Estimation of Background Stars over a Satellite Pass for Multi Object Adaptive Optics

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Introduction

We are developing a hybrid adaptive optics system for high-resolution imaging of satellites and space debris in Low Earth Orbit (LEO) [1]. One of the subsystems is for Multi Object Adaptive Optics (MOAO), which needs multiple stars in the background around the trajectory of the satellite to determine the spatially variant distortion function. To achieve this, a Geometric Wavefront Sensor (GWFS) is used to estimate phase distortions from multiple stars. Using the spatially variant point spread function information, the satellite and space debris are deconvolved in post-processing, as shown in the lower part of the fig 1.

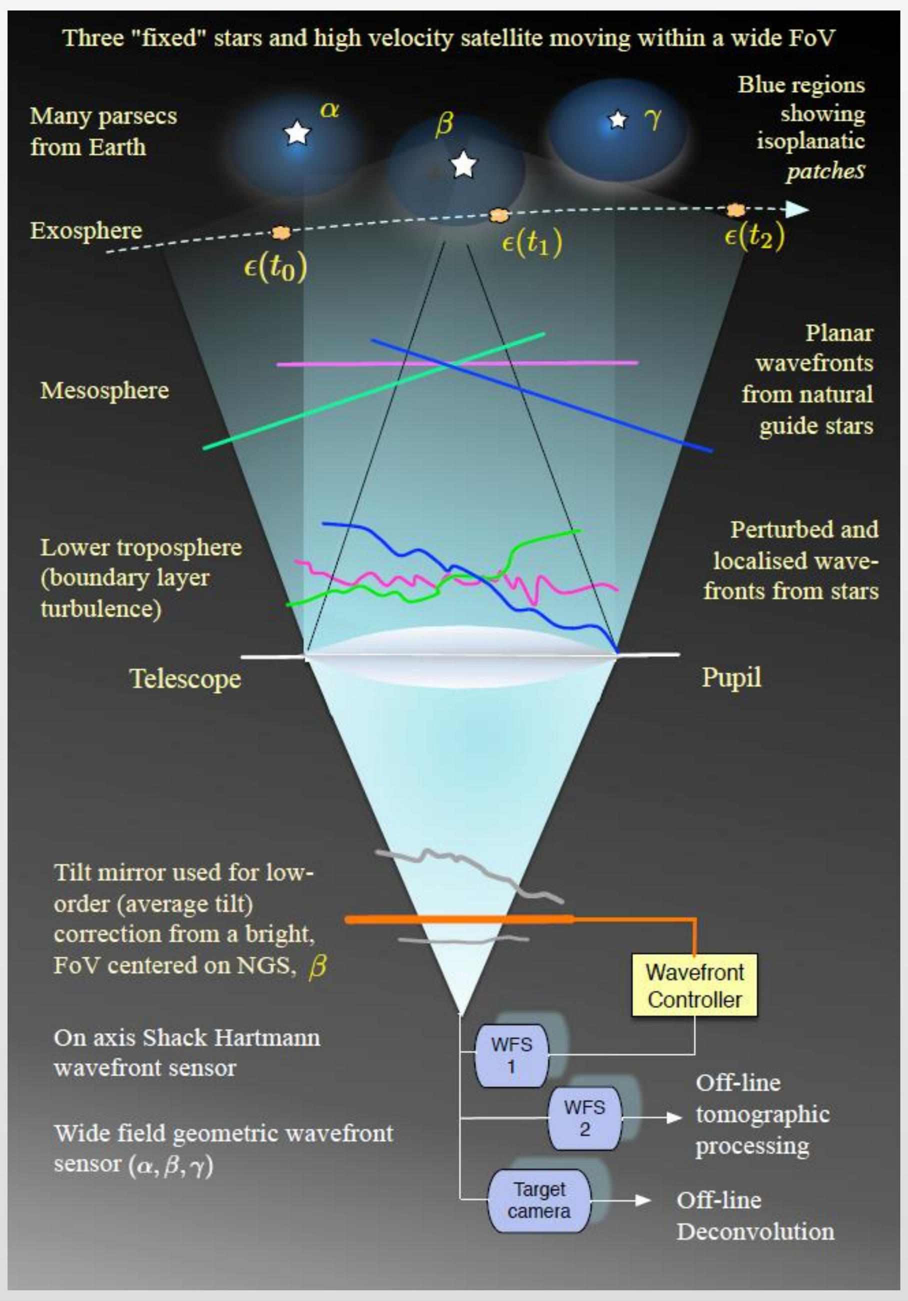

Fig.1: Hybrid adaptive optics system.

