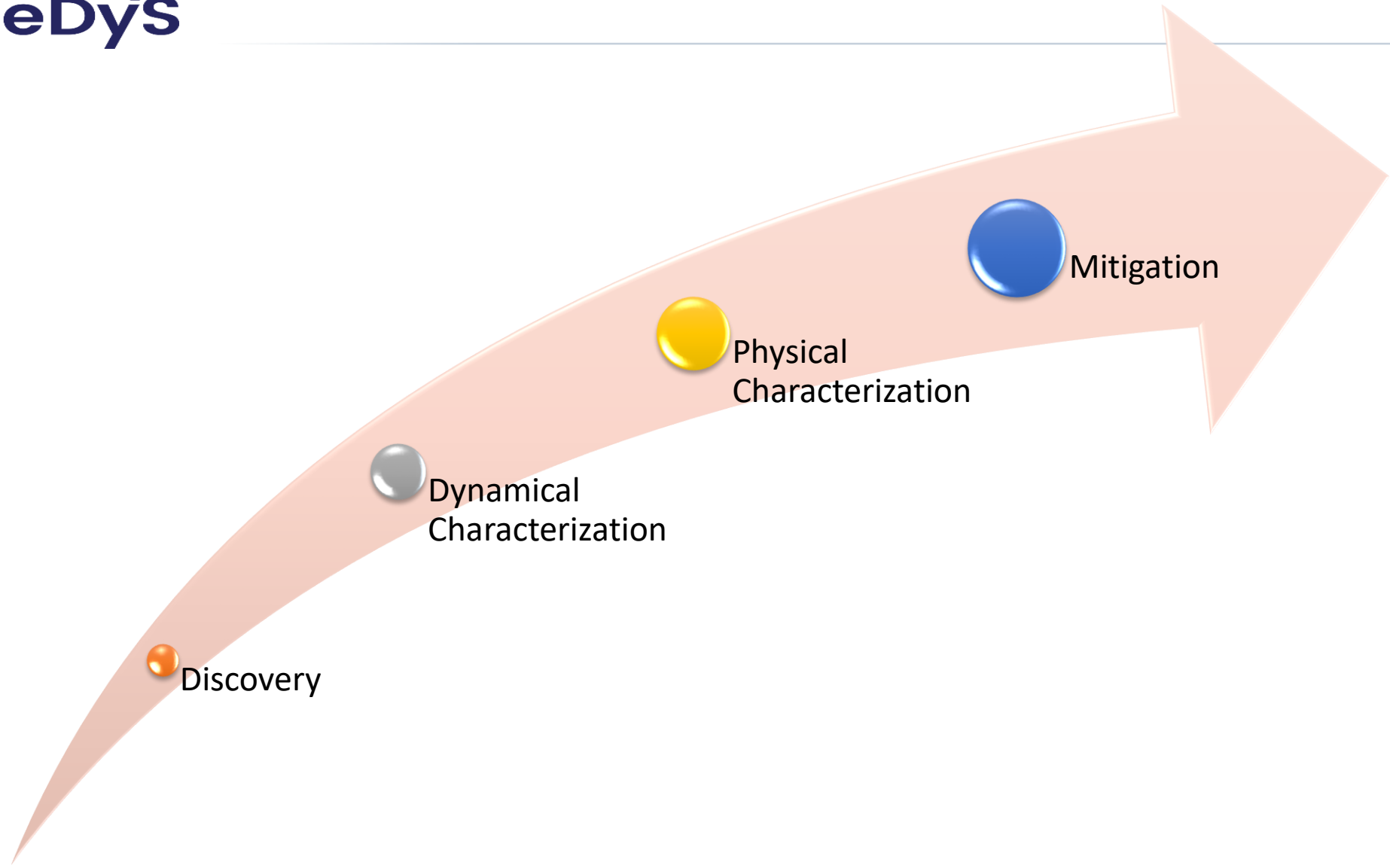
Improving the overall system efficiency from detection, through orbit determination and consolidation

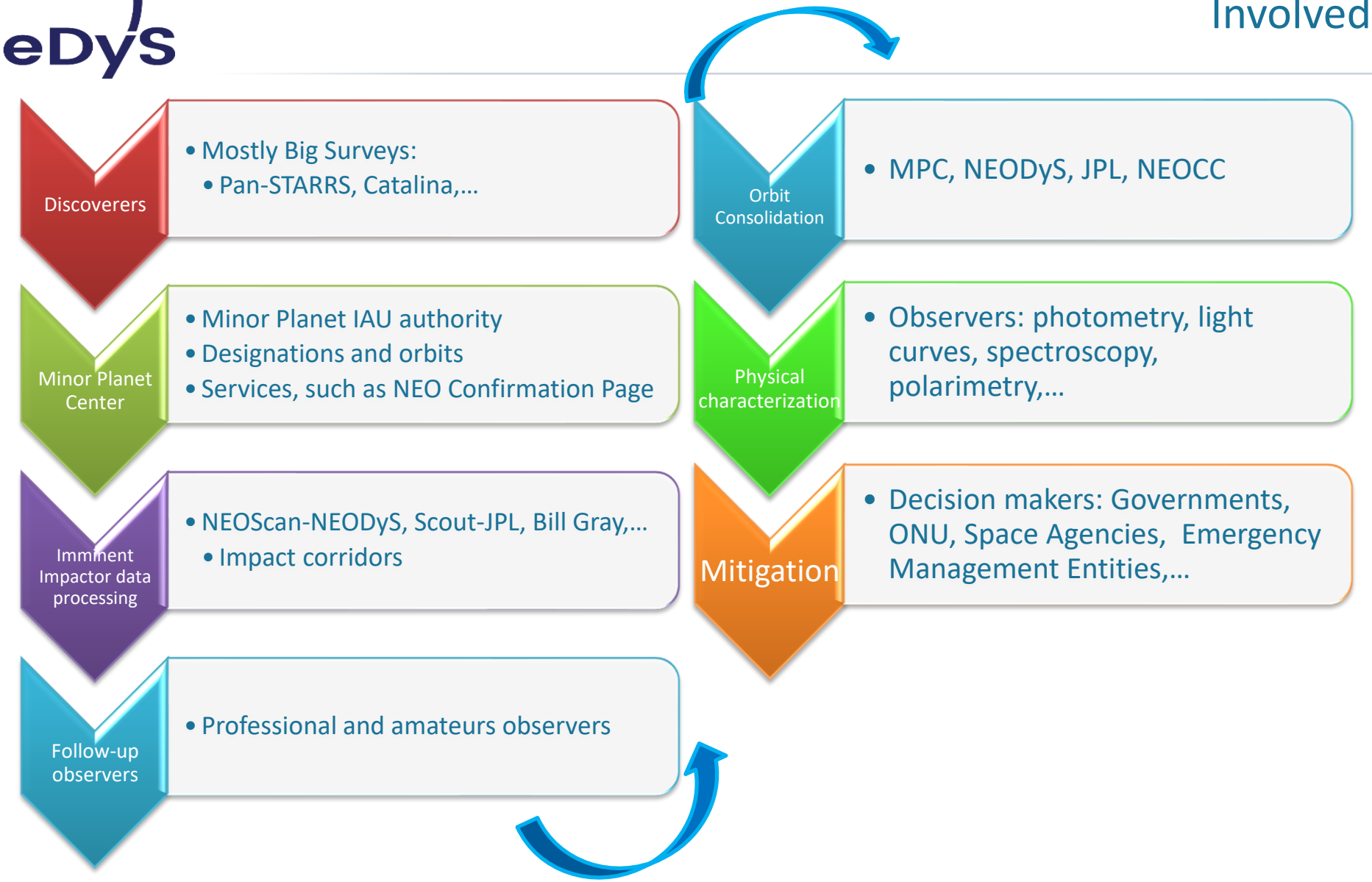
F. Bernardi (SpaceDyS)

