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The International Astronomical Search Collaboration (IASC)—Citizen Scientist System for Asteroid Discovery

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Abstract

We describe a citizen science asteroid detection system developed by the International Astronomical Search Collaboration (IASC) and the Institute for Astronomy at the University of Hawaii, utilizing data from the Pan-STARRS telescopes. The goals of this project are to (i) educate and engage citizen scientists (mostly high school students) in science and astronomy, (ii) search for new asteroids to extend the limiting magnitudes of existing asteroid surveys, and (iii) find missed Near-Earth Objects (NEOs—objects with perihelia $q < 1.3$ au) to support planetary defense efforts. Over the past 15 yr, 50,000 citizen scientists from 96 countries around the world have detected ∼12,000 main-belt asteroids and ∼5 NEOs. Citizen scientists use the software Astrometrica during scheduled campaigns to search for and measure asteroid astrometry and photometry, and submit the data to IASC for vetting. Candidate detections not already submitted by Pan-STARRS are then submitted to the Minor Planet Center, and are typically $\sim 0.30 \pm 0.07$ mag fainter.

Unified Astronomy Thesaurus concepts: Surveys (1671); Near-Earth objects (1092); Asteroids (72); Main belt asteroids (2036)

1. Introduction, Background, and Context

1.1. Large Asteroid Surveys

Near-Earth Objects (NEOs) are asteroids or comets that have perihelia $q < 1.3$ au. The United States Congress tasked NASA with finding 90% of all Near-Earth Asteroids (NEAs) with diameter $D > 1$ km, and more than 90% of these larger NEAs are believed to have been found (Mainzer et al. 2011). This goal was subsequently extended to find 90% of all asteroids with diameter $D > 140$ m, and in 2023, approximately 10,600 of these were known. Harris & D'Abramo (2015) state that this represents ∼42% of the total estimated population, while the more recent study of Grav et al. (2023) gives a lower completion rate of 38%. The vast majority of current world-wide Near-Earth Object discoveries come from surveys in the USA (augumented recently by telescopes in Chile and South Africa) funded by NASA's Near-Earth Object Observation program as part of their Planetary Defense program.[10] A wide network of telescopes across many countries provides follow-up observations of candidate NEOs so that preliminary orbits can be confirmed. This network includes both professional and amateur astronomers.

Asteroid detection systems have made great advances in recent years, most notably due to advances in large CCDs and detector arrays. More asteroids have been detected in the last decade than in all years prior, and most data acquisition and analysis systems have moving object pipelines. The large surveys have contributed significantly to asteroid science (see, e.g., the review by Jedicke et al. 2015). Denneau et al. (2013) describe the Pan-STARRS Moving Object Detection System (MOPS) and historical large surveys, and Wainscoat et al. (2021) describe the current Pan-STARRS search for NEOs.

[10] https://science.nasa.gov/planetary-science/programs/planetarydefense/

Large surveys have provided data for hundreds of thousands of asteroids, and typically take a multiple image sequence spaced over 30–60 minutes to find moving objects. However, fill factor effects, signal-to-noise requirements, and non-optimal sky-plane motion can prevent asteroids from being found by automated software. Citizen scientists are able to find some of these missed asteroids that failed to be identified by the pipelines, via careful manual inspection of images—essentially using Astrometrica's suite of tools, which includes blinking, for example. This is the regime where the IASC[11] has gained traction, and here we describe and show as a proof of concept that this collaboration between citizen scientists and Pan-STARRS can discover more asteroids, including Near-Earth Asteroids. While the work presented here is far from establishing a strong quantitative basis for a number of aspects of a search (e.g., detection efficiencies, turn-round times, limiting magnitudes, isolated tracklet follow-up, etc.), we demonstrate that our system for asteroid detection allows citizen scientists to more easily participate. We stress that while citizen scientists cannot compete with the automated algorithms of modern surveys, their engagement could not be accomplished otherwise. Our implementation of having experienced astronomers vet their discoveries allows for thousands of people to participate while maintaining a quality data set not polluted by false detections.

