CRRLpy Documentation

Release 0.1

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CHAPTER

ONE

CRRLPY

Tools for processing **C**arbon **R**adio **R**ecombination **L**ine spectra.

The models are not shipped with the modules and scripts.

The documentation can be found in: http://astrofle.github.io/CRRLpy/

CHAPTER

TWO

CRRLPY.CRRLS MODULE

crrlpy.crrls.**alphanum_key**(*s*)
Turn a string into a list of string and number chunks.

Parameters **s** – String

Returns List with strings and integers.

Return type list

Example

```
>>> alphanum_key("z23a")
["z", 23, "a"]
```

crrlpy.crrls.**average**(*data*, *axis*, *n*)
Averages data along the given axis by combining n adjacent values.

Parameters

- **data** (*numpy array*) – Data to average along a given axis.
- **axis** (*int*) – Axis along which to average.
- **n** (*int*) – Factor by which to average.

Returns Data decimated by a factor n along the given axis.

Return type numpy array

crrlpy.crrls.**best_match_indx**(*value*, *array*, *tol*)
Searchs for the best match to a value inside an array given a tolerance.

Parameters

- **value** (*float*) – Value to find inside the array.
- **tol** (*float*) – Tolerance for match.
- **array** (*numpy.array*) – List to search for the given value.

Returns Best match for val inside array.

Return type float

crrlpy.crrls.**best_match_indx2**(*value*, *array*)
Searchs for the index of the closest entry to value inside an array.

Parameters

- **value** (*float*) – Value to find inside the array.
- **array** (*list or numpy.array*) – List to search for the given value.

Returns Best match index for the value inside array.

Return type float

Example

```
>>> a = [1,2,3,4]
>>> best_match_indx2(3, a)
2
```

crrlpy.crrls.**best_match_value**(*value*, *array*)

Searchs for the closest ocurrence of value in array.

Parameters

- **value** (*float*) – Value to find inside the array.
- **array** (*list or numpy.array*) – List to search for the given value.

Returns Best match for the value inside array.

Return type float.

Example

```
>>> a = [1,2,3,4]
>>> best_match_value(3.5, a)
3
```

crrlpy.crrls.**blank_lines**(*freq*, *tau*, *reffreqs*, *v0*, *dv0*)

Blanks the lines in a spectra.

Parameters **freq** (*array*) – Frequency axis of the spectra.

:

crrlpy.crrls.**blank_lines2**(*freq*, *tau*, *reffreqs*, *dv*)

crrlpy.crrls.**df2dv**(*f0*, *df*)

Convert a frequency delta to a velocity delta given a central frequency.

Parameters

- **f0** (*float*) – Rest frequency. (Hz)
- **df** (*float*) – Frequency delta. (Hz)

Returns The equivalent velocity delta for the given frequency delta.

Return type float in Hz

crrlpy.crrls.**dv2df**(*f0*, *dv*)

Convert a velocity delta to a frequency delta given a central frequency.

Parameters

- **f0** (*float*) – Rest frequency. (Hz)
- **dv** (*float*) – Velocity delta. (m/s)

Returns The equivalent frequency delta for the given velocity delta.

Return type float in m s^{-1}

crrlpy.crrls.**dv_minus_doppler**(*dV*, *ddV*, *dD*, *ddD*)

Returns the Lorentzian contribution to the line width assuming that the line has a Voigt profile.

Parameters

- **dV** (*float*) – Total line width
- **ddV** (*float*) – Uncertainty in the total line width.
- **dD** (*float*) – Doppler contribution to the line width.
- **ddD** – Uncertainty in the Doppler contribution to the line width.

Returns The Lorentz contribution to the total line width.

Return type float

crrlpy.crrls.**dv_minus_doppler2**(*dV*, *ddV*, *dD*, *ddD*)
Returns the Lorentzian contribution to the line width assuming that the line has a Voigt profile.

Parameters

- **dV** (*float*) – Total line width
- **ddV** (*float*) – Uncertainty in the total line width.
- **dD** (*float*) – Doppler contribution to the line width.
- **ddD** – Uncertainty in the Doppler contribution to the line width.

Returns The Lorentz contribution to the total line width.

Return type float

crrlpy.crrls.**f2n**(*f*, *line*, *n_max=1500*)
Converts a given frequency to a principal quantum number n for a given line.

crrlpy.crrls.**find_lines_in_band**(*freq*, *species='CI'*, *transition='alpha'*, *z=0*, *verbose=False*)
Finds if there are any lines corresponding to transitions of the given species in the frequency range. The line transition frequencies are corrected for redshift.

