SAG19: Signal Detection Theory and Rigorous Performance Metrics for Exoplanet Imaging

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- Methods papers:
  - **Jensen-Clem et al. 2018**: letting the threshold hold change with separation to give the desired # of false positives
  - **Ruffio et al. *submitted***: setting up a Bayesian framework for detection and non-detection

- Application papers:
  - **Ruane et al. 2017**: using varying thresholds to place mass upper limits on planets in the disk gaps of TW Hydra
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- **The next step: data challenge!**

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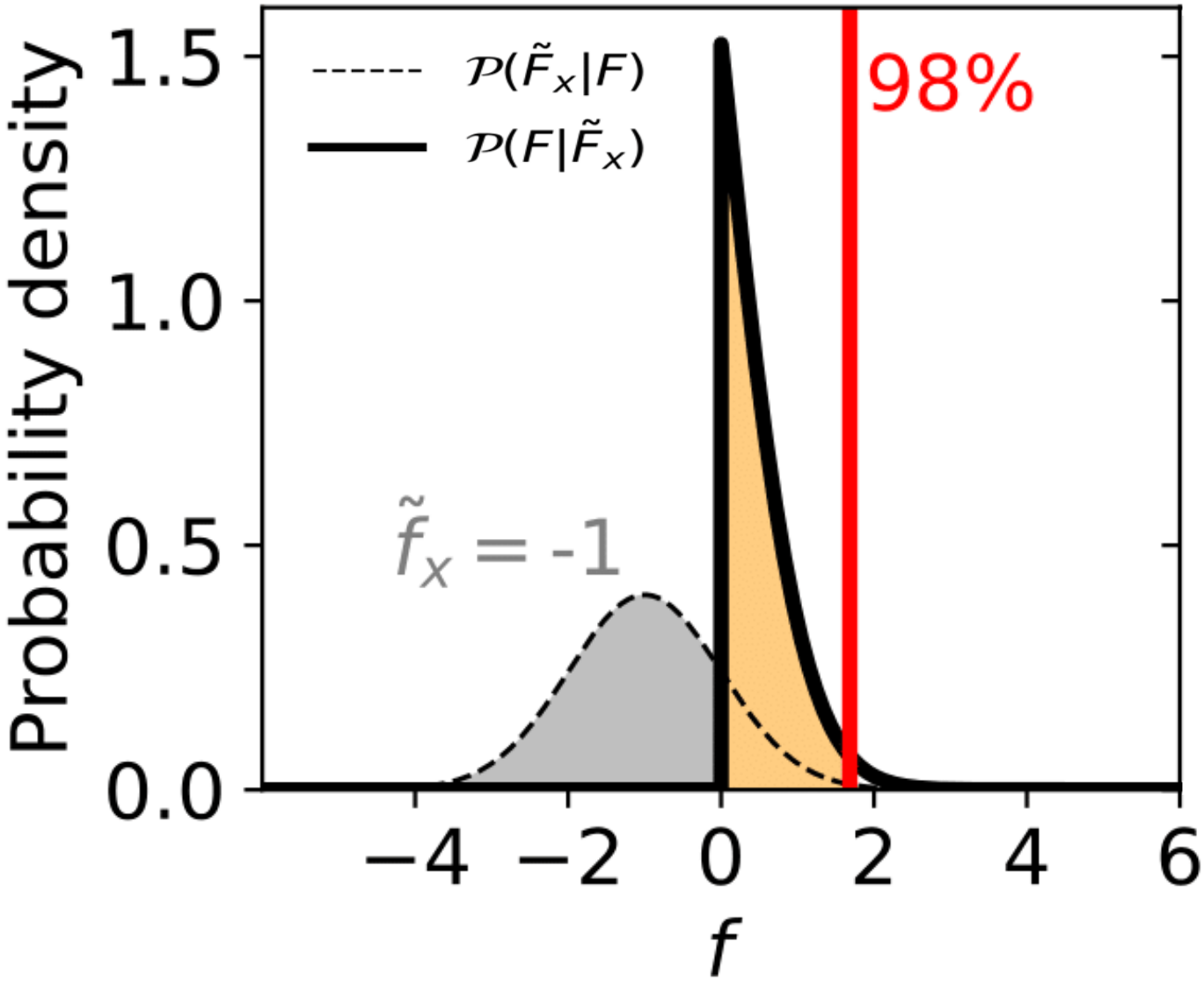
Bayesian upper limits for direct imaging

