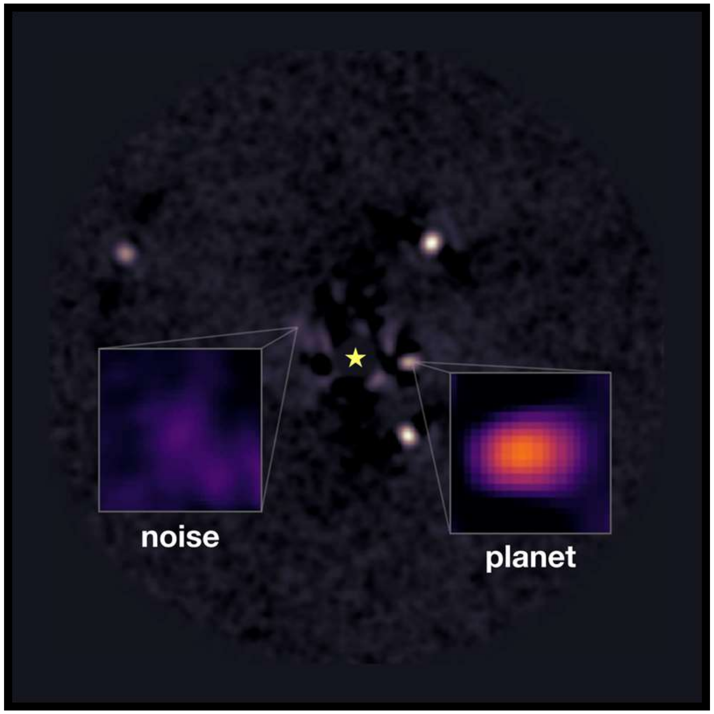



# SAG19 Update

# Exoplanet Imaging Data Challenge

## Benchmarking Image Processing Methods

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

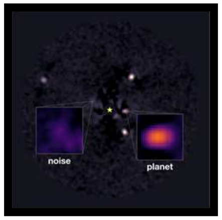
Faustine Cantalloube , Carlos Gomez-Gonzales, Olivier Absil, Carles Cantero, Bacher R., Bonse J. M., Bottom M., Dahlqvist C.-H., Desgrange C., Flasseur O., Fuhrmann T., Henning Th., Jensen-Clem R., Kenworthy M., Mawet D., Mesa D., Meshkat T., Mouillet D., Müller A., Nasedkin E., Pairet B., Pierard S.,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

*Data set host*

*Data challenge host*

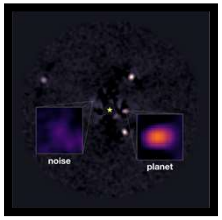
See Cantalloube et al. 2020 SPIE Proceedings paper!

# Context & Goals




- Goals
  - Provide a **library** of pre-processed HCI datasets to test the various algos.
  - Provide tools to **compare new algorithms** to the state-of-the-art.
- Context
  - **Collaborative initiative** between several institutes worldwide.
  - Direct **support** from the Grenoble Alpes Data Institute (France)
  - **Feedback** from a large international team of researchers.

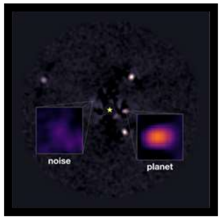
# Data sets




- **ADI subchallenge:** 9 datasets 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)
- **ADI+mSDI subchallenge:** 10 datasets from 2 instruments
    - **VLT/SPHERE-IFS** using an Apodized Lyot Coronagraph
    - **Gemini-S/GPI** using an Apodized Lyot Coronagraph

- All data are pre-reduced and cropped to 20 λ/D x 20 λ/D
- Data are given with the pixel scale (arcsec/px) of the instrument

# Injecting Synthetic Planetary Signals




- **Injected** synthetic exoplanet signals: 0 to 5 per image
- Injections are **standard** (no smearing, photometric variability, anisoplanetism etc.).
- For multispectral, a **specific spectrum** is used.
- The (separation; position angle) is randomly picked in the field-of-view
- The contrast is randomly chosen within a range close to the 5-sigma detection limit of the baseline annular Principal Component Analysis algorithm

Gomez Gonzalez et al. 2017

github.com/vortex-exoplanet/VIP

vip.readthedocs.io

# VIP - Vortex Image Processing package

pypi package 0.9.11 | Python 3.6, 3.7 | build failing | license MIT | arXiv 1705.06184 | docs passing | codecov 45%