Parameters

- **freq** –
- **species** –
- **z** – Redshift to apply to the rest frequencies.
- **verbose** (*bool*) – Verbose output?

Returns

Return type List of principal quantum numbers and list of reference frequencies.

crrlpy.crrls.**find_lines_sb**(*freq*, *transition*, *z=0*, *verbose=False*)
Finds if there are any lines corresponding to transitions of the given species in the frequency range. The line transition frequencies are corrected for redshift.

crrlpy.crrls.**fit_continuum**(*x*, *y*, *degree*, *p0*)
Divide tb by given a model and starting parameters p0. Returns: tb/model - 1

crrlpy.crrls.**fit_line**(*sb*, *n*, *ref*, *vel*, *tau*, *rms*, *model*, *v0=None*, *verbose=True*)

crrlpy.crrls.**fit_storage**()
Returns a dictionary with the entries for the parameters to be fitted.

crrlpy.crrls.**freq2vel**(*f0*, *f*)
Convert a frequency axis to a velocity axis given a central frequency. Uses the radio definition of velocity.

Parameters

- **f0** (*float*) – Rest frequency for the conversion. (Hz)

- **f** (*numpy array*) – Frequencies to be converted to velocity. (Hz)

Returns f converted to velocity given a rest frequency f_0.

Return type numpy array

crrlpy.crrls.**fwhm2sigma**(*fwhm*)
Converts a FWHM to the standard deviation of a Gaussian distribution.

crrlpy.crrls.**gauss_area**(*amplitude*, *sigma*)
Returns the area under a Gaussian of a given amplitude and sigma.

crrlpy.crrls.**gauss_area_err**(*amplitude*, *amplitude_err*, *sigma*, *sigma_err*)

crrlpy.crrls.**gauss_filter**(*y*, ***kwargs*)
Applies a Gaussian filter to y.

crrlpy.crrls.**gaussian**(*x*, *sigma*, *center*, *amplitude*)
1-d Gaussian with no amplitude offset.

crrlpy.crrls.**gaussian_off**(*x*, *amplitude*, *center*, *sigma*, *c*)
1-d Gaussian with a constant amplitude offset.

crrlpy.crrls.**get_axis**(*header*, *axis*)
Constructs a cube axis

Parameters

- **header** (*pyfits header*) – Fits cube header.
- **axis** (*int*) – Axis to reconstruct.

Returns cube axis

Return type numpy array

crrlpy.crrls.**get_line_mask**(*freq*, *reffreq*, *v0*, *dv0*)
Return a mask with ranges where a line is expected in the given frequency range for a line with a given reference frequency at expected velocity v0 and line width dv0.

Parameters

- **freq** (*numpy array or list*) – Frequency axis where the line is located.
- **reffreq** (*float*) – Reference frequency for the line.
- **v0** (*float, km/s*) – Velocity of the line.
- **dv0** (*float, km/s*) – Velocity range to mask.

Returns Mask centered at the line center and width *dv0* referenced to the input *freq*.

crrlpy.crrls.**get_line_mask2**(*freq*, *reffreq*, *dv*)
Return a mask with ranges where a line is expected in the given frequency range for a line with a given reference frequency and line width dv.

crrlpy.crrls.**get_min_sep**(*array*)
Get the minimum element separation in an array.

crrlpy.crrls.**get_rms**(*data*, *axis=None*)
Computes the rms of the given data.

Parameters

- **data** (*numpy array or list*) – Array with values where to compute the rms.
- **axis** (*int*) – Axis over which to compute the rms. Default: None

Returns The rms of data.

$$\mathrm{rms} = \sqrt{\langle \mathrm{data} \rangle^2 + V[\mathrm{data}]}$$

where V is the variance of the data.

crrlpy.crrls.**is_number**(*s*)
Checks wether a string is a number or not.

crrlpy.crrls.**line_width**(*dD*, *dL*)
http://en.wikipedia.org/wiki/Voigt_profile#The_width_of_the_Voigt_profile

crrlpy.crrls.**line_width_err**(*dD*, *dL*, *ddD*, *ddL*)
Computes the error in the FWHM of a Voigt profile. http://en.wikipedia.org/wiki/Voigt_profile#The_width_of_the_Voigt_profile

crrlpy.crrls.**linear**(*x*, *a*, *b*)
Linear model.

