The EURONEAR Moving Object Detection System

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Content

- Introduction – EURONEAR
- EURONEAR Discoveries
- The EURONEAR Moving Object Detection System
- Problems encountered
- Future works
- Q&A

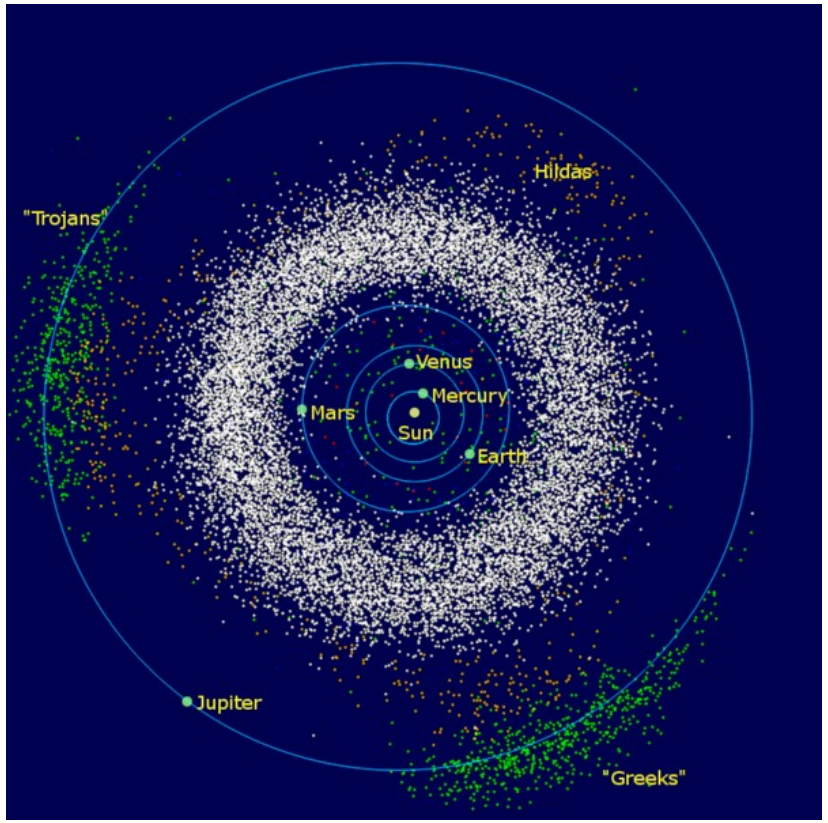
Introduction – EURONEAR

The **EURO**pean **N**ear **E**arth **A**steroid **R**esearch

- A project aiming to increase the European contribution in the Near Eart Asteroids (NEA) research;
- Born in 2006 at IMCCE Paris (by O. Vaduvescu and M. Birlan);
- Including people from 14 institutions in 8 European countries plus Chile;
- Proposing to improve orbital and physical properties of NEAs using a network of existing telescopes or maybe in the future some dedicated infrastructure (understood our logo?)
- A collaborative project contributing to education and public outreach, involving amateurs and students collaborators as reducers, discoverers and paper co-authors.

Introduction - EURONEAR

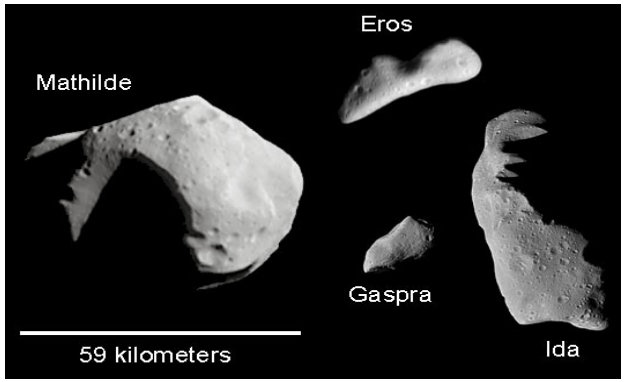
The inner Solar System and the asteroids



- January 2017:
  - More than …
    - 750,000 Main Belt Asteroids (MBAs)
    - 15,000 Near Earth Asteroids (NEAs)
    - 1,750 PHAs (Potentially Hazardous)
    - 500-600 Virtual Impactors (VIs)
  - … known objects (Minor Planet Center, MPC)

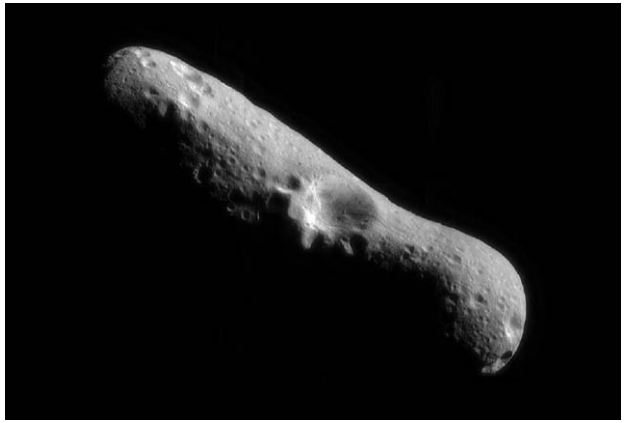
Introduction – EURONEAR

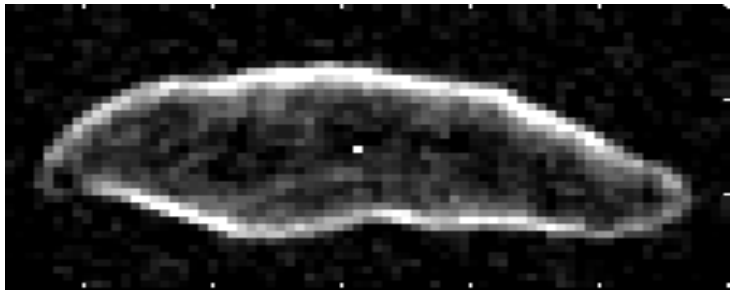
Only few asteroids & NEAs were visited by space missions:



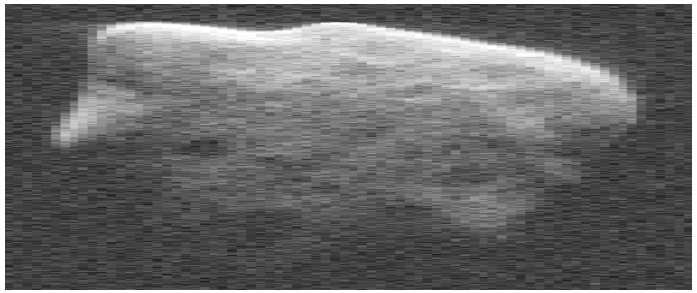
(951) Gaspra – Galileo 1991
(243) Ida – Galileo 1993
(253) Mathilde – NEAR 1997

NEA (433) Eros – NEAR 2000



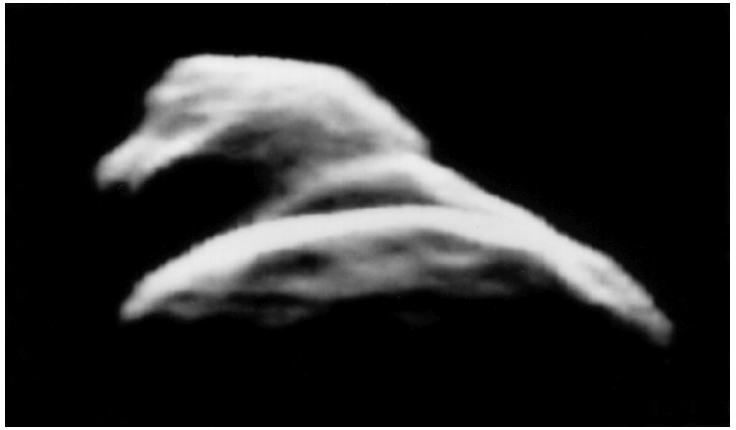


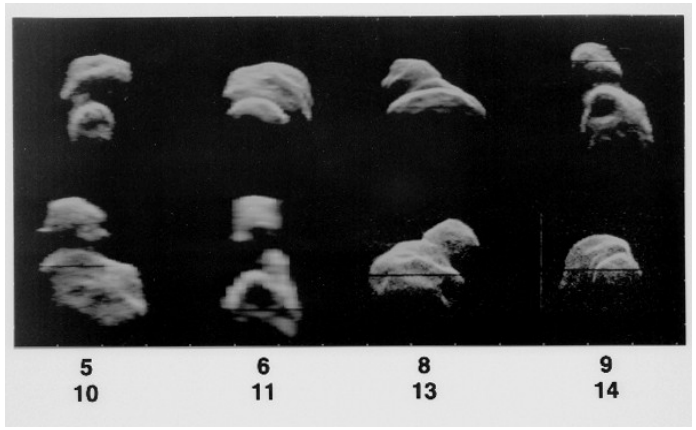
NEA (1620) Geographos – Goldstone 1994



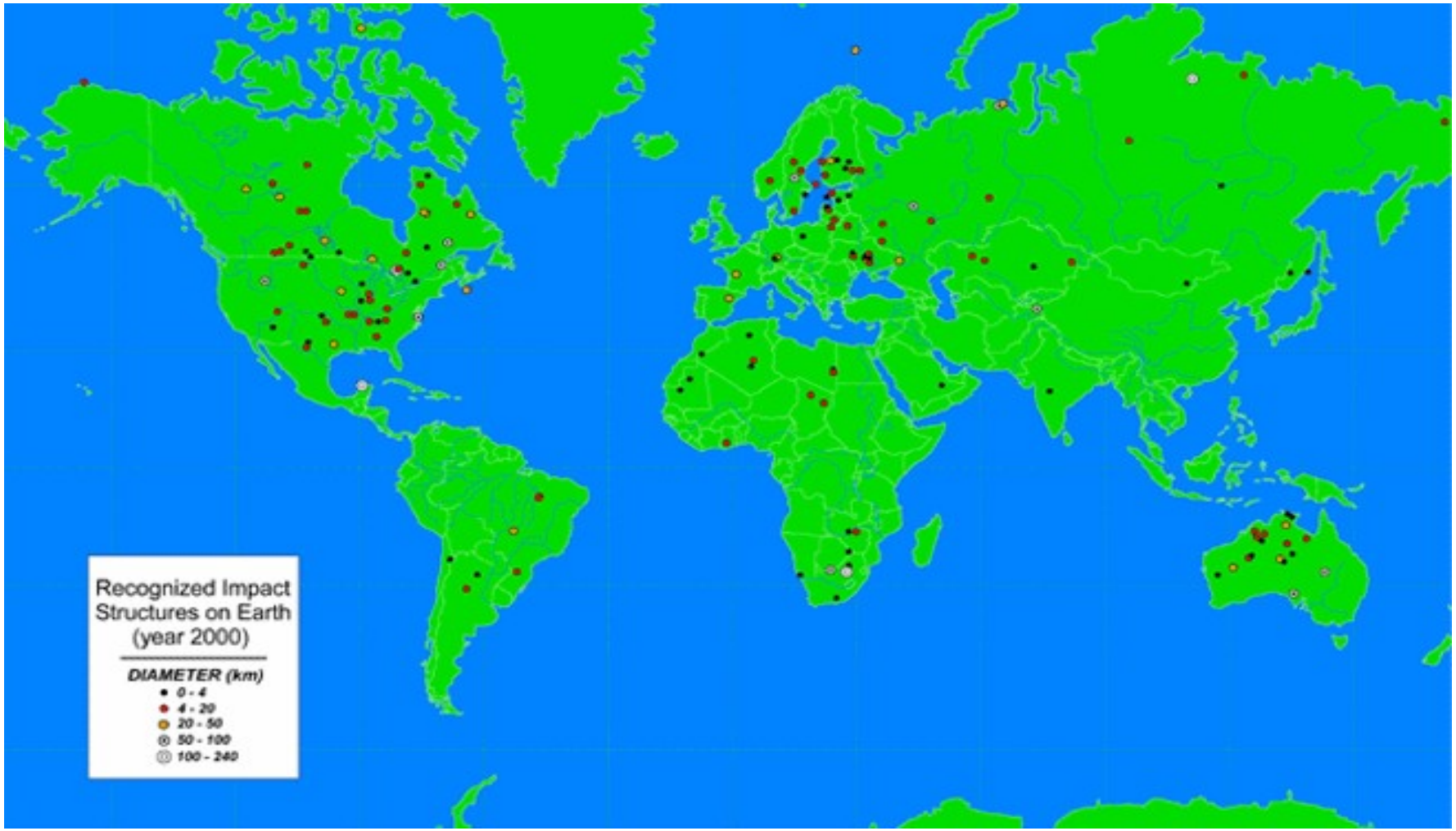
PHA (53319) 1999 JM8 – Goldstone 1999

And a few hundred NEAs were observed by radar





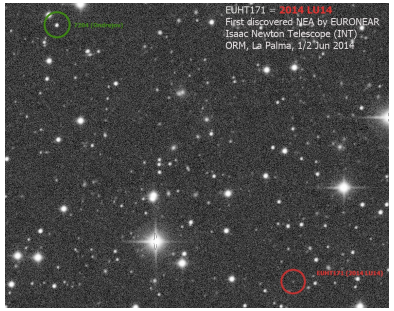
