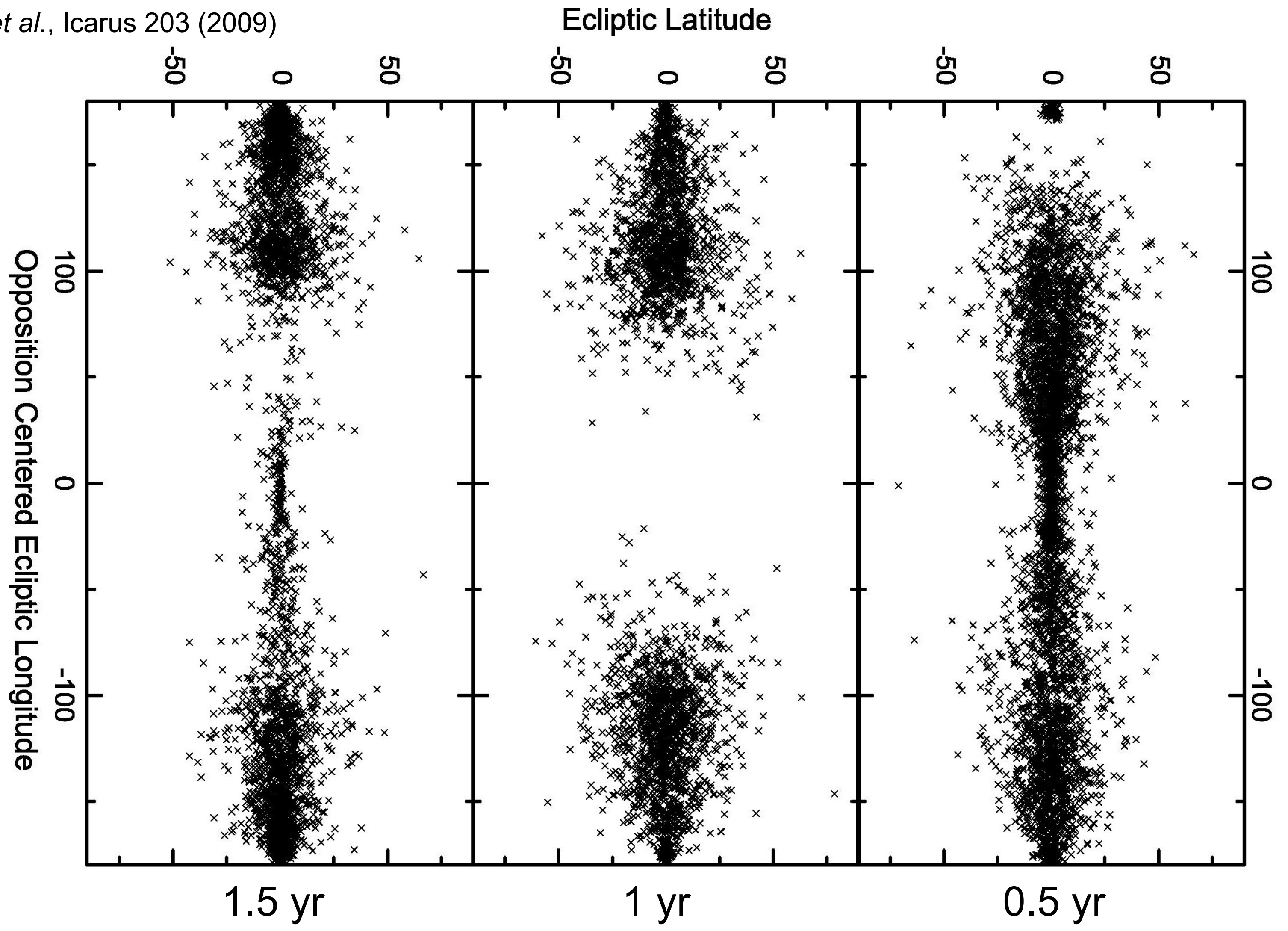
NEOMIR: detecting impactors in space

Luca Conversi

NEOMIR Study Scientist

Impactor distribution - 1

