A single point spread function model for all adaptive-optics systems

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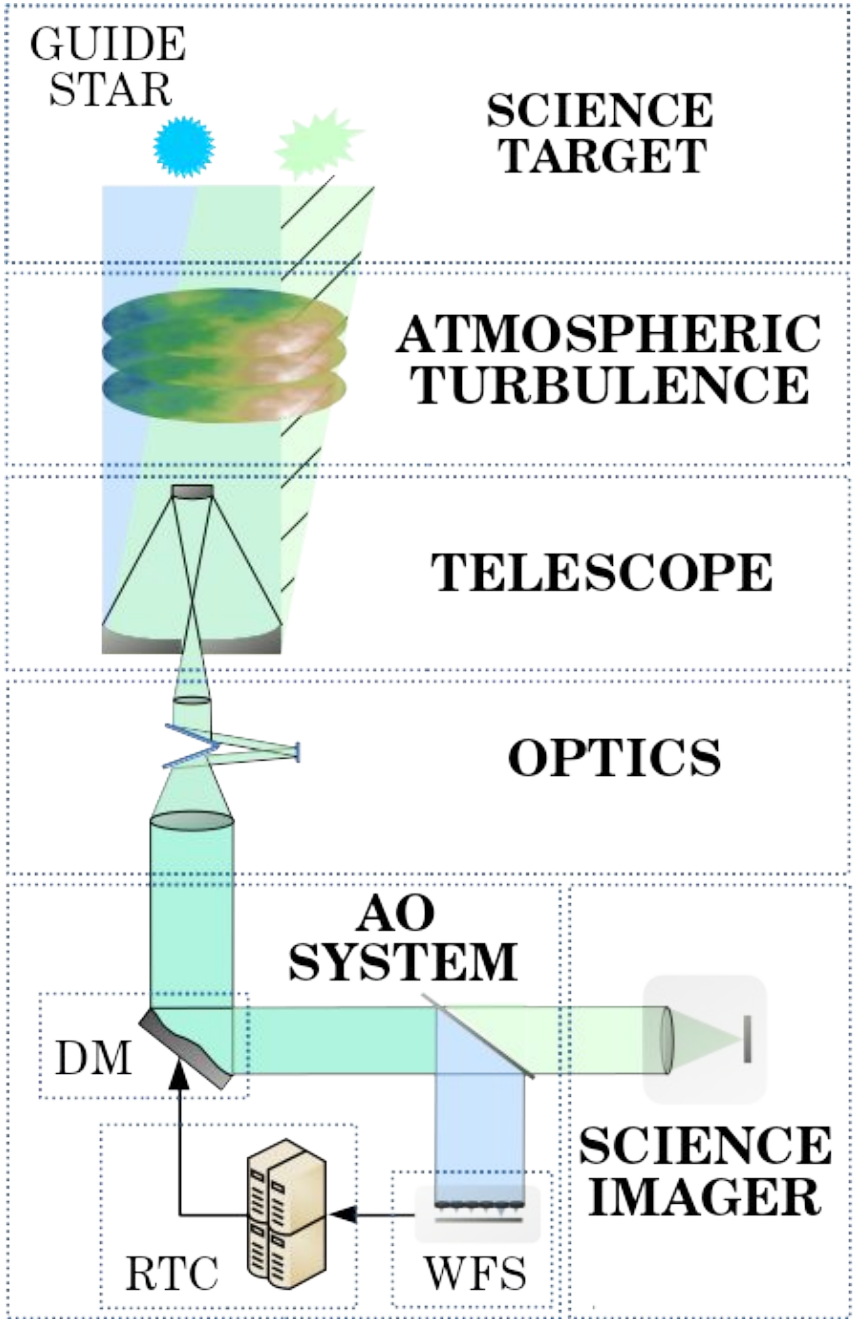
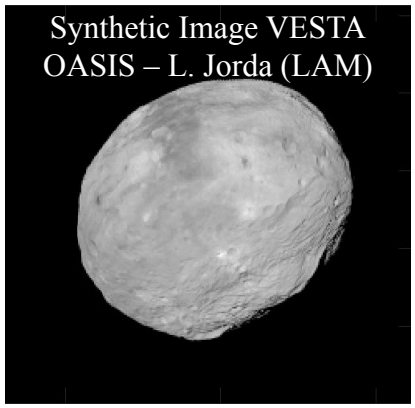
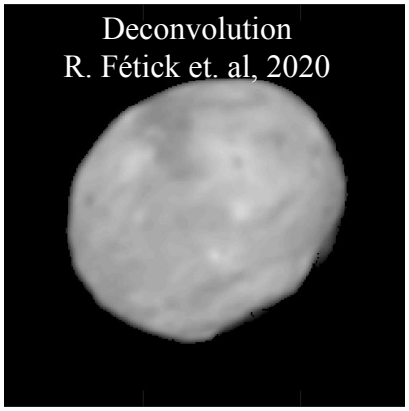
Context : the PSF is the key





model ?

$I = O * PSF + n$



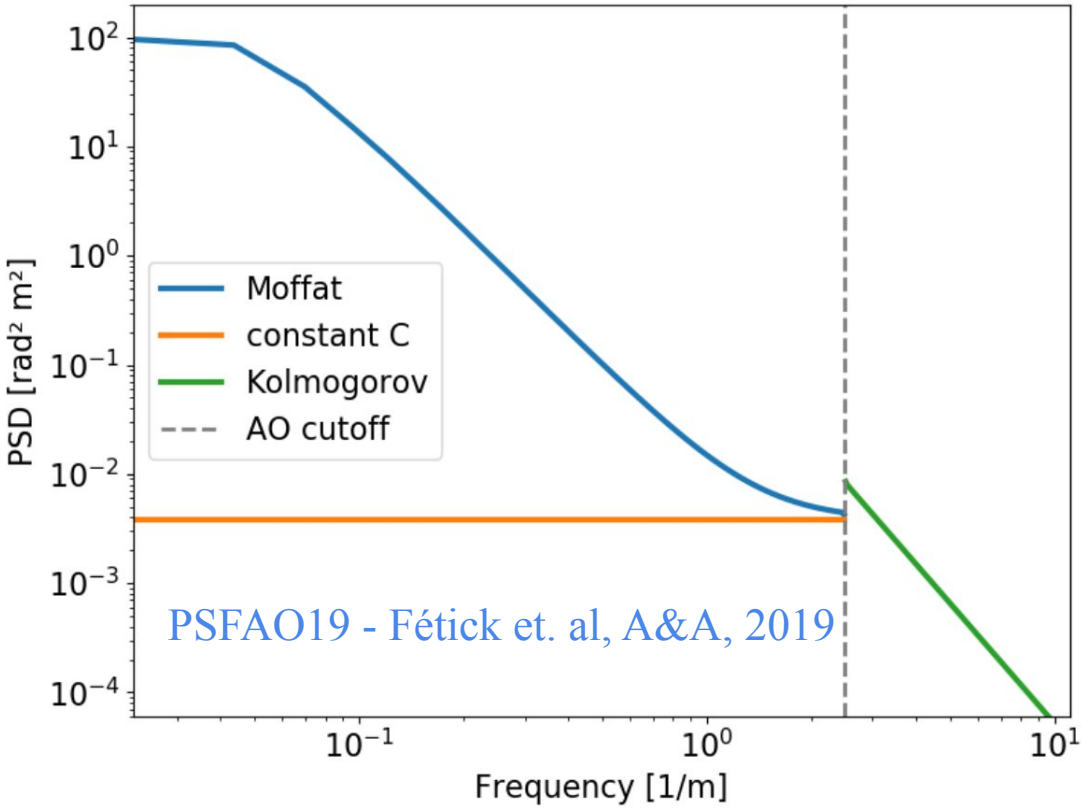
Post-processing

PSFAO19 model : model calibration

1 - Model of the wavefront **power spectrum density** (PSD)

