IAWN Global Planetary Defense Campaigns: Lessons Learned

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Outline

1. Overview of IAWN global observing campaigns thus far
2. Structure of IAWN observing campaigns: characterization exercises
3. Lessons learned to date from IAWN campaigns

IAWN Global Observing Campaigns

International Asteroid Warning Network (IAWN): A Coalition of the Willing

Campaign Window	Target	Focus	Participation
March 2017-Sept. 2018	2012 TC4	Astrometry, Characterization, Hazard Modeling	69 participants from 14 countries
Feb. 2019-March. 2021	1999 KW4 (66391 Moshup)	Characterization, Hazard Modeling	70+ participants from 13 countries
Oct. 2020-April 2022	99942 Apophis	Astrometry, Characterization, Hazard Modeling	103 participants from 19 countries
Oct. 2021-Dec. 2021	2019 XS	Timing	71 MPC Codes
Oct. 2022-Feb. 2023	2005 LW3	Timing	82 MPC Codes
March 2023	2023 DZ2	Characterization	33 participants from 12 countries

Davide Farnocchia Presentation in Session 3: NEO Discovery

To be continued… ACM, Flagstaff, AZ, USA, June 2023

Campaign Structure

- Intended to compliment interagency and international theoretical tabletop exercises by using real-world observing campaigns and actual asteroids
- Participation is voluntary
- Participants are organized into working groups with a lead
  - Typical Working Groups: Astrometry, Photometry, Spectroscopy, Radar, Direct Imaging, Spacecraft Missions, Impact Risk Modeling
- Regular telecons with updates from working groups
- Impact risk model is run at different epochs as information about the target is gathered by the observers
- Data quality/reduction timelines are set by operational rather than scientific needs
- Publication of campaign results (4 peer-reviewed papers so far)

2012 TC4 Campaign Goal: Exercise the Planetary Defense System

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NASA

1. Test the ability to quickly* assemble a worldwide observing campaign to reacquire, track, and characterize a potentially hazardous asteroid
2. To rapidly produce and share accurate data across institutions and international borders
3. To exercise emergency communication channels up through the Agency and Executive Branch, across government agencies, and to the public

Why 2012 TC4?

We wanted a NEA that did NOT pose a real hazard, but had enough uncertainty in its orbit to provide at least a little challenge to reacquire it, and one that had a relatively short timeline to closest approach.

*This is a relative term.

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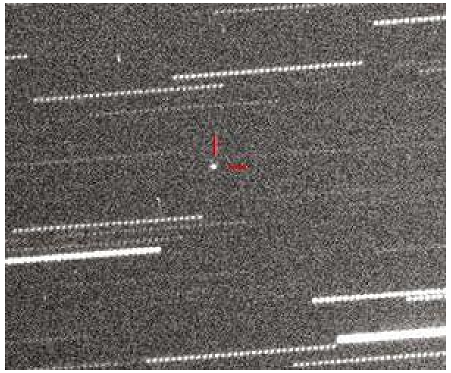
DEEP IMPACT

Will Asteroid 2012 TC4 Hit Earth in October 2017

by Tomasz Nowakowski for Astrowatch
Los Angeles CA (SPX) Apr 17, 2015

On Oct. 12, 2017, the asteroid 2012 TC4 is slated to whizz by Earth dangerously close. The exact distance of its closest approach is uncertain, as well as its size. Based on observations in October 2012 when the space rock missed our planet, astronomers estimate that its size could vary from 12 to 40 meters. The meteor that exploded over the Russian city of Chelyabinsk in February 2013, injuring 1,500 people and damaging over 7,000 buildings, was about 20 meters wide.


Asteroid 2012 TC4 as seen by the Remanzacco Observatory team of Ernesto Guido, Giovanni Sostero, Nick Howes on Oct. 9, 2012.

