3Ducl_pdr: A new three-dimensional algorithm for treating HII/PDR complexes.

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OVERVIEW OF THE CODE

Code based on the fully benchmarked one-dimensional UCL_PDR (Bell et al. 2006).

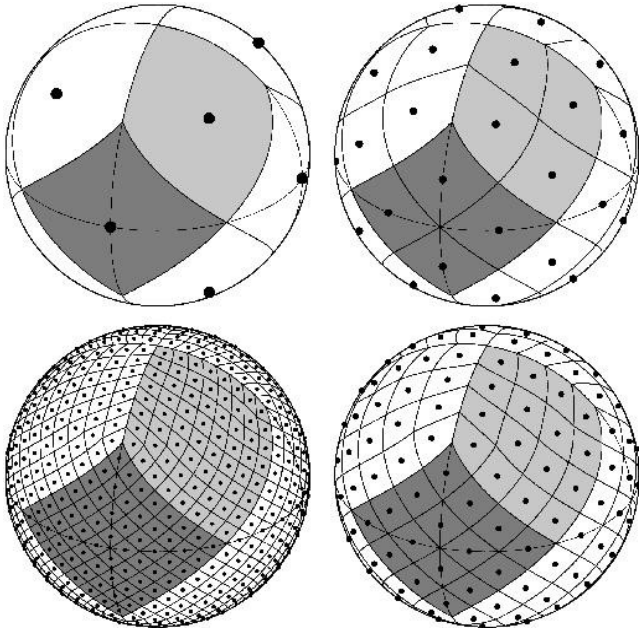
Solves the chemistry and thermal balance self-consistently in any given three-dimensional cloud of arbitrary density field.

The code uses a ray-tracing scheme based on the HEALPix package (Gorski et al. 2005) to calculate the total column densities and thus to evaluate the propagation of the UV radiation into the region, and the FIR/submm line emission out of the region.

An iterative cycle then begins in order to calculate the cooling and heating rates and to determine the gas temperature at which the thermal balance criterion is satisfied.

At each element within the cloud, it performs a depth- and time- dependent calculations of the abundances for a given chemical network.

HEALpix



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

Rays

Level of refinement

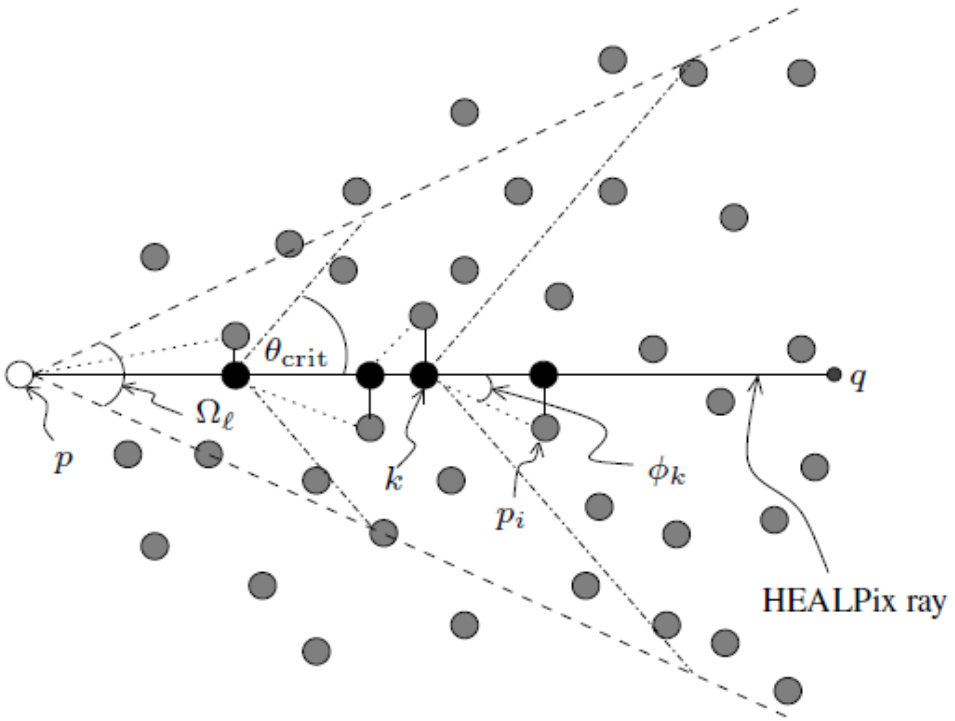
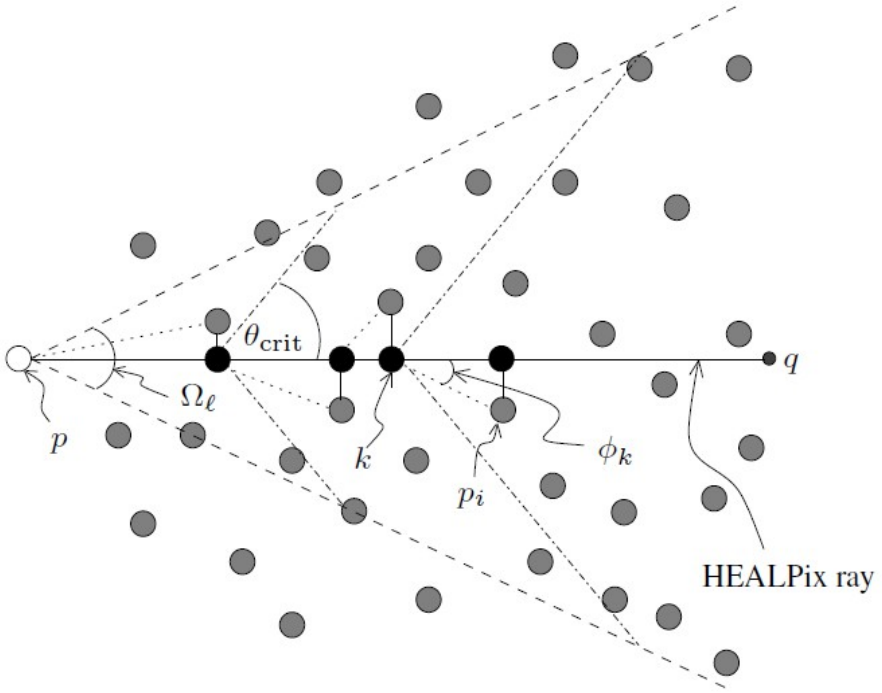


