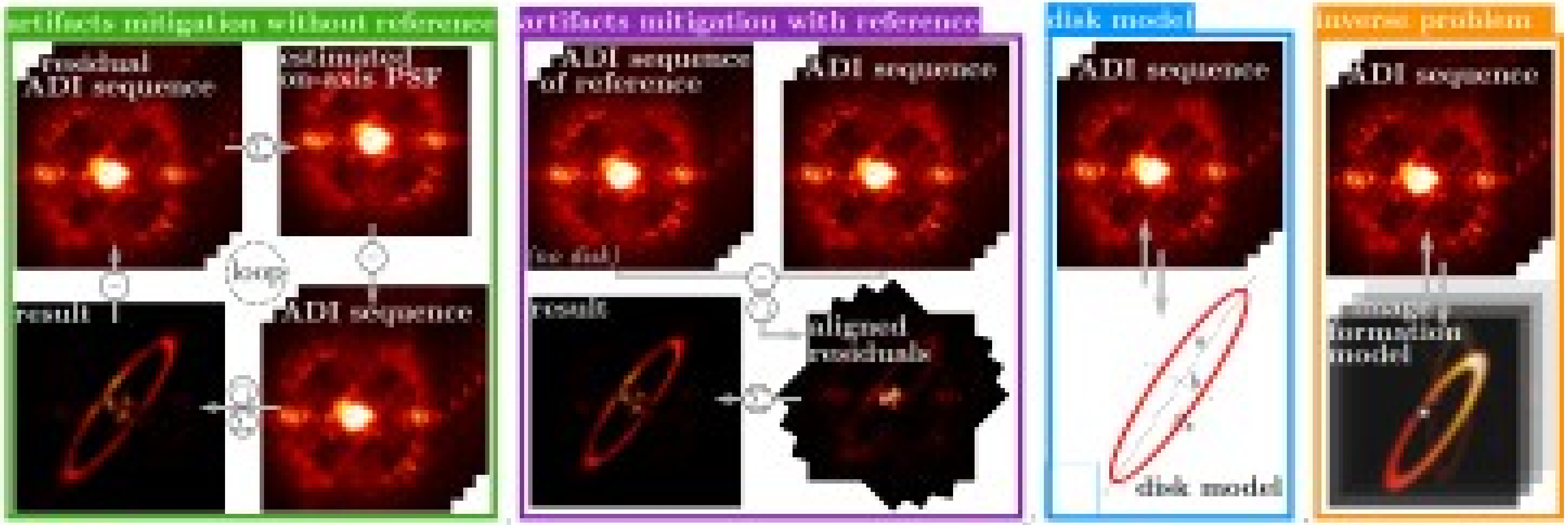
Disk FM

Different categories of algorithms for disk reconstruction

More advanced algorithms:



iterative PCA
(Pairet+, 2018)

data imputation strategy
(Ren+, 2020)

see Julien's & Sophia's focus

reference differential imaging (RDI)
= searching for similarities in images

RDI with a large library
(Gerard+, 2016) (Ren+, 2018)
(Xuan+, 2018) (Ruane+, 2019)

RDI with star hopping (Wahhaj+, 2021)

see Johan's focus

(physical) disk model
= parametric approaches

(Milli+, 2017)

(Esposito+, 2013)

DISKFM (Mazoyer+, 2020)

focus of this presentation

image formation model
= non-parametric approaches

MAYO (Pairet+, 2021)

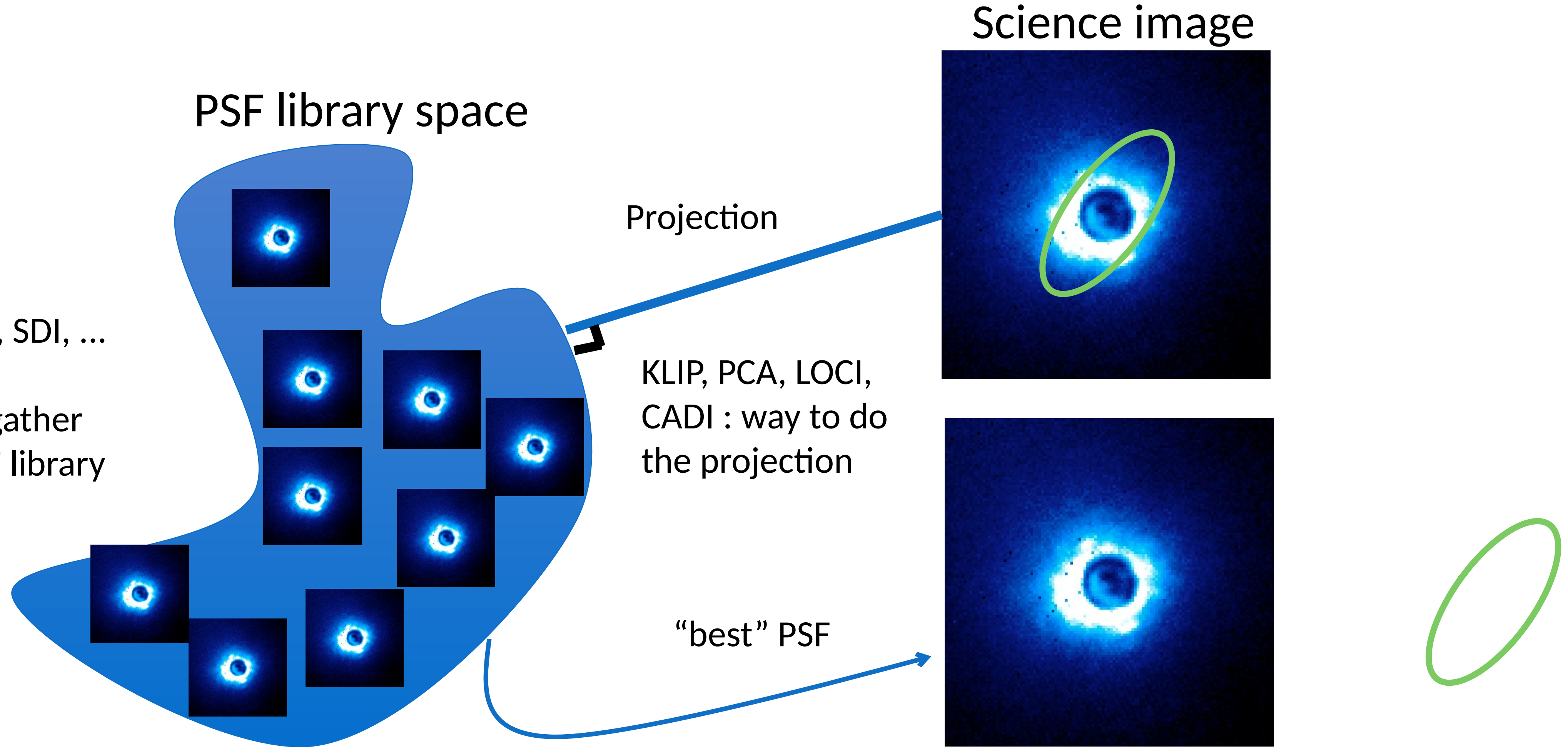
MUSTARD (Juillard+, 2022)

REXPACO (Flasseur+, 2021-22)

