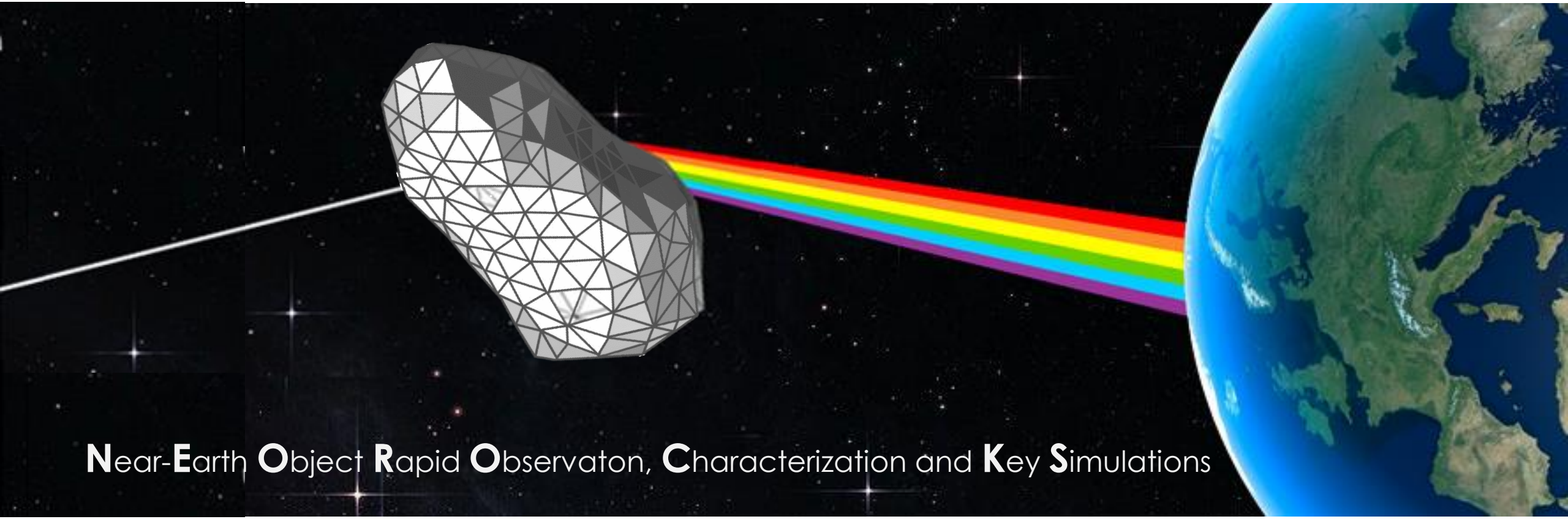
# The NEOROCKS Rapid Response Experiment

## lessons learned and future developments




**Elisabetta Dotto, Ettore Perozzi and the NEOROCKS Team**

EU-ESA Workshop on NEO Imminent Impactors Warning Coordination

12-14 December 2022
ESOC - Darmstadt

NEO ROCKS
Near Earth Object Rapid Observation, Characterization and Key Simulations

# PROPOSAL

**PROGRAMME**:
Horizon 2020 - Work Programme 2018-2020
Leadership in Enabling and Industrial Technologies – Space

**Call**: SU-SPACE-23-SEC-2019 – Advanced research in Near Earth Objects (NEOs) and new payload technologies for planetary defence.
*European Commission Decision C(2018)4708 of 24 July 2018*

**TIMELINE**:

Start: 1st January 2020
KOM: 20th January 2020
End: June 2023

| Participant organisation name | Country |
|---|---|
| Istituto Nazionale di Astrofisica (coordinator) | Italy |
| Agenzia Spaziale Italiana | Italy |
| University of Padova | Italy |
| LESIA-Observatoire de Paris | France |
| Observatoire de la Cote d'Azur | France |
| University of Edinburgh | UK |
| Astron. Inst. of Czech Academy of Sciences | Czech Rep. |
| Instituto de Astrofisica de Canarias | Spain |
| SpaceDyS s.r.l. | Italy |
| DEIMOS Space s.l.u. | Spain |
| DEIMOS Space s.r.l. | Romania |
| DEIMOS Castilla La Mancha | Spain |
| NeoSpace sp z.o.o | Poland |
| Resolvo Srl | Italy |