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

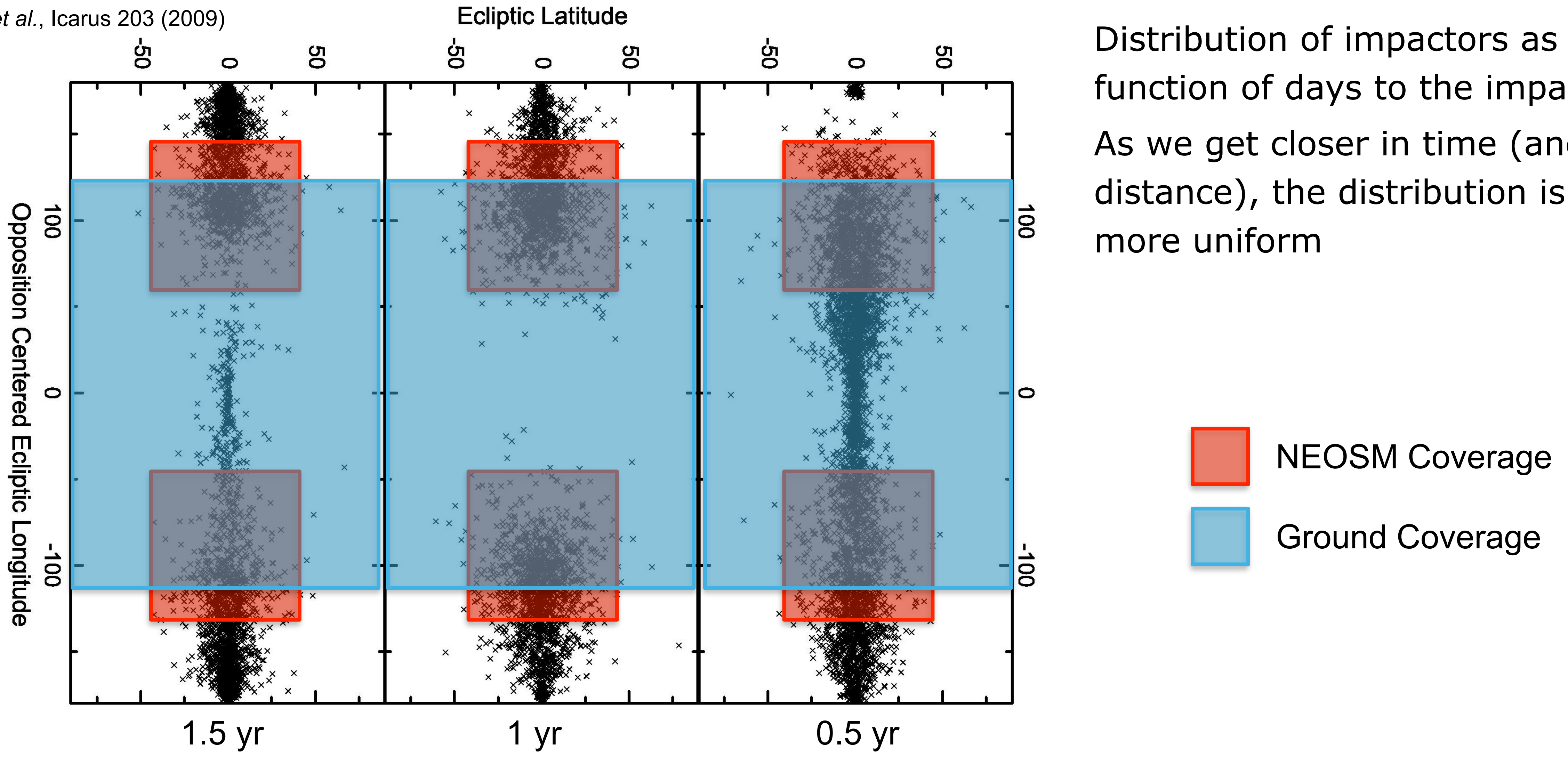


Distribution of impactors as a function of days to the impact.

