Object detectability near bright extended sources

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Abstract

The impact of bright extended sources on the observation and detection of faint sources has been studied. The effect has been characterized using the representative case of stars near the Jupiter disk and consists of three parts. First, an analytical representation of the PSF, including aberrations and electronic distortions, has been developed to produce images of Jupiter and solar type stars. Second, those images have been combined to produce fields of view including Jupiter and stellar patterns. Third, the CCD images have been fed to the VPU simulator to determine the limits until which detections are possible. This work can be useful for science cases such as GAREQ.

PSF generation

An analytical PSF formulation has been used to simulate images of the Jupiter disk and a solar type star. Optical aberrations follow the prescription in GAIASYS.NT.00134.T.ASTR and include diffraction, low and high frequency manufacturing errors, micro-roughness and particle contamination. PSF smearing due to time delay integration (TDI), across scan movement and CCD charge diffusion have also been considered. The PSF model has been implemented in Java and images of the Jupiter disk and solar-type stars have been generated. More details in AMF-002.

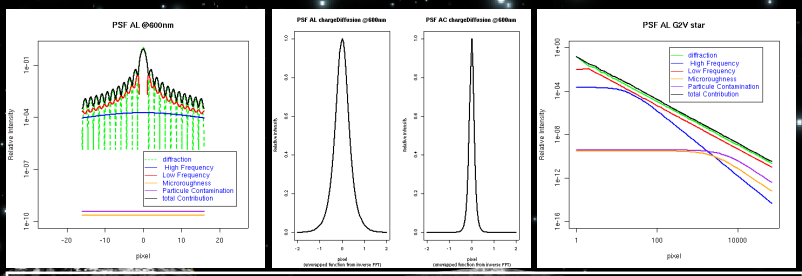

Fig. 1. Left: Optical contributors to monochromatic PSF. Middle: CCD charge diffusion PSF on AL and AC directions. Right: Optical contributors to G2V stellar polychromatic PSF AL.

CCD image generation

CCD images with the specifications required by the VPU algorithms prototype have been generated by a linear combination of the Jupiter and G2V individual images using Java. Poisson shot-noise, Gaussian read-out noise and electronic bias have been added.

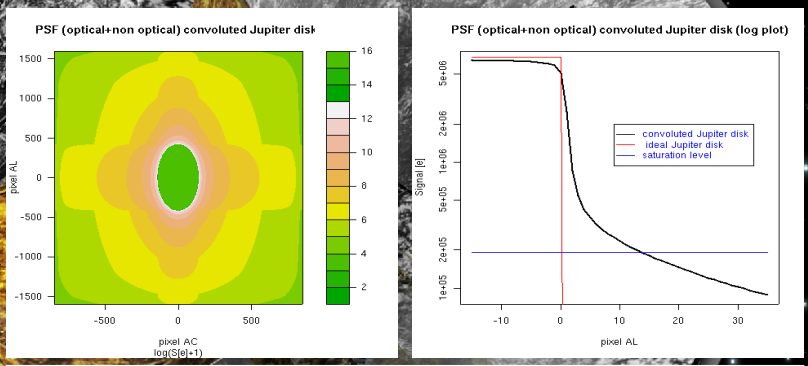

Fig. 2. Left: Jupiter disk contour plot of electrons collected on the CCD, logarithmic scale. Right: Trace AL of the 2-D image near the disk edge.

VPU: detection

Fields of view including Jupiter and patterns of stars under different configurations changing orientations, distances and magnitudes have been generated and analyzed with the VPU Algorithms Prototype v2 (delivered on 24/06/09), using VTCO1 default configuration for VPU parameters.

Stars in the magnitude range [13,16] (Class 1) were detected down to a distance of ~10″ near Jupiter. The problem is highly asymmetric: 13 magnitude stars can be detected in AL direction up to a distance of 9″ from Jupiter border and 14″ in AC direction. While 16 magnitude stars AL detection limit is 10″ and 18″ in AC direction.

Many false detections due to photon shot noise and diffraction pattern makes identification of stars extremely hard. Fake objects are located in the leading and trailing diffraction wings AL and surrounding the planet disk.

Additional work is needed to study the behavior for brighter stars and to improve the VPU rejection behavior. More details in an upcoming technical note.

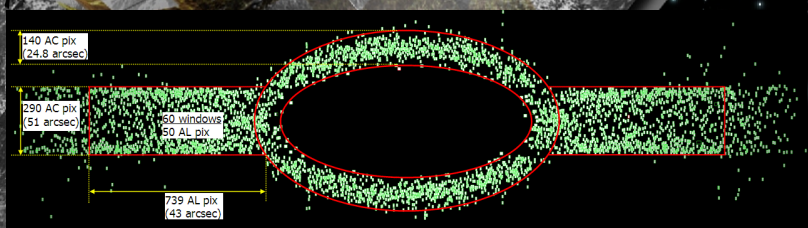

Fig. 3. Reconstruction of all windows assigned on AF1 by a Jupiter pass through the Gaia FPA. Photon shot noise and diffraction pattern generate false object detections on SM, many of them are confirmed on AF1 and observed through AF2 to AF9 CCDs.

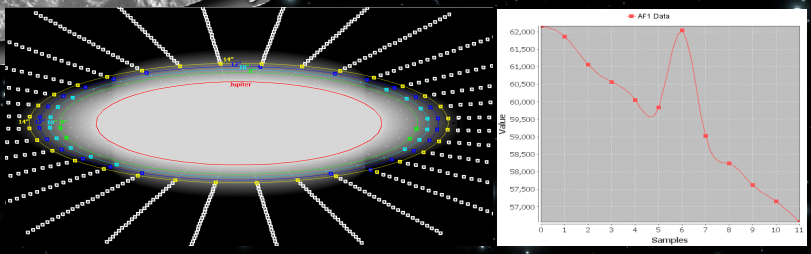

Fig. 4. Left: Detection limits depending on star distance and orientation to Jupiter for a 13.5 magnitude star. Right: 13.5 magnitude star detection at 8″ distance from the Jupiter border.