Exoplanet detection with high contrast imaging

First results on a small survey

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COBREX

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European Research Council

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Introduction

THESIS : Exoplanet detection with high contrast imaging

- Reprocess the entire SPHERE archive (young stars)
- Use of a new algorithm : PACO
- Test bed on a small sample of close and young solar-type stars

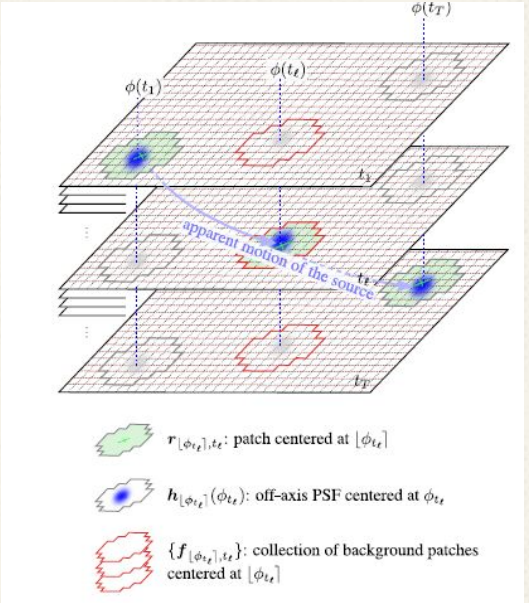
The PACO algorithm

Algorithm developed to process HCI observation (PAtch COvariance, Flasseur et al. 2018)

- Statistical data-driven modelling of noise at local scale
- Provide statistically-based SNR maps following N(0,1)
- No PSF subtraction step

We used robust PACO ASDI (Flasseur et al. 2020ab)

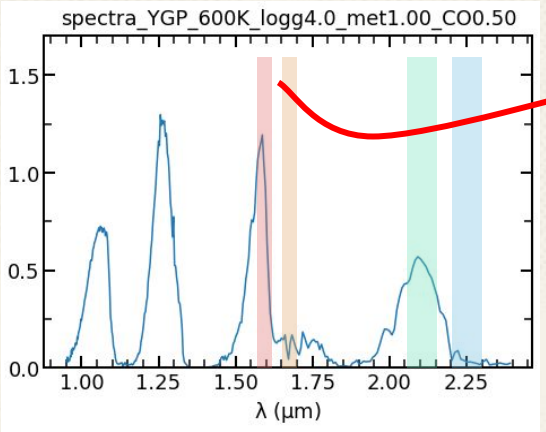
- Robustness to bad frames
- ASDI allow better noise estimation and optimal spectral combination following a prior



Priors creation for PACO ASDI

Priors are used to optimally combine multi wavelength data following weights → spectral priors, maximize snr of sources

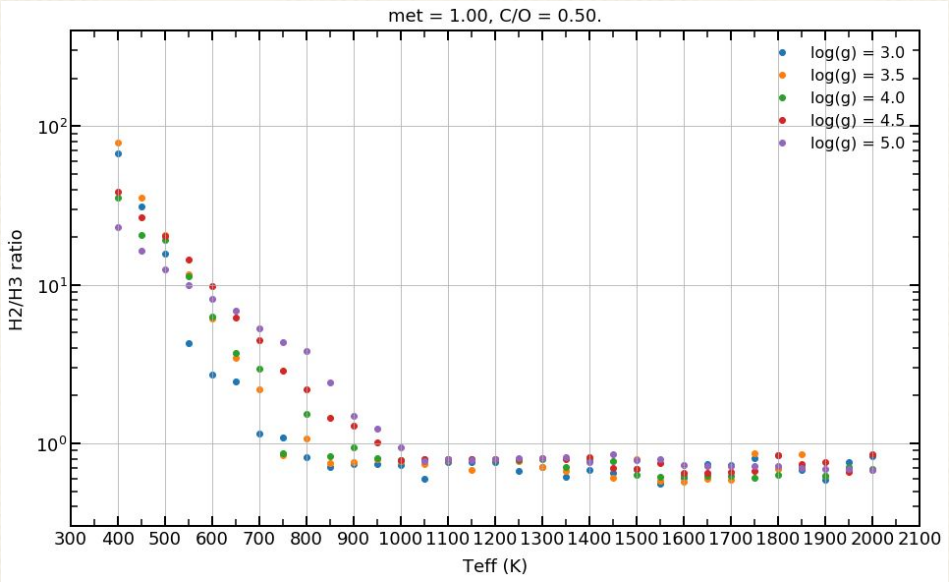
We choose to build our spectral priors based on Exo-Rem model (~10 000 spectra at R=500, Charnay et al. 2019)



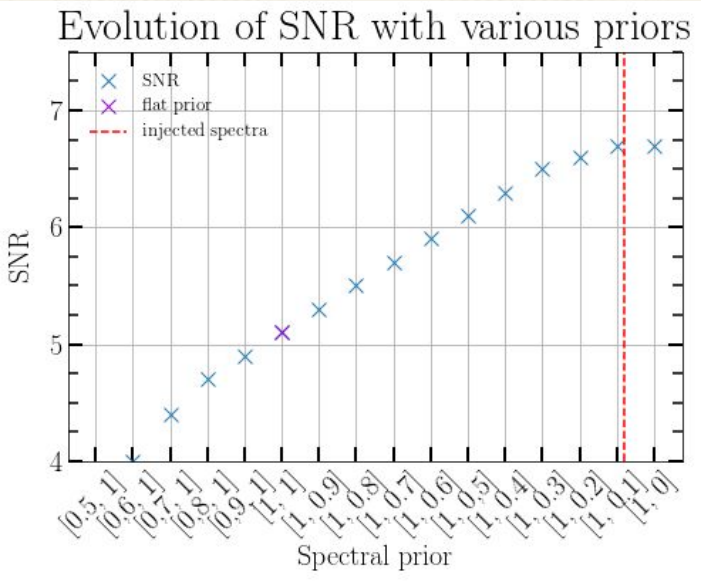
ratio H2/H3 = 10 → [1, 0.1]

