7th IAA Planetary Defense Conference

26-30 April 2021, Online Event

Hosted by UNOOSA in collaboration with ESA

Session 5b: Neo Discovery

Chairs: Kelly Fast

Presenters: L. Jones | A. Mainzer | F. Spoto | R. Weryk | M. Kelley

Discovering and Characterizing Near Earth Objects with Vera C. Rubin Observatory's *Legacy Survey of Space and Time* (LSST)

Lynne Jones, Siegfried Eggl,
Mario Jurić , Željko Ivezić

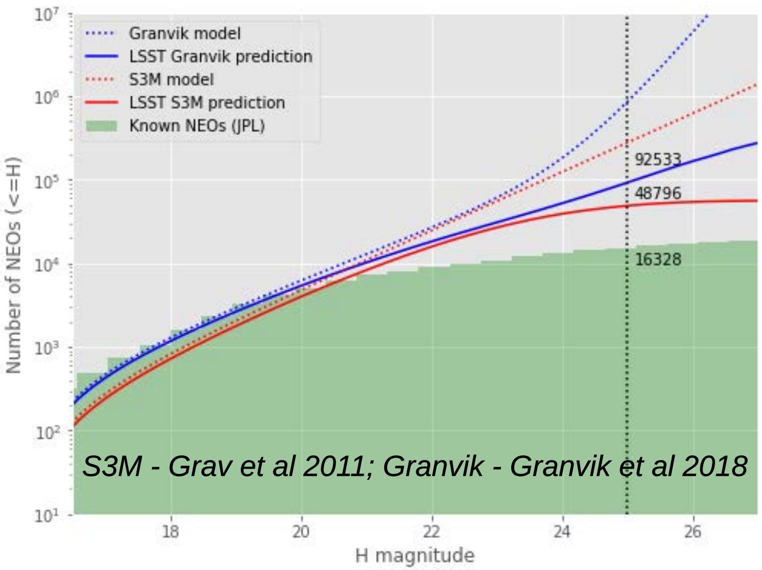
The Legacy Survey of Space and Time (LSST)

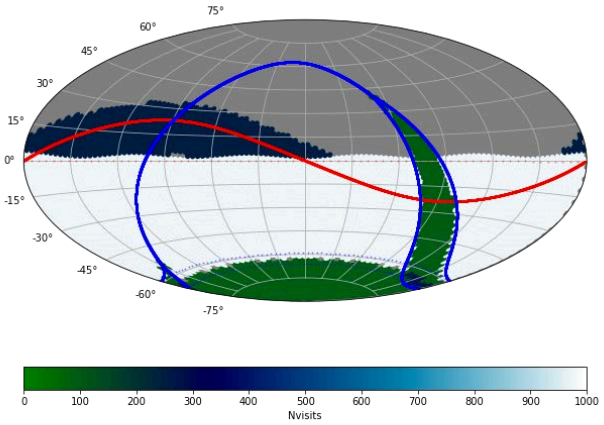
- Rubin Observatory
  - 8.4m (6.7m effective) telescope
  - 9.6 sq deg (3.2 Gpix) camera
  - Data processing pipelines to generate calibrated catalogs
- The LSST
  - 10 years of images in *ugrizy* filters
  - Primary science drivers
    - Dark energy / dark matter
    - Milky Way & Local Volume
    - Transient & Variable Universe
    - **Small bodies in the Solar System**

NEO & PHA discovery

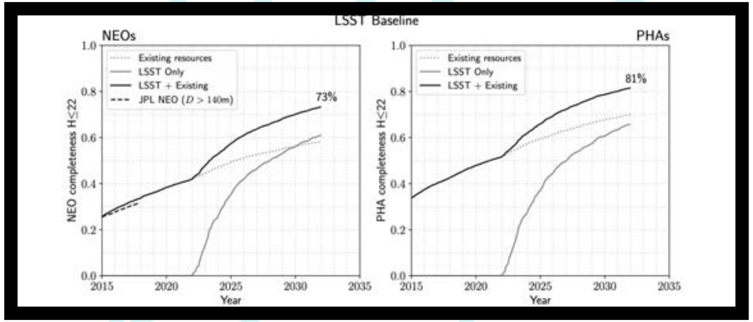
In current baseline strategy, after 10 years:

- 50-100K NEOs @ H<25
  - Total? Large uncertainties.
- 62% - 67% NEO completeness @H<22



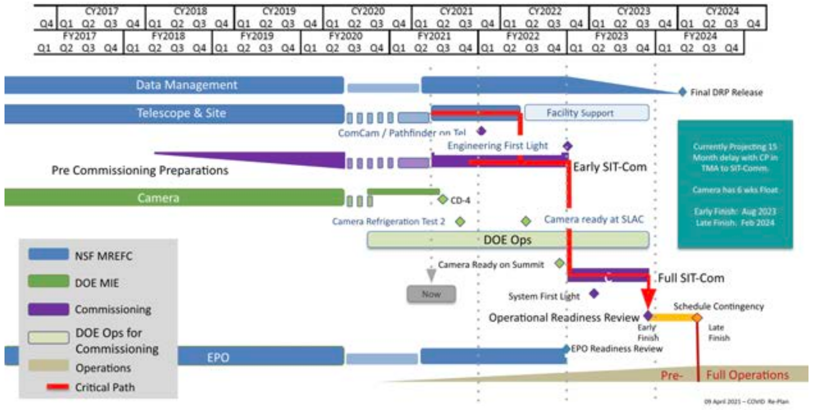


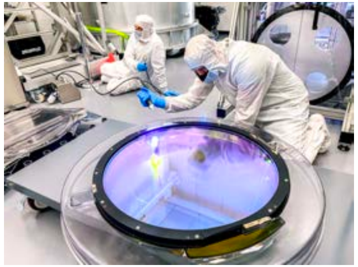
consistent with prior work:
Jones et al 2018,
Veres & Chesley 2017



Project Timeline

- Operations expected to start no sooner than Fall 2023 due to COVID delay





Amazing video of the TEA lift at http://ow.ly/1mZV50DTgnX

VERA C. RUBIN OBSERVATORY

Survey Strategy

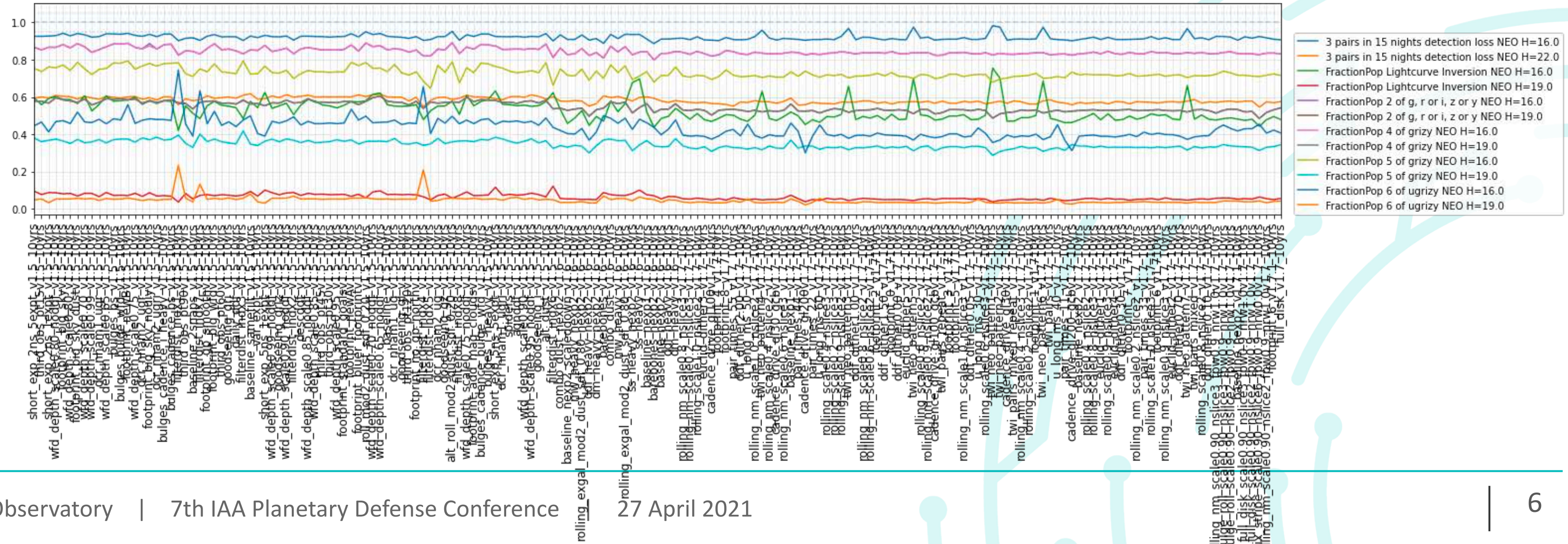
- Basic strategy in place but options for "how to survey the sky" under consideration

Survey Strategy Timeline

- 2018 whitepapers on survey strategy, refining baseline
- 2019 LSST Science Advisory Council (SAC) recommendations for survey strategy simulations
- Aug 2020 LSST project delivers simulations & analysis to SAC and community
- Nov 2020 1st workshop
- April 2021 Cadence Notes due to Survey Cadence Optimization Committee (SCOC) - comments on early simulations
- Fall 2021 - SCOC recommendations for draft survey strategy simulations & 2nd workshop
- Dec 2021 - SCOC recommendations for initial survey strategy
- Early 2022 - project releases recommended survey strategy simulation
- Summer 2022 - fine-tuning and incorporation of early science goals, possible 3rd workshop
- Dec 2022 - SCOC and project deliver initial survey strategy plan & simulation
- Early 2023 - Scheduler in commissioning
- Fall 2023 - Survey operations begin

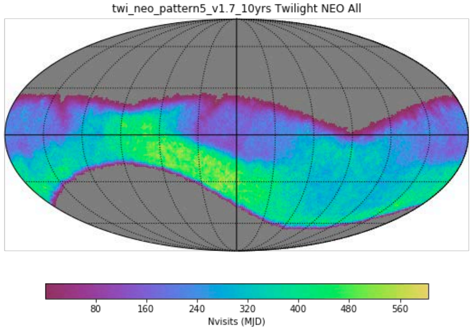
Survey Strategy

- 100’s of simulations complete; improvements in observatory model, fidelity of weather conditions and sky brightness ongoing
- Most changes to survey strategy do not significantly change NEO or PHA metrics

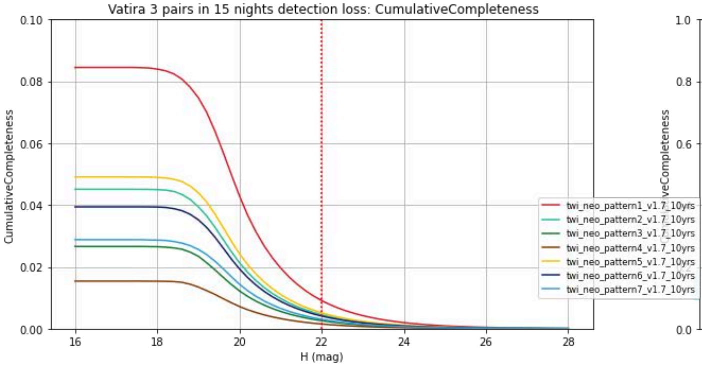


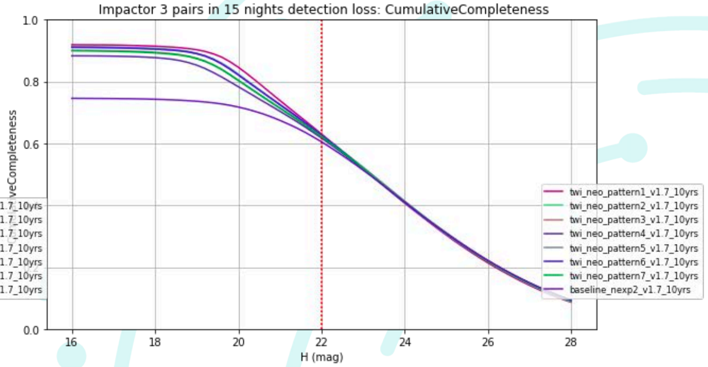
Adding a short exposure twilight NEO-focused survey

- One survey option **may** be to spend some of the time between nautical and astronomical twilight for short (1s) visits at low solar elongation (<65 deg)
- Visits are in *riz* filters, triplets in each night the mini-survey is active
- Enables discovery of Vatiras, improves discovery of large impactors by ~20%



Distribution of twilight NEO visits over the sky

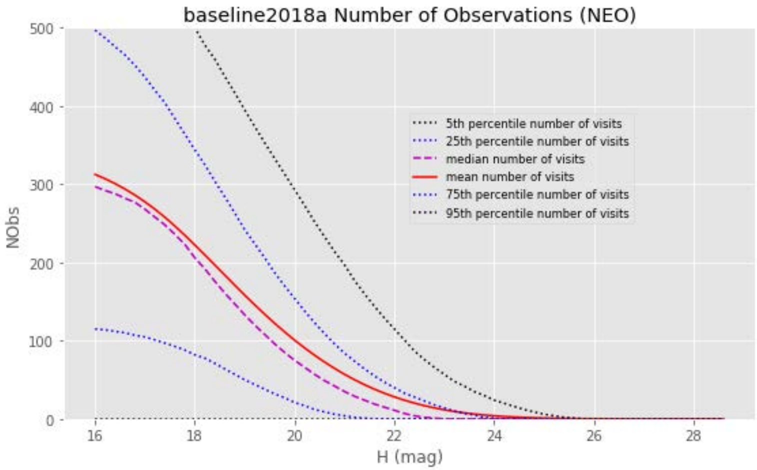


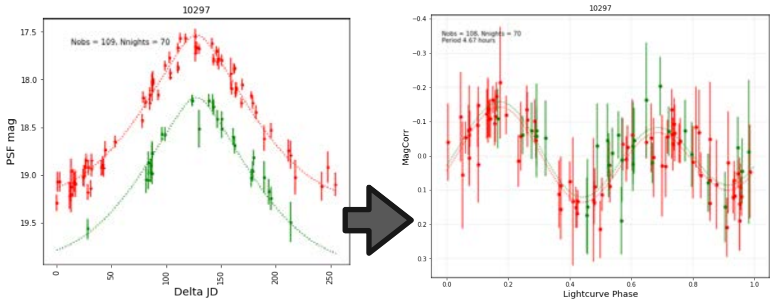


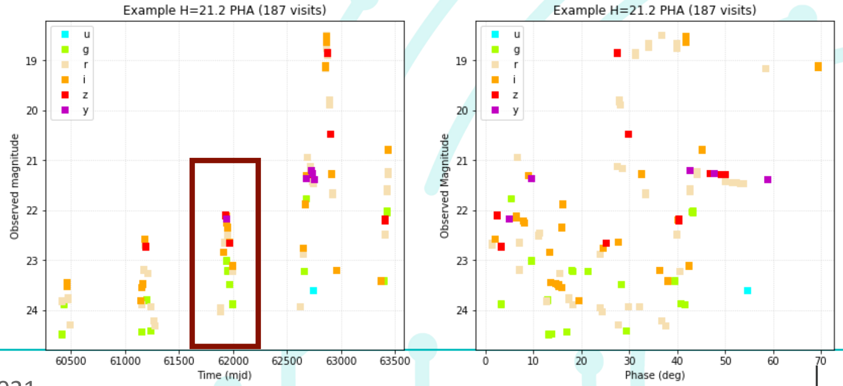
Vatira population based on Granvik et al 2018, modified by Eggl.
Impactor population prototype based on Chesley & Eggl, provided by Eggl.

