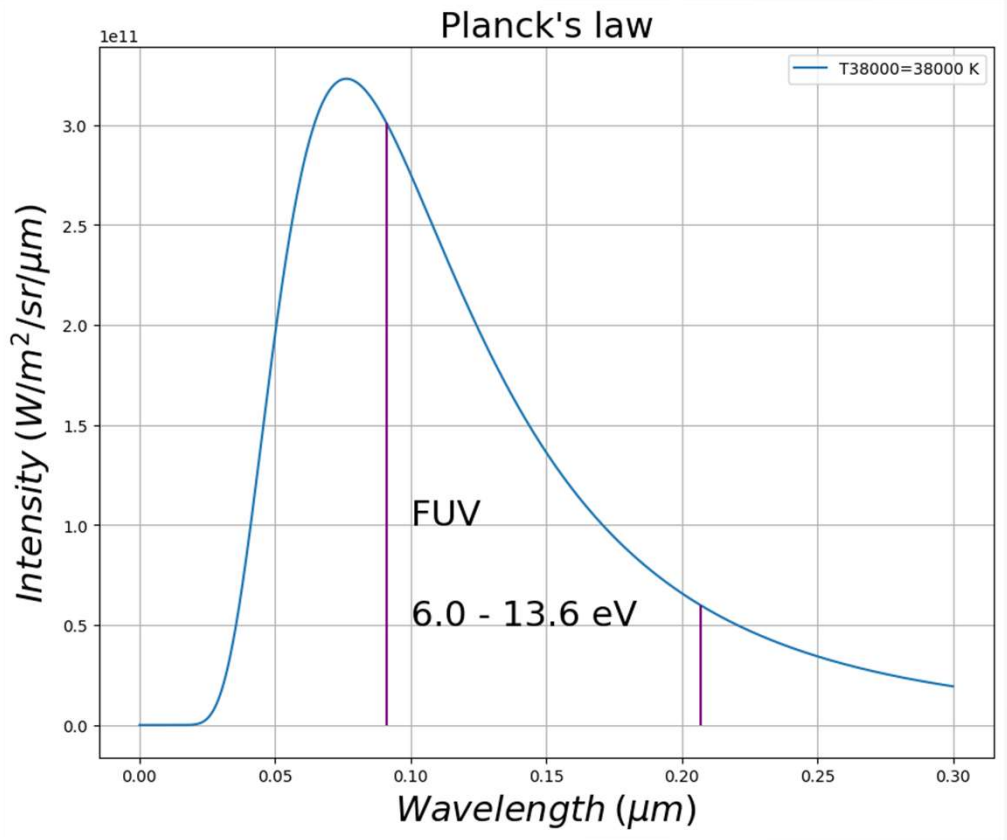


THE MODEL

- Radiation field:

- Modelled by a T=38 000 K blackbody.
- By the edge of the PDR photons have energies below 13.6 eV.
- Incident FUV–radiation field G_0=4.5*10^4 in Habing units.

(G_0 corresponds integral energy density over energies 6.0-13.6 eV. 1 Habing unit = 5.29*10e-14 erg/cm^3)



RESULTS: EFFECT OF THE DUST COMPOSITION

- Dust models:

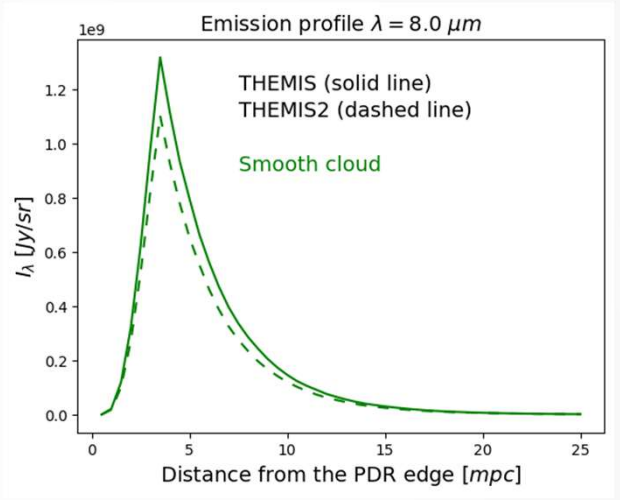
  THEMIS:

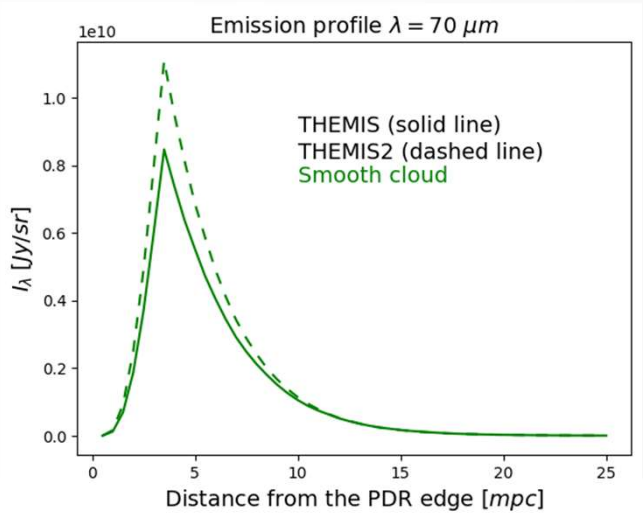
  Hydrogenated amorphous carbon material (a-C:H) and amorphous silicates (a-Sil).

  THEMIS2:

  The optical properties of THEMIS are updated and the polarised extinction and emission calculation allowed.

- Dust emission profile of THEMIS is higher than that of THEMIS2 at short wavelengths. At longer wavelengths it is the opposite.

