

PRE-IMPACT DETECTION OF CHELYABINSK-TYPE OBJECTS (AND 2024 YR4) IN THE THERMAL INFRARED

We investigate the feasibility of detecting decameter-scale objects on day-side trajectories in infrared wavelengths from space, prior to their close encounters with Earth. Specifically, we examine a 20-m object on a Chelyabinsk-progenitor (ChPG) orbit (Jan/Feb 2013) and the 60-m potentially hazardous asteroid 2024 YR4 (Nov/Dec 2024 & 2032) during their respective approaches to the Earth-Moon system. Considering the solar elongation constraints of the NEO Surveyor and NEOMIR missions (both located at L1), along with a detection threshold of $100 \mu\text{Jy}$ at $8 \mu\text{m}$, we find that both telescopes would be capable of detecting the objects - hours in advance with NEO Surveyor and several days ahead with NEOMIR. We also address limiting factors such as the elevated infrared sky background due to zodiacal dust emission and the rapidly changing apparent motion of targets near Earth. Finally, we discuss the challenges associated with observing asteroids at low solar elongation and large phase angles, where we lack good-quality IR validation data.

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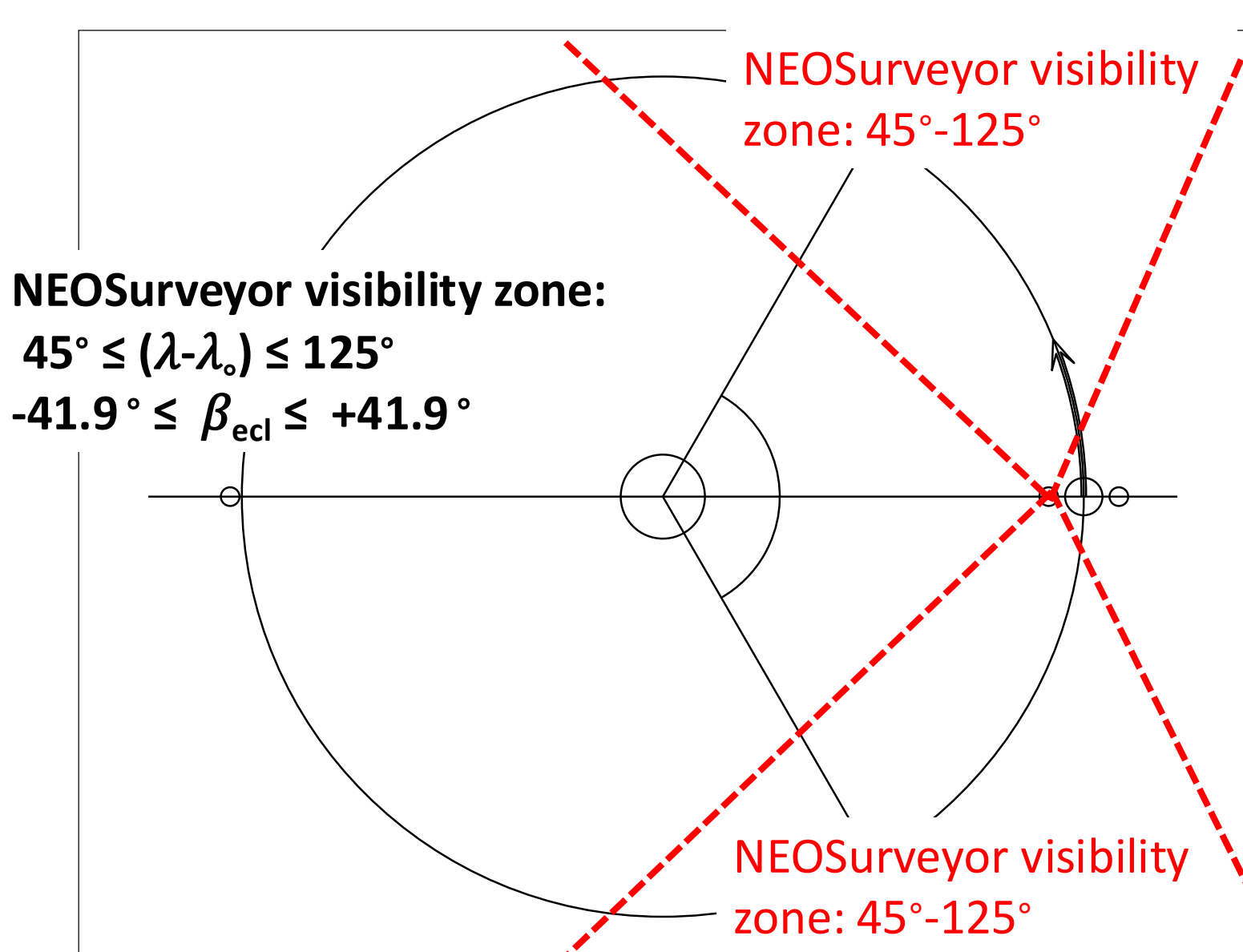
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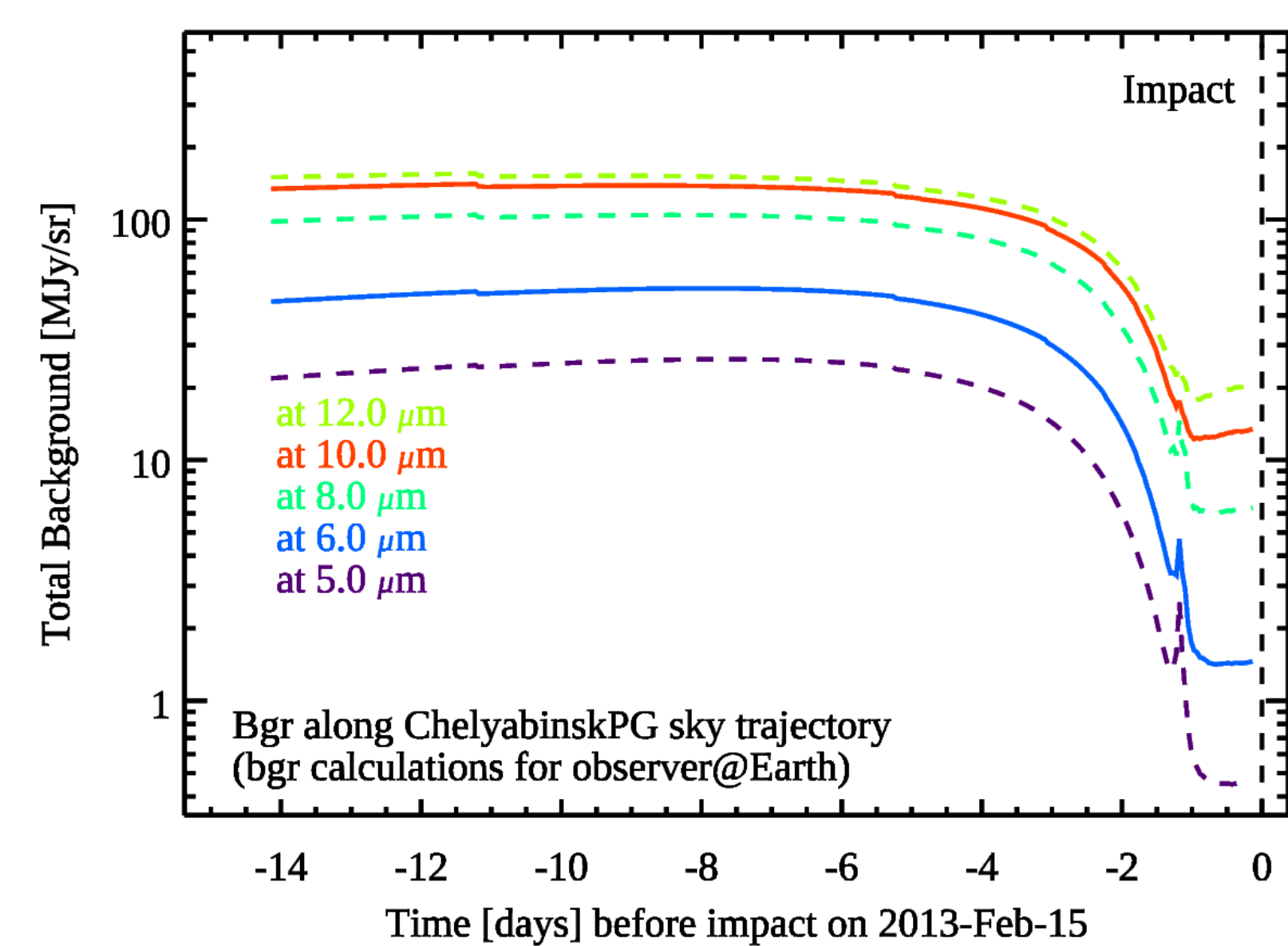
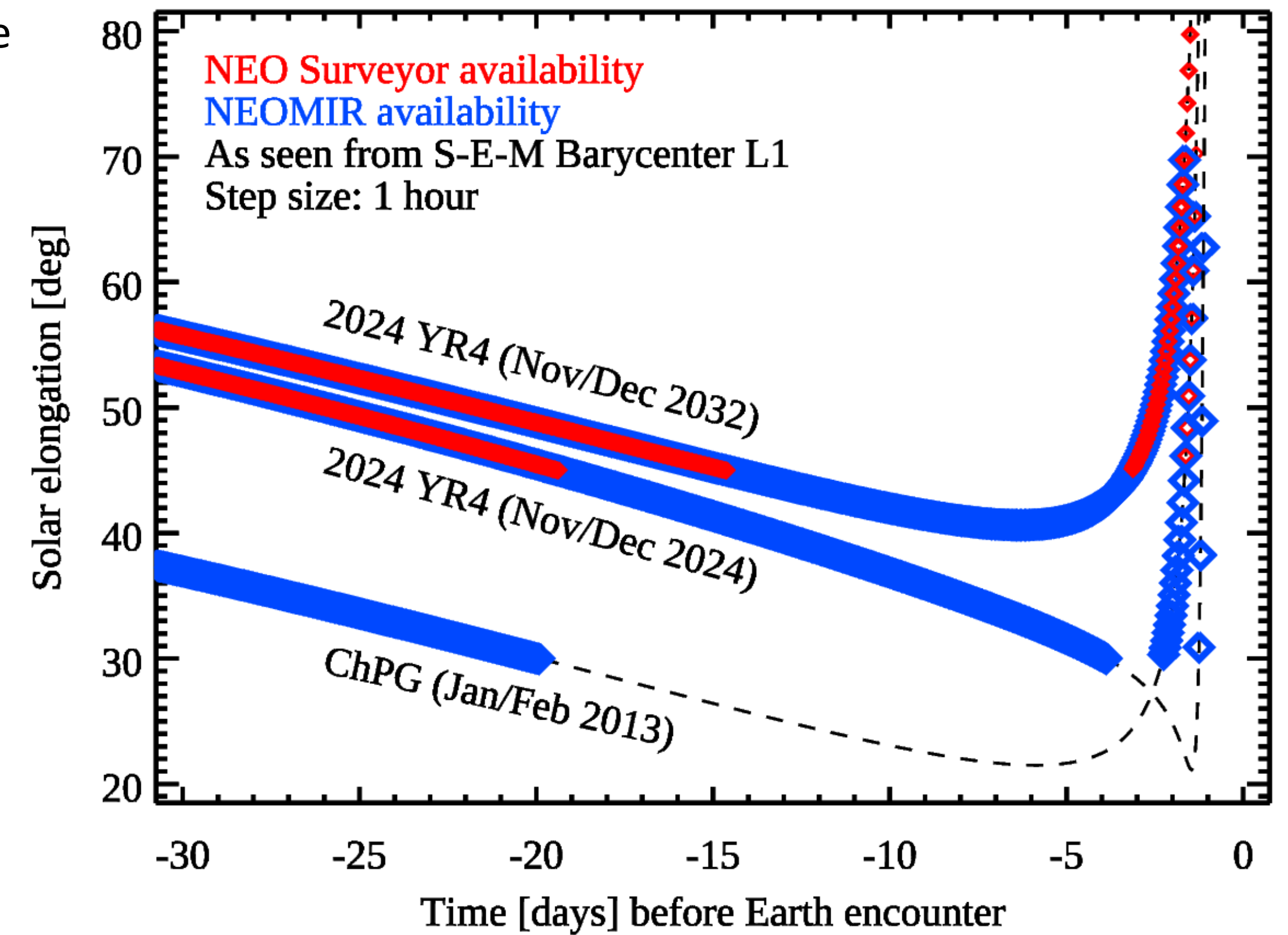
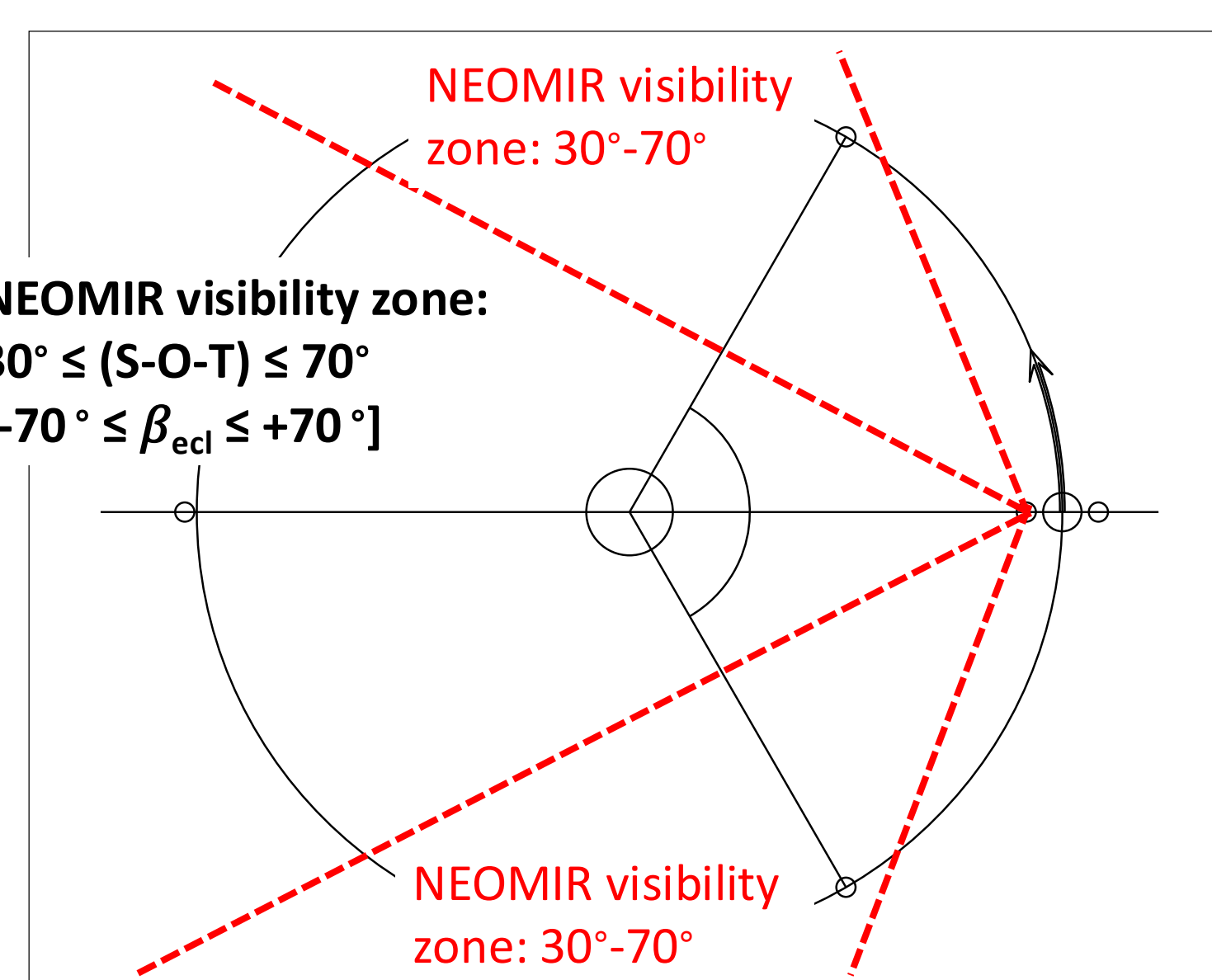