1.2. Citizen Science Asteroid Research

Asteroids are very attractive to citizen scientists, particularly in the 14–18 age group. Some studies indicate that the two most popular science topics for children are black holes and dinosaurs (private communication, Boston Museum of Science Staff). The idea that an asteroid impact caused the extinction of the dinosaurs spurs young people's imagination, including the realization that such impacts could occur again.

The learning curve for asteroid searching is steep but short, and students can master it within a few hours. Being able to report discoveries to the scientific community through the Minor Planet Center (MPC—at the Harvard-Smithsonian Astrophysical Observatory in Cambridge, Massachusetts) is a huge boost to students' self esteem, and to take part in an effort to find such NEOs gives them early exposure to science in their studies. Students are often observed to become more engaged in science, are proud of science, and learn key scientific skills.

IASC teaches citizen scientists key scientific skills, such as data measurement and its confirmation, documenting and reporting their progress, and working in a collaboration. Most of these skills are recognized in scientific communities as being essential for a scientist, and are also supported by International and National Science Education Standards.

[11] http://iasc.cosmosearch.org

Citizen scientists have previously made important contributions by finding and measuring asteroids in survey images. For example, the work of Solano et al. (2014) during fifteen months of the Sloan Digital Sky Survey resulted in 167,000 measurements that improved the orbital elements of 551 NEOs representing 6% of the total known population at that time. The Target Asteroids! (Hergenrother & Hill 2013) citizen science program supported the NASA OSIRIS-REx asteroid sample return mission, and their citizen scientists study asteroids that may be targets of future sample return missions by making low-precision photometric observations over a range of solar phase angles with smaller telescopes. Cosmoquest (Gugliucci et al. 2014) enabled citizen scientists to map craters on Vesta, and citizen scientists were also able to mark and measure craters on Vesta imaged by the Dawn spacecraft.

2. Methods

2.1. Pan-STARRS—The Panoramic Survey Telescope and Rapid Response System

The Pan-STARRS survey consists of two 1.8 m diameter telescopes owned and operated by the University of Hawaii (Kaiser et al. 2010; Chambers et al. 2016; Wainscoat et al. 2021), located on Haleakala on the island of Maui in the United States. Each telescope has a wide field-of-view a little over three degrees in diameter covering seven square degrees with a very large camera at the Cassegrain focus. The Pan-STARRS1 and 2 cameras have 1.4 and 1.5 billion pixels, respectively. When the Moon has set or is less than 60% illuminated, a wide *w*-band filter spanning 400–820 nm (Tonry et al. 2012) is used. When the moon is brighter, an infrared *i*-band filter is used except during the three brightest nights at full moon when a *z*-band filter is used. Fields with exposure times of 45 seconds are observed four times over approximately one hour to search for moving objects, producing a "quad." The limiting magnitude for *w*-band observations is strongly seeing dependent, but is $V \sim 22$ magnitude in typical seeing conditions for asteroids moving slower than $1^\circ\!.0\ \mathrm{day}^{-1}$. Faster moving asteroids are more difficult to detect due to trailing losses and a lack of appropriate trail fitting in the detection algorithm (although they are remeasured prior to submission).

Pan-STARRS1 has been operational since 2010, and spent its first 3.5 yr conducting a general purpose survey of the sky north of -30° decl. which led to the release of a very large (1.6 Pbyte) astronomical data set (Chambers et al. 2016), which is actively used for pre-discovery image searches. From 2014 April onward, 90% of the Pan-STARRS1 observing time has been used to search for NEOs. Pan-STARRS2 saw first light in 2015, and began regular surveying for NEOs in 2018. Its secondary mirror coating subsequently degraded, and this was corrected in 2021; its productivity in terms of NEO discovery is now similar to PS1.

Images from Pan-STARRS are processed by its Image Processing Pipeline (IPP; Magnier et al. 2020) and candidate sources are found by differencing of consecutive image pairs, although this does reduce the detection efficiency by increasing sky noise. The resulting source detections are passed to MOPS, which forms tracklets having at least three detections from the four epochs of observation. Stamp images are then extracted for a person to review and real objects are submitted to the MPC.

