diffsph

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CONTENTS:

`diffsph` is a Python package that computes diffuse signals (e.g. brightness) emitted by Milky-Way satellite dwarf spheroidal galaxies. The underlining physics is mostly based on[1].

[1] M. Vollmann, "Universal profiles for radio searches of dark matter in dwarf galaxies", doi:10.1088/1475-7516/2021/04/068 [arXiv:2011.11947 [astro-ph.HE]].

CHAPTER

ONE

DIFFSPH

1.1 diffsph package

1.1.1 Subpackages

diffsph.profiles package

Submodules

diffsph.profiles.analytics module

`diffsph.profiles.analytics.`**`cobrA`**(*t*, *rs*, *rh*)

Brightness H-function for the 'constant' top-hat source in the regime-A approximation

Parameters

- **`t`** – $D\sin(\theta)/r_h$, where θ (`theta`), r_h (`rh`) and D (`dist`) are defined below
- **`theta`** – angular radius in rad
- **`rs`** – scale radius
- **`rh`** – diffusion radius parameter
- **`dist`** – distance to the source

`diffsph.profiles.analytics.`**`cobrC`**(*t*, *rs*, *rh*)

Brightness H-function for the 'constant' source in the regime-C approximation

Parameters

- **`t`** – $D\sin(\theta)/r_h$, where θ (`theta`), r_h (`rh`) and D (`dist`) are defined below
- **`theta`** – angular radius in rad
- **`rs`** – scale radius
- **`rh`** – diffusion radius parameter

`diffsph.profiles.analytics.`**`cofdA`**(*theta*, *rs*, *rh*, *dist*)

Flux-density H-function for the 'constant' top-hat source in the regime-A approximation

Parameters

- **`theta`** – angular radius in rad
- **`rs`** – scale radius

- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.`**cofdAmax**(*rs*, *rh*, *dist*)

Maximum value for the flux-density H-function for the 'constant' top-hat source in the regime-A approximation

Parameters

- **rs** – scale radius
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.`**cofdC**(*theta*, *rs*, *rh*, *dist*)

Flux-density H-function for the 'constant' top-hat source in the regime-C approximation

Parameters

- **theta** – angular radius in rad
- **rs** – scale radius
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.`**cofdCmax**(*rs*, *rh*, *dist*)

Maximum value for the flux-density H-function for the 'constant' top-hat source in the regime-C approximation

Parameters

- **rs** – scale radius
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.`**psbrA**(*theta*, *rs*, *rh*, *dist*)

Brigthness H-function for point sources in the regime-A approximation

Parameters

- **theta** – angular radius in rad
- **rs** – scale radius
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.`**psbrC**(*t*, *rh*)

Brigthness H-function for point sources in the regime-C approximation Variable t is defined as

Parameters

- **t** – $D\sin(\theta)/r_h$, where θ (`theta`), r_h (`rh`) and D (`dist`) are defined below
- **theta** – angular radius in rad
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.psfdC(theta, rh, dist)`

Flux-density H-function for point sources in the regime-C approximation

Parameters

- **theta** – angular radius in rad
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.psfdCmax(rh, dist)`

Maximum value for the flux-density H-function for point sources in the regime-C approximation

Parameters

- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.sisbrA(t, sigmav, rh)`

Brightness H-function for the singular isothermal source in the regime-A approximation

Parameters

- **t** – $D\sin(\theta)/r_h$, where θ (theta), r_h (rh) and D (dist) are defined below
- **theta** – angular radius in rad
- **sigmav** – velocity dispersion parameter
- **rh** – diffusion radius parameter
- **dist** – distance to the source

`diffsph.profiles.analytics.sisbrC(t, sigmav, rh)`

Brightness H-function for the singular isothermal source in the regime-C approximation

Parameters

- **t** – $D\sin(\theta)/r_h$, where θ (theta), r_h (rh) and D (dist) are defined below
- **theta** – angular radius in rad
- **sigmav** – velocity dispersion parameter
- **rh** – diffusion radius parameter
- **dist** – distance to the source

diffsph.profiles.hfactors module

`diffsph.profiles.hfactors.D_factor(theta, dist, rad_temp, **kwargs)`

Generic "D" factor

Parameters

- **theta** – angular distance in rad units
- **dist** – distance to earth
- **rad_temp** – radial template

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
D factor

`diffsph.profiles.hfactors.`**`H_brightness`**(*theta*, *dist*, *rh*, *hyp*, *rad_temp*, *regime*, ***kwargs*)

Generic emissivity halo/bulge function in the Regime "A", "B" or "C" approximations

Parameters

- **theta** – angular distance in rad units
- **dist** – distance to earth
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`)
- **halo_model** – DM halo model
- **rad_temp** – radial template
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
brightness halo/bulge function

`diffsph.profiles.hfactors.`**`H_emissivity`**(*r*, *rh*, *hyp*, *rad_temp*, *regime*, ***kwargs*)

Generic emissivity halo/bulge function in the Regime "A", "B" or "C" approximations

Parameters

- **r** – galactocentric distance

- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`)
- **rad_temp** – radial template
- **regime** – regime of the approximation (upper/lower case a, b, c or I/II/III).

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
- **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
- **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
- **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
- **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
emissivity halo/bulge function

`diffsph.profiles.hfactors.`**`H_fluxdens`**(*theta*, *dist*, *rh*, *hyp*, *rad_temp*, *regime*, ***kwargs*)

Generic flux-density halo/bulge function in the Regime “A”, “B” or “C” approximations

Parameters

- **theta** – angular distance in rad units
- **dist** – distance to earth
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`)
- **halo_model** – DM halo model
- **rad_temp** – radial template
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
- **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
- **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
- **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile

- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
flux density halo/bulge function

`diffsph.profiles.hfactors.`**`H_fluxdens_approx`**(*theta*, *dist*, *rh*, *hyp*, *rad_temp*, *regime*, ***kwargs*)

Generic flux-density halo/bulge function in the Regime "A", "B" or "C" approximations (alternative formula)

Parameters

- **theta** – angular distance in rad units
- **dist** – distance to earth
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`)
- **halo_model** – DM halo model
- **rad_temp** – radial template
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
flux density halo/bulge function

`diffsph.profiles.hfactors.`**`Hem_A`**(*r*, *rh*, *hyp*, *rad_temp*, ***kwargs*)

Generic emissivity halo/bulge function for Regime A

Parameters

- **r** – galactocentric distance
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`)
- **rad_temp** – radial template

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density

- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
emissivity halo/bulge function using the Regime-A approximation

diffsph.profiles.hfactors.**Hem_B**(*r*, *rh*, *hyp*, *rad_temp*, ***kwargs*)

Generic emissivity halo/bulge function for Regime B

Parameters

- **r** – galactocentric distance
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: 'wimp' (**default**), 'decay' or 'generic')
- **rad_temp** – radial template

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
emissivity halo/bulge function using the Regime-B approximation

diffsph.profiles.hfactors.**Hem_C**(*r*, *rh*, *hyp*, *rad_temp*, ***kwargs*)

Generic emissivity halo/bulge function for Regime C

Parameters

- **r** – galactocentric distance
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: 'wimp' (**default**), 'decay' or 'generic')
- **rad_temp** – radial template

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
- **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
- **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
- **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
- **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
emissivity halo/bulge function using the Regime-C approximation

`diffsph.profiles.hfactors.`**`J_factor`**`(`*theta*, *dist*, *rad_temp*, ***kwargs*`)`

Generic "J" factor

Parameters

- **theta** – angular distance in rad units
- **dist** – distance to earth
- **rad_temp** – radial template

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
- **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
- **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
- **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
- **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
J factor

`diffsph.profiles.hfactors.`**`halo_factor`**`(`*n*, *rh*, *hyp*, *rad_temp*, ***kwargs*`)`

n-th order halo/bulge factor h_n for a given model (e.g. NFW, Einasto, Plummer, …) Arguments `'n'`, `'rh'`, `'hyp'` and `'rad_temp'` are necessary. Remaining arguments depend on the adopted halo model.