IRDIS spectral priors

Exploring the spectral diversity

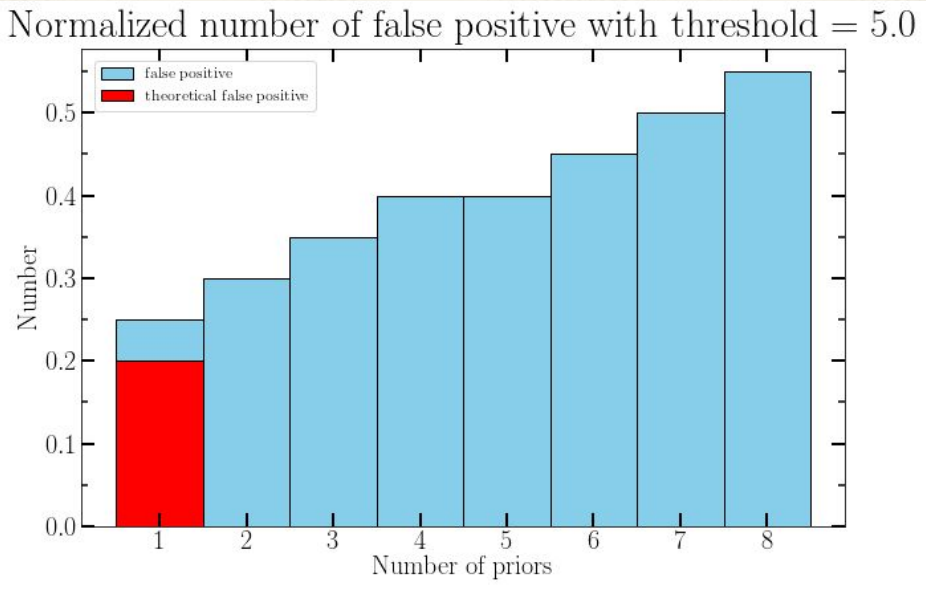


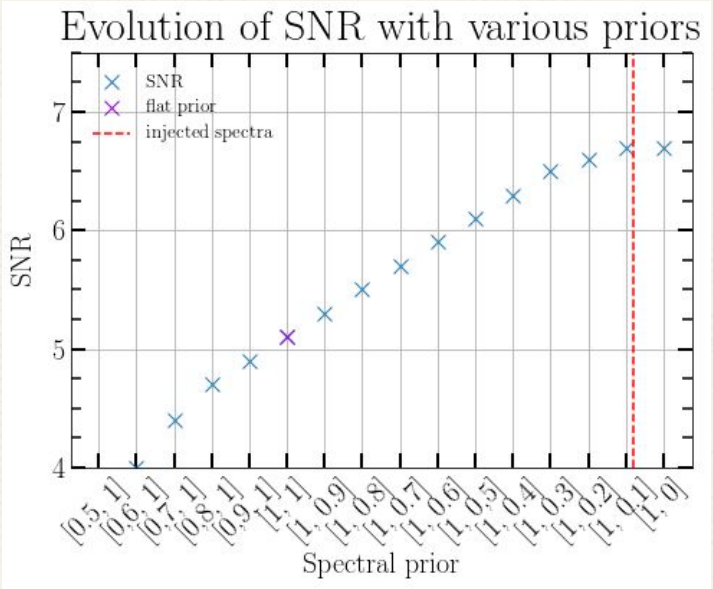
Study the sensibility of PACO to various number of priors with fake injected planet of various spectral types



IRDIS spectral priors

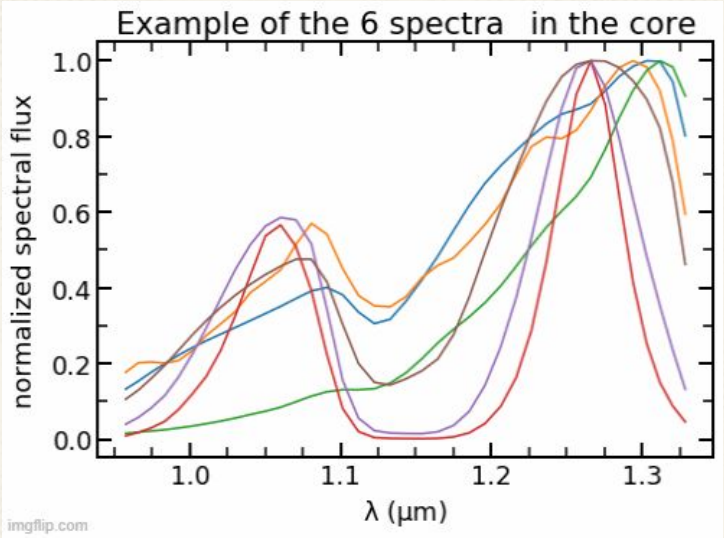
Impact on false positive rate of adding prior