Photon Count

The number of stars in the Field of View (FoV) is estimated by the limiting star magnitude of the imager and FoV. First, the limiting star magnitude of the imager is determined by the diameter of the aperture (0.6 m), exposure time (3 ms), average quantum efficiency (86%) and the ratio of incoming photons (1:4) [2]. In general, a few hundreds of photons are sufficient to detect a star with the GWFS [3]. Based on the above factors, the limiting star magnitude of the imager is estimated to be 11. Second, an Andor Marana will be used for the GWFS, with the B&C telescope, the FoV of 20 arc minutes is achievable.

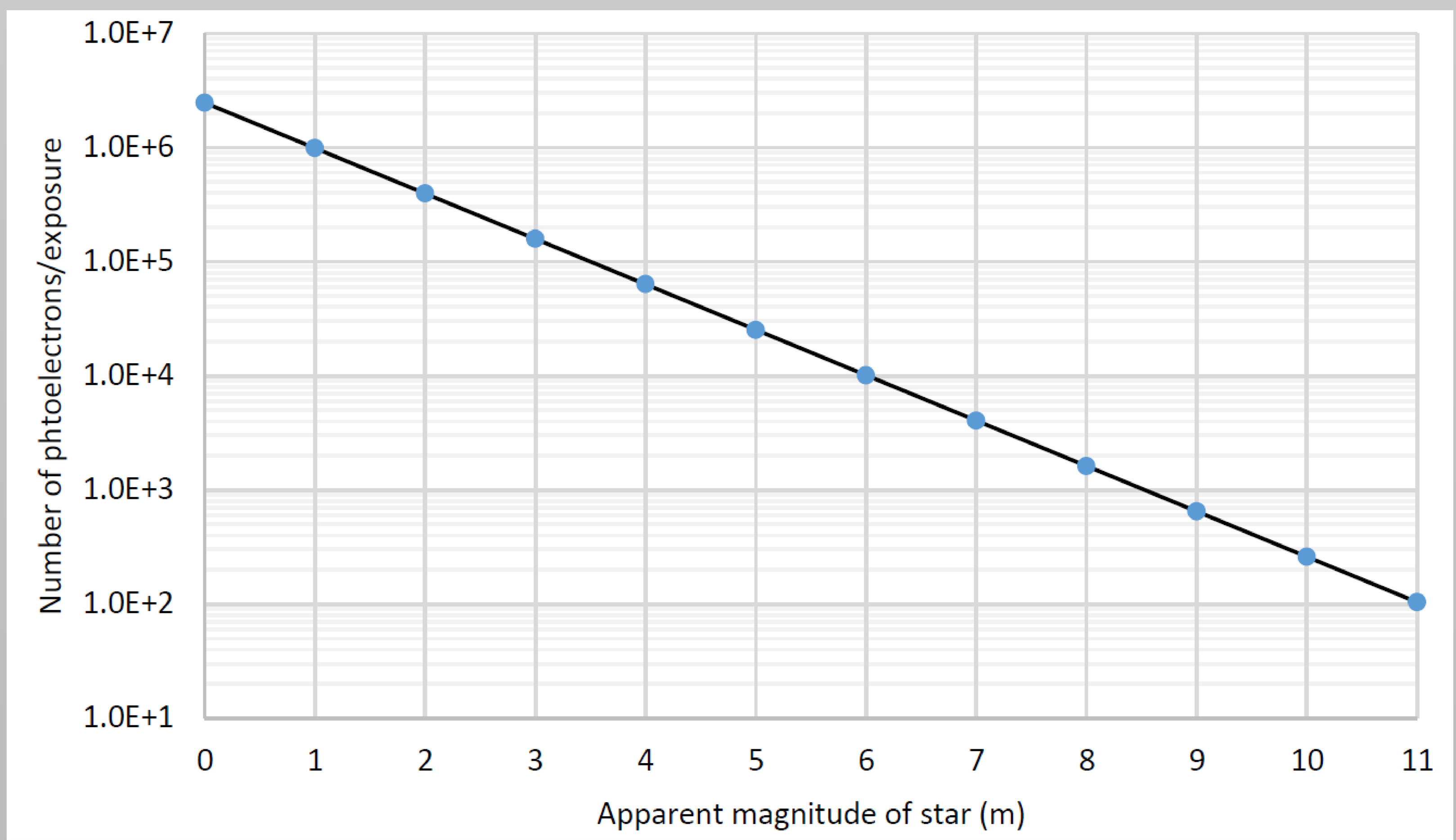

Fig.2: Estimation of photons detected per exposure by Marana versus apparent star magnitude.

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Star Distribution

Based on the location of Mount John University Observatory (MJUO), stars within +46° to -90° declination are visible. With the limiting magnitude of 11.0, in total 357,082 stars are accessible. The stars are distributed non-uniformly in the sky, but there is a pattern in star distribution with star density higher around the Galactic Equator (GE) compared to the rest of the sky, as shown in fig 3.