Figure 1. This figure illustrates how evaluation points are created in 3DUCL_PDR. Gray-filled circles are the elements of the cloud. The white circle on the left represents the element p from which a HEALPix ray (solid line) emanates. Dashed lines show the extent of solid angle Ω_ℓ. Black dots are the evaluation points. Dot-dashed lines show the extent of the search cone which has as vertex the k-th evaluation point and apex angle $2\theta_{\rm crit}$ ($0 < \theta_{\rm crit} \leqslant \pi/2$ is user-defined). The projection of an element p_i on the HEALPix ray will be taken if $\phi_k \equiv \widehat{p_i k q} \leqslant \theta_{\rm crit}$, where q is the HEALPix pixel, creating a new evaluation point. Every new evaluation point defines the vertex of the new search cone which however keeps the same apex angle in a sense that the cone 'moves' in parallel as we walk along the HEALPix ray.

Three-dimensional escape probability



$$\beta_{ij} = \int_0^\infty \frac{d\Omega}{4\pi}\left[\frac{1-e^{-\tau_{\rm L}}}{\tau_{\rm L}}\right]$$

$$\int_0^\infty \frac{d\Omega}{4\pi} = \frac{1}{\mathcal{N}_\ell}\sum_{q=0}^{\mathcal{N}_\ell}[\texttt{HEALPix}]$$

$$\beta_{ij}(p) = \frac{1}{\mathcal{N}_\ell}\sum_{\mathbf{q}=0}^{\mathcal{N}_\ell}\left[\frac{1-e^{-\tau_{ij}(\mathbf{q})}}{\tau_{ij}(\mathbf{q})}\right]$$

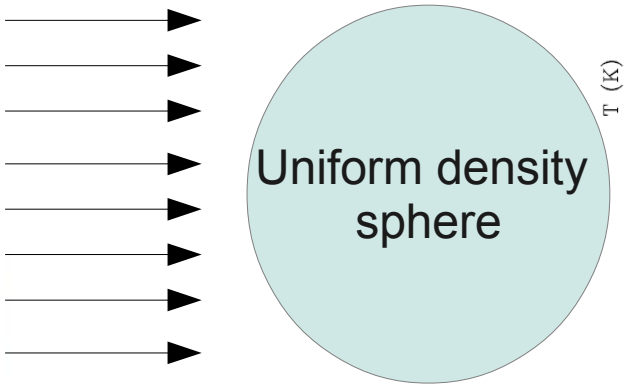
$$\tau_{ij}(\mathbf{q}) = \frac{A_{ij}c^3}{8\pi\nu_{ij}^3\Delta u(p)}\sum_{k=1}^{k_{\rm TOT}}\left[\frac{n_j(k)g_i - n_i(k)g_j}{g_j}\right]\Delta r$$