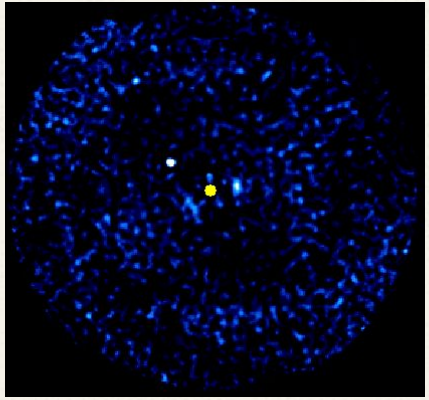


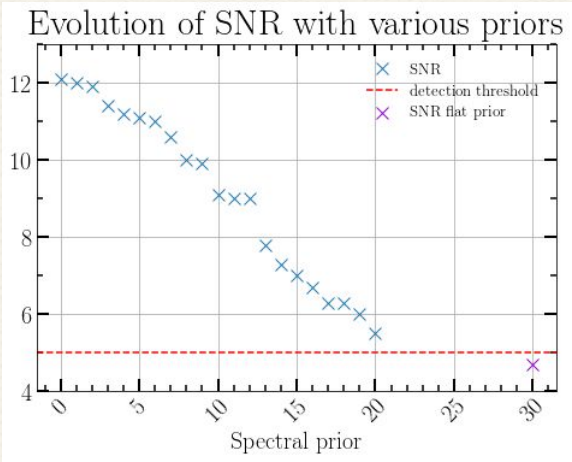
IFS spectral priors

Euclidian based method to explore the spectral diversity



HD206893 b
2017-07-13
YJ band

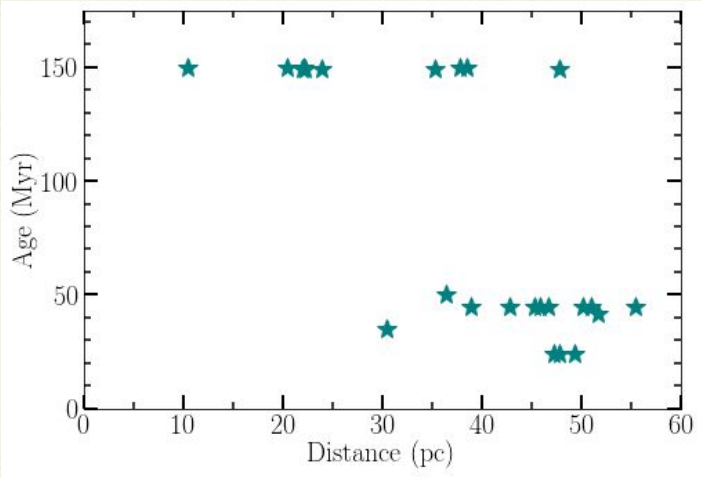


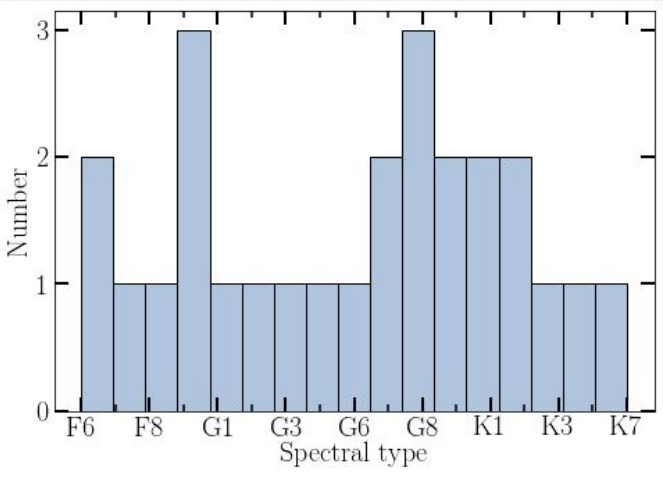


Mini-survey : sample definition

All (23) young (< 150 Myr), close (<60 pc) solar type stars observed during the SPHERE/SHINE F150 (part of the SPHERE GTO survey, Desidera et al. 2021) survey with H23/JY filters

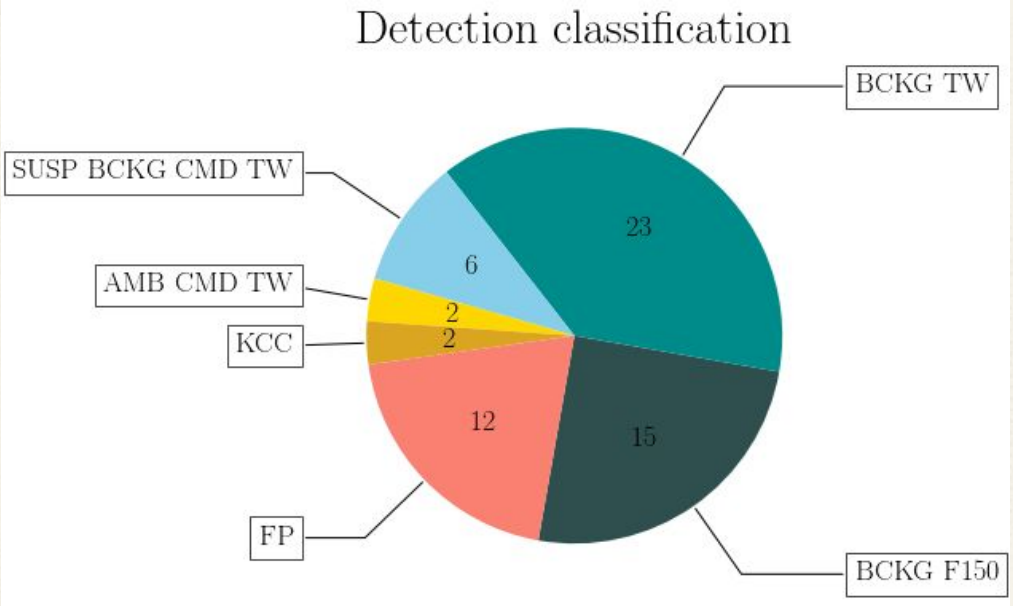
Designed as a test bed for the future massive reduction (all targets).