PCA based algorithms

ADI, RDI, SDI, …

Way to gather your PSF library

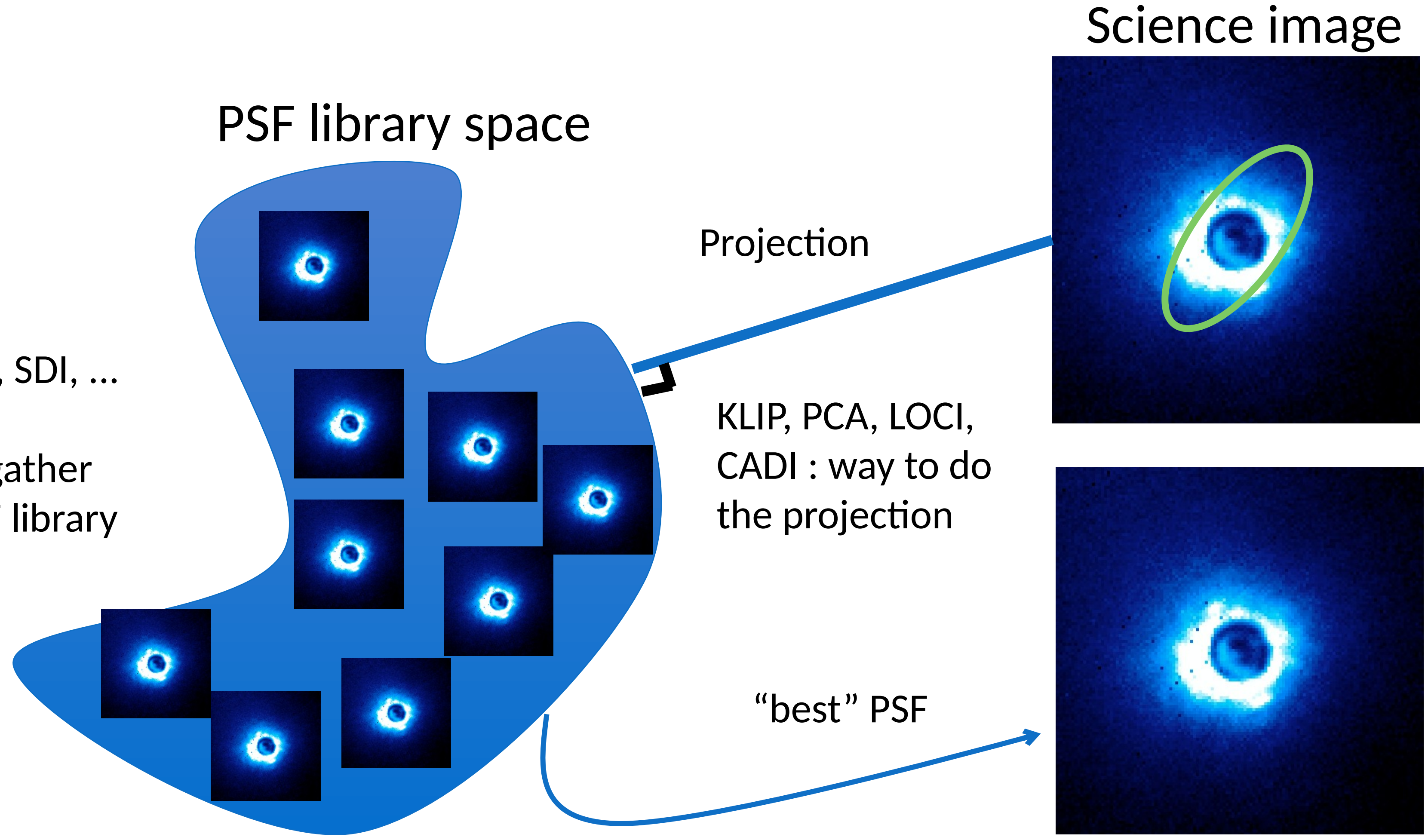


- Soummer et al. 2012 / Amara & Quantz 2012

Oversubtraction problem

ADI, RDI, SDI, …

Way to gather your PSF library



Over-subtraction : the PSF is removing part of the disk. Mostly a problem when the speckles are the main source of limitation: eg not super good coronagraph / very close to the mask.

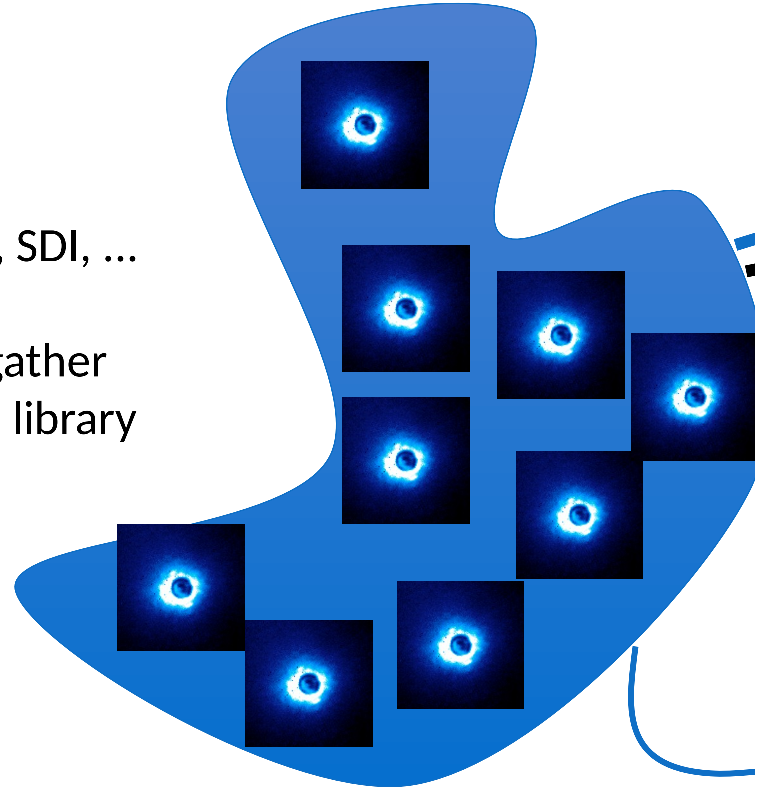
- Soummer et al. 2012 / Amara & Quantz 2012