NEO & PHA characterization

- Hundreds of observations in multiple filters
    - Colors
    - Rotation periods
    - Phase curves
    - Shapes
    - Detection of activity / volatiles / collisions







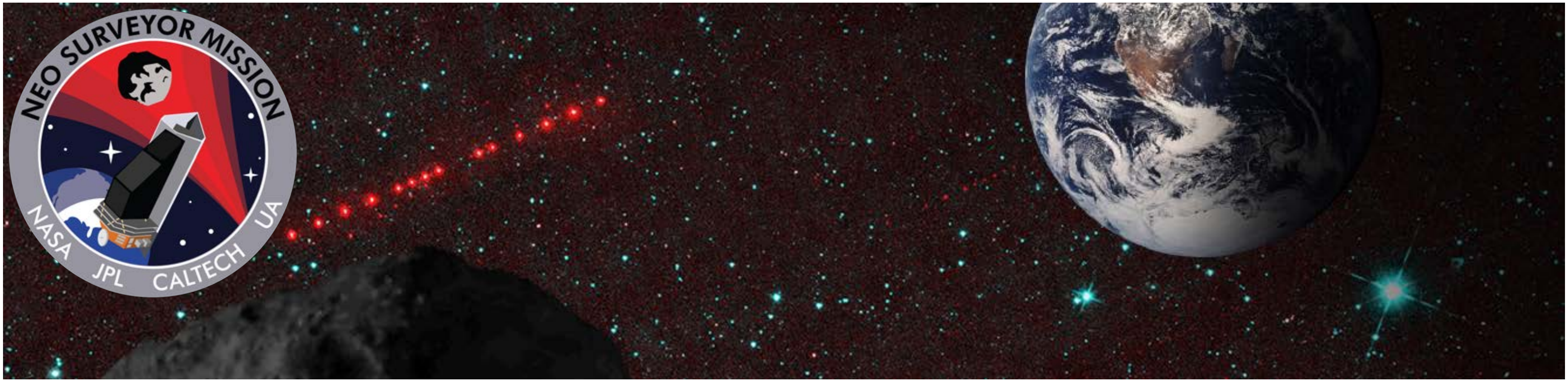
Solar System Processing

- Data products include 60-second Alerts as well as Daily Catalogs
- Alerts include any observations of any known objects (tracks not needed)
- Trailed source fitting will allow quick identification of trailed sources in Alerts
- See http://ls.st/Document-29545 for a summary of data products
- Development of pipelines ongoing
  - Integration test with MPC (see https://dmtn-180.lsst.io/)
  - New linking methods - HelioLinC3D

A. Real-time Alerts (>=2M SSO observations/night)	
Astrometry	±10 mas (bright; ±140 faint)
PSF flux	±10 mmag (bright end)
Aperture flux	±10 mmag (bright end)
Trailed source fit	Flux and on-sky motion for fast-moving (trailed) objects
Appearance characterization	Moments and extendedness of the object's image
Spuriousness score	Probability that the detection is an artifact
Nearby static objects	Information on adjacent objects (up to three)
MPC designation	Given for known objects
Predicted position and magnitude	Given for known objects

Rubin Observatory’s LSST

- The LSST will be a significant resource for planetary defense, discovery and study of NEOs and PHAs
- Anticipate between 50-100k NEOs with H<25
- Construction of observatory and pipelines is ongoing
- Survey strategy being refined
- The LSST Solar System Science Collaboration - http://lsst-sssc.github.io - is a great resource to get started and build additional connections



NEO Detection and The Future of Planetary Defense

NEO Surveyor Investigation Team

JPL | Ball | Space Dynamics Laboratory, Utah State University | ipac | TELEDYNE SCIENTIFIC & IMAGING Everywhereyoulook | University of Rochester

NEOs: The Critical Questions

- **Need to know when impacts could occur and how bad they will be**
  - "If you can't measure it, you can't manage it, and you can't fix it." –Michael Bloomberg

- **When: Comes from finding objects & determining good orbits for them**

- **How bad: Comes from measuring the impact energy (KE)**
  - Impact energy scales as KE = ½ mass x velocity^2
  - **Velocity** comes from orbit
  - Mass = density x volume = density x diameter^3
  - Impact energy depends strongly on **diameter**

What We Have Learned About NEOs from NEOWISE

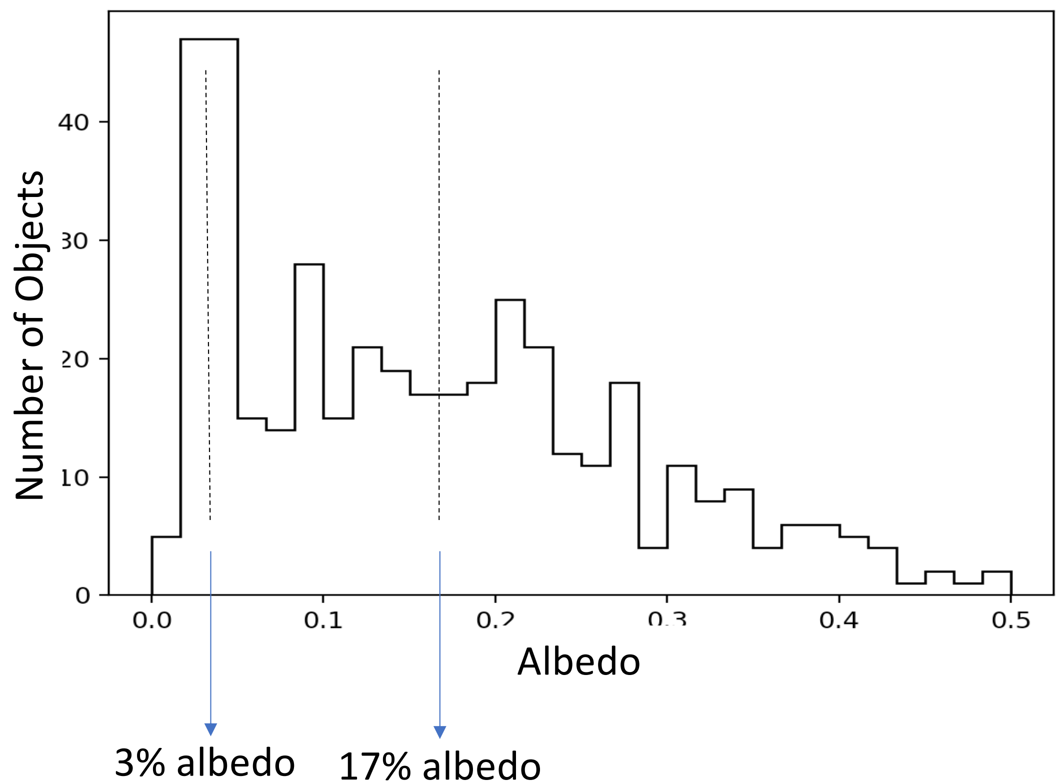
- Asteroid fluxes = $F_{reflected} + F_{emitted}$
- $\boxed{F_{reflected} \sim A\, D^2,\ F_{emitted} \sim D^2\,(1 - A) \sim D^2}$
  - where A = Bond albedo and is usually <<1
  - NEO albedos vary widely: ~3-50%
- Infrared → diameter errors ~±10-20% for modest # of observations
  - With dense, multi-epoch observations, can get within 5% of ground truth e.g. Ryugu (e.g. Müller et al. 2017)
  - Visible light →diameter errors of factors of ~2
- IR is sensitive to both low and high albedo objects
- Space-based survey has consistent biases
  - No weather, no seeing, no daytime

NEO Albedo Distribution

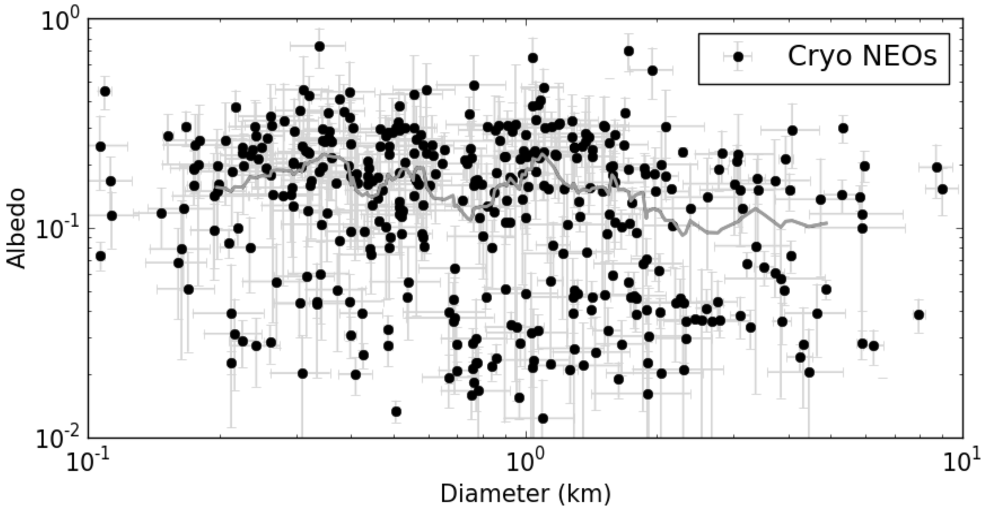
- **Approximately 30% of NEOs are very dark (3% albedo), and a population of less dark ones (17% albedo)**
  - Data from NEOWISE (Mainzer et al. 2011)
  - Data from Hayabusa 2 reveals that NEO Ryugu is extremely dark (few % albedo)

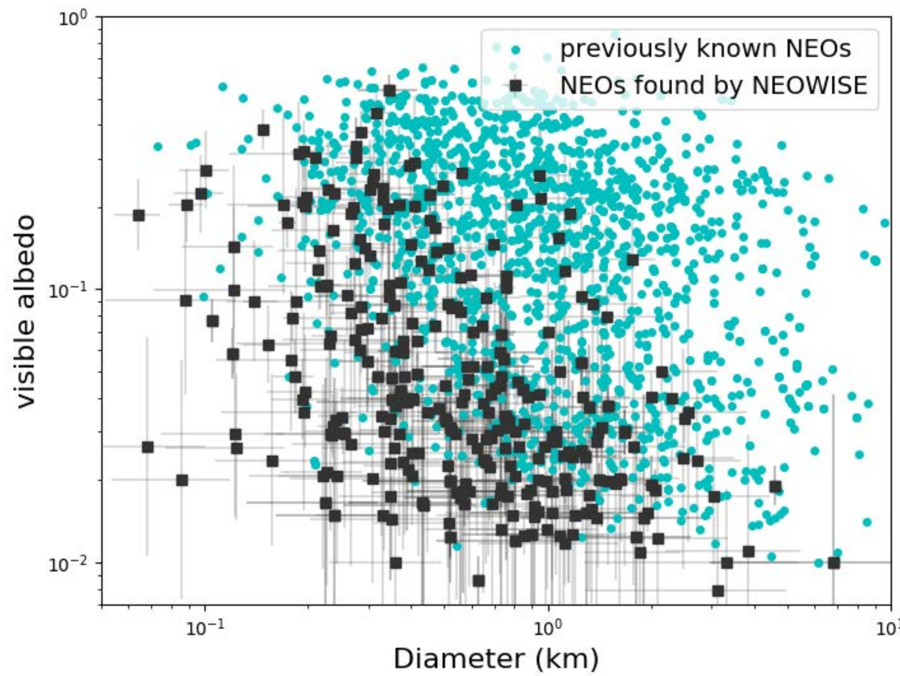
- **Wright et al. (2016) showed that H<22 mag is consequently not equivalent to 140 m: need to reach H<23 mag instead**

- **In order to reach 90% completeness, a system sensitive to dark NEOs as well as the bright ones is needed**



NEO Albedo Distribution



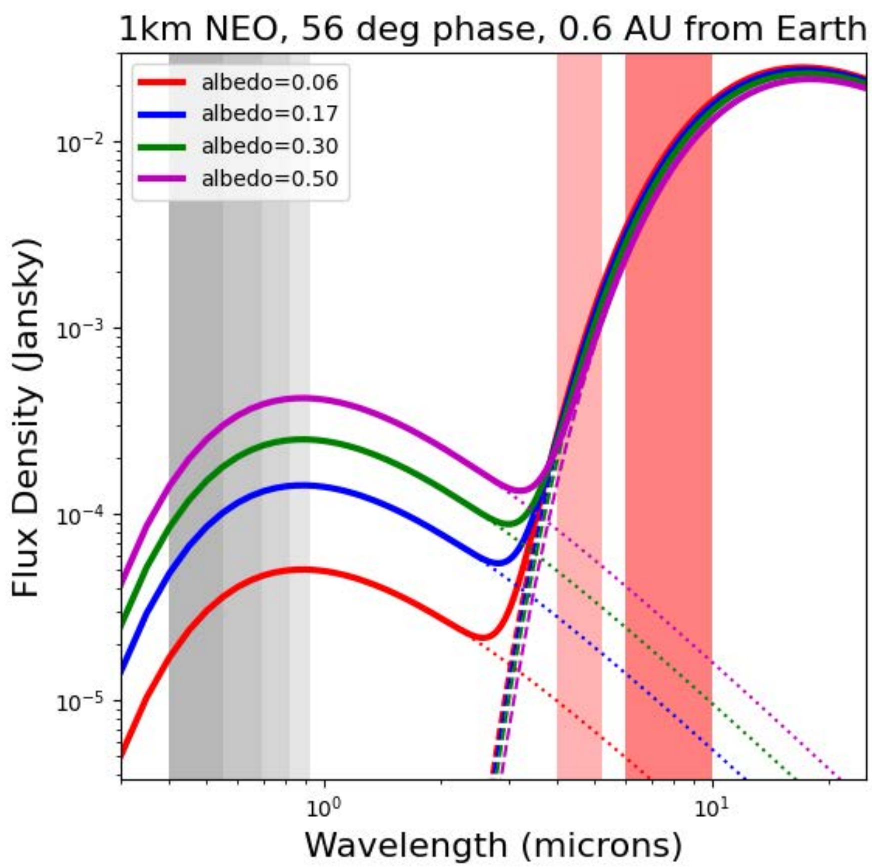


- **~430 NEOs selected based solely on 12um flux**
- **No significant change in albedo vs. diameter**
  - Albedo is constant all the way down to small sizes
- **Contrary to previous studies that are biased against small, low albedo objects**

- **Size vs visible albedo of asteroids observed (cyan circles) and discovered (black squares) by NEOWISE.**
- **NEOWISE discoveries are preferentially dark**

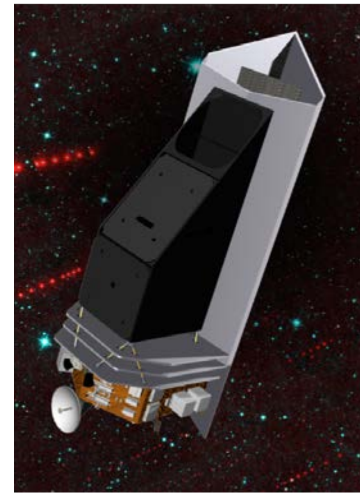
A New Mission: NEO Surveyor

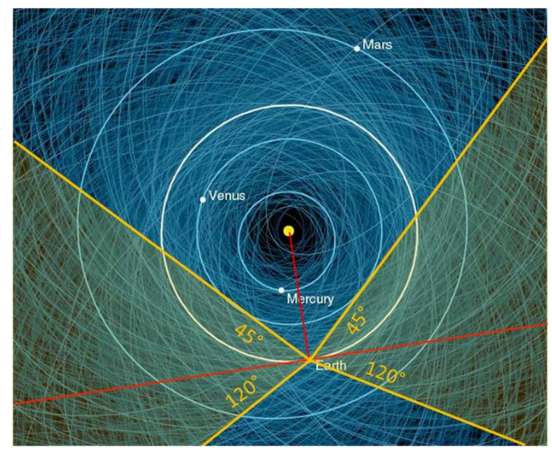
- **Mission Objectives:**
  - Find 2/3 of PHAs >140 m in 5 years (goal: 90%)
  - Produce diameters & compute albedos where visible data are available
  - Compute cumulative chance of impact over next century from PHAs >50 m and comets
  - Deliver tracklet data daily; images & extracted source lists every 6 months



Detecting NEOs

- **We observe the space where NEOs spend time**
  - 50 cm, passively cooled infrared telescope at the Earth-Sun L1 point
- **We survey repeatedly**
  - Mission lifetime – catch long synodic period objects
  - Survey redundancy – same area of sky many times
- **We survey thoroughly**
  - Pointing accuracy (to avoid gaps between fields)
  - Survey cadence optimized for NEO detection: no other science objectives
  - Survey design ensures highly reliable NEO tracklets
  - “Countable” tracklet: ≥ 4 linked observations, each pair of observations separated by < 12 hr
  - “Countable” object: ≥ 2 tracklets, ~ 12 days apart
  - Expect ~300k NEOs & millions of MBAs
- **We can target individual objects of interest**
  - Ability to rapidly respond to virtual impactors





Synergy Between Surveys

- **Vera C. Rubin Observatory and NEO Surveyor cover complementary regions of near-Earth space as shown in the two images to the right**
- **Rubin's LSST survey (yellow region) is most sensitive to NEOs outside the Earth's orbit (blue points; Amors & Apollos)**
- **NEO Surveyor's area of regard (pink region) is most sensitive to NEOs along or inside the Earth's orbit (Apollos, Atens, Interior-to-Earth objects).**
- **Rubin Observatory will provide an excellent catalog of main belt asteroids, which are a significant source of confusion for NEO detection**
- **Combined, these two systems will provide regular monitoring of objects over the majority of their orbits, constraining physical properties (diameter, albedo, thermal inertia) that are needed for impact hazard assessment.**