Parameters

- **n** – order of the halo/bulge factor
- **rh** – diffusion halo/bulge radius
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`)
- **rad_temp** – radial template

Keyword arguments

Parameters

- **rs** – scale radius
- **rhos** – characteristic density
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
halo/bulge factor

diffsph.profiles.massmodels module

`diffsph.profiles.massmodels.D`(*tharcmin*, *galaxy*, *rad_temp*, *manual=False*, ***kwargs*)

Model-specific D factor in GeV/cm ^{2}

Parameters

- **tharcmin** – angular radius in arcmin
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius
  - **rhos** – characteristic density
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile

- **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
D factor

`diffsph.profiles.massmodels.Hbr`(*tharcmin*, *galaxy*, *rad_temp*, *hyp*, *ratio*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific brightness halo/bulge function in the Regime "A", "B" or "C" approximations

Parameters

- **tharcmin** – angular radius in arcmin
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and the half-light radius (default value = 1)
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius
  - **rhos** – characteristic density
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
  - **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
  - **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
brightness halo/bulge function

`diffsph.profiles.massmodels.Hem`(*r*, *galaxy*, *rad_temp*, *hyp*, *ratio*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific emissivity halo/bulge function in the Regime "A", "B" or "C" approximations

Parameters

- **r** – galactocentric distance in kpc

- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and the half-light radius (default value = 1)
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius
  - **rhos** – characteristic density
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
  - **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
  - **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

  Returns
  emissivity halo/bulge function

`diffsph.profiles.massmodels.`**`Hfd`**(*tharcmin*, *galaxy*, *rad_temp*, *hyp*, *ratio*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific flux-density halo/bulge function in the Regime “A”, “B” or “C” approximations

Parameters

- **tharcmin** – angular radius in arcmin
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and the half-light radius (default value = 1)
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `manual = 'False'`

Parameters
`ref` – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

Parameters

- `rs` – scale radius
- `rhos` – characteristic density
- `alpha` – exponent α in the `diffsph.profiles.templates.hdz()` profile
- `beta` – exponent β in the `diffsph.profiles.templates.hdz()` profile
- `gamma` – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- `alphaE` – parameter α_E in the `diffsph.profiles.templates.enst()` profile
- `rc` – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
- `sigmav` – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
brightness halo/bulge function

`diffsph.profiles.massmodels.J`(*tharcmin*, *galaxy*, *rad_temp*, *manual=False*, ***kwargs*)

Model-specific J factor in Gev ^{2}/cm ^{5}

Parameters

- `tharcmin` – angular radius in arcmin
- `galaxy` (*str*) – name of the galaxy
- `rad_temp` (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- `manual` (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `manual = 'False'`

Parameters
`ref` – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

Parameters

- `rs` – scale radius
- `rhos` – characteristic density
- `alpha` – exponent α in the `diffsph.profiles.templates.hdz()` profile
- `beta` – exponent β in the `diffsph.profiles.templates.hdz()` profile
- `gamma` – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- `alphaE` – parameter α_E in the `diffsph.profiles.templates.enst()` profile

- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
J factor

`diffsph.profiles.massmodels.h(n, galaxy, rad_temp, hyp, ratio, manual=False, **kwargs)`

Model-specific n-th halo factor

Parameters

- **n** – order of the halo/bulge factor
- **rh** – diffusion halo/bulge radius
- **rad_temp** – radial template
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and the half-light radius
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius
  - **rhos** – characteristic density
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
  - **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
halo factor

`diffsph.profiles.massmodels.rho(r, rad_temp, manual=False, **kwargs)`

Dark matter density

Parameters

- **r** – galactocentric distance
- **rad_temp** – template ('NFW', 'Einasto', etc.)

- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = 'False')

Keyword arguments

- manual = 'False'

  Parameters
  ref – reference used ('Martinez' or '1309.2641', 'Geringer-Sameth' or '1408.0002', etc.)

- manual = 'True'

  Parameters
  - **rs** – scale radius
  - **rhos** – characteristic density
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
  - **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

  Returns
  dark matter density

diffsph.profiles.templates module

`diffsph.profiles.templates.`**`bkrt`**`(`*r*, *rs*, *rhos*`)`

Burkert dark-matter halo profile.

$$\rho(r) = \frac{\rho_s}{(1 + r/r_s)(1 + r^2/r_s^2)}$$

Parameters
- **r** – main variable (galactocentric distance)
- **rs** – scale radius
- **rhos** – charactieristic density

Returns
density at galactocentric distance r

`diffsph.profiles.templates.`**`cnfw`**`(`*r*, *rs*, *rhos*, *rc*`)`

Cored Navarro/Frenk/White dark-matter halo template.

$$\rho(r) = \frac{\rho_s}{(r/r_s + r_c/r_s)(1 + r/r_s)^2}$$

Parameters
- **r** – main variable (galactocentric distance)

- **rs** – scale radius
- **rhos** – chraracteristic density
- **rc** – core radius

Returns
density at galactocentric distance r

`diffsph.profiles.templates.const(r, rs)`

Constant (top-hat) template

$$\rho(r) = \frac{3}{4\pi r_s^3}\Theta(r_s - r)$$

Parameters
rs – characteristic radius

Returns
constant density

`diffsph.profiles.templates.enst(r, rs, rhos, alphaE=0.17)`

Einasto dark-matter halo profile.

$$\rho(r) = \rho_s \exp\left[-\frac{2}{\alpha_E}\left(\frac{r^{\alpha_E}}{r_s^{\alpha_E}} - 1\right)\right]$$

Parameters

- **r** – main variable (galactocentric distance)
- **rs** – scale radius
- **rhos** – charactieristic density
- **alphaE** – power-law slope of the Einasto profile, (default value = 0.17)

Returns
density at galactocentric distance r

`diffsph.profiles.templates.hdz(r, rs, rhos, alpha, beta, gamma)`

Hernquist/Diemand/Zhao dark-matter halo template.

$$\rho(r) = \frac{\rho_s}{(r/r_s)^\gamma(1 + (r/r_s)^\alpha)^{\frac{\beta-\gamma}{\alpha}}}$$

Using default values alpha = 1, beta = 3 and gamma = 1 results in the default NFW halo profile.

Parameters

- **r** – main variable (galactocentric distance)
- **rs** – scale radius
- **rhos** – chraracteristic density
- **alpha** – inner exponent
- **beta** – large-r exponent
- **gamma** – small-r exponent

Returns
density at galactocentric distance r

`diffsph.profiles.templates.nfw(r, rs, rhos)`

Navarro/Frenk/White dark-matter halo template.

$$\rho(r) = \frac{\rho_s}{(r/r_s)(1 + r/r_s)^2}$$

Parameters

- **r** – main variable (galactocentric distance)
- **rs** – scale radius
- **rhos** – chraracteristic density

Returns

density at galactocentric distance r

`diffsph.profiles.templates.plmm(r, rs)`

Plummer template

$$\rho(r) = \frac{3}{4\pi r_s^3}\frac{1}{(1 + r^2/r_s^2)^{5/2}}$$

Parameters

- **r** – main variable (distance to the center)
- **rs** – Plummer radius
- **rhoa** – central density

Returns

density of the Plummer sphere at distance r

`diffsph.profiles.templates.ps(r, rs)`

Point source template

$$\rho(r) = \frac{1}{4\pi r^2}\delta(r)$$

Parameters

- **r** – main variable (galactocentric distance)
- **rs** – characteristic radius

Returns

density at galactocentric distance r

`diffsph.profiles.templates.ps_iso(r, rs, rhos)`

Pseudo-isothermal sphere dark-matter halo profile.

