Automatic detection of hostless transients in FINK

Lilianne Nakazono (IAG-USP)
On behalf of the COIN Collaboration

Fink-Brazil Workshop - May 2024

COIN Residence Program #7

This project was led by Priscila Pessi (Stockholm University)

“An unstructured meeting, offering opportunities for collaboratiave research, learning, and transference of skills.

The CRPs are composed by young and senior researchers from astronomy, statistics, computer science and related disciplines alike.”

COIN

Cosmostatistics Initiative

Astronomy & Astrophysics manuscript no. main
April 30, 2024

ELEPHANT: ExtragaLactic alErt Pipeline for Hostless AstroNomical Transients

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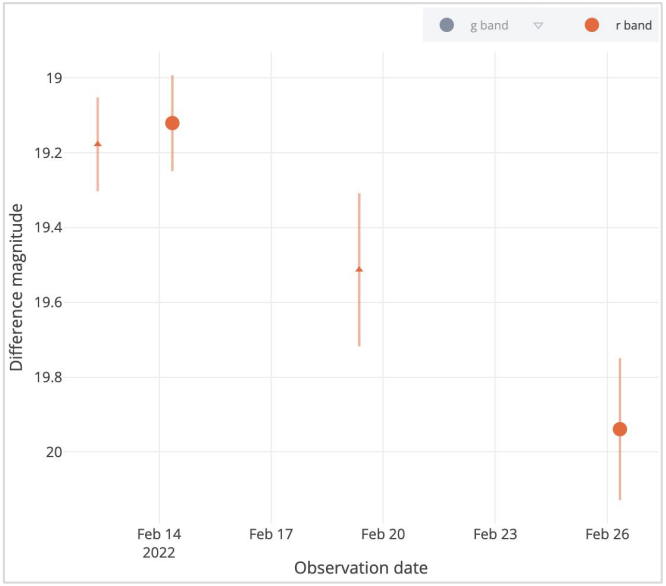
April 30, 2024

Recently uploaded to arXiv!
arXiv:2404.18165

What are hostless transients?

- Transients are brightness-variable events that have a large range of time scales from microseconds to years



Example of light curve for SN2022ann

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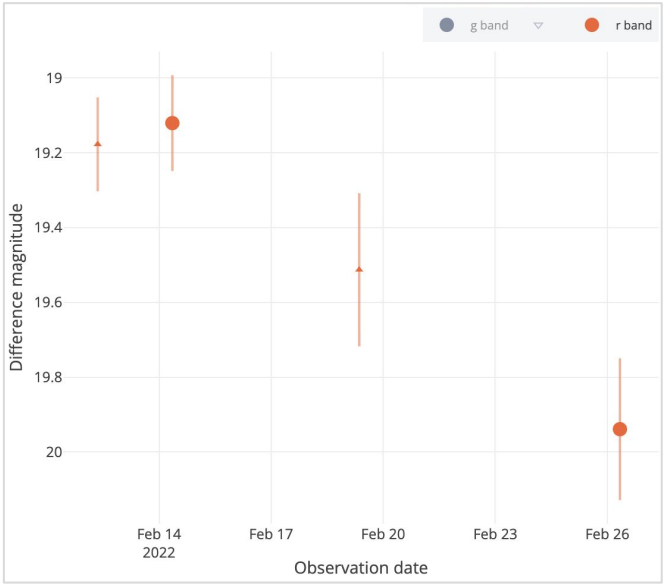

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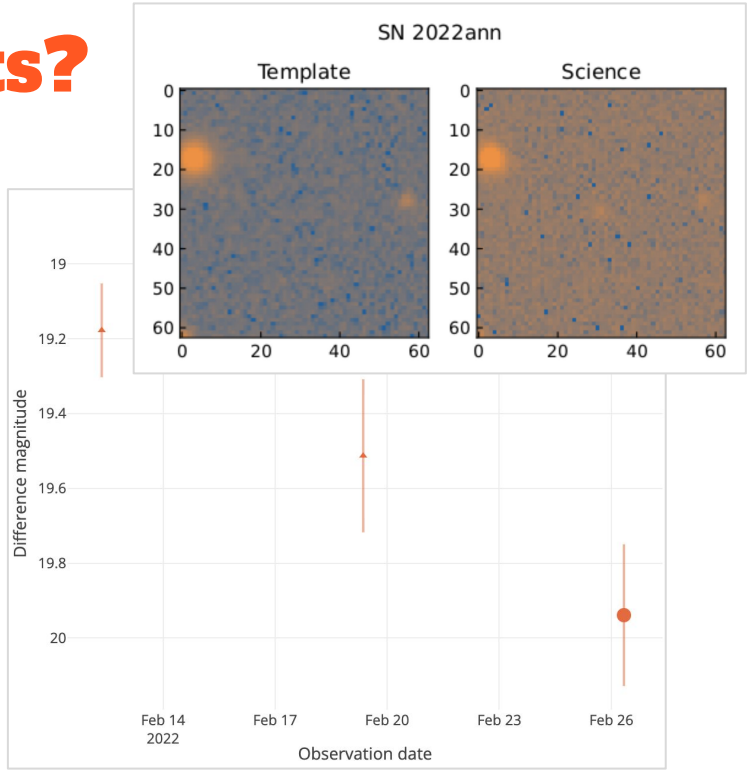
- A small fraction are **hostless transients**, exhibiting no discernible association with a host galaxy



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What are hostless transients?