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         Vortex Image Processing package
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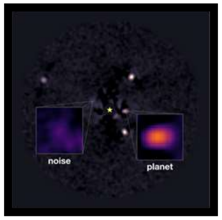
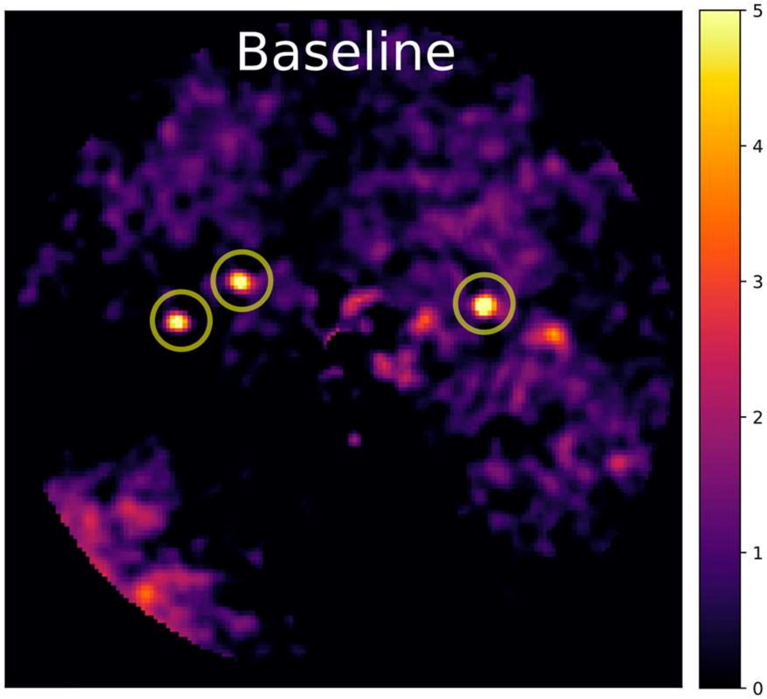
```

# Required Input from Participants

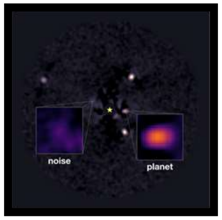



After running a given algorithm on **all** pre-reduced datasets, the participants must provide:

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

# Detection Metrics




**For each threshold, we count the:**

- True Positives (TP)
- False Negatives (FN)
- False Positives (FP)