$$\rho(r) = \frac{\rho_s}{1 + r^2/r_s^2}$$

Parameters

- **r** – main variable (galactocentric distance)
- **rs** – scale radius
- **rhos** – characteristic density

Returns

density at galactocentric distance r

`diffsph.profiles.templates.sis(r, sigmav)`

Singular isothermal sphere

$$\rho(r) = \frac{\sigma_v^2}{2\pi G r^2}$$

Parameters

- **r** – main variable (galactocentric distance)
- **sigmav** – velocity dispersion

Returns

density at galactocentric distance r

Module contents

diffsph.spectra package

Submodules

diffsph.spectra.analytics module

`diffsph.spectra.analytics.Fav(x)`

Synchrotron-power function for randomly-oriented magnetic fields[1].

$$F(x) = x^2 \left(K_{4/3}(x) K_{1/3}(x) - \frac{3}{5} x [K_{4/3}^2(x) - K_{1/3}^2(x)] \right)$$

Returns

Pitch-angle averaged synchrotron function as a function of x

`diffsph.spectra.analytics.M_C(xi, eta, delta)`

Master function in the Regime-C limit

$$\mathcal{M}_C(\xi, \eta, \delta) = \frac{\xi^\delta}{(1-\delta)\eta} F(\xi^2)$$

`diffsph.spectra.analytics.M_i(xi, eta, delta)`

Master function in the large η limit

$$\mathcal{M}_i(\xi, \eta, \delta) = \frac{\Gamma^2(1/3)\eta^{-\frac{5}{3(1-\delta)}}}{5\sqrt[3]{2}(1-\delta)} \Gamma\left(\frac{5}{3(1-\delta)}, \eta\,\xi^{1-\delta}\right) \exp\left(\eta\,\xi^{1-\delta}\right)$$

`diffsph.spectra.analytics.M_raw(xi, eta, delta)`

“Raw” master function

$$\mathcal{M}(\xi, \eta, \delta) = \int_\xi^\infty dx F(x^2) \exp\left(-\eta\left[x^{1-\delta} - \xi^{1-\delta}\right]\right)$$

Returns

above integral

[1] Formula extracted from Ghisellini et al, 1988

`diffsph.spectra.analytics.`**`anltc_Mst`**(*xi*, *eta*, *delta*)

Master function

$$\mathcal{M}(\xi,\eta,\delta)=\int_{\xi}^{\infty}dxF(x^2)\exp\left(-\eta\left[x^{1-\delta}-\xi^{1-\delta}\right]\right)$$

Note: Function evaluates the above integral only for those values where no numerical errors are present. Otherwise, it uses the approximate formulas *`diffsph.spectra.analytics.M_C()`* or *`diffsph.spectra.analytics.M_i()`*

`diffsph.spectra.analytics.`**`btot`**(*E*, *B*)

Total energy loss function in GeV/s

Parameters

- **`E`** – cosmic-ray energy in GeV
- **`B`** – magnitude of the magnetic field's smooth component in μG

Returns

energy-loss rate in GeV/s

`diffsph.spectra.analytics.`**`lam`**(*E*, *B*, *D0*, *delta=0.3333333333333333*)

Syrovatskii variable in kpc^2

Parameters

- **`E`** – cosmic-ray energy in GeV
- **`B`** – magnitude of the magnetic field's smooth component in μG
- **`D0`** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm^2/s
- **`delta`** – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3)

Returns

Syrovatskii variable in kpc^2

diffsph.spectra.synchrotron module

`diffsph.spectra.synchrotron.`**`Enu`**(*B*, *nu*)

Typical particle energy in GeV for synchrotron radiation at the frequency nu in GHz and for a magnetic field B in μG

Parameters

- **`B`** – magnitude of the magnetic field's smooth component in μG
- **`nu`** – frequency in GHz

Returns

Particle energy in GeV.

`diffsph.spectra.synchrotron.`**`Mst`**(*xi*, *eta*, *delta*)

Interpolation function for the kernel function $\hat{\mathcal{M}}(\xi,\eta,\delta)$

Parameters

- **`xi`** – ξ

- **eta** – η
- **delta** – δ

Returns
Spectral-function kernel (as an interpolation function)

`diffsph.spectra.synchrotron.`**`Mst_DM`**(*xi*, *eta*, *m*, *delta*, *channel*)

Master function for dark-matter hypotheses

Parameters

- **xi** – ξ
- **eta** – η
- **delta** – δ
- **m** – WIMP mass in GeV
- **channel** – annihilation/decay channel

Returns
Master function (as an interpolation function) for DM hypotheses

`diffsph.spectra.synchrotron.`**`Mst_pw`**(*eta*, *Gamma*, *delta*)

Master function for the generic power-law hypothesis

Parameters

- **eta** – η
- **Gamma** – Γ
- **delta** – δ

Returns
Master function (as an interpolation function) for the generic power-law hypothesis

`diffsph.spectra.synchrotron.`**`X`**(*nu*, *tau*, *delta*, *B*, *hyp*, ***kwargs*)

Spectral function in erg/GHz for all hypotheses built in diffsph

Parameters

- **nu** – frequency in GHz
- **tau** – diffusion time-scale parameter for a 1 GeV CRE in s
- **delta** – power-law exponent of the diffusion coefficient as a function of the CRE's energy
- **B** – magnitude of the magnetic field's smooth component in μG
- **hyp** (*str*) – hypothesis: `'wimp'`, `'decay'` or `'generic'`

Keyword arguments:

- If `hyp = 'wimp'` or `'decay'`

Parameters

- **mchi** – mass of the DM particle in GeV/c^2
- **channel** (*str*) – annihilation/decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- If `hyp = 'generic'`

Parameters

Gamma – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)

Returns

spectral function in erg/GHz

`diffsph.spectra.synchrotron.`**`X_DM`**(*k*, *mchi*, *channel*, *nu*, *tau*, *delta*, *B*)

Spectral function in erg/GHz for all DM hypotheses built in diffsph

Parameters

- **k** – hypothesis index (k=1 for decay and k=2 for annihilation)
- **mchi** – mass of the DM particle in GeV/c^2
- **channel** – annihilation/decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.
- **nu** – frequency in GHz
- **tau** – diffusion time-scale parameter for a 1 GeV CRE in s
- **delta** – power-law exponent of the diffusion coefficient as a function of the CRE's energy
- **B** – magnitude of the magnetic field's smooth component in μG

Returns

spectral function in erg/GHz

`diffsph.spectra.synchrotron.`**`X_gen`**(*Emin*, *Emax*, *S_func*, *nu*, *tau*, *delta*, *B*)

Spectral function in erg/GHz for generic CRE sources

$$X_{\text{gen}}(\nu) = \int_{E_m}^{E_M} dE' \hat{X}(\nu, E') S(E')$$

Parameters

- **Emin** – low-E cutoff energy in GeV of the CRE source `'S_func'`
- **Emax** – high-E cutoff energy in GeV of the CRE source `'S_func'`
- **S_func** – CRE source function
- **nu** – frequency in GHz
- **tau** – diffusion time-scale parameter for a 1 GeV CRE in s
- **delta** – power-law exponent of the diffusion coefficient as a function of the CRE's energy
- **B** – magnitude of the magnetic field's smooth component in μG

Returns
spectral function in erg/GHz

`diffsph.spectra.synchrotron.X_pw(Gamma, nu, tau, delta, B)`

Spectral function in erg/GHz for the generic power-law hypothesis

Parameters

- **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
- **nu** – frequency in GHz
- **tau** – diffusion time-scale parameter for a 1 GeV CRE in s
- **delta** – power-law exponent of the diffusion coefficient as a function of the CRE's energy
- **B** – magnitude of the magnetic field's smooth component in μG

Returns
spectral function in erg/GHz

`diffsph.spectra.synchrotron.eta(E, B, tau, delta)`

η variable as a function of the CRE's energy, magnetic field, tau and delta parameters