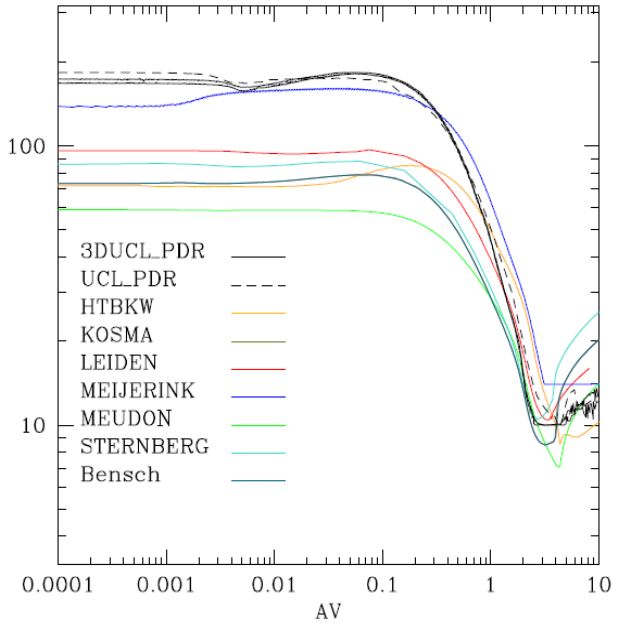
Adaptive step

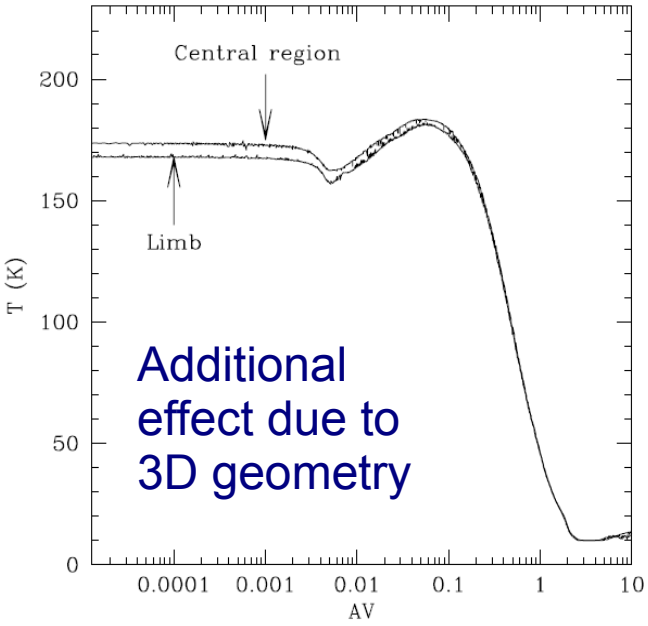
$$\Delta r = |r_k - r_{k-1}|$$

Model V1 in 3D

$n=10^3$ cm^{-3}, χ=10 Draine

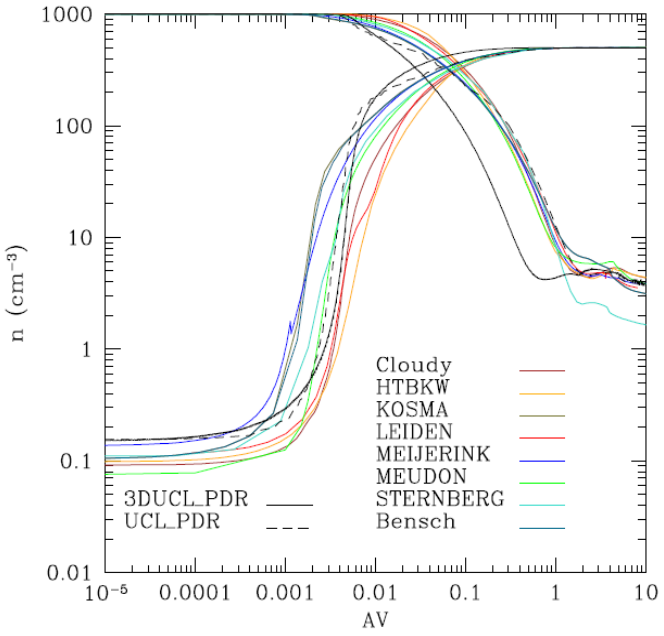


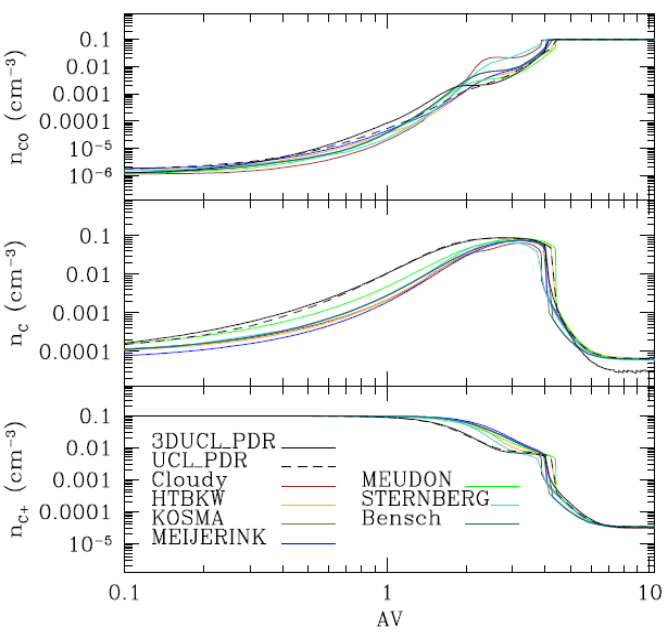




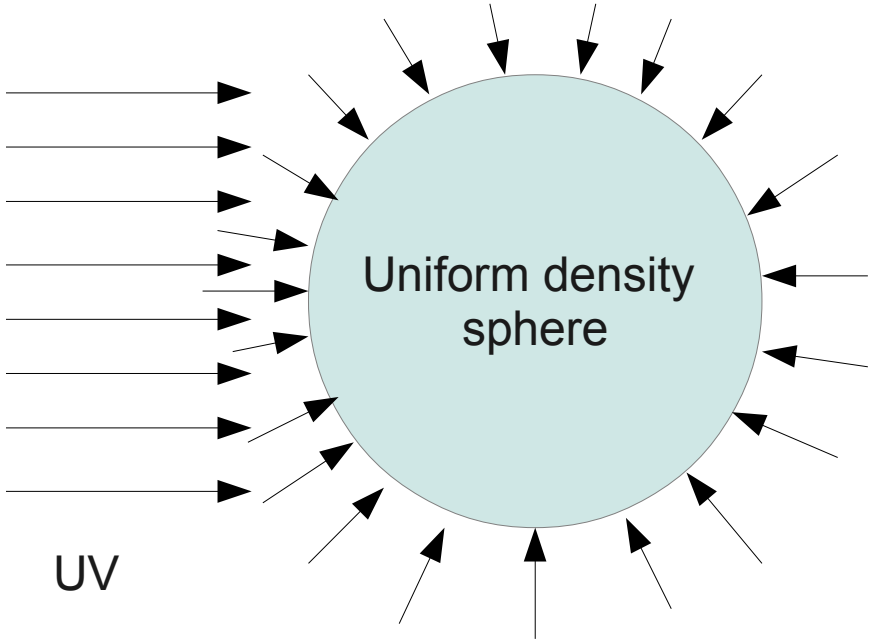
Additional effect due to 3D geometry

Very good agreement with the 1D codes for all V1-V4 models.

