Photon-dominated regions

Structure of PDR

- H II
- Photodissociation Region
- Ionization Front
- Dissociation Front
- Molecular Cloud

- H II
- H
- H
- H
- C
- C
- C
- C
- O
- O
- O

- uv radiation
- $T_{\text{gas}} = 10^4 \text{K}$, $6 \times 10^3 \text{K}$, $10^3 \text{K}$, $300 \text{K}$, $10^2 \text{K}$, $\sim 20 \text{K}$
- $\tau_{\text{UV}} = 0$
- $N_H = 0$
- $1 \times 10^{21}$, $3 \times 10^{21}$, $2 \times 10^{22}$
Photon-dominated regions

Constant radius, decreasing metallicity

Constant metallicity, decreasing radius
Photon-dominated regions

relevant heating processes

relative importance of atomic species in heating
Photon-dominated regions

Chemical network of

oxygen and carbon
Photon-dominated regions

Solution scheme of PDR models

\[ \frac{\partial n_i}{\partial t} = -n_i \left\{ \tilde{\xi}_i + \sum_{q} n_q \cdot k_{qi} (T) \right\} + \sum_{r} \sum_{s} k_{rs} (T) \cdot n_r \cdot n_s + \sum_{t} n_t \tilde{\xi}_{ti} \]

\[ \text{destruction} \quad \text{formation} \]

\[ I_{\nu} (\tau_{\nu}) = I_{\nu} (0) e^{-\tau_{\nu}} + \int_{0}^{\tau_{\nu}} e^{-\tau_{\nu}'} S_{\nu} (\tau_{\nu}') d\tau_{\nu}' \]

\[ \sum_{i} \Gamma_i (\vec{r}, \vec{n}, \chi, T) = \sum_{i} \Lambda_i (\vec{r}, \vec{n}, \chi, T) \]

\[ \text{heating} \quad \text{cooling} \]
Photon-dominated regions

PDR properties as a function of radiation field and density
Photon-dominated regions

PDR properties as a function of radiation field and density
Photon-dominated regions

prototypical PDR: „Orion bar“
Photon-dominated regions

Orion bar

blue: PAH

red: CO

green/yellow: H$_2$

Intensity of vibrational line of H$_2$ observed in white box
Photon-dominated regions

Telescopes to study PDRs: SOFIA

- 2.5-m telescope
- $\sim 1 \, \mu m \ldots 600 \, \mu m$
- altitude: 41000 ft. = 14300 m
- operation: $\geq$ end of 2008
Telescopes to study PDRs: Herschel

- 3.5-m telescope
- ~ 60 µm ... 670 µm
- 2nd Lagrange point of sun-earth system
- launched in May (together with Planck)
- operation: ~ 3 years
Photon-dominated regions

Spitzer image of DR21 star forming region in false colours (IRAC 5.8 \(\mu\)m in blue and 8.0 \(\mu\)m in green, and MIPS 24 \(\mu\)m in red), the green reveals the emission from large molecules.

Blue and red boxes: areas that have been surveyed for ionized carbon C\(^+\) at 1900 GHz.

The broad line at the position of the newly formed star (in red) reveals the presence of a powerful wind ripping the cloud apart. In contrast, the off-star position (in blue) shows emission from quiescent material, which has not (yet) been disturbed by this star.

Yellow stripe: region studied in lines of water (H\(_2\)O (1\(_{11} \rightarrow 0_{00}\)) at 1113 GHz, right) and carbon monoxide (\(^{13}\)CO (10 \(\rightarrow\) 9) at 1101 GHz, left) by HIFI.