A major impediment for automated processing is detector noise. The Pan-STARRS cameras use a mosaic of Orthogonal Transfer Array CCDs which are more complex to fabricate, are noisier, have more cosmetic defects than regular CCDs, and have a grid of insensitive silicon between CCD cells. The non-Gaussian noise produces many false positives due to the detection method used, and these false detections require the use of a sensitivity limit that eliminates many real detections. Manual inspection of the images allows fainter sources to be found.

2.2. IASC—The International Astronomical Search Collaboration

2.2.1. IASC History

IASC began with the advent of deep, large-field-of-view CCD cameras on multi-meter aperture telescopes. In the early 1990s, Gerson Goldhaber of UC Berkeley/Lawrence Berkeley National Laboratory in the United States suggested that the many asteroids in the supernova search images from the Victor Blanco 4m telescope at the Cerro Tololo Inter-American Observatory in Chile could be used by students for their own education. Several teachers from the Hands-On Universe project (HOU[12]) enthusiastically engaged, and students working in 1998 with Massachusetts High School teacher Hughes Pack discovered the 73rd Kuiper Belt Object—1998 FS_{144}. These observations were confirmed by teacher Tim Spuck and his students in Pennsylvania. From these pilot campaigns, it was clear that student citizen scientists had the capabilities to detect asteroids and that there was significant interest by enough students to build a team. With the slowing of the Berkeley cosmology efforts and the end of NSF funding for HOU, citizen science detections with deep images slowed for almost a decade.

In 2006, Patrick Miller of Hardin-Simmons University in the United States, working with undergraduate student Jeff Davis, restarted a search with a few images from the Blanco Telescope. Miller became re-energized for this type of work, and officially founded IASC. The goal of IASC was to be an online program for student citizen scientists to find main-belt asteroids, NEOs, and other minor planets in the solar system.

[12] https://handsonuniverse.org/

A more reliable source of images proved, in 2007, to be images from the Astronomical Research Institute (ARI) of Robert Holmes.[13] The IASC collaboration was broadened and started to regularly use images from the ARI's meter class telescope. The use of Astrometrica as the central asteroid detection software was introduced, and Miller recruited 40 schools from the the Global HOU collaboration to join in searching for asteroids from this telescope. Since IASC's founding, the number of citizen scientists has grown steadily.

2.2.2. Transition to Pan-STARRS

An important breakthrough in image quality and quantity occurred in 2010 when images from the Pan-STARRS telescopes first became available to IASC. This enabled tremendous growth for IASC, as many more asteroids could be detected and any one team of citizen scientists had the potential to detect a new asteroid once every three years or so. Soon with IASC's proposed "confirmation campaigns," citizen scientists had the opportunity to re-detect an asteroid in a follow-up field from Pan-STARRS a few days after its initial detection. This new type of campaign significantly broadened the science emerging from IASC. Detections that are stored in the Isolated Tracklet File will, upon successful recovery in the new field, be elevated to a "Provisional Designation."

2.2.3. IASC Infrastructure

NASA funding has been vital to support IASC staff so that images can reliably serve this rapidly growing group of citizen scientists. IASC is led by Patrick Miller in Abilene, Texas, USA, who employs 1.5 full-time equivalent (FTE) staff to help coordinate image distribution, citizen scientist training and vetting, and maintain general day-to-day operations. In addition, IASC employs four part-time software developers at about 0.5 FTE, and also maintains a volunteer network of about 20 regional coordinators. These volunteers are from India, Taiwan, Brazil, China, Germany, Uruguay, Iran, Panama, Colombia, Venezuela, Nigeria, the African Astronomical Society, and other nations, and they generally support the campaigns of IASC in their region. The role of a regional coordinator is to recruit, train, and coordinate among schools in their region.

