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NEO Search Using a Cluster of Small Synthetic Tracking Telescopes

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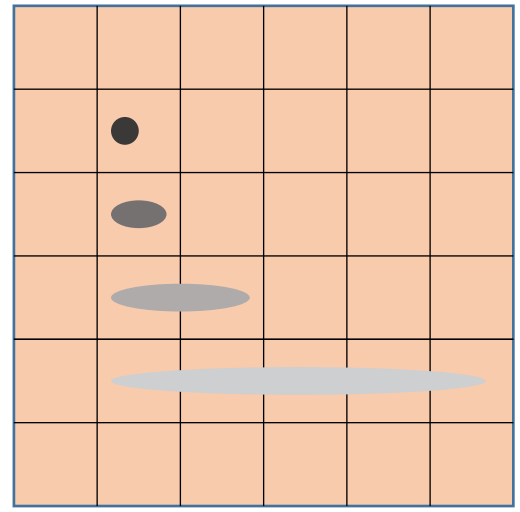
Celestron RASA
Schmidt telescope
f/2.22 prime focus
16Mpix CMOS
2 sqdeg FOV/telescope
Limiting mag ~21 mag

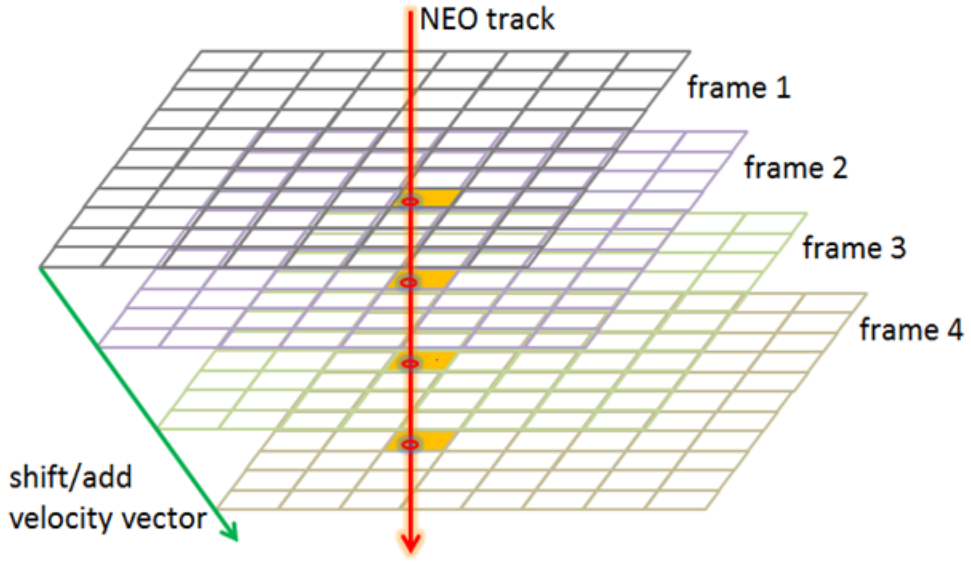
Outline

- What is synthetic tracking, what are its advantages
- Robotic telescope for NEO search /28cm Celestron, 16Mpix cmos, Nvidia GPU
- Example images
- Simulation of a cluster of 6 28cm telescopes for NEO search.
- The saturation effect (when doubling the cost/capability of the facility only increases the # unique discoveries by a few %.)

