Simulation of the Gaia Point Spread Functions for GIBIS

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Abstract

This note describes `psfmaker`, a package of the Gaia Simulator which creates the Gaia two-dimensional polychromatic PSFs from the new Gaia-2 WFE maps, for both the Astro and the MBP instruments. It includes smearings effects due to the pixel integration, TDI smearing, attitude induced motions, attitude rate errors, optical distortions and CCD charge diffusion. This package, based on [SAG-LL-025], is described here together with its usage in the Gaia Instrument and Basic Image Simulator GIBIS.

1 Introduction

The Point Spread Function (PSF) describes the observed shape of a point-source object. It is a combination of the optical transfer function (OTF), describing how the photons fall on the detector, leading to the optical PSF, and the modulation transfer function (MTF), describing any smearing added by the charge collection, leading to the effective PSF. In the Gaia case, the MTF includes the CCD read-out mode and defects as well as the source light motion during the integration due to the scanning law. The different elements that influence the Gaia PSF are summarised in table 1 with their effect.

`psfmaker` is based on [SAG-LL-025] and [GAIA-LL-046]. It has been developed to cover the GIBIS needs, which are accurate 2-D PSFs to be used for example for tests of the on-board algorithms, imaging capabilities, crowded fields reduction, bright star handling, etc... `psfmaker` handles both the Astro and Spectro PSFs. It uses the numerical calculation of the PSF instead of the parametrised function modeling used for GDAAS-II. The monochromatic optical PSFs are computed from the Gaia-2 WFE maps. The effective PSFs are computed by convolving the optical PSF with the MTF described in table 1, with the exception yet of the CTI effect. As in [SAG-LL-025], the polychromatic PSFs in the wide band (no filter: ASM, AF and SSM fields) are computed from basic spectra PSFs for different stellar V-I. The PSFs in filter bands (BBP and MBP fields), hereafter called filter PSFs, are computed independently of the star spectrum. To

Table 1: *The different elements contributing to the Gaia Point Spread Function. (*) indicates the elements that are not yet included in the* `psfmaker` *package. The spread induced can be along-scan (al), across-scan (ac) or both. They can lead to an asymmetric, wavelength dependent or charge level dependent PSF. The wavelength dependent effects are combined in the final polychromatic PSF.*

PSF	**Cause**	**Effect**			
		spread	*asymmetry*	*chromaticity*	*flux dep.*
Optical	optical diffraction	al, ac	no	yes	no
(OTF)	optical aberrations (WFE)	al, ac	yes	yes	no
Effective	pixel size integration	al, ac	no	no	no
(MTF)	TDI smearing	al	no	no	no
	attitude induced motion	ac,al	no	no	no
	attitude rate errors	al, ac	no	no	no
	optical design distortions	al, ac	no	no	no
	Astro additional rate errors	al, ac	no	no	no
	charge diffusion	al, ac	no	yes	yes*
	charge transfer inefficiency*	al*	yes*	?*	yes*
Polychromatic	source spectrum	$\sum$	$\sum$	$\sum$	$\sum$
	mirror reflectivity	$\sum$	$\sum$	$\sum$	$\sum$
	CCD QE	$\sum$	$\sum$	$\sum$	$\sum$
	filter transmission	$\sum$	$\sum$	$\sum$	$\sum$

obtain a modular package, the generation of the optical, effective and polychromatic PSFs have been decoupled. Figure 1 summarises the different steps of the PSF generation in `psfmaker`. As explained in section 3.1, the monochromatic PSFs must be computed on very small wavelength steps to simulate the wings of the polychromatic PSFs correctly. Even though the effective PSF is wavelength dependent through the CCD charge diffusion MTF, it would be far too much time consuming to compute it for every monochromatic PSF. The effective PSFs are then computed only on the quasi-monochromatic PSFs, either the basic spectra PSF or the filter PSF. The fact that the computation of the effective PSFs is independent of the optical ones makes it quick and easy to compute different effective PSFs in GIBIS, for example for the computation of the PSFs when gates are activated, when the across-scan motion is not the RMS one, etc... It will also be used later on to integrate directly the convolution with the asteroids velocity and shape.