Parameters

- **E** – CRE energy in GeV
- **B** – magnetic field strength in μG
- **tau** – diffusion time-scale parameter for a 1 GeV CRE in s
- **delta** – power-law exponent of the diffusion coefficient as a function of the CRE's energy

Returns
η variable

`diffsph.spectra.synchrotron.htX(E, nu, tau, delta, B, fast_comp=True)`

Spectral function kernel in erg/GHz $\hat{X}$

Parameters

- **E** – CRE energy in GeV
- **nu** – frequency in GHz
- **tau** – diffusion time-scale parameter for a 1 GeV CRE in s
- **delta** – power-law exponent of the diffusion coefficient as a function of the CRE's energy
- **B** – magnitude of the magnetic field's smooth component in μG
- **fast_comp** (*bool*) – if `'True'`, employs the interpolating method (default value = `'True'`)

Returns
spectral kernel in erg/GHz

`diffsph.spectra.synchrotron.lMst(Lxi, Leta, delta)`

Interpolation function for (kernel) $\log(\hat{\mathcal{M}})$

Parameters

- **Lxi** – $\log(\xi)$
- **Leta** – $\log(\eta)$
- **delta** – δ

Returns

$\log(\hat{\mathcal{M}})$ as a function of $\log(\xi)$, $\log(\eta)$ and δ

`diffsph.spectra.synchrotron.lMst_DM`(*Lxi*, *Leta*, *Lm*, *delta*, *channel*)

Interpolation function $\log(\mathcal{M})$ for DM hypotheses

Parameters

- **Lxi** – $\log(\xi)$
- **Leta** – $\log(\eta)$
- **Lm** – $\log(m/\mathrm{GeV})$ (m is the WIMP mass)
- **delta** – δ
- **channel** – annihilation/decay channel

Returns

$\log(\mathcal{M})$ as a function of $\log(\xi)$, $\log(\eta)$, $\log(m)$ and δ

`diffsph.spectra.synchrotron.lMst_pw`(*Leta*, *Gamma*, *delta*)

Interpolation function $\log(\mathcal{M})$ for the gereric power-law hypothesis

Parameters

- **Leta** – $\log(\eta)$
- **Gamma** – Γ
- **delta** – δ

Returns

$\log(\mathcal{M}_{\text{gen}})$ as a function of $\log(\eta)$, Γ and δ

Module contents

diffsph.utils package

Submodules

diffsph.utils.consts module

diffsph.utils.dictionaries module

diffsph.utils.tools module

`diffsph.utils.tools.TB`(*brightness*, *theta*, *nu*, **args*, ***kwargs*)

Brightness temperature conversion

$$T_B = \frac{c^2}{2\,k\,\nu^2} I_\nu$$

Parameters

- **brightness** – generic brightness function in Jy/sr
- **theta** – angular radius (as the first argument of the generic brighness function)
- **nu** – frequency (as the second argument of the generic brighness function)

Returns
brightness temperature in mK

diffsph.utils.tools.**approxhalo_fd**(*n*, *theta*, *dist*, *rh*)

Partial (θ-dependent) flux-density halo/bulge factor (approximate formula):

$$\mathcal{H}_n(\theta) = \mathcal{H}_n(r_h, R) - 2\int_{R\sin(\theta)}^{r_h} dr\, r\, \kappa_1(r, R, \theta)\frac{\sin\left(\frac{n\pi r}{r_h}\right)}{r}$$

where R, rh and n are, respectively the distance, halo radius and Fourier index

diffsph.utils.tools.**approxhalo_fd_tot**(*n*, *dist*, *rh*)

Total flux-density halo/bulge factor (approximate formula):

$$\mathcal{H}_n(r_h, R) \simeq 4\pi\int_0^{r_h} dr\, r^2\frac{\sin\left(\frac{n\pi r}{r_h}\right)}{r}\ ,$$

where R, rh and n are, respectively the distance, halo radius and Fourier index

diffsph.utils.tools.**delta_float**(*inp*)

Float number for variable `'delta'`

Parameters
inp – variable `'delta'` as *str* (`'kol'`, `'kra'`, etc.) or *float*

Returns
float number associated with `'inp'`

Return type
float

diffsph.utils.tools.**df**(*func*, ***kwargs*)

diffsph.utils.tools.**evaluate**(*f*, *x*, ***kwargs*)

Function converts string into a python function's name and evaluates it

Parameters

- **f** – function to be evaluated
- **x** – first argument of f

Returns
$f(x)$

diffsph.utils.tools.**f**(*n*, *x*)

Basis function in Fourier-expanded brightness formula

$$f_n(x) = 2\int_x^1 \frac{\sin(n\pi y)dy}{\sqrt{y^2 - x^2}}$$

Returns
f_n as a function of x

diffsph.utils.tools.**fwhm**(*brightness*, *thmax*, **args*, ***kwargs*)

Full width at half maximum

Parameters

- **brightness** – generic brightness function

- **thmax** – signal's angular radius

Returns
Full width at half maximum in arcmin

`diffsph.utils.tools.`**`g`**`(`*n*, *x*`)`

Basis function in Fourier-expanded flux density formula

$$g_n(x) = 2\int_x^1 \sqrt{y^2 - x^2}\,\sin(n\pi y) dy$$

Returns
g_n as a function of x

`diffsph.utils.tools.`**`halo_fd`**`(`*n*, *theta*, *dist*, *rh*`)`

Partial (θ-dependent) flux-density halo/bulge factor:

$$\mathcal{H}_n(\theta) = \mathcal{H}_n(r_h, R) - 2\int_{R\sin(\theta)}^{r_h} dr\, r\, \kappa_1(r, R, \theta) \frac{\sin\left(\frac{n\pi r}{r_h}\right)}{r}\ ,$$

where R, rh and n are, respectively the distance, halo radius and Fourier index

`diffsph.utils.tools.`**`halo_fd_tot`**`(`*n*, *dist*, *rh*`)`

Total flux-density halo/bulge factor:

$$\mathcal{H}_n(r_h, R) = 2\int_0^{r_h} dr\, r\, \kappa_0(r, R) \frac{\sin\left(\frac{n\pi r}{r_h}\right)}{r}\ ,$$

where R, rh and n are, respectively the distance, halo radius and Fourier index

Returns
Halo flux-density factor

`diffsph.utils.tools.`**`hfd`**`(`*fluxdens*, *thmax*, **args*, ***kwargs*`)`

Half-flux diameter

Parameters

- **brightness** – generic brightness function
- **thmax** – signal's angular radius

Returns
Half-flux diameter in arcmin

`diffsph.utils.tools.`**`hypothesis_index`**`(`*hyp*`)`

Index of the hypothesis (1 for decaying DM or generic scenario, 2 for WIMP self-annihilation).