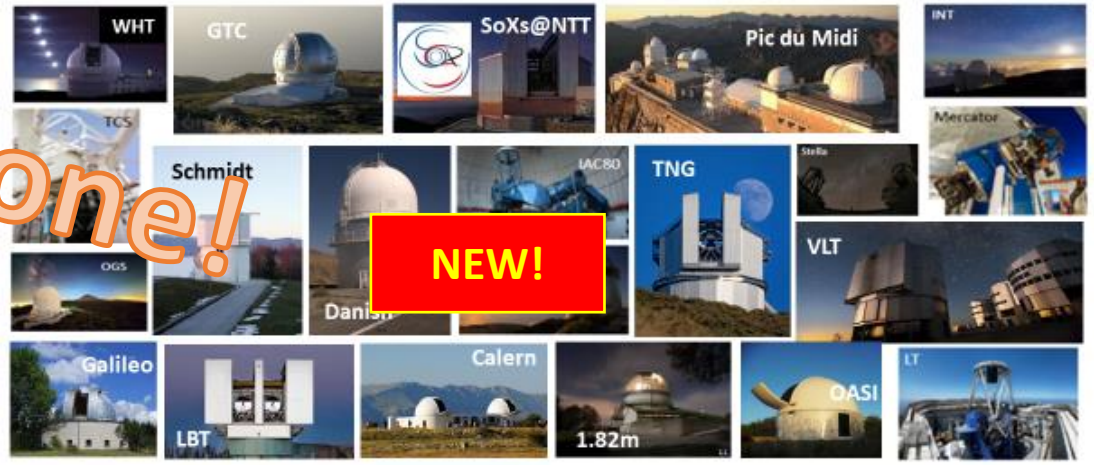
# AMBITIONS

**optimize observational activities, enhance modelling and simulation tasks, foster international coordination and speed-up response times**

Ambition 1: Networking large aperture telescopes

Ambition 2: Advancing NEO physical properties modelling and simulations

Ambition 3: Improving the orbit determination process

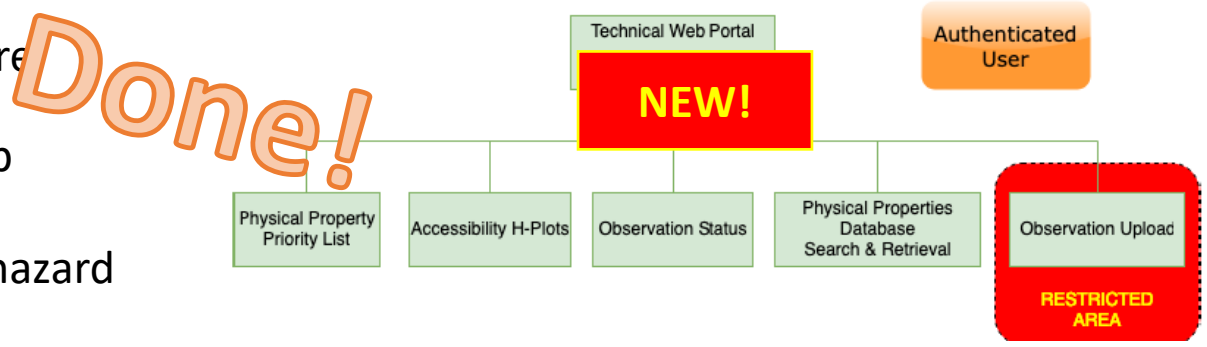



## Ambition 4: Addressing the imminent impactors monitoring

Ambition 5: Establishing a NEO physical properties data centre

Ambition 6: Fostering international cooperation for follow-up

Ambition 7: Raise the public awareness on NEO and impact hazard



# **Ambition 4:** organize a rapid response experiment

## SUMMARY

**To plan and execute breakthrough experiments** foreseeing the remote tasking of highly automatized robotic telescopes in order to provide a proof-of-concept rapid response system

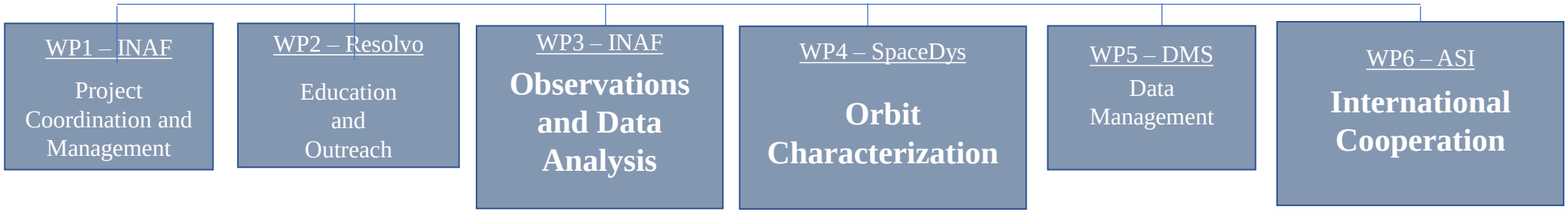
## AMBITION 4: ADDRESSING THE IMMINENT IMPACTORS MONITORING

To prepare for this scenario by prioritizing and coordinating quick follow-up observations either astrometric or physical. To this end, **an innovative tasking experiment of a rapid-response system will be organized** profiting of the experience gained by the DEIMOS Sky Survey (DeSS) in providing space debris observations in an operational environment

## EXPECTED IMPACTS

**To pave the way for the engineering developments** needed to prototype a rapid response system able to task ground based telescopes, linking together for the first time astrometric and physical characterization follow-up observations.

