Exoplanet Imaging Data Challenge:

benchmarking image processing methods for exoplanet direct detection

Faustine Cantalloube[1], Carlos Gomez-Gonzales[2,3], Olivier Absil[4], Carles Cantero[4,5]

Bacher R., Bonse J. M., Bottom M., Dahlqvist C.-H., Desgrange C., Flasseur O., Fuhrmann T., Henning Th., Jensen-Clem R., Kenworthy M., Mawet D., Mesa D., Meshkat T., Mouillet D., Müller A., Nasedkin E., Pairet B., Pierard S., Ruffio J.-B., Samland M., Stone J. and , Van Droogenbroeck M.

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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.

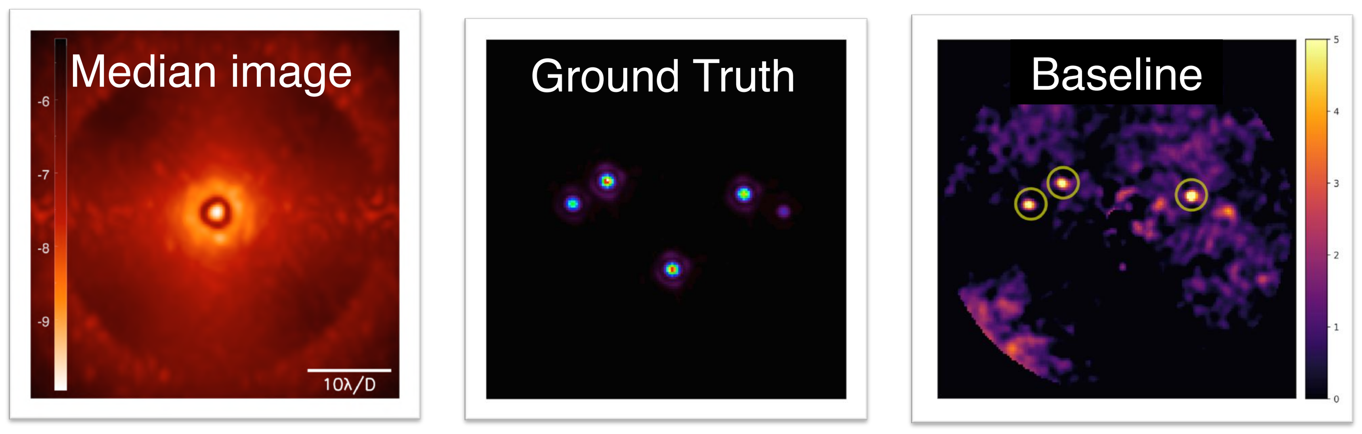
DATA SETS

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 (~1λ/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**).

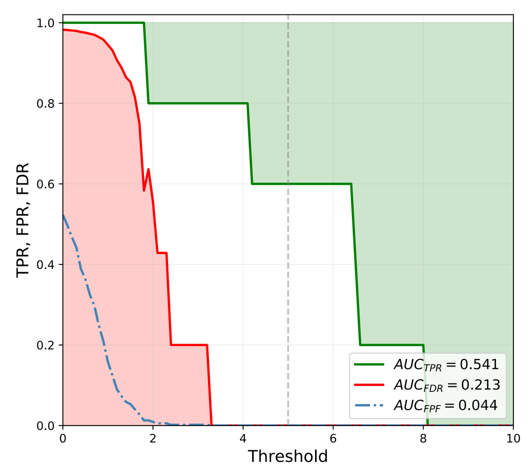


FIG.1: The green area (TPR) and the red area (FDR) must be minimal. The blue line (FPR) gives information about the residuals.

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

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.