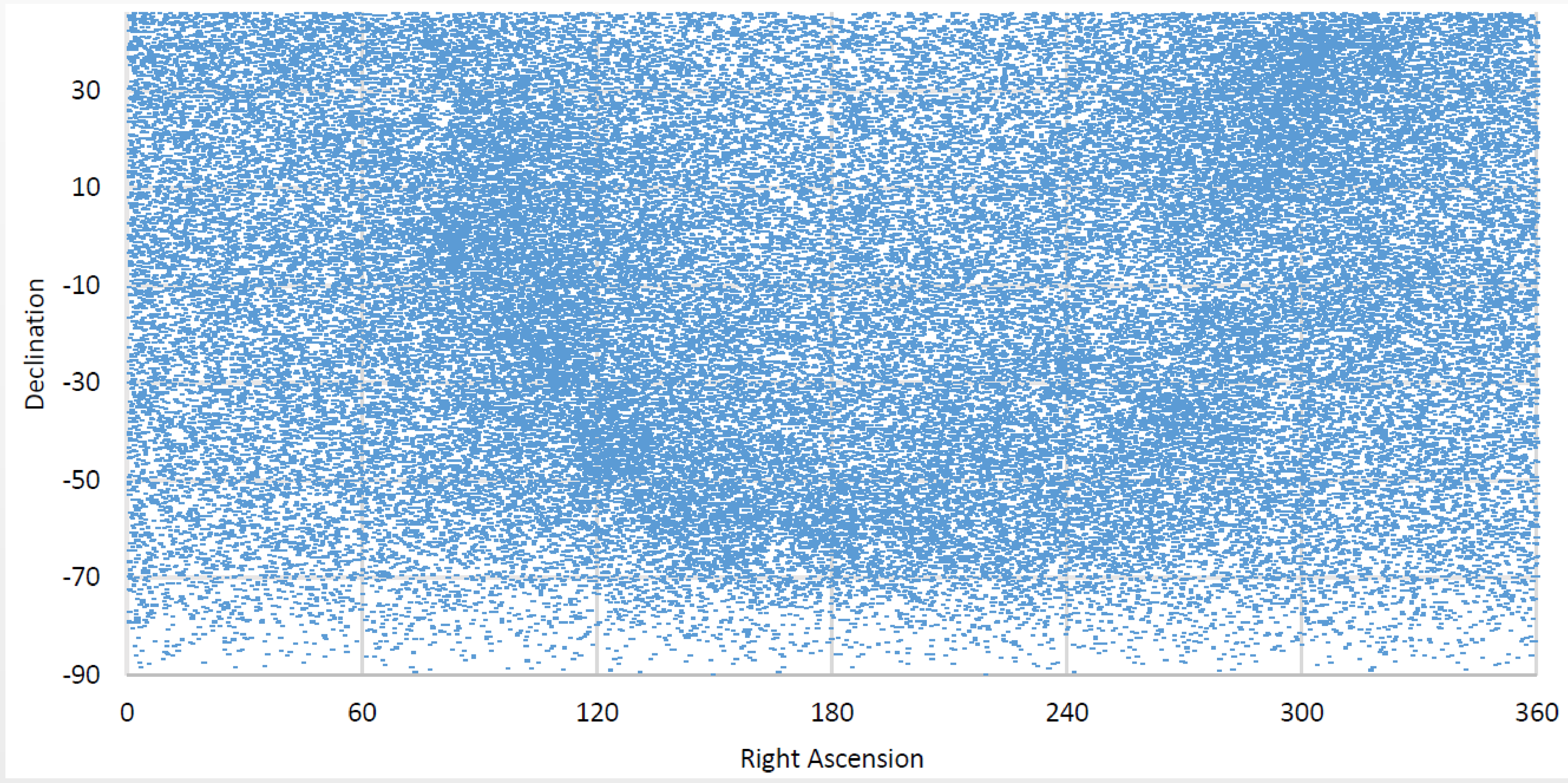

Fig.3: Star distribution over Mount John University Observatory.

Estimation of Background Stars with ISS in Foreground

To estimate the number of background stars over a satellite pass, the trajectory (RA, Dec) of the International Space Station (ISS) was plotted against the background sky for every second over a period of a single ISS pass on the 19th January 2020. Hence for every second, the number of background stars in the FoV of 20 arcminutes is estimated. The results show that by using stars with limiting magnitude of 11.0, a maximum of 15 stars appears in the FoV, and the average star density in the FoV over galactic plane (-20° < GE < 20°) and rest of the sky is five and two, respectively, which is shown in fig 4.