- Examples of what hostless transients have been associated with:
  - Superluminous supernovae (SLSNe; e.g. McCrum+15)
  - Gamma-ray bursts (GRBs; e.g. Ho+20)
  - Fast X-ray transients (FXTs; e.g. Gillanders+24)
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- Two physical scenarios
  - The host galaxy was not detected because it is faintest than the survey's limiting magnitude
  - The transient was produced by a progenitor that achieved hypervelocity and escaped its host galaxy (e.g. Martin+06, Zinn+11)

A needle in a haystack

- With the upcoming Vera C. Rubin Observatory's LSST, it is expected to detect around **10 million transient candidates per night** (Bellm+2019)

- ZTF currently detects a **few hundred thousand transient candidates per night**

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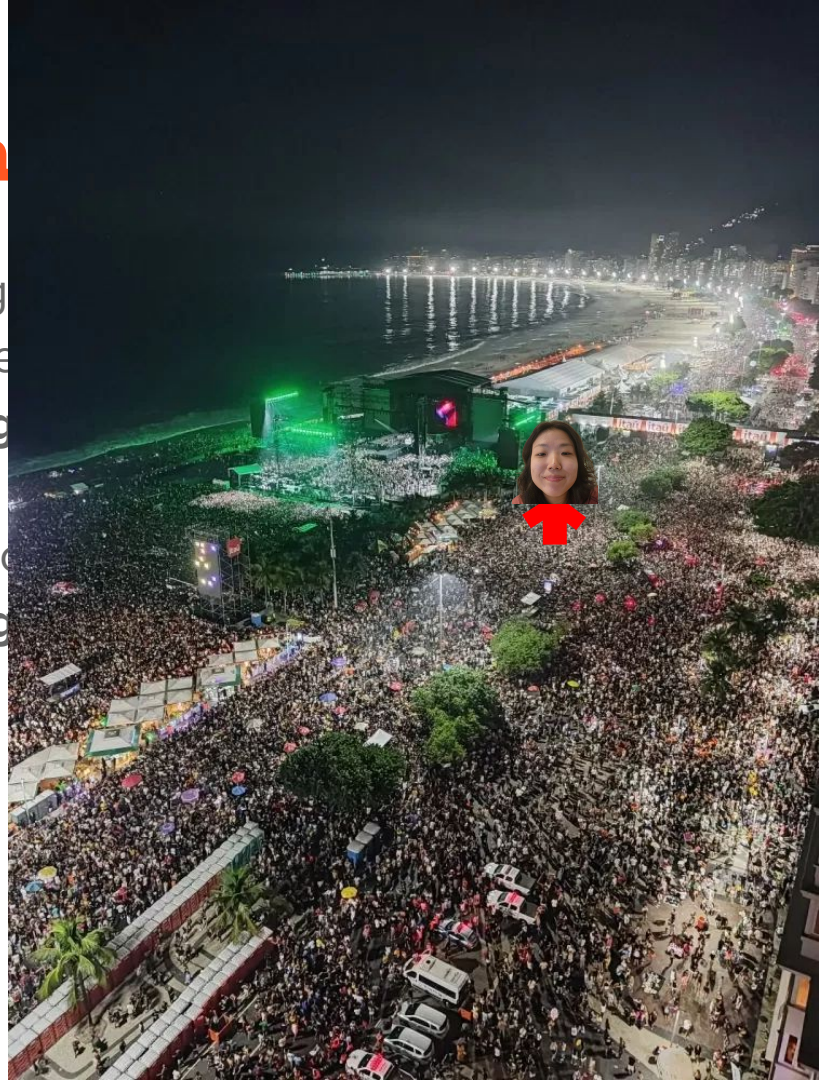

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- We only keep events:
  - Associated with an extragalactic transient classification (including all classes of AGNs, SNe, Kilonova candidates, etc)
  - Not associated with a known host from MANGROVE catalog (Ducoin+20), even if the host galaxy association is tentative
  - That have two or more alerts, in order to eliminate potentially bogus events

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→ 3.5% of the original alerts are kept after applying all conditions

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Addressing the ELEPHANT🐘 in the room

This pipeline analyses both template and science cutouts

Is there a host association?

https://github.com/COINtoolbox/extragalactic_hostless

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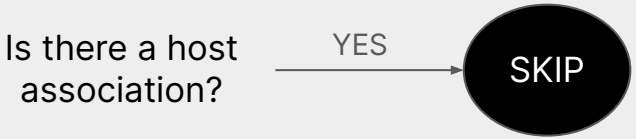

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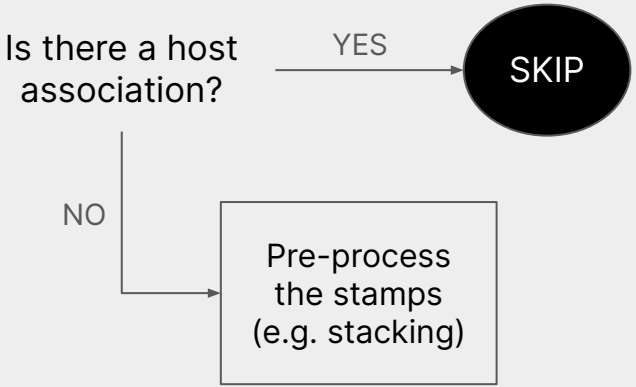

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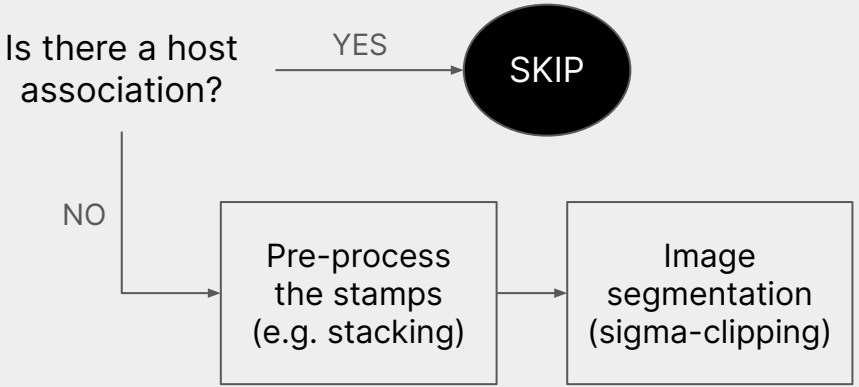