crrlpy.crrls.**load_model**(*prop*, *specie*, *temp*, *dens*, *other=None*)
Loads a model for the CRRL emission.

crrlpy.crrls.**load_ref**(*specie*, *trans*)
Loads the reference spectrum for the specified atomic specie and transition. Available species and transitions: CI alpha CI beta CI delta CI gamma CI13 alpha HeI alpha HeI beta HI alpha HI beta SI alpha SI beta

crrlpy.crrls.**load_ref2**(*transition*)
Loads the reference spectrum for the specified atomic specie and transition. Available transitions: CIalpha CIbeta CIdelta CIgamma CI13alpha HeIalpha HeIbeta HIalpha HIbeta SIalpha SIbeta

crrlpy.crrls.**lookup_freq**(*n*, *specie*, *trans*)
Returns the frequency of a given transition.

crrlpy.crrls.**lorentz_width**(*n*, *ne*, *Te*, *Tr*, *W*, *dn=1*)
Gives the Lorentzian line width due to a combination of radiation and collisional broadening. The width is the FWHM in Hz. It uses the models of Salgado et al. (2015).

crrlpy.crrls.**mask_outliers**(*data*, *m=2*)
Masks values larger than m times the data median.

crrlpy.crrls.**n2f**(*n*, *line*, *n_min=1*, *n_max=1500*, *unitless=True*)
Converts a given principal quantum number n to the frequency of a given line.

crrlpy.crrls.**natural_sort**(*l*)
Sort the given list in the way that humans expect. Sorting is done in place.

crrlpy.crrls.**plot_fit**(*fig*, *x*, *y*, *fit*, *params*, *vparams*, *sparams*, *rms*, *x0*, *refs*, *refs_cb=None*, *refs_cd=None*, *refs_cg=None*)

crrlpy.crrls.**plot_fit_single**(*fig*, *x*, *y*, *fit*, *params*, *rms*, *x0*, *refs*, *refs_cb=None*, *refs_cd=None*, *refs_cg=None*)

crrlpy.crrls.**plot_model**(*x*, *y*, *xm*, *ym*, *out*)

crrlpy.crrls.**plot_spec_vel**(*out*, *x*, *y*, *fit*, *A*, *Aerr*, *x0*, *x0err*, *sx*, *sxerr*)

crrlpy.crrls.**pressure_broad**(*n*, *Te*, *ne*)
Pressure induced broadening in Hz. Shaver (1975)

crrlpy.crrls.**pressure_broad_coefs**(*Te*)
Defines the values of the constants a and γ that go into the collisional broadening formula of Salgado et al. (2015).

Parameters **Te** (*float*) – Electron temperature.

Returns The values of a and γ.

Return type list

crrlpy.crrls.**pressure_broad_salgado**(*n*, *Te*, *ne*, *dn=1*)
Pressure induced broadening in Hz. This gives the FWHM of a Lorentzian line. Salgado et al. (2015)

Parameters

- **n** (*float or array*) – Principal quantum number for which to compute the line broadening.
- **Te** (*float*) – Electron temperature to use when computing the collisional line width.
- **ne** (*float*) – Electron density to use when computing the collisional line width.
- **dn** (*int*) – Difference between the upper and lower level for which the line width is computed. (default 1)

Returns The collisional broadening FWHM in Hz using Salgado et al. (2015) formulas.

Return type float or array

crrlpy.crrls.**radiation_broad**(*n*, *W*, *Tr*)
Radiation induced broadening in Hz.

crrlpy.crrls.**radiation_broad_salgado**(*n*, *W*, *Tr*)
Radiation induced broadening in Hz. This gives the FWHM of a Lorentzian line. Salgado et al. (2015)

crrlpy.crrls.**radiation_broad_salgado_general**(*n*, *W*, *Tr*, *nu0*, *alpha*)
Radiation induced broadening in Hz. This gives the FWHM of a Lorentzian line. The expression is valid for power law like radiation fields. Salgado et al. (2015)

crrlpy.crrls.**remove_baseline**(*freq*, *tb*, *model*, *p0*, *mask*)
Divide tb by given a model and starting parameters p0. Returns: tb/model - 1

crrlpy.crrls.**savgol**(*y*, ***kwargs*)

crrlpy.crrls.**sigma2fwhm**(*sigma*)
Converts the σ parameter of a Gaussian distribution to its FWHM.

