MEMO: SHARC II Pointing at Nasmyth Focus Using CRUSH
TO: Users of SHARC II, especially during September 2004
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General Advice for Data Reduction for SHARC II at Nasmyth Focus

The preferred reduction tool for SHARC II data is CRUSH. The current release (version 1.34-1) correctly handles the revised pointing algorithm and plate scale for the Nasmyth focus, is backwards compatible for Cassegrain focus, and should work without modification for 350 μm data.

<u>CRUSH and sharcpoint=sharcsolve use different pointing algorithms in the case that the reference pixel is not the IRC default value of (16.5, 6.5). This memo assumes pointing information is derived from CRUSH 1.34-1; prior versions of CRUSH defaulted to incorrect constants in the pointing algorithm for the Nasmyth platform.</u>

The plate scale is different at the Nasmyth focus (4.57 ″/detector) compared to the Cassegrain focus (4.85 ″/detector).

At the Nasmyth platform, the detector array is no longer fixed in alignment with respect to the azimuth-elevation coordinate system. (See Figure 2.) The orientation depends on elevation, and there is no mechanical rotator to counteract this.

September 2004 Pointing Residuals

The telescope pointing model used during the September 2004 SHARC II run was an approximate one, and there are unusual, significant systematic pointing trends. Fortunately, these can be corrected in CRUSH. For the period 2004 September 15-20, I find the following trends:

$$FAZO_{model} = -112.1'' - (0.599\ ''/^\circ)\ ZA + (0.00776\ ''/^{\circ 2})\ ZA^2 \quad \text{Eq. 1a}$$
$$FZAO_{model} = 37.7'' + (0.265\ ''/^\circ)\ ZA - (0.00575\ ''/^{\circ 2})\ ZA^2 \quad \text{Eq. 1b}$$

Instead of using this model directly in data reduction, it is much better to compare the model to pointing data of calibrators and apply the differences to the science target. This procedure tracks the slow time drifts in pointing, which is the aim of hourly pointing.

$$\Delta_{FAZO} = FAZO_{calibrator} - FAZO_{model}(ZA_{calibrator}) \quad \text{Eq. 2a}$$
$$\Delta_{FZAO} = FZAO_{calibrator} - FZAO_{model}(ZA_{calibrator}) \quad \text{Eq. 2b}$$

$FAZO_{calibrator}$ and $FZAO_{calibrator}$ are the results from “CRUSH –point”.

$$FAZO_{target} = FAZO_{model}(ZA_{target}) + \Delta_{FAZO} \quad \text{Eq. 3a}$$
$$FZAO_{target} = FZAO_{model}(ZA_{target}) + \Delta_{FZAO} \quad \text{Eq. 3b}$$

The pointing offsets given in Equation 3 can be entered into CRUSH with the "-FAZO=" and "-FZAO=" options. Different reference pixels would have different values of Δ_{FAZO} and Δ_{FZAO}.

After the pointing model is applied, I find ~2″ rms each in FAZO and FZAO for September 15-20.

<u>This is the conclusion of the main point of the memo. The material following is for experts only!</u>

