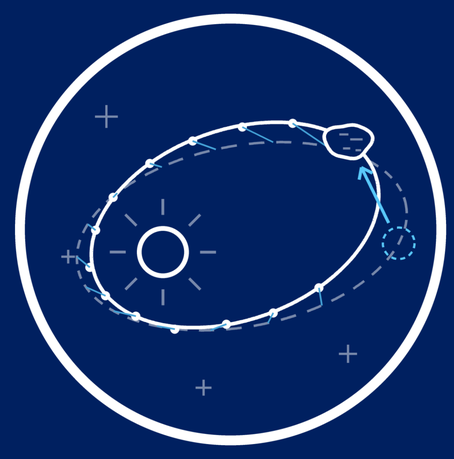
The NEOCC Observations Analysis Tool

Astrometric Residual Diagnostics and Unexplained Systematic Errors



Mining half a billion astrometric residuals of asteroid surveys

Why this study? Three motivations drove this work. **(1)** Residuals, the difference between the observed and computed asteroid's positions, expose both limits of the dynamical model and errors in the measurements, so analysing them drives improvements in both orbit modelling and astrometry. **(2)** For imminent impactors with only a few observations, biased astrometry can distort the orbit and the impact prediction. **(3)** Observers need timely, transparent feedback on the quality of their data.

The Observations Analysis Tool

- Free, public tools in the ESA NEOCC **NEO Portal**: the **Observations Analysis** and **Observatories** pages, plus a **Residuals** tab for every object.
- **Interactive** plots, advanced **filtering**, **per-observatory statistics** and **downloadable** data.
- Residuals on demand for **any object, any epoch and every observatory**, from the NEOCC orbit determination software **Aegis** [1].
- Helps observers spot **timing biases** and other systematic errors, and validate hardware, software and configuration.

Data and method

- All asteroid observations from the **MPC**; least-squares orbits with **Aegis** [1], weights from [2] and star-catalogue debiasing from [3].
- **> 1.3 million orbits** and **> 5 × 10^8 residuals**.
- RA and Dec residuals **averaged per calendar month** for each observatory.

Pattern 1: yearly cycle in large surveys

- From about **April 2018 (Gaia DR2** [4]**)** the scatter drops and the monthly means **oscillate with a ~1-year period**, with extremes close to **September** and **March** (Figs. 1, 2).
- Also seen at 703, F52, M22, V00, T05, T08; not at I41, K88, U68, W94 (fewer observations).
- Found with **independent orbit determination software**, so not a software artefact. Its origin, dynamical model or observing process, is **still open**.

Pattern 2: dependence on sky position

- Mean residuals (Fig. 3) in 5° × 5° RA/Dec bins, each averaging **≥ 10 000 observations**.
- **Coherent, large-scale structures** in direction and amplitude, correlated with position on the sky. Their origin is **still open**.

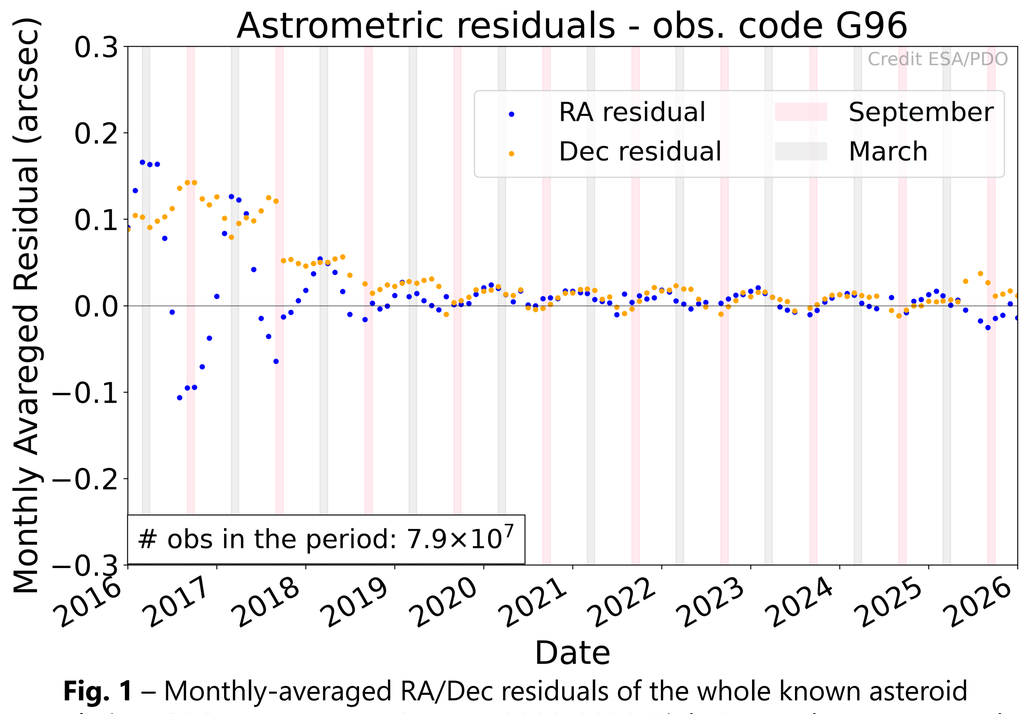


Fig. 1 – Monthly-averaged RA/Dec residuals of the whole known asteroid population, **G96** (Mt. Lemmon Survey), 2016–2026. Pink: September; grey: March.