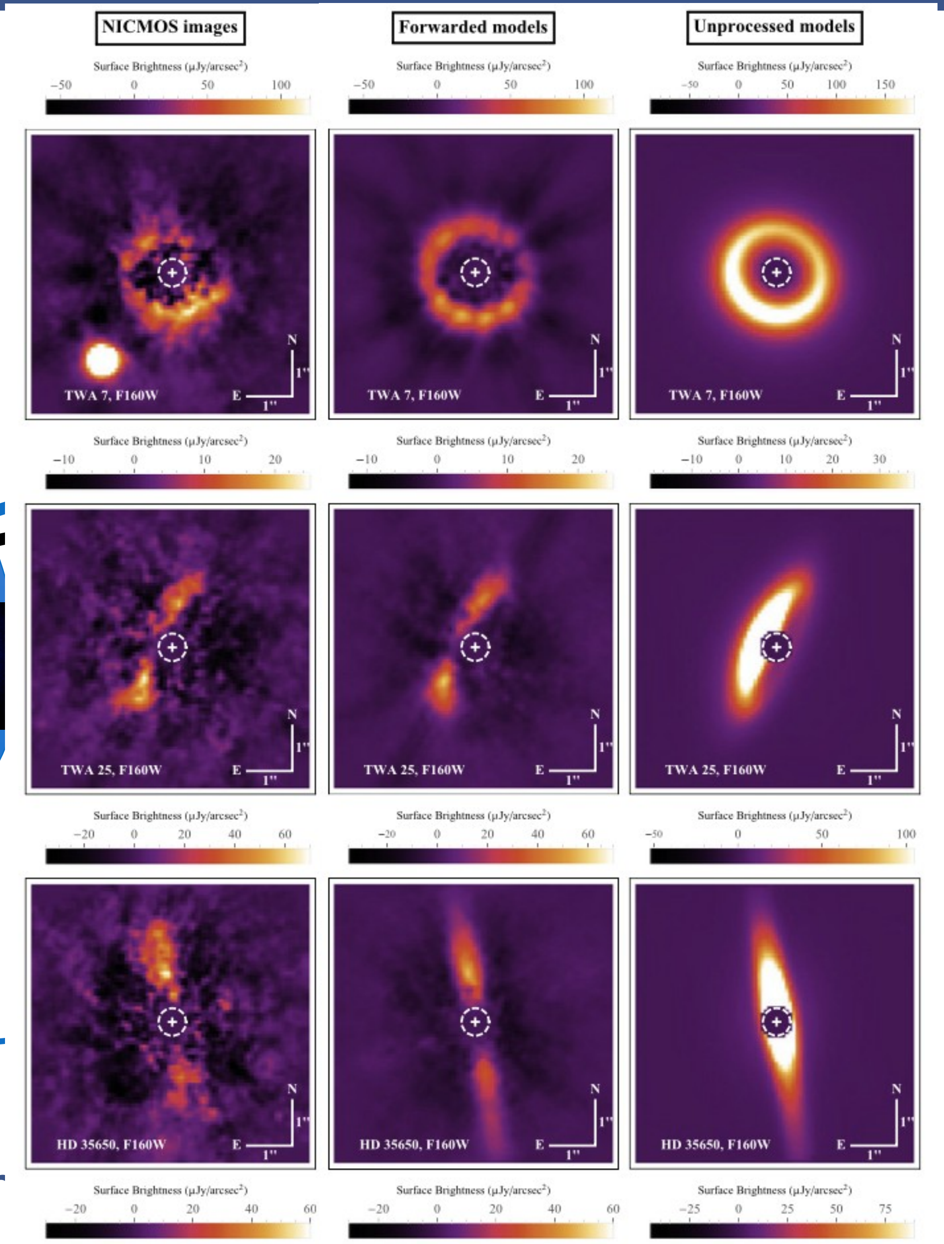
Oversubtraction problem

PSF library space

ADI, RDI, SDI, …

Way to gather your PSF library





Over-subtraction : the PSF is removing part of the disk. Mostly a problem when the speckles are the main source of limitation: eg not super good coronagraph / very close to the mask

