



Status of ZTF Asteroid Detection & Plans for Asteroid Marshal

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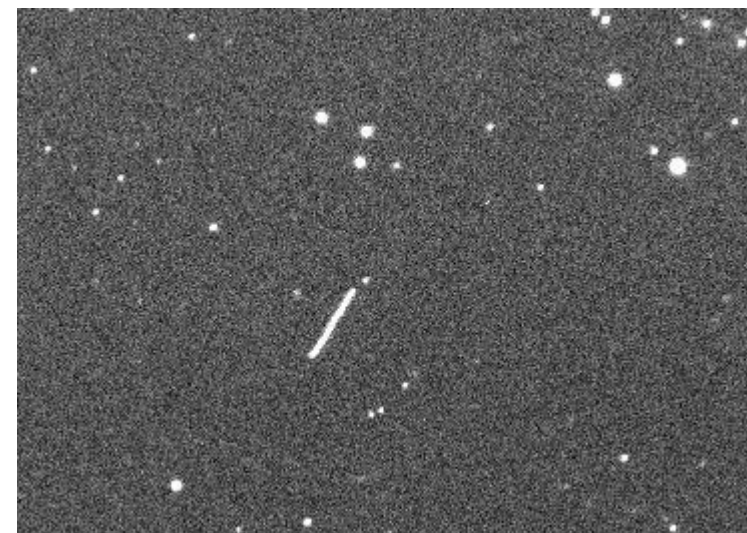
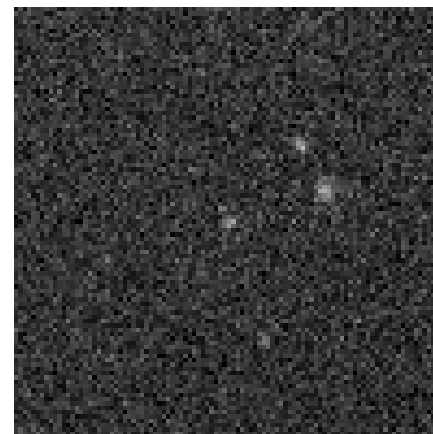
on behalf of the
ZTF Asteroid Detection Team



