Mining the Kilo-Degree Survey for Solar System Objects

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Software for tentative classification of serendipitously observed asteroids

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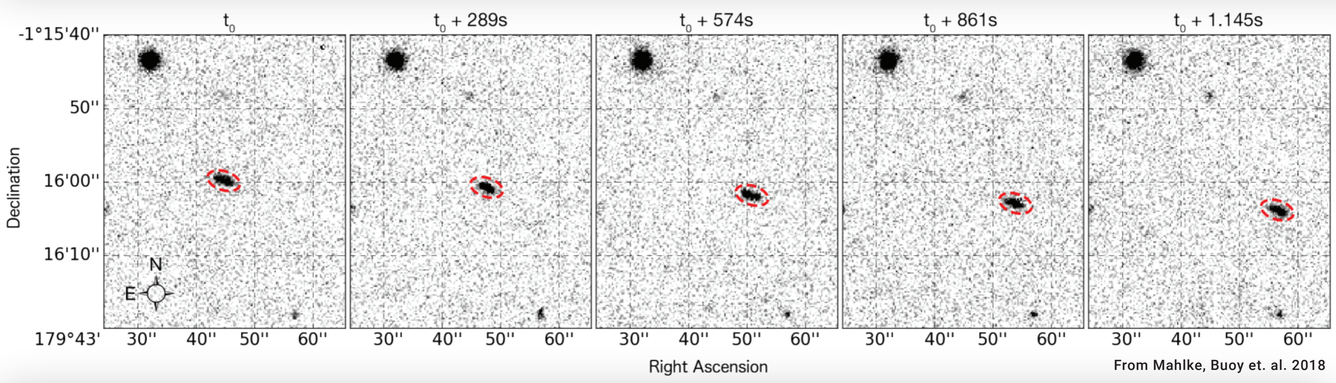
Introduction

This **Bachelor Research Project** aims to detect **Solar System objects** (SSOs) in the **Kilo-Degree Survey** (KiDS) using an existing **SSO detection pipeline**. We explore **constraining distances for these transient detections** by extending the pipeline with software.

KiDS is a wide-field optical imaging survey that uses the OmegaCAM imager of the **VLT Survey Telescope** (VST) at the ESO Paranal observatory in Chile. All KiDS data is calibrated and archived in **Astro-WISE**, an information system that connects an international network of storage servers, computing clusters, and databases.

The main focus of KiDS is to study weak gravitational lensing and redshifts to constrain the cosmological matter distribution. However the same observations can also be used to serendipitously discover SSOs.



From Mahlke, Buoy et. al. 2018

The SSO detection pipeline

The SSO detection pipeline used in this project was developed by **Max Mahlke** as published in Mahlke, Bouy et al. 2018. QR

The principal aim of the pipeline is detecting the SSOs' apparent celestial motion across the timespan between exposures, see the figure above.

The pipeline first uses **SExtractor and SCAMP** on individual KiDS exposures retrieved from Astro-WISE, see the box diagram to the left, to extract moving sources.

Subsequent **filtering to exclude contaminants** (such as cosmic rays, diffraction patterns, bright star halos) is performed using a **python script**.

The pipeline uses **web-based services** extensively, such at the **IMCCE SkyBoT service**, which associates known minor planets with the SSO detections.

The pipeline was performed on **362 square degrees** of KiDS. Resulting in **20673 SSO candidates** with a 0,05% false-positive rate.

Discussion and conclusion

The SSO detection pipeline was succesfully run on an additional **31 square degrees** for this project, more could not be studied due to time and computing constraints.

In the future the pipeline could be automated and run on all KiDS fields, and potentially the other surveys in Astro-WISE.

The circular orbit method of analysing the detected SSOs shows potential, but has to be expanded and validated to be useful. It is now a **proof-of-concept**.

The admissible regions approach could be used as **validation** for existing detections and minor planet associations, and for **selecting samples** for future study from any serendipitous SSO detections.

With the potentially **large number of yet undiscovered SSO candidates** in existing and future surveys the pipeline could open up a **large set of new data**. See Mahlke, Solano et al. 2019 QR for further development of the pipeline.

Link to full BSc thesis
(includes references)

THE DATA FLOW

KiDS VST DATA

Astro-WISE

KiDS data gets photometrically and astrometrically calibrated using the calibration pipeline in Astro-WISE.