2 The monochromatic optical PSFs

In a perfect system, the optical PSF is the result of the diffraction through the pupil aperture. Wavefront aberrations result from residual optics misalignment, polishing errors and distortions. The wavefront aberration function, $w(x, y)$ is the scalar distance between the aberrated wavefront and the ideal pupil surface. The complex amplitude of the incident wavefront in the pupil plane, also called pupil function, is $p(x, y) = \exp\left[i\frac{2\pi}{\lambda}w(x, y)\right]$ for (x,y) $\in$ pupil and 0 otherwise. The monochromatic PSF is obtained as the squared modulus of the Fourier transform of the pupil function :

$$P^o_\lambda(u, v) = \frac{1}{\lambda^2 DH}\left|\int_{-H/2}^{H/2}\int_{-D/2}^{D/2}\exp\left[i\frac{2\pi}{\lambda}(xu + yv + w(x, y))\right]dxdy\right|^2 \tag{1}$$

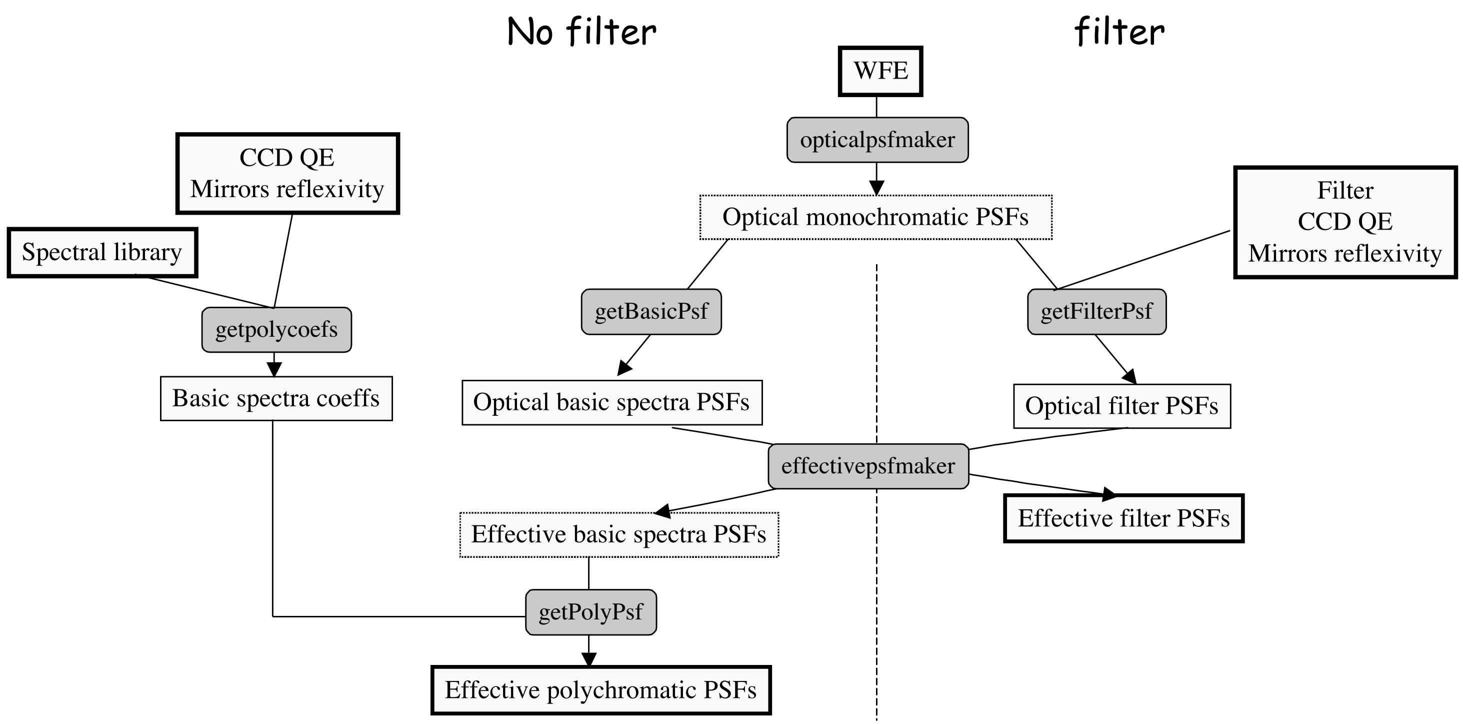

Figure 1: *Steps of the PSF generation in GIBIS in the case of wide band and filter band fields.*

with (x,y) the linear coordinates in the pupil plane, (u, v) the angular coordinates in the image plane, and D and H the dimensions of the rectangular pupil. (x,u,D) are along-scan, (y,v,H) are across-scan.