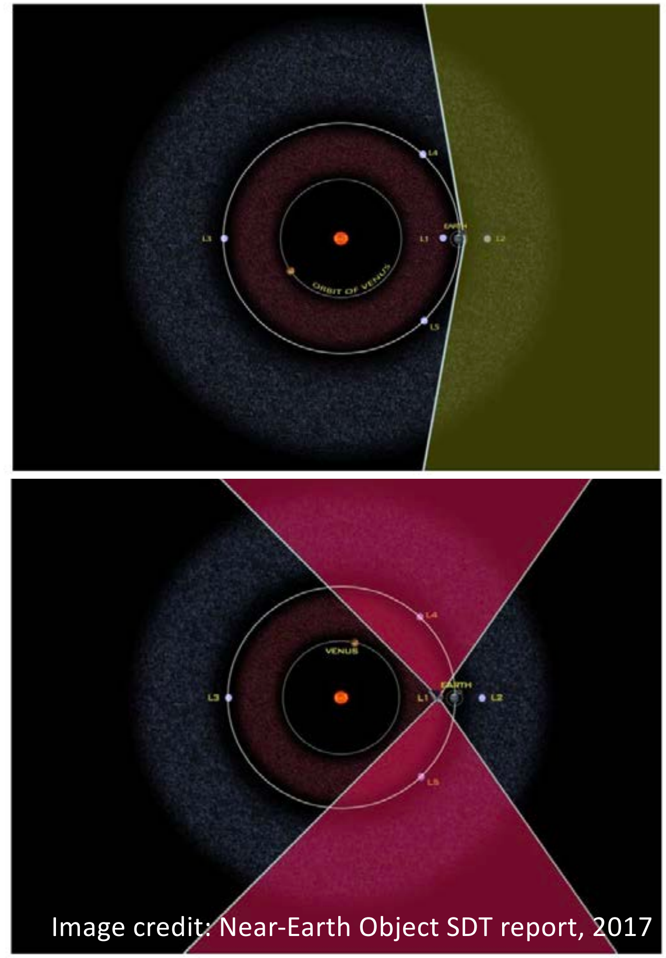
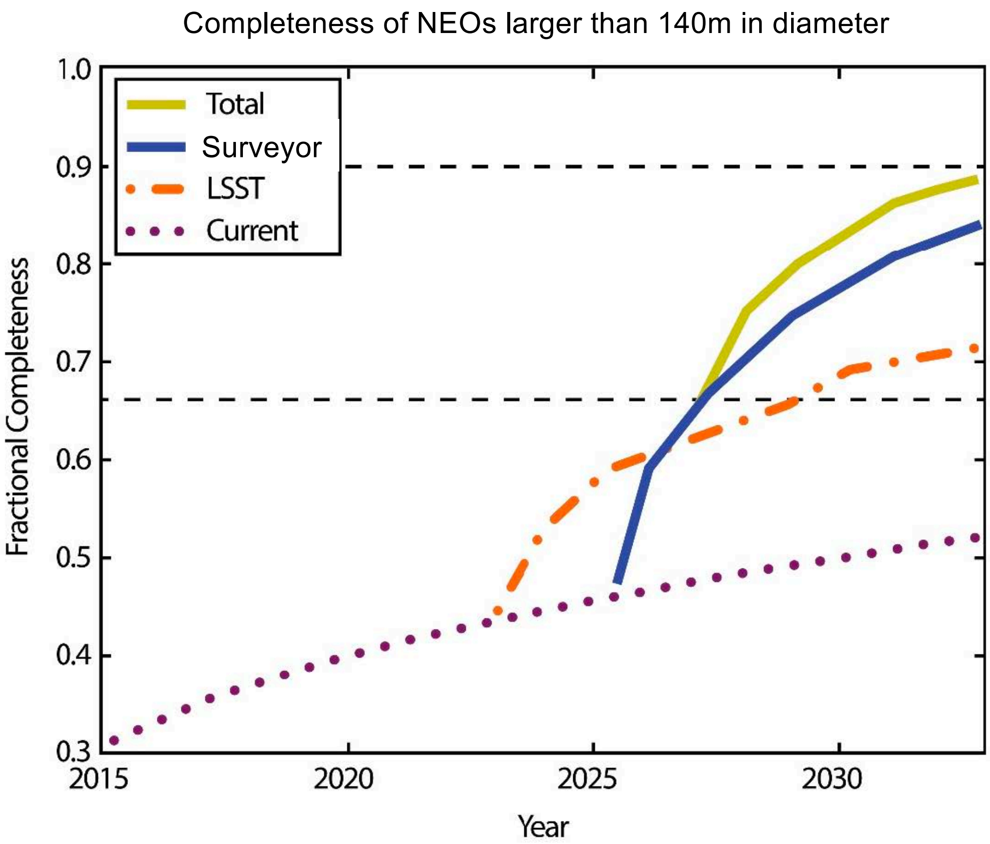


Image credit: Near-Earth Object SDT report, 2017

Synergy Between Surveys



- **Rubin Observatory is expected to begin surveying in late 2023**
- **NEO Surveyor currently on a schedule that would allow for a 2026 launch date with survey beginning 3 months later**
- **These two surveys will dramatically increase the state of knowledge of NEOs as shown in the plot to the left**
- **The NEO catalog will reach 90% completeness within 10 years of the launch of Surveyor, fulfilling the Congressional mandate to NASA**
- **See lightning talks by Grav, Lilly, Spahr, Surace, Wright**

The new MPC NEO Confirmation Page: Improvements and results

Federica Spoto[1], Matthew Payne[1], Matthew Holman[1] and Peter Vereš[1]

CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

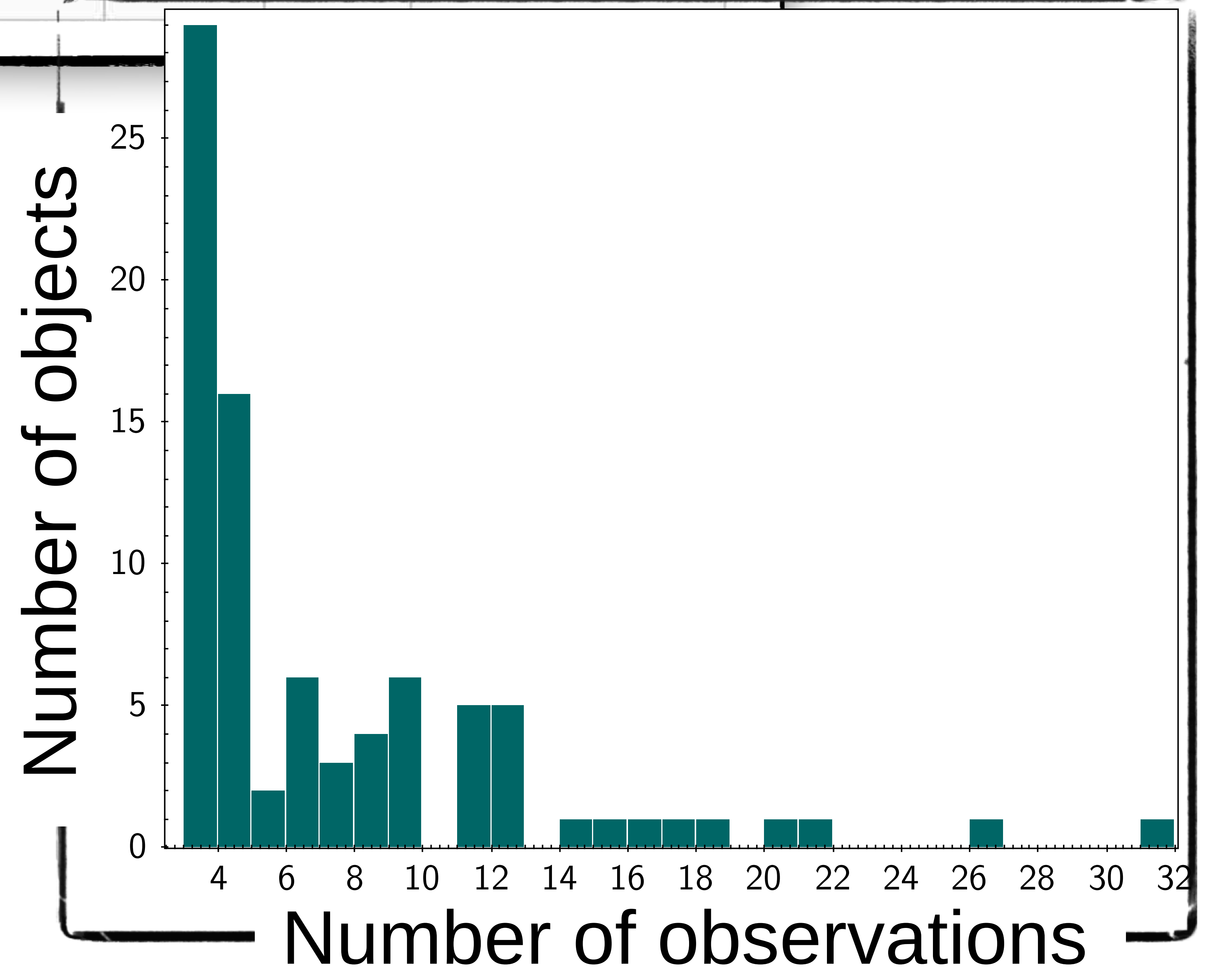
[1] Center for Astrophysics, Harvard & Smithsonian

VIENNA, AUSTRIA
IAA PLANETARY DEFENSE CONFERENCE 2021
26–30 APRIL 2021

The NEO Confirmation Page

Temp Desig	Score	Discovery	R.A.	Decl.	V	Updated	Note	NObs	Arc	H	Not Seen/dys
P11fbXR	97	2021 04 14.5	14 42.1	+03 08	21.1	Added Apr. 14.74 UT		3	0.02	19.5	0.217
P11fbPG	97	2021 04 14.6	15 24.2	+06 58	22.1	Added Apr. 14.70 UT		3	0.03	21.2	0.176
P11fbPq	99	2021 04 14.6	15 44.3	+07 07	22.4	Added Apr. 14.69 UT		3	0.02	21.7	0.161
P11fbPp	99	2021 04 14.6	15 24.2	+07 30	22.0	Added Apr. 14.69 UT		4	0.04	14.4	0.164
TMG0046	98	2021 04 14.6	16 56.9	+37 02	15.7	Updated Apr. 14.75 UT		23	0.15	26.5	0.023
P11fao5	71	2021 04 14.5	14 31.9	+06 43	22.0	Added Apr. 14.59 UT		3	0.02	15.8	0.233
P11fao4	78	2021 04 14.5	14 09.3	+04 24	22.0	Added Apr. 14.59 UT		3	0.03	17.0	0.223

NEOCP: https://minorplanetcenter.net/iau/NEO/toconfirm_tabular.html



Main goals:

- Real-time publication of **NEA candidates**
- Help and facilitate a rapid **follow-up**

Recent improvements - 1

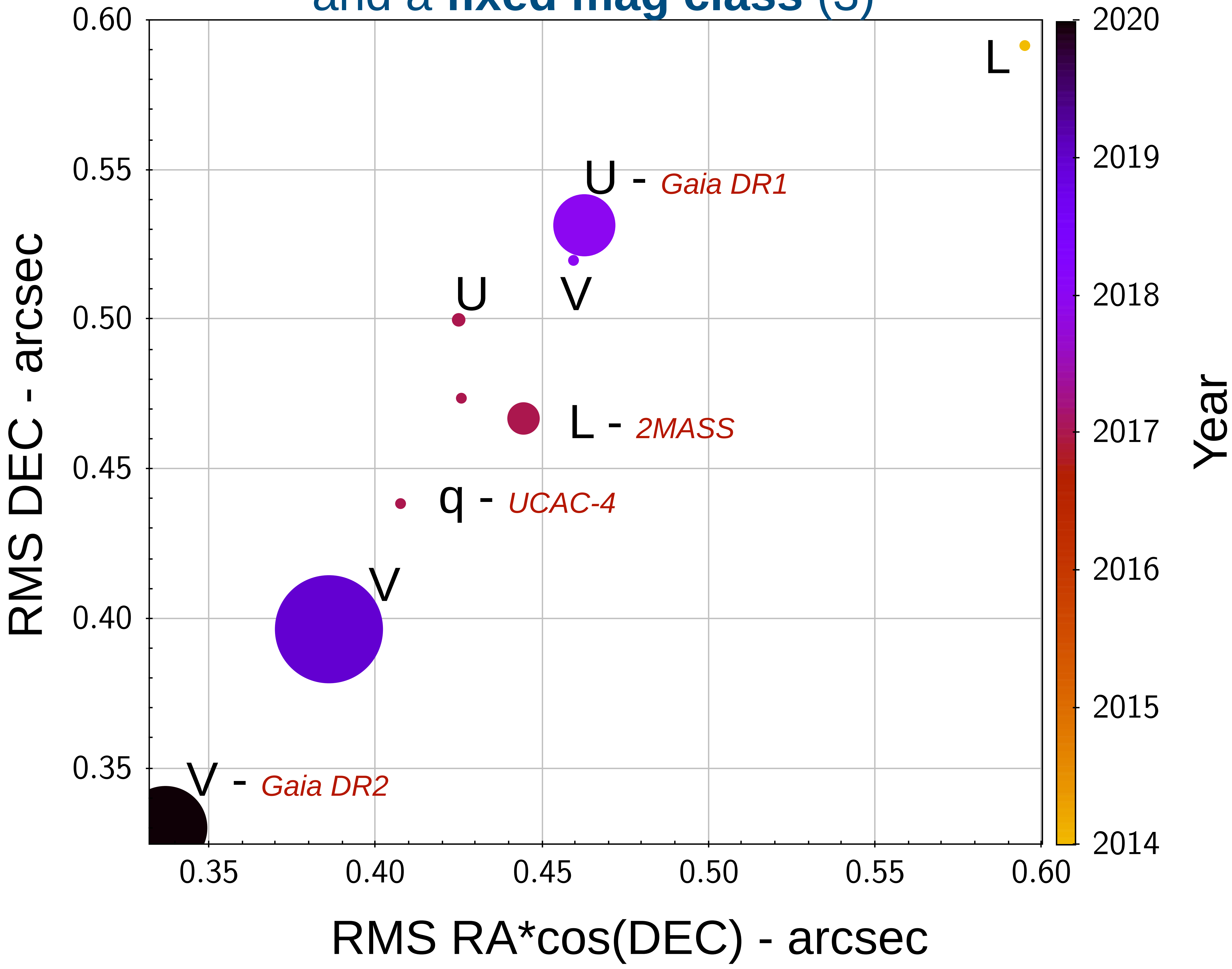
OrbFit @ MPC:
- Orbital elements **uncertainties**
- Use of a new **weighting scheme**
- Use of ADES
- …

Analysis of all the available residuals

- Grouped by:
  - **Observatories**
  - **Year**
  - **Stellar catalog (including no catalog)**
  - **Magnitude class (including no magnitude)**

(Spoto et al., in preparation)

Weights for T08 (ATLAS-MLO, Mauna Loa) and a **fixed mag class** (3)



Recent improvements - 2

Our error model

Year · *Obs and catalog code* · *RMS used* · *Mag class*

2014,	T08 ,	L,	19555,	11440,	0.585,	0.59496,	0.59166,	0.92946,	0.92027,	3,	0.59496,	0.59166
2017,	T08 ,	2,	118920,	118920,	1.000,	0.42596,	0.47360,	0.42596,	0.47360,	3,	0.42596,	0.47360
2017,	T08 ,	L,	952170,	925138,	0.972,	0.44471,	0.46662,	0.50289,	0.52312,	3,	0.44471,	0.46662
2017,	T08 ,	U,	356038,	356034,	1.000,	0.42506,	0.49973,	0.42516,	0.49987,	3,	0.42506,	0.49973
2017,	T08 ,	q,	28957,	28825,	0.995,	0.40744,	0.43853,	0.41992,	0.45592,	3,	0.40744,	0.43853
2018,	T08 ,	U,	1767943,	1767859,	1.000,	0.46265,	0.53138,	0.46323,	0.53188,	3,	0.46265,	0.53138
2018,	T08 ,	V,	6259,	6257,	1.000,	0.45945,	0.51985,	0.46149,	0.52465,	3,	0.45945,	0.51985
2019,	T08 ,	V,	3083272,	3083188,	1.000,	0.38613,	0.39627,	0.38684,	0.39655,	3,	0.38613,	0.39627
2020,	T08 ,	V,	2381419,	2381408,	1.000,	0.33708,	0.33001,	0.33715,	0.33022,	3,	0.33708,	0.33001

