Detectability of RSOs in the Near-Moon Environment: Optical and Short-Wave IR

Benjamin F. Cooke,*[1,2] Warwick SDA,[2] Dstl[3]

1 Department of Physics, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, UK
2 Centre for Space Domain Awareness, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, UK
3 Defence Science and Technology Laboratory, Portsdown West, Fareham, PO17 6AD, UK
∗ benjamin.cooke@warwick.ac.uk

UNIVERSITY OF WARWICK

CLASP (La Palma)

Credit: Paul Chote (Warwick)

Introduction

- Cislunar space is a region of increasing scientific and strategic importance. It encompasses the space between the Earth and Moon, including the near-Moon environment [1].
- Observations of targets in this regime are typically avoided due to the difficulties caused by dealing with lunar brightness effects and the poorly characterised detectability.
- In this work we endeavour to characterise the near-Moon environment as a function of lunar conditions, and define when, and to what level, RSOs are observable.

Data acquisition (m_i and m_s)

- We observe fields in the near-Moon environment every night across a lunar month. Observations are taken a range of lunar illuminations (m_i, up to 100%) and Moon separation distances (m_s, up to 15°).
- Observations are taken with our CLASP telescope in La Palma, using both optical (CMOS) and short-wave infrared (SWIR) cameras.
- Fig 1 shows the coordinates of observed fields for an example night. We observe 6 fields per night, recording m_i and m_s for each.

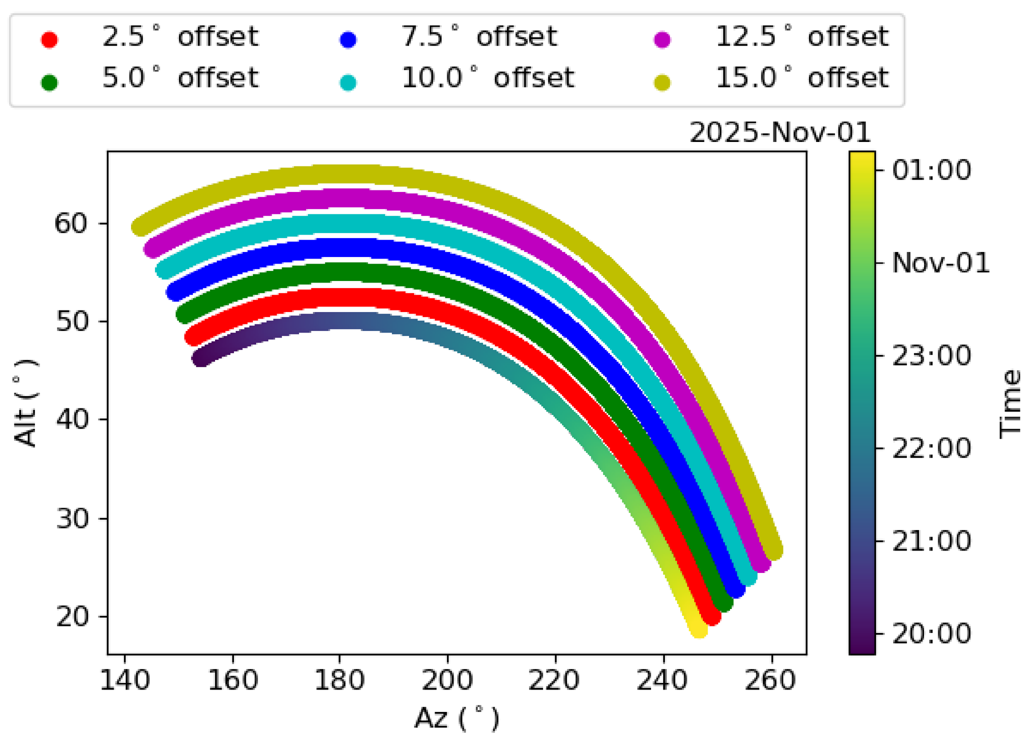

Fig 1. Pointings for the Moon and 6 fields for an example night mid-campaign.

- The data from each field are reduced using dark, bias and flat fields.
- We match observed fields to known catalogues (Gaia for CMOS, 2MASS for SWIR) to perform astrometry and calculate zero-points.

Background fits (B_{RMS})

- We now model sky brightness as a function of lunar illumination and separation (m_i and m_s).
- First, to account for Moon-induced internal scattered light, we remove regions of each frame with significantly high RMS scatter.
- Next, we calculate the background map of each frame and average per field.
- The result is a measurement of sky background for each combination of m_i and m_s.
- We fit the data with cubic interpolation, matching the observed increase in brightness with m_i and decrease with m_s.
- CMOS and SWIR measurement are handled separately, producing two independent datasets and models.
- The result is used to predict sky brightness for any pair of m_i and m_s.