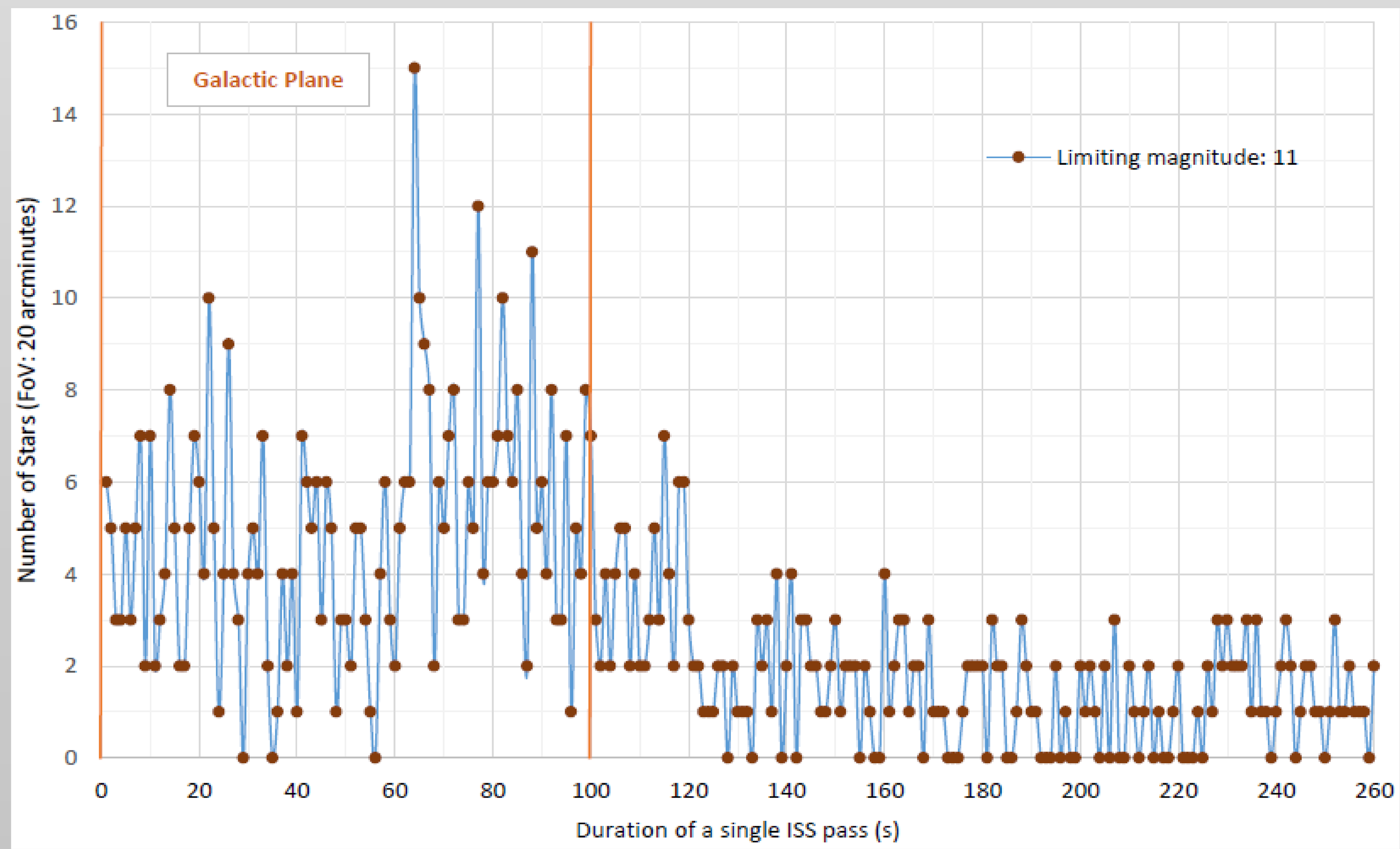

Fig.4: Estimated number of background stars with a FoV of 20 arc minutes over a single ISS pass in the foreground.

Conclusion

The MOAO require minimum three stars in a FoV. The results implies that when the ISS pass over the galactic plane, 81% of the time three stars are present in the FoV and over rest of the sky only 22% of the time three stars are present in the FoV.

References

[1] Weddell et al., *Near Earth Object Image Restoration with Multi-Object Adaptive Optics, NEO and Debris Detection Conference, Germany, January 2019*

[2] Weddell et al., *Optical Test-Benches for Multiple Source Wavefront Propagation and Spatiotemporal Point-Spread Function Emulation*, Applied Optics, 2014

[3] Pal et al., *Slope-based wavefront sensor optimisation with multi-resolution analysis,* Proceedings of SPIE 10703, *June 2018*