$PSD(\mathbf{k} <= \mathbf{k_{AO}}) = M(\mathbf{k}, A, \alpha, p, \beta) + C$

$PSD(\mathbf{k} > \mathbf{k_{AO}}) = 0.023 r_0^{-5/3} \mathbf{k}^{-11/3}$

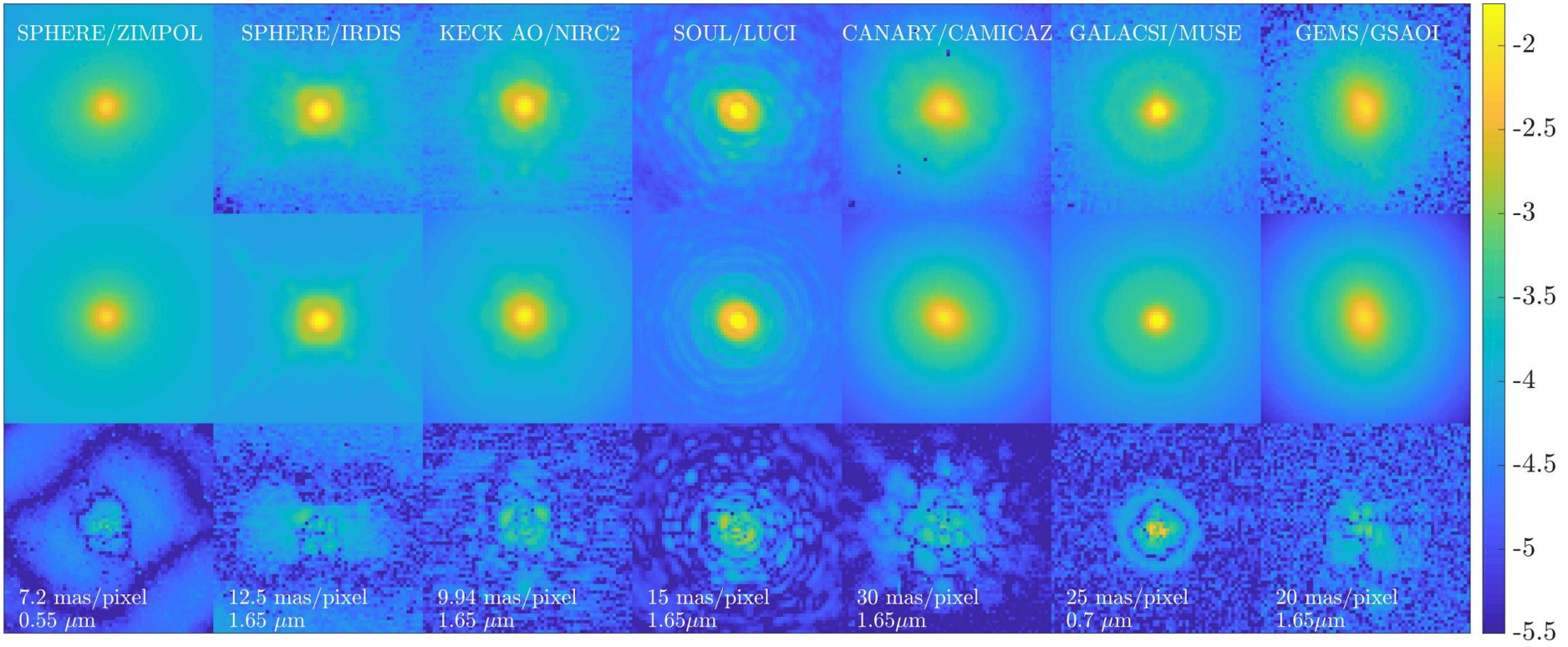


2 - Model of the **PSF** : $PSF(r_0, C, A, \alpha, p, \beta) \propto F^{-1}[OTF_{tel}.\exp(F^{-1}[PSD(r_0, C, A, \alpha, p, \beta)])]$

3 - **Fitting** : $J(F, x, y, bg, r_0, C, A, \alpha, p, \beta) = \sum_{i,j} W_{ij}.\|(I_{ij} - F \times PSF(r_0, C, A, \alpha, p, \beta) * \delta_{xy} + bg)\|^2$

