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Small Bodies Science with Twinkle

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Abstract

Twinkle is an upcoming 0.45m space-based telescope equipped with a visible and two near-infrared spectrometers over the spectral range 0.4 - 4.5μm with a resolving power R $\sim$ 250 (λ<2.42μm) and R $\sim$ 60 (λ>2.42μm). Here we explore Twinkle's capabilities for small bodies science and find that, given Twinkle's sensitivity, pointing stability, and spectral range, Twinkle could observe a large number of small bodies.

1. Introduction

Twinkle is designed for operation in a low Earth, Sun-synchronous orbit. The instrumentation consists of three spectrometers which cover the spectral range 0.4 - 4.5μm with a resolving power of R$\sim$250 (λ < 2.42μm) and R$\sim$60 (λ > 2.42μm). As a space-based general observatory, Twinkle has the capability to provide significant new data on Solar System objects, especially in regions of the spectrum dominated by telluric absorption.

The Twinkle Space Mission is a new, fast-track satellite designed for launch in 2022. It has been conceived for providing faster access to spectroscopic data from exoplanet atmospheres and Solar System bodies, but it is also capable of providing spectra of bright brown dwarfs and stars. Twinkle is equipped with a visible (0.4 - 1μm) and infrared (1.3 - 4.5μm) spectrometer (split into two channels at 2.42μm). Twinkle has been designed with a telescope aperture of 0.45m and will operate in a low Earth, Sun-synchronous orbit.

JPL's Horizons system[1] was accessed for $\sim$740,000 small bodies defined as NEOs, Inner, Main and Outer Belt asteroids or Trojan asteroids. Here, Near-Earth Objects (NEOs) include those that are classified by the Horizons database as Aten, Apollo and Amor. Additionally, the physical characteristics of $\sim$1000 comets were downloaded from the Minor Planet Centre[2]. The capability of Twinkle to observe these small bodies has been analysed. Firstly, the sensitivity of Twinkle is calculated and compared to the flux from an object of a given visible magnitude. The number, and brightness, of asteroids and comets which enter Twinkle's field of regard is then studied over three time periods of up to a decade.

2. Results

By assuming a requirement of SNR = 100 and the discussed instrument characteristics, the capability of Twinkle to observe small bodies is determined by calculating the sensitivity and saturation limits of Twinkle's instrumentation for each spectrometer. These are plotted in Figure 1 and, if an object lies between these limits for a given exposure time, Twinkle can achieve spectra at the instrumentation's highest resolution with an SNR >100. At shorter wavelengths (λ<2.42μm), targets of visible magnitudes brighter than m_v $\sim$13.5 could be observed at Twinkle's highest spectral resolution in 300s while for longer wavelengths the magnitude limit for this exposure time is m_v $\sim$12.

The number of asteroids which Twinkle could characterise depends upon the brightness of targets when entering the field of regard, which dictates the possibility of tracking it with the FGS and the data quality achievable. The cumulative number of asteroids of a given visible magnitude that enter Twinkle's field of regard with non-sidereal rates of <30 mas/s is shown in Figure 2. We find that several thousand Main Belt asteroids with a visible magnitude <15 enter Twinkle's field of regard over the time periods considered. Tens or a few hundred NEOs and Outer Belt asteroids are bright enough for on target tracking. Additionally, a handful of Trojans are bright enough to be tracked with the current FGS design as are tens of asteroids in the Inner Belt.

[1]https://ssd.jpl.nasa.gov

[2]https://minorplanetcenter.net

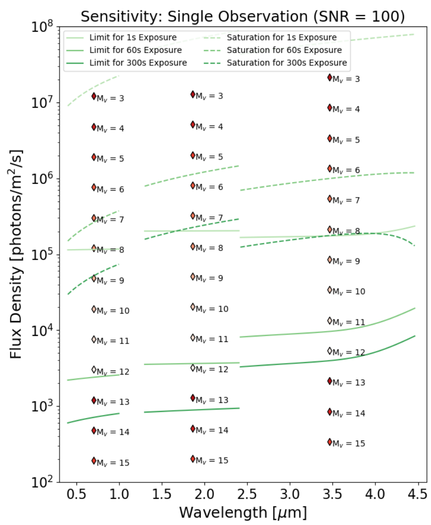

Figure 1: For a single observations of a given exposure time, the sensitivity and saturation limits of Twinkle assuming observational parameters of SNR = 100, R$\sim$250 (λ <2.42μm) and R$\sim$60 (λ >2.42μm). Additionally the average photon flux received per spectral band at Earth for a small body of a given visible magnitude are plotted.

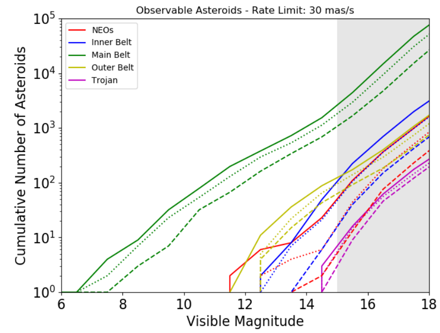

Figure 2: Cumulative number of asteroids of a given visible magnitude and type that enter Twinkle's field of regard over several time periods (dashed: 2022 - 2023, dotted: 2022 - 2025, solid: 2022 - 2032) with non-sidereal rates of <30 mas/s. The grey area indicates the cut-off due to the tracking capability of the current FGS design. Employing tracking via bright stars could alleviate this.

3. Summary and Conclusions

Twinkle's will have the capability to acquire high SNR spectra for a large variety of asteroid types including a vast number within the Main Belt. Spectra at Twinkle's highest resolution and with SNR>100 could be obtained for asteroids brighter than M_v = 12 in <300 seconds. Combining multiple observations, or reducing the observational requirements, will allow many fainter objects to be characterised.

Additionally to asteroid science, Twinkle will have the capability of investigating the comae of bright comets, providing valuable data sets on CO_2 production and the presence of water-ice and organics in the comae. Therefore, Twinkle potentially provides a resource that would push our understanding of asteroids and comets, and hence the formation and evolution of the Solar System, well beyond its current state.

References

[1] Edwards, B., Savini, G., Tinetti, G., Bowles, N. and Lindsay, S.; Small Bodies Science with Twinkle, Journal of Astronomical Telescopes, Instruments, and Systems, submitted