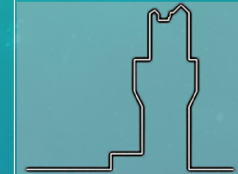
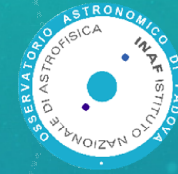


WFSensing  
in the VLT era II



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OTTICA  
ADATTIVA

# GIUSTO: GMCAO IDL UNRELEASED SIMULATION TOOL

VALENTINA VIOTTO, ELISA PORTALURI, ROBERTO RAGAZZONI, MARIA BERGOMI,  
MARCO DIMA, JACOPO FARINATO, DAVIDE GREGGIO, DEMETRIO MAGRIN

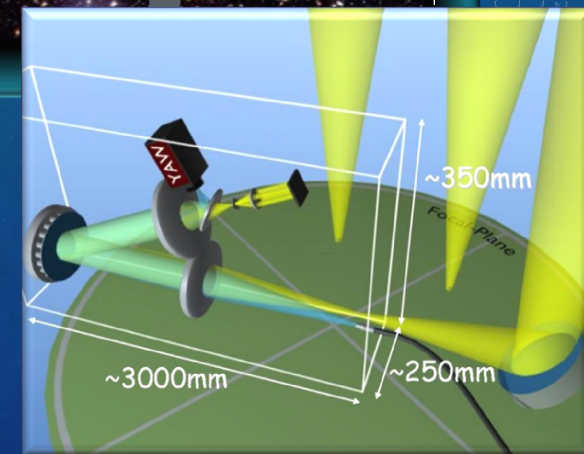
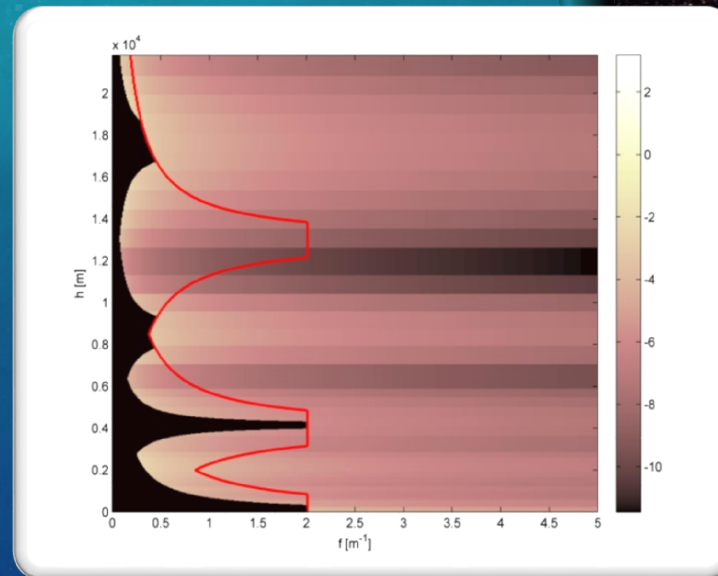
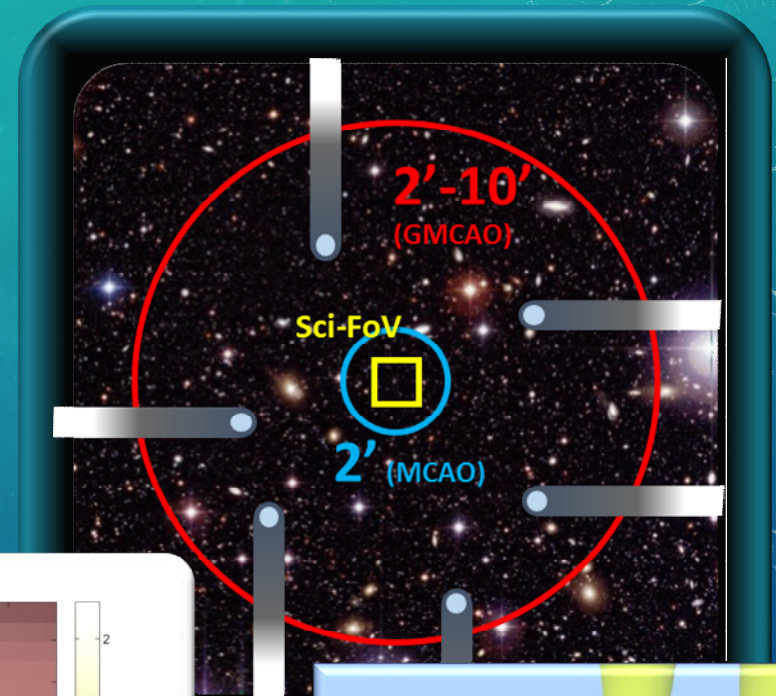
# GMCAO IN A NUTSHELL

GOAL: to increase the sky coverage (with NGSs)!!!

WHAT: using NGSs from a wide Technical FoV to correct a smaller central Scientific FoV.

INCLUDING:

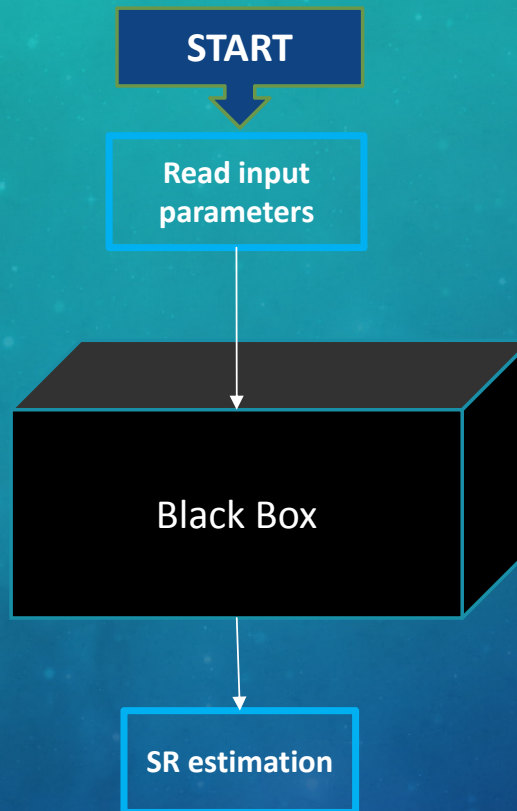
- Pyramid Wavefront sensing
- Layer Oriented MCAO
- Very Linear WFSensing
- Highly accurate wavefront metrology
- Virtual (live) DMs
- Referencing or DM with feedbacks



(Ragazzoni et al., AO4ELT 2009)

### Dataset:

- Atmospheric parameters
- Test case parameters
- Telescope parameters
- GMCAO parameters