PSFAO19 model : on-sky verification

Validation on ~4800 PSFs from 7 Vis./NIR instruments



Beltramo-Martin et. al, A&A, 2020

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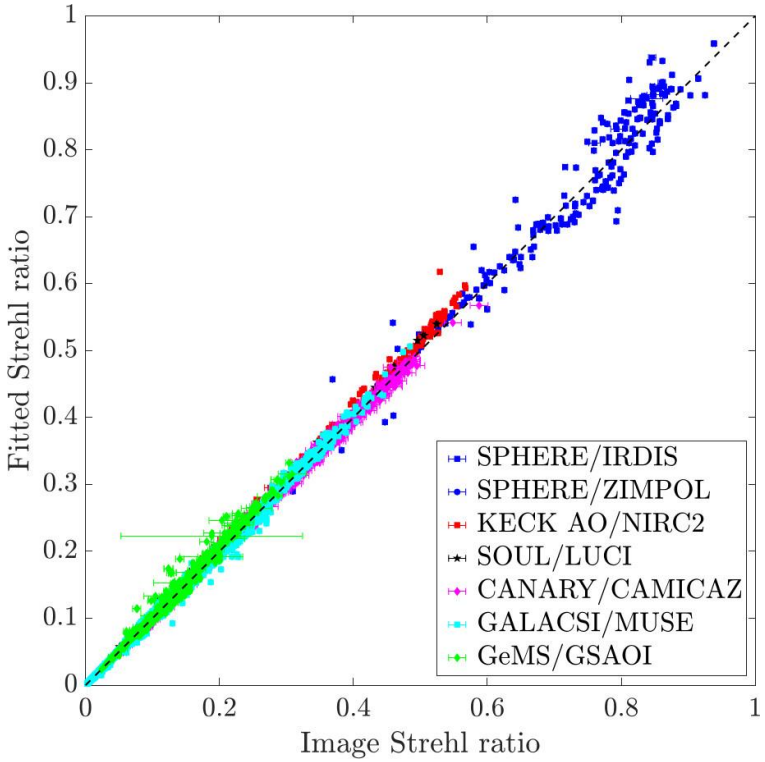
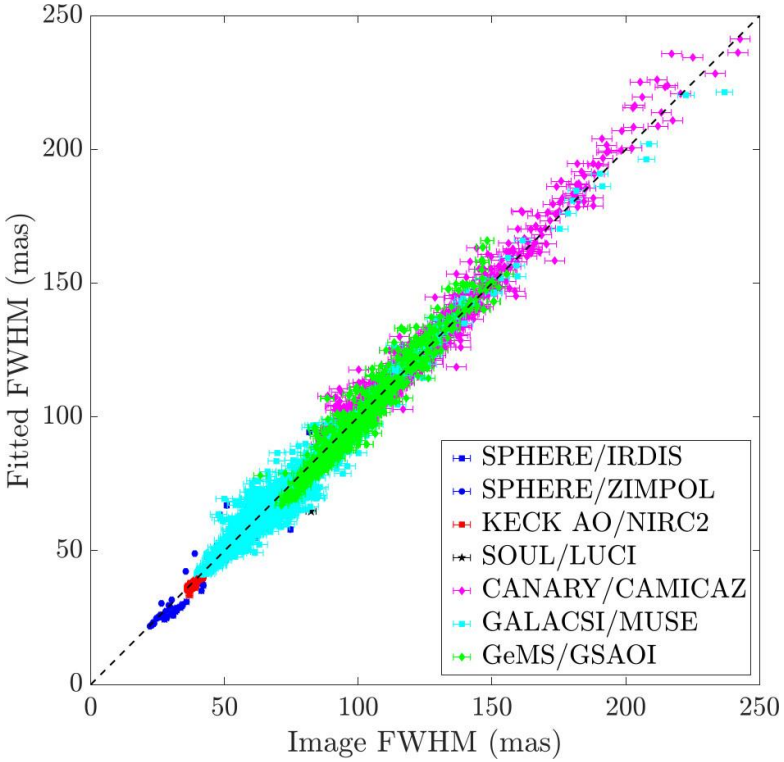
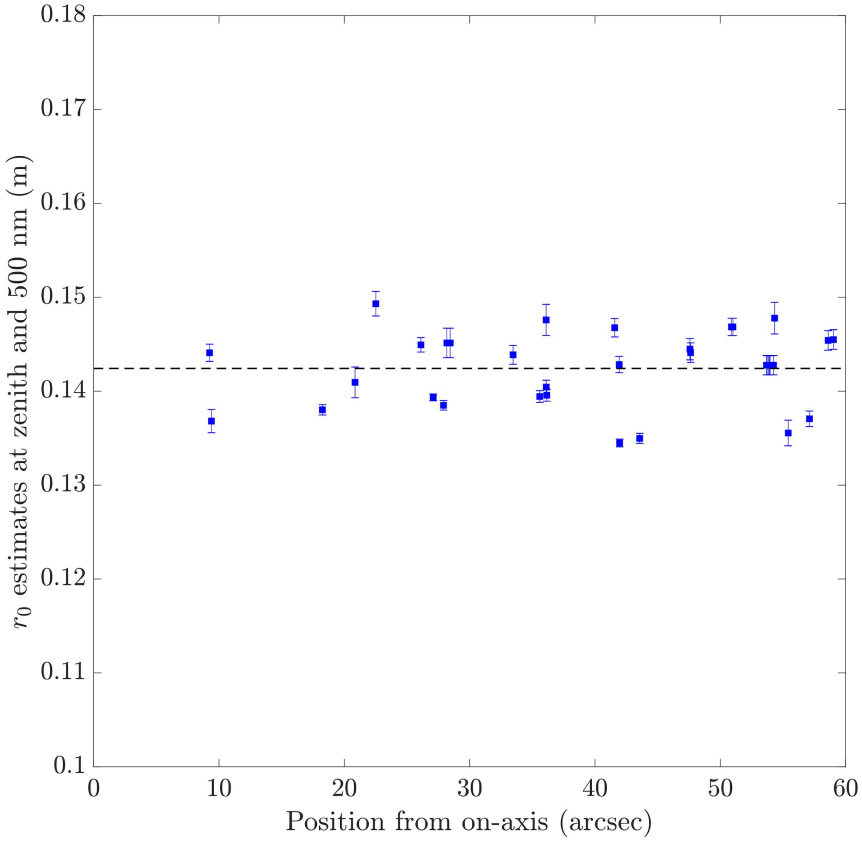




1. Correlation ~ 95%
2. SR error ~ 3%
3. FWHM error ~ 0.2 pix

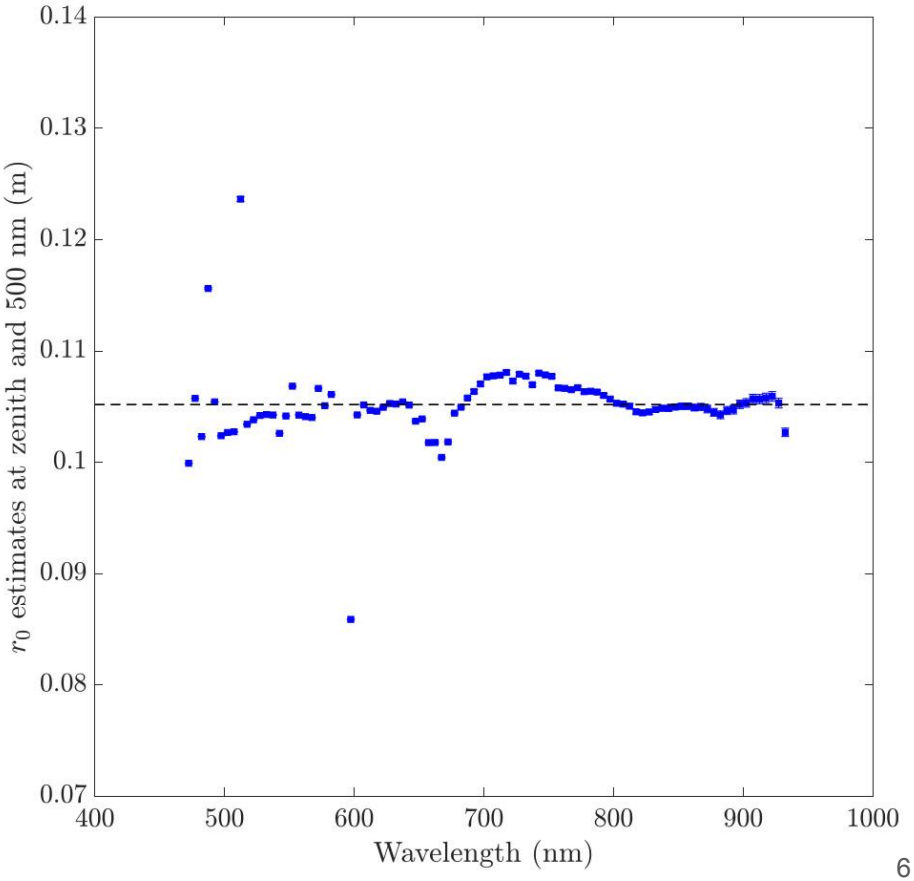
SYSTEM	λ (μm)	SR (%)				FWHM (mas)			
		Median	bias	std	Pearson	Median	bias	std	Pearson
SPHERE/ZIMPOL	0.55	6.2	0.5	0.3	0.998	32	-4.2	0.9	0.995
	0.64	12.4	0	0.38	0.999	26	1	2.9	0.96
SPHERE/IRDIS	1.67	61	-0.2	2.0	0.98	52	0.2	1.4	0.90
	2.25	80.0	0.7	3.2	0.98	66	0.8	1.5	0.88
GALACSI/MUSE	0.5	2.4	-0.02	0.2	0.993	80	-1.4	2.9	0.997
	0.7	10.3	0.1	0.3	0.998	69	-1.7	3.2	0.980
	0.9	25.0	0.2	0.7	0.998	58	0.08	5.4	0.90
KECK AO/NIRC2	1.65 (NGS)	39.4	1.1	0.9	0.998	37	-0.9	0.8	0.994
	2.2 (LGS)	22	0.7	0.6	0.999	70	-1.9	1.3	0.995
SOUL/LUCI	1.65	36.0	1.2	0.5	0.990	55	-2.5	3.3	0.980
CANARY/CAMICAZ	1.65	23.0	0.1	0.4	0.999	115	-0.1	3.7	0.993
GEMS/GSAOI	1.25	13.3	0	0.5	0.994	109	2.0	5.4	0.976
	1.64	7.6	0.4	0.5	0.990	98	-4.0	3.2	0.98
	2.2	15.6	0.4	0.7	0.994	94	-0.8	4.5	0.970