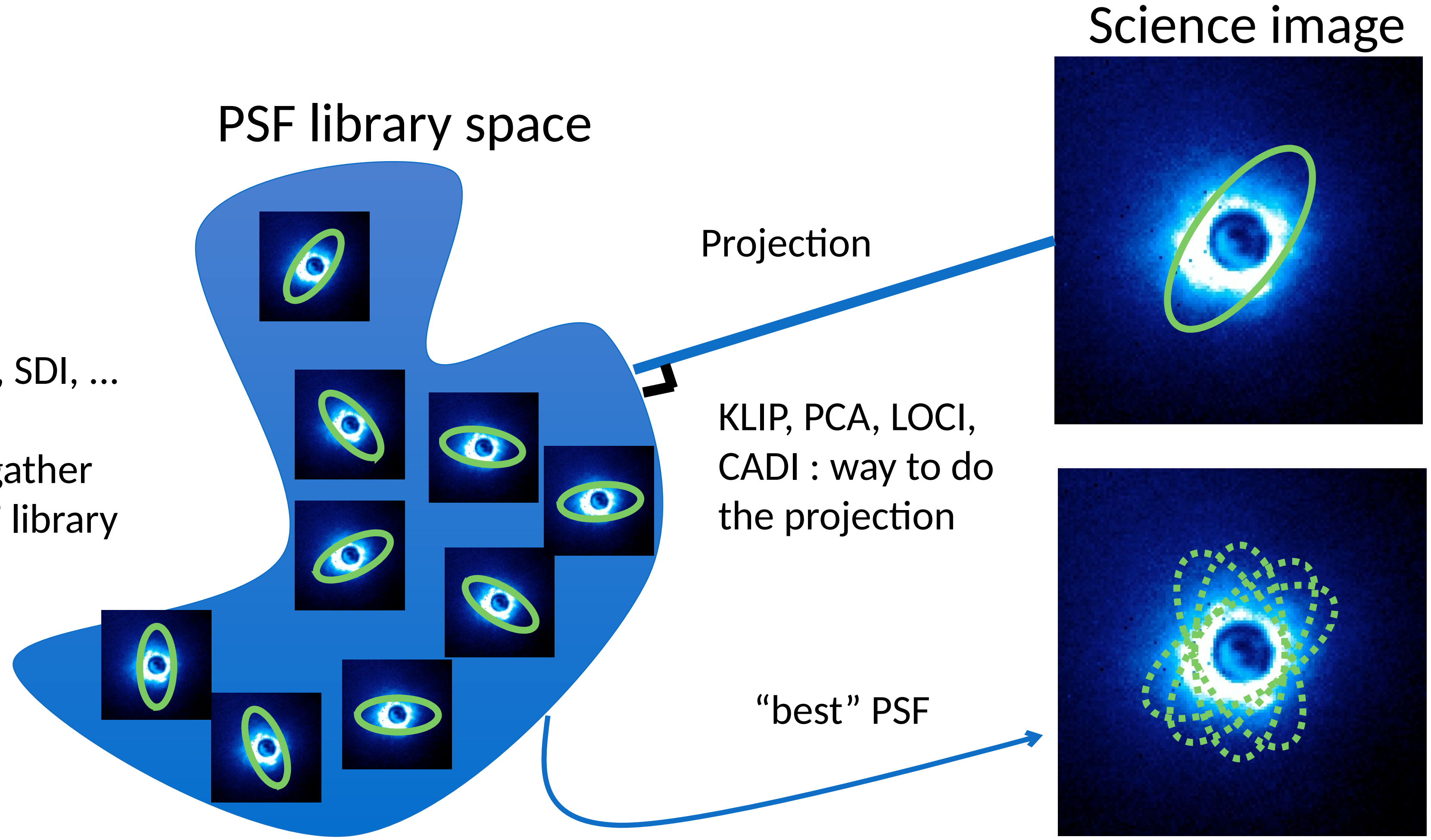
Choquet et al. 2016

- Soummer et al. 2012 / Ar

Angular Differential imaging

ADI, RDI, SDI, …

Way to gather
your PSF library



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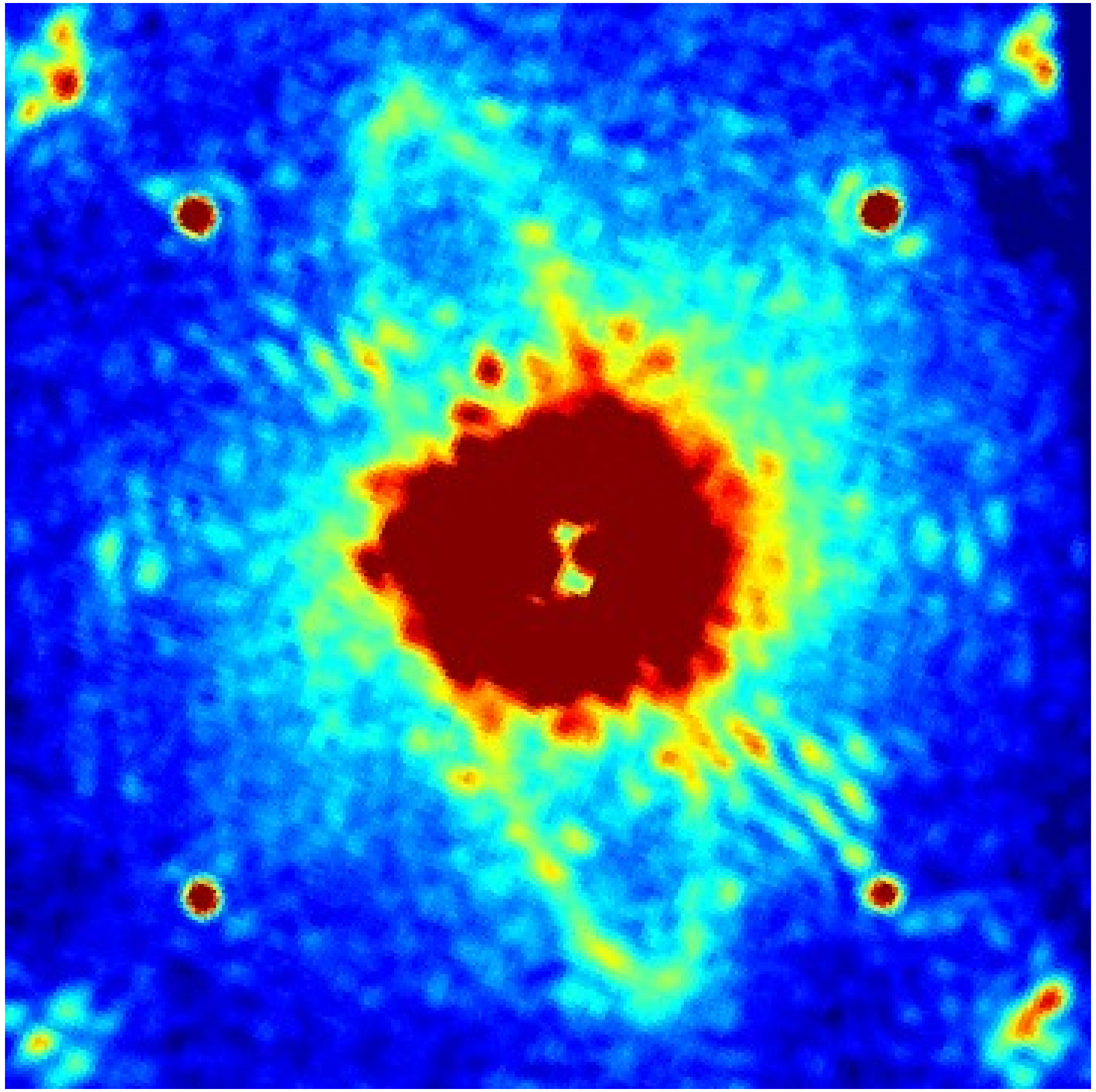
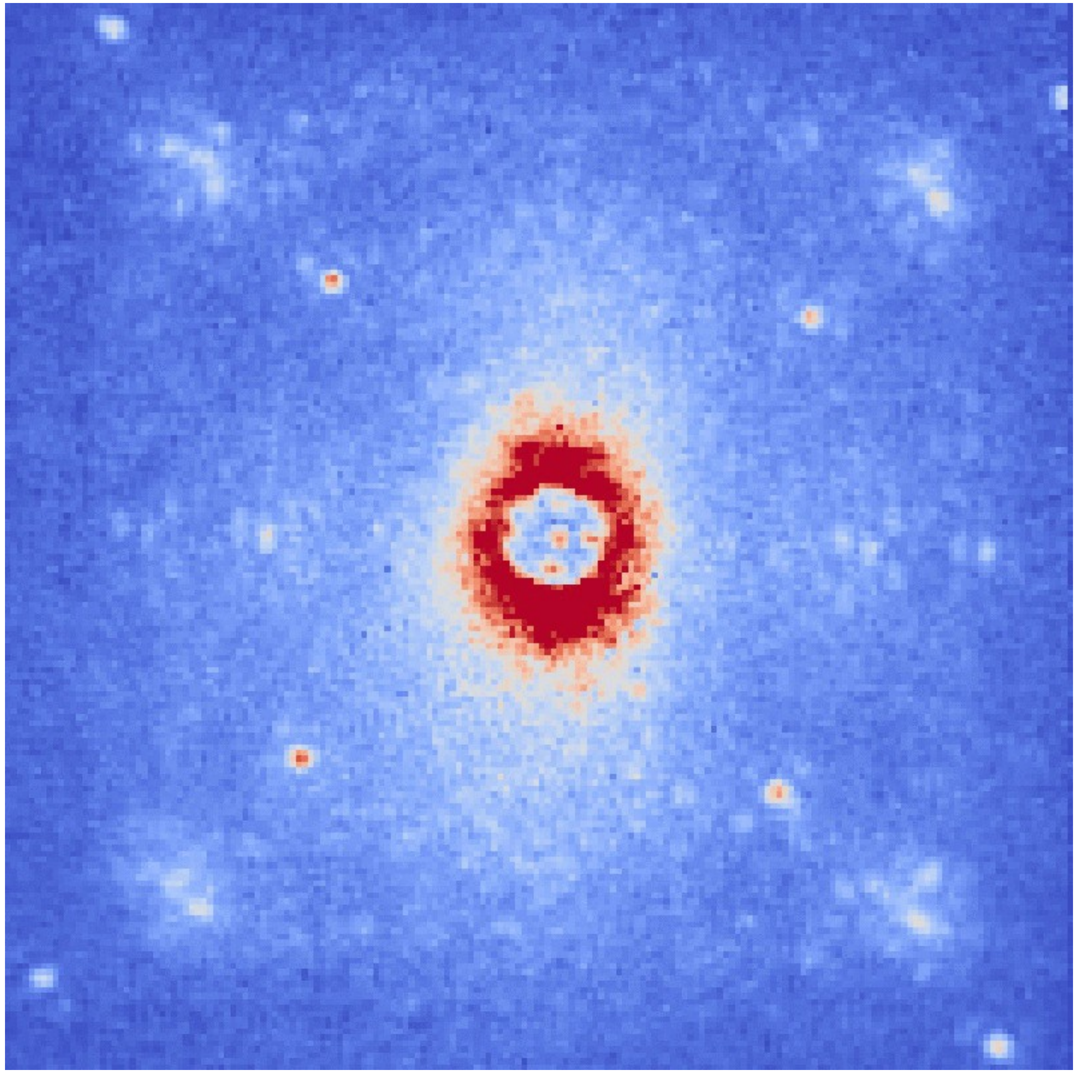
Angular Differential imaging