An essential role of IASC staff is to train and vet new teams. When a team applies to join IASC, they are sent training materials and instructions for running Astrometrica. Among the materials are older images from Pan-STARRS that have already been searched and are known to have asteroids in them. New applicants search these fields to "discover" these asteroids, after which they are included in future campaigns.

[13] https://www.astro-research.org/

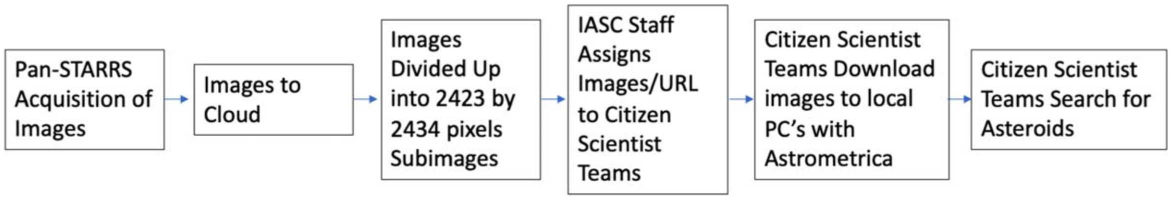

Figure 1. The IASC Data Distribution Pipeline. Most of the steps shown above are automated with little human intervention required, until the citizen scientists begin their search.

A total of 11 campaigns per year are run by IASC from the third to first quarter of each lunar cycle, with image sets distributed to 350–750 625 teams of citizen scientists.

2.2.4. Images from Pan-STARRS to the Classroom

Search campaigns begin near the third quarter moon using recently imaged *w*-band data, and not data from the public archive data release (Chambers et al. 2016). The observing log, telescope pointings, and submission statistics from Pan-STARRS are provided for each night. IASC reviews this information and chooses fields primarily based on the weather conditions noted in the observing logs. If survey operations have been shut down for a period due to poor weather, then they may select fields from a previous but recent lunation. Originally, only Pan-STARRS1 data were used, but Pan-STARRS2 data have since been made available as well.

Image sets are then created from the fields selected by IASC, and copied to a web-based storage system. IASC is then alerted to the file names and locations, as shown in Figure 1. Between 50 and 120 quads are made available to IASC during each month, and each set is partitioned into about 200 subfields of 4862 by 4870 pixels, for a total of ∼10,000–23,000 subfields during each campaign. These image sets and their corresponding masks and detection files are distributed through the Cloud to teams participating in a given monthly search campaign, with each campaign reaching between 350 and 750 teams. Each team receives 25 image sets from the divided quads, and each subimage takes a team of students about 15–20 minutes to search. With our careful vetting process, it takes 3–10 days from the time of image acquisition to the issue of the report to be submitted to the MPC.

We estimate that less than 10% of the Pan-STARRS fields are sent to IASC, but this is scalable if more citizen scientists are recruited.

2.2.5. IASC Growth and Resilience

IASC has grown by word of mouth, typically with no coordinated recruiting campaign. We find it encouraging that small asteroids, millions of kilometers away, can excite citizen scientists (and the general public) so profoundly. When a citizen scientist makes a detection, they sometimes are mentioned in their local newspapers and other media, such as the young Brazilian woman who detected[14] seven asteroids. Teachers stay with IASC for about seven years on average.

2.2.6. What Motivates IASC Citizen Scientists?

We have collected many accounts of why student citizen scientists want to stay engaged with IASC. Here we list a few:

1. Students enjoy real science, and many of them feel like they are scientists engaged in a scientific process that supersedes normal classroom education. They love to be part of a collaboration that makes many asteroid discoveries.
2. Students love to play a role, however small, in Planetary Defense.
3. Student communities, families, and friends, often recognize the value of their work. Being able to respond at the dinner table, when asked what they did at school, that they were part of a search for asteroids that might end all life on Earth, gives a sense of empowerment to students.

