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Optimisation of JWST operations with the help of Gaia

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Abstract. The James Webb Space Telescope (JWST) is scheduled for launch in 2018. To operate and observe efficiently, JWST will rely on various external astrometric and photometric catalogues, in particular the HST Guide Star Catalog (GSC), for instance to locate sources accurately on the sky. The incorporation of the Gaia astrometric catalog will improve the absolute astrometry of the GSC and is therefore relevant for JWST operations. We outline how the JWST Science and Operations Center hosted at the Space Telescope Science Institute (STScI) intends to use the Gaia survey results to improve upon operational aspects such as the guiding and the geometric focal plane characterisation of JWST.

Keywords. space vehicles: instruments, catalogs, astrometry

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1. Context

JWST (Gardner *et al.* 2006), the space observatory succeeding the Hubble Space Telescope (HST) has a 6.5 m diameter primary mirror that feeds four science instruments (MIRI, NIRSpec, NIRISS, NIRCam) that cover the near-to-mid-infrared spectral range with powerful and versatile observational modes. Two cameras (FGS) are used for guiding operations. STScI is in the process of incorporating Gaia astrometric catalog data into the HST Guide Star Catalog (GSC) and the JWST calibration field catalog in order to improve their astrometric accuracy. JWST will use the GSC for the selection of guide stars and it will observe the calibration field for various purposes. The Gaia astrometric catalogs will therefore be the backbone for the astrometric calibrations of JWST, e.g. for monitoring the observatory's focal plane alignment and for determining the geometric distortion of the instruments.

2. Focal plane geometric calibration

Accurate focal plane calibration is necessary for efficient observatory operations, e.g. for target acquisition and for maintaining pointing stability. For some modes it is critical, because stringent requirements at milli-arcsecond level exist, e.g. multi-object slit spectroscopy and coronagraphy. In-orbit focal plane alignment will be established and monitored by observing the JWST calibration field with several instruments in parallel and locking the observed star fields onto the Gaia reference system to determine relative positions and orientations (Figure 1). Because most Gaia stars lie at the bright end of stars observable with JWST full-frame imaging, we will bridge that magnitude gap using the GSC itself, SDSS, Pan-STARRS, VISTA, and other surveys, and propagate the exquisite absolute and relative astrometric accuracy of Gaia's catalogs.

3. The JWST astrometric calibration field

A field in the Large Magellanic Cloud was chosen in 2005 (Rhoads 2006) because it has a high density of faint stars with small proper motions and is situated in JWST's

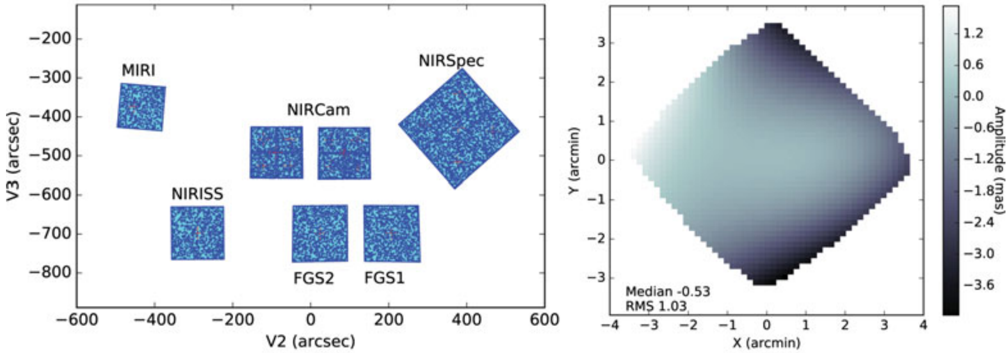

Figure 1. *Left*: JWST apertures in the observatory coordinate system. Dots indicate Gaia sources for a pointing in the JWST calibration field. *Right*: Offsets in Declination corresponding to higher-order distortions between the HST and Gaia catalogs of the JWST calibration field.

continuous viewing zone. It was observed with HST in 2006 and a catalog spanning 5'x5' with milli-arcsecond relative astrometry and deep optical photometry (V$\lesssim$25) was obtained (Anderson & Diaz 2011). This provides the basis for monitoring the astrometric calibration of the telescope and its instruments.

Gaia's first data release (Gaia Collaboration *et al.* 2016a,b) gave us the opportunity to verify the accuracy of the HST calibration field catalog. There are 2020 high-fidelity sources in common between the Gaia and HST catalogs. We mapped the two catalogs with a standard third-degree bivariate polynomial. Imposing Gaia as reference, we found offset, rotation, and scale terms that were within the known limitations of the HST absolute astrometric calibration. We also identified higher-order distortion terms at the level of $\sim$1 mas RMS across the field, see Figure 1 (Sahlmann 2017). The residual dispersion of the mapping is $\sim$2 mas, which roughly corresponds to the expected amplitude of the field's internal proper motion dispersion ($\sim$50 km/s at a distance of $\sim$50 kpc) over the 9 years between the HST and Gaia epochs. We recently acquired a second HST epoch of the field to generate a catalog on the Gaia reference frame that includes the faint-star proper motions and thus will conserve its accuracy during the JWST mission.

Initial work is being done with Gaia's first data release but we anticipate that the second data release catalogs will be used during JWST commissioning and early operations, capitalising on the improved astrometry and availability of proper motions for faint stars.

Acknowledgements

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