G.B. Valsecchi (INAF / SpaceDyS)

A. Bertolucci (SpaceDyS)

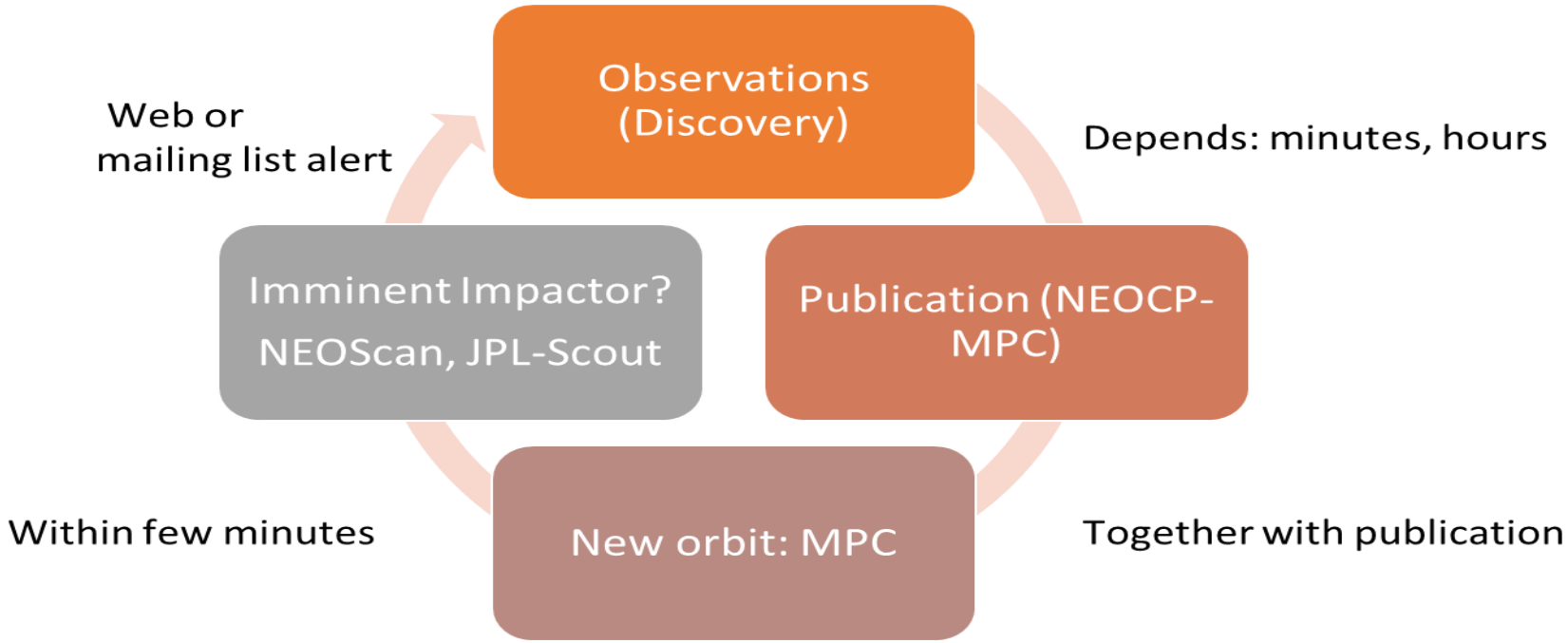

Mitigation
Physical
Characterization
Dynamical
Characterization
Discovery

Involved Players



Key point: Speed

- We want to reduce the time from discovery to the time when the orbit is well constrained, such that physical observations are possible.