The Fourier transform of the pupil function is computed using the Fast Fourier Transform (FFT), based on the Numerical Recipes algorithm in C. For this, x and u are discretised into N_x points and y and v into N_y points, with N_x and N_y powers of 2. For a given discretisation step in the image plane (Δx, Δy), the discretisation step in the frequency domain is given by $\frac{\Delta u}{\lambda} = \frac{1}{N_x \Delta x}$ and $\frac{\Delta v}{\lambda} = \frac{1}{N_y \Delta y}$. The PSF is computed on a sub-pixel grid, with an oversampling of $o_u \times o_v$ points per pixel size $p_u \times p_v$, so $\Delta u = \frac{p_u}{o_u}$ and $\Delta v = \frac{p_v}{o_v}$. To avoid aliasing, the oversampling should be chosen so that the image is sampled at least to the Nyquist frequency:

$$N_x \Delta x \geq 2D \quad \text{and} \quad N_y \Delta y \geq 2H \tag{2}$$

`opticalpsfmaker` is a software written in C that creates the optical monochromatic PSFs. It takes as input the wavelength, the WFE map, the pupil size ($D \times H$), the pixel size ($p_u \times p_v$) and the output PSF oversampling ($o_u \times o_v$) and size ($N_x \times N_y$). It checks that the sampling is up to the Nyquist frequency and then computes the optical PSF according to the above procedure. The resulting image is in the FITS format.

The new WFE maps, provided by Astrium for the Gaia-2 design for both Astro and Spectro, are described below.

2.1 Astro WFEs: maps

The Astro WFEs have been provided by Astrium on the 11/03/2004 for 59 points on the focal plane. According to Astrium, the high frequency fluctuations of the Astro WFE maps made polynomial fitting inadequate. For each point of the focal plane, a discretised map of the WFE values over the pupil was then provided. The WFE of Astro2 are assumed to be the same ones as the Astro1 ones, but as the field of view of the two telescopes are shifted across-scan by 64mm (about one CCD row), at a given point of the focal plane the WFE point to be used should be different between the two telescopes. This is illustrated in figure 2. In practice GIBIS is using the PSF of the closest WFE point, and as the shift between the two telescopes is slightly larger than one CCD, GIBIS is indeed using two different PSFs for the Astro1 and Astro2 telescopes. ASM aberrations have been given only for the strip 1 position, however in figure 2 the WFE points have been indicated as used: on strip1 for Astro1 and on strip2 for Astro2. At the far top and bottom of the focal plane (points 1-5, 31-35, 36, 42, 43-44, 55-56), the WFE maps have been simulated by Astrium taking into account the vignetting (the effective pupil size across-scan is smaller than the nominal one). WFE points for a BBP located at strip 5.5 have been provided by Astrium (points 57-59), but not simulated in GIBIS.

The discretisation step over the pupil of the WFE maps provided are of ~ 6 mm. The WFE values are obtained every Δx steps by a bilinear interpolation.

2.2 Spectro WFEs: Legendre polynomials

The MBP WFEs have been provided by Astrium on the 03/06/2004 as Legendre polynomials:

$$w(x, y) = \sum_{i+j=0}^{5} Q_{(i,j)} \hat{L}_i(x) \hat{L}_j(y)$$

with $\hat{L}_i(x)$ normalised Legendre polynomials, $\hat{L}_i(x) = \sqrt{2n+1}\ L_i(x)$, so that the RMS WFE over the pupil is given by the quadratic sum of the Legendre polynomials: $\sigma_w^2 = \sum_{i+j=1}^{5} Q_{(i,j)}$ [1]. Those WFE have been provided on 6 points of the MBP focal plane (figure 3).

[1]This is due the following property of the Legendre polynomials: $\int_{-1}^{1} L_n(x) L_m(x) dx = \frac{2}{2n+1} \delta_{mn}$