(Spoto et al., in preparation)

Use of observations in ADES format

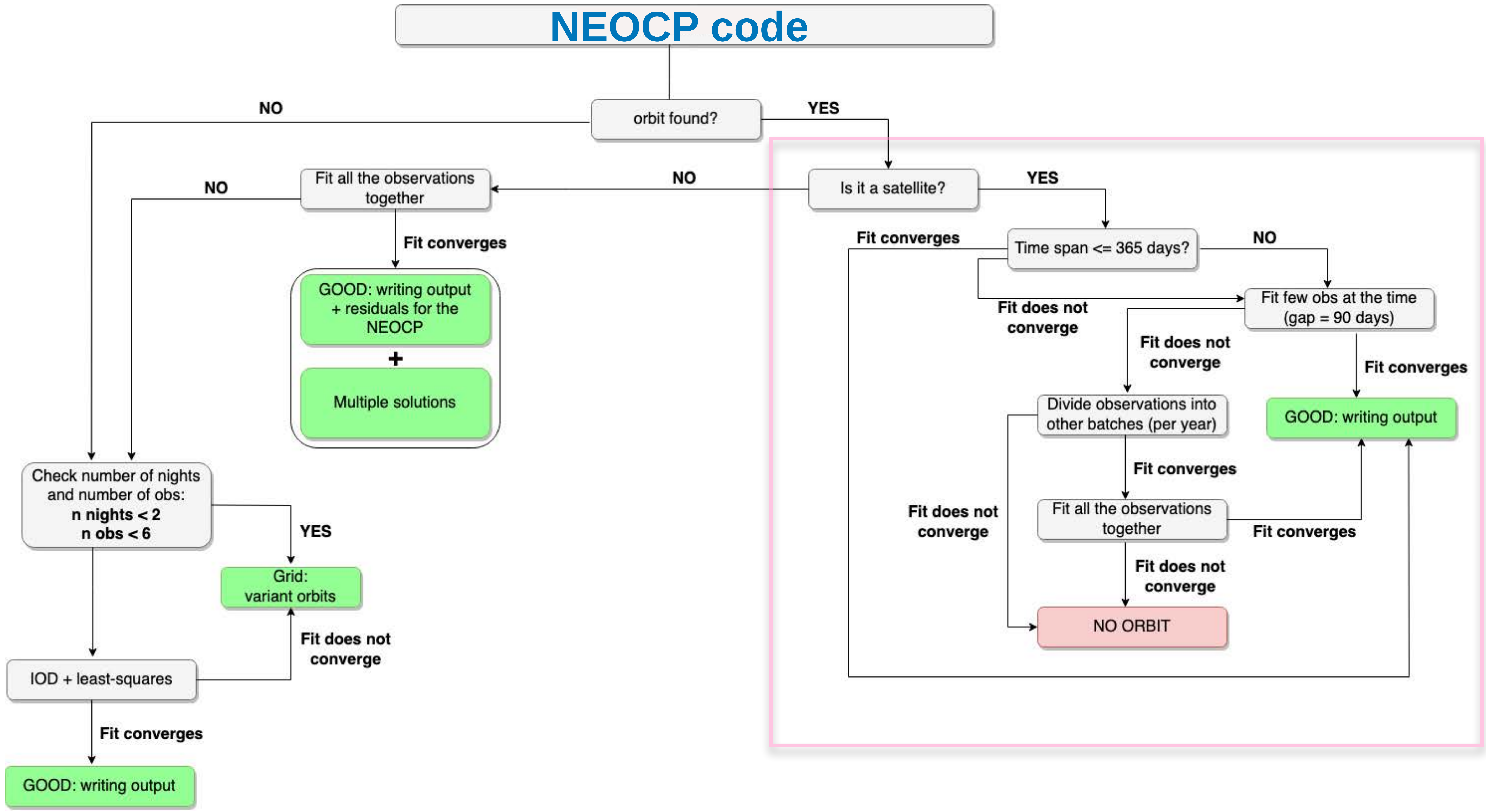
Epoch of the observation (UTC)	*RMS sent*		*Stellar catalog (V)*	*Mag*
2021-04-04T11:18:27.52Z	0.402	0.402	Gaia2	19.61
2021-04-04T10:50:49.64Z	0.369	0.369	Gaia2	19.74
2021-04-04T10:50:49.64Z	0.269	0.269	Gaia2	18.87
2021-04-04T09:12:48.89Z	0.351	0.351	Gaia2	19.75
2021-04-04T10:24:27.82Z	0.312	0.312	Gaia2	18.69
2021-04-04T11:19:47.23Z	0.305	0.305	Gaia2	19.47
2021-04-04T09:22:46.61Z	0.304	0.304	Gaia2	19.57
2021-04-04T10:36:11.78Z	0.322	0.322	Gaia2	18.98

ADES data in the MPC database sent by T08

- RMS sent < RMS computed → **RMS computed**
- RMS sent > RMS computed → **RMS sent**

NEOCP: new code

The International Astronomical Union
Minor Planet Center

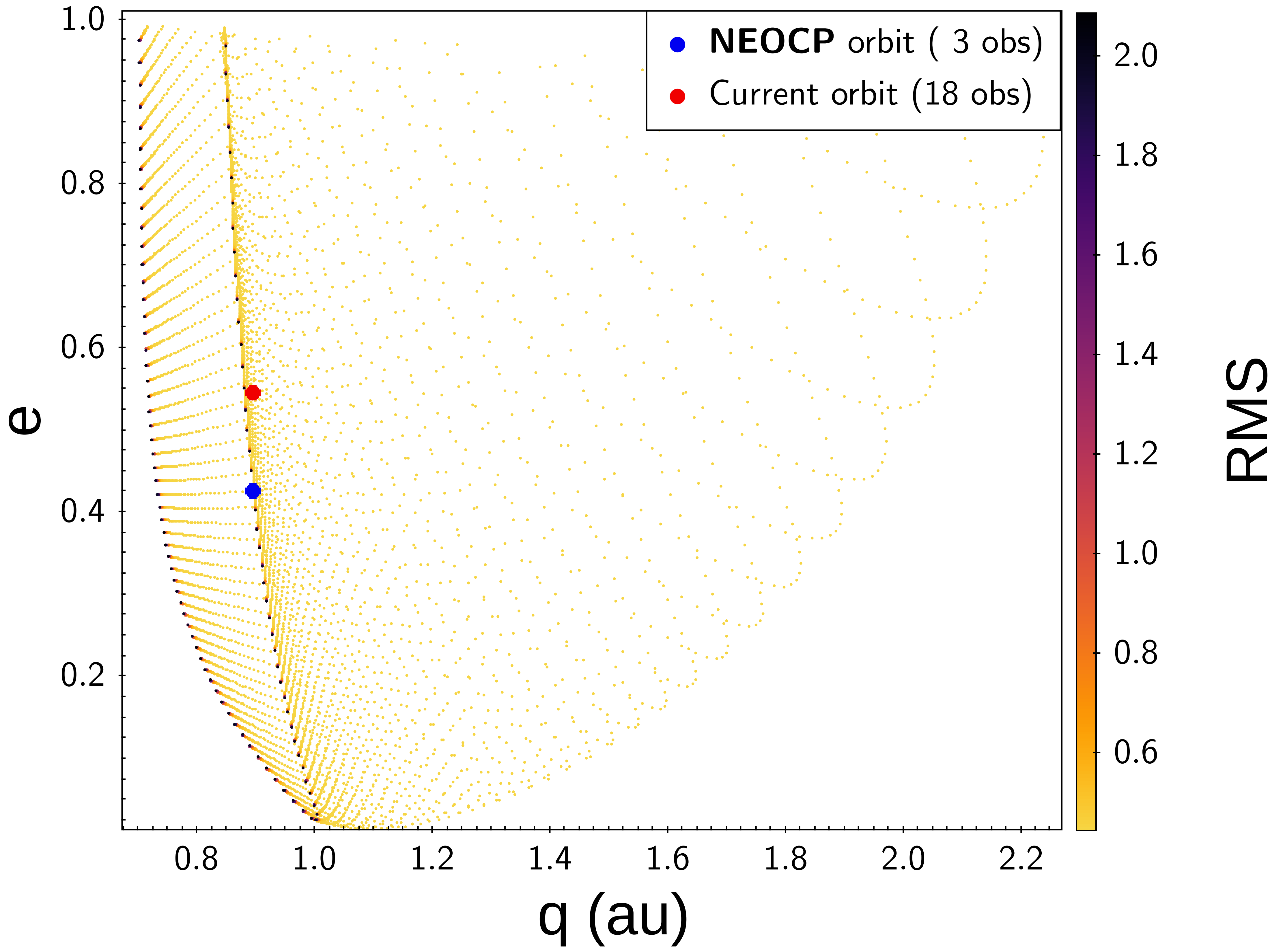


Choice of the nominal solution

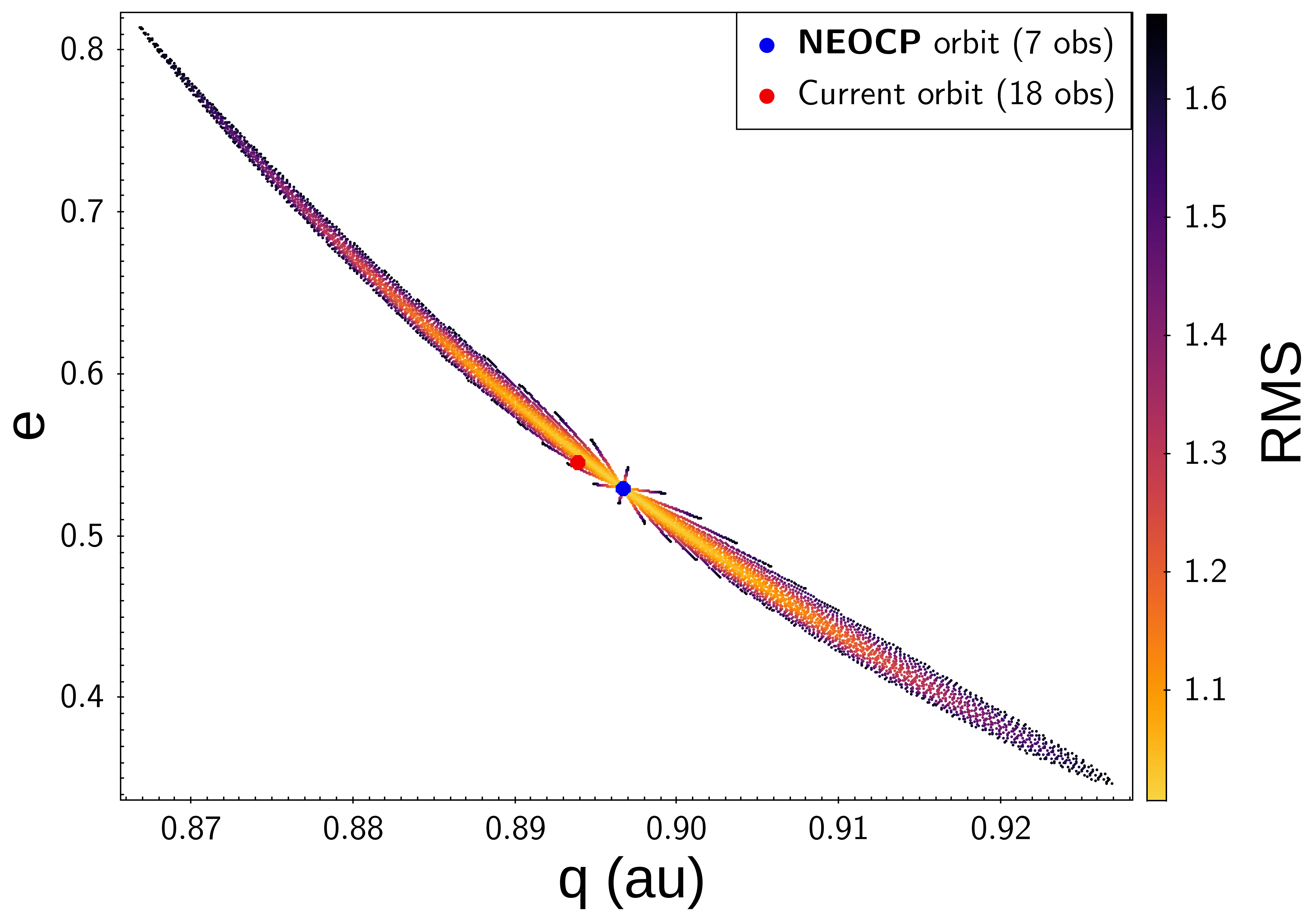
3 possible options:

- Orbit with the **minimum RMS**
- Orbit in the grid that is the **closest one to the orbit corresponding to the median** of the RA and DEC values (obtained from the prediction of each reliable orbit in the grid)
- Orbit that **corresponds to the median** of the RA and DEC value predictions

3 obs from 703



3 obs from 703 + 4 obs from G96



Vera Rubin/LSST exercise

The International Astronomical Union
Minor Planet Center

Main goals:

- Assess MPC's current and expected future ability to **ingest LSST-sized submissions**

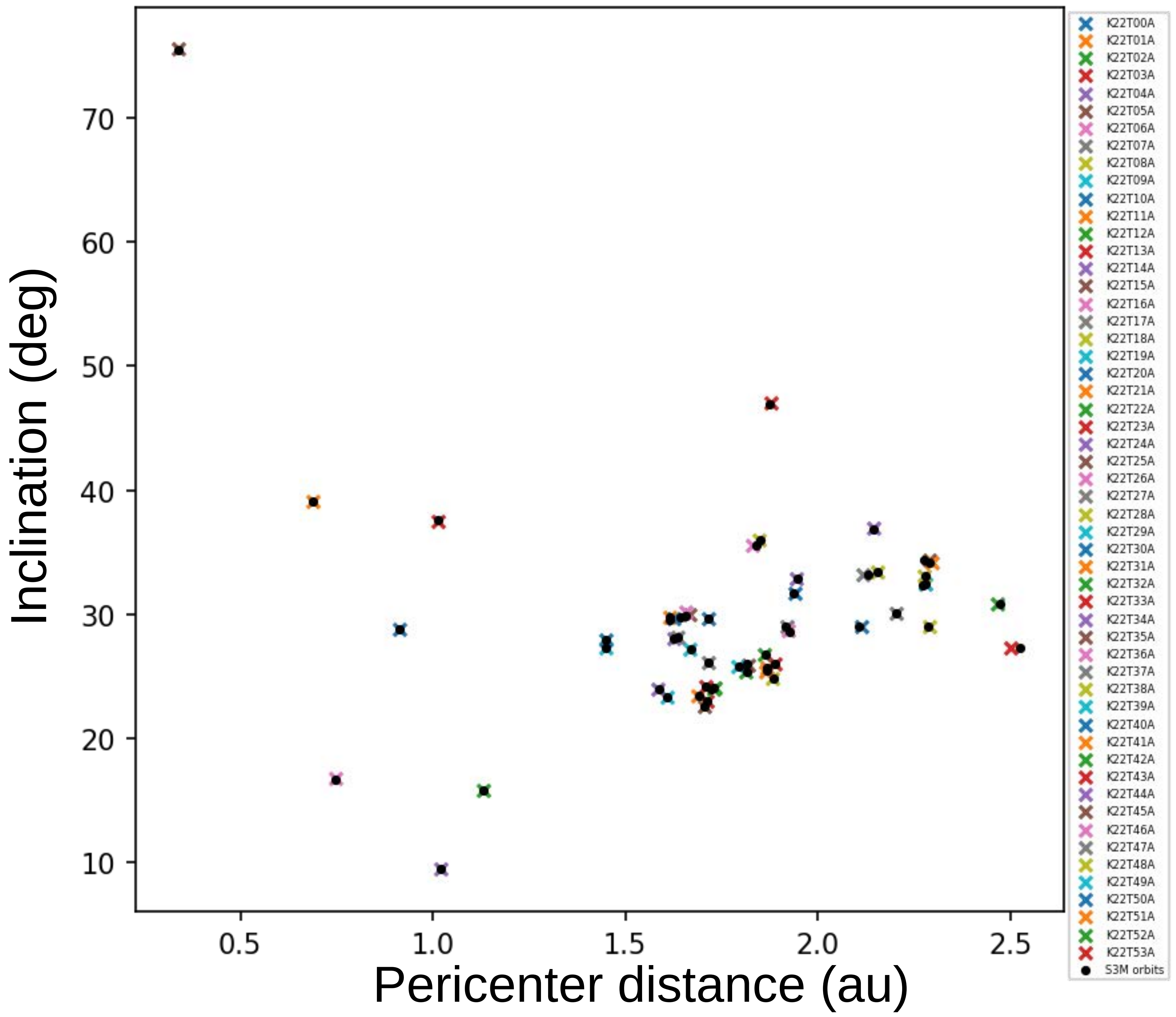
- Test the MPC's capability to re-fit orbits and **generate a new orbit catalog**