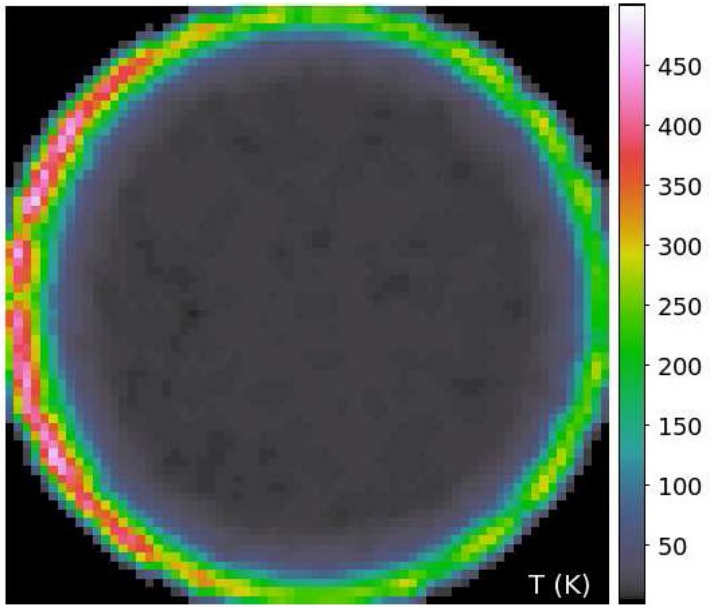




Multi-UV field application

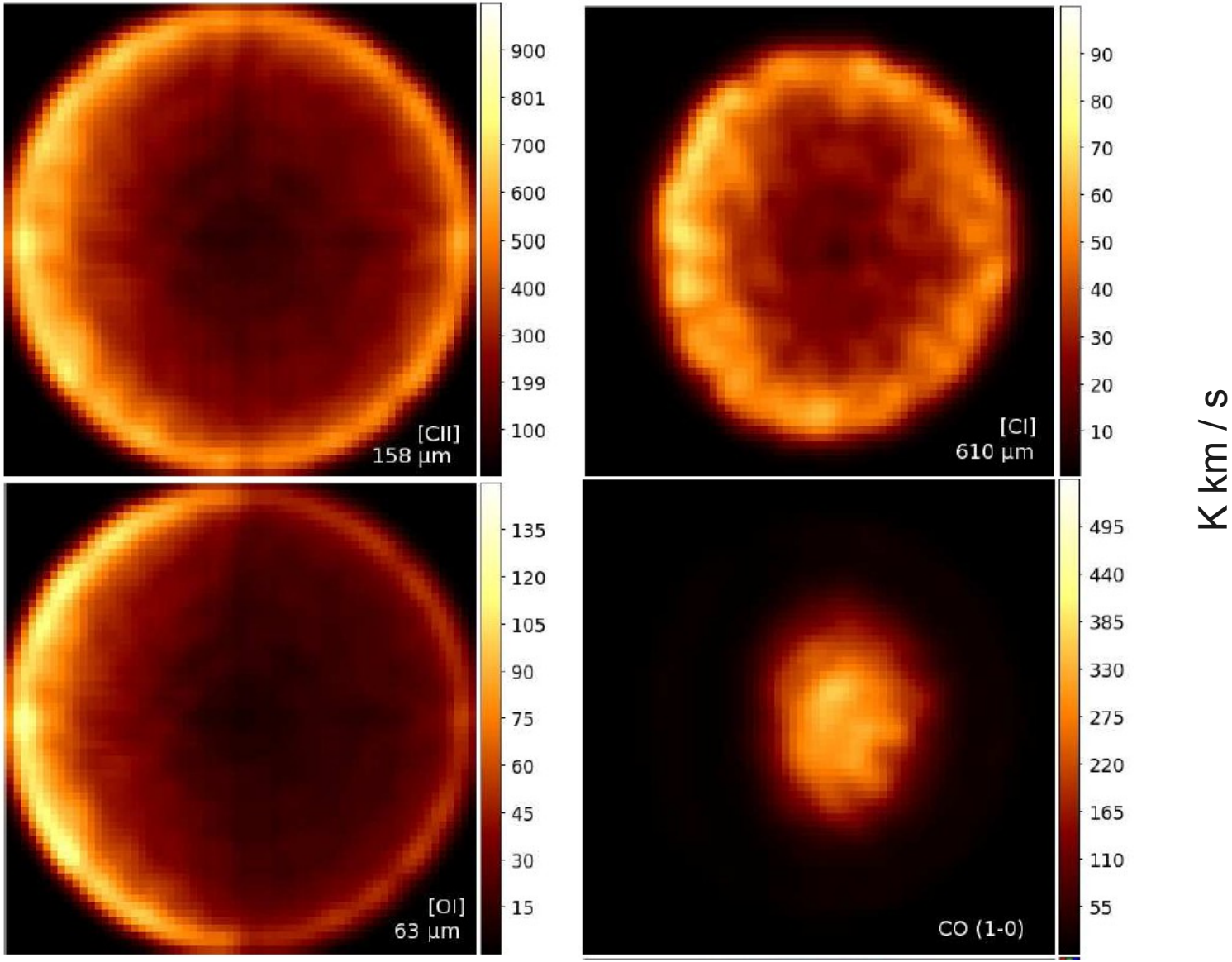


