

Exoplanet Imaging Data Challenge:

benchmarking image processing methods for exoplanet direct detection

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CONTEXT

The **Exoplanet Imaging Data Challenge (EIDC)** is a community-wide effort meant to offer a platform to enable a fair and common comparison of the various image processing methods dedicated to exoplanet direct detection.

<https://exoplanet-imaging-challenge.github.io/>

Open-source: data hosted on *ZenoDo*, competition on *CodaLab*

Benchmarking: (1) to support observers / users

(2) to guide publications of new algorithms

Sparking collaborations in the post-processing community

Phase 1: from 09/2019 to 10/2020

Focused on **detection** capabilities of the algorithms.

Pre-phase to receive feedbacks ended on 01/2020.

A **workshop** took place in 01/2020 to discuss the outcome.

DATA SETS

Because the performance of a given image processing method may be dependent upon the instrument and the observing conditions, we used several datasets from different high-contrast instruments.

High-contrast instruments:

(1) **ADI subchallenge:** temporal cube in pupil tracking (PT)

9 data sets from 3 instruments

VLT/SPHERE-IRDIS using an Apodized Lyot Coronagraph (H-band)

Keck/NIRC2 using an Annular Groove Phase Mask (L-band)

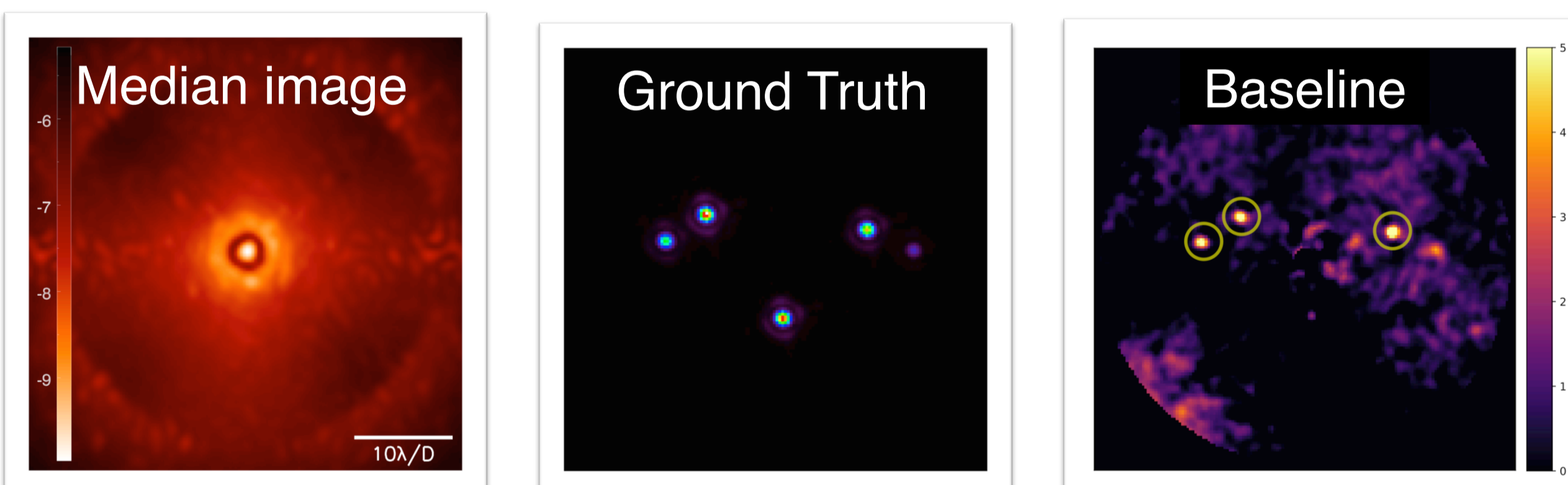
LBT/LMIRCam without coronagraph (L-band)

(2) **ADI+mSDI subchallenge:** multispectral cube in PT

10 datasets from 2 instruments

VLT/SPHERE-IFS using an Apodized Lyot Coronagraph

Gemini-S/GPI using an Apodized Lyot Coronagraph



Synthetic planetary signals Injections:

In each dataset, we injected from **0 to 5** synthetic planetary signals, using the **inverse** parallactic angles to smear out potential signals.