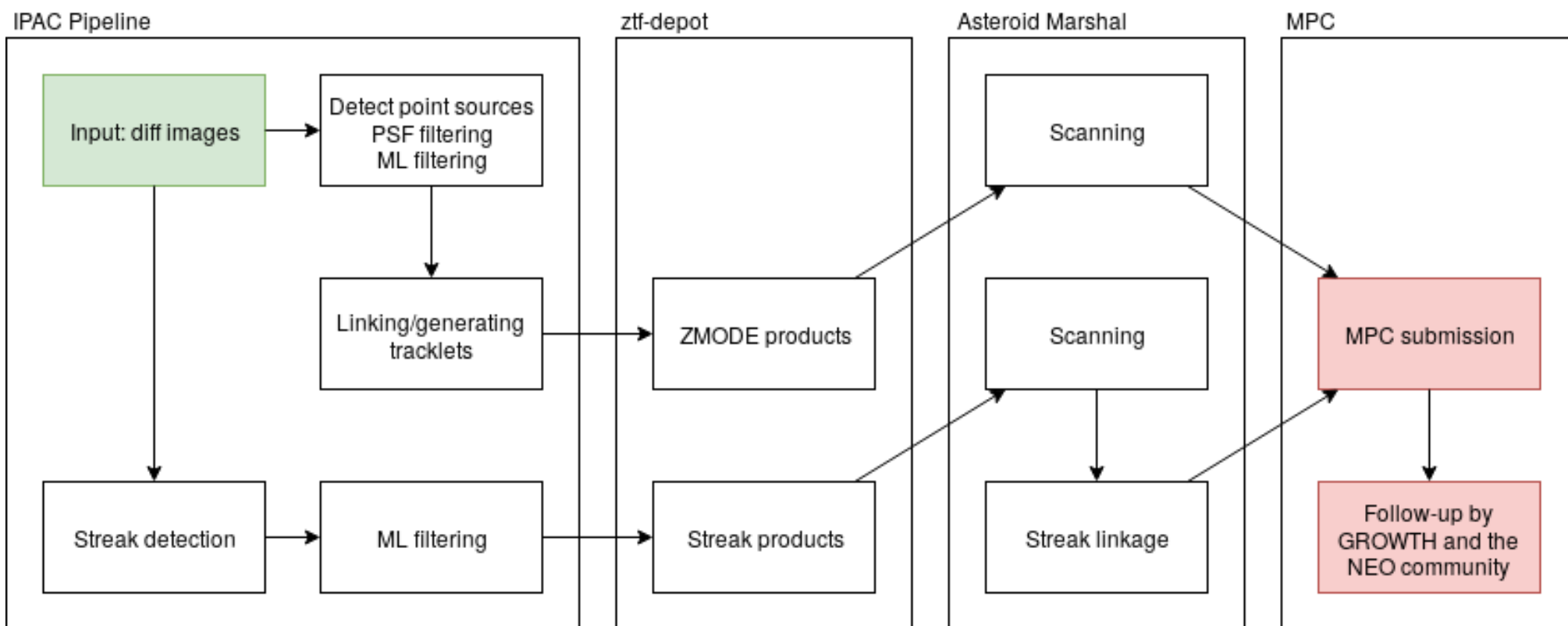
Asteroid detection with ZTF



- **Detect point-like moving object with ZMODE**
 - Most detections are main-belt asteroids; approximately $\sim 0.1\%$ are far-away NEAs
- **Detect trailed objects (streaks)**
 - Asteroids will trail when less than ~ 0.02 au from the Earth
 - Some “real” streaks are man-made objects; we do not know until orbital determination



Workflow



- **IPAC pipeline emits ZMODE products by PT noon**
 - MPC report and digest scores of intra/inter-night tracklets
 - Stamps of science and reference images
 - IPAC pipeline will label known SSOs
- **Review of ZMODE tracklets is usually done within 1-2 hours after they are emitted**
 - QA is done via a Jupyter notebook running on a workstation at IPAC

ZMODE review notebook



```
IPython QtConsole
File Edit View Kernel Window Help
ZTF0021 C2018 03 06.36116 11 58 41.28 +39 56 00.8 16.76r I41

sci

ref
Desig. RMS NEO N22 N18 Hun Pho MB1 MB2 MB3 Hil JTr MC Pal Han JFC
ZTF0021 0.28 97 36 0 0 0 0 0 0 0 3 0 0 1

!!! Possible NEO !!! Possible NEO !!! Possible NEO !!! Possible NEO !!! Possible NEO !!!

63/72 objects remaining... [a]ccept or [r]eject (default: r)?
=====
ZTF0009* C2018 03 06.26587 10 17 52.58 +17 25 40.0 18.21r I41
ZTF0009 C2018 03 06.28951 10 17 52.59 +17 25 40.0 18.15r I41
ZTF0009 C2018 03 06.29050 10 17 52.59 +17 25 40.1 18.12r I41
ZTF0009 C2018 03 06.29248 10 17 52.59 +17 25 40.0 18.29r I41
ZTF0009 C2018 03 06.31314 10 17 52.60 +17 25 39.8 18.39r I41

sci

ref
Desig. RMS NEO N22 N18 Hun Pho MB1 MB2 MB3 Hil JTr MC Pal Han JFC
ZTF0009 0.08 97 21 0 0 0 0 0 0 0 3 0 0 0

!!! Possible NEO !!! Possible NEO !!! Possible NEO !!! Possible NEO !!! Possible NEO !!!

62/72 objects remaining... [a]ccept or [r]eject (default: r)?
```

Status of streak detection



- **IPAC pipeline emits streak products “on-the-fly”**
 - Condensed summary file, MPC reports, stamps from the differenced image
- **All stamps in the night are posted on yupana ~6:30 PT in the morning for the scanning team**
- **Scanning is usually done by noon PT**
- **Scanners identify possible reals; the team lead makes final decision, links different sightings, and makes MPC submission**

(MPC submission requires a streak to be sighted for 2+ times)