PHA (4179) Toutatis – Goldstone 1992 (~5km size, one of the most dangerous)

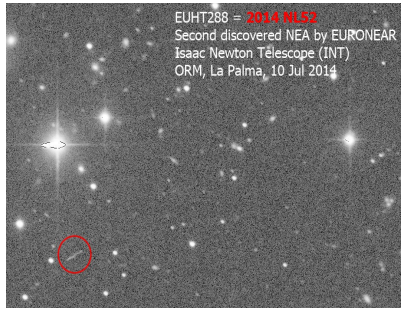


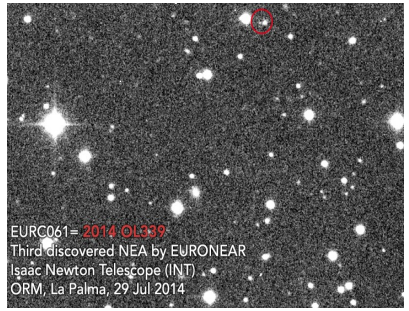
Earth Impact Database

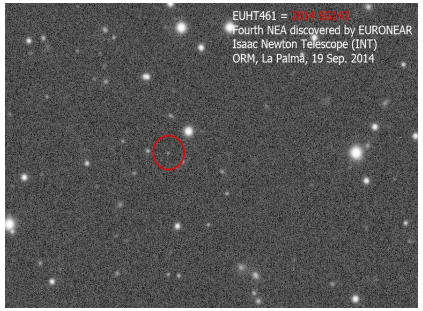
- (Univ. New Brunswick, Canada http://www.passc.net/EarthImpactDatabase)
  - We known about 160 craters due to cosmic collisions!

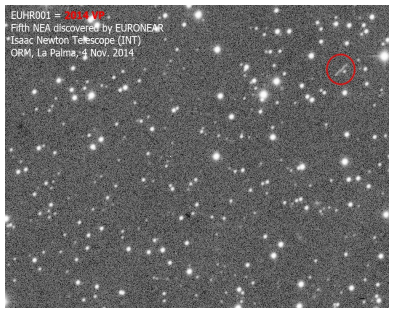
EURONEAR Discoveries (INT & ESO/MPG)