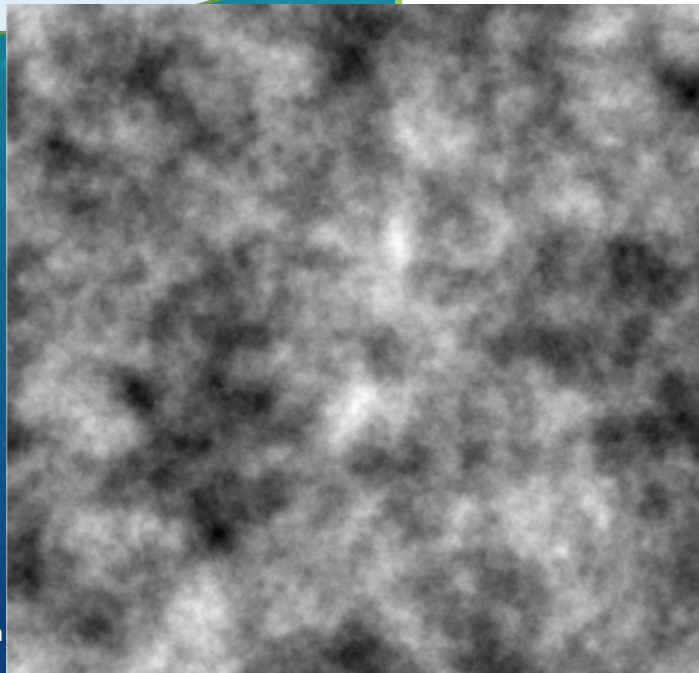
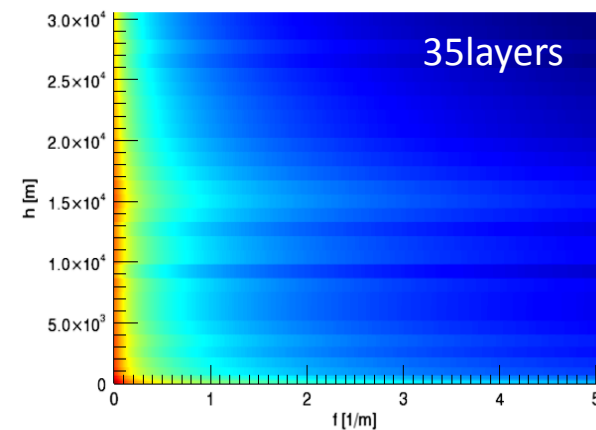
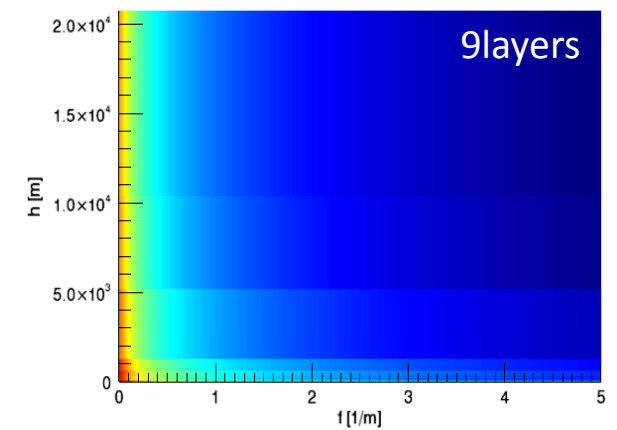
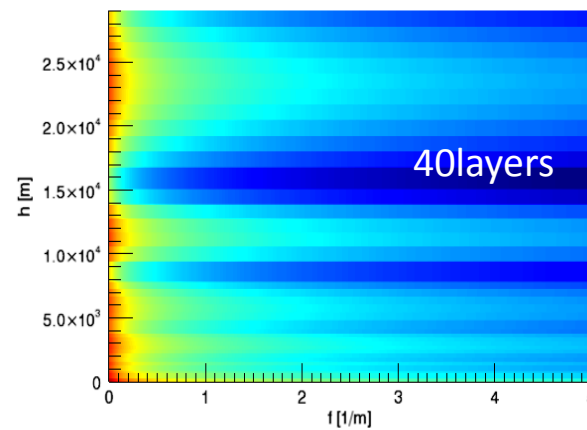
### Other inputs:

- Cn2 profile data file
- Single WFS performance

# TURBULENCE

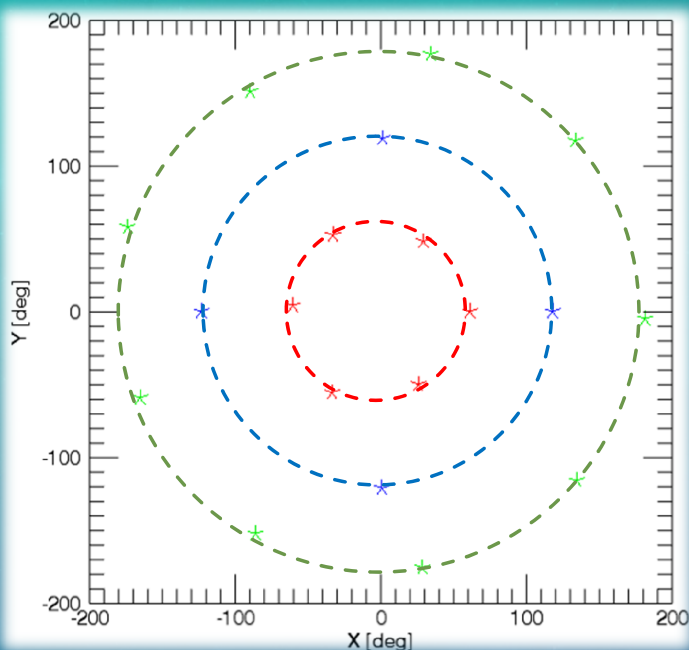
## INPUTs:

- $C_n^2$  profile
- Seeing value ( @  $\lambda_{WFS}$  )
- Spectrum Type (default: Von Karman)
- Other screen parameters

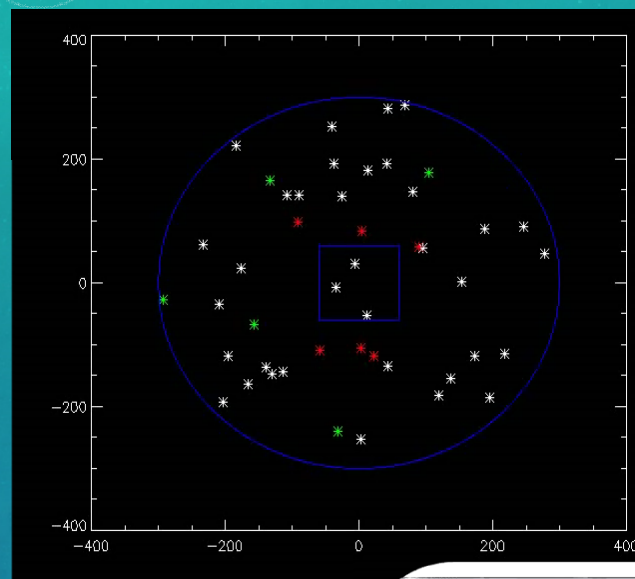


# ASTERISM

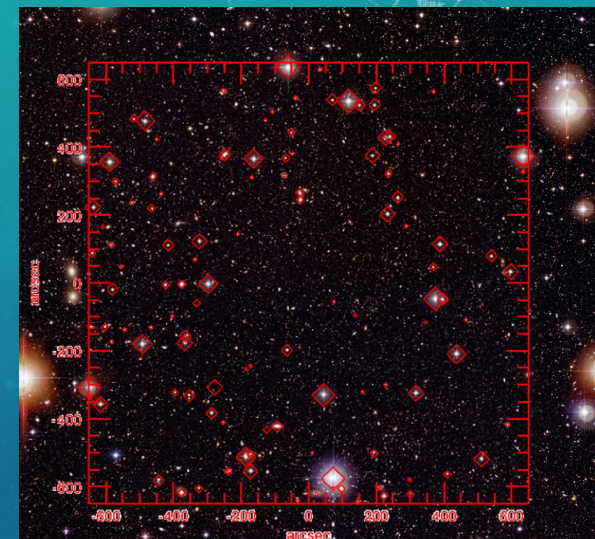
## Circular asterism



## Simulated random field



## Real field on sky



### INPUTs:

- Asterism type
- Radius?
- FoV
- Coordinates?