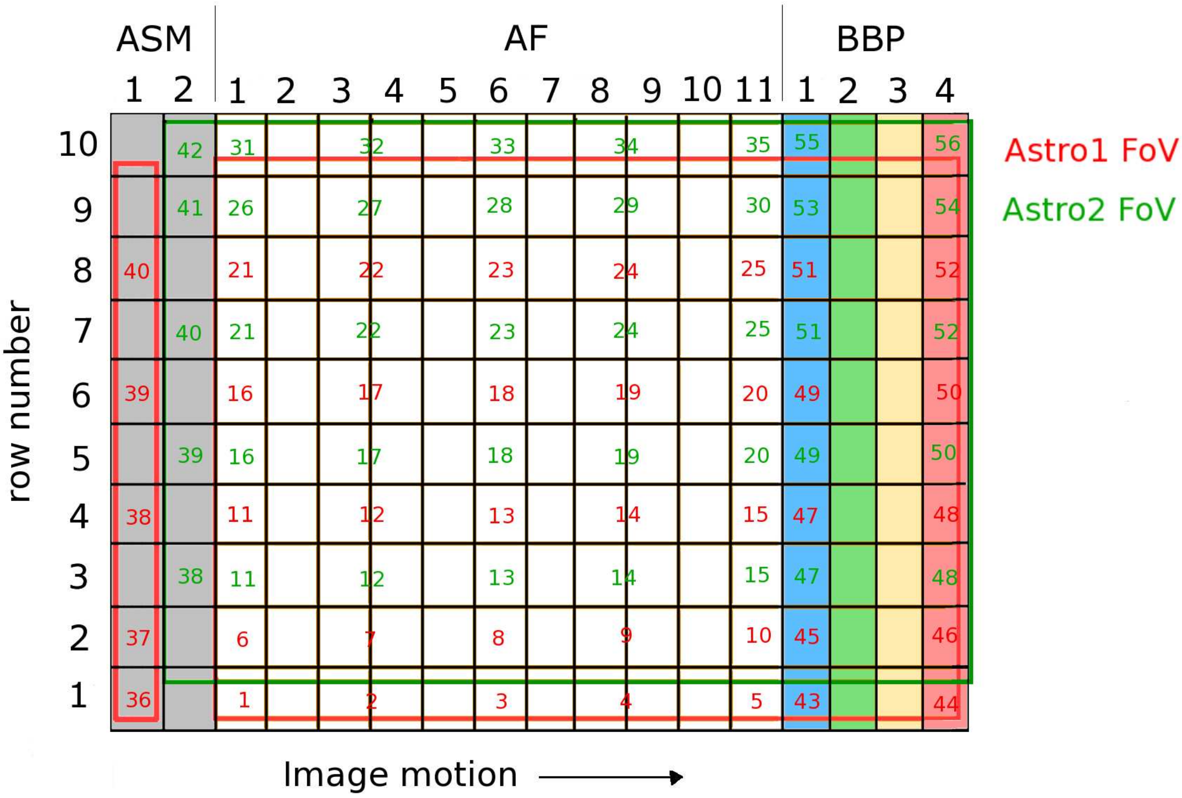

Figure 2: *Position on the focal plane of the Astro WFE points for which Astrium provided maps on the 11/03/2004. The red and green numbers represent the WFE points to be used for the Astro1 and the Astro2 telescope respectively.*

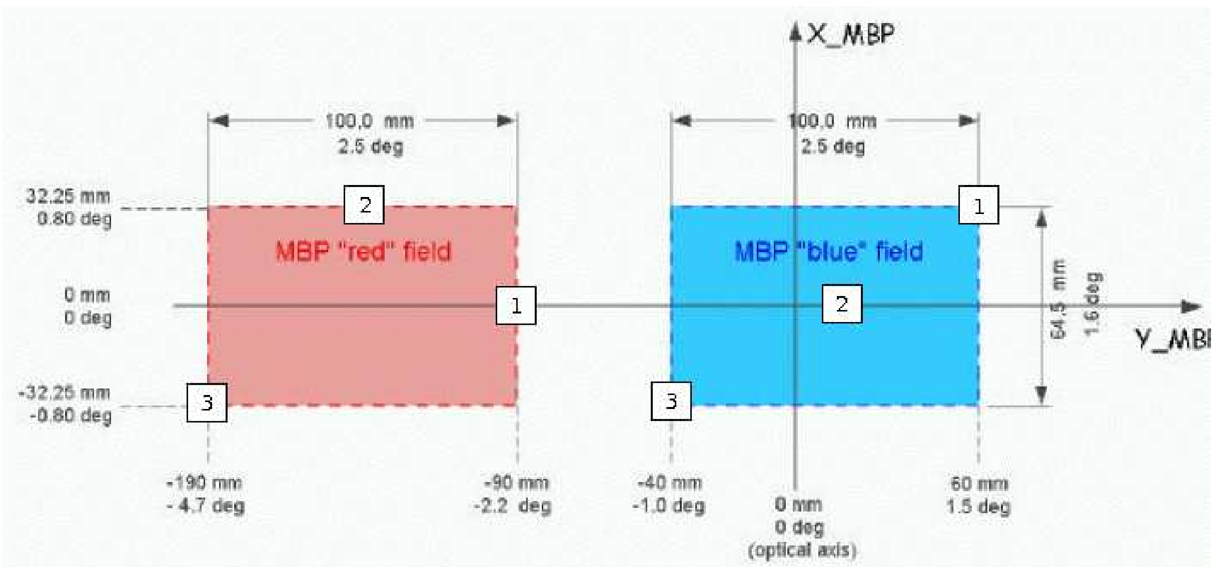

Figure 3: Position on the focal plane of the MBP WFE points for which Astrium provided maps on the 03/06/2004.