Spectral Differential imaging

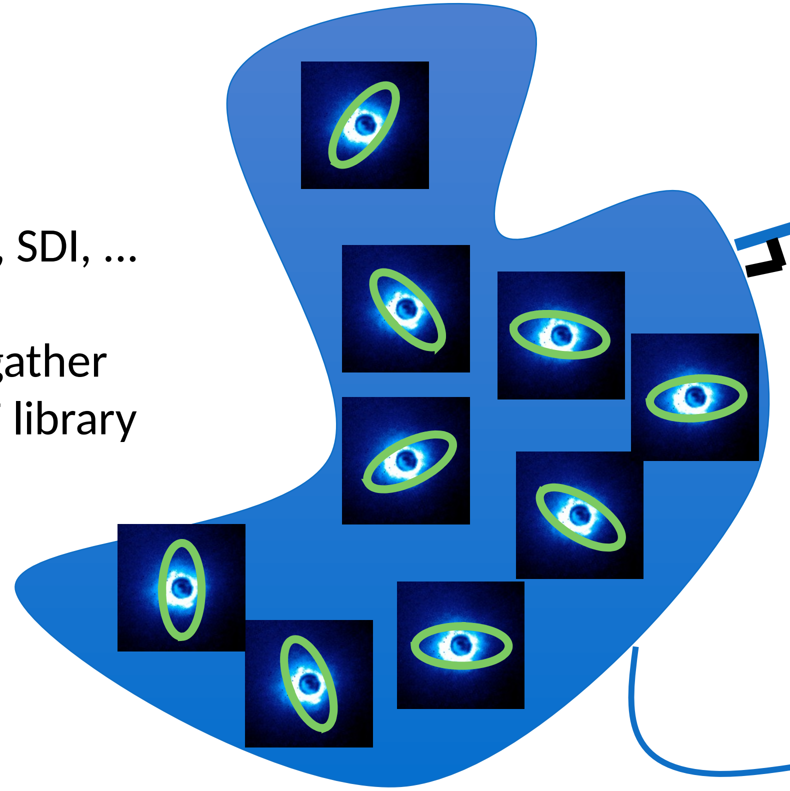


Self-subtraction problem

PSF library space

ADI, RDI, SDI, …

Way to gather your PSF library

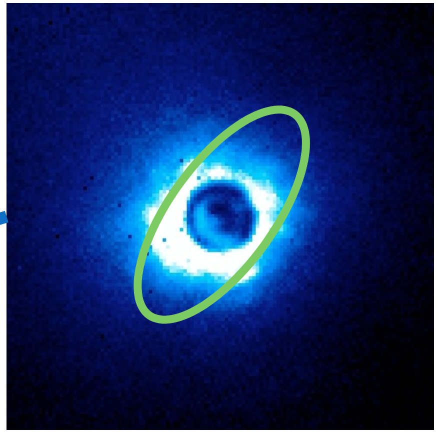


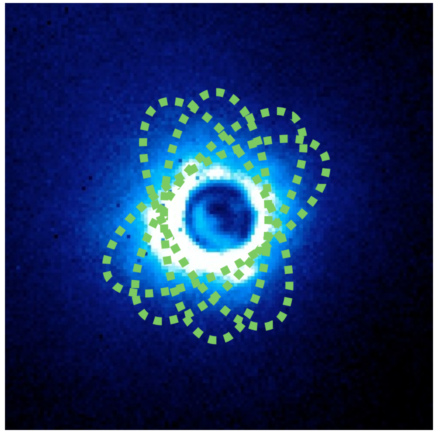
Projection

KLIP, PCA, LOCI, CADI : way to do the projection

“best” PSF

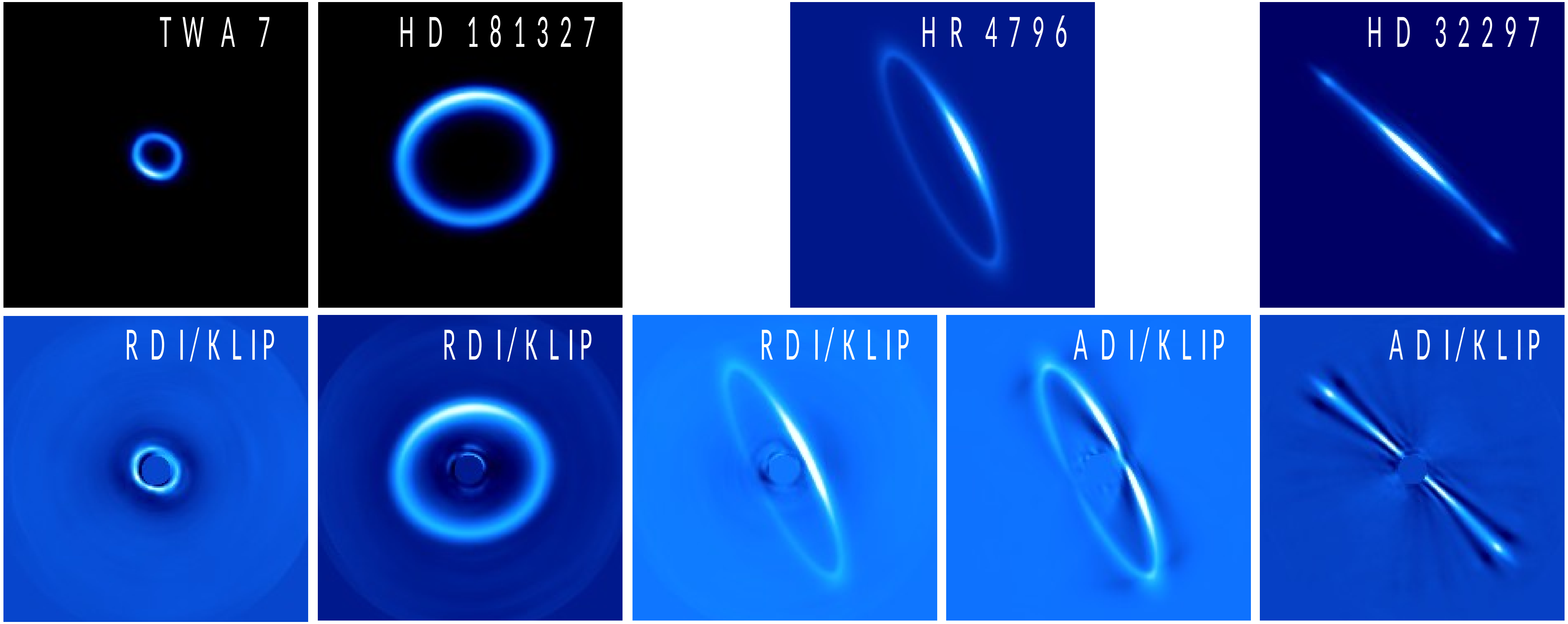
Science image





Self-subtraction : the PSF contained part of the disk: the disk is subtracting itself

Over subtraction + Self-subtraction



Mazoyer et al. 2020

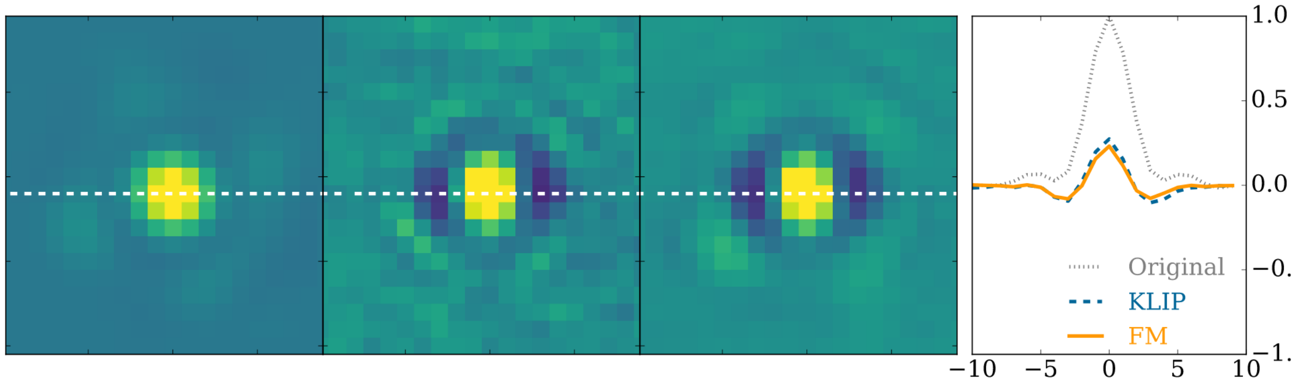
Forward modeling

- Pueyo 2016

Pueyo 2016 “introduce an analytical expansion that quantifies the propagation of the astrophysical signal through KLIP, even the presence of self-subtraction.”
=> we can predict the effect of over and self subtraction on a given model

“Moreover we show that when the astrophysical signal is small, this expansion only depends on $A(\boldsymbol{x})$ in a linear fashion. ”

That means that for faint planet
FM(**α** PSF) = **α** FM(PSF)
⇒ search in the whole reduce image is fast: only position parameters need to be explored .
Forward Model Matched Filter algorithm (Ruffio+ 2017)
Much increased astrometry of the object : Wang et al 2017



(a) Original (b) KLIP (c) Forward Model (d) Cut

Forward modeling for disks

Planets are “easy” because

1. we have the PSF => the shape of the object before reduction is already known
2. only 3 parameter : 2 of position (x,y) and 1 of flux / spectra (which we can assume scale linearly)