n=5x10^3 cm^{-3}, χ_{ISO}=150 Draine, χ_{UNI}=2000 Draine



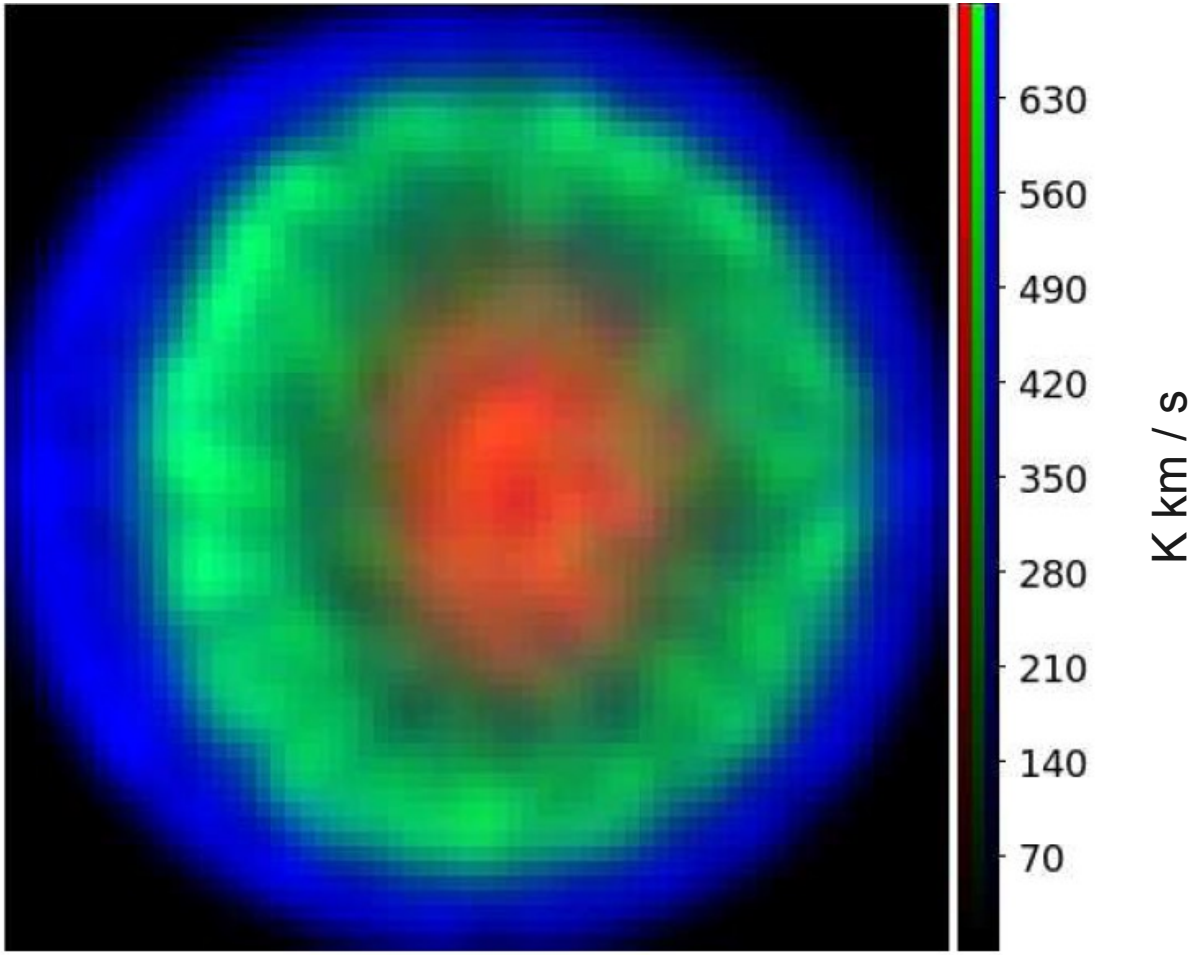
Cross section of the surface temperature