Hugely succesfull:

- Demonstrated **ingestion of multiple nights** of LSST data

- **Demonstrated MPC's capability to fit all "New" objects in ~2 hours** (using ~300 cores)

Simulated orbits vs derived MPC orbits



Courtesy of Siegfried Eggl (University of Washington)

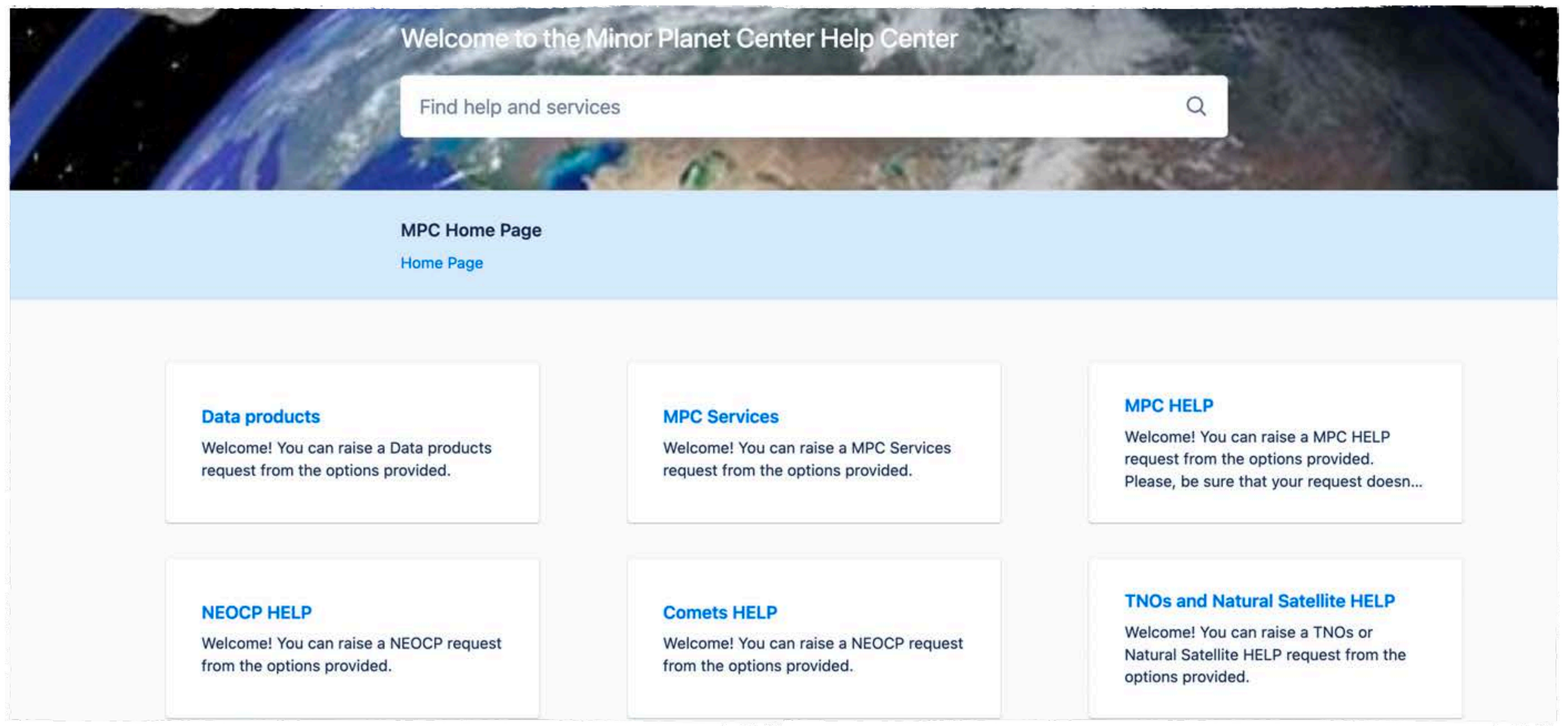
Near future plans

The International Astronomical Union
Minor Planet Center

Start flagging suspected artificial objects on the NEOCP (see Editorial, 2021 Apr 19th)

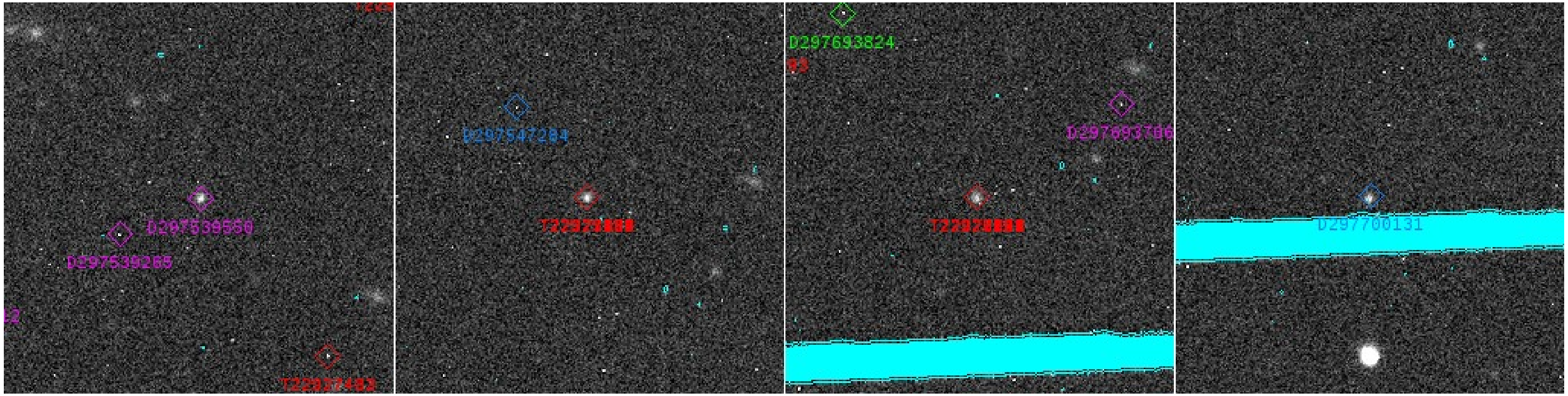
P11fmQd	100	2021 04 15.5	14 38.5	-04 04	22.3	Added Apr. 15.85 UT	S	3	0.03	26.7	0.574
P11fmQ3	100	2021 04 15.4	12 05.4	-04 22	22.2	Added Apr. 15.84 UT		3	0.02	25.5	0.673
P11fmCm	67	2021 04 15.3	11 15.7	+16 42	22.7	Added Apr. 15.81 UT		3	0.02	13.1	0.789
P11fmCi	100	2021 04 15.3	11 34.4	+11 35	22.7	Added Apr. 15.80 UT		3	0.04	19.5	0.784

Use the JIRA Helpdesk to submit requests



- **New NEOCP page**
- Producing and publishing **orbits** and **residuals** using **OrbFit**

NEOs in the Isolated Tracklet File



Robert Weryk[1,*], Richard Wainscoat[1], and Peter Vereš[2]

(1) Institute for Astronomy, University of Hawaii, Honolulu HI, USA
(2) Harvard & Smithsonian, Minor Planet Center, Cambridge MA, USA
(*) Physics and Astronomy, The University of Western Ontario, London ON, Canada

PDC 2021, Apr 26-30, virtual Vienna, Austria

Introduction

- Survey telescopes are very dependent on follow-up, but ...
  - The majority of tracklets do not post to the NEOCP
  - Initial orbit estimates might have too large uncertainty
  - Objects become too faint or weather is not ideal
- Unlinked data are relegated to the Isolated Tracklet File (ITF)
  - Rich repository for data mining, some data 20+ years old
  - Includes ‘was not confirmed’ NEOCP objects
  - Often easier to link tracklets versus a visual search of probable ephemeris locations in precovery images
  - May contain single night tracklets for second oppositions

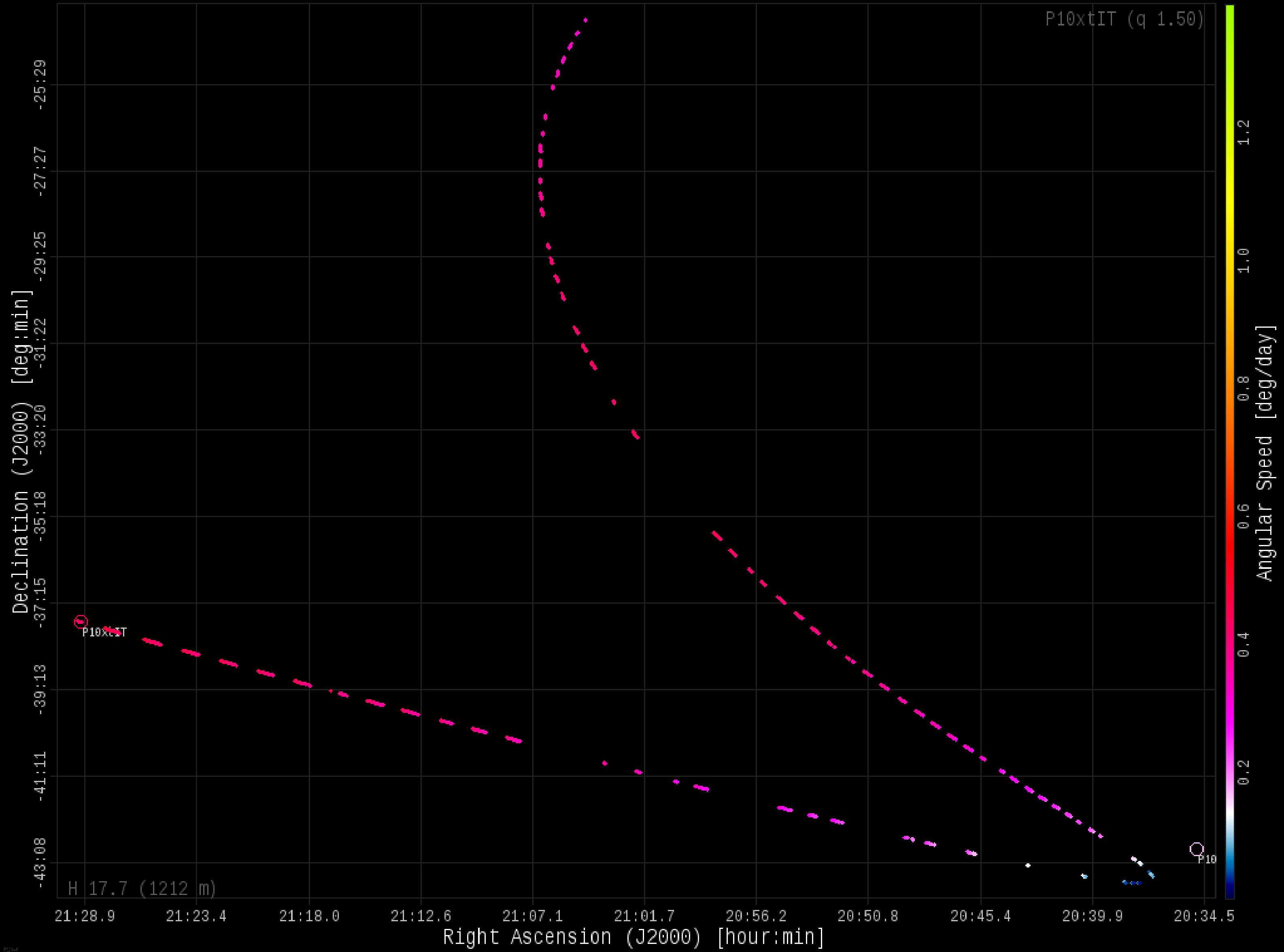
The Isolated Tracklet File (ITF)

- ~10 million detections with ~3 million unique tracklet names
- Recent linking activities has noticeably reduced its size

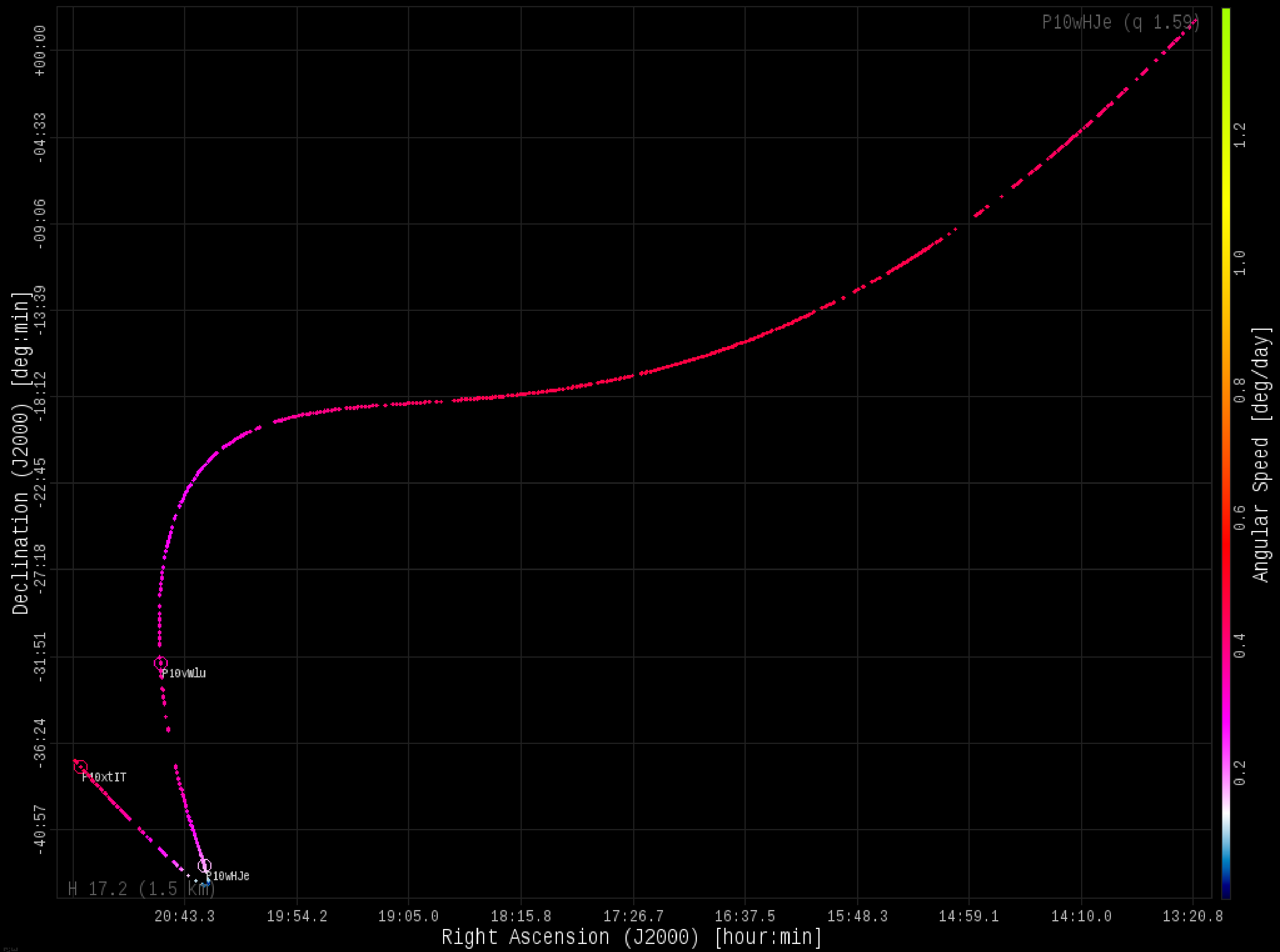
site	code	count	percent
Pan-STARRS 1, Haleakala	F51	4 995 424	47.7 %
Mt. Lemmon Survey	G96	2 826 063	27.0 %
Steward Observatory, Kitt Peak-Spacewatch	691	510 410	4.9 %
Catalina Sky Survey	703	253 295	2.4 %
Pan-STARRS 2, Haleakala	F52	235 829	2.3 %
Palomar Mountain/NEAT	644	108 068	1.0 %
---	---	1 539 381	15.7 %