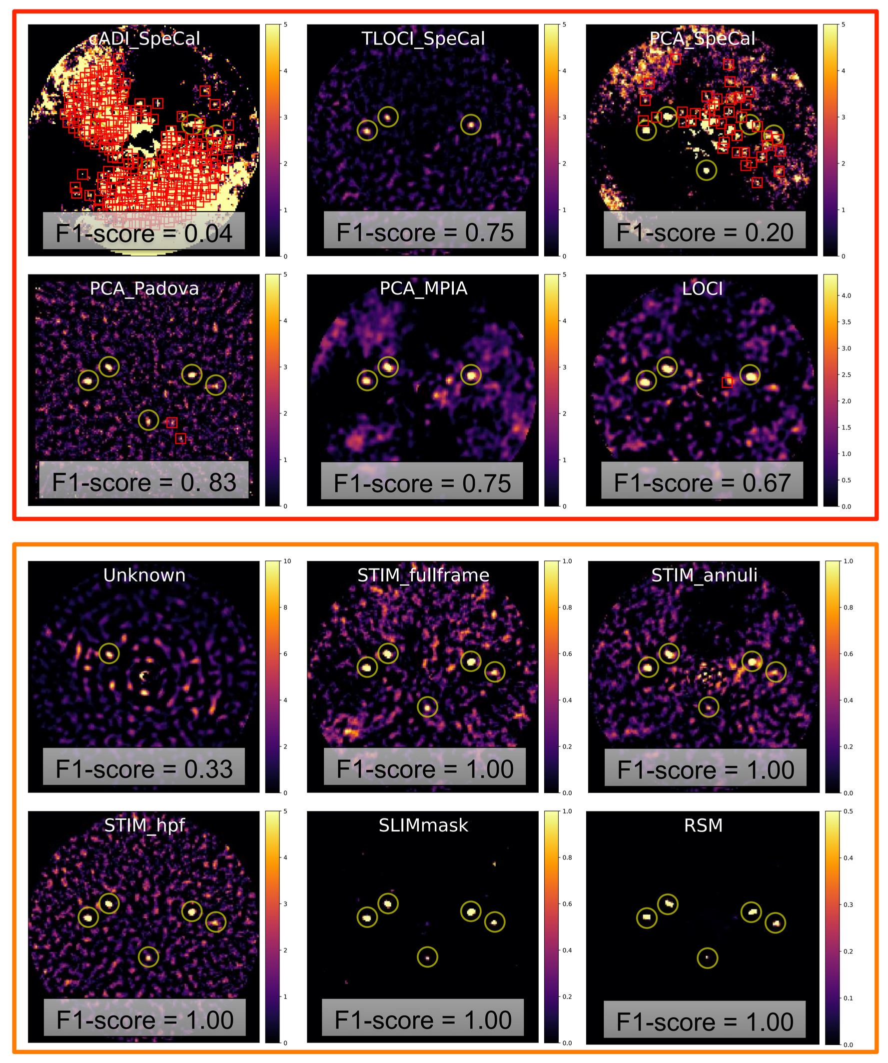
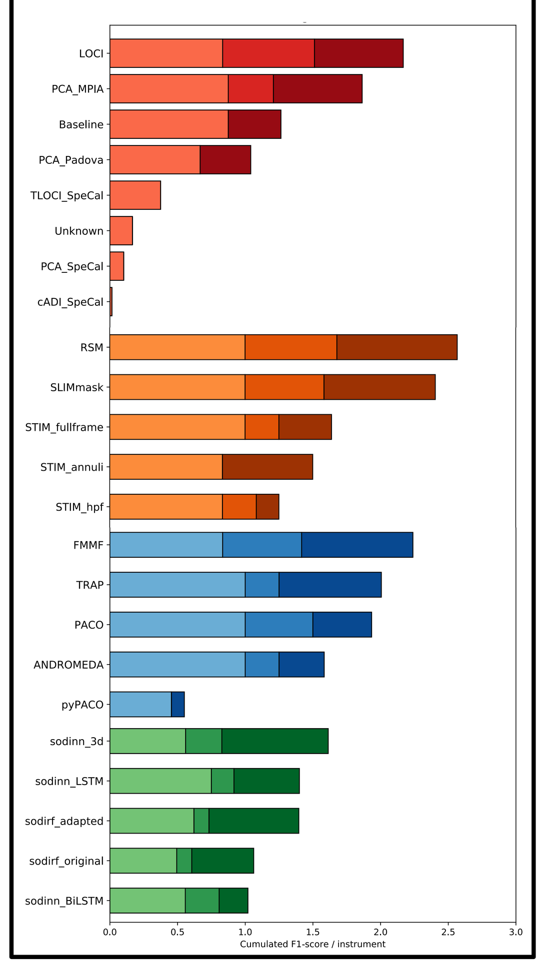


FIG. 3: Ranking based on the F1-score for the three instruments.