As we get closer in time (and distance), the distribution is more uniform

Impactor distribution - 1

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

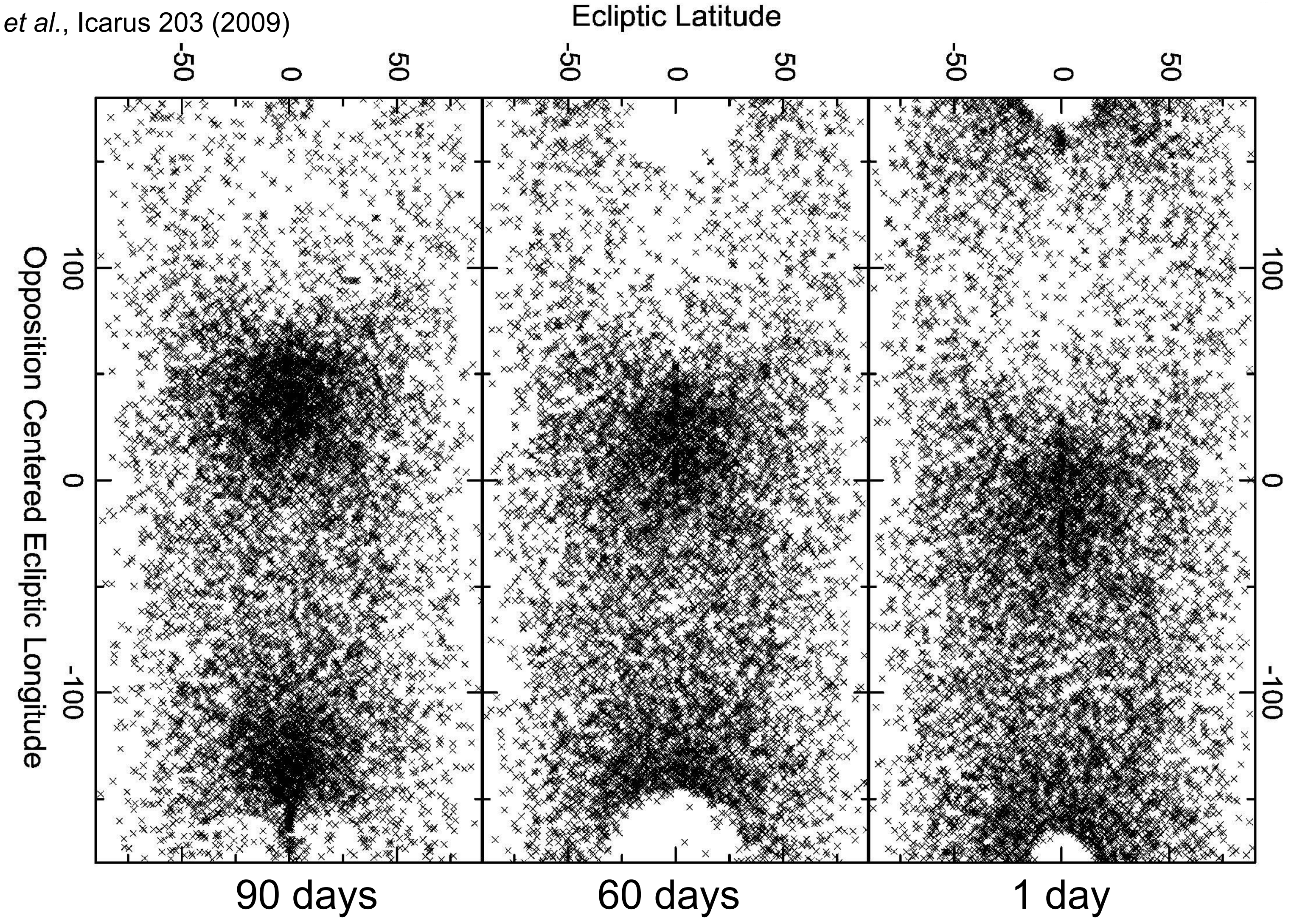


Distribution of impactors as a function of days to the impact.