Jean-Baptiste Ruffio (Stanford University)
GPIES *et al.*

Consider a non-detection where the planet's location is known

- Placing a "5σ" upper limit makes use of the noise at the planet's separation, but not the realization at the planet's exact location

- Instead, let's place a Bayesian upper limit where the likelihood is a Gaussian centered on the observed flux at the planet's location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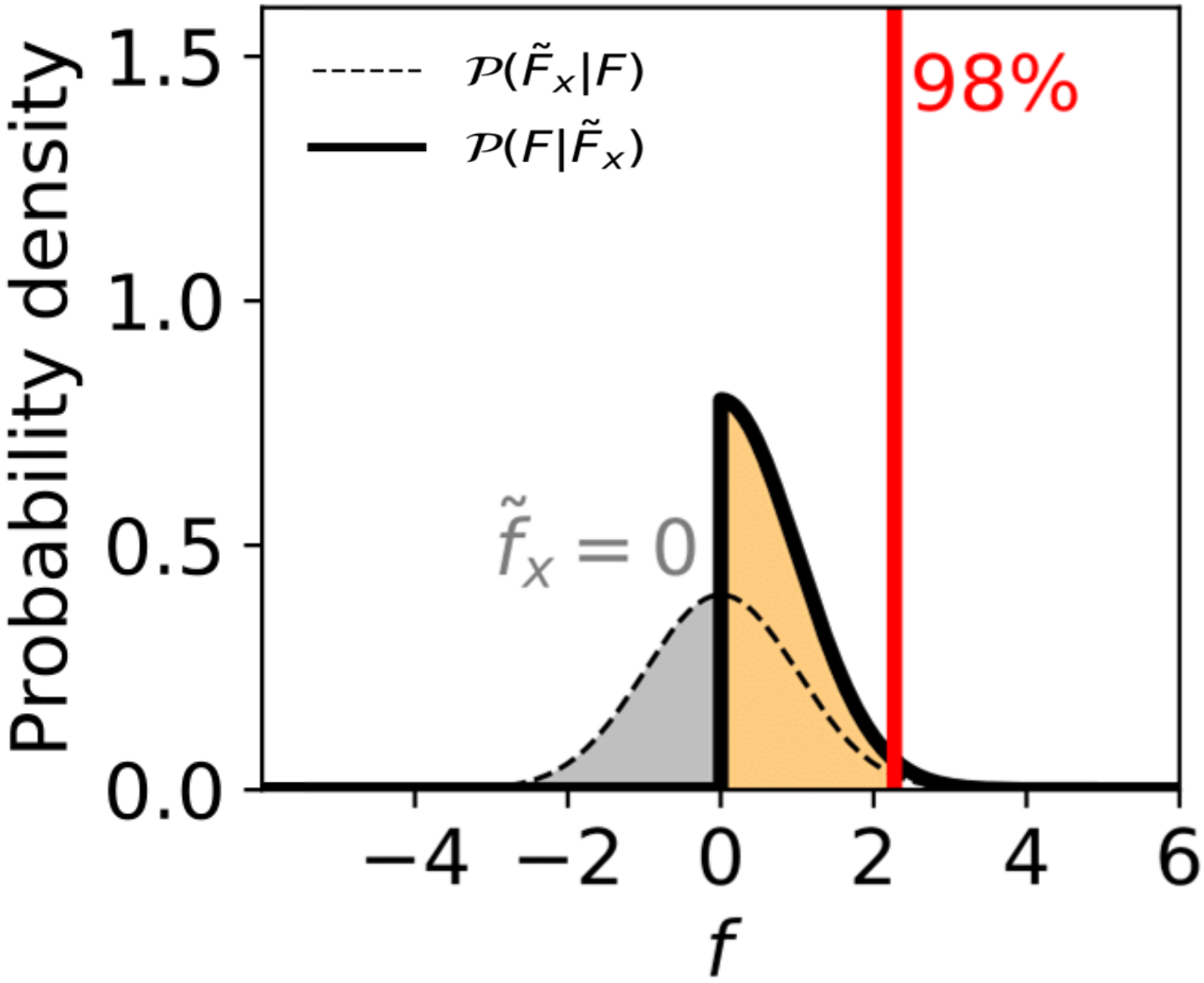
1.0
0.5
0.0
$\mathcal{P}(\tilde{F}_x|F)$
$\mathcal{P}(F|\tilde{F}_x)$
98%
$\tilde{f}_x = -1$
−4
−2
0
2
4
6
f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98%
$\tilde{f}_x = 0$