Multi-UV field application



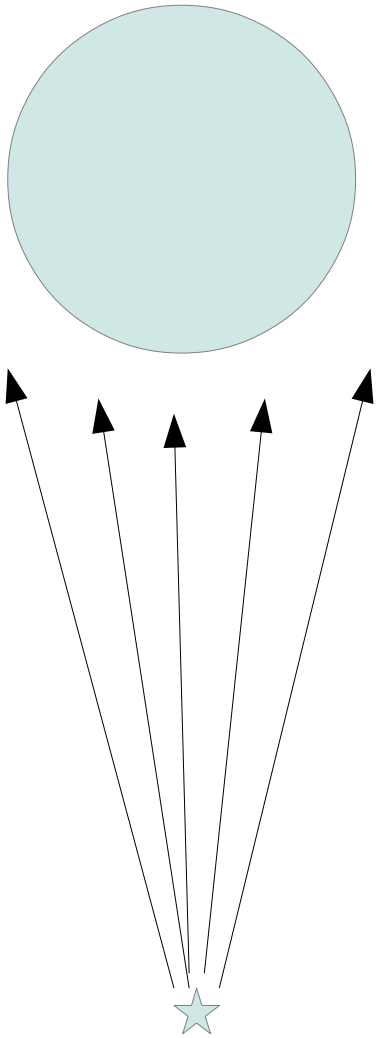
Emission maps for [CII] 158 µm, [CI] 610 µm, [OI] 63 µm, and CO(1-0)

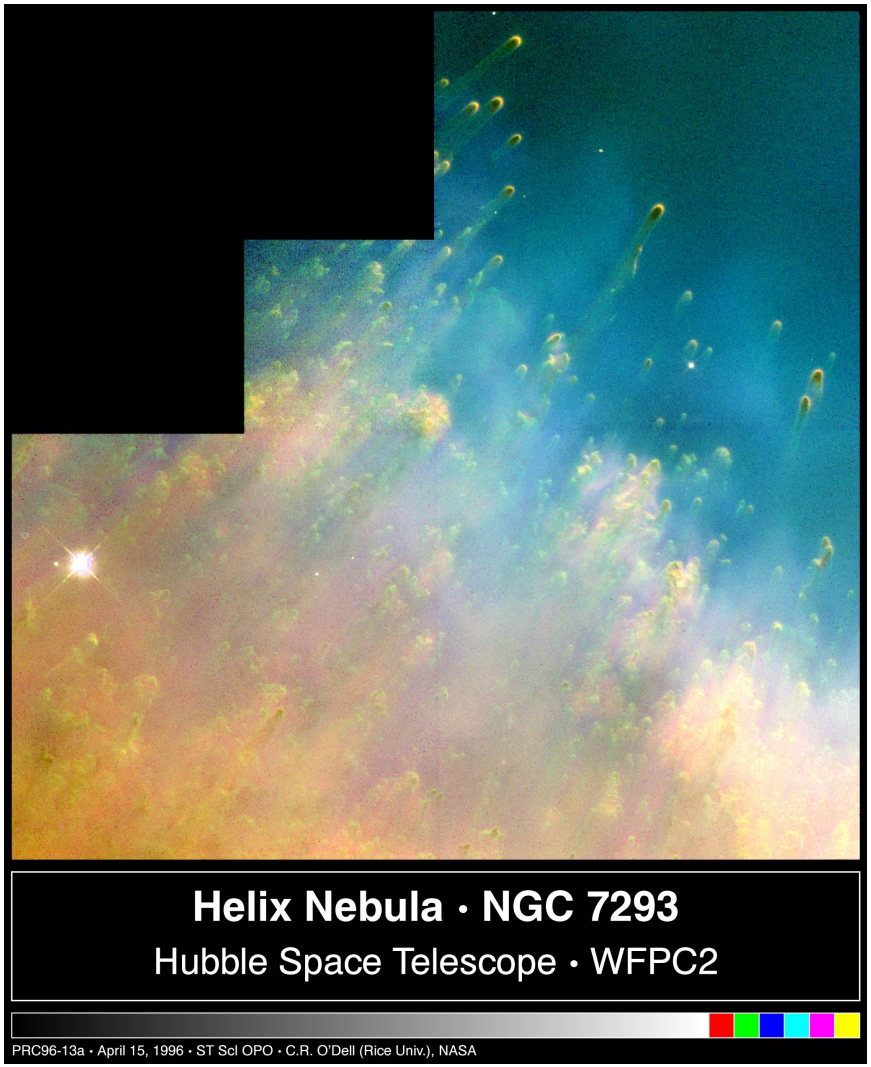
Multi-UV field application



RGB composite image for **CO(1-0)**, **[CI]**, **[CII]** emission maps.
The values correspond to the **[CII]** emission map.
RGB colour bar ratios of **5**:**1**:**10** for **CO(1-0)**:**[CI]**:**[CII]**.