3 The quasi-monochromatic PSFs

The polychromatic (optical or effective) PSF for a star of a given spectrum $S(\lambda)$ is obtained as a weighted sum of the monochromatic PSFs:

$$P(u,v) = \frac{\int S(\lambda)T(\lambda)Q(\lambda)F(\lambda)P_\lambda(u,v)d\lambda}{\int S(\lambda)T(\lambda)Q(\lambda)F(\lambda)d\lambda} \tag{3}$$

with T the instrument transmittance, Q the CCD quantum efficiency, and F the filter.

Equation 3 is discretised as a sum of monochromatic PSFs.

3.1 Monochromatic PSF steps

The discretisation step of the monochromatic PSFs should be small enough to be able to emulate the smoothing introduced by equation 3 on the wings of the PSF.

Indeed, in the absence of aberrations, the monochromatic optical PSFs (equation 1) are simply [2]:

$$P^o_\lambda = \frac{DH}{\lambda^2} sinc^2(\pi uD/\lambda) sinc^2(\pi vH/\lambda)$$

P^o_λ then presents an infinite number of zeros at $u = n\lambda/D$ or $v = n\lambda/H$, with n integer $\neq 0$. On the spectral region defined by a central wavelength λ_e and a limited width $\Delta\lambda$, the sinc argument, $\pi uD/\lambda$, can vary by more than π at angles u greater than about $\lambda_e^2/\Delta\lambda D$, leading to a smearing of the oscillations.

To ensure that those oscillations do disappear in the wings of the simulated PSF, the sampling of the sinc argument should be large enough at the largest angle u_{max} simulated:

$$d\lambda < \frac{\lambda_e^2}{4Du_{max}} \tag{4}$$

`opticalpsfmaker` can simulate a series of monochromatic PSFs for a given wavelength step $d\lambda$, and gives a warning when d_λ does not satisfy equation 4.

3.2 The basic spectra PSFs

Following [SAG-LL-025], the polychromatic PSFs of wide band fields (ASM, AF, SSM) will be computed as a weighted sum of basic spectra PSFs P_k corresponding to the basic spectrum B_k.

The basic spectra are defined on a knot sequence λ_0, λ_1, ...,λ_{n+1} by:

$$B_k(\lambda) = \frac{2}{\lambda_{k+1} - \lambda_{k-1}} \times \begin{cases} 0 & \text{if} \quad \lambda < \lambda_{k-1} \\ (\lambda - \lambda_{k-1})/(\lambda_k - \lambda_{k-1}) & \text{if} \quad \lambda_{k-1} \leq \lambda < \lambda_k \\ (\lambda_{k+1} - \lambda)/(\lambda_{k+1} - \lambda_k) & \text{if} \quad \lambda_k \leq \lambda < \lambda_{k+1} \\ 0 & \text{if} \quad \lambda_{k+1} \leq \lambda \end{cases} \tag{5}$$

$$P_k = \int P_\lambda B_k(\lambda) d\lambda$$

P_k is computed as the weighted mean of N (N being an even number) monochromatic PSFs at the wavelengths given by:

$$\lambda_j = \lambda_k + \frac{j}{N}|\lambda_{k+sign(j)} - \lambda_k| \quad \text{with} \quad j = \pm(2i+1) \quad \text{for} \quad i = 0, ..., \frac{N}{2} - 1$$

[2] $sinc = \sin x/x$

$$P_k \simeq \sum_{j=2i+1} P_{\lambda_j} \int_{\lambda_{j-1}}^{\lambda_{j+1}} B_k(\lambda) d\lambda = \sum_{j=2i+1} \omega_j P_{\lambda_j}$$

with

$$\omega_j = \frac{4}{N^2} \frac{|\lambda_{k+sign(j)} - \lambda_k|}{\lambda_{k+1} - \lambda_{k-1}} (N - |j|)$$

`getBasicPsf` is a C software which computes the optical basic spectra PSFs from the optical monochromatic PSFs according to this procedure. To simplify, the wavelength steps are fixed over the wavelength range: basic spectra PSFs are computed on a knot sequence of a given step $\lambda_{k+1} - \lambda_k = \Delta\lambda$, and each basic spectra PSF is computed as a sum of monochromatic PSFs by steps of $\lambda_{j+2} - \lambda_j = d\lambda$. N is then given by $N = 2 * \Delta\lambda / d\lambda$.