The injection separation and contrast are **randomly** picked in a range close to the detection limit (contrast curve) from the chosen baseline.

The **Baseline** algorithm is an annular Principal Component Analysis.

For the ADI+mSDI injections, **spectral features** are injected.

The injections are made using the *VIP* package: the synthetic planetary signals are injected without smearing, without photometric variation in time, and assuming a given center fixed for all images.

PHASE 1: EVALUATION

Required input from participants:

From running a given algorithm on **all** the pre-reduced datasets, the participants had to provide:

- A detection map for each dataset,
- A single threshold value for all datasets.

Counting the detections:

By definition, any signal above threshold triggers a detection.

We considered only one detection per unit of resolution element ($\sim 1\lambda/D$), computed from the instrumental point-spread function.

For various thresholds, we counted the true positives (TP), the true negatives (TN), the false positives (FP), the false negatives (FN).

From these we derived:

- True positive rate: $TPR = TP/(TP+FN)$
- False discovery rate: $FDR = FP/(FP+TP)$
- False positive rate: $FPR = FP/(FP+TN)$

At the submitted threshold, we compute:

- F1-score = $2 TP / (2 TP + FP + FN)$

All these scores must be between 0 and 1.

In the absence of injections (no positive), the TPR and the F1-score are undefined.

To study the sensitivity of the algorithms, we display the TPR, FPR and FDR scores with respect to a varying threshold value (**FIG. 1**).

The comparison metrics will be refined in a future dedicated paper.

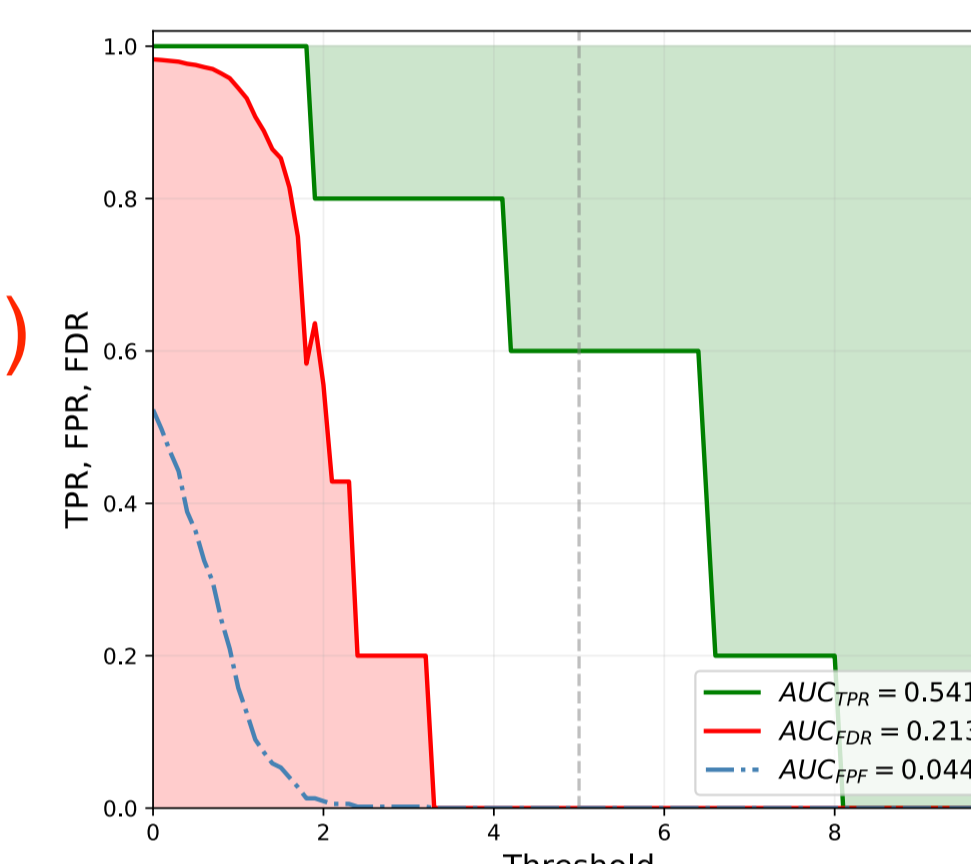


FIG. 1: The green area (TPR) and the red area (FDR) must be minimal. The blue line (FPR) gives information about the residuals.