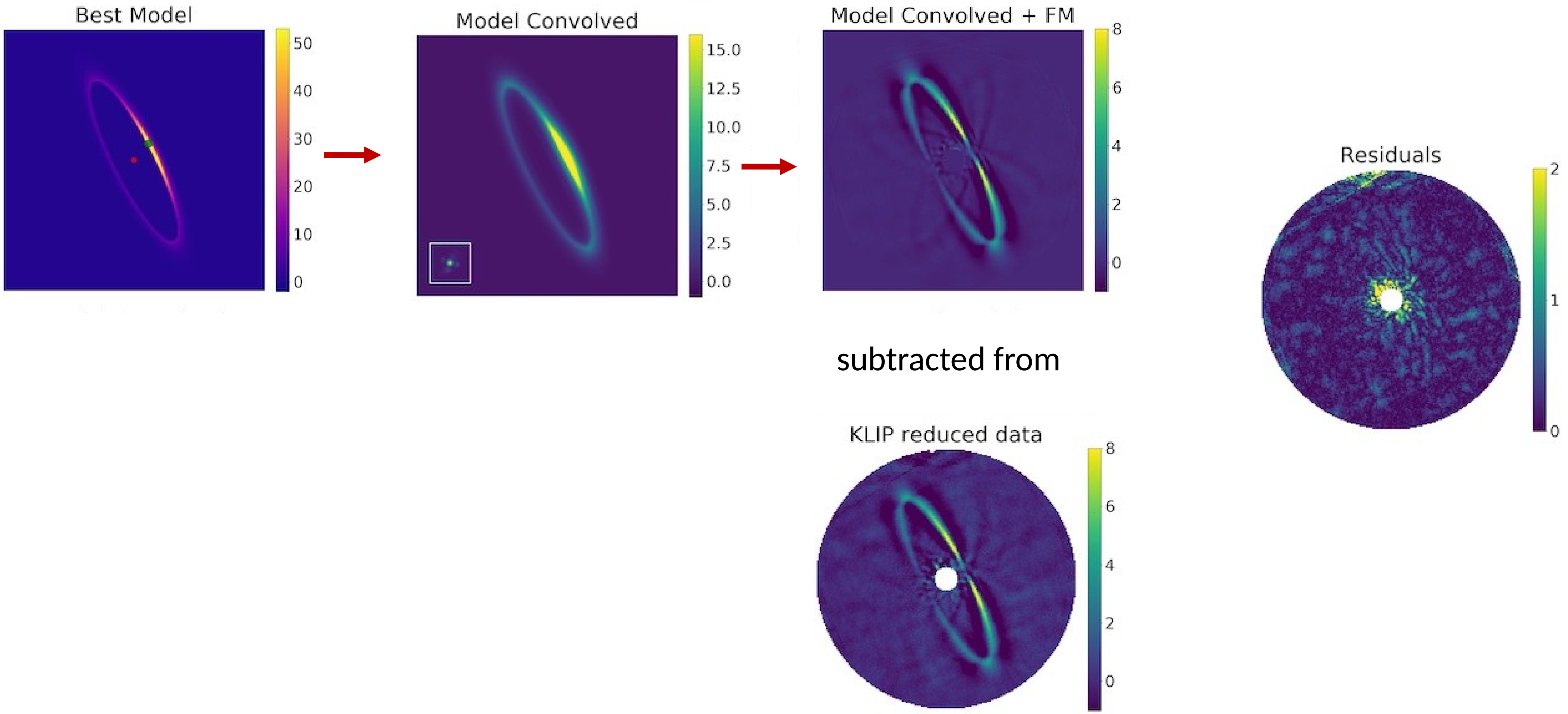
Disks are harder

1. “Note however that in practice Forward Modeling with disks is complicated by the fact that the [linear mode equation] cannot be simplified using a simple PSF as the astrophysical model: every hypothetical disk morphology must be explored. “
2. Easily ~10 parameter to debris disks and none of them scale linearly

You have to know the resulting model to measure the FM of the model => MCMC approaches to explore hundreds of thousands of models with slightly different parameters are well suited for this problem.

