Detecting Dancing Gems in the NOIRLab Source Catalog

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Abstract

The NOIRLab Source Catalog (NSC) is a "crowd-sourced" survey of nearly the entire sky (85%) using all public images in the NOIRLab Astro Data Archive. The second data release contains 3.9 billion objects with 68 billion measurements covering a baseline of 7 years. The third data release (late 2024) will include PSF photometry of ~500,000 DECam images and time-series information over a 10 year baseline. In addition, a new machine learning clustering algorithm (Yente) will better handle fast-moving objects than in previous releases. The NSC provides deep, multi-band photometry that can be used to study the "static" sky and search for faint dwarf galaxies. Moreover, the multi-epoch data can be used to explore the changing sky especially at the faint end. The NSC can be searched for variable stars, solar system objects, and high proper motion stars (e.g., white and M dwarfs), and other "rare gems".

Variable Stars

One of the great strengths of the NSC is that it contains much temporal information with over 1.5 billion objects having ten or more measurements. The photometric variability can be used to find objects that change their brightness over time such as variable stars, eclipsing binaries or AGN.

1. **8 robust variability metrics** are available in NSC DR2 to ascertain variability.
2. **2 million objects** show photometric variability above the noise at a 10σ level.
3. **17,843 RR Lyrae stars detected.** Of those, 8645 fainter than Gaia limit [2].

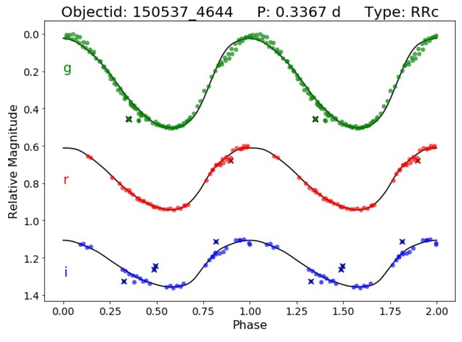

Figure 3 Example phase-folded NSC lightcurve of an RR Lyrae star [1,2].

NSC DR2 covers 85% of the sky with 68 billion measurements of 3.9 billion unique objects in seven different bands with depths of ~23rd mag and covering a baseline of 7 years.
1.5 billion objects have 10+ measurements.

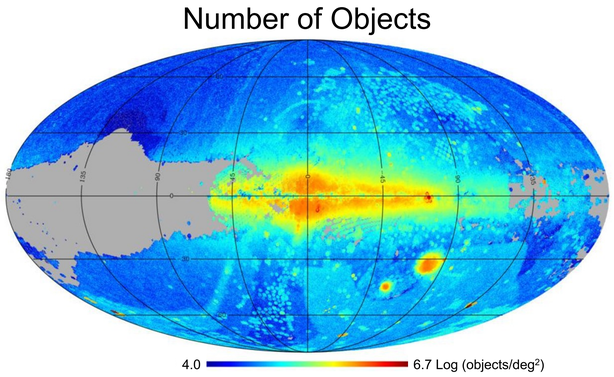

Figure 1: All-sky object density map of the second data release of the NSC (DR2) in 2021 [1].

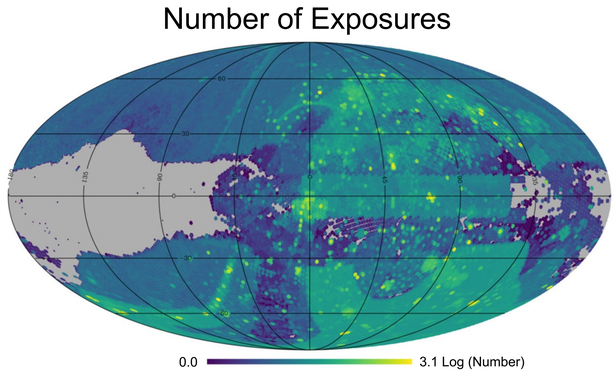

Figure 2: NSC DR2 number of exposures in galactic coordinates. Areas shaded in gray indicate no data.