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NEO Surveyor sky visibility (from L1)



NEOMIR sky visibility (from L1)

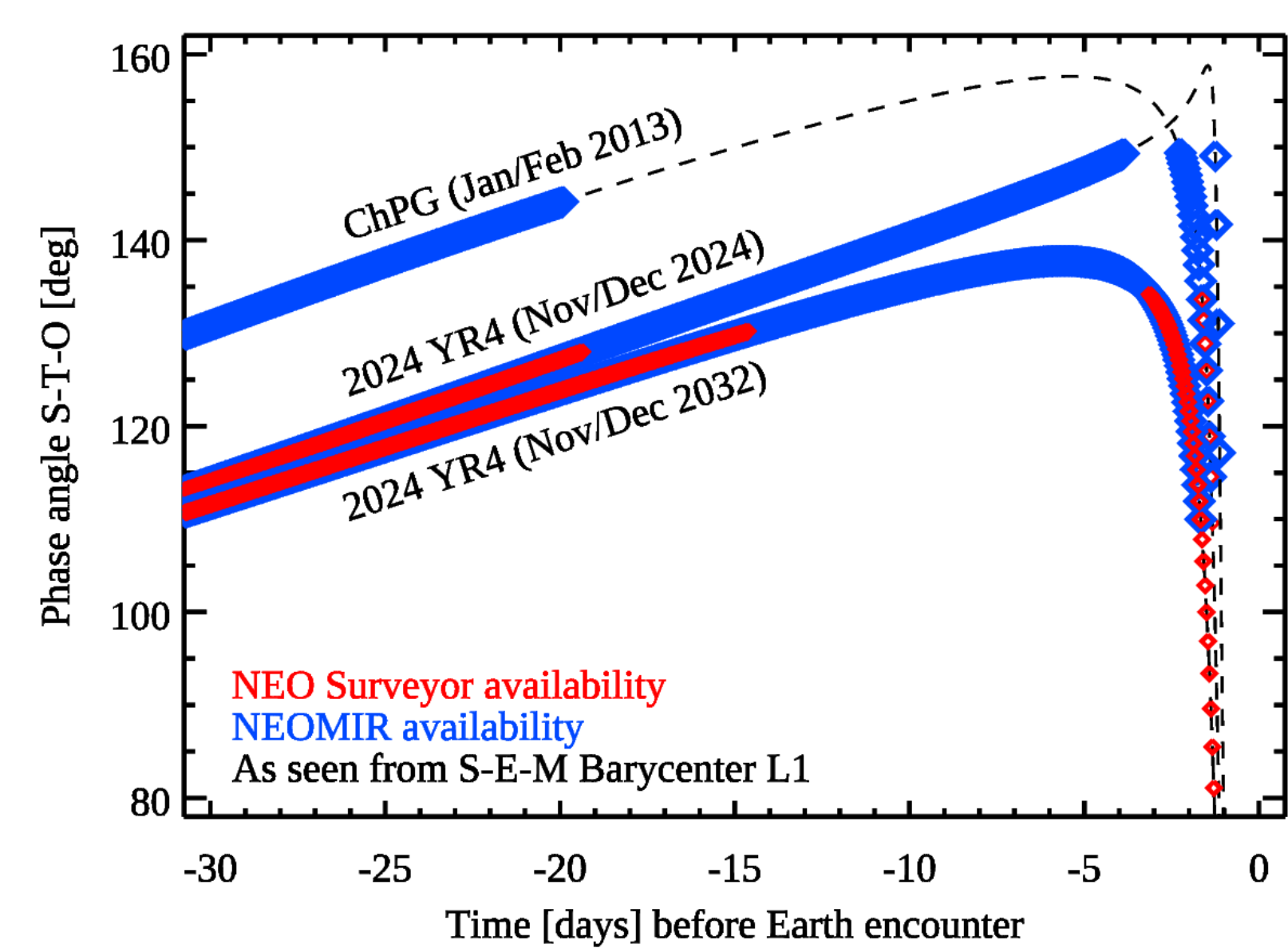
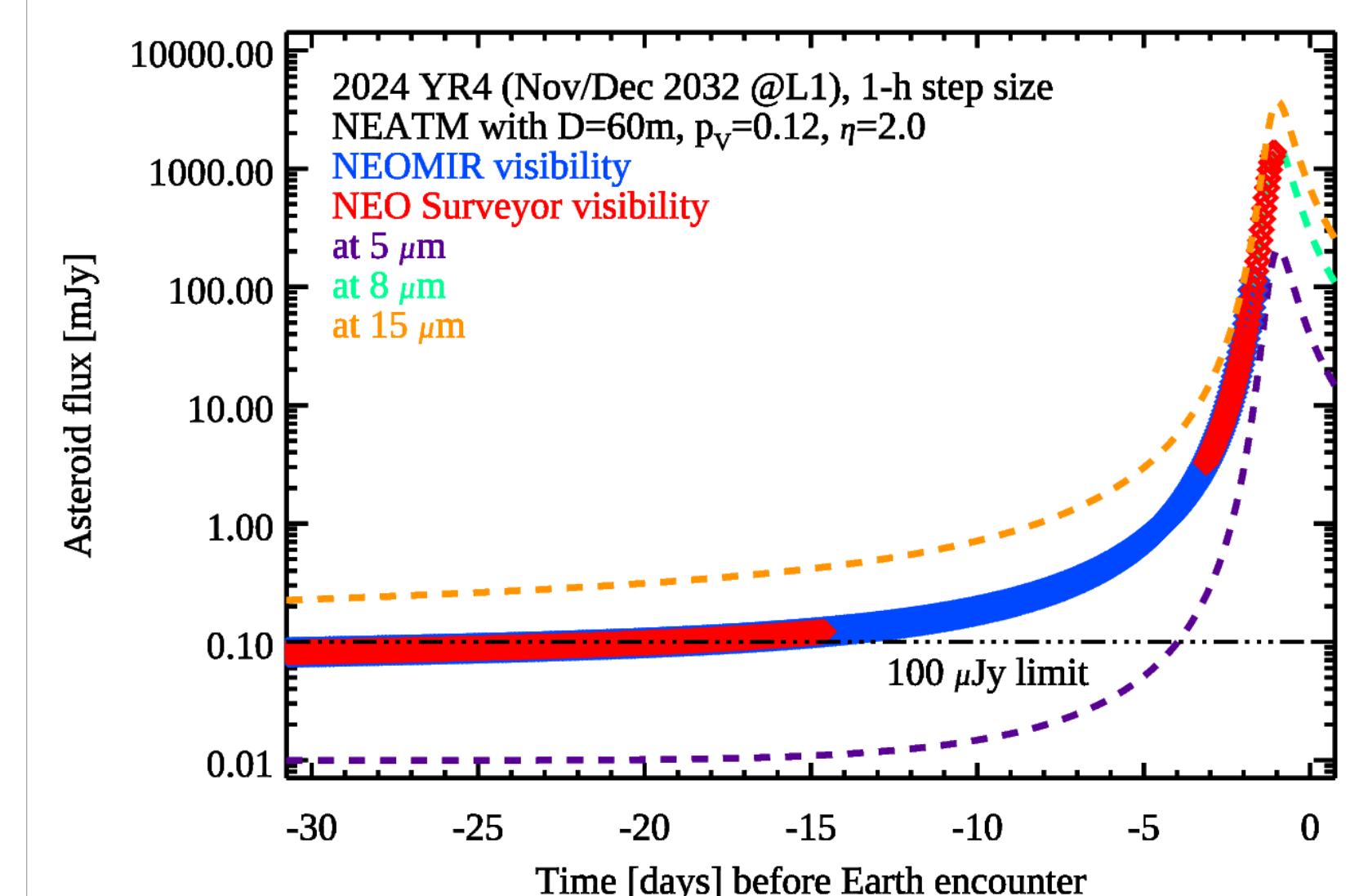
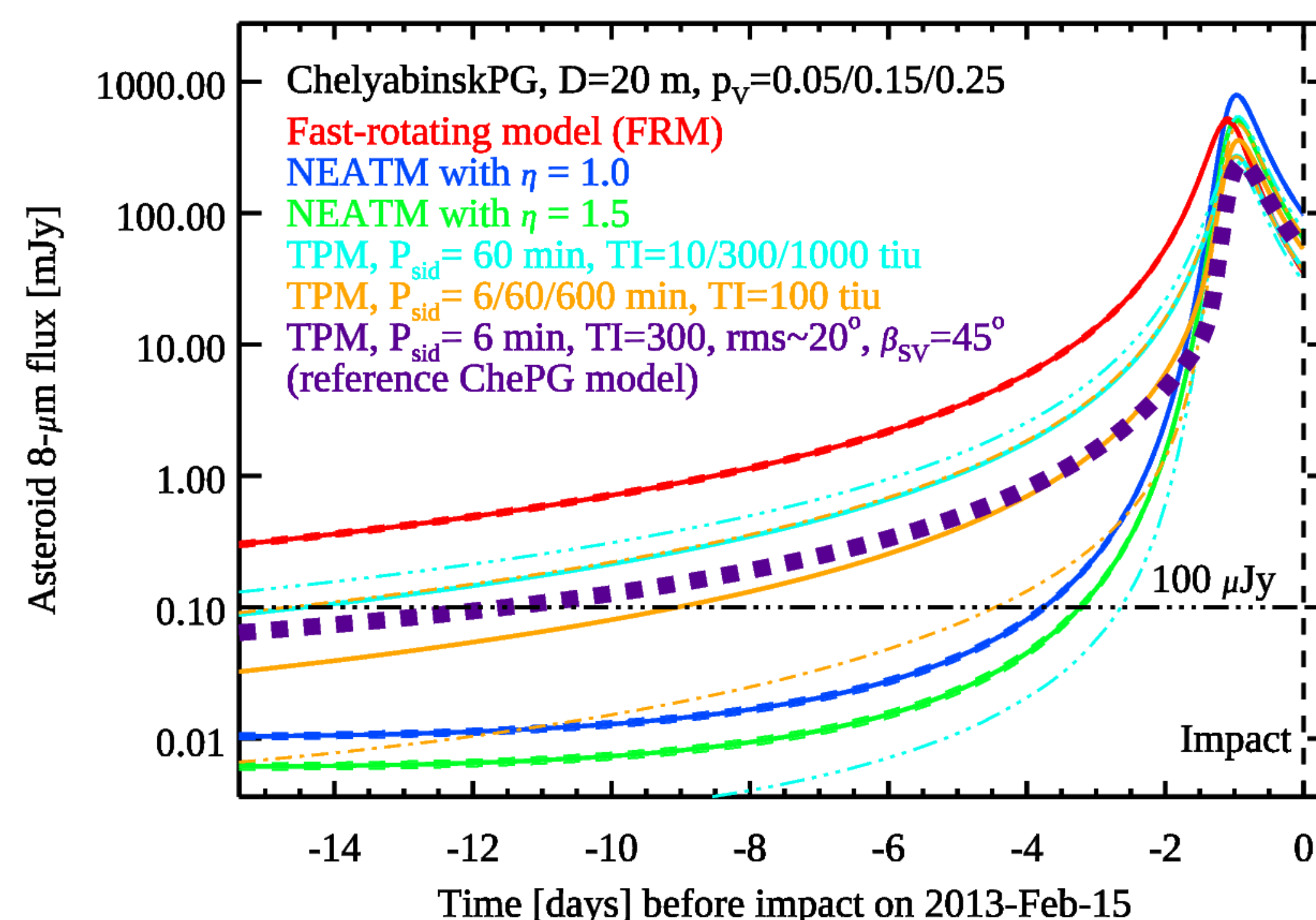
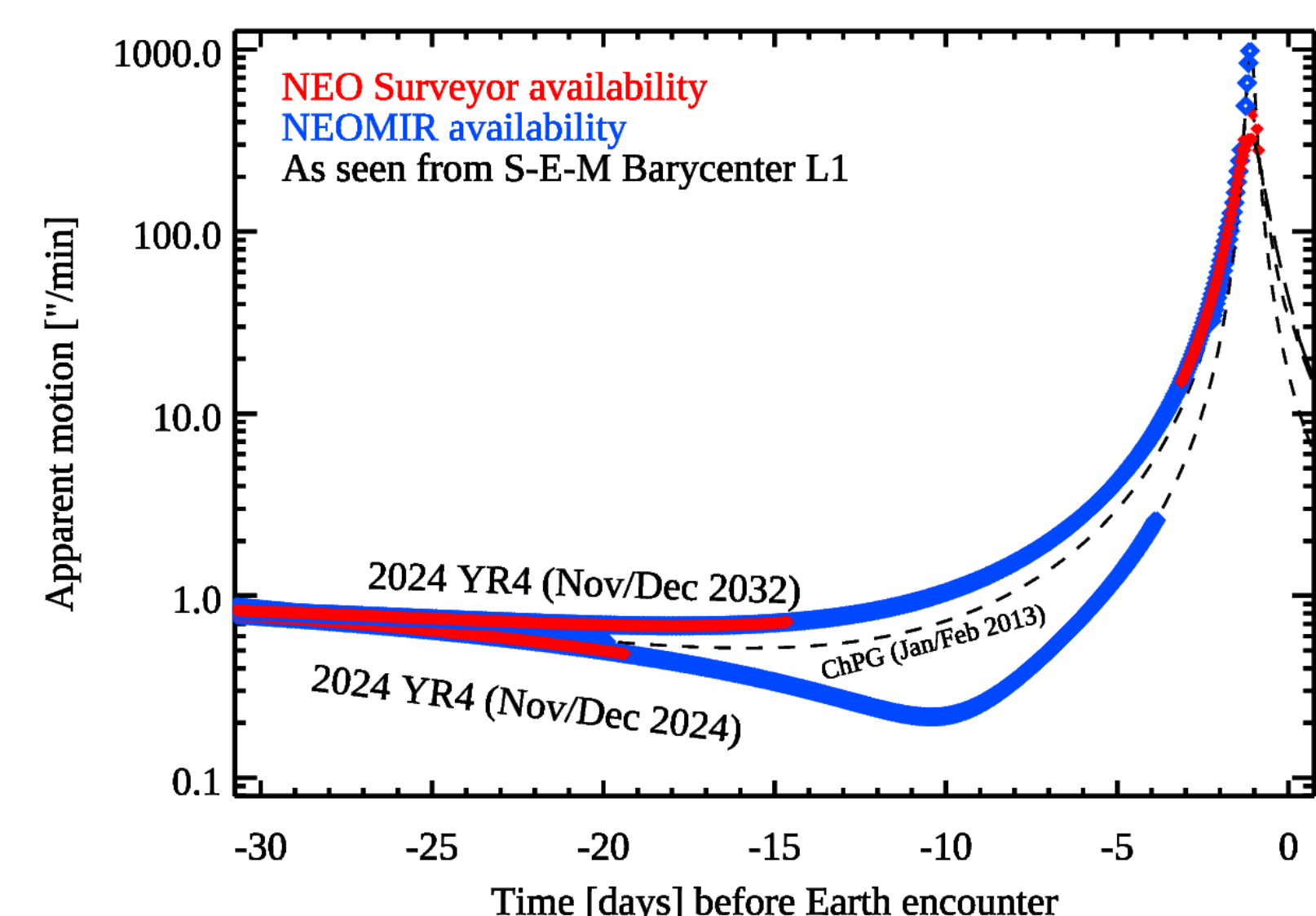


Left (top): The calculated sky background along the ChPG trajectory during the last 14 days before impact is shown for different wavelengths: $10 \mu\text{m}$ (red solid line), $6 \mu\text{m}$ (blue solid line), and $5, 8,$ and $12 \mu\text{m}$ (dashed lines). The background is dominated by zodiacal light emission. A small bump in the background appears approximately one day before impact. This increase is due to