Thus, the impact of 2012 TC4 could be even more devastating. "It is something to keep an eye on," Judit Gyorgyey-Ries, astronomer at the University of Texas' McDonald Observatory, told astrowatch.net. "We could see an airburst maybe broken windows, depending on where it hits."

The house-sized asteroid was discovered on Oct. 4, 2012 by the Pan-STARRS observatory in Hawaii. Week later, it gave Earth a close

2012 TC4 Observing Campaign Timeline

First suggested: NEOO Program review, January 9-10, 2017 in Tucson, AZ

Kickoff telecon: Early March 2017

Telecons: Monthly to start, more frequently around closest approach

Recovery: July 27 (confirmed August 5)

Closest Approach: October 12, 2017

Submission of science results for peer-review publication: Fall 2018

2012 TC4 Observing Campaign Participation

Number of non-NASA-HQ participants on e-mail distribution: ~50 (69 co-authors)

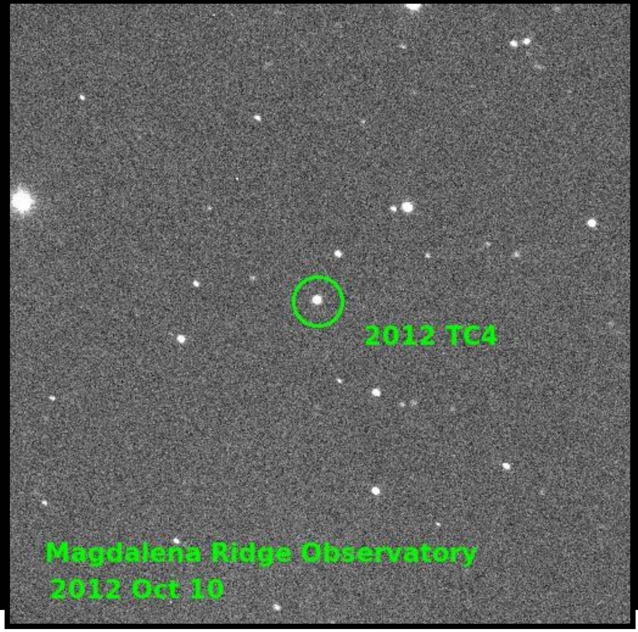
Number of institutions/facilities: >35

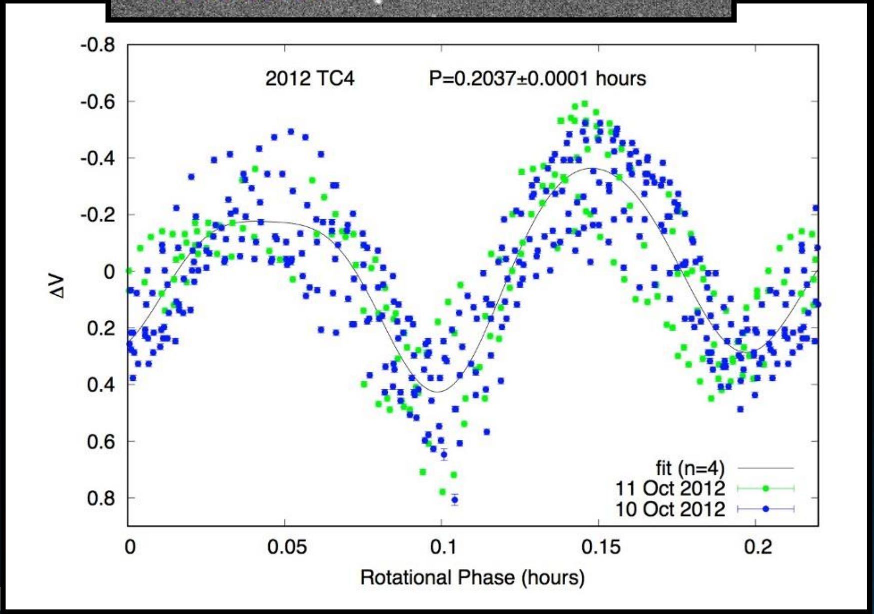
Countries represented: 14 (Australia, Canada, Chile, Columbia, Germany, Hungary, Israel, Italy, Japan, Korea, Netherlands, Russia, South Africa, and USA)