# **Ambition 4:** tasks and responsibilities




**WP3** – carry out physical characterization upon short notice through the project observational network

**WP4** – implement a basic **rapid response system** scenario based on existing robotic telescopes through developing the related procedures and tasking SW

**WP6** – analyze outcome and issue recommendations: *Final Report on international cooperation for NEO physical characterization and rapid response systems (D6.4)*

# rapid response experiment: scheduling

## SCHEDULING TOOL

- Monitoring NEOScan Priority List https://newton.spacedys.com/neodys2/NEOScan/index_nspl.html
- Runs in loop mode
- Configuration variables
- Generates files ingested by sensor control (very particular to each sensor/control SW)

**monitoring**

Variable poll : for next period -> now to 60 min def
Variable outputs 10 min def . intervals along next 60 min (6 lines per file)
Created new files overwrite for same objects

**visibility**

From MPC site Z66 def
Above > Elevº
Below < magnitude

**outputs**

ASCII files to sensor (interpolated at precise observing time) (1 per NEOCP target)
Filenames with provisional IDs and sorted by priority, 1 -> VU, 2 -> U, 3 -> N
Provides PA and Angular Speed (arcsec/min)
Provides suggested max expo times and nº of frames required (at tasking level)

Track and stack

**settings**

Monitoring -> polling intervals, nºoutputs/gap
Visibility -> MPC code, min elev,, max magnitude
Sensor -> scale pix resolution, sensitivity: exp/mag factor x 4 : 15mag/0.5sec

http://www.astrometrica.at/Papers/PointSources.pdf

NEOScan
Near Earth Objects - Dynamic Site
Sponsored by esa Università di Pisa SpaceDyS

Last Update: 2022-03-01 19:06 UTC

| NEOCP name | Priority class | Priority value | RA (hh:mm) | DEC (deg) | V mag. | ΔV mag. | Uncertainty (deg) | Sun elong. (deg) | Moon elong. (deg) | Gal. lat. (deg) |
|---|---|---|---|---|---|---|---|---|---|---|
| C09MZQ5 | VERY URGENT | 41.887 | 08:19 | 65°11' | 21.60 | 4.83 | 0.67389 | -116.5 | -126.6 | 33.6 |
| C7CN7Q2 | VERY URGENT | 34.760 | 12:48 | 11°37' | 21.23 | 1.53 | 2.27370 | 150.5 | 143.6 | 74.5 |
| C7CL7W2 | VERY URGENT | 32.117 | 11:58 | 7°42' | 20.81 | 0.48 | 1.34208 | 163.1 | 154.5 | 66.9 |
| C7CM312 | VERY URGENT | 31.748 | 12:09 | 15°32' | 21.05 | 1.10 | 0.82168 | 158.8 | 153.4 | 74.9 |
| C7CLJC2 | VERY URGENT | 31.678 | 12:19 | 10°25' | 21.22 | 0.38 | 0.64130 | 157.8 | 150.3 | 71.7 |
| C7CJN22 | VERY URGENT | 31.322 | 11:34 | 12°50' | 22.02 | 0.72 | 0.16788 | 167.8 | 161.5 | 67.0 |
| C7CNX82 | VERY URGENT | 29.523 | 13:24 | 10°35' | 20.34 | 0.26 | 0.36478 | 141.7 | 134.7 | 71.7 |
| P21s58d | VERY URGENT | 29.401 | 08:44 | -5°01' | 21.18 | 0.09 | 0.05123 | -146.3 | -148.6 | 22.3 |
| P21rKwH | VERY URGENT | 28.352 | 14:23 | -22°59' | 21.65 | 0.07 | 0.00635 | 119.7 | 108.9 | 35.2 |
| C7CP042 | VERY URGENT | 27.170 | 13:29 | 11°01' | 21.52 | 0.32 | 0.45345 | 140.6 | 133.7 | 71.6 |
| C09M2R5 | VERY URGENT | 26.829 | 12:05 | 40°38' | 22.51 | 0.19 | 0.02476 | 142.8 | 146.2 | 73.5 |
| P21s7YS | URGENT | 20.119 | 13:18 | -1°11' | 20.60 | 0.16 | 0.18079 | 141.9 | 132.5 | 60.9 |
| P21s6qA | URGENT | 18.804 | 13:12 | -22°21' | 21.34 | 0.19 | 0.03555 | 134.1 | 123.0 | 40.3 |
| C09N205 | URGENT | 15.818 | 13:16 | 54°25' | 22.17 | 0.19 | 0.20855 | 124.6 | 128.5 | 62.3 |
| C7CPMQ2 | URGENT | 12.536 | 16:17 | 11°48' | 19.87 | 0.55 | 0.65590 | 99.4 | 93.6 | 39.4 |
| C7CJ862 | URGENT | 11.463 | 11:28 | 14°16' | 21.79 | 0.24 | 0.29335 | 168.2 | 163.1 | 66.9 |
| C09M105 | NECESSARY | 8.974 | 08:40 | 64°12' | 22.21 | 0.02 | 0.00427 | -118.8 | -128.8 | 36.1 |
| C09LEN5 | NECESSARY | 8.958 | 16:24 | 15°46' | 22.06 | 0.01 | 0.00181 | 98.1 | 93.0 | 39.5 |
| P21rKyC | NECESSARY | 8.875 | 13:17 | -14°31' | 22.11 | 0.02 | 0.00720 | 137.3 | 126.5 | 47.9 |
| C7CGKG2 | NECESSARY | 8.509 | 10:50 | 9°47' | 21.69 | 0.09 | 0.04297 | -177.6 | 170.3 | 56.7 |
| C09M3H5 | NECESSARY | 8.331 | 12:07 | 39°28' | 22.48 | 0.02 | 0.00132 | 143.5 | 146.6 | 74.6 |
| P21rLPs | NECESSARY | 7.879 | 13:16 | 32°13' | 21.95 | 0.02 | 0.00311 | 137.8 | 136.6 | 82.5 |
| P21s7YT | NECESSARY | 7.851 | 13:19 | -1°52' | 20.07 | 0.11 | 0.13925 | 141.5 | 132.0 | 60.2 |
| C7CPFC2 | NECESSARY | 7.251 | 15:16 | 11°26' | 19.53 | 0.03 | 0.13522 | 114.3 | 108.0 | 52.6 |

