Extended PSF for Subaru Hyper-Suprime Camera

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Abstract. The low surface brightness Universe is one of the latest frontier in observational Astronomy. However, uncovering the precious information contained in ultra-deep imaging is technically challenging. In this contribution, we will present one of the fundamental tools in the toolbox of low surface brightness astronomers: the extended Point Spread Function (PSF). Having an extended PSF is fundamental to characterize the low surface brightness properties of astronomical objects like the extended stellar halos, colors, structural properties, etc. We show the first results in the estimation of extended PSFs of one of the most important nowadays deep surveys: the Hyper-Suprime Camera (HSC) on the 8.2m Subaru telescope. The techniques used here to build the PSFs can be applied to the next generation of deep imaging astronomical surveys as the LSST.

MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

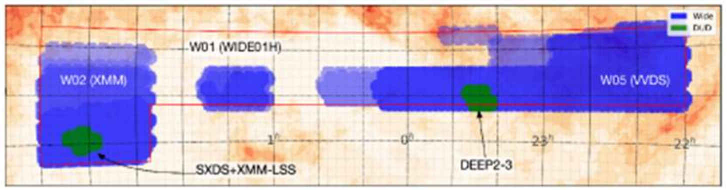
Fundación BBVA

1. Context of the research

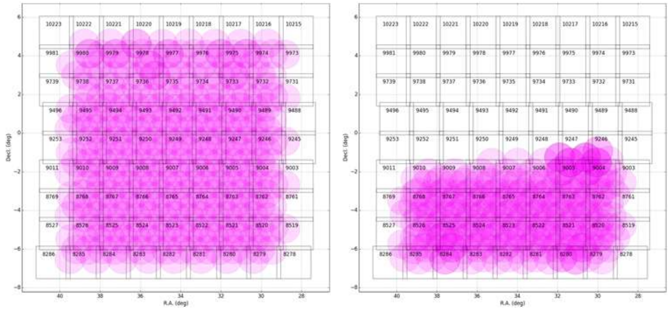
We want to study the faintest levels of emissions from galaxy outskirts, for which we need to correct the scattered light from foreground stars and the galaxy itself. For this purpose, we need to create an extended (R > 4 arcmin) PSF. We do this by sampling point-like sources at different brightnesses. A further goal is to automate the PSF creation and correction.

HSC - Subaru	8.2m	1.77 deg^2	0.17 arcsec/pix	grizY
LSST	8.4m	9.62 deg^2	0.20 arcsec/pix	ugrizY

- We have chosen HSC – Subaru for its similarities w.r.t. LSST in terms of spatial resolution, observing bands, and data reduction pipeline.
- HSC comprises 104 CCDs covering a 1.5 deg diameter FOV.

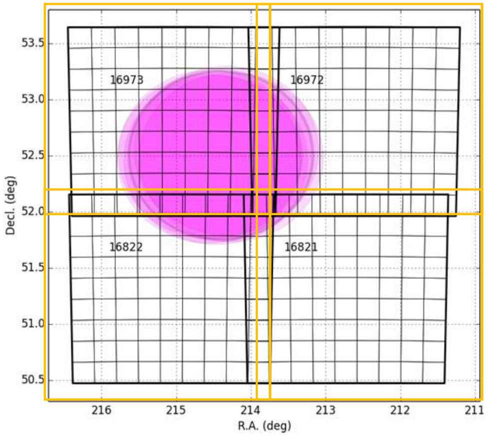


- In the wide survey, HSC is covering up to 1400 squared degrees.

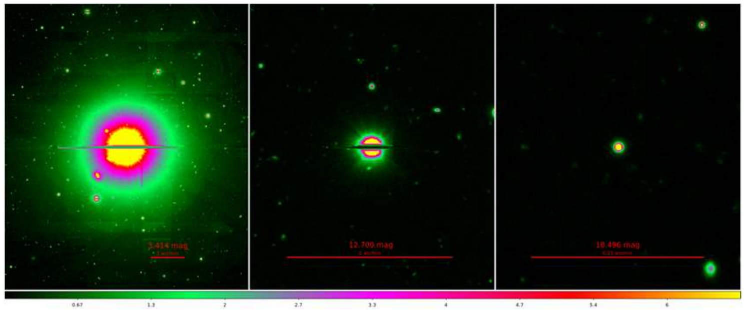


- Each region is divided in *tracts*. In this image, one can see the observed tracts at region W02 in bands r and i.