- True Negatives (TN)

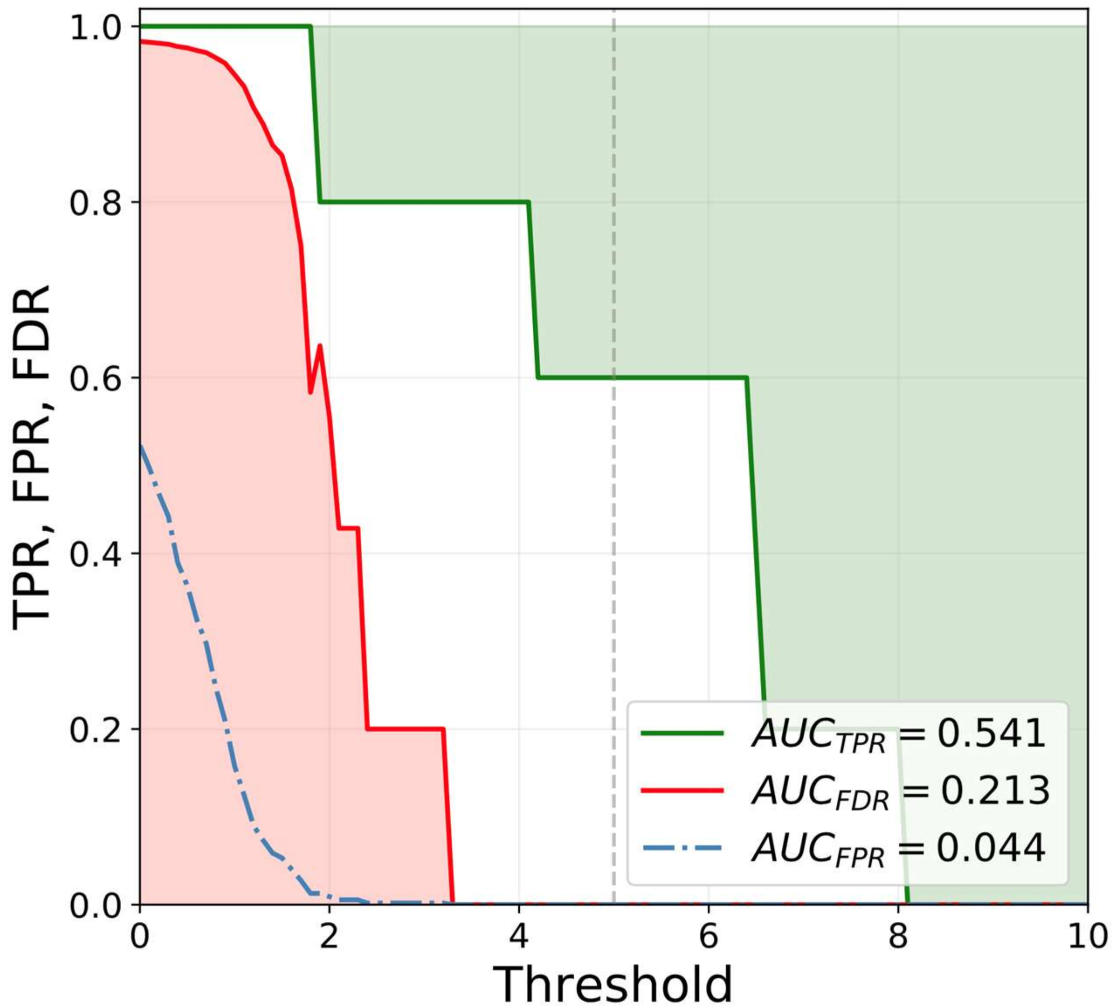
**Then, we define the:**

- True positive rate: TPR = TP/(TP+FN)
- False positive rate: FPR = FP/(FP+TN)
- False discovery rate: FDR = FP/(FP+TP)
- Final F1-score (or harmonic mean of TPR): **F1 = 2*TP/(2*TP+FP+FN)**

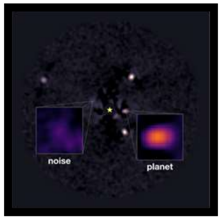
# Detection Metrics

1. F1-score (ideally 1)
2. AUC of the TPR (ideally 1)
3. AUC of the FDR (ideally 0)

AUC = Area Under Curve

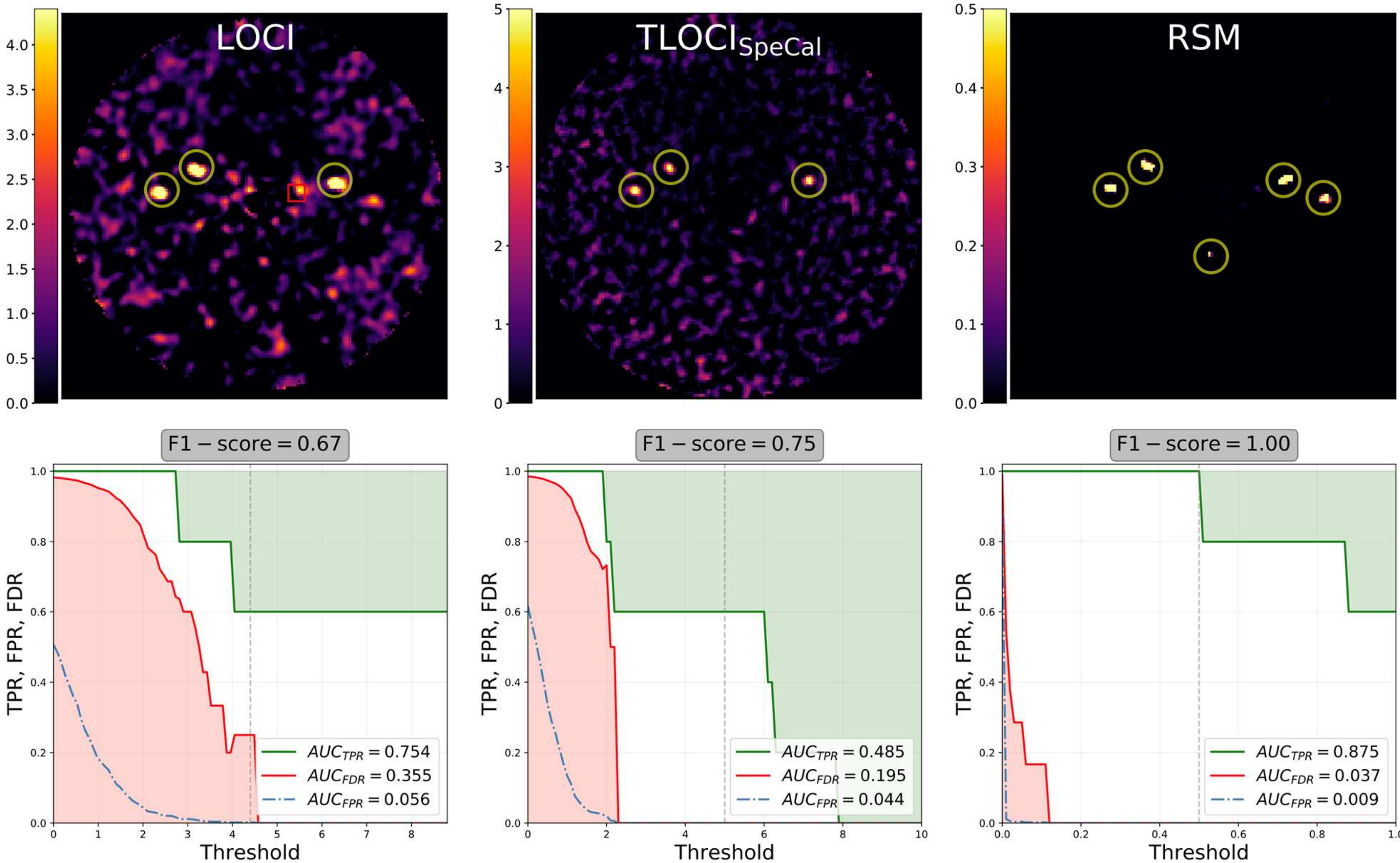


# Submissions

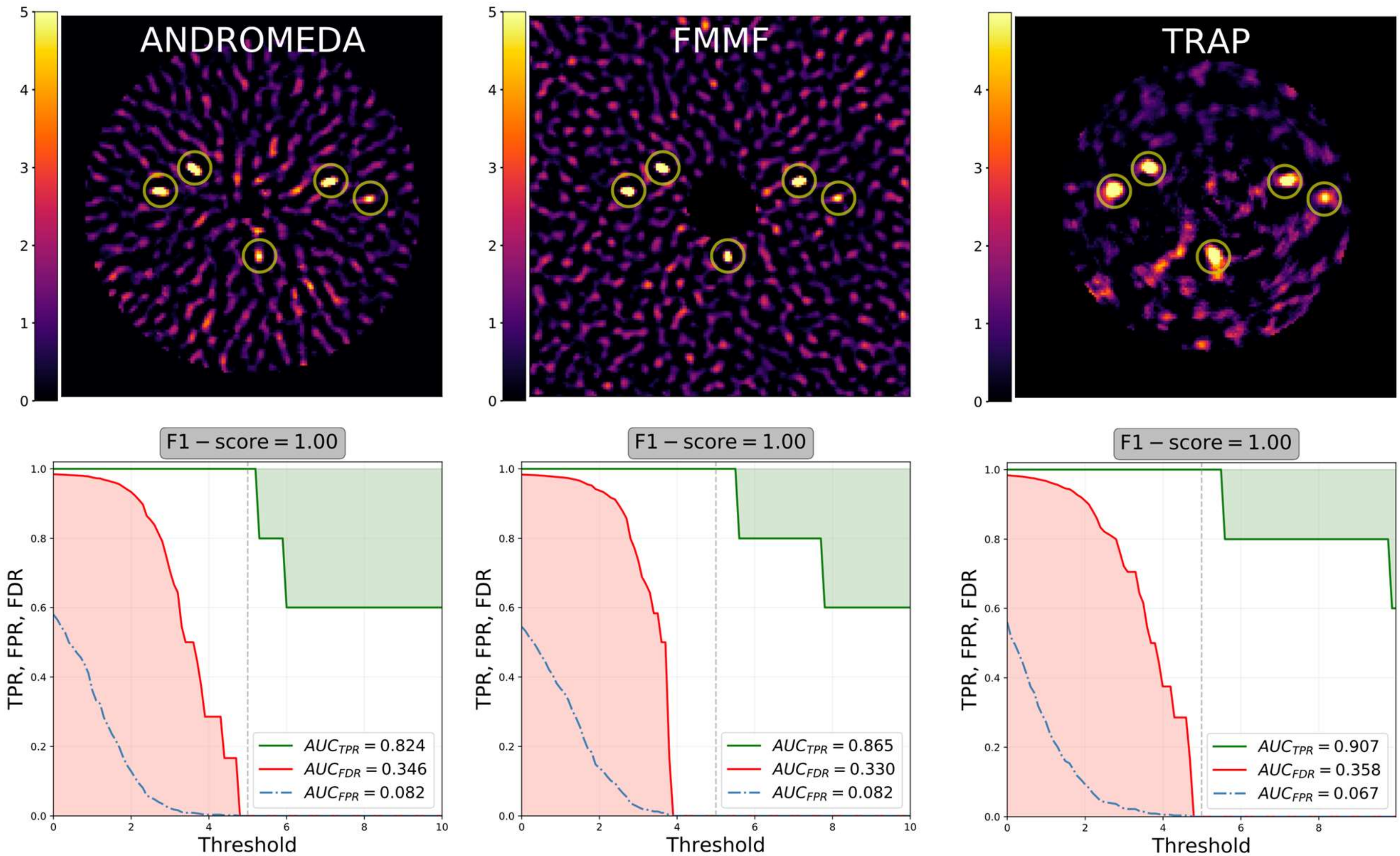


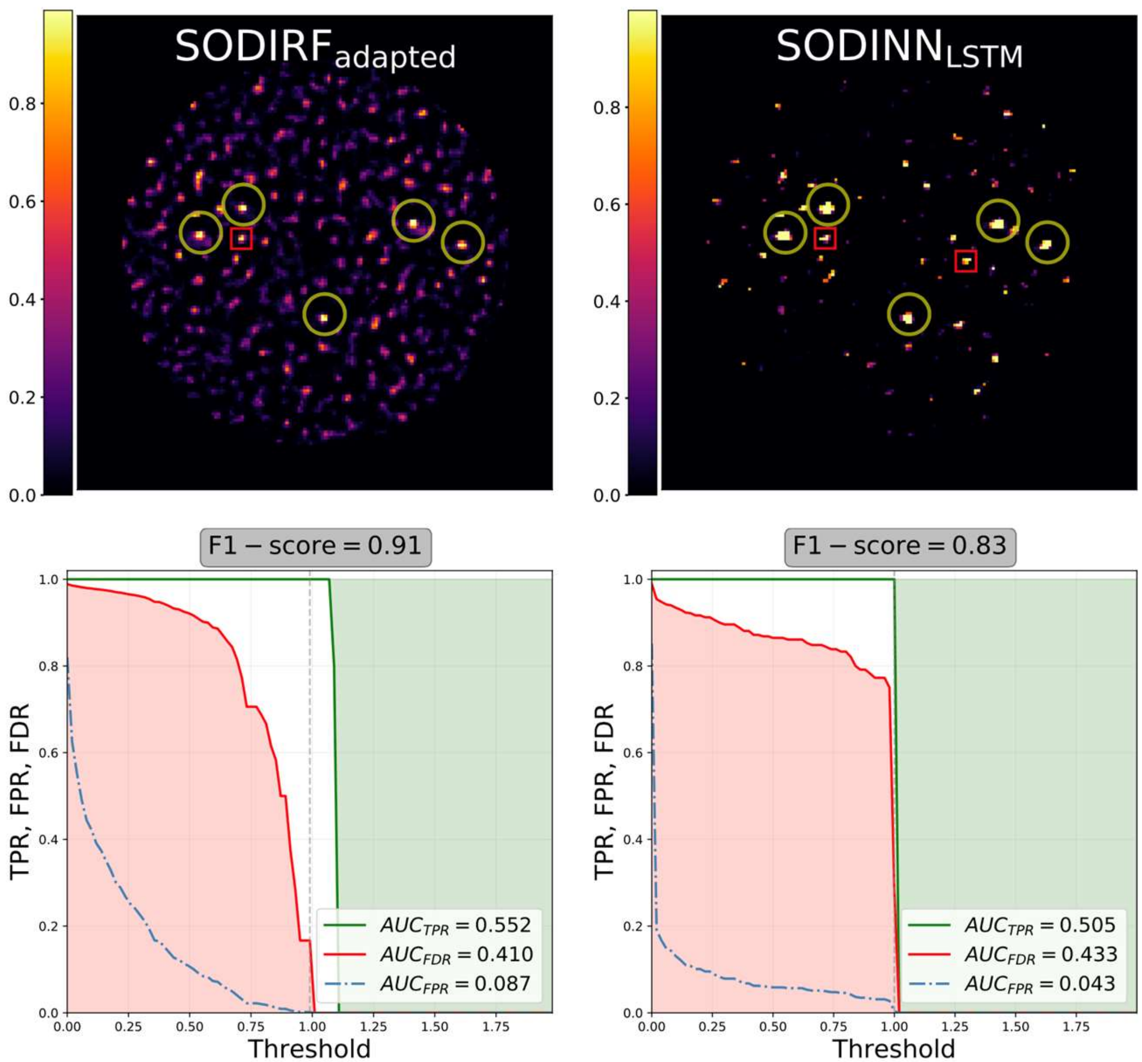

