PARSEC

Photodissociation Regions with Shocked zones using CLOUDY

Siddhartha, Katherine, Jose, Mabel,
Kumar, Suhail, Rahul, Sathyanarayan

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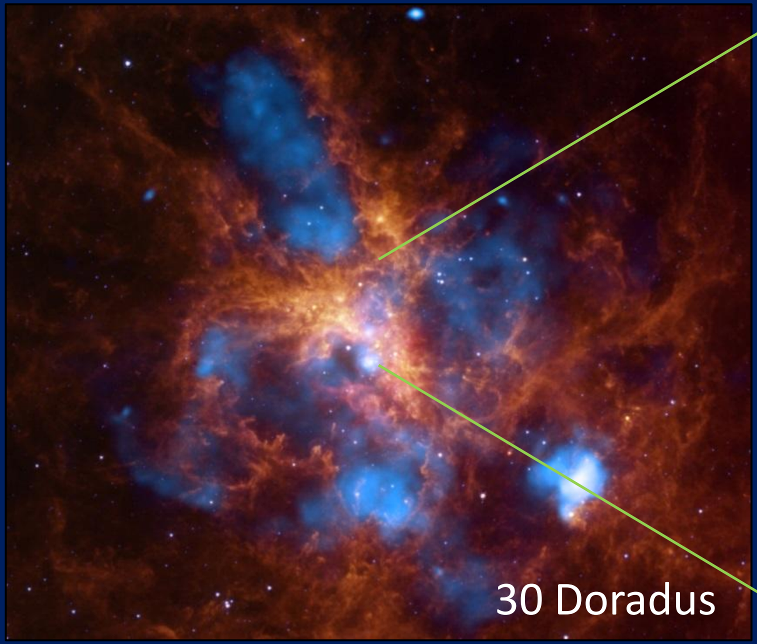
OUTLINE

- Motivation
- Interaction of star (or star cluster) with ISM
- Model to test our ideas
- Results
- Future plans

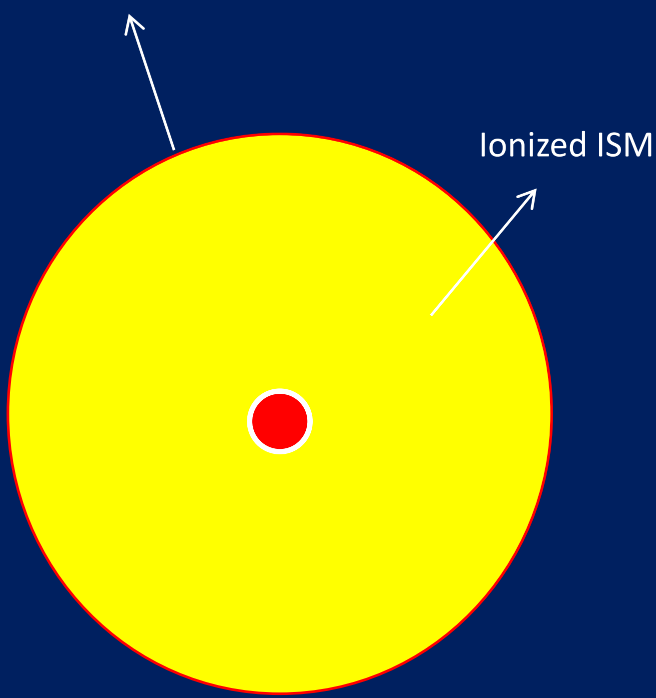
MOTIVATION

- To study how shocks impact the physical structure & chemical abundances of the photodissociation region.
- To build a realistic toy model that can be eventually applied to astrophysical regions of interest.