Both ground- and space-based assets were used (NEOWISE, NEOSat)

2012 TC4 – Results of Exercise

- Participation and interest were generated through the NASA-led International Asteroid Warning Network (IAWN)
- Astronomers on 6 continents tracked 2012 TC4
- Closest approach occurred at about 27,200 miles (43,800 km), or a little less than 7 Earth radii over the Pacific Ocean south of Australia
- Radar observations showed it to be oblong shaped and about 20 x 40 feet (6 x 12 meters) in size
- Lightcurve and radar measurements showed it tumbling with a primary period of about a 12 minutes
- Albedo calculations show it to be very reflective, which is compatible with spectroscopic measurements





2012 TC4 – Results of Exercise (cont.)

- Real world events affected the campaign (Hurricane Maria, Maunakea power outage)
- Aided some observatories in finding and correcting timing errors
- Modeling efforts included orbit determination, threat assessment and impact effects using measured 2012 TC4 parameters
- Events effectively communicated to NASA management, White House, and other federal agencies, as well as within the worldwide NEO community
- Worldwide, positive, public dissemination through online, print, radio and television media
- Precision orbit determination was able to rule out any impact by TC4 for the foreseeable future

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1999 KW4 Exercise

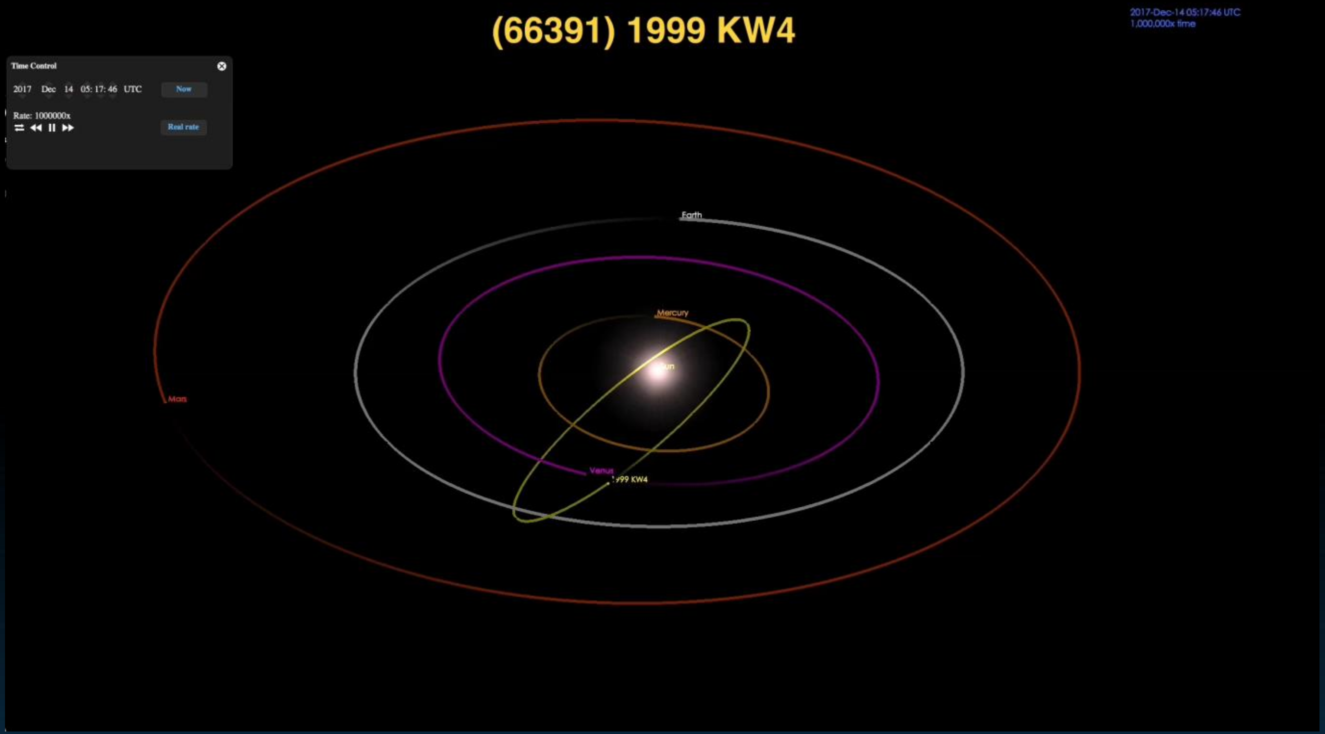
1. Limit scope to physical characterization observations and analyses, and impact prediction modeling
2. Have the International Asteroid Warning Network (IAWN) take the lead role in conducting this type of drill, and possibly increase the number of signatories
3. Try to improve turnaround time to publication