−4
−2
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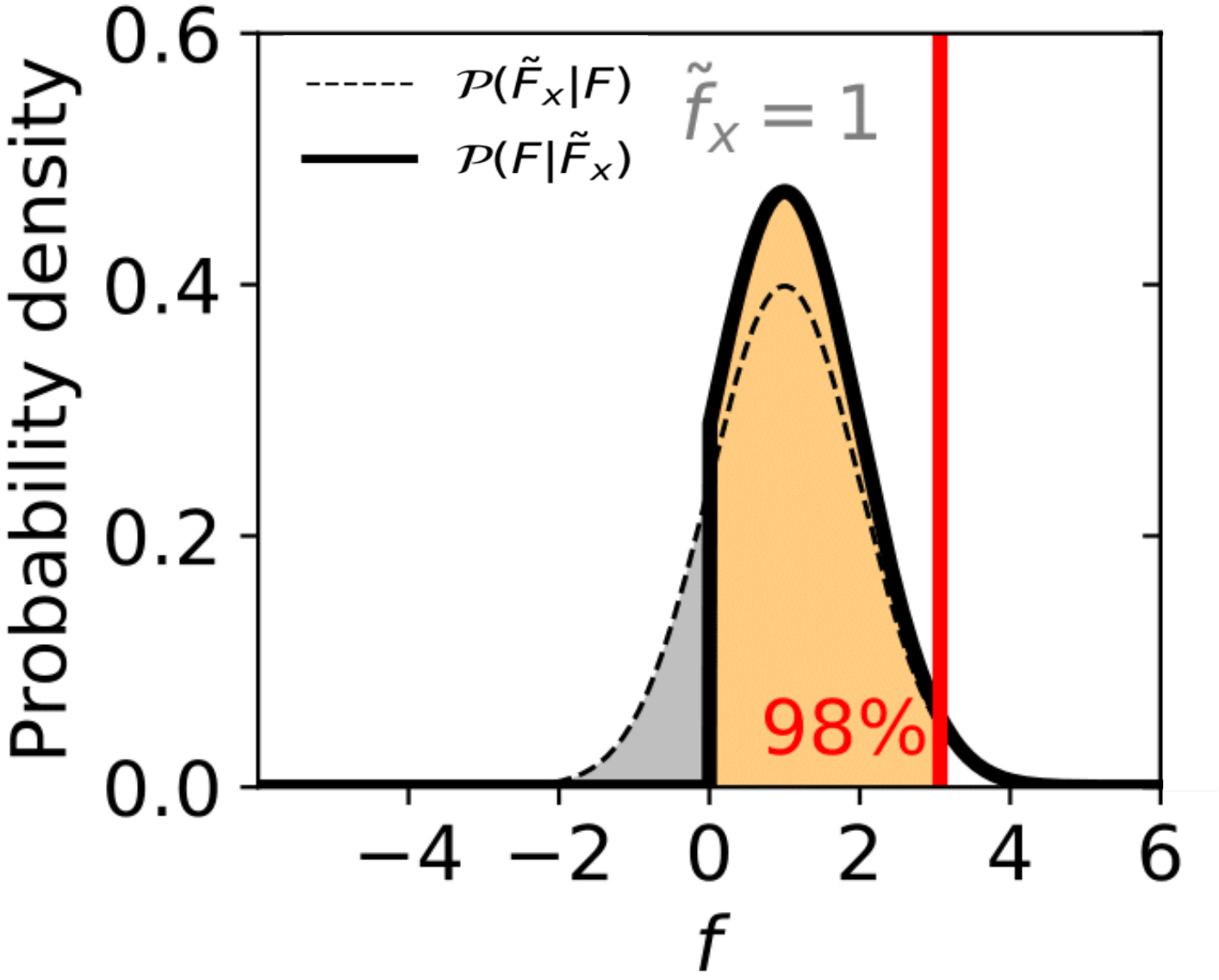
0.6
0.4
0.2
0.0
Probability density
$\mathcal{P}(\tilde{F}_x|F)$
$\mathcal{P}(F|\tilde{F}_x)$
$\tilde{f}_x = 1$
98%
−4
−2
0
2
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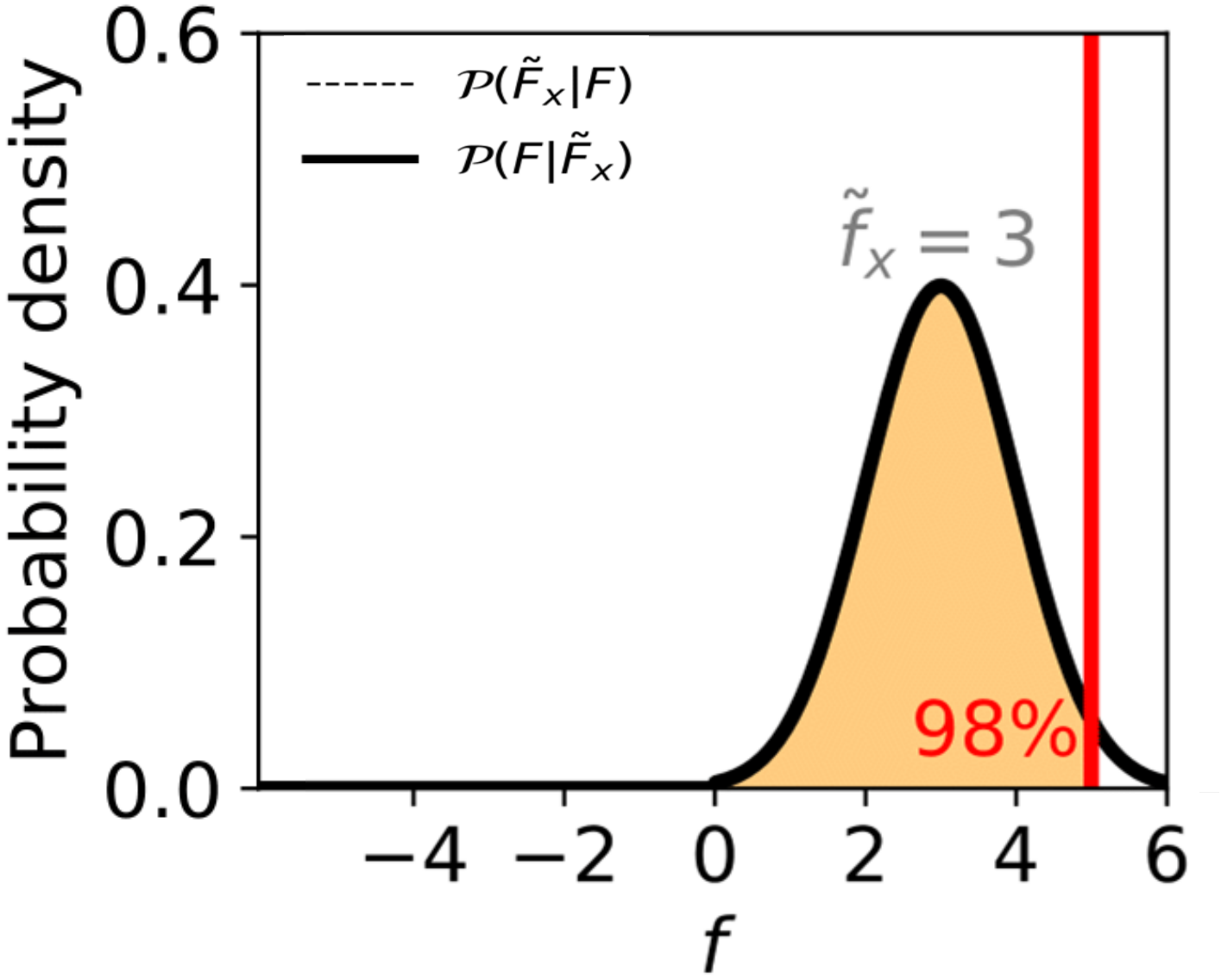
f