NEO ROCKS
Near Earth Object Rapid Observation, Characterization and Key Simulations

# rapid response experiment: 2022CE3

## CAMPAIGN

Tracker2: 40 cms aperture! -> limitations

NEOCP current magnitudes -> very few available, even less if only from priority list/criteria

Full moon period (Started bit too late…)

Last week: https://minorplanetcenter.net/mpec/K22/K22CE7.html
https://minorplanetcenter.net/mpec/K22/K22CE2.html
https://minorplanetcenter.net/mpec/K22/K22CE0.html

Not all get MPECed -> currently selecting -> trying priority list, already indept. confirmed, high NEO score

MPEC 2022-C140 : 2022 CE3
Issued 2022 February 8, 01:51 UT

MPEC 2022-C147 : 2022 CM3
Issued 2022 February 8, 02:02 UT

Da: **Julia de Leon** <jmlc@iac.es>
Date: mer 16 feb 2022 alle ore 14:55
Subject: Re: Observation Campaign
To: Dotto, Elisabetta <elisabetta.dotto@inaf.it>, Perna, Davide <davide.perna@inaf.it>
Cc: Marcel Popescu <popescu.marcel1983@gmail.com>, Javier Licandro <jlicandr@iac.es>, David Morate <damog@iac.es>

Dear Elisabetta,

we tried to observe 2022 CE3 on the night of Feb. 10 using the NOT and our service program, but unfortunately the weather was awful. Same thing at the Teide Observatory, where we tried with the 1.5m TCS… What a bad luck!