Parameters **sigma** (*float*) – σ value of the Gaussian distribution.

Returns The FWHM of a Gaussian with a standard deviation σ.

Return type float

crrlpy.crrls.**sigma2fwhm_err**(*dsigma*)
Converts the error on the sigma parameter of a Gaussian distribution to the error on the FWHM.

crrlpy.crrls.**stack_interpol**(*spectra*, *vmin*, *vmax*, *dv*, *show=True*, *rmsvec=False*)

crrlpy.crrls.**stack_irregular**(*lines*, *window='‘*, ***kargs*)
Stacks spectra by adding them together and then convolving with a window to reduce the noise. Available window functions: Gaussian, Savitzky-Golay and Wiener.

crrlpy.crrls.**sum_line**(*sb*, *n*, *ref*, *vel*, *tau*, *v0*, *tau0*, *dtau0*, *thr*, *rms*)
Integrate the spectrum near a given velocity v0. It stops when the channels are within a threshold from a reference level.

crrlpy.crrls.**sum_storage**()

crrlpy.crrls.**tryint**(*s*)

crrlpy.crrls.**vel2freq**(*f0*, *vel*)
Convert a velocity axis to a frequency axis given a central frequency. Uses the radio definition, $\nu = f_0(1 - v/c)$.

Parameters

- **f0** (*float*) – Rest frequency in Hz.
- **vel** (*float or array*) – Velocity to convert in m/s.

Returns The frequency which is equivalent to vel.

Return type float or array

crrlpy.crrls.**voigt**(*x*, *sigma*, *gamma*, *center*, *amplitude*)
The Voigt line shape in terms of its physical parameters.

Parameters

- **x** – independent variable
- **sigma** – HWHM of the Gaussian
- **gamma** – HWHM of the Lorentzian
- **center** – the line center
- **amplitude** – the line area

crrlpy.crrls.**voigt_**(*x*, *y*)

crrlpy.crrls.**voigt_area**(*amp*, *fwhm*, *gamma*, *sigma*)
Returns the area under a Voigt profile. This approximation has an error of less than 0.5%

crrlpy.crrls.**voigt_area_err**(*area*, *amp*, *damp*, *fwhm*, *dfwhm*, *gamma*, *sigma*)
Returns the error of the area under a Voigt profile. Assumes that the parameter c has an error of 0.5%.

crrlpy.crrls.**voigt_peak**(*A*, *alphaD*, *alphaL*)
Gives the peak of a Voigt profile given its Area and the HWHM of the Gaussian and Lorentz profiles.

crrlpy.crrls.**voigt_peak2area**(*peak*, *alphaD*, *alphaL*)
Converts the peak of a Voigt profile into the area under the profile given the HWHM of the profile.

crrlpy.crrls.**voigt_peak_err**(*peak*, *A*, *dA*, *alphaD*, *dalphaD*)
Gives the error on the peak of the Voigt profile.

crrlpy.crrls.**wiener**(*y*, ***kwargs*)

CHAPTER

THREE

CRRLPY.MODELS.RRLMOD MODULE

crrlpy.models.rrlmod.**I_Bnu**(*specie*, *Z*, *n*, *Inu_funct*, **args*)

Calculates the product $B_{n+\Delta n,n}I_\nu$ to compute the line broadening due to a radiation field I_ν.

Parameters

- **specie** (*str*) – Atomic specie to calculate for.
- **n** (*int or list*) – Principal quantum number at which to evaluate $\frac{2}{\pi}\sum_{\Delta n} B_{n+\Delta n,n}I_{n+\Delta n,n}(\nu)$.
- **Inu_funct** (*function*) – Function to call and evaluate $I_{n+\Delta n,n}(\nu)$. It's first argument must be the frequency.
- ***args** – Arguments to *Inu_funct*. The frequency must be left out. The frequency will be passed internally in units of MHz. Use the same unit when required. *Inu_funct* must take the frequency as first parameter.

Returns

Return type array, Hz

Example

```
>>> I_Bnu('CI', 1.,  500, I_broken_plaw, 800, 26*u.MHz.to('Hz'), -1., -2.6)
array([ 6.65540582])
```

crrlpy.models.rrlmod.**I_broken_plaw**(*nu*, *Tr*, *nu0*, *alpha1*, *alpha2*)

Returns the blackbody function evaluated at nu. As temperature a broken power law is used. The power law shape has parameters: Tr, nu0, alpha1 and alpha2.