## SYSTEM BOUNDARIES

- Inner FoV: stars in the scientific FoV are neglected
- Probes proximity: stars with a relative separation lower than a given value are neglected

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VALENTINA VIG

The USNO-B1.0 Catalog (Monet+ 2003)

1/284

The Whole-Sky USNO-B1.0 Catalog of 1,045,913,669 sources (1045175762 rows)

The USNO-B Catalog presents positions, proper motions, magnitudes in blue, red and infrared, as well as star/galaxy estimators for 1,045,175,762 objects derived from 3,648,812,040 separate observations. The data were taken during the last 50 years.

USNO-B1.0 catalog was created by Dave Monet and collaborators at <http://www.ngh.wavy.mil/data/fc/tpic/>

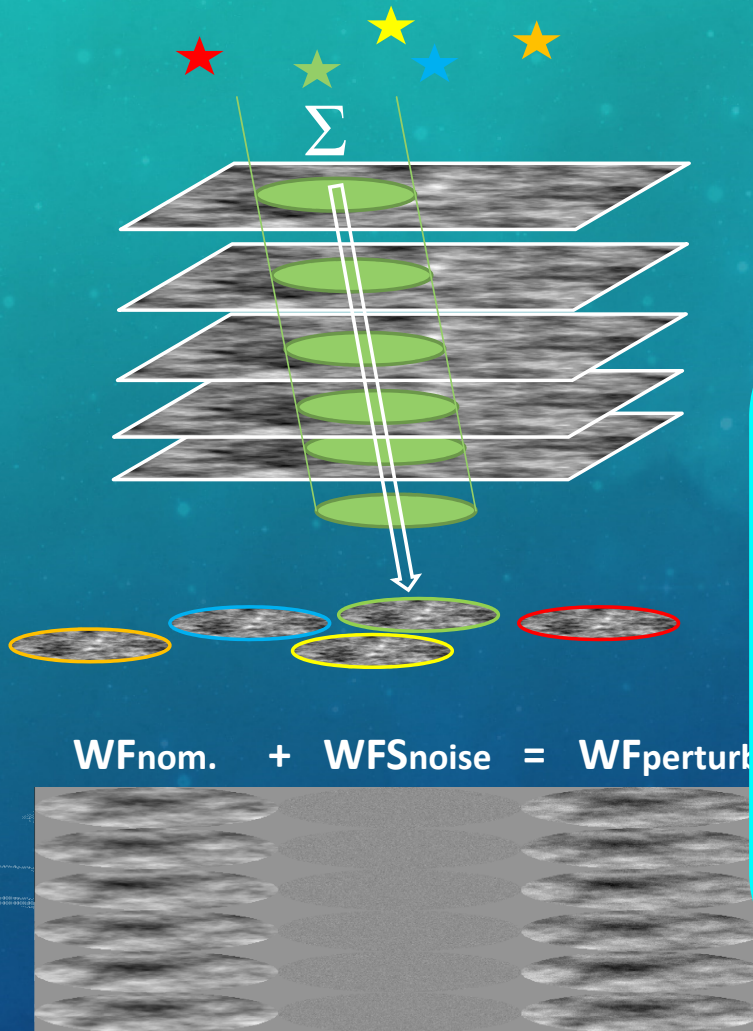
Note that the star/galaxy estimators may be mixed up in dense regions.

Show	Sort	Column	Clear	Constraint	Explain (UCD)
<input checked="" type="checkbox"/>	<input type="radio"/>	USNO-B1.0	(char)		Designation of the object ( <a href="#">Note 1</a> ) ( <a href="#">meta.id.meta.main</a> )
<input type="checkbox"/>	<input type="radio"/>	Tycho-2	(char)		Designation in the Tycho-2 Catalog ( <a href="#">1/259</a> ) ( <a href="#">meta.id</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	RAJ2000	deg		Right Ascension at Eq=J2000, Ep=J2000 ( <a href="#">Note 2</a> ) ( <a href="#">pos.eq.ra.meta.main</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	DEJ2000	deg		Declination at Eq=J2000, Ep=J2000 ( <a href="#">Note 2</a> ) ( <a href="#">pos.eq.dec.meta.main</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	e_RAJ2000	mas		Mean error on RAdeg*cos(DEdeg) at Epoch ( <a href="#">stat.error.pos.eq.ra</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	e_DEJ2000	mas		Mean error on DEdeg at Epoch ( <a href="#">stat.error.pos.eq.dec</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	Epoch	yr		Mean epoch of observation ( <a href="#">Note 2</a> ) ( <a href="#">time.epoch.obs</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	pmRA	mas/yr		Proper motion in RA (relative to YS4.0) ( <a href="#">pos.pm.pos.eq.ra</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	pmDE	mas/yr		Proper motion in DE (relative to YS4.0) ( <a href="#">pos.pm.pos.eq.dec</a> )
<input type="checkbox"/>	<input type="radio"/>	muPr	0.1		(n) Total Proper Motion probability ( <a href="#">Note 7</a> ) ( <a href="#">stat.probability</a> )
<input type="checkbox"/>	<input type="radio"/>	e_pmRA	mas/yr		Mean error on pmRA ( <a href="#">stat.error.pos.pm.pos.eq.ra</a> )
<input type="checkbox"/>	<input type="radio"/>	ALL cols	Reset All	Clear	(n) indicates a possible blank or NULL column
<input type="checkbox"/>	<input type="radio"/>	e_pmDE	mas/yr		Mean error on pmDE ( <a href="#">stat.error.pos.pm.pos.eq.dec</a> )
<input type="checkbox"/>	<input type="radio"/>	fit_RA	100mas		Mean error on RA fit ( <a href="#">stat.error</a> )
<input type="checkbox"/>	<input type="radio"/>	fit_DE	100mas		Mean error on DE fit ( <a href="#">stat.error</a> )
<input checked="" type="checkbox"/>	<input type="radio"/>	Ndet			[0.5] Number of detections ( <a href="#">Note 7</a> ) ( <a href="#">meta.number</a> )
<input type="checkbox"/>	<input type="radio"/>	Flags	(char)		[MsY] Flags on object ( <a href="#">Note 3</a> ) ( <a href="#">meta.code</a> )

# PERTURBED WAVEFRONTS

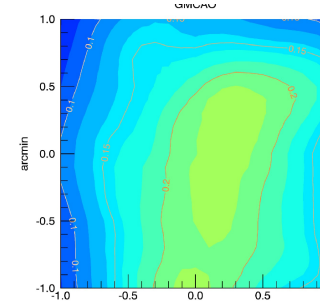
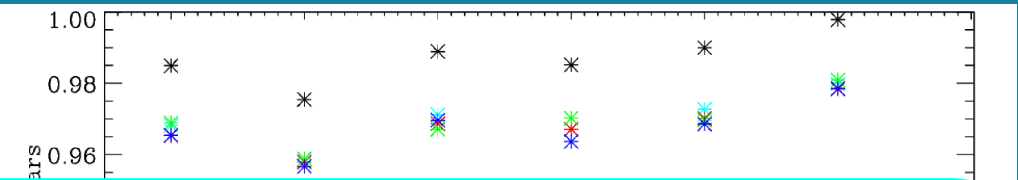
INPUTs:

- Layers altitude
- WFSs sampling
- WFS performance vs NGS magnitude

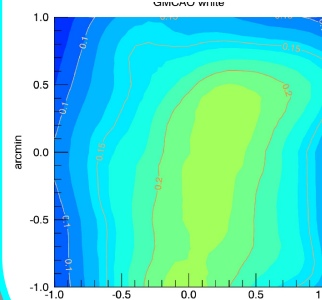


## Noise Spectrum TEST:

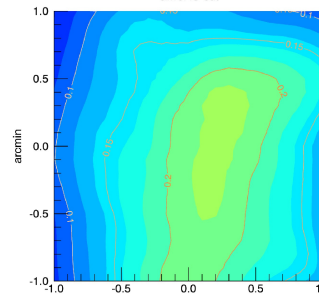
Different noise  
depending on



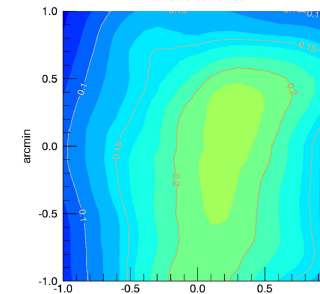
NO NOISE



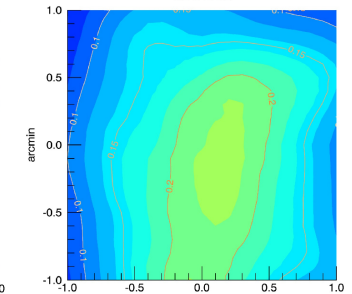
WHITE



CUT



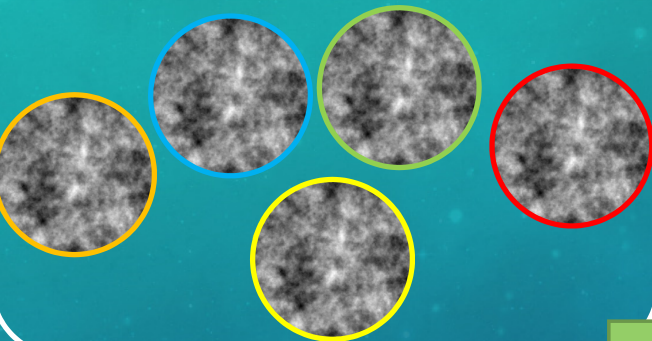
COMBINED



FULL

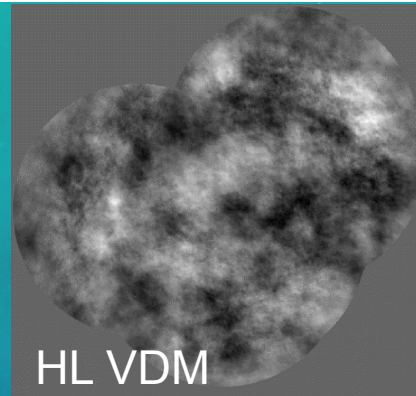
# VDMS COMPUTATION LOOP

Measured WFs

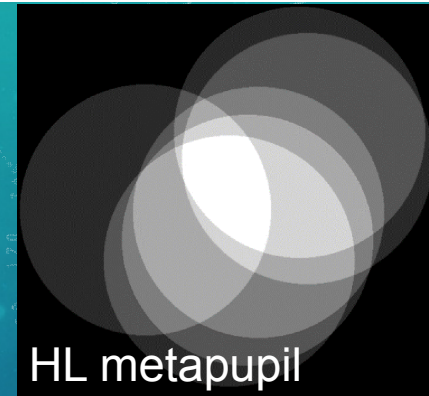


INPUTs:

- NGSs positions
- VDMs conjugation altitudes
- VDMs a-priori?