I know you were mostly interested in doing a taxonomical classification, but Marcel Popescu was able to get some astrometry using a robotized 25 cm telescope installed at his institution in Bucharest. He observed both 2022 CE3 and 2022 CM3 on the night of Feb. 9 and has reported results to the MPC (attached files here), which have been accepted.

```
Orbital elements:
2022 CE3                                          Earth MOID = 0.0123 AU
Epoch 2022 Jan. 21.0 TT = JDT 2459600.5               Veres
M  12.52622             (2000.0)            P             Q
n   0.44632914     Peri.  315.00504     +0.27146466     -0.96116546
a   1.6957659      Node   119.18397     +0.89826054     +0.23448811
e   0.5108843      Incl.    3.26195     +0.34559360     +0.14552076
P   2.21           H   24.22          G   0.15          U   7
Residuals in seconds of arc
220206 F52 (1.1- 0.3+)   220207 L01  0.8-  0.6-    220207 B49  1.1-  0.8+
220206 F52  0.0   0.0    220207 L01  1.2-  0.3+    220207 C95  0.0   0.5-
220206 F52  0.0   0.0    220207 L01  0.7-  0.5-    220207 C95  0.6+  0.1-
220207 703  0.5-  0.3+   220207 L01  0.1-  0.2+    220207 B49  0.1+  0.1+
220207 703  0.2+  0.2-   220207 L01  0.5-  0.4-    220207 K87  0.0   0.5-
220207 I52  0.4+  0.1-   220207 A17  0.0   0.1+    220207 130  0.4-  0.7-
220207 I52  0.3+  0.2+   220207 A17  0.1+  0.0     220207 C95  0.2+  0.0
220207 I52  0.4+  0.2-   220207 104  0.0   0.1-    220207 130  0.1-  0.1+
220207 I52  0.3+  0.0    220207 104  0.1+  0.1-    220207 K30  0.0   0.3+
220207 734  0.0   0.3+   220207 104  0.1-  0.1-    220207 Z66  1.9+  1.3-
220207 734  1.6-  1.1-   220207 A17  0.1+  0.1-    220207 K87  0.5-  0.6-
220207 734  0.1-  0.3+   220207 204  0.1+  0.2+    220207 K30  0.4+  0.4+
220207 734  0.2+  0.0    220207 204  0.0   0.0     220207 K74  0.1-  0.0
220207 734  0.5+  0.1+   220207 204  0.1-  0.0     220207 Z66  2.4+  1.4-
220207 734  0.4-  0.4+   220207 G15  0.1+  0.4+    220207 K30  0.4-  0.1+
220207 734  0.3-  0.1+   220207 G15  1.1-  0.1+    220207 K74  0.1+  0.1+
220207 I52  0.2+  0.2+   220207 K63  0.3-  1.1-    220207 Z66  2.4+  1.5-
220207 I52  0.1+  0.2+   220207 033  0.1+  0.0     220207 K87  0.2+  0.3+
220207 I52  0.1+  0.3-   220207 033  0.3+  0.0     220207 K74  0.3+  0.2-
220207 I52  0.1-  0.0    220207 033  0.0   0.1+    220207 G14  0.4-  0.4+
220207 I52  0.4+  0.0    220207 K63  0.1+  0.0     220207 Z33  0.0   0.2-
220207 I52  0.3+  0.0    220207 G15  0.1-  0.7+    220207 G14  0.9-  0.6+
220207 I52  0.1+  0.3-   220207 K63  0.0   1.2-    220207 Z33  0.0   0.2-
220207 I52  0.2+  0.1+   220207 K51  0.2+  0.9+    220207 G14  0.9-  1.4+
220207 T08  0.4-  0.8+   220207 K51  0.0   0.3+    220207 Z33  0.4+  0.2+
220207 T08  2.0+  1.3-   220207 K51  0.2-  0.1+    220207 Z33  0.1-  0.2+
220207 T08  0.1+  0.3+   220207 B49  0.3+  0.1+
220207 T08  0.5-  0.6+   220207 B49  0.0   0.3+
```

```
Z66 DeSS Deimos Sky Survey, Niefla Mountain.  Observers J. Nomen, M. Ortega.
    0.40-m f/5.5 reflector + CCD.
```

Near Earth Object Rapid Observation, Characterization and Key Simulations

# rapid response experiment: lessons learned

**TARGET SELECTION**

- ✓ Before new moon (to allow more useful nights)
- ✓ Approaching targets (V increases)
- ✓ Not too high declination (enable southern obs)
- ✓ Not too faint (enable spectroscopic observations)
- ✓ Not too low solar elongation
- ✓ Targets for which DESS astrometry can count
- ✓ Size of an imminent impactor (H range 22-27)
- ✓ Small telescopes need long integration times
- ✓ Use telegram for speeding up communications?

Expect to continue campaign next week (21/02) -> until? , current availability

Improve residuals

Time consuming for small sensor -> integrating light

Manual procedures: T&S and visual evaluation always required:

Confirm existence -> NEOCP -> DNE

Uncertainty on magnitude and positions

Features: cometary appearance, fast rotators

Shortening times from detection and first assessment

Geographical constraint for Z66 or/and for other sites?¿

Other objectives of the campaign?