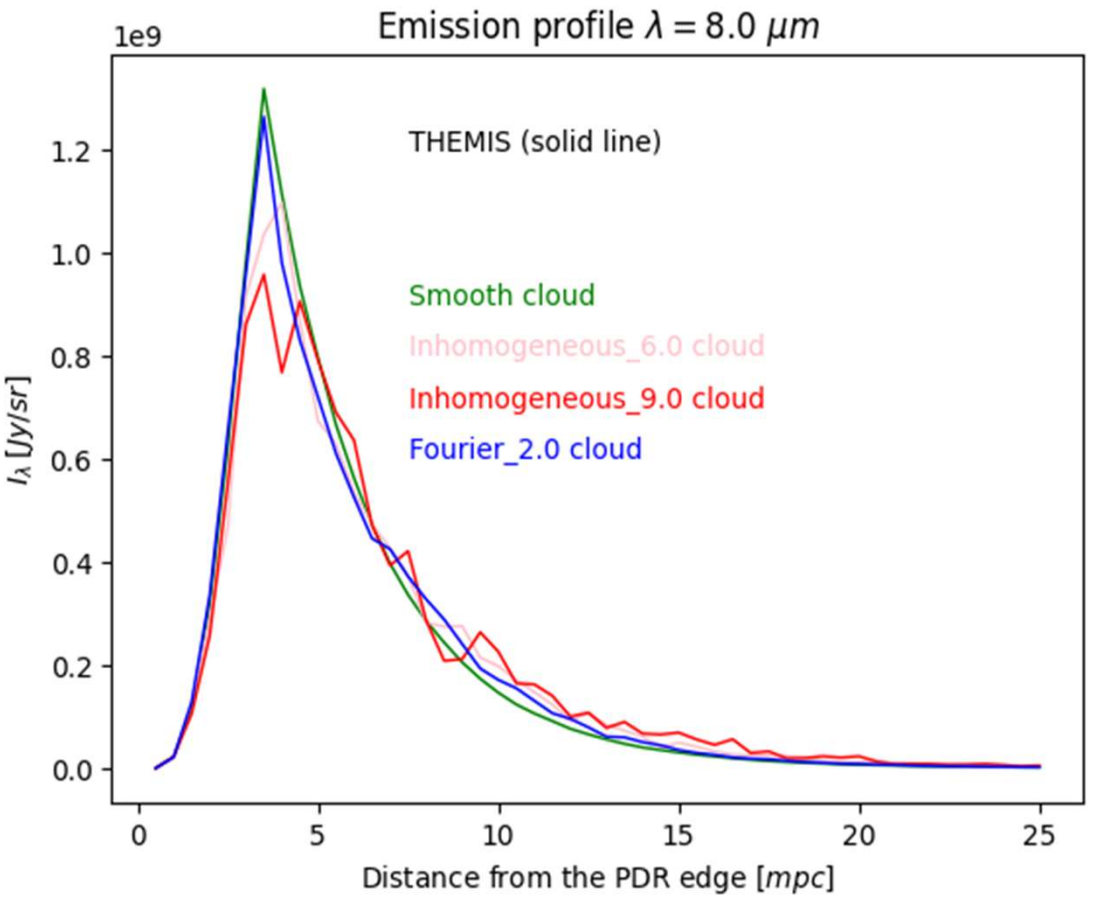




RESULTS: EMISSION PROFILES

- Effect of inhomogeneities observed on emission profiles:

- Peak at 0.003 pc (620 AU) has lower values.
- Arbitrary variation in the decaying part of the curve.
- Somewhat higher values in the decaying part of the curve.

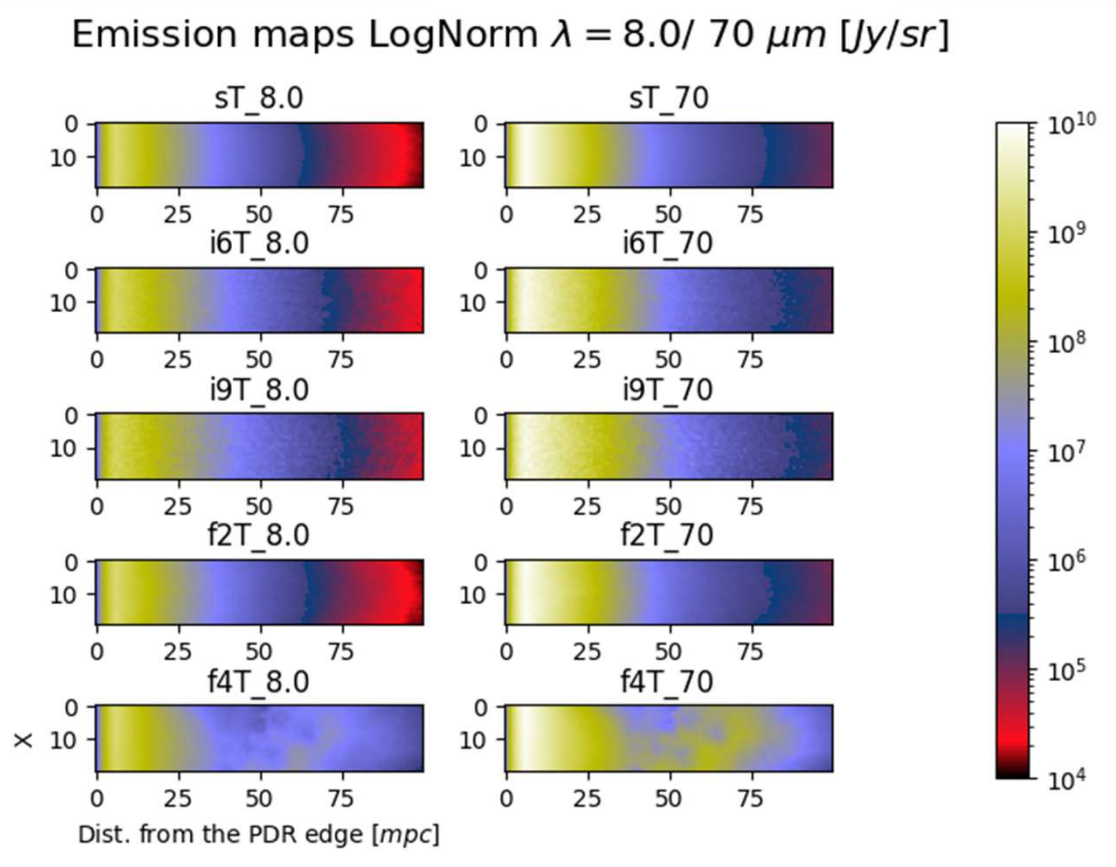


RESULTS: EMISSION MAPS

- Effect of inhomogeneities observed on emission maps:

- In general emission at MIR (5-30 μm) wavelengths is weaker than at FIR (50- μm) wavelengths.