PSFAO19 model : on-sky verification

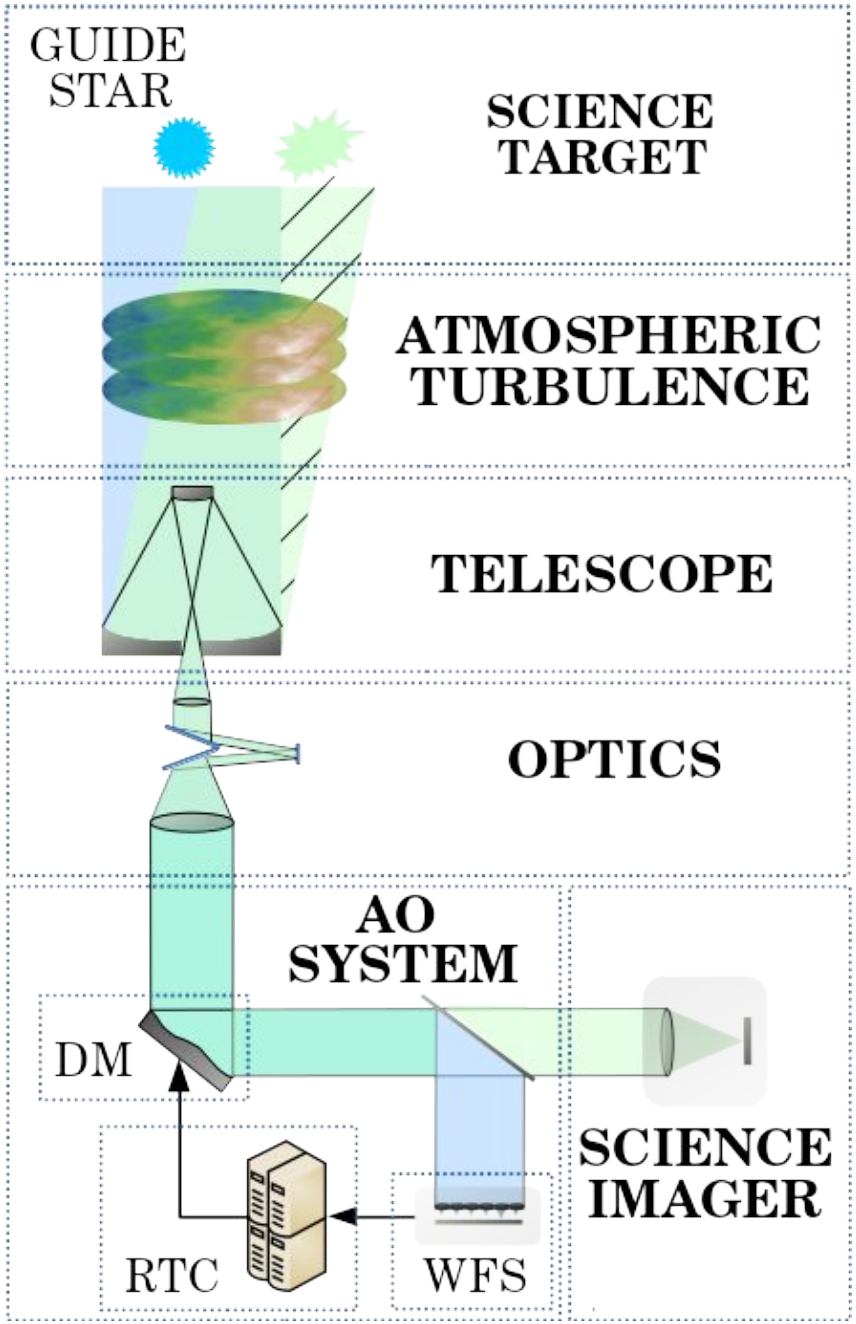


GSAOI : r_0 @500nm is not Θ-dependent

MUSE : r_0 @500nm is not λ-dependent



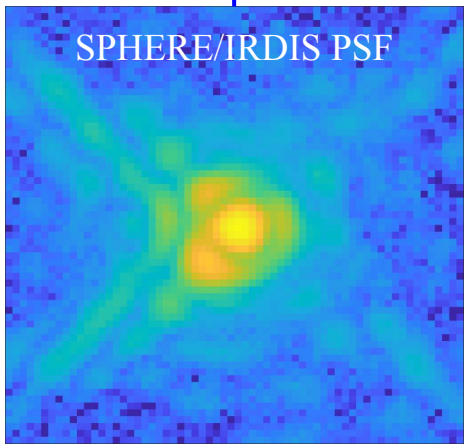
APPLY ANR : increase the estimation robustness with CNN



PSD parameters

Beltramo-Martin, Gray et. al, in prep.