- **ADI subchallenge:** 22 valid submissions from 12 participants
  - 12 submissions used speckle subtraction techniques:
    - cADI, PCA, LOCI, STIM map, RSM map
  - 5 submissions used inverse problem approaches:
    - ANDROMEDA, FMMF, PACO, TRAP
  - 5 submissions used supervised machine learning:
    - SODIRF, SODINN

- **ADI+mSDI subchallenge:** 4 valid submissions from 3 participants
  - 1 submission used a speckle subtraction technique: PCA-ASDI
  - 3 submissions used the inverse problem approach:
    - PACO-ASDI, FMMF, ANDROMEDA

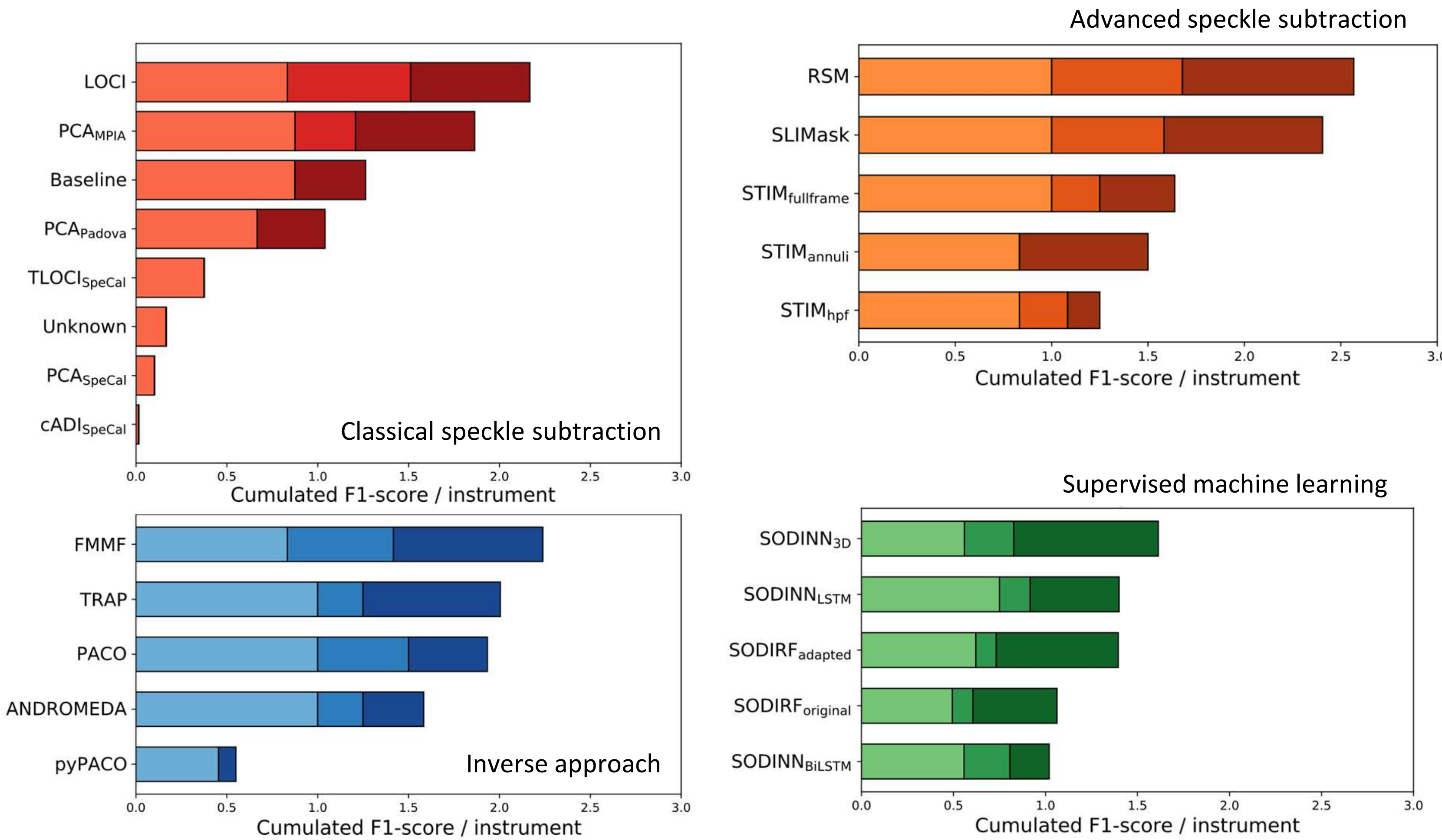