Why 1999 KW4?

Convenient timing – due to make close approach on May 25, 2019.

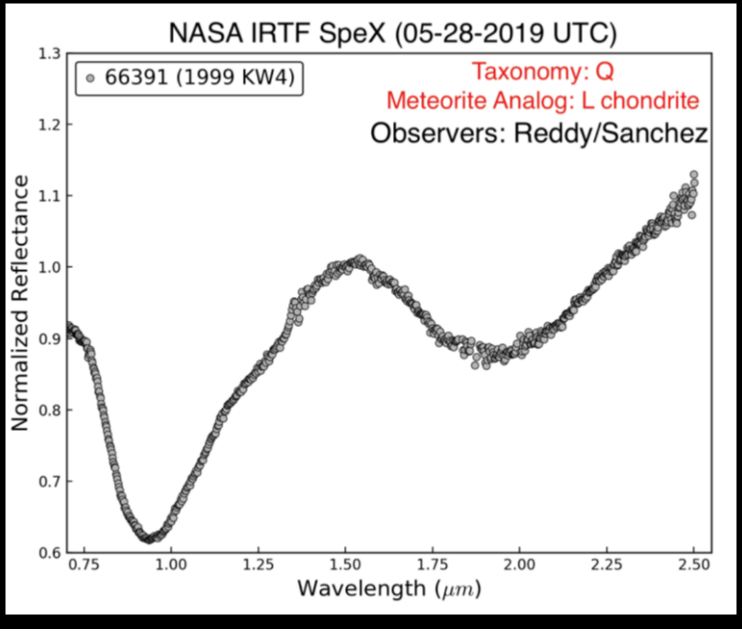
Binary asteroid presents additional challenges.

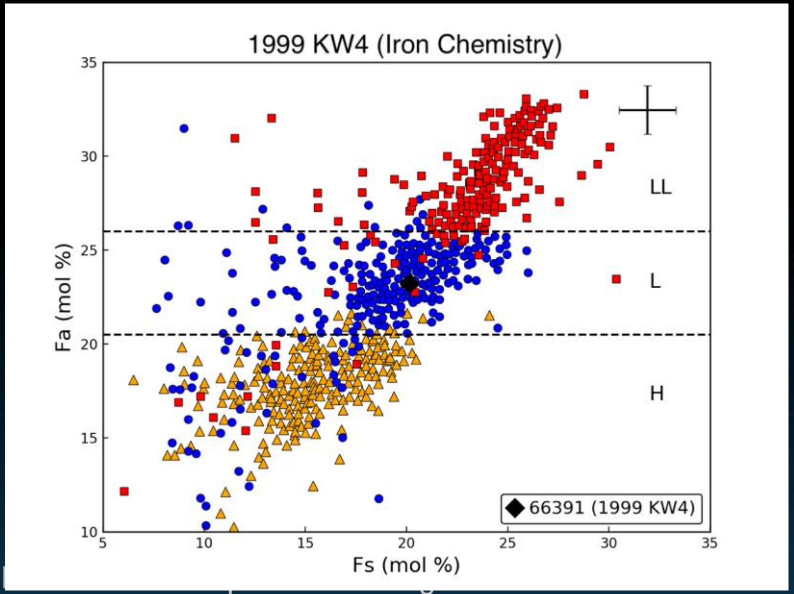
Thought to provide experience to feed into upcoming Didymos observing campaign for the DART mission.



