NEOMIR: ESA’s space-based infrared mission for NEO detection and early warning

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NEOMIR In A Nutshell: Mission Design

2021: first study in ESA's Concurrent Design Facility (phase 0)

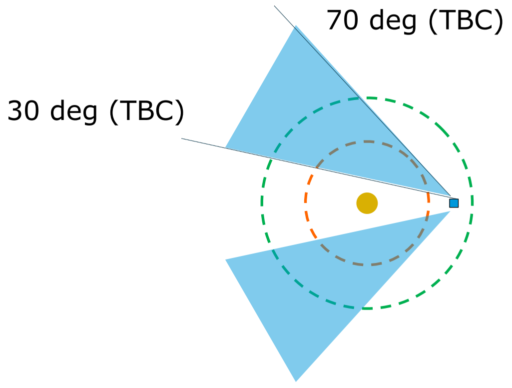
2023: first studies by European industries (phase A1)

2024: started second round of studies (phase A2)

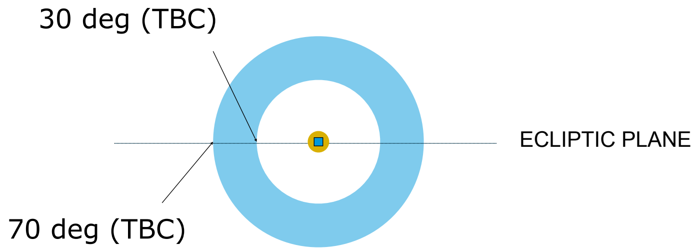
Out come of the studies regarding the mission design:

- Observatory at L1
- Spacecraft field of regard: 30º - 70º in solar elongation
- Multi-daily downlink; high data volume (similar to Euclid: up to 1.4 Gbit / day)
- Launch wet mass: ~1600 kg
- Launch with Ariane 6-2
- Launch possible in the early 2030s

View onto ecliptic plane



View through ecliptic plane



NEOMIR In A Nutshell: Payload Design

Optics

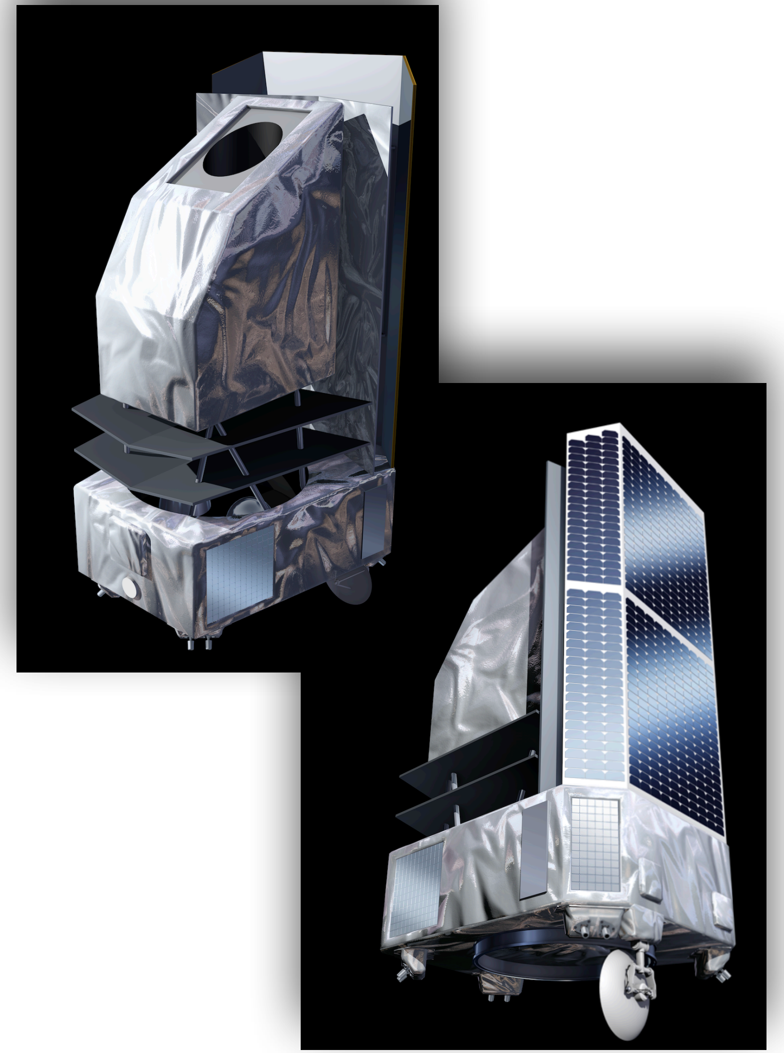
- Three-mirror anastigmat; M1 diameter is 55 cm
- PSF FWHM: 3”
- Field of view: 1.7º x 7º

Detectors

- 4 2k x 2k HgCdTe detectors covering one passbands: 6 - 10 µm
- Develop IR sensor capability in Europe