2.2.7. Astrometrica

The asteroid detection software Astrometrica[15] is central to IASC and is used by all participants. Astrometrica runs on standard PCs using the Windows operating system (commonly found in schools and homes), and finds asteroids by identifying all point sources in multiple aligned images, and checking for motion between them. Citizen scientists can use various Astrometrica tools to confirm asteroids, including blink comparisons, examining the point-spread function of a candidate, and performing other validation checks to confirm the validity of a candidate asteroid against statistical noise fluctuations and other systematic effects that could mimic an asteroid.

Candidates are reported to IASC staff for further vetting which reduces the chance for false positives. This vetting process essentially examines the PSF profile of a candidate detection to filter out known pathological cases specific to the

[14] https://www.firstpost.com/world/seven-year-old-brazilian-girl-discovers-7-asteroids-for-nasa-becomes-worlds-youngest-astronomer-9841341.html
[15] http://www.astrometrica.at/

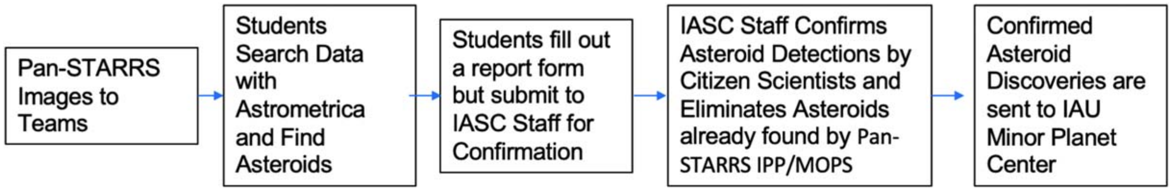

Figure 2. The IASC Asteroid Detection and Confirmation Cycle. The software Astrometrica is used by the citizen scientists to measure their detections and to draft reports that are submitted to the MPC after vetting by IASC staff. The vetting process by which IASC confirms detections is a key strength which ensures spurious detections are not submitted to the MPC's database.

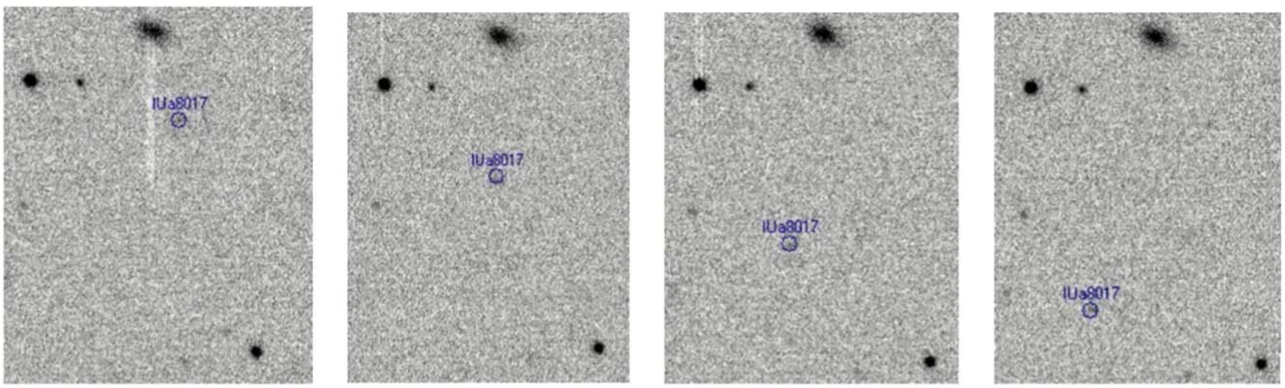

Figure 3. A faint asteroid (indicated with a blue circle) of $G \sim 22$ magnitude found in a series of four Pan-STARRS1 images, each separated by ∼14.4 minutes. This object, designated as 2020 OA_8 = IUa8017, is a Mars Crosser asteroid, and was recovered in 47 subsequent images from Pan-STARRS and the Mt. Lemmon Survey. The seeing in this image is $\sim 1\farcs4$, and the two peak pixels of the asteroid are $\sim 5\sigma$ above the background, with the total aperture flux being $\sim 8\sigma$ above the noise in a similar background aperture.