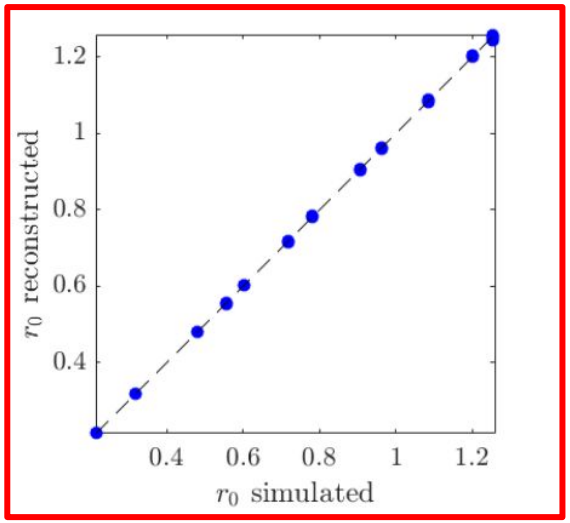
CNN

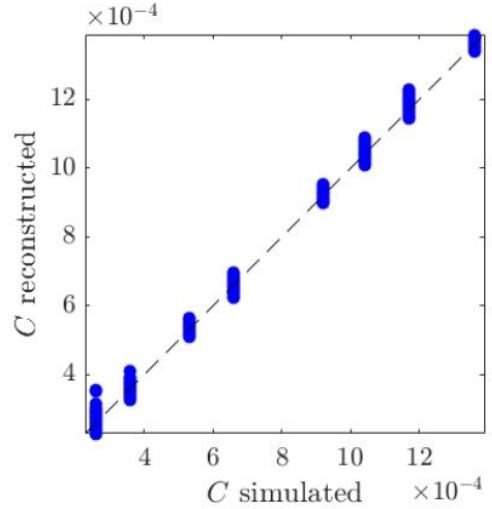


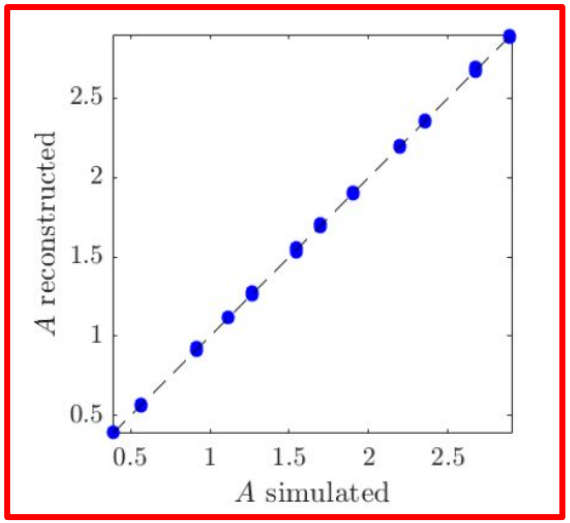
Preliminary results

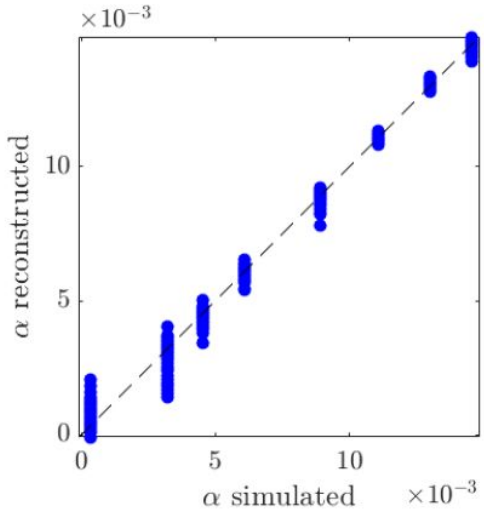
>99% of correlation - Primary parameters are estimated with ~0.2% of error

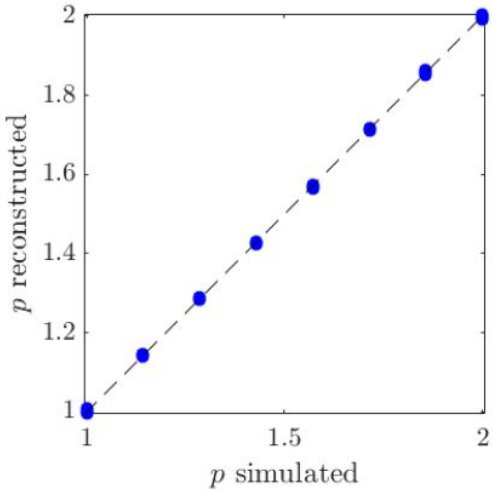
VGGNet - 5 conv. layers - 3 dense layers- trained with 500k simulated PSFs - no noise