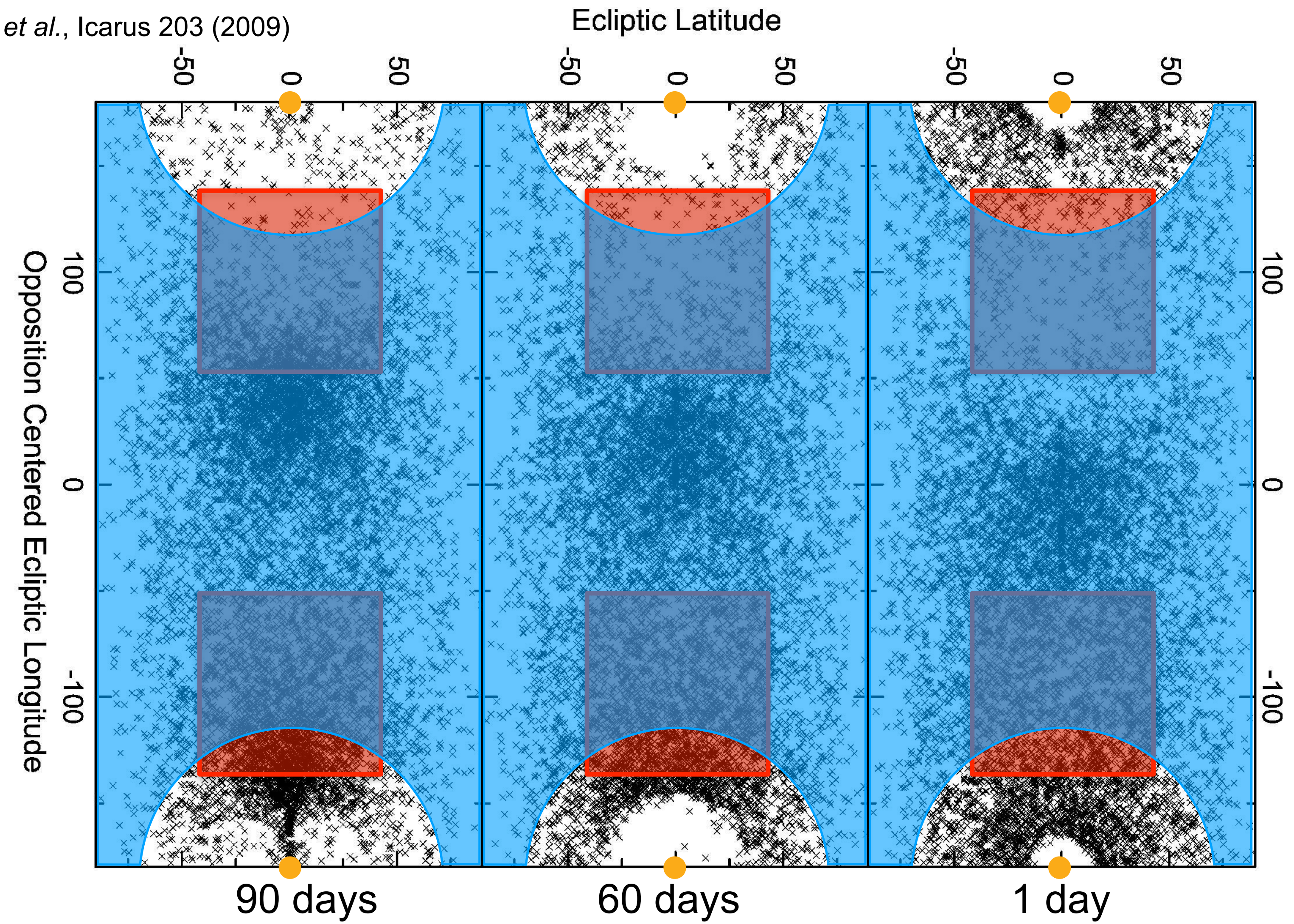
Thermal

- All payload (including telescope) passively cool down to ~55 K
- Trade-off on-going between passive cooling & active cryocooler to reach detectors’ operating temperature: 40 K



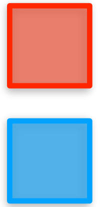
Impactor distribution

Veres *et al.*, Icarus 203 (2009)

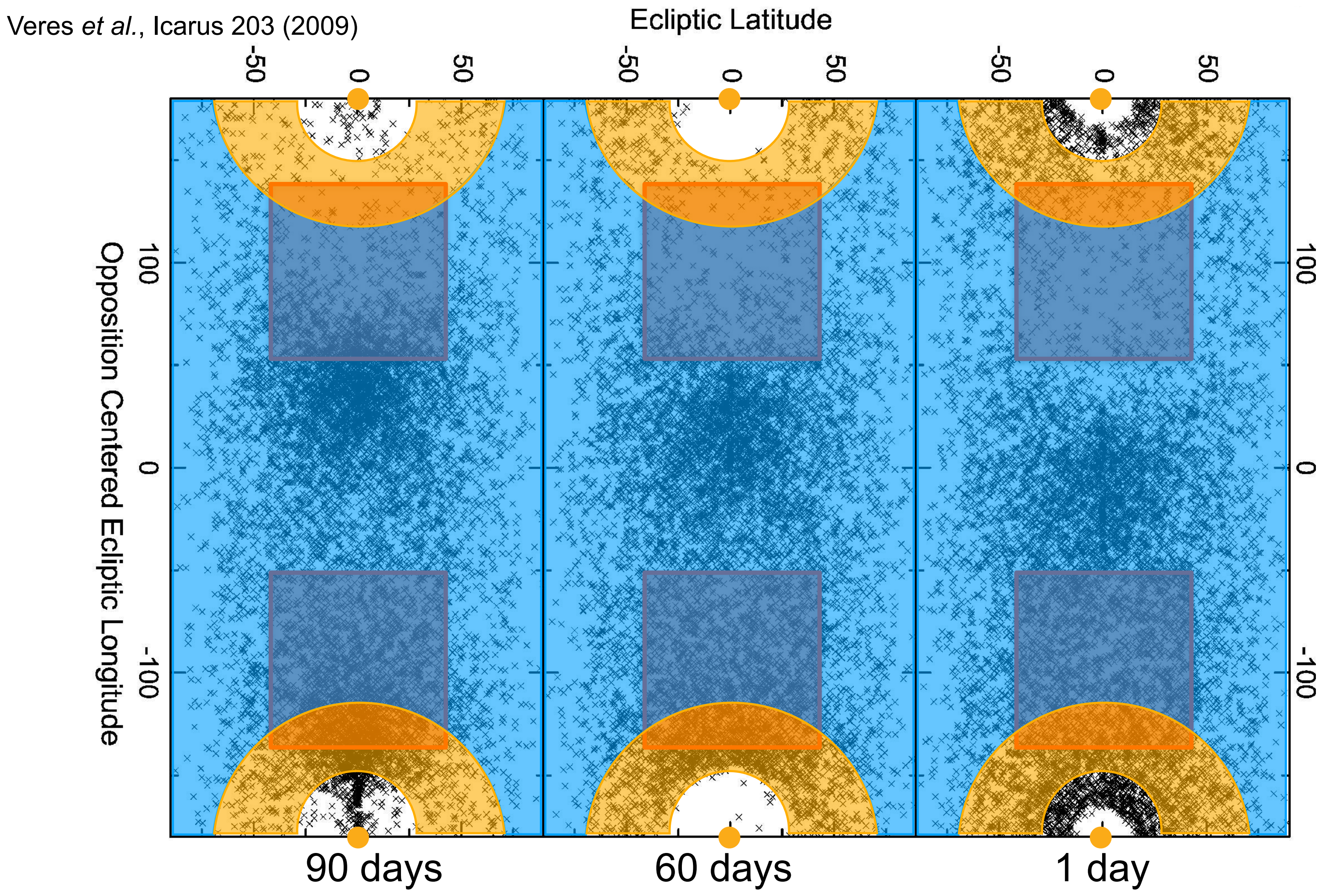


NASA's NEOSM aims at finding NEOs when they are *distant*.

However, due to survey strategy revisit time, it may miss the *smaller* ones (below 100 m) - only observable when *closer*, thus *faster*.



Impactor distribution



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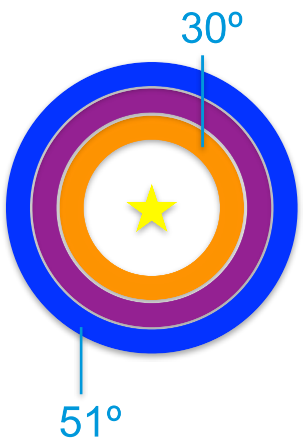
- NEOSM Coverage
- Ground Coverage
- NEOMIR Coverage

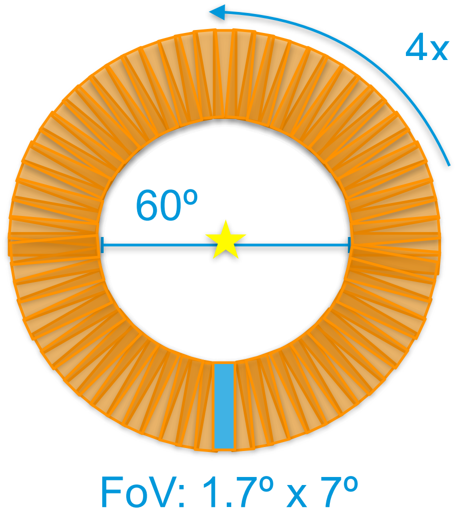
Observing Strategy

In order to "intersect" as many potential impactors as possible, NEOMIR baseline survey strategy is to observe rings around the Sun at a fixed elongation (constant solar aspect angle).