3.3 The filter PSF

For the photometric fields (BBP and MBP), the PSFs are assumed to be independent of the source spectral distribution. The optical filter PSF is then computed by a discrete weighted sum of step $d\lambda$ of the optical monochromatic PSFs, according to equation 3 with $S(\lambda) = 1$. This is done by the C software `getFilterPsf`.

4 The effective PSFs

`effectivepsfmaker` is a C software which convolves the optical PSF with most of the flux integration and read-out effects described in table 1. A practical and efficient way of adding these effects to the optical PSF is to perform convolution in the Fourier (frequency) domain. In the Fourier domain, the CPU expensive operation of the convolution becomes a simple multiplication. The algorithm can thus be summarised this way: the FFT of the input image is first computed, then the 2D convolution mask $M(f_x, f_y, \lambda)$ is created directly in the Fourier domain and multiplied to the image. The convolved optical PSF is then obtained by transforming back the image in spatial domain using the invert FFT. The convolution process is illustrated in figures 4 and 5.

The MTF currently contains the following effects:

- Pixel integration : this effect is due to the fact that the optical continuous signal is sampled with an array of finite pixel elements. It is modeled by a convolution with a rectangular box of the size of the pixel. The resulting convolved PSF is an integrated PSF, i.e. the flux given for each point of the output PSF file is the flux integrated on a pixel centered at that position.

$$M_{pix}(f_x, f_y) = sinc(\pi f_x p_u) sinc(\pi f_y p_v)$$

- TDI smearing : this effect is caused by the charge smearing during TDI pixel transfer. It corresponds to a convolution in the AL direction with a rectangle function of the size of a pixel divided by the number of TDI phases per pixel transfer, n_p.

$$M_{TDI}(f_x) = sinc(\pi f_x p_u / n_p)$$

- Attitude induced motion : this is the smearing caused by the apparent speed along and across scan of a star produced by the attitude motion. The across-scan motion V_{AC} is the largest effect. The along-scan motion V_{AL} is much smaller but depends on the across-scan position of the star ([GAIA-LL-056]). It corresponds to a convolution in each direction with a rectangle function of the size of the across or along scan motion during the CCD crossing time t_{cross}, e.g. $V_{AC} * t_{cross}, V_{AL} * t_{cross}$ expressed in meters.

$$M_{AM}(f_x, f_y) = sinc(\pi f_y V_{AC} * t_{cross}) sinc(\pi f_x V_{AL} * t_{cross})$$

- Attitude rate errors : this is the along-scan and across-scan smearing caused by the satellite attitude errors accumulated over the CCD crossing time t_{cross}. If we assume that the relative rate error in one direction has a normal distribution with zero mean and standard deviation σ_{RRE}, then with $\sigma_{RRE} * t_{cross}$ in meters we have:

$$M_{RRE}(f_x, f_y) = exp(-\frac{1}{2}(2\pi f_x \sigma_{RRE} * t_{cross})^2) exp(-\frac{1}{2}(2\pi f_y \sigma_{RRE} * t_{cross})^2)$$

- Optical distortions induced motion : this smearing is caused by the integration of the optical distortions during the object transit on the CCD. It corresponds to a convolution with rectangular box of the size of the CCD-integrated optical distortions. The distortions for MBP are taken from [GAIASYS.RP.00120.T.ASTR], section 4.4.2 (in meters). The distortions for Astro are taken from table 4.2-B and 4.2-C of [GAIASYS.RP.00120.T.ASTR], using the maximum Astro1 distortion values along-scan. Those are computed from the RMS values D_{urms} given in table 4.2-B assuming a uniform distribution of the distortions: $D_u = D_{urms}\sqrt{12}$ in meters.

$$M_{dist}(f_x, f_y) = sinc(\pi f_x D_u) sinc(\pi f_y D_v)$$

- Astro additional rate errors : here we include two effects described in [GAIASYS.RP.00120.T.ASTR] which contribute to a large fraction of the TDI error budget in Astro:
  - The focal length mismatch between the two Astro telescopes
  - The optical distortion added in orbit when performing the WFE compensation

