VLASS Project Memo: 22

VLASS Epoch 3 Quick Look and Quick Look median stack interim component lists

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Abstract

This Memo describes the radio component lists made for Epoch 3 Quick Look imaging and the Quick Look median stack. These are made on an interim basis for quick release prior to the start of Epoch 4.1 observations. The Epoch 3 catalog has similar characteristics to the Epoch 1 and 2 catalogs made by the CIRADA consortium in terms of positional and flux density accuracy. Apart from a depression of fitted fluxes due to uncorrected phase errors at the 3-5% level in the Quick Look images we find no evidence of flux density errors compared to the VLA standard Perley-Butler scale. The median stack component list has good completeness down to ≈ 0.7mJy/beam and detections to ≈ 0.5mJy/beam.

1 Background

Catalogs for the VLASS Quick Look images were originally excluded from the VLASS data products plan. The CIRADA [1] consortium took these on and produced a first epoch catalog (Gordon et al., 2021) and a subsequent second epoch catalog. [2] After the completion of the CIRADA project, responsibilty for the QL catalogs transitioned to NRAO as part of NRAO's in-kind contribution to the CIRADA project.

Whereas the Quick Look images for individual epochs are made by the VLASS project, the VLASS Quick Look median stack images were produced by Dillon Dong and have been made available via the VLASS webcache (`archive-new.nrao.edu/vlass/quicklook`) and through a HiPS service.[3] While high quality transient and persistent source catalogs will be made available in the future for all Quick Look epochs and the stacked Quick Look images (Dong et al., in preparation), it was considered a high priority to produce interim catalogs prior to the final VLASS 4.1 observations for both Epoch 3 and the median stack. In this Memo, we describe the production of these catalogs and their properties.

2 Catalog production

The pyBDSF package (Mohan & Rafferty, 2015) was used to make the radio component lists. Standard parameters were used, with rmbox= $[60, 30]$, island threshold thi=3.0 and peak threshold, thp=5.0. Unlike the CIRADA catalogs, empty islands (i.e. those without fitted peaks) were not included in the lists. A component list for each ≈ 1 deg^2 image was generated separately. The lists from each phase center were then combined and duplicate entries removed by matching components within an arcsecond and rejecting the component with the lower signal-to-noise (defined as the peak flux divided by the island RMS). For consistency with the CIRADA products the flux density units are mJy and source size parameters are in arcseconds. Properties of the VLASS Quick Look catalogs are summarized in Table 1.

2.1 Epoch 3 Quick Look catalog

Images from individual epochs often have false source component detections from the sidelobes of bright sources. 99.5% of the sky above Declination -40° is included in the catalog.

[1] `cirada.ca`
[2] Both catalogs are available from `https://cirada.ca/vlasscatalogueql0`
[3] NRAO/P/VLASS-Quicklook-MedianStack in Aladin, or `archive-new.nrao.edu/vlass/HiPS`

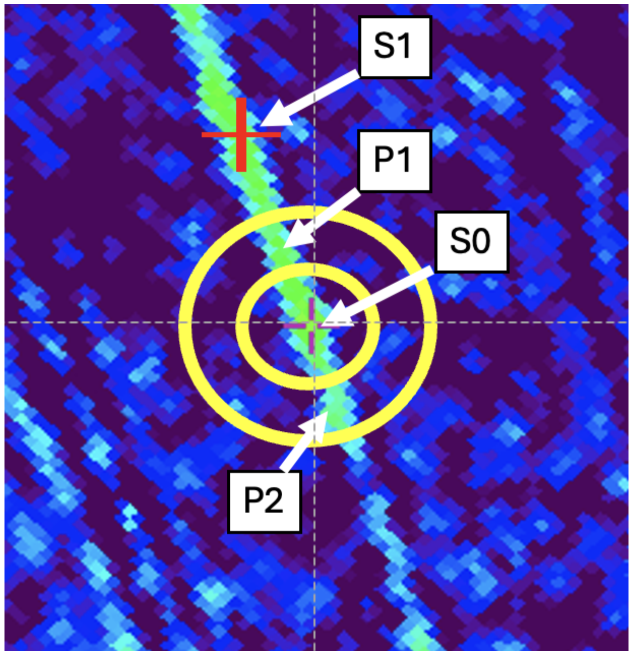

Figure 1: Modified peak-to-ring algorithm for detecting artifacts on diffraction spikes: for source S0, if there is another source, S1, within 20 arcseconds and if the maximum value in a 5-10 pixel radius around S0, P1, is such that P1 is at least half of the peak value of source S0, and further that the peak in the annulus on the other side of the ring is at least 1/4 of the peak of S0, the source S0 is flagged as a potential sidelobe.

Component list	Number of components	Matches to median stack	Reference
CIRADA_VLASS1QLv3.1	2418340 (3347423)	1923731	Gordon et al. (2021)
CIRADA_VLASS2QLv2	2369682 (2995025)	1956026	Gordon et al. (2021)
QL3_components	2376513	2026896	This memo
QL_median_stack_components	3380301	-	This memo

Table 1: A comparison of the VLASS QL Epoch 1, 2, 3 and median stack catalogs. The numbers in parentheses for the CIRADA catalogs include the empty islands that are excluded in the Epoch 3 and median stack catalogs.

The Quick Look component list includes a Flag column whose value is set to unity if the peak-to-ring value (Gordon et al., 2021) exceeds a threshold (in our case, 0.5). We modified the original peak-to-ring algorithm by also checking the value of the pixel on the opposite side of the source to the maximum (Figure 1). The modification of adding the check on the reflected peak was found to noticeably reduce the number of false positive flags due to double radio sources triggering the original criteria.