Parameters
hyp (*str*) – hypothesis: `'wimp'`, `'decay'` or `'generic'`)

Returns
hypothesis index

Return type
int

`diffsph.utils.tools.`**`ker_0`**`(`*r*, *dist*`)`

$$\kappa_0(r, R) = \frac{1}{R}\log\sqrt{\frac{R+r}{R-r}}$$

`diffsph.utils.tools.`**`ker_1`**`(`*r*, *theta*, *dist*`)`

$$\kappa_1(\theta, r, R) = \frac{1}{R} \log \frac{R\cos\theta + \sqrt{r^2 - R^2\sin^2\theta}}{\sqrt{R^2 - r^2}}$$

`diffsph.utils.tools.`**`load_data`**`(`*folder*`)`

Function loads data from folder

`diffsph.utils.tools.`**`sort_kwargs`**`(`***kwargs*`)`

Function sorts keyword arguments alphabetically

`diffsph.utils.tools.`**`var_to_str`**`(`*inp*`)`

Dictionary for variables `'delta'`, `'hyp'`, `'galaxy'`, `'ref'` and `'rad_temp'`

Parameters
`inp` – input string or number

Returns
default variable name

Return type
str

Module contents

1.1.2 Submodules

1.1.3 diffsph.limits module

`diffsph.limits.`**`decay_rate_gausslim`**`(`*nu*, *a_fit*, *sigma_fit*, *beam_size*, *galaxy*, *rad_temp*, *D0=3e+28*, *delta='kol'*, *B=2*, *mchi=50*, *channel='mumu'*, *manual=False*, ***kwargs*`)`

Maximum dark matter decay rate allowed by the exclusion of a Gaussian-shaped signal

$$a_{\rm fit} \exp\left(-\frac{\theta^2}{2\sigma^2_{\rm fit}}\right)$$

Parameters

- **`nu`** – frequency in GHz
- **`a_fit`** – fitted gaussian amplitude in μ Jy / beam
- **`sigma_fit`** – width parameter of the Gaussian template in arcmin
- **`galaxy`** (*`str`*) – name of the galaxy
- **`rad_temp`** (*`str`*) – dark matter halo model (`'NFW'`, `'Einasto'`, etc.)
- **`D0`** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **`delta`** (*`float, str`*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **`B`** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **`mchi`** – mass of the DM particle in GeV/c ^{2}

- **channel** (*str*) – decay channel: $b\bar{b}$ ('bb'), $\mu^+\mu^-$ ('mumu'), W^+W^- ('WW'), etc.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = 'False')

Beam_size
beam size in arcseconds

Keyword arguments

- manual = 'False'

  Parameters
  ref – reference used ('Martinez' or '1309.2641', 'Geringer-Sameth' or '1408.0002', etc.)

- manual = 'True'

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
  - **sigmav** – velocity dispersion in km/s for the isothermal sphere `diffsph.profiles.templates.sis()`

Returns
upper limit on the DM decay rate in 1/s

Return type
float

`diffsph.limits.decay_rate_limest`(*nu*, *rms_noise*, *beam_size*, *galaxy*, *rad_temp*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *mchi=50*, *channel='mumu'*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

(Estimated) maximum dark matter decay rate given the rms noise level of an observation

Parameters

- **nu** – frequency in GHz
- **rms_noise** – RMS noise level of the observation in μ Jy / beam
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – dark matter halo model ('NFW', 'Einasto', etc.)
- **ratio** – ratio between the diffusion halo and half-light radii
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or 'kol')
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)

- **mchi** – mass of the DM particle in GeV/c ^{2}
- **channel** (*str*) – decay channel: $b\bar{b}$ ('bb'), $\mu^+\mu^-$ ('mumu'), W^+W^- ('WW'), etc.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = 'False')
- **high_res** (*bool*) – spatial resolution. If 'True', synch_emissivity() computes as many terms as needed in order to converge at $r = 0$. (default value = 'False')
- **accuracy** – theoretical accuracy in % (default value = 1%)

Beam_size
beam size in arcseconds

Keyword arguments

- manual = 'False'

  Parameters
  ref – reference used ('Martinez' or '1309.2641', 'Geringer-Sameth' or '1408.0002', etc.)

- manual = 'True'

  Parameters
  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **sigmav** – velocity dispersion in km/s for the isothermal sphere *diffsph.profiles.templates.sis()*

  Returns
  Estimated upper limit on the DM decay rate in 1/s

  Return type
  float

diffsph.limits.**generic_rate_gausslim**(*nu*, *a_fit*, *sigma_fit*, *beam_size*, *galaxy*, *rad_temp*, *D0=3e+28*, *delta='kol'*, *B=2*, *Gamma=2*, ***kwargs*)

Maximum CRE production rate (generic power-law hypothesis) allowed by the exclusion of a Gaussian-shaped signal

$$a_{\rm fit}\exp\left(-\frac{\theta^2}{2\sigma_{\rm fit}^2}\right)$$

Parameters
- **nu** – frequency in GHz
- **a_fit** – fitted gaussian amplitude in μ Jy / beam
- **sigma_fit** – width parameter of the Gaussian template in arcmin
- **galaxy** (*str*) – name of the galaxy

- **rad_temp** (*str*) – dark matter halo model (`'NFW'`, `'Einasto'`, etc.)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$, default value = 2)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Beam_size
beam size in arcseconds

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **sigmav** – velocity dispersion in km/s for the isothermal sphere *diffsph.profiles.templates.sis()*

Returns
upper limit on the generic CRE production rate in 1/s

Return type
float

diffsph.limits.**generic_rate_limest**(*nu, rms_noise, beam_size, galaxy, rad_temp, ratio=1, D0=3e+28, delta='kol', B=2, Gamma=2, high_res=False, accuracy=1, **kwargs*)

(Estimated) maximum CRE production rate (generic power-law hypothesis) given the rms noise level of an observation

Parameters

- **nu** – frequency in GHz
- **rms_noise** – RMS noise level of the observation in μ Jy / beam
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – dark matter halo model (`'NFW'`, `'Einasto'`, etc.)
- **ratio** – ratio between the diffusion halo and half-light radii
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)

- **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$, default value = 2)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)
- **high_res** (*bool*) – spatial resolution. If `'True'`, `synch_emissivity()` computes as many terms as needed in order to converge at $r = 0$. (default value = `'False'`)
- **accuracy** – theoretical accuracy in % (default value = 1%)

Beam_size
beam size in arcseconds

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **sigmav** – velocity dispersion in km/s for the isothermal sphere `diffsph.profiles.templates.sis()`

Returns
Estimated upper limit on the generic CRE production rate in 1/s

Return type
float

`diffsph.limits.`**`sigmav_gausslim`**(*nu*, *a_fit*, *sigma_fit*, *beam_size*, *galaxy*, *rad_temp*, *D0=3e+28*, *delta='kol'*, *B=2*, *mchi=50*, *channel='mumu'*, *self_conjugate=True*, *manual=False*, ***kwargs*)

Maximum WIMP self-annihilation cross-section allowed by the exclusion of a Gaussian-shaped signal

$$a_{\rm fit}\exp\left(-\frac{\theta^2}{2\sigma_{\rm fit}^2}\right)$$

Parameters

- **nu** – frequency in GHz
- **a_fit** – fitted gaussian amplitude in μ Jy / beam
- **sigma_fit** – width parameter of the Gaussian template in arcmin
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – dark matter halo model (`'NFW'`, `'Einasto'`, etc.)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **mchi** – mass of the DM particle in GeV/c ^{2}

- **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.
- **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Beam_size
beam size in arcseconds

Keyword arguments

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile

Returns
upper limit for the WIMP self-annihilation cross-section in cm ^{3} /s

Return type
float

`diffsph.limits.`**`sigmav_limest`**(*nu*, *rms_noise*, *beam_size*, *galaxy*, *rad_temp*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *mchi=50*, *channel='mumu'*, *self_conjugate=True*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

(Estimated) maximum WIMP self-annihilation cross-section given the rms noise level of an observation

Parameters

- **nu** – frequency in GHz
- **rms_noise** – RMS noise level of the observation in μ Jy / beam
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – dark matter halo model (`'NFW'`, `'Einasto'`, etc.)
- **ratio** – ratio between the diffusion halo and half-light radii
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **mchi** – mass of the DM particle in GeV/c ^{2}

- **channel** (*str*) – annihilation channel: $b\bar{b}$ ('bb'), $\mu^+\mu^-$ ('mumu'), W^+W^- ('WW'), etc.
- **self_conjugate** – if set 'True' (default value) the DM particle is its own antiparticle
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = 'False')
- **high_res** (*bool*) – spatial resolution. If 'True', `synch_emissivity()` computes as many terms as needed in order to converge at $r = 0$. (default value = 'False')
- **accuracy** – theoretical accuracy in % (default value = 1%)

Beam_size
beam size in arcseconds

Keyword arguments

- `manual = 'False'`

Parameters
ref – reference used ('Martinez' or '1309.2641', 'Geringer-Sameth' or '1408.0002', etc.)

