Early Astrometric Coherence in 47 Tuc with DP1 (ComCam)

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Abstract

We validate the early astrometric coherence of **Rubin DP1 (ComCam)** in the crowded field of **47 Tuc** by means of a 1:1 *symmetric cross-match* **Rubin×Gaia DR3** (search radius $\leq 2''$). We report radial percentiles with 95% bootstrap CIs (B = 5000; seed = 47) and, for transparency, the **per-coordinate RMS** ($\Delta\alpha^{\star}$, $\Delta\delta$) with 95% CIs. A null test (offset $+60''$ in R.A.) yields 0 pairs $\leq 2''$, and propagating Gaia proper motions to the DP1 epoch indicates a negligible median bias ($\lesssim 0.02''$).

Final sample: $N = 1113$ 1:1 pairs.
Radial percentiles: P50 = $0.05097''$ (95% CI [0.05069, 0.05143]); P68 = $0.05333''$ (95% CI [0.05297, 0.05377]); P95 = $0.11584''$ (95% CI [0.09781, 0.17069]).
Per coordinate (RMS, mas**)**: RMS($\Delta\alpha^{\star}$) = 130.9 (95% CI [97.7, 162.3]); RMS($\Delta\delta$) = 146.9 (95% CI [104.3, 185.4]).

Scope w.r.t. SRD (LPM-17). Since the SRD specifies requirements *per coordinate*, we **do not** perform a direct compliance verification here: we provide per-coordinate RMS as quantitative context and keep the radial percentiles as the reproducible reference metric for this field.

Data and methods

Sources. Positions from Rubin DP1 (ComCam) and Gaia DR3.

Epochs and proper motions (PM). Gaia (epoch 2016.0) is propagated to the DP1 epoch (visits 2023-08-21/23; $\Delta t \approx 7.6$ yr). The expected median displacement $|\mu|\,\Delta t$ is $\lesssim 0.02''$ and matches the observed bias (negligible at the core level).

Matching. Search radius $\leq 2''$ and **1:1 symmetric deduplication** (nearest-neighbour Rubin↔Gaia) to minimize ambiguous associations under *crowding*.

Metrics.

- **Radial** (arcsec): P50/P68/P95 with 95% bootstrap CIs (B = 5000; seed = 47).
- **Per coordinate** (mas): residuals $\Delta\alpha^{\star} = (\alpha_{\rm R} - \alpha_{\rm G})\cos\bar{\delta}$ and $\Delta\delta = (\delta_{\rm R} - \delta_{\rm G})$; per-axis RMS with 95% CIs (bootstrap B = 5000; seed = 47).

Null test. Offset-match by shifting Rubin $+60''$ in R.A. $\Rightarrow$ 0 pairs $\leq 2''$, supporting that the core of the radial histogram is physical/geometric rather than random.

Results

Core and tail (radial). $N = 1113$; P50 = 0.05097″ (95% CI [0.05069, 0.05143]), P68 = 0.05333″ (95% CI [0.05297, 0.05377]), P95 = 0.11584″ (95% CI [0.09781, 0.17069]). The core (P50/P68) is tightly constrained; the tail broadens the P95 CI.

Per coordinate. RMS($\Delta\alpha^\star$) = 130.9 mas (95% CI [97.7, 162.3]); RMS($\Delta\delta$) = 146.9 mas (95% CI [104.3, 185.4]). These figures are informative but are not interpreted as an SRD verification (see note).

Instrumental scale. P50 $\approx$ 0.051″ corresponds to $\approx$ 0.255 pix at 0.2″/pix (ComCam), an intuitive reference for the core performance.

Sanity and robustness (r^2 and trimmed RMS)

We verify the in-plane identity

$$\overline{r^2} = \overline{(\Delta\alpha^\star)^2} + \overline{(\Delta\delta)^2},$$

which is numerically consistent on the published parquet. Decomposing at the radial quantile q_{95} gives:

- $q_{95} = 0.11583''$ ($0.116''$);
- $n_{\rm core} = 1057$, $n_{\rm tail} = 56$, so $w_{\rm core} = 1057/1113 \approx 0.9497$;
- $\mathbb{E}[r^2]_{\rm core} = 0.002439$ arcsec^2, $\mathbb{E}[r^2]_{\rm tail} = 0.723691$ arcsec^2;
- mixture $w_{\rm core}\,\mathbb{E}[r^2]_{\rm core} + (1-w_{\rm core})\,\mathbb{E}[r^2]_{\rm tail} \approx 0.03873$ arcsec$^2 \simeq \overline{r^2}$.

We additionally report *1% trimmed (robust) per-axis RMS* (trim by radial r, q_{01}–q_{99}) as a complement to the classical RMS:

$$\mathrm{RMS}_{\rm trim,1\%}(\Delta\alpha^\star) = 78.27 \text{ mas}, \qquad \mathrm{RMS}_{\rm trim,1\%}(\Delta\delta) = 58.57 \text{ mas}.$$

These checks demonstrate that a small ($\sim$5%) but very heavy tail in r^2 fully accounts for the classical per-axis RMS (131–147 mas) exceeding the core radial percentiles.

Robustness versus match radius

Radial metrics when tightening the maximum separation (on the same deduplicated parquet):

radius (″)	N	P50 (″)	P68 (″)	P95 (″)
0.4	1090	0.050877	0.053147	0.084029
0.8	1096	0.050970	0.053236	0.097704
1.0	1100	0.050970	0.053236	0.099700
1.2	1102	0.050970	0.053236	0.102142
1.5	1104	0.050970	0.053236	0.108180
2.0	1113	0.050970	0.053325	0.115842

Conclusion: the core (P50/P68) is stable as the radius varies; P95 increases with radius as expected (tail). Using 2″ is conservative without biasing the core, and the 1:1 deduplication minimizes chance associations.