Data Access through NOIRLab's Astro Data Lab: https://datalab.noirlab.edu

High Proper Motion Stars

The temporal information in the NSC can be used to measure proper motions, with DR2 having precise measurements (>5σ) for 90 million objects. Many high proper motion stars are nearby M and white dwarfs. The NSC can detect objects that are too faint for NEOWISE.

1. **Precise proper motions** for 90 million objects (40 million fainter than Gaia limit).
2. **12 million** high proper motion stars (>100 mas/yr), 7 million fainter than Gaia limit.

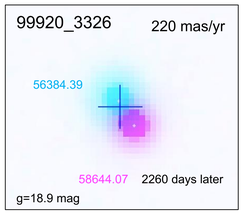

Figure 4: High proper motion star 99920_3326 identified in the NSC with a proper motion of 220 mas/yr.

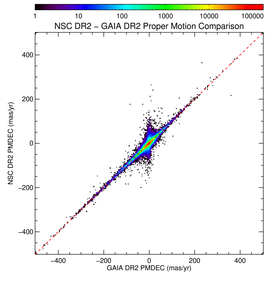

Figure 5: Comparison of NSC DR2 and Gaia DR2 proper motions [1].

Solar System Objects

Over 4 million measurements of SSOs, identified in 637,289 single-night observational arcs, were identified in NSC DR2 [1,3] in all 7 filters. 731,000 of these measurements are crossmatched with detections of numbered/unnumbered minor planets and isolated tracklets from the Minor Planet Center. Initial estimates of orbit using remaining measurements show that unknown objects from both inner and outer regions of the solar system are represented in the NSC.

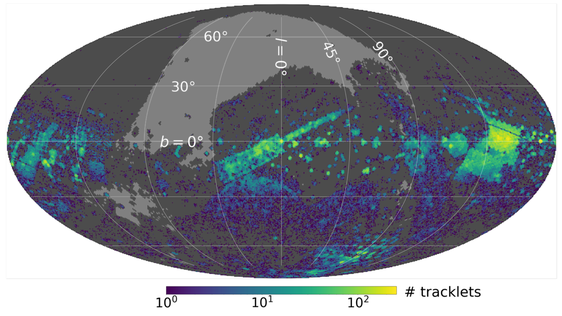

Figure 6: NSC DR2 tracklets in ecliptic latitude (l) and longitude (b). Areas shaded in black indicate no detections.

DR3 Improvements

The third data release (DR3) of the NSC is expected to be released by the end of 2024. Besides including more exposures, around 150,000 more, there are several other significant improvements.

1. **PSF photometry.** For DR1 and DR2, Source Extractor aperture photometry was used. In DR3, DAOPHOT PSF photometry and Source Extractor aperture photometry will be provided.
2. **Iterative Detection.** In previous data released, the NSC only performed a single round of detection on each exposure. In DR3, iterative detection will be used and will produce many more sources in crowded fields.
3. **Improved clustering.** A machine learning algorithm (Yente) will be used to improve the clustering of measurements from fast moving objects.

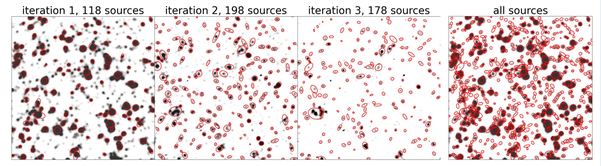

Figure 7: Iterative detection in an exposure of a crowded field. After each iteration, the best-fit PSF models are subtracted and the residual image is searched for new detections. The new detections are added to the master list and all sources are refit with PSF models.

References

1. D. L. Nidever et al 2021, *AJ* 161 192, *Second Data Release of the All-sky NOIRLab Source Catalog*
2. Matt, K. L. 2022, Montana State University, Master's Thesis
3. K. M. Fasbender & D. L. Nidever, 2021, *AJ* 162 244, *Exploring the Solar System with the NOIRLab Source Catalog I: Detecting Objects with CANFind*
4. K. M. Fasbender & D. L. Nidever, 2024, *in preparation*, *Exploring the Solar System with the NOIRLab Source Catalog II: Magnitude and Color in the Main Asteroid Belt*
5. Nidever, Fasbender et al., (2024), in preparation, *The Third Data Release of the NOIRLab Source Catalog*