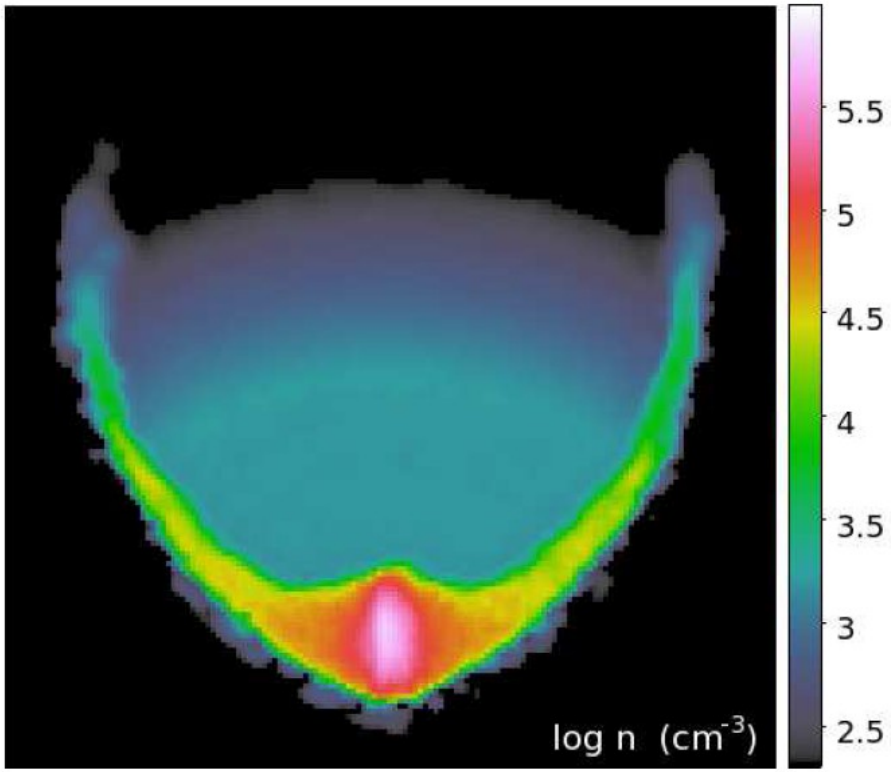
Radiation Driven Implosion





Radiation Driven Implosion

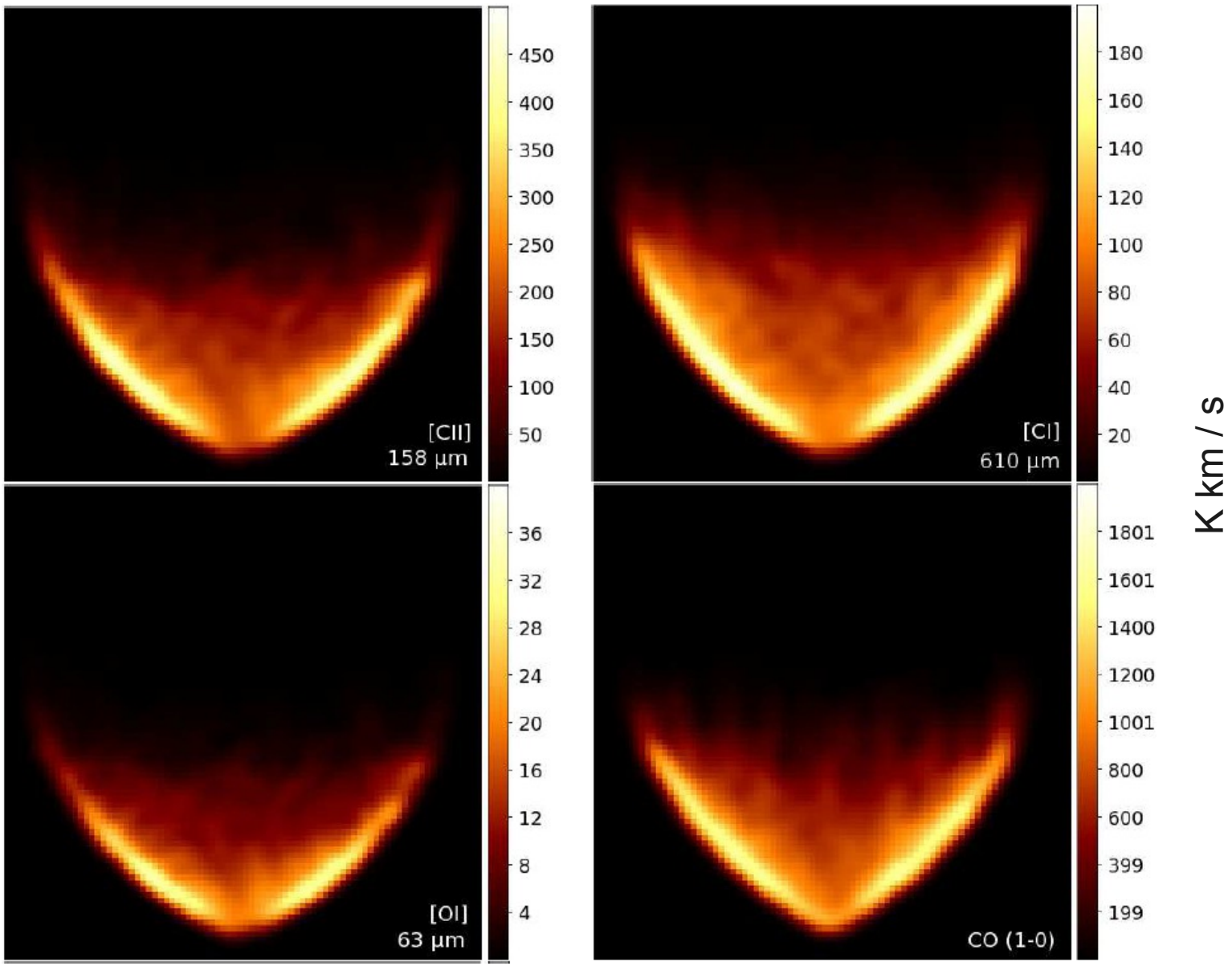
Simulation using Smoothed Particle Hydrodynamics