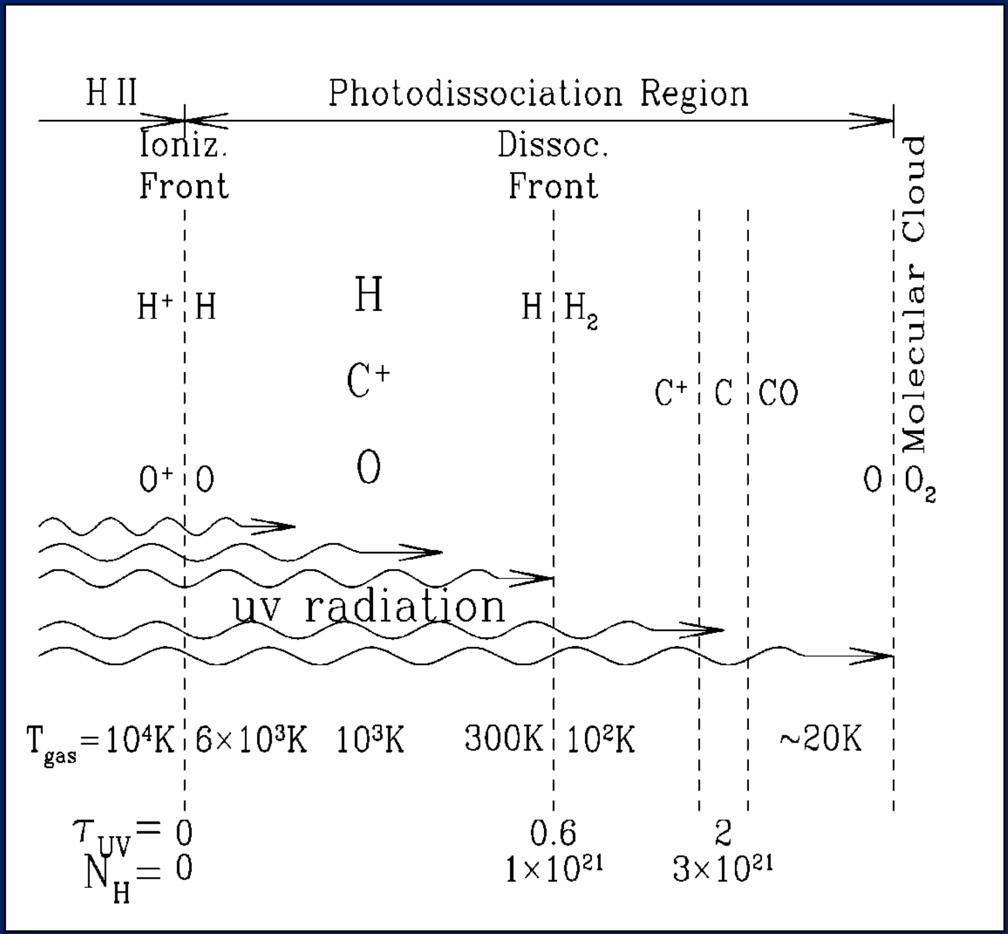


Images courtesy HST

PHOTODISSOCIATION REGIONS

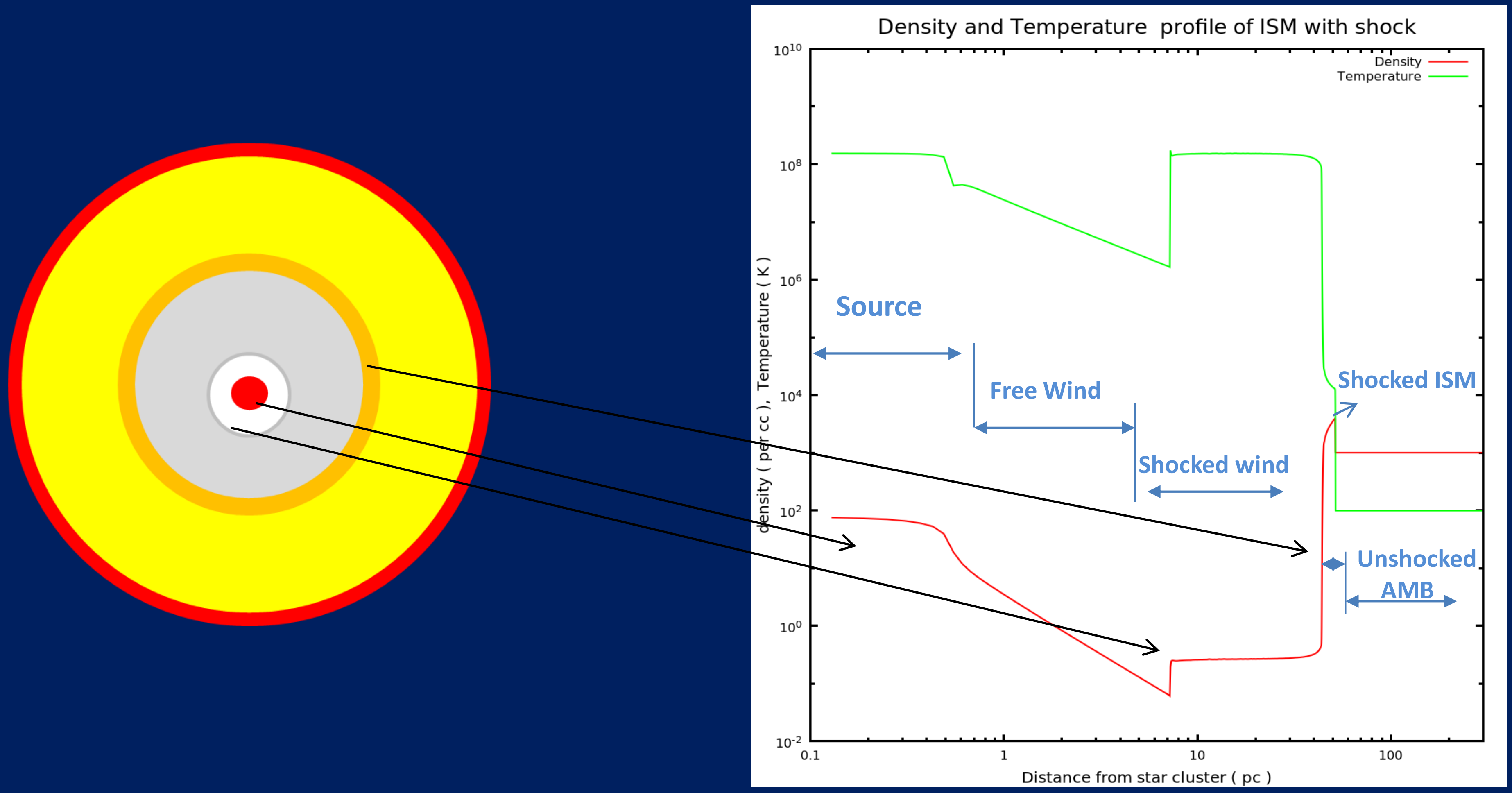


Expansion of ionization front in neutral ISM



Physics of the Interstellar & Intergalactic Medium, Bruce Draine, 2011

SHOCKS



Density and Temperature profile of ISM with shock
Density
Temperature
density (per cc), Temperature (K)
Distance from star cluster (pc)
Source
Free Wind
Shocked wind
Shocked ISM
Unshocked AMB

APPROACH

- Starburst99

  Input: Mass of star cluster, age

  Output: Photon flux, mechanical energy, mass loss rate

- PLUTO

  Input: Mass loss rate, mechanical energy

  Output: Density & temperature profile

- CLOUDY

  Input: Density & temperature profile from PLUTO

  Output: Physical processes, chemical abundances.

PLUTO INPUT PARAMETERS

Mass of star cluster & Age from Starburst99

↓

Parameter	Value
Density	10^3 particles per c.c.
Mass loss rate	10^{-3} $M_\odot$ yr^{-1}
Mechanical luminosity	10^{39} erg s^{-1}
Mass of star cluster	10^5 $M_\odot$
Age	10 Myr.