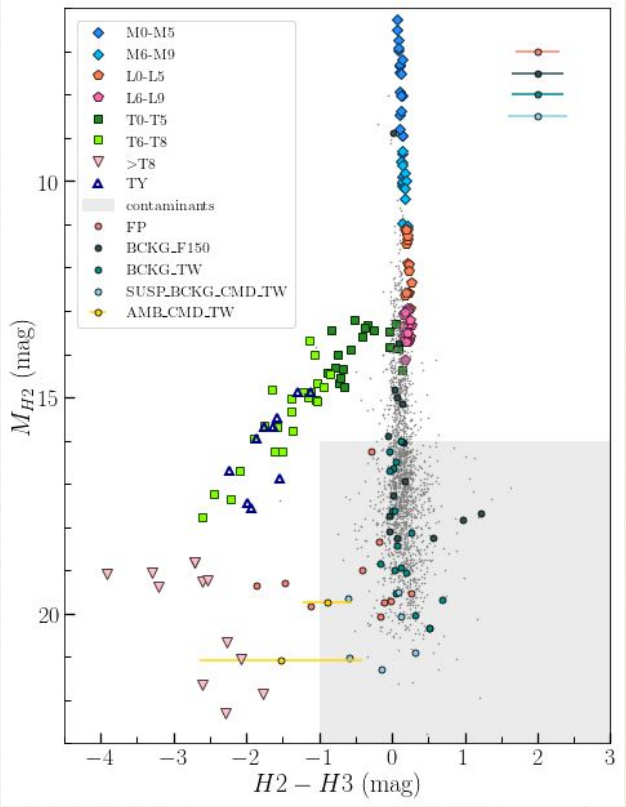




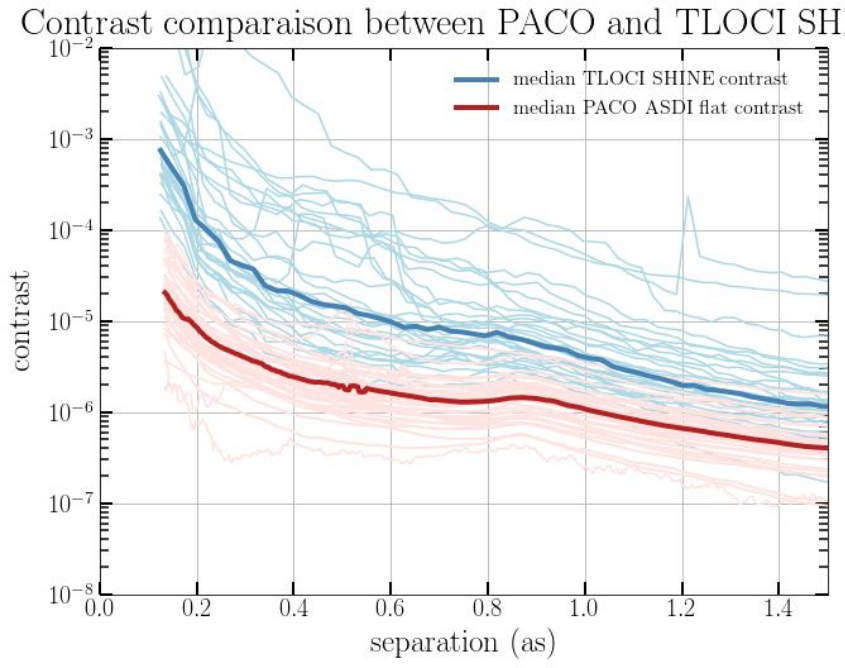
Results : detection classification

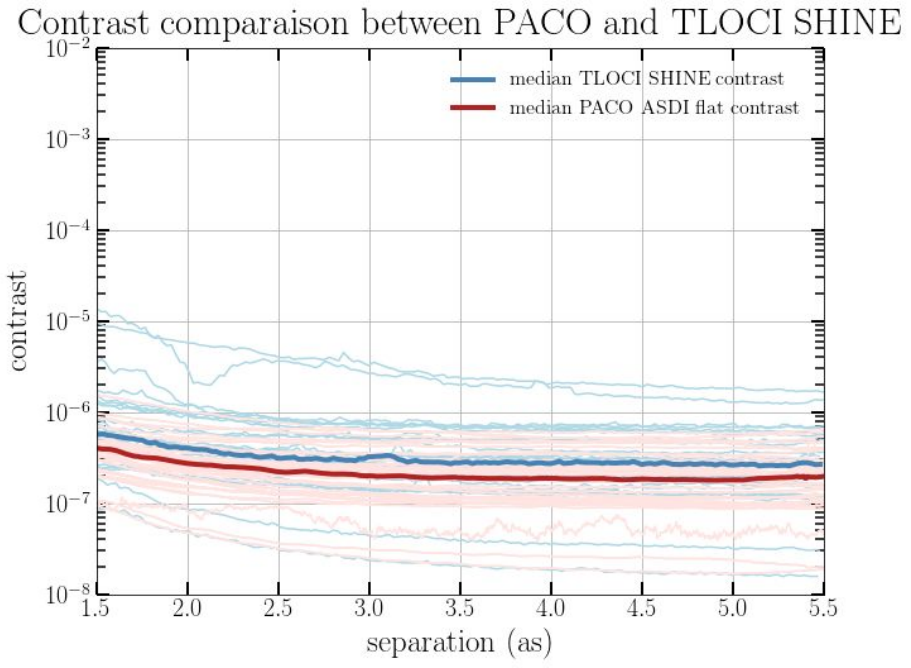
61 (20 new) detections above 5 sigma; 40 datasets





Results : IRDIS contrast comparison with SHINE F150





Improving astrometric and photometric error budget

- Updated astrometric error budget thanks to :
  - Lessons learn from 7 years of service of SPHERE (following Maire+2021)
  - Improved pré-reduction pipeline and centering (thanks to Jule's work)
- Improved photometric error budget
  - Using SPARTA data
  - Using the DTTS of SPHERE

Harnessing the power of Gaia and SPHERE

- Gaia allow us to have direct hints of the presence of a companion
  - Gaia alone cannot probe for long period companion (limited by the data duration)