Previous Linking Effort

- We previously reported (PDC 2017) on linking non-NEOs
  - Since then, >~160 000 objects and >20 000 identifications
  - Goal to stop ‘known’ objects from posting to the NEOCP
  - Massive help for PS survey review -> batch submissions
  - Required a lot of time to be merged at MPC
- Also reported (PDC 2019) on linking a small number of NEOs
  - More computationally intensive due to motion changes
  - Shrinking ITF makes search more computationally feasible
  - Required a lot of manual checking for mislinkages
  - From older tracklet data, no means of added follow-up
  -



P10xtIT (q 1.50)
P10xtIT
P10
H 17.7 (1212 m)
Declination (J2000) [deg:min]
-25:29
-27:27
-29:25
-31:22
-33:20
-35:18
-37:15
-39:13
-41:11
-43:08
21:28.9
21:23.4
21:18.0
21:12.6
21:07.1
21:01.7
20:56.2
20:50.8
20:45.4
20:39.9
20:34.5
Right Ascension (J2000) [hour:min]
Angular Speed [deg/day]
1.2
1.0
0.8
0.6
0.4
0.2



P10wHJe (q 1.59)
Declination (J2000) [deg:min]
+00:00
-04:33
-09:06
-13:39
-18:12
-22:45
-27:18
-31:51
-36:24
-40:57
P10vWlu
P10xtIT
P10wHJe
H 17.2 (1.5 km)
20:43.3
19:54.2
19:05.0
18:15.8
17:26.7
16:37.5
15:48.3
14:59.1
14:10.0
13:20.8
Right Ascension (J2000) [hour:min]
Angular Speed [deg/day]
0.2
0.4
0.6
0.8
1.0
1.2

Want to ‘automagically’ find NEOs

- Recent work has made our search method more efficient
  - Turned into an ‘ITF autolinker’ tool, with daily ITF retrieval
  - Allows finding low ‘digest score’ NEOs without the NEOCP
  - Submit linkages of most recent objects to the ‘ID pipeline’ at the MPC, meaning they are processed immediately
- Some improvements still to be made
  - Currently need at least five tracklets for single opposition
  - NEOs are not automatically submitted, nor are distant objects such as JFC like orbits or even perhaps Centaurs
  - Could submit them after more reliable residual checks

Apophis (part of IAWN campaign)

- Useful test : find Apophis in the (at the time) recent ITF
  - Motivated by IAWN campaign to study Apophis passage
  - Surveys submitted apophis tracklets as unknown candidates
- Major weakness in our existing method was search time
  - During dark time, processing could take over a week
  - Apophis ‘officially found’ by us on Dec 28, after C51 posted
  - So we restricted initial tracklet tests to those with score >=6 which means processing now completes on same day
- MPC has since made all V<19 objects post regardless of score
  - But V>19 still require a search tool like ours

Recent new NEOs from the ITF

- >=3 tracklet candidates are checked/verified each day
  - But can also test single tracklets for being recoveries
  - As the ITF shrinks further, we can relax the search criteria
- Dedicated MPECs (not DOUs) now sent for ITF designations

object	H	q [AU]	Arc [days]	notes
2021 AB8	19.9	1.15	123	450 metre NEO
2021 AF8	20.1	0.98	2327	400 metre PHA, pre-recovered
2021 ES5	21.7	0.88	4043	200 metre PHA, but is 2010 FF10
2017 FS188	18.7	1.29	1486	800 metre ‘NEO’ found as 2-opp

Progress is on-going

- It seems far fewer known objects now post to the NEOCP
  - Follow-up better spent on more worthy objects
- Only a handful of NEOs have been linked so far
  - It’s not very surprising, the NEOCP works well
  - Balance between how much manual review is required, certainly two tracklet cases could be looked at
  - Could also process lower SNR detection catalogues
- We continue to link ‘boring’ and ‘sporadic’ tracklets
  - Total minor planet count recently passed one million
  - One day, everything remaining will be interesting!

CATCHing Near-Earth Objects in Archival Survey Data

Mike Kelley, Dan Darg, James "Gerbs" Bauer
University of Maryland / PDS Small-Bodies Node
2021 Apr 27 – 7th Planetary Defense Conf.

Motivation

- Ground-based **NEO surveys** are producing millions of images per year.
- **Specialized tools** are necessary to keep them accessible and relevant.
- A key application is **object precovery.**

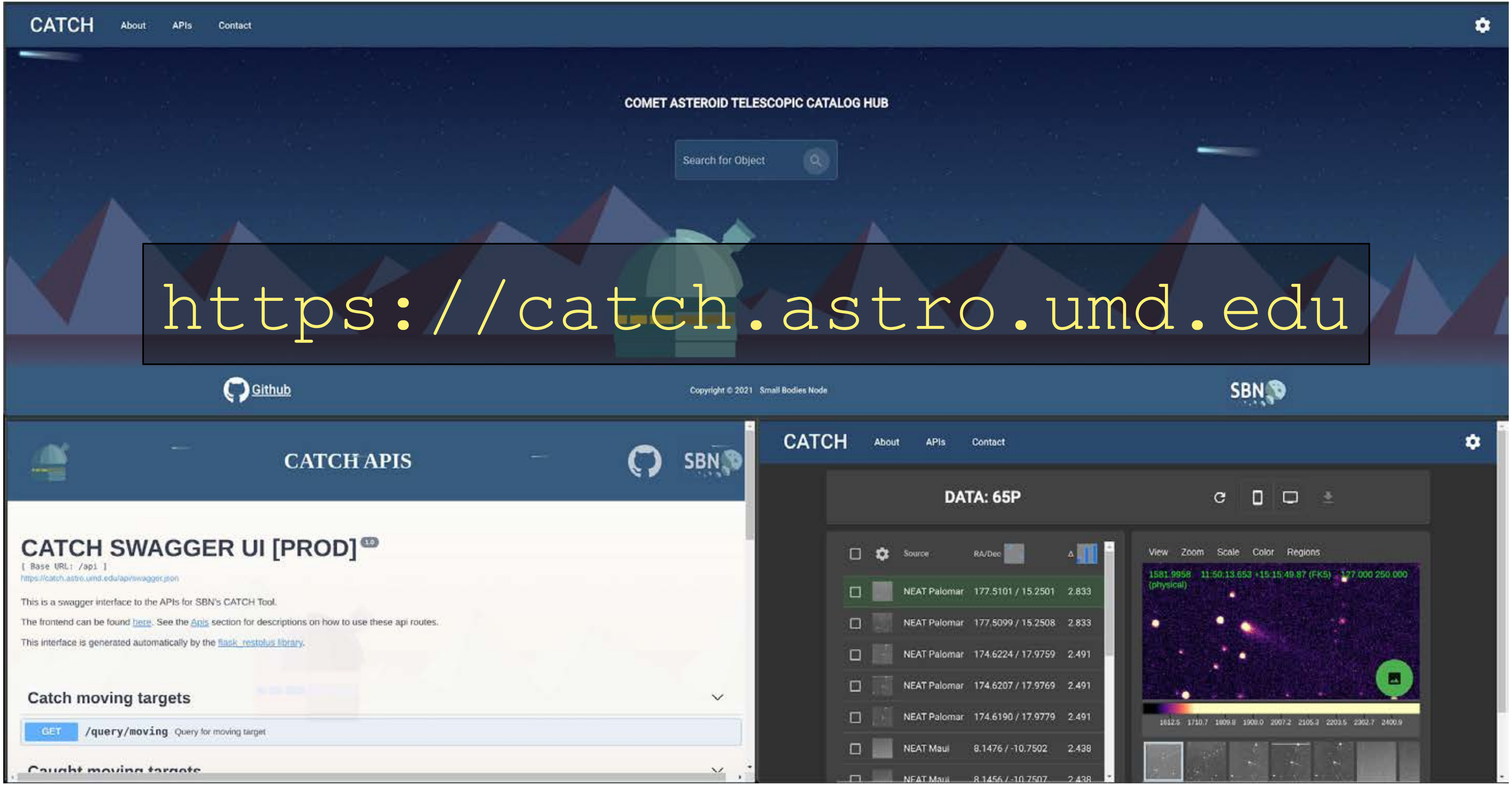
CATCH:
Comet Asteroid Telescopic Catalog Hub

Designed to quickly find comets and asteroids in wide-field time-domain survey data.

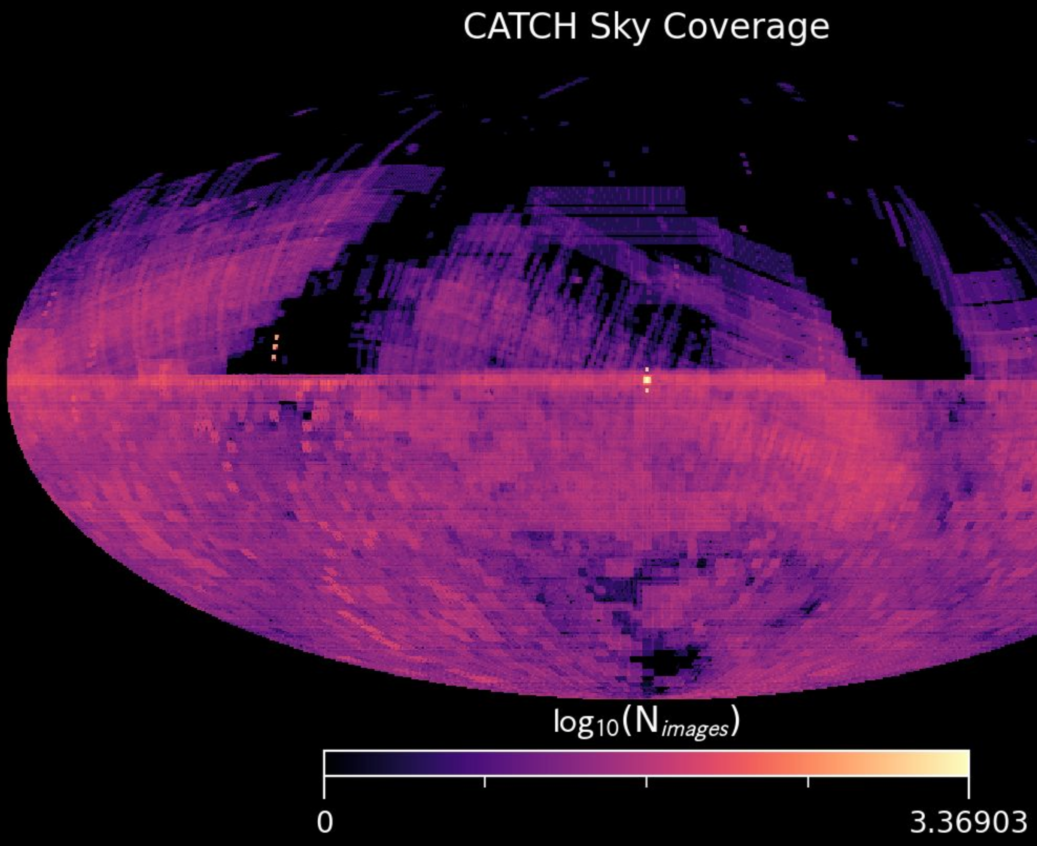
Searchable

Accessible

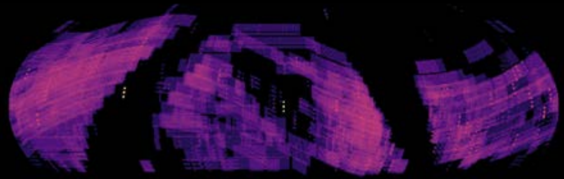
`Generalizable`


CATCH
About
APIs
Contact
COMET ASTEROID TELESCOPIC CATALOG HUB
Search for Object
https://catch.astro.umd.edu
Github
Copyright © 2021 Small Bodies Node
SBN
CATCH APIS
CATCH SWAGGER UI [PROD]
[Base URL: /api]
This is a swagger interface to the APIs for SBN's CATCH Tool.
The frontend can be found here. See the Apis section for descriptions on how to use these api routes.
This interface is generated automatically by the flask_restplus library.
Catch moving targets
GET /query/moving Query for moving target
DATA: 65P
Source
RA/Dec
NEAT Palomar 177.5101 / 15.2501 2.833
NEAT Palomar 177.5099 / 15.2508 2.833
NEAT Palomar 174.6224 / 17.9759 2.491
NEAT Palomar 174.6207 / 17.9769 2.491
NEAT Palomar 174.6190 / 17.9779 2.491
NEAT Maui 8.1476 / -10.7502 2.438
View
Zoom
Scale
Color
Regions