- The new fast-moving detections must be submitted to MPC as soon as possible:
  - Automatic detection
  - Fast validation
  - Fast submission
  - Time from detection to submission, ideally, within 20-30 min
- **Fast follow-up**, even before the NEOCP publication, is welcome:
  - Collaborating observers
  - Automatic alert (via telegram, whatsapp, emails, …)
  - Catalina is a good example for fast follow-up through its telescopes' network

MPC-NEOCP posting

- The NEOCP posting for new candidates seems quite fast, (within minutes?)
- Automation is a key issue
- …but also data quality check
- Both NEOScan and JPL-Scout are scanning the NEOCP web page very quickly

- NEOScan is the service, available at NEODyS, which performs the **imminent impactors scanning**: https://newton.spacedys.com//neodys2/NEOScan/
- It scans on a frequency of **2 minutes**
- As soon as new data are available from NEOCP, it uses data in ADES format directly from the MPC database replica @NEODyS: ADES has more information, in particular the expected measurements rms performance provided directly by the observer (or measurer)

NEOScan computation times

- NEOScan monitors the possible imminent impactors within the next month
- Typical computation times: from few minutes to few tens of minutes
- Results of imminent impactors are posted on the NEOScan Risk Page: https://newton.spacedys.com//neodys2/NEOScan/index_risk.html

- Imminent impactors alerts are automatically sent to major players:
  - MPC, JPL, NEOCC, Big Surveys, Tim Spahr, Bill Gray, follow-up observers,…
  - Alerts are sent via email when the significance is good (when the observed arc is long enough) and the impact flag ≥3 (depending upon the impact probability)
  - Email alerts include the impact location map plot
  - Comparison with JPL-Scout results

NEOScan weak points

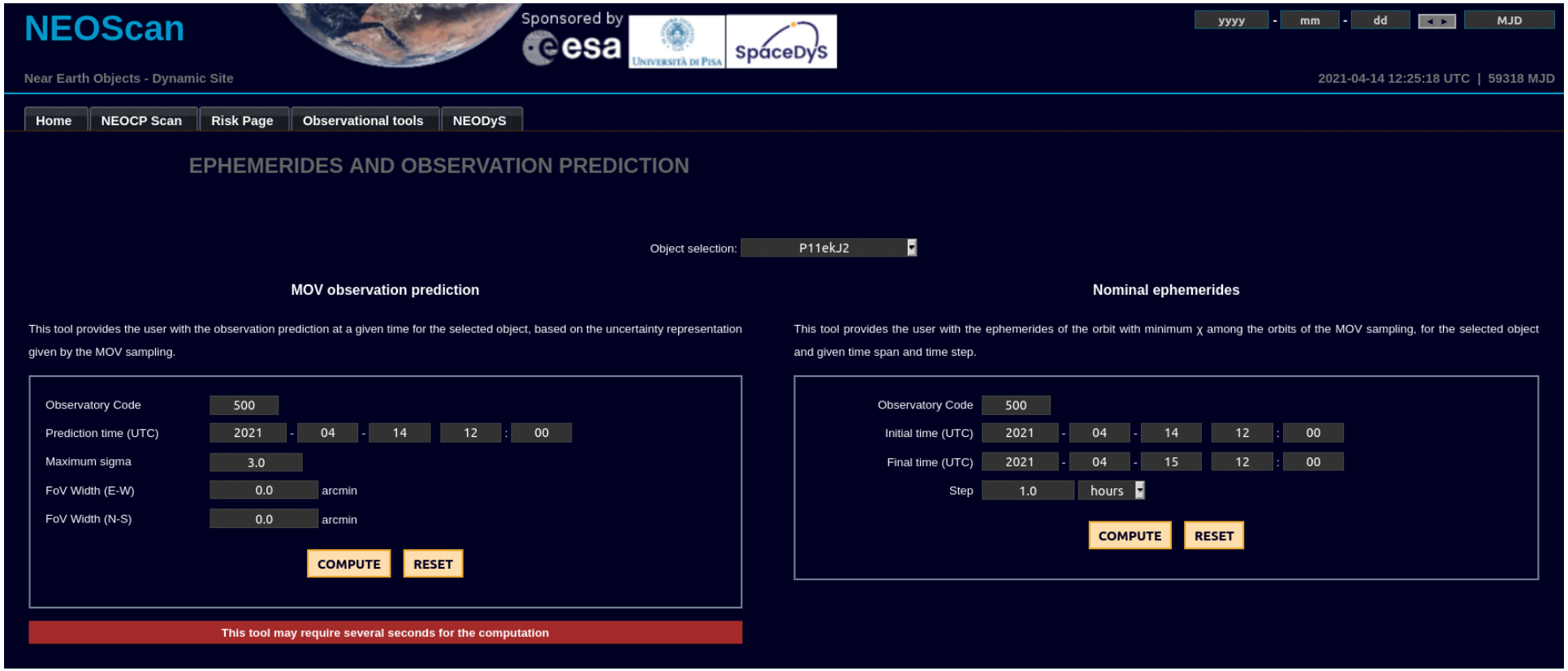
- Single run depending upon backlog runs
- If the foreseen impact is happening very soon (in few hours) and the data flow from observers is rapidly increasing, the computation might be not fast enough to catch up
- **Room for improvements**: this data processing issue can be fixed and the output release timing improved

- During the NEOROCKS project (**https://www.neorocks.eu**, EU grant n. **870403**), we developed some tools and services to support the follow-up observers:
  - Observation prediction tools
  - NEOCP Priority List
  - NEOs' Priority Lists (after MPECed)
  - E-mailing service for tailored priority lists
  - Follow-up observers ranking