  They are simulated by a convolution in the AL direction with a rectangle function of size D_{AARE}, computed by adding the two effects with the values given in figure 4.2-I of [GAIASYS.RP.00120.T.ASTR] (C2 and C4) and assuming that they have a uniform distribution (this leads to D_{AARE}=4.3 μm).

$$M_{AARE}(f_x) = sinc(\pi f_x D_{AARE})$$

- CCD charge diffusion : this effect is caused by the charge spreading which mainly occurs in the CCD field-free region. It is modeled with a convolution (rotationally symmetric) with the diffusion MTF using the model $M_{D\lambda}(f)$ described in section 3.2.3 of [Gaia-AS-002]. This model does not take into account the dependence on the size of the charge packet. The table of the Silicon absorption depth as a function of wavelength is taken from the [Gaia Parameter Database].

$$M_{diff}(f_x, f_y, \lambda) = M_{D\lambda}(\sqrt{f_x^2 + f_y^2})$$

- Charge transfer inefficiency (CTI) : this effect is due to charge smearing during the read out, e.g. charges left behind when the charge package has been moved by one pixel. Highly non-linear CTI effects are caused by charge trapping ([SAG-LL-022]): the silicon layer in which charge packets are transported contains localised points in which electrons may be captured and re-emitted later on. The traps filling and thus the CTI depend on the charge level. The CTI will increase with radiation damages. The CTI is not yet implemented in `psfmaker`.

$$M_{CTI} = 1$$

A more accurate simulation of all the induced motion effects (attitute, distortion and intrinsic source motion for asteroids) will be implemented later on as a single convolution.

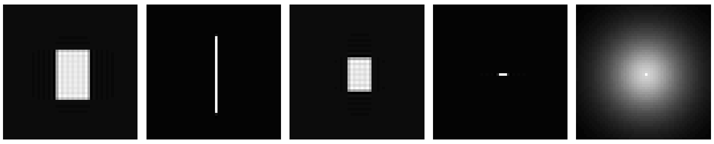

Figure 4: *Convolution masks in the spatial domain for (from left to right) : pixel integration, transverse motion, optical distortions, TDI smearing and CCD charge diffusion. The image size is 40 $\times$ 40 μm = 4 $\times$ 2.6 pixels in the MBP instrument*

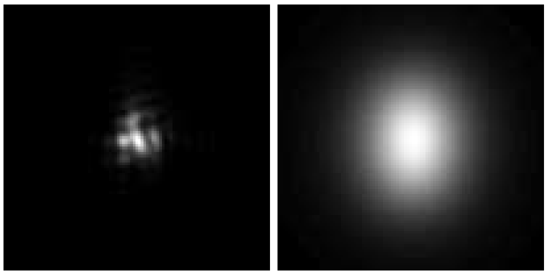

Figure 5: *Resulting effective PSF (right) of the convolution of a MBP optical PSF (left) with the MTF. The image size is 160 $\times$ 160 μm = 16 $\times$ 10.66 pixels.*

5 The polychromatic PSF

For wide band fields (ASM, AF, SSM), the polychromatic PSF is computed as a weighted sum of the basic spectra PSFs:

$$P^e(u,v) = \sum_{k=1}^{n} s_k P_k^e(u,v)$$

`getpolycoefs` is a software written in Fortran mainly by Lennart Lindegren and Jos de Bruijne to compute the coefficients s_k. Those coefficients are computed once for a given knot sequence, CCD QE and Mirror reflectivity. The coefficients are computed for the 131 stars of the [Pickles (1998)] library, plus an interstellar reddening A_V ranging from 0 to 5 mag. The colour index V-I is also computed for those stars for the Johnson V and Cousins I filter transmission curves from [Bessell (1990)]. The mean of the coefficients is computed for each V-I from -0.5 to 5.0 by step of 0.5.

The polychromatic PSF is finally computed from the basic spectra PSFs for each V-I using the coefficients $s_k(V-I)$ by the software `getPolyPsf`.

6 The PSFs in GIBIS

The PSFs simulated in GIBIS versions $\geq$ 2.0 uses `psfmaker`. All the parameters which do not have an explicit reference are taken from the [Gaia Parameter Database]. The default PSFs used in GIBIS are available at
`http://gibispc.obspm.fr:8080/gibis/files/psf/G2/`. The parameters used for the simulation of those PSFs are given in the FITS headers (table 3).