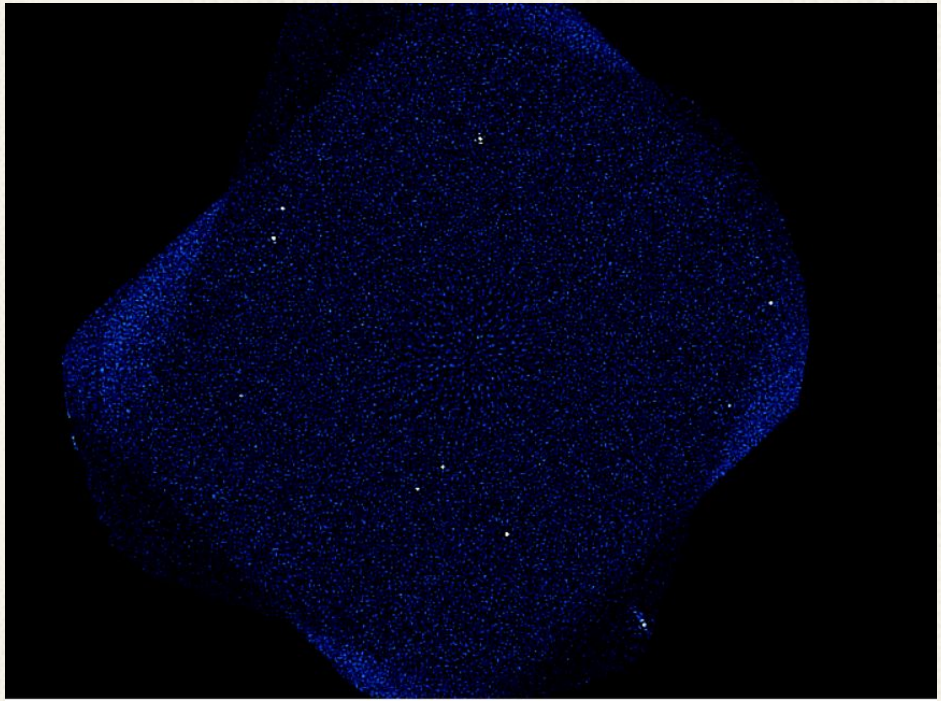
    → Use Gaia-Hipparcos PMa

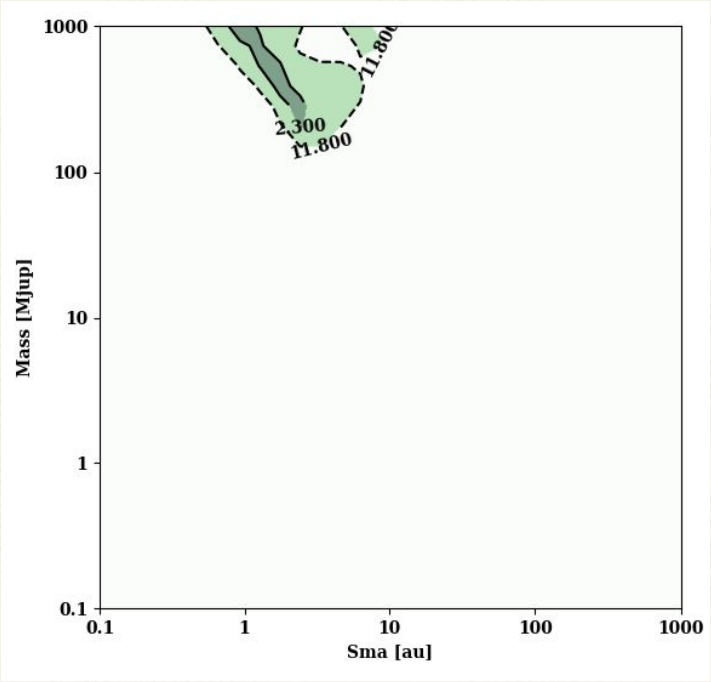
But using PMa to probe for HCI detectable companions is **not enough**

→ **we need to account for the excess noise**

Harnessing the power of Gaia and SPHERE

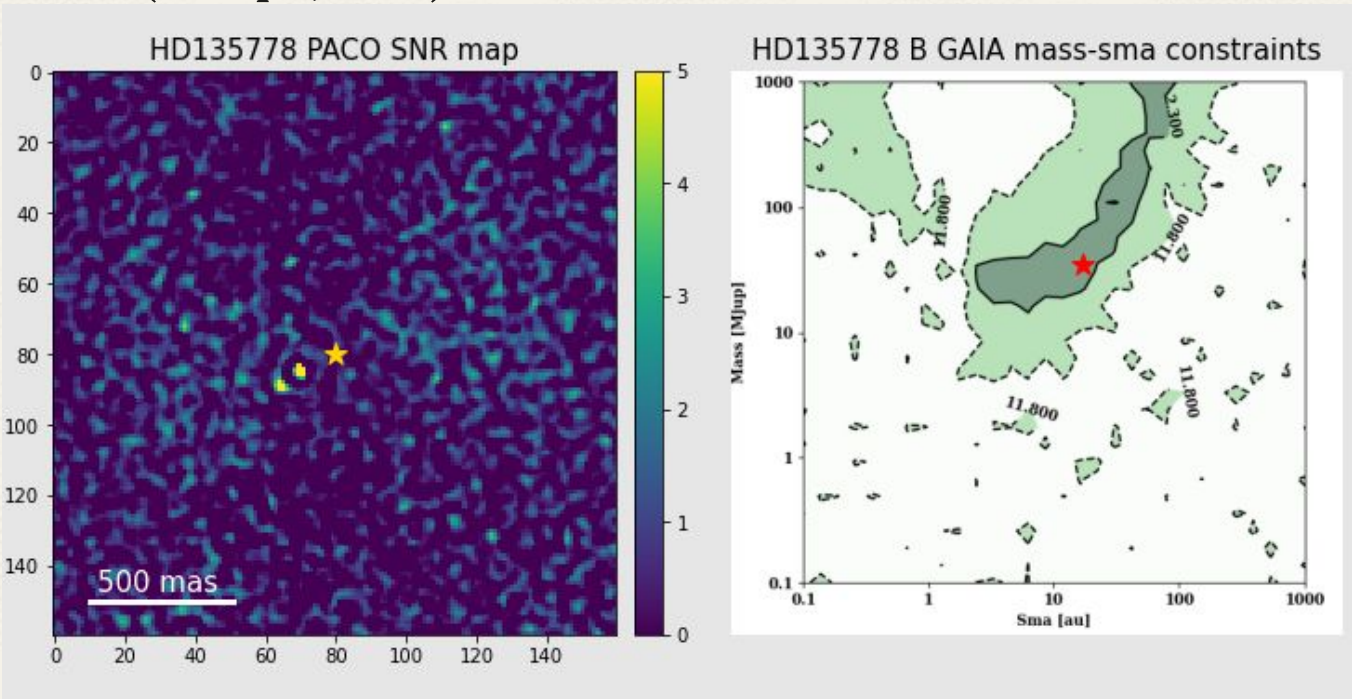
HD 104125 (100.4 pc, A2V) σ_{PMa} = 8.8 σ_{EN} = 31



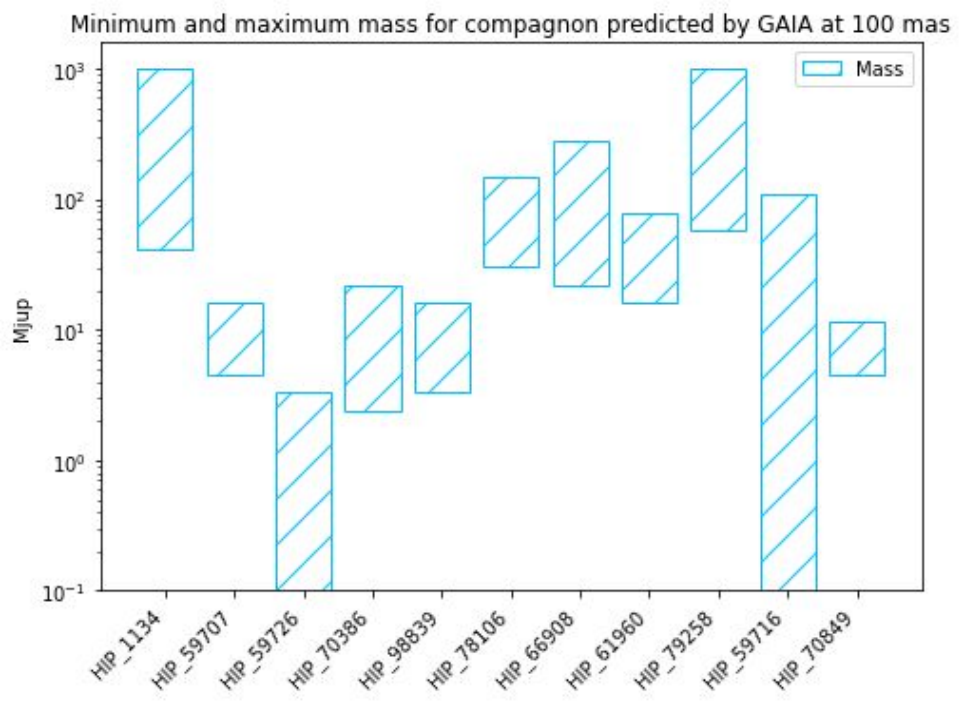


Harnessing the power of Gaia and SPHERE

HD 135778 (123 pc, F3V) $\sigma_{PMa} = 4.5$ $\sigma_{EN} = 0.3$



Harnessing the power of Gaia and SPHERE



P111 proposal focusing on unobserved (or bad observed) young stars with high σ_{PMa} and little to none σ_{EN}

\+ paper ?