NEO ROCKS

Near Earth Object Rapid Observation, Characterization and Key Simulations

Observer tools in NEOScan

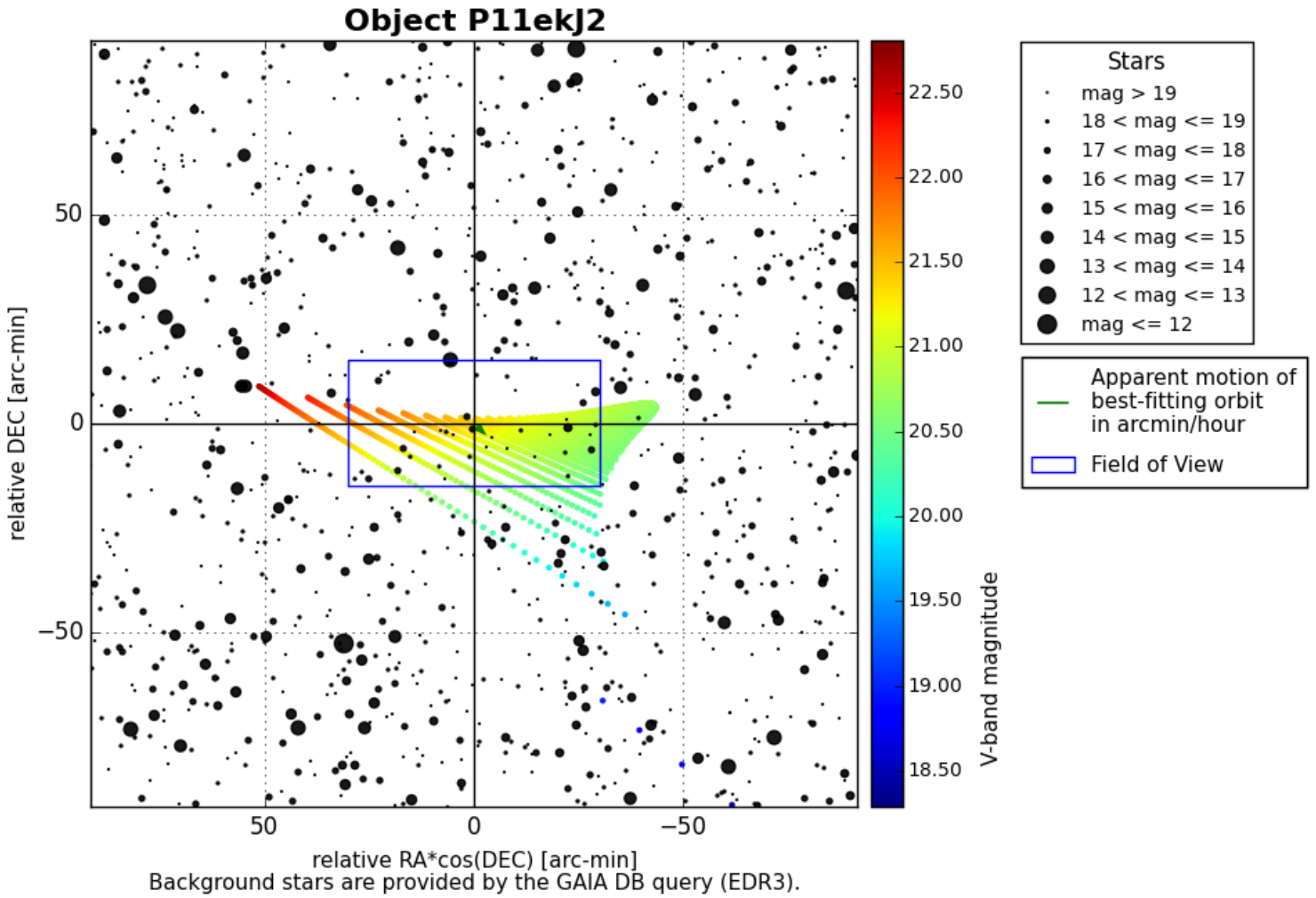


Fixed time, full uncertainty

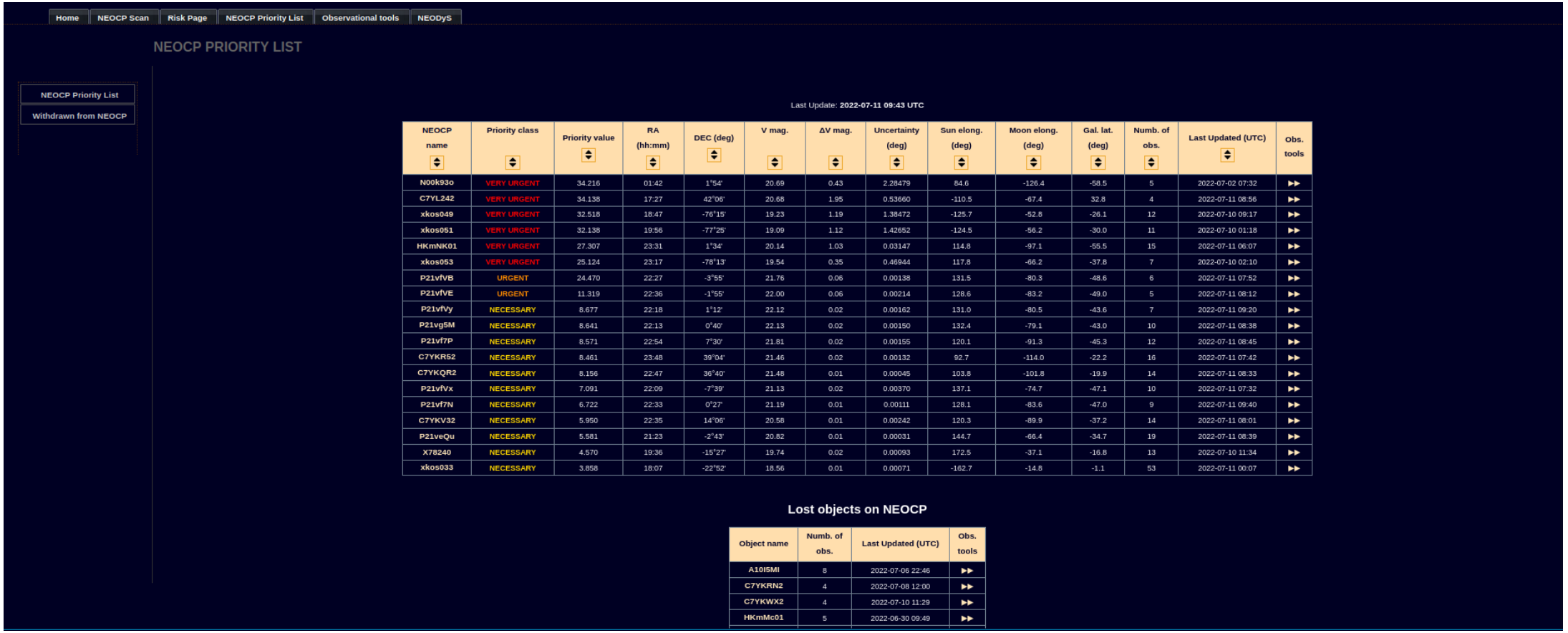
Time range, only nominal

Observation Prediction output at a fixed time

- Users can select a field of view box
- Output gives uncertainty with an associated magnitude color code
- It is possible to show NEO classes (Aten, Apollo,…)
- It can also show impactors (if any) to allow to focus on the most critical part of the sky