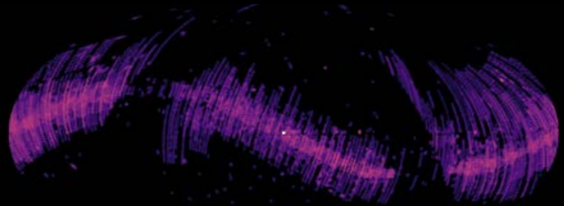
Currently loaded surveys



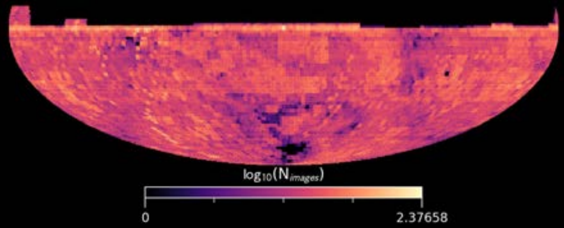
NEAT Palomar Tricam



NEAT Maui GEODSS

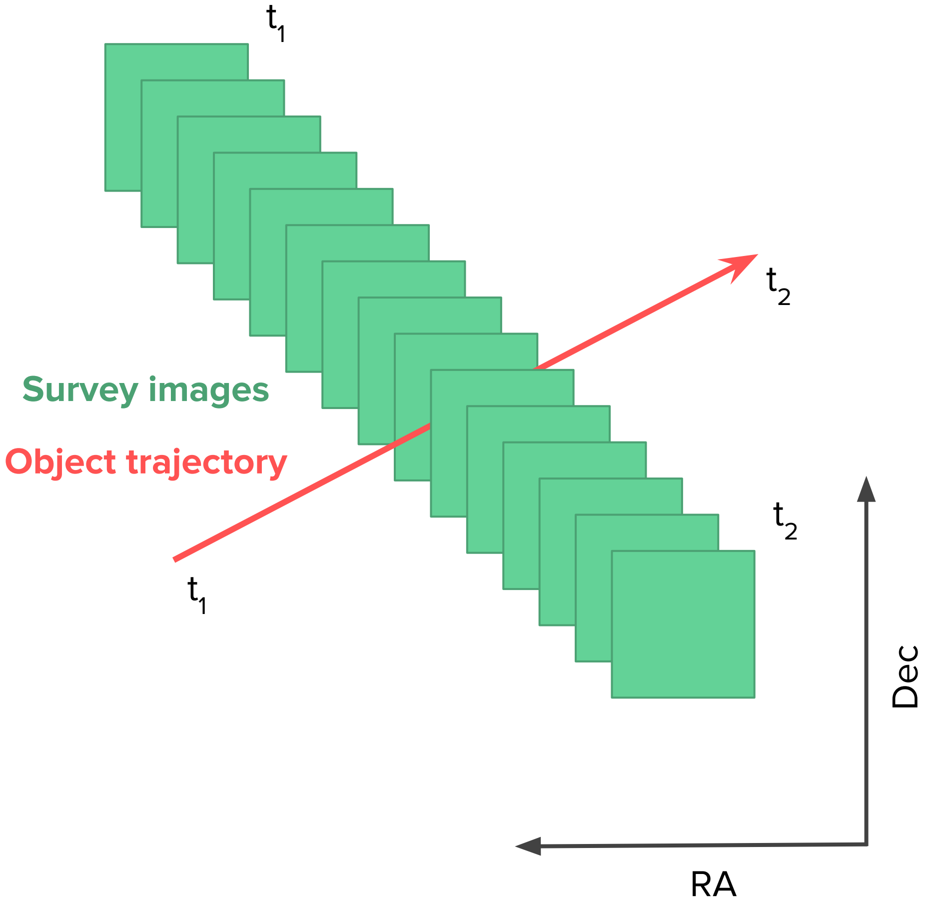


SkyMapper DR2



Needle in the haystack

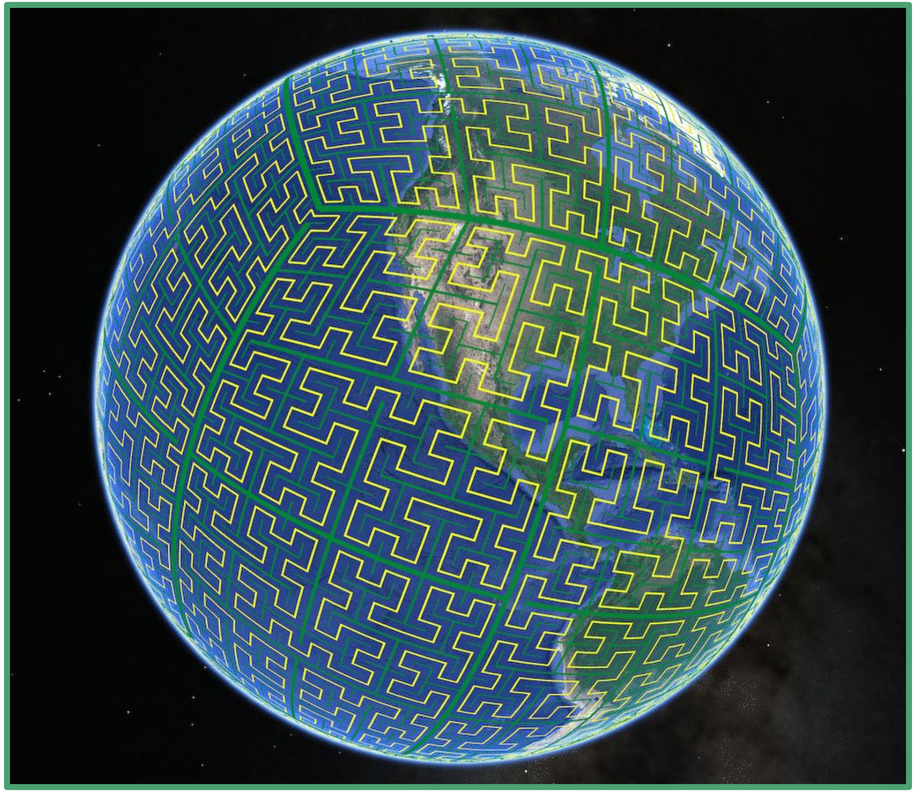
- Efficient search algorithms foremost about eliminating objects that do not match, leaving a few objects to examine in detail.
- CATCH uses an approach motivated by geolocation searches, e.g., to find the nearest COVID testing sites in Google Maps.



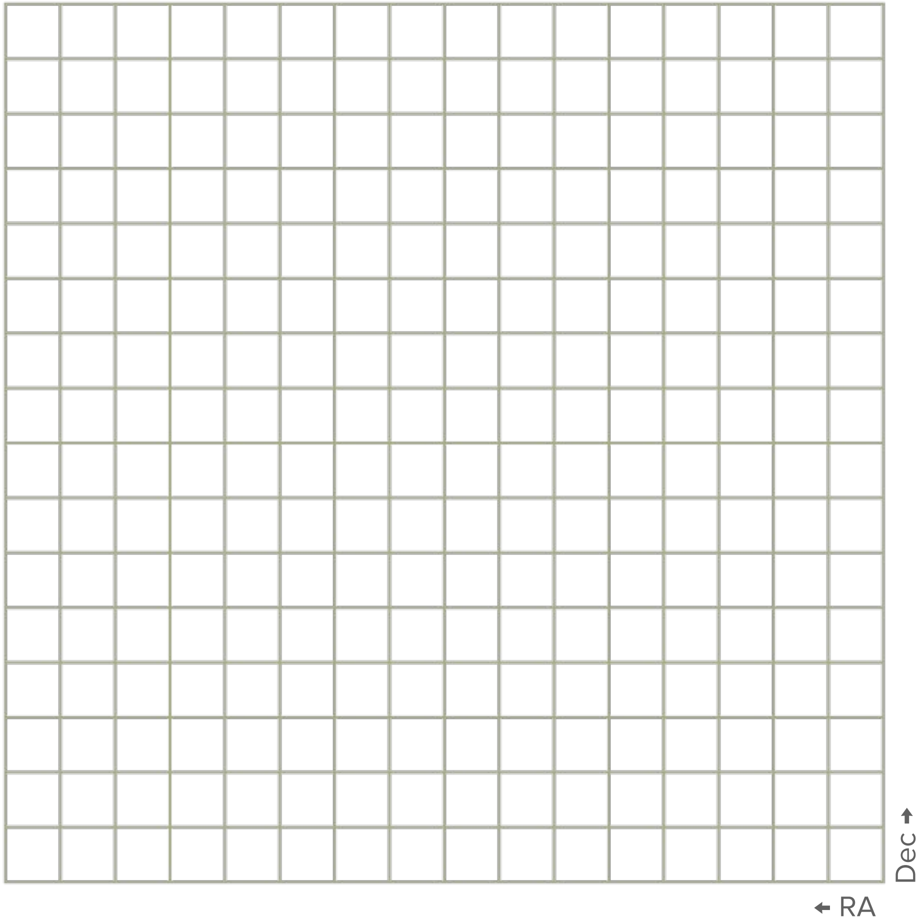
s2geometry (CATCH dev)

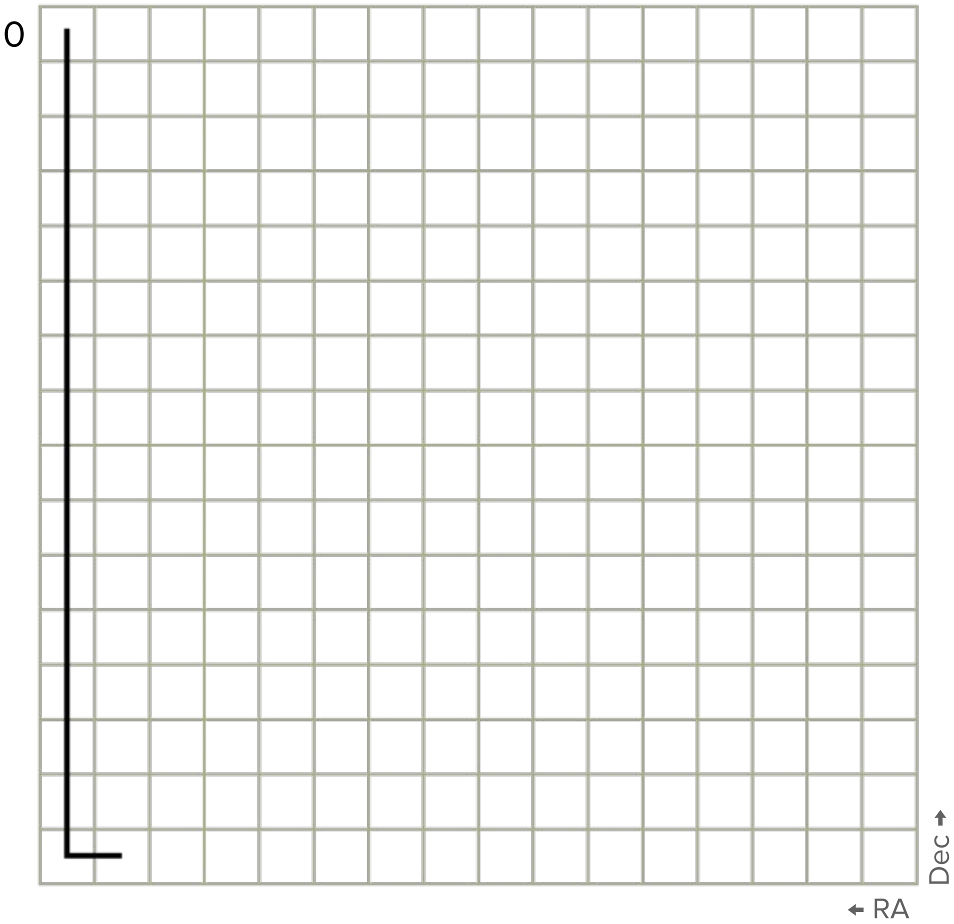
Google's s2geometry indexes the sphere with a space-filling (fractal) curve. Benefits:

- The (Hilbert) curve maximizes locality.
- Cell boundaries are geodesics.
- E-W flip from Earth to Celestial Sphere does not affect results.
- 100x faster than equivalent Hierarchical Triangular Mesh (HTM) indexing.

