This website contains numerical results reported in the paper

"Resonant Scattering of the He I 1.0833um Triplet in H II Regions: Emission Spectra"

(B.T. Draine 2026; ApJ in press)

Monte Carlo radiative transfer calculations have been carried out for resonant scattering of He I 1.0833um triplet photons emitted in uniform density spherical HII regions. The Monte Carlo methodology is described in the paper (Draine 2026). Scattering calculations are carried out both for models without dust, and for models with dust.

Dustless Models

The dustless models are characterized by two parameters:

TAU = tau_tot = sum of the line-center center-to-edge optical depths for the three lines in the 1.0833um triplet (see Eq. 11 and 12 of Draine 2026)

B5 = He Doppler broadening parameter b/kms.
b = sqrt(2)*sigma_v, where sigma_v is the one-dimensional velocity dispersion of the He atoms

Monte Carlo calculations have been carried out for

B5 = 6.45, 10, 15, 20
TAU = 0.1e0, 0.2e0, 0.3e0, 0.5e0, 1.0e0, 2.0e0, 3.0e0, 5.0e0,
1.0e1, 2.0e1, 3.0e1, 5.0e1, 1.0e2, 2.0e2, 3.0e2, 5.0e2,
1.0e3, 2.0e3, 3.0e3, 5.0e3, 1.0e4, 2.0e4, 3.0e4, 5.0e4,
1.0e5, 2.0e5, 3.0e5, 5.0e5, 1.0e6

In addition, calculations were carried out for

B5 = 22.0
TAU = 1.0e2, 2.0e2, 3.0e2, 5.0e2, 1.0e3, 2.0e3, 3.0e3, 5.0e3, 1.0e4

The dustless model spectra are organized into 5 directories:

b6.45
b10.0
b15.0
b20.0
b22.0

Each directory contains summary files with file names

scatprof3_B5sph.out

These files contain summary statistics for all cases, including
tau_tot = sum of line-center optical depths for the three lines
tau_d = 0 (dust optical depth)
tau_e = 0 (electron scattering optical depth)

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Ninj       = number of injected photons
Nesc/Ninj  = escaping photon fraction (=1 since no dust absorption)
Nsca/Nesc  = mean number of scatterings per escaping photon
unc        = statistical uncertainty in Nsca/Nesc
Nscae/Nesc = electron scatterings per escaping HeI 1.0833um photon
             (=0: e scattering neglected)
Lpath/R    = mean HeI 1.0833um photon path in HeII region/Radius of
             HeII region
<|mu|>     = <cos(theta)> for escaping photons, theta=angle wrt radial
<v>        = mean redshift/kms of escaping HeI 1.0833um photons
<v>_cens   = mean redshift/kms of escaping HeI 1.0833um photons
             with |x| < 10
FWHM       = FWHM/kms of escaping He I 1.0833um photons

Each directory also contains a "spectrum" file scatprof3_B5sph_TAU
(e.g., scatprof3_6.45sph_1.0e3) for each case

where

B5  = 6.45, 10.0, 15.0, 20.0, 22.0
TAU = 0.1e0, 0.2e0, 0.3e0, 0.5e0, 1.0e0, 2.0e0, 3.0e0, 5.0e0,
      1.0e1, 2.0e1, 3.0e1, 5.0e1, 1.0e2, 2.0e2, 3.0e2, 5.0e2,
      1.0e3, 2.0e3, 3.0e3, 5.0e3, 1.0e4, 2.0e4, 3.0e4, 5.0e4,
      1.0e5, 2.0e5, 3.0e5, 5.0e5, 1.0e6

Each "spectrum file" scatprof3_B5sph_TAU reports a number of
quantities for the spectrum of escaping triplet photons, including