Pan-STARRS cameras and to ensure the motion is consistent with what a natural object would have. It also filters against detections already identified by the Pan-STARRS IPP/MOPS software, although de-duplication is not 100%. Unreported real detections are then submitted to the MPC which attempts to link them to known objects. Unknown detections reported by IASC may be listed on the NEO Confirmation Page (NEOCP[16]) if they have unusual motion that suggests they are likely not MBAs, otherwise the remaining new candidates are relegated to the Isolated Tracklet File (ITF) to allow for linking to other observations in the future. On average, each team discovers about one new asteroid every two or three years.

Figures 1 and 2 show the current process of image acquisition and distribution, which ensures the rapid delivery of images to teams.

Figure 3 shows a sample detection made by a citizen scientist. This object,[17] first noticed and measured by IASC and designated as 2022 OA_8, was detected in Pan-STARRS1 images with magnitude $G \sim 22$.

[16] https://minorplanetcenter.net/iau/NEO/toconfirm_tabular.html
[17] https://minorplanetcenter.net/db_search/show_object?object_id=2020+OA8

2.3. Confirmation and Follow-Up

For all newly detected objects, a "digest2" score (Keys et al. 2019) is calculated, which is essentially a percentage likelihood that the object is not a main-belt asteroid. A high score represents an object with unusual motion, and objects with a score greater than 65 are placed on the NEOCP at the MPC for further follow-up and confirmation. Posted candidates are sent to Pan-STARRS staff for further scrutiny, and to search for pre-discovery images.

3. Results and Discussion

IASC teams have supplemented the detections of asteroids made by the nightly IPP/MOPS processing of Pan-STARRS images, and have found fainter asteroids which were not reported by Pan-STARRS. We believe the slightly fainter magnitude detection limit is due to the additional Poisson noise introduced by image differencing, which increases sky background noise.

Yearly statistics are presented in Table 1 for all tracklets submitted between 2019 January 3 and 2022 October 19. Some objects were observed as multiple IASC tracklets, and a small number of additional IASC submissions were marked as

Table 1
IASC Tracklets in Terms of their Orbit Types

2019	2020	2021	2022	Orbit Type
628	2832	2161	2391	Isolated Tracklets
352	1673	1109	498	Main Belters
5	12	10	6	Hungarias
3	16	5	4	Mars Crossers
0	2	2	1	Near-Earth Objects
1	15	7	2	Hildas
7	26	23	6	Jupiter Trojans
0	1	0	0	Distant Objects

Note. Those not linked to an existing designation are classified as Isolated Tracklets regardless of their digest2 score, and represent 68% of the total count. Main-belt asteroids represent 31% of the total tracklet count.

deletions and duplicates of tracklets already submitted by Pan-STARRS IPP/MOPS.

Among reasons why the IPP/MOPS nightly processing may miss some objects: (1) they may be fainter than the software detection limit (since image differencing increases the apparent skynoise by 40%); (2) detections can fall into the ubiquitous cell gaps in the Pan-STARRS detectors, which are not perfectly aligned in successive images; and (3) detections may be corrupted by other image artifacts or confusion coming from background objects. Astrometrica searches for point sources in individual non-differenced images, which are more easily visible when manually examined.

In addition to 32 main belt asteroids, IASC has discovered two NEOs, two Mars Crossers, and one Jupiter Trojan. These are summarized in Table 2.

3.1. Sample Observations and Detections in this Case Study

Figure 4 is a cumulative histogram of Pan-STARRS and IASC detections within the six month time frame of 2020 January to June during IASC campaigns. Citizen scientists searched less than 10% of the available image sets. It is apparent that the main contributions IASC can make to PS asteroid detection is in the regime fainter than $V \sim 22$ mag.