Outliers (> P95)

The top 5% (56 pairs with separation > 0.116″) shows no obvious quadrant clustering at first glance. We publish `data/47tuc_dp1/rnA_outliers_gtP95.csv` to facilitate further inspection (e.g., Gaia RUWE, brightness/colour, detector location) and to discriminate, case by case, between *crowding*, difficult centroids, or WCS residuals.

Note on SRD (LPM-17) and scope

What the SRD measures. LPM-17 specifies per-coordinate requirements: relative astrometry (intra-instrument repeatability; e.g., 10 mas) and absolute astrometry (per-coordinate error against an external frame; e.g., 50 mas).
What we measure here. We report Rubin×Gaia radial separations and, for transparency, Rubin×Gaia per-coordinate RMS. We do not evaluate intra-Rubin repeatability, nor do we claim numerical compliance with SRD tables.
Proper interpretation. This work characterizes early performance in 47 Tuc and sets a reproducible baseline; any strict SRD verification would require different measurement configurations and/or additional quality stratification.

Figure (reading guide)

Histogram of Rubin×Gaia radial separations (radius ≤ 2″; 1:1 match). The figure displays **the median (P50)** and **P95** as vertical lines. The **95% CIs** for P50/P68/P95 (bootstrap B = 5000; seed = 47) are reported in the text and JSON but *are not visualized* in this panel. Gaia positions were propagated to the DP1 epoch.

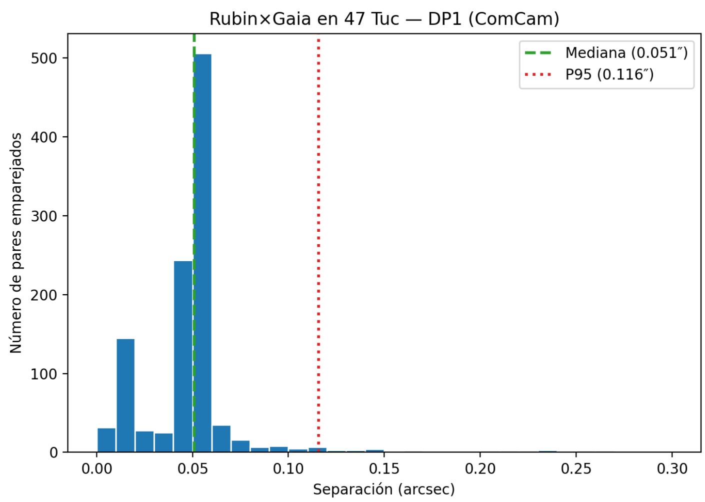

Figure 1: Histogram of Rubin×Gaia radial separations (DP1, 47 Tuc; 1:1 match, radius ≤ 2″). **P50 = 0.05097″** (median) and **P95 = 0.11584″** are shown as vertical lines; **N = 1113**. The **95% CIs** for P50/P68/P95 (bootstrap B=5000, seed 47) are given in the text/JSON and *are not plotted* here.

Data and code availability

GitHub (tag v1.0.4-rnA): `https://github.com/mreyes-astro/portafolio-rubin/releases/tag/v1.0.4-rnA`
Zenodo (version): 10.5281/zenodo.17017865
Concept DOI (all versions): 10.5281/zenodo.17017864

Published artefacts (this work uses derived products only):

- `data/47tuc_dp1/rnA_matched_minimal.parquet` — minimal table (`objectId`, `coord_ra/dec`, `source_id`, `ra_gaia/dec_gaia`, `separation_arcsec`).
- `data/47tuc_dp1/rnA_metrics.json` — radial metrics (P50/P68/P95) with 95% CIs; block `per_coordinate` (per-axis RMS in mas + 95% CIs); block `radii_check` (N/P50/P68/P95 vs radius); generator metadata (B = 5000; seed = 47).
- `data/47tuc_dp1/rnA_outliers_gtP95.csv` — tail pairs for inspection.
- `notebooks/47tuc/figs/rnA_hist_sep.png` — histogram with P50/P68/P95.
- `data/47tuc_dp1/rnA_influence_curve.csv` — influence-curve table (per-axis RMS vs included fraction).
- `notebooks/47tuc/figs/rnA_influence_curve.png` — influence-curve figure.
- `notebooks/47tuc/rnA_r2_sanity_and_influence.ipynb` — generating notebook (sanity on $\overline{r^2}$, core/tail, 1% trimmed RMS, influence curve).

Acknowledgments

Based on Rubin Observatory Data Preview 1 (Rubin Science Platform) and Gaia DR3. Only derived products are published.

References

References

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[Wainer et al.(2025)] Wainer, T., et al. (2025), *Crowded Field Photometry with Rubin: Exploring 47 Tucanae with DP1*, arXiv:2507.03228.

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Change log (v8)

- **SRD/wording:** clarified that no direct SRD compliance verification is performed; difference in metrics and scope made explicit.
- **Figures:** consolidated 95% CIs for P50/P68/P95 and RMS($\Delta\alpha^{\star}$, $\Delta\delta$) with $B = 5000$; seed $= 47$.
- **Robustness:** expanded table to $\{0.4, 0.8, 1.0, 1.2, 1.5, 2.0\}''$.
- **Outliers:** documented the top 5% (56 pairs) and provided a CSV for inspection.
- **Editorial cleanup:** unified units and headings; removed stray bullets from prior renders.