=> Cannot be used for disk detection, only for characterization

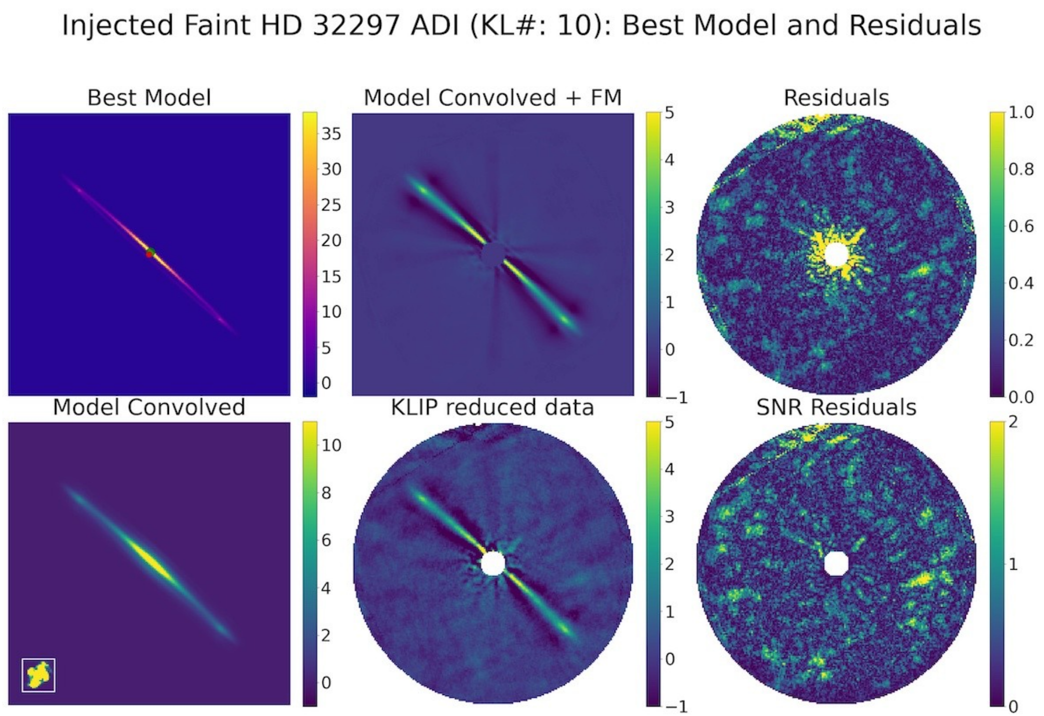
Forward modeling for disks

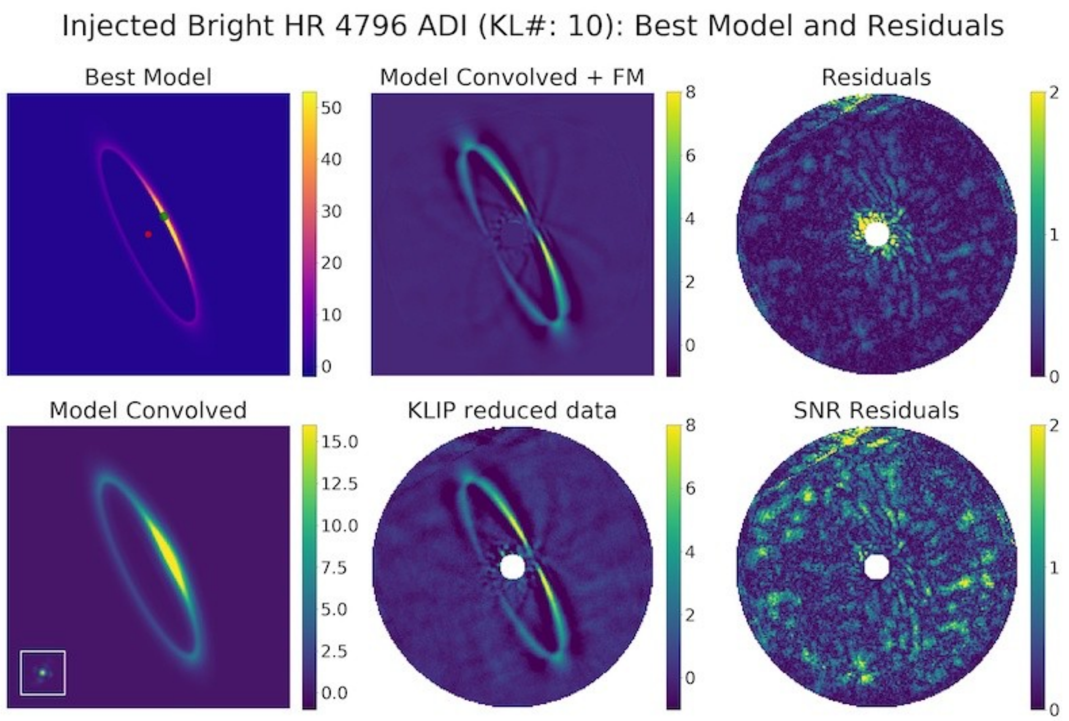


100’000 times

Disk FM

- Mazoyer et al. 2020





DiskFM : a way to quickly explore thousands of model in a few hours

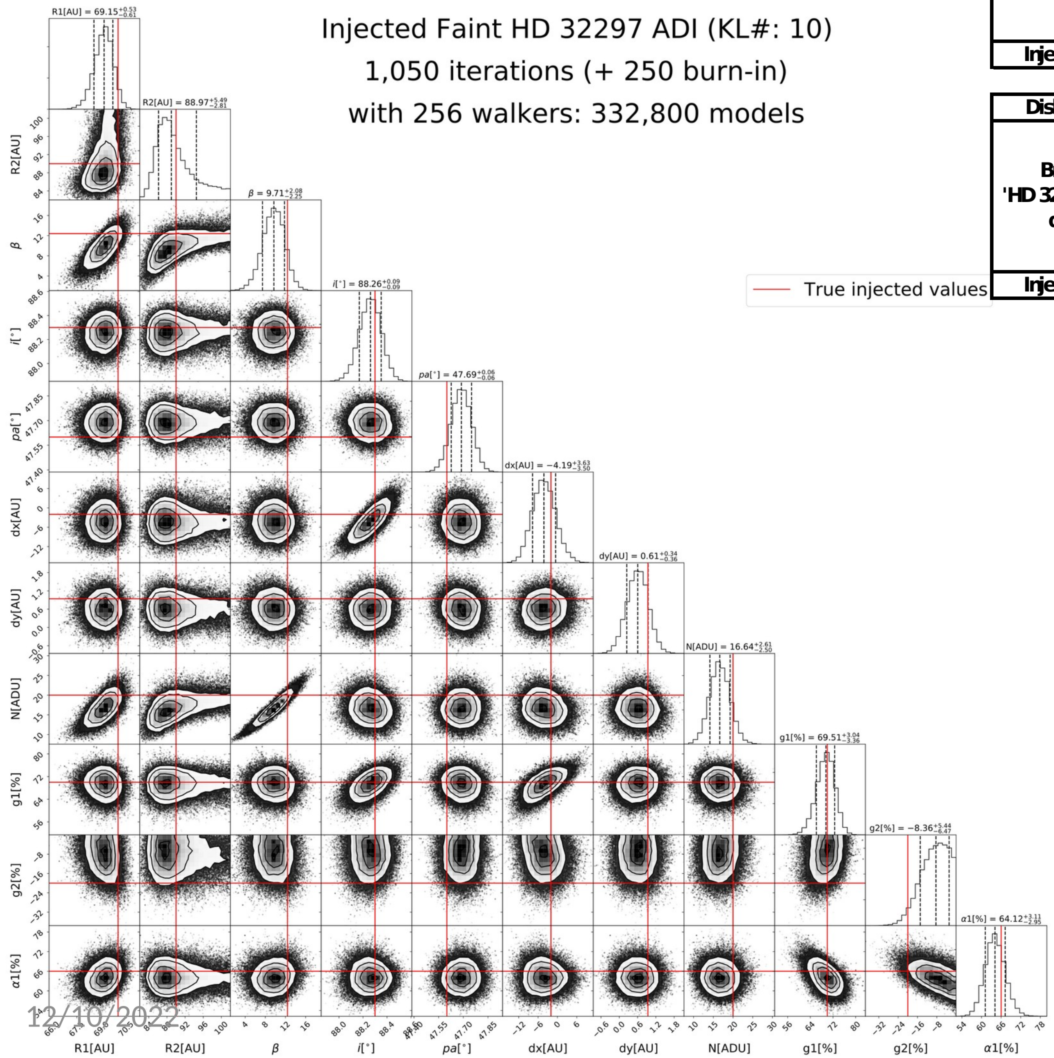
⇒ we can show that in most case we recover the parameter of the disks we injected

⇒ If we can model the resulting disk we will in most case do a parametric analysis => this is not a loss of time since the MCMC analysis will be done anyway

Disk FM

- Mazoyer et al. 2020

Injected Faint HD 32297 ADI (KL#: 10)
1,050 iterations (+ 250 burn-in)
with 256 walkers: 332,800 models



Disk Type	Reduction	KL #	R1[au]	R2[au]	βout	i[°]	PA[°]	dx[au]	dy[au]	N[ADU]	g1	g2	α
Faint 'HD 32297 like' disk	ADI	3	70.1 +/-0.6	89 +6/-4	13 + /-3	88.5 +/- 0.2	47.7 +/- 0.1	1 +5/-4	0.7 +/-0.4	17 +/-3	80 +7/-14	-8 +3 / -6	69 +/- 7
		10	69.2 +/-0.6	89 +5/-3	10 + /-2	88.3 +/- 0.1	47.7 +/- 0.1	-4 +/-4	0.6 +/-0.4	17 +/-3	70 +/- 3	-8 +5 / -7	64 +/- 3
		20	69.2 +/-0.6	89 +5/-3	10 +2 /-3	88.3 +/- 0.1	47.7 +/- 0.1	-3 +/-4	0.6 +/-0.4	17 +/-3	71 +/- 3	-9 +5 / -7	64 +/- 3
	RDI	5	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
		15	69 +/- 3	81 +12/-7	NC	89 +3/-1	47.6+0.6/-0.5	NC	2 +/-2	15 +8/6	NC	NC	NC
		25	70 +/- 2	84 NC/-7	NC	89 +2/-1	47.6 +/-0.4	NC	2 +/-2	16 +8/7	NC	NC	NC
Injected disk "true" parameters			70.0	90.0	12.4	88.3	47.6	-2.0	0.94	20	70	-20	66

