Imtrandetect: a new tool/methodology for detecting transients from large image-data streams down to low S/N

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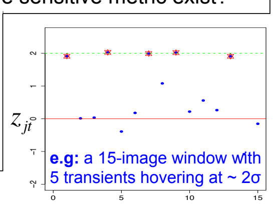
Goals / Overview

- One of the problems facing current and future synoptic sky surveys is how to detect transient candidates to low S/N levels **optimally, reliably, and quickly** from large data streams. This will increase our chances of discovering rare and new events, either through archival analyses or real-time follow-up of interesting events.
- By mining deeper, we need to be prepared for a higher rate of false-positives, e.g., instrumental glitches and contamination from a "fog" of uninteresting astrophysical transients. Hence we need to work harder at finding our diamonds. Consequently, we place more emphasis on reliability.
- A popular method for detecting transients is image differencing (with prior PSF-matching) against a deeper reference image. This is powerful, but can we do better? We have explored a few image-combination metrics [below].
- An *optimal* transient-detection method (in the max-likelihood sense) has been designed and implemented in a software tool (*imtrandetect*) for automated execution during a synoptic sky survey.
- The method is optimized for optical/IR data, where the *underlying* photon-noise is usually well into the Gaussian limit. The focus here is to detect transient candidates, not classify them, although the latter can assist the former. The software is a work in progress and will be released to the public.

Enhancing the S/N of suspect transients from "sub-significant" single epoch events

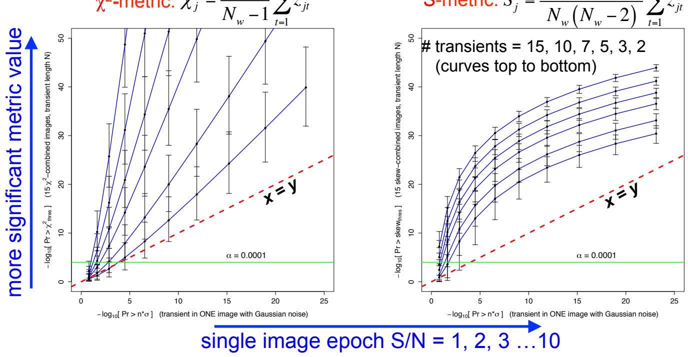
- We have extended the single image-epoch differencing method by combining multiple, consecutive epochs where a transient may be "active".
- Images are combined (collapsed) in moving block windows of length N_w along a growing time-series using a *chi-square* (χ^2) and *skew* (S) *metric*.
- Reason for windowing: reduce dilution from long-run baseline noise.
- We performed simulations to test the sensitivity of these metrics for a moving window of 15 images containing varying numbers of intermittent transients with different S/N where noise is purely Gaussian and uncorrelated vs time.
- We find the *skew* metric is **most** sensitive at detecting slight asymmetries in a time-collapsed pixel distribution. Q: does a more sensitive metric exist?
- **plots below:** probability that an observed pixel sequence with # transients will occur by chance if only Gaussian noise were present.
- **e.g.,** a transient with single-epoch S/N ~ 2σ needs to occur >~ 5 times out of 15-imgs to give a *S-metric* significance of α <~ 0.0001.



for pixel j and long-run estimates of m_j, σ_j: $z_{jt} = \dfrac{p_{jt} - m_j}{\sigma_j}$

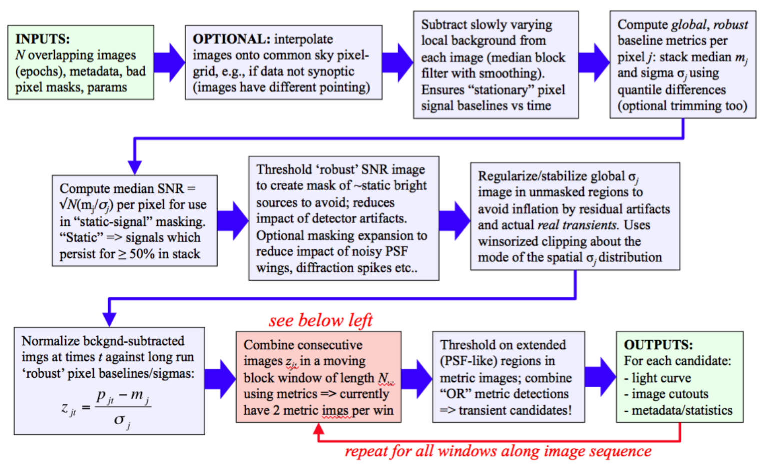
χ^2-metric: $\chi^2_j = \dfrac{1}{N_w - 1} \sum_{t=1}^{N_w} z^2_{jt}$

S-metric: $S_j = \dfrac{\sqrt{N_w(N_w-1)}}{N_w(N_w-2)} \sum_{t=1}^{N_w} z^3_{jt}$



The Software: features and processing flow

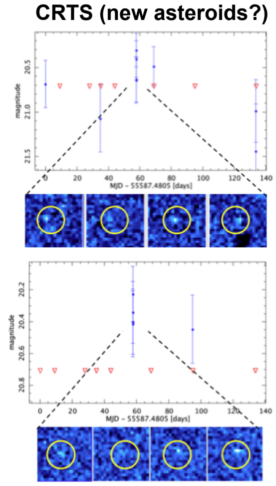
- Overall, the tool emphasizes masking of instrumental artifacts through use of img masks and dynamic masking of "static" bright sources and their artifacts
- There is minimal impact from PSF variations (temporal and spatially).
- It has the ability to combine images from multiple filters to maximize S/N.
- Can handle data with irregularly spaced observation times and large gaps.
- Can handle images with non-uniform overlap (varying depth) across epochs.
- Tunable to detect transients to different S/N thresholds and timescales.
- Optional use of light-curve templates to assist in isolating specific candidates
- Optional constraints to maximize reliability: e.g., must have at least n consec events above some S/N separated by < Δt, and must appear PSF-like.
- Generates light-curves, image cutouts, and other metadata.



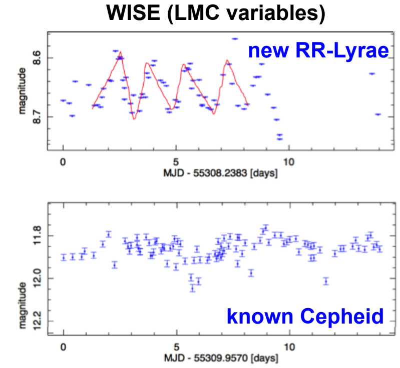
Some results from testing on real data

- We are in the process of testing on data from the Catalina Real-Time Transient Survey (CRTS) and the WISE mission. WISE is not a synoptic survey, but irregularly spaced epochs of non-uniform depth are available.
- For CRTS, we pushed down to a single epoch S/N ~ 3, found a spurious transient rate of ~8% and lots of faint asteroids [see below].
- For WISE, we performed a blind search for variables in the LMC at 3.4μm.

CRTS (new asteroids?)



WISE (LMC variables)



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