2. Description of the work & methodologies



- GAIA DR2 catalogue is used for every tract. Star magnitude ranges from 2 to 21
- Every tract is divided in 9x9 patches of 4100x4100 pixels (11.5x11.5 arcmin)
- The methodology is outlined in Infante-Sainz et al, MNRAS 491:4, (2020)
- GNU Astro tools are largely used, Akhlaghi and Ichikawa, AJSS 220:1, (2015)

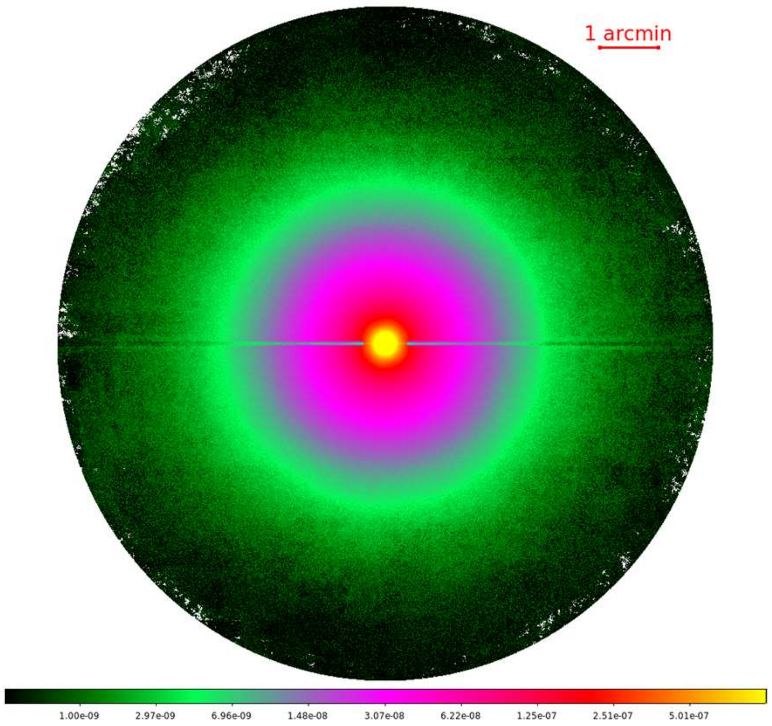


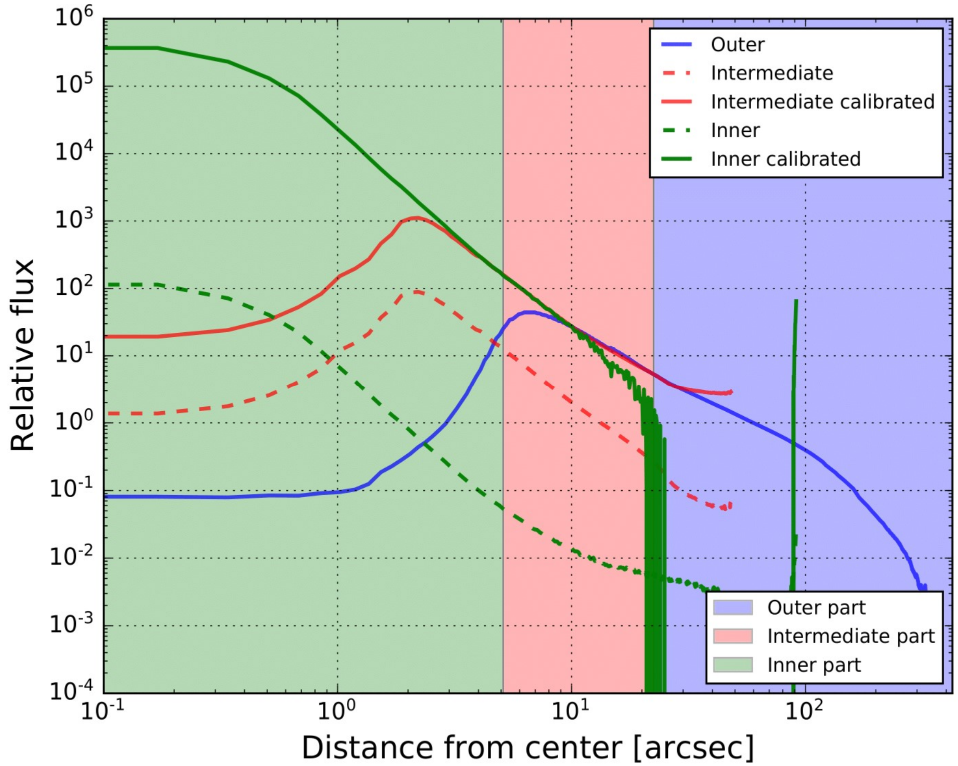
Examples of stars used to build the outer, intermediate and inner parts of the PSF