- `manual = 'True'`

Parameters

- **rs** – scale radius in kpc
- **rhos** – characteristic density in GeV/cm ^{3}
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile

Returns
Estimated upper limit on WIMP self-annihilation cross-section in cm ^{3} /s

Return type
float

1.1.4 diffsph.pyflux module

`diffsph.pyflux.coeff`(*n*, *nu*, *galaxy*, *rad_temp*, *hyp*, *ratio*, *D0*, *delta*, *B*, *manual=False*, ***kwargs*)

n-th coefficient participating in the Fourier-expanded Green's function solution of the CRE transport equation

$$s_n = h_n \times X_n$$

Parameters

- **n** – order of the halo/bulge factor
- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template ('NFW', 'Einasto', etc.)

- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters

  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile

- **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
- **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
- **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
- **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns

n-th coefficient in the *which_N* function

`diffsph.pyflux.synch_TB`(*theta*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

Model-specific brightness temperature from synchrotron radiation

Parameters

- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)
- **high_res** (*bool*) – spatial resolution. If `'True'`, `synch_emissivity()` computes as many terms as needed in order to converge at $r = 0$. (default value = `'False'`)
- **accuracy** – theoretical accuracy in % (default value = 1%)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s

- **mchi** – mass of the DM particle in GeV/c ^{2}
- **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
  - **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
Brightness temperature in mK

`diffsph.pyflux.`**synch_TB_approx**(*theta*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific brightness temperature in the Regime “A”, “B” or “C” approximations

Parameters

- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)

- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source $(1.1 < \Gamma < 3)$
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters

  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile

- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
Brightness temperature in mK

`diffsph.pyflux.synch_brightness`(*theta*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

Model-specific brightness from synchrotron radiation

Parameters

- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)
- **high_res** (*bool*) – spatial resolution. If `'True'`, *synch_emissivity()* computes as many terms as needed in order to converge at $r = 0$. (default value = `'False'`)
- **accuracy** – theoretical accuracy in % (default value = 1%)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters

  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
  - **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns
Brightness in Jy/sr

Return type
float

`diffsph.pyflux.`**`synch_brightness_approx`**(*theta*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific brightness from synchrotron radiation in the Regime “A”, “B” or “C” approximations

Parameters

- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE’s energy (default value = 1/3 or `'kol'`)

- **B** – magnitude of the magnetic field's smooth component in μ G (default value = 2μ G)
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
  - **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile

- **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
Brightness in Jy/sr

`diffsph.pyflux.`**`synch_emissivity`**(*r*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

Model-specific emissivity from synchrotron radiation

Parameters

- **r** – galactocentric distance in kpc
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)
- **high_res** (*bool*) – spatial resolution. If `'True'`, `synch_emissivity()` computes as many terms as needed in order to converge at $r = 0$ (default value = `'False'`)
- **accuracy** – theoretical accuracy in % (default value = 1%)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

Parameters

- **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
- **rate** – CRE production rate in 1/s

- `manual = 'False'`

Parameters

ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

Parameters

- **rs** – scale radius in kpc
- **rhos** – characteristic density in GeV/cm ^{3}
- **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
- **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
- **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
- **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
- **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
- **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

Returns

Emissivity in erg/cm ^{3} /Hz/s/sr

Return type

float

`diffsph.pyflux.`**`synch_emissivity_approx`**(*r*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific emissivity from synchrotron radiation in the Regime "A", "B" or "C" approximations

Parameters

- **r** – galactocentric distance in kpc
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)

- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
  - **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
  - **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns

Emissivity in erg/cm ^{3} /Hz/s/sr

`diffsph.pyflux.synch_flux_density`(*theta*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

Model-specific flux density from synchrotron radiation

Parameters

- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)
- **high_res** (*bool*) – spatial resolution. If `'True'`, *synch_emissivity()* computes as many terms as needed in order to converge at $r = 0$. (default value = `'False'`)
- **accuracy** – theoretical accuracy in % (default value = 1%)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
  - **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

  Returns
  Flux density in µJy

`diffsph.pyflux.`**synch_flux_density_approx**(*theta*, *nu*, *galaxy*, *rad_temp*, *hyp='wimp'*, *ratio=1*, *D0=3e+28*, *delta='kol'*, *B=2*, *regime='B'*, *manual=False*, ***kwargs*)

Model-specific flux density from synchrotron radiation in the Regime “A”, “B” or “C” approximations

Parameters

- **theta** – angular radius in arcmin
- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE’s energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field’s smooth component in μ G (default value $= 2\mu$ G)
- **regime** – regime of the approximation. Must be either upper or lower case a, b, c or I/II/III.
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the `diffsph.profiles.templates.hdz()` profile
  - **beta** – exponent β in the `diffsph.profiles.templates.hdz()` profile
  - **gamma** – exponent γ in the `diffsph.profiles.templates.hdz()` profile
  - **alphaE** – parameter α_E in the `diffsph.profiles.templates.enst()` profile
  - **rc** – core radius parameter r_c in the `diffsph.profiles.templates.cnfw()` profile
  - **sigmav** – velocity dispersion parameter σ_v in the `diffsph.profiles.templates.sis()` profile

Returns
Flux density in µJy

`diffsph.pyflux.which_N`(*nu*, *galaxy*, *rad_temp*, *hyp*, *ratio*, *D0*, *delta*, *B*, *manual=False*, *high_res=False*, *accuracy=1*, ***kwargs*)

Determines at which order should the Fourier-expanded Green's function solution be truncated and stores the associated $s_n = h_n \times X_n$ coefficients as an array in the `/cache` folder

Parameters

- **nu** – frequency in GHz
- **galaxy** (*str*) – name of the galaxy
- **rad_temp** (*str*) – radial template (`'NFW'`, `'Einasto'`, etc.)
- **hyp** (*str*) – hypothesis: `'wimp'` (**default**), `'decay'` or `'generic'`
- **ratio** – ratio between the diffusion halo/bulge and half-light radii (default value = 1)
- **D0** – magnitude of the diffusion coefficient for a 1 GeV CRE in cm ^{2}/s (default value = 3×10^{28} cm ^{2} /s)
- **delta** (*float, str*) – power-law exponent of the diffusion coefficient as a function of the CRE's energy (default value = 1/3 or `'kol'`)
- **B** – magnitude of the magnetic field's smooth component in μ G (default value $= 2\mu$ G)
- **manual** (*bool*) – manual input of parameter values in rad_temp (default value = `'False'`)
- **high_res** (*bool*) – spatial resolution. If `'True'`, *synch_emissivity()* computes as many terms as needed in order to converge at $r = 0$. (default value = `'False'`)
- **accuracy** – theoretical accuracy in % (default value = 1%)

Keyword arguments

- `hyp = 'wimp'` (default)

  Parameters

  - **sv** – annihilation rate (annihilation cross section times relative velocity) σv in cm ^{3}/s (default value = 3×10^{-26} cm ^{3} /s)
  - **self_conjugate** – if set `'True'` (default value) the DM particle is its own antiparticle
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – annihilation channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'decay'`

  Parameters

  - **width** – decay width of the DM particle in 1/s
  - **mchi** – mass of the DM particle in GeV/c ^{2}
  - **channel** (*str*) – decay channel: $b\bar{b}$ (`'bb'`), $\mu^+\mu^-$ (`'mumu'`), W^+W^- (`'WW'`), etc.

- `hyp = 'generic'`

  Parameters

  - **Gamma** – power-law exponent of the generic CRE source ($1.1 < \Gamma < 3$)
  - **rate** – CRE production rate in 1/s

- `manual = 'False'`

  Parameters
  ref – reference used (`'Martinez'` or `'1309.2641'`, `'Geringer-Sameth'` or `'1408.0002'`, etc.)