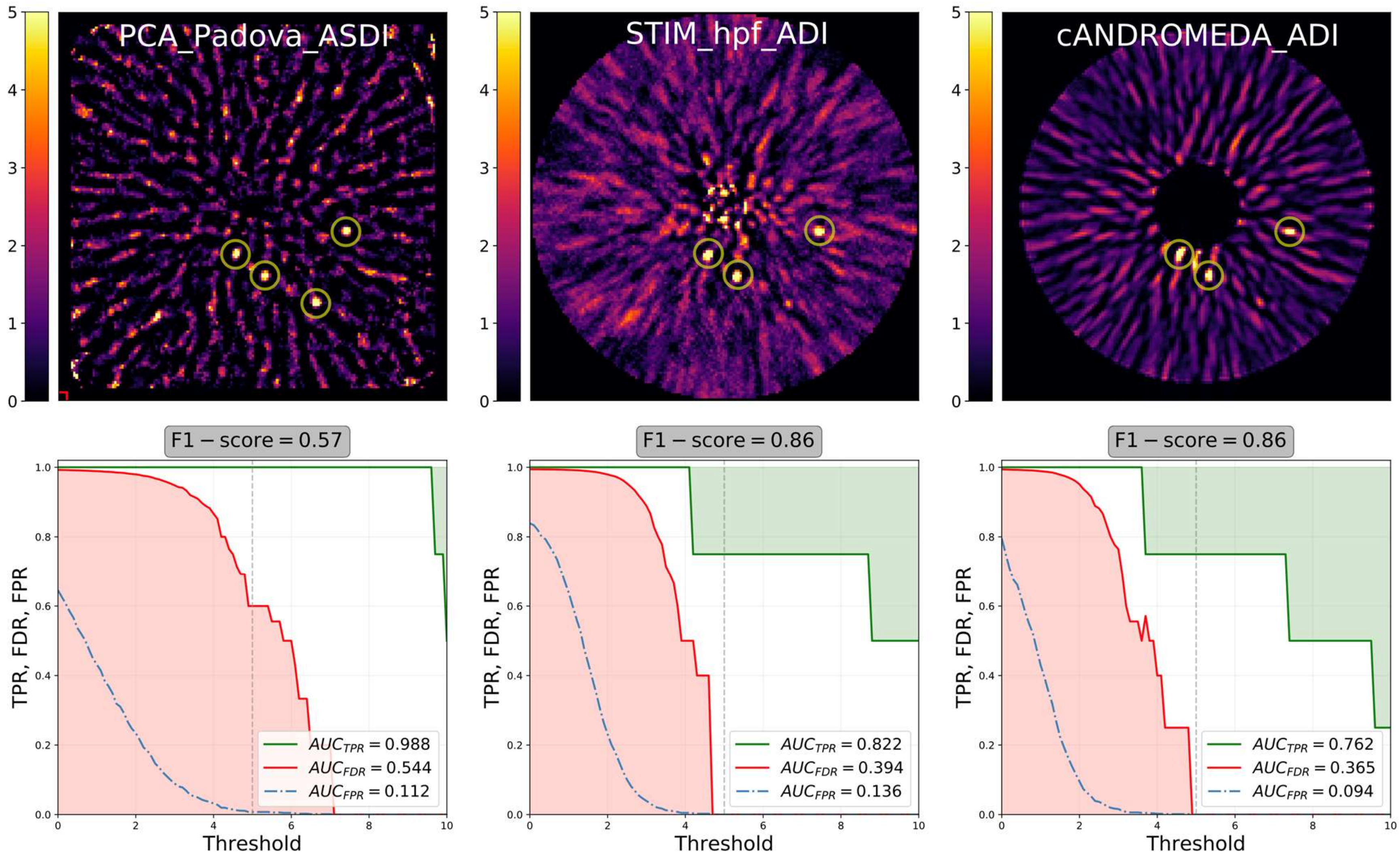
LOCI
TLOCI$_{SpeCal}$
RSM
F1 − score = 0.67
F1 − score = 0.75
F1 − score = 1.00
TPR, FPR, FDR
Threshold
$AUC_{TPR} = 0.754$
$AUC_{FDR} = 0.355$
$AUC_{FPR} = 0.056$
$AUC_{TPR} = 0.485$
$AUC_{FDR} = 0.195$
$AUC_{FPR} = 0.044$
$AUC_{TPR} = 0.875$
$AUC_{FDR} = 0.037$
$AUC_{FPR} = 0.009$


ANDROMEDA
FMMF
TRAP
F1 − score = 1.00
F1 − score = 1.00
F1 − score = 1.00
TPR, FPR, FDR
Threshold
$AUC_{TPR} = 0.824$
$AUC_{FDR} = 0.346$
$AUC_{FPR} = 0.082$
$AUC_{TPR} = 0.865$
$AUC_{FDR} = 0.330$
$AUC_{FPR} = 0.082$
$AUC_{TPR} = 0.907$
$AUC_{FDR} = 0.358$
$AUC_{FPR} = 0.067$


SODIRF$_{adapted}$
