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UV field in "Meudon" PDR code

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Appendix A: FUV radiation field

Throughout most of the code, we use wavelengths measured in Å as the independent variable. The basic physical quantity for radiation is the specific intensity $I(\lambda)$, measured in $\mathrm{erg\,cm^{-2}\,s^{-1}\,ster^{-1}\,Å^{-1}}$. The most useful derived quantities are the mean intensity $J(\lambda)$ (in $\mathrm{erg\,cm^{-2}\,s^{-1}\,Å^{-1}}$) defined by

$$J(\lambda) = \frac{1}{4\pi} \int I(\lambda)\, d\Omega$$

and the energy density $u(\lambda)$ (in $\mathrm{erg\,cm^{-3}\,Å^{-1}}$) defined by

$$u(\lambda) = \frac{1}{c} \int I(\lambda)\, d\Omega = \frac{4\pi}{c} J(\lambda)$$

If (and only if) the radiation field is isotropic, $I = J$. $I(\lambda)$ is the quantity to use for solving the transfer equation, however, most physical quantities that depend on the radiation field can be computed from $u(\lambda)$.

Our standard impinging radiation field is that of Draine (1978). Various incompatible expressions are found for that field, as discussed in Kopp (1996). We have chosen to use that of Sternberg & Dalgarno (1995) which reads

$$I(\lambda) = \frac{1}{4\pi} \left(\frac{6.300\,10^{7}}{\lambda^4} - \frac{1.0237\,10^{11}}{\lambda^5} + \frac{4.0812\,10^{13}}{\lambda^6} \right) \tag{A.1}$$

where λ is in Å, and $I(\lambda)$ in $\mathrm{erg\,cm^{-2}\,s^{-1}\,ster^{-1}\,Å^{-1}}$. That expression is used from the Lyman cut-off up to 2000 Å. Long ward, we use

$$I(\lambda) = 1.38243\,10^{-5}\,\lambda^{-0.3}$$

That field may be scaled by a factor χ, and may be further enhanced by the radiation from a nearby star taken as a diluted Black Body. The star is characterised by its effective temperature T_{eff}, its radius R_* and its distance to the cloud surface d_*.

It is customary to measure the strength of the radiation field by reference to Habing (1968). We use a reference value of $5.6\,10^{-14}\,\mathrm{erg\,cm^{-3}}$ between 912 Å and 2400 Å. Note that that cut-off correspond to 5.17 eV, whereas it is often given as 6 eV. Although small, that difference is one of the many leading to inconsistencies between various codes. Here, we *define* the radiation field strength at some point by

$$G = \frac{1}{5.6\,10^{-14}} \int_{912}^{2400} u(\lambda)\, d\lambda$$

The "usual" G_0 parameter is taken as the value of G without cloud (in free space). Since $u(\lambda)$ comes from an integration over 4π ster, that value differs from G at the cloud surface where half of the radiation is partly screened by the cloud itself. For a semi-infinite cloud, an isotropic radiation field, and taking into account back scattering of the radiation by dust, $G_{surface}$ is usually close to $0.54\,G_0$ (depending on the dust characteristics). This may lead to (close to) a factor of 2 of difference in the energy input of otherwise seemingly similar models, and is a major source of discrepancies.

Appendix B: Example

We present some numerical computations to illustrate the difficulties stressed above. We compute two quantities:

- An energy density, expressed in $\mathrm{erg\,cm^{-3}}$:

$$E(\lambda_c) = \int_{912}^{\lambda_c} u(\lambda)\, d\lambda$$

- An photon flux over 4π ster, expressed in $\mathrm{photon\,cm^{-2}\,s^{-1}}$:

$$F(\lambda_c) = \frac{1}{h} \int_{912}^{\lambda_c} \lambda\, u(\lambda)\, d\lambda$$

We use two "cut-off":

- $\lambda_{c1} = 2400$ Å (5.166 eV)

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– $\lambda_{c2} = 2066.37$ Å (6.0 eV)

We show three possible cases:

C1: In free space, far from any object.
C2: At the edge of a semi-infinite cloud, with strictly forward scatering for grains.
C3: At the edge of a semi -infinite cloud, with back scatering from grains ($g =< \cos >= 0.6$).

All computations are done for 10 times Draine's field, directly from within the PDR code.

$E(\lambda_c)$	λ_{c1} (2400 Å)	λ_{c2} (6.0 eV)	
C1	$1.046\,10^{-12}$	$8.938\,10^{-13}$	erg cm^{-3}
C2	$5.230\,10^{-13}$	$4.469\,10^{-13}$	
C3	$5.632\,10^{-13}$	$4.812\,10^{-13}$	

$F(\lambda_c)$	λ_{c1} (2400 Å)	λ_{c2} (6.0 eV)	
C1	$2.458\,10^{9}$	$1.945\,10^{9}$	photon cm^{-2} s^{-1}
C2	$1.229\,10^{9}$	$0.973\,10^{9}$	
C3	$1.324\,10^{9}$	$1.047\,10^{9}$	

One can see that the UV field **at** the cloud edge is indeed half that in free space for strictly forward scatering. That value is enhanced by about 7.5% if back-scatering by grains from within the cloud are included. If a different cut-off is used **and** different grain scatering is used, the difference rises to 25%, for the **same** field! If a different expression is used for Eq (A.1), things get worse...

References

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