Background Material on Coordinate Conversions at Nasmyth Focus

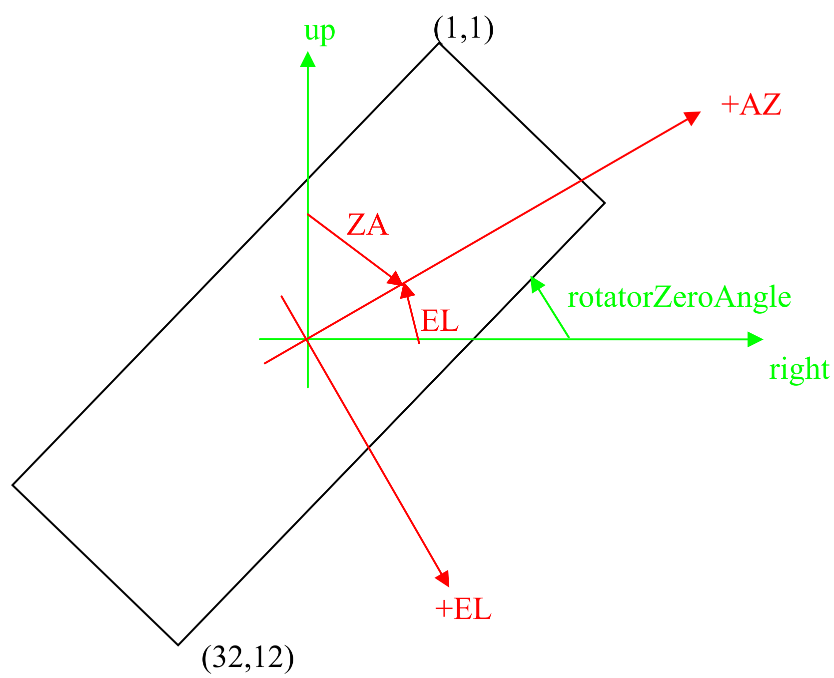

Figure 1. Physical coordinate systems at the Nasmyth focus. The green coordinates show a view from the optical table toward the elevation tube. Since this location is after an odd number of mirrors (primary, secondary, M3), the (AZ, EL) directions form a "left-handed" coordinate system with the optical axis, i.e., a mirror image. The rotatorZeroAngle is shown for the September 2004 value of 46 degrees.

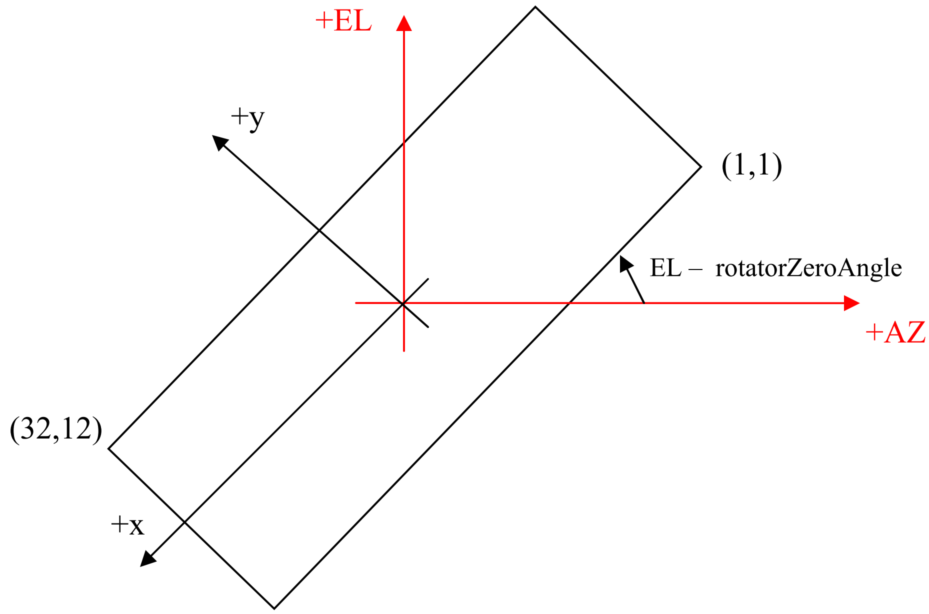

Figure 2. Orientation of detector array on the sky with respect to the azimuth-elevation coordinate system. This is a view of the sky from the telescope. For rotatorZeroAngle = 46 degrees, this picture implies a high elevation.

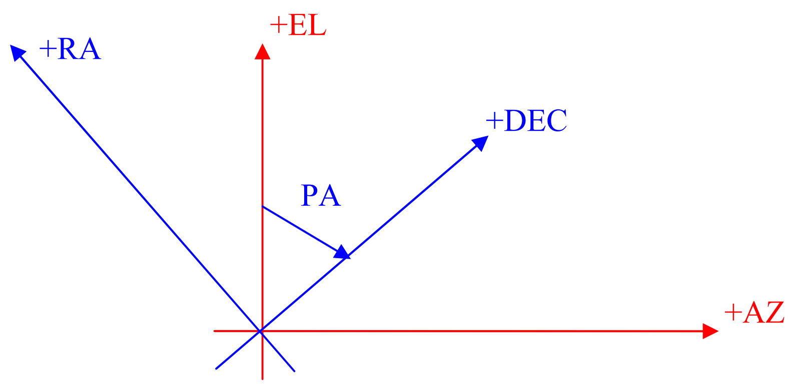

Figure 3. Definition of parallactic angle (PA). The orientation of this view is from the telescope, looking toward the sky.