2 observing strategies envisaged:

- "Classic": each field (and thus ring) is observed at least 4 times to build a "tracklet"
  - Pros: proven technique; less data generated
  - Cons: NEO must be detectable in every exposure
- "Synthetic tracking": short exposures taken & stack together via software trying many motion vectors
  - Pros: gain up to a factor of 2 in SNR
  - Cons: higher readout overhead & data volume

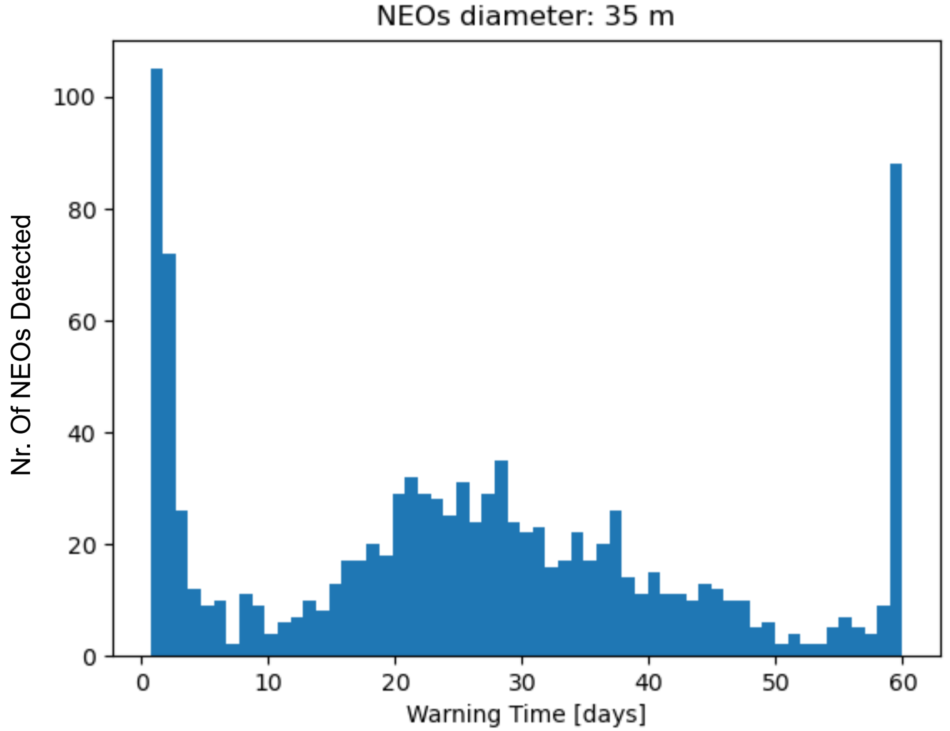


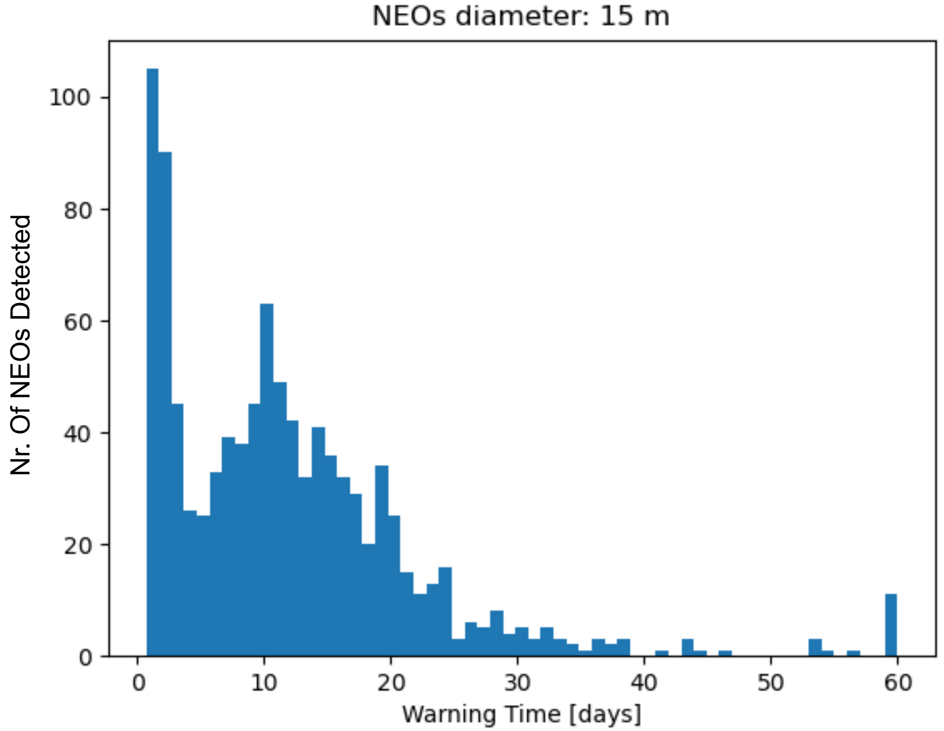


Ring Band	Number of fields	Time required for 4 visits [h]
30º - 37º	127	11.3
37º - 44º	147	13.1
44º - 51º	165	14.6
51º - 58º	180	16.0
58º - 65º	192	17.1

NEOMIR Detection Capabilities

We simulated a "population" of impactors: 1082 would pass in NEOMIR field of regard in the 60 days before impact. Then we assumed an object is detected if it has SNR > 5 while being in NEOMIR field of regard.





Assuming 35 m diameter, NEOMIR can detect 992 NEOs out to 1082 (92% success rate). ~180 are discovered ≤ 2 days before impact.

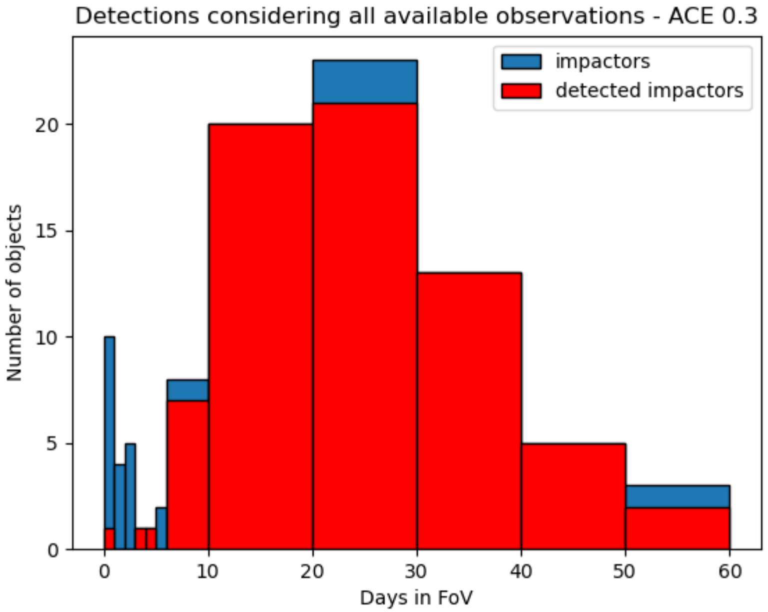
Assuming 15 m diameter, NEOMIR can detect 890 NEOs out to 1082 (82% success rate). ~200 are discovered ≤ 2 days before impact.