NEOCP Priority List



Home | NEOCP Scan | Risk Page | NEOCP Priority List | Observational tools | NEODyS

NEOCP PRIORITY LIST

NEOCP Priority List
Withdrawn from NEOCP

Last Update: **2022-07-11 09:43 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)	Numb. of obs.	Last Updated (UTC)	Obs. tools
N00k93o	VERY URGENT	34.216	01:42	1°54'	20.69	0.43	2.28479	84.6	-126.4	-58.5	5	2022-07-02 07:32	▶▶
C7YL242	VERY URGENT	34.138	17:27	42°06'	20.68	1.95	0.53660	-110.5	-67.4	32.8	4	2022-07-11 08:56	▶▶
xkos049	VERY URGENT	32.518	18:47	-76°15'	19.23	1.19	1.38472	-125.7	-52.8	-26.1	12	2022-07-10 09:17	▶▶
xkos051	VERY URGENT	32.138	19:56	-77°25'	19.09	1.12	1.42652	-124.5	-56.2	-30.0	11	2022-07-10 01:18	▶▶
HKmNK01	VERY URGENT	27.307	23:31	1°34'	20.14	1.03	0.03147	114.8	-97.1	-55.5	15	2022-07-11 06:07	▶▶
xkos053	VERY URGENT	25.124	23:17	-78°13'	19.54	0.35	0.46944	117.8	-66.2	-37.8	7	2022-07-10 02:10	▶▶
P21vfVB	URGENT	24.470	22:27	-3°55'	21.76	0.06	0.00138	131.5	-80.3	-48.6	6	2022-07-11 07:52	▶▶
P21vfVE	URGENT	11.319	22:36	-1°55'	22.00	0.06	0.00214	128.6	-83.2	-49.0	5	2022-07-11 08:12	▶▶
P21vfVy	NECESSARY	8.677	22:18	1°12'	22.12	0.02	0.00162	131.0	-80.5	-43.6	7	2022-07-11 09:20	▶▶
P21vg5M	NECESSARY	8.641	22:13	0°40'	22.13	0.02	0.00150	132.4	-79.1	-43.0	10	2022-07-11 08:38	▶▶
P21vf7P	NECESSARY	8.571	22:54	7°30'	21.81	0.02	0.00155	120.1	-91.3	-45.3	12	2022-07-11 08:45	▶▶
C7YKR52	NECESSARY	8.461	23:48	39°04'	21.46	0.02	0.00132	92.7	-114.0	-22.2	16	2022-07-11 07:42	▶▶
C7YKQR2	NECESSARY	8.156	22:47	36°40'	21.48	0.01	0.00045	103.8	-101.8	-19.9	14	2022-07-11 08:33	▶▶
P21vfVx	NECESSARY	7.091	22:09	-7°39'	21.13	0.02	0.00370	137.1	-74.7	-47.1	10	2022-07-11 07:32	▶▶
P21vf7N	NECESSARY	6.722	22:33	0°27'	21.19	0.01	0.00111	128.1	-83.6	-47.0	9	2022-07-11 09:40	▶▶
C7YKV32	NECESSARY	5.950	22:35	14°06'	20.58	0.01	0.00242	120.3	-89.9	-37.2	14	2022-07-11 08:01	▶▶
P21veQu	NECESSARY	5.581	21:23	-2°43'	20.82	0.01	0.00031	144.7	-66.4	-34.7	19	2022-07-11 08:39	▶▶
X78240	NECESSARY	4.570	19:36	-15°27'	19.74	0.02	0.00093	172.5	-37.1	-16.8	13	2022-07-10 11:34	▶▶
xkos033	NECESSARY	3.858	18:07	-22°52'	18.56	0.01	0.00071	-162.7	-14.8	-1.1	53	2022-07-11 00:07	▶▶