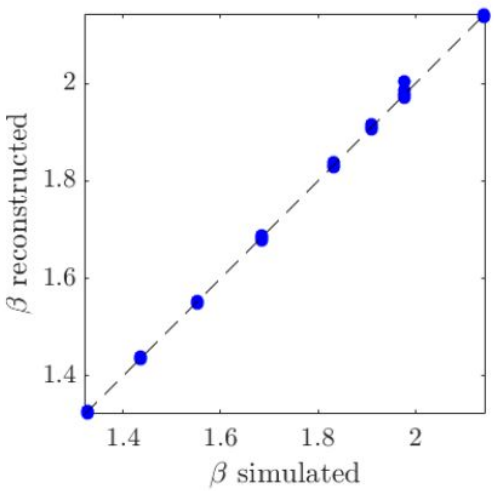








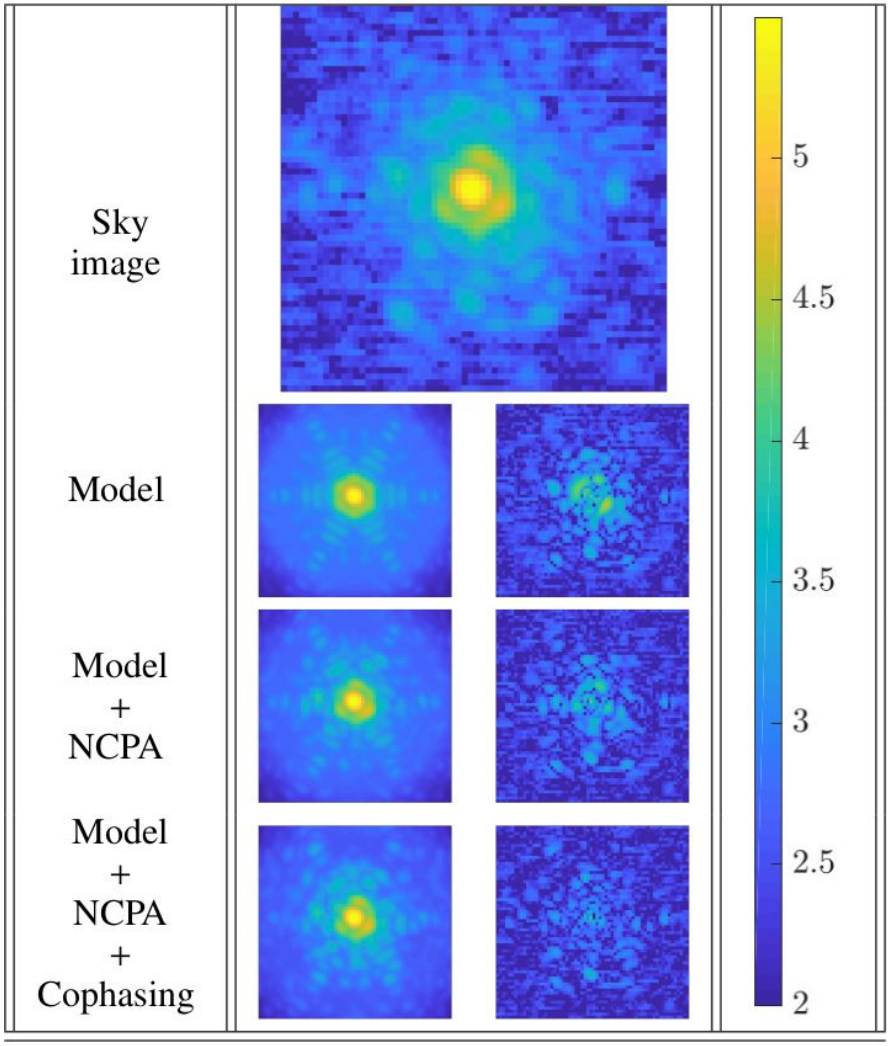


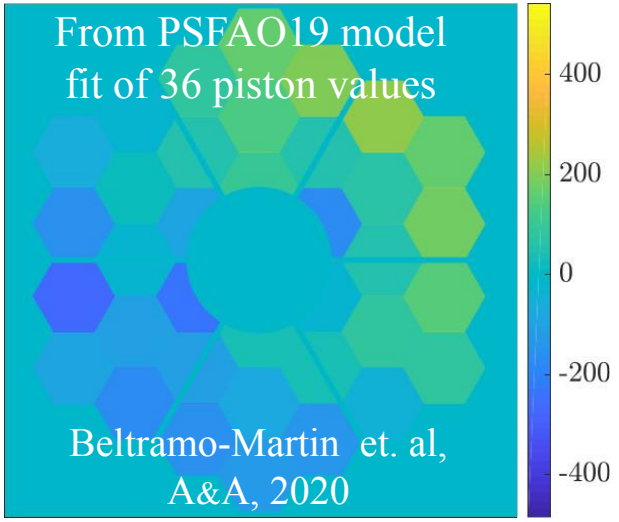


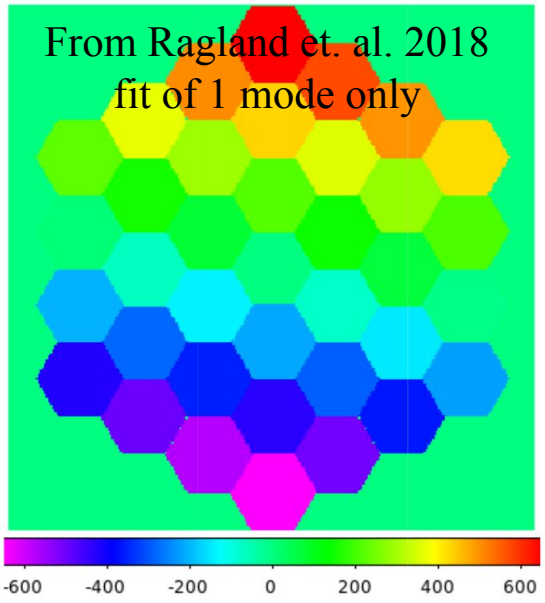
PSFAO19 model : including telescope aberrations

PSF model : $\mathrm{PSF}(\boldsymbol{\mu}_{stat}, r_0, C, A, \alpha, p, \beta) \propto F^{-1}[\mathrm{OTF}_{teL}(\boldsymbol{\mu}_{stat}).\exp(F^{-1}[\mathrm{PSD}(r_0, C, A, \alpha, p, \beta)])]$