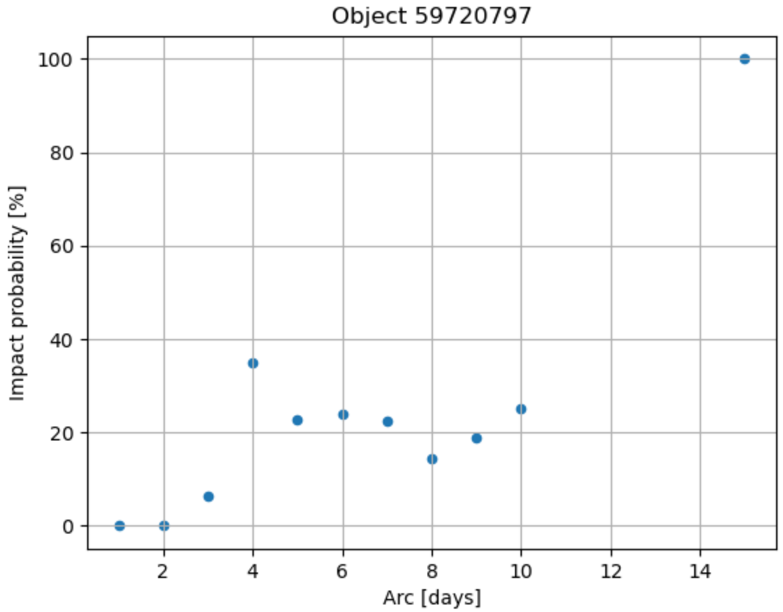
Time Dependency Of Orbit Convergence

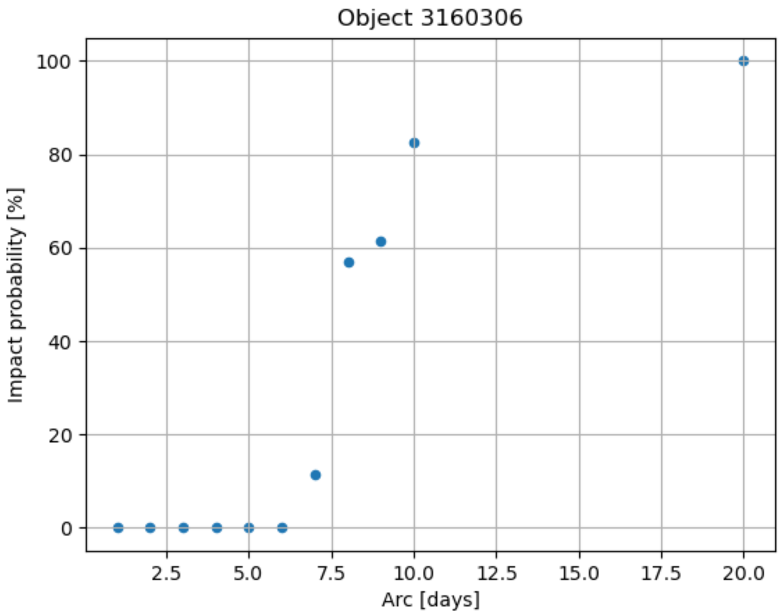
Can NEOMIR data alone distinguish if an NEO is on impact course?

We fit the orbit using the entire temporal arc for which the object remains observable by NEOMIR