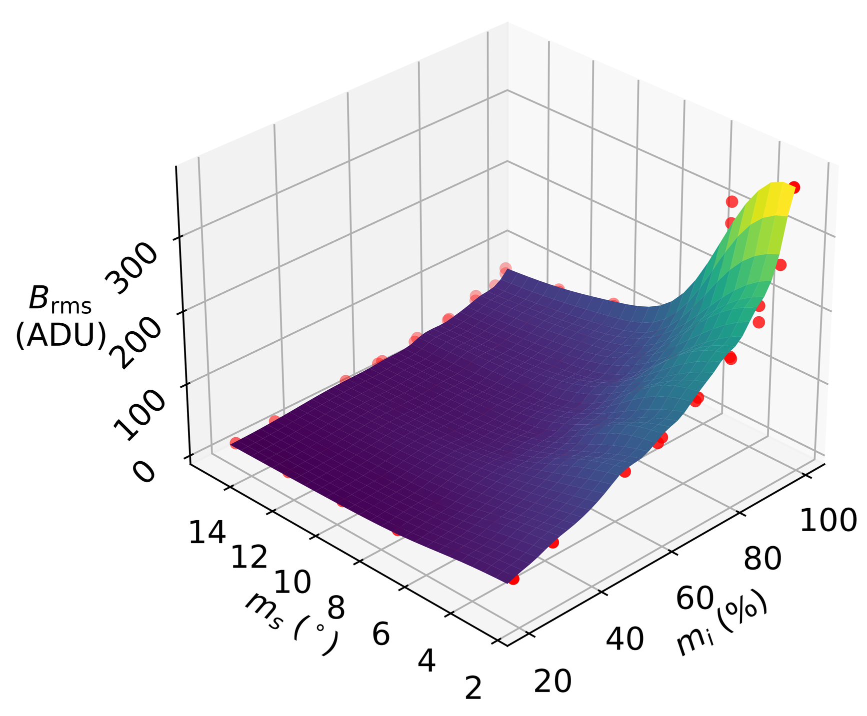

Fig 2. Interpolated fits to CMOS background RMS data.

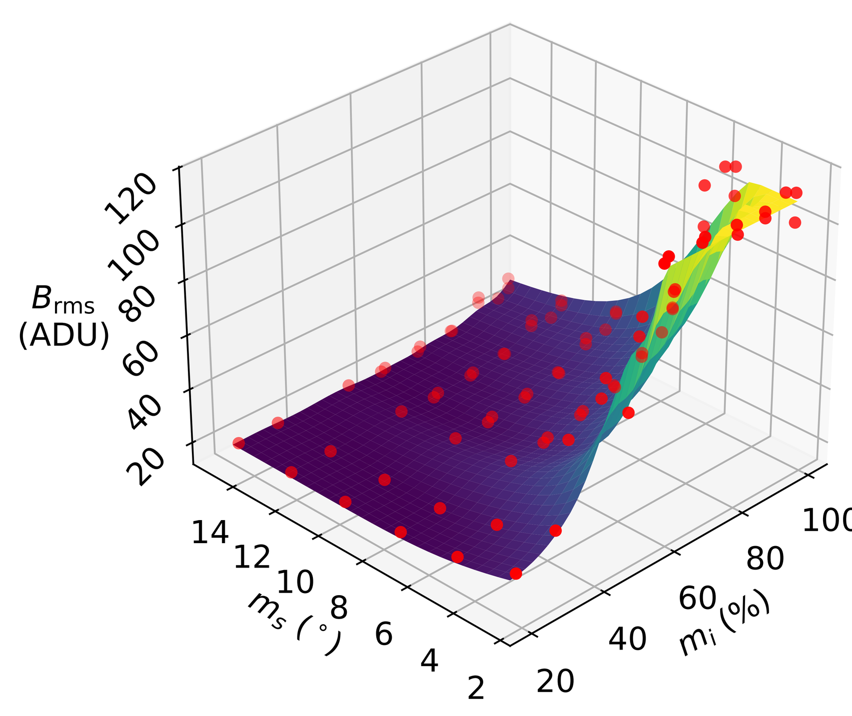

Fig 2. Interpolated fits to SWIR background RMS data.

Limiting magnitudes (r and n)

- We now convert sky brightness to limiting observable magnitude. This can occur in two regimes depending on the relative motion of a chosen target [2].
- **Regime one:** We assume a target moving relative to the telescope. This mimics a scenario in which we are observing unknown targets. The target must be detected in a single frame and its limiting magnitude is a function of its relative rate, r.
- **Regime two:** We assume a target stationary relative to the telescope. This mimics observations of a known target. Frames can thus be stacked, with the limiting magnitude a function of the number of frames, n.
- For each regime and camera, we determine the limiting magnitude for an RSO to be observable.
- This model is made publicly available, with the goal of allowing the near-Moon environment to be better utilised when attempting observations of RSOs.

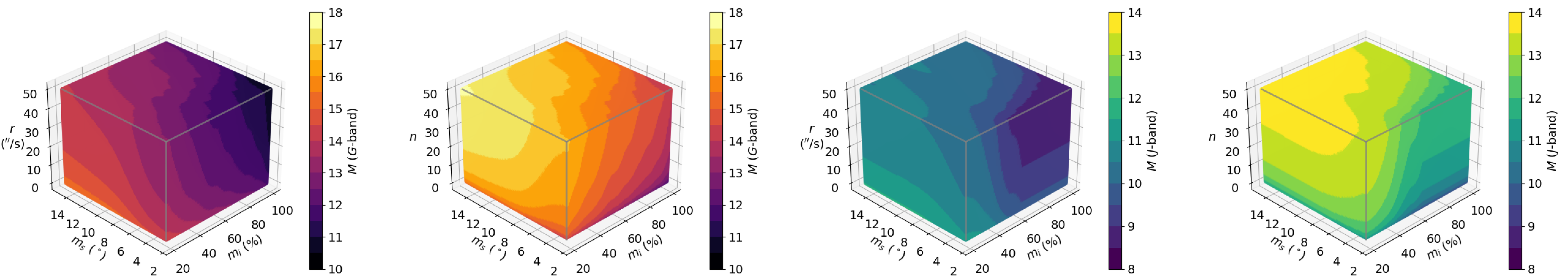

Fig 3. Limiting magnitude as a function of m_s and m_i. L – R: CMOS regime one, CMOS regime two, SWIR regime one, SWIR regime two.

Acknowledgments

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References

[1] A. P. Wilmer and R. A. Bettinger. Holding the high ground: Operational considerations for the earth-moon system. *Æther*, 2022.

[2] Benjamin F. Cooke et al. Predicting RSO populations using a neighbouring orbits technique. *RAS Techniques and Instruments*, 2024.