3.2. Near-Earth Objects

There are not many NEOs found among the submitted IASC tracklets, as shown in Table 1. We present here a summary of those that were:

1. `IUa7778` was a duplicate of `P2145po` from Pan-STARRS which was designated as 2020 OS_7.
2. `IUa8373` was linked to 2019 UP_{14}.
3. `IUb3094` (score 5) was linked to the CSS object `C5G9902` on the NEOCP and designated as 2021 AD_{24}. A search of archival images led it to now have a multi-opposition arc.
4. `IUb3444` was linked to 2021 CD_3.
5. `IUc0946` was posted on the NEOCP, but was not confirmed. This object was confirmed to be real by reinspecting its images, and it likely is an NEO.
6. `IUc5143` was recognized as a possible NEO and reported to the NEOCP. Confirmation images were found in the Pan-STARRS archive, and the object was designated as 2022 UT_{80}, a 300-m AMOR, having a multi-opposition arc.

3.3. Challenges for IASC and Future Growth

There are a number of challenges for the IASC project which we summarize here, and we endeavor to better address these challenges in the future.

3.3.1. Confirmation Campaigns

Part of IASC's goal is to elevate detections from the ITF to Provisional Designations, with a robust confirmation campaign. Since we have developed this sensitive system for finding asteroids from Pan-STARRS, it makes sense to increase the science impact, and also further engage the citizen scientists. This will be accomplished within IASC's next proposal, where confirmation campaigns will enable students to search for recovery observations from nights following an initial detection, in recenty acquired data.

As of this writing, the ITF contains 8012 tracklets from IASC, of which 517 have digest score ⩾3, 34 score ⩾30, 10 score ⩾66, and 7 score ⩾90. We investigated those with score ⩾66 (i.e.,: those that could be considered for the NEOCP). Five were real asteroids, three were not real ("ghosts"—images coming from reflections in the wide-field corrector), and two were likely not real (probable "burns"—residual signal from saturated stars in a previous exposure). However we stress that false detections typically have high digest scores, so this false positive rate is not typical of normal IASC detections. Some examples of image artifacts by Pan-STARRS are given by Denneau et al. (2013).

Many low score IASC tracklets in the ITF can be linked to a second tracklet, however, end users must link a minimum of four nights over a ten day arc in order for them to be designated by the MPC's id-pipeline.

`IUa3405` (score 100) is a likely NEO, but it was not submitted to the NEOCP. While the telescope data was provided to IASC soon after it was acquired, the latency between observations and the data review and vetting was too long. A later archival search failed to identify additional detections of this object. Because NEO candidates often have rapidly increasing positional uncertainties, short latency between observations and IASC student review is important,

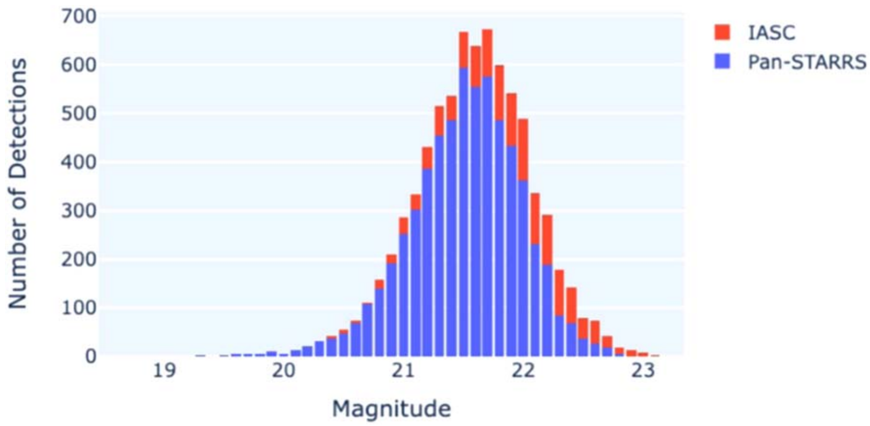

Figure 4. The magnitude distribution of the asteroids detected in the same fields by IASC and IPP/MOPS during the period 2020 January–June. There are more for IASC since it includes detections found by citizen scientists that were not found by Pan-STARRS IPP/MOPS.

