Astrometric Calibration for the Nancy Grace Roman Space Telescope Coronagraph Instrument

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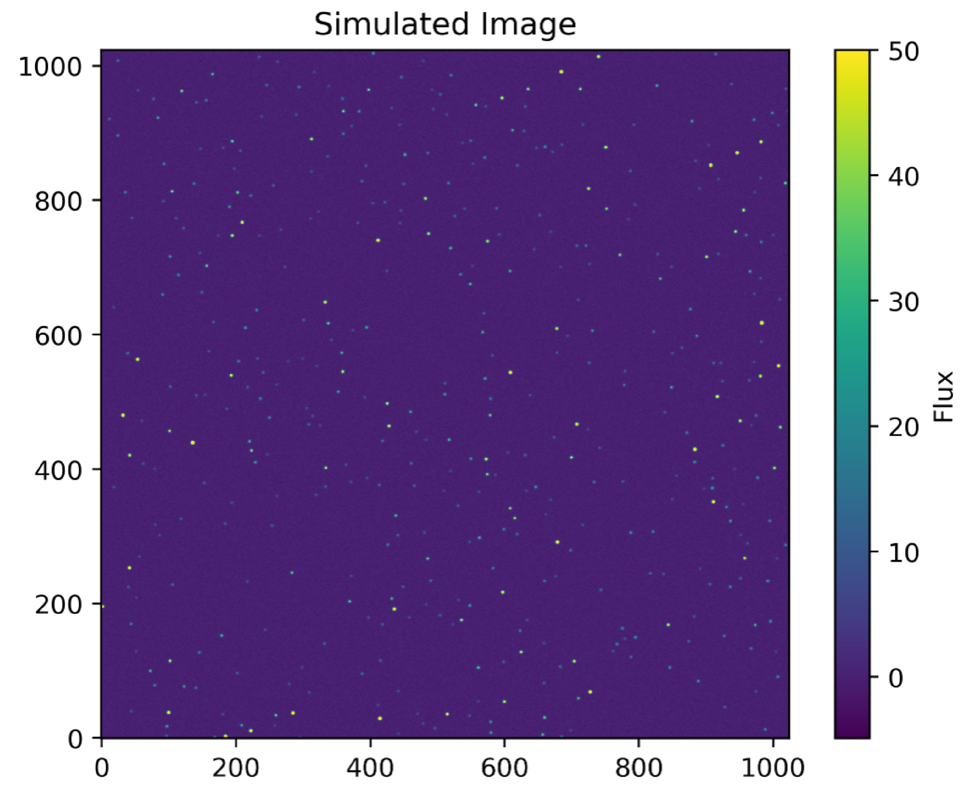
The Nancy Grace Roman Space Telescope

NASA's Roman Space Telescope[1] is a 2.4 meter observatory set to launch in mid 2027. Named after NASA's first Chief of Astronomy, Dr. Nancy Grace Roman, the telescope will be equipped with a Wide Field Imager and a Technology Demonstration Coronograph Instrument that will push the current limits of high contrast direct imaging (~10^{-9} contrast ratios). The work here relates to the astrometric calibration function of the Coronograph Data Reduction Pipeline.

Boresight Calibration

Motivation: The boresight calibration determines the offset in pointing of the telescope. The difference in position of the intended target and the detector center is calculated and used to return the true RA, DEC coordinates of the center pixel in the calibration image. This function requires the measurement of the detector plate scale and north angle as outlined in the sections below.

Calculation: (1) The target pointing coordinates (RA, DEC) are passed to the function along with the calibration image.
(2) The plate scale and north angle are derived from the calibration image (see below).
(3) Stellar coordinates in a given subfield are used to generate a simulated image with the previous plate scale and north angle given an exact centering of the target source.
(4) The x, y pixel offset between each source in the simulated image and each source in the calibration image source is computed.
(5) The offsets are averaged along their respective axes and converted from pixel units to RA, DEC coordinates that are returned.