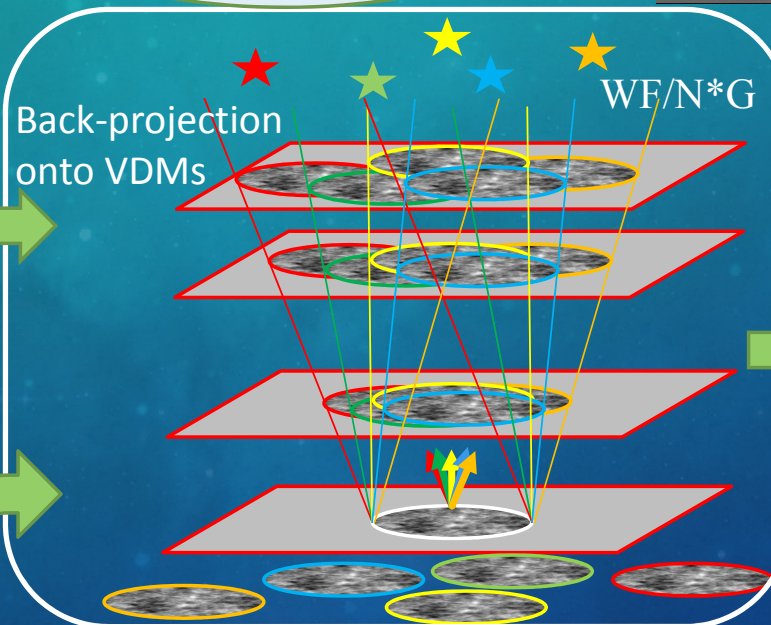


HL VDM

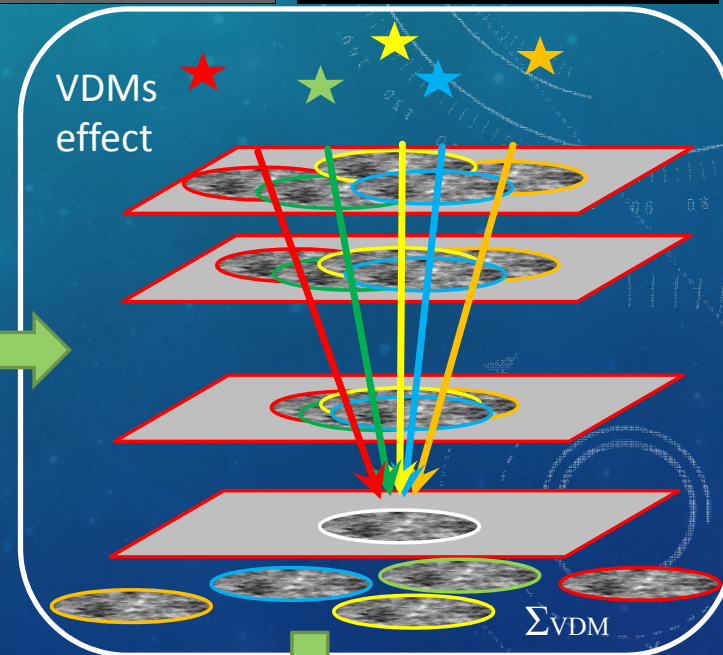


HL metapupil

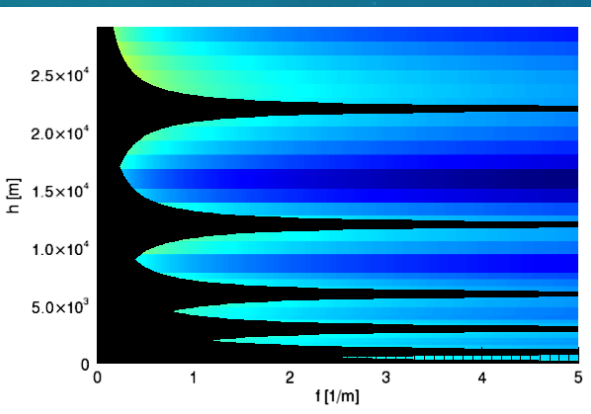
Back-projection  
onto VDMs



VDMs  
effect

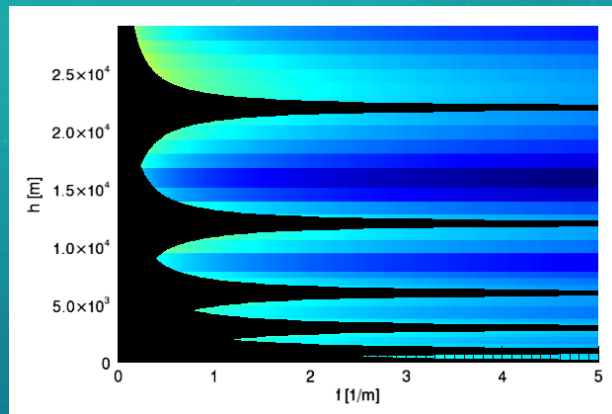


RESIDUALS =  
measured WFs – VDMs effect



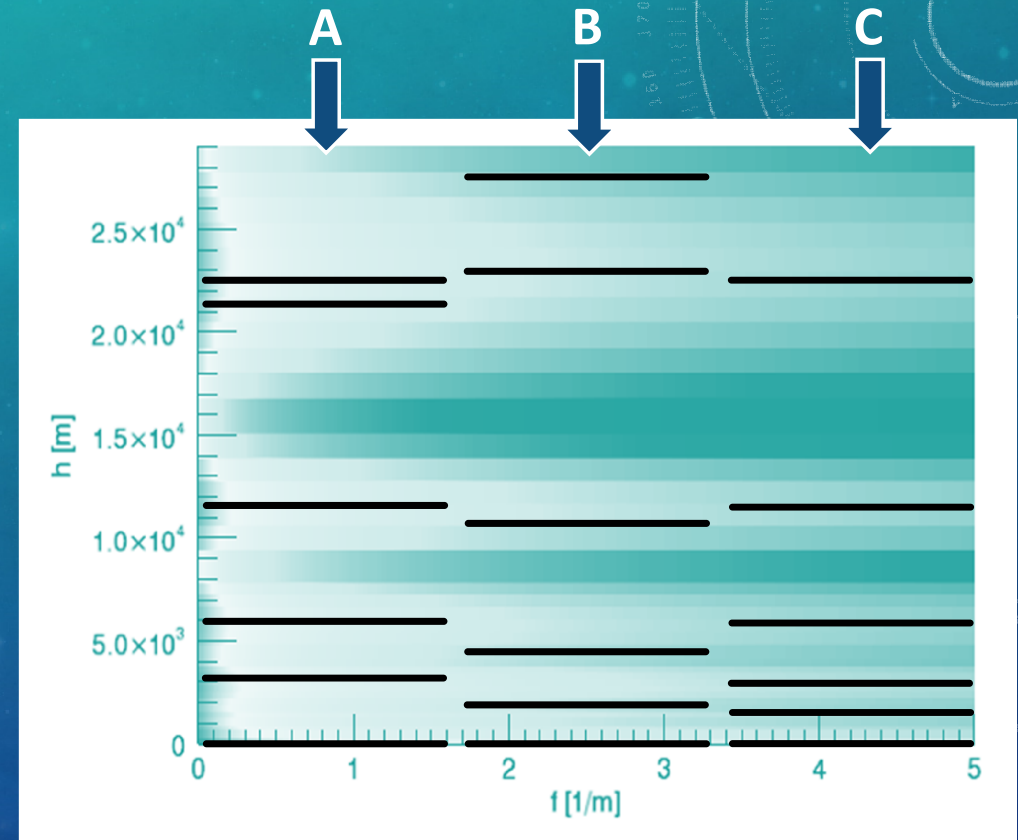
# VDMS COMPUTATION LOOP: ISSUES

## VDMs conjugation altitudes



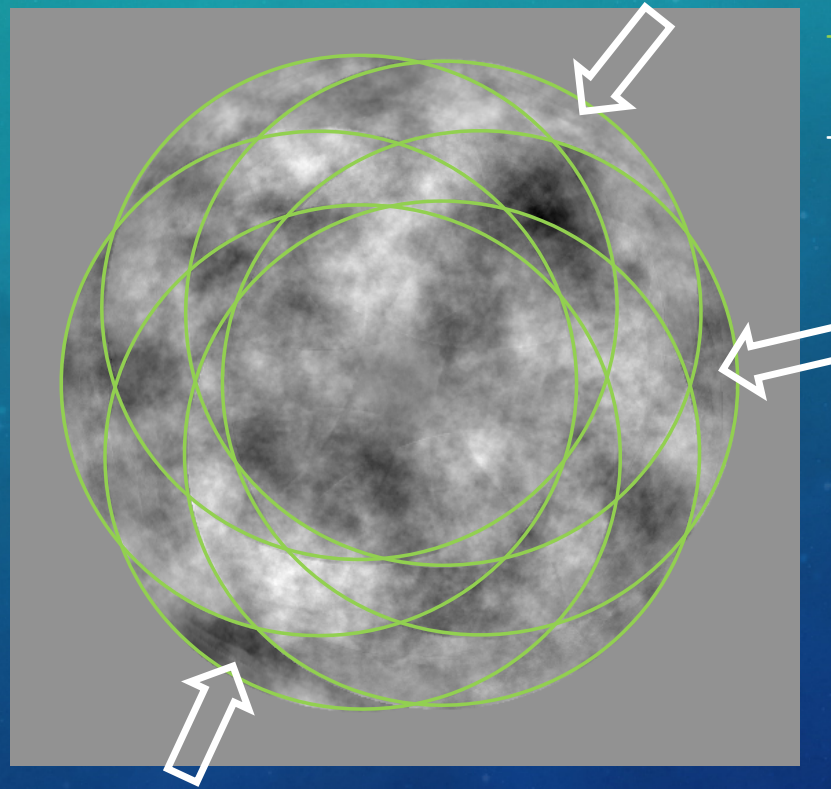
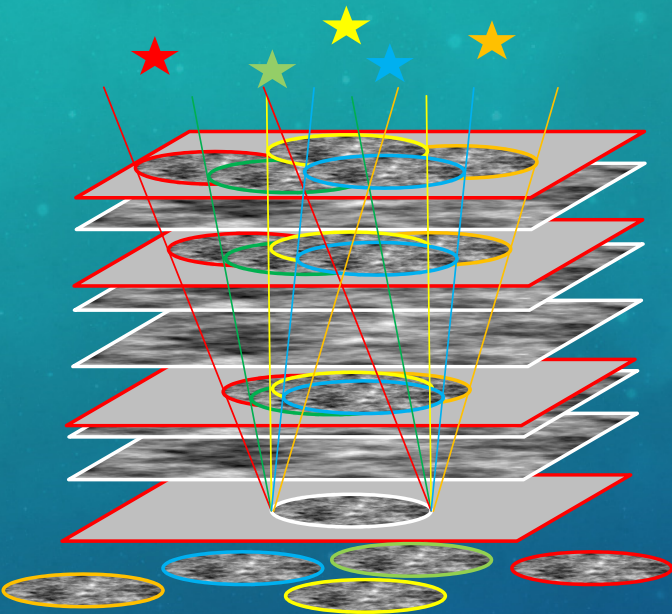
### How to define VDMs conjugation altitudes?

- User input
- Optimization  $h$ - $f$  plane filling:
  - Separation: equal, Log, random?
  - Max altitude: free, fixed, depending on asterism
  - ...