- `manual = 'True'`

  Parameters

  - **rs** – scale radius in kpc
  - **rhos** – characteristic density in GeV/cm ^{3}
  - **alpha** – exponent α in the *diffsph.profiles.templates.hdz()* profile
  - **beta** – exponent β in the *diffsph.profiles.templates.hdz()* profile
  - **gamma** – exponent γ in the *diffsph.profiles.templates.hdz()* profile
  - **alphaE** – parameter α_E in the *diffsph.profiles.templates.enst()* profile
  - **rc** – core radius parameter r_c in the *diffsph.profiles.templates.cnfw()* profile
  - **sigmav** – velocity dispersion parameter σ_v in the *diffsph.profiles.templates.sis()* profile

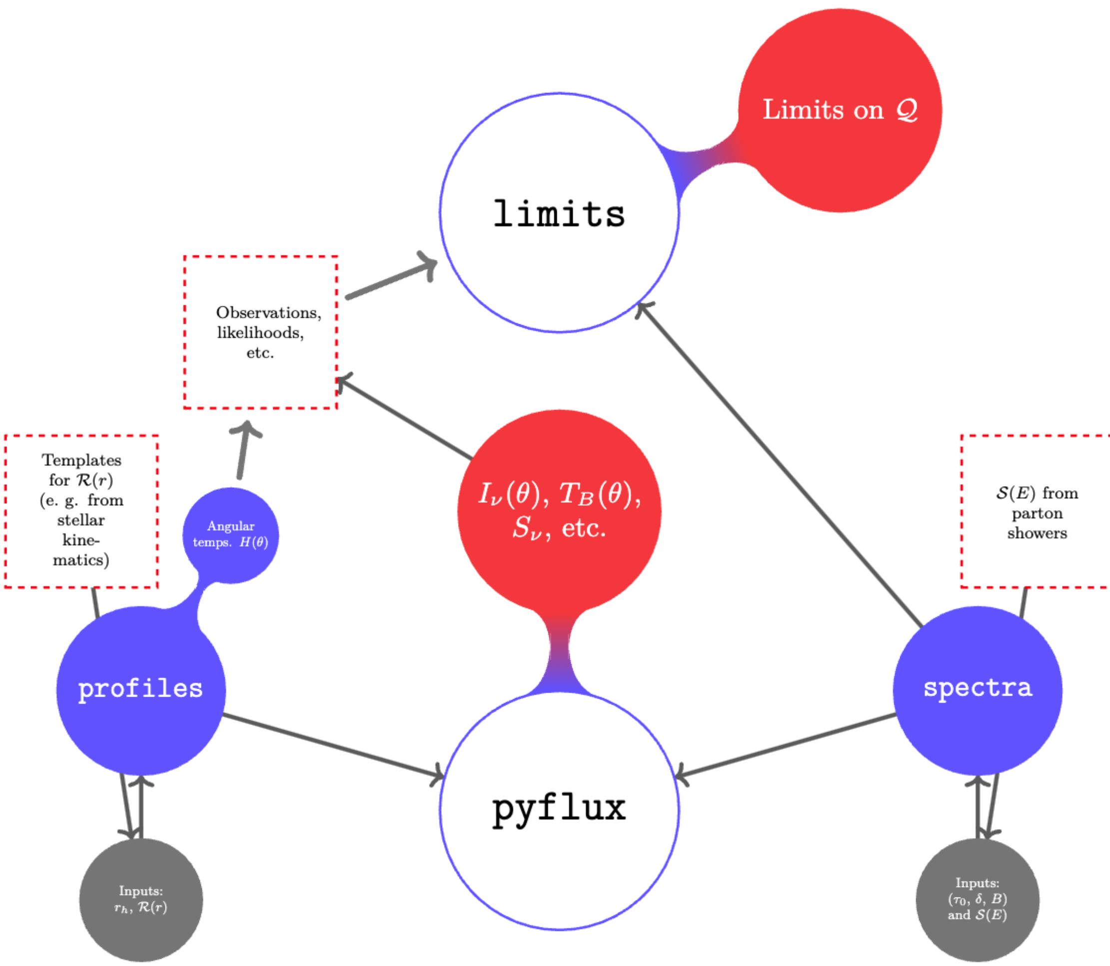
  Returns
  series truncation order N

1.1.5 Module contents

CHAPTER TWO

ARCHITECTURE

The code's structure can be summarized as follows:



Besides being able to compute fluxes with the `pyflux` (*diffsph.pyflux*) module, the `limits` (*diffsph.limits*) module enables users to produce 2σ limits on e.~g. annihilation cross sections or decay rates of dark matter particles.