Warning : Gaia can be sensitive to the a close massive companion, but a faint distant signal can be hidden in it

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Forthcoming work

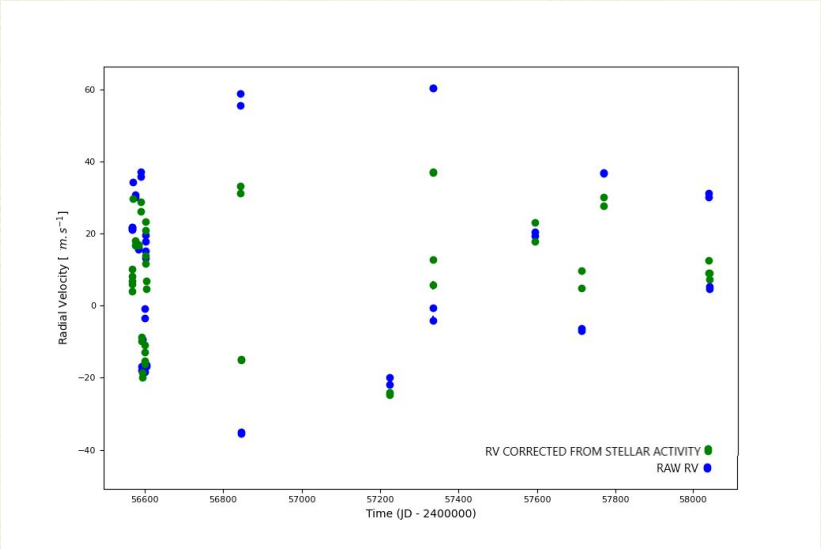
3 upcoming milestones :

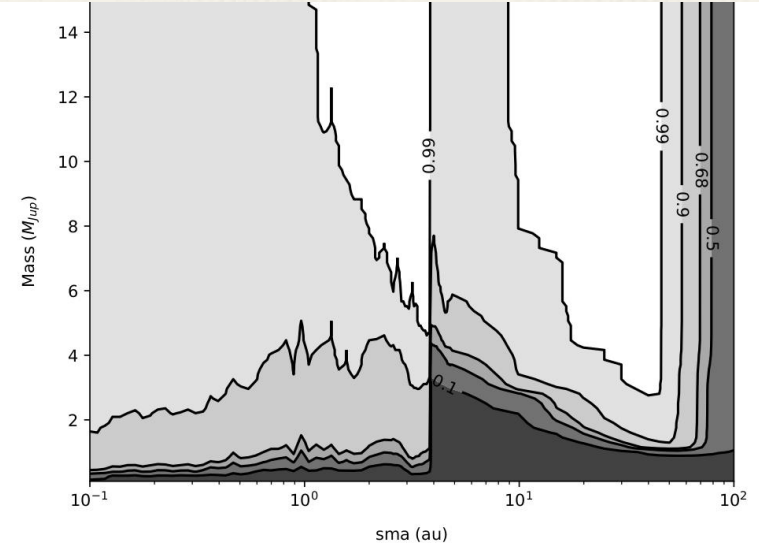
- Re-analysis of the F150 (IRDIS : ~ 280 PACO reductions ready)
- Analysis of the F250 : IRDIS ready to be launch
- The Sco-Cen sample (SPHERE x GPI) : IRDIS ready to be launch