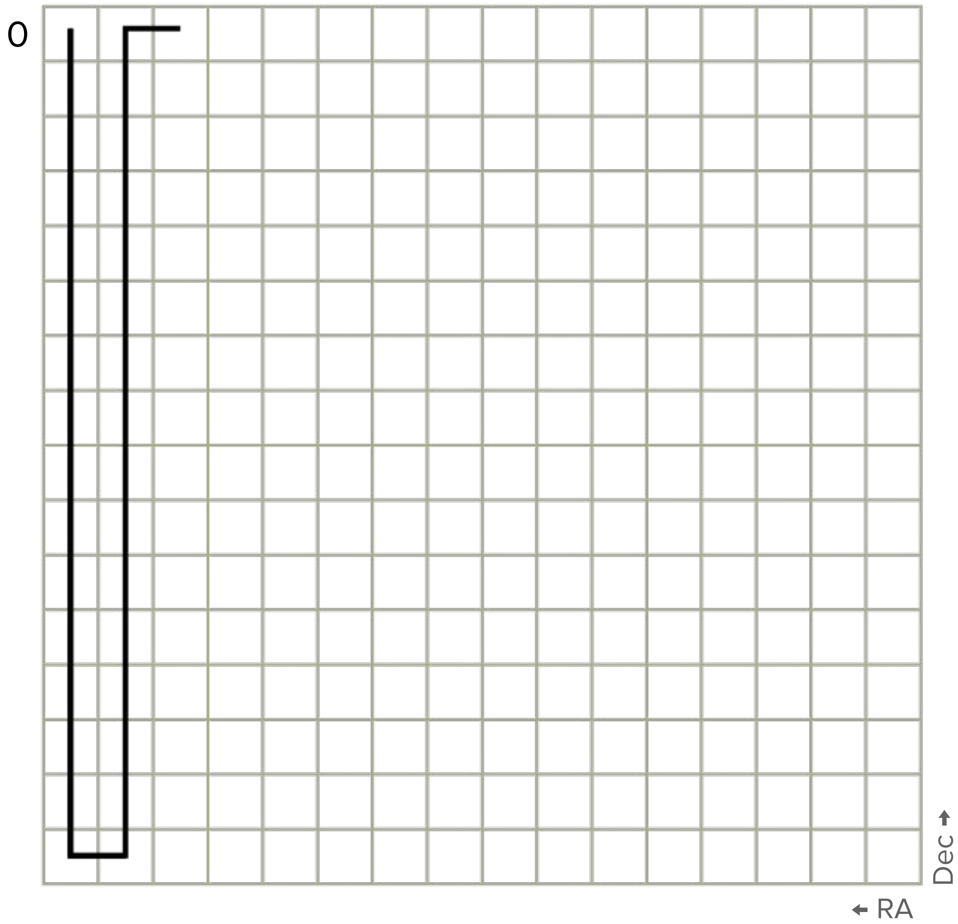


s2geometry.io


Dec
RA



0
Dec
RA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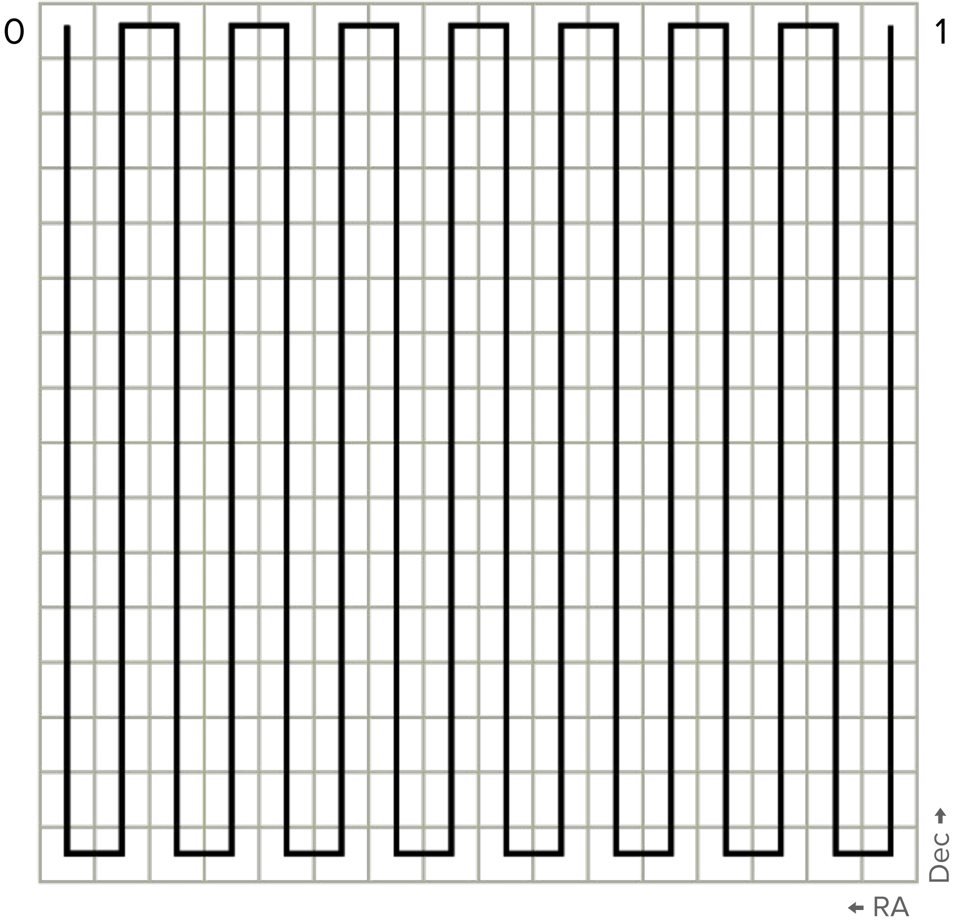
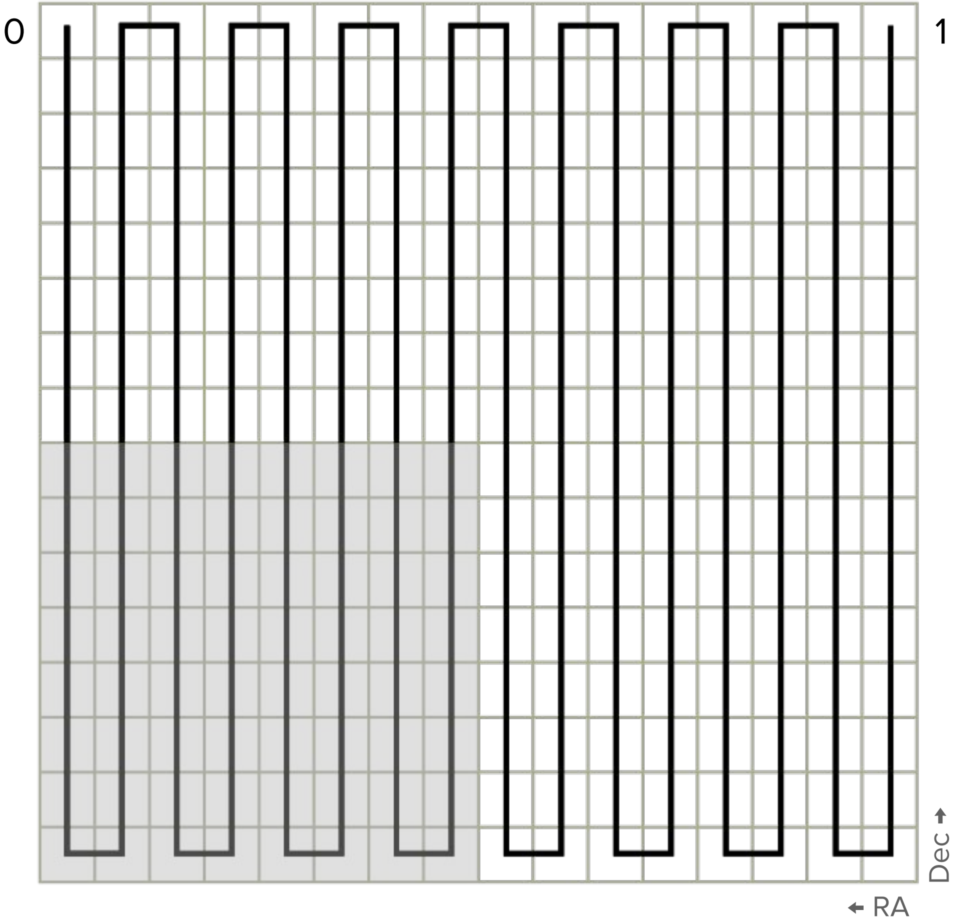
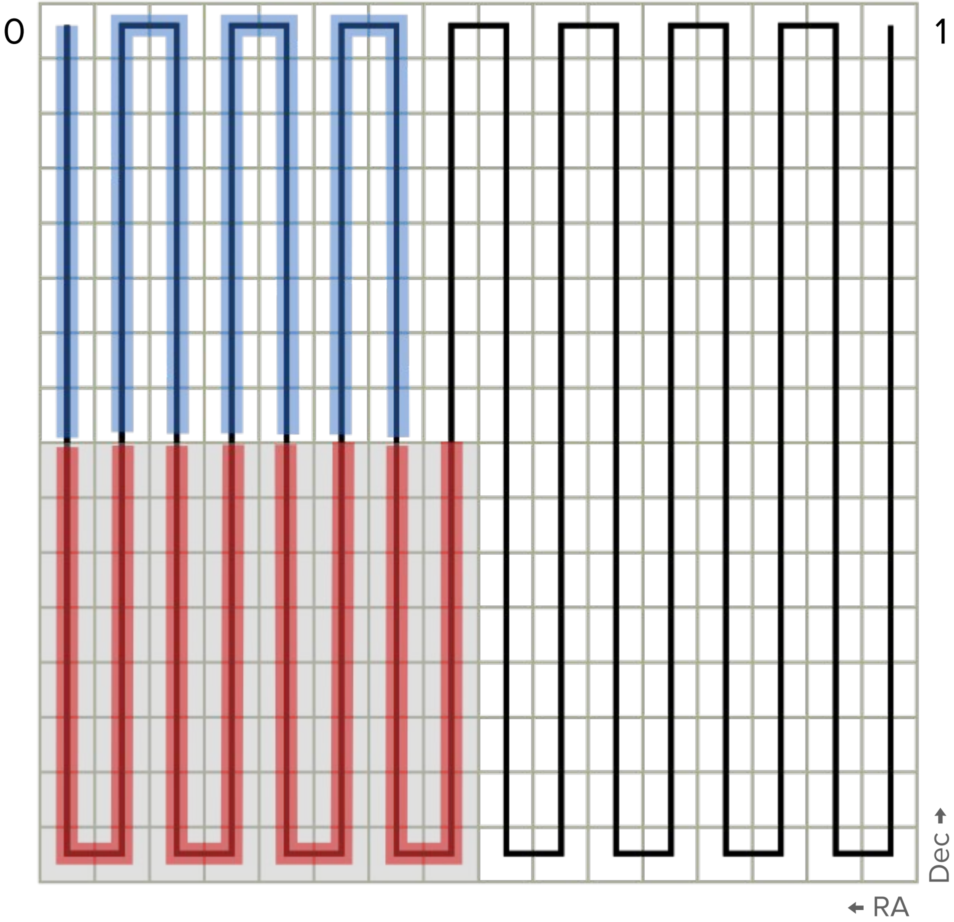
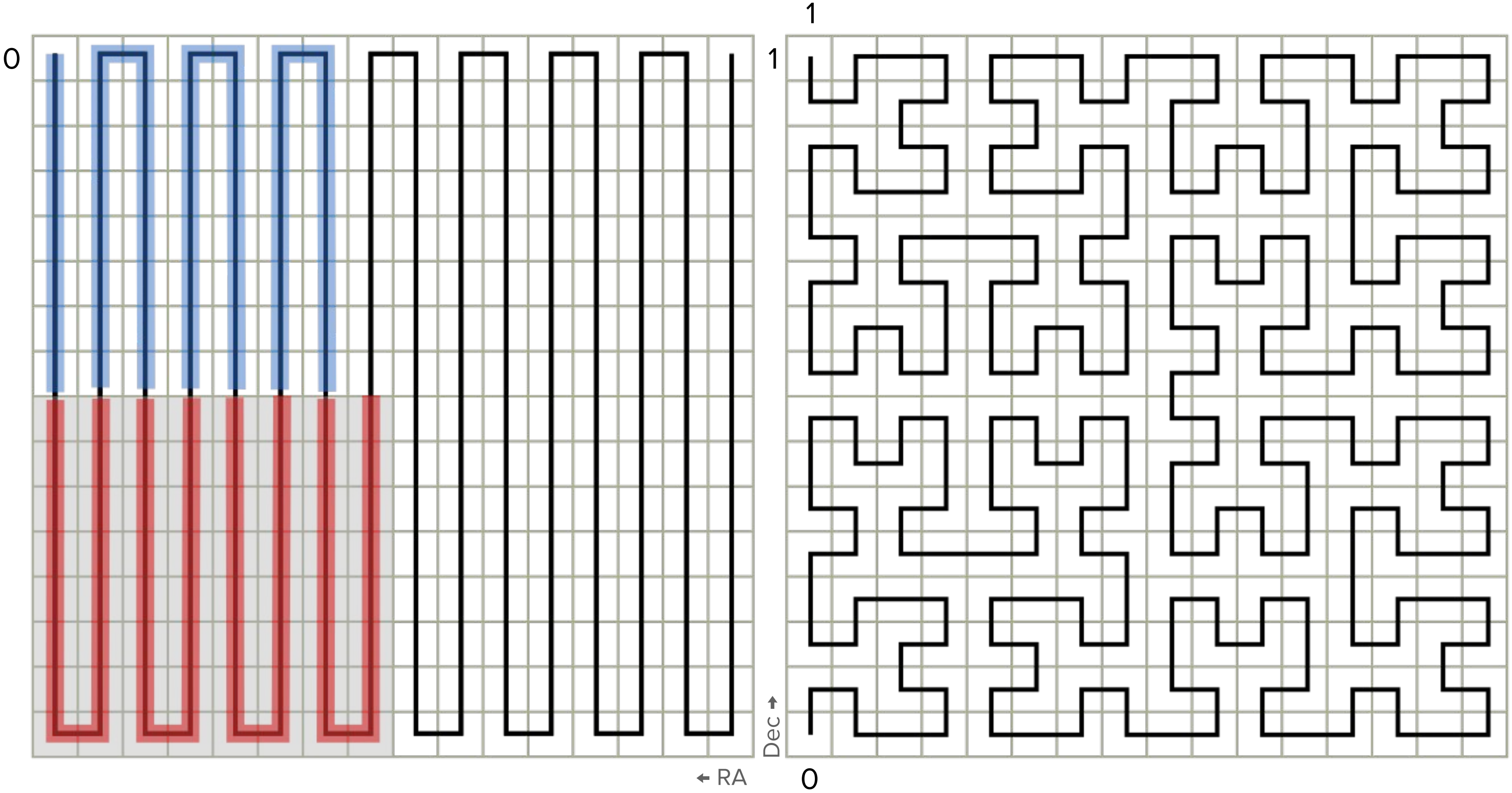
Dec
RA


0
1
Dec
RA

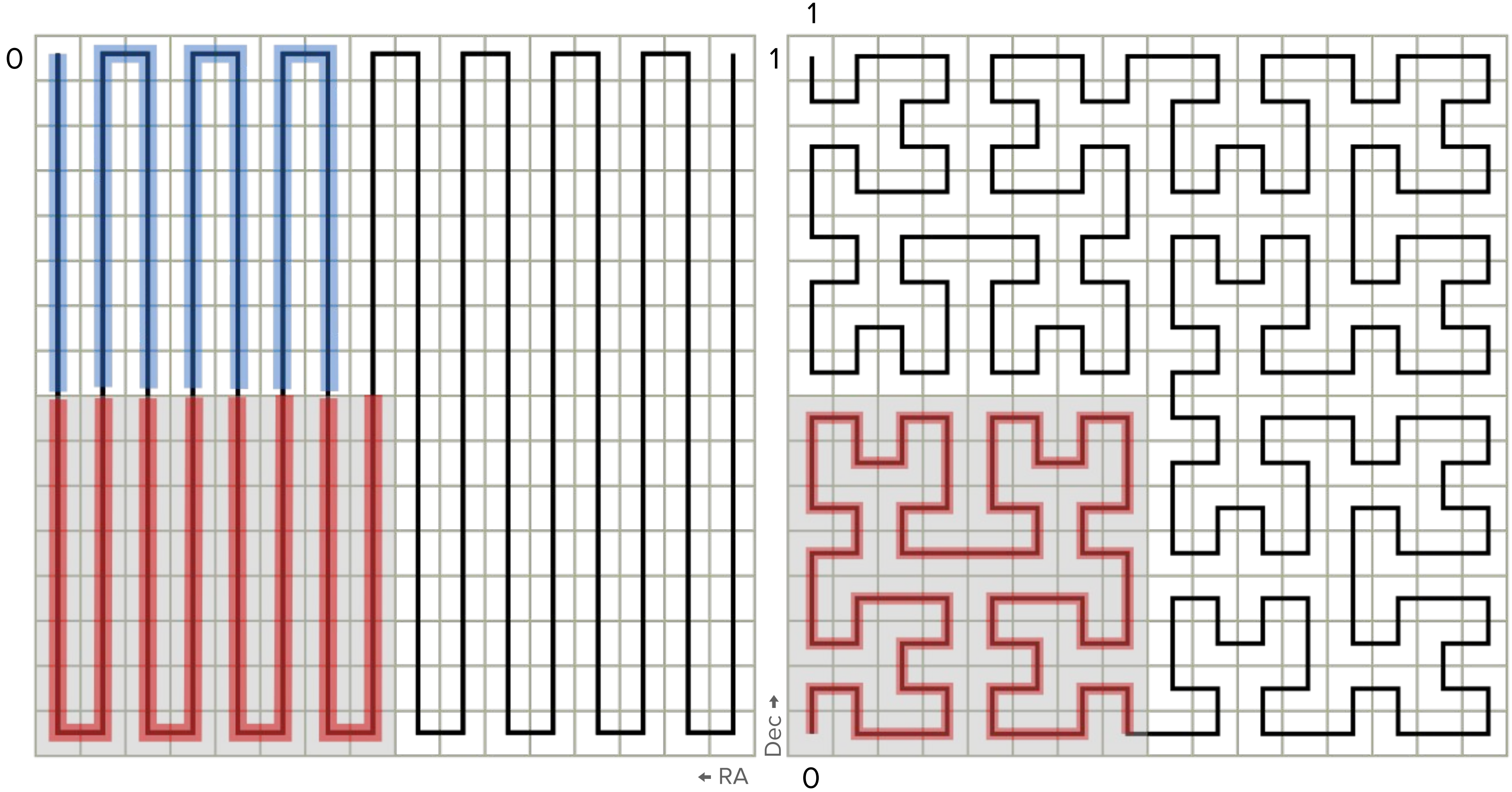


0
1
Dec
RA


0
1
Dec
RA

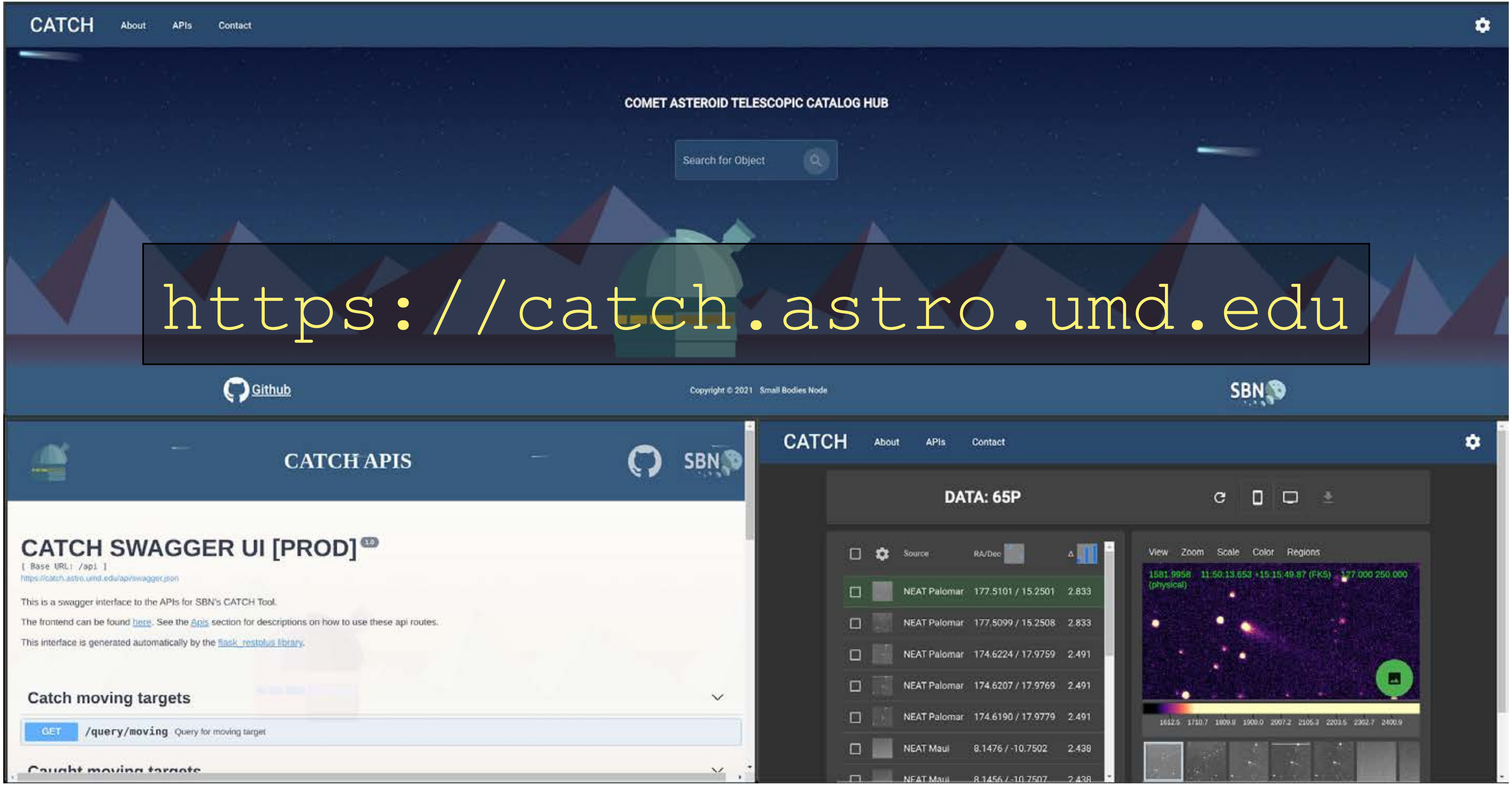


0
1
← RA
Dec →
1
0


0
1
1
← RA
Dec →
0

Future Developments

- ***More surveys:***
  - PanSTARRS DR2 (STScI/MAST).
  - ATLAS and Catalina Sky Survey (NASA PDS).
- *Performance updates.*
- `Sidereal queries:`
  - Astrophysical applications, transient sky.
  - IVOA Simple Image Access protocol (separate tool).
- Search by uncertainty ellipse.
- **Minor Planet Center integration:**
  - Candidate object searches (NEOCP & PCCP).
  - Considering MPC observation database visualization.



CATCH
About
APIs
Contact
COMET ASTEROID TELESCOPIC CATALOG HUB
Search for Object
https://catch.astro.umd.edu
Github
Copyright © 2021 Small Bodies Node
SBN
CATCH APIS
CATCH SWAGGER UI [PROD]
[Base URL: /api]
This is a swagger interface to the APIs for SBN's CATCH Tool.
The frontend can be found here. See the Apis section for descriptions on how to use these api routes.
This interface is generated automatically by the flask_restplus library.
Catch moving targets
GET /query/moving Query for moving target
DATA: 65P
Source
RA/Dec
NEAT Palomar 177.5101 / 15.2501 2.833
NEAT Palomar 177.5099 / 15.2508 2.833
NEAT Palomar 174.6224 / 17.9759 2.491
NEAT Palomar 174.6207 / 17.9769 2.491
NEAT Palomar 174.6190 / 17.9779 2.491
NEAT Maui 8.1476 / -10.7502 2.438
View
Zoom
Scale
Color
Regions

Q&A

Session 5b: NEO Discovery

7th IAA Planetary Defense Conference

26-30 April 2021, Online Event

Hosted by UNOOSA in collaboration with ESA

Break

Up next: Session 6b - NEO Characterization