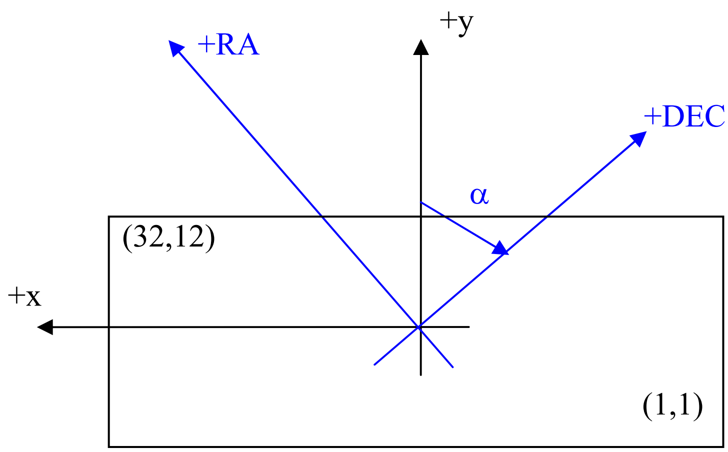

Figure 4. Orientation of detector array in RA/Dec coordinates. This view is aligned with the detector array, looking toward the sky. For the Nasmyth focus, α = PA + EL – rotatorZeroAngle.

Reference Pixel Not Coincident with Rotation Center

CRUSH treats the Reference Pixel as an azimuth-elevation offset. For EL = rotatorZeroAngle, CRUSH pointing determination leads to the source being centered in the Reference Pixel. However, as EL changes, that is no longer the case. For example, if the Reference Pixel is 10″ below the rotationCenter on the detector array, the source will be peaked 10" below the rotationCenter in azimuth-elevation coordinates, regardless of the orientation of the array.

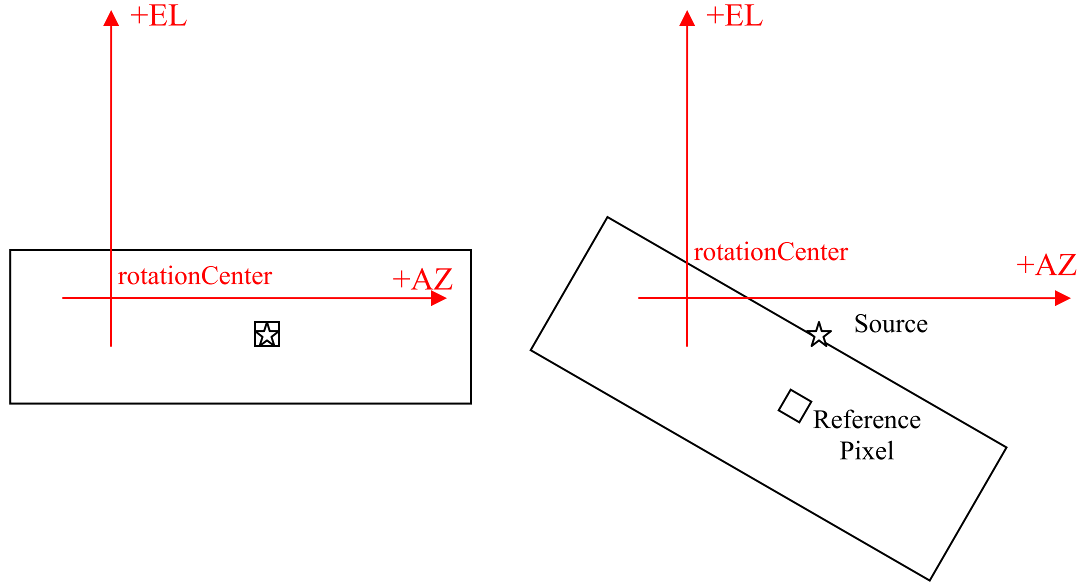

Figure 5. CRUSH pointing for fixed rotationCenter and Reference Pixel, but two different ZA. In the figure on the left, ZA = rotatorZeroAngle, so the Reference Pixel and source location correspond.

The advantage of this approach is that the (FAZO, FZAO) offsets are fixed for a given Reference Pixel. Furthermore, the telescope pointing model ("T Terms") expressing the ZA dependence are the same for every reference pixel. The main drawback is that it is awkward to locate the source on a specific part of the detector array.