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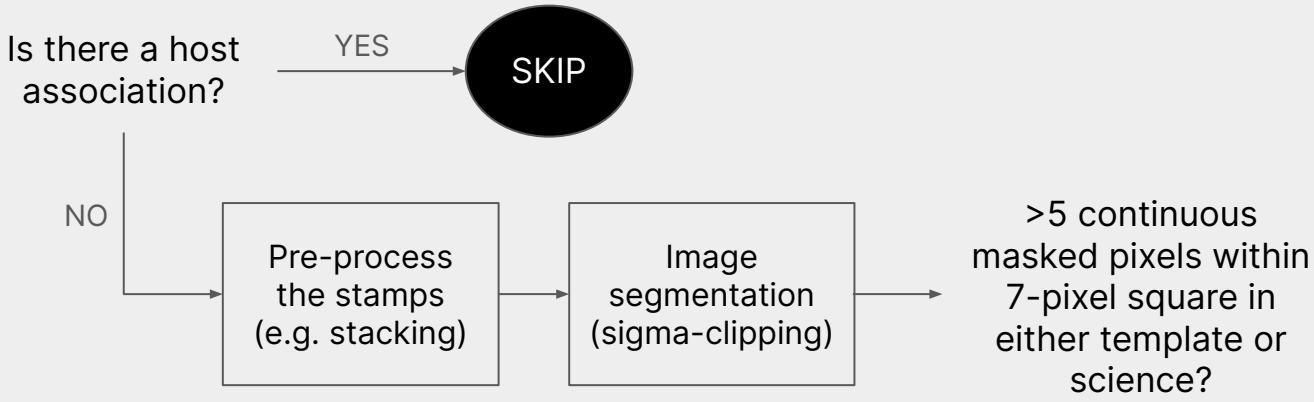

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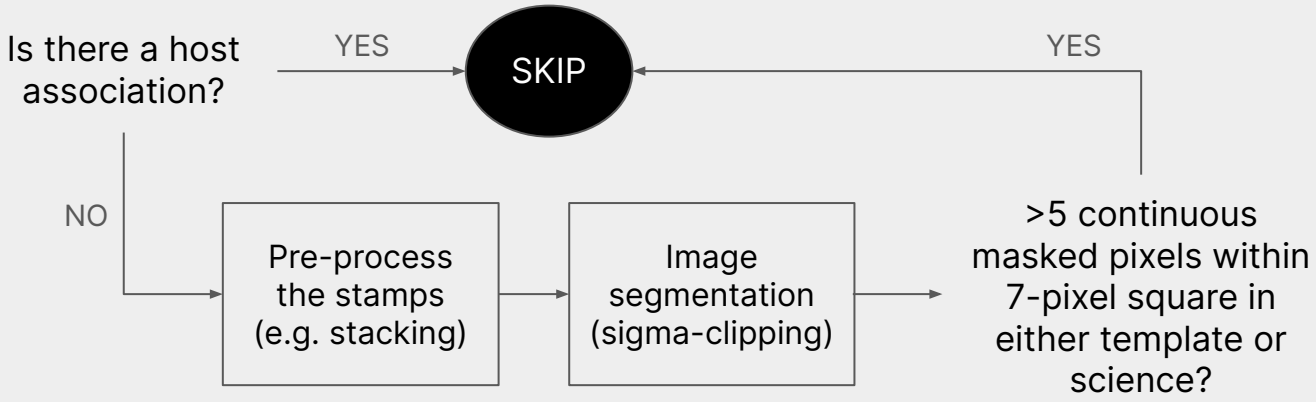

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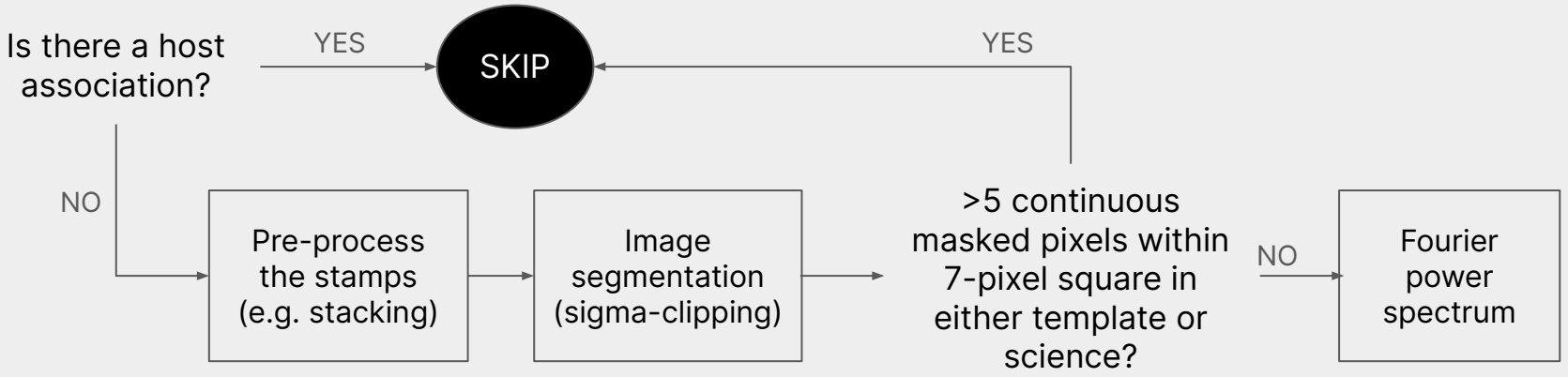