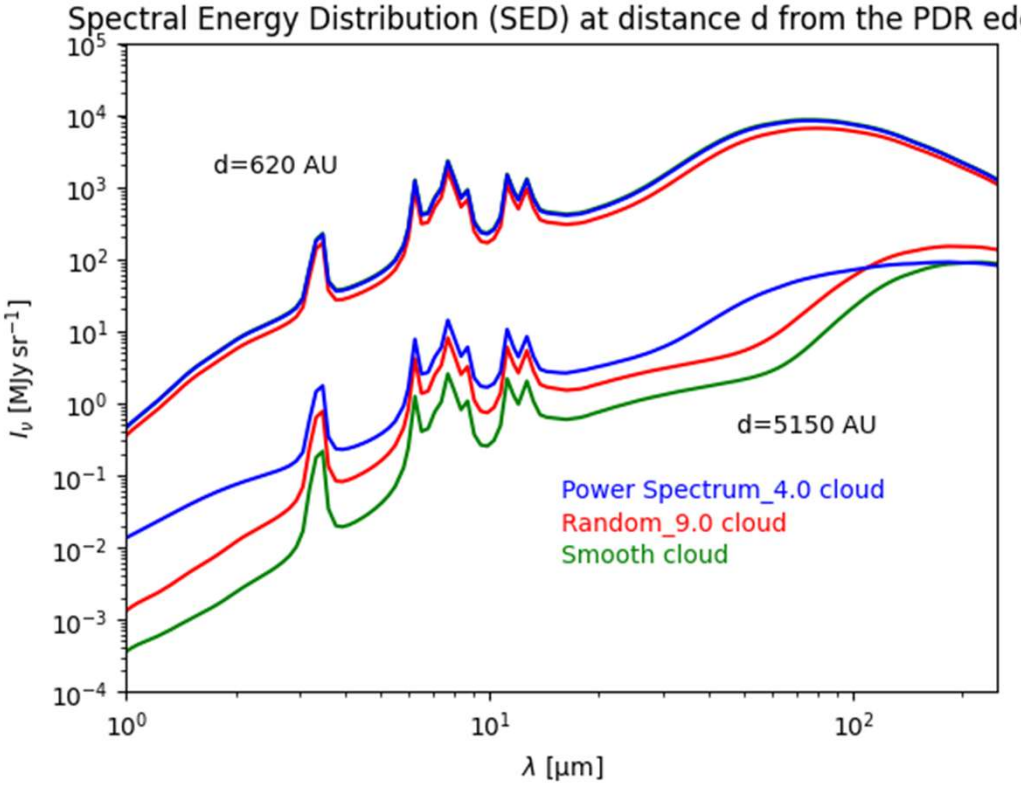
- In f4T model it is clearly seen that further away from the PDR edge IR-emission of the inhomogeneous medium is stronger than that of the homogeneous medium.



RESULTS: DUST EMISSION SPECTRAL ENERGY DISTRIBUTION (SED)