For one square degree KiDS tile the SSO detection pipeline analyzes per filter up to 5 dithers x 32 detectors = 160 calibrated detector frames of 2000x4000 pixels.

RegriddedScienceFrames

The SSO detection pipeline

SExtractor ← SExtractor configuration

Source catalogs

VizieR web service reference catalogue → SCAMP ← SCAMP configuration

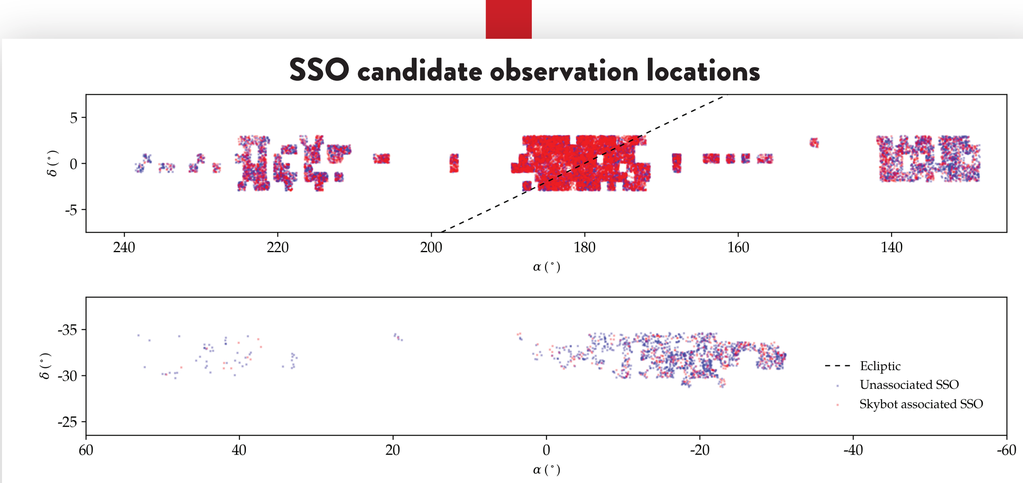
Source catalogs / Full and merged catalogs

Bright Sources Catalogue → python Filter routine ← SSO pipeline configuration

SSO candidate parameters table

SkyBoT Web Service → SSO candidates

Follows Mahlke, Solano et. al. 2019



Preliminary observation locations of the SSO candidates on the celestial plane

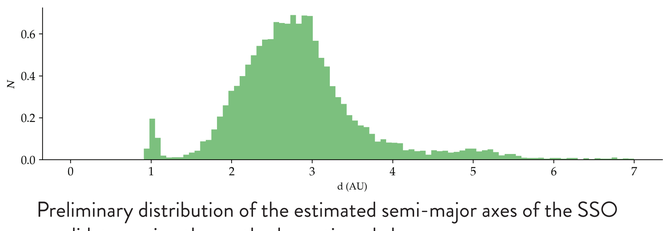
SSO candidates' parameters with possible SkyBoT associations

Tentative classification software for SSOs

IMPLEMENTED AS PYTHON NOTEBOOKS

Circular orbit method

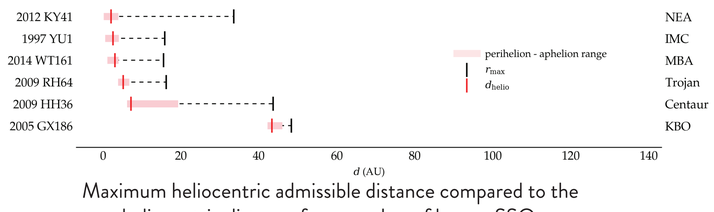
Using the assumption that many SSOs will be minor planets with **roughly circular orbits**, we use this assumption to get **estimates of the semi-major axes** for the entire sample of SSO candidates.



Preliminary distribution of the estimated semi-major axes of the SSO candidates, using the method mentioned above.

Admissable regions method

Using a method from Milani, Gronchi, et al. 2004 QR, we calculate a **maximum admissible distance** for each SSO candidate. This allows for a (conservative) upper limit to the heliocentric distance and size of the SSO.



Maximum heliocentric admissible distance compared to the true heliocentric distance for a number of known SSOs.

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