1999 KW4 Exercise – Results

- Diameter of the primary ~1.4 km, diameter of secondary ~480 m
- Rotation rate of primary is 2.5-3 hours, and orbital period of secondary is 17.1-17.6 hours
- Shape of primary may be similar to Bennu, target of the OSIRIS-REx mission
- Over 70 participants from dozens of institutions
- Canada, China, Czech Republic, France, Germany, Israel, Italy, Japan, Korea, Mexico, Russia, United Kingdom, United States





Apophis Campaign Timeline

- Apophis was 'discovered' by CSS Schmidt after NEOWISE triggered the discovery process in Dec. 2020 when it was put on NEOCP.
  - Impact probability was calculated with the real Apophis as follow up observations were made. As uncertainties and impact probability decreased, we switched to hypothetical impactor for the reminder of the exercise.
- Epoch 1: Using diameter and albedo from NEOWISE observations we ran the impact risk model on Dec. 23, 2020
  - NASA IRTF spectral observations helped constrain the taxonomy and identify the meteorite analog (L chondrite). This helped constrain the density for a range of assumed porosities. Photometric observations helped refine the H magnitude.
- Epoch 2: Included NASA IRTF observations for taxonomy and meteorite analog and ran the model on Jan. 22, 2021.
- Epoch 3: Included radar observations for diameter and ran the model in late March 2021.

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(99942) Apophis Exercise

The goal of IAWN-led Apophis Observing Campaign was to “discover”, track, and characterize Apophis as a potential impactor in order to exercise the Planetary Defense system from observations to impact prediction and modeling, and communication. *This campaign was open for participation by amateur astronomers from around the world.*

Summary

- Apophis no longer on the risk list as 2068 impact has been ruled out. No threats from Apophis in the next 100 years.
- IAWN campaigns have been very effective in identifying strengths and stress points of global planetary defense coordination efforts.
- Participants from this and previous campaigns are pleased with the process and results, and express enthusiasm for participating again in future campaigns.

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Apophis Planetary Defense Campaign

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Lessons Learned from our campaigns

- Given the scale and timeline, all IAWN observing campaigns have been remarkably successful with broad participation from signatories and others
- Astrometry, impact risk modeling, communications, and news media interactions worked well without any major problems
- Characterization efforts were hampered by both natural disasters and technical problems with TC4, but were remedied for KW4 and Apophis campaigns
- Publication of results took far longer than desired, but in the case of an actual impending impact event this wouldn't be a factor

Lessons Learned from our campaigns

- Participation in our campaigns *increased* during the COVID-19 pandemic (Apophis: 103 participants) giving us confidence that humanity could handle more than one global crisis at a time.
- Human factors, such as the end-of-year holiday season, had a distinct impact on characterization efforts and demonstrate the importance of building a broad coalition for planetary defense spanning continents and cultures.
- Future IAWN campaigns should focus on targets with shorter lead time (hours vs. months) and conducted on a rapid timeline.

More information about IAWN Observing Campaigns: https://iawn.net/campaigns.shtml

Published results:

- 2012 TC4: https://www.sciencedirect.com/science/article/pii/S0019103518307085
- 1999 KW4: https://www.sciencedirect.com/science/article/pii/S0019103521004401
- (99942) Apophis: https://iopscience.iop.org/article/10.3847/PSJ/ac66eb
- 2019 XS: https://iopscience.iop.org/article/10.3847/PSJ/ac7224

Questions?