TAU  = tau_{tot} = sum of the line-center center-to-edge optical
       depths for the three lines in the 1.0833um triplet
       (see Eq. 11 and 12 of Draine 2026)
TAUD = 0 (dust optical depth)
TAUE = 0 (electron scattering optical depth)
B5   = He Doppler broadening parameter b/kms.
       b = sqrt(2)*sigma_v, where sigma_v is the one-dimensional
       velocity dispersion of the He atoms
VFLOW= 0 (no systematic flow)
NINJ = number of injected photons
NSCA = mean number of scatterings per escaping photon
<x>  = mean redshift/b
<x'> = mean redshift/b for photons with |x|<20
<v>  = mean redshift (km/s) for escaping photons relative to mean
       frequency of injected photons
<v'> = mean redshift (km/s) of escaping photons with |x|<20
       relative to mean frequency of injected photons
<mu> = <|cos(theta_esc)|> of escaping photons where theta_esc =
       angle between propagation direction and radial direction
       when photon crosses r=R

<L/R>= (mean path length traveled by escaping photons before
       escaping)/R

Each spectrum is tabulated as
x  dP/dx  Lpath/R
..  ..    ..
```

where

x   = (f-f_0)/(f_0*b/c) , where
          f = photon frequency
          f_0 = mean frequency of injected photons
dP/dx   = probability distribution of escaping photons per unit x
Lpath/R = mean path length traveled by photons before escaping with
          frequency shift x

and the normalization is: integral (dP/dx) dx = 1

NB: the code accumulates the numbers of escaping photons in bins with width dx = 0.01, running from x=-100 to x=+100. The Voigt profile will occasionally lead to escaping photons with |x| > 100 ; when this occurs, thee photons are collected in the first and last bins (x=-100 and x=+100).

The output files list dP/dx starting from the first nonzero bin (which may be at x=-100) to the last nonzero bin (which may be at x=+100).

When the number of injected photons Ninj=1e7, a single escaping photon in one bin will give it a value of dP/dx = (1/1e7)/0.01 = 0.00001 Thus when dP/dx < 0.0001 there will be significant statistical "noise", and the dP/dx values should be smoothed before plotting.

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Dusty Models

The models with dust are characterized by three parameters:

TAU = tau_{tot} = sum of the line-center center-to-edge optical
      depths for the three lines in the 1.0833um triplet (see Eq. 11
      and 12 of Draine 2026)

TAUD= center-to-edge optical depth for dust absorption at 1.0833um

B5 = He Doppler broadening parameter b/kms.
      b = sqrt(2)*sigma_v, where sigma_v is the one-dimensional
      velocity dispersion of the He atoms

All models have B5 = 10

Parameters TAU and TAUD are chosen to be appropriate to uniform density H II regions with H nucleon density n_H = 10^3 * n_3 cm^{-3}, hydrogen ionization rate Q_0 = 10^{48} * Q_{48} s^{-1}, and xi=(Volume of He II zone)/(Volume of H II): see Draine (2026, Eq. 12, 21) for equations giving tautot.

Results for selected values of (Q_{48},n_3, xi) are collected in directories:

Q48=1 , n3=0.3 : directory q48n3_1e0_0.3
Q48=1 , n3=1.0 : directory q48n3_1e0_1.0
Q48=1 , n3=3.0 : directory q48n3_1e0_3.0

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Q48=10 , n3=0.3 : directory q48n3_1e1_0.3
Q48=10 , n3=1.0 : directory q48n3_1e1_1.0
Q48=10 , n3=3.0 : directory q48n3_1e1_3.0

Q48=30 , n3=0.3 : directory q48n3_3e1_0.3
Q48=30 , n3=1.0 : directory q48n3_3e1_1.0
Q48=30 , n3=3.0 : directory q48n3_3e1_3.0

Q48=1e2, n3=0.3 : directory q48n3_1e2_0.3
Q48=1e2, n3=1.0 : directory q48n3_1e2_1.0
Q48=1e2, n3=3.0 : directory q48n3_1e2_3.0

Q48=3e2, n3=0.3 : directory q48n3_3e2_0.3
Q48=3e2, n3=1.0 : directory q48n3_3e2_1.0
Q48=3e2, n3=3.0 : directory q48n3_3e2_3.0

Q48=1e3, n3=0.3 : directory q48n3_1e3_0.3
Q48=1e3, n3=1.0 : directory q48n3_1e3_1.0