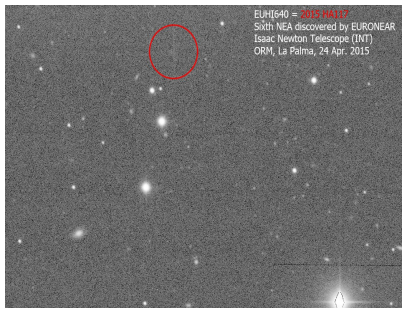


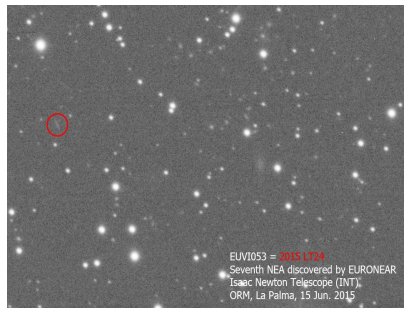


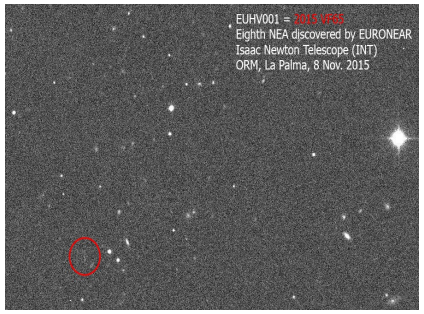




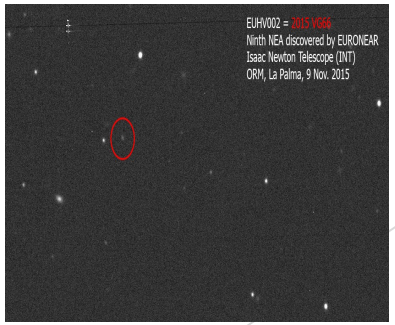






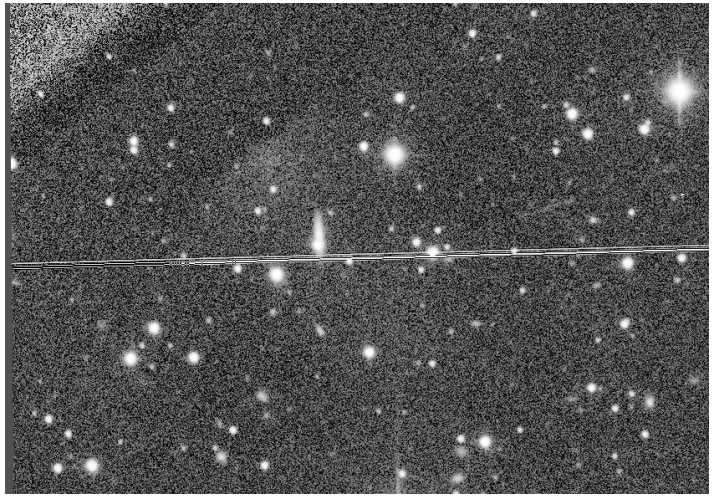


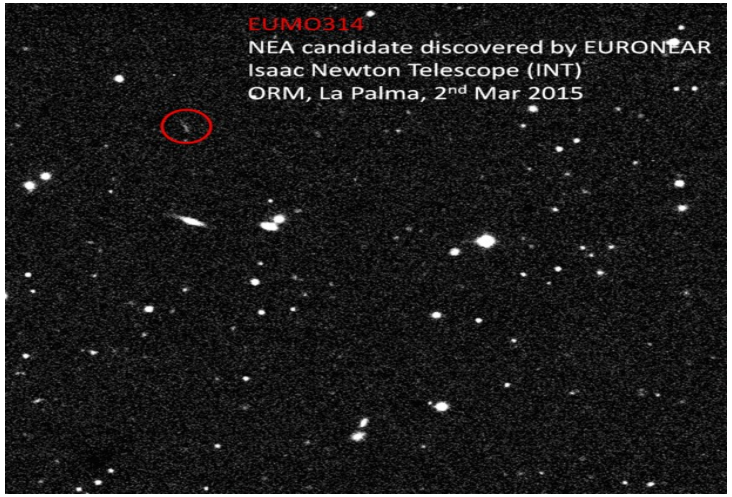
- Few hundreds MBAs (two mini-surveys);
- 9 secured serendipitous NEAs (the first in La Palma, during ToO time to recover known NEAs)
- Few lost NEAs (no follow-up time or other telescopes).



EURONEAR Discoveries

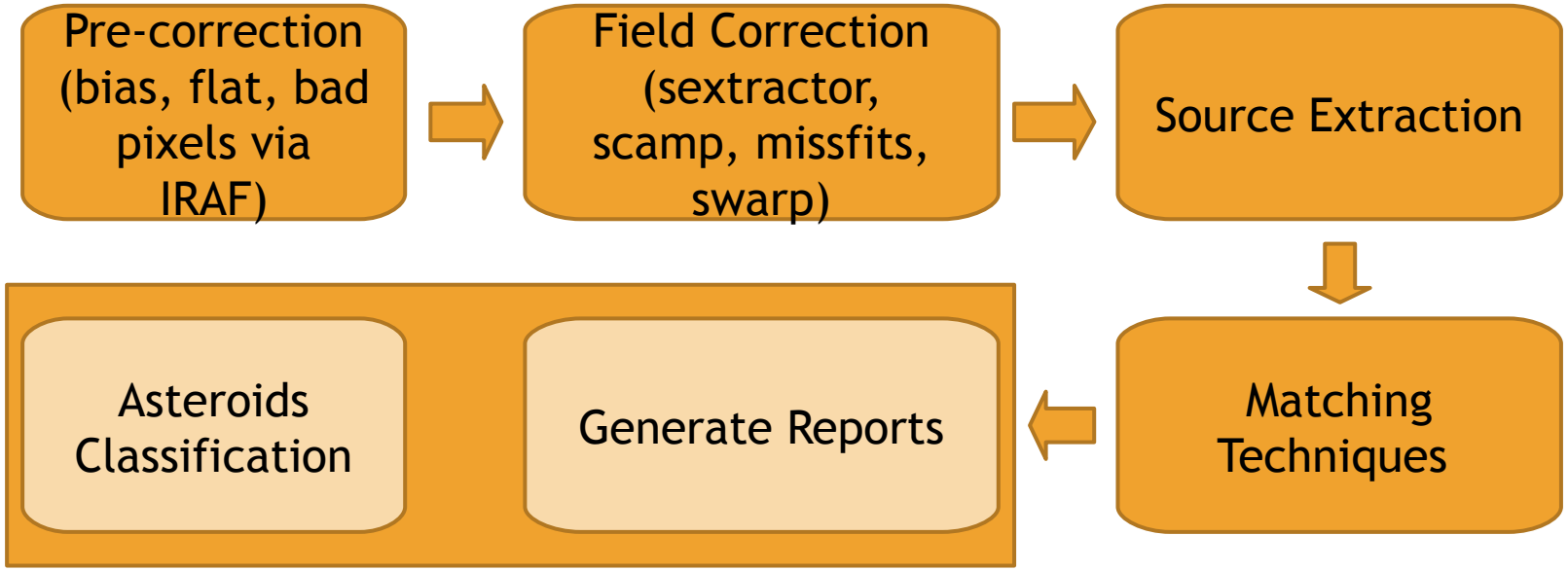
Found but Lost





The EURONEAR Moving Object Detection System

- a prototype pipeline written mainly in Python calling 3rdParty libraries for image pre-correction and correction