Table 2
Non Main Belt Asteroid Discoveries by IASC, for Submitted Objects from 2019 January 3 to 2022 October 19

Designation	Tracklet	School	q (au)	H	Orbit
2020 OZ_7	IUa7375	Astromanov (Russia)	1.42	21.6	Mars Crosser
2020 OA_8	IUa8017	Afaghrahbar Azarbaijan (Iran)	1.60	20.1	Mars Crosser
2020 QL_{94}	IUa9620	Colégio Vicentino São José (Brazil)	4.88	15.1	Jupiter Trojan
2021 AD_{24}	IUb3094	Escola Portuguesa de Macau (Macau)	1.03	22.9	NEO (Amor)
2022 UT_{80}	IUb5143	Mayoor Private School (UAE)	1.29	20.6	NEO (Amor)

but cannot always be achieved because of conflicting schedules of the students. Citizen scientists may have to wait until their classroom schedule allows them to review the data, for example.

3.3.2. Scalability

Scaling IASC to cover more of the sky that Pan-STARRS already observes is a future goal. At present, IASC utilizes less than 10% of the available fields, and we are eager to get more Pan-STARRS data and reach more citizen scientists. In particular, we will be simplifying our detection system to a cloud-based machine learning system, which will be simpler for citizen scientists. We are currently working with other groups to greatly extend our audience of citizen scientists, including the Astronomical Society of the Pacific and the Ministry of Science and Technology of Brazil. We also note that while the astronomers who vet citizen scientist discoveries could handle a modest increase in the number of detections, eventually they will require help with this very important step.

3.3.3. Discovery and Naming

New asteroids receive provisional designations and are credited as being "first observed" by the survey or observers who found them. When an asteroid's orbit becomes sufficiently well known, the object receives a permanent designation (essentially a number), eventually allowing it to be named by the discoverer. While it can take years or decades for an object to become numbered and therefore eligible for naming, how can we ensure continued interest among citizen scientists for that long? We are exploring assigning candidates to other citizen scientists, so that further observations can be made, and students could see their detections progress to a numbered asteroid, and eventually become eligible for naming. But given the difficulty and time required for an asteroid to be named, this may not be a wise policy. As we discussed earlier, many students are well motivated by the science alone.

3.4. What if IASC did not Exist?

One question we must ask is if IASC-discovered asteroids would have been found anyway later when they were imaged again? While there is no way to know this for sure, discovering objects sooner allows them to be identified and batch submitted in future observations, which improves the data review process. And the educational impact of their discovery by citizen scientists is very important—our experience indicates that detecting an asteroid can be an incredible experience for some students, and IASC should be near reaching hundreds of thousands of citizen scientists.

4. Why a Lack of Interest in the United States?

IASC currently faces challenges in reaching citizen scientists in the United States, where schools conduct standardized testing at the higher grade levels. In some states, the results of this testing are used to rate each school, so teachers often focus on this testing; online programs such as IASC are not incorporated as part of their curriculum. Compare this to other countries without that testing focus, where teachers make extensive use of IASC and similar citizen science outreach programs in their classrooms and labs.

There are two possible remedies for increasing the number of schools reached in the USA. The first is to align the IASC program with national science standards. Many states use these standards or a derivative thereof as their own. The second is to seek out collaborations with state education agencies, and work with these agencies to promote IASC in science classrooms of those states.

5. Conclusions and the Future

We described IASC—The International Astronomical Search Collaboration, a citizen science outreach project to find more asteroid discoveries using images from the Pan-STARRS telescopes.

Citizen scientists manually inspecting images have demonstrated that they can find detections that are too faint, too confused with artifacts, detector gaps, or background objects, or exhibiting motion that is too unusual for the automated detections pipelines to identify.

IASC has made a handful of discoveries including the NEOs 2021 AD_{24} and 2022 UT_{80}.

The main limitation that IASC currently faces is the latency between telescopic observations of the night sky and when citizen scientists are able to search these images, which mostly affects NEOs.

In the future, we plan to expand IASC with a robust confirmation campaign, by elevating detections from the ITF to Provisional Status, which will allow for many more new discoveries. We also intend to explore expanding IASC to other asteroid surveys.

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