DESAT package: a method for the reconstruction of the saturated pixel intensities for SDO/AIA images.

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1 Introduction

DESAT is an image reconstruction process that recovers the "true" image inside the primary saturation region for AIA images by using the diffraction fringes and the diffraction Point Spread Function (PSF) of the instrument.

The DESAT method is composed by the following three main procedures:

- *cross correlation* to determine the location of the primary saturated pixels as opposed to the secondary saturation produced by charge overflow known as *Blooming*.
- *Expectation Maximization* (EM) to recover the flux intensities inside the primary saturated region given the intensities of the diffraction fringes and the diffraction component of the PSF.
- A semi-empirical method to estimate the background intensity within the diffraction region.

The diffraction component of the PSF is computed here using a modified version of the function `aia_calc_psf.pro` (Grigis et al., 2012).

In this document we provide a use case for DESAT providing a complete description of its input parameters. For a more detailed description of the computational pipeline, please refer to Schwartz et al. (2014), Torre et al. (2015) and Schwartz et al. (2015).

2 The DESAT method use case

DESAT can be applied on both Level 1 and Level 1.5 AIA saturated data. Whenever it is possible, however, we recommend to apply the method on the Level 1 data because of filtering and sub-pixel registration processes, needed to pass from Level 1 to Level 1.5 data, which can reduce the quality of the final reconstruction. In this use case we will consider a set of saturated images distributed from the *ssw cutout service* (`http://www.lmsal.com/get_aia_data/`). The following command:

```
;;; Command to compose and submit queries to the ssw cutout service.
ssw_cutout_service, '2011/09/06 22:18:00', '2011/09/06 22:19:00', $
      ref_helio='N15W18', fovx=350, fovy=350, email= 'add your email address',$
      waves=[94,131,171,193,211,304,335], max_frames=1000, instrument='aia', aec=1
```

submits the query for all the AIA EUV observations of the Sep 6, 2011 flaring event on a minute time range starting from 22:18:00, over a field of view of 350 arcsec on both the X and Y axes (`fovx, fovy`). To get from DESAT the best reconstruction, we suggest to download the data on a broad time interval, also including the automatic exposure control corrected images (`aec = 1`) and process them on a narrow time range and set a `npix` pixel value never smaller than the default one. Once the confirmation email is received from the service, the data are finally downloadable into a local directory and ready to be processed by DESAT.

```
;;;Input parameter definition
 tstart = '06-sep-2011 22:18:00'                    ;start time
 tend = '06-sep-2011 22:19:00'                      ;end time
 path = 'path/to/directory/where/data/are/stored'   ;path to the data directory
 wav = ['94','131','171','193','211','304','335']  ;wavelength to process


;;;Generation of the DESAT object
 obj = is_class( obj, 'desat', /quiet) ?  obj :  obj_new('desat')


;;;Run the DESAT method
 result = obj -> desaturation( wav , tstart , tend , path , /use_prep,$
      lev = 1, npix = 501, /save_fts, /aec, /loud, /onewindow)

end
```

3 Syntax

```
result = obj -> desaturation(wav, ts, te, path, path_save=path_save, sat_lev=sat_lev,$
      lev=lev, it=it, npix=npix, core_dim=core_dim , dwavelength = dwavelength,$
      wavstrategy = wavstrategy, peaklam = peaklam, use_prep = use_prep,$
      save_fts=save_fts, aec = aec, loud=loud, psplot = psplot, onewindow = onewindow)
```

4 Return Value

This function returns a structure containing the final product of the desaturation process, characterised by the following internal tags:

- `result.data`: an array containing the desaturated dataset;

- `result.info`: a structure array containing the info of the desaturated dataset.

5 Arguments

Mandatory:

- `wav` [*string or array of strings*]: select a set of wavelengths from the original dataset to process.

- `ts`, `te` [*string*]: respectively the start and end limit of the selected time range on which the DESAT method has to be applied (only frames with observation time within the selected time range are processed). The supported time formats are the same supported by `anytim.pro`.

- `path` [*string*]: path to the directory where the original AIA dataset is stored.

Optional:

- `path_save` [*string*, default = './']: path to the directory where the DESAT results should be saved (this implies that `save_fts` = 1).

- `sat_lev` [*float*, default = 15000]: intensity saturation level. The default value is lower that the upper limit of the dynamic range of AIA (16383 DN pix^{-1}) to avoid possible non linear response of the CCD when the charge capacity limit is approached.

- `lev` [*float*, default = 1]: stopping rule parameter for the EM method.

- `it` [*int*, default = 300]: number of maximum iterations for the EM method.

- `npix` [*int*, default = 499]: dimension in pixel of the input image (`npix` × `npix`).

- `core_dim` [*int*, default = 5]: number of pixels corresponding to the radius of the circular Gaussian core of the PSF.

- `dwavelength` [*int*, default = 0]: displacement from the nominal passband wavelength given by: `dwavelength` = $\frac{(\lambda_{New} - \texttt{wav})}{\texttt{wav}}$.

Keyword:

- `use_prep` [*int*, default = 1]: apply the `aia_prep.pro` function to the desaturated dataset.

- `save_fts` [*int*, default = 1]: allows DESAT to save the processed dataset in the `path_save` directory. Filenames have the following structure:

  `aia_desat_`*`date_time_wavelength`*`.fts`

  where *`date_time`* are given by the function `time2file.pro` in terms of the observation time each single processed frame.

- `aec` [*int*, default = 1]: enable DESAT to process both short and long exposure time frames of the selected dataset otherwise only frames with a long exposure time will be processrd.

- `loud` [*int*, default = 1]: enable the plot of intermediate results during the process.

- `bkg_method` [*string*, default = quadratic]: interpolation strategy utilized within the background estimation step:
  - `lsquadratic`: interpolate using a least squares quadratic polynomial fit for each 4 point neighborhood $(x[i-1], x[i], x[i+1], x[i+2])$ surrounding the interval of the interpolate, $x[i] \leq xout < x[i+1]$.
  - `quadratic`: interpolate by fitting a quadratic polynomial to the three point neighborhood $(x[i-1], x[i], x[i+1])$ surrounding the interval $x[i] \leq xout < x[i+1]$.
  - `spline`: interpolate by fitting a cubic spline to the 4 point neighborhood $(x[i-1], x[i], x[i+1], x[i+2])$ surrounding the interval, $x[i] \leq xout < x[i+1]$.
- `peaklam` [*float*, default = `wav`] : set the wavelength value to use for the generation of the PSF if wavstrategy = 1
- `wavstrategy` [*int*, default = 0]: wavelength definition strategy adopted for the generation of the PSF.
  - `wavstrategy = 0`: generate the PSF using the nominal wavelength value associated to the passband
  - `wavstrategy = 1`: generate the PSF using the wavelength value passed as input by the parameter `peaklam`
  - `wavstrategy = 2`: generate the PSF using the wavelength associated to the BRIGHTEST EMISSIVITY value computed by flare_peak_wavelength.pro
- `bkg_filename`[`string`, default = ' ']: defines the name of the .fits of a pre-flare image to be considered as the background by the method instead of using the semi-empirical background estimation routine.
- `onewindow` [*int*, default = 0]: if `loud` =1 it enables a single window plotting process of the intermediate results.

References

Grigis, P., Su, Y., and Weber, M. (2012). Aia psf characterization and image deconvolution. *SDO Documentation (http://www. lmsal. com/sdodocs)*.

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