SODINN$_{LSTM}$
0.0
0.2
0.4
0.6
0.8
F1 − score = 0.91
F1 − score = 0.83
TPR, FPR, FDR
Threshold
$AUC_{TPR} = 0.552$
$AUC_{FDR} = 0.410$
$AUC_{FPR} = 0.087$
$AUC_{TPR} = 0.505$
$AUC_{FDR} = 0.433$
$AUC_{FPR} = 0.043$
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75

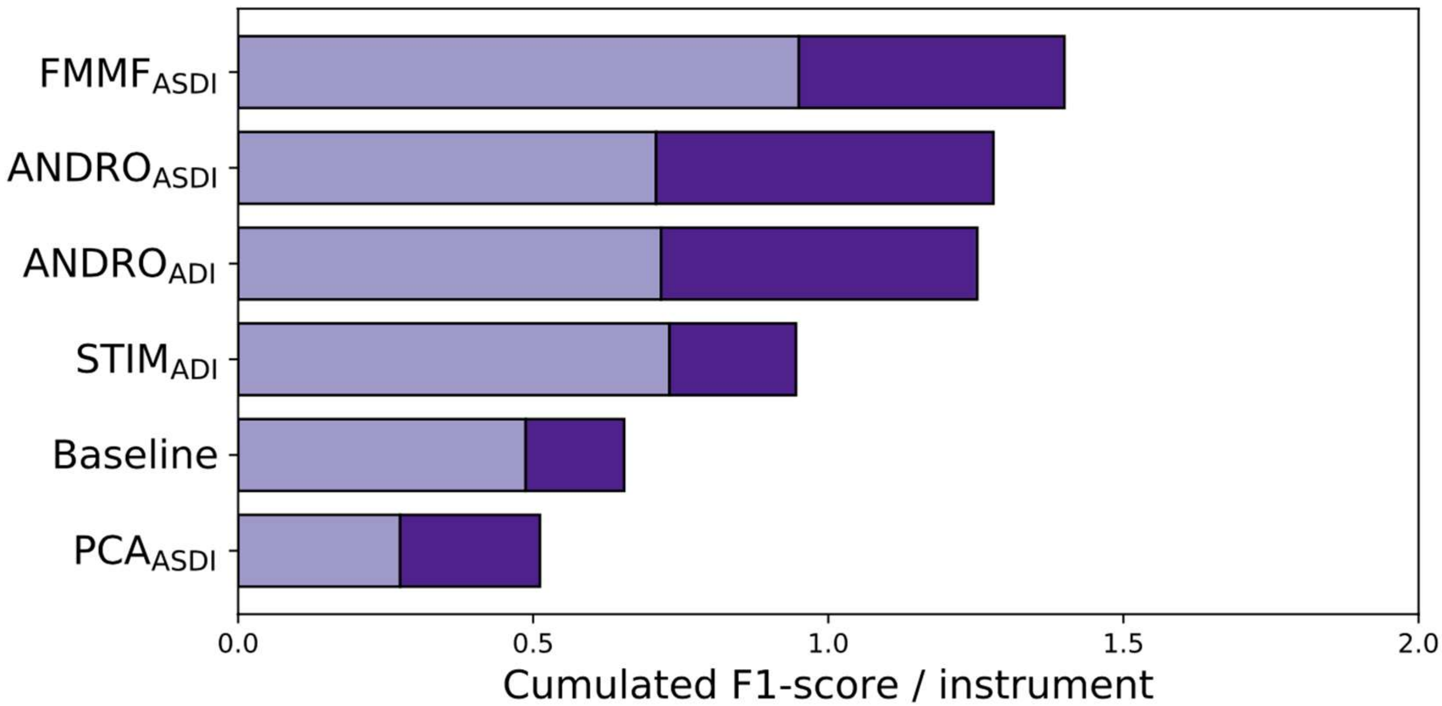
# ADI Subchallenge: Ranking the results by the F-1 score



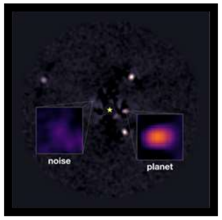


PCA_Padova_ASDI
STIM_hpf_ADI
cANDROMEDA_ADI
F1 − score = 0.57
F1 − score = 0.86
F1 − score = 0.86
TPR, FDR, FPR
Threshold
$AUC_{TPR} = 0.988$
$AUC_{FDR} = 0.544$
$AUC_{FPR} = 0.112$