As we get closer in time (and distance), the distribution is more uniform

Impactor distribution - 2

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

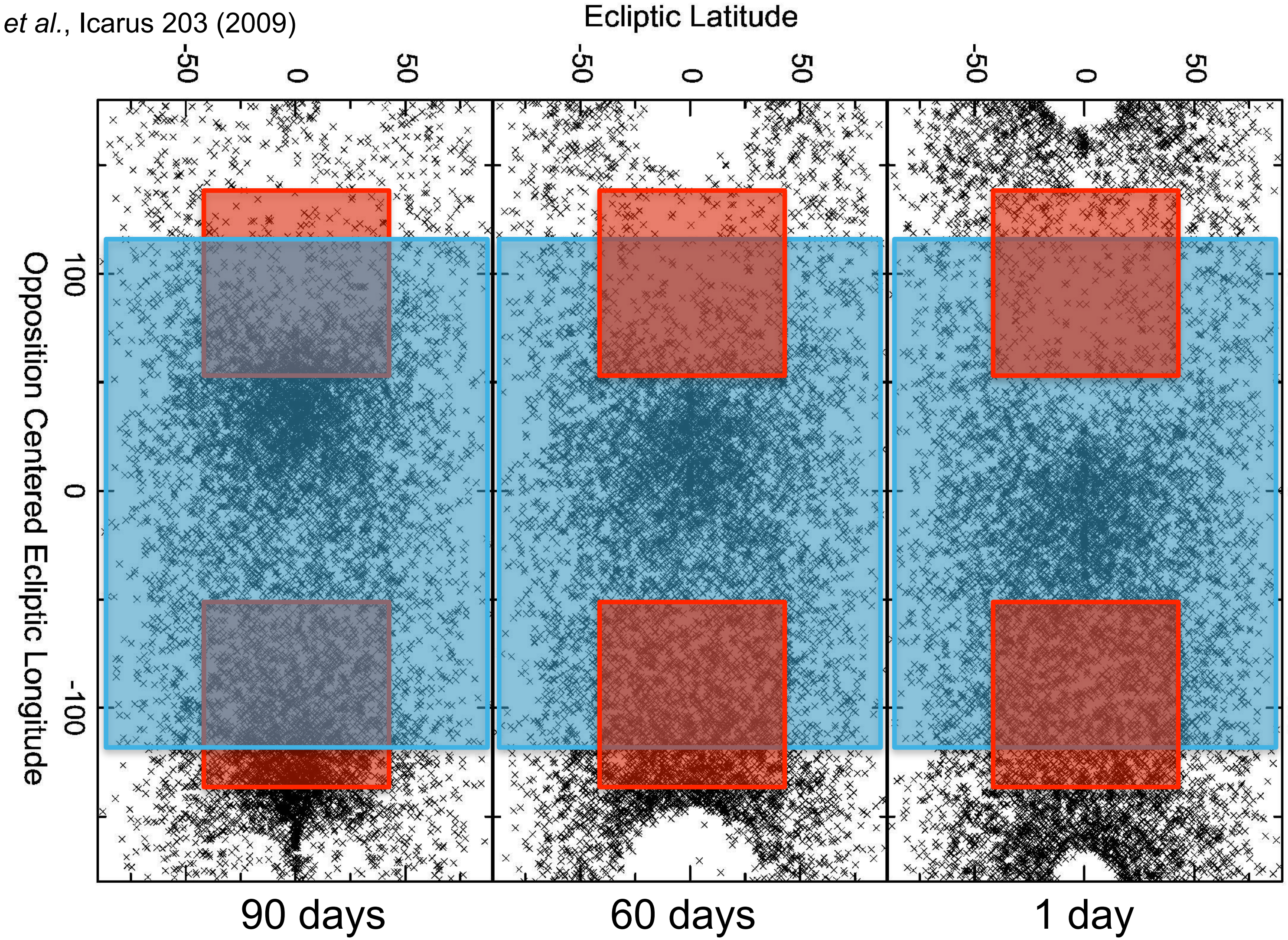


NEOSM aims at finding NEOs when they are *distant*.