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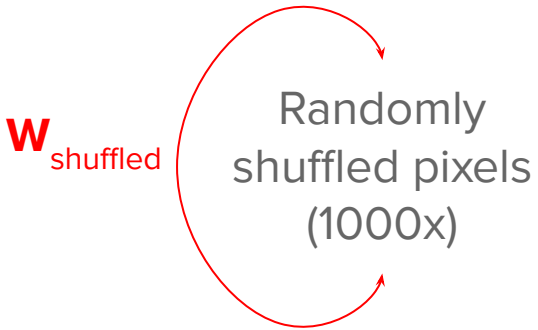
The Fourier power spectrum step

This step determines if there is any indication of a host presence, being effective even if the signal is faint. In summary:

1) Transform the stamps into the Fourier space -> 2-dimensional
2) Calculate the power spectrum -> 1-dimensional
3) Calculate the Wasserstein distance of pairs of power spectra (I will denote the distance distributions as **W**)



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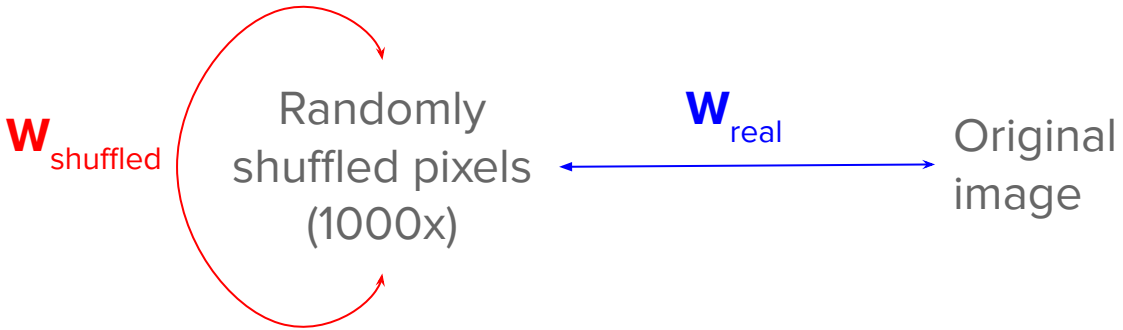

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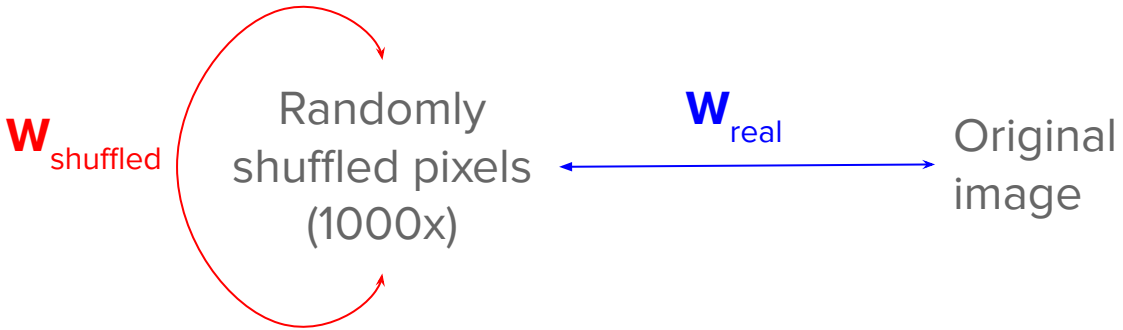
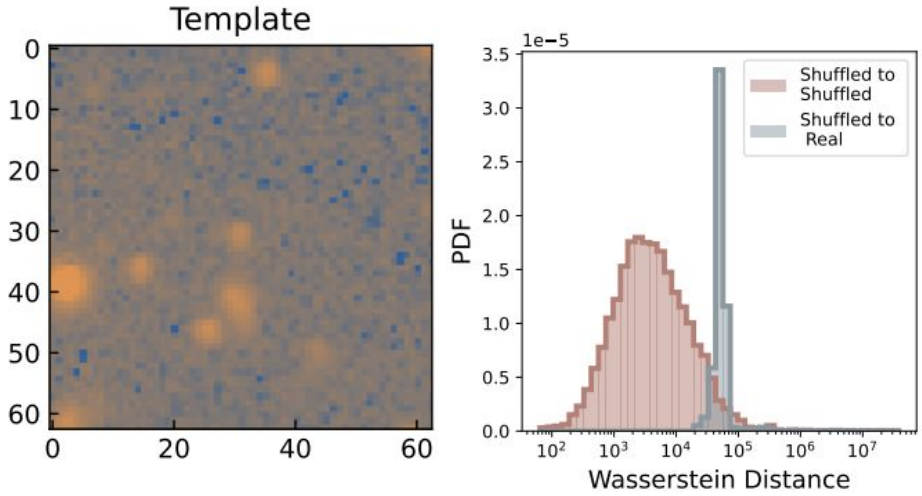


If absent: $\bar{w}_{\text{shuffled}} \sim \bar{w}_{\text{real}}$

If host: $\bar{w}_{\text{shuffled}} < \bar{w}_{\text{real}}$

The Fourier power spectrum step

ZTF18aajwbhh



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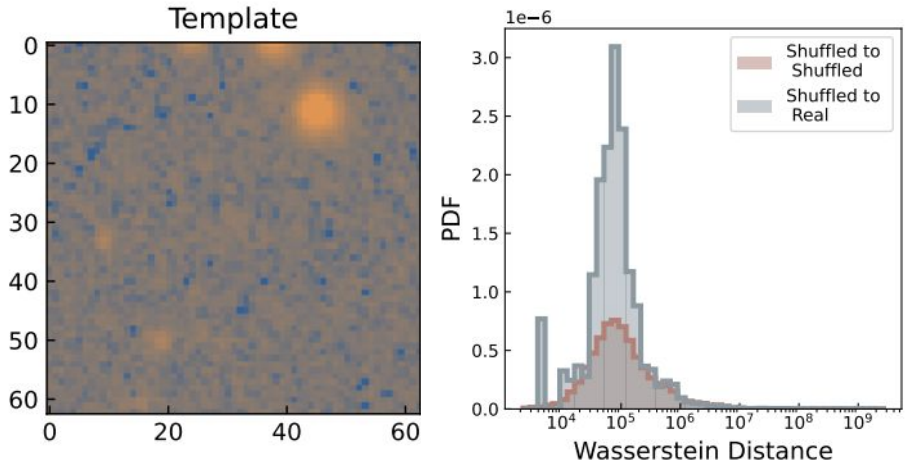
ZTF22aakkmri