enhanced interstellar medium (ISM) emission and confusion noise from stars in the dense regions of the galactic plane.

Left (middle and bottom): The apparent motion (as seen from L1) and the phase angle of the ChPG (2013) and YR4 (2024 & 2032) during the last 30 days before Earth encounter.

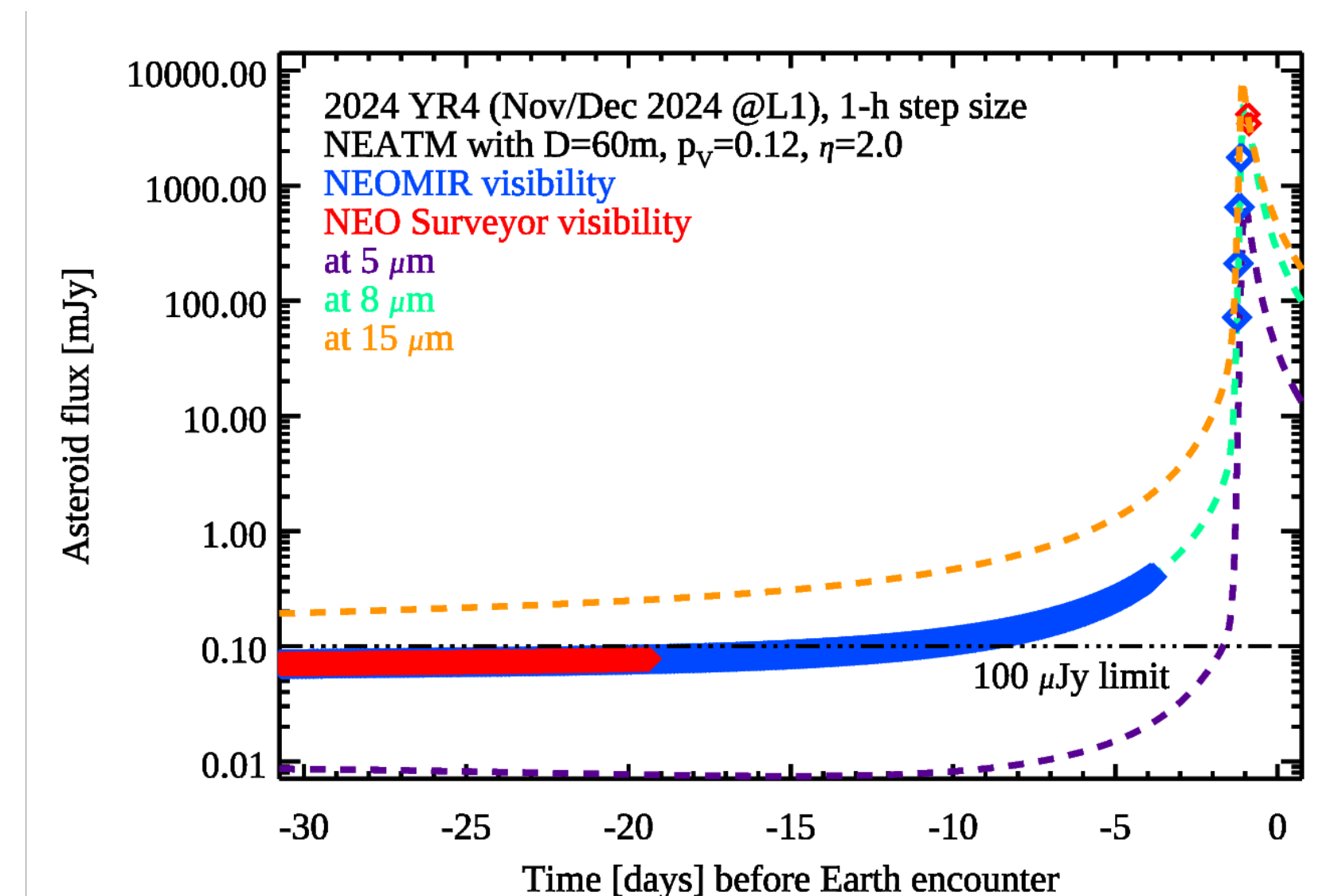
Right (middle and bottom): The baseline flux prediction for YR4 (2024 & 2032) before Earth encounter. Visibilities by NEO Surveyor and NEOMIR are shown as red and blue lines, respectively.

Center: A range of flux predictions for the 20-m ChPG during the last days before impact. Note, that the object would have been visible only under extreme phase angles (above $\sim 130^\circ$)