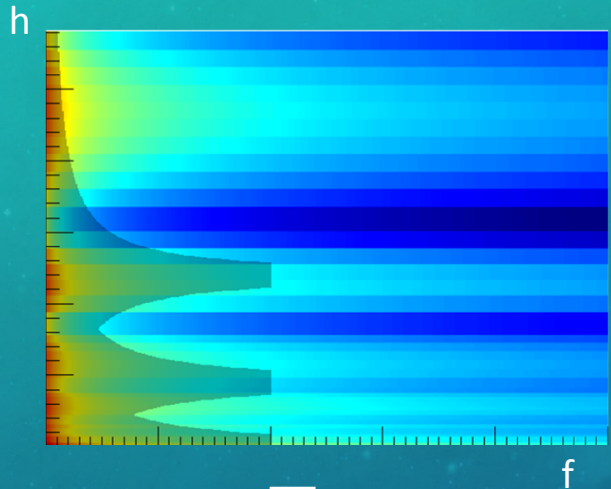
# VDMS COMPUTATION LOOP: ISSUES

## Pupils projections edges issue



- Primary edges: actual meta-pupil shape at that altitude
- Secondary edges: back-projections due to different VDMs cross-talk during the loop

# DMS COMPUTATION



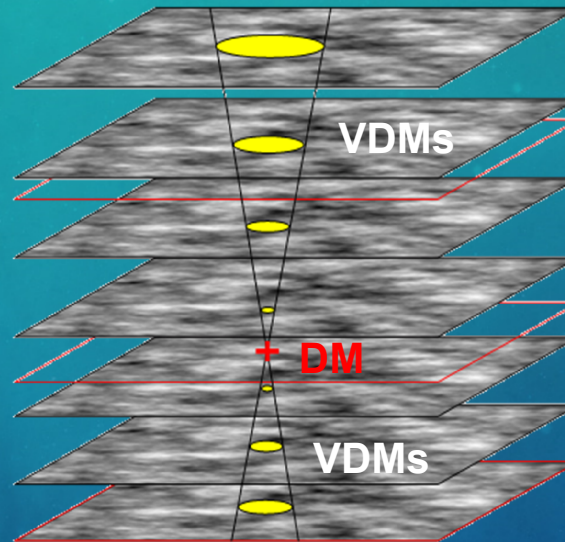
DMs **can** access spatial freq. up to:

- spatial sampling of the DM (@ conj. altitude)
- freq. related to the depth of focus (other altitudes)



FoV<sub>sci</sub> + distance from the DM conj.

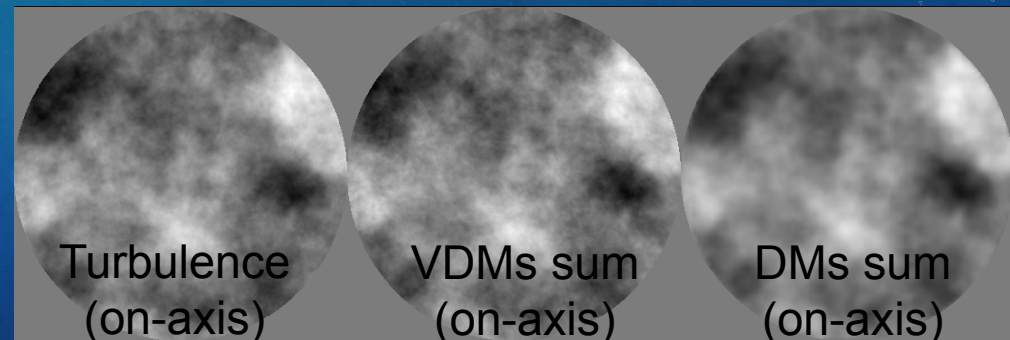
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## INPUTs:

- DMs conj. alt.
- Scientific FoV size
- DMs Interact. pitch

Each DM is the sum of all the VDMs, convolved with a circular kernel  $K(\text{sciFoV}, \Delta h)$ , and with a gain  $G(\Delta h)$ .  
 $\Delta h = h(\text{VDM}) - h(\text{DM})$