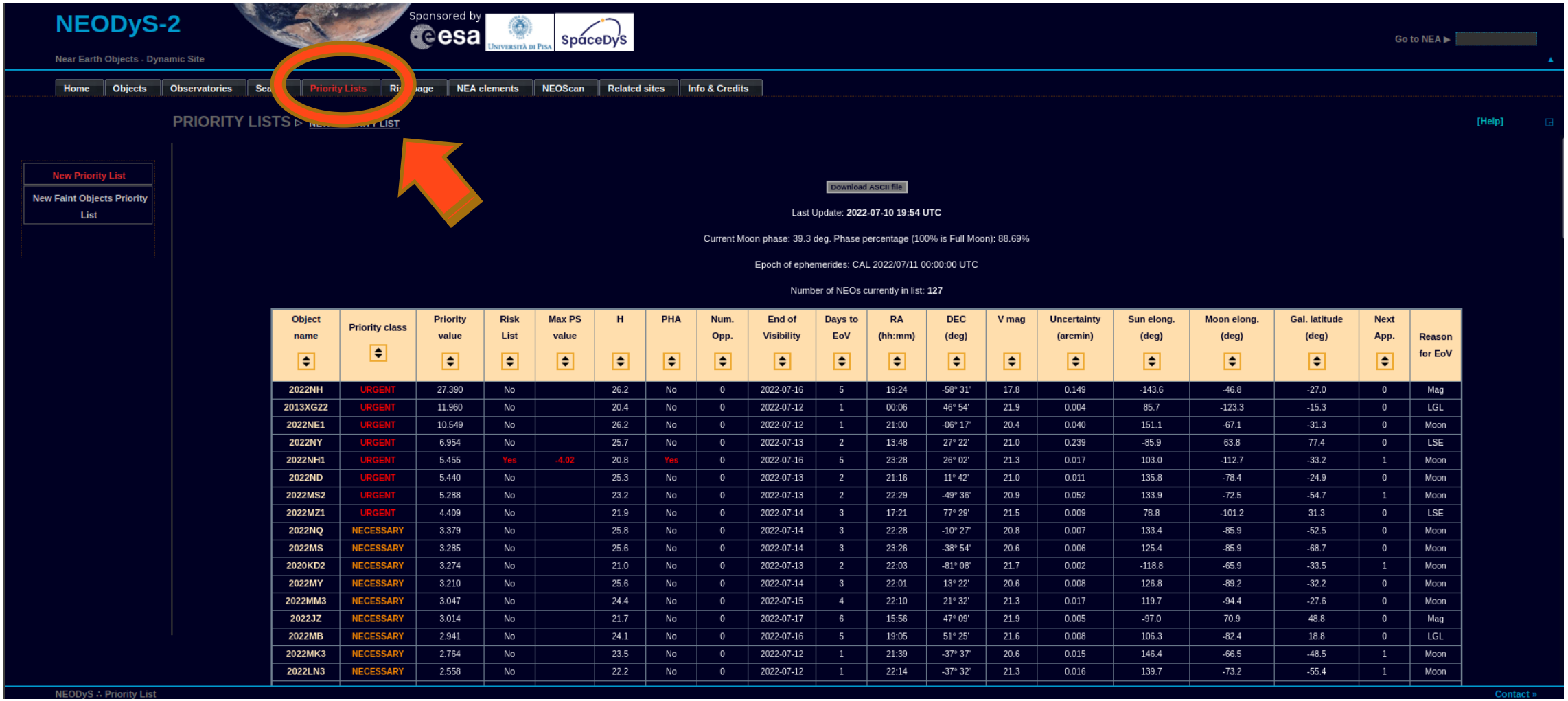
Lost objects on NEOCP

Object name	Numb. of obs.	Last Updated (UTC)	Obs. tools
A10I5MI	8	2022-07-06 22:46	▶▶
C7YKRN2	4	2022-07-08 12:00	▶▶
C7YKWX2	4	2022-07-10 11:29	▶▶
HKmMc01	5	2022-06-30 09:49	▶▶

Priority based upon:

- Impact Probability and End of Visibility determined by: Sky uncertainty, Visual Magnitude, Solar Elongation, Moon (phase and target lunar elongation) a nd Galactic Latitude

New Priority List General Layout



Object name	Priority class	Priority value	Risk List	Max PS value	H	PHA	Num. Opp.	End of Visibility	Days to EoV	RA (hh:mm)	DEC (deg)	V mag	Uncertainty (arcmin)	Sun elong. (deg)	Moon elong. (deg)	Gal. latitude (deg)	Next App.	Reason for EoV
2022NH	URGENT	27.390	No		26.2	No	0	2022-07-16	5	19:24	-58° 31'	17.8	0.149	-143.6	-46.8	-27.0	0	Mag
2013XG22	URGENT	11.960	No		20.4	No	0	2022-07-12	1	00:06	46° 54'	21.9	0.004	85.7	-123.3	-15.3	0	LGL
2022NE1	URGENT	10.549	No		26.2	No	0	2022-07-12	1	21:00	-06° 17'	20.4	0.040	151.1	-67.1	-31.3	0	Moon
2022NY	URGENT	6.954	No		25.7	No	0	2022-07-13	2	13:48	27° 22'	21.0	0.239	-85.9	63.8	77.4	0	LSE
2022NH1	URGENT	5.455	Yes	-4.02	20.8	Yes	0	2022-07-16	5	23:28	26° 02'	21.3	0.017	103.0	-112.7	-33.2	1	Moon
2022ND	URGENT	5.440	No		25.3	No	0	2022-07-13	2	21:16	11° 42'	21.0	0.011	135.8	-78.4	-24.9	0	Moon
2022MS2	URGENT	5.288	No		23.2	No	0	2022-07-13	2	22:29	-49° 36'	20.9	0.052	133.9	-72.5	-54.7	1	Moon
2022MZ1	URGENT	4.409	No		21.9	No	0	2022-07-14	3	17:21	77° 29'	21.5	0.009	78.8	-101.2	31.3	0	LSE
2022NQ	NECESSARY	3.379	No		25.8	No	0	2022-07-14	3	22:28	-10° 27'	20.8	0.007	133.4	-85.9	-52.5	0	Moon
2022MS	NECESSARY	3.285	No		25.6	No	0	2022-07-14	3	23:26	-38° 54'	20.6	0.006	125.4	-85.9	-68.7	0	Moon
2020KD2	NECESSARY	3.274	No		21.0	No	0	2022-07-13	2	22:03	-81° 08'	21.7	0.002	-118.8	-65.9	-33.5	1	Moon
2022MY	NECESSARY	3.210	No		25.6	No	0	2022-07-14	3	22:01	13° 22'	20.6	0.008	126.8	-89.2	-32.2	0	Moon
2022MM3	NECESSARY	3.047	No		24.4	No	0	2022-07-15	4	22:10	21° 32'	21.3	0.017	119.7	-94.4	-27.6	0	Moon
2022JZ	NECESSARY	3.014	No		21.7	No	0	2022-07-17	6	15:56	47° 09'	21.9	0.005	-97.0	70.9	48.8	0	Mag
2022MB	NECESSARY	2.941	No		24.1	No	0	2022-07-16	5	19:05	51° 25'	21.6	0.008	106.3	-82.4	18.8	0	LGL
2022MK3	NECESSARY	2.764	No		23.5	No	0	2022-07-12	1	21:39	-37° 37'	20.6	0.015	146.4	-66.5	-48.5	1	Moon
2022LN3	NECESSARY	2.558	No		22.2	No	0	2022-07-12	1	22:14	-37° 32'	21.3	0.016	139.7	-73.2	-55.4	1	Moon

Tailored priority list email for observers

NEODyS-2

Near Earth Objects - Dynamic Site

Sponsored by esa Università di Pisa SpaceDyS

Good Morning,

This email contains the ephemerides for objects in **NEODyS' Priority List**.