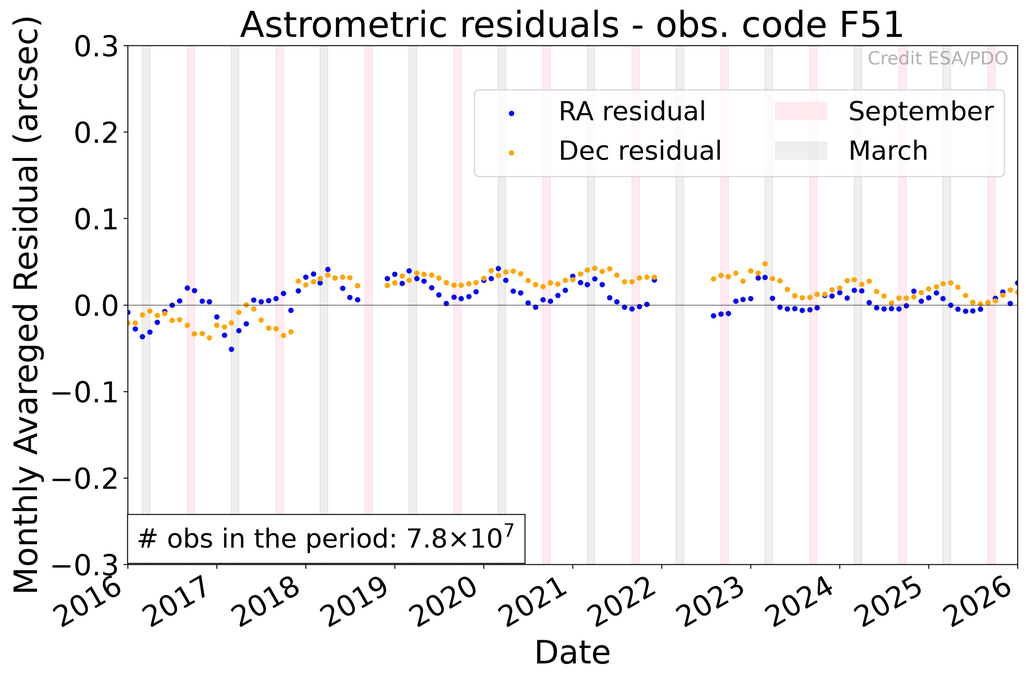


Fig. 2 – Same as Fig. 1 for **F51** (Pan-STARRS 1).

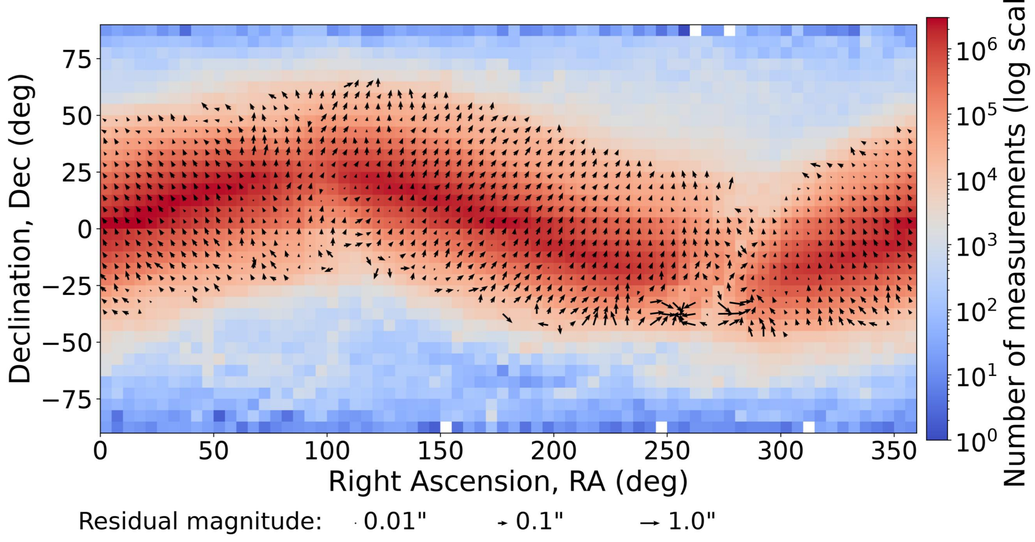


Fig. 3 – Observation density (colour) with direction and mean amplitude of the residuals (arrows) in equatorial coordinates.

Explore the residuals yourself: **https://neo.ssa.esa.int/observations-analysis**

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References:
[1] Fenucci, M., Faggioli, L., Gianotto, F., et al. 2024, CeMDA, 136, 58
[2] Vereš, P., Farnocchia, D., Chesley, S. R., & Chamberlin, A. B. 2017, Icarus, 296, 139
[3] Eggl, S., Farnocchia, D., Chamberlin, A. B., & Chesley, S. R. 2020, Icarus, 339, 113596
[4] Lindegren, L., Hernández, J., Bombrun, A., et al. 2018, A&A, 616, A2