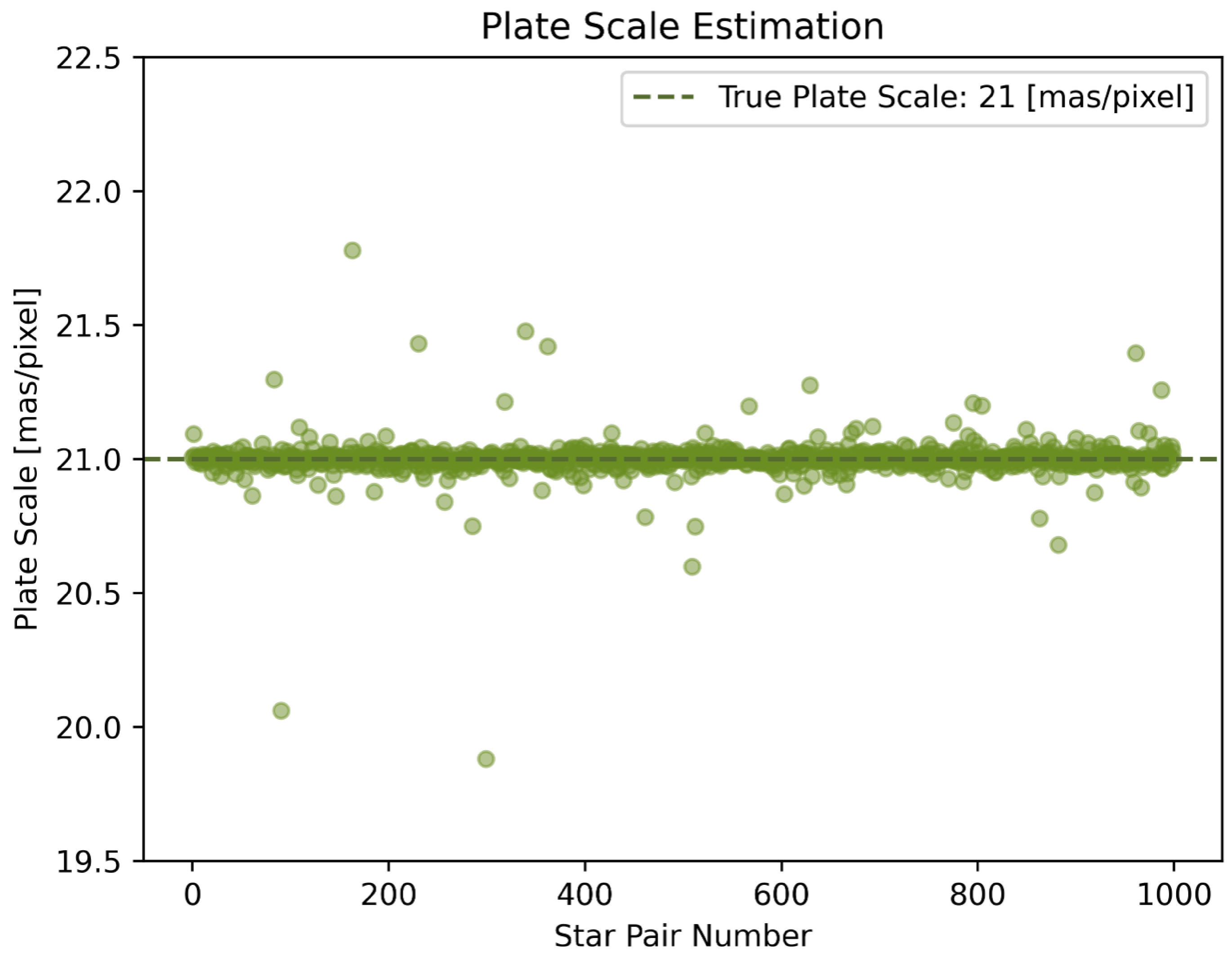


An example of the current simulated images being used for boresight calibration function testing.

Plate Scale

Motivation: This is the conversion metric from pixels to angular separation in the sky and provides an understanding of how the image scale.

Calculation: (1) 1,000 random source pairs are generated.
(2) The relative offset between source pairs is calculated by creating a psf stamp around a source, fitting it to the paired source, and measuring the x, y pixel difference between them.
(3) The true RA, DEC positions of the image sources are passed to the function and the angular separation between pairs is computed using Astropy SkyCoordinates.
(4) The ratio of pixel separation and sky separation is taken as the plate scale for each random pair.
(5) The averaged plate scale measurement is returned.