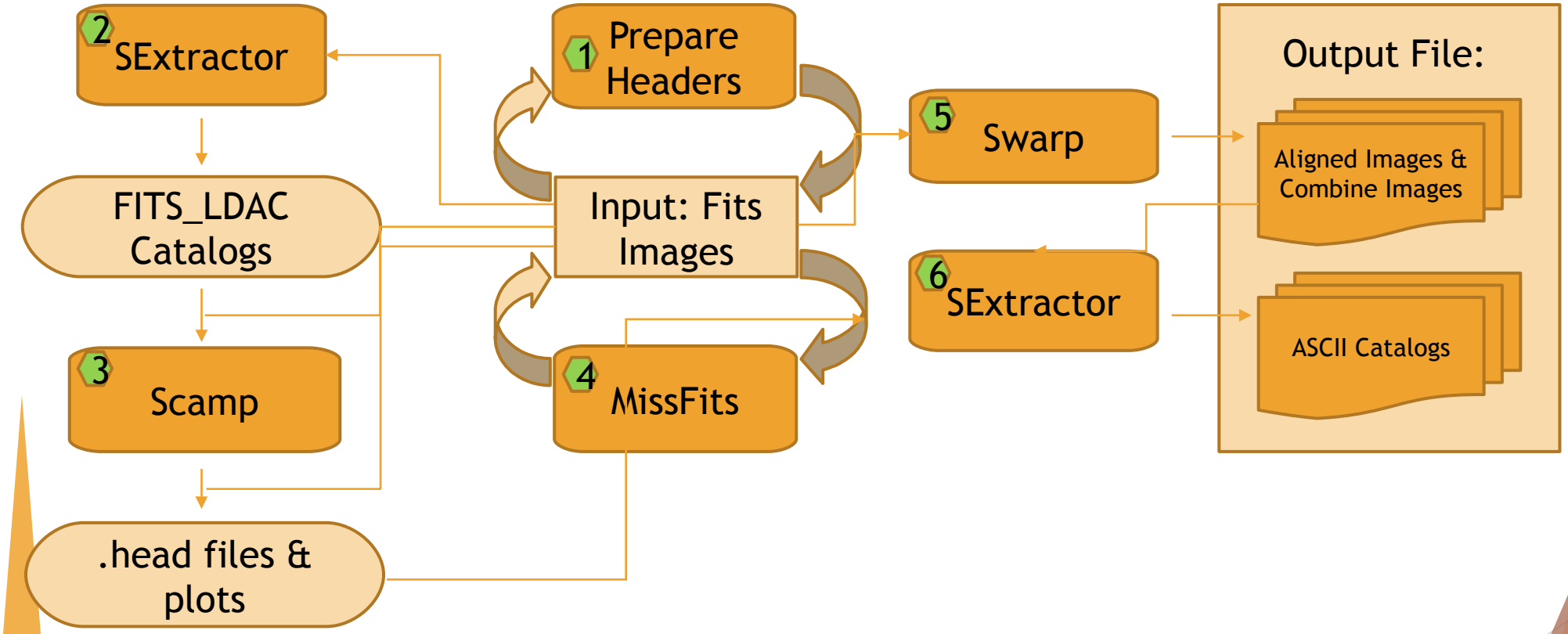


Pre-correction Module

- Python calls to IRAF in order to apply:
  - Bad pixels
  - Bias
  - Flat field

- Input: Raw FITS Images
- Output: Reduced FITS Images

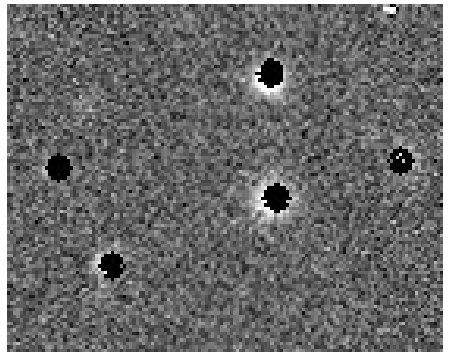
Field Correction Module



Source Extraction Module

- Pixel Based
- (using star subtraction)

- Using IRAF – not good enough



- Can be improved and used if the operation is done with tools like OpenCV (dedicated tool for image processing)

- Space Objects Based
- (using sources in catalogs)

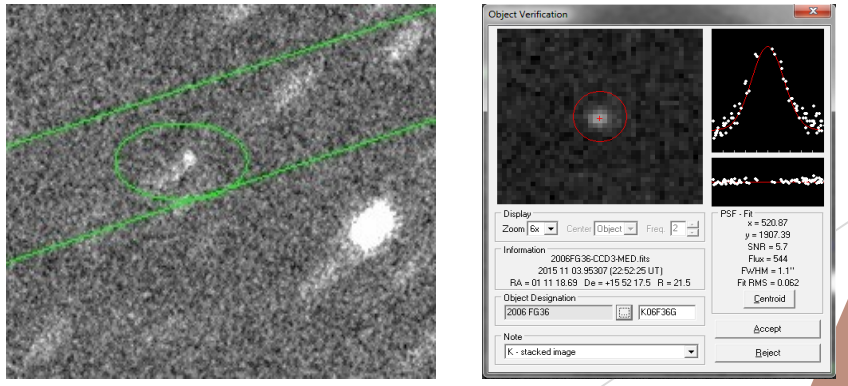
- Remove all fixed objects from individual catalogs that match sources from the combined catalog (using the combined image)

- The remaining objects are asteroids or noise, and should be paired in the individual images

Matching Module
Two Detection Techniques

- Improved “Blink“ Algorithm
- in series of a few (4-5) images, pairing (at least 3) sources moving linearly and rejecting noise

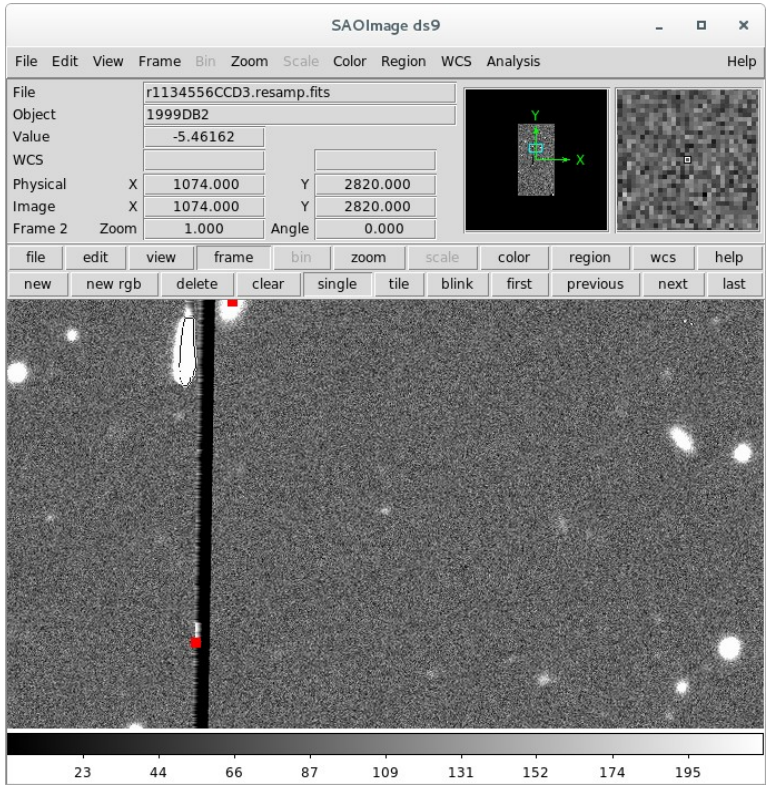
- “Synthetic (digital) tracking"
- using series of many (dozens) of images, in the search of unknown objects moving in any direction and with any proper motion