Parameters

- **nu** ((Hz) or astropy.units.Quantity) – Frequency. (Hz) or astropy.units.Quantity
- **Tr** – Temperature at nu0. (K) or astropy.units.Quantity
- **nu0** – Frequency at which the spectral index changes. (Hz) or astropy.units.Quantity
- **alpha1** – spectral index for $\nu < \nu_0$
- **alpha2** – spectral index for $\nu \geq \nu_0$

Returns Specific intensity in $\mathrm{erg\,cm^{-2}\,Hz^{-1}\,s^{-1}\,sr^{-1}}$. See astropy.analytic_functions.blackbody.blackbody_nu

Return type astropy.units.Quantity

crrlpy.models.rrlmod.**I_cont**(*nu*, *Te*, *tau*, *I0*, *unitless=False*)

Computes the specific intensity due to a blackbody at temperature T_e and optical depth τ. It considers that there is background radiation with I_0.

Parameters

- **nu** ((Hz) or astropy.units.Quantity) – Frequency.
- **Te** – Temperature of the source function. (K) or astropy.units.Quantity
- **tau** – Optical depth of the medium.
- **I0** – Specific intensity of the background radiation. Must have units of erg / (cm2 Hz s sr) or see *unitless*.
- **unitless** – If True the return

Returns The specific intensity of a ray of light after traveling in an LTE medium with source function $B_\nu(T_e)$ after crossing an optical depth τ_ν. The units are erg / (cm2 Hz s sr). See astropy.analytic_functions.blackbody.blackbody_nu

crrlpy.models.rrlmod.**I_external**(*nu*, *Tbkg*, *Tff*, *tau_ff*, *Tr*, *nu0=<Quantity 100000000.0 MHz>*, *alpha=-2.6*)

This method is equivalent to the IDL routine

Parameters **nu** – Frequency. (Hz) or astropy.units.Quantity

crrlpy.models.rrlmod.**I_total**(*nu*, *Te*, *tau*, *I0*, *eta*)

crrlpy.models.rrlmod.**Mdn**(*dn*)

Gives the $M(\Delta n)$ factor for a given Δn. ref. Menzel (1968)

Parameters **dn** – Δn.

Returns $M(\Delta n)$

Return type float

Example

```
>>> Mdn(1)
0.1908
>>> Mdn(5)
0.001812
```

crrlpy.models.rrlmod.**broken_plaw**(*nu*, *nu0*, *T0*, *alpha1*, *alpha2*)

Defines a broken power law.

$$T(\nu) = T_0 \left(\frac{\nu}{\nu_0}\right)^{\alpha_1} \text{ if } \nu < \nu_0$$

$$T(\nu) = T_0 \left(\frac{\nu}{\nu_0}\right)^{\alpha_2} \text{ if } \nu \geq \nu_0$$

Parameters

- **nu** – Frequency.
- **nu0** – Frequency at which the power law breaks.
- **T0** – Value of the power law at nu0.
- **alpha1** – Index of the power law for nu<nu0.
- **alpha2** – Index of the power law for nu>=nu0.

Returns Broken power law evalueated at nu.

crrlpy.models.rrlmod.**eta**(*freq*, *Te*, *ne*, *nion*, *Z*, *Tr*, *trans*, *n_max=1500*)

Returns the correction factor for the Planck function.

crrlpy.models.rrlmod.**itau**(*temp*, *dens*, *line*, *n_min=5*, *n_max=1000*, *other=''*, *verbose=False*, *value='itau'*)

Gives the integrated optical depth for a given temperature and density. The emission measure is unity. The output units are Hz.