Streak screening page



ZTF Fast Moving Object Screening Page - Mozilla Firefox

Yupana Caltech.edu/marshals/qye/streaks/20180307/20180307.htm

Candidates for the Night of UT 2018-03-07

Last updated on UT 2018-03-07 14:30:32

Number of candidates: 87

 apmag 16.2 score 70 4305054710150001	 apmag 15.7 score 87 4304508734150001	 apmag 16.5 score 50 4302505421150001	 apmag 16.5 score 66 4302648833150001	 apmag 16.4 score 67 4305039952150002	 apmag 17.1 score 71 4303434128150001	 apmag 15.9 score 56 4304918452150002	 apmag 17.6 score 55 4303453839150001	 apmag 15.7 score 57 4304873948150001	 apmag 15.9 score 100 4304219900150001
 apmag 17.6 score 66 4303174550150001	 apmag 17.0 score 95 4303679061150001	 mag 17.2 score 4303477138150001	 apmag 17.3 score 58 4302633956150001	 apmag 16.3 score 63 4304873907150001	 apmag 16.9 score 91 4304026750150001	 apmag 17.1 score 87 4303679061150001	 apmag 17.4 score 57 4302499831150001	 apmag 17.3 score 67 4302475153150001	 apmag 17.5 score 90 4302762345150001
 apmag 16.8 score 55 4302584453150001	 apmag 15.4 score 58 4302530051150001	 apmag 16.0 score 97 4304219901150001	 apmag 16.1 score 100 4304190152150001	 apmag 17.8 score 84 4302792101150001	 apmag 15.8 score 70 4304873907150004	 apmag 17.2 score 85 4303492029150001	 apmag 17.2 score 52 4303253520150001	 apmag 15.1 score 52 4304918452150001	 apmag 16.7 score 73 4303154701150001
 apmag 17.0 score 71 4304026714150001	 apmag 17.8 score 62 4302732743150001	 apmag 17.0 score 66 4303024349150002	 apmag 17.3 score 55 4303061204150001	 apmag 16.4 score 52 4303634663150001	 apmag 17.5 score 58 4302653725150001	 apmag 17.3 score 58 4302782156150001	 apmag 17.7 score 70 4302619027150001	 apmag 17.3 score 51 4302331512150001	 apmag 16.8 score 67 4303679061150003

03/20/18

ZTF Team Meeting

Performance so far



- **On a perfect night*, ZTF can:**
 - produces ~80,000 detections of ~20,000 unique asteroids, including ~10 NEAs and comets
 - discover ~50 new asteroids (mostly main-belts)
- **As of Mar 20, 2018:**
 - 531,725 observations (~10% of all MPC observations from Dec 3, 2017 to Mar 20, 2018)
 - 32,765 unique asteroids
 - 244 new asteroids, including 3 NEOs

*: Statistics based on the observations conducted during the reference building phase



- **Operation-level:**

- Point-source component is ready for survey operation
- Streak component is usable, but ML part needs more work

- **Collaboration-level**

- Asteroid Marshal is at alpha phase; needs more work too

Problems - 1. streaks



- **Several ML models exist; need to be benchmarked**
 - Some miss many fainter streaks while others generate a lot of garbage – “optimal point” not yet reached
 - Performance of different streak ML model needs thorough evaluation

Response: 1. gauge the efficiency of different ML models using known NEAs

2. working with the ZTF-ML group to construct a better real/bogus sample

3. explore Deep Learning as an alternative ML method

Problems - 2. marshal



- **Still largely rely on email for communication**
- **Marshal needs more work to streamline communication/coordination**
 - Desired functionalities:
 - On-page labeling and commenting
 - Streak linking tool
 - DB to keep track of labeling, submission etc.
 - Follow-up coordination with GROWTH marshal
 - Different requirement vs. other ZTF/GROWTH marshals (also the iPTF asteroid marshal); might be easier to start from scratch

Immediate Plans



- **Keep on doing daily review of ZMODE, streak products, submission to MPC as necessary**
- **Streak ML improvement**
 - Building up a “clean” streak real/bogus sample using available ZTF data; benchmark different ML models; explore different ML methods
 - Moves towards real time scanning with Asian/European collaborators
- **Marshal development**
 - Focus on key functionalities: on-page labeling/commenting; streak linking tool