The main parameters used in GIBIS 2.0 are indicated in table 2. Bigger PSFs are simulated only in ASM and in SSM (MBP red) fields, to study the false detections caused by the PSF wings of bright stars. In Spectro, the monochromatic PSF step dλ should be <0.2 nm for $N_x = 1024$ and <0.06 nm for $N_x = 4096$, however the MTF is so large that the wings are well smeared out with the steps adopted. The basic spectra knot sequence limits are given by the CCD QE,

Table 2: *Default GIBIS PSFs characteristics. N is the number of monochromatic PSFs used for the computation of a basic spectra PSF. A basic spectra PSF is computed every $\Delta\lambda$ nm while a monochromatic PSF is computed every $d\lambda$ nm.*

	$o_u = o_v$	$N_x = N_y$	PSF radius AL	dλ [nm]	$\Delta\lambda$ [nm]	N
ASTRO	5	1024	4.5″	1	50	100
ASTRO big	3	4096	30″	0.2	50	500
MBP	25	1024	18″	1	50	100
MBP big	25	4096	73″	0.2	50	500

which goes from 350 to 1050 by steps of Δ_λ=50 nm for the Astro CCDs, and from 250 to 1050 by steps of 50 nm for the MBP CCDs blue and red.

All the parameters for the effective Astro PSFs are computed for the Astro1 telescope, in particular the distortions. The difference between the Astro1 and Astro2 PSFs in GIBIS V2.0 is just in the fact that the WFE point chosen for a given CCD image can be different (cf section 2.1). The maximum along-scan image motion induced by the scanning law is derived according to the WFE point across-scan position. The RMS across-scan motion is used for the computation of the default PSFs, but if the option is activated, the effective PSF is computed on the fly according to the across-scan motion of the simulation. When gates are activated, the effective PSF is also computed on the fly.

More details on how those PSFs are used in GIBIS is described in the help page:
`http://gibispc.obspm.fr/~gibis/help/PSF.html`.

7 Acknowledgment

Many thanks to Lennart Lindegren for providing his original softwares and guidances.

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[GAIA-LL-046] L. Lindegren *Representation of LSF and PSF for GDAAS-2*, Gaia Internal Report, GAIA-LL-046, 2-may-2003

Table 3: *FITS header of the PSFs generated by* `psfmaker`

NAXIS1	along scan size N_x [oversampled pixels]
NAXIS2	across scan size N_y [oversampled pixels]
INSTRUME	instrument (ASTRO|MBPRED|MBPBLUE)
WFEPT	aberration field point (cf. figures 2 and 3)
WAVELENG	wavelength [nm] (only for monochromatic and basic spectra PSF)
MONODW	monochromatic PSF wavelength step $d\lambda$ [nm]
GRIDSTP1	grid step size AL Δu [micron] (only for monochromatic PSF)
GRIDSTP2	grid step size AC Δv [micron] (only for monochromatic PSF)
OSAMP1	pixel oversampling factor AL, o_u
OSAMP2	pixel oversampling factor AC, o_v
MUPIXAL	pixel size AL, p_u [micron]
MUPIXAC	pixel size AC, p_v [micron]
MASPIXAL	pixel size AL [arcsec]
MASPIXAC	pixel size AC [arcsec]
TDIPHASE	number of TDI phases per pixel, n_p
TRANVELO	transverse velocity, V_{AC} [arcsec/s]
ALVELO	along scan image speed, V_{AL} [arcsec/s]
RREAL	rms relative rate error AL, σ_{RRE} [arcsec/s]
RREAC	rms relative rate error AC, σ_{RRE} [arcsec/s]
EXPTIME	integration time, t_{cross} [second]
DISTOAL	distortion AL, D_u [micron]
DISTOAC	distortion AC, D_v [micron]
DISTAARE	Astro additional rate error, D_{AARE} [micron]
SILABSOR	Silicon absorption depth, $1/\alpha$ (not for polychromatic PSF) [m]
RECOMBVS	Backside-surface electron recombination vel., V_s [m/s]
SILDN	Silicon electron diffusion coefficient, D_n [m^2/s]
SILLN	Silicon diffusion length, L_n [m]
CCDTHICK	CCD total thickness, $x_d + x_{ff}$ [m]
CCDXFF	CCD free field thickness, x_{ff} [m]
COATING	mirror coating
QE	CCD QE
MIRRORNB	Number of mirrors
FILTER	filter (only for filter PSF)
VMI	mean V-I (only for polychromatic PSF)
PCOEFK	polychromatic coefficient, s_k (only for polychromatic PSF)

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