Limitation: it won't be complete below 150 m

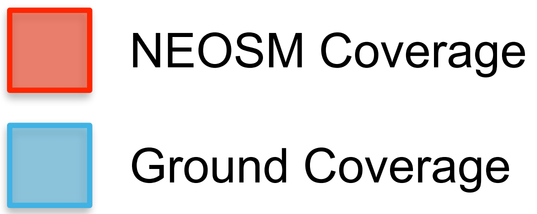
Impactor distribution - 2

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

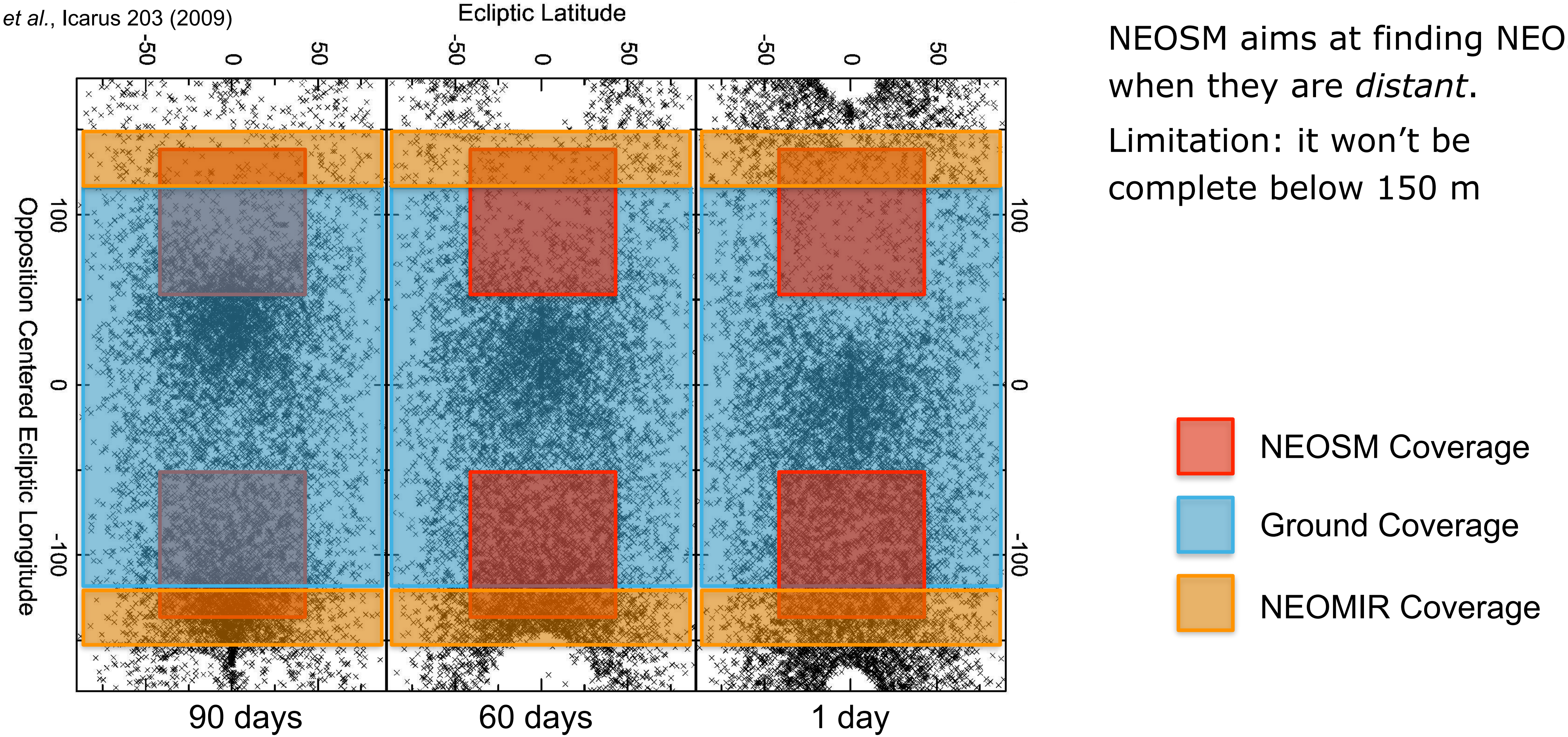


NEOSM aims at finding NEOs when they are *distant*.

Limitation: it won't be complete below 150 m



Impactor distribution - 2



NEOSM aims at finding NEOs when they are *distant*.

Limitation: it won't be complete below 150 m

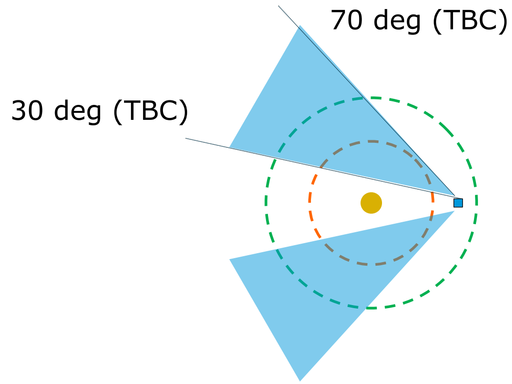
NEOMIR in a nutshell: mission design

NEOMIR was studied for at ESA's Concurrent Design Facility in Oct. 2021

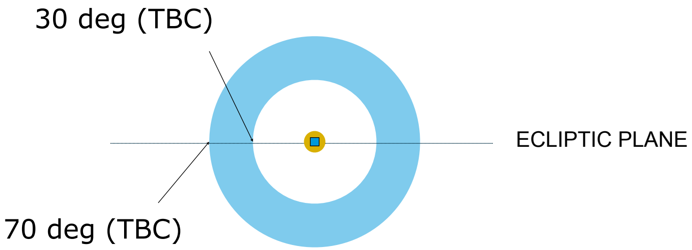
Outcome of the study regarding the mission design:

- Launch with Ariane 6-2 (single carrier)
- Observatory at L1
- Cryo-cooled IR telescope
- Observations via multiple short exposures, stacked and repeated every 3.5 – 6 h (TBC) to detect NEO motion
- Daily downlinks of high data payload volumes (expected to be ~6x NEOSM)
- Launch wet mass: ~2000 kg
- Not earlier than 2030