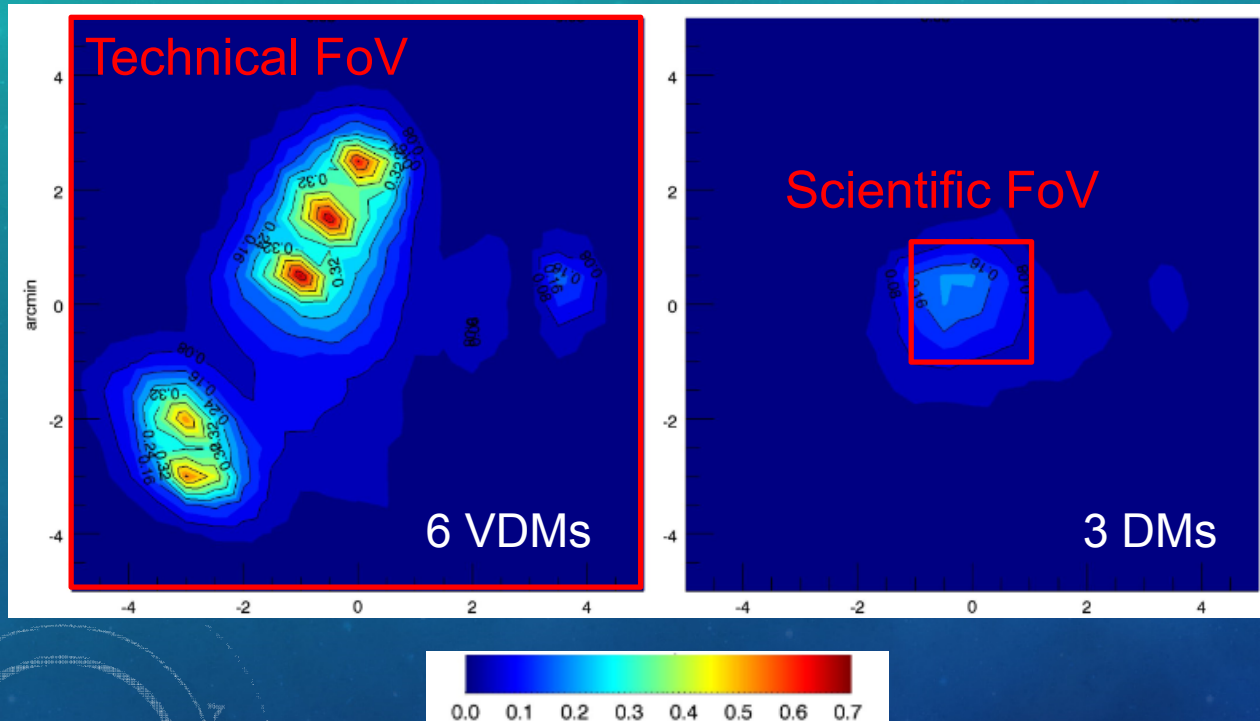
# SR ESTIMATION

INPUT:  
- FoV sampling

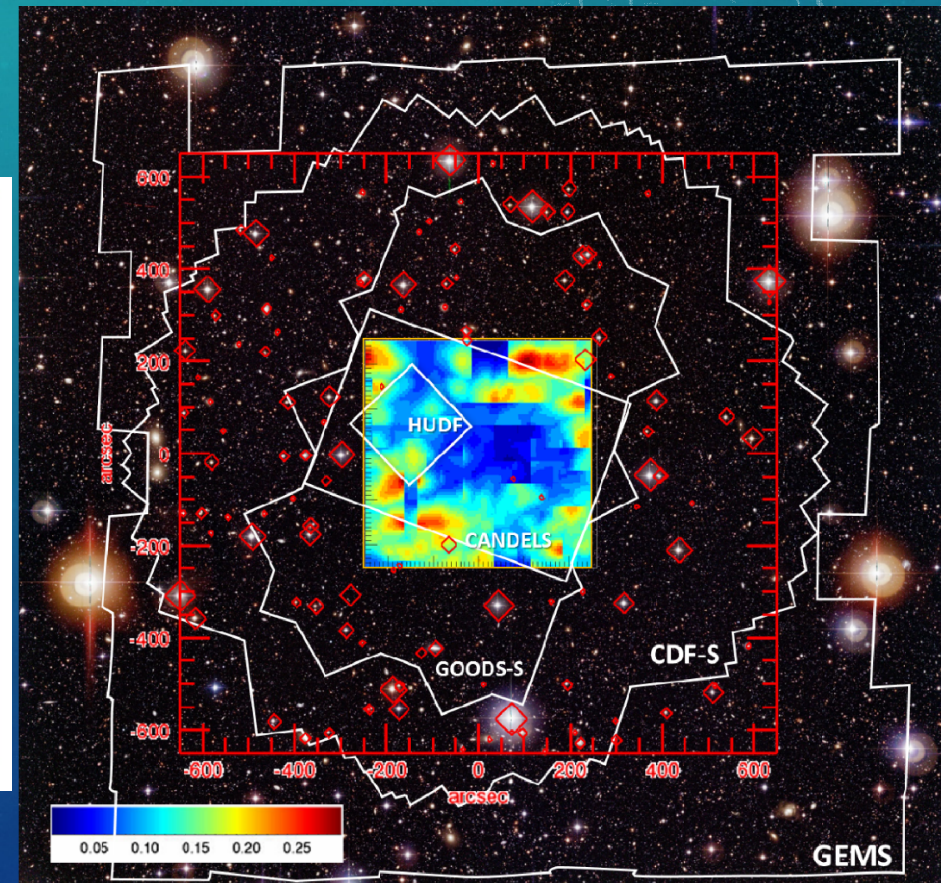
SR in the FoV is estimated from residuals RMS

Virtual SR with

Real SR with



Example of a real field  
SR estimation: **CDFS**



# APPLICATION OF RESULTS TO A SCIENCE CASE

Monthly Notices  
of the  
ROYAL ASTRONOMICAL SOCIETY  
MNRAS 466, 3569–3581 (2017)

doi:10.1093/mnras/stw321

## The *Chandra* Deep Field South as a test case for Global Multi Conjugate Adaptive Optics

E. Portaluri,<sup>1,2★</sup> V. Viotto,<sup>1,2★</sup> R. Ragazzoni,<sup>1,2★</sup> M. Gullieuszik,<sup>1,2</sup> M. Bergomi,<sup>1,2</sup>  
D. Greggio,<sup>1,2,3</sup> F. Biondi,<sup>1,2</sup> M. Dima,<sup>1,2</sup> D. Magrin,<sup>1,2</sup> and J. Farinato<sup>1,2</sup>

<sup>1</sup>INAF–Osservatorio Astronomico di Padova, vicolo dell’Osservatorio 5, I-35122 Padova, Italy

<sup>2</sup>ADONI–Laboratorio Nazionale Ottiche Adattive, Italy

<sup>3</sup>Dipartimento di Fisica e Astronomia ‘G. Galilei’, Università degli Studi di Padova, vicolo dell’Osservatorio 3, I-35122 Padova, Italy

Accepted 2016 December 7. Received 2016 December 6; in original form 2016 September 23

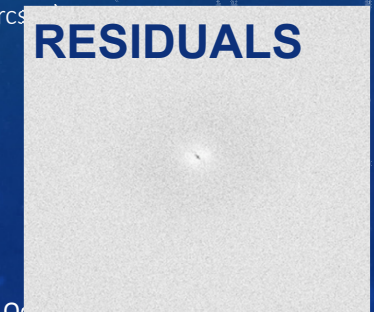
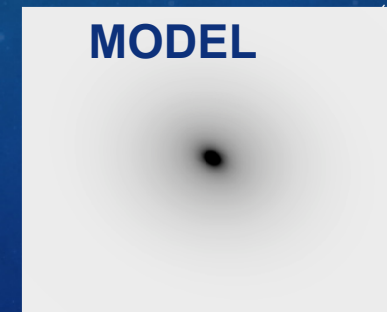
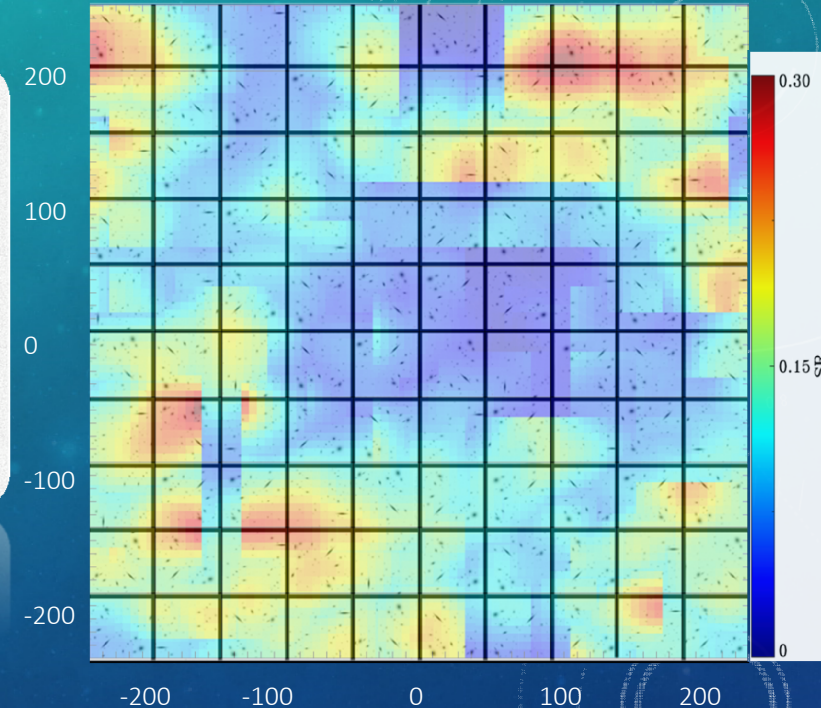
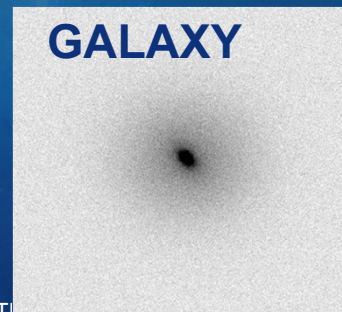
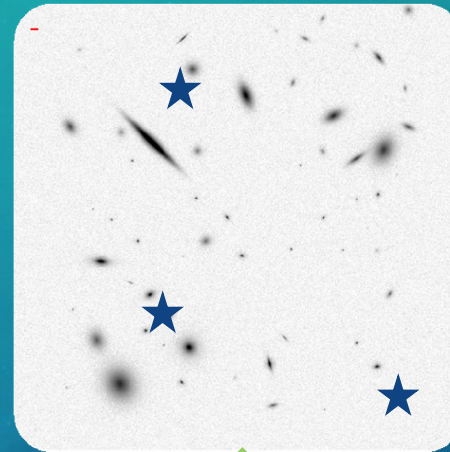
→ Mock-CDFS fields building-up:



→ No a-priori PSF knowledge for deconvolution  
(3  $R < 30$  stars randomly placed in each sector)