2.2 Quicklook median stack component list

The median stack component list contains the same fields as the Epoch 3 list, but does not include the peak-to-ring flag as the sidelobes are less severe in the median images. The median stack has larger gaps in coverage than the individual epochs as all three epochs needed to pass quality assurance before being included, nevertheless 98.9% of the sky above Declination -40° is included in the catalog. Comparing the source counts (Figure 2), it is clear that the median stack catalog is deeper than those from the individual epochs, with good completeness to a flux density level of ≈ 0.7mJy/beam.

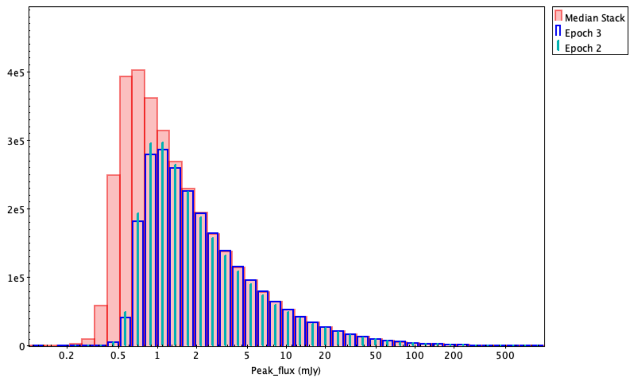

Figure 2: Peak flux density distributions for the CIRADA Epoch 2 catalog (green spikes), the Epoch 3 Quick Look catalog (open blue histogram) and the median stack catalog (red filled histogram).

3 Positional accuracy

The Quick Look images have been corrected for the positional errors due to the neglect of w-terms in imaging (see VLASS Memo 14 [4]). Comparing to the VLBI positions in the radio fundamental catalog (Petrov & Kovalev, 2025) we find 16,769 matches with Epoch 3 and 16,676 matches with the median stack, with scaled median absolute deviations of ≈ 0.1 arcsec in each of RA and Dec in both cases.

4 Flux density accuracy

4.1 Epoch 3 Quick Look

VLASS is calibrated on the Perley-Butler flux density scale, expected to be accurate to 3-5% (Perley & Butler, 2017, PB17). Phase errors in the Quick Look imaging, however, result in an overall depression of flux densities by 3-5% (see VLASS Memo 17 [5]). In addition, they can lead to bright sources ($S \gtrsim 100$mJy) erroneously being broken up into multiple gaussian components. Furthermore, the VLASS1.1 campaign had additional issues from calibration errors arising as a result of antenna mis-pointing (see VLASS Memo 13 [6]).

To assess how close the VLASS Epoch 3 QL images are to PB17, we used flux density estimates from the pointed observations of the phase calibrators that were derived by the VLASS calibration pipeline and compared them to the island total fluxes (Isl_Total_flux) in the QL catalogs made from the mosaicked QL images. The island totals are much less affected by phase errors than the gaussian fits for these bright sources. The ratio of Isl_Total_flux to the pipeline-derived flux densities for 22 calibrators (all $S > 200$mJy) had a median of 0.96 and a scaled median absolute deviation of 0.12. We thus find no evidence for a systematic departure of the flux density scale from PB17.

For fainter sources, we compared the peak flux densities between the Epoch 3 catalog and the CIRADA Epoch 2 catalog for bright (> 3mJy, $\approx 20\sigma$) sources (578,000 matches). The mean and median peak flux ratios were the same to within 0.2%, with a scaled absolute median deviation of 0.099. Assuming equal uncertainties in the two epochs this suggests that a typical flux density uncertainty for bright sources is $\approx 0.1/\sqrt{2}$, or $\approx 7\%$.

4.2 Median Stack

When comparing the peak fluxes in the median stack to those of the individual epochs we find that the median flux density ratio is indicative of a 3-6% reduction of the fluxes in the median stack, probably due to beam variations between epochs. Comparing the island total fluxes this difference is much smaller ($\approx 1\%$),

[4] https://library.nrao.edu/public/memos/vla/vlass/VLASS_014.pdf
[5] https://library.nrao.edu/public/memos/vla/vlass/VLASS_017.pdf
[6] https://library.nrao.edu/public/memos/vla/vlass/VLASS_013.pdf

consistent with this explanation. Users needing the most accurate fluxes for a source should therefore average the flux densities from individual epochs, or use the Isl_Total_flux. Similarly, for low siganl-to-noise sources, any significance of detection should be evaluated from combining the signal-to-noise from each epoch, as the process of medianing the data frames may introduce small deviations from Gaussianity in the noise.

5 Summary

We present interim component lists for the 3rd epoch VLASS Quick Look images and the median stack. The 3rd Epoch component list has similar characteristics to that for Epoch 2, with very good agreement between the flux densities of sources and can thus be used to select variable/transient objects. Other than a ≈3-5% depression of fluxes due to phase errors (which we expect to be improved in the self-calibrated and, where necessary, w-term corrected Single Epoch images) we find no evidence for VLASS flux densities to differ from the PB17 flux density scale used for the VLA. The median component list has good positional accuracy, but peak and total flux densities are 3-6% lower than those in the individual epochs.

References

Gordon, Y. A., Boyce, M. M., O'Dea, C. P., et al. 2021, ApJS, 255, 30

Mohan, N., & Rafferty, D. 2015, PyBDSF: Python Blob Detection and Source Finder, Astrophysics Source Code Library, record ascl:1502.007, ,

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