RDC.avi

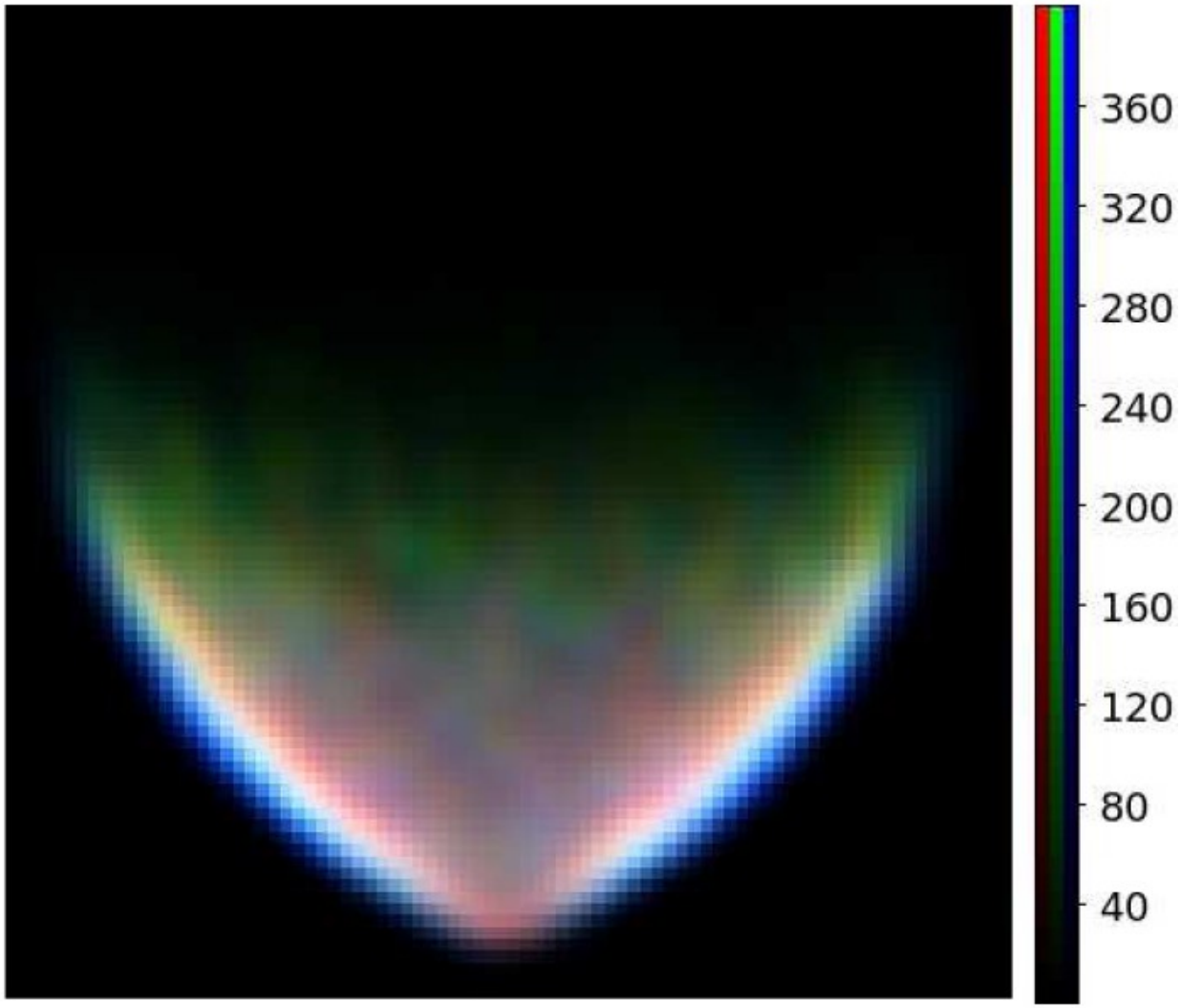
Snapshot at t=0.12Myr from the SPH simulation (see the movie)

Radiation Driven Implosion



Emission maps for [CII] 158 μm, [CI] 610 μm, [OI] 63 μm, and CO(1-0)

Radiation Driven Implosion



RGB composite image for **CO(1-0)**, **[CI]**, **[CII]** emission maps.
The values correspond to the **[CII]** emission map.
RGB colour bar ratios of **8**:**1**:**2** for **CO(1-0)**:**[CI]**:**[CII]**.