↓

Density & Temperature profile due to the shock

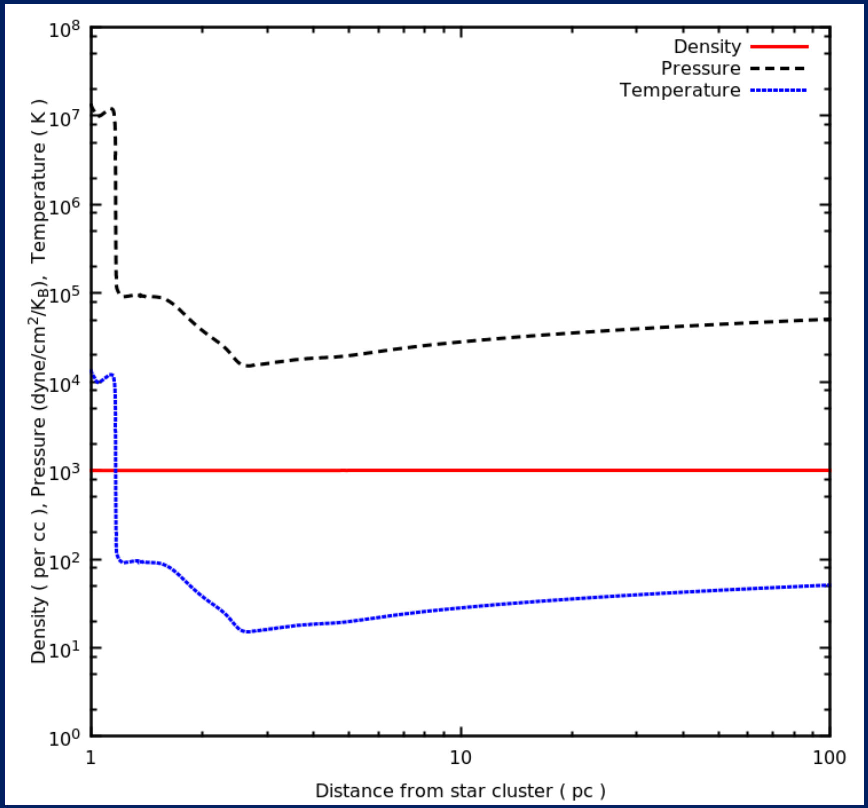
CLOUDY INPUT PARAMETERS

Parameter	Value
Blackbody temperature	10^5 K
Q(H)*	50 photons s^{-1}
Abundances	ISM
Extent	100 pc
Cosmic ray ionization rate	2×10^{-16} s^{-1} (Galactic background)

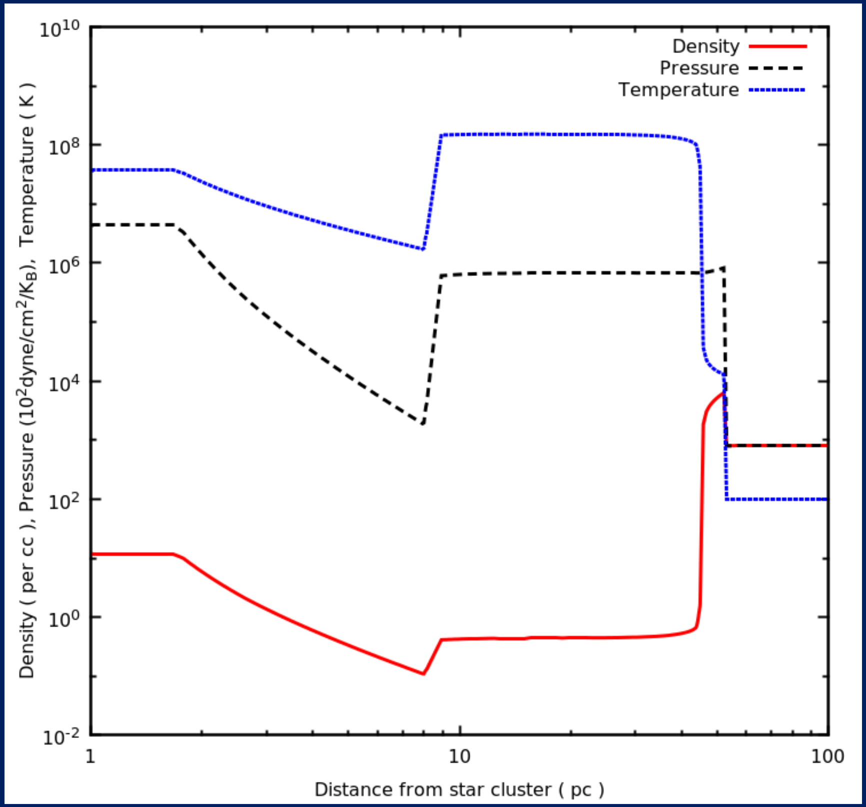
+ Density & Temperature profile from PLUTO