Parameters

- **temp** – Electron temperature. Must be a string of the form '8d1'.
- **dens** – Electron density. Float
- **line** – Line to load models for.
- **n_min** – Minimum n value to include in the output. Int Default 1
- **n_max** – Maximum n value to include in the output. Int Default 1500, Maximum allowed value 9900
- **other** – String to search for different radiation fields and others.
- **verbose** – Verbose output? Bool
- **value** – ['itau'|'bbnMdn'|none] Value to output. itau will output the integrated optical depth.

bbnMdn will output the $\beta_{n,n'} b_n$ times the oscillator strenght $M(\Delta n)$. :returns: The principal quantum number and its asociated value.

crrlpy.models.rrlmod.**itau_h**(*temp*, *dens*, *trans*, *n_max=1000*, *other=''*, *verbose=False*, *value='itau'*)

Gives the integrated optical depth for a given temperature and density. The emission measure is unity. The output units are Hz.

crrlpy.models.rrlmod.**itau_norad**(*n*, *te*, *b*, *dn*, *mdn*)

Returns the optical depth with only the approximate solution to the radiative transfer problem.

crrlpy.models.rrlmod.**j_line_lte**(*n*, *ne*, *nion*, *Te*, *Z*, *trans*)

crrlpy.models.rrlmod.**kappa_cont**(*freq*, *Te*, *ne*, *nion*, *Z*)

Computes the absorption coefficient for the free-free process.

crrlpy.models.rrlmod.**kappa_cont_base**(*nu*, *Te*, *ne*, *nion*, *Z*)

crrlpy.models.rrlmod.**kappa_line**(*Te*, *ne*, *nion*, *Z*, *Tr*, *trans*, *n_max=1500*)

Computes the line absorption coefficient for CRRLs between levels **:mat:'n_{i}'** and n_f, $n_i > n_f$. This can only go up to $n_{\max}$ 1500 because of the tables used for the Einstein Anm coefficients.

Parameters

- **Te** (*float*) – Electron temperature of the gas. (K)
- **ne** (*float*) – Electron density. (cm^{-3})
- **nion** (*float*) – Ion density. (cm^{-3})
- **Z** (*int*) – Electric charge of the atoms being considered.
- **Tr** (*float*) – Temperature of the radiation field felt by the gas. This specifies the temperature of the field at 100 MHz. (K)
- **trans** (*string*) – Transition for which to compute the absorption coefficient.
- **n_max** (*int<1500*) – Maximum principal quantum number to include in the output.

Returns

Return type array

crrlpy.models.rrlmod.**kappa_line_lte**(*nu*, *Te*, *ne*, *nion*, *Z*, *Tr*, *line*, *n_min=1*, *n_max=1500*)
Returns the line absorption coefficient under LTE conditions.

Parameters

- **nu** (*array*) – Frequency. (Hz)
- **Te** (*float*) – Electron temperature of the gas. (K)
- **ne** (*float*) – Electron density. (cm^{-3})
- **nion** (*float*) – Ion density. (cm^{-3})
- **Z** (*int*) – Electric charge of the atoms being considered.
- **Tr** (*float*) – Temperature of the radiation field felt by the gas. This specifies the temperature of the field at 100 MHz. (K)
- **trans** (*string*) – Transition for which to compute the absorption coefficient.
- **n_max** (*int<1500*) – Maximum principal quantum number to include in the output.

Returns

Return type array

crrlpy.models.rrlmod.**level_pop_lte**(*n*, *ne*, *nion*, *Te*, *Z*)
Returns the level population of level n. The return has units of cm^{-3}.

crrlpy.models.rrlmod.**load_betabn**(*temp*, *dens*, *other=''*, *trans='CIalpha'*, *verbose=False*)
Loads a model for the CRRL emission.

crrlpy.models.rrlmod.**load_betabn_h**(*temp*, *dens*, *other=''*, *trans='alpha'*, *verbose=False*)
Loads a model for the HRRL emission.

crrlpy.models.rrlmod.**load_bn**(*temp*, *dens*, *other=''*)
Loads the bn values from the CRRL models.

crrlpy.models.rrlmod.**load_bn2**(*temp*, *dens*, *other=''*)
Loads the bn values from the CRRL models.

crrlpy.models.rrlmod.**load_itau_all**(*trans='CIalpha'*, *n_min=5*, *n_max=1000*, *verbose=False*, *value='itau'*)
Loads all the available models for Carbon.

crrlpy.models.rrlmod.**load_itau_all_hydrogen**(*trans='alpha'*, *n_max=1000*, *verbose=False*, *value='itau'*)
Loads all the available models for Hydrogen.

crrlpy.models.rrlmod.**load_itau_all_match**(*trans_out='alpha'*, *trans_tin='beta'*, *n_max=1000*, *verbose=False*, *value='itau'*)
Loads all trans_out models that can be found in trans_tin. This is useful when analyzing line ratios.

crrlpy.models.rrlmod.**load_itau_all_norad**(*trans='alpha'*, *n_max=1000*)
Loads all the available models.