Observatory Code: **K83**

Observatory Name: **Beppe Forti Astronomical Observatory, Montelupo**

Limiting Magnitude: **20.5**

Declination Range: **-30** to **+90**

CAL 2021/Feb/16 00:00:00 UTC

Name	RA (HH MM SS)	DEC (DD MM SS)	Vmag	Elo.Sun (deg)	Ph. (deg)	El.Moo (deg)	Gal.lat. (deg)	Mot. ("/min)	Dir. (deg)	Uncertainty Ellipse (arcmin)	(arcmin)	(deg)	Urgency	End of Vis Recov	Ephemerides
2021CZ7	15 18 44	+ 4 41 17	20.5	100.5	79.0	145.9	48.4	86.2	165.9	1.373	0.043	164.9	URGENT	2021-02-18	2021CZ7 1-day Eph. for K83
2021CL4	15 29 48	+11 51 52	20.5	99.2	79.9	141.5	49.9	51.6	113.9	0.130	0.011	121.0	URGENT	2021-02-17	2021CL4 1-day Eph. for K83
2021CW8	9 49 30	+75 19 1	19.7	-117.1	61.5	-98.0	36.8	62.2	5.0	0.024	0.008	192.4	URGENT	2021-02-18	2021CW8 1-day Eph. for K83
2021CH8	7 54 34	+ 4 4 35	20.0	-148.4	30.0	-102.4	15.9	9.2	327.0	0.606	0.020	148.0	URGENT	2021-02-19	2021CH8 1-day Eph. for K83
2021CU8	10 32 14	+ 5 5 55	20.5	168.8	11.0	-141.4	50.2	21.8	93.0	0.119	0.011	91.5	NECESSARY	2021-02-19	2021CU8 1-day Eph. for K83
2021CX4	7 25 37	+44 57 58	20.3	-134.1	42.7	-92.6	24.6	8.4	308.5	0.019	0.004	136.8	NECESSARY	2021-02-19	2021CX4 1-day Eph. for K83
2021CD2	10 2 49	-14 38 10	19.4	152.9	24.6	-133.3	31.5	9.7	196.9	0.051	0.017	195.9	USEFUL	2021-02-20	2021CD2 1-day Eph. for K83
2021CY5	8 31 8	+ 6 51 52	20.3	-157.9	21.1	-111.3	25.3	8.2	332.5	0.012	0.004	154.3	USEFUL	2021-02-20	2021CY5 1-day Eph. for K83
2021CG8	11 35 31	+15 46 49	20.5	156.1	22.8	-152.0	69.1	13.3	273.5	0.108	0.012	94.1	USEFUL	2021-02-23	2021CG8 1-day Eph. for K83
2001CQ36	4 6 17	+31 0 22	20.5	-98.2	75.1	-52.0	-15.6	4.8	86.8	0.003	0.001	58.8	LOW	2021-02-17	2001CQ36 1-day Eph. for K83
2021CM1	11 25 42	-10 17 33	20.4	148.5	30.1	-154.0	47.2	10.7	129.1	0.097	0.011	124.3	LOW	2021-02-27	2021CM1 1-day Eph. for K83
2021CS4	14 17 39	+ 7 36 28	20.2	116.0	59.8	159.5	61.7	17.2	65.2	0.049	0.012	64.4	LOW	2021-02-22	2021CS4 1-day Eph. for K83
2010VU198	4 12 35	+26 23 21	20.4	-98.7	47.7	-51.5	-17.9	1.6	7.2	0.001	0.000	171.5	LOW	2021-02-17	2010VU198 1-day Eph. for K83
2017BL31	1 36 21	+34 46 5	19.9	-70.0	86.1	-34.0	-27.2	4.0	256.1	0.002	0.001	68.0	LOW	2021-02-17	2017BL31 1-day Eph. for K83
2021CQ1	9 59 40	+45 3 20	20.5	-147.4	25.6	-117.9	51.5	6.0	351.8	0.007	0.003	190.1	LOW	2021-02-22	2021CQ1 1-day Eph. for K83
2017YZ1	5 14 38	-25 56 2	20.5	-101.2	61.4	-66.3	-31.8	1.7	221.8	0.002	0.001	204.1	LOW	2021-02-19	2017YZ1 1-day Eph. for K83
2021CU5	9 32 50	+10 34 23	19.9	-173.6	6.1	-126.0	40.6	6.2	170.7	0.011	0.005	164.8	LOW	2021-02-22	2021CU5 1-day Eph. for K83

For any concern, please send an email to neodys-help@spacedys.com.

This service has beend developed for the NEOROCKS (***NEO Rapid Observation, Characterization And Key Simulation***) Project, which has received funding from the European's Horizon 2020 research and innovation programme under grant agreement **No 870403.**