* Log of no. of ionising photons emitted by central object per second

TEMPERATURE & DENSITY PROFILES



Constant density model

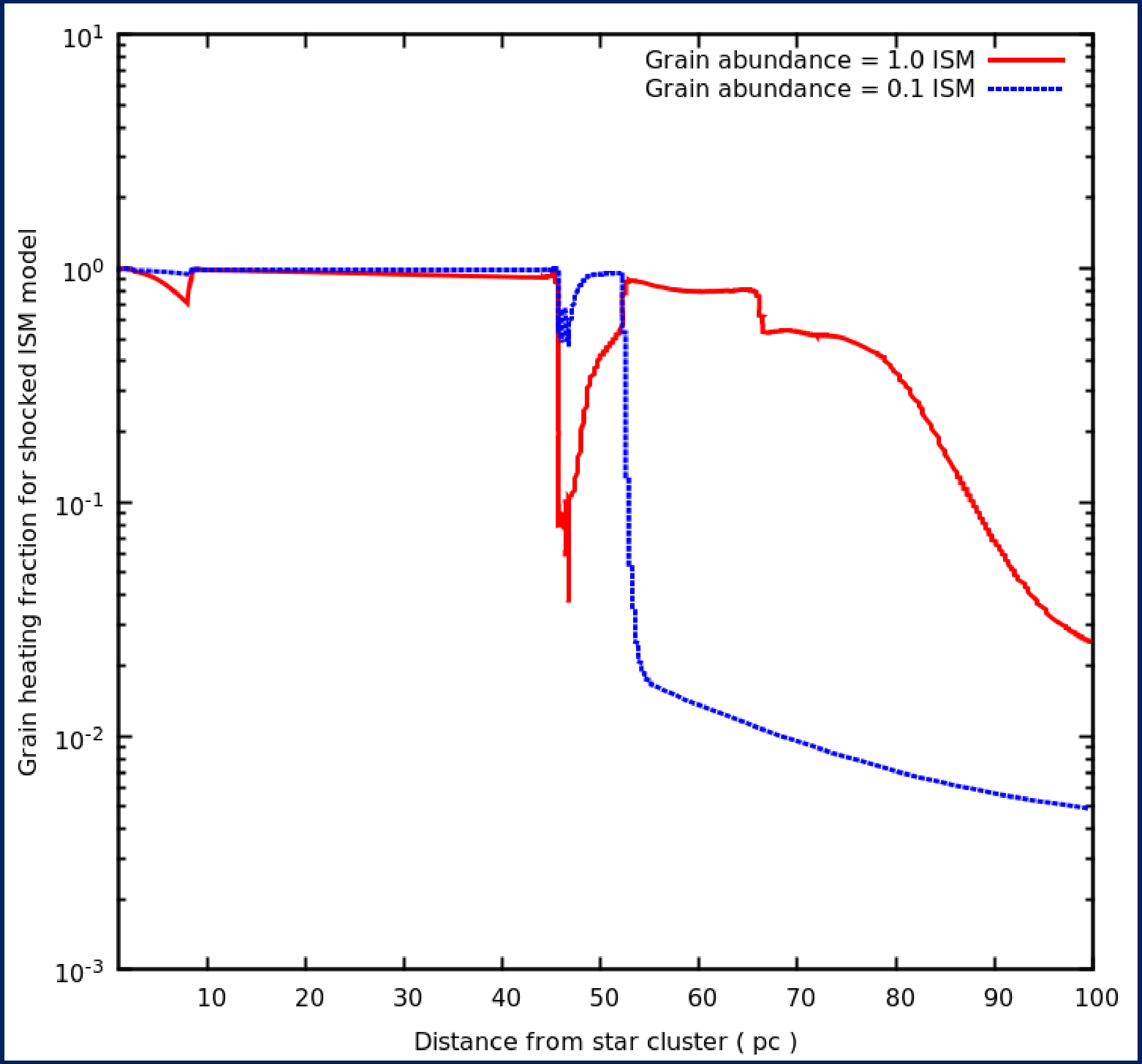


Shock model

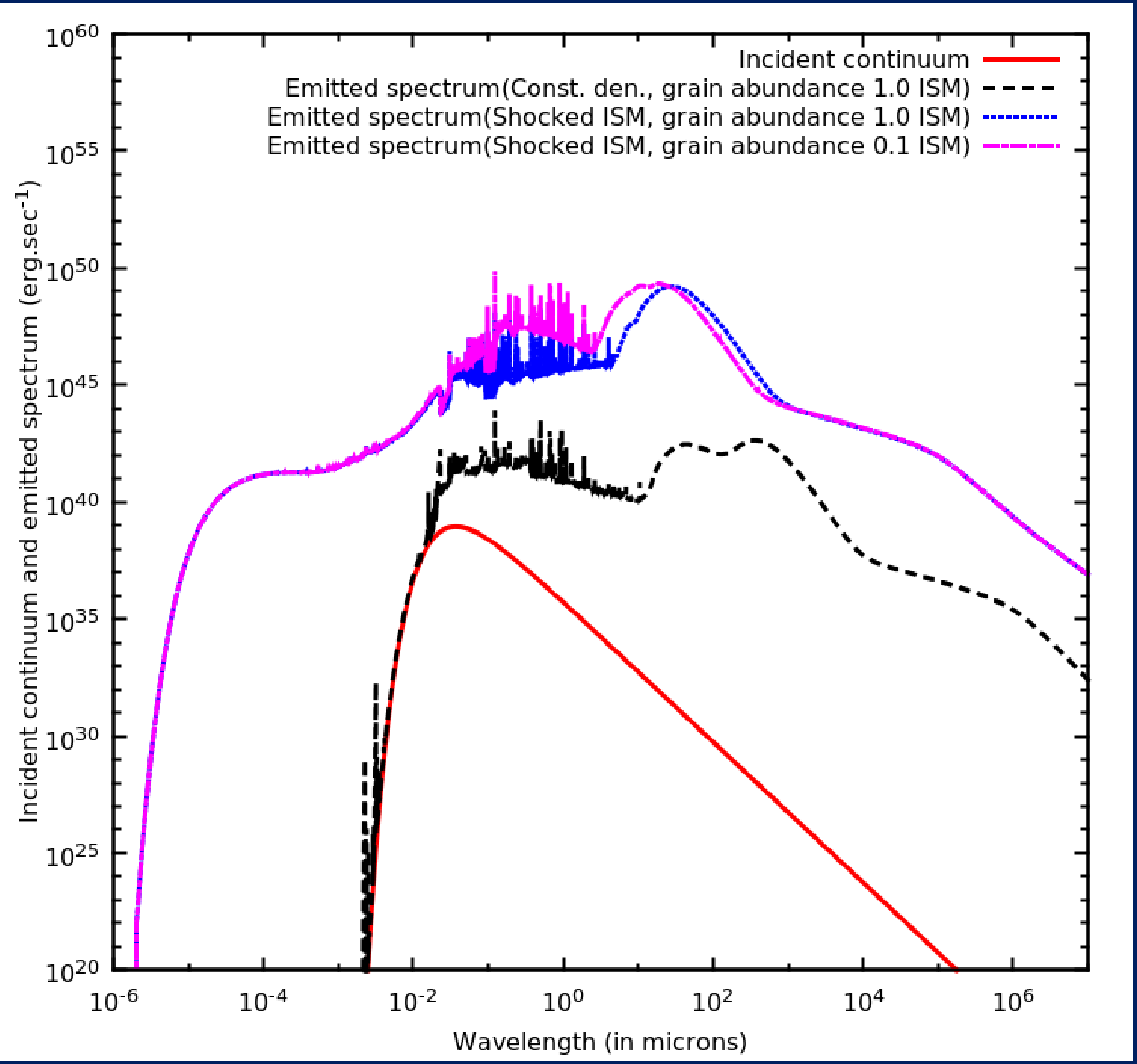
HEATING & COOLING PROCESSES

- Grain photoelectric heating is responsible almost entirely for gas heating in the shock model. For the constant density model, heating due to cosmic rays and photoionization of hydrogen also play an important role.
- Collisional cooling due to hydrogen lines.
- The evolution with depth of individual heating & cooling processes can be studied. We study only the grain photoelectric heating.