→ GALFIT deconvolution

WFSensing in the VLT/ELT era workshop II



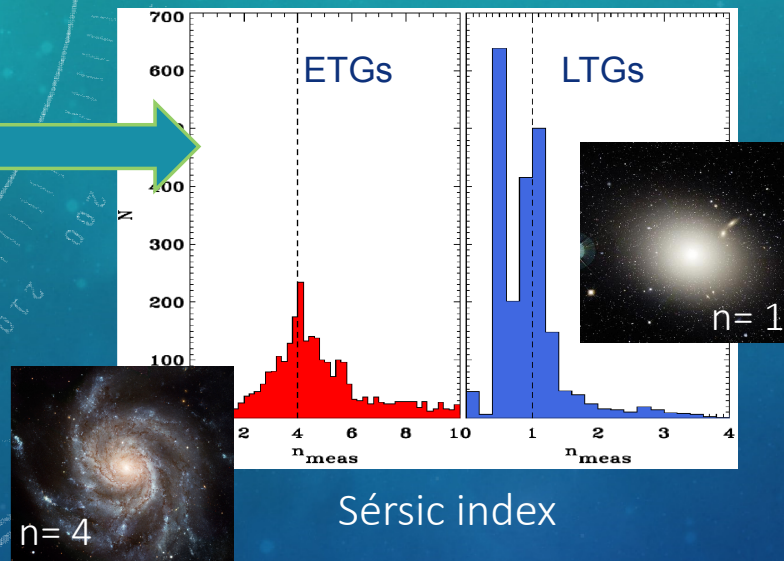
VALENTIN VIOOTTO

Padova, October 2 – 4, 2017

# DATA ANALYSIS AND RESULTS

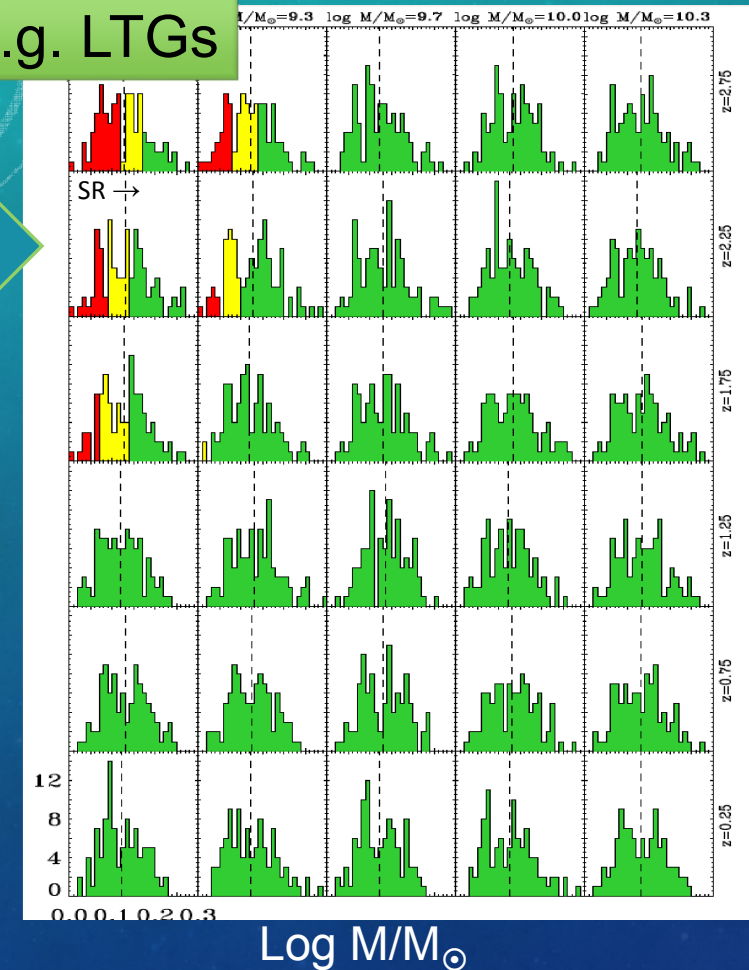
→ SExtractor completeness ( $2\sigma$  threshold level)  
99.7% (ETGs) - 89.4% (LTGs)

→ Morphological parameters



→ Results show a higher correlation of the retrieved parameter accuracy with the  $SR_{\text{star}}/SR_{\text{model}}$  than with the absolute  $SR_{\text{model}}$

e.g. LTGs



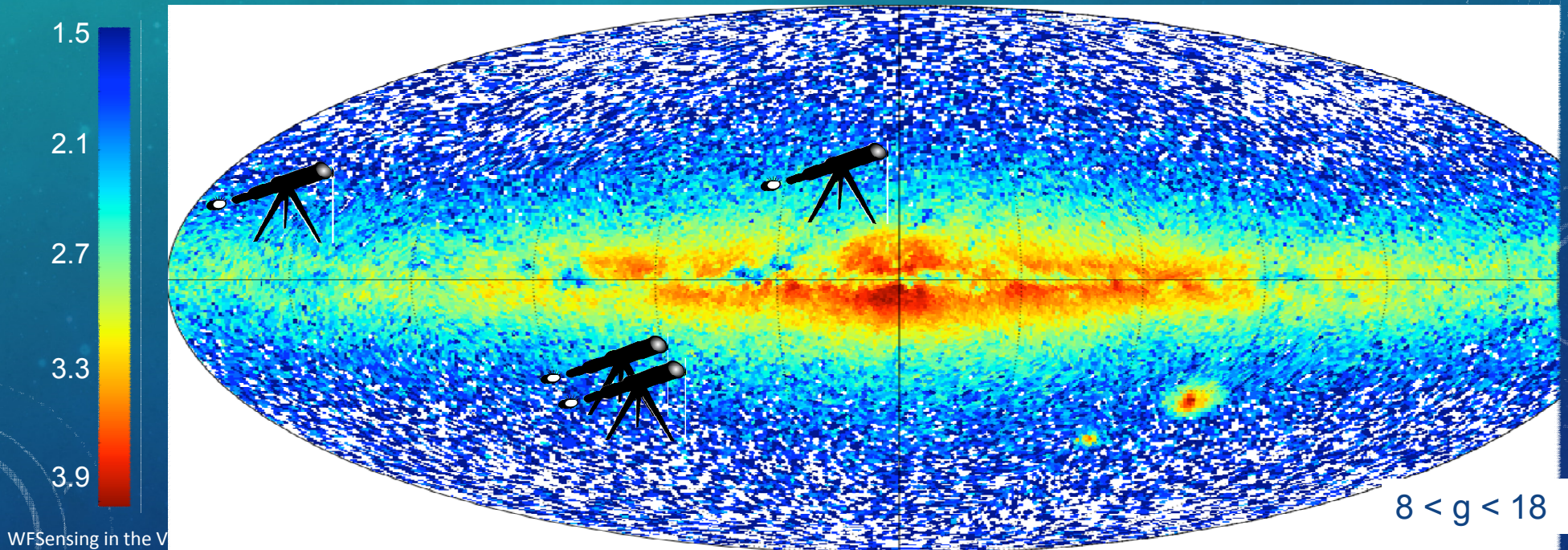
# WHAT'S GOING ON?

## FEASIBILITY OF OTHER SURVEYS

- 1) Object visibility (selected datasets)
- 2) MW stellar density



Observations → GAIA (1<sup>st</sup> release):  
Log of number of sources in GMCAO TechFoV



WFSensing in the V



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OTTICA  
ADATTIVA

# THANK YOU!