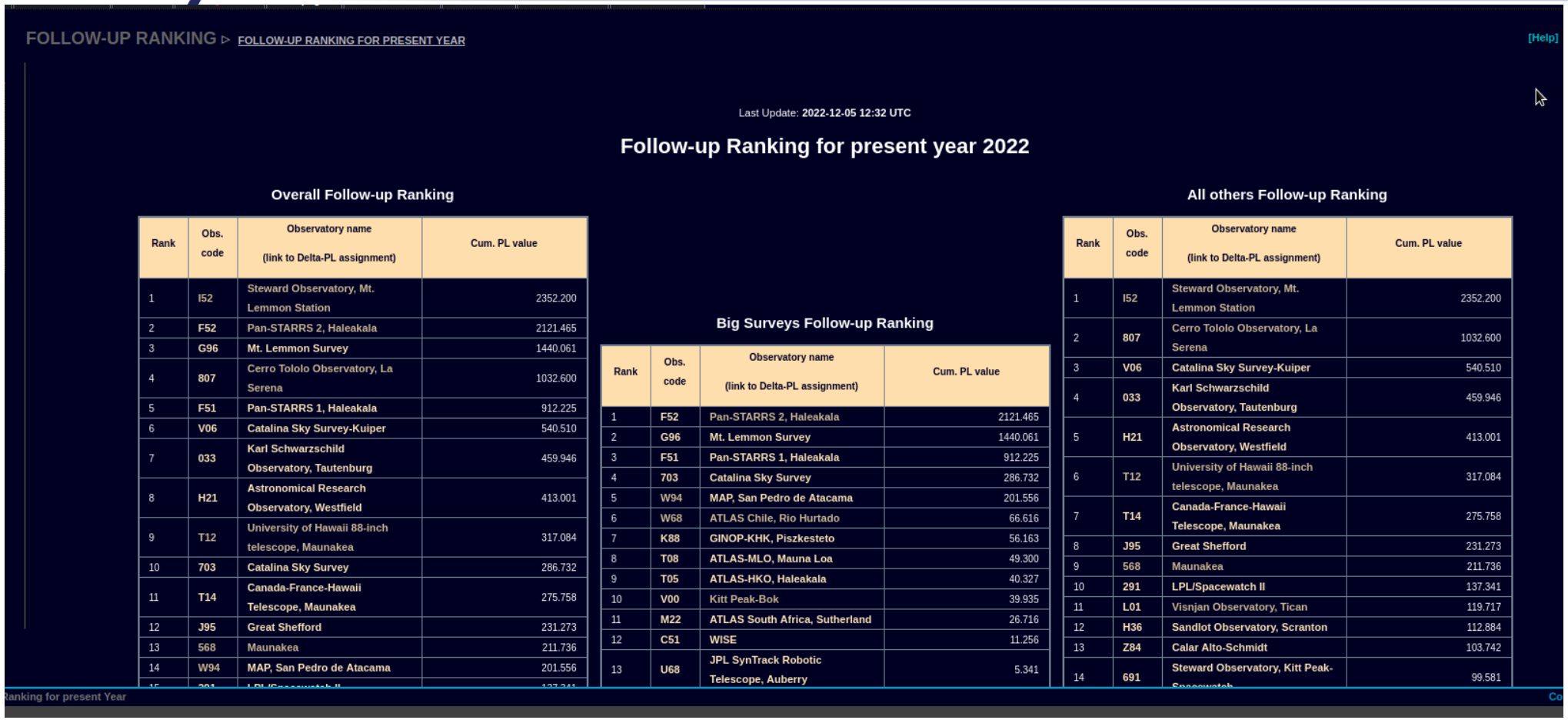
NEO ROCKS

Near Earth Object Rapid Observation, Characterization and Key Simulations

Automatic daily (or configurable) e-mail to subscribers with some customizations:

- Obscode ephemerides, limiting magnitude, declination range,…)

Follow-up ranking system



FOLLOW-UP RANKING ▷ FOLLOW-UP RANKING FOR PRESENT YEAR [Help]

Last Update: **2022-12-05 12:32 UTC**

Follow-up Ranking for present year 2022

Overall Follow-up Ranking

Rank	Obs. code	Observatory name (link to Delta-PL assignment)	Cum. PL value
1	I52	Steward Observatory, Mt. Lemmon Station	2352.200
2	F52	Pan-STARRS 2, Haleakala	2121.465
3	G96	Mt. Lemmon Survey	1440.061
4	807	Cerro Tololo Observatory, La Serena	1032.600
5	F51	Pan-STARRS 1, Haleakala	912.225
6	V06	Catalina Sky Survey-Kuiper	540.510
7	033	Karl Schwarzschild Observatory, Tautenburg	459.946
8	H21	Astronomical Research Observatory, Westfield	413.001
9	T12	University of Hawaii 88-inch telescope, Maunakea	317.084
10	703	Catalina Sky Survey	286.732
11	T14	Canada-France-Hawaii Telescope, Maunakea	275.758
12	J95	Great Shefford	231.273
13	568	Maunakea	211.736
14	W94	MAP, San Pedro de Atacama	201.556

Big Surveys Follow-up Ranking

Rank	Obs. code	Observatory name (link to Delta-PL assignment)	Cum. PL value
1	F52	Pan-STARRS 2, Haleakala	2121.465
2	G96	Mt. Lemmon Survey	1440.061
3	F51	Pan-STARRS 1, Haleakala	912.225
4	703	Catalina Sky Survey	286.732
5	W94	MAP, San Pedro de Atacama	201.556
6	W68	ATLAS Chile, Rio Hurtado	66.616
7	K88	GINOP-KHK, Piszkesteto	56.163
8	T08	ATLAS-MLO, Mauna Loa	49.300
9	T05	ATLAS-HKO, Haleakala	40.327
10	V00	Kitt Peak-Bok	39.935
11	M22	ATLAS South Africa, Sutherland	26.716
12	C51	WISE	11.256
13	U68	JPL SynTrack Robotic Telescope, Auberry	5.341

All others Follow-up Ranking

Rank	Obs. code	Observatory name (link to Delta-PL assignment)	Cum. PL value
1	I52	Steward Observatory, Mt. Lemmon Station	2352.200
2	807	Cerro Tololo Observatory, La Serena	1032.600
3	V06	Catalina Sky Survey-Kuiper	540.510
4	033	Karl Schwarzschild Observatory, Tautenburg	459.946
5	H21	Astronomical Research Observatory, Westfield	413.001
6	T12	University of Hawaii 88-inch telescope, Maunakea	317.084
7	T14	Canada-France-Hawaii Telescope, Maunakea	275.758
8	J95	Great Shefford	231.273
9	568	Maunakea	211.736
10	291	LPL/Spacewatch II	137.341
11	L01	Visnjan Observatory, Tican	119.717
12	H36	Sandlot Observatory, Scranton	112.884
13	Z84	Calar Alto-Schmidt	103.742
14	691	Steward Observatory, Kitt Peak-	99.581

anking for present Year

Purpose: motivate the observers after the MPEC release to continue to follow NEOs

Ranking obtained through the Priority List value metrics

SpaceDyS

Conclusions

- **Automation** is the key issue: from discoverers, MPC and imminent impactor scanners, but reliable data are needed (quality check)
- **Fast alert broadcasting** to follow-up observers is welcome: emails, telegram, whatsapp, push communication,… (see NEOROCKS experiment)
- Alerts communicated also to **physical observers** for rapid characterization
- In case of a certain impact event, **fast interface with decision makers** is needed
- Post-discovery MPEC support to observers for continue monitoring is welcome (not-strictly related to the imminent impactor problem)