CHAPTER

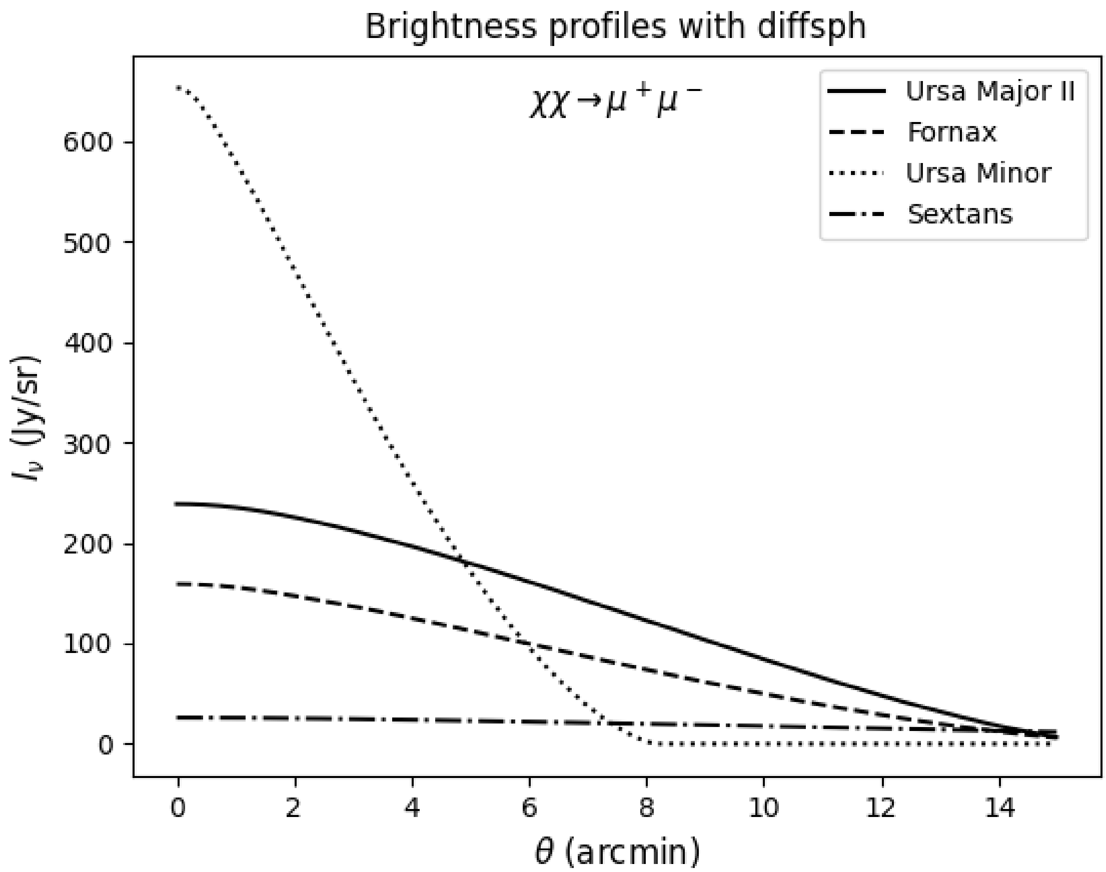
THREE

EXAMPLES

3.1 pyflux module

In order to get familiar with the code, the user can use the following set of commands in order to generate the figure below:

```
from diffsph import pyflux as pf
import matplotlib.pyplot as plt
%matplotlib inline

# Angle grid in arcmin

theta_grid = [15 * i / 1000 for i in range(0,1000)]

# List of satellite galaxies

dsph_list = ['Ursa Major II', 'Fornax', 'Ursa Minor', 'Sextans']

# diffsph's computations at nu = 150 MHz and for the given model

Inu = [[pf.synch_brightness(th, nu = .150, galaxy = gal, rad_temp = 'HDZ',
                            hyp = 'wimp', ref = '1408.0002', sv = 3e-26,
                            mchi = 10, channel = 'mumu', high_res = True,
                            accuracy = .1)
             for th in theta_grid]
            for gal in dsph_list]

# Plots

plt.plot(theta_grid, Inu[0], "k", label = dsph_list[0])
plt.plot(theta_grid, Inu[1], "--k", label = dsph_list[1])
plt.plot(theta_grid, Inu[2], ":k", label = dsph_list[2])
plt.plot(theta_grid, Inu[3], "-.k", label = dsph_list[3])
plt.legend()
plt.xlabel('$\\theta$ (arcmin)', size = 'large');
plt.ylabel('$I_\\nu$ (Jy/sr)', size = 'large');
plt.title('Brightness profiles with diffsph');
plt.text(7.5, 630, '$\chi\chi\, \\to\, \mu^+\mu^-$',
         horizontalalignment = 'center', size = 'large');
```



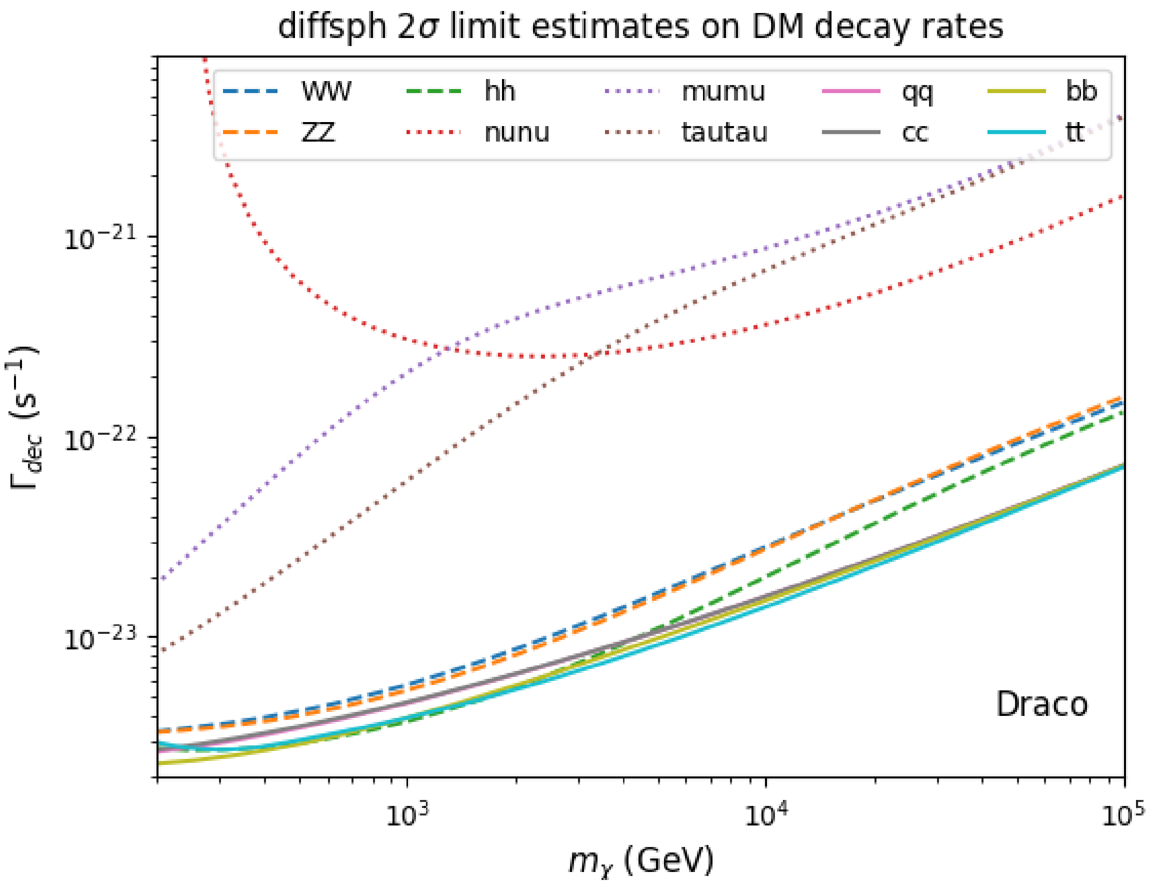
In this example, the ordering of the elements in the list `dshp_list` is not arbitrary. It was deliberately chosen in such a way that the total flux density of the first element is the largest while the rest are sorted in decreasing order. The following command line allows one to assess this quantitatively:

```
# Total flux density for each galaxy in mJy
Snu = [[gal, 1e-3 * pf.synch_flux_density(30, nu = .150, galaxy = gal,
                                          rad_temp = 'HDZ', hyp = 'wimp',
                                          ref = '1408.0002', sv = 3e-26,
                                          mchi = 10, channel = 'mumu',
                                          high_res = True, accuracy = .1)]
            for gal in dsph_list]

# Print
print(Snu)

>>> [['Ursa Major II', 5.205501952938485], ['Fornax', 3.2288461400011492],
['Ursa Minor', 2.8903428197065293], ['Sextans', 1.6467270289999836]]
```

3.2 `limits` module

The following example shows how to obtain limits on e.~g. the decay rate of dark matter particles using the given noise level of a non-detection image of Draco. It takes (without parallelization) about one hour to compute all:

```
from diffsph import limits as lims

# DM mass grid in GeV

mass_grid = [100 * 10 ** (3 * i / 1000) for i in range(0,1000)]

# List of decay channels

ch_list = ['WW', 'ZZ', 'hh', 'nunu', 'mumu', 'tautau', 'qq', 'cc', 'bb', 'tt']

# diffsph's computations at nu = 150 MHz and for the given image

rates = [[lims.decay_rate_limest(nu = .15, rms_noise = 100, beam_size = 20,
                                 galaxy = 'Draco', rad_temp = 'HDZ', mchi = mch,
                                 channel = ch, high_res = True, accuracy = .1,
                                 ref = '1408.0002')
          for mch in mass_grid]
         for ch in ch_list]

# Plots

[plt.loglog(mass_grid, rates_Draco[i], label = ch_list[i], ls = '--') for i in range(0,
↪3)]
[plt.loglog(mass_grid, rates_Draco[i], label = ch_list[i], ls = ':') for i in range(3,
↪6)]
[plt.loglog(mass_grid, rates_Draco[i], label = ch_list[i]) for i in range(6, len(ch_
↪list))]
plt.ylim([2e-24,8e-21]);
plt.xlim([200,1e5]);
plt.legend(loc = 'upper right', ncols = 5)
plt.xlabel('$m_\chi$ (GeV)', size = 'large');
plt.ylabel('$\Gamma_{dec}$ (s${}^{-1}$)', size = 'large');
plt.title('diffsph 2$\sigma$ limit estimates on DM decay rates');
plt.text(8e4, 4e-24, 'Draco', horizontalalignment = 'right', size = 'large');
```


diffsph 2σ limit estimates on DM decay rates
WW
ZZ
hh
nunu
mumu
tautau
qq
cc
bb
tt
Draco
10^{-21}
10^{-22}
10^{-23}
Γ_{dec} (s^{-1})
10^3
10^4
10^5
m_χ (GeV)

CHAPTER

FOUR

INDICES AND TABLES

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References

PYTHON MODULE INDEX

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