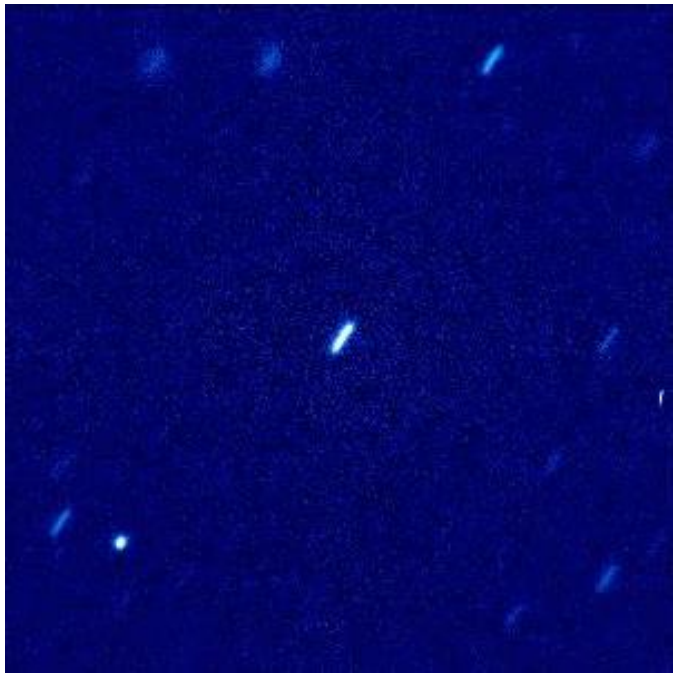
**add a «blind» experiment option**

# rapid response experiment: 2022 GC1

In the night between 3 and 4 April 2022 DEIMOS and SpaceDys coordinated in order to perform highly automatized astrometric observations of a sample of newly discovered NEOs

The information was quickly disseminated within the consortium in order to allow rapid follow-up observations of the targets' physical properties.

Aasteroid 2022 GC1 has been the subject of a rapid DDT (Director Discretionary Time) request to TNG (Telescopio Nazionale Galileo, Canary Islands).