View onto ecliptic plane



View through ecliptic plane



NEOMIR in a nutshell: payload design

Optics

- Tilted TMA: 3 mirrors; M2 tip/tilt/focus; M1 is 55 cm
- FoV and resolution similar to NEOSM
  - Pixel scale = 3” ; FoV = 1.7º * 7º

Focal Plane

- 2 Focal Plane Units (FPU): MWIR, LWIR
- Beam splitter
- Cold Front End Electronics (CFEE)

Detectors

- Develop IR sensor capability in Europe
- Alternatively, use Teledyne HxRG

Thermal

- Combination of passive and active cooling to reach 40 K

Impactors as seen from L1

How would the Chelyabinsk event (a ~20 m object) be seen from L1 at 45º elongation?

- It would have crossed the "ring" ~9 weeks before the impact, at 0.3 au from the Earth.
- At the time of crossing, the object's angular speed, as seen from Earth, was 1.1"/min.
- Not detectable with any ground-based telescope (visual magnitude >27) but it could be detected by an IR mission in L1 with right cadence and sensitivity.

We also analysed other known impactors as if they came from low elongation:

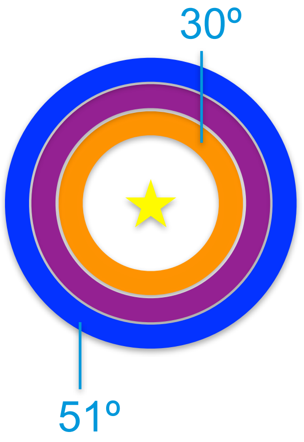
Asteroid	Time of crossing 45º from L1	Distance of the crossing from L1	Speed when crossing	Mag V
Chelyabinsk	60 days	0.3 au	1.1"/min	>27
2008 TC3	17 days	0.058 au	2.02"/min	25.5
2014 AA	5 days	0.004 au	60"/min	20
2018 LA	0 days	0.0 au	>10"/min	21.5 @ 3 days before impact
2019 MO	0 days	0.0 au	>10"/min	21.5 @ 3 days before impact

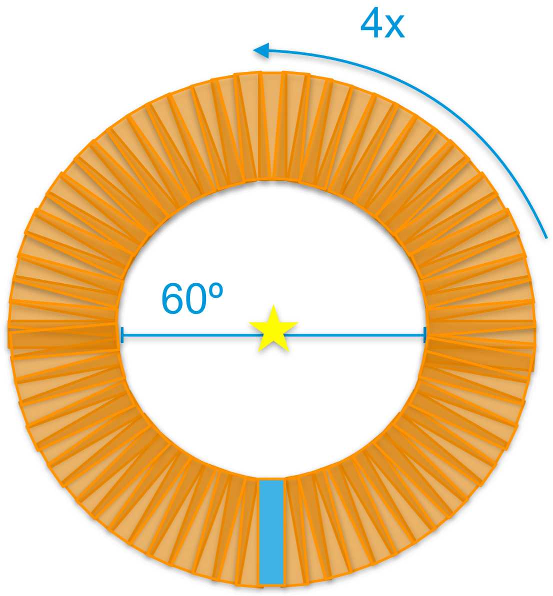
Survey strategy

In current baseline, we want max 60 s exposures per visit/field (3x less than our assumption on NEO Surveyor) such that:

- NEOs < 3″/min will not trail. Easy to detect NEOs up to 10″/min.
- A 3″/min NEO will cross the 7º FoV in 140 h, a 10″/min NEO will need 42 h: this gives an indication of the revisit time between tracklets, so as to avoid missing any.

Ring Band	Number of fields	Time required for 4 visits (in hours)
30º - 37º	127	11.3
37º - 44º	147	13.1
44º - 51º	165	14.6
30º - 51º	439	39.0