PHASE 1: SUBMISSIONS

For this first phase, **65 people** registered on the *CodaLab* platform.

(1) **ADI subchallenge:** 22 valid submissions from 12 participants:

We separated the submissions in 3 families:

(i) Speckle subtraction techniques: the most widely used techniques, providing either a residual map or a detection map.

→ 12 submissions:

[cADI](#), [PCA](#), [LOCI](#), [STIM map](#), [RSM map](#)

(ii) Inverse problem approaches: these techniques make a model of the expected planetary signal and track it in the data.

→ 5 submissions:

[ANDROMEDA](#), [FMMF](#), [PACO](#), [TRAP](#)

(iii) Supervised machine learning: after applying PCA, the algorithm is trained to classify detection vs. non-detections.

→ 5 submissions:

[SODIRF](#), [SODINN](#)

(2) **ADI+mSDI subchallenge:** 4 valid submissions from 3

participants. 1 submission is a speckle subtraction technique and the 3 others are based on an inverse problem approach.

[PCA-ASDI](#), [PACO-ASDI](#), [FMMF](#), [ANDROMEDA](#)

SOME RESULTS...

In the corresponding proceeding, you will find more details about the submitted algorithms and the comparison.

Subchallenge 1: The detection maps below are for the VLT/SPHERE-IRDIS dataset containing 5 injections.