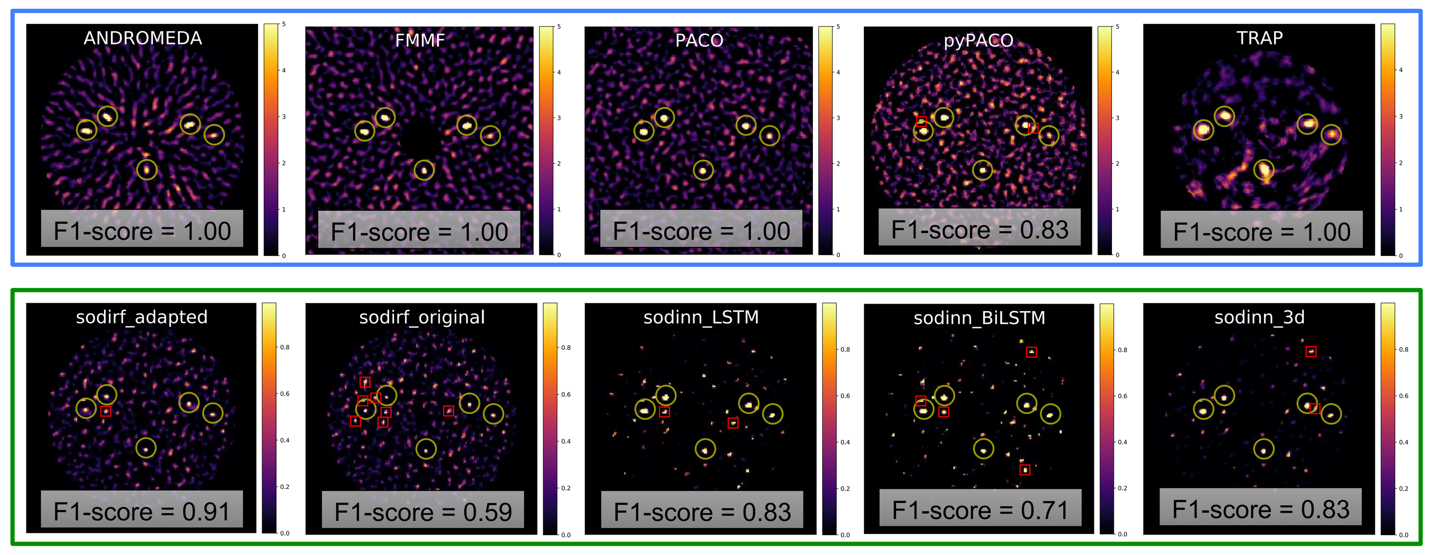
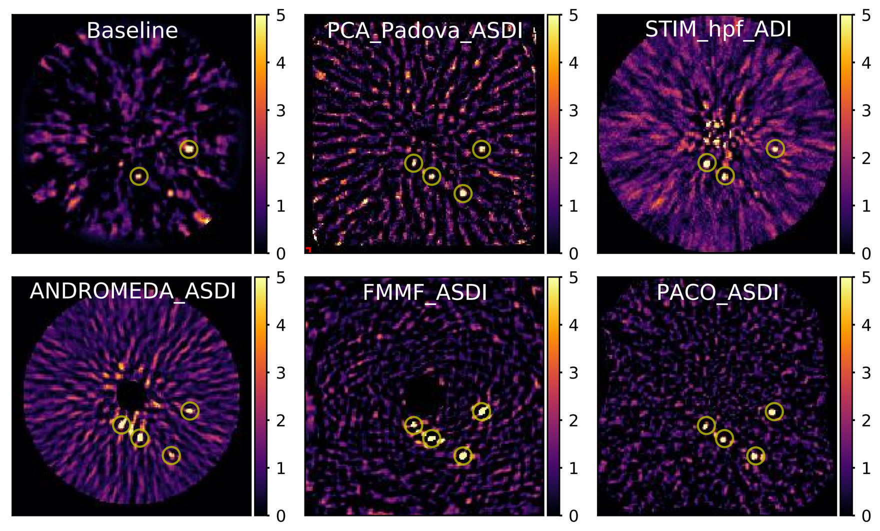
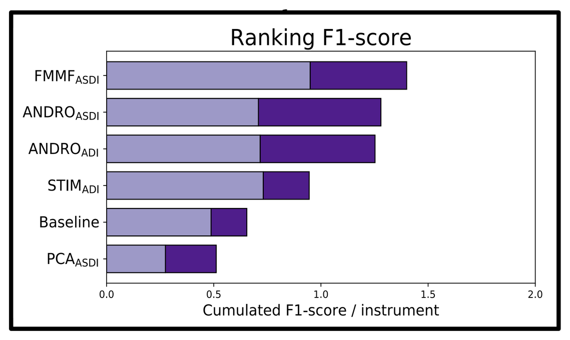


FIG.1: Detection maps (from 0 to threshold). FP are indicated with red squares, TP with yellow circles.

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

Affiliations: [1]Max-Planck-Institute for Astronomy, Heidelberg, Germany, [2]Barcelona Supercomputing Center, Spain, [3]Université Grenoble Alpes, CNRS, IPAG, Grenoble, France,
[4]Space Sciences, Technologies & Astrophysics Research (STAR) Institute, Université de Liège, Allée du six Août 19c, B-4000 Liège, Belgium, [5]Montefiore Institute,Université de Liège, 4000 Liège, Belgium.

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