Keck AO PSF in H-band - NCPA precalibrated







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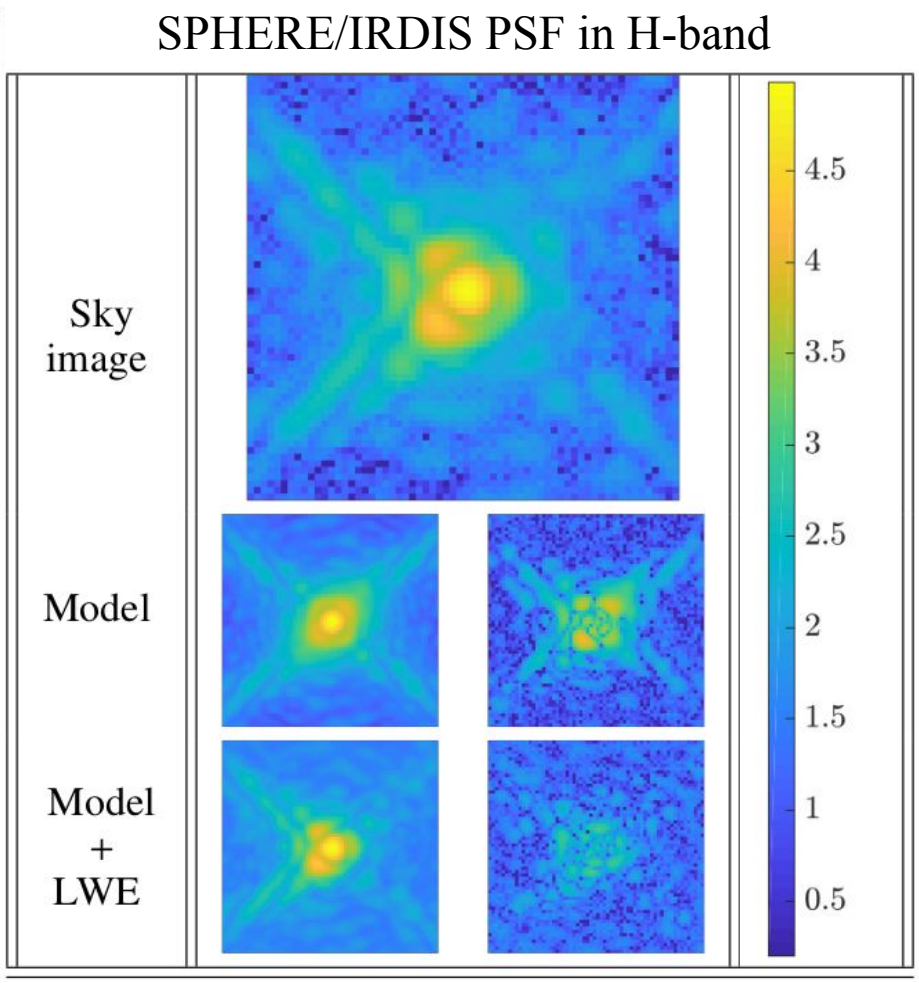
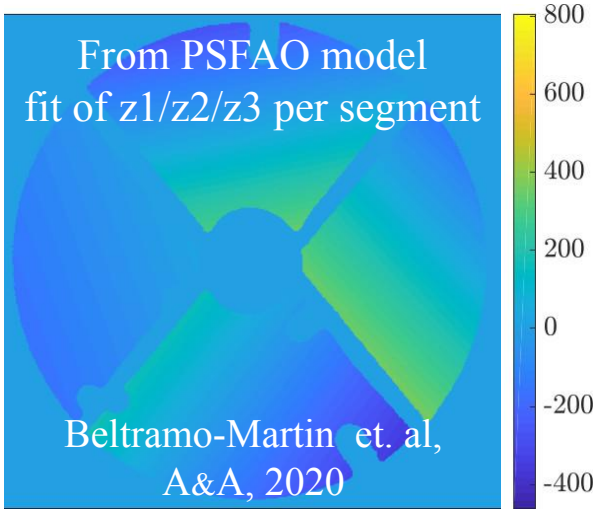
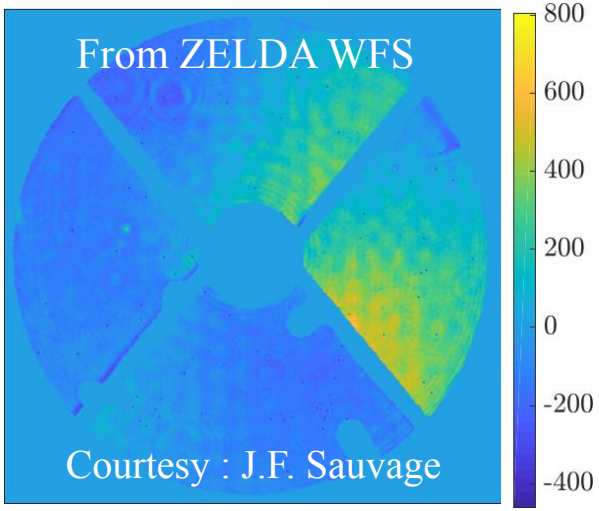
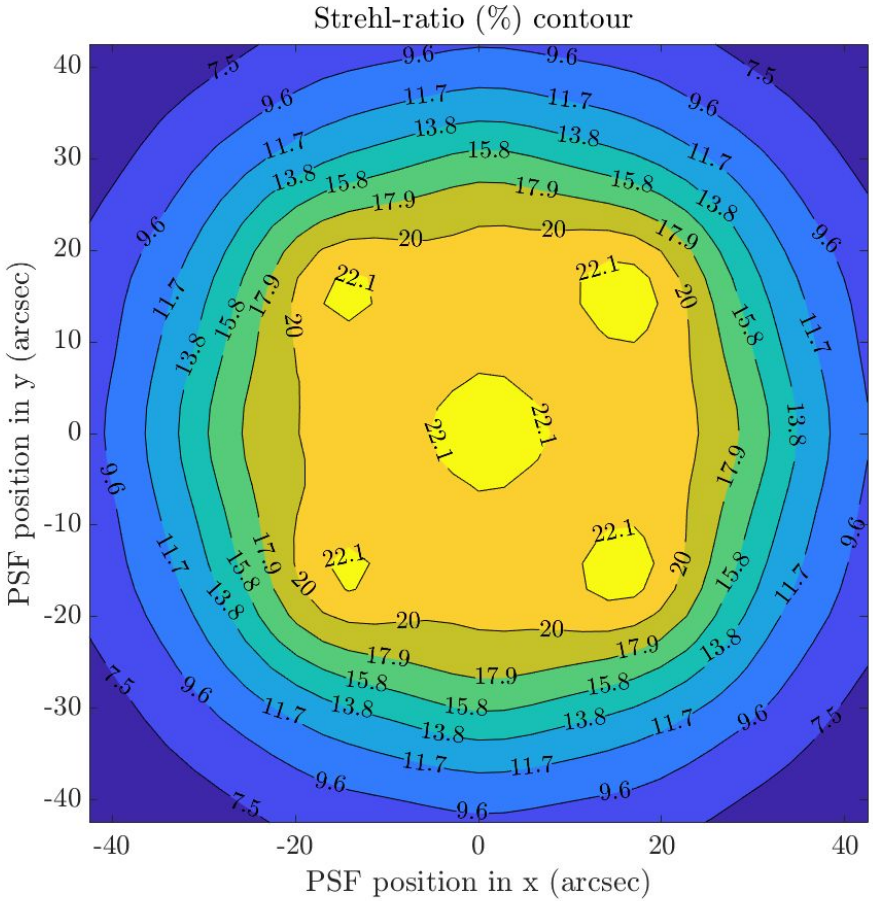






PSFAO19 model : enhance astrometry/photometry

GeMS/GSAOI simulations
of R136 observations



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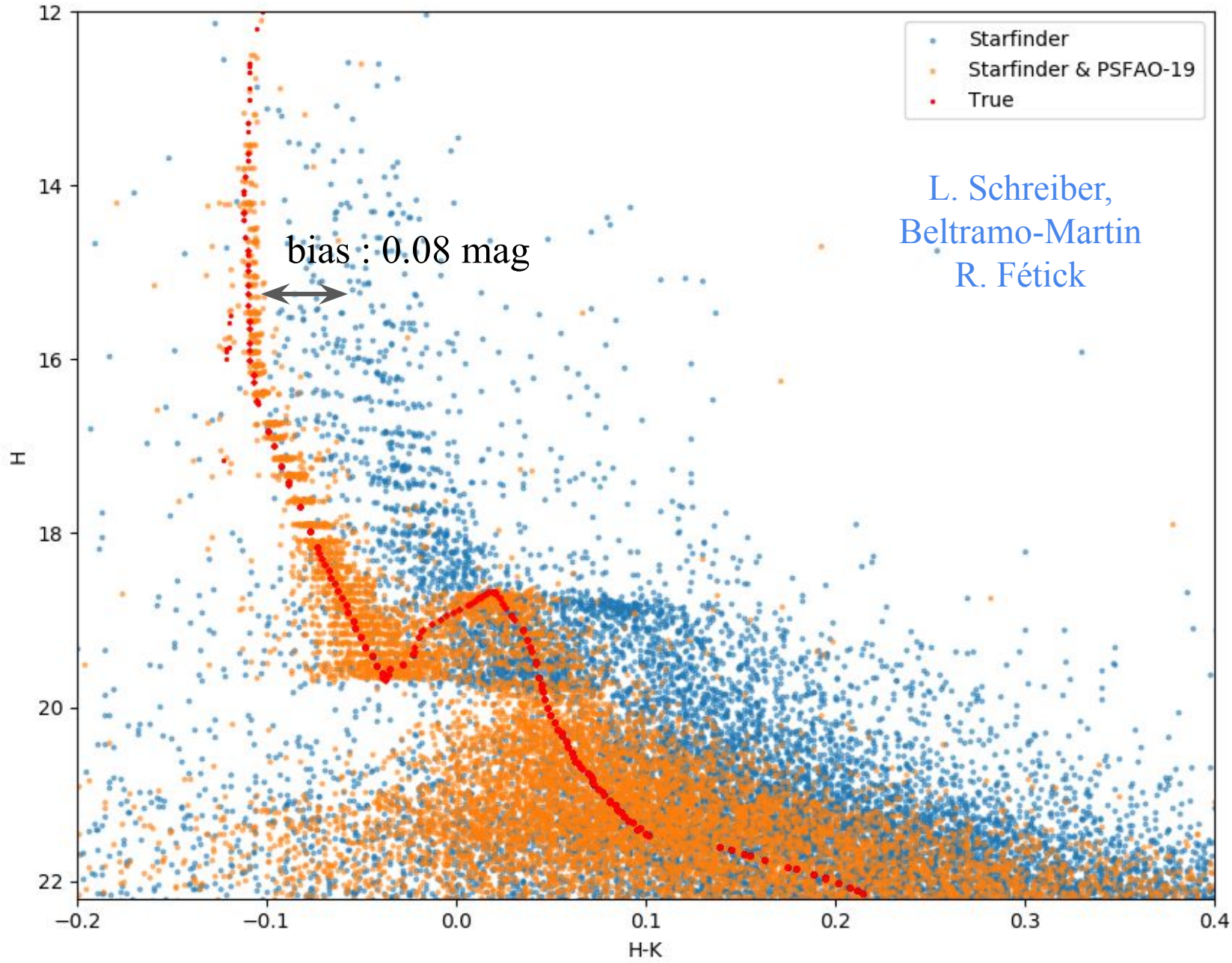