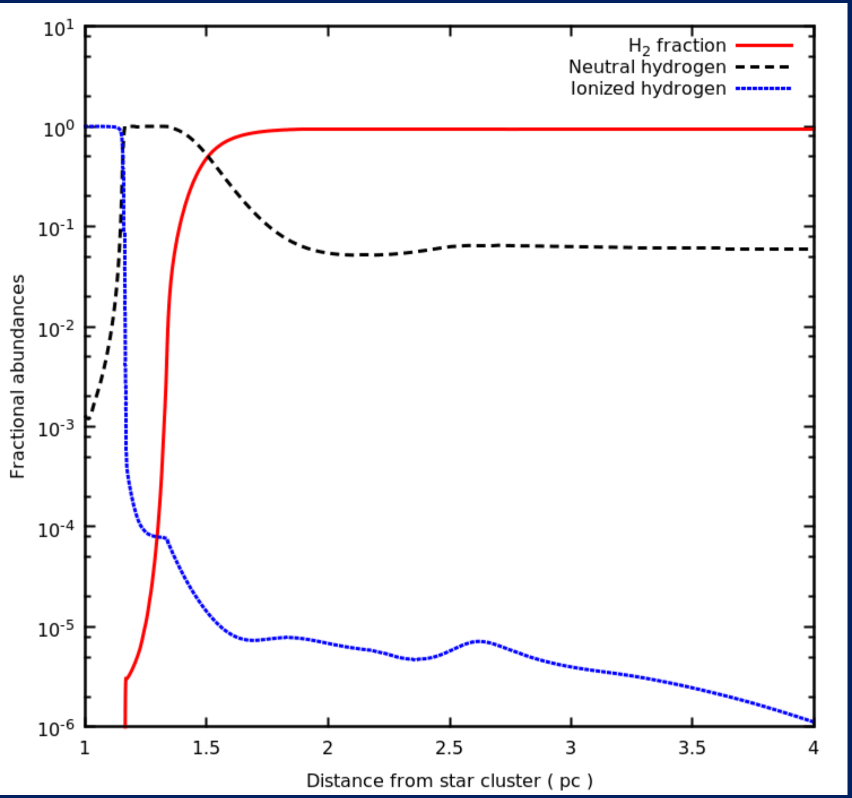
LESSER GRAINS IN SHOCK MODEL



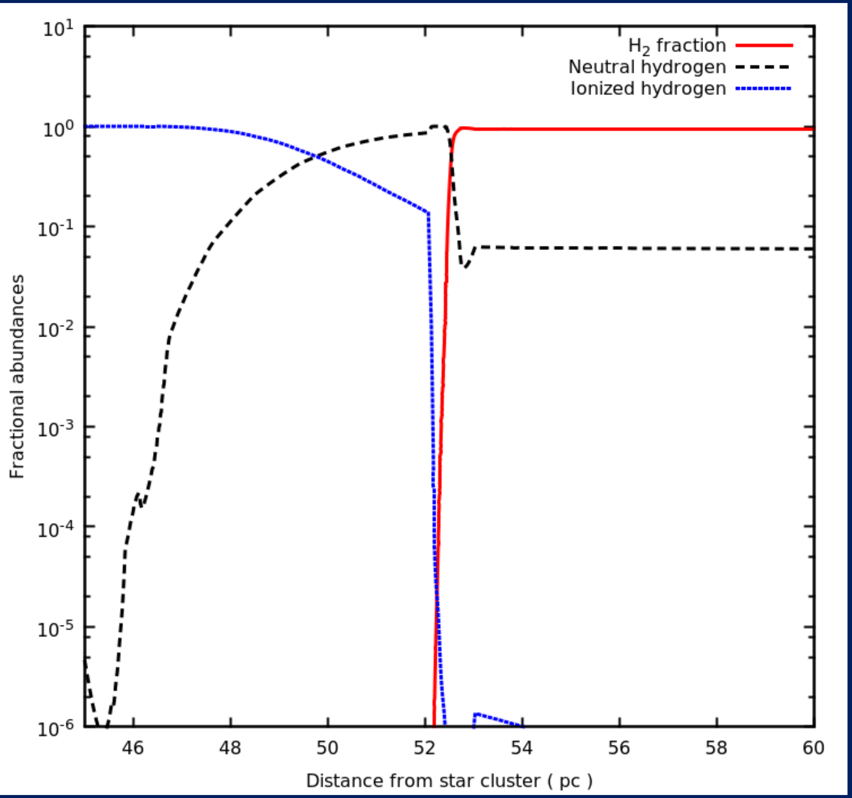
INCIDENT & EMITTED CONTINUA



FRACTIONAL ABUNDANCES

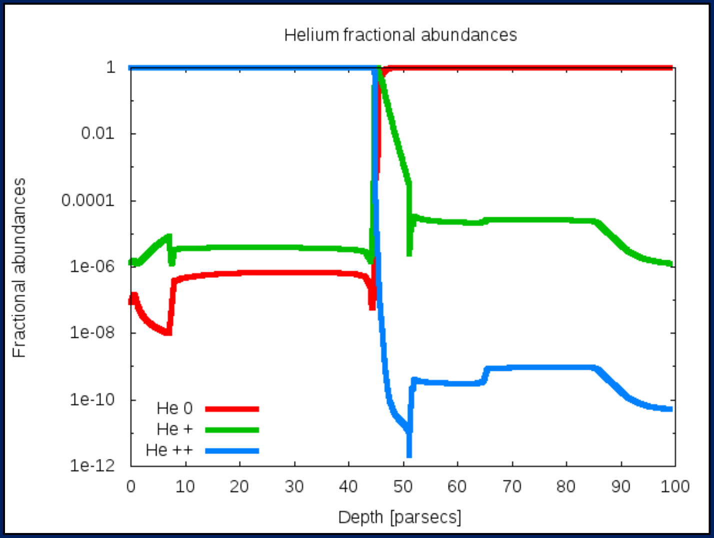


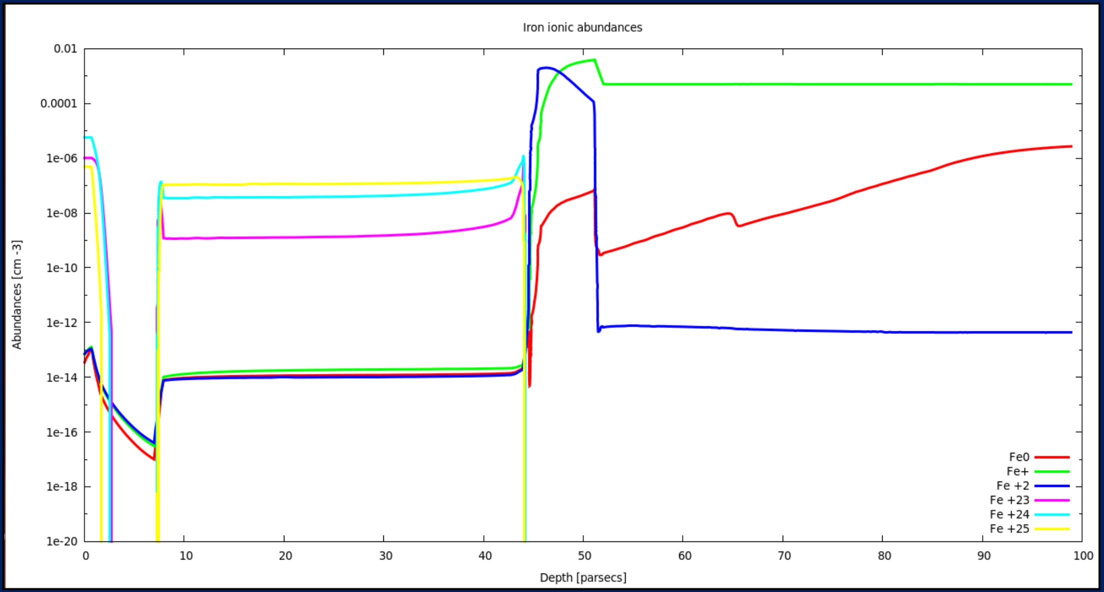
Constant density model



Shock model

ABUNDANCES OF ATOMIC SPECIES

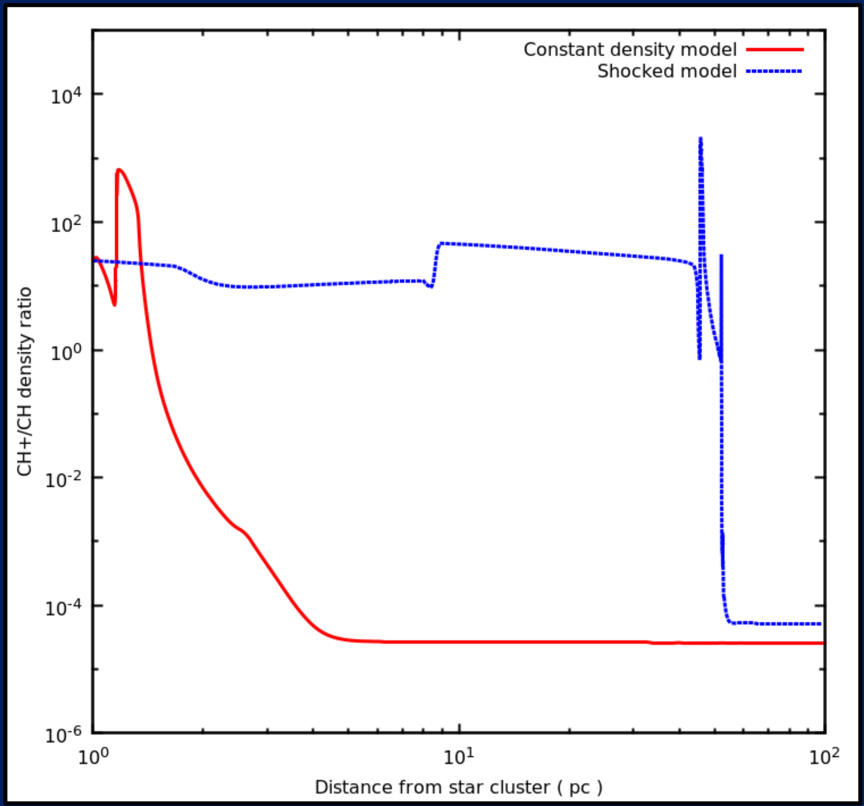




Helium fractional abundances & Iron species densities in various ionization states for the shock model

ABUNDANCES OF MOLECULAR SPECIES

- The shock model suppresses H_2 but enhances CO.
- In constant density case,
  H_2 (0, 0)/H_2: 0.82 ,
  H_2 (0, 1)/H_2: 0.18
- In the shock model,
  H_2 (0, 0)/H_2: 0.42,
  H_2 (0, 1)/H_2: 0.68



CH & CH^+ abundances

SUMMARY

- Shocks push the photodissociation region further away from the central object.
- In the shock model, gas heating is almost entirely through grain photoelectric heating.
- CH^+/CH ratio is higher in the shock model.

FUTURE POSSIBILITIES

- Study the time variability effects of the shock-induced temperature & density profiles on the features of the photodissociation region.
- Apply the model to star formation regions & gamma ray burst environments.

THANKS