$AUC_{TPR} = 0.822$
$AUC_{FDR} = 0.394$
$AUC_{FPR} = 0.136$
$AUC_{TPR} = 0.762$
$AUC_{FDR} = 0.365$
$AUC_{FPR} = 0.094$

# ADI+mSDI Subchallenge: Ranking the results by the F-1 score



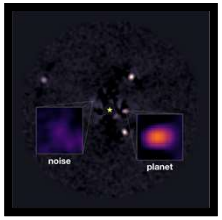
# Results




- **ADI subchallenge:**
  - The rankings based on the three scores generally give consistent results
  - The latest techniques (e.g. RSM) perform better than classical speckle subtraction techniques
  - However, the supervised machine learning techniques tested here suffer from high FPs
  - Performance depends on the instrument and dataset

- **ADI+mSDI subchallenge:**
  - Spectral information enables the detection of fainter sources
  - More recent methods are generally better, but with some exceptions
  - The inverse problem approach allows for a comparison between the candidate and speckle spectrum

# Future Work




- These results represent only Phase 1 of the data challenge!
- Future phases will:
    - Provide additional datasets, e.g. high spectral resolution data
    - Incorporate detection characterization (e.g. position and contrast)
    - Include extended sources to be detected
- Stay tuned for updates at future SPIE meetings!