- Sample of 100 objects → 23 of these have an arc between 0 and 5 days



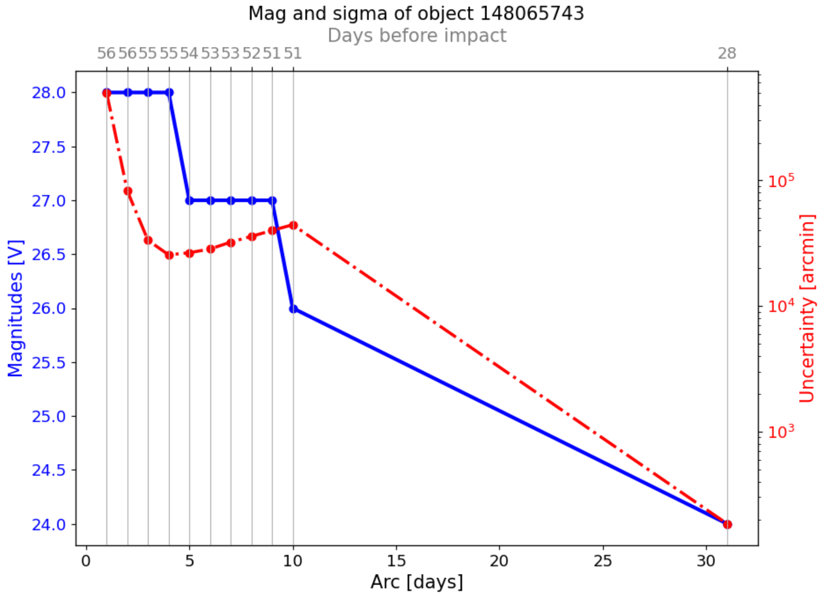


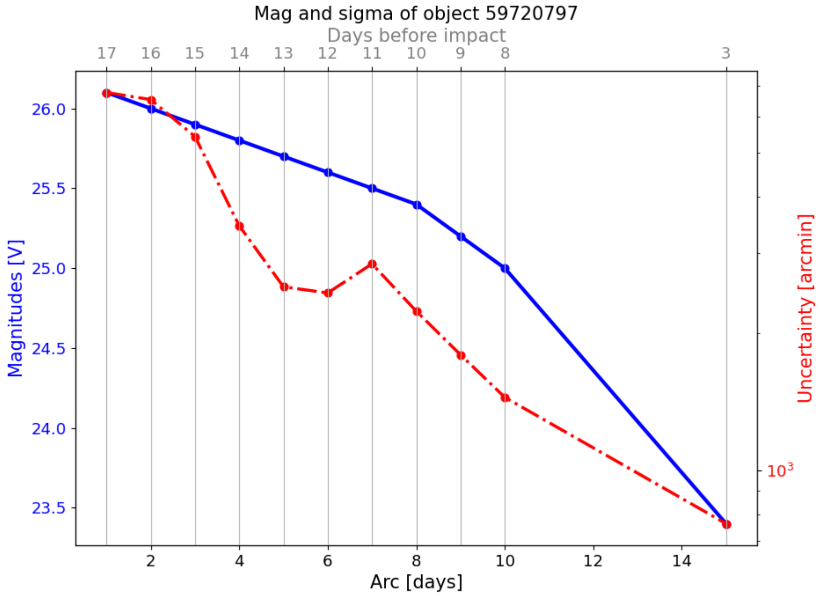


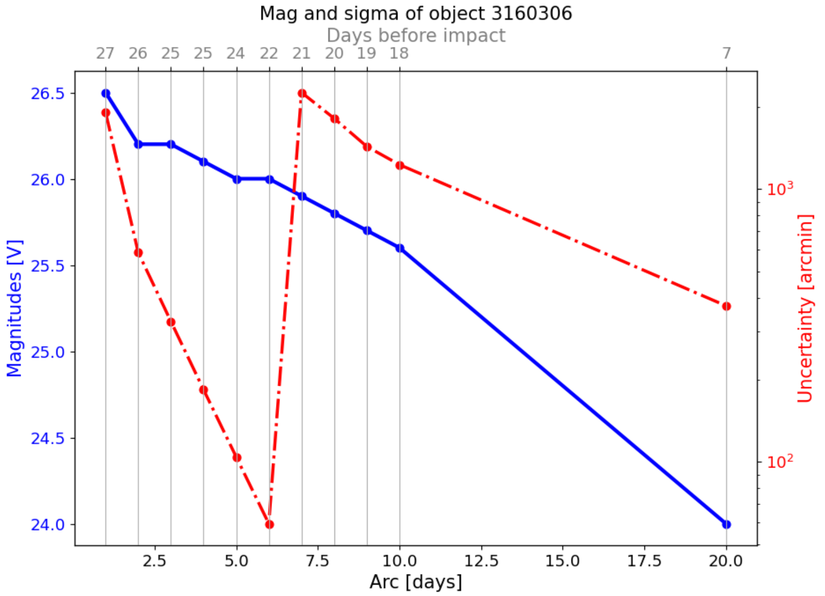
N.B.: in this case, “detected” means its impact probability is > 0%

Magnitude & Uncertainty Evolution

Evolution of magnitude and uncertainty of geocentric ephemerides (calculated from the obtained orbital fit) reported for the last day for which NEOMIR observed the object.





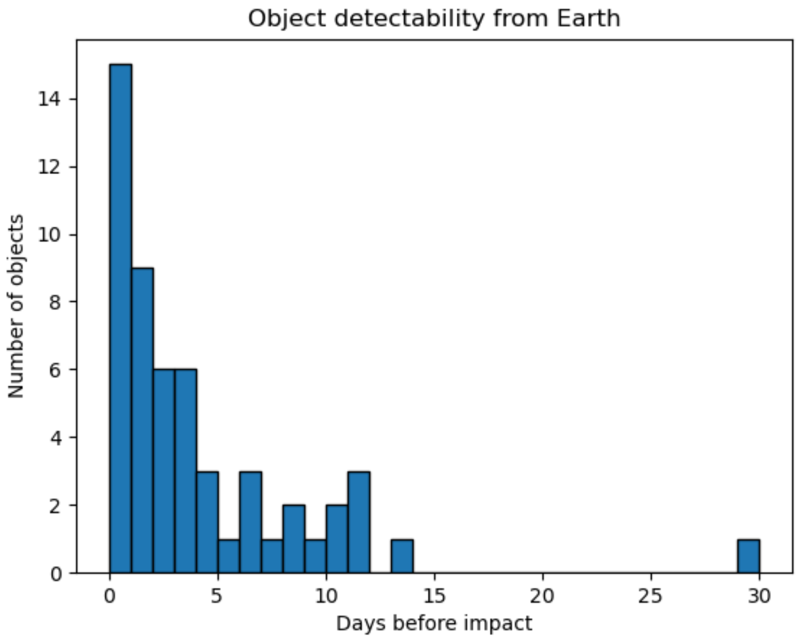


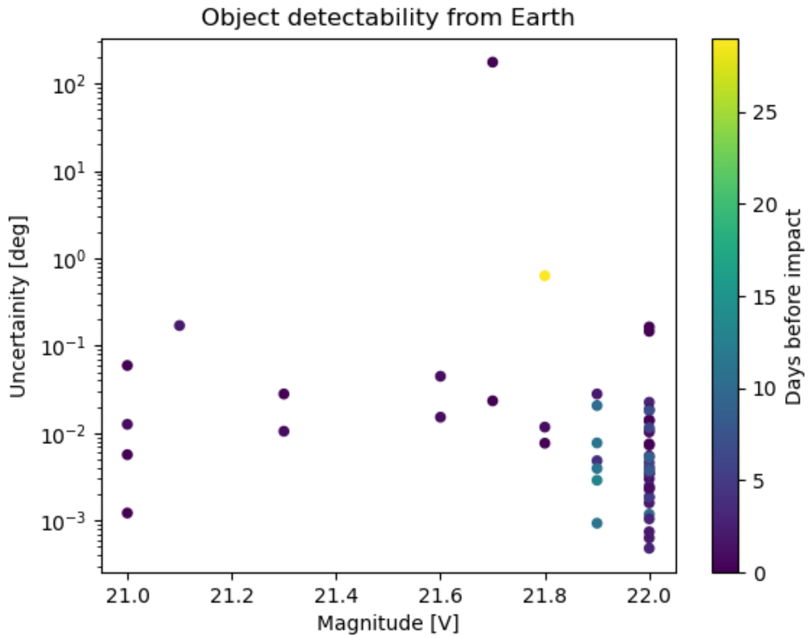
Is the object going to be observable from Earth? And if so, how many days before impact?

Detectability From Earth

Main challenge for Earth follow-up observations is the magnitude rather than the uncertainty