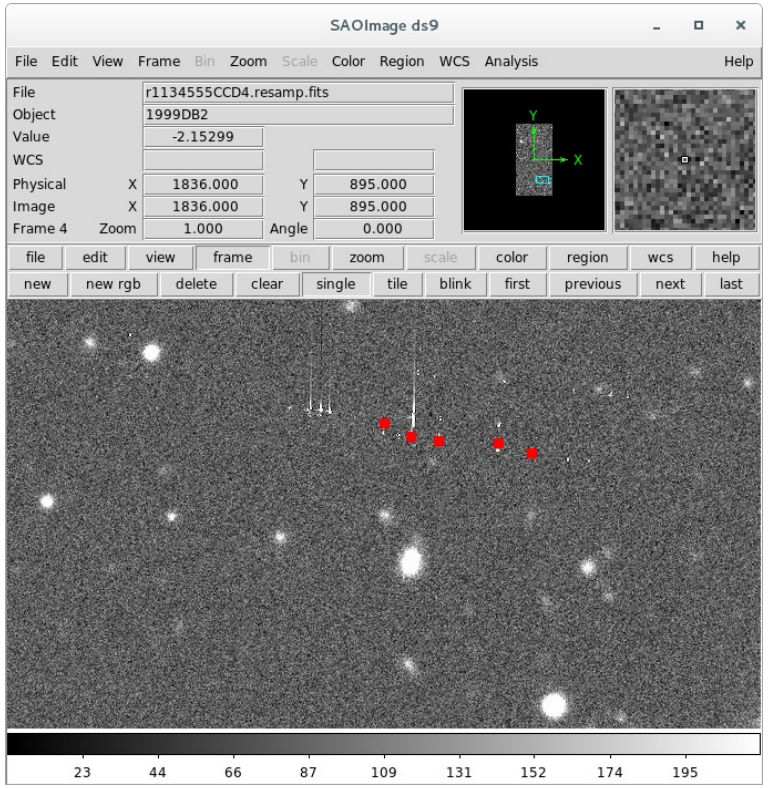


Track & Stack

Detection of very faint known NEA with INT from 6 images

Problems encountered

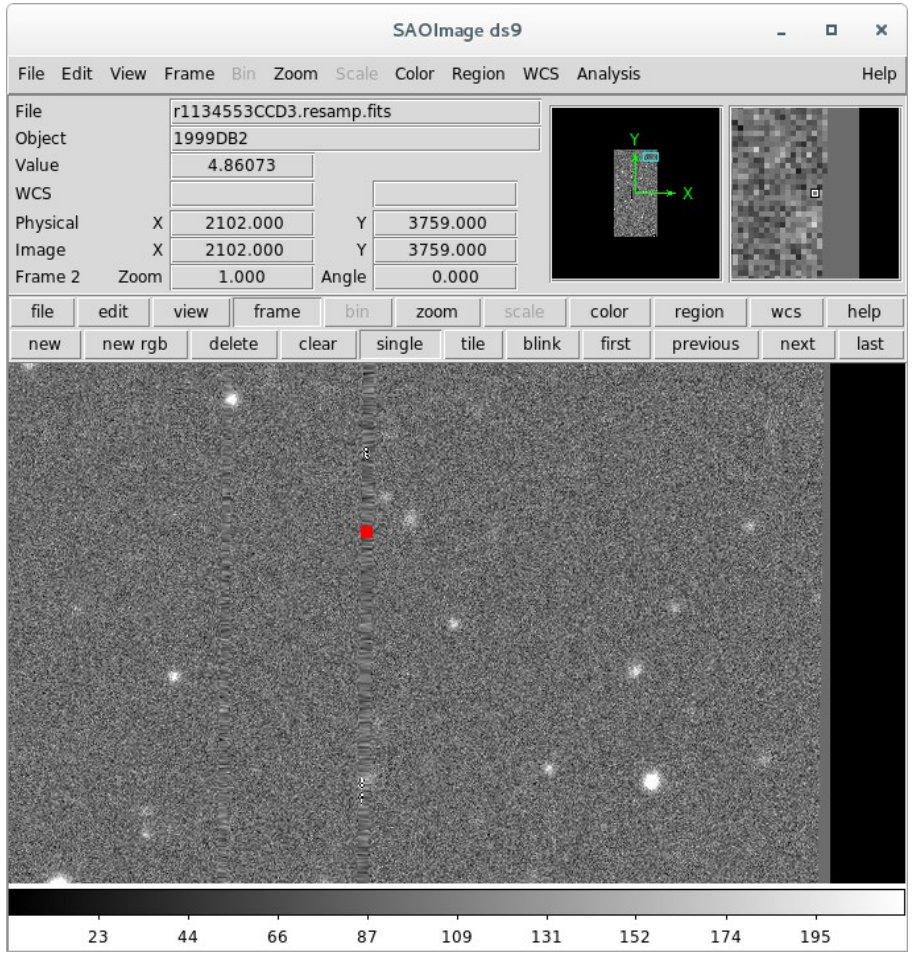




Caused by bad pixels

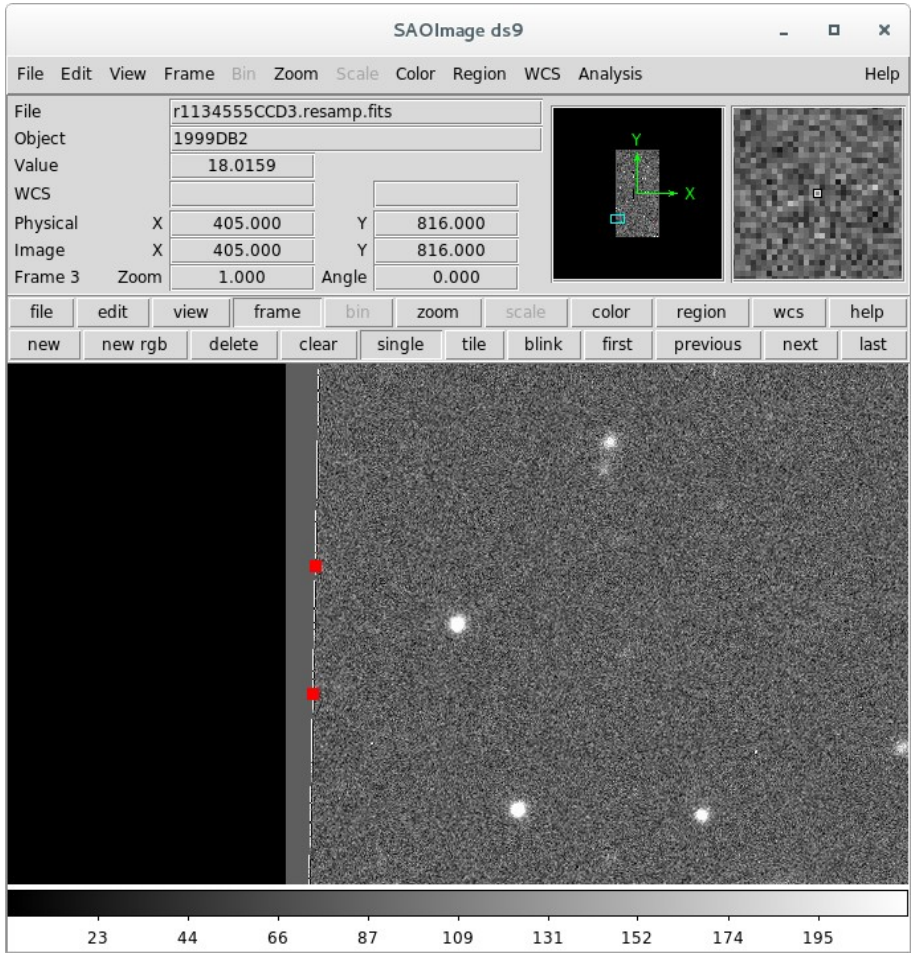
Problems encountered

Caused by interpolation



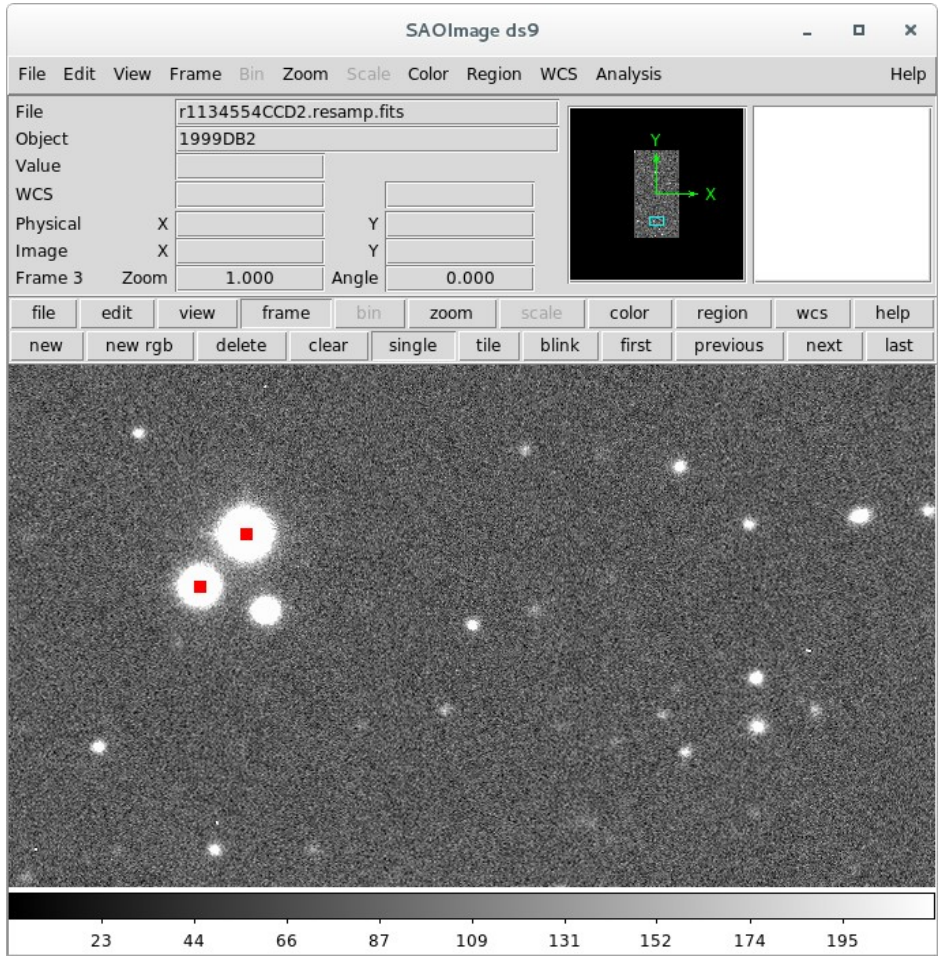
Problems encountered

Caused by image registration

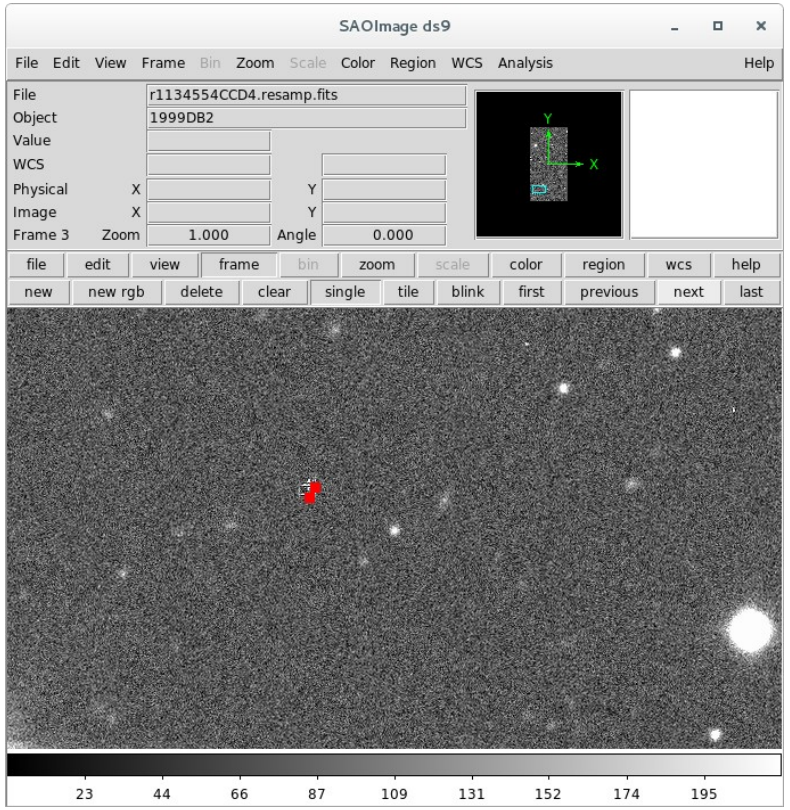


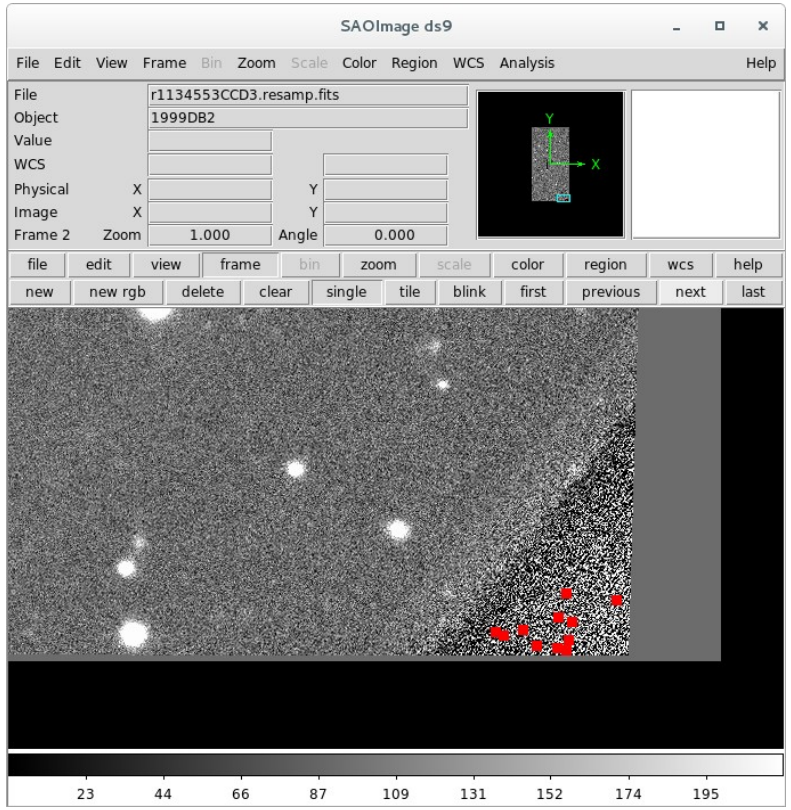
Problems encountered