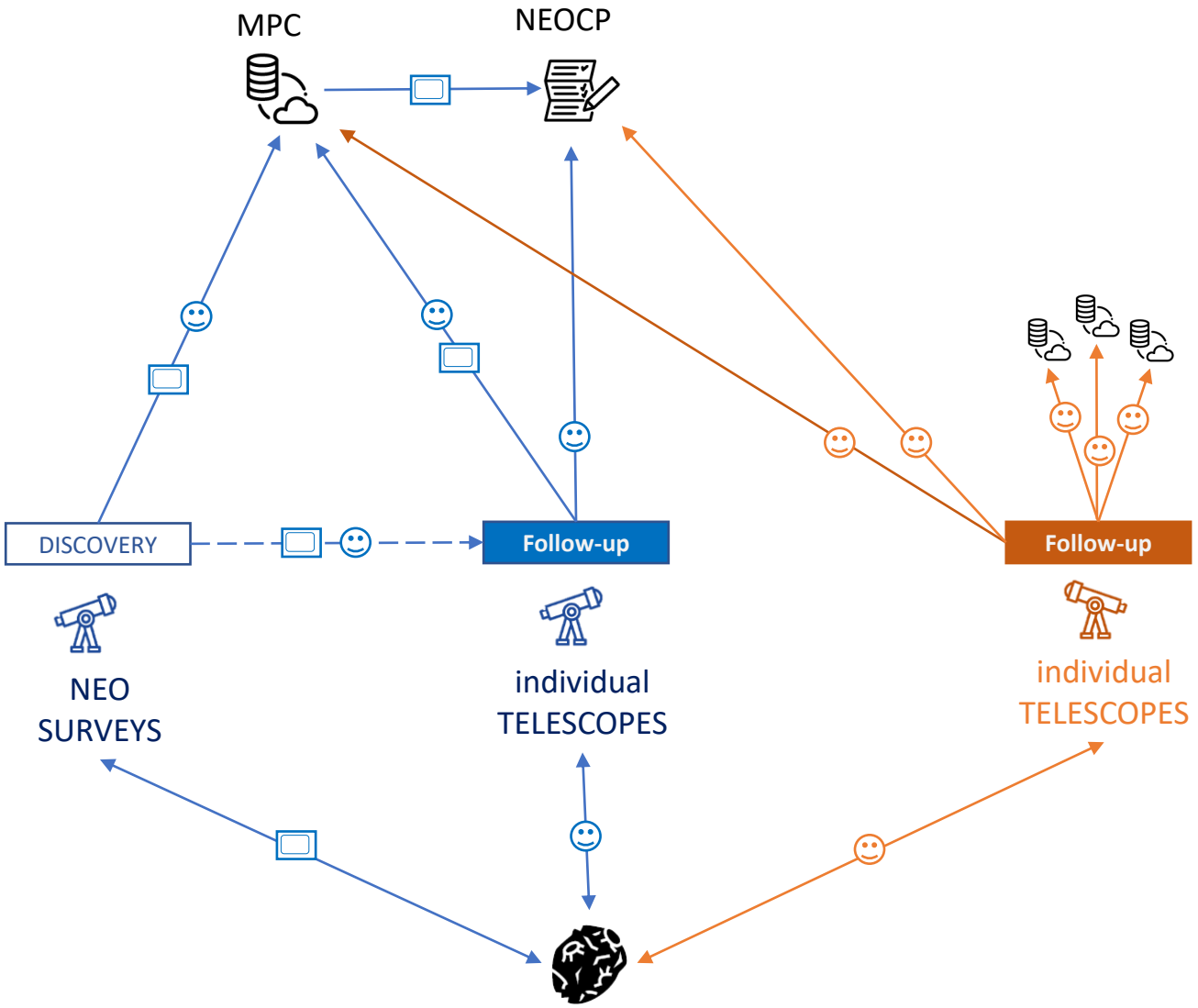


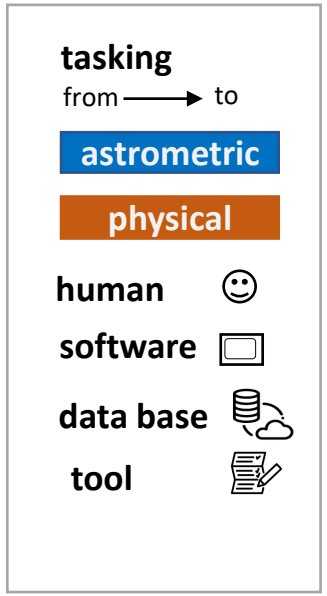
at the time of observations, 2022 GC1 was at 1.1 au from the Sun and 0.12 au from our planet.

**In the night between 5 th and 6th of April, despite a high proper velocity (about 200 arcsec/h), standard BVRI photometry was successfully obtained from TNG , thus closing the loop within days from discovery.**

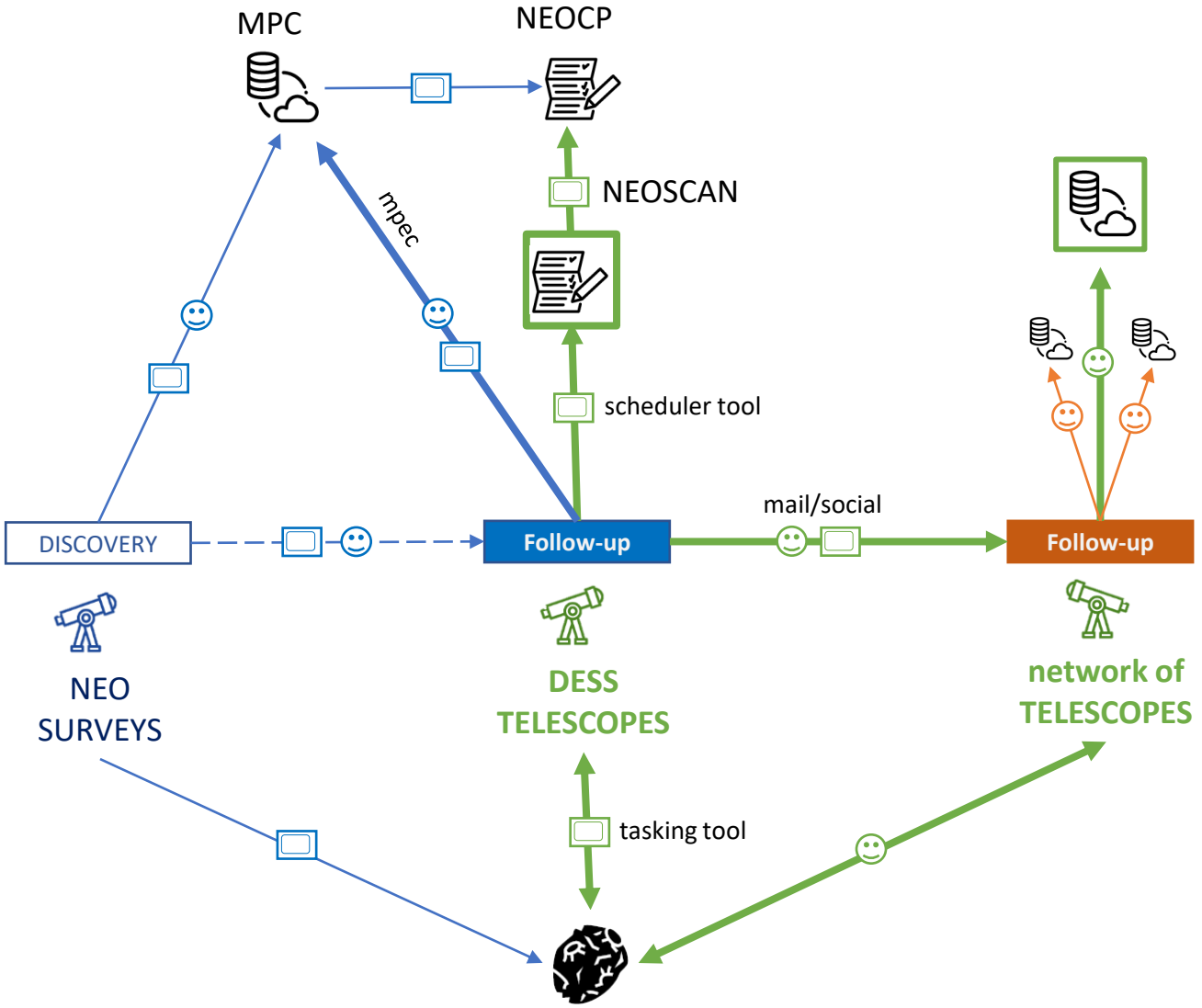
# Imminent Impactors: the NEOROCKS contribution