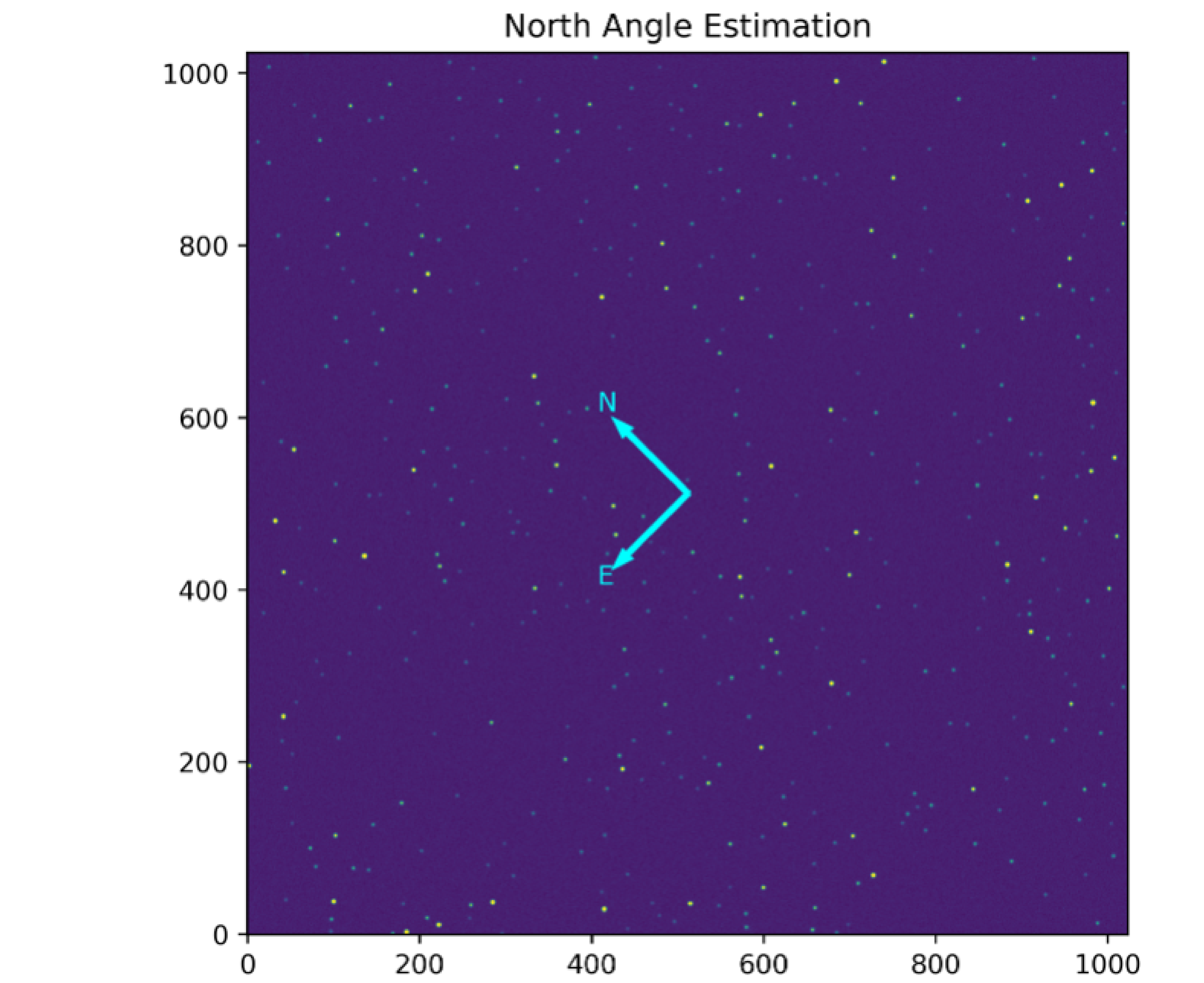


Individual plate scale measurements derived from 1000 random pairs of stars (green) compared to the true plate scale use to create the simulated image (green dashed line).

North Angle

Motivation: This provides the direction of true North (and East) in the calibration image and provides an understanding of the detector orientation with respect to the observed field.

Calculation: (1) The target pointing coordinates (RA, DEC) are passed to the function.
(2) The position angle from North sweeping counterclockwise is computed between all stars and the center of the image.
(3) The true RA, DEC positions of the image sources are passed to the function and the position angle between all sources and the target is computed using Astropy SkyCoordinates.
(4) The difference between the pixel position angle and sky position angle is computed for each pair.
(5) The averaged position angle difference is returned.



The north angle derived from all star pairs with the central target (cyan). The direction of true East is derived as 90 [deg] counterclockwise from true North.

Next Steps: Automated Source Finding and Matching

Context: Currently, the boresight calibration requires the knowledge of source locations in a given calibration image as well as the true RA, DEC positions of the sources in the image.

Goal: By providing an automated source finding and matching module, we can reduce the amount of required user input for the boresight calibration computation.