Caused by star saturation



Problems encountered

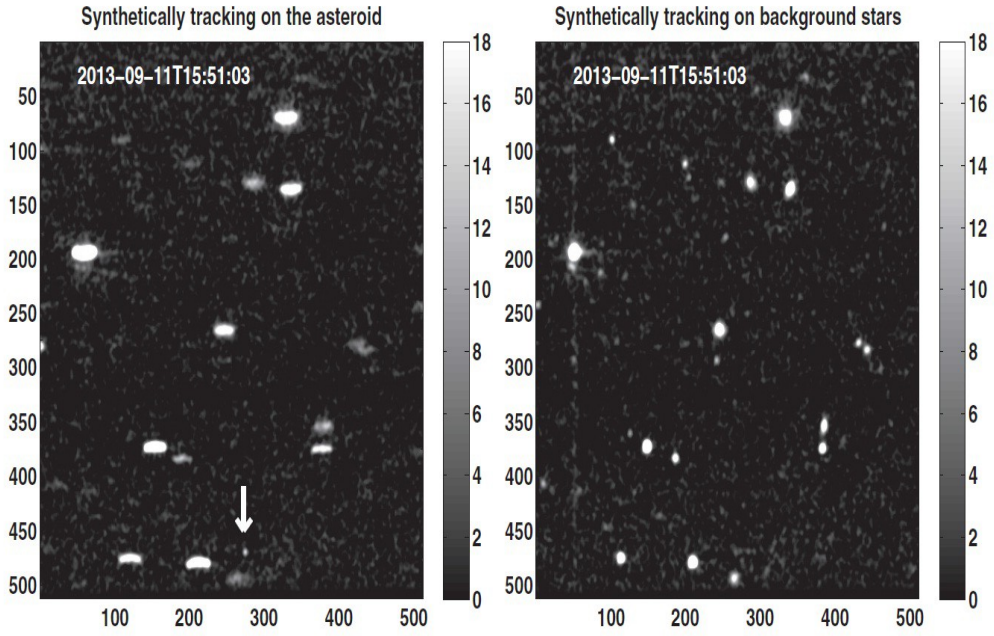




Caused by noise

Future works

- Astronomy:
  - Complete the latest “blink” modules
  - Test the pipeline using INT-WFC archive images and a future mini-survey;
  - Implementing the “Digital (or Synthetic) Tracking" method, assisted by modern computer infrastructure at two Romanian universities.



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Heinze, A. N., Metchev, S., & Trollo, J. (2015). Digital Tracking Observations Can Discover Asteroids Ten Times Fainter than Conventional Searches. *The Astronomical Journal*, 51.

Future works

- Computer Science:
  - Migrate modules to cloud as Docker Containers or as Virtual Machine
  - Replace some of the modules with OpenCV operations/algorithms
    - After that it can become even more accelerated with the GPU and using hardware accelerators tools such as CUDA or OpenCL (provided by NVIDIA)

Q&A

- Thank you for your attention!!!