IFS pipeline is (nearly) ready

Results : detection limits using MESS2

HIP13402, 2016-10-14, H23 band, DI+RV combination

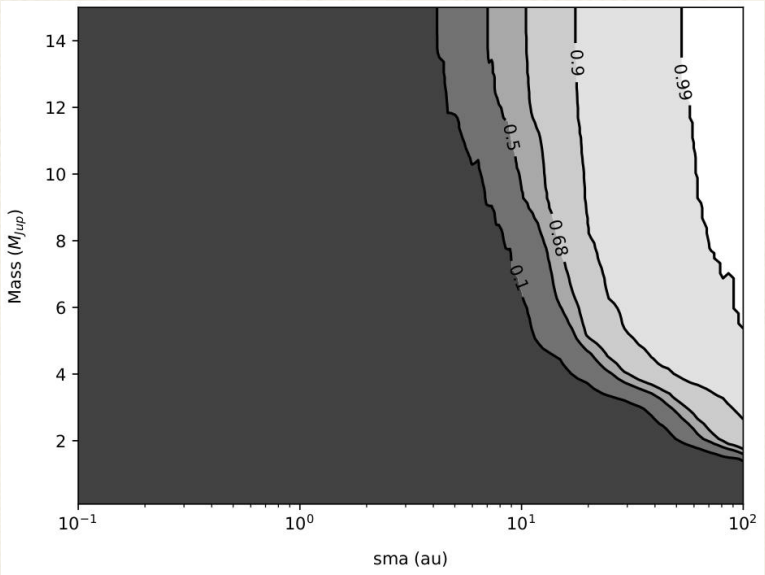




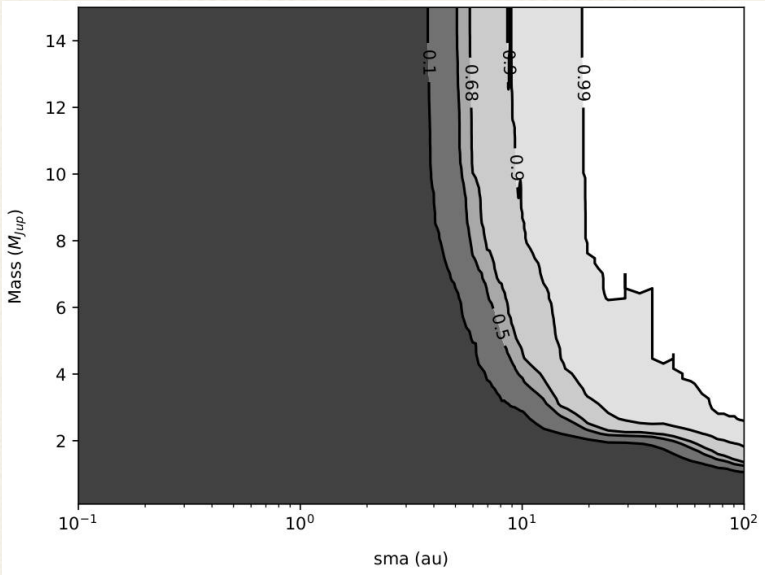
Grandjean et al, 2020

Results : detection limits using MESS2

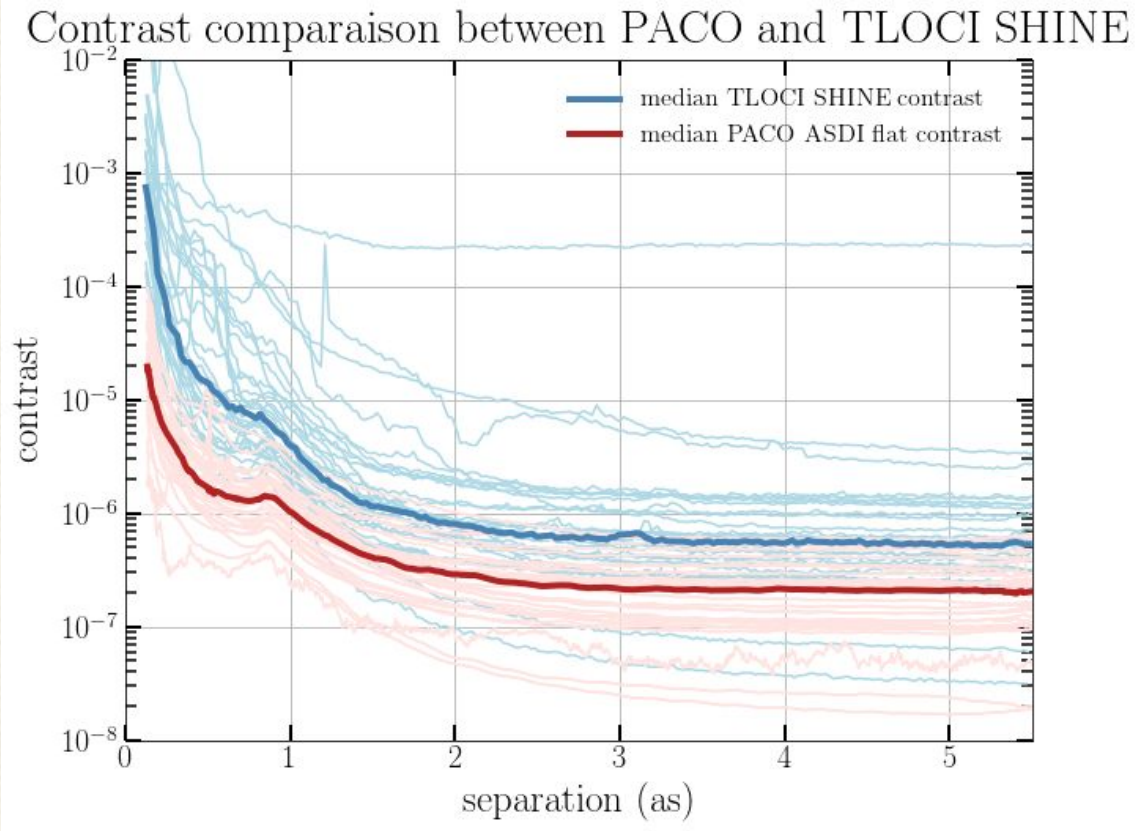
HIP 1481, 2015-10-26, H23 band, DI only



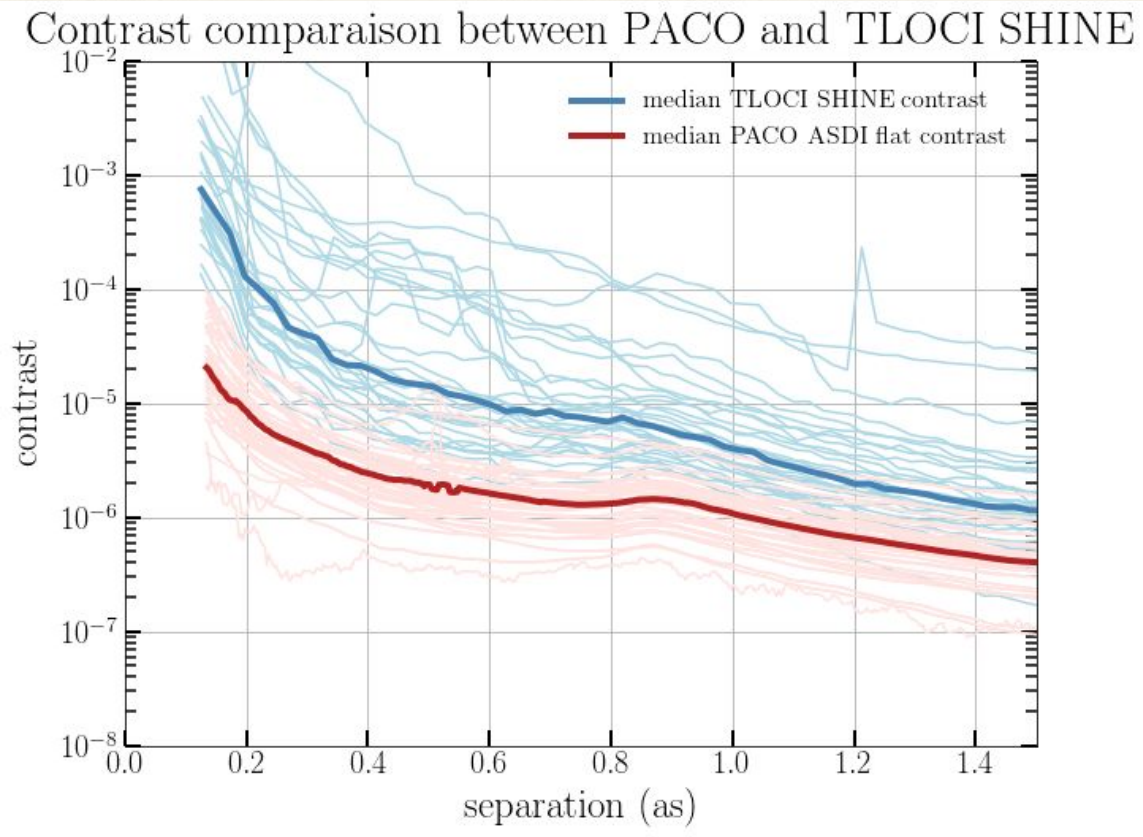
HIP 1481, 2015-10-26 + 2016-09-18, H23 band, DI only