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The Fourier power spectrum step

Image size (pix)	K-S threshold	Contamination (%)
7×7	0.25	27.01
15×15	0.50	25.97
29×29	0.90	27.33

Table 1: Kolmogorov-Smirnov statistic thresholds and corresponding contamination levels for different cutout sizes. The threshold was determined using only visually confirmed hostless objects with TNS classification and requiring completeness of 75%.

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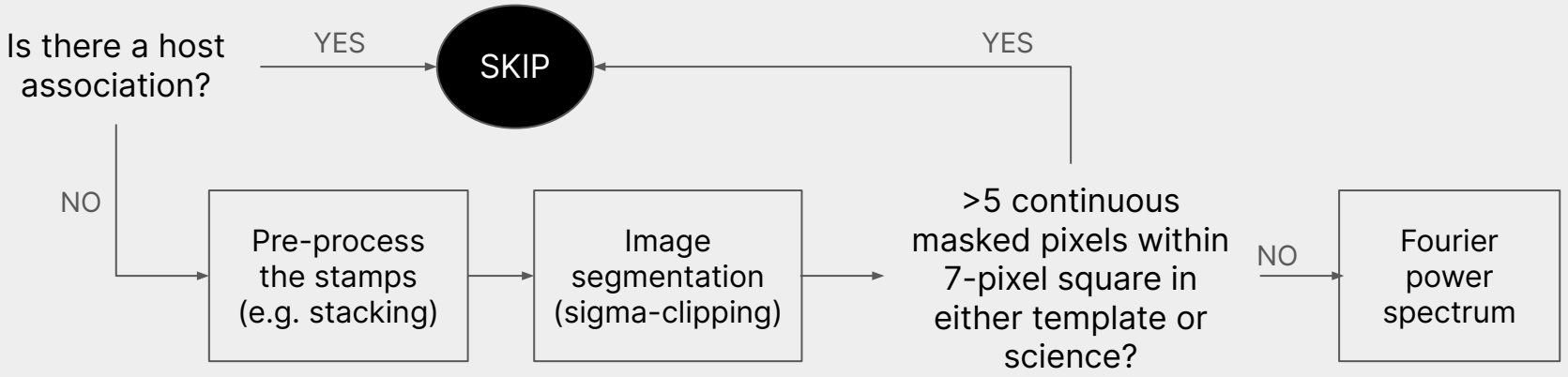

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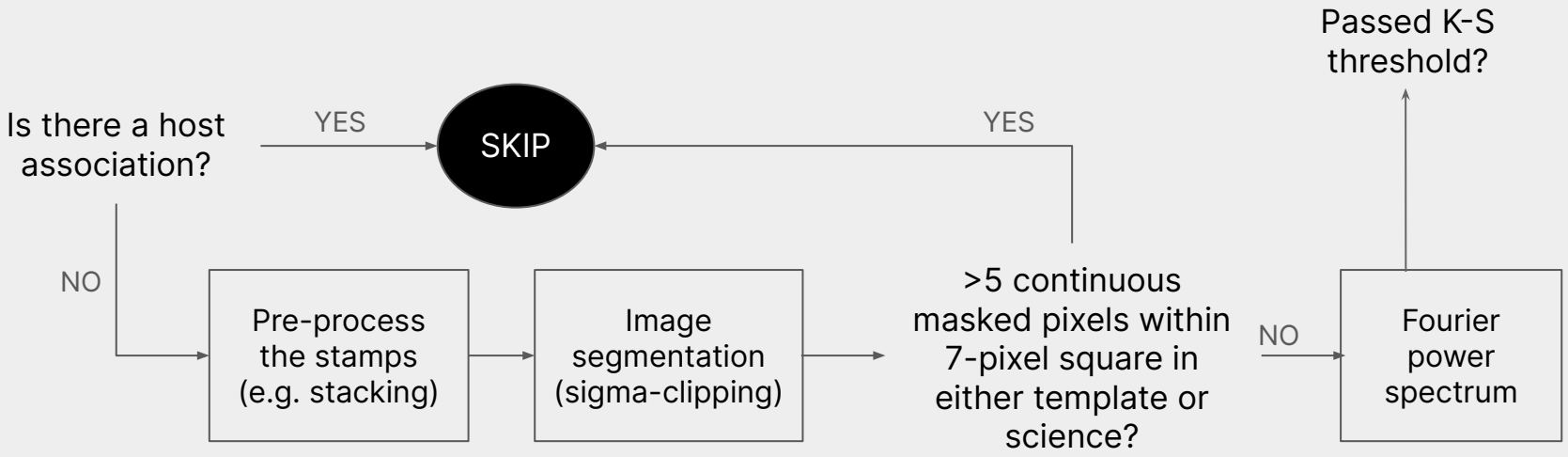