Q48=1e3, n3=3.0 : directory q48n3_1e3_3.0

Q48=3e3, n3=0.3 : directory q48n3_3e3_0.3
Q48=3e3, n3=1.0 : directory q48n3_3e3_1.0
Q48=3e3, n3=3.0 : directory q48n3_3e3_3.0

Q48=7.4, n3=3.5 : directory q48n3_7.4_3.5

Q48=8.2, n3=2.8 : directory q48n3_8.2_2.8

Within each directory, models have been calculated for selected values
of xi = (Volume of HeII region)/(Volume of HII region), typically

xi = 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.05, 0.01

Results are collected in summary files scatprof3_q48n3_Q48_N3.out

These files contain summary statistics for all cases, including

tau_tot    = sum of line-center center-to-edge optical depths for the
             three lines
taud       = center-to-edge of HeII region dust optical depth
taue       = center-to-edge Thomson scattering optical depth
             (=0 : e scattering neglected)
Ninj       = number of injected photons
Nesc/Ninj  = fraction of injected photons that escape
Nsca/Nesc  = mean number of scatterings per escaping photon
unc        = statistical uncertainty in Nsca/Nesc
Nscae/Nesc = mean number of e scatterings per escaping photon
             (=0 ; e scattering neglected)
Lpath/R    = mean photon path in HeII region/radius of HeII region
<|mu|>     = <cos(theta)> for escaping photons, theta=angle wrt radial
<v>        = mean redshift/kms of escaping HeI 1.0833um photons
<v>_cens   = mean redshift/kms of escaping HeI 1.0833um photons
             with |x| < 10
FWHM       = FWHM/kms of escaping He I 1.0833um photons
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Each directory also contains a "spectrum" file
scatprof3_B5_q48n3xi_Q48_N3_XI (e.g.,
scatprof3_10.0_q48n3xi_1.0_0.3_1.0) for each case

where

B5=10.0
Q48= value of Q_48
N3 = value of n_3
XI = value of xi

Each spectrum file scatprof3_B5_q48n3xi_Q48_N3_XI reports a number of
quantities for the spectrum of escaping triplet photons, including

TAU = tau_{tot} = sum of the line-center center-to-edge optical
depths
       for the three lines in the 1.0833um triplet (see Eq. 11 and 12
       of Draine 2026)
TAUD = center-to-edge (of HeII region) optical depth for dust
       absorption at 1.0833um
B5   = He Doppler broadening parameter b/kms.
       b = sqrt(2)*sigma_v, where sigma_v is the one-dimensional
       velocity dispersion of the He atoms
NINJ = number of injected photons
NSCA = mean number of scatterings per injected photon
<v> = mean Doppler shift (km/s) relative to mean frequency of
       injected photons. Positive <v> corresponds to redshift.
<mu> = <|cos(theta_esc)|> of escaping photons where theta_esc =
       angle between propagation direction and radial direction
       when photon crosses r=R
<L/R>= (mean path length traveled by photons before escaping)/R

Each spectrum is tabulated as
x dP/dx Lpath/R
.. ..   ..

where

x   = (f-f_0)/(f_0*b/c) , where
          f = photon frequency
          f_0 = mean frequency of injected photons
dP/dx   = probability distribution of escaping photons per unit x
Lpath/R = mean path length traveled by photons before escaping with
          frequency shift x

and the normalization is: integral (dP/dx) dx = 1

NB: the code accumulates the numbers of escaping photons in bins with
width dx = 0.01, running from x=-100 to x=+100. The Voigt profile
will occasionally lead to escaping photons with |x| > 100 ; when this
occurs, thee photons are collected in the first and last bins (x=-100
and x=+100).

The output files list dP/dx starting from the first nonzero bin (which
may be at x=-100) to the last nonzero bin (which may be at x=+100).

When the number of injected photons Ninj=1e7, a single escaping photon in one bin will give it a value of dP/dx = (1/1e7)/0.01 = 0.00001 Thus when dP/dx < 0.0001 there will be significant statistical "noise", and the dP/dx values should be smoothed before plotting.