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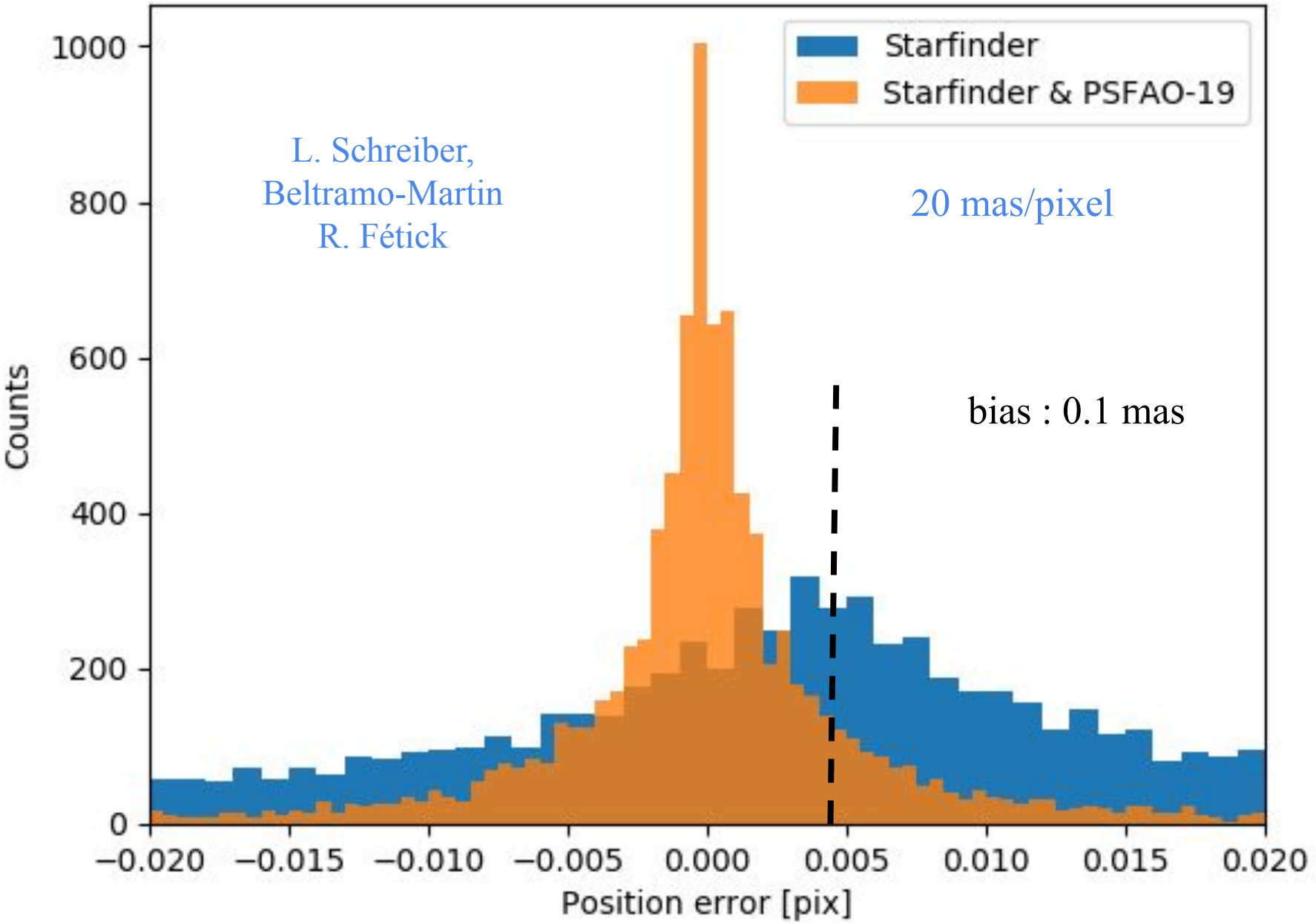
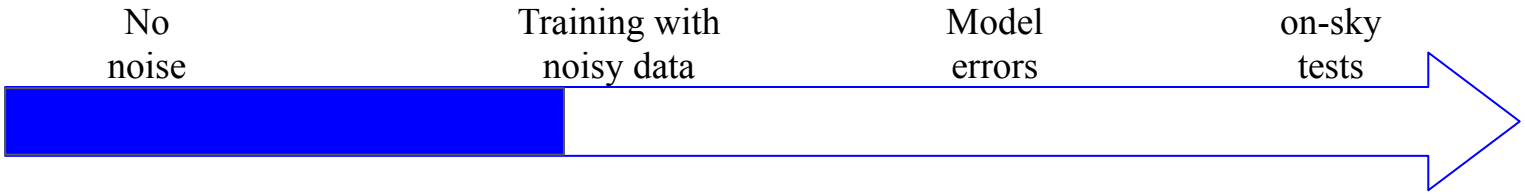


Ongoing and upcoming work

1. Convolutional neural networks for telescope/AO diagnostic



2. PSF recovery from AO control loop data with machine learning

- PSFAO19 parameters estimation from AO telemetry
- PhD thesis LAM/ONERA/ESO to start in sept. 2021

3. PSF determination for IFS with spectral regularization

- Perform the PSF recovery from 3D data cubes
- New PhD student@LAM : Alexis Lau

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