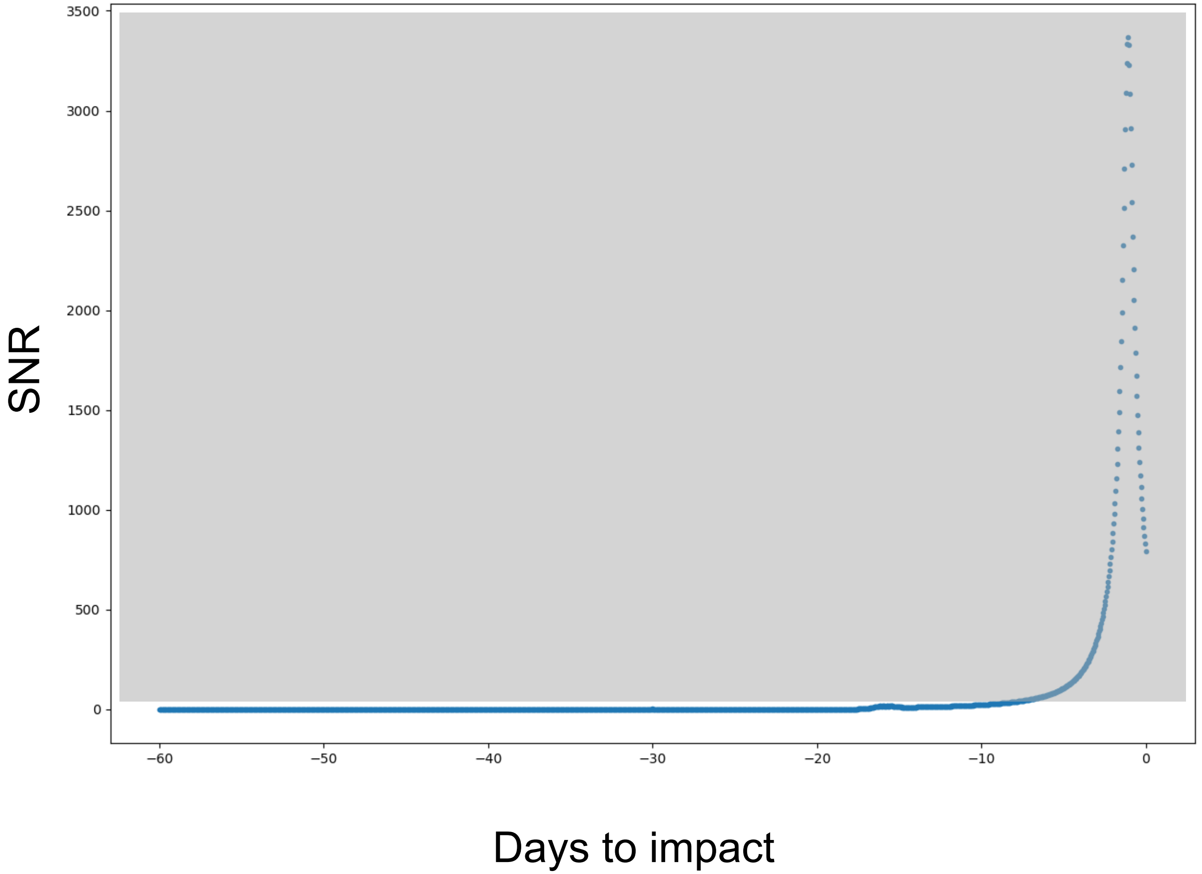
- Magnitude and ephemerides uncertainty obtained using the entire available arc
  - ➡ Uncertainties are much higher (up to tens of deg) using shorter arcs
- In this preliminary analysis, we assumed detectability only for $mag_V \leq 22$
  - ➡ 57% objects can be observed from Earth

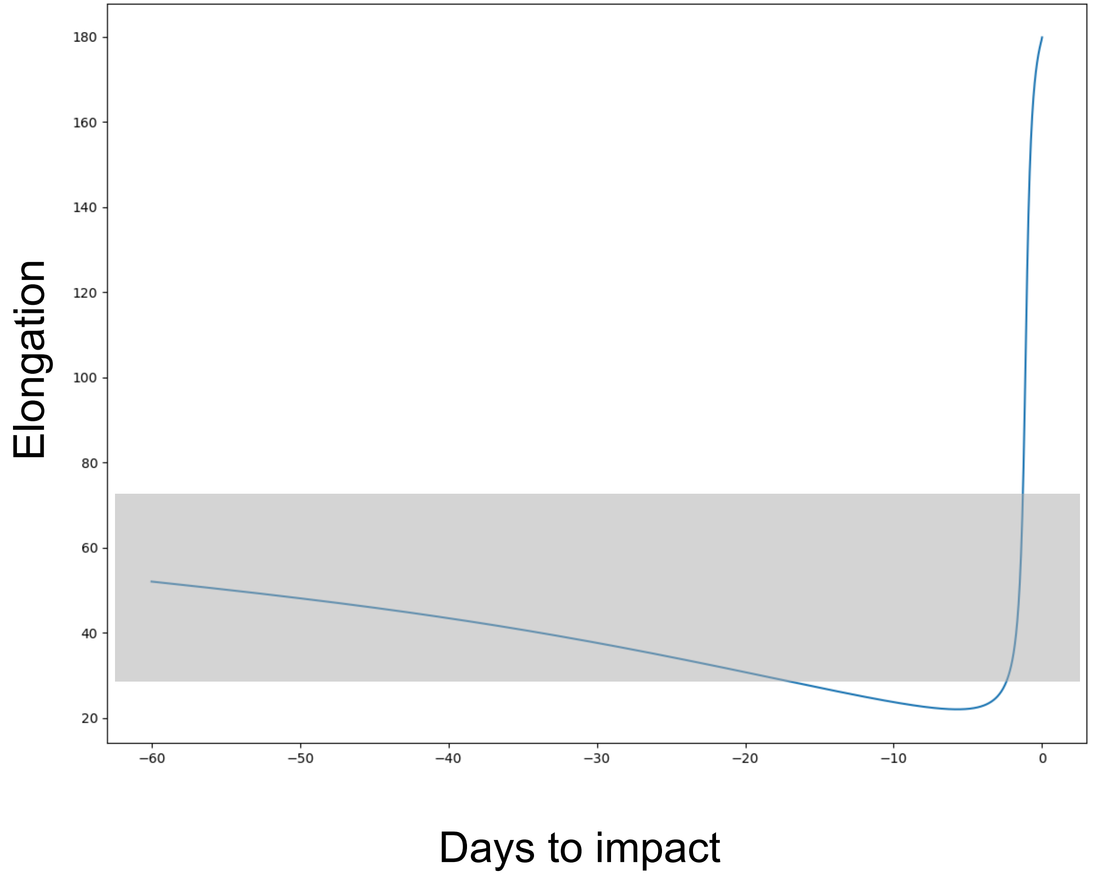




Could We Have Detected Chelyabinsk?