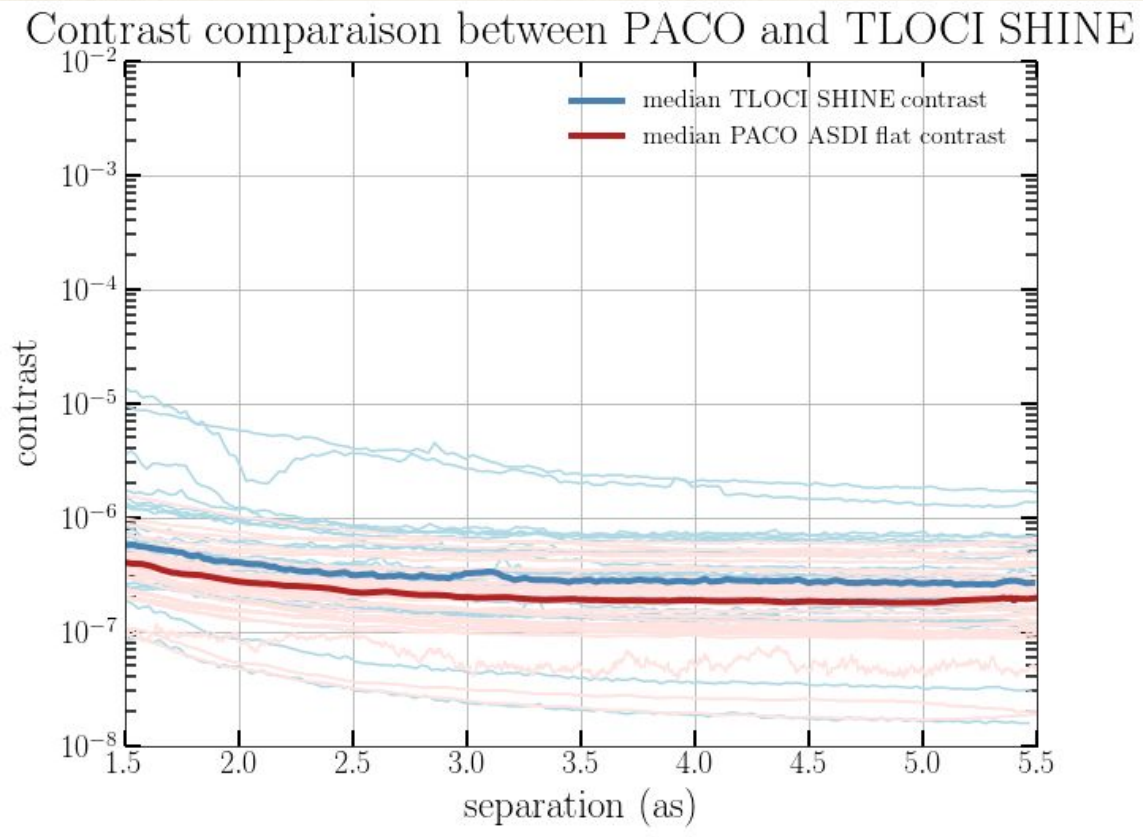
BACKUP SLIDE : contrast



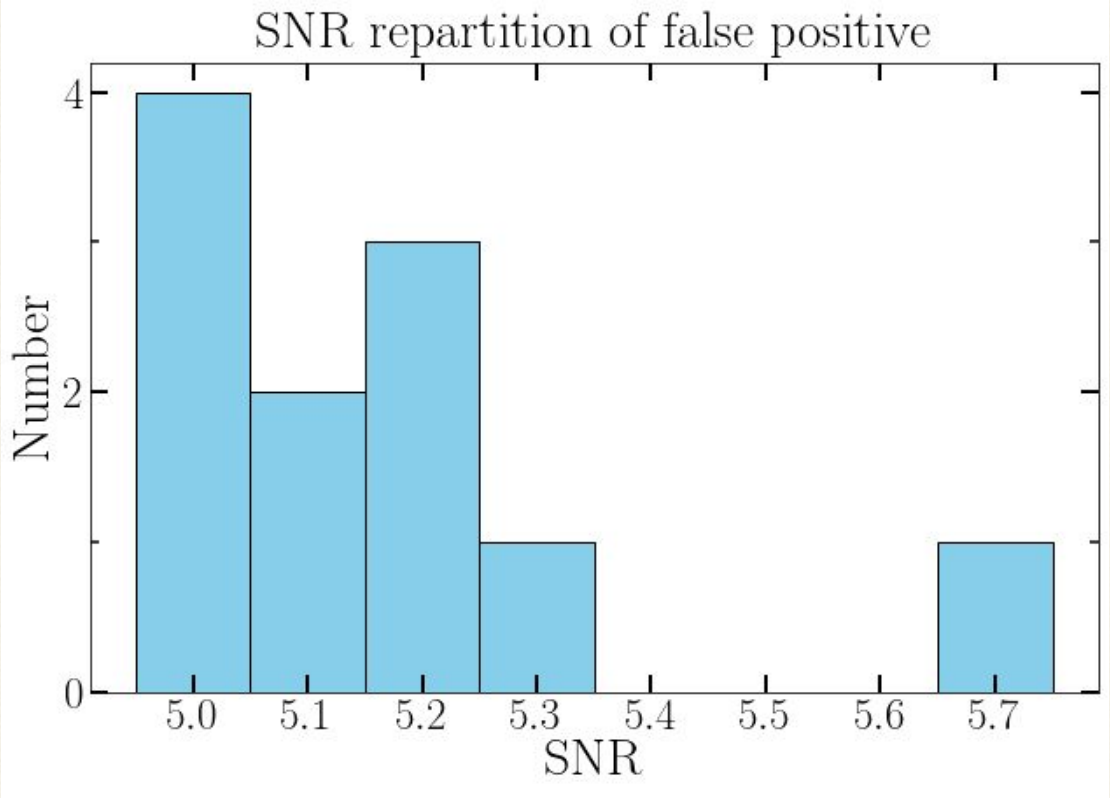
BACKUP SLIDE : contrast



BACKUP SLIDE : contrast



SNR of false positive



Contrast : All priors