0.6
0.4
0.2
0.0
Probability density
$\mathcal{P}(\tilde{F}_x|F)$
$\mathcal{P}(F|\tilde{F}_x)$
$\tilde{f}_x = 3$
98%
−4
−2
0
2
4
6
f

Bayesian upper limits for direct imaging

Jean-Baptiste Ruffio (Stanford University)
GPIES *et al.*

The paper also covers scenarios in which the planet's orbit is known, but not its precise location, as well as combining HCI and RV data (see also Mawet et al. *submitted*).

The exoplanet direct detection data challenge

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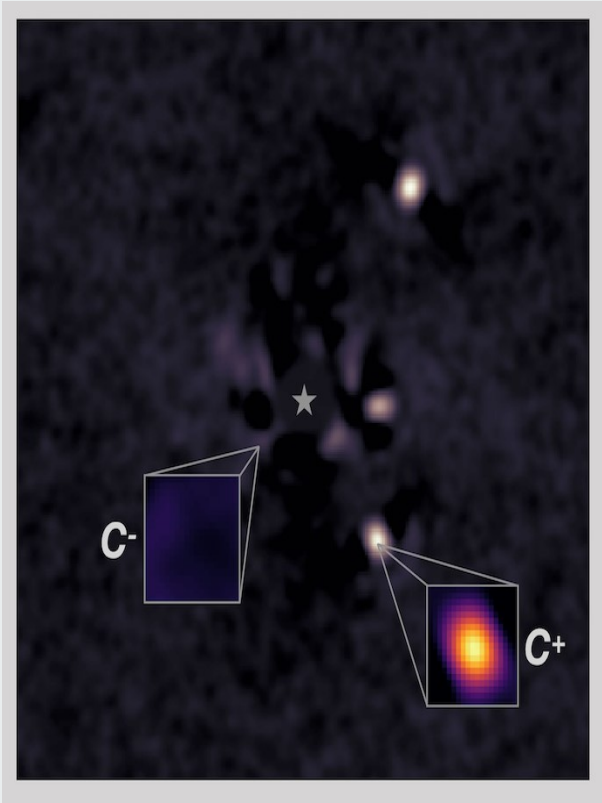
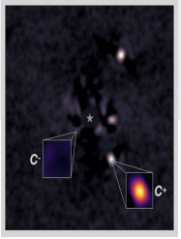
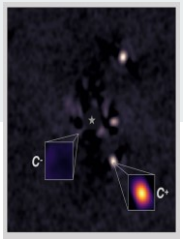




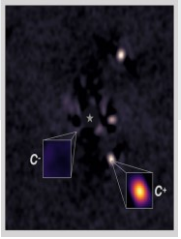
Context

- An **open-source** data challenge, welcoming broad participation
- Directly supported by the ***Grenoble Alpes Data Institute*** (France).
- **Feedback gathered** from a large team of researchers (O. Absil, JB. Ruffio, J. Wang, M. Bottom, D. Mawet, C. Marois, O. Guyon, D. Mouillet, others)
- See our website: https://carlgogo.github.io/exoimaging_challenge/.
- Workshop on “image processing for HCI” linked to the challenge.



Goals of the data challenge

- To benchmark image processing algorithms for exoplanet **detection** (extended structures are not included).
- Building a benchmark/standard library of HCI datasets.
- Agreeing on meaningful **metrics** for comparison and validation of current and new algorithms.
- Sharing knowledge, sparking **collaborations.**



Data sets

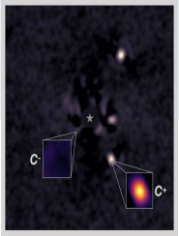
- Observing techniques: **pupil tracking (ADI) and multispectral (ASDI).**

- About 10 datasets (different targets) per HCI instrument.

- Several instruments: SPHERE, GPI, NACO, NIRC2, SCEXAO, NICI, others?

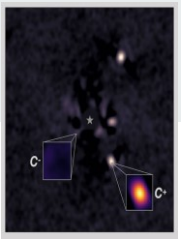
- 0 to 5 injected companions per dataset.

- Standard injection (no smearing, no variable photometry, etc).



Detection metrics

- Outputs: **detection maps** and critical thresholds
- Source counting by thresholding the detection map
- Receiver operating characteristic (**ROC**) curves
- Mapping the true positive rate vs # of false positives trade-off
- All at multiple separation regimes



Open questions

- Exact kick-off date (fall 2018)
- Exact detection metrics
- Optional submission of astrometry and photometry of companions
- Multispectral ASDI: real spectra or model for planet injection
- Storage solution for the HCI benchmark library
- Usage of metadata (atm. profiling, AO-telemetry, etc)
- Taking advantage of pre-constructed RDI libraries (e.g. GPI survey)

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- **The next step: data challenge and close out**