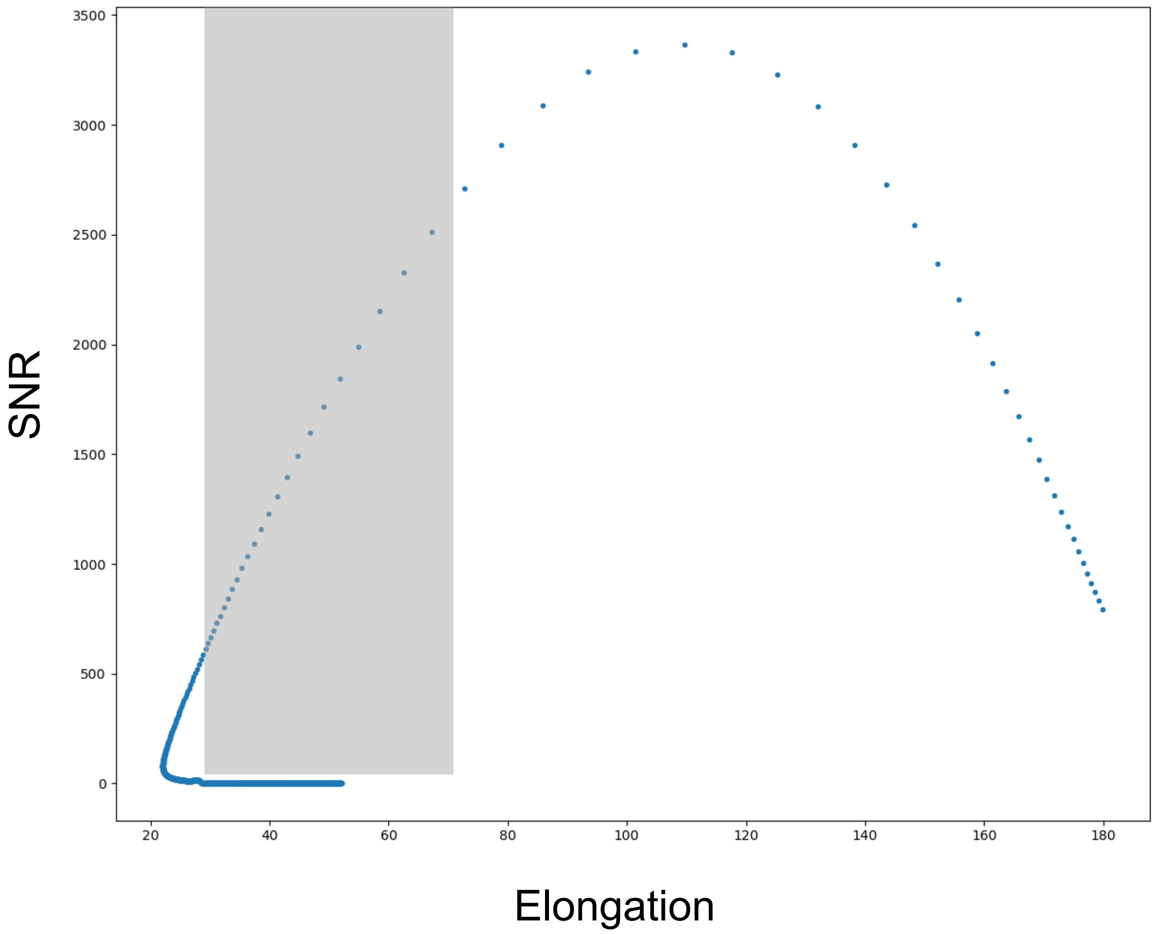
Shaded area: NEOMIR “visibility” zone

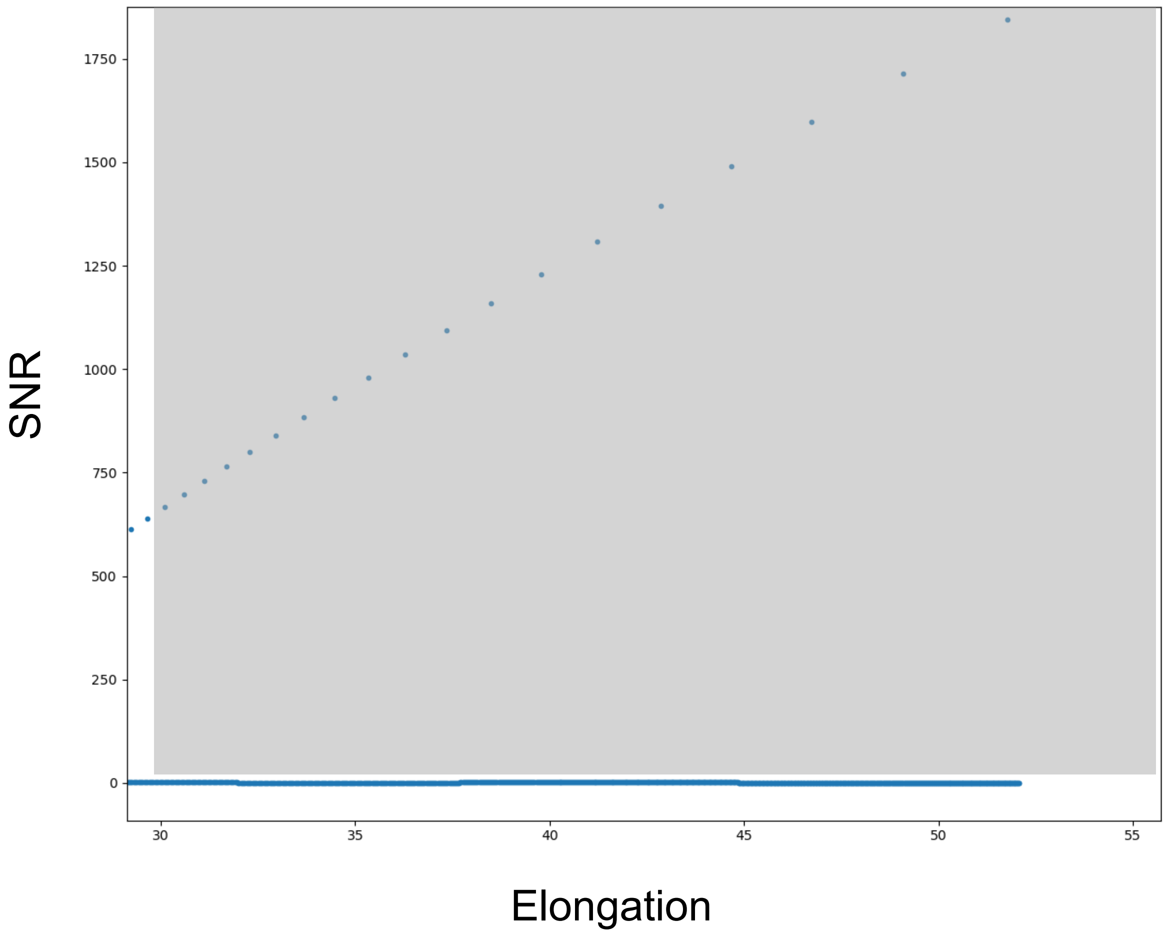




Chelyabinsk - Elongation vs SNR

Shaded area: NEOMIR “visibility” zone

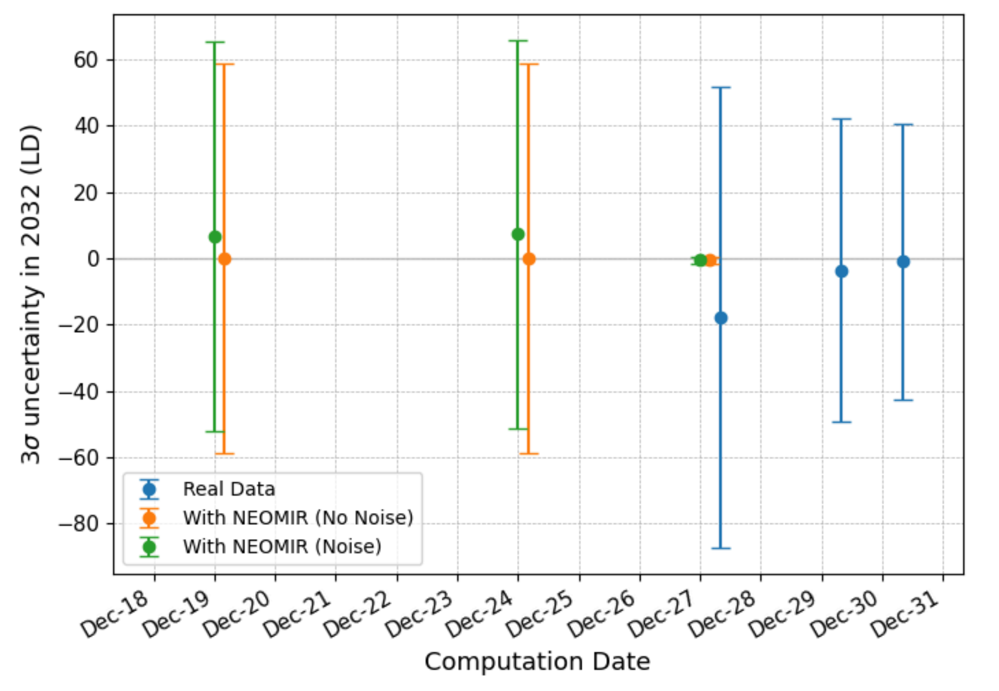


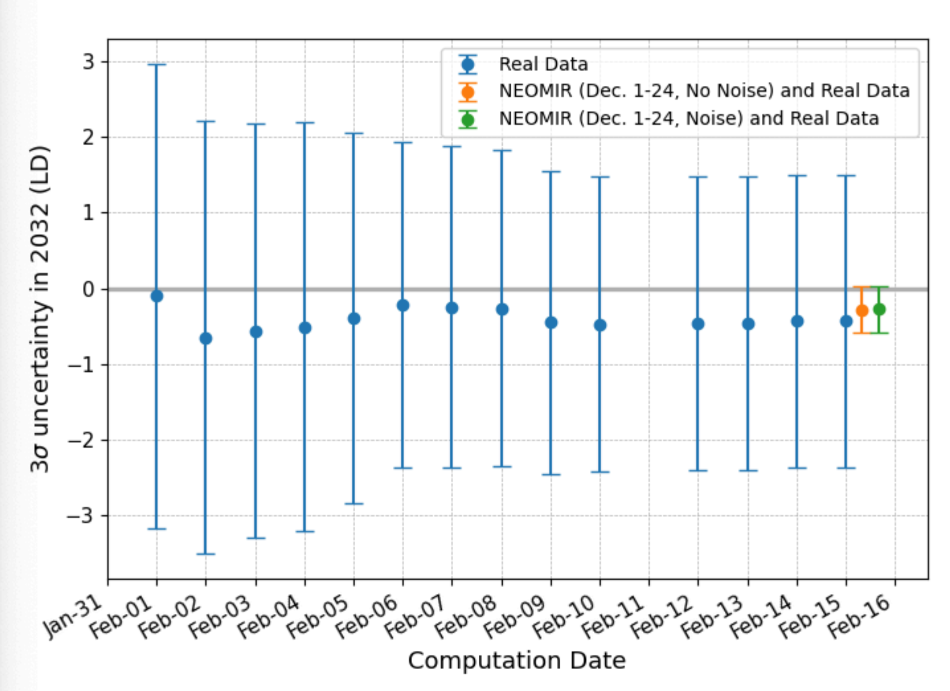


Could We Have Detected 2024 YR4?

NEOMIR would have detected 2024 YR4 about 1 month before the actual discovery

- Combining with ground-based observations → much lower astrometric uncertainties
- Plus, enough warning time to organise characterisation campaigns, e.g. radar observations!

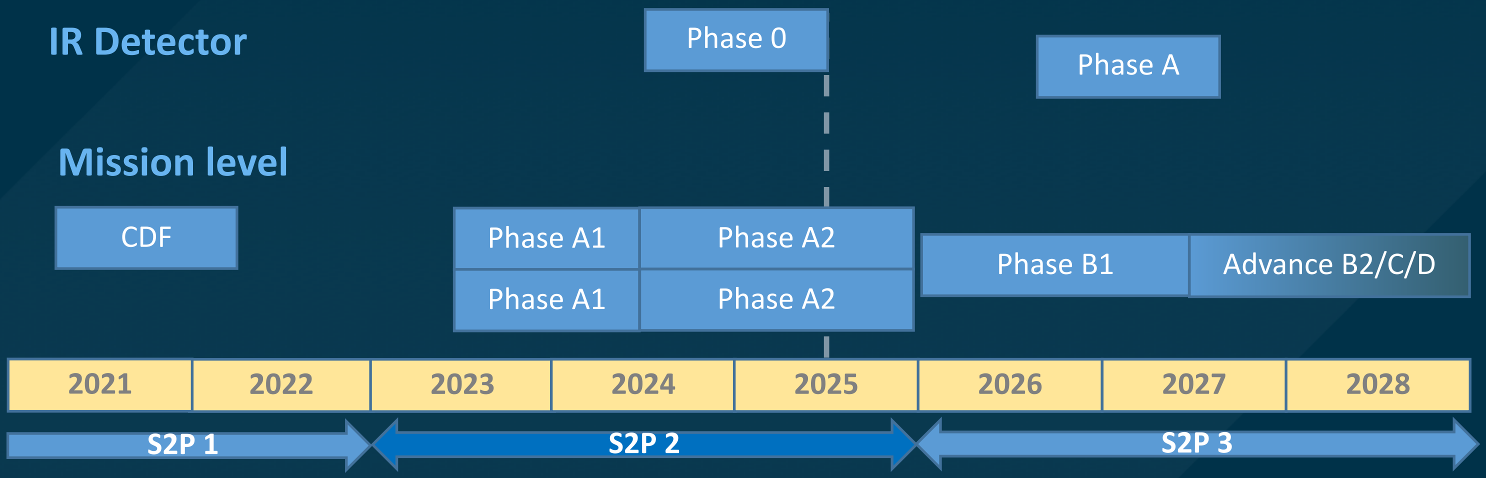




NEOMIR Roadmap

IR Detector development:

- Q2/2024: started Phase 0 study
- 2026: start Phase A



Mission level studies (funds secured until B1 included):

- 2021: ESA internal study
- 2023: 2x Phase A1 studies + SAG creation
- 2024: 2x Phase A2 studies on-going + SAG support continuation
- 2026: start of Phase B1 study (“mission definition” phase)
- 2027+: B2/C/D/E (mission adoption, operations, etc.)

Conclusions

ESA is continuing the study for a space-based infrared mission for NEO detection, characterisation and early warning: NEOMIR. It is a cryogenic mission working in thermal infrared (6-10 μm) focused on detecting smaller potential impactors. Funds are secured for up to phase B1.

Preliminary sims show that:

- it has ~92% probability of detecting impactors of 35 m diameter coming from the Sun direction, allowing on average 3 weeks' warning time
- Of these, it can determine the orbit of ~75% of the detected ones, without any follow-up needed
- Follow-up can be carried out for 57% of the objects, assuming a pessimistic limiting magnitude of 22

Further analyses are required, especially w.r.t.:

- IR detector development is required for a fully European S/C
- Survey and observing strategies