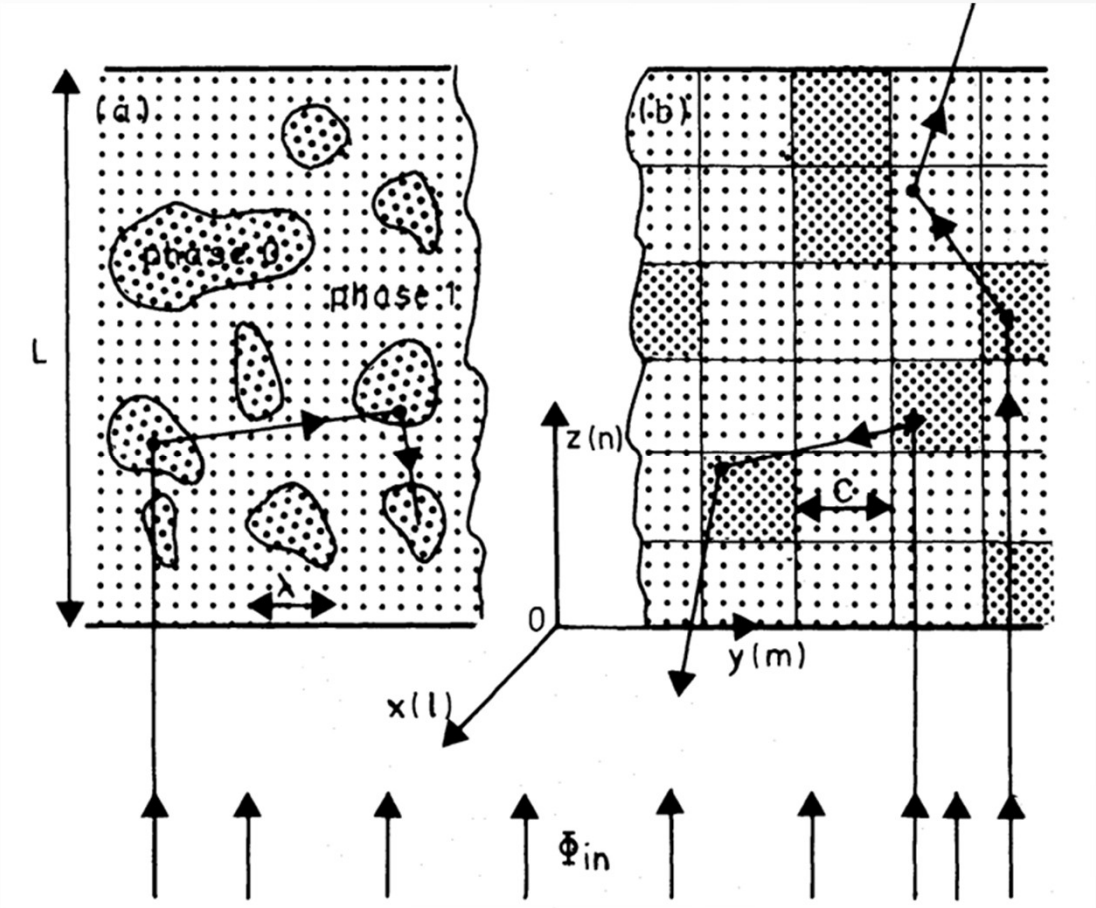
- Effect of inhomogeneities observed on SED:

- Near the PDR edge emission of the homogeneous medium is higher than that of the inhomogeneous medium.
- Further away from the PDR edge emission of inhomogeneous medium is higher than that of the homogeneous medium.



DISCUSSION

- The inhomogeneity of the medium in the PDRs affects the infrared observations.
- When constraining the properties of dust by comparing the results of model simulations with the space telescope observations the accuracy of the dust models is improved when the inhomogeneity of the medium is considered.



Density distribution in analytical model (left) and in Monte-Carlo simulation (right). Dark areas represent the dense phase. P. Boisse 1990

SUMMARY

- Photon dominated regions (PDRs) are located at the boundaries of the molecular clouds, which are under the influence of the far-ultraviolet (FUV) radiation from nearby massive stars
- IR-radiation originates in dust grains as they re-radiate the absorbed FUV radiation as thermal emission in the infrared range
- Thermal dust emission continuum is examined by performing 3D numerical simulations with the radiative transfer program SOC
- The inhomogeneity of the medium in the PDRs affects the infrared observations
- When constraining the properties of dust by comparing the results of model simulations with the space telescope observations the accuracy of the dust models is improved when the inhomogeneity of the medium is considered.

THANK YOU FOR LISTENING!
QUESTIONS?

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