	Outer part	Intermediate part	Inner part
Magnitude range	2.0 … 8.0	12.5 … 13.0	18.495 … 18.505
FOV (arcmin)	14.17	5.67	2.13
# pixels	5061 x 5061	2025 x 2025	761 x 761

# Stars	g	r	i	z	Y
Outer	216	280	179	296	139
Intermediate	1933	2443	1401	2210	1326
Inner	7552	8723	13254	8458	5407

3. Results





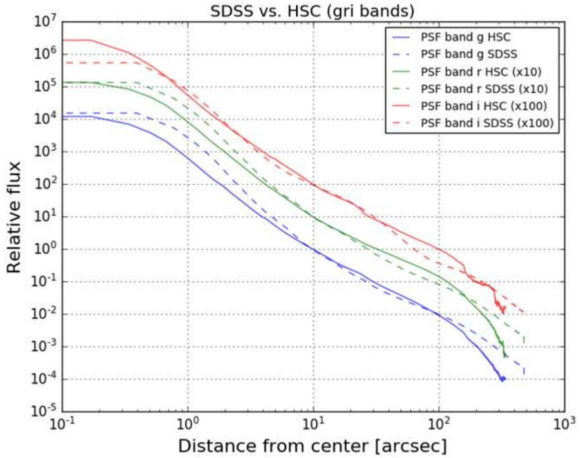
PSF at band r

- Central line accross the image is due to the saturation of bright stars.
- Blank points in the outer regions are due to the absence of information

Radial profiles

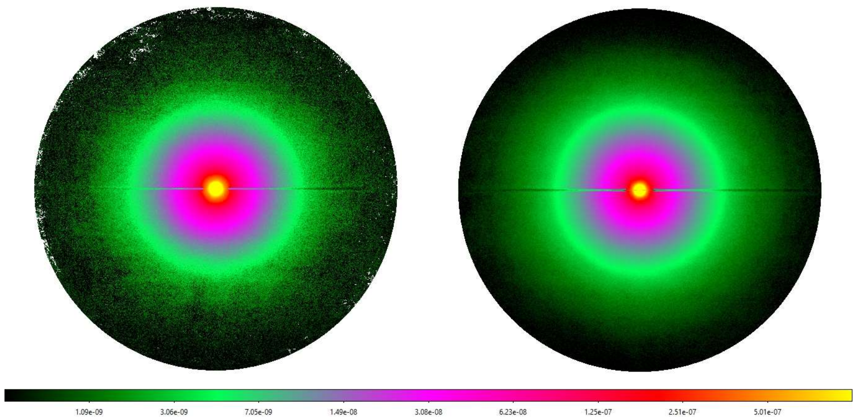
- Intermediate and inner regions are linked at 5 arcsec.
- Intermediate and outer regions are linked at 22 arcsec.