crrlpy.models.rrlmod.**load_itau_dict**(*dict*, *trans*, *n_min=5*, *n_max=1000*, *verbose=False*, *value='itau'*)
Loads the models defined by dict.

crrlpy.models.rrlmod.**load_itau_nelim**(*temp*, *dens*, *trad*, *trans*, *n_max=1000*, *verbose=False*, *value='itau'*)
Loads models given a temperature, radiation field and an upper limit for the electron density.

crrlpy.models.rrlmod.**load_models**(*models*, *trans*, *n_max=1000*, *verbose=False*, *value='itau'*)
Loads the models in backwards compatible mode. It will sort the models by Te, ne and Tr.

crrlpy.models.rrlmod.**make_betabn**(*line*, *temp*, *dens*, *n_min=5*, *n_max=1000*, *other=''*)

crrlpy.models.rrlmod.**make_betabn2**(*line*, *temp*, *dens*, *n_min=5*, *n_max=1000*, *other=''*)

crrlpy.models.rrlmod.**plaw**(*x*, *x0*, *y0*, *alpha*)

Returns a power law.

$$y(x) = y_0 \left(\frac{x}{x_0} \right)^{\alpha}$$

Parameters

- **x** (*float or array like*) – x values for which to compute the power law.
- **x0** (*float*) – x value for which the power law has amplitude *y0*.
- **y0** (*float*) – Amplitude of the power law at *x0*.
- **alpha** (*float*) – Index of the power law.

Returns A power law of index *alpha* evaluated at *x*, with amplitude *y0* at *x0*.

Return type float or array

crrlpy.models.rrlmod.**str2val**(*str*)

crrlpy.models.rrlmod.**val2str**(*val*)

Converts a float to the str format required for loading the CRRL models. E.g., a temperature of 70 K is 7d1.

crrlpy.models.rrlmod.**valid_ne**(*trans*)

Checks all the available models and lists the available ne values.

crrlpy.models.rrlmod.**xi**(*n*, *Te*, *Z*)

CHAPTER

FOUR

CRRLPY.CRRLS.FREC_CALC MODULE

crrlpy.frec_calc.**line_freq**(*Z*, *R_X*, *n*, *dn*)

Uses the Rydberg formula to get the frequency of a transition to quantum number n for a given atom.

Parameters

- **Z** (*int*) – Charge of the atom.
- **R_X** (*float*) –
- **n** (*int*) – Principal quantum number of the transition. $n + \Delta n \rightarrow n$.
- **dn** (*int*) – Difference between the principal quantum number of the initial state and the final state. $\Delta n = n_f - n_i$.

Returns The frequency of the transition in MHz.

Return type float

crrlpy.frec_calc.**main**()

Main body of the program. Useful for calling as a script.

crrlpy.frec_calc.**make_line_list**(*line*, *n_min=1*, *n_max=1500*, *unitless=True*)

Creates a list of frequencies for the corresponding line. The frequencies are in MHz.

Parameters

- **line** – Line to compute the frequencies for.
- **n_min** – Minimum n number to include in the list.
- **n_max** – Maximum n number to include in the list.
- **unitless** – If True the list will have no units. If not the list will be of astropy.units.Quantity objects.

Returns List with the frequency of the transitions for the line.

crrlpy.frec_calc.**set_dn**(*name*)

Sets the value of Delta n depending on the transition name.

Parameters **name** (*string*) – Name of the transition.

Returns Δn for the given transition.

Return type int

Example

```
>>> set_dn('CIalpha')
1
```

```
>>> set_dn('CIdelta')
4
```

crrlpy.frec_calc.**set_specie**(*specie*)

Sets atomic constants based on the atomic specie.

Parameters **specie** (*string*) – Atomic specie.

Returns Array with the atomic mass in a.m.u., ionization potential, abundance relative to HI, $V_X - V_H$ and the electric charge.

Example

```
>>> set_specie('CI')
[12.0, 11.4, 0.0003, 149.5, 1.0]
```

crrlpy.frec_calc.**set_trans**(*dn*)

Sets a name depending on the difference between atomic levels.

Parameters **dn** (*int*) – Separation between n_i and n_f, $\Delta n = n_i - n_f$.

Returns alpha, beta, gamma, delta or epsilon depending on Δn.

Return type string

CHAPTER

FIVE

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