Target	NEO Surveyor; 8- μm flux > $100 \mu\text{Jy}$	NEOMIR; 8- μm flux > $100 \mu\text{Jy}$	SOT > 20° ; 8- μm flux > $100 \mu\text{Jy}$
ChPG	14 hours	~ 1 day	~ 10 days
YR4 (2024)	2 hours	~ 10 days (2.5-day gap)	~ 10 days
YR4 (2032)	50 hours	~ 18 days	~ 20 days

Table 1: Detection lead time before Earth encounter for NEO Surveyor, NEOMIR, and when relaxing the solar elongation constraint to 20° . We considered object sizes of 20 m (ChPG) and 60 m (2024 YR4), default thermal model assumptions and a detection threshold of $100 \mu\text{Jy}$ at $8 \mu\text{m}$.



Placing a small, 0.5 m IR survey telescope in L1 has clear advantages over ground-based large visible survey telescopes. Mid-IR detections of decameter-scale objects are possible days to weeks before a close Earth encounter or impact, even if they come out of a close-to-Sun proximity zone (while being fainter than mag 26 in the visible). Table 1 summarizes the different pre-encounter constraints and time scales for the two targets considered here. In the context of the ChPG, YR4 (in 2024 and 2032), and other decameter-scale objects on similar trajectories, limitations are related to the solar elongation limits of the telescopes, the high (zodiacal) background close to the Sun, wavelength and width of instrument band(s), exposure times and observing strategy. At longer wavelength, closer to $10 \mu\text{m}$ or beyond, the target-to-background flux ratios are getting better, but limitations due to the detector's response function, possible straylight and thermal self-emission contributions kick in. Short exposure times (1-10 sec) would avoid streaking effects during phases where the objects have high apparent motions and would enable better quality astrometry. At the same time, short multiple exposures within a given telescope pointing, would allow for synthetic tracking techniques, similar to what has been done for JWST-MIRI observations to detect decameter-size asteroids (Burdanov et al. 2025, Nature 638, 8049).

A high uncertainty in estimating the lead times for the detections is related to modeling the thermal emission of asteroids seen under extreme phase angles larger than 100° (like a "sickle moon"). Thermophysical model predictions using "default" object properties for spin and thermal characteristics might be the solution. However, suitable IR validation measurements on well-known objects seen under a very wide range of phase angles are difficult to obtain via currently available IR facilities, thermal IR measurements of asteroids at phase angles $> 120^\circ$ are not existing.

A detailed discussion for the ChPG is presented in Müller et al., „Pre-Impact Detection of Chelyabinsk-type Objects in the Thermal Infrared: Possibilities and Limitations“, *Advances in Astronomy, Progress in Planetary Defense, Special Issue*, submitted (2025).