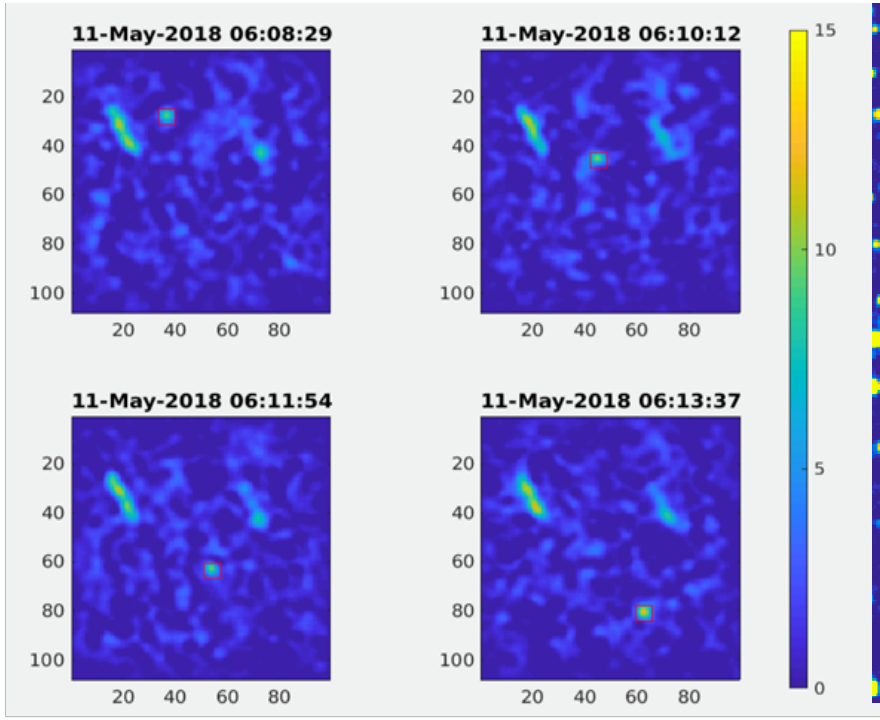
Detection of Moving Objects

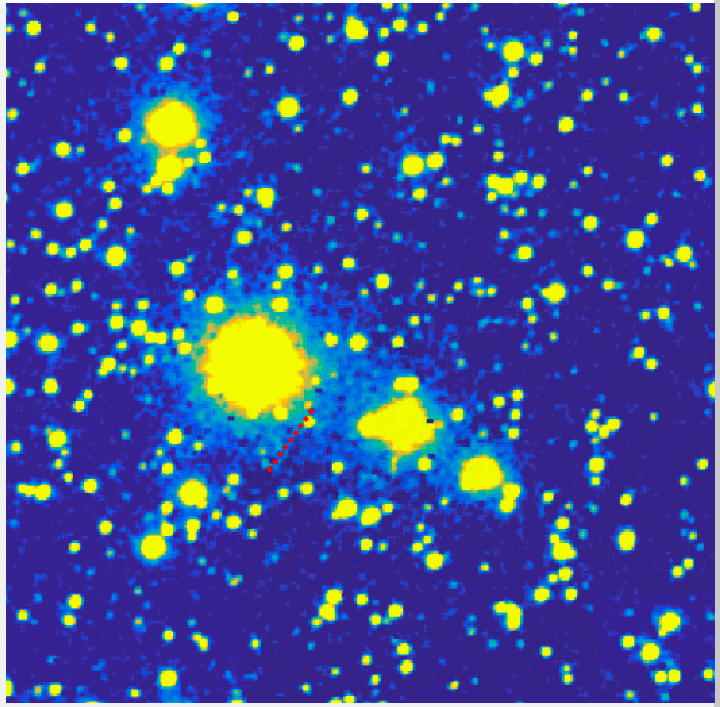
- When an object is moving across a focal plane the photons are deposited across a streak of pixels.
- The maximum SNR occurs for an integration time where the motion ~= PSF diameter.
  - Longer exposure times do no increase the peak flux, just the sky background noise.
- Synthetic tracking overcomes this by taking multiple short exposures and “stacking” them with a shift/add algorithm.
  - Requires a detector (read noise < sky phot)
  - And teraflop computing to search ~10^4 velocities.

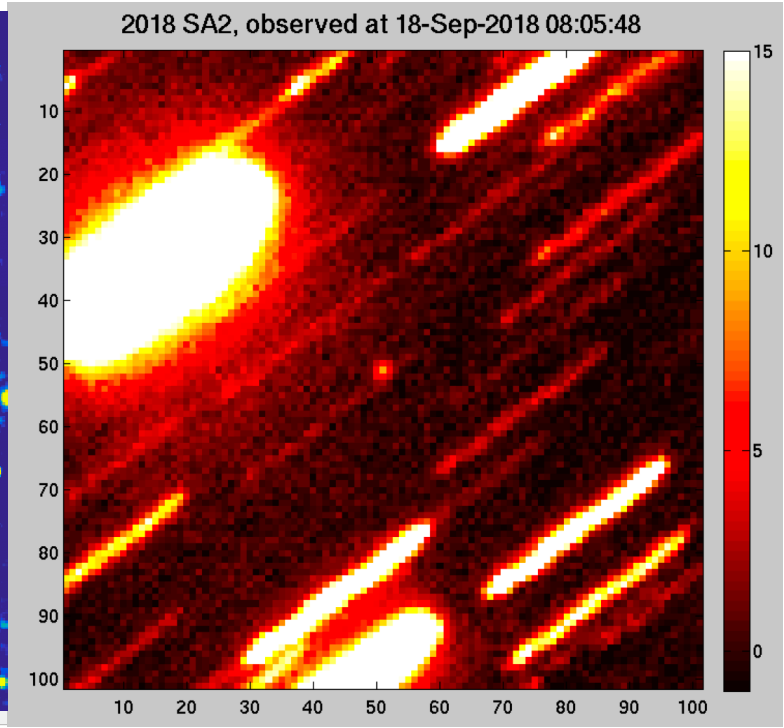




Example Data from a Ground based 28cm Syn Track Telescope







May 2018 ~19 mag NEO Each image is sum of 20 5 sec exposures . (total 400 sec integration, SNR~24)
Now improved to limiting mag ~20.8

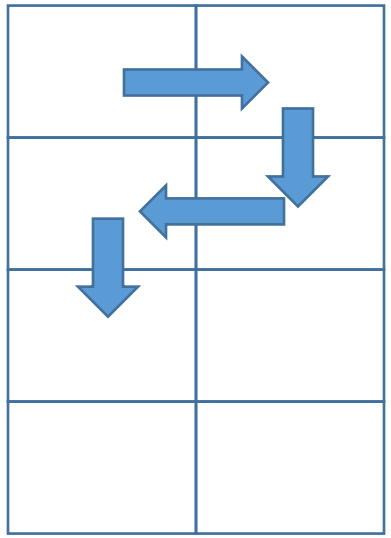
More recent, 1st detection 2018 SA2
Sep 18, 2018 19mag 400sec (80 5s images)
Observed twice (1hr apart) on 2 nights.