Simulating impactors detection

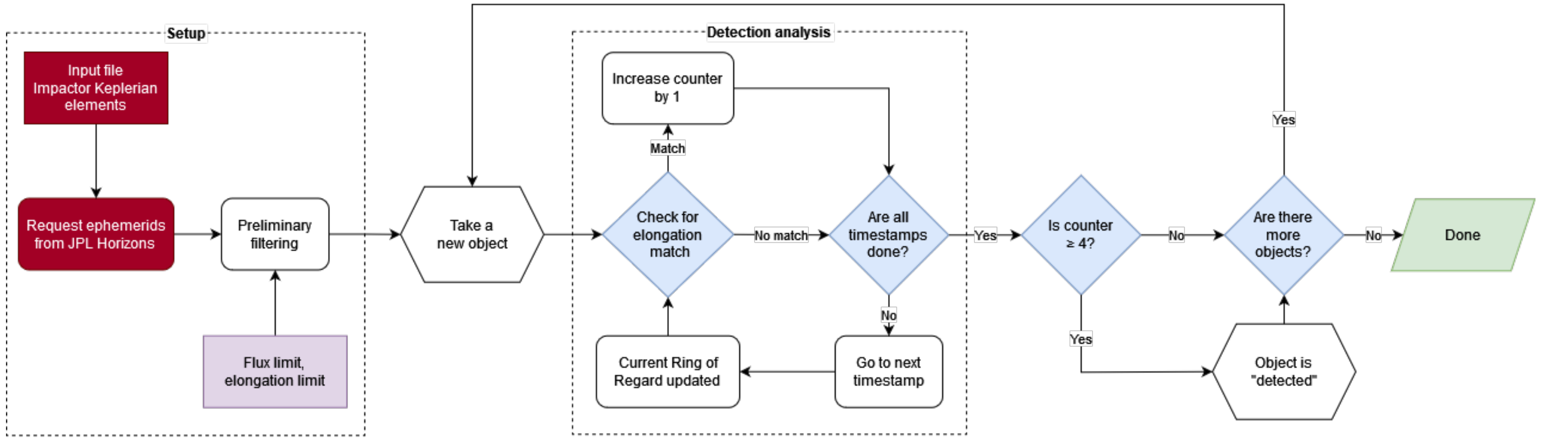
S. Chesley provided a list of 3000 impactors (see Chesley *et al.*, IEEE Aerospace Conference 2019)

- The list is representative in terms of orbit "distribution", not in frequency of the events
- We assume all objects to be H-mag = 25 (i.e. typically 35 m in diameter)

We generated ephemerides for 1 year before impact and checked for every impactor if it was:

- bright enough (flux ≥ 150 μJy);
- crossing NEOMIR's field of regard (30º ≤ SAA ≤ 45º).

Of the 3000 impactors,
700 passed both conditions.