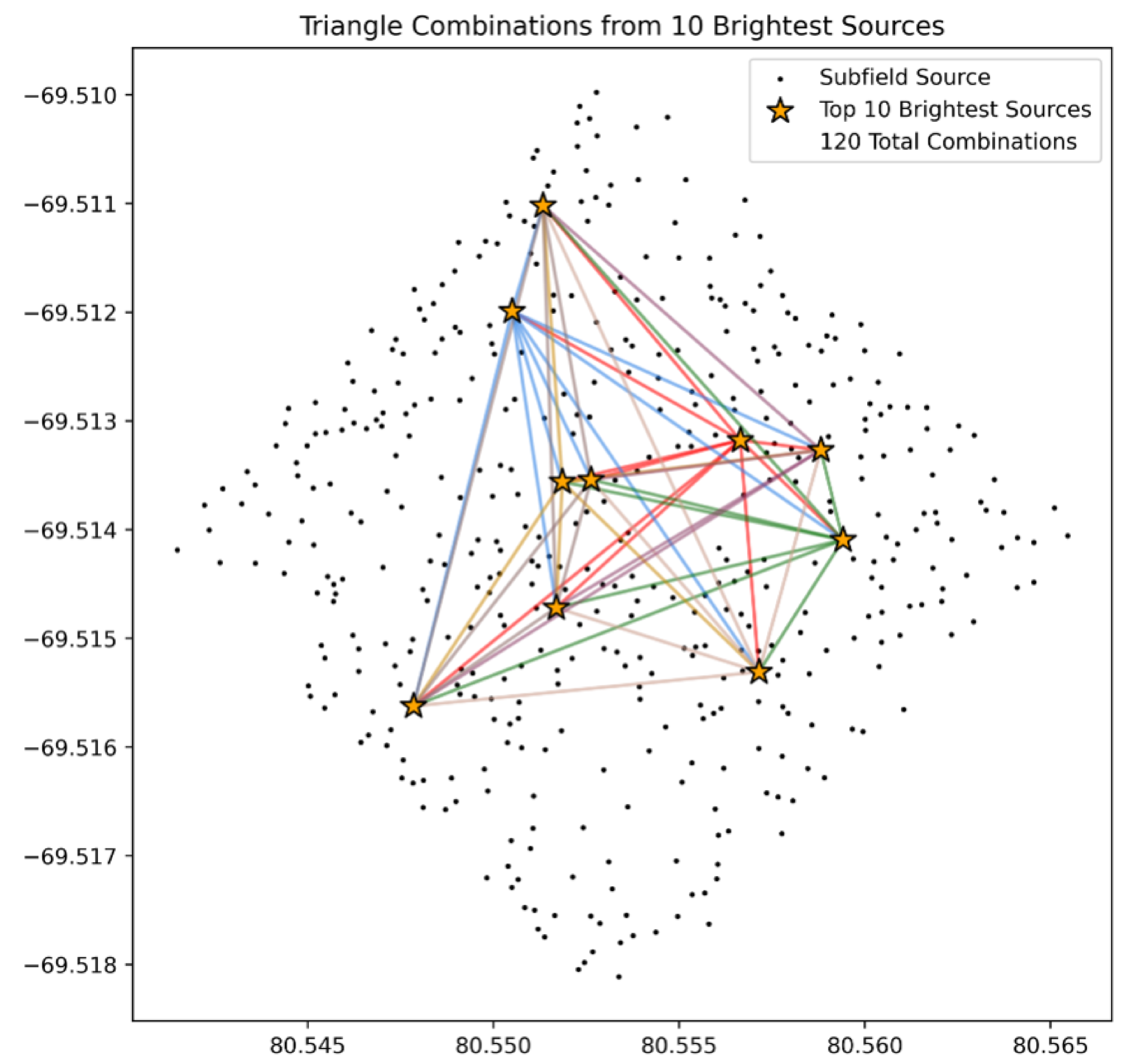
Source Finding Algorithm

- The algorithm finds the brightest pixel value in a given image, marks the location, and masks out a radius of (1) full width half at half maximum.
- 'Finding' is repeated until N sources are located.

Source Matching Algorithm

- The triangle formed from the three brightest sources in an image is compared to X number of triangle combinations from the brightest sources in a given field.
- The field triangle with the closest side length to perimeter ratios is marked as the true coordinate match.

Note: The implementation of an automated source finding and matching module is purely for convenience and does not affect any portion of the boresight calibration.



All possible triangle combinations made from the 10 brightest sources in our subfield (orange stars). The triangle formed from the 3 brightest sources in a calibration image are then matched to the possible source triangles shown here to find the corresponding RA, DEC coordinates.

Acknowledgements & Citations

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[1]Zellem, Robert T., et al. "Nancy Grace Roman Space Telescope coronagraph instrument observation calibration plan." *Space Telescopes and Instrumentation 2022: Optical, Infrared, and Millimeter Wave*. Vol. 12180. SPIE, 2022.