Disk Type	Reduction	KL #	R1[au]	R2[au]	βout	i[°]	PA[°]	dx[au]	dy[au]	N[ADU]	g1	g2	α
Brigth 'HD 32297 like' disk	ADI	3	69.9 +/-0.2	90 +/-2	11.6 +/-0.9	88.38+/-0.06	47.64+/-0.03	-1 +/-2	0.74 +/-0.14	64 +/- 4	70 +2/-3	-7 NC/-3	69 +/- 7
		10	69.7 +/-0.2	90 +2/-1	10.9 +/-0.8	88.36+/-0.03	47.64+/-0.02	-2 +1/-2	0.72 +/-0.12	66 +/- 4	68 +/-1	-14 +/-3	66 +/- 1
		20	69.7 +/-0.2	89 +/-1	10.5+0.8/-0.9	88.38+/-0.03	47.64+/-0.02	-1 +2/-1	0.75 +/-0.13	65 +/- 4	68 +/-1	-16 +/-3	66 +/- 1
	RDI	5	70.4 +/- 0.4	85 +5/-3	15 +/-3	88.4+/-0.1	47.61+/-0.06	-1 +/-3	0.5 +/-0.2	68 +/- 10	69 +4/-5	-6 NC/-2	61 +/- 4
		15	70.0 +/-0.7	84 +8/-4	15 +6/-7	88.3+/-0.1	47.61+/-0.08	-1 +4/-5	1.0 +/-0.4	70 +/- 20	68 +4/-5	-7 NC/-2	68 +5/- 4
		25	70.1 +/-0.6	84 +6/-3	14 +5/-6	88.3+/-0.1	47.61+/-0.08	-3 +/-4	0.8 +/-0.3	71 +19/-18	64 +/-5	-8 NC/-4	70 +5/- 4
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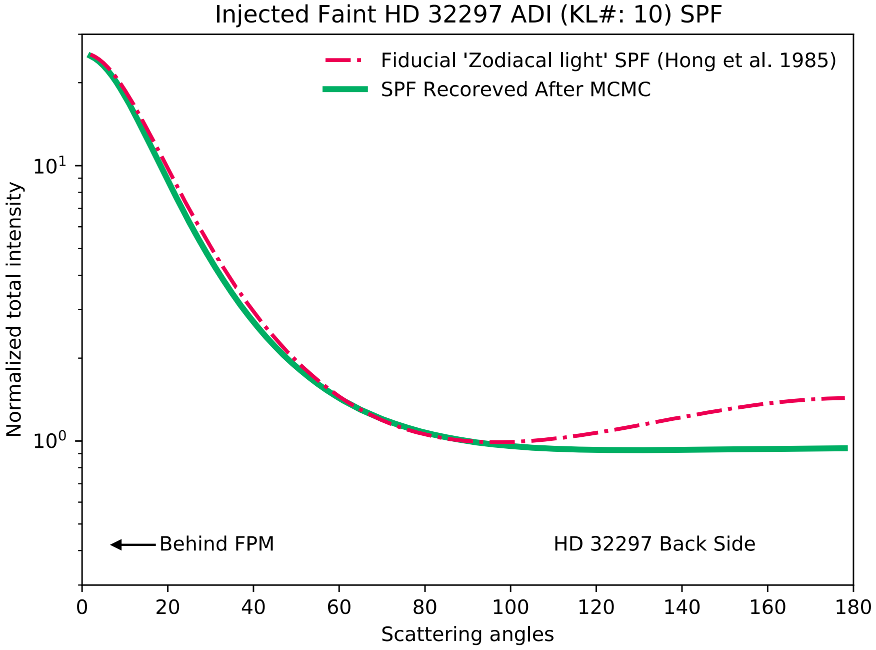
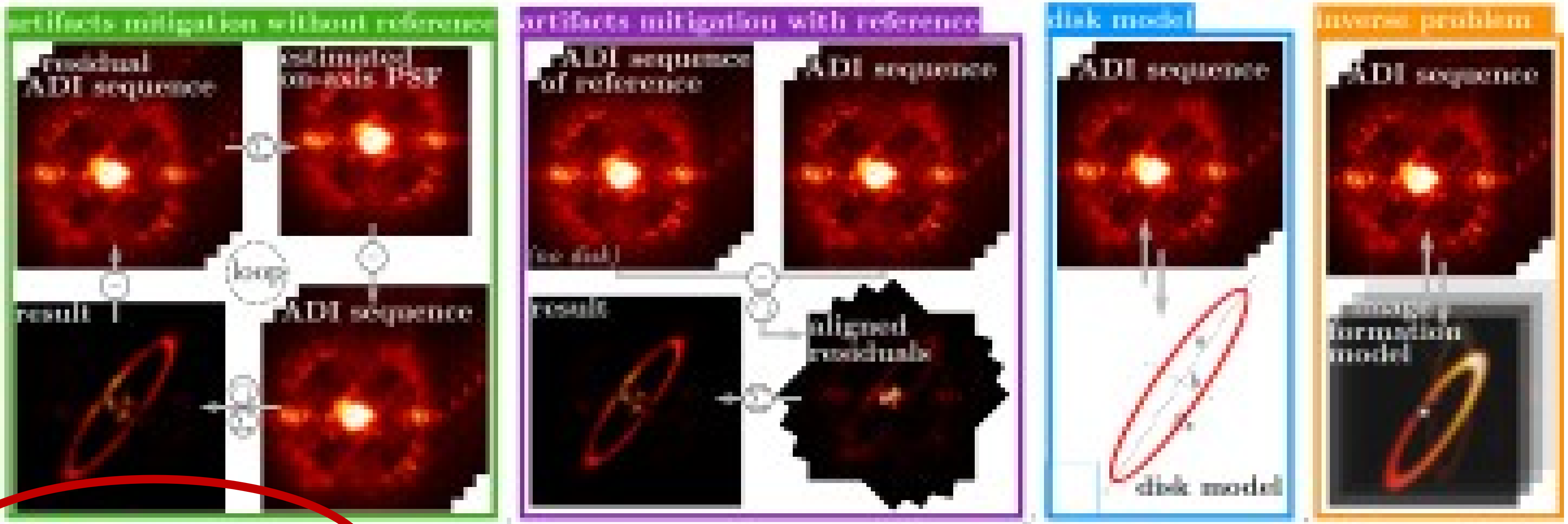


Iterative ADI

Different categories of algorithms for disk reconstruction

More advanced algorithms:



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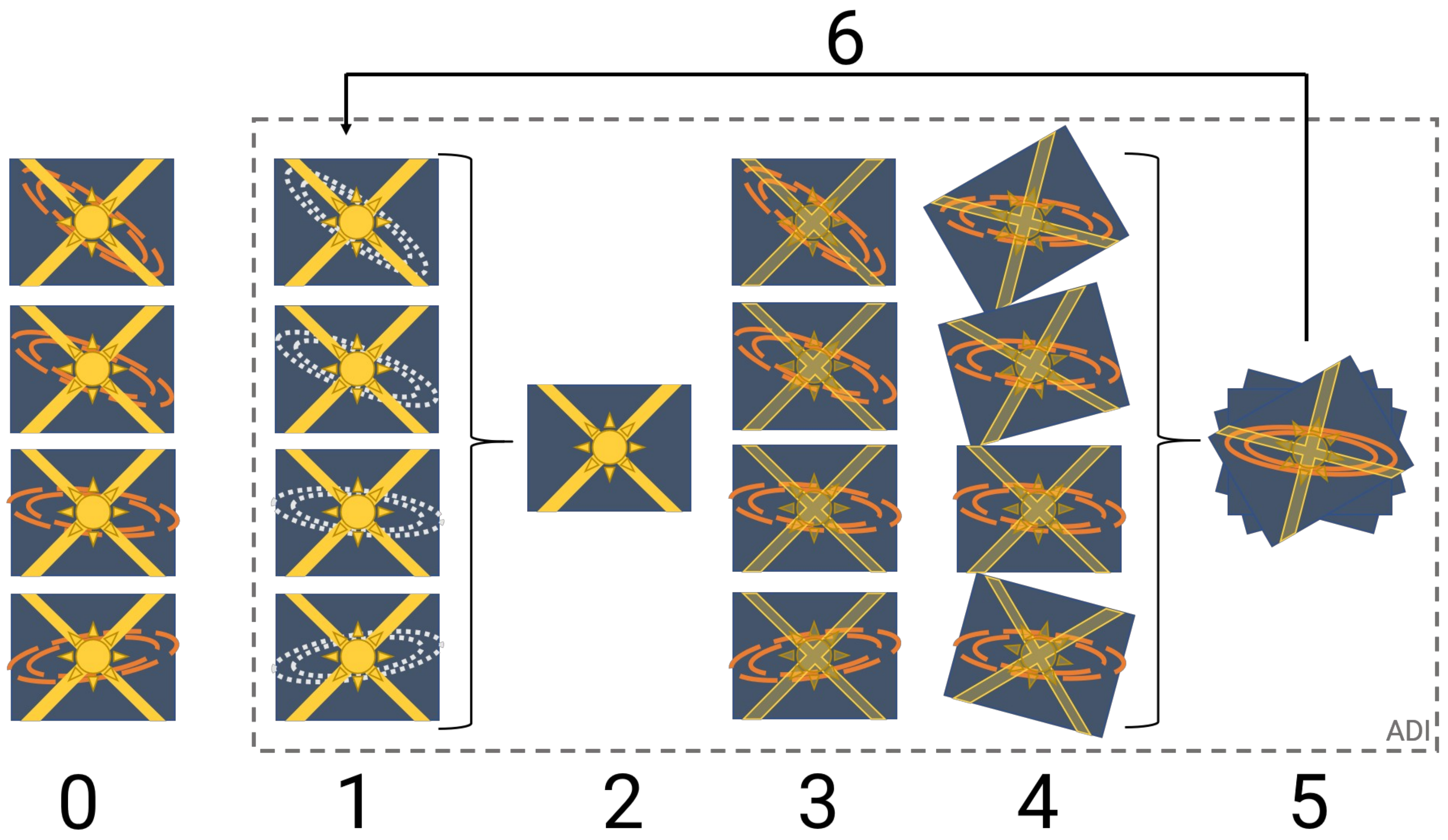
Iterative approach

- Pairet et al. 2018 et Stapper & Ginski 2022 (just accepted yesterday)



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