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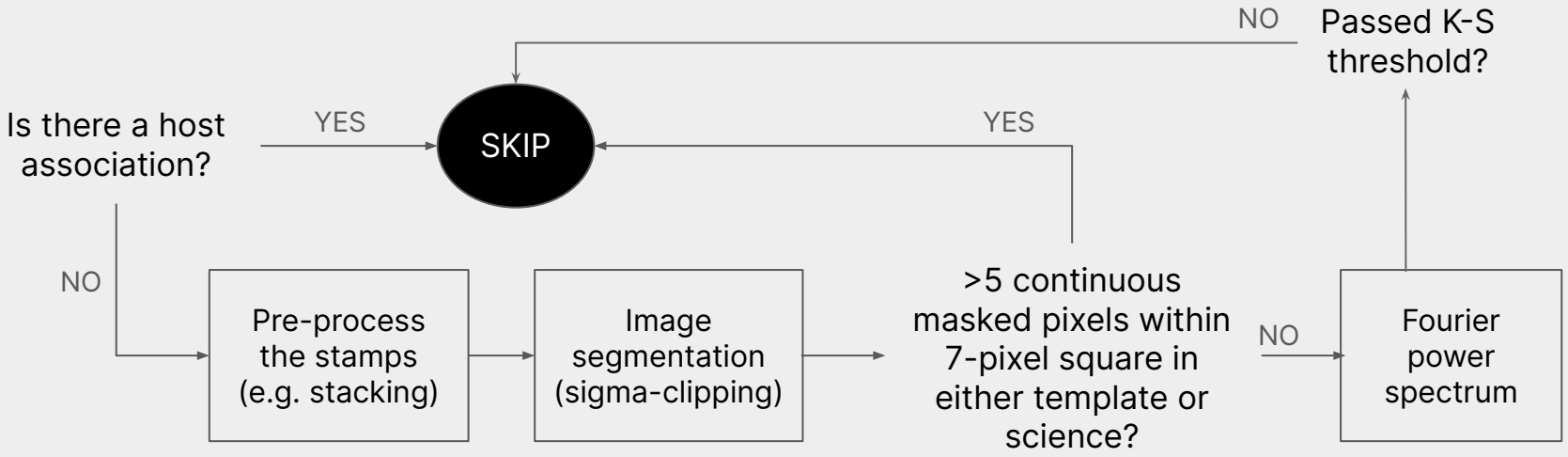

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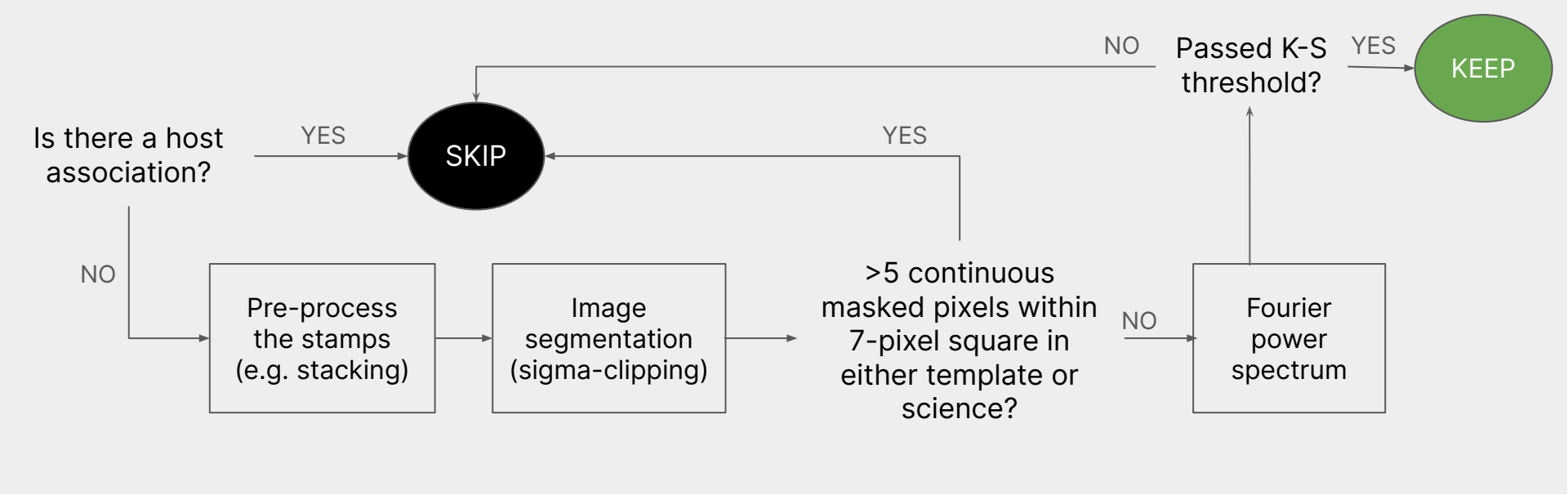