After our initial detection other observatories followed up with ~dozen other detections.

Preliminary tests show that 1 GPU (5 Tflop peak) can keep up with real time data analysis of 4 telescopes.

Current and final operations concept

- Scan the sky in a serpentine pattern
- Currently “revisit” the same part of the sky 1 hr later.
- Started with 1 telescope, eventually go to 4 telescopes on one mount, covering 8sqdeg FOV
- We plan to do “real time” data analysis and **“Trigger”** the follow up observation ~1 hr later.
  - At ~21mag if the object is moving fast, it may be difficult for other telescopes to do a follow up.
  - The triggered follow up may also **increase the integration time** if the mag is near the detection threshold
  - Will also consider “triggered” follow up observation 1 or more days afterward to obtain a 1~2 week track. (with < 50mas astrometric accuracy)

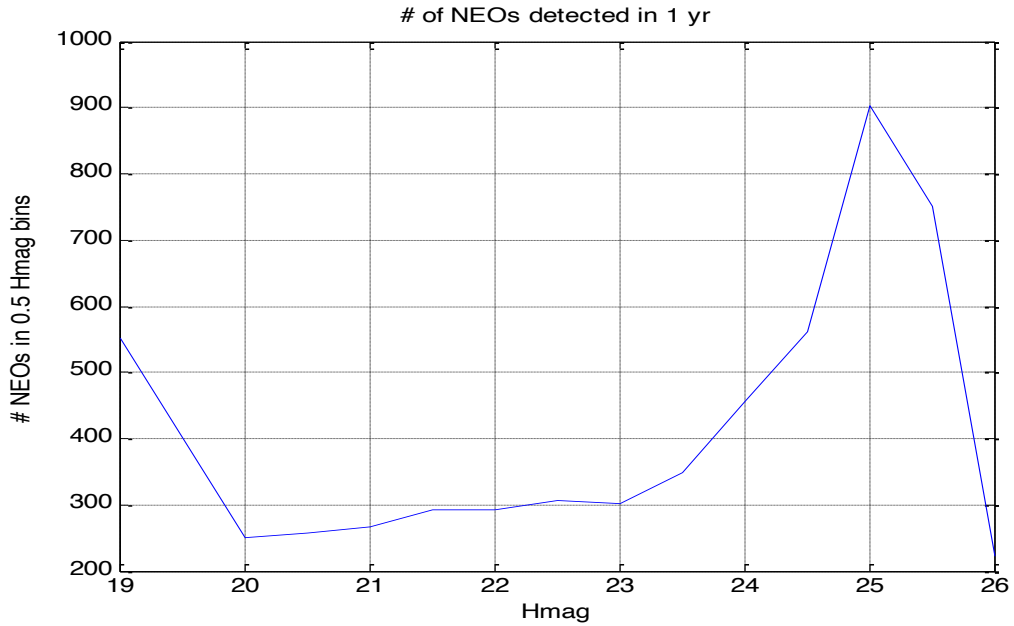


Dwell 400~500 sec at each telescope Pointing.

Triggered follow ups may use longer integration times (to have ~95% prob of detecting the object on follow up)
The longer integ can also will provide < 50mas astrometry.

NEO Search Simulation

- Start with Granvik NEO population model
- Simulate 1 yr operation (ignoring Moon, weather) 11,000 NEOs/yr
  - Cluster of 6 telescopes with total 12 sqdeg FOV
- Ground based telescope(s) ~2500 /yr
  - Includes:
    - 60% due to Moon
    - 75% from weather
    - 1hr Confirm only on detection
- Currently have 4 telescopes operating.
  - Still working on software.



Limiting mag	21.0mag	21.2m sky
1 exposure	5s	
Total Integ	500 s	
Sky	<60deg	Anti-Sun
Tel Dia/Pix	28cm	1.27 asec
#pix/FOV area	16Mpix	2.0 sqdeg

Looking Forward

- Still getting the software to be fully automated. But a cluster of 6 of telescopes has the potential to find > 2000 NEO/yr
- Hardware upgrades
- 36cm dia RASA telescope (f/2.2) with 4 deg FOV is now available
- In Dec 2018 ~jan 2019, a 11700x8700 pixel backside CMOS camera will become available.
  - ~100 Mpix camera with > 70% QE
- Together they provide a 7.5sqdeg FOV, and 21.6mag (500s, 21mag sky) from a single telescope.
  - A cluster of 4 of these telescopes would triple/quadruple the discovery rate of current NEO search facilities.

- The biggest impact of this technology will be in space based searches for NEOs. (multiple Low cost 24U to ESPA class spacecraft in solar orbit)