4. Results



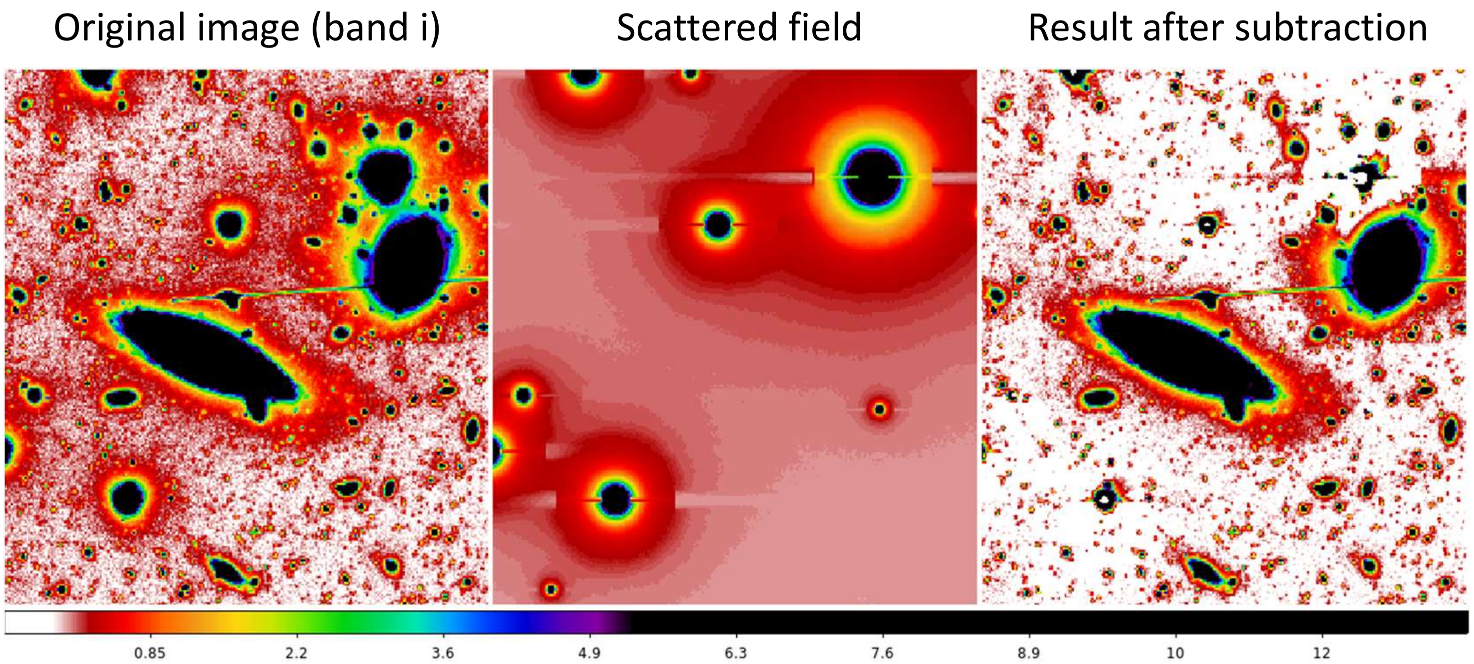
Comparison between SDSS and HSC PSFs at bands gri:

- HSC PSFs core is better concentrated, denoting a better seeing in Mauna Kea w.r.t. Arizona.
- HSC PSFs decay faster in the outer part due to a fewer number of available bright stars.
- In both cases, the decay follows a power law of -2.5, compatible with other observed long-exposure ground-based observations.



- Using more patches, i.e. more data, will increase the number of available stars, improving the SNR and, potentially, the PSF extension. One single star would not be enough to properly sample the PSF. Above, you can see the effect of doubling the number of stars used at the outer region of the PSF.

5. Impact and prospects for the future



Once an extended PSF has been estimated, e.g., it can be used to characterize the scattered light of stars which might interfere with galaxy haloes in the vicinities. We are working in algorithms based in machine learning to extend these techniques to huge surveys dataset such as Stripe82, HSC and LSST.