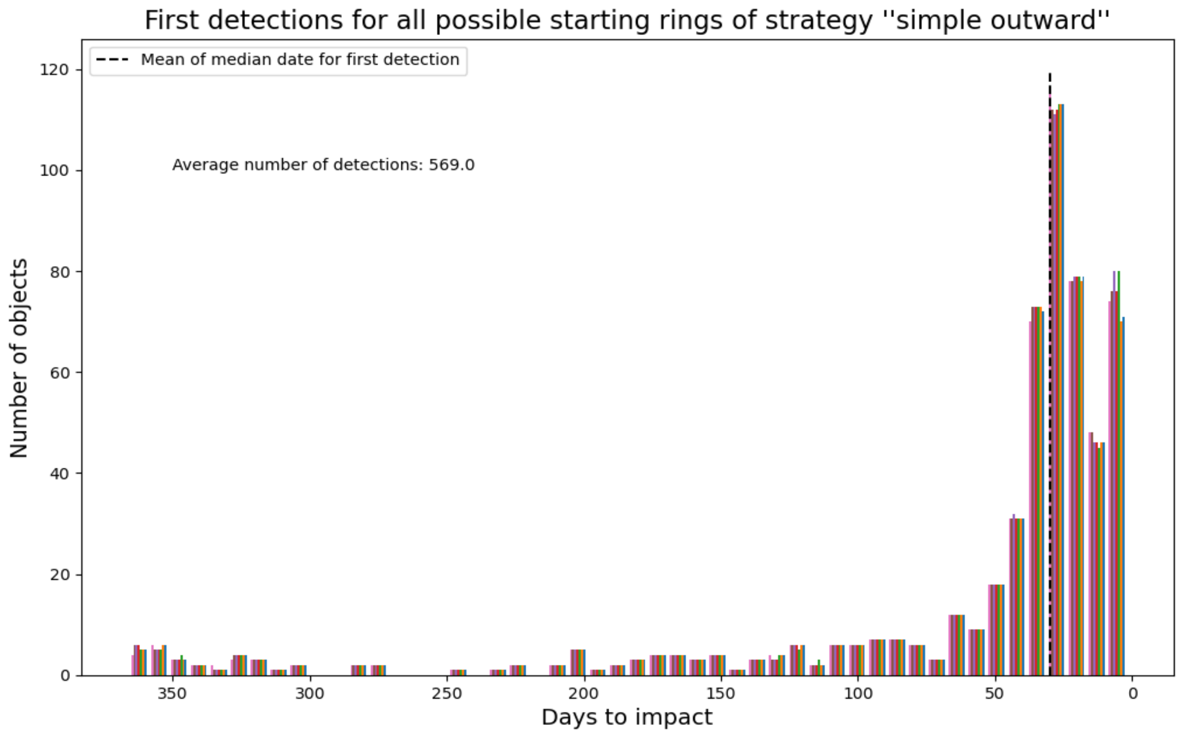
Results

Finally, we tested different survey strategies and considered an NEO detected if it was passing the previous 2 conditions for a least 4 consecutive revisits.

If so, we noted the number of “days to impact”

Results show that:

- We were able to detect 610 objects out of 700, i.e. a 87% success rate
- Most missing NEOs are too quick (crossing field of regard faster than 4 revisits)
- On average, NEOs were discovered ~1 month before impact



Critical aspect under investigation: Zodiacal light in the IR, especially close to the Sun

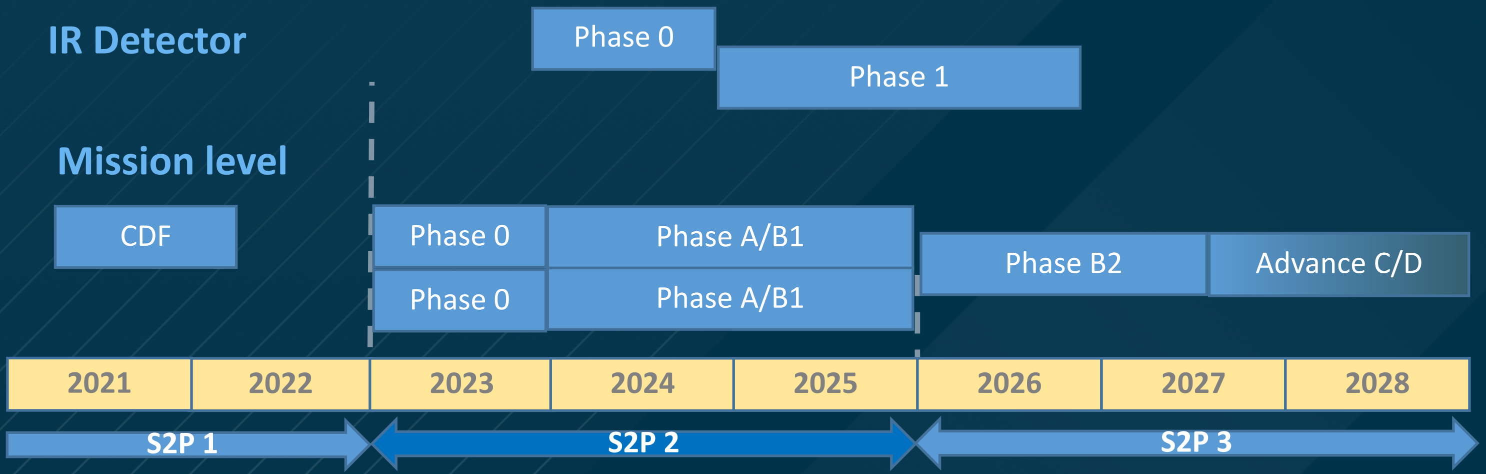
NEOMIR Roadmap

IR Detector development is required for a fully European spacecraft:

- Q3 2023: Phase 0 Study via preparatory Element
- 2025: Phase 1 Study from S2P

Mission level studies:

- 2022: contract for creation of a Science Advisory Group
- 2023: 2x Phase 0/A study from Preparatory Element
  - Contracts signed last week
- 2024: 2x Full Phase A/B1 studies
  - Funds already secured
- 2026: start of Phase B2 study in Period 3
- 2027+: Start C/D phases



Conclusions

ESA CDF studied the feasibility of a space-based infrared mission for NEO detection, characterisation and early warning: NEOMIR

The outcome of the study is that the mission is feasible and would fall into the financial envelope of a typical ESA's M-size class mission (~400M€). Funds for up to phase B1 are being secured.

Preliminary studies show that the mission would have ~87% probability of detecting an impactor as small as 35 m coming from the Sun direction, allowing on average one month's warning time.

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

- Zodiacal light in the IR, especially close to the Sun - already started within SAG
- IR detector development is required for a fully European S/C