**PRESENT**



# **Imminent Impactors:** the NEOROCKS contribution




**tasking**
from → to

**astrometric**

**physical**

**human**

**software**

**data base**

**tool**

**NEOROCKS**

# conclusions and future developments

**being able to timely carry out the physical characterization of an imminent impactor is a key feature for developing a rapid response system for civil protection purposes**

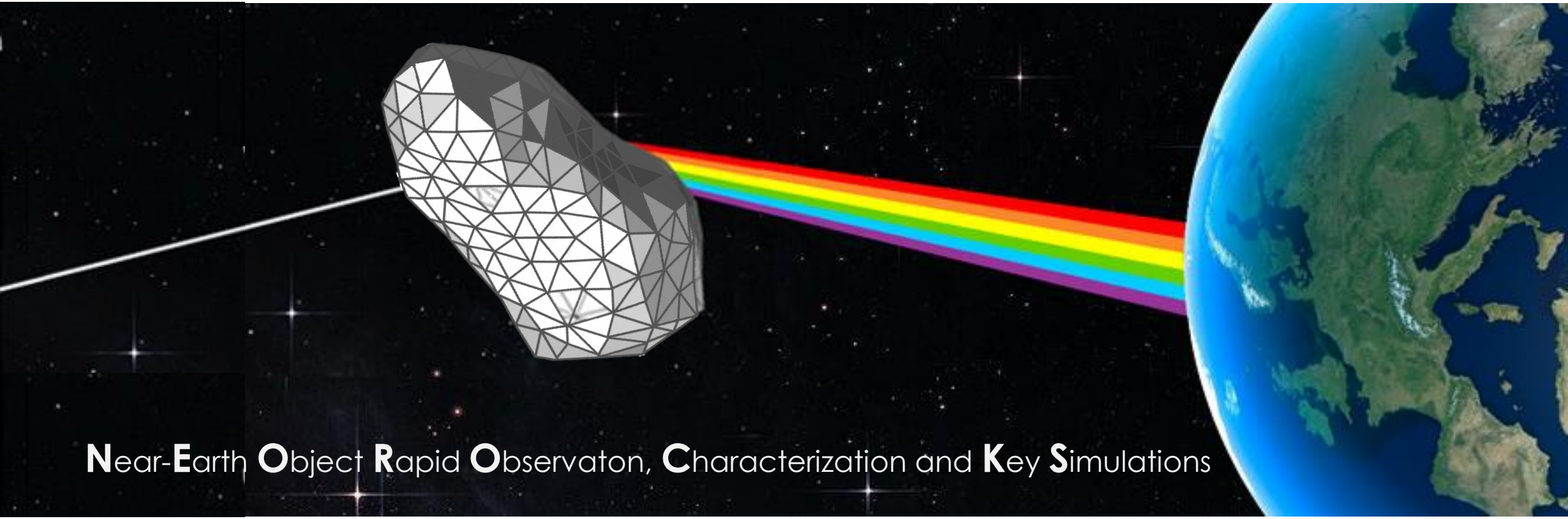
**we have demonstrated that using European existing assets it is possible to set-up an integrated imminent impactor rapid response system encompassing both, dynamical and physical characterization.**

**Future is to turn an experiment into a prototype through e.g.**

- **Extending the network of telescopes that can be directly tasked for astrometry**
- **Automating as far as possible the tasking of large telescopes for physical characterization (e.g. use social media?)**
- **Obtaining priority tasking of large telescopes through institutional empowerment (EU, IAU, UNOOSA…)**
- **Taking into account the need for secure communication**
- **(…)**

# The NEOROCKS Rapid Response Experiment

## lessons learned and future developments

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