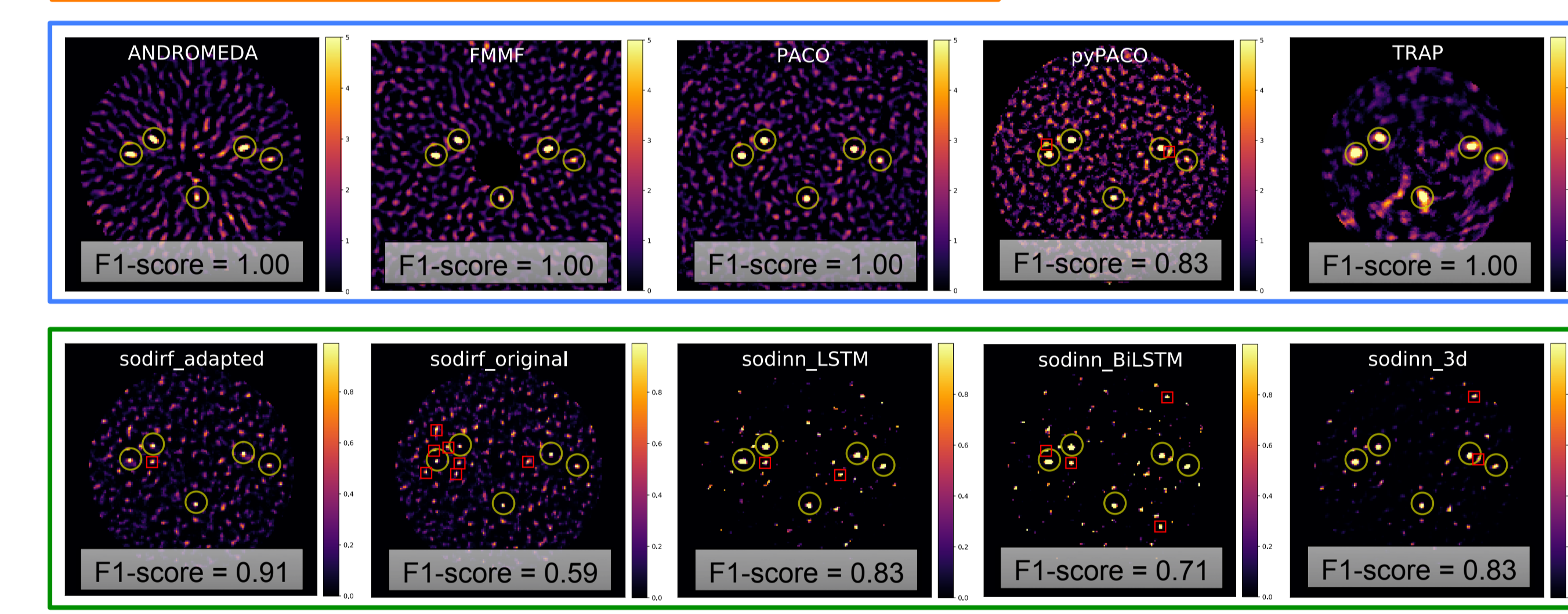
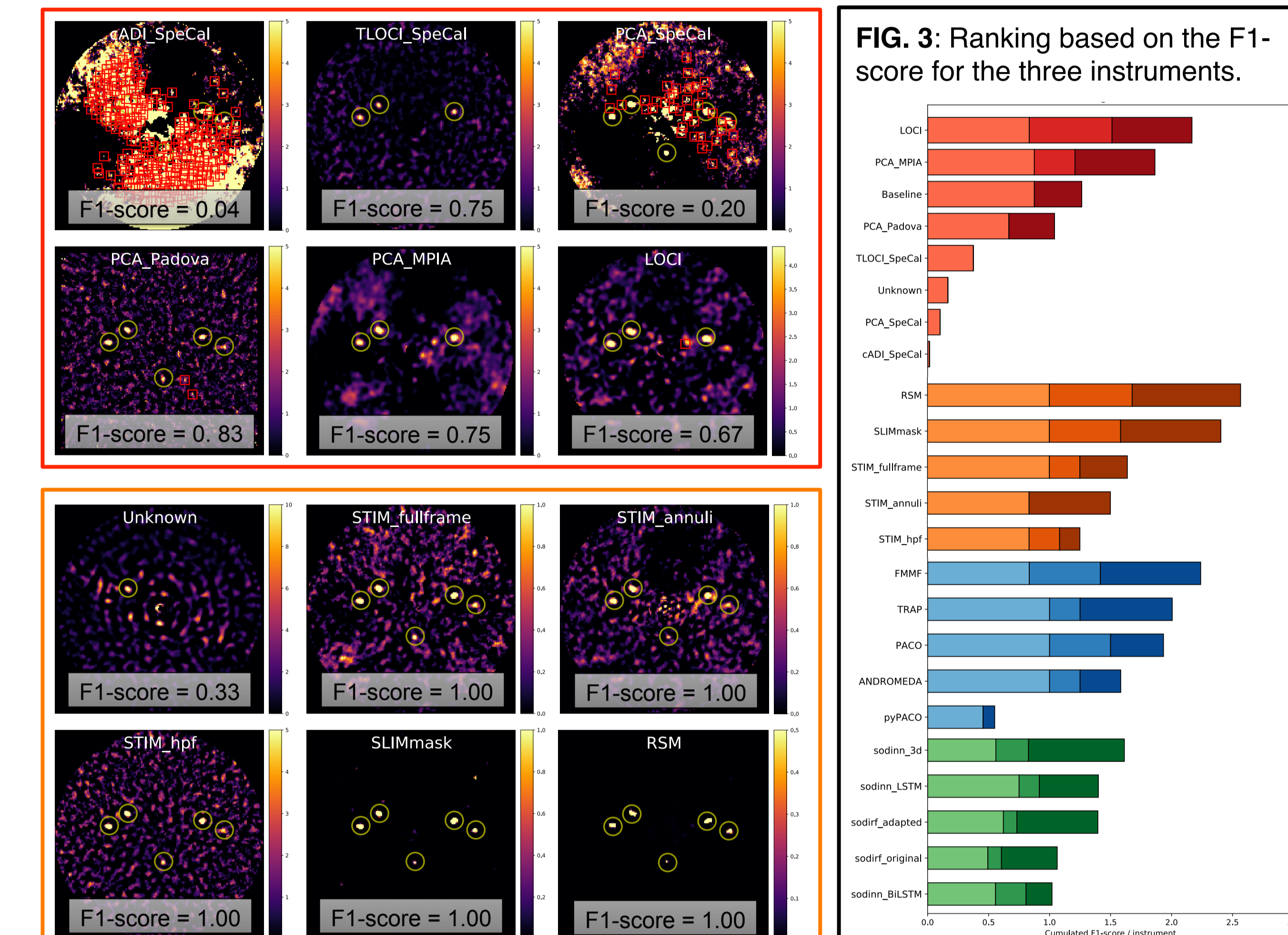
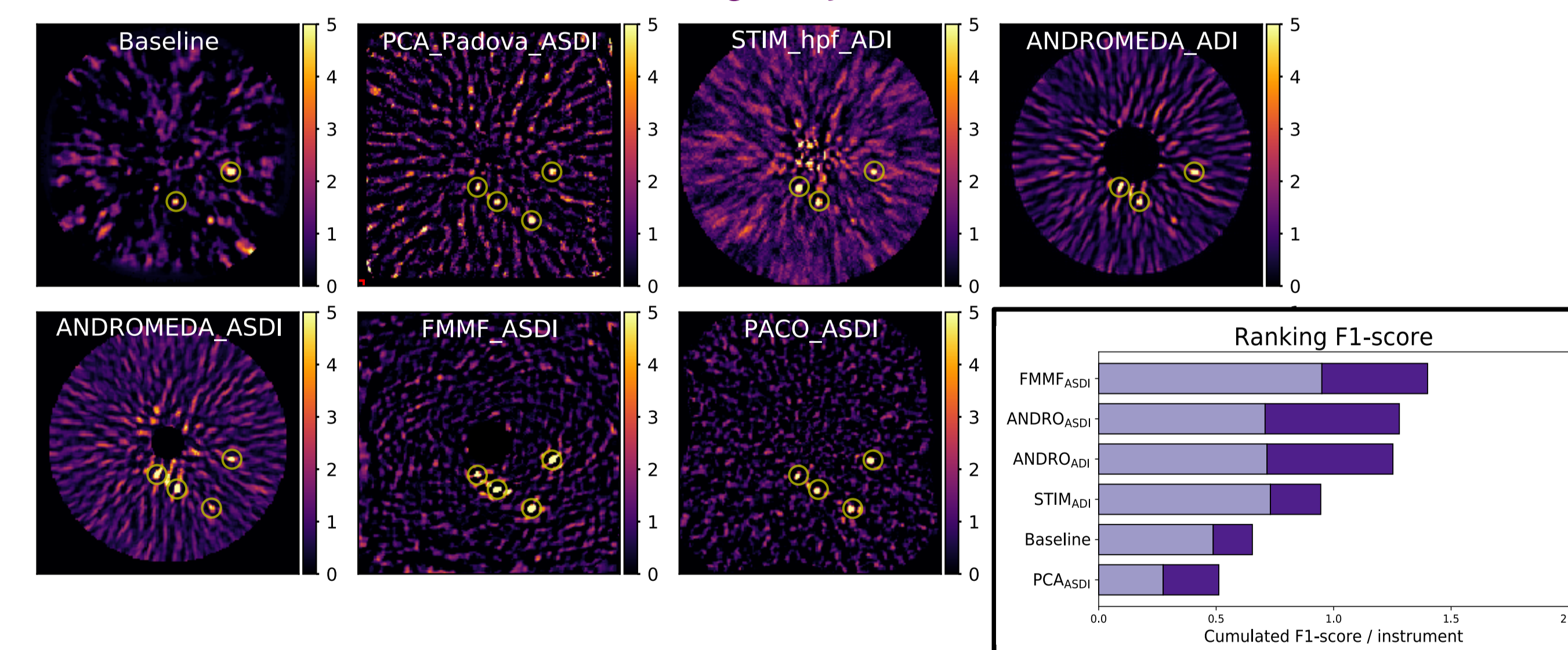


FIG. 1: Detection maps (from 0 to threshold). FP are indicated with red squares, TP with yellow circles.

Subchallenge 2: The detection maps below are for the Gemini-S/GPI dataset containing 4 injections.



THE FUTURE OF THE EIDC

The data will be permanently hosted by *Zenodo*.

For the next phases we intend to:

- (1) Include the characterization of companions
- (2) Add the detection of extended sources
- (3) Add hyperspectral data
- (4) ... more to come !

And have a report of the different phases of the EIDC published for the SPIE Astronomical Telescopes+Instrumentation conference