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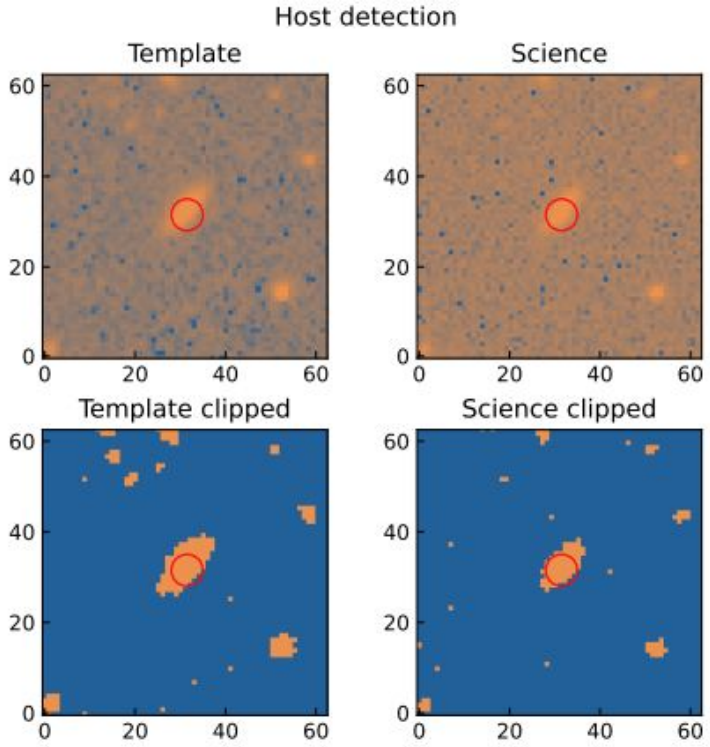
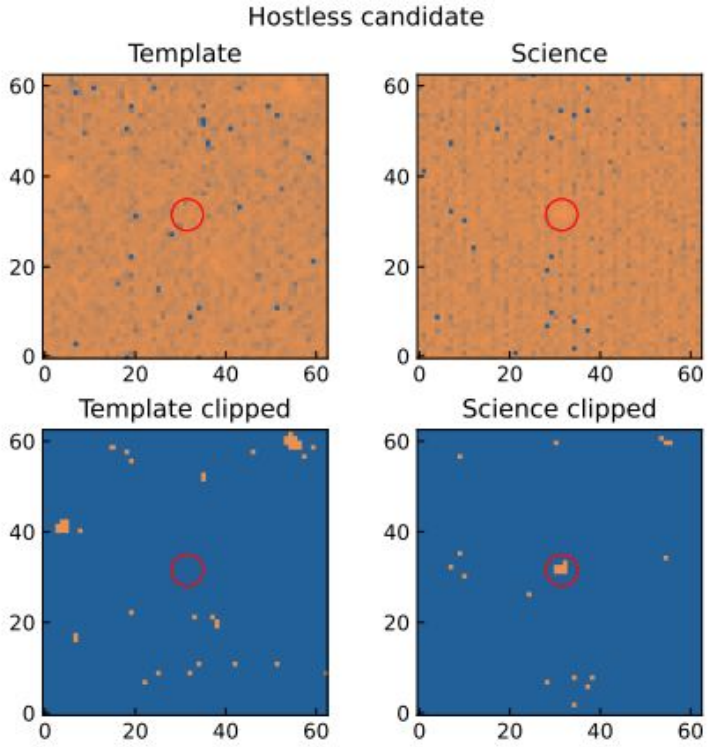
Results from Jan/22 - Dec/23





Results from Jan/22 - Dec/23

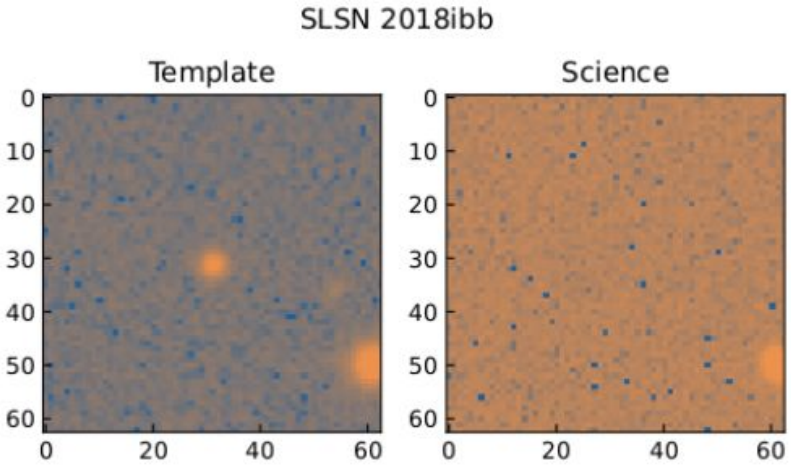
- ELEPHANT found a total of **1563 hostless candidates** (**<2%** of all analyzed transients are potentially hostless)

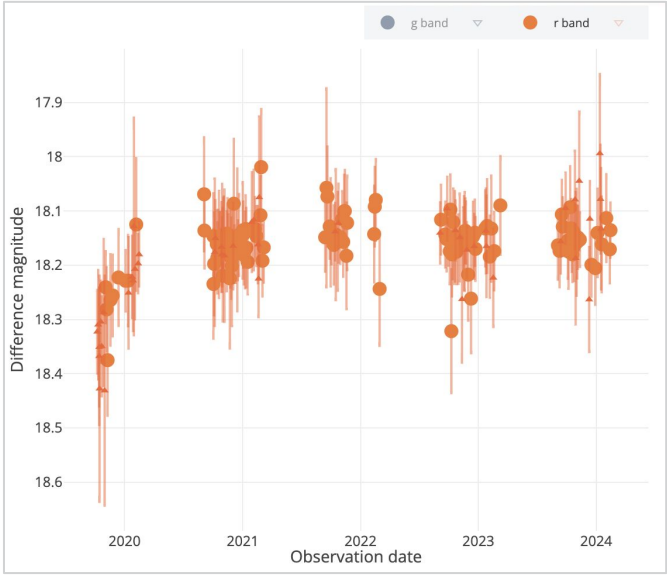
- Among them, 10% have a spectroscopic class reported on TNS: Type Ia supernova being the most common class, followed by SLSN

- 3 of the SNe reported in our list were found and followed-up in real time by different groups. They were studied in detail due to their rare nature. I will show them in the next slides.

Results from Jan/22 - Dec/23

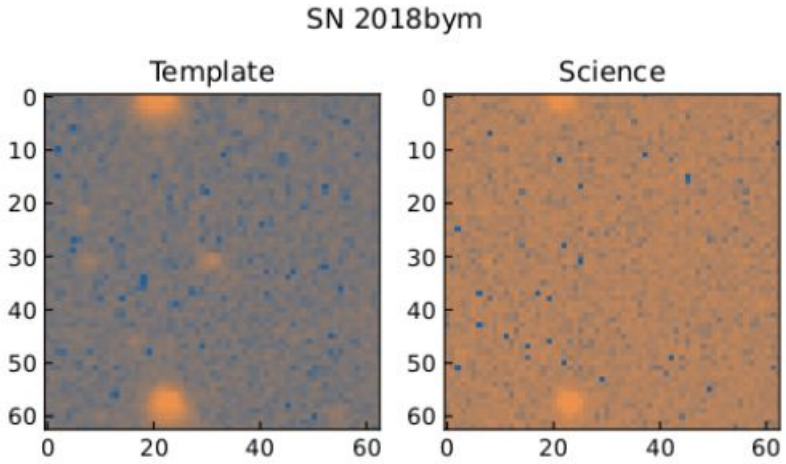
Identified by Schulze+24 as **the best pair-instability supernova (PISNe) candidate to date**. It has been proposed that PISNe mark the explosive death of Population III stars. It is associated with a faint dwarf host (m_r~24.4 mag)

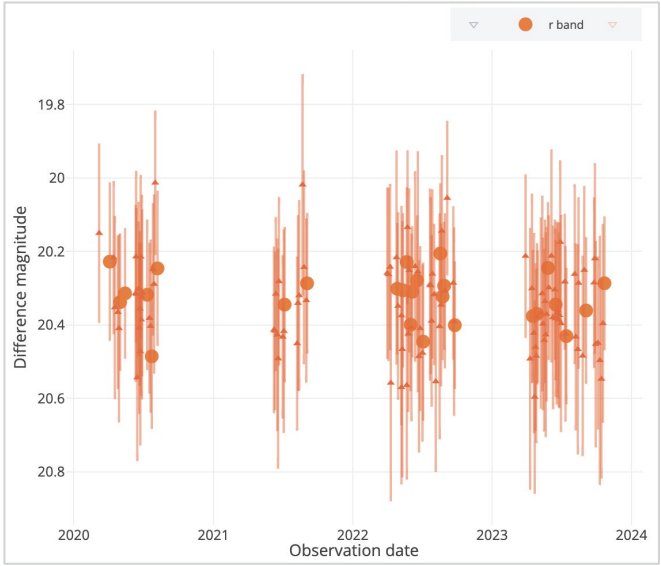




Results from Jan/22 - Dec/23

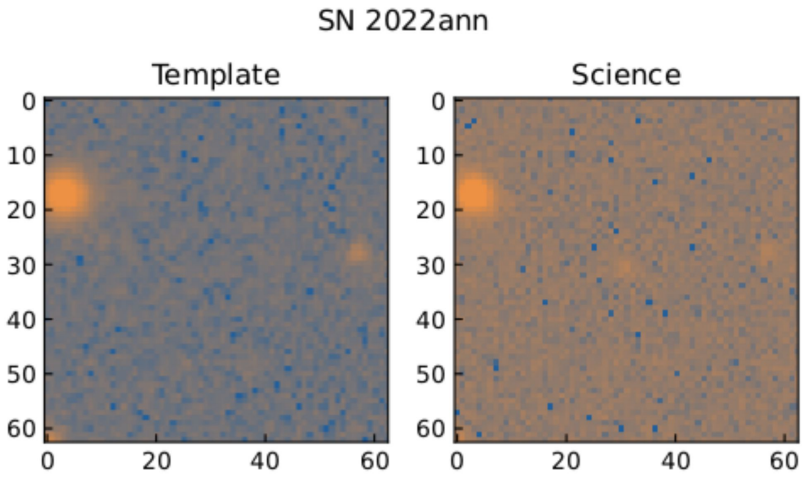
Studied by Lunnan+20 alongside three other SLSNe discovered by ZTF. It can be considered a **classical SLSN I** and it is associated with a faint dwarf galaxy (m_r~22.4 mag)

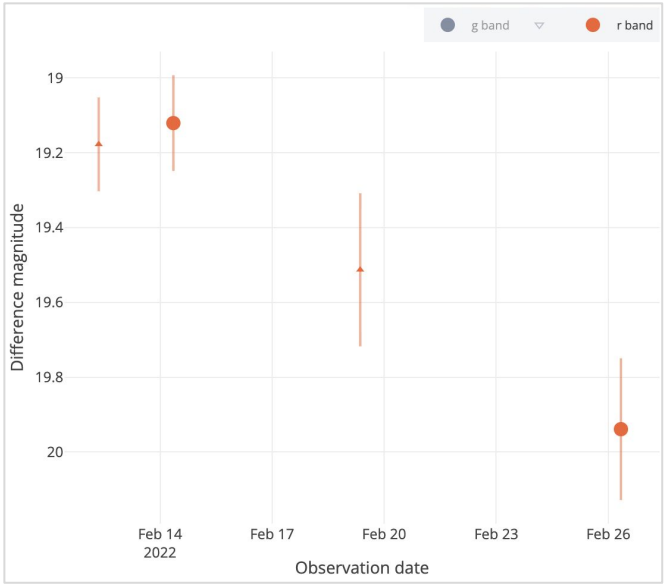




Results from Jan/22 - Dec/23

Studied by Davis+23 **as one of only five known SNe Icn**. It is associated with a faint dwarf host galaxy located in the lower end of the SN host galaxy luminosity distribution





Final remarks

- ELEPHANT can serve as a powerful tool to identify: SNe potentially associated to dwarf host galaxies; AGNs associated with low-mass galaxies; sources that been ejected from their host galaxies

- Currently, we are processing FINK alerts with ELEPHANT **every week**

- ELEPHANT will be fully implemented soon in the FINK broker to allow real-time detection of hostless candidates. It will be adapted to LSST data in the future

Thank you!

Check out our GitHub repository:
https://github.com/COINtoolbox/extragalactic_hostless

arXiv:2404.18165